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I. OVERVIEW

This review is an updating through November 1985 of the Review of Particle Properties [Particle Data Group (1984)], a compilation of experimental results on the properties of particles studied in elementary particle physics. These properties include masses, widths or lifetimes, branching ratios, and other experimentally determined properties. Where feasible, we provide a suggested "best" value of each parameter based on our own judgment, using the best available data. A discussion of some of the procedures that we apply, and a brief review of the historical performance of averages of measurements, may be found below (Section IV Part D).

The results of this compilation are presented in two sections, the "Summary Tables of Particle Properties" and the "Full Listings." The Summary Tables give our estimates of the properties of those states whose existence we consider well established. Our opinion of whether or not a particle is well established can change as new data become available. We attempt to be conservative, so particles awaiting confirmation are not included, even if they may be theoretically well understood.

All data used for the numerical estimates in the Summary Tables are included in the Full Listings, with references and our comments, if any. Those measurements considered recent enough or important enough to mention, but which for some reason were not used in the averaging, appear in parentheses. The Full Listings also contain information on unconfirmed particles and unsuccessful particle searches, as well as short "mini-reviews" about subjects of particular interest or data that have particular problems.

In the past, we have attempted to use the Full Listings as an archive of all reported data on particles of interest. This is no longer possible because the growth of information would require a 5 to 10% per year expansion in this Review. Therefore we refer interested readers to previous editions for references to data considered obsolete.

This edition we are implementing our new particle naming conventions [Barnett (1985) and Wohl (1984)], which primarily affect meson names. A few baryon states are renamed as well. In the Summary Tables of Particle Properties and the Full Listings each particle is listed by its new name, with the old name, if different, given below it. It is our hope that these new conventions, described in Section III below, if adopted by the community will bring order to the chaos of particle names and facilitate discussion and understanding. Since there will doubtless be a transition period during which the literature may contain a mixture of both old and new names, we will continue to list the old names with the new for several editions.

We categorize the particles into types, intended to correspond roughly to the different types of data and problems encountered:

STABLE PARTICLES — All particles stable under the strong interaction. These include the truly stable particles as well as those which decay weakly or electromagnetically, including the η, D, D_s (formerly called the F), Λ_c, W, Z^0, and so on.

MESONS — All meson resonances that decay strongly, including the ψ, χ, and Υ families.

BARYONS — All baryon resonances that decay strongly, including the resonant N and Δ families, dibaryon candidates, and so on.

This classification scheme is used to organize the Summary Tables and the Full Listings.

We include a section of "Miscellaneous Tables, Figures, and Formulae." These provide a quick reference for the practicing elementary particle physicist. They normally presuppose some understanding of the subject matter, and do not attempt to serve as a textbook. We welcome all suggestions and comments regarding topics for inclusion or deletion, any errors or confusing passages, etc.

A pocket-sized Particle Properties Data Booklet is available. This contains the complete Summary Tables of Particle Properties and the most frequently used parts of the Miscellaneous Section, but not the Full Listings. For North and South America, Australia, and the Far East, write to Technical Information Department, Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA. For all other areas, write to CERN Scientific Information Service, CH-1211 Geneva 23, Switzerland.

In 1984 we began a multiyear effort aimed at modernization and reorganization. In this edition, we have added Greek letters and larger fonts for headings in the Full Listings, as well as numerous more minor improvements in format. We are also modernizing our internal procedures, and some of these improvements are already in place.

II. AUTHORS AND CONSULTANTS

The primary responsibilities of the authors are as follows:

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(3) *Baryon resonances*: R.L. Crawford, G.P. Gopal, G. Höhler, D.M. Manley, L.D. Roper, and C.G. Wohl.

Consultants

Of increasing importance to the production of this Review is a world-wide network of consultants, experts in particular topics. We wish to mention the following people with thanks:

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The usefulness of this compilation depends in large part on interaction between the users and the authors and consultants. We appreciate comments, criticisms, and suggestions for improvements of all stages of data retrieval, evaluation, and presentation.

III. A NEW NAMING SCHEME FOR HADRONS

> *"Young man, if I could remember the names of these particles, I would have been a botanist."*
>
> *Enrico Fermi*

A. The need for a new scheme; guiding principles

We introduce in this edition a new naming scheme for the hadrons. Anyone who doubts the desirability of a better naming scheme is invited to give, without looking at the Meson Summary Table, the quantum numbers I, J, P, C, and G of the following established nonstrange mesons:

> $S(975)$, $\delta(980)$, $H(1190)$, $B(1235)$, $D(1285)$, $\epsilon(1300)$, $\pi(1300)$, $E(1420)$, $\iota(1440)$, $\rho(1600)$, $\omega(1670)$, $A(1680)$, $\phi(1680)$, $g(1690)$, $\theta(1690)$, $h(2030)$.

There is no rhyme or reason to this alphabet soup of symbols - they convey nothing about the properties of the particles they name. Nor is the use of five different symbols, K, K^*, Q, L, and κ, to name just nine strange mesons informative or economical. The symbols for mesons containing heavy quarks and for ordinary baryons are fairly sensible, but it seems wise, while in the grip of reformist zeal, to make some rules regarding names of particles yet to be discovered, such as the whole spectrum of baryons containing one or more heavy quarks.

There are several obvious virtues any rational naming scheme ought to embody. The symbols ought to be as few and as simple as possible, with those already in common use retained where possible; the symbols ought to convey unambiguously the important quantum numbers of the particles they name; and the quark model ought to guide the whole scheme. There are, however, constraints: it is not practical, for example, to now rename the ϕ meson the ω', or to call the K meson containing an s quark (as opposed to an $\bar{s}$) a K instead of a $\bar{K}$. Some compromise between simplicity and long-established usage is unavoidable.

The new scheme adopted here has evolved over the last two years in response to much discussion both within the Particle Data Group and with the larger community. Preliminary versions of the scheme were presented at the 1984 Santa Fe Meeting of the Division of Particles and Fields [Wohl (1984)] and at the 1985 International Conference on Hadron Spectroscopy [Barnett (1985)]. Several thousand copies of the proposal, with an invitation to comment, were distributed in the spring of 1985. A *Physics Today* news report discussed the proposal [Schwarzschild (1985)], and it has been discussed in the CERN *Courier* (November 1985).

As indicated above, many of the mesons have been renamed. The Meson Summary Table in this edition gives both the new and old names, and a table of equivalent names will appear in foreseeable editions. Only two particles in the Stable Particle and Baryon Summary Tables are renamed (the F and the A^+ become the D_s and the Ξ_c^+).

B. "Neutral-flavor" mesons ($S = C = B = T = 0$)

Table I shows the naming scheme for mesons having the strangeness and all heavy-flavor quantum numbers equal to zero. The mesons are assumed to be quark-antiquark states. The rows of the table give the possible $q\bar{q}$ content. The columns give the possible parity/charge-conjugation states, PC = $-+$, $+-$, $--$, and $++$; these combinations correspond one-to-one with the angular-momentum state $^{2S+1}L_J$ of the $q\bar{q}$ system being $^1(L\text{ even})_J$, $^1(L\text{ odd})_J$, $^3(L\text{ even})_J$, or $^3(L\text{ odd})_J$.[*] In addition, the spin J is added to the main symbol as a subscript except for pseudoscalar and vector mesons (L=0 states in the quark model), and the mass is given for any meson that decays strongly.

Experimental determination of the mass, quark content, and quantum numbers I, J, P, and C (or G) of a meson thus fixes its symbol. Conversely, these properties may be inferred unambiguously from the symbol.

If the main symbol cannot be assigned, because the quantum numbers (other than J) are unknown, the symbol X is used temporarily. Sometimes it is not known whether a meson is mainly the isospin-0 mix of $u\bar{u}$ and $d\bar{d}$ or is mainly $s\bar{s}$; the prime (or symbol ϕ) may be used to distinguish two such mixing states.

Names have been assigned for the anticipated $t\bar{t}$ mesons. No suggestion is made here for names for mesons (should any be found) with the "exotic" quantum numbers that a $q\bar{q}$ system cannot have, namely $J^{PC} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+}, \cdots$. Glueballs or other mesons that are not $q\bar{q}$ states would (if the quantum numbers are *not* exotic) be named just as if they were $q\bar{q}$ states, since they will probably be difficult to distinguish from such states and will likely mix with them.

The results of all this are as follows. None of the lowest

Table I. Symbols for mesons with the strangeness and all heavy-flavor quantum numbers equal to zero.

	$J^{PC}=$	0^{-+}	1^{+-}	1^{--}	0^{++}
		2^{-+}	3^{+-}	2^{--}	1^{++}
		⋮	⋮	⋮	⋮
$q\bar{q}$ content	$^{2S+1}L_J=$	$^1(L\text{ even})_J$	$^1(L\text{ odd})_J$	$^3(L\text{ even})_J$	$^3(L\text{ odd})_J$
$u\bar{d}$, $d\bar{d}-u\bar{u}$, $d\bar{u}$	(I=1)	π	b	ρ	a
$d\bar{d}+u\bar{u}$ and/or $s\bar{s}$	(I=0)	η,η'	h,h'	ω,ϕ	f,f'
$c\bar{c}$		η_c	h_c	$\psi^\dagger$	χ
$b\bar{b}$		η_b	h_b	Υ	χ_b
$t\bar{t}$		η_t	h_t	θ	χ_t

†The J/ψ remains the J/ψ.

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[*] The relations between the quantum numbers are

$$P=(-1)^{L+1} \qquad C=(-1)^{L+S} \qquad G=(-1)^{L+S+I},$$

where of course the C quantum number (charge conjugation) is only relevant to charge-zero mesons.

mass pseudoscalar or vector mesons (π, η, and η'; ρ, ω, and ϕ) change names, nor do any of the $c\overline{c}$ or $b\overline{b}$ mesons. Established mesons whose names change slightly are:

Old name	New name	Old name	New name
$H(1190)$	$h_1(1190)$	$A_2(1320)$	$a_2(1320)$
$B(1235)$	$b_1(1235)$	$f'(1525)$	$f_2'(1525)$
$f(1270)$	$f_2(1270)$	$\omega(1670)$	$\omega_3(1670)$
$A_1(1270)$	$a_1(1270)$	$\phi(1850)$	$\phi_J(1850)$

Established mesons whose names change completely are:

Old name	New name	Old name	New name
$S(975)$	$f_0(975)$	$\iota(1440)$	$\eta(1440)$
$\delta(980)$	$a_0(980)$	$A_3(1680)$	$\pi_2(1680)$
$D(1285)$	$f_1(1285)$	$g(1690)$	$\rho_3(1690)$
$\epsilon(1300)$	$f_0(1300)$	$\theta(1690)$	$f_2(1720)$
$E(1420)$	$f_1(1420)$	$h(2030)$	$f_4(2030)$

The $S(975)$, $D(1285)$, $\epsilon(1300)$, $E(1420)$, $\theta(1690)$, and $h(2030)$ all become f mesons; the new scheme reveals that all have PC=++ and are $^3(L\ \mathrm{odd})_J$ states.

C. Mesons with nonzero S, C, B, and/or T

Since the strangeness or a heavy flavor is nonzero, none of the mesons here are eigenstates of charge conjugation, and in each of them one of the quarks must be heavier than the other. The rules are:

(1) The main symbol is an upper-case Roman letter indicating the heavier quark as follows:[‡]

$s \rightarrow K \quad c \rightarrow D \quad b \rightarrow B \quad t \rightarrow T$.

(2) If the lighter quark is not a u or a d quark, its identity is given by a subscript.

(3) If the spin-parity is in the "normal" series $J^P = 0^+, 1^-, 2^+, \cdots$, a superscript "*" is added.

(4) The spin is added as a subscript unless the meson is a pseudoscalar or a vector (L=0 states in the quark model).

Thus the pseudoscalar and vector K, K^*, D, D^*, and B mesons do not change names. Established mesons whose names do change are:

Old name	New name	Old name	New name
$Q_1(1280)$	$K_1(1280)$	$L(1770)$	$K_2(1770)$
$\kappa(1350)$	$K_0^*(1350)$	$K^*(1780)$	$K_3^*(1780)$
$Q_2(1400)$	$K_1(1400)$	$K^*(2060)$	$K_4^*(2060)$
$K^*(1430)$	$K_2^*(1430)$	F	D_s

The most notable change is that of the F (the $c\overline{s}$ state) to a D_s. However, with the prospect of B_s, B_c, T_s, and similar mesons, there is no consistent and economical alternative. The rules can lead to cumbersome symbols, such as a D_{s2}^*, but such particles are unlikely to be often seen.

D. Baryons

The symbols N, Δ, Λ, Σ, Ξ, and Ω have been used for 20 years for the baryons made of light quarks (u, d, and s quarks), and no change is made to these symbols here. They tell the isospin and quark content, and the same information ought to be conveyed by the symbols used for the baryons containing one or more heavy quarks (c, b, and t quarks). The following system was invented earlier and independently by Hendry and Lichtenberg (1978) and by Samios (1980). The rules are (see also Fig. 1):

(1) Baryons with *three* u and/or d quarks are N's (isospin 1/2) or Δ's (isospin 3/2).

(2) Baryons with *two* u and/or d quarks are Λ's (isospin 0) or Σ's (isospin 1). If the third quark is a heavy quark (not an s quark) its identity is given by a subscript. This nomenclature is already used for the $\Lambda_c(2281)$, $\Sigma_c(2450)$, and $\Lambda_b(5500)$.

(3) Baryons with *one* u or d quark are Ξ's (isospin 1/2). One or two subscripts are used if one or both of the remaining quarks are heavy: thus Ξ_c, Ξ_{cc}, Ξ_b, etc. The possible but not established $A(2460)$ is renamed the $\Xi_c(2460)$.

(4) Baryons with *no* u or d quarks are Ω's (isospin 0), and subscripts indicate any heavy-quark content. The possible but not established $T(2740)$ is renamed the $\Omega_c(2740)$.

In short, the total number of u and d quarks together with the isospin determine the main symbol, and subscripts indicate any content of heavy quarks. A Σ always has isospin 1, an Ω always has isospin 0, etc. The only baryons whose names change are the A and the T.

Note in Fig. 1 that the SU(4) 20-plet that contains the basic SU(3) octet has an Ω_c and an Ω_{cc} although it has no Ω. It has *two* Ξ_c's, which would be distinguished by mass (they might also be distinguished by a prime on the heavier of the two).

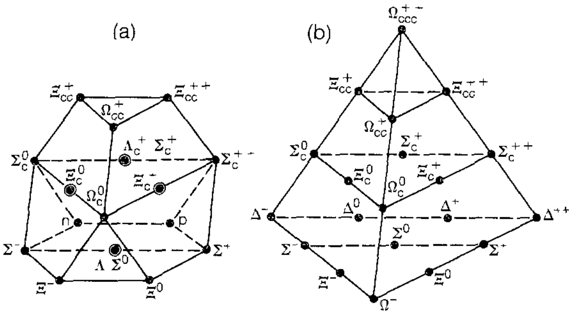

Fig. 1. SU(4) multiplets of baryons made of u, d, s, and c quarks. (a) The 20-plet with an SU(3) octet. (b) The 20-plet with an SU(3) decuplet.

[‡] Two different conventions exist in the literature for the sign of the flavor of b quarks. We have adopted the convention that *the sign of the flavor of a quark is the same sign as its charge*, which is true for all flavors. Thus the strangeness of the s quark is negative, the charm of the c quark is positive, and the bottom of the b quark is negative. In addition, I_3 of the u and d quarks is positive and negative, respectively. The effect of this convention is as follows: Any *flavor* carried by a *charged* meson has the *same* sign as its *charge*. Thus the K^+, D^+, and B^+, have positive strangeness, charm, and bottom, respectively, and all have positive I_3. The D_s^+ (formerly the F^+) has positive charm and strangeness. Furthermore, the Δ(flavor) = ΔQ rule, which is best known for the kaons, applies to every flavor.

IV. PROCEDURES

A. Selection and treatment of data

The Full Listings contain a complete record of all *relevant* data known to us. As a general rule, we do not include results from preprints or conference reports. It is our experience that preprinted results often change before publication. In some cases, such results may be cited but not used in computing the estimates given in the Summary Tables. There are a few exceptions to this exclusion, which we decide on a case-by-case basis after consultation with the experimenters.

As mentioned earlier, we no longer attempt to maintain an archival record of data of historical importance only. We do, however, quote the references of discoveries, even when the data are no longer useful.

If data are included in the Full Listings but not used in the final average given in the Summary Tables, they are enclosed in parentheses. We give explanatory comments in many such cases. If no comment is given, the reason the data were excluded is one or more of the following:

- The data are superseded or included in later results.
- No error was given.
- The data were contained in a preprint or conference report.
- The result involves some assumptions we do not wish to incorporate.
- The measurement has poor signal-to-noise ratio, low statistical significance, or is otherwise of much poorer quality than other data available.
- The measurement is clearly inconsistent with other results which appear to be highly reliable (see discussion in Section IV Part D below).
- The measurement is not independent of other results, e.g., it is from one of several partial-wave analyses, all of which use the same data, rendering averaging meaningless.

In some cases, *none* of the measurements is entirely reliable and no statistically meaningful average is quoted. For example, the masses of many of the baryon resonances, obtained from partial-wave analyses, are quoted as a range thought to probably include the true value rather than as an average with error. This is discussed in more detail in some of the mini-reviews in the Baryon Full Listings.

For upper limits, we normally quote in the Summary Tables the strongest limit available from a single experiment. We do not average or combine upper limits except in a very few cases where they may be re-expressed as measured numbers with Gaussian errors.

For quantum number assignments, we indicate in the Summary Tables those which are either well established or probable. In the Meson Summary Table, we underline those we consider well established; the others are inferred from whatever experimental evidence is available. In the Stable Particle Summary Table, nearly all quantum numbers are well established and we do not underline; those which are not well established are indicated by a footnote.

As is customary, we assume that antiparticles are the result of operating with *CPT* on particles, so both share the same spins, masses, and mean lives. There is an entry in the Miscellaneous Section, Tests of Conservation Laws, listing tests of *CPT* and other conservation laws.

B. Criteria for new states

An experimentalist who sees indications of a new state will of course want to know what has been seen in that region in the past. Hence, we include in the Full Listings all reported states which have not been, in our opinion, disproved by better (e.g., more reliable) data.

For the Summary Tables we are much more conservative. We include only those reported states which we feel have a large chance of survival. One's betting odds for survival are of course subjective; therefore no precise criteria can be defined. For more detailed discussions, see the mini-reviews in the Full Listings. In what follows we shall attempt to specify some guidelines.

(a) When energy-independent partial-wave analyses are available (mostly for πN resonances), approximate Breit-Wigner behavior of the amplitude appears to us to be the most satisfactory test for a resonance. We can check that the Argand plot follows roughly a left-hand circle, and that the "speed" of the amplitude also shows a maximum near the resonance energy; further, there should be data well above the resonance, showing that the speed again decreases. Indeed, proper behavior of the partial-wave amplitude often establishes a resonance even if its elasticity is too small to make a noticeable peak in the cross section.

(b) When there are insufficient data to perform energy-independent analyses, one often resorts to energy-dependent partial-wave analyses. In this case Breit-Wigner behavior is an input. We usually require that resonance solutions be found by several different analyses, preferably in different channels ($\overline{K}N \rightarrow \overline{K}N$, $\pi\Sigma$, etc.), before putting the claim in the Summary Tables.

(c) Stable particles, most meson resonances, Ξ resonances, and high-mass N, Δ, Λ, and Σ resonances fall into a category for which no partial-wave analyses exist. In general, we accept such states if they are experimentally reliable, of high statistical significance (4.5σ or better), or observed in several different production processes.

(d) Partial-wave analyses of three-body final states ($\pi N \rightarrow \pi\pi N$) are also available. While these analyses are based on the isobar model ($\pi N \rightarrow \rho N$, $\pi\Delta$, etc.) and are subject to theoretical objections of varying importance, they provide increasingly reliable information on inelastic decay modes of otherwise-established resonances.

C. Statistical Procedures

We divide this discussion on obtaining averages and errors into two sections:

1. The unconstrained case, or "simple averaging;" and
2. The constrained case.

In what follows, the term "error" means one standard deviation (1σ); that is, for central value $\overline{x}$ and error $\delta\overline{x}$, the range $\overline{x} \pm \delta\overline{x}$ constitutes a 68.3% confidence interval.

1. Unconstrained averaging

We use a standard Gaussian procedure with a "scale factor" applied to the errors as our method of averaging the data. The Student's t-distribution, the basis of an earlier experiment of ours in data averaging, would give more conservative (and perhaps more realistic) errors at the two-standard-deviation (2σ) and higher level, but we do not choose to quote such errors. It is worth bearing in mind, however, that a 2σ error might more realistically be somewhat larger than twice a 1σ error, owing to the non-Gaussian character of some sets of real measurements. This is a persistent problem in data averaging arising from the existence of mildly discrepant measurements.

We begin by assuming that measurements of a given quantity are uncorrelated, and thus we calculate a weighted average and error

$$\bar{x} \pm \delta\bar{x} = \left(\sum_i w_i x_i \Big/ \sum_i w_i\right) \pm \left(\sum_i w_i\right)^{-1/2},$$

$$w_i = \left[1/(\delta x_i)^2\right], \tag{1}$$

where x_i and δx_i are the value and error, respectively, reported by the ith experiment, and the sums run over N experiments. We also calculate χ^2 and compare it with its expectation value; assuming that the measurements obey a Gaussian distribution, this is $N - 1$.

If $\chi^2/(N - 1)$ is less than or equal to 1, and there are no known problems with the data, we accept the above results.

If $\chi^2/(N - 1)$ is very large, or if there is prior knowledge of extremely large inconsistencies among experiments, we may choose not to average the data at all. Alternatively, we may quote the calculated average, but then give an educated guess as to the error; such a guess is generally a quite conservative estimate designed to take into account known problems with the data.

Finally, if $\chi^2/(N - 1)$ is greater than 1, but not greatly so, we still average the data, but then also do the following:

(a) We plot an ideogram to display the pattern of the data. Sometimes only one or two data points lie apart from the main body; other times the data split into two or more roughly equal-sized groups. The reader may use this information in deciding upon an alternative average, but caution is urged, as "outlying" data points are sometimes the "correct" ones. An example of such an ideogram is given in Fig. 2 below. Each experiment appearing in the plot is represented by a Gaussian with central value x_i, error δx_i, and area proportional to $1/\delta x_i$. The choice of area is somewhat arbitrary; it assumes that an experimenter will work to reduce the systematic errors until they are slightly smaller (but seldom much smaller) than the statistical errors. Thus, as a physicist collects more events, he or she will use them both to reduce the statistical errors and to study the biases. Our confidence that a significant systematic error has not been made in a given experiment, as compared with other contradictory experiments, then tends to go up as $1/\delta x_i$.

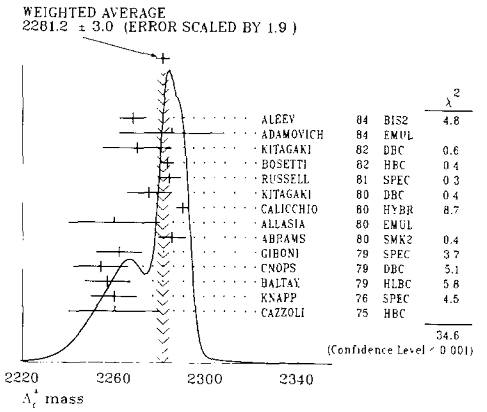

Fig. 2. Ideogram of measurements of the Λ_c^+ mass. The "data point" at the top shows the position of the weighted average, while the width of the error bar (and the shaded pattern beneath it) shows the error in the average after scaling by the SCALE factor. Only those experiments indicated by + error flags were precise enough to be accepted in the calculation of the SCALE factor; the column on the far right gives the χ^2 contribution of each of these experiments. The less precise experiments were included in the calculation of the weighted average, but not SCALE; they have $\perp$ error flags.

But why not assign a weight $1/(\delta x_i)^2$, as is done when computing a weighted average? We feel that this assignment is equivalent to assuming that large systematic errors are as infrequent as large statistical fluctuations, and that this assumption is unrealistic.

We emphasize the difference between least-squares averaging (where the weighting factor is the inverse square of the error) and the ideograms prepared for visual display. The former arithmetic is of course best if one has unbiased data whose errors are well understood. In particular, the error analysis assumes that the true error on each datum is sampled from a Gaussian whose width is correctly reported. Then we obtain a narrow Gaussian distribution centered at the weighted mean for the answer. The ideogram (often multipeaked and certainly not Gaussian) is based on the opposite hypothesis that some of the input is systematically in error. The idea behind least-squares averaging is that experiments 1, 2, 3, etc., are *all* valid (so we should multiply their probabilities). Our *ideograms* are based on the assumption that 1 *or* 2 *or* 3, etc., is valid, "hedged" with $1/\delta x_i$ betting odds; we then add their probabilities. Both approaches cannot simultaneously be right; we allow the reader to choose. However, we quote the least-squares result in the Summary Tables. This is the most precise value if the data satisfy the appropriate assumptions. A glance at the ideogram will show that the difference between the two approaches is usually not severe.

(b) The second way in which we try to take account of $\chi^2/(N - 1)$ being greater than 1 is to scale up our quoted error $\delta\bar{x}$ in Eq. (1) by a factor

$$\text{SCALE} = \left[\chi^2/(N - 1)\right]^{1/2}. \tag{2}$$

Our reasoning is as follows. Since we do not know which of the experiments are more than one standard deviation away from the correct value, we assume that all experimentalists underestimated their errors by the same scale factor (2). If we scale up all input errors by this factor, χ^2 becomes $N - 1$, and of course the output error scales up by the same factor.

If we are to combine experiments with widely varying errors, we modify this procedure slightly. This is because it is the more precise experiments that most influence not only the average value $\bar{x}$, but also the error $\delta\bar{x}$. Now, on the average, the low-precision experiments each contribute about unity to both the numerator and the denominator of SCALE, hence the χ^2 contribution of the sensitive experiments is diluted, i.e., reduced. Therefore, we evaluate SCALE by using *only* experiments for which the errors are not much greater than those of the more precise experiments, i.e., only those experiments with errors less than δ_0, where the ceiling δ_0 is (arbitrarily) chosen to be

$$\delta_0 = 3N^{1/2}\delta\bar{x}.$$

Here $\delta\bar{x}$ is the unscaled error of the mean of all the experiments. Note that if each experiment had the same error δx_i, then $\delta\bar{x}$ would be $\delta x_i/N^{1/2}$, so each individual experiment would be well under the ceiling on SCALE.

This scaling approach has the property that if there are two values with comparable errors separated by much more than their stated errors (with or without a number of other experiments of lower accuracy), the error on the mean value $\delta\bar{x}$ is increased so that it is approximately half the interval between the two discrepant values.

We wish to emphasize the fact that our scaling procedures for *errors* in no way affect central values. In addition, if one wishes to recover the unscaled error $\delta\bar{x}$, one need only divide the given error by the SCALE factor for that error.

2. Systematic errors and correlated measurements

Many experimental groups have now adopted the convention of presenting results with statistical and systematic errors explicitly indicated. Because of a lack of space in the Full Listings, we usually do not quote the two errors separately and at present we combine them.[§] In general we add the statistical and the systematic errors in quadrature. A comment is printed whenever this is done. When averages are calculated as described above in Eq. (1), the weight w_i is based upon the combined error.

It may happen that two measurements have correlated errors. For example, a group may improve the statistical or systematic errors by further data-taking or analysis. In this case we use only the improved result for averaging. The earlier result may still appear in the Listings (in parentheses), but in general we omit such obsolete entries.

A second case of correlated measurements is the occurrence of a common systematic error in experiments which are statistically independent. If two results $A_1 \pm \sigma_1 \pm S$ and $A_2 \pm \sigma_2 \pm S$ have completely correlated systematic errors S, one must first average $A_1 \pm \sigma_1$ and $A_2 \pm \sigma_2$ and then combine the resulting statistical error with S. One obtains, however, the same result by a second procedure, averaging $A_1 \pm X\cdot\sigma_1$ and $A_2 \pm X\cdot\sigma_2$ where

$$X = \left[1 + S^2/\sigma_1^2 + S^2/\sigma_2^2\right]^{1/2}. \tag{3}$$

The second procedure has the advantage that the modified entries $A_i \pm X\cdot\sigma_i$ may be averaged with further independent data as in Eq. (1). We therefore adopt this second procedure when appropriate.

3. Constrained fits

Except for trivial cases, all branching ratios and rate measurements are analyzed by making a simultaneous least-squares fit to all the data and extracting the partial decay fractions P_i, the width Γ, the partial widths Γ_i, and the associated error matrix.

Assume, for a simple example, that a state has only three partial decay fractions, P_1, P_2, and P_3 ($\sum P_i = 1$), which have been measured in four different ratios, $R_1, \cdots, R_4$, where, e.g., $R_1 = P_1/P_2$, $R_2 = P_1/P_3$, etc.[**] Further assume that *each* ratio r has been measured by N_r experiments (we designate each experiment with a subscript x, e.g., R_{1x}). We then find the best values of P_1, P_2, and P_3 by minimizing χ^2:

$$\chi^2 = \sum_{r=1}^{4}\left[\sum_{x=1}^{N_r}\left(\frac{R_{rx} - R_r(P_1,P_2,P_3)}{\delta R_{rx}}\right)^2\right]. \tag{3}$$

In addition to the fitted values $\bar{P}_i$, we calculate an error matrix $\langle\delta\bar{P}_i\delta\bar{P}_j\rangle$. We tabulate the diagonal elements of $\delta\bar{P}_i = \langle\delta\bar{P}_i\delta\bar{P}_i\rangle^{1/2}$ (except that some errors are scaled as discussed below). In the Full Listings we give the complete error matrix; we also calculate the fitted value of each ratio, for comparison with the input data, and list it below the relevant input, along with a simple unconstrained average of the same input.

Two further comments on the example above:

(1) There was no connection between measurements of the width and the branching ratios. But often we also have information on partial widths Γ_i as well as total width Γ. In this case we must introduce Γ as a parameter into the fit, along with the relations $\Gamma_i = \Gamma P_i$, $\sum \Gamma_i = \Gamma$. When appropriate, we tabulate the Γ_i along with the P_i, and give error matrices in the Full Listings.

(2) We do *not* allow for correlations between input data. We *do* try to pick those ratios and widths which are as independent and as close to the original data as possible.

For *asymmetric* errors, we use a continuous function of $\delta(P)^+$ and $\delta(P)^-$ in the fitting. When no errors are reported, we merely list the data for inspection.

Inconsistent constrained data. According to Eq. (3), the double sum for χ^2 is first summed over experiments $x = 1$ to N_r, leaving a single sum over ratios

$$\chi^2 = \sum_r \chi_r^2 .$$

We test for SCALE factors after the fit. Knowing the fitted χ_r^2 and its expectation value $\langle\chi_r^2\rangle$, we form SCALE factors (just as before), i.e.,

$$(\mathrm{SCALE})_r^2 = \chi_r^2/\langle\chi_r^2\rangle ,$$

and if any $(\mathrm{SCALE})_r$ is greater than 1, all N_r of the measurements of that particular ratio are equally penalized by having their errors increased by $(\mathrm{SCALE})_r$. We then recycle the full fit, yielding new values $\delta\bar{P}_i'$ for the errors in the partial decay modes, as well as new central values $\bar{P}_i'$.

Because of the constraint ($\sum P_i = 1$), some of the new SCALE factors may still be greater than 1. If this is so, the whole procedure (i.e., increasing errors by the new SCALE factors and recycling through the fit) is repeated until the process converges.

At the end, we have final estimated errors $\delta\bar{P}_i'$ for the $\bar{P}_i'$. If SCALE factors have been used, they normally will have caused a shift in the central fitted values $\bar{P}_i'$, as well as having given larger errors $\delta\bar{P}_i'$. Often we find that the shift $|\bar{P}_i - \bar{P}_i'|$ due to the SCALE factors is the same size as (or

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[§] We are considering a revision of the format of the Full Listings which would allow separation of these types of error, and also allow presentation of asymmetric errors.

[**] We can handle any ratio R of the form $\sum \alpha_i P_i / \sum \beta_i P_i$, where α_i and β_i are constants, usually 1 or 0. The forms $R = P_i\cdot P_j$ and $R = (P_i\cdot P_j)^{1/2}$ are also allowed.

greater than) the $\delta\overline{P}_i'$. We have decided to incorporate this shift into our errors as a reflection of the uncertainty due to the introduction of the SCALE factor; we tabulate an error

$$(\delta\overline{P}_i)_{\rm tab} = [(\delta\overline{P}_i')^2 + (\overline{P}_i - \overline{P}_i')^2]^{1/2} ,$$

where $\overline{P}_i$ is the fitted value of the ith partial decay mode before scaling, $\overline{P}_i'$ is its value after all scaling, and $\delta\overline{P}_i'$ is the error in $\overline{P}_i'$. The SCALE factors we finally list in such cases are defined by

$$({\rm SCALE})_i = (\delta\overline{P}_i)_{\rm tab}/\delta\overline{P}_i .$$

However, in line with our policy of not letting SCALE affect the central values, we quote the values of $\overline{P}_i$ obtained from the original (unscaled) fit [which are always less than or equal to one standard deviation from $\overline{P}_i'$, by construction of $(\delta\overline{P}_i)_{\rm tab}$].

D. Discussion

The entire question of averaging data containing discrepant values is nicely discussed by Taylor (1982). He considers a number of algorithms which attempt to incorporate data which are not completely consistent into a meaningful average. Problems occur because it is very difficult to develop a procedure which handles simultaneously in a reasonable way two basic types of situations: (a) data which seem to lie apart from the main body of the data are incorrect (contain unreported errors); and (b) the opposite (the main body of the data is systematically wrong). Unfortunately, as Taylor shows, case (b) is not infrequent. His conclusion is that the choice of procedure is less significant than the initial choice of data to include or exclude.

We place a great emphasis on the choice of data to include or exclude. Unfortunately, the volume of data precludes spending as much time on the problem as we would like. We address this problem by soliciting the help of as many outside experts (consultants) as possible. In the final analysis, however, it is often impossible to determine which (if either) of two discrepant measurements is correct. Our SCALE factor technique is an attempt to address this ignorance by increasing the error above that suggested by least-squares analysis. In effect, we are saying that present experiments do not allow a precise determination of this constant because of unresolvable discrepancies, and one must await further measurements. The reader is warned of this situation by the size of the SCALE factor; he or she is then able to go back to the literature (via the Full Listings) and redo the average as desired.

Our situation with regard to discrepant data is easier to handle than most of the cases Taylor considers, such as estimates of the fundamental constants like $\hbar$, etc. Most of the errors in his case are dominated by systematic effects. In particle properties data, statistical effects are often at least as large as systematic effects, and statistical errors are usually easier to estimate. A notable exception occurs in partial-wave analyses, where different techniques applied to the same data yield different results. In this case, as stated earlier, we often do not attempt an average, but just quote a range of values.

A brief history of Particle Data Group averages is given in Rosenfeld (1975). Updated versions of some of Rosenfeld's figures are shown in Fig. 3. The least-squares error is shown by the thick portion of the error bars; the full error bar exhibits the SCALE factor extension.

Some cases of rather wild fluctuation are shown; this usually represents the introduction of significant new data or the discarding of some older data. Older data are sometimes discarded in favor of more modern data if it is felt that the newer data had fewer systematic errors, had more checks on their systematic errors, made some corrections unknown at the time of the older experiments, or some such reason. Near the time at which a large jump takes place, the SCALE factor sometimes becomes large, reflecting the uncertainty introduced by the new existence of partly inconsistent data.

By and large, a full scan of our history plots shows a rather dull progression toward greater precision at a central value completely consistent with the first data point shown. These plots are available on request from the Berkeley Particle Data Group.

We conclude that the reliability of the combination of experimental data and Particle Data Group averaging procedures is usually good, but it is important to realize that fluctuations outside of the quoted errors can and do occur, perhaps with more frequency than expected for truly Gaussian errors.

ACKNOWLEDGMENTS

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SUMMARY TABLES OF PARTICLE PROPERTIES

April 1986

Particle Data Group

M. Aguilar-Benitez, R.M. Barnett, R.L. Crawford, R.A. Eichler, R. Frosch, G.P. Gopal, K.G. Hayes,
J.J. Hernandez, I. Hinchliffe, G. Höhler, G.R. Lynch, D.M. Manley, L. Montanet, F.C. Porter, J. Primack, A. Rittenberg,
M. Roos, L.D. Roper, R.H. Schindler, K.R. Schubert, T. Shimada, R.E. Shrock, N.A. Törnqvist, T.G. Trippe,
W.P. Trower, C.G. Wohl, G.P. Yost, and B. Armstrong and G.S. Wagman (Technical Associates)

(Closing date for data: Dec. 1, 1985) .

Stable Particle Summary Table

(stable under strong decay)

For additional parameters, see Addendum to this table.

Quantities in italics are new or have changed by more than one (old) standard deviation since April 1984.

Particle	$I^G(J^{PC})$ [a]	Mass [b] (MeV)	Mean life [b] τ (sec) $c\tau$ (cm)	Partial decay modes: Mode	Fraction [b]		p (MeV/c) [c]
			GAUGE BOSONS				
γ	$0,1(1^{--})$	$(<3\times10^{-33})$	-------	stable			
W	$J=1$	81.8 ±1.5 GeV	$\Gamma<6.5$ GeV	$e\nu$ $\mu\nu$	seen seen		40.9 GeV/c 40.9
Z		92.6 ±1.7 GeV	$\Gamma<4.6$ GeV	e^+e^- $\mu^+\mu^-$	seen seen		46.3 GeV/c 46.3
			LEPTONS				
ν_e	$J=\frac{1}{2}$	<46 eV [d]	stable $[\tau>3\times10^8 m_{\nu_e}$ sec (m_{ν_e} in MeV)$]$	stable			
e	$J=\frac{1}{2}$	0.5110034 ±0.0000014 MeV	stable $(>2\times10^{22}$years)	stable			
ν_μ	$J=\frac{1}{2}$	<0.25	stable $[\tau>1.1\times10^5 m_{\nu_\mu}$ sec (m_{ν_μ} in MeV)$]$	stable			
				$\mu^- \to$ (or $\mu^+ \to$chg. conj.)			
μ	$J=\frac{1}{2}$	105.65916	*2.19703*$\times10^{-6}$	$e^-\overline{\nu}\nu$	(100)%		53
		±0.00030	$\pm$*0.00004*	†$[e^-\overline{\nu}\nu\gamma$	[e](1.4 $\pm$ 0.4)%		53
		S=1.1*		$e^-\nu_e\overline{\nu}_\mu$	(<5)%$]$	*LF*	53
			$c\tau=6.5865\times10^4$	$e^-\overline{\nu}\nu e^+e^-$	[e](3.4 $\pm$ 0.4)$\times10^{-5}$		53
				$e^-\gamma$	(<1.7)$\times10^{-10}$	*LF*	53
				$e^-e^+e^-$	(<2.4)$\times10^{-12}$	*LF*	53
				$e^-\gamma\gamma$	(<8.4)$\times10^{-9}$	*LF*	53

Stable Particle Summary Table *(cont'd)*

Particle	$I^G(J^{PC})$ [a]	Mass [b] (MeV)	Mean life [b] τ (sec) $c\tau$ (cm)	Partial decay modes: Mode	Fraction [b]		p (MeV/c) [c]
ν_τ	$J=\frac{1}{2}$	< 70					
				$\tau^- \rightarrow$ (or $\tau^+ \rightarrow$chg. conj.)			
τ	$J=\frac{1}{2}$	1784.2	$(3.3\pm0.4)\times10^{-13}$	particle$^-$ neutrals	(*86.5* ± *0.3*)%		
		±3.2		$\mu^-\bar{\nu}\nu$	(17.6 ± 0.6)%		889
			$c\tau=0.010$	$e^-\bar{\nu}\nu$	(17.4 ± 0.5)%		892
				hadron$^-$ $\geqslant 0\pi^0\nu$	(*51.6* ± *0.7*)%		
				hadron$^-$ ν	(*10.8* ± *1.1*)%		
				$\pi^-\nu$	(10.1 ± 1.1)%		887
				$K^-\nu$	(*0.67* ± *0.17*)%		824
				hadron$^-$ $\geqslant 1\pi^0\nu$	(*40.8* ± *1.3*)%		
				$\rho^-\nu$	(21.8 ± 2.0)%		726
				$\pi^-\pi^0$ (non-res.) ν	(*0.3* ± *0.3*)%		881
				$\pi^-\pi^0\pi^0\nu$	(*6.0* ± *3.5*)%		866
				$\pi^-\pi^0\pi^0\pi^0\nu$	(*3.0* ± *2.7*)%		840
				$K^- \geqslant 1\pi^0\nu$	(*1.0* ± *0.3*)%		
				$\pi^-\pi^-\pi^+ \geqslant 0\pi^0\nu$	(*13.4* ± *0.3*)%		
				$\pi^-\pi^-\pi^+ \geqslant 1\pi^0\nu$	(*5.3* ± *0.8*)%		
				$\pi^-\pi^-\pi^+\nu$	(8.1 ± 0.7)%		865
				$\pi^-\rho^0\nu$	(5.4 ± 1.7)%		718
				$\pi^-\pi^-\pi^+$ (non-res.) ν	(<*1.4*)%		865
				$\pi^-\pi^-\pi^+K^0 \geqslant 0\gamma\nu$	(<*0.27*)%		
				K^- 2charged $\geqslant 0\pi^0\nu$	(<*0.6*)%		
				$K^-\pi^+\pi^- \geqslant 0\pi^0\nu$	(*0.2* ± *0.2*)%		
				$K^+K^-\pi^-\nu$	(*0.2* ± *0.2*)%		690
				$3\pi^-2\pi^+ \geqslant 0\pi^0\nu$	(*0.15* ± *0.04*)%		
				$3\pi^-2\pi^+\nu$	(*0.07* ± *0.03*)%		
				$3\pi^-2\pi^+\pi^0\nu$	(*0.07* ± *0.03*)%		
				†[$K^*(892)^-\nu$	(1.7 ± 0.7)%		669
				$K_2^*(1430)^-\nu$	(<0.9)%]		323

$\tau^- \downarrow$ (or $\tau^+ \rightarrow$chg. conj.)			
e^- chgd.parts. + μ^- chgd.parts.	(<4)%		
$\mu^-\gamma$	(<5.5)$\times10^{-4}$	*LF*	889
$e^-\gamma$	(<6.4)$\times10^{-4}$	*LF*	892
$\mu^-\mu^+\mu^-$	(<4.9)$\times10^{-4}$	*LF*	876
$e^-\mu^+\mu^-$	(<3.3)$\times10^{-4}$	*LF*	886
$\mu^-e^+e^-$	(<4.4)$\times10^{-4}$	*LF*	889
$e^-e^+e^-$	(<4.0)$\times10^{-4}$	*LF*	892
$\mu^-\pi^0$	(<8.2)$\times10^{-4}$	*LF*	884
$e^-\pi^0$	(<2.1)$\times10^{-3}$	*LF*	887
μ^-K^0	(<1.0)$\times10^{-3}$	*LF*	819
e^-K^0	(<1.3)$\times10^{-3}$	*LF*	823
$\mu^-\rho^0$	(<4.4)$\times10^{-4}$	*LF*	722
$e^-\rho^0$	(<3.7)$\times10^{-4}$	*LF*	726

Searches for massive neutrinos and lepton mixing ν bounds from astrophysics and cosmology Heavy lepton searches	} See Addendum and the Stable Particle Full Listings

LIGHT MESONS [a]

$[\pi^+ = u\bar{d},\ \pi^0 = (u\bar{u} - d\bar{d})/\sqrt{2},\ \pi^- = \bar{u}d,\ \eta = c_1(u\bar{u} + d\bar{d}) + c_2(s\bar{s})]$

				$\pi^+ \rightarrow$ (or $\pi^- \rightarrow$chg. conj.)			
$\pi^\pm$	$1^-(0^-)$	*139.5685*	2.6030×10^{-8}	$\mu^+\nu$	100%		30
		±0.0010	±0.0023	$e^+\nu$	(1.228±0.022)$\times10^{-4}$	S=1.8*	70
		S=1.5*		†[$\mu^+\nu\gamma$	[e](1.24 ±0.25)$\times10^{-4}$		30
			$c\tau=780.4$	$e^+\nu\gamma$	[e](5.6 ±0.7)$\times10^{-8}$]		70
				$e^+\nu\pi^0$	(1.025±0.034)$\times10^{-8}$		5
		$m_{\pi^\pm}-m_{\mu^\pm}$ =*33.9093*		$e^+\nu e^+e^-$	(<5)$\times10^{-9}$		70
		±0.0011		$\mu^+\bar{\nu}_e$	(<1.5)$\times10^{-3}$		30
		S=1.6*		$\mu^+\nu_e$	(<8)$\times10^{-3}$	*LF*	30
π^0	$1^-(0^{-+})$	134.9642	0.87×10^{-16}	$\gamma\gamma$	(98.799 ±0.030)%		67
		±0.0038	±0.04 S=1.8*	γe^+e^-	(1.198)%		67
				$e^+e^-e^+e^-$	[f](3.24)$\times10^{-5}$		67
		$m_{\pi^\pm}-m_{\pi^0}$ =4.6043	$c\tau=2.6\times10^{-6}$	$\gamma\gamma\gamma$	(<3.8)$\times10^{-7}$	*C*	67
		±0.0037		$\gamma\gamma\gamma\gamma$	(<4)$\times10^{-6}$		67
				e^+e^-	(1.8 ± 0.7)$\times10^{-7}$		67
				$\nu\nu$	(<2.4)$\times10^{-5}$		67
				$\mu^+e^- + \mu^-e^+$	(<7)$\times10^{-8}$	*LF*	26

Stable Particle Summary Table *(cont'd)*

Particle	$I^G(J^{PC})$ [a]	Mass [b] (MeV)	Mean life [b] τ (sec) $c\tau$ (cm)	Partial decay modes Mode	Fraction [b]		p (MeV/c) [c]
η	$0^+(0^{-+})$	548.8	$\Gamma=(1.05\pm0.15)$ keV	$\gamma\gamma$	$(38.9\pm0.4)\%$		274
		±0.6	S=1.7*	$3\pi^0$	$(31.90\pm0.35)\%$		180
		S=1.4*	Neutral decays	$\pi^0\gamma\gamma$	$(0.078\pm0.012)\%$		258
			$(70.9\pm0.6)\%$	$\gamma\gamma\gamma$	$(<5)\times10^{-4}$	*C*	274
				$\pi^+\pi^-\pi^0$	$(23.7\pm0.5)\%$		175
				$\pi^+\pi^-\gamma$	$(4.91\pm0.13)\%$		236
				$e^+e^-\gamma$	$(0.50\pm0.12)\%$		274
				$\mu^+\mu^-\gamma$	$(3.1\pm0.4)\times10^{-4}$		253
				e^+e^-	$(<3)\times10^{-4}$		274
				$\mu^+\mu^-$	$(6.5\pm2.1)\times10^{-6}$		253
			Charged decays	$\pi^+\pi^-e^+e^-$	$(0.13\pm0.13)\%$		236
			$(29.1\pm0.6)\%$	$\pi^+\pi^-\gamma\gamma$	$(<0.21)\%$		236
				$\pi^+\pi^-\pi^0\gamma$	$(<6)\times10^{-4}$		175
				$\pi^+\pi^-$	$(<0.15)\%$	*P*, *CP*	236
				$\pi^0e^+e^-$	$(<5)\times10^{-5}$	*C*	258
				$\pi^0\mu^+\mu^-$	$(<5)\times10^{-6}$	*C*	211
				$\pi^0\mu^+\mu^-\gamma$	$(<3)\times10^{-6}$		211
		STRANGE MESONS [a]		$[K^+=u\bar{s},\ K^0=d\bar{s},\ \bar{K}^0=\bar{d}s,\ K^-=\bar{u}s]$			
				$K^+\rightarrow$ (or $K^-\rightarrow$chg. conj.)			
$K^\pm$	$\frac{1}{2}(0^-)$	493.667	1.2371×10^{-8}	$\mu^+\nu$	$(63.51\pm0.16)\%$		236
		±0.014	±0.0026 S=1.9*	$\pi^+\pi^0$	$(21.17\pm0.15)\%$		205
				$\pi^+\pi^+\pi^-$	$(5.59\pm0.03)\%$	S=1.1*	125
			$c\tau$=370.9	$\pi^+\pi^0\pi^0$	$(1.73\pm0.05)\%$	S=1.4*	133
				$\pi^0\mu^+\nu$	$(3.18\pm0.10)\%$	S=1.9*	215
		$m_{K^0}-m_{K^\pm}=4.05$		$\pi^0e^+\nu$	$(4.82\pm0.05)\%$	S=1.1*	228
		±0.07		†[$\mu^+\nu\gamma$	$^{e}(5.4\pm0.3)\times10^{-3}$		236
				$\mu^+\nu\gamma$ (SD+)^{g}	$(<3.0)\times10^{-5}$		236
				$\pi^+\pi^0\gamma$	$^{h,e}(2.75\pm0.16)\times10^{-4}$		205
				$\pi^+\pi^+\pi^-\gamma$	$^{e}(1.0\pm0.4)\times10^{-4}$		125
				$\pi^0\mu^+\nu\gamma$	$^{e}(<6)\times10^{-5}$		215
				$\pi^0e^+\nu\gamma$	$^{e}(3.7\pm1.4)\times10^{-4}$]		228
				$\pi^0\pi^0e^+\nu$	$(1.8\,^{+2.4}_{-0.6})\times10^{-5}$		207
				$\pi^+\pi^-e^+\nu$	$(3.90\pm0.15)\times10^{-5}$		203
				$\pi^+\pi^+e^-\bar{\nu}$	$(<1.2)\times10^{-8}$	*SQ*	203
				$\pi^+\pi^-\mu^+\nu$	$(1.4\pm0.9)\times10^{-5}$		151
				$\pi^+\pi^+\mu^-\bar{\nu}$	$(<3.0)\times10^{-6}$	*SQ*	151
				$e^+\nu$	$(1.54\pm0.07)\times10^{-5}$		247
				$e^+\nu\gamma$ (SD+)^{g}	$(1.52\pm0.23)\times10^{-5}$		247
				$e^+\nu\gamma$ (SD−)^{g}	$(<1.6)\times10^{-4}$		247
				$\pi^+e^+e^-$	$(2.7\pm0.5)\times10^{-7}$	*FC*	227
				$\pi^-e^+e^+$	$(<1)\times10^{-8}$	*L*	227
				$\pi^+\mu^+\mu^-$	$(<2.4)\times10^{-6}$	*FC*	172
				$\pi^+\gamma\gamma$	$^{e}(<8)\times10^{-6}$		227
				$\pi^+\gamma\gamma\gamma$	$^{e}(<1.0)\times10^{-4}$		227
				$\pi^+\nu\bar{\nu}$	$(<1.4)\times10^{-7}$	*FC*	227
				$\pi^\mp e^+\mu^\pm$	$(<7)\times10^{-9}$	*LF*, or *L*	214
				$\pi^+e^-\mu^+$	$(<5)\times10^{-9}$	*LF*	214
				$e^+\nu\nu\bar{\nu}$	$(<6)\times10^{-5}$		247
				$\mu^+\nu\nu\bar{\nu}$	$(<6)\times10^{-6}$		236
				$\mu^+\nu e^+e^-$	$(11\pm3)\times10^{-7}$		236
				$\mu^-\nu e^+e^+$	$(<2.0)\times10^{-8}$	*LF*	236
				$e^+\nu e^+e^-$	$(2\,^{+2}_{-1})\times10^{-7}$		247
				$\mu^+\nu_e$	$(<4)\times10^{-3}$	*LF*	236
				$\mu^+\bar{\nu}_e$	$(<3.3)\times10^{-3}$	*L*	236
				$\pi^0e^+\bar{\nu}_e$	$(<3)\times10^{-3}$	*L*	228

Stable Particle Summary Table *(cont'd)*

Particle	$I(J^P)$ [a]	Mass [b] (MeV)	Mean life [b] τ (sec) $c\tau$ (cm)	Partial decay modes			
				Mode	Fraction [b]		p (MeV/c) [c]
K^0 $\overline{K}^0$	$\frac{1}{2}(0^-)$	497.72 ±0.07 S=1.4*		50 % K_S, 50% K_L			
K_S^0	$\frac{1}{2}(0^-)$		0.8923×10^{-10}	$\pi^+\pi^-$	$(68.61 \pm 0.24)\%$	S=1.1*	206
			±0.0022	$\pi^0\pi^0$	$(31.39)\%$		209
				†[$\pi^+\pi^-\gamma$	[e] $(1.85 \pm 0.10)\times10^{-3}$]		206
			$c\tau$=2.675	$\mu^+\mu^-$	$(<3.2)\times10^{-7}$	FC	225
				e^+e^-	$(<3.4)\times10^{-4}$	FC	249
				$\gamma\gamma$	$(<4)\times10^{-4}$		249
				$\pi^+\pi^-\pi^0$	$(<4.9)\times10^{-5}$		133
				$\pi^0\pi^0\pi^0$	$(<3.7)\times10^{-5}$		139
K_L^0	$\frac{1}{2}(0^-)$		5.183×10^{-8}	$\pi^0\pi^0\pi^0$	$(21.5 \pm 1.0)\%$	S=1.7*	139
			±0.040	$\pi^+\pi^-\pi^0$	$(12.40 \pm 0.20)\%$	S=1.3*	133
				$\pi^\pm\mu^\mp\nu$	$(27.1 \pm 0.4)\%$	S=1.4*	216
			$c\tau$=1554	$\pi^\pm e^\mp\nu$	$(38.7 \pm 0.6)\%$	S=1.5*	229
				$\pi^+\pi^-$	[i] $(0.203 \pm 0.005)\%$	S=1.1*	206
		$m_{K_L} - m_{K_S} = 0.5349\times10^{10}\ \hbar\ sec^{-1}$		$\pi^0\pi^0$	[i] $(0.094 \pm 0.019)\%$	S=1.5*	209
		±0.0022		†[$\pi e\nu\gamma$	[e] $(1.3 \pm 0.8)\%$		229
		$= 3.521\times10^{-12}$ MeV		$\pi^+\pi^-\gamma$	[e] $(4.41 \pm 0.32)\times10^{-5}$]		206
		±0.014		$\pi^0\gamma\gamma$	$(<2.4)\times10^{-4}$		231
				$\gamma\gamma$	$(4.9 \pm 0.4)\times10^{-4}$		249
				$e\mu$	[j] $(<6)\times10^{-6}$	LF	238
				$\mu^+\mu^-$	$(9.1 \pm 1.9)\times10^{-9}$	FC	225
				$\mu^+\mu^-\gamma$	$(2.8 \pm 2.8)\times10^{-7}$	FC	225
				$\pi^0\mu^+\mu^-$	$(<1.2)\times10^{-6}$	FC	177
				e^+e^-	[j] $(<2.0)\times10^{-7}$	FC	249
				$e^+e^-\gamma$	$(1.7 \pm 0.9)\times10^{-5}$	FC	249
				$\pi^0e^+e^-$	$(<2.3)\times10^{-6}$	FC	231
				$\pi^+\pi^-e^+e^-$	$(<2.5)\times10^{-6}$	FC	206
				$\pi^0\pi^\pm e^\mp\nu$	$(6.2 \pm 2.0)\times10^{-5}$		207
				$(\pi\mu$ atom$)\ \nu$	$(1.05 \pm 0.11)\times10^{-7}$		216
				$\mu^+\mu^-e^+e^-$	$(<5)\times10^{-6}$	FC	225
				$e^+e^-e^+e^-$	$(<2.6)\times10^{-6}$	FC	249
CHARMED MESONS [a]				$[D^+ = c\bar{d},\ D^0 = c\bar{u},\ \overline{D}^0 = \bar{c}u,\ D^- = \bar{c}d;\ D_s^+ = c\bar{s},\ D_s^- = \bar{c}s]$			
				[k] $D^+ \to$ (or $D^- \to$ chg. conj.)			
$D^\pm$	$\frac{1}{2}(0^-)$	1869.3	$(9.2^{+1.3}_{-1.0})\times10^{-13}$	e^+ anything	$(18.2 \pm 1.7)\%$		
		±0.6	$c\tau$=0.028	K^- anything	$(16 \pm 4)\%$		
				K^+ anything	$(6.0 \pm 3.3)\%$		
		$m_{D^\pm} - m_{D^0}$= 4.7		$\overline{K}^0$ any + K^0 any	$(48 \pm 15)\%$		
		±0.3		η anything	[ℓ] $(<13)\%$		
				$e^+\nu$	$(<2.5)\%$		935
				$\mu^+\nu$	$(<2)\%$		932
				$\pi^+\pi^0$	$(<0.5)\%$		925
				$\pi^+\pi^+\pi^-$	$(0.5 \pm 0.2)\%$		908
				†[$K^-\pi^+\pi^+$	$(11.4 \pm 1.1)\%$		845
				$K^-\pi^+\pi^+\pi^0$	$(6.4 \pm 1.5)\%$		816
				$K^-\pi^+\pi^+\pi^+\pi^-$	$(<6)\%$		772
				$\overline{K}^0\pi^+$	$(4.1 \pm 0.6)\%$		862
				$\overline{K}^0\pi^+\pi^0$	$(13.4 \pm 3.3)\%$		845
				$\overline{K}^0\pi^+\pi^+\pi^-$	$(15.2 \pm 5.8)\%$		814
				$\overline{K}^0K^+$	$(1.2 \pm 0.4)\%$		792
				$K^+K^-\pi^+$	$(<1.6)\%$		744
				$K^+\pi^+\pi^-$	$(<0.6)\%$]		845
				†[$\overline{K}^*(892)^0\pi^+$	$(<6.6)\%$		713
				$K^+K^-\pi^+$ (non-res.)	$(0.7 \pm 0.3)\%$		744
				$\phi\pi^+$	$(1.0 \pm 0.3)\%$		647
				$\overline{K}^*(892)^0K^+$	$(0.5 \pm 0.3)\%$]		613

Stable Particle Summary Table *(cont'd)*

Particle	$I(J^P)$ [a]	Mass [b] (MeV)	Mean life [b] τ (sec) $c\tau$ (cm)	Partial decay modes: Mode	Fraction [b]		p (MeV/c) [c]
				[k] $D^0 \rightarrow$ (or $\overline{D}^0 \rightarrow$ chg. conj.)			
$\mathbf{D^0}$ $\mathbf{\overline{D}^0}$	$\frac{1}{2}(0^-)$	1864.6 ± 0.6	$(4.3^{+0.5}_{-0.4})\times10^{-13}$ $c\tau$=0.013	e^+ anything	$(7.0 \pm 1.1)\%$		
				K^- anything	$(44 \pm 10)\%$	S=1.3*	
	$\lvert m_{D^0_1} - m_{D^0_2} \rvert < 6.5\times10^{-10}$ MeV [m]			K^+ anything	$(8 \pm 3)\%$		
				$\overline{K}^0$ any+ K^0 any	$(33 \pm 10)\%$		
	$\lvert \tau_{D^0_1} - \tau_{D^0_2} \rvert$ / average < 0.55 [m]			η anything	[ℓ] $(< 13)\%$		
				$\pi^+\pi^-$	$(0.18 \pm 0.05)\%$		922
	$\Gamma(D^0 \rightarrow \overline{D}^0 \rightarrow \mu^-$ any$)$ / $\Gamma(D^0 \rightarrow \mu^\pm$ any$)$ < 0.044			$\pi^+\pi^+\pi^-\pi^-$	$(1.5 \pm 0.6)\%$		880
				$\mu^+\mu^-$	$(<3.4)\times10^{-4}$	FC	926
				$\pi^+\pi^-\pi^0$	$(1.1 \pm 0.4)\%$		907
				†[$K^-\pi^+$	$(5.4 \pm 0.4)\%$		861
				$K^-\pi^+\pi^0$	$(17.3 \pm 1.7)\%$		844
				$K^-\pi^+\pi^+\pi^-$	$(10.9 \pm 1.0)\%$		812
				$K^-\pi^+\pi^0\pi^0$	(seen)		815
				$\overline{K}^0\pi^0$	$(4.0 \pm 1.8)\%$		860
				$\overline{K}^0\pi^+\pi^-$	$(8.5 \pm 1.4)\%$		842
				K^+K^-	$(0.64 \pm 0.11)\%$		791
				$\overline{K}^0K^0$	$(<0.6)\%$		788
				$\overline{K}^0K^+K^-$	$(1.6 \pm 0.5)\%$		544
				$K^0K^-\pi^+$ (non-res.) + c.c.	$(<1.6)\%$		739
				$\overline{K}^*(892)^0K^0$ + c.c.	$(<0.7)\%$		607
				$K^*(892)^-K^+$ + c.c.	$(1.1 \pm 0.5)\%$]		609
				[k] $D^0 \rightarrow$ (or $\overline{D}^0 \rightarrow$ chg. conj.)			
				†[$K^*(892)^-\pi^+$	$(7.1 \pm 2.5)\%$		711
				$\overline{K}^{*0}\pi^0$	$(2.3 \pm 2.1)\%$		711
				$K^-\rho^+$	$(9.9 \pm 3.5)\%$		679
				$\overline{K}^0\rho^0$	$(0.1 {}^{+0.9}_{-0.1})\%$		677
				$K^-\pi^+\pi^0$ (non-res.)	$(<4.3)\%$		844
				$\overline{K}^0\pi^+\pi^-$ (non-res.)	$(2.0 \pm 1.7)\%$		842
				$\overline{K}^*(892)^0\rho^0$	$(1.6 \pm 1.6)\%$		423
				$K^-\pi^+\rho^0$	$(9.3 {}^{+1.5}_{-2.6})\%$		613
				$\overline{K}^*(892)^0\pi^+\pi^-$	$(<2.9)\%$		685
				$K^-a_2(1320)^+$	$(<1.9)\%$		198
				$\overline{K}^0\phi$	$(1.5 \pm 0.4)\%$		520
				$\overline{K}^0K^+K^-$ (non-res.)	$(1.1 \pm 0.5)\%$]		544
				$D_s^+ \rightarrow$ (or $D_s^- \rightarrow$ chg. conj.)			
$\mathbf{D_s^\pm}$ *was* $F^\pm$	$0(0^-)$ [n]	1970.5 [n] ± 2.5 S=1.2*	$(2.8^{+1.6}_{-0.7})\times10^{-13}$ $c\tau$=0.008	$\phi\pi^+$	(seen)		713
				$\phi\pi^+\pi^+\pi^-$	(*seen*)		641
				$\eta\pi^+$	(possibly seen)		903
				$\eta\pi^+\pi^+\pi^-$	(possibly seen)		857
				$\eta'\pi^+\pi^+\pi^-$	(possibly seen)		679
				$\phi\rho^+$	(possibly seen)		411
BOTTOM MESONS [a]				$[B^+ = u\overline{b},\ B^0 = d\overline{b},\ \overline{B}^0 = \overline{d}b,\ B^- = \overline{u}b]$			
				$B^+ \rightarrow$ (or $B^- \rightarrow$ chg. conj.)			
$\mathbf{B^\pm}$	$\frac{1}{2}(0^-)$ [p]	5271.2 ± 3.0		$\overline{D}^0\pi^+$	$(1.1 \pm 0.6)\%$		2303
				$D^*(2010)^-\pi^+\pi^+$	$(2.7 \pm 1.7)\%$		2243
	$m_{B^0} - m_{B^\pm}$	=4.0 ± 3.4		$J/\psi(3097)K^+$	$(<2.6)\times10^{-3}$		1678
				$\rho^0\pi^+$	$(<6)\times10^{-4}$		2578
				$B^0 \rightarrow$ (or $\overline{B}^0 \rightarrow$ chg. conj.)			
$\mathbf{B^0}$ $\mathbf{\overline{B}^0}$	$\frac{1}{2}(0^-)$ [p]	5275.2 ± 2.8		$\overline{D}^0\pi^+\pi^-$	$(7 \pm 5)\%$		2299
				$D^*(2010)^-\pi^+$	$(1.7 \pm 0.7)\%$		2253
				$D^*(2010)^-\rho^+$	$(8 {}^{+7}_{-4})\%$		2180
				$J/\psi(3097)K^+\pi^-$	$(<6.3)\times10^{-3}$		1649
				$\pi^+\pi^-$	$(<5)\times10^{-4}$		2634
				e^+e^-	$(<3)\times10^{-4}$	FC	2638
				$\mu^+\mu^-$	$(<2)\times10^{-4}$	FC	2635
				$e^+\mu^-$ + c.c.	$(<3)\times10^{-4}$	LF	2637
$\mathbf{B^\pm, B^0, \overline{B}^0}$ (not separated) [q]			$(14.2 \pm 2.7)\times10^{-13}$ $c\tau$=0.043	$e^\pm\nu$ hadrons	$(12.3 \pm 0.8)\%$		
				$\mu^\pm\nu$ hadrons	$(11.0 \pm 0.9)\%$		
	$\dfrac{\Gamma(B \rightarrow \overline{B} \rightarrow \ell^-\text{ any})}{\Gamma(B \rightarrow \ell^\pm\text{ any})} < 0.12$			D^0 anything	$(80 \pm 28)\%$		
				K anything	(seen)		
				p anything	$(>3.6)\%$		
				Λ anything	$(>2.2)\%$		
	$\dfrac{\Gamma(B \rightarrow e^\pm\nu\text{ noncharm-hadrons})}{\Gamma(B \rightarrow e^\pm\nu\text{ hadrons})} < 0.04$			e^+e^- anything	$(<0.6)\%$		
				$\mu^+\mu^-$ anything	$(<0.6)\%$		
				$J/\psi(3097)$ anything	$(1.2 \pm 0.3)\%$		
				$D^*(2010)^\pm$ anything	$(23 \pm 9)\%$		

Stable Particle Summary Table *(cont'd)*

Particle	$I(J^P)$ [a]	Mass [b] (MeV)	Mean life [b] τ (sec) $c\tau$ (cm)	Partial decay modes Mode	 Fraction [b]	 p (MeV/c) [c]
			NUCLEONS [a]	$[p = uud,\ n = udd]$		
p	$\frac{1}{2}(\frac{1}{2}^+)$	938.2796	stable	Partial mean lifetimes of protons (units 10^{30} yr)	Partial mean lifetimes of bound neutrons (units 10^{30} yr)	
		± 0.0027	($> 1.6\times10^{25}$ yr or			
			$> 10^{31} - 3\times10^{32}$ yr)[r]	e^+ anything > 0.6	$\nu\gamma$ > 11	
	$\lvert q_p\rvert - \lvert q_e\rvert$	$< 10^{-21}\lvert q_e\rvert$ [s]		μ^+ anything > 12	$e^+\pi^-$ > 25	
				$e^+\gamma$ > 360	$\mu^+\pi^-$ > 38	
				$\mu^+\gamma$ > 280	e^+K^- > 1.3	
				$e^+\pi^0$ > 250	μ^+K^- > 0.4	
				$\mu^+\pi^0$ > 100	$\nu\pi^0$ > 7	
				e^+K^0 > 77	νK^0 > 10	
				μ^+K^0 > 40	$e^+\rho^-$ > 12	
				$\nu\pi^+$ > 5.8	$\mu^+\rho^-$ > 9	
				νK^+ > 9.6	$\nu K^*(892)^0$ > 7	
				$e^+\omega$ > 37	$\nu\nu\nu$ > 0.0005	
				$\mu^+\omega$ > 23	$e^+\pi^0$ any > 0.6	
				$e^+\rho^0$ > 17	$\nu\eta$ > 18	
				$\mu^+\rho^0$ > 16	$\nu\rho^0$ > 2	
				$e^+e^+e^-$ > 510	$\nu\omega$ > 16	
				$\mu^+\mu^+\mu^-$ > 190	$e^+e^-\nu$ > 26	
				$\nu K^*(892)^+$ > 9.6	$\mu^+\mu^-\nu$ > 19	
				$e^+\pi^0$ any > 0.6	$e^-\pi^+$ > 25	
				$e^+\eta$ > 200	$\mu^-\pi^+$ > 27	
				$\mu^+\eta$ > 46	$e^-\rho^+$ > 12	
				$\nu\rho^+$ > 8.4	$\mu^-\rho^+$ > 9	
n	$\frac{1}{2}(\frac{1}{2}^+)$	939.5731	898 ± 16	$pe^-\bar{\nu}$	100%	1.2
		± 0.0027	S=2.4*	$p\nu\bar{\nu}$	(<9)$\times10^{-24}$ Q	1.3
			$c\tau=2.7\times10^{13}$			
	$m_n - m_p$	$=1.293323$				
		± 0.000016				
	$\lvert q_n\rvert$	$< 10^{-21}\lvert q_e\rvert$ [s]				
			STRANGENESS −1 BARYONS [a]	$[\Lambda = uds,\ \Sigma^+ = uus,\ \Sigma^0 = uds,\ \Sigma^- = dds]$		
Λ	$0(\frac{1}{2}^+)$	1115.60	2.632×10^{-10}	$p\pi^-$	(64.2 ± 0.5)%	100
		± 0.05	± 0.020 S=1.6*	$n\pi^0$	(35.8)%	104
		S=1.2*		$pe^-\nu$	(8.35 ± 0.14)$\times10^{-4}$	163
			$c\tau=7.89$	$p\mu^-\nu$	(1.57 ± 0.35)$\times10^{-4}$	131
	$m_{\Sigma^0} - m_\Lambda$	$=76.86$		†[$p\pi^-\gamma$	[e](8.5 ± 1.4)$\times10^{-4}$]	100
		± 0.08				
$\boldsymbol{\Sigma^+}$	$1(\frac{1}{2}^+)$	1189.37	0.800×10^{-10}	$p\pi^0$	(51.64 ± 0.30)%	189
		± 0.06	± 0.004	$n\pi^+$	(48.36)%	185
		S=1.8*		$p\gamma$	(1.22 ± 0.10)$\times10^{-3}$ S=1.1*	225
			$c\tau=2.40$	†[$n\pi^+\gamma$	[e](4.5 ± 0.5)$\times10^{-4}$]	185
				$\Lambda e^+\nu$	(2.0 ± 0.5)$\times10^{-5}$	71
	$m_{\Sigma^-} - m_{\Sigma^+}$	$=7.97$	$\dfrac{\Gamma(\Sigma^+\to\ell^+n\nu)}{\Gamma(\Sigma^-\to\ell^-n\nu)} < 0.04$	$n\mu^+\nu$	(<3.0)$\times10^{-5}$ SQ	202
		± 0.07		$ne^+\nu$	(<5)$\times10^{-6}$ SQ	224
		S=1.3*		pe^+e^-	(<7)$\times10^{-6}$ FC	225
$\boldsymbol{\Sigma^0}$	$1(\frac{1}{2}^+)$[t]	1192.46	5.8×10^{-20}	$\Lambda\gamma$	100%	74
		± 0.08	± 1.3	Λe^+e^-	[f](5.45)$\times10^{-3}$	74
			$c\tau=1.7\times10^{-9}$	$\Lambda\gamma\gamma$	(<3)%	74
$\boldsymbol{\Sigma^-}$	$1(\frac{1}{2}^+)$	1197.34	1.482×10^{-10}	$n\pi^-$	100%	193
		± 0.05	± 0.011 S=1.3*	$ne^-\nu$	(1.022 ± 0.034)$\times10^{-3}$	230
				$n\mu^-\nu$	(4.5 ± 0.4)$\times10^{-4}$	210
	$m_{\Sigma^-} - m_{\Sigma^0}$	$=4.88$	$c\tau=4.44$	$\Lambda e^-\nu$	(5.74 ± 0.27)$\times10^{-5}$	79
		± 0.06		†[$n\pi^-\gamma$	[e](4.6 ± 0.6)$\times10^{-4}$]	193

Stable Particle Summary Table *(cont'd)*

Particle	$I(J^P)$ [a]	Mass [b] (MeV)	Mean life [b] τ (sec) $c\tau$ (cm)	Partial decay modes: Mode	Fraction [b]		p (MeV/c) [c]
STRANGENESS −2 BARYONS [a]					$[\Xi^0 = uss,\ \Xi^- = dss]$		
Ξ^0	$\frac{1}{2}(\frac{1}{2}^+)^t$	1314.9	2.90×10^{-10}	$\Lambda\pi^0$	100%		135
		±0.6	±0.10	$\Lambda\gamma$	(0.5 ± 0.5)%		184
				$\Sigma^0\gamma$	(<7)%		117
			$c\tau$=8.69	$p\pi^-$	$(<3.6)\times10^{-5}$	ΔS	299
				$pe^-\nu$	$(<1.3)\times10^{-3}$	ΔS	323
	$m_{\Xi^-}-m_{\Xi^0}$=6.4			$\Sigma^+e^-\nu$	$(<1.1)\times10^{-3}$		120
		±0.6		$\Sigma^-e^+\nu$	$(<0.9)\times10^{-3}$	SQ	112
				$\Sigma^+\mu^-\nu$	$(<1.1)\times10^{-3}$		65
				$\Sigma^-\mu^+\nu$	$(<0.9)\times10^{-3}$	SQ	49
				$p\mu^-\nu$	$(<1.3)\times10^{-3}$	ΔS	309
Ξ^-	$\frac{1}{2}(\frac{1}{2}^+)^t$	1321.32	1.642×10^{-10}	$\Lambda\pi^-$	100%		139
		±0.13	±0.015	$\Lambda e^-\nu$	$(5.5 \pm 0.6)\times10^{-4}$	S=2.0*	190
				$\Sigma^0e^-\nu$	$(8.7 \pm 1.7)\times10^{-5}$		123
			$c\tau$=4.92	$\Lambda\mu^-\nu$	$(3.5 \pm 3.5)\times10^{-4}$		163
				$\Sigma^0\mu^-\nu$	$(<8)\times10^{-4}$		70
				$n\pi^-$	$(<1.9)\times10^{-5}$	ΔS	303
				$ne^-\nu$	$(<3.2)\times10^{-3}$	ΔS	327
				$n\mu^-\nu$	$(<1.5)\times10^{-2}$	ΔS	313
				$\Sigma^-\gamma$	$(<1.2)\times10^{-3}$		118
				$p\pi^-\pi^-$	$(<4)\times10^{-4}$	ΔS	223
				$p\pi^-e^-\nu$	$(<4)\times10^{-4}$	ΔS	304
				$p\pi^-\mu^-\nu$	$(<4)\times10^{-4}$	ΔS	250
				$\Xi^0e^-\nu$	$(<2.3)\times10^{-3}$		6
STRANGENESS −3 BARYON [a]					$[\Omega^- = sss]$		
Ω^-	$0(\frac{3}{2}^+)^t$	1672.45	0.822×10^{-10}	ΛK^-	(67.8 ± 0.7)%		211
		±0.29	±0.013	$\Xi^0\pi^-$	(23.6 ± 0.7)%		294
				$\Xi^-\pi^0$	(8.6 ± 0.4)%		290
			$c\tau$=2.46	$\Xi^0e^-\nu$	$(5.6 \pm 2.8)\times10^{-3}$		319
				$\Xi(1530)^0\pi^-$	$(6.4\,^{+5.1}_{-2.0})\times10^{-4}$		
				$\Lambda\pi^-$	$(<1.9)\times10^{-4}$	ΔS	449
				$\Xi^-\gamma$	$(<2.2)\times10^{-3}$		314
				$\Xi^-\pi^+\pi^-$	$(4.3\,^{+3.4}_{-1.3})\times10^{-4}$		190
CHARMED BARYON [a]					$[\Lambda_c^+ = udc]$		
Λ_c^+	$0(\frac{1}{2}^+)^t$	2281.2	$(2.3^{+0.8}_{-0.5})\times10^{-13}$	$pK^-\pi^+$	(2.2 ± 1.0)%		820
		±3.0		$p\bar{K}^0$	(1.1 ± 0.7)%		870
		S=1.9*	$c\tau$=0.007	$p\bar{K}^0\pi^+\pi^-$	(<4, seen)%		751
				Λ anything	(33 ±29)%		
				†[$\Lambda\pi^+$	(0.6 ± 0.5)%		861
				$\Lambda\pi^+\pi^+\pi^-$	(< 3.1, seen)%		804
				$\Sigma^0\pi^+$	(seen)]		822
				†[pK^{*0}	(0.48 ± 0.30)%		681
				$\Delta^{++}K^-$	(0.45 ± 0.27)%		706
				$pK^{*-}\pi^+$	(seen)]		575
				e^+ anything	(4.5 ± 1.7)%		
				†[pe^+ anything	(1.8 ± 0.9)%		
				Λe^+ anything	(1.1 ± 0.8)%]		

Ξ_c^+ [*was* A^+]
Ω_c^0
Λ_b^0
} Not established; see the Stable Particle Full Listings

Searches for top hadrons, free quarks, magnetic monopoles, axions, supersymmetric particles, and other stable particles } See Addendum and the Stable Particle Full Listings

ADDENDUM TO

Stable Particle Summary Table

e[u] **Magnetic moment**

1.001 159 652 209 ± 0.000 000 000 031 $\frac{e\hbar}{2m_ec}$

μ[u] 1.001 165 923 ± 0.000 000 009 $\frac{e\hbar}{2m_\mu c}$

μ decay parameters[v]

$\rho = -0.752\pm0.003$

$\delta = 0.755\pm0.009$

$\xi'' = 0.65\pm0.36$

$\alpha/A = (0.4\pm4.3)\times10^{-3}$

$\beta/A = (3.9\pm6.2)\times10^{-3}$

$\bar{\eta} = 0.016\pm0.076$

$\eta = -0.007\pm0.079$

$\xi' = 0.998\pm0.042$

$\xi P_\mu\delta/\rho > 0.9966$[w]

$\alpha'/A = (-0.2\pm4.3)\times10^{-3}$

$\beta'/A = (1.5\pm6.3)\times10^{-3}$

τ **Michel parameter**

$\rho = 0.71\pm0.08$

η

Mode	Left-right asymmetry	Sextant asymmetry	Quadrant asymmetry
$\pi^+\pi^-\pi^0$	$(0.12\pm0.17)\%$	$(0.19\pm0.16)\%$	$(-0.17\pm0.17)\%$
$\pi^+\pi^-\gamma$	$(0.88\pm0.40)\%$		$\beta=0.047\pm0.062$ S=1.5*

K **Slope parameters for $K\to3\pi$**[x]

$K^+\to\pi^+\pi^+\pi^-$	$g=-0.215\pm0.004$	S=1.4*
$K^-\to\pi^-\pi^-\pi^+$	$g=-0.217\pm0.007$	S=2.5*
$K^\pm\to\pi^0\pi^0\pi^\pm$	$g=0.607\pm0.030$	S=1.3*
$K_L^0\to\pi^+\pi^-\pi^0$	$g=0.670\pm0.014$	S=1.6*

See Full Listings for quadratic coefficients.

Form factors for $K_{\ell3}$ decays[v]

K_{e3}^+:
- $\lambda_+ = 0.029\pm0.004$
- $|f_S/f_+| = 0.13\pm0.04$ S=1.3*
- $|f_T/f_+| = 0.22\pm0.14$

K_{e3}^0:
- $\lambda_+ = 0.0300\pm0.0016$ S=1.2*
- $|f_S/f_+| < 0.04$
- $|f_T/f_+| < 0.23$

$K_{\mu3}^+$:
- $\lambda_+ = 0.033\pm0.008$ S=1.6*
- $\lambda_0 = 0.004\pm0.007$ S=1.6*
- $|f_T/f_+| = 0.02\pm0.12$

$K_{\mu3}^0$:
- $\lambda_+ = 0.034\pm0.005$ S=2.3*
- $\lambda_0 = 0.025\pm0.006$ S=2.3*
- $|f_T/f_+| = 0.12 \pm 0.12$

$\Delta S = -\Delta Q$ in $K_{\ell3}^0$ decay

Re $x = 0.009\pm0.020$ S=1.4*

Im $x = -0.004\pm0.026$ S=1.1*

CP-violation parameters[y,i]

$|\eta_{+-}| = (2.275\pm0.021)\times10^{-3}$ $\left|\frac{\epsilon'}{\epsilon}\right| = (-3\pm4)\times10^{-3}$

$|\eta_{00}| = (2.299\pm0.036)\times10^{-3}$

$\phi_{+-} = (44.6\pm1.2)°$ $\phi_{00} = (54\pm5)°$ Re $\epsilon = (1.621\pm0.088)\times10^{-3}$

$|\eta_{+-0}|^2<0.12$ $|\eta_{000}|^2<0.1$ $\delta = (0.330\pm0.012)\%$

	Magnetic moment $(e\hbar/2m_pc)$	**Decay parameters**[z]					
			Measured		Derived		Coupling constant ratios
			α	ϕ(degree)	γ	Δ(degree)	
p[u]	*2.7928444* *±0.0000011*						
n[u]	*−1.91304308* *±0.00000054*	$pe^-\nu$					$g_A/g_V=-1.254\pm0.006$ $\phi_{AV}=(180.11\pm0.17)°$
Λ[u]	−0.613 ±0.004	$p\pi^-$	+0.642±0.013	−6.5±3.5	0.76	7.7±4.1	
		$n\pi^0$	+0.646±0.044				
		$pe^-\nu$					$g_A/g_V=-0.694\pm0.025$ S=1.3*
Σ⁺	2.379 ±0.020	$p\pi^0$	−0.980±0.015	36±34	0.16	187±6	
		$n\pi^+$	+0.068±0.013	167±20 S=1.1*	−0.97	-73^{+134}_{-10}	
		$p\gamma$	−0.72 ±0.29				
Σ⁻	−1.14 ±0.05 S=1.9*	$n\pi^-$	−0.068±0.008	10±15	0.98	249^{+12}_{-116}	
		$ne^-\nu$					$\lvert g_A/g_V\rvert=0.362\pm0.043$ S=1.7*
		$\Lambda e^-\nu$					$g_V/g_A=0.01\pm0.10$ S=1.5* $g_{WM}/g_A=2.4\pm1.7$
Ξ⁰	−1.250 ±0.014	$\Lambda\pi^0$	−0.413±0.022 S=2.0*	21±12	0.85	218^{+12}_{-18}	
Ξ⁻	*−0.69* *±0.04*	$\Lambda\pi^-$	−0.455±0.015 S=1.8*	4±5	0.89	187±9	
		$\Lambda e^-\nu$					$g_A/g_V=-0.25\pm0.05$
Ω⁻		ΛK^-	−0.024±0.028				
		$\Xi^0\pi^-$	*+0.09 ±0.14*				
		$\Xi^-\pi^0$	*+0.05 ±0.21*				

ADDENDUM TO

Stable Particle Summary Table

SEARCH LIMITS

Search limits usually are critically dependent on assumptions. Further details and other limits are given in the Full Listings. For complete information, the original literature should be consulted. All limits given below are for CL=0.90, except those marked with an asterisk (*), which are for CL=0.95.

Leptons

L^+ — charged lepton	$M > 22.5$ GeV*	if $\tau < 10$ nsec
E^0 — neutral paralepton	$M > 22.5$ GeV*	if E^0eW vertex is $V-A$
	> 24.5 GeV*	if E^0eW vertex is $V+A$
$e^{*\pm}$ — excited electron	$M > 72$ GeV*	if $\lambda = 1$
$\mu^{*\pm}$ — excited muon	$M > 25$ GeV*	if $\lambda = 1$
ν oscillation $\nu_\mu \rightarrow \nu_e$ ($\theta \equiv$ mixing angle)	$\sin^2 2\theta < 3.4\times10^{-3}$	if ΔM^2 is large
	$\Delta M^2 < 0.2$ eV^2	if $\sin^2 2\theta = 1$

Number of Light Neutrino Types (including ν_e, ν_μ, and ν_τ)

	$N \leqslant 7$	from Z width in standard model (cosmological limits are lower)

Additional W Bosons

W right-handed	$M \geqslant 475$ GeV*	assuming light right-handed neutrino
W with standard couplings decaying to $e\nu$	$M \geqslant 210$ GeV	

Additional Z Bosons

[First four are not in Full Listings; see L.S. Durkin and P. Langacker, Phys. Lett. **166B**, 436 (1986), and V. Barger et al., Phys. Rev. Lett. **56**, 30 (1986).]

Z' of $SU(2)_L \times SU(2)_R \times U(1)$	$M \geqslant 275$ GeV	if magnitudes of L & R coupling constants are equal
Z_χ of $SO(10) \rightarrow SU(5)\times U(1)$	$M \geqslant 220$ GeV	coupling constant derived from G.U.T.
Z_ψ of $E_6 \rightarrow SO(10)\times U(1)_\psi$	$M \geqslant 114$ GeV	coupling constant derived from G.U.T.
Z_η of $E_6 \rightarrow SU(3)\times SU(2)\times U(1)\times U(1)_\eta$	$M \geqslant 126$ GeV	coupling constant derived from G.U.T.; charges are $Q_\eta = \sqrt{3/8}Q_\chi - \sqrt{5/8}Q_\psi$
Z with standard couplings decaying to e^+e^-	$M \geqslant 160$ GeV	
Z right-handed	$M \geqslant 150$ GeV*	Rizzo-Senjanovic formalism

Higgs Bosons (or Technipions)

$H^\pm$	$M \geqslant 17$ GeV*	if $B(H^\pm \rightarrow \tau\nu) \geqslant 0.25$
	$M \geqslant 13$ GeV*	from hadronic decays, if $B(H^\pm \rightarrow bc)$ is small
H^0	No substantial limits	

Axions (including nonstandard axions)

A — axion with mass < 100 MeV	$M \geqslant 1$ MeV	assuming $\tau_A > 10^{-11}$ sec

Supersymmetric Particles

Assumptions include: 1) photino is lightest supersymmetric particle; 2) R-parity is conserved; 3) mass of exchanged particles is less than about 250 GeV; 4) unless otherwise stated, $M(\widetilde{f}_L) = M(\widetilde{f}_R)$, and u, d, s, c, and b scalar quarks are degenerate in mass. When two limits are quoted, the parenthetical number has $M(\widetilde{f}_R) \gg M(\widetilde{f}_L)$.

$\widetilde{\gamma}$ — photino ($\widetilde{\gamma}$ limits are from cosmology)	$M \leqslant 100$ eV	
or	$M \geqslant 0.5$ GeV	if $M_{\text{heavy}} = 20$ GeV
	$\geqslant 2$ GeV	$= 40$ GeV
	$\geqslant 5$ GeV	$= 100$ GeV
$\widetilde{\nu}$ — scalar neutrino	$[M(\widetilde{\nu}_\tau) + M(\widetilde{\nu}_{e,\mu})] \gtrsim 1.7$ GeV	
$\widetilde{e}$ — scalar electron	$M \geqslant 51$ (42) GeV	if $M_{\widetilde{\gamma}} = 0$ GeV
	$\geqslant 33$ (26) GeV	$= 10$ GeV
	$\geqslant 22$ (21) GeV*	$\leqslant 19$ (15) GeV
$\widetilde{\mu}$ — scalar muon	$M > 21$ GeV*	if $M_{\widetilde{\gamma}} \leqslant 15$ GeV
$\widetilde{\tau}$ — scalar tau	$M > 18$ GeV*	if $M_{\widetilde{\gamma}} < 13$ GeV
$\widetilde{q}$ — scalar quark	$M > 60$–70 GeV	depending on $M_{\widetilde{g}}$
$\widetilde{g}$ — gluino	$M > 50$–60 GeV	depending on $M_{\widetilde{q}}$
or	$M = 0$–4 GeV	if $M_{\widetilde{q}} > 330$ GeV
	$= 2$–4 GeV	$= 300$ GeV
	$= 3$–4 GeV	$= 150$ GeV
	Low mass not allowed	< 65 GeV
	Whether $M = 0$–0.5 GeV is allowed is the subject of dispute.	
$\chi^\pm$ — chargino (mixtures of $\widetilde{W}^\pm$ and $\widetilde{H}_i^\pm$)	$M \gtrsim 22$ GeV*	if $M_{\widetilde{\nu}} < 18$ GeV and if $B(\widetilde{\chi}^\pm \rightarrow \ell\widetilde{\nu}) \approx 100\%$
	$M > 16.5$ GeV*	if hadronic decays dominate
χ^0 — neutralino (mixtures of $\widetilde{\gamma}$, $\widetilde{Z}^0$, and $\widetilde{H}_i^0$)	Limits are extremely model dependent. Reported limits based on a set of very specific assumptions may exclude $M \approx 6$–33 GeV.	

Stable Particle Summary Table *(cont'd)*

- * S = Scale factor = $\sqrt{\chi^2/(N-1)}$, where $N \approx$ number of experiments. S should be ≈ 1. If S > 1, we have enlarged the error of the mean, $\delta\bar{x}$; i.e., $\delta\bar{x} \to S\delta\bar{x}$. This convention is still inadequate, since if S >> 1 the experiments are probably inconsistent, and therefore the real uncertainty is probably even greater than $S\delta x$. See the Introduction, and ideograms in the Full Listings.
- † Square brackets indicate subreactions of some previous unbracketed decay mode(s). Reactions in one set of brackets may overlap with reactions in another set of brackets. A radiative mode such as $\pi \to \mu\nu\gamma$ is a subreaction of its parent mode $\pi \to \mu\nu$.
- *a.* The strangeness S, charm C, and bottom B of the hadrons which appear in the Summary Table are given in the Nonrelativistic Quark Model section.
- *b.* Quoted upper limits correspond to a 90% confidence level. Masses, mean lives, and partial rates are evaluated assuming equality for particles and antiparticles. Decays which are forbidden by a conservation law are indicated by the following abbreviations: LF ≡ lepton family number, L ≡ total lepton number, B ≡ baryon number, Q ≡ electric charge, C ≡ charge conjugation, P ≡ parity, ΔS ≡ ($\Delta S = 2$), SQ ≡ ($\Delta S = \Delta Q$), FC ≡ flavor-changing neutral current. See the Tests of Conservation Laws section for further details.
- *c.* For a 2-body decay mode, this is the momentum of the decay products in the decay rest frame. For a 3-or-more-body mode, this is the maximum momentum any of the products can have in this frame.
- *d.* 99% confidence level. See footnote in the Full Listings.
- *e.* See the Full Listings for energy limits used in this measurement.
- *f.* Theoretical value; see also the Full Listings.
- *g.* Structure-dependent part with positive (SD+) and negative (SD−) photon helicity.
- *h.* The direct emission branching fraction is $(1.56 \pm .35) \times 10^{-5}$. For interference terms in $K \to \mu\nu\gamma$, see the Full Listings.
- *i.* The $K_S^0 \to \pi\pi$ and $K_L^0 \to \pi\pi$ branching fractions are from our branching-fraction and rate fits and do not include results of K_L^0–K_S^0 interference experiments. The $\pi\pi$ rate results are combined with the interference results to obtain the $|\eta_{+-}|$ and $|\eta_{00}|$ values given in the Addendum.
- *j.* The stronger limit $< 2 \times 10^{-9}$ of Clark et al., Phys. Rev. Lett. **26**, 1667 (1971) is not listed because of possible (but unknown) systematic errors; see the Full Listings.
- *k.* Many of the $D^\pm$ and D^0 hadronic branching fractions have been rescaled to reflect the cross section for charm production determined in a recent experiment. See the Full Listings for details.
- *ℓ.* This is a weighted average of $D^\pm$ (44%) and D^0 (56%) branching fractions.
- *m.* $D_1^0 - D_2^0$ limits inferred from limit on $D^0 \to \bar{D}^0 \to \mu^-$ anything.
- *n.* D_s mass determined from $\phi\pi$ mode. See note on conflicting D_s meson results in the Full Listings. Quantum numbers shown are favored but not yet established.
- *p.* Quantum numbers not measured. Values shown are quark model predictions.
- *q.* Except for the neutral-current decay modes ($\ell^+\ell^-$ anything), only data from $\Upsilon(10575)$ decays are used. Behrends et al. [Phys. Rev. Lett. **50**, 881 (1983)] estimate the $\Upsilon(10575) \to B^+B^-$ and $\Upsilon(10575) \to B^0\bar{B}^0$ branching fractions to be 60 ± 2 and 40 ± 2%.
- *r.* First limit is geochemical and independent of decay mode. Second limit assumes that the dominant decay modes are among those investigated. For antiprotons the best mean life limit, inferred from observation of cosmic ray $\bar{p}$'s, is $\tau_{\bar{p}} > 10^7$ yrs, the cosmic ray storage time.
- *s.* Limit from neutrality-of-matter experiments. Assumes $|q_n| = |q_p| - |q_e|$.
- *t.* P for Ξ, J^P for Ω^- and Σ^0, and J for Λ_c^+ not yet measured. Values shown are quark model predictions.
- *u.* For limits on electric dipole moment (forbidden by P and T invariance), see the Tests of Conservation Laws section.
- *v.* For more details and definitions of parameters, see the Full Listings.
- *w.* P_μ is muon longitudinal polarization from π decay. In standard V-A theory, $P_\mu = 1$ and $\rho = \delta = 3/4$.
- *x.* The definition of the slope parameter of the Dalitz plot is as follows [see also note in the Full Listings]:

$$|M|^2 = 1 + g(s_3 - s_0)/m_{\pi^+}^2.$$

- *y.* The definition for the CP-violation parameters is as follows [see also note in the Full Listings]:

$$\eta_{+-} = |\eta_{+-}|e^{i\phi_{+-}} = \frac{A(K_L^0 \to \pi^+\pi^-)}{A(K_S^0 \to \pi^+\pi^-)} \qquad \eta_{00} = |\eta_{00}|e^{i\phi_{00}} = \frac{A(K_L^0 \to \pi^0\pi^0)}{A(K_S^0 \to \pi^0\pi^0)}$$

$$\delta = \frac{\Gamma(K_L^0 \to \ell^+) - \Gamma(K_L^0 \to \ell^-)}{\Gamma(K_L^0 \to \ell^+) + \Gamma(K_L^0 \to \ell^-)}, \quad |\eta_{+-0}|^2 = \frac{\Gamma(K_S^0 \to \pi^+\pi^-\pi^0)^{\text{CP viol.}}}{\Gamma(K_L^0 \to \pi^+\pi^-\pi^0)}, \quad |\eta_{000}|^2 = \frac{\Gamma(K_S^0 \to \pi^0\pi^0\pi^0)^{\text{CP viol.}}}{\Gamma(K_L^0 \to \pi^0\pi^0\pi^0)}.$$

- *z.* The definition of these quantities is as follows [for more details and sign convention, see note in the Full Listings]:

$$\alpha = \frac{2|s||p|\cos\Delta}{|s|^2 + |p|^2} \qquad \beta = \sqrt{1-\alpha^2}\sin\phi \qquad g_A, g_V, g_{WM} \text{ defined by } \langle B_f|\gamma_\lambda(g_V - g_A\gamma_5) + (g_{WM}/m_{B_i})\sigma^{\lambda\nu}q_\nu|B_i\rangle$$

$$\beta = \frac{-2|s||p|\sin\Delta}{|s|^2 + |p|^2} \qquad \gamma = \sqrt{1-\alpha^2}\cos\phi \qquad \phi_{AV} \text{ defined by } g_A/g_V = |g_A/g_V|e^{i\phi_{AV}}$$

Meson Summary Table

April 1986

In addition to the entries in the Meson Summary Table, the Meson Full Listings contain all substantial claims for meson resonances. See Contents of the Meson Full Listings at end of this Summary Table.

Quantities in italics are new or have changed by more than one (old) standard deviation since April 1984.

				Partial decay modes			
Particle	$I^G(J^{PC})$ [a] ___ *estab.*	**Mass** M **(MeV)**	**Full width Γ (MeV)**	**Mode**	**Fraction(%)** [Upper limits (%) are 90% CL]		p [b] **(MeV/c)**
				NONFLAVORED MESONS			
$\pi^\pm$	$\underline{1^-(0^{-+})}$	139.57	0.0	See Stable Particle Summary Table			
π^0		134.96	7.57				
			±0.32 eV				
η	$\underline{0^+(0^{-+})}$	548.8	*1.05*	Neutral	70.9	See Stable Particle	
		±0.6	*±0.15* keV	Charged	29.1	Summary Table	
ρ(770)	$\underline{1^+(1^{--})}$	770	153	$\pi\pi$	≈ 100		358
		±3§	±2 MeV	$\pi\gamma$	0.046±0.005		372
				$\mu^+\mu^-$	0.0067±0.0012 [d]		370
Γ_{ee} = (*6.9*±*0.3*) keV				e^+e^-	0.0045±0.0002 [d]		384
				$\eta\gamma$	seen		189
M and Γ from neutral mode.				For upper limits, see footnote *e*			
ω(783)	$\underline{0^-(1^{--})}$	782.6	9.8	$\pi^+\pi^-\pi^0$	89.6±0.5		327
		±0.2	±0.3	$\pi^0\gamma$	8.7±0.5		380
		S=1.1*		$\pi^+\pi^-$	*1.7*±*0.2*		366
				$\pi^0\mu^+\mu^-$	0.010±0.002		349
				e^+e^-	0.0067±0.0004	S=1.2*	391
Γ_{ee} = (*0.66*±*0.04*) keV S=*1.2**				$\eta\gamma$	seen		199
				For upper limits, see footnote *f*			
η′(958)	$\underline{0^+(0^{-+})}$	957.57	0.24	$\eta\pi\pi$	65.2±1.6		231
		±0.25	±0.03	$\rho^0\gamma$	30.0±1.6		170
				$\omega\gamma$	2.7±0.5		159
				$\gamma\gamma$	1.9±0.2		479
				$3\pi^0$	0.17±0.04		430
				$\mu^+\mu^-\gamma$	0.009±0.002		467
				For upper limits, see footnote *g*			
f_0(975)	$\underline{0^+(0^{++})}$	975 [c]	33 [c]	$\pi\pi$	78±3		467
was S(975)		±4	±6	$K\bar{K}$	22±3		
		S=1.4*					
a_0(980)	$\underline{1^-(0^{++})}$	983 [h]	54 [h]	$\eta\pi$	seen		320
was δ(980)		±2	±7	$K\bar{K}$	seen		
φ(1020)	$\underline{0^-(1^{--})}$	1019.5	4.22	K^+K^-	49.5±1.5	S=1.9*	127
		±0.1	±0.13	$K_L K_S$	34.3±0.9	S=1.3*	110
		S=1.2*		$\pi^+\pi^-\pi^0$ (incl. $\rho\pi$)	14.9±1.4	S=2.3*	462
				$\eta\gamma$	1.3±0.1	S=1.1*	362
				$\pi^0\gamma$	0.131±0.013		501
				e^+e^-	0.031±0.001		510
				$\mu^+\mu^-$	0.025±0.003		499
Γ_{ee} = (*1.31*±*0.06*) keV				$\pi^+\pi^-$	0.02±0.01		490
				For upper limits, see footnote *i*			
h_1(1190)	$\underline{0^-(1^{+-})}$	1190	320	$\rho\pi$	seen		327
was H(1190)		±60	±50				

Meson Summary Table *(cont'd)*

Particle	$I^G(J^{PC})$ [a] ___ *estab.*	Mass M (MeV)	Full width Γ (MeV)	Partial decay modes: Mode	Fraction(%) [Upper limits (%) are 90% CL]	p [b] (MeV/c)
$b_1(1235)$	$\underline{1^+(1^{+-})}$	1233	150	$\omega\pi$	dominant	350
was $B(1235)$		$\pm 10^{\S}$	$\pm 10^{\S}$	$\eta\rho$	< 10	
				[D/S amplitude ratio = 0.29 ± 0.05]		
				For upper limits, see footnote *j*		
$f_2(1270)$	$\underline{0^+(2^{++})}$	1274	176	$\pi\pi$	84.3 ± 1.2	622
was $f(1270)$		$\pm 5^{\S}$	$\pm 20^{\S}$	$2\pi^+2\pi^-$	2.9 ± 0.4 S=1.2*	559
				$K\bar{K}$	2.9 ± 0.2	398
				$\eta\eta$	*0.31 ± 0.08* S=1.3*	323
				$\gamma\gamma$	0.0015 ± 0.0002	637
				$\pi^+\pi^-2\pi^0$	seen	562
				For upper limits, see footnote *k*		
$a_1(1270)$	$\underline{1^-(1^{++})}$	1275	316	$\rho\pi$	dominant	389
was $A_1(1270)$		± 28	± 45	$\pi(\pi\pi)_{S-\mathrm{wave}}$	$< 0.7^{\S}$	599
				$\pi^{\pm}\gamma$	*0.20 ± 0.08*	630
$f_1(1285)$	$\underline{0^+(1^{++})}$	1283	25	$K\bar{K}\pi$	11 ± 3	302
was $D(1285)$		$\pm 5^{\S}$	$\pm 3^{\S}$	$\eta\pi\pi$	49 ± 6	482
				†[$a_0(980)\pi$	36 ± 7]	236
				4π (prob. $\rho\pi\pi$)	40 ± 7	564
$f_0(1300)$	$\underline{0^+(0^{++})}$	~1300	150−400	$\pi\pi$	~90	635
was $\epsilon(1300)$				$K\bar{K}$	~10	418
				$\eta\eta$	seen	348
$\pi(1300)$	$\underline{1^-(0^{-+})}$	$1300^{\S}$	200−600	$\rho\pi$	seen	407
		$\pm 100^{\S}$		$\pi(\pi\pi)_{S-\mathrm{wave}}$	seen	612
Not a well-established resonance.						
$a_2(1320)$	$\underline{1^-(2^{++})}$	1318	110	$\rho\pi$	70.1 ± 2.2	419
was $A_2(1320)$		$\pm 5^{\S}$	$\pm 5^{\S}$	$\eta\pi$	14.5 ± 1.2	534
				$\omega\pi\pi$	10.6 ± 2.5	361
				$K\bar{K}$	4.9 ± 0.8	434
				$\pi\gamma$	0.27 ± 0.06	652
				$\gamma\gamma$	0.0008 ± 0.0001	659
				$\eta'\pi$	< 2 (CL=97%)	286
$f_1(1420)$‡	$\underline{0^+}(1^{+}_{-}{}^{+})$	1422	56	$K\bar{K}\pi$ (incl. $K^*\bar{K} + K\bar{K}^*$)	seen	423
was $E(1420)$		$\pm 10^{\S}$	± 3	$\eta\pi\pi$	possibly seen	565
				†[$a_0(980)\pi$	possibly seen]	348
$\eta(1440)$‡	$\underline{0^+(0^{-+})}$	$1440^{\S}$	76	$K\bar{K}\pi$ (incl. $K^*\bar{K} + K\bar{K}^*$)	*seen*	441
was $\iota(1440)$		$\pm 20^{\S}$	± 8	$\eta\pi\pi$	*seen*	579
			S=1.3*	†[$a_0(980)\pi$	*seen*]	366
$f_2'(1525)$	$\underline{0^+(2^{++})}$	1525	70	$K\bar{K}$	dominant	578
was $f'(1525)$		$\pm 5^{\S}$	$\pm 10^{\S}$	$\pi\pi$	possibly seen	750
				$\gamma\gamma$	*0.00016 ± 0.00007*	763
$f_0(1590)$	$\underline{0^+(0^{++})}$	*1587*	*287*	$\eta'\eta$	*dominant*	246
		± 16	*± 50*	$\eta\eta$	*large*	575
Seen by one group only.						
$\rho(1600)$	$\underline{1^+(1^{--})}$	$1590^{\S}$	$260^{\S}$	4π (incl. $\rho\pi^+\pi^-, a_1(1270)\pi$)	$60 \pm 7^{\S}$	733
		$\pm 20^{\S}$	$\pm 100^{\S}$	$\pi\pi$	$23 \pm 7^{\S}$	783
				$K^*\bar{K} + \bar{K}^*K$	9 ± 2	377
				$\eta\pi\pi$	7 ± 2	669
Γ_{ee} = (*7.5 ± 1.5*) keV				$\bar{K}K$	1 ± 0.5	623
				e^+e^-	0.0029 ± 0.0011	795

Meson Summary Table *(cont'd)*

Particle	$I^G(J^{PC})$ ^{a} ___ *estab.*	Mass M (MeV)	Full width Γ (MeV)	Partial decay modes			
				Mode	Fraction(%) [Upper limits (%) are 90% CL]		p ^{b} (MeV/c)
ω_3(1670)	$0^-(3^{--})$	1668	166	3π	seen		806
was ω(1670)		±5	$\pm 15^{\S}$	†[$\rho\pi$	seen]		648
			S=1.1*	5π	seen		740
				†[$\omega\pi\pi$ (prob. $b_1(1235)\pi$)	seen]		616
π_2(1680)	$1^-(2^{-+})$	$1680^{\S}$	$250^{\S}$	$f_2(1270)\pi$	53±5		336
was A_3(1680)		$\pm 30^{\S}$	$\pm 50^{\S}$	$\rho\pi$	34±6		656
				$\pi(\pi\pi)_{S\text{-wave}}$	9±5		813
				$K^*\bar{K} + \bar{K}^*K$	4±1.4		459
				For upper limits, see footnote ℓ			
ϕ(1680)	$0^-(1^{--})$	1685	$130^{\S}$	$K^*\bar{K} + \bar{K}^*K$	*seen*		466
		$+75^{\S}$	$\pm 50^{\S}$	$\omega\pi\pi$	seen		624
		−15		$K\bar{K}$	seen		683
				e^+e^-	*seen*		842
Not a well-established resonance.				$\pi^+\pi^-\pi^0$	*possibly seen*		814
ρ_3(1690)	$1^+(3^{--})$	1691	$200^{\S}$	2π	23.8±1.3		834
was g(1690)		$\pm 5^{\S}$	$\pm 20^{\S}$	4π (incl. $\pi\pi\rho,\rho\rho,a_2\pi,\omega\pi$)	70.9±1.9		787
				$K\bar{K}\pi$ (incl. $K^*\bar{K}+K\bar{K}^*$)	3.8±1.2		625
J^P, M, and Γ from the 2π and $K\bar{K}$ modes.				$K\bar{K}$	1.5±0.3	S=1.3*	684
f_2(1720)	$0^+(2^{++})$	1716	134	$\eta\eta$	seen		660
was θ(1690)		±8	±19	$K\bar{K}$	seen		699
ϕ_J(1850)	$0^-(3^{--})$	1853	96	$K\bar{K}$	seen		784
was ϕ(1850)		±10	±32	$K^*\bar{K} + \bar{K}^*K$	seen		601
f_4(2030)	$0^+(4^{++})$	2026	200	$\pi\pi$	17±2		1004
was h(2030)		±12	±13	$K\bar{K}$	$0.7^{+0.4}_{-0.2}$		883
				$\eta\eta$	*0.22±0.10*		852

$c\bar{c}$ MESONS

Particle	$I^G(J^{PC})$	Mass M (MeV)	Full width Γ (MeV)	Mode	Fraction(%)		p (MeV/c)
η_c(2980)	$0^+(0^{-+})$	2981	*11*	Decay modes into hadronic resonances			
		±2	*±4*	$\eta'\pi\pi$	*4.1±1.7*		1321
				$K^{*0}K^-\pi^+$+c.c.	*2.0±0.7*		1275
				$K^*\bar{K}^*$	*0.9±0.5*		1194
				$\phi\phi$	*0.8±0.3*		1087
				$a_0(980)\pi$	< 2.0		1324
				$a_2(1320)\pi$	< 2.0		1194
				$\rho\rho$	< 1.4		1277
				$f_2(1270)\eta$	< 1.1		1144
				$\omega\omega$	< 0.3		1269
				Decay modes into stable hadrons			
				$K\bar{K}\pi$	*5.4±1.8*	S=1.1*	1377
				$\eta\pi\pi$	*4.7±1.5*		1426
				$K^+K^-\pi^+\pi^-$	*1.7±0.6*		1343
				$2(\pi^+\pi^-)$	*1.30±0.47*		1458
				$p\bar{p}$	*0.12±0.06*		1158
				$\eta K\bar{K}$	< *3.1*		1261
				$\pi^+\pi^-p\bar{p}$	< *1.2*		1025
				Radiative decay modes			
				$\gamma\gamma$	< *0.06*		1491

Meson Summary Table *(cont'd)*

Particle	$I^G(J^{PC})$ [a] ____ *estab.*	Mass M (MeV)	Full width Γ (MeV)	Partial decay modes: Mode	Fraction(%) [Upper limits (%) are 90% CL]		p [b] (MeV/c)
$J/\psi(3097)$	$\underline{0^-(1^{--})}$	3096.9 ±0.1	0.063 ±0.009	e^+e^-	6.9±0.9		1548
				$\mu^+\mu^-$	6.9±0.9		1545
				hadrons + radiative	86.2±2.0		

Γ_{ee} = (*4.7±0.3*) keV
(assuming $\Gamma_{ee} = \Gamma_{\mu\mu}$)

Decay modes into stable hadrons

Mode	Fraction(%)		p
†[$2(\pi^+\pi^-)\pi^0$	3.4±0.3		1496
$3(\pi^+\pi^-)\pi^0$	2.9±0.6		1433
$\pi^+\pi^-\pi^0$	*1.50±0.15*		1533
$\pi^+\pi^-\pi^0K^+K^-$	1.2±0.3		1368
$4(\pi^+\pi^-)\pi^0$	0.9±0.3		1345
$\pi^+\pi^-K^+K^-$	0.72±0.23		1407
$K\overline{K}\pi$	*0.61±0.10*		1440
$p\overline{p}\pi^+\pi^-$	*0.60±0.05*	S=1.3*	1107
$\Sigma\overline{\Sigma}$	*0.45±0.07*		988
$2(\pi^+\pi^-)$	0.4±0.1		1517
$3(\pi^+\pi^-)$	0.4±0.2		1466
$n\overline{n}\pi^+\pi^-$	0.38±0.36		1106
$2(\pi^+\pi^-)K^+K^-$	0.31±0.13		1320
$\Xi\overline{\Xi}$	0.25±0.04		818
$p\overline{p}\pi^+\pi^-\pi^0$	*0.23±0.09*[m]	S=*1.9**	1033
$p\overline{p}$	0.22±0.01		1232
$p\overline{p}\eta$	0.21±0.02		948
$p\overline{n}\pi^-$ or $\overline{p}n\pi^+$	0.20±0.01		1174
$n\overline{n}$	0.18±0.09		1231
$\Lambda\overline{\Sigma}^{\pm}\pi^{\mp}$	*0.15±0.04*		1332
$\Lambda\overline{\Lambda}$	0.13±0.02	S=1.7*	1074
$p\overline{p}\pi^0$	0.11±0.01		1176
$pK^-\overline{\Lambda}$	*0.09±0.02*		876
$2(K^+K^-)$	0.07±0.03		1131
$pK^-\overline{\Sigma}^0$	*0.03±0.01*		820
K^+K^-	0.024±0.003		1468
$\pi^+\pi^-$	0.015±0.002		1542
$K_L^0K_S^0$	*0.010±0.002*		1466
$\Lambda\overline{\Sigma}$	< 0.015]		1032

Radiative decay modes

Mode	Fraction(%)		p
†[$\gamma\eta\pi\pi$	*0.62±0.11*		1486
$\gamma 2(\pi^+\pi^-)$	0.49±0.13		1517
$\gamma\eta(1440) \rightarrow \gamma K\overline{K}\pi$	0.46±0.07[n]		1214
$\gamma\eta'$	*0.42±0.05*		1400
$\gamma\omega\omega$	*0.18±0.05*		1336
$\gamma f_2(1270)$	0.16±0.02		1286
$\gamma\rho^0\rho^0$	*0.13±0.05*		1344
$\gamma\eta$	0.086±0.008		1500

Decay modes into hadronic resonances

Mode	Fraction(%)		p
†[$\rho\pi$	1.27±0.09		1449
$\omega 2\pi^+2\pi^-$	0.85±0.34		1392
$\rho a_2(1320)$	0.84±0.45		1126
$K\overline{K}^*(892)$	*0.75±0.09*	S=1.8*	1373
$\omega\pi^+\pi^-$	0.74±0.12		1435
$K^*(892)^0\overline{K}_2^*(1430)^0$ +c.c.	0.67±0.26		1011
$b_1(1235)^{\pm}\pi^{\mp}$	0.29±0.07		1298
$\omega f_2(1270)$	0.23±0.08	S=1.2*	1143
$\phi\pi^+\pi^-$	0.21±0.09		1365
$\omega\eta$	*0.19±0.04*		1394
$\phi K\overline{K}$	0.18±0.08		1176
$\Delta(1232)^{++}\overline{p}\pi^-$	*0.16±0.05*		1030
$\omega K\overline{K}$	0.16±0.10		1265
$\omega p\overline{p}$	0.13±0.03	S=1.3*	768
$\Delta(1232)^{++}\overline{\Delta}(1232)^{--}$	*0.11±0.03*		938
$\eta' p\overline{p}$	*0.09±0.04*	S=1.7*	596
$\Sigma(1385)^{\pm}\overline{\Sigma}(1385)^{\mp}$	*0.09±0.03*		692
$\overline{p}N(1440-1535)^+$	*0.09±0.04*		979
$\phi\eta$	0.067±0.008		1320
$\omega\pi$	*0.067±0.013*		1446
$pK^-\Sigma(1385)^0$	*0.05±0.03*		643
$\phi\eta'$	*0.037±0.006*		1192
$\omega\eta'$	*0.040±0.011*		1279
$\phi f_2'(1525)$	0.037±0.013		871
$\Sigma(1385)^{\pm}\overline{\Sigma}^{\mp}$	*0.03±0.01*		1234
$\phi f_0(975)$	0.026±0.006		1184
$\rho\eta$	*0.018±0.004*		1398
$\pi^{\pm}a_2^{\mp}(1320)$	< 0.43		1263
$K\overline{K}_2^*(1430)$	< *0.4*		1159
$K_2^*(1430)^0\overline{K}_2^*(1430)^0$	< 0.29		606
$\phi 2\pi^+2\pi^-$	< 0.15		1318
$K^*(892)^0\overline{K}^*(892)^0$	< 0.05		1266
$\phi f_2(1270)$	< 0.037		1037
$\rho p\overline{p}$	< *0.031*		780
$\omega f_2'(1525)$	< 0.016		1003
$\rho\eta'$	< 0.01		1283
$\phi\pi$	< 0.0013]		1377

Radiative decay modes (cont'd)

Mode	Fraction(%)		p
$\gamma\eta_c(2980)$	*1.27±0.36*		114
$\gamma f_2(1720)$	seen		1073
$\gamma p\overline{p}$	*0.038±0.010*		1232
$\gamma f_2'(1525)$	*0.016±0.005*		1173
$\gamma\pi^0$	0.004±0.001		1546
$\gamma f_1(1285)$	< 0.6		1283
$\gamma p\overline{p}\pi^+\pi^-$	< *0.08*		1107
2γ	< 0.05		1548
3γ	< 0.006]		1548

Meson Summary Table *(cont'd)*

				Partial decay modes			
Particle	$I^G(J^{PC})$ [a] ___ *estab.*	Mass M (MeV)	Full width Γ (MeV)	Mode	Fraction(%) [Upper limits (%) are 90% CL]		p [b] (MeV/c)
χ_0(3415)	$\underline{0^+(0^{++})}$	3414.9		$2(\pi^+\pi^-)$ (incl. $\pi\pi\rho$)	3.8 ± 0.8		1679
was χ(3415)		± 1.1		$\pi^+\pi^-K^+K^-$ (incl. $\pi K\bar{K}^*$)	2.9 ± 0.8		1580
				$3(\pi^+\pi^-)$	1.5 ± 0.5		1633
				$\pi^+\pi^-$	0.8 ± 0.2		1702
				$\gamma J/\psi(3097)$	0.7 ± 0.2	S=1.3*	303
				K^+K^-	0.7 ± 0.2		1635
				$p\bar{p}\pi^+\pi^-$	0.5 ± 0.2		1320
				$\gamma\gamma$	< 0.15		1707
				$p\bar{p}$	< 0.09		1427
χ_1(3510)	$\underline{0^+(1^{++})}$	*3510.7*	< *1.0*	$\gamma J/\psi(3097)$	25.8 ± 2.5		389
was χ(3510)		± *0.5*		$3(\pi^+\pi^-)$	2.2 ± 0.9		1683
		S=1.4*		$2(\pi^+\pi^-)$ (incl. $\pi\pi\rho$)	1.7 ± 0.5		1727
				$\pi^+\pi^-K^+K^-$ (incl. $\pi K\bar{K}^*$)	0.9 ± 0.4		1632
				$\pi^+\pi^-p\bar{p}$	0.14 ± 0.09		1381
				$\pi^+\pi^- + K^+K^-$	< 0.2		1749
				$\gamma\gamma$	< 0.15		1755
				$p\bar{p}$	< 0.12		1483
χ_2(3555)	$\underline{0^+(2^{++})}$	3556.3	*2.9*	$\gamma J/\psi(3097)$	14.8 ± 1.7		429
was χ(3555)		± 0.4	+ *1.8*	$2(\pi^+\pi^-)$ (incl. $\pi\pi\rho$)	2.2 ± 0.5		1750
			− *1.1*	$\pi^+\pi^-K^+K^-$ (incl. $\pi K\bar{K}^*$)	1.9 ± 0.5		1656
				$3(\pi^+\pi^-)$	1.1 ± 0.8		1706
				$p\bar{p}$	0.76 ± 0.30		1510
				$\pi^+\pi^-p\bar{p}$	0.33 ± 0.13		1410
				$\pi^+\pi^-$	0.19 ± 0.10		1772
				K^+K^-	0.15 ± 0.11		1708
				$J/\psi\pi^+\pi^-\pi^0$	< 1.5		185
				$\gamma\gamma$	< 0.06		1778
ψ(3685)	$\underline{0^-(1^{--})}$	3686.0	0.215	$e^+e^- + \mu^+\mu^-$	1.8 ± 0.3		1843
		± 0.1	± 0.040	hadrons + radiative	98.2 ± 0.3		
Γ_{ee} = (*2.1* ± *0.2*) keV							
(assuming $\Gamma_{ee} = \Gamma_{\mu\mu}$)				Decay modes into hadrons			
				†[$J/\psi\pi\pi$	*50* ± *4*		477
				$J/\psi\eta$	2.7 ± 0.4	S=1.6*	196
				$3(\pi^+\pi^-)\pi^0$	*0.35* ± *0.16*		1746
				$2(\pi^+\pi^-)\pi^0$	0.31 ± 0.07		1799
Radiative decay modes				$\pi^+\pi^-K^+K^-$	0.16 ± 0.04		1726
				$J/\psi\pi^0$	0.10 ± 0.03		528
†[$\gamma\chi_0(3415)$		9.4 ± 0.8	261	$p\bar{p}\pi^+\pi^-$	0.08 ± 0.02		1491
$\gamma\chi_1(3510)$		8.7 ± 0.8	172	$K^*(892)^0K^-\pi^+$ + c.c.	0.067 ± 0.025		1674
$\gamma\chi_2(3555)$		7.8 ± 0.8	128	$2(\pi^+\pi^-)$	0.05 ± 0.01		1817
$\gamma\eta_c(2980)$		0.28 ± 0.06	638	$\rho^0\pi^+\pi^-$	0.042 ± 0.015		1751
$\gamma\pi^0$		< 0.5 (CL=95%)	1841	$p\bar{p}$	0.019 ± 0.005		1586
$\gamma\eta$		< 0.02	1802	$3(\pi^+\pi^-)$	0.015 ± 0.010		1774
$\gamma\eta'$		< 0.02	1719	$p\bar{p}\pi^0$	*0.014* ± *0.005*		1543
$\gamma\eta(1440)\to\gamma K\bar{K}\pi$		< 0.012[n]]	1562	K^+K^-	0.010 ± 0.007		1776
				$\pi^+\pi^-\pi^0$	*0.009* ± *0.005*		1830
				$\pi^+\pi^-$	0.008 ± 0.005		1838
				$\Lambda\bar{\Lambda}$	< 0.04		1467
				$\rho\pi$	< 0.008		1760
				$K^+K^-\pi^0$	< *0.003*		1754
				$K^{\pm}K^*(892)^{\mp}$	< *0.002*]		1698
ψ(3770)	$(\underline{1^{--}})$	3769.9	25	e^+e^-	0.0011 ± 0.0002		1885
		± 2.4	± 3	$D\bar{D}$	dominant		242
		S=1.8*					
Γ_{ee} = (*0.26* ± *0.15*) keV S=*1.3**							

Meson Summary Table *(cont'd)*

Particle	$I^G(J^{PC})$ [a] ___ *estab.*	Mass M (MeV)	Full width Γ (MeV)	Partial decay modes Mode	 Fraction(%) [Upper limits (%) are 90% CL]	 p [b] (MeV/c)
$\psi(4030)$	$(\underline{1^{--}})$	$4030^{\S}$	52	e^+e^-	0.0014 ± 0.0004	2015
		$\pm 5^{\S}$	± 10	$D\bar{D}$	seen	752
				$D\bar{D}^*(2010)$ + c.c.	seen	559
$\Gamma_{ee} = (0.75 \pm 0.15)$ keV				$D^*(2010)\bar{D}^*(2010)$	seen	177
$\psi(4160)$	$(\underline{1^{--}})$	4159	78	e^+e^-	0.0010 ± 0.0004	2079
		± 20	± 20			
$\Gamma_{ee} = (0.77 \pm 0.23)$ keV						
$\psi(4415)$	$(\underline{1^{--}})$	4415	43	e^+e^-	0.0011 ± 0.0006	2207
		± 6	$\pm 20^{\S}$			
$\Gamma_{ee} = (0.47 \pm 0.10)$ keV						
				$b\bar{b}$ MESONS		
$\Upsilon(9460)$	$(\underline{1^{--}})$	9460.0	0.043	$\tau^+\tau^-$	3.2 ± 0.4	4381
or $\Upsilon(1S)$		± 0.2	± 0.003	$\mu^+\mu^-$	2.8 ± 0.2	4729
		S=1.5*		e^+e^-	2.8 ± 0.3	4730
$\Gamma_{ee} = (1.22 \pm 0.05)$ keV				$\rho\pi$	< 0.21	4698
				J/ψ + anything	< 2	
$\chi_{b0}(9860)$	$({}^{+\underline{+}})$	9859.8		$\Upsilon(9460)\gamma$	< 6	392
or $\chi_{b0}(1P)^{o}$		± 1.3				
$\chi_{b1}(9895)$	$({}^{+\underline{+}})$	9891.9		$\Upsilon(9460)\gamma$	35 ± 8	422
or $\chi_{b1}(1P)^{o}$		± 0.7				
$\chi_{b2}(9915)$	$({}^{+\underline{+}})$	9913.3		$\Upsilon(9460)\gamma$	22 ± 4	443
or $\chi_{b2}(1P)^{o}$		± 0.6				
$\Upsilon(10023)$	$(\underline{1^{--}})$	10023.4	0.030	$\mu^+\mu^-$	1.8 ± 0.4	5011
or $\Upsilon(2S)$		± 0.3	± 0.007	$\tau^+\tau^-$	1.7 ± 1.6	4683
				$\Upsilon(9460)\pi^+\pi^-$	18.7 ± 1.0	476
				$\Upsilon(9460)\pi^0\pi^0$	8.6 ± 1.1	481
				$\Upsilon(9460)\eta$	< 0.2	124
				$\chi_{b0}(9860)\gamma$	4.3 ± 1.0	162
$\Gamma_{ee} = (0.54 \pm 0.03)$ keV				$\chi_{b1}(9895)\gamma$	6.7 ± 0.9	131
				$\chi_{b2}(9915)\gamma$	6.6 ± 0.9	109
$\chi_{b1}(10255)$	$({}^{+\underline{+}})$	10255		$\gamma\Upsilon(9460)$	seen	763
or $\chi_{b1}(2P)^{o}$		± 2		$\gamma\Upsilon(10023)$	seen	228
Seen in one experiment only.						
$\chi_{b2}(10270)$	$({}^{+\underline{+}})$	10271		$\gamma\Upsilon(9460)$	seen	779
or $\chi_{b2}(2P)^{o}$		± 2		$\gamma\Upsilon(10023)$	seen	245
Seen in one experiment only.						
$\Upsilon(10355)$	$(\underline{1^{--}})$	10355.5	0.012	$\mu^+\mu^-$	3.3 ± 1.5	5177
or $\Upsilon(3S)$		± 0.5	$+0.010$	$\Upsilon(9460)\pi^+\pi^-$	4.5 ± 0.8	814
			-0.004	$\Upsilon(10023)\pi^+\pi^-$	3 ± 2	177
$\Gamma_{ee} = (0.40 \pm 0.03)$ keV				$\chi_{b1}(10255)\gamma$	15.6 ± 4.2	101
				$\chi_{b2}(10270)\gamma$	12.7 ± 4.1	84
$\Upsilon(10575)$	$(\underline{1^{--}})$	10577	24			
or $\Upsilon(4S)$		± 4	± 2			
$\Gamma_{ee} = (0.24 \pm 0.05)$ keV						
$\Upsilon(10860)$	$(\underline{1^{--}})$	10865	110			
or $\Upsilon(5S)$		± 8	± 13			
$\Gamma_{ee} = (0.31 \pm 0.07)$ keV						
$\Upsilon(11020)$	$(\underline{1^{--}})$	11019	79			
or $\Upsilon(6S)$		± 9	± 16			
$\Gamma_{ee} = (0.13 \pm 0.03)$ keV						

Meson Summary Table *(cont'd)*

Particle	$I\,(J^P)$ ___ *estab.*	Mass M (MeV)	Full width Γ (MeV)	Partial decay modes Mode	 Fraction(%) [Upper limits (%) are 90% CL]		 p^b (MeV/c)
STRANGE MESONS				$[K^+ = u\bar{s},\ K^0 = d\bar{s},\ \bar{K}^0 = \bar{d}s,\ K^- = \bar{u}s]$			
K^+ **K^0**	1/2(0^-)	493.67 497.72		See Stable Particle Summary Table			
$K^*(892)$	1/2(1^-)	892.1	51.1	$K\pi$	≈ 100		288
		±0.3	±0.8	$K^0\gamma$	*0.23±0.02*		309
		S=1.4*	S=1.1*	$K^\pm\gamma$	*0.10±0.01*		307
				$K\pi\pi$	< 0.05		216
M and Γ from charged mode; M^0 = *896.5±0.4* S=*1.6**							
$K_1(1280)$	1/2(1^+)	1270§	90§	$K\rho$	42±6		45
was $Q(1280)$		±10§	±20§	$K_0^*(1350)\pi$	28±4		
				$K^*(892)\pi$	16±5		298
				$K\omega$	11±2		
				$Kf_0(1300)$	3±2		
$K_0^*(1350)$	1/2(0^+)	~1350	~250	$K\pi$	seen		574
was $\kappa(1350)$							
$K_1(1400)$	1/2(1^+)	1406	184	$K^*(892)\pi$	94±6		403
was $Q(1400)$		±10	±9	$K\rho$	3±3		299
				$Kf_0(1300)$	2±2		
				$K\omega$	1±1		285
$K_2^*(1430)$	1/2(2^+)	1426	99	$K\pi$	44.9±2.7	S=3.2*	618
was $K^*(1430)$		±2	±3	$K^*(892)\pi$	23.6±1.8		417
		S=1.1*		$K^*(892)\pi\pi$	13.5±2.7	S=1.2*	366
				$K\rho$	8.6±0.8	S=1.1*	324
				$K\eta$	5.2±2.9	S=1.3*	485
				$K\omega$	4.3±1.6	S=1.1*	310
				$K\gamma$	0.24±0.05		627
M and Γ from charged mode; M^0 = 1423±2 S=1.1*							
$K_2(1770)$‡	1/2(2^-)	~1770§	~200§	$K_2^*(1430)\pi$	dominant		286
was $L(1770)$				$K^*(892)\pi$	seen		651
				$Kf_2(1270)$	seen		
				$K\phi$	seen		438
$K_3^*(1780)$‡	1/2(3^-)	1780	150	$K\pi\pi$	large		796
was $K^*(1780)$		±4	±17	†[$K\rho$	large]		620
			S=1.4*	†[$K^*(892)\pi$	large]		657
				$K\pi$	17±5§		815
$K_4^*(2060)$	1/2(4^+)	2060§	210§	$K\pi$	7±1		966
was $K^*(2060)$		±30§	±40§	$K^*(892)\pi\pi$	seen		809
				$\rho K\pi$	seen		751
				$\omega K\pi$	seen		744
Not a well-established resonance.				$K^*(892)\pi\pi\pi$	seen		775
CHARMED, NONSTRANGE MESONS				$[D^+ = c\bar{d},\ D^0 = c\bar{u},\ \bar{D}^0 = \bar{c}u,\ D^- = \bar{c}d]$			
D^+ **D^0**	1/2(0^-)	1869.3 1864.6		See Stable Particle Summary Table			
$D^*(2010)^+$	1/2(1^-)	2010.1	< 2.0	$D^0\pi^+$	*49±8*		39
		±0.7		$D^+\pi^0$	*34±7*		38
				$D^+\gamma$	*17±11*		136
	$m_{D^{*+}} - m_{D^0}$ = 145.45±0.07 MeV						
$D^*(2010)^0$	1/2(1^-)	2007.2	< 5	$D^0\pi^0$	51.5±7.6		44
		±2.1		$D^0\gamma$	48.5±7.6		137

Meson Summary Table *(cont'd)*

Particle	$I\,(J^P)$ —— *estab.*	Mass M (MeV)	Full width Γ (MeV)	Partial decay modes Mode	Partial decay modes Fraction(%) [Upper limits (%) are 90% CL]	p^b (MeV/*c*)
	CHARMED, STRANGE MESON			$[D_s^+ = c\bar{s},\ D_s^- = \bar{c}s]$		
D_s^+ *was* F^+	$0(0^-)$	1971		See Stable Particle Summary Table		
	BOTTOM MESON			$[B^+ = u\bar{b},\ B^0 = d\bar{b},\ \bar{B}^0 = \bar{d}b,\ B^- = \bar{u}b]$		
B^+ B^0	$1/2(0^-)$	5271 5275		See Stable Particle Summary Table		

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‡ See Meson Full Listings.

* Quoted error includes scale factor $S = \sqrt{\chi^2/(N-1)}$. See footnote to Stable Particle Summary Table.

† Square brackets indicate a subreaction of the previous (unbracketed) decay mode(s).

§ This is only an educated guess; the error given is larger than the error on the average of the published values. (See the Meson Full Listings for the latter.)

a. Charge conjugation C applies only to neutral states.

b. For a 2-body decay mode, this is the momentum of the decay products in the decay rest frame. For a 3-or-more-body mode, this is the maximum momentum any of the products can have in this frame. The momenta have been calculated by using the averaged central mass values, without taking into account the widths of the resonances.

c. From pole position $(M - i\Gamma/2)$.

d. The e^+e^- branching fraction is from $e^+e^- \rightarrow \pi^+\pi^-$ experiments only. The $\omega\rho$ interference is then due to $\omega\rho$ mixing only, and is expected to be small. The $\mu^+\mu^-$ branching fraction is compiled from 3 experiments, each possibly with substantial $\omega\rho$ interference. The error reflects this uncertainty; see notes in the Meson Full Listings. If $e\mu$ universality holds, $\Gamma(\rho^0 \rightarrow \mu^+\mu^-) = \Gamma(\rho^0 \rightarrow e^+e^-) \times 0.99785$.

e. Empirical limits on fractions for other decay modes of $\rho(770)$ are $\pi^\pm\eta < 0.8\%$ (CL=84%), $\pi^+\pi^+\pi^-\pi^- < 0.15\%$, $\pi^\pm\pi^+\pi^-\pi^0 < 0.2\%$ (CL=84%).

f. Empirical limits on fractions for other decay modes of $\omega(783)$ are $\pi^+\pi^-\gamma < 5\%$, $\pi^0\pi^0\gamma < 1\%$, η + neutral(s) $< 1.5\%$, $\mu^+\mu^- < 0.02\%$.

g. Empirical limits on fractions for other decay modes of $\eta'(958)$ are $\pi^+\pi^- < 2\%$ (CL=84%), $\pi^+\pi^-\pi^0 < 5\%$ (CL=84%), $\pi^+\pi^+\pi^-\pi^- < 1\%$ (CL=95%), $\pi^+\pi^+\pi^-\pi^-\pi^0 < 1\%$ (CL=84%), $6\pi < 1\%$, $\pi^+\pi^-e^+e^- < 0.6\%$, $\pi^0e^+e^- < 1.3\%$ (CL=84%), $\eta e^+e^- < 1.1\%$, $\pi^0\rho^0 < 4\%$, $\eta\mu^+\mu^- < 1.5 \times 10^{-5}$, $\pi^0\mu^+\mu^- < 6 \times 10^{-5}$.

h. The mass and width are from the $\eta\pi$ mode only. If the $K\bar{K}$ channel is strongly coupled, the width may be larger.

i. Empirical limits on fractions for other decay modes of $\phi(1020)$ are $\pi^+\pi^-\gamma < 0.7\%$, $\omega\gamma < 5\%$ (CL=84%), $\rho\gamma < 2\%$ (CL=84%), $2\pi^+2\pi^-\pi^0 < 1\%$ (CL=95%), $2\pi^+2\pi^- < 0.1\%$.

j. Empirical limits on fractions for other decay modes of $b_1(1235)$ are $\pi\pi < 15\%$, $K\bar{K} < 2\%$ (CL=84%), $4\pi < 50\%$ (CL=84%), $\phi\pi < 1.5\%$ (CL=84%), $\eta\pi < 25\%$, $(\bar{K}K)^\pm\pi^0 < 8\%$, $K_SK_S\pi^\pm < 2\%$, $K_SK_L\pi^\pm < 6\%$.

k. Empirical limits (CL=95%) on fractions for other decay modes of $f_2(1270)$ are $\eta\pi\pi < 1\%$, $K^0K^-\pi^+$ + c.c. $< 0.4\%$.

ℓ. Empirical limits on fractions for other decay modes of $\pi_2(1680)$ are $\eta\pi < 10\%$, $5\pi < 10\%$.

m. Includes $p\bar{p}\pi^+\pi^-\gamma$ and excludes $p\bar{p}\eta$, $p\bar{p}\omega$, $p\bar{p}\eta'$.

n. See $f_1(1420)$ mini-review.

o. Spectroscopic labeling for these states is theoretical, pending experimental information.

Meson Summary Table *(cont'd)*

Table of Contents of Meson Full Listings

● **Indicates particle appears in Meson Summary Table above. We do not regard the other entries as established resonances.**

Nonstrange ($S = 0$; $C,B = 0$)						Strange ($\lvert S \rvert = 1$; $C,B = 0$)	
entry	$I^G(J^{PC})$ [a]	entry	$I^G(J^{PC})$ [a]	entry	$I^G(J^{PC})$ [a]	entry	$I\ (J^P)$
● π	$1^-(0^{-+})$	● ρ (1600)	$1^+(1^{--})$	e^+e^- (1100—2200)	(1^{--})	● K	$1/2(0^-)$
● η	$0^+(0^{-+})$	● ω_3 (1670)	$0^-(3^{--})$	$\bar{N}N$ (1200—3600)		● K^* (892)	$1/2(1^-)$
● ρ (770)	$1^+(1^{--})$	● π_2 (1680)	$1^-(2^{-+})$	X (1900—3600)		● K_1 (1280)	$1/2(1^+)$
● ω (783)	$0^-(1^{--})$	● ϕ (1680)	$0^-(1^{--})$	● η_c (2980)	$0^+(0^{-+})$	● K_0^* (1350)	$1/2(0^+)$
● η' (958)	$0^+(0^{-+})$	● ρ_3 (1690)	$1^+(3^{--})$	● J/ψ (3097)	$0^-(1^{--})$	● K_1 (1400)	$1/2(1^+)$
● f_0 (975)	$0^+(0^{++})$	X (1700)	$^+$	● χ_0 (3415)	$0^+(0^{++})$	K^* (1410)	$1/2(1^-)$
● a_0 (980)	$1^-(0^{++})$	● f_2 (1720)	$0^+(2^{++})$	● χ_1 (3510)	$0^+(1^{++})$	● K_2^* (1430)	$1/2(2^+)$
● ϕ (1020)	$0^-(1^{--})$	f_0 (1730)	$0^+(0^{++})$	● χ_2 (3555)	$0^+(2^{++})$	K (1460)	$1/2(0^-)$
● h_1 (1190)	$0^-(1^{+-})$	π (1770)	$1^-(0^{-+})$	η_c (3590)	$(\ \ ^+)$	K_2 (1580)	$1/2(2^-)$
● b_1 (1235)	$1^+(1^{+-})$	f_2 (1810)	$0^+(2^{++})$	● ψ (3685)	$0^-(1^{--})$	● K_2 (1770)	$1/2(2^-)$
f_0 (1240)	$0^+(0^{++})$	● ϕ_J (1850)	0	● ψ (3770)	(1^{--})	● K_3^* (1780)	$1/2(3^-)$
ρ (1250)	$1^+(1^{--})$	X (1935)		● ψ (4030)	(1^{--})	K^* (1790)	$1/2(1^-)$
● f_2 (1270)	$0^+(2^{++})$	● f_4 (2030)	$0^+(4^{++})$	● ψ (4160)	(1^{--})	K (1830)	$1/2(0^-)$
● a_1 (1270)	$1^-(1^{++})$	a_4 (2040)	$1^-(4^{++})$	● ψ (4415)	(1^{--})	● K_4^* (2060)	$1/2(4^+)$
η (1275)	$0^+(0^{-+})$	a_3 (2050)	$1^-(3^{++})$	● Υ (9460)	(1^{--})	K_2 (2250)	$1/2(2^-)$
● f_1 (1285)	$0^+(1^{++})$	π_2 (2100)	$1^-(2^{-+})$	● χ_{b0} (9860)	$(\ ^{++})$	K_3 (2320)	$1/2(3^+)$
● f_0 (1300)	$0^+(0^{++})$	ρ (2150)	$1^+(1^{--})$	● χ_{b1} (9895)	$(\ ^{++})$	K_4 (2500)	$1/2(4^-)$
● π (1300)	$1^-(0^{-+})$	f_2 (2150)	$0^+(2^{++})$	● χ_{b2} (9915)	$(\ ^{++})$	Charmed ($\lvert C \rvert = 1$)	
● a_2 (1320)	$1^-(2^{++})$	X (2220)	$0\ (\ ^{++})$	● Υ (10023)	(1^{--})	● D	$1/2(0^-)$
f_2 (1410)	$0^+(2^{++})$	f_2 (2240)	$0^+(2^{++})$	χ_{b0} (10235)	$(\ ^{++})$	● D^* (2010)	$1/2(1^-)$
● f_1 (1420)	$0^+(1^{++})$	ρ_3 (2250)	$1^+(3^{--})$	● χ_{b1} (10255)	$(\ ^{++})$	D^* (2420)	$1/2(\ \ )$
● η (1440)	$0^+(0^{-+})$	f_4 (2300)	$0^+(4^{++})$	● χ_{b2} (10270)	$(\ ^{++})$	● D_s	$0\ \ (0^-)$
● f_2' (1525)	$0^+(2^{++})$	ρ_5 (2350)	$1^+(5^{--})$	● Υ (10355)	(1^{--})	D_s^* (2110)	
f_1 (1530)	$0^+(1^{++})$	a_6 (2450)	$1^-(6^{++})$	● Υ (10575)	(1^{--})	Bottom ($\lvert B \rvert = 1$)	
● f_0 (1590)	$0^+(0^{++})$	f_6 (2510)	$0^+(6^{++})$	● Υ (10860)	(1^{--})	● B	
				● Υ (11020)	(1^{--})	B^* (5325)	
						Exotics	

Baryon Summary Table

April 1986

The first, short table gives the name, the quantum numbers (where known), and the status of every entry in the Baryon Full Listings. Only the baryons with 3- or 4-star status are included in the main Baryon Summary Table. Due to insufficient data or uncertain interpretation, the other entries in the short table are not established as baryons.

N(939) P11	****
N(1440) P11	****
N(1520) D13	****
N(1535) S11	****
N(1540) P13	*
N(1650) S11	****
N(1675) D15	****
N(1680) F15	****
N(1700) D13	***
N(1710) P11	***
N(1720) P13	****
N(1960) ?	*
N(1990) F17	**
N(2000) F15	**
N(2080) D13	**
N(2090) S11	*
N(2100) P11	*
N(2190) G17	****
N(2200) D15	**
N(2220) H19	****
N(2250) G19	****
N(2600) I111	***
N(2700) K113	**
N(~3000)	
Δ(1232) P33	****
Δ(1550) P31	*
Δ(1600) P33	**
Δ(1620) S31	****
Δ(1700) D33	****
Δ(1900) S31	***
Δ(1905) F35	****
Δ(1910) P31	****
Δ(1920) P33	***
Δ(1930) D35	***
Δ(1940) D33	*
Δ(1950) F37	****
Δ(2000) F35	**
Δ(2150) S31	*
Δ(2200) G37	*
Δ(2300) H39	**
Δ(2350) D35	*
Δ(2390) F37	*
Δ(2400) G39	**
Δ(2420) H311	****
Δ(2750) I313	**
Δ(2950) K315	**
Δ(~3000)	
Z_0(1780) P01	*
Z_0(1865) D03	*
Z_1(1725) P11	*
Z_1(1900) P13	*
Z_1(2150)	*
Z_1(2500)	*
Λ(1116) P01	****
Λ(1405) S01	****
Λ(1520) D03	****
Λ(1600) P01	***
Λ(1670) S01	****
Λ(1690) D03	****
Λ(1800) S01	***
Λ(1800) P01	***
Λ(1820) F05	****
Λ(1830) D05	****
Λ(1890) P03	****
Λ(2000)	*
Λ(2020) F07	*
Λ(2100) G07	****
Λ(2110) F05	***
Λ(2325) D03	*
Λ(2350)	***
Λ(2585)	**
Σ(1193) P11	****
Σ(1385) P13	****
Σ(1480)	*
Σ(1560)	**
Σ(1580) D13	**
Σ(1620) S11	**
Σ(1660) P11	***
Σ(1670) D13	****
Σ(1690)	**
Σ(1750) S11	***
Σ(1770) P11	*
Σ(1775) D15	****
Σ(1840) P13	*
Σ(1880) P11	**
Σ(1915) F15	****
Σ(1940) D13	***
Σ(2000) S11	*
Σ(2030) F17	****
Σ(2070) F15	*
Σ(2080) P13	**
Σ(2100) G17	*
Σ(2250)	***
Σ(2455)	**
Σ(2620)	**
Σ(3000)	*
Σ(3170)	*
Ξ(1318) P11	****
Ξ(1530) P13	****
Ξ(1630)	*
Ξ(1680)	**
Ξ(1820) 13	***
Ξ(1940)	**
Ξ(2030) 1	***
Ξ(2120)	*
Ξ(2250)	**
Ξ(2370) 1	**
Ξ(2500)	*
Ω(1672) P03	****
Λ_c(2281)	****
Σ_c(2450)	**
Ξ_c(2460)	*
Ω_c(2740)	*
Λ_b(5500)	*
Dibaryons	
NN(2170) 1D2	**
NN(2250) 3F3	**
NN(?)	*
ΛN(2130) 3S1	**
ΞN(?)	*

****	Good, clear, and unmistakable.
***	Good, but in need of clarification or not absolutely certain.
**	Not established; needs confirmation.
*	Evidence weak; likely to disappear.

Particle [a]	J^P	$L_{2I\cdot 2J}$	P_{beam} [b] (GeV/c) $\sigma = 4\pi\lambdabar^2$ (mb)	Mass [c] M (MeV)	Full [d] width Γ (MeV)	Decay modes: Mode [e]	Decay modes: Fraction [f] (%)	Decay modes: p [g] (MeV/c)
			N RESONANCES (S=0, I=1/2)			$[N^+ = uud,\ N^0 = udd]$		
p	$1/2^+$			938.3		See Stable Particle Table		
n				939.6				
N(1440)	$1/2^+$	P_{11}	$P = 0.61$	1400 to	120 to	$N\pi$	50-70	397
			$\sigma = 31.0$	1480	350	$N\pi\pi$	30-50	342
					(200)	$\Delta\pi$	10-20	143
						$N\rho$	10-15	†
						$N(\pi\pi)_S$	5-20	342
						$p\gamma$	0.08-0.10	414
						$n\gamma$	0.01-0.06	413
N(1520)	$3/2^-$	D_{13}	$P = 0.74$	1510 to	100 to	$N\pi$	50-60	456
			$\sigma = 23.5$	1530	140	$N\eta$	~0.1	149
					(125)	$N\pi\pi$	40-50	410
						$\Delta\pi$	20-30	228
						$N\rho$	15-25	†
						$N(\pi\pi)_S$	< 5	410
						$p\gamma$	0.43-0.57	470
						$n\gamma$	0.34-0.51	470

Baryon Summary Table *(cont'd)*

Particle [a]	J^P	$L_{2I\cdot 2J}$	P^{b}_{beam} (GeV/c) $\sigma = 4\pi\lambda\!\!^{-2}$ (mb)	Mass [c] M (MeV)	Full [d] width Γ (MeV)	Decay modes		
						Mode [e]	Fraction [f] (%)	p [g] (MeV/c)
$N(1535)$	$1/2^-$	S_{11}	$P = 0.76$	1520 to	100 to	$N\pi$	35-50	467
			$\sigma = 22.5$	1560	250	$N\eta$	45-55	182
					(150)	$N\pi\pi$	~10	422
						$\Delta\pi$	< 5	242
						$N\rho$	~ 5	†
						$N(\pi\pi)_S$	~ 5	422
						$p\gamma$	0.1-0.2	481
						$n\gamma$	0.15-0.35	480
$N(1650)$	$1/2^-$	S_{11}	$P = 0.96$	1620 to	100 to	$N\pi$	55-65	547
			$\sigma = 16.4$	1680	200	$N\eta$	~1.5	346
					(150)	ΛK	~ 8	161
						$N\pi\pi$	20-35	511
						$\Delta\pi$	<10	344
						$N\rho$	5-30	†
						$N(\pi\pi)_S$	<15	511
						$p\gamma$	0.04-0.16	558
						$n\gamma$	0-0.17	557
$N(1675)$	$5/2^-$	D_{15}	$P = 1.01$	1660 to	120 to	$N\pi$	35-40	563
			$\sigma = 15.4$	1690	180	$N\eta$	~ 1	374
					(155)	ΛK	~0.1	209
						$N\pi\pi$	60-65	529
						$\Delta\pi$	55-60	364
						$N\rho$	<10	†
						$N(\pi\pi)_S$	< 5	529
						$p\gamma$	~0.01	575
						$n\gamma$	0.07-0.12	574
$N(1680)$	$5/2^+$	F_{15}	$P = 1.01$	1670 to	110 to	$N\pi$	55-65	567
			$\sigma = 15.2$	1690	140	$N\eta$	< 1	379
					(125)	ΛK	not seen	218
						$N\pi\pi$	35-45	532
						$\Delta\pi$	10-15	369
						$N\rho$	10-20	†
						$N(\pi\pi)_S$	15-20	532
						$p\gamma$	0.21-0.30	578
						$n\gamma$	0.02-0.05	577
$N(1700)$	$3/2^-$	D_{13}	$P = 1.05$	1670 to	70 to	$N\pi$	5-15	580
			$\sigma = 14.5$	1730	120	$N\eta$	~ 4	400
					(100)	ΛK	~0.2	250
						$N\pi\pi$	80-90	547
						$\Delta\pi$	15-70	385
						$N\rho$	<20	†
						$N(\pi\pi)_S$	<70	547
						$p\gamma$	~0.01	591
$N(1710)$	$1/2^+$	P_{11}	$P = 1.07$	1680 to	90 to	$N\pi$	10-20	587
			$\sigma = 14.2$	1740	130	$N\eta$	~25	410
					(110)	ΛK	~15	264
						ΣK	2-10	138
						$N\pi\pi$	<50	554
						$\Delta\pi$	10-20	393
						$N\rho$	5-35	48
						$N(\pi\pi)_S$	5-35	554
$N(1720)$	$3/2^+$	P_{13}	$P = 1.09$	1690 to	125 to	$N\pi$	10-20	594
			$\sigma = 13.9$	1800	250	$N\eta$	~3.5	420
					(200)	ΛK	~ 5	278
						ΣK	2-5	162
						$N\pi\pi$	<75	561
						$\Delta\pi$	<15	401
						$N\rho$	<75	104
						$N(\pi\pi)_S$	<20	561

Baryon Summary Table *(cont'd)*

						Decay modes		
Particle[a]	J^P	$L_{2I\cdot 2J}$	P_{beam}[b] (GeV/c) $\sigma = 4\pi\lambdabar^2$ (mb)	Mass[c] M (MeV)	Full[d] width Γ (MeV)	Mode[e]	Fraction[f] (%)	p[g] (MeV/c)
N(2190)	$7/2^-$	G_{17}	$P = 2.07$	2120 to	200 to	$N\pi$	~14	888
			$\sigma = 6.21$	2230	500	$N\eta$	~ 3	790
					(350)	ΛK	~0.3	712
N(2220)	$9/2^+$	H_{19}	$P = 2.14$	2150 to	300 to	$N\pi$	~18	905
			$\sigma = 5.97$	2300	500	$N\eta$	~0.5	811
					(400)	ΛK	~0.2	732
N(2250)	$9/2^-$	G_{19}	$P = 2.21$	2130 to	200 to	$N\pi$	~10	923
			$\sigma = 5.74$	2270	500	$N\eta$	~ 2	831
					(300)	ΛK	~0.3	754
N(2600)	$11/2^-$	I_{111}	$P = 3.12$	2580 to	>300	$N\pi$	~ 5	1126
			$\sigma = 3.86$	2700	(400)			
Δ RESONANCES (S=0, I=3/2)				$[\Delta^{++} = uuu,$	$\Delta^{+} = uud,$	$\Delta^{0} = udd,$	$\Delta^{-} = ddd]$	
Δ(1232)	$3/2^+$	P_{33}	$P = 0.30$	1230 to	110 to	$N\pi$	99.4	227
			$\sigma = 94.8$	1234	120	$N\gamma$	0.56-0.66	259
					(115)			
Δ(1620)	$1/2^-$	S_{31}	$P = 0.91$	1600 to	120 to	$N\pi$	25-35	526
			$\sigma = 17.7$	1650	160	$N\pi\pi$	65-75	488
					(140)	$\Delta\pi$	60-70	318
						$N\rho$	10-20	†
						$N\gamma$	~0.03	538
Δ(1700)	$3/2^-$	D_{33}	$P = 1.05$	1630 to	190 to	$N\pi$	10-20	580
			$\sigma = 14.5$	1740	300	$N\pi\pi$	80-90	547
					(250)	$\Delta\pi$	50-90	385
						$N\rho$	<35	†
						$N\gamma$	0.14-0.33	591
Δ(1900)	$1/2^-$	S_{31}	$P = 1.44$	1850 to	130 to	$N\pi$	5-15	710
			$\sigma = 9.71$	2000	300	ΣK	~10	410
					(150)			
Δ(1905)	$5/2^+$	F_{35}	$P = 1.45$	1890 to	250 to	$N\pi$	5-15	713
			$\sigma = 9.62$	1920	400	ΣK	< 3	415
					(300)	$N\pi\pi$	<75	687
						$\Delta\pi$	~25	542
						$N\rho$	<50	421
						$N\gamma$	0.01-0.05	721
Δ(1910)	$1/2^+$	P_{31}	$P = 1.46$	1850 to	200 to	$N\pi$	15-25	716
			$\sigma = 9.54$	1950	330	ΣK	2-20	421
					(220)	$N\pi\pi$	<75	691
						$\Delta\pi$	small	545
						$N\rho$	small	426
						$N(1440)\pi$	large	393
Δ(1920)	$3/2^+$	P_{33}	$P = 1.48$	1860 to	190 to	$N\pi$	15-20	722
			$\sigma = 9.38$	2160	300	ΣK	~ 5	431
					(250)			
Δ(1930)	$5/2^-$	D_{35}	$P = 1.50$	1890 to	150 to	$N\pi$	5-15	729
			$\sigma = 9.21$	1960	350	ΣK	<10	441
					(250)	$N\pi\pi$	not seen	704
Δ(1950)	$7/2^+$	F_{37}	$P = 1.54$	1910 to	200 to	$N\pi$	35-45	741
			$\sigma = 8.91$	1960	340	ΣK	< 1	460
					(240)	$N\pi\pi$	<40	716
						$\Delta\pi$	~30	574
						$N\rho$	<10	469
						$N\gamma$	0.08-0.17	749
Δ(2420)	$11/2^+$	H_{311}	$P = 2.64$	2380 to	300 to	$N\pi$	5-15	1023
			$\sigma = 4.68$	2450	500			
					(300)			

Baryon Summary Table *(cont'd)*

Particle [a]	J^P	$L_{I\cdot 2J}$	P_{beam} [b] (GeV/c) $\sigma = 4\pi\lambda\!\!\!^{-2}$ (mb)	Mass [c] M (MeV)	Full [d] width Γ (MeV)	Decay modes		
						Mode	Fraction [f] (%)	p [g] (MeV/c)
		Λ RESONANCES ($S=-1$, $I=0$)				[$\Lambda^0 = uds$]		
Λ	$1/2^+$			1115.6		See Stable Particle Table		
Λ(1405)	$1/2^-$	S_{01}	Below $\bar{K}N$	1405	40 ± 10^h	$\Sigma\pi$	100	152
			threshold	$\pm5^h$				
Λ(1520)	$3/2^-$	D_{03}	$P = 0.395$	1519.5	15.6	$N\bar{K}$	45 ± 1	244
			$\sigma = 82.3$	$\pm1.0^h$	$\pm1.0^h$	$\Sigma\pi$	42 ± 1	267
						$\Lambda\pi\pi$	10 ± 1	252
						$\Sigma\pi\pi$	0.9 ± 0.1	152
						$\Lambda\gamma$	0.8 ± 0.2	351
Λ(1600)	$1/2^+$	P_{01}	$P = 0.58$	1560 to	50 to	$N\bar{K}$	15-30	343
			$\sigma = 41.6$	1700	250	$\Sigma\pi$	10-60	336
					(150)			
Λ(1670)	$1/2^-$	S_{01}	$P = 0.74$	1660 to	25 to	$N\bar{K}$	15-25	414
			$\sigma = 28.5$	1680	50	$\Sigma\pi$	20-60	393
					(35)	$\Lambda\eta$	15-35	64
Λ(1690)	$3/2^-$	D_{03}	$P = 0.78$	1685 to	50 to	$N\bar{K}$	20-30	433
			$\sigma = 26.1$	1695	70	$\Sigma\pi$	20-40	409
					(60)	$\Lambda\pi\pi$	$\sim$25	415
						$\Sigma\pi\pi$	$\sim$20	350
Λ(1800)	$1/2^-$	S_{01}	$P = 1.01$	1720 to	200 to	$N\bar{K}$	25-40	528
			$\sigma = 17.5$	1850	400	$\Sigma\pi$	seen	493
					(300)	$\Sigma(1385)\pi$	seen	345
						$N\bar{K}^*(892)$	seen	†
Λ(1800)	$1/2^+$	P_{01}	$P = 1.01$	1750 to	50 to	$N\bar{K}$	20-50	528
			$\sigma = 17.5$	1850	250	$\Sigma\pi$	10-40	493
					(150)	$\Sigma(1385)\pi$	seen	345
						$N\bar{K}^*(892)$	30-60	†
Λ(1820)	$5/2^+$	F_{05}	$P = 1.06$	1815 to	70 to	$N\bar{K}$	55-65	545
			$\sigma = 16.5$	1825	90	$\Sigma\pi$	8-14	508
					(80)	$\Sigma(1385)\pi$	5-10	362
Λ(1830)	$5/2^-$	D_{05}	$P = 1.08$	1810 to	60 to	$N\bar{K}$	3-10	553
			$\sigma = 16.0$	1830	110	$\Sigma\pi$	35-75	515
					(95)	$\Sigma(1385)\pi$	>15	371
Λ(1890)	$3/2^+$	P_{03}	$P = 1.21$	1850 to	60 to	$N\bar{K}$	20-35	599
			$\sigma = 13.6$	1910	200	$\Sigma\pi$	3-10	559
					(100)	$\Sigma(1385)\pi$	seen	420
						$N\bar{K}^*(892)$	seen	233
Λ(2100)	$7/2^-$	G_{07}	$P = 1.68$	2090 to	100 to	$N\bar{K}$	25-35	751
			$\sigma = 8.68$	2110	250	$\Sigma\pi$	$\sim$ 5	704
					(200)	$\Lambda\eta$	<3	617
						ΞK	<3	483
						$\Lambda\omega$	<8	443
						$N\bar{K}^*(892)$	10-20	514
Λ(2110)	$5/2^+$	F_{05}	$P = 1.70$	2090 to	150 to	$N\bar{K}$	5-25	757
			$\sigma = 8.53$	2140	250	$\Sigma\pi$	10-40	711
					(200)	$\Lambda\omega$	seen	455
						$\Sigma(1385)\pi$	seen	589
						$N\bar{K}^*(892)$	10-60	524
Λ(2350)	$9/2^+$		$P = 2.29$	2340 to	100 to	$N\bar{K}$	$\sim$12	915
			$\sigma = 5.85$	2370	250	$\Sigma\pi$	$\sim$10	867
					(150)			

Baryon Summary Table *(cont'd)*

Particle [a]	J^P	$L_{I\cdot 2J}$	P_{beam} [b] (GeV/c) $\sigma = 4\pi\lambdabar^2$ (mb)	Mass [c] M (MeV)	Full [d] width Γ (MeV)	Decay modes		
						Mode	Fraction [f] (%)	p [g] (MeV/c)
Σ RESONANCES ($S=-1$, $I=1$)						$[\Sigma^+ = uus,\ \Sigma^0 = uds,\ \Sigma^- = dds]$		
Σ^+	$1/2^+$			1189.4		See Stable Particle Table		
Σ^0				1192.5				
Σ^-				1197.3				
$\Sigma(1385)^+$	$3/2^+$	P_{13}	Below	1382.8 ± 0.4	36 ± 1	$\Lambda\pi$	88 ± 2	208
			$\bar{K}N$	S=2.0[i]		$\Sigma\pi$	12 ± 2	127
$\Sigma(1385)^0$			threshold	1383.7 ± 1.0	36 ± 5			
				S=1.4[i]				
$\Sigma(1385)^-$				1387.2 ± 0.6	39 ± 2			
				S=2.2[i]	S=1.7[i]			
$\Sigma(1660)$	$1/2^+$	P_{11}	$P = 0.72$	1630 to	40 to	$N\bar{K}$	10-30	405
			$\sigma = 29.9$	1690	200	$\Lambda\pi$	seen	439
					(100)	$\Sigma\pi$	seen	385
$\Sigma(1670)$	$3/2^-$	D_{13}	$P = 0.74$	1665 to	40 to	$N\bar{K}$	7-13	414
			$\sigma = 28.5$	1685	80	$\Lambda\pi$	5-15	447
					(60)	$\Sigma\pi$	30-60	393
$\Sigma(1750)$	$1/2^-$	S_{11}	$P = 0.91$	1730 to	60 to	$N\bar{K}$	10-40	486
			$\sigma = 20.7$	1800	160	$\Lambda\pi$	seen	507
					(90)	$\Sigma\pi$	< 8	455
						$\Sigma\eta$	15-55	81
$\Sigma(1775)$	$5/2^-$	D_{15}	$P = 0.96$	1770 to	105 to	$N\bar{K}$	37-43	508
			$\sigma = 19.0$	1780	135	$\Lambda\pi$	14-20	525
					(120)	$\Sigma\pi$	2-5	474
						$\Sigma(1385)\pi$	8-12	324
						$\Lambda(1520)\pi$	17-23	198
$\Sigma(1915)$	$5/2^+$	F_{15}	$P = 1.26$	1900 to	80 to	$N\bar{K}$	5-15	618
			$\sigma = 12.8$	1935	160	$\Lambda\pi$	seen	622
					(120)	$\Sigma\pi$	seen	577
						$\Sigma(1385)\pi$	< 5	440
$\Sigma(1940)$	$3/2^-$	D_{13}	$P = 1.32$	1900 to	150 to	$N\bar{K}$	<20	637
			$\sigma = 12.1$	1950	300	$\Lambda\pi$	seen	639
					(220)	$\Sigma\pi$	seen	594
						$\Sigma(1385)\pi$	seen	460
						$\Lambda(1520)\pi$	seen	354
						$\Delta(1232)\bar{K}$	seen	410
						$N\bar{K}^*(892)$	seen	320
$\Sigma(2030)$	$7/2^+$	F_{17}	$P = 1.52$	2025 to	150 to	$N\bar{K}$	17-23	702
			$\sigma = 9.93$	2040	200	$\Lambda\pi$	17-23	700
					(180)	$\Sigma\pi$	5-10	657
						ΞK	< 2	412
						$\Sigma(1385)\pi$	5-15	529
						$\Lambda(1520)\pi$	10-20	430
						$\Delta(1232)\bar{K}$	10-20	498
						$N\bar{K}^*(892)$	< 5	438
$\Sigma(2250)$	?		$P = 2.04$	2210 to	60 to	$N\bar{K}$	<10	851
			$\sigma = 6.76$	2280	150	$\Lambda\pi$	seen	842
					(100)	$\Sigma\pi$	seen	803

Baryon Summary Table *(cont'd)*

Particle [a]	J^P	$L_{2I\cdot 2J}$	Mass [c] M (MeV)	Full [d] width Γ (MeV)	Decay modes Mode	 Fraction (%)	 p [g] (MeV/c)
Ξ RESONANCES ($S=-2$, $I=1/2$)					[$\Xi^0 = uss$, $\Xi^- = dss$]		
Ξ^0	$1/2^+$		1314.9		See Stable Particle Table		
Ξ^-			1321.3				
$\Xi(1530)^0$	$3/2^+$	P_{13}	1531.8 ± 0.3 $S = 1.3$[i]	9.1 ± 0.5	$\Xi\pi$	100	148
$\Xi(1530)^-$			1535.0 ± 0.6	10.1 ± 1.9			
$\Xi(1820)$	3/2		1822 ± 6[h]	26^{+15}_{-10}[h]	$\Lambda\overline{K}$	~45	396
					$\Sigma\overline{K}$	~10	306
					$\Xi\pi$	small	413
					$\Xi(1530)\pi$	~45	231
$\Xi(2030)$	?		2025 ± 6[h]	20^{+15}_{-5}[h]	$\Lambda\overline{K}$	~20	587
					$\Sigma\overline{K}$	~80	524
					$\Xi\pi$	small	573
					$\Xi(1530)\pi$	small	418
OTHER BARYONS					[$\Omega^- = sss$, $\Lambda_c^+ = udc$]		
Ω^-	$3/2^+$		1672.4		See Stable Particle Table		
Λ_c^+	$1/2^+$		2281		See Stable Particle Table		

Only the established baryons are included in this Baryon Summary Table. See the short table at the front of this main Table for a list of *all* the baryons for which there is evidence. *See also the Notes on N and Δ resonances, on Λ and Σ resonances, on Ξ resonances, and on dibaryons, introducing those sections of the Baryon Full Listings. In particular, there are Argand diagrams of all the πN and $\overline{K}N$ elastic partial-wave amplitudes, and lengthy discussions of the main analyses of elastic and inelastic channels.*

†. This mode is energetically forbidden when the nominal mass of the decaying resonance (and of any resonance in the final state) is used, but is in fact allowed due to the nonzero width(s) of the resonance(s).

a. The nominal mass here (in MeV) is used for identification; see column 5 for the actual mass.

b. The quantities here are calculated using the nominal mass of column 1.

c. Usually a conservatively large range of masses rather than a statistical average of the various determinations of the mass is given. In these cases, the mass determinations are nearly entirely from various phase-shift analyses of more or less the same data. It is thus not appropriate to treat the determinations as independent measurements or to average them together. The masses, widths, and branching fractions in this Table are Breit-Wigner parameters. The Baryon Full Listings also include pole parameters when they are available, and there is a table of pole parameters for N and Δ resonances in the "Note on N and Δ Resonances" in the Listings.

d. Usually a conservatively large range of widths rather than a statistical average of the various determinations of the width is given (see note *c* for the reason). The nominal value in parentheses is then simply a best guess.

e. The indented modes are subreactions of the $N\pi\pi$ mode. The $(\pi\pi)_S$ is the isospin-0, S-wave state of two pions (this used to be called the ϵ).

f. Most of the inelastic branching fractions come from partial-wave analyses, and these determine $(xx')^{1/2}$, where x and x' are the elastic and inelastic branching fractions, not x' directly. Thus any uncertainty (and it is often considerable) in x carries over into x'. When x' so determined is really poorly known, we here simply note that the mode is seen. The values of $(xx')^{1/2}$ are given in the Baryon Full Listings.

g. For a 2-body decay mode, this is the momentum of the decay products in the decay rest frame. For a 3-or-more-body mode, this is the maximum momentum any of the products can have in this frame. The nominal mass of column 1 is used, as is the nominal mass of any resonance in the final state.

h. The error given here is only an educated guess. It is larger than the error on the weighted average of the published values (the error on the weighted average is given in the Baryon Full Listings).

i. The error given here has been scaled up by an "S factor" (see the * footnote to the Stable Particle Summary Table for how S is defined) because the various measurements disagree more seriously than one would expect from statistics.

PHYSICAL CONSTANTS*

Quantity	Symbol, equation	Value	Uncert. (ppm)
speed of light	c	$2.997\,924\,58(1.2)\times10^{8}$ m s^{-1} (see note**)	0.004
Planck constant	h	$6.626\,176(36)\times10^{-34}$ J s	5.4
Planck constant, reduced	$\hbar \equiv h/2\pi$	$1.054\,588\,7(57)\times10^{-34}$ J s	5.4
		$= 6.582\,173(17)\times10^{-22}$ MeV s	2.6
electron charge magnitude	e	$1.602\,189\,2(46)\times10^{-19}$ C $= 4.803\,242(14)\times10^{-10}$ esu	2.9, 2.9
conversion constant	$\hbar c$	197.328 58(51) MeV fm	2.6
conversion constant	$(\hbar c)^2$	0.389 385 7(20) GeV^2 mbarn	5.2
electron mass	m_e	0.511 003 4(14) MeV/c^2 $= 9.109\,534(47)\times10^{-31}$ kg	2.8, 5.1
proton mass	m_p	938.279 6(27) MeV/c^2 $= 1.672\,648\,5(86)\times10^{-27}$ kg	2.8, 5.1
		= 1.007 276 470(11) amu = 1836.151 52(70) m_e †	0.011, 0.38
deuteron mass	m_d	1875.628 0(53) MeV/c^2	2.8
atomic mass unit (amu)	(mass C^{12} atom)/12 = (1 g)/N_A	931.501 6(26) MeV/c^2 $= 1.660\,565\,5(86)\times10^{-27}$ kg	2.8, 5.1
permittivity of free space	ϵ_0 } $\epsilon_0\mu_0 = 1/c^2$	$8.854\,187\,818(71)\times10^{-12}$ C^2 N^{-1} m^{-2}	0.008
permeability of free space	μ_0 } $\epsilon_0\mu_0 = 1/c^2$	$4\pi\times10^{-7} = 1.256\,637\,061\,4\times10^{-6}$ N A^{-2}	—
fine structure constant	$\alpha = e^2/4\pi\epsilon_0\hbar c$	1/137.036 04(11) †	0.82
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	$2.817\,938\,0(70)\times10^{-15}$ m	2.5
electron Compton wavelength	$\lambda\!\!\!^{-}_e = \hbar/m_e c = r_e\alpha^{-1}$	$3.861\,590\,5(64)\times10^{-13}$ m	1.6
Bohr radius ($m_{\text{nucleus}} = \infty$)	$a_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2 = r_e\alpha^{-2}$	$5.291\,770\,6(44)\times10^{-11}$ m	0.82
Rydberg energy	$hcR_\infty = m_e e^4/2(4\pi\epsilon_0)^2\hbar^2 = m_e c^2\alpha^2/2$	13.605 804(36) eV	2.6
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	0.665 244 8(33) barn	4.9
Bohr magneton	$\mu_B = e\hbar/2m_e$	$5.788\,378\,5(95)\times10^{-11}$ MeV T^{-1}	1.6
nuclear magneton	$\mu_N = e\hbar/2m_p$	$3.152\,451\,5(53)\times10^{-14}$ MeV T^{-1}	1.7
electron cyclotron freq./field	$\omega^e_{\text{cycl}}/B = e/m_e$	$1.758\,804\,7(49)\times10^{11}$ rad s^{-1} T^{-1}	2.8
proton cyclotron freq./field	$\omega^p_{\text{cycl}}/B = e/m_p$	$9.578\,756(28)\times10^{7}$ rad s^{-1} T^{-1}	2.8
gravitational constant	G_N	$6.672\,0(41)\times10^{-11}$ m^3 kg^{-1} s^{-2}	615
		$= 6.7065\,(41)\times10^{-39}$ $\hbar c$ (GeV/c^2)$^{-2}$	615
grav. accel., sea level, 45° lat.	g	9.8062 m s^{-2}	—
Fermi coupling constant	$G_F/(\hbar c)^3$	$1.166\,37(2)\times10^{-5}$ GeV^{-2}	17
Avogadro number	N_A	$6.022\,045(31)\times10^{23}$ mol^{-1} †	5.1
Boltzmann constant	k	$1.380\,662(44)\times10^{-23}$ J K^{-1}	32
		$= 8.617\,35(28)\times10^{-5}$ eV K^{-1}	32
molar volume, ideal gas at STP	$N_A k$(273.15 K)/(1 atmosphere)	$22.413\,83(70)\times10^{-3}$ m^3 mol^{-1}	31
Stefan-Boltzmann constant	$\sigma = \pi^2 k^4/60\hbar^3 c^2$	$5.670\,32(71)\times10^{-8}$ W m^{-2} K^{-4}	125

$\pi = 3.141\,592\,653\,589\,793\,238$ $\quad e = 2.718\,281\,828\,459\,045\,235$ $\quad \gamma = 0.577\,215\,664\,901\,532\,861$

1 in ≡ 0.0254 m
1 barn ≡ 10^{-28} m^2
1 eV = $1.602\,189\,2\times10^{-19}$ J
1 gauss (G) ≡ 10^{-4} tesla (T)
1 Å ≡ 10^{-10} m
1 dyne ≡ 10^{-5} newton (N)
1 eV/c^2 = $1.782\,676\times10^{-36}$ kg
1 atmosphere = $1.013\,25\times10^{5}$ N/m^2
1 fm ≡ 10^{-15} m
1 erg ≡ 10^{-7} joule (J)
$2.997\,924\,58\times10^{9}$ esu = 1 coulomb (C)
0° C ≡ 273.15 K

SI units take as their base: length (m), mass (kg), time (s), electric current (A), themodynamic temperature (K), amount of a substance (mol), and luminous intensity (candela, cd), and the two supplementary units plane angle (rad) and solid angle (sr).

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* Revised 1985 by B.N. Taylor. Based mainly on the "1973 Least-Squares Adjustment of the Fundamental Constants," by E.R. Cohen and B.N. Taylor, J. Phys. Chem. Ref. Data **2**, 663 (1973). The figures in parentheses after the values give the 1-standard-deviation uncertainties in the last digits; the uncertainties in parts per million (ppm) are given in the last column. The uncertainties of the values from a least-squares adjustment are in general correlated, and the laws of error propagation must be used in calculating additional quantities. The set of constants resulting from the 1973 adjustment has been recommended for international use by CODATA (Committee on Data for Science and Technology), and is the most up-to-date, generally accepted set currently available.

† Since 1973, new experiments have yielded better values for some of the constants: $N_A = 6.022\,097\,8(63)\times10^{23}$ mol^{-1} (1.04 ppm); α^{-1} = 137.035 963(15) (0.11 ppm); and m_p/m_e = 1836.152 701(100) (0.054 ppm - error increased by us pending final determination). However, since a change in the value of one constant usually leads to changes in the adjusted values of others, caution is required in using together the values from the 1973 adjustment and the results of more recent experiments.

** In 1983, the Conf. Génerale des Poids et Mesures adopted a new definition of the meter: it is the distance traveled by light in vacuum in 1/299 792 458 s. Thus the speed of light is *defined* to be 299 792 458 m/s. For a discussion, see B.W. Petley, Nature **303**, 373 (1983).

ASTROPHYSICAL CONSTANTS*

Quantity	Symbol, equation	Value
Planck mass	M_{Planck}	$1.221\ 10(37)\times10^{19}$ GeV/c^2
	$= (\hbar c/G_N)^{1/2}$	$= 2.176\ 83(66)\times10^{-8}$ kg
Hubble parameter[1]	H_0	$100h_0$ km s^{-1} Mpc^{-1}
		$= h_0\times1.0\times10^{-10}$ year^{-1}
normalized Hubble parameter[1]	h_0	$0.4 < h_0 < 1$
density parameter of the universe[1]	$\Omega_0 \equiv \rho_0/\rho_c$	$0.05 \leqslant \Omega_0 \leqslant 4$
critical density of the universe[1]	$\rho_c = 3H_0^2/8\pi G_N$	$1.88\times10^{-26}\ h_0^2$ kg m^{-3}
		$= 2.8\times10^{11}\ h_0^2\ M_\odot$ Mpc^{-3}

Quantity	Symbol	Value
cosmological constant	Λ	$\lvert\Lambda\rvert < 3\times10^{-52}$ m^{-2}
age of the universe[1]	t_0	$1.5(5)\times10^{10}$ years
solar mass	$M_\odot$	$1.989(2)\times10^{30}$ kg
solar luminosity	$L_\odot$	$3.826(8)\times10^{26}$ J s^{-1}
solar radius	$R_\odot$	$6.959\ 9(7)\times10^{8}$ m

1 tropical year $\simeq$ $3.155\ 69\times10^7$ s
1 light year = $9.460\ 528\times10^{15}$ m
1 parsec (pc) = 3.261 633 light years
1 astro. unit = $1.495\ 979\times10^{11}$ m

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[*] Compiled with the help of K.A. Olive, J. Primack, and S. Rudaz. Some values are taken from C.W. Allen, *Astrophysical Quantities* (Athlone Press, London, 1973).

[1] Subscript 0 indicates present-day values.

BIG BANG COSMOLOGY*

All observational evidence to date indicates that our universe is very nearly homogeneous and isotropic. The most general space-time interval with these properties is the Friedmann-Robertson-Walker metric (with $c = 1$):

$$ds^2 = dt^2 - R^2(t)\left[\frac{dr^2}{1-\kappa r^2} + r^2(d\theta^2 + \sin^2\theta\, d\phi^2)\right],$$

where $\kappa = +1, -1$, or 0 corresponds to closed, open, or spatially flat geometries; $R(t)$ is a scale factor for distances in comoving coordinates. Einstein's equations lead to the Friedmann equation

$$H^2 \equiv \left(\frac{\dot R}{R}\right)^2 = \frac{8\pi G_N\rho}{3} - \frac{\kappa}{R^2} + \frac{\Lambda}{3},$$

as well as to

$$\frac{\ddot R}{R} = \frac{\Lambda}{3} - \frac{4\pi G_N}{3}(\rho + 3p),$$

where $H(t)$ is the Hubble parameter, ρ is the total mass-energy density, p is the isotropic pressure, and Λ is the cosmological constant. (For limits on Λ, see the Table of Astrophysical Constants; we will assume here $\Lambda = 0$.) The Friedmann equation serves to define the density parameter Ω_0 (subscript 0 indicates present-day values):

$$\kappa/R_0^2 = H_0^2(\Omega_0 - 1), \quad \Omega_0 = \rho_0/\rho_c ;$$

and the critical density is defined as

$$\rho_c \equiv \frac{3H_0^2}{8\pi G_N} = 1.88\times10^{-26}\, h_0^2 \text{ kg m}^{-3},$$

with

$$H_0 = 100h_0 \text{ km s}^{-1}\text{ Mpc}^{-1}.$$

Observational bounds give $0.4 < h_0 < 1$. The three possible values of κ, +1, −1, and 0, correspond to $\Omega_0 > 1$, < 1, and $= 1$, i.e., to closed, open, and flat (critical) universes. The value of Ω_0 is inferred from velocity measurements on scales greater than 100 kpc, which are all consistent with $0.1 \lesssim \Omega_0 \lesssim 0.4$. Conservative bounds are $0.05 \leqslant \Omega_0 \leqslant 4$. The portion of Ω in luminous matter is much smaller, $0.005 \leqslant \Omega_{\text{lum}} \leqslant 0.02$. The excess of Ω_0 over Ω_{lum} leads to the inference that most of the matter in the universe is nonluminous "dark" matter.

Energy conservation implies that $\dot\rho = -3(\dot R/R)(\rho + p)$, so that for a matter-dominated ($p = 0$) universe $\rho \propto R^{-3}$, while for a radiation-dominated ($p = 1/3\rho$) universe $\rho \propto R^{-4}$. Thus the less singular curvature term κ/R^2 in the Friedmann equation can be neglected at early times when R is small. Energy conservation also implies that the universe expands adiabatically, $R^3 s$ = constant, where the entropy density $s = (\rho + p)/T$ and T is temperature.

The energy density of radiation can be expressed as

$$\rho_r = \frac{\pi^2 k^4}{30} N(T) T^4,$$

with $\hbar = 1$, where $N(T)$ counts the effectively massless degrees of freedom of bosons and fermions:

$$N(T) = \sum_B g_B + \frac{7}{8}\sum_F g_F .$$

For example, for $m_\mu > kT > m_e$, $N(T) = g_\gamma + 7/8(g_e + 3g_\nu) = 2 + 7/8[4 + 3(2)] = 43/4$. For $m_\pi > kT > m_\mu$, $N(T) = 57/4$.

In the early universe when $\rho \sim \rho_r$, then $\dot R \sim 1/R$, so that $R \propto t^{1/2}$ and $Ht \rightarrow 1/2$; the time-temperature relation then follows:

$$t = 2.4[N(T)]^{-1/2}\left(\frac{1\text{MeV}}{kT}\right)^2 \text{ s}.$$

Today, the energy density in photons is $\rho_\gamma = (\pi^2 k^4/15)T_0^4$, where the present temperature of the microwave background is $T_0 = 2.73 \pm 0.05$K, and the number density of photons n_γ is $400(T_0/2.7\text{K})^3$ cm^{-3}. For nonrelativistic matter (such as baryons) today, the energy density is $\rho_B = m_B n_B$ with $n_B \propto R^{-3}$, so that for most of the history of the universe n_B/s is constant. Today, the entropy density is related to the photon density by $s \simeq 7n_\gamma$. Big Bang nucleosynthesis calculations limit $\eta = n_B/n_\gamma$ to $3\times10^{-10} \leqslant \eta \leqslant 10^{-9}$. The parameter η is also related to the portion of Ω in baryons

$$\Omega_B = 3.6\times10^7 \eta h_0^{-2}(T_0/2.7\text{K})^3,$$

so that $0.01 < \Omega_B h_0^2 < 0.04$ and hence the universe cannot be closed by baryons.

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[*] Written December 1985 by K.A. Olive and S. Rudaz.

ATOMIC AND NUCLEAR PROPERTIES OF MATERIALS[*]

Material	Z	A	Nuclear[a] total cross section σ_T [barn]	Nuclear[b] inelastic cross section σ_I [barn]	Nuclear[c] collision length λ_T [g/cm^2]	Nuclear[c] interaction length λ_I [g/cm^2]	dE/dx min[d]		Radiation length[e] L_{rad}		Density[f] [g/cm^3] () is for gas [g/ℓ]	Refractive index n[f] () is $(n-1)\times10^6$ for gas
							$\overline{\Delta E}$ $\left[\frac{\text{MeV}}{\text{g/cm}^2}\right]$	ΔE_{mp}, 1 cm [MeV] () is for gas [keV]	[g/cm^2]	[cm] () is for gas		
H_2	1	1.01	0.0387	0.033	43.3	50.8	4.12	(0.19)	61.28	865	0.0708(0.090)	1.112(140)
D_2	1	2.01	0.073	0.061	45.7	54.7	2.07	(0.17)	122.6	757	0.162(0.177)	1.128
He	2	4.00	0.133	0.102	49.9	65.1	1.94	(0.16)	94.32	755	0.125(0.178)	1.024(35)
Li	3	6.94	0.211	0.157	54.6	73.4	1.58	0.70	82.76	155	0.534	—
Be	4	9.01	0.268	0.199	55.8	75.2	1.61	2.61	65.19	35.3	1.848	—
C	6	12.01	0.331	0.231	60.2	86.3	1.78	3.57	42.70	18.8	2.265[g]	—
N_2	7	14.01	0.379	0.265	61.4	87.8	1.82	(0.93)	37.99	47.0	0.808(1.25)	1.205(300)
O_2	8	16.00	0.420	0.292	63.2	91.0	1.82	(1.31)	34.24	30.0	1.14(1.43)	1.22(266)
Ne	10	20.18	0.507	0.347	66.1	96.6	1.73	(0.75)	28.94	24.0	1.207(0.90)	1.092(67)
Al	13	26.98	0.634	0.421	70.6	106.4	1.62	3.81	24.01	8.9	2.70	—
Si	14	28.09	0.660	0.440	70.6	106.0	1.66	3.36	21.82	9.36	2.33	—
Ar	18	39.95	0.868	0.566	76.4	117.2	1.51	(1.30)	19.55	14.0	1.40(1.78)	1.233(283)
Fe	26	55.85	1.120	0.703	82.8	131.9	1.48	10.7	13.84	1.76	7.87	—
Cu	29	63.54	1.232	0.782	85.6	134.9	1.44	11.85	12.86	1.43	8.96	—
Sn	50	118.69	1.967	1.21	100.2	163	1.26	8.3	8.82	1.21	7.31	—
Xe	54	131.30	2.120	1.29	102.8	169	1.24	(3.57)	8.48	2.77	3.057(5.89)	(705)
W	74	183.85	2.767	1.65	110.3	185	1.16	21.1	6.76	0.35	19.3	—
Pb	82	207.19	2.960	1.77	116.2	194	1.13	11.7	6.37	0.56	11.35	—
U	92	238.03	3.378	1.98	117.0	199	1.09	19.3	6.00	≈0.32	≈18.95	—
Air, 20°C, 1 atm. (STP in paren.)					62.0	90.0	1.82	(1.12)	36.66	(30420)	0.001205(1.29)	1.000273(293)
H_2O					60.1	84.9	2.03	1.72	36.08	36.1	1.00	1.33
Shielding concrete[h]					67.4	99.9	1.70	3.68	26.7	10.7	2.5	—
SiO_2 (quartz)					67.0	99.2	1.72	3.28	27.05	12.3	2.64	1.458
H_2 (bubble chamber 26°K)					43.3	50.8	4.12	0.20	61.28	≈1000	≈0.063[i]	1.100
D_2 (bubble chamber 31°K)					45.7	54.7	2.07	0.22	122.6	≈900	≈0.140[i]	1.110
H-Ne mixture (50 mole percent)[j]					65.0	94.5	1.84	0.59	29.70	73.0	0.407	1.092
Ilford emulsion G5					82.0	134	1.44	4.79	11.0	2.89	3.815	—
NaI					94.8	152	1.32	4.13	9.49	2.59	3.67	1.775
BaF_2					92.1	146	1.35	5.72	9.91	2.05	4.89	1.56
BGO ($Bi_4Ge_3O_{12}$)					97.4	156	1.27	8.07	7.98	1.12	7.1	2.15
Polystyrene, scintillator (CH)[k]					58.4	82.0	1.95	1.72	43.8	42.4	1.032	1.581
Lucite, Plexiglas ($C_5H_8O_2$)					59.2	83.6	1.95	1.98	40.55	≈34.4	1.16–1.20	≈1.49
Polyethylene (CH_2)					56.9	78.8	2.09	1.68	44.8	≈47.9	0.92–0.95	—
Mylar ($C_5H_4O_2$)					60.2	85.7	1.86	2.24	39.95	28.7	1.39	—
Borosilicate glass (Pyrex)[ℓ]					66.2	97.6	1.72	3.32	28.3	12.7	2.23	1.474
CO_2					62.4	90.5	1.82	(1.92)	36.2	(18310)	(1.977)	(410)
Methane CH_4					54.7	74.0	2.41	(0.91)	46.5	(64850)	0.423(0.717)	(444)
Isobutane C_4H_{10}					56.3	77.4	2.22	(3.43)	45.2	(16930)	(2.67)	(1270)
Freon 12 (CCl_2F_2) gas, 26°C, 1 atm.[m]					70.6	106	1.62	4.49	23.7	4810	(4.93)	1.001080
Silica Aerogel[n]					65.5	95.7	1.83	0.28	29.85	≈150	0.1-0.3	$1.0+0.25\rho$
G10 plate[o]					62.6	90.2	1.87	2.7	33.0	19.4	1.7	—

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[*] Table revised April 1986 by W. Carithers. σ_T, σ_I, λ_T, and λ_I are energy dependent. Values quoted apply to high energy range given in footnote *a* or *b*, where energy dependence is weak.

a. σ_{total} at 80–240 GeV for neutrons ($\approx \sigma$ for protons) from Murthy et al., Nucl. Phys. **B92**, 269 (1975). This scales approximately as $A^{0.77}$.

b. $\sigma_{\text{inelastic}}=\sigma_{\text{total}}-\sigma_{\text{elastic}}-\sigma_{\text{quasielastic}}$; for neutrons at 60–375 GeV from Roberts et al., Nucl. Phys., **B159**, 56 (1979). For protons and other particles, see Carroll et al., Phys. Lett. **80B**, 319 (1979); note that $\sigma_I(p) \approx \sigma_I(n)$. σ_I scales approximately as $A^{0.71}$.

c. Mean free path between collisions (λ_T) or inelastic interactions (λ_I), calculated from $\lambda = A/(N\times\sigma)$, where N is the Avogadro number.

d. For minimum-ionizing protons and pions. $\overline{\Delta E}$ is energy loss per g/cm^2 from Barkas and Berger, *Tables of Energy Losses and Ranges of Heavy Charged Particles*, NASA-SP-3013 (1964). For electrons and positrons see: M.J. Berger and S.M. Seltzer, *Stopping Powers and Ranges of Electrons and Positrons* (2nd Ed.), U.S. National Bureau of Standards report NBSIR 82-2550-A (1982). ΔE_{mp} is the most probable deposited energy in one cm, in MeV for solids and liquids, in keV for gases. E_{mp} varies with depth in a nonproportional manner. [See Sect. (1) of Passage of Particles Through Matter.] Parentheses refer to gaseous form at STP (0°C, 1 atm.).

e. From Y.S. Tsai, Rev. Mod. Phys. **46**, 815 (1974); L_{rad} data for all elements up to uranium may be found here. Corrections for molecular binding applied for H_2, and D_2. Parentheses refer to gaseous form at STP (0°C, 1 atm.).

f. Values for solids, or the liquid phase at boiling point, except as noted. Values in parentheses for gaseous phase at STP (0°C, 1 atm.). Refractive index given for sodium *D* line.

g. For pure graphite; industrial graphite density may vary 2.1 - 2.3 g/cm^3.

h. Standard shielding blocks, typical composition O_2 52%, Si 32.5%, Ca 6%, Na 1.5%, Fe 2%, Al 4%, plus reinforcing iron bars. The attenuation length, $\ell = 115 \pm 5$ g/cm^2, is also valid for earth (typical $\rho = 2.15$), from CERN-LRL-RHEL Shielding exp., UCRL-17841 (1968).

i. Density may vary about ±3%, depending on operating conditions.

j. Values for typical working conditions with H_2 target: 50 mole percent, 29°K, 7 atm.

k. Typical scintillator; e.g., PILOT B and NE 102A have an atomic ratio H/C = 1.10.

ℓ. Main components: 80% SiO_2 + 12% B_2O_3 + 5% Na_2O.

m. Used in Cerenkov counters. Values at 26°C and 1 atm. Indices of refraction from E.R. Hayes, R.A. Schluter, and A. Tamosaitis, ANL-6916 (1964).

n. $n(SiO_2) + 2n(H_2O)$ used in Cerenkov counters, ρ = density in g/cm^3. From M. Cantin et al., Nucl. Instr. Meth. **118**, 177 (1974).

o. G10-plate, typical 60% SiO_2 and 40% epoxy.

EXPECTED PARAMETERS OF FUTURE HIGH ENERGY COLLIDERS

The numbers shown here were received from authorized representatives of each collider in November 1985. All numbers are subject to change, and many are only estimates.

H ≡ horizontal direction, V ≡ vertical direction, s.c. ≡ supercounducting

	TEVATRON (Fermilab)	TRISTAN (KEK)	SLC (SLAC)	LEP (CERN)	HERA (DESY)	UNK (Serpukhov)	SSC (unknown)
Start date	Sept. 1986	Nov. 1986	March 1987	Early 1989	Spring 1990	1993	1994
Particles collided	$p\bar{p}$	e^+e^-	e^+e^-	e^+e^-	ep	pp	pp
Max. beam energy (TeV)	0.8-1.0	0.03	0.05	0.06	0.026/0.82 e/p	3 (Stage II)	20
Injection energy (TeV)	0.15	0.008	0.05	0.02	0.014/0.040 e/p	0.4–0.6	1
Luminosity (10^{30} cm^{-2} s^{-1})	1	20	6 (0.6 1st yr)	16	15	100	1000
Circumference (km)	6.28	3.02	1.45 + 1.47	26.66	6.336	20.77	82.9
No. of interaction regions	2 high $\mathscr{L}$ 2 low $\mathscr{L}$	4	1	4	3	4	4
No. of particles per bunch (units 10^{10})	6	32	7.2 (5 1st yr)	41.6	3.48/10 e/p	5	0.73
No. of bunches per ring per species	3	2	1	4	220	12,000	17,280
Average beam current per species (mA)	1.4	10	0.0014	3	58/163 e/p	1400	73
Beam-beam tune shift per crossing (units 10^{-4})	17	300	–	300	250/20 e/p	2	9
Filling time (min)	2–3	20	–	0.25 mA/min	10/20 e/p	5	30
Luminosity lifetime (hr)	10–20	3–4	–	5	>3	1	73
Crossing angle (μ rad)	0	0	0.00	0	0	0–500	75
Energy spread (units 10^{-3})	0.12	1.64	0.2	0.82	0.91/0.4 e/p	0.13	0.5
Transverse emittance (10^{-9} π rad-m)	4.2	H: 180	0.42	H: 56 V: 2.2	H: 34.5/8.6 e/p V: 6.90/4.3 e/p	47	0.047
RF frequency (MHz)	53	508	–	352.2	499.7/208.2 e/p	200	375
Acceleration period (sec)	50	300	–	80		100	1000
Bunch length (cm)	50	1.2	0.1	1.6	0.78/15 e/p	50	7
Repetition rate (Hz)			180 (120 1st yr)				
β^*, amplitude function at interaction point (m)	1	H: 0.8 V: 0.05	0.01	H: 1.75 V: 0.07	H: 2/10 e/p V: 0.70/1.0 e/p	3	H: 0.5 V: 0.5
Free space at interaction point (m)	±6.5	±2.5 ±4.5 (initial)	±2.2	±3.5	±5.5	±9	±20
Beam radius (10^{-6} m)	65	H: 367 V: 23	1.7 (2.1 1st yr)	H: 312 V: 12.5	H: 263/293 e/p V: 69/66 e/p	375	4.8
No. of utility insertions	4	8	–	2	4	4	4
Length of standard cell (m)	59.5	16.1	5.2	79	23.5/47 e/p	91.8	192
Phase advance per cell (deg)	65	60	108	60	60/90 e/p	82.5	60
Magnetic length of dipole (m)	6.12	5.86	2.5	11.66/pair	9.2/8.9 e/p	5.8	16.5
No. of dipoles in ring	774	272	460+440	3280+24 inj. + 64 weak	400/416 e/p	2176	H: 3840×2 (s.c.)
No. of quadrupoles in ring	216	400	–	520+288 + 8 s.c.	568/242 e/p	454	920 (1 ring) 1808 (2 r.)(s.c.)
Magnet type	s.c. cos θ warm iron	room temp. C type	AGF in arcs cold bore cold iron nonsat.	iron domin. + 8 s.c. quads	C-shaped e s.c., collared, cold iron p	s.c.	s.c., collared, cold iron
Peak magnetic field (T)	4.4	0.406	0.597	0.135	0.165/4.65 e/p	5	6.6
$\bar{p}$ source accum. rate (hr^{-1})	4×10^{10}	–	–	–	–	–	–
Max. no. $\bar{p}$ in accum. ring	4×10^{11}	–	–	–	–	–	–

PERIODIC TABLE OF THE ELEMENTS

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H Hydrog. 1.00794																	2 He Helium 4.00260
3 Li Lithium 6.941	4 Be Beryll. 9.01218											5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrog. 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.179
11 Na Sodium 22.98977	12 Mg Magnes. 24.305											13 Al Alumin. 26.98154	14 Si Silicon 28.0855	15 P Phosph. 30.97376	16 S Sulfur 32.06	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potass. 39.0983	20 Ca Calcium 40.08	21 Sc Scand. 44.9559	22 Ti Titan. 47.88	23 V Vanad. 50.9415	24 Cr Chrom. 51.996	25 Mn Mangan. 54.9380	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.69	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge German. 72.59	33 As Arsenic 74.9216	34 Se Selen. 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubid. 85.4678	38 Sr Stront. 87.62	39 Y Yttrium 88.9059	40 Zr Zircon. 91.22	41 Nb Niobium 92.9064	42 Mo Molybd. 95.94	43 Tc Technet. (98)	44 Ru Ruthen. 101.07	45 Rh Rhod. 102.9055	46 Pd Pallad. 106.42	47 Ag Silver 107.8682	48 Cd Cadm. 112.41	49 In Indium 114.82	50 Sn Tin 118.69	51 Sb Antimon. 121.75	52 Te Tellur. 127.60	53 I Iodine 126.9045	54 Xe Xenon 131.29
55 Cs Cesium 132.9054	56 Ba Barium 137.33	57-71 Rare Earths	72 Hf Hafnium 178.49	73 Ta Tantal. 180.9479	74 W Tungst. 183.85	75 Re Rhen. 186.207	76 Os Osmium 190.2	77 Ir Iridium 192.22	78 Pt Platin. 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thall. 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.9804	84 Po Polon. (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Franc. (223)	88 Ra Radium 226.0254	89-103 Acti- nides	104 (261)	105 (262)	106 (263)	107 (262)	108 (265)	109 (266)									

57 La Lanthan. 138.9055	58 Ce Cerium 140.12	59 Pr Praseody. 140.9077	60 Nd Neodym. 144.24	61 Pm Prometh. (145)	62 Sm Samar. 150.36	63 Eu Europ. 151.96	64 Gd Gadolin. 157.25	65 Tb Terb. 158.9254	66 Dy Dyspros. 162.50	67 Ho Holm. 164.9304	68 Er Erbium 167.26	69 Tm Thulium 168.9342	70 Yb Ytterb. 173.04	71 Lu Lutet. 174.967	Rare earths (Lanthanide series)
89 Ac Actin. 227.0278	90 Th Thorium 232.0381	91 Pa Protactin. 231.0359	92 U Uranium 238.0289	93 Np Neptun. 237.0482	94 Pu Pluton. (244)	95 Am Americ. (243)	96 Cm Curium (247)	97 Bk Berkel. (247)	98 Cf Californ. (251)	99 Es Einstein. (252)	100 Fm Fermi. (257)	101 Md Mendel. (258)	102 No Nobel. (259)	103 Lr Lawrenc. (260)	Actinide series

The atomic number (top left) is the number of protons in the nucleus. The atomic mass (bottom) is weighted by isotopic abundance in earth's surface, relative to the mass of the carbon 12 isotope, which has been arbitrarily assigned a mass of 12.00000 atomic mass units (amu). Relative isotopic abundances vary considerably for many elements in naturally occurring specimens; commercially available samples may also vary due to undisclosed or inadvertent isotope separation. Numbers in parentheses are mass numbers (the whole number nearest the atomic mass, in amu) of most stable isotope of that element. Adapted from the *Handbook of Chemistry and Physics, 66th Ed., 1985-1986.*

ELECTRONIC STRUCTURE OF THE ELEMENTS

At. no.	Name	Chem. Symbol	K	L		M			N			O	
			s	s	p	s	p	d	s	p	d	s	p
1	Hydrogen	H	1										
2	Helium	He	2										
3	Lithium	Li	2	1									
4	Beryllium	Be	2	2									
5	Boron	B	2	2	1								
6	Carbon	C	2	2	2								
7	Nitrogen	N	2	2	3								
8	Oxygen	O	2	2	4								
9	Fluorine	F	2	2	5								
10	Neon	Ne	2	2	6								
11	Sodium	Na	2	2	6	1							
12	Magnesium	Mg	2	2	6	2							
13	Aluminum	Al	2	2	6	2	1						
14	Silicon	Si	2	2	6	2	2						
15	Phosphorus	P	2	2	6	2	3						
16	Sulfur	S	2	2	6	2	4						
17	Chlorine	Cl	2	2	6	2	5						
18	Argon	Ar	2	2	6	2	6						
19	Potassium	K	2	2	6	2	6	..	1				
20	Calcium	Ca	2	2	6	2	6	..	2				
21	Scandium	Sc	2	2	6	2	6	1	2				
22	Titanium	Ti	2	2	6	2	6	2	2				
23	Vanadium	V	2	2	6	2	6	3	2				
24	Chromium	Cr	2	2	6	2	6	5*	1				
25	Manganese	Mn	2	2	6	2	6	5	2				
26	Iron	Fe	2	2	6	2	6	6	2				
27	Cobalt	Co	2	2	6	2	6	7	2				
28	Nickel	Ni	2	2	6	2	6	8	2				
29	Copper	Cu	2	2	6	2	6	10*	1				
30	Zinc	Zn	2	2	6	2	6	10	2				
31	Gallium	Ga	2	2	6	2	6	10	2	1			
32	Germanium	Ge	2	2	6	2	6	10	2	2			
33	Arsenic	As	2	2	6	2	6	10	2	3			
34	Selenium	Se	2	2	6	2	6	10	2	4			
35	Bromine	Br	2	2	6	2	6	10	2	5			
36	Krypton	Kr	2	2	6	2	6	10	2	6			
37	Rubidium	Rb	2	2	6	2	6	10	2	6	..	1	
38	Strontium	Sr	2	2	6	2	6	10	2	6	..	2	
39	Yttrium	Y	2	2	6	2	6	10	2	6	1	2	
40	Zirconium	Zr	2	2	6	2	6	10	2	6	2	2	
41	Niobium	Nb	2	2	6	2	6	10	2	6	4*	1	
42	Molybdenum	Mo	2	2	6	2	6	10	2	6	5	1	
43	Technetium	Tc	2	2	6	2	6	10	2	6	6	1	
44	Ruthenium	Ru	2	2	6	2	6	10	2	6	7	1	
45	Rhodium	Rh	2	2	6	2	6	10	2	6	8	1	
46	Palladium	Pd	2	2	6	2	6	10	2	6	10*	0	
47	Silver	Ag	2	2	6	2	6	10	2	6	10	1	
48	Cadmium	Cd	2	2	6	2	6	10	2	6	10	2	
49	Indium	In	2	2	6	2	6	10	2	6	10	2	1
50	Tin	Sn	2	2	6	2	6	10	2	6	10	2	2
51	Antimony	Sb	2	2	6	2	6	10	2	6	10	2	3
52	Tellurium	Te	2	2	6	2	6	10	2	6	10	2	4
53	Iodine	I	2	2	6	2	6	10	2	6	10	2	5
54	Xenon	Xe	2	2	6	2	6	10	2	6	10	2	6

At. no.	Name	Chem. Symbol	K	L		M			N				O				P			Q
			s	s	p	s	p	d	s	p	d	f	s	p	d	f	s	p	d	s
55	Cesium	Cs	2	2	6	2	6	10	2	6	10	..	2	6	..	..	1			
56	Barium	Ba	2	2	6	2	6	10	2	6	10	..	2	6	..	..	2			
57	Lanthanum	La	2	2	6	2	6	10	2	6	10	..	2	6	1	..	2			
58	Cerium	Ce	2	2	6	2	6	10	2	6	10	2*	2	6	..	..	2			
59	Praseodymium	Pr	2	2	6	2	6	10	2	6	10	3	2	6	..	..	2			
60	Neodymium	Nd	2	2	6	2	6	10	2	6	10	4	2	6	..	..	2			
61	Promethium	Pm	2	2	6	2	6	10	2	6	10	5	2	6	..	..	2			
62	Samarium	Sm	2	2	6	2	6	10	2	6	10	6	2	6	..	..	2			
63	Europium	Eu	2	2	6	2	6	10	2	6	10	7	2	6	..	..	2			
64	Gadolinium	Gd	2	2	6	2	6	10	2	6	10	7	2	6	1	..	2			
65	Terbium	Tb	2	2	6	2	6	10	2	6	10	9*	2	6	..	..	2			
66	Dysprosium	Dy	2	2	6	2	6	10	2	6	10	10	2	6	..	..	2			
67	Holmium	Ho	2	2	6	2	6	10	2	6	10	11	2	6	..	..	2			
68	Erbium	Er	2	2	6	2	6	10	2	6	10	12	2	6	..	..	2			
69	Thulium	Tm	2	2	6	2	6	10	2	6	10	13	2	6	..	..	2			
70	Ytterbium	Yb	2	2	6	2	6	10	2	6	10	14	2	6	..	..	2			
71	Lutetium	Lu	2	2	6	2	6	10	2	6	10	14	2	6	1	..	2			
72	Hafnium	Hf	2	2	6	2	6	10	2	6	10	14	2	6	2	..	2			
73	Tantalum	Ta	2	2	6	2	6	10	2	6	10	14	2	6	3	..	2			
74	Tungsten	W	2	2	6	2	6	10	2	6	10	14	2	6	4	..	2			
75	Rhenium	Re	2	2	6	2	6	10	2	6	10	14	2	6	5	..	2			
76	Osmium	Os	2	2	6	2	6	10	2	6	10	14	2	6	6	..	2			
77	Iridium	Ir	2	2	6	2	6	10	2	6	10	14	2	6	7	..	2			
78	Platinum	Pt	2	2	6	2	6	10	2	6	10	14	2	6	9	..	1			
79	Gold	Au	2	2	6	2	6	10	2	6	10	14	2	6	10	..	1			
80	Mercury	Hg	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2			
81	Thallium	Tl	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	1		
82	Lead	Pb	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	2		
83	Bismuth	Bi	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	3		
84	Polonium	Po	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	4		
85	Astatine	At	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	5		
86	Radon	Rn	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	6		
87	Francium	Fr	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	6	..	1
88	Radium	Ra	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	6	..	2
89	Actinium	Ac	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	6	1	2
90	Thorium	Th	2	2	6	2	6	10	2	6	10	14	2	6	10	..	2	6	2	2
91	Protactinium	Pa	2	2	6	2	6	10	2	6	10	14	2	6	10	2*	2	6	1	2
92	Uranium	U	2	2	6	2	6	10	2	6	10	14	2	6	10	3	2	6	1	2
93	Neptunium	Np	2	2	6	2	6	10	2	6	10	14	2	6	10	4	2	6	1	2
94	Plutonium	Pu	2	2	6	2	6	10	2	6	10	14	2	6	10	6	2	6	..	2
95	Americium	Am	2	2	6	2	6	10	2	6	10	14	2	6	10	7	2	6	..	2
96	Curium	Cm	2	2	6	2	6	10	2	6	10	14	2	6	10	7	2	6	1	2
97	Berkelium	Bk	2	2	6	2	6	10	2	6	10	14	2	6	10	9*	2	6	..	2
98	Californium	Cf	2	2	6	2	6	10	2	6	10	14	2	6	10	10	2	6	..	2
99	Einsteinium	Es	2	2	6	2	6	10	2	6	10	14	2	6	10	11	2	6	..	2
100	Fermium	Fm	2	2	6	2	6	10	2	6	10	14	2	6	10	12	2	6	..	2
101	Mendelevium	Md	2	2	6	2	6	10	2	6	10	14	2	6	10	13	2	6	..	2
102	Nobelium	No	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	..	2
103	Lawrencium	Lr	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	1	2
104	---	---	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	2	2

*Note irregularity

PARTICLE DETECTORS*

In this section we give various parameters for common detectors. The quoted numbers are usually based on some typical apparatus, and obviously should be regarded as rough approximations, valid only for preliminary design when applied to other cases. A more detailed introduction to detectors can be found in "A Consumer's Guide to Particle Detectors," by D.J. Miller, Rutherford Lab Report RL-76-072, July 1976.

(1) Scintillators: The photon yield in the frequency range of practical photomultiplier tubes is $\cong 1\gamma$ per 100 eV of charged particle ionization energy loss in plastic scintillator[1] and $\cong 1\gamma/25$ eV in NaI.[1,2]

(2) Cerenkov:[3] The half-angle θ_c of the Cerenkov cone aperture in terms of the velocity β and the index of refraction n is:

$$\theta_c = \text{arc cos}\left(\frac{1}{\beta n}\right) \cong \left[2\left(1-\frac{1}{\beta n}\right)\right]^{1/2} .$$

The threshold velocity is: $\beta_t = 1/n$; $\gamma_t = 1/(1-\beta_t^2)^{1/2}$. Therefore, $\beta_t\gamma_t = 1/(2\delta+\delta^2)^{1/2}$, where $\delta = n-1$. Values of δ for various commonly used gases are given as a function of pressure and wavelength in Ref. 4; for values at atmospheric pressure, see the Table of Atomic and Nuclear Properties.

The number of photons N per cm of path length is given by:

$$N = \frac{\alpha}{c}\int\left(1-\frac{1}{\beta^2 n^2}\right)2\pi d\nu = \frac{\alpha}{c}\beta_t^2\int\left(\frac{1}{\beta_t^2\gamma_t^2}-\frac{1}{\beta^2\gamma^2}\right)2\pi d\nu$$

$$\cong 500 \sin^2\theta_c/\text{cm (visible spectrum)} .$$

(3) Photon collection: In addition to the photon yield, one should take into account the light collection efficiency ($\lesssim 10\%$ for typical 1-cm-thick scintillator), the attenuation length ($\cong 1$ to 4 m for typical scintillators[5]), and the quantum efficiency of the photomultiplier cathode ($\lesssim 25\%$).

(4) Typical detector characteristics:

Detector Type	Accuracy (rms)	Resolution Time	Dead Time
Bubble chamber	$\cong \pm 10$ to $\cong \pm 150\mu$m	$\cong$ 1 ms	$\cong 1/20$ s[a]
Streamer chamber	$\pm 300\mu$m	$\cong$ 2 μs	$\cong$100 ms
Proportional chamber	$\geqslant \pm 300\mu m$[b,c]	$\cong$ 50 ns	$\cong$200 ns
Drift chamber	± 50 to 300μm	$\cong$ 2 ns[d]	$\cong$100 ns
Scintillator	—	$\cong$150 ps	$\cong$ 10 ns
Emulsion	$\pm 1\mu$m	—	—
Silicon strip	$\pm 2.5\mu$m	[e]	[e]

[a] Multiple pulsing time.
[b] 300μm is for 1 mm pitch.
[c] Delay line cathode readout can give $\pm 150\mu$m parallel to anode wire.
[d] For two chambers.
[e] Limited at present by noise and readout time of attached electronics.

(5) Shower detectors: We give below typical energy resolutions (FWHM) for an incident electron in the 1 GeV range; E is in GeV. For a fixed number of radiation lengths, FWHM in the last three detectors would be expected to be proportional to $\sqrt{t}$ for t (= plate thickness) $\geqslant$ 0.2 radiation lengths.[6]

For all detectors, operational resolution may be up to 50% worse due to dead areas, non-normally incident tracks, and other effects.

NaI (20 rad. lengths):[7] $\dfrac{2\%}{E^{1/4}}$

Lead glass (14 rad. lengths):[8] $\dfrac{10-12\%}{\sqrt{E}}$

Lead-liquid argon (15.75 rad. lengths):[6] $\dfrac{16\%}{\sqrt{E}}$
(42 cells: 1.1 mm lead, 2 mm liquid argon,
2.3 mm lead-G10, 2 mm liquid argon)

Lead-scintillator sandwich (12.5 rad. lengths):[9] $\dfrac{17\%}{\sqrt{E}}$
(66 cells: 1 mm lead, 5 mm scintillator)

Proportional wire shower chamber (17 rad. lengths):[10] $\dfrac{40\%}{\sqrt{E}}$
(36 cells: 0.474 rad. length type-metal + Al,
9.5 mm 80% Ar - 20% CH_4 gas)

(6) *dE/dx* resolution in argon: Particle identification (relativistic, $Q = 1$ incident particles) by dE/dx is dependent on the width of the distribution:

Multiple-sample Ar gas counters (no lead):[11]

$$\frac{FWHM\left(\left.\dfrac{dE}{dx}\right|_{\text{most probable}}\right)}{\left.\dfrac{dE}{dx}\right|_{\text{most probable}}} = 0.96N^{-0.46}(tp)^{-0.32} ;$$

N = no. samples, t = thickness per sample (cm), p = pressure (atm.); most commonly used chamber gases (except Xe) give approximately the same resolution.

(7) Proportional chamber wire instability: The limit on the voltage V for a wire tension T, due to mechanical effects when the electrostatic repulsion of adjacent wires exceeds the restoring force of wire tension, is given by (MSKA)[12]

$$V < \frac{S}{\ell C}\sqrt{4\pi\epsilon_0 T} ,$$

where s, ℓ, and C are the wire spacing, length, and capacitance per unit length. An approximation to C for chamber half-gap t and wire diameter d (good for $s \lesssim t$) gives[13]

$$V \lesssim 59T^{1/2}\left[\frac{t}{\ell}+\frac{s}{\pi\ell}\,\ell n\left(\frac{s}{\pi d}\right)\right],$$

where V is in kV, and T is in grams-weight equivalent.

(8) Proportional and drift chamber potentials: The potential distributions and fields in a proportional or drift chamber can usually be calculated with good accuracy from the exact formula for the potential around an array of parallel line charges q (coul/m) along z and located at $y = 0$, $x = 0, \pm s, \pm 2s, \ldots,$

$$V(x,y) = -\frac{q}{4\pi\epsilon_0}\,\ell n\left\{4\left[\sin^2\left(\frac{\pi x}{s}\right)+\sinh^2\left(\frac{\pi y}{s}\right)\right]\right\}.$$

Errors from the presence of cathodes, mechanical defects, TPC-type edge effects, etc., are usually small and are beyond the scope of this review.

PARTICLE DETECTORS (Cont'd)

(9) Silicon strip detectors and photodiodes: These are silicon diodes operated with a reverse bias voltage V (typically 30–300 volts) sufficient to deplete the sensitive volume of most mobile charge carriers (electrons and holes). The active (depletion layer) thickness t (cm) is given in a simple model by

$$t = \sqrt{\frac{2\epsilon V}{ne}} = \sqrt{2\rho\mu\epsilon V}\ ,$$

where

n = number of impurity centers/cm^3
e = electron charge
ϵ = dielectric constant $\cong$ 1 pF/cm $\cong$ 11.9 ϵ_0
ρ = resistivity $\cong$ 1–20 kΩ-cm
μ = majority charge carrier mobility
$\cong$ 1300–1500 cm^2/volt-sec (electrons)
$\cong$ 450–600 cm^2/volt-sec (holes).

A minimum-ionizing particle has a Landau energy-loss distribution with average energy loss 39 keV/100 μm, most probable energy loss 26 keV in 100 μm (which scales within $\sim \pm 10\%$ from $\sim$20 to $\sim$300 μm), and full width at half-maximum of roughly $0.1t/\beta^2$ keV, where t is the detector thickness in microns and $\beta = v_{\text{inc}}/c$. The width is usually increased further by electronic noise ($\sigma \sim$1–10 keV) and for thin layers by a Gaussian contribution due to atomic effects $[\sigma \sim (0.3\text{–}0.4)\sqrt{t}$ keV$]$. The average energy required to produce an electron-hole pair is 3.6 eV, from which one can estimate total charge of either sign released. Silicon detectors can tolerate integrated charged-particle fluxes of up to $\sim 10^{10}\text{-}10^{14}$/cm^2 and still operate as efficient detectors.

Typical photodiodes are sensitive (quantum efficiencies greater than ~ 10%) to wavelengths from ~ 200 nm to 1100 nm.

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* Updated April 1986 by Sherwood Parker, Ray Hagstrom, and Geoff Hall.

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COSMIC RAY FLUXES*

The fluxes of particles of different types depend at the ~10% level on the latitude, their energy, and the conditions of measurement. Some typical sea-level values[1] for charged particles are given below:

I_v flux per unit solid angle per unit horizontal area about vertical direction
$\equiv j(\theta{=}0, \phi)$ $[\theta$ = zenith angle, ϕ = azimuthal angle$]$;

J_1 total flux crossing unit horizontal area from above
$\equiv \int_{\theta \leq \pi/2} j(\theta, \phi) \cos\theta \, d\Omega \quad [d\Omega = \sin\theta \, d\theta \, d\phi]$;

J_2 total flux from above (impinging on a sphere of unit cross-sectional area)
$\equiv \int_{\theta \leq \pi/2} j(\theta, \phi) \, d\Omega$.

	Total Intensity	Hard Component	Soft Component	
I_v	1.1×10^2	0.8×10^2	0.3×10^2	m^{-2} sec^{-1} sterad^{-1}
J_1	1.8×10^2	1.3×10^2	0.5×10^2	m^{-2} sec^{-1}
J_2	2.4×10^2	1.7×10^2	0.7×10^2	m^{-2} sec^{-1}

Very approximately, about 75% of all particles at sea level are penetrating, and are muons (the dominant portion of the hard component at sea level). The sea-level vertical flux ratio for protons to muons (both charges together) is about 3½% at 1 GeV/c, decreasing to about ½% at 10 GeV/c.

The muon flux at sea level has a mean energy of 2 GeV and a differential spectrum falling as E^{-2}, steepening smoothly to $E^{-3.6}$ above a few TeV. The angular distribution is $\cos^2\theta$, changing to $\sec\theta$ at energies above a TeV, where θ is the zenith angle at production. The $+-$ charge ratio is 1.25–1.30. The mean energy of muons originating in the atmosphere is roughly 300 GeV at slant depths $\gtrsim$ a few hundred meters. Beyond slant depths of ~10 km water-equivalent, the muons are due primarily to in-the-earth neutrino interactions (roughly 1/8 interaction ton^{-1} year^{-1} for $E_\nu >$ 300 MeV, ~ constant throughout the earth).[2] Muons from this source arrive with a mean energy of 20 GeV, and have a flux of 2×10^{-9} m^{-2} sec^{-1} sterad^{-1} in the vertical direction and about twice that in the horizontal,[3] down at least as far as the deepest mines.

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* Updated April 1986.

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PASSAGE OF PARTICLES THROUGH MATTER*

(1) Energy loss rates for heavy charged projectiles: A heavy projectile (much more massive than an electron) of charge $Z_{\text{inc}}e$, incident at speed βc ($\beta >> 1/137$) through a slowing medium, dissipates energy principally via interactions with the electrons of the medium. The mean rate of such energy loss per unit path length x, called the stopping power, is given by the Bethe-Bloch equation:[1]

$$\left(\frac{dE}{dx}\right)_{\text{inc}} = \frac{D\, Z_{\text{med}}\, \rho_{\text{med}}}{A_{\text{med}}} \left(\frac{Z_{\text{inc}}}{\beta}\right)^2$$

$$\times \left[\ell n \left(\frac{2m_e\gamma^2\beta^2c^2}{I} \right) - \beta^2 - \frac{\delta}{2} - \frac{C}{Z_{\text{med}}} \right] \left\{ 1 + \nu \right\},$$

where $D = 4\pi N_A r_e^2 \mathrm{m}_e c^2 = 0.3070$ MeV cm^2/g (see Physical Constants Table). Mean range and energy loss figures appear at the end of this section.

Here, Z_{med} and A_{med} are the charge and mass numbers of the medium and ρ_{med} is the mass density of the medium; I, δ, C, and ν are phenomenological functions. Frequently, the values of δ, C, and ν are negligibly small; the parameter I characterizes the binding of the electrons of the medium. As a rule of thumb, we may estimate I for an idealized medium as $I \cong 16\ (Z_{\text{med}})^{0.9}$ eV when $Z_{\text{med}} > 1$. For realistic media the value of I will vary at the 10% level from this estimate. Variations of this order occur due to atomic effects such as completion of a shell, also due to chemical binding, and even due to the phase of the substance. Hydrogen, perhaps the most sensitive, has I of about 15 eV in the atomic mode, rising to about 19.2 eV as H_2 gas and to 21.8 eV as H_2 liquid.[2] For many substances, the transition from gas to solid is accompanied by a 20-30% increase in I.[2] We may *approximately* treat media which are chemical mixtures or compounds by computing

$$\frac{dE}{dx} \cong \sum_{n=1}^{N} \left(\frac{dE}{dx}\right)_n ,$$

with $(dE/dx)_n$ appropriate to the n^{th} chemical constituent (using $\rho^{(n)}_{\text{med}}$ as the partial density in the formula for dE/dx).[3] For many chemical compounds, small corrections to this additivity rule may be found in Ref. 2.

The function δ represents the density effect upon the energy loss rate; it is non-negligible only for highly relativistic projectiles in denser media.[4] For ultra-relativistic projectiles, δ approaches $2\ell n \gamma$ + constant, where the value of the constant depends upon the density of the medium as well as its chemical composition.

The function C represents shell corrections to the energy loss rate.[1] These effects are non-negligible only for projectiles with speeds not much faster than the speeds of the fastest electrons bound in the medium.

The function ν represents corrections due to higher order electrodynamics.[5] These effects become important when $|Z_{\text{inc}}/\beta|$ is comparable to 137. For relativistic unit-charge projectiles, $|\nu|$ is of the order of 1%; positively charged projectiles lose energy more rapidly than do their charge conjugates.[5,6]

For nonrelativistic projectiles, our formulae above are inapplicable. At the very slowest speeds, total energy loss rates are believed to be proportional to β, rising through a peak at projectile speeds comparable to atomic speeds (β on the order of αc), after having passed through a smaller peak (due to elastic Coulomb collisions with the *nuclei* of the slowing medium[7]) at intermediate speeds. For example, for protons in Si, $dE/dx = 61.23\ \beta$ GeV/(gm cm^{-2}) for $\beta < 0.005$; the peak occurs at $\beta = 0.0126$ where $dE/dx = 522$ MeV/(gm cm^{-2}). In some cases, energy loss rates depend significantly upon the relation of the projectile trajectory to the crystalline structure of the slowing medium.[8]

For relativistic projectiles, $(dE/dx)_{\text{inc}}$ falls rapidly with increasing β until reaching a minimum around $\beta = 0.96$ (almost independent of medium), followed by a slow rise. Because of the density effect, the quantity in square brackets approaches $\ell n \gamma$ + constant for large γ.

The quantity $(dE/dx)_{\text{inc}}\delta x$ is the *mean* total energy loss via interactions with electrons of the medium in a layer of thickness δx. For any finite δx, Poisson fluctuations can cause the actual energy loss to deviate from the mean. For thin layers, the distribution is broad and skewed, being peaked below $(dE/dx)\delta x$, and having a long tail toward large energy losses.[9] Only for a very thick layer $[(dE/dx)\delta x >> 2m_e\beta^2\gamma^2c^2]$ will the distribution of energy losses become nearly Gaussian. The large fluctuations of the total energy loss rate from the mean are due to a small number of collisions involving large energy transfers. The fluctuations are greatly reduced for the so-called restricted energy loss rate, described in Section (4).

(2) Ionization yields: Physicists frequently relate total energy loss to the number of ion pairs produced near the projectile's track. This relation becomes complicated for relativistic projectiles due to the wandering of energetic knock-on electrons whose ranges exceed the dimensions of the fiducial volume. For a qualitative appraisal of the nonlocality of energy deposition by such modestly energetic knock-on electrons in various media, see Ref. 10. Furthermore, the mean local energy dissipation per local ion pair produced, W, while essentially constant for relativistic projectiles, increases at slow projectile speeds.[11] The numerical value of W for gases can be surprisingly sensitive to trace amounts of various contaminants.[11] Of course, in addition to the preceding effects, practical ionization yields may be greatly influenced by subsequent recombinations and other factors.[12]

(3) Energetic knock-on electrons: For a relativistic point-charge projectile, the production of high energy (kinetic energy $T >> I$) electrons is given by:[13]

$$\frac{d^2N}{dTdx} = \frac{1}{2} D \left(\frac{Z_{\text{med}}}{A_{\text{med}}}\right) \left(\frac{Z_{inc}}{\beta}\right)^2 \rho_{\text{med}} \frac{1}{T^2} F ,$$

for $I << T \leq T_{\text{max}}$, where

$$T_{\text{max}} = \frac{2m_e\beta^2\gamma^2c^2}{1 + 2\gamma \dfrac{m_e}{M_{\text{inc}}} + \left(\dfrac{m_e}{M_{\text{inc}}}\right)^2} ,$$

M_{inc} is the mass of the incident projectile, and all other quantities except F are as in Sec. (1). F ($\cong 1$ for $T << T_{\text{max}}$) is a factor dependent upon the spin of the projectile.

For spin-0 projectiles,

$$F = 1 - \beta^2 \frac{T}{T_{\text{max}}} ;$$

for spin-1/2 projectiles,

$$F = 1 - \beta^2 \frac{T}{T_{\text{max}}} + \frac{1}{2} \left(\frac{T}{T_{\text{inc}} + M_{\text{inc}}c^2}\right)^2 ,$$

where T_{inc} is the kinetic energy of the projectile; for electrons incident,

$$F = \beta^2 T^2 \left[\frac{T_{\text{inc}}}{T(T_{\text{inc}} - T)} - \frac{1}{T_{\text{inc}}} \right]^2 ;$$

and for positrons incident,

$$F = \beta^2 \left[1 - \frac{T}{T_{\text{inc}}} + \left(\frac{T}{T_{\text{inc}}}\right)^2 \right]^2 .$$

For incident electrons, the indistinguishability of projectile and target means that the range of T is only up to $T_{\text{inc}}/2$. For additional formulas see Ref. 14. Our formula is inaccurate for T close to I; for $2I \lesssim T \lesssim 10I$, the $1/T^2$ dependence above becomes $\approx T^{-\eta}$ with $3 \lesssim \eta \lesssim 5$.[15]

(4) Rates of restricted energy loss for relativistic charged projectiles: The variability of energy loss for heavy projectiles is due primarily to the variability in the production of energetic knock-on electrons. Bremsstrahlung and pair-production processes make this variability even greater for electrons than for heavy particles as projectiles (see, e.g., the figure Fractional Energy Loss for Electrons and Positrons in Lead). If an instrument, such as a bubble chamber, is capable of isolating these high-energy-loss interactions, then it is appropriate to consider the rate of energy loss excluding them, i.e., a restricted energy loss rate. The mean energy loss rate via all collisions which have energy transfer T such that $T \leqslant E_{\max} \ll T_{\max}$ is:[1]

$$\left[\frac{dE}{dx}\right]_{\leqslant E_{\max}} = \frac{1}{2} D \frac{Z_{\text{med}}\rho_{\text{med}}}{A_{\text{med}}} \left[\frac{Z_{\text{inc}}}{\beta}\right]^2 \times \left[\ell n \left[\frac{E_{\max} T_{\max}}{I^2}\right] - \beta^2 - \delta - \frac{2C}{Z_{\text{med}}}\right]$$

Notice the overall factor of 1/2. See Sec. (1) above for definitions of the quantities in this equation.

The density effect causes the restricted energy loss rate to approach a constant, the Fermi plateau value, for the fastest projectiles.

(5) Multiple scattering through small angles: As a charged particle traverses a medium it is deflected by many small-angle elastic scatterings. The bulk of this deflection is due to elastic Coulomb scattering from the nuclei within the medium, hence the usual identification as multiple Coulomb scattering (note, however, that strong interactions do contribute to the total multiple scattering for hadronic projectiles). For both Coulomb and strong interactions, the Central Limit Theorem provides little useful guidance in establishing the precise nature of the distribution of the total deflections resulting from multiple scattering. The true distribution is roughly Gaussian only for small deflection angles, while it shows much greater probability for large-angle scatterings ($\gtrsim$ a few θ_0, see below, depending on absorber) than the Gaussian would suggest. These tails on the distribution (a few per cent of peak height in the region where the Gaussian part becomes negligible) are more pronounced for hadrons than for muons as projectiles. The large-angle behavior of these distributions is best estimated by computing the exact distribution for the vectorial sum of the largest deflections based upon the true elastic scattering cross section of the projectile against the medium,[16] or, when applicable, by interpolation from tabular data.[17] An easier alternative which may suffice for noncritical applications would be to use a Gaussian approximation with the following width:[18]

$$\theta_0 = \frac{14.1 \text{ MeV}/c}{p\beta} Z_{\text{inc}} \sqrt{L/L_R}\left[1 + \frac{1}{9}\log_{10}(L/L_R)\right] \text{(radians)},$$

where p, β, and Z_{inc} are the momentum (in MeV/c), velocity, and charge number of the incident particle, and L/L_R is the thickness, in radiation lengths, of the scattering medium. L_R for certain materials is given in the Table of Atomic and Nuclear Properties of Materials. See also Sec. (7) below. The angle, θ_0, is a fit to Moliere[16] theory, accurate to about 5% for $10^{-3} < L/L_R < 10$ except for very light elements or low velocity where the error is about 10 to 20%. In this Gaussian approximation, θ_0 has the meaning

$$\theta_0 = \theta_{\text{plane}_{\text{rms}}} = \frac{1}{\sqrt{2}} \theta^{\text{rms}}_{\text{space}} .$$

The nonprojected (space) and projected (plane) angular distributions are given approximately[16] by the Gaussian forms:

$$\frac{1}{2\pi\theta_0^2} \exp\left[-\frac{\theta^2_{\text{space}}}{2\theta_0^2}\right] d\Omega,$$

$$\frac{1}{\sqrt{2\pi}\,\theta_0} \exp\left[-\frac{\theta^2_{\text{plane}}}{2\theta_0^2}\right] d\theta_{\text{plane}},$$

where θ is the deflection angle.

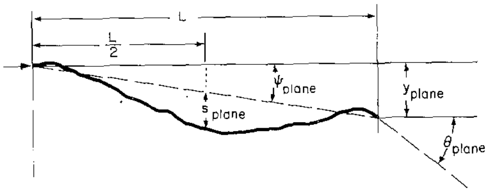
Other quantities are sometimes used to describe the amount of multiple Coulomb scattering: the auxiliary quantities ψ_{plane}, y_{plane}, and s_{plane} (see the figure) obey:

$$\psi^{\text{rms}}_{\text{plane}} = \frac{1}{\sqrt{3}} \theta^{\text{rms}}_{\text{plane}} = \frac{1}{\sqrt{3}}\theta_0 ,$$

$$y^{\text{rms}}_{\text{plane}} = \frac{1}{\sqrt{3}} L\, \theta^{\text{rms}}_{\text{plane}} = \frac{1}{\sqrt{3}} L\theta_0 ,$$

and

$$s^{\text{rms}}_{\text{plane}} = \frac{1}{4\sqrt{3}} L\, \theta^{\text{rms}}_{\text{plane}} = \frac{1}{4\sqrt{3}} L\theta_0 .$$



All the quantitative estimates in this section apply only in the limit of small $\theta^{\text{rms}}_{\text{plane}}$ and in the absence of large-angle scatters.

(6) Longitudinal distribution of electromagnetic showers: A photon of energy $E \geqslant 0.1$ GeV converting in a semi-infinite medium produces an electromagnetic cascade whose intensity initially increases with depth and then falls off. The average number of $e^{\pm}$ with kinetic energy above 1.5 MeV, crossing a plane at a depth of L radiation lengths from the beginning of the medium, in a material of atomic number Z, calculated using the Monte Carlo program EGS,[19] can be fit by the empirical formula[20]

$$N = N_0 L^a e^{-bL} ,$$

where $N_0 = 5.51\, E(\text{GeV}) \sqrt{Z}\, b^{a+1}/\Gamma(a+1)$ and $b = 0.634 - 0.0021\, Z$. For $Z \geqslant 26$, a $= 2.0 - Z/340 + (0.664 - Z/340)\ell n\, E$. For $Z = 13$, $a = 1.77 - 0.52\ell n\, E$. The maximum intensity, $N_{\max}$, occurs at the depth $L = a/b$. The maximum error of the fit occurs in the vicinity of this depth and is less than 0.15 $N_{\max}$. The integral of the tail, $\int_{1.5a/b}^{\infty} N\, dL$ is fit to better than 2.5%. The total longitudinally projected $e^{\pm}$ path length, $\int_0^{\infty} N\, dL = 5.51\, \text{E} \sqrt{Z}$, is less than the total $e^{\pm}$ path length due primarily to multiple Coulomb scattering.

(7) Radiation length: For the passage of electromagnetically interacting particles through a medium it is convenient to measure

PASSAGE OF PARTICLES THROUGH MATTER (Cont'd)

thickness in terms of radiation length.[21] For most electromagnetic processes (Bremsstrahlung, Coulomb scattering, showering, pair production, etc.), over large energy intervals, some or all of the dependence upon the medium is contained in the radiation length.

The radiation length may be defined as the distance L_R over which a high energy electron ($\gtrsim$ 1 GeV for most materials) loses all but a fraction $1/e$ of its energy to Bremsstrahlung, on average. For a homogeneous monoatomic medium, $Z \geqslant 5$,

$$\frac{1}{L_R} = \frac{4\alpha r_e^2 N_A Z^2}{A} \left\{ \ell n\left(\frac{184.15}{Z^{1/3}}\right) + \frac{1}{Z}\ell n\left(\frac{1194}{Z^{2/3}}\right) - 1.202\alpha^2 Z^2 \right.$$

$$\left. + 1.0369\alpha^4 Z^4 - \frac{1.008\alpha^6 Z^6}{1+\alpha^2 Z^2} \right\} = \frac{Z^2 \left\{\ \right\}}{716.405A} ,$$

where α, r_e, and N_A are found in the Physical Constants Table, and Z and A are the atomic number and weight of the medium. For $Z < 5$, a more complex numerical calculation is required. Radiation lengths for many substances are tabulated in the Table of Atomic and Nuclear Properties of Materials. For media which are chemical mixtures or compounds,

$$\frac{1}{L_R} \cong \sum_i \frac{f_i}{L_R^i} ,$$

where f_i is the fraction by mass of atoms of type i, radiation length L_R^i. Chemical binding can lower L_R from this, typically by a few per cent.

For electrons of energy below about one GeV, the average fractional energy loss per unit length decreases as the energy decreases (see Fractional Energy Loss for Electrons and Positrons in Lead figure). With distances measured in units of L_R, dependence of the Bremsstrahlung fractional energy loss upon Z of the medium in the low energy region ($\gtrsim$ 10 MeV) is of order a few percent or less.

For photons of infinite energy, the total pair-production cross section is

$$\sigma = \frac{7}{9}(A/L_R N_A) .$$

This is accurate to within a few per cent down to ~1 GeV for most materials. For energies below about 1 GeV, the cross section varies in a manner which may be determined from the Photon Mass Attenuation figures. See also Contributions to Photon Cross Section in Carbon and Lead figure.

(8) Electron practical range: The electron "practical range" — a common measure of straight-line penetration distance — is shorter than the total path length because of multiple Coulomb scattering, which becomes increasingly important as the electron slows down. E.g., for a fast electron the rms projected angle due to multiple Coulomb scattering reaches 1 radian by the time the electron has slowed to 0.4 MeV in hydrogen, 1.5 MeV in carbon, 9 MeV in copper, and 24 MeV in lead. Electrons which have energy less than 0.2 MeV in Ar, 1.5 MeV in Cu, 3.5 MeV in Sn, and 5 MeV in Pb are likely to deposit 10% of their energy *behind* their starting plane. The practical range, R_p, is defined as that absorber thickness obtained by extrapolating to zero the linearly decreasing part of the curve of penetration probability vs. absorber thickness. Data for Al in the T range up to about 10 MeV are available, and fit (to $\sim \pm 10\%$) $R_p = AT[1-B/(1+CT)]$ mg cm^{-2}, a form suggested in Ref. 22, with $A = 0.55$ mg cm^{-2} keV^{-1}, $B = 0.9841$, and $C = 0.0030$ keV^{-1}. At this penetration depth, 90 - 95% of the incident electrons have stopped. Data for other elements are sketchy, but suggest that higher-Z ($\lesssim 50$) elements have $1 \lesssim R_p/R_p(\mathrm{Al}) \lesssim 1.4$ below ~10 keV, and $0.6 \lesssim R_p/R_p(\mathrm{Al}) \lesssim 1$ above ~ 100 keV. The "critical energy" (above which the energy loss due to bremsstrahlung exceeds that due to ionization, and showering becomes important) is 400 MeV for hydrogen, 100 MeV for carbon, 25 MeV for copper, and 10 MeV for lead. The mean positron range may differ from the mean electron range by several percent. See Refs. 23 and 24. Electron energy deposition and penetration probability vs. range are discussed in Refs. 10, 25, and 26.

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* Updated April 1984 by Sherwood Parker and Ray Hagstrom.

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COMMONLY USED RADIOACTIVE SOURCES

			Principal emissions E(keV)/Intensity (%)		
Nuclide	$t_{1/2}$(y)	Decay mode	α	β	γ
^{22}Na	2.602	β^+,EC		546/90	(511) 1275/100
^{54}Mn	0.854	EC			5.4/22 X 835/100
^{55}Fe	2.68	EC			5.89/25 X 6.49/3.3 X
^{57}Co	0.742	EC			14.4/10 122/86 136/11
^{60}Co	5.271	β^-		318/100	1173/100 1332/100
^{68}Ge (^{68}Ga)	0.742	EC $\rightarrow\beta^+$		1899/88	(511) 9.4/44 X
^{90}Sr (^{90}Y)	28.5	$\beta^-\rightarrow\beta^-$		546/100 2284/100	
^{106}Ru (^{106}Rh)	1.020	$\beta^-\rightarrow\beta^-$		39/100 3541/79	512/21 622/10
^{109}Cd	1.267	EC		62/42 84/44 87/10 } e^-	22/83 X 25/17 X 88/3.7
^{113}Sn	0.315	EC		364/28 388/7 } e^-	24/79 X 392/65
^{137}Cs	30.17	β^-		512/95 1173/5	662/85
^{133}Ba	10.54	EC		45/48 75/7 } e^-	81/33 303/18 356/60
^{207}Bi	32.2	EC		482/2 976/7 1048/2 } e^-	570/98 1064/75 1770/7
^{228}Th	1.913	$6\alpha, 2\beta^-$	(5341 −8785)	334/85 1794/18 2246/48	239/45 583/30 2615/36
(^{224}Ra, ^{220}Rn, ^{216}Po, ^{212}Pb, ^{212}Bi, ^{212}Po)					
^{241}Am	432.2	α	5443/13 5486/85		14/13 X 18/20 X 60/36 X
^{244}Cm	18.10	α	5763/24 5805/76		14/4 X 18/4 X
^{252}Cf	2.638	0.12 fission neutron, 0.6 γ ($\lesssim$1 MeV)/decay of Cf			
Am/Be	432.2	6×10^{-5} neutron, 4×10^{-5} γ (4.43 MeV)/decay of Am			

EC denotes electron capture, X an atomic X-ray. Maximum $\beta^{\pm}$ energies are listed, unless followed by e^- indicating monoenergetic conversion electrons. (511) indicates annihilation radiation, where intensity depends on the number of stopped positrons. In some cases, the γ-ray values are approximate weighted averages of two or more close-together lines. Daughter isotopes, the actual sources of some lines, are listed in parentheses where appropriate.

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RADIOACTIVITY & RADIATION PROTECTION

The International Commission on Radiation Units and Measurements (ICRU) recommends the use of SI units. Therefore we list SI units first, followed by cgs (or other common) units in parentheses, where they differ.

Unit of activity = becquerel (curie):
1 Bq = 1 disintegration/sec $[= 1/(3.7\times10^{10})$ Ci$]$.

Unit of exposure, the quantity of X- or γ- radiation at a point in space integrated over time, in terms of charge of either sign produced by showering electrons in a small volume of air about the point:
= 1 coul/kg of air (roentgen: 1 R = 2.58×10^{-4} coul/kg
= 1 esu/cm^3 = 87.8 erg released energy per g of air); implicit in the definition is the assumption that the small test volume is embedded in a sufficiently large uniformly irradiated volume that the number of secondary electrons entering the volume equals the number leaving.

Unit of absorbed dose = gray (rad):
1 Gy = 1 joule/kg (= 10^4 erg/g = 10^2 rad)
= 6.24×10^{12} MeV/kg deposited energy.

Unit of dose equivalent (for biological damage) = sievert $[= 10^2$ rem (roentgen equivalent for man)$]$:
Dose equivalent in Sv = grays × Q, where Q (quality factor) expresses long-term risk (primarily cancer and leukemia) from low-level chronic exposure; it depends upon the type of radiation and other factors. For γ rays and β particles, $Q \cong 1$; for protons, $Q \cong 1$ at ~10 MeV, rising gradually to $\cong 2$ at ~1 GeV; for thermal neutrons, $Q \cong 3$; for fast neutrons, Q ranges up to 10; and for α particles and heavy ions (assuming internal deposition — skin and clothing are usually sufficient protection against external sources), $Q \cong 20$.

Natural annual background, all sources: Most world areas, whole-body dose equivalent rate $\cong$ (0.4-4) mSv (40-400 millirems). Can range up to 50 mSv (5 rems) in certain areas. U.S. average $\cong$ 0.8 mSv. The lungs receive an additional $\cong$ 0.1 mSv ($\cong$ 10 mrem) from inhaled natural radioactivity, mostly radon and radon daughters (good to $\cong$ factor of 2 in open areas; can range an order of magnitude higher in buildings and up to 1000× in poorly ventilated mines).

Cosmic ray background in counters (Earth's surface): ~10^4/min/m^2/ster. For more accurate estimates and more details, see Cosmic Rays section.

Fluxes (per m^2) to deposit one Gy in one kg of matter, assuming uniform irradiation:
$\cong$ **(charged particles)** $6.24\times10^{12}/(dE/dx)$, where dE/dx (MeV m^2/kg), the energy loss per unit length, may be obtained (after conversion of units) from the Mean Range and Energy Loss figures.
$\cong 3.5\times10^{13}$ minimum-ionizing singly charged particles in carbon.
$\cong$ **(photons)** $6.24\times10^{12}/[E(\text{MeV})/(\lambda f)(\text{m}^2/\text{kg})]$, for photons of energy E, attenuation length λ (see Photon Attenuation Length figures), and fraction $f \leqslant 1$ expressing the fraction of the photon's energy deposited in a small volume of thickness $\ll \lambda$ but large enough to contain the secondary electrons.
$\cong 2\times10^{15}$ photons of 1 MeV energy on carbon.
(Quoted fluxes good to about a factor of 2 for all materials.)

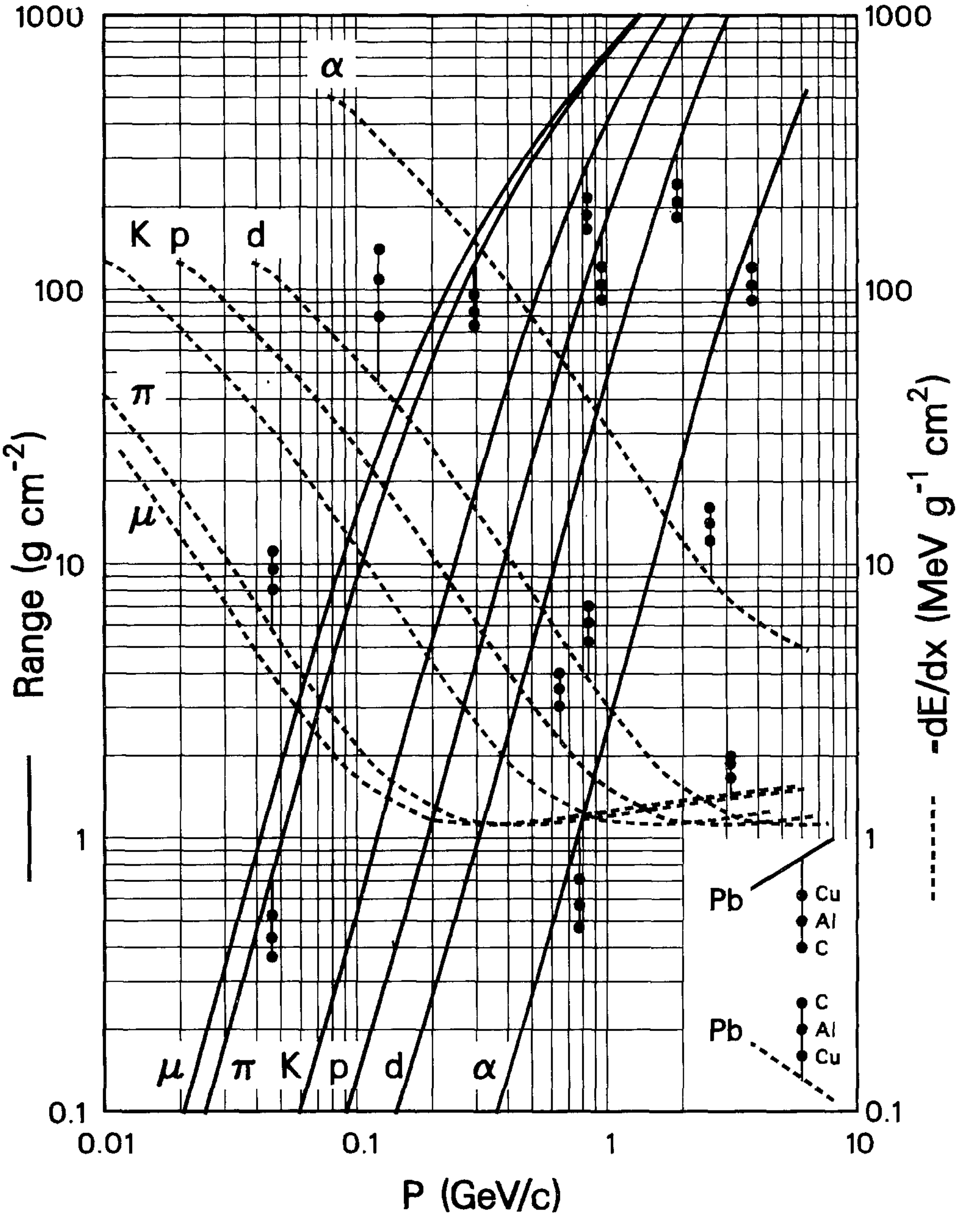
U.S. maximum permissible occupational whole-body dose:
50 mSv/year (5 rem/year).

Lethal dose: Whole-body dose from penetrating ionizing radiation resulting in 50% mortality in 30 days (assuming no medical treatment), 2.5-3.0 Gy (250-300 rads) as measured internally on body longitudinal center line; surface dose varies due to variable body attenuation and may be a strong function of energy.

For a recent review, see E. Pochin, *Nuclear Radiation: Risks and Benefits* (Clarendon Press, Oxford, 1983).

MEAN RANGE AND ENERGY LOSS

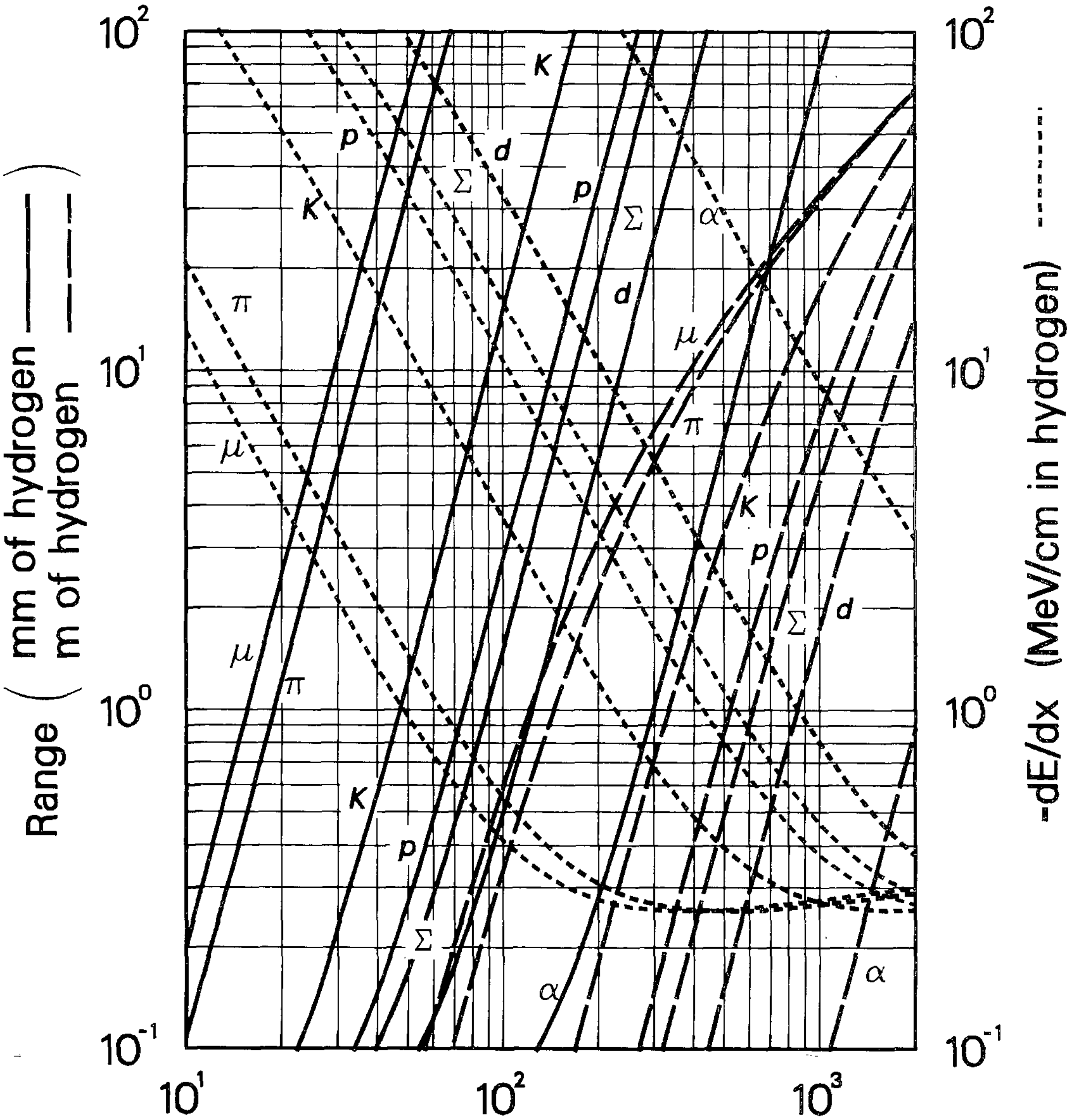
Mean Range and Energy Loss in Lead, Copper, Aluminum, and Carbon



Mean range and energy loss due to ionization for the indicated particles in Pb, with scaling to Cu, Al, and C indicated, using Bethe-Bloch equation [See Sec. (1) of Passage of Particles Through Matter] with corrections. Calculated by M.J. Berger, using ionization potentials and density effect corrections as discussed in M.J. Berger and S.M. Seltzer, "Stopping Powers and Ranges of Electrons and Positrons," (2^{nd} ed.), U.S. National Bureau of Standards Report NBSIR 82-2550-A (1982). The average ionization potentials (I) assumed were: Pb (823 eV), Cu (322 eV), Al (166 eV), and C (78.0 eV). Figure indicates total path length; observed range may be smaller (by ~ 1 % - 2% in heavy elements) due to multiple scattering, primarily from small energy-loss collisions with nuclei. The functional forms have not been experimentally verified to better than roughly ± 1%. For higher energies refer to discussion by Cobb ["A Study of Some Electromagnetic Interactions of High Velocity Particles with Matter," University of Oxford Report HEP/T/55 (1973)] and by Turner ["Penetration of Charged Particles in Matter: A Symposium," National Academy of Sciences, Washington D.C. (1970), p. 48]. For lower energies both data and theory are not well understood. Scaling to other beam particles is, to a good approximation, described by the expression on the next page.

MEAN RANGE AND ENERGY LOSS (Cont'd)

Mean Range and Energy Loss in Liquid Hydrogen

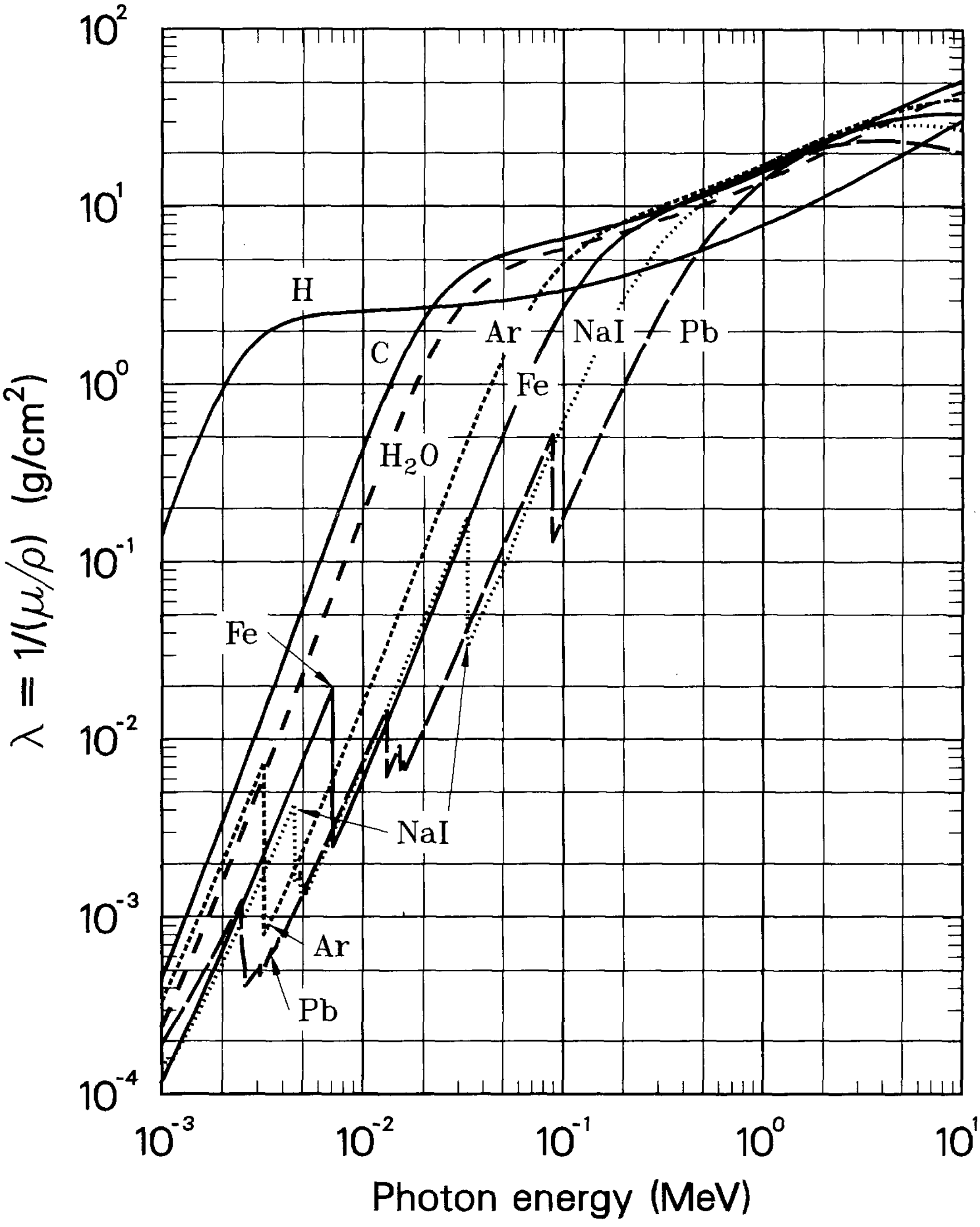


Range and energy loss in liquid hydrogen bubble chamber, based on Bethe-Bloch equation [See Sec. (1) of Passage of Particles Through Matter], using an average ionization potential for H_2 of $I = 20.0$ eV, which is an approximate average of the experimental result of Garbincius and Hyman [Phys. Rev. **A2**, 1834 (1970)] and the theoretical result of Ford and Browne [Phys. Rev. **A7**, 418 (1973)]. Bubble chamber conditions are chosen to be those of Garbincius and Hyman: parahydrogen of density = 0.0625 g/cm^3 (note: range $\propto$ 1/density), with vapor-pressure 60.8 lb/in^2 (absolute) and temperature 26.2°K. The functional dependence of the Bethe-Bloch equation is not experimentally verified to better than about ± 1% over large momentum ranges. It should be noted that the number of bubbles per cm of a track in a bubble chamber is nearly proportional to $1/\beta^2$, not dE/dx. For the linear portions of the range curves, $R \propto p^{3.6}$. ***Scaling law for particles of other mass or charge*** *(except electrons):* for a given medium, the range R_b of any beam particle with mass M_b, charge z_b, and momentum p_b is given in terms of the range R_a of any other particle with mass M_a, charge z_a, and momentum $p_a = p_b M_a / M_b$ (i.e., having the same velocity) by the expression:

$$R_b(M_b, z_b, p_b) = \left[\frac{M_b/M_a}{z_b^2/z_a^2} \right] R_a(M_a, z_a, p_a = p_b M_a / M_b) \,.$$

PHOTON AND ELECTRON ATTENUATION

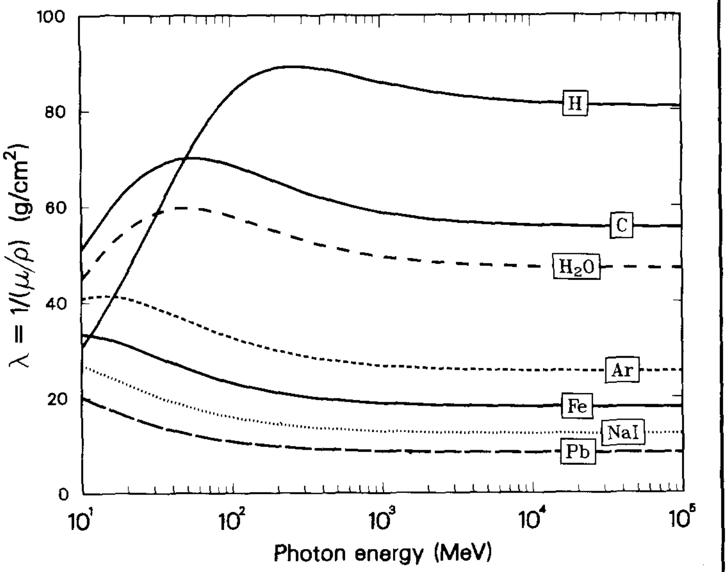
Photon Attenuation Length



The photon mass attenuation length $\lambda = 1/(\mu/\rho)$ (also known as mfp, mean free path) for various absorbers as a function of photon energy, where μ is the mass attenuation coefficient. For a homogeneous medium of density ρ, the intensity I remaining after traversal of thickness t is given by the expression $I = I_0 \exp(-t\rho/\lambda)$. The accuracy is a few percent. Interpolation to other Z should be done in the cross section $\sigma = A/\lambda N_A$ cm^2/atom, where A is the atomic weight of the absorber material in grams and N_A is the Avogadro number. For a chemical compound or mixture, use $(1/\lambda)_{\mathrm{eff}} \cong \sum w_i (1/\lambda)_i$, accurate to a few percent, where w_i is the proportion by weight of the i^{th} constituent. See next page for high energy range. From Hubbell, Gimm, and Øverbø, J. Phys. Chem. Ref. Data 9, 1023 (1980). See also J.H. Hubbell, Int. J. of Applied Rad. and Isotopes 33, 1269 (1982). Data courtesy J.H. Hubbell.

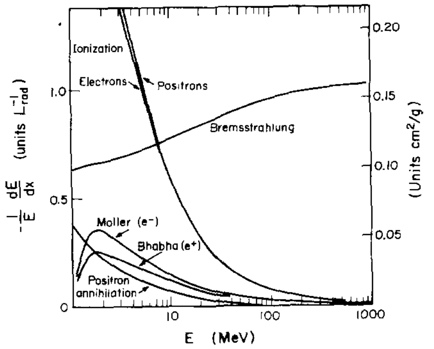
PHOTON AND ELECTRON ATTENUATION (Cont'd)

Photon Attenuation Length (High Energy)



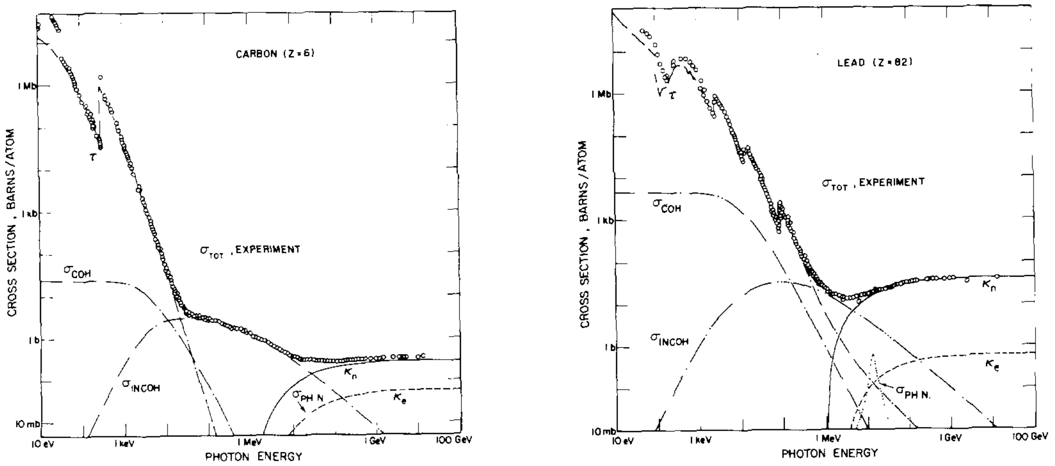
The photon mass attenuation length, high energy range (note that ordinate is linear scale). See caption on previous page for details.

Fractional Energy Loss for Electrons and Positrons in Lead



Fractional energy loss per radiation length in lead as a function of electron or positron energy. Electron (positron) scattering is considered as ionization when the energy loss per collision is below 0.255 MeV, and as Moller (Bhabha) scattering when it is above. Adapted from Fig. 3.2 from Messel and Crawford, *Electron-Photon Shower Distribution Function Tables for Lead, Copper, and Air Absorbers*, Pergamon Press, 1970. Messel and Crawford use $L_r(\mathrm{Pb}) = 5.82$ g/cm^2, but we have modified the figures to reflect the value given in the Table of Atomic and Nuclear Properties of Materials, namely $L_r(\mathrm{Pb}) = 6.4$ g/cm^2. The development of electron-photon cascades is approximately independent of absorber when the results are expressed in terms of inverse radiation lengths (i.e., scale on left of plot).

Contributions to Photon Cross Section in Carbon and Lead



Photon total cross sections as a function of energy in carbon and lead, showing the contributions of different processes.

τ = Atomic photo-effect (electron ejection, photon absorption)
σ_{COH} = Coherent scattering (Rayleigh scattering — atom neither ionized nor excited)
σ_{INCOH} = Incoherent scattering (Compton scattering off an electron)
κ_n = Pair production, nuclear field
κ_e = Pair production, electron field
$\sigma_{PH.N.}$ = Photonuclear absorption (nuclear absorption, usually followed by emission of a neutron or other particle)

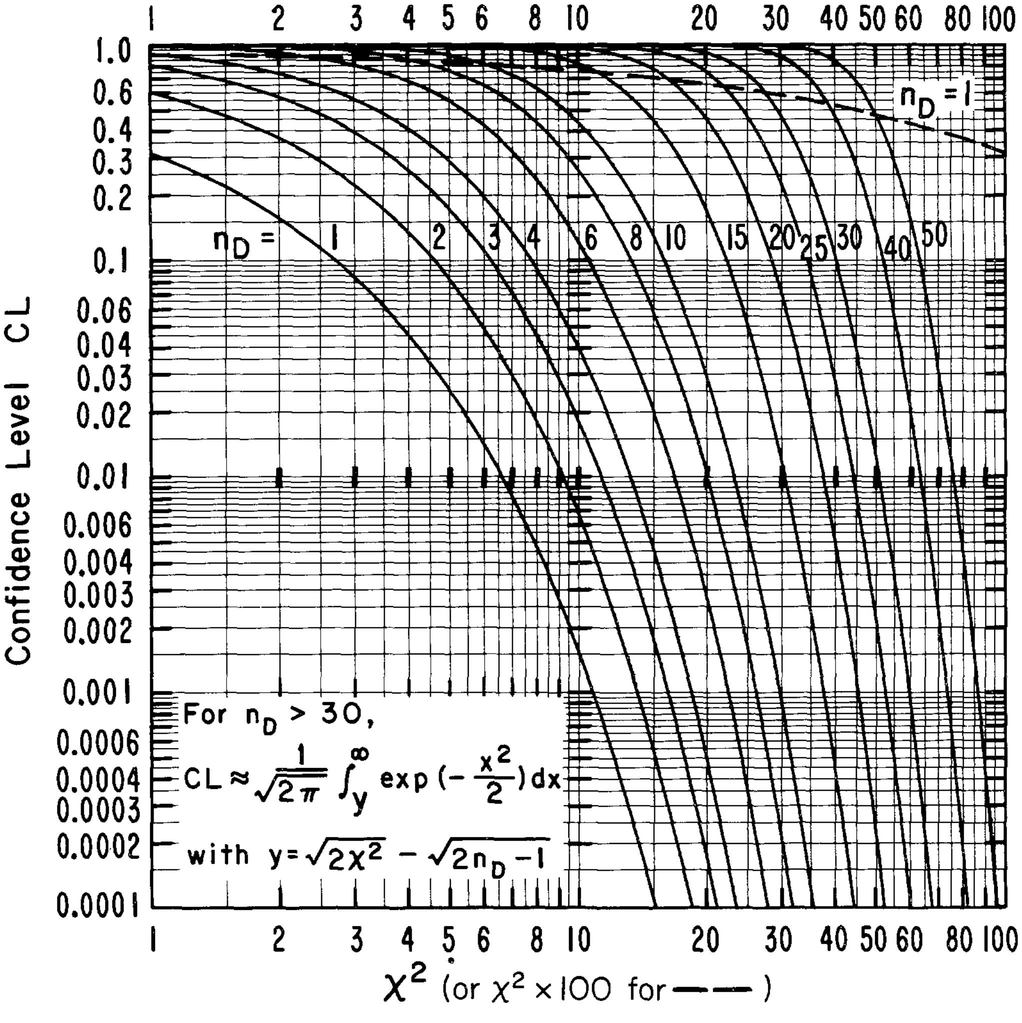
From Hubbell, Gimm, and Øverbø, J. Phys. Chem. Ref. Data 9, 1023 (1980). Figures courtesy J.H. Hubbell.

PROBABILITY AND STATISTICS

A. PROBABILITY DISTRIBUTIONS AND CONFIDENCE LEVELS

We give here properties of four probability distributions commonly encountered in high energy physics: normal (or Gaussian), chi-squared (χ^2), Poisson, and binomial. We *warn* the reader that there is no universal convention for the term "confidence level"; thus, explicit definitions that correspond to common usage are given below. We explain below how confidence levels for the first three distributions may be extracted from the following figure.

χ^2 Confidence Level vs. χ^2 for n_D Degrees of Freedom



For $n_D > 30$,

$$CL \approx \frac{1}{\sqrt{2\pi}} \int_y^\infty \exp\left(-\frac{x^2}{2}\right) dx$$

with $y = \sqrt{2\chi^2} - \sqrt{2n_D - 1}$

PROBABILITY AND STATISTICS (Cont'd)

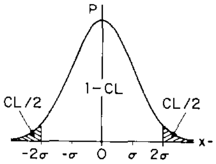
A.1 Normal distribution

The normal distribution with mean $\bar{x} = \mu$ and standard deviation σ (variance σ^2) is:

$$P(x)dx = \frac{1}{\sigma\sqrt{2\pi}}\, e^{-(x-\mu)^2/2\sigma^2} dx \ . \qquad (1)$$

The *confidence level* associated with an observed deviation $\pm\delta$ from the mean is the probability that $|x-\mu| > \delta$, i.e.,

$$\mathrm{CL} = 2 \int_{\mu+\delta}^{\infty} dx\ P(x)\,, \qquad (2)$$



since the distribution is symmetric about μ. The small figure in Eq. (2) is drawn with $\delta = 2\sigma$. CL is given by the ordinate of the $n_D = 1$ curve in the large figure at $\chi^2 = (\delta/\sigma)^2$. The *odds* against exceeding δ in an observation, (1−CL)/CL, for $\delta = 1\sigma$ are 2.15:1; 2σ, 21:1; 3σ, 370:1; 4σ, 16,000:1; 5σ, 1,700,000:1. Other measures of the *width* are related to σ as follows: probable error (CL = 0.5) = 0.67σ; mean absolute deviation = 0.80σ; RMS deviation = σ; half width at half maximum = 1.18σ.

The probability that a random observation of x will have $|x - \mu| < \delta$ is (1 − CL). Therefore, for a given measurement x_0, the interval $x_0 - \delta$ to $x_0 + \delta$ can be expected to contain μ a fraction (1 − CL) of the time. Refer to Sec. B.1 below to combine *multiple* observations and treat them as a single measurement with appropriate variance. This interval is a (1 − CL) confidence interval for an unknown μ when σ is known. Frequently used choices for CL and δ are:

CL(%)	δ
31.7	1σ
4.6	2σ
0.3	3σ
6×10^{-3}	4σ
6×10^{-5}	5σ

CL(%)	δ
10	1.64σ
5	1.96σ
1	2.58σ
0.1	3.29σ
0.01	3.89σ

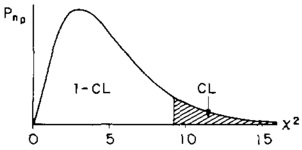
A.2 χ^2 distribution

The χ^2 distribution for n_D degrees of freedom is:

$$P_{n_D}(\chi^2)d\chi^2 = \frac{1}{2^h\Gamma(h)}\,(\chi^2)^{h-1}e^{-\chi^2/2}d\chi^2 \quad (\chi^2 \geqslant 0), \qquad (3)$$

where h (for "half") = $n_D/2$. The mean and variance are n_D and $2n_D$ respectively. In evaluating Eq. (3) one may use *Stirling's approximation*: $\Gamma(h) \cong 2.507\, e^{-h}\, h^{(h-1/2)}(1 + 0.0833/h)$, which is accurate to ± 0.1% for all $h \geqslant 1/2$. The *confidence level* associated with a given value of n_D and an observed value of χ_0^2 is the probability of the χ^2 in a random measurement exceeding the observed value, i.e.,

$$\mathrm{CL} = \int_{\chi_0^2}^{\infty} d\chi^2\, P_{n_D}(\chi^2) \qquad (4)$$



The small figure in Eq. (4) is drawn with $n_D = 5$ and CL = 10%. CL is plotted as a function of χ^2 for several values of n_D in the large figure. For *large* n_D, χ^2 becomes normally distributed about n_D. Thus,

$$y_1 = (\chi^2 - n_D)/\sqrt{2n_D} \qquad (5)$$

becomes normally distributed with unit standard deviation and mean zero. A *better* approximation is that χ, not χ^2, becomes normally distributed; specifically,

$$y_2 = \sqrt{2\chi^2} - \sqrt{2n_D - 1} \qquad (6)$$

approaches normality with unit standard deviation and mean zero. For small CL's in particular, y_2 is much more accurate than y_1. Thus, for $n_D = 50$ and $\chi^2 = 80$, the true CL = 0.45%, but y_1 is 3.0 corresponding to a CL of 0.13%, while y_2 is 2.7 corresponding to a CL of 0.35%.

A.3 Poisson distribution

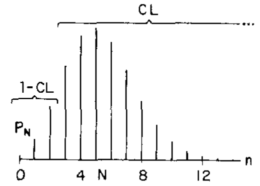
The Poisson distribution with mean μ is:

$$P_\mu(n) = \frac{e^{-\mu}\mu^n}{n!} \quad (n = 0, 1, 2, \cdots). \qquad (7)$$

The observed result of a Poisson process is a non-negative integer n; the parameter μ, which is equal to both the mean and the variance, is any non-negative real number. When μ is large ($\gtrsim 7$ or 8), one may often usefully approximate the distribution of n by a normal of mean μ and variance $\sigma^2 = \mu$, as though n were a continuous variable. Two or more Poisson processes (e.g., *signal* plus *background*, with parameters μ_S and μ_B respectively) which independently contribute amounts n_S and n_B to a given measurement will produce an observed number $n = n_S + n_B$ which is distributed according to a new Poisson distribution with parameter $\mu = \mu_S + \mu_B$.

When an observed value n_0 of n is small, one is often interested in obtaining an *upper limit* N (not necessarily an integer) to the parameter μ such that one may be, e.g., 90% or 95% confident that the true value of μ lies below N. We define this N to be that value of μ such that it would be exactly 90% (or 95%) probable that a random observation of n would lie above the actual observation n_0. That is, if CL = 0.90 or 0.95,

$$\mathrm{CL} = \sum_{n=n_0+1}^{\infty} P_N(n) = 1 - \sum_{n=0}^{n_0} P_N(n) \qquad (8)$$



The small figure in Eq. (8) illustrates the case with $n_0 = 2$ and CL = 0.90, for which it may be shown that $N = 5.3$. We can obtain N for any desired n_0 and CL from the large χ^2 figure, because of a particular relation between Poisson and χ^2 confidence levels: at the level 1−CL on the curve $n_D = 2(n_0 + 1)$, the desired N is 1/2 the χ^2 value of that point. Some useful values are:

Poisson upper limits N for n_0 observed events

n_0	CL= 90%	CL= 95%	n_0	CL= 90%	CL= 95%
0	2.30	3.00	6	10.53	11.84
1	3.89	4.74	7	11.77	13.15
2	5.32	6.30	8	13.00	14.44
3	6.68	7.75	9	14.21	15.71
4	7.99	9.15	10	15.41	16.96
5	9.27	10.51			

Tables of confidence levels for all three of these distributions, the relation between Poisson and χ^2 confidence levels, and numerous other useful tables and relations may be found in Ref. 1.

PROBABILITY AND STATISTICS (Cont'd)

A.4 Binomial distribution

Any process with exactly two possible outcomes is a *Bernoulli* process. If the process is repeated n times independently, and if the probability of obtaining a certain outcome (a "success") in each trial is p, then the probability of obtaining exactly r successes is given by the binomial distribution:

$$P_{n,p} = \binom{n}{r} p^r q^{n-r} = \frac{n!}{r!(n-r)!} p^r q^{n-r} , \tag{9}$$

where $q = 1 - p$ and the order in which the successes and failures come is assumed irrelevant. The mean of r is equal to np and the variance is npq. If r successes are observed in n_r Bernoulli trials with probability p of success, and if s successes are observed in n_s similar trials, then $t = r + s$ is also binomial with $n_t = n_r + n_s$.

B. STATISTICS

The probability density functions we have shown enable us to predict the frequency with which a random observation of the variable x (or n or χ^2) will lie in a certain region, once the parameters μ and σ (or n_D) are known. In statistics (*parametric* statistics) we have the opposite problem of estimating the parameters of the distribution from a set of actual observations.

Suppose one is presented with N independent data, $y_n \pm \sigma_n$, and it is desired to make some *inference* about the "true" value of the quantity represented by these data. For this purpose we interpret each datum y_n as a single sample point drawn randomly from a distribution having true mean μ_n (which we wish to estimate) and variance σ_n^2. We do not require that they be normally distributed. (Identification of the true σ_n with the σ_n datum is often an *approximation* which may become seriously inaccurate when σ_n is an appreciable fraction of y_n.) Some methods of estimation commonly used in high energy physics are given below; see Ref. 2 for numerous applications. Section B.1 deals with the case in which all μ_n are the same, i.e., several different measurements of the same quantity. Sec. B.2 deals with the case in which the true value of y_n, μ_n, is a variable dependent upon another variable x_n; i.e., $\mu_n = f(x_n)$. An example is the energy deposited in a calorimeter as a function of the energy of the incident particle, $y_n = f(E_n)$.

B.1 Single mean and variance estimates

(1) If the y_n represent a set of values all supposedly drawn from a single distribution with mean μ and variance σ^2 (i.e., the σ_n are all the same, but their common value is unknown), then

$$\hat{y} = \frac{1}{N} \sum_{n=1}^{N} y_n \quad \text{and} \tag{10}$$

$$\hat{\sigma}^2 = \frac{1}{N-1} \sum_{n=1}^{N} (y_n - \hat{y})^2 = \frac{N}{N-1}\left[\langle (y^2) \rangle - (\hat{y})^2\right] \tag{11}$$

are unbiased *estimates* of μ and σ^2; the angular brackets denote an average over the data. The variance of $\hat{y}$ is σ^2/N. If the parent distribution is normal and N is large, the variance of $\hat{\sigma}^2$ is $2\sigma^4/N$.

(2) If the y_n are independent estimates of the same μ, and the σ_n are known, then the weighted average

$$\hat{y} = \frac{1}{w} \sum_n w_n y_n , \tag{12}$$

where $w_n = 1/\sigma_n^2$ and $w = \sum w_n$, is an appropriate unbiased estimate of μ. This choice of weighting factors in Eq. (12) minimizes the variance of the estimate, which is $1/w$.

B.2 Linear least-squares fit

We wish to determine the best fit of unbiased data y_n, measured at N points x_n (assumed known with negligible error), to the form $y(x) = \Sigma a_i f_i(x)$, where the f_i are known, linearly independent functions (e.g., Legendre polynomials) which are single-valued over the allowed range of x, and the sum runs from 1 to k. We require $k \leq N$, and at least k of the x_n must be distinct. We wish to estimate the linear coefficients a_i.

The Method of Least Squares assumes that each measured y_n is equal to this sum plus an error ϵ_n. If the distribution of ϵ_n has an expectation value of zero (unbiased) and has a finite, known variance which is fixed (does not depend on the parameters of the fit), then the estimates of a_i obtained by minimizing the sum of squares $\mathrm{SS} = \sum_n [y_n - \sum a_i f_i(x_n)]^2/\sigma_n^2$ will be unbiased and have the smallest possible variance of all linear unbiased estimates (Gauss-Markov Theorem). If the point errors ϵ_n are also Gaussian, then $\mathrm{SS} = \sum_n \epsilon_n^2/\sigma_n^2$ will be distributed, over a large number of similar experiments, as a χ^2 with $N-k$ degrees of freedom. If, more generally, the measured y_n's are not independent, then the set of σ_n^2's must be replaced by the $N \times N$ variance matrix V_y. Then, in matrix notation, if H is the $N \times k$ matrix with element $H_{ni} = f_i(x_n)$, the vector (all vectors are column vectors) of solutions $\hat{a}$, with k elements, is given by

$$\hat{a} = (H^T V_y^{-1} H)^{-1} H^T V_y^{-1} \bar{y} \equiv D\bar{y} , \tag{13}$$

where $\bar{y}$ is the N-element vector of measured y_n's. In terms of the $k \times N$ matrix D, the standard variance matrix for the $\hat{a}$ is estimated by

$$V_{\hat{a}} = D V_y D^T . \tag{14a}$$

If the measured y_n's are independent, V_y is diagonal with nn^{th} element σ_n^2 and

$$\left[V_{\hat{a}}^{-1}\right]_{ij} = \sum_n f_i(x_n) f_j(x_n)/\sigma_n^2 . \tag{14b}$$

The estimated variance of an interpolated or extrapolated value of y at a point x, $\hat{y} = \sum \hat{a}_i f_i(x)$, is

$$\sigma^2(\hat{y}) = \sum_{ij} (V_{\hat{a}})_{ij} f_i(x) f_j(x) . \tag{15}$$

The same results may be obtained by numerical or other techniques from the sum of squares, SS, directly, if we have a reasonable first guess $\bar{a}_0$ for the solution vector:

$$\hat{a} = \bar{a}_0 - \left(\frac{\partial^2 \mathrm{SS}}{\partial a^2}\right)^{-1}_{\bar{a}_0} \cdot \left.\frac{\partial \mathrm{SS}}{\partial a}\right|_{\bar{a}_0} \tag{16a}$$

and

$$V_{\hat{a}} = 2\left(\frac{\partial^2 \mathrm{SS}}{\partial a^2}\right)^{-1}_{\hat{a}} , \tag{16b}$$

where $\partial\mathrm{SS}/\partial a$ is a k-element vector whose i^{th} element is $\partial\mathrm{SS}/\partial a_i$, $\partial^2\mathrm{SS}/\partial a^2$ is a $k \times k$ matrix with ij^{th} element $\partial^2\mathrm{SS}/(\partial a_i \cdot \partial a_j)$, and all derivatives are to be evaluated at the points indicated. If SS is a χ^2, the second-derivative matrix is independent of $\bar{a}$, and the shape of the χ^2 as a function of $\bar{a}$ is a parabola; otherwise one may need to iterate Eq. (16a) to arrive at a solution (Newton-Raphson method).

PROBABILITY AND STATISTICS (Cont'd)

Note that the errors on the solution $\hat{a}$ are independent of the value of SS or χ^2 at minimum – they depend only upon the shape about the minimum. Eq. (16b) implies that one-standard-deviation limits on the elements of $\hat{a}$ are given by the set of $\vec{a}'$ such that

$$\mathrm{SS}(\vec{a}') = \mathrm{SS}_{\min} + 1 \,. \tag{17}$$

This equation, which defines a contour in $\vec{a}$-space, is often convenient for estimating errors in applications of least-squares techniques to nonlinear cases, where the second derivative [Eq. (16b)] may be a rapidly varying function of $\vec{a}$. In general, contours at m standard deviations may be found by replacing the 1 in Eq. (17) by m^2. If the problem is highly nonlinear, all such contours are at best only approximations to confidence regions with some given probability of covering the true value of $\vec{a}$.

If SS is a χ^2 with $N-k$ degrees of freedom, its value at minimum may be used as a test of goodness-of-fit. If the model for y is correct and the measurements y_n are distributed as Gaussians with known variance matrix V_y, then the large figure above will give the probability that a similar experiment would be expected to yield the observed $\chi^2_{\min}$ or larger. If this probability is smaller than some agreed-upon value, one should question the assumptions about the data or the validity of the model.

Example — Straight-Line Fit
For the case of a *straight line fit*, $y(x) = a + bx$, one obtains, for independent measurements y_n, the following estimates of a and b,

$$\hat{a} = (S_y S_{xx} - S_x S_{xy})/D, \tag{18}$$

$$\hat{b} = (S_1 S_{xy} - S_x S_y)/D,$$

where

$$S_1, S_x, S_y, S_{xx}, S_{xy} = \sum (1, x_n, y_n, x_n^2, x_n y_n)/\sigma_n^2 \,, \tag{19}$$

respectively, and

$$D = S_1 S_{xx} - S_x^2 \,.$$

The covariance matrix of the fitted parameters is:

$$\begin{bmatrix} V_{aa} & V_{ab} \\ V_{ab} & V_{bb} \end{bmatrix} = \frac{1}{D} \begin{bmatrix} S_{xx} & -S_x \\ -S_x & S_1 \end{bmatrix} . \tag{20}$$

The estimated variance of an interpolated or extrapolated value of y at point x is:

$$(\hat{y} - y_{\mathrm{true}})^2 \big|_{\mathrm{est}} = \frac{1}{S_1} + \frac{S_1}{D} \left[x - \frac{S_x}{S_1} \right]^2 . \tag{21}$$

B.3 Limits in the Case of Bounded Physical Regions

In certain statistical problems the true value of the parameter to be estimated, μ, is constrained to lie within a bounded *physical region* (e.g., the mass of a neutrino is bounded from below by 0). However, due to random measurement error, real measured values may or may not occur inside the physical region. For this case no completely satisfactory approach exists, but here we suggest a technique for obtaining approximate limits within the physical region at specified confidence levels.

We assume a measurement x, which represents one observation (or the result of combining multiple measurements as in Sec. B.1) from a normal of true (but unknown) mean μ and known, fixed, variance σ^2. We *estimate* μ by $\hat{\mu} = x$ and attempt to construct a confidence interval for μ from the resultant Gaussian, as in A.1. If $\hat{\mu}$ or a portion of the accepted region [*un*shaded in the figure with Eq. (2)] lies in the unphysical region, the result, while statistically perfectly correct as stated, is physically unsatisfactory.

If we assume μ is bounded from below by $\mu_{\min}$ (the argument for μ bounded from above is similar), we may estimate an upper limit for μ at the CL (e.g., 90% or 95%) level by the following procedure: 1) *renormalize* the normal probability distribution for x such that the integral of Eq. (1) with $\mu = \hat{\mu}$ over x from $\mu_{\min}$ to infinity (i.e., over the physical region) is equal to 1.0; 2) find the value μ_1 such that the integral over x of the renormalized distribution from $\mu_{\min}$ to μ_1 is equal to the desired value of CL; 3) set μ_1 to be the desired upper limit with confidence CL. In fact, it can be shown that this is *conservative*, in the sense that the probability that this interval actually covers the true value of μ is $\geqslant$ CL.

For $\mu - \mu_{\min} >> \sigma$, this technique, which may be applied for any measured x (physical or unphysical), converges smoothly to that of Sec. A.1, since x is then effectively confined to the physical region.

One should exercise caution for values of x which lie many standard deviations outside the physical region. It may be that the particular probability model (normal with variance σ^2) may not be a correct description of the measurement process (e.g., the true variance may have unanticipated components and be $> \sigma^2$, or there may be a bias), in which case confidence levels of this sort will not be correct.

C. ERROR PROPAGATION

Suppose one wishes to calculate the value and error of a function of some other quantities with errors, e.g., in a Monte Carlo program. Let $\{y\}$ be a set of random variables with observed means $\{\bar{y}\}$ and covariance matrix V. Then the mean and variance of a function f of these variables are approximately (to second order in $\{y - \bar{y}\}$):

$$\bar{f} \cong f(\{\bar{y}\}) + \frac{1}{2} \sum_{mn} V_{mn} \left[\frac{\partial^2 f}{\partial y_m \partial y_n} \right]_{\{y\} = \{\bar{y}\}} , \tag{22}$$

$$\overline{(f - \bar{f})^2} \cong \sum_{mn} V_{mn} \left[\frac{\partial f}{\partial y_m} \right]_{\{y\} = \{\bar{y}\}} \left[\frac{\partial f}{\partial y_n} \right]_{\{y\} = \{\bar{y}\}} . \tag{23}$$

E.g., the mean and variance of a function of a *single variable* with mean $\bar{y}$ and variance σ^2 are

$$\bar{f} \cong f(\bar{y}) + \frac{1}{2}\sigma^2 f''(\bar{y}) \,, \tag{24}$$

$$\overline{(f - \bar{f})^2} \cong \sigma^2 f'(\bar{y})^2 \,. \tag{25}$$

If, as is often the case, the observed mean $\bar{y}_n$ differs from the true mean μ_n by an amount of order $\sqrt{V_{nn}}$, then the second-order terms in Eqs. (22) and (24) may be small compared with the first-order errors introduced by the substitution.

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1. M. Abramowitz and I. Stegun, eds., *Handbook of Mathematical Functions* (Dover, New York, 1972).
2. W.T. Eadie, D. Drijard, F.E. James, M. Roos, and B. Sadoulet, *Statistical Methods in Experimental Physics* (North Holland, Amsterdam and London, 1971); S.L. Meyer, *Data Analysis for Scientists and Engineers* (John Wiley and Sons, Inc., New York, 1975); A.G. Frodesen, O. Skjeggestad, and H. Tøfte, *Probability and Statistics in Particle Physics* (Universitetsforlaget, Oslo, Norway, 1979).

ELECTROMAGNETIC RELATIONS

Quantity	Gaussian CGS	MKSA
Units and conversions:		
Charge:	2.99792×10^9 esu	$= 1$ coul $= 1$ amp-sec
Potential:	$(1/299.792)$ statvolt $= (1/299.792)$ erg/esu	$= 1$ volt $= 1$ joule/coul
Magnetic field:	10^4 gauss $= 10^4$ dyne/esu	$= 1$ tesla $= 1$ nt/amp-m
Electron charge:	$e = 4.803\,242\times10^{-10}$ esu	$= 1.602\,189\,2\times10^{-19}$ coul
Lorentz force:	$\mathbf{F} = q(\mathbf{E} + \frac{\mathbf{v}}{c}\times\mathbf{B})$	$\mathbf{F} = q(\mathbf{E} + \mathbf{v}\times\mathbf{B})$
Maxwell equations:	$\nabla\cdot\mathbf{D} = 4\pi\rho$ $\nabla\times\mathbf{E} = -\frac{1}{c}\frac{\partial\mathbf{B}}{\partial t}$ $\nabla\cdot\mathbf{B} = 0$ $\nabla\times\mathbf{H} = \frac{4\pi\mathbf{j}}{c} + \frac{1}{c}\frac{\partial\mathbf{D}}{\partial t}$	$\nabla\cdot\mathbf{D} = \rho$ $\nabla\times\mathbf{E} = -\frac{\partial\mathbf{B}}{\partial t}$ $\nabla\cdot\mathbf{B} = 0$ $\nabla\times\mathbf{H} = \mathbf{j} + \frac{\partial\mathbf{D}}{\partial t}$
Materials:	$\mathbf{D} = \epsilon\mathbf{E},\ \mathbf{B} = \mu\mathbf{H}$	$\mathbf{D} = \epsilon\mathbf{E},\ \mathbf{B} = \mu\mathbf{H}$
Permittivity of free space:	$\epsilon_{\rm vac} = 1$	$\epsilon_{\rm vac} = \epsilon_0$
Permeability of free space:	$\mu_{\rm vac} = 1$	$\mu_{\rm vac} = \mu_0$
Fields:	$\mathbf{E} = -\nabla V - \frac{1}{c}\frac{\partial\mathbf{A}}{\partial t}$ $\mathbf{B} = \nabla\times\mathbf{A}$	$\mathbf{E} = -\nabla V - \frac{\partial\mathbf{A}}{\partial t}$ $\mathbf{B} = \nabla\times\mathbf{A}$
Static potentials: (coulomb gauge)	$V = \sum\limits_{\rm charges}\frac{q}{r}$ $\mathbf{A} = \frac{1}{c}\sum\limits_{\rm currents}\frac{\mathbf{I}}{r}$	$V = \frac{1}{4\pi\epsilon_0}\sum\limits_{\rm charges}\frac{q}{r}$ $\mathbf{A} = \frac{\mu_0}{4\pi}\sum\limits_{\rm currents}\frac{\mathbf{I}}{r}$
Relativistic transformations: (v is the velocity of primed system as seen in unprimed system)	$\mathbf{E}'_\parallel = \mathbf{E}_\parallel$ $\mathbf{E}'_\perp = \gamma(\mathbf{E}_\perp + \frac{1}{c}\mathbf{v}\times\mathbf{B})$ $\mathbf{B}'_\parallel = \mathbf{B}_\parallel$ $\mathbf{B}'_\perp = \gamma(\mathbf{B}_\perp - \frac{1}{c}\mathbf{v}\times\mathbf{E})$	$\mathbf{E}'_\parallel = \mathbf{E}_\parallel$ $\mathbf{E}'_\perp = \gamma(\mathbf{E}_\perp + \mathbf{v}\times\mathbf{B})$ $\mathbf{B}'_\parallel = \mathbf{B}_\parallel$ $\mathbf{B}'_\perp = \gamma(\mathbf{B}_\perp - \frac{1}{c^2}\mathbf{v}\times\mathbf{E})$

$$4\pi\epsilon_0 = \frac{1}{c^2}10^7\frac{\text{coul}^2}{\text{nt sec}^2} = \frac{1}{8.987\,55}\times10^{-9}\frac{\text{coul}^2}{\text{nt m}^2}$$

$$\frac{\mu_0}{4\pi} = 10^{-7}\frac{\text{nt sec}^2}{\text{coul}^2}\ ;\quad c = 2.997\,924\,58\times10^8\ \text{m sec}^{-1}$$

Impedances (MKSA)

ρ = resistivity in $10^{-8}\ \Omega$m:

~ 1.7 for Cu
~ 2.4 for Au
~ 2.8 for Al
(Al alloys may have double this value.)
~ 5.5 for W
~ 73 for SS 304
~ 100 for Nichrome

For alternating currents, instantaneous current I, voltage V, angular frequency ω:

$$V = V_0 e^{i\omega t} = ZI\ .$$

Impedance of self-inductance L: $Z = i\omega L$.

Impedance of capacitance C: $Z = 1/i\omega C$.

Impedance of free space: $Z = \sqrt{\mu_0/\epsilon_0} = 376.7\ \Omega$.

Impedance per unit length of a flat conductor of width w (high frequency, ν):

$$Z = \frac{(1+i)\rho}{w\delta}\ ,\ \text{where } \delta = \text{effective skin depth}\ ;$$

$$\delta = \sqrt{\frac{\rho}{\pi\nu\mu}} \cong \frac{6.6\ \text{cm}}{\sqrt{\nu(\text{sec}^{-1})}}\ \text{for Cu}\ .$$

Capacitance $\hat{C}$ and inductance $\hat{L}$ per unit length (MKSA)

Flat rectangular plates of width w, separated by $d \ll w$:

$$\hat{C} = \epsilon\frac{w}{d}\ ;\quad \hat{L} = \mu\frac{d}{w}\ ;$$

$$\frac{\epsilon}{\epsilon_0} = 2 \text{ to } 6 \text{ for plastics; } 4 \text{ to } 8 \text{ for porcelain, glasses.}$$

Coaxial cable of inner radius r_1, outer radius r_2:

$$\hat{C} = \frac{2\pi\epsilon}{\ell n(r_2/r_1)}\ ;\quad \hat{L} = \frac{\mu}{2\pi}\ell n(r_2/r_1)\ .$$

Transmission lines (no loss):

Impedance: $Z = \sqrt{\hat{L}/\hat{C}}$.

Velocity: $v = 1/\sqrt{\hat{L}\hat{C}} = 1/\sqrt{\mu\epsilon}$.

Motion of charged particles in a uniform, static, magnetic field

The path of motion of a charged particle of momentum p is a helix of constant radius R and constant pitch angle λ, with the axis of the helix along **B**:

$$p(\text{GeV}/c)\cos\lambda = 0.29979\ q\ B(\text{tesla})\ R(\text{m})\ ,$$

where the charge q is in units of the electronic charge. The angular velocity about the axis of the helix is

$$\omega(\text{rad sec}^{-1}) = 8.98755\times10^7\ q\ B(\text{tesla})/E(\text{GeV})\ ,$$

where E is the energy of the particle.

ELECTROMAGNETIC RELATIONS (Cont'd)

Synchrotron radiation (CGS)

For a relativistic particle of charge e, velocity β, γ, energy E, traveling in a circular orbit of radius R:

$$\text{Energy loss/revolution (MeV)} = \frac{4\pi}{3}\frac{e^2}{R}\beta^3\gamma^4$$

$$\cong 0.0885\ [E(\text{GeV})]^4/R(\text{m}) \text{ for } e^\pm \text{ if } \beta \cong 1.$$

Energy spectrum: The energy radiated into the photon energy interval $d(\hbar\omega)$ is

$$dI = \alpha\gamma F(\omega/\omega_c)d(\hbar\omega)\,,$$

where $\alpha = e^2/(\hbar c)$ is the fine-structure constant,

$F(y) = 2\sqrt{3}y\int_{2y}^{\infty} dx\ K_{5/3}(x)$, with $K_{5/3}(x)$ a modified cylindrical Bessel function of the third kind, and $\omega_c = 3\gamma^3 c/R$ is a critical frequency;

$$\hbar\omega_c\ (\text{keV}) \cong 4.44\ [E(\text{GeV})]^3/R(\text{m}) \text{ for } e^\pm \text{ if } \beta \cong 1.$$

In the limit $\gamma >> 1$,

for $\omega << \omega_c$:

$$\frac{dI}{d(\hbar\omega)} \cong 3.3\alpha\left[\frac{\omega R}{c}\right]^{1/3};$$

for $\frac{\omega}{\omega_c} = (0.01, 0.1, 0.2, 1.0, 2.0)$:

$$\frac{dI}{d(\hbar\omega)} \cong (1.0,\ 1.6,\ 1.6,\ 0.5,\ 0.08)\alpha\gamma\,, \text{ respectively;}$$

for $\omega \gtrsim 2\omega_c$:

$$\frac{dI}{d(\hbar\omega)} \cong \sqrt{3\pi}\alpha\gamma\left[\frac{\omega}{\omega_c}\right]^{1/2} e^{-2\omega/\omega_c}\,.$$

The radiation is confined to angles $\lesssim 1/\gamma$ relative to the instantaneous direction of motion.

See J.D. Jackson, *Classical Electrodynamics*, 2nd edition (John Wiley & Sons, New York, 1975) for more formulae and details. (Prepared April 1974; revised April 1984.)

CROSS SECTIONS, DECAYS, STRUCTURE FUNCTIONS, AND KINEMATICS

A. LORENTZ TRANSFORMATIONS

The energy E and three-momentum $\vec{p}$ of a particle form a four-vector $p = (E, \vec{p})$. If the particle has rest mass m and velocity $\vec{v}$, then $\vec{p} = \gamma m\vec{v}$ and $E = \gamma mc^2$. It follows that the velocity expressed as a fraction of the speed of light is $\vec{\beta} \equiv \vec{v}/c = \vec{p}c/E$. In what follows we adopt units where $c = 1$. Viewed from a second frame with velocity $\beta\hat{z}$ relative to the original frame, the components of p are $(E', \vec{p}')$, where

$$E' = \gamma E - \beta\gamma p_z\,,$$

$$p_z' = \gamma p_z - \beta\gamma E\,,$$

$$p_x' = p_x;\ p_y' = p_y\,,$$

and where $\gamma = (1-\beta^2)^{-1/2}$. It follows that the scalar product of two momenta, $p_1 \cdot p_2 = E_1E_2 - \vec{p}_1 \cdot \vec{p}_2$, is invariant, that is, frame independent.

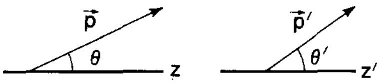
If the lab frame of two colliding particles of masses m_1 and m_2 is the frame in which m_2 is at rest, then the lab velocity of the center of mass is

$$\beta_{\text{cm}} = p_1/(E_1 + m_2)\,.$$

The total energy available in the center of mass is

$$E_{\text{cm}}^{\text{tot}} = (m_1^2 + m_2^2 + 2E_1m_2)^{1/2}\,.$$

If $\vec{p}$ makes an angle θ with the z-axis, then $\vec{p}'$ makes an angle θ' with the z-axis,



where

$$\tan\theta' = \frac{|\vec{p}|\sin\theta}{\gamma|\vec{p}|\cos\theta - \beta\gamma E}\,.$$

In particular, if the unprimed frame is the center of mass and the primed frame is the lab, and if the velocity of the center of mass in the lab frame is $\beta^*\hat{z}$, we use $\beta = -\beta^*$ above to find (denoting $p_{\text{cm}} = |\vec{p}_{\text{cm}}|$)

$$\tan\theta_{\text{lab}} = \frac{p_{\text{cm}}\sin\theta_{\text{cm}}}{\gamma^* p_{\text{cm}}\cos\theta_{\text{cm}} + \beta^*\gamma^* E_{\text{cm}}}\,.$$

If $\beta^* > p_{\text{cm}}/E_{\text{cm}}$, the particle is necessarily moving forward in the lab and

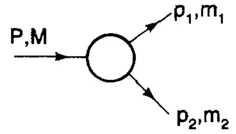
$$(\tan\theta_{\text{lab}})_{\max} = \frac{p_{\text{cm}}}{\gamma^* E_{\text{cm}}}\,\frac{1}{\sqrt{\beta^{*2} - p_{\text{cm}}^2/E_{\text{cm}}^2}}\,.$$

We denote $p_\perp = p_\perp' = |\vec{p}|\sin\theta_{\text{cm}}$. Then given a fixed p_{cm} and E_{cm}, as, for example, in a two-to-two scattering process, as θ_{cm} varies from 0 to 2π the lab momentum describes an ellipse:

$$\frac{(p_z' - \beta^*\gamma^* E_{\text{cm}})^2}{\gamma^{*2}p_{\text{cm}}^2} + \frac{p_\perp'^2}{p_{\text{cm}}^2} = 1\,.$$

B. DECAYS

B.1.a Two-body kinematics:



In the rest frame of the decaying particle,

$$E_1 = \frac{M^2 + m_1^2 - m_2^2}{2M} ,$$

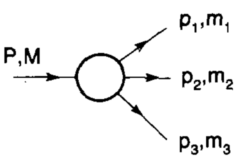
$$|\vec{p}_1| = \left[\frac{[M^2 - (m_1 + m_2)^2][M^2 - (m_1 - m_2)^2]}{4M^2} \right]^{1/2} .$$

B.1.b Two-body partial decay rate: If $\mathcal{M}$ is the Lorentz invariant matrix element (see Section D below), the partial decay rate in the rest frame of the decaying particle is

$$d\Gamma = \frac{1}{32\pi^2} |\mathcal{M}|^2 \frac{|\vec{p}_1|\, d\Omega}{M^2} ,$$

where $d\Omega$ is the differential solid angle in the rest frame of the decaying particle.

B.2.a Three-body kinematics:



We denote

$$p_{12} = p_1 + p_2 \,, \; m_{12}^2 = p_{12}^2 \,, \text{ etc.}$$

Then

$$m_{12}^2 + m_{23}^2 + m_{13}^2 = M^2 + m_1^2 + m_2^2 + m_3^2 .$$

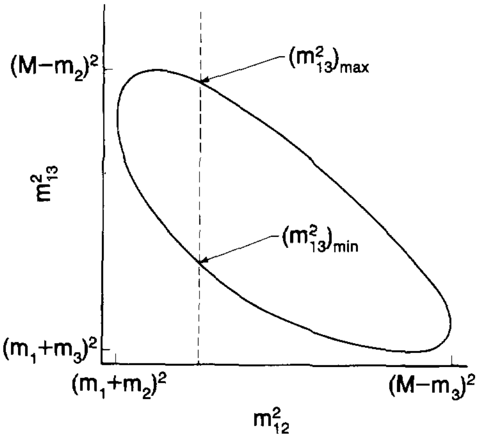
The invariant mass of the pair 1-2 is related to the energy of particle 3 in the rest frame of M,

$$m_{12}^2 = (P - p_3)^2 = M^2 + m_3^2 - 2ME_3 .$$

B.2.b Dalitz plot: If the orientation of the decaying particle is ignored, there are two kinematic variables, which may be chosen to be m_{12}^2 and m_{13}^2. For fixed m_{12}^2, the range of m_{13}^2 is determined by letting $\vec{p}_1$ be parallel or antiparallel to $\vec{p}_3$. In the rest frame of (p_1+p_2), the energy of particle 3 is $E_3^* = (M^2 - m_{12}^2 - m_3^2)/(2m_{12})$, and that of particle 1 is $E_1^* = (m_{12}^2 + m_1^2 - m_2^2)/(2m_{12})$. Thus for a given m_{12}^2,

$$(m_{13}^2)_{\max} = (E_1^* + E_3^*)^2 - \left[\sqrt{E_1^{*2} - m_1^2} - \sqrt{E_3^{*2} - m_3^2} \right]^2$$

$$(m_{13}^2)_{\min} = (E_1^* + E_3^*)^2 - \left[\sqrt{E_1^{*2} - m_1^2} + \sqrt{E_3^{*2} - m_3^2} \right]^2 .$$



The scatter plot in m_{12}^2 and m_{13}^2 is called a Dalitz plot. Phase space density is uniform across the plot. See below.

B.2.c Three-body phase space: Fixing the energies E_1 and E_2 of two of the final state particles in the M rest frame determines the relative orientation of the three outgoing particles. Their momenta may then be regarded as a rigid body whose orientation with respect to the initial particle is specified by the Euler angles α, β, and γ. The partial decay rate in the M rest frame is

$$d\Gamma = \frac{(2\pi)^{-5}}{16M} |\mathcal{M}|^2 \, dE_1 \, dE_2 \, d\alpha \, d\cos\beta \, d\gamma .$$

If the angles are integrated out, we have the Dalitz plot form,

$$d\Gamma = \frac{(2\pi)^{-3}}{8M} |\mathcal{M}|^2 \, dE_1 \, dE_2 = \frac{(2\pi)^{-3}}{32M^3} |\mathcal{M}|^2 \, dm_{12}^2 \, dm_{23}^2 .$$

An alternative expression is

$$d\Gamma = \frac{(2\pi)^{-5}}{16M^2} |\mathcal{M}|^2 \, |\vec{p}_1^{\,*}| \, |\vec{p}_3| \, dm_{12} \, d\Omega_1^* \, d\Omega_3 ,$$

where

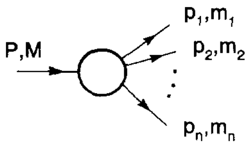
$$|\vec{p}_1^{\,*}| = \left[\frac{[m_{12}^2 - (m_1 + m_2)^2][m_{12}^2 - (m_1 - m_2)^2]}{4m_{12}^2} \right]^{1/2}$$

is the momentum of particle 1 in the rest frame of m_{12},

$$|\vec{p}_3| = \left[\frac{[M^2 - (m_{12} + m_3)^2][M^2 - (m_{12} - m_3)^2]}{4M^2} \right]^{1/2}$$

is the momentum of particle 3 in the M rest frame, $d\Omega_1^*$ is the solid angle element for particle 1 in the 1–2 rest frame, and $d\Omega_3$ is the solid angle element for particle 3 in the M rest frame.

B.3 *n*-body phase space:



The partial decay rate in the M rest frame is

$$d\Gamma = \frac{(2\pi)^4}{2M}\,|\mathcal{M}|^2\,d\Phi_n\,(P;p_1,\cdots,p_n)\,,$$

where

$$d\Phi_n(P;p_1,\cdots,p_n) = \delta^4(P-\sum_{i=1}^{n}p_i)\prod_{i=1}^{n}\frac{d^3p_i}{(2\pi)^3 2E_i}\,.$$

In particular,

$$d\Phi_2(P;p_1,p_2) = (2\pi)^{-6}\frac{|\vec{p}_1^{\,*}|}{4M}d\Omega_1^*\,,$$

where $|\vec{p}_1^{\,*}|$ is the momentum of particle 1 in the M rest frame and $d\Omega_1^*$ is the solid angle element in the same frame.

Phase space for n particles can be related to that for $n-1$ by treating particles 1 and 2 as a single system of momentum $p_{12} = p_1+p_2$ and mass squared $m_{12}^2 = p_{12}^2$. Thus

$$d\Phi_n(P;p_1,p_2,\cdots,p_n) = d\Phi_{n-1}(P;p_{12},p_3,\cdots,p_n)$$

$$\times d\Phi_2(p_{12};p_1,p_2)\,(2\pi)^3 dm_{12}^2\,.$$

C. CROSS SECTIONS AND STRUCTURE FUNCTIONS

Throughout Section C, we set $\hbar = 1$, $c = 1$. Use $\hbar c = 197.3$ MeV fermi, and $(\hbar c)^2 = 0.3894$ GeV^2 mb for conversions.

C.1 Partial waves: The amplitude in the center of mass for elastic scattering of spinless particles may be written in a partial wave expansion

$$f(k,\theta) = \frac{1}{k}\sum_{\ell}(2\ell+1)\,a_\ell\,P_\ell(\cos\theta)\,,$$

where k is the c.m. momentum, θ is the c.m. scattering angle, $a_\ell = (\eta_\ell e^{2i\delta_\ell}-1)/2i$, $0 \leq \eta_\ell \leq 1$, and δ_ℓ is the phase shift of the ℓ^{th} partial wave. For purely elastic scattering, $\eta_\ell = 1$. The differential cross section is

$$\frac{d\sigma}{d\Omega} = |f(k,\theta)|^2\,.$$

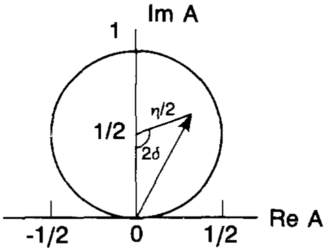
The optical theorem is

$$\sigma_{\text{tot}} = \frac{4\pi}{k}\,\text{Im}\,f(k,0)\,,$$

and the cross section in the ℓ^{th} partial wave is

$$\sigma_\ell = \frac{4\pi}{k^2}(2\ell+1)\,|a_\ell|^2 \leq \frac{4\pi(2\ell+1)}{k^2}\,.$$

The partial-wave amplitude a_ℓ can be displayed in an Argand plot.



The usual Lorentz invariant matrix element $\mathcal{M}$ (see Section D below) for the elastic process is related to $f(k,\theta)$ by

$$\mathcal{M} = -8\pi\sqrt{s}\;f(k,\theta)\,,$$

so

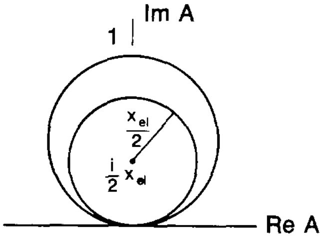
$$\sigma_{\text{tot}} = -\frac{1}{2k\sqrt{s}}\,\text{Im}\mathcal{M}(t=0)\,,$$

where s and t are the center-of-mass energy squared and momentum transfer squared, respectively (see Section C.3.a).

C.2 Resonances: The Breit-Wigner form for a_ℓ with a resonance at c.m. energy E_R, elastic width Γ_{el}, and total width Γ_{tot} is

$$a_\ell = \frac{\frac{1}{2}\Gamma_{\text{el}}}{E_R - E - \frac{i}{2}\Gamma_{\text{tot}}}\,,$$

where E is the c.m. energy. This gives a circle in the Argand plot with center $ix_{\text{el}}/2$ and radius $x_{\text{el}}/2$, where $x_{\text{el}} = \Gamma_{\text{el}}/\Gamma_{\text{tot}}$. The quantity x_{el} is called the elasticity. The amplitude has a pole at $E = E_R - i\Gamma_{\text{tot}}/2$.

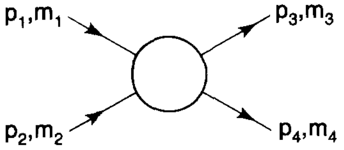


The Breit-Wigner cross section for a spin-J resonance produced in the collision of particles of spin S_1 and S_2 is

$$\sigma_{BW}(E) = \frac{(2J+1)}{(2S_1+1)(2S_2+1)}\,\frac{\pi}{k^2}\,\frac{B_{\text{in}}B_{\text{out}}\Gamma_{\text{tot}}^2}{(E-E_R)^2+\Gamma_{\text{tot}}^2/4}\,,$$

where k is the c.m. momentum, E is the c.m. energy, and B_{in} and B_{out} are the branching fractions of the resonance into the entrance and exit channels. The $2S+1$ factors are the multiplicities of the incident spin states, so they are replaced by 2 for photons, etc.

C.3.a Two-body scattering kinematics:



In the center of mass,

$$E_{1\text{cm}} = \frac{s+m_1^2-m_2^2}{2\sqrt{s}}\,,$$

$$p_{1\text{cm}} = \left[\frac{[s-(m_1+m_2)^2][s-(m_1-m_2)^2]}{4s}\right]^{1/2}$$

$$= \frac{p_{1\text{lab}}m_2}{\sqrt{s}}\,,$$

CROSS SECTIONS, DECAYS, STRUCTURE FUNCTIONS, AND KINEMATICS (Cont'd)

where $\sqrt{s}$ is the total c.m. energy. The Lorentz invariant Mandelstam variables are

$$
\begin{aligned}
s &= (p_1+p_2)^2 = (p_3+p_4)^2 \\
&= m_1^2 + 2E_1E_2 - 2\vec{p}_1\cdot\vec{p}_2 + m_2^2 \,, \\
t &= (p_1-p_3)^2 = (p_2-p_4)^2 \\
&= m_1^2 - 2E_1E_3 + 2\vec{p}_1\cdot\vec{p}_3 + m_3^2 \,, \\
u &= (p_1-p_4)^2 = (p_2-p_3)^2 \\
&= m_1^2 - 2E_1E_4 + 2\vec{p}_1\cdot\vec{p}_4 + m_4^2 \,,
\end{aligned}
$$

and they satisfy

$$s + t + u = m_1^2 + m_2^2 + m_3^2 + m_4^2 \,.$$

If $\theta_{\rm cm}$ is the c.m. scattering angle between particles 1 and 3, then (denoting $p_{1\rm cm} = |\vec{p}_{1\rm cm}|$, $p_{3\rm cm} = |\vec{p}_{3\rm cm}|$)

$$t = (E_{1\rm cm} - E_{3\rm cm})^2 - (p_{1\rm cm} - p_{3\rm cm})^2 - 4p_{1\rm cm}p_{3\rm cm}\sin^2(\theta_{\rm cm}/2) \,.$$

For $\theta_{\rm cm} = 0$, $-t$ is a minimum.

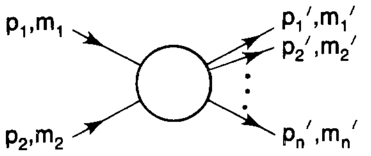
C.3.b Two-body differential cross sections: In the center of mass or lab,

$$\frac{d\sigma}{dt} = \frac{1}{64\pi s}\,\frac{1}{p_{1\rm cm}^2}\,|\mathscr{M}|^2.$$

In the center of mass,

$$\frac{d\sigma}{d\Omega_{\rm cm}} = \frac{p_{1\rm cm}p_{3\rm cm}}{\pi}\,\frac{d\sigma}{dt} \,.$$

C.4 *n*-body differential cross sections:



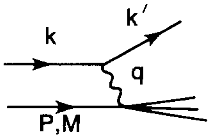
In the c.m. or lab

$$d\sigma = \frac{(2\pi)^4|\mathscr{M}|^2}{4\sqrt{(p_1\cdot p_2)^2 - m_1^2m_2^2}}\, d\Phi_n(p_1+p_2;p_1',p_2',\cdots,p_n') \,,$$

where n-body phase space, $d\Phi_n$, is described in Section B.3 above.

Note that $\sqrt{(p_1\cdot p_2)^2 - m_1^2m_2^2} = p_{1\rm lab}m_2 = p_{1\rm cm}\sqrt{s}$.

C.5.a Leptoproduction kinematics:



q = $k - k'$ is the four-momentum transferred to the target.

Invariant quantities:

$\nu = \dfrac{q\cdot P}{M} = E - E'$ is the lepton's energy loss in the lab (in earlier literature sometimes $\nu = q\cdot P$). Here, E and E' are the initial and final lepton energies in the lab.

$Q^2 = -q^2 = 2(EE' - \vec{\rm k}\cdot\vec{\rm k}') - m_\ell^2 - m_{\ell'}^2$ where $m_\ell(m_{\ell'})$ is the initial (final) lepton mass. If $EE'\sin^2(\theta/2) \gg m_\ell^2, m_{\ell'}^2$, then

$\cong 4EE'\sin^2(\theta/2)$, where θ is the lepton's scattering angle in the lab.

$x = \dfrac{Q^2}{2M\nu}$ In the parton model, x is the fraction of the target nucleon's momentum carried by the struck quark. See section on QCD.

$y = \dfrac{q\cdot P}{k\cdot P} = \dfrac{\nu}{E}$ is the fraction of the lepton's energy lost in the lab.

$W^2 = (P+q)^2 = M^2 + 2M\nu - Q^2$ is the mass squared of the system recoiling against the lepton.

C.5.b Leptoproduction cross sections:

$$\frac{d^2\sigma}{dx\,dy} = 2M\nu E\,\frac{d^2\sigma}{d\nu\,dQ^2} = \frac{2\pi M\nu}{E'}\,\frac{d^2\sigma}{d\Omega_{\rm lab}\,dE'} = 2xME\frac{d^2\sigma}{dx\,dQ^2}$$

C.5.b.i Electroproduction structure functions:

$$\frac{d^2\sigma}{dx\,dy} = \frac{8\pi\alpha^2ME}{Q^4}\left[\frac{1+(1-y)^2}{2}\,2xF_1^{\rm em} + (1-y)(F_2^{\rm em} - 2xF_1^{\rm em}) - \frac{M}{2E}xyF_2^{\rm em}\right].$$

$F_1^{\rm em}(x,Q^2)$ and $F_2^{\rm em}(x,Q^2)$ are the (unpolarized) structure functions, which are, in the naive parton model, independent of Q^2.

C.5.b.ii Neutrino production structure functions:

$$\frac{d^2\sigma^\nu}{dx\,dy} = \frac{G_F^2ME}{\pi}\left[(1-y-\frac{M}{2E}xy)\,F_2^\nu + \frac{y^2}{2}2xF_1^\nu + (y-\frac{y^2}{2})xF_3^\nu\right],$$

$$\frac{d^2\sigma^{\overline{\nu}}}{dx\,dy} = \frac{G_F^2ME}{\pi}\left[(1-y-\frac{M}{2E}xy)\,F_2^{\overline{\nu}} + \frac{y^2}{2}2xF_1^{\overline{\nu}} - (y-\frac{y^2}{2})xF_3^{\overline{\nu}}\right].$$

The structure functions $F_i^{\nu,\overline{\nu}}$ are related to quark distributions in the parton model (see section on QCD). There are separate F_i's for neutral- and charged-current processes.

C.6.a e^+e^- annihilation: For pointlike spin-1/2 fermions in the c.m., the differential cross section for $e^+e^- \to f\bar{f}$ via single photon annihilation is

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4s}\beta\left[1+\cos^2\theta + (1-\beta^2)\sin^2\theta\right]Q_f^2 \,,$$

where β is the velocity of the final state fermion in the center of mass and Q_f is the charge of the fermion in units of the proton charge. For $\beta \to 1$,

$$\sigma = \frac{4\pi\alpha^2}{3s} Q_f^2 = \frac{86.8\, Q_f^2\ nb}{s(GeV^2)} .$$

At higher energies the Z^0 (mass M_Z and width Γ_Z) must be included, and the differential cross section for $e^+e^- \to f\bar{f}$ becomes

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2\beta}{4s}\Big[Q_f^2[1+\cos^2\theta + (1-\beta^2)\sin^2\theta]$$

$$-2Q_f\chi_1\Big\{VV_f[1+\cos^2\theta+(1-\beta^2)\sin^2\theta] - 2a_f\beta\cos\theta\Big\}$$

$$+\chi_2\Big\{V_f^2(1+V^2)[1+\cos^2\theta+(1-\beta^2)\sin^2\theta]$$

$$+\beta a_f^2(1+V^2)[1+\cos^2\theta] - 8\beta VV_f a_f\cos\theta\Big\}\Big] ,$$

$$\chi_1 = \frac{1}{16\sin^2\theta_W\cos^2\theta_W}\ \frac{s(s-M_Z^2)}{(s-M_Z^2)^2+\Gamma_Z^2M_Z^2} ,$$

$$\chi_2 = \frac{1}{256\sin^4\theta_W\cos^4\theta_W}\ \frac{s^2}{(s-M_Z^2)^2+\Gamma_Z^2M_Z^2} ,$$

$$V = -1 + 4\sin^2\theta_W ,$$

$$a_f = 2T_{3f} ,$$

$$V_f = 2T_{3f} - 4Q_f\sin^2\theta_W ,$$

where the subscript f refers to the particular fermion and

$T_3 = +1/2$ for $\nu_e, \nu_\mu, \nu_\tau, u, c, t$,
$T_3 = -1/2$ for $e^-, \mu^-, \tau^-, d, s, b$.

C.6.b e$^+$e$^-$ two-photon process: In the equivalent photon approximation, the cross section for $e^+e^- \to e^+e^-X$ is related to the cross section for $\gamma\gamma \to X$ by

$$d\sigma_{e^+e^-\to e^+e^-X}(s) = \eta^2\int d\omega f(\omega)\, d\sigma_{\gamma\gamma\to X}(\omega s) ,$$

where

$$\eta \cong \frac{\alpha}{2\pi}\ell n\left[\frac{s}{4m_e^2}\right]$$

and

$$f(\omega) = \frac{1}{\omega}\left[(2+\omega)^2\ell n\frac{1}{\omega} - 2(1-\omega)(3+\omega)\right] .$$

For the production of a resonance of mass m_R and spin J,

$$\sigma(e^+e^-\to e^+e^-R) = \eta^2\frac{(2J+1)8\pi^2\Gamma(R\to\gamma\gamma)}{m_R s} f(\frac{m_R^2}{s}) .$$

C.7 Inclusive hadronic reactions: A particle's momentum can be parametrized by selecting a particular direction for the z-axis and writing

$$(E = m_\perp\cosh y,\ p_z = m_\perp\sinh y,\ p_x, p_y\ ) ,$$

where

$$m_\perp^2 = m^2 + p_x^2 + p_y^2 ,$$

$$y = \frac{1}{2}\ell n\left(\frac{E+p_z}{E-p_z}\right) = \ell n\left(\frac{E+p_z}{m_\perp}\right) = \tanh^{-1}\left(\frac{p_z}{E}\right) .$$

The variable y is called the rapidity. A boost in the z-direction then modifies y by $y \to y + \Delta$, where $\gamma = \cosh\Delta$, $\beta = \tanh\Delta$. Thus the shape of the distribution dN/dy is invariant under such a boost, and

$$E\frac{d^3\sigma}{d^3p} = \frac{d^3\sigma}{dy\, d^2p_\perp} .$$

A variable which may be easier to measure experimentally is the pseudorapidity η

$$\eta = \ell n(\cot\theta/2)$$

where θ is the angle between the particle and the beam. In the limit $E \gg m$, it follows that $\eta = y$.

Feynman's x variable is defined to be

$$x = \left(\frac{p_z}{p_{z\,\max}}\right)_{\rm cm} \approx \frac{2p_{z\,\rm cm}}{\sqrt{s}} \approx \frac{2m_\perp\sinh y_{\rm cm}}{\sqrt{s}} .$$

For $y_{\rm cm}$ not small ($e^{-2y_{\rm cm}} \ll 1$)

$$x \approx \frac{m_\perp}{\sqrt{s}}\, e^{y_{\rm cm}}$$

and

$$(y_{\rm cm})_{\max} = \ell n\frac{\sqrt{s}}{m} .$$

D. LORENTZ INVARIANT AMPLITUDES

The quantity $-i\mathcal{M}$ is determined in perturbation theory by the Feynman rules. Our convention above is consistent with the Appendices of Bjorken and Drell except that fermion spinors are normalized so that $\bar{u}u = 2m$, etc. In particular, the S-matrix for two-body scattering is

$$\langle p_1'p_2'|S|p_1p_2\rangle = I - i(2\pi)^4\delta^4(p_1+p_2-p_1'-p_2')$$

$$\times\frac{\mathcal{M}(p_1,p_2;p_1',p_2')}{(2E_1)^{1/2}(2E_2)^{1/2}(2E_1')^{1/2}(2E_2')^{1/2}} ,$$

where the states are normalized so

$$\langle p'|p\rangle = (2\pi)^3\delta^3(\vec{p}-\vec{p}\,') .$$

C.M. ENERGY AND MOMENTUM VS. BEAM MOMENTUM

(for scattering on a proton target)

$$E_{cm} dE_{cm} = m_p dT_{beam} = m_p v_{beam} dP_{beam} \approx m_p dP_{beam}$$

P_{beam} (GeV/*c*)	E_{cm} (GeV)				Momentum in c.m. (GeV/*c*)			
	γp,νp ≈*ep*	*πp*	*Kp*	*pp*	*γp,νp* ≈*ep*	*πp*	*Kp*	*pp*
0.00	.938	1.078	1.432	1.877	.000	.000	.000	.000
0.02	.958	1.079	1.432	1.877	.020	.017	.013	.010
0.04	.977	1.083	1.433	1.877	.038	.035	.026	.020
0.06	.996	1.089	1.434	1.878	.056	.052	.039	.030
0.08	1.015	1.096	1.436	1.878	.074	.068	.052	.040
0.10	1.033	1.105	1.439	1.879	.091	.085	.065	.050
0.12	1.051	1.116	1.441	1.880	.107	.101	.078	.060
0.14	1.069	1.127	1.445	1.882	.123	.117	.091	.070
0.16	1.087	1.139	1.448	1.883	.138	.132	.104	.080
0.18	1.104	1.152	1.453	1.885	.153	.147	.116	.090
0.20	1.121	1.165	1.457	1.887	.167	.161	.129	.099
0.22	1.137	1.178	1.462	1.889	.182	.175	.141	.109
0.24	1.154	1.192	1.468	1.892	.195	.189	.153	.119
0.26	1.170	1.206	1.473	1.894	.209	.202	.166	.129
0.28	1.186	1.219	1.480	1.897	.222	.215	.178	.138
0.30	1.201	1.233	1.486	1.900	.234	.228	.189	.148
0.32	1.217	1.247	1.493	1.903	.247	.241	.201	.158
0.34	1.232	1.261	1.500	1.906	.259	.253	.213	.167
0.36	1.247	1.275	1.507	1.910	.271	.265	.224	.177
0.38	1.262	1.288	1.514	1.913	.282	.277	.235	.186
0.40	1.277	1.302	1.522	1.917	.294	.288	.247	.196
0.42	1.292	1.315	1.530	1.921	.305	.300	.258	.205
0.44	1.306	1.329	1.538	1.925	.316	.311	.268	.214
0.46	1.320	1.342	1.546	1.929	.327	.322	.279	.224
0.48	1.335	1.356	1.554	1.934	.337	.332	.290	.233
0.50	1.349	1.369	1.563	1.938	.348	.343	.300	.242
0.52	1.362	1.382	1.571	1.943	.358	.353	.310	.251
0.54	1.376	1.395	1.580	1.947	.368	.363	.321	.260
0.56	1.390	1.408	1.589	1.952	.378	.373	.331	.269
0.58	1.403	1.421	1.598	1.957	.388	.383	.341	.278
0.60	1.416	1.434	1.607	1.962	.397	.393	.350	.287
0.62	1.430	1.447	1.616	1.968	.407	.402	.360	.296
0.64	1.443	1.459	1.625	1.973	.416	.412	.370	.304
0.66	1.456	1.472	1.634	1.978	.425	.421	.379	.313
0.68	1.468	1.484	1.643	1.984	.434	.430	.388	.322
0.70	1.481	1.496	1.653	1.989	.443	.439	.397	.330
0.72	1.494	1.509	1.662	1.995	.452	.448	.406	.339
0.74	1.506	1.521	1.671	2.001	.461	.457	.415	.347
0.76	1.519	1.533	1.681	2.007	.470	.465	.424	.355
0.78	1.531	1.545	1.690	2.013	.478	.474	.433	.364
0.80	1.543	1.557	1.699	2.019	.486	.482	.442	.372
0.82	1.555	1.569	1.709	2.025	.495	.490	.450	.380
0.84	1.567	1.580	1.718	2.031	.503	.499	.459	.388
0.86	1.579	1.592	1.728	2.037	.511	.507	.467	.396
0.88	1.591	1.604	1.737	2.043	.519	.515	.475	.404
0.90	1.603	1.615	1.747	2.050	.527	.523	.484	.412
0.92	1.615	1.627	1.756	2.056	.535	.531	.492	.420
0.94	1.626	1.638	1.765	2.062	.542	.538	.500	.428
0.96	1.638	1.649	1.775	2.069	.550	.546	.508	.435
0.98	1.649	1.661	1.784	2.075	.558	.554	.515	.443
1.00	1.660	1.672	1.794	2.082	.565	.561	.523	.451
1.02	1.672	1.683	1.803	2.088	.573	.569	.531	.458
1.04	1.683	1.694	1.812	2.095	.580	.576	.538	.466
1.06	1.694	1.705	1.822	2.102	.587	.583	.546	.473
1.08	1.705	1.716	1.831	2.108	.594	.591	.553	.481
1.10	1.716	1.726	1.840	2.115	.601	.598	.561	.488
1.12	1.727	1.737	1.850	2.122	.609	.605	.568	.495
1.14	1.738	1.748	1.859	2.129	.616	.612	.575	.502
1.16	1.748	1.759	1.868	2.136	.622	.619	.583	.510
1.18	1.759	1.769	1.877	2.142	.629	.626	.590	.517
1.20	1.770	1.780	1.887	2.149	.636	.633	.597	.524
1.22	1.780	1.790	1.896	2.156	.643	.639	.604	.531
1.24	1.791	1.800	1.905	2.163	.650	.646	.611	.538
1.26	1.801	1.811	1.914	2.170	.656	.653	.618	.545
1.28	1.812	1.821	1.923	2.177	.663	.660	.624	.552
1.30	1.822	1.831	1.932	2.184	.669	.666	.631	.559
1.32	1.832	1.841	1.941	2.191	.676	.673	.638	.565
1.34	1.843	1.851	1.950	2.198	.682	.679	.645	.572
1.36	1.853	1.862	1.959	2.205	.689	.685	.651	.579
1.38	1.863	1.872	1.968	2.212	.695	.692	.658	.585
1.40	1.873	1.882	1.977	2.219	.701	.698	.664	.592
1.42	1.883	1.891	1.986	2.226	.708	.704	.671	.599
1.44	1.893	1.901	1.995	2.233	.714	.711	.677	.605
1.46	1.903	1.911	2.004	2.240	.720	.717	.684	.612
1.48	1.913	1.921	2.013	2.247	.726	.723	.690	.618
1.50	1.922	1.931	2.022	2.254	.732	.729	.696	.624
1.52	1.932	1.940	2.031	2.261	.738	.735	.702	.631
1.54	1.942	1.950	2.039	2.268	.744	.741	.709	.637
1.56	1.951	1.959	2.048	2.275	.750	.747	.715	.643
1.58	1.961	1.969	2.057	2.282	.756	.753	.721	.650
1.60	1.970	1.978	2.065	2.289	.762	.759	.727	.656
1.62	1.980	1.988	2.074	2.296	.768	.765	.733	.662
1.64	1.989	1.997	2.083	2.304	.773	.770	.739	.668
1.66	1.999	2.006	2.091	2.311	.779	.776	.745	.674
1.68	2.008	2.016	2.100	2.318	.785	.782	.751	.680
1.70	2.018	2.025	2.109	2.325	.791	.788	.756	.686
1.72	2.027	2.034	2.117	2.332	.796	.793	.762	.692
1.74	2.036	2.043	2.126	2.339	.802	.799	.768	.698
1.76	2.045	2.053	2.134	2.346	.807	.805	.774	.704
1.78	2.054	2.062	2.143	2.353	.813	.810	.780	.710
1.80	2.064	2.071	2.151	2.360	.818	.816	.785	.716
1.82	2.073	2.080	2.159	2.367	.824	.821	.791	.721
1.84	2.082	2.089	2.168	2.374	.829	.827	.796	.727
1.86	2.091	2.098	2.176	2.381	.835	.832	.802	.733
1.88	2.100	2.107	2.184	2.388	.840	.837	.808	.739
1.90	2.109	2.115	2.193	2.395	.845	.843	.813	.744
1.92	2.117	2.124	2.201	2.402	.851	.848	.819	.750
1.94	2.126	2.133	2.209	2.409	.856	.853	.824	.756
1.96	2.135	2.142	2.217	2.416	.861	.859	.829	.761
1.98	2.144	2.151	2.226	2.423	.867	.864	.835	.767
2.0	2.153	2.159	2.234	2.430	.872	.869	.840	.772
2.1	2.196	2.202	2.274	2.465	.897	.895	.866	.799
2.2	2.238	2.244	2.314	2.500	.922	.920	.892	.826
2.3	2.280	2.286	2.353	2.534	.947	.944	.917	.852
2.4	2.320	2.326	2.392	2.568	.970	.968	.941	.877
2.5	2.360	2.366	2.430	2.602	.994	.991	.965	.901
2.6	2.400	2.405	2.468	2.636	1.02	1.01	.989	.926
2.7	2.439	2.444	2.505	2.669	1.04	1.04	1.01	.949
2.8	2.477	2.482	2.542	2.702	1.06	1.06	1.03	.972
2.9	2.514	2.520	2.578	2.735	1.08	1.08	1.06	.995
3.0	2.551	2.556	2.613	2.768	1.10	1.10	1.08	1.02
3.1	2.588	2.593	2.649	2.800	1.12	1.12	1.10	1.04
3.2	2.624	2.629	2.683	2.832	1.14	1.14	1.12	1.06
3.3	2.660	2.664	2.718	2.863	1.16	1.16	1.14	1.08
3.4	2.695	2.699	2.752	2.895	1.18	1.18	1.16	1.10
3.5	2.729	2.734	2.785	2.926	1.20	1.20	1.18	1.12
3.6	2.763	2.768	2.818	2.957	1.22	1.22	1.20	1.14
3.7	2.797	2.801	2.851	2.987	1.24	1.24	1.22	1.16
3.8	2.830	2.835	2.884	3.018	1.26	1.26	1.24	1.18
3.9	2.863	2.868	2.916	3.048	1.28	1.28	1.26	1.20
4.0	2.896	2.900	2.947	3.077	1.30	1.29	1.27	1.22
4.1	2.928	2.932	2.979	3.107	1.31	1.31	1.29	1.24
4.2	2.960	2.964	3.010	3.136	1.33	1.33	1.31	1.26
4.3	2.992	2.996	3.041	3.165	1.35	1.35	1.33	1.27
4.4	3.023	3.027	3.071	3.194	1.37	1.36	1.34	1.29
4.5	3.054	3.058	3.101	3.223	1.38	1.38	1.36	1.31
4.6	3.084	3.088	3.131	3.251	1.40	1.40	1.38	1.33
4.7	3.115	3.118	3.161	3.279	1.42	1.41	1.40	1.34
4.8	3.144	3.148	3.190	3.307	1.43	1.43	1.41	1.36
4.9	3.174	3.178	3.220	3.335	1.45	1.45	1.43	1.38
5.0	3.204	3.207	3.248	3.363	1.46	1.46	1.44	1.40
5.2	3.262	3.265	3.305	3.417	1.50	1.49	1.48	1.43
5.4	3.319	3.322	3.362	3.471	1.53	1.53	1.51	1.46
5.6	3.375	3.378	3.417	3.524	1.56	1.56	1.54	1.49
5.8	3.430	3.433	3.471	3.576	1.59	1.59	1.57	1.52
6.0	3.484	3.487	3.524	3.627	1.62	1.61	1.60	1.55
6.2	3.538	3.541	3.577	3.678	1.64	1.64	1.63	1.58
6.4	3.590	3.593	3.629	3.728	1.67	1.67	1.65	1.61
6.6	3.642	3.645	3.680	3.778	1.70	1.70	1.68	1.64
6.8	3.693	3.696	3.731	3.827	1.73	1.73	1.71	1.67
7.0	3.744	3.747	3.781	3.875	1.75	1.75	1.74	1.70
7.2	3.794	3.797	3.830	3.923	1.78	1.78	1.76	1.72
7.4	3.843	3.846	3.878	3.970	1.81	1.81	1.79	1.75
7.6	3.891	3.894	3.926	4.016	1.83	1.83	1.82	1.78
7.8	3.939	3.942	3.974	4.062	1.86	1.86	1.84	1.80
8.0	3.987	3.989	4.021	4.108	1.88	1.88	1.87	1.83
8.2	4.033	4.036	4.067	4.153	1.91	1.91	1.89	1.85
8.4	4.080	4.082	4.113	4.198	1.93	1.93	1.92	1.88
8.6	4.125	4.128	4.158	4.242	1.96	1.95	1.94	1.90
8.8	4.171	4.173	4.203	4.286	1.98	1.98	1.96	1.93
9.0	4.215	4.218	4.247	4.329	2.00	2.00	1.99	1.95
9.2	4.260	4.262	4.291	4.372	2.03	2.03	2.01	1.97
9.4	4.303	4.306	4.335	4.415	2.05	2.05	2.03	2.00
9.6	4.347	4.349	4.378	4.457	2.07	2.07	2.06	2.02
9.8	4.390	4.392	4.420	4.498	2.09	2.09	2.08	2.04
10.0	4.432	4.435	4.462	4.540	2.12	2.12	2.10	2.07
10.5	4.537	4.539	4.566	4.641	2.17	2.17	2.16	2.12
11.0	4.639	4.642	4.668	4.741	2.22	2.22	2.21	2.18
11.5	4.739	4.742	4.767	4.839	2.28	2.28	2.26	2.23
12.0	4.837	4.839	4.864	4.934	2.33	2.33	2.31	2.28
12.5	4.933	4.935	4.960	5.028	2.38	2.38	2.36	2.33
13.0	5.027	5.030	5.053	5.120	2.43	2.43	2.41	2.38
13.5	5.120	5.122	5.145	5.211	2.47	2.47	2.46	2.43
14.0	5.211	5.213	5.236	5.300	2.52	2.52	2.51	2.48
14.5	5.300	5.302	5.324	5.388	2.57	2.57	2.56	2.53
15.0	5.388	5.390	5.412	5.474	2.61	2.61	2.60	2.57
15.5	5.474	5.476	5.498	5.559	2.66	2.66	2.65	2.62
16.0	5.559	5.561	5.582	5.642	2.70	2.70	2.69	2.66
16.5	5.643	5.645	5.666	5.725	2.74	2.74	2.73	2.70
17.0	5.726	5.727	5.748	5.806	2.79	2.79	2.78	2.75
17.5	5.807	5.809	5.829	5.886	2.83	2.83	2.82	2.79
18.0	5.887	5.889	5.909	5.965	2.87	2.87	2.86	2.83
18.5	5.966	5.968	5.988	6.043	2.91	2.91	2.90	2.87
19.0	6.044	6.046	6.066	6.120	2.95	2.95	2.94	2.91
19.5	6.122	6.123	6.142	6.196	2.99	2.99	2.98	2.95
20	6.198	6.199	6.218	6.272	3.03	3.03	3.02	2.99
21	6.347	6.349	6.367	6.419	3.10	3.10	3.09	3.07
22	6.493	6.495	6.513	6.564	3.18	3.18	3.17	3.14
23	6.636	6.638	6.655	6.705	3.25	3.25	3.24	3.22
24	6.776	6.778	6.795	6.843	3.32	3.32	3.31	3.29
25	6.913	6.915	6.932	6.979	3.39	3.39	3.38	3.36
26	7.048	7.049	7.066	7.112	3.46	3.46	3.45	3.43
27	7.180	7.181	7.197	7.243	3.53	3.53	3.52	3.50
28	7.309	7.311	7.326	7.371	3.59	3.59	3.59	3.56
29	7.436	7.438	7.453	7.497	3.66	3.66	3.65	3.63
30	7.562	7.563	7.578	7.621	3.72	3.72	3.71	3.69
31	7.685	7.686	7.701	7.743	3.79	3.78	3.78	3.76
32	7.806	7.807	7.822	7.864	3.85	3.85	3.84	3.82
33	7.925	7.926	7.941	7.982	3.91	3.91	3.90	3.88
34	8.043	8.044	8.058	8.099	3.97	3.97	3.96	3.94
35	8.158	8.160	8.174	8.214	4.03	4.02	4.02	4.00
36	8.273	8.274	8.288	8.327	4.08	4.08	4.08	4.06
37	8.385	8.386	8.400	8.439	4.14	4.14	4.13	4.11
38	8.496	8.498	8.511	8.549	4.20	4.20	4.19	4.17
39	8.606	8.607	8.621	8.658	4.25	4.25	4.24	4.23
40	8.715	8.716	8.729	8.766	4.31	4.31	4.30	4.28
41	8.822	8.823	8.836	8.872	4.36	4.36	4.35	4.34
42	8.927	8.928	8.941	8.978	4.41	4.41	4.41	4.39
43	9.032	9.033	9.046	9.081	4.47	4.47	4.46	4.44
44	9.135	9.136	9.149	9.184	4.52	4.52	4.51	4.50
45	9.237	9.238	9.251	9.286	4.57	4.57	4.56	4.55
46	9.338	9.339	9.352	9.386	4.62	4.62	4.62	4.60
47	9.438	9.439	9.451	9.486	4.67	4.67	4.67	4.65
48	9.537	9.538	9.550	9.584	4.72	4.72	4.72	4.70
49	9.635	9.636	9.648	9.681	4.77	4.77	4.77	4.75
50	9.732	9.733	9.745	9.778	4.82	4.82	4.81	4.80
52	9.923	9.924	9.935	9.968	4.92	4.92	4.91	4.89
54	10.11	10.11	10.12	10.15	5.01	5.01	5.01	4.99
56	10.29	10.30	10.31	10.34	5.10	5.10	5.10	5.08
58	10.47	10.48	10.49	10.52	5.20	5.19	5.19	5.17
60	10.65	10.65	10.66	10.69	5.28	5.28	5.28	5.26
62	10.83	10.83	10.84	10.87	5.37	5.37	5.37	5.35
64	11.00	11.00	11.01	11.04	5.46	5.46	5.45	5.44
66	11.17	11.17	11.18	11.21	5.54	5.54	5.54	5.53
68	11.34	11.34	11.35	11.37	5.63	5.63	5.62	5.61
70	11.50	11.50	11.51	11.54	5.71	5.71	5.71	5.69
72	11.66	11.66	11.67	11.70	5.79	5.79	5.79	5.77
74	11.82	11.82	11.83	11.86	5.87	5.87	5.87	5.85
76	11.98	11.98	11.99	12.02	5.95	5.95	5.95	5.93
78	12.13	12.14	12.14	12.17	6.03	6.03	6.03	6.01
80	12.29	12.29	12.30	12.32	6.11	6.11	6.10	6.09
82	12.44	12.44	12.45	12.48	6.18	6.18	6.18	6.17
84	12.59	12.59	12.60	12.63	6.26	6.26	6.26	6.24
86	12.74	12.74	12.75	12.77	6.33	6.33	6.33	6.32
88	12.88	12.89	12.89	12.92	6.41	6.41	6.40	6.39
90	13.03	13.03	13.04	13.06	6.48	6.48	6.48	6.46
92	13.17	13.17	13.18	13.21	6.55	6.55	6.55	6.54
94	13.31	13.32	13.32	13.35	6.62	6.62	6.62	6.61
96	13.45	13.46	13.46	13.49	6.69	6.69	6.69	6.68
98	13.59	13.59	13.60	13.63	6.76	6.76	6.76	6.75
100	13.73	13.73	13.74	13.76	6.83	6.83	6.83	6.82
150	16.80	16.80	16.81	16.83	8.38	8.38	8.37	8.36
200	19.40	19.40	19.40	19.42	9.68	9.67	9.67	9.66
250	21.68	21.68	21.69	21.70	10.8	10.8	10.8	10.8
300	23.75	23.75	23.75	23.76	11.9	11.9	11.9	11.8
350	25.65	25.65	25.65	25.66	12.8	12.8	12.8	12.8
400	27.41	27.41	27.42	27.43	13.7	13.7	13.7	13.7
450	29.07	29.07	29.08	29.09	14.5	14.5	14.5	14.5
500	30.65	30.65	30.65	30.66	15.3	15.3	15.3	15.3
550	32.14	32.14	32.14	32.15	16.1	16.1	16.1	16.0
600	33.57	33.57	33.57	33.58	16.8	16.8	16.8	16.8
650	34.94	34.94	34.94	34.95	17.5	17.5	17.5	17.4
700	36.26	36.26	36.26	36.27	18.1	18.1	18.1	18.1
800	38.76	38.76	38.76	38.77	19.4	19.4	19.4	19.4
900	41.11	41.11	41.11	41.12	20.5	20.5	20.5	20.5
1000	43.33	43.33	43.33	43.34	21.7	21.7	21.7	21.6
2000	61.27	61.27	61.27	61.28	30.6	30.6	30.6	30.6
5000	96.87	96.87	96.87	96.87	48.4	48.4	48.4	48.4
10000	137.0	137.0	137.0	137.0	68.5	68.5	68.5	68.5
20000	193.7	193.7	193.7	193.7	96.9	96.9	96.9	96.9
50000	306.3	306.3	306.3	306.3	153	153	153	153
1×10^5	433.2	433.2	433.2	433.2	217	217	217	217
2×10^5	612.6	612.6	612.6	612.6	306	306	306	306
5×10^5	968.6	968.6	968.6	968.6	484	484	484	484
1×10^6	1370	1370	1370	1370	685	685	685	685

CLEBSCH-GORDAN COEFFICIENTS, SPHERICAL HARMONICS, AND *D* FUNCTIONS

Note: A √‾ is to be understood over <u>every</u> coefficient; e.g., for -8/15 read $-\sqrt{8/15}$.

Notation:

		J	J	...
		M	M	...
m_1	m_2	Coefficients		
m_1	m_2			
.	.			
.	.			
.	.			

1/2 × 1/2

		1
		+1
+1/2	+1/2	1

		1	0
		0	0
+1/2	-1/2	1/2	1/2
-1/2	+1/2	1/2	-1/2

		1
		-1
-1/2	-1/2	1

1 × 1/2

		3/2
		+3/2
+1	+1/2	1

		3/2	1/2
		+1/2	+1/2
+1	-1/2	1/3	2/3
0	+1/2	2/3	-1/3

		3/2	1/2
		-1/2	-1/2
0	-1/2	2/3	1/3
-1	+1/2	1/3	-2/3

		3/2
		-3/2
-1	-1/2	1

2 × 1

		3
		+3
+2	+1	1

		3	2
		+2	+2
+2	0	1/3	2/3
+1	+1	2/3	-1/3

		3	2	1
		+1	+1	+1
+2	-1	1/15	1/3	3/5
+1	0	8/15	1/6	-3/10
0	+1	6/15	-1/2	1/10

		3	2	1
		0	0	0
+1	-1	1/5	1/2	3/10
0	0	3/5	0	-2/5
-1	+1	1/5	-1/2	3/10

		3	2	1
		-1	-1	-1
0	-1	6/15	1/2	1/10
-1	0	8/15	-1/6	-3/10
-2	+1	1/15	-1/3	3/5

		3	2
		-2	-2
-1	-1	2/3	1/3
-2	0	1/3	-2/3

		3
		-3
-2	-1	1

1 × 1

		2
		+2
+1	+1	1

		2	1
		+1	+1
+1	0	1/2	1/2
0	+1	1/2	-1/2

		2	1	0
		0	0	0
+1	-1	1/6	1/2	1/3
0	0	2/3	0	-1/3
-1	+1	1/6	-1/2	1/3

		2	1
		-1	-1
0	-1	1/2	1/2
-1	0	1/2	-1/2

		2
		-2
-1	-1	1

$$Y_1^0 = \sqrt{\frac{3}{4\pi}}\cos\theta$$

$$Y_1^1 = -\sqrt{\frac{3}{8\pi}}\sin\theta\, e^{i\phi}$$

$$Y_2^0 = \sqrt{\frac{5}{4\pi}}\left(\frac{3}{2}\cos^2\theta - \frac{1}{2}\right)$$

$$Y_2^1 = -\sqrt{\frac{15}{8\pi}}\sin\theta\cos\theta\, e^{i\phi}$$

$$Y_2^2 = \frac{1}{4}\sqrt{\frac{15}{2\pi}}\sin^2\theta\, e^{2i\phi}$$

$$Y_\ell^{-m} = (-1)^m Y_\ell^{m*}$$

2 × 1/2

		5/2
		+5/2
+2	1/2	1

		5/2	3/2
		+3/2	+3/2
+2	-1/2	1/5	4/5
+1	+1/2	4/5	-1/5

		5/2	3/2
		+1/2	+1/2
+1	-1/2	2/5	3/5
0	+1/2	3/5	-2/5

		5/2	3/2
		-1/2	-1/2
0	-1/2	3/5	2/5
-1	+1/2	2/5	-3/5

		5/2	3/2
		-3/2	-3/2
-1	-1/2	4/5	1/5
-2	+1/2	1/5	-4/5

		5/2
		-5/2
-2	-1/2	1

3/2 × 1/2

		2
		+2
+3/2	+1/2	1

		2	1
		+1	+1
+3/2	-1/2	1/4	3/4
+1/2	+1/2	3/4	-1/4

		2	1
		0	0
+1/2	-1/2	1/2	1/2
-1/2	+1/2	1/2	-1/2

		2	1
		-1	-1
-1/2	-1/2	3/4	1/4
-3/2	+1/2	1/4	-3/4

		2
		-2
-3/2	-1/2	1

3/2 × 1

		5/2
		+5/2
+3/2	+1	1

		5/2	3/2
		+3/2	+3/2
+3/2	0	2/5	3/5
+1/2	+1	3/5	-2/5

		5/2	3/2	1/2
		+1/2	+1/2	+1/2
+3/2	-1	1/10	2/5	1/2
+1/2	0	3/5	1/15	-1/3
-1/2	+1	3/10	-8/15	1/6

		5/2	3/2	1/2
		-1/2	-1/2	-1/2
+1/2	-1	3/10	8/15	1/6
-1/2	0	3/5	-1/15	-1/3
-3/2	+1	1/10	-2/5	1/2

		5/2	3/2
		-3/2	-3/2
-1/2	-1	3/5	2/5
-3/2	0	2/5	-3/5

		5/2
		-5/2
-3/2	-1	1

$$d^{\ell}_{m,0} = \sqrt{\frac{4\pi}{2\ell+1}}\, Y_\ell^m e^{-im\phi}$$

$$\langle j_1 j_2 m_1 m_2 | j_1 j_2 J M\rangle = (-1)^{J-j_1-j_2}\langle j_2 j_1 m_2 m_1 | j_2 j_1 J M\rangle$$

$$d^j_{m',m} = (-1)^{m-m'} d^j_{m,m'} = d^j_{-m,-m'}$$

2 × 3/2

		7/2
		+7/2
+2	+3/2	1

		7/2	5/2
		+5/2	+5/2
+2	+1/2	3/7	4/7
+1	+3/2	4/7	-3/7

		7/2	5/2	3/2
		+3/2	+3/2	+3/2
+2	-1/2	1/7	16/35	2/5
+1	1/2	4/7	1/35	-2/5
0	3/2	2/7	-18/35	1/5

		7/2	5/2	3/2	1/2
		+1/2	+1/2	+1/2	+1/2
+2	-3/2	1/35	6/35	2/5	2/5
-1	-1/2	12/35	5/14	0	-3/10
0	1/2	18/35	-3/35	-1/5	1/5
-1	3/2	4/35	-27/70	2/5	-1/10

		7/2	5/2	3/2	1/2
		-1/2	-1/2	-1/2	-1/2
+1	-3/2	4/35	27/70	2/5	1/10
0	-1/2	18/35	3/35	-1/5	-1/5
-1	1/2	12/35	-5/14	0	3/10
-2	3/2	1/35	-6/35	2/5	-2/5

		7/2	5/2	3/2
		-3/2	-3/2	-3/2
0	-3/2	2/7	18/35	1/5
-1	-1/2	4/7	-1/35	-2/5
-2	1/2	1/7	-16/35	2/5

		7/2	5/2
		-5/2	-5/2
-1	-3/2	4/7	3/7
-2	-1/2	3/7	-4/7

		7/2
		-7/2
-2	-3/2	1

3/2 × 3/2

		3
		+3
+3/2	+3/2	1

		3	2
		+2	+2
+3/2	+1/2	1/2	1/2
+1/2	+3/2	1/2	-1/2

		3	2	1
		+1	+1	+1
+3/2	-1/2	1/5	1/2	3/10
+1/2	+1/2	3/5	0	-2/5
-1/2	+3/2	1/5	-1/2	3/10

		3	2	1	0
		0	0	0	0
+3/2	-3/2	1/20	1/4	9/20	1/4
+1/2	-1/2	9/20	1/4	-1/20	-1/4
-1/2	+1/2	9/20	-1/4	-1/20	1/4
-3/2	+3/2	1/20	-1/4	9/20	-1/4

		3	2	1
		-1	-1	-1
+1/2	-3/2	1/5	1/2	3/10
-1/2	-1/2	3/5	0	-2/5
-3/2	+1/2	1/5	-1/2	3/10

		3	2
		-2	-2
-1/2	-3/2	1/2	1/2
-3/2	-1/2	1/2	-1/2

		3
		-3
-3/2	-3/2	1

$$d^{1/2}_{1/2,1/2} = \cos\frac{\theta}{2} \qquad d^{1/2}_{1/2,-1/2} = -\sin\frac{\theta}{2}$$

$$d^1_{1,1} = \frac{1+\cos\theta}{2} \qquad d^1_{1,0} = -\frac{\sin\theta}{\sqrt{2}}$$

$$d^1_{1,-1} = \frac{1-\cos\theta}{2}$$

$$d^1_{0,0} = \cos\theta$$

2 × 2

		4
		4
+2	+2	1

		4	3
		+3	+3
+2	+1	1/2	1/2
+1	+2	1/2	-1/2

		4	3	2
		+2	+2	+2
+2	0	3/14	1/2	2/7
+1	1	4/7	0	-3/7
0	2	3/14	-1/2	2/7

		4	3	2	1
		+1	+1	+1	+1
+2	-1	1/14	3/10	3/7	1/5
+1	0	3/7	1/5	-1/14	-3/10
0	1	3/7	-1/5	-1/14	3/10
-1	2	1/14	-3/10	3/7	-1/5

		4	3	2	1	0
		0	0	0	0	0
+2	-2	1/70	1/10	2/7	2/5	1/5
+1	-1	8/35	2/5	1/14	-1/10	-1/5
0	0	18/35	0	-2/7	0	1/5
-1	1	8/35	-2/5	1/14	1/10	-1/5
-2	2	1/70	-1/10	2/7	-2/5	1/5

		4	3	2	1
		-1	-1	-1	-1
+1	-2	1/14	3/10	3/7	1/5
0	-1	3/7	1/5	-1/14	-3/10
-1	0	3/7	-1/5	-1/14	3/10
-2	1	1/14	-3/10	3/7	-1/5

		4	3	2
		-2	-2	-2
0	-2	3/14	1/2	2/7
-1	-1	4/7	0	-3/7
-2	0	3/14	-1/2	2/7

		4	3
		-3	-3
-1	-2	1/2	1/2
-2	-1	1/2	-1/2

		4
		-4
-2	-2	1

$$d^{3/2}_{3/2,3/2} = \frac{1+\cos\theta}{2}\cos\frac{\theta}{2}$$

$$d^{3/2}_{3/2,1/2} = -\sqrt{3}\,\frac{1+\cos\theta}{2}\sin\frac{\theta}{2}$$

$$d^{3/2}_{3/2,-1/2} = \sqrt{3}\,\frac{1-\cos\theta}{2}\cos\frac{\theta}{2}$$

$$d^{3/2}_{3/2,-3/2} = -\frac{1-\cos\theta}{2}\sin\frac{\theta}{2}$$

$$d^{3/2}_{1/2,1/2} = \frac{3\cos\theta-1}{2}\cos\frac{\theta}{2}$$

$$d^{3/2}_{1/2,-1/2} = -\frac{3\cos\theta+1}{2}\sin\frac{\theta}{2}$$

$$d^2_{2,2} = \left(\frac{1+\cos\theta}{2}\right)^2$$

$$d^2_{2,1} = -\frac{1+\cos\theta}{2}\sin\theta$$

$$d^2_{2,0} = \frac{\sqrt{6}}{4}\sin^2\theta$$

$$d^2_{2,-1} = -\frac{1-\cos\theta}{2}\sin\theta$$

$$d^2_{2,-2} = \left(\frac{1-\cos\theta}{2}\right)^2$$

$$d^2_{1,1} = \frac{1+\cos\theta}{2}(2\cos\theta-1)$$

$$d^2_{1,0} = -\sqrt{\frac{3}{2}}\sin\theta\cos\theta$$

$$d^2_{1,-1} = \frac{1-\cos\theta}{2}(2\cos\theta+1)$$

$$d^2_{0,0} = \left(\frac{3}{2}\cos^2\theta - \frac{1}{2}\right)$$

Sign convention is that of Wigner (*Group Theory*, Academic Press, New York, 1959), also used by Condon and Shortley (*The Theory of Atomic Spectra*, Cambridge Univ. Press, New York, 1953), Rose (*Elementary Theory of Angular Momentum*, Wiley, New York, 1957), and Cohen (*Tables of the Clebsch-Gordan Coefficients*, North American Rockwell Science Center, Thousand Oaks, Calif., 1974). The signs and numbers in the current tables have been calculated by computer programs written independently by Cohen and at LBL. (Table extended April 1974.)

SU(3) ISOSCALAR FACTORS AND REPRESENTATION MATRICES

The most commonly used isoscalar factors, corresponding to the singlet, octet, and decuplet content of 8 ⊗ 8 and 10 ⊗ 8, are displayed at the right. The notation uses particle names to identify the coefficients, so that the pattern of relative couplings can be seen at a glance. We illustrate the use of the coefficients by example; see J.J de Swart, Rev. Mod Phys. **35**, 916 (1963) for detailed explanation and phase conventions.

A $\surd$ is understood over every integer in the matrices; the exponent ½ is a reminder of this. For example, in de Swart's notation the $\Xi \to \Omega K$ element of our 10 → 10 ⊗ 8 matrix reads

$$\left(\begin{array}{cc|c} 10 & 8 & 10 \\ 0\ {-2} & \tfrac{1}{2}\ 1 & \tfrac{1}{2}\ {-1} \end{array}\right) = \frac{-\sqrt{6}}{\sqrt{24}} .$$

Intramultiplet relative decay strengths can be read directly from our matrices. Thus, the partial widths for $\Delta \to (N\pi)_{I=3/2}$ and $\Omega^* \to (\Xi\bar{K})_{I=0}$ are in the ratio

$$\frac{\Gamma(\Omega^* \to (\Xi\bar{K})_{I=0})}{\Gamma(\Delta \to (N\pi)_{I=3/2})} = \frac{12}{6} \times (\text{phase space factors}) .$$

Supplying isospin Clebsch-Gordan coefficients, one obtains, e.g.,

$$\frac{\Gamma(\Omega^{*-} \to \Xi^0 K^-)}{\Gamma(\Delta^+ \to p\pi^0)} = \frac{1/2}{2/3} \times \frac{12}{6} \times p.s.f. = \frac{3}{2} \times p.s.f.$$

Partial widths for 8 → 8 ⊗ 8 involve a linear superposition of 8_1 (symmetric) and 8_2 (antisymmetric) couplings. For example,

$$\Gamma(\Xi^* \to \Xi\pi) \sim \left(-\sqrt{\frac{9}{20}}g_1 + \sqrt{\frac{3}{12}}g_2\right)^2 .$$

The relation between g_1,g_2 (with de Swart's normalization) and the standard D,F couplings appearing in the interaction Lagrangian,

$$\mathscr{L} = -\sqrt{2}D\ Tr([\bar{B},B]_+M) + \sqrt{2}F\ Tr([\bar{B},B]_-M) ,$$

is

$$D = \frac{\sqrt{30}}{40}g_1 ,\quad F = \frac{\sqrt{6}}{24}g_2 .$$

Thus,

$$\Gamma(\Xi^* \to \Xi\pi) \sim (1-2\alpha)^2$$

where $\alpha \equiv D/(D+F)$.

When acting upon a representation of dimension d, the generators of SU(3) transformations, λ_a (a=1,8), are $d \times d$ matrices which obey the following relationships:

$$\left[\lambda_a,\lambda_b\right] = 2if_{abc}\lambda_c$$
$$\left\{\lambda_a,\lambda_b\right\} = \tfrac{4}{3}\delta_{ab}I + 2d_{abc}\lambda_c$$

where I is a $d \times d$ unit matrix. The f_{abc} are odd under the permutation of any pair of indices, while the d_{abc} are even. The nonzero elements are

abc	f_{abc}	abc	d_{abc}	abc	d_{abc}
123	1	118	$1/\sqrt{3}$	355	1/2
147	1/2	146	1/2	366	−1/2
156	−1/2	157	1/2	377	−1/2
246	1/2	228	$1/\sqrt{3}$	448	$-1/(2\sqrt{3})$
257	1/2	247	−1/2	558	$-1/(2\sqrt{3})$
345	1/2	256	1/2	668	$-1/(2\sqrt{3})$
367	−1/2	338	$1/\sqrt{3}$	778	$-1/(2\sqrt{3})$
458	$\sqrt{3}/2$	344	1/2	888	$-1/\sqrt{3}$
678	$\sqrt{3}/2$				

1 → 8 ⊗ 8

$$\left(\Lambda\right)_1 \to \left(N\bar{K}\ \ \Sigma\pi\ \ \Lambda\eta\ \ \Xi K\right)_{8\otimes 8} = \frac{1}{\sqrt{8}}\left(2\ \ \ 3\ \ -1\ \ -2\right)^{1/2}$$

8_1 → 8 ⊗ 8

$$\left(\begin{array}{c} N \\ \Sigma \\ \Lambda \\ \Xi \end{array}\right)_{8_1} \to \left(\begin{array}{c} N\pi\ \ N\eta\ \ \Sigma K\ \ \Lambda K \\ N\bar{K}\ \ \Sigma\pi\ \ \Lambda\pi\ \ \Sigma\eta\ \ \Xi K \\ N\bar{K}\ \ \Sigma\pi\ \ \Lambda\eta\ \ \Xi K \\ \Sigma\bar{K}\ \ \Lambda\bar{K}\ \ \Xi\pi\ \ \Xi\eta \end{array}\right)_{8\otimes 8} = \frac{1}{\sqrt{20}}\left(\begin{array}{c} 9\ \ \ -1\ \ \ -9\ \ \ -1 \\ -6\ \ \ 0\ \ \ 4\ \ \ 4\ \ \ -6 \\ 2\ \ -12\ \ \ -4\ \ \ -2 \\ 9\ \ \ -1\ \ \ -9\ \ \ -1 \end{array}\right)^{1/2}$$

8_2 → 8 ⊗ 8

$$\left(\begin{array}{c} N \\ \Sigma \\ \Lambda \\ \Xi \end{array}\right)_{8_2} \to \left(\begin{array}{c} N\pi\ \ N\eta\ \ \Sigma K\ \ \Lambda K \\ N\bar{K}\ \ \Sigma\pi\ \ \Lambda\pi\ \ \Sigma\eta\ \ \Xi K \\ N\bar{K}\ \ \Sigma\pi\ \ \Lambda\eta\ \ \Xi K \\ \Sigma\bar{K}\ \ \Lambda\bar{K}\ \ \Xi\pi\ \ \Xi\eta \end{array}\right)_{8\otimes 8} = \frac{1}{\sqrt{12}}\left(\begin{array}{c} 3\ \ \ 3\ \ \ 3\ \ \ -3 \\ 2\ \ \ 8\ \ \ 0\ \ \ 0\ \ \ -2 \\ 6\ \ \ 0\ \ \ 0\ \ \ 6 \\ 3\ \ \ 3\ \ \ 3\ \ \ -3 \end{array}\right)^{1/2}$$

10 → 8 ⊗ 8

$$\left(\begin{array}{c} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{array}\right)_{10} \to \left(\begin{array}{c} N\pi\ \ \ \ \Sigma K \\ N\bar{K}\ \ \Sigma\pi\ \ \Lambda\pi\ \ \Sigma\eta\ \ \Xi K \\ \Sigma\bar{K}\ \ \Lambda\bar{K}\ \ \Xi\pi\ \ \Xi\eta \\ \Xi\bar{K} \end{array}\right)_{8\otimes 8} = \frac{1}{\sqrt{12}}\left(\begin{array}{c} -6\ \ \ \ \ \ 6 \\ -2\ \ \ 2\ \ \ -3\ \ \ 3\ \ \ 2 \\ 3\ \ \ -3\ \ \ 3\ \ \ 3 \\ 12 \end{array}\right)^{1/2}$$

8 → 10 ⊗ 8

$$\left(\begin{array}{c} N \\ \Sigma \\ \Lambda \\ \Xi \end{array}\right)_{8} \to \left(\begin{array}{c} \Delta\pi\ \ \Sigma K \\ \Delta\bar{K}\ \ \Sigma\pi\ \ \Sigma\eta\ \ \Xi K \\ \Sigma\pi\ \ \Xi K \\ \Sigma\bar{K}\ \ \Xi\pi\ \ \Xi\eta\ \ \Omega K \end{array}\right)_{10\otimes 8} = \frac{1}{\sqrt{15}}\left(\begin{array}{c} -12\ \ \ 3 \\ 8\ \ \ -2\ \ \ -3\ \ \ 2 \\ -9\ \ \ 6 \\ 3\ \ \ -3\ \ \ -3\ \ \ 6 \end{array}\right)^{1/2}$$

10 → 10 ⊗ 8

$$\left(\begin{array}{c} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{array}\right)_{10} \to \left(\begin{array}{c} \Delta\pi\ \ \Delta\eta\ \ \Sigma K \\ \Delta\bar{K}\ \ \Sigma\pi\ \ \Sigma\eta\ \ \Xi K \\ \Sigma\bar{K}\ \ \Xi\pi\ \ \Xi\eta\ \ \Omega K \\ \Xi\bar{K}\ \ \Omega\eta \end{array}\right)_{10\otimes 8} = \frac{1}{\sqrt{24}}\left(\begin{array}{c} 15\ \ \ 3\ \ \ -6 \\ 8\ \ \ 8\ \ \ 0\ \ \ -8 \\ 12\ \ \ 3\ \ \ -3\ \ \ -6 \\ 12\ \ -12 \end{array}\right)^{1/2}$$

In the fundamental 3-dimensional representation, the λ_a's are given by

$$\lambda_1 = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \qquad \lambda_2 = \begin{pmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \qquad \lambda_3 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

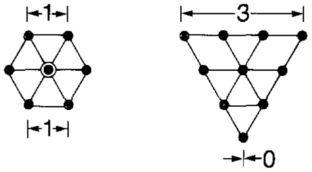
$$\lambda_4 = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix} \qquad \lambda_5 = \begin{pmatrix} 0 & 0 & -i \\ 0 & 0 & 0 \\ i & 0 & 0 \end{pmatrix} \qquad \lambda_6 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

$$\lambda_7 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{pmatrix} \qquad \lambda_8 = \begin{pmatrix} 1/\sqrt{3} & 0 & 0 \\ 0 & 1/\sqrt{3} & 0 \\ 0 & 0 & -2/\sqrt{3} \end{pmatrix}$$

SU(N) MULTIPLETS AND YOUNG DIAGRAMS

This note tells how SU(n) particle multiplets are identified or labeled, how to find the number of particles in a multiplet from its label, how to draw the Young diagram for a multiplet, and how to use Young diagrams to determine the overall multiplet structure of a composite system, such as a 3-quark or a meson-baryon system.

(1) **Multiplet labels** — An SU(n) multiplet is uniquely identified by a string of $(n-1)$ nonnegative integers: $(\alpha,\beta,\gamma,\cdots)$. Any such set of integers specifies a multiplet. For an SU(2) multiplet such as an isospin multiplet, the single integer α is the number of *steps* from one end of the multiplet to the other (i.e., it is one fewer than the number of particles in the multiplet). In SU(3), the two integers α and β are the numbers of steps across the top and bottom levels of the multiplet diagram. Thus the labels for the SU(3) octet and decuplet



are (1,1) and (3,0). For larger n, the interpretation of the integers in terms of the geometry of the multiplets, which exist in an $(n-1)$-dimensional space, is not so readily apparent.

The label for the SU(n) singlet is (0,0,...,0). In a flavor SU(n), the n quarks together form a (1,0,...,0) multiplet, and the n antiquarks belong to a (0,...,0,1) multiplet. These two multiplets are *conjugate* to one another, which means their labels are related by $(\alpha,\beta,\ldots) \longleftrightarrow (\ldots,\beta,\alpha)$.

(2) **Number of particles** — The number of particles in a multiplet, $N = N(\alpha,\beta,\ldots)$, is given as follows (note the pattern of the equations). In SU(2), $N = N(\alpha)$ is

$$N = \frac{(\alpha+1)}{1} .$$

In SU(3), $N = N(\alpha,\beta)$ is

$$N = \frac{(\alpha+1)}{1} \cdot \frac{(\beta+1)}{1} \cdot \frac{(\alpha+\beta+2)}{2} .$$

In SU(4), $N = N(\alpha,\beta,\gamma)$ is

$$N = \frac{(\alpha+1)}{1} \cdot \frac{(\beta+1)}{1} \cdot \frac{(\gamma+1)}{1} \cdot \frac{(\alpha+\beta+2)}{2} \cdot \frac{(\beta+\gamma+2)}{2} \cdot \frac{(\alpha+\beta+\gamma+3)}{3} .$$

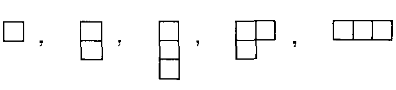
Note that there is no factor with $(\alpha+\gamma+2)$: only a *consecutive* sequence of the label integers appears in any factor. One more example should make the pattern clear for any SU(n). In SU(5), $N = N(\alpha,\beta,\gamma,\delta)$ is

$$N = \frac{(\alpha+1)}{1} \cdot \frac{(\beta+1)}{1} \cdot \frac{(\gamma+1)}{1} \cdot \frac{(\delta+1)}{1} \cdot \frac{(\alpha+\beta+2)}{2} \cdot \frac{(\beta+\gamma+2)}{2} \times$$

$$\frac{(\gamma+\delta+2)}{2} \cdot \frac{(\alpha+\beta+\gamma+3)}{3} \cdot \frac{(\beta+\gamma+\delta+3)}{3} \cdot \frac{(\alpha+\beta+\gamma+\delta+4)}{4} .$$

Multiplets that are conjugate to one another obviously have the same number of particles, but so can other multiplets. For example, the SU(4) multiplets (3,0,0) and (1,1,0) each have 20 particles.

(3) **Young diagrams** — A Young diagram consists of an array of boxes (or some other symbol) arranged in one or more *left-justified* rows, with each row being *at least as long* as the row beneath. The correspondence between a diagram and a multiplet label is: The top row juts out α boxes to the right past the end of the second row, the second row juts out β boxes to the right past the end of the third row, etc. A diagram in SU(n) has at most n rows. There can be any number of "completed" columns of n boxes buttressing the left of a diagram; these don't affect the label. Thus in SU(3) the diagrams



represent the multiplets (1,0), (0,1), (0,0), (1,1), and (3,0). In any SU(n), the quark multiplet is represented by a single box, the antiquark multiplet by a column of $(n-1)$ boxes, and a singlet by a completed column of n boxes.

(4) **Coupling multiplets together** — The following recipe tells how to find the multiplets that occur in coupling two multiplets together. To couple together more than two multiplets, first couple two, then couple the third with each of the multiplets obtained from the first two, etc.

First a definition: A sequence of the letters $a,b,c,\ldots$ is *admissible* if at any point in the sequence at least as many a's have been reached as b's, at least as many b's have been reached as c's, etc. Thus *abcd* and *aabcb* are admissible sequences and *abb* and *acb* are not. Now the recipe:

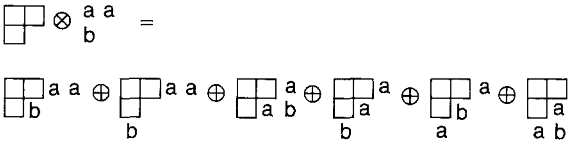
(a) Draw the Young diagrams for the two multiplets, but in one of the diagrams replace the boxes in the first row with a's, the boxes in the second row with b's, etc. The unlettered diagram forms the *upper left-hand corner* of all the enlarged diagrams constructed below.

(b) Add the a's from the lettered diagram to the unlettered diagram to form all possible legitimate Young diagrams that have no more than one a per column. (All the a's appear in each new diagram.)

(c) Use the b's to further enlarge the diagrams already obtained, subject to the same rules. Throw away any diagram in which the sequence of letters formed by reading *right to left* in the first row, then the second row, etc., is not admissible.

(d) Proceed as in (c) with the c's, etc.

Thus, for example, the calculation to find the multiplets that can occur in a system made up of two SU(3) octets (one might be the π-meson octet, the other the N-baryon octet) is as follows:



where only the diagrams with admissible sequences and with fewer than four rows (since $n = 3$) have been kept. In terms of multiplet labels, the above may be written

$$(1,1) \otimes (1,1) = (2,2) \oplus (3,0) \oplus (0,3) \oplus (1,1) \oplus (1,1) \oplus (0,0) ,$$

or in terms of numbers of particles,

$$\mathbf{8} \otimes \mathbf{8} = \mathbf{27} \oplus \mathbf{10} \oplus \overline{\mathbf{10}} \oplus \mathbf{8} \oplus \mathbf{8} \oplus \mathbf{1} .$$

The product of the numbers of the left is equal to the sum on the right. (See the section on the Nonrelativistic Quark Model for results for 3-quark systems.)

TESTS OF CONSERVATION LAWS*

In response to the current interest in tests of conservation laws, we have made a list of experimental limits on all weak and electromagnetic decays, mass differences, moments, and a few reactions, whose observation would violate conservation laws. The list is given only in the full Review of Particle Properties, not in the Data Booklet. For the benefit of Data Booklet readers, we have included the best limits from the list in the following text. The list is in two parts: "Discrete Space-Time Symmetries," i.e., C, P, T, CP, and CPT; and "Number Conservation Laws," i.e., lepton, baryon, hadronic flavor, and charge conservation. The references for these data can be found in the Stable Particle Section of the Full Listings in this Review. A discussion of these tests follows.

CPT INVARIANCE

General principles of relativistic field theory require invariance under the combined transformation CPT. The simplest tests of CPT invariance are the equality of the masses and lifetimes of a particle and its antiparticle. The best test comes from a limit on the mass difference between K^0 and $\overline{K}^0$. Any such mass difference contributes to the CP-violating parameter ϵ. In fact ϵ can be explained by a CPT-conserving but CP-violating mixing of K^0 and $\overline{K}^0$, which yields a prediction that $\phi_{+-} \approx 44°$, while a $K^0-\overline{K}^0$ mass difference would yield $\phi_{+-} \approx 44° + 90°$. It is thus possible to deduce that $|m(K^0)-m(\overline{K}^0)| < 10^{-4}|m(K_S)-m(K_L)| < 3\times10^{-10}$ eV. Also, an upper limit on $|m(D^0)-m(\overline{D}^0)|$ can be derived from the bound $|m(D_1{}^0)-m(D_2{}^0)| < 6.5\times10^{-10}$ MeV (inferred from bound on $D^0 \to \overline{D}^0 \to \mu^-$ anything), given an input value of, or bound on, the CP-violation parameter ϵ for $D^0-\overline{D}^0$ mixing.

CP AND *T* INVARIANCE

Given CPT invariance, CP violation and T violation are equivalent. So far the only evidence for CP or T violation comes from the measurements of η_{+-}, η_{00}, and the semileptonic decay charge asymmetry for K_L, e.g., $|\eta_{+-}| = |A(K_L^0 \to \pi^+\pi^-)/A(K_S^0 \to \pi^+\pi^-)| = (2.275\pm0.021)\times10^{-3}$ and $[\Gamma(K_L^0 \to \pi^-e^+\nu) - \Gamma(K_L^0 \to \pi^+e^-\overline{\nu})] / [\text{sum}] = (0.333\pm0.014)\%$. Other searches for CP or T violation should be divided into (a) those that involve weak interactions or parity violation, and (b) those that involve processes allowed by the strong or electromagnetic interactions. In class (a) the most sensitive is probably the search for an electric dipole moment of the neutron, which is measured to be $(2.3\pm2.3)\times10^{-25}e$ cm. A nonzero value requires both P and T violation to be nonzero. Class (b) searches involve looking for C or T violation in strong or electromagnetic processes. Examples are the search for C violation in η decay, believed to be an electromagnetic process, e.g., as measured by $\Gamma(\eta \to \mu^+\mu^-\pi^0)/\Gamma(\eta \to \text{all}) < 5\times10^{-6}$, and the search for T violation in a number of nuclear and electromagnetic reactions.

CONSERVATION OF LEPTON NUMBERS

Present experimental evidence and the standard electroweak theory are consistent with the absolute conservation of three separate lepton numbers: electron number L_e, muon number L_μ, and τ-number L_τ. Searches for violations are of the following types:

a) $\Delta L = 2$ for one type of lepton. The best limit comes from the search for neutrinoless double beta decay $(Z,A) \to (Z+2,A) + e^- + e^-$. The best laboratory limit is $t_{1/2} > 0.7\times10^{23}$ yr (CL=0.90) for ^{76}Ge.

b) Conversion of one lepton type to another. For purely leptonic processes, the best limits are on $\mu \to e\gamma$ and $\mu \to 3e$, measured as $\Gamma(\mu \to e\gamma)/\Gamma(\mu \to \text{all}) < 1.7\times10^{-10}$ and $\Gamma(\mu \to 3e)/\Gamma(\mu \to \text{all}) < 2.4\times10^{-12}$. For semileptonic processes, the best limit comes from the coherent conversion process in a muonic atom $\mu^- + (Z,A) \to e^- + (Z,A)$, measured as $\Gamma(\mu^-\text{Ti} \to e^-\text{Ti})/\Gamma(\mu^-\text{Ti} \to \text{all}) < 1.6\times10^{-11}$. Of special interest is the case in which the hadronic flavor also changes, as in $K_L \to e\mu$ and $K^+ \to \pi^+e^+\mu^-$, measured as $\Gamma(K_L \to e\mu)/\Gamma(K_L \to \text{all}) < 6\times10^{-6}$ and $\Gamma(K^+ \to \pi^+e^-\mu^+)/\Gamma(K^+ \to \text{all}) < 5\times10^{-9}$. Limits on the conversion of τ into e or μ are found in τ decay and are much less stringent that those for $\mu \to e$ conversion, e.g., $\Gamma(\tau \to \mu\gamma)/\Gamma(\tau \to \text{all}) < 5.5\times10^{-4}$ and $\Gamma(\tau \to e\gamma)/\Gamma(\tau \to \text{all}) < 6.4\times10^{-4}$.

c) Conversion of one type of lepton into another type of antilepton. The case most studied is $\mu^- + (Z,A) \to e^+ + (Z-2,A)$, the strongest limit being $\Gamma(\mu^-\,{}^{127}\text{I} \to e^+\,{}^{127}\text{Sb}^{\text{stable}})/\Gamma(\mu^-\,{}^{127}\text{I} \to \text{all}) < 3\times10^{-10}$.

d) Relation to neutrino mass. If neutrinos have masses then it is expected even in the standard electroweak theory that separate lepton numbers are not conserved as a consequence of lepton mixing analogous to the Cabibbo quark mixing. However, in this case lepton-number-violating processes such as $\mu \to e\gamma$ are expected to have extremely small probability. For small neutrino masses, the lepton-number violation would be observed first in neutrino oscillations, which have been the subject of extensive experimental searches. For example, $\overline{\nu}_e \not\to \overline{\nu}_e$ gives measured limits $\Delta(m^2) < 0.016$ eV^2 for $\sin^2(2\theta) = 1$, and $\sin^2(2\theta) < 0.16$ for large $\Delta(m^2)$, where θ is the neutrino mixing angle. Searches for $\nu_\mu \to \nu_e$ set limits $\Delta(m^2) < 0.2$ eV^2 for $\sin^2(2\theta) = 1$, and $\sin^2(2\theta) < 0.0034$ for large $\Delta(m^2)$. For larger neutrino masses ($>> 1$ keV), lepton-number violation is searched for by looking for anomalous decays such as $\pi \to e\nu_x$, where ν_x is a massive neutrino. If the $\Delta L = 2$ type of violation occurs, it is expected that neutrinos will have a nonzero mass of the Majorana type.

CONSERVATION OF HADRONIC FLAVORS

The conversion of quarks of a given charge, (d,s,b) or (u,c,t), into one another is forbidden in strong and electromagnetic interactions by the conservation of hadron flavors: S (strangeness), C (charm), B (bottomness), and T (topness). The weak interactions violate these conservation laws as a result of the Cabibbo or Kobayashi-Maskawa mixing (see the section on the Kobayashi-Maskawa Mixing Matrix). The way in which these conservation laws are violated is tested as follows:

a) ΔS = ΔQ rule. In the semileptonic decay of strange particles, the strangeness change equals the change in charge of the hadrons. Tests come from limits on decay rates such as $\Gamma(\Sigma^+ \to ne^+\nu)/\Gamma(\Sigma^+ \to \text{all}) < 5\times10^{-6}$, and from a detailed analysis of $K_L \to \pi e\nu$, which yields the parameter x, measured to be $(\text{Re}\,x, \text{Im}\,x) = (0.009\pm0.020, -0.004\pm0.026)$. A corresponding rule for charm decays is ΔC = ΔQ .

b) Change of flavor by 2 units. In the standard model this occurs only in second-order weak interactions. The one example for which this has been measured is the ΔS = 2 $K^0-\overline{K}^0$ mixing, which is directly measured by $m(K_S)-m(K_L) = (3.521\pm0.014)\times10^{-12}$ MeV. A limit on the ΔC = 2 $D^0-\overline{D}^0$ mixing, $\Gamma(D^0 \to \overline{D}^0 \to \mu^-\text{ anything})/\Gamma(D^0 \to \mu^+\text{ anything}) < 0.044$, provides a limit $|m(D^0)-m(\overline{D}^0)| < 6.5\times10^{-10}$ MeV.

c) Flavor-changing neutral currents. In the standard model the neutral-current interactions do not change flavor. The low rate $\Gamma(K_L \to \mu^+\mu^-)/\Gamma(K_L \to \text{all}) = (9.1\pm1.9)\times10^{-9}$ puts limits on such interactions; the nonzero value for this rate is attributed to a combination of the weak and electromagnetic interactions. The best test should come from a limit on $K^+ \to \pi^+\nu\overline{\nu}$, which occurs in the standard model only as a second-order weak process with a branching fraction of 10^{-10} to 10^{-11}. Limits for charm-changing or bottom-changing neutral currents are much less stringent: $\Gamma(D^0 \to \mu^+\mu^-)/\Gamma(D^0 \to \text{all}) < 3.4\times10^{-4}$ and $\Gamma(B^0 \to \mu^+\mu^-)/\Gamma(B^0 \to \text{all}) < 2\times10^{-4}$.

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* Revised April 1986 by T.G. Trippe and L. Wolfenstein.

TESTS OF CONSERVATION LAWS (Cont'd)

Discrete Space-Time Symmetries

Quantity(a)	Value(b)	Symmetry tested or violated
$\pi^0 \to \gamma\gamma\gamma$ / all	$< 3.8 \times 10^{-7}$	C
$(e^+e^-)_{J=1} \to \gamma\gamma\gamma$ / all	$(5 \pm 3) \times 10^{-4}$(c)	C
$\eta \to \gamma\gamma\gamma$ / all	$< 7 \times 10^{-4}$	C
$\eta \to e^+e^-\pi^0$ / all	$< 5 \times 10^{-5}$	C (single photon process)
$\eta \to \mu^+\mu^-\pi^0$ / all	$< 5 \times 10^{-6}$	C (single photon process)
$\eta \to \pi^+\pi^-\pi^0$ parameters: left-right asymmetry	$(1.2 \pm 1.7) \times 10^{-3}$	C
sextant asymmetry	$(1.9 \pm 1.6) \times 10^{-3}$	C
quadrant asymmetry	$(-1.7 \pm 1.7) \times 10^{-3}$	C
$\eta \to \pi^+\pi^-\gamma$ parameters: left-right asymmetry	$(8.8 \pm 4.0) \times 10^{-3}$	C
β (D-wave)	0.047 ± 0.062	C
$\eta \to \pi^+\pi^-$ / all	$< 1.5 \times 10^{-3}$	P and CP
e electric dipole moment	$< 3 \times 10^{-24}$ e cm	T and P
μ electric dipole moment	$(3.7 \pm 3.4) \times 10^{-19}$ e cm	T and P
p electric dipole moment	$< 4 \times 10^{-21}$ e cm	T and P
n electric dipole moment	$(2.3 \pm 2.3) \times 10^{-25}$ e cm	T and P
Λ electric dipole moment	$< 1.5 \times 10^{-16}$ e cm	T and P
α' / a from $\mu \to e\overline{\nu}\nu$	$(-0.2 \pm 4.3) \times 10^{-3}$	T
β' / a from $\mu \to e\overline{\nu}\nu$	$(1.5 \pm 6.3) \times 10^{-3}$	T
e pol. $\perp$ μ spin and e^+ mom. from $\mu \to e\overline{\nu}\nu$	0.007 ± 0.023	T
Im ξ in $K^{\pm}_{\mu 3}$ decay (from transverse μ pol.)	-0.017 ± 0.025	T
Im ξ in $K^{0}_{\mu 3}$ decay (from transverse μ pol.)	-0.020 ± 0.022	T
$\phi(g_A) - \phi(g_V)$ for n	$(180.11 \pm 0.17)^\circ$	T (0 ° or 180°)
n 3-vector corr. coeff.	-0.0007 ± 0.0014	T
$K^{\pm} \to \pi^{\pm}\pi^+\pi^-$ rate difference / average	$(0.07 \pm 0.12)\%$	CP
$K^{\pm} \to \pi^{\pm}2\pi^0$ rate difference / average	$(-0.03 \pm 0.55)\%$	CP
$K^{\pm} \to \pi^{\pm}\pi^0\gamma$ rate difference / average	$(0.9 \pm 3.3)\%$	CP
$K \to 3\pi^{\pm}$ slope $(g^+ - g^-)$ / sum	$(-0.7 \pm 0.5)\%$	CP
$\lvert\eta_{+-0}\rvert^2 = \Gamma(K_S^0 \to \pi^+\pi^-\pi^0) / \Gamma(K_L^0 \to \pi^+\pi^-\pi^0)$	< 0.12	CP
$\lvert\eta_{000}\rvert^2 = \Gamma(K_S^0 \to 3\pi^0) / \Gamma(K_L^0 \to 3\pi^0)$	< 0.1	CP
Charge asymm. j in $K_L^0 \to \pi^+\pi^-\pi^0$	0.0011 ± 0.0008	CP
$K_L^0 \to (\pi^-\mu^+\nu - \pi^+\mu^-\overline{\nu})$ / sum	$(0.319 \pm 0.038)\%$	CP (violated)
$K_L^0 \to (\pi^-e^+\nu - \pi^+e^-\overline{\nu})$ / sum	$(0.333 \pm 0.014)\%$	CP (violated)
$\lvert\eta_{00}\rvert = \lvert A(K_L^0 \to \pi^0\pi^0)/A(K_S^0 \to \pi^0\pi^0)\rvert$	$(2.299 \pm 0.036) \times 10^{-3}$	CP (violated)
$\lvert\eta_{+-}\rvert = \lvert A(K_L^0 \to \pi^+\pi^-)/A(K_S^0 \to \pi^+\pi^-)\rvert$	$(2.275 \pm 0.021) \times 10^{-3}$	CP (violated)
$\lvert\epsilon'/\epsilon\rvert = (1 - \lvert\eta_{00}/\eta_{+-}\rvert)/3$	$(-3 \pm 4) \times 10^{-3}$	CP
ϕ_{+-}: phase of η_{+-}	$(44.6 \pm 1.2)^\circ$	CP (violated)
ϕ_{00} : phase of η_{00}	$(54 \pm 5)^\circ$	CP (violated)
Re ϵ in K_L^0 decay	$(1.621 \pm 0.088) \times 10^{-3}$	CP (violated)
$\alpha_\Lambda / \alpha_{\overline{\Lambda}}$	-1.04 ± 0.29	CP
$(g_{e^+} - g_{e^-})$ / average	$(2.2 \pm 6.4) \times 10^{-11}$	CPT
$(g_{\mu^+} - g_{\mu^-})$ / average	$(-2.6 \pm 1.6) \times 10^{-8}$	CPT
$(\mu_p - \mu_{\overline{p}})$ / average	$(-1 \pm 7) \times 10^{-3}$	CPT
$\pi^+ - \pi^-$ mass difference / average	$(2 \pm 5) \times 10^{-4}$	CPT
$K^+ - K^-$ mass difference / average	$(-0.6 \pm 1.8) \times 10^{-4}$	CPT
$\lvert K^0 - \overline{K}^0\rvert$ mass difference / average	$< 6\times10^{-19}$	CPT
$p - \overline{p}$ mass difference / average	$(7 \pm 4) \times 10^{-5}$	CPT
$\Lambda - \overline{\Lambda}$ mass difference / average	$(7 \pm 7) \times 10^{-5}$	CPT
$\Xi^- - \overline{\Xi}^+$ mass difference / average	$(1.1 \pm 2.7) \times 10^{-4}$	CPT
$\Omega^- - \overline{\Omega}^+$ mass difference / average	$(-0.7 \pm 4.7) \times 10^{-4}$	CPT
$\mu^+ - \mu^-$ mean life difference / average	$(3 \pm 8) \times 10^{-5}$	CPT
$\pi^+ - \pi^-$ mean life difference / average	$(5 \pm 7) \times 10^{-4}$	CPT
$K^+ - K^-$ mean life difference / average	$(1.1 \pm 0.9) \times 10^{-3}$	CPT
$\Lambda - \overline{\Lambda}$ mean life difference / average	$(4.4 \pm 8.5) \times 10^{-2}$	CPT
$\Xi^- - \overline{\Xi}^+$ mean life difference / average	(0.02 ± 0.18)	CPT
$K^{\pm} \to \mu^{\pm}\nu$ rate difference / average	$(-0.54 \pm 0.41)\%$	CPT
$K^{\pm} \to \pi^{\pm}\pi^0$ rate difference / average	$(0.8 \pm 1.2)\%$	CPT(d)

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a. Branching fractions are described by a shorthand notation, e.g., "$\mu^+ \to e^+\gamma$/all" means $\Gamma(\mu^+ \to e^+\gamma)/\ \Gamma(\mu^+ \to \text{all})$.

b. Limits are given at 90% confidence level while errors are given as ±1 standard deviation.

c. Orthopositronium data are from Liu and Roberts, Phys. Rev. Lett. **16**, 67 (1966).

d. Neglecting photon channels. See, e.g., A. Pais and S.B. Treiman, Phys. Rev. **D12**, 2744 (1975).

TESTS OF CONSERVATION LAWS (Cont'd)

Number Conservation Laws

Quantity(a)	Value(b)	Conservation law tested
$\mu^+ \to e^+\overline{\nu}_e\nu_\mu$ / all	$< 5 \times 10^{-2}$	Lepton family number(c,d)
$\to e^+\gamma$ / all	$< 1.7 \times 10^{-10}$	Lepton family number(d)
$\to e^+e^+e^-$ / all	$< 2.4 \times 10^{-12}$	" " "
$\to e^+\gamma\gamma$ / all	$< 8.4 \times 10^{-9}$	" " "
$\mu^-\ {}^{32}\mathrm{S} \to e^-\ {}^{32}\mathrm{S}$ / all	$< 7 \times 10^{-11}$	" " "
μ^- Cu $\to e^-$ Cu / all	$< 1.6 \times 10^{-8}$	" " "
μ^- Ti $\to e^-$ Ti / all	$< 1.6 \times 10^{-11}$	" " "
coupling for $(\mu^+e^- \to \mu^-e^+)_{\text{bound}}$	$< 42\ G_F$	" " "
$\tau^+ \to \mu^+\gamma$ / all	$< 5.5 \times 10^{-4}$	" " "
$\to e^+\gamma$ / all	$< 6.4 \times 10^{-4}$	" " "
$\to \mu^+\mu^+\mu^-$ / all	$< 4.9 \times 10^{-4}$	" " "
$\to e^+\mu^+\mu^-$ / all	$< 3.3 \times 10^{-4}$	" " "
$\to \mu^+e^+e^-$ / all	$< 4.4 \times 10^{-4}$	" " "
$\to e^+e^+e^-$ / all	$< 4.0 \times 10^{-4}$	" " "
$\to \mu^+\pi^0$ / all	$< 8.2 \times 10^{-4}$	" " "
$\to e^+\pi^0$ / all	$< 2.1 \times 10^{-3}$	" " "
$\to \mu^+K^0$ / all	$< 1.0 \times 10^{-3}$	" " "
$\to e^+K^0$ / all	$< 1.3 \times 10^{-3}$	" " "
$\to \mu^+\rho^0$ / all	$< 4.4 \times 10^{-4}$	" " "
$\to e^+\rho^0$ / all	$< 3.7 \times 10^{-4}$	" " "
$\pi^+ \to \mu^+\nu_e$ / all	$< 8.0 \times 10^{-3}$(e)	" " "
$\pi^0 \to e\mu$ / all	$< 7 \times 10^{-8}$	" " "
$K^+ \to \pi^+e^+\mu^-$ / all	$< 7 \times 10^{-9}$	" " "
$\to \pi^+e^-\mu^+$ / all	$< 5 \times 10^{-9}$	" " "
$\to \mu^+\nu_e$ / all	$< 4 \times 10^{-3}$(e)	" " "
$\to \mu^-\nu e^+e^+$ / all	$< 2 \times 10^{-8}$	" " "
$K_L^0 \to e\mu$ / all	$< 6 \times 10^{-6}$	" " "
$B^0 \to e\mu$ / all	$< 3 \times 10^{-4}$	" " "
ν oscillations		
$\Delta(m^2)$ for $\sin^2(2\theta)=1$		
$\overline{\nu}_e \not\to \overline{\nu}_e$	$< 0.016\ \mathrm{eV}^2$	" " "
$\nu_\mu \to \nu_e$	$< 0.2\ \mathrm{eV}^2$	" " "
$\overline{\nu}_\mu \to \overline{\nu}_e$	$< 0.9\ \mathrm{eV}^2$	" " "
$\nu_\mu \to \nu_\tau$	$< 3\ \mathrm{eV}^2$	" " "
$\overline{\nu}_\mu \to \overline{\nu}_\tau$	$< 2.2\ \mathrm{eV}^2$	" " "
$\nu_\mu \not\to \nu_\mu$	$< 0.23\ \mathrm{eV}^2$ or $> 1500\ \mathrm{eV}^2$	" " "
$\nu_e \not\to \nu_e$	$< 2.3\ \mathrm{eV}^2$	" " "
$\sin^2(2\theta)$ for large $\Delta(m^2)$		
$\overline{\nu}_e \not\to \overline{\nu}_e$	< 0.16	" " "
$\nu_\mu \to \nu_e$	< 0.0034	" " "
$\overline{\nu}_\mu \to \overline{\nu}_e$	< 0.013	" " "
$\nu_\mu \to \nu_\tau$	< 0.013	" " "
$\overline{\nu}_\mu \to \overline{\nu}_\tau$	< 0.044	" " "
$\nu_\mu \not\to \nu_\mu$	$< 0.02\ [\Delta(m^2) = 110\ \mathrm{eV}^2]$	" " "
$\nu_e \not\to \nu_e$	< 0.07	" " "
$\overline{\nu}_e \to \overline{\nu}_\tau$	< 0.7	" " "
For other lepton mixing effects in particle decays, see Full Listings.		
$\mu^-\ {}^{32}\mathrm{S} \to e^+\ {}^{32}\mathrm{Si}^*$ / all	$< 9 \times 10^{-10}$	Total lepton number(f)
$\mu^-\ {}^{127}\mathrm{I} \to e^+\ {}^{127}\mathrm{Sb}^{\text{stable}}$ / all	$< 3 \times 10^{-10}$	" " "
μ^- Cu $\to e^+$ Co / all	$< 2.6 \times 10^{-8}$	" " "
$\pi^+ \to \mu^+\overline{\nu}_e$ / all	$< 1.5 \times 10^{-3}$(e)	" " "
$K^+ \to \pi^-e^+e^+$ / all	$< 1 \times 10^{-8}$	" " "
$\to \pi^-e^+\mu^+$ / all	$< 7 \times 10^{-9}$	" " "
$\to \mu^+\overline{\nu}_e$ / all	$< 3.3 \times 10^{-3}$(e)	" " "
$\to e^+\pi^0\overline{\nu}_e$ / all	$< 3 \times 10^{-3}$(e)	" " "
neutrinoless double beta decay	See Full Listings	" " "

TESTS OF CONSERVATION LAWS (Cont'd)

Number Conservation Laws (Cont'd)

Quantity(a)	Value(b)	Conservation law tested
τ_p / BR($p \to e^+\pi^0$)	$> 2.5 \times 10^{32}$ years	Baryon number
τ_p / BR($p \to \mu^+\pi^0$)	$> 1.0 \times 10^{32}$ years	″ ″
τ_p / BR($p \to e^+K^0$)	$> 0.8 \times 10^{32}$ years	″ ″
τ_p / BR($p \to \mu^+K^0$)	$> 0.4 \times 10^{32}$ years	″ ″
For other nucleon decay channels, see Stable Particle Summary Table.		
mean time for $n \to \overline{n}$ transition	> 3 years	″ ″
e mean life	$> 2 \times 10^{22}$ years	Charge
$n \to p\nu\overline{\nu} / pe^-\overline{\nu}$	$< 9 \times 10^{-24}$	″
Re x from $K^0 \to \pi e \nu$	0.009 ± 0.020	$\Delta S = \Delta Q$ (g)
Im x from $K^0 \to \pi e \nu$	-0.004 ± 0.026	″
$K^+ \to \pi^+\pi^+e^-\overline{\nu}$ / all	$< 1.2 \times 10^{-8}$	″
$\to \pi^+\pi^+\mu^-\overline{\nu}$ / all	$< 3 \times 10^{-6}$	″
$\Sigma^+ \to ne^+\nu$ / all	$< 5 \times 10^{-6}$	″
$\to n\mu^+\nu$ / all	$< 3 \times 10^{-5}$	″
$(\Sigma^+ \to n\ell^+\nu) / (\Sigma^- \to n\ell^-\overline{\nu})$	< 0.04	″
$\Xi^0 \to \Sigma^-e^+\nu$ / all	$< 9 \times 10^{-4}$	″
$\to \Sigma^-\mu^+\nu$ / all	$< 9 \times 10^{-4}$	″
$\to pe^-\overline{\nu}$ / all	$< 1.3 \times 10^{-3}$	$\Delta S = 2$ forbidden(g)
$\to p\mu^-\overline{\nu}$ / all	$< 1.3 \times 10^{-3}$	″ ″
$\Xi^- \to ne^-\overline{\nu}$ / all	$< 3.2 \times 10^{-3}$	″ ″
$\to n\mu^-\overline{\nu}$ / all	$< 1.5 \times 10^{-2}$	″ ″
$\to p\pi^-e^-\overline{\nu}$ / all	$< 4 \times 10^{-4}$	″ ″
$\to p\pi^-\mu^-\overline{\nu}$ / all	$< 4 \times 10^{-4}$	″ ″
$\Xi^0 \to p\pi^-$ / all	$< 3.6 \times 10^{-5}$	″ ″
$\Xi^- \to n\pi^-$ / all	$< 1.9 \times 10^{-5}$	″ ″
$\to p\pi^-\pi^-$ / all	$< 4 \times 10^{-4}$	″ ″
$\Omega^- \to \Lambda\pi^-$ / all	$< 1.9 \times 10^{-4}$	″ ″
$m_{K_L} - m_{K_S}$	$(3.521 \pm 0.014) \times 10^{-12}$ MeV	″ ″
$(D^0 \to \overline{D}^0 \to K^+\pi^-) / (D^0 \to K\pi)$	< 0.08	$\Delta C = 2$ forbidden(g)
$(D^0 \to \overline{D}^0 \to \mu^-$ anything$) / (D^0 \to \mu^+$ anything$)$	< 0.044	″ ″
$\lvert m_{D_1{}^0} - m_{D_2{}^0} \rvert$ (from previous limit)	$< 6.5 \times 10^{-10}$ MeV	″ . ″
$(B^0 \to \overline{B}^0$ via mixing$) / (B^0 \to$ all$)$	< 0.12	$\Delta B = 2$ forbidden(g)
$K_L^0 \to \mu^+\mu^-$ / all	$(9.1 \pm 1.9) \times 10^{-9}$	no flav. chng. neut. curr.
$\to e^+e^-$ / all	$< 2.0 \times 10^{-7}$	″ ″ ″ ″ ″
$\to \mu^+\mu^-\gamma$ / all	$(2.8 \pm 2.8) \times 10^{-7}$	″ ″ ″ ″ ″
$\to e^+e^-\gamma$ / all	$(1.7 \pm 0.9) \times 10^{-5}$	″ ″ ″ ″ ″
$\to \pi^0\mu^+\mu^-$ / all	$< 1.2 \times 10^{-6}$	″ ″ ″ ″ ″
$\to \pi^0e^+e^-$ / all	$< 2.3 \times 10^{-6}$	″ ″ ″ ″ ″
$\to \pi^+\pi^-e^+e^-$ / all	$< 9 \times 10^{-6}$	″ ″ ″ ″ ″
$\to \mu^+\mu^-e^+e^-$ / all	$< 4.9 \times 10^{-6}$	″ ″ ″ ″ ″
$\to e^+e^-e^+e^-$ / all	$< 2.6 \times 10^{-6}$	″ ″ ″ ″ ″
$K_S^0 \to \mu^+\mu^-$ / all	$< 3.2 \times 10^{-7}$	″ ″ ″ ″ ″
$\to e^+e^-$ / all	$< 3.4 \times 10^{-4}$	″ ″ ″ ″ ″
$K^+ \to \pi^+e^+e^-$ / all	$(2.7 \pm 0.5) \times 10^{-7}$	″ ″ ″ ″ ″
$\to \pi^+\mu^+\mu^-$ / all	$< 2.4 \times 10^{-6}$	″ ″ ″ ″ ″
$\to \pi^+\nu\overline{\nu}$ / all	$< 1.4 \times 10^{-7}$	″ ″ ″ ″ ″
$D^0 \to \mu^+\mu^-$	$< 3.4 \times 10^{-4}$	″ ″ ″ ″ ″
$B^0 \to e^+e^-$ / all	$< 3 \times 10^{-4}$	″ ″ ″ ″ ″
$\to \mu^+\mu^-$ / all	$< 2 \times 10^{-4}$	″ ″ ″ ″ ″
$\Sigma^+ \to pe^+e^-$ / all	$< 7 \times 10^{-6}$	″ ″ ″ ″ ″

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a. Branching fractions are described by a shorthand notation, e.g., "$\mu^+ \to e^+\gamma$/all" means $\Gamma(\mu^+ \to e^+\gamma) / \Gamma(\mu^+ \to$ all$)$.

b. Limits are given at 90% confidence level while errors are given as ±1 standard deviation.

c. Test of additive vs. multiplicative lepton family number conservation.

d. Lepton family number conservation means separate conservation of e-number, μ-number, and τ-number.

e. These limits are derived from the analysis of neutrino oscillation experiments.

f. Violation of total lepton number conservation also implies violation of lepton family number conservation.

g. Can be violated in second-order weak interactions.

NONRELATIVISTIC QUARK MODEL

A. QUANTUM NUMBERS

Each quark has spin 1/2. The additive quantum numbers (other than baryon number = 1/3) of the known (and presumed) quarks are shown in the table.

Quantum number	Quark type (flavor)					
	d	u	s	c	b	t
Q — electric charge	$-\frac{1}{3}$	$+\frac{2}{3}$	$-\frac{1}{3}$	$+\frac{2}{3}$	$-\frac{1}{3}$	$+\frac{2}{3}$
I_z — z-component of isospin	$-\frac{1}{2}$	$+\frac{1}{2}$	0	0	0	0
S — strangeness	0	0	−1	0	0	0
C — charm	0	0	0	+1	0	0
B — bottomness	0	0	0	0	−1	0
T — topness	0	0	0	0	0	+1

With these conventions the strangeness S of the K^+ is +1 and the bottomness B of the B^+ is +1.

The G-parity operator is defined to be $G = Ce^{-i\pi I_y}$, where C is the charge conjugation operator. The mesons with S = C = B = T = 0 are eigenstates of G. If a meson is also an eigenstate of the charge conjugation operator with charge conjugation C, then $G = C(-1)^I$, where I is its isospin; all the other particles in the same isomultiplet have the same value of G: $G(\pi^\pm) = G(\pi^0) = -1$, $G(\rho^\pm) = G(\rho^0) = +1$, etc.

B. MESONS

Nearly all known mesons can be understood as bound states of a quark q and an antiquark $\bar{q}'$ (the flavors of q and q' may be different). If the orbital angular momentum of the $q\bar{q}'$ state is L, then the parity $P = (-1)^{L+1}$. A state $q\bar{q}$ of a quark and its own antiquark is also an eigenstate of charge conjugation with $C = (-1)^{L+S}$, where the spin $S = 0$ or 1. The $L = 0$ states are the pseudoscalars, $J^P = 0^-$, and the vectors, $J^P = 1^-$. See table below.

States in the "normal" spin-parity series, $P = (-1)^J$, must, according to the above, have $S = 1$ and hence $CP = +1$. Thus mesons with normal spin-parity and $CP = -1$ are forbidden in the $q\bar{q}'$ quark model. The $J^{PC} = 0^{--}$ state is forbidden as well. Mesons with such J^{PC} could exist, but would lie outside the $q\bar{q}'$ model.

States with the same J^P and additive quantum numbers can mix (if they are eigenstates of charge conjugation, they must also have the same value of C). Thus the physical $J^P = 1^+$, strangeness S = 1 states, $K_1(1280)$ and $K_1(1400)$, are mixtures of the pure quark model states K_{1A} and K_{1B}. The $\psi(3770)$ is a mixture of ${}^3S_1$ and ${}^3D_1$. The η and η' are mixtures of the SU(3) octet and singlet states.

For the pseudoscalar mesons, the Gell-Mann-Okubo formula is

$$m_\eta^2 = \frac{1}{3}(4m_K^2 - m_\pi^2) ,$$

assuming no octet-singlet mixing. However, the octet η_8 and singlet η_1 mix because of SU(3) breaking. The physical states η and η' are given by

$$\eta = \eta_8 \cos\theta_P - \eta_1 \sin\theta_P$$

$$\eta' = \eta_8 \sin\theta_P + \eta_1 \cos\theta_P .$$

These combinations diagonalize the mass-squared matrix

$$M^2 = \begin{pmatrix} M_{11}^2 & M_{18}^2 \\ M_{18}^2 & M_{88}^2 \end{pmatrix} ,$$

where $M_{88}^2 = \frac{1}{3}(4m_K^2 - m_\pi^2)$. It follows that

$$\tan^2\theta_P = \frac{M_{88}^2 - m_\eta^2}{m_{\eta'}^2 - M_{88}^2} .$$

The sign of θ_P is meaningful in the quark model. If

$$\eta_1 = (u\bar{u} + d\bar{d} + s\bar{s})/\sqrt{3}$$

$$\eta_8 = (u\bar{u} + d\bar{d} - 2s\bar{s})/\sqrt{6} ,$$

then the matrix element M_{18}^2, which is due mostly to the strange

Standard quark model assignments for some of the known mesons. Some assignments, especially for 0^{++}, are controversial. Note that only the states in the $u\bar{u}$, $d\bar{d}$, $s\bar{s}$, $c\bar{c}$, and $b\bar{b}$ columns and the neutral states in the $I = 1$ column are eigenstates of charge conjugation C.

${}^{2S+1}L_J$	J^{PC}	$u\bar{d}$, $u\bar{u}$, $d\bar{d}$ $I = 1$	$u\bar{u}$, $d\bar{d}$, $s\bar{s}$ $I = 0$	$c\bar{c}$ $I = 0$	$b\bar{b}$ $I = 0$	$\bar{s}u$, $\bar{s}d$ $I = 1/2$	$c\bar{u}$, $c\bar{d}$ $I = 1/2$	$c\bar{s}$ $I = 0$	$\bar{b}u$, $\bar{b}d$ $I = 1/2$
${}^1S_0$	0^{-+}	π	η, η'	η_c		K	D	D_s	B
${}^3S_1$	1^{--}	ρ	ϕ, ω	J/ψ	Υ	$K^*(892)$	$D^*(2010)$		
${}^1P_1$	1^{+-}	$b_1(1235)$	$h_1(1190)$			K_{1B}			
${}^3P_0$	0^{++}	$a_0(980)$	$f_0(975)$, $f_0(1300)$	$\chi_0(3415)$	$\chi_{b0}(9860)$	$K_0^*(1350)$			
${}^3P_1$	1^{++}	$a_1(1270)$	$f_1(1285)$, $f_1(1420)$	$\chi_1(3510)$	$\chi_{b1}(9895)$	K_{1A}			
${}^3P_2$	2^{++}	$a_2(1320)$	$f_2'(1525)$, $f_2(1270)$	$\chi_2(3555)$	$\chi_{b2}(9915)$	$K_2^*(1430)$			
${}^1D_2$	2^{-+}	$\pi_2(1680)$							
${}^3D_1$	1^{--}			$\psi(3770)$					
${}^3D_2$	2^{--}					$K_2(1770)$			
${}^3D_3$	3^{--}	$\rho_3(1690)$	$\omega_3(1670)$			$K_3^*(1780)$			

quark mass, is negative. From the relation

$$\tan\theta_P = \frac{M_{88}^2 - m_\eta^2}{M_{18}^2} ,$$

we find $\theta_P < 0$.

For the vector mesons we replace $\pi \to \rho$, $K \to K^*$, $\eta \to \phi$, and $\eta' \to \omega$, so

$$\phi = \omega_8 \cos\theta_V - \omega_1 \sin\theta_V$$

$$\omega = \omega_8 \sin\theta_V + \omega_1 \cos\theta_V .$$

For "ideal mixing," $\phi = s\bar{s}$, $\tan\theta_V = 1/\sqrt{2}$, so $\theta_V \approx 35.3°$. Experimentally, θ_V is near 35°, the sign being determined by a formula analogous to that for $\tan\theta_P$. Following this procedure we find the mixing angles below. There are uncertainties of a few degrees arising from electromagnetic mass splittings and uncertainties in resonance masses.

Singlet-octet mixing for the pseudoscalar, vector, and tensor mesons. The sign conventions are as above. The value of θ_{quad} is obtained from the equations above, and θ_{lin} is obtained by replacing $m^2 \to m$ throughout. Of the two isosinglets, the mostly octet one is listed first.

J^{PC}	Nonet Members	θ_{quad}	θ_{lin}
0^{-+}	π, K, η, η'	−10°	−23°
1^{--}	ρ, $K^*(892)$, ϕ, ω	39°	36°
2^{++}	$a_2(1320)$, $K_2^*(1430)$, $f_2'(1525)$, $f_2(1270)$	28°	26°
3^{--}	$\rho_3(1690)$, $K_3^*(1780)$, $\phi_J(1850)$, $\omega_3(1670)$	29°	28°

C. BARYONS

All the established baryons are apparently 3-quark (qqq) states, and each such state is an SU(3) color singlet, a completely antisymmetric state of the three possible colors. Since the quarks are fermions, the state function for any baryon must be antisymmetric under interchange of any two of its quarks. Thus the state is *symmetric* under interchange of the quantum labels other than color:

$$|qqq\rangle_A = |\text{color}\rangle_A \times |\text{space, spin, flavor}\rangle_S ,$$

where the subscripts S and A indicate symmetry or antisymmetry under interchange of any two of the quarks. Note the contrast with the state function for the three nucleons in ^{3}H or ^{3}He:

$$|NNN\rangle_A = |\text{space, spin, isospin}\rangle_A .$$

This difference has major implications for internal structure, magnetic moments, etc. (For a nice discussion, see Ref. 1.)

Few of the baryons containing c or heavier quarks have yet been discovered, so we restrict further attention to baryons made up of just d, u, and s quarks. The three flavors imply a flavor SU(3), which requires that baryons made of these quarks belong to the multiplets on the right side of

$$\mathbf{3} \otimes \mathbf{3} \otimes \mathbf{3} = \mathbf{10}_S \oplus \mathbf{8}_M \oplus \mathbf{8}_M \oplus \mathbf{1}_A$$

(see the section on SU(n) Multiplets and Young Diagrams). Here the subscripts indicate symmetric, mixed-symmetry, or antisymmetric states under interchange of any two quarks. The figure shows particle assignments in these multiplets. States Λ_8 and Λ_1 that have the same spin and parity can mix; an example is the mainly octet D_{03} $\Lambda(1690)$ and mainly singlet D_{03} $\Lambda(1520)$. The formalism is the same as for η–η' or ϕ–ω mixing (see above), except that for baryons the mass M instead of M^2 is used. The section SU(3) Isoscalar Factors shows how relative decay rates in, say, $\mathbf{10} \to \mathbf{8} \otimes \mathbf{8}$ decays may be calculated. A summary of results of fits to the observed baryon masses and decay rates for the best-known SU(3) multiplets is given in Appendix II of our 1982 edition.[2]

Flavor and spin may be combined in a flavor-spin SU(6) in which the six basic states are $d\uparrow$, $d\downarrow$, $\cdots$, $s\downarrow$ ($\uparrow$, $\downarrow$ = spin up, down). Then the baryons belong to the multiplets on the right side of

$$\mathbf{6} \otimes \mathbf{6} \otimes \mathbf{6} = \mathbf{56}_S \oplus \mathbf{70}_M \oplus \mathbf{70}_M \oplus \mathbf{20}_A .$$

These SU(6) multiplets decompose into flavor SU(3) multiplets as follows:

$$\mathbf{56} = {}^4\mathbf{10} \oplus {}^2\mathbf{8}$$

$$\mathbf{70} = {}^2\mathbf{10} \oplus {}^4\mathbf{8} \oplus {}^2\mathbf{8} \oplus {}^2\mathbf{1}$$

$$\mathbf{20} = {}^2\mathbf{8} \oplus {}^4\mathbf{1} ,$$

where the superscript $(2S+1)$ gives the net spin S of the quarks for each particle in the SU(3) multiplet. The $J^P = 1/2^+$ octet containing the nucleon and the $J^P = 3/2^+$ decuplet containing the $\Delta(1232)$ together make up the "ground-state" 56-plet in which the orbital angular momenta between the quarks are zero (so that the spatial part of the state function is trivially symmetric). The **70** and **20** require some excitation of the spatial part of the state function in order to make the overall state function symmetric.

The quark model for baryons is extensively reviewed in Ref. 3.

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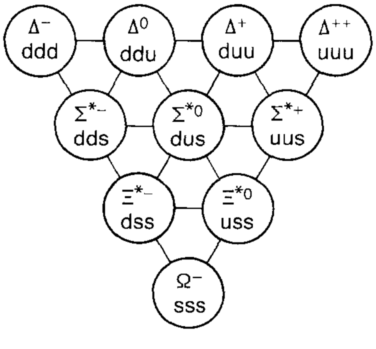
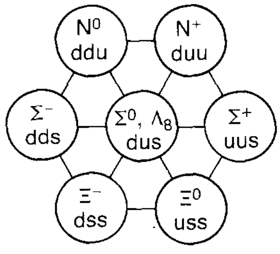
1. F.E. Close, in *Quarks and Nuclear Forces* (Springer-Verlag, 1982), p. 56.
2. Particle Data Group, Phys. Lett. **111B** (1982).
3. A.J.G. Hey and R.L. Kelly, Phys. Reports **96**, 71 (1983).





QCD

A. THE QCD COUPLING CONSTANT

The QCD coupling constant $\alpha_s(Q^2)$ has a Q^2 dependence given by

$$\frac{d\alpha_s(Q^2)}{d\,\ell n\,(Q^2)} = -\frac{\alpha_s(Q^2)}{4\pi}[\beta_0 + \frac{\alpha_s(Q^2)}{4\pi}\beta_1 + \cdots]$$

where

$$\beta_0 = 11 - \frac{2n_f}{3}\,, \quad \beta_1 = 102 - \frac{38n_f}{3}\,,$$

and n_f is the number of light quark flavors, i.e., those with masses much less than $Q/2$. This equation can be solved given a boundary condition: the value of $\alpha_s(Q^2)$ at some arbitrary scale Q_0. This is the only parameter of QCD apart from quark masses. The solution to this equation in lowest order, i.e., retaining only the first term on the right-hand side of the equation, is

$$\alpha_s(Q^2) = \frac{12\pi}{(33 - 2n_f)\,\ell n\,(Q^2/\Lambda^2)}\,.$$

Here a parameter Λ has been introduced. It replaces the boundary condition $\alpha_s(Q_0^2)$.

To next order the solution is obtained by multiplying the right-hand side of the above equation by

$$\left\{1 - \frac{6(153 - 19n_f)}{(33 - 2n_f)^2}\,\frac{\ell n\,[\,\ell n\,(Q^2/\Lambda^2)]}{\ell n\,(Q^2/\Lambda^2)}\right\}.$$

B. THE QCD PARTON MODEL

The structure functions of deep inelastic scattering given in Secs. C.5.b.i and C.5.b.ii of Cross Sections, Decays, Structure Functions, and Kinematics can be written in terms of quark distribution functions in the QCD parton model. $q(x,Q^2)dx$ is the probability that a parton (quark, antiquark, or gluon) carries a momentum fraction between x and $x + dx$ of the nucleon's momentum in a frame where the nucleon's momentum is large. The energy scale Q is the invariant mass of the virtual probe (photon, W, or Z) which hits the nucleon. The structure functions referred to in Cross Sections, Decays, Structure Functions, and Kinematics, Sec. C.5.b, are given by

$$F_2^{\nu\mathrm{CC}} = 2x\,[d(x) + s(x) + \overline{u}(x) + \overline{c}(x)]$$

$$xF_3^{\nu\mathrm{CC}} = 2x\,[d(x) + s(x) - \overline{u}(x) - \overline{c}(x)]$$

$$F_2^{\overline{\nu}\mathrm{CC}} = 2x\,[u(x) + c(x) + \overline{d}(x) + \overline{s}(x)]$$

$$xF_3^{\overline{\nu}\mathrm{CC}} = 2x\,[u(x) + c(x) - \overline{d}(x) - \overline{s}(x)]$$

$$F_2^{\mathrm{em}} = x\left[\tfrac{4}{9}\Big(u(x) + \overline{u}(x)\Big) + \tfrac{1}{9}\Big(d(x) + \overline{d}(x)\Big) + \cdots\right]$$

$$\begin{aligned} F_2^{\nu\mathrm{NC}} = 2\rho^2 x\Big\{&\left[\tfrac{1}{4} - \tfrac{2}{3}\sin^2\theta_W + \tfrac{8}{9}\sin^4\theta_W\right]\left[u(x) + \overline{u}(x)\right] \\ &+ \left[\tfrac{1}{4} - \tfrac{1}{3}\sin^2\theta_W + \tfrac{2}{9}\sin^4\theta_W\right]\left[d(x) + \overline{d}(x)\right]\Big\} \end{aligned}$$

$$\begin{aligned} xF_3^{\nu\mathrm{NC}} = 2\rho^2 x\Big\{&\left[\tfrac{1}{4} - \tfrac{2}{3}\sin^2\theta_W\right]\left[u(x) - \overline{u}(x)\right] \\ &+ \left[\tfrac{1}{4} - \tfrac{1}{3}\sin^2\theta_W\right]\left[d(x) - \overline{d}(x)\right]\Big\} \end{aligned}$$

$F_2 = 2xF_1$ in all cases (This is the Callan-Gross relation, and ignores parton transverse momentum and higher order QCD corrections.)

$$F_i^{\overline{\nu}\mathrm{NC}} = F_i^{\nu\mathrm{NC}}\,,$$

where $\rho = M_W^2/(M_Z^2\cos^2\theta_W)$.

The Q^2 dependence has been suppressed for the above distributions and structure functions. The x dependence of the structure functions for $10 < Q^2 < 30$ GeV^2 is shown in the Structure Functions Section of the Plots of Cross Sections and Related Quantities. The Q^2 dependence of the structure functions is predicted by QCD and is controlled by α_s. The dependence is logarithmic and consequently slow. It is also shown in the Structure Functions plots. Over the limited Q^2 range shown relatively little net change is seen. The coupling constant, or Λ, can be determined from these data.[1]

The QCD parton model can also be applied to purely hadronic collisions. For example, the cross section for the production of two jets in a hadronic collision is given by

$$\sigma(s) = \sum_{i,j}\int f_i(x_1, Q^2) f_j(x_2, Q^2)\hat{\sigma}_{ij}(\hat{s})dx_1 dx_2\,.$$

Here $\hat{s} = sx_1x_2$ is the invariant mass squared of the parton-parton system and s is that of the proton-proton system. In this formula $f_i(x,Q^2)$ is the probability of a parton of type i being inside the proton with fraction x of the proton's momentum. The sums i and j run over all partons: quarks, for which $f_i(x,Q^2) = q(x,Q^2)$; antiquarks, for which $f_i(x,Q^2) = \overline{q}(x,Q^2)$; and gluons for which $f_i(x,Q^2) = g(x,Q^2)$. The quantity $\hat{\sigma}_{ij}$ is the cross section for the scattering of the two partons i and j. The scale Q appearing in the distribution functions is not well defined. It is characteristic of the momentum transfers in the partonic process and can be determined operationally only after computing higher order corrections.

In order to describe one-particle inclusive production in e^+e^- annihilation or deep inelastic scattering, it is convenient to introduce a fragmentation function $D_i^h(z,Q^2)/z$ which is the probability that a parton of type i and momentum p will fragment into a hadron of type h and momentum zp. The Q^2 evolution is predicted by QCD and is similar to that of the parton distribution functions (see above). The $D_i^h(z,Q^2)$ are normalized so that

$$\sum_h \int D_i^h(z,Q^2)dz = 1\,.$$

If the contributions of the Z boson and three-jet events are neglected, the cross section for producing a hadron h in e^+e^- annihilation is given by

$$\frac{1}{\sigma_{\mathrm{had}}}\frac{d\sigma}{dz} = \frac{\sum_i e_i^2 D_i^h(z,Q^2)}{\sum_i e_i^2}\,,$$

where e_i is the charge of quark-type i, σ_{had} is the total hadronic cross section, and the momentum of the hadron is $zE_{\mathrm{cm}}/2$.

In the case of deep inelastic muon scattering, the cross section for producing a hadron of energy E_h is given by

$$\frac{1}{\sigma_{\mathrm{tot}}}\frac{d\sigma}{dz} = \frac{\sum_i e_i^2 q_i(x,Q^2) D_i^h(z,Q^2)}{\sum_i e_i^2 q_i(x,Q^2)}\,,$$

where $E_h = \nu z$. (For the kinematics of deep inelastic scattering, see section C.5 of the Cross Sections, Decays, Structure Functions, and

Kinematics section of this Review.) The fragmentation functions for light and heavy quarks have different z dependence; the former peak near $z = 0$. They are illustrated in a figure in the section on Plots of Cross Sections and Related Quantities.

C. TESTS OF QCD

When a process is calculated beyond leading order in perturbative QCD, the coupling constant must be renormalized (defined). In the case of QED, the coupling constant can be defined as the strength of the electron-electron-photon vertex in the limit of zero photon momentum. Such a definition is related directly to a physical process, namely Thompson scattering. Such a definition is not possible in perturbative QCD since the coupling constant is too large for perturbation theory to be applicable to such a process. Rather, the coupling constant must be defined by some more formal procedure. Two such renormalization schemes are in common use: modified minimal subtraction ($\overline{\mathrm{MS}}$)[2] and momentum space subtraction (MOM).[3] They are related by

$$\alpha_{\mathrm{MOM}}(Q^2) = \alpha_{\overline{\mathrm{MS}}}(Q^2)\left[1 + (1.86 - 0.48 n_f)\alpha_{\overline{\mathrm{MS}}}(Q^2) + \cdots\right].$$

The corresponding Λ's are then obtained from the equations of Sec. A above. If a process is calculated in perturbation theory, the coefficient of the next-to-leading term depends upon the procedure used. This coefficient can also be altered by changing the value of the scale Q^2 at which the coupling constant is evaluated. Care should therefore be exercised in estimating how well the perturbation series is converging.

The parameter $\alpha_s(Q_0^2)$ or Λ is extracted by comparing a QCD prediction with some data. The values of α_s extracted from different experiments will agree if and only if the following criteria are satisfied:

1) The same renormalization scheme is used.

2) The perturbation series is convergent. As indicated above, the series may appear to be more convergent depending upon the choice of scheme and of Q^2. The choice of scheme is arbitrary. The choice of Q^2 is sometimes clearly indicated by the physics, for example in the case of deep inelastic scattering. In other cases it is not clear; for example, in the case of jet production, it could be either of the Mandelstam variables t or s appropriate to the partonic process or the transverse momentum of the jet. In these ambiguous cases, it should be taken to be the value which minimizes the next-to-leading term in the perturbation series. In this event, a statement concerning the convergence of the perturbation expansion is not possible until the next-to-next-to-leading-order term has been computed. The size of the next-to-leading corrections varies widely from process to process. The corrections are largest in processes with a small Q, where α_s is larger. There are corrections of order 30% to single W or Z production in proton-antiproton collisions at $\sqrt{s} = 540$ GeV. By contrast the corrections to the total hadronic cross section in e^+e^- annihilation are only a few percent at $\sqrt{s} = 30$ GeV.

3) The process must be free of so-called higher twist corrections. These are terms proportional to M^2/Q^2, where M is some mass scale of order 1 GeV. These corrections consequently become irrelevant as Q^2 is increased. These corrections cannot be calculated in perturbative QCD. They afflict attempts to extract α_s from deep inelastic scattering and from 3-jet events in e^+e^- annihilation. In the latter case, they are manifested in the different α_s values which are extracted using different Monte-Carlos to describe the materialization of quarks and gluons into hadrons.

4) If there are quark thresholds in the region of Q^2 being used for the measurement, these thresholds should be correctly dealt with. This involves removing kinematic corrections and taking care to indicate how Λ depends on the thresholds.

Among the processes used to determine α_s are: deep inelastic scattering,[4] the total hadronic cross section in e^+e^- annihilation,[5] the distribution of 3-jet events in e^+e^- annihilation,[6] the flow of energy in e^+e^- annihilation,[7] the branching fractions $\Upsilon \to \gamma + X$ and $\Upsilon \to \mu^+\mu^-$,[8] the behavior of form factors,[9] measurements of the photon structure functions,[10] and the hyperfine splittings in the ψ system.[11]

In view of all the problems both theoretical and experimental, it is remarkable that all these different measurement agree so well and all are consistent with a value of $\Lambda_{\overline{\mathrm{MS}}}$ of order 200 MeV.

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THE KOBAYASHI-MASKAWA MIXING MATRIX*

In the "standard model" with SU(2)×U(1) as the gauge group of electroweak interactions, both the quarks and leptons are assigned to be left-handed doublets and right-handed singlets. The quark mass eigenstates are not the same as the weak eigenstates, and the matrix connecting them has become known as the Kobayashi-Maskawa matrix[1] since an explicit parametrization in the six-quark case was first published by them in 1973.

By convention, the three charge 2/3 quarks (u, c, and t) are unmixed, and all the mixing is expressed in terms of a 3×3 unitary matrix V operating on the charge $-1/3$ quarks (d, s, b):

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} . \tag{1}$$

The values of individual K-M matrix elements can in principle all be determined from weak decays of the relevant quarks, or, in some cases, from deep inelastic neutrino scattering. Using the constraints discussed below, together with unitarity, and assuming only three generations, the 90% confidence limits on the magnitude of the elements of the complete matrix are:

$$\begin{pmatrix} 0.9742 \text{ to } 0.9756 & 0.219 \text{ to } 0.225 & 0 \text{ to } 0.008 \\ 0.219 \text{ to } 0.225 & 0.973 \text{ to } 0.975 & 0.037 \text{ to } 0.053 \\ 0.002 \text{ to } 0.018 & 0.036 \text{ to } 0.052 & 0.9986 \text{ to } 0.9993 \end{pmatrix} . \tag{2}$$

The ranges shown are for the individual matrix elements. The constraints of unitarity connect different elements, so choosing a specific value for one element restricts the range of the others.

There are several parametrizations of the K-M matrix. The form due to Maiani[2] has a number of convenient properties:

$$V = \begin{pmatrix} c_\beta c_\theta & c_\beta s_\theta & s_\beta \\ -s_\gamma c_\theta s_\beta e^{i\delta'} - s_\theta c_\gamma & c_\gamma c_\theta - s_\gamma s_\beta s_\theta e^{i\delta'} & s_\gamma c_\beta e^{i\delta'} \\ -s_\beta c_\gamma c_\theta + s_\gamma s_\theta e^{-i\delta'} & -c_\gamma s_\beta s_\theta - s_\gamma c_\theta e^{-i\delta'} & c_\gamma c_\beta \end{pmatrix} \tag{3}$$

where θ, β, γ, and δ' are angles and $c_\beta = \cos\beta$, $s_\beta = \sin\beta$, etc. With $\beta = \gamma = 0$, the first two generations of quarks decouple from the third, and θ is directly the Cabibbo angle.

In view of the need for a "standard" parametrization in the literature, we propose this form and request public comment.

Kobayashi and Maskawa[1] chose a parametrization involving the four angles, θ_1, θ_2, θ_3, δ:

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} c_1 & -s_1 c_3 & -s_1 s_3 \\ s_1 c_2 & c_1 c_2 c_3 - s_2 s_3 e^{i\delta} & c_1 c_2 s_3 + s_2 c_3 e^{i\delta} \\ s_1 s_2 & c_1 s_2 c_3 + c_2 s_3 e^{i\delta} & c_1 s_2 s_3 - c_2 c_3 e^{i\delta} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} , \tag{4}$$

where $c_i = \cos\theta_i$ and $s_i = \sin\theta_i$ for $i = 1,2,3$. In the limit $\theta_2 = \theta_3 = 0$, this also reduces to the usual Cabibbo mixing with θ_1 identified (up to a sign) with the Cabibbo angle. The angles θ_1, θ_2, θ_3 can all be made to lie in the first quadrant (so that all s_i, c_i are positive) by an appropriate redefinition of quark field phases.

Slightly different forms of the Kobayashi-Maskawa parametrization are found in the literature. The *K-M* matrix used in the 1982 Review of Particle Properties is obtained by letting $s_1 \to -s_1$ and $\delta \to \delta+\pi$ in the matrix given above. An alternative used in another review[3] is to change Eq. (4) by $s_1 \to -s_1$ but leave δ unchanged. With this change in s_1, θ_1 becomes the usual Cabibbo angle, with the "correct" sign (i.e., $d' = d\cos\theta_1 + s\sin\theta_1$), in the limit $\theta_2 = \theta_3 = 0$. The angles θ_1, θ_2, θ_3 can, as before, all be taken to lie in the first quadrant by adjusting quark field phases. Since all these parametrizations are referred to as "the" Kobayashi-Maskawa form, some care about which one is being used is needed when the quadrant in which δ lies is under discussion.

Another parametrization, which emphasizes the relative sizes of the matrix elements by expressing them in powers of the Cabibbo angle, was introduced by Wolfenstein.[4] Still other parametrizations[5] have come into the literature in connection with attempts to define "maximal *CP* violation." No physics can depend on which of the above parametrizations (or any other) is used as long as it is used consistently and care is taken to be sure that no other choice of phases is in conflict.

Our present knowledge of the matrix elements comes from the following sources:

(1) Nuclear beta decay, when compared to muon decay, gives[6]

$$|V_{ud}| = 0.9729 \pm 0.0012 . \tag{5}$$

Recent refinements (wherein leading log radiative corrections are summed using the renormalization group and structure-dependent $O(\alpha)$ terms are analyzed and estimated) have been included, thereby lowering $|V_{ud}|$ by 0.13%.

(2) An analysis of hyperon and K_{e3} decays yields[7]

$$|V_{us}| = 0.221 \pm 0.002 . \tag{6}$$

The isospin violation between K_{e3}^+ and K_{e3}^0 decays has been taken into account, bringing the values of $|V_{us}|$ extracted from these two decays into agreement at the 1% level of accuracy. The hyperon data alone tend to give a higher value, but theoretically they have larger possible uncertainties because of first-order symmetry-breaking effects in the axial-vector couplings. A simultaneous fit to both data sets shows that the difference is not statistically significant and yields the mean value given above.

(3) From neutrino and antineutrino production of charm, the CDHS group has deduced[8]

$$|V_{cd}| = 0.24 \pm 0.03 . \tag{7}$$

(4) Values of $|V_{cs}|$ from such experiments are dependent on assumptions about the strange-quark density in the parton sea. Using the conservative assumption that the strange-quark sea does not exceed the value corresponding to an SU(3) symmetric sea, a bound on $|V_{cs}|$ results[8] which is comparable to that given below. A different source of information on $|V_{cs}|$ arises from comparing the experimental value for $\Gamma(D \to \overline{K}e^+\nu_e)$ with the expression that follows from the standard weak interaction amplitude:

$$\Gamma(D \to \overline{K}e^+\nu_e) = |f_+^D(0)|^2 \, |V_{cs}|^2 (1.54\times10^{11} \text{ sec}^{-1}) . \tag{8}$$

Here $f_+^D[(p_D - p_K)^2]$ is the form factor for $D_{\ell3}$ decay which is the analogue of $f_+[(p_K - p_\pi)^2]$ for $K_{\ell3}$ decay. With the parametrization $f_+^D(t)/f_+^D(0) = M^2/(M^2 - t)$ and $M = 2.1$ GeV from recent measurements,[9] its variation has been taken into account in deriving Eq. (8). From combining data on $\text{BR}(D^+ \to \overline{K}^0 e^+\nu_e)$ and $\text{BR}(D^0 \to K^- e^+\nu_e)$ with world-average values[9] of τ_{D^+} and τ_{D^0}, the resulting value of the left-hand side of Eq. (8) is $0.79 \pm 0.11\times10^{11}$ sec^{-1}. Therefore,

$$|f_+^D(0)|^2 |V_{cs}|^2 = 0.51 \pm 0.07 . \tag{9}$$

With sufficient confidence in a theoretical calculation of $|f_+^D(0)|$, a value of $|V_{cs}|$ follows;[10] but even with the very conservative assumption that $|f_+^D(0)| < 1$, it follows that

$$|V_{cs}| > 0.66 . \tag{10}$$

The constraint of unitarity when there are only three generations gives a much tighter bound [see matrix (2)].

THE KOBAYASHI-MASKAWA MIXING MATRIX (Cont'd)

(5) The ratio $|V_{ub}/V_{cb}|$ is obtained from the semileptonic decay of B mesons by fitting to the lepton energy spectrum as a sum of contributions involving $b \to u$ and $b \to c$. The relative overall phase-space factor between the two processes is calculated from the usual four-fermion interaction with one massive fermion (c quark or u quark) in the final state. The value of this factor is between 0.4 and 0.5, depending on the quark masses used. We use 0.45. The lack of observation of the higher momentum leptons characteristic of $b \to u\ell\bar{\nu}_\ell$, as compared to $b \to c\ell\bar{\nu}_\ell$, results in a limit which depends on the lepton energy spectrum assumed for each decay. As more data have accumulated, the inadequacy of previously used parametrizations has become clear.[9] Conservatively using only the lepton momentum region beyond the endpoint for $b \to c\ell\bar{\nu}_\ell$ results in[9]

$$\frac{\Gamma(b \to u\ell\bar{\nu}_\ell)}{\Gamma(b \to c\ell\bar{\nu}_\ell)} < 0.08\,, \tag{11}$$

which translates to

$$|V_{ub}/V_{cb}| < 0.19\,. \tag{12}$$

Being slightly less conservative and including the last 200 MeV/c of the $b \to c\ell\bar{\nu}_\ell$ spectrum gives a stronger limit[9]

$$\frac{\Gamma(b \to u\ell\bar{\nu}_\ell)}{\Gamma(b \to c\ell\bar{\nu}_\ell)} < 0.04\,, \tag{13}$$

which coincides with previous limits[11] and translates to

$$|V_{ub}/V_{cb}| < 0.14\,. \tag{14}$$

There are some theoretical uncertainties in this analysis stemming from the fact that the physical decays involve actual hadrons and not just quarks as is assumed in the calculations of the lepton spectra for $b \to u\ell\bar{\nu}_\ell$ and $b \to c\ell\bar{\nu}_\ell$.

(6) The magnitude of V_{cb} itself can be determined if the measured semileptonic bottom hadron partial width is assumed to be that of a b quark decaying through the usual V-A interaction:

$$\Gamma(b \to c\ell\bar{\nu}_\ell) = \frac{BR(b \to c\ell\bar{\nu}_\ell)}{\tau_b} = \frac{G_F^2 m_b^5}{192\pi^3} F(m_b, m_c)\,|V_{cb}|^2\,, \tag{15}$$

where τ_b is the b lifetime and $F(m_b, m_c)$ is the phase-space factor chosen above as 0.45.

Using an average semileptonic branching ratio measured in the continuum of[9] 12.1 ± 0.8% [which from Eq. (11) is BR($b \to c\ell\bar{\nu}_\ell$) to within 8%], a world-average bottom hadron lifetime[9] of $1.26 \pm 0.16 \times 10^{-12}$ sec, and m_b between 4.8 and 5.2 GeV, we get

$$0.037 < |V_{cb}| < 0.053\,. \tag{16}$$

where the range of m_b values used in extracting V_{cb} has been treated as a theoretical systematic error on top of the errors arising from experimental measurements.

The results for three generations of quarks, from Eqs. (5), (6), (7), (10), (12), and (16) plus unitarity, are given in matrix (2). The ranges there are different from those given in Eqs. (5)–(16) because of the constraint of unitarity, but are consistent with the quoted one-standard-deviation errors.

The data do not preclude there being more than three generations. Moreover, the entries deduced from unitarity might be altered when the K-M matrix is expanded to accommodate more generations. Conversely, the known entries restrict the possible values of additional elements if the matrix is expanded to account for additional generations. For example, unitarity and the known elements of the first row require that[6] any additional element in the first row have a magnitude $|V_{ub'}| < 0.088$. When there are more than three generations, the allowed ranges (at 90% C.L.) of the matrix elements connecting the first three generations are

$$\begin{pmatrix} 0.9710 \text{ to } 0.9748 & 0.218 \text{ to } 0.224 & 0 \text{ to } 0.01 & \cdots \\ 0.192 \text{ to } 0.288 & 0.66 \text{ to } 0.98 & 0.037 \text{ to } 0.053 & \cdots \\ 0 \text{ to } 0.14 & 0 \text{ to } 0.72 & 0 \text{ to } 0.999 & \cdots \\ \vdots & \vdots & \vdots & \end{pmatrix} \tag{17}$$

where we have used unitarity (for the expanded matrix) and Eqs. (5), (6), (7), (10), (12), and (16).

Further information on the angles requires theoretical assumptions. In particular, as CP-violating amplitudes involve $\sin\delta$, assuming that observed CP violation is solely related to a nonzero value of δ allows additional constraints to be brought to bear. While hadronic matrix elements whose values are imprecisely known now enter, the constraints from CP violation in the neutral kaon system are tight enough that there may be no solution at all for certain quark masses, values of δ, etc. See the reviews in Ref. 12.

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STANDARD MODEL OF ELECTROWEAK INTERACTIONS*

The couplings of the photon, $W^{\pm}$, and Z to fundamental fermions are

$$\overline{\psi}\gamma^{\mu}\left[eQA_{\mu} + \frac{e(1-\gamma_5)}{2\sqrt{2}\sin\theta_W}\left(T^{+}W_{\mu}^{+} + T^{-}W_{\mu}^{-}\right) + \frac{e}{\sin\theta_W\cos\theta_W}\left(\tfrac{1}{2}(1-\gamma_5)T_3 - \sin^2\theta_w Q\right)Z_{\mu}\right]\psi\,, \tag{1}$$

where

ψ = $\begin{pmatrix} u \\ d' \end{pmatrix}, \begin{pmatrix} c \\ s' \end{pmatrix}, \begin{pmatrix} t \\ b' \end{pmatrix}, \begin{pmatrix} \nu_e \\ e^- \end{pmatrix}, \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix}, \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}$;
for mixing effects defining d', s', and b', see the section on the Kobayashi-Maskawa Mixing Matrix, Eq. (1);

T^{+} = weak isospin raising operator ($T^{\pm}$ act on left-handed fermions);

T_3 = third component of weak isospin (i.e., 1/2 for ν_e, ν_μ, ν_τ, u, c, t; $-1/2$ for e^-, μ^-, τ^-, d, s, b);

Q = electric charge operator, in units of proton charge;

θ_W = weak mixing angle;

A = electromagnetic vector potential.

Thus, for example, the $We\nu$ coupling is

$$\left(\frac{e}{\sqrt{2}\sin\theta_W}\right)\left[W_{\mu}^{-}\,\overline{e}\,\gamma^{\mu}\,\tfrac{1}{2}(1-\gamma_5)\nu + W_{\mu}^{+}\,\overline{\nu}\,\gamma^{\mu}\,\tfrac{1}{2}(1-\gamma_5)e\right]$$

and the $Zu\overline{u}$ coupling is

$$\left(\frac{e}{\sin\theta_W\cos\theta_W}\right)Z_{\mu}\overline{u}\gamma^{\mu}\left[\tfrac{1}{4}(1-\gamma_5)-\tfrac{2}{3}\sin^2\theta_W\right]u\,.$$

The physical, neutral fields A and Z are mixtures of W_3, the partner of $W^{\pm}$, and another field B:

$$A = W_3\sin\theta_W + B\cos\theta_W\,,\quad Z = W_3\cos\theta_W - B\sin\theta_W\,.$$

The SU(2) × $U(1)$ gauge couplings g and g' appear as

$$g\mathbf{W}_{\mu}\cdot\mathbf{T} + g'B_{\mu}\frac{Y}{2}\,,$$

where electric charge Q, T_3, and $Y/2$ are connected by $Q = T_3 + Y/2$. The couplings and mixing angle are related by $\tan\theta_W = g'/g$, $\sin\theta_W = e/g$.

Branching fractions of the $W^{\pm}$ and Z are predicted to be roughly

$$\begin{aligned} &\mathrm{BF}(W^{+}\rightarrow e^{+}\nu_e) = 0.08\,, && \mathrm{BF}(W^{+}\rightarrow u\overline{d}) = 0.24\,,\\ &\mathrm{BF}(Z\rightarrow \nu_e\overline{\nu}_e) = 0.06\,, && \mathrm{BF}(Z\rightarrow e^{+}e^{-}) = 0.03\,,\\ &\mathrm{BF}(Z\rightarrow u\overline{u}) = 0.10\,, && \mathrm{BF}(Z\rightarrow d\overline{d}) = 0.13\,, \end{aligned}$$

etc., and similarly for the other generations, assuming there is no suppression for phase space even for the t quark. The total widths are expected to be (with M_Z = 94 GeV, $M_{\text{top quark}}$ = 30 GeV): $\Gamma(W)$ = 2.8 GeV and $\Gamma(Z) = 2.8\pm0.1$ GeV.

In the standard model, the best fit[1] to current data yields $\sin^2\theta_W = 0.226\pm0.004$, which corresponds to $M_Z = 92.5\pm0.5$ GeV, with theoretical uncertainties of about ±0.005 for $\sin^2\theta_W$ and ±0.7 GeV for M_Z.

The minimal SU(2)×U(1) model of electroweak interactions, which has only one Higgs doublet, has three fundamental parameters (aside from the masses of the fermions and the Higgs boson). In the Lagrangian they are the SU(2) coupling constant g, the U(1) coupling constant g', and the vacuum expectation value (v.e.v.) of the Higgs SU(2) doublet field.

It is best to choose the three parameters so they are identified with physical quantities. Two of the parameters can be taken to be $\alpha = 1/137.036$, which is obtained from measurements of the Josephson effect, and $G_F = 1.16637\times10^{-5}$ GeV^{-2}, which is derived from the muon lifetime once QED corrections are taken into account, viz.:

$$\tau_{\mu}^{-1} = \frac{G_F^2 m_{\mu}^5}{192\pi^3}\left[1+\frac{\alpha}{2\pi}\left(\frac{25}{4}-\pi^2\right)\left(1+\frac{2\alpha}{3\pi}\ell n\,\frac{m_\mu}{m_e}\right)\right] \times\left[1-\frac{8m_e^2}{m_\mu^2}\right]. \tag{2}$$

The third parameter will be taken to be M_Z, since it will soon be known accurately from measurements at LEP and SLC. The W mass M_W is then predicted to be

$$M_W = \frac{M_Z}{\sqrt{2}}\left[1+\left\{1-\frac{4\pi\alpha}{\sqrt{2}M_Z^2 G_F(1-\Delta r)}\right\}^{1/2}\right]^{1/2} \tag{3}$$

The quantity Δr is 0.0696 ± 0.0020. It arises from radiative corrections[2-4] and depends only slightly on the t quark mass (taken to be 36 GeV), the Higgs mass (taken equal to M_Z), and the Z mass itself (taken to be 92 GeV). Historically the third parameter was taken to be the weak mixing angle θ_W. This mixing angle can be defined by

$$\cos\theta_W \equiv \frac{M_W}{M_Z}\,. \tag{4}$$

In lowest order, this mixing angle is the same as that introduced in Eq. (1). Once radiative corrections are taken into account, this ceases to be true, and it would appear that the consequent confusion can be reduced by not regarding θ_W as one of the fundamental parameters. These $O(\alpha)$ radiative corrections are of three types:

i) QED vacuum polarization;
ii) QED bremsstrahlung and graphs involving virtual photons in loops — these are detector dependent and must be carefully calculated for each process, taking experimental cuts and energy resolution into account;
iii) graphs involving weak particles in virtual loops.

At present precise measurements of electroweak interactions are made in a number of experiments and are conventionally expressed in terms of $\sin^2\theta_W$ defined by Eq. (4). Among the experiments are:

1. Neutrino and antineutrino deep inelastic scattering from isosinglet targets.
2. Neutrino and antineutrino deep inelastic scattering by protons.
3. Elastic $\nu_\mu p$ and $\overline{\nu}_\mu p$ scattering.
4. Exclusive and inclusive π production in neutral-current events.
5. Neutrino disintegration of the deuteron: $\overline{\nu}_e d \rightarrow \overline{\nu}_e np$.
6. Polarized-electron deuteron deep inelastic scattering.
7. Forward-backward asymmetry in $e^+e^- \rightarrow \mu^+\mu^-$.
8. Elastic $\nu_\mu e$ and $\overline{\nu}_\mu e$ scattering.
9. Parity non-conservation in heavy atoms.

The data for these processes and a comparison with the predictions of the standard model are given in three extensive reviews.[1,5-6] The conclusion of these and all similar studies is that all available data are consistent with the standard model.

STANDARD MODEL OF ELECTROWEAK INTERACTIONS (Cont'd)

As stated above, a global fit to to the data gives[1] $\sin^2\theta_W = 0.226 \pm 0.004$, which corresponds to the value 92.5 ± 0.5 GeV for the remaining fundamental parameter M_Z.

Table 1 shows the values of M_Z, and the derived quantity $\sin^2\theta_W$, extracted from different experiments (quoted uncertainties include both statistical and experimental systematic errors). The remarkable consistency is a strong confirmation of the standard electroweak model.

Table 1

Process	M_Z	$\sin^2\theta_W$	Ref.
$e^+e^- \to \mu^+\mu^-$	103 ± 4.8	0.17 ± 0.02	7
$\nu p \to \nu p$ $\bar{\nu} p \to \bar{\nu} p$	91.8 ± 2.8	0.23 ± 0.02	1,8
ed asymmetry	93.3 ± 2.1	0.220 ± 0.014	1,9
$\nu_\mu e \to \nu_\mu e$	91.8 ± 2.8	$0.23 \pm 0.02^\dagger$	1,10
Parity violation in atoms	98.5 ± 7.9	0.19 ± 0.04	11
$\bar{\nu} N \to \mu X, \bar{\nu} X$ $\nu N \to \mu X, \nu X$	92.4 ± 0.6	$0.226 \pm 0.004^\ddagger$	12

†Two recent experiments average to $\sin^2\theta_W = 0.212 \pm 0.023$, whereas seven measurements by four 1979-era experiments average to $\sin^2\theta_W = 0.277 \pm 0.034$.

‡These results from deep inelastic scattering also have theoretical uncertainties (largely from the imprecisely known *c*-quark mass) which are about ± 0.005 for $\sin^2\theta_W$ and ± 0.7 GeV for M_Z. Two recent experiments have given us modified values (which we have included) due to discovery of an error in their radiative correction program; these are unpublished.

In the case of neutrino deep inelastic scattering, the charged- and neutral-current cross sections for the standard model are given by:

$$R_{\nu N} = \frac{\sigma^{NC}_{\nu N}}{\sigma^{CC}_{\nu N}} =$$

$$\frac{\frac{1}{2} - \sin^2\hat{\theta}_W + \frac{20}{27}\sin^4\hat{\theta}_W + \epsilon(\frac{1}{6} - \frac{1}{3}\sin^2\hat{\theta}_W + \frac{20}{27}\sin^4\hat{\theta}_W)}{1 + \frac{1}{3}\epsilon} ,$$

$$R_{\bar{\nu} N} = \frac{\sigma^{NC}_{\bar{\nu} N}}{\sigma^{CC}_{\bar{\nu} N}} =$$

$$\frac{\frac{1}{6} - \frac{1}{3}\sin^2\hat{\theta}_W + \frac{20}{27}\sin^4\hat{\theta}_W + \epsilon(\frac{1}{2} - \sin^2\hat{\theta}_W + \frac{20}{27}\sin^4\hat{\theta}_W)}{\frac{1}{3} + \epsilon} . \qquad (5)$$

In lowest order, the quantity $\sin^2\hat{\theta}_W$ is equal to $\sin^2\theta_W$ defined above. When radiative corrections are taken into account, $\sin^2\hat{\theta}_W = \sin^2\theta_W + \delta$, with δ of order 0.01. Its precise value is dependent upon the kinematics of a particular experiment.[13]

The parameter $\epsilon \simeq 0.2$ is the ratio of antiquark momentum to quark momentum in the nucleon. It is related to the ratio of the neutrino charged-current cross section to the antineutrino charged-current cross section:

$$\frac{\sigma^{CC}_{\nu N}}{\sigma^{CC}_{\bar{\nu} N}} = \frac{1 + \frac{1}{3}\epsilon}{\frac{1}{3} + \epsilon} .$$

The polarized-electron deuteron scattering experiment measured the asymmetry in the cross section for left-handed (σ_L) and right-handed (σ_R) electrons:

$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} .$$

In the quark parton model, this has the form (with $q^2 > 0$ for deep inelastic scattering)

$$\frac{A}{q^2} = a_1 + a_2\left[\frac{1-(1-y)^2}{1+(1-y)^2}\right] , \qquad (6)$$

where y is the fraction of the incident lepton's energy lost in the collision. For an isoscalar target like the deuteron, and ignoring the antiquarks, the standard model gives

$$a_1 = -\frac{G_F}{2\sqrt{2}\pi\alpha}\frac{9}{10}\left(1 - \frac{20}{9}\sin^2\hat{\theta}_W\right)$$

$$a_2 = -\frac{G_F}{2\sqrt{2}\pi\alpha}\frac{9}{10}\left(1 - 4\sin^2\hat{\theta}_W\right) . \qquad (7)$$

In the case of the SLAC *ed* experiment,[3] $\sin^2\hat{\theta}_W = \sin^2\theta_W + 0.006$.

Neutrino electron elastic-scattering cross sections were calculated with the following formulae:

$$R_{\nu\bar{\nu}} = \frac{\sigma(\nu_\mu e \to \nu_\mu e)}{\sigma(\bar{\nu}_\mu e \to \bar{\nu}_\mu e)}$$

$$\simeq \frac{3 - 12\sin^2\hat{\theta}_W + 16\sin^4\hat{\theta}_W}{1 - 4\sin^2\hat{\theta}_W + 16\sin^4\hat{\theta}_W} \qquad (8)$$

$$R_{NC,CC} = \frac{\sigma(\nu_\mu e \to \nu_\mu e)}{\sigma(\nu_\mu e \to \nu_e \mu)}$$

$$\simeq \frac{3 - 12\sin^2\hat{\theta}_W + 16\sin^4\hat{\theta}_W}{12}\left(1 - \frac{m_\mu^2}{2m_e E_\nu}\right)^{-2} \qquad (9)$$

The standard model agrees very well with the data; however, there is no direct evidence concerning the Higgs structure. If the model contains Higgs representations other than doublets, the theory has an additional parameter. It is useful to take this parameter to be the W mass. It is traditional to parametrize such models by a parameter ρ, defined by

$$\rho = \frac{\sqrt{2}M_W}{M_Z\left[1 + \left(1 - \frac{4\pi\alpha}{\sqrt{2}M_Z^2 G_F(1-\Delta r)}\right)^{1/2}\right]^{1/2}} .$$

so that $\rho \equiv 1$ in the standard model. The definition of the weak mixing angle becomes

$$\cos\theta_W = \frac{M_W}{\rho M_Z} .$$

STANDARD MODEL OF ELECTROWEAK INTERACTIONS (Cont'd)

Data can then be fitted to the two parameters M_Z and M_W (or $\sin^2\theta_W$ and ρ). For example, Eq. (5) has an additional factor of ρ^2 multiplying the right-hand side. A two-parameter fit (excluding some recent data) yields[1]

$$\sin^2\theta_W = 0.223 \pm 0.006$$

$$\rho = 1.006 \pm 0.008\ .$$

Note that ρ is consistent with the standard model value of 1.

It is useful to compare the values of M_Z (inferred from the data discussed above) and M_W [calculated from Eq. (3)] with the observed W and Z masses. Table 2 shows the comparison. Detailed tests of the model await higher precision data on the weak boson masses, lepton asymmetries at SLC and LEP, and elastic $\nu_\mu e$ and $\bar{\nu}_\mu e$. Such data will permit a single test involving the four measured parameters α, G_F, M_W, and M_Z, and two additional tests comparing the derived quantity $\sin^2\theta_W$ with the values obtained in neutral-current experiments.

Table 2

	UA1[14]	UA2[15]	Values[2] obtained using Table 1
M_W (GeV)	$83.5^{+1.1}_{-1.0} \pm 2.7$	$81.2 \pm 1.1 \pm 1.3$	81.4 ± 0.6 (79.8 without radiative corr.)
M_Z (GeV)	$93.0 \pm 1.4 \pm 3$	$92.5 \pm 1.3 \pm 1.5$	92.5 ± 0.5 (90.2 without radiative corr.)

Should such a high-precision test reveal a discrepancy with the radiatively corrected theory, it could indicate that the model needs fundamental modification. Small deviations from the predictions described above could arise if the t quark mass or Higgs boson mass is far from the value assumed, if there are additional generations of fermions or scalars, or if additional currents beyond isospin and electromagnetic exist.[4] At present there is no indication of the need for a modification of the theory.

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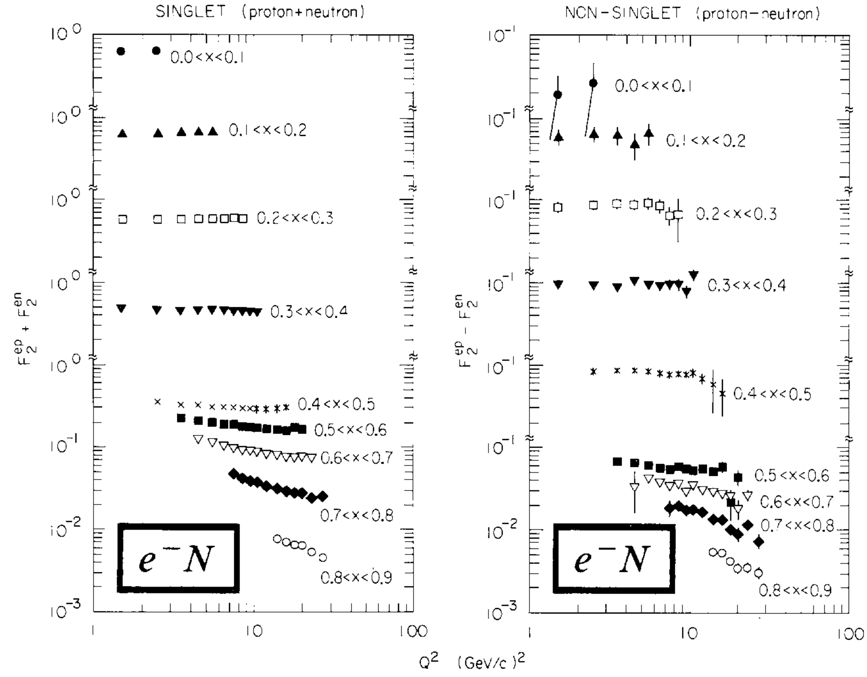
* This section prepared with contributions from B. Lynn, L.S. Durkin, and P. Langacker.

1. L.S. Durkin and P. Langacker, Univ. of Penn. preprint UPR-0287T (1985); and P. Langacker, Univ. of Penn. preprint UPR-0288T (1985) to appear in the *Proceedings of the 1985 International Symposium on Lepton and Photon Interactions at High Energies* (Kyoto, Japan, 1985). See also Ref. 12.
2. Radiative corrections have been discussed by many authors. Here we rely on W.J. Marciano and A. Sirlin, "Testing the Standard Model by Precise Determinations of $W^\pm$ and Z Masses," Phys. Rev. **D29**, 945 (1984).
3. C.H. Llewellyn-Smith and J. Wheater, Phys. Lett. **105B**, 486 (1981). This reference uses $\sin^2\theta_W^{MS} = \sin^2\theta_W/1.006$.
4. B.W. Lynn, M.E. Peskin, and R.G. Stuart, in *Proceedings of the 1985 LEP Physics Workshop* (Geneva, Switzerland, 1985).
5. G. Altarelli, ROME-464-1985, and in *Proceedings of the 1985 LEP Physics Workshop* (Geneva, Switzerland, 1985).
6. C. Gewiniger, in *Neutrino Physics and Astrophysics 1984*, K. Kleinknecht and E.A. Paschos, eds. (World Scientific Publishing Co., Singapore, 1984).
7. L. DiLella, in *Proceedings of the 1985 International Symposium on Lepton and Photon Interactions at High Energies* (Kyoto, Japan, 1985).
8. L.A. Ahrens et al., Univ. of Penn. preprint E-734-85-1 (1985).
9. C. Prescott et al., Phys. Lett. **84B**, 524 (1979); and J.E. Kim et al., Rev. Mod. Phys. **53**, 211 (1981).
10. F. Bergsma et al., Phys. Lett. **147B**, 481 (1984); and L.A. Ahrens et al., Phys. Rev. Lett. **54**, 18 (1985).
11. M.A. Bouchiat et al., Phys. Lett. **134B**, 465 (1984); and E.W. Fortson and L.L. Lewis, Phys. Rep. **113**, 289 (1984).
12. Private communication from L.S. Durkin and P. Langacker.
13. A. Sirlin and W. Marciano, Nucl. Phys. **B189**, 442 (1981).
14. UA1 Collaboration, G. Arnison et al., CERN preprint EP-85-185, submitted to Phys. Lett.
15. UA2 Collaboration, J.A. Appel et al., CERN preprint EP-85-166, submitted to Z. Phys. C.

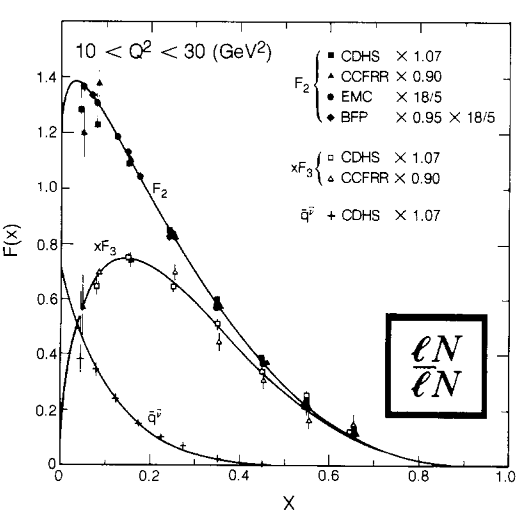
PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES

NOTE: THE FIGURES IN THIS SECTION ARE INTENDED TO SHOW THE "BEST" OR "MOST REPRESENTATIVE" DATA IN THE OPINION OF THE COMPILER. THEY ARE NOT NECESSARILY COMPLETE COMPILATIONS OF ALL THE WORLD'S RELIABLE DATA.

Structure Functions



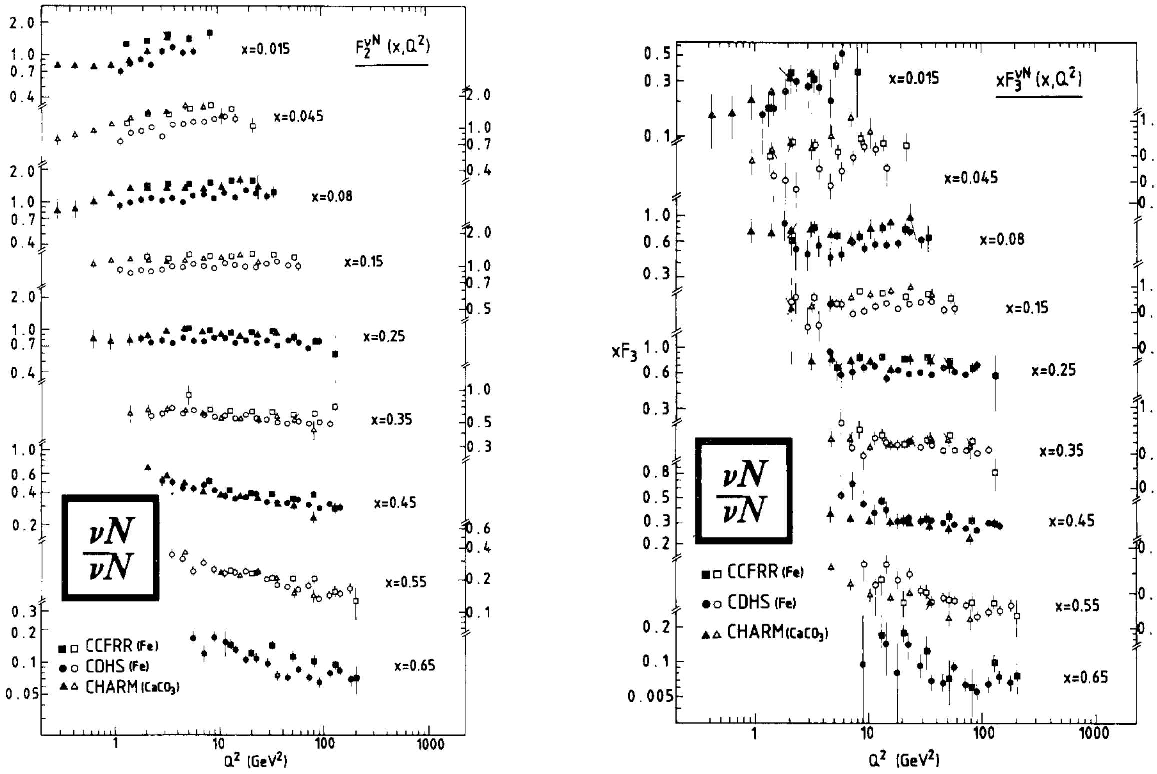
F_2 structure functions derived from inelastic electron-nucleon data taken at SLAC with recoil mass > 2 GeV and four-momentum transfer squared $Q^2 > 1$ (GeV/c)^2 are shown. For definitions of F_2, x, and Q^2, see the Cross Sections, Decays, Structure Functions, and Kinematics Section. $R \equiv \sigma_L/\sigma_T = 0.21$ [3] was assumed. Systematic errors are comparable in size to the data point symbols. Corrections for nucleon motion in deuterium have been made. These corrections are small except for $x > 0.7$. No error was included to account for uncertainties in this correction. References: 1) A. Bodek et al., Phys. Rev. **D20**, 1471 (1979); 2) W.B. Atwood et al., SLAC Report No. 185 (1975); 3) M.D. Mestayer, SLAC Report No. 214 (1978); 4) S. Stein et al., Phys. Rev. **D12**, 1884 (1975). Courtesy W.B. Atwood, SLAC.



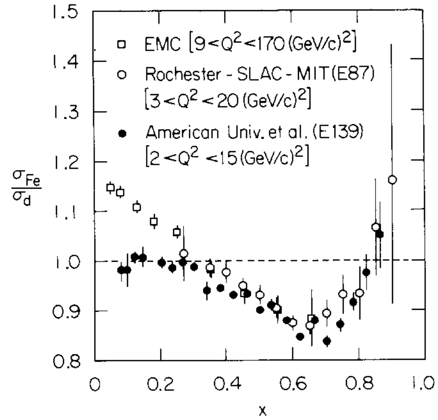
Structure functions F_2, xF_3, and $\overline{q}^{\overline{\nu}}$, measured in different experiments, for fixed Q^2 versus x, plotted assuming $R = \sigma_L/\sigma_T = 0$. The electromagnetic structure function $F_2^{\mu N}$ measured by EMC and BFP is compared with the charged-current structure function $F_2^{\nu N}$ using the 18/5 factor from the average charge squared of the quarks. No correction has been applied for the difference between the strange and charm sea quarks so the interpretation is $F_2 = x\left[q + \overline{q} - \frac{3}{5}(s + \overline{s} - c - \overline{c})\right]$. (In this Q^2 range, $F_2^{\nu N}$ is depleted by a similar amount due to charm threshold effects in the transition $s \rightarrow c$.) The antiquark distribution measured from antineutrino scattering is $\overline{q}^{\overline{\nu}} = x(\overline{u} + \overline{d} + 2\overline{s})$. The solid lines, valid for $10 < Q^2 < 30$ GeV^2, have the forms: $F_2 = 3.9x^{0.55}(1 - x)^{3.2} + 1.1(1 - x)^8$, $xF_3 = 3.6x^{0.55}(1 - x)^{3.2}$, $\overline{q}^{\overline{\nu}} = 0.7(1 - x)^8$. Relative normalization factors have been fitted to optimize agreement between the different data sets, and absolute changes have been arbitrarily chosen as indicated. References: **CDHS** — H. Abramowicz et al., Zeit. Phys. **C17**, 283 (1983); **CCFRR** — F. Sciulli, private communication; **EMC** — J.J. Aubert et al., Phys. Lett. **105B**, 322 (1981); and A. Edwards, private communication; **BFP** — A.R. Clark et al., Phys. Rev. Lett. **51**, 1826 (1983); and P. Meyers, Ph.D. Thesis, LBL-17108 (1983), Univ. of Calif., Berkeley. Courtesy J. Carr, Colorado.

PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES (Cont'd)

Structure Functions



Structure functions F_2 and xF_3 for nucleons, measured in charged-current neutrino and antineutrino scattering from iron and marble targets with $20 < E_\nu < 300$ GeV, versus Q^2 for fixed bins of x, plotted assuming $R = \sigma_L/\sigma_T = 0.1$ or $R = 0.0$ for CHARM. The point-to-point systematic errors are generally smaller or of the same order as the statistical errors. In addition, CDHS quote an overall scale error of ±6% for F_2 and ±8% for xF_3; for the CCFRR data, the scale error is estimated to be ±4%; and for CHARM, these uncertainties are ±7% for F_2 and ±8% for xF_3. References: **CDHS** — H. Abramowicz et al., Zeit. Phys. **C17**, 283 (1983); **CCFRR** — D.B. MacFarlane et al., Zeit. Phys. **C26**, 1 (1984); **CHARM** — F. Bergsma et al., Phys. Lett. **123B**, 269 (1983); and F. Bergsma et al., Phys. Lett. **141B**, 129 (1984). Courtesy K. Winter, CERN and J. Carr, Colorado. From F. Dydak, "Experimental Results from Lepton-Hadron and Photon-Hadron Scattering: Structure Functions and Final States," *Proceedings of the 1983 International Lepton/Photon Symposium* (Cornell, 1983), p. 634.

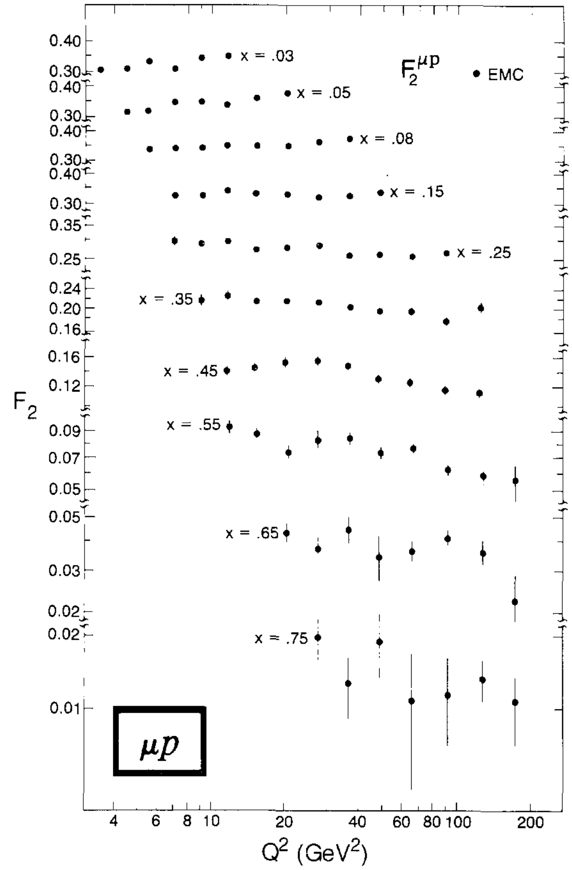


μFe / μd

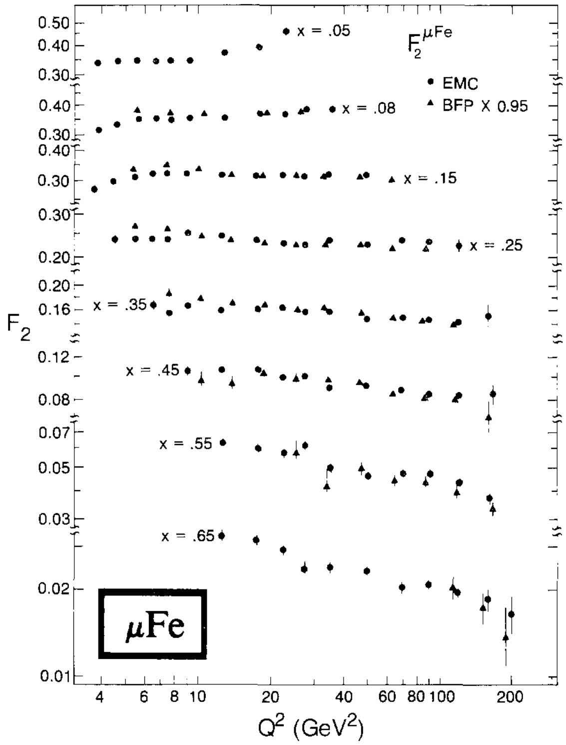
The "EMC" effect: the ratio of the differential cross section per nucleon, σ_{Fe}/σ_d, measured in electromagnetic deep inelastic scattering on iron and deuterium targets. For equal values of $R = \sigma_L/\sigma_T$ on each target, $\sigma_{Fe}/\sigma_d = F_2^{Fe}/F_2^d$. The errors plotted are statistical only. References: **American University et al.** (electrons) — Phys. Rev. Lett. **52**, 727 (1984); **Rochester-SLAC-MIT** (electrons) — Phys. Rev. Lett. **50**, 1431 (1983); and **EMC** (muons) — Phys. Lett. **123B**, 275 (1983). Forthcoming results from the BCDMS collaboration (CERN-EP/85-112) agree with EMC in the x range $0.2 < x < 0.7$. Courtesy D. Coward, SLAC.

PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES (Cont'd)

Structure Functions

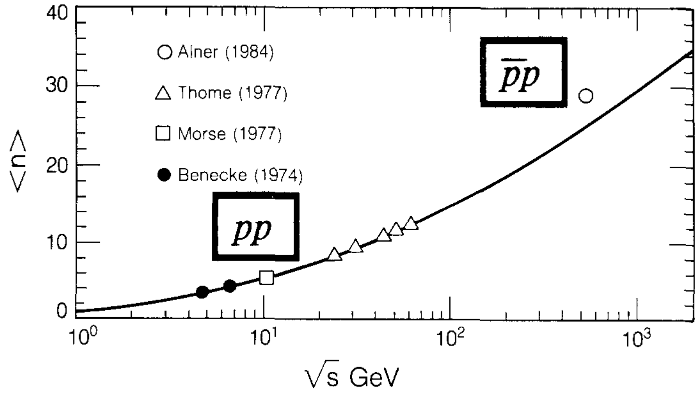


Structure function F_2^p, measured in electromagnetic muon scattering from a hydrogen target with beam energies 120, 200, 240, 280 GeV, versus Q^2 for fixed bins of x, plotted assuming R = σ_L/σ_T = 0. Reference: J.J. Aubert et al., Nucl. Phys. **B259**, 189 (1985). Courtesy J. Carr, Colorado.



Structure function F_2 per nucleon, measured in electromagnetic muon scattering from iron targets with beam energies 120, 200, 250, 280 GeV (EMC) and 93, 215 GeV (BFP), versus Q^2 for fixed bins of x, plotted assuming $R = \sigma_L/\sigma_T = 0$. A relative normalization factor has been fitted to optimize agreement between the different data sets and has been arbitrarily applied to one data set as indicated. References: **EMC** — J.J. Aubert et al., Phys. Lett. **105B**, 322 (1981); and A. Edwards, private communication; **BFP** — A.R. Clark et al., Phys. Rev. Lett. **51**, 1826 (1983); and P. Meyers, Ph.D. Thesis, LBL-17108 (1983), Univ. of Calif., Berkeley. Courtesy J. Carr, Colorado.

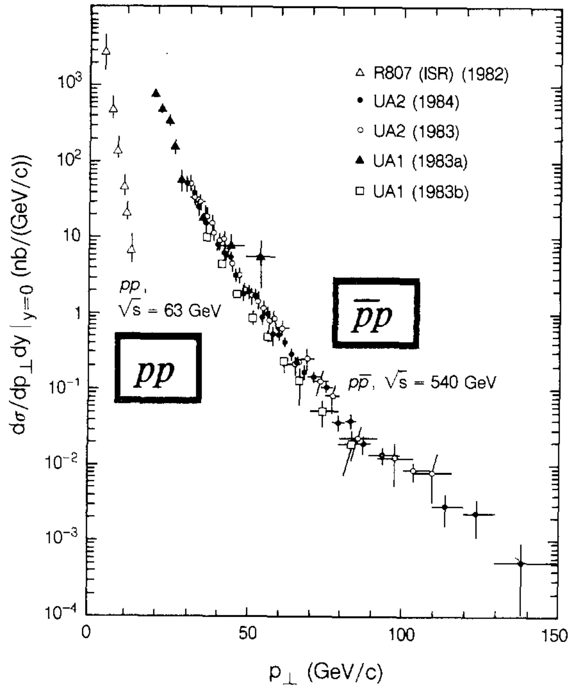
Average *pp* and $\bar{p}p$ Multiplicity



Average multiplicity as a function of $\sqrt{s}$ for $p\bar{p}$ at the S$\bar{p}p$S (open circles) and for pp at the ISR. Solid curve is a fit by Thomé et al. to their data (triangles) with the form $\langle n \rangle = 0.88 + 0.44 \ln s + 0.118 (\ln s)^2$. References: $p\bar{p}$ — G.J. Alner et al., Phys. Lett. **138B**, 304 (1984); pp — W. Thomé et al., Nucl. Phys. **B129**, 365 (1977); W.M. Morse et al., Phys. Rev. **D15**, 66 (1977); and J. Benecke et al., Nucl. Phys. **B76**, 29 (1974).

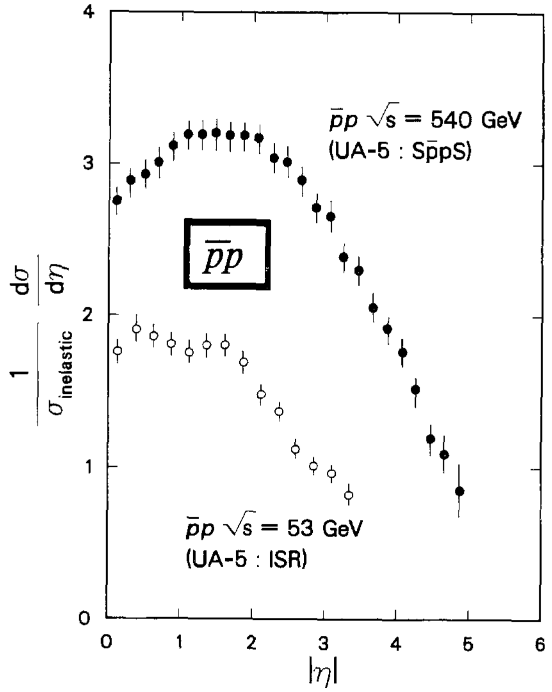
PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES (Cont'd)

Jet Production in *pp* and $\bar{p}p$ Interactions



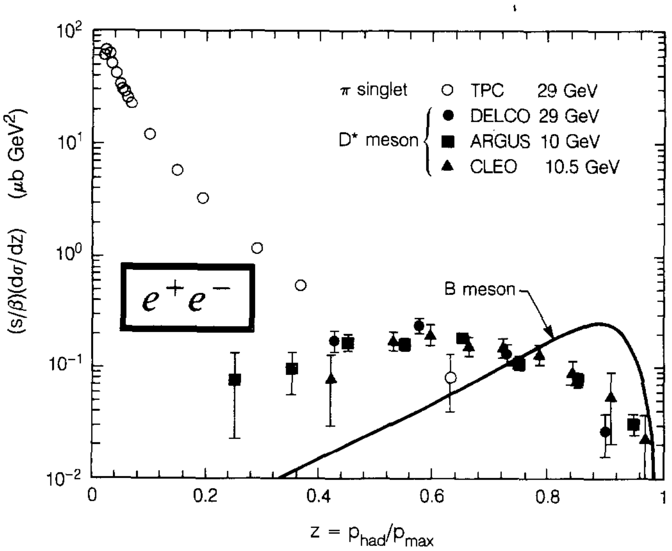
Differential cross sections for observation of a single jet of rapidity $y = 0$ as a function of the jet transverse momentum. ISR (*pp*) and S$\bar{p}p$S collider ($\bar{p}p$) data compared. Error bars include a contribution due to estimated systematic error in defining jet direction and p_T. References: **ISR** – T. Akesson et al., Phys. Lett. **118B**, 185 (1982); **UA2** – P. Bagnaia et al., Phys. Lett. **138B**, 430 (1984); and P. Bagnaia et al., Z. Phys. **C20**, 117 (1983); **UA1** – G. Arnison et al., Phys. Lett. **123B**, 115 (1983a); and G. Arnison et al., Phys. Lett. **132B**, 144 (1983b).

Pseudorapidity in $\bar{p}p$ Interactions



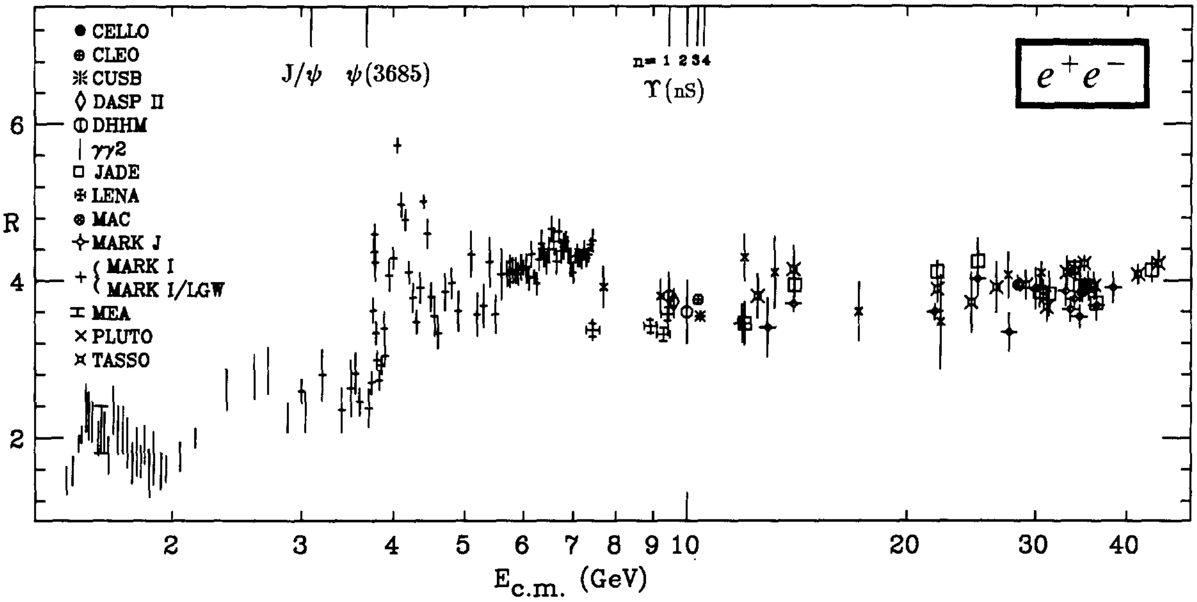
Comparison of the distribution of the pseudorapidity $\eta = -\ell n(\tan\theta_{\text{cm}}/2)$ for charged-particle production in proton-antiproton collisions at $\sqrt{s}$ = 53 GeV (1) and 540 GeV (2). References: (1) K. Alpgard et al., Phys. Lett. **112B**, 209 (1982); (2) UA5 Collaboration, presented by J. Rushbrooke in the *Proceedings of the XIV International Symposium on Multiparticle Dynamics*, eds. J.F. Gunion and P.M. Yager (World Scientific Publishing Co., Singapore, 1984).

Fragmentation Functions



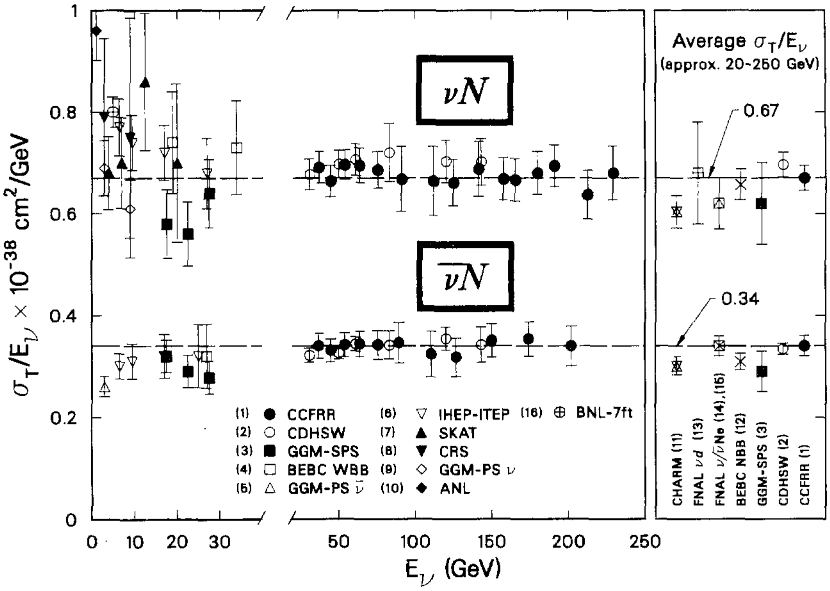
The cross section $(s/\beta)\, d\sigma/dz$ versus z for producing a hadron h in e^+e^- annihilation, measured in different experiments, for fixed energies $Q^2 = s$. This quantity is closely related to the fragmentation function $D_i^h(z, Q^2)$ as discussed in the QCD section. Note, however, that here we use the definition $z \equiv p_{\text{had}}/(E^2_{\text{beam}} - m^2_{\text{had}})^{1/2}$, whereas $z \equiv E_{\text{had}}/E_{\text{beam}}$ is used by some experimenters, and theorists use $z \equiv (E + p_{\parallel})_{\text{had}}/(E + p_{\parallel})_{\text{quark}}$. The data are shown for pions (singlet term) and for D^* mesons (where b-quark contribution has been subtracted out). The data for heavy quarks are frequently parametrized by the Peterson et al. form, $D(z) = Nz\,(1-z)^2/[(1-z)^2 + \epsilon_{\text{had}} z\,]^2$. The ϵ_c parameter ranges from 0.10 to 0.37 for the three D^* data sets shown. The B-meson curve corresponds to ϵ_b = 0.014, which is an average derived from many experiments using an indirect method from B decays to e or μ (N was chosen arbitrarily). References: C. Peterson et al., Phys. Rev. **D27**, 105 (1983); **TPC** — H. Aihara et al., Zeit. Phys. **C27**, 495 (1985); **DELCO** — H. Yamamoto, Ph.D. thesis (Cal Tech), report no. CALT-68-1318 (1985); **ARGUS** — H. Albrecht et al., Phys. Lett. **150B**, 235 (1985); and **CLEO** — C. Bebek et al., Phys. Rev. Lett. **49**, 610 (1982).

PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES (Cont'd)

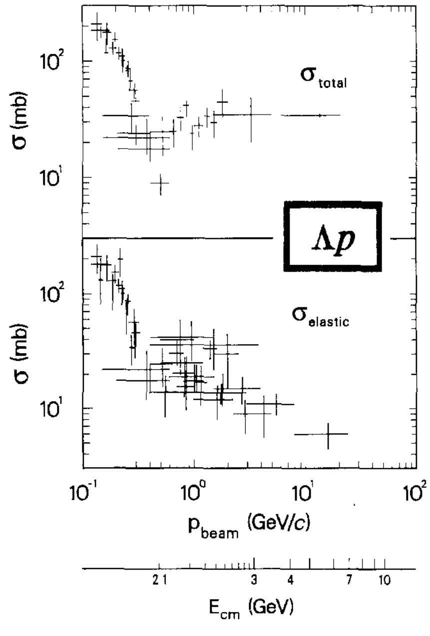


Selected measurements of $R \equiv \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$, where the annihilation proceeds via one photon. The denominator is a calculated quantity; see the section on Cross Sections, Decays, Structure Functions, and Kinematics. Radiative corrections and, where important, corrections for two-photon processes and τ production have been made. Note that the ADONE data ($\gamma\gamma2$ and MEA) is for ≥ 3 hadrons. The points in the $\psi(3770)$ region are from the MARK I - Lead Glass Wall experiment. To preserve clarity only a representative subset of the available measurements is shown — references to additional data are included below. Also for clarity, some points have been combined or shifted slightly ($<4\%$) in E_{cm}, and some points with low statistical significance have been omitted. Systematic normalization errors are not included; they range from ~ 5 - 20%, depending on experiment. Note the suppressed zero. The horizontal extent of the plot symbols has no significance. The positions of the $J/\psi(3097)$, $\psi(3685)$, and the four lowest Υ vector-meson resonances are indicated at the top of the figure. References: **CELLO** — H.-J. Behrend et al., DESY 81-029; **CLEO** — R. Giles et al., Phys. Rev. **D29**, 1285 (1984); and D. Besson et al., Phys. Rev. Lett. **54**, 381 (1985); **CUSB** — E. Rice et al., Phys. Rev. Lett. **48**, 906 (1982); **DASP** — R. Brandelik et al., Phys. Lett. **76B**, 361 (1978); **DASP II** — Phys. Lett. **116B**, 383 (1982); **DHHM** — P. Bock et al. (DESY-Hamburg-Heidelberg-MPI München Collab.), Zeit. fur Physik **C6**, 125 (1980); **$\gamma\gamma2$** — C. Bacci et al., Phys. Lett. **86B**, 234 (1979); **JADE** — W. Bartel et al., Phys. Lett. **129B**, 145 (1983); and W. Bartel et al., Phys. Lett. **160B**, 337 (1985); **HRS** — D. Bender et al., Phys. Rev. **D31**, 1 (1985); **MAC** — E. Fernandez et al., Phys. Rev. **D31**, 1537 (1985); **MARK J** — B. Adeva et al., Phys. Rev. Lett. **50**, 799 (1983); and H. Newman, private communication; **MARK I** — J.L. Siegrist et al., Phys. Rev. **D26**, 969 (1982); **MARK I + Lead Glass Wall** — P.A. Rapidis et al., Phys. Rev. Lett. **39**, 526 (1977); and P.A. Rapidis, thesis, SLAC-Report-220 (1979); **MEA** — B. Esposito et al., Lett. Nuovo Cimento **19**, 21 (1977); **PLUTO** — A. Bäcker, thesis Gesamthochschule Siegen, DESY F33-77/03 (1977); C. Gerke, thesis, Hamburg Univ. (1979); Ch. Berger et al., Phys. Lett. **81B**, 410 (1979); and W. Lackas, thesis, RWTH Aachen, DESY PLUTO-81/11 (1981); **TASSO** — R. Brandelik et al., Phys. Lett. **113B**, 499 (1982); and M. Althoff et al., Phys. Lett. **138B**, 441 (1984).

PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES (Cont'd)

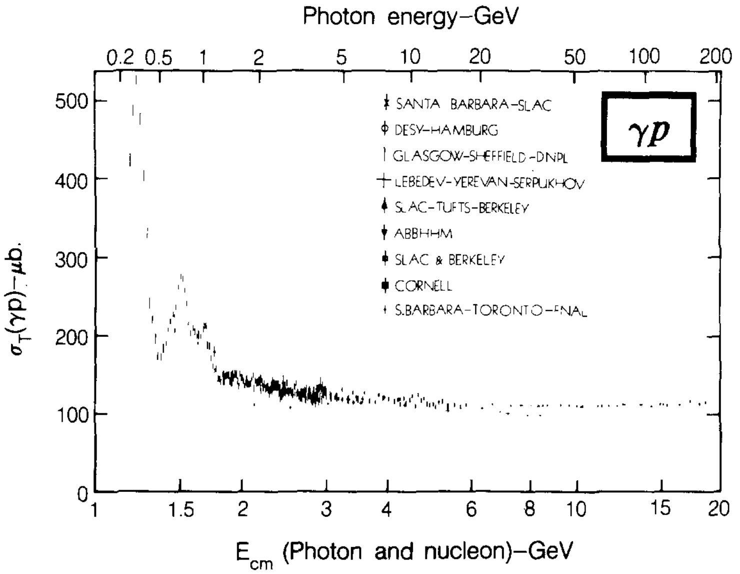


σ_T/E_ν for the muon neutrino and antineutrino charged-current total cross section as a function of neutrino energy. The error bars include both statistical and systematic errors. The straight lines are averages for the CCFRR measurement. Note the change in the energy scale between 30 and 50 GeV. The data points on the right give averages for other high energy measurements. References: (1) R. Blair et al., Phys. Rev. Lett. **51**, 343 (1983), and J.R. Lee, Ph.D. Thesis, Caltech (1981), "Measurements of νN Charged Current Cross Sections from E_ν = 25 GeV to E_ν = 260 GeV;" (2) H. Abramowicz et al., Zeit. fur Physik **C17**, 283 (1983); (3) J. Morfin et al., Phys. Lett. **104B**, 235 (1981); (4) D.C. Colley et al., Zeit. fur Physik **C2**, 187 (1979); (5) O. Erriquez et al., Phys. Lett. **80B**, 309 (1979); (6) A.S. Vovenko et al., Sov. J. Nucl. Phys. **30**, 527 (1979); (7) D.S. Baranov et al., Phys. Lett. **81B**, 255 (1979); (8) C. Baltay et al., Phys. Rev. Lett. **44**, 916 (1980); (9) S. Ciampolillo et al., Phys. Lett. **84B**, 281 (1979); (10) S.J. Barish et al., Phys. Rev. **D19**, 2521 (1979); (11) M. Jonker et al., Phys. Lett. **99B**, 265 (1981), E_ν = 20–200 GeV; (12) P. Bosetti et al., Phys. Lett. **110B**, 167 (1982), E_ν = 20–200 GeV; (13) T. Kitagaki et al., Phys. Rev. Lett. **49**, 98 (1982), E_ν = 10–200 GeV; (14) N.J. Baker et al., Phys. Rev. Lett. **51**, 735 (1983), E_ν = 10–240 GeV; (15) G.N. Taylor et al., Phys. Rev. Lett. **51**, 739 (1983), E_ν = 5–250 GeV; (16) N.J. Baker et al., Phys. Rev. **D25**, 617 (1982), E_ν = 1.6–10 GeV. Courtesy M.H. Shaevitz, Columbia University (Nevis Laboratory).

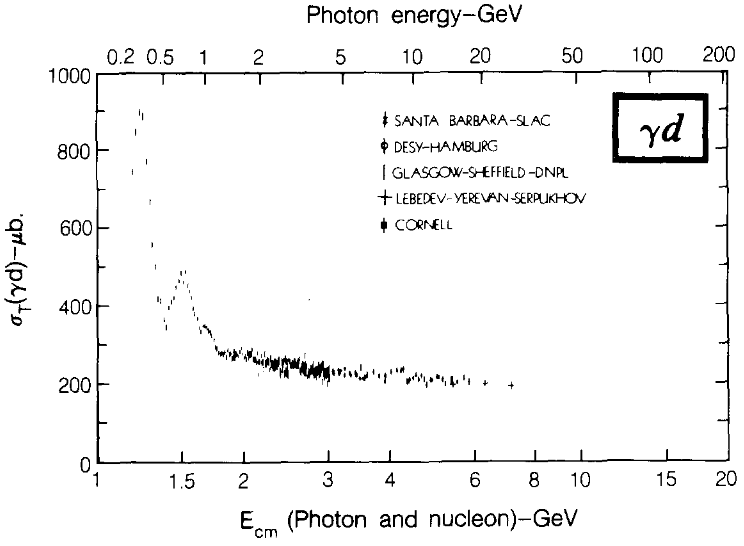


Λp total and elastic cross sections vs. laboratory beam momentum p_{beam} and total center-of-mass energy E_{cm}. Data courtesy A. Baldini, V. Flaminio, W.G. Moorhead, D.R.O. Morrison, and N. Rivoire, CERN; and COMPAS Group, IHEP, Serpukhov, USSR. See CERN HERA Group compilations for references.

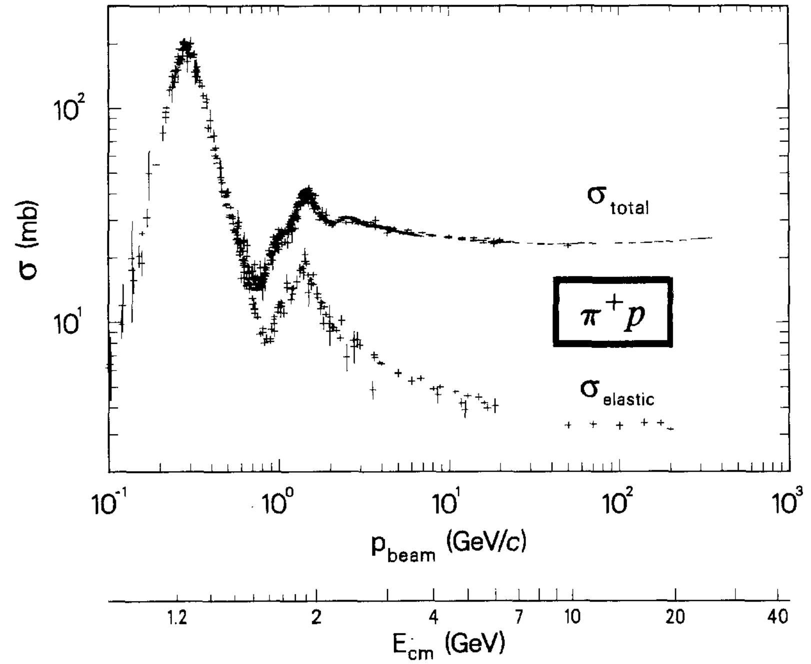
PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES (Cont'd)

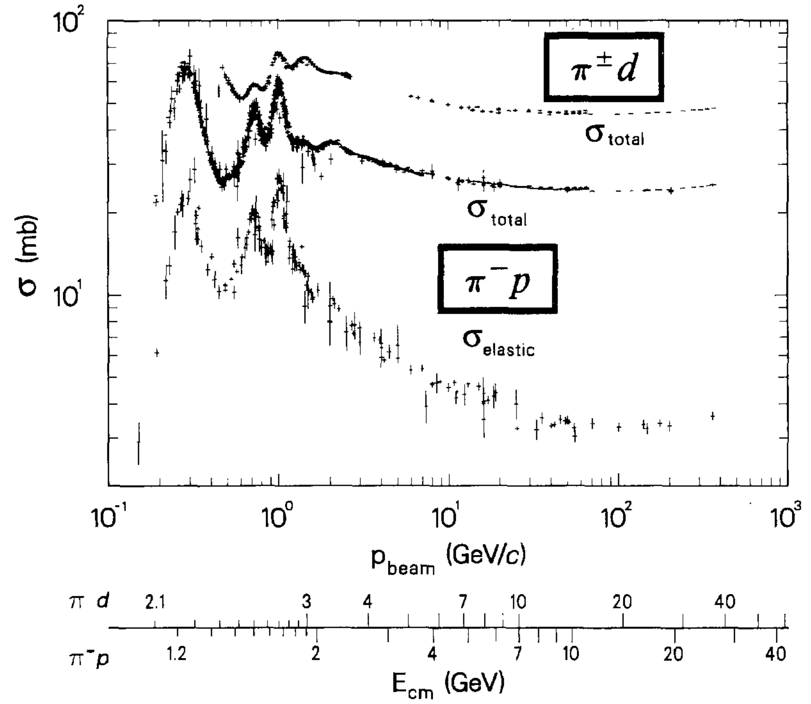


γp total cross section versus photon energy (top scale) and photon-plus-nucleon total center-of-mass energy (lower scale). References: **SANTA BARBARA-SLAC** — D.O. Caldwell et al., Phys. Rev. **D7**, 1362 (1973); **DESY-HAMBURG** — H. Meyer et al., Phys. Lett. **33B**, 189 (1970); **GLASGOW-SHEFFIELD-DNPL** — T.A. Armstrong et al., Phys. Rev. **D5**, 1640 (1972); **LEBEDEV-YEREVAN-SERPUKHOV** — A.S. Belousov et al., Preprint 19, Moscow, (1973); A. S. Belousov et al., Sov. Phys. Doklady **19**, 123 (1974); and A. S. Belousov et al., Sov. J. Nucl. Phys. **21**(3), 289 (1975); **SLAC-BERKELEY-TUFTS** — J. Ballam et al., Phys. Rev. **D5**, 545 (1972); **ABBHHM** — H.G. Hilpert et al., Phys. Lett. **27B**, 474 (1968); **SLAC** and **BERKELEY** — J. Ballam et al., Phys. Rev. Lett. **21**, 1544 (1968), and H.H. Bingham et al., Phys. Rev. **D8**, 1277 (1973); **CORNELL** — S. Michalowski et al., Phys. Rev. Lett. **39**, 737 (1977); **SANTA BARBARA-TORONTO-FNAL** — D.O. Caldwell et al., Phys. Rev. Lett. **40**, 1222 (1978). See, also, the ep data of E.D. Bloom et al., SLAC-PUB-653 (1969). Courtesy Gething M. Lewis, Glasgow.

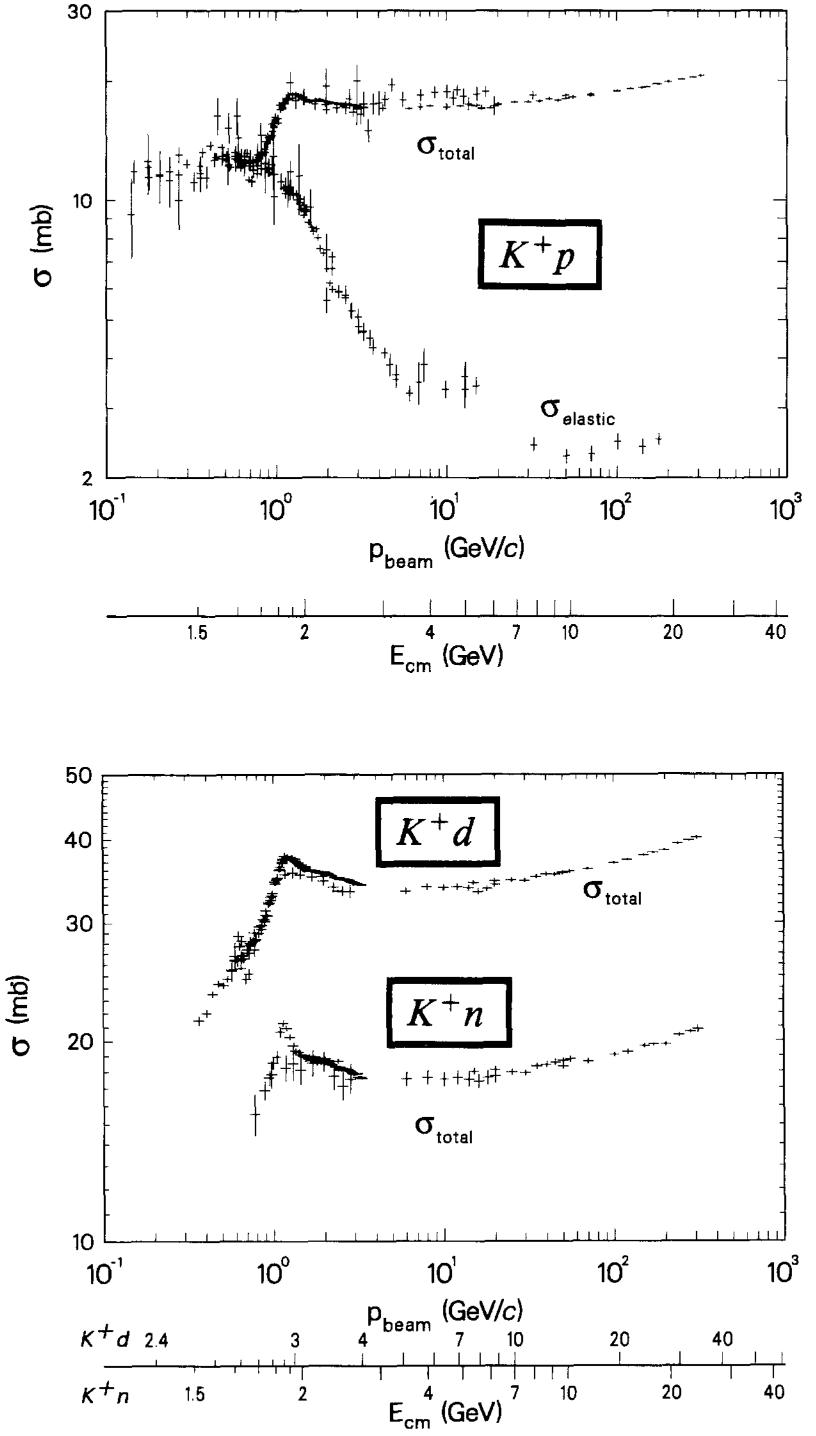


γd total cross section versus photon energy (top scale) and photon-plus-single-nucleon total center-of-mass energy (lower scale). References: **SANTA BARBARA-SLAC** — D.O. Caldwell et al., Phys. Rev. **D7**, 1362 (1973); **DESY-HAMBURG** — H. Meyer et al., Phys. Lett. **33B**, 189 (1970); **GLASGOW-SHEFFIELD-DNPL** — T.A. Armstrong et al., Nucl. Phys. **B41**, 445 (1972); **LEBEDEV-YEREVAN-SERPUKHOV** — A.S. Belousov et al., Sov. J. Nucl. Phys. **21**(3), 289 (1975); **CORNELL** — S. Michalowski et al., Phys. Rev. Lett. **39**, 737 (1977). Courtesy Gething M. Lewis, Glasgow.



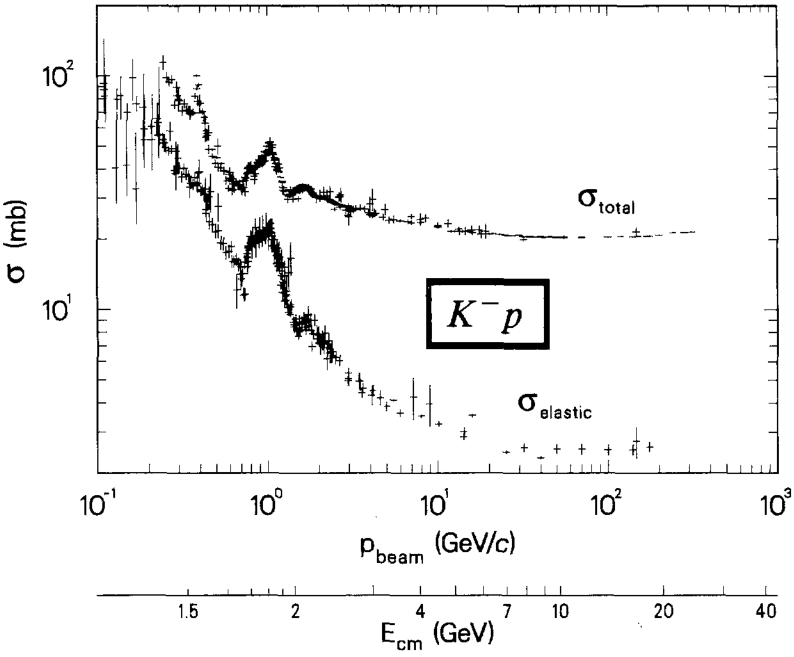


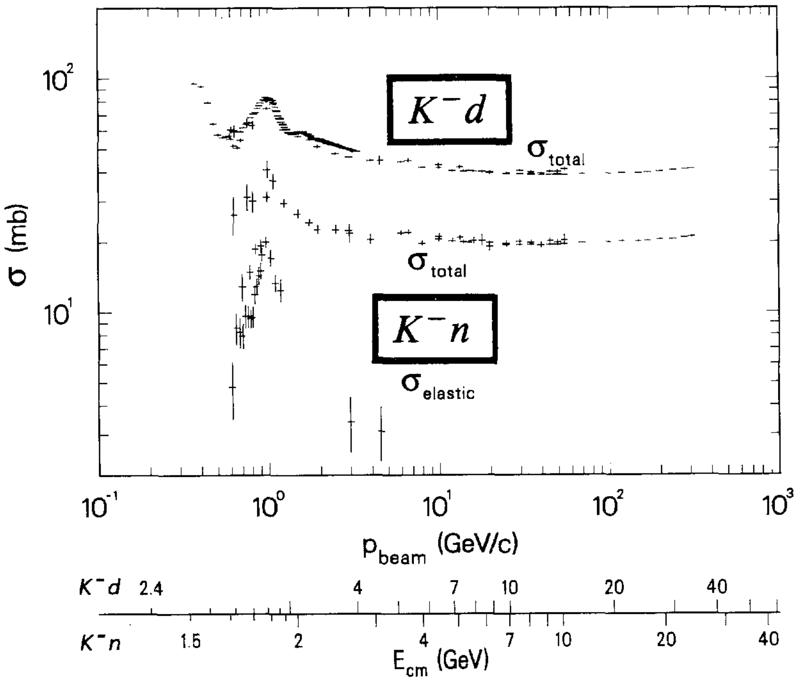
Hadronic total and elastic cross sections vs. laboratory beam momentum p_{beam} and total center-of-mass energy E_{cm}. Data courtesy A. Baldini, V. Flaminio, W.G. Moorhead, D.R.O. Morrison, and N. Rivoire, CERN; and COMPAS Group, IHEP, Serpukhov, USSR. See CERN HERA Group compilations for references.



Hadronic total and elastic cross sections vs. laboratory beam momentum p_{beam} and total center-of-mass energy E_{cm}. Data courtesy A. Baldini, V. Flaminio, W.G. Moorhead, D.R.O. Morrison, and N. Rivoire, CERN; and COMPAS Group, IHEP, Serpukhov, USSR. See CERN HERA Group compilations for references.

PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES (Cont'd)





Hadronic total and elastic cross sections vs. laboratory beam momentum p_{beam} and total center-of-mass energy E_{cm}. Data courtesy A. Baldini, V. Flaminio, W.G. Moorhead, D.R.O. Morrison, and N. Rivoire, CERN; and COMPAS Group, IHEP, Serpukhov, USSR. See CERN HERA Group compilations for references.

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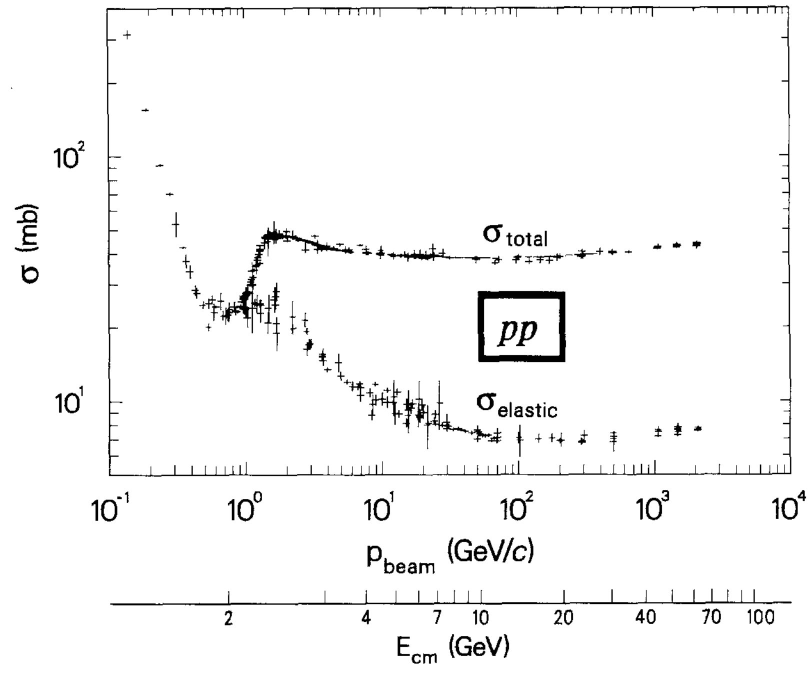

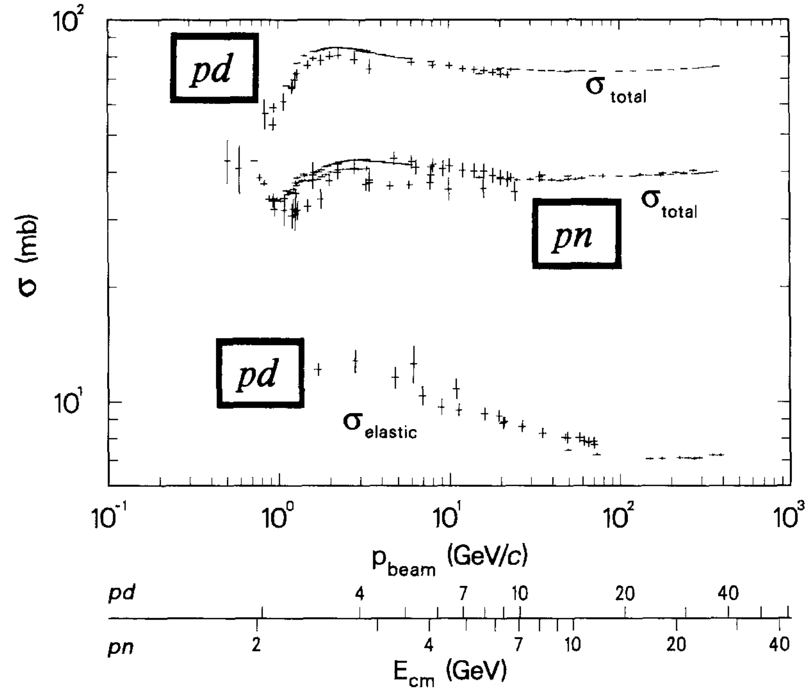

Hadronic total and elastic cross sections vs. laboratory beam momentum p_{beam} and total center-of-mass energy E_{cm}. Data courtesy A. Baldini, V. Flaminio, W.G. Moorhead, D.R.O. Morrison, and N. Rivoire, CERN; and COMPAS Group, IHEP, Serpukhov, USSR. See CERN HERA Group compilations for references.

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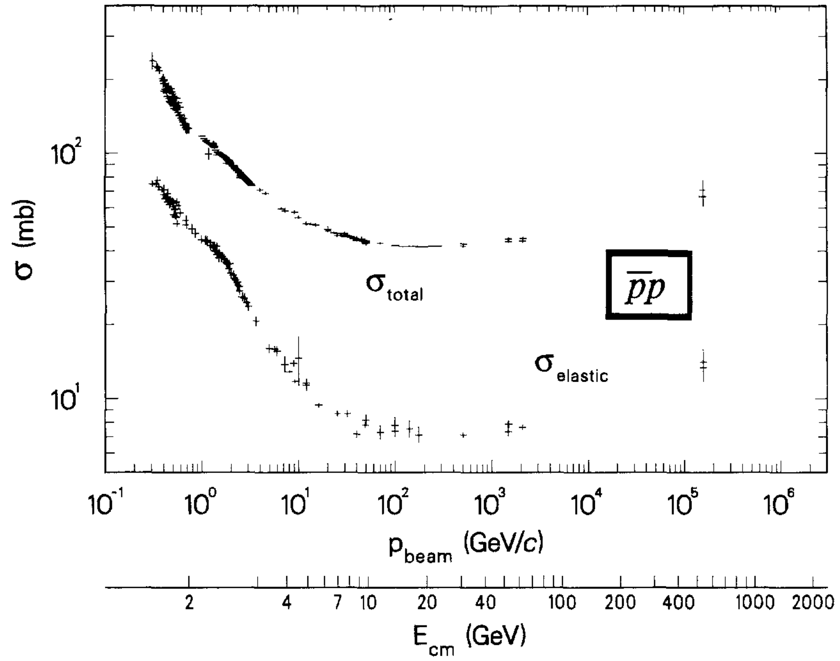
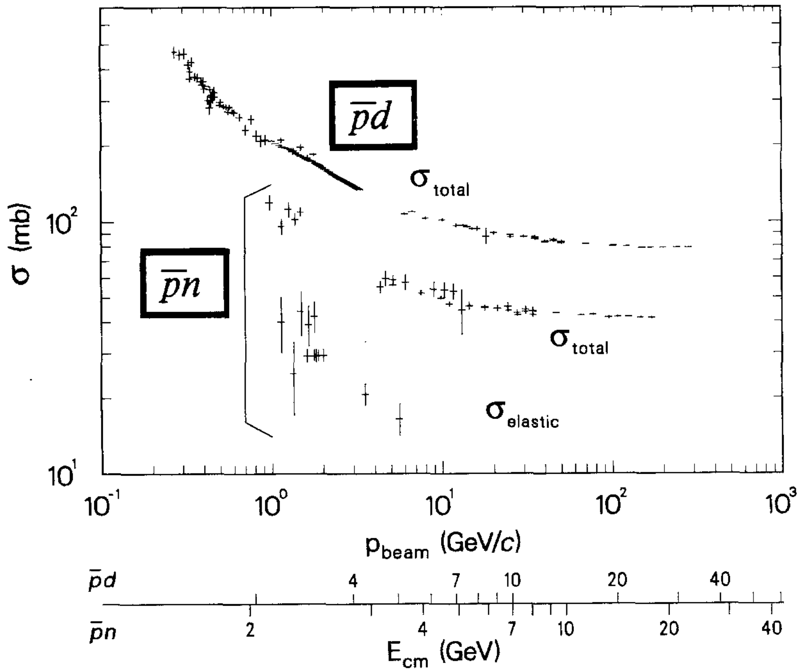




Hadronic total and elastic cross sections vs. laboratory beam momentum p_{beam} and total center-of-mass energy E_{cm}. Data courtesy A. Baldini, V. Flaminio, W.G. Moorhead, D.R.O. Morrison, and N. Rivoire, CERN; and COMPAS Group, IHEP, Serpukhov, USSR. See CERN HERA Group compilations for references.

Illustrative Key to the Full Listings

Name of particle ("old" name used before recent renaming scheme also given if different; see Introductory Text for details).

Indicates particle omitted from Particle Properties Summary Table, implying particle's existence is not confirmed.

$a_0(1200)$ was $XX(1200)$

$I^G(J^{PC}) = 1^-(0^{+-})$

```
EVIDENCE NOT COMPELLING. MAY BE A
KINEMATIC EFFECT.
```

OMITTED FROM SUMMARY TABLE

Particle quantum numbers (where known).

General comments on particle.

Quantity tabulated below.

Code for quantity tabulated (M=mass, W=width, etc.).

Symbol used to key together data and related comments.

Number of events *above background.*

Measured value *(parentheses indicate value not used in average;* see Introductory Text for explanations).

±error in measured value (− field blank if error symmetric; parentheses on *error only* indicate data not used in average due to problems with error estimation).

$a_0(1200)$ MASS (MeV)

```
M          1216.      11.           MERRILL   81 HBC    0 3.2 K-P
M  L  150(1192.)     (16.)          LYNCH     81 HBC   +- 2.7 PI-P
M  L     LYNCH DATA HAS QUESTIONABLE BACKGROUND SUBTRACTION
M          1198.      10.      7.   PIERCE    83 ASPK +   2.1 K-P
M         (1208.)                   FENNER    83 HBC    0 4.2 PI+P
M  S    80 1210.       8.           SMITH     85 MMS  -   3.5 PI-P       |
M  S     SUPERSEDES EARLIER RESULT
M          . . . . . . . . .
M    AVG   1206.9      5.1      AVERAGE
```

Abbreviated reference for this result; full reference given below.

Measurement technique (see abbreviations on next page).

Charge(s) of particle(s) detected.

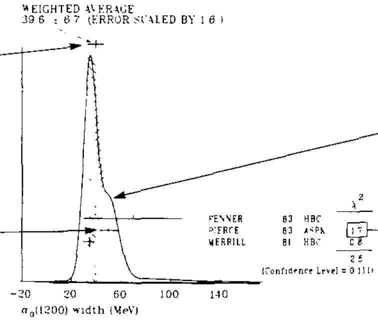
Average value (and error) of quantity tabulated.

Top "data point" indicates average; width of error bar (and shaded pattern below) is ±error on average, scaled by "scale factor."

Value and error for each experiment.

$a_0(1200)$ WIDTH (MeV)

```
W           35.       5.           MERRILL   81 HBC    0 3.2 K-P
W           50.       8.           PIERCE    83 ASPK +   2.1 K-P
W           70.      40.           FENNER    83 HBC    0 4.2 PI+P
W          (60.)   OR LESS         SMITH     85 MMS  -   3.5 PI-P      |
W          . . . . . . . . .
W    AVG    39.6      6.7      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
                             (SEE IDEOGRAM BELOW)
```



Reaction producing particle, or general comments.

"Change bar" indicates result added or changed since previous edition.

Scale factor > 1 indicates possibly inconsistent data.

Ideogram to display possibly inconsistent data, curve is sum of Gaussians, one for each experiment (area of Gaussian = 1/error; width of Gaussian = ±error). See Introductory Text for discussion.

Contribution of experiment to χ^2 (if no entry present, experiment not used in calculating χ^2 or scale factor because of very large error).

$a_0(1200)$ PARTIAL DECAY MODES

Partial decay mode (labeled by P_i).

		DECAY MASSES
P1	$a_0(1200) \rightarrow 3\pi$	140+ 140+ 140
P2	$a_0(1200) \rightarrow K\bar{K}$	494+ 494

Representative masses of decay products (used for calculating decay momentum in last column of Particle Property Summary Tables).

$a_0(1200)$ BRANCHING RATIOS

Branching ratio (labeled by R_j).

Value (and error) of quantity tabulated, as determined from constrained fit (using *all* measured branching ratios for this particle).

$a_0(1200) \rightarrow (3\pi)/\text{total}$ (P1)

```
R1            .66       .02         MERRILL   81 HBC    0 3.2 K-P
R1  L        (.68)     (.03)        LYNCH     81 HBC   +- 2.7 PI-P
R1  L   LYNCH DATA HAS QUESTIONABLE BACKGROUND SUBTRACTION
R1          . . . . . . . . .
R1  FIT      0.675     0.012   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$a_0(1200) \rightarrow (K\bar{K})/\text{total}$ (P2)

```
R2            .35       .05         PIERCE    83 ASPK +   2.1 K-P
R2          . . . . . . . . .
R2  FIT      0.325     0.012   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$a_0(1200) \rightarrow (K\bar{K})/(3\pi)$ (P2)/(P1)

```
R3            .50       .03         FENNER    83 HBC    0 4.2 PI+P
R3            .41       .04         SMITH     85 MMS  -   3.5 PI-P      |
R3          . . . . . . . . .
R3  AVG      0.468     0.043   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)
R3  FIT      0.480     0.027   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

Branching ratio R_j in terms of partial decay mode fractions P_i above.

REFERENCES FOR $a_0(1200)$

References, ordered by year, then author.

Abbreviated reference form used on data entries above.

Journal, report, preprint, etc. (see abbreviations on next page).

```
MERRILL  81 PRL 47 143        A. MERRILL               (SACLAY+CERN)IJP
LYNCH    81 PR D24 610        B. LYNCH                         (BNL)
PIERCE   83 PL 123B 230       N. PIERCE                       (FNAL)
FENNER   83 NP B213 372       D. FENNER,B. BEANE         (NYSE+AMEX)
SMITH    85 PRL 55 14         J. SMITH                        (SLAC)
```

Author(s).

Quantum number determinations in this reference.

Institution(s) of author(s) (see abbreviations on next page).

Abbreviations Used in the Full Listings

Journals

ADVP	Advances in Physics
AFIS	Anales de Fisica
ANP	Annals of Physics
APAH	Acta Phys. Acad. Hungarica
APJ	Astrophysical Journal
APP	Acta Physica Polonica
ARNPS	Annual Review of Nuclear & Particle Science
ARNS	Annual Review of Nuclear Science
BAPS	Bulletin of the American Physical Society
BASUP	Bulletin of the Academy of Science, USSR (Physics)
CJP	Canadian Journal of Physics
CNPP	Comments on Nuclear and Particle Physics
CZJP	Czechoslovak Journal of Physics
JAP	Journal of Applied Physics
JETP	English Translation of Soviet Physics JETP
JETPL	Letters of Soviet Physics JETP
JP	Journal of Physics (A,B,G)
JPSJ	Journal of the Physical Society of Japan
LNC	Letters to Nuovo Cimento
NAT	Nature
NC	Nuovo Cimento
NIM	Nuclear Instruments and Methods
NP	Nuclear Physics
PL	Physics Letters
PN	Particles and Nuclei
PPSL	Proc. of the Physical Society of London
PR	Physical Review
PRAM	Pramana
PRL	Physical Review Letters
PRPL	Physics Reports (Physics Letters C)
PRSE	Proc. of the Royal Society of Edinburgh
PRSL	Proc. of the Royal Society of London
PS	Physica Scripta
PTP	Progress of Theoretical Physics
RA	Radiochimica Acta
RMP	Reviews of Modern Physics
RNC	La Rivista del Nuovo Cimento
RPP	Reports on Progress in Physics
RRP	Revue Romaine de Physique
SCI	Science
SJNP	Soviet Journal of Nuclear Physics
SPU	Soviet Physics - Uspekhi
ZNAT	Zeitschrift fur Naturforschung
ZPHY	Zeitschrift fur Physik

Conferences

Conferences are generally referred to by the location at which they were held (e.g., HAMBURG, TORONTO, CORNELL, BRIGHTON, etc.).

Measurement Techniques (i.e., Detectors and Methods of Analysis)

AEMS	Argonne effective mass spectrometer
ARG	ARGUS detector at DORIS
ASP	Anomalous single-photon detector
ASPK	Automatic spark chambers
BDMP	Beam dump
BEBC	Big European bubble chamber at CERN
BIS2	BIS-2 spectrometer at Serpukhov
BONA	Bonanza nonmagnetic detector at DORIS
BPWA	Barrelet-zero partial-wave analysis
CALO	Calorimeter
CBAL	Crystal Ball detector at SLAC-SPEAR or DORIS
CC	Cloud chamber
CELL	CELLO detector at DESY
CHRM	CHARM neutrino detector at CERN
CIBS	CERN-IHEP boson spectrometer
CLEO	Cornell magnetic detector at CESR
CNTR	Counters
COSM	Cosmology and astrophysics
CUSB	Columbia U. - Stony Brook segmented NaI detector at CESR
DASP	DESY double-arm spectrometer
DBC	Deuterium bubble chamber
DLCO	DELCO detector at SLAC-SPEAR or SLAC-PEP
DM1	Detector at Orsay DM1 collider
DPWA	Energy-dependent partial-wave analysis
ELEC	Electronic combination
EMC	European muon collaboration detector at CERN
EMUL	Emulsions
FBC	Freon bubble chamber
FIT	Fit to previously existing data
FRAB	ADONE $B\bar{B}$ group detector
FRAG	ADONE $\gamma\gamma$ group detector
FRAM	ADONE MEA group detector
FRBC	Freon bubble chamber
GAM2	IHEP hodoscope Cerenkov γ calorimeter GAMS-2000
GAM4	CERN hodoscope Cerenkov γ calorimeter GAMS-4000
GOLI	CERN Goliath spectrometer
HBC	Hydrogen bubble chamber
HDBC	Hydrogen and deuterium bubble chambers
HEBC	Helium bubble chamber
HLBC	Heavy-liquid bubble chamber
HRS	SLAC high-resolution spectrometer
HYBR	Hybrid: bubble chamber + electronics
INDU	Magnetic induction
IPWA	Energy-independent partial-wave analysis
JADE	JADE detector at DESY
LASS	Large-angle superconducting solenoid spectrometer at SLAC
LENA	Nonmagnetic lead-glass NaI detector at DORIS
MAC	MAC detector at PEP/SLAC
MBR	Molecular beam resonance technique
MICA	Underground mica deposits
MMS	Missing mass spectrometer
MPS	Multiparticle spectrometer at BNL
MPSF	Multiparticle spectrometer at Fermilab
MPWA	Model-dependent partial-wave analysis
MRKJ	Mark-J detector at DESY
MRS	Magnetic resonance spectrometer
NEUL	Neuland large-angle neutrino spectrometer
OLYA	Detector at VEPP-4, Novosibirsk
OMEG	CERN OMEGA spectrometer
OSPK	Optical spark chamber
PBC	Propane bubble chamber
PLAS	Plastic detector
PLUT	DESY PLUTO detector
PWA	Partial-wave analysis
REDE	Resonance depolarization
RVUE	Review of previous data
SFM	CERN split-field magnet
SILI	Silicon detector
SMAG	SPEAR magnetic detector
SMK2	SLAC Mark-II detector
SMK3	SLAC Mark-III detector
SPEC	Spectrometer
SPRK	Spark chamber
STRC	Streamer chamber
TASS	DESY TASSO detector
THEO	Theoretical or heavily model-dependent result
TPC	TPC detector at PEP/SLAC
TPS	Tagged photon spectrometer at Fermilab
UA1	UA1 detector at CERN
UA2	UA2 detector at CERN
UA5	UA5 detector at CERN
WIRE	Wire chamber
XEBC	Xenon bubble chamber

Institutions

AACH	Technische Univ. Aachen	Aachen, West Germany
AARH	Univ. of Aarhus	Aarhus, Denmark
ABO	Abo Akademi	Abo, Finland
ADEL	Adelphi Univ.	Garden City, NY, USA
AERE	Atomic Energy Res. Estab.	Harwell, Berks., England
AICH	Aichi Univ. of Education	Kariya, Aichi Pref., Japan
AIKO	Inst. Kernphys. Onderzoek	Amsterdam, Netherlands
ALAH	Univ. of Alabama at Huntsville	Huntsville, AL, USA
ALBA	State Univ. of New York at Albany	Albany, NY, USA
AMST	Univ. of Amsterdam	Amsterdam, Netherlands
ANIK	Amsterdam NIKHEF	Amsterdam, Netherlands
ANKA	Middle East Technical Univ.	Ankara, Turkey
ANL	Argonne National Lab.	Argonne, IL, USA
ARIZ	Univ. of Arizona	Tucson, AZ, USA
ARZS	Arizona State Univ.	Tempe, AZ, USA
ATEN	Nuclear Res. Centre Demokritos	Athens, Greece
ATHU	Univ. of Athens	Athens, Greece
AUCK	Univ. of Auckland	Auckland, New Zealand
BARC	Univ. de Barcelona	Barcelona, Spain
BARI	Univ. di Bari	Bari, Italy
BART	Bartol Research Foundation	Swarthmore, PA, USA
BASL	Univ. of Basel	Basel, Switzerland
BAYR	Univ. Bayreuth	Bayreuth, West Germany
BELG	Inst. Interuniv. des Sci. Nuc.	Bruxelles, Belgium
BELL	Bell Labs.	Murray Hill, NJ, USA
BERG	Univ. of Bergen	Bergen, Norway
BERL	Inst. Hochenergiephys. DAW	Berlin-Zeuthen, East Germany
BERN	Univ. Bern	Bern, Switzerland
BGNA	Univ. di Bologna	Bologna, Italy
BHAB	Bhabha Atomic Research Center	Bombay, India
BHEP	Inst. of High Energy Physics	Beijing, China
BIEL	Univ. Bielefeld	Bielefeld, West Germany
BING	State Univ. of New York at Binghamton	Binghamton, NY, USA
BIRM	Birmingham Univ.	Birmingham, England
BNL	Brookhaven National Lab.	Upton, L.I., NY, USA
BOHR	Niels Bohr Inst.	Copenhagen, Denmark

Abbreviations Used in the Full Listings *(cont'd)*

Institutions *(cont'd)*

BOIS	Boise State Univ.	Boise, ID, USA
BOMB	Univ. of Bombay	Bombay, India
BONN	Univ. Bonn	Bonn, West Germany
BORD	Univ. de Bordeaux	Bordeaux, France
BOST	Boston Univ.	Boston, MA, USA
BRAN	Brandeis Univ.	Waltham, MA, USA
BRCO	Univ. of British Columbia	Vancouver, BC, Canada
BRIS	H. H. Wills Phys. Lab., U. of Bristol	Bristol, England
BROW	Brown Univ.	Providence, RI, USA
BRUX	Univ. Libre de Bruxelles	Bruxelles, Belgium
BUCH	Bucharest State Univ.	Bucharest, Romania
BUDA	Central Research Inst. of Physics	Budapest, Hungary
BUFF	State Univ. of New York at Buffalo	Buffalo, NY, USA
BURE	Inst. des Hautes Etutes Sci.	Bures-sur-Yvette, France
CAEN	Lab. de Phys. Corpusculaire	Caen, France
CAGL	Cagliari Univ.	Cagliari, Italy
CAIW	Carnegie Inst. of Washington	Washington, DC, USA
CAMB	Cambridge Univ.	Cambridge, England
CANB	Australian National Univ.	Canberra, Australia
CARL	Carleton Univ.	Ottawa, ON, Canada
CARN	Carnegie-Mellon Univ.	Pittsburgh, PA, USA
CASE	Case Western Reserve Univ.	Cleveland, OH, USA
CATH	Catholic Univ. of America	Washington, DC, USA
CAVE	Cavendish Lab., Cambridge Univ.	Cambridge, England
CCAC	Community College of Allegheny County	Pittsburgh, PA, USA
CDEF	College de France	Paris, France
CEA	Cambridge Electron Accel.	Cambridge, MA, USA
CENG	CEN, Grenoble	Grenoble, France
CERN	European Org. for Nuclear Research	Geneva, Switzerland
CHIC	Univ. of Chicago	Chicago, IL, USA
CINC	Univ. of Cincinnati	Cincinnati, OH, USA
CIT	Calif. Inst. of Technology	Pasadena, CA, USA
CLEV	Cleveland State Univ.	Cleveland, OH, USA
CNRC	Canadian National Research Council	Ottawa, ON, Canada
COLO	Univ. of Colorado	Boulder, CO, USA
COLU	Columbia Univ.	New York, NY, USA
CORN	Cornell Univ.	Ithaca, NY, USA
COSU	Colorado State Univ.	Fort Collins, CO, USA
CRAC	Inst. for Nuclear Research	Cracow, Poland
CUNY	City Univ. of New York	New York, NY, USA
CURI	Laboratoire Joliot-Curie	Paris, France
DALH	Dalhausie Univ.	Halifax, NS, Canada
DARE	Daresbury Nuclear Physics Lab.	Daresbury, England
DELH	Univ. of Delhi	Delhi, India
DESY	Deutsches Elektronen-Synchrotron	Hamburg, West Germany
DOE	U.S. Department of Energy	Washington, DC, USA
DORT	Univ. Dortmund	Dortmund, West Germany
DUKE	Duke Univ.	Durham, NC, USA
DURH	Univ. of Durham	Durham, England
DUUC	University College	Dublin, Ireland
EDIN	Univ. of Edinburgh	Edinburgh, Scotland
EFI	Enrico Fermi Inst. for Nucl. Studies	Chicago, IL, USA
ELMT	Elmhurst College	Elmhurst, IL, USA
EPOL	Ecole Polytechnique	Palaiseau, France
ERLA	Univ. Erlangen-Nurnberg	Erlangen, West Germany
ETH	Swiss Federal Inst. of Technology	Zurich, Switzerland
FIRZ	Univ. di Firenze	Firenze, Italy
FISK	Fisk Univ.	Nashville, TN, USA
FLOR	Univ. of Florida	Gainsville, FL, USA
FNAL	Fermi National Accelerator Lab.	Batavia, IL, USA
FOM	Found. for Fundamental Res. on Matter	Utrecht, Netherlands
FRAS	Lab. Nazionali del C.N.E.N.	Frascati, Italy
FREI	Univ. of Freiburg	Freiburg, West Germany
FSU	Florida State Univ.	Tallahassee, FL, USA
GENO	Univ. di Genova	Genova, Italy
GESC	General Electric Res. and Dev. Center	Schenectady, NY, USA
GEVA	Univ. de Geneve	Geneva, Switzerland
GLAS	Univ. of Glasgow	Glasgow, Scotland
GMAS	George Mason Univ.	Fairfax, VA, USA
GRAZ	Univ. Graz	Graz, Austria
GREN	Inst. des Sci. Nuc., Univ. de Grenoble	Grenoble, France
GSCO	Geological Survey of Canada	Ottawa, ON, Canada
GUEL	Guelph Univ.	Guelph, ON, Canada
HAIF	Technion - Israel Inst. of Technology	Haifa, Israel
HAMB	Univ. Hamburg	Hamburg, West Germany
HARV	Harvard Univ.	Cambridge, MA, USA
HAWA	Univ. of Hawaii	Honolulu, HI, USA
HEBR	Hebrew Univ.	Jerusalem, Israel
HEID	Univ. Heidelberg	Heidelberg, West Germany
HELS	Helsingin Yliopisto	Helsinki, Finland
HIRO	Hiroshima Univ.	Hiroshima, Japan
HOUS	Univ. of Houston	Houston, TX, USA
HPC	Hewlett-Packard Corp.	Cupertino, CA, USA
IAS	Inst. for Advanced Study	Princeton, NJ, USA
IBAR	Ibaraki Univ., Mito	Ibaraki-ken, Japan
IBM	International Business Machines	Palo Alto, CA, USA
IFRJ	Inst. de Fisica, Rio de Janeiro	Rio de Janeiro, Brazil
IIT	Illinois Inst. of Tech.	Chicago, IL, USA
ILL	Univ. of Illinois	Urbana, IL, USA
ILLC	Univ. of Illinois at Chicago	Chicago, IL, USA
ILLG	Inst. Laue-Langevin	Grenoble, France
IND	Indiana Univ.	Bloomington, IN, USA
INEL	Idaho National Engineering Lab.	Idaho Falls, ID, USA
INFN	Ist. Nazionale di Fisica Nuclear	Roma, Italy
INNS	Phys. Inst., Univ. Innsbruck	Innsbruck, Austria
INRM	Inst. for Nuclear Research	Moscow, USSR
INUS	Inst. for Nuclear Study at Tokyo Univ.	Tokyo, Japan
IOFF	Ioffe Inst. of Physics and Tech.	Leningrad, USSR
IOWA	Univ. of Iowa	Iowa City, IA, USA
IPCR	Inst. of Physical and Chemical Research	Saitama-ken, Japan
IPN	Inst. de Phys. Nucleaire	Orsay, France
IPNP	Inst. de Physique Nucleaire	Paris, France
IPPC	Inst. for Particle Physics of Canada	Montreal, PQ, Canada
IRAD	Inst. du Radium	Paris, France
ISU	Iowa State Univ.	Ames, IA, USA
ITEP	Inst. for Theor. and Exp. Phys.	Moscow, USSR
ITHA	Ithaca College	Ithaca, NY, USA
ITPU	Inst. for Theoretical Physics	Utrecht, Netherlands
IUPU	Indiana U. - Purdue U. at Indianapolis	Indianapolis, IN, USA
JAGL	Jagellonian Univ.	Cracow, Poland
JHU	Johns Hopkins Univ.	Baltimore, MD, USA
JINR	Joint Inst. for Nucl. Research	Dubna, USSR
KAGO	Kagoshima Univ.	Kagoshima, Japan
KANS	Univ. of Kansas	Lawrence, KS, USA
KARL	Univ. Karlsruhe	Karlsruhe, West Germany
KAZA	Kazakh Academy of Science	Alma-Ata, USSR
KEK	Nat. Lab for High Energy Phys., Japan	Tsukuba-gun, Japan
KENT	Kent Univ. at Cantebury, Kent	Cantebury, England
KEYN	Open Univ.	Milton Keynes, England
KHAR	Phys.-Tech. Inst., Acad. Sci., Ukr.SSR	Kharkov, USSR
KIAE	Kurchatov Inst. of Atomic Energy	Moscow, USSR
KIEL	Kiel Univ.	Kiel, West Germany
KIEV	Physical-Technical Inst.	Kiev, USSR
KINK	Kinki Univ.	Osaka, Japan
KNTY	Univ. of Kentucky	Lexington, KY, USA
KOBE	Kobe Univ.	Kobe, Japan
KONS	B. P. Konstantinov Inst. of Nucl. Phys.	USSR
KYOT	Kyoto Univ.	Kyoto, Japan
LALO	Linear Accelerator Lab, Orsay	Orsay, France
LANC	Lancaster Univ.	Lancaster, England
LANL	U.C. Los Alamos National Lab.	Los Alamos, NM, USA
LAPP	Lab. d'Annecy de Phys. des Particules	Annecy, France
LASL	U.C. Los Alamos Scientific Lab.	Los Alamos, NM, USA
LAUS	Univ. of Lausanne	Lausanne, Switzerland
LBL	U.C. Lawrence Berkeley Lab.	Berkeley, CA, USA
LCGT	Lab. di Cosmo-Geofisica del CNR	Torino, Italy
LEBD	Lebedev Physics Inst.	Moscow, USSR
LEED	Univ. of Leeds	Leeds, England
LEHI	Lehigh Univ.	Bethlehem, PA, USA
LEHM	Herbert H. Lehman College	Bronx, NY, USA
LEID	Inst. Lorentz	Leiden, Netherlands
LEMO	Le Moyne College	Syracuse, NY, USA
LENI	Inst. of Nucl. Phys., USSR Acad. Sci.	Leningrad, USSR
LIBH	Lab. Interuniv. Belge High Eng.	Bruxelles, Belgium
LINZ	Linz Inst. fur Physik, Kepler Hoch.	Linz, Austria
LISB	Univ. de Lisboa	Lisboa, Codex, Portugal
LIVP	Liverpool Univ.	Liverpool, England
LJUB	Univ. of Ljubljana	Ljubljana, Yugoslavia
LLL	Lawrence Livermore Lab.	Livermore, CA, USA
LOIC	Imperial Col. of Sci. and Tech.	London, England
LOQM	Queen Mary College	London, England
LOUC	University College	London, England
LOWC	Westfield College	London, England
LPNP	Lab. de Phys. Nucl. et Hautes Energies	Paris, France
LPTP	Lab. de Phys. Theor. et Hautes Energies	Paris, France
LRL	U.C. Lawrence Berkeley Lab.	Berkeley, CA, USA
LSU	Louisiana State Univ.	Baton Rouge, LA, USA
LUND	Univ. I Lund	Lund, Sweden
LVLN	Univ. Catholique de Louvain	Louvain-La-Neuve, Belgium
LYON	Univ. de Lyon	Villeurbanne, France
MADR	Junta de Energia Nuclear	Madrid, Spain
MADU	Univ. Autonome de Madrid	Madrid, Spain
MANI	Univ. of Manitoba	Winnipeg, MB, Canada
MANZ	Univ. Mainz	Mainz, West Germany
MARS	Center National de la Recherche Sci.	Marseille, France
MASA	Univ. of Massachusetts	Amherst, MA, USA
MCGI	McGill Univ.	Montreal, PQ, Canada
MCHS	Univ. Manchester	Manchester, England
MCMS	McMaster Univ.	Hamilton, ON, Canada
MEIS	Meisei Univ.	Hino, Tokyo, Japan
MELB	Univ. of Melbourne	Parkville, Australia
MHCO	Mount Holyoke College	South Hadley, MA, USA
MICH	Univ. of Michigan	Ann Arbor, MI, USA
MILA	Univ. di Milano	Milano, Italy
MINN	Univ. of Minnesota	Minneapolis, MN, USA
MIT	Massachusetts Inst. of Technology	Cambridge, MA, USA

Abbreviations Used in the Full Listings *(cont'd)*

Institutions *(cont'd)*

MONP	Univ. de Montpellier	Montpellier, France
MONS	Univ. de l'Etat, Mons	Mons, Belgium
MONT	Univ. de Montreal	Montreal, PQ, Canada
MOSU	Moscow State Univ.	Moscow, USSR
MPIH	Max Planck Inst. fur Kernphysik	Heidelberg, West Germany
MPIM	Max Planck Inst. fur Phys.-Astrophys.	Munich, West Germany
MSU	Michigan State Univ.	East Lansing, MI, USA
MTHO	Mt. Holyoke College	South Hadley, MA, USA
MULH	Centre Univ. du Haut-Rhin	Mulhouse, France
MUNI	Univ. of Munich	Munich, West Germany
MURA	Midwestern Univ. Research Assoc.	Stroughton, WI, USA
NAGO	Nagoya Univ.	Nagoya, Japan
NAPL	Univ. di Napoli	Napoli, Italy
NASA	NASA, Goddard Space Flight Center	Greenbelt, MD, USA
NBS	U.S. National Bureau of Standards	Washington, DC, USA
NDAM	Univ. of Notre Dame	Notre Dame, IN, USA
NEAS	Northeastern Univ.	Boston, MA, USA
NEUC	Univ. de Neuchatel	Neuchatel, Switzerland
NIJM	R. K. Univ. Nijmegen	Nijmegen, Netherlands
NMSU	New Mexico State Univ.	Las Cruces, NM, USA
NORD	Nordisk Inst. for Teor. Atomfys.	Copenhagen, Denmark
NOVO	Inst. of Nucl. Phys.	Novosibirsk, USSR
NPOL	Northern Polytechnic	London, England
NRL	Naval Research Laboratory	Washington, DC, USA
NSF	U.S. National Science Foundation	Washington, DC, USA
NTUA	National Technical Univ.	Athens, Greece
NWES	Northwestern Univ.	Evanston, IL, USA
NYU	New York Univ.	New York, NY, USA
OHIO	Ohio Univ.	Athens, OH, USA
OKAY	Okayama Univ.	Okayama, Japan
OKLA	Univ. of Oklahoma	Norman, OK, USA
OKSU	Oklahoma State Univ.	Stillwater, OK, USA
OREG	Univ. of Oregon	Eugene, OR, USA
ORNL	Oak Ridge National Lab.	Oak Ridge, TN, USA
ORSA	Univ. de Paris, Fac. des Sci.	Orsay, France
OSAK	Osaka Univ.	Osaka, Japan
OSKC	Osaka City Univ.	Osaka, Japan
OSLO	Oslo Univ.	Oslo, Norway
OSU	Ohio State Univ.	Columbus, OH, USA
OTTA	Univ. of Ottawa	Ottawa, ON, Canada
OXF	Oxford Univ.	Oxford, England
PADO	Univ. di Padova	Padova, Italy
PATR	Univ. of Patras	Patras, Greece
PAVI	Univ. di Pavia	Pavia, Italy
PENN	Univ. of Pennsylvania	Philadelphia, PA, USA
PGIA	Univ. di Perugia	Perugia, Italy
PHIL	Philipps Univ.	Marburg, West Germany
PISA	Univ. di Pisa	Pisa, Italy
PITT	Univ. of Pittsburgh	Pittsburgh, PA, USA
PNL	Pacific Northwest Lab.	Richland, WA, USA
PPA	Princeton-Penn. Proton Accel.	Princeton, NJ, USA
PRAG	Inst. of Physics, CSAV	Prague, Czechoslovakia
PRIN	Princeton Univ.	Princeton, NJ, USA
PSLL	Physical Science Lab.	Las Cruces, NM, USA
PUCB	Pontificia Univ. Catolica	Rio de Janeiro, Brazil
PURD	Purdue Univ.	Lafayette, IN, USA
QUKI	Queens Univ.	Kingston, ON, Canada
RAL	Rutherford Appleton Lab. (formerly RL)	Chilton, Did., Berks., England
REGE	Univ. Regensburg	Regensburg, West Germany
REHO	Weizmann Inst. of Sci.	Rehovoth, Israel
RHEL	Rutherford High Energy Lab.	Chilton, Did., Berks., England
RICE	William Marsh Rice Univ.	Houston, TX, USA
RISO	Research Estab. Riso	Roskilde, Denmark
RL	Rutherford Lab. (formerly RHEL)	Chilton, Did., Berks., England
RMCS	Royal Military College of Science	Shrivenham, England
ROCH	Univ. of Rochester	Rochester, NY, USA
ROCK	Rockefeller Univ.	New York, NY, USA
ROMA	Univ. di Roma	Roma, Italy
ROSE	Rose Polytechnic Inst.	Terre Haute, IN, USA
RPI	Rensselaer Polytechnic Inst.	Troy, NY, USA
RUTG	Rutgers Univ.	New Brunswick, NJ, USA
SACL	Cntr. d'Etudes Nucl. Saclay	Gif-sur-Yvette, France
SAGA	Saga Univ.	Saga, Japan
SANI	Ist. Superiore di Sanita	Roma, Italy
SBER	San Bernardino State College	San Bernardino, CA, USA
SCUC	Univ. of South Carolina	Columbia, SC, USA
SEAT	Seattle Pacific College	Seattle, WA, USA
SEIB	Research Center Seibersdorf	Vienna, Austria
SEOU	Korea Univ.	Seoul, Korea
SERP	Inst. of High Energy Physics	Serpukov, USSR
SETO	Seton Hall Univ.	South Orange, NJ, USA
SFLA	Univ. of South Florida	Tampa, FL, USA
SFSU	San Francisco State Univ.	San Francisco, CA, USA
SHEF	Univ. of Sheffield	Sheffield, England
SHMP	Univ. of Southampton	Southampton, England
SIBE	Inst. of Nucl. Phys., USSR Acad. Sci.	Siberia, USSR
SIEG	Gesamthochschule Siegen	Huttental, West Germany
SIN	Swiss Inst. of Nuclear Research	Villigen, Switzerland
SLAC	Stanford Linear Accel. Center	Stanford, CA, USA
SMAS	Southeastern Massachusetts Univ.	North Dartmouth, MA, USA
SOFI	Bulgarian Acad. of Sci.	Sofia, Bulgaria
STAN	Stanford Univ.	Stanford, CA, USA
STEV	Stevens Inst. of Tech.	Hoboken, NJ, USA
STLO	St. Louis Univ.	St. Louis, MO, USA
STOH	Stockholm Univ.	Stockholm, Sweden
STON	State Univ. of New York at Stony Brook	Stony Brook, L.I., NY, USA
STRB	Centre des Res. Nucleaires	Strasbourg, France
SUSS	Univ. of Sussex	Falmer, Brighton, England
SYDN	Univ. of Sydney	Sydney, Australia
SYRA	Syracuse Univ.	Syracuse, NY, USA
TAMU	Texas A and M Univ.	College Station, TX, USA
TBLI	Tbilisi State Univ.	Tbilisi, USSR
TELA	Univ. of Tel-Aviv	Tel-Aviv, Israel
TEMP	Temple Univ.	Philadelphia, PA, USA
TENN	Univ. of Tennessee	Knoxville, TN, USA
TEXA	Univ. of Texas	Austin, TX, USA
THES	Univ. of Thessaloniki	Thessaloniki, Greece
TIFR	Tata Inst. of Fundamental Research	Bombay, India
TINT	Tokyo Inst. of Technology	Tokyo, Japan
TMSK	Nucl. Phys. Inst., Tomsk Polytech Inst.	Tomsk, USSR
TMU	Tokyo Metropolitan Univ.	Tokyo, Japan
TNTO	Univ. of Toronto	Toronto, ON, Canada
TOHO	Tohoku Univ.	Sendai, Japan
TOKY	Univ. of Tokyo	Tokyo, Japan
TORI	Univ. di Torino	Torino, Italy
TRIK	Rikkyo Univ.	Tokyo, Japan
TRIN	Trinity College	Dublin, Ireland
TRIU	TRIUMF, Univ. of British Columbia	Vancouver, BC, Canada
TRST	Univ. di Trieste	Trieste, Italy
TSUK	Univ. of Tsukuba	Tsukuba, Japan
TTAM	Tamagawa Univ.	Tokyo, Japan
TUFT	Tufts Univ.	Medford, MA, USA
TWAS	Waseda Univ.	Tokyo, Japan
UBEL	Univ. of Belgrade	Belgrade, Yugoslavia
UCB	Univ. of Calif. at Berkeley	Berkeley, CA, USA
UCD	Univ. of Calif. at Davis	Davis, CA, USA
UCI	Univ. of Calif. at Irvine	Irvine, CA, USA
UCLA	Univ. of Calif. at Los Angeles	Los Angeles, CA, USA
UCND	Union Carbide Nuclear Division	Oak Ridge, TN, USA
UCR	Univ. of Calif. at Riverside	Riverside, CA, USA
UCSB	Univ. of Calif. at Santa Barbara	Santa Barbara, CA, USA
UCSC	Univ. of Calif. at Santa Cruz	Santa Cruz, CA, USA
UCSD	Univ. of Calif. at San Diego	La Jolla, CA, USA
UDCF	Univ. de Clermont-Ferrand	Aubiere, France
UMD	Univ. of Maryland	College Park, MD, USA
UNCS	Union College	Schenectady, NY, USA
UNM	Univ. of New Mexico	Albuquerque, NM, USA
UOEH	Univ. of Occup. and Environ. Health	Kitakyushu, Japan
UPNJ	Upsala College	East Orange, NJ, USA
UPPS	Gustaf Werner Inst.	Uppsala, Sweden
USC	Univ. of Southern California	Los Angeles, CA, USA
USCC	Univ. of South Carolina	Columbia, SC, USA
USTL	Univ. Sci. et Tech. du Languedoc	Montpellier, France
UTAH	Univ. of Utah	Salt Lake City, UT, USA
UTRE	Univ. of Utrecht	Utrecht, Netherlands
VAND	Vanderbilt Univ.	Nashville, TN, USA
VICT	Univ. of Victoria	Victoria, BC, Canada
VIEN	Inst. for High Energy Physics, A. A. S.	Vienna, Austria
VIRG	Univ. of Virginia	Charlottesville, VA, USA
VPI	Virginia Polytechnic Inst./State Univ.	Blacksburg, VA, USA
VRIJ	Vrije Univ.	Amsterdam, Netherlands
WARS	Univ. of Warsaw	Warsaw, Poland
WASH	Univ. of Washington	Seattle, WA, USA
WAYN	Wayne State Univ.	Detroit, MI, USA
WIEN	Univ. Wien	Wien, Austria
WILL	College of William and Mary	Williamsburg, VA, USA
WINR	Warsaw Inst. of Nuclear Research	Warsaw, Poland
WISC	Univ. of Wisconsin	Madison, WI, USA
WITW	Univ. of the Witwatersrand	Johannesburg, S. Africa
WMIU	Western Michigan Univ.	Kalamazoo, MI, USA
WOOD	Woodstock College	Woodstock, MD, USA
WUPG	Gesamthochschule Wuppertal	Wuppertal, West Germany
WUPP	Univ. Wuppertal	Wuppertal, West Germany
WURZ	Univ. Wurzburg	Wurzburg, West Germany
WUSL	Washington Univ.	St. Louis, MO, USA
WYOM	Univ. of Wyoming	Laramie, WY, USA
YALE	Yale Univ.	New Haven, CT, USA
YERE	Yerevan Physics Inst.	Yerevan, Armenia, USSR
YOKO	Yokohama Univ.	Yokohama, Japan
YORK	York Univ.	Toronto, ON, Canada
ZAGR	Inst. Rudjer Boskovic	Zagreb, Yugoslavia
ZARA	Univ. of Zaragosa	Zaragosa, Spain
ZEEM	Zeeman Lab., Univ. of Amsterdam	Amsterdam, Netherlands
ZURI	Univ. Zurich	Zurich, Switzerland

GAUGE BOSONS

γ

$I(J^{PC}) = 0,1(1^{--})$

γ MASS (MeV)

```
M   F       (6. E-21)OR LESS                PATEL     65          SATELLITE DATA
M           (6. E-21)OR LESS                GINTSBURG 64          SATELLITE DATA
M           (2.3E-21)OR LESS                GOLDHABER 68          SATELLITE DATA
M   F       (6. E-23)OR LESS                FRANKEN   71          LOW FREQ RES CIR
M           (1. E-20)OR LESS                WILLIAMS  71 CNTR     TESTS GAUSS LAW
M           (7.3E-22)OR LESS                HOLLWEG   74          ALFVEN WAVES
M           (6. E-22)OR LESS  CL=.997       DAVIS     75          JUPITER MAGFIELD
M            3. E-33 OR LESS                CHIBISOV  76          GALACTIC MAG FLD
M   F   VALIDITY QUESTIONABLE. SEE CRITICISM IN KROLL 71 AND GOLDHABER 71.
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REFERENCES FOR γ

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GINTSBUR 64 SOV ASTR AJ7 536  M. A. GINTSBURG                   (ACAD SCI,USSR)
PATEL    65 PL    14  105     V. L. PATEL                              (DURHAM)
GOLDHABE 68 PRL   21  567     A. GOLDHABER,M. NIETO              (STONY BROOK)
FRANKEN  71 PRL 26 115        P A FRANKEN, G W AMPULSKI                  (MICH)
WILLIAMS 71 PRL 26 721        +FALLER,HILL                           (WESLEYAN)

HOLLWEG  74 PRL 32 961        J V HOLLWEG  (NATL CENTER FOR ATMOS RESRCH)
DAVIS    75 PRL 35 1402       +GOLDHABER,NIETO                  (CIT+STON+LASL)
CHIBISOV 76 SPU 19 624        G.B.CHIBISOV                               (LEBD)

                              PAPERS NOT REFERRED TO IN DATA LISTINGS

GOLDHABE 71 RMP 43 277        A S GOLDHABER, M M NIETO      (STON+BOHR+UCSB)
KROLL    71 PRL 26 1395       N M KROLL                                  (SLAC)
BYRNE    77 AST.SP.SCI.46 115 J.C.BYRNE                                  (LOIC)
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W

$J = 1$

MEASUREMENTS OF CHARGED WEAK GAUGE BOSON PARAMETERS ARE LISTED HERE. SEE ALSO OTHER STABLE PARTICLE SEARCHES SECTION.

W MASS (GeV)

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M       6  (81.)      (5.)              ARNISON    83 UA1  REPL.BY ARNISON2 83
M      27  (80.9)     (2.9)             ARNISON2   83 UA1  P PBAR ECM=546 GEV
M   B      (81.0)     (2.8)             BAGNAIA    83 UA2  P PBAR ECM=546 GEV
M       4  (80.)     (10.)      (6.)    BANNER     83 UA2  P PBAR ECM=546 GEV
M   C  14  (81.)      (6.)      (7.)    ARNISON2   84 UA1  P PBAR ECM=546 GEV
M    D 37  (83.1)     (2.3)             BAGNAIA    84 UA2  P PBAR ECM=546 GEV
M    E 119  81.2       1.7              APPEL      86 UA2  P PBAR ECM=546+630
M    F 86   83.5       2.9              ARNISON    86 UA1  P PBAR ECM=546+630
M
M   B   BAGNAIA 83 MASS IS PRELIMINARY VALUE OBTAINED IN Z0 EXPERIMENT
M   C   USING W+- INTO MU+- NU
M    D  STAT. (1.9) AND SYST.(1.3) ERRORS ADDED IN QUADRATURE.
M    E  ERRORS ADDED IN QUADRATURE INCLUDE STAT. (+-1.0), SYST. WHICH
M    E  CANCELS IN MW/MZ (+-1.3), AND NON-CANCELLING SYST. (+-0.5).
M    F  THIS IS ENHANCED SUBSAMPLE OF 172 TOTAL EVENTS.
M    F  STAT (+1.1-1.0) AND SYST (2.7) ERRORS ADDED IN QUADRATURE.
M          . . . . . . . . . .
M   AVG     81.8       1.5      AVERAGE
```

W WIDTH (GeV)

```
W       27   (7.)   OR LESS  CL=.90   ARNISON2  83 UA1  P PBAR ECM=546 GEV
W      119   (7.)   OR LESS  CL=.90   APPEL     86 UA2  P PBAR ECM=546+630
W    F  86    6.5   OR LESS  CL=.90   ARNISON   86 UA1  P PBAR ECM=546+630
W    F  IF SYSTEMATIC ERROR IS NEGLECTED, RESULT IS 2.7+1.4-1.5 GEV.
W    F  THIS IS ENHANCED SUBSAMPLE OF 172 TOTAL EVENTS.
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W ANOMALOUS MAGNETIC MONENT

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WMG      A.M.M.=1 IN STANDARD THEORY.
WMG  A                                  HERZOG    84 THY
WMG  A  HERZOG 84 CONSIDER THE CONTRIBUTION OF W-BOSON TO MUON MAGNETIC
WMG  A  MOMENT INCLUDING ANOMALOUS COUPLING OF W-W-GAMMA.  OBTAIN A LIMIT
WMG  A  0 < A.M.M. < 2 IF MASS SCALE OF UNDERLYING THEORY(CUT-OFF) IS 1 TEV
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W PARTIAL DECAY MODES

		DECAY MASSES	
P1	$W^{\pm} \rightarrow e^{\pm}\nu$	.511+	0
P2	$W^{\pm} \rightarrow \mu^{\pm}\nu$	106+	0
P3	$W^{\pm} \rightarrow e^{\pm}\nu\gamma$	.511+ 0+	0
P4	$W^{\pm} \rightarrow \mu^{\pm}\nu\gamma$	106+ 0+	0

W BRANCHING RATIOS

$W^{\pm} \rightarrow (e^{\pm}\nu)$/total (P1)

```
R1     119    SEEN                      APPEL     86 UA2  P PBAR ECM=546-630
R1     172    SEEN                      ARNISON   86 UA1  P PBAR ECM=546+630
```

$W^{\pm} \rightarrow (\mu^{\pm}\nu)$/total (P2)

```
R2      14    SEEN                      ARNISON2  84 UA1  P PBAR ECM=546 GEV
```

$W^{\pm} \rightarrow (\mu^{\pm}\nu)/(e^{\pm}\nu)$ (P2)/(P1)

```
R3             1.24      0.6      0.4   ARNISON2  84 UA1  P PBAR ECM=546 GEV
```

$W^{\pm} \rightarrow e^{\pm}\nu\gamma$ (P3)

```
R4   A   1 EVT VS 52 W--> E NU EVTS     ARNISON   84 UA1  P PBAR ECM=546 GEV
R4       0 EVT VS 119 W--> E NU EVTS    APPEL     86 UA2  P PBAR ECM=546+630
R4   A  ARNISON 84 W-->E NU GAMMA ONE EVENT IS CONSISTENT WITH QED BREMS.
R4   A  MASS NOT RESTRICTED TO W MASS.
```

$W^{\pm} \rightarrow \mu^{\pm}\nu\gamma$ (P4)

```
R5   A   0 EVT VS 18 W--> MU NU EVTS    ARNISON   84 UA1  P PBAR ECM=546 GEV
R5   A  MASS NOT RESTRICTED TO W MASS.
```

$W^{\pm} \rightarrow (e^{\pm}\nu\gamma)/(e^{\pm}\nu)$ (P3/P1)

```
R6   A        0.1   OR LESS  CL=.90    ARNISON   84 UA1  P PBAR ECM=546 GEV
R6   A  AFTER ACCOUNT FOR SELECTION EFFICIENCY AND GEOMETRIC ACCEPTANCE.
```

REFERENCES FOR W

```
ARNISON  83 PL  122B 103       UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HELS+LOQM+)
ARNISON2 83 PL  129B 273       UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HELS+LOQM+)
BAGNAIA  83 PL  129B 130       UA2 COLLAB. (BERN+CERN+BOHR+LALO+PAVI+SACL)
BANNER   83 PL  122B 476       UA2 COLLAB. (BERN+CERN+BOHR+LALO+PAVI+SACL)
ARNISON  84 PL  135B 250       UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HELS+LOQM+)
ARNISON2 84 PL  134B 469       UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HARV+HELS+)
BAGNAIA  84 ZPHY C24 1         UA2 COLLAB.(BERN+CERN+BOHR+ORSA+PAVI+SACL+)
HERZOG   84 PL  148B 355       F.HERZOG                              (WISC)
APPEL    86 ZPHY C TO BE PUB   UA2 COLLAB.(BERN+CERN+BOHR+HEID+ORSA+PAVI+)
ARNISON  86 PL B TO BE PUB     UA1 COLLAB.(AACH+ANIK+LAPP+BIRM+CERN+HARV+)
```

Z

$J = 1$

MEASUREMENTS OF NEUTRAL WEAK GAUGE BOSON PARAMETERS ARE LISTED HERE. SEE ALSO OTHER STABLE PARTICLE SEARCHES SECTION. SPIN FROM STANDARD MODEL.

Z MASS (GeV)

```
M       5  (95.2)     (2.5)             ARNISON    83 UA1  REPL.BY ARNISON2 83
M       5  (95.6)     (3.2)             ARNISON2   83 UA1  P PBAR ECM=546 GEV
M       4  (91.9)     (1.9)             BAGNAIA    83 UA2  P PBAR ECM=546 GEV
M   A      (85.8)     (7.0)     (5.4)   ARNISON2   84 UA1  P PBAR ECM=546 GEV
M    B  4  (92.7)     (2.2)             BAGNAIA    84 UA2  P PBAR ECM=546 GEV
M    C 13   92.5       2.0              APPEL      86 UA2  P PBAR ECM=546+630
M    D 14   93.0       3.3              ARNISON    86 UA1  P PBAR ECM=546+630
M   A   FROM 4 MU+ MU-, 1 MU+ MU- GAMMA.
M    B  REANALYSIS OF BAGNAIA 83 AFTER RECALIBRATION OF CALORIMETER.
M    B  STAT. (1.7) AND SYST. (1.4) ERRORS ADDED IN QUADRATURE.
M    C  STAT. (1.3) AND SYST. (1.5) ERRORS ADDED IN QUADRATURE.
M    D  STAT. (1.4) AND SYST. (3.0) ERRORS ADDED IN QUADRATURE.
M          . . . . . . . . . .
M   AVG     92.6       1.7      AVERAGE
```

Z WIDTH (GeV)

```
W        4  (10.2)  OR LESS  CL=.90   ARNISON   83 UA1  REPL.BY ARNISON2 83
W        4   (8.5)  OR LESS  CL=.90   ARNISON2  83 UA1  P PBAR ECM=546 GEV
W        4  (11.)   OR LESS  CL=.90   BAGNAIA   83 UA2  P PBAR ECM=546 GEV
W        4   (6.5)  OR LESS  CL=.90   BAGNAIA   84 UA2  P PBAR ECM=546 GEV
W    B   4   (2.6)  OR LESS  CL=.90   BAGNAIA   84 UA2  P PBAR ECM=546 GEV
W       13    4.6   OR LESS  CL=.90   APPEL     86 UA2  P PBAR ECM=546+630
W    C  13   (3.2)  OR LESS  CL=.90   APPEL     86 UA2  P PBAR ECM=546+630
W    C  13   (2.2)     (0.7)    (0.5) APPEL     86 UA2  P PBAR ECM=546+630
W    D  14   (8.3)  OR LESS  CL=.90   ARNISON   86 UA1  P PBAR ECM=546+630
W    B  RATIO OF Z AND W PRODUCTION GIVES Z-WIDTH < W-WIDTH *(0.93+-0.09).
W    B  ASSUMING W-WIDTH = 2.77 GEV, GIVES Z-WIDTH < 2.6+-0.3 GEV.
W    C  RATIO OF Z AND W PRODUCTION GIVES EITHER
W    C    Z-WIDTH < W-WIDTH * (1.2+-0.1)  CL=.90
W    C    Z-WIDTH = W-WIDTH * (0.83+0.26-0.22).
W    C  ASSUMING STD MODEL VALUE W-WIDTH =2.65 GEV THEN GIVES
W    C    Z-WIDTH < (3.2+-0.2)  OR = 2.2+0.7-0.5 WITH SYST. ERROR=0.22.
W    D  IF SYSTEMATIC ERROR IS NEGLECTED, RESULT IS 3.9+2.3-1.5 GEV.
```

Z PARTIAL DECAY MODES

		DECAY MASSES	
P1	$Z \rightarrow e^{+}e^{-}$	.511+.511	
P2	$Z \rightarrow \mu^{+}\mu^{-}$	106+ 106	
P3	$Z \rightarrow e^{+}e^{-}\gamma$	.511+.511+	0
P4	$Z \rightarrow \mu^{+}\mu^{-}\gamma$	106+ 106+	0

Z BRANCHING RATIOS

$Z \rightarrow (e^{+}e^{-})$/total (P1)

```
R1        4   SEEN                      ARNISON   83 UA1  P PBAR ECM=546 GEV
R1    B   8   SEEN                      BAGNAIA   83 UA2  P PBAR ECM=546 GEV
R1       13   SEEN                      APPEL     86 UA2  P PBAR ECM=546+630
R1       16   SEEN                      ARNISON   86 UA1  P PBAR ECM=546+630
R1    B  BAGNAIA 83 INTERPRET THEIR EVENTS AS EITHER (Z-->E+ E-) OR
R1    B  (Z-->E+ E- GAMMA) .
```

$Z \to (\mu^+\mu^-)$/total (P2)

```
R2        1     SEEN                         ARNISON   83 UA1  P PBAR ECM=546 GEV
```

$Z \to (e^+e^-\gamma)$/total (P3)

```
R4        1983 RADIATIVE Z0 DECAY EVENTS (Z0-->E+E-GAMMA, Z0-->MU+MU-GAMMA)
R4        ARE IN EXCESS OF EXPECTED BREMSSTRAHLUNG RATE.  IF
R4        Z0-->X GAMMA WITH X-->E+E-, THE TWO E+E- GAMMA EVENTS GIVE
R4        MX=40-50 GEV. ELECTRON WIDTH OF X ABOUT 1 MEV. SEE ALSO SUBSECTIONS
R4        ON W-->E NU GAM AND ON X HYPOTH IN OTHER STABLE PARTICLE SEARCHES.
R4    A    1 SEEN     IN 4 E+E- EVTS     ARNISON   83 UA1  P PBAR ECM=546 GEV
R4    B    1 SEEN     IN 8 E+E- EVTS     BAGNAIA   83 UA2  P PBAR ECM=546 GEV
R4    C    1 SEEN    IN 13 E+E- EVTS     APPEL     86 UA2  P PBAR ECM=546+630
R4    A   ARNISON 83 EVENT HAS NEGATIVE TRACK OF 9+-1 GEV WITH CALORIMETER
R4    A   DEPOSITION OF 48+-1 GEV. INTERPRETED AS HARD GAMMA PLUS E-.
R4    B   BAGNAIA 83 EVENT HAS 3 BODY TOPOLOGY WITH GAMMA AND E- HIT SEPARATE
R4    B   CELLS.
R4    C   INCLUDES EVT OF BAGNAIA 83.  PROB OF INTERNAL BREM = 19 PERCENT.
```

$Z \to (\mu^+\mu^-\gamma)$/total (P4)

```
R5    A   1     SEEN                         ARNISON   84 UA1  P PBAR ECM=546 GEV
R5        2     SEEN IN 5 MU+MU- EVENTS ARNISON2  84 UA1  P PBAR ECM=546 GEV
R5    A   ARNISON 84 EVENT HAS HARD PHOTON WITH ENERGY FRACTION OF 0.35 AND
R5    A   ANGLE OF 9 DEGREES FROM MU+.  HARD TO INTERPRET AS INTERNAL BREMS.
```

CHARGE ASYMMETRY IN $e^+e^- \to \mu^+\mu^-$ (including rad. corrections)

```
Z0A   A                                      BARTEL    82 JADE ECM=25.-36.8GEV
Z0A   B                                      FERNANDEZ 83 MAC  ECM=29 GEV
Z0A   C                                      ALTHOFF   84 TASS ECM=34.4 GEV
Z0A   D                                      ADEVA     85 MRKJ ECM=14.-46.8 GEV
Z0A   E                                      ASH       85 MAC  ECM=29 GEV
Z0A   F                                      BARTEL    85 JADE ECM=12.-46.  GEV
Z0A   G                                      DERRICK   85 HRS  ECM=29 GEV
Z0A
Z0A   A   BARTEL 82 OBTAINED A=-0.118+-.038 AFTER RAD. COR. AND FOR
Z0A   A   COS(THETA) WITHIN (+-0.8).  CONSISTENT WITH STANDARD MODEL
Z0A   A   PREDICTION A=-0.078).
Z0A
Z0A   B   FERNANDEZ 83 GOT A=-.076+.018-.003.ST.MODEL(INCL.RC) GIVES A=-.060.
Z0A
Z0A   C   ALTHOFF 84 OBTAINED A=-.098+-.023+-.005, SIN(THETA/W)**2=.27+-.07.
Z0A
Z0A   D   ADEVA 85 OBSERVE ASYMMETRY  (STD MODEL) VS S**1/2
Z0A   D                   +5.3+-5.0    (-1.5)       14.0 GEV
Z0A   D                  -11.7+-1.7    (-8.5)       34.6 GEV
Z0A   D                  -16.7+-4.0   (-16.0)       44.6 GEV
Z0A
Z0A   E   ASH 85 OBSERVE -0.063+-0.008+-0.002.  STD MODEL GIVES -0.063
Z0A   E   FROM 16000 EVENTS.
Z0A
Z0A   F   BARTEL 85 OBSERVE ASYMMETRY (STD MODEL) VS S**1/2
Z0A   F                   +2.4+-4.3    (-1.2)       13.9 GEV
Z0A   F               -10.3+-1.6+-0.9  (-7.6)       34.4 GEV
Z0A   F               -17.7+-3.8+-1.6 (-12.5)       42.4 GEV
Z0A
Z0A   G   DERRICK 85 OBSERVE A=-0.049+-0.015+-0.005 CONSISTENT WITH THEORY
Z0A   G   VALUE (WITH RAD. CORR'S) OF 0.059.
```

CHARGE ASYMMETRY IN $e^+e^- \to \tau^+\tau^-$ (including rad. corrections)

```
Z0T   A                                     BARTEL2   85 JADE ECM=30-46.8 GEV
Z0T   A   BARTEL2 85 OBSERVE ASYMMETRY (STD MODEL) VS S**1/2
Z0T   A               -6.0+-2.5+-1.0   (-8.8)       34.6 GEV
Z0T   A              -11.8+-4.6+-1.0  (-14.8)       43.0 GEV
```

REFERENCES FOR Z

```
BARTEL    82 PL 108B 140         JADE C.  (DESY+HAMB+HEID+LANC+MCHS+RL+TOKY)
ARNISON   83 PL 126B 398         UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HELS+LOQM+)
ARNISON2  83 PL 129B 273         UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HELS+LOQM+)
BAGNAIA   83 PL 129B 130         UA2 COLLAB. (BERN+CERN+BOHR+LALO+PAVI+SACL)
FERNANDE  83 PRL 50 1238         + (COLO+FRAS+HOUS+NEAS+STAN+SLAC+UTAH+WISC)
ALTHOFF   84 ZPHY C22 13         TASSO C. (AACH+BONN+DESY+HAMB+LOIC+OXF+RL+)
ARNISON   84 PL 135B 250         UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HELS+LOQM+)
ARNISON2  84 PL 147B 241         UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HARV+HELS+)
BAGNAIA   84 ZPHY C24 1          UA2 COLLAB.(BERN+CERN+BOHR+ORSA+PAVI+SACL+)
ADEVA     85 PRL 55 665          MARK-J C (AACH+BNL+CIT+DESY+MIT+MADR+ANIK+)
     ALSO 82 PRL 48 1701         MARK-J C      (AACH+DESY+MIT+MADR+ANIK+BHEP)
ASH       85 PRL 55 1831         MAC C. (COLO+FRAS+HOUS+NEAS+SLAC+UTAH+WISC)
BARTEL    85 ZPHY C26 507        JADE C.(DESY+HAMB+HEID+LANC+MCHS+UMD+RHEL+)
BARTEL2   85 PL 161B 188         JADE C.(DESY+HAMB+HEID+LANC+MCHS+UMD+RHEL+)
DERRICK   85 PR D31 2352         HRS C.          (ANL+INDI+MICH+PURD+LBL+SLAC)
APPEL     86 ZPHY C TO BE PUB    UA2 COLLAB.(BERN+CERN+BOHR+HEID+ORSA+PAVI+)
ARNISON   86 PL B TO BE PUB      UA1 COLLAB.(AACH+ANIK+LAPP+BIRM+CERN+HARV+)
```

LEPTONS

NOTE ON NEUTRINOS

(by R.E. Shrock, State Univ. of New York, Stony Brook)

With the 1982 edition of this Review, the section on neutrino properties was expanded and reorganized. As before, there are listings which deal specifically with ν_e, ν_μ, and ν_τ. In addition, in the category of searches near the end of the Stable Particle Full Listings, we include sections which deal with correlated bounds on neutrino masses and lepton mixing but which do not pertain to any one weak eigenstate individually. Furthermore, we include constraints from cosmological and astrophysical data. (Since this Review is a compendium of data traditionally derived more or less directly from particle and nuclear physics, we have been somewhat less comprehensive in our coverage of astrophysical data.)

To summarize the current (December 1985) status, there is no undisputed experimental evidence for nonzero neutrino masses or mixing. The ITEP reports of a nonzero $m(\nu_e)$ observed in the decay $^3\mathrm{H} \to {}^3\mathrm{He} + e^- + \bar{\nu}_e$ (LUBIMOV 80, LUBIMOV 83, BORIS 85) remain the only definite claims not directly contradicted by other experiments. However, from independent theoretical analysis of these data, it has been argued (SIMPSON 84, BERKVI1 85, BERKVI2 85) that, contrary to the ITEP claims, the ITEP data do not imply a nonzero value of $m(\nu_e)$.

In contrast to the other particles in this Review, the neutrinos ν_e, ν_μ, and ν_τ are defined as weak eigenstates (that is, states which couple weakly with unit strength to e, ν, and τ) and are not, in general, states of definite mass. In the standard model, where all neutrinos are assumed to be massless and hence degenerate, it is possible to define the weak eigenstates to be simultaneously mass eigenstates. However, in the general case of possibly massive (nondegenerate) neutrinos, the weak eigenstates have no well-defined masses, but instead are linear combinations of mass eigenstates. Let us denote the charged leptons as the set $\{\ell_a\}$, a = 1, $\cdots$, n, where $n \geqslant 3$ is the number of generations, with $\ell_1 \equiv e$, $\ell_2 \equiv \mu$, $\ell_3 \equiv \tau$. In the standard $\mathrm{SU}(2)_L \times U(1)$ electroweak theory[1] the mixing of the left-handed components of the mass eigenstates $(\nu_j)_L$ to form the weak gauge-group eigenstates $(\nu_{\ell_a})_L$ is specified by the transformation

$$(\nu_{\ell_a})_L = \sum_{j=1}^{n} U_{aj}(\nu_j)_L ,$$

where $U^\dagger = U^{-1}$. (In the case of Dirac neutrinos there are right-handed components of the ν_j, but they are singlets under the gauge group; in the case of Majorana neutrinos in the standard theory there are no independent right-handed components.) The ordering of the mass eigenbasis is defined such that U is as nearly diagonal as possible, i.e., $|U_{jj}|$ (no sum on j) $\geqslant |U_{jk}|$, $k \neq j$. This does not imply that $m(\nu_j) > m(\nu_k)$ if $j >$

k, although this ordering might be regarded as natural in view of the similar one that obtains in the quark sector. The virtue of this convention is that a mass limit on "$m(\nu_{\ell_a})$" can be used as a definite limit on ν_j, $j = a$, the dominantly coupled mass eigenstate in ν_{ℓ_a}.

Thus, in this general case of n possibly massive (Dirac or Majorana) neutrinos, decays such as ${}^3\text{H} \rightarrow {}^3\text{He} + e^- + \overline{\nu}_e$ and $\pi^+ \rightarrow \mu^+ + \nu_\mu$, which have been used to set the best bounds on the respective neutrino masses, really consist of incoherent sums of the separate decay modes ${}^3\text{H} \rightarrow {}^3\text{He} + e^- + \overline{\nu}_j$ and $\pi^+ \rightarrow \mu^+ + \nu_k$, where the ν_j, ν_k are mass eigenstates, and the indices j and k range over the subset $\{1, \cdots, n\}$ allowed by phase space in these two respective decays.[2] The coupling strengths for the j^{th} modes are given for the two decays by the factors $|U_{1j}|^2$ and $|U_{2j}|^2$, respectively. There are, in addition, certain kinematic factors depending on the $m(\nu_j)$ which enter in determining the branching ratio for the j^{th} decay mode. Assuming that the off-diagonal elements of the lepton mixing matrix U are small relative to the diagonal elements, the dominantly coupled decays are the ones with coupling strength $|U_{aj}|^2$, $a = j$, i.e., ${}^3\text{H} \rightarrow {}^3\text{He} + e^- + \overline{\nu}_1$ and $\pi^+ \rightarrow \mu^+ + \nu_2$.

It follows that the old neutrino mass limits quoted in the literature for "$m(\nu_e)$", "$m(\nu_\mu)$" and "$m(\nu_\tau)$" are meaningful only insofar as they are reinterpreted as limits on the corresponding mass eigenstates. Specifically, a bound such as the Bergkvist limit,[3] "$m(\nu_e)$" < 60 eV (90% CL), really constitutes a weighted limit on each of the mass eigenstates ν_j in the weak eigenstate ν_e which are kinematically allowed to occur in tritium decay and which are coupled with strength $|U_{1j}|^2$ sufficiently large to make a significant contribution to the observed spectrum. It is thus certainly a limit on ν_1. If leptonic mixing is hierarchical as quark mixing is known to be (at least for the first three generations), i.e., $|U_{jj}|^2 >> |U_{jk}|^2$, $j \neq k$, then ν_1 is the only mass eigenstate significantly constrained by a bound on "$m(\nu_e)$." Furthermore, a neutrino mass limit cannot be stated in isolation; it always contains some implicit dependence on the relevant lepton mixing angles. Fortunately, this dependence is relatively unimportant for the dominantly coupled decay modes, i.e., $e\overline{\nu}_1$, $\mu\overline{\nu}_2$, and $\tau\overline{\nu}_3$. Since these modes were the ones responsible for the mass limits given previously, the latter can be reinterpreted without significant complication as proper limits on $m(\nu_j)$, $j = 1$, 2, and 3, respectively.

In addition to mass and lifetime limits, we have added data on neutrino magnetic dipole moments. These are of interest because a massless, purely chiral (empirically, left-handed) Dirac neutrino cannot have a magnetic (or electric) dipole moment. The same is true for a Majorana neutrino, whether massless or massive, because of its defining property of being self-conjugate.

If one considers the possibility of nonzero masses for neutrinos, for consistency one must also consider the leptonic mixing which would in general occur concomitantly. Accordingly we have devoted one category in the searches section to correlated bounds on neutrino masses and lepton mixing angles. These can be divided into two types. First, there are those due to decays involving neutrinos in the final state, which must be recognized to have the possible multimode structure pointed out above. In the two most sensitive cases suggested as tests for neutrino masses and mixing,[2] one obtains a limit on $m(\nu_j)$ and $|U_{aj}|^2$ individually for each j. Second, there are those due to processes involving the propagation and subsequent interaction of neutrinos. The latter are often called neutrino "oscillation"[3] limits, although this term is correct only if the differences in neutrino masses are sufficiently small relative to their momenta that the propagation is effectively coherent in a quantum mechanical sense; otherwise, the individual ν_j from a given decay such as $\pi_{\mu 2}$ or $K_{\mu 2}$ propagate in a measurably incoherent manner and there is no "oscillation." Experimentalists usually present their results in terms of a simplifying model in which mixing is assumed to occur only between two neutrino species. Then the transformation equation becomes

$$\begin{pmatrix} \nu_{\ell_a} \\ \nu_{\ell_b} \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} \nu_i \\ \nu_j \end{pmatrix}$$

Let the distance between the source of the neutrinos and their point of interaction be labeled as x, and their energy as E. Assume furthermore that the $m(\nu_j)$ are such that the coherence assumption is valid. Then, the probability of an initial ν_{ℓ_a} being equal to ν_{ℓ_b} at time t, or equivalently (given the above assumption) at distance $x = t$, is

$$|\langle \nu_{\ell_b}(0) | \nu_{\ell_a}(t) \rangle|^2 = \sin^2 2\theta \sin^2 \left(\frac{\Delta m^2 x}{4E} \right) ,$$

where

$$\Delta m^2 = m(\nu_i)^2 - m(\nu_j)^2 .$$

Thus, neutrino oscillation experiments cannot measure individual neutrino masses, but only differences of masses squared, and indeed these are generally weighted in a more complicated way by mixing-matrix coefficients than in the two-species model. Experimental results are presented as allowed regions on a plot, the axes of which are $|\Delta m^2|$ and $\sin^2 2\theta$. These are often summarized in terms of the asymptotic limits $|\Delta m^2|_{\max}$ for $\sin^2 2\theta = 1$, and $\sin^2 2\theta$ for "large" $|\Delta m^2|$, i.e., sufficiently large $|\Delta m^2|$ that the detector averages over many cycles of oscillation (or there ceases to be any coherence). We refer the reader to the original papers for the two-dimensional plots; for the purpose of these Full Listings, we shall give only the asymptotic limits.

An important question has to do with whether neutrinos are Dirac or Majorana (self-conjugate) particles. In the former case neutrinoless double beta decay, (Z,A) → $(Z+2, A) + e^- + e^-$, is forbidden from occurring.[4] In the Majorana case it may occur if (a) neutrinos are massive and/or (b) there are right-handed leptonic currents. In the light-neutrino case an upper limit on neutrinoless double beta decay yields a correlated upper bound on the quantity

$$\bar{m} \equiv \left| \sum_{j=1}^{n} U_{1j}^2 \, m(\nu_j) \right|$$

and η, the fractional admixture of right-handed leptonic current.

The correlated limits given in the section on Massive Neutrinos and Lepton Mixing are in digital form. For recent compendia of limits in convenient graphical form, see Refs. 5 and 6, and Figs. 1 and 2 (pp. 332-333) of Ref. 7.

Further explanatory notes are included in the Full Listings.

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$\boxed{\nu_e}$ $J=\frac{1}{2}$

NOT IN GENERAL A MASS EIGENSTATE

ν_e "MASS" (eV)

APPLIES TO NU(1), THE PRIMARY MASS EIGENSTATE IN NU(E). WOULD ALSO APPLY TO ANY OTHER NU(J) WHICH MIXES STRONGLY IN NU(E) AND HAS SUFFICIENTLY SMALL MASS THAT IT CAN OCCUR IN THE RESPECTIVE DECAYS. THE NEUTRINO MASS MAY BE OF DIRAC OR MAJORANA TYPE; THE FORMER CONSERVES TOTAL LEPTON NUMBER WHILE THE LATTER VIOLATES IT.
IN GENERAL, EITHER WOULD VIOLATE LEPTON FAMILY NUMBER, SINCE NOTHING FORCES THE NEUTRINO MASS EIGENSTATES TO COINCIDE WITH THE NEUTRINO INTERACTION EIGENSTATES. FOR LIMITS ON MAJORANA NU(E) MASS, SEE THE SECTION ON MASSIVE NEUTRINOS AND LEPTON MIXING, PART 5(C), ENTITLED SEARCHES FOR NEUTRINOLESS DOUBLE BETA DECAY.

NOTE -- THE ABBREVIATION ANU IS USED BELOW FOR NUBAR

```
M         (250.)    OR LESS              LANGER    52 CNTR    ANU(E), TRITIUM
M         (500.)    OR LESS              HAMILTON  53 CNTR    ANU(E), TRITIUM
M         (550.)    (280.)               FRIEDMAN  58 CNTR    ANU(E), TRITIUM
M        (4100.)    OR LESS   CL=.67     BECK      68 CNTR    NU, SODIUM 22
M  D      (500.)    OR LESS   CL=.90     DARIS     69 CNTR    ANU(E), TRITIUM
M         (320.)    OR LESS   CL=.90     SALGO     69 CNTR    ANU(E), TRITIUM
M          (60.)    OR LESS   CL=.90     BERGKVIS  72 CNTR    ANU(E), TRITIUM
M          (86.)    OR LESS   CL=.90     RODE      72 CNTR    ANU(E), TRITIUM
M         (100.)    OR LESS              PIEL      73 CNTR    ANU(E), TRITIUM
M          (4.5E5)OR LESS     CL=.90     CLARK     74 ASPK    KE3 DECAY
M    L     (35.)    OR LESS   CL=.90     TRETYAKOV 76 SPEC    ANU(E), TRITIUM
M    L     (14.)  TO 46.      CL=.99     LUBIMOV   80 SPEC    ANU(E), TRITIUM
M          (65.)    OR LESS   CL=.95     SIMPSON   81 CNTR    ANU(E), TRITIUM
M        (1300.)    OR LESS              ANDERSEN  82 CNTR    NU, HOLMIUM 163
M          (50.)    OR LESS   CL=.90     DERBIN    83 CNTR    ANU(E), TRITIUM
M         (500.)    OR LESS   CL=.90     JONSON    83 CNTR    NU, PLATINUM 193
M   P      (20.)    OR MORE   CL=.95     LUBIMOV   83 CNTR    ANU(E), TRITIUM
M   Y    (1250.)    OR LESS              YASUMI    83 CNTR    NU, HOLMIUM 163
M   B      (20.)  TO 45.      NO CL      BORIS     85 CNTR    ANU(E), TRITIUM
M  D    DARIS 69 VALUE 75EV(CL=.67) DISAGREES WITH THEIR FIG.6. WE USE
M  D    FIG.6.
M    L  TRETYAKOV 76 DATA INCLUDED, AT LEAST IN PART, IN LUBIMOV 80.
M    L  NOTE THAT LUBIMOV 83 REMARKS THAT THE 14 EV LOWER LIMIT GOES TO
M    L  ZERO IF THE INTRINSIC RESOLUTION OF THE CONVERSION LINES USED FOR
M    L  CALIBRATION ARE TAKEN INTO ACCOUNT.  A DETAILED DISCUSSION IS GIVEN
M    L  BY SIMPSON 84.  SEE ALSO THE DISCUSSION OF THE LUBIMOV 80 RESULT
M    L  BY BERGKVIST 80.  WE CONTINUE TO USE UPPER LIMIT FROM LUBIMOV 80
M    L  IN THE STABLE PARTICLE SUMMARY TABLE.
M   Y   LIMIT OBTAINED BY YASUMI 83 ASSUMES UPPER LIMIT ON Q-VALUE
M   Y   REPORTED BY ANDERSEN 82.
M   P  PRELIMINARY RESULT FROM BRIGHTON CONF.  SEE SIMPSON 84 AND BERGKVI1
M   P  WHOSE INDEPENDENT THEORETICAL ANALYSES OF LUMIMOV 83 DATA DISAGREE
M   P  WITH LUBIMOV 83 CLAIM OF NONZERO MASS.
M   B  INDEPENDENT THEORETICAL ANALYSIS BY BERGKVI2 85 OF BORIS 85 DATA
M   B  (LUBIMOV DATA) DISAGREES WITH BORIS 85 CLAIM OF NONZERO MASS.
```

$\nu_1 - \overline{\nu}_1$ MASS DIFFERENCE (eV)

```
      TEST OF CPT FOR A DIRAC NU (NOT A VERY STRONG TEST)

DM          (4100.)    OR LESS  CL=.67   BECK       68 CNTR     NU, SODIUM 22
DM             (4.5E5)OR LESS  CL=.90   CLARK      74 ASPK     KE3 DECAY
DM          (1300.)    OR LESS           ANDERSEN   82 CNTR     NU, HOLMIUM 163
DM    Y       1250.    OR LESS           YASUMI     83 CNTR     NU, HOLMIUM 163
DM    Y   ASSUMES UPPER LIMIT ON Q-VALUE REPORTED BY ANDERSEN 82.
```

ν_1(MEAN LIFE)/MASS (sec/eV)

```
T     R       3. E 2  OR MORE             REINES    74 CNTR    NUBAR
T     R   REINES 74 LOOKED FOR NU(E) OF NON-ZERO MASS DECAYING TO A NEUTRAL
T     R   OF LESSER MASS + GAMMA.  USED LIQUID SCINT. DETECTOR NEAR FISSION
T     R   REACTOR.  FINDS LAB LIFETIME 6.E7 SEC OR MORE.  ABOVE VALUE OF
T     R   (MEAN LIFE)/MASS ASSUMES AVG. EFFECTIVE NEUTRINO ENERGY OF 0.2MEV.
T     R   TO OBTAIN THE LIMIT 6.E7 SEC REINES 74 ASSUMED THAT THE FULL
T     R   NUBAR(E) REACTOR FLUX COULD BE RESPONSIBLE FOR YIELDING DECAYS
T     R   WITH PHOTON ENERGIES IN THE INTERVAL 0.1 MEV TO 0.5 MEV.  THIS
T     R   REPRESENTS SOME OVERESTIMATE SO THEIR LOWER LIMIT IS AN OVER-
T     R   ESTIMATE OF THE LAB LIFETIME (P. VOGEL, PRIV. COMM., 1984).
```

ν_1 MAGNETIC MOMENT (eV/gauss)

```
      MUST VANISH FOR MAJORANA NEUTRINO OR PURELY CHIRAL MASSLESS
      DIRAC NEUTRINO

MM  B      (1.1E-17)OR LESS             BERNSTEIN 63
MM  B   BERNSTEIN 63 IS A THEORETICAL ANALYSIS OF REACTOR NUBAR(E)
MM  B   SCATTERING DATA.
```

REFERENCES FOR ν_e

```
LANGER   52 PR  88  689          L M LANGER,R J D MOFFAT              (INDIANA)
HAMILTON 53 PR  92  1521         D HAMILTON,W P ALFORD,L GROSS   (PRINCETON)
FRIEDMAN 58 PR 109  2214         LEWIS FRIEDMAN,LINCOLN G SMITH           (BNL)
BERNSTEI 63 PR 132 1227          BERNSTEIN,RUDERMAN,FEINBERG        (NYU+COLU)
BECK     68 ZPHY 216 229         E BECK,H DANIEL                         (MPIH)
DARIS    69 NP A138 545          R DARIS,C ST-PIERRE              (LAVAL-QUEBEC)
SALGO    69 NP A138 417          R C SALGO,H H STAUB                   (ZURICH)

BERGKVIS 72 NP B39 317           KARL-ERIK BERGKVIST          (UNIV STOCKHOLM)
RODE     72 LNC 5 139            B RODE,H DANIEL                  (MUNICH+MPIH)
PIEL     73 NP A203 369          WILLIAM F. PIEL, JR.                     (IND)
CLARK    74 PR. D9 533           +ELIOFF,FRISCH,JOHNSON,KERTH,SHEN+      (LBL)
REINES   74 PRL 32 180           +SOBEL,GURR                              (UCI)
    ALSO 78  PRIVATE COMM.       V. BARNES                               (PURD)

TRETYAKO 76 BASUP 40 10-1        TRETYAKOV+                              (ITEP)
    ALSO 76 NU CONF. AACHEN      TRETYAKOV,MYASODEDOV,APALIKOV,KONYAEV+(ITEP)
BERGKVIS. 80 NEUTRINO 80,ERICE K.E.BERGKVIST                            (STOH)
LUBIMOV  80 PL 94B 266           +NOVIKOV,NOZIK,TRETYAKOV,KOSIK          (ITEP)
    ALSO 80 SJNP 32 154          (YF 32 301) KOZIK,LUBIMOV,NOVIKOV,+   (ITEP)
    ALSO 81 JETP 54 616          (ZETF 81 1158) LUBIMOV,NOVIKOV,NOZIK+(ITEP)
SIMPSON  81 PR D23 649           J.J.SIMPSON                             (GUEL)

ANDERSEN 82 PL 113B 72           +BEYER,CHARPAK,DERUJULA +  (AARH+CERN+RISO)
DERBIN   83 SJNP 38 665          DERBIN,POPEKO                      (LENINGRAD)
JONSON   83 NP A396 479C         +ANDERSEN,BEYER+       (CERN+AARH+BOHR+LUND)
LUBIMOV  83 BRIGHTON CONF.       PROC. OF HEP 83, P. 386                 (ITEP)
YASUMI   83 PL 122B 461          +RAJASEKARAN,ANDO+(KEK+OSAK+TINT+TOHO+TSUK)
SIMPSON  84 PR D30 1110           J.J. SIMPSON                           (GUEL)

BERGKVI1 85 PL 154B 224           K.E. BERGKVIST                         (STOH)
BERGKVI2 85 PL 159B 408           K.E. BERGKVIST                         (STOH)
BORIS    85 PL 159B 217           +GOLUTVIN,LAPTIN,LUBIMOV,+             (ITEP)
    ALSO 85 JETPL 42 130          BORIS,GOLUTVIN,LAPTIN,LUBIMOV,+        (ITEP)
```

$\boxed{e}$

$J = \frac{1}{2}$

e MASS (MeV)

```
M         (0.511006 0.00002)          COHEN      65 RVUE
M         (0.5110041 .0000016)        TAYLOR     69 RVUE     USING NEW E/H
M          0.5110034 .0000014         COHEN      73 RVUE
```

e MEAN LIFE / BRANCHING FRACTION (years)

```
                        TEST OF CHARGE CONSERVATION

T   MS      (2. E21) OR MORE              MOE        65 CNTR     SEE NOTE S BELOW
T           (4. E22) OR MORE              MOE        65 CNTR     E- --> NU GAMMA
T     S     (5.3E21) OR MORE              STEINBERG  75 CNTR     SEE NOTE S BELOW
T     S       2. E22   OR MORE  CL=.68    KOVALCHUK  79 CNTR     SEE NOTE S BELOW
T           (3.5E23) OR MORE  CL=.68      KOVALCHUK  79 CNTR     E- --> NU GAMMA
T           (3. E23) OR MORE  CL=.68      BELLOTTI   83 CNTR     E- --> NU GAMMA
T     B       2. E22   OR MORE  CL=.68    BELLOTTI   83 CNTR     SEE NOTE B BELOW
T   M   SEE MOE 65 FOR DISCUSSION OF EARLIER EXPERIMENTS.
T   M   MOE 65 LIMIT REESTIMATED BY STEINBERG 75 TO BE (1. E20).
T     S   THESE LIMITS ARE FOR ALL MODES IN WHICH DECAY PARTICLES ESCAPE
T     S   FROM THE DETECTOR WITHOUT DEPOSITING ENERGY.
T     B   SECOND LIMIT OF BELLOTTI 83 IS FOR DISAPPEARANCE OF K-ELECTRONS IN
T     B   GE-ATOMS. THIS WOULD PRODUCE A PEAK IN THE GE(LI) COUNTER SPECTRUM.
```

e MAGNETIC MOMENT $(e/2m_e)$

```
MM      ELECTRON OR POSITRON G/2-VALUE
MM       THIS IS MAGNETIC MOMENT IN UNITS (E/2ME-) FOR E-, (E/2ME+) FOR E+.
MM       FOR REVIEWS OF THEORY AND EXPERIMENTS, SEE KINOSHIA 78, LAUTRUP 72,
MM       AND RICH 72.
MM       FOR MOST ACCURATE THEORETICAL CALCULATION, SEE KINOSHITA 81.
MM         (1.0011609)    +-(24)E-7      SCHUPP    61 CNTR  -
MM         (1.001159622) +-(27)E-9       WILKINSON 63 CNTR -
MM         (1.001168)     +-(22)E-6      RICH      66 CNTR +  POSITRON
MM R       (1.001159557) +-(30)E-9       RICH      68 CNTR -
MM         (1.0011596389)+-(31)E-10      TAYLOR    69 RVUE
MM         (1.001159644) +-(7)E-9        WESLEY    70 CNTR
MM         (1.0011596577)+-(35)E-10      WESLEY    71 CNTR -
MM         (1.0011603)    +-(12)E-7      GILLELAND 72 CNTR +
MM         (1.0011596567)+-(35)E-10      COHEN     73 RVUE
MM         (1.001159667) +-(24)E-9       WALLS     73 CNTR -  BOLOMETRIC TECHN
MM         (1.00115965241)+-(20)E-11     VANDYCK   77 CNTR -  RPL.BY VANDYCK79
MM V        1.001159652200+-(40)E-12     VANDYCK   79 CNTR -  PENNING TRAP
MM          1.001159652222+-(50)E-12     SCHWINBER 81 CNTR +  PENNING TRAP
MM R     RICH 68 IS REEVALUATION OF WILKINSON 63.
MM V     VANDYCK 79 CONFIRMED FINAL BY H. DEHMELT, PRIV. COMM.
MM         . . . . . . . . . . . . . .
MM  AVG    1.001159652209+-(31)E-12 AVERAGE                                  |
MM      AVERAGE ASSUMING EQUAL G/2-VALUES FOR E+ AND E- BY CPT.

MMR     POSITRON/ELECTRON G-FACTOR RATIO MINUS ONE, (G+/G-)-1
MMR      TEST OF CPT
MMR         (1.6E-8) OR LESS  CL=.95    SEREDNYAK 77 CNTR ME+=ME- ASSUMED
MMR           2.2E-11  6.4E-11          SCHWINBER 81 ELEC    PENNING TRAP
```

e ELECTRIC DIPOLE MOMENT (units 10^{-23} e-cm)

```
                 FORBIDDEN BY BOTH T INVARIANCE AND P INVARIANCE

EDM             0.3   OR LESS  CL=.90   WEISSKOPF 68 MRS     CESIUM
EDM            (0.07)    (0.22) CL=.90  PLAYER    70 MRS     XENON
EDM            (0.19)    (0.34) CL=.90  SANDARS   75 MRS     THALLIUM
EDM            (8.1)    (11.6)          VASILEV   78
EDM            (0.4)     (1.4)          FLAMBAUM  85 THEO    USE EDM OF  129XE  |
```

REFERENCES FOR e

```
SCHUPP   61 PR  121   1          A A SCHUPP,R W PIDD,H R CRANE          (MICH)
WILKINSO 63 PR 130 852           D T WILKINSON,H R CRANE                 (MICH)
COHEN    65 RMP 37 537           COHEN,DUMOND  (N.A.AVIATION SCI.CENTER+CIT)
MOE      65 PR 140 B 992         M K MOE,F REINES     (CASE INST TECHNOLOGY)

RICH     66 PRL  17  271         A RICH, H R CRANE                       (MICH)
RICH     68 PRL 20 967           A RICH                                  (MICH)
WEISSKOP 68 PRL 21 1645          WEISSKOPF,CARRICO,GOULD,LIPWORTH+     (BRAN)
TAYLOR   69 RMP 41 375           +PARKER,LANGENBERG              (PRIN+UCI+PENN)

PLAYER   70 JPB 3 1620           M.A.PLAYER,P.G.H.SANDARS                 (OXF)
WESLEY   70 PRL 24 1320          J C WESLEY,A.RICH                       (MICH)
WESLEY   71 PR A4 1341           J C WESLEY,A RICH                       (MICH)
GILLELAN 72 PR A5 38             J GILLELAND,A RICH                      (MICH)
LAUTRUP  72 PRPL 3 193           B.LAUTRUP,A.PETERMAN,E.DE RAFAEL(CERN+BURE)
RICH     72 RMP 44 250           A RICH,J C WESLEY                       (MICH)

COHEN    73 J.PHYS.CHEM.REF.DATA 2, P.663, E.R.COHEN,B.N.TAYLOR
WALLS    73 PRL 31 975           F.L.WALLS,T.S.STEIN                     (WASH)
SANDARS  75 PR A11 473           P.G.H.SANDARS,R.M.STERNHEIMER      (OXF+BNL)
STEINBER 75 PR D12 2582          R.I.STEINBERG,KWIATKOWSKI,MAENHAUT+    (UMD)
SEREDNYA 77 PL 66B 102           SEREDNYAKOV,SIDOROV,SKRINSKY+          (NOVO)
VANDYCK  77 PRL 38 310           +SCHWINBERG,DEHMELT                     (WASH)
KINOSHIT 78  TOKYO HEP P.571     T. KINOSHITA                            (CORN)

VASILEV  78 JETP 47 243          +KOLYCHEVA                              (JINR)
KOVALCHU 79 JETPL 29 145         KOVALCHUK,POMANSKY,SMOLNIKOV            (INRM)
VANDYCK  79 BAPS 24 758          +SCHWINBERG,DEHMELT                     (WASH)
    ALSO 81 AT.PHYS. 7, P.337 H.DEHMELT(EDS.KLEPPNER+,PLENUM,NY,81)(WASH)
KINOSHIT 81 PRL 47 1573          T.KINOSHITA, W.B.LINDQUIST              (CORN)
SCHWINBE 81 PRL 47 1679          SCHWINBERG,VAN DYCK,DEHMELT             (WASH)
BELLOTTI 83 PL 124B 435          +CORTI,FIORINI,LIGUORI,PULLIA+          (MILA)
FLAMBAUM 85 JETP 62? TOBE PUB FLAMBAUM,KHRIPLOVICH                       (NOVO)
```

$\boxed{\nu_\mu}$

$J = \frac{1}{2}$

```
        NOT IN GENERAL A MASS EIGENSTATE.  SEE NOTE ON NEUTRINOS
        IN THE ELECTRON NEUTRINO SECTION ABOVE.
```

ν_μ "MASS" (MeV)

```
      APPLIES TO NU(2), THE PRIMARY MASS EIGENSTATE IN NU(MU).  WOULD ALSO
      APPLY TO ANY OTHER NU(J) WHICH MIXES STRONGLY IN NU(MU) AND HAS
      SUFFICIENTLY SMALL MASS THAT IT CAN OCCUR IN THE RESPECTIVE DECAYS.
      (THIS WOULD BE NONTRIVIAL ONLY FOR J .GE. 3, GIVEN THE NU(E)
      ''MASS'' LIMIT ABOVE.)

M              (3.5)  OR LESS             BARKAS    56 EMUL
M              (4.0)  OR LESS             DUDZIAK   59 CNTR
M              (3.6)  OR LESS             FEINBERG  63 RVUE
M              (3.0)  OR LESS             ALLCOCK   65 RVUE
M              (2.5)  OR LESS             BARDON    65 ASPK
M              (2.8)  OR LESS  CL=.90     SHAFER    65 CNTR
M              (1.6)  OR LESS  CL=.90     BOOTH     67 CNTR
M              (2.2)  OR LESS  CL=.90     HYMAN     67 HEBC     0. K- HE
M   B M        (1.2)  OR LESS  CL=.90     BACKENSTO 71 CNTR     M**2=-1.28+-1.24
M   S          (1.15) OR LESS  CL=.90     SHRUM     71 CNTR     M**2=-1.55+-1.14
M   B M        (1.15) OR LESS  CL=.90     BACKENSTO 73 CNTR     M**2=-0.29+-0.90
M              (0.65) OR LESS  CL=.90     CLARK     74 ASPK     KMU3 DECAY
M              (0.57) OR LESS  CL=.90     DAUM      79 SPEC     M**2= 0.13+-0.14
M     L        (0.52) OR LESS  CL=.90     LU        80 CNTR     M**2=0.102+-.119
M              (0.50) OR LESS  CL=.90     ANDERHUB  82 SPEC     M**2=-0.14+-0.20
M     A         0.25  OR LESS  CL=.90     ABELA     84 SPEC     M**2=-0.16+-0.08  |
M     M  WE CALCULATE UPPER LIMIT AT CL=.90 FROM M**2.
M   B    BACKENSTOSS 73 REPLACES BACKENSTOSS 71 AND USES THEIR NEW PI- MASS.
M   S    SHRUM 71 USES SHAFER 67 PI- MASS VALUE AND CRANE 71 MU MASS VALUE.
```

```
M     L  LU 80 COMBINES DAUM 79 PI+ --> MU+ NU(MU) MEASUREMENT WITH NEW LU80
M     L  PI- MASS AND REPLACES DAUM 79.
M     A  ABELA 84 USE PDG84 VALUE FOR PI+- MASS, IN CONJUNCTION WITH  MU      |
M     A  MOMENTUM MEASUREMENT IN PI -> MU NU(MU) DECAY.                       |
```

$\nu_2 - \overline{\nu}_2$ MASS DIFFERENCE (MeV)

```
      TEST OF CPT FOR A DIRAC NEUTRINO (NOT A VERY STRONG TEST)

DM          (0.45) OR LESS  CL=.90   CLARK     74 ASPK KMU3 DECAY
```

ν_2(MEAN LIFE)/MASS (sec/eV)

```
T     B   0 (3. E-3) OR MORE  CL=.90   BELLOTTI  76 HLBC NU, CERN GGM
T     B   1 (1.3E-2) OR MORE  CL=.90   BELLOTTI  76 HLBC NUBAR, CERN GGM
T     B   0 (2.2E-3) OR MORE  CL=.90   BARNES    77 DBC  NU, ANL 12FT.
T     B   0 (1.0E-2) OR MORE  CL=.90   BLIETSCHA 78 HLBC NU(MU) CERN GGM
T     B   0 (1.7E-2) OR MORE  CL=.90   BLIETSCHA 78 HLBC NUBAR(MU)U CERN GGM
T     B   0    0.11  OR MORE  CL=.90   FRANK     81 CNTR NU, NUBAR LAMPF
T     B  THESE EXPERIMENTS LOOK FOR NU(MU) --> NU(E)+GAMMA OR NUBAR(MU) -->
T     B  ANU(E)+GAMMA.
```

$\left|\frac{v-c}{c}\right|$ ($v\equiv\nu_2$ VELOCITY) (units 10^{-4})

```
                         EXPECTED TO BE ZERO FOR MASSLESS NEUTRINO

V       77    (2.0)  OR LESS  CL=.99   ALSPECTOR 76 SPEC >50GEV NU
V       26    (4.0)  OR LESS  CL=.99   ALSPECTOR 76 SPEC <50GEV NU
V     9800    (0.4)  OR LESS  CL=.95   KALBFLEIS 79 SPEC
```

ν_2 MAGNETIC MOMENT (eV/gauss)

```
      MUST VANISH FOR MAJORANA NEUTRINO OR PURELY CHIRAL MASSLESS
      DIRAC NEUTRINO

MM   K     (4.7 E-17)OR LESS           KIM       74
MM   K   KIM 74 IS A THEORETICAL ANALYSIS OF NUBAR(MU) REACTION DATA.
```

REFERENCES FOR ν_μ

```
BARKAS   56 PR 101  778          W H BARKAS,W BIRNBAUM,F M SMITH        (LRL)
DUDZIAK  59 PR 114  336          W F DUDZIAK,R SAGANE,J VEDDER          (LRL)
FEINBERG 63 ARNS 13 431          G FEINBERG, L M LEDERMAN          (COLUMBIA)
ALLCOCK  65 PPSL  85  875        G R ALLCOCK                      (LIVERPOOL)
BARDON   65 PRL  14 449          BARDON,NORTON,PEOPLES +  (COLU+STONY BROOK)

SHAFER   65 PRL  14 923          R E SHAFER,CROWE,JENKINS               (LRL)
BOOTH    67 PL 26B  39           BOOTH,JOHNSON,WILLIAMS,WORMALD  (LIVERPOOL)
HYMAN    67 PL 25B 376           +LOKEN,PEWITT,MCKENZIE+     (ANL+CARN+NWES)
BACKENST 71 PL 36B 403           BACKENSTOSS,DANIEL,KOCH+   (CERN,KARL,HEID)
SHRUM    71 PL 37B 114           E V SHRUM,K O H ZIOCK    (UNIV OF VIRGINIA)
BACKENST 73 PL 43B 539           BACKENSTOSS,DANIEL,KOCH+ (CERN+KARL+MUNICH)

CLARK    74 PR D9 533            +ELIOFF,FRISCH,JOHNSON,KERTH,SHEN +   (LBL)
KIM      74 PR D9 3050           J.E.KIM,V.S.MATHER,S.OKUBO           (ROCH)
ALSPECTO 76 PRL 36 837           ALSPECTOR +          (BNL+PURD+CIT+FNAL+ROCK)
BELLOTTI 76 LNC 17 553           +CAVALLI,FIORINI,ROLLIER              (MILA)
BARNES   77 PRL 38 1049          +CARMONY,DAUWE,FERNANDEZ +        (PURD+ANL)
BLIETSCH 78 NP B133 205          BLIETSCHAU+(AACH+LIBH+CERN+EPOL+MILA+ORSA+)

KALBFLEI 79 PRL 43 1361          KALBFLEISCH,BAGGETT,FOWLER+(FNAL+PURD+BELL)
DAUM     79 PR D20 2692          +EATON,FROSCH,HIRSCHMANN,MCCULLOCH+   (SIN)
    ALSO 76 PL 60B 380           DAUM,DUBAL,EATON,FROSCH,MCCULLOCH+(SIN+ETH)
    ALSO 78 PL 74B 126           DAUM,EATON,FROSCH,HIRSCHMANN,+        (SIN)
LU       80 PRL 45 1066          +DELKER,DUGAN,WU,CAFFREY+   (YALE+COLU+JHU)
FRANK    81 PR D24 2001          +BURMAN+ (LASL+YALE+MIT+SACL+SIN+CNRC+BERN)
ANDERHUB 82 PL 114B 76           +BOECKLIN,HOFER,KOTTMANN+         (ETH+SIN)
ABELA    84 PL 146B 431          +DAUM,EATON,FROSCH,JOST,KETTLE+       (SIN)
```

$\boxed{\mu}$

$J = \frac{1}{2}$

μ MASS (MeV)

```
M          (105.659)  (0.002)          FEINBERG  63 RVUE
M          (105.6599) (0.0014)         TAYLOR    69 RVUE    USING NEW E/H
M     C    (105.6597) (0.0005)         CRANE     71 CNTR INCLUDED IN COHEN73
M     D    (105.6594) (0.0004)         CROWE     72 CNTR INCLUDED IN COHEN73
M          (105.65948)(0.00035)        COHEN     73 RVUE
M     A    (105.65945)(0.00033)        CASPERSON 77 CNTR +
M     K    (105.65933)(0.00029)        KLEMPT    82 CNTR + INCL IN MARIAM 82
M     M     105.65928  0.00029         MARIAM    82 CNTR +
M     C  CRANE 71 GIVES MU/ME=206.76878(85).  WE USE ME=.5110041(16)MEV.
M     D  CROWE 72 GIVES MU/ME=206.7682(5) AND USES ME=.5110041(16)MEV.
M     A  CASPERSON 77 GIVES MU/ME=206.76859(29).  WE USE ME=.5110034(14)MEV.
M     K  KLEMPT 82 GIVES MU/ME=206.76835(11).  WE USE ME=.5110034(14)MEV.
M     M  MARIAM 82 GIVES MMU/ME=206.768259(62). WE USE ME=.5110034(14)MEV.
M           . . . . . . . . . . .
M    FIT    105.65916  0.00030 FROM FIT (ERROR INCL. SCALE FACTOR 1.1)       |
```

μ MEAN LIFE (μsec)

```
T          2.198    0.001    0.001   FARLEY    62 CNTR
T          2.203    0.004            LUNDY     62 CNTR    CONLEV=.98
T          2.202    0.003    0.003   ECKHAUSE  63 CNTR
T          2.197    0.005    0.002   MEYER     63 CNTR +
T          2.198    0.002    0.002   MEYER     63 CNTR -
T    W    (2.20026)(0.00081)         WILLIAMS  72 CNTR +
T          2.1973   0.0003           DUCLOS    73 CNTR +
T          2.19711  0.00008          BALANDIN  74 CNTR +
T          2.1948   0.0010           BAILEY2   77 CNTR -  STORAGE RINGS
T          2.1966   0.0020           BAILEY2   77 CNTR +  STORAGE RINGS
T         (2.197182 0.000121)        BARDIN    81 CNTR REPL. BY BARDIN 84
T          2.197078 0.000073         BARDIN    84 CNTR +
T          2.197025 0.000155         BARDIN    84 CNTR -
T          2.19695  0.00006          GIOVANETT 84 CNTR +                     |
T    W   WILLIAMS 72 MEAN LIFE MEASUREMENT WAS NOT THE PRIMARY PURPOSE OF
T    W   THEIR EXPERIMENT AND DISAGREES STRONGLY WITH LATER EXPTS. NOT AVGD.
T          . . . . . . . . . . .
T    AVG   2.197033 0.000039 0.000038 AVERAGE
```

μ^+/μ^- MEAN LIFE RATIO

```
DT       TEST OF CPT
DT         1.000    0.001            MEYER     63 CNTR  MEAN LIFE MU+/MU-
DT         1.0008   0.0010           BAILEY    79 CNTR    STORAGE RING
DT         1.000024 0.000078         BARDIN    84 CNTR
DT         . . . . . . . . . . .
DT   AVG   1.000029 0.000078  AVERAGE
```

μ ANOMALOUS MAGNETIC MOMENT (units $10^{-6}e/2m_\mu$)

```
MM      FOR REVIEWS OF THEORY AND EXPERIMENTS, SEE HUGHES 85, KINOSHITA 84,
MM      COMBLEY 81, FARLEY 79, AND CALMET 77.
MM        (1162.0)     (5.0)             CHARPAK   62 CNTR +
MM        (1166.16)    (0.31)            BAILEY    68 CNTR +- STOR. RINGS
MM   IA   (1165.922)   (0.009)           BAILEY    77 CNTR +- STORAGE RING
MM   I    (1165.910)   (0.011)           BAILEY    79 CNTR +  STORAGE RING
MM   I    (1165.937)   (0.012)           BAILEY    79 CNTR -  STORAGE RING
MM    I     1165.923    0.0085           BAILEY    79 CNTR +- STORAGE RING
MM    I  BAILEY 79 IS FINAL RESULT. INCLUDES BAILEY 77 DATA.
MM    I  WE USE MUON/PROTON MAGNETIC MOMENT RATIO = 3.183 345 2 AND
MM    I  RECALCULATE THE BAILEY 79 VALUES.
MM    I  THIRD BAILEY 79 RESULT IS FIRST TWO COMBINED.

MMR     MU+/MU- G-FACTOR RATIO MINUS ONE, (G+/G-)-1
MMR      TEST OF CPT
MMR         -2.6E-8   1.6E-8             BAILEY    79
```

μ ELECTRIC DIPOLE MOMENT (units 10^{-19} e–cm)

```
                FORBIDDEN BY BOTH T INVARIANCE AND P INVARIANCE

EDM B        (8.6)      (4.5)            BAILEY    78 CNTR +  STORAGE RINGS
EDM B        (0.8)      (4.3)            BAILEY    78 CNTR -  STORAGE RINGS
EDM  B        3.7        3.4             BAILEY    78 CNTR +- STORAGE RING
EDM  B   BAILEY 78 YIELDS EDM < 1.05*10**-18 WITH CL=.95.  THIRD RESULT IS
EDM  B   FIRST TWO COMBINED ASSUMING CPT.
```

μ/p MAGNETIC MOMENT RATIO

```
MPR      THIS RATIO IS USED TO OBTAIN A PRECISE VALUE OF THE MUON MASS.
MPR        (3.1865) (0.0022)             COFFIN    58 CNTR +  SPIN RESONANCE
MPR        (3.1830) (0.0011)             LUNDY     58 CNTR +  PRECESSION STROB
MPR        (3.176)  (0.013)              LUNDY     58 CNTR -  PRECESSION STROB
MPR        (3.1834) (0.0002)             GARWIN    60 CNTR +  PRECESSION PHASE
MPR        (3.18336)(0.00007)            BINGHAM   63 CNTR +  PRECESSION STROB
MPR        (3.1808) (0.0004)             BINGHAM   63 CNTR -  PRECESSION STROB
MPR        (3.18338)(0.00004)            HUTCHINS  63 CNTR +  PRECESSION PHASE
MPR D      (3.183351 0.000016)           EHRLICH   69 CNTR    HFS SPLITTING
MPR C      (3.183314 0.000034)           THOMPSON  69 CNTR    HFS SPLITTING
MPR        (3.183330 0.000044)           HUTCHINS  70 CNTR +  PRECESSION PHASE
MPR H      (3.183347 0.000009)           HAGUE     70 CNTR +  PRECESSION PHASE
MPR  C     (3.183336 0.000013)           CRANE     71 CNTR    HFS SPLITTING
MPR  D     (3.183349 0.000015)           DEVOE     71 CNTR    HFS SPLITTING
MPR F      (3.183326 0.000013)           FAVART    71 CNTR    HFS SPLITTING
MPR  H     (3.1833467 .0000082)          CROWE     72 CNTR +  PRECESSION PHASE
MPR  R   THE RESULTS THROUGH 1972 ARE INCLUDED IN COHEN 73.
MPR  R      3.1833402 .0000072           COHEN     73 RVUE
MPR E      (3.1833299 .0000025)          CASPERSON 75 CNTR
MPR         3.1833403 .0000044           CASPERSON 77 CNTR +  HFS SPLITTING
MPR        (3.1833448 .0000029)          CAMANI    78 CNTR +  REPL.BY KLEMPT82
MPR         3.1833441 .0000017           KLEMPT    82 CNTR +  PRECESSION STROB
MPR         3.1833461 .0000011           MARIAM    82 CNTR +  HFS SPLITTING
MPR  D   DEVOE 71 SUPERCEDES EHRLICH 69.  THIS IS NOT A DIRECT MEASUREMENT.
MPR  D   WE GIVE A NEW VALUE WHICH CONTAINS A THEORETICAL CORRECTION OF
MPR  D   -7.8+-2.3 PPM, AS DISCUSSED IN FOOTNOTE 35A OF CROWE 72.
MPR C    CRANE 71 SUPERSEDES THOMPSON 69. THIS IS NOT A DIRECT MEASUREMENT.
MPR H    CROWE 72 SUPERSEDES HAGUE 70.
MPR F    FAVART 71 ASSUMES A ZERO VALUE FOR THE PROTON POLARIZABILITY.
MPR  E   USES INCORRECT THEO. EXPRESSION FOR NU(HFS). SEE KLEMPT 82, TBL.XI.
MPR         . . . . . . . . . . .
MPR AVG     3.1833452 .0000010  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

μ PARTIAL DECAY MODES

		DECAY MASSES			
P1	$\mu^- \rightarrow e^-\overline{\nu}_e\nu_\mu$	.511+	0+	0	
P2	$\mu^- \rightarrow e^-\overline{\nu}_e\nu_\mu\gamma$	.511+	0+	0+	0
P3	$\mu^- \rightarrow e^-\nu_e\overline{\nu}_\mu$	.511+	0+	0	
P4	$\mu^- \rightarrow e^-\gamma$	.511+	0		
P5	$\mu^- \rightarrow 3e^-$	.511+	.511+	.511	
P6	$\mu^- \rightarrow e^-2\gamma$	.511+	0+	0	
P7	$\mu^- \rightarrow e^-e^+e^-\overline{\nu}_e\nu_\mu$	.511+	.511+	.511+	0+

μ BRANCHING RATIOS

$\mu^- \to (e^- \overline{\nu}_e \nu_\mu \gamma)$/total (P2)

```
R1       27 EVENTS SEEN                ASHKIN    59 CNTR
R1            1.4E-2   0.4E-2          CRITTENDE 61 CNTR T(GAM) GT 10 MEV
R1           (3.3E-3) (1.3E-3)         CRITTENDE 61 CNTR T(GAM) GT 20 MEV
R1      862 EVENTS SEEN                BOGART    67 CNTR T(GAM) GT 14.5 MEV
```

$\mu^+ \to (e^+ \overline{\nu}_e \nu_\mu)$/total (P3)

```
R2       FORBIDDEN BY ADDITIVE CONSERVATION LAW FOR LEPTON FAMILY NUMBER.
R2       MULTIPLICATIVE LAW PREDICTS THIS BRANCHING RATIO TO BE 1/2.
R2       FOR A REVIEW SEE NEMETHY 81.
R2            (0.25) OR LESS  CL=.90   EICHTEN   73 HLBC +
R2            (0.13)   (0.15)          BLIETSCHA 78 HLBC +- AVG. OF 4 VALUES
R2            (0.09) OR LESS  CL=.90   JONKER    80 CALO REPL. BY BERGSMA 83
R2           (-0.001)  (0.061)         WILLIS    80 CNTR +
R2    A        0.05  OR LESS  CL=.90   BERGSMA   83 CALO ANUMU E -->MU- ANUE
R2    A  BERGSMA 83 GIVES LIMIT ON INVERSE MUON DECAY CROSS SECTION RATIO
R2    A  SIG(NUBAR(MU) E- --> MU- NUBAR(E)) / SIG(NU(MU) E- --> MU- NU(E)),
R2    A  WHICH IS ESSENTIALLY EQUIVALENT TO R2 FOR SMALL VALUES LIKE THAT
R2    A  QUOTED.
```

$\mu \to (e \gamma)$/total (units 10^{-8}) (P4)

```
R3       FORBIDDEN BY LEPTON FAMILY NUMBER CONSERVATION
R3            (4.3)  OR LESS  CL=.90   FRANKEL1  63 OSPK
R3            (2.2)  OR LESS  CL=.90   PARKER    64 OSPK
R3            (2.9)  OR LESS  CL=.90   KORENCH1  71 OSPK +  DUBNA
R3            (0.10) OR LESS  CL=.90   SCHAAF    80 ELEC +  SIN
R3             0.017 OR LESS  CL=.90   KINNISON  82 SPEC +  LAMPF
R3            (0.10) OR LESS  CL=.90   AZUELOS   83 CNTR +
```

$\mu \to (3e)$/total (units 10^{-10}) (P5)

```
R4       FORBIDDEN BY LEPTON FAMILY NUMBER CONSERVATION
R4 F       (5000.)   OR LESS  CL=.90   PARKER    62 CNTR
R4 F       (1300.)   OR LESS  CL=.90   ALIKHANOV 62 OSPK
R4 F       (1500.)   OR LESS  CL=.90   FRANKEL2  63 CNTR
R4 F       (1200.)   OR LESS  CL=.90   BABAEV    63 OSPK
R4 K         (62.)   OR LESS  CL=.90   KORENCH2  71 OSPK    DUBNA
R4 K         (19.)   OR LESS  CL=.90   KORENCHEN 76 SPEC +  DUBNA
R4 K          (1.6)  OR LESS  CL=.90   BERTL     84 SPEC +  SINDRUM
R4 K          (1.3)  OR LESS  CL=.90   BOLTON    84 CNTR    LANL
R4 K           0.024 OR LESS  CL=.90   BERTL     85 SPEC +  SINDRUM
R4 F     FOUR ABOVE EXPERIMENTS EVALUATED UPPER LIMITS ASSUMING A SECOND
R4 F     ORDER V-A NEUTRINO LOOP DIAGRAM. LIMITS NOT SIGNIFICANTLY CHANGED
R4 F     BY ASSUMING A CONSTANT MATRIX ELEMENT.
R4 K     THESE EXPERIMENTS ASSUME A CONSTANT MATRIX ELEMENT.
```

$\mu \to (e\, 2\gamma)$/total (units 10^{-7}) (P6)

```
R5       FORBIDDEN BY LEPTON FAMILY NUMBER CONSERVATION
R5          (160.)   OR LESS  CL=.90   FRANKEL1  63 OSPK +
R5 P         (40.)   OR LESS  CL=.90   POUTISSOU 74 CNTR +  LBL
R5    A       (0.5)  OR LESS  CL=.90   BOWMAN    78 CNTR DEPOMMIER 77 DATA
R5    B        0.084 OR LESS  CL=.90   AZUELOS   83 CNTR +
R5 P     POUTISSOU 74 LIMIT APPLIES TO SUM OF ALL NEUTRINOLESS MU+ DECAYS.
R5    A  BOWMAN 78 ASSUMES INT. LAGRANG. LOCAL ON SCALE OF INVERSE MU MASS.
R5    B  AZUELOS 83 USES PHASE SPACE DISTRIBUTION OF BOWMAN 78. SEE ABOVE.
```

$\mu \to (e^- e^+ e^- \overline{\nu}_e \nu_\mu)$/total (units 10^{-5}) (P7)

```
R6  L     3   (1.5)     (1.0)          LEE       59 HBC  +
R6  G     1   (2.)                     GUREVICH  60 EMUL +
R6  C     7   (2.2)     (1.5)          CRITTENDE 61 HLBC +     E(E+E-)>10MEV
R6   B7443     3.4       0.4           BERTL     85 SPEC +  SINDRUM
R6  L    IN THE THREE LEE 59 EVENTS, THE SUM OF ENERGIES S=E(E+)+E(E-)+E(E+)
R6  L    WAS S=51 MEV, 55 MEV, AND 33 MEV .
R6  G    GUREVICH 60 INTERPRET THEIR EVENT AS EITHER VIRTUAL OR REAL PHOTON
R6  G    CONVERSION.  E+ AND E- ENERGIES NOT MEASURED .
R6  C    CRITTENDEN 61 COUNT ONLY THOSE DECAYS WHERE TOTAL ENERGY OF EITHER
R6  C    (E+,E-) COMBINATION IS >10 MEV )
R6   B   BERTL 85 HAS TRANSVERSE MOMENTUM CUT PT> 17 MEV/C.
R6   B   STAT ERROR (0.2) AND SYST ERROR (INCREASED BY US) ADDED IN QUADR.
```

LIMIT ON $\mu^- \to e^-$ CONVERSION

```
         FORBIDDEN BY LEPTON FAMILY NUMBER CONSERVATION
```

$\sigma(\mu^-\ {}^{32}\mathrm{S} \to e^-\ {}^{32}\mathrm{S})/\sigma(\mu^-\ {}^{32}\mathrm{S} \to \nu_\mu\ {}^{32}\mathrm{P}^*)$

```
RE            (4. E-10)OR LESS  CL=.90   BADERTSCH 77 STRC    SIN
RE             0.7E-10 OR LESS  CL=.90   BADERTSCH 80 STRC    SIN
```

$\sigma(\mu^-\ \mathrm{Cu} \to e^-\ \mathrm{Cu})/\sigma(\mu^-\ \mathrm{Cu} \to$ capture)

```
RF             1.6E-8  OR LESS  CL=.90   BRYMAN    72 SPEC
```

$\sigma(\mu^-\ \mathrm{Ti} \to e^-\ \mathrm{Ti})/\sigma(\mu^-\ \mathrm{Ti} \to$ capture)

```
RG             1.6E-11 OR LESS  CL=.90   BRYMAN    85 SPEC    TRIUMF
```

LIMIT ON $\mu^- \to e^+$ CONVERSION

```
         FORBIDDEN BY TOTAL LEPTON NUMBER CONSERVATION
```

$\sigma(\mu^-\ {}^{32}\mathrm{S} \to e^+\ {}^{32}\mathrm{Si}^*)/\sigma(\mu^-\ {}^{32}\mathrm{S} \to \nu_\mu\ {}^{32}\mathrm{P}^*)$

```
RP1           (1.5E-9) OR LESS  CL=.90   BADERTSCH 78 STRC    SIN
RP1            0.9E-9  OR LESS  CL=.90   BADERTSCH 80 STRC    SIN
```

$\sigma(\mu^-\ {}^{127}\mathrm{I} \to e^+\ {}^{127}\mathrm{Sb}^*)/\sigma(\mu^-\ {}^{127}\mathrm{I} \to$ anything)

```
RP2  A         0.3E-9  OR LESS  CL=.90   ABELA     80 CNTR RADIOCHEMICAL TECH.
RP2  A   ABELA 80 IS UPPER LIMIT FOR MU- E+ CONVERSION LEADING TO PARTICLE-
RP2  A   STABLE STATES OF SB127. LIMIT FOR TOTAL CONVERSION RATE IS HIGHER
RP2  A   BY A FACTOR LESS THAN 4 (G. BACKENSTOSS, PRIVATE COMM.)
```

$\sigma(\mu^-\ \mathrm{Cu} \to e^+\ \mathrm{Co})/\sigma(\mu^-\ \mathrm{Cu} \to \nu_\mu\ \mathrm{Ni})$

```
RP3           (2.2E-7) OR LESS  CL=.90   CONFORTO  62 OSPK
RP3            2.6E-8  OR LESS  CL=.90   BRYMAN    72 SPEC
```

LIMIT ON (μ^+,e^-) BOUND STATE CONVERSION TO (μ^-,e^+)

```
         FORBIDDEN BY LEPTON FAMILY NUMBER CONSERVATION
```

$R_g = g_C/g_F$

```
MC       WHERE GF = 1.16637E-5 GEV**(-2) IS THE FERMI CONSTANT AND
MC       GC IS AN EFFECTIVE COUPLING (DIMENSIONS GEV**(-2)) FOR A
MC       FOUR-FERMION INTERACTION ASSUMED TO BE RESPONSIBLE FOR THE
MC       CONVERSION OF THE (MU+,E-) BOUND STATE TO (MU-,E+).
MC
MC            42   OR LESS  CL=.95   MARSHALL  82 CNTR
```

NOTE ON MUON DECAY PARAMETERS

(by F. Scheck, University of Mainz, West Germany and K. Mursula, Nordita, Copenhagen, Denmark)

The muon decay parameters describe the momentum spectrum (ρ and η), the asymmetry (ξ and δ), and the polarization of the electron (ξ', ξ'', α, β, α', β') in the process $\mu^- \to e^- + \nu_\mu + \overline{\nu}_e$. Assuming a local, lepton-number-conserving, derivative-free, four-fermion interaction, the matrix element in charge-*changing* form may be written as[1]

$$\begin{aligned} \frac{G_F}{\sqrt{2}} \Big\{ & \sum_1^2 h_{ik} \langle \overline{e} | 1[1 + (-)^{i-1}\gamma_5] | \nu_e \rangle \\ & \quad \times \langle \overline{\nu}_\mu | 1[1 + (-)^{k-1}\gamma_5] | \mu \rangle \\ & + \sum_1^2 g_{ik} \langle \overline{e} | \gamma^\alpha [1 + (-)^{i-1}\gamma_5] | \nu_e \rangle \\ & \quad \times \langle \overline{\nu}_\mu | \gamma_\alpha [1 + (-)^{k-1}\gamma_5] | \mu \rangle \\ & + \sum_1^2 f_{ii} \tfrac{1}{2} \langle \overline{e} | \sigma^{\alpha\beta} [1 + (-)^{i-1}\gamma_5] | \nu_e \rangle \\ & \quad \times \langle \overline{\nu}_\mu | \sigma_{\alpha\beta} [1 + (-)^{i-1}\gamma_5] | \mu \rangle \Big\} \end{aligned} \qquad (1)$$

The definitions of covariants and the sign conventions are the ones of Sachs and Sirlin (1975)[2] and Scheck (1978).[3] The connection to other charge-changing and charge-retention forms is worked out in Mursula and Scheck (1985).[4] Note that for massless particles the covariants chosen above project onto states of definite helicity. In the standard model, $g_{22} = 1$ and all other coupling constants vanish.

All electron observables can be expressed, in a model-independent way, as functions of the ten standard real constants (see references above) a, b, c, a', b', c', α, β, α', and β'. The rate is proportional to $A = a + 4b + 6c$. The above decay parameters depend on nine of these constants only:

$$\begin{aligned}
&\rho-\tfrac{3}{4}=\tfrac{3}{4}[-a+2c]/A\ ,\\
&\eta=[\alpha-2\beta]/A\ ,\\
&\delta-\tfrac{3}{4}=\frac{9}{4}\,\frac{[a'-2c']/A}{1-[a+3a'+4(b+b')+6c-14c']/A}\ ,\\
&1-\xi\frac{\delta}{\rho}=4\,\frac{[(b+b')+2(c-c')]/A}{1-[a-2c]/A}\ ,\\
&1-\xi'=[a+a'+4(b+b')+6(c+c')]/A\ ,\\
&1-\xi''=[-2a+20c]/A\ ,\\
&\alpha/A,\ \beta/A,\ \alpha'/A,\ \beta'/A,
\end{aligned}\tag{2}$$

the last four of which are obtained from the transverse components of the electron polarization. These real constants are easily related to bilinear combinations of coupling constants in any form of the interaction. For the case of the form (1), they are given by [note the scale factor $G_F/\sqrt{2}$ in Eq. (1)],

$$\left.\begin{matrix}a\\a'\end{matrix}\right\}=16(|g_{12}|^2\pm|g_{21}|^2)\pm|h_{11}+6f_{11}|^2+|h_{22}+6f_{22}|^2\ ,\tag{3}$$

$$\left.\begin{matrix}b\\b'\end{matrix}\right\}=4(|g_{11}|^2\pm|g_{22}|^2)\pm|h_{12}|^2+|h_{21}|^2\ ,\tag{4}$$

$$\left.\begin{matrix}c\\c'\end{matrix}\right\}=\frac{1}{2}\Big[\pm|h_{11}-2f_{11}|^2+|h_{22}-2f_{22}|^2\Big]\ ,\tag{5}$$

$$\left.\begin{matrix}\alpha\\\alpha'\end{matrix}\right\}=\left.\begin{matrix}\mathrm{Re}\\\mathrm{Im}\end{matrix}\right\}8[g_{21}(h^*_{22}+6f^*_{22})\pm g_{12}(h^*_{11}+6f^*_{11})]\ ,\tag{6}$$

$$\left.\begin{matrix}\beta\\\beta'\end{matrix}\right\}=\left.\begin{matrix}\mathrm{Re}\\\mathrm{Im}\end{matrix}\right\}(-4)[g_{22}h^*_{21}\pm g_{11}h^*_{12}]\ .\tag{7}$$

As the decay parameters (2) depend on $(b+b')$ but not on $(b-b')$, the constant h_{12} appears only in β and β', Eq. (7). However, g_{11} is found to be compatible with zero, so the decay parameters do not determine h_{12}. (The coupling constant h_{12} does occur in the rate parameter A and may, in principle, be obtained by comparing μ decay to other data.) By using Eqs. (2) and the experimental determinations of ρ, η, $\xi\delta/\rho$, δ, ξ', ξ'', α, β, α', and β', limits can be placed on the nine parameters a/A, a'/A, $(b+b')/A$, c/A, c'/A, α/A, α'/A, β/A, and β'/A. These are given in the Listings. These limits are easily translated into limits on specific coupling constants in Eq. (1), depending on what kind of extension of the standard model one wishes to test. Examples such as tests for right-handed interactions or for scalar/pseudoscalar effective couplings are given in Mursula and Scheck (1985).[4]

The limits on a, a', $\cdots$, can be recast into limits on the effective charge-retention coordinates g_S/g_V, g_P/g_V, g_A/g_V, g_T/g_V, ϕ_{VA}, and ψ_{VA}, which were used in the earlier literature (cf., e.g., DERENZO 69). The most recent values are found in BURKARD2 85.

Note that the radiative corrections are unambiguous only if h_{11}, h_{22}, g_{12}, g_{21}, f_{11}, and f_{22} vanish.

References

1. F. Scheck, in *Leptons, Hadrons, and Nuclei* (North Holland, Amsterdam, 1983).
2. A.M. Sachs and A. Sirlin, in *Muon Physics II*, eds. C.S. Wu and V. Hughes (Academic Press, New York, 1975), p. 49.
3. F. Scheck, Phys. Rep. **44**, 187 (1978).
4. K. Mursala and F. Scheck, Nucl. Phys. **B253**, 189 (1985); and K. Mursala et al., Nucl. Phys. **B219**, 321 (1983).

μ DECAY PARAMETERS

ρ PARAMETER **(V−A theory predicts ρ=0.75)**

```
RHO C         (0.741)  (0.027)         DUDZIAK   59 CNTR +  20-53 MEV E+
RHO  P9213     0.745    0.025          PLANO     60 HBC  +  WHOLE SPECTRUM
RHO  P  TWO PARAMETER FIT TO RHO AND ETA.
RHO C 2276    (0.751)  (0.034)         BLOCK     62 HEBC  - WHOLE SPECTRUM
RHO D         (0.64)   (0.04)          BARLOW    64 CNTR  - WHOLE SPECTRUM
RHO D         (0.661)  (0.016)         BARLOW    64 CNTR +  WHOLE SPECTRUM
RHO D         (0.867)  (0.035)         PONTECORV 64 CC    -
RHO D   RESULTS IN DOUBT.
RHO C 800K    (0.7503) (0.0026)        PEOPLES   66 ASPK +  20-53 MEV E+
RHO C 280K    (0.760)  (0.009)         SHERWOOD  67 ASPK +  25-53 MEV E+
RHO C 170K    (0.762)  (0.008)         FRYBERGER 68 ASPK +  25-53 MEV E+
RHO C   ETA CONSTRAINED =0. THESE VALUES INCORPORATED INTO A TWO PARAMETER
RHO C   FIT TO RHO AND ETA BY DERENZO 69.
RHO            0.7518   0.0026         DERENZO   69 RVUE
RHO          . . . . . . . . . . .
RHO AVG        0.7517   0.0026  AVERAGE
```

η PARAMETER **(V−A theory predicts η=0)**

```
ETA P 9213  (-2.0)     (0.9)           PLANO     60 HBC  +  WHOLE SPECTRUM
ETA P   TWO PARAMETER FIT TO RHO AND ETA- PLANO 60 DISCOUNTS VALUE FOR ETA
ETA C 800K   (0.05)    (0.5)           PEOPLES   66 ASPK +  20-53 MEV E+
ETA C 280K  (-0.7)     (0.6)           SHERWOOD  67 ASPK +  25-53 MEV E+
ETA C 170K  (-0.7)     (0.5)           FRYBERGER 68 ASPK +  25-53 MEV E+
ETA C   RHO CONSTRAINED =0.75.
ETA   6346   -0.12      0.21           DERENZO   69 HBC  +  1.6-6.8 MEV E+
ETA  B5.3M    0.011     0.085          BURKARD2  85 CNTR +  9-53 MEV E+
ETA DB5.3M  (-0.012)   (0.016)         BURKARD2  85 CNTR +  9-53 MEV E+
ETA  B  STATISTICAL (0.081) AND SYSTEMATIC ERRORS ADDED IN QUADRATURE.
ETA  B  MEASURED VALUE OF ETA IS AN ENERGY AVERAGE.
ETA D   ALPHA=ALPHA-PRIME=0 ASSUMED.
ETA          . . . . . . . . . .
ETA AVG      -0.007     0.079   AVERAGE
```

ξ'' PARAMETER

```
XPP  B326K    0.65      0.36           BURKARD1  85 CNTR +  BHABHA + ANNIHIL
XPP  B  BURKARD1 85 MEASURE (XI''-XI*XI')/XI AND XI'
XPP  B  AND SET XI=1.
```

(ξ PARAMETER)*(μ LONGITUDINAL POLARIZATION)

```
XI                           (V-A THEORY PREDICTS XI=1, LONG.POL.=1)
XI       9K  (0.97)     (0.05)         BARDON    59 CNTR    BROMOFORM TARGET
XI     8354  (0.93)     (0.06)         PLANO     60 HBC  +  8.8 KGAUSS
XI  A        (0.903)    (0.027)        ALI-ZADE  61 EMUL +  27 KGAUSS
XI  A   DEPOLARIZATION BY MEDIUM NOT KNOWN SUFFICIENTLY WELL.
XI      66K  (0.975)    (0.030)        GUREVICH  64 EMUL REPL.BY AKHMANOV 68
XI           (0.975)    (0.015)        AKHMANOV  68 EMUL    140 KGAUSS
```

(ξ PARAMETER)*(μ LONGITUDINAL POLARIZATION)*δ/ρ

```
XID          (0.9959)OR MORE  CL=.90   CARR      83 SPEC +  11 KGAUSS
XID  S        0.9966 OR MORE  CL=.90   STOKER    85 SPEC +  MU-SPIN ROT
XID  S  STOKER 85 FIND (XI*PMU*DELTA/RHO)>0.9955 AND >0.9966, WHERE FIRST
XID  S  LIMIT IS FROM NEW MU-SPIN ROTATION DATA AND SECOND IS FROM
XID  S  COMBINATION WITH CARR 83 DATA.  (DELTA/RHO)=1.0 IN V-A THEORY.
```

δ PARAMETER **(V−A theory predicts δ=0.75)**

```
DEL  8354     0.78      0.05           PLANO     60 HBC  +  WHOLE SPECTRUM
DEL           0.782     0.031          KRUGER    61
DEL   490K    0.752     0.009          FRYBERGER 68 ASPK +  25-53 MEV E+
DEL     VOSSLER 69 HAS MEASURED THE ASYMMETRY BELOW 10 MEV
DEL          . . . . . . . . . .
DEL AVG       0.7551    0.0085  AVERAGE
```

ξ' = LONGITUDINAL POLARIZATION OF e^+

```
PL       (V-A THEORY PREDICTS THE LONG. POL=+-1 FOR E+- RESPECTIVELY)
PL       WE HAVE FLIPPED THE SIGN FOR E- SO OUR PROGRAMS CAN AVERAGE
PL D          (0.28)   (0.16)          DICK      63 CNTR +  ANNIHILATION
PL D     IN DOUBT- POSITRONS POSSIBLY DEPOLARIZED IN BE MODERATOR.
PL             1.05     0.30           BUHLER    63 CNTR +  ANNIHILATION
PL             0.94     0.38           BLOOM     64 CNTR +  BREMS TRANSMISS
PL             1.04     0.18           DUCLOS    64 CNTR +  BHABHA SCATT
PL      29K    0.89     0.28           SCHWARTZ  67 OSPK  - MOLLER SCATT
PL       1M    0.998    0.045          BURKARD1  85 CNTR +  BHABHA + ANNIHIL  |
PL            . . . . . . . . .
PL  AVG        0.998    0.042   AVERAGE
```

TRANSVERSE e^+ POLARIZATION IN PLANE OF μ SPIN, e^+ MOM

```
PT1  B5.3M     0.016    0.023          BURKARD2  85 CNTR +  ANNIHIL 9-53 MEV  |
PT1  B  STAT. ERROR (0.021) AND SYSTEMATIC ERROR ADDED IN QUADRATURE.         |
```

TRANSVERSE e^+ POLAR. NORMAL TO PLANE OF μ SPIN, e^+ MOM

```
PT2      ZERO IF TIME REVERSAL INVARIANCE HOLDS.                              |
PT2  B5.3M     0.007    0.023          BURKARD2  85 CNTR +  ANNIHIL 9-53 MEV  |
PT2  B  STAT. ERROR (0.022) AND SYSTEMATIC ERROR ADDED IN QUADRATURE.         |
```

α/A (units 10^{-3})

```
AL   B 5.3M  (15.)    (52.)            BURKARD2  85 CNTR +  9-53 MEV E+       |
AL    F         0.4      4.3           BURKARD2  85  FIT                      |
AL   B   STAT. ERROR (50) AND SYSTEMATIC ERROR ADDED IN QUADRATURE.           |
AL    F  GLOBAL FIT TO ALL MEASURED PARAMETERS.  CORRELATION COEFFICIENTS     |
AL    F  ARE GIVEN IN BURKARD2 85.                                            |
```

α'/A (units 10^{-3})

```
ALP      ZERO IF T INVARIANCE HOLDS.
ALP BC5.3M (-47.)     (52.)            BURKARD2  85 CNTR +  9-53 MEV E+       |
ALPF           -0.2      4.3           BURKARD2  85  FIT                      |
ALP   C  BURKARD2 85 MEASURE PT1 AND PT2 VERSUS E+ ENERGY.                    |
ALP B    STAT. ERROR (50) AND SYSTEMATIC ERROR ADDED IN QUADRATURE.           |
ALPF     GLOBAL FIT TO ALL MEASURED PARAMETERS.  CORRELATION COEFFICIENTS     |
ALPF     ARE GIVEN IN BURKARD2 85.                                            |
```

β/A (units 10^{-3})

```
BT   B 5.3M   (2.)    (18.)            BURKARD2  85 CNTR +  9-53 MEV E+       |
BT    F         3.9      6.2           BURKARD2  85  FIT                      |
BT   B   STAT. ERROR (17) AND SYSTEMATIC ERROR ADDED IN QUADRATURE.           |
BT    F  GLOBAL FIT TO ALL MEASURED PARAMETERS.  CORRELATION COEFFICIENTS     |
BT    F  ARE GIVEN IN BURKARD2 85.                                            |
```

β'/A (units 10^{-3})

```
BTP      ZERO IF T INVARIANCE HOLDS.
BTP BC5.3M  (17.)     (18.)            BURKARD2  85 CNTR +  9-53 MEV E+       |
BTPF            1.5      6.3           BURKARD2  85  FIT                      |
BTP   C  BURKARD2 85 MEASURE PT1 AND PT2 VERSUS E+ ENERGY.                    |
BTP B    STAT. ERROR (17) AND SYSTEMATIC ERROR ADDED IN QUADRATURE.           |
BTPF     GLOBAL FIT TO ALL MEASURED PARAMETERS.  CORRELATION COEFFICIENTS     |
BTPF     ARE GIVEN IN BURKARD2 85.                                            |
```

a/A (units 10^{-3})

```
SA    F        15.9   OR LESS  CL=.90  BURKARD2  85  FIT                      |
SA    F  GLOBAL FIT TO ALL MEASURED PARAMETERS.  CORRELATION COEFFICIENTS     |
SA    F  ARE GIVEN IN BURKARD2 85.                                            |
```

a'/A (units 10^{-3})

```
SAP   F         5.3      4.1           BURKARD2  85  FIT                      |
SAP   F  GLOBAL FIT TO ALL MEASURED PARAMETERS.  CORRELATION COEFFICIENTS     |
SAP   F  ARE GIVEN IN BURKARD2 85.                                            |
```

$(b'+b)/A$ (units 10^{-3})

```
SBP   F         1.04  OR LESS  CL=.90  BURKARD2  85  FIT                      |
SBP   F  GLOBAL FIT TO ALL MEASURED PARAMETERS.  CORRELATION COEFFICIENTS     |
SBP   F  ARE GIVEN IN BURKARD2 85.                                            |
```

c/A (units 10^{-3})

```
SC    F         6.4   OR LESS  CL=.90  BURKARD2  85  FIT                      |
SC    F  GLOBAL FIT TO ALL MEASURED PARAMETERS.  CORRELATION COEFFICIENTS     |
SC    F  ARE GIVEN IN BURKARD2 85.                                            |
```

c'/A (units 10^{-3})

```
SCP   F         3.5      2.0           BURKARD2  85  FIT                      |
SCP   F  GLOBAL FIT TO ALL MEASURED PARAMETERS.  CORRELATION COEFFICIENTS     |
SCP   F  ARE GIVEN IN BURKARD2 85.                                            |
```

$\overline{\eta}$ PARAMETER (V−A theory predicts $\overline{\eta}=0$)

```
ETB      ETA-BAR AFFECTS SPECTRUM OF RADIATIVE MUON DECAY.
ETB          +0.09      0.14           BOGART    67 CNTR +
ETB          -0.014     0.090          EICHENBER 84 ELEC +  RHO FREE
ETB         (-0.035)   (0.098)         EICHENBER 84 ELEC +  RHO=0.75 ASSUMED
ETB           . . . . . . . . . .
ETB AVG        0.016    0.076   AVERAGE
```

REFERENCES FOR μ

```
COFFIN   58 PR 109 973          +GARWIN,PENMAN,LEDERMAN,SACHS    (COLUMBIA)
LUNDY    58 PRL 1 38            +SENS,SWANSON,TELEGDI,YOVANOVITCH (CHICAGO)
ASHKIN   59 NC 14 1266          +FAZZINI,FIDECARO,LIPMAN,MERRISON +  (CERN)
BARDON   59 PRL   2   56        M BARDON, D BERLEY, L LEDERMAN   (COLUMBIA)
DUDZIAK  59 PR  114  336        W DUDZIAK,R SAGANE, J VEDDER          (LRL)
LEE      59 PRL 3 55            JULIET LEE, N. P. SAMIOS             (COLU)
GARWIN   60 PR 118 271          GARWIN,HUTCHINSON,PENMAN,SHAPIRO (COLUMBIA)
GUREVICH 60 JETP 10 225         GUREVICH,NIKOLSKII,SURKOVA           (ITEP)
PLANO    60 PR  119 1400        R J PLANO                        (COLUMBIA)

ALI-ZADE 61 JETP  13  313       ALI-ZADE,GUREVICH,NIKOLSKI           (USSR)
CRITTEND 61 PR 121 1823         CRITTENDEN,WALKER,BALLAM         (WISC+MSU)
KRUGER   61 UCRL-9322 (UNPUB)   H KRUGER                              (LRL)
ALIKHANO 62 CERN CONF 423       A I ALIKHANOV,A BABAEV +     (ITEP MOSCOW)
BLOCK    62 NC   23  1114       BLOCK,FIORINI,KIKUCHI+(DUKE,BOLOGNA,MILANO)
CHARPAK  62 PL    1  16         G CHARPAK,F J M FARLEY,R L GARWIN +  (CERN)
CONFORTO 62 NC 26 261           CONFORTO,CONVERSI,DILELLA,+(INFN+ROMA+CERN)
FARLEY   62 CERN CONF 415       FARLEY,MASSAM,MULLER,ZICHICHI        (CERN)

LUNDY    62 PR 125 1686         RICHARD A LUNDY                       (EFI)
PARKER   62 NC  23  485         S PARKER,S PENMAN                     (EFI)
BABAEV   63 JETP 16 1397        BABAEV,BALATS,KAFTANOV,LANDSBERG +   (ITEP)

BINGHAM  63 NC 27 1352          G.MCD.BINGHAM                         (LRL)
BUHLER   63 PL   7  368         +CABIBBO,FIDECARO,MASSAM,MULLER+     (CERN)
DICK     63 PL   7  150         DICK,FEUVRAIS,SPIGHEL                (CERN)

ECKHAUSE 63 PR 132  422         M ECKHAUSE,T A FILIPPAS +        (CARNEGIE)
FEINBERG 63 ARNS 13 431         GERALD FEINBERG, L M LEDERMAN    (COLUMBIA)
FRANKEL1 63 NC  27  894         S FRANKEL,W FRATI,J HALPERN +        (PENN)
FRANKEL2 63 PR 130  351         S FRANKEL,W FRATI,J HALPERN +        (PENN)
HUTCHINS 63 PR 131 1351         HUTCHINSON,MENES,PATLACH,SHAPIRO (COLUMBIA)
MEYER    63 PR  132  2693       S L MEYER,ANDERSON,BLESER,LEDERMAN+  (COLU)

BARLOW   64 PPSL  84  239       +BOOTH,CARROL,COURT,DAVIES,EDWARDS+  (LIVP)
BLOOM    64 PL   8   87         +DICK,FEUVRAIS,HENRY,MACQ,SPIGHEL    (CERN)
DUCLOS   64 PL   9   62         +HEINTZE,DE RUJULA,SOERGEL           (CERN)
GUREVICH 64 PL   11  185        GUREVICH,MAKARIYNA+                  (KIAE)
PONTECOR 64 DUBNA CONF          PONTECORVO,SULYAEV                 (MOSCOW)
PARKER   64 PR 133B 768         S PARKER,H L ANDERSON,C REY           (EFI)

PEOPLES  66 NEVIS-147 (UNPUB) J PEOPLES                          (COLUMBIA)
BOGART   67 PR 156 1405         +DICAPUA,NEMETHY,STRELZOFF           (COLU)
SCHWARTZ 67 PR  162 1306        D M SCHWARTZ                          (EFI)
SHERWOOD 67 PR  156 1475        B A SHERWOOD                          (EFI)
AKHMANOV 68 SJNP 6 230          +GUREVICH,DOBRETSOV,MAKARINA+        (KIAE)
BAILEY   68 PL   28B  287       +BARTL,VON BOCHMANN,BROWN,FARLEY+    (CERN)
    ALSO 72 NC 9A 369           +BARTL,VON BOCHMANN,BROWN,FARLEY+    (CERN)
FRYBERGE 68 PR  166 1379        D FRYBERGER                           (EFI)

DERENZO  69 PR  181 1854        S DERENZO                             (EFI)
EHRLICH  69 PRL 23 513          +HOFER,MAGNON,STOWELL,SWANSON+    (CHICAGO)
TAYLOR   69 RMP 41 375          +PARKER,LANGENBERG         (PRIN+UCI+PENN)
THOMPSON 69 PRL 22 163          +AMATO,CRANE,HUGHES,MOBLEY+          (YALE)
HAGUE    70 PRL 25 628          +ROTHBERG,SCHENCK,WILLIAMS+      (WASH+LRL)
HUTCHINS 70 PRL 24 1254         HUTCHINSON,LARSON,SCHOEN,SOBER,+      (PPA)

CRANE    71 PRL 27 474          +CASPERSON,CRANE,EGAN,HUGHES+        (YALE)
DEVOE    71 PRL 25 1779(ER)     +MCINTGRE,MAGNON,STOWELL,SWANSON+ (CHICAGO)
    ALSO 71 PRL 26 213          DEVOE,MCINTGRE,MAGNON,STOWELL+    (CHICAGO)
FAVART   71 PRL 27 1336         +MCINTYRE,STOWELL,TELEGDI,DEVOE+  (CHICAGO)
KORENCH1 71 SJNP 13 190         KORENCHENKO,KOSTIN,MICELMACHER+      (JINR)
KORENCH2 71 SJNP 13 728         KORENCHENKO,KOSTIN,MICELMACHER+      (JINR)

BRYMAN   72 PRL 28 1469         +BLECHER,GOTOW,POWERS                 (VPI)
CROWE    72 PR D5 2145          +HAGUE,ROTHBERG,SCHENCK+         (LBL+WASH)
WILLIAMS 72 PR D6 737           R W WILLIAMS,D L WILLIAMS      (WASHINGTON)
COHEN    73 J.PHYS.CHEM.REF.DATA 2, P.663, E.R.COHEN,B.N.TAYLOR
DUCLOS   73 PL 47B 491          +MAGNON,PICARD                       (SACL)
EICHTEN  73 PL 46B 281          +DEDEN+(AACH+BELG+CERN+EPOL+MILA+LALO+LOUC)

BALANDIN 74 JETP 40 811         +GREBENYUK,ZINOV,KONIN,PONOMAREV     (JINR)
POUTISSO 74 NP B80 221          POUTISSOU,FELAWKA,INGRAM +      (MONT+BRCO)
CASPERSO 75 PL 59B 397          CASPERSON,CRANE+ (YALE+LASL+HEID+BERN+WYOM)
KORENCHE 76 JETP 43 1           KORENCHENKO,KOSTIN,MITSELMAKHER+     (JINR)
BADERTSC 77 PRL 39 1385         BADERTSCHER,BORER,CZAPEK,FLUECKIGER+ (BERN)

BAILEY   77 PL 67B 225          +BORER+(CERN+DARE+BERN+SHEF+MANZ+RMCS+BIRM)
      OR 77 PL 68B 191          +BORER+(CERN+DARE+BERN+SHEF+MANZ+RMCS+BIRM)
    ALSO 75 PL 55B 420          BAILEY+(CERN+DARE+BERN+SHEF+MANZ+RMCS+BIRM)
BAILEY2  77 NATURE 268 301             (DARE+BERN+SHEF+CERN+MANZ+RMCS+BIRM)
    ALSO 79 BAILEY
CASPERSO 77 PRL 38 956          CASPERSON,CRANE+ (BERN+HEID+LASL+WYOM+YALE)

BADERTSC 78 PL 79B 371          BADERTSCHER,BORER,CZAPEK,FLUECKIGER+ (BERN)
BAILEY   78 JPG 4 345                  (DARE+BERN+SHEF+MANZ+RMCS+CERN+BIRM)
    ALSO 79 BAILEY
BLIETSCH 78 NP B133 205         BLIETSCHAU+(AACH+LIBH+CERN+EPOL+MILA+ORSA+)
BOWMAN   78 PRL 41 442          +CHENG,LI,MATIS           (LASL+IAS+CARN+EFI)
CAMANI   78 PL 77B 326          +GYGAX,KLEMPT,SCHENCK,SCHULZE+   (ETH+MANZ)
BAILEY   79 NP B150 1             (DARE+BERN+SHEF+MANZ+RMCS+CERN+BIRM+LBL+)

ABELA    80 PL 95B 318          +BACKENSTOSS,SIMONS,WUEST +     (BASL+KARL)
BADERTSC 80 LNC 28 401          BADERTSCHER,BORER,CZAPEK,FLUECKIGER+ (BERN)
    ALSO 82 NP A377 406         BADERTSCHER,BORER,CZAPEK,FLUCKIGER+  (BERN)
JONKER   80 PL 93B 203          CHARM COLLAB.    (ANIK+CERN+HAMB+ITEP+ROMA)
SCHAAF   80 NP A340 249         +ENGFER,POVEL,DEY+             (ZURI+ETH+SIN)
    ALSO 77 PL 72B 183          POVEL,DEY,WALTER,PFEIFFER +   (ZURI+ETH+SIN)
WILLIS   80 PRL 44 522          +HUGHES+ (YALE+LBL+LASL+SACL+SIN+CNRC+BERN)
    ALSO 80 PRL 45 1370         WILLIS+  (YALE+LBL+LASL+SACL+SIN+CNRC+BERN)

BARDIN   81 NP A352 365         +DUCLOS,MAGNON+        (SACL+CERN+BGNA+TRIU)
NEMETHY  81 CNPP 10 147         P.NEMETHY,V.W.HUGHES             (LBL+YALE)
KINNISON 82 PR D25 2846         +ANDERSON,MATIS,WRIGHT +    (EFI+STAN+LANL)
    ALSO 79 PRL 42 556          BOWMAN,COOPER,HAMM,+        (LASL+EFI+STAN)
KLEMPT   82 PR D25 652          +SCHULZE,WOLF,CAMANI,GYGAX+      (MANZ+ETH)
MARIAM   82 PRL 49 993          +BEER,BOLTON,EGAN,GARDNER+ (YALE+HEID+BERN)
MARSHALL 82 PR D25 1174         +WARREN,ORAM,KIEFL                   (BRCO)

AZUELOS  83 PRL 51 164          +DEPOMMIER,LEROY,MARTIN+   (MONT+TRIU+BRCO)
    ALSO 77 PRL 39 1113         DEPOMMIER,MARTIN+(MONT+BRCO+TRIU+VICT+MELB)
BERGSMA  83 PL 122B 465         CHARM COLLAB.    (ANIK+CERN+HAMB+ITEP+ROMA)
CARR     83 PRL 51 627          +GIDAL,GOBBI,JODIDIO,ORAM+  (LBL+NWES+TRIU)

BARDIN   84 PL 137B 135         +DUCLOS,MAGNON+        (SACL+CERN+BGNA+FIRZ)
BERTL    84 PL 140B 299         SINDRUM C.,EICHLER+     (ETH+ZURI+SIN+SACL)
BOLTON   84 PRL 53 1415         +BOWMAN,CARLINI+     (LANL+CHIC+STAN+TEMP)
EICHENBE 84 NP A412 523         EICHENBERGER,ENGFER,VAN DER SCHAFF   (ZURI)
GIOVANET 84 PR D29 343          GIOVANETTI,DEY,ECKHAUSE,HART+        (WILL)
KINOSHIT 84 PRL 52 717          KINOSHITA,NIZIC,OKAMOTO              (CORN)

BERTL    85 NP B260 1           SINDRUM C.,EGLI,EICHLER+(ETH+ZURI+SIN+SACL)
BRYMAN   85 PRL 55 465          +          (TRIU+CNRC+BRCO+LANL+CHIC+CARL+)
BURKARD1 85 PL 150B 242         BURKARD,CORRIVEAU,EGGER+      (ETH+SIN+MANZ)
BURKARD2 85 PL 160B 343         BURKARD,CORRIVEAU,EGGER+      (ETH+SIN+MANZ)
    ALSO 81 PR D24 2004         CORRIVEAU,EGGER,FETSCHER +    (ETH+SIN+MANZ)
    ALSO 83 PL 129B 260         CORRIVEAU,EGGER,FETSCHER+     (ETH+SIN+MANZ)
HUGHES   85 CNPP 14 341         HUGHES,KINOSHITA                (YALE+CORN)
MURSULA  85 NP B253 189         MURSULA, SCHECK                 (BERN+MANZ)
STOKER   85 PRL 54 1887         STOKER,BALKE,CARR,GIDAL, +  (LBL+NWES+TRIU)

                                PAPERS NOT REFERRED TO IN DATA LISTINGS

FISHER   59 PRL  3  349         FISHER,LEONTIC,LUNDBY,MEUNIER,STROOT (CERN)
ASTBURY  60 ROCH CONF 60 542    ASTBURY,HATTERSLEY,HUSSAIN +    (LIVERPOOL)
DEVONS   60 PRL  5  330         DEVONS,GIDAL,LEDERMAN,SHAPIRO    (COLUMBIA)
LATHROP  60 NC    17 109        J LATHROP,R A LUNDY,V L TELEGDI +     (EFI)
LATHROP  60 NC    17 114        J LATHROP,R A LUNDY,S PENMAN +        (EFI)
REITER   60 PRL   5  22         REITER,ROMANOWSKI,SUTTON +       (CARNEGIE)
TELEGDI  60 ROCH CONF 60 713    V L TELEGDI                          (CERN)

CHARPAK  61 PRL   6 128         CHARPAK,FARLEY,GARWIN,MULLER,SENS +  (CERN)
HUTCHINS 61 PRL   7 129         D P HUTCHINSON,J MENES +         (COLUMBIA)
SHAPIRO  62 PR 125 1022         G SHAPIRO,L M LEDERMAN           (COLUMBIA)
FAIRLEY  66 NC 45A 281          FAIRLEY,BAILEY,BROWN,GIESCH +        (CERN)
VOSSLER  69 NC 63A 423          C VOSSLER                             (EFI)

LAUTRUP  72 PRPL 3 193          B.LAUTRUP,A.PETERMAN,E.DE RAFAEL(CERN+BURE)
RICH     72 RMP 44 250          A RICH,J C WESLEY                    (MICH)
```

Stable Particle Full Listings

μ, ν_τ, τ

```
COMBLEY  74 PRPL 14 1          F.COMBLEY,E.PICASSO                (CERN)
CALMET   77 RMP 49 21          J.CALMET,S.NARISON,M.PERROTTET+    (MARS)
KINOSHIT 78  TOKYO HEP P.571   T. KINOSHITA                       (CORN)
SCHECK   78 PRPL 44C 187       F. SCHECK                          (MANZ)
FARLEY   79 ARNPS 29 243       F.J.M.FARLEY,E.PICASSO        (RMCS+CERN)
DEPOMMIE 80 NP A335 97         P.DEPOMMIER                        (MONT)
COMBLEY  81 PRPL 68 93         COMBELY,FARLEY,PICASSO   (SHEF+RMCS+CERN)
```

$\boxed{\nu_\tau}$

$J = \frac{1}{2}$

```
EXISTENCE INDIRECTLY ESTABLISHED FROM TAU DECAY DATA COMBINED
WITH NU REACTION DATA.  SEE FOR EXAMPLE FELDMAN 81.  KIRKBY 79
RULE OUT J=3/2 USING TAU --> PI NU(TAU) BRANCHING RATIO.

NOT IN GENERAL A MASS EIGENSTATE.  SEE NOTE ON NEUTRINOS
IN THE ELECTRON NEUTRINO SECTION ABOVE.
```

ν_τ "MASS" (MeV)

```
      APPLIES TO NU(3), THE PRIMARY MASS EIGENSTATE IN NU(TAU).  WOULD
      ALSO APPLY TO ANY OTHER NU(J) WHICH MIXES STRONGLY IN NU(TAU) AND
      HAS SUFFICIENTLY SMALL MASS THAT IT CAN OCCUR IN THE RESPECTIVE
      DECAYS.  (THIS WOULD BE NONTRIVIAL ONLY FOR A HYPOTHETICAL J .GE. 4,
      GIVEN THE NU(E) AND NU(MU) ''MASS'' LIMITS ABOVE.)

M   BA 594 (250.)   OR LESS  CL=.95   BACINO    79 DLCO E+E- ECM=3.5-7.4GEV
M    C     (250.)   OR LESS  CL=.95   BLOCKER   82 SMK2 E+E- ECM=5.2 GEV
M    E 102   70.    OR LESS  CL=.95   ALBRECHT  85 ARG  E+E- ECM=10 GEV
M    F   3 (125.)   OR LESS  CL=.95   BURCHAT   85 SMK2 E+E- ECM=29 GEV
M    G   4 (157.)   OR LESS  CL=.95   MILLS     85 DLCO E+E- ECM=29 GEV
M    H  22 (143.)   OR LESS  CL=.95   MATTEUZZI 85 SMK2 E+E- ECM=29 GEV
M    I  10  (84.)   OR LESS  CL=.95   ABACHI    86 HRS  E+E- ECM=29 GEV
M    P  PERL 77 IS E+E- TO TAU+ TAU- EXPT. VALUE QUOTED ASSUMES V-A DECAY
M    P  AND TAU MASS=1900 MEV.
M    B  BACINO 79 EXPT RULES OUT V+A DECAY, DISFAVORS PURE V OR A, AND IS
M    B  IN GOOD AGREEMENT WITH V-A.
M    A  BOUND COMES FROM ANALYSIS OF LEPTONIC DECAY SPECTRUM.
M    C  BOUND COMES FROM ANALYSIS OF TAU -> PI NU(TAU) DECAY MODE.
M    E  BOUND COMES FROM ANALYSIS OF TAU -> 3PI+- NU(TAU) DECAY MODE.
M    F  BOUND COMES FROM ANALYSIS OF TAU -> 5PI+- (PI0) NU(TAU) DECAY.
M    G  BOUND COMES FROM ANALYSIS OF TAU -> K+- K-+ PI+- NU(TAU) DECAY
M    G  MODE.
M    H  BOUND COMES FROM ANALYSIS OF TAU -> 3PI+- PI0 NU(TAU) DECAY MODE.
M    I  BOUND COMES FROM ANALYSIS OF TAU -> 5PI+- PI0 NU(TAU) DECAY MODE
M    I  (5 EVENTS) AND TO A LESSER EXTENT FROM TAU -> 5PI+- NU(TAU) MODE
M    I  (5 EVENTS).
```

ν_τ BOUNDS ON MASS AND MIXING

LIMITS ON $|U_{e\tau}|^2$ AS FUNCTION OF ν_τ MASS

```
UET          (1.E-2)OR LESS    CL=.90 BERGSMA   83 BDMP   M(NU(TAU))=10 MEV
UET          (9.E-9)OR LESS    CL=.90 BERGSMA   83 BDMP              =100 MEV
```

REFERENCES FOR ν_τ

```
ALLES    79 LNC 25 404          W.ALLES                                (BGNA)J
BACINO   79 PRL 42 749          +FERGUSON,NODULMAN+    (UCLA+SLAC+UCI+STON)
KIRKBY   79  SLAC-PUB-2419      J.KIRKBY(LEPTON PHOTON SYMP. BATAVIA)(SLAC)J
FELDMAN  81  SLAC-PUB-2839      G.J.FELDMAN(SANTA CRUZ APS 1981)(SLAC+STAN)
BLOCKER  82 PL 109B 119         +DORFAN,ABRAMS,ALAM,BLONDEL+      (LBL+SLAC)
BERGSMA  83 PL 128B 361         +DORENBOSCH+      (ANIK+CERN+HAMB+ITEP+INFN)
ALBRECHT 85 PL 163B 404         ARGUS C,+BINDER+(DESY+DORT+HEID+IPPC+KANS+)
BURCHAT  85 PRL 54 2489         MARK II C,+SCHMIDKE,YELTON+ (SLAC+LBL+HARV)
MATTEUZZ 85 PR D32 800          MARK II C,MATTEUZZI,BARKLOW+(SLAC+LBL+HARV)
MILLS    85 PRL 54 624          DELCO C.,PAL,ATWOOD,BAILLON+(CIT+SLAC+STAN)
ABACHI   86 PRL (TO BE PUBL.)   HRS C.,+AKERLOFF+    (ANL+IND+LBL+MICH+PURD)
```

$\boxed{\tau}$

$J = \frac{1}{2}$

```
TAU DISCOVERY PAPER IS PERL 75.
E+E- --> TAU+TAU- CROSS SECTION THRESHOLD BEHAVIOR AND
MAGNITUDE CONSISTENT WITH POINTLIKE SPIN 1/2 DIRAC PARTICLE.
BRANDELIK 78 RULES OUT POINTLIKE SPIN 0 OR SPIN 1 PARTICLE.
FELDMAN 78 RULES OUT J=3/2.  KIRKBY 79 ALSO RULES OUT
J=INTEGER, J=3/2.
```

τ MASS (MeV)

```
M     A 692 1783.      3.      4.    BACINO    78 DLCO E+E- 3.1-7.4GEV ECM
M     R 299 1787.     10.     18.    BARTEL    78 SPEC E+E- 3.6-4.4GEV ECM
M           1807.     20.            BRANDELIK 78 DASP E+E- 3.1-5.2GEV ECM
M           1787.     10.            BLOCKER   80 SMK2 E+E- 3.5-6.7GEV ECM
M      1138(1803.)   (16.)           BLOCKER1  82 SMK2 INCL. IN BLOCKER 80
M
M     A  BACINO 78 VALUE COMES FROM E+- X-+ THRESHOLD. PUBLISHED MASS 1782
M     A  MEV INCREASED BY 1 MEV USING THE HIGH PRECISION PSI(3685) MASS
M     A  MEASUREMENT OF ZHOLENTZ 80 TO ELIMINATE THE ABSOLUTE SPEAR ENERGY
M     A  CALIBRATION UNCERTAINTY.
M
M     R  BARTEL 78 FITS ENERGY DEPENDENCE OF CS FOR E+- AND MU+- EVENTS.
M     R  MASS VALUE NOT DEPENDENT ON WHETHER V-A OR V+A DECAY ASSUMED.
M             . . . . . . . . . .
M    AVG    1784.2       3.2     AVERAGE
```

τ MEAN LIFE (units 10^{-13} sec)

```
T       102   4.6     1.9            FELDMAN   82 SMK2 E+E- ECM=29 GEV
T       121   4.9     2.0            FORD      82 MAC  E+E- ECM=28,29 GEV
T       143   4.7     3.9      2.9   BEHREND2  83 CELL E+E- ECM=22,34 GEV
T       156   3.20    0.54           JAROS     83 SMK2 E+E- ECM=29 GEV
T        50   3.18    0.81     0.94  ALTHOFF   84 TASS E+E- ECM=43 GEV
T     B 10K   3.15    0.6            FERNANDE  85 MAC  E+E- ECM=29 GEV
T     B  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.36 AND 0.4.
T            . . . . . . . . . . .
T    AVG      3.30    0.35    AVERAGE
```

τ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\tau^\pm \to \mu^\pm \nu_\mu \nu_\tau$	106+ 0+ 0
P2	$\tau^\pm \to e^\pm \nu_e \nu_\tau$	.511+ 0+ 0
P3	$\tau^\pm \to 5\pi^\pm \nu_\tau$	
P4	$\tau^\pm \to 5\pi^\pm \pi^0 \nu_\tau$	
P5	$\tau^\pm \to K^+ K^- \pi^\pm \nu_\tau$	494+ 494+ 140+ 0
P6	$\tau^\pm \to K^\pm \pi^+ \pi^- (\geqslant 0\ \pi^0)\ \nu_\tau$	
P7	$\tau^\pm \to K^\pm \nu_\tau$	494+ 0
P9	$\tau^\pm \to \rho^0 \pi^\pm \nu_\tau$	769+ 140+ 0
P10	$\tau^\pm \to a_1(1270)^\pm \nu_\tau$	1275+ 0
P11	$\tau^\pm \to K^\pm$ neutral(s)	
P12	$\tau^\pm \to \pi^\pm \nu_\tau$	140+ 0
P13	$\tau^\pm \to 2\pi^\pm \pi^\mp \nu_\tau$ (including P9, P10)	140+ 140+ 140+ 0
P16	$\tau^\pm \to \rho^\pm \nu_\tau$	769+ 0
P17	$\tau^\pm \to 3$ hadrons$^\pm \nu_\tau$	
P18	$\tau^\pm \to 3$ hadrons$^\pm \gamma$(s) ν_τ	
P19	$\tau^\pm \to$ hadron$^\pm$ (not P7,P12,OR P16) neutral(s)	
P20	$\tau^\pm \to 5$ hadrons$^\pm$ neutral(s)	
P21	$\tau^\pm \to K^*(892)\ \nu_\tau$	892+ 0
P22	$\tau^\pm \to K_2^*(1430)\ \nu_\tau$	1425+ 0
P24	$\tau^\pm \to \pi^\pm \pi^0$(non-resonant) ν_τ	140+ 135+ 0
P25	$\tau^\pm \to \pi^+ \pi^- \pi^\pm \pi^0 \nu_\tau$	140+ 140+ 140+ 135+
P26	$\tau^\pm \to \pi^\pm \pi^0 \pi^0 \pi^0 \nu_\tau$	140+ 135+ 135+ 135+
P27	$\tau^\pm \to \pi^\pm \pi^0 \pi^0 \nu_\tau$	140+ 135+ 135+ 0
P28	$\tau^\pm \to K^\pm$(2 charged) ($\geqslant$0 neutrals) ν_τ	
P29	$\tau^\pm \to 3\pi^\pm K^0 (\geqslant 0\ \gamma)\ \nu_\tau$	
P30	$\tau^\pm \to$ hadron$^\pm (\geqslant 1\ \pi^0)\ \nu_\tau$	

LEPTON FAMILY NUMBER VIOLATING MODES.

P31	$\tau^\pm \to \mu^\pm \gamma$	106+ 0
P32	$\tau^\pm \to e^\pm \gamma$	.511+ 0
P33	$\tau^\pm \to \mu^\pm$ charged particles	
P34	$\tau^\pm \to e^\pm$ charged particles	
P35	$\tau^\pm \to \mu^\pm \mu^+ \mu^-$	106+ 106+ 106
P36	$\tau^\pm \to e^\pm \mu^+ \mu^-$	.511+ 106+ 106
P37	$\tau^\pm \to \mu^\pm e^+ e^-$	106+.511+.511
P38	$\tau^\pm \to e^\pm e^+ e^-$	.511+.511+.511
P39	$\tau^\pm \to \mu^\pm \pi^0$	106+ 135
P40	$\tau^\pm \to e^\pm \pi^0$	.511+ 135
P41	$\tau^\pm \to \mu^\pm K^0$	106+ 498
P42	$\tau^\pm \to e^\pm K^0$	.511+ 498
P43	$\tau^\pm \to \mu^\pm \rho^0$	106+ 769
P44	$\tau^\pm \to e^\pm \rho^0$	.511+ 769

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1      P 2      P 7      P12      P16      P17      P18      P19      P20
P 1   .1757+-.0055
P 2  -.204    .1735+-.0051
P 7  -.005   -.003    .0067+-.0017
P12  -.026   -.102   -.024    .1011+-.0112
P16  -.035   -.057    .000    .008    .2181+-.0203
P17  -.001   -.001   -.000   -.001    .000    .0810+-.0073
P18  -.008   -.006   -.001   -.009    .001   -.922    .0527+-.0078
P19  -.143   -.069   -.058   -.450   -.840   -.003   -.039    .1896+-.0236
P20  -.003   -.002   -.000   -.003    .000   -.000   -.001   -.013    .0015+-.0004
```

τ BRANCHING RATIOS

$\tau^{\pm} \rightarrow (\mu^{\pm}\nu_{\mu}\nu_{\tau})$/total (P1)

```
R1     220    0.15     0.03              BURMEST1  77 PLUT ASSUMES V-A DECAY
R1            0.175    0.040             PERL      77 SMAG    E+E- TO MU+- X-+
R1            0.22     0.10      0.07    CAVALLISF 77 SPEC    E+E- TO MU+- X-+
R1      11    0.22     0.07      0.08    SMITH     78 SPEC    E+E- TO MU+MU-X0
R1            0.35     0.14              BRANDELIK 80 TASS    E+E- ECM=30GEV
R1            0.178    0.027             BERGER    81 PLUT    E+E- 9-32GEV ECM
R1   E  47    0.176    0.033             BEHREND   83 CELL    E+E- ECM=34 GEV.
R1   F        0.129    0.018             ALTHOFF   85 TASS E+E- ECM=34.5 GEV
R1   I 473    0.183    0.010             ASH       85 MAC  E+E- ECM=29 GEV
R1   J       (0.173)  (0.005)            ASH       85 MAC  E+E- ECM=29 GEV
R1   H        0.180    0.012             BALTRUSA  85 SMK3 E+E- ECM=3.77 GEV
R1   G 153    0.194    0.023             BERGER    85 PLUT E+E- ECM=34.6 GEV
R1   E  STATISTICAL AND SYSTEMATIC ERRORS COMBINED IN QUADRATURE.
R1   F  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.017 AND +0.007 -0.005.
R1   I  ERROR CORRELATED WITH FERNANDEZ 85 1-PRONG VALUE.
R1   I  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.009 AND 0.005.
R1   J  COMBINED RESULT OF ASH 85 R1, R2, AND R4 MEASUREMENTS ASSUMING
R1   J  BR(MU NU NU)/BR(E NU NU)=0.97.
R1   H  ERROR CORRELATED WITH BALTRUSAI 85 E NU NU VALUE.
R1   H  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.01 AND 0.006.
R1   G  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.016 AND 0.017.
R1          . . . . . . . . . . .
R1  AVG       0.1753   0.0069  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
R1  FIT       0.1757   0.0055 FROM FIT
```

$\tau^{\pm} \rightarrow (e^{\pm}\nu_{e}\nu_{\tau})$/total (P2)

```
R2   B 459    0.160    0.013             BACINO    78 DLCO E+E- ECM=3.1-7.4GEV
R2            0.19     0.09              BRANDELIK 80 TASS E+E- ECM=30GEV
R2   E  60    0.183    0.031             BEHREND   83 CELL E+E- ECM=34 GEV.
R2   F        0.204    0.033             ALTHOFF   85 TASS E+E- ECM=34.5 GEV
R2   I 390    0.180    0.011             ASH       85 MAC  E+E- ECM=29 GEV
R2   J       (0.178)  (0.005)            ASH       85 MAC  E+E- ECM=29 GEV
R2   H        0.182    0.009             BALTRUSA  85 SMK3 E+E- ECM=3.77 GEV
R2   G        0.130    0.035             BERGER    85 PLUT E+E- ECM=34.6 GEV
R2   B  BACINO 78 VALUE COMES FROM FIT TO EVENTS WITH E+- AND 1 OTHER
R2   B  NONELECTRON CHARGED PRONG.
R2   E  STATISTICAL AND SYSTEMATIC ERRORS COMBINED IN QUADRATURE.
R2   F  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.030 AND +0.014 -0.009.
R2   I  ERROR CORRELATED WITH FERNANDEZ 85 1-PRONG VALUE.
R2   I  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.009 AND 0.006.
R2   J  COMBINED RESULT OF ASH 85 R1, R2, AND R4 MEASUREMENTS ASSUMING
R2   J  BR(MU NU NU)/BR(E NU NU)=0.97.
R2   H  ERROR CORRELATED WITH BALTRUSAI 85 R1.
R2   H  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.007 AND 0.005.
R2   G  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.019 AND 0.029.
R2          . . . . . . . . . . .
R2  AVG       0.1763   0.0058  AVERAGE
R2  FIT       0.1735   0.0051 FROM FIT
```

$\tau^{\pm} \rightarrow \sqrt{(\mu^{\pm}\nu_{\mu}\nu_{\tau})*(e^{\pm}\nu_{e}\nu_{\tau})}$

```
R3                                                           SQRT(P1*P2)
R3   P 105    0.17     0.06      0.03    PERL      76 SMAG
R3   B 144    0.186    0.030             PERL      77 SMAG
R3   B  21    0.224    0.055             BARBARO-G 77 SMAG
R3   B  13    0.182    0.031             BRANDELIK 78 DASP ASSUMES V-A DECAY
R3   B  WE HAVE COMBINED STATISTICAL AND SYSTEMATIC ERRORS QUADRATICALLY.
R3   P  ASSUMES V-A COUPLING, TAU MASS=1.8 GEV, TAU NEUTRINO MASS=0.
R3   B  ASSUMES V-A COUPLING, TAU MASS=1.9 GEV, TAU NEUTRINO MASS=0.
R3          . . . . . . . . . . .
R3  AVG       0.186    0.018   AVERAGE
R3  FIT       0.1746   0.0033 FROM FIT
```

$\tau^{\pm} \rightarrow (\mu^{\pm}\nu_{\mu}\nu_{\tau})*(e^{\pm}\nu_{e}\nu_{\tau})$ (P1)*(P2)

```
R4   B  20    0.034    0.009             BACINO1   79 DLCO E+E- ECM=3.6-7.4GEV
R4     257    0.030    0.005             BLOCKER1  82 SMK2 E+E- ECM=3.5-6.7GEV
R4   A        0.0288   0.0025            ASH       85 MAC  E+E- ECM=29 GEV
R4   B  BACINO1 79 QUOTES BR(MU)=0.21+-0.058(STAT.+SYST. ERRORS COMBINED IN
R4   A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.0017 AND 0.0019.
R4   B  QUADRATURE) ASSUMING BR(E)=0.16.  WE MULTIPLY BY 0.16 TO GET ABOVE
R4   B  VALUE.
R4          . . . . . . . . . . .
R4  AVG       0.0293   0.0022  AVERAGE
R4  FIT       0.0305   0.0012 FROM FIT
```

$\tau^{\pm} \rightarrow (e^{\pm}\nu_{e}\nu_{\tau})/(\mu^{\pm}\nu_{\mu}\nu_{\tau})$ (P2)/(P1)

```
R5      PREDICTED TO BE 1 FOR SEQUENTIAL LEPTON, 2 FOR PARAELECTRON,
R5      AND 1/2 FOR PARAMUON. PARAELECTRON ALSO RULED OUT BY HEILE 78.
R5      21    0.92     0.37              BURMEST2  77 PLUT ASSUMES V-A DECAY
R5   B  18    1.09     0.38              BRANDELIK 78 DASP E+E- 3.1-5.2GEV ECM
R5   L 154    0.75     0.23              BLOCKER1  82 SMK2 E+E- ECM=3.5-6.7GEV
R5   A 390   (0.98)   (0.08)             ASH       85 MAC  E+E- ECM=29 GEV
R5   B  BRANDELIK 78 QUOTES THE INVERSE OF THIS RATIO AS .92+-.32 .
R5   L  BLOCKER 82 GIVES THE INVERSE OF THIS RATIO AS 1.33+-.18+-.36 .
R5   A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.07 AND 0.04.
R5   A  NOT INDEPENDENT OF ASH 85 R1 AND R2 VAULES.
R5          . . . . . . . . . . .
R5  AVG       0.86     0.17    AVERAGE
R5  FIT       0.988    0.047  FROM FIT
```

$\tau^{\pm} \rightarrow (\pi^{\pm}\nu_{\tau})$/total (P12)

```
R6    1138    0.117    0.019             BLOCKER1  82 SMK2 E+E- ECM=3.5-6.7GEV
R6   E  34    0.099    0.021             BEHREND   83 CELL E+E- ECM=34 GEV.
R6   E  STATISTICAL AND SYSTEMATIC ERRORS COMBINED IN QUADRATURE.
R6          . . . . . . . . . . .
R6  AVG       0.109    0.014   AVERAGE
R6  FIT       0.101    0.011  FROM FIT
```

$\tau^{\pm} \rightarrow (K^{\pm}\nu_{\tau})$/total (P7)

```
R7      15    0.013    0.005             BLOCKER2  82 SMK2 E+E- ECM=3.9-6.7GEV
R7      16    0.0059   0.0018            MILLS     84 DLCO E+E- ECM=29 GEV
R7          . . . . . . . . . . .
R7  AVG       0.0067   0.0023  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
R7  FIT       0.0067   0.0017 FROM FIT
```

$\tau^{\pm} \rightarrow (\rho^{\pm}\nu_{\tau})$/total (P16)

```
R8            0.221    0.025             BEHREND   84 CELL E+E- ECM=14,22 GEV
R8          . . . . . . . . . . .
R8  FIT       0.218    0.020  FROM FIT
```

$\tau^{\pm} \rightarrow (K^{*}(892)^{\pm}\nu_{\tau})$/total (P21)

```
R9      11    0.017    0.007             DORFAN    81 SMK2 E+E- 4.2-6.7GEV ECM
```

$\tau^{\pm} \rightarrow (K_{2}^{*}(1430)^{\pm}\nu_{\tau})$/total (P22)

```
R10      0    0.009 OR LESS  CL=.95      DORFAN    81 SMK2 E+E- 4.2-6.7GEV ECM
```

$\tau^{\pm} \rightarrow (a_{1}(1270)^{\pm}\nu_{\tau})$/total (P10)

```
R11 W   27   (0.108)  (0.034)            WAGNER    80 PLUT E+E- 4-5 GEV ECM
R11 W   NOT INDEPENDENT OF WAGNER 80 R22 VALUE BELOW.  ASSUMES THAT ALL
R11 W   (NU RHO0 PI+-) EVENTS ARE (NU A1+-) AND BR(L+- NU NU)=
R11 W   .173+-.013 .
```

$\tau^{\pm} \rightarrow (\rho^{\pm}\nu_{\tau})*(\mu^{\pm}\nu_{\mu}\nu_{\tau})$ (P16)*(P1)

```
R16    103    0.041    0.009             BLOCKER   80 SMK2 E+E- ECM=3.5-6.7GEV
R16         . . . . . . . . . . .
R16 FIT       0.0383   0.0037 FROM FIT
```

$\tau^{\pm} \rightarrow (\rho^{\pm}\nu_{\tau})*(e^{\pm}\nu_{e}\nu_{\tau})$ (P16)*(P2)

```
R17    139    0.034    0.008             BLOCKER   80 SMK2 E+E- ECM=3.5-6.7GEV
R17         . . . . . . . . . . .
R17 FIT       0.0379   0.0036 FROM FIT
```

$\tau^{\pm} \rightarrow (\pi^{\pm}\nu_{\tau})*(e^{\pm}\nu_{e}\nu_{\tau})$ (P12)*(P2)

```
R18  A  23    0.015    0.006             ALEXAND2  78 PLUT E+E- ECM=3.6-5 GEV
R18  B  10    0.013    0.006             BACINO1   79 DLCO E+E- ECM=3.6-7.4GEV
R18  A  ALEXANDER2 78 QUOTE BR(PI)=.090+-.038(STAT.+SYST.ERRORS COMBINED IN
R18  A  QUADRATURE) USING BR(E)=.167+-.010. WE MPY. BY .167 TO GET ABV.VAL.
R18  B  BACINO1 79 QUOTES BR(PI)=0.080+-0.035(STAT.+SYST.ERRORS COMBINED IN
R18  B  QUADRATURE) ASSUMING BR(E)=0.16.  WE MPY. BY 0.16 TO GET ABOVE VAL.
R18         . . . . . . . . . . .
R18 AVG       0.0140   0.0042  AVERAGE
R18 FIT       0.0176   0.0020 FROM FIT
```

$\tau^{\pm} \rightarrow (\pi^{\pm}\pi^{0}$(non-resonant) $\nu_{\tau})$/total (P24)

```
R19           0.003    0.003             BEHREND   84 CELL E+E- ECM=14;22 GEV
```

$\tau^{\pm} \rightarrow (\pi^{\pm}2\pi^{0}\nu_{\tau})$/total (P27)

```
R20           0.060    0.035             BEHREND   84 CELL E+E- ECM=14,22 GEV
```

$\tau^{\pm} \rightarrow (\pi^{\pm}3\pi^{0}\nu_{\tau})$/total (P26)

```
R21           0.030    0.027             BEHREND   84 CELL E+E- ECM=14,22 GEV
```

$\tau^{\pm} \rightarrow (\pi^{\pm}\rho^{0}\nu_{\tau})$/total (P9)

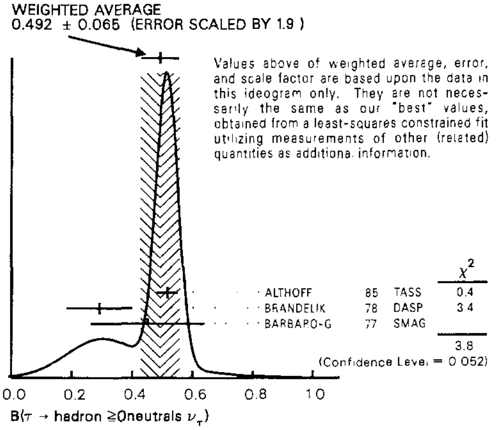
```
R22     27    0.054    0.017             WAGNER    80 PLUT E+E- 4-5 GEV ECM
```

$\tau^{\pm} \rightarrow$ ((1 charged) ($\geq$0 neutrals) ν_{τ})/total

```
R24                                                 (P1+P2+P7+P12+P16+P19)
R24     CHARGED PARTICLE CAN BE E, MU, OR HADRON.
R24     SINCE 5 PRONG BR. FRACTION IS VERY SMALL THIS BR. FRACTION
R24     IS NOT INDEPENDENT OF 3 PRONG VALUE (R31).
R24     672   (0.840)  (0.020)            BEHREND   82 CELL E+E- 32-36.8GEV ECM
R24 B   764   (0.86)   (0.022)            BLOCKER3  82 SMK2 E+E- ECM = 29 GEV
R24 A   660   (0.852)  (0.017)            AIHARA    84 TPC  E+E- ECM=29 GEV
R24 D  4098   (0.869)  (0.004)            AKERLOF   85 HRS  E+E- ECM=29 GEV
R24 F   169   (0.847)  (0.019)  (0.017)ALTHOFF   85 TASS E+E- ECM=34.5 GEV
R24 J         (0.861)  (0.010)            BARTEL    85 JADE E+E- ECM=34.6 GEV
R24 G         (0.878)  (0.041)            BERGER    85 PLUT E+E- ECM=34.6 GEV
R24 C         (0.867)  (0.007)            FERNANDE  85 MAC  E+E- ECM=29 GEV
R24  B  SYSTEMATIC AND STATISTICAL ERRORS COMBINED IN QUADRATURE.
R24  A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.009 AND 0.015.
R24  D  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.002 AND 0.003.
R24  F  NOT INDEPENDENT OF ALTHOFF 85 R1, R2, R25, AND R31 VALUES.
R24  F  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.011 AND +0.016 -0.013.
R24  J  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.005 AND 0.009.
R24  G  NOT INDEPENDENT OF (1-PRONG + 0PI0) AND (1-PRONG + >= 1PI0) VALUES.
R24  G  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.013 AND 0.039.
R24  C  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.003 AND 0.006.
R24         . . . . . . . . . . .
R24 FIT       0.8648   0.0030 FROM FIT
```

$\tau^{\pm} \rightarrow$ (hadron$^{\pm}$ ($\geq$0 neutrals) ν_{τ})/total (P7+P12+P16+P19)

```
R25     19    0.45     0.19              BARBARO-G 77 SMAG
R25           0.29     0.11              BRANDELIK 78 DASP ASSUMES V-A DECAY
R25 B        (0.22)   (0.14)             BRANDELIK 80 TASS E+E- ECM=30GEV
R25  F        0.515    0.033    0.039 ALTHOFF   85 TASS E+E- ECM=34.5 GEV
R25 B  NOT INDEPENDENT OF BRANDELIK 80 R1, R2 AND R24 VALUES.
R25  F  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.029 AND +0.016 -0.026.
R25         . . . . . . . . . . .
R25 AVG       0.492    0.065   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.9)
R25 FIT       0.5156   0.0073 FROM FIT
                       (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$\tau^{\pm} \rightarrow (K^{\pm} (\geqslant 0 \text{ neutrals}) \ \nu_{\tau})$/total (P11)

```
R26  B     SMALL                      BRANDELIK 77 DASP   3.6-5.2ECM E+E-
R26    53    0.0171   0.0029          MILLS     84 DLCO   E+E- ECM=29 GEV
R26  B  BRANDELIK 77 FINDS 0.07+-0.06 K+- PER EVT IN E+E- --> E+- PRONG-+.
```

$\tau^{\pm} \rightarrow (2\pi^{\pm} \pi^{\mp} \nu_{\tau})$/total (P17)

```
R28     DECAY MODES WITH KAONS ARE MEASURED TO BE SMALL, SO ALL HADRONS
R28     ARE ASSUMED TO BE PIONS.  BEHREND 84 SUBTRACTS KAONS BY HAND.
R28 J   13   (0.07)   (0.05)          JAROS     78 SMAG E+E- ECM > 6 GEV
R28           0.09     0.06           BRANDELIK 80 TASS E+E- ECM=30GEV
R28           0.097    0.024          BEHREND   84 CELL E+E- ECM=14,22 GEV
R28   1255    0.081    0.008          FERNANDE  85 MAC  E+E- ECM=29 GEV
R28 J   JAROS 78 EVENTS CONSISTENT WITH BEING RHO PI OR A1.
R28         . . . . . . . . . .
R28 AVG       0.0827   0.0075  AVERAGE
R28 FIT       0.0810   0.0073 FROM FIT
```

$\tau^{\pm} \rightarrow (2\pi^{\pm} \pi^{\mp} (\text{non-resonant}) \ \nu_{\tau})$/total (P13-P9)

```
R29           0.014 OR LESS  CL=.95   WAGNER    80 PLUT E+E- 4-5 GEV ECM
```

$\tau^{\pm} \rightarrow (3\pi^{\pm} \pi^{0} \nu_{\tau})$/total (P25)

```
R30     WE FIT THIS AS P18 (TAU+- INTO 3 HADRONS+- GAMMA(S) NU(TAU)) AND
R30     ASSUME THAT THE MULTI-PIO FRACTION IS SMALL.
R30          (0.11)   (0.07)          JAROS     78 SMAG E+E- ECM > 6 GEV
R30           0.15     0.07           BRANDELIK 80 TASS E+E- ECM=30GEV
R30           0.062    0.029          BEHREND   84 CELL E+E- ECM=14,22 GEV
R30         . . . . . . . . . .
R30 AVG       0.075    0.031   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
R30 FIT       0.0527   0.0078 FROM FIT
```

$\tau^{\pm} \rightarrow (3\pi^{\pm} (\geqslant 0 \ \pi^{0}) \ \nu_{\tau})$/total (P17+P18)

```
R31     DECAY MODES WITH KAONS ARE MEASURED TO BE SMALL, SO ALL HADRONS
R31     ARE ASSUMED TO BE PIONS.
R31 E  692   (0.32)   (0.05)          BACINO    78 DLCO E+E- ECM=3.1-7.4GEV
R31 E        (0.35)   (0.11)          BRANDELIK 78 DASP ASSUMES V-A DECAY
R31 E   33   (0.18)   (0.065)         JAROS     78 SMAG E+E- ECM > 6 GEV
R31     35    0.24     0.06           BRANDELIK 80 TASS E+E- ECM=30 GEV
R31    186    0.150    0.020          BEHREND   82 CELL E+E- 32-36.8GEV ECM
R31    152    0.14     0.02           BLOCKER3  82 SMK2 E+ E- ECM = 29 GEV
R31  A 660    0.148    0.017          AIHARA    84 TPC  E+E- ECM=29 GEV
R31  C4098    0.130    0.004          AKERLOF   85 HRS  E+E- ECM=29 GEV
R31  F 367    0.153    0.017    0.019 ALTHOFF   85 TASS E+E- ECM=34.5 GEV
R31  J        0.136    0.009          BARTEL    85 JADE E+E- ECM=34.6 GEV
R31  G        0.122    0.041          BERGER    85 PLUT E+E- ECM=34.6 GEV
R31  B        0.133    0.007          FERNANDE  85 MAC  E+E- ECM=29 GEV
R31 E   LOW ENERGY EXPERIMENTS ARE NOT IN AVERAGE OR FIT BECAUSE THE
R31 E   SYSTEMATIC ERRORS IN BACKGROUND SUBTRACTION ARE JUDGED TO BE LARGE.
R31  A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.009 AND 0.015.
R31  C  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.002 AND 0.003.
R31  F  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.011 AND +0.013 -0.016.
R31  J  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.005 AND 0.008.
R31  G  NOT INDEPENDENT OF BERGER 85 R1, R2, R42, AND R43.
R31  G  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.013 AND 0.039.
R31  B  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.003 AND 0.007.
R31         . . . . . . . . . .
R31 AVG       0.1334   0.0030  AVERAGE
R31 FIT       0.1337   0.0030 FROM FIT
```

$\tau^{\pm} \rightarrow (5\pi^{\pm} (\geqslant 0 \ \pi^{0}) \ \nu_{\tau})$/total (P20)

```
R33          (0.06) OR LESS  CL=.95   BRANDELIK 80 TASS E+E- ECM=30GEV
R33     10    0.010    0.004          BEHREND   82 CELL E+E- 32-36.8GEV ECM
R33      2   (0.005)OR LESS  CL=.95   BLOCKER3  82 SMK2 E+E- ECM = 29 GEV
R33      4   (0.003)OR LESS  CL=.90   AIHARA    84 TPC  E+E- ECM=29 GEV
R33      1   (0.009)OR LESS  CL=.95   BEHREND   84 CELL E+E- ECM=14,22 GEV
R33      0   (0.007)OR LESS  CL=.95   ALTHOFF   85 TASS E+E- ECM=34.5 GEV
R33  J        0.003    0.002          BARTEL    85 JADE E+E- ECM=34.6 GEV
R33     10    0.0013   0.0004         BELTRAMI  85 HRS  E+E- ECM=29 GEV
R33  C   4    0.0016   0.0009         BURCHAT   85 SMK2 E+E- ECM=29 GEV
R33      2   (0.0017)OR LESS CL=.95   FERNANDE  85 MAC  E+E- ECM=29 GEV
R33  J  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.001 AND 0.002.
R33  C  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.0008 AND 0.0004.
R33         . . . . . . . . . .
R33 AVG       0.00147  0.00036  AVERAGE
R33 FIT       0.00147  0.00036 FROM FIT
```

$\tau^{\pm} \rightarrow (K^{\pm} (2 \text{ charged}) \ (\geqslant 0 \text{ neutrals}) \ \nu_{\tau})$/total (P28)

```
R34           0.006 OR LESS  CL=.90   AIHARA    84 TPC  E+E- ECM=29 GEV
```

$\tau^{\pm} \rightarrow (3 \text{ hadrons}^{\pm} \nu_{\tau})$/

```
R35                  (3 HADRONS+- (>=0 GAMMAS) NU(TAU))  (P17)/(P17+P18)
R35   . (NOT INDEPENDENT OF R28 AND R31 VALUES.)
R35    103    0.37     0.35     0.20  ALTHOFF   85 TASS E+E- ECM=34.5 GEV
R35  B        0.61     0.06           FERNANDE  85 MAC  E+E- ECM=29 GEV
R35  B  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.03 AND 0.05.
R35         . . . . . . . . . .
R35 AVG       0.599    0.059   AVERAGE
```

$\tau^{\pm} \rightarrow (3\pi^{\pm} K^{0} (\geqslant 0 \ \gamma) \ \nu_{\tau})$/total (P29)

```
R37           0.0027 OR LESS  CL=.90  BELTRAMI  85 HRS  E+E- ECM=29 GEV
```

$\tau^{\pm} \rightarrow (5\pi^{\pm} \nu_{\tau})$/total (P3)

```
R38  B   5    0.00067  0.00030        BELTRAMI  85 HRS  E+E- ECM=29 GEV
R38  B  THE ERROR QUOTED IS STATISTICAL ONLY.
```

$\tau^{\pm} \rightarrow (5\pi^{\pm} \pi^{0} \nu_{\tau})$/total (P4)

```
R39  B   5    0.00067  0.00030        BELTRAMI  85 HRS  E+E- ECM=29 GEV
R39  B  THE ERROR QUOTED IS STATISTICAL ONLY.
```

$\tau^{\pm} \rightarrow (K^{+} K^{-} \pi^{\pm} \nu_{\tau})$/total (P5)

```
R40  M   9    0.0022   0.0017  0.0011 MILLS     85 DLCO E+E- ECM=29 GEV
R40  M  ERROR CORRELATED WITH MILLS 85 (K PI PI PIO NU) VALUE.  EXCLUDES
R40  M  23% SYSTEMATIC ERROR.
```

$\tau^{\pm} \rightarrow (K^{\pm} \pi^{+} \pi^{-} (\geqslant 0 \ \pi^{0}) \ \nu_{\tau})$/total (P6)

```
R41  M   9    0.0022   0.0016  0.0013 MILLS     85 DLCO E+E- ECM=29 GEV
R41  M  ERROR CORRELATED WITH MILLS 85 (K K PI NU) VALUE.  EXCLUDES 23%
R41  M  SYSTEMATIC ERROR.
```

$\tau^{\pm} \rightarrow (\text{hadron}^{\pm} (\geqslant 1 \ \pi^{0}) \ \nu_{\tau})$/total (P30)

```
R42  G        0.427    0.035          BERGER    85 PLUT E+E- ECM=34.6 GEV
R42  G  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.020 AND 0.029.
R42         . . . . . . . . . .
R42 FIT       0.408    0.013   FROM FIT
```

$\tau^{\pm} \rightarrow (\text{hadron}^{\pm} \nu_{\tau})$/total (P12+P7)

```
R43  G        0.130    0.045          BERGER    85 PLUT E+E- ECM=34.6 GEV
R43  G  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.020 AND 0.040.
R43         . . . . . . . . . .
R43 FIT       0.108    0.011   FROM FIT
```

$\tau^{\pm} \rightarrow (\mu^{\pm}$ charged particles $+ \ e^{\pm}$ charged particles)/total (P33+P34)

```
R52     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R52  B        0.04  OR LESS  CL=.90   BURMEST2  77 PLUT E+E- 4-5 GEV ECM
R52  B  ASSUMES SAME MU,E MOM. SPEC. AS (MU E + NOTHING DETECTED).
```

$\tau^{\pm} \rightarrow (\mu^{\pm} \gamma)$/total (P31)

```
R53     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R53         5.5E-4  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (e^{\pm} \gamma)$/total (P32)

```
R54     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R54         6.4E-4  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (\mu^{\pm} \mu^{+} \mu^{-})$/total (P35)

```
R55     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R55         4.9E-4  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (e^{\pm} \mu^{+} \mu^{-})$/total (P36)

```
R56     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R56         3.3E-4  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (\mu^{\pm} e^{+} e^{-})$/total (P37)

```
R57     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R57         4.4E-4  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (e^{\pm} e^{+} e^{-})$/total (P38)

```
R58     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R58         4.0E-4  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (\mu^{\pm} \pi^{0})$/total (P39)

```
R59     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R59         8.2E-4  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (e^{\pm} \pi^{0})$/total (P40)

```
R60     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R60         2.1E-3  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (\mu^{\pm} K^{0})$/total (P41)

```
R61     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R61         1.0E-3  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (e^{\pm} K^{0})$/total (P42)

```
R62     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R62         1.3E-3  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (\mu^{\pm} \rho^{0})$/total (P43)

```
R63     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R63         4.4E-4  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

$\tau^{\pm} \rightarrow (e^{\pm} \rho^{0})$/total (P44)

```
R64     TEST OF LEPTON FAMILY NUMBER CONSERVATION
R64         3.7E-4  OR LESS  CL=.90   HAYES     82 SMK2 E+E- 3.8-6.8GEV ECM
```

τ DECAY PARAMETERS

ρ (MICHEL) PARAMETER (V−A theory predicts $\rho = 0.75$)

```
RHO    594    0.72     0.15           BACINO2   79 DLCO E+E- ECM=3.5-7.4GEV
RHO  A1426    0.71     0.095          BEHRENDS  85 CLEO  E+E- NEAR UPS(4S)
RHO  A  STAT. ERROR (0.09) AND SYST. ERROR (0.03) ADDED IN QUADRATURE.
RHO  A  USED 699 (727) EVENTS WITH AN ELECTRON (MUON).
RHO         . . . . . . . . . .
RHO AVG       0.713    0.080   AVERAGE
```

τ/μ CHARGED COUPLING−CONSTANT RATIO

```
CC   C        0.94     0.15     0.13  ALTHOFF   84 TASS   E+E- ECM=43 GEV
CC   C  STATISTICAL AND SYSTEMATIC ERRORS ARE +0.12 -0.09 AND 0.09.
```

REFERENCES FOR τ

```
PERL      75 PRL 35 1489          +ABRAMS,BOYARSKI,BREIDENBACH +   (LBL+SLAC)
PERL      76 PL 63B 466           +FELDMAN,ABRAMS,ALAM,BOYARSKI +  (SLAC+LBL)

BARBARO-  77 PRL 39 1058          BARBARO-GALTIERI+       (LBL+NWES+SLAC+HAWA)
BRANDELI  77 PL 70B 125           BRANDELIK +       (AACH+DESY+HAMB+MPIM+TOKY)
BURMEST1  77 PL 68B 297           BURMESTER,CRIEGEE +   (DESY+HAMB+SIEG+WUPG)
BURMEST2  77 PL 68B 301           BURMESTER,CRIEGEE +   (DESY+HAMB+SIEG+WUPG)
CAVALLIS  77 LNC 20 337           CAVALLI-SFORZA,GOGGI +       (PAVI+PRIN+UMD)
PERL      77 PL 70B 487           +FELDMAN,ABRAMS,ALAM,BOYARSKI+   (SLAC+LBL)

ALEXAND2  78 PL 78B 162           ALEXANDER+         (DESY+AACH+HAMB+SIEG+WUPG)
BACINO    78 PRL 41 13            +FERGUSON,NODULMAN +   (UCLA+SLAC+UCI+STON)J
    ALSO  78 TOKYO CONF. P.249    J.KIRZ(19TH INTL.CONF. ON HEP)          (STON)
    ALSO  80 PL 96B 214           ZHOLENTZ,KURDADZE,LELCHUK,MISHNEV+     (NOVO)
BARTEL    78 PL 77B 331           +DITTMANN,DUINKER,OLSSON,ONEILL+(DESY+HEID)

BRANDELI  78 PL 73B 109           BRANDELIK +      (AACH+DESY+HAMB+ MPIM+TOKY)J
HEILE     78 NP B138 189          +PERL,ABRAMS,ALAM,BOYARSKI+         (SLAC+LBL)
JAROS     78 PRL 40 1120          +ABRAMS,ALAM+            (SLAC+LBL+NWES+HAWA)
SMITH     78 PR D18 1             +FORD,MORSE,MANN,RESVANIS+ (COLO+PENN+WISC)

ALLES     79 LNC 25 404           W.ALLES                                (BGNA)J
BACINO1   79 PRL 42 6             +FERGUSON,NODULMAN +   (UCLA+SLAC+UCI+STON)
BACINO2   79 PRL 42 749           +FERGUSON,NODULMAN+    (UCLA+SLAC+UCI+STON)
```

```
BLOCKER  80  LBL-10801,THESIS C.A.BLOCKER                           (LBL)
BRANDELI 80 PL 92B 199        BRANDELIK + (AACH+BONN+DESY+HAMB+LOIC+OXF+)
WAGNER   80 ZPHY C3 193       +ALEXANDER+      (AACH+DESY+HAMB+SIEG+WUPG)
ZHOLENTZ 80 PL 96B 214        +KURDADZE,LELCHUK,MISHNEV,NIKITIN+   (NOVO)
    ALSO 81 YAD.PHYS.34 1471  ZHOLENTZ +                           (NOVO)
BERGER   81 PL 99B 489        +GENZEL+(AACH+BERG+DESY+HAMB+UMD+SIEG+WUPG)
DORFAN   81 PRL 46 215        +BLOCKER,ABRAMS,ALAM +           (SLAC+LBL)

BEHREND  82 PL 114B 282       +CHEN+       (DESY+KARL+MPIM+LALO+LPNP+SACL)
BLOCKER1 82 PL 109B 119       +DORFAN,ABRAMS,ALAM,BLONDEL+     (LBL+SLAC)J
BLOCKER2 82 PRL 48 1586       +ABRAMS,ALAM,BLONDEL,BOYARSKI +  (SLAC+LBL)
BLOCKER3 82 PRL 49 1369       +LEVI,ABRAMS,AMIDEI,BACKER+ (HARV+LBL+SLAC)
FELDMAN  82 PRL 48 66         +TRILLING,ABRAMS,AMIDEI+    (SLAC+LBL+HARV)
FORD     82 PRL 49 106        +SMITH+(COLO+FRAS+NEAS+STAN+SLAC+UTAH+WISC)
HAYES    82 PR D25 2869       +PERL,ALAM,BOYARSKI,BREIDENBACH+ (SLAC+LBL)

BEHREND  83 PL 127B 270       +CHEN+       (DESY+KARL+MPIM+LALO+LPNP+SACL)
BEHREND2 83 NP B211 369       +CHEN+       (DESY+KARL+MPIM+LALO+LPNP+SACL)
JAROS    83 PRL 51 955        +AMIDEI,TRILLING+           (SLAC+LBL+HARV)
AIHARA   84 PR D30 2436       TPC C,+ALSTON-GARNJOST+ (LBL+UCLA+UCR+JHU+)
ALTHOFF  84 PL 141B 264       TASSO C. (AACH+BONN+DESY+HAMB+LOIC+OXF+RL+)
BEHREND  84 ZPHY C23 103      CELLO COLL. (DESY+KARL+MPIM+LALO+LPNP+SACL)
MILLS    84 PRL 52 1944       DELCO COLLABORATION         (CIT+SLAC+STAN)

AKERLOF  85 PRL 55 570        HRS C,+BARANKO+(ANL+IND+MICH+PURD+LBL+STAN)
ALTHOFF  85 ZPHY C26 521      TASSO C,   (AACH+BONN+BRIS+DESY+HAMB+LOIC+)
ASH      85 PRL 55 2118       MAC C,+BAND+    (COLO+FRAS+HOUS+NEAS+SLAC+)
BALTRUSA 85 PRL 55 1842       MARK III C,BALTRUSAITIS+    (CIT+UCSC+ILL+)
BARTEL   85 PL 161 188        JADE C,+(DESY+HAMB+HEID+LANC+MCHS+UMD+RAL+)
BEHRENDS 85 PR D32 2468       CLEO C.,+   (ROCH+RUTG+SYRA+VAND+ALBA+CMU+)
BELTRAMI 85 PRL 54 1775       HRS C,+BYLSMA+ (PURD+ANL+IND+MICH+LBL+SLAC)
BERGER   85 ZPHY C28 1        PLUTO C,+GENZEL+(AACH+BERG+DESY+GLAS+HAMB+)
BURCHAT  85 PRL 54 2489       MARK II C,+SCHMIDKE,YELTON+ (SLAC+LBL+HARV)
FERNANDE 85 PRL 54 1624       MAC C,FERNANDEZ+(COLO+FRAS+HOUS+NEAS+SLAC+)
MILLS    85 PRL 54 624        DELCO C,+PAL,ATWOOD,BAILLON+(CIT+SLAC+STAN)

                              REVIEWS

AZIMOV   78 SPU 21 225        +FRANKFURT,KHOZE                     (LENI)
FELDMAN  78 TOKYO CONF.,P.777 G.J.FELDMAN (19TH INTL. CONF. ON HEP)(SLAC)J
PERL     78  SLAC-PUB-2219    M.L.PERL (KARLSRUHE SUMMER INST.1978)(SLAC)

FLUGGE   79 ZPHY C1 121       G.FLUGGE                             (DESY)
KIRKBY   79  SLAC-PUB-2419    J.KIRKBY(LEPTON PHOTON SYMP. BATAVIA)(SLAC)J
PERL     80 ARNPS 30 299      M.L.PERL                             (SLAC)
```

SEARCHES FOR MASSIVE NEUTRINOS AND LEPTON MIXING

OMITTED FROM SUMMARY TABLE

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SEE THE NOTE ON NEUTRINOS BY R.E. SHROCK IN THE ELECTRON NEUTRINO
SECTION NEAR THE BEGINNING OF THESE DATA LISTINGS.

SEARCHES FOR INDIRECT EFFECTS OF NEUTRINO MASSES AND LEPTON MIXING
ARE LISTED HERE.  DIRECT SEARCHES FOR MASSES OF DOMINANTLY COUPLED
NEUTRINOS ARE LISTED IN THE APPROPRIATE SECTION ON NU(MU), NU(E),
OR NU(TAU).  RESULTS OF THESE INDIRECT SEARCHES ARE CORRELATED
UPPER BOUNDS ON MIXING MATRIX COEFFICIENTS U(A,J) VERSUS
NEUTRINO MASS.  THESE RESULTS ARE DIVIDED INTO THREE SECTIONS--
      (A) BOUNDS FROM PARTICLE AND NUCLEAR DECAYS
      (B) BOUNDS FROM NEUTRINO REACTIONS
      (C) SEARCHES FOR NEUTRINOLESS DOUBLE BETA DECAY

THE SITUATION CAN BE SUMMARIZED AS FOLLOWS.  CURRENT EXPERIMENTS
YIELD NULL RESULTS, I.E. ONLY UPPER BOUNDS, WITH TWO EXCEPTIONS
BOTH OF WHICH ARE IN STRONG CONFLICT WITH SUBSEQUENT EXPERIMENTS:
      (1) CAVAIGNAC 84, REPORT EVIDENCE FOR NEUTRINO OSCILLATIONS
          OF THE TYPE NUBAR(E) -/-> NUBAR(E), FROM REACTOR
          NEUTRINO EXPERIMENT AT BUGEY.  HOWEVER, ZACEK 85 RULES
          OUT ALMOST ALL OF THE ALLOWED REGION IN SIN(2*THETA)**2
          AND DELTA(M**2) CLAIMED BY CAVAIGNAC 84.
      (2) SIMPSON 85 REPORTS OBSERVATION OF ADMIXED HEAVY
          NEUTRINO IN TRITIUM BETA DECAY WITH M(NU(J))=17.1 KEV,
          CABS(U(1,J))**2=0.03+-0.01.  HOWEVER, THE CLAIM OF
          SIMPSON 85 IS STRONGLY REFUTED BY ALTZITZOGLU 85,
          OHI 85, AND APALIKOV 85.

SEE ALSO BOUNDS ON MASSES OF NEUTRINOS ABOVE.
```

(A). BOUNDS FROM PARTICLE AND NUCLEAR DECAYS

LIMITS ON $|U_{1,j}|^2$ AS FUNCTION OF MASS(ν_j)

```
U1J
U1J     APPLICATION OF KINK AND PEAK SEARCH TEST TO EXISTING DATA.
U1J  D       1.        OR LESS  CL=.95   SIMPSON   81      M(NU(J))=0.1 KEV
U1J  D       4. E-3    OR LESS  CL=.95   SIMPSON   81              =10 KEV
U1J  A       0.1       OR LESS  CL=.68   SHROCK    80      M(NU(J))=0.1-3 MEV
U1J  B       1. E-4    OR LESS  CL=.68   SHROCK1   81      M(NU(J))=10 MEV
U1J  B       5. E-6    OR LESS  CL=.68   SHROCK1   81              =60 MEV
U1J  C       1. E-5    OR LESS  CL=.68   SHROCK    80      M(NU(J))=80 MEV
U1J  C       3. E-6    OR LESS  CL=.68   SHROCK    80              =160 MEV
U1J  D   APPLICATION OF KINK SEARCH TEST TO TRITIUM BETA DECAY KURIE PLOT.
U1J  A   APPLICATION OF TEST TO SEARCH FOR KINKS IN BETA DECAY KURIE PLOTS.
U1J  B   ANALYSIS OF (PI+ --> E+ NU(E))/(PI+ --> MU+ NU(MU)) AND
U1J  B   (K+ --> E+ NU(E))/(K+ --> MU+ NU(MU)) DECAY RATIOS.
U1J  C   ANALYSIS OF (K+ --> E+ NU(E)) SPECTRUM.
U1J
U1J     NEW EXPERIMENTS TO APPLY PEAK AND KINK SEARCH TESTS.
U1J          1. E-4    OR LESS  CL=.90   BRYMAN    83 CNTR M(NU(J))=5 MEV
U1J          1.5E-6    OR LESS  CL=.90   BRYMAN    83 CNTR         =53 MEV
U1J          1. E-5    OR LESS  CL=.90   BRYMAN    83 CNTR         =70 MEV
U1J          1. E-4    OR LESS  CL=.90   BRYMAN    83 CNTR         =130 MEV
U1J
U1J     SEARCHES FOR DECAYS OF MASSIVE NU
U1J  B       1. E-2    OR LESS  CL=.90   BERGSMA   83 CNTR M(NU(J))=10 MEV
U1J  B       1. E-5    OR LESS  CL=.90   BERGSMA   83 CNTR         =110 MEV
U1J  B       6. E-7    OR LESS  CL=.90   BERGSMA   83 CNTR         =410 MEV
U1J          1. E-5    OR LESS  CL=.90   GRONAU    83      M(NU(J))=160 MEV
U1J          1. E-6    OR LESS  CL=.90   GRONAU    83      M(NU(J))=480 MEV
U1J  C       0.7E-6    OR LESS  CL=.90   COOPER-SA 85 HLBC M(NU(J))=0.4 GEV
U1J  C       0.8E-7    OR LESS  CL=.90   COOPER-SA 85 HLBC M(NU(J))=1.5 GEV
```

```
U1J  B  BERGSMA 83 ALSO QUOTE LIMITS ON CABS(U(1,3))**2 WHERE THE INDEX 3
U1J  B  REFERS TO THE MASS EIGENSTATE DOMINANTLY COUPLED TO THE TAU.  THOSE
U1J  B  LIMITS WERE BASED ON ASSUMPTIONS ABOUT THE D/S MASS AND D/S -->
U1J  B  TAU NUTAU BRANCHING RATIO WHICH ARE NO LONGER VALID.  SEE COOPER-
U1J  B  SARKAR 85.
U1J  C  COOPER-SARKER 85 ALSO GIVE LIMITS BASED ON MODEL-DEPENDENT
U1J  C  ASSUMPTIONS FOR NU(TAU) FLUX.  WE DO NOT LIST THESE.
U1J  C  NOTE THAT FOR THIS BOUND TO BE NON-TRIVIAL, J IS NOT EQUAL TO 3,
U1J  C  I.E. NU(J) CANNOT BE THE DOMINANT MASS EIGENSTATE IN NU(TAU) SINCE
U1J  C  M(NU(3))<70 MEV (ALBRECHT 85).  ALSO, OF COURSE, J IS NOT EQUAL TO
U1J  C  1 OR 2, SO A FOURTH GENERATION WOULD BE REQUIRED FOR THIS BOUND TO
U1J  C  BE NONTRIVIAL.

U1J
U1J    KINK SEARCH IN NUCLEAR BETA DECAY
U1J         2.5E-2  OR LESS  CL=.90   SCHRECKEN 83 CNTR M(NU(J))=30 KEV
U1J         0.4E-2  OR LESS  CL=.90   SCHRECKEN 83 CNTR        =140 KEV
U1J         0.8E-2  OR LESS  CL=.90   SCHRECKEN 83 CNTR        =440 KEV
U1J
U1J  S       0.03     (0.01)          SIMPSON   85     M(NU(J))=17.1+-0.2KEV
U1J  A      4.  E-3 OR LESS  CL=.99   ALTZITZO  85      FOR M(NU(J))=17 KEV
U1J  A      7.5 E-3 OR LESS  CL=.99   ALTZITZO  85     M(NU(J))=5-50 KEV
U1J  A      8.  E-3 OR LESS  CL=.90   APALIKOV  85 SPEC    M(NU(J))=80 KEV
U1J  A      1.5 E-3 OR LESS  CL=.90   APALIKOV  85 SPEC            =60 KEV
U1J  A      8.  E-3 OR LESS  CL=.90   APALIKOV  85 SPEC            =30 KEV
U1JB A      3.  E-3 OR LESS  CL=.90   APALIKOV  85 SPEC            =17 KEV
U1J  A      4.5 E-2 OR LESS  CL=.90   APALIKOV  85 SPEC            = 4 KEV
U1J  A      3.0 E-3 OR LESS  CL=.90   MARKEY    85 SPEC  M(NU(J))=5-50 KEV
U1J  A      2.5 E-3 OR LESS  CL=.90   MARKEY    85 SPEC            =17 KEV
U1J  A      0.62E-3 OR LESS  CL=.90   OHI       85 CNTR    M(NU(J)) =48 KEV
U1J  A      0.90E-3 OR LESS  CL=.90   OHI       85 CNTR             =30 KEV
U1J  A      1.30E-3 OR LESS  CL=.90   OHI       85 CNTR             =20 KEV
U1J  A      1.50E-3 OR LESS  CL=.90   OHI       85 CNTR             =17 KEV
U1J  A      3.30E-3 OR LESS  CL=.90   OHI       85 CNTR             =10 KEV
U1J
U1J  A  DATA FROM SULFUR-35 BETA DECAY.
U1J  S  DATA FROM TRITIUM BETA DECAY CONTRADICTED BY ALTZITZOGLOU 85,
U1J  S  APALIKOV 85, MARKEY 85, AND BY OHI 85.  ALSO COMMENT IN HAXTON 85
U1J  S  AND KALBFLEISCH 85.
U1JB    THIS LIMIT WAS TAKEN FROM THE FIG. 3 OF APALIKOV 85; THE TEXT GIVES
U1JB    A MORE RESTRICTIVE LIMIT OF 1.7E-3 AT CL=.90.
```

LIMITS ON $|U_{2,j}|^2$ AS FUNCTION OF MASS(ν_j)

```
U2J
U2J    APPLICATION OF PEAK SEARCH TEST TO EXISTING DATA.
U2J  A      5. E-2  OR LESS  CL=.95   SHROCK    80       M(NU(J))=4-6 MEV
U2J  A      3. E-2  OR LESS  CL=.95   SHROCK1   81       M(NU(J))=7 MEV
U2J  A      1. E-2  OR LESS  CL=.95   SHROCK1   81               =13 MEV
U2J  A      1. E-4  OR LESS  CL=.68   SHROCK1   81       M(NU(J))=13 MEV
U2J  A      3. E-5  OR LESS  CL=.68   SHROCK1   81               =33 MEV
U2J  B      6. E-3  OR LESS  CL=.68   SHROCK1   81       M(NU(J))=80 MEV
U2J  B      5. E-3  OR LESS  CL=.68   SHROCK1   81               =120 MEV
U2J  C      6. E-6  OR LESS  CL=.95   ASANO     81       M(NU(J))=240 MEV
U2J  C      5. E-7  OR LESS  CL=.95   ASANO     81               =280 MEV
U2J  C      6. E-6  OR LESS  CL=.95   ASANO     81               =300 MEV
U2J
U2J     NEW EXPERIMENTS TO APPLY PEAK SEARCH TEST.
U2J  D      1. E-1  OR LESS  CL=.90   ABELA     81       M(NU(J))=4 MEV
U2J  D      7. E-5  OR LESS  CL=.90   ABELA     81               =11 MEV
U2J  D      2. E-4  OR LESS  CL=.90   ABELA     81       M(NU(J))=11 MEV
U2J  D      2. E-5  OR LESS  CL=.90   ABELA     81               =16 MEV
U2J  D      2. E-5  OR LESS  CL=.90   ABELA     81       M(NU(J))=16-30 MEV
U2J  D      1. E-2  OR LESS  CL=.95   CALAPRICE 81       M(NU(J))=7 MEV
U2J  D      3. E-3  OR LESS  CL=.95   CALAPRICE 81               =33 MEV
U2J  E      2. E-5  OR LESS  CL=.95   ASANO     81       M(NU(J))=170 MEV
U2J  E      3. E-6  OR LESS  CL=.95   ASANO     81               =210 MEV
U2J  E      3. E-6  OR LESS  CL=.95   ASANO     81               =230 MEV
U2J  E      1. E-4  OR LESS  CL=.90   HAYANO    82       M(NU(J))=70 MEV
U2J  E      9. E-7  OR LESS  CL=.90   HAYANO    82               =250 MEV
U2J  E      5. E-6  OR LESS  CL=.90   HAYANO    82               =330 MEV
U2J  D      3. E-2  OR LESS  CL=.90   MINEHART  84       M(NU(J))=2 MEV
U2J  D      1. E-3  OR LESS  CL=.90   MINEHART  84       M(NU(J))=4 MEV
U2J  D      3. E-4  OR LESS  CL=.90   MINEHART  84       M(NU(J))=10 MEV
U2J  A  ANALYSIS OF MAG. SPEC. EXP., BC EXP. AND EMUL. EXP. ON PI+ --> MU+
U2J  A  NU(MU) DECAY.
U2J  B  ANALYSIS OF MAG. SPEC. EXP. ON K-->MU,NU(MU) DECAY.
U2J  C  ANALYSIS OF EXP. ON K+ --> MU+ NU(MU) NU(X) NUBAR(X) DECAY.
U2J  D  PI+ --> MU+ NU(MU)  PEAK SEARCH EXP.
U2J  E  K+ --> MU+ NU(MU)  PEAK SEARCH EXP.
U2J
U2J    PEAK SEARCH IN MUON-CAPTURE
U2J    LIMIT ON CABS(U(2,J))**2 AS FUNCTION OF MASS(NU(J))
U2J         1.E-1   OR LESS           DEUTSCH   83       M(NU(J))=45 MEV
U2J         7.E-3   OR LESS           DEUTSCH   83               =70 MEV
U2J         1.E-1   OR LESS           DEUTSCH   83               =85 MEV
U2J
U2J    SEARCHES FOR DECAYS OF MASSIVE NU
U2J  F      0.8E-5  OR LESS  CL=.90   COOPER-SA 85 HLBC M(NU(J))=0.4 GEV
U2J  F      1.0E-7  OR LESS  CL=.90   COOPER-SA 85 HLBC M(NU(J))=1.5 GEV
U2J  F  COOPER-SARKER 85 ALSO GIVE LIMITS BASED ON MODEL-DEPENDENT
U2J  F  ASSUMPTIONS FOR NU(TAU) FLUX.  WE DO NOT LIST THESE.
U2J  F  NOTE THAT FOR THIS BOUND TO BE NON-TRIVIAL, J IS NOT EQUAL TO 3,
U2J  F  I.E. NU(J) CANNOT BE THE DOMINANT MASS EIGENSTATE IN NU(TAU) SINCE
U2J  F  M(NU(3))<70 MEV (ALBRECHT 85).  ALSO, OF COURSE, J IS NOT EQUAL TO
U2J  F  1 OR 2, SO A FOURTH GENERATION WOULD BE REQUIRED FOR THIS BOUND TO
U2J  F  BE NONTRIVIAL.
```

LIMITS ON $|U_{a,j}|^2$

```
UAJ    WHERE A=1,2, FROM RHO PARAM. IN MU DECAY.
UAJ         1. E-2  OR LESS  CL=.68   SHROCK2   81       M(NU(J))=10 MEV
UAJ         2. E-3  OR LESS  CL=.68   SHROCK2   81               =40 MEV
UAJ         4. E-2  OR LESS  CL=.68   SHROCK2   81               =70 MEV
```

LIMITS ON $|U_{1,j}{}^*U_{2,j}|$ AS FUNCTION OF MASS(ν_j)

```
PRO
PRO         1. E-2  OR LESS  CL=.90   BERGSMA   83 CNTR M(NU(J))=10 MEV
PRO         1. E-5  OR LESS  CL=.90   BERGSMA   83 CNTR         =140 MEV
PRO         7. E-7  OR LESS  CL=.90   BERGSMA   83 CNTR         =370 MEV
```

(B). BOUNDS FROM ν REACTIONS

--------- SOLAR ν EXPERIMENTS ---------

SOLAR ν FLUX (units, SNU)

```
S      (1 SOLAR NEUTRINO UNIT, SNU, =1.E-36 CAPTURES/SEC/TARGET ATOM)
S           (7.3)     (1.5)               BAHCALL    80          THEOR.CALC.FLUX
S            2.1       0.3                DAVIS      81          MEAS. FLUX
S           (7.0)     (3.0)               FILIPPONE  82          THEOR.CALC.FLUX
S        SEE ALSO THE REVIEW BY BAHCALL 82 AND THE ANALYSIS BY EHRLICH 82.
```

Stable Particle Full Listings

SEARCHES FOR MASSIVE ν's & LEPTON MIXING

DEEP MINE EXPERIMENTS

R= (MEASURED FLUX OF ν_μ)/(EXPECTED FLUX OF ν_μ)

```
DU              0.62      0.17                CROUCH     78          CASE WEST/UCI
DU   B          0.95      0.22                BOLIEV     81          BAKSAN
DU
DU      LIMITS ON DELTA(M**2) FOR SIN(2*THETA)=1  (EV**2)
DU  L  EXCLUDE (2.2-11.2)E-5  CL=.90  LOSECCO    85 CNTR     IMB, FLUX-INDEP.
DU
DU   B  FROM THIS DATA BOLIEV 81 OBTAIN THE LIMIT DELTA(M**2) .LE. 6.E-3
DU   B  EV**2 FOR MAXIMAL MIXING, NU(MU) -/-> NU(MU) TYPE OSCILLATION.
DU  L   NO LIMTS EXIST FOR (SIN 2*ETA)**2 < 0.22
DU        . . . . . . . . . .
DU  AVERAGE MEANINGLESS (SCALE FACTOR = 1.2)
```

REACTOR $\overline{\nu}$ EXPERIMENTS

EVENTS (OBSERVED/EXPECTED) FROM REACTOR $\overline{\nu}_e$ EXPTS.

```
RD  B         (0.89)   (0.15)             BOEHM      80        ANU(E) P --> E+ N
RD A R         0.38     0.21              REINES     80        SEE NOTE A
RD A R         0.40     0.22              REINES     80        SEE NOTE A
RD   B         0.955    0.12              KWON       81        ANU(E) P --> E+ N
RD   V         1.05     0.054             VUILLEUMI  82        ANU(E) P --> E+ N
RD   B  KWON 81 REPRESENTS AN ANALYSIS OF A LARGER SET OF DATA FROM THE
RD   B  SAME EXPERIMENT AS BOEHM 80. SYST.+STAT. ERRORS COMBINED IN
RD   B  QUADRATURE.
RD   A  REINES 80 INVOLVES COMPARISON OF NEUTRAL- AND CHARGED-CURRENT
RD   A  REACTIONS NUBAR(E) D --> N P NUBAR(E) AND NUBAR(E) D --> N N E+
RD   A  RESPECTIVELY. COMBINED ANALYSIS OF REACTOR NUBAR(E) EXPTS. WAS
RD   A  PERFORMED BY SILVERMAN 81.
RD   R  THE TWO REINES 80 VALUES CORRESPOND TO THE CALCULATED NUBAR(E)
RD   R  FLUXES OF AVIGNONE-GREENWOOD AND DAVIS ET AL RESPECTIVELY.
RD   V  STATISTICAL AND SYSTEMATIC ERRORS COMBINED IN QUADRATURE.
```

$\overline{\nu}_e \not\to \overline{\nu}_e$

$\Delta(m^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
RD1         1.3E-1   OR LESS              BELENKII  83        ANU(E) P -> E+ N
RD1  G      1.6E-2   OR LESS  CL=.90      GABATHULE 84        ANU(E) P -> E+ N
RD1         7. E-2   OR LESS  CL=.90      AFONIN    85        ANU(E) P -> E+ N
RD1  J      2.0E-2   OR LESS  CL=.90      ZACEK     85        ANU(E) P -> E+ N
RD1  G  THIS BOUND COMES FROM A COMBINATION OF THE VUILLEUMIER 82 DATA AT
RD1  G  DISTANCE 37.9 M FROM GOSGEN REACTOR AND NEW DATA AT 45.9M
RD1  J  SEE COMMENT J FOR SECTION RS1 BELOW.
```

$\Delta(m^2)$ FOR GIVEN $\sin^2(2\theta)$ (units eV^2)

```
RD2  C        0.2       0.1               CAVAIGNA  84        ANU(E) P -> E+ N
RD2  C  SIN(2*THETA)**2=0.25+-0.1.
RD2  C  THESE ARE FROM BEST FIT TO DATA; SEE CAVAIGNAC 84 FOR PLOT OF
RD2  C  ALLOWED REGIONS IN THESE VARIABLES. THESE DATA FROM BUGEY REACTOR.
```

$\sin^2(2\theta)$ FOR "LARGE" $\Delta(m^2)$

```
RS1  H      0.4      OR LESS              BELENKII  83        ANU(E) P -> E+ N
RS1  G      0.16     OR LESS  CL=.90      GABATHULE 84        ANU(E) P -> E+ N
RS1         0.34     OR LESS  CL=.90      AFONIN    85        ANU(E) P -> E+ N
RS1  J      0.19     OR LESS  CL=.90      ZACEK     85        ANU(E) P -> E+ N
RS1  G  THIS BOUND COMES FROM A COMBINATION OF THE VUILLEUMIER 82 DATA AT
RS1  G  DISTANCE 37.9 M FROM GOSGEN REACTOR AND NEW DATA AT 45.9M
RS1  H  THIS BOUND HOLDS FOR DELTA(M**2) > 4EV**2
RS1  J  ZACEK 85 (GOSGEN REACTOR) GIVES TWO SETS OF BOUNDS DEPENDING ON
RS1  J  WHAT ASSUMPTIONS ARE USED IN THE DATA ANALYSIS.  THE BOUNDS IN
RS1  J  FIG. 3(A) OF ZACEK 85 ARE PROGRESSIVELY POORER FOR LARGE
RS1  J  DELTA(M**2) WHEREAS THOSE OF FIG. 3(B) APPROACH A CONSTANT. WE LIST
RS1  J  THE LATTER.  BOTH SETS OF BOUNDS USE COMBINATION OF DATA FROM
RS1  J  37.9, 45.9, AND 64.7 M DISTANCE FROM REACTOR. ZACEK 85 STATES
RS1  J  ''OUR EXPERIMENT EXCLUDES THIS AREA (THE OSCILLATION PARAMETER
RS1  J  REGION ALLOWED BY THE BUGEY DATA, CAVAIGNAC 84) ALMOST COMPLETELY,
RS1  J  THUS DISPROVING THE INDICATIONS OF NEUTRINO OSCILLATIONS OF
RS1  J  (CAVAIGNAC 84) WITH A HIGH DEGREE OF CONFIDENCE.''
```

ACCELERATOR EXPERIMENTS

BOUNDS ON $\Delta(m^2)$ VS. $\sin^2(2\theta)$

```
WHERE DELTA(M**2) IS MAGNITUDE OF (MASS(NU(I))**2 - MASS(NU(J))**2)
AND THETA IS THE MIXING ANGLE FOR THE SIMPLIFYING ASSUMPTION OF
MIXING BETWEEN TWO NEUTRINO FAMILIES ONLY.
FOR A RECENT SET OF BOUNDS ASSUMING THREE NEUTRINO FAMILIES,
SEE BLUMER 85.

EACH EXPERIMENTAL RESULT IS A PLOT GIVING ALLOWED AND EXCLUDED
REGIONS AS FUNCTIONS OF DELTA(M**2) AND SIN(2*THETA)**2.  WE QUOTE
TWO REPRESENTATIVE LIMITS FROM EACH PLOT --
   1)  DELTA(M**2) FOR SIN(2*THETA)**2=1.
   2)  SIN(2*THETA)**2 FOR ''LARGE'' DELTA(M**2), I.E. SUFFICIENTLY
       LARGE DELTA(M**2) THAT THE DETECTOR WOULD MEASURE ONLY AN
       EFFECT AVERAGED OVER MANY OSCILLATIONS.
EXPERIMENTS ARE OF TWO GENERAL TYPES --
   (A) THOSE WHICH SEARCH FOR NU(A)-->NU(B) (B NOT EQUAL A), I.E.
       THE APPEARANCE OF L(B) FROM CHARGED CURRENT REACTION OF A
       NU(A) BEAM.
   (B) THOSE WHICH SEARCH FOR THE 'DISAPPEARANCE' OF PART OF THE
       INITITAL NU(A) BEAM BY COMPARING THE NUMBER OF OBSERVED L(A)
       EVENTS WITH THE NUMBER EXPECTED FROM FLUX CALCULATIONS.
       THESE EXPERIMENTS DO NOT TRY TO OBSERVE THE ANOMALOUS
       L(B)'S.  WE LABEL SUCH EXPERIMENTS AS NU(A) -/-> NU(A)
```

$\nu_\mu \to \nu_e$

$\Delta(m^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
D1          1.2      OR LESS  CL=.95   BELLOTTI  76 HLBC GGM CERN PS
D1          1.2      OR LESS  CL=.95   BLIETSCHA 78 HLBC GGM CERN PS
D1          1.7      OR LESS  CL=.90   ARMENISE  81 HLBC GGM CERN SPS
D1          0.6      OR LESS  CL=.90   BAKER     81 HLBC 15FT FNAL
D1          1.7      OR LESS  CL=.90   ERRIQUEZ  81 HLBC BEBC CERN SPS
D1          0.20     OR LESS  CL=.90   BERGSMA   84 CNTR CHARM CERN PS
D1          0.43     OR LESS  CL=.90   AHRENS    85 CNTR BNL AGS
```

$\sin^2(2\theta)$ FOR "LARGE" $\Delta(m^2)$

```
S1          1. E-2   OR LESS  CL=.95   BELLOTTI  76 HLBC GGM CERN PS
S1          4. E-3   OR LESS  CL=.95   BLIETSCHA 78 HLBC GGM CERN PS
S1          1. E-2   OR LESS  CL=.90   ARMENISE  81 HLBC GGM CERN SPS
S1          6. E-3   OR LESS  CL=.90   BAKER     81 HLBC 15FT FNAL
S1          1. E-2   OR LESS  CL=.90   ERRIQUEZ  81 HLBC BEBC CERN SPS
S1          0.24     OR LESS  CL=.90   BERGSMA   84 CNTR CHARM CERN PS
S1          3.4E-3   OR LESS  CL=.90   AHRENS    85 CNTR BNL AGS
```

$\overline{\nu}_\mu \to \overline{\nu}_e$

$\Delta(m^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
D2          1.       OR LESS  CL=.95   BLIETSCHA 78 HLBC GGM CERN PS
D2          0.91     OR LESS  CL=.90   NEMETHY   81 CNTR LAMPF
D2          2.4      OR LESS  CL=.90   TAYLOR    83 HLBC    15 FT FNAL
```

$\sin^2(2\theta)$ FOR "LARGE" $\Delta(m^2)$

```
S2          4. E-3   OR LESS  CL=.95   BLIETSCHA 78 HLBC GGM CERN PS
S2          0.2      OR LESS  CL=.90   NEMETHY   81 CNTR LAMPF
S2          1.3E-2   OR LESS  CL=.90   TAYLOR    83 HLBC    15 FT FNAL
```

$\nu_\mu \to \nu_\tau$

$\Delta(m^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
D3          4.6      OR LESS  CL=.90   ARMENISE  81 HLBC GGM CERN SPS
D3          3.       OR LESS  CL=.90   BAKER     81 HLBC 15FT FNAL
D3          6.       OR LESS  CL=.90   ERRIQUEZ  81 HLBC BEBC CERN SPS
D3          3.       OR LESS  CL=.90   USHIDA    81 EMUL FNAL
```

$\sin^2(2\theta)$ FOR "LARGE" $\Delta(m^2)$

```
S3          1.7E-2   OR LESS  CL=.90   ARMENISE  81 HLBC GGM CERN SPS
S3          6. E-2   OR LESS  CL=.90   BAKER     81 HLBC 15FT FNAL
S3          5. E-2   OR LESS  CL=.90   ERRIQUEZ  81 HLBC BEBC CERN SPS
S3          1.3E-2   OR LESS  CL=.90   USHIDA    81 EMUL FNAL
S3         11. E-2   OR LESS  CL=.90   BALLAGH   84 HLBC 15FT FNAL
```

$\overline{\nu}_\mu \to \overline{\nu}_\tau$

$\Delta(m^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
D4          2.2      OR LESS  CL=.90   ASRATYAN  81 HLBC FNAL
D4          7.4      OR LESS  CL=.90   TAYLOR    83 HLBC    15 FT FNAL
```

$\sin^2(2\theta)$ FOR "LARGE" $\Delta(m^2)$

```
S4          4.4E-2   OR LESS  CL=.90   ASRATYAN  81 HLBC FNAL
S4          8.8E-2   OR LESS  CL=.90   TAYLOR    83 HLBC    15 FT FNAL
```

$\nu_\mu \not\to \nu_\mu$

$\Delta(m^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
D5       THESE EXPERIMENTS ALSO ALLOW SUFFICIENTLY LARGE DELTA(M**2)
D5          8.0      OR LESS  CL=.90   BELIKOV   83 CNTR    OR > 1000.
D5          0.29     OR LESS  CL=.90   BERGSMA   84 CNTR    OR > 22.
D5          0.23     OR LESS  CL=.90   DYDAK     84 CNTR    OR > 100.
D5         10.       OR LESS  CL=.90   STOCKDALE 84 CNTR    OR > 1250.
D5          7.       OR LESS  CL=.90   BELIKOV   85 CNTR    SERPUKHOV
D5          8.0      OR LESS  CL=.90   STOCKDALE 85 CNTR    OR > 1250.
```

$\sin^2(2\theta)$ AS FUNCTION OF $\Delta(m^2)$

```
S5   A      0.1      OR LESS  CL=.90   BELIKOV   83 CNTR  SERPUKHOV
S5   B      0.27     OR LESS  CL=.90   BERGSMA   84 CNTR  CHARM  CERN PS
S5   C      0.1      OR LESS  CL=.90   DYDAK     84 CNTR  CERN PS
S5   D      0.02     OR LESS  CL=.90   STOCKDALE 84 CNTR  FNAL
S5   E      0.07     OR LESS  CL=.90   BELIKOV   85 CNTR    SERPUKHOV
S5   F      0.02     OR LESS  CL=.90   STOCKDALE 85 CNTR  FNAL
S5   A  BOUND HOLDS FOR DELTA(M**2)=20-1000 EV**2
S5   B  THIS BOUND APPLIES FOR DELTA(M**2)=0.7-9. EV**2.  LESS STRINGENT
S5   B  BOUNDS APPLY FOR OTHER DELTA(M**2); THESE ARE NONTRIVIAL FOR
S5   B  0.28 < DELTA(M**2) < 22 EV**2.
S5   C  THIS BOUND APPLIES FOR DELTA(M**2)=1.-10. EV**2.  LESS STRINGENT
S5   C  BOUNDS APPLY FOR OTHER DELTA(M**2); THESE ARE NONTRIVIAL FOR
S5   C  0.23 < DELTA(M**2) < 90 EV**2.
S5   D  THIS BOUND APPLIES FOR DELTA(M**2)=110 EV**2.  LESS STRINGENT
S5   D  BOUNDS APPLY FOR OTHER DELTA(M**2); THESE ARE NONTRIVIAL FOR
S5   D  10 < DELTA(M**2) < 1250 EV**2.
S5   E  THIS BOUND APPLIES FOR A WIDE RANGE OF DELTA(M**2) > 7 EV**2.  FOR
S5   E  SOME VALUES OF DELTA(M**2), THE VALUE IS LESS STRINGENT; THE LEAST
S5   E  RESTRICTIVE, NONTRIVIAL BOUND OCCURS APPROXIMATELY AT DELTA(M**2)=
S5   E  300 EV**2 WHERE SIN(2*THETA)**2 < 0.13 AT CL=.90.
S5   F  THIS BOUND APPLIES FOR DELTA(M**2)=100 EV**2.  LESS STRINGENT
S5   F  BOUNDS APPLY FOR OTHER DELTA(M**2); THESE ARE NONTRIVIAL FOR
S5   F  8 < DELTA(M**2) < 1250 EV**2.
```

$\nu_e \not\to \nu_e$

$\Delta(m^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
D6          8.       OR LESS  CL=.90   BAKER     81 HLBC 15FT FNAL
D6         56.       OR LESS  CL=.90   DEDEN     81 HLBC BEBC CERN SPS
D6         10.       OR LESS  CL=.90   ERRIQUEZ  81 HLBC BEBC CERN SPS
D6         2.3 TO 8 EXCLUDED CL=.90   NEMETHY   81 CNTR LAMPF
```

$\sin^2(2\theta)$ FOR "LARGE" $\Delta(m^2)$

```
S6          0.6      OR LESS  CL=.90   BAKER     81 HLBC 15FT FNAL
S6          0.3      OR LESS  CL=.90   DEDEN     81 HLBC BEBC CERN SPS
S6          7.E-2    OR LESS  CL=.90   ERRIQUEZ  81 HLBC BEBC CERN SPS
```

$\overline{\nu}_e \to \overline{\nu}_\tau$

$\sin^2(2\theta)$ FOR "LARGE" $\Delta(m^2)$

```
S7   F      0.7      OR LESS  CL=.90   FRITZE    80 HYBR BEBC CERN SPS
S7   F   AUTHORS GIVE P(NU(E)-->NU(TAU))< .35, EQUIVALENT TO ABOVE LIMIT.
```

$\overline{\nu}_\mu \not\to \overline{\nu}_\mu$

$\Delta(m^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
D8          7.       OR LESS  CL=.90   STOCKDALE 85 CNTR  OR > 1200
```

$\sin^2(2\theta)$ AS FUNCTION OF $\Delta(m^2)$

```
S8   G      0.02     OR LESS  CL=.90   STOCKDALE 85 CNTR  FNAL
S8
S8   G  THIS BOUND APPLIES FOR DELTA(M**2) BETWEEN 190 AND 320 OR=530 EV**2
S8   G  LESS STRINGENT BOUNDS APPLY FOR OTHER DELTA(M**2); THESE ARE NON-
S8   G  TRIVIAL FOR 7 < DELTA(M**2) < 1200 EV**2.
```

$\nu_\mu \rightarrow (\overline{\nu}_e)_L$

THIS IS A LIMIT ON LEPTON FAMILY-NUMBER VIOLATION AND TOTAL LETPON-NUMBER VIOLATION. (NUBAR(E))-L DENOTES A HYPOTHETICAL LEFT-HANDED ANTI-ELECTRON NEUTRINO. THE BOUND IS QUOTED IN TERMS OF DELTA (M**2), SIN(2*THETA), AND ALPHA, WHERE ALPHA DENOTES THE FRACTIONAL ADMIXTURE OF (V+A) CHARGED CURRENT.

$\alpha\,\Delta(\mathrm{m}^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
AD1  C       7.E-1  OR LESS  CL=.90   COOPER    82 HLBC
AD1  C  EXISTING BOUNDS ON V+A CURRENTS REQUIRE ALPHA SMALL - SEE COOPER82.
```

$\alpha^2\sin^2(2\theta)$ FOR "LARGE" $\Delta(\mathrm{m}^2)$

```
AS1  C       1.E-3  OR LESS  CL=.90   COOPER    82 HLBC
AS1  C  EXISTING BOUNDS ON V+A CURRENTS REQUIRE ALPHA SMALL - SEE COOPER82.
```

$\nu_e \rightarrow (\overline{\nu}_e)_L$

SEE NOTE FOR NU(MU) --> (NUBAR(E))-L LIMIT

$\alpha\,\Delta(\mathrm{m}^2)$ FOR $\sin^2(2\theta)=1$ (units eV^2)

```
AD2  C       7.     OR LESS  CL=.90   COOPER    82 HLBC
AD2  C  EXISTING BOUNDS ON V+A CURRENTS REQUIRE ALPHA SMALL - SEE COOPER82.
```

$\alpha^2\sin^2(2\theta)$ FOR "LARGE" $\Delta(\mathrm{m}^2)$

```
AS2  C       5.E-2  OR LESS  CL=.90   COOPER    82 HLBC
AS2  C  EXISTING BOUNDS ON V+A CURRENTS REQUIRE ALPHA SMALL - SEE COOPER82.
```

(C). SEARCHES FOR NEUTRINOLESS DOUBLE β DECAY

THE DECAY (Z,A) --> (Z+2,A) + E- + E-, I.E. NEUTRINOLESS DOUBLE BETA DECAY, VIOLATES TOTAL LEPTON NUMBER BY TWO UNITS. IT IS FORBIDDEN IF NEUTRINOS ARE DIRAC PARTICLES BUT CAN OCCUR IF NEUTRINOS ARE MAJORANA PARTICLES AND (A) THEY ARE MASSIVE OR (B) THEY HAVE NON (V-A) COUPLINGS. PRIMAKOFF 81, ROSEN 81, AND HAXTON 83 DISCUSS CORRELATED BOUNDS ON MNUW AND RIGHT-HANDED COUPLINGS. FURTHER THEORETICAL DISCUSSIONS INCLUDE DOI 81, HAXTON 82, AND GROTZ 83.
THE PRIMARY INFORMATION FROM THESE EXPERIMENTS IS LIFETIME. FROM LIFETIME TO NEUTRINO MASS ONE NEEDS TO INVOKE NUCLEAR STRUCTURE. THE NEUTRINO MASS LIMITS BELOW ARE, THEREFORE, MODEL DEPENDENT. *DIFFERENT EXPERIMENTS HAVE USED DIFFERENT MODELS.*

```
MW      MNUW, THE EFFECTIVE WEIGHTED SUM OF NEUTRINO MASSES CONTRIBUTING TO
MW      NEUTRINOLESS DOUBLE BETA DECAY   (UNITS EV)
MW        MNUW= CABS(SUM FROM 1 TO N OF U(1,J)**2*M(NU(J))), WHERE N= NUMBER
MW        OF NEUTRINO GENERATIONS, AND NU(J) IS A MAJORANA NEUTRINO.  NOTE
MW        THAT U(1,J)**2, NOT CABS(U(1,J))**2, OCCURS IN THE SUM; THE
MW        POSSIBILITY OF CANCELLATIONS HAS BEEN STRESSED IN WOLFENSTEIN 81.
MW
MW           10      OR LESS  CL=.90   AVIGNONE  83 CNTR +THY GE-76
MW   B       22      OR LESS  CL=.68   BELLOTTI  83 CNTR +THY1  GE-76
MW   B        8.3    OR LESS  CL=.68   BELLOTTI  83 CNTR +THY2  GE-76
MW            5.6    OR LESS  CL=.95   KIRSTEN   83 SPEC +THY TE-128/TE-130
MW   E        3.8    OR LESS  CL=.68   BELLOTTI  84 CNTR +THY   GE-76      |
MW           22.     OR LESS           FORSTER   84 CNTR +THY   GE-76      |
MW   C        6.     OR LESS  CL=.68   CALDWELL  85 CNTR +THY   GE-76      |
MW   N                                 HUBERT    85 CNTR        GE-76      |
MW   B  LIMITS ARE OBTAINED FROM ANALYSIS OF DATA USING THEORETICAL
MW   B  CALCULATIONS BY DOI-83 (=THY1) AND ROSEN 81 (=THY2).
MW   E  SEE TABLE 1 OF BELLOTTI 84 FOR THEIR ASSESSMENT OF PREVIOUS BOUNDS. |
MW   E  HALF LIFE FOR 0+ --> 0+ TRANSITION >> E22 YR (CL=.90), >1.2E23 YR  |
MW   E  (CL=.68).                                                         |
MW   C  USES RESULTS OF HAXTON 81,82.  AUTHORS STATE THAT BOUND COULD BE  |
MW   C  ''TWO OR THREE TIMES LARGER.''  HALF LIFE FOR 0+ --> 0+ TRANSITION |
MW   C  > 5E22 YR (CL=.68).                                               |
MW   N  SEE HUBERT 85 FOR LIFETIME LIMITS ON NEUTRINOLESS DOUBLE BETA DECAY |
MW   N  OF GE-76 TO EXCITED STATES OF SE-76.                              |

ETA     LIMITS ON LEPTON-NUMBER VIOLATING (V+A) CURRENT ADMIXTURE
ETA       ETA IS DEFINED AS THE FRACTIONAL ADMIXTURE OF (V+A)
ETA       CHARGED CURRENT, RELATIVE TO (V-A) IN ELECTRON-TYPE
ETA       LEPTON SECTOR.
ETA
ETA          2.4E-5  OR LESS           AVIGNONE  83 CNTR +THY GE-76
ETA  B       4. E-5  OR LESS  CL=.68   BELLOTTI  83 CNTR +THY1  GE-76
ETA  B       1.5E-5  OR LESS  CL=.68   BELLOTTI  83 CNTR +THY2  GE-76
ETA          2.4E-5  OR LESS  CL=.95   KIRSTEN   83 SPEC +THY TE-128/TE-130
ETA  C       0.8E-5  OR LESS  CL=.68   BELLOTTI  84 CNTR +THY   GE-76      |
ETA  C       0.6E-5  OR LESS  CL=.68   BELLOTTI  84 CNTR +THY   GE-76      |
ETA  C       1.4E-5  OR LESS  CL=.68   CALDWELL  85 CNTR +THY   GE-76      |
ETA  C       0.9E-5  OR LESS  CL=.68   CALDWELL  85 CNTR +THY   GE-76      |
ETA  B  LIMITS ARE OBTAINED FROM ANALYSIS OF DATA USING THEORETICAL
ETA  B  CALCULATIONS BY DOI-83 (=THY1) AND ROSEN 81 (=THY2).
ETA  C  TWO BOUNDS GIVEN, DEPENDING ON TYPES OF CHIRALITY MIXING. SEE REFS. |
```

REFERENCES FOR BOUNDS ON ν MASS, MIXING

```
BELLOTTI 76 LNC 17 553           +CAVALLI,FIORINI,ROLLIER                  (MILA)
BLIETSCH 78 NP B133 205          BLIETSCHAU+(AACH+LIBH+CERN+EPOL+MILA+ORSA+)
CROUCH   78 PR D18 2239          +LANDECKER,LATHROP,REINES+  (CASE+UCI+WITW)

BAHCALL  80 PRL 45 945           +LUBOW,HUEBNER+    (IAS+LASL+YALE+LLL+UCLA)
    ALSO 76 SCIENCE 191 264      J.N.BAHCALL,R.DAVIS                (IAS+BNL)
BOEHM    80 PL 97B 310           +CAVAIGNAC,FEILITZSCH+ (ILLG+CIT+GREN+MUNI)
FRITZE   80 PL 96B 427           +GRASSLER+   (AACH+BONN+CERN+LOIC+OXF+SACL)

REINES   80 PRL 45 1307          F.REINES,H.W.SOBEL,E.PASIERB              (UCI)
    ALSO 59 PR 113 273           F.REINES,C.L.COWAN                       (LASL)
    ALSO 66 PR 142 852           F.A.NEZRICK,F.REINES                     (CASE)
    ALSO 76 PRL 37 315           F.REINES,H.S.GURR,H.W.SOBEL               (UCI)
SHROCK   80 PL 96B 159           R.E.SHROCK                               (STON)

ABELA    81 PL 105B 263          +DAUM,EATON,FROSCH,JOST,KETTLE,STEINER(SIN)
ARMENISE 81 PL 100B 182          +FOGLI-MUCIACCIA+     (BARI+CERN+MILA+LALO)
ASANO    81 PL 104B 84           +HAYANO,KIKUTANI,KUROKAWA+  (KEK+TOKY+OSAK)
    ALSO 81 SHROCK1
ASRATYAN 81 PL 105B 301          +EFREMENKO,FEDOTOV +  (ITEP+FNAL+SERP+MICH)
BAKER    81 PRL 47 1576          +CONNOLLY,KAHN,KIRK,MURTAGH+      (BNL+COLU)
    ALSO 78 PRL 40 144           CNOPS,CONNOLLY,KAHN,KIRK+         (BNL+COLU)

BALTAY   81 NU 81 CONF HAWAII C.BALTAY                                (COLU)
BOLIEV   81 SJNP 34 787          +BUTKEVICH,ZAKIDYSHEV,MAKOEV,MIKHEEV+(INRM)
CALAPRIC 81 PL 106B 175          CALAPRICE,SCHREIBER,SCHNEIDER +  (PRIN+IND)
DAVIS    81  BNL NU WKSHP        B.T.CLEVELAND,R.DAVIS JR., J.K.ROWLEY (BNL)
DEDEN    81 PL 98B 310           +         (AACH+BONN+CERN+ATEN+LOIC+OXF+SACL)
DOI      81 PL 103B 219          +KOTANI,NISHIURA,OKUDA,TAKASUGI        (OSAK)
    ALSO 81 PTP 66 1739          DOI,KOTANI,NISHIURA,OKUDA,TAKASUGI     (OSAK)
    ALSO 81 PTP 66 1765          DOI,KOTANI,NISHIURA,OKUDA,TAKASUGI     (OSAK)

ERRIQUEZ 81 PL 102B 73           +NATALI+    (BARI+BIRM+LIBH+EPOL+RHEL+SACL+)
HAXTON   81 PRL 47 153           +G.J.STEPHENSON,D.STROTTMAN      (PURD,LASL)
KWON     81 PR D24 1097          +BOEHM,HAHN,HENRIKSON+      (CIT+GREN+MUNI)
NEMETHY  81 PR D23 262           +     (YALE+LBL+LASL+MIT+SACL+SIN+CNRC+BERN)

PRIMAKOF 81 ARNS 31 145          H.PRIMAKOFF,S.P.ROSEN                    (PURD)
ROSEN    81 NU 81 CONF HAWAII S.P.ROSEN                               (PURD)
    ALSO 78 RMP 50 11            D.BRYMAN,C.PICCIOTTO               (TRIU,VICT)
SHROCK1  81 PR D24 1232          R.E.SHROCK                               (STON)
SHROCK2  81 PR D24 1275          R.E.SHROCK                               (STON)

SILVERMA 81 PRL 46 467           D.SILVERMAN,A.SONI                   (UCI+UCLA)
SIMPSON  81 PR D24 2971          J.SIMPSON                                (GUEL)
USHIDA   81 PRL 47 1694            (AICH+FNAL+KOBE+SEOU+MCGI+NAGO+OSU+OKAY+)
WOLFENST 81 PL 107B 77           L.WOLFENSTEIN                            (CARN)

BAHCALL  82 RMP 54 767           +HUEBNER,LUBOW+     (IAS+LANL+HPC+YALE+UCLA)
COOPER   82 PL 112B 97           +GUY,MICHETTE,TYNDEL,VENUS                  (RL)
EHRLICH  82 PR D25 2282          R.EHRLICH                                (GMAS)
FILIPPON 82 APJ 253 393          B.W.FILIPPONE,D.N.SCHRAMM             (ANL+EFI)
HAXTON   82 PR D25 2360          +STEPHENSON,STROTTMAN                (LANL+PURD)
HAYANO   82 PRL 49 1305          +TANIGUCHI,YAMANAKA +           (TOKY+KEK+TSUK)
VUILLEUM 82 PL 114B 298          VUILLEUMIER,BOEHM,EGGER +        (CIT+SIN+MUNI)

AVIGNONE 83 PRL 50 721           +BRODZINSKI,BROWN,EVANS,HENSLEY+ (SCUC+PNL)
BELENKII 83 JETPL 38 493         +DOBRYNIN,ZEMLYAKOV,MIKAELYAN+         (KIAE)
BELIKOV  83 JETPL 38 661         +VOLKOV,KOCHETKOV,MUKHIN,SVIRIDOV+     (SERP)
BELLOTTI 83 PL 121B 72           +FIORINI,LIGURORI,PULLIA,SARRACINO+    (MILA)
BERGSMA  83 PL 128B 361          CHARM COLLAB.     (ANIK+CERN+HAMB+ITEP+INFN)
BRYMAN   83 PRL 50 1546          +DUBOIS,NUMAO,OLANIYI,OLIN+         (TRIU+CNRC)
    ALSO 83 PRL 50 7             BRYMAN,DUBOIS,NUMAO,OLANIYA+        (TRIU+CNRC)
DEUTSCH  83 PR D27 1644          J.P.DEUTSCH,M.LEBRUN,R.PRIEELS         (LVLN)
DOI      83 PTP 69 602           +KOTANI,NISHIURA,TAKASUGI          (OSAK+KYOT)
GRONAU   83 PR D28 2762          GRONAU                                   (HAIF)
GROTZ    83 JPG 9 L169           K.GROTZ,H.V.KLAPDOR,J.METZINGER        (MPIH)
HAXTON   83 CNPP 11 41           W.C.HAXTON                         (LASL+PURD)
KIRSTEN  83 PRL 50 474           T.KIRSTEN,H.RICHTER,E.JESSBERGER       (MPIH)
    ALSO 83 ZPHY 16 189          T.KIRSTEN,H.RICHTER,E.JESSBERGER       (MPIH)
SCHRECKE 83 PL 129B 265          SCHRECKENBACH,COLVIN+              (GREN+ILLG)
TAYLOR   83 PR D28 2705          +CENCE,HARRIS,JONES+           (HAWA+LBL+FNAL)

BALLAGH  84 PR D30 2271          +BINGHAM,+    (UCB+LBL+FNAL+HAWA+WASH+WISC)
BELLOTTI 84 PL 146B 450          +CREMONESI,FIORINI,LIGUORI,PULLIA+     (MILA)
BERGSMA  84 PL 142B 103          CHAR C.           (AMST+CERN+HAMB+ITEP+INFN)
CAVAIGNA 84 PL 148B 387          CAVAIGNAC,HOUMMADA,KOANG+           (ILLG+LAPP)
DYDAK    84 PL 134B 281          +FELDMAN,GUYOT,+ (CERN+DORT+HEID+SACL+WARS)
FORSTER  84 PL 138B 301          +KWON,MARKEY,BOEHM,HENRIKSON             (CIT)
GABATHUL 84 PL 138B 449          GABATHULER,BOEHM+                (CIT+SIN+MUNI)
MINEHART 84 PRL 52 804           +ZIOCK,MARSHALL,STEPHENS,DAUM+     (VIRG+SIN)
STOCKDAL 84 PRL 52 1384          STOCKDALE,BODEK,+       (ROCH+CHIC+COLU+FNAL)
AFONIN   85 JETPL 41 435         AFONIN,BOROVOI,DOBRYNIN,+                (KIAE)
    ALSO 85 JETPL 42 285         AFONIN,BOGATOV,BOROVOI,DOBRYNIN,+        (KIAE)
AHRENS   85 PR D31 2732          +ARNOSON,+     (BNL+BROW+KEK+OSAK+PENN+STON)
ALTZITZO 85 PRL 55 799           ALTZITZOGLOU,CALAPRICE,DEWEY,+           (PRIN)
APALIKOV 85 JETPL 42 289         +BORIS,GOLUTVIN,LAPTIN,LUBIMOV+          (ITEP)
BELIKOV  85 SJNP 41 589          +VOLKOV,KOCHETKOV,MUKHIN+                (SERP)
BLUMER   85 PL 161B 407          BLUMER,KLEINKNECHT                       (DORT)
CALDWELL 85 PRL 54 281           +EISBERG,GRUMM,HALE,WITHERELL+     (UCSB+LBL)
COOPER-S 85 PL 160B 207          COOPER-SARKAR,HAYWOOD+(CERN+LOIC+OXF+SACL+)
HAXTON   85 PRL 55 807           W.HAXTON                                 (LASL)
HUBERT   85 NC 85A 19            +LECCIA,DASSIE,MENNRATH+            (BORD+ZARA)
KALBFLEI 85 PRL 55 2225          KALBFLEISCH,MILTON                       (OKLA)
LOSECCO  85 PRL 54 2299          +BIONTA+BLEWITT+BRATTON+       (UCI+MICH+BNL+)
MARKEY   85 PR C32 2215          MARKEY,BOEHM                              (CIT)
OHI      85 PL 160B 322          OHI,NAKAJIMA,TAMURA+            (TOKY+INUS+KEK)
SIMPSON  85 PRL 54 1891          SIMPSON                                  (GUEL)
STOCKDAL 85 ZPHY C27 53          STOCKDALE,BODEK,+       (ROCH+CHIC+COLU+FNAL)
ZACEK    85 PL 164B 193          ZACEK,ZACFK,BOEHM+               (MUNI+CIT+SIN)
```

LIMITS ON NUMBER OF LIGHT NEUTRINO TYPES

OMITTED FROM SUMMARY TABLE

The neutrinos referred to in this section are those of the standard SU(2)×U(1) electroweak model. Light neutrinos are those with $M(\nu) << M(Z^0)$. The limits are on the number of neutrino families or species. See also cosmological limits in the "ν Bounds from Astrophysics and Cosmology" section.

In the subsection on "Limits from $p\overline{p}$ Colliders," the results assume that there are only three families of quarks and three families of charged leptons light enough to contribute to W or Z decay. The results were derived from

$$N_\nu = [\Gamma_Z(\text{measured}) - \Gamma_Z(\text{3-family theory})]/C_\nu + 3\,.$$

The term "3" above is for ν_e, ν_μ, and ν_τ; C_ν is approximately 0.18 GeV; and the Γ's are measured in GeV. For the results reported here, Γ_Z(measured) is not a directly measured number, but rather an inferred number based on measured cross sections times branching fractions:

$$\Gamma_Z = \Gamma_W \frac{\Gamma(Z \to e^+e^-)}{\Gamma(W \to e\nu)} \frac{\sigma_Z}{\sigma_W} \left[\frac{\sigma_W \cdot B(W \to e\nu)}{\sigma_Z \cdot B(Z \to e^+e^-)} \right]$$

For each result, Γ_W and $\frac{\Gamma(Z \to e^+e^-)}{\Gamma(W \to e\nu)}$ are calculated from the standard model with three families, while σ_Z/σ_W is calculated from QCD (most uncertainties in QCD are thought to cancel in this ratio). Only $\frac{\sigma_W \cdot B(W \to e\nu)}{\sigma_Z \cdot B(Z \to e^+e^-)}$ is a measured quantity. The errors quoted include the uncertainties from each theoretical and experimental quantity except Γ_W.

LIMITS FROM $p\bar{p}$ COLLIDERS

```
NP      NUMBER OF NU TYPES INCLUDING NU(E), NU(MU), NU(TAU).
NP       SEE ABOVE NOTE FOR METHOD OF DERIVATION AND CRUCIAL ASSUMPTIONS.
NP   A      7.3      OR LESS   CL=.90  APPEL     86 UA2  ECM=546+630 GEV
NP   B    (10.)      OR LESS   CL=.90  ARNISON   86 UA1  ECM=546+630 GEV
NP
NP   A  ASSUME MASS(T-QUARK)=40 GEV, C(NU)=0.177 GEV, GAMMA(W)=2.65 GEV
NP   A  AND GAMMA(Z, 3FAMILY THEORY)=2.72 GEV.  APPEL 86 REPORTED THEIR
NP   A  LIMIT AS 5.6+-1.7 OR LESS AND WE CHOSE THE UPPER VALUE.
NP   B  ASSUME MASS(T-QUARK)=40 GEV, C(NU)=0.182 GEV, GAMMA(W)=2.82 GEV
NP   B  AND GAMMA(Z, 3FAMILY THEORY)=2.83 GEV.
```

REFERENCES FOR LIMITS ON NUMBER OF LIGHT ν TYPES

```
APPEL    86 ZPHY C TO BE PUB  UA2 COLLAB.(BERN+CERN+BOHR+HEID+ORSA+PAVI+)
ARNISON  86 PL B TO BE PUB    UA1 COLLAB.(AACH+ANIK+LAPP+BIRM+CERN+HARV+)
```

NEUTRINO BOUNDS FROM ASTROPHYSICS AND COSMOLOGY

OMITTED FROM SUMMARY TABLE

```
        SEE THE NOTE ON NEUTRINOS BY R.E. SHROCK IN THE ELECTRON NEUTRINO
        SECTION NEAR THE BEGINNING OF THESE CARD LISTINGS.  FOR
        INFORMATION ON NEUTRINOS DERIVED FROM MORE CONVENTIONAL
        (TERRESTRIAL) EXPERIMENTS, SEE THE NU(E), NU(MU), NU(TAU), AND
        HEAVY-NU SECTIONS ABOVE.
```

NOTE ON ν MASS LIMITS

These limits apply to m_{tot} given by

$$m_{\text{tot}} = \sum_{j=1,n} \left(\frac{g_{\nu_j}}{2} \right) m_{\nu_j} ,$$

where n is the number of neutrino species and g_{ν_j} is the number of independent components in the neutrino field: $g_{\nu_j} = 4$ for Dirac neutrinos; $g_{\nu_j} = 2$ for chiral Majorana neutrinos.

ν MASS (eV)

```
M       LIMIT ON TOTAL NU MASS, SUMMED OVER ALL SPIN COMPONENTS,
M       OF EFFECTIVELY STABLE NEUTRINOS (I.E. THOSE WITH MEAN LIVES ROUGHLY
M       EQUAL TO OR GREATER THAN THE AGE OF THE UNIVERSE)  (UNITS EV)
M    A       132.    OR LESS                  COWSIK    72 COSM
M    A        80.    OR LESS                  LEE       77 COSM
M            100.    OR LESS                  OLIVE     81 COSM
M    A  COWSIK 72 AND LEE 77 HAVE BEEN GENERALIZED TO APPLY TO M(TOT) AS
M    A  DEFINED ABOVE, WHERE ONE ALLOWS EITHER DIRAC OR MAJORANA NEUTRINOS.
M    A  THESE PAPERS ASSUMED DIRAC NEUTRINOS.
M       FOR OTHER LIMITS, SEE SATO 77, VYSOTSKY 77, DICUS 78, HUT 79,
M       ZELDOVICH 80, FREESE 84, AND SCHRAMM 84.

ML      ASTROPHYSICAL AND COSMOLOGICAL LIMITS ON NU MASSES. (UNITS EV)
ML
ML      ANALYSES OF MASS/LIGHT RATIOS AND DYNAMICS OF GALAXIES AND
ML      CLUSTERS ARE CONSISTENT WITH PRESENCE OF DARK MATTER.  TREMAINE 79
ML      STATED THAT THE DARK MATTER COULD NOT BE MUON OR ELECTRON NEUTRINOS
ML      OF NONZERO REST MASS OR ANY NEUTRAL LEPTON LESS MASSIVE THAN 1 MEV.
ML      AUTHORS BOND 81, DAVIS 81, AND SCHRAMM 81 CLAIMED THAT THIS DARK
ML      MATTER COULD CONSISTENTLY BE ASCRIBED TO MASSIVE NEUTRINOS
ML      WITH SUFFICIENTLY LONG LIFETIMES.  SUBSEQUENT ANALYSES HAVE
ML      CHALLENGED THIS CLAIM; SEE PRIMACK 83.  FOR DEGENERATE NEUTRINOS,
ML      SEE FREESE 83.
ML
ML                                            TREMAINE  79 COSM  ISOTHERMAL
ML       ORDER 30                             BOND      81 COSM  ADIABATIC
ML         50-100                             DAVIS     81 COSM  ADIA.+DECAYING NUS
ML          4-20                              SCHRAMM   81 COSM  ISOTHERMAL
ML          NO CONSISTENT VALUE               PRIMACK   83 COSM
ML   S   1000  OR LESS                        SARKAR    84 COSM
ML   M     22  OR MORE                        MADSEN    85 COSM  ASSUME ISOTROPY
ML   M     18  OR MORE                        MADSEN    85 COSM  SOME ANISOTROPY
ML
ML   S  SARKAR 84 RESULTS APPLY TO UNSTABLE NU(TAU) OR OTHER DIRAC NEUTRINO
ML   S  WITH SIGNIFICANT RADIATIVE DECAY MODES.  THEY ASSUME THAT STANDARD
ML   S  COSM MODEL OF PRIMORDIAL NUCLEOSYNTHESIS IS NOT DISRUPTED BY
ML   S  NU(TAU) DECAY.
ML
ML   M  MADSEN 85 ASSUME STABLE NEUTRINO (NU(E)) TO BE DARK MATTER IN
ML   M  GALAXY HALOS (ONLY DATA ON BIG GALAXIES).
ML   M  SECOND MADSEN 85 VALUE IS ALLOWING MAX REASONABLE ANISOTROPY.
ML   M  NOTE HOWEVER THAT IN MADSEN 84 THE ADDITIONAL ASSUMPTION THAT NU(E)
ML   M  IS THE DARK MATTER IN DWARF AS WELL AS BIG GALAXY HALOS (ASSUMING
ML   M  ISOTROPY) LEADS TO THE LIMIT 127 EV OR MORE IN CONFLICT WITH THE
ML   M  EXPERIMENTAL UPPER LIMIT OF 46 EV.  FURTHERMORE THE ADDITIONAL
ML   M  ASSUMPTION THAT THE DISTRIBUTION OF DARK MATTER IS AN ISOTHERMAL
ML   M  SPHERE LEADS TO THE LIMIT (LIN 83) OF 500 EV OR MORE.

MSW     LIMITS ON MASSES OF STABLE RIGHT-HANDED NU
MSW     (WITH NECESSARILY SUPPRESSED INTERACTION STRENGTHS)
MSW  O                                        OLIVE     82
MSW  O  ALLOWED VALUES OF MASS ARE STRONGLY CORRELATED WITH INTERACTION
MSW  O  STRENGTH.  SEE FIG. 1 OF OLIVE 82.
```

ν RADIATIVE MEAN LIFE VERSUS MASS

```
T                                             COWSIK    77 COSM
T                                             DICUS     77 COSM
T                                             GOLDMAN   77 COSM
T                                             FALK      78 COSM
T              STRONGLY CORRELATED            COWSIK    79 COSM
T              LIMITS. SEE REFERENCES         GOLDMAN   79 COSM
T                                             DERUJULA  80 COSM
T                                             STECKER   80 COSM
T                                             HENRY     81 COSM
T                                             KIMBLE    81 COSM
T                                             REPHAELI  81 COSM
T                                             TURNER    81 COSM
T                                             KRAUSS    83 COSM
T                                             BINETRUY  84 COSM
```

NUMBER OF LIGHT TWO-COMPONENT ν TYPES

(LIGHT MEANS < ABOUT 1 MEV)

```
N       NUMBER COUPLING WITH FULL WEAK STRENGTH
N                                             SHVARTSMA 69 COSM
N             (7)    OR LESS                  STEIGMAN  77 COSM
N             (4)    OR LESS                  YANG      79 COSM
N    S      CRITICISM OF BOUND                STECKER2  80 COSM
N           MAYBE NO FIRM BOUND               OLIVE     81 COSM
N             (4)    OR LESS                  TURNER    81 COSM
N           CRITICISM OF BOUND                RANA      82 COSM
N             (4)    OR LESS                  SCHRAMM   82 COSM
N            (FROM 10 TO 1000) OR LESS        ELLIS     83      ASTROPHYS MODEL-DEP
N             (4)    OR LESS                  YANG      84 COSM
N    S  SEE, HOWEVER OLIVE2 81 CRITIQUE AND STECKER 81 REPLY.
N       UNCERTAINTIES AND CRITICISMS COME FROM DIFFERING ESTIMATES OF LOWER
N       LIMIT ON BARYON DENSITY OF THE UNIVERSE AND UPPER LIMIT ON THE
N       PRIMORDIAL HELIUM-4 ABUNDANCE.  SEE ALSO BERNSTEIN 82.

NSW     NUMBER COUPLING WITH LESS THAN FULL WEAK STRENGTH
NSW  A        (20)   OR LESS                  STEIGMAN  79 COSM
NSW  A  LIMIT VARIES WITH STRENGTH OF COUPLING.
```

MAGNETIC MOMENT OF SUFFICIENTLY LIGHT ν

(UNITS EV/GAUSS)

```
MM   S     (4.9E-19)OR LESS                   SUTHERLAN 76 COSM FOR M(NU)<10 KEV.
MM   S  USES SUTHERLAND 76 EQ.3 WITH F<1/3 FROM THEIR TABLE AS MODIFIED TO
MM   S  APPLY AS A LIMIT ON ANY ONE NEUTRINO SPECIES INDIVIDUALLY.
```

REFERENCES FOR ν BOUNDS FROM ASTRO. AND COSM.

```
SHVARTSM 69 JETPL 9 184       V. F. SHVARTSMAN                        (MOSU)
COWSIK   72 PRL 29 669        R.COWSIK,J.MC CLELLAND                   (UCB)
SUTHERLA 76 PR D13 2700       SUTHERLAND,NG,FLOWERS,+       (PENN+COLU+NYU)
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COWSIK 77 PRL 39 784 R. COWSIK (MPIM+TIFR)
ALSO 79 COWSIK
DICUS 77 PRL 39 168 D.A.DICUS,E.W.KOLB,V.L.TEPLITZ (TEXA+VPI)
GOLDMAN 77 PR D16 2256 T.GOLDMAN, G.J.STEPHENSON (LASL)
LEE 77 PRL 39 165 B. W. LEE, S. WEINBERG (FNAL+STAN)
SATO 77 PTP 58 1775 K.SATO,M.KOBAYASHI (KYOT)
STEIGMAN 77 PL 66B 202 G.STEIGMAN,D.SCHRAMM,J.GUNN (YALE,CHIC,CIT)
VYSOTSKY 77 JETPL 26 188 VYSOTSKY,DOLGOV,ZELDOVICH (ITEP)

DICUS 78 PR D17 1529 +KOLB,TEPLITZ,WAGONER (TEXA+VPI+STAN)
FALK 78 PL 79B 511 S. FALK, D. SCHRAMM (CHIC)
ALSO 78 APJ 223 1015 GUNN,LEE+ (CIT+CAMB+FNAL+CHIC+YALE)

COWSIK 79 PR D19 2219 R. COWSIK (TIFR)
GOLDMAN 79 PR D19 2215 T.GOLDMAN,G.J.STEPHENSON (LASL)
HUT 79 PL 87B 144 P.HUT,K.A.OLIVE (AMSTERDAM+EFI)
STEIGMAN 79 PRL 43 239 G.STEIGMAN,K.OLIVE,D.SCHRAMM (BART+EFI)
TREMAINE 79 PRL 42 407 S. TREMAINE, J. E. GUNN (CIT+CAMB+CAIW)
YANG 79 APJ 227 697 YANG,SCHRAMM,STEIGMAN,ROOD (CHIC+YALE+VIRG)
ALSO 79 STEIGMAN FOOTNOTE 4

DERUJULA 80 PRL 45 942 A.DE RUJULA,S.L.GLASHOW (MIT+HARV)
STECKER 80 PRL 45 1460 F.W.STECKER (NASA)
ALSO 81 NU 81 CONF HAWAII F.W.STECKER (PROC. V.1, P. 124) (NASA)
STECKER2 80 PRL 44 1237 F.W.STECKER (NASA)
ZELDOVIC 80 SJNP 31 664 ZELDOVICH,KLYPIN,KHLOPOV,CHECHETKIN

BOND 81 NU 81 CONF HAWAII J.R.BOND, A.S.SZALAY (UCB+CHIC)
DAVIS 81 APJ 250 423 M.DAVIS,M.LECAR,C.PRYOR,E.WITTEN(HARV+PRIN)
HENRY 81 PRL 47 618 R.C.HENRY, P.D.FELDMAN (JHU)
KIMBLE 81 PRL 46 80 R.KIMBLE,S.BOWYER,P.JAKOBSEN (UCB)

OLIVE 81 APJ 246 557 +SCHRAMM,STEIGMAN,TURNER,YANG+ (CHIC+BART)
OLIVE2 81 PRL 46 516 K.A.OLIVE,M.S.TURNER (EFI)
REPHAELI 81 PL 106B 73 Y.REPHAELI,A.S.SZALAY (UCSB+CHIC)
SCHRAMM 81 APJ 243 1 D. N. SCHRAMM, G. STEIGMAN (CHIC+BART)
STECKER 81 PRL 46 517 F.W.STECKER (NASA)
TURNER 81 NU 81 CONF HAWAII M.S.TURNER (UCSB+CHIC)

BERNSTEI 82 PRL 48 774 J.BERNSTEIN (STEV)
OLIVE 82 PR D25 213 K.A.OLIVE,M.S.TURNER (CHIC+UCSB)
RANA 82 PRL 48 209 N.C.RANA (TIFR)
SCHRAMM 82 PRSL A307 43 D.N. SCHRAMM (CHIC)

ELLIS 83 NP B223 256 J.ELLIS,K.A.OLIVE (CERN)
FREESE 83 PR D27 1689 K.FREESE,E.W.KOLB,M.S.TURNER (CHIC+LANL)
KRAUSS 83 PL 128B 37 L.M.KRAUSS (HARV)
LIN 83 APJ 266 L21 LIN,FABER (UCSC)
PRIMACK 83 PHILADELPHIA J.PRIMACK (4TH WKSHP. ON GRAND.UNIF.)(UCSC)
ALSO 82 NAT 299 37 BLUMENTHAL,PAGELS,PRIMACK (UCSC+ROCK)
BINETRUY 84 PL 134B 174 P.BINETRUY,G.GIRARDI,P.SALATI (LAPP)
FREESE 84 NP B233 167 +SCHRAMM (CHIC+FNAL)
MADSEN 84 APJ 282 11 J.MADSEN,R.EPSTEIN (AARH+LANL)
SARKAR 84 PL 148B 347 S.SARKAR,A.M.COOPER (OXF+CERN)
SCHRAMM 84 PL 141B 337 SCHRAMM,STEIGMAN (FNAL+BART)
YANG 84 APJ (TO BE PUBL) +TURNER,STEIGMAN,SCHRAMM,OLIVE (CHIC+BART)
MADSEN 85 PRL 54 2720 J.MADSEN,R.EPSTEIN (AARH+LANL)

HEAVY LEPTON SEARCHES

OMITTED FROM SUMMARY TABLE

Data on the $\tau^{\pm}$ are listed in a separate section above, following the e and μ listings.

The following section contains information on searches for heavy leptons of other types and searches for the $\tau^{\pm}$ in collisions other than e^+e^-.

Several types of heavy leptons (that is, non-strongly-interacting fermions other than e and μ) have been proposed. In the Full Listings we distinguish four types.[1,2] Each has a corresponding antiparticle with opposite charge and lepton number. For convenience we omit writing the antiparticles in the following descriptions. The four types are:

Sequential leptons (L^-,ν_L). Such a pair is assumed to have its own separately strictly conserved lepton number $n_L = +1$. This means that the radiative decays

$$\left.\begin{array}{l} L^- \rightarrow e^-\gamma \\ L^- \rightarrow \mu^-\gamma \end{array}\right\} \text{ are forbidden ,}$$

while the weak decays (assuming m_{L^-} sufficiently large)

$$\left.\begin{array}{l} L^- \rightarrow \nu_L\, e^-\bar{\nu}_e \\ L^- \rightarrow \nu_L\, \mu^-\bar{\nu}_\mu \\ L^- \rightarrow \nu_L \text{ hadrons} \end{array}\right\} \text{ are allowed .}$$

There could be an increasing mass sequence of such pairs. It is frequently assumed that the neutrinos are massless.

Decay rates are assumed calculable from conventional weak interaction theory. For an L^- mass between 1 and 3 GeV, the branching fraction to each of the two leptonic modes above should be roughly 10 to 20%. For an L^- mass above 1 GeV, the mean life should be $\lesssim 10^{-12}$ second.

Paraleptons (E^+, E^0) *and* (M^+, M^0). These pairs have the same lepton numbers as the opposite-charge ordinary leptons, i.e., e^- and μ^-, respectively. Radiative decays are again forbidden and decays similar to those allowed for L^- are allowed here, e.g.,

$$M^+ \rightarrow \nu_\mu\, e^+\nu_e$$

or

$$M^+ \rightarrow \nu_\mu\, \mu^+\nu_\mu \, .$$

However, the lightest member is not stable as is the case for sequential leptons, so that bizarre decay schemes such as (assuming $m_{E^0} < m_{E^+}$)

$$\begin{array}{l} E^+ \rightarrow E^0\mu^+\nu_\mu \\ \quad \llcorner\!\!\longrightarrow e^-e^+\nu_e \end{array}$$

are allowed.

Heavy leptons of this type were proposed (before the discovery of the Z^0 boson) in unified gauge theories of weak and electromagnetic interactions to cancel unphysical high energy behavior in such processes as $e^+e^- \rightarrow W^+W^-$.[3]

Ortholeptons (F^- *and* N^-). These have the same lepton numbers as e^- and μ^-, respectively. They may or may not have associated neutral leptons. Radiative decays are allowed in addition to weak modes similar to those of sequential leptons. The radiative mode can dominate or can be relatively unimportant depending on the model.[4] Decays such as

$$F^- \rightarrow e^- + \text{hadrons}$$

are also allowed.

Long-lived penetrating particles. Heavy leptons could have long mean lives under certain circumstances. For example, if $m_{\nu_L} > m_{L^-}$, then L^-, the sequential lepton, is completely stable since its lepton number is conserved.

Experimental results. The results are summarized in the Full Listings below. Mass limits for sequential leptons are listed in subsection MS, while all other types are listed together in subsection M.

The Full Listings also contain cross-section upper limits reported as results of unsuccessful searches. We no longer list cross sections for anomalous $e\mu$ events in e^+e^- collisions. These cross sections are consistent with coming from $e^+e^- \to \tau^+\tau^-$ where the $\tau^\pm$ is assumed to be a spin-1/2 Dirac point particle with a mass about 1785 MeV.

References

1. M.L. Perl and P. Rapidis, SLAC-PUB-1496 (October 1974).
2. C.H. Llewellyn Smith, Invited paper presented at the Royal Society Meeting on New Particles and New Quantum Numbers, 11 March 1976, Oxford Ref. 33/76.
3. J.D. Bjorken and C.H. Llewellyn Smith, Phys. Rev. **D7**, 887 (1973).
4. F. Wilczek and A. Zee, Nucl. Phys. **B106**, 461 (1976).

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SEE PERL 81 FOR A REVIEW

PROPERTIES OF THE TAU+-(1785) HEAVY LEPTON AND ITS ASSOCIATED
NEUTRINO ARE LISTED SEPARATELY ABOVE FOLLOWING THE E AND MU
LISTINGS.  THE FOLLOWING SECTION CONTAINS INFORMATION ON SEARCHES
FOR HEAVY LEPTONS OF OTHER TYPES AND SEARCHES FOR TAU+- IN
COLLISIONS OTHER THAN E+E-.  WE LIST MASS LIMITS AND CROSS SECTION
UPPER LIMITS REPORTED AS NEGATIVE SEARCH RESULTS.  WE NO LONGER
LIST CROSS SECTIONS FOR THE ESTABLISHED PROCESS E+ E- --> TAU+ TAU-
AS WAS DONE IN OUR 1977 SUPPLEMENT.  SEARCHES FOR FRACTIONALLY
CHARGED HEAVY LEPTONS ARE INCLUDED IN THE FREE QUARK SEARCH SECTION.
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HEAVY LEPTON MASS LIMITS

```
     LIMITS APPLY ONLY TO HEAVY LEPTON TYPE GIVEN IN COMMENT AT RIGHT ON
     DATA LISTING.  SEE REVIEW ABOVE FOR DESCRIPTION OF TYPES.
     L,E,M,F,N STAND FOR SEQUENTIAL LEPTON,PARA-ELECTRON,PARA-MUON,
     ORTHO-ELECTRON,ORTHO-MUON RESPECTIVELY.

MS     SEQUENTIAL HEAVY LEPTON MASS LIMITS (GEV)
MS   A       (13.)   OR MORE             AZIMOV    80        +-
MS   B       (16.)   OR MORE  CL=.95     BARBER    80 CNTR +-
MS   C  NONE 4GEV TO 14.5GEV CL=.95     BERGER    81 PLUT +-
MS   D       (15.5)  OR MORE  CL=.95     BRANDELIK 81 TASS +-
MS           (14.)   OR MORE  CL=.95     ADEVA     82 MRKJ +-
MS   E       (18.)   OR MORE             ADEVA     83 MRKJ +-
MS   F       (18.0)  OR MORE  CL=.95     BARTEL    83 JADE +-
MS   G        22.5   OR MORE  CL=.95     ADEVA     85 MRKJ +- ECM=40-47 GEV
MS
MS   A  AZIMOV 80 ESTIMATED PROBABILITIES FOR M+N TYPE EVENTS IN E+ E- -->
MS   A  L+ L- DEDUCING SEMI-HADRONIC DECAY MULTIPLICITIES OF L FROM E+ E-
MS   A  ANNIHILATION DATA AT WCM=(2/3)*ML. OBTAINED ABOVE LIMIT COMPARING
MS   A  THESE WITH E+E- DATA (BRANDELIK 80,PL 92B 199).
MS
MS   B  BARBER 80 LOOKED FOR E+ E- --> L+ L-, L-->NU(L)+X WITH MARK-J AT
MS   B  DESY-PETRA.
MS
MS   C  BERGER 81 IS DESY DORIS AND PETRA EXPT. LOOKING FOR E+E- --> L+L-.
MS
MS   D  BRANDELIK 81 IS DESY PETRA EXPT. LOOKING FOR E+E- --> L+L-.
MS
MS   E  ADEVA 83 LOOKED FOR MUON OPPOSITE AGAINST A HADRON JET.
MS
MS   F  BARTEL 83 LIMIT IS FROM PETRA E+E- EXP WITH AVERAGE WCM=34.2 GEV.
MS
MS   G  ADEVA 85 ANALYZE ONE-ISOLATED-MUON DATA AND SENSITIVE TO TAU < 10
MS   G  NANOSEC.  ASSUME BR(LEPTON)=0.30.
```

```
M       HEAVY LEPTON MASS LIMITS (GEV)
M    A   0     1.0    OR MORE            BEHREND   65 SPEC -  ORTHOELECTRON(F)
M    B  NONE BETWEEN 0.12 AND 0.57       BETOURNE  65 SPEC -  ORTHOELECTRON(F)
M    C  NONE BETWEEN 0.3  AND 0.7        BUDNITZ   66 SPEC -  ORTHOELECTRON(F)
M    D  NONE BETWEEN 0.2  AND 0.92       BARNA     68 CNTR -  LONG-LIVED
M    D  NONE BETWEEN 0.97 AND 1.03       BARNA     68 CNTR -  LONG-LIVED
M    E  NONE BETWEEN 0.1  AND 1.3        BOLEY     68 SPEC -  ORTHOELECTRON(F)
M    F  NONE BETWEEN 0.2  AND 0.6        LIBERMAN  69 OSPK -  ORTHOMUON(N)
M    G         0.490 OR MORE             ROTHE     69 RVUE
M    H  NONE BETWEEN 0.26 AND 1.32       LICHTENST 70 SPEC -  ORTHOELECTRON(F)
M    I  20    (0.424)  (0.013)  (0.002)RAMM        70 HLBC 0
M    I  22    (0.431)  (0.004)           RAMM      71 HLBC -  ORTHOMUON(N)
M    J   0     0.1    OR MORE            ANSORGE   73 HBC  -  LONG-LIVED
M    K   0     0.6    OR MORE            BACCI     73 ELEC +- ORTHOELECTRON(F)
M    K   0     2.2    OR MORE            BACCI     73 ELEC +- ORTHOELECTRON(F)
M    L   0     2.0    OR MORE  CL=.90    BARISH    73 ASPK +  PARAMUON (M)
M    M   0     1.4    OR MORE  CL=.95    BERNARDIN 73 ASPK +- ANY NON-RAD TYPE
M    M   0     1.0    OR MORE  CL=.95    BERNARDIN 73 ASPK +- ANY NON-RAD TYPE
M    N  NONE BETWEEN 0.55 AND 4.5        BUSHNIN   73 CNTR -  LONG-LIVED
M    O   0     2.4    OR MORE  CL=.90    EICHTEN   73 HLBC +  PARAMUON (M)
M    P         7.8    OR MORE  CL=.95    HANSON    73 WIRE    ORTHOELECTRON(F)
M    Q         1.8    OR MORE  CL=.90    ASRATYAN  74 HLBC +- ORTHOMUON (N)
M    R         8.4    OR MORE  CL=.90    BARISH    74 SPEC +  PARAMUON (M)
M    S   NONE BETWEEN 0 AND 2.0          GITTLESON 74 SPEC    ORTHOMUON (N)
M    T   0     1.15   OR MORE  CL=.95    ORITO     74 ASPK +- ANY NON-RAD TYPE
M    U   NONE BETWEEN 0.25 AND 2.3       BACCI     77 SPEC +- ORTHOELECTRON(F)
M    V         1.2    OR MORE            MEYER     77 SMAG 0  NEUTRAL
M    W        10.3    OR MORE  CL=.98    ASRATYAN  78      -  ORTHOMUON (N)
M    X   0     7.5    OR MORE            CNOPS     78 HLBC -  ORTHOMUON (N)
M    X   0     9.0    OR MORE            CNOPS     78 HLBC +  PARAMUON (M)
M    Y        10.0    OR MORE            ERRIQUEZ  78 BEBC
M    Z        12.     OR MORE  CL=.90    HOLDER    78 CNTR +  PARAMUON (M)
M    1  NONE 1 GEV TO 9 GEV    CL=.90    CLARK     81 SPEC 0  PARAMUON(MOBAR)
M    1  NONE 1 GEV TO 9 GEV    CL=.90    CLARK     81 SPEC ++
M    2  NONE BETWEEN 0.6 AND 3.3         HAYES     82 SMK2 +- ORTHOMUON (N)
M    2  NONE BETWEEN 0.5 AND 3.3         HAYES     82 SMK2 +- ORTHOELECTRON(F)
M    3        24.5    OR MORE  CL=.95    BARTEL    83 JADE 0  PARAELECTRON(EO)
M    3        22.5    OR MORE  CL=.95    BARTEL    83 JADE 0  PARAELECTRON(EO)
M
M    A  BEHREND 65 IS DESY EXPT. LOOKS FOR E P-->F P, F--> E GAMMA.
M    A  THIS MASS LIMIT CORRESPONDS TO A LIMIT ON LAMBDA**2 OF 6.25*10**-4.
M
M    B  BETOURNE 65 IS ORSAY EXPT. LOOKS FOR E P -->F P. MASS OF .12
M    B  CORRESPONDS TO COUPLING CONSTANT LAMBDA**2 GT .0016, MASS OF .57
M    B  TO LAMBDA**2 GT .22.
M
M    C  BUDNITZ 66 IS CEA EXPT. LOOKS FOR E P-->F P.
M
M    D  BARNA 68 IS SLAC PHOTOPRODUCTION EXPT.
M
M    E  BOLEY 68 IS CEA EXPT. LOOKS FOR E P-->F P. MASS OF .1 CORRESPONDS
M    E  TO COUPLING CONSTANT LAMBDA**2 GT 3*10**-4, MASS LIMIT OF 1.3 TO
M    E  LAMBDA**2 GT .01.
M
M    F  LIBERMAN 69 IS A BNL EXPT MEASURING MUON BREMSSTRAHLUNG.
M
M    G  ROTHE 69 EXAMINES PREVIOUS DATA ON MU PAIR PROD AND PI AND K DECAYS
M
M    H  LICHTENSTEIN 70 IS CORNELL EXPT MEASURING E BREMSSTRAHLUNG.
M    H  MASS LIMIT DEPENDS ON COUPLING CONSTANT. FIRST VALUE ABOVE IS FOR
M    H  LAMBDA**2 GT .17, SECOND IS FOR LAMBDA**2 GT .42.
M
M    I  RAMM 70 FINDS PEAK IN MU PI COMBINED MASS PRODUCED BY NEUTRINO
M    I  INTERACTIONS. HE ALSO CLAIMS EVIDENCE FOR THIS IN KOMU3 DECAYS IN
M    I  HBC WHERE PI MU COMBINED MASS PEAKS IN SAME REGION. CLARK 72 FINDS
M    I  NO EVIDENCE FOR PI MU PEAK IN HIGH STATISTICS KL3 EXPT.
M    I  RAMM 71 SEES PEAK IN MU GAMMA COMBINED MASS PRODUCED BY NEUTRINOS.
M
M    J  ANSORGE 73 LOOKS FOR ELECTRON PAIR PROD AND ELECTRON-LIKE BREMSS.
M
M    K  BACCI 73 IS FRASCATI E+E- EXPT. LOOKS FOR F --> E GAMMA.
M    K  MASS LIMIT DEPENDS ON COUPLING CONSTANT LAMBDA FOR THIS DECAY.
M    K  FIRST VALUE ABOVE IS FOR LAMBDA**2 GT 9*10**-5, 2ND IS FOR
M    K  LAMBDA**2 GT 10**-3.
M
M    L  BARISH 73 IS FNAL 50,145 GEV NU EXPT.  LOOKS FOR (NU NUCLEON -->
M    L  M+ ANYTHING). ASSUMES (M+ --> MU+ NU NU) WITH BR=.3.
M
M    M  BERNARDINI 73 IS FRASCATI E+E- EXPT. FIRST VALUE ASSUMES UNIVERSAL
M    M  COUPLING TO ORDINARY LEPTONS.  SECOND VALUE ALSO ASSUMES COUPLING
M    M  TO HADRONS.
M
M    N  BUSHNIN 73 IS SERPUKOV 70 GEV P EXPT. MASSES ASSUME MEAN LIFE ABOVE
M    N  7E-10 AND 3E-8 RESPECTIVELY. CALCULATED FROM CROSS SEC(DC BELOW)
M    N  AND 30 GEV MUON PAIR PRODUCTION DATA.
M
M    O  EICHTEN 73 IS CERN 1-10GEV NU EXPT. LOOKS FOR M+ PRODUCED IN
M    O  NU NUCL --> M+ HADRONS ASSUMING 15 PERCENT DECAY TO E+ NU NU.
M
M    P  HANSON 73 LOOK FOR DEVIATIONS FROM QED IN E+ E- -->2GAMMA. THEY
M    P  MEASURE THE PRODUCT OF THE F MASS * THE COUPLING CONSTANT LAMBDA,
M    P  WHICH IS THE VALUE QUOTED ABOVE.
M
M    Q  ASRATYAN 74 USES EICHTEN 73 DATA ON NU NUCL --> E- HADRONS AND
M    Q  NUBAR NUCL --> E+ HADRONS TO SET LIMITS ON ORTHOMUON PRODUCTION.
M
M    R  BARISH 74 IS FNAL 50,135 GEV NU EXPT.  LOOKS FOR (NU NUCLEON -->
M    R  M+ ANYTHING).  ASSUMES (M+ -->MU+ NU NU) WITH BR=.3.
M
M    S  GITTLESON 74 IS MU P --> P ORTHOMUON SEARCH. COUPLING CONSTANT
M    S  LAMBDA**2 IS <.01 FOR MASS UP TO .7 GEV, LIMIT ON LAMBDA**2 RISES
M    S  TO <.1 FOR MASS OF 2.0 GEV.
M
M    T  ORITO 74 LOOKED FOR H+H- PAIRS GIVING MU-E PAIRS. MASS LIMIT REFERS
M    T  TO ANY NON-RADIATIVE TYPE HEAVY LEPTON -- L, E, M, F, N.
M    T  COUPLING TO HADRON ASSUMED FROM THEORETICAL MODELS.
M
M    U  BACCI 77 IS SAME TYPE AS BACCI 73. LOWER MASS LIMIT CORRESPONDS TO
M    U  LAMBDA**2 LIMIT OF 4*10**-5, UPPER VALUE IS FOR LAMBDA**2 LIMIT OF
M    U  1.5*10**-3.
M
M    V  MEYER 77 LOOKS FOR NARROW NEUTRAL RESONANCE IN(E PI)AND(MU PI)
M    V  CHANNELS PRODUCED BY E+E- AT 6.8 GEV (ECM). ASSUMED TO BE DECAY
M    V  PRODUCT OF THE TAU. SEE SECTION NE BELOW.
M
M    W  ASRATYAN 78 ANALYZES DEPENDENCE OF N.C./C.C. ON ENERGY OF ASSOC.
M    W  HADRONS. USES DATA OF HOLDER 77 (PL 72B, 254)--NU(MU) INTERACTIONS
M    W  AT CERN-SPS.
M
M    X  CNOPS 78 IS FNAL EXPT LOOKING FOR NU(MU) NE --> L+(-), FOLLOWD BY
M    X  L+(-) --> E+(-) NU NU.
M
M    Y  ERRIQUEZ 78 IS CERN SPS EXPT. LOOKS FOR NU(MU) NUCLEON-->MU- E+ X.
M    Y  FINDS CS FOR PRODUCING HVY LEPT--> E+ <.7*10**-3 *C.C. CS.
M
M    Z  HOLDER 78 IS A CERN NU EXPT LOOKING FOR NU(MU) NUCLEON --> MU+ ANY
M    Z  THING. ASSUMES M+ --> MU+ 2NU(MU) WITH BR=0.2 .
```

```
M     1  CLARK 81 IS FNAL EXP WITH 209 GEV MUONS. BOUNDS APPLY TO MO WHICH
M     1  COUPLES WITH FULL WEAK STRENGTH TO MUON. SEE ALSO SECTION MU.
M
M     2  HAYES 82 IS SLAC SPEAR EXPT.  THEIR TBL.5,6 GIVES CROSS SEC. LIMITS
M     2  FOR ORTHOMUON AND ORTHOELECTRON FOR MASSES IN ABOVE RANGE.
M
M     3  BARTEL 83 IS PETRA E+E- EXP WITH AVERAGE WCM=34.2 GEV.FIRST(SECOND)
M     3  LIMIT IS FOR V+A(V-A) TYPE W-E0-E COUPLING.
```

HEAVY LEPTON PROD. CROSS SECTION (μN) (cm^2)

```
MU      SEE ALSO SECT 'MU' IN CHARM SEARCHES AND OTHER NEW PARTICLE SEARCHES
MU    A     1.22E-34 OR LESS             LEBRITTON 80 SPEC    MO-->MU+ MU- NU
MU    B   0  4. E-38 OR LESS             CLARK     81 SPEC O  PARAMUON(MOBAR)
MU    B   0  6. E-38 OR LESS             CLARK     81 SPEC ++
MU
MU    A  LEBRITTON 80 IS BNL EXP WITH 10.5GEV MUONS. TRIMUONS ARE CONSISTENT
MU    A  WITH QED TRIDENT AND DIFFRACTIVELY PRODUCED RHO DECAY.
MU
MU    B  CLARK 81 IS FNAL EXP WITH 209 GEV MUON. LOOKED FOR MU+ N-->MOBAR X,
MU    B  MOBAR-->MU+ MU- NUBAR(MU) AND MU+ N-->M++ X,M++-->2MU+ NU(MU).
MU    B  ABOVE LIMITS ARE FOR CS*BR TAKEN FROM THEIR MASS-DEP PLOT FIG.2.
```

HEAVY LEPTON PROD. DIFFERENCE CROSS SEC. ($p N$) (cm^2/sr$-$GeV)

```
DC    A   0  1.6E-37 OR LESS  CL=.90   GOLOVKIN  72 CNTR- 70GEV P, SERPUKHOV
DC    B   0  4. E-38 OR LESS  CL=.90   BUSHNIN   73 CNTR- 70GEV P, SERPUKHOV
DC
DC    A  MASS RANGE 1 TO 4.5 GEV,THETA=0,P=25 GEV/C.
DC
DC    B  BUSHNIN 73 HEAVY LEPTON PATH TRAVERSES 6800 GM/CM**2 ABSORBER.
DC    B  DIFFERENTIAL CROSS SECTION MEASURED AT P=30 GEV/C THETA= 2 MRAD.
```

PRODUCTION OF HEAVY LEPTON IN BEAM DUMP

```
BD    A                                LOSECCO   81 CALO    28 GEV PROTONS
BD    A  LOSECCO 81 AT BNL AGS SET LIMIT FOR CS(PROD)*CS(INT) RATIO OF
BD    A  SLOW (BETA<0.89) HEAVY LEPTONS TO PROMPT NU'S AS 2.2E-2(CL=.90).
```

INVARIANT HEAVY LEPTON PROD. CROSS SEC. ($p N$) (cm^2/GeV^2)

```
IC    A   0  5.4E-39 OR LESS  CL=.90   CRONIN    74 SPEC -  M=1-6.8 GEV
IC    B   0  6.4E-35 OR LESS  CL=.90   BINTINGER 75 SPEC +- M=1-5 GEV
IC    C   0  1.8E-33 OR LESS  CL=.90   ARMITAGE  79 SPEC    M=1.87 GEV
IC
IC    A  CRONIN 74 IS AN FNAL 300 GEV P CU EXPT.  LOOKED FOR LONG LIVED
IC    A  PENETRATING PARTICLES.  ABOVE LIMIT ASSUMES STABLE.  MULTIPLY IT BY
IC    A  EXP(1.22E-8*M/TAU) FOR MASS M(GEV) AND LIFETIME TAU(SEC). LIMIT
IC    A  OBTAINED AT THETA(LAB) = 77 MRAD, PT = 2.38 GEV/C.
IC
IC    B  BINTINGER 75 IS A 30-300 GEV P C EXPT.  LOOKED FOR LONG LIVED
IC    B  PENETRATING PARTICLES.  ABOVE LIMIT ASSUMES STABLE.  MULTIPLY IT BY
IC    B  EXP(3.5E-8*M/TAU/P) FOR MASS M(GEV), LIFETIME TAU(SEC), MOM.P(GEV).
IC    B  OBTAINED AT THETA(LAB) = 91 MRAD, PT = 1-2.25 GEV/C.
IC
IC    C  ARMITAGE 79 IS CERN-ISR EXPT AT ECM=53 GEV.  VALUE IS FOR X=0.1 AND
IC    C  PT=.15.
```

HEAVY LEPTON PROD. CROSS SEC. (σ(HEAVY LEPTON)/$\sigma(\pi)$)

```
RPI   A   0  7. E-12 OR LESS  CL=.95   BUSSIERE  80 CNTR Q= -1   M=4-4.5 GEV
RPI   A   0  2.5E-12 OR LESS  CL=.95   BUSSIERE  80 CNTR Q= -2   M=5-7.5 GEV
RPI
RPI   A  BUSSIERE 80 IS CERN-SPS EXPT WITH 200-240 GEV PROTONS ON BE AND AL
RPI   A  TARGET SEARCHING FOR LONG-LIVED PARTICLES.  FOR LIMITS AT OTHER
RPI   A  MASS RANGES SEE THEIR FIG. 7.
```

NEUTRAL HEAVY LEPTON PROD. CROSS SECTION (cm^2)

```
CN    A   5 (1. E-37 OR MORE)          KRISHNASW 75 CNTR +0-  M=2-5 GEV
CN    B   0                            BENVENUTI 75 SPEC  0
CN
CN    A  KRISHNASWAMY 75 IS KOLAR GOLD MINE COSMIC RAY EXPT.  TYPICAL EVENT
CN    A  HAS VERTEX IN AIR 70 CM FROM WALL WITH THREE OBSERVED CHARGED
CN    A  TRACKS.  AUTHORS SUGGEST NU+ROCK GIVES NEW PARTICLE WITH MEAN LIFE
CN    A  10E-9 SEC OR LONGER.  DE RUJULA 75 GIVES ANOTHER INTERPRETATION.
CN    A  SEE ALSO RAJASEKARAN 75.
CN
CN    B  BENVENUTI 75 IS AN FNAL EXPERIMENT WHICH ROUGHLY SIMULATES THE
CN    B  KRISHNASWAMY 75 EXPT. BUT APPARENTLY CONTRADICTS IT, FINDING NO
CN    B  EVENTS. SENSITIVE TO DECAYS OF NEUTRAL PENETRATING PARTICLES
CN    B  PRODUCED BY THE PRIMARY PROTONS OR BY SECONDARY NEUTRINO
CN    B  INTERACTIONS IN THE 1 KM. NEUTRINO BEAM EARTH SHIELD.
```

NEUTRAL HEAVY LEPTON PRODUCED IN ν INTERACTIONS

```
N     A   1      POSSIBLY SEEN           BARANOV   77 HLBC  0 SERPUKHOV
N     A   2      POSSIBLY SEEN           BARANOV   79 HLBC  0 SERPUKHOV
N
N     A  BARANOV HEAVY LEPTON CLAIM REFUTED BY BALTAY 78.
```

NEUTRAL HEAVY LEPTON PROD. CROSS SEC. ($p N$) (cm^2)

```
CP    A   0  1. E-29 OR LESS           FAISSNER  76 HLBC 0
CP    B   0  2.8E-35 OR LESS  CL=.90   BECHIS    78 SPEC  0
CP    C   0  8.2E-40 OR LESS  CL=.90   AGAKISHIE 80 SPRK 0 M=4GEV,TAU=E-7 S
CP
CP    A  FAISSNER 76 LIMIT ASSUMES STABLE NEUTRAL WEAKLY INTERACTING LEPTON.
CP    A  ALSO RULES OUT DE RUJULA 75 INTERP. OF 5 KRISHNASWAMY 75 EVENTS AS
CP    A  (P NUCLEON --> L+ X, L+ --> L0 X) UNLESS L+ MASS IS ABOVE 3 GEV.
CP
CP    B  BECHIS 78 IS 400 GEV FNAL EXPT. LOOKS FOR P NUCLEON --> L+,
CP    B  L+ --> L0 X, L0 --> MU PI OR E PI. RESULT IS CL=.90 FOR MASS OF L0
CP    B  < 1 GEV, LIFETIME BETW 10**-10 AND 10**-8 SEC.(VALID ONLY FOR CASES
CP    B  WHEN L0 UNACCOMPANIED BY MUON OF P>10 GEV.)
CP
CP    C  AGAKISHIEV 80 REANALYZED BEAM DUMP DATA FROM 70 GEV PROTON ON IRON
CP    C  (ASRATYAN 78 PL 79B,497). ASSUMED DRELL-YAN PROD OF CHGD HVY LEPTON
CP    C  PAIR FOLLOWED BY DECAY INTO NEUTRAL HVY LEPTON. ABOVE VALUE IS WHEN
CP    C  LIMIT IS MOST STRINGENT. FOR OTHER MASS AND LIFE,SEE THEIR TABLE 1,
CP    C  AND FOR LIMIT DEDUCED FOR PI NUCLEON INTERACTION,SEE THEIR TABLE 2.
```

NEUTRAL HEAVY LEPTON PROD. CROSS SEC. (e^+e^-) (10^{-5} nb)

```
NE
NE      CS*BR(TAU--> NEW NEUTRAL LEPTON)*BR(NEUTRAL LEPTON--> E OR MU PI)
NE    A    450         OR LESS  CL=.90   MEYER     77 SMAG FOR M(L)=0.5 GEV
NE    A    250         OR LESS  CL=.90   MEYER     77 SMAG FOR M(L)=1.5 GEV
NE
NE      CS(L LBAR)*(BR(L INTO E NU X) + BR(LBAR INTO E NU X))
NE    B      8         OR LESS  CL=.90   ERREDE    84 HRS  FOR M(L)=1 GEV
NE    B     18         OR LESS  CL=.90   ERREDE    84 HRS  FOR M(L)=2 GEV
NE    B     20         OR LESS  CL=.90   ERREDE    84 HRS  FOR M(L)=3 GEV
NE    B     11         OR LESS  CL=.90   ERREDE    84 HRS  FOR M(L)=4 OR 5 GEV
NE    B     13         OR LESS  CL=.90   ERREDE    84 HRS  FOR M(L)=6 GEV
NE    B     17         OR LESS  CL=.90   ERREDE    84 HRS  FOR M(L)=7 GEV
NE
NE      CS(L1+L2)*BR(L1 --> ONLY LIGHT NEUTRINOS)
NE    C        4.7     OR LESS  CL=.90   AKERLOF   85 HRS  FOR M(L)=2 GEV
NE    C       18.      OR LESS  CL=.90   AKERLOF   85 HRS  FOR M(L)=10 GEV
NE
NE      CS(L LBAR)*BR1*BR2/CS(STANDARD VIA VIRTUAL Z)
NE       WHERE BR1 AND BR2 ARE BRANCHING RATIOS LEADING TO EVENTS WITH
NE       TWO OR FOUR CHARGED PARTICLES, AND CS(STANDARD)=
NE       0.35(BETA(3+BETA**2)/4) PB WITH BETA= VELOCITY/C OF L.
NE    D   0.1-0.2 OR LESS      CL=.90   PERL      85 SMK2 FOR M(L)<1 GEV
NE
NE    A  MEYER 77 EXPT LOOKS FOR NARROW NEUTRAL RESONANCE IN E-PI AND MU-PI
NE    A  CHANNELS. SEE HEAVY LEPTON MASS LIMITS SECTION ABOVE.
NE
NE    B  ASSUMING X=MU; IF X=MESON, LIMITS ARE 20% HIGHER.  ERREDE 84 SAY
NE    B  THESE LIMITS ARE COMPARABLE TO THOSE EXPECTED FROM NAIVE THEORY.
NE    B  E+E-, ECM=29 GEV.  SEE ALSO GRONAU 85, RIZZO 85.
NE
NE    C  AKERLOF 85 OBSERVE NO MONOJETS ABOVE BACKGROUND.  THEY USE STANDARD
NE    C  COUPLINGS TO Z TO FIND CS(L1+L2)=0.36 PB. ABOVE DATA THEN IMPLY
NE    C  B(L1-->LIGHT NEUTRINOS)< 13-50 PER CENT FOR M(L)=2-10 GEV.
NE
NE    D  PERL 85 EXAMINE A VARIETY OF MODELS AND PROCESSES.  THEY SEARCH UP
NE    D  TO M(L)=14 GEV BUT ARE MOST SENSITIVE FOR M(L)<1 GEV.  THEY REQUIRE
NE    D  LEPTON LIFETIME < M(L)*1E-11 SEC (M(L) IN GEV) WHICH LIMITS THEIR
NE    D  ABILITY TO CONSTRAIN THE MIXING OF A 4TH CONVENTIONAL GENERATION.
```

LIMIT ON ν_τ PRODUCTION IN BEAM DUMP EXPERIMENT

```
TNU   A                                 FRITZE    80 HYBR
TNU
TNU   A  FRITZE 80 IS CERN SPS EXP WITH BEBC. NC/CC RATIO CORRESPONDS TO
TNU   A  R=(PROMPT-NU(TAU)-INDUCED EVENTS)/(ALL PROMPT-NU EVENTS) <0.1.
TNU   A  MIXING PROBABILITY P(NU(E)-->NU(TAU)) < 0.35 AT CL=.90.
```

LIMITS ON EXCITED e AND μ (e^* AND μ^*)

```
EXC   A  NONE BELOW 58 GEV     CL=.95   ADEVA     82 MRKJ    E* PROD IN E+E-
EXC   A  NONE BELOW 10 GEV     CL=.95   ADEVA     82 MRKJ    MU* PROD IN E+E-
EXC   B                                 BUKIN     82         E* PROD IN E+E-
EXC   C                                 RENARD    82         G-2 OF E*,MU*
EXC   D                                 FORD      83 MAC     MU* PROD IN E+E-
EXC   E         20.GEV OR MORE          ADEVA     84 MRKJ    LAMBDA=0.2
EXC   E         70.GEV OR MORE          ADEVA     84 MRKJ    LAMBDA=1.0
EXC   F         22.GEV OR MORE  CL=.95  BARTEL    84 JADE    MU*
EXC   F         34.GEV OR MORE  CL=.95  BARTEL    84 JADE    MU* LAMBDA=0.2
EXC   E         72.GEV OR MORE  CL=.95  ADEVA     85 MRKJ    E* LAMBDA=1
EXC             25.GEV OR MORE  CL=.95  ADEVA     85 MRKJ    MU* LAMBDA=1
EXC
EXC   A  ADEVA 82 M(E*) LIMIT ASSUMES E* COUPLING EQUALS TO THAT OF E.
EXC   A  SEE THEIR FIG.2 FOR DEPENDENCE ON THE COUPLING.
EXC
EXC   B  BUKIN 82 IS VEPP-2M RING EXP FOR E+E- -->E+ E- GAMMA WITH WCM=0.64-
EXC   B  1.4 GEV. OBSERVED NO PEAK IN M(E GAM) SPECTRUM. SET CL=.95 LIMIT
EXC   B  CS(E*+E-)/CS(E+E-) < (0.2-6)*10**-4 FOR M(E*)=0.2-1.0 GEV.
EXC
EXC   C  RENARD 82 DERIVED FROM G-2 DATA LIMITS ON MASS AND COUPLINGS OF E*
EXC   C  AND MU*.  SEE FIGS.2 AND 3 OF THE PAPER.
EXC
EXC   D  FORD 83 AT PEP-MAC (WCM=29 GEV) SET CL=.90 LIMITS
EXC   D  CS(MU*MU*)/CS(MU+MU-) < (1-2)*10**-3 FOR M(MU*)=2-14 GEV, AND
EXC   D  CS(MU* MU)/CS(MU+MU-) < (1-2)*10**-3 FOR M(MU*)=2.5-27 GEV.
EXC
EXC   E  ADEVA 84 AND 85 LIMITS DEPEND ON E* E GAM COUPLING = LAMBDA.
EXC   E  FROM E-E+ --> 2GAM WITH E* EXCHANGE.
EXC
EXC   F  BARTEL 84 OBSERVED 270 MU+ MU- GAMMA EVENTS AND 16 MU+ MU- 2GAMMA
EXC   F  EVENTS.  DISTRIBUTIONS ARE CONSISTENT WITH QED.  ABOVE LIMIT IS
EXC   F  FROM 2GAMMA EVENTS AND ASSUMES MU* IS POINT-LIKE.  THE 1GAMMA
EXC   F  EVENTS GIVE AT CL=0.95 LAMBDA<0.02 - 0.15 AS M(MU*) VARIES BETWEEN
EXC   F  22 AND 34 GEV.
```

REFERENCES FOR HEAVY LEPTON SEARCHES

```
BEHREND  65 PRL 15 900         +BRASSE,ENGLER,GANSSAUGE+        (DESY+KARL)
BETOURNE 65 PL  17 70          +NGUYEN NGOC,PEREZ Y JORBA+          (ORSA)
BUDNITZ  66 PR  141 1313       +DUNNING,GOITEIN,RAMSEY,WALKER,WILSON(HARV)
BARNA    68 PR  173 1391       +COX,MARTIN,PERL,TAN,TONER,ZIPF+(SLAC+STAN)
BOLEY    68 PR  167 1275       +ELIAS,FRIEDMAN,HARTMANN,KENDALL+ (MIT+CEA)

LIBERMAN 69 PRL 22 663         +HOFFMAN,ENGELS,IMRIE+(HARV+CASE+MCGI+SLAC)
ROTHE    69 NP B10 241         K.W.ROTHE,A.M.WOLSKY                 (PENN)
LICHTENS 70 PR D1 825          LICHTENSTEIN,ASH,BERKELMAN,HARTILL+  (CORN)
RAMM     70 NATURE 227 1323    C.A.RAMM                             (CERN)
    ALSO 72 NATURE 237 388     CLARK,ELIOFF,FIELD,FRISCH,JOHNSON+    (LBL)

RAMM     71 NAT.PH.SC.230 145  C.A.RAMM                             (CERN)
GOLOVKIN 72 PL 42B 136         +GRACHEV,KHODYREV,KUBAROVSKY+        (SERP)
ANSORGE  73 PR D7 26           +BAKER,KRZESINSKI,NEALE,RUSHBROOKE+  (CAVE)
BACCI    73 PL 44B 530         +PARISI,PENSO,SALVINI,STELLA+   (ROMA+FRAS)
BARISH   73 PRL 31 410         +BARTLETT,BUCHHOLZ,HUMPHREY+     (CIT+FNAL)

BERNARDI 73 NC 17A 383         BERNARDINI,BOLLINI,BRUNINI+(CERN+BGNA+FRAS)
    ALSO 70 LNC 4 1156         ALLES-BORELLI,BERNARDINI,BOLLINI+    (CERN)
BUSHNIN  73 NP B58 476         +DUNAYTZEV,GOLOVKIN,KUBAROVSKY +     (SERP)
    ALSO 72 PL 42B 136         GOLOVKIN,GRACHEV,SHODYREV +          (SERP)
EICHTEN  73 PL 46B 281         +DEDEN+(AACH+BELG+CERN+EPOL+MILA+LALO+LOUC)
HANSON   73 LNC 7 587          +LEONG,NEWMAN,LAW,LITKE+(MIT+HARV+CEA+HAIF)

ASRATYAN 74 PL 49B 488         +GERSHTEIN,KAFTANOV,KUBANTZEV,LAPIN+ (SERP)
BARISH   74 PRL 32 1387        +BARTLETT,BUCHHOLZ,MERRITT +     (CIT+FNAL)
CRONIN   74 PR D10 3093        +FRISCH,SHOCHET,BOYMOND,MERMOD + (EFI+PRIN)
GITTLESO 74 PR D10 1379        GITTLESON,KIRK+       (HARV+ROCH+COLU+FNAL)
ORITO    74 PL 48B 165         +VISENTIN,CERADINI,CONVERSI +   (FRAS+ROMA)
```

```
BENVENUT 75 PRL 35 1486      BENVENUTI,CLINE,FORD+ (HARV+PENN+WISC+FNAL)
BINTINGE 75 PRL 34 982       BINTINGER,CURRY+       (EFI+HARV+PENN+WISC)
BACCI    77 PL 71B 227       +DEZORZI,PENSO,STELLA+           (ROMA+FRAS)
KRISHNAS 75 PL 57B 105       KRISHNASWAMY,MENON+           (BOMBAY+OSAKA)
    ALSO 75 PRL 35 628       DE RUJULA,GEORGI,GLASHOW                (HARV)
    ALSO 75 PRAMANA 5 78     RAJASEKARAN,SARMA                       (TIFR)

FAISSNER 76 PL 60B 401       +HASERT+(AACH+BELG+CERN+EPOL+MILA+OXF+LOUC)
BARANOV  77 PL 70B 269       +VOLKOV,GERSHTEIN,IVANILOV +            (SERP)
    ALSO 77 SJNP 26 57       BARANOV,VOLKOV,GERSHTEIN,IVANILOV      +(SERP)
BENVENU1 77 PRL 38 1110      BENVENUTI,CLINE+ (FNAL+HARV+PENN+RUTG+WISC)
    ALSO 77 PRL 38 1187      ALBRIGHT,SMITH,VERMASEREN          (FNAL+STON)
    ALSO 77 PRL 38 1190      BARGER,GOTTSCHALK+       (WISC+ZARAGOZA+RHEL)
BENVENU2 77 PRL 38 1183      BENVENUTI,CLINE+ (FNAL+HARV+PENN+RUTG+WISC)

MEYER    77 PL 70B 469       +NGUYEN,ABRAMS,ALAM+     (SLAC+LBL+NWES+HAWA)
ASRATYAN 78 PL 76B 237       ASRATYAN,KUBANTSEV                      (ITEP)
BALTAY   78  TOKYO CONF.     C.BALTAY (19TH INTL. CONF. ON HEP)      (COLU)

BECHIS   78 PRL 40 602       +CHANG,DOMBECK,ELLSWORTH,GLASSER,LAU+ (UMD)
BOSETTI  78 PL 73B 380       +DEDEN +      (AACH+BONN+CERN+LOIC+OXF+SACL)
CNOPS    78 PRL 40 144       +CONNOLLY,KAHN,KIRK,MURTAGH +      (BNL+COLU)
ERRIQUEZ 78 PL 77B 227                BARI+BIRM+BRUX+EPOL+RHEL+SACL+LOUC
HOLDER   78 PL 74B 277       +KNOBLOCH,MAY +  (CERN+DORT+HEID+SACL+BGNA)
SMITH    78  NU 78 CONF      J.SMITH                                 (COLU)

ARMITAGE 79 NP B150 87       +BENZ,BOBBINK+ (CERN+DARE+FOM+MCHS+UTRECHT)
BARANOV  79 PL 81B 261       +IVANILOV,KONYUSHKO,KORABLEV+           (SERP)
    ALSO 79 SJNP 29 622      BARANOV,+VOLKOV,IVANILOV,KONYUSHKO,+ (SERP)

AGAKISHI 80 SJNP 32 345      AGAKISHIEV,VOVENKO,GORYACHEV,MUKHIN  (SERP)
AZIMOV   80 JETPL 32 665     YA.I.AZIMOV,V.A.KHOZE                   (KONS)
BARBER   80 PRL 45 1904      +BECKER,BEI+        (AACH+DESY+MIT+AIKO+BHEP)
BUSSIERE 80 NP B174 1        +GIACOMELLI,LESQUOY+          (BGNA+SACL+LAPP)
FRITZE   80 PL 96B 427       AACH+BONN+CERN+LOIC+OXF+SACL COLLABORATION
LEBRITTO 80 PL 89B 271       LEBRITTON,MCCAL,MELISSINOS+  (ROCH+BNL+NSF)

BERGER   81 PL 99B 489       +GENZEL+(AACH+BERG+DESY+HAMB+UMD+SIEG+WUPP)
BRANDELI 81 PL 99B 163       BRANDELIK+  (AACH+BONN+DESY+HAMB+LOIC+OXF+)
CLARK    81 PRL 46 299       +JOHNSON,KERTH,LOKEN+    (UCB+LBL+FNAL+PRIN)
    ALSO 82 PR D25 2762      SMITH,CLARK,JOHNSON+     (UCB+LBL+FNAL+PRIN)
LOSECCO  81 PL 102B 209      +SULAK,GALIK,HORSTKOTTE+     (MICH+PENN+BNL)

ADEVA    82 PRL 15 967       MARK-J C (AACH+DESY+MIT+MADR+ANIK+CIT+BHEP)
BUKIN    82 SJNP 35 844      +KURDADZE,LELCHUK,PANIN,SIDOROV+        (SIBE)
HAYES    82 PR D25 2869      +PERL,ALAM,BOYARSKI,BREIDENBACH+ (SLAC+LBL)
RENARD   82 PL 116B 264      F.M.RENARD                              (CERN)

ADEVA    83 PRL 51 443       MARKJ C. (AACH+DESY+MIT+MADR+AIKO+BHEP+CIT)
BARTEL   83 PL 123B 353      +CORDS+(DESY+HAMB+HEID+LANC+MCHS+RHEL+TOKY)
FORD     83 PRL 51 257       +READ,SMITH+(COLO+FRAS+NEAS+SLAC+UTAH+WISC)
ADEVA    84 PRL 53 134       MARK-J COLLAB (AACH+BNL+CIT+DESY+MIT+MADR+)
BARTEL   84 ZPHY C24 223     JADE C.(DESY+HAMB+HEID+LANC+MCHS+UMD+RHEL+)
ERREDE   84 PL 149B 519      HRS COLLAB.     (MICH+ANL+IND+PURD+LBL+SLAC)
GRONAU   84 PR D29 2539      GRONAU,LEUNG,ROSNER           (SYRA+FNAL+CHIC)
RIZZO    84 PL 136B 251      T.RIZZO                                  (ISU)
ADEVA    85 PL 152B 439      MARK-J C.(AACH+BNL+CIT+DESY+MIT+MADR+ANIK+)
    ALSO 84 PRPL 109 131     MARK-J C.,ADEVA+    (AACH+BNL+CIT+DESY+MIT+)
AKERLOF  85 PL 156B 271      HRS C.          (MICH+ANL+IND+PURD+LBL+SLAC)
PERL     85 PR D32 2859      MK II C.,+BARKLOW,BOYARSKI+ (SLAC+LBL+HARV)

                             REVIEWS

PERL     81  SLAC-PUB-2752   M.L.PERL, PHYS. IN COLL. CONF, V.P.I.(SLAC)
```

LIGHT MESONS

$\pi^{\pm}$ $I^G(J^P) = 1^-(0^-)$

$\pi^{\pm}$ MASS (MeV)

```
M            139.37      0.20           CROWE     54 CNTR  -
M            139.68      0.15           BARKAS    56 EMUL +
M   S       (139.577)   (0.013)         SHAFER    67 CNTR  - MESONIC ATOMS
M   B       (139.549)   (0.008)         BACKENSTO 71 CNTR  - MESONIC ATOMS
M    S       139.566     0.013          SHAFER    72 CNTR  - MESONIC ATOMS
M    B       139.569     0.008          BACKENSTO 73 CNTR  - MESONIC ATOMS
M            139.571     0.010          BRANDAODO 76 CNTR  - MESONIC ATOMS
M            139.5686    0.0020         CARTER    76 CNTR  - MESONIC ATOMS
M    M       139.5667    0.0024         MARUSHENK 76 CNTR  - MESONIC ATOMS
M            139.5675    0.0009         LU        80 CNTR  - MESONIC ATOMS
M   D       (139.5704) (0.0011)         ABELA     84 SPEC +  PI+ --> MU+ NU   |
M    S  SHAFER 72 UPDATES SHAFER67 WITH NEW ALPHA AND NEW CALIB. LINE ENER.
M    B  BACKENSTOSS 73 CORRECTS BACKENSTOSS 71 WITH NEW VACUUM POL. CALC.
M    M  THIS MARUSHENKO 76 VALUE USED AT AUTHORS REQUEST BECAUSE IT USES
M    M  ACCEPTED SET OF CALIBRATION GAMMA ENERGIES.  ERROR INCREASED FROM
M    M  .0017 TO INCLUDE QED CALC. ERROR OF .0017 (12 PPM).
M   D   ABELA84 VALUE DEPENDS ON ASSUMED MU+ MASS M(MU)=105.65932+-0.00029   |
M   D   ENTERS OUR FIT VIA PI-MU MASS DIFF. BELOW WHICH IS INDEP. OF M(MU).
M            . . . . . . . . . . .
M   AVG      139.56761  0.00077  AVERAGE
M   FIT      139.5685   0.0010  FROM FIT (ERROR INCL. SCALE FACTOR OF 1.5)   |
```

$\pi^+ - \mu^+$ MASS DIFFERENCE (MeV)

```
D              34.00     0.076          BARKAS    56 EMUL
D              33.89     0.076          BARKAS    56 EMUL
D       145    33.881    0.035          HYMAN     67 HEBC  + K-HE
D              33.925    0.025          BOOTH     70 CNTR  + MAGNETIC SPECT.
D              33.9111   0.0011         ABELA     84 SPEC    SEE NOTE D ABOVE  |
D            . . . . . . . . . . .
D   AVG        33.9111   0.0011  AVERAGE
D   FIT        33.9093   0.0011 FROM FIT (ERROR INCL. SCALE FACTOR OF 1.6)    |
```

$(\pi^+ - \pi^-)$/AVG., MASS DIFFERENCE (%)

```
DM      TEST OF CPT
DM           0.02      0.05             AYRES     71 CNTR
```

$\pi^{\pm}$ MEAN LIFE (units 10^{-9} sec)

```
T              25.6      0.5       0.5   CROWE     57 RVUE
T              25.6      0.8       0.8   ANDERSON  60 CNTR
T      8000    25.46     0.32      0.32  ASHKIN    60 CNTR +
T              26.02     0.04            ECKHAUSE  65 CNTR +
T              25.6      0.3             BARDON    66 CNTR
T              25.9      0.3             DUNAITSEV 66 CNTR
T   N         (26.40)   (0.08)           KINSEY    66 CNTR +
T   N   SYSTEMATIC ERRORS IN CALIBR.IN THIS EXP.DISCUSSED BY NORDBERG 67
T              26.67     0.24            LOBKOWICZ 66 CNTR
T              26.04     0.05            NORDBERG  67 CNTR +
T              26.02     0.04            AYRES     71 CNTR +-
T              26.09     0.08            DUNAITSEV 73 CNTR +
T            . . . . . . . . . . .
T   AVG        26.030    0.023     0.023  AVERAGE
```

$(\pi^+ - \pi^-)$/AVG., MEAN LIFE DIFFERENCE (%)

```
DT  N   THIS QUANTITY IS A MEASURE OF CPT INVARIANCE IN W.I.

DT             0.23      0.40            LOBKOWICZ 66 CNTR      SEE NOTE L
DT  L   ABOVE IS THE MOST CONSERVATIVE VALUE QUOTED BY AUTHORS
DT             0.4       0.7             BARDON    66 CNTR
DT            -0.14      0.29            PETRUKHIN 68 CNTR
DT             0.055     0.071           AYRES     71 CNTR
DT           . . . . . . . . . . .
DT  AVG        0.053     0.068   AVERAGE
```

$\pi^{\pm}$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\pi^{\pm} \to \mu^{\pm}\nu_{\mu}$	106+ 0
P2	$\pi^{\pm} \to e^{\pm}\nu_e$	.511+ 0
P3	$\pi^{\pm} \to \mu^{\pm}\nu_{\mu}\gamma$	106+ 0+ 0
P4	$\pi^{\pm} \to \pi^0 e^{\pm}\nu_e$	135+.511+ 0
P5	$\pi^{\pm} \to e^{\pm}\nu\gamma$	.511+ 0+ 0
P6	$\pi^{\pm} \to e^{\pm}\nu e^+ e^-$	.511+ 0+.511+.511
P7	$\pi^+ \to \mu^+\overline{\nu}_e$	106+ 0
P8	$\pi^+ \to \mu^+\nu_e$	106+ 0

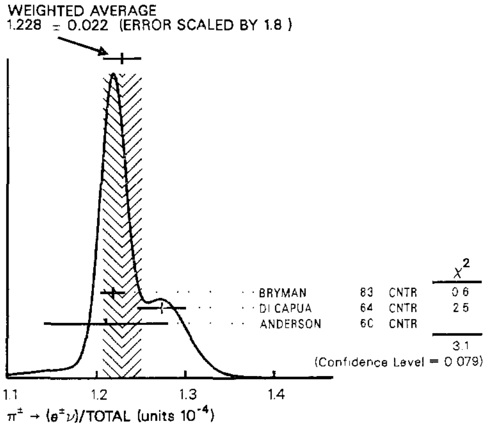
$\pi^{\pm}$ BRANCHING RATIOS

$\pi^{\pm} \to (\mu^{\pm}\nu\gamma)$/total (units 10^{-4}) (P3)

```
R1       26      1.24      0.25             CASTAGNOL 58 EMUL    E(MU).LT.3.38 MV
```

$\pi^{\pm} \to (e^{\pm}\nu)$/total (units 10^{-4}) (P2)

```
R2                1.21      0.07            ANDERSON  60 CNTR
R2 D    11K       1.273     0.028           DI CAPUA  64 CNTR
R2      32K       1.218     0.014           BRYMAN    83 CNTR +
R2 D    DI CAPUA 64 UPDATED USING CURRENT MEAN LIFE.                          |
R2            . . . . . . . . . . .
R2  AVG           1.228     0.022   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)
                                    (SEE IDEOGRAM BELOW)
```



$\pi^{\pm} \rightarrow (\pi^{0} e^{\pm} \nu)$/total (units 10^{-8}) (P4)

```
R3  D   52   (1.15)   (0.22)              DEPOMMI1  63 CNTR +
R3   D  36    0.97     0.20               BARTLETT  64 OSPK +
R3   D  38    1.07     0.21               BACASTOW  65 OSPK +
R3   D        1.10     0.26               BERTRAM   65 OSPK +
R3   D  43    1.1      0.2                DUNAITSEV 65 CNTR +
R3     332    1.00     0.08      0.10     DEPOMMIER 68 CNTR +
R3 M  1224    1.026    0.039              MCFARLANE 85 CNTR +  DECAY IN FLIGHT   |
R3  D   DEPOMMIER 68 STATES THAT THE RESULT OF DEPOMMIER 63 IS AT LEAST
R3  D   10 PERCENT TOO LARGE BECAUSE OF A SYSTEMATIC ERROR IN THE PIO
R3  D   DETECTION EFFICIENCY.  THIS MAY BE TRUE OF ALL THE PREVIOUS
R3  D   MEASUREMENTS ACCORDING TO DEPOMMIER 68 AND V.SOERGEL, PRIVATE
R3  D   COMMUNICATION, 1972.
R3 M    COMBINES MEASURED RATE(.394+-.015)/SEC WITH 1982 PDG MEAN LIFE.           |
R3          . . . . . . . . . .
R3  AVG       1.025    0.034   AVERAGE
```

$\pi^{\pm} \rightarrow (e^{\pm} \nu \gamma)$/total (units 10^{-8}) (P5)

```
R4      143   (3.0)                       DEPOMMI2  63 CNTR + E+, GAM KE >48MEV
R4    S 226    5.6      0.7               STETZ     78 SPEC + E MOM >56 MEV/C.
R4    S  STETZ 78 IS FOR E-GAMMA OPENING ANGLE >132DEG.  OBTAINS 3.7 WHEN
R4    S  USING SAME CUTOFFS AS DEPOMMIER.
```

$\pi^{\pm} \rightarrow (e^{\pm} \nu e^{+} e^{-})$/total (units 10^{-8}) (P6)

```
R5          (3.4)  OR LESS  CL=.90   KORENCHEN 71 OSPK +
R5           0.48  OR LESS  CL=.90   KORENCHEN 76 SPEC +
```

$\pi^{+} \rightarrow (\mu^{+} \overline{\nu}_{e})$/total (units 10^{-3}) (P7)

```
R6      FORBIDDEN BY TOTAL LEPTON NUMBER CONSERVATION.
R6           1.5   OR LESS  CL=.90   COOPER    82 HLBC WIDEBAND NU BEAM
```

$\pi^{+} \rightarrow (\mu^{+} \nu_{e})$/total (units 10^{-3}) (P8)

```
R7      FORBIDDEN BY LEPTON FAMILY NUMBER CONSERVATION.
R7           8.0   OR LESS  CL=.90   COOPER    82 HLBC WIDEBAND NU BEAM
```

$\pi^{\pm}$ POLARIZATION OF EMITTED $\mu^{\pm}$

```
POL    PI+- INTO MU+- NU
POL     TESTS LORENTZ STRUCTURE OF LEPTONIC CHARGED WEAK INTERACTIONS
POL          (0.9959)OR MORE   CL=.90 FETSCHER  84 RVUE                        |
```

REFERENCES FOR $\pi^{\pm}$

```
CROWE    54 PR  96  470          K M CROWE,R H PHILLIPS                  (LRL)
BARKAS   56 PR 101  778          W H BARKAS,W BIRNBAUM,F M SMITH         (LRL)
CROWE    57 NC   5  541          K M CROWE                     (STANFORD HEPL)
CASTAGNO 58 PR 112 1779          C CASTAGNOLI,M MUCHNIK                 (ROMA)

ANDERSON 60 PR 119 2050          H L ANDERSON,T FUJII,R H MILLER +       (EFI)
ASHKIN   60 NC  16  490          ASHKIN,FAZZINI,FIDECARO,LIPMAN +       (CERN)
DEPOMMI1 63 PL 5 61              DEPOMMIER,HEINTZE,RUBBIA,SOERGEL       (CERN)
DEPOMMI2 63 PL 7 285             P DEPOMMIER,HEINTZE,RUBBIA,SOERGEL     (CERN)
BARTLETT 64 PR 136B 1452         BARTLETT,DEVONS,MEYER,ROSEN        (COLUMBIA)
DI CAPUA 64 PR 133B 1333         DI CAPUA,GARLAND,PONDROM,STRELZOFF     (COLU)
    ALSO 86 PRIVATE COMM.        L. PONDROM                             (WISC)

BACASTOW 65 PR 139 B407          +GHESQUIERE,WIEGAND,LARSEN         (LRL+SLAC)
BERTRAM  65 PR 139 B 617         BERTRAM,MEYER,CARRIGAN+      (MICH+CARNEGIE)
DUNAITSE 65 JETP 20 58           DUNAITSEV,PETRUKHIN,PROKOSHKIN +      (DUBNA)
ECKHAUSE 65 PL 19 348            ECKHAUSE,HARRIS,SHULER+  (WILLIAM AND MARY)

BARDON   66 PRL 16 775           BARDON,DORE,DORFAN,KRIEGER +       (COLUMBIA)
DUNAITSE 66 PL 23 283            +KUTYIN,PROKOSHKIN,RASUVAEV,SIMONOV (DUBNA)
KINSEY   66 PR 144   1132        KINSEY,LOBKOWICZ,NORDBERG  (ROCHESTER UNIV)
LOBKOWIC 66 PRL  17  548         LOBKOWICZ,MELISSINOS,NAGASHIMA+  (ROCH+BNL)

HYMAN    67 PL 25B 376           +LOKEN,PEWITT,DERRICK +      (ANL+CARN+NWES)
NORDBERG 67 PL 24B  594          NORDBERG,LOBKOWICZ,BURMAN  (ROCHESTER UNIV)
SHAFER   67 PR 163 1451          ROBERT E. SHAFER                        (LRL)
    ALSO 65 PRL 14 923           SHAFER,CROWE,JENKINS                    (LRL)

DEPOMMIE 68 NP B4 189            DEPOMMIER,DUCLOS,HEINTZE,KLEINKNECHT+(CERN)
PETRUKHI 68 JINR-P1-3862         PETRUKHIN,RYKALIN,KHAZINS,CISEK     (DUBNA)
BOOTH    70 PL 32B 723           +JOHNSON,WILLIAMS,WORMALD              (LIVP)
AYRES    71 PR 3D 1051           +CORMACK,GREENBERG,KENNEY +       (LRL,UCSB)
    ALSO 67 PR  157  1288        AYRES,CALDWELL,GREENBERG,KENNEY,KURZ+ (LRL)
    ALSO 68 PRL 21 261           AYRES,CORMACK,GREENBERG,KENNEY+  (LRL,UCSB)
    ALSO 69 UCRL-18369           DAVID S AYRES (THESIS)                  (LRL)
    ALSO 69 PRL 23 1267          GREENBERG,AYRES,CORMACK,KENNEY+  (LRL,UCSB)

BACKENST 71 PL 36B 403           BACKENSTOSS,DANIEL,KOCH+   (CERN,KARL,HEID)
    ALSO 70 THESIS               C. VON DER MALSBURG             (HEIDELBERG)
KORENCHE 71 SJNP 13 189          KORENCHENKO,KOSTIN,MICELMACHER+        (JINR)
SHAFER   72 PRIVATE COMM.        R. SHAFER, 1972                        (FNAL)
BACKENST 73 PL 43B 539           BACKENSTOSS,DANIEL,KOCH+ (CERN+KARL+MUNICH)
    ALSO 73 SUBMITTED TO NP      L. TAUSCHER
DUNAITSE 73 SJNP 16 292          DUNAITSEV,PROKOSHKIN,RAZUVAEV+         (SERP)

BRANDAOD 76 ZNAT 31A 1150        BRANDAO D'OLIVERA,DANIEL,VON EGIDY+  (MUNI)
CARTER   76 PRL 37 1380          +DIXIT,SUNDARESAN+     (CARL+CNRC+CHIC+CIT)
KORENCHE 76 JETP 44 35           KORENCHENKO,KOSTIN,MICELMACHER+        (JINR)
MARUSHEN 76 JETPL 23 72          MARUSHENKO,MEZENTSEV,PETRUNIN+         (LENI)
    ALSO 76  PRIVATE COMM.       R. SHAFER                              (FNAL)
    ALSO 78  PRIVATE COMM.       A. I. SMIRNOV                          (LENI)

STETZ    78 NP B138 285          +CARROLL,ORTENDAHL,PEREZ-MENDEZ+ (LBL+UCLA)
LU       80 PRL 45 1066          +DELKER,DUGAN,WU,CAFFREY+   (YALE+COLU+JHU)
COOPER   82 PL 112B 97           +GUY,MICHETTE,TYNDEL,VENUS               (RL)
BRYMAN   83 PRL 50 7             +DUBOIS,NUMAO+   (TRIU+VICT+CNRC+BRCO+QUKI)
    ALSO 86 PR (TO BE PUBL)      BRYMAN,DIXIT,DUBOIS,MACDONALD+  (TRIU+CNRC)
FETSCHER 84 PL 140B 117          FETSCHER                                (ETH)
ABELA    84 PL 146B 431          +DAUM,EATON,FROSCH,JOST,KETTEL,STEINER(SIN)
    ALSO 78 PL 74B 126           DAUM,EATON,FROSCH,HIRSCHMANN,+          (SIN)
    ALSO 79 PR D20 2692          DAUM,EATON,FROSCH,HIRSCHMANN,+          (SIN)
MCFARLAN 85 PR D32 547           MCFARLANE,AUERBACH,GAILLE+        (TEMP+LANL)

                                 PAPERS NOT REFERRED TO IN DATA LISTINGS

CARTWRIG 53 PR 91 677            CARTWRIGHT,RICHMAN,WHITEHEAD,WILCOX   (LRL)J
MERRISON 62 ADVP 11 1            A W MERRISON                      (LIVERPOOL)
SHAPIRO  62 PR 125 1022          G SHAPIRO,L M LEDERMAN             (COLUMBIA)
CZIRR    63 PR 130 341           JOHN B CZIRR                            (LRL)
CARRIGAN 68 NP B6 662            R.A.CARRIGAN JR.                       (CARN)J
DEPOMMIE 80 NP A335 97           P.DEPOMMIER                            (MONT)
WILKIN   80 JPG 6 L5             C. WILKIN                             (LOUC)P
BRYMAN   82 PRPL 88 151          BRYMAN,DEPOMMIER,LEROY      (TRIU+MONT+LVLN)
```

$\boxed{\pi^{0}}$

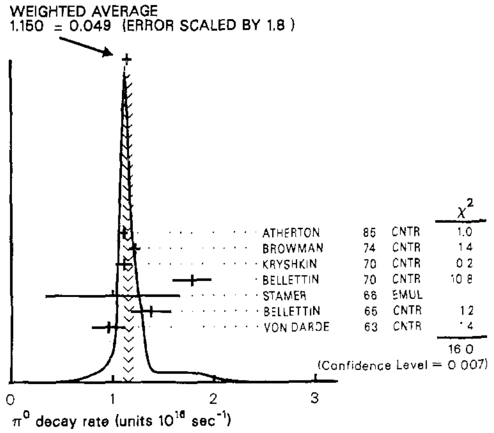
$I^{G}(J^{PC}) = 1^{-}(0^{-+})$

$\pi^{\pm} - \pi^{0}$ MASS DIFFERENCE (MeV)

```
D            (5.37)   (1.0)             PANOFSKY  51 CNTR  -
D             4.50     0.31             CHINOWSKY 54 CNTR  -
D             4.62     0.05             HADDOCK   59 CNTR  -
D             4.60     0.04             HILLMAN   59 CNTR
D             4.55     0.07             CASSELS   59 CNTR
D             4.69     0.07             SAMIOS    60 HBC
D             4.6056   0.0055           CZIRR     63 CNTR
D             4.59     0.03             PETRUKHIN 63 CNTR  -
D             4.6034   0.0052           VASILEVSK 66 CNTR  -
D          . . . . . . . . . .
D    AVG      4.6043   0.0037  AVERAGE
```

π^{0} MEAN LIFE (units 10^{-16} sec)

```
T   N   76   (1.9)    (0.5)    (0.5)  GLASSER   61 EMUL
T   N   45   (2.3)    (1.1)    (1.0)  TIETGE    62 EMUL
T   N   88   (2.8)    (0.9)    (0.9)  KOLLER    63 EMUL    SEE STAMER 66
T             1.05     0.18     0.18  VON DARDE 63 CNTR
T   N   75   (1.7)    (0.5)           SHWE      64 EMUL
T             0.730    0.105          BELLETTIN 65 CNTR
T   N   67   (1.6)    (0.6)    (0.5)  EVANS     65 EMUL
T  K   232    1.0      0.5            STAMER    66 EMUL
T             0.56     0.06           BELLETTIN 70 CNTR    PRIM.EFF. ON NUC
T             0.9      0.068          KRYSHKIN  70 CNTR    PRIMAKOFF EFFECT
T  B          0.82     0.04           BROWMAN   74 CNTR    PRIMAKOFF EFFECT
T    A        0.897    0.028          ATHERTON  85 CNTR                      |
T   N   OLD EMULSION MEASUREMENTS NOT USED BECAUSE OF POSSIBLE SYSTEMATIC
T   N   SHIFT TO LARGER MEAN LIFE VALUES.
T  K    INCLUDES EVENTS OF KOLLER 63.
T  B    BROWMAN GIVES PIO WIDTH=8.02+-.42EV.  MEAN LIFE IS HBAR/WIDTH.
T    A  STAT ERROR (0.022) AND SYST ERR (0.017) ADDED IN QUADRATURE.         |
T          . . . . . . . . . .
T   AVG       0.869    0.038    0.036  AVERAGE (ERROR INCL. SCALE FACTOR OF 1.8)
                       (SEE IDEOGRAM BELOW)
```



π^{0} PARTIAL DECAY MODES

		DECAY MASSES
P1	$\pi^{0} \rightarrow 2\gamma$	0+ 0
P2	$\pi^{0} \rightarrow e^{+}e^{-}\gamma$	.511+.511+ 0
P3	$\pi^{0} \rightarrow 4e$	.511+.511+.511+.511
P4	$\pi^{0} \rightarrow 3\gamma$	0+ 0+ 0
P5	$\pi^{0} \rightarrow 4\gamma$	0+ 0+ 0+ 0
P6	$\pi^{0} \rightarrow e^{+}e^{-}$	.511+.511
P7	$\pi^{0} \rightarrow 2\nu$	0+ 0
P8	$\pi^{0} \rightarrow \mu^{+}e^{-} + \mu^{-}e^{+}$	106+.511

π^{0} BRANCHING RATIOS

$\pi^{0} \rightarrow (\gamma e^{+} e^{-})/(2\gamma)$ (%) (P2)/(P1)

```
R1          (1.196)  THEORET. CALC.  JOSEPH    60          QUANTUM ELECT.
R1      27    1.17     0.15          BUDAGOV   60 HBC
R1    3071    1.166    0.047         SAMIOS    61 HBC      PI- P --> PIO N
R1            1.25     0.04          SCHARDT   81 SPEC     PI- P --> PIO N
R1  S   SAMIOS VALUE USES PANOFSKY RATIO = 1.62
R1         . . . . . . . . . .
R1  AVG       1.213    0.030   AVERAGE
```

$\pi^0 \rightarrow (3\gamma)$/total (units 10^{-6}) (P4)

```
R2       FORBIDDEN BY C INVARIANCE.
R2   D    0   (4.9)  OR LESS  CL=.90   DUCLOS    65 CNTR
R2   D        (4.9)  OR LESS  CL=.90   KUTIN     65 CNTR
R2   D   THESE EXPTS. GIVE BR(3GAMMA/2GAMMA)<5.0*10**-6.
R2        0   (1.5)  OR LESS  CL=.90   AUERBAC1  78 CNTR
R2        0    0.38  OR LESS  CL=.90   HIGHLAND  80 CNTR
```

$\pi^0 \rightarrow (e^+e^+e^-e^-)/(2\gamma)$ (units 10^{-5}) (P3)/(P1)

```
R3   N  146   (3.18)   (0.30)          SAMIOS    62 HBC      SEE NOTE N BELOW
R3              3.28   THEORET. CALC.  MIYAZAKI  73          QUANTUM ELECT.
R3   N   ABOVE VALUE USES PANOFSKY RATIO = 1.62
```

$\pi^0 \rightarrow (4\gamma)$/total (units 10^{-5}) (P5)

```
R4   A    0   (6.0)  OR LESS  CL=.90   ABRAMS    73 ASPK
R4   A   ABRAMS 73 GIVES BR(4GAMMA/2GAMMA)<6.1*10**-5.
R4        0   (3.8)  OR LESS  CL=.90   AUERBAC2  78 CNTR
R4        0    0.44  OR LESS  CL=.90   AUERBACH  80 CNTR
```

$\pi^0 \rightarrow (e^+e^-)$/total (units 10^{-6}) (P6)/(P1)

```
R5   D        (2.0)  OR LESS  CL=.90   DAVIES    74 RVUE
R5            (4.0)  OR LESS  CL=.90   SCHACHER  77 STRC     PI- P --> PIO N
R5        8    0.223    0.240    0.110 FISCHER2  78 SPRK     K+ EXPT. CL=.90
R5       58   (0.18)   (0.06)          MISCHKE   82 SPEC     REPL.BY FRANK 83
R5       59    0.17     0.07           FRANK     83 SPEC     PI- P --> PIO N
R5   D   DAVIES 74 EXTRACTS THIS INFORMATION FROM BLOCH 75 K+ EXPERIMENT.
R5            . . . . . . . . . . .
R5   AVG       0.177    0.065   AVERAGE
```

$\pi^0 \rightarrow (2\nu)$/total (units 10^{-5}) (P7)

```
R6        0    2.4   OR LESS  CL=.90   HERCZEG   81 RVUE
```

$\pi^0 \rightarrow (\mu^+e^- + \mu^-e^+)$/total (P8)

```
R7       FORBIDDEN BY LEPTON FAMILY NUMBER CONSERVATION
R7             7E-8  OR LESS           BRYMAN    82 RVUE     K+ --> PI+ MU E
R7           (14E-8) OR LESS           HERCZEG   84 RVUE     K+ --> PI+ MU E
R7            (2E-15)OR LESS           HERCZEG   84 THEO     MU- --> E- CONV
```

π^0 ELECTROMAGNETIC FORM FACTOR

THE AMPLITUDE FOR THE PROCESS PIO --> E+ E- GAMMA CONTAINS A FORM FACTOR GAMMA(X**2) AT THE (PIO GAMMA GAMMA) VERTEX WHERE X=MASS(E+E-)/MASS(PIO). THE PARAMETER A IN THE LINEAR EXPANSION GAMMA(X**2)=1+A*(X**2) IS LISTED BELOW.

LINEAR COEFFICIENT OF π^0 ELECTROMAGNETIC FORM FACTOR

```
A           (-0.15)   (0.10)          KOBRAK    61 HBC      NO RAD. CORR.
A     3071  (-0.24)   (0.16)          SAMIOS    61 HBC      NO RAD. CORR.
A     2200  (+0.01)   (0.11)          DEVONS    69 OSPK     NO RAD. CORR.
A   F 30K    +0.10     0.03           FISCHER1  78 SPEC     RAD. CORR.
A   T                                 TUPPER    83 THEO     FISCHER1 78 DATA
A   F  ERROR STATISTICAL ONLY.  RESULT WITHOUT RAD. CORR.=+0.05+-0.03.
A   T  TUPPER 83 IS THEORETICAL ANALYSIS OF FISCHER1 78 INCLUDING TWO-
A   T  PHOTON EXCHANGE. THEIR ESTIMATE OF THE IMPACT OF THESE CORRECTIONS
A   T  IS THAT THE MODIFIED NUMBER WULD BE 0.12+0.05-0.04.
```

REFERENCES FOR π^0

```
PANOFSKY 51 PR    81  565       W K H PANOFSKY,R L AAMODT,J HADLEY     (LRL)
CHINOWSK 54 PR    93  586       W CHINOWSKY,J STEINBERGER         (COLUMBIA)
CASSELS  59 PPSL 74    92       CASSELS,JONES,MURPHY,O.NEILL     (LIVERPOOL)
HADDOCK  59 PRL    3  478       HADDOCK,ABASHIAN,CROWE,CZIRR           (LRL)
HILLMAN  59 NC    14  887       HILLMAN,MIDDELKOOP,YAMAGATA,ZAVATTINI(CERN)

BUDAGOV  60 JETP 11  755        BUDAGOV,VIKTOR,DZHELEPOV,ERMOLOV +    (JINR)
JOSEPH   60 NC 16 997           D W JOSEPH                             (EFI)
SAMIOS   60 NC 18 154           N P SAMIOS                        (COLUMBIA)
GLASSER  61 PR   123 1014       R G GLASSER,N SEEMAN,B STILLER         (NRL)
KOBRAK   61 NC 20 1115          H.KOBRAK                               (EFI)
SAMIOS   61 PR   121  275       N P SAMIOS                    (COLUMBIA+BNL)
SAMIOS   62 PR 126 1844         SAMIOS,PLANO,PRODELL +        (COLUMBIA+BNL)
TIETGE   62 PR   127 1324       J TIETGE,W PUESCHEL       (MAX PLANCK INST)

CZIRR    63 PR   130  341       JOHN B CZIRR                           (LRL)
KOLLER   63 NC    27 1405       E L KOLLER,S TAYLOR,T HUETTER     (STEVENS)
    ALSO 66 STAMER
PETRUKHI 63 SIENA CONF 208      V I PETRUKHIN,YU D PROKOSHKIN         (JINR)
VON DARD 63 PL     4   51       VON DARDEL,DEKKERS,MERMOD,VAN PUTTEN+(CERN)

SHWE     64 PR   136B 1839      H SHWE,F M SMITH,W H BARKAS            (LRL)
BELLETTI 65 NC 40 A 1139        BELLETTINI,BEMPORAD,BRACCINI+(PISA+FIRENZE)
DUCLOS   65 PL 19 253           DUCLOS,FREYTAG,HEINTZE +  (CERN+HEIDELBERG)
EVANS    65 PR 139 B 982        D A EVANS                           (OXFORD)
KUTIN    65 JETP LETT 2 243     KUTIN,PETRUKHIN,PROKOSHKIN            (JINR)

STAMER   66 PR 151  1108        STAMER,TAYLOR,KOLLER,HUETTER+     (STEVENS)
VASILEVS 66 PL  23  281         VASILEVSKY,VISHNYAKOV,DUNAITSEV +   (DUBNA)
DEVONS   69 PR 184 1356         +NEMENTHY,NISSIM-SABAT,DI CAPUA+(COLU+ROMA)
BELLETTI 70 NC 66A 243          BELLETTINI,BEMPORAD,LUBELSMEY+  (PISA+BONN)
KRYSHKIN 70 JETP 30 1037        +STERLIGOV,USOV       (TOMSK POLYTECH.INST.)

ABRAMS   73 PL 45B 66           +CARROLL,KYCIA,LI,MICHAEL,MOCKETT +    (BNL)
MIYAZAKI 73 PR D8 2051          T.MIYAZAKI,E.TAKASUGI                 (TOKY)
BROWMAN  74 PRL 33 1400         +DEWIRE,GITTELMAN,HANSON+        (CORN+BING)
DAVIES   74 NC 24A 324          +GUY,ZIA                    (BIRM+RHEL+SHMP)

SCHACHER 77 LNC 20 177          +CZAPEK,HAHN,MARTI                    (BERN)
AUERBAC1 78 PRL 41 275          AUERBACH,HIGHLAND,JOHNSON,  +    (TEMP+LASL)
AUERBAC2 78 PL 78B 353          AUERBACH,HIGHLAND,JOHNSON,  +    (TEMP+LASL)
FISCHER1 78 PL 73B 359          +EXTERMANN,GUISAN,MERMOD,+       (GEVA+SACL)
FISCHER2 78 PL 73B 364          +EXTERMANN,GUISAN,MERMOD,MOREL+  (GEVA+SACL)

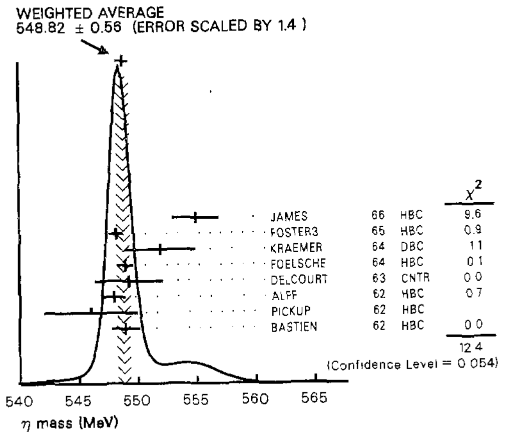
AUERBACH 80 PL 90B 317          +HAIK,HIGHLAND,MCFARLANE,MACEK+  (TEMP+LASL)
HIGHLAND 80 PRL 44 628          +AUERBACH,HAIK,MCFARLANE,MACEK+  (TEMP+LASL)
HERCZEG  81 PL 100B 347         P. HERCZEG, C. M. HOFFMAN             (LANL)
SCHARDT  81 PR D23 639          +FRANK,HOFFMANN,MISCHKE,MOIR +   (ARZS+LANL)
BRYMAN   82 PR D26 2538         D. BRYMAN                             (TRIU)
MISCHKE  82 PRL 48 1153         +FRANK,HOFFMAN,MOIR,SARRACINO +  (LANL+ARZS)
FRANK    83 PR D28 423          +HOFFMAN,MISCHKE,MOIR+           (LANL+ARZS)
TUPPER   83 PR D28 2905         +GROSE,SAMUEL                         (OKSU)
HERCZEG  84 PR D29 1954         +HOFFMAN                              (LANL)
ATHERTON 85 PL 158B 81          +BOVET,COET,+       (CERN+ISU+LUND+LPTP+EFI)
```

η

$I^G(J^{PC}) = 0^+(0^{-+})$

η MASS (MeV)

```
M      53  549.0      1.2              BASTIEN   62 HBC
M      35  546.0      4.0              PICKUP    62 HBC
M      91  548.0      1.0              ALFF      62 HBC
M          549.3      2.9              DELCOURT  63 CNTR
M     148  549.0      0.7              FOELSCHE  64 HBC
M     325  552.0      3.0              KRAEMER   64 DBC
M          548.2      0.65             FOSTER3   65 HBC
M     250  555.0      2.0              JAMES     66 HBC
M          . . . . . . . . . .
M   AVG    548.82     0.56    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
                      (SEE IDEOGRAM BELOW)
```



η WIDTH

```
WM     ETA WIDTH DETERMINED FROM MASS SPECTRUM (UNITS MEV)
WM      91  (10.0)  OR LESS            ALFF      62 HBC
WM     148  (10.0)  OR LESS            FOELSCHE  64 HBC
WM      31  (12.0)  OR LESS            JAMES     66 HBC
WM           (4.0)  OR LESS            BALTAY    66 DBC
WM           (0.9)  OR LESS  CL=.95    JONES     66 CNTR

W      ETA WIDTH DETERMINED FROM DECAY RATE (UNITS KEV)
W       THIS IS THE PARTIAL DECAY RATE (W1) FOR THE MODE (ETA INTO 2GAMMA)
W       DIVIDED BY THE FITTED BRANCHING FRACTION (P1) FOR THAT MODE.
W            . . . . . . . . . .
W   FIT        1.05      0.15   FROM FIT
```

η PARTIAL DECAY MODES

		DECAY MASSES
P1	$\eta \rightarrow 2\gamma$	0+ 0
P2	$\eta \rightarrow 3\pi^0$	135+ 135+ 135
P3	$\eta \rightarrow \pi^+\pi^-\pi^0$	140+ 140+ 135
P4	$\eta \rightarrow \pi^+\pi^-\gamma$	140+ 140+ 0
P5	$\eta \rightarrow e^+e^-\pi^0$	135+.511+.511
P6	$\eta \rightarrow e^+e^-\pi^+\pi^-$	140+ 140+.511+.511
P7	$\eta \rightarrow \pi^0 2\gamma$	135+ 0+ 0
P8	$\eta \rightarrow e^+e^-\gamma$	.511+.511+ 0
P10	$\eta \rightarrow \pi^+\pi^-\pi^0\gamma$	140+ 140+ 135+ 0
P11	$\eta \rightarrow \pi^+\pi^- 2\gamma$	140+ 140+ 0+ 0
P12	$\eta \rightarrow \mu^+\mu^-$	106+ 106
P13	$\eta \rightarrow \mu^+\mu^-\gamma$	106+ 106+ 0
P14	$\eta \rightarrow \mu^+\mu^-\pi^0$	106+ 106+ 135
P15	$\eta \rightarrow \pi^+\pi^-$	140+ 140
P16	$\eta \rightarrow e^+e^-$	.511+.511
P17	$\eta \rightarrow \mu^+\mu^-\pi^0\gamma$	106+ 106+ 135+ 0
P18	$\eta \rightarrow 3\gamma$	0+ 0+ 0

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1      P 2      P 3      P 4      P 7      P 8
P 1   .3894+-.0040
P 2   .458    .3190+-.0035
P 3  -.856   -.809    .2368+-.0053
P 4  -.745   -.704    .798    .0491+-.0013
P 7   .026    .021   -.045   -.040    .00078+-.00012
P 8  -.110   -.105   -.055   -.054   -.006    .0050+-.0012
```

FITTED PARTIAL DECAY MODE RATES

The matrix below is the branching fraction matrix above, transformed into rate space; i.e., $G_i \equiv \Gamma_i = \Gamma_{total}P_i$, in appropriate units. In analogy to the matrix above, the diagonal elements are $G_i \pm \delta G_i$, where $\delta G_i = \sqrt{\langle \delta G_i \delta G_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta G_i \delta G_j \rangle / (\delta G_i \cdot \delta G_j)$. Note that, because of the error in Γ_{total}, the errors and correlations here are not directly derivable from those above.

```
        G 1      G 2      G 3      G 4      G 7      G 8
G 1   .4082+-.0595
G 2   .996    .3344+-.0489
G 3   .978    .978    .2482+-.0369
G 4   .974    .974    .998    .0515+-.0077
G 7   .682    .682    .672    .669    .00081+-.00017
G 8   .525    .525    .521    .518    .361    .0052+-.0014
```

NOTE ON THE η WIDTH TO TWO PHOTONS

(by S. Cooper, SLAC)

Measurements of $\Gamma(\eta \rightarrow \gamma\gamma)$ via Primakoff effect and via two-photon production disagree, as shown in the table below. The discrepancy is not yet understood.

$\Gamma(\eta \rightarrow \gamma\gamma)$ (keV)	Technique	Reference
(1.00 ± 0.22)*	Primakoff	BEMPORAD 67
0.324 ± 0.046	Primakoff	BROWMAN 74
0.56 ± 0.16	two-photon	WEINSTEIN 83 (Crystal Ball-SPEAR)
0.53 ± 0.04 ± 0.04	two-photon	BARTEL 85 (JADE)
0.64 ± 0.14 ± 0.13	two-photon	TPC/Two Gamma[1]
0.58 ± 0.02 ± 0.06 (preliminary)	two-photon	Crystal Ball-DORIS[2]

0.56 ± 0.04	two-photon	average

*corrected for $B(\eta \rightarrow \gamma\gamma) = 0.38 \pm 0.01$

The Primakoff effect is production of η's in the Coulomb field of a nucleus. Background comes from η's produced in its hadronic field. They are separated by fitting the η angular distribution, which is calculated to be different for the two effects. The systematic error of this calculation may have been underestimated. BROWMAN 74 has better angular resolution, higher statistics, and a larger range of beam energies than BEMPORAD 67. Both the Primakoff and two-photon techniques can be "calibrated" at the π^0. BROWMAN 74's measurement $\Gamma(\pi^0 \rightarrow \gamma\gamma) = 8.0 \pm 0.4$[3] agrees with $7.3 \pm 0.2 \pm 0.1$ from the very accurate π^0 lifetime measurement of Atherton et al.[4]

The two-photon calculation to get $\Gamma(\eta \rightarrow \gamma\gamma)$ from the observed rate of $e^+e^- \rightarrow e^+e^-\eta$ is pure QED and noncontroversial. These experiments are in good agreement with each other. A preliminary two-photon measurement $\Gamma(\pi^0 \rightarrow \gamma\gamma) = 7.9 \pm 1.4 \pm 1.6$[2] agrees with Atherton et al., but the error is large.

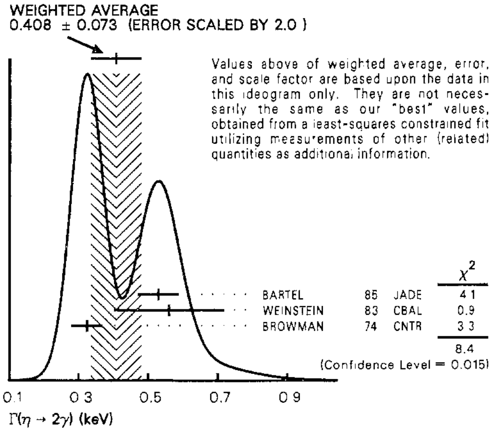
References

1. H. Aihara et al. (TPC/Two Gamma), UCLA-85-013 (1985).
2. K. Wacker (Crystal Ball), presented to *International Europhysics Conference on High Energy Physics* (Bari, Italy, 1985).
3. A. Browman et al., Phys. Rev. Lett. **33**, 1400 (1974).
4. H.W. Atherton et al., Phys. Lett. **158B**, 81 (1985).

η DECAY RATES

$\eta \rightarrow 2\gamma$ **(keV)** (G1)

```
W1  B      (1.00)   (0.22)        BEMPORAD  67 CNTR    PRIMAKOFF EFFECT
W1          0.324    0.046        BROWMAN   74 CNTR    PRIMAKOFF EFFECT
W1     56   0.56     0.16         WEINSTEIN 83 CBAL    E+E- -> E+E- ETA
W1   J      0.53     0.06         BARTEL    85 JADE E+ E- --> E+ E- ETA
W1  B   BEMPORAD 67 GIVES W1=1.21+-.26 KEV ASSUMING THAT W1/TOTAL=0.314.
W1  B   BEMPORAD PRIVATE COMMUNICATION GIVES MORE GENERAL RESULT AS
W1  B   W1*W1/TOTAL=.380+-.083.  WE EVALUATE THIS USING W1/TOTAL=.38+-.01.
W1  B   NOT INCLUDED IN AVERAGE BECAUSE THE UNCERTIANTY RESULTING FROM THE
W1  B   SEPARATION OF THE COULOMB AND NUCLEAR AMPLITUDES HAS APPARENTLY
W1  B   BEEN UNDERESTIMATED.
W1   J  STAT ERROR (0.04) AND SYST ERROR (0.04) ADDED IN QUADRATURE.
W1         . . . . . . . . . . .
W1  AVG     0.408    0.073   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.0)
W1  FIT     0.408    0.059  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.7)
                     (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

η BRANCHING RATIOS

$\eta \rightarrow (2\gamma + 3\pi^0 + \pi^0 2\gamma)/(\pi^+\pi^-\pi^0 + \pi^+\pi^-\gamma + e^+e^-\gamma)$

```
R1                                                   (P1+P2+P7)/(P3+P4+P8)
R1  N   10   (2.5)    (1.0)          PICKUP    62 HBC
R1  N   53   (3.20)   (1.26)         BASTIEN   62 HBC
R1  N  280   (4.5)    (1.0)          JAMES     66 HBC
R1  N   THESE EXPERIMENTS HAVE NOT BEEN USED IN COMPUTING THE AVERAGES
R1  N   AS THEY WERE UNABLE TO SEPARATE CLEARLY PARTIAL MODES (3) AND (4)
R1  N   FROM EACH OTHER.  THE REPORTED VALUES THUS PROBABLY CONTAIN
R1  N   SOME (UNKNOWN) FRACTION OF MODE (4).
R1           2.64     0.23           BALTAY2   67 DBC
R1         . . . . . . . . . . .
R1  FIT      2.438    0.076  FROM FIT
```

Stable Particle Full Listings

$\eta \to 2\gamma/(\pi^+\pi^-\pi^0 + \pi^+\pi^-\gamma + e^+e^-\gamma)$

```
R2                                                   (P1)/(P3+P4+P8)
R2             0.99     0.48           CRAWFORD  63 HBC
R2         75  1.51     0.93           KENDALL   74 OSPK
R2           . . . . . . . . . . .
R2  AVG        1.10     0.43    AVERAGE
R2  FIT        1.339    0.042  FROM FIT
```

$\eta \to (\pi^0 2\gamma)/(2\gamma + 3\pi^0 + \pi^0 2\gamma)$ (P7)/(P1+P2+P7)

```
R3      OTHER RESULTS ARE IN SECTION R22.
R3            (0.04) OR LESS  CL=.90   ABROSIMOV 80 HLBC
R3             0.0010   0.0002         ALDE      84 CNTR
R3           . . . . . . . . . . .
R3  FIT       0.00109  0.00017 FROM FIT
```

$\eta \to (\pi^+\pi^-\gamma)/(\pi^+\pi^-\pi^0)$ (P4)/(P3)

```
R4             0.14     0.08           FOELSCHE  64 HBC
R4         24 (0.73)   (0.25)          PAULI     64 DBC
R4             0.30     0.06           CRAWFORD  66 HBC
R4             0.10     0.10           KRAEMER   64 DBC
R4             0.196    0.041          FOSTER3   65 HBC
R4             0.25     0.035          LITCHFIEL 67 DBC
R4             0.28     0.04           BALTAY2   67 DBC
R4       7250  0.201    0.006          GORMLEY   70 ASPK
R4        18K  0.209    0.004          THALER    73 ASPK
R4           . . . . . . . . . . .
R4  AVG        0.2074   0.0037  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
R4  FIT        0.2074   0.0033 FROM FIT
```

$\eta \to 3\pi^0/2\gamma$ (P2)/(P1)

```
R6            (0.90) OR MORE           CHRETIEN  62 PBC
R6            (1.25)   (0.39)          BACCI     63 CNTR INVERSE BR REPORTED
R6             0.88     0.16           BALTAY1   67 DBC
R6             1.1      0.2            CENCE     67 OSPK
R6             0.91     0.14           COX       70 HBC
R6             0.75     0.09           DEVONS    70 OSPK
R6           . . . . . . . . . . .
R6  AVG        0.842    0.065   AVERAGE
R6  FIT        0.8193   0.0090 FROM FIT
```

$\eta \to 2\gamma/(\pi^+\pi^-\pi^0)$ (P1)/(P3)

```
R7             1.61     0.39           FOSTER1   65 HBC
R7        401  1.72     0.25           BAGLIN    69 HLBC
R7           . . . . . . . . . . .
R7  AVG        1.69     0.21    AVERAGE
R7  FIT        1.644    0.052  FROM FIT
```

$\eta \to (2\gamma + 3\pi^0 + \pi^0 2\gamma)/(\pi^+\pi^-\pi^0)$ (P1+P2+P7)/(P3)

```
R8         50  3.6      0.8            KRAEMER   64 DBC
R8             3.8      1.1            PAULI     64 DBC
R8             2.89     0.56           ALFF-STEI 66 HBC
R8        244  3.6      0.6            FLATTE2   67 HBC
R8         29  3.4      1.1            AGUILAR-B 72 HBC
R8 B       70  2.83     0.80           BLOODWORT 72 HBC
R8         74  2.54     1.89           KENDALL   74 OSPK
R8 B    ERROR INCREASED FROM PUBLISHED VALUE 0.5 BY BLOODWORTH, PRIV. COMM.
R8           . . . . . . . . . . .
R8  AVG        3.26     0.30    AVERAGE
R8  FIT        2.995    0.094  FROM FIT
```

$\eta \to (e^+e^-\pi^0)/(\pi^+\pi^-\pi^0)$ (units 10^{-4}) (P5)/(P3)

```
R9      SINGLE PHOTON PROCESS FORBIDDEN BY C-PARITY
R9           (110.)    OR LESS         PRICE     65 HBC
R9          0 (77.)    OR LESS         FOSTER2   65 HBC
R9            (42.)    OR LESS  CL=.90 BAGLIN1   67 HLBC
R9          0 (16.)    OR LESS  CL=.90 BILLING   67 HLBC
R9              1.9    OR LESS  CL=.90 JANE1     75 OSPK
```

$\eta \to (e^+e^-\pi^+\pi^-)/\text{total}$ (units 10^{-2}) (P6)

```
R10           (0.7)    OR LESS         RITTENBER 65 HBC
```

$\eta \to (e^+e^-\pi^+\pi^-)/(\pi^+\pi^-\gamma)$ (P6)/(P4)

```
R11         1  0.026    0.026          GROSSMAN  66 HBC
```

$\eta \to 2\gamma/(2\gamma + 3\pi^0 + \pi^0 2\gamma)$ (P1)/(P1+P2+P7)

```
R12           (0.416)  (0.044)         DIGIUGNO  66 CNTR    ERROR DOUBLED
R12           (0.44)   (0.07)          GRUNHAUS  66 OSPK
R12           (0.579)  (0.052)         FELDMAN   67 OSPK
R12 T         (0.39)   (0.06)          JONES     66 CNTR
R12 T   THIS RESULT FROM COMBINING CROSS SECTIONS FROM TWO DIFFERENT EXPTS.
R12            0.59     0.033          BUNIATOV  67 OSPK
R12            0.535    0.018          BUTTRAM   70 OSPK
R12           (0.57)   (0.09)          STRUGALSK 71 HLBC
R12       113  0.60     0.14           KENDALL   74 OSPK
R12        88  0.52     0.09           ABROSIMOV 80 HLBC
R12            0.549    0.004          ALDE      84 CNTR
R12          . . . . . . . . . . .
R12 AVG        0.5489   0.0039  AVERAGE
R12 FIT        0.5491   0.0027 FROM FIT
```

$\eta \to 3\pi^0/(2\gamma + 3\pi^0 + \pi^0 2\gamma)$ (P2)/(P1+P2+P7)

```
R13           (0.209)  (0.054)         DIGIUGNO  66 CNTR    ERROR DOUBLED
R13           (0.29)   (0.10)          GRUNHAUS  66 OSPK
R13           (0.177)  (0.035)         FELDMAN   67 OSPK
R13           (0.41)   (0.033)         BUNIATOV  67 OSPK NOT INDEP. OF R12
R13            0.439    0.024          BUTTRAM   70 OSPK
R13           (0.32)   (0.09)          STRUGALSK 71 HLBC
R13        75  0.44     0.08           ABROSIMOV 80 HLBC
R13            0.450    0.004          ALDE      84 CNTR
R13          . . . . . . . . . . .
R13 AVG        0.4497   0.0039  AVERAGE
R13 FIT        0.4498   0.0027 FROM FIT
```

$\eta \to (e^+e^-\pi^0)/\text{total}$ (units 10^{-2}) (P5)

```
R15     SINGLE PHOTON PROCESS FORBIDDEN BY C-PARITY
R15           (0.7)  OR LESS           RITTENBER 65 HBC
R15           (0.084)OR LESS  CL=.90   BAZIN     68 DBC
R15         0 (0.016)OR LESS  CL=.90   MARTYNOV  76 HLBC
```

$\eta \to (\pi^+\pi^-\pi^0\gamma)/(\pi^+\pi^-\pi^0)$ (units 10^{-2}) (P10)/(P3)

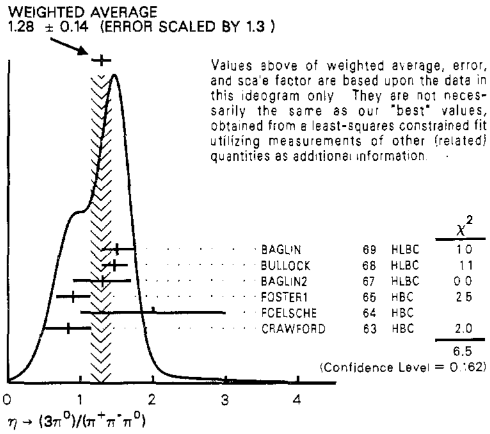
```
R17           (7.0)  OR LESS           FLATTE    67 HBC
R17           (0.9)  OR LESS           PRICE     67 HBC
R17           (1.6)  OR LESS  CL=.95   BALTAY2   67 DBC
R17           (1.7)  OR LESS  CL=.90   ARNOLD    68 HLBC
R17         0  0.24  OR LESS  CL=.90   THALER    73 ASPK
```

$\eta \to (\pi^+\pi^- 2\gamma)/(\pi^+\pi^-\pi^0)$ (P11)/(P3)

```
R18            0.009 OR LESS           PRICE     67 HBC
R18           (0.016)OR LESS  CL=.95   BALTAY2   67 DBC
```

$\eta \to 3\pi^0/(\pi^+\pi^-\pi^0)$ (P2)/(P3)

```
R19            0.83     0.32           CRAWFORD  63 HBC
R19            2.0      1.0            FOELSCHE  64 HBC
R19            0.90     0.24           FOSTER1   65 HBC
R19            1.3      0.4            BAGLIN2   67 HLBC
R19            1.47     0.20     0.17  BULLOCK   68 HLBC
R19       199  1.50     0.15     0.29  BAGLIN    69 HLBC
R19          . . . . . . . . . . .
R19 AVG        1.28     0.14    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
R19 FIT        1.347    0.043  FROM FIT
                        (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$\eta \to (2\gamma + 3\pi^0 + \pi^0 2\gamma)/\text{total}$ (P1+P2+P7)

```
R21            0.79     0.08           BUNIATOV  67 OSPK
R21       16K  0.705    0.008          BASILE    71 CNTR MM SPECTROMETER
R21          . . . . . . . . . . .
R21 AVG        0.7058   0.0080  AVERAGE
R21 FIT        0.7091   0.0064 FROM FIT
```

$\eta \to (\pi^0 2\gamma)/\text{total}$ (P7)

```
R22         0  (0.003)OR LESS  CL=.90  DAVYDOV   81 CNTR PI- P-->ETA N
R22        70 0.00095  0.00023         BINON     82 CNTR PI- P-->ETA N
R22          . . . . . . . . . . .
R22 FIT       0.00078  0.00012 FROM FIT
```

$\eta \to \mu^+\mu^-/\text{total}$ (units 10^{-5}) (P12)

```
R23         0  (2.)    OR LESS  CL=.95 WEHMANN   68 OSPK
R23        27   0.65     0.21          DZHELYA2  80 SPEC PI- P-->ETA N
```

$\eta \to \mu^+\mu^-\pi^0/\text{total}$ (units 10^{-4}) (P14)

```
R24     SINGLE PHOTON PROCESS FORBIDDEN BY C-PARITY
R24            (5.)    OR LESS         WEHMANN   68 OSPK
R24             0.05   OR LESS  CL=.90 DZHELYADI 81 SPEC PI- P-->ETA N
```

$\eta \to \mu^+\mu^-/2\gamma$ (units 10^{-5}) (P12)/(P1)

```
R25            (5.9)    (2.2)          HYAMS     69 OSPK
```

$\eta \to (\pi^+\pi^-)/\text{total}$ (units 10^{-2}) (P15)

```
R27     VIOLATES P AND CP INVARIANCE
R27         0   0.15   OR LESS         THALER    73 ASPK CON. LEV. NOT GIVEN
```

$\eta \to (e^+e^-\gamma)/(\pi^+\pi^-\pi^0)$ (units 10^{-2}) (P8)/(P3)

```
R28  J     80   2.1      0.5           JANE2     75 OSPK
R28  J  VALUE CHANGED BY ERRATUM.
R28          . . . . . . . . . . .
R28 FIT         2.10     0.50   FROM FIT
```

$\eta \to (e^+e^-)/\text{total}$ (units 10^{-4}) (P16)

```
R29  D          3.     OR LESS  CL=.90 DAVIES    74 RVUE
R29  D  DAVIES 74 EXTRACTS THIS INFORMATION FROM ESTEN 67.
```

$\eta \to (\mu^+\mu^-\gamma)/\text{total}$ (units 10^{-4}) (P13)

```
R30       100  (1.5)    (0.75)         BUSHNIN   78 SPEC REPL.BY DZHELYA1 80
R30       600   3.1      0.4           DZHELYA1  80 SPEC PI- P-->ETA N
```

$\eta \to (\mu^+\mu^-\pi^0\gamma)/\text{total}$ (units 10^{-6}) (P17)

```
R31             3.     OR LESS  CL=.90 DZHELYADI 81 SPEC PI- P-->ETA N
```

$\eta \to (3\gamma)/(2\gamma + 3\pi^0 + \pi^0 2\gamma)$ (P18)/(P1+P2+P7)

```
R33     FORBIDDEN BY C INVARIANCE.
R33             7.E-4 OR LESS  CL=.95  ALDE      84 CNTR
```

NOTE ON η DECAY PARAMETERS

C violation in η decays

As a test of possible C violation in electromagnetic interactions, a number of experiments have looked for possible charge asymmetries in the decays $\eta \rightarrow \pi^+\pi^-\pi^0$ and $\eta \rightarrow \pi^+\pi^-\gamma$. We list the following parameters:

(a) The left-right asymmetry

$$A = (N^+ - N^-)/(N^+ + N^-) ,$$

where $N^\pm$ means the number of events with the $\pi^\pm$ energy greater than the $\pi^\mp$ energy in the η rest frame.

(b) The sextant asymmetry

$$A_s = \frac{N_1 + N_3 + N_5 - N_2 - N_4 - N_6}{N_1 + N_2 + N_3 + N_4 + N_5 + N_6}$$

for the decay $\eta \rightarrow \pi^+\pi^-\pi^0$. The numbers refer to sextants of the Dalitz plot (see, for example, Layter et al.[1]). A_s is sensitive to an $I = 0$ C-violating asymmetry.

(c) The quadrant asymmetry A_q, defined in a similar way as A_s, but with each sector of the Dalitz plot now containing $\pi/2$ rather than $\pi/3$ radians. A_q is sensitive to an $I = 2$ C-violating final state.

(d) The D-wave contribution to the C-violating amplitude in the decay $\eta \rightarrow \pi^+\pi^-\gamma$. The upper limit for this contribution is measured by the parameter β, defined by

$$dN/d\,|\cos\theta| \propto \sin^2\theta(1 + \beta\cos^2\theta) ,$$

where θ is the angle between the π^+ and the γ in the dipion center of mass. A term proportional to $\cos^2\theta$ could also be due to P- and F-wave interference.

We list A for the decay modes $\eta \rightarrow \pi^+\pi^-\pi^0$ and $\eta \rightarrow \pi^+\pi^-\gamma$, A_s and A_q for the decay $\eta \rightarrow \pi^+\pi^-\pi^0$, and β for the decay $\eta \rightarrow \pi^+\pi^-\gamma$ in the Full Listings below.

Dalitz plot for $\eta \rightarrow \pi^+\pi^-\pi^0$

The Dalitz plot for the decay $\eta \rightarrow \pi^+\pi^-\pi^0$ may be fit by the distribution

$$|M(x,y)|^2 \propto 1 + ay + by^2 + cx + dx^2 + exy .$$

Here,

$$x = \sqrt{3}(T_+ - T_-)/Q, \quad y = (3T_0/Q) - 1 ,$$

T_+, T_-, and T_0 are the kinetic energies of the π^+, π^-, and π^0 in the η rest system, and $Q = m_\eta - m_{\pi^+} - m_{\pi^-} - m_{\pi^0}$. The coefficient of the term linear in x is sensitive to C-violation due to an $I = 0$ or $I = 2$ final state. We list papers presenting determinations of the parameters a, b, c, and d in the section DP below. However, we do not tabulate values of these parameters because the assumptions made by different authors are not compatible and do not allow comparison of the numerical values.

Dalitz plot for $\eta \rightarrow \pi^0\pi^0\pi^0$

The Dalitz plot for the decay $\eta \rightarrow \pi^0\pi^0\pi^0$ may be fit to the expression

$$|M|^2 \propto 1 + 2\alpha z ,$$

where

$$z = \frac{2}{3}\sum_{i=1}^{3} [3(m_\eta - 3m_\pi)^{-1}(E_i - \tfrac{1}{3}m_\eta)]^2 = \rho^2/\rho^2_{\text{max}} .$$

Here E_i is the energy of the i^{th} pion in the η rest frame, and ρ is the distance to the center of the Dalitz plot. We list the parameter α in section A0 below.

Reference

1. J.G. Layter et al., Phys. Rev. Lett. **29**, 316 (1972).

η C−NONCONSERVING DECAY PARAMETERS

$\pi^+\pi^-\pi^0$ LEFT−RIGHT ASYMMETRY PARAMETER (units 10^{-2})

```
A1     1351    7.2       2.8                  BALTAY    66 DBC
A1     1300    5.8       3.4                  CLPWY     66 HBC
A1    10665   (0.3)     (1.0)                 CNOPS     66 OSPK REPL BY MULLER 69
A1      705   -6.1       4.0                  LARRIBE   66 HBC
A1   G36800   (1.5)     (0.5)                 GORMLEY3  68 ASPK
A1    10709    0.3       1.1                  MULLER    69 OSPK
A1     1138   -1.4       3.                   CARPENTR  70 HBC
A1      349    3.2       5.4                  DANBURG   70 DBC
A1     220K   -0.05      0.22                 LAYTER    72 ASPK
A1     165K    0.28      0.26                 JANE1     74 OSPK
A1   G   GORMLEY3 68 ASYMMETRY PROBABLY DUE TO UNMEASURED (E X B) SPK. CH.
A1   G   EFFECTS.  NEW EXPTS. WITH (E X B) CONTROLS DONT OBSERVE ASYMMETRY.
A1           . . . . . . . . . . .
A1   AVG        0.12      0.17    AVERAGE
```

$\pi^+\pi^-\gamma$ LEFT−RIGHT ASYMMETRY PARAMETER (units 10^{-2})

```
A2       33   -2.       17.                   CRAWFORD  66 HBC
A2            -4.        8.                   LITCHFIEL 67 DBC
A2 N   1620    1.5       2.5                  MULLER    69 OSPK
A2     7257    1.22      1.56                 GORMLEY   70 ASPK
A2      36K    0.5       0.6                  THALER    72 ASPK
A2      35K    1.2       0.6                  JANE2     74 OSPK
A2 N  MULLER 69 IS SENSITIVE ONLY TO UPPER .4 OF GAMMA-RAY SPECTRUM.
A2           . . . . . . . . . . .
A2   AVG        0.88      0.40    AVERAGE
```

$\pi^+\pi^-\pi^0$ SEXTANT ASYMMETRY PARAMETER (units 10^{-2})

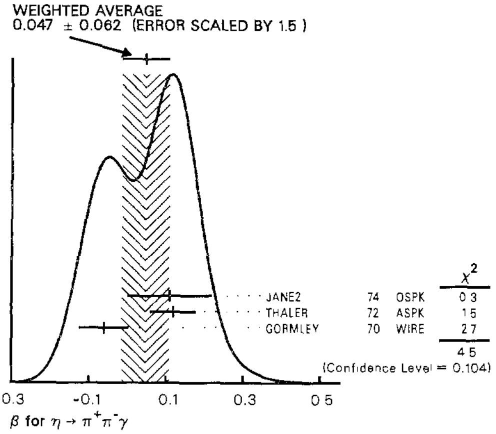
```
AS     1300    6.8       3.3                  CLPWY     66 HBC
AS      705   -2.4       4.0                  LARRIBE   66 HBC
AS      37K    0.5       0.5                  GORMLEY3  68 WIRE
AS     220K    0.10      0.22                 LAYTER    72 ASPK
AS     165K    0.20      0.25                 JANE1     74 OSPK
AS           . . . . . . . . . . .
AS   AVG        0.19      0.16    AVERAGE
```

$\pi^+\pi^-\pi^0$ QUADRANT ASYMMETRY PARAMETER (units 10^{-2})

```
AQ     220K   -0.07      0.22                 LAYTER    72 ASPK
AQ     165K   -0.30      0.25                 JANE1     74 OSPK
AQ           . . . . . . . . . . .
AQ   AVG       -0.17      0.17    AVERAGE
```

β FOR $\eta \rightarrow \pi^+\pi^-\gamma$. SENSITIVE TO *D*-wave CONTRIBUTION.

```
BET    DN/DCOS THETA = SIN**2 THETA * (1 + BETA * COS**2 THETA)
BET   7250   -0.060     0.065                 GORMLEY   70 WIRE
BET  L        0.12      0.06                  THALER    72 ASPK
BET    35K    0.11      0.11                  JANE2     74 OSPK
BET  L  AUTHORS DONT BELIEVE THIS TO INDICATE D-WAVE BECAUSE DEPENDENCE OF
BET  L  BETA ON GAMMA ENERGY INCONSISTENT WITH THEOR. PREDICTION.
BET  L  COS**2 DEPENDENCE MAY ALSO COME FROM P AND F-WAVE INTERFERENCE.
BET          . . . . . . . . . . .
BET AVG       0.047     0.062    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
                                 (SEE IDEOGRAM BELOW)
```



ENERGY DEPENDENCE OF η DALITZ PLOT

SEE NOTE ON η DECAY PARAMETERS ABOVE.

```
DP        THE FOLLOWING EXPTS FIT TO ONE OR MORE OF THE COEFFICIENTS
DP        A,B,C,D, OR E FOR ETA INTO PI+ PI- PI0
DP        MATRIX ELEMENT**2=1 + A*Y + B*(Y**2) + C*X + D*(X**2) + E*X*Y
DP      1300 SEE NOTE ABOVE                CLPWY      66 HBC
DP       705 SEE NOTE ABOVE                LARRIBE    66 HBC
DP      7170 SEE NOTE ABOVE                CNOPS      68 OSPK
DP       37K SEE NOTE ABOVE                GORMLEY3   68 WIRE
DP       526 SEE NOTE ABOVE                BAGLIN     69 HLBC
DP      1138 SEE NOTE ABOVE                CARPENTR   70 HBC
DP       349 SEE NOTE ABOVE                DANBURG    70 DBC
DP      7250 SEE NOTE ABOVE                GORMLEY    70 WIRE
DP      220K SEE NOTE ABOVE                LAYTER     72 ASPK
DP       81K SEE NOTE ABOVE                LAYTER     73 ASPK
```

α PARAMETER FOR $\eta \to 3\pi^0$

```
A0        MATRIX ELEMENT **2 = 1 + 2*ALPHA*Z (SEE NOTE ABOVE)
A0       192   -0.32     0.37              BAGLIN     70 HLBC
```

REFERENCES FOR η

```
PEVSNER  61 PRL 7 421            PEVSNER,KRAEMER,NUSSBAUM,RICHARDSON + (JHU)

ALFF     62 PRL 9 322            ALFF,BERLEY,COLLEY,BRUGGER + (COLU+RUTGERS)
BASTIEN  62 PRL 8 114            BASTIEN,BERGE,DAHL,FERRO-LUZZI +      (LRL)
CHRETIEN 62 PRL  9  127          CHRETIEN+   (BRAN+BROWN+HARVARD+MIT+PADOVA)
PICKUP   62 PRL 8 329            E PICKUP,ROBINSON,SALANT          (CNRC+BNL)

BACCI    63 PRL 11 37            BACCI,PENSO,SALVINI +            (ROMA+FRAS)
CRAWFORD 63 PRL 10 546           F S CRAWFORD,LLOYD,FOWLER         (LRL+DUKE)
   ALSO  66 PRL 16 907           F S CRAWFORD,L LLOYD,E FOWLER     (LRL+DUKE)
DELCOURT 63 PL 7 215             DELCOURT,LEFRANCOIS,PEREZ Y JORBA+  (ORSAY)

FOELSCHE 64 PR 134 B 1138        H W FOELSCHE,H L KRAYBILL              (YALE)
KRAEMER  64 PR 136 B 496         KRAEMER,MADANSKY,FIELDS +   (JHU+NWES+WOOD)
PAULI    64 PL 13 351            E PAULI,A MULLER                     (SACLAY)

FOSTER1  65 PR 138 B 652         FOSTER,PETERS,MEER,LOEFFLER + (WISC+PURDUE)
FOSTER2  65 ATHENS               FOSTER,GOOD,MEER                 (WISCONSIN)
FOSTER3  65 THESIS               M.C.FOSTER                       (WISCONSIN)
PRICE    65 PRL  15  123         L.R.PRICE,F.S.CRAWFORD                  (LRL)
RITTENBE 65 PRL 15 556           RITTENBERG,KALBFLEISCH              (LRL+BNL)

ALFF-STE 66 PR 145 1072          ALFF-STEINBERGER,BERLEY+ (COLUMBIA+RUTGERS)
BALTAY   66 PRL 16 1224          +FRANZINI,KIM,KIRSCH+(COLUMBIA+STONY BROOK)
CLPWY    66 PR 149  1044         COLUMBIA,LRL,PURDUE,WISCONSIN,YALE
CNOPS    66 PL 22 546            CNOPS,FINOCCHIARS,LASSALLE,+(CERN,ETH,SACL)
CRAWFORD 66 PRL  16  333         F.S.CRAWFORD,L.R.PRICE                  (LRL)

DIGIUGNO 66 PRL 16 767           DIGIUGNO,GIORGI,SILVESTRI+ (NAPL,TRST,FRAS)
GROSSMAN 66 PR 146  993          R GROSSMAN,L PRICE,F CRAWFORD           (LRL)
GRUNHAUS 66 THESIS               J.GRUNHAUS                         (COLUMBIA)
JAMES    66 PR 142   896         F E JAMES,H L KRAYBILL             (YALE+BNL)
JONES    66 PL 23  597           JONES,BINNIE,DUANE,HORSEY,MASON,(LOIC,RHEL)
LARRIBE  66 PL 23 600            LARRIBE,LEVEQUE,MULLER,PAULI,+  (SACL+RHEL)

BAGLIN1  67 PL 24B 637           BAGLIN,BEZAGUET,DEGRANGE,+         (EPOL+UCB)
BAGLIN2  67 BAPS 12 567          BAGLIN,BEZAGUET,DEGRANGE,+         (EPOL+UCB)
BALTAY1  67 PRL 19 1495          BALTAY,FRANZINI,KIM,NEWMAN+       (COLU+BRAN)
BALTAY2  67 PRL 19 1498          BALTAY,FRANZINI,KIM,NEWMAN+       (COLU+STON)
BEMPORAD 67 PL 25B 380           BEMPORAD,BRACCINI,FOA,LUBELSMEY+(PISA,BONN)
    ALSO    PRIVATE COMMUNICATION

BILLING  67 PL 25B 435           BILLING,BULLOCK,ESTEN,GOVAN,+     (LOUC,OXF)
BOWEN    67 PL 24B 206           BOWEN,CNOPS ,FINOCCHIARO,+  (CERN+ETH+SACL)
BUNIATOV 67 PL 25B 560           BUNIATOV,ZAVATTINI,DEINET,+     (CERN+KARL)
CENCE    67 PRL 19 1393          CENCE,PETERSON,STENGER,CHIU+   (HAWAII+LRL)
ESTEN    67 PL 24B 115           +GOVAN,KNIGHT,MILLER,TOVEY+      (LOUC+OXF)

FELDMAN  67 PRL 18 868           FELDMAN,FRATI,GLEESON,HALPERN,+      (PENN)
FLATTE   67 PRL 18 976           S.M.FLATTE                            (LRL)
FLATTE2  67 PR 163 1441          S.M.FLATTE AND C.G.WOHL               (LRL)
LITCHFIE 67 PL 24B 486           LITCHFIELD,RANGAN,SEGAR,SMITH+(RHEL+SACLAY)
PRICE    67 PRL 18 1207          L.R.PRICE,F.S.CRAWFORD                (LRL)

ARNOLD   68 PL 27B 466           +PATY,BAGLIN,BINGHAM+  (STRB+MADR+EPOL+UCB)
BAZIN    68 PRL 20 895           BAZIN,GOSHAW,ZACHER,+    (PRINCETON,QUEENS)
BULLOCK  68 PL 27B 402           +ESTEN,FLEMING,GOVAN,HENDERSON,OWEN+ (LOUC)
GORMLEY3 68 PRL 21 402           GORMLEY,HYMAN,LEE,NASH,PEOPLES+  (COLU+BNL)
WEHMANN  68 PRL 20 748           WEHMANN,ENGELS,+ (HARV+CASE+SLAC+CORN+MCGI)

BAGLIN   69 PL 29B 445           BAGLIN,BEZAGUET,+       (EPOL,UCB,MADR,STRB)
    ALSO 70 NP B22 66            +BEZAGUET,DEGRANGE,MUSSET +(EPOL,MADR,STRB)
HYAMS    69 PL 29B 128           HYAMS,KOCH,POTTER,VON LINDERN,+ (CERN,MPIM)
MULLER   69 THESIS               ARMAND MULLER                          (STRB)

BAGLIN   70 NP B22 66            +BEZAGUET,DEGRANGE,MUSSET+ (EPOL+MADR+STRB)
BUTTRAM  70 PRL 25 1358          +KREISLER,MISCHKE                      (PRIN)
CARPENTR 70 PR D1 1303           CARPENTER,BINKLEY,CHAPMAN,COX,DAGAN+ (DUKE)
COX      70 PRL 24 534           COX,FORTNEY,GOLSON                     (DUKE)

DANBURG  70 PR D2 2564           +ABOLINS,DAHL,DAVIES,HOCH,KIRZ,+        (LRL)
DEVONS   70 PR D1 1936           +GRUNHAUS,KOZLOWSKI,NEMETHY +   (COLU,SYRA)
GORMLEY  70 PR D2 501            GORMLEY,HYMAN,LEE,NASH,PEOPLES+  (COLU+BNL)
    ALSO 70 NEVIS 181(THESIS) MICHAEL GORMLEY                       (COLU)

BASILE   71 NC 3A 796            +BOLLINI,DALPIAZ,FRABETTI+ (CERN,BGNA,STRB)
STRUGALS 71 NP B27 429           +CHUVILO,GEMESY,IVANOVSKAYA+           (JINR)
AGUILAR- 72 PR D6 29             AGUILAR-BENITEZ,CHUNG,EISNER,SAMIOS   (BNL)
BLOODWOR 72 NP B39 525           BLOODWORTH,JACKSON,PRENTICE,YOON  (TORONTO)
LAYTER   72 PRL 29 316           +APPEL,KOTLEWSKI,LEE,STEIN,THALER     (COLU)
THALER   72 PRL 29 313           +APPEL,KOTLEWSKI,LAYTER,LEE,STEIN     (COLU)

LAYTER   73 PR D7 2565           +APPEL,KOTLEWSKI,LEE,STEIN,THALER     (COLU)
THALER   73 PR D7 2569           +APPEL,KOTLEWSKI,LAYTER,LEE,STEIN     (COLU)
BROWMAN  74 PRL 32 1067          +DEWIRE,GITTELMAN,HANSON,LOH +  (CORN+BING)
DAVIES   74 NC 24A 324           +GUY,ZIA                     (BIRM+RHEL+SHMP)
JANE1    74 PL 48B 260           +JONES,LIPMAN,OWEN,PENNEY+ (RHEL+LOWC+SUSS)
JANE2    74 PL 48B 265           +JONES,LIPMAN,OWEN,PENNEY+ (RHEL+LOWC+SUSS)
KENDALL  74 NC 21A 387           +LANOU,MASSIMO,SHAPIRO +    (BROW+BARI+MIT)

JANE1    75 PL 59B 99            +GRANNIS,JONES,LIPMAN,OWEN +    (RHEL+LOWC)
JANE2    75 PL 59B 103           +GRANNIS,JONES,LIPMAN,OWEN +    (RHEL+LOWC)
    ALSO 78 PL 73B 503           ERRATUM, M.R.JANE, PRIVATE COMMUNICATION.
MARTYNOV 76 SJNP 23 48           +SALTYKOV,TARASOV,UZHINSKII            (JINR)
BUSHNIN  78 PL 79B 147           +DZHELYADIN,GOLOVKIN,GRITSUCK +        (SERP)
    ALSO 78 SJNP 28 775          BUSHNIN,GOLOVKIN,GRITSUK,DZHELYADIN+ (SERP)

ABROSIMO 80 SJNP 31 195          ABROSIMOV,ILINA,NISZCZ,OKHRIMENKO+    (JINR)
DZHELYA1 80 PL 94B 548           DZHELYADIN,GOLOVKIN,KACHANOV +        (SERP)
    ALSO 80 SJNP 32 516 (YF 32 998) VIKTOROV, GOLOVKIN +               (SERP)
DZHELYA2 80 PL 97B 471           DZHELYADIN,GOLOVKIN,KACHANOF +        (SERP)
    ALSO 80 SJNP 32 518 (YF 32 1002) VIKTOROV, GOLOVKIN +              (SERP)

DAVYDOV  81 LNC 32 45            +DONSKOV,INYAKIN +    (SERP+BELG+LAPP+CERN)
    ALSO 81 SJNP 33 825 (YF 33 1534) BINON,BRICMAN+ (SERP+BELG+LAPP+CERN)
DZHELYAD 81 PL 105B 239          DZHELYADIN,GOLOVKIN,KONSTANTINOV +    (SERP)
    ALSO 81 SJNP 33 822 (YF 33 1529) VIKTOROV,GOLOVKIN+                (SERP)
BINON    82 SJNP 36 391          +BRICMAN,GOUANERE+    (SERP+BELG+LAPP+CERN)
    ALSO 82 NC 71A 497           BINON,BRICMAN,DAVYDOV+(SERP+BELG+LAPP+CERN)
WEINSTEI 83 PR D28 2896          WEINSTEIN+          (HARV+CIT+PRIN+STAN+SLAC)
ALDE     84 ZPHY C25 225         ALDE+BINON+BRICMAN+DONSKOV+(ITEP+BELG+LAPP)
    ALSO 84 SJNP 40 918          ALDE+BINON+BRICMAN+        +(ITEP+BELG+LAPP)
BARTEL   85 PL 160B 421          JADE C+(DESY+HAMB+HEID+LANC+MCHS+RAL+TOKY+)

        QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA LISTINGS

BASTIEN  62 PRL 8 114            BASTIEN,BERGE,DAHL,FERRO-LUZZI,MILLER+(LRL)
CARMONY  62 PRL 8 117            D CARMONY,A ROSENFELD,VAN DE WALLE     (LRL)
ROSENFEL 62 PRL 8 293            A ROSENFELD,D CARMONY,VAN DE WALLE     (LRL)
```

STRANGE MESONS

$K^{\pm}$

$I(J^P) = \frac{1}{2}(0^-)$

$K^{\pm}$ MASS (MeV)

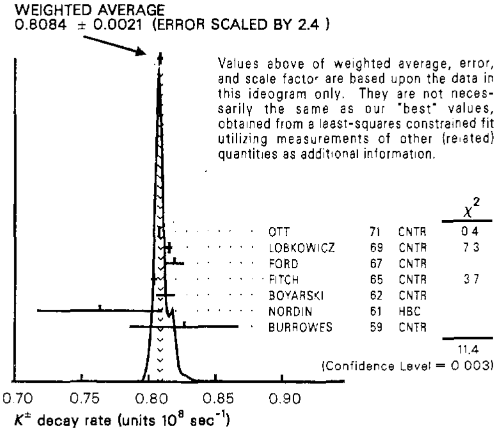
```
M              493.9       0.2                COHEN      57 RVUE +
M              493.7       0.3                BARKAS     63 EMUL  -
M              493.78      0.17               GREINER    65 EMUL +
M             (493.87)    (0.19)              KUNSELMAN  71 CNTR REPL.BY KUNSELMAN74
M              493.691     0.040              BACKENSTO  73 CNTR  - KAONIC ATOMS
M              493.662     0.19               KUNSELMAN  74 CNTR  - KAONIC ATOMS
M              493.657     0.020              CHENG      75 CNTR -  KAONIC ATOMS
M              493.670     0.029              BARKOV     79 EMUL +- E+E- --> K+ K-
M              493.640     0.054              LUM        81 CNTR -  KAONIC ATOMS
M             . . . . . . . . .
M    AVG       493.666     0.015   AVERAGE
M    FIT       493.667     0.014  FROM FIT
```

$K^+ - K^-$ MASS DIFFERENCE (MeV)

```
DM        TEST OF CPT
DM F  1.5M    -0.032     0.090            FORD       72 ASPK +-
DM F      FORD 72 USES M(PI+)-M(PI-) = +28+-70 KEV.
```

$K^{\pm}$ MEAN LIFE (units 10^{-8} sec)

```
T          K+- MEAN LIFE
T    0         (0.95)    (0.36)    (0.25) ILOFF       56 EMUL
T    0    52   (1.60)    (0.3)     (0.3)  EISENBERG   58 EMUL
T               1.21      0.06      0.06  BURROWES    59 CNTR
T    0    33   (1.38)    (0.24)    (0.24) FREDEN      60 EMUL
T    0         (1.25)    (0.22)    (0.17) BARKAS      61 EMUL
T    0    51   (1.27)    (0.36)    (0.23) BHOWMIK     61 EMUL
T        293    1.31      0.08      0.08  NORDIN      61 HBC   -
T              (1.24)    (0.07)           NORDIN      61 RVUE  -
T               1.231     0.011     0.011 BOYARSKI    62 CNTR +
T               1.2443    0.0038          FITCH       65 CNTR +  K AT REST
T               1.221     0.011           FORD        67 CNTR +-
T               1.2272    0.0036          LOBKOWICZ   69 CNTR +  K IN FLIGHT
T         3M    1.2380    0.0016          OTT         71 CNTR  +  STOPPING  K
T    0    OLD EXPERIMENTS WITH LARGE ERRORS EXCLUDED FROM AVERAGING
T            . . . . . . . . . .
T    AVG        1.2370    0.0032    0.0032 AVERAGE (ERROR INCL. SCALE FACTOR OF 2.4)
T    FIT        1.2371    0.0026 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.9)
                          (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$(K^+ - K^-)$/AVG., MEAN LIFE DIFFERENCE (%)

```
      THIS QUANTITY IS A MEASURE OF CPT INVARIANCE IN W.I.

DT             0.47     0.30          FORD       67 CNTR
DT             0.090    0.078         LOBKOWICZ 69 CNTR
DT          . . . . . . . . . .
DT   AVG       0.114    0.093   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

$K^{\pm}$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K^{\pm} \rightarrow \mu^{\pm}\nu$	106+ 0
P2	$K^{\pm} \rightarrow \pi^{\pm}\pi^0$	140+ 135
P3	$K^{\pm} \rightarrow \pi^{\pm}\pi^+\pi^-$	140+ 140+ 140
P4	$K^{\pm} \rightarrow \pi^{\pm}2\pi^0$	140+ 135+ 135
P5	$K^{\pm} \rightarrow \pi^0\mu^{\pm}\nu$ (called $K_{\mu3}$)	135+ 106+ 0
P6	$K^{\pm} \rightarrow \pi^0 e^{\pm}\nu$ (called K_{e3})	135+.511+ 0
P7	$K^+ \rightarrow \pi^+\pi^- e^+\nu$ (called K_{e4})	140+ 140+.511+ 0
P8	$K^+ \rightarrow \pi^+\pi^+ e^-\nu$	140+ 140+.511+ 0
P9	$K^+ \rightarrow \pi^+\pi^-\mu^+\nu$ (called $K_{\mu4}$)	140+ 140+ 106+ 0
P10	$K^+ \rightarrow \pi^+\pi^+\mu^-\nu$	140+ 140+ 106+ 0
P11	$K^{\pm} \rightarrow e^{\pm}\nu$	.511+ 0
P12	$K^{\pm} \rightarrow \mu^{\pm}\nu\gamma$	106+ 0+ 0
P13	$K^{\pm} \rightarrow \pi^{\pm}\pi^0\gamma$	140+ 135+ 0
P14	$K^{\pm} \rightarrow \pi^{\pm}\pi^+\pi^-\gamma$	140+ 140+ 140+ 0
P15	$K^{\pm} \rightarrow \pi^{\pm}e^+e^-$	140+.511+.511
P16	$K^{\pm} \rightarrow \pi^{\pm}\mu^+\mu^-$	140+ 106+ 106
P17	$K^{\pm} \rightarrow \pi^{\pm}\gamma\gamma$	140+ 0+ 0
P18	$K^{\pm} \rightarrow \pi^0 e^{\pm}\nu\gamma$	135+.511+ 0+ 0
P19	$K^{\pm} \rightarrow \pi^{\mp}e^{\pm}e^{\pm}$	140+.511+.511
P20	$K^{\pm} \rightarrow \pi^{\pm}\nu\nu$	140+ 0+ 0
P21	$K^{\pm} \rightarrow e^{\pm}\nu\gamma$	.511+ 0+ 0
P22	$K^{\pm} \rightarrow \pi^{\pm}\gamma$	140+ 0
P23	$K^{\pm} \rightarrow \pi^{\pm}3\gamma$	140+ 0+ 0+ 0
P24	$K^{\pm} \rightarrow \pi^0\pi^0 e^{\pm}\nu$	135+ 135+.511+ 0
P25	$K^+ \rightarrow \pi^- e^+\mu^+$	140+.511+ 106
P26	$K^+ \rightarrow \pi^+ e^+\mu^-$	140+.511+ 106
P27	$K^{\pm} \rightarrow \mu^{\pm}\nu\nu\overline{\nu}$	106+ 0+ 0+ 0
P28	$K^{\pm} \rightarrow \pi^0\mu^{\pm}\nu\gamma$	135+ 106+ 0+ 0
P29	$K^+ \rightarrow \pi^+\mu^+e^-$	140+ 106+.511
P30	$K^{\pm} \rightarrow \mu^{\pm}\nu e^+e^-$	106+ 0+.511+.511
P31	$K^{\pm} \rightarrow \mu^{\mp}\nu e^{\pm}e^{\pm}$	106+ 0+.511+.511
P32	$K^{\pm} \rightarrow \nu e^{\pm}e^+e^-$	0+.511+.511+.511
P33	$K^{\pm} \rightarrow e^{\pm}\nu\nu\overline{\nu}$	.511+ 0+ 0+ 0
P34	$K^+ \rightarrow \mu^+\nu_e$	106+ 0
P35	$K^+ \rightarrow \mu^+\overline{\nu}_e$	106+ 0
P36	$K^+ \rightarrow \pi^0 e^+\overline{\nu}_e$	135+.511+ 0

$K^{\pm}$ CONSTRAINED FIT

```
OVERALL FIT OF MEAN LIFE, WIDTHS AND BRANCHING
RATIOS USES 59 DATA POINTS TO DETERMINE SIX
QUANTITIES.  OVERALL FIT HAS CHISQ=78.0.  MAIN
CONTRIBUTION (13.2) COMES FROM R19 OF HAIDT
71 (WE SEE NO REASON TO REJECT THIS EXPERIMENT
AT THIS TIME)
```

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle\delta P_i \delta P_i\rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle\delta P_i \delta P_j\rangle/(\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1     P 2     P 3     P 4     P 5     P 6
 P 1   .6351+-.0016
 P 2  -.720   .2117+-.0015
 P 3  -.175  -.021   .0559+-.0003
 P 4  -.158   .050   .223   .0173+-.0005
 P 5  -.291  -.252  -.165  -.357   .0318+-.0010
 P 6  -.340  -.145   .141   .004   .221   .0482+-.0005
```

FITTED PARTIAL DECAY MODE RATES

The matrix below is the branching fraction matrix above, transformed into rate space; i.e., $G_i \equiv \Gamma_i = \Gamma_{total}P_i$, in appropriate units. In analogy to the matrix above, the diagonal elements are $G_i \pm \delta G_i$, where $\delta G_i = \sqrt{\langle\delta G_i \delta G_i\rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle\delta G_i \delta G_j\rangle/(\delta G_i \cdot \delta G_j)$. Note that, because of the error in Γ_{total}, the errors and correlations here are not directly derivable from those above.

```
        G 1     G 2     G 3     G 4     G 5     G 6
 G 1   .5134+-.0017
 G 2  -.317   .1711+-.0013
 G 3  -.086   .012   .0452+-.0002
 G 4  -.090   .063   .226   .0140+-.0004
 G 5  -.181  -.219  -.173  -.353   .0257+-.0008
 G 6  -.157  -.087   .143   .009   .227   .0390+-.0004
```

$K^{\pm}$ DECAY RATES

$K^{\pm} \rightarrow \mu^{\pm}\nu$ (units 10^6 sec^{-1}) (G1)

```
W1            51.2      0.8            FORD      67 CNTR +-
W1          . . . . . . . . . .
W1   FIT      51.34     0.17   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

$K^{\pm} \rightarrow \pi^{\pm}\pi^+\pi^-$ (units 10^6 sec^{-1}) (G3)

```
W2   F       (4.496)  (0.030)          FORD      67 CNTR +- SEE NOTE F
W2   F 3.2M  (4.529)  (0.032)          FORD      70 ASPK    SEE NOTE F
W2            4.511    0.024           FORD      70 ASPK    SEE NOTE F
W2   F   THE LAST IS THE COMBINED RESULT OF FORD 67 AND FORD 70
W2          . . . . . . . . . .
W2   FIT      4.518    0.023   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$(K^+ - K^-)$/AVG., DECAY RATE DIFFERENCE (%)

$K^{\pm} \rightarrow \mu^{\pm}\nu$ RATE DIFFERENCE (%) ((G1+)-(G1-))/G1

```
D1       TEST OF CPT CONSERVATION
D1           -0.54     0.41            FORD      67 CNTR
```

$K^{\pm} \rightarrow \pi^{\pm}\pi^+\pi^-$ RATE DIFFERENCE (%) ((G3+)-(G3-))/G3

```
D2       TEST OF CP CONSERVATION
D2           -0.50     0.90            FLETCHER  67 OSPK
D2   F      (-0.04)   (0.21)           FORD      67 CNTR    SEE NOTE F
D2   F 3.2M  (0.10)   (0.14)           FORD      70 ASPK    SEE NOTE F
D2 F          0.08     0.12            FORD      70 ASPK    SEE NOTE F
D2   S      (-0.02)   (0.16)           SMITH     73 ASPK +-
D2   F   SECOND FORD 70 VALUE IS FIRST FORD 70 COMBINED WITH FORD 67.
D2   S   SMITH 73 VALUE OF D2 IS DERIVED FROM SMITH 73 VALUE OF D3.
D2          . . . . . . . . . .
D2   AVG      0.07     0.12    AVERAGE
```

$K^{\pm} \rightarrow \pi^{\pm}2\pi^0$ RATE DIFFERENCE (%) ((G4+)-(G4-))/G4

```
D3       TEST OF CP CONSERVATION
D3     1802  -1.1      1.8             HERZO     69 OSPK
D3            0.08     0.58            SMITH     73 ASPK +-
D3          . . . . . . . . . .
D3   AVG     -0.03     0.55    AVERAGE
```

$K^{\pm} \rightarrow \pi^{\pm}\pi^0$ RATE DIFFERENCE (%) ((G2+)-(G2-))/G2

```
D4       TEST OF CPT CONSERVATION
D4            0.8      1.2             HERZO     69 OSPK
```

$K^{\pm} \rightarrow \pi^{\pm}\pi^0\gamma$ RATE DIFFERENCE (%) ((G13+)-(G13-))/G13

```
D5       TEST OF CP CONSERVATION
D5      24    0.0      24.0            EDWARDS   72 OSPK    PI KE 58-90 MEV
D5    4000    1.0       4.0            ABRAMS    73 ASPK +- PI KE 51-100 MEV
D5    2461    0.8       5.8            SMITH     76 WIRE +- PI+-KE 55-90 MEV
D5          . . . . . . . . . .
D5   AVG      0.9       3.3    AVERAGE
```

$K^{\pm}$ BRANCHING RATIOS

$K^{\pm} \rightarrow (\mu^{\pm}\nu)$/total (units 10^{-2}) (P1)

```
R1   O       (58.5)    (3.0)           BIRGE     56 EMUL +
R1   O       (56.9)    (2.6)           ALEXANDER 57 EMUL +
R1   O   OLD EXPERIMENTS NOT INCLUDED IN AVERAGING
R1      62K   63.24     0.44           CHIANG    72 OSPK +  1.84 GEV/C K+
R1          . . . . . . . . . .
R1   FIT      63.51     0.16   FROM FIT
```

Stable Particle Full Listings

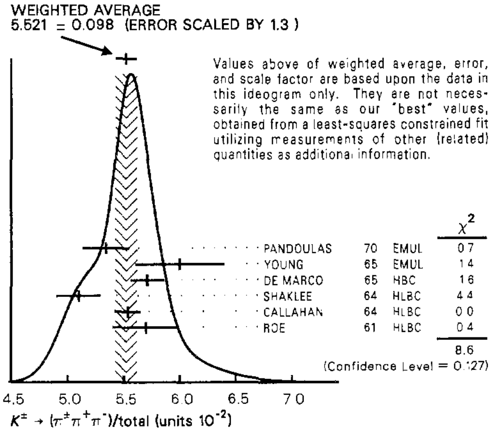
$K^{\pm}$

$K^{\pm} \rightarrow (\pi^{\pm}\pi^{0})$/total (units 10^{-2}) (P2)

```
R2  O       (27.7)    (2.7)             BIRGE      56 EMUL +
R2  O       (23.2)    (2.2)             ALEXANDER  57 EMUL +
R2  O   EARLIER EXPERIMENTS NOT AVERAGED
R2          (21.0)    (0.6)             CALLAHAN   65 HLBC     SEE R17
R2          (21.6)    (0.6)             TRILLING   65 RVUE
R2     16K   21.18     0.28             CHIANG     72 OSPK +  1.84 GEV/C K+
R2           . . . . . . . . .
R2  FIT      21.17     0.15    FROM FIT
```

$K^{\pm} \rightarrow (\pi^{\pm}\pi^{+}\pi^{-})$/total (units 10^{-2}) (P3)

```
R3  O        (5.6)    (0.4)             BIRGE      56 EMUL +
R3  O        (6.8)    (0.4)             ALEXANDER  57 EMUL +
R3  O        (5.2)    (0.3)             TAYLOR     59 EMUL +
R3  O   EARLIER EXPERIMENTS NOT AVERAGED
R3            5.7      0.3              ROE        61 HLBC +
R3    2332    5.54     0.12             CALLAHAN   64 HLBC +
R3     540    5.1      0.2              SHAKLEE    64 HLBC +
R3            5.71     0.15             DE MARCO   65 HBC
R3      44    6.0      0.4              YOUNG      65 EMUL +
R3 P   693    5.34     0.21             PANDOULAS  70 EMUL +
R3  C 2330   (5.56)   (0.20)            CHIANG     72 OSPK +  1.84 GEV/C K+
R3  C   THIS VALUE IS NOT INDEPENDENT OF CHIANG 72 R1,R2,R4,R5, AND R6
R3 P    INCLUDES EVENTS OF TAYLOR 59.
R3           . . . . . . . . .
R3  AVG       5.521    0.098   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
R3  FIT       5.589    0.030  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
                       (SEE IDEOGRAM BELOW)
```

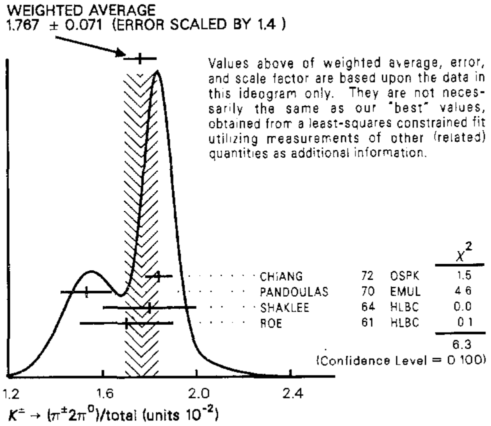


Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$K^{\pm} \rightarrow (\pi^{\pm}\pi^{+}\pi^{-})$/total (units 10^{-2})

$K^{\pm} \rightarrow (\pi^{\pm}2\pi^{0})$/total (units 10^{-2}) (P4)

```
R4  O        (2.1)    (0.5)             BIRGE      56 EMUL +
R4  O        (2.2)    (0.4)             ALEXANDER  57 EMUL +
R4  O        (1.5)    (0.2)             TAYLOR     59 EMUL +
R4  O   EARLIER EXPERIMENTS NOT AVERAGED
R4            1.7      0.2              ROE        61 HLBC +
R4     108    1.8      0.2              SHAKLEE    64 HLBC +
R4 P   198    1.53     0.11             PANDOULAS  70 EMUL +
R4    1307    1.84     0.06             CHIANG     72 OSPK +  1.84 GEV/C K+
R4 P    INCLUDES EVENTS OF TAYLOR 59.
R4           . . . . . . . . .
R4  AVG       1.767    0.071   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
R4  FIT       1.733    0.046  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.4)
                       (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$K^{\pm} \rightarrow (\pi^{\pm}2\pi^{0})$/total (units 10^{-2})

$K^{\pm} \rightarrow (\pi^{0}\mu^{\pm}\nu)$/total (units 10^{-2}) (P5)

```
R5  O        (2.8)    (1.0)             BIRGE      56 EMUL +
R5  O        (5.9)    (1.3)             ALEXANDER  57 EMUL +
R5  O        (2.8)    (0.4)             TAYLOR     59 EMUL +
R5  O   EARLIER EXPERIMENTS NOT AVERAGED
R5    2345    3.33     0.16             CHIANG     72 OSPK +  1.84 GEV/C K+
R5           . . . . . . . . .
R5  FIT       3.180    0.095  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.9)
```

$K^{\pm} \rightarrow (\pi^{0}e^{\pm}\nu)$/total (units 10^{-2}) (P6)

```
R6  O        (3.2)    (1.3)             BIRGE      56 EMUL +
R6  O        (5.1)    (1.3)             ALEXANDER  57 EMUL +
R6  O   EARLIER EXPERIMENTS NOT AVERAGED
R6            5.0      0.5              ROE        61 HLBC +
R6     429    4.7      0.3              SHAKLEE    64 HLBC +
R6    3516    4.86     0.10             CHIANG     72 OSPK +  1.84 GEV/C K+
R6           . . . . . . . . .
R6  AVG       4.849    0.093   AVERAGE
R6  FIT       4.819    0.052  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K^{\pm} \rightarrow (\pi^{\pm}\pi^{0} + \mu^{\pm}\pi^{0}\nu)$/total (units 10^{-2}) (P2+P5)

```
R7      WE COMBINE THESE TWO MODES FOR EXPTS MEASURING THEM IN XENON BC
R7      BECAUSE OF DIFFICULTIES OF SEPARATING THEM THERE
R7           23.4      1.1              ROE        61 HLBC +
R7     886   25.4      0.9              SHAKLEE    64 HLBC +
R7           . . . . . . . . .
R7  AVG      24.60     0.98    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
R7  FIT      24.35     0.15   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K^{+} \rightarrow (\pi^{+}\pi^{+}e^{-}\nu)$/total (units 10^{-7}) (P8)

```
R8      TEST OF DELTA-S = DELTA-Q RULE
R8         (20.)   OR LESS  CL=.95   BIRGE      65 FBC  +
R8      0   (6.9)  OR LESS  CL=.95   ELY        69 HLBC +
R8      0   (9.0)  OR LESS  CL=.95   SCHWEINBE  71 HLBC +
```

$K^{+} \rightarrow (\pi^{+}\pi^{-}\mu^{+}\nu)$/total (units 10^{-5}) (P9)

```
R9      1   (0.77)   (0.54)   (0.50) CLINE      65 FBC  +
```

$K^{+} \rightarrow (\pi^{+}\pi^{+}\mu^{-}\nu)$/total (units 10^{-6}) (P10)

```
R10     TEST OF DELTA-S = DELTA-Q RULE
R10     0    3.0   OR LESS  CL=.95   BIRGE      65 FBC  +
```

$K^{\pm} \rightarrow (e^{\pm}\nu)$/total (units 10^{-5}) (P11)

```
R11       (160.0)  OR LESS  CL=.95   BORREANI   64 HBC  +
R11     4   (2.1)    (1.8)    (1.3)  BOWEN      67 OSPK +
```

$K^{\pm} \rightarrow (\pi^{\pm}\gamma\gamma)$/total (units 10^{-4}) (P17)

```
R12     ALL VALUES GIVEN HERE ASSUME A PHASE SPACE PION ENERGY SPECTRUM
R12        (-0.1)    (0.6)           CHEN       68 OSPK +  T(PI) 60-90 MEV
R12     0   (0.5)  OR LESS  CL=.90   KLEMS      71 OSPK +  T(PI)GT 117 MEV
R12     0   (0.35) OR LESS  CL=.90   LJUNG      73 HLBC +  6-102,114-127MEV
R12     0  (-0.42)   (0.52)          ABRAMS     77 SPEC +  T(PI)LT 92 MEV
R12     0    0.084 OR LESS  CL=.90   ASANO      82 CNTR +  TPI=117-127 MEV
```

$K^{\pm} \rightarrow (\pi^{\pm}\pi^{0}\gamma)$/total (units 10^{-4}) (P13)

```
R13 O   18  (2.2)     (0.7)          CLINE      64 FBC  +  PI+ KE 55-80 MEV
R13      0  (1.9)  OR LESS  CL=.90   EMMERSON   69 OSPK    PI+ KE 55-80 MEV
R13  M   0  (1.0)  OR LESS           MALTSEV    70 HLBC +  PI+ KE LT 55 MEV
R13  A2100    2.71      0.19         ABRAMS     72 ASPK +- PI+ KE 55-90 MEV
R13 O   24  (2.4)     (0.8)          EDWARDS    72 OSPK    PI+ KE 58-90 MEV
R13 L       (1.5)     (1.1)   (0.6)  LJUNG      73 HLBC +  PI+ KE 55-80 MEV
R13 L       (2.6)     (1.5)   (1.1)  LJUNG      73 HLBC +  PI+ KE 55-90 MEV
R13 OL  17  (6.8)     (3.7)   (2.1)  LJUNG      73 HLBC +  PI+ KE 55-102MEV
R13   2461    2.87      0.32         SMITH      76 WIRE +- PI+-KE 55-90 MEV
R13 O   ONLY HIGH STATISTICS EXPERIMENTS ARE AVERAGED.
R13  M  MALTSEV 70 SELECTS LOW PI+ ENERGY TO ENHANCE DIRECT EMISSION CONTR.
R13  L  THE LJUNG 73 VALUES ARE NOT INDEPENDENT.
R13  A  ABRAMS 72 OBSERVES DIRECT EMISSION BR. RATIO OF (1.56+-0.35)*10**-5
R13  A  +-0.5*10**-5 ADDNL. SYST. ERROR  AND INNER BREMSSTRAHLUNG BR. RATIO
R13  A  OF (2.55+-0.18)*10**-4.  WE QUOTE THE SUM OF THESE BR. RATIOS.
R13         . . . . . . . . .
R13 AVG       2.75      0.16   AVERAGE
```

$K^{\pm} \rightarrow (\pi^{\pm}\pi^{+}\pi^{-}\gamma)$/total (units 10^{-4}) (P14)

```
R14           1.0       0.4          STAMER     65 EMUL +  EGAM GT 11MEV
```

$K^{\pm} \rightarrow (\pi^{\pm}e^{+}e^{-})$/total (units 10^{-6}) (P15)

```
R15     TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY COMBINED
R15     FIRST ORDER WEAK AND E.M. INTERACTIONS.
R15      1  (2.45) OR LESS  CL=.90   CAMERINI   64 FBC  +
R15         (4.4)  OR LESS  CL=.90   BISI       67 DBC  +
R15  C      (0.4)  OR LESS           CLINE1     67 FBC  +
R15  C      (0.88) OR LESS  CL=.90   CLINE2     67 FBC  +
R15        (32.0)  OR LESS  CL=.90   BEIER      72 OSPK +-
R15         (1.7)  OR LESS  CL=.90   CENCE      74 ASPK +  THREE TRACK EVTS
R15         (0.27) OR LESS  CL=.90   CENCE      74 ASPK +  TWO TRACK EVENTS
R15  C  CLINE2 REPLACES CLINE1.  CLINE1 IS NOT FOR CL=.90 .
```

$K^{\pm} \rightarrow (\pi^{\pm}\mu^{+}\mu^{-})$/total (units 10^{-6}) (P16)

```
R16     TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY COMBINED
R16     FIRST ORDER WEAK AND E.M. INTERACTIONS.
R16         (3.0)  OR LESS  CL=.90   CAMERINI   65 FBC  +
R16          2.4   OR LESS  CL=.90   BISI       67 DBC  +
```

$K^{\pm} \rightarrow (\pi^{\pm}\pi^{0})/(\pi^{\pm}\pi^{+}\pi^{-})$ (P2)/(P3)

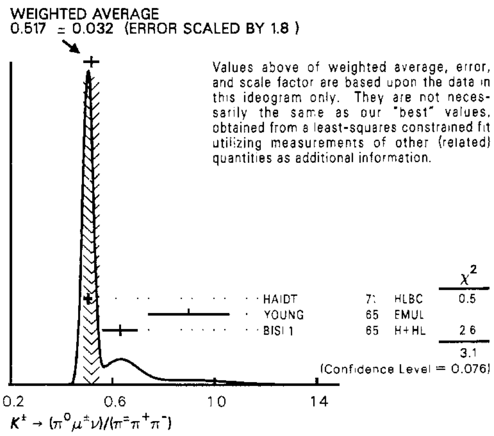
```
R17    134    3.24      0.34         YOUNG      65 EMUL +
R17   1045    3.96      0.15         CALLAHAN   66 FBC  +
R17         . . . . . . . . .
R17 AVG       3.84      0.27   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.9)
R17 FIT       3.787     0.034 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K^{\pm} \rightarrow (\pi^{\pm}2\pi^{0})/(\pi^{\pm}\pi^{+}\pi^{-})$ (P4)/(P3)

```
R18   2027    0.303     0.009        BISI       65 H+HL +
R18     17    0.393     0.099        YOUNG      65 EMUL +
R18         . . . . . . . . .
R18 AVG       0.3037    0.0090 AVERAGE
R18 FIT       0.3100    0.0079 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$K^\pm \to (\pi^0\mu^\pm\nu)/(\pi^\pm\pi^+\pi^-)$ (P5)/(P3)

```
R19  B2845    0.63     0.07            BISI 1    65 H+HL +
R19     38    0.90     0.16            YOUNG     65 EMUL +
R19 H 1505   (0.510)  (0.017)          EICHTEN   68 HLBC +
R19  H1505    0.503    0.019           HAIDT     71 HLBC +
R19  B  ERROR ENLARGED FOR BACKGROUND PROBLEMS.  SEE GAILLARD 70.
R19  H  HAIDT 71 IS A REANALYSIS OF EICHTEN 68.
R19          . . . . . . . . . . .
R19 AVG       0.517    0.032   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)
R19 FIT       0.569    0.018  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.9)
                       (SEE IDEOGRAM BELOW)
```



$K^\pm \to (\pi^0 e^\pm\nu)/(\pi^\pm\pi^+\pi^-)$ (P6)/(P3)

```
R20    230    0.90     0.06            BORREANI  64 HBC  +
R20     37    0.90     0.16            YOUNG     65 EMUL +
R20    854    0.94     0.09            BELLOTT2  67 HLBC
R20 H 4385   (0.846)  (0.021)          EICHTEN   68 HLBC +
R20  H4385    0.850    0.019           HAIDT     71 HLBC +
R20   2827    0.856    0.040           BRAUN     75 HLBC +
R20  H  HAIDT 71 IS A REANALYSIS OF EICHTEN 68.
R20          . . . . . . . . . . .
R20 AVG       0.858    0.016   AVERAGE
R20 FIT       0.8622   0.0098 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K^+ \to (\pi^+\pi^- e^+\nu)/(\pi^+\pi^+\pi^-)$ (units 10^{-4}) (P7)/(P3)

```
R21     69    6.7      1.5             BIRGE     65 FBC  +
R21    269    5.83     0.63            ELY       69 HLBC +
R21    500    7.36     0.68            BOURQUIN  71 ASPK
R21    106    7.0      0.9             SCHWEINBE 71 HLBC +
R21    30K    7.21     0.32            ROSSELET  77 SPEC +
R21          . . . . . . . . . . .
R21 AVG       6.98     0.26    AVERAGE
```

$K^+ \to (\pi^+\pi^-\mu^+\nu)/(\pi^+\pi^+\pi^-)$ (units 10^{-4}) (P9)/(P3)

```
R22      1   (2.5)   APPROX            GREINER   64 EMUL +
R22      7    2.57     1.55            BISI      67 DBC  +
```

$K^\pm \to (\pi^0 e^\pm\nu)/(\mu^\pm\nu + \pi^\pm\pi^0)$ (units 10^{-2})

```
R23                                                      (P6)/(P1+P2)
R23   1679    5.89     0.21            CESTER    66 OSPK +
R23   5110    6.16     0.22            ESCHSTRUT 68 OSPK +
R23  W        5.92     0.65            WEISSENBE 76 SPEC +
R23  W  VALUE CALCULATED FROM WEISSENBERG 76 (PI0 E NU), (MU NU), AND
R23  W  (PI PI0) VALUES TO ELIMINATE DEPENDENCE ON OUR 1974 (PI 2PI0)
R23  W  AND (PI PI+ PI-) FRACTIONS.
R23          . . . . . . . . . . .
R23 AVG       6.01     0.15    AVERAGE
R23 FIT       5.691    0.067  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K^\pm \to (\pi^\pm\pi^0)/(\mu^\pm\nu)$ (P2)/(P1)

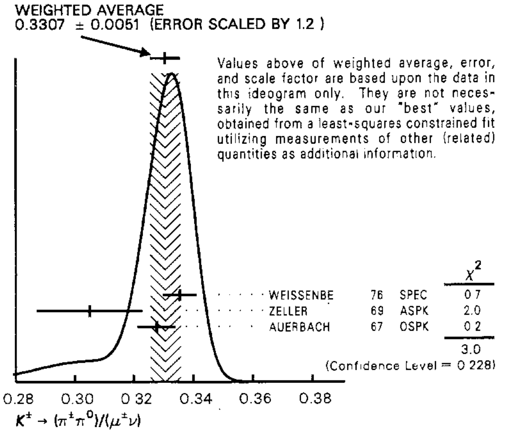
```
R24  A4517    0.3277   0.0065          AUERBACH  67 OSPK +
R24   1600    0.305    0.018           ZELLER    69 ASPK +
R24 W  25K   (0.328)  (0.005)          WEISSENBE 74 STRC +
R24  W        0.3355   0.0057          WEISSENBE 76 SPEC +
R24  A  AUERBACH 67 CHANGED FROM .3253+-.0065.  SEE COMMENT WITH RATIO R26.
R24  W  WEISSENBERG 76 REVISES WEISSENBERG 74.
R24          . . . . . . . . . . .
R24 AVG       0.3307   0.0051  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
R24 FIT       0.3333   0.0030 FROM FIT
                       (SEE IDEOGRAM BELOW)
```

$K^\pm \to (\pi^0 e^\pm\nu)/(\mu^\pm\nu)$ (P6)/(P1)

```
R25  A 295    0.0791   0.0054          AUERBACH  67 OSPK +
R25    960    0.0775   0.0033          BOTTERI1  68 ASPK +
R25    561    0.069    0.006           GARLAND   68 OSPK +
R25    350    0.069    0.006           ZELLER    69 ASPK +
R25  A  AUERBACH 67 CHANGED FROM .0797+-.0054.  SEE COMMENT WITH RATIO R26.
R25  A  THE VALUE .0785+-.0025 GIVEN IN AUERBACH 67 IS AN AVERAGE OF
R25  A  AUERBACH 67 R25 AND CESTER 66 R23.
R25          . . . . . . . . . . .
R25 AVG       0.0752   0.0024  AVERAGE
R25 FIT      0.07588  0.00091 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K^\pm \to (\pi^0\mu^\pm\nu)/(\mu^\pm\nu)$ (P5)/(P1)

```
R26  A 307    0.0486   0.0040          AUERBACH  67 OSPK +
R26  G 424    0.0480   0.0037          GARLAND   68 OSPK +
R26    240    0.054    0.009           ZELLER    69 ASPK +
R26  A  AUERBACH 67 CHANGED FROM .0602+-.0046 BY ERRATUM WHICH BRINGS THE
R26  A  MU-SPECTRUM CALCULATION INTO AGREEMENT WITH GAILLARD 70 APPENDIX B.
R26  G  GARLAND 68 CHANGED FROM .055+-.004 IN AGREEMENT WITH MU-SPECTRUM
R26  G  CALCULATION OF GAILLARD 70 APPENDIX B.  L.G.PONDROM, PRIV.COMM.(73)
R26          . . . . . . . . . . .
R26 AVG       0.0488   0.0026  AVERAGE
R26 FIT       0.0501   0.0015 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.8)
```



$K^\pm \to (\mu^\pm\nu)/(\pi^\pm\pi^+\pi^-)$ (P1)/(P3)

```
R27 R  427  (10.38)   (0.82)           YOUNG     65 EMUL +
R27 R   DELETED FROM OVERALL FIT BECAUSE YOUNG 65 CONSTRAINS HIS RESULTS.
R27 R   TO ADD UP TO 1.  ONLY YOUNG MEASURED (MU NU) DIRECTLY.
R27          . . . . . . . . . . .
R27 FIT      11.363    0.072  FROM FIT
```

$K^\pm \to (e^\pm\nu)/(\mu^\pm\nu)$ (units 10^{-5}) (P11)/(P1)

```
R28     10    1.9      0.7      0.5    BOTTERILL 67 ASPK +
R28      8    1.8      0.8      0.6    MACEK     69 ASPK +
R28    112    2.42     0.42            CLARK     72 OSPK +
R28    534    2.37     0.17            HEARD2    75 SPEC +
R28    404    2.51     0.15            HEINTZE   76 SPEC +
R28                   . . . .
R28 AVG       2.42     0.11    AVERAGE
```

$K^\pm \to (\pi^0\mu^\pm\nu)/(e^\pm\pi^0\nu)$ (P5)/(P6)

```
R29  C1509    0.703    0.056           CALLAHA1  66 HLBC
R29   5601    0.667    0.017           BOTTERI2  68 ASPK +
R29 H 1398   (0.604)  (0.022)          EICHTEN   68 HLBC
R29 H        (0.596)  (0.025)          HAIDT     71 HLBC +
R29  D3480    0.698    0.025           CHIANG    72 OSPK +  1.84 GEV/C K+
R29  L 554    0.705    0.063           LUCAS2    73 HBC  -  DALITZ PRS ONLY
R29 B 1585   (0.608)  (0.014)          BRAUN     75 HLBC +
R29           0.67     0.12            WEISSENBE 76 SPEC +
R29 E        (0.670)  (0.014)          HEINTZE   77 SPEC +
R29                 COMMENTS
R29  C  FROM CALLAHAN1 66 WE USE ONLY THE MU3/E3 RATIO AND DO NOT
R29  C  INCLUDE IN THE FIT THE RATIOS MU3/(PI PI+ PI0) AND E3/(PI PI+ PI0),
R29  C  SINCE THEY SHOW LARGE DISAGREEMENTS WITH THE REST OF THE DATA.
R29 H   HAIDT 71 IS A REANALYSIS OF EICHTEN 68.
R29 H   ONLY INDIVIDUAL RATIOS INCLUDED IN FIT (SEE R19 AND R20).
R29  D  CHIANG 72 R29 IS STATISTICALLY INDEPENDENT OF CHIANG 72 R5 AND R6.
R29  L  LUCAS 73 GIVES N(MU3)=554+-7.6PCT, N(E3)=786+-3.1PCT.  WE DIVIDE.
R29 B   BRAUN 75 VALUE IS FROM FORM FACTOR FIT.  ASSUMES MU-E UNIVERSALITY.
R29 E   HEINTZE 77 VALUE FROM FIT TO LAMBDA0. ASSUMES MU-E UNIVERSALITY.
R29          . . . . . . . . . . .
R29 AVG       0.679    0.013   AVERAGE
R29 FIT       0.660    0.019  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.8)
```

$K^\pm \to (\pi^0 e^\pm\nu\gamma)/(\pi^0 e^\pm\nu)$ (units 10^{-2}) (P18)/(P6)

```
R30          (1.2)    (0.8)            BELLOTT1  67 HLBC +  EGAM GT 30MEV
R30  R  13    0.76     0.28            ROMANO    71 HLBC    EGAM GT 10MEV
R30 R        (0.53)   (0.22)           ROMANO    71 HLBC +  EGAM GT 30 MEV
R30 L   16   (0.48)   (0.20)           LJUNG     73 HLBC +  EGAM GT 30 MEV
R30 L        (0.22)   (0.15)   (0.10)  LJUNG     73 HLBC +  EGAM GT 30 MEV
R30 L   FIRST LJUNG VALUE IS FOR COS(ELECT-GAMMA)L.T. 0.9, SECOND VALUE IS
R30 L   FOR COS(ELECT-GAMMA) BETW 0.6 AND 0.9 FOR COMPARISON WITH ROMANO.
R30 R   BOTH ROMANO VALUES ARE FOR COS(ELECT-GAMMA) BETW 0.6 AND 0.9.
R30 R   SECOND VALUE IS FOR COMPARISON WITH SECOND LJUNG VALUE. WE USE
R30 R   LOWEST EGAM CUT FOR SUMMARY TABLE VALUE. SEE ROMANO FOR EGAM DEPEND
```

$K^- \to (\pi^+ e^- e^-)$/total (units 10^{-5}) (P19)

```
R31     TEST OF TOTAL LEPTON NUMBER CONSERVATION.
R31          (1.5)  OR LESS            CHANG     68 HBC  -
```

$K^\pm \to (\pi^\pm\nu\nu)$/total (units 10^{-6}) (P20)

```
R32     TEST FOR DELTA-S = 1 WEAK NEUTRAL CURRENT
R32 C        (1.4)  OR LESS  CL=.90   KLEMS     71 OSPK +  T(PI) 117-127MEV
R32 C        (0.94) OR LESS  CL=.90   CABLE     73 CNTR +  T(PI) 60-105 MEV
R32  C       (0.56) OR LESS  CL=.90   CABLE     73 CNTR +  T(PI) 60-127 MEV
R32  L   0  (57.0)  OR LESS  CL=.90   LJUNG     73 HLBC +
R32           0.14  OR LESS  CL=.90   ASANO     81 CNTR +  T(PI) 116-127MEV
R32  C  KLEMS 71 AND CABLE 73 ASSUME PI SPECTRUM SAME AS KE3 DECAY.
R32  C  SECOND CABLE LIMIT COMBINES CABLE AND KLEMS DATA FOR VECTOR INT.
R32  L  LJUNG 73 ASSUMES VECTOR INTERACTION.
```

$K^\pm \to (e^\pm\nu\gamma)$/total (units 10^{-5}) (P21)

```
R33  M       (7.1)  OR LESS            MACEK     70 OSPK +  P(E) 234 TO 247
R33  M  ABOVE IS MEASUREMENT OF STRUCTURE-DEPENDENT DECAY ONLY.
```

$K^\pm \to (\pi^\pm\gamma)$/total (units 10^{-6}) (P22)

```
R34     VIOLATES ANGULAR MOMENTUM CONSERVATION.  NOT LISTED IN SUMM.TABLES.
R34  K       (4.0)  OR LESS  CL=.90   KLEMS     71 OSPK +
R34          (1.4)  OR LESS  CL=.90   ASANO     82 CNTR +
R34  K  TEST OF MODEL OF SELLERI, NC 60A, 291(1969).
```

$K^\pm \to (\pi^\pm 3\gamma)$/total (units 10^{-4}) (P23)

```
R36     VALUES GIVEN HERE ASSUME A PHASE SPACE PION ENERGY SPECTRUM.
R36          (3.0)  OR LESS  CL=.90   KLEMS     71 OSPK +  T(PI) GT 117MEV
R36           1.0   OR LESS  CL=.90   ASANO     82 CNTR +  TPI=117-127 MEV
```

$K^+ \to (\pi^+\pi^+e^-\nu)/(\pi^+\pi^-e^+\nu)$ **(units 10^{-4})** (P8)/(P7)

```
R37      TEST OF DELTA-S = DELTA-Q RULE
R37       0 (130.)    OR LESS  CL=.95   BOURQUIN  71 ASPK
R37  B    3    3.6    OR LESS  CL=.95   BLOCH     76 SPEC
R37  B   CORRESPONDS TO 3E10-4 AT CL=.90.
```

$K^{\pm} \to (\pi^0\pi^0e^{\pm}\nu)/(\pi^0e^{\pm}\nu)$ **(units 10^{-4})** (P24)/(P6)

```
R38       0  (37.0)   OR LESS  CL=.90   ROMANO    71 HLBC +
R38       2    3.8       5.0      1.2   LJUNG     73 HLBC +
```

$K^+ \to (\pi^-e^+\mu^+)$**/total (units 10^{-8})** (P25)

```
R39     K- INTO (PI+ E- MU-)/TOTAL IS ALSO INCLUDED HERE
R39           (2.8)   OR LESS  CL=.90   BEIER     72 OSPK +-
```

$K^+ \to (\pi^+e^+\mu^-)$**/total (units 10^{-8})** (P26)

```
R40     K- INTO (PI- E- MU+)/TOTAL IS ALSO INCLUDED HERE
R40           (1.4)   OR LESS  CL=.90   BEIER     72 OSPK +-
```

$K^{\pm} \to (\mu^{\pm}3\nu)$**/total (units 10^{-6})** (P27)

```
R41  P    0    6.0    OR LESS  CL=.90   PANG      73 CNTR +
R41  P   PANG 73 ASSUMES MU SPECTRUM FROM NU-NU INTERACTION OF BARDIN 70.
```

$K^{\pm} \to (\pi^0\mu^{\pm}\nu\gamma)$**/total(units 10^{-5})** (P28)

```
R42       0    6.1    OR LESS  CL=.90   LJUNG     73 HLBC +  EGAM GT 30 MEV
```

$K^{\pm} \to (\pi^0e^{\pm}\nu)/(\pi^{\pm}\pi^0)$ (P6)/(P2)

```
R43  L 786    0.221    0.012            LUCAS2    73 HBC  -  DALITZ PRS ONLY
R43  L   LUCAS 73 GIVES N(E3)=786+-3.1PCT, N(PI2)=3564+-3.1PCT.  WE DIVIDE.
R43           . . . . . . . . . . .
R43 FIT       0.2277   0.0031 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K^{\pm} \to (\pi^{\pm}2\pi^0)/(\pi^{\pm}\pi^0)$ (P4)/(P2)

```
R44  L 574    0.081    0.005            LUCAS2    73 HBC  -  DALITZ PRS ONLY
R44  L   LUCAS 73 GIVES N(PI 2PI0)=574+-5.9 PCT, N(PI2)=3564+-3.1 PCT.
R44  L   WE QUOTE 0.5*N(PI 2PI0)/N(PI2) WHERE 0.5 IS BECAUSE ONLY DALITZ
R44  L   PAIR PI0'S WERE USED.
R44           . . . . . . . . . . .
R44 FIT       0.0819   0.0022 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$K^{\pm} \to (\mu^{\pm}\nu\gamma)$**/total (units 10^{-3})** (P12)

```
R45      SEE ALSO SECTIONS R60, R61, AND R62 BELOW.
R45      12   (5.8)    (3.5)            WEISSENBE 74 STRC +  E-GAMMA GT 9 MEV
R45  A         5.4      0.3             AKIBA     85 SPEC    P(MU)<231.5MEV/C  |
R45  A   ASSUMES MU-E UNIVERSALITY AND USES CONSTRAINTS FROM K-->E NU GAMMA.   |
```

$K^{\pm} \to (\pi^{\pm}e^+e^-)/(\pi^+\pi^-e^{\pm}\nu)$ **(units 10^{-3})** (P15)/(P7)

```
R46      TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY COMBINED
R46      FIRST ORDER WEAK AND E.M. INTERACTIONS.
R46  B   41    7.0      1.3             BLOCH     75 SPEC -
R46  B   BLOCH 75 QUOTES THIS RESULT MULTIPLIED BY OUR 1974 KE4 BR.FRAC.
```

$K^{\pm} \to (e^{\pm}\nu\gamma)/(e^{\pm}\nu)$ (P21)/(P11)

```
R47      STRUCTURE DEPENDENT PART WITH + GAMMA HELICITY.
R47 H    56   (1.05)   (0.25)   (0.30) HEARD1    75 SPEC +  P(E) 236 TO 247
R47 H    THIS VALUE IS INCLUDED IN THE SECOND HEINTZE 79 VALUE IN SEC.R54
R47 H    BELOW.
```

$K^+ \to (\pi^{\pm}\mu^{\mp}e^+)/(\pi^+\pi^-e^+\nu)$ **(units 10^{-4})** (P25+P26)/(P7)

```
R48      TEST OF LEPTON FAMILY NUMBER OR TOTAL LEPTON NUMBER CONSERVATION.
R48  D    0    1.9    OR LESS  CL=.90   DIAMANTBE 76 SPEC +
R48  D   DIAMANTBE 76 QUOTES THIS RESULT TIMES OUR 1975 KE4 BR. RATIO.
```

$K^+ \to (\pi^+\mu^+e^-)/(\pi^+\pi^-e^+\nu)$ **(units 10^{-4})** (P29)/(P7)

```
R49      TEST OF LEPTON FAMILY NUMBER CONSERVATION.
R49  D    0    1.3    OR LESS  CL=.90   DIAMANTBE 76 SPEC +
R49  D   DIAMANTBE 76 QUOTES THIS RESULT TIMES OUR 1975 KE4 BR RATIO.
```

$K^{\pm} \to (\mu^{\pm}\nu e^+e^-)/(\pi^+\pi^-e^{\pm}\nu)$ **(units 10^{-3})** (P30)/(P7)

```
R50 D    14   (3.3)    (0.9)            DIAMANTBE 76 SPEC +  M(EE) GT 140
R50  D   14   27.       8.              DIAMANTBE 76 SPEC +  EXTRAPOLATED BR
R50  D   DIAMANTBE 76 QUOTES THESE RESULTS TIMES OUR 1975 KE4 BR RATIO.
R50  D   THE SECOND DIAMANTBE 76 VALUE IS THE FIRST VALUE EXTRAPOLATED TO 0
R50  D   TO INCLUDE LOW MASS E PAIRS.
```

$K^+ \to (\pi^-e^+e^+\ )/(\pi^+\pi^-e^+\nu)$ **(units 10^{-4})** (P19)/(P7)

```
R51      TEST OF TOTAL LEPTON NUMBER CONSERVATION
R51  D    0    2.5    OR LESS  CL=.90   DIAMANTBE 76 SPEC +
R51  D   DIAMANTBE 76 QUOTES THIS RESULT TIMES OUR 1975 BR RATIO.
```

$K^+ \to (\mu^-\nu e^+e^+)/(\pi^+\pi^-e^+\nu)$ **(units 10^{-3})** (P31)/(P7)

```
R52      TEST OF LEPTON FAMILY NUMBER CONSERVATION.
R52  D    0    0.5    OR LESS  CL=.90   DIAMANTBE 76 SPEC +
R52  D   DIAMANTBE 76 QUOTES THIS RESULT TIMES OUR 1975 KE4 BR RATIO.
```

$K^+ \to (\nu e^+e^+e^-)/(\pi^+\pi^-e^+\nu)$ **(units 10^{-2})** (P32)/(P7)

```
R53       4    0.54     0.54     0.27  DIAMANTBE 76 SPEC +
R53  D   DIAMANTBE 76 QUOTES THIS RESULT TIMES OUR 1975 KE4 BR RATIO.
```

$K^{\pm} \to (e^{\pm}\nu\gamma)/(\mu^{\pm}\nu)$ **(units 10^{-5})** (P21)/(P1)

```
R54      STRUCTURE DEPENDENT PART WITH + GAMMA HELICITY
R54 H    51   (2.33)   (0.42)           HEINTZE   79 SPEC +
R54  H 107     2.40     0.36            HEINTZE   79 SPEC +
R54  H   SECOND HEINTZE 79 RESULT IS FIRST COMBINED WITH HEARD1 75 RESULT
R54  H   FROM SECTION R47 ABOVE.
```

$K^{\pm} \to (e^{\pm}\nu\gamma)$**/total (units 10^{-4})** (P21)

```
R55      STRUCTURE DEPENDENT PART WITH - GAMMA HELICITY
R55  H         1.6    OR LESS  CL=.90   HEINTZE   79 SPEC +
R55  H   IMPLIES (AXIAL VEC./VECTOR) AMPL. RATIO OUTSIDE RANGE -1.8 TO -.54.
```

$K^{\pm} \to (e^{\pm}\nu\nu\overline{\nu})/(e^{\pm}\nu)$ (P33)/(P11)

```
R56       0    3.8    OR LESS  CL=.90   HEINTZE   79 SPEC +
```

$K^+ \to (\mu^+\nu_e)$**/total** (P34)

```
R57      FORBIDDEN BY LEPTON FAMILY NUMBER CONSERVATION.
R57       0    0.004 OR LESS  CL=.90   LYONS     81 HLBC 200GEV K+ N.B. BEAM
R57          (0.012)OR LESS  CL=.90   COOPER    82 HLBC WIDEBAND NU BEAM
```

$K^+ \to \mu^+\overline{\nu}_e$**/total (units 10^{-3})** (P35)

```
R58      FORBIDDEN BY TOTAL LEPTON NUMBER CONSERVATION.
R58            3.3    OR LESS  CL=.90   COOPER    82 HLBC WIDEBAND NU BEAM
```

$K^+ \to \pi^0e^+\overline{\nu}_e$**/total** (P36)

```
R59      FORBIDDEN BY TOTAL LEPTON NUMBER CONSERVATION.
R59            0.003 OR LESS  CL=.90   COOPER    82 HLBC WIDEBAND NU BEAM
```

$K^{\pm} \to (\mu^{\pm}\nu\gamma)$**/total (units 10^{-5})** (P12)

```
R60      STRUCTURE DEPENDENT PART WITH + GAMMA HELICITY (SD+ TERM).
R60      BRANCHING RATIOS R60, R61, AND R62 ARE COMPONENTS OF R45 ABOVE.
R60            3.0    OR LESS  CL=.90   AKIBA     85 SPEC                    |
```

$K^{\pm} \to (\mu^{\pm}\nu\gamma)$**/total (units 10^{-5})** (P12)

```
R61      INTERFERENCE TERM BETWEEN INTERNAL BREMSSTRAHLUNG AND SD+ TERM.
R61            2.7    OR LESS  CL=.90   AKIBA     85 SPEC                    |
```

$K^{\pm} \to (\mu^{\pm}\nu\gamma)$**/total (units 10^{-4})** (P12)

```
R62      SUM OF STRUCTURE DEPENDENT PART WITH - GAMMA HELICITY (SD- TERM)
R62      AND INTERFERENCE TERM BETWEEN INTERNAL BREMSSTRAHLUNG AND SD- TERM.
R62  A         2.6    OR LESS  CL=.90   AKIBA     85 SPEC                    |
R62  A   ASSUMES MU-E UNIVERSALITY AND USES CONSTRAINTS FROM K-->E NU GAMMA.  |
```

$K^{\pm}$ LONGITUDINAL POLARIZATION OF EMITTED $\mu^{\pm}$

```
POL    K+- INTO MU+- NU
POL     TESTS FOR RIGHT-HANDED CURRENTS IN STRANGENESS-CHANGING DECAY.
POL          -0.970    0.047            HAYANO    84 CNTR            |
POL          -1.0      0.1              CUTTS     69 SPRK            |
POL          -0.96     0.12             COOMBES   57 CNTR            |
POL           . . . . . . . . . . .
POL AVG      -0.974    0.040   AVERAGE
```

NOTE ON DALITZ PLOT PARAMETERS FOR $K \to 3\pi$ DECAYS

The Dalitz plot distribution for $K^{\pm} \to \pi^{\pm}\pi^{\pm}\pi^{\mp}$, $K^{\pm} \to \pi^0\pi^0\pi^{\pm}$, and $K_L^0 \to \pi^+\pi^-\pi^0$ can be parametrized by a series expansion such as that introduced by Weinberg.[1] We use the form

$$|M|^2 \propto 1 + g\frac{(s_3-s_0)}{m_{\pi^+}^2} + h\left[\frac{s_3-s_0}{m_{\pi^+}^2}\right]^2 + j\frac{(s_2-s_1)}{m_{\pi^+}^2} + k\left[\frac{s_2-s_1}{m_{\pi^+}^2}\right]^2 + \cdots, \tag{1}$$

where $m_{\pi^+}^2$ has been introduced to make the coefficients g, h, j, and k dimensionless, and

$$s_i = (P_K - P_i)^2 = (m_K - m_i)^2 - 2m_KT_i, \quad i = 1,2,3,$$

$$s_0 = \frac{1}{3}\sum_i s_i = \frac{1}{3}(m_K^2 + m_1^2 + m_2^2 + m_3^2).$$

Here the P_i are four-vectors, m_i and T_i are the mass and kinetic energy of the i^{th} pion, and the index 3 is used for the odd pion.

The coefficient g is a measure of the slope in the variable s_3 (or T_3) of the Dalitz plot, while h and k measure the quadratic dependence on s_3 and $(s_2 - s_1)$, respectively. The coefficient j is related to the asymmetry of the plot and must be zero if CP invariance holds. Note also that if CP is good, g, h, and k must be the same for $K^+ \to \pi^+\pi^+\pi^-$ as for $K^- \to \pi^-\pi^-\pi^+$.

Since different experiments use different forms for $|M|^2$, in order to compare the experiments we have converted to g, h, j, and k whatever coefficients have been measured. For details of this conversion and discussion of the data, see the April 1982 version of this note.[2]

See also the review of Devlin and Dickey,[3] which contains an analysis of $K \rightarrow 2\pi$ and $K \rightarrow 3\pi$ data in terms of transition amplitudes with appropriate energy dependence.

References

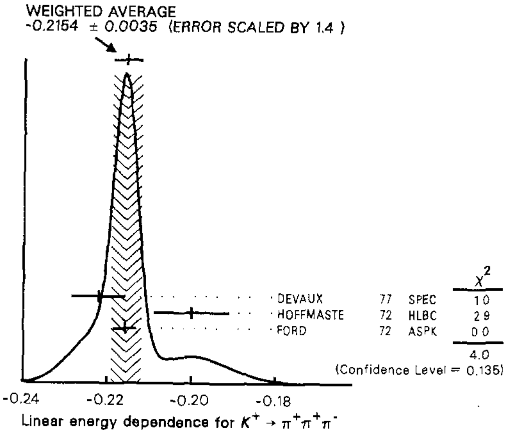
1. S. Weinberg, Phys. Rev. Lett. **4**, 87 (1960).
2. Particle Data Group, Phys. Lett. **111B**, 69 (1982).
3. T.J. Devlin and J.O. Dickey, Rev. Mod. Phys. **51**, 237 (1979).

$K^{\pm}$ ENERGY DEPENDENCE OF DALITZ PLOT

```
MATRIX ELEMENT SQUARED = 1 + G*U + H*U**2 + K*V**2
WHERE U=(S3-S0)/(MPI**2) AND V=(S1-S2)/(MPI**2)
```

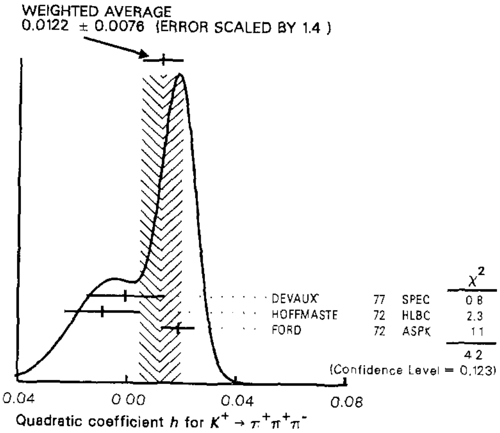
LINEAR COEFFICIENT g_{τ^+} FOR $K^+ \rightarrow \pi^+\pi^+\pi^-$

```
GT+        SOME  EXPTS USE DALITZ VARIABLES X AND Y. WE GIVE AY=COEFF OF Y
GT+        TERM AT RIGHT. SEE MINI-REVIEW ABOVE.
GT+ZL 5428  (-0.22)   (0.024)           ZINCHENKO 67 HBC  +  AY=0.28+-.03
GT+ L 9994  (-0.218)  (0.016)           BUTLER    68 HBC  +  AY=0.277+-.020
GT+ G17898  (-0.196)  (0.012)           GRAUMAN   70 HLBC +  AY=0.228+-.030
GT+   750K   -0.2157   0.0028           FORD      72 ASPK +  AY=0.2734+-.0035
GT+H 39819   -0.200    0.009            HOFFMASTE 72 HLBC +
GT+   225K   -0.2221   0.0065           DEVAUX    77 SPEC +  AY=0.2814+-.0082
GT+ L   EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE.
GT+ Z   ALSO INCLUDES DBC EVENTS
GT+ G   EMULS. DATA ADDED - ALL EVENTS INCLUDED BY HOFFMASTER 72
GT+H    HOFFMASTER 72 INCLUDES GRAUMAN 70 DATA.
GT+           . . . . . . . . . .
GT+ AVG      -0.2154   0.0035  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
                               (SEE IDEOGRAM BELOW)
```



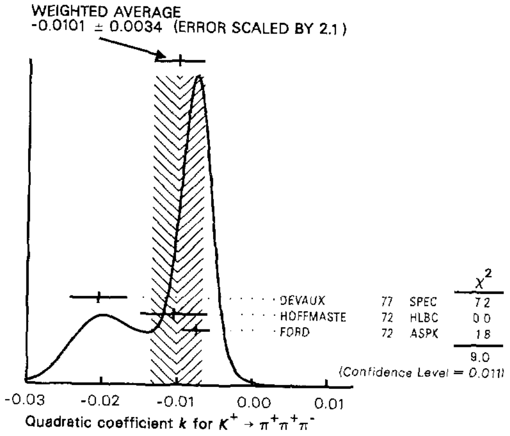
QUADRATIC COEFFICIENT h FOR $K^+ \rightarrow \pi^+\pi^+\pi^-$

```
HT+   750K    0.0187   0.0062           FORD      72 ASPK +
HT+  39819   -0.009    0.014            HOFFMASTE 72 HLBC +
HT+   225K   -0.0006   0.0143           DEVAUX    77 SPEC +
HT+           . . . . . . . . . .
HT+ AVG       0.0122   0.0076  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
                               (SEE IDEOGRAM BELOW)
```



QUADRATIC COEFFICIENT k FOR $K^+ \rightarrow \pi^+\pi^+\pi^-$

```
KT+   750K   -0.0075   0.0019           FORD      72 ASPK +
KT+  39819   -0.0105   0.0045           HOFFMASTE 72 HLBC +
KT+   225K   -0.0205   0.0039           DEVAUX    77 SPEC +
KT+           . . . . . . . . . .
KT+ AVG      -0.0101   0.0034  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.1)
                               (SEE IDEOGRAM BELOW)
```



LINEAR COEFFICIENT g_{τ^-} FOR $K^- \rightarrow \pi^-\pi^-\pi^+$

```
GT-        FOR DEFINITION OF AY SEE NOTE IN SECTION GT+ ABOVE.
GT- F 1347  (-0.220)  (0.035)           FERRO-LUZ 61 HBC  - AY=0.28+-.045
GT-ML 5778  (-0.190)  (0.023)           MOSCOSO   68 HBC  - AY=0.242+-.029
GT-  50919   -0.193    0.010            MAST      69 HBC  - AY=0.244 +-.013
GT-   750K   -0.2186   0.0028           FORD      72 ASPK - AY=0.2770+-.0035
GT- Q  81K  (-0.199)  (0.008)           LUCAS1    73 HBC  - AY=0.252+-.011
GT- F   NO RADIATIVE CORRECTIONS INCLUDED.
GT- L   EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE.
GT- M   ALSO INCLUDES DBC EVENTS.
GT- Q  QUADRATIC DEPENDENCE IS REQUIRED BY KL EXPTS.  FOR COMPARISON WE
GT- Q  AVERAGE ONLY THOSE K+- EXPERIMENTS WHICH QUOTE QUADRATIC FIT VALUES.
GT-           . . . . . . . . . .
GT- AVG      -0.2167   0.0066  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.5)
```

QUADRATIC COEFFICIENT h FOR $K^- \rightarrow \pi^-\pi^-\pi^+$

```
HT-  50919   -0.001    0.012            MAST      69 HBC  -
HT-   750K    0.0125   0.0062           FORD      72 ASPK -
HT-           . . . . . . . . . .
HT- AVG       0.0097   0.0055  AVERAGE
```

QUADRATIC COEFFICIENT k FOR $K^- \rightarrow \pi^-\pi^-\pi^+$

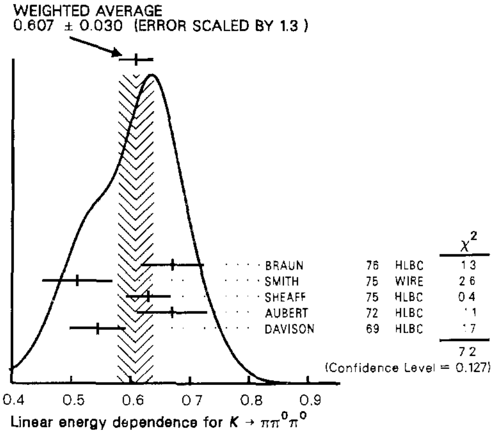
```
KT-  50919   -0.014    0.012            MAST      69 HBC  -
KT-   750K   -0.0083   0.0019           FORD      72 ASPK -
KT-           . . . . . . . . . .
KT- AVG      -0.0084   0.0019  AVERAGE
```

$(g_{\tau^+} - g_{\tau^-})/(g_{\tau^+} + g_{\tau^-})$ IN PERCENT

```
DG       A NON-ZERO VALUE FOR THIS QUANTITY INDICATES CP VIOLATION
DG    3.2M   -0.70     0.53             FORD      70 ASPK
```

LINEAR COEFFICIENT g FOR $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$.

```
GTP     UNLESS OTHERWISE STATED, ALL EXPTS INCLUDE TERMS QUADRATIC IN
GTP     (S3-S0)/(MPI**2). SEE MINI-REVIEW ABOVE.
GTP K 1792   (0.48)   (0.04)           KALMUS     64 HLBC +
GTP K 1874   (0.586)  (0.098)          BISI       65 HLBC +  ALSO HBC
GTP   4048    0.544    0.048           DAVISON    69 HLBC +  ALSO EMUL
GTP L  198   (0.5 7,  (0.102)          PANDOULAS  70 EMUL +
GTP   1365    0.67     0.06            AUBERT     72 HLBC +
GTP K  574   (0.484)  (0.084)          LUCAS2     73 HBC  -  DALITZ PRS ONLY
GTP   5635    0.630    0.038           SHEAFF     75 HLBC +
GTP    27K    0.510    0.060           SMITH      75 WIRE +
GTP L 4639   (0.806)  (0.220)          BERTRAND   76 EMUL +
GTP   3263    0.670    0.054           BRAUN      76 HLBC +
GTP K   AUTHORS GIVE LINEAR FIT ONLY.
GTP L   EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE.
GTP         . . . . . . . . . . .
GTP AVG       0.607    0.030   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
                       (SEE IDEOGRAM BELOW)
```



QUADRATIC COEFFICIENT h FOR $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$.

```
HTP      SEE MINI-REVIEW ABOVE.
HTP   4048    0.026    0.050           DAVISON    69 HLBC +  ALSO EMUL
HTP L  198   (0.018)  (0.124)          PANDOULAS  70 EMUL +
HTP   1365   -0.01     0.08            AUBERT     72 HLBC +
HTP   5635    0.041    0.030           SHEAFF     75 HLBC +
HTP    27K    0.009    0.040           SMITH      75 WIRE +
HTP L 4639   (0.164)  (0.121)          BERTRAND   76 EMUL +
HTP   3263    0.152    0.082           BRAUN      76 HLBC +
HTP L    EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE.
HTP         . . . . . . . . . . .
HTP AVG       0.034    0.020   AVERAGE
```

NOTE ON $K^{\pm}_{\ell 3}$ AND $K^{0}_{\ell 3}$ FORM FACTORS

Assuming that only the vector current contributes to $K \rightarrow \pi\ell\nu$ decays, we write the matrix element as

$$M \propto f_{+}(t)[(P_K + P_\pi)_\mu \bar{\ell}\gamma_\mu(1+\gamma_5)\nu]$$
$$+ f_{-}(t)[m_\ell \bar{\ell}(1+\gamma_5)\nu] , \qquad (1)$$

where P_K and P_π are the four-momenta of the K and π mesons, m_ℓ is the lepton mass, and f_+ and f_- are dimensionless form factors which can depend only on $t = (P_K - P_\pi)^2$, the square of the four-momentum transfer to the leptons. If time-reversal invariance holds, f_+ and f_- are relatively real. $K_{\mu 3}$ experiments measure f_+ and f_-, while K_{e3} experiments are sensitive only to f_+ because the small electron mass makes the f_- term negligible.

(a) $K_{\mu 3}$ experiments. Analyses of $K_{\mu 3}$ data frequently assume a linear dependence of f_+ and f_- on t, i.e.,

$$f_{\pm}(t) = f_{\pm}(0)[1 + \lambda_{\pm}(t/m_\pi^2)] . \qquad (2)$$

Most $K_{\mu 3}$ data are adequately described by Eq. (2) for f_+ and a constant f_- (i.e., $\lambda_- = 0$). There are two equivalent parametrizations commonly used in these analyses:

(1) λ_+, $\xi(0)$ parametrization. Analyses of $K_{\mu 3}$ data often introduce the ratio of the two form factors

$$\xi(t) = f_{-}(t)/f_{+}(t) .$$

The $K_{\mu 3}$ decay distribution is then described by the two parameters λ_+ and $\xi(0)$ (assuming time reversal invariance and $\lambda_- = 0$). These parameters can be determined by three different methods:

Method A. By studying the Dalitz plot or the pion spectrum of $K_{\mu 3}$ decay. The Dalitz plot density is (see, e.g., Chounet et al.[1]):

$$\rho(E_\pi, E_\mu) \propto f_+^2(t)[A + B\xi(t) + C\xi(t)^2] ,$$

where

$$A = m_K(2E_\mu E_\nu - m_K E'_\pi) + m_\mu^2(\tfrac{1}{4}E'_\pi - E_\nu) ,$$

$$B = m_\mu^2(E_\nu - \tfrac{1}{2}E'_\pi) ,$$

$$C = \tfrac{1}{4}m_\mu^2 E'_\pi ,$$

$$E'_\pi = E_\pi^{\max} - E_\pi = (m_K^2 + m_\pi^2 - m_\mu^2)/2m_K - E_\pi$$

Here E_π, E_μ, and E_ν are, respectively, the pion, muon, and neutrino energies in the kaon center of mass. The density ρ is fit to the data to determine the values of λ_+, $\xi(0)$, and their correlation.

Method B. By measuring the $K_{\mu 3}/K_{e3}$ branching ratio and comparing it with the theoretical ratio (see, e.g., Fearing et al.[2]) as given in terms of λ_+ and $\xi(0)$, assuming μ-e universality:

$$\Gamma(K^{\pm}_{\mu 3})/\Gamma(K^{\pm}_{e3}) = 0.6457 + 1.4115\lambda_+ + 0.1264\xi(0)$$
$$+ 0.0192\xi(0)^2 + 0.0080\lambda_+\xi(0) ,$$

$$\Gamma(K^{0}_{\mu 3})/\Gamma(K^{0}_{e3}) = 0.6452 + 1.3162\lambda_+ + 0.1264\xi(0)$$
$$+ 0.0186\xi(0)^2 + 0.0064\lambda_+\xi(0) .$$

This cannot determine λ_+ and $\xi(0)$ simultaneously but simply fixes a relationship between them.

Method C. By measuring the muon polarization in $K_{\mu 3}$ decay. In the rest frame of the K, the μ is expected to be polarized in the direction **A** with $\mathbf{P} = \mathbf{A}/|\mathbf{A}|$, where **A** is given (Cabibbo and Maksymowicz[3]) by

$$\mathbf{A} = a_1(\xi)\mathbf{p}_\mu - a_2(\xi)\left[\frac{\mathbf{p}_\mu}{m_\mu}\left\{m_K - E_\pi + \frac{\mathbf{p}_\pi\cdot\mathbf{p}_\mu}{|\mathbf{p}_\mu|^2}(E_\mu - m_\mu)\right\} + \mathbf{p}_\pi\right] + m_K\,\mathrm{Im}\xi(t)(\mathbf{p}_\pi\times\mathbf{p}_\mu)\,.$$

If time-reversal invariance holds, ξ is real, and thus there is no polarization perpendicular to the K-decay plane. Polarization experiments measure the weighted average of $\xi(t)$ over the t range of the experiment, where the weighting accounts for the variation with t of the sensitivity to $\xi(t)$.

(2) λ_+, λ_0 *parametrization.* Most of the more recent $K_{\mu3}$ analyses have parametrized in terms of the form factors f_+ and f_0 which are associated with vector and scalar exchange, respectively, to the lepton pair. f_0 is related to f_+ and f_- by

$$f_0(t) = f_+(t) + [t/(m_K^2 - m_\pi^2)]f_-(t)\,.$$

Here $f_0(0)$ must equal $f_+(0)$ unless $f_-(t)$ diverges at $t = 0$. The earlier assumption that f_+ is linear in t and f_- is constant leads to f_0 linear in t:

$$f_0(t) = f_0(0)[1 + \lambda_0(t/m_\pi^2)]\,.$$

With the assumption that $f_0(0) = f_+(0)$, the two parametrizations, (λ_+, $\xi(0)$) and (λ_+, λ_0) are equivalent as long as correlation information is retained. (λ_+, λ_0) correlations tend to be less strong than (λ_+, $\xi(0)$) correlations.

The experimental results for $\xi(0)$ and its correlation with λ_+ are listed in the $K^\pm$ and K_L^0 sections of the Stable Particle Full Listings in section XIA, XIB, or XIC depending on whether method A, B, or C discussed above was used. The corresponding values of λ_+ are listed in subsection L+M.

Because recent experiments tend to use the (λ_+, λ_0) parametrization, we include a subsection L0 for λ_0 results. Wherever possible we have converted $\xi(0)$ results into λ_0 results and vice versa.

See the 1982 version of this note[4] for additional discussion of the $K_{\mu3}^0$ parameters, correlations, and conversion between parametrizations, and also for a comparison of the experimental results.

(b) K_{e3} *experiments.* Analysis of K_{e3} data is simpler than that of $K_{\mu3}$ because the second term of the matrix element assuming a pure vector current [Eq. (1) above] can be neglected. Here f_+ is usually assumed to be linear in t, and the linear coefficient λ_+ of Eq. (2) is determined.

If we remove the assumption of a pure vector current, then the matrix element for the decay, in addition to the terms in Eq. (2), would contain

$$+\,2m_K f_S \bar{\ell}(1+\gamma_5)\nu$$

$$+\,(2f_T/m_K)(P_K)_\lambda(P_\pi)_\mu \bar{\ell}\sigma_{\lambda\mu}(1+\gamma_5)\nu\,,$$

where f_S is the scalar form factor, and f_T is the tensor form factor. In the case of the K_{e3} decays where the f_- term can be neglected, experiments have yielded limits on $|f_S/f_+|$ and $|f_T/f_+|$.

The K_{e3} results for λ_+, $|f_S/f_+|$, and $|f_T/f_+|$ are listed in the subsections L+M, FS, and FT, respectively, of the $K^\pm$ and K_L^0 sections of the Stable Particle Full Listings.

References

1. L.M. Chounet, J.M. Gaillard, and M.K. Gaillard, Phys. Rep. **4C**, 199 (1972).
2. H.W. Fearing, E. Fischbach, and J. Smith, Phys. Rev. **D2**, 542 (1970).
3. N. Cabibbo and A. Maksymowicz, Phys. Lett. **9**, 352 (1964).
4. Particle Data Group, Phys. Lett. **111B**, 73 (1982).

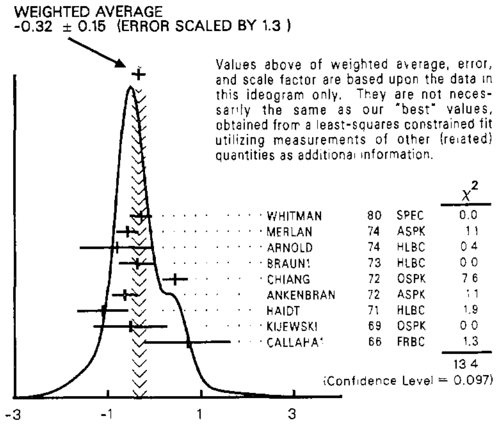
$K^\pm$ FORM FACTORS

```
IN THE FORM FACTOR COMMENTS, THE FOLLOWING ABBREVIATIONS ARE USED.
F+ AND F- ARE FORM FACTORS FOR THE VECTOR MATRIX ELEMENT.
FS AND FT REFER TO THE SCALAR AND TENSOR TERM.
FO = (F+) + (F-)*T/(MK**2-MPI**2)
L+, L- AND LO ARE THE LINEAR EXPANSION COEFFS. OF F+, F- AND FO.
L+ REFERS TO THE KMU3 VALUE EXCEPT IN THE KE3 SECTIONS.
DXI/DL IS THE CORRELATION BETWEEN XI(0) AND L+ IN KMU3.
DLO/DL+ IS THE CORRELATION BETWEEN LO AND L+ IN KMU3.
T  = MOMENTUM TRANSFER TO THE PI IN UNITS OF MPI**2.
DP = DALITZ PLOT ANALYSIS
PI = PI SPECTRUM ANALYSIS
MU = MU SPECTRUM ANALYSIS
POL= MU POLARIZATION ANALYSIS
BR = KMU3/KE3 BRANCHING RATIO ANALYSIS
E  = POSITRON OR ELECTRON SPECTRUM ANALYSIS
RC = RADIATIVE CORRECTIONS
```

$\xi_A = f_-/f_+$ **(DETERMINED FROM SPECTRA)**

```
XIA      76  (+1.8)     (0.6)               BROWN      62 XEBC +  DP+BR, L+=0
XIA      87  (+0.7)     (0.5)               GIACOMELL  64 EMUL +  MU+BR RVUE, L+=0
XIA J        (-0.08)    (0.7)               JENSEN     64 XEBC +  DP+BR(KMU3,KE3)
XIA    2648   (0.0)     (1.1)      (0.9)    CALLAHA1   66 FRBC +  MU, L+=0, T UNKN
XIA  C 444   +0.72       0.93               CALLAHA1   66 FRBC +  PI, DXI/DL=-17
XIA      78  (-0.5)     (0.9)               EISLER     68 HLBC +  PI,L+=0,NO DX/DL
XIA  K2041   -0.5        0.8                KIJEWSKI   69 OSPK +  PI, DXI/DL=-26
XIA  H3240   -1.1        0.56               HAIDT      71 HLBC +  DP, DXI/DL=-29
XIA  A4025   -0.62       0.28               ANKENBRAN  72 ASPK +  PI, DXI/DL=-12
XIA  B3480   +0.45       0.28               CHIANG     72 OSPK +  DP, DXI/DL=-15
XIA  D1897   -0.36       0.40               BRAUN1     73 HLBC +  DP, DXI/DL=-19
XIA  N 490   -0.8        0.8                ARNOLD     74 HLBC +  DP, DXI/DL=-20
XIA  M6527   -0.57       0.24               MERLAN     74 ASPK +  DP, DXI/DL= -9
XIA    3973  -0.27       0.25               WHITMAN    80 SPEC +  DP, DXI/DL=-17
XIA           . . . . . . . . . .
XIA AVG      -0.32       0.15    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
XIA FIT      -0.35       0.15   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.6)  |
                        (SEE IDEOGRAM BELOW)

XIA      FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
XIA J    JENSEN 64 GIVES L+M=L+E=-.020+-.027. DXI/DL UNKNOWN. INCLUDES
XIA J    SHAKLEE 64 XIB(KMU3/KE3).
XIA  C   CALLAHAN 66 TABLE 1 (PI ANAL) GIVES DXI/DL=(.72-.05)/(0-.04)=-17,
XIA  C   ERROR RAISED FROM .80 TO AGREE WITH DXI0=.37 FOR FIXED L+.
XIA  K   KIJEWSKI 69 FIG. 17 WAS USED TO OBTAIN DXI/DL AND ERRORS.
XIA  H   HAIDT 71 TABLE 8 (DP ANAL) GIVES DXI/DL=(-1.1+0.5)/(.050-.029)=-29,
XIA  H   ERROR RAISED FROM .50 TO AGREE WITH DXI0=.20 FOR FIXED L+.
XIA  A   ANKENBRANDT 72 FIG. 3 WAS USED TO OBTAIN DXI/DL.
XIA  B   CHIANG 72 FIG. 10 WAS USED TO OBTAIN DXI/DL.
XIA  B   FIT HAD L-=L+ BUT WOULD NOT CHANGE FOR L-=0.  L.PONDROM,PRIV.COM.74
XIA  D   BRAUN1 73 GIVES XI(T)=-.34+-.20, DXI(T)/DL+=-14 FOR L+=.027, T=6.6.
XIA  D   WE CALCULATE ABOVE XI(0) AND DXI(0)/DL+ FOR THEIR L+=.025+-.017 .
XIA  N   ARNOLD 74 FIG. 4 WAS USED TO OBTAIN XIA AND DXI/DL.
XIA  M   MERLAN 74 FIG.5 WAS USED TO OBTAIN DXI/DL.
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$\xi_A = f_-/f_+$ for $K^+_{\mu3}$ decay spectra

$\xi_B = f_-/f_+$ (DETERMINED FROM $K_{\mu3}/K_{e3}$)

```
XIB      THE KMU3/KE3 BRANCHING RATIO FIXES A RELATIONSHIP BETWEEN XI(0)
XIB      AND L+.  WE QUOTE THE AUTHORS XI(0) AND ASSOCIATED L+ BUT DO NOT
XIB      AVERAGE BECAUSE THE L+ VALUES DIFFER.  THE FIT RESULT AND SCALE
XIB      FACTOR GIVEN IN THE ABOVE NOTE ON KL3 FORM FACTORS ARE NOT OBTAINED
XIB      FROM THESE XIB VALUES.  INSTEAD THEY ARE OBTAINED DIRECTLY FROM THE
XIB      FITTED KMU3/KE3 RATIO (R29), WITH THE EXCEPTION OF HEINTZE 77.
XIB          (-0.17)    (0.75)    (0.99) SHAKLEE   64 XEBC +  BR, L+=0
XIB          (+0.6)     (0.5)            BISI 1    65 HBC  +  BR, L+=0
XIB     500  (+0.8)     (0.6)            CUTTS     65 OSPK +  BR, L+=0
XIB     636  (+0.4)     (0.4)            CALLAHA1  66 FRBC +  BR, L+=0
XIB     306  (+0.75)    (0.50)           AUERBACH  67 OSPK +  BR, L+=0
XIB B 5601   (-0.08)    (0.15)           BOTTERIL2 68 ASPK +  BR,L+=.023+-.008
XIB E 1398   (-0.60)    (0.20)           EICHTEN   68 HLBC +  BR, SEE NOTE E
XIB     986  (+1.0)     (0.6)            GARLAND   68 OSPK +  BR, L+=0
XIB          (+0.91)    (0.82)           ZELLER    69 ASPK +  BR, L+=.023
XIB  B       (-0.35)    (0.22)           BOTTERIL  70 OSPK +  BR,L+=.045+-.015
XIB  E1505   (-0.81)    (0.27)           HAIDT     71 HLBC +  BR,L+=.028,FIG.8
XIB   5825    (0.0)     (0.15)           CHIANG    72 OSPK +  BR,L+=.03,FIG.10
XIB  H 55K    -0.12      0.12            HEINTZE   77 CNTR +  BR,L+=.029
XIB          . . . . . . . . . .
XIB FIT       -0.35      0.15   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.6)  |

XIB      FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
XIB  B   BOTTERIL 70 IS REEVALUATION OF BOTTERIL 2 68 WITH DIFFERENT L+.
XIB E    EICHTEN 68 HAS L+=.023+-.008, T=4, INDEP. OF L-. REPL. BY HAIDT 71.
XIB  H   CALCULATED BY US FROM LO AND L+ GIVEN BELOW.
```

$\xi_C = f_-/f_+$ (DETERMINED FROM μ POLARIZATION IN $K_{\mu3}$)

```
XIC      THE MU POLARIZATION IS A MEASURE OF XI(T). NO ASSUMPTIONS ON L+-
XIC      NECESSARY, T (WEIGHTED BY SENSITIVITY TO XI0) SHOULD BE SPECIFIED.
XIC     IN L+,XI(0) PARAMETERIZATION THIS IS XI(0) FOR L+=0.  DXI/DL=XI*T.
XIC      FOR RAD. CORR. TO MUON POLARIZATION IN KMU3 SEE GINSBERG 71.
XIC T 2100  (+1.2)     (2.4)     (1.8)  BORREANI  65 HLBC +  POLARIZATION
XIC T  500 BTWN -4.0 AND +1.7           CUTTS     65 OSPK +  LONG. POL.
XIC T  397  (-1.4)     (1.8)            CALLAHA1  66 FRBC +  TOTAL POL.
XIC T 2950  (-0.7)     (0.9)     (3.3)  CALLAHA1  66 FRBC +  LONG. POL.
XIC  B6000   -1.0       0.3             BETTELS   68 HLBC +  TOTAL POL. T=4.9
XIC  C3133   -0.95      0.3             CUTTS     69 OSPK +  TOTAL POL. T=4.0
XIC M  40K  (-0.64)    (0.27)           MERLAN    74 ASPK +  POL,DXI/DL=+1.7
XIC  D1585   -0.25      1.20            BRAUN     75 HLBC +  POL. T=4.2
XIC         . . . . . . . . . .
XIC AVG      -0.95      0.21    AVERAGE
XIC FIT      -0.35      0.15   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.6)  |

XIC      FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
XIC T    T VALUE NOT GIVEN.
XIC  B   BETTELS 68 DXI/DL=XI*T=-1.0*4.9=-4.9 .
XIC  C   CUTTS 69 T=4.0 WAS CALCULATED FROM FIG.8. DXI/DL=XI*T=-.95*4=-3.8 .
XIC M    MERLAN 74 POLARIZATION RESULT (FIG.5) NOT POSSIBLE.  SEE DISCUSSION
XIC M    OF POLARIZATION EXPERIMENTS IN NOTE ON KL3 FORM FACTORS ABOVE.
XIC  D   BRAUN 75 DXI/DL=XI*T=-.25*4.2=-1.0 .
```

IMAGINARY PART OF ξ (TEST OF T REVERSAL)

```
IXI    2648    0.0       1.0               CALLAHA1  66 FRBC +  MU
IXI     397   +1.6       1.3               CALLAHA1  66 FRBC +  TOTAL POL.
IXI    2950    0.5       1.4       0.5     CALLAHA1  66 FRBC +  LONG. POL.
IXI    6000   -0.1       0.3               BETTELS   68 HLBC +  TOTAL POL.
IXI    3133   -0.3       0.3       0.4     CUTTS     69 OSPK +  TOTAL POL. FIG.7
IXI     20M   -0.016     0.025             CAMPBELL  81 CNTR +  POL.
IXI B   32M  (-0.010)   (0.019)            BLATT     83 CNTR    POLARIZATION
IXI B   COMBINED RESULT OF MORSE 80 (K0MU3) AND CAMPBELL 81 (K+MU3).
IXI          . . . . . . . . . .
IXI AVG       -0.017     0.025   AVERAGE
```

λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN $K_{\mu3}$ DECAY)

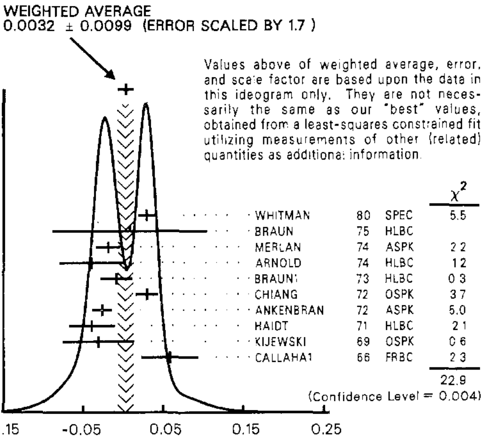
```
L+M      SEE ALSO THE CORRESPONDING ENTRIES AND FOOTNOTES IN SECTIONS XIA,
L+M      XIC, AND LO.
L+M      FOR RAD.COR. OF KMU3 DP SEE GINSBURG 70 AND BECHERRAWY 70.
L+M     444    0.0       0.05              CALLAHA1  66 FRBC +  PI
L+M    2041    0.009     0.026             KIJEWSKI  69 OSPK +  PI
L+M    3240    0.050     0.018             HAIDT     71 HLBC +  DP
L+M   A4025    0.024     0.019             ANKENBRAN 72 ASPK +  PI
L+M    3480   -0.006     0.015             CHIANG    72 OSPK +  DP
L+M    1897    0.025     0.017             BRAUN1    73 HLBC +  DP
L+M     490    0.025     0.030             ARNOLD    74 HLBC +  DP
L+M    6527    0.027     0.019             MERLAN    74 ASPK +  DP
L+M    3973   +0.050     0.013             WHITMAN   80 SPEC +  DP
L+M          . . . . . . . . . .
L+M AVG        0.0272    0.0072  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
L+M FIT        0.033     0.008  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.6)  |

L+M      FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
L+M  A   ANKENBRANDT 72 L+ FROM FIG.3 TO MATCH DXI/DL. TEXT GIVES .024+-.022
```

λ_0 (LINEAR ENERGY DEPENDENCE OF f_0 IN $K_{\mu3}$ DECAY)

```
LO       WHEREVER POSSIBLE, WE HAVE CONVERTED THE ABOVE VALUES OF XI(0) INTO
LO       VALUES OF LO USING THE ASSOCIATED L+M AND DXI/DL.
LO W   444    +0.058    0.036             CALLAHA1  66 FRBC +  PI,DLO/DL+=-0.37
LO L  6000    -0.063   (0.024)            BETTELS   68 HLBC +  POL,DLO/DL+=+.60
LO L  3133    -0.056   (0.024)            CUTTS     69 OSPK +  POL,DLO/DL+=+.69
LO W  2041    -0.031    0.045             KIJEWSKI  69 OSPK +  PI,DLO/DL+=-1.10
LO W  3240    -0.039    0.029             HAIDT     71 HLBC +  DP,DLO/DL+=-1.34
LO W  4025    -0.026    0.013             ANKENBRAN 72 ASPK +  PI,DLO/DL+=+0.03
LO W  3480    +0.030    0.014             CHIANG    72 OSPK +  DP,DLO/DL+=-0.21
LO     D1897  -0.008    0.020             BRAUN1    73 HLBC +  DP,DLO/DL+=-0.53
LO       490  -0.040    0.040             ARNOLD    74 HLBC +  DP,DLO/DL+=-0.62
LO   B       (-0.017)  (0.011)            BRAUN     74 HLBC +  KMU3/KE3 VS. T
LO M  6527    -0.019    0.015             MERLAN    74 ASPK +  DP,DLO/DL+=+0.27
LO L  1585    +0.008    0.097             BRAUN     75 HLBC +  POL,DLO/DL+=+.92
LO     H 55K  +0.019   (0.010)            HEINTZE   77 SPEC +  BR,DLO/DL+=+0.03
LO      3973  +0.029    0.011             WHITMAN   80 SPEC +  DP,DLO/DL+=-0.37
LO          . . . . . . . . . .
LO  AVG        0.0032   0.0099  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)
LO  FIT       +0.004    0.007  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.6)  |
                        (SEE IDEOGRAM BELOW)

LO       FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
LO W     LO CALCULATED BY US FROM XI0, L+M, AND DXI/DL.
LO L     LO VALUE IS FOR L+=0.03  CALCULATED BY US FROM XI0 AND DXI/DL.
LO    D  THIS VALUE AND ERROR ARE TAKEN FROM BRAUN 75 BUT CORRESPOND TO THE
LO    D  BRAUN1 73 L+M RESULT.  DLO/DL+ IS FROM BRAUN1 73 DXI/DL IN XIA ABV.
LO   B   BRAUN 74 IS A COMBINED KMU3-KE3 RESULT.  IT IS NOT INDEPENDENT OF
LO   B   BRAUN1 73 (KMU3) AND BRAUN2 73 (KE3) FORM FACTOR RESULTS.
LO M     MERLAN 74 LO AND DLO/DL+ WERE CALCULATED BY US FROM XIA, L+M, AND
LO M     DXI/DL.  THEIR FIG.6 GIVES LO=-0.025+-0.012 AND NO DLO/DL+.
LO    H  HEINTZE 77 USES L+=0.029+-0.003.  DLO/DL+ ESTIMATED BY US.
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

λ_0 (Linear energy dependence of f_0, $K^+_{\mu3}$ decay)

λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN K_{e3} DECAY)

```
L+E      FOR RAD.COR. OF KE3 DP SEE GINSBURG 67 AND BECHERRAWY 70.
L+E     217   +0.036    0.045             BROWN     62 XEBC +  PI, NO RC
L+E     407   -0.010    0.029             JENSEN    64 XEBC +  PI, NO RC
L+E     230   -0.04     0.05              BORREANI  64 HBC  +  E+, NO RC
L+E     854    0.045    0.017     0.018   BELLOTT2  67 FBC  +  DP, USES RC
L+E    1393   +0.016    0.016             IMLAY     67 OSPK +  DP, NO RC
L+E     515   +0.028    0.013     0.014   KALMUS    67 FBC  +  E+, PI, NO RC
L+E     960    0.08     0.04              BOTTERIL1 68 ASPK +  E+, USES RC
L+E      90   -0.02     0.08      0.12    EISLER    68 HLBC +  PI, USES RC
L+E    1458    0.045    0.015             BOTTERIL  70 OSPK    PI, USES RC
L+E    2707    0.027    0.010             STEINER   71 HLBC +  DP, USES RC
L+E    4017    0.029    0.011             CHIANG    72 OSPK +  DP, RC NEGLIGBLE
L+E  A         0.027    0.008             BRAUN2    73 HLBC +  DP, NO RC
L+E B         (0.025)  (0.007)            BRAUN     74 HLBC +  KMU3/KE3 VS. T
L+E  A   BRAUN2 73 STATES THAT RC OF GINSBERG 67 WOULD LOWER L+E BY .002 BUT
L+E  A   THAT RC OF BECHERRAWY DISAGREES AND WOULD RAISE L+E BY .005 .
L+E B    BRAUN 74 IS A COMBINED KMU3-KE3 RESULT.  IT IS NOT INDEPENDENT OF
L+E B    BRAUN1 73 (KMU3) AND BRAUN2 73 (KE3) FORM FACTOR RESULTS.
L+E          . . . . . . . . . .
L+E AVG        0.0285   0.0043  AVERAGE
```

$|f_S/f_+|$ FOR K_{e3} DECAY

```
FS      RATIO OF SCALAR TO F+ COUPLINGS
FS             (0.18) OR LESS  CL=.90   BELLOTT2  67 HLBC
FS             (0.30) OR LESS  CL=.95   KALMUS    67 HLBC +
FS             (0.23) OR LESS  CL=.90   BOTTERIL1 68 ASPK
FS     2707     0.14      0.03    0.04  STEINER   71 HLBC +  L+,FS,FT,PHI FIT
FS     4017    (0.13) OR LESS  CL=.90   CHIANG    72 OSPK +
FS     2827     0.00      0.10          BRAUN     75 HLBC +
FS           . . . . . . . . . .
FS  AVG         0.125     0.044   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$|f_T/f_+|$ FOR K_{e3} DECAY

```
FT      RATIO OF TENSOR TO F+ COUPLINGS
FT             (0.58) OR LESS  CL=.90   BELLOTT2  67 HLBC
FT             (1.1)  OR LESS  CL=.95   KALMUS    67 HLBC +
FT             (0.58) OR LESS  CL=.90   BOTTERIL1 68 ASPK
FT     2707     0.24      0.16    0.14  STEINER   71 HLBC +  L+,FS,FT,PHI FIT
FT     4017    (0.75) OR LESS  CL=.90   CHIANG    72 OSPK +
FT     2827     0.07      0.37          BRAUN     75 HLBC +
FT           . . . . . . . . . .
FT  AVG         0.22      0.14    AVERAGE
```

f_T/f_+ FOR $K_{\mu3}$ DECAY

```
FTM     RATIO OF TENSOR TO F+ COUPLINGS
FTM    1585     0.02      0.12          BRAUN     75 HLBC
```

DECAY FORM FACTORS FOR $K^{\pm} \rightarrow \pi^{+}\pi^{-}e^{\pm}\nu$

```
KE4      GIVEN IN THE FOLLOWING PAPERS
KE4                                          BASILE    71 ASPK +
KE4                                          BEIER     73 OSPK +-
KE4                                          ROSSELET  77 SPEC +
```

REFERENCES FOR $K^{\pm}$

```
BIRGE    56 NC   4   834      BIRGE,PERKINS,PETERSON,STORK,WHITEHEA (LRL)
ILOFF    56 PR 102   927      ILOFF,GOLDHABER,LANNUTTI,GILBERT +    (LRL)
ALEXANDE 57 NC   6   478      ALEXANDER,JOHNSTON,OCEALLAIGH (DUBLIN INST)
COHEN    57 FUND.CONS.PHYS.   +CROWE,DUMOND       (ATOMICS INTER.+LRL+CIT)
COOMBES  57 PR 108 1348       +CORK,GALBRAITH,LAMBERTSON,WENZEL     (LBL)
EISENBER 58 NC   8   663      EISENBERG,KOCH,LOHRMANN,NIKOLIC +    (BERN)
BURROWES 59 PRL  2   117      BURROWES,CALDWELL,FRISCH,HILL +       (MIT)
TAYLOR   59 PR 114   359      S TAYLOR,HARRIS,OREAR,LEE,BAUMEL (COLUMBIA)

FREDEN   60 PR 118  564       S C FREDEN,F C GILBERT,R S WHITE      (LRL)
BARKAS   61 PR 124 1209       BARKAS,DYER,MASON,NORRIS,NICKOLS,SMIT (LRL)
BHOWMIK  61 NC  20  857       B BHOWMIK,P C JAIN,P C MATHUR  (DELHI UNIV)
FERRO-LU 61 NC   22  1087     FERRO-LUZZI,MILLER,MURRAY,ROSENFELD+  (LRL)
NORDIN   61 PR 123 2166       PAUL NORDIN JR                        (LRL)
ROE      61 PRL  7  346       ROE,SINCLAIR,BROWN,GLASER +       (MICH+LRL)
BOYARSKI 62 PR 128 2398       BOYARSKI,LOH,NIEMELA,RITSON           (MIT)
BROWN    62 PRL  8  450       BROWN,KADYK,TRILLING,ROE+        (LRL,MICH)
BARKAS   63 PRL 11   26       W H BARKAS,J N DYER,H H HECKMAN       (LRL)

BORREANI 64 PL    12 123      G BORREANI,G RINAUDO,A WERBROUCK    (TURIN)
CALLAHAN 64 PR   136 B 1463   A CALLAHAN,R MARCH,R STARK      (WISCONSIN)
CAMERINI 64 PRL   13 318      CAMERINI,CLINE,FRY,POWELL   (WISCONSIN+LRL)
CLINE    64 PRL   13 101      D CLINE, W F FRY                (WISCONSIN)
GIACOMEL 64 NC 34  1134       GIACOMELLI,MONTI,QUARENI+  (BOLOGNA,MUNICH)
GREINER  64 PRL   13 284      D GREINER, W OSBORNE, W BARKAS        (LRL)
JENSEN   64 PR   136 B1431    JENSEN,SHAKLEE,ROE,SINCLAIR          (MICH)
KALMUS   64 PRL    13   99    +KERNAN,PU,POWELL,DOWD           (LRL,WISC)
SHAKLEE  64 PR   136 B 1423   SHAKLEE,JENSEN,ROE,SINCLAIR          (MICH)

BIRGE    65 PR 139 B 1600     BIRGE,ELY,GIDAL,CAMERINI,CLINE + (LRL+WISC)
BISI     65 NC   35  768      BISI,BORREANI,CESTER,FERRARO +     (TORINO)
BISI 1   65 PR 139 B 1068     BORREANI,MARZARI-CHIESA,RINAUDO+   (TORINO)
BORREANI 65 PR 140 B1686      BORREANI,GIDAL,RINAUDO,CAFORIO+ (BARI,TORI)
CALLAHAN 65 PRL  15   129     A CALLAHAN,D CLINE              (WISCONSIN)
CAMERINI 65 NC 37 1795        +CLINE,GIDAL,KALMUS,KERNAN       (WISC+LRL)
CLINE    65 PL   15  293      A CLINE,W F FRY                 (WISCONSIN)
CUTTS    65 PR 138 B969       CUTTS,ELIOFF,STIENING                 (LRL)

DE MARCO 65 PR 140 B 1430     DE MARCO,GROSSO,RINAUDO       (TORINO+CERN)
FITCH    65 PR 140 B 1088     FITCH,QUARLES,WILKINS(PRINCETON+MT HOLYOKE)
GREINER  65 ARNS  15  67      QUOTED BY BARKAS                      (LRL)
STAMER   65 PR  138 B 440     STAMER,HUETTER,KOLLER,TAYLOR,GRAUMAN (STEV)
TRILLING 65 UCRL 16473        GEORGE H TRILLING                     (LRL)
    UPDATED FROM 1965 ARGONNE CONF., PAGE 5.
YOUNG    65 UCRL 16362        POH-SHIEN YOUNG (THESIS,BERKELEY)     (LRL)
    ALSO 67 PR 156 1464       P-S YOUNG,W.Z.OSBORNE,W.H.BARKAS      (LRL)

CALLAHA1 66 PR 150 1153       CALLAHAN,CAMERINI+(WISC,LRL,RIVERSIDE,BARI)
CALLAHAN 66 NC  44A 90        A C CALLAHAN                    (WISCONSIN)
CESTER   66 PL 21 343         CESTER,ESCHSTRUTH,ONEILL+  (PRINCETON-PENN)
    ALSO 67 AUERBACH, FOOTNOTE 1.

AUERBACH 67 PR 155  1505      +DOBBS,MANN,MCFARLANE,WHITE+    (PENN,PRIN)
    ALSO 74 PR D9 3216        ERRATUM
BELLOTT1 67 HEIDELBERG CONF   BELLOTTI,PULLIA                     (MILAN)
BELLOTT2 67 NC 52A  1287      BELLOTTI,FIORINI,PULLIA             (MILAN)
    ALSO 66 PL  20  690       BELLOTTI,FIORINI,PULLIA+            (MILAN)
BISI     67 PL 25B  572       BISI,CESTER,CHIESA,VIGONE          (TORINO)

BOTTERIL 67 PRL  19  982      BOTTERILL,BROWN,CORBETT,CULLIGAN + (OXFORD)
    ALSO 68 BOTTERIL
BOWEN    67 PR 154 1314       BOWEN,MANN,MCFARLANE,HUGHES+(PENN-PRINCETO)
CLINE1   67 HEIDELBERG CONF   CLINE,HAGGERTY,SINGLETON,FRY+   (WISCONSIN)
CLINE2   67 HERCEG NOVI TBL.4 D.CLINE,PROC.INTL.SCH.ON ELEM.PART.PHYSICS

FLETCHER 67 PRL  19  98       FLETCHER,BEIER,EDWRADS,+         (ILLINOIS)
FORD     67 PRL 18 1214       +LEMONICK,NAUENBERG,PIROUE      (PRINCETON)
IMLAY    67 PR 160  1203      IMLAY,ESCHSTRUTH,FRANKLIN+      (PRINCETON)
KALMUS   67 PR  159  1187     KALMUS,KERNAN                         (LRL)
ZINCHENK 67 RUTGERS(THESIS)   ZINCHENKO                         (RUTGERS)

BETTELS  68 NC 56A 1106       AACHEN-BARI-BERGEN-CERN-EP-NIJMEGEN-ORSAY+
    ALSO 71 HAIDT
BOTTERIL 68 PR 171 1402       BOTTERILL,BROWN,CLEGG,CORBETT +    (OXFORD)
BOTTERI1 68 PR 174 1661       BOTTERILL,BROWN,CLEGG,CORBETT +    (OXFORD)
BOTTERI2 68 PRL 21 766        BOTTERILL,BROWN,CLEGG,CORBETT +    (OXFORD)
BUTLER   68 UCRL-18420        +BLAND,GOLDHABER,GOLDHABER,HIRATA+    (LRL)
CHANG    68 PRL 20  510       CHANG,YODH,EHRLICH,PLANO+(MARYLAND,RUTGERS)

CHEN     68 PRL 20 73         CHEN,CUTTS,KIJEWSKI,STIENING +    (LRL,MIT)
EICHTEN  68 PL 27B 586        AACHEN-BARI-CERN-EP-ORSAY-PADOVA-VALENCIA
EISLER   68 PR   169  1090    EISLER,FUNG,MARATECK,MEYER,PLANO  (RUTGERS)
ESCHSTRU 68 PR   165  1487    ESCHSTRUTH,FRANKLIN,HUGHES+(PRINCETON,PENN)
GARLAND  68 PR   167  1225    +TSIPIS,DEVONS,ROSEN+  (COLUMBIA,RUTG,WISC)
MOSCOSO  68  THESIS           M L MOSCOSO               (UNIV PARIS ORSAY)

CUTTS    69 PR 184 1380       +STIENING,WIEGAND,DEUTSCH         (LRL,MIT)
    ALSO 68 PRL 20 955        CUTTS,STIENING,WIEGAND,DEUTSCH    (LRL,MIT)
DAVISON  69 PR   180 1333     +BACASTOW,BARKAS,EVANS,FUNG,PORTER+   (UCR)
ELY      69 PR   180 1319     ELY,GIDAL,HAGOPIAN,KALMUS+  (LOUC+WISC+LRL)
EMMERSON 69 PRL 23 393        EMMERSON,QUIRK                     (OXFORD)

HERZO    69 PR 186 1403       +BANNER,BEIER,BERTRAM,EDWARDS +       (ILL)
KIJEWSKI 69 UCRL-18433 THESIS P K KIJEWSKI                          (LBL)
LOBKOWIC 69 PR 185 1676       +MELISSINOS,NAGASHIMA,TEWKSBURY+ (ROCH,BNL)
    ALSO 66 PRL 17 548        LOBKOWICZ,MELISSINOS,NAGASHIM+   (ROCH+BNL)
MACEK    69 PRL  22   32      MACEK,MANN,MC FARLANE,ROBERTS+(PENN,TEMPLE)
MAST     69 PR   183 1200     +GERSHWIN,ALSTON-GARNJOST,BANGERTER+  (LRL)
ZELLER   69 PR   182 1420     ZELLER,HADDOCK,HELLAND,PAHL+     (UCLA,LRL)

BOTTERIL 70 PL 31B 325        +BROWN,CLEGG,CORBETT,CULLIGAN+        (OXF)
FORD     70 PRL 25 1370       +PIROUE,REMMEL,SMITH,SOUDER          (PRIN)
GRAUMAN  70 PR D1 1277        +KOLLER,TAYLOR,PANDOULAS+  (STEV,SETO,LEHI)
    ALSO 69 PRL 23 737        +KOLLER,TAYLOR,PANDOULAS+  (STEV,SETO,LEHI)
MACEK    70 PR D1 1249        +MANN,MCFARLANE,ROBERTS              (PENN)
MALTSEV  70 SJNP 10 678       +PESTOVA,SOLODOVNIKOVA,FADEEV +      (JINR)
PANDOULA 70 PR D2 1205        +TAYLOR,KOLLER,GRAUMAN +        (STEV,SETO)

BASILE   71 PL 36B 619        +BREHIN,DIAMANT-BERGER,KUNZ+    (SACL+GEVA)
BOURQUIN 71 PL 36B 615        +BOYMOND,EXTERMANN,MARASCO+     (GEVA,SACL)
HAIDT    71 PR D3 10          AACHEN+BARI+CERN+EP+NIJMEGEN+ORSAY+PADOVA+
    ALSO 69 PL  29B 691       +(AACH,BARI,CERN,EPOL,NIJM,ORSAY,PADO,TORI)
KLEMS    71 PR D4 66          +HILDEBRAND,STIENING             (CHIC,LRL)
    ALSO 70 PRL 24 1086       KLEMS,HILDEBRAND,STIENING        (LRL,CHIC)
    ALSO 70 PRL 25 473        KLEMS,HILDEBRAND,STIENING        (LRL,CHIC)

KUNSELMA 71 PL 34B 485        R. KUNSELMAN                      (WYOMING)
OTT      71 PR D3 52          OTT,PRITCHARD                        (LOQM)
ROMANO   71 PL 36B 525        +RENTON,AUBERT,BURBAN-LUTZ (BARI,CERN,ORSA)
SCHWEINB 71 PL 36B 246        AACHEN+BELGIUM+CERN+NIJMEGEN+PADOVA COLLAB
STEINER  71 PL 36B 521        AACHEN+BARI+CERN+EPOL+ORSA+NIJM+PADO+TORIN

ABRAMS   72 PRL 29 1118       +CARROLL,KYCIA,LI,MENES,MICHAEL +     (BNL)
ANKENBRA 72 PRL 28 1472       ANKENBRANDT,LARSEN+    (BNL+LASL+FNAL+YALE)
AUBERT   72 NC 12A 509        +HEUSSE,PASCAUD,VIALLE+    (ORSA+BRUX+EPOL)
BEIER    72 PRL 29 678        +BUCHHOLZ,MANN,PARKER        (PENNSYLVANIA)
CHIANG   72 PR D6 1254        +ROSEN,SHAPIRO,HANDLER,OLSEN+   (ROCH+WISC)

CLARK    72 PRL 29 1274       +CORK,ELIOFF,KERTH,MCREYNOLDS,NEWTON+ (LBL)
EDWARDS  72 PR D5 2720        +BEIER,BERTRAM,HERZO,KOESTER +        (ILL)
FORD     72 PL 38B 335        +PIROUE,REMMEL,SMITH,SOUDER     (PRINCETON)
HOFFMAST 72 NP B36 1          HOFFMASTER,KOLLER,TAYLOR+  (STEV+SETO+LEHI)

ABRAMS   73 PRL 30 500        +CARROLL,KYCIA,LI,MENES,MICHAEL +     (BNL)
BACKENST 73 PL 43B 431        BACKENSTOSS,BAMBERGER+(CERN+KARL+HEID+STOH)
BEIER    73 PRL 30 399        +BUCHHOLZ,MANN,PARKER,ROBERTS        (PENN)
BRAUN1   73 PL 47B 182        AACHEN+BARI+BRUSSELS+CERN COLLABORATION
    ALSO 75 BRAUN
BRAUN2   73 PL 47B 185        AACHEN+BARI+BRUSSELS+CERN COLLABORATION
    ALSO 75 BRAUN
CABLE    73 PR D8 3807        +HILDEBRAND,PANG,STIENING         (EFI+LBL)

LJUNG    73 PR D8 1307        D.LJUNG,D.CLINE                      (WISC)
    ALSO 72 PRL 28 523        D.LJUNG                              (WISC)
    ALSO 72 PRL 28 1287       D.CLINE,D.LJUNG                      (WISC)
    ALSO 69 PRL 23 326        CAMERINI,LJUNG,SHEAFF,CLINE          (WISC)
LUCAS1   73 PR D8 719         LUCAS,TAFT,WILLIS                    (YALE)
LUCAS2   73 PR D8 727         LUCAS,TAFT,WILLIS                    (YALE)
PANG     73 PR D8 1989        +HILDEBRAND,CABLE,STIENING   (EFI+ARIZ+LBL)
    ALSO 72 PL 40B 699        CABLE,HILDEBRAND,PANG,STIENING    (EFI+LBL)
SMITH    73 NP B60 411        +BOOTH,RENSHALL,JONES+ (GLAS+LIVP+OXF+RHEL)

ARNOLD   74 PR D9 1221        C L ARNOLD,B P ROE,D SINCLAIR        (MICH)
BRAUN    74 PL 51B 393        +CORNELSSEN,MARTYN +  (AACH+BARI+BRUX+CERN)
CENCE    74 PR D10 776        +HARRIS,JONES,MORGADO +     (HAWA+LBL+WISC)
    ALSO 73 THESIS (UNPUBL.)  D B CLARKE                           (WISC)
KUNSELMA 74 PR C9 2469        R.KUNSELMAN                          (WYOM)
MERLAN   74 PR D9 107         +KASHA,WANDERER,ADAIR+      (YALE+BNL+LASL)
WEISSENB 74 PL 48B 474        WEISSENBERG,EGOROV,MINERVINA +  (ITEP+LEBD)

BLOCH    75 PL 56B 201        +BREHIN,BUNCE,DEVAUX+           (SACL+GEVA)
BRAUN    75 NP B89 210        +CORNELSSEN,MARTYN+   (AACH+BARI+BRUX+CERN)
CHENG    75 NP A254 381       +ASANO,CHEN,DUGAN,HU,WU,HUGHES+ (COLU+YALE)
HEARD1   75 PL 55B 324        +HEINTZE,HEINZELMANN+           (CERN+HEID)
HEARD2   75 PL 55B 327        +HEINTZE,HEINZELMANN+           (CERN+HEID)
SHEAFF   75 PR D12 2570       M. SHEAFF                            (WISC)
SMITH    75 NP B91 45         +BOOTH,RENSHALL,JONES+ (GLAS+LIVP+OXF+RHEL)

BERTRAND 76 NP B114 387       +SACTON +         (BRUX+UBEL+DUUC+LOUC+WARS)
BLOCH    76 PL 60B 393        +BUNCE,DEVAUX,DIAMANT-BERGER+   (GEVA+SACL)
BRAUN    76 LNC 17 521        +MARTYN,ERRIQUEZ +    (AACH+BARI+BELG+CERN)
DIAMANTB 76 PL 62B 485        DIAMANT-BERGER,BLOCH,DEVAUX +   (SACL+GEVA)
HEINTZE  76 PL 60B 302        +HEINZELMANN,IGO-KEMENES,MUNDHENKE+  (HEID)
SMITH    76 NP B109 173       +BOOTH,RENSHALL,JONES+ (GLAS+LIVP+OXF+RHEL)
WEISSENB 76 NP B115 55        WEISSENBERG,EGOROV,MINERVINA+   (ITEP+LEBD)

ABRAMS   77 PR D15 22         +CARROLL,KYCIA,LI,MICHAEL,MOCKETT +   (BNL)
DEVAUX   77 NP B126 11        +BLOCH,DIAMANT-BERGER,MAILLARD+ (SACL+GEVA)
HEINTZE  77 PL 70B 482        +HEINZELMANN,IGO-KEMENES,+      (HEID+CERN)
ROSSELET 77 PR D15 574        +EXTERMANN,FISCHER,GUISAN +     (GEVA+SACL)
BARKOV   79 NP B148 53        +VASSERMAN,ZOLOTOREV,KRUPIN+    (NOVO+KIAE)
HEINTZE  79 NP B149 365       +HEINZELMANN,IGO-KEMENES+       (HEID+CERN)

WHITMAN  80 PR D21 652        +ABRAMS,CARROLL,KYCIA,LI+    (ILLC+BNL+ILL)
ASANO    81 PL 107B 159       +KIKUTANI,KUROKAWA,MIYACHI+ (KEK+TOKY+OSAK)
CAMPBELL 81 PRL 47 1032       +BLACK,BLATT,KASHA,SCHMIDT +     (YALE+BNL)
    ALSO 83 BLATT
LUM      81 PR D23 2522       +WIEGAND,KESSLER,DESLATTES,SEKI+ (LBL+NBS+)
LYONS    81 ZPHY C10 215      +ALBAJAR,MYATT                        (OXF)
ASANO    82 PL 113B 195       +KIKUTANI,KUROKAWA,MIYACHI+ (KEK+TOKY+OSAK)
COOPER   82 PL 112B 97        +GUY,MICHETTE,TYNDEL,VENUS             (RL)
BLATT    83 PR D27 1056       +ADAIR,BLACK,CAMPBELL,KASHA+     (YALE+BNL)
HAYANO   84 PRL 52 329        +YAMANAKA,TANIGUCHI,ISHIKAWA+    (TOKY+KEK)
AKIBA    85 PR D32 2911       +ISHIKAWA,IWASAKI+     (TOKY+TINT+TSUK+KEK)

         QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA LISTINGS

BLOCK    62 CERN CONF 371     BLOCK,LENDINARA,MONARI       (NWES+BOLOGNA)

                              PAPERS NOT REFERRED TO IN DATA LISTINGS

BRENE    61 NP 22 553         BRENE,EGARDT,QVIST                   (NORD)
BIRGE    63 PRL  11  35       BIRGE,ELY,GIDAL,CAMERINI +  (LRL+WISC+BARI)
ADAIR    64 PL 12  67         ADAIR,LEIPUNER                   (YALE,BNL)
CABIBBO  64 PL   9 352        CABIBBO,MAKSYMOWICZ                  (CERN)
    ALSO 64 PL 11 360         CABIBBO,MAKSYMOWICZ                  (CERN)
    ALSO 65 PL 14  72         CABIBBO,MAKSYMOWICZ                  (CERN)

CABIBBO  66 BERKELEY CONF 33  CABIBBO                              (CERN)
GINSBERG 67 PR 162  1570      EDWARD S GINSBERG         (U. MASS BOSTON)
WILLIS   67 HEIDELBERG 273    W J WILLIS -RAPPORTEUR TALK          (YALE)
CRONIN   68 VIENNA CONF 241   RAPPORTEUR TALK                 (PRINCETON)
HAIDT 2  69 PL 29B 696        + (AACH,BARI,CERN,EPOL,NIJM,ORSA,PADO,TORI)

BARDIN   70 PL 32B 121        BARDIN,BILENKY,PONTECORVO            (JINR)
BECHERRA 70 PR D1 1452        T.BECHERRAWY                         (ROCH)
FEARING  70 PR D3 542         +FISCHBACK,SMITH                (STON+BOHR)
GAILLARD 70 CERN 70-14        M K GAILLARD, L M CHOUNET       (CERN+ORSA)
GINSBERG 70 PR D1 229         E S GINSBERG                    (IIT HAIFA)

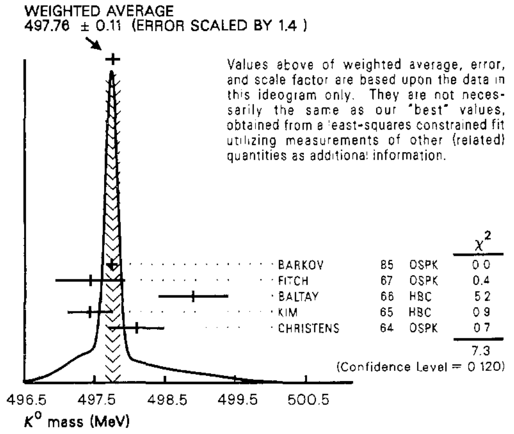
GINSBERG 71 PR D4 2893        E S GINSBERG                          (MIT)
CHOUNET  72 PL 4C 199         (PHYS. REPTS.)CHOUNET,2*GAILLARD(ORSA+CERN)
```

K^0

$I(J^P)=\frac{1}{2}(0^-)$

K^0 MASS (MeV)

```
M           498.1      0.4             CHRISTENS 64 OSPK
M     2223  497.44     0.33            KIM       65 HBC    K0 FROM PBAR P
M     4500  498.9      0.5             BALTAY    66 HBC    K0 FROM PBAR P
M           497.44     0.50            FITCH     67 OSPK
M      780  497.742    0.085           BARKOV    85 OSPK   E+ E- TO KL KS
M          . . . . . . . . . .
M   AVG     497.76     0.11   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
M   FIT     497.718    0.069  FROM FIT
                       (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

K^0 − $K^\pm$ MASS DIFFERENCE (MeV)

```
D            3.9      0.6             ROSENFELD 59 HBC   -
D            5.4      1.1             CRAWFORD  59 HBC   +
D        9   3.90     0.25            BURNSTEIN 65 HBC   -
D        7   3.71     0.35            KIM       65 HBC   -   K- P TO K0 N
D      417   3.95     0.21            HILL      68 DBC   +   K+D TO K0PP
D          . . . . . . . . .
D   AVG      3.92     0.14    AVERAGE
D   FIT      4.051    0.070  FROM FIT
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REFERENCES FOR K^0

```
CRAWFORD 59 PRL   2  112       CRAWFORD,CRESTI,GOOD,STEVENSON,TICHO  (LRL)
ROSENFEL 59 PRL   2  110       A H ROSENFELD,F SOLMITZ,R D TRIPP     (LRL)
CHRISTEN 64 PRL 13 138         CHRISTENSON,CRONIN,FITCH,TURLAY (PRINCETON)
BURNSTEI 65 PR   138 B 895     R A BURNSTEIN,H A RUBIN          (MARYLAND)
KIM      65 PR  140 B 1334     J K KIM,L KIRSCH,D MILLER        (COLUMBIA)

BALTAY   66 PR  142   932      BALTAY,SANDWEISS,STONEHILL +     (YALE+BNL)
FITCH    67 PR  164  1711      FITCH,ROTH,RUSS,VERNON          (PRINCETON)
HILL     68 PR  168  1534      HILL,ROBINSON,SAKITT,CANTER  (BNL,CARNEGIE)
BARKOV   85 JETPL 42 139       +BLINOV,VASSERMAN+                   (NOVO)
```

K_S^0

$I(J^P)=\frac{1}{2}(0^-)$ SHORT-LIVED K^0

K_S^0 MEAN LIFE (units 10^{-10} sec)

```
T       KS MEAN LIFE (PRE-1971 EXPERIMENTS)
T   O   90   (1.07)   (0.13)   (0.13) BOLDT     58 CC
T      512    0.94     0.05     0.05  CRAWFORD  59 HBC
T   O   63   (1.09)   (0.18)   (0.15) BOWEN     60 CC
T   O   OLD EXPTS WITH LOW STATISTICS NOT INCLUDED IN AVERAGE.
T      378    0.94     0.05     0.05  BERTANZA  62 HBC
T      503    0.87     0.05           CHRETIEN  63 HLBC
T      545    0.86     0.04           KREISLER  64 OSPK
T             0.866    0.016          ALFF-STEI 66 OSPK
T      572    0.90     0.06     0.05  AUERBACH  66 OSPK
T     4500    0.92     0.04           BALTAY    66 HBC
T   B        (0.904)  (0.024)         BOTT-BODE 66 OSPK
T     5000    0.843    0.013          KIRSCH    66 HBC
T    19994    0.856    0.008          DONALD    68 HBC
T   H 20000   0.872    0.009          HILL      68 DBC
T           . . . . . . . . . .
T   AVG       0.8641   0.0065   0.0065 AVERAGE (ERROR INCL. SCALE FACTOR OF 1.3)
```

```
T       KS MEAN LIFE (POST-1971 EXPERIMENTS)
T        THESE VALUES ARE USED TO DETERMINE THE STABLE PARTICLE SUMM. TABLE
T        VALUES OF THE KS MEAN LIFE AND RATES.
T  H   50K    0.8958   0.0045          SKJEGGEST 72 HBC
T   F 2173   (0.867)  (0.024)          FACKLER   73 OSPK
T       6M    0.8937   0.0048          GEWENIGER 74 ASPK
T  C          0.8913   0.0032          CARITHERS 75 SPEC
T      26K    0.881    0.009           ARONSON   76 SPEC
T   A        (0.905)  (0.007)          ARONSON   82 SPEC    E=30-110 GEV
T           . . . . . . . . . .
T   AVG       0.8923   0.0022   0.0022 AVERAGE
T   FIT       0.8923   0.0022 FROM FIT

                   COMMENTS
T  H     HILL 68 HAS BEEN CHANGED BY THE AUTHORS FROM THE PUBLISHED VALUE
T  H     (0.865+-0.009) BECAUSE OF A CORRECTION IN THE SHIFT DUE TO ETA+-.
T  H     SKJEGGESTAD 72 AND HILL 68 GIVE DETAILED DISCUSSIONS OF SYSTEMATICS
T  H     ENCOUNTERED IN THIS TYPE OF EXPERIMENT.
T   B    KS MEAN LIFE NOT THE PRIMARY QUANTITY MEASURED IN THIS EXPT.
T   F    FACKLER 73 DOES NOT INCLUDE SYSTEMATIC ERRORS.
T  C     CARITHERS 75 VALUE IS FOR KL-KS MASS DIFFERENCE DM=.5348+-.0021.
T  C     THE DM DEPENDENCE OF THE TOTAL DECAY RATE (INVERSE MEAN LIFE) IS
T  C     GAMMA(KS)=((1.122+-.004)+.16*(DM-.5348)/DM)*10**10 /SEC.
T  C     VALUE WOULD NOT CHANGE WITH OUR CURRENT DM=.5349+-.0022.
T   A    ARONSON 82 FIND THAT KS MEAN LIFE MAY DEPEND ON THE KAON ENERGY.
```

K_S^0 PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_S^0 \to \pi^+\pi^-$	140+ 140
P2	$K_S^0 \to \pi^0\pi^0$	135+ 135
P3	$K_S^0 \to \mu^+\mu^-$	106+ 106
P4	$K_S^0 \to e^+e^-$	.511+.511
P5	$K_S^0 \to \pi^+\pi^-\gamma$	140+ 140+ 0
P6	$K_S^0 \to \gamma\gamma$	0+ 0
P7	$K_S^0 \to 3\pi^0$	135+ 135+ 135
P8	$K_S^0 \to \pi^+\pi^-\pi^0$	140+ 140+ 135

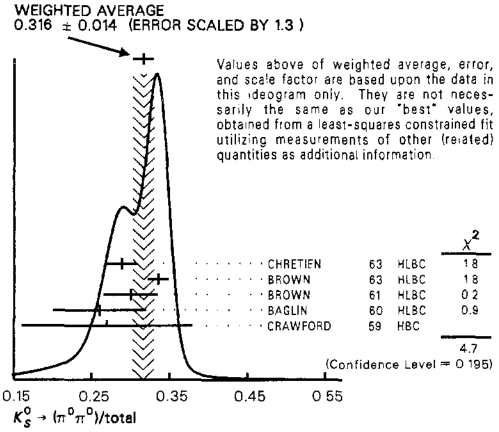
K_S^0 BRANCHING RATIOS

$K_S^0 \to (\pi^+\pi^-)$/total (P1)

```
R1             0.68      0.04             CRAWFORD  59 HBC
R1             0.70      0.08             COLUMBIA  60 HBC
R1  U         (0.740)   (0.024)           ANDERSON  62 HBC
R1 U  3447     0.670     0.010            DOYLE     69 HBC     PI- P TO LAM K0
R1  U   ANDERSON RESULT NOT PUBLISHED, EVENTS ADDED TO DOYLE SAMPLE
R1           . . . . . . . . . .
R1  AVG        0.6710    0.0096  AVERAGE
R1  FIT        0.6861    0.0024 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K_S^0 \to (\pi^0\pi^0)$/total (P2)

```
R2             0.27      0.11             CRAWFORD  59 HBC
R2             0.26      0.06             BAGLIN    60 HLBC
R2             0.30      0.035            BROWN     61 HLBC
R2      1066   0.335     0.014            BROWN     63 HLBC
R2       198   0.288     0.021            CHRETIEN  63 HLBC
R2           . . . . . . . . . .
R2  AVG        0.316     0.014   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
R2  FIT        0.3139    0.0024 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
                         (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$K_S^0 \rightarrow (\pi^+\pi^-)/(\pi^0\pi^0)$ (P1)/(P2)

```
R3  N  267    (2.12)    (0.17)          BOZOKI    69 HLBC
R3  G 3016   (2.285)   (0.055)          GOBBI     69 OSPK    K+N TO KOP
R3     3700    2.10      0.06           MORFIN    69 HLBC    K+N TO KOP
R3 G  7944    2.282     0.043           MOFFETT   70 OSPK    K+N TO KOP
R3 B  6150    2.22      0.095           BALTAY    71 HBC  K-P TO KO +NEUTRALS
R3 A  3068    2.22      0.10            ALITTI    72 HBC     K+P TO PI+ P KO
R3    6380    2.22      0.08            MORSE     72 DBC     K+N TO KOP
R3 N   701    2.10      0.11            NAGY      72 HLBC    K+N TO KOP
R3    4799    2.16      0.08            HILL      73 DBC     K+D TO KO P P
R3     16K    2.169     0.094           COWELL    74 OSPK    PI- P TO LAM KO
R3    1315    2.11      0.09            EVERHART  76 WIRE    PI- P TO LAM KO
R3 N    NAGY 72 IS A FINAL RESULT WHICH INCLUDES BOZOKI 69.
R3 G    MOFFETT 70 IS A FINAL RESULT WHICH INCLUDES GOBBI 69.
R3 B    THE DIRECTLY MEASURED QUANTITY IS KS TO PI+PI-/ALL KOBAR=.345+-.005
R3 A    THE DIRECTLY MEASURED QUANTITY IS KS TO PI+ PI-/ALL KO=.345+-.005
R3         . . . . . . . . . .
R3  AVG       2.197     0.026   AVERAGE
R3  FIT       2.186     0.025  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K_S^0 \rightarrow (\mu^+\mu^-)/(\pi^+\pi^-)$ (units 10^{-5}) (P3)/(P1)

```
R4      TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R4      WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R4          (10.0)  OR LESS  CL=.90   BOTT-BODE 67 OSPK
R4          (20.0)  OR LESS  CL=.90   BOHM      69 OSPK
R4           (1.07) OR LESS  CL=.90   HYAMS     69 OSPK
R4    S     (32.6)  OR LESS  CL=.90   STUTZKE   69 OSPK
R4           0.047 OR LESS  CL=.90   GJESDAL   73 ASPK
R4    S  VALUE CALCULATED BY US, USING 2.3 INSTEAD OF 1 EVENT, 90 PERC.CL
```

$K_S^0 \rightarrow (\pi^+\pi^-\gamma)/(\pi^+\pi^-)$ (units 10^{-3}) (P5)/(P1)

```
R5      27       NO RATIO GIVEN        BELLOTTI  66 HBC     PG GT 50 MEV/C
R5      10    3.3       1.2            WEBBER    70 HBC     PG GT 50 MEV/C
R5 B          2.8       0.6            BURGUN    73 HBC     PG GT 50 MEV/C
R5 C    29   (3.0)     (0.6)           BOBISUT   74 HLBC    PG GT 40 MEV/C
R5   T        2.68      0.15           TAUREG    76 SPEC    PG GT 50 MEV/C
R5 B    BURGUN 73 ESTIMATES THAT DIRECT EMISSION CONTRIBUTION IS .3+-.6 .
R5 C    BOBISUT 74 NOT INCLUDED IN AVERAGE BECAUSE P(GAMMA) CUT DIFFERS.
R5 C    ESTIMATES DIRECT EMISSION CONTRIBUTION TO BE 0.5 OR LESS, CL=.95.
R5   T  TAUREG 76 FIND DIRECT EMISSION CONTRIB LT .06,CL=.90.
R5         . . . . . . . . . .
R5  AVG       2.70      0.14    AVERAGE
```

$K_S^0 \rightarrow (e^+e^-)/(\pi^+\pi^-)$ (units 10^{-5}) (P4)/(P1)

```
R6      TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R6      WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R6           50.0   OR LESS  CL=.90   BOHM       69 OSPK
```

$K_S^0 \rightarrow 2\gamma$/total (units 10^{-3}) (P6)

```
R7 R     0  (21.0)  OR LESS  CL=.90   BANNER     69 OSPK
R7 R     0   (2.2)  OR LESS  CL=.90   REPELLIN   71 OSPK
R7 R     0   (0.71) OR LESS  CL=.90   BANNER     72 OSPK
R7       0   (2.0)  OR LESS  CL=.90   MORSE      72 DBC
R7       0    0.4   OR LESS  CL=.90   BARMIN2    73 HLBC
R7 R    THESE LIMITS ARE FOR MAXIMUM INTERFERENCE IN KS-KL TO 2GAMMAS
```

$K_S^0 \rightarrow (\pi^+\pi^-\pi^0)$/total (units 10^{-4}) (P8)

```
R8           (0.85) OR LESS  CL=.90   METCALF    72 ASPK
R8            0.49  OR LESS  CL=.90   BARMIN     85 HLBC    K+ 850 MEV         |
```

$K_S^0 \rightarrow (\pi^0\pi^0\pi^0)$/total (units 10^{-4}) (P7)

```
R9           (4.3)  OR LESS  CL=.90   BARMIN1    73 HLBC
R9            0.37  OR LESS  CL=.90   BARMIN     83 HLBC
```

NOTE ON *CP* VIOLATION IN $K_S^0 \rightarrow 3\pi$

For $K_S^0 \rightarrow 3\pi$, the quantities which measure *CP* violation are the ratios of amplitudes

$$\eta_{+-0} = \frac{A_S(K_S \rightarrow \pi^+\pi^-\pi^0)}{A_L(K_L \rightarrow \pi^+\pi^-\pi^0)} ,$$

$$\eta_{000} = \frac{A_S(K_S \rightarrow \pi^0\pi^0\pi^0)}{A_L(K_L \rightarrow \pi^0\pi^0\pi^0)} .$$

If one assumes that *CPT* invariance holds and that there are no transitions to $I = 3$ states, then $\mathrm{Re}(\eta_{+-0})$ and $\mathrm{Re}(\eta_{000})$ can be neglected, and *CP* violation would be observed as nonzero values of $\mathrm{Im}(\eta_{+-0})$ and $\mathrm{Im}(\eta_{000})$. Sections ET+ and ET0 list the relative rates

$$(\mathrm{Im}\eta_{+-0})^2 = \frac{\Gamma(K_S \rightarrow \pi^+\pi^-\pi^0)}{\Gamma(K_L \rightarrow \pi^+\pi^-\pi^0)}$$

$$(\mathrm{Im}\eta_{000})^2 = \frac{\Gamma(K_S \rightarrow \pi^0\pi^0\pi^0)}{\Gamma(K_L \rightarrow \pi^0\pi^0\pi^0)}$$

obtained under the above assumptions.

In the above expressions the three pions are restricted to the dominant symmetric $I = 1$ state, a $CP = -1$ state which couples to K_S only if *CP* is violated. The decay $K_S \rightarrow \pi^+\pi^-\pi^0$ also has *CP*-allowed amplitudes to $I = 0$ and $I = 2$ states of the three pions. The angular momenta in these states cannot be *S* wave so they are strongly suppressed by centrifugal barrier effects, and, for the $I = 2$ state, by the $\Delta I = 1/2$ rule as well. For comparison with the *CP*-violating rate, we list in section RSQ the *CP*-conserving rate relative to $K_L \rightarrow \pi^+\pi^-\pi^0$ decay. The *CP*-conserving limit is large and thus determines the branching ratio limit $\Gamma(K_S \rightarrow \pi^+\pi^-\pi^0)$/total given in section R8.

CP VIOLATION PARAMETERS IN K_S^0 DECAY

$\mathrm{Im}(\eta_{+-0})^2$

```
ET+      WHERE ETA+-0 = A(KS -> PI+ PI- PIO, CP VIOL.)/A(KL -> PI+ PI- PIO).
ET+      CPT ASSUMED VALID - (I.E. RE(ETA+-0)=0)
ET+       18   (3.8)  OR LESS  CL=.90   ANDERSON  65 HBC  INCL. IN WEBBER 70
ET+            (0.45) OR LESS  CL=.90   BEHR      66 HLBC
ET+       71   (0.8)  OR LESS  CL=.90   WEBBER    70 HBC
ET+       99   (1.2)  OR LESS  CL=.90   CHO       71 DBC
ET+       98   (1.0)  OR LESS  CL=.90   JAMES     71 HBC  INCL. IN JAMES 72
ET+ M     50   (1.2)  OR LESS  CL=.95   MEISNER   71 HBC      CL=.9 NOT AVAIL.
ET+      180   (0.66) OR LESS  CL=.90   JAMES     72 HBC
ET+       99   (1.2)  OR LESS  CL=.90   JONES     72 OSPK
ET+      384    0.12  OR LESS  CL=.90   METCALF   72 ASPK
ET+      148   (0.71) OR LESS  CL=.90   MALLARY   73 OSPK     RE(A)=-.05+-.17
ET+      192   (1.2)  OR LESS  CL=.90   BALDOCEOL 75 HLBC
ET+   B 601    (0.23) OR LESS  CL=.90   BARMIN    85 HLBC     K+ 850 MEV        |
ET+ M    THESE AUTHORS FIND REAL(A)= 2.75+-.65, ABOVE VALUE AT RE(A)=0
ET+   B  BARMIN 85 FIND RE(ETA+-0)=(0.05+-0.17) AND IM(ETA+-0)=(0.15+-0.33).  |
```

ρ^2

```
RSQ      WHERE RHO=CABS(A(KS -> PI+ PI- PIO, CP CONS.)/A(KL -> PI+ PI- PIO)).
RSQ      CONSERVES CP BUT LISTED HERE FOR COMPARISON WITH SECTION ET+ ABOVE.
RSQ      THIS LIMIT DETERMINES BRANCHING RATIO R8 ABOVE.
RSQ      384    0.42  OR LESS  CL=.90   METCALF   72 ASPK
```

$\mathrm{Im}(\eta_{000})^2$

```
ETO      WHERE ETA000 = A(KS INTO 3PIO, CP VIOLATING)/A(KL INTO 3PIO)
ETO      SEE COMMENTS IN SECTION ET+ ABOVE.
ETO      THIS LIMIT DETERMINES BRANCHING RATIO R9 ABOVE.
ETO       22   (1.2)  OR LESS  CL=.90   BARMIN1   73 HLBC
ETO   G        (0.28) OR LESS  CL=.90   GJESDAL   74 SPEC     INDIRECT MEAS.
ETO   B 632     0.1   OR LESS  CL=.90   BARMIN    83 HLBC
ETO   G  GJESDAL 74 USES K2PI, KMU3 AND KE3 DECAY RESULTS, UNITARITY, AND
ETO   G  CPT.  CALCULATES ABS(ETA000)=.26+-.20.  WE CONVERT TO UPPER LIMIT.
ETO   B  BARMIN 83 FIND RE(ETA000)=(-.08+-.18) AND IM(ETA000)=(-.05+-.27) .
ETO   B  ASSUMING CPT INVARIANCE THEY OBTAIN THE LIMIT QUOTED ABOVE .
```

REFERENCES FOR K_S^0

```
BOLDT    58 PRL   1  150         E BOLDT,D O CALDWELL,Y PAL                (MIT)
CRAWFORD 59 PRL   2  266         CRAWFORD,CRESTI,DOUGLASS,GOOD,TICHO + (LRL)

BAGLIN   60 NC    18 1043        BAGLIN,BLOCH,BRISSON,HENNESSY +       (EPOL)
BOWEN    60 PR   119 2030        BOWEN,HARDY,REYNOLDS,SUN,MOORE+  (PRIN+BNL)
COLUMBIA 60 ROCH CONF 727        M SCHWARTZ +                       (COLUMBIA)

BROWN    61 NC    19 1155        BROWN,BRYANT,BURNSTEIN,GLASER,KADYK+ (MICH)
ANDERSON 62 CERN CONF 836        J A ANDERSON,F S CRAWFORD +            (LRL)
BERTANZA 62  PREPRINT D105       BERTANZA,CONNOLLY,CULWICK,EISLER +     (BNL)
    UNPUBLISHED, BUT RECERTIFIED BY AUTHORS, AUGUST 66.

CHRETIEN 63 PR  131 2208         CHRETIEN+     (BRANDEIS+BROWN+HARVARD+ MIT)
BROWN    63 PR  130  769         BROWN,KADYK,TRILLING,ROE +        (LRL+MICH)
KREISLER 64 PR  136 B 1074       M KREISLER,O OVERSETH,J CRONIN  (PRINCETON)
ANDERSON 65 PRL 14 475           +CRAWFOR,GOLDEN,STERN,BINFORD +  (LRL+WISC)

ALFF-STE 66 PL 21 595            ALFF-STEINBERGER,HEUER,KLEINKNECHT + (CERN)
AUERBACH 66 PR 149 1052          AUERBACH,DOBBS,LANDE,MANN,SCIULLI+   (PENN)
    ALSO 65 AUERBACH
BALTAY   66 PR 142   932         BALTAY,SANDWEISS,STONEHILL +     (YALE+BNL)
BEHR     66 PL  22  540          BEHR,BRISSON,PETIAU+ (EPOL,MILA,PADO,ORSAY)
BELLOTTI 66 NC 45A 737           +PULLIA,BALDO-CEOLIN +         (MILAN+PADUA)
BOTT-BOD 66 PL  23 277           BOTT-BODENHAUSEN,DE BOUARD +          (CERN)
KIRSCH   66 PR  147  939         L KIRSCH,P SCHMIDT                 (COLUMBIA)

BOTT-BOD 67 PL 24B 194           BOTT-BODENHAUSEN,DE BOUARD,CASSEL+   (CERN)
DONALD   68 PL 27B  58           DONALD,EDWARDS,NISAR+ (LIVP,CERN,IPNP,CDEF)
HILL     68 PR 171 1418          HILL,ROBINSON,SAKITT +         (BNL,CARNEGIE)

BANNER   69 PR 188 2033          +CRONIN,LIU,PILCHER                (PRINCETON)
BOHM     69 THESIS               A. BOHM                                (AACH)
BOZOKI   69 PL 30B 498           +FENYVES,GOMBOSI,NAGY,SURANYI+   (BUDAPEST)
DOYLE    69 UCRL 18139-THESIS J.C. DOYLE                                (LRL)
GOBBI    69 PRL 22 682           GOBBI,GREEN,HAKEL,MOFFETT,ROSEN+(ROCHESTER)
HYAMS    69 PL  29B 521          +KOCH,POTTER,VON LINDERN,LORENZ+(CERN+MPIM)
MORFIN   69 PRL    23  660       MORFIN,SINCLAIR                       (MICH)
STUTZKE  69 PR    177  2009      +ABASHIAN,JONES,MANTSCH,ORR,SMITH(ILLINOIS)

MOFFETT  70 BAPS 15 512          +GOBBI,GREEN,HAKEL;ROSEN           (ROCHESTER)
WEBBER   70 PR D1 1967           +SOLMITZ,CRAWFORD,ALSTON-GARNJOST      (LRL)
    ALSO 69 UCRL 19226 THESIS B R WEBBER                                (LRL)
```

```
BALTAY   71 PRL 27 1678         +BRIDGEWATER,COOPER,GERSHWIN,HABIBI+ (COLU)
    ALSO 71 NEVIS-187 THESIS    WILLIAM A. COOPER                (COLUMBIA)
CHO      71 PR D3 1557          +DRALLE,CANTER,ENGLER,FISK+ (CARN+BNL+CASE)
JAMES    71 PL 35B 265          +MONTANET,PAUL,PAULI+      (CERN+SACL+OSLO)
MEISNER  71 PR D3 59            +MANN,HERTZBACH,KOFLER +    (MASA+BNL+YALE)
REPELLIN 71 PL 36B 603          +WOLFF,CHOLLET,GAILLARD,JANE+   (ORSA+CERN)

ALITTI   72 PL 39B 568          J ALITTI,E LESQUOY,A MULLER        (SACLAY)
BANNER   72 PRL 29 237          +CRONIN,HOFFMAN,KNAPP,SHOCHET   (PRINCETON)
JAMES    72 NP B49 1            +MONTANET,PAUL,SAETRE+     (CERN+SACL+OSLO)
JONES    72 NC 9A 151           +ABASHIAN,GRAHAM,MANTSCH,ORR,SMITH+   (ILL)

METCALF  72 PL 40B 703          +NEUHOFER,NIEBERGALL+      (CERN+IPN+WIEN)
MORSE    72 PRL 28 388          +NAUENBERG,BIERMAN,SAGER+  (COLO+PRIN+UMD)
NAGY     72 NP B47 94           +TELBISZ,VESZTERGOMBI           (BUDAPEST)
    ALSO 69 PL 30B 498          BOZOKI,FENYVES,GOMBOSI,NAGY+    (BUDAPEST)
SKJEGGES 72 NP B48 343          SKJEGGESTAD,JAMES,MONTANET+(OSLO+CERN+SACL)

BARMIN1  73 PL 46B 465          +BARYLOV,DAVIDENKO,DEMIDOV+          (ITEP)
BARMIN2  73 PL 47B 463          +BARYLOV,DAVIDENKO,DEMIDOV+          (ITEP)
BURGUN   73 PL 46B 481          +BERTRANET,LESQUOY,MULLER,PAULI+(SACL+CERN)
FACKLER  73 PRL 31 847          +FRISCH,MARTIN,SMOOT,SOMPAYRAC        (MIT)
GJESDAL  73 PL 44B 217          +PRESSER,STEFFEN,STEINBERGER+   (CERN+HEID)
HILL     73 PR D8 1290          +SAKITT,SAMIOS,BURRIS,ENGLER+    (BNL+CARN)
MALLARY  73 PR D7 1953          +BINNIE,GALLIVAN,GOMEZ,PECK,SCIULLI+  (CIT)

BOBISUT  74 LNC 11 646          +HUZITA,MATTIOLI,PUGLIERIN           (PADO)
COWELL   74 PR D10 2083         +LEE-FRANZINI,ORCUTT,FRANZINI + (STON+COLU)
GEWENIGE 74 PL 48B 487          GEWENIGER,GJESDAL,PRESSER+      (CERN+HEID)
GJESDAL  74 PL 52B 119          +PRESSER,STEFFEN,STEINBERGER +  (CERN+HEID)

BALDOCEO 75 NC 25A 688          BALDO-CEOLIN,BOBISUT,CALIMANI+  (PADO+WISC)
CARITHER 75 PRL 34 1244         CARITHERS,MODIS,NYGREN,PUN +     (COLU+NYU)
ARONSON  76 NC 32A 236          +MCINTYRE,ROEHRIG +    (WISC+EFI+UCSD+ILLC)
EVERHART 76 PR D14 661          +KRAUS,LANDE,LONG,LOWENSTEIN +       (PENN)
TAUREG   76 PL 65B 92           +ZECH,DYDAK,NAVARRIA+      (HEID+CERN+DORT)
ARONSON  82 PRL 48 1306         +BOCK,CHENG,FISCHBACH      (BNL+CHIC+PURD)
    ALSO 82 PL 116B 73          FISCHBACH,CHENG,ARONSON,BOCK(PURD+BNL+CHIC)
    ALSO 83 PR D28 476          ARONSON,BOCK,CHENG,FISCHBACH(BNL+CHIC+PURD)
    ALSO 83 PR D28 495          ARONSON,BOCK,CHENG,FISCHBACH(BNL+CHIC+PURD)
BARMIN   83 PL 128B 129         +BARYLOV,CHISTYAKOVA,CHUVILO+   (ITEP+PADO)
    ALSO 84 SJNP 39 269         BARMIN,BARYLOV,GOLUBCHIKOV+     (ITEP+PADO)
BARMIN   85 NC 85A 67           +BARYLOV,CHISTYAKOVA,CHUVILO+   (ITEP+PADO)

                                PAPERS NOT REFERRED TO IN DATA

BIRGE    60 ROCH CONF 601       R W BIRGE,P P ELY +        (LRL+WISCONSIN)
MULLER   60 PRL   4  418        MULLER,BIRGE,FOWLER,GOOD,PICCIONI+(LRL+BNL)
FITCH    61 NC   22 1160        V FITCH,P PIROUE,R PERKINS      (PRIN+LASL)
GOOD     61 PR  124 1223        GOOD,MATSEN,MULLER,PICCIONI +         (LRL)

CRAWFORD 62 CERN CONF 827       F S CRAWFORD                          (LRL)
AUERBACH 65 PRL 14 192          AUERBACH,LANDE,MANN,SCIULLI,UTO +    (PENN)
TRILLING 65 UCRL 16473          GEORGE H TRILLING                     (LRL)
    UPDATED FROM 1965 ARGONNE CONF., PAGE 115.
```

$\boxed{K_L^0}$ $I(J^P) = \frac{1}{2}(0^-)$ LONG-LIVED K^0

$K_L^0 - K_S^0$ MASS DIFFERENCE

```
    WE GIVE (KL-KS MASS DIFFERENCE / HBAR) IN UNITS OF 10**10 SEC-1

D  TX        (2.20)   (0.35)            FITCH     61 CNTR
D   X        (0.84)   (0.29)      (0.22)GOOD      61 HLBC
D  TXC       (1.02)   (0.23)            CAMERINI  62 HLBC
D  TX        (0.55)   (0.24)            AUBERT    65 HLBC
D   X        (0.26)   (0.36)      (0.26)BALDO-CEO 65 HLBC     ASSUMES CP CONS.
D  TXA       (0.64)   (0.12)            CHRISTENS 65 OSPK
D  TX        (0.70) OR LESS             FITCH     65 OSPK     CF. MEISNER 66
D   V   130  (0.89)   (0.15)            VISHNEVSK 65 OSPK     CU AND AL REGEN
D   X        (0.514)  (0.039)           ALFF-STEI 66 OSPK
D   X    84  (0.42)   (0.24)     (0.36) BALDO-CEO 66 HLBC     K0+N INTO HYPER.
D   B        (0.531)  (0.027)           BOTT-BODE 66 OSPK     C REGEN
D  TX    77  (0.58)   (0.17)            CAMERINI  66 HBC, DBC K0+N INTO HYPER
D   N    72 (+0.64)   (0.18)            CANTER    66 DBC      K0 SCATTER IN D2
D   X    95  (0.62)   (0.10)     (0.16) CHANG     66 HBC      K0+P INTO HYPER.
D   X        (0.81)   (0.17)            FUJII     66 OSPK     IRON REGENERATOR
D   X    59  (0.74)   (0.34)            MEISNER1  66 HBC
D          + SIGN FAVORED               MEISNER2  66 HBC
D   X        (0.38)   (0.16)            JOVANOVIC 66 OSPK     C+URANIUM REGEN.
D  TX   136 (+0.64)   (0.19)            CANTER    67 DBC      K0+D INTO HYPER.
D   X        (0.65)   (0.11)            MISCHKE   67 OSPK
D   X   590  (0.59)   (0.13)            BALATZ    68 OSPK     AL REGENERATOR
D   X        (0.520)  (0.044)           CARNEGIE  68 HBC      GAP METHOD
D  TX       (+0.487)  (0.046)           MELHOP    68 OSPK     ST.STEEL REGEN
D  BX        (0.547)  (0.024)           BOTT-BODE 69 OSPK     C REGEN
D  FX        (0.555)  (0.020)           FAISSNER  69 ASPK     REGEN IN CU
D             0.542    0.006            CULLEN    70 CNTR
D   R        (0.542)  (0.006)           ARONSON   70 ASPK     GAP METHOD
D   X        (0.481)  (0.052)   (0.075)BALATS    71 OSPK
D   R        (0.534)  (0.007)           CARNEGIE  71 ASPK     GAP METHOD
D  TH   119 (+0.67)   (0.14)            HILL      71 DBC
D   S  1757  (0.557)  (0.038)           FACKLER   73 OSPK
D             0.5340   0.0030           GEWENIG3  74 SPEC     GAP METHOD
D             0.5334   0.0040           GJESDAL   74 SPEC     CHG ASYMMETRY
D   Z        (0.482)  (0.014)           ARONSON2  82 SPEC     E=30-110 GEV
D                  COMMENTS
D   X   NO ATTEMPT HAS BEEN MADE TO CORRECT OLDER EXPERIMENTS WITH LARGE
D   X   ERRORS FOR THE SUBSEQUENT CHANGES IN THE KS MEAN LIFE OR IN ETA+-.
D  T    A KS MEAN LIFE OF 0.862 10**-10 SEC WAS USED IN CONVERTING THE
D  T    MASS DIFFERENCE FROM UNITS OF INVERSE KS MEAN LIVES TO ABSOLUTE
D  T    UNITS. VALUES NOT BEARING THIS FOOTNOTE EITHER WERE GIVEN IN
D  T    ABSOLUTE UNITS OR WERE CONVERTED USING THE AUTHORS' VALUE OF THE
D  T    KS MEAN LIFE.
D    C  CAMERINI 62 VALUE CHANGED FROM 1.7 (SEE TABLE 1 OF CAMERINI 66)
D    A  CHRISTENSON 65 CORRECTED FOR INTERFERENCE BY FITCH 65 FOOTNOTE.
D   V   VISHNEVSKY 65 NOT CORRECTED FOR INTERFERENCE EFFECTS.
D   N   CANTER 66 ERROR IGNORES UNCERTAINTY OF PHASE SHIFTS.  THESE EVENTS
D   N   ARE USED IN HILL 71.
D  B    BOTT-BODENHAUSEN 69 IS A REEVALUATION OF BOTT-BODENHAUSEN 66.
D  F    FAISSNER 69 HAS ADDNL. SYSTEMATIC ERROR LESS THAN TWO PERCENT.
D   R   ARONSON 70 AND CARNEGIE 71 USE KS MEAN LIFE=.862+-.006 E-10 SEC.
D   R   WE HAVE NOT ATTEMPTED TO ADJUST THESE VALUES FOR THE SUBSEQUENT
D   R   CHANGE IN THE KS MEAN LIFE OR IN ETA+-.
D   H   HILL 71 PRIMARY RESULT IS THAT DM IS POSITIVE.
D   H   THE MAGNITUDE MAY HAVE AN ADDITIONAL SYSTEMATIC ERROR OF ABOUT 0.12
D   S   NOT AVERAGED BECAUSE ERROR IS LARGE AND SYSTEMATICS NOT DISCUSSED.
D   Z   ARONSON 82 FIND THAT DELTA-M MAY DEPEND ON THE KAON ENERGY .
D            . . . . . . . . . .
D   AVG        0.5349   0.0022  AVERAGE
```

K_L^0 MEAN LIFE (units 10^{-8} sec)

```
T        KL MEAN LIFE
T       34    8.1      3.2      2.4    BARDON    58 CNTR
T       ASSUMED DS=DQ AND DELTA I=1/2 CRAWFORD  59 HBC
T       15    5.1      2.4      1.3    DARMON    62 FBC
T             5.3      0.6             FUJII     64 OSPK
T     1700    6.1      1.5      1.2    ASTBURY3  65 CNTR
T             5.15     0.14            DEVLIN    67 CNTR
T   L        (5.0)    (0.5)            LOWYS     67 HLBC
T     0.4M    5.154    0.044           VOSBURGH  72 CNTR
T   L   SUM OF PARTIAL DECAY RATES.
T          . . . . . . . . . .
T   AVG       5.158    0.042    0.042  AVERAGE
T   FIT       5.183    0.040  FROM FIT
```

K_L^0 PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_L^0 \to 3\pi^0$	135+ 135+ 135
P2	$K_L^0 \to \pi^+\pi^-\pi^0$	140+ 140+ 135
P3	$K_L^0 \to \pi\mu\nu$ (called $K_{\mu 3}$)	140+ 106+ 0
P4	$K_L^0 \to \pi e\nu$ (called K_{e3})	140+.511+ 0
P5	$K_L^0 \to \pi^+\pi^-$	140+ 140
P6	$K_L^0 \to \mu^+\mu^-$	106+ 106
P7	$K_L^0 \to e^+e^-$	.511+.511
P8	$K_L^0 \to e\mu$	.511+ 106
P9	$K_L^0 \to 2\gamma$	0+ 0
P10	$K_L^0 \to \pi^+\pi^-\gamma$	140+ 140+ 0
P11	$K_L^0 \to \pi^0\pi^0$	135+ 135
P12	$K_L^0 \to \pi e\nu\gamma$	140+.511+ 0+ 0
P13	$K_L^0 \to \pi^0 2\gamma$	135+ 0+ 0
P14	$K_L^0 \to e^+e^-\gamma$	.511+.511+ 0
P15	$K_L^0 \to \mu^+\mu^-\gamma$	106+ 106+ 0
P16	$K_L^0 \to \mu^+\mu^-\pi^0$	106+ 106+ 135
P17	$K_L^0 \to \pi^+\pi^-e^+e^-$	140+ 140+.511+.511
P18	$K_L^0 \to \pi^0\pi^\pm e^\mp\nu$	135+ 140+.511+ 0
P19	$K_L^0 \to (\pi\mu$ atom$)\ \nu$	
P20	$K_L^0 \to \pi^0 e^+e^-$	135+.511+.511
P21	$K_L^0 \to \mu^+\mu^-e^+e^-$	106+ 106+.511+.511
P22	$K_L^0 \to e^+e^-e^+e^-$	.511+.511+.511+.511

K^0 CONSTRAINED FIT

```
OVERALL FIT OF MEAN LIFE, WIDTHS AND BRANCHING
RATIOS USES 65 DATA POINTS TO DETERMINE SIX
QUANTITIES.  OVERALL FIT HAS CHI-SQUARED=69.9
```

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
       P 1      P 2      P 3      P 4      P 5      P11
P 1   .2147+-.0101
P 2  -.664    .1240+-.0020
P 3  -.859    .460     .2711+-.0043
P 4  -.914    .490     .625     .3873+-.0056
P 5  -.498    .545     .383     .407     .00203+-.00005
P11   .233   -.167    -.215    -.228    -.125     .00094+-.00019
```

FITTED PARTIAL DECAY MODE RATES

The matrix below is the branching fraction matrix above, transformed into rate space; i.e., $G_i \equiv \Gamma_i = \Gamma_{total} P_i$, in appropriate units. In analogy to the matrix above, the diagonal elements are $G_i \pm \delta G_i$, where $\delta G_i = \sqrt{\langle \delta G_i \delta G_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta G_i \delta G_j \rangle / (\delta G_i \cdot \delta G_j)$. Note that because of the error in Γ_{total}, the errors and correlations here are not directly derivable from those above.

```
       G 1      G 2      G 3      G 4      G 5      G11
G 1   .0414+-.0020
G 2  -.485    .0239+-.0004
G 3  -.650    .511     .0523+-.0009
G 4  -.683    .540     .667     .0747+-.0011
G 5  -.379    .571     .422     .446     .00039+-.00001
G11   .242   -.128    -.170    -.178    -.099     .00018+-.00004
```

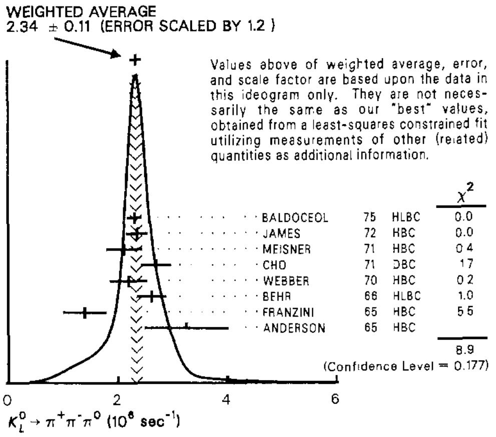
K_L^0 DECAY RATES

$K_L^0 \to \pi^0\pi^0\pi^0$ (units $10^6\,sec^{-1}$) (G1)

```
W1      54    5.22      1.03      0.84  BEHR        66 HLBC     ASSUMES CP
W1           . . . . . . . . . . .
W1  FIT       4.14      0.20   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.7)
```

$K_L^0 \rightarrow \pi^+\pi^-\pi^0$ (units $10^6 \mathrm{sec}^{-1}$) (G2)

```
W2        18    3.26     0.77             ANDERSON  65 HBC
W2        14    1.4      0.4              FRANZINI  65 HBC
W2       136    2.62     0.28     0.27    BEHR      66 HLBC    ASSUMES CP
W2        53    2.20     0.35             WEBBER    70 HBC     ASSUMES CP
W2        99    2.71     0.28             CHO       71 DBC     ASSUMES CP
W2   J    98   (2.5)    (0.3)             JAMES     71 HBC     ASSUMES CP
W2        50    2.12     0.33             MEISNER   71 HBC     ASSUMES CP
W2  J    180    2.35     0.20             JAMES     72 HBC     ASSUMES CP
W2       192    2.32     0.13     0.15    BALDOCEOL 75 HLBC    ASSUMES CP
W2       IN THE OVERALL FIT THIS RATE IS WELL DETERMINED BY THE MEAN LIFE AN
W2       THE BRANCHING RATIO R2. FOR THIS REASON THE DISCREPANCY BETWEEN THE
W2       W2 MEASUREMENTS DOES NOT AFFECT THE SCALE FACTOR OF THE OVERALL FIT
W2  J    JAMES 72 IS A FINAL MEASUREMENT AND INCLUDES JAMES 71.
W2          . . . . . . . . . .
W2   AVG        2.34     0.11     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
W2   FIT        2.392    0.040  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
                         (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$K_L^0 \rightarrow \pi e \nu$ (units $10^6 \mathrm{sec}^{-1}$) (G4)

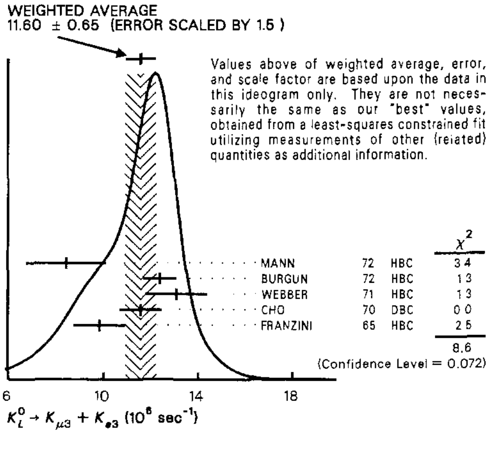
```
W3            7.52     0.85     0.72  AUBERT    65 HLBC    DS=DQ,CP ASSUMED
W3     620    7.81     0.56           CHAN      71 HBC
W3          . . . . . . . . . . .
W3  AVG       7.71     0.46     AVERAGE
W3  FIT       7.47     0.11   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$K_L^0 \rightarrow \pi \ell \nu + \pi^+\pi^-\pi^0$ (units $10^6 \mathrm{sec}^{-1}$) (G2+G3+G4)

```
W4     KL INTO CHARGED (UNITS 10**6 SEC-1)                 (G2+G3+G4)
W4      L=E OR MU
W4      98   15.1      1.9            AUERBACH  66 OSPK
W4          . . . . . . . . . . .
W4  FIT      15.09     0.21   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.4)
```

$K_L^0 \rightarrow \pi \ell \nu$ (units $10^6 \mathrm{sec}^{-1}$) (G3+G4)

```
W5   D 109     9.85     1.15     1.05  FRANZINI  65 HBC
W5  C  335   (10.3)    (0.8)           HILL      67 DBC     K+N TO KO P
W5   D 393    11.6      0.9            CHO       70 DBC     K+N TO KOP
W5   D 252    13.1      1.3            WEBBER    71 HBC     K- P TO KOBAR N
W5   D 410    12.4      0.7            BURGUN    72 HBC     K+P TO KOPPI+
W5   D 126     8.47     1.69           MANN      72 HBC     K- P TO KOBAR N
W5  C  CHO 70 INCLUDES EVENTS OF HILL 67
W5   D  ASSUMES DS=DQ RULE
W5          . . . . . . . . . . .
W5  AVG       11.60     0.65    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
W5  FIT       12.70     0.18   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.4)
                        (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$K_L^0 \rightarrow \pi \mu \nu$ (units $10^6 \mathrm{sec}^{-1}$) (G3)

```
W6     19    4.54     1.24     1.08  LOWYS     67 HLBC
W6         . . . . . . . . . . .
W6  FIT      5.231    0.087  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

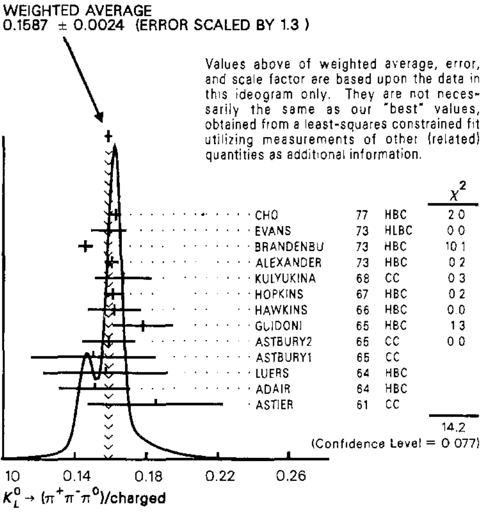
K_L^0 BRANCHING RATIOS

$K_L^0 \rightarrow (\pi^0\pi^0\pi^0)/(\pi \ell \nu + \pi^+\pi^-\pi^0)$ (P1)/(P2+P3+P4)

```
R1      L=E OR MU.
R1      24    0.24     0.08           ANIKINA   64 CC
R1     549    0.251    0.014          BUDAGOV   68 HLBC    ORSAY MEASUR.
R1     444    0.277    0.021          BUDAGOV   68 HLBC    EC. POLYTEC.MEAS
R1      29    0.31     0.07     0.06  KULYUKINA 68 CC
R1          . . . . . . . . . . .
R1  AVG       0.260    0.011    AVERAGE
R1  FIT       0.274    0.016  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.8)
```

$K_L^0 \rightarrow (\pi^+\pi^-\pi^0)/(\pi \ell \nu + \pi^+\pi^-\pi^0)$ (P2)/(P2+P3+P4)

```
R2      L=E OR MU.
R2      59    0.185    0.038          ASTIER    61 CC
R2      79    0.151    0.020          ADAIR     64 HBC
R2      75    0.157    0.03     0.04  LUERS     64 HBC
R2      66    0.15     0.03     0.04  ASTBURY1  65 CC
R2     326    0.159    0.015          ASTBURY2  65 CC
R2     566    0.178    0.017          GUIDONI   65 HBC
R2    1729   (0.144)  (0.004)         HOPKINS   65 HBC     SEE HOPKINS 67
R2     126    0.162    0.015          HAWKINS   66 HBC
R2            0.161    0.005          HOPKINS   67 HBC
R2    1402    0.167    0.016          KULYUKINA 68 CC
R2    1590    0.1605   0.0038         ALEXANDER 73 HBC
R2    3200    0.146    0.004          BRANDENBU 73 HBC
R2     558    0.159    0.010          EVANS     73 HLBC
R2    6499    0.163    0.003          CHO       77 HBC
R2          . . . . . . . . . . .
R2  AVG       0.1587   0.0024  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
R2  FIT       0.1585   0.0019 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
                       (SEE IDEOGRAM BELOW)
```



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$K_L^0 \rightarrow (\pi \mu \nu)/(\pi \ell \nu + \pi^+\pi^-\pi^0)$ (P3)/(P2+P3+P4)

```
R3      L=E OR MU.
R3  C  251   (0.356)  (0.07)           LUERS     64 HBC
R3  C  172   (0.39)   (0.08)   (0.10)  ASTBURY1  65 CC
R3  C  330   (0.335)  (0.055)          KULYUKINA 68 CC
R3  C THIS MODE NOT MEASURED INDEPENDENTLY FROM R2 AND R4
R3          . . . . . . . . . . .
R3  FIT       0.3465   0.0028 FROM FIT
```

$K_L^0 \rightarrow (\pi e \nu)/(\pi \ell \nu + \pi^+\pi^-\pi^0)$ (P4)/(P2+P3+P4)

```
R4      L=E OR MU.
R4      24    0.46     0.11            NEAGU     61 CC
R4     153    0.487    0.05            LUERS     64 HBC
R4     202    0.46     0.08     0.10   ASTBURY1  65 CC
R4     500    0.498    0.052           KULYUKINA 68 CC
R4          . . . . . . . . . . .
R4  AVG       0.485    0.032    AVERAGE
R4  FIT       0.4950   0.0029 FROM FIT
```

$K_L^0 \rightarrow (\pi e \nu)/((\pi e \nu)+(\pi \mu \nu))$ (P4)/(P3+P4)

```
R5     320    0.415    0.120           ASTIER    61 CC
R5          . . . . . . . . . . .
R5  FIT       0.5882   0.0032 FROM FIT
```

$K_L^0 \rightarrow (\pi^+\pi^-\pi^0)$/total (P2)

```
R6
R6          . . . . . . . . . . .
R6  FIT       0.1240   0.0020 FROM FIT
```

$K_L^0 \rightarrow (\pi \ell \nu)$/total (P3+P4)

```
R7
R7          . . . . . . . . . . .
R7  FIT       0.6584   0.0089 FROM FIT
```

$K_L^0 \to (2\gamma)$/total (units 10^{-4}) (P9)

```
R8  C        (1.3)    (0.6)           CRIEGEE   66 OSPK
R8      32    6.7      2.2            TODOROFF  67 OSPK   REPL.  CRIEGEE66
R8  K   33   (7.4)    (1.6)           CRONIN 1  67 OSPK
R8      90    5.5      1.1            KUNZ      68 OSPK   NORM.TO 3PI(C+N)
R8      23    4.5      1.0            ENSTROM   71 OSPK   KL 1.5-9 GEV/C
R8 R          5.0     (1.0)           REPELLIN  71 OSPK
R8 B          4.54     0.84           BANNER2   72 OSPK
R8 B    THIS VALUE USES (E00/E+-)**2=1.05+-0.14. IN GENERAL, S13R8 =
R8 B    (4.32+-0.55)*(10**-4)*((E00/E+-)**2).
R8 R    ASSUMES REGEN AMPL IN COPPER AT 2GEV IS 22  MB. TO EVALUATE
R8 R    FOR A GIVEN REGEN AMPL AND ERROR, MULTIPLY BY (REGEN AMPL/22MB)**2
R8  C      CRIEGEE 66 REPLACED BY TODOROFF 67
R8  K      CRONIN1 67 REPLACED BY KUNZ 68.
R8      R21 BELOW GIVES (4.82+-.52)E-4. COMBINED AVG (4.85+-.37)E-4.
R8         . . . . . . . . . . .
R8  AVG       4.89     0.54    AVERAGE
```

$K_L^0 \to (\pi^+\pi^-)/(\pi \ell \nu + \pi^+\pi^-\pi^0)$ (units 10^{-3})

```
R9                                                          (P5)/(P2+P3+P4)
R9      L=E OR MU.
R9  O   45   (2.0)     (0.4)          CHRISTENS 64 OSPK ETA+- = 1.95+-0.20
R9  O   54   (2.08)    (0.35)         GALBRAITH 65 OSPK ETA+- = 1.99+-0.16
R9  O        (1.93)    (0.26)         BASILE    66 OSPK ETA+- = 1.92+-0.13
R9  O        (1.993)   (0.080)        BOTT-BODE 66 OSPK ETA+- = 1.95+-0.04
R9  M 4200   (2.60)    (0.07)         MESSNER   73 ASPK ETA+- = 2.23+-0.05
R9  O   OLD EXPERIMENTS EXCLUDED FROM FIT.  SEE SUBSECTION E+- BELOW FOR
R9  O   AVERAGE ETA+- OF THESE EXPERIMENTS AND FOR NOTE ON DISCREPANCY.
R9  M   FROM SAME DATA AS R27 MESSNER 73,BUT WITH DIFFERENT NORMALIZATION.
R9          . . . . . . . . . . .
R9  FIT       2.598    0.053  FROM FIT
```

$K_L^0 \to (\pi \mu \nu)/(\pi e \nu)$ (P3)/(P4)

```
R10           0.81     0.19           ADAIR     64 HBC
R10           0.82     0.10           DEBOUARD  67 OSPK
R10    273    0.7      0.2            HAWKINS   67 HBC
R10           0.81     0.08           HOPKINS   67 HBC
R10    770    0.71     0.05           BUDAGOV   68 HLBC
R10 K        (0.67)   (0.13)          KULYUKINA 68 CC
R10 B  569   (0.71)   (0.04)          BEILLIERE 69 HLBC
R10   1309   (0.648)  (0.030)         EVANS     69 HLBC REPL. BY EVANS 73
R10   3548    0.68     0.08           BASILE    70 OSPK
R10   6700    0.741    0.044          BRANDENBU 73 HBC
R10   1309    0.662    0.030          EVANS     73 HLBC
R10    10K    0.662    0.037          WILLIAMS  74 ASPK
R10    33K    0.702    0.011          CHO       80 HBC
R10 K   KULYUKINA 68 R10 IS NOT MEASURED INDEPENDENTLY FROM R2 AND R4.
R10 B  BEILLIERE 69 IS A SCANNING EXPT USING SAME EXPOSURE AS BUDAGOV 68
R10         . . . . . . . . . . .
R10 AVG       0.7001   0.0093  AVERAGE
R10 FIT       0.7001   0.0092 FROM FIT
```

$K_L^0 \to (\mu^+\mu^-)/(\pi \ell \nu + \pi^+\pi^-\pi^0)$ (units 10^{-6})

```
R11                                                         (P6)/(P2+P3+P4)
R11     L=E OR MU.
R11     TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R11     WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R11        (100.0)  OR LESS           ANIKINA   65 CC
R11        (250.0)  OR LESS  CL=.90   ALFF-STEI 66 OSPK
R11          (2.0)  OR LESS  CL=.90   BOTT-BODE 67 OSPK
R11         (35.0)  OR LESS  CL=.90   FITCH     67 OSPK
```

$K_L^0 \to (\pi^+\pi^-\gamma)$/total (units 10^{-3}) (P10)

```
R12         (15.0)  OR LESS           ANIKINA   65 CC
R12       0  (5.0)  OR LESS           BELLOTTI  66 HLBC    GAM KE 40-130 MV
R12       1  (3.0)  OR LESS           NEFKENS   66 OSPK    GAM KE 120 MEV
R12          (0.4)  OR LESS  CL=.90   THATCHER  68 OSPK    GAM KE 20-170 MV
R12          (3.2)  OR LESS  CL=.90   BOBISUT   74 HLBC    GAM KE GT 40 MEV
R12  D  24   (0.062)  (0.021)         DONALDS1  74 SPEC
R12          (0.46) OR LESS  CL=.90   WOO       74 SPEC
R12 H  516   (0.0152) (0.0016)        CARROLL2  80 SPEC +-0GAM KE GT 20 MEV
R12 J  546   (0.0289) (0.0028)        CARROLL2  80 SPEC +-0
R12  K1062    0.0441   0.0032         CARROLL2  80 SPEC +-0GAM KE GT 20 MEV
R12  D  USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.126
R12 H   INTERNAL BREMSSTRAHLUNG COMPONENT ONLY.
R12 J   DIRECT GAMMA EMISSION COMPONENT ONLY.
R12  K  BOTH COMPONENTS. USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.1239 .
```

$K_L^0 \to (e^+e^-)/(\pi \ell \nu + \pi^+\pi^-\pi^0)$ (units 10^{-6})

```
R13                                                         (P7)/(P2+P3+P4)
R13     L=E OR MU.
R13     TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R13     WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R13       (1000.0)  OR LESS           ANIKINA   65 CC
R13        (200.0)  OR LESS  CL=.90   ALFF-STEI 66 OSPK
R13         (23.0)  OR LESS  CL=.90   BOTT-BODE 67 OSPK
```

$K_L^0 \to (e \mu)/(\pi \ell \nu + \pi^+\pi^-\pi^0)$ (units 10^{-4})

```
R14                                                         (P8)/(P2+P3+P4)
R14     L=E OR MU.
R14     TEST OF LEPTON FAMILY NUMBER CONSERVATION.
R14         (10.0)  OR LESS           ANIKINA   65 CC
R14          (1.0)  OR LESS  CL=.90   CARPENTER 66 OSPK
R14          (0.1)  OR LESS  CL=.90   BOTT-BODE 67 OSPK
R14           0.08  OR LESS  CL=.90   FITCH     67 OSPK
```

$K_L^0 \to (\pi^- e^+ \nu)/(\pi^+ e^- \nu)$

```
R15 O   97   (0.90)    (0.18)         NEAGU     61 CC
R15 O        (1.01)    (0.16)         LUERS     64 HBC
R15 O  894   (0.99)    (0.023)        KULYUKINA 66 CC
R15 O 1539   (1.06)    (0.05)         VERHEY    66 OSPK
R15 O   LOW PRECISION EXPTS NOT AVERAGED.  FOR MORE PRECISE VALUE,
R15 O   SEE S13A2 IN THE CP VIOLATION SECTION BELOW.
```

$K_L^0 \to (\pi^- \mu^+ \nu)/(\pi^+ \mu^- \nu)$

```
R16     1M    1.0081   0.0027         DORFAN    67 OSPK
R16     SEE ALSO S13A2 AND S13AL IN THE CP VIOLATION SECTION BELOW.
```

$K_L^0 \to (\pi^0\pi^0)$/total (units 10^{-3}) (P11)

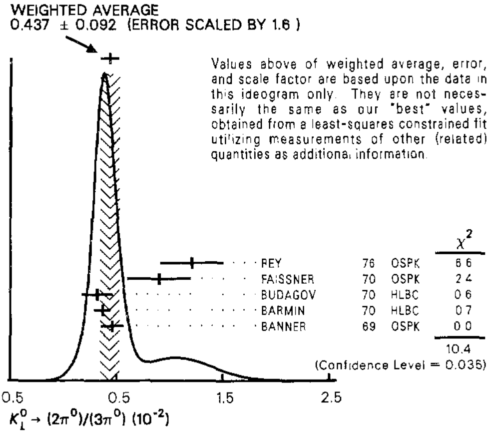
```
R17 C    7   (1.2)     (1.5)     (1.2)  CRIEGEE   66 OSPK
R17 C   CRIEGEE EXPT NOT DESIGNED TO MEASURE 2PI0 DECAY MODE
R17 G  189   (2.5)     (0.8)            GAILLARD  69 OSPK    E00=3.6+-0.6
R17 G   LATEST RESULT OF THIS EXPERIMENT GIVEN BY FAISSNER 70 R19
R17         . . . . . . . . . . .
R17 FIT       0.94     0.19   FROM FIT
```

$K_L^0 \to (3\pi^0)/(\pi^+\pi^-\pi^0)$ (P1)/(P2)

```
R18    188    2.0      0.6            ALEKSANYA 64 FBC
R18   1010    1.80     0.13           BUDAGOV   68 HLBC
R18    883   (1.65)   (0.07)          BARMIN2   72 HLBC    ERROR STAT. ONLY
R18         . . . . . . . . . . .
R18 AVG       1.81     0.13    AVERAGE
R18 FIT       1.73     0.10   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.7)
```

$K_L^0 \to (2\pi^0)/(3\pi^0)$ (units 10^{-2}) (P11)/(P1)

```
R19 C  109   (1.89)    (0.31)         CRONIN 1  67 OSPK    ETA00=4.9+-0.5
R19 C        (1.36)    (0.18)         CRONIN 2  67 OSPK    ETA00=3.92+-0.3
R19 C      CRONIN2 IS FURTHER ANALYSIS OF CRONIN1, NOW BOTH WITHDRAWN
R19       NO EVENTS SEEN              BARTLETT  68 OSPK    SEE E00 BELOW
R19     57    0.46     0.11           BANNER    69 OSPK    ETA00=2.2+-0.3
R19 R  133   (1.31)   (0.31)          CENCE     69 OSPK    ETA00=3.7+-0.5
R19     29    0.37     0.08           BARMIN    70 HLBC    ETA00=2.02+-0.23
R19     30    0.32     0.15           BUDAGOV   70 HLBC    ETA00=1.9+-0.5
R19  F 172    0.90     0.30           FAISSNER  70 OSPK    ETA00=3.2+-0.5
R19  R 150    1.21     0.30           REY       76 OSPK    ETA00=3.8+-0.5
R19  F FAISSNER 70 CONTAINS SAME 2PI0 EVENTS AS GAILLARD 69 R17
R19  R  CENCE 69 EVENTS ARE INCLUDED IN REY 76.
R19         . . . . . . . . . . .
R19 AVG       0.437    0.092   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
R19 FIT       0.437    0.085  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5)
                       (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$K_L^0 \to (\pi^+\pi^-)/(\pi \ell \nu)$ (units 10^{-3}) (P5)/(P3+P4)

```
R20 O  309   (2.51)    (0.23)         DEBOUARD  67 OSPK    ETA+-=2.00+-0.09
R20 O  525   (2.35)    (0.19)         FITCH     67 OSPK    ETA+-=1.94+-0.08
R20   2703    3.04     0.14           DEVOE     77 SPEC    ETA+-=2.25+-0.05
R20   1687    3.13     0.14           COUPAL    85 SPEC    ETA+-=2.28+-0.06  |
R20 O   OLD EXPERIMENTS EXCLUDED FROM FIT.  SEE SUBSECTION E+- BELOW FOR
R20 O   AVERAGE ETA+- OF THESE EXPERIMENTS AND FOR NOTE ON DISCREPANCY.
R20         . . . . . . . . . . .
R20 AVG       3.085    0.099   AVERAGE
R20 FIT       3.087    0.066  FROM FIT
```

$K_L^0 \to (2\gamma)/(3\pi^0)$ (units 10^{-3}) (P9)/(P1)

```
R21     16    2.5      0.7            ARNOLD    68 HLBC    VACUUM DECAY
R21    115    2.24     0.28           BANNER    69 OSPK
R21     28    2.13     0.43           BARMIN    71 HLBC
R21         . . . . . . . . . . .
R21 AVG       2.24     0.22    AVERAGE
```

$K_L^0 \to (\mu^+\mu^-)/(\pi^+\pi^-)$ (units 10^{-6}) (P6)/(P5)

```
R22     TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R22     WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R22      0 (140.)   OR LESS  CL=.90   FOETH     69 SPEC
R22      0  (18.)   OR LESS  CL=.90   DARRIULAT 70 SPEC
R22 A    0   (1.53) OR LESS  CL=.90   CLARK     71 SPEC
R22  C   9    5.8      2.3      1.5   CARITHERS 73 SPEC
R22  F   3    4.2      5.1      2.6   FUKUSHIMA 76 SPEC
R22     15    4.0      1.4      0.9   SHOCHET   79 SPEC
R22 A   CLARK 71 LIMIT RAISED FROM 1.2 E-06 BY FIELD 74 REANALYSIS.
R22 A   NOT IN AGREEMENT WITH SUBSEQUENT EXPTS. SO NOT AVERAGED.
R22  C  CARITHERS 73 ERRORS ARE AT CL=0.68, W.CARITHERS, PRIV.COMM. 1979.
R22  F  FUKUSHIMA 76 ERRORS ARE AT CL=90 PERCENT.
R22         . . . . . . . . . . .
R22 AVG       4.47     0.95    AVERAGE
```

$K_L^0 \to (e^+e^-)/(\pi^+\pi^-)$ (units 10^{-5}) (P7)/(P5)

```
R23     TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R23     WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R23      0   10.0   OR LESS  CL=.90   FOETH     69 ASPK
R23 A        (0.10) OR LESS  CL=.90   CLARK     71 ASPK
R23 A   POSSIBLE (BUT UNKNOWN) SYSTEMATIC ERRORS.  SEE NOTE A IN R22 ABOVE.
```

$K_L^0 \to (e \mu)/(\pi^+\pi^-)$ (units 10^{-5}) (P8)/(P5)

```
R24     L=E OR MU
R24  A       (0.10) OR LESS  CL=.90   CLARK     71 ASPK
R24  A  POSSIBLE (BUT UNKNOWN) SYSTEMATIC ERRORS.  SEE NOTE A IN R22 ABOVE.
```

$K_L^0 \to (\pi e \nu \gamma)/(K_{e3})$ (units 10^{-2}) (P12)/(P3)

```
R25     10    3.3      2.0            PEACH     71 HLBC GAM KE GT 15 MEV
```

$K_L^0 \to (\pi^0 2\gamma)/(3\pi^0)$ (units 10^{-3}) (P13)/(P1)

```
R26      0    1.1   OR LESS  CL=.90   BANNER    69 OSPK
```

$K_L^0 \rightarrow (\pi^+\pi^-)/(\pi^+\pi^-\pi^0)$ (units 10^{-2}) (P5)/(P2)

```
R27   4200    1.64     0.04              MESSNER   73 ASPK    ETA+- = 2.23
R27              . . . . . . . . . .
R27 FIT         1.639    0.033  FROM FIT
```

$K_L^0 \rightarrow (e^+e^-\gamma)$/total (units 10^{-5}) (P14)

```
R28      TEST FOR DELTA(S)= 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R28      WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R28  B    0   (2.7)  OR LESS  CL=.90   BARMIN1   72 HLBC
R28  C    4    1.74     0.87           CARROLL1  80 SPEC +-0
R28  B  USES KL TO 3PI0/TOTAL=0.214 .
R28  C  USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.1239 .
```

$K_L^0 \rightarrow (\mu^+\mu^-\gamma)$/total (units 10^{-6}) (P15)

```
R29      TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R29      WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R29  D        (7.81) OR LESS  CL=.90   DONALDS3  74 SPEC
R29  C    1    0.28     0.28           CARROLL1  80 SPEC +-0
R29  D  USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.126 .
R29  C  USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.1239 .
```

$K_L^0 \rightarrow (\mu^+\mu^-\pi^0)$/total (units 10^{-5}) (P16)

```
R30      TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R30      WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R30  D        (5.66) OR LESS  CL=.90   DONALDS3  74 SPEC
R30  C    0    0.12  OR LESS  CL=.90   CARROLL1  80 SPEC
R30  D  USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.126 .
R30  C  USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.1239 .
```

$K_L^0 \rightarrow (\pi^+\pi^-e^+e^-)$/total (units 10^{-6}) (P17)

```
R31      TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R31      WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R31         (30.)   OR LESS            ANIKINA   73 STRC
R31  D        (8.81) OR LESS  CL=.90   DONALDSON 76 SPEC
R31   0     2.5    OR LESS  CL=.90   BALATS    83 SPEC                 |
R31  D  USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.126 .
```

$K_L^0 \rightarrow (\pi^0\pi^\pm e^\mp\nu)$/total (units 10^{-3}) (P18)

```
R32  D        (2.2)  OR LESS  CL=.90   DONALDS3  74 SPEC
R32      16    0.062    0.020          CARROLL3  80 SPEC
R32  D  DONALDSON3 74 USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.126 .
```

$K_L^0 \rightarrow ((\pi\mu$ atom$)\nu)/(\pi\mu\nu)$ (10^{-7}) (P19)/(P3)

```
R33      18  SEEN                      COOMBES   76 WIRE
R33     155    3.88     0.41           ARONSON   82 SPEC
```

$K_L^0 \rightarrow (e^+e^-\pi^0)$/total (units 10^{-6}) (P20)

```
R34      TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R34      WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R34  C    0     2.3   OR LESS  CL=.90   CARROLL1  80 SPEC
R34  C  USES KL TO PI+PI-PI0/ALL KL DECAYS = 0.1239 .
```

$K_L^0 \rightarrow (\mu^+\mu^-e^+e^-)$/total (units 10^{-6}) (P21)

```
R35      TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R35      WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R35             4.9   OR LESS  CL=.90   BALATS    83 SPEC                 |
```

$K_L^0 \rightarrow (e^+e^-e^+e^-)$/total (units 10^{-6}) (P22)

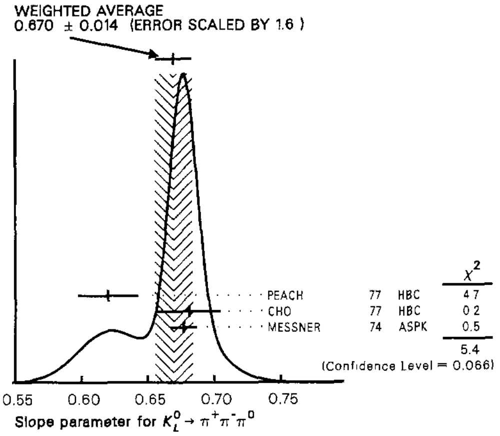
```
R36      TEST FOR DELTA(S) = 1 WEAK NEUTRAL CURRENT.  ALLOWED BY FIRST ORDER
R36      WEAK INTERACTION COMBINED WITH ELECTROMAGNETIC INTERACTION.
R36             2.6   OR LESS  CL=.90   BALATS    83 SPEC                 |
```

K_L^0 ENERGY DEPENDENCE OF DALITZ PLOT

```
      FOR DISCUSSION, SEE NOTE ON SLOPE PARAMETERS IN THE K+-
      SECTION OF THE FULL LISTINGS ABOVE.

     MATRIX ELEMENT SQUARED = 1 + G*U + H*U**2 + J*V + K*V**2
     WHERE U=(S3-S0)/(MPI**2) AND V=(S1-S2)/(MPI+**2)
```

LINEAR COEFFICIENT g FOR $|M(K_L^0 \rightarrow \pi^+\pi^-\pi^0)|^2$

```
GTO Q   79   (0.55)    (0.23)             ADAIR     64 HBC  AV=-7.6 +- 1.7
GTO Q   77   (0.51)    (0.20)             LUERS     64 HBC  AV=-7.3 +- 1.6
GTO Q   66   (0.32)    (0.13)             ASTBURY1  65 CC   AV=-5.5 +- 1.5
GTO Q  310   (0.51)    (0.09)             ASTBURY2  65 CC   AV=-(7.3 +.6 -.8)
GTO Q  280   (0.64)    (0.17)             ANIKINA   66 CC   AV=-(8.2 +.9 -1.3)
GTO Q  126   (0.70)    (0.12)             HAWKINS   66 HBC  AV=-8.6 +- 0.7
GTO Q 1350   (0.649)   (0.044)            HOPKINS   67 HBC  AT=-0.294 +- .018
GTO Q 1198   (0.428)   (0.055)            NEFKENS   67 OSPK AU=-0.204 +- .025
GTO Q 2446   (0.400)   (0.045)            BASILE2   68 OSPK AT=-0.188 +- .020
GTO Q  29K   (0.650)   (0.012)            ALBROW    70 ASPK AY=-0.858+-.015
GTO QB 36K   (0.593)   (0.022)            BUCHANAN  70 SPEC AU=-0.278 +- .010
GTO Q 4400   (0.664)   (0.056)            SMITH     70 OSPK AT=-0.306 +-0.024
GTO Q  180   (0.50)    (0.11)             JAMES     72 HBC
GTO Q 1486   (0.608)   (0.043)            KRENZ     72 HLBC AT=-0.277 +- .018
GTO Q  384   (0.688)   (0.074)            METCALF   72 ASPK AT=-0.31  +- .03
GTO Q        (0.612)   (0.032)            ALEXANDER 73 HBC
GTO Q 3200   (0.73)    (0.04)             BRANDENBU 73 HBC
GTO QC 20K   (0.619)   (0.027)            BISI      74 ASPK AT=-0.282 +- .011
GTO   509K    0.677     0.010             MESSNER   74 ASPK AY=-0.917+-.013
GTO Q  192   (0.69)    (0.07)             BALDOCEOL 75 HLBC
GTO Q  56K   (0.590)   (0.022)            BUCHANAN  75 SPEC AU=-0.277 +- .010
GTO  H6499    0.681     0.024             CHO       77 HBC
GTO   4709    0.620     0.023             PEACH     77 HBC
GTO Q   QUADRATIC DEPENDENCE REQUIRED BY SOME EXPERIMENTS (SEE SECTIONS
GTO Q   HTO AND KTO BELOW).  CORRELATIONS PREVENT US FROM AVERAGING RESULTS
GTO Q   OF FITS NOT INCLUDING G, H, AND K TERMS.
GTO  B  BUCHANAN 70 RESULT REVISED BY BUCHANAN 75 TO INCLUDE RADIATIVE COR.
GTO  B  AND TO USE MORE RELIABLE KL MOM.SPECT. OF 2ND EXPT.(HAD SAME BEAM).
GTO  C  BISI 74 VALUE COMES FROM QUADRATIC FIT WITH QUAD. TERM CONSISTENT
GTO  C  WITH ZERO.  GTO ERROR IS THUS LARGER THAN IF LINEAR FIT WERE USED.
GTO            . . . . . . . . . .
GTO AVG       0.670     0.014   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
                             (SEE IDEOGRAM BELOW)
```



Slope parameter for $K_L^0 \rightarrow \pi^+\pi^-\pi^0$

QUAD. COEFFICIENT h FOR $|M(K_L^0 \rightarrow \pi^+\pi^-\pi^0)|^2$

```
HTO Q  29K  (-0.011)  (0.018)            ALBROW    70 ASPK
HTO Q 4400   (0.043)  (0.052)            SMITH     70 OSPK
HTO   509K    0.079    0.007             MESSNER   74 ASPK
HTO   6499    0.095    0.032             CHO       77 HBC
HTO   4709    0.048    0.036             PEACH     77 HBC
HTO     SEE NOTES IN SECTION GTO ABOVE.
HTO          . . . . . . . . . .
HTO AVG       0.0786   0.0067  AVERAGE
```

QUAD. COEFFICIENT k FOR $|M(K_L^0 \rightarrow \pi^+\pi^-\pi^0)|^2$

```
KTO   509K    0.0097   0.0018            MESSNER   74 ASPK
KTO   6499    0.024    0.010             CHO       77 HBC
KTO   4709   -0.008    0.012             PEACH     77 HBC
KTO          . . . . . . . . . .
KTO AVG       0.0098   0.0018  AVERAGE
```

LINEAR COEFFICIENT j FOR $K_L^0 \rightarrow \pi^+\pi^-\pi^0$ CP VIOLATING TERM

```
JTR     LISTED IN CP VIOLATION SECTION BELOW.
```

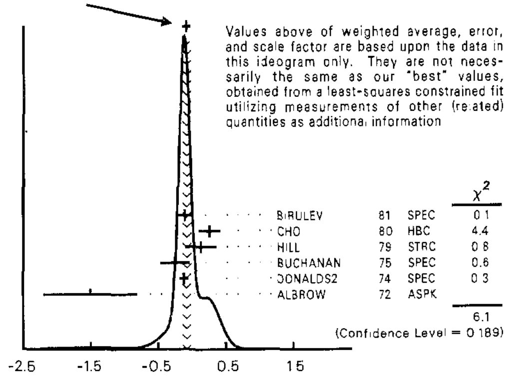
K_L^0 FORM FACTORS

```
      FOR DISCUSSION, SEE NOTE ON FORM FACTORS IN THE K+-
      SECTION OF THE FULL LISTINGS ABOVE.

      IN THE FORM FACTOR COMMENTS, THE FOLLOWING ABBREVIATIONS ARE USED.
      F+ AND F- ARE FORM FACTORS FOR THE VECTOR MATRIX ELEMENT.
      FS AND FT REFER TO THE SCALAR AND TENSOR TERM.
      F0 = (F+) + (F-)*T/(MK**2-MPI**2)
      L+, L- AND L0 ARE THE LINEAR EXPANSION COEFFS. OF F+, F- AND F0.
      L+ REFERS TO THE KMU3 VALUE EXCEPT IN THE KE3 SECTIONS.
      DXI/DL IS THE CORRELATION BETWEEN XI(0) AND L+ IN KMU3.
      DL0/DL+ IS THE CORRELATION BETWEEN L0 AND L+ IN KMU3.
      T  = MOMENTUM TRANSFER TO THE PI IN UNITS OF MPI**2.
      DP = DALITZ PLOT ANALYSIS
      PI = PI SPECTRUM ANALYSIS
      MU = MU SPECTRUM ANALYSIS
      POL= MU POLARIZATION ANALYSIS
      BR = KMU3/KE3 BRANCHING RATIO ANALYSIS
      E  = POSITRON OR ELECTRON SPECTRUM ANALYSIS
      RC = RADIATIVE CORRECTIONS
```

$\xi_A = f_-/f_+$ (DETERMINED FROM SPECTRA)

```
XIA  A1341   +1.2      (0.8)             CARPENTER 66 OSPK    DP, DXI/DL=-18
XIA B 3140  (-3.9)     (0.4)             BASILE    70 OSPK    DP, INDEP OF L+
XIA C  16K  (-0.68)    (0.12)    (0.20)  CHIEN     70 ASPK    DP, DXI/DL=-26
XIA  D9086   -1.5       0.7              ALBROW    72 ASPK    DP, DXI/DL=-28
XIA C  16K  (+0.50)    (0.61)            DALLY     72 ASPK    DP, DXI/DL UNKN.
XIA  E1385   -1.00     (0.45)            PEACH     73 HLBC    DP, DXI/DL=-20
XIA  F1.6M   -0.11      0.07             DONALDS2  74 SPEC    DP, DXI/DL=-17
XIA  G 32K   -0.25      0.22             BUCHANAN  75 SPEC    DP, DXI/DL=-5.9
XIA  H 16K   +0.13      0.23             HILL      79 STRC    DP, DXI/DL=-20
XIA  H 14K   +0.26      0.16             CHO       80 HBC     DP, DXI/DL=-13
XIA  I150K   -0.10      0.09             BIRULEV   81 SPEC    DP, DXI/DL=-12
XIA          . . . . . . . . . .
XIA AVG      -0.074     0.061   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
XIA FIT   .  -0.11      0.09   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.3)  |
                          (SEE IDEOGRAM BELOW)

XIA      FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
XIA  A   CARPENTER 66 XI(0) IS FOR L+=0.  DXI/DL IS FROM FIG. 9.
XIA B    BASILE 70 IS INCOMPATIBLE WITH ALL OTHER RESULTS.  AUTHORS SUGGEST
XIA B    THAT EFFICIENCY ESTIMATES MIGHT BE RESPONSIBLE.
XIA C    CHIEN 70 ERRORS ARE STATISTICAL ONLY.  DXI/DL FROM FIG.4.
XIA  C   DALLY 72 IS A REANALYSIS OF CHIEN 70.  THE DALLY 72 RESULT IS
XIA  C   NOT COMPATIBLE WITH ASSUMPTION L-=0 SO NOT INCLUDED IN OUR FIT.
XIA  C   THE NON-ZERO L- VALUE AND THE RELATIVELY LARGE L+ VALUE FOUND BY
XIA  C   DALLY 72 COME MAINLY FROM A SINGLE LOW T BIN (FIGS.1,2).
XIA  C   THE (F+,XI) CORRELATION WAS IGNORED.
XIA  C   WE ESTIMATE FROM FIG. 2 THAT FIXING L-=0 WOULD GIVE XI(0)=-1.4+-0.3
XIA  C   AND WOULD ADD 10 TO CHI SQUARED.  DXI/DL IS NOT GIVEN.
XIA  D   ALBROW 72 FIT HAS L- FREE, GETS L-=-.030+-.060 OR LAM=+.15+.17-.11.
XIA  E   PEACH 73 GIVES XI0=-.95+-.45 FOR L+=L-=.025 .  THE ABOVE VALUE IS
XIA  E   FOR L-=0.  K.PEACH, PRIVATE COMMUNICATION(1974).
XIA  F   DONALDSON2 74 GIVES XI=-.11+-.02 NOT INCLUDING SYSTEMATICS.  ABOVE
XIA  F   ERROR AND DXI/DL WERE CALCULATED BY US FROM L0 AND L+ ERRORS (WHICH
XIA  F   INCLUDE SYSTEMATICS) AND DL0/DL+.
XIA  G   BUCHANAN 75 IS CALCULATED BY US FROM L0, L+ AND DL0/DL+ BECAUSE
XIA  G   THEIR APPENDIX A VALUE -.20+-22 ASSUMES XI(T) CONSTANT, I.E. L-=L+.
XIA  H   HILL 79 AND CHO 80 CALCULATED BY US FROM L0, L+, AND DL0/DL+.
XIA  I   BIRULEV 81 ERROR, DXI/DL CALC. BY US FROM L0, L+.  DL0/DL+=0 USED.
```

WEIGHTED AVERAGE
-0.074 ± 0.061 (ERROR SCALED BY 1.2)


Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$\xi_A = f_-/f_+$ for $K^0_{\mu3}$ decay spectra

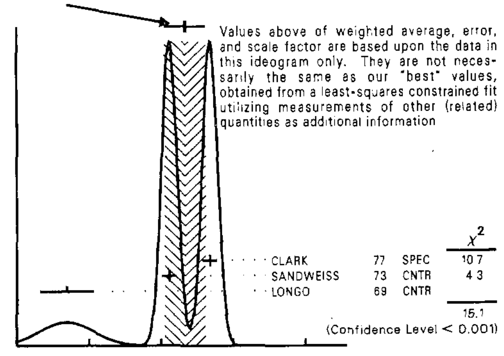
$\xi_B = f_-/f_+$ (DETERMINED FROM $K_{\mu3}/K_{e3}$)

```
XIB      THE KMU3/KE3 BRANCHING RATIO FIXES A RELATIONSHIP BETWEEN XI(0)
XIB      AND L+.  WE QUOTE THE AUTHORS XI(0) AND ASSOCIATED L+ BUT DO NOT
XIB      AVERAGE BECAUSE THE L+ VALUES DIFFER.  THE FIT RESULT AND SCALE
XIB      FACTOR GIVEN IN THE NOTE ON KL3 FORM FACTORS IN THE K+- SECTION OF
XIB      THE DATA LISTINGS ARE NOT OBTAINED FROM THESE XIB VALUES.  INSTEAD
XIB      THEY ARE OBTAINED DIRECTLY FROM THE AUTHORS KMU3/KE3 BRANCHING
XIB      RATIO VIA THE FITTED KMU3/KE3 RATIO (R10).
XIB    389  (+1.1)     (1.1)                ADAIR     64 HBC     BR, L+=0
XIB         (+0.66)    (0.9)      (1.3)  LUERS     64 HBC     BR, L+=0
XIB         (+0.2)     (0.8)      (1.2)  KULYUKINA 68 CC      BR, L+=0
XIB    569  (+0.45)    (0.28)               BEILLIERE 69 HLBC    BR, L+=0
XIB E 1309  (-0.22)    (0.30)               EVANS     69 HLBC
XIB   3548  (-0.5)     (0.5)                BASILE    70 OSPK    BR, L+=.02
XIB   6700   (0.5)     (0.4)                BRANDENBU 73 HBC     BR,L+=.019+-.013
XIB  E1309  (-0.08)    (0.25)               EVANS     73 HLBC    BR, L+=.02
XIB          . . . . . . . . . .
XIB FIT       -0.11     0.09   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.3)  |

XIB      FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
XIB  E   EVANS 73 REPLACES EVANS 69.
```

$\xi_C = f_-/f_+$ (DETERMINED FROM μ POLARIZATION IN $K_{\mu3}$)

```
XIC      THE MU POLARIZATION IS A MEASURE OF XI(T). NO ASSUMPTIONS ON L+-
XIC      NECESSARY, T (WEIGHTED BY SENSITIVITY TO XI0) SHOULD BE SPECIFIED.
XIC      IN L+,XI(0) PARAMETERIZATION THIS IS XI(0) FOR L+=0.  DXI/DL=XI*T.
XIC       FOR RAD. CORR. TO MUON POLARIZATION IN KMU3, SEE GINSBERG 73.
XIC T 2608  (-1.2)     (0.5)                AUERBACH  66 OSPK    POLARIZATION
XIC T  638  (-1.6)     (0.5)                ABRAMS    68 OSPK    POLARIZATION
XIC  L        -1.81     0.50      0.26  LONGO     69 CNTR    POL. T=3.3
XIC  S2.2M    -0.385    0.105               SANDWEISS 73 CNTR    POL,DXI/DL=-6
XIC  H207K    +0.178    0.105               CLARK     77 SPEC    POL,DXI/DL=+.68
XIC          . . . . . . . . . .
XIC AVG       -0.17 -   0.28    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 3.9)
XIC FIT       -0.11     0.09   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.3)  |
                               (SEE IDEOGRAM BELOW)

XIC      FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
XIC T    T VALUE NOT GIVEN.
XIC  L   LONGO 69 T=3.3 CALC. FROM DXI/DL=-6.0 (TABLE 1) DIVIDED BY XI=-1.81
XIC  S   SANDWEISS 73 IS FOR L+=0 AND T=0.
XIC  H   CLARK 77 T=+3.80, DXI/DL=XI(T)*T=.178*3.80=+.68 .
```

WEIGHTED AVERAGE
-0.17 ± 0.28 (ERROR SCALED BY 3.9)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$\xi_C = f_-/f_+$ for $K^0_{\mu3}$ decay μ polarization

IMAGINARY PART OF ξ (TEST OF T REVERSAL)

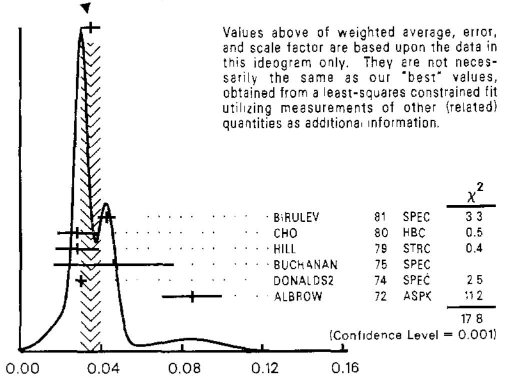
```
IXI            -0.2       0.6                ABRAMS    68 OSPK    POLARIZATION
IXI            -0.02      0.08               LONGO     69 CNTR    POL. T=3.3
IXI   2.2M     -0.060     0.045              SANDWEISS 73 CNTR    POL, T=0
IXI  S2.2M     -0.085     0.064              SANDWEISS 73 CNTR    POL,T=0
IXI  C207K      0.35      0.30               CLARK     77 SPEC    POL, T=0
IXI            (0.012)   (0.026)             SCHMIDT   79 CNTR    REPL.BY MORSE 80
IXI    12M      0.009     0.030              MORSE     80 CNTR    POLARIZATION
IXI  S  SANDWEISS 73 VALUE CORRECTED FROM VALUE QUOTED IN THEIR PAPER DUE
IXI  S  TO NEW VALUE OF RE(XI). SEE FTNOTE 4 OF SCHMIDT 79.
IXI  C  CLARK 77 VALUE HAS ADDITIONAL XI0 DEPENDENCE +0.21*RE(XI0).
IXI          . . . . . . . . . .
IXI AVG        -0.020     0.022   AVERAGE
```

λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN $K_{\mu3}$ DECAY)

```
L+M      SEE ALSO THE CORRESPONDING ENTRIES AND NOTES IN SECTION XIA AND L0.
L+M      FOR RAD.COR. OF KMU3 DP SEE GINSBURG 70 AND BECHERRAWY 70.
L+M     16K    (0.07)    (0.02)              CHIEN     70 ASPK REPL. BY DALLY 72
L+M   A9086     0.085     0.015              ALBROW    72 ASPK    DP
L+M     16K    (0.11)    (0.04)              DALLY     72 ASPK    DP
L+M     82K    (0.046)   (0.008)             ALBRECHT  74 WIRE REPL. BY BIRULEV 81
L+M    1.6M     0.030     0.003              DONALDS2  74 SPEC    DP
L+M     32K     0.046     0.030              BUCHANAN  75 SPEC    DP
L+M    129K    (0.0337)  (0.0033)            DZHORDZHA 77 SPEC REPL. BY BIRULEV 81
L+M     16K     0.028     0.011              HILL      79 STRC    DP
L+M     14K     0.028     0.010              CHO       80 HBC     DP
L+M    150K     0.0427    0.0044             BIRULEV   81 SPEC    DP
L+M          . . . . . . . . . .
L+M AVG         0.0347    0.0049  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.1)
L+M FIT         0.034     0.005  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.3)  |
                                 (SEE IDEOGRAM BELOW)

L+M      FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
```

WEIGHTED AVERAGE
0.0347 ± 0.0049 (ERROR SCALED BY 2.1)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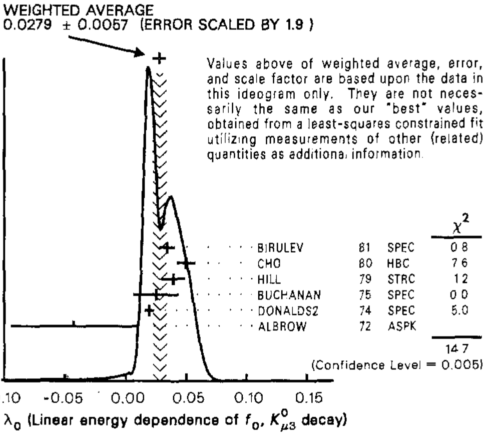
λ_+ (Linear energy dependence of f_+, $K^0_{\mu3}$ decay)

λ_0 (LINEAR ENERGY DEPENDENCE OF f_0 IN $K_{\mu3}$ DECAY)

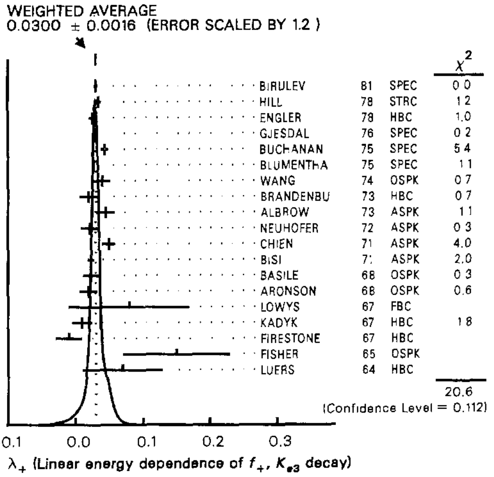
```
L0       WHEREVER POSSIBLE, WE HAVE CONVERTED THE ABOVE VALUES OF XI(0) INTO
L0       VALUES OF L0 USING THE ASSOCIATED L+M AND DXI/DL.
L0 L  1371    +0.08     (0.07)              CARPENTER 66 OSPK    DP,DL0/DL+=-0.54
L0 L          -0.140    (0.043)  (0.022)LONGO     69 CNTR    POL,DL0/DL+=+.49
L0  B 3140   (-0.333)   (0.034)             BASILE    70 OSPK    DP,DL0/DL+=+1.
L0 A  9086    -0.043     0.052              ALBROW    72 ASPK    DP,DL0/DL+=-1.39
L0  C  16K   (-0.067)   (0.227)             DALLY     72 ASPK    DP,DL0/DL+ UNKN.
L0  R 6700   (+0.06)    (0.03)              BRANDENBU 73 HBC     BR,L+=.019+-.013
L0 P  1385    -0.060    (0.038)             PEACH     73 HLBC    DP,DL0/DL+=-0.71
L0 L  2.2M    -0.018    (0.009)             SANDWEISS 73 CNTR    POL,DL0/DL+=+.49
L0      82K  (+0.024)   (0.011)             ALBRECHT  74 WIRE REPL. BY BIRULEV 81
L0 E  1.6M    +0.019     0.004              DONALDS2  74 SPEC    DP,DL0/DL+=-0.47
L0    F 32K   +0.025     0.019              BUCHANAN  75 SPEC    DP,DL0/DL+=+0.5
L0 L  207K    +0.047    (0.009)             CLARK     77 SPEC    POL,DL0/DL+=1.06
L0      47K  (+0.0485)  (0.0076)            DZHORDZHA 77 SPEC REPL. BY BIRULEV 81
L0      16K   +0.039     0.010              HILL      79 STRC    DP,DL0/DL+=-0.67
L0      14K   +0.050     0.008              CHO       80 HBC     DP,DL0/DL+=-0.11
L0  G   14K   (0.041)   (0.008)             CHO       80 HBC     BR, L+=0.028
L0 H  150K     0.0341    0.0067             BIRULEV   81 SPEC    DP,DL0/DL+=?
L0           . . . . . . . . . .
L0  AVG        0.0279    0.0057  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.9)
L0  FIT        0.025     0.006  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.3)  |
                                (SEE IDEOGRAM BELOW)

L0       FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN 1982 EDITION.
L0 L     L0 VALUE IS FOR L+=0.03  CALCULATED BY US FROM XI0 AND DXI/DL.
L0  B    BASILE 70 L0 IS FOR L+=0.  CALCULATED BY US FROM XIA WITH DXI/DL=0.
L0  B    BASILE 70 IS INCOMPATIBLE WITH ALL OTHER RESULTS.  AUTHORS SUGGEST
L0  B    THAT EFFICIENCY ESTIMATES MIGHT BE RESPONSIBLE.
L0 A     ALBROW 72 L0 IS CALCULATED BY US FROM XIA,L+ AND DXI/DL.  THEY GIVE
L0 A     L0=-.043+-.039 FOR L-=0.  WE USE OUR LARGER CALCULATED ERROR.
L0  C    DALLY 72 GIVES F0=1.20+-.35, L0=-.080+-.272, L0PRIME=-.006+-.045,
L0  C    BUT WITH A DIFFERENT DEFINITION OF L0.  OUR QUOTED L0 IS HIS L0/F0.
L0  C    WE CANNOT CALCULATE TRUE L0 ERROR WITHOUT HIS (L0,F0) CORRELATIONS.
L0  C    SEE ALSO NOTE C IN SECTION XIA.
L0 P     PEACH 73 ASSUMES L+=0.025.  CALCULATED BY US FROM XI0 AND DXI0/DL+.
L0  R    FIT FOR L0 DOES NOT INCLUDE THIS VALUE BUT INSTEAD INCLUDES THE
L0  R    KMU3/KE3 RESULT FROM THIS EXPERIMENT.
L0 E     DONALDSON2 74 DL0/DL+ OBTAINED FROM FIG. 18.
L0   F   BUCHANAN 75 VALUE IS FROM THEIR APPENDIX A AND USES ONLY KMU3 DATA.
L0   F   DL0/DL+ WAS OBTAINED BY PRIVATE COMMUNICATION, C.BUCHANAN, 1976.
L0   G   CHO 80 BR RESULT NOT INDEPENDENT OF THEIR DP RESULT.
L0   H   BIRULEV 81 GIVES DL0/DL+=-1.5, GIVING AN UNREASONABLY NARROW ERROR
L0   H   ELLIPSE WHICH DOMINATES ALL OTHER RESULTS.  WE USE DL0/DL+=0.
```



λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN K_{e3} DECAY)

```
L+E      FOR RAD.COR. OF KE3 DP SEE GINSBURG 67 AND BECHERRAWY 70.
L+E     153   +0.07      0.06                LUERS     64 HBC      DP, NO RC
L+E     577   +0.15      0.08                FISHER    65 OSPK     DP, NO RC
L+E     762   -0.01      0.02                FIRESTONE 67 HBC      DP, NO RC
L+E     531   +0.01      0.015               KADYK     67 HBC      E,PI, NO RC
L+E     240   +0.08      0.10       0.08     LOWYS     67 FBC      PI
L+E    1000    0.02      0.013               ARONSON   68 OSPK     PI
L+E    4800   +0.023     0.012               BASILE    68 OSPK     DP, NO RC
L+E     42K    0.023     0.005               BISI      71 ASPK     DP
L+E     16K    0.05      0.01                CHIEN     71 ASPK     DP, NO RC
L+E    1910    0.022     0.014               NEUHOFER  72 ASPK     PI
L+E    5600    0.045     0.014               ALBROW    73 ASPK     DP
L+E    1871    0.019     0.013               BRANDENBU 73 HBC      PI TRANSV.
L+E    2171    0.040     0.012               WANG      74 OSPK     DP
L+E     25K    0.0270    0.0028              BLUMENTHA 75 SPEC     DP
L+E     24K    0.044     0.006               BUCHANAN  75 SPEC     DP
L+E     48K   (0.032)   (0.0042)             BIRULEV   76 SPEC REPL. BY BIRULEV 81
L+E    500K    0.0312    0.0025              GJESDAL   76 SPEC     DP
L+E  E  12K    0.025     0.005               ENGLER    78 HBC      DP
L+E     18K    0.0348    0.0044              HILL      78 STRC     DP
L+E     26K   (0.0286)  (0.0049)             BIRULEV   79 SPEC REPL. BY BIRULEV 81
L+E E   19K   (0.029)   (0.005)              CHO       80 HBC      DP
L+E     74K    0.0306    0.0034              BIRULEV   81 SPEC     DP
L+E E    ENGLER 78 USES UNIQUE KE3 SUBSET OF CHO 80 EVENTS AND IS LESS
L+E E    SUBJECT TO SYSTEMATIC EFFECTS.
L+E           . . . . . . . . . . .
L+E AVG        0.0300    0.0016  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
                         (SEE IDEOGRAM BELOW)
```



$|f_S/f_+|$ FOR K_{e3} DECAY

```
FS      RATIO OF SCALAR TO F+ COUPLINGS
FS              (0.15) OR LESS  CL=.68   KULYUKINA 67 CC
FS      5600    (0.19) OR LESS  CL=.95   ALBROW    73 ASPK
FS       25K     0.04  OR LESS  CL=.68   BLUMENTHA 75 SPEC
FS       48K    (0.07) OR LESS  CL=.68   BIRULEV   76 SPEC SEE ALSO BIRULEV 81
FS       18K    (0.095)OR LESS  CL=.95   HILL      78 STRC
```

$|f_T/f_+|$ FOR K_{e3} DECAY

```
FT      RATIO OF TENSOR TO F+ COUPLINGS
FT              (1.0)  OR LESS  CL=.68   KULYUKINA 67 CC
FT      5600    (1.0)  OR LESS  CL=.95   ALBROW    73 ASPK
FT       25K     0.23  OR LESS  CL=.68   BLUMENTHA 75 SPEC
FT       48K    (0.34) OR LESS  CL=.68   BIRULEV   76 SPEC SEE ALSO BIRULEV 81
FT       18K    (0.40) OR LESS  CL=.95   HILL      78 STRC
```

$|f_T/f_+|$ FOR $K_{\mu3}$ DECAY

```
FTM     RATIO OF TENSOR TO F+ COUPLINGS
FTM              0.12     0.12               BIRULEV   81 SPEC
```

NOTE ON *CP* VIOLATION IN K_L^0 DECAY

We list the parameters which measure *CP* violation in K_L^0 decays and compare them with superweak model predictions.

Parameters

There are two different K_L^0 decays in which *CP* violation has been observed (for details, see Kleinknecht[1]).

(a) Asymmetry in the $K_L \to \pi^{\mp}\ell^{\pm}\nu$ decays. The quantity measured and compiled here is

$$\delta = \frac{\Gamma(K_L \to \pi^- \ell^+ \nu) - \Gamma(K_L \to \pi^+ \ell^- \nu)}{\Gamma(K_L \to \pi^- \ell^+ \nu) + \Gamma(K_L \to \pi^+ \ell^- \nu)} .$$

This asymmetry violates *CP* invariance. If *CPT* is good, for a pure K_L^0 beam, δ can be written as

$$\delta = 2[(1 - |x|^2)/(|1 - x|^2)] \operatorname{Re} \epsilon ,$$

where x is defined below in the "Note on the $\Delta S = \Delta Q$ Rule in K^0 Decay," and ϵ is the parameter of the expansion

$$|K_L\rangle = [(1+\epsilon)|K\rangle - (1-\epsilon)|\bar{K}\rangle]/[2(1+|\epsilon|^2)]^{1/2}, \quad \text{(1a)}$$

$$|K_S\rangle = [(1+\epsilon)|K\rangle + (1-\epsilon)|\bar{K}\rangle]/[2(1+|\epsilon|^2)]^{1/2}. \quad \text{(1b)}$$

We list δ separately for $K_L^0 \to \pi\mu\nu$ and $K_L^0 \to \pi e\nu$ in sections A1 and A2 respectively, and list the combined values in section AL.

(b) $K_L \to 2\pi$ decay. The relevant parameters are

$$\eta_{+-} = A(K_L \to \pi^+\pi^-)/A(K_S \to \pi^+\pi^-)$$

$$= |\eta_{+-}| \exp(i\phi_{+-}) ,$$

$$\eta_{00} = A(K_L \to \pi^0\pi^0)/A(K_S \to \pi^0\pi^0)$$

$$= |\eta_{00}| \exp(i\phi_{00}) ,$$

ϵ, defined in Eqs. (1) above, and

$$\epsilon' = \frac{1}{2} i \sqrt{2} \exp[i(\delta_2 - \delta_0)] \operatorname{Im}(A_2/A_0) .$$

Here the decay amplitudes to $\pi\pi$ states with definite isospin I are given by

$$\langle I{=}0|T|K\rangle = \exp(i\delta_0)A_0\,,$$

$$\langle I{=}2|T|K\rangle = \exp(i\delta_2)A_2\,.$$

where the δ_I are the $\pi\pi$ scattering phase shifts at the K mass. Wu and Yang[2] derived the relationships

$$\eta_{+-} = \epsilon + \epsilon'\,,\quad \eta_{00} = \epsilon - 2\epsilon'\,,$$

assuming *CPT* invariance, using a phase convention in which A_0 is real, and neglecting small corrections of order $\mathrm{Re}A_2/\mathrm{Re}A_0$.

Measurements of $|\eta_{+-}|$, $|\eta_{00}|^2$, ϕ_{+-}, and ϕ_{00} are listed in sections E+ −, E0S, F+ −, and F00. The FIT values given in these sections come from constrained fits which include the $|\eta_{00}|/|\eta_{+-}|$ and $\phi_{00} - \phi_{+-}$ measurements from sections ER and DF, respectively.

One can determine the values of $|\epsilon|$ and $|\epsilon'|$ using theoretical input on their phases. The phase of ϵ is determined from unitarity and *CPT* invariance to be within a few degrees of the "superweak value" of 44° (for a recent analysis, see V. Barmin et al.[3]). The phase of ϵ' is given by $\delta_2 - \delta_0 + \pi/2$, which equals $48\pm8°$ from an analysis of $\pi\pi$ phase shifts.[4] Thus ϵ and ϵ' have the same phase within 10 to 15°. Therefore to a good approximation

$$\frac{\epsilon'}{\epsilon} = \frac{1}{6}\left\{|\eta_{+-}/\eta_{00}|^2 - 1\right\} = (-3.3\pm4.2)\times10^{-3}.$$

The value of $\phi_{00} - \phi_{+-}$ is not used in this analysis, since taken literally it represents a violation of *CPT* invariance.[3]

Superweak model predictions for $|\eta_{00}/\eta_{+-}|$, ϕ_{+-}, and Re ϵ

The superweak model[5] predicts that[6]

$$|\eta_{00}/\eta_{+-}| = 1\,,$$

$$\phi_{+-} = \phi_{00} = \tan^{-1}\left[\frac{2\Delta m\,\tau_S}{\hbar}\right]\,,$$

and

$$\mathrm{Re}\,\epsilon = |\eta_{+-}|\left[1+\left[\frac{2\Delta m\,\tau_S}{\hbar}\right]^2\right]^{-1/2}$$

The latter two expressions and the values of the K_L^0 − K_S^0 mass difference $\Delta m = (0.5349 \pm 0.0022)\times10^{10}\ \hbar$ sec^{-1}, the K_S^0 mean life $\tau_S = (0.8923 \pm 0.0022)\times10^{-10}$ sec, and the magnitude of the $(K_L^0 \to \pi^+\pi^-)/(K_S^0 \to \pi^+\pi^-)$ amplitude ratio $|\eta_{+-}| = (2.275 \pm 0.021)\times10^{-3}$, all from the current edition, result in the predictions that

$$\phi_{+-} = \phi_{00} = (43.67 \pm 0.14)°$$

and

$$\mathrm{Re}\,\epsilon = (1.646 \pm 0.016)\times10^{-3}\,.$$

The above predictions can be compared with the experimental values

$$|\eta_{00}/\eta_{+-}| = 1.010 \pm 0.013\,,$$

$$\phi_{+-} = (44.6 \pm 1.2)°\,,$$

$$\phi_{00} = (54.5 \pm 5.3)°\,,$$

$$\mathrm{Re}\,\epsilon = (1.621 \pm 0.088)\times10^{-3}\,,$$

where Re ϵ has been computed using the relation

$$\mathrm{Re}\,\epsilon = \frac{\delta}{2}\left(\frac{|1-x|^2}{1-|x|^2}\right)\,,$$

and our current values of the charge asymmetry parameter for leptonic K_L^0 decay $\delta = (0.330 \pm 0.012)\%$ and the $\Delta S = -\Delta Q$ amplitude (Rex, Imx) = (0.009 ± 0.020, −0.004 ± 0.026).

The superweak predictions are within one standard deviation of the data except for the measured value of ϕ_{00}, which is two standard deviations above the prediction. This results primarily from the CHRISTENSON1 79 measurement $\phi_{00} = (55.7 \pm 5.8)°$.

Searches for *CP* violation in $K_L \to 3\pi$

As was discussed in the note on $K \to 3\pi$ decay in the $K^\pm$ section of the Full Listings, the Dalitz plot distribution for this decay contains a charge asymmetry term with coefficient j, the presence of which would indicate *CP* violation. Experimenters have used several forms for this *CP*-violation term. As described in the "Note on Slope Parameters for $K \to 3\pi$ Decays" in the 1982 edition of this Review,[7] we have converted all results to coefficient j and have listed the results in section JT0 below. The coefficient j is consistent with zero, i.e., absence of *CP* violation.

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5. L. Wolfenstein, Phys. Rev. Lett. **13**, 562 (1964).

6. T.D. Lee and L. Wolfenstein, Phys. Rev. **138B**, 1490 (1965).
7. Particle Data Group, Phys. Lett. **111B**, 69 (1982).

CP VIOLATION PARAMETERS IN K^0_L DECAYS

--------- CHARGE ASYM. $\pi^+\pi^-\pi^0$ DECAYS ---------

CP VIOL. COEFFICIENT j FOR $|M(K^0_L \to \pi^+\pi^-\pi^0)|^2$.

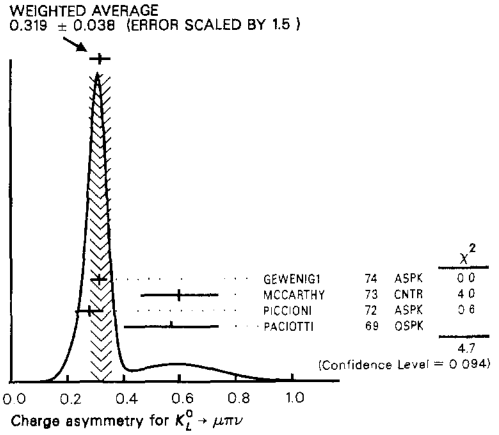
```
JTO    DEFINED AT BEGINNING OF SECTION GTO ABOVE. SEE ALSO NOTE ON SLOPE
JTO    PARAMETERS IN K+- SECTION AND NOTE ON CP VIOLATION IN KL
JTO    DECAY ABOVE.
JTO   238K     0.001    0.004          BLANPIED  68
JTO     3M     0.0013   0.0009         SCRIBANO  70
JTO   4400     0.0      0.017          SMITH     70 OSPK
JTO   6499     0.001    0.011          CHO       77
JTO   4709    -0.001    0.003          PEACH     77
JTO              . . . . . . . . . .
JTO AVG        0.00110  0.00084  AVERAGE
```

--------- CHARGE ASYM. IN LEPTONIC DECAYS ---------

```
       SUCH ASYMMETRY VIOLATES CP . IT IS RELATED TO REAL(EPSILON).
```

$K^0_L \to ((\mu^+\pi^-\nu)-(\mu^-\pi^+\nu))/((\mu^+\pi^-\nu)+(\mu^-\pi^+\nu))$ **(%)**

```
A1  D   1M    (0.403)  (0.134)          DORFAN    67 OSPK    DERIVED FROM R16
A1 D    1M     0.57     0.17            PACIOTTI  69 OSPK
A1     7.7M    0.278    0.051           PICCIONI  72 ASPK
A1     4.1M    0.60     0.14            MCCARTHY  73 CNTR
A1      15M    0.313    0.029           GEWENIG1  74 ASPK
A1 D    PACIOTTI 69 IS A REANALYSIS OF DORFAN 67 AND IS CORRECTED FOR
A1 D    MU+ MU- RANGE DIFFERENCE IN MC CARTHY 72.
A1            . . . . . . . . . .
A1  AVG        0.319    0.038    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
                                 (SEE IDEOGRAM BELOW)
```



$K^0_L \to ((e^+\pi^-\nu)-(e^-\pi^+\nu))/((e^+\pi^-\nu)+(e^-\pi^+\nu))$ **(%)**

```
A2  B  10M    (0.224)  (0.036)          BENNETT   67 CNTR
A2 B   10M     0.246    0.059           SAAL      69 CNTR
A2     10M     0.346    0.033           MARX      70 CNTR
A2    600K     0.36     0.18            ASHFORD   72 ASPK
A2     40M     0.318    0.038           FITCH     73 ASPK
A2     34M     0.341    0.018           GEWENIG1  74 ASPK
A2  B SAAL 69 IS A REANALYSIS OF BENNETT 67
A2            . . . . . . . . . .
A2  AVG        0.333    0.014    AVERAGE
```

$K^0_L \to (\ell^+\pi^-\nu) - (\ell^-\pi^+\nu)/(\ell^+\pi^-\nu) + (\ell^- \quad \pi^+\nu)$ **(%)**

```
AL                     (COMBINED A1 AND A2)
AL B   10M     0.246    0.059           SAAL      69 CNTR    KE3
AL D    1M     0.57     0.17            PACIOTTI  69 OSPK    KMU3
AL     10M     0.346    0.033           MARX      70 CNTR    KE3
AL    600K     0.36     0.18            ASHFORD   72 ASPK    KE3
AL    7.7M     0.278    0.051           PICCIONI  72 ASPK    KMU3
AL     40M     0.318    0.038           FITCH     73 ASPK    KE3
AL    4.1M     0.60     0.14            MCCARTHY  73 CNTR    KMU3
AL     33M     0.333    0.050           WILLIAMS  73 ASPK    KMU3+KE3
AL     15M     0.313    0.029           GEWENIG1  74 ASPK    KMU3
AL     34M     0.341    0.018           GEWENIG1  74 ASPK    KE3
AL      SEE FOOTNOTES IN SECTIONS A1 AND A2 ABOVE.
AL            . . . . . . . . . .
AL  AVG        0.330    0.012    AVERAGE
```

--------- PARAMETERS FOR $K^0_L \to 2\pi$ DECAY ---------

```
     ETA+- = A(KL INTO PI+PI-)/A(KS INTO PI+PI-)
     ETA00 = A(KL INTO PI0PI0)/A(KS INTO PI0PI0)

     THE FITTED VALUES OF ETA+- AND ETA00 GIVEN BELOW ARE THE RESULTS
     OF A FIT TO ETA+-, ETA00 AND ETA00/ETA+- RESULTS.  THE VALUES LISTED
     BELOW WHICH ARE NOT PARENTHESIZED ENTER THE FIT AS SHOWN.  THE
     VALUES WHICH ARE PARENTHESIZED AND BEAR THE FOOTNOTE X DO NOT ENTER
     THE FIT AS SHOWN.  THESE EXPERIMENTS GIVE BRANCHING RATIOS AND ENTER
     THE FIT VIA THE QUANTITY ACTUALLY MEASURED -- BRANCHING RATIOS
     R9, R20 AND R27 (ETA+-) AND R17 AND R19 (ETA00).  THESE BRANCHING
     RATIOS ARE COMBINED WITH CURRENT NORMALIZATIONS AND CURRENT KL AND KS
     MEAN LIVES TO OBTAIN PI PI RATES.  THE ETA+- AND ETA00 VALUES OBTAINED
     FROM THESE RATES ARE ENTERED BELOW WITH THE NAME 'GKL/GKS'.
```

$|\eta_{00}|^2 = |A(K^0_L \to 2\pi^0)/A(K^0_S \to 2\pi^0)|^2$

```
EOS                                                  (UNITS 10**-6)
EOS X    0  (-2.)      (7.0)          BARTLETT  68 OSPK
EOS X   57   (4.9)     (1.2)          BANNER    69 OSPK
EOS XR 133  (14.1)     (3.4)          CENCE     69 OSPK
EOS XF 180  (13.)      (4.)           GAILLARD  69 OSPK
EOS X   29   (4.08)    (0.9)          BARMIN    70 HLBC
EOS X   30   (3.61)    (1.9)          BUDAGOV   70 HLBC
EOS  C        8.7       3.7           CHOLLET   70 OSPK    CU REG.,4GAMMAS
EOS XF 172   (9.9)     (3.4)          FAISSNER  70 OSPK
EOS  C  56    7.4       2.0           WOLFF     71 OSPK    CU REG.,4GAMMAS
EOS XR 150  (14.1)     (3.4)          REY       76 OSPK
EOS           5.43      0.84          CHRISTE1  79 ASPK
EOS  X        5.1       1.0           GKL/GKS   86 RVUE BR SCALE FACTOR=1.5
EOS X   SEE NOTE ABOVE REGARDING FITTED VALUES OF ETA+- AND ETA00.
EOS  R  CENCE 69 EVENTS ARE INCLUDED IN REY 76.
EOS  F  FAISSNER 70 CONTAINS SAME 2PI0 EVENTS AS GAILLARD 69
EOS  C  CHOLLET 70 GIVES ETA00=(1.23+-0.24)*(REGEN AMPL,2GEV/C CU)/10000MB
EOS  C  WOLFF 71   GIVES ETA00=(1.13+-0.12)*(REGEN AMPL,2GEV/C CU)/10000MB
EOS  C  WE COMPUTE BOTH ETA00**2 VALUES FOR (REGEN AMPL,2GEV/C CU)=24+-2MB.
EOS  C  THIS REGEN AMPL RESULTS FROM AVERAGING OVER FAISSNER 69,
EOS  C  EXTRAPOLATED USING OPTICAL MODEL CALCULTIONS OF BOHM ET AL.
EOS  C  PL 27B 594 (1968) AND THE DATA OF BALATS 71. (FROM H. FAISSNER,
EOS  C  PRIVATE COMMUNICATION)
EOS  F  FAISSNER 70 CONTAINS SAME 2PI0 EVENTS AS GAILLARD 69
EOS           . . . . . . . . . .
EOS AVG       5.58      0.60    AVERAGE
EOS FIT       5.29      0.17   FROM FIT
```

$|\eta_{00}| = |A(K^0_L \to 2\pi^0)/A(K^0_S \to 2\pi^0)|$ **(units 10^{-3})**

```
EOO     THE FIT VALUE ABOVE FOR ETA00**2 CORRESPONDS TO ETA00=2.299+-0.036
```

$|\eta_{+-}| = |A(K^0_L \to \pi^+\pi^-)/A(K^0_S \to \pi^+\pi^-)|$ **(units 10^{-3})**

```
E+- X   45    (1.95)    (0.20)          CHRISTENS 64 OSPK
E+- X   54    (1.99)    (0.16)          GALBRAITH 65 OSPK
E+- X         (1.92)    (0.13)          BASILE    66 OSPK
E+- X         (1.95)    (0.04)          BOTT-BODE 66 OSPK
E+- X         (2.00)    (0.09)          DEBOUARD  67 OSPK
E+- X         (1.94)    (0.08)          FITCH     67 OSPK
E+- AX        (1.95)    (0.03)          GKL/GKS   71 RVUE    EXPTS. BEFORE 71
E+- A   AVERAGE OF ABOVE EXPERIMENTS.  THESE ARE EXCLUDED FROM THE GKL/GKS,
E+- A   AVERAGE, AND FIT VALUES BELOW SINCE THEY DO NOT AGREE WITH MORE
E+- A   RECENT PRECISE AND IN PRINCIPLE SUPERIOR EXPERIMENTS.
E+- X 4200    (2.23)    (0.05)          MESSNER   73 ASPK
E+-            2.30      0.035          GEWENIG2  74 ASPK
E+- X 2703    (2.25)    (0.05)          DEVOE     77 SPEC
E+-            2.27      0.12           CHRISTE2  79 ASPK
E+- Z         (2.09)    (0.02)          ARONSON2  82 SPEC    E=30-110 GEV
E+-  C1687     2.28      0.06           COUPAL    85 SPEC    P(K)=70 GEV/C
E+-  X         2.258     0.027          GKL/GKS   86 RVUE    BR EXP. AFTER 71
E+- Z   ARONSON 82 FIND THAT ETA+- MAY DEPEND ON THE KAON ENERGY .
E+- X   SEE NOTE ABOVE REGARDING FITTED VALUES OF ETA+- AND ETA00.
E+-  C  COUPAL 85 CONCLUDES: NO ENERGY DEPENDENCE OF E+-, BECAUSE THEIR
E+-  C  VALUE IS CONSISTENT WITH ABOVE VALUES WHICH OCCUR AT LOWER ENERGIES
E+-            . . . . . . . . . .
E+- AVG        2.274     0.020   AVERAGE
E+- FIT        2.275     0.021  FROM FIT
```

$|\eta_{00}/\eta_{+-}|$

```
ER      APPROX EQUAL TO 1-3*EPSILON'/EPSILON.
ER     124     1.03      0.07           BANNER1   72 OSPK
ER     167     1.00      0.06           HOLDER    72 ASPK
ER  C         (1.00)    (0.09)          CHRISTE1  79 ASPK
ER   B3152     1.014     0.017          BERNSTEIN 85 SPEC
ER    1122     0.995     0.025          BLACK     85 SPEC
ER  C   NOT INDEPENDENT OF E+- AND EOS VALUES WHICH ARE INCLUDED IN FIT.
ER   B  STAT ERROR (0.016) AND SYST ERROR (0.007) ADDED IN QUADRATURE.
ER             . . . . . . . . . .
ER  AVG        1.008     0.013   AVERAGE
ER  FIT        1.010     0.013  FROM FIT
```

ϕ_{+-}, **PHASE OF** η_{+-} **(degrees)**

```
F+-     THE DEPENDENCE OF THE PHASE ON THE KL-KS MASS DIFFERENCE
F+-     IS GIVEN FOR EACH EXPERIMENT IN THE COMMENTS BELOW, WHERE DM IS
F+-     (MASS DIFF./HBAR) IN UNITS 10**10 SEC-1.  WE HAVE EVALUATED THESE
F+-     MASS DEPENDENCES USING OUR APRIL 1982 VALUE, DM=0.5349+-0.0022
F+-     TO OBTAIN THE VALUES AND AVERAGE QUOTED BELOW. WE ALSO GIVE THE
F+-     REGENERATOR PHASE FR IN THE COMMENTS BELOW.
F+- O        (45.0)    (50.0)           FITCH     65 OSPK    BE REGEN
F+- O        (30.0)    (45.0)           FIRESTONE 66 HBC
F+- O        (70.0)    (21.0)           BOTT-BODE 67 OSPK    C REGEN
F+- O        (25.0)    (35.0)           MISCHKE   67 OSPK    CU REGEN
F+- O   OLD EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE.
F+- N        (51.0)    (11.0)           BENNETT2  68 CNTR    CU REG. USES
F+-  C        34.2      10.0            BENNETT   69 CNTR    CU REGEN
F+-  B        45.3      12.0            BOHM      69 OSPK    VACUUM REGEN
F+-  F        45.2       7.4            FAISSNER  69 ASPK    CU REGEN
F+-  J        40.6       4.2            JENSEN    70 ASPK    VACUUM REGEN
F+-  D        37.2      12.0            BALATS    71 OSPK    CU REGEN
F+-  P        36.2       6.1            CARNEGIE  72 ASPK    CU REGEN
F+-  G        46.5       1.6            GEWENIG2  74 ASPK    VACUUM REGEN
F+-  H        45.5       2.8            CARITHERS 75 SPEC    C REGEN
F+-           41.7       3.5            CHRISTE2  79 ASPK
F+- A        (35.3)     (3.9)           ARONSON2  82 SPEC    E=30-110 GEV
F+-           . . . . . . . . . .
F+- AVG       44.6       1.2     AVERAGE
F+- FIT       44.6       1.2    FROM FIT
```

ϕ_{00}, PHASE OF η_{00} (degrees)

```
FOO         FIRST QUADRANT PREFERRED   GOBBI     69 OSPK
FOO  C       51.0      30.0          · CHOLLET   70 OSPK    CU REG.,4GAMMAS
FOO  W  56   38.0      25.0            WOLFF     71 OSPK    CU REG.,4GAMMAS
FOO          55.7       5.8            CHRISTE1  79 ASPK
FOO  C  CHOLLET 70 USES REGENERATOR PHASE FR=-46.5+-4.4 DEG.
FOO  W  WOLFF 71   USES REGENERATOR PHASE FR=-48.2+-3.5 DEG.
FOO         . . . . . . . . .
FOO AVG      54.7       5.6     AVERAGE
FOO FIT      54.5       5.3    FROM FIT                                  |
```

PHASE DIFFERENCE $\phi_{00} - \phi_{+-}$ (degrees)

```
DF B          7.6      18.0            BARBIELLI 73 ASPK
DF  C       (12.6)     (6.2)           CHRISTE1  79 ASPK
DF B    INDEPENDENT OF REGENERATOR MECHANISM,DM,AND LIFETIMES.
DF  C   NOT INDEPENDENT OF PHI+- AND PHI00 VALUES WHICH ARE INCLUDED IN FIT
DF          . . . . . . . . .
DF  FIT       9.8       5.4    FROM FIT                                  |
```

NOTE ON $\Delta S = \Delta Q$ RULE IN K^0 DECAYS

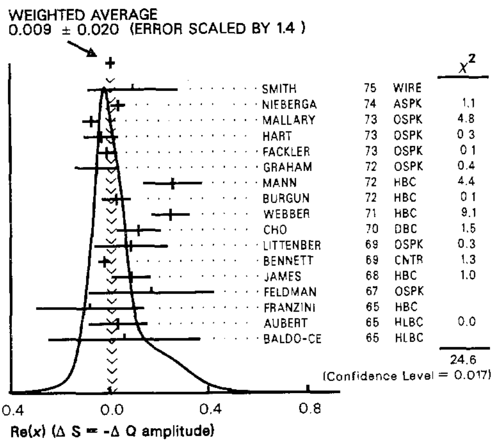
The relative amount of $\Delta S \neq \Delta Q$ component present is measured by the parameter x, defined as

$$x = A(\bar{K}^0 \to \pi^- \ell^+ \nu)/A(K^0 \to \pi^- \ell^+ \nu)\,.$$

We list Re$\{x\}$ and Im$\{x\}$ for K_{e3} and $K_{\mu 3}$ combined.

x = (ΔS=$-\Delta$Q AMPLITUDE)/(ΔS=+ΔQ AMPLITUDE)

```
REX     REAL PART OF X
REX   C 152    0.06      0.18      0.44  BALDO-CE  65 HLBC    K+ CHARGE EXCHNG
REX     196    0.035     0.11      0.13  AUBERT    65 HLBC    K+ CHARGE EXCHNG
REX   F 109   -0.08      0.16      0.28  FRANZINI  65 HBC     PBAR P
REX     116    0.17      0.16      0.35  FELDMAN   67 OSPK    PI-P TO K0 LMBDA
REX N   335   (0.17)    (0.10)           HILL      67 DBC     K+D YIELDS K0PP
REX B         (0.03)    (0.03)           BENNETT1  68 CNTR
REX     121    0.09      0.07      0.09  JAMES     68 HBC     PBAR P
REX  B        -0.020     0.025           BENNETT   69 CNTR    CHAR ASYM+ CU RE
REX     686    0.09      0.14      0.16  LITTENBER 69 OSPK    K+N TO K0P
REX   N 215    0.12      0.09            CHO       70 DBC     K+D TO K0PP
REX U   222   (0.04)    (0.07)    (0.08) BURGUN    71 HBC     K+P TO K0PPI+
REX     252    0.25      0.07      0.09  WEBBER    71 HBC     K-P TO KBAR N
REX   U 410    0.03      0.06      0.06  BURGUN    72 HBC     K+P TO K0PPI+
REX     126    0.26      0.10      0.14  MANN      72 HBC     K-P TO K0BAR N
REX G   342  (-0.13)    (0.11)           MANTSCH   72 OSPK    KE3  FROM K0 LMB
REX G   100   (0.04)    (0.10)    (0.13) GRAHAM    72 OSPK    KMU3 FROM K0 LMB
REX   G 442   -0.05      0.09            GRAHAM    72 OSPK    PI-P TO K0 LMBDA
REX    1757   -0.008     0.044           FACKLER   73 OSPK    KE3 FROM K0
REX    1367   -0.03      0.07            HART      73 OSPK    KE3 FROM K0 LMB
REX    1079   -0.070     0.036           MALLARY   73 OSPK    KE3 FROM K0 LM +
REX    4724    0.04      0.03            NIEBERGA  74 ASPK    K+P TO K0PPI+
REX      79    0.10      0.18      0.19  SMITH     75 WIRE    PI-P TO K0 LMBDA
REX   C  BALDO-CE 65 GIVES X AND THETA.CONVERTED BY US TO REX AND IMX.
REX   F  FRANZINI 65 GIVES X AND THETA.FOR REX AND IMX SEE SCHMIDT 67.
REX N    CHO 70 IS ANALYSIS OF UNAMBIGUOUS EVENTS IN NEW DATA AND HILL 67.
REX   U  BURGUN 72 IS A FINAL RESULT WHICH INCLUDES BURGUN 71.
REX   B  BENNETT 69 IS A REANALYSIS OF BENNETT1 68.
REX G    SECOND GRAHAM 72 VALUE IS FIRST GRAHAM 72 VALUE COMBINED WITH
REX G    MANTSCH 72.
REX         . . . . . . . . .
REX AVG        0.009     0.020   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
                        (SEE IDEOGRAM BELOW)
```



```
IMX      IMAGINARY PART OF X
IMX       (ASSUMES M(KL)-M(KS) POSITIVE -- SEE LISTING ABOVE)
IMX  C 152    -0.44      0.32      0.19  BALDO-CE  65 HLBC    K+ CHARGE EXCHNG
IMX    196    -0.21      0.11      0.15  AUBERT    65 HLBC    K+ CHARGE EXCHNG
IMX  F 109    +0.24      0.40      0.30  FRANZINI  65 HBC     PBAR P
IMX    116     0.0       0.25            FELDMAN   67 OSPK    PI-P TO K0 LMBDA
IMX N  335   (-0.20)    (0.10)           HILL      67 DBC     K+D YIELDS K0PP
IMX    121    +0.22      0.37      0.29  JAMES     68 HBC     PBAR P
IMX    686    -0.11      0.10      0.11  LITTENBER 69 OSPK    K+N TO K0P
IMX  N 215    -0.08      0.07            CHO       70 DBC     K+D TO K0PP
IMX U  222    (0.12)    (0.08)    (0.09) BURGUN    71 HBC     K+P TO K0PPI+
IMX    252     0.0       0.08            WEBBER    71 HBC     K-P TO KBAR N
IMX  U 410     0.07      0.06      0.07  BURGUN    72 HBC     K+P TO K0PPI+
IMX    126     0.21      0.15      0.12  MANN      72 HBC     K-P TO K0BAR N
IMX G  342   (-0.04)    (0.16)           MANTSCH   72 OSPK    KE3  FROM K0 LMB
IMX G  100    (0.12)    (0.17)    (0.16) GRAHAM    72 OSPK    KMU3 FROM K0 LMB
IMX  G 442     0.05      0.13            GRAHAM    72 OSPK    PI-P TO K0 LMBDA
IMX   1757    -0.017     0.060           FACKLER   73 OSPK    KE3 FROM K0
IMX   1367     0.09      0.07            HART      73 OSPK    KE3 FROM K0 LMB
IMX   1079     0.107     0.092     0.074 MALLARY   73 OSPK    KE3 FROM K0 LM +
IMX   4724    -0.06      0.05            NIEBERGA  74 ASPK    K+P TO K0PPI+
IMX     79    -0.10      0.16      0.19  SMITH     75 WIRE    PI-P TO K0 LMBDA
IMX  C  BALDO-CE 65 GIVES X AND THETA.CONVERTED BY US TO REX AND IMX.
IMX  F  FRANZINI 65 GIVES X AND THETA.FOR REX AND IMX SEE SCHMIDT 67.
IMX N   FTNOTE 10 OF HILL 67 SHOULD READ +0.58, NOT -0.58 (PRIV.COMM.).
IMX N   CHO 70 IS ANALYSIS OF UNAMBIGUOUS EVENTS IN NEW DATA AND HILL 67.
IMX  U  BURGUN 72 IS A FINAL RESULT WHICH INCLUDES BURGUN 71.
IMX G   SECOND GRAHAM 72 VALUE IS FIRST GRAHAM 72 VALUE COMBINED WITH
IMX G   MANTSCH 72.
IMX         . . . . . . . . . . .
IMX AVG       -0.004     0.026   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

REFERENCES FOR K_L^0

```
BARDON   58 ANP 5 156            M BARDON,K LANDE,L LEDERMAN  (COLUMBIA+BNL)
CRAWFORD 59 PRL 2 361            CRAWFORD,CRESTI,DOUGLASS,GOOD +        (LRL)
ASTIER   61 AIX CONF 1 227       ASTIER,BLASKOVIC,RIVET,SIAUD +        (EPOL)
FITCH    61 NC  22 1160          V FITCH,P PIROUE,R PERKINS       (PRINCETON)
GOOD     61 PR 124 1223          GOOD,MATSEN,MULLER,PICCIONI,POWELL +  (LRL)
NEAGU    61 PRL  6  552          NEAGU,OKONOV,PETROV,ROSANOVA,RUSAKOV (JINR)
    ALSO 61 JETP 13 1138         NYAGU,OKONOV,PETROV,ROZANOVA,RUSAKOV (JINR)

CAMERINI 62 PR 128 362           CAMERINI,FRY,GAIDOS,BIRGE,ELY +  (WISC+LRL)
DARMON   62 PL 3 57              J DARMON,A ROUSSET,J SIX              (EPOL)

ADAIR    64 PL 12 67             R K ADAIR,L B LEIPUNER            (YALE+BNL)
ALEKSANY 64 DUBNA 2 102          ALEKSANYAN,ALIKHANYAN,VARTAZARYAN+ (EREVAN)
    ALSO 64 JETP 19 1019         ALEKSANYAN+   (LEBEDEV+MOS ENG PHYS+EREVAN)
ANIKINA  64 JETP 19 42           ANIKINA,ZHURAVLEVA+ (GEORG ACAD SCI+ DUBNA)
CHRISTEN 64 PRL 13 138           CHRISTENSON,CRONIN,FITCH,TURLAY (PRINCETON)
FUJII    64 DUBNA 2 146          FUJII,JOVANOVICH,TURKOT+ (BNL,MARYLAND,MIT)
LUERS    64 PR 133 B 1276        LUERS,MITTRA,WILLIS,YAMAMOTO           (BNL)

ANIKINA  65 JINR P 2488          ANIKINA,VARDENGA,ZHURAVLEVA,KOTLYA+ (DUBNA)
ANDERSON 65 PRL 14 475           ANDERSON,CRAWFORD,GOLDEN,STERN + (LRL+WISC)
ASTBURY1 65 PL 16 80             ASTBURY,FINOCCHIARO,BEUSCH +  (CERN+ZURICH)
    ALSO 65 HELV.PH.AC.39 523 M PEPIN
ASTBURY2 65 PL 18 175            ASTBURY,MICHELINI,BEUSCH +    (CERN+ZURICH)
ASTBURY3 65 PL 18 178            ASTBURY,MICHELINI,BEUSCH +    (CERN+ZURICH)

AUBERT   65 PL 17 59             AUBERT,BEHR,CANAVAN,CHOUNET+   (EPOL+ORSAY)
    ALSO 67 LOWYS
BALDO-CE 65 NC 38 684            BALDO-CEOLIN,CALIMANI,CIAMPOLILLO +  (PADO)
CHRISTEN 65 PR 140 B 74          CHRISTENSON,CRONIN,FITCH,TURLAY (PRINCETON)
FISHER   65 ANL 7130 83          FISHER,ABASHIAN,ABRAMS,CARPENTER+     (ILL)
FITCH    65 PRL 15 73            FITCH,ROTH,RUSS,VERNON           (PRINCETON)

FRANZINI 65 PR 140 B 127         FRANZINI,KIRSCH,PLANO +  (COLUMBIA+RUTGERS)
GALBRAIT 65 PRL 14 383           GALBRAITH,MANNING,JONES +  (AERE+BRIS+RHEL)
GUIDONI  65 ARGONNE CONF 49      +BARNES,FOELSCHE,FERBEL,FIRESTO+ (BNL+YALE)
HOPKINS  65 ARGONNE CONF 67      H W K HOPKINS,BACON,EISLER   (VAND+RUTGERS)
VISHNEVS 65 PL  18   339         VISHNEVSKY,GALANINA,SEMENOV +        (ITEP)

ALFF-STE 66 PL 21 595            ALFF-STEINBERGER,HEUER,RUBBIA +      (CERN)
ANIKINA  66 SJNP 2 339           ANIKINA, VARDENGA, ZHURAVLEVA+       (JINR)
AUERBACH 66 PRL  17  980         AUERBACH,MANN,MCFARLANE,SCIULLI      (PENN)
AUERBACH 66 PR  149 1052         AUERBACH,DOBBS,LANDE,MANN,SCIULLI+   (PENN)
    ALSO 65 PRL  14  192         +LANDE,MANN,SCIULLI,UTO,WHITE,YOUNG  (PENN)
BALDO-CE 66 NC  45A  733         BALDO-CEOLIN,CALIMANI,CIAMPOLILLO+  (PADUA)
BASILE   66  BALATON CONF        BASILE,CRONIN,THEVENET +           (SACLAY)

BEHR     66 PL  22 540           +BRISSON,BALDO-CEOLIN,AUBERT+   (PADO,EPOL)
BELLOTTI 66 NC  45A  737         BELLOTTI,PULLIA,BALDO-CEOLIN+ (MILAN,PADUA)
BOTT-BOD 66 PL  23  277          BOTT-BODENHAUSEN,DE BOUARD,CASSEL+   (CERN)
CAMERINI 66 PR  150 1148         CAMERINI,CLINE,ENGLISH,FISCHBEIN+WISCONSIN
CANTER   66 PRL 17 942           +CHO,ENGLER,FISK,HILL +     (CARNEGIE+BNL)
CARPENTE 66 PR  142  871         CARPENTER,ABASHAN,ABRAMS,FISHER  (ILLINOIS)
CHANG    66 PL  23  702          CHANG,BASSANO,KIKUCHI,DODD+  (SYRACUSE,BNL)

CRIEGEE  66 PRL 17 150           +FOX,FRAUENFELDER,HANSON,MOSCAT+ (ILLINOIS)
FIRESTON 66 PRL 16 556           FIRESTONE,KIM,LACH,SANDWEISS+    (YALE,BNL)
FIRESTON 66 PRL 17 116           FIRESTONE,KIM,LACH,SANDWEISS+    (YALE,BNL)
FUJII    66 PRL 13 253           FUJII,JOVANOVICH,TURKOT,ZORN (BNL+MARYLAND)
    FUJII 66 IS THE CORRECTED VALUE GIVEN BY JOVANOVICH+ 66
HAWKINS  66 PL 21 238            C J B HAWKINS                        (YALE)
    ALSO 67 PR  156  1444        C J B HAWKINS                        (YALE)

JOVANOVI 66 PRL 17 1075          JOVANOVICH,FUJII,TURKOT,ZORN +(BNL+UMD+MIT)
KULYUKIN 66  BERKELEY 2B         KULYUKINA,MESTVIRISHVILI,NEAGU,PETR+ (JINR)
MEISNER1 66 PRL 16 278           G W MEISNER,B B CRAWFORD,F CRAWFORD   (LRL)
MEISNER2 66 PRL  17  492         G MEISNER,B CRAWFORD,F CRAWFORD       (LRL)
NEFKENS  66 PL 19 706            NEFKENS,ABASHIAN,ABRAMS,CARPENTER+    (ILL)
VERHEY   66 PRL 17 669           VERHEY,NEFKENS,ABASHIAN+              (ILL)

BENNETT  67 PRL  19  993         BENNETT,NYGREN,SAAL,STEINBERGER +(COLUMBIA)
BOTT-BOD 67 PL  24B  194         BOTT-BODENHAUSEN,DEBOUARD,CASSEL +   (CERN)
BOTT-BOD 67 PL  24B  438         BOTT-BODENHAUSEN,DEBOUARD,DEKKERS+   (CERN)
    ALSO 66 PL  20  212          BOTT-BODENHAUSEN,DEBOUARD,CASSEL+    (CERN)
    ALSO 66 PL  23  277          BOTT-BODENHAUSEN,DEBOUARD,CASSEL+    (CERN)
CANTER   67 THESIS               J.M. CANTER                      (CARNEGIE)

CRONIN 1 67 PRL 18 25            +KUNZ,RISK,WHEELER               (PRINCETON)
CRONIN 2 67 PRINC CONF(11/67)    +KUNZ,RISK,WHEELER               (PRINCETON)
DEBOUARD 67 NC  52A  662         DEBOUARD,DEKKERS,JORDAN,MERMOD +     (CERN)
    ALSO 65 PL  15  58           DE BOUARD,DEKKERS,SCHARFF+ (CERN+ORSA+MPIM)
DEVLIN   67 PRL 18 54            DEVLIN,SOLOMON,SHEPARD,BEALL+    (PRIN+UMD)
    ALSO 68 PR 169 1045          SAYER,BEALL,DEVLIN,SHEPHARD+ (UMD+PPA+PRIN)
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DORFAN   67 PRL  19  987         DORFAN,ENSTROM,RAYMOND,SCHWARTZ +(SLAC+LRL)
FELDMAN  67 PR  155  1611        FELDMAN,FRANKEL,HIGHLAND,SLOAN        (PENN)
FIRESTON 67 PRL 18  176          FIRESTONE,KIM,LACH,SANDWEISS,+   (YALE,BNL)
FITCH    67 PR 164  1711         FITCH,ROTH,RUSS,VERNON          (PRINCETON)
HAWKINS  67 PR  156  1444        C J B HAWKINS                        (YALE)
HILL     67 PRL  19  668         HILL,LUERS,ROBINSON,CANTER+  (BNL,CARNEGIE)

HOPKINS  67 PRL 19  185          HOPKINS,BACON,EISLER                  (BNL)
KADYK    67 PRL 19  597          KADYK,CHAN,DRIJARD,OREN,SHELDON       (LRL)
KULYUKIN 67  PREPRINT            KULYUKINA+MESTVIRISHVILI+NEAGU +     (JINR)
LOWYS    67 PL  24B  75          LOWYS,AUBERT,CHOUNET,PASCAUD+   (EPOL,ORSA)
MISCHKE  67 PRL 18  138          MISCHKE,ABASHIAN,ABRAMS+         (ILLINOIS)
NEFKENS  67 PR  157  1233        +ABASHIAN,ABRAMS,CARPENTER,FISHER+    (ILL)
TODOROFF 67  THESIS              JOHN A TODOROFF                  (ILLINOIS)

ABRAMS   68 PR   176  1603       +ABASHIAN,MISCHKE,NEFKENS,SMITH+ (ILLINOIS)
ARNOLD   68 PL 28B 56            ARNOLD,BUDAGOV,CUNDY,AUBERT+   (CERN+ORSAY)
ARONSON  68 PRL 20 287           S.H.ARONSON, K.W.CHEN           (PRINCETON)
    ALSO 69 PR  175 1708         S H ARONSON, K W CHEN           (PRINCETON)
BALATZ   68 PL 26B  320          BALATZ,BEREZIN,VISHNEVSKY,GALANINA+  (ITEP)
BARTLETT 68 PRL 21 558           BARTLETT,CARNEGIE,FITCH+        (PRINCETON)

BASILE   68 PL 26B  542          BASILE,CRONIN,THEVENET,TURLAY+     (SACLAY)
BASILE2  68 PL 28B  58           +CRONIN,THEVENET,TURLAY,ZYLBERAJCH+(SACLAY)
BENNETT1 68 PL 27B 244           BENNETT,NYGREN,STEINBERGER+ (COLUMBIA+CERN)
BENNETT2 68 PL 27B 248           BENNETT,NYGREN,STEINBERGER+ (COLUMBIA+CERN)
BLANPIED 68 PRL 21 1650          BLANPIED,LEVIT,ENGELS+      (CASE+HARV+MCGI)
BUDAGOV  68 NC 57A 182           BUDAGOV,BURMEISTER,CUNDY+  (CERN,ORSA,IPNP)
    ALSO 68 PL  28B 215          +CUNDY,MYATT,NEZRICK+      (CERN,ORSA,EPOL)

CARNEGIE 68 PRINC TR44 THESIS R.K.CARNEGIE                   (PRINCETON)
JAMES    68 NP  B8 365           F JAMES, H BRIAND               (IPNP,CERN)
    ALSO 68 PRL 21 257           HELLAND,LONGO,YOUNG             (UCLA,MICH)
KULYUKIN 68 JETP 26 20           KULYUKINA,MESTVIRISHVILI,NEAGU+      (JINR)
KUNZ     68 THESIS (PU 46)       P F KUNZ                        (PRINCETON)
MELHOP   68 PR 172 1613          MELHOP MURTY BOWLES,BURNETT+     (LA JOLLA)
THATCHER 68 PR 174 1674          THATCHER,ABASHIAN,ABRAMS,CARPENTER +  (ILL)

BANNER   69 PR 188 2033          +CRONIN,LIU,PILCHER             (PRINCETON)
    ALSO 68 PRL 21 1103          BANNER,CRONIN,LIU,PILCHER       (PRINCETON)
    ALSO 68 PRL 21 1107          BANNER CRONIN,LIU,PILCHER       (PRINCETON)
BEILLIER 69 PL  30B 202          BEILLIERE,BOUTANG,LIMON              (EPOL)
BENNETT  69 PL  29B 317          +NYGREN,SAAL,STEINBERGER+        (COLU,BNL)
BOHM     69 NP  B9 605           +DARRIULAT,GROSSO,KAFTANOV+          (CERN)
    ALSO 68 PL 27B 321           BOHM,DARRIULAT,GROSSO,KAFTANOV       (CERN)

BOTT-BOD 69 CERN 69-7 329        BOTT-BODENHAUSEN,DE BOUARD,CASSEL+   (CERN)
CENCE    69 PRL 22 1210          CENCE,JONES,PETERSON,STENGER+  (HAWAII,LRL)
EVANS    69 PRL 23 427           EVANS,GOLDEN,MUIR,PEACH+   (EDINBURGH,CERN)
FAISSNER 69 PL  30B 204          +FOETH,STAUDE,TITTEL+      (AACH,CERN,TORI)
FOETH    69 PL 30B 282           +HOLDER,RADERMACHER +  (AACHEN,CERN,TORINO)

GAILLARD 69 NC  59A 453          +GALBRAITH,HUSSRI,JANE+  (CERN,RHEL,AACHEN)
    ALSO 67 PRL 18 20            +KRIENEN,GALBRAITH,HUSSRI+ (CERN+RHEL+AACH)
GOBBI    69 PRL 22 685           +GREEN,HAKEL,MOFFETT,ROSEN,GOZ+ (ROCH+RUTG)
LITTENBE 69 PRL 22 654           LITTENBERG,FIELD,PICCIONI,MEHLHOP+   (UCSD)
LONGO    69 PR 181  1808         M J LONGO,K K YOUNG,J A HELLAND (MICH,UCLA)
PACIOTTI 69 THESIS,UCRL 19446 M A PACIOTTI                         (LRL)
SAAL     69 THESIS               H J SAAL                         (COLUMBIA)

ALBROW   70 PL 33B 516           +ASTON,BARBER,BIRD,ELLISON +    (MCHS+DARE)
ARONSON  70 PRL 25 1057          +EHRLICH,HOFER,JENSEN+     (EFI,ILLC,SLAC)
BARMIN   70 PL 33B 377           +BARYLON,BORISOV,BYSHEVA+       (ITEP,JINR)
BASILE   70 PR D2 78             +CRONIN,THEVENT,TURLAY,ZYLBERAJCH +  (SACL)
BUCHANAN 70 PL 33B 623           +DRICKEY,RUDNICK,SHEPARD+   (SLAC,JHU,UCLA)
    ALSO 71 PRIVATE COMMUNICATION, B. COX, FEB. 71

BUDAGOV  70 PR D2 815            +CUNDY,MYATT,NEZRICK+     (CERN, ORSA,EPOL)
    ALSO 68 PL  28B 215          +CUNDY,MYATT,NEZRICK+      (CERN,ORSA,EPOL)
CHIEN    70 PL 33B 627           C-Y.CHIEN,COX,ETTLINGER +   (JHU+SLAC+UCLA)
    ALSO 71 PRIVATE COMMUNICATION, B. COX, FEB. 71.
CHO      70 PR D1 3031           +DRALLE,CANTER,ENGLER,FISK+ (CARN,BNL,CASE)
    ALSO 67 PRL 19 668           HILL,LUERS,ROBINSON,SAKITT +     (BNL,CARN)

CHOLLET  70 PL 31B 658           +GAILLARD,JANE,RATCLIFFE,REPELLIN +  (CERN)
CULLEN   70 PL 32B 523           +DARRIULAT,DEUTSCH,FOETH + (AACH,CERN,TORI)
DARRIULA 70 PL 33B 249           +FERRERO,GROSSO,HOLDER +   (AACH,CERN,TORI)
FAISSNER 70 NC 70A 57            +REITHLER,THOME,GAILLARD+  (AACH,CERN,RHEL)
JENSEN   70 THESIS               D.A. JENSEN                           (EFI)
    ALSO 69 PRL 23 615           JENSEN,ARONSON,EHRLICH,FRYBERGER+ (EFI,ILL)

MARX     70 PL 32B 219           +NYGREN,PEOPLES,STEINBERGE+(COLU,HARV,CERN)
    ALSO 70 THESIS,NEVIS 179  JAY MARX                        (COLUMBIA)
SCRIBANO 70 PL 32B 224           +MANNELLI,PIERAZZINI,MARX+ (PISA,COLU,HARV)
SMITH    70 PL 32B 133           +WANG,WHATLEY,ZORN,HORNBOSTEL     (UMD,BNL)
WEBBER   70 PR D1 1967           +SOLMITZ,CRAWFORD,ALSTON-GARNJOST     (LRL)
    ALSO 69 UCRL 19226 THESIS B R WEBBER                           (LRL)

BALATS   71 SJNP 13 53           +BEREZIN,VISHNEVSKII,GALANINA+       (ITEP)
BARMIN   71 PL 35B 604           +BARYLOV,VESELOVSKY,DAVIDENKO+       (ITEP)
BISI     71 PL 36B 533           +DARRIULAT,FERRERO,RUBBIA+ (AACH,CERN,TORI)
BURGUN   71 LNC 2 1169           +LESQUOY,MULLER,PAULI+     (SACL+CERN+OSLO)
CARNEGIE 71 PR D4 1              +CESTER,FITCH,STROVINK,SULAK         (PRIN)
CHAN     71 LBL-350  THESIS      J.HIONG-SING CHAN                     (LBL)

CHIEN    71 PL 35B 261           +COX,ETTLINGER,RESVANIS+    (JHU,SLAC,UCLA)
    ALSO 72 DALLY
CHO      71 PR D3 1557           +DRALLE,CANTER,ENGLER,FISK+ (CARN,BNL,CASE)
CLARK    71 PRL 26 1667          +ELIOFF,FIELD,FRISCH,JOHNSON,KERTH+   (LRL)
    ALSO 70 UCRL 19709-THESIS ROLLAND JOHNSON                      (LRL)
    ALSO 71 UCRL 20264-THESIS HENRY FRISCH                         (LRL)
    ALSO 74  SLAC-PUB-1498       R.C.FIELD (UNPUBLISHED)              (SLAC)

ENSTROM  71 PR D4 2629           +AKAVIA,COOMBES,DORFAN+         (SLAC,STAN)
    ALSO 70 THESIS (SLAC 125) J E ENSTROM                     (STANFORD)
HILL     71 PR D4 7              +SAKITT,SKJEGGESTAD,CANTER+ (BNL,CARN,CASE)
JAMES    71 PL 35B 265           +MONTANET,PAUL,PAULI+      (CERN+SACL+OSLO)
MEISNER  71 PR D3 59             +MANN,HERTZBACH,KOFLER +    (MASA+BNL+YALE)
PEACH    71 PL 35B 351           +EVANS,MUIR,BUDAGOV,HOPKINS+    (EDIN,CERN)

REPELLIN 71 PL 36B 603           +WOLFF,CHOLLET,GAILLARD,JANE+   (ORSA,CERN)
WEBBER   71 PR D3 64             +SOLMITZ,CRAWFORD,ALSTON-GARNJOST     (LRL)
    ALSO 68 PRL 21 498           WEBBER,SOLMITZ,CRAWFORD,ALSTONGARNJOST(LRL)
    ALSO 69 UCRL 19266-THESIS B R WEBBER                           (LRL)
WOLFF    71 PL 36B 517           +CHOLLET,REPELLIN,GAILLARD+     (ORSA,CERN)

ALBROW   72 NP B44 1             +ASTON,BARBER,BIRD,ELLISON+     (MCHS+DARE)
ASHFORD  72 PL 38B 47            +BROWN,MASEK,MAUNG,MILLER,RUDERMAN+  (UCSD)
BANNER1  72 PRL 28 1597          +CRONIN,HOFFMAN,KNAPP,SHOCHET   (PRINCETON)
BANNER2  72 PRL 29 237           +CRONIN,HOFFMAN,KNAPP,SHOCHET   (PRINCETON)
BARMIN1  72 SJNP 15 636          +DAVIDENKO,DEMIDOV,DOLGOLENKO+       (ITEP)
BARMIN2  72 SJNP 15 638          +BARYLOV,DAVIDENKO,DEMIDOV+          (ITEP)
BURGUN   72 NP B50 194           +LESQUOY,MULLER,PAULI,+    (SACL+CERN+OSLO)
CARNEGIE 72 PR D6 2335           +CESTER,FITCH,STROVINK,SULAK    (PRINCETON)

DALLY    72 PL 41B 647           +INNOCENTI,SEPPI,CHIEN,COX+ (SLAC+JHU+UCLA)
    ALSO 70 CHIEN
    ALSO 71 CHIEN
GRAHAM   72 NC 9A 166            +ABASHIAN,JONES,MANTSCH,ORR+     (ILL+NEAS)
HOLDER   72 PL 40B 141           +RADERMACHER,STAUDE+       (AACH+CERN+TORI)
JAMES    72 NP B49 1             +MONTANET,PAUL,SAETRE+     (CERN+SACL+OSLO)
KRENZ    72 LNC 4 213            +HOPKINS,EVANS,MUIR,PEACH  (AACH+CERN+EDIN)

MANN     72 PR D6 137            +KOFLER,MEISNER,HERTZBACH+  (MASA+BNL+YALE)
MANTSCH  72 NC 9A 160            +ABASHIAN,GRAHAM,JONES,ORR+      (ILL+NEAS)
METCALF  72 PL 40B 703           +NEUHOFER,NIEBERGALL+       (CERN+IPN+WIEN)
NEUHOFER 72 PL 41B 642           +NIEBERGALL,REGLER,STIER+  (CERN+ORSA+VIEN)
PICCIONI 72 PRL 29 1412          +COOMBES,DONALDSON,DORFAN,FRYBERGER+ (SLAC)
    ALSO 74 PR D9 2939           PICCIONI,DONALDSON +       (SLAC+UCSC+COLO)
VOSBURGH 72 PR D6 1834           +DEVLIN,ESTERLING,GOZ,BRYMAN +  (RUTG,MASA)
    ALSO 71 PRL 26 866           VOSBURGH,DEVLIN,ESTERLING,GOZ + (RUTG,MASA)

ALBROW   73 NP B58 22            +ASTON,BARBER,BIRD,ELLISON+     (MCHS+DARE)
ALEXANDE 73 NP B65 301           ALEXANDER,BENARY,BOROWITZ,LANDE+(TELA+HEID)
ANIKINA  73  P1-7539 COM.JINR +BALASHOV,BANNIK +                  (JINR)
BARBIELL 73 PL 43B 529           BARBIELLINI,DARRIULAT,FAINBERG+      (CERN)
BRANDENB 73 PR D8 1978           BRANDENBURG,JOHNSON,LEITH,LOOS+      (SLAC)
CARITHER 73 PRL 31 1025          CARITHERS,NYGREN,GORDON+    (COLU+BNL+CERN)
    ALSO 73 PRL 30 1336          CARITHERS,MODIS,NYGREN,PUN+ (COLU+CERN+NYU)
EVANS    73 PR D7 36             +MUIR,PEACH,BUDAGOV+       (EDINBURGH+CERN)
    ALSO 69 PRL 23 427           EVANS,GOLDEN,MUIR,PEACH+   (EDINBURGH+CERN)

FACKLER  73 PRL 31 847           +FRISCH,MARTIN,SMOOT,SOMPAYRAC        (MIT)
FITCH    73 PRL 31 1524          +HEPP,JENSEN,STROVINK,WEBB      (PRINCETON)
    ALSO 72 COO-3072-13          R.C.WEBB (THESIS)               (PRINCETON)
HART     73 NP B66 317           +HUTTON,FIELD,SHARP,BLACKMORE+  (CAVE+RHEL)
MALLARY  73 PR D7 1953           +BINNIE,GALLIVAN,GOMEZ,PECK,SCIULLI + (CIT)
    ALSO 70 PRL 25 1214          SCIULLI,GALLIVAN,BINNIE,GOMEZ +       (CIT)

MCCARTHY 73 PR D7 687            +BREWER,BUDNITZ,ENTIS,GRAVEN,MILLER+  (LBL)
    ALSO 72 PL 42B 291           MCCARTHY,BREWER,BUDNITZ,ENTIS,GRAVEN+ (LBL)
    ALSO 71 THESIS LBL-550       R.L.MCCARTHY                          (LBL)
MESSNER  73 PRL 30 876           +MORSE,NAUENBERG,HITLIN +  (COLO+SLAC+UCSC)
PEACH    73 PL 43B 441           +EVANS,MUIR,HOPKINS,KRENZ  (EDIN+CERN+AACH)
SANDWEIS 73 PRL 30 1002          +SUNDERLAND,TURNER,WILLIS,KELLER (YALE+ANL)
WILLIAMS 73 PRL 31 1521          +LARSEN,LEIPUNER,SAPP,SESSOMS+   (BNL+YALE)

ALBRECHT 74 PL 48B 393           DUBNA+BERLIN+BUDAPEST+PRAGUE+SERPUKH+SOFIA
BISI     74 PL 50B 504           BISI,FERRERO                         (TORI)
BOBISUT  74 LNC 11 646           +HUZITA,MATTIOLI,PUGLIERIN           (PADO)
DONALDS1 74 PRL 33 554           DONALDSON,HITLIN,KENNELLY,KIRKBY +   (SLAC)
    ALSO 74 DONALDSON 3
    ALSO 76 DONALDSON
DONALDS2 74 PR D9 2960           DONALDSON,FRYBERGER,HITLIN,LIU+ (SLAC+UCSC)
    ALSO 73 PRL 31 337           DONALDSON,FRYBERGER,HITLIN,LIU+ (SLAC+UCSC)
DONALDS3 74  SLAC 184-THESIS     GREGORY J. DONALDSON                 (SLAC)
    ALSO 76 DONALDSON

GEWENIG1 74 PL 48B 483           GEWENIGER,GJESDAL,KAMAE,PRESSER+(CERN+HEID)
    ALSO 74 CERN INT. REPT.      VERA LUTH (THESIS-INT. REPT. 74-4)   (HEID)
GEWENIG2 74 PL 48B 487           GEWENIGER,GJESDAL,PRESSER +     (CERN+HEID)
    ALSO 74 PL 52B 119           GJESDAL,PRESSER,STEFFEN +       (CERN+HEID)
GEWENIG3 74 PL 52B 108           GEWENIGER,GJESDAL,PRESSER +     (CERN+HEID)
GJESDAL  74 PL 52B 113           +PRESSER,KAMAE,STEFFEN+         (CERN+HEID)

MESSNER  74 PRL 33 1458·         +FRANKLIN,MORSE,NAUENBERG+ (COLO+SLAC+UCSC)
NIEBERGA 74 PL 49B 103           NIEBERGALL,REGLER,STIER +  (CERN+ORSA+VIEN)
WANG     74 PR D9 540            +SMITH,WHATLEY,ZORN,HORNBOSTEL    (UMD+BNL)
WILLIAMS 74 PRL 33 240           +LARSEN,LEIPUNER,SAPP,SESSOMS +  (BNL+YALE)
WOO      74 LNC 10 38            +BUCHANAN,PEPPER                     (UCLA)

BALDOCEO 75 NC 25A 688           BALDO-CEOLIN,BOBISUT,CALIMANI+  (PADO+WISC)
BLUMENTH 75 PRL 34 164           BLUMENTHAL,FRANKEL,NAGY +  (PENN+CHIC+TEMP)
BUCHANAN 75 PR D11 457           +DRICKEY,PEPPER,RUDNICK +   (UCLA+SLAC+JHU)
CARITHER 75 PRL 34 1244          CARITHERS,MODIS,NYGREN,PUN +     (COLU+NYU)
SMITH    75 UCSD THESIS-UNPUB JAMES G. SMITH                      (UCSD)

BIRULEV  76 SJNP 24, 178         +VESTERGOMBI,VOVENKO,VOTRUBA,GENCHEV+(JINR)
COOMBES  76 PRL 37 249           +FLEXER,HALL,KENNELLY,KIRKBY +   (STAN+NYU)
DONALDSO 76 PR D14 2839          DONALDSON,HITLIN,KENNELLY,KIRKBY,LIU+(SLAC)
    ALSO 74  SLAC 184-THESIS     GREGORY J. DONALDSON                 (SLAC)
FUKUSHIM 76 PRL 36 348           FUKUSHIMA,JENSEN,SURKO,THALER+  (PRIN+MASA)
GJESDAL  76 NP B109 118          +KAMAE,PRESSER,STEFFEN +        (CERN+HEID)
REY      76 PR D13 1161          +CENCE,JONES,PARKER +       (NDAM+HAWA+LBL)
    ALSO 69 CENCE

CHO      77 PR D15 587           +DERRICK,LISSAUER,MILLER,ENGLER+ (ANL+CARN)
CLARK    77 PR D15 553           +FIELD,HOLLEY,JOHNSON,KERTH,SAH,SHEN  (LBL)
    ALSO 75 LBL-4275 THESIS      GILBERT SHEN                          (LBL)
DEVOE    77 PR D16 565           +CRONIN,FRISCH,GROSSO-PILCHER+    (EFI+ANL)
DZHORDZH 77 SJNP 26 478          DZHORDZHADZE,KEKELIDZE,KRIVOKHIZHIN+ (JINR)
PEACH    77 NP B127 399          +CAMERON +        (BGNA+EDIN+GLAS+PISA+RHEL)

ENGLER   78 PR D18 623           +KEYES,KRAEMER,TANAKA,CHO+        (CARN+ANL)
HILL     78 PL 73B 483           +SAKITT,SNAPE,STEVENS+     (BNL+SLAC+SBER)
BIRULEV  79 SJNP 29 778          +VESTERGOMBI,GVAKHARIYA,GENCHEV+     (JINR)
CHRISTE1 79 PRL 43 1209          CHRISTENSON,GOLDMAN,HUMMEL,ROTH+      (NYU)
CHRISTE2 79 PRL 43 1212          CHRISTENSON,GOLDMAN,HUMMEL,ROTH+      (NYU)
HILL     79 NP B153 39           +SAKITT,SNAPE,STEVENS+     (BNL+SLAC+SBER)
SCHMIDT  79 PRL 43 556           +BLATT,CAMPBELL,GRANNAN+         (YALE+BNL)
SHOCHET  79 PR D19 1965          +LINSAY,GROSSO-PILCHER,FRISCH+    (EFI+ANL)
    ALSO 77 PRL 39 59            SHOCHET,LINSAY,GROSSO-PILCHER,+   (EFI+ANL)

CARROLL1 80 PRL 44 525           +CHIANG,KYCIA,LI,LITTENBERG,MARX+(BNL+ROCH)
CARROLL2 80 PRL 44 529           +CHIANG,KYCIA,LI,LITTENBERG,MARX+(BNL+ROCH)
CARROLL3 80 PL 96B 407           +CHIANG,KYCIA,LI,LITTENBERG,MARX+(BNL+ROCH)
CHO      80 PR D22 2688          +DERRICK,MILLER,SCHLERETH,ENGLER+(ANL+CARN)
MORSE    80 PR D21 1750          +LEIPUNER,LARSEN,SCHMIDT,BLATT+  (BNL+YALE)
BIRULEV  81 NP B182 1            +DZHORDZHADZE,GENCHEV,GRIGALASHVILI+ (JINR)
    ALSO 80 SJNP 31 622          BIRULEV,VESTERGOMBI,GENCHEV +        (JINR)
ARONSON  82 PRL 48 1078          +BERNSTEIN,BOCK +      (BNL+CHIC+STAN+WISC)
ARONSON2 82 PRL 48 1306          +BOCK,CHENG,FISCHBACH       (BNL+CHIC+PURD)
    ALSO 82 PL 116B 73           FISCHBACH,CHENG,ARONSON,BOCK(PURD+BNL+CHIC)
    ALSO 83 PR D28 476           ARONSON,BOCK,CHENG,FISCHBACH(BNL+CHIC+PURD)
    ALSO 83 PR D28 495           ARONSON,BOCK,CHENG,FISCHBACH(BNL+CHIC+PURD)
BALATS   83 SJNP 38 556          +BEREZIN,BOGDANOV,VISHNEVSKII+       (ITEP)
BERNSTEI 85 PRL 54 1631          BERNSTEIN,BOCK,CARLSMITH,COUPAL+(CHIC+SACL)
BLACK    85 PRL 54 1628          +BLATT,CAMPBELL,KASHA,MANNELLI+  (BNL+YALE)
COUPAL   85 PRL 55 566           +BERNSTEIN,BOCK,CARLSMITH,     +(CHIC+SACL)

                                 PAPERS NOT REFERRED TO IN DATA LISTINGS

ALEXANDE 62 PRL 9 69             G ALEXANDER,S ALMEIDA,F CRAWFORD      (LRL)
JOVANOVI 63 BNL CONF 42          JOVANOVIC,FISCHER,BURRIS +  (BNL+MARYLAND)
STERN    64 PRL 12 459           STERN,BINFORD,LIND,ANDERSON +    (WISC+LRL)
BEHR     65 ARGONNE CONF 59      BEHR,BRISSON,BELLOTTI+     (EPOL,MILA,PADO)
MESTVIRI 65 JINR P 2449          MESTVIRISHVILI,NYAGU,PETROV,RUSAKOV+ (JINR)
TRILLING 65 UCRL 16473           GEORGE H TRILLING                     (LRL)
    UPDATED FROM 1965 ARGONNE CONF., PAGE 115.
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GINSBERG 67 PR 162  1570        EDWARD S GINSBERG           (U. MASS BOSTON)
RUBBIA   67 PL  24B  531        C.RUBBIA,J.STEINBERGER           (CERN+COLU)
  ALSO 1 66 PL  20  207         ALFF-STEINBERGER,HEUER,KLEINKNECHT+  (CERN)
  ALSO 2 66 PL  21  595         ALFF-STEINBERGER,HEUER,KLEINKNECHT+  (CERN)
  ALSO 3 66 PL  23  167         C.RUBBIA,J.STEINBERGER           (CERN+COLU)
SCHMIDT  67 NEVIS 160(THESIS) P. SCHMIDT                         (COLUMBIA)

CRONIN   68 VIENNA CONF P.281 CRONIN,RAPPORTEURS TALK           (PRINCETON)
BECHERRA 70 PR D1 1452        T BECHERRAWY                           (ROCH)
GINSBERG 70 PR D1 229         E S GINSBERG                     (IIT HAIFA)
HEUSSE   70 LNC  3 449        +AUBERT,PASCAUD,VIALLE               (ORSAY)
GINSBERG 73 PR D8 3887        E S GINSBERG, J SMITH             (MIT+STON)
KLEINKNE 76 ARNS 26 1         K. KLEINKNECHT                        (DORT)
```

CHARMED MESONS

$D^\pm$

$I(J^P) = \frac{1}{2}(0^-)$

$D^\pm$ MASS (MeV)

```
M       50(1876.)   (15.)              PERUZZI   76 SMAG +- K-+PI+-PI+-
M         (1874.)    (5.)              GOLDHABER 77 SMAG +- D0,D+ RECOIL SPC
M   P     (1868.3)   (0.9)             PERUZZI   77 SMAG +- E+E- 3.77GEV ECM
M         (1874.)   (11.)              PICCOLO   77 SMAG +- E+E-4.03,4.41ECM
M   P     (1868.4)   (0.5)             SCHINDLER 81 SMK2 +- E+E- 3.77GEV ECM
M    P     1869.4     0.6              TRILLING  81 RVUE +- E+E- 3.77GEV ECM
M        6 1860.     16.               ADAMOVICH 84 EMUL    PHOTOPRODUCTION
M          1863.      4.               DERRICK   84 HRS     E+E- 29GEV ECM
M    P  PERUZZI 77 AND SCHINDLER 81 ERRORS DO NOT INCLUDE THE 0.13 PERCENT
M    P  UNCERTAINTY IN THE ABSOLUTE SPEAR ENERGY CALIBRATION.  TRILLING 81
M    P  USES THE HIGH PRECISION J/PSI AND PSI(3685) MEASUREMENTS OF
M    P  ZHOLENTZ 80 TO DETERMINE THIS UNCERTAINTY AND COMBINES THE
M    P  PERUZZI 77 AND SCHINDLER 81 RESULTS TO OBTAIN THE VALUE QUOTED.
M          . . . . . . . . . .
M   AVG    1869.25    0.59    AVERAGE
```

$D^\pm$ MEAN LIFE (units 10^{-13} sec)

```
T           (8.)    OR LESS  CL=.90   ARMENISE  79 HYBR NU P -->DIMUONS +
T       4    2.5       2.2      1.1   ALLASIA   80 EMUL NU WIDEBAND
T   A      (10.4)    (3.9)    (2.9)   BACINO    80 DLCO E+E- 3.77 GEV ECM
T   C   1   (2.2)    (2.3)    (1.1)   BALLAGH   81 HYBR FNAL 15FT, NU HE-H2
T    E 70    9.5       3.1      1.9   ALBINI    82 SILI CERN GAM SI
T      15    8.4       3.5      2.2   AGUILAR   83 HYBR PI- P, P P
T       7    6.3       5.0      2.7   BADERTSCH 83 HYBR CERN PI- NUCL.
T      11   11.5       7.5      3.5   USHIDA    83 EMUL REPL. USHIDA 80
T    H 21    7.2       2.3      2.0   ABE       84 HYBR    SLAC GAM P 20GEV
T    G 12    3.91      2.35     1.25  ADAMOVICH 84 EMUL    PHOTOPRODUCTION
T      28   10.6       3.6      2.4   BAILEY    85 SILI +  PI-BE 200 GEV
T   A   USES THEORETICAL RATE D TO (K E NU)=1.4*10**11 SEC**-1 .
T   C   BALLAGH 81 VALUE QUOTED HERE ASSUMES THAT ALL DILEPTON EVENTS
T   C   CONTAIN D0 OR D+, EACH WITH EQUAL NUMBERS OF SEMILEPTONIC DECAYS.
T    E  ALBINI 82 ASSUMES D MOMENTUM IS 1/2 BEAM MOMENTUM.
T    H  SOME EVENTS MAY BE D/S+ AND 5 EVENTS COULD BE LAMBDA/C+.
T    G  ESTIMATE SYSTEMATIC ERROR LESS THAN +1.2  -1.3
T          . . . . . . . . . .
T   AVG      9.2       1.3      1.0    AVERAGE
```

$D^\pm$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$D^+ \to K^-\pi^+\pi^+$	494+ 140+ 140
P2	$D^+ \to \bar{K}^0\pi^+$	498+ 140
P3	$D^+ \to \pi^+\pi^+\pi^-$	140+ 140+ 140
P4	$D^+ \to \pi^+K^+K^-$	140+ 494+ 494
P5	$D^+ \to K^+\pi^+\pi^-$	494+ 140+ 140
P6	$D^+ \to e^+\nu_e$	.511+ 0
P7	$D^+ \to e^+$ anything	
P8	$D^+ \to K^-$ anything	
P9	$D^+ \to \bar{K}^0$ anything + K^0 anything	
P10	$D^+ \to K^+$ anything	
P11	$D^+ \to \bar{K}^*(892)^0\pi^+$	892+ 140
P12	$D^+ \to \bar{K}^0\pi^+\pi^0$	498+ 140+ 135
P13	$D^+ \to \bar{K}^0\pi^+\pi^+\pi^-$	498+ 140+ 140+ 140
P14	$D^+ \to K^-\pi^+\pi^+\pi^+\pi^-$	494+ 140+ 140+ 140+
P15	$D^+ \to \pi^+\pi^0$	140+ 135
P16	$D^+ \to \bar{K}^0K^+$	498+ 494
P17	$D^+ \to K^-\pi^+\pi^+\pi^0$	494+ 140+ 140+ 135
P18	$D^+ \to \bar{K}^0\rho^+$	498+ 769
P19	$D^+ \to$ unfitted modes (keeps fit program happy)	
P20	$D^+ \to \mu^+\nu_\mu$	106+ 0
P21	$D^+ \to \eta$ anything	
P22	$D^+ \to \mu^+$ anything	
P23	$D^+ \to \mu^+\mu^-$ anything	
P24	$D^+ \to \phi\pi^+$	140+1020
P25	$D^+ \to \bar{K}^*(892)^0K^+$	892+ 494
P26	$D^+ \to \pi^+K^+K^-$(non-resonant)	140+ 494+ 494

D- MODES ARE CHARGE CONJUGATES OF THE ABOVE MODES

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1      P17      P19
P 1   .1144+-.0112
P17   .105    .0636+-.0155
P19  -.639   -.832    .8220+-.0200
```

NOTE ON CHARMED PARTICLE BRANCHING FRACTIONS

The determination of D^0 and D^+ hadronic branching fractions has been performed by three distinct techniques. The earliest measurements (PERUZZI 77, SCHARRE 78, and SCHINDLER 81) come from e^+e^- collisions at the $\psi(3770)$ resonance. The rate at which D mesons are observed in a given channel is divided by the height of the resonance (assumed to decay wholly to $D\bar{D}$ pairs) to obtain branching fractions. The height of the resonance is determined from a fine energy scan. The second technique (employed by AGUILAR 84 and AGUILAR2 84), in πp and pp scattering, relies on a determination of branching fractions through the identification of specific 3- and 4-body final states relative to all 3- and 4-charged-prong vertices. These are normalized by the absolute topological branching fractions of D mesons determined from tagged e^+e^- data. The third technique (BALTRUSAITIS 86), also coming from e^+e^- collisions at the $\psi(3770)$ resonance, compares the number of fully reconstructed $D\bar{D}$ pairs with the number of single D mesons reconstructed. This provides an absolute measurement which does not rely on the resonance height and assumptions about its decay to charmed particles.

The third technique is the most direct way of measuring the D meson branching fractions, relying solely on kinematics. The results indicate significantly higher branching fractions than the first technique, and are consistent with the second. For consistency in normalization, the results of SCHINDLER 81 have been rescaled to reflect the cross section for charm production determined in BALTRUSAITIS 86. Earlier e^+e^- results are excluded from the averages unless they are in ratios independent of this scale. The technique is justified, as the production rates ($\sigma_D \cdot B$) in e^+e^- experiments at E_{cm} = 3.77 GeV are generally in agreement, implying that the discrepancy in branching fractions lies either in the direct resonance-height determination or in the assumptions about the resonance decay. Other experiments measuring D branching fractions by relative measurements have been rescaled (when possible) to the measurement of BALTRUSAITIS 86.

$D^{\pm}$ BRANCHING RATIOS

$D^+ \to (K^- \text{ anything})/\text{total}$ (P8)

```
R1         3   0.10     0.07              VUILLEMIN 78 SMAG E+E- 3.772 GEV ECM
R1        26   0.19     0.05              SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R1           . . . . . . . . . .
R1   AVG       0.160    0.043    AVERAGE
```

$D^+ \to (K^+ \text{ anything})/\text{total}$ (P10)

```
R2         2   0.06     0.06              VUILLEMIN 78 SMAG E+E- 3.772 GEV ECM
R2        12   0.06     0.04              SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R2           . . . . . . . . . .
R2   AVG       0.060    0.033    AVERAGE
```

$D^+ \to (\overline{K}^0 \text{ anything} + K^0 \text{ anything})/\text{total}$ (P9)

```
R3         3   0.39     0.29              VUILLEMIN 78 SMAG E+E- 3.772 GEV ECM
R3        15   0.52     0.18              SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R3           . . . . . . . . . .
R3   AVG       0.48     0.15     AVERAGE
```

D^+ and $D^0 \to (\eta \text{ anything})/(\text{total } D^+ \text{ and } D^0)$

```
R4    B       (0.02) OR LESS              BRANDELIK 79 DASP     E+E- ECM=4.03GEV
R4             0.13  OR LESS              PARTRIDGE 81 CBAL     E+E- ECM=3.77GEV
R4    B BRANDELIK 79 RESULT BASED ON ABSENCE OF ETA SIGNAL AT 4.03 GEV.
R4    B PARTRIDGE 81 OBSERVE SUBSTANTIALLY HIGHER ETA CROSS SECTION AT 4.03.
```

$D^+ \to (e^+ \text{ anything})/\text{total}$ (P7)

```
R5             0.220    0.044    0.022 BACINO    80 DLCO E+E- 3.77 GEV ECM
R5        23   0.168    0.064          SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R5    A 158    0.170    0.020          BALTRUSAI 85 SMK3    E+E- 3.77GEV ECM
R5    A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.019 AND 0.007.
R5           . . . . . . . . . .
R5   AVG       0.182    0.017    AVERAGE
```

D^+ and $D^0 \to (\mu^+ \text{ anything})/(\text{total charm})$ (P22)

```
R6    C        0.082    0.023    0.016 ALTHOFF   84 TASS    E+E- ECM=34.5GEV
R6  A C        0.089    0.031          BARTEL    85 JADE    E+E- ECM=34.6GEV
R6    C  AVERAGE BR FOR C--> MU+ X.  THE MIXTURE OF CHARMED PARTICLES
R6    C  IS UNKNOWN AND MAY ACTUALLY CONTAIN STATES OTHER THAN D MESONS.
R6  A    STATISTICAL AND SYSTEMATIC ERRORS ARE 0.018 AND 0.025.
R6           . . . . . . . . . .
R6   AVG       0.084    0.017    AVERAGE
```

$(D^+ \to e^+ \nu_e)/(D^+ \to e^+ \text{ anything} + D^0 \to e^+ \text{ anything})$

```
R7             0.10   OR LESS   CL=.90   BRANDELIK 77 DASP E+E- 3.99-4.08 GEV
```

$D^+ \to (\mu^+ \nu_\mu)/\text{total}$ (P20)

```
R8    A   0    0.02  OR LESS  CL=.90   AUBERT    83 SPEC    MU+ FE, 250 GEV
R8    A  AUBERT 83 OBTAIN UPPER LIMIT 0.014 ASSUMING THAT FINAL STATE
R8    A  CONTAINS EQUAL MIXTURE OF (D+,D-),(D+,AD0),(D-,D0) AND (D0,AD0) .
R8    A  WE QUOTE THE LIMIT WHICH THEY GET UNDER MORE GENERAL ASSUMPTIONS .
```

D^+ and $D^0 \to (\mu^+ \mu^- \text{ anything})/(\text{total charm})$ (P23)

```
R9    C       (0.007)OR LESS  CL=.95   ALTHOFF   84 TASS    E+E- ECM=34.5GEV
R9    C  AVERAGE BR FOR C-->MU+ MU- X.  THE MIXTURE OF CHARMED PARTICLES
R9    C  IS UNKNOWN AND MAY ACTUALLY CONTAIN STATES OTHER THAN D MESONS.
```

D^+ and $D^0 \to (e^+ \text{ anything})/(\text{total } D^+ \text{ and } D^0)$

```
R10      IF MEASURED AT THE PSI(3772) GIVES A WEIGHTED AVERAGE OF
R10      D+ (44 PCT.) AND D0 (56 PCT.) BRANCHING FRACTIONS.
R10
R10      ONLY EXPERIMENTS AT 3.77 GEV ARE INCLUDED IN THE AVERAGE.
R10
R10            0.072    0.028             FELLER    78 SMAG E+E- 3.772 GEV ECM
R10 A         (0.08)   (0.015)            BACINO    79 DLCO E+E- 3.772 GEV ECM
R10  B         0.10     0.032             SCHINDLER 81 SMK2    E+E- 3.771 GEV
R10  C        (0.092)  (0.046)            ALTHOFF2  84 TASS    E+E- 34.6GEV ECM
R10  C        (0.091)  (0.013)            KOOP      84 DLCO    E+E- ECM=29 GEV
R10 EC        (0.091)  (0.016)            AIHARA    85 TPC     E+E- ECM=29 GEV
R10     295    0.117    0.011             BALTRUSA  85 SMK3    E+E- 3.77GEV ECM
R10  F        (0.116)  (0.011)  (0.009)PAL          86 DLCO    E+E- 29 GEV ECM
R10 A   NOT INDEPENDENT OF BACINO 80 R5 (D+) AND R5 (D0).
R10  B  ISOLATES D+ AND D0 INTO E+ ANYTHING AND WEIGHTS FOR RELATIVE
R10  B  PRODUCTION (44% TO 56%)
R10  C  AVERAGE BR FOR C-->E+X.  UNLIKE ECM=3.77 GEV, THE ADMIXTURE OF
R10  C  CHARMED MESONS IS UNKNOWN.
R10 E   THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.009 AND 0.013.
R10  F  THIS MEASUREMENT SUPERSEDES KOOP 84.
R10          . . . . . . . . . .
R10 AVG        0.110    0.011   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$D^+ \to (\pi^+ \pi^0)/\text{total}$ (P15)

```
R11        1   (0.0053)OR LESS CL=.90   BALTRUS2  85 SMK3    E+E- 3.77 GEV
```

$D^+ \to (\overline{K}^0 \pi^+)/\text{total}$ (P2)

```
R12A S  17     0.041    0.016             PERUZZI   77 SMAG    E+E- 3.77GEV ECM
R12B S  36     0.042    0.011             SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R12    161     0.041    0.007             BALTRUSA  86 SMK3    E+E- 3.77GEV ECM
R12  S  CORRECTED BY US USING THE SIGMA D+=3.35 NB FROM BALTRUSA 86.
R12A    THE UNCORRECTED VALUE WAS 0.015+-0.006.
R12B    THE UNCORRECTED VALUE WAS 0.023+-0.007.
R12          . . . . . . . . . .
R12 AVG        0.0413   0.0055  AVERAGE
```

$D^+ \to (\overline{K}^0 K^+)/\text{total}$ (P16)

```
R13  A  31    (0.013)  (0.005)            BALTRUSA  86 SMK3    E+E- 3.77GEV ECM
R13  A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.004 AND 0.002.
```

$D^+ \to (\overline{K}^*(892)^0 \pi^+)/\text{total}$ (P11)

```
R14     92 EVENTS SEEN                    DRIJARD   79 SFM  +  P P,ECM=53 GEV
R14  S         0.066 OR LESS  CL=.90   SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R14  S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D+=3.35 NB FROM
R14  S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.037 OR LESS.
```

$D^+ \to (\overline{K}^*(892)^0 K^+)/\text{total}$ (P25)

```
R16   A  19   (0.006)  (0.003)            BALTRUSA  86 SMK3    E+E- 3.77GEV ECM
R16   A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.003 AND 0.001.
```

$D^+ \to (\phi \pi^+)/\text{total}$ (P24)

```
R17     234 EVENTS SEEN                   GEORGIOP  85 SPEC +  PROT-NUCL 400GEV
R17   R  21   (0.010)  (0.003)            BALTRUSA  86 SMK3  + E+E- 3.77 GEV
R17   R  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.003 AND 0.001.
```

$D^+ \to (\pi^+ \pi^+ \pi^-)/\text{total}$ (P3)

```
R18   A  57   (0.005)  (0.002)            BALTRUSA  86 SMK3    E+E- 3.77GEV ECM
R18   A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.002 AND 0.001.
```

$D^+ \to (K^- \pi^+ \pi^+)/\text{total}$ (P1)

```
R19A S  85     0.107    0.025             PERUZZI   77 SMAG    E+E- 3.77GEV ECM
R19B S 239     0.113    0.023             SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R19      8     0.14     0.06      0.05    AGUILAR   84 HYBR     PI-P PP 360 GEV
R19   1164     0.116    0.016             BALTRUSA  86 SMK3    E+E- 3.77GEV ECM
R19   S  CORRECTED BY US USING THE SIGMA D+=3.35 NB FROM BALTRUSA 86.
R19A     THE UNCORRECTED VALUE WAS 0.039+-0.010.
R19B     THE UNCORRECTED VALUE WAS 0.063+-0.015.
R19          . . . . . . . . . .
R19 AVG        0.114    0.011    AVERAGE
R19 FIT        0.114    0.011   FROM FIT
```

$D^+ \to (\overline{K}^0 \pi^+ \pi^0)/\text{total}$ (P12)

```
R20   S  10    0.233    0.147             SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R20     159    0.129    0.034             BALTRUSA  86 SMK3    E+E- 3.77GEV ECM
R20   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D+=3.35 NB FROM
R20   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.129+-0.084.
R20          . . . . . . . . . .
R20 AVG        0.134    0.033    AVERAGE
```

$D^+ \to (K^- K^+ \pi^+ \text{ non-resonant})/\text{total}$ (P26)

```
R21   A  37   (0.007)  (0.003)            BALTRUSA  86 SMK3    E+E- 3.77GEV ECM
R21   A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.003 AND 0.001.
```

$D^+ \to (\overline{K}^0 \pi^+ \pi^+ \pi^-)/\text{total}$ (P13)

```
R22   S  21    0.152    0.058             SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R22   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D+=3.35 NB FROM
R22   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.084+-0.035.
```

$D^+ \to (K^- \pi^+ \pi^+ \pi^0)/\text{total}$ (P17)

```
R23   A 175    0.063    0.018             BALTRUSA  86 SMK3    E+E- 3.77GEV ECM
R23   A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.014 AND 0.012.
R23          . . . . . . . . . .
R23 FIT        0.064    0.015   FROM FIT
```

$D^+ \to (K^- \pi^+ \pi^+ \pi^+ \pi^-)/\text{total}$ (P14)

```
R24   S        0.060 OR LESS  CL=.90   SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R24   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D+=3.35 NB FROM
R24   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.041 OR LESS.
```

$D^+ \to (\pi^+ \pi^0)/(\overline{K}^0 \pi^+)$ (P15)/(P2)

```
R25           (0.30) OR LESS  CL=.90   SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R25   A   1    0.13  OR LESS  CL=.90   BALTRUS2  85 SMK3    E+E- 3.77 GEV
R25   A  THIS ENTRY WAS CORRECTED BY US USING THE REVISED VALUE OF
R25   A  B(K0BAR PI+)=0.041 FROM BALTRUSA 86.
```

$D^+ \to (\overline{K}^0 K^+)/(\overline{K}^0 \pi^+)$ (P16)/(P2)

```
R26       6    0.25     0.15              SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R26   B  31    0.317    0.100             BALTRUS2  85 SMK3    E+E- 3.77 GEV
R26   B  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.086 AND 0.048.
R26          . . . . . . . . . .
R26 AVG        0.296    0.083    AVERAGE
```

$D^+ \to (\overline{K}^0 \pi^+)/(K^- \pi^+ \pi^+)$ (P2)/(P1)

```
R27   P       (0.45) OR LESS  CL=.90   PICCOLO   77 SMAG +- E+E- 4.03GEV ECM
R27   P  OBTAINED FROM SIGMA*BR VALUES OF TABLE I.
```

$D^+ \to (\phi \pi^+)/(K^- \pi^+ \pi^+)$ (P24/P1)

```
R28   B  21    0.084    0.024             BALTRUS2  85 SMK3  + E+E- 3.77 GEV
R28   B  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.021 AND 0.011.
```

$D^+ \to (\overline{K}^*(892)^0 K^+)/(K^- \pi^+ \pi^+)$ (P25/P1)

```
R29   B  14    0.048    0.024             BALTRUS2  85 SMK3  + E+E- 3.77 GEV
R29   B  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.021 AND 0.011.
```

$D^+ \to (\pi^+ \pi^+ \pi^-)/(K^- \pi^+ \pi^+)$ (P3)/(P1)

```
R30   P       (0.08) OR LESS  CL=.90   PICCOLO   77 SMAG +- E+E- 4.03GEV ECM
R30           (0.084)OR LESS  CL=.90   SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R30   B  57    0.042    0.019             BALTRUS2  85 SMK3 +  E+E- 3.77 GEV
R30   P  OBTAINED FROM SIGMA*BR VALUES OF TABLE I.
R30   B  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.016 AND 0.010.
```

$D^+ \to (\pi^+ K^+ K^-)/(K^- \pi^+ \pi^+)$ (P4)/(P1)

```
R31      THESE MEASUREMENT DO NOT DISTINGUISH POSSIBLE RESONANT SUBSTRUCTURE
R31   P       (0.15) OR LESS  CL=.90   PICCOLO   77 SMAG +- E+E- 4.03GEV ECM
R31            0.14  OR LESS  CL=.90   SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R31   Q   5   (0.25)   (0.20)             BAILEY    84 SILI    HADROPRODUCTION
R31   P  OBTAINED FROM SIGMA*BR VALUES OF TABLE I.
R31   Q  ONE EVENT CONSISTENT WITH D+- --> PHI PI+
```

$D^+ \to (\pi^+ K^+ K^- \text{ non-resonant})/(K^- \pi^+ \pi^+)$ (P26/P1)

```
R32   R  37    0.059    0.028             BALTRUS2  85 SMK3  + E+E- 3.77 GEV
R32   R  THIS MEASUREMENT EXCLUDES CONTRIBUTIONS TO
R32   R  K+ K- PI+ FROM PHI PI+ AND K*(892)0 K+.
R32   R  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.026 AND 0.009.
```

$D^+ \to (K^+ \pi^+ \pi^-)/(K^- \pi^+ \pi^+)$ (P5)/(P1)

```
R33   P        0.05  OR LESS  CL=.90   PICCOLO   77 SMAG +- E+E- 4.03GEV ECM
R33   P  OBTAINED FROM SIGMA*BR VALUES OF TABLE I.
```

$D^+ \to (K^- \pi^+ \pi^+ \pi^0)/(K^- \pi^+ \pi^+)$ (P17)/(P1)

```
R34       1    0.57     0.65      0.17  AGUILAR2  83 HYBR     PI- P,360GEV
R34          . . . . . . . . . .
R34 FIT        0.56     0.14    FROM FIT
```

REFERENCES FOR $D^{\pm}$

```
GOLDHABE 76 PRL 37 255          GOLDHABER,PIERRE,ABRAMS,ALAM+    (LBL+SLAC)
PERUZZI  76 PRL 37 569          +PICCOLO,FELDMAN,NGUYEN,WISS+    (SLAC+LBL)
WISS     76 PRL 37 1531         +GOLDHABER,ABRAMS,ALAM,BOYARSKI+ (LBL+SLAC)

BRANDELI 77 PL 70B 387          BRANDELIK +      (AACH+DESY+HAMB+MPIM+TOKY)
GOLDHABE 77 PL 69B 503          GOLDHABER,WISS,ABRAMS,ALAM +     (LBL+SLAC)
PERUZZI  77 PRL 39 1301         +PICCOLO,FELDMAN+      (SLAC+LBL+NWES+HAWA)
PICCOLO  77 PL 70B 260          +PERUZZI,LUTH,NGUYEN,WISS,ABRAMS+(SLAC+LBL)

FELLER   78 PRL 40 274          +LITKE,MADARAS,RONAN+  (LBL+SLAC+NWES+HAWA)
VUILLEMI 78 PRL 41 1149         VUILLEMIN,FELDMAN +    (LBL+SLAC+NWES+HAWA)

ARMENISE 79 PL 86B 115          +ERRIQUEZ+       (BARI+CERN+EPOL+MILA+ORSA)
BACINO   79 PRL 43 1073         +FERGUSON,NODULMAN+     (UCLA+SLAC+UCI+STON)
BRANDELI 79 PL 80B 412          BRANDELIK+       (AACH+DESY+HAMB+MPIM+TOKY)
DRIJARD  79 PL 81B 250          +FISCHER,GEIST+         (CERN+CDEF+HEID+KARL)

ALLASIA  80 NP B176 13           (ANKA+LIBH+CERN+DUUC+LOUC+KEYN+PISA+ROMA+)
BACINO   80 PRL 45 329          +FERGUSON+         (UCLA+SLAC+STAN+UCI+STON)
ZHOLENTZ 80 PL 96B 214          +KURDADZE,LELCHUK,MISHNEV,NIKITIN+   (NOVO)
    ALSO 81 YAD.PHYS.34 1471    ZHOLENTZ +                           (NOVO)

BALLAGH  81 PR D24 7            +BINGHAM+     (LBL+UCB+FNAL+HAWA+WASH+WISC)
    ALSO 80 PL 89B 423          BALLAGH +     (LBL+UCB+FNAL+HAWA+WASH+WISC)
PARTRIDG 81 PRL 47 760          PARTRIDGE,PECK+   (CIT+HARV+PRIN+STAN+SLAC)
SCHINDLE 81 PR D24 78           MARK II COLLABORATION, SCHINDLER (SLAC+LBL)

ALBINI   82 PL 110B 339         ALBINI+     (FRAS+MILA+PISA+ROMA+TORI+TRST)
AGUILAR  83 PL 122B 312         LEBC-EHS COLLAB.,  AGUILAR-BENITEZ+ (CERN+)
AGUILAR2 83 PL 123B 98          LEBC-EHS COLLAB.,  AGUILAR-BENITEZ+ (CERN+)
AUBERT   83 NP B213 31          EUROPEAN MUON COLLAB.     (CERN+DESY+FREI+)
BADERTSC 83 PL 123B 471         BADERTSCHER,HAHN,HUGENTOBLER+   (BERN+MPIM)
USHIDA   83 PRL 51 2362           (AICH+FNAL+KOBE+SEOU+MCGI+NAGO+OSU+OKAY+)

ABE      84 PR D30 1            SLAC HYBRID FACILITY PHOTON COL.(BIRM+BROW)
ADAMOVIC 84 PL 140B 119         WA58 C., ADAMOVICH+  (BGNA+CERN+FIRZ+GENO+)
AGUILAR  84 PL 135B 237         LEBC-EHS C.(ANIK+BRUX+CERN+MADR+MONS+NIJM+)
ALTHOFF  84 ZPHY C22 219        TASSO C. (AACH+BONN+DESY+HAMB+LOIC+OXF+RL+)
ALTHOFF2 84 PL 146B 443         TASSO C.    (AACH+BONN+DESY+HAMB+LOIC+OXF+)
BAILEY   84 PL 139B 320         ACCMOR C.     (ANIK+BRIS+CERN+CRAC+MPIM+RL)
DERRICK  84 PRL 53 1971         HRS C, DERRICK+(ANL+IND+MICH+PURD+LBL+SLAC)
KOOP     84 PRL 52 970          DELCO COLLABORATION           (CIT+SLAC+STAN)
AIHARA   85 ZPHY C27 39         TPC COLL.(LBL+UCLA+UCR+JHU+YALE+TOKY+MASA+)
BAILEY   85 ZPHY C28 357        ABCCMR COLLAB.(ANIK+BRIS+CERN+CRAC+RL+MPIM)
BALTRUSA 85 PRL 54 1976         MARK III C., BALTRUSAITIS+  (CIT+UCSC+ILL+)
BALTRUS2 85 PRL 55 150          MARK III C., BALTRUSAITIS+ (SLAC+CIT+UCSC+)
BARTEL   85 PL 163B 277         JADE C. (DESY+HAMB+HEID+LANC+MCHS+RL+TOKY+)
GEORGIOP 85 PL 152B 428         GEORGIOPOULOS+   (TUFT+ARIZ+FNAL+FSU+NDAM+)
BALTRUSA 86  SLAC-PUB-3861      MARK III C., BALTRUSAITIS+ (SLAC+CIT+UCSC+)
PAL      86  CALT-68-1283       DELCO COLLABORATION           (CIT+SLAC+STAN)

                                REVIEWS

BARBAROG 78  LBL-8537           A.BARBARO-GALTIERI (ERICE 1978)        (LBL)
WOJCICKI 78  SLAC-PUB-2232      S.WOJCICKI (SLAC SUMMER INST.1978)    (SLAC)
KIRKBY   79  SLAC-PUB-2419      J.KIRKBY (LEPTON CONF. BATAVIA, 1979)(SLAC)
TRILLING 81 PRPL 75 57          G.H.TRILLING                       (LBL+UCB)J
```

D^0

$I(J^P) = \frac{1}{2}(0^-)$

D^0 MASS (MeV)

```
M       234(1865.)    (15.)          GOLDHABER 76 SMAG    K PI AND K 3PI
M          (1863.)     (3.)          GOLDHABER 77 SMAG    D0,D+ RECOIL SPC
M   P      (1863.3)    (0.9)         PERUZZI   77 SMAG    E+E- 3.77GEV ECM
M          (1868.)    (11.)          PICCOLO   77 SMAG    E+E-4.03,4.41ECM
M        64(1850.)    (15.)          BALTAY    78 HBC     NU NUCL,K0PIPI
M   A    94(1854.)     (6.)          ATIYA     79 SPEC GAM NUC-->D0 D0BAR
M       238(1863.0)    (2.5)         ASTON     80 OMEG GAMMA P-->D0BAR
M   A   143(1860.)     (2.)          AVERY     80 SPEC    GAMMA NUC-->D*+
M   A    35(1869.)     (4.)          AVERY     80 SPEC    GAMMA NUC-->D*+
M         1(1847.)     (7.)          FIORINO   81 EMUL GAMMA NUC-->D0BAR +
M   P      (1863.8)    (0.5)         SCHINDLER 81 SMK2    E+E- 3.77GEV ECM
M    P       1864.7     0.6          TRILLING  81 RVUE +- E+E- 3.77GEV ECM
M        22 1856.      36.           ADAMOVICH 84 EMUL    PHOTOPRODUCTION
M            1861.      4.0          DERRICK   84 HRS     E+E- 29GEV ECM
M    P  PERUZZI 77 AND SCHINDLER 81 ERRORS DO NOT INCLUDE THE 0.13 PERCENT
M    P  UNCERTAINTY IN THE ABSOLUTE SPEAR ENERGY CALIBRATION.  TRILLING 81
M    P  USES THE HIGH PRECISION J/PSI AND PSI(3685) MEASUREMENTS OF
M    P  ZHOLENTZ 80 TO DETERMINE THIS UNCERTAINTY AND COMBINES THE
M    P  PERUZZI 77 AND SCHINDLER 81 RESULTS TO OBTAIN THE VALUE QUOTED.
M    A  ERROR DOES NOT INCLUDE POSSIBLE SYSTEMATIC MASS SCALE SHIFT,
M    A  ESTIMATED TO BE LESS THAN 5 MEV.
M            . . . . . . . . .
M   AVG      1864.62      0.59    AVERAGE
```

$D_1^0 - D_2^0$ MASS DIFFERENCE (units 10^{-4} eV)

```
D      D01 AND D02 ARE THE CP EIGENSTATES OF THE D0 MESON.
D     B         6.5    OR LESS  CL=.90   BODEK      82 SPEC    PI-,P FE-->D0
D     B  BODEK 82 LIMIT IS FOR THE ABSOLUTE VALUE OF THE MASS DIFFERENCE.
D     B  LIMIT INFERRED FROM D0-D0BAR MIXING, RATIO R8 BELOW.
```

$D^{\pm} - D^0$ MASS DIFFERENCE (MeV)

```
DM    A         5.0       0.8              PERUZZI   77 SMAG +- E+E- 3.77GEV ECM
DM    A         4.7       0.3              SCHINDLER 81 SMK2 +- E+E- 3.77GEV ECM
DM    A  NOT INDEPENDENT OF D+- AND D0 MASS MEASUREMENTS.
DM           . . . . . . . . .
DM   AVG        4.74      0.28    AVERAGE
```

D^0 MEAN LIFE (units 10^{-13} sec)

```
T            (8.0)  OR LESS  CL=.90   ARMENISE  79 HYBR NU P -->DIMUONS +
T   E    3   (0.53)   (0.57)   (0.25) ALLASIA   80 EMUL NU WIDEBAND
T   C        (2.1)  OR LESS  CL=.95   BACINO    80 DLCO E+E- 3.77 GEV ECM
T   B    2   (2.8)    (2.2)    (1.3)  BALLAGH   81 HYBR FNAL 15FT, NU NE-H2
T   A    1   (2.1)                    ADEVA     81 HYBR LEBC CERN-SPS PI- P
T   A    1   (5.9)                    ADEVA     81 HYBR LEBC CERN-SPS PI- P
T        5    3.1      2.0      1.6   FUCHI     81 EMUL CERN-SPS PI- NUC
T    G  16    2.3      0.8      0.5   USHIDA    82 EMUL FNAL NU,ANU WIDEBND
T       16    4.1      1.3      0.9   AGUILAR   83 HYBR    PI- P, P P
T        9    4.1      2.6      1.4   BADERTSCH 83 HYBR    CERN PI- NUCL.
T       22    6.8      2.3      1.8   ABE       84 HYBR    SLAC GAM P 20GEV
T    J  22    2.11     1.21     0.63  ADAMOVICH 84 EMUL    PHOTOPRODUCTION
T       27    4.2      1.6      1.4   YELTON    84 SMK2    E+E- ECM=29 GEV
T       11    3.5      1.4      0.9   AGUILAR2  84 HYBR  0 PI- P 360 GEV
T       26    3.7      1.0      0.7   BAILEY    85 SILI  0 PI-BE 200 GEV
T    K 269    4.6      1.7            YAMAMOT2  85 DLCO    E+E- 29 GEV ECM
T   E   ALLASIA 80 ASSUMES NO LONG-LENGTH LOSSES.  VISIBILITY PROBLEMS IN
T   E   THE EMUL.
T   C   USES THEORETICAL RATE D TO (K E NU)=1.4*10**11 SEC**-1 .
T   B   BALLAGH 81 VALUE QUOTED HERE ASSUMES THAT ALL DILEPTON EVENTS
T   B   CONTAIN D0 OR D+, EACH WITH EQUAL NUMBERS OF SEMILEPTONIC DECAYS.
T   A   ADEVA 81 FIRST AND SECOND VALUES ARE PROPER LIFETIMES OF D0 AND AD0
T   A   FROM SINGLE EVENT.  DETECTION EFFICIENCY LOW FOR LIFETIMES 10**-13
T   A   SEC OR LESS.
T   D   CERN NA16 (LEBC-EHS) EXPT.  PRESENTED AT MORIOND CONF. 82.
T    G  USHIDA 82 HAVE 3 SEMI-LEPTONIC DECAYS NOT INCLUDED IN THIS NUMBER,
T    G  BUT BELIEVED TO HAVE MUCH LONGER LIFETIMES.
T    J  ESTIMATE SYSTEMATIC ERROR LESS THAN +0.8  -0.7
T    K  STATISTICAL AND SYSTEMATIC ERRORS ARE 1.5 AND (+0.6-0.5)
T    K  USES IMPACT PARAMETER TECHNIQUE.
T            . . . . . . . . .
T   AVG       4.29      0.53      0.42   AVERAGE
```

$(D_1^0 - D_2^0)$/AVG., MEAN LIFE DIFFERENCE

```
DT     D01 AND D02 ARE THE CP EIGENSTATES OF THE D0 MESON.
DT    B         0.55  OR LESS  CL=.90   BODEK      82 SPEC    PI-,P FE-->D0
DT    B  BODEK 82 LIMIT IS FOR THE ABSOLUTE VALUE OF THE MEAN LIFE
DT    B  DIFFERENCE.  LIMIT INFERRED FROM D0-D0BAR MIXING, RATIO R8 BELOW.
```

$D^{\pm}/D^0$ MEAN LIFE RATIO

```
TR       NOT USED BY US TO CONSTRAIN BEST VALUES OF D LIFETIMES FOR SUMMARY
TR       TABLE.
TR   A        (4.3)  OR MORE  CL=.95   BACINO    80 DLCO E+E- 3.77 GEV ECM
TR   A         3.1      4.6      1.4   SCHINDLER 81 SMK2 E+E- 3.77 GEV ECM
TR             2.8      1.1      0.8   BAILEY    85 SILI    PI-BE 200 GEV
TR   AB        2.3      0.5      0.4   BALTRUSAI 85 SMK3    E+E- 3.77GEV ECM
TR   A   FROM RATIO OF D+ TO D0 SEMILEPTONIC BRANCHING FRACTIONS.
TR   B   STATISTICAL ERROR +0.5 -0.4 SYSTEMATIC ERROR +-0.1.
TR          . . . . . . . . .
TR  AVG        2.40      0.40    AVERAGE
```

D^0 PARTIAL DECAY MODES

		DECAY MASSES
P1	$D^0 \rightarrow K^- \pi^+$	494+ 140
P2	$D^0 \rightarrow K^- \pi^+ \pi^+ \pi^-$	494+ 140+ 140+ 140
P3	$D^0 \rightarrow \overline{K}^0 \pi^+ \pi^-$	498+ 140+ 140
P4	$D^0 \rightarrow \overline{K}^0 \pi^+ \pi^- \pi^+ \pi^-$	498+ 140+ 140+ 140+
P5	$D^0 \rightarrow \pi^+ \pi^-$	140+ 140
P6	$D^0 \rightarrow K^+ \pi^-$(via $\overline{D}^0$)	494+ 140
P7	$D^0 \rightarrow K^+ K^-$	494+ 494
P8	$D^0 \rightarrow K^- \pi^+ \pi^0$	494+ 140+ 135
P9	$D^0 \rightarrow \overline{K}^0 \pi^0$	498+ 135
P10	$D^0 \rightarrow e^+$ anything	
P11	$D^0 \rightarrow K^-$ anything	
P12	$D^0 \rightarrow K^+$ anything	
P13	$D^0 \rightarrow \overline{K}^0$ anything $+$ K^0 anything	
P14	$D^0 \rightarrow K^*(892)^- \pi^+$	892+ 140
P15	$D^0 \rightarrow \overline{K}^*(892)^0 \pi^0$	892+ 135
P16	$D^0 \rightarrow K^- \rho^+$	494+ 769
P17	$D^0 \rightarrow \overline{K}^0 \rho^0$	498+ 769
P18	$D^0 \rightarrow \pi^- \pi^- \pi^+ \pi^+$	140+ 140+ 140+ 140
P19	$D^0 \rightarrow$ unfitted modes (keeps fit program happy)	
P20	$D^0 \rightarrow K^- \pi^+ \pi^0 \pi^0$	494+ 140+ 135+ 135
P21	$D^0 \rightarrow \eta$ anything	
P	(SEE D+- SECTION FOR D+- AND D0 INTO ETA)	
P22	$D^0 \rightarrow \overline{K}^*(892)^0 \rho^0$	892+ 769
P23	$D^0 \rightarrow K^- \pi^+ \rho^0$	494+ 140+ 769
P24	$D^0 \rightarrow \overline{K}^*(892)^0 \pi^+ \pi^-$	892+ 140+ 140
P25	$D^0 \rightarrow K^- a_2(1320)^+$	494+1318
P26	$D^0 \rightarrow \mu^-$ anything (via $\overline{D}^0$)	
P27	$D^0 \rightarrow \mu^+$ anything	
P28	$D^0 \rightarrow \mu^+ \mu^-$	106+ 106
P29	$D^0 \rightarrow \pi^- \pi^+ \pi^0$	140+ 140+ 135
P30	$D^0 \rightarrow \overline{K}^0 \phi$	498+1020
P31	$D^0 \rightarrow \overline{K}^0 K^+ K^-$	498+ 494+ 494
P32	$D^0 \rightarrow K^- \pi^+ \pi^0$(non-resonant)	494+ 140+ 135
P33	$D^0 \rightarrow \overline{K}^0 \pi^+ \pi^-$ (non-resonant)	498+ 140+ 140
P34	$D^0 \rightarrow \overline{K}^0 K^+ K^-$(non-resonant)	498+ 494+ 494
P35	$D^0 \rightarrow \overline{K}^0 K^0$	498+ 498

P36 $D^0 \rightarrow K^0 K^- \pi^+ + \overline{K}^0 K^+ \pi^-$(non-resonant) 498+ 494+ 140
P37 $D^0 \rightarrow \overline{K}^*(892)^0 K^0 + K^*(892)^0 \overline{K}^0$ 892+ 498
P38 $D^0 \rightarrow K^*(892)^- K^+ + K^*(892)^+ K^-$ 892+ 494

```
        D0BAR MODES ARE CHARGE CONJUGATES OF ABOVE MODES
```

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1      P 2      P 3      P 5      P 7      P19
 P 1   .0540+-.0037
 P 2   .227     .1093+-.0096
 P 3   .047     .011     .0846+-.0144
 P 5   .236     .054     .011     .0018+-.0005
 P 7   .420     .095     .020     .099     .0064+-.0011
 P19  -.384    -.575    -.791    -.117    -.208    .7440+-.0186
```

D^0 BRANCHING RATIOS

```
        SEE NOTE IN D+- SECTION CONCERNING REVISIONS TO HADRONIC
        BRANCHING FRACTIONS.
```

$D^0 \rightarrow (K^-\ \text{anything})/\text{total}$ (P11)

```
R1       19    0.35     0.10              VUILLEMIN 78 SMAG E+E- 3.772 GEV ECM
R1      121    0.55     0.11              SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R1            . . . . . . . . . .
R1  AVG        0.440    0.100   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$D^0 \rightarrow (K^+\ \text{anything})/\text{total}$ (P12)

```
R2       25    0.08     0.03              SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
```

$D^0 \rightarrow (\overline{K}^0\ \text{anything} + K^0\ \text{anything})/\text{total}$ (P13)

```
R3        6    0.57     0.26              VUILLEMIN 78 SMAG E+E- 3.772 GEV ECM
R3       13    0.29     0.11              SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R3            . . . . . . . . . .
R3  AVG        0.33     0.10    AVERAGE
```

$D^0 \rightarrow (e^+\ \text{anything})/\text{total}$ (P10)

```
R5        0   (0.04) OR LESS  CL=.95   BACINO    80 DLCO E+E- 3.77 GEV ECM
R5       12    0.055    0.037            SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
R5        3    0.051    0.048    0.014 AGUILAR   83 HYBR PI- P, P P
R5    A 137    0.075    0.012            BALTRUSAI 85 SMK3   E+E- 3.77GEV ECM  |
R5    A  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.011 AND 0.004.           |
R5            . . . . . . . . . .
R5  AVG        0.070    0.011   AVERAGE
```

$D^0 \rightarrow (\mu^+ \mu^-)/\text{total}$ (P28)

```
R7            3.4E-4  OR LESS  CL=.90   AUBERT    85 EMC  0  DEEP INEL MU-NUC  |
```

$D^0 \rightarrow (\mu^-\ \text{anything, via}\ \overline{D}^0)/(\mu^+\ \text{any} + \mu^-\ \text{any})$ (P26)/(P26+P27)

```
R8       THIS IS A D0-D0BAR MIXING LIMIT.
R8             0.044 OR LESS  CL=.90   BODEK     82 SPEC    PI-,P FE-->D0
```

$D^0 \rightarrow (K^+ \pi^-,\ \text{via}\ \overline{D}^0)/(K^- \pi^+ + K^+ \pi^-)$ (P6)/(P1+P6)

```
R9       THIS IS A D0-D0BAR MIXING LIMIT.
R9            (0.16) OR LESS  CL=.90   FELDMAN   77 SMAG    D*+ TO D0 PI+
R9            (0.18) OR LESS  CL=.90   GOLDHABER 77 SMAG
R9            (0.11) OR LESS  CL=.90   AVERY     80 SPEC    GAMMA NUC -->D*+
R9    A       (0.23) OR LESS  CL=.90   ALTHOFF   84 TASS    E+E- 34.4 GEV      |
R9             0.081 OR LESS  CL=.90   YAMAMOTO  85 DLCO 0  E+E- 29 GEV ECM    |
R9      2     (0.11) OR LESS  CL=.90   ALBRECHT  85 ARG  0  E+E- 10 GEV ECM    |
R9    A  TECHNIQUE USES K+ PI DECAY TO DERIVE LIMIT
R9    A  ALSO DERIVE RATIO OF CHARM TO AVERAGE ALPHA-STRONG OF
R9    A  1.00+-0.20+-0.20  AT 34.4 GEV USING K+ PION MODES
```

$D^0 \rightarrow (\pi^+ \pi^-)/\text{total}$ (P5)

```
R10   A  39   (0.0018) (0.0007)         BALTRUSA  86 SMK3    E+E- 3.77GEV ECM  |
R10   A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.0006 AND 0.0004.             |
R10   A  NOT INDEPENDENT OF BALTRUSA2 85 R26.                                  |
```

$D^0 \rightarrow (K^+ K^-)/\text{total}$ (P7)

```
R11   A 118   (0.0068) (0.0013)         BALTRUSA  86 SMK3    E+E- 3.77GEV ECM  |
R11   A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.0011 AND 0.0007.             |
R11   A  NOT INDEPENDENT OF BALTRUSA2 85 R27.                                  |
```

$D^0 \rightarrow (K^- \pi^+)/\text{total}$ (P1)

```
R12A S 130     0.056    0.012           PERUZZI   77 SMAG    E+E- 3.77GEV ECM
R12B S 263     0.054    0.008           SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R12  C 930     0.056    0.005           BALTRUSA  86 SMK3    E+E- 3.77GEV ECM  |
R12  S  CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM BALTRUSA 86.           |
R12A    THE UNCORRECTED VALUE WAS 0.022-0.006.                              P
R12B    THE UNCORRECTED VALUE WAS 0.030+-0.006.                                |
R12  C  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.004 AND 0.003.             |
R12           . . . . . . . . . .
R12 AVG        0.0555   0.0040  AVERAGE
R12 FIT        0.0540   0.0037 FROM FIT
```

$D^0 \rightarrow (\overline{K}^0 \pi^0)/\text{total}$ (P9)

```
R13           (0.06) OR LESS  CL=.90   SCHARRE   78 SMAG    E+E- 3.77 GEV
R13   S   8    0.040    0.018           SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R13   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM        |
R13   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.022+-0.011.                 |
```

$D^0 \rightarrow (\overline{K}^0 \rho^0)/\text{total}$ (P17)

```
R14   S   1    0.0013   0.0094  0.0013 SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R14   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM        |
R14   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.001+0.006-0.001.            |
```

$D^0 \rightarrow (K^- \rho^+)/\text{total}$ (P16)

```
R15   S  31    0.129    0.051    0.053 SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R15   A  13    0.075    0.053    0.041 SUMMERS   84 TPS  0  PHOTOPRODUCTION   |
R15   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM       |
R15   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.072+0.030-0.031.           |
R15   A  THIS ENTRY WAS CORRECTED BY US USING B(K- PI+)=0.056 FROM BALTRUSA   |
R15   A  86.  THE UNCORRECTED VALUE WAS 0.032+-0.023.                         |
R15           . . . . . . . . . .
R15 AVG        0.099    0.035   AVERAGE
```

$D^0 \rightarrow (K^*(892)^- \pi^+)/\text{total}$ (P14)

```
R16   S  25    0.070    0.027           SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R16   A   5    0.079    0.090    0.064 SUMMERS   84 TPS  0  PHOTOPRODUCTION   |
R16   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM       |
R16   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.034+-0.014.                |
R16   A  THIS ENTRY WAS CORRECTED BY US USING B(K- PI+)=0.056 FROM BALTRUSA   |
R16   A  86.  THE UNCORRECTED VALUE WAS 0.034+-0.039.                         |
R16           . . . . . . . . . .
R16 AVG        0.071    0.025   AVERAGE
```

$D^0 \rightarrow (\overline{K}^*(892)^0 \pi^0)/\text{total}$ (P15)

```
R17   S   4    0.025    0.040    0.025 SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R17   A   2    0.021    0.033    0.021 SUMMERS   84 TPS  0  PHOTOPRODUCTION   |
R17   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM       |
R17   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.014+0.023-0.014.           |
R17   A  THIS ENTRY WAS CORRECTED BY US USING B(K- PI+)=0.056 FROM BALTRUSA   |
R17   A  86.  THE UNCORRECTED VALUE WAS 0.009+-0.014.                         |
R17           . . . . . . . . . .
R17 AVG        0.023    0.021   AVERAGE
```

$D^0 \rightarrow (\pi^+ \pi^- \pi^0)/\text{total}$ (P29)

```
R18   A  10    0.011    0.004           BALTRUS2  85 SMK3    E+E- 3.77 GEV     |
R18   A  ALL EVENTS CONSISTENT WITH RHO0 PI0.  STATISTICAL AND SYSTEMATIC      |
R18   A  ERRORS ARE 0.004 AND 0.002.                                           |
```

$D^0 \rightarrow (K^- \pi^+ \pi^0)/\text{total}$ (P8)

```
R19       7   (0.12)   (0.06)           SCHARRE   78 SMAG    E+E- 3.77 GEV
R19   S  37    0.152    0.054           SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R19   B 931    0.175    0.018           BALTRUSA  86 SMK3    E+E- 3.77GEV ECM  |
R19   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM        |
R19   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.085+-0.032.                 |
R19   B  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.013 AND 0.013.            |
R19           . . . . . . . . . .
R19 AVG        0.173    0.017   AVERAGE
```

$D^0 \rightarrow (K^- \pi^+ \pi^0\ \text{non-resonant})/\text{total}$ (P32)

```
R20   S        0.043 OR LESS  CL=.90   SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R20   A  21   (0.121)  (0.065)          SUMMERS   84 TPS  0  PHOTOPRODUCTION   |
R20   S  THIS ENTRY WAS CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM       |
R20   S  BALTRUSA 86.  THE UNCORRECTED VALUE WAS 0.023+-0.007.                |
R20   A  THIS ENTRY WAS CORRECTED BY US USING B(K- PI+)=0.056 FROM BALTRUSA   |
R20   A  86.  THE UNCORRECTED VALUE WAS 0.052+-0.029.                         |
```

$D^0 \rightarrow (\overline{K}^0 \pi^+ \pi^-)/\text{total}$ (P3)

```
R21A S  28     0.103    0.029           PERUZZI   77 SMAG    E+E- 3.77GEV ECM
R21B S  32     0.067    0.019           SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R21  S  CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM BALTRUSA 86.           |
R21A    THE UNCORRECTED VALUE WAS 0.040+-0.013.                                |
R21B    THE UNCORRECTED VALUE WAS 0.038+-0.012.                                |
R21           . . . . . . . . . .
R21 AVG        0.078    0.017    AVERAGE
R21 FIT        0.085    0.014   FROM FIT
```

$D^0 \rightarrow (\overline{K}^0 \pi^+ \pi^-\ \text{non-resonant})/\text{total}$ (P33)

```
R22   S  10    0.020    0.017    0.016 SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R22   S  CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM BALTRUSA 86.          |
R22   S  THE UNCORRECTED VALUE WAS 0.011+-0.009.                               |
```

$D^0 \rightarrow (\pi^+ \pi^- \pi^+ \pi^-)/\text{total}$ (P18)

```
R23   B   9    0.015    0.006           BALTRUS2  85 SMK3    E+E- 3.77 GEV     |
R23   B  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.006 AND 0.002.                |
```

$D^0 \rightarrow (K^- \pi^+ \pi^+ \pi^-)/\text{total}$ (P2)

```
R24A S  44     0.080    0.024           PERUZZI   77 SMAG    E+E- 3.77GEV ECM
R24B S 185     0.152    0.030           SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM   |
R24       6    0.10     0.04            AGUILAR   84 HYBR    PI-P PP 360 GEV   |
R24       8    0.071    0.025           AGUILAR2  84 HYBR 0  PI- P 360 GEV     |
R24  C 992     0.118    0.014           BALTRUSA  86 SMK3    E+E- 3.77GEV ECM  |
R24  S  CORRECTED BY US USING THE SIGMA D0=4.48 NB FROM BALTRUSA 86.           |
R24A    THE UNCORRECTED VALUE WAS 0.032+-0.011.                                |
R24B    THE UNCORRECTED VALUE WAS 0.085+-0.021.                                |
R24  C  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.009 AND 0.011.             |
R24           . . . . . . . . . .
R24 AVG        0.107    0.012    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
R24 FIT        0.1093   0.0096 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
                        (SEE IDEOGRAM BELOW)
```

$D^0 \rightarrow (K^- \pi^+ \pi^0 \pi^0)/\text{total}$ (P20)

```
R25       1 SEEN                        ADEVA     81 HYBR    PI- P-->D0 D0BAR
```

$D^0 \rightarrow (\pi^+ \pi^-)/(K^- \pi^+)$ (P5)/(P1)

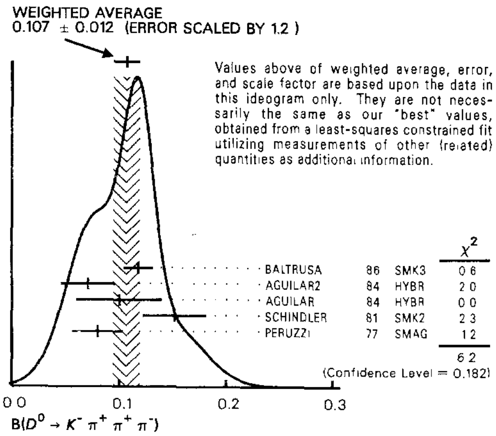
```
R26           (0.07) OR LESS  CL=.90   PICCOLO   77 SMAG    E+E- 4.03 GEVECM
R26            0.033    0.015           ABRAMS    79 SMK2    E+E- 3.77GEV ECM
R26   B  39    0.033    0.012           BALTRUS2  85 SMK3  0 E+E- 3.77 GEV     |
R26   B  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.010 AND 0.006.                |
R26           . . . . . . . . . .
R26 AVG        0.0330   0.0094   AVERAGE
R26 FIT        0.0330   0.0094 FROM FIT
```

$D^0 \rightarrow (K^+ K^-)/(K^- \pi^+)$ (P7)/(P1)

```
R27           (0.07) OR LESS  CL=.90   PICCOLO   77 SMAG    E+E- 4.03GEV ECM
R27            0.113    0.030           ABRAMS    79 SMK2    E+E- 3.77GEV ECM
R27   B 118    0.122    0.022           BALTRUS2  85 SMK3  0 E+E- 3.77 GEV     |
R27   B  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.018 AND 0.012.            |
R27           . . . . . . . . . .
R27 AVG        0.119    0.018    AVERAGE
R27 FIT        0.119    0.018   FROM FIT
```

$D^0 \rightarrow (\overline{K}^0 \pi^+ \pi^-)/(K^- \pi^+)$ (P3)/(P1)

```
R28     116    2.8      1.0             PICCOLO   77 SMAG    E+E-4.03,4.41ECM
R28      35    1.7      0.8             AVERY     80 SPEC    GAMMA NUC-->D*+
R28           . . . . . . . . . .
R28 AVG        2.13     0.62     AVERAGE
R28 FIT        1.57     0.28    FROM FIT
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$D^0 \to (K^-\pi^+\pi^+\pi^-)/(K^-\pi^+)$ (P2)/(P1)

```
R29  P 214    2.2       0.8               PICCOLO   77 SMAG    E+E-4.03,4.41ECM
R29     10    2.0       1.0               BAILEY    83 SPEC    PI- BE--> D0
R29  E        2.17      0.36              ALBRECHT  85 ARG     E+E- 10 GEV ECM
R29  P THIS CHANNEL DOMINATED BY K- PI+ RHO0 (85+-15 PERCENT).
R29  P K* PI+ PI- AND K- A2+ CONSISTENT WITH 0, K* RHO0 FRAC IS 0.1+-0.1 .
R29  E  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.28 AND 0.23.
R29  E  NOT INDEPENDENT OF (K- 3PI)/TOTAL.
R29        . . . . . . . . . .
R29 AVG       2.16      0.31     AVERAGE
R29 FIT       2.02      0.20    FROM FIT
```

$D^0 \to (K^- a_2(1320)^+)/(K^-\pi^+\pi^+\pi^-)$ (P25)/(P2)

```
R31     FOLLOWED BY DECAY A2+ --> PI+ PI+ PI- (B.R.=0.35)
R31           0.06   OR LESS              PICCOLO   77 SMAG    E+E-4.03,4.41ECM
```

$D^0 \to (K^-\pi^+\rho^0)/(K^-\pi^+\pi^+\pi^-)$ (P23)/(P2)

```
R32     180   0.85      0.11      0.22    PICCOLO   77 SMAG    E+E-4.03,4.41ECM
R32       2  (0.2)     (0.2)    CL=.90    BAILEY    83 SPEC    PI BE --> D0
```

$D^0 \to (\overline{K}^*(892)^0\pi^+\pi^-)/(K^-\pi^+\pi^+\pi^-)$ (P24)/(P2)

```
R33     FOLLOWED BY DECAY K*BAR(892)0 --> K- PI+ (B.R.=0.67)
R33  P    0  (0.0)     (0.2)     (0.0)    PICCOLO   77 SMAG    E+E-4.03,4.41ECM
R33       0   0.18   OR LESS   CL=.90     BAILEY    83 SPEC    PI BE --> D0
R33  P  CORRESPONDS TO 0.33 AT CL=.90.
```

$D^0 \to (\overline{K}^0\phi)/(\overline{K}^0\pi^+\pi^-)$ (P30)/(P3)

```
R34      26   0.186     0.052             ALBRECH2  85 ARG     E+E- 10 GEV ECM
```

$D^0 \to (\overline{K}^0 K^+ K^-)/(\overline{K}^0\pi^+\pi^-)$ (P31)/(P3)

```
R35  A  52    0.185     0.055             ALBRECH2  85 ARG     E+E- 10 GEV ECM
R35  A  RESONANT CONTRIBUTIONS TO K0BAR K+ K- ARE NOT DISTINGUISHED
R35  A  (K0BAR PHI IS INCLUDED).
```

$D^0 \to (\overline{K}^*(892)^0\rho^0)/(K^-\pi^+\pi^+\pi^-)$ (P22)/(P2)

```
R36     FOLLOWED BY DECAY K*BAR(892)0 --> K- PI+ (B.R.=0.67)
R36     20    0.10      0.11      0.10    PICCOLO   77 SMAG    E+E-4.03,4.41ECM
R36      5   (0.5)     (0.2)    CL=.90    BAILEY    83 SPEC    PI BE --> D0
```

$D^0 \to (\pi^-\pi^-\pi^+\pi^+)/(K^-\pi^+\pi^+\pi^-)$ (P18)/(P2)

```
R37           0.21   OR LESS  CL=.90    SCHINDLER 81 SMK2 E+E- 3.771 GEV ECM
```

$D^0 \to (\overline{K}^0\phi)$/total (P30)

```
R38  B        0.011     0.008     0.005 BALTRUS2  86 SMK3    E+E- 3.77 GEV
R38  B  STAT ERROR (+.007-.005) AND SYST ERROR (+.004-.002) ADDED IN QUADR.
```

$D^0 \to (\overline{K}^0 K^+ K^-$ non-resonant)/total (P34)

```
R39  B        0.011     0.005     0.004 BALTRUS2  86 SMK3    E+E- 3.77 GEV
R39  B  EXCLUDES CONTRIBUTIONS FROM D0 --> K0BAR PHI.
R39  B  STAT ERROR (+.004-.003) AND SYST ERROR (+.003-.002) ADDED IN QUADR.
```

$D^0 \to (\overline{K}^0 K^0)$/total (P35)

```
R40           0.006 OR LESS  CL=.90   BALTRUS2  86 SMK3    E+E- 3.77 GEV
```

$D^0 \to (K^0 K^-\pi^+ + \overline{K}^0 K^+\pi^-$ non-resonant)/total (P36)

```
R41  B        0.016 OR LESS  CL=.90   BALTRUS2  86 SMK3    E+E- 3.77 GEV
R41  B  EXCLUDES CONTRIBUTIONS FROM D0 --> K*(892) K.
```

$D^0 \to (\overline{K}^*(892)^0 K^0 + K^*(892)^0\overline{K}^0)$/total (P37)

```
R42           0.0073 OR LESS  CL=.90  BALTRUS2  86 SMK3    E+E- 3.77 GEV
```

$D^0 \to (K^*(892)^- K^+ + K^*(892)^+ K^-)$/total (P38)

```
R43           0.011     0.005           BALTRUS2  86 SMK3    E+E- 3.77 GEV
```

REFERENCES FOR D^0

GOLDHABE 76 PRL 37 255 GOLDHABER,PIERRE,ABRAMS,ALAM+ (LBL+SLAC)
FELDMAN 77 PRL 38 1313 +PERUZZI,PICCOLO,ABRAMS,ALAM + (SLAC+LBL)
GOLDHABE 77 PL 69B 503 GOLDHABER,WISS,ABRAMS,ALAM + (LBL+SLAC)
PERUZZI 77 PRL 39 1301 +PICCOLO,FELDMAN+ (SLAC+LBL+NWES+HAWA)
PICCOLO 77 PL 70B 260 +PERUZZI,LUTH,NGUYEN,WISS,ABRAMS+(SLAC+LBL)

BALTAY 78 PRL 41 73 +CAROUMBALIS,FRENCH,HIBBS,HYLTON+(COLU+BNL)
SCHARRE 78 PRL 40 74 +BARBARO-GALTIERI + (SLAC+LBL+NWES+HAWA)
VUILLEMI 78 PRL 41 1149 VUILLEMIN,FELDMAN + (LBL+SLAC+NWES+HAWA)
ABRAMS 79 PRL 43 481 +ALAM,BLOCKER,BOYARSKI+ (SLAC+LBL)
ARMENISE 79 PL 86B 115 +ERRIQUEZ+ (BARI+CERN+EPOL+MILA+ORSA)
ATIYA 79 PRL 43 414 +HOLMES,KNAPP,LEE+ (COLU+ILL+FNAL)

ALLASIA 80 NP B176 13 (ANKA+LIBH+CERN+DUUC+LOUC+KEYN+PISA+ROMA+)
ASTON 80 PL 94B 113 +(BONN+CERN+EPOL+GLAS+LANC+MCHS+LALO+LPNP+)
AVERY 80 PRL 44 1309 +WISS,BUTLER,GLADDING+ (ILL+FNAL+COLU)
BACINO 80 PRL 45 329 +FERGUSON+ (UCLA+SLAC+STAN+UCI+STON)
ZHOLENTZ 80 PL 96B 214 +KURDADZE,LELCHUK,MISHNEV,NIKITIN+ (NOVO)
ALSO 81 YAD.PHYS.34 1471 ZHOLENTZ + (NOVO)

ADEVA 81 PL 102B 285 +AGUILAR-BENITEZ + (LEBC-EHS COLLABORATION)
BALLAGH 81 PR D24 7 +BINGHAM+ (LBL+UCB+FNAL+HAWA+WASH+WISC)
ALSO 80 PL 89B 423 BALLAGH + (LBL+UCB+FNAL+HAWA+WASH+WISC)
FIORINO 81 LNC 30 166 FIORINO+ (PHOTON-EMUL, OMEGA-PHOTON COLLS.)
FUCHI 81 LNC 31 199 +HOSHINO,MIYANISHI+ (NAGO+AICH+TOKY+YOKO)
SCHINDLE 81 PR D24 78 SCHINDLER,ALAM,BOYARSKY + (SLAC+LBL)
BODEK 82 PL 113B 82 +BREEDON,COLEMAN+ (ROCH+CIT+CHIC+FNAL+STAN)
USHIDA 82 PRL 48 844 (AICH+FNAL+KOBE+SEOU+MCGI+NAGO+OSU+OKAY+)
AGUILAR 83 PL 122B 312 LEBC-EHS COLLAB., AGUILAR-BENITEZ+ (CERN+)
BADERTSC 83 PL 123B 471 BADERTSCHER,HAHN,HUGENTOBLER+ (BERN+MPIM)
BAILEY 83 PL 132B 237 ACCMOR COLLAB., +BARDSLEY,BECKER+ (CERN+)

ABE 84 PR D30 1 SLAC HYBRID FACILITY PHOTON COL.(BIRM+BROW)
ADAMOVIC 84 PL 140B 123 WA58 C., ADAMOVICH+ (BGNA+CERN+FIRZ+GENO+)
AGUILAR 84 PL 135B 237 LEBC-EHS C.(ANIK+BRUX+CERN+MADR+MONS+NIJM+)
AGUILAR2 84 PL 146B 266 LEBC-EHS C.(ANIK+BRUX+CERN+MADR+MONS+NIJM+)
ALTHOFF 84 PL 138B 317 TASSO C. (AACH+BONN+DESY+HAMB+LOIC+OXF+RL+)
DERRICK 84 PRL 53 1971 HRS C, DERRICK+(ANL+IND+MICH+PURD+LBL+SLAC)
SUMMERS 84 PRL 52 410 + (UCSB+CARL+COLO+FNAL+TNTO+OKLA+CNRC)
YELTON 84 PRL 52 2019 MARK II COLLABORATION (SLAC+LBL+HARV)
ALBRECHT 85 PL 150B 235 ARGUS C. (DESY+DORT+HEID+IPPC+KANS+LUND+)
ALBRECH2 85 PL 158B 525 ARGUS C. (DESY+DORT+HEID+IPPC+KANS+LUND+)
AUBERT 85 PL 155B 461 EMC COLL. (CERN+DESY+FREI+KIEL+LANC+LAPP+)
BAILEY 85 ZPHY C28 357 ABCCMR COLLAB.(ANIK+BRIS+CERN+CRAC+RL+MPIM)
BALTRUSA 85 PRL 54 1976 MARK III C., BALTRUSAITIS+ (CIT+UCSC+ILL+)
BALTRUS2 85 PRL 55 150 MARK III C., BALTRUSAITIS+ (SLAC+CIT+UCSC+)
YAMAMOTO 85 PRL 54 522 DELCO COLLAB. (CIT+SLAC+STAN)
YAMAMOT2 85 PR D32 2901 DELCO COLLAB. YAMAMOTO+ (CIT+SLAC+STAN)
BALTRUSA 86 SLAC-PUB-3861 MARK III C., BALTRUSAITIS+ (SLAC+CIT+UCSC+)
BALTRUS2 86 SLAC-PUB-3858 MARK III C., BALTRUSAITIS+ (SLAC+CIT+UCSC+)

QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA LISTINGS

NGUYEN 77 PRL 39 262 +WISS,ABRAMS,ALAM,BOYARSKI+ (LBL+SLAC)J

REVIEWS

BARBAROG 78 LBL-8537 A.BARBARO-GALTIERI (ERICE 1978) (LBL)
WOJCICKI 78 SLAC-PUB-2232 S.WOJCICKI (SLAC SUMMER INST.1978) (SLAC)
KIRKBY 79 SLAC-PUB-2419 J.KIRKBY (LEPTON CONF. BATAVIA, 1979)(SLAC)
TRILLING 81 PRPL 75 57 G.H.TRILLING (LBL+UCB)J

CHARMED STRANGE MESON

$D_s^{\pm}$ was $F^{\pm}$

$I(J^P) = 0(0^-)$

QUANTUM NUMBERS NOT MEASURED. VALUES ARE ASSIGNED HERE ASSUMING CHARMED-STRANGE GROUND STATE D/S MESON. CHEN 83 OBSERVATIONS ARE CONSISTENT WITH J=0.

NOTE ON THE D_s MESON (by W. Toki, SLAC)

The mass of the $D_s(c\overline{s})$ meson (formerly called the F meson) is not as controversial as it was two years ago. Recent results from ARGUS, HRS, and ACCMOR confirmed the decay $D_s^{\pm} \to \phi\pi^{\pm}$, first seen by CLEO. The table summarizes the published masses and branching fractions (B) to $\phi\pi^{\pm}$.

Expt.	Mass (MeV)	Mode	Production	B $(D_s^{\pm} \to \phi\pi^{\pm})$
CLEO[1]	1970 $\pm 5 \pm 5$	$\phi\pi^{\pm}$	e^+e^-	4.4 $\pm 1.1\%$
TASSO[2]	1975 $\pm 9 \pm 10$	$\phi\pi^{\pm}$	e^+e^-	13 $\pm 5\%$
ARGUS[3]	1972.8 $\pm 3.1 \pm 3.0$	$\phi\pi^{\pm}$	e^+e^-	3.2 $\pm 0.7 \pm 0.5\%$
ARGUS	1975.7 $\pm 4.7 \pm 3.0$	$\phi 3\pi^{\pm}$	e^+e^-	
HRS[4]	1963 $\pm 3 \pm 3$	$\phi\pi^{\pm}$	e^+e^-	3.3 $\pm 1\%$
ACCMOR[5]	1975 ± 4	$K^+K^-\pi^{\pm}$	Hadron + Be	

In addition, ACCMOR has published a $D_s^\pm$ lifetime based on 3 events of $(3.2^{+3.0}_{-1.3})\times10^{-13}$ sec, and HRS has submitted for publication a lifetime based on 17 events measured at 1964 MeV of $(3.5^{+2.4}_{-1.8}\pm0.9)\times10^{-13}$ sec.[6]

The TPC and ARGUS collaborations have published evidence for the D_s^*. TPC observed $D_s^{*\pm} \to \gamma K^+K^-\pi^\pm$ with a $D_s^* - D_s$ mass difference of $139.5\pm8.3\pm9.7$ MeV.[7] ARGUS observed $D_s^{*\pm} \to \gamma\phi\pi^\pm$ with a $D_s^* - D_s$ mass difference of $144\pm9\pm7$ MeV.[8] In both measurements the D_s^* was seen only when the γ was associated with a $K^+K^-\pi^\pm$ mass near 1970 MeV.

In π^-p collisions the LEBC-EHS collaboration has published upper limits for $D_s^\pm \to \phi\pi^\pm$.[9] No cross section has been given by ACCMOR, so a comparison is not possible.

The evidence for the $D_s^\pm \to \eta\pi^\pm$ decay mode disagrees with the $\phi\pi^\pm$ evidence. The original DASP measurement of $D_s^\pm \to \eta\pi^\pm$ had a mass of 2030 ± 60 MeV.[10,11] Although this mass is consistent with the 1970 MeV mass, some results are in conflict with CRYSTAL BALL measurements. DASP observed a large threshold in inclusive η production slightly above charm threshold, whereas CRYSTAL BALL measured no increase.[12] Also the DASP cross section $\sigma(e^+e^- \to D_sD_s^*) \times B(D_s^\pm \to \eta\pi^\pm)$ was 0.41 ± 0.18 nb, and the CRYSTAL BALL upper limit to this mode was 0.09–0.29 nb.[13] In photoproduction, the Omega group has published evidence for $D_s \to \eta\pi^\pm$, $\eta3\pi^\pm$, $\eta'3\pi^\pm$, and $\phi\rho^\pm$ at 2020 ± 10 MeV and also has set upper limits for $D_s \to \phi\pi^\pm$.[14–16] The upper limit on $\phi\pi^\pm$ is 35 times smaller than the combination of the other modes they have observed.

The recent evidence indicates that the D_s mass is 1970 MeV. The weighted mean of the masses in the table (using statistical errors only) is 1970 ± 3 MeV.

The branching fractions for $D_s^\pm \to \phi\pi$ have been calculated using a crude estimate of $\sigma_{D_s\bar{D}_s}$ by counting quarks, assuming an $s\bar{s}$ sea of 15% and scaling the hadron rate. (See the CLEO and TASSO publications.) The TASSO result is 2σ higher than the other results, which are in reasonable agreement with each other. The weighted mean of these estimated branching fractions is $3.6\pm0.3\%$.

The TASSO and HRS groups have published x $(2E/\sqrt{s})$ distributions. The TASSO distribution is peaked at $x = 0.5$, and the HRS distribution is softer. Neither result is statistically compelling.

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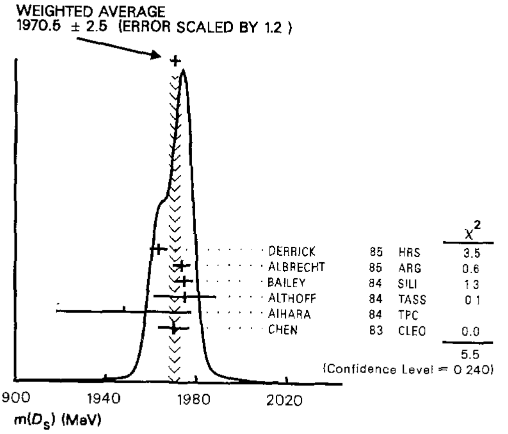
$D_s^\pm$ MASS (MeV)

```
M         4(2030.)    (60.)             BRANDELIK 77 DASP +- IN BRANDELIK 79
M         6(2030.)    (60.)             BRANDELIK 79 DASP +- E+E- ECM=4.42GEV
M         1(2017.)    (25.)             AMMAR     80 HYBR +  NU WIDEBAND
M         1(2026.)    (56.)             USHIDA    80 EMUL  - FNAL NU WIDEBAND
M         1(2089.)   (121.)             USHIDA    80 EMUL +  FNAL NU WIDEBAND
M    A  460(2020.)    (22.)             ASTON     81 OMEG +- GAMMA P
M        30(2049.)    (15.)             ASTON2    81 OMEG +- GAMMA P
M          (1970.)    (10.)             ARGUS     83 ARG     PRELIMINARY
M    C   17(2017.)    (13.)             ATKINSON  83 OMEG +- GAMMA P
M     S 104 1970.       7.              CHEN      83 CLEO +- E+E- ECM=10.5GEV
M     B  65 1948.      30.              AIHARA    84 TPC  +  E+E- 29 GEV ECM
M     S  49 1975.      14.              ALTHOFF   84 TASS +- E+E- ECM14-25GEV
M         3 1975.0      4.0             BAILEY    84 SILI  HAD+BE--> PHI PI+X
M     L 163 1973.6      4.0             ALBRECHT  85 ARG     E+E- 10 GEV ECM
M     D  30 1963.       4.              DERRICK   85 HRS  +  E+E- 29 GEV ECM
M    A   ERROR QUOTED BY ASTON 81 IS 10 MEV STAT AND <20 MEV SYST.
M    A   AVERAGE OF THREE MODES LISTED IN SECTIONS R2, R3, AND R4 BELOW.
M    C   ATKINSON 83 MASS ERROR INCLUDES SYSTEMATIC UNCERTAINTIES.
M     S  STATISTICAL AND SYSTEMATIC ERRORS COMBINED IN QUADRATURE.
M     B  STAT. AND SYST. ERRORS COMBINED IN QUADR. FROM PEAK IN K+ K- PI
M     D  STATISTICAL AND SYSTEMATIC ERRORS ADDED IN QUADRATURE.
M     L  STATISTICAL AND SYSTEMATIC ERRORS ARE 2.6 AND 3.0.
M
M    AVG    1970.5      2.5      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
                              (SEE IDEOGRAM BELOW)
```



Stable Particle Full Listings

$D_s^\pm, B^\pm, B^0$

$D_s^\pm$ MEAN LIFE (units 10^{-13} sec)

```
T          2   (2.24)   (2.78)   (1.05) USHIDA    80 EMUL    NU WIDEBAND
T          1   (1.4)                    AMMAR     80 HYBR +  NU WIDEBAND
T          4    1.9       1.3      0.7   USHIDA    83 EMUL REPL. USHIDA 80
T          3    3.2       3.0      1.3   BAILEY    84 SILI  HAD+BE--> PHI PI+X
T     B   17    3.5       2.6      2.0   JUNG      86 HRS  +  E+E- -> PHI PI+X
T     B  STAT. ERROR (+2.4 -1.8) AND SYST. ERROR (0.9) ADDED IN QUADR.
T             . . . . . . . . . . .
T    AVG        2.80      1.57     0.74   AVERAGE
```

$D_s^\pm$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$D_s^\pm \to \eta\pi^\pm$	549+ 140
P2	$D_s^\pm \to \eta$ anything	549+ 0
P3	$D_s^\pm \to \eta\pi^\pm\pi^+\pi^-$	549+ 140+ 140+ 140
P4	$D_s^\pm \to \eta'\pi^\pm\pi^+\pi^-$	958+ 140+ 140+ 140
P5	$D_s^\pm \to \phi\rho^\pm$	1020+ 769
P6	$D_s^\pm \to \phi\pi^\pm$	1020+ 140
P7	$D_s^\pm \to \mu^\pm\nu$	106+ 0
P8	$D_s^\pm \to \phi\pi^\pm\pi^+\pi^-$	1020+ 140+ 140+ 140

$D_s^\pm$ BRANCHING RATIOS

$D_s^\pm \to (\eta\pi^\pm)/(\eta$ anything) (P1)/(P2)

```
R1   A    6   (0.09)   (0.06)          BRANDELIK 79 DASP    E+E- ECM=4.42GEV
R1   A   DENOMINATOR INCONSISTENT WITH PARTRIDGE 81 (CRYSTAL BALL)
```

$D_s^\pm \to \eta\pi^\pm$ (P1)

```
R2        40 +- 9 EVENTS SEEN             ASTON      81 OMEG    GAMMA P
R2        17 +- 6 EVENTS SEEN             ATKINSON   83 OMEG    GAMMA P
```

$D_s^\pm \to \eta\pi^\pm\pi^+\pi^-$ (P3)

```
R3       360 +- 90 EVENTS SEEN            ASTON      81 OMEG    GAMMA P
```

$D_s^\pm \to \eta'\pi^\pm\pi^+\pi^-$ (P4)

```
R4        60 +- 20 EVENTS SEEN            ASTON      81 OMEG    GAMMA P
```

$D_s^\pm \to \phi\rho^\pm$ (P5)

```
R5        83 +- 26 EVENTS SEEN            ASTON2     81 OMEG    GAMMA P
```

$D_s^\pm \to (\phi\pi^\pm)$/total (P6)

```
R6          (SEEN)                        ARGUS      83 ARG     PRELIMINARY
R6   A  104   (0.044)                     CHEN       83 CLEO +- E+E- ECM=10.5GEV
R6   A   49   (0.13)   (0.05)   (0.08) ALTHOFF    84 TASS +- E+E- ECM14-25GEV
R6      100      EVENTS SEEN              ALBRECHT   85 ARG     E+E- 10 GEV ECM    |
R6   B   30   (0.033)  (0.011)            DERRICK    85 HRS  +  E+E- 29 GEV ECM    |
R6   A   BOTH VALUES BASED ON SAME CRUDE ESTIMATE OF D/S+- PRODUCTION LEVEL.
R6   A   ALTHOFF 84 ERRORS ARE STATISTICAL AND SYSTEMATIC COMBINED IN
R6   A   QUADRATURE WITH ADDITIONAL NEGATIVE ERROR FOR D/S+- FROM PRIMARY B.
R6   B   SAME ASSUMPTIONS AS (A) APPLY; STATISTICAL ERRORS ONLY.               |
```

$D_s^\pm \to (\mu^\pm\nu)$/total (P7)

```
R7   A    0   (0.03) OR LESS              AUBERT     83 SPEC    MU+ FE, 250 GEV
R7   A   AUBERT 83 OBTAIN THIS LIMIT ASSUMING THAT D/S+- PRODUCTION RATE IS
R7   A   20 PERCENT OF TOTAL CHARM PRODUCTION RATE .
```

$D_s^\pm \to \phi\pi^\pm\pi^+\pi^-$ (P8)

```
R8        62 EVENTS SEEN                  ALBRECHT   85 ARG     E+E- 10 GEV ECM    |
```

$D_s^\pm \to (\phi\pi^\pm\pi^+\pi^-)/(\phi\pi^\pm)$ (P8/P6)

```
R9    A         1.11      0.46            ALBRECHT   85 ARG     E+E- 10 GEV ECM    |
R9    A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.37 AND 0.28.                      |
```

REFERENCES FOR $D_s^\pm$

```
BRANDELI 77 PL 70B 132          BRANDELIK +       (AACH+DESY+HAMB+MPIM+TOKY)
BRANDELI 79 PL 80B 412          BRANDELIK+        (AACH+DESY+HAMB+MPIM+TOKY)
AMMAR    80 PL 94B 118          +      (KANS+FNAL+SERP+ITEP+CRAC+JINR+WASH+)
USHIDA   80 PRL 45 1053           (AICH+FNAL+KOBE+SEOU+MCGI+NAGO+OSU+OKAY+)

ASTON    81 PL 100B 91           (BONN+CERN+EPOL+GLAS+LANC+MCHS+LALO+LPNP+)
ASTON2   81 NP B189 205          (BONN+CERN+EPOL+GLAS+LANC+MCHS+LALO+LPNP+)
PARTRIDG 81 PRL 47 760          PARTRIDGE,PECK+    (CIT+HARV+PRIN+STAN+SLAC)

ARGUS    83 CERN COUR. 23 423 ARGUS COLLABORATION (PRELIMINARY)
ATKINSON 83 ZPHY C17 1          +    (BONN+CERN+GLAS+LANC+MCHS+LPNP+RL+SHEF)
AUBERT   83 NP B213 31          EUROPEAN MUON COLLAB.      (CERN+DESY+FREI+)
CHEN     83 PRL 51 634          +  (SYRA+VAND+HARV+OSU+CORN+ITHA+ROCH+RUTG)
USHIDA   83 PRL 51 2362           (AICH+FNAL+KOBE+SEOU+MCGI+NAGO+OSU+OKAY+)
AIHARA   84 PRL 53 2465         TPC COLL. (LBL+UCLA+UCR+JHU+YALE+TOKY+MASA)
ALTHOFF  84 PL 136B 130         TASSO C. (AACH+BONN+DESY+HAMB+LOIC+OXF+RL+)
BAILEY   84 PL 139B 320         ACCMOR C.      (ANIK+BRIS+CERN+CRAC+MPIM+RL)
ALBRECHT 85 PL 153B 343         ARGUS C.   (DESY+DORT+HEID+IPPC+KANS+LUND+)
DERRICK  85 PRL 54 2568         HRS COLL.      (ANL+IND+MICH+PURD+LBL+SLAC)
JUNG     86 PRL (TO BE PUBL.) HRS C.,+ABACHI       (IND+ANL+MICH+PURD+LBL)

                                REVIEWS

TRILLING 81 PRPL 75 57          G.H.TRILLING                       (LBL+UCB)
```

BOTTOM MESONS

$B^\pm$

$I(J^P) = \frac{1}{2}(0^-)$

QUANTUM NUMBERS NOT MEASURED. VALUES SHOWN ARE QUARK MODEL PREDICTIONS. SEE ALSO THE LISTING FOR THE B (FOLLOWING THE ENTRY FOR THE B0) FOR MEASUREMENTS WHICH DO NOT IDENTIFY THE CHARGE STATE.

$B^\pm$ MASS (MeV)

```
M     A  6 (5270.8)    (3.0)             BEHRENDS  83 CLEO +- D*- PI+ PI+ + CC
M     G     5271.2      3.0              GILES     84 CLEO    E+E- UPSILON 4S   |
M     A  STATISTICAL (2.3 MEV) AND SYSTEMATICAL (2.0 MEV) ERRORS COMBINED.
M     G  STATISTICAL AND SYSTEMATIC ERRORS ARE 2.2 AND 2.0.                     |
```

$B^\pm$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$B^+ \to \bar{D}^0\pi^+$	1865+ 140
P2	$B^+ \to D^*(2010)^-\pi^+\pi^+$	2007+ 140+ 140
P3	$B^+ \to J/\psi(3097)\ K^+$	3097+ 494
P4	$B^+ \to \rho^0\pi^+$	769+ 140

B- MODES ARE CHARGE CONJUGATES OF THE ABOVE MODES.

$B^\pm$ BRANCHING RATIOS

$B^+ \to (\bar{D}^0\pi^+)$/total (P1)

```
R1  CB  2    (0.023)  (0.023)          BEHRENDS  83 CLEO    E+ E-, UPSIL(4S)  |
R1 G B        0.011    0.006           GILES     84 CLEO    E+E- UPSILON 4S   |
R1 G    STATISTICAL AND SYSTEMATIC ERRORS ARE 0.004 AND 0.003.                |
R1   B  CORRECTED BY US USING OUR NEW VALUE (0.054) FOR D0--> K- PI+.         |
R1   B  UNCORRECTED VALUES WERE A FACTOR 1.8 LARGER.                          |
R1   B  INCLUDES CONTAMINATION FROM (D*0 PI+ PI-) AND (D*- PI+).              |
R1  C   ADDED STATISTICAL AND SYSTEMATIC ERRORS IN QUADRATURE.                |
```

$B^+ \to (D^*(2010)^-\pi^+\pi^+)$/total (P2)

```
R2   G  6     0.027    0.017           BEHRENDS  83 CLEO    E+ E-, UPSIL(4S)  |
R2   G  ADDED STATISTICAL AND SYSTEMATIC ERRORS IN QUADRATURE.                |
R2   G  CORRECTED BY US USING OUR NEW VALUE (0.054) FOR D0--> K- PI+.         |
R2   G  UNCORRECTED VALUES WERE A FACTOR 1.8 LARGER.                          |
```

$B^+ \to (J/\psi(3097)\ K^+)$/total (P3)

```
R3      1     0.0026 OR LESS CL=.90   GILES      84 CLEO +  E+E- UPSILON 4S   |
```

$B^+ \to (\rho^0\pi^+)$/total (P4)

```
R4      0     0.0006 OR LESS CL=.90   GILES      84 CLEO +  E+E- UPSILON 4S   |
```

REFERENCES FOR $B^\pm$

```
BEHRENDS 83 PRL 50 881        +  (ROCH+RUTG+SYRA+VAND+CORN+ITHA+HARV+OSU)
GILES    84 PR D30 2279       CLEO C.(HARV+OSU+ROCH+RUTG+SYRA+VAND+CORN+)
```

B^0

$I(J^P) = \frac{1}{2}(0^-)$

QUANTUM NUMBERS NOT MEASURED. VALUES SHOWN ARE QUARK MODEL PREDICTIONS. SEE ALSO THE LISTING FOR THE B (FOLLOWING THIS ENTRY) FOR MEASUREMENTS WHICH DO NOT IDENTIFY THE CHARGE STATE.

B^0 MASS (MeV)

```
M     A  5 (5274.2)    (2.8)             BEHRENDS  83 CLEO 0  D*- PI+ + CC
M     G     5275.2      2.8              GILES     84 CLEO    E+E- UPSILON 4S   |
M     A  STATISTICAL (1.9 MEV) AND SYSTEMATICAL (2.0 MEV) ERRORS COMBINED.
M     G  STATISTICAL AND SYSTEMATIC ERRORS ARE 1.9 AND 2.0.                     |
```

$B^0 - B^+$ MASS DIFFERENCE (MeV)

```
DM    A       (3.4)    (3.6)             BEHRENDS  83 CLEO    E+E-, UPSIL(4S)
DM    G        4.0      3.4              GILES     84 CLEO    E+E- UPSILON 4S   |
DM    A  STATISTICAL (3.0) AND SYSTEMATICAL (2.0) ERRORS COMBINED.
DM    G  STATISTICAL AND SYSTEMATIC ERRORS ARE 2.7 AND 2.0.                     |
```

B^0 PARTIAL DECAY MODES

		DECAY MASSES
P1	$B^0 \rightarrow \overline{D}^0\pi^+\pi^-$	1865+ 140+ 140
P2	$B^0 \rightarrow D^*(2010)^-\pi^+$	2007+ 140
P3	$B^0 \rightarrow D^*(2010)^-\rho^+$	2007+ 769
P4	$B^0 \rightarrow J/\psi(3097)\ K^+\pi^-$	3097+ 494+ 140
P5	$B^0 \rightarrow \pi^+\pi^-$	140+ 140
P6	$B^0 \rightarrow e^+e^-$	.511+.511
P7	$B^0 \rightarrow \mu^+\mu^-$	106+ 106
P8	$B^0 \rightarrow (e^+\mu^-) + (e^-\mu^+)$	.511+ 106
P9	$B^0 \rightarrow \overline{B}^0$ via mixing	

BOBAR MODES ARE CHARGE CONJUGATES OF THE ABOVE MODES.

B^0 BRANCHING RATIOS

$B^0 \rightarrow (\overline{D}^0\pi^+\pi^-)$/total (P1)

```
R1   G  5       0.07     0.05            BEHRENDS  83 CLEO    E+ E-, UPSIL(4S)
R1   G  GILES 84 ADDED STATISTICAL AND SYSTEMATIC ERRORS IN QUADRATURE.
R1   G  CORRECTED BY US USING OUR NEW VALUE (0.054) FOR D0--> K- PI+.
R1   G  UNCORRECTED VALUES WERE A FACTOR 1.8 LARGER.
R1   G  INCLUDES CONTAMINATION FROM (D*0 PI+ PI-).
```

$B^0 \rightarrow (D^*(2010)^-\pi^+)$/total (P2)

```
R2  B   5     (0.014)  (0.011)           BEHRENDS  83 CLEO  0 E+ E-, UPSIL(4S)
R2   G 41     0.017    0.007             GILES     84 CLEO    E+E- UPSILON 4S
R2  B   ADDED STATISTICAL AND SYSTEMATIC ERRORS IN QUADRATURE.
R2  B   CORRECTED BY US USING OUR NEW VALUE (0.054) FOR D0--> K- PI+.
R2  B   UNCORRECTED VALUES WERE A FACTOR 1.8 LARGER.
R2  B   ASSUMES B(D*+ -> D PI) = 0.6   -
R2   G  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.005 AND 0.005.  ASSUMES
R2   G  B(D*+ ->D PI)=0.6.  ALSO ASSUMES CHARGED/NEUTRAL B RATIO FROM
R2   G  UPS(4S) IS 6 TO 4.  QUOTED NUMBER IS CORRECTION DESCRIBED IN
R2   G  CHEN 85.
```

$\overline{B}^0 \rightarrow (D^*(2010)^+\rho^-)$/total (P3)

```
R3   C 19     0.081    0.066    0.038 CHEN      85 CLEO  0 E+ E-, UPSIL(4S)
R3   C  USES B(D* ->D0 PI+)=0.6 AND B(UPS(4S)->B0 B0-BAR)=0.4.  STATISTICAL
R3   C  AND SYSTEMATIC ERRORS COMBINED IN QUADRATURE.
```

$B^0 \rightarrow (J/\psi(3097)\ K^+\pi^-)$/total (P4)

```
R4      2     0.0063 OR LESS CL=.90   GILES     84 CLEO    E+E- UPSILON 4S
```

$B^0 \rightarrow (\pi^+\pi^-)$/total (P5)

```
R5      4     0.0005 OR LESS CL=.90   GILES     84 CLEO  0 E+E- UPSILON 4S
```

$B^0 \rightarrow (e^+e^-)$/total (P6)

```
R6      TEST FOR DELTA(B) = 1 WEAK NEUTRAL CURRENT.
R6            0.0003 OR LESS CL=.90   GILES     84 CLEO  0 E+E- UPSILON 4S
```

$B^0 \rightarrow (\mu^+\mu^-)$/total (P7)

```
R7      TEST FOR DELTA(B) = 1 WEAK NEUTRAL CURRENT.
R7            0.0002 OR LESS CL=.90   GILES     84 CLEO    E+E- UPSILON 4S
```

$B^0 \rightarrow ((e^+\mu^-) + (e^-\mu^+))$ /total (P8)

```
R8      TEST OF LEPTON FAMILY NUMBER CONSERVATION.
R8            0.0003 OR LESS CL=.90   GILES     84 CLEO    E+E- UPSILON 4S
```

$B^0 \rightarrow (\overline{B}^0$ via mixing)/total (P9)

```
R9   A       (0.30) OR LESS  CL=.90   AVERY     84 CLEO    E+E- UPSILON 4S
R9   B        0.12  OR LESS  CL=.90   SCHAAD    85 SMK2  0 E+E- ECM=29 GEV
R9   A  SAME SIGN DILEPTON EVENTS.  LIMIT ASSUMES SEMILEPTONIC BR
R9   A  FOR B+ AND B0 EQUAL.  IF B0/B+- RATIO <0.58, NO LIMIT EXISTS.
R9   B  LIMIT IS AVERAGE PROB. FOR HADRON CONTAINING B QUARK
R9   B  TO PRODUCE A POSITIVE LEPTON.  CM ENERGY HIGH ENOUGH TO ALLOW
R9   B  PRODUCTION OF B-STRANGE HADRONS.
```

REFERENCES FOR B^0

```
BEHRENDS 83 PRL 50 881        +  (ROCH+RUTG+SYRA+VAND+CORN+ITHA+HARV+OSU)
AVERY    84 PRL 53 1309       CLEO C.(CORN+ITHA+HARV+OSU+ROCH+RUTG+SYRA+)
GILES    84 PR D30 2279       CLEO C.(HARV+OSU+ROCH+RUTG+SYRA+VAND+CORN+)
CHEN     85 PR D31 2386       CLEO C(SYRA+VAND+ALBA+CORN+HARV+ITHA+ROCH+)
SCHAAD   85 PL 160B 188       MARK II C., NELSON,ABRAMS+  (SLAC+LBL+HARV)
```

B

$$I(J^P) = \tfrac{1}{2}(0^-)$$

QUANTUM NUMBERS NOT MEASURED. VALUES SHOWN ARE QUARK MODEL PREDICTIONS. THIS ENTRY LISTS MEASUREMENTS OF B MESON PARAMETERS FOR WHICH THE CHARGE STATES ARE NOT SEPARATED. MEASUREMENTS IN WHICH THE CHARGE STATE IS CLEARLY IDENTIFIED ARE LISTED IN THE PRECEDING B+- AND B0 ENTRIES.

B MASS (MeV)

```
M    A        5180 TO 5290            ANDREWS   80 CLEO UPSIL(4S) THRESHOLD
M    A        5289  OR LESS           FINOCCHIA 80 CUSB UPSIL(4S) THRESHOLD
M    AB       5263 TO 5278            SCHAMBERG 82 CUSB UPSIL(4S) THRESHOLD
M    G     5273.0       2.4           GILES     84 CLEO    E+E- UPSILON 4S
M    A  REDETERMINATION OF THE CESR ENERGY SCALE CHANGED THE ANDREWS 80,
M    A  FINOCCHIARO 80, AND SCHAMBERGER 82 LIMITS FROM THEIR PUBLISHED
M    A  VALUES TO THOSE GIVEN ABOVE.
M    AB SCHAMBERGER 82 DEDUCED ABOVE LIMITS FROM NON-OBSERVATION OF 50 MEV
M    AB GAMMAS FROM B* --> B GAMMA AND UPSIL(4S) --> B B*.
M    G  STATISTICAL AND SYSTEMATIC ERRORS ARE 1.3 AND 2.0.
```

B MEAN LIFE (units 10^{-13} sec)

```
T              14.     OR LESS  CL=.95   BARTEL    82 JADE E+E-,AVG ECM 34 GEV
T    A         18.       7.2             FERNAND2  83 MAC  E+E- AT ECM=29 GEV
T    B         12.0      5.4       4.7   LOCKYER   83 SMK2 E+E- AT ECM=29 GEV
T    C         18.3      5.3       5.0   ALTHOFF2  84 TASS 0  E+E- 30-46.8 GEV
T    D  46     11.6      4.4       4.1   KLEM      84 DLCO E+E- AT ECM=29 GEV
T    E   2  POSS.DIFF.BETW. B+ AND B0 ALBANESE  85 HYBR    350GEV PI-P EMUL
T    A  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 6 AND 4.
T    B  THE STATISTICAL ERRORS ARE +4.5 AND -3.6, THE SYSTEMATIC ERROR IS
T    B  3.0.  THE LIFETIME IS AN AVERAGE OVER BOTTOM PARTICLES PRODUCED.
T    C  STATISTICAL AND SYSTEMATIC ERRORS ARE +3.8 -3.7 AND +3.7 -3.4
T    D  STATISTICAL ERRORS +3.7 -3.4  SYSTEMATIC ERRORS +-2.3.
T    E THE MEAN FLIGHT TIME FOR THE ONE B0 WAS 5E-13 SEC WHILE THE ONE B-
T    E WAS 0.8E-13 SEC.
T            . . . . . . . . . .
T   AVG        14.2      2.7      AVERAGE
```

B PARTIAL DECAY MODES

P1	$B \rightarrow e\nu$ hadrons
P2	$B \rightarrow \mu\nu$ hadrons
P3	$B \rightarrow e^+e^-$ anything
P4	$B \rightarrow \mu^+\mu^-$ anything
P5	$B \rightarrow K$ anything
P6	$B \rightarrow J/\psi(3097)$ anything
P7	$B \rightarrow D^0$ anything
P8	$B \rightarrow p$ anything
P9	$B \rightarrow \Lambda$ anything
P10	$B \rightarrow e\nu$ hadrons (noncharm)
P11	$B \rightarrow D^*(2010)^+$ anything
P12	$B \rightarrow D^0\pi^+,\ D^-\pi^+,\ D^*(2010)^0\pi^+$, or $D^*(2010)^-\pi^+$

B BRANCHING RATIOS

$B \rightarrow (e\nu$ hadrons)/total (P1)

```
R1   D        0.132    0.016            KLOPFENST 83 CUSB DIRECT E AT UPS(4S)
R1   E       (0.116)  (0.027)           NELSON    83 SMK2 E+E-,ECM=29 GEV
R1   G        0.111    0.052            ALTHOFF3  84 TASS    E+E- 34.6GEV ECM
R1   F        0.120    0.009            CHEN      84 CLEO    DIR E    UPS(4S)
R1           (0.146)  (0.028)           KOOP      84 DLCO    E+E- ECM=29 GEV
R1  H        (0.110)  (0.021)           AIHARA    85 TPC     E+E- ECM=29 GEV
R1   I       (0.149)  (0.022)  (0.019)PAL       86 DLCO    E+E- 29 GEV ECM
R1   D  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.008 AND 0.014.
R1   E  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.021 AND 0.017.
R1   F  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.007 AND 0.005
R1   G  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.034 AND 0.040.
R1  H   THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.018 AND 0.010.
R1   I  THIS MEASUREMENT SUPERSEDES KOOP 84.
R1
R1      ONLY THE EXPERIMENTS AT THE UPSILON(4S) ARE USED IN THE AVERAGE.
R1
R1           . . . . . . . . . .
R1  AVG       0.1226   0.0078  AVERAGE
```

$B \rightarrow (\mu\nu$ hadrons)/total (P2)

```
R2   A       (0.105)  (0.020)           ADEVA2    83 MRKJ E+E- ECM=33-38.5GEV
R2           (0.155)  (0.054) (0.029)   FERNAND1  83 MAC  E+E- AT ECM=29 GEV
R2   D       (0.117)  (0.030)           ALTHOFF   84 TASS E+E- ECM=34.5 GEV
R2   C        0.108    0.012            CHEN      84 CLEO    DIR MU   UPS(4S)
R2   E        0.112    0.013            LEVMAN    84 CUSB    DIR MU   UPS(4S)
R2   F       (0.114)  (0.031)           BARTEL    85 JADE E+E- ECM=34.6 GEV
R2   A  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.015 AND 0.013.
R2   D  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.028 AND 0.010.
R2   C  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.006 AND 0.01.
R2   E  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.009 AND 0.01.
R2   F  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.018 AND 0.025.
R2
R2      THE AVERAGE OF THE FOUR HIGH-ENERGY RESULTS IS 0.113+-0.014.
R2      THESE EXPERIMENTS PRODUCE OTHER BOTTOM PARTICLES IN ADDITION TO
R2      THE B MESON.
R2           . . . . . . . . . .
R2  AVG       0.1098   0.0088  AVERAGE
```

$B \rightarrow (e^+e^-$ anything)/total (P3)

```
R3      TEST FOR DELTA(B) = 1 WEAK NEUTRAL CURRENT.
R3            0.05  OR LESS  CL=.90   BEBEK     81 CLEO E+ E- AT UPSIL(4S)
```

$B \rightarrow (\mu^+\mu^-$ anything)/total (P4)

```
R4      TEST FOR DELTA(B) = 1 WEAK NEUTRAL CURRENT.
R4           (0.017)OR LESS  CL=.90   CHADWICK  81 CLEO E+ E- AT UPSIL(4S)
R4            0.007 OR LESS  CL=.95   ADEVA1    83 MRKJ E+E- 30<WCM<38 GEV
R4            0.007 OR LESS  CL=.95   BARTEL    83 JADE E+E- 33<WCM<36.7GEV
R4           (0.02)  OR LESS  CL=.95  ALTHOFF   84 TASS E+E-, ECM=34.5 GEV
```

$B \rightarrow$ (dilepton anything)/total (P3+P4)

```
R5      TEST FOR DELTA(B) = 1 WEAK NEUTRAL CURRENT.
R5           (0.008)OR LESS  CL=.90   MATTEUZZI 83 SMK2 E+ E- AT ECM=29 GEV
R5   A        0.0062 OR LESS CL=.90   AVERY     84 CLEO    E+E- UPSILON 4S
R5   A  DETERMINE RATIO OF B+ TO B0 SEMILEPTONIC DECAYS TO BE IN THE RANGE
R5   A  0.25 TO 2.9
```

$B \rightarrow (K$ anything)/total (P5)

```
R6   C       SEEN                     BRODY     82 CLEO KAONS AT UPSIL(4S)
R6   D       SEEN                     GIANNINI  82 CUSB KAONS AT UPSIL(4S)
R6   C  ASSUMING UPSILON(4S) --> B BBAR, A TOTAL OF 3.38+-0.34+-0.68 KAONS
R6   C  PER UPSILON(4S) DECAY IS FOUND (THE SECOND ERROR IS SYSTEMATIC). IN
R6   C  THE CONTEXT OF THE STANDARD B-DECAY MODEL, THIS LEADS TO A VALUE
R6   C  FOR (B-QUARK --> C-QUARK)/(B-QUARK --> ALL) OF 1.09+-0.33+-0.13.
R6   D  GIANNINI 82 AT CESR-CUSB OBSERVED 1.58+-.35 K0 PER HADRONIC EVENT
R6   D  MUCH HIGHER THAN 0.82+-0.10 BELOW THRESHOLD. CONSISTENT WITH
R6   D  PREDOMINANT B-->C X DECAY.
```

$B \to (J/\psi(3097)\ \text{anything})/\text{total}$ (P6)

```
R7          (0.049)OR LESS  CL=.90   MATTEUZZI 83 SMK2 E+ E- AT ECM=29 GEV
R7   A   7    0.014    0.006    0.005 ALBRECHT  85 ARG     E+E- NEAR UPS(4S)
R7   C  46    0.011    0.003          HAAS      85 CLEO    E+E- NEAR UPS(4S)
R7   A  STATISTICAL AND SYSTEMATIC ERRORS WERE ADDED IN QUADRATURE.
R7   A  ALBRECHT 85 ALSO REPORT A CL=.90 LIMIT OF 0.007 FOR B--> J/PSI + X
R7   A  WHERE M(X)<1 GEV.
R7   C  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.0021 AND 0.0023.
R7   C  DIMUON AND DIELECTRON EVENTS USED.
R7           . . . . . . . . . .
R7  AVG       0.0117   0.0026  AVERAGE
```

$B \to (D^0\ \text{anything})/\text{total}$ (P7)

```
R8   A        0.8      0.28           GREEN     83 CLEO E+ E- AT UPSIL(4S)
R8   A  OBSERVED 0.8+-0.2(STAT.)+-0.2(SYST.) D0 PER B DECAY.
```

$B \to (p\ \text{anything})/\text{total}$ (P8)

```
R9   A        0.036 OR MORE           ALAM      83 CLEO PROTONS AT UPSI(4S)
R9   A  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.006 AND 0.009. VALUES
R9   A  ARE FOR (BR(B-->P X)+BR(B-->PBAR X)/2. DATA ARE CONSISTENT WITH
R9   A  EQUAL YIELDS OF BARYONS AND ANTIBARYONS. USING ASSUMED YIELDS
R9   A  BELOW CUT, BR(B-->P+X)=0.03 NOT INCLUDING PROTONS FROM LAM.DECAYS.
```

$B \to (\Lambda\ \text{anything})/\text{total}$ (P9)

```
R10  A        0.022 OR MORE           ALAM      83 CLEO LAMBDAS AT UPSI(4S)
R10  A  THE STATISTICAL AND SYSTEMATIC ERRORS ARE 0.007 AND 0.004. VALUES
R10  A  ARE FOR (BR(LAMBDA X)+BR(LAMBDABAR X)/2. DATA ARE CONSISTENT WITH
R10  A  EQUAL YIELDS OF BARYONS AND ANTIBARYONS. USING ASSUMED YIELDS
R10  A  BELOW CUT, BR(B-->LAMBDA X)=0.03.
```

$B \to e\,\nu\ \text{hadrons (noncharm)}/(e\,\nu\ \text{hadrons})$ (P10/P1)

```
R11         (0.055)OR LESS  CL=.90   KLOPFENST 83 CUSB DIRECT E AT UPS(4S)
R11          0.04  OR LESS  CL=.90   CHEN      84 CLEO    E+E-DIR E  UPS4S
```

$B \to (D^*(2010)^+\ \text{anything})/\text{total}$ (P11)

```
R12  A 510    0.23     0.09           CSORNA    85 CLEO    E+E- UPSILON(4S)
R12  A  ASSUMES UPS(4S)->B BBAR, AND V-A MOMENTUM SPECTRUM TO
R12  A  EXTRAPOLATE BELOW 1 GEV/C D* MOMENTUM.  STAT AND SYST. ERRORS
R12  A  COMBINED IN QUADR.
```

$B \to (D^0\pi^+,\ D^-\pi^+,\ D^*(2010)^0\pi^+,\ D^*(2010)^-\pi^+)/\text{total}$ (P12)

```
R13  G        0.020    0.008          GILES     84 CLEO    E+E- UPSILON 4S
R13  G  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.006 AND 0.005.
R13  G  NO DEPENDENCE ON D; USED FAST-PI MOMENTUM.
```

REFERENCES FOR BOTTOM MESON B

```
ANDREWS  80 PRL 45 219       +       (CORN+HARV+ITHA+SYRA+ROCH+RUTG+VAND)
FINOCCHI 80 PRL 45 222       FINOCCHIARO,GIANNINI,+       (STON+COLU+LSU)
BEBEK    81 PRL 46 84        +       (HARV+ITHA+SYRA+ROCH+RUTG+VAND+CORN)
CHADWICK 81 PRL 46 88        +GANCI+(ROCH+RUTG+SYRA+VAND+CORN+HARV+ITHA)

BARTEL   82 PL 114B 71       JADE C.(DESY+HAMB+HEID+LANC+MCHS+RHEL+TOKY)
BRODY    82 PRL 48 1070      +CHEN,+(SYRA+VAND+CORN+ITHA+HARV+ROCH+RUTG)
GIANNINI 82 NP B206 1        +FINOCCHIARO,FRANZINI+ (STON+COLU+LSU+MPIM)
SCHAMBER 82 PR D26 720       SCHAMBERGER+                (STON+COLU+LSU+MPIM)

ADEVA1   83 PRL 50 799       MARKJ C. (AACH+DESY+MIT+MADR+AIKO+BHEP+CIT)
ADEVA2   83 PRL 51 443       MARKJ C. (AACH+DESY+MIT+MADR+AIKO+BHEP+CIT)
ALAM     83 PRL 51 1143      + (VAND+HARV+OHIO+CORN+ITHA+ROCH+RUTG+SYRA)
BARTEL   83 PL 132B 241      JADE C.(DESY+HAMB+HEID+LANC+MCHS+RHEL+TOKY)
FERNAND1 83 PRL 50 2054      +MAC.C.(COLO+FRAS+HOUS+NEAS+SLAC+UTAH+WISC)
FERNAND2 83 PRL 51 1022      +MAC.C.(COLO+FRAS+HOUS+NEAS+SLAC+UTAH+WISC)
GREEN    83 PRL 51 347       + (RUTG+SYRA+VAND+HARV+OHIO+CORN+ITHA+ROCH)
KLOPFENS 83 PL 130B 444      KLOPFENSTEIN, CUSB C. (STON+COLU+CORN+LSU+)
LOCKYER  83 PRL 51 1316      +JAROS,NELSON,ABRAMS,+  (SLAC+LBL+UCB+HARV)
MATTEUZZ 83 PL 129B 141      MATTEUZZI,ABRAMS,AMIDEI+(SLAC+LBL+UCB+HARV)
NELSON   83 PRL 50 1542      +BLONDEL,TRILLING+      (LBL+UCB+SLAC+HARV)

ALTHOFF  84 ZPHY C22 219     TASSO C. (AACH+BONN+DESY+HAMB+LOIC+OXF+RL+)
ALTHOFF2 84 PL 149B 524      TASSO C.   (AACH+BONN+DESY+BRIS+HAMB+LOIC+)
ALTHOFF3 84 PL 146B 443      TASSO C.    (AACH+BONN+DESY+HAMB+LOIC+OXF+)
AVERY    84 PRL 53 1309      CLEO C.(CORN+ITHA+HARV+OSU+ROCH+RUTG+SYRA+)
CHEN     84 PRL 52 1084      CLEO C (SYRA+VAND+CORN+ITHA+HARV+OSU+ROCH+)
GILES    84 PR D30 2279      CLEO C (HARV+OSU+ROCH+RUTG+SYRA+VAND+CORN+)
KLEM     84 PRL 53 1873      DELCO COLLABORATION           (CIT+SLAC+STAN)
KOOP     84 PRL 52 970       DELCO COLLABORATION           (CIT+SLAC+STAN)
LEVMAN   84 PL 141B 271      CUSB C.             (LSU+MPIM+STON+COLU+CORN)
AIHARA   85 ZPHY C27 39      TPC COLL. (LBL+UCLA+UCR+JHU+YALE+TOKY+MASA)
ALBANESE 85 PL 158B 186      WA75 EXPER.(BARI+CERN+DUUC+LOUC+NAGO+INFN+)
ALBRECHT 85 PL 162B 395      ARGUS C.   (DESY+DORT+HEID+IPPC+KANS+LUND+)
BARTEL   85 PL 163B 277      JADE C. (DESY+HAMB+HEID+LANC+MCHS+RL+TOKY+)
CSORNA   85 PRL 54 1894      CLEO C.    (SYRA+VAND+ALBA+CORN+ITHA+ROCH+)
HAAS     85 PRL 55 1248      CLEO C.    (OHIO+ROCH+RUTG+SYRA+VAND+ALBA+)
PAL      86  CALT-68-1283    DELCO COLLABORATION           (CIT+SLAC+STAN)
```

NUCLEONS

$\boxed{p}$ $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

p MASS (MeV)

```
M          (938.256)  (0.005)          COHEN      65 RVUE
M          (938.2592) (0.0052)         TAYLOR     69 RVUE    USING NEW E/H
M           938.2796   0.0027          COHEN      73 RVUE
```

$\bar{p}$ MASS (MeV)

```
M1          938.3      0.5             BAMBERGER 70 CNTR
M1          938.179    0.058           HU        75 CNTR    EXOTIC ATOMS
M1          938.229    0.049           ROBERSON  77 CNTR
M1          938.30     0.13            ROBERTS   78 CNTR
M1          . . . . . . . . .
M1  AVG     938.216    0.036   AVERAGE
```

NOTE ON PROTON MEAN LIFE LIMITS

(by M. Goldhaber, Brookhaven National Laboratory, and F. Reines, University of California, Irvine)

Current ideas on the unification of the weak, electromagnetic, and strong forces suggest that baryon number might not be strictly conserved, so that the proton could decay. In the Particle Properties Summary Tables there are nearly thirty particles listed with a mass smaller than that of the proton (if we count both particles and antiparticles and different members of multiplets separately). Ten of these particles are fermions and the remainder bosons. There are then a great many possible two-body decay modes of the proton and an even larger number of three-body, etc., decay modes which satisfy charge, energy, momentum, and angular momentum conservation. Each decay mode has to contain at least one fermion to satisfy angular momentum conservation.

The "decay signature" distributions as well as the backgrounds depend on detector characteristics (the material from which the detector is made, the method of detection, timing information, time resolution, etc.). The background, due chiefly to atmospheric neutrinos, depends also on the geomagnetic latitude and on the phase of the solar cycle with which the magnetic field of the sun is associated. The depth-dependent cosmic ray background is due to cosmic ray muons and their progeny. For each possible proton decay signature there is a finite probability of a background event with a similar signature, where the probability depends on the detector characteristics.

The simplest grand unified theory, minimal SU(5), predicts $e^+\pi^0$ to be the predominant proton decay mode. The IMB lower limit on the partial mean life for this mode, 2×10^{32} years, is at least a factor of 10 higher than predicted by minimal SU(5) theory.

See also the reviews by Reines and Schultz, Surveys in High Energy Physics **1**, 89 (1980); Goldhaber, Langacker, and Slansky, Science **210**, 851 (1980); Goldhaber and Sulak, Comments Nucl. Part. Phys. **10**, 215 (1981); D.H. Perkins, Ann. Rev. Nucl. Part. Sci. **34**, 1 (1984); and J.M. LoSecco, Comments Nucl. Part. Phys. **15**, 23 (1985).

See also the neutron-antineutron oscillations section NAN in the neutron Full Listings below for another test of baryon conservation.

p MEAN LIFE (years)

```
T        TEST OF BARYON CONSERVATION
T        SEE PROTON PARTIAL MEAN LIVES SECTION FOR LIMITS WHICH DEPEND ON
T        DECAY MODES.
T        P=PROTON  N=BOUND NEUTRON
T               LIMIT      CONFIDENCE   REFERENCE    DET    PARTICLE
T               (YEARS)     LEVEL
T   H          >1.6E25                  EVANS     77 TE130   P,N
T   H          >3. E23                  DIX       70 CNTR    P
T   H          >3. E23                  FLEROV    58 TH232   P,N
T   H    CONVERTED TO MEAN LIFE BY DIVIDING HALF-LIFE BY LN(2)=.693 .
```

$\overline{p}$ MEAN LIFE (units hours)

```
TA         (3.3E-8) OR MORE  CL=.95   GANGULI   78 HBC      PBAR-->ANYTHING
TA    B   (32.)     OR MORE           BREGMAN   78 CNTR     PBAR-->ANYTHING
TA    E  1700.)     OR MORE  CL=.90   BELL      79 CNTR     PBAR-->E- PIO
TA    G     1.E11   OR MORE           GOLDEN    79 SPEC     PBAR-->ANYTHING
TA    B   BREGMAN 78 STORED ANTIPROTONS IN ICE STORAGE RING AT CERN 85 HOURS.
TA    E   BELL 79 STORED ANTIPROTONS IN ICE STORAGE RING FOR 10 DAYS.
TA    G   GOLDEN 79 VALUE INFERRED FROM PBAR/P RATIO IN COSMIC RAYS.
```

p PARTIAL DECAY MODES

		DECAY MASSES
P1	$N \to e^+$ anything	.511
P2	$N \to \mu^+$ anything	106
P3	$p \to e^+\gamma$	.511+ 0
P4	$p \to \mu^+\gamma$	106+ 0
P5	$p \to \nu\gamma$	0+ 0
P6	$N \to e^+\pi$	.511+ 135
P7	$N \to \mu^+\pi$	106+ 135
P8	$N \to e^+K$	.511+ 498
P9	$N \to \mu^+K$	106+ 498
P10	$N \to \nu\pi$	0+ 140
P11	$N \to \nu K$	0+ 494
P12	$p \to e^+\omega$	.511+ 783
P13	$p \to \mu^+\omega$	106+ 783
P14	$N \to e^+\rho$	.511+ 769
P15	$N \to \mu^+\rho$	106+ 769
P16	$p \to e^+e^+e^-$	.511+.511+.511
P17	$p \to \mu^+\mu^+\mu^-$	106+ 106+ 106
P18	$N \to \nu K(892)$	0+ 892
P19	$N \to e^+\pi^0$ anything	.511+ 135
P20	$N \to \nu$ anything	0
P21	$n \to 3\nu$	0+ 0+ 0
P22	$p \to e^+\eta$	.511+ 549
P23	$p \to \mu^+\eta$	106+ 549
P24	$n \to \nu\eta$	0+ 549
P25	$N \to \nu\rho$	0+ 769
P26	$n \to \nu\omega$	0+ 783
P27	$n \to e^+e^-\nu$	.511+.511+ 0
P28	$n \to \mu^+\mu^-\nu$	106+ 106+ 0
P29	$n \to e^-\pi^+$	.511+ 135
P30	$n \to \mu^-\pi^+$	106+ 135
P31	$n \to e^-\rho^+$	.511+ 769
P32	$n \to \mu^-\rho^+$	106+ 769

p PARTIAL MEAN LIVES (10^{30} years)

```
    MEAN LIFE DIVIDED BY BRANCHING FRACTION.

    DECAYING PARTICLE --  P=PROTON  OR  N=BOUND NEUTRON.  SEE COMMENTS
      FIELD.
    FOR POSSIBLE EVENTS --  SAME EVENT MAY APPEAR UNDER MORE THAN ONE
      PARTIAL DECAY MODE.
    FOR POSSIBLE EVENTS --  PARENTHETICAL NUMBERS ARE BACKGROUND
      ESTIMATES WHICH MAY BE ACCURATE TO A FACTOR OF 2.
    QUOTED LIMITS ARE WITHOUT BACKGROUND SUBTRACTION.

    EVENTS      LIMIT    CONFIDENCE   REFERENCE    DET    PARTICLE
     (BKGD EST)             LEVEL
```

$N \to e^+$ anything (10^{30} years) (P1)

```
T01 D           >0.6         CL=.90   LEARNED   79 CNTR    P,N
T01 D  THE ELECTRON MAY BE PRIMARY OR SECONDARY.
```

$N \to \mu^+$ anything (10^{30} years) (P2)

```
T02 DC 2       >12.          CL=.90   CHERRY    81 CNTR    P,N
T02 D          > 1.8         CL=.90   COWSIK    80 CNTR    P,N
T02 D          > 6.          CL=.90   LEARNED   79 CNTR    P,N
T02 D  THE MUON MAY BE PRIMARY OR SECONDARY.
T02  C WE HAVE CONVERTED 2 POSS EVENTS TO .90 CL LIMIT.
```

$p \to e^+\gamma$ (10^{30} years) (P3)

```
T03    0(.2)  > 87.         CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T03    0(.2)  >360.         CL=.90   BLEWITT   85 CNTR    P
T03 C         >  0.1        CL=.90   GURR      67 CNTR    P
T03 C  WE HAVE CONVERTED HALF-LIFE TO .90 CL MEAN LIFE.
```

$p \to \mu^+\gamma$ (10^{30} years) (P4)

```
T04    0(.2)  > 61.         CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T04    0(.6)  >280.         CL=.90   BLEWITT   85 CNTR    P
T04 C         >  0.3        CL=.90   GURR      67 CNTR    P
T04 C  WE HAVE CONVERTED HALF-LIFE TO .90 CL MEAN LIFE.
```

$n \to \nu\gamma$ (10^{30} years) (P5)

```
T05   28(19)   >11.         CL=.90   PARK      85 CNTR    N
```

$N \to e^+\pi$ (10^{30} years) (P6)

```
T06    0(.2)  > 82.         CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T06    0(.2)  >250.         CL=.90   BLEWITT   85 CNTR    P
T06    4(4)   > 25.         CL=.90   PARK      85 CNTR    N
T06 B  1(.3)  >  0.5        CL=.90   BARTELT   83 CNTR    P
T06 B  1(.3)  >  0.5        CL=.90   BARTELT   83 CNTR    N
T06    0      > 15.         CL=.90   BATTISTON 83 CNTR    P,N
T06 K  2      >  5.8        CL=.90   KRISHNASW 82 CNTR    P
T06 K  2      >  5.8        CL=.90   KRISHNASW 82 CNTR    N
T06 G         >  0.1        CL=.90   GURR      67 CNTR    N
T06 B  LIMIT BASED ON ZERO EVENTS.
T06 K  WE HAVE CALCULATED .90 CL LIMIT FROM 1 CONFINED EVENT.
T06 G  WE HAVE CONVERTED HALF-LIFE TO .90 CL MEAN LIFE.
```

$N \to \mu^+\pi$ (10^{30} years) (P7)

```
T07    0(.2)  > 59.         CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T07    1(.4)  >100.         CL=.90   BLEWITT   85 CNTR    P
T07    1(4)   > 38.         CL=.90   PARK      85 CNTR    N
T07    0      > 10.         CL=.90   BATTISTON 83 CNTR    P,N
T07    0      >  1.3        CL=.90   ALEKSEEV  81 CNTR    P,N
```

$N \to e^+K$ (10^{30} years) (P8)

```
T08    7(8.5)  >24.         CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T08    5(4)    >77.         CL=.90   BLEWITT   85 CNTR    P
T08    0       > 1.3        CL=.90   ALEKSEEV  81 CNTR    P,N
```

$N \to \mu^+K$ (10^{30} years) (P9)

```
T09   11(13)   > 6.7        CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T09    7(8)    >40.         CL=.90   BLEWITT   85 CNTR    P
T09 B  0       > 0.6        CL=.90   BARTELT   83 CNTR    P
T09 B  0       > 0.4        CL=.90   BARTELT   83 CNTR    N
T09    1       > 6.         CL=.90   BATTISTON 83 CNTR    P
T09 K  2       > 5.8        CL=.90   KRISHNASW 82 CNTR    P
T09    0       > 2.0        CL=.90   CHERRY    81 CNTR    P
T09 G          > 0.2        CL=.90   GURR      67 CNTR    N
T09 B  LIMIT BASED ON ZERO EVENTS.
T09 K  WE HAVE CALCULATED .90 CL LIMIT FROM 1 CONFINED EVENT.
T09 G  WE HAVE CONVERTED HALF-LIFE TO .90 CL MEAN LIFE.
```

$N \to \nu\pi$ (10^{30} years) (P10)

```
T10   28(19)     >7.        CL=.90   PARK      85 CNTR    N
T10    0         >7.        CL=.90   BATTISTON 83 CNTR    N
T10   =<3        >2.        CL=.90   BATTISTON 83 CNTR    P
T10 K  1         >5.8       CL=.90   KRISHNASW 82 CNTR    P
T10 C  2         >0.3       CL=.90   CHERRY    81 CNTR    P
T10 G            >0.1       CL=.90   GURR      67 CNTR    P
T10 K  WE HAVE CALCULATED .90 CL LIMIT FROM 1 CONFINED EVENT.
T10 C  WE HAVE CONVERTED 2 POSS EVENTS TO .90 CL LIMIT.
T10 G  WE HAVE CONVERTED HALF-LIFE TO .90 CL MEAN LIFE.
```

$N \to \nu K$ (10^{30} years) (P11)

```
T11    6(11)   > 1.8        CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T11    6(5)    > 9.6        CL=.90   BLEWITT   85 CNTR    P
T11    2(2)    >10.         CL=.90   PARK      85 CNTR    N
T11 B  0       > 0.3        CL=.90   BARTELT   83 CNTR    N
T11 B  0       > 0.1        CL=.90   BARTELT   83 CNTR    P
T11    0       > 5.         CL=.90   BATTISTON 83 CNTR    N
T11    0       > 2.         CL=.90   BATTISTON 83 CNTR    P
T11 K  1       > 5.8        CL=.90   KRISHNASW 82 CNTR    P
T11 C  2       > 0.3        CL=.90   CHERRY    81 CNTR    N
T11 B  LIMIT BASED ON ZERO EVENTS.
T11 K  WE HAVE CALCULATED .90 CL LIMIT FROM 1 CONFINED EVENT.
T11 C  WE HAVE CONVERTED 2 POSS EVENTS TO .90 CL LIMIT.
```

$p \to e^+\omega$ (10^{30} years) (P12)

```
T12    6(7.5)  >12.         CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T12    6(5.7)  >37.         CL=.90   BLEWITT   85 CNTR    P
T12 B  1(.3)   > 0.6        CL=.90   BARTELT   83 CNTR    P
T12 K  1       > 9.8        CL=.90   KRISHNASW 82 CNTR    P
T12 C  2       > 2.8        CL=.90   CHERRY    81 CNTR    P
T12 B  LIMIT BASED ON ZERO EVENTS.
T12 K  WE HAVE CALCULATED .90 CL LIMIT FROM 0 CONFINED EVENTS.
T12 C  WE HAVE CONVERTED 2 POSS EVENTS TO .90 CL LIMIT.
```

$p \to \mu^+\omega$ (10^{30} years) (P13)

```
T13    9(8.7)  > 6.5        CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T13    8(7)    >23.         CL=.90   BLEWITT   85 CNTR    P
```

$N \to e^+\rho$ (10^{30} years) (P14)

```
T14    6(6)    > 6.7        CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T14    7(7)    >17.         CL=.90   BLEWITT   85 CNTR    P
T14    4(2)    >12.         CL=.90   PARK      85 CNTR    N
T14 B  1(.3)   > 0.6        CL=.90   BARTELT   83 CNTR    N
T14 B  1(.3)   > 0.5        CL=.90   BARTELT   83 CNTR    P
T14 K  1       > 9.8        CL=.90   KRISHNASW 82 CNTR    P
T14 C  2       > 0.8        CL=.90   CHERRY    81 CNTR    P
T14 B  LIMIT BASED ON ZERO EVENTS.
T14 K  WE HAVE CALCULATED .90 CL LIMIT FROM 0 CONFINED EVENTS.
T14 C  WE HAVE CONVERTED 2 POSS EVENTS TO .90 CL LIMIT.
```

$N \to \mu^+\rho$ (10^{30} years) (P15)

```
T15    4(5)    > 5.5        CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T15    4(5)    >16.         CL=.90   BLEWITT   85 CNTR    P
T15    1(2)    > 9.         CL=.90   PARK      85 CNTR    N
```

$p \to e^+e^+e^-$ (10^{30} years) (P16)

```
T16    0(.5)  > 89.         CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T16    0(.7)  >510.         CL=.90   BLEWITT   85 CNTR    P
```

$p \to \mu^+\mu^+\mu^-$ (10^{30} years) (P17)

```
T17      1(.7)  > 44.          CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T17      1(.9)  >190.          CL=.90   BLEWITT   85 CNTR    P
T17 B    1      >  2.1         CL=.90   BATTISTON 82 CNTR    P
T17 B   WE HAVE CONVERTED 1 POSS EVENT TO .90 CL LIMIT.
```

$N \to \nu K^*(892)$ (10^{30} years) (P18)

```
T18     10(16)     >5.8        CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T18      7(6)      >9.6        CL=.90   BLEWITT   85 CNTR    P
T18      1(4)      >7.         CL=.90   PARK      85 CNTR    N
T18 B    1         >2.1        CL=.90   BATTISTON 82 CNTR    P
T18 B   WE HAVE CONVERTED 1 POSS EVENT TO .90 CL LIMIT.
```

$N \to e^+\pi^0$ anything (10^{30} years) (P19)

```
T19      0         >0.6        CL=.90   LEARNED   79 CNTR    P,N
```

$N \to \nu$ anything (years) (P20)

```
T20 L    0         >2.E26      CL=.90   LEARNED   79 CNTR    P,N
T20 L   ANYTHING = PI, RHO, K, ETC.
```

$n \to 3\nu$ (years) (P21)

```
T21      0         >5.E26      CL=.90   LEARNED   79 CNTR    N
```

$p \to e^+\eta$ (10^{30} years) (P22)

```
T22      5(6.5) > 64.          CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T22      5(4.7) >200.          CL=.90   BLEWITT   85 CNTR    P
T22 C    2      >  1.2         CL=.90   CHERRY    81 CNTR    P
T22 C   WE HAVE CONVERTED 2 POSS EVENTS TO .90 CL LIMIT.
```

$p \to \mu^+\eta$ (10^{30} years) (P23)

```
T23      6(6)      >17.        CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T23      7(8)      >46.        CL=.90   BLEWITT   85 CNTR    P
```

$n \to \nu\eta$ (10^{30} years) (P24)

```
T24      4(3)      >18.        CL=.90   PARK      85 CNTR    N
T24 C    2         > 0.6       CL=.90   CHERRY    81 CNTR    N
T24 C   WE HAVE CONVERTED 2 POSS EVENTS TO .90 CL LIMIT.
```

$N \to \nu\rho$ (10^{30} years) (P25)

```
T25      6(7)      > 4.1       CL=.90   BLEWITT   85 CNTR    P (FREE PROTON)
T25      6(5)      > 8.4       CL=.90   BLEWITT   85 CNTR    P
T25      7(3)      > 2.        CL=.90   PARK      85 CNTR    N
T25 C    2         > 0.9       CL=.90   CHERRY    81 CNTR    P
T25 C    2         > 0.6       CL=.90   CHERRY    81 CNTR    N
T25 C   WE HAVE CONVERTED 2 POSS EVENTS TO .90 CL LIMIT.
```

$n \to \nu\omega$ (10^{30} years) (P26)

```
T26      1(2)      >16.        CL=.90   PARK      85 CNTR    N
T26 C    2         > 2.0       CL=.90   CHERRY    81 CNTR    N
T26 C   WE HAVE CONVERTED 2 POSS EVENTS TO .90 CL LIMIT.
```

$n \to e^+e^-\nu$ (10^{30} years) (P27)

```
T27      4(3)      >26.        CL=.90   PARK      85 CNTR    N
```

$n \to \mu^+\mu^-\nu$ (10^{30} years) (P28)

```
T28      4(7)      >19.        CL=.90   PARK      85 CNTR    N
```

$n \to e^-\pi$ (10^{30} years) (P29)

```
T29      2(4)      >25.        CL=.90   PARK      85 CNTR    N
```

$n \to \mu^-\pi$ (10^{30} years) (P30)

```
T30      2(3)      >27.        CL=.90   PARK      85 CNTR    N
```

$n \to e^-\rho$ (10^{30} years) (P31)

```
T31      5(3)      >12.        CL=.90   PARK      85 CNTR    N
```

$n \to \mu^-\rho$ (10^{30} years) (P32)

```
T32      2(2)       >9.        CL=.90   PARK      85 CNTR    N
```

$N \to$ 2 BODIES, ν−FREE (10^{30} years) (P6+P7+P8+P9)

```
T33      0          >1.3       CL=.90   ALEKSEEV  81 CNTR    P,N
```

p MAGNETIC MOMENT ($e/2m_p$)

```
MM          (2.79276)(0.00002)          COHEN     65 RVUE
MM          (2.792782 0.000017)         TAYLOR    69 RVUE    USING NEW E/H
MM    A       2.7928456 .0000011        COHEN     73 RVUE
MM    A  COHEN 73 HAVE MADE A CORRECTION (MULTIPLYING BY 1.0000256) OF THE
MM    A  ORIGINAL DATA FOR DIAMAGNETIC SCREENING OF THE PROTON IN THE WATER
MM    A  MOLECULE.  MAMYRIN 83 REPORT THAT ACCOUNTING FOR NEW ATOMIC MASS
MM    A  VALUES (AND OTHER CORRECTIONS) WILL REDUCE THE QUOTED VALUE BY
MM    A  1.000 000537)(WHICH WOULD GIVE 2.7928444 AFTER THE WATER
MM    A  CORRECTION).
```

$\overline{p}$ MAGNETIC MOMENT ($e/2m_p$)

```
MM1 O       (-1.8)     (1.2)            BUTTON    62 CNTR
MM1 R       (-2.83)    (0.10)           FOX       72 CNTR
MM1 R       (-2.819)   (0.056)          ROBERTS   74 CNTR
MM1           -2.791    0.021           HU        75 CNTR    EXOTIC ATOMS
MM1  R        -2.817    0.048           ROBERTS   78 CNTR
MM1 O    OLD EXPERIMENT WITH LARGE ERROR.  NOT AVERAGED.
MM1  R   ROBERTS 74 IS REANALYSIS OF FOX 72 DATA.  REPLACES OLD FOX VALUE.
MM1  R   ROBERTS 78 IS A REANALYSIS OF ROBERTS 74.
MM1         . . . . . . . . . . .
MM1 AVG       -2.795    0.019    AVERAGE
```

p ELECTRIC DIPOLE MOMENT (units 10^{-23} *e*–cm)

```
            FORBIDDEN BY BOTH T INVARIANCE AND P INVARIANCE

EDM      1G  (700.)   (900.)            HARRISON  69 MBR
EDM        (55000.)  OR LESS            KHRIPLOVI 76
EDM   A       (130.)   (200.)           WILKENING 84
EDM   A        900.     1400.           WILKENING 84
EDM           (400.)  OR LESS           DZUBA     85 THEO    USE EDM OF 129XE
EDM   A  FIRST WILKENING 84 NUMBER INCLUDES A FINITE SIZE EFFECT AND A
EDM   A  MAGNETIC EFFECT; SECOND NUMBER IS MORE CAUTIOUS AND EXCLUDES FINITE
EDM   A  SIZE EFFECT WHICH RELIES ON UNCERTAIN NUCLEAR INTEGRALS.
```

p − *e* CHARGE DIFFERENCE (units *e*)

```
      SEE ALSO SECTION Q IN THE FULL LISTINGS FOR NEUTRONS BELOW.

DQ    D      1.0E-21  OR LESS           DYLLA     73        NEUTRALITY OF SF6
DQ          (0.8E-21) OR LESS           MARINELLI 84 RVUE
DQ    D    ASSUMES THAT Q(NEUTRON)=Q(PROTON)-Q(E-).  SEE DYLLA 73 FOR A
DQ    D    SUMMARY OF EXPERIMENTS ON THE NEUTRALITY OF MATTER.
```

REFERENCES FOR *p*

```
BLEWITT  85 PRL 55 2114        +    (UCI+MICH+BNL+CIT+CLEV+HAWA+LOUC+WARS)
DZUBA    85 PL 154B 53         DZUBA,FLAMBAUM,SILVESTROV               (NOVO)
PARK     85 PRL 54 22          +    (UCI+MICH+BNL+CIT+CLEV+HAWA+LOUC+WARS)
MARINELL 84 PL 137B 439        MARINELLI,MORPURGO                      (GENO)
WILKENIN 84 PR A29 425         WILKENING,RAMSEY,LARSON            (HARV+VIRG)
BARTELT  83 PRL 50 651         +COURANT,HELLER,JOYCE,MARSHAK+     (MINN+ANL)
BATTISTO 83 PL 133B 454        BATTISTONI,BELLOTTI+  (FRAS+MILA+LCGT+CERN)
MAMYRIN  83 JETP 57 1152       +ARUEV,ALEKSEENKO                       (IOFF)
BATTISTO 82 PL 118B 461        BATTISTONI,BELLOTTI+  (FRAS+MILA+LCGT+CERN)
KRISHNAS 82 PL 115B 349        KRISHNASWAMY,MENON,MONDAL+ (TIFR+OSKC+TOKY)
ALEKSEEV 81 JETPL 33 651       +BAKATANOV,BUTKEVICH,VOEVODSKII +       (LENI)
CHERRY   81 PRL 47 1507        +DEAKYNE,LANDE,LEE,STEINBERG +    (PENN+BNL)
COWSIK   80 PR D22 2204        R.COWSIK,V.S.NARASIMHAN                 (TIFR)
BELL     79 PL 86B 215         +CALVETTI,CARRON,CHANEY,CITTOLIN+       (CERN)
GOLDEN   79 PRL 43 1196        +HORAN,MAUGER,BADHWAR,LACY+       (NASA+PSLL)
LEARNED  79 PRL 43 907         +REINES,SONI                             (UCI)
BREGMAN  78 PL 78B 174         +CALVETTI,CARRON,CITTOLIN,HAUER,HERR+(CERN)
GANGULI  78 PL 74B 130         +MALHOTRA,RAGHAVAN,SUBRAMANIAN +        (TIFR)
ROBERTS  78 PR D17 358         B. L. ROBERTS                      (WILL+RHEL)
EVANS    77 SCIENCE 197 989    +STEINBERG                          (BNL+PENN)
ROBERSON 77 PR C16 1945        +KING,KUNSELMAN+   (WYOM+CIT+CARN+VPI+WILL)
KHRIPLOV 76 JETP 44 25         I.B.KHRIPLOVICH    (NUC.PHYS.INST.,SIBERIA)
HU       75 NP A254 403        +ASANO,CHEN,CHENG,DUGAN+           (COLU+YALE)
ROBERTS  74 PRL 33 1181        +COX,ECKHAUSE+ (WILL+VPI+CARN+WYOM+CIT+BNL)
    ALSO 75 PR D12 1232        ROBERTS,COX +  (WILL+VPI+CARN+WYOM+CIT+BNL)
COHEN    73 J.PHYS.CHEM.REF.DATA 2, P.663, E.R.COHEN,B.N.TAYLOR
DYLLA    73 PR A7 1224         H.F.DYLLA, J.G.KING                      (MIT)
FOX      72 PRL 29 193         +BARNES,EISENSTEIN+(BNL+CARN+VPI+WILL+WYOM)
BAMBERGE 70 PL 33B 233         BAMBERGER,LYNEN,PIEKARZ+   (MPIH+CERN+KARL)
DIX      70 THESIS CASE        F E DIX                                 (CASE)
HARRISON 69 PRL 22 1263        HARRISON,SANDARS,WRIGHT  (CLARENDON OXFORD)
TAYLOR   69 RMP 41 375         +PARKER,LANGENBERG            (PRIN+UCI+PENN)
GURR     67 PR 158 1321        GURR,KROPP,REINES,MEYER (CASE,JOHANNESBURG)
COHEN    65 RMP 37 537         +DUMOND (N.AMER.AVIATION SCIENCE CENT.,CIT)
BUTTON   62 PR 127 1297        J BUTTON,B MAGLIC                        (LBL)
FLEROV   58 SOV PHYS DOK 3 79 FLEROV,KLOCHKOV,SKOBKIN,TERENTEV         (USSR)

        QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA LISTINGS

KALOGERO 76 PRL 37 1037        KALOGEROPOULOS,CHIU,SUDARSHAN   (SYRA+TEXA)P
FRANKLIN 77 PR D16 910         JERROLD FRANKLIN                        (HAIF)P
```

n

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

n MASS (MeV)

```
M    T      (939.5527) (0.0052)         TAYLOR    69 RVUE    USING NEW E/H
M   T        939.5731   0.0027          COHEN     73 RVUE
M    T      (939.5730) (0.0026)         GREENWOOD 80 CNTR    N P --> D GAMMA
M   T    THESE DETERMINATIONS OF NEUTRON MASS NOT INDEPENDENT OF
M   T    NEUTRON-PROTON MASS DIFFERENCE MEASUREMENTS BELOW.
```

n − *p* MASS DIFFERENCE (MeV)

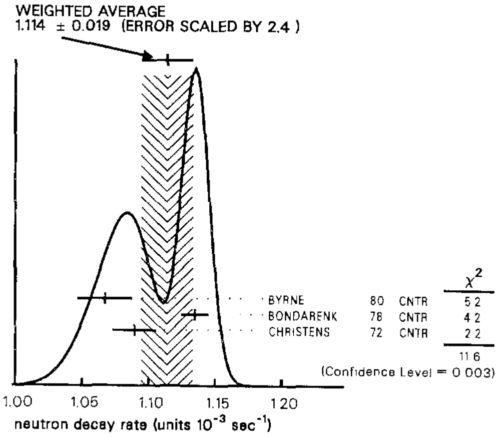
```
D   M     (1.29344) (0.00007)           MATTAUCH  65 RVUE
D         (1.293429)(0.000036)          COHEN     73 RVUE
D   M       1.293330  0.000040          VYLOV     78 CNTR    N P --> D GAMMA
D   M       1.293322  0.000017          GREENWOOD 80 CNTR    N P --> D GAMMA
D   M    WE HAVE CONVERTED MEASURED NEUTRON-HYDROGEN MASS DIFFERENCE TO
D   M    NEUTRON-PROTON MASS DIFFERENCE USING CURRENT VALUE OF ELECTRON MASS
D   M    AND A HYDROGEN BINDING ENERGY OF 13.6 EV.
D           . . . . . . . . . . .
D    AVG     1.293323 0.000016  AVERAGE
```

n MEAN LIFE (units 10^3 sec)

```
      THE ORIGIN OF THE DISCREPANCIES BETWEEN MEASUREMENTS OF THE
      NEUTRON MEAN LIFE IS NOT KNOWN.  WE AVERAGE THE HIGHEST PRECISION
      MODERN EXPERIMENTS AND INCLUDE THE RESULTING SCALE FACTOR IN THE
      ERROR, AS USUAL.  THE IDEOGRAM SHOWS THE INVERSE MEAN LIFE, THE
      QUANTITY ACTUALLY USED IN CALCULATING OUR AVERAGE VALUE.

      LIFETIMES FOR BOUND NEUTRONS ARE GIVEN IN THE PROTON MEAN LIVES
      SECTION

T          (1.013)  (0.026)        SOSNOVSKI 59 CNTR
T          (0.935)  (0.014)        CHRISTENS 67 CNTR REPL BY CHRISTENS72
T           0.918    0.014         CHRISTENS 72 CNTR
T    A      0.881    0.008         BONDARENK 78 CNTR
T           0.937    0.018         BYRNE     80 CNTR
T          (0.875)  (0.095)        KOSVINTSE 80 CNTR
T   B      (0.902)  (0.010)        WILKINSON 82 RVUE    INFERRED VALUE
T    A  INCLUDES CORRECTION FOR RECOIL PROTON SCATTERING SEE BONDARENKO 82.
T   B   WILKINSON 82 VALUE INFERRED FROM N DECAY CORRELATIONS.
T          . . . . . . . . . .
T   AVG     0.898    0.016    0.016  AVERAGE (ERROR INCL. SCALE FACTOR OF 2.4)
                     (SEE IDEOGRAM BELOW)
```



n MAGNETIC MOMENT (NUCLEAR MAGNETONS, 938.2 MeV)

```
MM       (-1.913148   0.000066)        COHEN     56 RVUE
MM       (-1.91304211 0.00000088)      GREENE    77 MRS  REPL. BY GREENE 79
MM       (-1.91304184 0.00000088)      GREENE    79 MRS
MM    A   -1.91304308 0.00000054       GREENE    82 MRS  REPLACES GREENE 79
MM    A  GREENE 82 MEASURES THE NEUTRON MAGNETIC MOMENT IN BOHR MAGNETONS
MM    A  TO BE 1.041 875 64E-3+-0.000 000 26E-3.  THE VALUE QUOTED ABOVE IS
MM    A  OBTAINED BY MULTIPLYING BY M(PROTON)/M(ELECTRON)=1836.153000.
MM    A  A MODIFIED VALUE WOULD BE OBTAINED USING A NEW UNPUBLISHED VALUE OF
MM    A  1836.152701)
```

n ELECTRIC DIPOLE MOMENT (units $10^{-23}e$–cm)

```
                FORBIDDEN BY BOTH T INVARIANCE AND P INVARIANCE

EDM M      (-20.)     (30.)           MILLER     67 MRS
EDM         +24.       39.            SHULL      67 CNTR
EDM  M      (30.)    OR LESS          DRESS      68 MRS  ABSOLUTE VALUE
EDM          (5.)    OR LESS          BAIRD      69 MRS  INCLUDED IN DRESS73
EDM         - 2.       39.            APOSTOLES  70 MRS
EDM          0.32      0.75           DRESS      73 MRS  < 10**-23 (CL=.80)
EDM          0.04      0.15           DRESS      77 MRS  < 3  E-24 (CL=.90)
EDM  A       0.040     0.075          ALTAREV    79 MRS  < 1.6E-24 (CL=.90)
EDM  A       0.021     0.024          ALTAREV    81 MRS  < 6  E-25 (CL=.90)
EDM  M  DRESS 68 INCLUDES DATA OF MILLER 67.
EDM  A  ALTAREV 79 AND 81 USE ULTRACOLD NEUTRONS.
EDM         . . . . . . . . . .
EDM AVG      0.023     0.023    AVERAGE
```

n CHARGE

```
      SEE ALSO SECTION DQ IN THE FULL LISTINGS FOR PROTONS ABOVE

Q                       NEUTRON CHARGE (UNITS 10**-20 E)
Q          (-1.5)     (2.2)  CL=.90    GAHLER     82 CNTR    REACTOR N BEAM
```

LIMIT ON $n-\overline{n}$ OSCILLATIONS

```
NAN     MEAN TIME FOR N-ANTIN TRANSITION IN VACUUM  (UNITS SEC.)
NAN      TEST OF BARYON CONSERVATION.
NAN      LIMITS ARE DERIVED FROM EXPERIMENTAL LIMITS ON DELTA-B = 2 NUCLEAR
NAN      DECAY PROCESSES, USING THEORETICAL ASSUMPTIONS FOR NUCLEAR PHYSICS
NAN      EFFECTS.  SEE ALSO THE THEORETICAL ANALYSIS OF DOVER, GAL, AND
NAN      RICHARDS, PR D27, 1090 (1983).  SEE THE REVIEWS OF H.L. ANDERSON,
NAN      PROC. LASL CONF. ON NUCLEAR PARTICLE PHYSICS AT ENERGIES UP TO 31
NAN      GEV, 1981.
NAN          (1.E8) OR MORE              CHETYRKIN 81 THEO
NAN          (5.E7) OR MORE CL=.90       COWSIK    81 THEO
NAN          (3.E7) OR MORE              ALBERICO  82 THEO
NAN          (2.E7) OR MORE              CHERRY    83 CNTR+THY
NAN          (3.E7) OR MORE              BATTISTON 84 CNTR
NAN          (2.7E7)TO 1.1E8  OR MORE JONES     84 CNTR+THY
NAN          (1.E6) OR MORE  CL=.90      FIDECARO  85 CNTR    FREE REACTOR N
NAN           8.8E7 OR MORE  CL=.90      PARK      85 CNTR+THY
```

n PARTIAL DECAY MODES

		DECAY MASSES DECAY MASSES
P1	$n \to p e^- \overline{\nu}_e$	938+.511+ 0
P2	$n \to p \nu_e \overline{\nu}_e$	938+ 0+ 0

n BRANCHING RATIOS

$n \to (p\,\nu_e\overline{\nu}_e)/(p\,e^-\overline{\nu}_e)$ (P2)/(P1)

```
R1       FORBIDDEN BY CHARGE CONSERVATION
R1          (3. E-19)OR LESS             NORMAN    79 CNTR RB87-->SR87M+NEUTRL
R1            9. E-24 OR LESS            BARABANOV 80 CNTR GA71-->GE71 + ANY
R1          (7.9E-21)OR LESS             VAIDYA    83 CNTR RB87-->SR87M+NEUTRL
R1   R      (9.7E-18)OR LESS  CL=.90     ROY       83 CNTR
R1   R   CD113 --> IN113M + NEUTRALS
```

NOTE ON BARYON DECAY PARAMETERS

A/V ratio for baryon leptonic decays

Consider the decay

$$B_i \to B_f + \ell + \nu\,.$$

Assuming V, A theory, neglecting "induced" scalar, "induced" pseudoscalar, and axial weak-magnetism terms, and neglecting the q^2 dependence of the form factors, the baryon part of the matrix element for these decays may be written as[1]

$$\overline{B}_f\,[\gamma_\lambda(g_V - g_A\gamma_5) + (g_W/m_{B_i})\sigma^{\lambda\nu}q_\nu]B_i\,.$$

Here B_i and $\overline{B}_f$ are spinors which represent initial and final baryons, g_A and g_V are the axial and vector coupling constants, g_W is the weak magnetism coupling constant, and q_ν is the sum of the lepton momenta. The Pauli representation is used for the γ matrices. The ratio g_A/g_V may be written as

$$g_A/g_V = |g_A/g_V|\exp(i\phi)\,,$$

where ϕ is 0 plus $n\pi$ if time reversal holds.[2]

Experiments on the leptonic decays of baryons other than the neutron have generally assumed ϕ to be either 0 or π, and have thus measured the magnitude and sign of g_A/g_V. In studying neutron beta decay, however, experiments have been sensitive enough to measure ϕ more precisely, and we include the phase angle in our Listings for this case. It is consistent with time-reversal invariance, and by using the above definition of the matrix element with the Pauli representations, the value of g_A/g_V in neutron beta decay is negative.

Due to statistical limitations, the weak magnetism form factor g_W is usually assumed from CVC and SU(3), so that usually only g_A and g_V are determined experimentally. This determination is accomplished in a variety of ways:

(a) The lepton-neutrino angular correlation provides a measure of the absolute value of g_A/g_V (for relevant formulas, see, e.g., Albright[3]).

(b) The up-down asymmetry of the lepton from polarized baryon decays provides a measure of g_A/g_V with its sign (for relevant formulas, see, e.g., Albright[3]).

(c) The lepton spectrum, given enough statistics, provides a measure of g_A/g_V with its sign (for relevant formulas, see, e.g., Bender et al.[4]). The lepton spectrum also provides a measure of g_W/g_A if the CVC-SU(3) assumption is relaxed.

(d) The polarization of the decay baryon, from polarized or unpolarized initial baryon, also provides g_A/g_V with its sign (for formulas, see, e.g., Willis and Thompson[5]).

(e) The presence of a triple correlation term proportional to

$$\sigma_{B_i}\cdot(\mathbf{p}_e\times\mathbf{p}_\nu)\,,$$

where the initial baryon is polarized or

$$\sigma_{B_f}\cdot(\mathbf{p}_e\times\mathbf{p}_\nu)\,,$$

where the polarization of the decay baryon is observed provides a measure of the deviation of ϕ from 0 or π, and is thus a test of time-reversal invariance (see, e.g., Willis and Thompson[5]).

We compile the ratio g_A/g_V with its sign, for those decays for which it has been measured.

All the coupling constants and decay rates for baryon leptonic decays are related by Cabibbo's theory,[6] extended to six quarks (and three mixing angles) by Kobayashi and Maskawa.[7] A discussion of the Kobayashi-Maskawa mixing matrix is given in the Miscellaneous Section of this Review.

Asymmetry parameters in nonleptonic hyperon decays

The transition matrix for hyperon decay may be written as

$$M = s + p(\boldsymbol{\sigma}\cdot\mathbf{q})\,, \qquad (1)$$

where s and p are the parity-changing and the parity-conserving amplitudes, respectively; $\boldsymbol{\sigma}$ is the Pauli spin operator, and $\mathbf{q}$ is a unit vector along the direction of the decay baryon in the hyperon rest frame.

The asymmetry parameters are defined by the relations

$$\alpha = 2\,\mathrm{Re}(s^*p)/(|s|^2+|p|^2)\,,$$

$$\beta = 2\,\mathrm{Im}(s^*p)/(|s|^2+|p|^2)\,,$$

$$\gamma = (|s|^2-|p|^2)/(|s|^2+|p|^2)\,.$$

With the transition matrix M given by Eq. (1) above, the angular distribution of the decay baryon, in the hyperon rest system, is of the form

$$I = 1 + \alpha\mathbf{P}_Y\cdot\mathbf{q}\,,$$

where $\mathbf{P}_Y = \langle Y|\boldsymbol{\sigma}|Y\rangle$ is the hyperon polarization. In the notation of Lee and Yang,[8] the polarization P_B of the decay baryons is

$$\mathbf{P}_B = \frac{(\alpha+\mathbf{P}_Y\cdot\mathbf{q})\mathbf{q}+\beta(\mathbf{P}_Y\times\mathbf{q})+\gamma\mathbf{q}\times(\mathbf{P}_Y\times\mathbf{q})}{1+\alpha\mathbf{P}_Y\cdot\mathbf{q}}\,,$$

where $\mathbf{P}_B$ is defined in that rest system of the baryon obtained by a Lorentz transformation along $\mathbf{q}$ from the hyperon rest system in which $\mathbf{q}$ and $\mathbf{P}_Y$ are defined. Note that α is the helicity of the decay baryon for unpolarized hyperons.

The three parameters α, β, and γ satisfy the relation

$$\alpha^2+\beta^2+\gamma^2 = 1\,.$$

It is then convenient to describe hyperon nonleptonic decays in terms of the two independent parameters α and the angle ϕ defined by

$$\beta = (1-\alpha^2)^{1/2}\sin\phi\,,$$

$$\gamma = (1-\alpha^2)^{1/2}\cos\phi\,,$$

which has a more nearly Gaussian distribution of measurement error than β or γ. Evidently

$$-\tfrac{1}{2}\pi \leqslant \phi \leqslant \tfrac{1}{2}\pi \quad \text{for } \gamma > 0\,,$$

$$+\tfrac{1}{2}\pi \leqslant \phi \leqslant \tfrac{3}{2}\pi \quad \text{for } \gamma < 0\,.$$

In discussing time-reversal invariance, the quantity of interest is Δ, defined by

$$\alpha = 2|s||p|\cos\Delta/(|s|^2+|p|^2)\,,$$

$$\beta = -2|s||p|\sin\Delta/(|s|^2+|p|^2)\,;$$

that is, Δ is the phase angle of s relative to p. Evidently

$$-\tfrac{1}{2}\pi \leqslant \Delta \leqslant \tfrac{1}{2}\pi \quad \text{for } \alpha > 0\,,$$

$$+\tfrac{1}{2}\pi \leqslant \Delta \leqslant \tfrac{3}{2}\pi \quad \text{for } \alpha < 0\,.$$

Under the assumption of time-reversal invariance, the angle Δ must satisfy the relation

$$\Delta = \delta_s - \delta_p ,$$

modulo π, where δ_s and δ_p are the pion-baryon scattering phase shifts at the appropriate energy and for the appropriate isospin state. For Λ decay, assuming the validity of the $|\Delta I| = 1/2$ rule,

$$\Delta = \delta_s - \delta_p = (7.0 \pm 1.0) \text{ deg.}$$ [9]

In the Stable Particle Full Listings we give α and ϕ for each decay since they are the most closely related to the experiments and are essentially uncorrelated. Whenever necessary we have changed the signs of the reported values, so as to agree with our conventions. In the Stable Particle Summary Table we give α, ϕ, and Δ with errors; and for convenience we also give the central value of γ, without an error.

References

1. M.L. Goldberger and S.B. Treiman, Phys. Rev. **11**, 354 (1958).
2. J.D. Jackson, S.B. Treiman, and H.W. Wyld Jr., Phys. Rev. **106**, 517 (1957).
3. C.H. Albright, Phys. Rev. **115**, 750 (1959).
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6. N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963).
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9. This value for δ_s-δ_p is derived from the phase-shift analyses by R. Ayed, CEA-N-192, Saclay thesis (1976). The error is our estimation of the uncertainty allowing for possible correlations.

DECAY PARAMETERS FOR $n \rightarrow p e^- \nu$

g_A/g_V (see note above for sign convention)

```
AV  C       (-1.250)  (0.044)          CONFORTO  67 RVUE  SEE NOTE C BELOW
AV EP       (-1.23)   (0.01)           CHRISTENS 67 CNTR  N DECAY FT VALUE
AV  P       (-1.22)   (0.08)           GRIGOREV  68 CNTR E-NU ANG CORREL
AV  P       (-1.26)   (0.02)           CHRISTENS 70 CNTR PE,NEUT SPIN CORREL
AV EP       (-1.27)   (0.025)          EROZOLIMS 71 CNTR REPL.BY EROZOLIMS79
AV EP       (-1.239)  (0.011)          CHRISTENS 72 CNTR    N DEC.+ FT VALUE
AV  P       (-1.263)  (0.016)          KROPF     74 RVUE    N DECAY ALONE
AV   P       -1.250    0.009           KROPF     74 RVUE    N DEC.+ FT VALUE
AV E        (-1.250)  (0.036)          DOBROZEMS 75 CNTR REPL.BY STRATOWA 78
AV   K       -1.253    0.021           KROHN     75 CNTR PE,NEUT SPIN CORREL
AV          (-1.263)  (0.015)          EROZOLIMS 77 CNTR REPL.BY EROZOLIMS79
AV E         -1.259    0.017           STRATOWA  78 CNTR PROTON RECOIL SPECT
AV E         -1.261    0.012           EROZOLIMS 79 CNTR PE,NEUT SPIN CORREL
AV           -1.226    0.042           MOSTOVOY  83 RVUE
AV  C   CONFORTO 67 COMBINES FREE NEUTRON DATA TO 1967.  REPL. BY KROPF 74.
AV E    THESE EXPERIMENTS MEASURE THE ABSOLUTE VALUE OF GA/GV ONLY
AV   P  KROPF 74 VALUE OBTAINED BY FITTING ALL DATA THROUGH 1972.
AV   K  KROHN 75 PAPER GIVES -1.258+-.015 INCLUDING EVENTS OF CHRISTENS 70.
AV   K  THE VALUE QUOTED ABOVE IS DERIVED FROM HIS A,BASED ON NEW EXPT ONLY
AV          . . . . . . . . . .
AV  AVG      -1.2539   0.0063  AVERAGE
```

PHASE ANGLE OF g_A RELATIVE TO g_V (degrees)

```
F        TIME REVERSAL INVARIANCE WOULD REQUIRE THIS TO BE 0 OR 180 DEGREES
F   P     (175.)     (10.)             BURGY     60 CNTR    POLAR. NEUTRONS
F   P     (198.)     (27.)             CLARK     60 CNTR    POLAR. NEUTRONS
F   C     (176.1)     (6.4)            CONFORTO  67 RVUE
F   P     (181.3)     (1.3)            EROZOLIMS 70 CNTR    POLAR. NEUTRON
F          180.35     0.43             EROZOLIMS 74 CNTR    POLAR. NEUTRONS
F    P     181.1      1.3              KROPF     74 RVUE    N DECAY
F          180.14     0.22             STEINBERG 74 CNTR    POLAR. NEUTRONS
F          179.71     0.39             EROZOLIMS 78 CNTR    POLAR. NEUTRONS
F   C   CONFORTO 67 COMBINES FREE NEUTRON DATA TO 1967.  REPL. BY KROPF 74.
F    P  KROPF 74 VALUE OBTAINED BY FITTING ALL DATA THROUGH 1972.
F          . . . . . . . . . .
F   AVG    180.11     0.17    AVERAGE
```

TRIPLE CORRELATION COEFFICIENT

```
D1      D1 MEASURES COMPONENT OF NEUTRON SPIN PERPENDICULAR TO THE DECAY
D1      PLANE IN BETA DECAY. SHOULD BE ZERO IF T-INVARIANCE NOT
D1      VIOLATED.  SEE NOTE ON BARYON DECAY PARAMETERS ABOVE.
D1           -0.01     0.01            EROZOLIMS 70 CNTR    POLAR. NEUTRONS
D1   E       -0.0027   0.0050          EROZOLIMS 74 CNTR    POLAR. NEUTRONS
D1   E       -0.0011   0.0017          STEINBERG 74 CNTR    POLAR. NEUTRONS
D1           +0.0022   0.0030          EROZOLIMS 78 CNTR    POLAR. NEUTRONS
D1   E  EROZOLIMSKII 78 SAYS ASYMMETRIC PROTON LOSSES AND NON-UNIFORM BEAM
D1   E  POLARIZATION MAY GIVE SYSTEMATIC ERROR UP TO 0.003, THUS INCREASING
D1   E  THE EROZOLIMSKII 74 ERROR TO 0.005 .  STEINBERG 74, 76 ESTIMATES
D1   E  THESE SYSTEMATIC ERRORS TO BE INSIGNIFICANT IN THEIR EXPERIMENT.
D1         . . . . . . . . . .
D1  AVG      -0.0007   0.0014  AVERAGE
```

REFERENCES FOR *n*

```
COHEN    56 PR 104 283          V W COHEN, CORNGOLD, RAMSEY  (BNL+HARVARD)
SOSNOVSK 59 JETP  9  717        SOSNOVSKII,SPIVAK,PROKOFEV +  (IAE MOSCOW)
BURGY    60 PR 120 1829         +KROHN,NOVEY,RINGO                (ANL+CHIC)
CLARK    60 CJP 38 693          +ROBSON

MATTAUCH 65 NP 67 1             +THIELE,WAPSTRA     (MAX PLANCK INST.CHEM.)
CHRISTEN 67 PL 26B 11           CHRISTENSEN,NIELSON,BAHNSEN,BROWN+   (RISO)
CONFORTO 67 APAH 22 15          G. CONFORTO                          (CERN)
MILLER   67 PRL 19 381          +DRESS,BAIRD,RAMSEY              (ORNL+HARV)
SHULL    67 PRL 19 384          C.G.SHULL, R.NATHANS               (MIT+BNL)
DRESS    68 PR 170 1200         +BAIRD,MILLER,RAMSEY             (ORNL+HARV)
GRIGOREV 68 SJNP 6 239          +GRISHIN,VLADIMIRSKII,NIKOLAEVSKII + (ITEP)

BAIRD    69 PR  179  1285       +MILLER,DRESS,RAMSEY             (ORNL,HARV)
TAYLOR   69 RMP 41 375          +PARKER,LANGENBERG           (PRIN+UCI+PENN)
APOSTOLE 70 RRP 15 343          APOSTOLESCU,IONESCU,IONESCU-BUJOR +  (BUCH)
CHRISTEN 70 PR C1 1693  .       CHRISTENSEN,KROHN,RINGO               (ANL)
EROZOLIM 70 SJNP 11 583         EROZOLIMSKI,BONDARENKO,  +           (KIAE)
    ALSO    PL 27B 557          EROZOLIMSKY,BONDARENKO  +            (KIAE)

EROZOLIM 71 JETPL 13 252        EROZOLIMSKII,BONDARENKO +            (KIAE)
CHRISTEN 72 PR D5 1628          CHRISTENSEN,NIELSON,BAHNSEN,BROWN+   (RISO)
COHEN    73 J.PHYS.CHEM.REF.DATA 2, P.663, E.R.COHEN,B.N.TAYLOR
DRESS    73 PR D7 3147          DRESS,MILLER,RAMSEY              (ORNL+HARV)
KROPF    74 ZPHY 267 129        A KROPF,H PAUL                       (LINZ)
    ALSO 70 NP A154 160         H PAUL                               (VIEN)

EROZOLIM 74 JETPL 20 345        EROZOLIMSKII,MOSTOVOI,FEDUNIN,FRANK+
STEINBER 74 PRL 33 41           STEINBERG,LIAUD,VIGNON,HUGHES   (YALE+GREN)
    ALSO 76 PR D13 2469         STEINBERG,LIAUD,VIGNON,HUGHES   (YALE+GREN)
DOBROZEM 75 PR D11 510          DOBROZEMSKY,KERSCHBAUM,MORAW,PAUL +  (SEIB)
KROHN    75 PL 55B 175          KROHN,RINGO                           (ANL)

DRESS    77 PR D15 9            +MILLER,PENDLEBURY,PERRIN+ (ORNL+GREN+HARV)
EROZOLIM 77 JETPL 23 663        EROZOLIMSKII,FRANK,MOSTOVOI+         (KIAE)
GREENE   77 PL 71B 297          +RAMSEY,MAMPE+   (HARV+ILLG+SUSS+ORNL+CENG)
EROZOLIM 78 SJNP 28 48          EROZOLIMSKII,MOSTOVOI,FEDUNIN,FRANK+ (KIAE)
STRATOWA 78 PR D18 3970         +DOBROZEMSKY,WEINZIERL               (SEIB)
BONDAREN 78 JETPL 28 303        BONDARENKO,KURGUZOV,PROKOFEV+        (KIAE)
    ALSO 82 SMOLENICE CONF.     L.N.BONDARENKO                       (KIAE)
VYLOV    78 SJNP 28 585         +GROMOV,IVANOV,OSIPENKO,FROLOV       (JINR)

ALTAREV  79 JETPL 29 730        +BORISOV,BRANDIN,EGOROV,EZHOV,IVANOV+(LENI)
EROZOLIM 79 SJNP 30 356         EROZOLIMSKII,FRANK,MOSTOVOI+         (KIAE)
GREENE   79 PR D20 2139         +RAMSEY,MAMPE+   (HARV+ILLG+SUSS+ORNL+CENG)
NORMAN   79 PRL 43 1226         E.B.NORMAN, A.G.SEAMSTER             (WASH)

BARABANO 80 JETPL 32 359        BARABANOV,VERETENKIN,GAVRIN +        (LENI)
BYRNE    80 PL 92B 274          +MORSE,SMITH,SHAIKH,GREEN,GREENE  (SUSS+RL)
GREENWOO 80 PR C21 498          R.C.GREENWOOD,R.C.CHRIEN         (INEL+BNL)
KOSVINTS 80 JETPL 31 236        KOSVINTSEV,KUSHNIR,MOROZOV,TEREKHOV  (JINR)

ALTAREV  81 PL 102B 13          +BORISOV,BOROVIKOVA,BRANDIN,EGOROV + (LENI)
CHETYRKI 81 PL 99B 358          CHETYRKIN,KAZARNOVSKY,KUZMIN+        (INRM)
COWSIK   81 PL 101B 237         COWSIK,NUSSINOV                       (UMD)
ALBERICO 82 PL 114B 266         +BOTTINO,MOLINARI                (CERN+TORI)
GAHLER   82 PR D25 2887         +KALUS,MAMPE                     (BAYR+ILLG)
GREENE   82 METROLOGIA 18 93    +RAMSEY+    (YALE+HARV+ILLG+SUSS+ORNL+CENG)
WILKINSO 82 NP A377 474         D.H.WILKINSON                     (SUSS+BNL)
CHERRY   83 PRL 50 1354         +LANDE,LEE,STEINBERG,CLEVELAND    (PENN+BNL)
MOSTOVOY 83 JETPL 37 196        YU.A.MOSTOVOY                        (KIAE)
ROY      83 PR D28 1770         +VAIDYA,EPHRAIM,DATAR,BHATKI+        (TIFR)
VAIDYA   83 PR D27 486          +ROY,EPHRAIM,DATAR,BHATTACHERJEE     (TIFR)
BATTISTO 84 PL 133B 454         BATTISTONI,BELLOTTI+  (FRAS+MILA+LCGT+CERN)
JONES    84 PRL 52 720          IMB COLLAB(UCI+MICH+BNL+CIT+CLEV+HAWA+LOUC)
FIDECARO 85 PL 156B 122         +LANCERI+          (CERN+ILLG+PADO+RAL+SUSS)
PARK     85 NP B252 261         IMB COLLAB(UCI+MICH+BNL+CIT+CLEV+HAWA+LOUC)

                                PAPERS NOT REFERRED TO IN DATA LISTINGS

JACKSON  57 PR 106 517          JACKSON,TREIMAN,WYLD            (PRINCETON)
COHEN    65 RMP 37 537          +DUMOND (N.AMER.AVIATION SCIENCE CENT.,CIT)
BHALLA   66 PL 19  691          C P BHALLA                        (ALABAMA)
BYRNE    82 RPP 45 115          J.BYRNE                              (SUSS)
FRANK    82 SPU 25 280          A.I.FRANK                            (KIAE)
WILKINSO 82 NP A377 474         WILKINSON                            (SUSS)
```

STRANGENESS −1 BARYONS

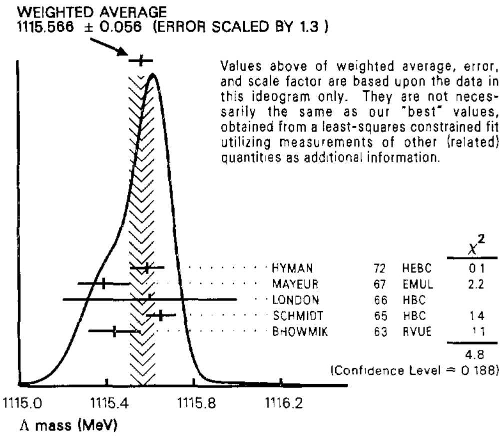
Λ

$I(J^P) = 0(\frac{1}{2}^+)$

Λ MASS (MeV)

```
          SINCE OUR FINAL VALUES FOR THE SIGMA AND LAMBDA MASSES COME FROM
          DOING AN OVERALL FIT TO ALL MEASURED MASSES AND MASS DIFFERENCES,
          WE HAVE USED THE UNCORRELATED MEASUREMENTS FROM SCHMIDT 65 RATHER
          THAN THE ONES COMING FROM THE OVERALL FIT REPORTED IN THAT PAPER.
          SINCE THERE SEEMS TO BE NO CONVINCING ARGUMENT AS TO WHY ONE SHOULD
          IGNORE DATA USING RANGE MEASUREMENTS, WE HAVE INCLUDED HERE VALUES
          DEPENDING ON PROTON AND PION RANGES.  THE SCHMIDT 65 MASSES HAVE
          BEEN REEVALUATED USING OUR APRIL 1973 PROTON AND K+- AND PI+-
          MASSES.  P. SCHMIDT, PRIVATE COMMUNICATION, (1974).

M            1115.44      0.12             BHOWMIK   63 RVUE +  SEE NOTE L BELOW
M     L   ABOVE LAMBDA MASS HAS BEEN RAISED 35 KEV TO ACCOUNT FOR 46 KEV
M     L   INCREASE IN PROTON MASS AND 11 KEV DECREASE IN PI+- MASS.
M     S  635(1115.86)   (0.09)             BALTAY    65 HBC    ERROR IS STATIS.
M         488 1115.65     0.07             SCHMIDT   65 HBC  SEE NOTE N
M     S 1147(1115.74)   (0.04)             CHIEN     66 HBC      6.9 PBAR P
M     S  972(1115.69)   (0.05)             CHIEN     66 HBC      6.9 PBAR PANTIL
M            1115.6       0.4              LONDON    66 HBC
M           (1116.0)     (0.2)             BADIER    67 HBC      2.4 PBAR P,LLBAR
M         195 1115.39     0.12             MAYEUR    67 EMUL
M     B 1524(1115.52)   (0.03)             BOHM      70 EMUL
M         935 1115.59     0.08             HYMAN     72 HEBC
M     B   AVERAGE OF VERY INCONSISTENT DATA. ERROR STATISTICAL ONLY. AUTHORS
M     B   DETECT SYSTEMATIC EFFECT OF ABOUT .15 MEV, WHICH THEY ATTRIBUTE
M     B   TO ERROR IN RANGE-ENERGY RELATIONS, IN REGION BETA=0.6-0.7.
M     B   THIS EFFECT, IF CONFIRMED, WOULD AFFECT VERY LITTLE THE VALUES OF
M     B   BHOWMICK 63 AND MAYEUR 67.
M     S   ERROR PURELY STATISTICAL.
M            . . . . . . . . . . .
M     AVG    1115.566     0.056   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
M     FIT    1115.596     0.046  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)  |
                          (SEE IDEOGRAM BELOW)
```



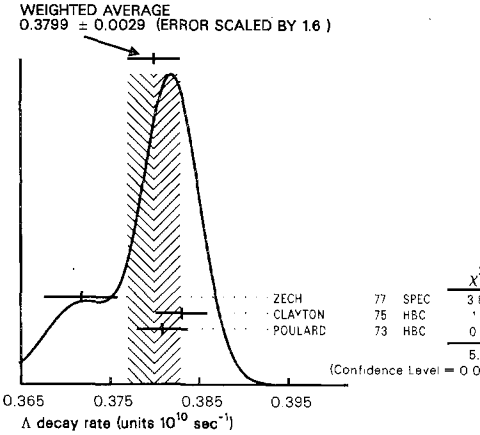
Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

Λ−$\overline{\Lambda}$ MASS DIFFERENCE (MeV)

```
DM       TEST OF CPT
DM              0.05      0.06             CHIEN     66 HBC      6.9 PBAR P
DM              0.29      0.15             BADIER    67 HBC      2.4 PBAR P
DM             . . . . . . . . . .
DM   AVG        0.083     0.083    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
```

Λ MEAN LIFE (units 10^{-10} sec)

```
T    O   188    (2.63)    (0.21)    (0.21) BOLDT     58 CC
T    O   825    (2.72)    (0.16)    (0.16) CRAWFORD  59 HBC
T    O   140    (2.72)    (0.29)    (0.27) BOWEN     60 CC
T    O   186    (2.60)    (0.28)    (0.20) CHANG     62 HBC
T    O   799    (2.69)    (0.11)    (0.11) HUMPHREY  62 HBC
T    O  2239    (2.36)    (0.06)    (0.06) BLOCK     63 HEBC
T    O   706    (2.76)    (0.20)           CHRETIEN  63 HLBC
T    O   794    (2.59)    (0.09)           HUBBARD   64 HBC
T    O  2260    (2.31)    (0.10)           KREISLER  64 OSPK
T    O  1378    (2.59)    (0.07)           SCHWARTZ  64 HBC
T    O   635    (2.51)    (0.16)           BALTAY    65 HBC
T    O  2534    (2.6)     (0.1)            HILL      65 OSPK
T    O   916    (2.35)    (0.09)           BURAN     66 HLBC
T    S  1147    (2.50)    (0.14)           CHIEN     66 HBC      6.9 PBAR P
T    S   972    (2.70)    (0.20)           CHIEN     66 HBC      6.9 PBAR P,ANTI
T    O  2213    (2.452)   (0.056)   (0.054)ENGELMANN 66 HBC
T    O   585    (2.68)    (0.13)    (0.11) AUERBACH  67 OSPK
T    O          (2.44)    (0.15)           BADIER    67 HBC      2.4 PBAR P
T    O          (2.55)    (0.15)           BADIER    67 HBC      2.4 PBAR P,ANTIL
T    O  8342    (2.535)   (0.035)          GRIMM     68 HBC
T    O  2600    (2.47)    (0.08)           HEPP      68 HBC
T    O  1059    (2.39)    (0.10)           DEMIDOV   70 HLBC PI-P, 3.86 GEV/C
T    O  4572    (2.54)    (0.04)           BALTAY    71 HBC      K-P AT REST
T    O  6582    (2.69)    (0.05)           ALTHOFF2  73 OSPK     PI+N TO K+LAMBDA
T          36K   2.626     0.020           POULARD   73 HBC      K-P,KMOM .4TO2.3
T          34K   2.611     0.020           CLAYTON   75 HBC      K-P,KMOM .96-1.4
T          53K   2.69      0.03            ZECH      77 SPEC NEUTRAL HYP. BEAM
T    O   OLD LOWER STATISTICS EXPERIMENTS NOT INCLUDED IN AVERAGE.
T    S   ERROR PURELY STATISTICAL.
T             . . . . . . . . . .
T    AVG         2.632     0.020    0.020  AVERAGE (ERROR INCL. SCALE FACTOR OF 1.6)
                           (SEE IDEOGRAM BELOW)
```



(Λ−$\overline{\Lambda}$)/AVG., MEAN LIFE DIFFERENCE

```
DT      TEST OF CPT
DT             0.044     0.085            BADIER    67 HBC      2.4 PBAR P
```

Λ MAGNETIC MOMENT (MAGNETONS, 938.26 MeV)

```
MM              -1.5      0.5              COOL      62 OSPK
MM               0.0      0.6              KERNAN    63 CC
MM      8553    -1.39     0.72             ANDERSON  64 HBC
MM       151    -0.5      0.28             CHARRIERE 65 EMUL
MM        49   (-0.67)   (0.31)    (0.37)  BARKOV    71 EMUL    PRELIM. RESULT
MM      1300    -0.66     0.07             DAHLJENSE 71 EMUL    MAG FIELD=200KG
MM      3868    -0.73     0.18             HILL      71 OSPK
MM        57    -0.65     0.28             BARKOV    72 EMUL INCLUDES BARKOV 71
MM      1.2M    -0.57     0.05             BUNCE     76 SPEC
MM      350K    -0.59     0.07             HELLER    77 SPEC
MM        3M    -0.6138   0.0047           SCHACHING 78 SPEC
MM      200K    -0.606    0.015            COX       81 SPEC
MM            . . . . . . . . . .
MM   AVG        -0.6130   0.0044   AVERAGE
```

Λ ELECTRIC DIPOLE MOMENT (units 10^{-14} e-cm)

NONZERO VALUE IMPLIES VIOLATION OF T AND P

```
EDM            (5.0)   OR LESS   CL=.95   GIBSON    66 EMUL
EDM   B        (1.0)   OR LESS   CL=.95   BARONI    71 EMUL
EDM   P         0.015 OR LESS    CL=.95   PONDROM   81 SPEC
EDM   B  BARONI MEASURES (-5.9+-2.9)*10**-15 E CM
EDM   P  PONDROM 81 MEASURE (-3.0+-7.4)*10**-17 E CM .
```

Λ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda \to p\,\pi^-$	938+ 140
P2	$\Lambda \to n\,\pi^0$	940+ 135
P3	$\Lambda \to p\,\mu^-\nu$	938+ 106+ 0
P4	$\Lambda \to p\,e^-\nu$	938+.511+ 0
P5	$\Lambda \to p\,\pi^-\gamma$	938+ 140+ 0

Λ BRANCHING RATIOS

$\Lambda \to (p\,\pi^-)/((p\,\pi^-)+(n\,\pi^0))$ (P1)/(P1+P2)

```
R1              0.627     0.031            CRAWFORD  59 HBC
R1              0.65      0.05             COLUMBIA  60 HBC
R1   U         (0.685)   (0.017)           ANDERSON  62 HBC
R1       903    0.643     0.016            HUMPHREY  62 HBC
R1 U    6736    0.635     0.007            DOYLE     69 HBC     PI-P TO LAM. KO
R1      4572    0.646     0.008            BALTAY    71 HBC     K-P AT REST
R1   U   ANDERSON RESULT NOT PUBLISHED, EVENTS ADDED TO DOYLE SAMPLE.
R1           . . . . . . . . . .
R1   AVG        0.6399    0.0049   AVERAGE
R1   FIT        0.6419    0.0049  FROM FIT
```

$\Lambda \rightarrow (n\,\pi^0)/((p\,\pi^-)+(n\,\pi^0))$ (P2)/(P1+P2)

```
R2              0.23      0.09                 EISLER    57 HLBC
R2              0.43      0.14                 CRAWFORD  59 HBC
R2              0.28      0.08                 BAGLIN    60 HLBC
R2              0.35      0.05                 BROWN     63 HLBC
R2        75    0.291     0.034                CHRETIEN  63 HLBC
R2            . . . . . . . . . . .
R2   AVG        0.304     0.025   AVERAGE
R2   FIT        0.3581    0.0049 FROM FIT
```

$\Lambda \rightarrow (p\,e^-\,\nu)/\text{total}$ (units 10^{-3}) (P4)/(P1+P2)

```
R3  O   15   (2.0)     (0.5)              HUMPHREY  61 RVUE
R3  O    8   (2.9)     (1.5)       (1.2)  AUBERT    62 FBC
R3  N  150   (0.82)    (0.12)             ELY       63 FBC      K- AT REST
R3  N  102   (0.78)    (0.12)     (0.13)  BAGLIN    64 FBC      K- AT 1.45 GEV/C
R3  O   20   (1.55)    (0.34)             LIND      64 HBC
R3  N  143   (0.80)    (0.08)             MALONEY   69 HBC
R3  N   86   (0.78)    (0.09)             CANTER    71 HBC      K-P AT REST
R3  N  218   (0.88)    (0.10)             LINDQUIST 71 OSPK     PI- P TO K0 LAM
R3  N    THESE VALUES HAVE BEEN CHANGED BY US INTO RATIOS TO PROTON PI-,
R3  N    BECAUSE THAT IS THE DIRECTLY MEASURED QUANTITY. SEE R5 BELOW
R3  O    LOW STATISTICS EXPERIMENTS.  NOT AVERAGED
```

$\Lambda \rightarrow (p\,\mu^-\,\nu)/\text{total}$ (units 10^{-4}) (P3)/(P1+P2)

```
R4         1    (0.2)   OR MORE               GOOD       62 HBC
R4         1    (1.0)   OR LESS               ALSTON     63 HBC
R4         2    (1.0)   OR LESS               KERNAN     64 FBC
R4       BETWEEN 1.3 AND 6.0                  LIND       64 HBC
R4         3     1.3       0.7                LIND       64 RVUE
R4         2     1.5       1.2                RONNE      64 FBC
R4         9     2.4       0.8                CANTER1    71 HBC      STOPPED K-P
R4        14     1.4       0.5                BAGGETT2   72 HBC      STOP K-
R4             . . . . . . . . . . .
R4  AVG          1.57      0.35     AVERAGE
```

$\Lambda \rightarrow (p\,e^-\,\nu)/(p\,\pi^-)$ (units 10^{-3}) (P4)/(P1)

```
R5       150     1.23      0.20               ELY        63 FBC
R5       120     1.17      0.18               BAGLIN     64 FBC
R5       143     1.20      0.12               MALONEY    69 HBC
R5      1078     1.31      0.06               ALTHOFF1   71 OSPK
R5    C   86     1.17      0.13               CANTER     71 HBC      K-P AT REST
R5   LC  218    (1.32)    (0.15)              LINDQUIST  71 OSPK     PI-P TO K0 LAM
R5      1089     1.27      0.07               KATZ       73 HBC
R5    L  544     1.23      0.11               LINDQUIST  77 SPEC     PI-P TO K0 LAM
R5       10K     1.313     0.024              WISE       80 SPEC
R5      7111     1.335     0.056              BOURQUIN   83 SPEC SPS HYPERON BEAM
R5    C  CALCULATED BY US FROM R3 ASSUMING THE AUTHORS USED (P PI-)/TOT=2/3
R5    L  LINDQUIST 77 INCLUDES DATA OF LINDQUIST 71.
R5             . . . . . . . . . . .
R5  AVG          1.301     0.019    AVERAGE
```

$\Lambda \rightarrow (p\,\pi^-\,\gamma)/(p\,\pi^-)$ (units 10^{-3}) (P5)/(P1)

```
R6        72     1.32      0.22               BAGGETT3   72 HBC  PI- MOM LT 95 MEV/C
```

Λ DECAY PARAMETERS

SEE NOTE ON BARYON DECAY PARAMETERS IN NEUTRON SECTION ABOVE.

$\alpha_-(\Lambda \rightarrow \pi^-\,p)$

```
A-     1156     0.62      0.07                CRONIN     63 CNTR     LAMBDA FROM PI-P
A-             (0.663)   (0.022)              BERGE      66 RVUE   INCLUDES ABOVE
A-    10130     0.645     0.017               OVERSETH   67 OSPK     LAMBDA FROM PI-P
A-   M 2529    (0.747)   (0.086)              MERRILL    68 HBC   REPL BY DAUBER 68
A-     3520     0.67      0.06                DAUBER     69 HBC   FROM XI DECAY
A-    10325     0.649     0.023               CLELAND    72 OSPK     LAMBDA FROM PI-P
A-     8500     0.584     0.046               ASTBURY    75 SPEC     LAMBDA FROM PI-P
A-            . . . . . . . . . . .
A-   AVG        0.642     0.013    AVERAGE
```

α_0/α_- FOR Λ $(\Lambda \rightarrow \pi^0 n/\Lambda \rightarrow \pi^- p)$

```
A0               1.10      0.27               CORK       60 CNTR
A0 O   4760      1.000     0.068              OLSEN      70 OSPK PI+N TO K+ LAMBDA
A0 O     DONE BY COMPARING PROTON DISTR.WITH N DISTR. FROM LAMBDA DECAY.
A0            . . . . . . . . . . .
A0   AVG         1.006     0.066   AVERAGE
```

$\alpha(\bar{\Lambda})/\alpha(\Lambda)$

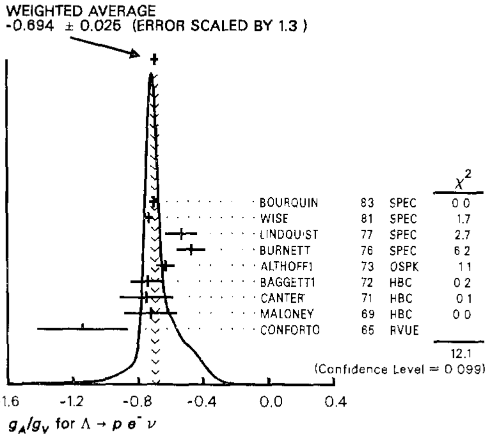
```
AL       TEST OF CP
AL A    10K    -1.04      0.29                CHAUVAT    85 CNTR     PP, PBAR P ISR
AL A     ASSUMES POLARIZATION IS SAME IN PBAR P TO LAMBDABAR X AND P P TO
AL A     LAMBDA X.  TESTS OF THIS ASSUMPTION, BASED ON C-INVARIANCE AND
AL A     FRAGMENTATION, ARE SATISIFIED BY THE DATA.
```

ϕ ANGLE (degrees) $(\tan\phi = \beta/\gamma)$

```
F-     1156     13.0      17.0                CRONIN     63 OSPK     LAMBDA FROM PI-P
F-    10130     -8.0       6.0                OVERSETH   67 OSPK     LAMBDA FROM PI-P
F-     7377    (-9.2)     (5.2)               CLELAND    67 OSPK REPL BY CLELAND 72
F-    10325     -7.0       4.5                CLELAND    72 OSPK     LAMBDA FROM PI-P
F-            . . . . . . . . . . .
F-   AVG        -6.5       3.5     AVERAGE
```

g_A/g_V FOR $\Lambda \rightarrow p\,e^-\,\nu$

```
AV       (FOR SIGN CONVENTION, SEE NOTE ON BARYON DECAY PARAMETERS IN
AV       NEUTRON SECTION ABOVE.)
AV   C    22   (-1.03)                        LIND        64 HBC
AV   C   102    (0.6)   OR MORE               BAGLIN      65 HLBC     NO SIGN GIVEN
AV   C       BETW 0. AND -1.1                 BARLOW      65 OSPK
AV   C   102    (0.7)   OR MORE  CL=.95       ELY         65 HLBC      ABS. VALUE
AV   C   EXPERIMENTS INCLUDED IN CONFORTO 65, RVUE
AV              -1.14      0.23       0.33    CONFORTO    65 RVUE
AV M     148    -0.72      0.14       0.19    MALONEY     69 HBC
AV   A 1078   (-0.62)    (0.08)     (0.09)    ALTHOFF2    71 OSPK     POLARIZED LAMBDA
AV M     141    -0.75      0.15       0.18    CANTER      71 HBC
AV   L   173  (-0.40)    (0.13)     (0.17)    LINDQUIST   71 OSPK   E-NU AND UP-DOWN
AV M     352    -0.74      0.09       0.12    BAGGETT1    72 HBC      STOP.K-
AV A     817    -0.63      0.06               ALTHOFF1    73 OSPK     POLARIZED LAMBDA
AV       405    -0.47      0.09               BURNETT     76 SPEC     E-NU AND SPIN
AV    L 441     -0.53      0.09       0.11    LINDQUIST   77 SPEC POL LAMBDA, 3 ASYMM
AV M     10K    -0.734     0.031              WISE        81 SPEC E-NU ANG. CORREL.
AV      7111    -0.70      0.03               BOURQUIN    83 SPEC XI- --> LAMBDA PI-
AV   A   ALTHOFF1 73 INCLUDES DATA OF ALTHOFF2 71.  USES PROT SPECTRUM AND
AV   A   THREE SPIN ASYMMETRIES.
AV M     EXPT MEASURES ONLY THE ABSOLUTE VALUE OF A/V
AV    L  LINDQUIST 77 INCLUDES DATA OF LINDQUIST 71.
AV            . . . . . . . . . . .
AV   AVG        -0.694     0.025   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
                          (SEE IDEOGRAM BELOW)
```



REFERENCES FOR Λ

```
EISLER   57 NC      5 1700      EISLER,PLANO,SAMIOS,SCHWARTZ +   (COLU+BNL)
BOLDT    58 PRL     1  148      E BOLDT,D O CALDWELL,Y PAL            (MIT)
CRAWFORD 59 PRL     2  266      CRAWFORD,CRESTI,DOUGLASS,GOOD +       (LRL)

BAGLIN   60 NC     18 1043      BAGLIN,BLOCH,BRISSON,HENNESSY +      (EPOL)
BOWEN    60 PR    119 2030      BOWEN,HARDY,REYNOLDS,SUN +      (PRINCETON)
CORK     60 PR    120 1000      CORK,KERTH,WENZEL,CRONIN+    (LRL+PRIN+BNL)
COLUMBIA 60 ROCH CONF 726       M SCHWARTZ +                     (COLUMBIA)
HUMPHREY 61 PRL     6  478      HUMPHREY,KIRZ,ROSENFELD,RHEE +   (LRL+SYRA)

ANDERSON 62 CERN CONF 832       ANDERSON,CRAWFORD,GOLDEN,LLOYD +      (LRL)
AUBERT   62 NC     25  479      AUBERT,BRISSON,HENNESSY,SIX +        (EPOL)
CHANG    62 THESIS DUKE         CHUEN CHUEN CHANG                    (DUKE)
COOL     62 PR    127 2223      COOL,HILL,MARSHALL +     (BNL+MIT+NYU+ANL)
GOOD     62 PRL     9  518      M L GOOD,V G LIND               (WISCONSIN)
HUMPHREY 62 PR    127 1305      W E HUMPHREY,R R ROSS                 (LRL)

ALSTON   63 UCRL 10926          ALSTON,KIRZ,NEUFELD,SOLMITZ,WOHLMUT   (LRL)
BHOWMIK  63 NC     28 1494      B BHOWMIK,D P GOYAL                 (DELHI)
BLOCK    63 PR    130  766      BLOCK,GESSAROLI,RATTI+(NWES+BGNA+SYRA+ORNL)
BROWN    63 PR    130  769      BROWN,KADYK,TRILLING,ROE +       (LRL+MICH)
CHRETIEN 63 PR    131  2208     CHRETIEN,CROUCH+   (BRAN+BROWN+HARVARD+MIT)
CRONIN   63 PR    129 1795      J W CRONIN,O E OVERSETH         (PRINCETON)
ELY      63 PR    131  868      ELY,GIDAL,KALMUS,OSWALD,POWELL +      (LRL)
KERNAN   63 PR    129  870      KERNAN,NOVEY,WARSHAW,WATTENBERG   (ANL+ILL)

ANDERSON 64 PRL    13  167      J A ANDERSON,F S CRAWFORD             (LRL)
BAGLIN   64 NC     35  977      BAGLIN,BINGHAM+  (EPOL+CERN+LOUC+RHEL+BERG)
HUBBARD  64 PR    135 B 183     HUBBARD,BERGE,KALBFLEISCH,SHAFER +    (LRL)
KERNAN   64 PR    133 B 1271    KERNAN,POWELL,SANDLER +          (LRL+LOUC)
KREISLER 64 PR 136 B 1074       M N KREISLER,O OVERSETH,J CRONIN     (PRIN)
LIND     64 PR    135 B 1483    LIND,BINFORD,GOOD,STERN         (WISCONSIN)
RONNE    64 PL     11   357     RONNE+          (CERN+EPOL+LOUC++UNIV.BERGEN)
SCHWARTZ 64 UCRL 11360 THESIS   JOSEPH ADAM SCHWARTZ                  (LRL)

BAGLIN   65 NC 35 977           BAGLIN +         (EPOL,CERN,LOUC,RHEL,BERGEN)
BALTAY   65 PR 140 B 1027       BALTAY,SANDWEISS,CULWICK,KOPP +  (YALE+BNL)
BARLOW   65 PL   18  64         J BARLOW,BLAIR,CONFORTO+   (CERN+RHEL+PENN)
CHARRIER 65 PL    15    66      CHARRIERE,GIBSON+      (EPOL+BRIS+CERN+MPIM)
    ALSO 66 NC   46A  205       CHARRIERE,GIBSON +     (EPOL,BRIS,CERN,MPIM)
CONFORTO 65 EC INT HERZEGNOVI   G CONFORTO                           (CERN)
ELY      65 PR 137 B1302        ELY,GIDAL,KALMUS,POWELL +       (LRL,LOUC)
HILL     65 PRL 15 85           HILL,LI,JENKINS,KYCIA,RUDERMAN    (MIT,BNL)
SCHMIDT  65 PR 140 B 1328       P SCHMIDT                        (COLUMBIA)

BERGE    66  BERKELEY 46        BERGE,CABIBBO              ((RVUE) LRL,CERN)
BURAN    66 PL 20 318           BURAN,EIVINDSON,SKJEGGESTAD,TOFTE +  (OSLO)
CHIEN    66 PR   152  1171      +LACH,SANDWEISS,TAFT,YEH,OREN +  (YALE+BNL)
ENGELMAN 66 NC 45A  1038        ENGELMANN,FILTHUTH,ALEXANDER+   (HEID,REHO)
GIBSON   66 NC 45A 882          W M GIBSON,K GREEN                   (BRIS)
LONDON   66 PR 143 1034         LONDON,RAU,GOLDBERG,LICHTMAN+    (BNL,SYRA)

AUERBACH 67 NC  47A  19         AUERBACH,BOWEN,DOBBS,LANDE,MANN+     (PENN)
BADIER   67 PL 25B 152          +BONNET,BRIANDET,SADOULET            (EPOL)
CLELAND  67 PL 26B 45           CLELAND,BIENLEIN,CONFORTO+ (CERN+GEVA+LUND)
MAYEUR   67 U.LIBR.BRUX.BUL32 C.MAYEUR,E.TOMPA,J.WICKENS        (BELG,LOUC)
OVERSETH 67 PRL  19  391        O E OVERSETH, R F ROTH          (MICH+PRIN)
GRIMM    68 NC 54A 187          H.-J.GRIMM                     (HEIDELBERG)
HEPP     68 ZPHY 214 71         V.HEPP,H. SCHLEICH             (HEIDELBERG)
MERRILL  68 PR 167 1202         MERRILL,SHAFER                        (LRL)

DAUBER   69 PR  179 1262        +BERGE,HUBBARD,MERRILL,MILLER         (LRL)
DOYLE    69 UCRL 18139-THESIS J.C. DOYLE                              (LRL)
MALONEY  69 PRL 23 425          MALONEY,SECHI-ZORN         (UNIV MARYLAND)
BOHM     70 NC 70A 384          + KRECKER + (BERL+BRUX+DUUC+LOUC+LOWC+WARS)
DEMIDOV  70 SJNP 10 681         +KIRILLOV-UGRYUMOV,PONOSOV,PROTASOV+ (ITEP)
OLSEN    70 PRL 24 843          +PONDROM,HANDLER,LIMON,SMITH +  (WISC,MICH)

ALTHOFF1 71 PL 37B 531          +BROWN,FREYTAG,HEARD,HEINTZE +  (CERN,HEID)
ALTHOFF2 71 PL 37B 535          +BROWN,FREYTAG,HEARD,HEINTZE +  (CERN,HEID)
BALTAY   71 PR D4 670           +BRIDGEWATER,COOPER,HABIBI+     (COLU+BING)
BARKOV   71 JETPL 14 60         +GUREVICH,MAKARINA,MARTEMYANOV+      (ITEP)
BARONI   71 LNC 2 1256          G BARONI,S PETRERA,G ROMANO          (ROMA)
CANTER   71 PRL 26 868          +COLE,LEE-FRANZINI,LOVELESS +   (STON+COLU)

CANTER1  71 PRL 27 59           +COLE,LEE-FRANZINI,LOVELESS+    (STON+COLU)
DAHLJENS 71 NC 3A 1             DAHL-JENSEN +    (CERN+ANKA+LAUS+MPIM+ROMA)
HILL     71 PR D4 1979          +LI,JENKINS,KYCIA,RUDERMAN         (MIT,BNL)
    ALSO 65 PRL 15 85           HILL,LI,JENKINS,KYCIA,RUDERMAN     (MIT,BNL)
LINDQUIS 71 PRL 27 612          LINDQUIST,SUMNER+           (EFI,WUSL,OSU,ANL)

BAGGETT1 72 ZPHY 249 279        +BAGGETT,EISELE,FILTHUTH,FREHSE+     (HEID)
BAGGETT2 72 ZPHY 252 362        +BAGGETT,EISELE,FILTHUTH,FREHSE+     (HEID)
BAGGETT3 72 PL 42B 379          +BAGGETT,EISELE,FILTHUTH,FREHSE,HEPP+(HEID)
BARKOV   72 JETPL 16 104        +GUREVICH,MAKARINA,MARTEMYANOV +     (ITEP)
CLELAND  72 NP B40 221          +CONFORTO,EATON,GERBER+    (CERN+GEVA+LUND)
HYMAN    72 PR D5 1063          +BUNNELL,DERRICK,FIELDS,KATZ+    (ANL+CARN)
```

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ALTHOFF1 73 PL 43B 237          +BROWN,FREYTAG,HEARD,HEINTZE+   (CERN+HEID)
ALTHOFF2 73 NP B66 29           +BROWN,FREYTAG,HEARD,HEINTZE+   (CERN+HEID)
KATZ     73 THESIS (MARYLAND) C.N.KATZ                                 (UMD)
POULARD  73 PL 46B 135          +GIVERNAUD,BORG                        (SACL)

ASTBURY  75 NP B99 30           +GALLIVAN,JAFAR +      (LOIC+CERN+ETH+SACL)
CLAYTON  75 NP B95 130          +BACON,BUTTERWORTH,WATERS +     (LOIC+RHEL)
BUNCE    76 PRL 36 1113         +HANDLER,MARCH,MARTIN +    (WISC+MICH+RUTG)
BURNETT  76 NC 34A 14           +INNES,MASEK,MAUNG,MILLER,RUDERMAN+  (UCSC)

HELLER   77 PL 68B 480          +OVERSETH,BUNCE,DYDAK +    (MICH+WISC+HEID)
LINDQUIS 77 PR D16 2104         LINDQUIST,SWALLOW,SUMNER +    (EFI+OSU+ANL)
    ALSO 76 JPG 2 L211          LINDQUIST,SWALLOW,SUMNER+(EFI+WUSL+OSU+ANL)
ZECH     77 NP B124 413         +DYDAK,NAVARRIA+        (SIEG+CERN+DORT+HEID)
SCHACHIN 78 PRL 41 1348         SCHACHINGER,BUNCE,COX +    (MICH+RUTG+WISC)

WISE     80 PL 91B 165          +JENSEN,KREISLER,LOMANNO,POSTER+ (MASA+BNL)
COX      81 PRL 46 877          +DWORKIN +           (MICH+WISC+RUTG+MINN+BNL)
PONDROM  81 PR D23 814          +HANDLER,SHEAFF,COX + (WISC+MICH+RUTG+MINN)
WISE     81 PL 98B 123          +JENSEN,KREISLER,LOMANNO,POSTER+ (MASA+BNL)
BOURQUIN 83 ZPHY C21 1          +BROWN+         (BRIS+GEVA+HEID+LALO+RL+STRB)
CHAUVAT  85 PL 163B 273         +ERHAN,HAYES,+          (CERN+UDCF+UCLA+SACL)

                                PAPERS NOT REFERRED TO IN DATA LISTINGS

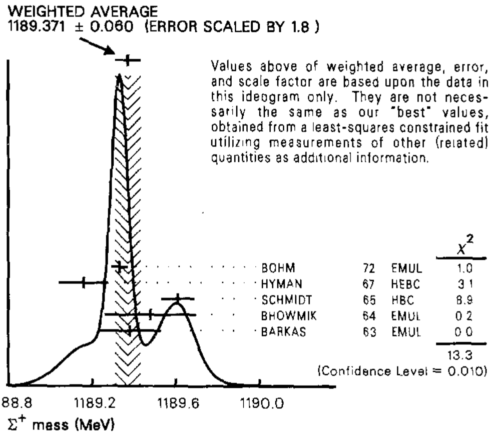
ARMENTER 62 CERN CONF 236       ARMENTEROS+(CERN+EPOL+LOIC+BIRM+CEN-SACLAY)
BALTAY   62 CERN CONF 233       BALTAY,FOWLER,SANDWEISS,CULWICK+ (YALE+BNL)
BERGE    63 THESIS (BERKELEY) J PETER BERGE                            (LRL)
```

$\boxed{\Sigma^+}$ $I(J^P) = 1(\frac{1}{2}^+)$

Σ^+ MASS (MeV)

```
      SEE NOTE PRECEDING LAMBDA MASS LISTINGS

M        144 1189.38     0.15             BARKAS    63 EMUL +  SEE NOTE S BELOW
M         58 1189.48     0.22             BHOWMIK   64 EMUL +  SEE NOTE S BELOW
M    S  ABOVE SIGMA+ MASSES HAVE BEEN RAISED 30  KEV TO ACCOUNT FOR 46 KEV
M    S  INCREASE IN PROTON MASS AND 21 KEV DECREASE IN PION MASS
M       4205 1189.61     0.08             SCHMIDT   65 HBC  SEE NOTE N
M            1189.16     0.12             HYMAN     67 HEBC
M      B 607 1189.33     0.04             BOHM      72 EMUL
M      B  BOHM 72 UPDATED WITH PDG APR. 73 K-, PI- AND PIO MASSES.
M            . . . . . . . . . .
M    AVG     1189.371    0.060   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)
M    FIT     1189.365    0.057  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.8)  |
                         (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

Σ^+ MEAN LIFE (units 10^{-10} sec)

```
T                                          GLASER    58 RVUE
T       127     0.98      0.16      0.12  PUSCHEL   60 EMUL
T        41     0.82      0.34      0.20  EVANS     60 EMUL
T       117     0.85      0.14      0.11  FREDEN    60 EMUL
T        54     0.80      0.10      0.067 KAPLON    60 EMUL
T        23     0.76      0.22      0.14  CHIESA    61 EMUL
T        49     0.75      0.13      0.09  BERTHELOT 61 HLBC
T       140     0.82      0.10      0.08  BARKAS    61 EMUL
T       192     0.749     0.056     0.052 GRARD     62 HBC
T       456     0.765     0.04            HUMPHREY  62 HBC
T       203     0.84      0.12      0.08  BHOWMIK   64 EMUL
T       181     0.84      0.09            BALTAY    65 HBC
T       900     0.76      0.03            CARAYAN   65 HBC
T   C  1300     0.83      0.032           CHANG     66 HBC
T    S  125    (0.86)    (0.15)           CHIEN     66 HBC  +   6.9 PBAR P
T    S  117    (1.10)    (0.24)           CHIEN     66 HBC   -  6.9 PBAR P,ANTI
T       381     0.80      0.07            COOK      66 OSPK
T     10664     0.803     0.008           BARLOUTAU 69 HBC     K-P .4-1.2 GEV/C
T       20K     0.795     0.010           EISELE    70 HBC     K-P AT REST
T       526     0.83      0.04            BAKKER    71 DBC     K-N TO SIG+ 2PI-
T      5719     0.807     0.013           CONFORTO  76 HBC     K-P 1-1.4 GEV/C
T       30K     0.798     0.005           MARRAFFIN 80 HBC     K- P TO SIG+ PI-
T   C    CHANG ERROR 0.018 RAISED BY US.  SEE 1970 EDITION, RMP 42,123(1970)
T    S   ERROR PURELY STATISTICAL
T           . . . . . . . . . .
T    AVG        0.7997    0.0036    0.0036 AVERAGE
```

Σ^+ MAGNETIC MOMENT (MAGNETONS, 938.26 MeV)

```
MM     381    1.5       1.1                 COOK      66 OSPK
MM      52    3.5       1.5                 KOTELCHUC 67 EMUL     K-P AT 1.15BEV/C
MM      51    3.0       1.2                 SULLIVAN  67 EMUL     PHOTOPRODUCTION
MM      69    3.5       1.2                 COMBE     68 EMUL
MM   29333    2.1       1.0                 MAST      68 HBC      K-P AT .4 GEV/C
MM     955    2.67      0.97                ALLEY     71 OSPK     1.28 GEV/C PI+P
MM    2651    2.7       0.9                 SAHA      73 HLBC     K-P.25TO.55GEV/C
MM  S 8503   (2.95)    (0.31)               DOBLE     77 HBC      K-P .46 GEV/C
MM   S 14K    2.30      0.14                SETTLES   79 HBC      K-P.42TO.50GEV/C
MM     44K    2.38      0.02                ANKENBRAN 83 CNTR     210GEV HYP.BEAM
MM   S  SETTLES 79 INCLUDES DOBLE 77 DATA.
MM           . . . . . . . . . .
MM  AVG        2.379     0.020   AVERAGE
```

Σ^+ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma^+ \to p\,\pi^0$	938+ 135
P2	$\Sigma^+ \to n\,\pi^+$	940+ 140
P3	$\Sigma^+ \to n\,\pi^+\gamma$	940+ 140+ 0
P4	$\Sigma^+ \to \Lambda\,e^+\nu$	1116+.511+ 0
P5	$\Sigma^+ \to p\,\gamma$	938+ 0
P6	$\Sigma^+ \to n\,\mu^+\nu$	940+ 106+ 0
P7	$\Sigma^+ \to n\,e^+\nu$	940+.511+ 0
P8	$\Sigma^+ \to p\,e^+e^-$	938+.511+.511

Σ^+ BRANCHING RATIOS

$\Sigma^+ \to (n\,\pi^+)/(N\,\pi)$ (P2)/(P1+P2)

```
R1      308     0.490     0.024            HUMPHREY  62 HBC
R1      534     0.46      0.02             CHANG     66 HBC
R1     1331     0.488     0.010            BARLOUTAU 69 HBC     K-P .4-1.2 GEV/C
R1      537     0.484     0.015            TOVEE     71 EMUL
R1     1861     0.488     0.008            NOWAK     78 HBC   BRITISH 1.5M (TST)
R1    M 10K     0.4828    0.0036           MARRAFFIN 80 HBC     K-P 420-500MEV/C
R1    M  MARRAFFINO 80 GIVES BR TO (P PIO)/ALL.  WE QUOTE 1-BR.
R1           . . . . . . . . . .
R1   AVG        0.4836    0.0030  AVERAGE
```

$\Sigma^+ \to (n\,\pi^+\gamma)/(\pi^+ n)$ (units 10^{-3}) (P3)/P2

```
R2             (1.8)      ABOUT            BAZIN2    65 HBC     PI+ LT 116 MEV/C
R2       29    (0.27)    (0.05)            ANG       69 HBC     PI+ LT 110 MEV/C
R2      180     0.93      0.10             EBENHOH   73 HBC     PI+ LT 150 MEV/C
R2       PI+ MOMENTUM CUTS DIFFER, NOT AVERAGED. LATEST VALUE USED IN
R2       SUMMARY TABLE.
```

$\Sigma^+ \to (\Lambda\,e^+\nu)$/total (units 10^{-5}) (P4)

```
R3  W     4    (3.3)     (1.7)             WILLIS    64 HBC     STOP. K-
R3  W                    EVENTS FROM THIS EXPERIMENT,INCLUDED IN EISELE1 69
R3        6     2.0       0.8              BARASH    67 HBC     STOP K-
R3        5     1.6       0.7              BALTAY    69 HBC     STOP K-
R3       10     2.9       1.0              EISELE1   69 HBC     STOP K-
R3           . . . . . . . . . .
R3   AVG        2.02      0.47    AVERAGE
```

$\Sigma^+ \to (p\,\gamma)/(p\,\pi^0)$ (units 10^{-2}) (P5)/(P1)

```
R4        1    (0.068)OR LESS              CARRARA   64 HBC
R4       24     0.37      0.08             BAZIN     65 HBC
R4        4    (0.17)                      QUARENI   65 EMUL
R4       45     0.21      0.03             ANG       69 HBC     STOP K-
R4       31     0.276     0.051            GERSHWIN  69 HBC
R4       46     0.211     0.038            MANZ      80 HBC  K- P-->SIGMA+ PI-
R4      155     0.246     0.030     0.035 BIAGI     85 CNTR    CERN HYPER. BEAM  |
R4           . . . . . . . . . .
R4   AVG        0.236     0.019   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$\Sigma^+ \to (n\,e^+\nu)/(n\,\pi^+)$ (units 10^{-5}) (P7)/(P2)

```
R5       TEST OF DELTA-S = DELTA-Q RULE
R5 EO     0    (16220)EFFECTIVE DENOM.  COURANT   64 HBC      SEE NOTE E
R5 EO     0     (2720)EFFECTIVE DENOM.  MURPHY    64 HBC      SEE NOTE E
R5 EO     1     (9690)EFFECTIVE DENOM.  NAUENBERG 64 HBC      SEE NOTE E
R5  O     0    (32406)EFFECTIVE DENOM.  BIERMAN   68 HBC
R5 UA     0    (80400)EFFECTIVE DENOM.  EISELE2   69 HBC      STOP K-
R5 UO     1    (30000)EFFECTIVE DENOM.  NORTON    69 HBC
R5  O    OLDER LOWER STATISTICS EXPTS. NOT INCLUDED IN AVERAGE.
R5 U      0    105000 EFFECTIVE DENOM.  SECHIZORN 73 HBC      STOP K-
R5 U A    0    111000 EFFECTIVE DENOM.  EBENHOH   74 HBC      STOP K-
R5 U                  EFFECTIVE DENOM.  CALCULATED BY US
R5 E                  EFFECTIVE DENOM.  TAKEN FROM EISELE 67
R5   A  EISELE2 69 REPLACED BY BY EBENHOH 74.
R5           . . . . . . . . . .
R5   AVG        1.1   OR LESS  CL=.90  OUR AVERAGE  (2.3 EVTS)/(EFF.DNOM.SUM)  |
R5       NUMBER OF EVENTS INCREASED TO 2.3 FOR 90PC CONFIDENCE LEVEL           |
```

$\Sigma^+ \to (n\,\mu^+\nu)/(\pi^+ n)$ (units 10^{-5}) (P6)/(P2)

```
R6       TEST OF DELTA-S = DELTA-Q RULE
R6        1      (120)ANALYSED EVENTS   GALTIERI  62 EMUL     NO RATIO QUOTED
R6 E      0     10150 EFFECTIVE DENOM.  COURANT   64 HBC      SEE NOTE E
R6 E      0      1710 EFFECTIVE DENOM.  NAUENBERG 64 HBC      SEE NOTE E
R6 U      2     62000 EFFECTIVE DENOM.  EISELE2   69 HBC
R6        0     33800 EFFECTIVE DENOM.  BAGGETT   69 HBC
R6 E                  EFFECTIVE DENOM.  TAKEN FROM EISELE 67
R6 U                  EFFECTIVE DENOM.  CALCULATED BY US
R6           . . . . . . . . . .
R6   AVG        6.2   OR LESS  CL=.90  OUR AVERAGE  (6.7 EVTS)/(EFF.DNOM.SUM)  |
R6       NUMBER OF EVENTS INCREASED TO 6.7 FOR 90PC CONFIDENCE LEVEL           |
```

$(\Sigma^+ \to n\,\ell^+\nu)/(\Sigma^- \to n\,\ell^-\nu)$

```
R7       TEST OF DELTA-S = DELTA-Q RULE.
R7        0    (0.034)OR LESS               BAGGETT   67 HBC
R7        1    (0.08) OR LESS               NORTON    69 HBC
R7           . . . . . . . . . .
R7   AVG        0.043 OR LESS  CL=.90  OUR AVERAGE   USING R5 AND R6          |
```

$\Sigma^+ \to (p\,e^+e^-)$/total (units 10^{-6}) (P8)

```
R8              7.0   OR LESS               ANG       69 HBC      STOP K-
R8   A   ANG 69 FOUND 3 E+E- EVENTS IN AGREEMENT WITH GAMMA CONVERSION OF
R8   A   PROTON GAMMA DECAY -LIMIT GIVEN HERE IS FOR NEUTRAL CURRENT
```

$(\Sigma^+ \rightarrow n\,\mu^+\nu)/(\Sigma^- \rightarrow n\,\mu^-\nu)$

```
R9        2    0.06      0.045    0.03  EISELE2    69 HBC  +- STOP K-
R9              . . . . . . . . . .
R9  AVG         0.12  OR LESS  CL=.90  OUR AVERAGE   USING R6           |
```

$(\Sigma^+ \rightarrow n\,e^+\nu)/(\Sigma^- \rightarrow n\,e^-\nu)$

```
R10 E    0   (0.03) OR LESS  CL=.90   EISELE2    69 HBC  +- STOP K-
R10      0   (0.12) OR LESS  CL=.95   COLE       71 HBC  +- STOP K-
R10      0   (0.018)OR LESS  CL=.90   SECHIZORN  73 HBC  +- STOP K-,POISSON
R10  E   0   (0.019)OR LESS  CL=.90   EBENHOH    74 HBC  +- STOP K-
R10  E  EISELE2 69 REPLACED BY EBENHOH 74.
R10             . . . . . . . . . .
R10  AVG        0.009 OR LESS  CL=.90  OUR AVERAGE   USING R5           |
```

Σ^+ DECAY PARAMETERS

```
    SEE NOTE ON BARYON DECAY PARAMETERS IN NEUTRON SECTION ABOVE.
```

α_+/α_0 FOR $\Sigma^+(\Sigma^+ \rightarrow \pi^+ n)/(\Sigma^+ \rightarrow \pi^0 p)$

```
A+0           (+0.04)   (0.11)             CORK      60 CNTR    SIG+ FROM PI+P
A+0           (+0.20)   (0.24)             TRIPP     62 HBC     REPLAC.BY BANGER
A+0 O 3500    (-.014)   (0.052)            BANGERTER 66 HBC     SIG+ FROM K-P
A+0 O 2600    (-.047)   (0.07)             BERLEY    66 HBC     SIG+ FROM K-P
A+0     20K  (-0.104)   (0.028)            REUCROFT  77 HBC REPL.BY MARRAFFINO80
A+0     23K   -0.073     0.021             MARRAFFIN 80 HBC     K- P TO SIG+ PI-
A+0 O         OLD RESULTS, HAVE BEEN REPLACED. SEE BELOW.
A+0             . . . . . . . . . .
A+0 FIT       -0.069     0.013   FROM FIT                                   |
```

α_+ FOR $\Sigma^+(\Sigma^+ \rightarrow \pi^+ n)$

```
A+    35000    0.069     0.017             BANGERTER 69 HBC     K-P AT 400 MEV/C
A+     4101    0.037     0.049             BERLEY    70 HBC
A+              . . . . . . . . . .
A+   AVG       0.066     0.016   AVERAGE
A+   FIT       0.068     0.013   FROM FIT                                   |
```

α_0 FOR $\Sigma^+(\Sigma^+ \rightarrow \pi^0 p)$

```
A0              -0.80     0.16             BEALL     62 CNTR
A0             (-0.90)   (0.25)            TRIPP     62 HBC     REPLAC. BY BANGE
A0   O 5200   (-0.986)   (0.072)           BANGERTER 66 HBC     K-P TO SIG+ PI-
A0    32000    -0.999     0.022            BANGERTER 69 HBC
A0 H   1335    -0.98      0.05      0.02   HARRIS    70 OSPK    PI+P TO SIG+ K+
A0      16K    -0.940     0.045            BELLAMY   72 ASPK    PI+P TO SIG+ K+
A0 L   1259    -0.945     0.055     0.042  LIPMAN    73 OSPK    PI+P TO SIG +
A0 L    DECAY PROTONS SCATTERED OFF ALUMINUM.
A0 H    DECAY PROTONS SCATTERED OFF CARBON.
A0              . . . . . . . . . .
A0   AVG       -0.979     0.016   AVERAGE
A0   FIT       -0.980     0.015   FROM FIT                                  |
```

ϕ_+ ANGLE $(\Sigma^+ \rightarrow n\,\pi^+)$ (degrees) $(\tan\phi_+ = \beta/\gamma)$

```
F+  O  370 (180.)     (30.)                BERLEY    66 HBC     NEUTRON RESCATT.
F+     560  143.       29.                 BANGERT1  69 HBC
F+   C1054  184.       24.                 BERLEY    70 HBC     K-P AT 400 MEV/C
F+   C  CHANGED FROM 176 TO 184 TO AGREE WITH SIGN CONVENTION.
F+              . . . . . . . . . .
F+  AVG      167.3      20.1     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

α_γ FOR $\Sigma^+(\Sigma^+ \rightarrow p\,\gamma)$

```
AG       61   -1.03      0.52      0.42  GERSHWIN  69 HBC      K-P TO SIG PI
AG       46   -0.53      0.38      0.36  MANZ      80 HBC  K- P-->SIGMA+ PI-
AG              . . . . . . . . . .
AG  'AVG      -0.72      0.29      AVERAGE
```

ϕ_0 ANGLE $(\Sigma^+ \rightarrow \pi^0 p)$ (degrees) $(\tan\phi_0 = \beta/\gamma)$

```
F0 H          22.0      90.0               HARRIS    70 OSPK PI+P TO SIG+ K+
F0 L  1259    38.1      35.7      37.1     LIPMAN    73 OSPK    PI+P TO SIG+K+
F0 L    DECAY PROTON SCATTERED OFF ALUMINUM.
F0 H    DECAY PROTONS SCATTERED OFF CARBON.
F0              . . . . . . . . . .
F0  AVG       35.8      33.7      AVERAGE
```

REFERENCES FOR Σ^+

```
CORK      60 PR 120 1000        CORK,KERTH,WENZEL,CRONIN,COOL(LRL+PRIN+BNL)
EVANS     60 NC 15 873          BRIST+BRUSS+IAS-U.COL-DUBLIN+LON+MILAN+PAD
FREDEN    60 NC 16 611          S FREDEN,H KORNBLUM,R WHITE            (LRL)
KAPLON    60 ANP 9 139          M KAPLON,A MELISSINOS,YAMANOUCHI      (ROCH)
PUSCHEL   60 NP 20 254          W PUSCHEL                (MAX PLANCK INST)

BARKAS    61 PR 124 1209        BARKAS,DYER,MASON,NICHOLS,SMITH        (LRL)
BERTHELO  61 NC 21 693          BERTHELOT,DAUDIN,GOUSSU +    (SACLAY+ORSAY)
CHIESA    61 NC 19 1171         CHIESA,QUASSIATI,RINAUDO       (INFN-TURIN)

BEALL     62 PRL 8 75           BEALL,CORK,KEEFE,MURPHY,WENZEL         (LRL)
GRARD     62 PR 127 607         F GRARD,G A SMITH                      (LRL)
GALTIERI  62 PRL 9 26           GALTIERI,BARKAS,HECKMAN,PATRICK,SMITH  (LRL)
HUMPHREY  62 PR 127 1305        W E HUMPHREY,R R ROSS                  (LRL)
TRIPP     62 PRL 9 66           R D TRIPP,M B WATSON,M FERRO-LUZZI     (LRL)

BARKAS    63 PRL 11 26          W H BARKAS,J N DYER,H H HECKMANN       (LRL)
    ALSO  61 UCRL 9450          JOHN DYER (THESIS, BERKELEY)           (LRL)

BHOWMIK   64 NP 53 22           B BHOWMIK,P JAIN,P MATHUR,LAKSHMI    (DELHI)
CARRARA   64 PL 12 72           CARRARA,CRESTI,GRIGOLETTO,PERUZZO+  (PADOVA)
COURANT   64 PR 136 B 1791      COURANT,FILTHUTH+    (CERN+HEID+UMD+NRL+BNL)
MURPHY    64 PR 134 B 188       C THORNTON MURPHY                (WISCONSIN)
NAUENBER  64 PRL 12 679         NAUENBERG,MARATECK,+        (COLU+RUTG+PRIN)
WILLIS    64 PRL 13 291         WILLIS,COURANT,ENGELMAN+(BNL,CERN,HEID,UMD)

BALTAY    65 PR 140 B 1027      BALTAY,SANDWEISS,CULWICK,KOPP +  (YALE+BNL)
BAZIN     65 PRL 14 154         BAZIN,BLUMENFELD,NAUENBERG +     (PRIN+COLU)
BAZIN2    65 PR 140  B1358      BAZIN,PLANO,SCHMIDT+         (PRIN,RUTG,COLU)
CARAYAN   65 PR 138 B 433       CARAYANNOPOULOS,TAUTFEST,WILLMANN  (PURDUE)
QUARENI   65 NC 40 A 928        QUARENI,CARTACCI +    (BGNA,FIRZ,GENO,PARMA)
SCHMIDT   65 PR 140 B 1328      P SCHMIDT                         (COLUMBIA)

BANGERTE  66 PRL  17  495       BANGERTER,GALTIERI,BERGE,MURRAY+       (LRL)
BERLEY    66 PRL 17 1071        +HERZBACH,KOFLER,YAMAMOTO + (BNL+MASA+YALE)
CHANG     66 PR  151  1081      CHUNG YUN CHANG                   (COLUMBIA)
    ALSO  65 NEVIS 145  THESIS  CHUNG YUN CHANG                   (COLUMBIA)
CHIEN     66 PR  152  1171      +LACH,SANDWEISS,TAFT,YEH,OREN +  (YALE+BNL)
COOK      66 PRL  17  223       V COOK,EWART,MASEK,ORR,PLATNER (WASHINGTON)

BAGGETT   67 PRL 19 1458        BAGGETT,DAY,GLASSER,KEHOE,KNOP+  (MARYLAND)
    ALSO  68 VIENNA ABS. 374    BAGGETT,KEHOE                    (MARYLAND)
    ALSO  68 PRIVATE COMM.      N. BAGGETT                       (MARYLAND)

BARASH    67 PRL 19  181        BARASH,DAY,GLASSER,KEHOE,KNOP +  (MARYLAND)
EISELE    67 ZPHY 205 409       +ENGELMANN,FILTHUTH,FOLISH,HEPP+     (HEID)
HYMAN     67 PL 25 B 376        +LOKEN,PEWITT,MCKENZIE,+    (ANL+CARN+NWES)
KOTELCHU  67 PRL 18 1166        KOTELCHUCK,GOZA,SULLIVAN,ROSS  (VANDERBILT)
SULLIVAN  67 PRL 18 1163        SULLIVAN,MCINTURFF,KOTELCHUCH  (VANDERBILT)
    ALSO  64 PRL 13 246         A D MCINTURFF,C E ROOS         (VANDERBILT)

BIERMAN   68 PRL 20 1459        BIERMAN,KOUNOSU,NAUENBERG +     (PRINCETON)
COMBE     68 NC 57A 54          CERN-BRISTOL-LAUSANNE-MUNICH-ROME-COLLABOR
MAST      68 PRL 20 1312        MAST,GERSHWIN,ALSTON-GARNJOST +        (LRL)

ANG       69 ZPHY 228 151       +EBENHOH,EISELE,ENGELMANN,FILTHUTH+  (HEID)
BAGGETT   69 MDDP-TR-973        N V BAGGETT (THESIS)                   (UMD)
BALTAY    69 PRL 22 615         BALTAY,FRANZINI,NEWMAN,NORTON+  (COLU,STON)
BANGERTE  69 UCRL-19244         ROGER ODELL BANGERTER (THESIS)         (LRL)
BANGERT1  69 PR 187 1821        BANGERTER,GARNJOST,GALTIERI,GERSHWIN+ (LRL)

BARLOUTA  69 NP B14 153         BARLOUTAUD,BELLEFON,GRANET+(SACL+CERN+HEID)
EISELE1   69 ZPHY 221 1         +ENGELMANN,FILTHUTH,FOHLISCH,HEPP+   (HEID)
EISELE2   69 ZPHY 221 401       +ENGELMANN,FILTHUTH,FOHLISCH,HEPP+   (HEID)
GERSHWIN  69 PR 188 2077        +ALSTON-GARNJOST,BANGERTER +           (LRL)
    ALSO     UCRL 19246 THESIS  LAWRENCE K GERSHWIN                    (LRL)
NORTON    69 NEVIS 175 (THESIS) HERBERT NORTON                    (COLUMBIA)

BERLEY    70 PR D1 2015         +YAMIN,HERTZBACH,KOFLER +   (BNL,MASA,YALE)
EISELE    70 ZPHY 238 372       +FILTHUTH,HEPP,PRESSER,ZECH    (HEIDELBERG)
HARRIS    70 PRL 24 165         +OVERSETH,PONDROM,DETTMANN       (MICH,WISC)

ALLEY     71 PR  D3  75         +BENBROOK,COOK,GLASS,GREEN,HAGUE +   (WASH)
BAKKER    71 LNC 1 37           +,SABRE COLLAB.  (ZEEM+SACL+BGNA+REHO+EPOL)
COLE      71 PR D4 631          +LEE-FRANZINI,LOVELESS,BALTAY+  (STON,COLU)
TOVEE     71 NP B33 493         LOUC,BELGRADE,BERL,BRUX,DUBLIN,WARS COLLAB
BELLAMY   72 PL 39B 299         +ANDERSON,CRAWFORD,OSMON+  (LOWC+RHEL+SUSS)
BOHM      72 NP B48 1           BERLIN+BELGRADE+BRUX+DUBLIN+LOUC+WARSAW
    ALSO  73 IIHE-73.2 NOV      BRUSSELS BULLETIN, SAME COLLABORATION

EBENHOH   73 ZPHY 264 413       +EISELE,FILTHUTH,HEPP,LEITNER,THOUW+ (HEID)
LIPMAN    73 PL 43B 89          +UTO,WALKER,MONTGOMERY+    (RHEL+SUSS+LOWC)
SAHA      73 PR D7 3295         +FETKOVICH,HEINTZELMAN,MELTZER +     (CARN)
SECHIZOR  73 PR D8 12           B.SECHI-ZORN,G.SNOW                    (UMD)

EBENHOH   74 ZPHY 266 367       +EISELE,ENGELMANN,FILTHUTH,HEPP +    (HEID)
CONFORTO  76 NP B105 189        +GOPAL,KALMUS,LITCHFIELD,ROSS + (RHEL+LOIC)
DOBLE     77 PL 67B 483         +GOTTSTEIN,HANSL,HERYNEK+  (MPIM+BOHR+VAND)
REUCROFT  77 PR D15 5           +ROOS,WATERS,WEBSTER,HANSL +    (VAND+MPIM)
NOWAK     78 NP B139 61         +ARMSTRONG,DAVIS+     (LOUC+BELG+DURH+WARS)

SETTLES   79 PR D20 2154        +MANZ,MATT,HANSL,HERYNEK,DOBLE+ (MPIM+VAND)
MANZ      80 PL 96B 217         +REUCROFT,SETTLES,WOLF +        (MPIM+VAND)
MARRAFFI  80 PR D21 2501        MARRAFFINO,REUCROFT,ROOS,WATERS+(VAND+MPIM)
ANKENBRA  83 PRL 51 863         ANKENBRANDT,BERGE+     (FNAL+IOWA+ISU+YALE)
BIAGI     85 ZPHY C28 495       +BOURQUIN+ (BRIS+CERN+GEVA+HEID+LAUS+LOQM+)

                                PAPERS NOT REFERRED TO IN DATA LISTINGS

GLASER    58 CERN CONF 270      GLASER,GOOD,MORRISON                (MICH+LRL)

        QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA LISTINGS

TRIPP     62 PRL 8 175          R TRIPP,M WATSON,M FERRO-LUZZI         (LRL) P
ALFF      63 SIENA CONF 1 205   ALFF,NAUENBERG,KIRSCH,+       (COLU+RUTG+BNL)
    ALSO  65 PR 137 B 1105      ALFF,GELFAND,BRUGGER,BERLEY+(COLU+RUTG+BNL)
COURANT   63 SIENA CONF 1 73    COURANT,FILTHUTH,BURNSTEIN,DAY+  (CERN+UMD)
```

Σ^-

$I(J^P) = 1(\frac{1}{2}^+)$

Σ^- MASS (MeV)

```
M   N   SEE NOTE PRECEDING LAMBDA MASS LISTINGS

M     3000 1197.43     0.08          SCHMIDT   65 HBC  SEE NOTE N
M          1197.24     0.15          DUGAN     75 CNTR   EXOTIC ATOMS
M          . . . . . . . . . .
M   AVG    1197.388    0.079  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)  |
M   FIT    1197.34     0.05   FROM FIT
```

$\Sigma^- - \Sigma^+$ MASS DIFFERENCE (MeV)

```
D       87     8.25     0.40         BARKAS    63 EMUL
D     2500     8.25     0.25         DOSCH     65 HBC
D       86     7.91     0.23         BOHM      72 EMUL
D           . . . . . . . . . .
D   AVG        8.09     0.16   AVERAGE
D   FIT        7.97     0.07   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)  |
```

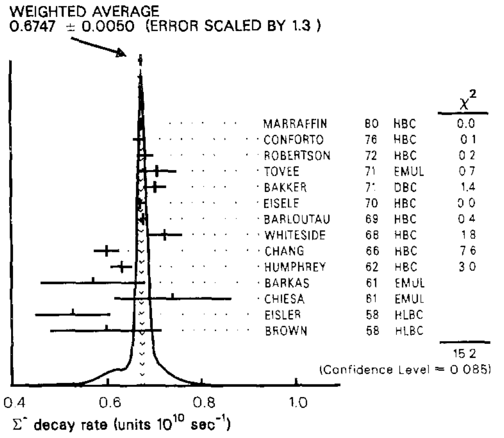
$\Sigma^- - \Lambda$ MASS DIFFERENCE (MeV)

```
DL  N   SEE NOTE PRECEDING LAMBDA MASS LISTINGS.

DL            81.70     0.19         BURNSTEIN 64 HBC
DL      85    81.80     0.13         SCHMIDT   65 HBC  SEE NOTE N
DL    2279    81.64     0.09         HEPP      68 HBC
DL          . . . . . . . . . .
DL  AVG       81.693    0.069  AVERAGE
DL  FIT       81.741    0.052  FROM FIT                                       |
```

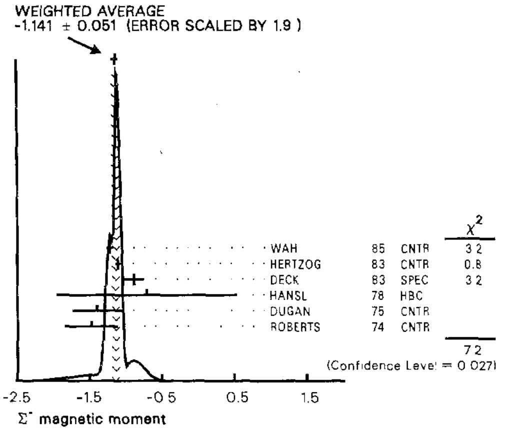
Σ^- MEAN LIFE (units 10^{-10} sec)

```
T              1.67      0.40      0.28  BROWN     58 HLBC
T              1.89      0.33      0.25  EISLER    58 HLBC
T        45    1.35      0.32      0.17  CHIESA    61 EMUL
T        41    1.75      0.39      0.30  BARKAS    61 EMUL
T      1208    1.58      0.06      0.06  HUMPHREY  62 HBC      STOP. K-
T  C   3267    1.666     0.075           CHANG     66 HBC      STOP. K-
T   S    61   (2.08)    (0.22)           CHIEN     66 HBC   -   6.9 PBAR P
T   S    64   (1.46)    (0.31)           CHIEN     66 HBC   +   6.9 PBAR P,ANTI
T       506    1.38      0.07            WHITESIDE 68 HBC      STOP. K-
T     10253    1.472     0.016           BARLOUTAU 69 HBC      K-P .4-1.2 GEV/C
T      0.1M    1.485     0.022           EISELE    70 HBC      K-P AT REST
T      1383    1.42      0.05            BAKKER    71 DBC      K-N TO SIG- 2PI
T              1.41      0.09      0.08  TOVEE     71 EMUL
T      2400    1.463     0.039           ROBERTSON 72 HBC      K-P .25 GEV/C
T      8437    1.49      0.03            CONFORTO  76 HBC      K-P 1-1.4 GEV/C
T       16K    1.480     0.014           MARRAFFIN 80 HBC      K- P TO SIG- PI+
T  C    CHANG ERROR 0.018 RAISED BY US.  SEE 1970 EDITION, RMP 42,123(1970)
T   S   ERROR PURELY STATISTICAL.
T               . . . . . . . . . . .
T   AVG        1.482     0.011     0.011  AVERAGE (ERROR INCL. SCALE FACTOR OF 1.3)
                         (SEE IDEOGRAM BELOW)
```



Σ^- MAGNETIC MOMENT (MAGNETONS, 938.26 MeV)

```
MM  R        BTWN -1.6 AND +0.8             FOX        73 CNTR    SIG-ATOM FINE ST
MM   R          -1.48      0.37             ROBERTS    74 CNTR    SIG-ATOM FINE ST
MM   D          -1.40      0.41      0.28   DUGAN      75 CNTR    SIG-ATOM FINE ST
MM  D           (0.65)    (0.28)    (0.40)  DUGAN      75 CNTR    SIG-ATOM FINE ST
MM      28K     -0.71      1.25             HANSL      78 HBC     K-P-->SIG- PI+
MM     516K     -0.89      0.14             DECK       83 SPEC    P BE-->SIGMA- X
MM              -1.111     0.033            HERTZOG    83 CNTR    SIG-ATOM FINE ST
MM   W          -1.23      0.05             WAH        85 CNTR    P CU -> SIGMA- X
MM   R  ROBERTS 74 INCLUDES DATA FROM FOX 73.
MM   D  DUGAN 75 NEGATIVE VALUE AVERAGED SINCE IT AGREES WITH ROBERTS 74.
MM   W  STATISTICAL AND SYSTEMATIC ERRORS ARE EACH 0.03.
MM              . . . . . . . . . . .
MM  AVG         -1.141     0.051   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.9)
                           (SEE IDEOGRAM BELOW)
```



Σ^- PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma^- \to n\pi^-$	940+ 140
P2	$\Sigma^- \to n\pi^-\gamma$	940+ 140+ 0
P3	$\Sigma^- \to n\mu^-\nu$	940+ 106+ 0
P4	$\Sigma^- \to ne^-\nu$	940+.511+ 0
P5	$\Sigma^- \to \Lambda e^-\nu$	1116+.511+ 0

Σ^- BRANCHING RATIOS

$\Sigma^- \to (n\mu^-\nu)/(n\pi^-)$ (units 10^{-3}) (P3)/(P1)

```
R1      22    0.66      0.15            COURANT   64 HBC
R1      11    0.56      0.20            BAZIN     65 HBC      FROM STOP. K-
R1      56    0.43      0.09            BAGGETT   69 HBC     STOP. K-
R1      72    0.43      0.06            ANG 1     69 HBC     STOP K-
R1      13    0.38      0.11            COLE      71 HBC     STOP K-
R1           . . . . . . . . . . .
R1  AVG       0.447     0.043   AVERAGE
```

$\Sigma^- \to (ne^-\nu)/(n\pi^-)$ (units 10^{-3}) (P4)/(P1)

```
R2       9   (1.0)     (0.4)     (0.3)  MURPHY    64 HLBC
R2      16   (1.37)    (0.34)           NAUENBERG 64 HBC
R2      16   (1.15)    (0.4)            MILLER    64 FBC
R2      31   (1.4)     (0.3)            COURANT   64 HBC
R2     180    1.11      0.09            BIERMAN   68 HBC
R2     331   (1.02)    (0.08)           ANG 1     69 HBC  REPL. BY EBENHOH 74
R2      57    0.97      0.15            COLE      71 HBC     STOP K-
R2   A 455    1.05      0.07      0.13  SECHIZORN 73 HBC     STOP K-
R2   A 601    1.09      0.06      0.08  EBENHOH   74 HBC     STOP K-
R2    2847    0.96      0.05            BOURQUI1  83 SPEC SPS HYPERON BEAM
R2   A  ADDITIONAL NEGATIVE SYSTEMATIC ERROR INCLUDED FOR INTERNAL
R2   A  RADIATIVE CORRECTIONS AND LATEST FORM FACTORS.  SEE BOURQUIN1 83.
R2           . . . . . . . . . . .
R2  AVG       1.022     0.034   AVERAGE
```

$\Sigma^- \to (\Lambda e^-\nu)/(n\pi^-)$ (units 10^{-4}) (P5)/(P1)

```
R3      11    0.75      0.28            COURANT   64 HBC     STOP. K-
R3      35    0.64      0.12            BARASH    67 HBC     STOP K-
R3      31    0.69      0.12            EISELE1   69 HBC     STOP K-
R3      31    0.52      0.09            BALTAY    69 HBC     STOP K-
R3  H  122   (0.60)    (0.11)           HERBERT   78 ASPK    HYPERON BEAM
R3   H 114    0.63      0.11            THOMPSON  80 ASPK    HYPERON BEAM
R3 B  1620    0.561     0.031           BOURQUIN  82 SPEC    SPS HYPERON BEAM
R3  H   HERBERT 78 REPLACED BY THOMPSON 80.
R3 B    VALUE IS FROM BOURQUIN2 83. INCLUDES RAD. CORR. AND NEW ACCEPTANCE.
R3           . . . . . . . . . . .
R3  AVG       0.574     0.027   AVERAGE
```

$\Sigma^- \to (n\pi^-\gamma)/(n\pi^-)$ (units 10^{-3}) (P2)/(P1)

```
R4           (1.1)APPROXIM.             BAZIN     65 HBC     PI- LT 166 MEV/C
R4      23   (0.10)    (0.02)           ANG 2     69 HBC     PI- LT 110 MEV/C
R4     292    0.46      0.06            EBENHOH   73 HBC     PI+ LT 150 MEV/C
R4      PI+ MOMENTUM CUTS DIFFER, NOT AVERAGED. LATEST VALUE USED IN
R4      SUMMARY TABLE.
```

Σ^- DECAY PARAMETERS

SEE NOTE ON BARYON DECAY PARAMETERS IN NEUTRON SECTION ABOVE.

$\alpha_-(\Sigma^-)$

```
A-           (-0.16)   (0.21)           TRIPP     62 HBC     REPL.BY BANGERTE
A-  O 6500   (-0.010)  (0.043)          BANGERTER 66 HBC     K-P TO SIG- PI+
A-  O 6068   (-0.104)  (0.04)           BERLEY    67 HBC     K-P TO SIG- PI+
A-   51000    -0.071    0.012           BANGERTER 69 HBC
A-  B 5978   (-0.134)  (0.034)          BERLEY    70 HBC     K-P AT 400 MEV/C
A-   60000    -0.067    0.011           BOGERT    70 HBC     K-P AT 400 MEV/C
A-     28K    -0.062    0.024           HANSL     78 HBC     K-P-->SIG- PI+
A-  O   OLD RESULTS.  HAVE BEEN REPLACED.
A-  B   BERLEY 70 REPLACED BY BOGERT 70
A-           . . . . . . . . . . .
A-  AVG       -0.0681   0.0077  AVERAGE
```

ϕ ANGLE (degrees) ($\tan\phi = \beta/\gamma$)

```
F-  O 1006 (+22.)     (30.)             BERLEY    67 HBC     K-P TO SIG- PI+
F-    1385   14.       19.              BANGERT1  69 HBC
F-   C1092  + 5.       23.              BERLEY    70 HBC     NEUTRON RESCATT.
F-  C   CHANGED FROM -5 TO +5 TO AGREE WITH SIGN CONVENTION
F-           . . . . . . . . . . .
F-  AVG       10.3      14.6    AVERAGE
```

NOTE ON $\Sigma^- \to \Lambda e^- \nu$

(by J.A. Thompson, University of Pittsburgh)

The decay $\Sigma^- \to \Lambda e^- \nu$ is of special interest because its form is predicted by the strong form of CVC and is not sensitive to the current octet assumptions or SU(3) structure constants which enter into Cabibbo's predictions for the other hyperon decays. For $\Delta S = 0$ transitions, the weak interaction vector current is related to the electromagnetic current through a multiplicative constant, set by neutron beta decay, and an isospin rotation.

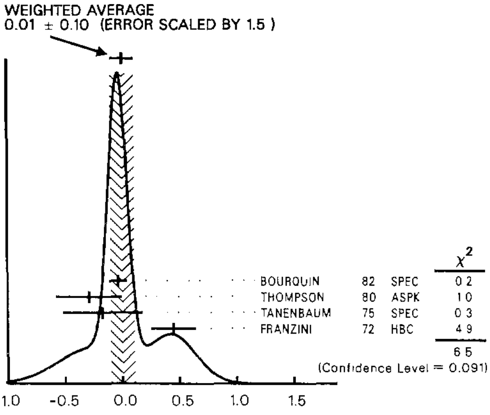
The decay $\Sigma^0 \rightarrow \Lambda\gamma$ (the isospin-rotation analogue of $\Sigma^- \rightarrow \Lambda e^-\nu$) is mediated predominantly through the magnetic interaction, assuming there are no inhomogeneities in the Σ^0, Λ charge distributions. Thus we expect the g_{WM} term,

$$g_{WM} \sim \frac{\mu_{\Sigma\Lambda}}{\sqrt{2}} \sim -\frac{\sqrt{3}}{2}\mu_n \text{ [by SU(3)]} ,$$

to dominate the vector part of the weak current. The strong CVC predictions are thus: $g_V/g_A = 0$ and $g_{WM} \sim 1.6$.

g_V/g_A FOR $\Sigma^- \rightarrow \Lambda e^-\nu$

```
AV      (FOR SIGN CONVENTION, SEE NOTE ON BARYON DECAY PARAMETERS IN
AV      NEUTRON SECTION ABOVE.)
AV      PREDICTED TO BE ZERO BY CONSERVED VECTOR CURRENT THEORY.
AV      VALUES AVERAGED ASSUME CVC-SU3 WEAK MAGNETISM TERM.
AV  FB  45   (0.31)   (0.30)           BARASH    67 HBC
AV  FS  51   (0.7)    (0.4)            BALTAY    69 HBC     USING SIG+-
AV  FS  81  (+0.22)   (0.28)           EISELE1   69 HBC
AV F S 186    0.45     0.20            FRANZINI  72 HBC     USING SIG+-
AV      55   -0.17     0.35            TANENBAUM 75 SPEC    BNL HYPERON BEAM
AV     114   -0.29     0.29            THOMPSON  80 ASPK    BNL HYPERON BEAM
AV S  1620   -0.034    0.080           BOURQUIN  82 SPEC    SPS HYPERON BEAM
AV   B  BARASH 67 MEASURED ABSOLUTE VALUE.
AV   S  SIGN CHANGED TO AGREE WITH OUR CONVENTION.
AV F    FRANZINI 72 INCLUDES EVENTS OF BARASH 67, EISELE1 69, BALTAY 69.
AV          . . . . . . . . . . .
AV  AVG       0.01     0.10    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
                       (SEE IDEOGRAM BELOW)
```



g_{WM}/g_A FOR $\Sigma^- \rightarrow \Lambda e^-\nu$

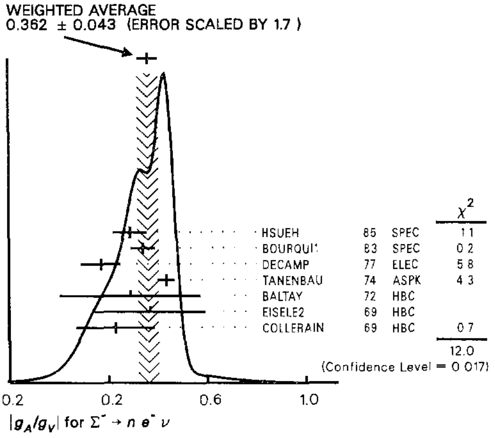
```
WM      VALUES QUOTED ASSUME THE CVC PREDICTION GV=0.
WM      186     2.4      2.1            FRANZINI  72 HBC     USING SIG+-
WM       55     3.5      4.5            TANENBAUM 75 SPEC    BNL HYPERON BEAM
WM      114     1.75     3.5            THOMPSON  80 ASPK    BNL HYPERON BEAM
WM          . . . . . . . . . . .
WM  AVG         2.4      1.7      AVERAGE
```

g_A/g_V FOR $\Sigma^- \rightarrow n e^-\nu$

```
AV1     (FOR SIGN CONVENTION, SEE NOTE ON BARYON DECAY PARAMETERS IN
AV1     NEUTRON SECTION ABOVE.)
AV1     57   (0.05)   (0.23)   (0.32) GERSHWIN  68 HBC  REPLACED BY GER.69
AV1     61   +0.19     0.20     0.17  GERSHWIN  69 HBC  POLARIZED SIGMAS
AV1     63   -0.33     0.30     0.85  BOGERT    70 HBC  K-P AT 400 MEV/C
AV1     43   -0.4      0.52     1.5   ELLIS     72 ASPK POLARIZED SIGMAS
AV1  S 193   +0.15  OR LESS  CL=.95   KELLER    82 SPEC POLARIZED SIGMAS
AV1B S4456   +0.33                    BOURQUI1  83 SPEC SPS HYPERON BEAM
AV1H S 25K   +0.29     0.07           HSUEH     85 SPEC 250 GEV/C SIGMA-
AV1  S  SIGN CHANGED TO AGREE WITH OUR CONVENTION.
AV1B    THE VALUE +0.33 IS PREFERRED OVER -0.33 BY AT LEAST 2.6 STD. DEV.
AV1B    INCLUDING SYSTEMATIC ERRORS.
AV1H    FROM MEASUREMENT OF ELECTRON ASYMMETRY AE = -0.53+-0.14
```

$|g_A/g_V|$ FOR $\Sigma^- \rightarrow n e^-\nu$

```
AV2       49     0.23     0.16            COLLERAIN 69 HBC     NEUTRON SCATTER
AV2       33     0.37     0.26     0.19   EISELE2   69 HBC     NEUTRON SCATTER
AV2       36     0.29     0.28     0.29   BALTAY    72 HBC     NEUTRON SCATTER
AV2     3507     0.435    0.035           TANENBAU  74 ASPK
AV2      519     0.17     0.07     0.09   DECAMP    77 ELEC    H.E.HYPERON BEAM
AV2  B4456       0.34     0.05            BOURQUI1  83 SPEC SPS HYPERON BEAM
AV2H   25K       0.29     0.07            HSUEH     85 SPEC 250 GEV/C SIGMA-
AV2  B  POSITIVE SIGN OF GA/GV FAVORED BY AT LEAST 2.6 STANDARD DEVIATIONS.
AV2H    FROM MEASUREMENT OF ELECTRON ASYMMETRY AE = -0.53+-0.14
AV2          . . . . . . . . . . .
AV2 AVG          0.362    0.043   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)
                          (SEE IDEOGRAM BELOW)
```



REFERENCES FOR Σ^-

```
BROWN    58 CERN CONF 270      BROWN,GLASER,GRAVES,PERL,CRONIN +    (MICH)
EISLER   58 NC SER10 10 150    EISLER,BASSI,CONVERSI+ (COLU,BNL,BGNA,PISA)

BARKAS   61 PR 124 1209        BARKAS,DYER,MASON,NICKOLS,SMITH         (LRL)
CHIESA   61 NC 19 1171         A M CHIESA,B QUASSIATI,G RINAUDO      (TURIN)
HUMPHREY 62 PR 127 1305        W E HUMPHREY,R R ROSS                   (LRL)
TRIPP    62 PRL 9 66           R D TRIPP,M WATSON,M FERRO-LUZZI        (LRL)

BARKAS   63 PRL 11 26          W H BARKAS,J N DYER,H H HECKMAN         (LRL)
BURNSTEI 64 PRL 13 66          BURNSTEIN,DAY,KEHOE,SECHI ZORN,SNOW    (UMD)
COURANT  64 PR 136 B 1791      COURANT,FILTHUTH+   (CERN+HEID+UMD+NRL+BNL)
MILLER   64 PL 11 262          MILLER,STANNARD,BEZAGUET+  (LOUC,EPOL+BERG)
MURPHY   64 PR 134 B 188       C THORNTON MURPHY                 . (WISCONSIN)
NAUENBER 64 PRL 12 679         NAUENBERG,SCHMIDT,MARATECK+(COLU+RUTG+PRIN)

BAZIN    65 PR 140 B 1358      BAZIN,PLANO,SCHMIDT +        (PRIN+RUTG+COLU)
DOSCH    65 PL 14 239          DOSCH,ENGELMANN,FILTHUTH,HEPP,KLUGE+ (HEID)
    ALSO 66 PR  151  1081      CHUNG YUN CHANG                    (COLUMBIA)
SCHMIDT  65 PR 140 B 1328      P SCHMIDT                          (COLUMBIA)
BANGERTE 66 PRL  17  495       BANGERTER,GALTIERI,BERGE,MURRAY+        (LRL)
CHANG    66 PR  151 1081       CHUNG YUN CHANG                    (COLUMBIA)
CHIEN    66 PR  152  1171      +LACH,SANDWEISS,TAFT,YEH,OREN +  (YALE+BNL)

BARASH   67 PRL 19  181        BARASH,DAY,GLASSER,KEHOE,KNOP +  (MARYLAND)
BERLEY   67 PRL  19  979       BERLEY,HERTZBACH,KOFLER +   (BNL,MASA,YALE)
BIERMAN  68 PRL 20 1459        BIERMAN,KOUNOSU,NAUENBERG +      (PRINCETON)
GERSHWIN 68 PRL 20 1270        GERSHWIN,ALSTON-GARNJOST,BANGERTER+   (LRL)
HEPP     68 ZPHY 214 71        V.HEPP,H. SCHLEICH               (HEIDELBERG)
WHITESID 68 NC  54A  537       H. WHITESIDE,J. GOLLUB              (OBERLIN)

ANG 1    69 ZPHY 223 103       ANG,EISELE,ENGELMANN,FILTHUTH +        (HEID)
ANG 2    69 ZPHY 228 151       +EBENHOR,EISELE,ENGELMANN,FILTHUTH+  (HEID)
BAGGETT  69 PRL 23 249         BAGGETT,KEHOE,SNOW            (UNIV MARYLAND)
BALTAY   69 PRL 22 615         BALTAY,FRANZINI,NEWMAN,NORTON+  (COLU,STON)
BANGERTE 69 UCRL-19244         ROGER ODELL BANGERTER (THESIS)          (LRL)
BANGERT1 69 PR 187 1821        BANGERTER,GARNJOST,GALTIERI,GERSHWIN+ (LRL)

BARLOUTA 69 NP B14 153         BARLOUTAUD,BELLEFON,GRANET+(SACL+CERN+HEID)
COLLERAI 69 PRL 23 198         COLLERAINE,DAY,GLASSER,KNOP+(UNIV MARYLAND)
EISELE1  69 ZPHY 221 1         +ENGELMANN,FILTHUTH,FOHLISCH,HEPP+   (HEID)
EISELE2  69 ZPHY 223 487       EISELE,ENGELMANN,FILTHUTH,FOHLISCH+  (HEID)
GERSHWIN 69 UCRL-19246         LAWRENCE KENNETH GERSHWIN (THESIS)      (LRL)

BERLEY   70 PR D1 2015         +YAMIN,HERTZBACH,KOFLER +   (BNL,MASA,YALE)
BOGERT   70 PR D2 6            +LUCAS,TAFT,WILLIS,BERLEY + (BNL,MASA,YALE)
EISELE   70 ZPHY 238 372       +FILTHUTH,HEPP,PRESSER,ZECH    (HEIDELBERG)

BAKKER   71 LNC 1 37           +,SABRE COLLAB.  (ZEEM+SACL+BGNA+REHO+EPOL)
COLE     71 PR D4 631          +LEE-FRANZINI,LOVELESS,BALTAY+  (STON,COLU)
    ALSO 69 NEVIS-175 THESIS   HERBERT NORTON                     (COLUMBIA)
TOVEE    71 NP B33 493         LOUC,BELGRADE,BERL,BRUX,DUBLIN,WARS COLLAB

BALTAY   72 PR D5 1569         +FEINMAN,FRANZINI,NEWMAN,YEH+   (COLU+STON)
BOHM     72 NP B48 1           BERLIN+BELGRADE+BRUX+DUBLIN+LOUC+WARSAW
ELLIS    72 NP B39 77          OXF+AERE+RHEL+LOQM+LYON+NWES+ITEP COLLABOR
FRANZINI 72 PR D6 2417         COLUMBIA+HEIDELBERG+MARYLAND+STONY BROOK
ROBERTSO 72 THESIS             R.M.ROBERTSON                           (IIT)

EBENHOH  73 ZPHY 264 413       +E1SELE,FILTHUTH,HEPP,LEITNER,THOUW+ (HEID)
FOX      73 PRL 31 1084        +LAM,BARNES,EISENSTEIN+ (BNL+VPI+WILL+WYOM)
SECHIZOR 73 PR D8 12           B.SECHI-ZORN,G.SNOW                     (UMD)

EBENHOH  74 ZPHY 266 367       +EISELE,ENGELMANN,FILTHUTH,HEPP +     (HEID)
ROBERTS  74 PRL 32 1265        WILL+VPI+CARN+WYOM+CIT COLLABORATION
    ALSO 74 PRL 33 122         ERRATUM TO ROBERTS 74
    ALSO 75 PR D12 1232        ROBERTS,COX +  (WILL+VPI+CARN+WYOM+CIT+BNL)
TANENBAU 74 PRL 33 175         TANENBAUM,HUNGERBUEHLER +    (YALE+FNAL+BNL)
    ALSO 75 TANENBAUM

DUGAN    75 NP A254 396        +ASANO,CHEN,CHENG,HU,LIDOFSKY+  (COLU+YALE)
TANENBAU 75 PR D12 1871        TANENBAUM,HUNGERBUEHLER +    (YALE+FNAL+BNL)
CONFORTO 76 NP B105 189        +GOPAL,KALMUS,LITCHFIELD,ROSS + (RHEL+LOIC)
DECAMP   77 PL 66B 295         +BADIER,BLAND,CHOLLET,GAILLARD+ (LALO+EPOL)

HANSL    78 NP B132 45         +MANZ,MATT,REUCROFT,SETTLES +    (MPIM+VAND)
HERBERT  78 PRL 40 1230        +CLELAND,COOPER,DRIS,ENGELS +     (PITT+BNL)
MARRAFFI 80 PR D21 2501        MARRAFFINO,REUCROFT,ROOS,WATERS+(VAND+MPIM)
THOMPSON 80 PR D21 25          +CLELAND,COOPER,DRIS,ENGELS+      (PITT+BNL)

BOURQUIN 82 ZPHY C12 307       +BROWN +       (BRIS+GEVA+HEID+LALO+RL+STRB)
    ALSO 83 BOURQUI2
KELLER   82 PRL 48 971         +LESNIK,ROMANOWSKI,KEIG +     (OSU+CHIC+ANL)
BOURQUI1 83 ZPHY C21 17        BOURQUIN+      (BRIS+GEVA+HEID+LALO+RL+STRB)
BOURQUI2 83 ZPHY C21 27        BOURQUIN+      (BRIS+GEVA+HEID+LALO+RL+STRB)
```

DECK   83 PR D28 1   +BERETVAS,DEVLIN,LUK+ (RUTG+WISC+MICH+MINN)
HERTZOG   83 PRL 51 1131   +ECKHAUSE+   (WILL+BOST+CIT+CARN+WYOM)
HSUEH   85 PRL 54 2399   +MULLER, +   (CHIC+ELMT+FNAL+ISU+LENI+YALE)
WAH   85 PRL 55 2551   +CARDELLO,COOPER,TEIG, +   (FNAL+IOWA+ISU)

PAPERS NOT REFERRED TO IN DATA LISTINGS

BROWN   57 PR 108 1036   J BROWN, D GLASER, M PERL   (MICH+BNL)
NIETO   68 RMP 40 140   M NIETO   (STON)

Σ^0

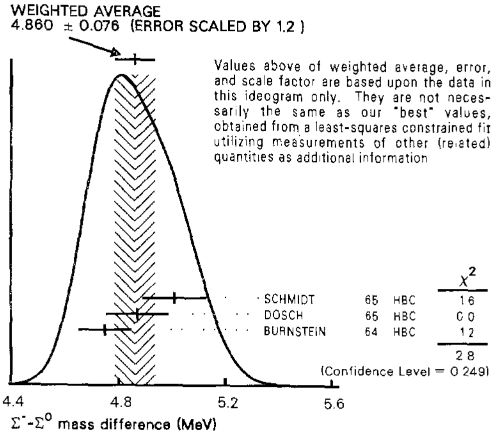
$I(J^P) = 1(\frac{1}{2}^+)$

```
JP NOT MEASURED FOR SIGMAO.  ASSUMED SAME AS SIGMA+
AND SIGMA- TO ALLOW ISOTRIPLET ASSOCIATION.
```

$\Sigma^- - \Sigma^0$ MASS DIFFERENCE (MeV)

```
     SEE NOTE PRECEDING LAMBDA MASS LISTINGS.

D1         18    4.75     0.1              BURNSTEIN 64 HBC
D1         37    4.87     0.12             DOSCH     65 HBC
D1         12    5.01     0.12             SCHMIDT   65 HBC  SEE NOTE N
D1            . . . . . . . . . .
D1   AVG         4.860    0.076   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
D1   FIT         4.881    0.063  FROM FIT
                          (SEE IDEOGRAM BELOW)
```



$\Sigma^0 - \Lambda$ MASS DIFFERENCE (MeV)

```
     SEE NOTE PRECEDING LAMBDA MASS LISTINGS.

DL      208   76.63      0.28           SCHMIDT   65 HBC  SEE NOTE N
DL      109   76.23      0.55           COLAS     75 HLBC    LAMBDA-GAMMA DEC
DL          . . . . . . . . . .
DL   AVG      76.55      0.25    AVERAGE
DL   FIT      76.86      0.08   FROM FIT
```

Σ^0 MEAN LIFE (units 10^{-19} sec)

```
T            (E-14 OR LESS)          DAVIS     62 EMUL
T             0.58     0.13          DYDAK     77 SPEC PRIMAKOFF EFFECT
```

Σ^0 PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma^0 \to \Lambda\gamma$	1116+ 0
P2	$\Sigma^0 \to \Lambda e^+ e^-$	1116+.511+.511
P3	$\Sigma^0 \to \Lambda\gamma\gamma$	1116+ 0+ 0

Σ^0 BRANCHING RATIOS

$\Sigma^0 \to (\Lambda e^+ e^-)$/total (P2)/(P1+P2)

```
R1          0.00545    THEORET. CAL. FEINBERG  58          QUANTUM ELECT.
```

$\Sigma^0 \to (\Lambda\gamma\gamma)/(\Lambda\gamma)$ (P3)/(P1)

```
R2           0.03  OR LESS  CL=.90   COLAS      75 HLBC
```

REFERENCES FOR Σ^0

FEINBERG 58 PR 109 1019   G.FEINBERG   (BNL)
DAVIS   62 PR 127 605   D DAVIS,R SETTI,M RAYMOND,G TOMASIN   (EFI)
BURNSTEI 64 PRL 13 66   BURNSTEIN,DAY,KEHOE,SECHI ZORN,SNOW   (UMD)
DOSCH   65 PL 14 239   DOSCH,ENGELMANN,FILTHUTH,HEPP,KLUGE+ (HEID)
SCHMIDT 65 PR 140 B 1328   P SCHMIDT   (COLUMBIA)

COLAS   75 NP B91 253   +FARWELL,FERRER,SIX   (ORSA)
DYDAK   77 NP B118 1   +NAVARRIA,OVERSETH,STEFFEN+(CERN+DORT+HEID)

PAPERS NOT REFERRED TO IN DATA LISTINGS

COURANT 63 PRL 10 409   COURANT,FILTHUTH,FRANZINI+   (CERN+UMD+NRL)

QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA LISTINGS

ALFF   65 PR 137 B1105   ALFF,GELFAND,NAUENBERG+ (COLUMBIA+RUTG+BNL)P

STRANGENESS −2 BARYONS

Ξ^-

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

```
P NOT YET MEASURED.  VALUE SHOWN IS QUARK MODEL PREDICITION.
```

Ξ^- MASS (MeV)

```
M   H   11(1317.0)    (2.2)            WANG      61 HLBC
M   H   18(1317.9)    (1.9)            FOWLER    61 HLBC
M   H   (OLD DATA AND LOW STATISTICS DROPPED ON SUGGESTION OF J R HUBBARD)
M      517 1321.4      0.4             JAUNEAU   63 FBC
M       62 1321.1      0.65            SCHNEIDER 63 HBC
M      241 1321.1      0.3             BADIER1   64 HBC
M       ALL MASSES ABOVE WERE RAISED 0.09 MEV BECAUSE LAMBDA MASS RAISED
M      149 1321.3      0.4             PJERROU   65 HBC
M        6 1321.67     0.52            CHIEN     66 HBC   -  6.9 PBAR P
M      299 1321.4      1.1             LONDON    66 HBC
M  G   195 1321.87     0.51            GOLDWASSE 70 HBC     5.5 K-P
M   G   USES LAMBDA MASS OF 1115.58-M(XI) IS 1322.18 IF M(LAMBDA)=1115.84
M      268 1321.12     0.41            WILQUET   72 HLBC
M      632 1321.46     0.34            DIBIANCA  75 DBC     4.9 GEV/C K-D
M          . . . . . . . . . .
M   AVG    1321.34     0.14    AVERAGE
M   FIT    1321.32     0.13   FROM FIT
```

$\overline{\Xi}^+$ MASS (MeV)

```
M1        1(1322.0)    (1.3)           BROWN     62 HBC     XIBAR+
M1        5 1320.69     0.93           CHIEN     66 HBC  +  6.9 PBAR P,ANTI
M1   S   12(1321.7)    (0.6)           SHEN      67 HBC     XIBAR+
M1       34 1321.2      0.4            STONE     70 HBC
M1       35 1321.6      0.8            VOTRUBA   72 HBC     10 GEV/C K+ P
M1   S   THE ERROR IS STATISTICAL ONLY
M1          . . . . . . . . . .
M1   AVG    1321.20     0.33   AVERAGE
M1   FIT    1321.32     0.13  FROM FIT
```

$\Xi^- - \overline{\Xi}^+$ MASS DIFFERENCE (MeV)

```
DM            1.0       1.1            CHIEN     66 HBC      6.9 PBAR P
DM      MASS DIFFERENCE FROM SECTIONS M-M1 IS +0.14+-0.36 MEV.
```

Ξ^- MAGNETIC MOMENT (MAGNETONS, 938.26 MeV)

```
MM    2724   -0.1      2.1             BINGHAM   70 OSPK  - 1.8 GEV/C K-P
MM    2436   -2.1      0.8             COOL      74 OSPK -  1.8 GEV/C K-P
MM    218K   -0.69     0.04            RAMEIKA   84 SPEC -  400 GEV P + BE
MM          . . . . . . . . . .
MM   AVG      -0.693   0.040   AVERAGE
```

Ξ^- MEAN LIFE (units 10^{-10} sec)

```
T   H    11   (3.5)    (3.4)    (1.23) WANG      61 HLBC
T   H    18   (1.28)   (0.41)   (0.25) FOWLER    61 HLBC
T   H   (OLD DATA AND LOW STATISTICS DROPPED ON SUGGESTION OF J R HUBBARD)
T       517    1.86     0.15     0.14  JAUNEAU   63 FBC
T        62    1.55     0.31     0.31  SCHNEIDER 63 HBC
T       356   (1.77)   (0.12)          CARMONY   64 HBC    REP BY PJERROU 65
T       794    1.69     0.07           HUBBARD   64 HBC
T       246    1.70     0.12           PJERROU   65 HBC
T   S     6   (1.37)   (0.51)          CHIEN     66 HBC   -  6.9 PBAR P
T       299    1.80     0.16           LONDON    66 HBC
T   S         (1.67)   (0.07)          BURGUN    68 HBC     K-P AT 1.3-1.8
T      2610    1.61     0.04           DAUBER    69 HBC
T       680    1.73     0.08     0.07  MAYEUR    72 HLBC    2.1 GEV/C K-
T      4303    1.63     0.03           BALTAY    74 HBC     1.75 GEV/C K-
T   S 2436    (1.637)  (0.050)         COOL      74 OSPK -  1.8 GEV/C K-P
T              1.67     0.08           DIBIANCA  75 DBC     4.9 GEV/C K-D
T      4286    1.609    0.028          HEMINGWAY 78 HBC     4.2 GEV/C K- P
T       41K    1.665    0.065          BOURQUIN  79 SPEC    HYPERON BEAM
T       32K    1.652    0.051          BOURQUIN  84 SPEC    HYPERON BEAM
T   S   THE ERROR IS STATISTICAL ONLY
T           . . . . . . . . . .
T   AVG        1.642    0.015    0.015  AVERAGE
```

$\overline{\Xi}^+$ MEAN LIFE (units 10^{-10} sec)

```
T1  S    5   (1.51)   (0.55)            CHIEN      66 HBC  +   6.9 PBAR P,ANTI
T1  S   12   (1.9)    (0.7)     (0.5)   SHEN       67 HBC     XIBAR+
T1      34    1.6      0.3              STONE      70 HBC
T1  S   35   (1.55)   (0.35)    (0.20)  VOTRUBA    72 HBC      10 GEV/C K+ P
T1  S   THE ERROR IS STATISTICAL ONLY
```

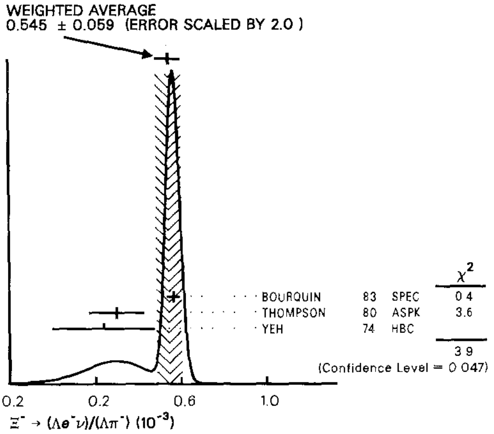
Ξ^- PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi^- \rightarrow \Lambda\pi^-$	1116+ 140
P2	$\Xi^- \rightarrow \Lambda e^-\nu$	1116+.511+ 0
P3	$\Xi^- \rightarrow n\pi^-$	940+ 140
P4	$\Xi^- \rightarrow \Lambda\mu^-\nu$	1116+ 106+ 0
P5	$\Xi^- \rightarrow \Sigma^0 e^-\nu$	1192+.511+ 0
P6	$\Xi^- \rightarrow \Sigma^0\mu^-\nu$	1192+ 106+ 0
P7	$\Xi^- \rightarrow n e^-\nu$	940+.511+ 0
P8	$\Xi^- \rightarrow n\mu^-\nu$	940+ 106+ 0
P9	$\Xi^- \rightarrow \Sigma^-\gamma$	1197+ 0
P10	$\Xi^- \rightarrow p\pi^-\pi^-$	938+ 140+ 140
P11	$\Xi^- \rightarrow p\pi^- e^-\nu$	938+ 140+.511+ 0
P12	$\Xi^- \rightarrow p\pi^-\mu^-\nu$	938+ 140+ 106+ 0
P13	$\Xi^- \rightarrow \Xi^0 e^-\nu$	1315+.511+ 0

Ξ^- BRANCHING RATIOS

$\Xi^- \rightarrow (\Lambda e^-\nu)/(\Lambda\pi^-)$ (units 10^{-3}) (P2)/(P1)

```
R1         1       155 EFFECTIVE DENOM.  CARMONY    63 HBC
R1         0       260 EFFECTIVE DENOM.  JAUNEAU    63 HBC
R1         0       220 EFFECTIVE DENOM.  BERGE      66 HBC
R1         1       155 EFFECTIVE DENOM.  LONDON     66 HBC
R1         0       717 EFFECTIVE DENOM.  TRIPPE     67 HBC
R1         2      1976 EFFECTIVE DENOM.  HUBBARD    68 HBC
R1    H    4   (1.15)    (0.90)   (0.55) HUBBARD    68 RVUE
R1    H   HUBBARD 68 (RVUE) INCLUDES ALL ABOVE EVENTS
R1         1    0.24      0.24           YEH        74 HBC
R1        11   (0.31)    (0.11)          HERBERT    78 ASPK REPL.BY THOMPSON 80
R1        11    0.30      0.13           THOMPSON   80 ASPK    HYPERON BEAM
R1      2857    0.564     0.031          BOURQUIN   83 SPEC SPS HYPERON BEAM
R1           . . . . . . . . . .
R1    AVG       0.545     0.059   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.0)
                                  (SEE IDEOGRAM BELOW)
```



$\Xi^- \rightarrow (n\pi^-)/(\Lambda\pi^-)$ (units 10^{-3}) (P3)/(P1)

```
R2       DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R2           (5.0)   OR LESS             FERRO-LUZ 63 HBC
R2           (1.1)   OR LESS             DAUBER    69 HBC
R2       0   (3.0)   OR LESS   CL=.90    YEH       74 HBC        760 EFF.DENOM.
R2            0.019  OR LESS   CL=.90    BIAGI2    82 SPEC CERN-SPS HYPERON BM
```

$\Xi^- \rightarrow (\Lambda\mu^-\nu)$/total (units 10^{-3}) (P4)

```
R3          (12.0)   OR LESS             BERGE     66 HBC
R3           (1.3)   OR LESS             DAUBER    69 HBC
R3       1    0.35       0.35            YEH       74 HBC       2859 EFF.DENOM.
R3       0   (2.3)   OR LESS    CL=.90   THOMPSON  80 ASPK      1017 EFF.DENOM.
```

$\Xi^- \rightarrow (\Sigma^0 e^-\nu)$/total (units 10^{-3}) (P5)

```
R4           (3.0)   OR LESS             BERGE     66 HBC
R4           (0.5)   OR LESS             DAUBER    69 HBC
R4       0   (0.53)  OR LESS   CL=.90    YEH       74 HBC       4363 EFF.DENOM.
R4       0   (0.14)  OR LESS   CL=.90    THOMPSON  80 ASPK     16000 EFF.DENOM.
R4     154    0.087      0.017           BOURQUIN  83 SPEC SPS HYPERON BEAM
```

$\Xi^- \rightarrow (\Sigma^0\mu^-\nu)/(\Lambda\pi^-)$ (units 10^{-3}) (P6)/(P1)

```
R5           (5.0)   OR LESS             BERGE     66 HBC
R5       0    0.76   OR LESS   CL=.90    YEH       74 HBC       3026 EFF.DENOM.
```

$\Xi^- \rightarrow (n e^-\nu)/(\Lambda\pi^-)$ (units 10^{-3}) (P7)/(P1)

```
R6       DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R6          (10.0)   OR LESS   CL=.90    BINGHAM   65 RVUE
R6       0    3.2    OR LESS   CL=.90    YEH       74 HBC        715 EFF.DENOM.
```

$\Xi^- \rightarrow (\Sigma^0 e^-\nu\ +\ \Lambda e^-\nu)$/total (units 10^{-3}) (P2+P5)

```
R7  D   17   (0.68)   (0.22)            DUCLOS    71 OSPK    SEE NOTE D
R7  B 3011   (0.651)  (0.031)           BOURQUIN  83 SPEC SPS HYPERON BEAM
R7  D   THIS EXPERIMENT CANNOT DISTINGUISH SIGMA0 FROM LAMBDA. THE CABIBBO
R7  D   THEORY PREDICTS SIGMA0 RATE ABOUT A FACTOR 6 SMALLER THAN THE
R7  D   LAMBDA.
R7  B   BOURQUIN 83 VALUE IS CORRELATED WITH THEIR RESULT FOR R1 AND R4.
```

$\Xi^- \rightarrow (n\mu^-\nu)/(\Lambda\pi^-)$ (units 10^{-3}) (P8)/(P1)

```
R8      DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R8       0    15.3   OR LESS  CL=.90   YEH        74 HBC        150 EFF.DENOM.
```

$\Xi^- \rightarrow (\Sigma^-\gamma)/(\Lambda\pi^-)$ (units 10^{-4}) (P9)/(P1)

```
R9       0    11.5   OR LESS  CL=.90   YEH        74 HBC       2000 EFF.DENOM.
```

$\Xi^- \rightarrow (p\pi^-\pi^-)/(\Lambda\pi^-)$ (units 10^{-4}) (P10)/(P1)

```
R10     DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R10      0     3.7   OR LESS  CL=.90   YEH        74 HBC       6200 EFF.DENOM.
```

$\Xi^- \rightarrow (p\pi^- e^-\nu)/(\Lambda\pi^-)$ (units 10^{-4}) (P11)/(P1)

```
R11     DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R11      0     3.7   OR LESS  CL=.90   YEH        74 HBC       6200 EFF.DENOM.
```

$\Xi^- \rightarrow (p\pi^-\mu^-\nu)/(\Lambda\pi^-)$ (units 10^{-4}) (P12)/(P1)

```
R12     DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R12      0     3.7   OR LESS  CL=.90   YEH        74 HBC       6200 EFF.DENOM.
```

$\Xi^- \rightarrow (\Xi^0 e^-\nu)/(\Lambda\pi^-)$ (units 10^{-3}) (P13)/(P1)

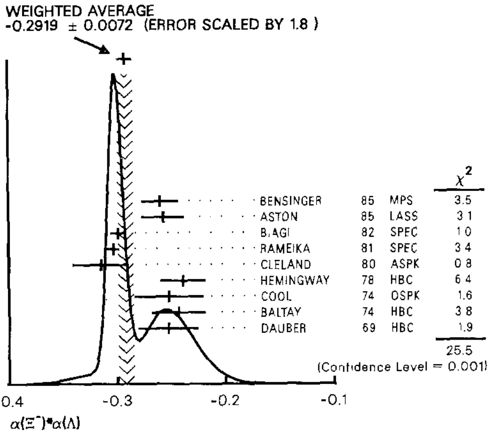
```
R13      0     2.3   OR LESS  CL=.90   YEH        74 HBC       1000 EFF.DENOM.
```

Ξ^- DECAY PARAMETERS

SEE NOTE ON BARYON DECAY PARAMETERS IN NEUTRON SECTION ABOVE.

$\alpha(\Xi^-)\ \alpha(\Lambda)$

```
AA    2781   -0.253     0.028              DAUBER    69 HBC
AA    4303   -0.243     0.025              BALTAY    74 HBC     1.75 GEV/C K-
AA    2436   -0.252     0.032              COOL      74 OSPK    1.8 GEV/C K-P
AA    6599   -0.239     0.021              HEMINGWAY 78 HBC     4.2 GEV/C K- P
AA    9046   -0.315     0.026              CLELAND   80 ASPK    BNL HYPERON BEAM
AA    192K   -0.303     0.006              RAMEIKA   81 SPEC
AA    150K   -0.299     0.007              BIAGI     82 SPEC    CERN-SPS HYP.BM.
AA     11K   -0.257     0.020              ASTON     85 LASS    K- P
AA     21K   -0.260     0.017              BENSINGER 85 MPS     5 GEV/C K- P
AA          . . . . . . . . . .
AA   AVG     -0.2919    0.0072  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)
                                (SEE IDEOGRAM BELOW)
```



$\alpha(\Xi^-)$

```
A       THE ABOVE AVERAGE, ALPHA(XI-)*ALPHA(LAMBDA)=-0.2919+-0.0072, S*=1.8
A       DIVIDED BY OUR CURRENT AVERAGE ALPHA(LAMBDA)=0.642+-0.013 GIVES
A       THE FOLLOWING AVERAGE VALUE FOR ALPHA(XI-).
A            . . . . . . . . . .
A   AVG      -0.455     0.015   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)
```

ϕ ANGLE (degrees) ($\tan\phi = \beta/\gamma$)

```
F   O       (-16.0)    (45.0)           JAUNEAU   63 FBC     SEE NOTE D BELOW
F   O    62  (45.0)    (36.0)           SCHNEIDER 63 HBC     SEE NOTE D BELOW
F       356   54.0      30.0            CARMONY   64 HBC     SEE NOTE D BELOW
F      1004    0.       12.             BERGE     66 HBC     SEE NOTE D BELOW
F   L   364    0.0      20.4            LONDON    66 HBC     SEE NOTE D BELOW
F      2529   (9.8)    (11.6)           MERRILL   68 HBC   REPL. BY DAUBER 69
F      2781  -14.       11.             DAUBER    69 HBC     SEE NOTE A BELOW
F      2724  -26.0      30.0            BINGHAM   70 OSPK
F      4303   11.0       9.0            BALTAY    74 HBC     1.75 GEV/C K-
F      2436    5.0      16.0            COOL      74 OSPK -  1.8 GEV/C K-P
F       11K    5.0      10.0            ASTON     85 LASS    K- P
F   E   21K   14.7      16.0            BENSINGER 85 MPS     5 GEV/C K- P
F   O   OLD DATA NOT INCLUDED IN AVERAGE.
F   D   ERRORS MULTIPLIED BY 1.2 DUE TO APPROXIMATIONS USED FOR XI
F   D   POLARIZATION. (SEE DAUBER 68 FOR DETAILED DISCUSSION)
F   L   LONDON 66 USES ALPHA(LAMBDA) = 0.62
F   A   USED ALPHA(LAMBDA) = 0.647 +- 0.020.
F   E   BENSINGER 85 USED ALPHA(LAMBDA) = 0.642+-0.013.
F            . . . . . . . . . .
F   AVG       3.6        4.5    AVERAGE
```

g_A/g_V FOR $\Xi^- \to \Lambda e^- \nu$

```
AV      (FOR SIGN CONVENTION, SEE NOTE ON BARYON DECAY PARAMETERS IN
AV      NEUTRON SECTION ABOVE.)
AV    1992   -0.25     0.05            BOURQUIN  83 SPEC SPS HYPERON BEAM
```

REFERENCES FOR Ξ^-

```
FOWLER   61 PRL 6 134            FOWLER,BIRGE,EBERHARD,ELY,GOOD,POWELL+(LRL)
WANG     61 JETP 13 512          K WANG,T WANG,VIRYASOV,TING,SOLOVEV+ (JINR)
BROWN    62 PRL 8 255            BROWN,CULWICK,FOWLER,GAILLOUD +  (BNL+YALE)

CARMONY  63 PRL  10  381         CARMONY,PJERROU                       (UCLA)
FERRO-LU 63 PR 130 1568          FERRO-LUZZI,ALSTON,ROSENFELD,WOJCICKI (LRL)
JAUNEAU  63 SIENA CONF 4         JAUNEAU+        (EPOL+CERN+LOUC+RHEL+BERGEN)
   ALSO  63 PL   5  261          JAUNEAU,+       (EPOL,CERN,LOUC,RHEL,BERGEN)
SCHNEIDE 63 PL 4 360             H SCHNEIDER                           (CERN)

CARMONY  64 PRL 12 482           CARMONY,PJERROU,SCHLEIN,SLATER,STORK+(UCLA) J
BADIER1  64 DUBNA CONF I 593     BADIER,DEMOULIN,BARLOUTAUD+(EPOL,SACL,ZEEM)
HUBBARD  64 PR 135 B 183         HUBBARD,BERGE,KALBFLEISCH,SHAFER +     (LRL)
BINGHAM  65 PRSL  285  202       H H BINGHAM                           (CERN)
PJERROU  65 PRL 14 275           + SCHLEIN,SLATER,SMITH,STORK,TICHO    (UCLA)
PJERROU  65 THESIS               G M PJERROU                           (UCLA)

BERGE    66 PR  147  945         BERGE,EBERHARD,HUBBARD,MERRILL +       (LRL)
LONDON   66 PR 143 1034          LONDON,RAU,GOLDBERG,LICHTMAN+(BNL+SYRACUSE)
CHIEN    66 PR  152  1171        +LACH,SANDWEISS,TAFT,YEH,OREN +  (YALE+BNL)
SHEN     67 PL 25 B 443          B.C.SHEN,A.FIRESTONE,G.GOLDHABER  (UCB+LRL)
TRIPPE   67 PRIV. COMM.          T. TRIPPE                             (UCLA)

BURGUN   68 NP B8 447            +MEYER,PAULI,TALLINI, +    (SACL+CDEF+RHEL)
HUBBARD  68 PRL 20 465           HUBBARD,BERGE,DAUBER                   (LRL)
MERRILL  68 PR 167 1202          MERRILL,SHAFER                         (LRL)J

DAUBER   69 PR  179 1262         +BERGE,HUBBARD,MERRILL,MILLER          (LRL)J
BINGHAM  70 PR D1 3010           +COOK,HUMPHREY,SANDER,WILLIAMS+ (UCSD,WASH)
GOLDWASS 70 PR D1 1960           GOLDWASSER, SCHULTZ                    (ILL)
STONE    70 PL 32B 515           +BERLINGHIERI,BROMBERG,COHEN,FERBEL +(ROCH)

DUCLOS   71 NP B32 493           +FREYTAG,HEINTZE,HEINZELMAN,JONES+    (CERN)
MAYEUR   72 NP B47 333           +VAN BINST,WILQUET+   (BRUX+CERN+TUFT+LOUC)
VOTRUBA  72 NP B45 77            VOTRUBA,SAFDER,RATCLIFFE          (BIRM+EDIN)
WILQUET  72 PL 42B 372           +FLIAGINE,GUY,KNIGHT+ (BRUX+CERN+TUFT+LOUC)

BALTAY   74 PR D9 49             +BRIDGEWATER,COOPER,GERSHWIN+   (COLU+BING)J
COOL     74 PR D10 792           +GIACOMELLI,JENKINS,KYCIA,LEONTIC,LI+ (BNL)
   ALSO  72 PRL 29 1630          COOL,GIACOMELLI,JENKINS,KYCIA,LEONTIC+(BNL)
YEH      74 PR D10 3545          +GAIGALAS,SMITH,ZENDLE,BALTAY + (BING+COLU)
DIBIANCA 75 NP B98 137           F.A.DIBIANCA, R.J.ENDORF              (CARN)

HEMINGWA 78 NP B142 205          HEMINGWAY,ARMENTEROS+  (CERN+ZEEM+NIJM+OXF)
HERBERT  78 PRL 40 1230          +CLELAND,COOPER,DRIS,ENGELS +     (PITT+BNL)
BOURQUIN 79 PL 87B 297                     (BRIS+GEVA+HEID+ORSA+RHEL+STRB)
CLELAND  80 PR D21 12            +COOPER,DRIS,ENGELS,HERBERT+      (PITT+BNL)
THOMPSON 80 PR D21 25            +CLELAND,COOPER,DRIS,ENGELS+      (PITT+BNL)
RAMEIKA  81  RU-81-64(THESIS)    R.A.RAMEIKA                           (RUTG)
BIAGI    82 PL 112B 265          +         (BRIS+CAMB+GEVA+HEID+LAUS+LOQM+RL)
BIAGI2   82 PL 112B 277          +         (LOQM+GEVA+RL+HEID+CAMB+LAUS+BRIS)
BOURQUIN 83 ZPHY C21 1           +BROWN+         (BRIS+GEVA+HEID+LALO+RL+STRB)
BOURQUIN 84 NP B241 1                           (BRIS+GEVA+HEID+LALO+RAL+STRB)
RAMEIKA  84 PRL 52 581           +BERETVAS,DECK,DEVLIN+(RUTG+MICH+WISC+MINN)
ASTON    85 PR D32 2270          +CARNEGIE,DUNWOODIE,+ (SLAC+CARL+CNRC+CINC)
BENSINGE 85 NP B252 561          BENSINGER,+  (CHIC+ELMT+FNAL+ISU+LENI+SMAS)
```

Ξ^0

$$I(J^P) = \tfrac{1}{2}(\tfrac{1}{2}^+)$$

P NOT YET MEASURED. VALUE SHOWN IS QUARK MODEL PREDICITION.

Ξ^0 MASS (MeV)

```
M         1 1313.4       1.8              PALMER    68 HBC
M        49 1315.2       0.92             WILQUET   72 HLBC
M           . . . . . . . . . .
M    AVG    1314.83      0.82    AVERAGE
M    FIT    1314.91      0.55   FROM FIT
```

Ξ^- − Ξ^0 MASS DIFFERENCE (MeV)

```
D        23    6.8       1.6              JAUNEAU   63 FBC
D        45   (6.1)     (1.6)             CARMONY   64 HBC    REP BY PJERROU 65
D        88    6.1       0.9              PJERROU   65 HBC
D        29    6.9       2.2              LONDON    66 HBC
D           . . . . . . . . . .
D    AVG       6.34      0.74    AVERAGE
D    FIT       6.41      0.55   FROM FIT
```

Ξ^0 MEAN LIFE (units 10^{-10} sec)

```
T        24    3.9       1.4       0.80  JAUNEAU   63 FBC
T        45   (3.5)     (1.0)     (0.8)  CARMONY   64 HBC    REP BY PJERROU 65
T       101    2.5       0.4        0.3  HUBBARD   64 HBC
T        80    3.0       0.5             PJERROU   65 HBC
T       340    3.07      0.22      0.20  DAUBER    69 HBC
T   M   157    2.90      0.32      0.27  MAYEUR    72 HLBC     2.1 GEV/C K-
T       652    2.88      0.21      0.19  BALTAY    74 HBC      1.75 GEV/C K-
T   Z  6300    2.77      0.16            ZECH      77 SPEC NEUTRAL HYP. BEAM
T   M    MAYEUR 72 VALUE MODIFIED BY ERRATUM.
T   Z    ZECH 77 VALUE IS FOR LAMBDA LIFETIME=2.69E-10. FOR LAM LIFETIME
T   Z    DIFFERENT FROM THIS, TAUXI0=(2.77-(TAULAMBDA-2.69))E-10.
T           . . . . . . . . . .
T    AVG       2.903     0.099     0.093  AVERAGE
```

Ξ^0 MAGNETIC MOMENT (MAGNETONS, 938.26 MeV)

```
MM     42K   -1.20     0.06             BUNCE     79 SPEC
MM    270K   -1.253    0.014            COX       81 SPEC
MM           . . . . . . . . . .
MM   AVG     -1.250    0.014   AVERAGE
```

Ξ^0 PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi^0 \to \Lambda \pi^0$	1116+ 135
P2	$\Xi^0 \to p \pi^-$	938+ 140
P3	$\Xi^0 \to p e^- \nu$	938+.511+ 0
P4	$\Xi^0 \to \Sigma^+ e^- \nu$	1189+.511+ 0
P5	$\Xi^0 \to \Sigma^- e^+ \nu$	1197+.511+ 0
P6	$\Xi^0 \to \Sigma^+ \mu^- \nu$	1189+ 106+ 0
P7	$\Xi^0 \to \Sigma^- \mu^+ \nu$	1197+ 106+ 0
P8	$\Xi^0 \to p \mu^- \nu$	938+ 106+ 0
P9	$\Xi^0 \to \Lambda \gamma$	1116+ 0
P10	$\Xi^0 \to \Sigma^0 \gamma$	1192+ 0

Ξ^0 BRANCHING RATIOS

$\Xi^0 \to (p \pi^-)/(\Lambda \pi^0)$ (units 10^{-5}) (P2)/(P1)

```
R1      DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R1        (2700.)    OR LESS              TICHO      63 HBC
R1         (500.)    OR LESS              HUBBARD    66 HBC
R1          (90.)    OR LESS              DAUBER     69 HBC
R1       0 (180.)    OR LESS  CL=.90      YEH        74 HBC        1300 EFF.DENOM.
R1           3.6     OR LESS  CL=.90      GEWENIGER  75 SPEC
```

$\Xi^0 \to (p e^- \nu)/(\Lambda \pi^0)$ (units 10^{-3}) (P3)/(P1)

```
R2      DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R2          (27.0)   OR LESS              TICHO      63 HBC
R2           (6.0)   OR LESS              HUBBARD    66 HBC
R2            1.3    OR LESS              DAUBER     69 HBC
R2       0   (3.4)   OR LESS  CL=.90      YEH        74 HBC         670 EFF.DENOM.
```

$\Xi^0 \to (\Sigma^+ e^- \nu)/(\Lambda \pi^0)$ (units 10^{-3}) (P4)/(P1)

```
R3          (13.0)   OR LESS              TICHO      63 HBC
R3           (7.0)   OR LESS              HUBBARD    66 HBC
R3           (1.5)   OR LESS              DAUBER     69 HBC
R3       0    1.1    OR LESS  CL=.90      YEH        74 HBC        2100 EFF.DENOM.
```

$\Xi^0 \to (\Sigma^- e^+ \nu)/(\Lambda \pi^0)$ (units 10^{-3}) (P5)/(P1)

```
R4      TEST OF DELTA-S = DELTA-Q RULE
R4           (6.0)   OR LESS              HUBBARD    66 HBC
R4           (1.5)   OR LESS              DAUBER     69 HBC
R4       0    0.9    OR LESS  CL=.90      YEH        74 HBC        2500 EFF.DENOM.
```

$\Xi^0 \to (\Sigma^+ \mu^- \nu)$/total (units 10^{-3}) (P6)

```
R5           (7.0)   OR LESS              HUBBARD    66 HBC
R5           (1.5)   OR LESS              DAUBER     69 HBC
R5       0    1.1    OR LESS  CL=.90      YEH        74 HBC        2100 EFF.DENOM.
```

$\Xi^0 \to (\Sigma^- \mu^+ \nu)$/total (units 10^{-3}) (P7)

```
R6      TEST OF DELTA-S = DELTA-Q RULE
R6           (6.0)   OR LESS              HUBBARD    66 HBC
R6           (1.5)   OR LESS              DAUBER     69 HBC
R6       0    0.9    OR LESS  CL=.90      YEH        74 HBC        2500 EFF.DENOM.
```

$\Xi^0 \to (p \mu^- \nu)$/total (units 10^{-3}) (P8)

```
R7      DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R7           (6.0)   OR LESS              HUBBARD    66 HBC
R7            1.3    OR LESS              DAUBER     69 HBC
R7       0   (3.5)   OR LESS  CL=.90      YEH        74 HBC         664 EFF.DENOM.
```

$\Xi^0 \to (\Lambda \gamma)/(\Lambda \pi^0)$ (units 10^{-3}) (P9)/(P1)

```
R8       1    5.         5.               YEH        74 HBC         200 EFF.DENOM.
```

$\Xi^0 \to (\Sigma^0 \gamma)/(\Lambda \pi^0)$ (units 10^{-2}) (P10)/(P1)

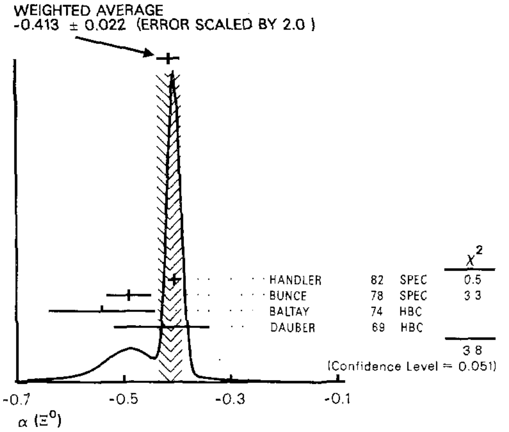
```
R9      0-1   6.5    OR LESS  CL=.90      YEH        74 HBC          60 EFF.DENOM.
```

Ξ^0 DECAY PARAMETERS

SEE NOTE ON BARYON DECAY PARAMETERS IN NEUTRON SECTION ABOVE.

$\alpha(\Xi^0)$

```
A   X        (-0.09)   (0.46)           PJERROU   65 HBC      SEE NOTE D BELOW
A   X   146  (-0.13)   (0.17)           BERGE     66 HBC      SEE NOTE D BELOW
A   X    46  (-0.2)    (0.4)            LONDON    66 HBC      SEE NOTE D BELOW
A  A    739   -0.43     0.09            DAUBER    69 HBC      1.7-2.6 GEV/C K-
A   X   130  (-0.84)   (0.27)           MAYEUR    72 HLBC     2.1 GEV/C K-
A  B    652   -0.54     0.10            BALTAY    74 HBC      1.75 GEV/C K-
A  U   6075   -0.490    0.042           BUNCE     78 SPEC FNAL HYPERON BEAM
A  H   300K   -0.405    0.012           HANDLER   82 SPEC FNAL HYPERON BEAM
A   X   LOW STATISTICS EXPERIMENTS EXCLUDED FROM AVERAGE.
A   D   ERRORS MULTIPLIED BY 1.1 DUE TO APPROXIMATIONS USED FOR XI
A   D   POLARIZATION. (SEE DAUBER 69 FOR DETAILED DISCUSSION)
A  A    DAUBER 69 USES ALPHA LAMBDA = 0.650 +- 0.019.
A  B    BALTAY 74 USES ALPHA-LAMBDA = 0.645
A  U    BUNCE 78 USES ALPHA-LAMBDA = 0.647
A  H    HANDLER 82 USES ALPHA-LAMBDA=0.642+-0.013
A           . . . . . . . . . .
A   AVG       -0.413    0.022   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.0)
                                (SEE IDEOGRAM BELOW)
```



ϕ ANGLE (degrees) ($\tan\phi = \beta/\gamma$)

```
F        146    -8.       30.                  BERGE      66 HBC      SEE NOTE D BELOW
F   A    739    38.       19.                  DAUBER     69 HBC      SEE NOTE A BELOW
F        652    16.0      17.0                 BALTAY     74 HBC      1.75 GEV/C K-
F    A    USED ALPHA LAMBDA = 0.647 +- 0.020.
F    D    ERRORS MULTIPLIED BY 1.2 DUE TO APPROXIMATIONS USED FOR XI
F    D    POLARIZATION. (SEE DAUBER 69 FOR DETAILED DISCUSSION)
F               . . . . . . . . . .
F    AVG        20.7      11.7        AVERAGE
```

REFERENCES FOR Ξ^0

```
ALVAREZ   59 PRL 2 215            ALVAREZ,EBERHARD,GOOD,GRAZIANO,TICHO+ (LRL)
JAUNEAU   63 SIENA CONF 1 1       JAUNEAU+        (EPOL+CERN+LOUC+RHEL+BERGEN)
    ALSO  63 PL 4 49              JAUNEAU+        (EPOL+CERN+LOUC+RHEL+BERGEN)
TICHO     63 BNL CONF 410         HAROLD K TICHO                        (UCLA)

CARMONY   64 PRL 12 482           CARMONY,PJERROU,SCHLEIN,SLATER,STORK+(UCLA)
HUBBARD   64 PR 135 B 183         HUBBARD,BERGE,KALBFLEISCH,SHAFER +     (LRL)
PJERROU   65 PRL 14 275           + SCHLEIN,SLATER,SMITH,STORK,TICHO    (UCLA)
PJERROU   65 THESIS               G M PJERROU                           (UCLA)

BERGE     66 PR  147  945         BERGE,EBERHARD,HUBBARD,MERRILL +       (LRL)
HUBBARD   66 UCRL 11510           J RICHARD HUBBARD (THESIS,BERKELEY)    (LRL)
LONDON    66 PR 143 1034          LONDON,RAU,GOLDBERG,LICHTMAN+(BNL+SYRACUSE)

PALMER    68 PL 26B  323          PALMER,RADOJICIC,RAU,RICHARDSON+ (BNL,SYRA)
DAUBER    69 PR  179 1262         +BERGE,HUBBARD,MERRILL,MILLER          (LRL)

MAYEUR    72 NP B47 333           +VAN BINST,WILQUET+   (BRUX+CERN+TUFT+LOUC)
    ALSO  73 NP B53 268           ERRATUM TO MAYEUR 72
WILQUET   72 PL 42B 372           +FLIAGINE,GUY,KNIGHT+ (BRUX+CERN+TUFT+LOUC)

BALTAY    74 PR D9 49             +BRIDGEWATER,COOPER,GERSHWIN+    (COLU+BING)J
YEH       74 PR D10 3545          +GAIGALAS,SMITH,ZENDLE,BALTAY + (BING+COLU)
GEWENIGE  75 PL 57B 193           GEWENIGER,GJESDAL,PRESSER +      (CERN+HEID)
ZECH      77 NP B124 413          +DYDAK,NAVARRIA+       (SIEG+CERN+DORT+HEID)

BUNCE     78 PR D18 633           +HANDLER,MARCH,MARTIN+      (WISC+MICH+RUTG)
BUNCE     79 PL 86B 386           +OVERSETH,COX,DWORKIN+ (BNL+MICH+RUTG+WISC)
COX       81 PRL 46 877           +DWORKIN +          (MICH+WISC+RUTG+MINN+BNL)
HANDLER   82 PR D25 639           +GROBEL,PONDROM+       (WISC+MICH+MINN+RUTG)
```

STRANGENESS −3 BARYON

$\boxed{\Omega^-}$ $I(J^P) = 0(\frac{3}{2}^+)$

QUANTUM NUMBERS ASSIGNED FROM SU3

Ω^- MASS (MeV)

```
M    E     1(1615.)                            EISENBERG 54 EMUL
M     F    1 1672.1       1.                   FRY1      55 EMUL
M     F    1 1670.6      (1.)                  FRY2      55 EMUL
M          1 1673.0       8.0                  ABRAMS    64 HBC    INTO XI- PIO
M          3 1673.3       1.0                  PALMER    68 HBC    K-P 4.6,5. GEV/C
M          3 1671.8       0.8                  SCHULTZ   68 HBC    K-P 5.5 GEV/C
M          5 1674.2       1.6                  SCOTTER   68 HBC    K-P 6.  GEV/C
M    B     6(1671.9)     (1.2)                 SPETH     69 HBC    K-P 10. GEV/C
M    B    13(1671.43)    (0.78)                ABCLV     73 HBC    K-P 10. GEV/C
M     D    4 1673.4       1.7                  DIBIANCA  75 DBC    4.9 GEV/C K-D
M         41 1673.0       0.8                  BAUBILLIE 78 HBC    8.25 GEV/C K-P
M         27 1671.7       0.6                  HEMINGWAY 78 HBC    4.2 GEV/C K-P
M        100 1673.        1.                   HARTOUNI  85 SPEC   80-280 GEV KL C    |
M            . . . . . . . . .
M    AVG     1672.43      0.32      AVERAGE
```

```
M
M         THE UNAMBIGUOUS DISCOVERY OF OMEGA- IN BOTH PRODUCTION AND DECAY
M         MODES OCCURRED IN BARNES1 64.
M    E    EISENBERG 54 MASS CALCULATED FOR DECAY IN FLIGHT. ALVAREZ 73 HAS
M    E    SHOWN THAT THE OMEGA INTERACTED WITH AG NUCLEUS TO GIVE K- XI AG.
M     F   BOTH FRY EVENTS IDENTIFIED AS OMEGA- BY ALVAREZ 73.
M     F   FRY MASSES ASSUME DECAY TO LAMBDA K- AT REST.  DECAY FROM ATOMIC
M     F   ORBIT COULD DOPPLER SHIFT THE K- ENERGY AND RESULTING OMEGA- MASS
M     F   BY SEVERAL MEV FOR FRY 2.  THIS SHIFT IS NEGLIGIBLE FOR FRY 1
M     F   BECAUSE THE OMEGA DECAY IS APPROXIMATELY PERPENDICULAR TO ITS
M     F   ORBITAL VELOCITY, AS IS KNOWN BECAUSE THE LAMBDA STRIKES THE
M     F   NUCLEUS (L.ALVAREZ, PRIVATE COMM. 1973).  WE HAVE CALCULATED THE
M     F   ERROR ASSUMING THAT ORBITAL N IS 4 OR LARGER.
M    B    ABCLV VALUE INCLUDES THE SPETH 69 EVENTS. EXCLUDED FROM AVERAGE.
M    B    SEE NOTE D IN THE OMEGA- MEAN LIFE SECTION BELOW.
M     D   DIBIANCA 75 GIVES MASS FOR EACH EVENT.  WE QUOTE AVERAGE.
```

$\overline{\Omega}^+$ MASS (MeV)

```
MB         1 1673.1      1.0                FIRESTONE 71 HBC     12 GEV/C K+D
MB        72 1672.       1.                 HARTOUNI  85 SPEC    80-280 GEV KL C   |
MB           . . . . . . . . .
MB   AVG     1672.55     0.71     AVERAGE
```

Ω^- MEAN LIFE (units 10^{-10} sec)

```
T        40    0.80     0.16      0.12  BAUBILLIE 78 HBC      8.25 GEV/C K-P
T   D   101   (1.41)   (0.15)    (0.24) DEUTSCHMA 78 HBC      10,16 GEV/C K- P
T        39    0.75     0.14      0.11  HEMINGWAY 78 HBC      4.2 GEV/C K-P
T      9875    0.823    0.013           BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
T   D   DEUTSCHMANN 78 EXCLUDED FROM AVERAGE BECAUSE OF SIGNIFICANT
T   D   DISAGREEMENT WITH OTHER RECENT EXPERIMENTS, POSSIBLY DUE TO XI-
T   D   CONTAMINATION.
T             . . . . . . . . . .
T   AVG        0.822    0.013     0.013  AVERAGE
```

Ω^- PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Omega^- \to \Lambda K^-$	1116+ 494
P2	$\Omega^- \to \Xi^0\pi^-$	1315+ 140
P3	$\Omega^- \to \Xi^-\pi^0$	1321+ 135
P4	$\Omega^- \to \Lambda\pi^-$	1116+ 140
P5	$\Omega^- \to \Xi^-\gamma$	1321+ 0
P6	$\Omega^- \to \Xi(1530)^0\pi^-$	1533+ 140
P7	$\Omega^- \to \Xi^0 e^-\nu$	1315+.511+ 0
P8	$\Omega^- \to \Xi^-\pi^+\pi^-$	1321+ 140+ 140

Ω^- BRANCHING RATIOS

$\Omega^- \to \Lambda K^-$ (P1)

```
R1     14K     0.678     0.007            BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

$\Omega^- \to \Xi^0\pi^-$ (P2)

```
R2    1947     0.236     0.007            BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

$\Omega^- \to \Xi^-\pi^0$ (P3)

```
R3     759     0.086     0.004            BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

$\Omega^- \to (\Lambda\pi^-)$/total (units 10^{-3}) (P4)

```
R4     DELTA(S)=2.  FORBIDDEN IN FIRST ORDER WEAK INTERACTION.
R4      0      0.19  OR LESS  CL=.90    BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

$\Omega^- \to (\Xi^-\gamma)$/total (units 10^{-3}) (P5)

```
R5      9      2.2   OR LESS  CL=.90    BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

$\Omega^- \to (\Xi(1530)^0\pi^-)$/total (units 10^{-3}) (P6)

```
R6      4      0.64      0.51      0.20 BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

$\Omega^- \to (\Xi^0 e^-\nu)$/total (units 10^{-2}) (P7)

```
R7     14      0.56      0.28           BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

$\Omega^- \to (\Xi^-\pi^+\pi^-)$/total (units 10^{-4}) (P8)

```
R8      4      4.3       3.4       1.3  BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

Ω^- DECAY PARAMETERS

SEE NOTE ON BARYON DECAY PARAMETERS IN NEUTRON SECTION ABOVE.

α FOR $\Omega^- \to K^-\Lambda$

```
AL   K   15   (-0.66)    (0.36)    (0.30) KOCHER    74 HBC      10 GEV/C K-P
AL       40     0.58      0.50            BAUBILLIE 78 HBC      8.25 GEV/C K-P
AL       40    -0.2       0.4             HEMINGWAY 78 HBC      4.2 GEV/C K-P
AL      12K    -0.025     0.028           BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
AL   K   SEE NOTE D IN THE OMEGA- MEAN LIFE SECTION ABOVE.
AL            . . . . . . . . . .
AL   AVG       -0.024     0.028   AVERAGE
```

α FOR $\Omega^- \to \pi^-\Xi^0$

```
AX0   1630     0.09      0.14             BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

α FOR $\Omega^- \to \pi^0\Xi^-$

```
AX-    614     0.05      0.21             BOURQUIN  84 SPEC CERN SPS HYPERON BM  |
```

REFERENCES FOR Ω^-

```
EISENBER 54 PR 96 541          Y EISENBERG                           (CORNELL)
FRY1     55 PR 97 1189         FRY,SCHNEPS,SWAMI                        (WISC)
FRY2     55 NC 2 346           FRY,SCHNEPS,SWAMI                        (WISC)

ABRAMS   64 PRL 13 670         + BURNSTEIN,GLASSER +                 (UMD+NRL)
BARNES1  64 PRL  12  204       V E BARNES,CONNOLLY,CRENNELL,CULWICK+ (BNL)

PALMER   68 PL 26B 323         PALMER,RADOJICIC,RAU,RICHARDSON+ (BNL,SYRA)
SCHULTZ  68 PR  168  1509      SCHULTZ+   (ILL,ARGONNE,NORTHWESTERN,WISC)
SCOTTER  68 PL 26B 474         SCOTTER+    (BIRM,GLASGOW,LOIC,MUNICH,OXF)
SPETH    69 PL  29B 252        SPETH+      (AACHEN,BERLIN,CERN,LOIC,VIEN)

FIRESTON 71 PRL 26 410         +GOLDHABER,LISSAUER,SHELDON,TRILLING  (LRL)
ABCLV    73 NP B61 102         AACHEN+BERLIN+CERN+LONDON+VIENNA COLLABOR.
ALVAREZ  73 PR D8 702          LUIS W. ALVAREZ                          (LBL)
KOCHER   74 PL 51B 193         KOCHER,WERNHARD                    (INNS+VIEN)
DIBIANCA 75 NP B98 137         F.A.DIBIANCA, R.J.ENDORF                (CARN)

BAUBILLI 78 PL 78B 342         BAUBILLIER +       (BIRM+CERN+GLAS+MSU+LPNP)
DEUTSCHM 78 PL 73B 96          DEUTSCHMANN+(AACH+BERL+CERN+INNS+LOIC+VIEN)
HEMINGWA 78 NP B142 205        HEMINGWAY,ARMENTEROS+  (CERN+ZEEM+NIJM+OXF)
BOURQUIN 84 NP B241 1                   (BRIS+GEVA+HEID+LALO+RAL+STRB)
    ALSO 79 PL 87B 297         BOURQUIN,          (BRIS+GEVA+HEID+LALO+RAL)
    ALSO 79 PL 88B 192         BOURQUIN,          (BRIS+GEVA+HEID+LALO+RAL)
HARTOUNI 85 PRL 54 628         +ATIYA,HOLMES,KNAPP,LEE,+    (COLU+ILL+FNAL)
```

CHARMED BARYONS

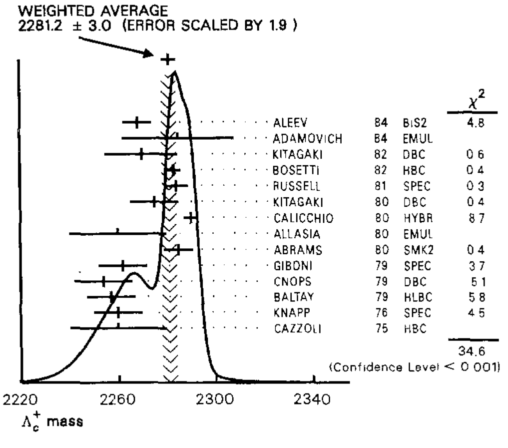
Λ_c^+

$I(J^P) = 0(\frac{1}{2}^+)$

```
J NOT YET MEASURED.  VALUE SHOWN IS QUARK MODEL PREDICTION.
FOR THE (SIGMA/C)-(LAMBDA/C) MASS DIFFERENCE SEE THE SIGMA/C
SECTION OF THE FULL LISTINGS FOR BARYONS.
```

Λ_c^+ MASS (MeV)

```
M       1  2260.      20.               CAZZOLI   75 HBC  +  LAMBDA 2PI+ PI-
M      60  2260.      10.               KNAPP     76 SPEC -  ANTILAM 2PI- PI+
M       1 (2248.)   OR MORE             BARISH    77 DBC     MODE P15 BELOW
M       6  2257.      10.               BALTAY    79 HLBC +  LAMBDA PI+
M       1  2254.      12.               CNOPS     79 DBC     P K*(892)- PI+
M    A 30  2262.      10.               GIBONI    79 SPEC    K- P PI+
M    A  GIBONI 79 RESULT CHANGED FROM 2255+-4 BY AUTHORS.   SEE KERNAN 79.
M      39  2285.       6.               ABRAMS    80 SMK2 +- K- P PI+ + C.C.
M       1  2260.      20.               ALLASIA   80 EMUL    P K- PI+
M       1  2290.       3.               CALICCHIO 80 HYBR    P K- PI+
M      19  2275.      10.               KITAGAKI  80 DBC     LAM PI+, KOBAR P
M      55  2284.0      5.0              RUSSELL   81 SPEC +- KOBAR P + C.C.
M       3  2283.0      3.0              BOSETTI   82 HBC  +  P K- PI+
M       3  2270.0     15.0              KITAGAKI  82 DBC     SIGMA0 PI+
M       3  2285.      23.               ADAMOVICH 84 EMUL    PHOTOPRODUCTION      |
M    C 187 2268.       6.               ALEEV     84 BIS2    N CARBON 58 GEV      |
M    C  THIS MEASUREMENT USES LAM 3PI AND KOP PI+ PI- DECAYS.
M           . . . . . . . . . . .
M   AVG    2281.2      3.0     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.9)
                              (SEE IDEOGRAM BELOW)
```



Λ_c^+ MEAN LIFE (units 10^{-13} sec)

```
T        1   (7.3)                      ANGELINI  79 HYBR P K- PI+
T        8    2.3      1.0       0.6    USHIDA    83 EMUL REPL. USHIDA 80
T    A   8    2.22     1.34      0.75   ADAMOVICH 84 EMUL    PHOTOPRODUCTION    |
T    A  ESTIMATE SYSTEMATIC ERROR LESS THAN +0.6  -0.5.
T          . . . . . . . . . . .
T   AVG       2.27     0.81      0.47    AVERAGE
```

Λ_c^+ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda_c^+ \to \Lambda \pi^+ \pi^+ \pi^-$	1116+ 140+ 140+ 140
P2	$\Lambda_c^+ \to \Lambda \pi^+$	1116+ 140
P3	$\Lambda_c^+ \to p \bar{K}^0$	938+ 498
P4	$\Lambda_c^+ \to p K^- \pi^+$	938+ 494+ 140
P5	$\Lambda_c^+ \to K^*(892)^0 p$	892+ 938
P6	$\Lambda_c^+ \to \Delta(1232)^{++} K^-$	1232+ 494
P7	$\Lambda_c^+ \to p \bar{K}^0 \pi^- \pi^+$	938+ 498+ 140+ 140
P8	$\Lambda_c^+ \to p K^*(892)^- \pi^+$	938+ 892+ 140
P9	$\Lambda_c^+ \to \Sigma^+ \pi^0$	1189+ 135
P10	$\Lambda_c^+ \to \Sigma^0 \pi^+$	1192+ 140
P11	$\Lambda_c^+ \to \Sigma^+ \eta$	1189+ 549
P12	$\Lambda_c^+ \to e^+$ anything	
P13	$\Lambda_c^+ \to p e^+$ anything	
P14	$\Lambda_c^+ \to \Lambda e^+$ anything	
P15	$\Lambda_c^+ \to p \pi^- \pi^0 K^0 e^+ \nu$	938+ 140+ 135+ 498+
P16	$\Lambda_c^+ \to \Lambda$ anything	

Λ_c^+ BRANCHING RATIOS

$\Lambda_c^+ \to (p K^- \pi^+)/\text{total}$ (P4)

```
R1      90   (SEEN)                    DRIJARD   79 SFM  P P AT 62.8 GEV ECM
R1      98   (SEEN)                    GIBONI    79 SPEC P P AT 63 GEV ECM
R1      18   (SEEN)                    LOCKMAN   79 SPEC P P 53, 62 GEV ECM
R1      39    0.022     0.010          ABRAMS    80 SMK2 E+E- 5.2 GEV ECM
R1       1   (SEEN)                    CALICCHIO 80 HBC  NU P IN BEBC-TST
R1      74   (SEEN)                    IRION     81 SPEC P P AT 63 GEV ECM
```

$\Lambda_c^+ \to (p K^*(892)^0)/(p K^- \pi^+)$ (P5)/(P4)

```
R2       1   (SEEN)                    ANGELINI  79 HYBR NU EMUL WITH BEBC
R2      47   (SEEN)                    DRIJARD   79 SFM  P P AT 52.5 GEV ECM
R2            0.18      0.10           WEISS     80 SMK2 E+ E- 5.2 GEV ECM
R2      12    0.42      0.24           BASILE    81 CNTR P P -> LAM/C+ E- X
R2      THE ABOVE RATIOS INCLUDE THE KOBAR PIO MODE OF THE K*0.
R2          . . . . . . . . . . .
R2  AVG       0.216     0.092    AVERAGE
```

$\Lambda_c^+ \to (\Delta(1232)^{++} K^-)/(p K^- \pi^+)$ (P6)/(P4)

```
R3      40   (SEEN)                    DRIJARD   79 SFM  P P AT 52.5 GEV ECM
R3            0.17      0.07           WEISS     80 SMK2 E+ E- 5.2 GEV ECM
R3      17    0.40      0.17           BASILE    81 CNTR P P -> LAM/C+ E- X
R3          . . . . . . . . . . .
R3  AVG       0.203     0.081    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$\Lambda_c^+ \to p \bar{K}^0$ (P3)

```
R4       5   (SEEN)                    BALTAY    79 HLBC NU NE-H2 IN 15-FT
R4      10   (SEEN)                    KITAGAKI  80 DBC  NU D IN FNAL 15-FT
R4      55   (SEEN)              55/75 RUSSELL   81 SPEC PHOTOPRODUCTION
```

$\Lambda_c^+ \to (p \bar{K}^0)/(p K^- \pi^+)$ (P3)/(P4)

```
R5      12    0.5       0.25           WEISS     80 SMK2 E+ E- 5.2 GEV ECM
```

$\Lambda_c^+ \to (p K^- \pi^+)/(p \bar{K}^0)$ (P4)/(P3)

```
R6      50   (1.5)  OR LESS  CL=.90    RUSSELL   81 SPEC PHOTOPRODUCTION
```

$\Lambda_c^+ \to \Lambda \pi^+$ (P2)

```
R7       6   (SEEN)                    BALTAY    79 HLBC NU NE-H2 IN 15-FT
R7       9   (SEEN)                    KITAGAKI  80 DBC  NU D IN FNAL 15-FT
R7       3   (SEEN)                    SON       83 DBC     NU D QUASIELAST   |
```

$\Lambda_c^+ \to (\Lambda \pi^+)/(p K^- \pi^+)$ (P2)/(P4)

```
R8          (0.8)  OR LESS  CL=0.9     WEISS     80 SMK2 E+ E- 5.2 GEV ECM
```

$\Lambda_c^+ \to (\Lambda \pi^+)/(p \bar{K}^0)$ (P2)/(P3)

```
R9   K   5    0.67      0.78      0.35 BALTAY    79 HLBC NU NE-H2 IN 15-FT
R9       9    0.51      0.62      0.27 KITAGAKI  80 DBC  NU D IN FNAL 15-FT
R9      40   (0.4)  OR LESS  CL=.90    RUSSELL   81 SPEC PHOTOPRODUCTION
R9   K  CALCULATED BY KITAGAKI 80 FROM BALTAY 79 RESULTS.
R9          . . . . . . . . . . .
R9  AVG       0.57      0.35     AVERAGE
```

$\Lambda_c^+ \to \Lambda \pi^+ \pi^+ \pi^-$ (P1)

```
R10      1    SEEN                     CAZZOLI   75 HBC  NU P IN BNL 7-FT
R10     60    SEEN                     KNAPP     76 SPEC GAMMA BE
R10      2    SEEN                     BALTAY    79 HLBC NU NE-H2 IN 15-FT
R10     12    SEEN                     GIBONI    79 SPEC P P AT 63 GEV ECM
R10     18    SEEN                     LOCKMAN   79 SPEC P P 53, 62 GEV ECM
R10     57    SEEN                     ALEEV     84 BIS2    N CARBON 58 GEV     |
R10  A  70   (0.028)   (0.013)         BOWCOCK   85 CLEO    E+E- ECM=10.5GEV    |
R10  A  BR(LAMBDA/C INTO LAMBDA 3PI) MAKES ASSUMPTIONS ON CHARM                 |
R10  A  PRODUCTION AND LAMBDA/C PRODUCTION FROM CHARM.                          |
R10  A  STATISTICAL AND SYSTEMATIC ERRORS ARE 0.007 AND 0.011.                  |
```

$\Lambda_c^+ \to (\Lambda \pi^+ \pi^+ \pi^-)/(p K^- \pi^+)$ (P1)/(P4)

```
R11           1.4   OR LESS  CL=0.9    WEISS     80 SMK2 E+ E- 5.2 GEV ECM
```

$\Lambda_c^+ \to (\Lambda \pi^+ \pi^+ \pi^-)/ (p \bar{K}^0)$ (P1)/(P3)

```
R12    220   (3.1)  OR LESS  CL=.90    RUSSELL   81 SPEC PHOTOPRODUCTION
```

$\Lambda_c^+ \to (p \bar{K}^0 \pi^- \pi^+)/(\Lambda 2\pi^+ \pi^-)$ (P7)/(P1)

```
R13    130    4.3       1.2            ALEEV     84 BIS2 N CARBON 40-70 GEV   |
```

$\Lambda_c^+ \to (p \bar{K}^0 \pi^- \pi^+)/(p \bar{K}^0)$ (P7)/(P3)

```
R14     45    3.3   OR LESS  CL=.90    RUSSELL   81 SPEC PHOTOPRODUCTION
```

$\Lambda_c^+ \to \Sigma^0 \pi^+$ (P10)

```
R15      3    SEEN                     KITAGAKI  82 DBC  NU D IN FNAL 15-FT
```

$\Lambda_c^+ \to p K^*(892)^- \pi^+$ (P8)

```
R16      1    SEEN                     CNOPS     79 DBC  NU N IN BNL 7-FT
```

$\Lambda_c^+ \rightarrow (e^+$ anything)/total (P12)

```
R17          0.045    0.017           VELLA     82 SMK2 E+ E- 4.5-6.8 GEV
```

$\Lambda_c^+ \rightarrow (p\, e^+$ anything)/total (P13)

```
R18  M       0.018    0.009           VELLA     82 SMK2 E+ E- 4.5-6.8 GEV
R18  M  THIS INCLUDES PROTONS FROM LAMBDA DECAY.
```

$\Lambda_c^+ \rightarrow (\Lambda\, e^+$ anything)/total (P14)

```
R19       1   (0.022)OR LESS  CL=.90  BALLAGH   81 HYBR NU NE-H2 IN 15-FT
R19  N       0.011    0.008           VELLA     82 SMK2 E+ E- 4.5-6.8 GEV
R19  N  THIS INCLUDES LAMBDAS FROM SIGMA0 DECAY.
```

$\Lambda_c^+ \rightarrow (\Lambda\, e^+$ anything)/(Λ anything) (P14)/(P16)

```
R20  S       0.027    0.017           SON       82 DBC  NU D IN FNAL 15-FT
R20  V       0.065    0.041           VELLA     82 SMK2 E+E- 4.5-6.8 GEV
R20  S  SON 82 USES OWN DATA AND MU- E+ LAMBDA EVENTS OF MURTAGH 79 .
R20  V  THIS VALUE DEDUCED BY SON 82 FROM DATA OF VELLA 82.
R20         . . . . . . . . . .
R20 AVG      0.033    0.016   AVERAGE
```

REFERENCES FOR Λ_c^+

```
CAZZOLI  75 PRL 34 1125         +CNOPS,CONNOLLY,LOUTTIT,MURTAGH, +    (BNL)
KNAPP    76 PRL 37 882          +LEE,LEUNG,SMITH +     (COLU+HAWA+ILL+FNAL)
BARISH   77 PR D15 1            +DERRICK,DOMBECK,MUSGRAVE +      (ANL+PURD)

ANGELINI 79 PL 84B 150           (ANKA+LIBH+CERN+DUUC+LOUC+KEYN+PISA+ROMA+)
BALTAY   79 PRL 42 1721         +CAROUMBALIS,FRENCH,HIBBS, +      (COLU+BNL)
CNOPS    79 PRL 42 197          +CONNOLLY,KAHN,KIRK,MURTAGH,PALMER+   (BNL)
DRIJARD  79 PL 85B 452          +FISCHER+   (CERN+CDEF+DORT+HEID+LAPP+WARS)
GIBONI   79 PL 85B 437          +DIBITONTO+  (AACH+CERN+HARV+MUNI+NWES+UCR)
KERNAN   79  LEPTON CONF.FNAL A. KERNAN                              (UCR)
LOCKMAN  79 PL 85B 443          +MEYER,RANDER,SCHLEIN,WEBB+     (UCLA+SACL)
MURTAGH  79 FERMILAB.SYMP.277 M.J. MURTAGH                          (FNAL)

ABRAMS   80 PRL 44 10           +ALAM,BLOCKER,BOYARSKI, +        (SLAC+LBL)
ALLASIA  80 NP B176 13           (ANKA+LIBH+CERN+DUUC+LOUC+KEYN+PISA+ROMA+)
CALICCHI 80 PL 93B 521          + (BARI+BIRM+BRUX+CERN+EPOL+RHEL+SACL+LOUC)
KITAGAKI 80 PRL 45 955          +TANAKA,YUTA,ABE, +(TOHO+IIT+UMD+STON+TUFT)
WEISS    80 TORONTO CONF 319  J M WEISS                             (SLAC)

BALLAGH  81 PR D24 7            +BINGHAM +    (LBL+UCB+FNAL+HAWA+WASH+WISC)
BASILE   81 NC 62A 14           +CARA ROMEO +          (CERN+BGNA+PGIA+FRAS)

IRION    81 PL 99B 495          +SEEBRUNNER, +   (AACH+CERN+HARV+MUNI+NWES)
RUSSELL  81 PRL 46 799          +AVERY,BUTLER,GLADDING +    (ILL+FNAL+COLU)
BOSETTI  82 PL 109B 234         +GRAESSLER, +      (AACH+BONN+CERN+MPIM+OXF)
KITAGAKI 82 PRL 48 299          +TANAKA,YUTA,ABE,+ (TOHO+IIT+UMD+STON+TUFT)
SON      82 PRL 49 1128         +SNOW,CHANG,KUNORI+(UMD+IIT+STON+TOHO+TUFT)
VELLA    82 PRL 48 1515         +TRILLING,ABRAMS,ALAM,+      (SLAC+LBL+UCB)
SON      83 PR D28 2129         +SNOW,CHANG,KUNORI+(UMD+IIT+STON+TOHO+TUFT)
USHIDA   83 PRL 51 2362           (AICH+FNAL+KOBE+SEOU+MCGI+NAGO+OSU+OKAY+)
ADAMOVIC 84 PL 140B 119         ADAMOVICH,WA58 C.    (BGNA+CERN+FIRZ+GENO+)
ALEEV    84 ZPHY C23 333        BIS-2 COLLAB(BERL+JINR+LEBD+MOSU+PRAG+SOFI)
BOWCOCK  85 PRL 55 923          CLEO C.     (HARV+OHIO+ROCH+RUTG+SYRA+VAND+)

                                THEORY AND REVIEW

DERUJULA 75 PR D12 147          +GEORGI,GLASHOW                     (HARV)
GAISSER  76 PR D14 3153         T.K.GAISSER,F.HALZEN           (BART+WISC)
LEE      77 PR D15 157          +QUIGG,ROSNER                       (FNAL)
MULLER   79 CERN/EP 79-148      F.MULLER (CARGESE LEC.1979)         (CERN)
DIBITONT 81 MADISON CONF.       D.DIBITONTO                         (CERN)
TRILLING 81 PRPL 75 57          G H TRILLING                         (LBL)
```

Ξ_c^+ was A^+

OMITTED FROM SUMMARY TABLE

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

A NARROW SIGNAL (WIDTH COMPATIBLE WITH THE 23-MEV RESOLUTION) INTERPRETED AS A STABLE CHARMED STRANGE BARYON (QUARK CONTENT CSU). THIS INTERPRETATION NEEDS CONFIRMATION.

BIAGI2 85 LOOK FOR THE ISOSPIN PARTNER XI/C0 IN LAMBDA K- PI+ AND OTHER CHANNELS WITHOUT SUCCESS.

Ξ_c^+ MASS (MeV)

```
M       82 2460.      25.              BIAGI      83 SPEC    SIG- BE-->XI/C+ X
```

Ξ_c^+ MEAN LIFE (units 10^{-13} sec)

```
T       53    4.8      2.9       1.8   BIAGI1     85 SPEC    SIG- BE-->XI/C+ X
```

Ξ_c^+ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi_c^+ \rightarrow \Lambda K^- \pi^+ \pi^+$	1116+ 494+ 140+ 140

Ξ_c^+ BRANCHING RATIOS

$\Xi_c^+ \rightarrow \Lambda K^- \pi^+ \pi^+$ (P1)

```
R1   A   82    SEEN                    BIAGI     83 SPEC   SIG- BE-->XI/C+ X
R1
R1   A   BIAGI2 85 LOOK FOR BUT DO NOT SEE THE XI/C+ IN P K- KOBAR PI+
R1   A   (BRANCHING FRACTION < 0.08 WITH 90 PERCENT CL), P 2K- 2PI+ (<0.03,
R1   A   90 PERCENT CL), OMEGA- K+ PI+, LAMBDA K*0 PI+, AND SIGMA(1385)+ K-
R1   A   PI+.
```

REFERENCES FOR Ξ_c^+

```
BIAGI    83 PL 122B 455        +  (BRIS+CERN+GEVA+HEID+LAUS+LOQM+MELB+RL)
BIAGI1   85 PL 150B 230        + (BRIS+CERN+GEVA+HEID+LAUS+LOQM+MELB+RAL)
BIAGI2   85 ZPHY C28 175       + (BRIS+CERN+GEVA+HEID+LAUS+LOQM+MELB+RAL)
```

Ω_c^0 was T^0

OMITTED FROM SUMMARY TABLE

$I(J^P) = (\quad)$

A CLUSTER OF THREE XI- K- PI+ PI+ EVENTS. THE (OMEGA/C0 - XI/C+) MASS DIFFERENCE IS 280+-10 MEV. THE INTERPRETATION AS BEING THE OMEGA/C0 NEEDS CONFIRMATION.

Ω_c^0 MASS (MeV)

```
M        3 2740.      20.              BIAGI     85 SPEC   SIG- BE-->
```

REFERENCES FOR Ω_c^0

```
BIAGI    85 ZPHY C28 175       + (BRIS+CERN+GEVA+HEID+LAUS+LOQM+MELB+RAL)
```

BOTTOM BARYON

Λ_b^0

OMITTED FROM SUMMARY TABLE

$I(J^P) = 0(\frac{1}{2}^+)$

QUANTUM NUMBERS NOT ESTABLISHED, TAKEN FROM QUARK MODEL. THE CLAIM BY BASILE 81 IS HOTLY DISPUTED BY DRIJARD 82. BASILE 82 IS THE REPLY, AND DRIJARD1 82 IS THE REPLY TO THAT.

Λ_b^0 MASS (MeV)

```
M          5425.0    175.0     75.0   BASILE     81 SFM   0  P P 62 GEV ECM
```

Λ_b^0 PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda_b^0 \rightarrow p D^0 \pi^-$	938+1865+ 140

Λ_b^0 BRANCHING RATIOS

$\Lambda_b^0 \rightarrow (p\, D^0 \pi^-)$/total (P1)

```
R1             SEEN                    BASILE    81 SFM  D0 TO K- PI+
```

REFERENCES FOR Λ_b^0

```
BASILE   81 LNC 31 97          +BONVICINI,CARA ROMEO+(CERN+BGNA+FRAS+PGIA)
BASILE   82 NC 68A 289         +BONVICINI,CARA ROMEO+     (CERN+BGNA+FRAS)
DRIJARD  82 PL 108B 361        +FISCHER,+  (CERN+CDEF+DORT+HEID+LAPP+WARS)
DRIJARD1 82 CERN/EP 82-31      +FISCHER,+  (CERN+CDEF+DORT+HEID+LAPP+WARS)
```

SEARCHES

TOP HADRON SEARCHES

OMITTED FROM SUMMARY TABLE

TOP HADRON SEARCHES IN e^+e^- COLLISIONS

```
TE    A   NONE ECM=22-31.6 GEV            BARTEL1   79 JADE R
TE    B   NONE ECM=22-31.6 GEV            BARTEL2   79 JADE <S>
TE    C   NONE ECM=31.6 GEV               BARBER    79 MRKJ R,<S>,<T>
TE    D   NONE ECM=22-31.6 GEV            BERGER    79 PLUT R,<S>,<T>,MU
TE    E   NONE ECM=30-36 GEV              BARBER    80 MRKJ R,<T>,MU
TE    F   NONE ECM=12-31.6 GEV            BERGER    80 PLUT MU
TE    G   NONE ECM=33-35.8 GEV            BARTEL    81 JADE MU
TE    H   NONE ECM=14-36.7 GEV            BRANDELIK 82 TASS R
TE    I   NONE ECM < 38.54 GEV CL=.99     ADEVA1    83 MRKJ    R,<T>,(MU+MU-X)
TE        NONE ECM < 38 GEV               ADEVA2    83 MRKJ    PT(MU),<T>
TE    K   NONE ECM 39.8 - 45.2 GEV        ALTHOFF   84 TASS    R, EVENT SHAPE
TE    L   NONE ECM 12. - 43. GEV          ALTHOFF2  84 TASS    APLANARITY
TE    M   NONE ECM=33-36.72 GEV CL=.95    BEHREND   84 CELL    APLANARITY
TE    M   NONE ECM=38.66-46.78  CL=.95    BEHREND   84 CELL    APLANARITY
TE    N   NONE ECM=40-46.78 GEV CL=.95    ADEVA     85 MRKJ    MU
TE
TE                                        COMMENTS
TE        ALL ABOVE MEASUREMENTS ARE DONE AT DESY-PETRA. THE LAST COLUMN
TE        SPECIFIES MEASURED QUANTITIES.
TE
TE    A   BARTEL1 79 SAW NO EVIDENCE OF NEW Q=2/3 QUARK PROD. IN R-RATIO.
TE
TE    B   BARTEL2 79 OBSERVE NO SIGNIFICANT ACCUMULATION OF SPHERICAL EVENTS.
TE
TE    C   BARBER 79 R,THRUST,SPHEROCITY INDICATE TOP-PRODUCTION UNLIKELY.
TE
TE    D   BERGER 79 FIND R=3.88+0.22 WHICH ALONG WITH SPHERICITY AND THRUST
TE    D   BEHAVIORS IS AGAINST OPEN TOP ANTI-TOP CHANNEL BELOW 30GEV. FINAL
TE    D   MUONS ARE ALSO CONSISTENT WITH EXPECTATION WITHOUT TOP QUARK STATE.
TE
TE    E   BARBER 80 FIND NO EVIDENCE FOR AN OPEN TOP ANTI-TOP THRESHOLD IN R,
TE    E   THRUST DIST. AND INCLUSIVE MUONS. ENERGY SCAN IN THE RANGE 29.9<ECM
TE    E   <31.6GEV REVEALS NO HADRON RESONANCE CORRESPONDING TO A (TOP-QUARK
TE    E   ANTI-TOP-QUARK) BOUND STATE.
TE
TE    F   BERGER 80  MEASURES INCLUSIVE MUONS WITH MOMENTUM >2 GEV/C. AGREE
TE    F   WITH EXPECTED SEMILEPTONIC DECAYS FROM CHARMED AND BOTTOM MESONS.
TE
TE    G   BARTEL 81 MEASURES INCLUSIVE MUONS WITH MOMENTUM  >1.4 GEV/C. AGREE
TE    G   WITH EXPECTED SEMILEPTONIC DECAYS FROM CHARMED AND BOTTOM MESONS.
TE
TE    H   BRANDELIK 82 GOT R=4.01+-0.03+-0.2 WITH NO STEP FOR W>14GEV. NARROW
TE    H   STATE SEARCH FOR W=33-36.7GEV SETS EE-WIDTH*BR(HAD)<1.5KEV(CL=.95).
TE
TE    I   ADEVA1 ENERGY SCAN EXCLUDES OPEN TOP CONTINUUM BELOW 38.54 GEV AND
TE    I   TOPONIUM BETWEEN 29.90 AND 38.63 GEV (HAD.BR*E-WIDTH < 2.0 KEV AT
TE    I   CL=.95). ALSO SET LIMIT BR(B-->MU+MU-X) < 0.007 (CL=.95) WHICH
TE    I   EXCLUDES FLAVOR-CHANGING NEUTRAL CURRENT IN TOPLESS MODELS.
TE
TE    K   ALTHOFF 84 NARROW STATE SEARCH SETS LIMIT EE WIDTH*BR(HAD)<2.4 KEV
TE    K   CL=.95 AND HEAVY CHRG 1/3 (2/3) QUARK PAIR PRODUCTION M>21 GEV
TE    K   (22 GEV), CL=.95
TE
TE    L   ALTHOFF2 84 EXCLUDE HEAVY QUARK PAIR PRODUCTION FOR MASSES IN GEV
TE    L   5<M<20.3 (2/3 CHARGE) AND 7<M<19 (1/3 CHARGE) USING APLANARITY.
TE    L   DISTRIBUTIONS (CL=.95)
TE
TE    M   BEHREND 84 EXCLUDE TOPONIUM BELOW 46.7 GEV AND CONTINUUM PRODUCTION
TE    M   BELOW 23.3 GEV (2/3 CHARGE) AND 22.7 GEV (1/3 CHARGE) AT CL=.90.
TE    M   TOPONIUM SEARCH SETS LIMIT WIDTH(EE)*BR(HAD) < 2.9 KEV WHERE
TE    M   TOPONIUM IS EXPECTED TO HAVE WIDTH(EE)=4-5 KEV.
TE
TE    N   ADEVA 85 EXCLUDE TOPONIUM BELOW 46.6 GEV AND OPEN TOP CONTINUUM
TE    N   BELOW 23.3 GEV AT CL=.95.  TOPONIUM SEARCH SETS LIMIT
TE    N   WIDTH(EE)*BR(HAD) < 3 KEV.
TE
TE                                        COMMENT
TE
TE        RECENT UPPER LIMITS ON THE FLAVOR CHANGING NEUTRAL CURRENT DECAY
TE        OF BOTTOM MESON ARE IN CONFLICT WITH THE EXPECTED RATE IN THE
TE        TOPLESS MODEL AND SERVE AS INDIRECT SUPPORT FOR THE TOP QUARK.
TE        SEE PARTIAL DECAY MODE B-->MU+ MU- X OF THE BOTTOM MESON SECTION.
```

TOP HADRON SEARCHES IN $p\bar{p}$ COLLISIONS

```
TP    A                                   ARNISON   83 CALO    UA1 COLLAB.
TP=   1                                   BARGER    83 RVUE
TP=   2                                   BASILE    83 RVUE
TP=   3                                   GODBOLE   83 RVUE
TP    B                                   ARNISON   84 UA1  P PBAR ECM=546+630
TP    C                                   DILELLA   85 RVUE
TP
TP    A   ARNISON 83 OBSERVED  11 LARGE-PT ELECTRON EVENTS WITH A JET OPPO-
TP    A   SITE TO THE TRACK WITHIN A 30 DEGREE AZIMUTHAL ANGLE.
TP    A   INTERPRETATION OF THESE AS T-->E NU JET IS GIVEN BY 3 RVUES BELOW.
TP
TP    B   ARNISON 84 OBSERVE EVENTS WITH ISOLATED LARGE-PT LEPTON AND 2
TP    B   CENTRALLY-PRODUCED JETS.  THESE EVENTS CLUSTER AROUND THE W MASS.
TP    B   ARNISON 84 ARGUE THAT THESE HAVE NO KNOWN SOURCE AND ARE CONSISTENT
TP    B   WITH W-->T B(BAR) FOLLOWED BY T-->B LEPTON NU WHERE THE MASS OF
TP    B   THE T-QUARK WOULD BE 30-50 GEV. EVENTS INCLUDE 9 WITH E, 3 WITH MU.
TP
TP    C   DILELLA 85 DICUSSES LIMITATIONS OF ABOVE UA1 DATA.  W--> T B(BAR)
TP    C   RATE WITH T-->B E NU CAN BE PREDICTED FROM MEASURED CS(W) GIVING
TP    C   1-3 EVENTS NOT 9 EVENTS.  HOWEVER OTHER EVENTS MAY RESULT FROM
TP    C   T T(BAR) PRODUCTION FOLLOWED BY SEMI-LEPTONIC DECAY OF T OR T(BAR).
TP    C   IN THIS LATTER CASE, THE CLUSTER AT THE W MASS IS COINCIDENCE OF
TP    C   T T(BAR) THRESHOLD AND DECREASE OF T T(BAR) PRODUCTION.  MUON
TP    C   EVENTS HAVE DIFFERENT HADRONIC BACKGROUNDS SO FINAL MUON ANALYSIS
TP    C   WILL STRENGTHEN (OR WEAKEN) T-QUARK HYPOTHESIS.
```

REFERENCES FOR TOP HADRON SEARCHES

```
BARTEL1  79 PL 88B 171      JADE C.(DESY+HAMB+HEID+MCHS+LANC+RHEL+TOKY)
BARTEL2  79 PL 89B 136      JADE C.(DESY+HAMB+HEID+MCHS+LANC+RHEL+TOKY)
BARBER   79 PL 85B 463      MARK-J COLLAB.    (AACH+DESY+MIT+AIKO+BHEP)
BERGER   79 PL 86B 413      PLUTO C.(AACH+BERG+DESY+HAMB+UMD+SIEG+WUPP)
BARBER   80 PRL 44 1722     MARK-J COLLAB.    (AACH+DESY+MIT+AIKO+BHEP)
BERGER   80 PRL 45 1533     PLUTO C.(AACH+BERG+DESY+HAMB+UMD+SIEG+WUPP)
BARTEL   81 PL 99B 277      +CORDS+(DESY+HAMB+HEID+LANC+MCHS+RHEL+TOKY)
BRANDELI 82 PL 113B 499     TASSO C.  (AACH+BONN+DESY+HAMB+LOIC+OXF+RL)

ADEVA1   83 PRL 50 799      MARKJ C. (AACH+DESY+MIT+MADR+AIKO+BHEP+CIT)
ADEVA2   83 PRL 51 443      MARKJ C. (AACH+DESY+MIT+MADR+AIKO+BHEP+CIT)
ARNISON  83 PL 122B 103     UA1-C.(AACH+LAPP+BIRM+CERN+HELS+LOQM+CDEF+)
BARGER   83 PL 125B 339     +MARTIN,PHILLIPS              (DURH+WISC+RHEL)
BASILE   83 LNC 37 255      +BERBIERS,BONVICINI,CARA+  (CERN+BGNA+FRAS)
GODBOLE  83 PRL 50 1539     R.M.GODBOLE,S.PAKVASA,D.P.ROY   (BOMB+TIFR)
ALTHOFF  84 PL 138B 441     TASSO C. (AACH+BONN+DESY+HAMB+LOIC+OXF+RL+)
ALTHOFF2 84 ZPHY C22 307    TASSO C. (AACH+BONN+DESY+HAMB+LOIC+OXF+RL+)
ARNISON  84 PL 147B 493     UA1 C.(AACH+LAPP+BIRM+CERN+HARV+HELS+KIEL+)
BEHREND  84 PL 144B 297     CELLO C.   (DESY+GLAS+HAMB+KARL+MPIP+ORSA+)
ADEVA    85 PL 152B 439     MARK-J C.(AACH+BNL+CIT+DESY+MIT+MADR+AIKO+)
DILELLA  85 BARI CONF.      ALSO ISSUED AS CERN-EP-85-184          (CERN)
```

FREE QUARK SEARCHES

OMITTED FROM SUMMARY TABLE

(by W.P. Trower, Virginia Polytechnic Institute and State University)

The basis for much of the theory of particle scattering and hadron spectroscopy is the construction of the hadrons from a set of fractionally charged constituents (quarks). Central to this theory, QuantumChromo-Dynamics, is the as yet unproven prohibition that quarks must forever be confined to the mesons and baryons they make up.

Experiments show that it is at best difficult to "unglue" quarks. Accelerator searches at increasing energies have produced no evidence for free quarks, while only a few cosmic-ray and matter searches have produced uncorroborated events.

This compilation is only a guide to the literature, since the quoted experimental limits are often only indicative.

QUARK PROD. CROSS SECTION -- ACCELER. SEARCHES

```
C
C         QUARK   X-SECT CHARGE      MASS     REFERENCE   DET        BEAM
C        EVENTS    CM2    1/3E        GEV                           GEV
C
C     .G    0     <1E-4 +-1,2,4        <4   ALBRECHT  85 ARG      10E+E-
C      H    0     <6E-5    +-1,2        1   BANNER    85 UA2     540P AP
C      G    0     <5E-3       -4      1-8   AIHARA1   84 TPC      29E+E-
C      G    0     <1E-2    +-1,2     1-13   AIHARA2   84 TPC      29E+E-
C    H I    0     <2E-4      +-1        -   BARWICK   84 CNTR     72AR40
C           0     <1E-40   +-1,2      <10   BERGSMA   84 CHRM       P,NU NUBAR
C      G    0     <1E-4      +-2      <.4   BONDAR    84 CNTR    1.4E+E-
C      G    0     <5E-1    +-1,2      <13   GURYN     84 CNTR     29E+E-
C           0     <1E-36   +-1,2       <9   AUBERT    83 SPEC    200MU
C      H    0     <3E-3    +-1,2       <2   BANNER    83 CNTR    540P AP
C      H    0     <1E-4    +-1,2        -   LINDGREN  83 CNTR    106FE56
C    H I    0     <3E-3   >+-1/6        -   PRICE     83 PLAS     74AR40
C      G    0     <1E-2    +-1,2      <14   MARINI1   82 CNTR     29E+E-
C      G    0     <8E-2    +-1,2      <12   ROSS      82 CNTR     29E+E-
C      C    0     <2E-10   +-2,4      1-3   BUSSIERE  80 CNTR    200PROT
C    E F    0     <5E-38    +1,2       >5   STEVENSO  79 CNTR    300PROT
C           0     <1E-33     +-1      <20   BASILE1   78 SPEC     52P P
C      E    0     <9E-39   +-1,2       <6   ANTREASY  77 SPEC    400PROT
C      D    0     <8E-35    +1,2      <20   FABJAN    75 CNTR     52P P
C           0     <5E-38    -1,2      4-9   NASH      74 CNTR    200PROT
C           0     <1E-32    +2,4     4-24   ALPER     73 SPEC     52P P
C           0     <5E-31  +1,2,4      <12   LEIPUNER  73 CNTR    300PROT
C           0     <6E-34   +-1,2      <13   BOTT      72 CNTR     52P P
C           0     <1E-36      -4        4   ANTIPOV   71 CNTR     70PROT
C      B    0     <1E-35   +-1,2        2   ALLABY    69 CNTR     28PROT
C      C    0     <4E-37      -2       <5   ANTIPOV1  69 CNTR     70PROT
C      B    0     <3E-37    -1,2      2-5   ANTIPOV2  69 CNTR     70PROT
C           0     <1E-35    +1,2       <7   DORFAN    65 CNTR     30PROT
C      A    0     <2E-35      -2  <2.5-5   FRANZINI  65 CNTR     30PROT
C           0     <5E-35    +1,2     <2.2   BINGHAM   64 HLBC     21PROT
C           0     <1E-32   +1,+2     <4.0   BLUM      64  HBC     28PROT
C      A    0     <1E-35   +1,+2     <2.5   HAGOPIAN  64  HBC     31PROT
C           0     <1E-34      +1       <2   LEIPUNER  64 CNTR     28PROT
C           0     <1E-33    +1,2     <2.4   MORRISON  64  HBC     24PROT
```

```
C     I - BOUND TO NUCLEI.
C     H - FOR X-SECT READ FRACTION OF FRAGMENTS.
C     G - FOR X-SECTION READ X-SECT(Q-Q X)/X-SECT(MU-MU)
C     F - 3E-5 < LIFETIME < 1E-3 S.
C     E - X-SECTION  CM2/GEV2.
C     D - INCLUDES BOTT 72 RESULTS.
C     C - HADRONIC OR LEPTONIC QUARKS.
C     B - ASSUMES ISOTROPIC CM PRODUCTION.
C     A - CROSS SECTION INFERRED FROM FLUX.
```

QUARK DIFFERENTIAL PROD. CROSS SECT. -- ACCELER. SEARCHES

```
D
D        QUARK  X-SECT    CHARGE    MASS     REFERENCE   DET         BEAM
D       EVENTS CM2/SR/GEV 1/3E       GEV                            GEV
D
D           0     <4E-36   -2,4   1.5-6   BALDIN     76 CNTR     70PROT
D           0     <2E-33    +-4    5-20   ALBROW     75 SPEC     52P P
D           0     <5E-34     <7    7-15   JOVANOVIC  75 CNTR     44P P
D     A     0     <5E-35      -       -   GALIK      74 CNTR     20GAMMA
D           0     <9E-35   -1,2       -   NASH       74 CNTR    200PROT
D           0     <4E-36     -4 2.3-2.7   ANTIPOV    71 CNTR     70PROT
D           0     <3E-35  +-1,2    <2.7   ALLABY     69 CNTR     27PROT
D           0     <7E-38   -1,2    <2.5   ANTIPOV2   69 CNTR     70PROT

D     A - X-SECTION IN  CM**2/SR/EQUIV. QUANTA .
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QUARK FLUX -- ACCELERATOR SEARCHES

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FR
FR       QUARK    FLUX/  CHARGE     MASS     REFERENCE   DET         BEAM
FR      EVENTS  NUEVENT   1/3E      GEV                             GEV
FR
FR    E   0     <3E-4       +-2    1.8-2   WEISS      81 SMK2       7E+E-
FR    E   0     <5E-2 +1,2,4,5     2-12   BARTEL     80 JADE      27E+E-
FR  A B   0     <2E-5      +1,2       -   BASILE     80 CNTR         NU
FR  * D   0     <3E-10   +-2,4      1-3   BOZZOLI    79 CNTR     200PROT
FR    *   0     <6E-11      +-1     <21   BASILE1    78 SPEC      52P P
FR        0     <5E-3         -       -   BASILE2    78 CNTR        NU(MU)
FR    *   0     <2E-9       +-1     <26   BASILE     77 SPEC      62P P
FR  * C   0     <7E-10     +1,2     <20   FABJAN     75 CNTR      52PROT
FR  A B   0        -       +1,2    >4.5   GALIK      74 CNTR        GAMMA
FR  A B   0        -       +1,2    >1.5   BELLAMY    68 CNTR      12E-
FR    A   0        -       +1,2    >0.9   BATHOW     67 CNTR        GAMMA
FR    A   0        -       +1,2    >0.9   FOSS       67 CNTR       6GAMMA
FR
FR    E - FOR FLUX READ QUARK PROD. X-SECTION  RATIO TO CSE+E->MU+MU  .
FR    D - QUARK LIFETIMES >1.E-8 S.
FR    C - ONE CANDIDATE M <.17 GEV.
FR    B - HADRONIC QUARK.
FR    A - LEPTONIC QUARK.
FR    * - QUARK FLUX PER CHARGED PARTICLE.
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QUARK FLUX -- COSMIC RAY SEARCHES

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F
F       QUARK    FLUX    CHARGE     MASS     REFERENCE   DET     SHIELDING
F      EVENTS /CM2/S/SR 1/3E        GEV                           KG/CM2
F
F     C   0     <1E-12  +-2,3/2       -   KAWAGOE    84 PLAS       -70.
F         0     <9E-10  +-1,2         -   WADA       84 PLAS        0.3
F         7     (4E-9)  +-4           -   WADA       84 PLAS        0.3
F         0     <2E-12 +-1,2,3        -   MASHIMO    83 CNTR       -0.3*
F         0     <3E-10  +-1,2         -   MARINI2    82 CNTR        0.3
F         0     <2E-11  +-1,2         -   MASHIMO    82 CNTR          -
F     C   0     <8E-10  +-1,2         -   NAPOLITAN  82 CNTR        0.3
F     F   3        -          -       -   YOCK       78 CNTR          -
F     A   0     <1E-9         -       -   BRIATORE   76 ELEC          -
F     B   0     <2E-11       +1       -   HAZEN      75 CC            -
F         0     <2E-10     +1,2       -   KRISOR     75 CNTR          -
F   B E   0     <1E-7      +1,2       -   CLARK      74 CC            -
F         0     <3E-10       +1     >20   KIFUNE     74 CNTR          -
F     B   0     <8E-11       +1       -   ASHTON     73 CNTR          -
F         0     <2E-8      +1,2       -   HICKS      73 CNTR          -
F         0     <5E-10       +4       -   BEAUCHAMP  72 CNTR        2.8*
F     B   0     <1E-10     +1,2       -   BOHM       72 CNTR          -
F         0     <1E-10     +1,2       -   COX        72 ELEC        2.8*
F         0     <3E-10       +2       -   CROUCH     72 CNTR          -
F     A   0     <3E-8         -       -   DARDO      72 CNTR          7
F     B   0     <4E-9        +1       -   EVANS      72 CC            -
F     A   0     <2E-9         -     >10   TONWAR     72 CNTR          -
F         0     <2E-10       +1       -   CHIN       71 CNTR        2.8*
F     B   0     <3E-10     +1,2       -   CLARK      71 CC            -
F     B   0     <1E-10     +1,2       -   HAZEN      71 CC            -
F         0     <5E-10     +1,2       -   BOSIA      70 CNTR        3.5*
F     B   1      (-)       +1,2    <6.5   CHU        70 HLBC          -
F         0     <2E-9        +1       -   FAISSNER   70 CNTR          -
F         0     <2E-10     +1,2       -   KRIDER     70 CNTR        0.8*
F         4     <5E-11       +2       -   CAIRNS     69 CC            -
F         0     <8E-10     +1,2     <10   FUKUSHIMA  69 CNTR          -
F    BD   1      (-)       (+2)     (-)   MCCUSKER   69 CC            -
F     A   0     <1E-10        -      >5   BJORNBOE   68 CNTR    1.7,3.6
F     C   0     <1E-8 +-1,2,4         -   BRIATORE   68 CNTR     6.3,.2*
F         0     <3E-8         -      >2   FRANZINI   68 CNTR          -
F         0     <9E-11   +-1,2        -   GARMIRE    68 CNTR          -
F         0     <4E-10     +-1        -   HANAYAMA   68 CNTR          -
F         0     <3E-8         -     >15   KASHA1     68 OSPK          -
F         0     <2E-10       +2       -   KASHA2     68 CNTR          -
F         0     <2E-10       +4       -   KASHA3     68 CNTR          -
F         0     <2E-10       +2       -   BARTON     67 CNTR          6
F         0     <2E-7        +4       -   BUHLER1    67 CNTR  0.008,0.5*
F         0     <5E-10      1,2       -   BUHLER2    67 CNTR  0.008,0.5*
F         0     <4E-10     +1,2       -   GOMEZ      67 CNTR          -
F         0     <2E-9        +2       -   KASHA      67 CNTR          -
F         0     <2E-10       +2       -   BARTON     66 CNTR        220
F         0     <2E-9      +1,2       -   BUHLER     66 CNTR        0.5*
F         0     <3E-9      +1,2       -   KASHA      66 CNTR          -
F         0     <2E-9      +1,2       -   LAMB       66 CNTR          -
F         0     <2E-8      +1,2      >7   DELISE     65 CNTR        2.8*
F         0     <5E-8        +2    >2.5   MASSAM     65 CNTR        0.5*
F         0     <2E-8        +1       -   BOWEN      64 CNTR        2.5*
F         0     <2E-7        +1       -   SUNYAR     64 CNTR        0.8
F
F     F - LIFETIME >10**-8 S; CHARGE +-.70,.68,.42; AND MASS
F     F   >4.4, 4.8, AND 20 GEV, RESPECTIVELY.
F     E - ALSO 1/4 AND 1/6E CHARGES.
F     D - NO EVENTS IN SUBSEQUENT EXPTS.
F     C - LEPTONIC QUARKS.
F     B - PROMPT AIR SHOWER SEARCH.
F     A - TIME DELAYED AIR SHOWER SEARCH.
F     * - ALTITUDE IN KM. ALL OTHERS SEA LEVEL.
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QUARK DENSITY -- MATTER SEARCHES

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RHO
RHO     QUARK  QUARKS/ CHARGE     MASS     REFERENCE  MATERIAL/METHOD
RHO    EVENTS  NUCLEON  1/3E      GEV
RHO
RHO       0     <2E-20    >+-1  .2-250   MILNER    85  NIOBIUM+TUNGS/ION BEAM
RHO       0     <1E-21     +-1       -   SMITH     85  LEVITATED NIOBIUM
RHO       0     <5E-22       -       -   MARINELL  84  LEVITATED STEEL
RHO       0      (-)      +1,2    <100   KUTSCHER  84  NIOBIUM/MASS SPEC
RHO       0     <9E-20   +-<13       -   JOYCE     83  WATER/OIL DROP
RHO       0     <2E-21  +->1/2       -   LIEBOWIT  83  LEVITATED STEEL
RHO       0     <1E-19   +-1,2       -   VANDESTE  83  PHOTO ION SPEC
RHO   B   0     <2E-20       -       -   HODGES    81  MERCURY/OIL DROP
RHO       4     <2E-20      -1       -   LARUE     81  LEVITATED NIOBIUM
RHO       4     <2E-20      +1       -   LARUE     81  LEVITATED NIOBIUM
RHO       0     <1E-21       -       -   MARINELL  80  LEVITATED STEEL
RHO       0     <6E-16       -       -   BOYD      79  HELIUM/MASS SPEC
RHO       3     <5E-21      +1       -   LARUE     79  LEVITATED NIOBIUM
RHO       0     <4E-28       -       -   OGORODNI  79  EARTH+/ION BEAM
RHO       0     <5E-15      +1       -   BOYD1     78  TUNGSTEN/MASS SPEC
RHO       0     <5E-16      +3    <1.7   BOYD2     78  HYDROGEN/MASS SPEC
RHO       0     <1E-21   +-2,4       -   LUND      78  WATER/ION BEAM
RHO       0     <6E-15    >1/2       -   PUTT      78  LEVITATED TUNGSTEN
RHO       0     <1E-22       -       -   SCHIFFER  78  METALS/MASS SPEC
RHO       0     <5E-15       -       -   BLAND     77  LEVITATED TUNGSTEN OX
RHO       0     <3E-21       -       -   GALLINAR  77  LEVITATED IRON
RHO       1     (1E-2)      -1       -   LARUE     77  LEVITATED NIOBIUM
RHO       2     (1E-2)      +1       -   LARUE     77  LEVITATED NIOBIUM
RHO       0     <1E-13      +3    <7.7   MULLER    77  HYDROGEN/MASS SPECTRA
RHO       0     <5E-27       -       -   OGORODNI  77  WATER+/ION BEAM
RHO       0     <1E-21       -       -   STEVENS   76  LUNAR+/ION SPEC
RHO       0     <1E-15      +1     <60   ELBERT    70  OXYGEN+/ION SPEC
RHO       0     <5E-19       -       -   MORPURGO  70  LEVITATED GRAPHITE
RHO       0     <5E-23       -       -   COOK      69  WATER+/ATOM BEAM
RHO       0     <1E-17   +-1,2       -   BRAGINSK  68  LEVITATED GRAPHITE
RHO       0     <1E-17       -       -   RANK      68  WATER+/UV SPEC
RHO       0     <3E-19     +-1       -   STOVER    67  LEVITATED IRON
RHO   A   0     <1E-10       -       -   BENNETT   66  SUN/UV SPEC
RHO       0     <1E-17    +1,2       -   CHUPKA    66  METORITES+/ION BEAM
RHO       0     <1E-16     +-1       -   GALLINAR  66  LEVITATED GRAPHITE
RHO       0     <1E-22       -       -   HILLAS    59  ARGON/ELECTROMETER
RHO       1        -        -2       -   MILLIKAN  10  LEVITATED OIL
RHO
RHO   B - ALSO SET LIMITS FOR Q=+-1/6E.
RHO   A - LIMIT INFERRED BY JONES 77 (RMP 69, 717).
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REFERENCES FOR QUARK SEARCHES

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ALBRECHT 85 PL 156B 134        ARGUS C.   (DESY+DORT+HEID+IPPC+KANS+LJUB+)
BANNER   85 PL 156B 129        UA2 C.       (SACL+BERN+CERN+ORSA+PAVI+BOHR)
MILNER   85 PRL 54 1472        +COOPER,CHANG,WILSON,LABRENZ,MCKEOWN  (CIT)
SMITH    85 PL 153B 188        +HOMER,LEWIN,WALFORD,JONES       (RAL+LOIC)
AIHARA1  84 PRL 52 168         +          (LBL+UCLA+UCR+JHU+MASA+TOKY+YALE)
AIHARA2  84 PRL 52 2332        +          (LBL+UCLA+UCR+JHU+MASA+TOKY+YALE)
BARWICK  84 PR D30 691         +MUSSER,STEVENSON                     (UCB)
BERGSMA  84 ZPHY C24 217       +ALLABY,ABT+     (ANIK+CERN+HAMB+ITEP+ROMA)
BONDAR   84 JETPL 40 1265      +KURADZE,LELCHUK,PANIN,SIDOROV+      (SIBE)
GURYN    84 PL 139B 313        +PARKER,FRIES+    (FRAS+LBL+NWES+STAN+HAWA)
KAWAGOE  84 LNC 41 604         +MASHIMO,NAKAMURA,NOZAKI,ORITO       (TOKY)
KUTSCHER 84 PR D29 791         KUTSCHERA,SCHIFFER,FREKERS+      (ANL+FNAL)
MARINELL 84 PL 137B 439        MARINELLI,MORPURGO                   (GENO)
WADA     84 LNC 40 329         T.WADA,Y.YAMASHITA,I.YAMAMOTO        (OKAY)
AUBERT   83 PL 133B 461         (CERN+DESY+FREI+KIEL+LANC+LAPP+LIVP+MARS+)
BANNER   83 PL 121B 187         UA2          (BERN+CERN+BOHR+LALO+PAVI+SACL)
JOYCE    83 PRL 51 731         +ABRAMS,BLAND,JOHNSON,LINDGREN+      (SFSU)
LIEBOWIT 83 PRL 50 1640        LIEBOWITZ,BINDER,ZIOCK               (VIRG)
LINDGREN 83 PRL 51 1621        +JOYCE,ABRAMS+ (SFSU+UCR+UCI+SLAC+LBL+LANL)
MASHIMO  83 PL 128B 327        +ORITO,KAWAGOE,NAKAMURA,NOZAKI       (TOKY)
PRICE    83 PRL 50 566         +TINCKNELL,TARLE,AHLEN,FRANKEL+       (UCB)
VANDESTE 83 PRL 50 1234        VANDESTEEG,JONGBLOETS,WYDER          (NIJM)
MARINI1  82 PRL 48 1649        +PERUZZI,PICCLO+  (FRAS+LBL+NWES+STAN+HAWA)
MARINI2  82 PR D26 1777        +PERUZZI,PICCLO+  (FRAS+LBL+NWES+STAN+HAWA)
MASHIMO  82 JPSJ 51 3067       +KAWAGOE,KOSHIBA                     (TOKY)
NAPOLITA 82 PR D25 2837        NAPOLITANO,BESSET+(STAN+FRAS+LBL+NWES+HAWA)
ROSS     82 PL 118B 199        +RONGA,BESSET+    (FRAS+LBL+NWES+STAN+HAWA)
HODGES   81 PRL 47 1651        +ABRAMS,BADEN,BLAND,JOYCE,ROYER+ (UCR+SFSU)
LARUE    81 PRL 46 967         +PHILLIPS,FAIRBANK                   (STAN)
WEISS    81 PL 101B 439        +ABRAMS,ALAM,BLOCKER,BLONDEL+(SLAC+LBL+UCB)
BARTEL   80 ZPHY C6 295         JADE  (DESY+HAMB+HEID+LANC+MCHS+RHEL+TOKY)
BASILE   80 LNC 29 251         +BERBIERS,CONTIN+(BGNA+CERN+FRAS+ROMA+BARI)
BUSSIERE 80 NP B174 1          +GIACOMELLI,LESQUOY+        (BGNA+SACL+LAPP)
MARINELL 80 PL 94B 433         MARINELLI,MORPURGO                   (GENO)
    ALSO 80 PL 94B 427         MARINELLI,MORPURGO                   (GENO)
BOYD     79 PRL 43 1288        +BLATT,DONOGHUE,DRIES,HAUSMAN,SUITER  (OSU)
BOZZOLI  79 NP B159 363        +BUSSIERE,GIACOMELLI+ (BGNA+LAPP+SACL+CERN)
LARUE    79 PRL 42 142         +FAIRBANK,PHILLIPS                   (STAN)
  ERRATA 79 PRL 42 1019        LARUE,FAIRBANK,PHILLIPS
OGORODNI 79 JETP 49 953        OGORODNIKOV,SAMOILOV,SOLNTSEV        (KIAE)
STEVENSO 79 PR D20 82          STEVENSON                             (LBL)
YOCK     78 PR D18 641         YOCK                                 (AUCK)
BASILE1  78 NC 45A 171         +CARAROMEO,CIFARELLI,CONTIN+    (CERN+BGNA)
BASILE2  78 NC 45A 281         +CARAROMEO,CIFARELLI,CONTIN+    (CERN+BGNA)
BOYD1    78 PRL 40 216         +ELMORE,MELISSINOS,SUGARBAKER        (ROCH)
BOYD2    78 PL 72B 484         +ELMORE,NITZ,OLSEN,SUGARBAKER,WARREN+(ROCH)
LUND     78 RA 25 75           +BRANDT,FARES                        (PHIL)
PUTT     78 PR D17 1466        +YOCK                                (AUCK)
SCHIFFER 78 PR D17 2241        +RENNER,GEMMELL,MOORING          (CHIC+ANL)
ANTREASY 77 PRL 39 513         ANTREASYAN,COCCONI,CRONIN,FRISCH+(EFI+PRIN)
BASILE   77 NC 40A 41          +CARA ROMEO,CIFARELLI,GIUSTI+   (CERN+BGNA)
BLAND    77 PRL 39 369         +BOCOBO,EUBANK,ROYER                 (SFSU)
GALLINAR 77 PRL 38 1255        GALLINARO,MARINELLI,MORPURGO         (GENO)
LARUE    77 PRL 38 1011        +FAIRBANK,HEBARD                     (STAN)
MULLER   77 SCI 196 521        +ALVAREZ,HOLLEY,STEPHENSON            (LBL)
OGORODNI 77 JETP 45 857        OGORODNIKOV,SAMOILOV,SOLNTSEV        (KIAE)
BALDIN   76 SJNP 22 264        +VERTOGRADOV,VISHNEVSKII,GRISHKEVICH+(JINR)
BRIATORE 76 NC 31A 553         +DARDO,PIAZZOLI,MANNOCCHI+ (LCGT+FRAS+FREI)
STEVENS  76 PR D14 716         +SCHIFFER,CHUPKA                      (ANL)
ALBROW   75 NP B97 189         +BARBER,BENZ+(CERN+DARE+FOM+LANC+MCHS+UTRE)
FABJAN   75 NP B101 349        +GRUHN,PEAK,SAULI,CALDWELL+     (CERN+MPIM)
HAZEN    75 NP B95 189         +HODSON,WINTERSTEIN,GREEN,KASS+ (MICH+LEED)
JOVANOVI 75 PL 56B 105         JOVANOVICH+ (MANI+AACH+CERN+GENO+HARV+TORI)
KRISOR   75 NC 27A 132         KRISOR                               (AACH)
CLARK    74 PR D10 2721        +FINN,HANSEN,SMITH                    (LLL)
GALIK    74 PR D9 1856         +JORDAN,RICHTER,SEPPI,SIEMANN+  (SLAC+FNAL)
KIFUNE   74 JPSJ 36 629        +HIEDA,KUROKAWA,TSUNEMOTO,KIMURA+(TOKY+KEK)
NASH     74 PRL 32 858         +YAMANOUCHI,NEASE,SCULLI    (FNAL+CORN+NYU)
ALPER    73 PL 46B 265         + (CERN+LIVP+LUND+BOHR+RHEL+STOH+BERG+LOUC)
ASHTON   73 JPA 6 577          +COOPER,PARVARESH,SALEH              (DURH)
HICKS    73 NC 14A 65          +FLINT,STANDIL                       (MANI)
LEIPUNER 73 PRL 31 1226        +LARSEN,SESSOMS,SMITH,WILLIAMS+  (BNL+YALE)
BEAUCHAM 72 PR D6 1211         BEAUCHAMP,BOWEN;COX,KALBACH          (ARIZ)
BOHM     72 PRL 28 326         +DIEMONT,FAISSNER,FASOLD,KRISOR+     (AACH)
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BOTT     72 PL 40B 693          +CALDWELL,FABJAN,GRUHN,PEAK+    (CERN+MPIM)
COX      72 PR D6 1203          +BEUCHAMP,BOWEN,KALBACH               (ARIZ)
CROUCH   72 PR D5 2667          +MORI,SMITH                           (CASE)
DARDO    72 NC 9A 319           +NAVARRA,PENENGO,SITTE                (TORI)
EVANS    72 PRSE A70 143        +FANCEY,MUIR,WATSON              (EDIN+LEED)
TONWAR   72 JPA 5 569           +NARANAN,SREEKANTAN                   (TIFR)
ANTIPOV  71 NP B27 374          +KACHANOV,KUTJIN,LANDSBERG,LEBEDEV+   (SERP)
CHIN     71 NC 2A 419           +HANAYAMA,HARA,HIGASHI,TSUJI          (OSAK)
CLARK    71 PRL 27 51           +ERNST,FINN,GRIFFIN,HANSEN,SMITH+ (LLL+LBL)
HAZEN    71 PRL 26 582          HAZEN                                 (MICH)
BOSIA    70 NC 66A 167          +BRIATORE                             (TORI)
CHU      70 PRL 24 917          +KIM,BEAM,KWAK               (OSU+ROSE+KANS)
    ALSO 70 PRL 25 550          ALLISON,DERRICK,HUNT,SIMPSON,VOYVODIC (ANL)
ELBERT   70.NP B20 217          +ERWIN,HERB,NIELSEN,PETRILAK,WEINBERG(WISC)
FAISSNER 70 PRL 24 1357         +HOLDER,KRISOR,MASON,SAWAF,UMBACH     (AACH)
KRIDER   70 PR D1 835           +BOWEN,KALBACH                        (ARIZ)
MORPURGO 70 NIM 79 95           +GALLINARO,PALMIERI                   (GENO)
ALLABY   69 NC 64A 75           +BIANCHINI,DIDDENS,DOBINSON,HARTUNG+ (CERN)
ANTIPOV1 69 PL 29B 245          +KARPOV,KHROMOV,LANDSBERG,LAPSHIN+    (SERP)
ANTIPOV2 69 PL 30B 576          +BOLOTOV,DEVISHEV,DEVISHEVA,ISAKOV+   (SERP)
CAIRNS   69 PR 186 1394         +MCCKUSKER,PEAK,WOOLCOTT              (SYDN)
COOK     69 PR 188 2092         +DEPASQUALI,FRAUENFELDER,PEACOCK +     (ILL)
FUKUSHIM 69 PR 178 2058         FUKUSHIMA,KIFUNE,KONDO,KOSHIBA+       (TOKY)
MCCUSKER 69 PRL 23 658          +CAIRNS                               (SYDN)
BELLAMY  68 PR 166 1391         +HOFSTADTER,LAKIN,PERL,TONER     (STAN+SLAC)
BJORNBOE 68 NC B53 241          +DAMGARD,HANSEN+       (BOHR+TIFR+BERN+BERG)
BRAGINSK 68 JETP 27 51          +ZELDOVICH,MARTYNOV,MIGULIN           (MOSU)
BRIATORE 68 NC 57A 850          +CASTAGNOLI,BOLLINI,MASSAM+(TORI+CERN+BGNA)
FRANZINI 68 PRL 21 1013         +SHULMAN                              (COLU)
GARMIRE  68 PR 166 166          +LEONG,SREEKATAN                       (MIT)
HANAYAMA 68 CJP 46 S734         +HARA,HIGASHI,KITAMURA,MIONO+         (OSAK)
KASHA1   68 PR 172 1297         +STEFANSKI                        (BNL+YALE)
KASHA2   68 PRL 20 217          +LARSEN,LEIPUNER,ADAIR            (BNL+YALE)
KASHA3   68 CJP 46 S730         +LARSEN,LEIPUNER,ADAIR            (BNL+YALE)
RANK     68 PR 176 1635         RANK                                  (MICH)
BARTON   67 PRSL 90 87          BARTON                                (NPOL)
BATHOW   67 PL 25B 163          +FREYTAG,SCHULZ,TESCH                 (DESY)
BUHLER1  67 NC 49A 209          +FORTUNATO,MASSAM+ZICHICHI       (CERN+BGNA)
BUHLER2  67 NC 51A 837          +DALPIAZ,MASSAM,ZICHICHI    (CERN+BGNA+STRB)
FOSS     67 PL 25B 166          +GARELICK,HOMMA,LOBAR,OSBORNE,UGLUM    (MIT)
GOMEZ    67 PRL 18 1022         +KOBRAK,MOLINE,MULLINS,ORTH,VANPUTTEN+(CIT)
KASHA    67 PR 154 1263         +LEIPUNER,WANGLER,ALSPECTOR,ADAIR(BNL+YALE)
STOVER   67 PR 164 1599         +MORAN,TRISCHKA                       (SYRA)
BARTON   66 PL 21 360           +STOCKEL                              (NPOL)
BENNETT  66 PRL 17 1196         BENNETT                               (YALE)
BUHLER   66 NC 45A 520          +FORTUNATO,MASSAM,MULLER+   (CERN+BGNA+STRB)
CHUPKA   66 PRL 17 60           +SCHIFFER,STEVENS                      (ANL)
GALLINAR 66 PL 23 609           GALLINARO,MORPURGO                    (GENO)
KASHA    66 PR 150 1140         +LEIPUNER,ADAIR                   (BNL+YALE)
LAMB     66 PRL 17 1068         +LUNDY,NOVEY,YOVANOVITCH               (ANL)
MASSAM   65 NC 40A 589          +MULLER,ZICHICHI                      (CERN)
FRANZINI 65 PRL 14 196          +LEONTIC,RAHM,SAMIOS,SCHWARTZ    (BNL+COLU)
DORFAN   65 PRL 14 999          +EADES,LEDERMAN,LEE,TING              (COLU)
DELISE   65 PR 140B 458         +BOWEN                                (ARIZ)
BINGHAM  64 PL 9 201            +DICKINSON,DIEBOLD,KOCH,LEITH+  (CERN+EPOL)
BLUM     64 PRL 13 353A         +BRANDT,COCCONI,CZYZEWSKI,DANYSZ+     (CERN)
BOWEN    64 PRL 13 728          +DELISE,KALBACH,MORTARA               (ARIZ)
HAGOPIAN 64 PRL 13 280          +SELOVE,EHRLICH,LEBOY,LANZA,RAHM+(PENN+BNL)
LEIPUNER 64 PRL 12 423          +CHU,LARSEN,ADAIR                 (BNL+YALE)
MORRISON 64 PL 9 199            MORRISON                              (CERN)
SUNYAR   64 PR 136B 1157        +SCHWARZSCHILD,CONNORS                 (BNL)
HILLAS   59 NAT 184 892         +CRANSHAW                             (AERE)
MILLIKAN 10 PHIL MAG 19 209     MILLIKAN                              (CHIC)

                               REVIEWS

LYONS    85 PRPL C129 225       LYONS                                  (OXF)
MARINELL 82 PRPL 85 161         MARINELLI,MORPURGO                    (GENO)
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MAGNETIC MONOPOLE SEARCHES

OMITTED FROM SUMMARY TABLE

(by W.P. Trower, Virginia Polytechnic Institute and State University)

Although the usual formulation of Maxwell's equations suggests magnetic monopoles, no observed phenomenon requires them for explanation.[1] A monopole anywhere in the universe results in electric charge quantization everywhere, and leads to the prediction of a least magnetic charge $G = e/2\alpha$, the Dirac charge.[2] Recently monopoles have become indispensable in many gauge theories, which endow them with a variety of extraordinarily large masses.

Monopole detectors have predominantly used either induction or ionization. Induction experiments measure the monopole magnetic charge and are independent of monopole electric charge, mass, and velocity. A solitary monopole candidate event (CABRERA 82) has been detected by this method. Ionization experiments rely on a magnetic charge producing more ionization than an electrical charge with the same velocity. However, the ability to distinguish a monopole by ionization diminishes with velocity.

Cosmic rays are the most likely source of massive monopoles, since accelerator energies are insufficient to produce them. Evidence for such monopoles may also be obtained from astrophysical observations.

This compilation is only a guide to the literature, since the quoted experimental limits are often only indicative.

References

1. J.D. Jackson, CERN-77-17 (1977).
2. P.A.M. Dirac, Proc. Royal Soc. London **A133**, 60 (1931).

MONOPOLE PROD. CROSS SECT. -- ACCELER. SEARCHES

```
C
C       MONOPOLE X-SECT       MASS  CHG      REFERENCE   DET          BEAM
C        EVENTS  CM**2         GEV   G                               GEV
C
C          0     <3E-38              <3    FRYBERGER 84 PLAS        29E+E-
C          0     <1E-31          -  1,3    AUBERT    83 PLAS        540P AP
C          0     <4E-38        <10   <6    MUSSET    83 PLAS        34E+E-
C     A    0     <8E-36        <20    -    DELL      82 CNTR        52P P
C          0     <9E-37        <30   <3    KINOSHITA 82 PLAS        29E+E-
C          0     <1E-37        <20  <24    CARRIGAN  78 CNTR        63P P
C          0     <1E-37        <30   <3    HOFFMANN  78 PLAS        56P P
C     A    0       -             -    -    DELL      76 SPRK        62P P
C     A    0     <4E-33          -    -    STEVENS   76 SPRK       300PROT
C     C    0     <1E-40         <5   <2    ZRELOV    76 CNTR        70PROT
C     A    0     <2E-30          -    -    BURKE     75 OSPK       300NEUT
C     B    0     <1E-38          -    -    CARRIGAN  75 HLBC         8NU
C          0     <5E-43        <12  <10    EBERHARD  75 INDU       400PROT
C          0     <2E-36        <30   <3    GIACOMELL 75 PLAS        60P P
C          0     <5E-42        <13  <24    CARRIGAN  74 CNTR       400PROT
C          0     <6E-42        <12  <24    CARRIGAN  73 CNTR       300PROT
C     C    0     <2E-36          -    1    BARTLETT  72 CNTR       .001GAMA
C          0     <1E-41         <5    -    GUREVICH  72 EMUL        70PROT
C          0     <1E-40         <3   <2    AMALDI    63 EMUL        28PROT
C          0     <2E-40         <3   <2    PURCELL   63 CNTR        30PROT
C          0     <1E-35         <3   <4    FIDECARO  61 CNTR        28PROT
C          0     <2E-35         <1    1    BRADNER   59 EMUL         6PROT
C
C     C - CHERENKOV RADIATION POLARIZATION.
C     B - REEXAMINES CERN NEUTRINO EXPTS.
C     A - MULTIPHOTON EVENTS.
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MONOPOLE FLUX -- COSMIC RAY SEARCHES

```
F
F       MONOPOLE  FLUX        MASS  CHG     REFERENCE  DET       COMMENTS
F        EVENTS /CM2/S/SR     GEV    G                           (B=BETA=V/C)
F
F     C    -     <1E-23         -     -    ARAFUNE   85 COSM    JOVIAN PLANETS
F          0     <5E-12         -     1    BERMON    85 INDU
F          0     <1E-16       E15     -    BRACCI    85 COSM    SOLAR TRAPPING
F          0     <6E-12         -     1    CAPLIN    85 INDU
F          0     <6E-10         -     1    EBISU     85 INDU
F     C    0     <3E-15         -     -    PARK      85 CNTR    1E-3<B<1E-1
F     C    0     <1E-18         -     1    HARVEY    84 COSM    -
F          0     <7E-12         -     1    INCANDEL  84 INDU    -
F     F    0     <7E-13         -     1    KAJINO1   84 CNTR    3E-4<B
F          0     <2E-12         -     1    KAJINO2   84 CNTR    3E-4<B<1E-1
F          0     <6E-13         -     1    KAWAGOE   84 CNTR    5E-4<B<1
F     C    0     <2E-14         -     -    KRISHNAS  84 CNTR    1E-3<B
F          0     <4E-13         -     1    LISS      84 CNTR    6E-4<B<2E-3
F     E    0     <1E-16         -     -    PRICE1    84 MICA    3E-4<B<1E-3
F          0     <1E-13         -     1    PRICE2    84 PLAS    1E-4<B
F          0     <4E-13         -     1    TARLE     84 CNTR    6E-4<B<2E-3
F     D    7       -            -     -    ANDERSON  83 EMUL
F          0     <4E-13         -     1    BARTELT   83 CNTR    E-2<B<E-3
F          0     <1E-12         -     1    BARWICK   83 PLAS    7E-3<B<1
F          0     <5E-12         -     1    BATTISTO  83 CNTR    1E-4<B<1
F          0     <3E-13         -     1    BONARELL  83 CNTR    1E-3<B<4E-1
F     C    0     <3E-12         -     -    BOSETTI   83 CNTR    5E-4<B<5E-2
F          0     <4E-11         -     1    CABRERA   83 INDU
F          0     <5E-15         -     1    DOKE      83 PLAS    1E-2<B<1
F     C    0     <8E-15         -     -    ERREDE    83 CNTR    1E-4<B<1E-1
F     C    0     <7E-22         -     -    FREESE    83 COSM    PULSARS
F          0     <5E-12         -     1    GROOM     83 CNTR    1E-4<B<3E-2
F          0     <2E-12         -     -    MASHIMO   83 CNTR    6E-4<B<1
F     C    0     <1E-18     <1E18     1    REPHAELI  83 COSM    INTERGLAC. FIELD
F          0     <1E-13         -     1    ALEXEYEV  82 CNTR    B=3E-3
F          0     <2E-12         -     1    BONARELL  82 CNTR    7E-3<B<6E-1
F          1      6E-10         -     1    CABRERA   82 INDU    DG=+-.06
F     C    0     <1E-23         -     -    DIMOPOUL  82 COSM    NEUTRON STARS
F     C    0     <5E-22         -     -    KOLB      82 COSM    NEUTRON STARS
F          0     <2E-11         -     -    MASHIMO   82 CNTR    1E-2<B<1E-1
F     B    0     <1E-12         -     1    TURNER    82 COSM    B=3E-3
F          0     <2E-15         -     -    BARTLETT  81 PLAS    CONCENTRATOR
F          0     <2E-40         -     -    BONNARDE  81 COSM    NEUTRON STARS
F          0     <1E-13        >1     -    KINOSHIT  81 PLAS    1E-3<B
F          0     <5E-11     <1E17     -    ULLMAN    81 CNTR    3E-4<B<1E-3
F          0     <2E-11         -     -    BARTLETT  78 PLAS    CONCENTRATOR
F     A    1     (1E-1)      >200     2    PRICE     75 PLAS    -
F          0     <2E-13         -    >2    FLEISCHE  71 PLAS    -
F          0     <1E-16         -     1    PARKER    70 COSM    GALACTIC FIELD
F          0     <1E-19         -    >2    FLEISCH3  69 PLAS    OBSIDIAN, MICA
F          0     <5E-15       <15    <3    CARITHERS 66 ELEC    CONCENTRATOR
F          0     <2E-11         -  <1-3    MALKUS    51 EMUL    CONCENTRATOR
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F     F - USED DKMPR MECHANISM AND PENNING EFFECT.
F     E - ASSUMES MONOPOLE ATTACHES FERMION NUCLEUS.
F     D - ANOMALOUS LONG-RANGE ALPHA TRACKS.
F     C - CATALYSIS OF NUCLEON DECAY.
F     B - REEVALUATES PARKER 70 LIMIT FOR GUT MONOPOLES.
F     A - ALVAREZ 75, FLEISCHER 75, FRIEDLANDER 75, ROSS 76 EXPLAIN AS
F         FRAGMENTING NUCLEUS. EBERHARD 75 DISCUSSES CONFLICT WITH OTHER
F         EXPTS. HAGSTROM 77 REINTERPRETS AS ANTINUCLEUS. PRICE 78
F         REASSESSES.
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MONOPOLE DENSITY -- MATTER SEARCHES

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D
D      MONOPOLE   DENSITY       CHARGE    REFERENCE  DET   MATERIAL
D       EVENTS                    G
D
D         0      <4E-6/GRAM       >.6    EBISU     85 INDU  IRON ORE
D     C   0      <1E-9/GRAM        1     ARAFUNE   83 COSM  SUN, CATALYSIS
D        >1      >1E-14/GRAM     >1/3    MIKHAILO  83 SPEC  IRON AEROSOLS
D         0      <6E-33/NUCL       1     SCHATTEN  83 ELEC  MOON WAKE
D         0      <2E-28/NUCL       -     CARRIGAN  80 COSM  EARTH HEAT
D         0      <2E-4/PROT        -     BRODERIC  79 COSM  42-CM ABSORPTION
D         0      <6E-4/GRAM        -     CARRIGAN  76 CNTR  AIR, SEAWATER
D         0      <5E-1/GRAM       >.04   CABRERA   75 INDU  11 MATERIALS
D         0      <2E-4/GRAM       >.05   ROSS      73 INDU  MOON ROCK
D         0      <6E-7/GRAM       <140   KOLM      71 CNTR  SEAWATER
D         0      <2E-13/M**3       -     SCHATTEN  70 ELEC  MOON WAKE
D         0      <1E-4/GRAM        >0    FLEISCH2  69 PLAS  MANGANESE
D         0      <1E-2/GRAM       <120   FLEISCH1  69 PLAS  MANGANESE NODULES
D         0      <2E-3/GRAM       <1-3   GOTO      63 EMUL  MAGNETITE, METEOR
D         0      <2E-2/GRAM        -     PETUKHOV  63 CNTR  METEORITE
D
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REFERENCES FOR MAGNETIC MONOPOLE SEARCHES

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ARAFUNE  85 PR D32 2586      +FUKUGITA,YANAGITA            (TOKY+KYOT+IBAR)
BERMON   85 PRL 55 1850      +CHAUDHARI,CHI,TESCHE,TSUEI              (IBM)
BRACCI   85 NP B258 726      +FIORENTINI,MEZZORANI              (PISA+CAGL)
    ALSO 85 LNC 42 123       +FIORENTINI                             (PISA)
CAPLIN   85 NAT 317 234      +GUY,HARDIMAN,PARK,SCHOUTEN             (LOIC)
EBISU    85 JPG 11 883       +WATANABE                               (KOBE)
PARK     85 NP B252 261      +    (UCI+MICH+BNL+CIT+CLEV+HAWA+LOUC+WARS)
FRYBERGE 84 PR D29 1524      +COAN,KINOSHITA,PRICE               (SLAC+UCB)
HARVEY   84 NP B236 255      HARVEY                                  (PRIN)
INCANDEL 84 PRL 53 2067      INCANDELA,CAMPBELL,FRISCH+ (CHIC+FNAL+MICH)
KAJINO1  84 PRL 52 1373      +MATSUNO,YUAN,KITAMURA                  (TOKY)
KAJINO2  84 JPG 10 447       +MATSUNO,KITAMURA,AOKI,YUAN,MITSUI+  (TOKY)
KAWAGOE  84 LNC 41 315       +MASHIMO,NAKAMURA,NOZAKI,ORITO          (TOKY)
KRISHNAS 84 PL 142B 99       KRISHNASWAMY,MENON,+          (TIFR+OSKC+TOKY)
LISS     84 PR D30 884       +AHLEN,TARLE                     (UCB+IND+MICH)
PRICE1   84 PRL 52 1265      +GUO,AHLEN,FLEISCHER    (ROMA+UCB+IND+GESC)
PRICE2   84 PL 140B 112      PRICE                                   (CERN)
TARLE    84 PRL 52 90        +AHLEN,LISS                      (UCB+MICH+IND)
ANDERSON 83 PR D28 2308      +LORD,STRAUSZ,WILKES                    (WASH)
ARAFUNE  83 PL 133B 380      +FUKUGITA                          (TOKY+KYOT)
AUBERT   83 PL 120B 465      +MUSSET,PRICE,VIALLE               (CERN+LAPP)
BARWICK  83 PR D28 2338      +KINOSHITA,PRICE                         (UCB)
BARTELT  83 PRL 50 655       +COURANT,HELLER,JOYCE,MARSHAK+    (MINN+ANL)
BATTISTO 83 PL 133B 454      BATTISTONI,BELLOTTI+  (FRAS+MILA+TORI+CERN)
BONARELL 83 PL 126B 137      BONARELLI,CAPILUPPI,DANTONE             (BGNA)
BOSETTI  83 PL 133B 265      +GORHAM,HARRIS,LEARNED+       (AACH+HAWA+TOKY)
CABRERA  83 PRL 51 1933      +TABER,GARDNER,BOURG                    (STAN)
DOKE     83 PL 129B 370      +HAYAHSI,HAMASAKI+       (TWAS+TRIK+TTAM+IPCR)
ERREDE   83 PRL 51 245       +STONE+    (UCI+MICH+BNL+CIT+CLEV+HAWA+LOUC)
FREESE   83 PRL 51 1625      +TURNER,SCHRAMM                         (CHIC)
GROOM    83 PRL 50 573       +LOH,NELSON,RITSON                 (UTAH+STAN)
MASHIMO  83 PL 128B 327      +ORITO,KAWAGOE,NAKAMURA,NOZAKI          (TOKY)
MIKHAILO 83 PL 130B 331      MIKHAILOV                               (KAZA)
MUSSET   83 PL 128B 333      +PRICE,LOHRMANN                    (CERN+HAMB)
REPHAELI 83 PL 121B 115      +TURNER                                 (CHIC)
SCHATTEN 83 PR D27 1525      SCHATTEN                                (NASA)
ALEXEYEV 82 LNC 35 413       +BOLIEV,CHUDAKOV,MAKOEV,MIKHEYEV+       (INRM)
BONARELL 82 PL 112B 100      BONARELLI,CAPILUPPI,DANTONE,+           (BGNA)
CABRERA  82 PRL 48 1378      CABRERA                                 (STAN)
DIMOPOUL 82 PL 119B 320      DIMOPOULOS,PRESKILL,WILCZEK        (HARV+UCSB)
DELL     82 NP B209 45       +YUAN,ROBERTS,DOOHER+AMALDI+(BNL+ADEL+ROMA)
KINOSHIT 82 PRL 48 77        KINOSHITA,PRICE,FRYBERGER          (UCB+SLAC)
KOLB     82 PRL 49 1373      +COLGATE,HARVEY                    (LASL+PRIN)
MASHIMO  82 JPSJ 51 3067     +KAWAGOE,KOSHIBA                        (TOKY)
TURNER   82 PR D26 1296      +PARKER,BOGDAN                          (CHIC)
BARTLETT 81 PR D24 612       +SOO,FLEISCHER,HART,MOGROCAMPERO(COLO+GESC)
BONNARDE 81 PR D23 323       BONNARDEAU                              (MPIM)
KINOSHIT 81 PR D24 1707      KINOSHITA,PRICE                          (UCB)
ULLMAN   81 PRL 47 289       ULLMAN                              (LEHM+BNL)
CARRIGAN 80 NAT 288 348      CARRIGAN                                (FNAL)
BRODERIC 79 PR D19 1046      BRODERICK,FICENEC,TEPLITZ,TEPLITZ        (VPI)
BARTLETT 78 PR D18 2253      +SOO,WHITE                         (COLO+PRIN)
CARRIGAN 78 PR D17 1754      +STRAUSS,GIACOMELLI                (FNAL+BGNA)
HOFFMANN 78 LNC 23 357       +KANTARDJIAN,DILIBERTO,MEDDI+   (CERN+ROMA)
PRICE    78 PR D18 1382      +SHIRK,OSBORNE,PINSKY              (UCB+HOUS)
HAGSTROM 77 PRL 38 729       HAGSTROM                                 (LBL)
CARRIGAN 76 PR D13 1823      +NEZRICK,STRAUSS                        (FNAL)
DELL     76 LNC 15 269       +UTO,YUAN,AMALDI+        (CERN+BNL+ROMA+ADEL)
ROSS     76  LBL-4665        ROSS                                     (LBL)
STEVENS  76 PR D14 2207      +COLLINS,FICENEC,TROWER,FISCHER+  (VPI+BNL)
ZRELOV   76 CZJP B26 1306    +KOLLAROVA,KOLLAR,LUPILTSEV,PAVLOVIC+(JINR)
ALVAREZ  75  LBL-4260        ALVAREZ                                  (LBL)
BURKE    75 PL 60B 113       +GUSTAFSON,JONES,LONGO                  (MICH)
CABRERA  75 PHD THESIS       CABRERA                                 (STAN)
CARRIGAN 75 NP B91 279       +NEZRICK                                (FNAL)
    ALSO 71 PR D3 56         +NEZRICK                                (FNAL)
EBERHARD 75  LBL-4289        EBERHARD                                 (LBL)
EBERHARD 75 PR D11 3099      +ROSS,TAYLOR,ALVAREZ,OBERLACK      (LBL+MPIM)
FLEISCHE 75 PRL 35 1412      FLEISCHER,WALKER                   (GESC+WUSL)
FRIEDLAN 75 PRL 35 1167      FRIEDLANDER                             (WUSL)
GIACOMEL 75 NC 28A 21        GIACOMELLI,ROSSI,+    (BGNA+CERN+SACL+ROMA)
PRICE    75 PRL 35 487       +SHIRK,OSBORNE,PINSKY              (UCB+HOUS)
CARRIGAN 74 PR D10 3867      +NEZRICK,STRAUSS                        (FNAL)
CARRIGAN 73 PR D8 3717       +NEZRICK,STRAUSS                        (FNAL)
ROSS     73 PR D8 698        +EBERHARD,ALVAREZ,WATT             (LBL+SLAC)
    ALSO 71 PR D4 3260       EBERHARD,ROSS,ALVAREZ,WATT         (LBL+SLAC)
    ALSO 70 SCI 167 701      ALVAREZ,EBERHARD,ROSS,WATT         (LBL+SLAC)
BARTLETT 72 PR D6 1817       +LAHANA                                 (COLO)
GUREVICH 72 PL 38B 549       +KHAKIMOV,MARTEMIANOV+      (KIAE+NOVO+SERP)
    ALSO 72 JETP 34 917      BARKOV,GUREVICH,ZOLOTAREV  (KIAE+NOVO+SERP)
    ALSO 70 PL 31B 394       +KHAKIMOV,MARTEMIANOV      (KIAE+NOVO+SERP)
FLEISCHE 71 PR D4 24         FLEISCHER,HART,NICHOLS,PRICE            (GESC)
KOLM     71 PR D4 1285       +VILLA,ODIAN                        (MIT+SLAC)
PARKER   70 APJ 160 383      PARKER                                  (CHIC)
SCHATTEN 70 PR D1 2245       SCHATTEN                                (NASA)
FLEISCH1 69 PR 177 2029      FLEISCHER,JACOBS,SCHWARTZ,PRICE  (GESC+FSU)
FLEISCH2 69 PR 184 1393      FLEISCHER,HART,JACOBS,+     (GESC+UNCS+GSCO)
FLEISCH3 69 PR 184 1398      FLEISCHER,PRICE,WOODS                   (GESC)
    ALSO 70 JAP 41 958       +HART,JACOBS,PRICE,SCHWARTZ,WOODS       (GESC)
CARITHER 66 PR 149 1070      CARITHERS,STEFANSKI,ADAIR           (YALE+BNL)
AMALDI   63 NC 28 773        +BARONI,MANFREDINI,BRADNER+(ROMA+UCSD+CERN)
GOTO     63 PR 132 387       +KOLM,FORD                     (TOKY+MIT+BRAN)
PETUKHOV 63 NP 49 87         +YAKIMENKO                              (LEBD)
PURCELL  63 PR 129 2326      +COLLINS,FUJII,HORNBOSTEL,TURKOT (HARV+BNL)
FIDECARO 61 NC 22 657        +FINOCCHIARO,GIACOMELLI                 (CERN)
BRADNER  59 PR 114 603       +ISBELL                                  (LBL)
MALKUS   51 PR 83 899        MALKUS                                  (CHIC)

                             BIBLIOGRAPHIES

CRAVEN   85  FERMILAB-85/13  +TROWER                             (FNAL+VPI)
RUZICKA  80  JINR 2-80-850   +ZRELOV                                 (JINR)

                             REVIEWS

GIACOMEL 84 RNC 7 12 1       GIACOMELLI                              (BGNA)
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AXION SEARCHES

OMITTED FROM SUMMARY TABLE

VARIOUS AXION SEARCHES IN PRODUCTION OR DECAY

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AX      (VALUES QUOTED ARE AXION PRODUCTION RATIO TO PI0 PROD CROSS SEC.)
AX       FOR THEORY AND REVIEW SEE WEINBERG PRL 40, 223 (1978); WILCZEK
AX       PRL 40, 279 (1978); DONNELLY PR D18, 1607 (1978); BARSHAY ET AL.,
AX       PRL 46, 1361 (1981); BARROSO+MUKHOPADHYAY PL 106, 91 (1981); AND
AX       PECCEI, PROC. INTL. NEUTRINO CONF., MAUI(1981), ED. CENCE (HAWAII).
AX       FOR INVISIBLE-AXION THEORY SEE E.G. WISE, GEORGI AND GLASHOW
AX       PRL 47, 402 (1981), AND FOR VERY HEAVY AXION THEORY SEE E.G. TYE
AX       PRL 47, 1035 (1981).  FOR K --> PI A0 SEE ALSO E.G., GOLDMAN
AX       AND HOFFMAN, PRL 40, 220 (1978), FRERE ET AL., PL 103B, 129 (1981).
AX
AX
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AXION PROD. IN HADR. COLLISIONS + BEAM DUMP EXPTS.

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AXP     LIMITS ARE FOR CS(A0)/CS(PI0).
AXP         1. E-8    OR LESS  CL=.90   ALIBRAN   78 HYBR    BEAM DUMP
AXP         6. E-9    OR LESS  CL=.95   ASRATYAN  78 CALO    BEAM DUMP
AXP  A      5.4E-14   OR LESS  CL=.90   BELLOTTI  78 HLBC    FOR MASS=1.5 MEV
AXP  A      4.1E- 9   OR LESS  CL=.90   BELLOTTI  78 HLBC    FOR MASS=1 MEV
AXP  A      1.5E- 8   OR LESS  CL=.90   BELLOTTI  78 HLBC    BEAM DUMP
AXP  B      1. E-8    OR LESS  CL=.90   BOSETTI   78 HYBR    BEAM DUMP
AXP  C                                  DONNELLY  78
AXP         0.5E-8    OR LESS  CL=.90   HANSL1    78 WIRE    BEAM DUMP
AXP  D                                  MICELMAC  78
AXP  E                                  VYSOTSSK  78
AXP  F                                  BECHIS    79 CNTR
AXP  G      1. E-8    OR LESS  CL=.90   COTEUS    79 OSPK    BEAM DUMP
AXP  H      1. E-3    OR LESS  CL=.95   DISHAW    79 CALO    400 GEV P P
AXP  I   0                              FAISSNER  80 OSPK BEAM DUMP,A0-->E+E-
AXP  J      1. E-8    OR LESS  CL=.90   JACQUES   80 HLBC    28 GEV PROTONS
AXP  J      1. E-14   OR LESS  CL=.90   JACQUES   80 HLBC    BEAM DUMP
AXP  K                                  SOUKAS    80 CALO    28GEV P   B.DUMP
AXP  L  12                              FAISSNE1  81 OSPK CERN PS NU WIDEBAND
AXP  M  15                              FAISSNE2  81 OSPK BEAM DUMP,A0-->2GAM
AXP  N   8                              KIM       81 OSPK 26 GEV P NUC-->A0 X
AXP  O                                  FETSCHER  82 RVUE    CF.FAISSNER2 81
AXP  P  24                              FAISSNER  83 OSPK BEAM-DUMP,A0-->2GAM
AXP  Q                                  FAISSNER2 83 RVUE LAMPF BEAM DUMP
AXP  R                                  FRANK     83 RVUE LAMPF BEAM DUMP
AXP  S                                  HOFFMAN   83 CNTR PI-P-->N(A0-->E+E-)
AXP  T   0 2. E-11    OR LESS  CL=.90   BERGSMA   85 CHRM CERN BEAM DUMP
AXP  T   0 1. E-13    OR LESS  CL=.90   BERGSMA   85 CHRM CERN BEAM DUMP
AXP
AXP  A  BELLOTTI 78 FIRST VALUE COMES FROM SEARCH FOR A-->E+E-. SECOND
AXP  A  VALUE COMES FROM SEARCH FOR A-->2GAMMA, ASSUMING MASS<2*MASS(E-).
AXP  A  FOR ANY MASS SATISFYING THIS,LIMIT IS ABOVE VALUE*(MASS**-4).
AXP  A  THIRD VALUE USES DATA OF PL 60B 401 AND QUOTES CS(PROD)*CS(INTER-
AXP  A  ACTION)<10**-67 CM**4.
AXP
AXP  B  BOSETTI 78 QUOTES CS(PROD)*CS(INTERACT)< 2.E-67 CM**4
AXP
AXP  C  DONNELLY 78 EXAMINES DATA FROM REACTOR NEUTRINO EXPTS OF REINES 76
AXP  C  AND GURR 74 AS WELL AS SLAC BEAM DUMP EXPT. EVIDENCE IS NEGATIVE.
AXP
AXP  D  MICELMACHER 78 FINDS NO EVIDENCE OF AXION EXISTENCE IN REACTOR
AXP  D  EXPTS OF REINES 76 AND GURR 74. (SEE REF UNDER DONNELLY 78 BELOW).
AXP
AXP  E  VYSOTSSKII 78 DERIVED LOWER LIMIT FOR THE AXION MASS. 25 KEV FROM
AXP  E  LUMINOSITY OF THE SUN AND 200 KEV FROM RED SUPERGIANTS.
AXP
AXP  F  BECHIS 79 LOOKED FOR THE AXION PRODUCTION IN LOW ENERGY ELECTRON
AXP  F  BREMSSTRAHLUNG AND THE SUBSEQUENT DECAY INTO EITHER 2GAMMAS OR
AXP  F  E+ E-. NO SIGNAL FOUND. C.L.=0.90 LIMITS FOR MODEL PARAMETER(S)
AXP  F  ARE GIVEN.
AXP
AXP  G  COTEUS 79 IS A BEAM DUMP EXPERIMENT AT BNL.
AXP
AXP  H  DISHAW 79 IS A CALORIMETRIC EXPERIMENT AND LOOKS FOR LOW ENERGY
AXP  H  TAIL OF ENERGY DISTRIBUTUIONS DUE TO ENERGY LOST TO WEAKLY
AXP  H  INTERACTING PARTICLES.
AXP
AXP  I  FAISSNER 80 IS SIN BEAM DUMP EXPT WITH 590 MEV PROTONS LOOKING FOR
AXP  I  A0-->E+ E- DECAY. ASSUMING A0/PI0=5.5E-7,OBTAINED DECAY RATE LIMIT
AXP  I  20/(A0 MASS) MEV/SEC (CL=.90),WHICH IS ABOUT 10**-7 BELOW THEORY
AXP  I  AND INTERPRETED AS UPPER LIMIT TO MASS(A0) < 2* MASS(E-).
AXP
AXP  J  JACQUES 80 IS A BNL BEAM DUMP EXP.  FIRST LIMIT ABOVE COMES FROM
AXP  J  NON-OBSERVATION OF EXCESS NC-TYPE EVENTS (CS(PROD)*CS(INTERACT) <
AXP  J  7.E-68 CM**4,CL=0.90).  SECOND LIMIT IS FROM NON-OBSERVATION OF
AXP  J  AXION DECAYS INTO TWO GAMMAS OR E+E-, AND FOR AXION MASS A FEW MEV.
AXP
AXP  K  SOUKAS 80 AT BNL OBSERVED NO EXCESS OF NC-TYPE EVENTS IN BEAM DUMP.
AXP
AXP  L  FAISSNER1 81 SEE EXCESS MU E EVENTS. SUGGEST AXION INTERACTIONS.
AXP
AXP  M  FAISSNER2 81 IS SIN 590MEV PROTON BEAM DUMP. OBSERVED 14.5+-5.0 EVS
AXP  M  OF 2GAMMA DECAY OF LONG-LIVED NEUTRAL PENETRATING PARTICLE WITH
AXP  M  M(2GAMMA) < APPROX. 1 MEV. AXION INTERPR. WITH ETA-A0 MIXING GIVES
AXP  M  M(A0)=(250+-25)KEV, TAU(2GAMMA)=(7.3+-3.7)E-3 SEC FROM ABOVE RATE.
AXP  M  SEE CRITICAL REMARKS BELOW IN COMMENTS OF FETSCHER 82, FAISSNER 83,
AXP  M  FAISSNER2 83, FRANK 83, AND BERGSMA 85.  ALSO SEE IN THE NEXT
AXP  M  SUBSECTION ALEKSEEV 82, CAVAIGNAC 83, AND ANANEV 85.
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Stable Particle Full Listings

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AXP   N  KIM 81 ANALYZED 8 CANDIDATES FOR A0-->2GAMMA OBTAINED BY AACHEN-
AXP   N  PADOVA EXPT AT CERN WITH 26 GEV PROTONS ON BE. ESTIMATED AXION MASS
AXP   N  IS ABOUT 300 KEV AND LIFE IS (0.86 TO 5.6)E-3 S DEPENDING MODELS.
AXP   N  FAISSNER, PRIV. COMM, SAYS AXION PROD. UNDERESTIMATED AND MASS
AXP   N  OVERESTIMATED.  CORRECT VALUE AROUND 200 KEV.
AXP
AXP   O  FETSCHER 82 RE-ANALYZES SIN BEAM-DUMP DATA OF FAISSNER 81. CLAIMS
AXP   O  NO EVIDENCE FOR AXION SINCE 2-GAMMA PEAK RATE REMARKABLY DECREASES
AXP   O  IF IRON WALL IS SET IN FRONT OF THE DECAY REGION.
AXP
AXP   P  FAISSNER 83 OBSERVED 19 1-GAMMA AND 12 2-GAMMA EVENTS WHERE A BKGD
AXP   P  OF 4.8 AND 2.3 RESPECTIVELY IS EXPECTED. A SMALL-ANGLE PEAK IS
AXP   P  OBSERVED EVEN IF IRON WALL IS SET IN FRONT OF THE DECAY REGION.
AXP
AXP   Q  FAISSNER2 83 EXTRAPOLATE SIN GAM SIGNAL TO LAMPF NU EXP CONDITION.
AXP   Q  RESULTING 370 GAMMAS ARE NOT AT VARIANCE WITH LAMPF UPPER LIMIT
AXP   Q  OF 450 GAMMAS. DERIVED FROM LAMPF LIMIT THAT (DSIGMA(A0)/DOMEGA AT
AXP   Q  90 DEG)*M(A0)/TAU(A0) < 14*10**-35 CM**2*SR**-1*MEV*MILLISEC**-1.
AXP   Q  SEE FRANK 83 (COMMENT R).
AXP
AXP   R  FRANK 83 STRESS THE IMPORTANCE OF LAMPF DATA BINS WITH NEGATIVE NET
AXP   R  SIGNAL. BY STATISTICAL ANALYSIS SAY THAT LAMPF AND SIN-A0 ARE AT
AXP   R  VARIANCE WHEN EXTRAPOLATION BY PHASE SPACE MODEL IS DONE.
AXP   R  THEY FIND LAMPF UPPER LIMIT IS 248 NOT 450 GAMMAS.  SEE FAISSNER2
AXP   R  AND COMMENT Q.
AXP
AXP   S  HOFFMAN 83 SET CL=.90 LIMIT DSIGMA/DT*BR(E+E-)<3.5E-32 CM**2/GEV**2
AXP   S  FOR 140 <M(A0)<160 MEV. LIMIT ASSUMES TAU(A0) < 10**-9 SEC.
AXP
AXP   T  BERGSMA 85 LOOK FOR A0-->2GAMMA, E+ E-, MU+ MU-.  FIRST LIMIT ABOVE
AXP   T  IS FOR M(A0)=1 MEV; SECOND IS FOR 200 MEV.  SEE THEIR FIG.4 FOR
AXP   T  EXCLUDED REGION ON FA0-M(A0) PLANE, WHERE FA0 IS A0 DECAY CONSTANT.
AXP   T  FOR PECCEI-QUINN A0, M(A0)<180 KEV AND TAU > 0.037 SEC. (CL=0.90).
AXP   T  FOR THE AXION OF FAISSNER2 81 AT 250 KEV, BERGSMA 85 EXPECT 15
AXP   T  EVENTS BUT OBSERVE ZERO.
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AXION SEARCHES FROM POSITRONIUM OR QUARKONIUM ETC.

```
AXD     DECAY OR TRANSITION OF POSITRONIUM, QUARKONIUM, KAON, NUCLEON, AND
AXD     RADIOACTIVE NUCLEUS.  LIMITS ARE FOR BRANCHING RATIO.
AXD   A                                    CALAPRIC  79          CARBON
AXD   B                                    ZHITNITS  79          HEAVY AXION
AXD   C   0                                ASANO     81 CNTR STOPPED K+-->PI+ A0
AXD   D                                    VUILLEUM  81 CNTR REACTOR,A0--> 2GAM
AXD   E   0                                ZEHNDER   81 CNTR BA*-->(A0-->2GAM)BA
AXD   F                                    ALEKSEEV  82 CNTR LI*,D* TR. A0->2GAM
AXD   G   0                                ASANO     82 CNTR STOPPED K+-->PI+ A0
AXD   H                                    BARROSO   82      PHOTO-PROD.IN STARS
AXD   I                                    DATAR     82 CNTR LIGHT WATER REACTOR
AXD   J      1.4 E-5  OR LESS  CL=.90      EDWARDS   82 CBAL J/PSI-->A0 GAMMA
AXD   K                                    LEHMANN   82 CNTR CU*-->(A0-->2GAM)CU
AXD   L      3.5 E-4  OR LESS  CL=.90      SIVERTZ   82 CUSB UPSI(1S)-->A0 GAMMA
AXD   L      1.2 E-4  OR LESS  CL=.90      SIVERTZ   82 CUSB UPSI(3S)-->A0 GAMMA
AXD   M   0                                ZEHNDER   82 CNTR LI*,NB*DECAY,N-CAPT
AXD   N      3.  E-4  OR LESS  CL=.90      ALAM      83 CLEO UPSI(1S)-->A0 GAMMA
AXD   O                                    CARBONI   83 CNTR ORTHO-POSITRONIUM
AXD   P                                    CAVAIGNA  83 CNTR NB97*,D*TR.A0->2GAM
AXD   Q      9.1 E-4  OR LESS  CL=.90      NICZYPOR  83 LENA UPSI(1S)-->A0 GAMMA
AXD   R   (1.5-4)E-6  OR LESS  CL=.90      YAMAZAKI  84 SPEC K-DECAY     M<100MEV
AXD   R       2. E-5  OR LESS  CL=.90      YAMAZAKI  84 SPEC    FOR 160<M<260MEV
AXD   S                                    ANANEV    85 CNTR LI*,D*  A0->2GAMMA
AXD
AXD   A  CALAPRICE 79 SAW NO AXION EMISSION FROM EXCITED STATES OF CARBON.
AXD   A  SENSITIVE TO AXION MASS BETWEEN 1 AND 15 MEV.
AXD
AXD   B  ZHITNITSKII 79 ARGUE THAT A HEAVY AXION BY YANG (3<M<40 MEV)
AXD   B  CONTRADICTS EXPERIMENTAL MUON ANOM. MAGNETIC MOMENTS.
AXD
AXD   C  ASANO 81 IS KEK EXPT. SET BR(K+ -->PI+ A0) < 3.8E-8 AT CL=.90.
AXD
AXD
AXD   D  VUILLEUMIER 81 IS AT GRENOBLE REACTOR. SET LIMIT M(A0)<280 KEV.

AXD   E  ZEHNDER 81 LOOKED FOR BA*-->A0 BA TRANSITION WITH A0-->2GAMMA.
AXD   E  OBTAINED 2GAMMA COINCIDENCE RATE < 2.2E-5 /SEC(CL=.95) EXCLUDING
AXD   E  MASS(A0)>160 KEV(OR 200 KEV DEPENDING ON HIGGS MIXING).
AXD   E  HOWEVER, SEE BARROSO + MUKHOPADHYAY, REF. ABOVE.
AXD
AXD   F  ALEKSEEV 82 WITH IBR-2 PULSED REACTOR EXCLUDE STANDARD A0 AT CL=.95
AXD   F  MASS-RANGES M(A0)<400 KEV (LI* DECAY) AND 330 KEV<M(A0)<2.2MEV
AXD   F  (DEUT* DECAY).
AXD
AXD   G  ASANO 82 AT KEK SET LIMITS FOR BR(K+-->PI+ A0) FOR M(A0)<100 MEV AS
AXD   G  BR <4.E-8 FOR TAU(A0-->N-GAMMAS)>1.E-9S, BR<1.4E-6 FOR TAU<1.E-9S.
AXD
AXD   H  BARROSO 82 DERIVE IN DFS-MODEL(PL104B,199)  A0 MASS LIMITS FROM
AXD   H  STELLER-ENERGY-LOSS BOUND. ALLOWED MASS REGIONS ARE
AXD   H  M(A0)<10 EV (AXION INVISIBLE DUE TO VERY SMALL COUPLING), AND
AXD   H  M(A0) AROUND 200 KEV (CORRESPONDING DFS-A0 PARAM IS HARDLY
AXD   H  COMPATIBLE WITH REACTOR DATA OF ZEHNDER 81).
AXD
AXD   I  DATAR 82 LOOKED FOR A0-->2GAMMA IN NEUTRON CAPTURE (N P-->D A0) AT
AXD   I  TARAPUR 500 MW REACTOR. SENSITIVE TO SUM OF I=0 AND I=1 AMPLITUDES.
AXD   I  WITH ZEHNDER 81((I=0)-(I=1)) RESULT, ASSERT NON-EX OF STANDARD A0.
AXD
AXD   J  EDWARDS 82 LOOKED FOR J/PSI-->GAMMA+AXION DECAYS BY LOOKING FOR
AXD   J  EVENTS WITH A SINGLE GAMMA (OF ENERGY APPROX. 1/2 THE J/PSI MASS),
AXD   J  PLUS NOTHING ELSE IN THE DETECTOR. THE LIMIT IS INCONSISTENT WITH
AXD   J  THE AXION INTERPRETATION OF THE FAISSNER2 81 RESULT.
AXD
AXD   K  LEHMANN 82 OBTAINED A0-->2GAM RATE<6.2E-5 /SEC (CL=.95) EXCLUDING
AXD   K  MASS(AXION) BETWEEN 100 AND 1000 KEV.
AXD
AXD   L  SIVERTZ 82 IS CESR EXPT. LOOKED FOR UPSI-->GAMMA A0, A0 UNDETECTED.
AXD   L  LIMIT FOR 1S(3S) IS VALID FOR M(A0)<7 GEV (4 GEV).
AXD
AXD   M  ZEHNDER 82 USED GOESGEN 2.8GW LIGHT-WATER REACTOR TO CHECK A0 PROD.
AXD   M  NO TWO GAMMA PEAK IN LI*,NB* DECAY(BOTH SINGLE P TRANSITION) NOR IN
AXD   M  N CAPTURE(COMB WITH PREVIOUS BA* NEG RESULT) RULES OUT STANDARD A0.
AXD   M  SET LIMIT M(A0)<60KEV FOR ANY A0.
AXD
AXD   N  ALAM 83 IS AT CESR. THIS LIMIT COMBINED WITH LIMIT FOR BR(J/PSI-->
AXD   N  A0 GAMMA) (EDWARDS 82) EXCLUDES STANDARD AXION.
AXD
AXD   O  CARBONI 83 LOOKED FOR ORTHOPOSITRONIUM-->A0 GAMMA. SET LIMIT FOR A0
AXD   O  ELECTRON COUPLING SQUARED, G(EEA0)**2/(4*PI) < 6.E-10 TO 7.E-9 FOR
AXD   O  M(A0)FROM 150 TO 900 KEV(CL=.997). THIS IS ABOUT 1/10 OF G-2 BOUND.
AXD
AXD   P  CAVAIGNAC 83 AT BUGEY REACTOR EXCLUDE AXION AT ANY MASS(NB97*DECAY)
AXD   P  AND AXION WITH M(A0) BETWEEN 275 AND 288 KEV (DEUTERON* DECAY).
AXD
AXD   Q  NICZYPORUK 83 IS DESY-DORIS EXPERIMENT. THIS LIMIT TOGETHER WITH
AXD   Q  LOWER LIMIT 9.2 E-4 OF BR(UPSI-->A0 GAMMA)   DERIVED FROM BR(J/PSI
AXD   Q  -->A0 GAMMA) LIMIT (EDWARDS 82) EXCLUDES STANDARD AXION.
AXD   R  YAMAZAKI 84 LOOKED FOR A DISCRETE LINE IN K+ -->PI+ X. SENSITIVE TO
AXD   R  WIDE MASS RANGE (5-300MEV), INDEPENDENT OF WHETHER X DECAYS
AXD   R  PROMPTLY OR NOT.
AXD
AXD   S  ANANEV 85 WITH IBR-2 PULSED REACTOR EXCLUDE STANDARD A0 AT CL=.95
AXD   S  MASSES BELOW 470 KEV (LI* DECAY) AND BELOW 2*MASS(ELECTRON) FOR
AXD   S  DEUT* DECAY.
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REFERENCES FOR AXION SEARCHES

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ALIBRAN   78 PL 74B 134         AACH+BARI+BERG+BRUX+CERN+EPOL+MILA+ORSA+
ASRATYAN  78 PL 79B 497         +EPSTEIN,FAKHRUTDINOV+           (ITEP+SERP)
BELLOTTI  78 PL 76B 223         +FIORINI,ZANOTTI                      (MILA)
BOSETTI   78 PL 74B 143         +DEDEN+       (AACH+BONN+CERN+LOIC+OXF+SACL)

DONNELLY  78 PR D18 1607        +FREEDMAN,LYTEL,PECCEI,SCHWARTZ       (STAN)
    ALSO  76 PRL 37 315         REINES,GURR,SOBEL
    ALSO  74 PRL 33 179         GURR,REINES,SOBEL
HANSL1    78 PL 74B 139         +HOLDER,KNOBLOCH+(CERN+DORT+HEID+SACL+BGNA)
MICELMAC  78 LNC 21 441         MICELMACHER,PONTECORVO                (JINR)
VYSOTSSK  78 JETPL 27 502       VYSOTSSKII+(INST.APPL.MATH.,USSR ACA. SCI.)

BECHIS    79 PRL 42 1511        +DOMBECK+    (UMD+COLU+A.F.R.R.I.-BETHESDA)
CALAPRIC  79 PR D20 2708        CALAPRICE,DUNFORD,KOUZES,MILLER+      (PRIN)
COTEUS    79 PRL 42 1438        +DIESBURG,FINE,LEE,SOKOLSKY+ (COLU+ILL+BNL)
DISHAW    79 PL 85B 142         +DIAMANT-BERGER,FAESSLER,LIU+    (SLAC+CIT)
ZHITNITS  79 SJNP 29 517        ZHITNITSKII,SKOVPEN                   (NOVO)

FAISSNER  80 PL 96B 201         +FRENZEL,HEINRIGS,PREUSSGER,SAMM,SAMM(AACH)
JACQUES   80 PR D21 1206        +KALELKAR,MILLER,PLANO+    (RUTG+STEV+COLU)
SOUKAS    80 PRL 44 564         +WANDERER,WENG,BREGMAN+(BNL+HARV+ORNL+PENN)

ASANO     81 PL 107B 159        +KIKUTANI,KUROKAWA+         (KEK+TOKY+OSAK)
FAISSNE1  81 ZPHY C10 95        FAISSNER,FRENZEL,GRIMM,HANSL,HOFFMAN+(AACH)
FAISSNE2  81 PL 103B 234        FAISSNER,FRENZEL,HEINRIGS,PREUSSGER+ (AACH)
KIM       81 PL 105B 55         B.R.KIM,CH.STAMM                      (AACH)
VUILLEUM  81 PL 101B 341        VUILLEUMIER,BOEHM,HAHN,KWON+      (CIT+MUNI)
ZEHNDER   81 PL 104B 494        A.ZEHNDER                              (ETH)

ALEKSEEV  82 JETPL 36 116       +KALININA,KRUGLOV,KULIKOV +      (MOSU+JINR)
ASANO     82 PL 113B 195        +KIKUTANI,KUROKAWA+         (KEK+TOKY+OSAK)
BARROSO   82 PL 116B 247        A.BARROSO,C.BRANCO                    (LISB)
DATAR     82 PL 114B 63         +BABA,BETIGERI,SINGH                  (BHAB)
EDWARDS   82 PRL 48 903         +PARTRIDGE,PECK+  (CIT+HARV+PRIN+STAN+SLAC)

FETSCHER  82 JPG 8 L147         W.FETSCHER                             (ETH)
LEHMANN   82 PL 115B 270        +LESQUOY,MULLER,ZYLBERAJCH            (SACL)
SIVERTZ   82 PR D26 717         +LEE-FRANZINI+         (STON+COLU+LSU+MPIM)
ZEHNDER   82 PL 110B 419        +GABATHULER,VUILLEUMIER        (ETH+SIN+CIT)

ALAM      83 PR D27 1665        + (VAND+CORN+ITHA+HARV+OHIO+ROCH+RUTG+SYRA)
CARBONI   83 PL 123B 349        G.CARBONI,W.DAHME                (CERN+MUNI)
CAVAIGNA  83 PL 121B 193        CAVAIGNAC,HOUMMADA,KOANG,OST+    (GREN+LAPP)
FAISSNER  83 PR D28 1198        +HEINRIGS,PREUSSGER,SAMM              (AACH)
FAISSNE2  83 PR D28 1787        FAISSNER,FRENZEL,HEINRIGS,PREUSSGER+ (AACH)
FRANK     83 PR D28 1790        +    (LANL+YALE+LBL+MIT+SACL+SIN+CNRC+BERN)
HOFFMAN   83 PR D28 660         +FRANK,MISCHKE,MOIR,SCHARDT      (LANL+ARZS)
NICZYPOR  83 ZPHY C17 197       NICZYPORUK+ LENA COLLAB.  (CRAC+ERLA+DESY+)
YAMAZAKI  84 PRL 52 1089        +ISHIKAWA,TANIGUCHI,YAMANAKA+     (TOKY+KEK)
ANANEV    85 SJNP 41 585        +KALINA,LUSHCHIKOV,OLSHEVSKII,+       (JINR)
BERGSMA   85 PL 157B 458        CHARM COLLAB.    (ANIK+CERN+HAMB+ITEP+ROME)
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SUPERSYMMETRIC PARTICLE SEARCHES

OMITTED FROM SUMMARY TABLE

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      ALL RESULTS SHOWN BELOW (EXCEPT WHERE STATED OTHERWISE) INVOLVE
      THE FOLLOWING "MINIMAL" ASSUMPTIONS:

      1) THE PHOTINO IS THE LIGHTEST SUPERSYMMETRIC PARTICLE.
      2) R-PARITY IS CONSERVED.
      3) THE MASS OF EXCHANGED PARTICLES IS LESS THAN ABOUT 250 GEV.
      4) MASS(L) = MASS(R) WHERE L AND R REFER TO THE SCALAR PARTNERS
         OF LEFT-AND RIGHT-HANDED FERMIONS.

      LIMITS INVOLVING NON-MINIMAL ASSUMPTIONS EITHER ARE IDENTIFIED
      WITH COMMENTS OR ARE IN THE MISCELLANEOUS SECTION.
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SCALAR ν MASS LIMIT

```
SNU   A                                KANE      84 RVUE TAU-DECAY PRODUCT
SNU   B                                WARE      84 RVUE E+E- ECM=29 GEV
SNU   B                                FERNANDEZ 85 MAC  E+E- ECM=29 GEV
SNU
SNU   A  ABOVE LIMIT IS FOR M(W-INO)=M(W). FOR OTHER CASES SEE THEIR FIG 2.
SNU   A  FROM TAU --> (E S-NU(E) S-NU(TAU)) OR (MU S-NU(MU) S-NU(TAU)) OR
SNU   A  (E S-NU(E) S-NU(MU)).
SNU   A  M(S-NU(TAU)) + M(S-NU) > M(TAU)
SNU   A  M(S-NU(MU)) + M(S-NU(E)) > M(MU)
SNU
SNU   B  WARE 84 AND FERNANDEZ 85 ASSUME S-NEUTRINO IS LIGHTEST STABLE SUSY
SNU   B  PARTICLE OR DECAYS INVISIBLY.  ALSO ASSUME W-INO MASS IS 20-29 GEV.
SNU   B  LOOKED FOR SINGLE GAMMA EVENT (E+E- --> SNU SNUBAR GAMMA).  LIMIT
SNU   B  FROM 1 OBSERVED EVENT CONSISTENT WITH NU NUBAR GAMMA BACKGROUND IS
SNU   B  M(SNU) > 10 GEV AT CL=.90.
```

SCALAR e MASS LIMIT

```
SE       NONE 2GEV TO 16.8GEV CL=.95   BEHREND   82 CELL E+E-
SE    A    NONE BELOW 16.6GEV CL=.95   BRANDELIK 82 TASS E+E-
SE    B    NONE BELOW 22.2GEV CL=.95   GLADNEY   83 SMK2 E+E-
SE    C                       CL=.95   BARTEL    84 JADE E+E-
SE    D                                BARTEL2   84 JADE E+E- M(Z-INO)<30GEV
SE    E    NONE BELOW 22.4GEV CL=.95   FERNANDEZ 84 MAC  E+E-
SE         NONE BELOW 22  GEV CL=.95   ADEVA     85 MRKJ E+E- ECM=40-47 GEV
SE    F    NONE BELOW 25.2GEV CL=.95   BARTEL    85 JADE E+E- ECM=32-47 GEV
SE    F    NONE BELOW 22  GEV CL=.95   BARTEL    85 JADE E+E- ECM=32-47 GEV
SE    G    NONE BELOW 37  GEV CL=.90   FERNANDEZ 85 MAC  E+E- ECM=29 GEV
SE    H    NONE BELOW 51  GEV CL=.90   BARTHA    86 ASP  FOR M(PHTNO)=0  GEV
SE    H    NONE BELOW 48  GEV CL=.90   BARTHA    86 ASP  FOR M(PHTNO)=5  GEV
SE    H    NONE BELOW 33  GEV CL=.90   BARTHA    86 ASP  FOR M(PHTNO)=10 GEV
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SE   A  BRANDELIK 82 LIMIT IS FROM NO ENHANCEMENT IN EVENTS WITH THETA NEAR
SE   A  90 DEG(LIGHT SCALAR) AND WITH LARGE ACOPLANARITY (HEAVY SCALAR).
SE
SE   B  GLADNEY 83 LOOKED FOR LARGE PT E FROM SINGLY PRODUCED S-ELECTRONS.
SE
SE   C  BARTEL 84 MAKE NON-STANDARD ASSUMPTION THAT PHOTINO DECAYS TO
SE   C  GOLDSTINO +GAMMA. THEY LOOK FOR 2GAM EVTS FROM PHOTINO PAIR PROD.
SE   C  FOR SUPERSYM BREAKING PARAM D=(100 GEV)**2, THEY FIND AT CL=.95
SE   C  M(S-ELECTRON) > 80 GEV. LIMIT IS ALSO APPLICABLE IF THE PHOTINO
SE   C  DECAYS RADIATIVELY WITHIN THE DETECTOR.
SE
SE   D  BARTEL2 84 LIMIT IS FROM NEUTRALINO SEARCH ASSUMING THAT
SE   D  MASS(NEUTRALINO) < 30 GEV.  USING ACOPLANAR EVENTS WITH MISSING PT.
SE   D  UNDER THESE CONDITIONS, M(S-ELECTRON) > 50 GEV AT CL=.90.
SE
SE   E  FERNANDEZ 84 ANALYZED SINGLE ELECTRON EVENTS FROM SINGLY PRODUCED
SE   E  S-ELECTRON. ENERGY DISTRIBUTION IS CONSISTENT WITH E+E-GAMMA BKGD.
SE
SE   F  BARTEL 85 CONSIDER SINGLE AND PAIR S-ELECTRON PRODUCTION AS WELL AS
SE   F  PHOTINO PAIR+GAMMA.  FIRST LIMIT IS FOR MASSLESS PHOTINO AND SECOND
SE   F  IS FOR M(PHOTINO) < 15 GEV.  BOTH ASSUME EQUAL MASS FOR LEFT AND
SE   F  RIGHT S-ELECTRON.  FOR M(SE(R)) >> M(SE(L)) AND MASSLESS PHOTINO,
SE   F  LIMIT IS 21.8 GEV (SEE ALSO THEIR FIG.2).
SE
SE   G  FERNANDEZ 85 ANALYZE SINGLE GAMMA EVENT EXPECTED FROM E+E- -->
SE   G  PHOTINO PAIR+GAMMA.  ABOVE LIMIT IS FOR M(PHOTINO)=0 AND EQUAL
SE   G  MASS LEFT AND RIGHT S-E.  (SEE ALSO FIG.2).  FOR M(RIGHT) >>
SE   G  M(LEFT), LIMIT IS 30 GEV.
SE
SE   H  BARTHA 86 SEARCH FOR ANOMALOUS PHOTONS FROM E+E- -->
SE   H  (PHOTINO PHOTINO PHOTON) WHERE PHOTINOS ARE ASSUMED TO LEAVE
SE   H  APPARATUS UNDETECTED.  FOR M(RIGHT) >> M(LEFT) AND M(PHOTINO)=0,
SE   H  LIMIT IS 42 GEV AT CL=.90.
```

SCALAR μ MASS LIMIT

```
SMU     NONE 3GEV   TO 15GEV  CL=.95  BARBER    80 MRKJ E+E-
SMU     NONE 3.3GEV TO 16GEV  CL=.95  BEHREND   82 CELL E+E-
SMU  A     NONE BELOW 16.4GEV CL=.95  BRANDELIK 82 TASS E+E-
SMU  B     NONE BELOW 13.8GEV CL=.95  FERNANDEZ 83 MAC  E+E-
SMU  B    NONE BELOW 20  GEV CL=.95   ADEVA     85 MRKJ E+E- ECM=40-47 GEV
SMU  C    NONE BELOW 21. GEV CL=.95   BARTEL2   85 JADE E+E- ECM=32-47 GEV
SMU  C    NONE BELOW 20.9GEV CL=.95   BARTEL2   85 JADE E+E- STABLE S-MU
SMU
SMU  A  BRANDELIK 82 LIMIT IS FROM NO ENHANCEMENT IN EVENTS WITH THETA NEAR
SMU  A  90 DEG(LIGHT SCALAR) AND WITH LARGE ACOPLANARITY (HEAVY SCALAR).
SMU
SMU  B  FERNANDEZ 83 AND ADEVA 85 OBSERVED NO EXCESS ACOPLANAR MU+MU-
SMU  B  EVENTS.
SMU
SMU  C  BARTEL2 85 SECOND LIMIT IS FOR STABLE S-MU FROM NON-OBSERVATION OF
SMU  C  SMU-PAIR PROD.  FIRST LIMIT IS FOR S-MU --> MU + STABLE-PHOTINO
SMU  C  FROM NON-OBSERVATION OF ACOPLANAR MU PAIR WITH LARGE MISSING PT
SMU  C  AND APPLIES IF M(PHOTINO) < 15 GEV.  FIRST LIMIT ASSUMES M(LEFT)=
SMU  C  M(RIGHT); IF M(LEFT) >> M(RIGHT) THE LIMIT IS 20.3 GEV.
```

SCALAR τ MASS LIMIT

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STA     SCALAR-TAU-->TAU PHOTINO LOOKS IDENTICAL TO CHGD-HIGGS-->TAU NU
STA     AS IN STABLE PARTICLE SEARCH SECTION. WHERE TAKEN FROM RESULTS
STA     QUOTED FOR CHGD-HIGGS, THE LIMITS BELOW CORRESPOND TO
STA     BR(TAU NU)=1.0 LINE IN MASS-LIMIT GRAPHS FOR PAIR OF
STA     CGHD-HIGGS-->(TAU NU)+(TAU NU).
STA          14GEV  OR MORE   CL=.95  ADEVA     82 MRKJ
STA     NONE 4GEV TO 14GEV    CL=.95  BARTEL    82 JADE
STA  A  NONE 6GEV TO 15.3GEV  CL=.95  BEHREND   82 CELL
STA  A  NONE M(TAU) TO 3.8GEV CL=.95  BEHREND   82 CELL
STA     NONE M(TAU) TO 9.9GEV CL=.90  BLOCKER   82 SMK2
STA  B  NONE BELOW 17  GEV    CL=.95  ADEVA     85 MRKJ E+E- ECM=40-47 GEV
STA
STA  A  BEHREND 82 FIRST LIMIT FOR SCALAR TAU IS FROM PT-CUT TAU-PAIR
STA  A  ANALYSIS, SECOND LIMIT FROM NO EXCESS TAU PAIR EVENTS.
STA
STA  B  NO EXCESS ACOPLANAR MU AND HADRONIC JET.
```

SCALAR QUARK MASS LIMIT

```
SQK  A   NONE BELOW 3 GEV                   NAPPI     82 RVUE Q=2/3 SQUARK ONLY
SQK  B     1300GEV  OR LESS                 HINCHLIFF 82 RVUE    M(GLUINO)=2 GEV
SQK  B     3100GEV  OR LESS                 HINCHLIFF 82 RVUE    M(GLUINO)=4 GEV
SQK  C   NONE BELOW 100 GEV                 BERGSMA   83 RVUE FOR M(GLUINO)<2 GEV
SQK  D   NONE BELOW 40 GEV                  BARGER    84 RVUE P PBAR ECM=540 GEV
SQK  E   NONE BELOW 40 GEV                  ELLIS2    84 RVUE M(GLNO) >> M(SQK)
SQK  F                                      BAER      85 RVUE P PBAR
SQK  E   NONE BELOW 25 GEV                  REYA      85 RVUE M(GLNO) >> M(SQK)
SQK  G   NONE BELOW 70 GEV      CL=.90      BARNETT   86 RVUE FOR M(GLNO)= 80 GEV
SQK  G   NONE BELOW 60 GEV      CL=.90      BARNETT   86 RVUE FOR M(GLNO)> 80 GEV
SQK
SQK  A  NAPPI 82 LIMIT APPLIES TO CHARGE 2/3 SQUARK.  NO LIMIT FOUND FOR
SQK  A  CHARGE 1/3.  LIMIT FROM P-WAVE SQUARK-SQUARK BOUND STATE NON-
SQK  A  OBSERVATION IN E+E- ANNIHILATION.
SQK
SQK  B  ABSTRACTED FROM DISCUSSION OF BEAM CONTAMINATION EXPER AT FNAL
SQK  B  IN HINCHLIFFE 82. ASSUMES GLUINO--> QUARK QUARK PHOTINO.
SQK
SQK  C  REANALYSIS OF CERN-SPS BEAM DUMP DATA. SEE THEIR FIG. 1.
SQK
SQK  D  BARGER 84 USE MONOJET + MISSING-PT EVENTS OBSERVED IN UA1
SQK  D  EXPERIMENT AT ECM=546 GEV AS UPPER LIMIT DUE TO SQUARK -->
SQK  D  QUARK+PHOTINO ASSUMING M(GLUINO)=2*M(SQUARK).
SQK
SQK  E  ELLIS2 84 AND REYA 85 USE UA1 MONOJET+MISSING-PT EVENTS AT ECM=546
SQK  E  GEV.  ASSUME SQUARK --> QUARK+PHOTINO.
SQK
SQK  F  BAER 85 EVALUATE THE CONTRIBUTION OF SQUARK-->QUARK +Z-INO, W-INO.
SQK  F  NO CHANGE IS NEEDED OF LIMIT ON M(GLUINO), M(SQUARK) DERIVED
SQK  F  ASSUMING THE DOMINANCE OF SQUARK--> QUARK+PHOTINO.
SQK
SQK  G  BARNETT 86 USE THE UA1 MONOJET+MISSING-PT EVENTS AT 630 GEV.
SQK  G  THEY CONSIDER ALL SUPERSYMMETRIC PROCESSES CONSISTENT WITH
SQK  G  M(GLUINO) > M(PHOTINO) AND NEGLECT DECAYS TO W-INOS AND Z-INOS.
SQK  G  THEY CONCLUDE UA1 MONOJETS CANNOT ORIGINATE IN GLUINO OR
SQK  G  SCALAR QUARK PRODUCTION.
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GLUINO MASS LIMIT

```
GNO     THERE IS AN ONGOING CONTROVERSY (REFLECTED IN THESE LISTINGS) ABOUT
GNO     WHETHER VERY LIGHT GLUINOS ARE RULED OUT.  THESE PAPERS SOMETIMES
GNO     MAKE DIFFERENT ASSUMPTIONS AND USE DIFFERENT CALCULATIONAL
GNO     TECHNIQUES.
GNO  A  NONE BELOW 2-3GEV               KANE      82 RVUE BEAM DUMP
GNO  B  NONE BELOW 2 GEV                BERGSMA   83 RVUE FOR M(S-QK)<100 GEV
GNO  C                                  BALL      84 CALO IF PHOTINO DECAYS
GNO  D                                  FARRAR    84 RVUE
GNO  E  NONE BELOW 3.7GEV CL=.68        LLEWELLYN 84 RVUE FOR M(S-QK)=30 GEV
GNO  F  NONE BELOW 60 GEV               ALLAN     85 RVUE FOR M(SQ)=20-35 GEV
GNO  G  NONE BETWEEN 15-40 GEV          ALTARELLI 85 RVUE FOR M(SQ)=100 GEV
GNO  H                                  BAER      85 RVUE P PBAR
GNO  I  NONE BETWEEN 0.5-4 GEV          COOPER-SA 85 BDMP FOR M(SQ)< 65 GEV
GNO  I  NONE BETWEEN 0.5-3 GEV          COOPER-SA 85 BDMP FOR M(SQ)=150 GEV
GNO  I  NONE BETWEEN 0.5-2 GEV          COOPER-SA 85 BDMP FOR M(SQ)=300 GEV
GNO  J  NONE BETWEEN 2-4 GEV            DAWSON    85 RVUE TAU > E-7 SEC
GNO  J  NONE BETWEEN 1-2.5 GEV          DAWSON    85 RVUE FOR M(SQK)=100 GEV
GNO  K                                  DERUJULA  85 RVUE FOR M(SQ)=80 GEV
GNO  L  NONE BELOW 40 GEV               ELLIS     85 RVUE P PBAR ECM=546 GEV
GNO  M  NONE BETWEEN .5-4.1GEV CL=.90 FARRAR    85 RVUE FNAL BEAM DUMP
GNO  N  NONE BELOW 1 GEV                GOLDMAN   85 RVUE GLUONIUM
GNO  P  NONE BELOW 1-2 GEV              HABER     85 RVUE
GNO  Q   NONE BELOW 25 GEV              REYA      85 RVUE M(SQK) >> M(GLNO)
GNO  R                                  BARGER    86 RVUE FOR M(SQ)= 100 GEV
GNO  S  NONE BETWEEN 3-62 GEV  CL=.90 BARNETT   86 RVUE FOR M(SQ)= 75 GEV
GNO  S  NONE BETWEEN 3-50 GEV  CL=.90 BARNETT   86 RVUE FOR M(SQ)> 75 GEV
GNO
GNO  A  KANE 82 INFERED ABOVE GLUINO MASS LIMIT FROM RETROACTIVE ANALYSIS
GNO  A  OF HADRONIC COLLISION AND BEAM DUMP EXPERIMENTS. LIMITS VALID IF
GNO  A  GLUINO DECAYS INSIDE DETECTOR.
GNO
GNO  B  BERGSMA 83 IS REANALYSIS OF CERN-SPS BEAM-DUMP DATA. SEE THEIR
GNO  B  FIG. 1.
GNO
GNO  C  BALL 84 IS FNAL BEAM DUMP EXPERIMENT.  OBSERVED NO INTERACTIONS OF
GNO  C  PHOTINO IN THE CALORIMETER, WHERE PHOTINOS ARE EXPECTED TO COME
GNO  C  FROM PAIR-PRODUCED GLUINOS.  SEARCH FOR LONG-LIVED PHOTINO
GNO  C  INTERACTING IN CALORIMETER 56M FROM TARGET. LIMIT IS FOR M(S-QUARK)
GNO  C  =40 GEV AND PROD CROSS SECTION PROPORTIONAL TO A**0.72.  BALL 84
GNO  C  FIND NO GLUINO ALLOWED BELOW 4.1 GEV AT CL=.90.  THEIR FIG.1 SHOWS
GNO  C  DEPENDENCE ON M(S-QUARK) AND A.  SEE ALSO KANE 82 (PHYS. LETT.
GNO  C  112B, 227)
GNO
GNO  D  FARRAR 84 ARGUES THAT M(GLUINO) < 100 MEV IS NOT RULED OUT IF THE
GNO  D  LIGHTEST R-HADRONS ARE LONG-LIVED.  A LONG LIFETIME WOULD OCCUR IF
GNO  D  R-HADRONS ARE LIGHTER THAN PHOTINOS OR IF M(SQUARK)> 100 GEV.
GNO
GNO  E  FROM BEBC DATA.
GNO
GNO  F  ALLAN 85 LIMIT IS FROM CONSIDERING Q+GLUON--> SQ+GLUINO FOLLOWED BY
GNO  F  SQ--> Q+PHOTINO AND GLUINO--> Q+SQ--> Q+QBAR+PHOTINO ASSUMING
GNO  F  M(GLUINO)>M(SQUARK).  LIMIT IS FOR SQUARK MASS BETWEEN 20 GEV TO 35
GNO  F  GEV, AND USED THE UA1 MONOJET DATA AT ECM=546 GEV.
GNO
GNO  G  ALTARELLI 85 SAY THAT M(GLUINO)<15 GEV CANNOT BE EXCLUDED BY UA1
GNO  G  MONOJET DATA AT 546 GEV DUE TO UNCERTAINTY IN FRAGMENTATION OF
GNO  G  OF LIGHT GLUINOS.  THEY ANALYZE GLUINO-GLUINO PRODUCTION.
GNO
GNO  H  BAER 85 EVALUATE THE CONTRIBUTION OF SQUARK-->QUARK +Z-INO, W-INO.
GNO  H  NO CHANGE IS NEEDED OF LIMIT ON M(GLUINO), M(SQUARK) DERIVED
GNO  H  ASSUMING THE DOMINANCE OF SQUARK--> QUARK+PHOTINO.
GNO
GNO  I  COOPER-SARKAR 85 IS BEBC BEAM-DUMP. GLUINOS DECAYING IN DUMP WOULD
GNO  I  YIELD PHOTINOS IN THE DETECTOR GIVING NEUTRAL-CURRENT-LIKE
GNO  I  INTERACTIONS.  FOR M(SQUARK) > 330 GEV, NO LIMIT IS SET.
GNO
GNO  J  DAWSON 85 FIRST LIMIT FROM NEUTRAL PARTICLE SEARCH.  SECOND LIMIT
GNO  J  BASED ON FNAL BEAM DUMP EXPERIMENT.
GNO
GNO  K  DERUJULA 85 SAY THAT M(GLUINO)=3 GEV CANNOT BE EXCLUDED BY UA1
GNO  K  MONOJET DATA AT 546 GEV DUE TO UNCERTAINTY IN FRAGMENTATION OF
GNO  K  OF LIGHT GLUINOS.  THEY ANALYZE GLUINO-GLUINO PRODUCTION.
GNO
GNO  L  ELLIS 85 USE UA1 MONOJET+MISSING-PT EVENTS AT ECM=546 GEV AS UPPER
GNO  L  LIMIT FOR GLUINO PAIR PRODUCTION WITH GLUINO --> Q QBAR PHOTINO.
GNO  L  GLUINO WITH MASS AROUND 3 GEV TO 20 GEV SEEMS EXCLUDED EVEN AFTER
GNO  L  THE EFFECT OF VARIOUS REFINEMENTS ARE INCLUDED.
GNO
GNO  M  FARRAR 85 POINTS OUT THAT BALL 84 ANALYSIS APPLIES ONLY IF THE
GNO  M  GLUINOS DECAY BEFORE INTERACTING, I.E. M(SQUARK)<80*M(GLUINO)**1.5.
GNO  M  FARRAR 85 FINDS M(GLUINO)<0.5 NOT EXCLUDED FOR M(SQ)=30-1000 GEV
GNO  M  AND M(GLUINO)<1.0 NOT EXCLUDED FOR M(SQ)=100-500 GEV BY BALL 84
GNO  M  EXPERIMENT.
GNO
GNO  N  GOLDMAN 85 USE NON-OBSERVATION OF A PSEUDOSCALAR GLUINO-GLUINO
GNO  N  BOUND STATE IN RADIATIVE PSI DECAY.
GNO
GNO  P  HABER 85 IS BASED ON SURVEY OF ALL PREVIOUS SEARCHES SENSITIVE TO
GNO  P  LOW MASS GLUINOS.  LIMIT MAKES ASSUMPTIONS REGARDING THE LIFETIME
GNO  P  AND ELECTRIC CHARGE OF THE LIGHTEST SUPERSYMMETRIC PARTICLE.
GNO
GNO  Q  REYA 85 USE UA1 MONOJET+MISSING-PT EVENTS AT ECM=546 GEV.  ASSUME
GNO  Q  GLUINO --> QUARK+QUARK+PHOTINO.
GNO
GNO  R  BARGER 86 SAY THAT M(GLUINO)=3-5 GEV CANNOT BE EXCLUDED BY UA1
GNO  R  MONOJET DATA AT 546 GEV DUE TO UNCERTAINTY IN FRAGMENTATION OF
GNO  R  OF LIGHT GLUINOS.  THEY ANALYZE GLUINO-GLUINO PRODUCTION.  THEY
GNO  R  ALSO ANALYZE THE GLUINO DISTRIBUTION FUNCTION AND ITS ROLE IN
GNO  R  GLUINO PRODUCTION.
GNO
GNO  S  BARNETT 86 USES INCREASED STATISTICS OF UA1 MONOJET RESULTS AT
GNO  S  ECM=630 GEV PLUS A HIGHER-ORDER PROCESS TO RULE OUT LIGHT GLUINOS
GNO  S  WITH M(GLUINO)=3-15 GEV.
GNO  S  BARNETT 86 CONSIDER ALL SUPERSYMMETRIC PROCESSES CONSISTENT WITH
GNO  S  M(GLUINO) > M(PHOTINO) AND NEGLECT DECAYS TO W-INOS AND Z-INOS.
GNO  S  THEY CONCLUDE UA1 MONOJETS CANNOT ORIGINATE IN GLUINO OR
GNO  S  SCALAR QUARK PRODUCTION.
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PHOTINO MASS LIMIT

```
PHO      THE NON-COSMOLOGICAL LIMITS BELOW ASSUME THAT THE PHOTINO DECAYS
PHO      INTO GOLDSTINO+GAMMA.  HOWEVER, THIS IS NOT TRUE IN CURRENTLY
PHO      POPULAR THEORETICAL MODELS.
PHO   A                              CABIBBO   81 RVUE COSMOLOGY
PHO   B                              BEHREND   83 CELL E+E-
PHO   C                              GOLDBERG  83 RVUE COSMOLOGY
PHO   D                              KRAUSS    83 RVUE COSMOLOGY
PHO   C                              VYSOTSKII 83 RVUE COSMOLOGY
PHO   E                              BALL      84 CALO BEAM-DUMP
PHO   B                              BARTEL    84 JADE E+E-
PHO   C    NONE BETWEEN 100 EV-2 GEV  ELLIS     84 COSM FOR M(HVY)=40 GEV
PHO   C    NONE BETWEEN 100 EV-5 GEV  ELLIS     84 COSM FOR M(HVY)=100 GEV
PHO   C                              SILK      84 RVUE COSMOLOGY
PHO   F                              ADEVA     85 MRKJ E+E- ECM=40-47 GEV
PHO
PHO   A  CABIBBO 81 CONSIDER PHOTINO --> GAMMA+GOLDSTINO.  PHOTINO MUST BE
PHO   A  EITHER LIGHT ENOUGH (<30 EV) TO SATISFY COSMOLOGY BOUND, OR HEAVY
PHO   A  ENOUGH (>0.3 MEV) TO HAVE DISAPPEARED AT EARLY UNIVERSE.
PHO
PHO   B  BEHREND 83 AND BARTEL 84 LOOK FOR 2GAMMA EVENTS FROM PHOTINO PAIR
PHO   B  PRODUCTION.  WITH SUPERSYM BREAKING PARAM D=(100 GEV)**2 AND
PHO   B  M(S-ELECTRON)=40 GEV THE EXCLUDED REGIONS AT CL=.95 WOULD BE
PHO   B  M(PHOTINO)= 100 MEV - 13 GEV FOR BEHREND 83
PHO   B  M(PHOTINO)=  80 MEV - 18 GEV FOR BARTEL  84
PHO   B  LIMIT IS ALSO APPLICABLE IF THE PHOTINO DECAYS RADIATIVELY WITHIN
PHO   B  THE DETECTOR.
PHO
PHO   C  THESE AUTHORS REQUIRE THAT RELIC PHOTINOS FROM THE BIG BANG DO NOT
PHO   C  GENERATE TOO LARGE A CONTRIBUTION TO THE ENERGY DENSITY OF THE
PHO   C  UNIVERSE.
PHO
PHO   D  KRAUSS 83 FINDS M(PHOTINO) NOT 30EV TO 2.5GEV.
PHO   D  KRAUSS 83 TAKES INTO ACCOUNT THE GRAVITINO DECAY. FIND THAT LIMITS
PHO   D  DEPEND STRONGLY ON REHEATED TEMPERATURE. FOR EXAMPLE A NEW ALLOWED
PHO   D  REGION M(PHOTINO)=4-20MEV EXISTS IF M(GRAVITINO)< 40TEV. SEE FIG.2.
PHO
PHO   E  BALL 84 IS FNAL BEAM DUMP EXPERIMENT.  OBSERVED NO PHOTINO DECAY,
PHO   E  WHERE PHOTINOS ARE EXPECTED TO COME FROM GLUINOS PRODUCED AT THE
PHO   E  TARGET.  THREE POSSIBLE PHOTINO LIFETIMES ARE CONSIDERED.  GLUINO
PHO   E  DECAY TO GOLDSTINO+GLUON IS ALSO CONSIDERED.
PHO
PHO   F  ADEVA 85 IS SENSITIVE TO PHOTINO DECAY PATH < 5 CM. WITH
PHO   F  M(S-ELECTRON)= 50 GEV; LIMIT (CL=.90) IS M(PHOTINO) > 20.5 GEV.
PHO   F  ASSUME PHOTINO DECAYS TO PHOTON+GOLDSTINO AND SEARCH FOR ACOPLANAR
PHO   F  PHOTONS WITH LARGE MISSING PT.
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CHARGINO MASS LIMITS

```
WNO      CHARGINOS ARE UNKNOWN MIXTURES OF W-INOS AND CHARGED HIGGSINOS
WNO      (THE SUPERSYMMETRIC PARTNERS OF W AND HIGGS BOSONS).  MASS LIMITS
WNO      ARE RELATIVELY MODEL-DEPENDENT, SO ASSUMPTIONS CONCERNING BRANCHING
WNO      RATIOS NEED TO BE SPECIFIED.  WE QUOTE EXAMPLE VALUES.
WNO
WNO   A    NONE BELOW 25 GEV   CL=.95  ADEVA     84 MRKJ E+E- ECM=30-47 GEV
WNO   B    NONE BELOW 22.5 GEV CL=.95  BARTEL3   85 JADE E+E- ECM=27-46 GEV
WNO
WNO   A  ADEVA 84 OBSERVED NO EVENTS WITH SIGNATURE OF ACOPLANAR LEPTON PAIR
WNO   A  WITH MISSING ENERGY.  LIMIT IS FOR M(CHARGINO) >> M(PHOTINO) AND
WNO   A  M(S-NU).  ASSUMES CHARGINO --> SNEUTRINO + LEPTON DOMINATES.
WNO
WNO   B  BARTEL3 85 SEARCH CHARGINO DECAY MODES (L SNU), (L NU PHOTINO),
WNO   B  (QUARK QUARK PHOTINO) AND (QUARK QUARK GLUINO) WITH GLUINO -->
WNO   B  (QUARK QUARK PHOTINO).  THEY USE ACOPLANAR JETS, ACOPLANAR LEPTONS,
WNO   B  SPHERICAL HADRONIC EVENTS, R-MEASUREMENT, ETC. TO SEARCH. THE ABOVE
WNO   B  LIMIT IS TYPICAL OF MOST OF THEIR RESULTS; DETAILS WITH VARIOUS
WNO   B  BRANCHING RATIOS AND PHOTINO MASSES APPEAR IN FIG'S IN BARTEL3 85.
```

NEUTRALINO MASS LIMITS

```
ZNO      NEUTRALINOS ARE UNKNOWN MIXTURES OF Z-INOS, NEUTRAL HIGGSINOS,
ZNO      AND PHOTINOS (THE SUPERSYMMETRIC PARTNERS OF Z AND HIGGS BOSONS
ZNO      AND OF PHOTONS).  IT IS NOT POSSIBLE TO QUOTE RIGOROUS MASS
ZNO      LIMITS BECAUSE THEY ARE EXTREMELY MODEL-DEPENDENT; I.E. - THEY
ZNO      DEPEND ON BRANCHING RATIOS OF VARIOUS NEUTRALINO DECAY MODES, ON
ZNO      THE MASSES OF DECAY PRODUCTS (S-ELECTRON, PHOTINO, SQUARK, GLUINO),
ZNO      AND ON THE S-ELECTRON MASS EXCHANGED AT NEUTRALINO PRODUCTION.
ZNO      OFTEN LIMITS ARE GIVEN AS CONTOUR PLOTS IN THE M(NEUTRALINO)-
ZNO      M(S-ELECTRON) PLANE VS OTHER PARAMETERS.  WE QUOTE VALUES ONLY AS
ZNO      EXAMPLES.
ZNO
ZNO   A    NONE BELOW 35 GEV  CL=.95   ADEVA     84 MRKJ E+E- ECM=29 GEV
ZNO   B    NONE BELOW 28 GEV  CL=.95   BARTEL2   84 JADE E+E- ECM=27-46 GEV
ZNO   C                                AKERLOF   85 HRS  E+E- ECM=29 GEV
ZNO   D                                BEHREND   85 CELL E+E- -->MONOJET+X
ZNO   E                                ELLIS     85 RVUE COSMOLOGY
ZNO
ZNO   A  ADEVA 84 OBSERVED NO EVENTS WITH SIGNATURE OF ACOPLANAR LEPTON
ZNO   A  PAIR WITH MISSING ENERGY.  ABOVE EXAMPLE LIMIT IS FOR M(PHOTINO) <2
ZNO   A  GEV AND M(S-E) < 40 GEV, AND ASSUMES BR(NEUTRALINO --> MU+ MU-
ZNO   A  PHOTINO)=(E+E- PHOTINO)=0.10.  BR=0.05 GIVES 33.5 GEV LIMIT.
ZNO
ZNO   B  BARTEL2 84 SEARCH FOR E+E- -->NEUTRALINO+PHOTINO WITH NEUTRALINO-->
ZNO   B  PHOTINO + E+E-, MU+MU-, Q QBAR, ETC.  THEY SEE NO ACOPLANAR EVENTS
ZNO   B  WITH MISSING-PT DUE TO TWO PHOTINOS.  ABOVE EXAMPLE LIMIT IS FOR
ZNO   B  M(S-ELECTRON)=40 GEV AND FOR LIGHT STABLE PHOTINO WITH
ZNO   B  BR(NEUTRALINO --> E+E- PHOTINO) = 0.1.
ZNO
ZNO   C  AKERLOF 85 IS E+E- MONOJET SEARCH MOTIVATED BY UA1 MONOJET EVENTS.
ZNO   C  OBSERVED ONLY ONE EVENT CONSISTENT WITH E+E- --> PHOTINO+NEUTRALINO
ZNO   C  WHRE NEUTRALINO --> MONOJET.  ASSUMING THAT MISSING-PT IS DUE TO
ZNO   C  PHOTINO, AND MONOJET DUE TO NEUTRALINO, LIMITS DEPENDENT ON THE
ZNO   C  MIXING AND M(S-ELECTRON) ARE GIVEN, SEE THEIR FIG.4.
ZNO
ZNO   D  BEHREND 85 FIND NO MONOJET AT ECM=40-46 GEV. CONSIDER NEUTRALINO
ZNO   D  PAIR PROD VIA Z0.  ONE IS ASSUMED AS MASSLESS AND ESCAPES DETECTOR.
ZNO   D  LIMIT IS FOR THE HEAVIER ONE, DECAYING INTO A JET AND MASSLESS
ZNO   D  NEUTRALINO.  BOTH NEUTRALINOS ARE ASSUMED TO BE PURE HIGGSINO.  FOR
ZNO   D  THESE VERY MODEL-DEPENDENT RESULTS, BEHREND 85 EXCLUDES M=1.5-19.5
ZNO   D  GEV.
ZNO
ZNO   E  ELLIS 85 FIND IF LIGHTEST NEUTRALINO IS STABLE, THEN M(NEUTRALINO)
ZNO   E  NOT 100 EV - 2 GEV.  THE UPPER LIMIT DEPENDS ON M(SQUARK) (SIMILAR
ZNO   E  TO THE PHOTINO LIMIT) AND ON NATURE OF NEUTRALINO.  FOR PURE
ZNO   E  HIGGSINO THE UPPER LIMIT IS 5 GEV.
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SUPERSYMMETRY MISCELLANEOUS RESULTS

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OTH      WHICH DO NOT APPEAR IN OTHER HEADINGS OR WHICH
OTH      MAKE NON-MINIMAL ASSUMPTIONS.
OTH   A                              BEHREND   83 CELL E-E+-->PHOTINO PAIR
OTH   B                              HOFFMAN   83 CNTR PI-P-->N(E+E-)
OTH
OTH   A  BEHREND 83 AT DESY-PETRA SET CL=.95 LIMIT OF 1.1 PB FOR PHOTINO-
OTH   A  ANTIPHOTINO PRODUCTION (M(PHOTINO)<2GEV) AT WCM AROUND 34GEV.
OTH
OTH   B  HOFFMAN 83 SET CL=.90 LIMIT DSIGMA/DT*BR(E+E-)<3.5E-32 CM**2/GEV**2
OTH   B  FOR SPIN-1 PARTNER OF GOLDSTONE FERMIONS WITH 140<M<160 MEV
OTH   B  DECAYING INTO E+E- PAIR.
OTH
OTH      BARBER 84 CONSIDER THAT S-MUON AND S-ELECTRON MAY MIX LEADING
OTH      TO NU-->E PHOTINO PHOTINO. THEY DISCUSS MASS-MIXING LIMITS FROM
OTH      DECAY DIST ASYM IN LBL-TRIUMF DATA AND E+ POLARIZATION IN
OTH      SIN DATA.
OTH
OTH      CHANOWITZ 83 FIND IN BAG-MODEL THAT CHARGED S-HADRON EXISTS
OTH      WHICH IS STABLE AGAINST STRONG DECAY IF M(GLUINO)> 1 GEV.
OTH      THIS IS IMPORTANT SINCE TRACKS FROM DECAY OF NEUTRAL S-HADRON
OTH      CANNOT BE RECONSTRUCTED TO PRIMARY VERTEX BECAUSE OF MISSED
OTH      PHOTINO. CHARGED S-HADRON LEAVES TRACK FROM VERTEX.
OTH
OTH      BRICK 84 REANALYZED FNAL 147GEV HBC DATA FOR R-DELTA++ WITH
OTH      TAU>10**-9 SEC AND PLAB> 2GEV. SET CL=.90 UPPER LIMITS 6.1,4.4,AND
OTH      29 MICROBARNS IN PP, PI+P, K+P COLLISIONS RESPECTIVELY.
OTH      R-DELTA++ IS DEFINED AS BEING GLUINO AND 3 UP QUARKS.  IF
OTH      MASS=1.2-1.5 GEV, THEN LIMITS MAY BE LOWER THAN THEORY PREDICTIONS.
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REFERENCES FOR SUPERSYMMETRIC PARTICLE SEARCHES

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BARBER   80 PRL 45 1904          +BECKER,BEI+        (AACH+DESY+MIT+AIKO+BHEP)
CABIBBO  81 PL 105B 155          N.CABIBBO,G.R.FARRAR,L.MAIANI    (ROMA+RUTG)
ADEVA    82 PL 115B 345          MARK-J COLLAB(AACH+DESY+MIT+MADR+ANIK+BHEP)
BARTEL   82 PL 114B 211          JADE C.  (DESY+HAMB+HEID+LANC+MCHS+RL+TOKY)
BEHREND  82 PL 114B 287          CELLO C.     (DESY+KARL+MPIM+ORSA+LPNP+SACL)
BLOCKER  82 PRL 49 517           +MATTEUZZI,ABRAMS+            (HARV+SLAC+LBL)
BRANDELI 82 PL 117B 365          BLANDELIK+ TASSO C.  (AACH+BONN+DESY+HAMB+)
HINCHLIF 82 PROC SNOWMASS 82     HINCHLIFFE, LITTENBERG              (LBL+BNL)
KANE     82 PL 112B 227          G.L.KANE,J.P.LEVEILLE                  (MICH)
NAPPI    82 PR D25 84            C.NAPPI                                (PRIN)
SHANKER  82 NP B204 375          O.SHANKER                              (TRIU)
BEHREND  83 PL 123B 127          + CELLO COL.(DESY+KARL+MPIM+ORSA+LPNP+SACL)
BERGSMA  83 PL 121B 429          + CHARM COLLAB.  (ANIK+CERN+HAMB+MOSU+ROMA)
CHANOWIT 83 PL 126B 225          M.CHANOWITZ,S.SHARPE                (UCB+LBL)
FERNANDE 83 PR D28 2721          FERNANDEZ+ (COLO+FRAS+HOUS+NEAS+SLAC+UTAH+)
GLADNEY  83 PRL 51 2253          +HOLLEBEEK,LECLAIRE,ABRAMS+ (SLAC+LBL+HARV)
GOLDBERG 83 PRL 50 1419          H.GOLDBERG                             (NEAS)
HOFFMAN  83 PR D28 660           +FRANK,MISCHKE,MOIR,SCHARDT     (LANL+ARZS)
KRAUSS   83 NP B227 556          L.M.KRAUSS                             (HARV)
VYSOTSKI 83 SJNP 37 948          M.I.VYSOTSKII                          (ITEP)
ADEVA    84 PRL 53 1806          MARK-J C.(AACH+BNL+CIT+DESY+MIT+MADR+ANIK+)
ARNISON  84 PL 139B 115          UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HARV+HELS+)
BALL     84 PRL 53 1314          +COFFIN+          (MICH+FIRZ+OSU+FNAL+WISC)
BARBER   84 PL 139B 427          J.S.BARBER, R.E.SHROCK                 (STON)
BARGER   84 PL 145B 147          V.BARGER,K.HAGIWARA,W.Y.KEUNG    (WISC+BNL)
BARTEL   84 PL 139B 327          JADE C.(DESY+HEID+LANC+MCHS+UMD+RHEL+TOKY+)
BARTEL2  84 PL 146B 126          JADE C.(DESY+HAMB+HEID+LANC+MCHS+UMD+RHEL+)
BRICK    84 PR D30 1134          +    (BROW+CAMB+IIT+IND+MIT+MONS+NIJM+ORNL)
ELLIS    84 NP B238 453          +HAGELIN,NANOPOULOS,OLIVE,SREDNICKI  (CERN)
ELLIS2   84 NP B246 189          J.ELLIS,H.KOWALSKI                (CERN+DESY)
FARRAR   84 PRL 53 1029          G.R.FARRAR                             (RUTG)
FERNANDE 84 PRL 52 22            FERNANDEZ+MAC COLL.  (COLO+FRAS+HOUS+NEAS+)
KANE     84 NP B232 21           G.L.KANE,W.B.ROLNICK              (MICH+WAYN)
LLEWELLY 84 PRPL 105 53          C.H.LLEWELLYN SMITH                     (OXF)
SILK     84 PRL 53 624           J.SILK,M.SREDNICKI                (UCB+UCSB)
WARE     84 PL 147B 415          J.D.WARE AND M.E.MACHACEK              (NEAS)
ADEVA    85 PL 152B 439          MARK-J C.(AACH+BNL+CIT+DESY+MIT+MADR+ANIK+)
    ALSO 84 PRPL 109 131         MARK-J C., ADEVA+  (AACH+BNL+CIT+DESY+MIT+)
AKERLOF  85 PL 156B 271          HRS C.         (MICH+ANL+IND+PURD+LBL+SLAC)
ALLAN    85 NP B259 77           A.ALLAN,E.GLOVER,S.GRAYSON             (DURH)
ALTARELL 85 PL 160B 317          G.ALTARELLI,B.MELE,S.PETRARCA   (ROMA+INFN)
BAER     85 PL 161B 175          +ELLIS,GELMINI,NANOPOULOS,TATA         (CERN)
BARTEL   85 PL 152B 385          JADE C.(DESY+HAMB+HEID+LANC+MCHS+UMD+RHEL+)
BARTEL2  85 PL 152B 392          JADE C.(DESY+HAMB+HEID+LANC+MCHS+UMD+RHEL+)
BARTEL3  85 ZPHY 29 505          JADE C.(DESY+HAMB+HEID+LANC+MCHS+UMD+RHEL+)
BEHREND  85 PL 161B 182          CELLO COL.,+    (DESY+GLAS+HAMB+KARL+MPIM+)
COOPER-S 85 PL 160B 212          WA66 C.,COOPER-SARKAR+(CERN+MPIM+OXF+LOIC+)
DAWSON   85 PR D31 1581          S.DAWSON,E.EICHTEN,C.QUIGG       (LBL+FNAL)
DERUJULA 85 NP B261 587          A. DE RUJULA,R. PETRONZIO              (CERN)
ELLIS    85 PL 157B 437          J.ELLIS AND H.KOWALSKI            (CERN+DESY)
    ALSO 85 NP B259 109          J.ELLIS AND H.KOWALSKI            (CERN+DESY)
FARRAR   85 PRL 55 895           G.R.FARRAR                             (RUTG)
FERNANDE 85 PRL 54 1118          MAC COLL.,FERNANDEZ+ (COLO+FRAS+HOUS+NEAS+)
GOLDMAN  85 PHYSICA 15D 181      T.GOLDMAN,H.HABER                 (LANL+UCSC)
HABER    85 PRPL 117 75          H.HABER,G.KANE                    (UCSC+MICH)
REYA     85 PR D32 645           E.REYA,D.P.ROY                         (DORT)
ARNISON  86 PL B TO BE PUB       UA1 COLLAB.(AACH+ANIK+LAPP+BIRM+CERN+HARV+)
BARGER   86 PR D33 57            BARGER,JACOBS,WOODSIDE,HAGIWARA (WISC+DESY)
BARNETT  86 NP B267 625          M.BARNETT,H.HABER,G.KANE    (LBL+UCSC+MICH)
BARTHA   86 PRL 56 685           ASP C.,+BURKE,EXTERMANN,+    (SLAC+MIT+WASH)
```

OTHER STABLE PARTICLE SEARCHES

OMITTED FROM SUMMARY TABLE

We collect here those searches which do not appear in any of the above search categories. These include searches for Higgs bosons (H and HKK), technipions (HGC), right-handed gauge bosons (MR), other nonstandard gauge bosons (W1C and Z1E), leptoquarks (EGT), familons (FCA), and centauros (CEN). Also shown are heavy particle searches in accelerator experiments (EE, CH, CS, D, ICH, RPI, CA), in cosmic rays (F), and in matter (CON). Searches are also listed for light particles (C), highly ionizing particles (ION), penetrating non-neutrino-like particles (BD), and tachyons (TCF, TCM, TCD). Note that axion, supersymmetry, heavy neutrino, and heavy lepton searches appear in separate sections above.

CENTAURO PROD. CROSS SEC. IN ACCELERATOR EXPER (cm²)

```
CEN  A   0                            ALPGARD   82 UA5  P PBAR COLLIDER
CEN  B   0 (1. E-30)OR LESS           ARNISON   83 UA1  P PBAR COLLIDER
CEN  A  ALPGARD 82 IS CERN COLLIDER EXPERIMENT WITH WCM=540 GEV(155 TEV LAB
CEN  A  EQUIVALENT). OBSERVED NO LARGE CHGD MULTIPLICITY EVENTS WITH PHOTON
CEN  A  MULTIPLICITY CONSISTENT WITH ZERO IN 3600 INELASTIC EVENTS.
CEN  B  ARNISON 83 IS CERN COLLIDER EXPT WITH WCM=540GEV. LOOKED FOR EVENTS
CEN  B  WITH LARGE HAD. AND LOW EM CONTENT. NONE IN 48000 LOW BIAS EVENTS.
```

LIGHT (BETWEEN μ AND e MASSES) PARTICLE MASS

```
C       (UNITS-ELECTRON MASSES)
C        0   NONE BETWEEN 6 AND 25     BELOUSOV  60 CNTR  SPINOR,TAU>1 E-8
C        0   NONE BETWEEN 2 AND 25     GORBUNOV  60 CC    SPINOR,TAU>1 E-9
C        0   NONE BETWEEN 5 AND 175    COWARD    63 CNTR  SPINOR,TAU>22 E-10
C        0   NONE BETWEEN 5 AND 175    COWARD    63 CNTR  SCALAR,TAU>68 E-10
C    A   0   NONE BETWEEN 2 AND 13     BLAGOV    75 CNTR SPINOR,TAU>2E-10SEC
C    A   0   NONE BETWEEN 2 AND 10.6   BLAGOV    75 CNTR SCALAR,TAU>2E-10SEC
C    B   0   NONE BETWEEN 110 AND 180 VIERTEL    78 CNTR TAU >2.E-5 SEC
C
C    A  BLAGOV 75 BOUNDS ON LIFETIME DEPEND ON MASS AND IMPROVE AS MASS
C    A  DECREASES.  AT 2 GEV THE EXPERIMENT IS SENSITIVE TO TAU>3E-11 SEC
C    A  FOR SPINOR, TAU>5E-11 SEC FOR SCALAR.
C
C    B  VIERTEL 78 SEARCHES FOR MU+ -->X+ NU. FINDS BR<8.5E-6 IN MASS
C    B  RANGE GIVEN ABOVE (CL=.90). BEST LIMIT BR<5.E-7 (CL=.90) IS  FOUND
C    B  AT MASS=80 MEV.
```

RIGHT−HANDED W BOSON MASS LIMITS (GeV)

```
MR   A                                 BERGSMA   83 CHRM +  NU(MU)E-->MU NUE
MR   B      380.    OR MORE  CL=.90    CARR      83 ELEC +  MU+ DECAY
MR   C      400.    OR MORE  CL=.95    STOKER    85 ELEC +  ANY L-R MIX ANG.
MR   C      475.    OR MORE  CL=.95    STOKER    85 ELEC +  L-R MIX ANG<.041
MR
MR   A  BERGSMA 83 SET LIMIT M(W2)/M(W1) > 1.9 AT CL=.90.  ASSUMES NON-ZERO
MR   A  NEUTRINO MASS.
MR
MR   B  CARR 83 IS TRIUMF EXPERIMENT WITH A HIGHLY POLARIZED MU+ BEAM.
MR   B  LOOKED FOR DEVIATION FROM V-A AT THE HIGH MOMENTUM END OF THE DECAY
MR   B  E+ ENERGY SPECTRUM. LIMIT FROM PREVIOUS WORLD-AV.MUON POLARIZATION
MR   B  PARAMETER IS M(WR)> 240 GEV. ASSUMES A LIGHT RIGHT-HANDED NEUTRINO.
MR
MR   C  STOKER 85 IS SAME TRIUMF EXPERIMENT AS CARR 83.  HERE THEY MEASURE
MR   C  THE DECAY E+ SPECTRUM ASYMMETRY ABOVE 46MEV/C USING A MUON-SPIN-
MR   C  ROTATION TECHNIQUE.  ASSUMED A LIGHT RIGHT-HANDED NEUTRINO.
MR   C  QUOTED LIMITS ARE FROM COMBINING WITH CARR 83.
```

RIGHT−HANDED Z^0 BOSON MASS LIMITS (GeV)

```
MRZ     FOLLOWING FORMALISM OF RIZZO AND SENJANOVIC,
MRZ     PHYS. REV. D24, 704 (1981)
MRZ  A      150.    OR MORE   CL=.95  ADEVA     85 MRKJ ECM=14.-46.8 GEV
MRZ  A  ADEVA 85 MEASURE ASYMMETRY OF MU-PAIR PRODUCTION.
```

CONSTRAINT ON COEFF (C) OF ADDITIONAL NEUTRAL CURRENT

```
U1      TERM IN SU(2)*U(1)*G THEORY.  C DEPENDS ON THE GROUP G.
U1   A        0.035 OR LESS   CL=.95  ADEVA     85 MRKJ ECM=14.-46.8 GEV
U1   A  ADEVA 85 MEASURE ASYMMETRY OF MU-PAIR PRODUCTION.  SEE ALSO
U1   A  ADEVA ET AL. IN PHYS. REP. 109, 133 (1984) FOR MORE DETAILS
```

SEARCH FOR A HEAVY CHARGED BOSON

```
W1C     OTHER THAN W IN COLLIDER EXPTS.
W1C  A     NONE BELOW 170 GEV CL=.90  ARNISON2  83 UA1  E NU MODE
W1C  B     NONE BELOW 210 GEV CL=.90  ARNISON   86 UA1  E NU MODE
W1C
W1C  A  ARNISON2 83 FIND AMONG 47 W-->E NU CANDIDATES NO EVENT WITH EXCESS
W1C  A  PT. ALSO SET SIGMA*BR(E NU) < 30 PB WITH CL=.90 AT ECM=540 GEV.
W1C
W1C  B  ARNISON 86 FIND NO EXCESS AT LARGE PT IN 148 W--> E NU EVENTS.
W1C  B  SET LIMIT SIGMA*BR(E NU) < 10 PB AT CL=.90 AT ECM=546 AND 630 GEV.
```

SEARCH FOR A HEAVY NEUTRAL BOSON OTHER THAN Z

```
Z1E     IN E+E- REACTIONS
Z1E     THESE SEARCHES MOTIVATED BY REPORTED Z--> X GAMMA WITH X--> E+ E-
Z1E  A  NONE 39.8 TO 45.5 GEV          ADEVA     84 MRKJ
Z1E  A  NONE BELOW 47.8 GEV   CL=.95   ADEVA     84 MRKJ G(X0-->E+E-)=2MEV
Z1E  A  NONE 39.8 TO 45.2 GEV          BEHREND   84 CELL
Z1E  A  NONE BELOW Z  MASS    CL=.95   BEHREND   84 CELL G(Z -->EEGAM)>20MEV
Z1E  B  NONE BELOW 46.6 GEV   CL=.95   ADEVA     85 MRKJ E+E- ECM=40-47 GEV
Z1E  B  NONE BELOW 48   GEV   CL=.95   ADEVA     85 MRKJ E+E- ECM=40-47 GEV
Z1E
Z1E  A  ADEVA 84 AND BEHREND 84 HAVE ECM=39.8-45.5 GEV. MRKJ SEARCHED
Z1E  A  X0 IN E+E- --> HADRONS, 2GAMMA, MU+MU-, E+E- AND CELLO IN THE
Z1E  A  SAME CHANNELS PLUS TAU PAIR. NO NARROW OR BROAD X0 IS FOUND IN THE
Z1E  A  ENERGY RANGE. THEY ALSO SEARCHED FOR THE EFFECT OF X0 WITH MX > ECM
Z1E  A  VIA INTERFERENCE. THE 2ND LIMITS ARE FROM BHABHA DATA AND FOR SPIN-
Z1E  A  0-DOUBLET AND SPIN-0 SINGLET IN MRKJ AND CELLO RESPECTIVELY. THE
Z1E  A  ORIGINAL PAPERS ALSO LIST LIMITS IN INDIVIDUAL CHANNELS.
Z1E
Z1E  B  ADEVA 85 FIRST LIMIT IS FROM 2GAMMA, MU+MU-, HADRONS ASSUMING X0
Z1E  B  IS SCALAR.  SECOND LIMIT IS FROM E+E- CHANNEL.
```

SEARCH FOR A HEAVY NEUTRAL BOSON

```
Z1C     OTHER THAN Z IN COLLIDER EXPTS.
Z1C  A     NONE BELOW 160 GEV CL=.90  ARNISON   86 UA1  E+ E- MODE
Z1C  A  ARNISON 86 FIND NO EXCESS E+E- PAIRS AMONG 13 PAIRS FROM Z.
Z1C  A  SET LIMIT SIGMA*BR(E+E-) < 13 PB AT CL=.90 AT ECM=546 AND 630 GEV.
```

HIGGS BOSON MASS LIMIT (GeV)

```
H     A   D  0.409   OR MORE              DZHELYADI 81      ETAPRIM-->ETA HIGGS
H     B   D  0.325   OR MORE              WILLEY    82 RVUE K+-->DILEPTON+PI+
H     C                                   HOFFMAN   83 CNTR PI-P-->N(H0-->E+E-)
H     D   NONE .003   TO .014  CL=.95     FREEDMAN  84 CNTR HE*-->HE(H0-->E+E-)
H     E   NONE .00103 TO .00584           MUKHOPADH 84 RVUE  O*--> O(H0-->E+E-)
H
H     A  DZHELYADIN 81 OBTAINED BR(ETA PRIM-->ETA MU+MU-)<1.5E-5 (CL=.90)
H     A  WHICH EXCLUDES A LIGHT HIGGS BOSON IN MU+MU- CHANNEL.
H
H     B  WILLEY 82 CALCULATED BR(K+-->H0+PI+) BY ONE-LOOP S-->D H0 AND QUARK
H     B  MODEL. EXCLUDE M(H0) < M(K)-M(PI).
H
H     C  HOFFMAN 83 LOOKED FOR E+E- PEAK FROM HIGGS PRODUCED IN PI-P CEX AT
H     C  300MEV/C. SET CL=.90 LIM. DSIGMA/DT*BR(E+E-)<3.5 E-32 CM**2/GEV**2
H     C  FOR  140 < M(H0) < 160 MEV.
H
H     D  FREEDMAN 84 IS ANL EXP WITH DYNAMITRON PROTON BOMBARDING TRITIUM TO
H     D  FORM HE*. THEY ALSO REANALYZE KOHLER 74 HE* DATA TO FIND NO MASS
H     D  REGION IS EXCLUDED BY THAT DATA.  SEE ALSO COMMENT CARDS E BELOW.
H
H     E  MUKHOPADHYAY 84 EXAMINE KOHLER 74 HE* AND C* DATA. CLAIM THAT NO
H     E  MASS REGION CAN BE EXCLUDED BY 74 HE* DATA AS PROTON DECAY WIDTH OF
H     E  HE* IS LARGE (BR(HE*-->HIGGS HE)=3.4 E-11 IS VERY SMALL). ABOVE
H     E  LIMIT IS FROM KOHLER 74 O* DECAY DATA. (KOHLER 74, PRL 33, 1628).
H
H                                COMMENT
H        FOR EARLY HIGGS SEARCH PAPERS, SEE
H         J.ELLIS, M.K.GAILLARD, D.V.NANOPOULOS, NUCL. PHYS. B106, 292, 1976
```

CHARGED HIGGS (OR TECHNI−PION) MASS LIMIT

```
HGC     IN E+ E- REACTION
HGC      EXCLUDED MASS REGION DEPENDS ON BRANCHING RATIO.  SINCE HIGGS
HGC      COUPLES TO HEAVY PARTICLES, DOMINANT EXPECTED MODES ARE (TAU NU)
HGC      AND (CHARM ANTI-S) IN THE SIMPLEST HIGGS MODELS.  ALTHOUGH HIGGS IN
HGC      SIMPLEST MODELS HAVE THE USUAL K-M MIXING ANGLES, THIS MAY NOT BE
HGC      TRUE IN OTHER MODELS.  IN PARTICULAR IF THE (C B) MIXING ANGLE WERE
HGC      NOT SMALL, THE (C B) MODE WOULD DOMINATE ABOVE (C B) THRESHOLD,
HGC      AND THE RESULTS BELOW WOULD NOT APPLY.  SEE GRAPHS IN INDIVIDUAL
HGC      PAPERS. WE QUOTE ONLY A SAMPLE LIMIT FOR BR(TAU NU) SPECIFIED.
HGC      FOR A DISCUSSION, SEE EICHTEN ET AL., FERMILAB-PUB-85/145-T.
HGC  A   NONE 5GEV TO 13GEV    CL=.95   ADEVA      82 MRKJ BR(TAU NU)=.25
HGC  A   NONE 3GEV TO 13GEV    CL=.95   BARTEL     82 JADE BR(TAU NU)=0.2-1.0
HGC  B   NONE 7GEV TO 14GEV    CL=.95   BEHREND    82 CELL BR(TAU NU)=.80
HGC  A   NONE 4GEV TO  9GEV    CL=.90   BLOCKER    82 SMK2 BR(TAU NU)=.10-.90
HGC  C   NONE 5GEV TO 13GEV    CL=.95   ALTHOFF    83 TASS H+ -->C S (U D)
HGC      NONE BELOW 14 GEV              ADEVA      83 MRKJ H+H- -->MU HAD.JET
HGC  D   NONE BELOW M(B-MESON)          CHEN       83 RVUE B DECAY AT UPSI(4S)
HGC  A   NONE BELOW 17 GEV     CL=.95   ADEVA      85 MRKJ BR(TAU NU)>.25
HGC
HGC  A   STUDIED H+ H- -->(TAU NU)+(TAU NU),(TAU NU)+HADRONS.
HGC  A   SEARCH FOR MUON OPPOSITE HADRONIC SHOWER.
HGC
HGC  B   BEHREND 82 STUDIED H+ H- -->(TAU NU)+(TAU NU). SEE THEIR FIG.3.
HGC
HGC  C   ALTHOFF 83 ANALYZED 4-JETS. LIMIT IS FOR H+ DECAYING PREDOMINANTLY
HGC  C   INTO HADRONS. COMBINING WITH (TAU NU)RESULTS LIMIT APPLIES TO H+
HGC  C   WITH ANY HADRONIC BRANCHING RATIOS. ASSUME (C B) NOT IMPORTANT.
HGC
HGC  D   CHEN 83 EXCLUDE A MODEL WHERE B-->H+ LIGHT-QUARK AT BR=1. OBSERVED
HGC  D   BR(B-->E X) WOULD REQUIRE BR(H+-->TAU X)=1 BUT THEN CHARGED ENERGY
HGC  D   FRACTION WOULD BE SMALLER THAN EXPT VALUE(.60+-.03).(CLEO DATA)
```

SEARCHES FOR $X(2200)$ (A HIGGS CANDIDATE)

```
HKK      LIMITS ARE FOR BRANCHING RATIOS OR PRODUCTS OF BRANCHING RATIOS.
HKK  A      2.E-4     OR LESS  CL=.90   BEHRENDS  84 CLEO UPSI(1S), K+K- MODE
HKK  A      9.E-5     OR LESS  CL=.90   BEHRENDS  84 CLEO UPSI(2S), K+K- MODE
HKK  A      3.E-3     OR LESS  CL=.90   BEHRENDS  84 CLEO B-MESON , K+K- MODE
HKK  B   (.5-1.5)E-3 OR LESS  CL=.90   YOUSSEF   84 CUSB UPSI(1S)-->GAMMA X
HKK  B   (.4-1.2)E-3 OR LESS  CL=.90   YOUSSEF   84 CUSB UPSI(1,2S) TWO-CHGD
HKK
HKK  A   BEHRENDS 84 1ST AND 2ND LIMITS ARE FOR BR(UPSI-->GAMMA XI)*BR(XI
HKK  A   -->K+K-), THE 3RD IS FOR BR(B--> XI X)*BR(XI -->K+K-). ALL FOR MASS
HKK  A   OF XI 2.2GEV, BUT WILL BE SIMILAR FOR 1.5-4GEV(1ST,2ND) AND FOR 2-3
HKK  A   GEV(3RD).
HKK
HKK  B   CUSB 84 1ST LIMIT IS FOR INCLUSIVE RADIATIVE DECAY, THE 2ND IS FOR
HKK  B   BR(UPSI-->XI GAMMA)*BR(XI-->2CHGD). FOR M(XI)=1-7GEV.
```

PARTICLES IN EXTENDED GAUGE THEORIES

```
EGT      MASS BOUNDS DERIVED
EGT  A   NONE BELOW 0.5TEV(MTOP=20GEV) SHANKER   82 RVUE CHGD-HIGGS
EGT  A   NONE BELOW 1. TEV             SHANKER   82 RVUE PS-LEPTOQUARK
EGT  A   NONE BELOW 125TEV             SHANKER   82 RVUE VECTOR-LEPTOQUARK
EGT  A   NONE BELOW 350 GEV            BRYMAN    83 CNTR CHGD-HIGGS
EGT  B   NONE BELOW 350 TEV            DESHPANDE 83 RVUE PATI-SALAM X-BOSON
EGT  C                                 BALTRUSAI 85 SMK3 GOLDSTONE-BOSON
EGT
EGT  A   FROM (PI-->E NU)/(PI-->MU NU) RATIO.  BRYMAN 83 BASED ON SHANKER 82
EGT  A   MODEL WITH HIGGS-FERMION COUPLINGS PROPORTIONAL TO HEAVY FERMION
EGT  A   MASSES.
EGT
EGT  B   DESHPANDE 83 USED UPPER LIMIT ON KL -->MU E DECAY WITH R.G.EQUATION
EGT  B   TO ESTIMATE COUPLING AT THE HEAVY BOSON MASS.
EGT  B   SEE ALSO DIMOPOULOS ET AL., NP B182, 77 (1981).
EGT
EGT  C   BALTRUSAITIS 85 SEARCH FOR LIGHT GOLDSTONE BOSON(G) OF BROKEN U(1).
EGT  C   CL=.95 LIMITS ARE BR(TAU-->MU+ G)/BR(TAU-->MU+ NU NU) < 0.125 AND
EGT  C   BR(TAU-->E+ G)/BR(TAU-->E+ NU NU) < 0.04.  INFERRED LIMIT FOR THE
EGT  C   SYMMETRY BREAKING SCALE IS M > 3000 TEV.
```

PROD. OF PARTICLES IN EXTENDED GAUGE THEORIES

```
EGP  A                                 VERGADOS  82 CNTR 2BETA DECAY, SCALAR
EGP
EGP  A   VERGADOS 82 SETS LIMIT GH.LT.4E-3 FOR (DIMENSIONLESS) LEPTON-NUMBER
EGP  A   VIOLATING COUPLING, GH, OF SCALAR BOSON TO NEUTRINOS, FROM ANALYSIS
EGP  A   OF DATA ON DOUBLE BETA DECAY OF CA48.
```

Stable Particle Full Listings

OTHER STABLE PARTICLE SEARCHES

OBS. OF EVENTS WITH LARGE MISSING p_T IN COLL. EXPTS

```
MPT  A   7 EVENTS                       ARNISON   84 UA1  P AP, ECM=540 GEV
MPT  B   4 EVENTS                       BAGNAIA   84 UA2  P AP, ECM=540 GEV
MPT
MPT  A  ARNISON 84 OBSERVED 7 EVENTS WITH MISSING PT >40 GEV, 5 ASSOCIATED
MPT  A  WITH A NARROW HADRONIC JET, 2 WITH NEUTRAL EM CLUSTER. EXCEPT ONE
MPT  A  OF THE LATTER EVENTS, NONE OF THEM CAN BE INTERPRETED BY W-->E NU
MPT  A  AND ARNISON 84 SAYS THEY ARE UNLIKELY TO BE STANDARD BACKGROUND.
MPT  A  THESE HAVE BEEN REFERRED TO AS MONOJET EVENTS.  PRELIMINARY UA1
MPT  A  RESULTS (REPORTED AT 1985 CONFERENCES) WITH A LARGER INTEGRATED
MPT  A  LUMINOSITY INDICATE THAT MANY OR POSSIBLY ALL OF THE MONOJET
MPT  A  EVENTS ARE DUE TO THE SUM OF SEVERAL DIFFERENT STANDARD MODEL
MPT  A  BACKGROUNDS.
MPT
MPT  B  BAGNAIA 84 OBSERVED 4 EVENTS WITH MISSING PT > 25 GEV, WITH JET(S)
MPT  B  OF PT >30 GEV, AND WITH ELECTRON OF PT >15 GEV.  PRELIMINARY UA2
MPT  B  RESULTS (REPORTED AT 1985 CONFERENCES) WITH A LARGER INTEGRATED
MPT  B  LUMINOSITY CONTAIN NO ADDITIONAL EVENTS.
```

HIGHLY IONIZING PARTICLE FLUX (number/m^2−year)

```
ION      0    0.4   OR LESS  CL=.95   KINOSHITA 81 PLAS Z/BETA 30-100
```

TACHYON FLUX IN COSMIC RAYS (number/cm^2−sec−sr)

```
TCF     SEE SMITH 77 FOR A REVIEW OF EARLIER COSMIC RAY AND ACCELERATOR
TCF     EXPERIMENTS.
TCF  A     NONE                         PRESCOTT  76 CNTR
TCF  B     NONE                         SMITH     77 CNTR
TCF  C   0  2.3E-10 OR LESS  CL=.95     BHAT      79 CNTR
TCF  D   0  2.4E-9  OR LESS  CL=.90     MARINI    82 CNTR V/C>1.2
TCF
TCF  A  PRESCOTT 76 REANALYZED CLAY AND CROUCH(C.C.)74 DATA(NATURE 248,28).
TCF  A  FOUND APPARATUS EFFECT,CORRECTION FOR WHICH MUCH REDUCES THE STAT.
TCF  A  SIGNIFICANCE OF POSITIVE C.C.RESULT. ALSO PERFORMED TWO NEW EXPTS
TCF  A  ONE USING C.C.APPARATUS,ANOTHER WITH NEW APPARATUS. SET UPPER LIMIT
TCF  A  AT CL=.95 OF ABOUT 30 TACHYONS PER SHOWER WITH AVERAGE SIZE N=6E+5.
TCF
TCF  B  SMITH 77 ANALYZED MORE THAN 200000 SHOWERS(223 DAYS) WITH E>1.E+14
TCF  B  EV SCANNING 290 E-6 SEC PERIOD BEFORE EACH SHOWER. OBSERVED EXCESS
TCF  B  46+-40 EVS DOES NOT CONSTITUTE STATISTICALLY SIGNIFICANT EVIDENCE.
TCF
TCF  C  BHAT 79 IS AT OOTACAMUND(2200M ABOVE SEA). NO SIGNAL IN 3621 HOURS.
TCF
TCF  D  MARINI 82 IS TOF MEASUREMENT USING PEP-CNTR AT SEA LEVEL.

TCM    TACHYON SEARCHES IN E+ E- ANNIHILATION
TCM  A   0  1. E-6  OR LESS  CL=.90   PEREPELIT 77 CNTR V*U(EQ) < 1
TCM  A   0  1. E-5  OR LESS  CL=.90   PEREPELIT 77 CNTR 1 < V*U(EQ) < 15
TCM
TCM  A  PEREPELITSA 77 IS MICHELSON-TYPE EXPT FOR PAIR-PRODUCED TACHYONS
TCM  A  IN E+ E- ANNIHILATION (E+ FROM CU ISOTOPE). ABOVE LIMITS ARE FOR
TCM  A  CS(E+E- -->TACHYON PAIR)/CS(E+E- -->2GAMMA) AND V*U(EQ) IS TACHYON
TCM  A  VELOCITIES TIMES EARTH EQUATOR COMPONENT OF VELOCITY OF PREFERRED
TCM  A  REFERENCE FRAME.

TCD    SEARCHES FOR TACHYONIC DECAY (LOWER LIMIT FOR MEAN LIFE IN YEARS)
TCD     SEE LJUBICIC 75 FIG. 1 FOR REVIEW OF EARLIER EXPERIMENTS.
TCD  A      4.6E+13 OR MORE              LJUBICIC  75 ELEC M(TACHYON)> 1.1 KEV
TCD
TCD  A  LJUBICIC 75 USED LEAD OXIDE CATHODE AND ELECTRON MULTIPLIER LOOKING
TCD  A  FOR IONIZATION DUE TO TACHYONIC DECAY (SPONTANEOUS ACQUISITION OF
TCD  A  ENERGY) OF BOUND-STATE E-. SENSITIVE TO PROPER TACHYON MASS>1.1KEV.
TCD  A  ABOVE LIMIT IS OBTAINED FROM OBSERVED E- EMISSION RATE 3/HOUR.
```

FLAVOR−CHANGING AXIONLIKE PARTICLE (FAMILON=FA)

```
FCA  A                                  DICUS     83 RVUE COSMOLOGY
FCA  A  THE PRIMORDIAL HEAVY NEUTRINO MUST DECAY INTO NU AND FA EARLY SO
FCA  A  THAT THE RED-SHIFTED DECAY PRODUCTS ARE BELOW CRITICAL DENSITY, SEE
FCA  A  THEIR TABLE. IN ADDITION,K-->PI FA AND MU-->E FA ARE UNSEEN. COM-
FCA  A  BINING THESE EXCLUDES M(HEAVY NU) BETWEEN 5E-5 TO 5E-4MEV(MU DECAY)
FCA  A  AND M(HEAVY NU) BETWEEN 5.E-5 TO 0.1MEV(K-DECAY).
```

```
BD     PROD. OF NEW PENETRATING NON-NU LIKE STATES
BD     IN BEAM DUMP
BD   A                                  LOSECCO   81 CALO    28 GEV PROTONS
BD   A  NO EXCESS N.C.EVS LEADS TO CSP*CSI*ACCEPTANCE<2.26E-71 CM**4/NUC**2
BD   A  (CL=.90)FOR LIGHT NEUTRALS. ACC. DEPENDS ON MODELS (0.1 TO 4.E-4).
```

HEAVY PARTICLE PROD. CROSS SECTION IN e^+e^-

```
EE     (RATIO TO CS(E+E- -->MU+MU-)). SEE ALSO IN QUARK SEARCH AND MAGNETIC
EE     MONOPOLE SEARCHES.
EE   A   0 5.0 E-2  OR LESS  CL=.90   BARTEL    80 JADE Q=(3,4,5)/3 2-12GEV
EE   B   0 1.6 E-2  OR LESS  CL=.95   KINOSHITA 82 PLAS Q=3-180,M<14.5GEV
EE
EE   A  BARTEL 80 IS DESY PETRA EXPT WITH WCM=27-35 GEV. ABOVE LIMIT IS FOR
EE   A  INCLUSIVE PAIR PROD AND RANGES BETWEEN 1.E-1 - 1.E-2 DEPENDING ON
EE   A  MASS AND PROD MOMENTUM DIST. (SEE THEIR FIGS.9,10,11).
EE
EE   B  KINOSHITA 82 IS SLAC PEP EXPT AT WCM=29 GEV USING LEXAN AND CR-39
EE   B  PLASTIC SHEETS SENSITIVE TO HIGHLY IONIZING PARTICLES.
```

HEAVY PARTICLE PROD. CROSS SECTION (cm^2)

```
CH   A   0  1. E-31 OR LESS             LEIPUNER  73 CNTR +- M=3-11 GEV
CH   B    0.3-1.3E-31 OR LESS           CARROLL   78 SPEC    M=2.-2.5 GEV
CH
CH   A  LEIPUNER 73 IS AN NAL 300 GEV P EXPT. WOULD HAVE DETECTED PARTICLES
CH   A  WITH LIFETIME GREATER THAN 200 NSEC.
CH
CH   B  CARROLL 78 LOOK FOR NEUTRAL, S=-2 DIHYPERON RESONANCE IN
CH   B  P P --> 2K+ X. CS VARIES WITHIN ABOVE LIMITS OVER MASS RANGE AND
CH   B  PLAB=5.1-5.9 GEV/C.
```

HEAVY PARTICLE PROD. CROSS SECTION (cm^2/N)

```
CS   A   0  2.5E-35 OR LESS             GUSTAFSON 76 CNTR 0  TAU GT 10**-7
CS
CS   A  GUSTAFSON 76 IS A 300 GEV FNAL EXPT LOOKING FOR HEAVY (M GT 2 GEV)
CS   A  LONGLIVED NEUTRAL HADRONS IN THE M4 NEUTRAL BEAM. THE ABOVE TYPICAL
CS   A  VALUE IS FOR M=3 GEV AND ASSUMES AN INTERACTION CROSS SECTION OF
CS   A  1 MB.  VALUES AS A FUNCTION OF MASS AND INTERACTION CROSS SECTION
CS   A  ARE GIVEN IN FIG. 2.
```

HEAVY PARTICLE PROD. DIFFERENTIAL CROSS SECTION (cm^2/sr−GeV)

```
D    A   0  1.5E-36 OR LESS             DORFAN    65 CNTR BE TARGET  M=3-7GEV
D    A   0  3.0E-36 OR LESS             DORFAN    65 CNTR FE TARGET  M=3-7GEV
D        0  2.4E-35 OR LESS  CL=.90     BINON     69 CNTR Q=- M=1-1.8 GEV
D    B   0  2.4E-35 OR LESS  CL=.90     ANTIPOV1  71 CNTR Q=- M=1.2-1.7,2.1-4
D    C   0  1.2E-35 OR LESS  CL=.90     ANTIPOV2  71 CNTR Q=- M=2.2-2.8
D    D   0  5.8E-34 OR LESS  CL=.90     ALPER     73 SPEC +- M=1.5-24 GEV
D    E   0  1. E-31 OR LESS  CL=.90     APPEL     74 CNTR +- M=3.2-7.2 GEV
D    F   0  2.2E-33 OR LESS  CL=.90     ALBROW    75 SPEC Q=+-1  M=4-15 GEV
D    F   0  1.1E-33 OR LESS  CL=.90     ALBROW    75 SPEC Q=+-2  M=6-27 GEV
D    G   0  8. E-35 OR LESS  CL=.90     JOVANOVIC 75 CNTR +- M=15-26 GEV
D    G   0  1.5E-34 OR LESS  CL=.90     JOVANOVIC 75 CNTR Q=+-2, M=3-10 GEV
D    G   0  6. E-35 OR LESS  CL=.90     JOVANOVIC 75 CNTR Q=+-2, M=10-26 GEV
D    H   0  2.6E-36 OR LESS  CL=.90     BALDIN    76 CNTR Q=-1, M=2.1-9.4 GEV
D
D    A  DORFAN 65 IS A 30 GEV/C P EXPT AT BNL.  UNITS ARE PER GEV MOMENTUM
D    A  PER NUCLEUS.
D
D    B  ANTIPOV1 71 LIMIT INFERRED FROM FLUX RATIO. 70 GEV P EXPERIMENT.
D
D    C  ANTIPOV2 71 IS FROM SAME 70 GEV P EXP. AS ANTIPOV1 71 AND BINON 69.
D
D    D  ALPER 73 IS CERN ISR 26+26 GEV P+P EXPT.  P>.9 GEV, .2< BETA <.65.
D
D    E  APPEL 74 IS NAL 300 GEV P+W EXPERIMENT. STUDIES FORWARD PRODUCTION
D    E  OF HEAVY (UP TO 24 GEV) CHARGED PARTICLES WITH MOMENTA 24-200GEV(-)
D    E  AND 40-150GEV (+CHG).  ABOVE TYPICAL VALUE IS FOR 75 GEV AND IS
D    E  PER GEV MOMENTUM PER NUCLEON.
D
D    F  ALBROW 75 IS A CERN ISR EXPT WITH ECM=53 GEV. THETA=40 MR. SEE
D    F  FIG. 5 FOR MASS RANGES UP TO 35 GEV.
D
D    G  JOVANOVICH 75 IS A CERN ISR 26+26 AND 15+15 GEV P+P EXPERIMENT.
D    G  FIG.4 COVERS RANGES Q=1/3 TO 2 AND M=3 TO 26 GEV.
D    G  VALUE IS PER GEV MOMENTUM.
D
D    H  BALDIN 76 IS A 70 GEV SERP EXP.  VALUE IS PER AL NUCLEUS AT
D    H  THETA=0.  FOR OTHER CHARGES IN RANGE -0.5 TO -3.0, CL=.90 LIMIT IS
D    H  (2.6E-36)/ABS(CHARGE) FOR MASS RANGE (2.1 TO 9.4GEV)*ABS(CHARGE).
D    H  ASSUMES STABLE PARTICLE INTERACTING WITH MATTER AS DO ANTIPROTONS.
```

LONGLIVED HEAVY PARTICLE INVARIANT C.S. (cm^2/GeV^2/N)

```
ICH  A   0  1.1E-37 OR LESS  CL=.90    CUTTS     78 CNTR MASS=4-10 GEV
ICH  B   0  3.0E-37 OR LESS  CL=.90    VIDAL     78 CNTR MASS=4.5-6 GEV
ICH  C   0  6. E-33 OR LESS  CL=.90    ARMITAGE  79 SPEC    M=1.87 GEV
ICH  C   0  1.5E-33 OR LESS  CL=.90    ARMITAGE  79 SPEC    M=1.5-3.0 GEV
ICH  D   0                             BOZZOLI   79 CNTR Q=+-(2/3,1,4/3,2)
ICH  E   0  2.5E-36 OR LESS  CL=.90    THRON     85 CNTR Q=-1 M=4-12 GEV
ICH  E   1  1. E-35 OR LESS  CL=.90    THRON     85 CNTR Q=+1 M=4-12 GEV
ICH
ICH  A  CUTTS 78 IS P BE EXPT AT FNAL SENSITIVE TO PARTICLES OF TAU>5E-8SEC
ICH  A  VALUE IS FOR -.3<X<0 AND PT=0.175.
ICH
ICH  B  VIDAL 78 IS FNAL 400 GEV PROTON EXPT. VALUE IS FOR X=0 AND PT=0.
ICH  B  PUTS LIFETIME LIMIT OF <5*10**-8 SEC ON PARTICLE IN THIS MASS RANGE
ICH
ICH  C  ARMITAGE 79 IS CERN-ISR EXPT AT ECM=53 GEV. VALUE IS FOR X=0.1 AND
ICH  C  PT=0.15. OBSERVED PARTICLES AT M=1.87 GEV ARE FOUND ALL CONSISTENT
ICH  C  WITH BEING ANTIDEUTERONS.
ICH
ICH  D  BOZZOLI 79 IS CERN-SPS 200 GEV P N EXPERIMENT. LOOKS FOR PARTICLE
ICH  D  WITH TAU LARGER THAN 10**-8 SEC. SEE THEIR FIG.11-18 FOR PRODUCTION
ICH  D  CROSS SECTION UPPER LIMITS VS MASS.
ICH
ICH  E  THRON 85 IS FNAL 400 GEV PROTON EXP.  MASS DETERMINED FROM MEASURED
ICH  E  VELOCITY AND MOMENTUM.  LIMITS ARE FOR TAU> 3*10**-9 SEC.
```

LONGLIVED HEAVY PARTICLE PRODUCTION

```
RPI     (CS(HEAVY PARTICLE)/CS(PION))  KD
RPI  A   0                              BUSSIERE  80 CNTR Q=+-(2/3,1,4/3,2)
RPI
RPI  A  BUSSIERE 80 IS CERN-SPS EXPT WITH 200-240 GEV PROTONS ON BE AND AL
RPI  A  TARGET. SEE THEIR FIG.6-7 FOR CS RATIO VS MASS.
```

PROD. AND CAPT. OF LONG−LIVED MASSIVE PARTICLES (cm^2)

```
CA   A   0  0.1-9E-36 OR LESS           FRANKEL   74 CNTR TAU=1 TO 1000 HRS
CA   B   0  1.4-9E-36 OR LESS           FRANKEL   75 CNTR TAU=50 MS TO 10 HRS
CA   C   0   2-20E-34 OR LESS           ALEKSEE1  76 ELEC TAU=100 MS TO 1 DAY
CA   C   0  0.2-8E-34 OR LESS           ALEKSEE2  76 ELEC TAU=5 MS TO 1 DAY
CA
CA   A  FRANKEL 74 LOOKS FOR PARTICLES PRODUCED IN THICK AL TARGETS BY
CA   A  300-400 GEV/C PROTONS.
CA
CA   B  FRANKEL 75 IS EXTENSION OF FRANKEL 74.
CA
CA   C  ALEKSEEV(1,2) 76 ARE 61-70 GEV P SERP EXPT. CS IS PER PB NUCLEUS.
```

HEAVY PARTICLE FLUX IN COSMIC RAYS

```
F       (NUMBER/CM**2-SEC-SR)
F         0  5.0E-11 OR LESS  CL=.90   JONES     67 ELEC     M=5 TO 15 GEV
F         0  3.0E-10 OR LESS           BJORNBOE  68 CNTR     M ABOVE 5 GEV
F         0  3.0E-8  OR LESS           DARDO     72 CNTR
F         0  1.5E-9  OR LESS           TONWAR    72 CNTR     M GT 10 GEV
F     A   5  6. E-9  OR MORE           YOCK      74 CNTR     M GT 6 GEV
F         0  7. E-10 OR LESS  CL=.90   YOCK      75 ELEC +- Q GT 7 OR LT -7E
F         0  1.0E-9  OR LESS           BRIATORE  76 ELEC
F     B      1.3E-9  OR LESS  CL=.90   BHAT      78 CNTR +- M GT 1 GEV
F         3  4.3+-1.3 E-11             GOODMAN   79 ELEC     M>= 5 GEV
F     C   3  3.0E-9                    YOCK      80 SPRK     M APPROX.=4.5 MP
F     D   0  3.5E-11 OR LESS  CL=.90   ULLMAN    81 CNTR PLANCK-MASS E+19GEV
F     D   0  7. E-11 OR LESS  CL=.90   ULLMAN    81 CNTR M=1.E-16GEV OR LESS
F     E   3  2. E-9                    YOCK      81 SPRK Q=+-1 M ABOUT 4.5MP
F     E   3                            YOCK      81 SPRK FRACTIONALLY CHGD
F     F   0  1.7E-11 OR LESS  CL=.99   BHAT      82 CC
F     G   0  1. E-9  OR LESS  CL=.90   MARINI    82 CNTR Q=+-1 M ABOUT 4.5MP
F     H                                SAKUYAMA  83 PLAS     M ABOUT 1 TEV
F     I   0  1.4E-12 OR LESS  CL=.90   MINCER    85 CALO M >= 1 TEV
F     J   0  3.2E-11 OR LESS  CL=.90   NAKAMURA  85 CNTR MASS >1.5 E-13 GRAM
F
F     A  YOCK 74 EVENTS COULD BE TRITONS.
F
F     B  BHAT 78 IS AT KOLAR GOLD FIELDS. LIMIT IS FOR TAU > 10**-6 SEC.
F
F     C  YOCK 80 EVENTS ARE WITH CHARGE EXACTLY OR APPROX. EQUAL TO UNITY.
F
F     D  ULLMAN 81 IS SENSITIVE FOR HEAVY SLOW SINGLY CHARGE PARTICLE
F     D  REACHING EARTH WITH VERTICAL VELOCITY 100-350 KM/S.
F
F     E  YOCK 81 SAW ANOTHER 3 EVENTS WITH Q=+-1 AND M ABOUT 4.5MP AS WELL
F     E  AS 2 EVS WITH M>5.3MP,Q=+-.75+-.05 AND M>2.8MP,Q=+-.70+-.05 AND 1
F     E  EVENT WITH M=(9.3+-3.)MP,Q=+-.89+-.06 AS POSSIBLE HEAVY CANDIDATES.
F
F     F  BHAT 82 OBSERVED 12 EVENTS WITH DELAY>2.E-8 SEC AND WITH MORE THAN
F     F  40 PARTICLES. 1 EV HAS GOOD HADRON SHOWER. HOWEVER ALL EVENTS ARE
F     F  DELAYED IN ONLY ONE OF TWO DETECTORS IN CLOUD C.,AND COULD NOT BE
F     F  DUE TO STRONGLY INTERACTING MASSIVE PARTICLE.
F
F     G  MARINI 82 APPLIED PEP-CNTR FOR TOF. ABOVE LIMIT IS FOR VELOCITY=.54
F     G  OF LIGHT. LIMIT IS INCONSISTENT WITH YOCK 80,81 EVENTS IF ISOTROPIC
F     G  DEPENDENCE ON ZENITH ANGLE IS ASSUMED.
F
F     H  SAKUYAMA 83  ANALYZED 6000 EXTENDED AIR SHOWER EVENTS. INCREASE OF
F     H  DELAYED PARTICLES AND CHANGE OF LATERAL DISTRIBUTION ABOVE 10**17EV
F     H  MAY INDICATE PRODUCTION OF VERY HEAVY PARENT AT TOP OF ATOMOSPHERE.
F
F     I  MINCER 85 IS HIGH STATISTICS STUDY OF CALO-SIGNALS DELAYED BY
F     I  20-200 NSEC.  CALIBRATION WITH AGS BEAM SHOWS THEY CAN BE ACCOUNTED
F     I  FOR BY RARE FLUCTUATIONS IN SIGNALS FROM LOW-ENERGY HADRONS IN THE
F     I  SHOWER.  CLAIM THAT PREVIOUS DELAYED SIGNALS INCLUDING BJORNBOE 68,
F     I  DARDO 72, BHAT 82, SAKUYAMA 83 ABOVE MAY BE DUE TO THIS FAKE EFFECT
F
F     J  NAKAMURA 85 AT KEK SEARCHED FOR QUARK-MATTER.  THESE MIGHT BE LUMPS
F     J  OF STRANGE QUARK MATTER WITH ROUGHLY EQUAL NUMBERS OF U,D,S QUARKS.
F     J  THESE LUMPS OR NUCLEARITES WERE ASSUMED TO HAVE M>1.5E-13 G AND
F     J  VELOCITY/C OF E-4 TO E-3.
```

CONCENTRATION OF HEAVY (CHARGE+1) STABLE PARTICLES

```
CON     IN MATTER
CON    2.E-22 TO 1.E-21 OR LESS          SMITH      79 SPEC WATER,M=6-350 MPROT
CON         (1. E-29)OR LESS             SMITH      82 SPEC WATER,M=30-400MPROT
CON         (2. E-28)OR LESS             SMITH      82 SPEC WATER,M=12-1000MPRO
CON         (1. E-14)OR LESS             SMITH      82 SPEC WATER,M>1000 MPROT
```

REFERENCES FOR OTHER NEW PARTICLE SEARCHES

```
BELOUSOV 60 JETP 11 1143      +RUSAKOV,TAMM,CERENKOV                  (LEBD)
GORBUNOV 60 JETP 11 51        +SPIRIDONOV,CERENKOV                    (LEBD)
COWARD   63 PR 131 1782       +GITTELMAN,LYNCH,RITSON                 (STAN)
DORFAN   65 PRL 14 999        +EADES,LEDERMAN,LEE,TING                (COLU)
JONES    67 PR 164 1584          (MICH+WISC+LBL+UCLA+MINN+COSU+COLO+MURA)

BJORNBOE 68 NC B53 241        +DAMGARD,HANSEN,CHATTERGEE+        (BOHR+BERN)
BINON    69 PL 30B 510        DUTEIL,KACHANOV,KHROMOV,KUTYIN+         (SERP)

ANTIPOV1 71 PL 34B 164        +DENISOV,DONSKOV,GORIN,KACHANOV+        (SERP)
ANTIPOV2 71 NP B31 235        +DENISOV,DONSKOV,GORIN,KACHANOV+        (SERP)
DARDO    72 NC 9A 319         DARDO,NAVARRA,PENENGO,SITTE             (TORI)
TONWAR   72 JPA 5 569         TONWAR,NARANAN,SREEKANTAN               (TIFR)
ALPER    73 PL 46B 265          (CERN+LIVP+LUND+BOHR+RHEL+STOH+BERG+LOUC)
LEIPUNER 73 PRL 31 1226       +LARSEN,SESSOMS,SMITH,WILLIAMS+  (BNL+YALE)

APPEL    74 PRL 32 428        +BOURQUIN,GAINES,LEDERMAN,PAAR+ (COLU+FNAL)
FRANKEL  74 PR D9 1932        +FRATI,RESVANIS,YANG,NEZRICK    (PENN+FNAL)
YOCK     74 NP B76 175        P.C.M.YOCK                (UNIV OF AUCKLAND)

ALBROW   75 NP B97 189        +BARBER,BENZ+(CERN+DARE+FOM+LANC+MCHS+UTRE)
BLAGOV   75 YAD.FIZ. 21,300   +KOMAR,MURASHOVA,SYREISHCHIKOVA+        (LEBD)
FRANKEL  75 PR D12 2561       +FRATI,RESVANIS,YANG,NEZRICK    (PENN+FNAL)
JOVANOVI 75 PL 56B 105        JOVANOVICH+ (MANI+AACH+CERN+GENO+HARV+TORI)
LJUBICIC 75 PR D11 696        +PAVLOVIC,PISK,LOGAN                (ZAGR+OTTA)
YOCK     75 NP B86 216        P.C.M. YOCK          (UNIV OF AUCKLAND+SLAC)

ALEKSEE1 76 SJNP 22 531       ALEKSEEV,ZAITSEV,KALININA,KRUGLOV+      (JINR)
ALEKSEE2 76 SJNP 23 633       ALEKSEEV,ZAITSEV,KALININA,KRUGLOV+      (JINR)
BALDIN   76 SJNP 22 264       +VERTOGRADOV,VISHNEVSKII,GRISHKEVICH+(JINR)
BRIATORE 76 NC 31A 553        +DARDO,PIAZZOLI,MANNOCCHI+ (LCGT+FRAS+FREI)
GUSTAFSO 76 PRL 37 474        GUSTAFSON,AYRE,JONES,LONGO,MURTHY       (MICH)
PRESCOTT 76 JPG 2 261         J.R.PRESCOTT                        (ADELAIDE)

PEREPELI 77 PL 67B 471        V.P.PEREPELITSA                         (ITEP)
SMITH    77 CJP 55 1280       G.R.SMITH,S.STANDIL                     (MANI)

BHAT     78 PRAM 10 115       +RAMANA MURTY                           (TIFR)

CARROLL  78 PRL 41 777        +CHIANG,JOHNSON,KYCIA,KI +          (BNL+PRIN)
CUTTS    78 PRL 41 363        +DULUDE +      (BROW+FNAL+ILL+BARI+MIT+WARS)
HANSL2   78 PL 77B 114        +HOLDER,KNOBLOCH+(CERN+DORT+HEID+SACL+BGNA)
    ALSO 78 NP B142 381       HANSL,HOLDER+     (CERN+DORT+HEID+SACL+BGNA)

HOLDER   78 PL 73B 105        +KNOBLOCH,MAY+    (CERN+DORT+HEID+SACL+BGNA)
LOVELESS 78 PL 78B 505        +BENADA+         (WISC+LBL+UCB+FNAL+HAWA+WASH)
MORI     78 PRL 40 432        +BENVENUTI+        (FNAL+HARV+PENN+RUTG+WISC)
VIDAL    78 PL 77B 344        +HERB,LEDERMAN,SNYDER+ (COLU+FNAL+STON+UCB)
VIERTEL  78 LNC 22 235        +HAHN,SCHACHER                          (BERN)

ARMITAGE 79 NP B150 87        +BENZ,BOBBINK+ (CERN+DARE+FOM+MCHS+UTRECHT)
BHAT     79 JPG 5 L13         BHAT,GOPALAKRISHNAN,GUPTA,TONWAR        (TIFR)
BOZZOLI  79 NP B159 363       +BUSSIERE,GIACOMELLI  (BGNA+CERN+LAPP+SACL)

GOODMAN  79 PR D19 2572       +ELLSWORTH,ITO,MACFALL,SIOHAN +          (UMD)
SMITH    79 NP B149 525       +BENNETT                                (RHEL)

BARTEL   80 ZPHY C6 295       JADE C.(DESY+HAMB+HEID+LANC+MCHS+RHEL+TOKY)
BUSSIERE 80 NP B174 1         +GIACOMELLI,LESQUOY+         (BGNA+SACL+LAPP)
YOCK     80 PR D22 61         YOCK                                    (AUCK)

DZHELYAD 81 PL 105B 239       +GOLOVKIN,KONSTANTINOV,KONSTANTINOV+ (SERP)
    ALSO 81 SJNP 33 822 (YF 33 1529) VIKTOROV,GOLOVKIN+               (SERP)
KINOSHIT 81 PR D24 1707       K.KINOSHITA,P.B.PRICE                    (UCB)
LOSECCO  81 PL 102B 209       +SULAK,GALIK,HORSTKOTTE+     (MICH+PENN+BNL)
ULLMAN   81 PRL 47 289        J.D.ULLMAN                          (LEHM+BNL)
YOCK     81 PR D23 1207       P.C.M.YOCK                              (AUCK)

ADEVA    82 PL 115B 345       MARK-J COLLAB(AACH+DESY+MIT+MADR+ANIK+BHEP)
ALPGARD  82 PL 115B 71        + UA5 COLLAB.    (BONN+BRUX+CAVE+CERN+STOH)
BARTEL   82 PL 114B 211       JADE C.  (DESY+HAMB+HEID+LANC+MCHS+RL+TOKY)
BEHREND  82 PL 114B 287       CELLO C.     (DESY+KARL+MPIM+ORSA+LPNP+SACL)
BHAT     82 PR D25 2820       +GUPTA,RAMANA MURTHY,SREEKANTAN+        (TIFR)
BLOCKER  82 PRL 49 517        +MATTEUZZI,ABRAMS+             (HARV+SLAC+LBL)

KINOSHIT 82 PRL 48 77         KINOSHITA,PRICE,FRYBERGER          (UCB+SLAC)
MARINI   82 PR D26 1777       +PERUZZI,PICCOLO+ (FRAS+LBL+NWES+STAN+HAWA)
SHANKER  82 NP B204 375       O.SHANKER                               (TRIU)
SMITH    82 NP B206 333       +BENNETT,HOMER,LEWIN,WALFORD,SMITH       (RAL)
VERGADOS 82 PL 109B 96        J.D.VERGADOS                            (CERN)
    ALSO 82 PL 113B 513       J.D.VERGADOS                            (CERN)
    ALSO 83 NP 218B 109       J.D.VERGADOS                            (CERN)
WILLEY   82 PR D26 3287       R.S.WILLEY,H.L.YU                       (PITT)

ADEVA    83 PRL 51 443        MARKJ C. (AACH+DESY+MIT+MADR+AIKO+BHEP+CIT)
ALTHOFF  83 PL 122B 95        TASSO C.     (AACH+BONN+DESY+HAMB+LOIC+OXF+)
ARNISON  83 PL 122B 189       + UA1 COLLAB.   (AACH+LAPP+BIRM+CERN+HELS+)
ARNISON2 83 PL 129B 273       UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HELS+LOQM+)
BEHREND  83 PL 123B 127       + CELLO COL.(DESY+KARL+MPIM+ORSA+LPNP+SACL)
BERGSMA  83 PL 122B 465       CHARM C.          (ANIK+CERN+HAMB+ITEP+ROMA)
BRYMAN   83 PRL 50 7          +DUBOIS,NUMAO+    (TRIU+VICT+CNRC+BRCO+QUKI)

CARR     83 PRL 51 627        +GIDAL,GOBBI,JODIDIO,ORAM+  (LBL+NWES+TRIU)
CHEN     83 PL 122B 317       + (SYRA+VAND+CORN+ITHA+HARV+OHIO+ROCH+RUTG)
DESHPAND 83 PR D27 1193       DESHPANDE,JOHNSON                       (OREG)
DICUS    83 PR D28 1778       D.A.DICUS,V.L.TEPLITZ               (TEXA+UMD)
HOFFMAN  83 PR D28 660        +FRANK,MISCHKE,MOIR,SCHARDT        (LANL+ARZS)
SAKUYAMA 83 LNC 37 17         H.SAKUYAMA,N.NUZUKI                     (MEIS)
    ALSO 83 LNC 36 389        H.SAKUYAMA,K.WATANABE                   (MEIS)
    ALSO 83 NC 78A 147        H.SAKUYAMA,K.WATANABE                   (MEIS)
    ALSO 83 NC 6C 371         H.SAKUYAMA,K.WATANABE                   (MEIS)

ADEVA    84 PRL 53 134        MARK-J COLLAB (AACH+BNL+CIT+DESY+MIT+MADR+)
ARNISON  84 PL 139B 115       UA1 COLLAB.(AACH+LAPP+BIRM+CERN+HARV+HELS+)
BAGNAIA  84 PL 139B 105       UA2 COLLAB. (BERN+CERN+BOHR+LALO+PAVI+SACL)
BEHREND  84 PL 140B 130       CELLO COL. (DESY+GLAS+HAMB+KARL+MPIM+LALO+)
BEHRENDS 84 PL 137B 277       CLEO C.     (ROCH+RUTG+SYRA+VAND+CORN+ITHA+)
FREEDMAN 84 PRL 52 240        +NAPOLITANO,CAMP,KROUPA             (ANL+CHIC)
MUKHOPAD 84 PR D29 565        MUKHOPADHYAY,GOUDSMIT+          (RPI+SIN+LISB)
YOUSSEF  84 PL 139B 332       CUSB COLLABORATION(COLU+STON+CORN+LSU+MPIM)

ADEVA    85 PL 152B 439       MARK-J C.(AACH+BNL+CIT+DESY+MIT+MADR+ANIK+)
    ALSO 84 PRPL 109 131      MARK-J C., ADEVA+  (AACH+BNL+CIT+DESY+MIT+)
BALTRUSA 85 PRL 55 1842       MARK3 C.,BALTRUSAITIS+(CIT+UCSC+ILL+SLAC +)
MINCER   85 PR D32 541        +FREUDENREICH,GOODMAN+        (UMD+GMAS+NSF)
NAKAMURA 85 PL 161B 417       +HORIE,TAKAHASHI,TANIMORI          (KEK+TOKYO)
STOKER   85 PRL 54 1887       +BALKE,CARR,GIDAL,JODIDIO+  (LBL+NWES+TRIU)
THRON    85 PR D31 451        +CARDELLO,COOPER,TEIG,WAH+ (YALE+FNAL+IOWA)
ARNISON  86 PL B TO BE PUB    UA1 COLLAB.(AACH+ANIK+LAPP+BIRM+CERN+HARV+)
```

Meson Full Listings

$\pi^{\pm}$, π^0, η, $\rho(770)$

$S=0$, $C=0$, $B=0$ MESON STATES

$\pi^{\pm}$

$I^G(J^P) = 1^-(0^-)$

SEE STABLE PARTICLE FULL LISTINGS

π^0

$I^G(J^{PC}) = 1^-(0^{-+})$

SEE STABLE PARTICLE FULL LISTINGS

η

$I^G(J^{PC}) = 0^-(0^{--})$

SEE STABLE PARTICLE FULL LISTINGS

$\rho(770)$

$I^G(J^{PC}) = 1^+(1^{--})$

OUR LATEST MINIREVIEW ON THIS PARTICLE
CAN BE FOUND IN THE 1984 EDITION.

$\rho(770)$ MASS (MeV)

WE NO LONGER LIST S-WAVE BREIT-WIGNER FITS, PBAR P DATA WITH HIGH
COMBINATORIAL BACKGROUND, AND INSIGNIFICANT OR DOUBTFUL DATA.

```
M2  CHARGED ONLY
M2  R       (760.0)    (9.0)              CARMONY   64 HBC  +   3.5 PI+P,TCUT 4
M2  R       (768.0)    (5.0)              BLIEDEN   65 MMS   -  3-5 PI- P
M2  R       (765.0)    (5.0)              ALFF-STEI 66 HBC  +   2-3 PI+ P
M2  R       (760.0)    (5.0)              HAGOPIAN1 66 HBC   -  3.0 PI- P
M2  R       (765.0)    (5.0)              HAGOPIAN2 66 HBC   -  2.14 PI-,TCUT12
M2  R 2775  (753.5)   (10.5)              JACOBS    66 HBC   -  2-3PI-,T CUT 20
M2  R       (758.0)   (10.0)              JAMES     66 HBC  +   2.1 PI+,TCUT2.5
M2  R       (749.0)    (3.0)              WEST      66 HBC   -  2.1 PI- P
M2  R       (768.0)    (5.0)              MILLER    67 HBC   -  2.7 PI-,T CUT20
M2  R       (773.0)    (2.0)              BATON     68 HBC   -  2.8 PI-,T CUT13
M2
M2 Z   900  767.       6.                 EISNER    67 HBC   -  4.2 PI-,T CUT10
M2 A  9650  766.8      1.5                PISUT     68 RVUE  -  1.7-3.2PI-,CT10
M2 X  6500  766.       7.                 BYERLY    73 OSPK  -  5. PI- P
M2          . . . . . . . . . . .
M2  AVG     766.8      1.4     AVERAGE

M0  NEUTRAL ONLY
M0 P  4000  765.       5.0                ASBURY 2  67 CNTR   0 GAMMA + PB
M0 P        765.0     10.0                ALVENSLEB 70 CNTR   0 GAMMA A,TCUT.01
M0 P        775.       5.                 GLADDING  73 CNTR   0 2.9-4.7 GAMMA P
M0 P  140K  767.7      1.9                BIGGS     70 CNTR   0 PHOTOPROD.
M0 P  1930  767.0      4.0                BALLAM    72 HBC    0 2.8 GAMMA P
M0 P  2430  770.0      4.0                BALLAM    72 HBC    0 4.7 GAMMA P
M0 P        767.6      2.7                BARTALUCC 78 CNTR   0 BREMS,E+E-P
M0          . . . . . . . . . . .
M0  AVG     768.1      1.3     AVERAGE

M0  R  300 (760.0)   (10.0)               ABOLINS   63 HBC    0 3.5 PI+P
M0  R  500 (770.0)   (10.0)               GOLDHABER 64 HBC    0 3.7 PI+P
M0  R      (750.0)    (5.0)               ALFF-STEI 66 HBC    0 2-3 PI+ P
M0  R      (775.0)    (5.0)               HAGOPIAN1 66 HBC    0 3.0 PI- P
M0  R      (770.)     (5.)                HAGOPIAN2 66 HBC    0 2.1 PI-,TCUT 12
M0  R 4207 (758.0)    (7.5)               JACOBS    66 HBC    0 2-3PI-,T CUT 20
M0  R      (765.0)    (8.0)               JAMES     66 HBC    0 2.1 PI+ P
M0  R      (760.0)    (3.0)               WEST      66 HBC    0 2.1 PI- P
M0  R      (768.0)    (2.0)               BACON     67 HBC    0 1.7 PI-P
M0  R      (761.)     (3.)                HUWE      67 HBC    0 2.4 PI- P
M0  R      (770.0)    (4.0)               MILLER    67 HBC    0 2.7 PI-,T CUT20
M0  R      (775.0)    (2.0)               ARMENISE  68 DBC    0 5.1 PI+D
M0  R      (768.4)    (2.4)               MALAMUD   69 RVUE   0 2-4 PI-P
M0  H      (778.)     (2.)                HYAMS     73 ASPK   0 17.PI-P,PI+PI-N
M0  H      (770.)     (9.)                ESTABROOK 74 RVUE   0 17 PI-P,PI+PI-N
M0  G      (775.)     (2.)                GRAYER    74 ASPK   0 17.PI-P,PI+PI-N
M0  D      (776.3)    (0.4)               ROOS      75 RVUE   0 PHASE SHIFTS
M0  G      (776.1)    (2.6)               BECKER    79 ASPK   0 17.PI-P POLARIZ
M0  CH     (769.5)    (0.7)               LANG      79 RVUE   0
M0  B      (770.)     (2.)                HEYN      80 RVUE     PION FORM FACTOR
M0
M0     2250  775.0      3.0               HYAMS     68 OSPK   0  11.2 PI- P
M0 A 13300  769.2      1.5                PISUT     68 RVUE   0 1.7-3.2PI-,CT10
M0     1700  774.0      3.0               REYNOLDS  69 HBC    0 2.26 PI- P
M0 Z 11200  773.5      1.7                JACOBS    72 HBC    0 2.8 PI- P
M0     6800  764.0      3.0               RATCLIFF  72 ASPK   0 15. PI-P,TCUT.3
M0 C 32000  775.0      4.0                PROTOPOPE 73 HBC    0 7.1 PI+P,TCUT.4
M0     4100  767.       4.                ENGLER    74 DBC    0 6. PI+N,PI+PI-P
M0    76000  768.0      1.0               DEUTSCHMA 76 HBC    0 16. PI+ P
M0 X         769.0      3.0               WICKLUND  78 ASPK   0 3,4,6 PI+-PN
M0 C H       768.0      4.0               BOHACIK   80 RVUE   0
M0 G         777.4      2.0               CHABAUD   83 ASPK   0 17 PI-P POLARIZ
M0 K         775.9      1.1               BARKOV    85 OLYA   0 PION FORM FACT.  |
M0          . . . . . . . . . . .
M0  AVG      771.7      1.2     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.2)
                       (SEE IDEOGRAM BELOW)
```

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M        ----------NOTES----------

M   A    FROM FIT OF 3-PARAMETER RELATIVISTIC P-WAVE BREIT WIGNER TO TOTAL
M   A    MASS DISTRIBUTION.
M   B    HEYN 80 INCLUDES ALL SPACELIKE AND TIMELIKE F(PI)
M   B    VALUES UNTIL 1978.
M   C    FROM POLE EXTRAPOLATION
M   D    ENERGY-DEPENDENT ANALYSIS OF BATON 70, HYAMS 73,
M   D    PROTOPOPESCU 73 PHASE SHIFTS.
M   G    FROM FIT OF 3-PARAMETER RELATIVISTIC BREIT-WIGNER TO
M   G    HELICITY ZERO PART OF P-WAVE INTENSITY. CHABAUD 83 AND BECKER 79
M   G    INCLUDE DATA OF GRAYER 74.
M   H    FROM PHASE SHIFT ANALYSIS OF GRAYER 74 DATA.
M  P     FROM PHOTOPRODUCTION.
M   R    INCLUDED IN PISUT 68 RVUE
M  X     PHASE SHIFT ANALYSIS. SYSTEMATIC ERRORS ADDED CORRESPONDING
M  X     TO SPREAD OF DIFFERENT FITS.
M  Z     MASS ERRORS ENLARGED BY US TO WIDTH/SQRT(N),SEE K* TYPED NOTE
M  K     FROM THE GOUNARIS-SAKURAI PARAMETRIZATION OF THE PION FORM FACTOR
```
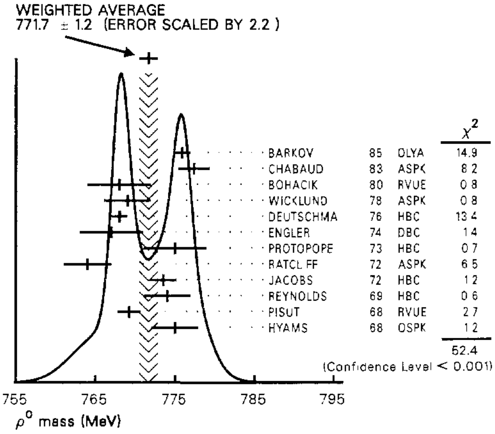
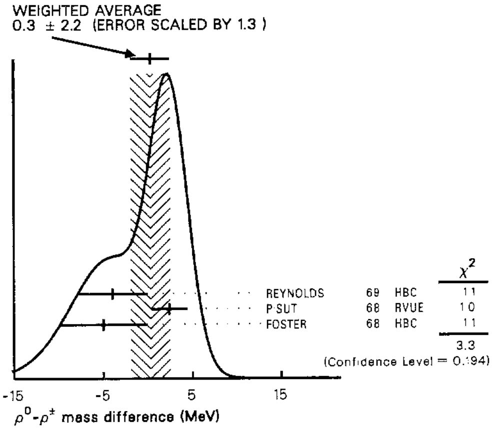



$\rho^0 - \rho^{\pm}$ MASS DIFFERENCE (MeV)

```
D  A  3600   -5.       5.               FOSTER    68 HBC  +-0 PBAR P AT REST
D    22950    2.4      2.1              PISUT     68 RVUE     PI N TO RHO N
D  A  3000   -4.0      4.0              REYNOLDS  69 HBC   -0 2.26 PI- P
D           . . . . . . . . .
D   AVG       0.3      2.2    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
                       (SEE IDEOGRAM BELOW)

D  A    FROM QUOTED MASSES OF CHARGED AND NEUTRAL MODES
```



$\rho(770)$ RANGE PARAMETER (GeV^{-1})

```
R          5.3       0.9       0.7    CHABAUD   83 ASPK  0 17 PI-P POLARIZ
```

$\rho(770)$ WIDTH (MeV)

```
         WE NO LONGER LIST S-WAVE BREIT-WIGNER FITS, PBAR P DATA WITH HIGH
         COMBINATORIAL BACKGROUND, AND INSIGNIFICANT OR DOUBTFUL DATA.

W2  CHARGED ONLY
W2  R        (77.0)    (20.0)              CARMONY   64 HBC   +   3.5 PI+P,TCUT 4
W2  R       (100.0)                        ALFF-STEI 66 HBC   +   2-3 PI+ P
W2  R       (127.0)     (5.0)              BLIEDEN   66 MMS   -   3-5 PI- P
W2  R       (150.0)    (20.0)              HAGOPIAN1 66 HBC   -   3.0 PI- P
W2  R       (135.0)    (20.0)              HAGOPIAN2 66 HBC   -   2.14 PI-,TCUT12
W2  R 2775  (137.1)    (20.0)              JACOBS    66 HBC   -   2-3PI-,T CUT 20
W2  R       (147.0)    (19.0)              JAMES     66 HBC   +   2.1 PI+,TCUT2.5
W2  R       (149.0)     (13.0)             WEST      66 HBC   -   2.1 PI- P
W2  R       (153.0)    (13.0)              MILLER    67 HBC   -   2.7 PI-,T CUT20
W2  R       (150.0)     (5.0)              BATON     68 HBC   -   2.8 PI- P
W2
W2     900  146.        13.                EISNER    67 HBC   -   4.2 PI-,T CUT10
W2 A  9650  148.2        4.1               PISUT     68 RVUE  -   1.7-3.2PI-,CT10
W2 X  6500  146.        12.                BYERLY    73 OSPK  -   5. PI- P
W2          . . . . . . . . . .
W2  AVG     147.8        3.7      AVERAGE

W0  NEUTRAL ONLY
W0 P  4000  130.         5.                ASBURY 2  67 CNTR    0 GAMMA + PB
W0 P        160.0       10.0               LANZEROTT 68 CNTR    0 GAMMA P
W0 P        140.0        5.0               ALVENSLEB 70 CNTR    0 GAMMA A,TCUT.01
W0 P        147.        11.                GLADDING  73 CNTR    0 BREMS.
W0 P  140K  146.1        2.9               BIGGS     70 CNTR    0 PHOTOPROD.
W0 P Z2430  155.0       12.0               BALLAM    72 HBC     0 4.7 GAMMA P
W0 P Z1930  145.0       13.0               BALLAM    72 HBC     0 2.8 GAMMA P
W0 P        150.9        3.0               BARTALUCC 78 CNTR    0 BREMS,E+E-P
W0          . . . . . . . . . .
W0  AVG     145.7        2.7      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)

W0  R  300  (90.0)    (10.0)               ABOLINS   63 HBC     0 3.5 PI+P
W0  R  500 (130.0)                         GOLDHABER 64 HBC     0 3.7 PI+P
W0  R      (100.0)                         ALFF-STEI 66 HBC     0 2-3 PI+ P
W0  R      (120.0)    (10.0)               HAGOPIAN1 66 HBC     0 3.0 PI- P
W0  R      (135.0)    (20.0)               HAGOPIAN2 66 HBC     0 2.14 PI-P,LOW T
W0  R 4207 (122.2)    (15.0)               JACOBS    66 HBC     0 2-3PI-,T CUT 20
W0  R      (103.0)    (13.0)               JAMES     66 HBC     0 2.1 PI+ P
W0  R      (173.0)    (13.0)               WEST      66 HBC     0 2.1 PI- P
W0  R      (148.0)     (8.0)               BACON     67 HBC     0 1.7 PI-P
W0  R      (152.)     (15.)                HUWE      67 HBC     0 2.4 PI- P
W0  R      (160.0)    (15.0)               MILLER    67 HBC     0 2.7 PI-,T CUT20
W0  R      (167.0)     (6.0)               ARMENISE  68 DBC     0 5.1 PI+D
W0  R      (132.0)    (13.0)               MALAMUD   69 RVUE    0 2-4 PI-P
W0  H      (152.)      (2.)                HYAMS     73 ASPK    0 17.PI-P,PI+PI-N
W0  H      (143.)     (13.)                ESTABROOK 74 RVUE    0 17 PI-P,PI+PI-N
W0  G      (163.)      (4.)                GRAYER    74 ASPK    0 17.PI-P,PI+PI-N
W0  D      (154.5)     (1.0)               ROOS      75 RVUE    0 PHASE SHIFTS
W0  G      (161.8)     (7.6)     (7.2)     BECKER    79 ASPK    0 17.PI-P POLARIZ
W0 EB      (155.)      (1.)                HEYN      80 RVUE    0 PION FORM FACT.

W0 Z  2250  145.0       12.0               HYAMS     68 OSPK    0 11.2 PI- P
W0 A 13300  163.0       15.0               PISUT     68 RVUE    0 1.7-3.2PI-,CT10
W0    1700  143.0        8.0               REYNOLDS  69 HBC     0 2.26 PI- P
W0    6800  157.0        8.0               RATCLIFF  72 ASPK    0 15. PI-P,TCUT.3
W0 C 32000  160.0       10.0               PROTOPOPE 73 HBC     0 7.1 PI+P,TCUT.4
W0    4100  146.        14.                ENGLER    74 DBC     0 6. PI+N,PI+PI-P
W0   76000  154.0        2.0               DEUTSCHMA 76 HBC     0 16. PI+ P
W0 X        152.0        9.0               WICKLUND  78 ASPK    0 3,4,6 PI+-PN
W0  CH     (148.0)      (1.3)              LANG      79 RVUE    0
W0 C H      148.0        6.0               BOHACIK   80 RVUE    0
W0 G        160.0        4.1       4.0     CHABAUD   83 ASPK    0 17 PI-P POLARIZ
W0 K        150.5        3.0               BARKOV    85 OLYA    0 PION FORM FACT.  |
W0          . . . . . . . . . .
W0  AVG     153.3        1.4      AVERAGE

W         -----------NOTES-----------

W   A   FROM FIT OF 3-PARAMETER RELATIVISTIC P-WAVE BREIT WIGNER TO TOTAL
W   A   MASS DISTRIBUTION.
W   B   HEYN 80 INCLUDES ALL SPACELIKE AND TIMELIKE F(PI)
W   B   VALUES UNTIL 1978.
W   C   FROM POLE EXTRAPOLATION
W   D   ENERGY-DEPENDENT ANALYSIS OF BATON 70, HYAMS 73,
W   D   PROTOPOPESCU 73 PHASE SHIFTS.
W   G   FROM FIT OF 3-PARAMETER RELATIVISTIC BREIT-WIGNER TO
W   G   HELICITY ZERO PART OF P-WAVE INTENSITY. CHABAUD 83 AND BECKER 79
W   G   INCLUDE DATA OF GRAYER 74.
W   H   FROM PHASE SHIFT ANALYSIS OF GRAYER 74 DATA.
W   P   FROM PHOTOPRODUCTION, MODEL DEPENDENT.
W   R   INCLUDED IN PISUT 68 RVUE
W  X    PHASE SHIFT ANALYSIS. SYSTEMATIC ERRORS ADDED CORRESPONDING
W  X    TO SPREAD OF DIFFERENT FITS.
W  Z    WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N),SEE K* TYPED NOTE
W  K    FROM THE GOUNARIS-SAKURAI PARAMETRIZATION OF THE PION FORM FACTOR
```

$\rho(770)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\rho \to 2\pi$	140+ 140
P2	$\rho \to 4\pi$	140+ 140+ 140+ 140
P3	$\rho \to \pi\gamma$	140+ 0
P4	$\rho \to e^+e^-$	.511+.511
P5	$\rho \to \pi\eta$(VIOLATES G)	140+ 549
P6	$\rho \to \mu^+\mu^-$	106+ 106
P7	$\rho \to \pi^+\pi^-\pi^0$(VIOLATES G)	140+ 140+ 135
P8	$\rho \to \eta\gamma$	549+ 0

$\rho(770)$ PARTIAL WIDTHS (keV)

$\rho \to (\pi\gamma)$ (G3)

```
W3          (35.0)    (10.0)          GOBBI      74 OSPK  - 23. PI-A,PI-PIOA
W3           71.0       7.0           JENSEN     83 SPEC  - PI-A,PI- PIO A
```

$\rho(770)$ BRANCHING RATIOS

$\rho \to 4\pi/2\pi$ (P2)/(P1)

```
R1      RHO+- INTO (PI+- PI+ PI- PIO) / (PI+- PIO)
R1            (0.002)OR LESS            FERBEL     66 HBC  +- PI+- P ABOVE 2.5
R1             0.0035   0.004           JAMES      66 HBC  +    2.1 PI+P

R1      RHOO INTO (PI+ PI- PI+ PI-) / (PI+ PI-)
R1            (0.008)OR LESS            JAMES      66 HBC     0 2.1 PI+P
R1            (0.002)OR LESS            CHUNG      68 HBC     0 3.2,4.2 PI-P
R1            (0.002)OR LESS  CL=.90    HUSON      68 HLBC    0 16.0 PI- P
R1            (0.0015)R LESS  CL=.90    ERBE       69 HBC     0 2.5-5.8 GAMMA P
```

$\rho \to (e^+e^-)/(\pi^+\pi^-)$ (units 10^{-4}) (P4)/(P1)

```
R3
R3  P   94   (0.65)    (0.14)           ASBURY 1  67 CNTR      PHOTOPRODUCTION
R3  H        (0.65)    (1.1)     (0.5)  HERTZBACH 67 OSPK ASSUME SU(3)+MIXING
R3  A   33   (0.53)    (0.11)           ASTVACATU 68 OSPK ASSUME SU(3)+MIXING
R3           (0.50)    (0.10)           AUSLENDER 69 OSPK      E+E- COLLID.BEAM
R3  F        (0.49)    (0.12)    (0.15) BIGGS     70 CNTR     PHOTOPRODUCTION
R3           (0.41)    (0.05)           BENAKSAS  72 OSPK      E+E- COLL.BEAMS
R3 S          0.450     0.021           BARKOV    85 OLYA      E+E-                |

R3  A          NOT SEPARATED FROM OMEGA DECAY. ERROR STATISTICAL ONLY.
R3  F          ASSUMING RHO WIDTH 140 MEV. ERROR STATISTICAL ONLY.
R3 S           SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R3  H          NOT SEPARATED FROM OMEGA DECAY.
R3  P          POSSIBLY LARGE RHO-OMEGA INTERFERENCE
```

$\rho \to (\pi\eta)/(2\pi)$ (P5)/(P1)

```
R4            (0.008)OR LESS            FERBEL     66 HBC  +- PI+- P ABOVE 2.5
```

$\rho \to (\mu^+\mu^-)/(\pi^+\pi^-)$ (units 10^{-4}) (P6)/(P1)

```
R5
R5    H        0.97      0.31      0.33  HYAMS      67 OSPK     11 PI- LI H
R5    R        0.82      0.16      0.36  ROTHWELL   69 CNTR     PHOTOPRODUCTION
R5    W        0.56      0.15            WEHMANN    69 OSPK      12 PI- ON C,FE
R5             . . . . . . . . .
R5   AVG       0.67      0.12      AVERAGE

R5    H        HYAMS MASS RESOL. IS 20 MEV. THE OMEGA REGION WAS EXCLUDED.
R5    R        POSSIBLY LARGE RHO-OMEGA INTERFERENCE LEADS US TO INCREASE
R5    R        THE MINUS ERROR
R5    W        RESULT CONTAINS (11 +- 11) PER CENT CORRECTION USING SU(3)
R5    W        FOR CENTRAL VALUE. THE ERROR ON THE CORRECTION TAKES ACCOUNT
R5    W        OF POSSIBLE RHO-OMEGA INTERFERENCE AND THE UPPER LIMIT AGREES
R5    W        WITH THE UPPER LIMIT OF (OMEGA INTO MU+ MU-) FROM THIS EXPT.
```

$\rho \to (\pi^+\pi^-\pi^0)/(\pi^+\pi^-)$ (P7)/(P1)

```
R6   G        (0.01) OR LESS  CL=.84   ABRAMS     71 HBC     0 3.7 PI+ P
R6   G      MODEL DEPENDENT,ASSUMES I = 1,2,OR 3 FOR THE 3PI SYSTEM
```

$\rho \to (\eta\gamma)$/total (units 10^{-4}) (P8)

```
R7   A        (3.6)     (0.9)          ANDREWS    77 CNTR  0 6.7-10 GAMMA CU
R7   B        (5.4)     (1.1)          ANDREWS    77 CNTR  0 6.7-10 GAMMA CU
R7   A   SOLUTION CORRESPONDING TO CONSTRUCTIVE OMEGA-RHO INTERFERENCE
R7   A   THE QUARK MODEL PREDICTS A RELATIVE DECAY PHASE OF ZERO.
R7   B   SOLUTION CORRESPONDING TO DESTRUCTIVE OMEGA-RHO INTERFERENCE
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REFERENCES FOR $\rho(770)$

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ANDERSON 61 PRL 6 365            ANDERSON,BANG,BURKE,CARMONY,SCHMITZ    (LRL)
ERWIN    61 PRL 6 628            A.R.,R.MARCH,W.D.WALKER,E.WEST        (WISC)

KENNEY   62 PR 126 736           V P KENNEY,W D SHEPHARD,C D GALL (KENTUCKY)
SAMIOS   62 PRL 9 139            SAMIOS,BACHMAN,LEA+    (BNL+CUNY+COLU+KNTY)
XUONG    62 PR 128 1849          NGUYEN HUU XUONG,GERALD R LYNCH         (LRL)

ABOLINS  63 PRL 11 381           ABOLINS,LANDER,MEHLHOP,NGUYEN,YAGER  (UCSD)
ALITTI   63 NC 29 515            ALITTI,BATON,ARMENISE+(SACL+ORSA+BARI+BGNA)
CHADWICK 63 PRL 10 62            CHADWICK,DAVIES,DERRICK,CRESTI + (OXF+PADO)
GUIRAGOS 63 PRL 11 85            ZAVEN GUIRAGOSSIAN                      (LRL)
SACLAY   63 SIENA CONF 1 239     SACLAY+ORSAY+BARI + BOLOGNA- COLLABORATION

BONDAR   64 NC 31 729            BONDAR+    (AACHEN+BIRM+BONN+DESY+LOIC+MPIM)
CARMONY  64 DUBNA CONF 1 486     CARMONY,HOA,LANDER,NG.H.XUONG,YAGER  (UCSD)
GOLDHABE 64 PRL 12 336           GOLDHABER,BROWN,KADYK,SHEN+       (LRL+UCB)

ALYEA    65 PL 15 82             ALYEA,CRITTENDEN,MARTIN,RHODE +   (INDIANA)
ARMENISE 65 NC 37 361            SACLAY+ORSAY+BARI+BOLOGNA    COLLABORATION
BLIEDEN  65 PL 19 444            CERN MISSING MASS SPECTROMETER GROUP (CERN)
CLARK    65 PR 139 B 1556        A CLARK,CHRISTENSON,CRONIN,TURLAY(PRINCETO)
GUTAY    65 NC 39 381            GUTAY,LANNUTTI,TULI                   (FSU)
LANZEROT 65 PRL 15 210           LANZEROTTI,BLUMENTHAL,EHN,FAISSLER + (HARV)
ZDANIS   65 PRL 14 721           ZDANIS,MADANSKY,KRAEMER +         (JHU+BNL)

ACCENSI  66 PL 20 557            ACCENSI,ALLES-BORELLI,FRENCH,FRISK+  (CERN)
ALFF-STE 66 PR 145 1072          ALFF-STEINBERGER,BERLEY,BRUGGER+(COLU+RUTG)
BALTAY   66 PR 145 1103          +FRANZINI,LUTJENS,SEVERINS,TYCKO+(COLUMBIA)
BLIEDEN  66 NC 43 71             CERN MISSING MASS SPECTROMETER GROUP (CERN)
CAMBRIDG 66 PR  146  994         CAMBRIDGE BUBBLE CHAMBER GROUP  (MIT+HARV+)
CASON    66 PR  148  1282        N M CASON                       (WISCONSIN)
DEUTSCHM 66 PL 20 82             DEUTSCHMANN,STEINBERG + (AACH+BERLIN+ CERN)
FERBEL   66 PL 21 111            FERBEL                          (ROCHESTER)
FIDECARO 66 PL  23  163          G+M FIDECARO,J POIRIER,P SCHIAVON    (CERN)
HAGOPIA1 66 PR 145 1128          HAGOPIAN,SELOVE,ALITTI,BATON+ (PENN+SACLAY)
HAGOPIA2 66 PR  152  1183        HAGOPIAN,PAN    (PENNSYLVANIA,LRL-BERKELEY)
HUSON    66 PL 20 91             HUSON,ALLARD,DRIJARD,HENNESSY+ (ORSAY+EPOL)
JACOBS   66 UCRL-16877           L.D.JACOBS                              (LRL)
JAMES    66 PR 142 896           F E JAMES,KRAYBILL          (YALE+BROOKHAVEN)
WEST     66 PR 149 1089          WEST,BOYD,ERWIN,WALKER          (WISCONSIN)

ALLES-BO 67 NC 50 A 776          ALLES-BORELLI,FRENCH,FRISK,+    (CERN+BONN)
ASBURY 1 67 PRL 19 869           +BECKER+BERTRAM+JOOS+JORDAN+    (DESY+COLU)
ASBURY 2 67 PRL 19 865           +BECKER+BERTRAM+JOOS+JORDAN+    (DESY+COLU)
BACON    67 PR 157 1263          +FICKINGER,HILL,HOPKINS,ROBINSON+     (BNL)
BANNER   67 PL  25 B  300        +FAYOUX,HAMEL,ZSEMBERY,CHEZE+ (SACLAY+CAEN)
BARLOW   67 NC 50A 701           +LILLESTOL+MONTANET+  (CERN+CDEF+IRAD+LIVP)
BATON    67 PL 25 B 419          J.BATON,G.LAURENS,J.REIGNIER       (SACLAY)
    ALSO 67 NP B 3  349          J.BATON,G.LAURENS,J.REIGNIER       (SACLAY)
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CLEAR    67 NC 49A 399              +JOHNSTON+COOPER+MANNER+     (TNTO+ANL+WISC)
DANYSZ   67 NC 51 A 801             DANYSZ+FRENCH+SIMAK                   (CERN)
EISNER   67 PR 164 1699             +JOHNSON+KLEIN+PETERS+SAHNI+YEN+    (PURDUE)
FRENCH   67 NC 52A 442              +KINSON+MCDONALD+RIDDIFORD+      (CERN+BIRM)
HERTZBAC 67 PR 155  1461            HERTZBACH,KRAEMER,MADANSKI,ZDANIS+(JHU+BNL)
HUWE     67 PL 24B 252              +MARQUIT+OPPENHEIMER+SCHULTZ+WILSON   (COLU)
HYAMS    67 PL 24B 634              +KOCH+PELLETT+POTTER+VONLINDERN+(CERN+MPIM)
MILLER   67 PR 153 1423             MILLER,GUTAY,JOHNSON,LOEFFLER +     (PURDUE)
POIRIER  67 PR 163 1462             +BISWAS,CASON,DERADO,KENNEY+     (NDAM+PENN)

ABC COLL 68 NP B4 501                         AACHEN+BERLIN+CERN COLLABORATION
ARMENISE 68 NC 54A 999              +GHIDINI,FORINO+      (BARI+BGNA+FIRZ+ORSAY)
ASTVACAT 68 PL 27 B  45             ASTVACATUROV,AZIMOV,BALDIN+   (JINR+MOSCOW)
BATON    68 PR 176 1574             J.P. BATON, G. LAURENS              (SACLAY)
BLECHSCH 68 NC  53 A  1045          BLECHSCHMIDT,DOWD,ELSNER,+       (DESY+MCHS)
    ALSO 67 NC  52 A  1348
CHUNG    68 PR 165 1491             S.U.CHUNG,O.I.DAHL,J.KIRZ,D.H.MILLER   (LRL)
DONALD   68 NP B 6 174              +EDWARDS,FRODESEN,BETTINI+ (LIVP+OSLO+PADO)
FOSTER   68 NP B 6 107              +GAVILLET+LABROSSE+MONTANET+     (CERN+CDEF)
HUSON    68 PL 28B 208              +LUBATTI,SIX,VEILLET,+      (ORSA+MILA+UCLA)
HYAMS    68 NP B 7 1                +KOCH,POTTER,WILSON,VON LINDERN+(CERN+MPIM)
JONES    68 PR 166 1405             +BLEULER,CALDWELL,ELSNER,HARTING+     (CERN)
JOHNSON  68 PR 176 1651             +POIRIER,BISWAS,GUTAY+      (NDAM+PURD+SLAC)
KEY      68 PR 166 1430             +PRENTICE+COOPER+MANNER+     (TNTO+ANL+WISC)
LAMSA    68 PR 166 1395             +CASON+BISWAS+DERADO+GROVES+     (NOTREDAME)
LANZEROT 68 PR 166 1365             LANZEROTTI,BLUMENTHAL,EHN,FAISSLER + (HARV)
MARATECK 68 PRL 21 1613             +HAGOPIAN,+  (PENN+LRL+COLO+PURD+TNTO+WISC)
PISUT    68 NP B 6 325              J.PISUT,M.ROOS                        (CERN)

AUGUSTI1 69 PL 28 B 508             +BIZOT+BUON+HAISSINSKI+LALANNE+      (ORSAY)
AUGUSTI2 69 LNC 2 214               +LEFRANCOIS,LEHMANN,MARIN,+          (ORSAY)
AUSLENDE 69 SJNP 9  69              AUSLENDER,BUDKER,PANTUSOVA,PESTOV+    (NOVO)
ERBE     69 PR 188  2060            GERMAN BUBBLE CHAMBER COLL.           (DESY)
HAISSINS 69 ARGONNE CONF. 373 J.HAISSINSKI                               (ORSAY)
JUHALA   69 PR 184  1461            +LEACOCK,RHODE,KOPELMAN,LIBBY,+  (ISU+COLO)
MALAMUD  69 ARGONNE CONF.P.93 E.MALAMUD, P.SCHLEIN                       (UCLA)
MILLER   69 PR 178 2061             R.MILLER,LICHTMAN,WILLMANN          (PURDUE)
MOTT     69 PR 177 1966             +AMMAR,DAVIS,KROPAC,SLATE,DAGAN+ (NWES+ANL)
REYNOLDS 69 PR 184 1424             +ALBRIGHT,BRADLEY,BRUCKER,HARMS+       (FSU)
ROOS     69 NP B 10 563             M.ROOS,J.PISUT           (CERN+BRATISLAVA)
ROTHWELL 69 PRL 23 1521             +CHASE,EARLES,GETTNER,GLASS,WEINSTEI+(NEAS)
SCHAREN  69 ARGONNE CONF.306  SCHARENGUIVEL                             (PURDUE)
WEHMANN  69 PR 178  2095            +ENGELS,WILSON,+ (HARV+CASE+SLAC+CORN+MCGI)

ALVENSLE 70 PRL 24 786              ALVENSLEBEN,BECKER,BERTRAM,CHEN,COHEN(DESY)
BATON    70 PL 33 B 528             +LAURENS,REIGNIER                   (SACLAY)
BIGGS    70 PRL 24 1197             +BRABEN,CLIFFT,GABATHULER,KITCHING+  (DARE)
BINGHAM  70 PRL 24 955              +FRETTER,MOFFEIT,BALLAM+    (LRL+SLAC+TUFT)
GALLOWAY 70 PR D 1 3077             +MOTT,ALYA,LEE,MARTIN,PRICKETT         (IND)

ABRAMS   71 PR D 4 653              +BARNHAM,BUTLER,COYNE,GOLDHABER,HALL,+(LBL)
BLOODWOR 71 NP B 35 133             BLOODWORTH,JACKSON,PRENTICE,YOON  (TORONTO)
DEERY    71 PR D 3 635              +BISWAS,CASON,GROVES,JOHNSON,+ (NOTRE DAME)

BAILLON  72 PL 38 B 555             +CARNEGIE,KLUGE,LEITH,LYNCH,RATCLIFF+(SLAC)
BALLAM   72 PR D 5 545              +CHADWICK,BINGHAM,MILBURN,+ (SLAC+LBL+TUFT)
BASDEVAN 72 PL 41 B 178             BASDEVANT,FROGGATT,PETERSEN           (CERN)
BENAKSAS 72 PL 39 B 289             +COSME,JEAN-MARIE,JULLIAN,LAPLANCHE,+(ORSA)
DRIVER   72 NP B 38 1               +HEINLOTH,HOHNE,HOFMANN,RATHJE,+(DESY+HAMB)
EISENBER 72 PR D 5 15               EISENBERG,BALLAM,DAGAN,+    (REHO+SLAC+TELA)
GRAYER   72 PHIL.CONF.PROC. 5 +HYAMS,JONES,SCHLEIN,BLUM,DIETL+(CERN+MPIM)
GRAYER   72 NP B 50 29              +HYAMS,JONES,WEILHAMMER,BLUM,+  (CERN+MPIM)
JACOBS   72 PR D 6 1291             L.D.JACOBS                          (SACLAY)
RATCLIFF 72 PL 38 B 345             +BULOS,CARNEGIE,KLUGE,LEITH,LYNCH,+  (SLAC)
TAKAHASH 72 PR D 6 1266             TAKAHASHI,BARISH,+     (TOHO+PENN+NDAM+ANL)

BYERLY   73 PR D 7 637              +ANTHONY,COFFIN,MEANLEY,MEYER,RICE,+ (MICH)
CHARLESW 73 NP B 65 253             CHARLESWORTH,EMMS,BELL,+   (RHEL+BIRM+DURH)
GLADDING 73 PR D 8 3721             +RUSSEL,TANNENBAUM,WEISS,THOMSON      (HARV)
HYAMS    73 NP B 64 134             +JONES,WEILHAMMER,BLUM,DIETL,+  (CERN+MPIM)
PROTOPOP 73 PR D 7 1280             PROTOPOPESCU,GARNJOST,GALTIERI,FLATTE+(LBL)

CARROLL  74 PR D 10 1430            +MATTHEWS,WALKER+      (SLAC+DUKE+WISC+TNTO)
ENGLER   74 PR D 10 2070            +KRAEMER,TOAFF,WEISSER,DIAZ+     (CARN+CASE)
ESTABROO 74 NP B 79 301             P.ESTABROOKS,A.D.MARTIN               (DURH)
GOBBI    74 PRL 33 1450             +ROSEN,SCOTT,SHAPIRO+       (NWES+ROCH+CARN)
GRAYER   74 NP B 75 189             G.GRAYER,HYAMS,BLUM,DIETL,+      (CERN+MPIM)
HABER    74 PR D10 1387             +HODOUS,HULSIZER,KISTIAKOWSKY,LEVY+    (MIT)
NORDBERG 74 PL 51 B 106             +ABRAMSON,ANDREWS,HARVEY,+       (CORN+ROCH)
SPITAL   74 PR D 9 126              R.SPITAL,D.R.YENNIE                   (CORN)

MONTONEN 75 LNC 12 627              C.MONTONEN,M.ROOS,N.TORNQVIST         (HELS)
ROOS     75 NP B 97 165             M.ROOS                                (HELS)

DEUTSCHM 76 NP B 103 426            +KIRK,+(AACH+BERL+BONN+CERN+CRAC+HEID+WARS)

ANDREWS  77 PRL 38 198              +FUKUSHIMA,HARVEY,LOBKOWICZ,MAY,+     (ROCH)

BALTAY   78 PR D 17 62              +CAUTIS,COHEN,CSORNA,SMITH,YEH,+(COLU+BING)
BARTALUC 78 NC 44 A 587             BARTALUCCI,BASINI,BERTOLUCCI,   (DESY+FRAS)
QUENZER  78 PL 76 B 512             +RIBES,RUMPF,BERTRAND,BIZOT,CHASE,+  (LALO)
WICKLUND 78 PR D 17 1197            +AYRES,DIEBOLD,GREENE,KRAMER,PAWLICKI (ANL)

BECKER   79 NP B 151  46            +BLANAR,BLUM,CERRADA+ (MPIM+CERN+ZEEM+CRAC)
LANG     79 PR D 19 956             C.B.LANG,A.MAS-PARAREDA               (GRAZ)

BERG     80 PRL 44 706              +CHANDLEE,BIEL,HEPPELMANN,+(ROCH+FNAL+MINN)
BOHACIK  80 PR D 21 1342            J.BOHACIK,H.KUHNELT        (BRATISLAVA+WIEN)
HEYN     80 ZPHY C 7 169            M.F.HEYN,C.B.LANG                     (GRAZ)

ALEKSEEV 82 JETP 55 591             ALEKSEEVA,KARTAMYSHEV,MAKARIN+        (KIAE)

CHABAUD  83 NP B 223 1              +GORLICH,CERRADA+           (CERN+CRAC+MPIM)
JENSEN   83 PR D 27 26              +BERG,BIEL,COLLICK+         (ROCH+FNAL+MINN)
KURDADZE 83 JETPL 37 613            +LELCHUK,PAKHTUSOVA+                  (NOVO)

BARKOV   85 NP B 256 365            +CHILINGAROV,EIDELMAN,KHAZIN,LELCHUK+(NOVO)
RYBICKI  85 ZPHY C 28 65            RYBICKI,SAKREJDA                      (CRAC)
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$\boxed{\omega(783)}$

$I^G(J^{PC}) = 0^-(1^{--})$

ω(783) MASS (MeV)

```
M   R 2198 (783.4)    (0.7)           BALTAY    67 HBC     0.0 PBAR P
M   R      (784.0)    (0.7)           ATHERTON  70 HBC     3.6 PBAR P, 7 PI
M  SR 4800 (782.0)    (0.8)           OREN      74 HBC     2.3 PBAR P,5PI
M
M     2400  782.4      0.5            BIZZARRI  69 HBC      0 PBAR P
M      750  784.1      1.2            ABRAMOVIC 70 HBC      3.9 PI- P
M    F      783.2      1.6            BIGGS     70 CNTR    PHOTOPRODUCTION
M      248  783.4      1.0            BIZZARRI  71 HBC      0.0 P PBAR K+K-
M      510  781.0      0.6            BIZZARRI  71 HBC      0.0 P PBAR K1K1
M  D        783.7      1.0            COYNE     71 HBC     3.7 PI+ P
M      418  782.5      0.8            AGUILAR   72 HBC     3.9,4.6 K- P
M  B  7000  782.4      0.5            KEYNE     76 CNTR    PI-P, OMEGA N
M     2100  783.5      0.8            GESSAROLI 77 HBC     11 PI-P,OMEGA PI
M      535  782.7      0.9            APELDOORN 78 HBC     7.2 PB P,PB P OM
M     1430  781.8      0.6            COOPER    78 HBC     .7-.8 PB P,5 PI
M     3000  782.6      0.8            BENKHEIRI 79 OMEG    9-12 PI+- P
M           783.3      0.4            CORDIER   80 WIRE    E+E-,PI+PI-PIO
M    33260  782.5      0.8            ROOS      80 RVUE    0-3.6 PBAR P
M           782.4      0.4            KURDADZ2  83 OLYA     E+E-
M           . . . . . . . . .
M   AVG     782.58     0.18    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)

M  B    OBSERVED BY THRESHOLD-CROSSING TECHNIQUE. MASS RESOL.=4.8 MEV FWHM
M  D    FROM BEST-RESOLUTION SAMPLE OF COYNE 71
M   F   FROM OMEGA-RHO INTERFERENCE IN THE PI+PI- MASS SPECTRUM
M   F   ASSUMING OMEGA WIDTH 12.6 MEV.
M   R   INCLUDED IN ROOS 77,79 RVUE
M  S    ERROR INCLUDES 0.5 MEV MASS SCALE ERROR
M
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ω(783) WIDTH (MeV)

```
W      750    8.8      3.0            ABRAMOVIC 70 HBC      3.9 PI- P
W            11.2      2.7            ATHERTON  70 HBC     3.6 PBAR P, 7 PI
W      510   10.3      1.4            BIZZARRI  71 HBC      0.0 P PBAR K1K1
W      248   12.8      3.0            BIZZARRI  71 HBC      0.0 P PBAR K+K-
W     4270    9.5      1.0            COYNE     71 HBC     3.7 PI+ P
W      418   13.3      2.             AGUILAR   72 HBC     3.9,4.6 K- P
W             9.1      0.8            BENAKSAS1 72 OSPK    E+E- COLL.BEAMS
W            10.5      1.5            BORENSTEI 72 HBC     2.18 K-P
W  E   940    7.70     1.07           BROWN     72 MMS     2.5 PI- P,N MMS
W  B 20000   10.22     0.43           KEYNE     76 CNTR    PI-P, OMEGA N
W     2100    9.4      2.5            GESSAROLI 77 HBC     11 PI-P,OMEGA PI
W     1430   12.0      2.0            COOPER    78 HBC     .7-.8 PB P,5 PI
W             9.0      0.8            CORDIER   80 WIRE    E+E-,PI+PI-PIO
W             9.8      0.9            KURDADZ2  83 OLYA     E+E-
W           . . . . . . . . .
W   AVG       9.81     0.27    AVERAGE

W  B    OBSERVED BY THRESHOLD-CROSSING TECHNIQUE. MASS RESOL.=4.8 MEV FWHM
W  E    ERROR TAKES ACCOUNT OF SYSTEMATICS ADDED QUADRATICALLY
```

ω(783) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\omega \to \pi^+\pi^-\pi^0$	140+ 140+ 135
P2	$\omega \to \pi^+\pi^-$(VIOLATES G)	140+ 140
P3	$\omega \to \pi^0\gamma$	135+ 0
P4	$\omega \to \pi^+\pi^-\gamma$	140+ 140+ 0
P5	$\omega \to 2\pi^0\gamma$	135+ 135+ 0
P6	$\omega \to \eta\gamma$	549+ 0
P7	$\omega \to e^+e^-$	.511+.511
P8	$\omega \to \mu^+\mu^-$	106+ 106
P9	$\omega \to \eta\pi^0$(VIOLATES C)	549+ 135
P10	$\omega \to 3\gamma$	0+ 0+ 0
P11	$\omega \to \pi^0\mu^+\mu^-$	135+ 106+ 106

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1        P 2        P 3
 P 1 .8961+-.0052
 P 2   -.4116  .0170+-.0022
 P 3   -.9081    -.0079  .0869+-.0047
```

$\omega(783)$ BRANCHING RATIOS

$\omega \to$ **neutrals**$/(\pi^+\pi^-\pi^0)$ (P3+...)/(P1)

```
R1        20    0.11      0.02                BUSCHBECK 63 HBC       1.5 K-P
R1        35    0.08      0.03                KRAEMER   64 DBC       1.2 PI+D
R1   C    65    (0.10)    (0.04)              ALFF-STEI 66 HBC CORR.BY SCHULTZ(COL)
R1       850    0.134     0.026               DIGIUGNO  66 CNTR      1.4 PI-P
R1       348    0.097     0.016               FLATTE    66 HBC       1.8 K-P
R1              0.06      0.05      0.02      JAMES     66 HBC       2.1 PI+P
R1        19    0.10      0.03                BARASH    67 HBC       0.0 PBAR P
R1        46    0.15      0.04                AGUILAR   72 HBC      3.9,4.6 K- P
R1   C    CORR. BY SCHULTZ(COL)69
R1            . . . . . . . . . .
R1   AVG        0.1035    0.0093  AVERAGE
R1   FIT        0.0970    0.0058 FROM FIT
```

$\omega \to (\pi^+\pi^-)/(\pi^+\pi^-\pi^0)$. **SEE ALSO R15** (P2)/(P1)

```
R2 R          (0.011)OR MORE  CL=.95    ABRAMOVIC 70 HBC        3.9 PI- P
R2  B         (0.014)  (0.005)  (0.004)BIGGS     70 CNTR      PHOTOPRODUCTION
R2 R          (0.035)OR LESS  CL=.95    BIZZARRI  70 DBC        PBAR N AT REST
R2            (0.019)OR MORE  CL=.95    CHAPMAN   70 HBC       1.6-2.2 P PBAR
R2 R            0.022     0.009    0.01 ROOS      70 RVUE
R2              0.028     0.006         BEHREND   71 ASPK      PHOTOPRODUCTION
R2 S            0.021     0.028   0.009 RATCLIFF  72 ASPK      15.PI- P,N 2PI
R2            (0.0115)OR MORE           BURNS     73 HBC       .6-1.1 PBAR P
R2  C         (0.04)    (0.02)          LYONS     77 HBC       3-4 K-P,LAM OMEG
R2            . . . . . . . . . .
R2  AVG         0.0259    0.0049  AVERAGE
R2  FIT         0.0189    0.0025 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)

R2  B   RE-EVALUATED UNDER R2 BY BEHREND 71 USING MORE ACCURATE OMEGA
R2  B   TO RHO PHOTOPRODUCTION CROSS-SECTION RATIO.
R2  C   ASSUMING COMPLETE RHO-OMEGA COHERENCE
R2 R    ROOS 70 COMBINES ABRAMOVICH 70 AND BIZZARRI 70
R2 S    SIGNIFICANT INTERFERENCE EFFECT OBSERVED.NB OF OMEGA INTO 3PI
R2 S    COMES FROM AN EXTRAPOLATION.
```

$\omega \to (\pi^0\gamma)/(\pi^+\pi^-\pi^0)$ (P3)/(P1)

```
R3              0.13      0.04          JACQUET   69 HLBC
R3              0.081     0.020         BALDIN    71 HLBC      2.9 PI+ P
R3              0.109     0.025         BENAKSAS2 72 OSPK      E+E- COLL.BEAMS
R3              0.084     0.013         KEYNE     76 CNTR      PI-P, OMEGA N
R3            . . . . . . . . . .
R3  AVG         0.0898    0.0097  AVERAGE
R3  FIT         0.0970    0.0058 FROM FIT
```

$\omega \to (\pi^+\pi^-\gamma)/(\pi^+\pi^-\pi^0)$ (P4)/(P1)

```
R4            (0.05) OR LESS  CL=.90    FLATTE    66 HBC        1.8 K-P
R4             (.066)OR LESS  CL=.90    KALBFLEI  75 HBC       2.2 K- P,GAMMA +
```

$\omega \to (\mu^+\mu^-)/(\pi^+\pi^-\pi^0)$(**units** 10^{-3}) (P8)/(P1)

```
R6            (1.2)  OR LESS            GALTIERI  65 HBC        2.7 K-P
R6            (1.7)  OR LESS  CL=.74    FLATTE    66 HBC        1.8 K-P
R6            (0.2)  OR LESS            WILSON    69 OSPK       12 PI- ON C,FE
```

$\omega \to (2\pi^0\gamma)/(\pi^0\gamma)$ (P5)/(P3)

```
R7            (0.1)  OR LESS            BARMIN    64 HLBC       1.3-2.8 PI-P
R7            (0.14) OR LESS            BALDIN    71 HLBC      2.9 PI+ P
R7            (0.15) OR LESS  CL=.90    BENAKSAS2 72 OSPK      E+E- COLL. BEAMS
R7            (0.18) OR LESS  CL=0.95   KEYNE     76 CNTR      PI-P,OMEGA N
```

$\omega \to (\eta\pi^0 + \eta\gamma)/(\pi^+\pi^-\pi^0)$ (P9+P6)/(P1)

```
R8            (0.017)OR LESS  CL=.90    FLATTE    66 HBC        1.8 K-P
R8            (0.045)OR LESS  CL=.95    JACQUET   69 HLBC
```

$\omega \to$ **neutrals/charged** (P3+...)/(P1+P2...)

```
R9              0.124     0.021         FELDMAN   67 OSPK       1.2 PI- P
R9            . . . . . . . . . .
R9  FIT         0.0952    0.0057 FROM FIT
```

$\omega \to (2\pi^0\gamma)/(\pi^+\pi^-\pi^0)$ (P5)/(P1)

```
R10           (0.08) OR LESS  CL=.95    JACQUET   69 HLBC
```

$\omega \to (\eta\gamma)/(\pi^0\gamma)$ (P6)/(P3)

```
R11             0.010     0.045         APEL      72 OSPK      4-8 PI- P,N 3GAM
```

$\omega \to (\pi^0\mu^+\mu^-)$/**total (units** 10^{-3}) (P11)

```
R12             0.096     0.023         DZHELYADI 81 CNTR      25-33 PI-P,OME N
```

$\omega \to (e^+e^-)$/**total (units** 10^{-4}) (P7)

```
R13 A    33   (0.65)    (0.13)          ASTVACATU 68 OSPK ASSUME SU(3)+MIXING
R13 Z         (0.40)    (0.21)          BOLLINI1  68 CNTR       1.7 PI-P
R13 E         (0.92)    (0.07)          AUGUSTI1  69 OSPK      E+E-, 2PI
R13             0.83      0.10          BENAKSAS1 72 OSPK      E+E-, 3PI
R13             0.675     0.069         CORDIER   80 WIRE      E+ E-,3PI
R13             0.64      0.04          KURDADZ2  83 OLYA       E+E-
R13           . . . . . . . . . .
R13 AVG         0.668     0.041   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)

R13 A           NOT RESOLVED  FROM  RHO  DECAY. ERROR STATISTICAL ONLY.
R13 E           RESCALED BY US TO CORRESPOND TO OMEGA WIDTH 10.1 MEV.
R13 Z           MASS RESOLUTION OF BOLLINI 1 IS +-10 MEV.HIS ERROR IS +-.15
R13 Z           WITHOUT RHO-OMEGA INTERFERENCE. COMPLETE INTERFERENCE WOULD
R13 Z           CHANGE VALUE BY +-35 PER CENT. THEREFORE WE INCREASED ERROR.
```

$\omega \to$ **neutrals/total** (P3+...)

```
R14             0.084     0.015         BOLLINI   68 CNTR      2.1 PI- P
R14             0.079     0.019         DEINET    69 OSPK      1.5 PI- P
R14             0.075     0.025         BIZZARRI  71 HBC        0.0 P PBAR
R14      42     0.073     0.018         BASILE    72 CNTR      1.67 PI- P
R14           . . . . . . . . . .
R14 AVG         0.0788    0.0092  AVERAGE
R14 FIT         0.0869    0.0047 FROM FIT
```

$\omega \to (\pi\pi)$/**total. SEE ALSO R2** (P2)

```
R15         (0.032)  (0.028)  (0.019)AUGUSTI2  69 OSPK     E+E- COLL.BEAMS
R15         (0.003)OR MORE  CL=.95   GOLDHABER 69 HBC        3.7-4.0 PI+P
R15         (0.014)OR MORE  CL=.95   ALLISON   70 HBC      1.3-1.7 PBAR P
R15 B       (0.0080) (0.0028) (0.002)BIGGS     70 CNTR     PHOTOPRODUCTION
R15          0.0122   0.0030         ALVENSLEB 71 CNTR     PHOTOPRODUCTION
R15          0.013    0.012    0.009 MOFFEIT   71 HBC      2.8,4.7 GAMMA P
R15         (0.036)  (0.024)  (0.018)BENAKSAS  72 OSPK      E+E- COLL.BEAMS
R15 F       (0.035)  (0.018)         BRANDENBU 76 ASPK     13.K-P,PI+PI-
R15 F       (0.04)   (0.03)   (0.02) HOLMGREN  77 HBC      4.2 K-P,PI+PI-
R15          0.016    0.009    0.007 QUENZER   78 CNTR     E+E- COLL.BEAMS
R15 F       (0.010)  (0.001)         WICKLUND  78 ASPK     3,4,6 PI+-PN
R15          0.023    0.005          BARKOV    85 OLYA      E+E-
R15        . . . . . . . . . .
R15 AVG      0.0150   0.0026  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
R15 FIT      0.0170   0.0022 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)

R15 B   RE-EVALUATED UNDER R2 BY BEHREND 71 USING MORE ACCURATE OMEGA
R15 B   TO RHO PHOTOPRODUCTION CROSS-SECTION RATIO.
R15 F   FROM A MODEL DEPENDENT ANALYSIS ASSUMING COMPLETE COHERENCE.
```

$\omega \to (2\pi^0\gamma)$/**neutrals** (P5)/(P3+...)

```
R17         (0.19) OR LESS  CL=.90   DEINET    69 OSPK
R17 D       (0.22)   (0.07)          DAKIN     72 OSPK     1.4 PI- P,N MMO
R17 D      SEE R18
```

$\omega \to (\pi^0\gamma)$/(**neutrals**) (P3)/(P3+...)

```
R18         (0.81) OR MORE  CL=.90   DEINET    69 OSPK
R18 D       (0.78)   (0.07)          DAKIN     72 OSPK     1.4 PI- P,N MMO
R18 D      ERROR STATISTICAL ONLY.AUTHORS OBTAIN GOOD FIT ALSO ASSUMING
R18 D      PI0 GAMMA AS THE ONLY NEUTRAL DECAY.
```

$\omega \to (\eta\gamma)$/**total (units** 10^{-4}) (P6)

```
R19 A         (3.0)     (2.5)    (1.8)  ANDREWS   77 CNTR     6.7-10 GAMMA CU
R19 B        (29.0)     (7.0)           ANDREWS   77 CNTR     6.7-10 GAMMA CU
R19 A   SOLUTION CORRESPONDING TO CONSTRUCTIVE OMEGA-RHO INTERFERENCE
R19 A   THE QUARK MODEL PREDICTS A RELATIVE DECAY PHASE OF ZERO
R19 B   SOLUTION CORRESPONDING TO DESTRUCTIVE OMEGA-RHO INTERFERENCE
```

$\omega \to (\pi^0\mu^+\mu^-)/(\mu^+\mu^-)$ (P11)/(P8)

```
R20 S   30   (1.2)     (0.6)            DZHELYADI 79 CNTR     25-33 PI- P
R20 S   SUPERSEDED BY DZHELYADIN 81 RESULT ABOVE.
```

REFERENCES FOR $\omega(783)$

```
MAGLIC   61 PRL 7 178          B MAGLIC,ALVAREZ,ROSENFELD,STEVENSON  (LRL)
PEVSNER  61 PRL 7 421          PEVSNER,KRAEMER,NUSSBAUM,RICHARD+(JHU+NWES)
XUONG    61 PRL 7 327          NGUYEN HUU XUONG,GERALD R LYNCH        (LRL)

ALFF     62 PRL 9 325          ALFF,BERLEY,COLLEY,GELFAND + (COLU+RUTGERS)
ARMENTER 62 CERN CONF 90       R ARMENTEROS,R BUDDE +      (CERN+CDEF+EPOL)
STEVENSO 62 PR 125 687         STEVENSON,ALVAREZ,MAGLIC,ROSENFELD     (LRL)

ARMENTER 63 SIENA CONF 1 296   ARMENTEROS,EDWARDS,JACOBSEN+     (CERN+CDEF)
BARMIN   63 SIENA CONF 1 207   BARMIN,DOLGOLENKO,KRESTNIKOV+          (ITEP)
BUSCHBEC 63 SIENA CONF 1 166   BUSCHBECK,CZAPP+    (VIENNA+CERN+AMSTERDAM)
GELFAND  63 PRL 11 436         GELFAND,MILLER,NUSSBAUM,RATAU+  (COLU+RUTG)
MURRAY   63 PL 7 358           MURRAY,FERROLUZZI,HUWE,SHAFER,SOLMITZ+(LRL)

BARMIN   64 JETP 18 1289       BARMIN,DOLGOLENKO,KRESTNIKOV +         (ITEP)
KRAEMER  64 PR 136 B 496       KRAEMER,MADANSKY,MEER+        (JHU+NWES+WOOD)

BINNIE   65 PL 18 348          BINNIE,DUANE,JANE,W JONES+        (LOIC+MCHS)
GALTIERI 65 PRL 14 279         A BARBARO GALTIERI,R D TRIPP            (LRL)
MILLER D 65  CU-237/NEVIS-131  DAVID C MILLER  (THESIS)           (COLUMBIA)
ZDANIS   65 PRL 14 721         ZDANIS,MADANSKY,KRAEMER,HERTZBACH+(JHU+BNL)

ALFF-STE 66 PR 145 1072        ALFF-STEINBERGER,BERLEY,BRUGGER+(COLU+RUTG)
DIGIUGNO 66 NC 44A 1272        DI GIUGNO,PERUZZI,TROISE+  (NAPL+FRAS+TRST)
FLATTE   66 PR  145  1050      +HUWE,MURRAY,BUTTON-SHAFER,SOLMITZ+   (LRL)
JAMES    66 PR 142 896         F E JAMES,KRAYBILL          (YALE+BROOKHAVEN)

BALTAY   67 PRL  18  93        +FRANZINI,SEVERIENS,YEH,ZANELLO  (COLUMBIA)
BARASH   67 PR  156  1399      BARASH,KIRSCH,MILLER,TAN           (COLUMBIA)
FELDMAN  67 PR 159 1219        +FRATI,GLEESON,HALPERN,NUSSBAUM+       (PENN)
HERTZBAC 67 PR 155, 1461       HERTZBACH,KRAEMER,MADANSKI,ZDANIS+(JHU+BNL)

ASTVACAT 68 PL 27 B  45        ASTVACATUROV,AZIMOV,BALDIN+   (JINR+MOSCOW)
BOLLINI  68 NC 56 A 531        +BUHLER,DALPIAZ,MASSAM+     (CERN+BGNA+STRB)
BOLLINI1 68 NC 57 A 404        +BUHLER,DALPIAZ,MASSAM+     (CERN+BGNA+STRB)
KEY      68 PR 166 1430        +PRENTICE+COOPER+MANNER      (TNTO+ANL+WISC)
PISUT    68 NP B 6 325         J.PISUT,M.ROOS                          (CERN)
WEHMANN  68 PRL 20 748         +ENGELS+ (HARVARD+CASE+SLAC+CORNELL+MCGILL)

AUGUSTI1 69 PL 28 B 513        +BENAKSAS,BUON,GRACCO,HAISSINSKI,+  (ORSAY)
AUGUSTI2 69 LNC 2 214          +LEFRANCOIS,LEHMANN,MARIN,+          (ORSAY)
BIZZARRI 69 NP B 14 169        +FOSTER,GAVILLET,MONTANET,+     (CERN+CDEF)
DANBURG  69 UCRL-19275         JEROME S. DANBURG, THESIS               (LRL)
DEINET   69 PL 30 B 426        +MENZIONE,MULLER,BUNIATOV+      (KARL+CERN)
ERWIN    69 NP B 9 364         +WALKER,GOSHAW,WEINBERG     (WISC+PRIN+VAND)
GOLDHABE 69 PRL 23,1351        +BUTLER,COYNE,HALL,MACNAUGHTON,TRILING(LRL)
JACQUET  69 NC 63 A 743        +NGUYEN-KHAC,HAATUFT,HALSTEINSLI(EPOL+BERG)
MILLER   69 PR 178 2061        R.MILLER,LICHTMAN,WILLMANN           (PURDUE)
STRUGALS 69 PL 29 B 532        +CHUVILO,FENYVES,+          (WARS+JINR+BUDA)
WILSON   69  PRIVATE COMM.     RICHARD WILSON (SEE ALSO PR 178 2095)(HARV)

ABRAMOVI 70 NP B 20 209        ABRAMOVICH,BLUMENFELD,BRUYANT,+        (CERN)
BIZZARRI 70 PRL 25 1385        +CIAPETTI,DORE,GASPERO,GUIDONI,+(ROMA+SYRA)
ALLISON  70 PRL 24 618         +COOPER,FIELDS,RHINES                   (ANL)
ATHERTON 70 NP B 18 221        +BLAIR,CELNIKER,DOMINGO,FRENCH+  (CERN+IPN)
BIGGS    70 PRL 24 1201        +CLIFFT,GABATHULER,KITCHING,RAND       (DARE)
CASON    70 PR D 1 851         +ANDREWS,BISWAS,GROVES,HARRINGTON,+  (NDAM)
CHAPMAN  70 NP B 24 445        +DAVIDSON,GREEN,LYS,ROE,VANDER VELDE (MICH)
DANBURG  70 PR D 2 2564        +ABOLINS,DAHL,DAVIES,HOCH,KIRZ,MILLER+(LRL)
FLATTE   70 PR D 1 1           STANLEY M. FLATTE                       (LRL)
GOLDHABE 70 PHILA.CONF.P.59    GERSON GOLDHABER,REVIEW                 (LRL)
HAGOPIAN 70 PRL 25 1050        S. AND V.HAGOPIAN,BOGART,SELOVE  (FSU+PENN)
ROOS     70 DNPL/R7 P.173      PROC. DARESBURY STUDY WEEKEND NO 1.  (CERN)
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ABRAMS   71 PR D 4 653          +BARNHAM,BUTLER,COYNE,GOLDHABER,HALL,+(LBL)
ALVENSLE 71 PRL 27 888          ALVENSLEBEN,BECKER,BUSZA,CHEN,COHEN,+(DESY)
ANGELOW  71 SJNP 12 427         +GRAMENITSKY,KANASIRSKY,KERATSCHEW,+ (JINR)
BALDIN   71 SJNP 13 758         +YERGAKOV,TREBUKHOVSKY,SHISHOV       (ITEP)
BARDADIN 71 PR D4 2711          BARDADIN-OTWINOWSKA,HOFMOKL,MICHEJDA+(WARS)
BEHREND  71 PRL 27 61           +LEE,NORDBERG,WEHMAN,+     (ROCH+CORN+FNAL)
BIZZARRI 71 NP B 27 140         +MONTANET,NILSSON,D-ANDLAU,+    (CERN+CDEF)
BLOODWOR 71 NP B 35 133         BLOODWORTH,JACKSON,PRENTICE,YOON  (TORONTO)
CHAPMAN  71 PR D 3 38           +FORTNEY,FOWLER                      (DUKE)
COYNE    71 NP B 32 333         +BUTLER,FANG-LANDAU,MACNAUGHTON       (LRL)
FIELDS   71 PRL 27 1749         +COOPER,RHINES,ALLISON            (ANL+OXF)
MATTHEWS 71 PRL 26 400          +PRENTICE,YOON,CARROLL,WALKER,+ (TNTO+WISC)
MOFFEIT  71 NP B 29 349         +BINGHAM,FRETTER,BALLAM+(LRL+UCB+SLAC+TUFT)

AGUILAR  72 PR D 6 29           AGUILAR-BENITEZ,CHUNG,EISNER,SAMIOS   (BNL)
APEL     72 PL 41 B 234         +AUSLANDER,MULLER,BERTOLUCCI,+  (KARL+PISA)
BASILE   72 PHIL.CONF.PROC153 +BOLLINI,BROGLIN,DALPIAZ,FRABETTI,+  (CERN)
BENAKSAS 72 PL 39 B 289         +COSME,JEAN-MARIE,JULLIAN,LAPLANCHE,+(ORSA)
BENAKSA1 72 PL 42 B 507         BENAKSAS,COSME,JEAN-MARIE,JULLIAN   (ORSAY)
BENAKSA2 72 PL 42 B 511         BENAKSAS,COSME,JEAN-MARIE,JULLIAN  +(ORSAY)
BROWN    72 PL 42 B 117         +DOWNING,HOLLOWAY,HULD,BERNSTEIN+(ILL+ILLC)
DAKIN    72 PR D 6 2321         +HAUSER,KREISLER,MISCHKE        (PRINCETON)
EISENBER 72 PR D 5 15           EISENBERG,BALLAM,DAGAN,+   (REHO+SLAC+TELA)
RATCLIFF 72 PL 38 B 345         +BULOS,CARNEGIE,KLUGE,LEITH,LYNCH,+  (SLAC)
BORENSTE 72 PR D 5 1559         BORENSTEIN,DANBURG,KALBFLEISCH,+ (BNL+MICH)

BINNIE   73 PR D 8 2789         +CARR,DEBENHAM,DUANE,GARBUTT,+  (LOIC+SHMP)
BURNS    73 PR D 7 1310         +CONDON,KIM,MANDELKERN,PRICE,SCHULTZ  (UCI)

ESTABROO 74 NP B 81 70          ESTABROOKS,HYAMS,JONES,BLUM,    (CERN+MPIM)
GREGORIO 74 NC 20 A 437         M.A.GREGORIO                 (ICTP-TRIESTE)
KRAMER   74 PRL 33 505          +AYRES,DIEBOLD,GREENE,PAWLICKI+       (ANL)
OREN     74 NP B 71 189         +COOPER,FIELDS,RHINES,ALLISON+    (ANL+OXF)

EMMS     75 NP B98 1            +KINSON,STACEY,BELL,DALE+  (BIRM+DURH+RHEL)
KALBFLEI 75 PR D 11 987         KALBFLEISCH,STRAND,CHAPMAN       (BNL+MICH)
ROOS     75 NP B 97 165         M.ROOS                               (HELS)

BRANDENB 76 NP B 104 413        BRANDENBURG,CARNEGIE,CASHMORE,DAVIER+(SLAC)
KEYNE    76 PR D 14 28          +BINNIE,CARR,DEBENHAM,GARBUTT,+ (LOIC+SHMP)
    ALSO 73 BINNIE

ANDREWS  77 PRL 38 198          +FUKUSHIMA,HARVEY,LOBKOWICZ,MAY,+    (ROCH)
BARTKE   77 NP B 118 360        + (AACH+BERL+BONN+CERN+CRAC+LOIC+WIEN+WARS)
GESSAROL 77 NP B 126 382        GESSAROLI,+  (BGNA+FIRZ+GENO+MILA+OXF+PAVI)
HOLMGREN 77 PL 66 B 191         +JONGEJANS,ENGELEN,+   (CERN+AMST+NIJM+OXF)
LYONS    77 NP B 125 207        +COOPER,CLARK                         (OXF)
ROOS     77 LNC 19 419          M.ROOS                           (HELSINKI)

APELDOOR 78 NP B 133 245        VAN APELDOORN,GRUNDEMAN,HARTING,+    (ZEEM)
COOPER   78 NP B 146 1          +GURTU,MONTANET,+      (TIFR+CERN+CDEF+MADR)
QUENZER  78 PL 76 B 512         +RIBES,RUMPF,BERTRAND,BIZOT,CHASE,+  (LALO)
WICKLUND 78 PR D 17 1197        +AYRES,DIEBOLD,GREENE,KRAMER,PAWLICKI (ANL)

BENKHEIR 79 NP B 150 268        BENKHEIRI,EISENSTEIN,+(EPOL+CERN+CDEF+LALO)
DZHELYAD 79 PL 84 B  143        DZHELYADIN,GOLOVKIN,GRITSUK,+        (SERP)

CORDIER  80 NP B 172 13         +DELCOURT,ESCHSTRUTH,FULDA,+         (LALO)
ROOS     80 LNC 27 321          +PELLINEN                            (HELS)

DZHELYAD 81 PL 102 B 296        DZHELYADIN,GOLOVKIN,KONSTANTINOV,+   (SERP)

KURDADZ1 83 JETPL 37 613        +LELCHUK,PAKHTUSOVA+                 (NOVO)
KURDADZ2 83 JETPL 36 274        +PAKHTUSOVA,SIDOROV+                 (NOVO)

BARKOV   85 NP B 256 365        +CHILINGAROV,EIDELMAN,KHAZIN,LELCHUK+(NOVO)
```

$\eta'(958)$

$I^G(J^{PC}) = 0^+(0^{-+})$

```
OUR LATEST MINIREVIEW ON THIS PARTICLE
CAN BE FOUND IN THE 1984 EDITION.
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$\eta'(958)$ MASS (MeV)

```
M          957.     1.            RITTENBER 69 HBC     1.7-2.7 K- P
M    3415  956.1    1.1           BASILE1   71 CNTR    1.6 PI- P,N X0
M     535  957.4    1.4           BASILE1   71 CNTR    1.6 PI- P,N X0
M    1414  958.2    0.5           DANBURG   73 HBC     2.2 K-P,LAM X0
M     400  958.     1.            JACOBS    73 HBC     2.9 K-P,LAM X0
M          957.46   0.33          DUANE     74 MMS     PI- P,N MM
M         . . . . . . . . . .
M   AVG    957.57   0.25    AVERAGE
```

$\eta'(958)$ WIDTH (MeV)

```
     WE INCLUDE DIRECT MEASUREMENTS OF THE ETA' TOTAL WIDTH
     AND GAMMA GAMMA PARTIAL WIDTH TOGETHER WITH THE MEASURED
     BRANCHING RATIOS IN THE FIT FOR THE PARTIAL DECAY RATES.

W     1000    0.28     0.10             BINNIE    79 MMS    0 PI- P,N MM
W           . . . . . . . . . . . .
W   FIT       0.243    0.028  FROM FIT
```

$\eta'(958)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\eta' \to \pi^+\pi^-\eta$ P1(N) ETAS DECAY INTO ALL NEUTRALS P1(C) ETAS DECAY CHARGED	140+ 140+ 549
P2	$\eta' \to \pi^0\pi^0\eta$ P2(N) ETAS DECAY INTO ALL NEUTRALS P2(C) ETAS DECAY CHARGED	135+ 135+ 549
P3	$\eta' \to \pi^+\pi^-\gamma$ (including $\rho\gamma$)	140+ 140+ 0
P4	$\eta' \to \gamma\gamma$	0+ 0
P5	$\eta' \to \omega\gamma$	783+ 0
P6	$\eta' \to 3\pi^0$(VIOLATES ISOSPIN CONSERV.)	135+ 135+ 135
P7	$\eta' \to \rho^0\gamma$	769+ 0
P10	$\eta' \to \pi^+\pi^-e^+e^-$	140+ 140+.511+.511
P11	$\eta' \to 2\pi$	140+ 140
P12	$\eta' \to 3\pi$	140+ 140+ 135
P13	$\eta' \to 4\pi$	140+ 140+ 140+ 140
P14	$\eta' \to 5\pi$	
P15	$\eta' \to 6\pi$	
P16	$\eta' \to \pi^0e^+e^-$(VIOLATES C IN BORN APPROX)	135+.511+.511
P17	$\eta' \to \eta e^+e^-$(VIOLATES C IN BORN APPROX)	549+.511+.511
P18	$\eta' \to \pi^0\rho^0$(VIOLATES C)	135+ 769
P19	$\eta' \to \pi^0\omega$(VIOLATES C)	135+ 783
P20	$\eta' \to \mu^+\mu^-\gamma$	106+ 106+ 0
P21	$\eta' \to \eta\mu^+\mu^-$	549+ 106+ 106
P22	$\eta' \to \pi^0\mu^+\mu^-$	135+ 106+ 106

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
          P 1          P 2          P 3          P 4          P 5          P 6
 P 1 .4260+-.0174
 P 2   -.6506  .2265+-.0206
 P 3   -.2723    -.5056  .2997+-.0160
 P 4    .0352    -.1090       .0053  .0185+-.0016
 P 5    .0687    -.2097     -.1420     -.0033  .0275+-.0054
 P 6   -.2353     .3447     -.1854     -.0379     -.0758  .0017+-.0004
```

FITTED PARTIAL DECAY MODE RATES

The matrix below is the branching fraction matrix above, transformed into rate space; i.e., $G_i \equiv \Gamma_i = \Gamma_{total} P_i$, in appropriate units. In analogy to the matrix above, the diagonal elements are $G_i \pm \delta G_i$, where $\delta G_i = \sqrt{\langle \delta G_i \delta G_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta G_i \delta G_j \rangle / (\delta G_i \cdot \delta G_j)$. Note that, because of the error in Γ_{total}, the errors and correlations here are not directly derivable from those above.

```
          G 1          G 2          G 3          G 4          G 5          G 6
 G 1 .1034+-.0126
 G 2    .6286  .0550+-.0085
 G 3    .8243     .6004  .0727+-.0093
 G 4    .6600     .5158      .6269  .0045+-.0004
 G 5    .4987     .2974      .4081      .3462  .0067+-.0015
 G 6    .3339     .5183      .3180      .2761      .1573  .0004+-.0001
```

$\eta'(958)$ PARTIAL WIDTHS (keV)

$\eta' \to (\gamma\gamma)$ (G4)

```
W4     USING B.R. (ETA' INTO RHOO GAMMA) = 0.30
W4   C 213    5.0      1.0               BARTEL    82 JADE    E+E-,E+E- RHO GA
W4   C  43    6.2      1.6               BEHREND   83 CELL    E+E-,E+E- RHO GA
W4   C  95    5.8      1.6               JENNI     83 SMK2    E+E-,E+E- RHO GA
W4   C        5.1      0.8               ALTHOFF   84 TASS    E+E-,E+E-PI+PI-G
W4   C        3.8      0.5               BERGER    84 PLUT    E+E-,E+E-PI+PI-G
W4   C       (4.2)    (0.7)              SENS      85 TPC     E+E-,E+E-2PI GAM
W4         . . . . . . . . . .
W4  AVG       4.47     0.39    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
W4  FIT       4.50     0.37   FROM FIT

W4   C THE SYSTEMATIC ERROR HAS BEEN ADDED QUADRATICALLY
```

$\eta'(958)$ BRANCHING RATIOS

$\eta' \to (\pi^+\pi^-\eta$(neutral decay))/total (P1N)

```
R1     281    0.314    0.026             RITTENBER 69 HBC       1.7-2.7 K-P
R1          . . . . . . . . . .
R1  FIT       0.302    0.012  FROM FIT
```

$\eta' \to (\pi^+\pi^- +$ neutrals)/total (P1N+P2C+P5)

```
R2      33    0.35     0.06              BADIER    65 HBC       3.0 K-P
R2      39    0.4      0.1               LONDON    66 HBC       2.2 K-P
R2          . . . . . . . . . .
R2  AVG       0.363    0.051   AVERAGE
R2  FIT       0.393    0.011  FROM FIT
```

$\eta' \to (\pi^+\pi^-\eta$(charged decay))/total (P1C)

```
R3       7    0.07     0.04              BADIER    65 HBC       3.0 K-P
R3      10    0.1      0.04              LONDON    66 HBC       2.2 K-P
R3     107    0.123    0.014             RITTENBER 69 HBC       1.7-2.7 K-P
R3          . . . . . . . . . .
R3  AVG       0.116    0.013   AVERAGE
R3  FIT       0.1240   0.0051 FROM FIT
```

$\eta' \to (\pi^+\pi^- + \textbf{neutrals})/\textbf{total}$ (P2C+P5)

```
R4         EXCLUDING (PI+ PI- ETA(NEUTRAL DECAY))/TOTAL
R4      42   0.045    0.029             RITTENBER 69 HBC     1.7-2.7 K-P
R4         . . . . . . . . . . .
R4  FIT      0.0907   0.0069 FROM FIT
```

$\eta' \to \textbf{neutrals/total}$ (P2N+P4)

```
R5     123   0.189    0.026             RITTENBER 69 HBC     1.7-2.7 K-P
R5     535   0.185    0.022             BASILE1   71 CNTR   1.6 PI- P,N X0
R5         . . . . . . . . . . .
R5  AVG      0.187    0.017   AVERAGE
R5  FIT      0.182    0.014  FROM FIT
```

$\eta' \to (\pi^+\pi^-\gamma\,(\textbf{including}\ \rho\gamma))/\textbf{total}$ (P3)

```
R6      35   0.34     0.09              BADIER    65 HBC     3.0 K-P
R6      20   0.2      0.1               LONDON    66 HBC     2.2 K-P
R6     298   0.329    0.033             RITTENBER 69 HBC     1.7-2.7 K-P
R6         . . . . . . . . . . .
R6  AVG      0.319    0.030   AVERAGE
R6  FIT      0.300    0.016  FROM FIT
```

$\eta' \to (\pi^+\pi^-\gamma\,(\textbf{including}\ \rho\gamma))/(\pi\pi\eta)$ (P3)/(P1+P2)

```
R7           0.31     0.15              DAVIS     68 HBC     5.5 K- P
R7         . . . . . . . . . . .
R7  FIT      0.459    0.035  FROM FIT
```

$\eta' \to (\pi^0 e^+ e^-)/\textbf{total}$ (P16)

```
R8          (0.013)OR LESS              RITTENBER 65 HBC          2.7 K-P
```

$\eta' \to (\eta e^+ e^-)/\textbf{total}$ (P17)

```
R9          (0.011)OR LESS              RITTENBER 65 HBC          2.7 K-P
```

$\eta' \to (\pi^0\rho^0)/\textbf{total}$ (P18)

```
R10         (0.04) OR LESS              RITTENBER 65 HBC          2.7 K-P
```

$\eta' \to (\pi^+\pi^- e^+ e^-)/\textbf{total}$ (P10)

```
R12         (0.006)OR LESS              RITTENBER 65 HBC          2.7 K-P
```

$\eta' \to (2\pi)/\textbf{total}$ (P11)

```
R13         (0.07) OR LESS              LONDON    66 HBC    COMPILATION
```

$\eta' \to (3\pi)/\textbf{total}$ (P12)

```
R14         (0.07) OR LESS              LONDON    66 HBC    COMPILATION
```

$\eta' \to (4\pi)/\textbf{total}$ (P13)

```
R15         (0.01) OR LESS              LONDON    66 HBC    COMPILATION
```

$\eta' \to (6\pi)/\textbf{total}$ (P15)

```
R16         (0.01) OR LESS              LONDON    66 HBC    COMPILATION
```

$\eta' \to (\omega\gamma)/(\pi^+\pi^-\eta)$ (P5)/(P1)

```
R17     68   0.068    0.013             ZANFINO   77 ASPK   8.4 PI-P
R17        . . . . . . . . . . .
R17 FIT      0.065    0.013  FROM FIT
```

$\eta' \to (\pi^+\pi^-\gamma(\textbf{including}\rho\gamma))/(\pi\pi\eta + \omega\gamma)$

```
R18                                                     (P3)/(P1+P2+P5)
R18          0.25     0.14              DAUBER    64 HBC       1.95 K-P
R18        . . . . . . . . . . .
R18 FIT      0.441    0.034  FROM FIT
```

$\eta' \to (2\gamma)/\textbf{total}$ (P4)

```
R19     31   0.020    0.008     0.006 HARVEY    71 OSPK   3.65 PI- P,N X0
R19     68   0.0171   0.0033          DALPIAZ   72 CNTR   1.6 PI- P,N X0
R19          0.025    0.007           DUANE     74 MMS    PI-P,N MM
R19   6000   0.018    0.002           APEL      79 CNTR   15-40 PI- P
R19        . . . . . . . . . . .
R19 AVG      0.0183   0.0016  AVERAGE
R19 FIT      0.0185   0.0016 FROM FIT
```

$\eta' \to (\pi^+\pi^-)/\textbf{total}$ (P11)

```
R20         (0.02) OR LESS            RITTENBER 69 HBC      1.7-2.7 K-P
R20         (0.08) OR LESS  CL=.95    DANBURG   73 HBC     2.2 K-P,LAM X0
```

$\eta' \to (\pi^+\pi^-\pi^0)/\textbf{total}$ (P12)

```
R21         (0.05) OR LESS            RITTENBER 69 HBC      1.7-2.7 K-P
R21         (0.09) OR LESS  CL=.95    DANBURG   73 HBC     2.2 K-P,LAM X0
```

$\eta' \to (\pi^+\pi^+\pi^-\pi^-)/\textbf{total}$ (P13)

```
R22         (0.01) OR LESS            RITTENBER 69 HBC      1.7-2.7 K-P
R22         (0.01) OR LESS  CL=.95    DANBURG   73 HBC     2.2 K-P,LAM X0
```

$\eta' \to (\pi^+\pi^+\pi^-\pi^-\pi^0)/\textbf{total}$ (P14)

```
R23         (0.01) OR LESS            RITTENBER 69 HBC      1.7-2.7 K-P
```

$\eta' \to (\pi^+\pi^+\pi^-\pi^- + \textbf{neutrals})/\textbf{total}$ (P15+...)

```
R24         (0.01) OR LESS            RITTENBER 69 HBC      1.7-2.7 K-P
```

$\eta' \to (\rho^0\gamma)/(\pi^+\pi^-\gamma)$ (P7)/(P3)

```
R25          0.94     0.20            AGUILAR   70 HBC     3.9-4.6K-P
R25  E 473   1.15     0.10            DANBURG   73 HBC     2.2 K-P,LAM X0
R25  E 473  (0.95) OR MORE  CL=.95    DANBURG   73 HBC     2.2 K-P,LAM X0
R25    137   1.01     0.15            JACOBS    73 HBC     2.9 K-P,LAM X0
R25        . . . . . . . . . . .
R25 AVG      1.082    0.077   AVERAGE

R25  E  EQUIVALENT STATEMENTS
```

$\eta' \to (\pi^0\pi^0\eta\,(3\pi^0\ \textbf{decay}))/\textbf{total}$ (P2N(3PI0))

```
R26      4   0.11     0.06            BENSINGER 70 DBC     2.2 PI+ D
R26        . . . . . . . . . . .
R26 FIT      0.0680   0.0062 FROM FIT
```

$\eta' \to (\pi^+\pi^-\gamma)/(\pi^+\pi^-\eta(\textbf{neutral decay}))$ (P3)/(P1N)

```
R27    473   0.92     0.14              DANBURG   73 HBC     2.2 K-P,LAM X0
R27    192   1.11     0.18              JACOBS    73 HBC     2.9 K-P,LAM X0
R27        . . . . . . . . . . .
R27 AVG      0.99     0.11    AVERAGE
R27 FIT      0.992    0.075  FROM FIT
```

$\eta' \to (2\gamma)/(\pi^0\pi^0\eta(\textbf{neutral decay}))$ (P4)/(P2N)

```
R28     16   0.188    0.058             APEL      72 OSPK   3.8 PI- P,N X0
R28        . . . . . . . . . . .
R28 FIT      0.115    0.015  FROM FIT
```

$\eta' \to (\gamma\mu^+\mu^-)/(2\gamma)(\textbf{units}\ 10^{-3})$ (P20)/(P4)

```
R29     33   4.9      1.2               VIKTOROV  80 CNTR   25,33 PI-P,2MU G
```

$\eta' \to (\eta\mu^+\mu^-)/\textbf{total}\ (\textbf{units}\ 10^{-5})$ (P21)

```
R30         (1.5)  OR LESS  CL=.90      DZHELYAD  81 CNTR   30 PI-P,ETAP N
```

$\eta' \to (\pi^0\mu^+\mu^-)/\textbf{total}\ (\textbf{units}\ 10^{-5})$ (P22)

```
R31         (6.0)  OR LESS  CL=.90      DZHELYAD  81 CNTR   30 PI-P,ETAP N
```

$\eta' \to (3\pi^0)/(\pi^0\pi^0\eta)$ (P6)/(P2)

```
R32          0.0075   0.0018            BINON     84 SPEC   30-40 PI-P,G GAM
R32        . . . . . . . . . . .
R32 FIT      0.0075   0.0018 FROM FIT
```

$\eta'(958)$ C−NONCONSERVING DECAY PARAMETER

```
      SEE THE NOTE ON ETA DECAY PARAMETERS IN THE STABLE PARTICLE
      FULL LISTINGS FOR DEFINITION OF THIS PARAMETER

A   DECAY ASYMMETRY PARAMETER FOR PI+ PI- GAMMA
A      152      .07       .08            RITTENBE  65 HBC     2.1-2.7 K-P
A      103      .00       .10            KALBFLEI  75 HBC     2.2 K-P
A      295     -.069      .078           GRIGORIA  75 STRC    2.1 PI-P
A          . . . . . . . . . . .
A   AVG        -0.001     0.049   AVERAGE
```

REFERENCES FOR $\eta'(958)$

```
DAUBER   64 PRL 13 449          DAUBER,SLATER,SMITH,STORK,TICHO        (UCLA)JP
    ALSO 64 DUBNA CONF 1 418    DAUBER,SLATER,L T SMITH,STORK,TICHO   (UCLA)
GOLDBERG 64 PRL 12 546          +GUNDZIK,LICHTMAN,CONNOLLY,HART,+(SYRA+BNL)
GOLDBERG 64 PRL 13 249          +GUNDZIK,LEITNER,CONNOLLY,HART,+ (SYRA+BNL)
KALBFLE1 64 PRL 12 527          KALBFLEISCH,ALVAREZ,BARBARO-GALTIERI,+(LRL)JP
KALBFLE2 64 PRL 13 349          G.R.KALBFLEISCH,O.DAHL,A.RITTENBERG    (LRL)JP

BADIER   65 PL 17 337           BADIER,DEMOULIN,BARLOUTAUD+(EPOL+SACL+AMST)
KIENZLE  65 PL 19 438           KIENZLE,MAGLIC,LEVRAT,LEFEBVRES +     (CERN)
RITTENBE 65 PRL 15 556          RITTENBERG,KALBFLEISCH             (LRL+BNL)
TRILLING 65 PL 19 427           +BROWN,GOLDHABERS,KADYK,SCANIO          (LRL)

COHN     66 PL 21 347           COHN,MCCULLOCH,BUGG,CONDO  (ORNL+TENN+UCND)
LONDON   66 PR 143 1034         LONDON,RAU,SAMIOS,GOLDBERG + (BNL+SYRACUSE)IJP
MARTIN   66 PL 22,352           MARTIN,CRITTENDEN,SCHROEDER      (INDIANA U)I

BARBARO- 68 PRL 20 349          BARBARO-GALTIERI,MATISON,RITTENBERG+  (LRL)I=0
BARLOUTA 68 PL 26 B  674        BARLOUTAUD+     (SACLAY+AMST+BGNA+REHO+EPOL)I=0
BOLLINI  68 NC 58 A  289        +BUHLER,DALPIAZ,MASSAM+      (CERN+BGNA+STRB)
DAVIS    68 PL 27 B 532         +AMMAR,MOTT,DAGAN,DERRICK,FIELDS (NWES+ANL)

DUFEY    69 PL 29 B 605         +GOBBI,POUCHON,CNOPS,+        (ETH+CERN+SACL)IJP
MOTT     69 PR 177 1966         +AMMAR,DAVIS,KROPAC,SLATE,DAGAN+ (NWES+ANL)
RITTENBE 69  UCRL-18863         ALAN RITTENBERG (THESIS)              (LRL)I=0

AGUILAR  70 PRL 25 1635         AGUILAR-BENITEZ,BASSANO,SAMIOS,BARNES+(BNL)
BENSINGE 70 PL 33 B 505         BENSINGER,ERWIN,THOMPSON,W.D.WALKER  (WISC)

BARDADIN 71 PR D4 2711          BARDADIN-OTWINOWSKA,HOFMOKL,MICHEJDA+(WARS)
BASILE1  71 NC 3 A 371          +BOLLINI,DALPIAZ,FRABETTI,+(CERN+BGNA+STRB)
BASILE2  71 NP B 33 29          +BOLLINI,DALPIAZ,FRABETTI,+(CERN+BGNA+STRB)
HARVEY   71 PRL 27 885          +MARQUIT,PETERSON,RHOADES,+      (MINN+MICH)
OGIEVETS 71 PL 35 B 69          OGIEVETSKY,TYBOR,ZASLAVSKY            (DUBNA)

AGUILAR  72 PR D 6 29           AGUILAR-BENITEZ,CHUNG,EISNER,SAMIOS   (BNL)
APEL     72 PL 40 B 680         +AUSLANDER,MULLER,BERTOLUCCI,+  (KARL+PISA)
BINNIE   72 PL 39 B 275         +CAMILLERI,DUANE,GARBUTT,BURTON+(LOIC+SHMP)
BLOODWOR 72 NP B 39 525         BLOODWORTH,JACKSON,PRENTICE,YOON  (TORONTO)
DALPIAZ  72 PL 42 B 377         +FRABETTI,MASSAM,NAVARRIA,ZICHICHI   (CERN)
RADER    72 PR D 6 3059         +ABOLINS,DAHL,DANBURG,DAVIES,HOCH,+   (LBL)

DANBURG  73 PR D 8 3744         +KALBFLEISCH,BORENSTEIN,CHAPMAN,+(BNL+MICH)  JP
JACOBS   73 PR D 8 18           +CHANG,GAUTHIER,+       (BRAN+UMD+SYRA+TUFT)  JP
KALBFLEI 73 PRL 31 333          KALBFLEISCH,CHAPMAN,+          (BNL+MICH+LBL)  JP

BALTAY   74 PR D9 2999          +COHEN,CSORNA,HABIBI,KALELKAR,+ (COLU+BING)  JP
DUANE    74 PRL 32 425          +BINNIE,CAMILLERI,CARR,DEBENHAM+(LOIC+SHMP)
GAULT    74 NC 24 A 259         +JONES,SCADRON,THEWS         (DURH+LOIC+ARIZ)
KALBFLEI 74 PR D10 916          G.R.KALBFLEISCH                         (BNL)

GRIGORIA 75 NP B91 232          GRIGORIAN,LADAGE,MELLEMA,RUDNICK,+   (UCLA)
KALBFLEI 75 PR D11 987          KALBFLEISCH,STRAND,CHAPMAN        (BNL+MICH)

CERRADA  77 NP B 126 189        +WAGNER,BLOCKZIJL,+     (CERN+AMST+NIJM+OXF)  JP
DELAGUIL 77 PR D16 2833         F.DEL AGUILA AND M.G.DONCEL      (BARCELONA)  JP
GESSAROL 77 NP B 126 382        GESSAROLI,+  (BGNA+FIRZ+GENO+MILA+OXF+PAVI)
LEDNICKY 77  E2-10521,22,23     R.LEDNICKY                            (JINR)  JP
ZANFINO  77 PRL 38 930          +BROCKMAN,DANKOWYCH,+ (CARL+MCGI+OHIO+TNTO)

ABRAMS   79 PRL 43 477          +ALAM,BLOCKER,BOYARSKI,+          (SLAC+LBL)
APEL     79 PL 83 B 131         +AUGENSTEIN,BERTOLUCCI(KARL+PISA+SERP+WIEN)
BINNIE   79 PL 83 B 141         +CARR,DEBENHAM,JONES,KARAMI,KEYNE+   (LOIC)
DZHELYAD 79 PL B 88 379         DZHELYADIN,GOLOVKIN,GRITZUK,KACHANOV+(SERP)

VIKTOROV 80 SJNP 32 520         +GOLOVKIN,DZHELYADIN,ZAITSEV,MUKHIN,+(NOVO)

DZHELYAD 81 PL 105 B 239        DZHELYADIN,GOLOVKIN,KONSTANTINOV,+   (SERP)

BARTEL   82 PL 113 B 190        +CORDS+(DESY+HAMB+HEID+LANC+MCHS+RHEL+TOKY)
BICKERST 82 ZPHY C 16 171       BICKERSTAFF,MCKELLAR                  (MELB)

BEHREND  83 PL 125 B 518        +D-AGOSTINI+(DESY+KARL+MPIM+LALO+LPNP+SACL)
    ALSO 82 PL 114 B 378        BEHREND+    (DESY+KARL+MPIM+LALO+LPNP+SACL)
JENNI    83 PR D 27 1031        +BURKE,TELNOV,ABRAMS,BLOCKER+     (SLAC+LBL)
```

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ALTHOFF  84 PL 147 B 487                       (TASSO COLLABORATION)
BERGER   84 PL 142 B 125         (AACH+BERG+DESY+GLAS+HAMB+UMD+SIEG+TELA+)
BINON    84 PL 140 B 264     +DONSKOV,DUTEIL,+      (SERP+BELG+LAPP+CERN)

SENS     85  SLAC-PUB-3754    PHYSICS IN COLLISION V CONFERENCE    (SLAC)
```

$f_0(975)$ was $S(975)$

$I^G(J^{PC}) = 0^+(0^{++})$

```
FORMERLY CALLED S*
UNDER THIS ENTRY WE LIST PARAMETERS OF THE POLE IN
THE ISOSCALAR S-WAVE.

FOR EARLY WORK USING BREIT-WIGNER OR SCATTERING
LENGTH PARAMETRIZATION IN FITS TO THE K KBAR MASS
SPECTRUM, SEE REFERENCE SECTION AND OUR 1972 EDITION.
```

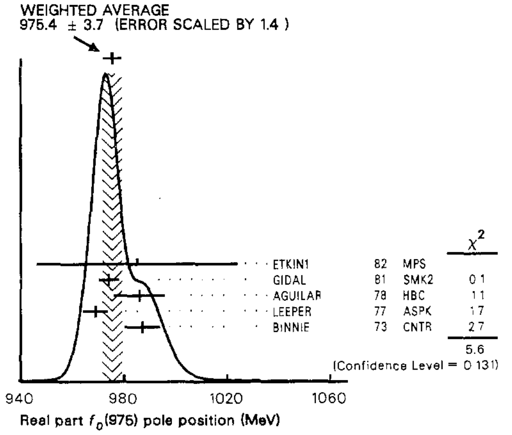
$f_0(975)$ MASS OR REAL PART OF POLE POSITION (MeV)

```
M1  POLE POSITION DETERMINATIONS
M1  R     (997.)     (6.)              PROTOPOPE 73 HBC      PI+ P
M1  A     (997.)                       ESTABROOK 73 ASPK     17 PI-P,PI+PI-N
M1  R    (1012.)     (6.)              GRAYER    73 ASPK     17 PI-P,PI+PI-N
M1  R    (1007.)    (20.)              HYAMS     73 ASPK     17 PI-P,N PI+PI-
M1  A     (986.)     (5.)              FUJII     75 RVUE     17 PI-P,PI+PI-N
M1  AD    (998.0)    (7.0)             BOHACIK   80 RVUE
M1  E     (988.)                       IRVING    81 RVUE
M1  F     (966.)                       IRVING    81 RVUE

M2          987.      7.               BINNIE    73 CNTR     PI- P,MM N
M2          969.0     5.0              LEEPER    77 ASPK     2-2.4 PI-P
M2   C      986.     10.               AGUILAR   78 HBC      .7 PBAR P, KS KS
M2         (986.)                      MARTIN    79 RVUE
M2          974.0     4.0              GIDAL     81 SMK2     J/PSI DECAY
M2   G      985.0    39.0              ETKIN1    82 MPS      23 PI-P,2KOS N
M2         . . . . . . . . . . .
M2  AVG     975.4     3.7     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
                             (SEE IDEOGRAM BELOW)

M3  MASS DETERMINATIONS (REAL PART OF MASS MATRIX EIGENVALUE)
M3   B     (975.)                      ACHASOV   80 RVUE
M3   B     (985.)                      TORNQVIST 82 RVUE

M   A   FROM SINGLE CHANNEL FIT TO HYAMS 73 DATA.
M    B  COUPLED CHANNEL ANALYSIS WITH FINITE WIDTH CORRECTIONS.
M    D  POLE POSITIONS FROM ALMOST MODEL-INDEPENDENT PARAMETRIZATION
M    C  FROM COUPLED CHANNEL FIT TO HYAMS 73  AND PROTOPOPESCU 73 DATA.
M    C  WITH A SIMULTANEOUS FIT TO  THE PI PI PHASE-SHIFTS,
M    C  INELASTICITY AND TO  THE KS KS INVARIANT MASS.
M   E   FROM COUPLED CHANNEL ANALYSIS OF PI N --> PI PI N OR K KBAR N DATA
M   E   FROM GRAYER 73 AND COHEN 80
M   F   SIMILAR TO (E), BUT OMIT PI N --> PI PI N MOMENTS, AND INCLUDE
M   F   K- P --> PI+ PI- Y DATA
M   R   INCLUDED IN AGUILAR 78 FIT
M    G  ETKIN1 82 QUOTES ERRORS +9/-39 MEV. WE USE +-39 MEV IN THE AVERAGE.
```



$f_0(975)$ WIDTH OR IMAG PART OF POLE POSITION (MeV)

```
                                                                     (MEV)
W1  POLE POSITION DETERMINATIONS (CORRESPONDS TO HALF-WIDTH,NOT FULL WIDTH)
W1  R      (27.)     (8.)              PROTOPOPE 73 HBC      7. PI+ P
W1  A       (5.)                       ESTABROOK 73 ASPK     17 PI-P,PI+PI-N
W1  R      (16.)     (5.)              GRAYER    73 ASPK     17 PI-P,PI+PI-N
W1  R      (15.)     (5.)              HYAMS     73 ASPK     17 PI-P,N PI+PI-
W1  A      (19.)     (3.)              FUJII     75 RVUE     17 PI-P,PI+PI-N
W1  AD     (19.0)    (6.0)             BOHACIK   80 RVUE
W1  E       (8.)                       IRVING    81 RVUE
W1  F      (24.)                       IRVING    81 RVUE

W2          24.       7.               BINNIE    73 CNTR     PI- P,MM N
W2          15.0      4.0              LEEPER    77 ASPK     2-2.4 PI-P
W2   C      50.      40.               AGUILAR   78 HBC      .7 PBAR P, KS KS
W2          (7.)                       MARTIN    79 RVUE
W2          14.0      5.0              GIDAL     81 SMK2     J/PSI DECAY
W2          60.0    141.0      10.0    ETKIN1    82 MPS      23 PI-P,2KOS N
W2         . . . . . . . . . . .
W2  AVG     16.4      2.8      AVERAGE

W3  FULL WIDTH DETERMINATIONS (FROM IMAG PART OF MASS MATRIX EIGENVALUE)
W3   B        70 TO 300                ACHASOV   80 RVUE
W3   B       (400.)   APPROX.          TORNQVIST 82 RVUE

W   A   FROM SINGLE CHANNEL FIT TO HYAMS 73 DATA.
W    B  COUPLED CHANNEL ANALYSIS WITH FINITE WIDTH CORRECTIONS.
W    C  FROM COUPLED CHANNEL FIT TO HYAMS 73  AND PROTOPOPESCU 73 DATA.
W    C  WITH A SIMULTANEOUS FIT TO  THE PI PI PHASE-SHIFTS,
W    C  INELASTICITY AND TO  THE KS KS INVARIANT MASS.
W    D  POLE POSITIONS FROM ALMOST MODEL-INDEPENDENT PARAMETRIZATION
W   E   FROM COUPLED CHANNEL ANALYSIS OF PI N --> PI PI N OR K KBAR N DATA
W   E   FROM GRAYER 73 AND COHEN 80
W   F   SIMILAR TO (E), BUT OMIT PI N --> PI PI N MOMENTS, AND INCLUDE
W   F   K- P --> PI+ PI- Y DATA
W   R   INCLUDED IN AGUILAR 78 FIT
```

$f_0(975)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_0(975) \rightarrow K\bar{K}$	498+ 498
P2	$f_0(975) \rightarrow \pi\pi$	140+ 140
P3	$f_0(975) \rightarrow \eta\eta$	549+ 549

$f_0(975)$ BRANCHING RATIOS

$f_0(975) \rightarrow (\pi\pi)$/total (P2)

```
R1           (0.71)                     HYAMS     75 ASPK    17.2 PI-P,PI+PI-
R1            0.78     0.03             WETZEL    76 OSPK    8.9 PI-P,KS KS N
R1            0.81     0.09      0.04   CASON     78 STRC    7. PI- P,KS KS N
R1            0.67     0.09             LOVERRE   80 HBC     4. PI- P,K K N
R1         . . . . . . . . . . .
R1  AVG       0.776    0.026   AVERAGE
```

REFERENCES FOR $f_0(975)$

```
WANG     61 JETP 13 323          WANG TSU-TSENG,VEKSLER,VRANA,+        (JINR)

BIGI     62 CERN CONF 247        A BIGI,S BRANDT, R CARRARA +          (CERN)
BINGHAM  62 CERN CONF 240        H H BINGHAM,M BLOCH +            (EPOL+CERN)
ERWIN    62 PRL 9 34             ERWIN,HOYER,MARCH,WALKER,WANGLER (WISC+BNL)

BALTAY   64 DUBNA CONF 1 409     BALTAY,LACH,CRENNELL,OREN,STUMP +(YALE+BNL)
BARMIN   64 DUBNA CONF 1 433     BARMIN,DOLGOLENKO,YEROFEEV,KRESTNI+  (ITEP)

CRENNELL 66 PRL 16 1025          CRENNELL,KALBFLEISCH,LAI,SCARR,SCHU+  (BNL)
HESS     66 PRL 17 1109          +DAHL+HARDY+KIRZ+MILLER               (LRL)

BARLOW   67 NC 50A 701           +LILLESTOL+MONTANET+  (CERN+CDEF+IRAD+LIVP)
BEUSCH   67 PL 25 B 357          +FISCHER,GOBBI,ASTBURY+          (ETH+CERN)
DAHL     67 PR 163 1377          +HARDY+HESS+KIRZ+MILLER               (LRL)

ALITTI   68 PRL 21 1705          +BARNES,CRENNELL,FLAMINIO,GOLDBERG,+  (BNL)
LAI      68 PHILAD.CONF.P.303 KWAN WU LAI                              (BNL)
PHELAN   68 THESIS               JAMES J. PHELAN        (ANL+ST.LOUIS UNIV)
   ALSO  68 PRL 21 316           HOANG,EARTLY,PHELAN,ROBERTS+(ANL+CHIC+NDAM)

AGUILAR- 69 PL 29 B  241         M.AGUILAR-BENITEZ,J.BARLOW,+    (CERN+CDEF)
   ALSO  69 NP B 14 195          M.AGUILAR-BENITEZ,J.BARLOW,+    (CERN+CDEF)
HOANG    69 NC 61 A 325          T.F.HOANG                             (ANL)
HOANG    69 PR 184  1363         +EARTLY,PHELAN,ROBERTS,+         (ANL+ILLC)

BADIER   70 NP B 22 512          +BONNET,DREVILLON,BAUBILLIER,+  (EPOL+IPNP)
BATON    70 PL 33 B 528          +LAURENS,REIGNIER                  (SACLAY)
BEUSCH   70 PHILA.CONF.P.185     W.BEUSCH                         (ETH+CERN)
HYAMS    70 PHILA.CONF.P.41      +KOCH,BEUSCH,+    (CERN+MPIM+ETH+LOIC+HAWA)
   ALSO  70 NP B 22 189          HYAMS,KOCH,POTTER,VON LINDERN,+ (CERN+MPIM)
OH       70 PR D 1 2494          +GARFINKEL,MORSE,WALKER,PRENTICE(WISC+TNTO)

ALSTON-G 71 PL 36 B 152          ALSTON-GARNJOST,BARBARO-GALTIERI,+    (LBL)

BASDEVAN 72 PL 41 B 178          BASDEVANT,FROGGATT,PETERSEN          (CERN)
DAMERI   72 NC 9 A 1             +BORZATTA,GOUSSU,+         (GENO+MILA+SACL)
DUBOC    72 NP B 46 429          +GOLDBERG,MAKOWSKI,DONALD,+     (LPNP+LIVP)
FLATTE   72 PL 38 B 232          +ALSTON-GARNJOST,BARBARO-GALTIERI,+   (LBL)
GRAYER   72 PHIL.CONF.PROC. 5 +HYAMS,JONES,SCHLEIN,BLUM,DIETL+(CERN+MPIM)
WILLIAMS 72 PR D 6 3178          P.K.WILLIAMS                          (FSU)

BINNIE   73 PRL 31 1534          +CARR,DEBENHAM,DUANE,GARBUTT,+  (LOIC+SHMP)
DIAMOND  73 PR D 7 1977          +BINKLEY,+        (WISC+DUKE+COLO+TNTO+OHIO)
ESTABROO 73  TALLAHASSEE         ESTABROOKS,MARTIN,GRAYER,HYAMS+ (CERN+MPIM)
FUJII    73 NC 13 A 311          Y.FUJII,M.KATO                      (TOKYO)
GRAYER   73  TALLAHASSEE         +HYAMS,JONES,BLUM,DIETL,KOCH+   (CERN+MPIM)
HYAMS    73 NP B 64 134          +JONES,WEILHAMMER,BLUM,DIETL,+  (CERN+MPIM)
OCHS     73 THESIS               W.OCHS                               (MPIM)
PROTOPOP 73 PR D 7 1280          PROTOPOPESCU,GARNJOST,GALTIERI,FLATTE+(LBL)

GRAYER   74 NP B 75 189          +HYAMS,JONES,BLUM,DIETL,KOCH+   (CERN+MPIM)
GRAYER   74 NP B 76 375          +HYAMS,JONES,BLUM,DIETL         (CERN+MPIM)
MORGAN   74 PL 51B 71            D.MORGAN                             (RHEL)

FUJII    75 NP B85 179           Y.FUJII,M.FUKUGITA                   (TOKY)
HYAMS    75 NP B 100 205         +JONES,WEILHAMMER,BLUM,DIETL+   (CERN+MPIM)
MORGAN   75 ARGONNE CONF. 45     D. MORGAN                            (RHEL)
PAWLICKI 75 PR D12 631           +AYRES,DIEBOLD,GREENE,KRAMER,WICKLUND (ANL)

BRANDEB  76 NP B 104 413         +CARNEGIE,CASHMORE,DAVIER,LASINSKI,+ (SLAC)
BUTTRAM  76 PR D 13 1153         +CRAWLEY,DUKE,LAMB,LEEPER,PETERSON    (ISU)
CERRADA  76 PL 62 B 353          +GONZALEZ-ARROYO,RUBIO,YNDURAIN (CERN+MADR)
FLATTE   76 PL 63 B 228          S.M.FLATTE                           (CERN)
WETZEL   76 NP B 115 208         +FREUDENREICH,BEUSCH,+       (ETH+CERN+LOIC)
WILKINS  76 PR D 13 1831         +ALBRIGHT,S+V HAGOPIAN,LANNUTTI       (FSU)

FROGATT  77 NP B 129 89          +PETERSEN             (GLASGOW+COPENHAGEN)
LEEPER   77 PR D 16 2054         +BUTTRAM,CRAWLEY,DUKE,LAMB,PETERSON   (ISU)
MARTIN   77 NP B 121 514         +OZMUTLU,SQUIRES                   (DURHAM)
PAWLICKI 77 PR D 15 3196         +AYRES,COHEN,DIEBOLD,KRAMER,WICKLUND  (ANL)I J

AGUILAR  78 NP B 140 73          +CERRADA,+         (MADRID+BOMBAY+CERN+PARIS)
BALAND   78 NP B 140 220         +GRARD,JOHNSON,+ (MONS+BELG+CERN+LOIC+LALO)
CASON    78 PRL 41 271           +BAUMBAUGH,BISHOP,BISWAS,KENNEY,+(NDAM+ANL)
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ACHASOV  79 PL 88 B 367        +DEVYANIN,SHESTAKOV                (NOVO)
APEL     79 NP B 160 42        +AUSLANDER,MULLER,REHAK+       (KARL+PISA)
BECKER   79 NP B 151  46       +BLANAR,BLUM,CERRADA+ (MPIM+CERN+ZEEM+CRAC)
CORDEN   79 NP B 157 250       +DOWELL,GARVEY,JOBES,+(BIRM+RHEL+TELA+LOWC)  JP
ESTABROO 79 PR D 19 2678       P.ESTABROOKS                       (CARL)
GREENHUT 79 PR D 20 2326       +INTEMANN                          (SETO)
MARTIN   79 NP B 158 520       +OZMUTLU                           (DURH)I,JP
POLYCHRO 79 PR D 19 1317       POLYCHRONAKOS,CASON,BISHOP+    (NDAM+ANL)

ACHASOV  80 SJNP 32 566        +DEVYANIN,SHESTAKOV                (NOVO)
BOHACIK  80 PR D 21 1342       J.BOHACIK,H.KUHNELT      (BRATISLAVA+WIEN)
COHEN    80 PR D 22 2595       +AYRES,DIEBOLD,KRAMER,PAWLICKI+     (ANL)I,JP
LOVERRE  80 ZPHY C 6 187       +ARMENTEROS,DIONISI+  (CERN+CDEF+MADR+STOH)I,JP
WICKLUND 80 PRL 45 1469        +AYRES,COHEN,DIEBOLD,PAWLICKI       (ANL)

ACHASOV  81 PL 102 B 196       +DEVYANIN,SHESTAKOV                (NOVO)
AGUILAR  81 ZPHY C 10 299      AGUILAR-BENITEZ,DONE,MARTIN    (MADR+DURH)
GIDAL    81 PL 107 B 153       +GOLDHABER,GUY,MILLIKAN,ABRAMS,+ (SLAC+LBL)
IRVING   81 ZPHY C 10 45       +MARTIN,DONE                   (LIVP+DURH)
ROUSSARI 81 PL 105 B 304       ROUSSARIE,BURKE,ABRAMS,ALAM,+    (SLAC+LBL)

BARBER   82 ZPHY C 12 1        +DAINTON,BRODBECK,BROOKES,+(DARE+LANC+SHEF)
ETKIN1   82 PR D 25 1786       +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)
ETKIN2   82 PR D 25 2446       +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)
TORNQVIS 82 PRL 49 624         N.A.TORNQVIST                      (HELS)

MENNESSI 83 ZPHY C 16 241      G.MENNESSIER                       (MONP)
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$a_0(980)$
was $\delta(980)$

$I^G(J^{PC}) = 1^-(0^{++})$

OUR LATEST MINIREVIEW ON THIS PARTICLE
CAN BE FOUND IN THE 1984 EDITION.

$a_0(980)$ MASS (MeV)

```
M  ETA PI FINAL STATE ONLY.
M       10 (960.)      APPROX.           CHUNG S   68 HBC    -  3.2 PI-P
M       80 (975.0)                        DEFOIX    68 HBC   +-  1.2 PB P,ETA PI
M       15 (980.0)   (10.0)              MILLER    69 HBC    -  4.5 K-N,ETA PI
M       21 (948.0)    (7.0)              BARDADIN  71 HBC   +- 8 PI+P,P F1 PI
M
M       30  980.0     10.0               AMMAR     68 HBC   +-     ,5.5K-,ETA PI
M       20  970.0     15.0               BARNES    69 HBC    -  4-5 K-P,PI-ETA
M           980.      10.                CAMPBELL  69 DBC   +- 2.7 PI+ D
M      150  972.      10.                DEFOIX    72 HBC   +- 0.7 PBAR P,7 PI
M  C    70  989.0     10.0               WELLS     75 HBC    - 3.1-6 K-P,ETA PI
M       80  981.0      6.0               GAY       76 HBC    - 4.2 K-P,ETA PI
M           977.0      7.0               GRASSLER  77 HBC    - 16 PI-+P,ETA PI
M       47  980.      11.                CONFORTO  78 OSPK -  4.5 PI-P,P X-
M       50  978.0     16.0               CORDEN    78 OMEG +- 12-15PI-P,ETA PI
M    R 145  990.0      7.0               GURTU     79 HBC  +- 4.2 K- P,ETA PI
M    R 500  986.       3.                EVANGELIS 81 OMEG    12 PI-P,ETA3PIP
M           976.       6.                ATKINSON  84 OMEG +- 25-55GAM P,ETAPI  |
M
M   REVIEW ARTICLES
M   B       (982.)                       ACHASOV1  80 RVUE
M           (970.)                       TORNQVIST 82 RVUE
M           . . . . . . . . . .
M   AVG     982.6      1.9      AVERAGE

M  C    SYSTEMATIC ERROR 6 MEV DUE TO ENERGY CALIBRATION ADDED
M   B   COUPLED CHANNEL ANALYSIS WITH FINITE WIDTH CORRECTIONS.
M    R  FROM F1(1285) DECAY

M  K KBAR ONLY, SEE THE TYPED NOTE ABOVE
M      143(1003.3)     7.0+SYSTEMATIC ROSENFELD 65 RVUE +-
M  A   100(1016.)    (10.)              ASTIER    67 HBC  +-  0 PBAR P
M      316  976.       6.               DE BILLY  80 HBC  +- 1.2-2 PB P,D OMG

M  A    ASTIER 67 INCLUDES DATA OF BARLOW 67,CONFORTO 67,ARMENTEROS 65.
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$a_0(980)$ WIDTH (MeV)

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W  ETA PI  FINAL STATE ONLY
W      80  (25.0)                         DEFOIX    68 HBC  +-  1.2 PB P,ETA PI
W      20  (50.0)  OR LESS                BARNES    69 HBC   -  4-5 K-P,PI-ETA
W     150  (30.)      (5.)                DEFOIX    72 HBC  +- 0.7 PBAR P,7 PI
W      70  (16.0)    (25.0)     (16.0)    WELLS     75 HBC   - 3.1-6 K-P,ETA PI

W      30   80.0      30.0                AMMAR     68 HBC  +-     ,5.5K-,ETA PI
W           40.       15.                 CAMPBELL  69 DBC  +- 2.7 PI+ D
W      15   60.0      30.0                MILLER    69 HBC   -  4.5 K-N,ETA PI
W      21   31.0      28.0                BARDADIN  71 HBC  +- 8 PI+P,P F1 PI
W   N       55.0      15.0                GAY       76 HBC   - 4.2 K-P  ETA PI
W           44.0      22.0                GRASSLER  77 HBC   - 16 PI-+P,ETA PI
W      47   60.       50.       30.       CONFORTO  78 OSPK -  4.5 PI-P,P X-
W   D  50   86.0      60.0      50.0      CORDEN    78 OMEG +- 12-15PI-P,ETA PI
W   R 145   60.0      20.0                GURTU     79 HBC  +- 4.2 K- P,ETA PI
W   R 500   62.       15.                 EVANGELIS 81 OMEG    12 PI-P,ETA3PIP
W
W   REVIEW ARTICLES
W   F       80 TO 300                     FLATTE    76 RVUE -  4.2 K-P,ETA PI
W   B      103 TO 262                     ACHASOV1  80 RVUE
W   B     (500.)   APPROX.                TORNQVIST 82 RVUE
W         . . . . . . . . . .
W   AVG     53.7       6.7      AVERAGE

W   B   COUPLED CHANNEL ANALYSIS WITH FINITE WIDTH CORRECTIONS.
W  F    USING A TWO CHANNEL RESONANCE PARAMETRIZATION OF GAY 76 DATA.
W   N   THE ERROR IN THE PAPER IS WRONGLY QUOTED AT ONE POINT
W   R   FROM F1(1285) DECAY

W  K KBAR ONLY, SEE THE TYPED NOTE ABOVE
W     143  (57.0)    13.0+SYSTEMATIC ROSENFELD 65 RVUE +-
W  A  100  (25.) APPROX.                  ASTIER    67 HBC  +- SEE NOTE A ABOVE
W   M     (120.) APPROX.                  MORGAN    75 RVUE    1.2 PBAR P

W  A    ASTIER 67 INCLUDES DATA OF BARLOW 67,CONFORTO 67,ARMENTEROS 65.
W   M   FROM COUPLED CHANNEL FIT TO DUBOC 72 DATA
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$a_0(980)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$a_0(980) \rightarrow \eta\pi$	549+ 135
P2	$a_0(980) \rightarrow \rho\pi$	769+ 135
P3	$a_0(980) \rightarrow K\overline{K}$	498+ 498
P4	$a_0(980) \rightarrow \pi\eta'$	140+ 958

$a_0(980)$ BRANCHING RATIOS

$a_0(980) \rightarrow (\rho\pi)/(\eta\pi)$ (P2)/(P1)

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R1          (0.25) OR LESS  CL=.70   AMMAR      70 HBC  +- 4.1,5.5K-,ETA PI
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$a_0(980) \rightarrow (K\overline{K})/(\eta\pi)$ (P3)/(P1)

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R2  L       (0.25)   (0.08)          DEFOIX     72 HBC  +-  0.7 PBAR P
R2        SEEN                       GAY        76 HBC   - 4.2 K-P  ETA PI
R2   L      (0.7)    (0.3)           CORDEN     78 OMEG    12-15PI-P
R2  B       (0.75)TO 4.2             ACHASOV1   80 RVUE
R2  B   COUPLED CHANNEL ANALYSIS WITH FINITE WIDTH CORRECTIONS.
R2  L   FROM THE DECAY OF F1(1285).
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REFERENCES FOR $a_0(980)$

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TURKOT   63 SIENA CONF 1 661  +COLLINS,FUJII,KEMP+       (BNL+PITTSBURGH)

ARMENTER 65 PL 17 344         ARMENTEROS,EDWARDS, JACOBSEN +  (CERN+CDEF)
BARASH   65 PR  139 B  1659   +FRANZINI,KIRSCH,MILLER,STEINBERGER+ (COLU)
KIENZLE  65 PL   19  438      + MAGLIC,LEVRAT,LEFEBVRES +          (CERN)
ROSENFEL 65 OXFORD CONF 58    A H ROSENFELD                   (LRL--RVUE)

ALLEN D  66 PL 27  543        +GP FISHER,G GODDEN,L MARSHALL,SEARS (COLO)G=+
BALTAY   66 PR  142 B  932    +LACH,SANDWEISS,TAFT,YEH,STONEHILL+  (YALE)
FOCACCI  66 PRL  17  890      + KIENZLE,LEVRAT,MAGLIC,MARTIN       (CERN)
OOSTENS  66 PL   22  708      +CHAVANON,CROZON,TOCQUEVILLE  (SACLAY,CDEF)I=1

ALLISON  67 PL 25B 619        +CRUZ+        (OXF+MPIM+BIRM+RHEL+GLAS+LOIC)
ASTIER   67 PL  25 B  294     +MONTANET,BAUBILLIER,DUBOC+(CDEF+CERN+IRAD)
  ASTIER 67 INCLUDES DATA OF BARLOW 67,CONFORTO 67,ARMENTEROS 65.
BAILLON  67 NC 50A 393        +EDWARDS+D-ANDLAU+ASTIER+  (CERN+CDEF+IRAD)
BANNER 1 67 PL  25 B  300     +FAYOUX,HAMEL,ZSEMBERY,CHEZE+ (SACLAY+CAEN)
BANNER 2 67 PL 25 B 569       +CHEZE,HAMEL,MAREL,TEIGER+       (CDEF+SACL)
BARLOW   67 NC  50 A  701     +MONTANET,D-ANDLAU+   (CERN+CDEF+IRAD+LIVP)
CONFORTO 67 NP B3 469         CONFORTO,MARECHAL+    (CERN+CDEF+IPNP+LIVP)

AMMAR    68 PRL 21 1832       +DAVIS,KROPAC,DERRICK,FIELDS,+   (NWES+ANL)
CHUNG S  68 PR 165 1491        +O.DAHL, J. KIRZ, D.H.MILLER          (LRL)
DEFOIX   68 PL 28 B 253       +RIVET,SIAUD,CONFORTO+      (CDEF+IPNP+CERN)
GALTIERI 68 PRL 20 349        BARBARO-GALTIERI,MATISON,RITTENBERG+  (LRL)
JUHALA   68 PL 27 B 257       +LEACOCK,RHODE,KOPELMAN,LIBBY+  (IOWA+COLO)
SABRE CO 68 PL 26 B 674       BARLOUTAUD+       (SACL+AMST+BGNA+REHO+EPOL)

BARNES   69 PRL 23 610        +CHUNG,EISNER,BASSANO,GOLDBERG+  (BNL+SYRA)
CAMPBELL 69 PRL 22 1204       J.H.CAMPBELL,LICHTMAN,LOEFFLER,+   (PURDUE)
CRENNELL 69 PRL 22 1398       +KARSHON,KWAN WU LAI,+             (BNL+NYU)
JUHALA   69 PR 184  1461      +LEACOCK,RHODE,KOPELMAN,LIBBY,+  (ISU+COLO)
KRUSE    69 PR 177 1951       KRUSE,LOOS,GOLDWASSER            (ILLINOIS)
LIPKIN   69 PRL 22 212        +MESHKOV                         (REHO+NBS)   JP
MILLER   69 PL 29 B  255      D.H.MILLER,S.L.KRAMER,D.D.CARMONY,+(PURDUE)
    ALSO 69 PR 188 2011       YEN,AMMANN,CARMONY,ELSNER,+        (PURDUE)
SCHROEDE 69 PR 188  2081      SCHROEDER,KERNAN,FISHER,LIBBY,+  (ISU+COLO)

ABOLINS  70 PRL 25 469        +GRAVEN,MCCARTHY,G.SMITH,L.SMITH+ (LRL+UCD)
AMMAR    70 PR D 2 430        +KROPAC,DAVIS,DERRICK,+(KANS+NWES+ANL+WISC)
COOPER   70 NP B 23 605       +HANNER,MUSGRAVE,POLLARD,VOYVODIC     (ANL)
YIOU     70  THESIS, A 646    TCHIU-PUNG YIOU                     (ORSAY)

ANDERSON 71 PRL 26 108        +DIXIT,+   (CHIC+ANL+CARL+LASL+CNRC+NAGOYA)
BARDADIN 71 PR D4 2711        BARDADIN-OTWINOWSKA,HOFMOKL,MICHEJDA+(WARS)

BINNIE   72 PL 39 B 275       +CAMILLERI,DUANE,GARBUTT,BURTON+(LOIC+SHMP)
CHESHIRE 72 PRL 28 520        +HOFFMAN,GARFINKEL,+        (IOWA+ANL+PURD)
DEFOIX   72 NP B 44 125       +NASCIMENTO,BIZZARRI,+           (CDEF+CERN)
DUBOC    72 NP B 46 429       +GOLDBERG,MAKOWSKI,DONALD,+      (LPNP+LIVP)
HOLLOWAY 72 PHIL.CONF.PROC.133+HULD,KOETZ,KRUSE,BERNSTEIN,+    (ILL+ILLC)

ATHERTON 73 PL 43 B 249       +FRANEK,FRENCH,GHIDINI,HILPERT,+      (CERN)

BINNIE   74 PRL 32 392        +CAMILLERI,CARR,DEBENHAM,+       (LOIC+SHMP)
KALBFLEI 74 NP B69 279        KALBFLEISCH,VANDERBURG,+     (BNL+RUTG+IND)
MORGAN   74 PL 51B 71         D.MORGAN                              (RHEL)

BUTTRAM  75 PRL 35 970        +CRAWLEY,DUKE,LAMB,LEEPER,PETERSON     (ISU)
MORGAN   75 ARGONNE CONF. 45  D.MORGAN                              (RHEL)
WELLS    75 NP B 101 333      +RADOJICIC,ROSCOE,LYONS                (OXF)

GAY      76 PL 63 B 220       +CHALOUPKA,BLOKZIJL,HEINEN+(CERN+AMST+NIJM)  JP
FLATTE   76 PL 63 B 224       S.M.FLATTE                            (CERN)

GRASSLER 77 NP B 121 189      +      (AACH+BERL+BONN+CERN+CRAC+HEID+WARS)
IRVING   77 PL 70 B 217       A.C.IRVING                       (LIVERPOOL)
MARTIN   77 NP B 121 514      +OZMUTLU,SQUIRES                    (DURHAM)
MAY      77 PR D 16 1983      +ABRAMSON,ANDREWS,BUSNELLO,+     (ROCH+CORN)

CONFORTO 78 LNC 23 419        B+G CONFORTO,KEY+(RHEL+TNTO+CHIC+FNAL+WISC)
CORDEN   78 NP B 144 253      +CORBETT,ALEXANDER,+  (BIRM+RHEL+TELA+LOWC)
MARTIN   78 ANP  114 1        A.D.MARTIN,M.R.PENNINGTON             (CERN)

ACHASOV  79 PL 88 B 367       +DEVYANIN,SHESTAKOV                   (NOVO)
ESTABROO 79 PR D 19 2678      P.ESTABROOKS                          (CARL)
GURTU    79 NP B 151 181      +GAVILLET,BLOKZIJL,+   (CERN+ZEEM+NIJM+OXF)
MARTIN   79 NP B 158 520      +OZMUTLU                              (DURH)

ACHASOV1 80 SJNP 32 566       +DEVYANIN,SHESTAKOV                   (NOVO)
ACHASOV2 80 PL 96 B 168.      +DEVYANIN,SHESTAKOV                   (NOVO)
BRAMON   80 PL 93 B 65        +MASSO                                (BARC)
DE BILLY 80 NP B 176 1        +BRIAND,DUBOC,LEVY+   (CURI+LAUS+NEUC+GLAS)

EVANGELI 81 NP B 178 197      EVANGELISTA+(BARI+BONN+CERN+DARE+LIVP+MILA)

ACHASOV  82  TP-20-130        +DEVYANIN,SHESTAKOV                   (NOVO)
BICKERST 82 ZPHY C 16 171     BICKERSTAFF,MCKELLAR                  (MELB)
TORNQVIS 82 PRL 49 624        N.A.TORNQVIST                         (HELS)

BRAMON   83 PL 120 B 240      +MASSO                                (BARC)
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Meson Full Listings

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ATKINSON 84 PL 138 B 459       ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
BITUKOV  84 PL 144 B 133       +DOROFEEV,DZHELYADIN,GOLOVKIN,KULIK,+(SERP)
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$\phi(1020)$

$I^G(J^{PC}) = 0^-(1^{--})$

ϕ(1020) MASS (MeV)

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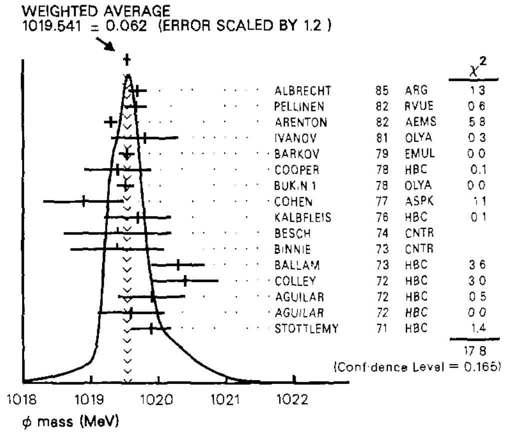
                WE ONLY AVERAGE MASS AND WIDTH VALUES WHEN THE
                SYSTEMATIC ERRORS HAVE BEEN EVALUATED.

M       410 1019.9      0.3             STOTTLEMY 71 HBC      2.9 K-P,Y K KBAR
M     D 120 1019.6      0.5             AGUILAR   72 HBC      3.9,4.6 K- P
M     D 100 1019.9      0.5             AGUILAR   72 HBC      3.9,4.6 K- P
M       131 1020.4      0.5             COLLEY    72 HBC      10.K+ P,K+ P PHI
M       100 1020.3      0.4             BALLAM    73 HBC      2.8 - 9.3 G P
M           1019.4      0.7             BINNIE    73 CNTR     PI-P,PHI N
M    AR 500(1019.5)    (0.6)            AYRES     74 ASPK     3-6PI/K-P,K+K-
M       984 1019.4      0.8             BESCH     74 CNTR     2 GAMMA P,PK+K-
M    AR 170(1020.3)    (0.4)            DE GROOT  74 HBC      4.2 K-P,L K+K-
M       454 1019.7      0.5             KALBFLEIS 76 HBC      2.18 K-P,K KBAR
M    AR1300(1019.7)    (0.2)            AKERLOF   77 SPEC     400 P+A,K+K-
M    AR 905(1020.4)    (0.3)            BALDI     77 CNTR     10 K-P,K-PHI P
M    A  383(1020.0)    (1.0)            BALDI     77 CNTR     10 PI-P,PI-PHI P
M    AR2504(1020.0)    (0.2)            BALDI     77 CNTR     10 K+P,K+PHI P
M    AR 721(1022.0)    (1.0)            BALDI     77 CNTR     10 P P,P PHI P
M       800 1018.9      0.6             COHEN     77 ASPK     6 PI- PN,K+K-PN
M           1019.52     0.13            BUKIN 1   78 OLYA     E+E- COLL.BEAMS
M       337 1019.4      0.5             COOPER    78 HBC      .7-.8 PB P,KS K0
M      1100 1019.54     0.12            BARKOV    79 EMUL     E+E- COLL.BEAMS
M    R 6730(1019.7)    (0.1)            DAUM      81 SPEC     P BE,K+ K- X
M   C   766 1019.8      0.5             IVANOV    81 OLYA     1-1.4 E+E-,K+K-    |
M      1500 1019.3      0.1             ARENTON   82 AEMS     11.8 POL.P P,KK
M     25080 1019.67     0.17            PELLINEN  82 RVUE
M    A     (1021.0)    (0.2)            ARMSTRONG 83 OMEG     18.5 K-P,K-K+LAM
M    A     (1020.0)    (0.5)            ARMSTRONG 83 OMEG     18.5 K-P,K-K+LAM
M    A     (1019.7)    (0.3)            BARATE    83 GOLI     190 PI-BE,2MU
M   C  5079 1019.7      0.14            ALBRECHT  85 ARG      E+E-,HADRONS       |
M           . . . . . . . . . .
M    AVG    1019.541    0.062   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
                        (SEE IDEOGRAM BELOW)

M    A   SYSTEMATIC ERRORS NOT EVALUATED.
M   C    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
M     D  MASS ERRORS ENLARGED BY US TO WIDTH/SQRT(N),SEE K* TYPED NOTE
M     R  INCLUDED IN PELLINEN 82 RVUE
```



ϕ(1020) WIDTH (MeV)

```
W               WE ONLY AVERAGE MASS AND WIDTH VALUES WHEN THE
W               SYSTEMATIC ERORRS HAVE BEEN EVALUATED.

W     D 150     4.2       1.4           AUGUSTIN  69 OSPK     E+ E- COLL.BEAMS
W               4.09      0.29          BIZOT     70 OSPK     E+ E- COLL.BEAMS
W     D 681     4.67      0.72          BALAKIN   71 OSPK      E+ E- COLL.BEAM
W     D 120     4.6       1.7           AGUILAR   72 HBC      3.9,4.6 K- P
W     D 100     4.7       1.9           AGUILAR   72 HBC      3.9,4.6 K- P
W     D 131     5.0       1.8           COLLEY    72 HBC      10.K+ P,K+ P PHI
W     D 454     3.8       0.7           BORENSTEI 72 HBC      2.18 K-P,K KBAR
W     D 100     3.8       1.5           BALLAM    73 HBC      2.8 - 9.3 G P
W               4.5       1.1           BINNIE    73 CNTR     PI-P,PHI N
W    AD 500    (4.5)     (0.8)          AYRES     74 ASPK     3-6PI/K-P,K+K-
W     D 984     4.4       0.6           BESCH     74 CNTR     2 GAMMA P,PK+K-
W               3.81      0.37          COSME 2   74 OSPK     E+E- COLL.BEAMS
W    AD 170    (4.2)     (1.3)          DE GROOT  74 HBC      4.2 K-P,L K+K-
W   A D1300     4.5       0.50          AKERLOF   77 SPEC     400 P+A,K+K-
W   B D3681     4.36      0.29          BUKIN 1   78 OLYA     E+E- COLL.BEAMS
W     D 337     3.6       0.8           COOPER    78 HBC      .7-.8 PB P,KS K0
W     D1100     4.58      0.55          BARKOV    79 EMUL     E+E- COLL.BEAMS
W     D         4.3       0.6           CORDIER   80 WIRE     E+E-,PI+PI-PI0
W     D 766     4.2       0.6           IVANOV    81 OLYA     1-1.4 E+E-,K+K-
W      1500     4.5       0.7           ARENTON   82 AEMS     11.8 POL.P P,KK
W           . . . . . . . . . .
W    AVG        4.22      0.13    AVERAGE

W    A   SYSTEMATIC ERRORS NOT EVALUATED.
W   B    NUMBER OF EVENTS INCLUDES A SMALL BACKGROUND CONTRIBUTION.
W     D  WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N), SEE K* TYPED NOTE
```

ϕ(1020) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\phi \to K^+K^-$	494+ 494
P2	$\phi \to K_L^0 K_S^0$	498+ 498
P3	$\phi \to \pi^+\pi^-\pi^0$(including $\rho\pi$)	140+ 140+ 135
P4	$\phi \to \eta\gamma$	549+ 0
P5	$\phi \to e^+e^-$	.511+.511
P6	$\phi \to \mu^+\mu^-$	106+ 106
P7	$\phi \to \pi^0\gamma$	135+ 0
P8	$\phi \to \pi^+\pi^-$(VIOLATES G)	140+ 140
P9	$\phi \to \pi^+\pi^-\gamma$	140+ 140+ 0
P10	$\phi \to \omega\gamma$(VIOLATES C)	783+ 0
P11	$\phi \to \eta\pi^0$(VIOLATES C)	549+ 135
P12	$\phi \to \rho\gamma$(VIOLATES C)	769+ 0
P13	$\phi \to \eta$ + neutrals	
P14	$\phi \to 5\pi$	140+ 140+ 140+ 140+
P15	$\phi \to \pi^+\pi^-\pi^+\pi^-$(VIOLATES G)	140+ 140+ 140+ 140
P16	$\phi \to \rho\pi$	769+ 140

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle\delta P_i \delta P_i\rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle\delta P_i \delta P_j\rangle/(\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
          P 1         P 2         P 3         P 4
 P 1 .4950+-.0152
 P 2   -.4602  .3434+-.0092
 P 3   -.8005     -.1623  .1488+-.0137
 P 4   -.0118     -.0261     -.0111  .0128+-.0006
```

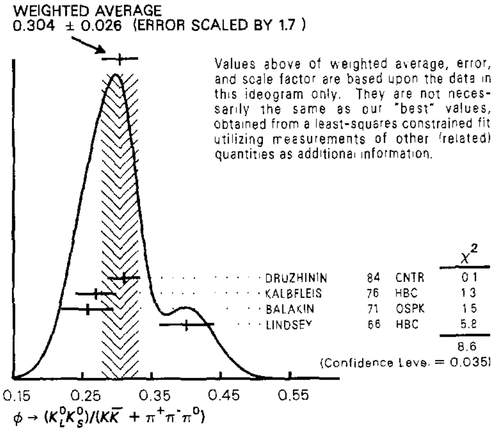
ϕ(1020) BRANCHING RATIOS

$\phi \to (K^+K^-)/(K\bar{K} + \pi^+\pi^-\pi^0)$ (P1)/(P1+P2+P3)

```
R1     252    0.48     0.04             LINDSEY   66 HBC       2.7 K-P
R1            0.540    0.034            BALAKIN   71 OSPK      E+ E- COLL.BEAM
R1            0.486    0.044            CHATELUS  71 OSPK     E+ E- COLL.BEAMS
R1     270    0.49     0.06             DE GROOT  74 HBC      4.2 K-P,L PHI
R1     321    0.45     0.05             KALBFLEIS 76 HBC      2.18 K-P
R1            . . . . . . . . . .
R1   AVG      0.497    0.019    AVERAGE
R1   FIT      0.501    0.015   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.9)
```

$\phi \to (K_L^0 K_S^0)/(K\bar{K} + \pi^+\pi^-\pi^0)$ (P2)/(P1+P2+P3)

```
R2     167    0.40     0.04             LINDSEY   66 HBC       2.7 K-P
R2            0.257    0.038            BALAKIN   71 OSPK     E+ E- COLL.BEAMS
R2     133    0.27     0.03             KALBFLEIS 76 HBC      2.18 K-P
R2            0.310    0.024            DRUZHININ 84 CNTR     E+E-,KL KS          |
R2            . . . . . . . . . .
R2   AVG      0.304    0.026    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)
R2   FIT      0.3479   0.0094 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
                       (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$\phi \to (\pi^+\pi^-\pi^0$(including$\rho\pi$))/total (P3)

```
R3 E          0.139    0.007              PARROUR2  76 OSPK     E+E- COLL.BEAMS
R3 E    USING TOTAL WIDTH 4.1 MEV. THE 3PI MODE IS MORE THAN 80 PER CENT
R3 E    RHO PI AT THE 90 PER CENT C.L.
R3            . . . . . . . . . .
R3  FIT       0.149    0.014   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.3)
```

$\phi \rightarrow (K_L^0 K_S^0)/(K\bar{K})$ (P2)/(P1+P2)

```
R5      10   0.40     0.10                SCHLEIN   63 HBC      2.0 K-P
R5      52   0.48     0.07                BADIER    65 HBC      3.0 K-P
R5           0.44     0.07                LONDON    66 HBC      2.2 K-P
R5         . . . . . . . . . .
R5  AVG      0.448    0.044   AVERAGE
R5  FIT      0.410    0.012  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5)
```

$\phi \rightarrow (\pi^+\pi^-\pi^0(\text{including}\rho\,\pi))/(K\bar{K})$ (P3)/(P1+P2)

```
R6           0.30     0.15                LONDON    66 HBC      2.2 K-P
R6           0.237    0.039               CERRADA   77 HBC     4.2 K-P,LAM 3PI
R6         . . . . . . . . . .
R6  AVG      0.241    0.038   AVERAGE
R6  FIT      0.177    0.019  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.3)
```

$\phi \rightarrow (\pi^+\pi^-\pi^0(\text{including}\rho\,\pi))/(K_L^0 K_S^0)$ (P3)/(P2)

```
R7           0.47     0.06                COSME 1   74 OSPK    E+E- COLL.BEAMS
R7           0.56     0.13                BUKIN 1   78 OLYA    E+ E- COLL.BEAMS
R7         . . . . . . . . . .
R7  AVG      0.486    0.054   AVERAGE
R7  FIT      0.433    0.043  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.0)
```

$\phi \rightarrow (\mu^+\mu^-)$/total (units 10^{-4}) (P6)

```
R10          2.34     1.01                MOY       69 CNTR     PHOTOPROD.
R10          2.17     0.60                EARLES    70 CNTR     6.0 BREMSSTR.
R10          2.69     0.46                HAYES     71 CNTR    PHOTOPROD.
R10        . . . . . . . . . .
R10 AVG      2.48     0.34    AVERAGE
```

$\phi \rightarrow (\eta\,\gamma)$/total (P4)

```
R11A    54   0.015    0.004               COSME     76 OSPK    E+E- COLL.BEAMS
R11B        (0.024)OR LESS  CL=0.95       COSME     76 OSPK    E+E- COLL.BEAMS
R11          0.0135   0.0029              ANDREWS   77 CNTR    6.7-10 GAMMA CU
R11    290   0.0088   0.0020              KURDADZE  83 OLYA     E+E-,3 GAMMA
R11A         0.0130   0.0006              DRUZHININ 84 CNTR    E+E-,3 GAMMA
R11C         0.014    0.002               DRUZHININ 84 CNTR    E+E-,6 GAMMA
R11        . . . . . . . . . .
R11 AVG     0.01282  0.00066  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
R11 FIT     0.01283  0.00057 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)

R11A    FROM 2GAMMA DECAY MODE OF ETA
R11B    FROM PI+PI-PI0 DECAY MODE OF ETA
R11C    FROM 3PI0 DECAY MODE OF ETA
```

$\phi \rightarrow (\pi^+\pi^-\gamma)$/total (P9)

```
R12         (0.04) OR LESS                LINDSEY   65 HBC      2.7 K-P
R12         (0.007)OR LESS  CL=.90        COSME 1   74 OSPK    E+E- COLL.BEAMS
R12          (.06) OR LESS  CL=.90        KALBFLEI  75 HBC     2.2 K- P,GAMMA +
```

$\phi \rightarrow (\omega\,\gamma)$/total (P10)

```
R14         (0.05) OR LESS                LINDSEY   66 HBC      2.7 K-P
```

$\phi \rightarrow (\rho\,\gamma)$/total (P12)

```
R15         (0.02) OR LESS                LINDSEY   66 HBC      2.7 K-P
```

$\phi \rightarrow (e^+e^-)$/total (units 10^{-4}) (P5)

```
R16          2.81     0.25                BALAKIN   71 OSPK    E+ E- COLL.BEAMS
R16          3.50     0.27                CHATELUS  71 OSPK    E+ E- COLL.BEAMS
R16          3.3      0.3                 COSME 1   74 OSPK    E+ E- COLL.BEAMS
R16  E       3.10     0.14                PARROUR1  76 OSPK    E+ E- COLL.BEAMS
R16          3.00     0.21                BUKIN 1   78 OLYA    E+ E- COLL.BEAMS
R16        . . . . . . . . . .
R16 AVG      3.107    0.096   AVERAGE

R16  E    USING TOTAL WIDTH 4.2 MEV. THEY DETECT 3PI MODE AND OBSERVE
R16  E    SIGNIFICANT INTERFERENCE WITH OMEGA TAIL. THIS IS ACCOUNTED FOR
R16  E    IN THE RESULT QUOTED ABOVE
```

$\phi \rightarrow (\pi^0\gamma)$/total (units 10^{-3}) (P7)

```
R17     32   1.4      0.5                 COSME     76 OSPK    E+E- COLL. BEAMS
R17          1.30     0.13                DRUZHININ 84 CNTR    E+E-,3 GAMMA
R17        . . . . . . . . . .
R17 AVG      1.31     0.13    AVERAGE
```

$\phi \rightarrow (\pi^+\pi^-)$/total (units 10^{-4}) (P8)

```
R18         (2.7)  OR LESS  CL=.95   ALVENSLE  72 OSPK    GAMMA+C
R18         (4.0)  OR LESS  CL=.95   JULLIAN   76 OSPK    E+ E- COLL.BEAMS
R18         (6.6)  OR LESS  CL=.95   BUKIN 2   78 OLYA    E+ E- COLL.BEAMS
R18A         1.94     1.03     0.81  VASSERMAN 81 OLYA    E+ E- COLL.BEAMS
R18A    USING PHI INTO (E+ E-)/TOTAL = 3.1
```

$\phi \rightarrow (K_L^0 K_S^0)/(K^+K^-)$ (P2)/(P1)

```
R19    144   0.89     0.10                AGUILAR   72 HBC     3.9,4.6 K- P
R19    125  (1.15)   (0.15)               COLLEY    72 HBC     10.K+ P,K+ P PHI
R19          0.71     0.05                LAVEN     77 HBC     10 K-P,K+K-LAMBD
R19          0.71     0.08                LYONS     77 HBC     3-4 K-P,LAMB PHI
R19          0.70     0.05                BUKIN 1   78 OLYA    E+ E- COLL.BEAMS
R19          0.82     0.08                LOSTY     78 HBC     4.2 K-P,PHI HYP
R19        . . . . . . . . . .
R19 AVG      0.736    0.030   AVERAGE
R19 FIT      0.694    0.034  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5)
```

$\phi \rightarrow (\pi^+\pi^-\pi^0(\text{including}\rho\,\pi))/(K^+K^-)$ (P3)/(P1)

```
R20     34   0.28     0.09                AGUILAR   72 HBC     3.9,4.6 K- P
R20        . . . . . . . . . .
R20 FIT      0.301    0.036  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.4)
```

$\phi \rightarrow (2\pi^+2\pi^-\pi^0)/(K^+K^-)$ (P14)/(P1)

```
R21         (0.02) OR LESS  CL=0.95  AGUILAR   72 HBC     3.9,4.6 K- P
```

$\phi \rightarrow (\pi^+\pi^-\pi^+\pi^-)$/total (units 10^{-4}) (P15)

```
R22         (8.7)  OR LESS  CL=.90   CORDIER   79 WIRE    E+ E-,4PI
```

$\phi \rightarrow (\rho\,\pi)/(\pi^+\pi^-\pi^0)$ (P16)/(P3)

```
R23         (0.8)  OR MORE  CL=.90   JULLIAN   76 OSPK     E+ E- COLL.BEAM
```

REFERENCES FOR $\phi(1020)$

```
BERTANZA 62 PRL 9 180          BERTANZA,BRISSON,CONNOLLY,HART + (BNL+SYRA)

ARMENTER 63 SIENA CONF 2 70    ARMENTEROS,EDWARDS,ASTIER+      (CERN+CDEF)
GELFAND  63 PRL 11 438         GELFAND,MILLER,NUSSBAUM,KIRSCH+ (COLU+RUTG)
SCHLEIN  63 PRL 10 368         SCHLEIN,SLATER,SMITH,STORK,TICHO     (UCLA)

BADIER   65 PL 17 337          BADIER,DEMOULIN,BARLOUTAUD+     (SACL+AMST)
BERLEY   65 PR 139 B 1097      D BERLEY,N GELFAND          (BNL+COLUMBIA)
GALTIERI 65 PRL 14 279         A BARBARO GALTIERI,R D TRIPP          (LRL)
LINDSEY  65 PRL 15 221         JAMES S LINDSEY,GERALD A SMITH        (LRL)
   LINDSEY 65 DATA INCLUDED IN LINDSEY 66 BELOW
MILLER   65 CU-237(NEVIS 131) DAVID C MILLER  (THESIS)          (COLUMBIA)

GRAY     66 PRL  17  501       +HAGERTY,BIZZARRI,CIAPETTI +    (SYRA+ROMA)JPG
LINDSEY  66 PR  147  913       JAMES S LINDSEY, GERALD A SMITH       (LRL)
LINDSEY1 66 PL 20 93           J.S.LINDSEY, G.A.SMITH                (LRL)
LONDON   66 PR 143 1034        LONDON,RAU,SAMIOS,GOLDBERG + (BNL+SYRACUSE)

ABRAMS   67 MD TECH REP 720    GERALD ABRAMS , THESIS           (MARYLAND)
BARLOW   67 NC 50A 701         +LILLESTOL+MONTANET+  (CERN+CDEF+IRAD+LIVP)
CHASE    67 PRL 18 710         R.C.CHASE,P.ROTHWELL,R.WEINSTEIN (CEA+NEAS)
DAHL     67 PR 163 1377        +HARDY+HESS+KIRZ+MILLER               (LRL)
HERTZBAC 67 PR 155  1461       HERTZBACH,KRAEMER,MADANSKI,ZDANIS+(JHU+BNL)
KHACHATU 67 PL 24B 349         KHACHATURYAN+AZIMOV+BALDIN+BELOUSOV+(DUBNA)

ABRAMS   68 PR 175 1697        +GLASSER,KEHOE,SECHI-ZORN,WOLSKY (MARYLAND)
ASTVACAT 68 PL 27 B  45        ASTVACATUROV,AZIMOV,BALDIN+   (JINR+MOSCOW)
    ALSO 67 PRL 19 869         ASBURY,BECKER,BERTRAM,TING+ (DESY+COLUMBIA)
BECKER   68 PRL 21 1504        +BERTRAM,BINKLEY,JORDAN,KNASEL+  (DESY+MIT)
BINNIE   68 PL 27B 106         +DUANE+FARUQI+HORSEY+           (LOIC+RHEL)
BOLLINI  68 NC 56 A 1171       +BUHLER,DALPIAZ,MASSAM+    (CERN+BGNA+STRB)
MOSTEK   68 PRL 20 1057        +EISENHANDLER,MCCLELLAN,MISTRY+   (CORNELL)
WEHMANN  68 PRL 20 748         +ENGELS+ (HARVARD+CASE+SLAC+CORNELL+MCGILL)

AUGUSTIN 69 PL 28 B 517        +BIZOT,BUON,DELCOURT,HAISSINSKI,+   (ORSAY)
MOY      69  THESIS            KEN MIN MOY        (NORTHEASTERN UNIVERSITY)
SCOTTER  69 NC 62 A 1057       +ERSKINE,PALER,+  (BIRM+GLAS+LOIC+MPIM+OXF)

BIZOT    70 PL 32 416          +BUON,CHATELUS,JEANJEAN,LALANNE,+    (ORSA)
    ALSO 69 PEREZ-Y-JORBA, LIVERPOOL SYMP.69
BIZOT2   70 LNC 4 1273         +DELCOURT,JEANJEAN,LALANNE,+        (ORSAY)
EARLES   70 PRL 25 1312        +FAISSLER,GETTNER,LUTZ,MOY,TANG,+    (NEAS)
HYAMS    70 NP B 22 189        +KOCH,POTTER,V.LINDERN,LORENZ,LUTJENS(CERN)

ALVENSLE 71 PRL 27 441         ALVENSLEBEN,BECKER,BUSZA,CHEN,+  (MIT+DESY)
BALAKIN  71 PL 34 B 328        +BUDKER,PAKHTUSOVA,SIDOROV,SKRINSKY,+(NOVO)
CHATELUS 71  LAL 1247(THESIS) Y.CHATELUS                     (STRASBOURG)
    ALSO 70 BIZOT
DIBIANCA 71 NP B 35 13         +EINSCHLAG,ENDORF,ENGLER,FISK,+      (CORN)
HAYES    71 PR D 4 899         +IMLAY,JOSEPH,KEIZER,STEIN           (CORN)
STOTTLEM 71  ORO 2504 170      A.R.STOTTLEMYER,THESIS           (MARYLAND)

AGUILAR  72 PR D 6 29          AGUILAR-BENITEZ,CHUNG,EISNER,SAMIOS   (BNL)
ALVENSLE 72 PRL 28 66          ALVENSLEBEN,BECKER,BIGGS,BINKLEY+(MIT+DESY)
BALAKIN  72 PL 40 B 431        +BOKIN,PAKHTUSOVA,SIDOROV,+   (NOVOSIBIRSK)
BASILE   72 NP B 44 605        +DALPIAZ,FRABETTI,ZICHICHI+(CERN+BGNA+STRB)
BENAKSAS 72 PL 42 B 511        +COSME,JEAN-MARIE,JULLIAN,LAPLANCHE+(ORSAY)
BORENSTE 72 PR D 5 1559,       BORENSTEIN,DANBURG,KALBFLEISCH,+ (BNL+MICH)
COLLEY   72 NP B 50 1          +JOBES,RIDDIFORD,GRIFFITHS,+    (BIRM+GLAS)

BALLAM   73 PR D 7 3150        +CHADWICK,EISENBERG,BINGHAM,+    (SLAC+LBL)
BINNIE   73 PR D 8 2789        +CARR,DEBENHAM,DUANE,GARBUTT,+  (LOIC+SHMP)

AYRES    74 PRL 32 1463        +DIEBOLD,GREENE,KRAMER,LEVINE,+       (ANL)
BESCH    74 NP B70 257         +HARTMANN,KOSE,KRAUTSCHNEIDER,PAUL,+ (BONN)
BIZZARRI 74 NC 20A 393         +CIAPETTI,DIONISI,DORE,GASPERO+      (ROMA)
COSME 1  74 PL 48 B 155        +JEAN-MARIE,JULLIAN,LAPLANCHE,+     (ORSAY)
COSME 2  74 PL 48 B 159        +JEAN-MARIE,JULLIAN,LAPLANCHE,+     (ORSAY)
DE GROOT 74 NP B74 77          +HOOGLAND,JONGEJANS,METZGER+    (AMST+NIJM)

KALBFLEI 75 PR D11 987         KALBFLEISCH,STRAND,CHAPMAN       (BNL+MICH)

COSME    76 PL 63 B 352        +COURAU,DUDELZAK,GRELAUD,JEAN-MARIE+(ORSAY)
JULLIAN  76 TBILISI VOL.2 R19 S.JULLIAN                            (ORSAY)
KALBFLEI 76 PR D 13 22         KALBFLEISCH,STRAND,CHAPMAN       (BNL+MICH)
PARROUR1 76 PL 63 B 357        +GRELAUD,COSME,COURAU,DUDELZAK,+    (ORSAY)
PARROUR2 76 PL 63 B 362        +GRELAUD,COSME,COURAU,DUDELZAK,+    (ORSAY)

AKERLOF  77 PRL 39 861         +ALLEY,BINTINGER,DITZLER,+ (FNAL+MICH+PURD)
ANDREWS  77 PRL 38 198         +FUKUSHIMA,HARVEY,LOBKOWICZ,MAY,+    (ROCH)
BALDI    77 PL 68 B 381        +BOHRINGER,DORSAZ,HUNGERBUHLER,+   (GENEVA)
CERRADA  77 NP B 126 241       +BLOCKZIJL,HEINEN,+    (AMST+CERN+NIJM+OXF)
COHEN    77 PRL 38 269        +AYRES,DIEBOLD,KRAMER,PAWLICKI,WICKLUND(ANL)
COURANT  77 PR D 16 1          +MAKDISI,MARSHAK,PETERSON,RUDDICK,+  (MINN)
EVANGEL  77 NP B 127 384       EVANGELISTA,+   (BARI+BONN+CERN+DARE+GLAS+)
LAVEN    77 NP B 127 43        +OTTER,KLEIN,+   (AACH+BERL+CERN+LOIC+WIEN)
LYONS    77 NP B 125 207       +COOPER,CLARK                         (OXF)

BARTALUC 78 NC 44 A 587        BARTALUCCI,BASINI,BERTOLUCCI+   (DESY+FRAS)
BUKIN 1  78 SJNP 27 516        +KURDADZE,SEREDNYAKOV,SIDOROV+       (NOVO)
BUKIN 2  78 SJNP 27 521        +KURDADZE,SIDOROV,SKRINSKII+         (NOVO)
COOPER   78 NP B 146 1         +GURTU,MONTANET,+     (TIFR+CERN+CDEF+MADR)
LOSTY    78 NP B 133 38        +HOLMGREN,BLOKZIJL,+   (CERN+AMST+NIJM+OXF)

BARKOV   79  IYAF 79-93        +ZOLOTOREV,MAKARINA,MISHAKOVA,+      (NOVO)
CORDIER  79 PL B 81 389        +DELCOURT,ESCHSTRUTH,FULDA,+         (LALO)

CORDIER  80 NP B172 13         +DELCOURT,ESCHSTRUTH,FULDA+         (ORSAY)
ROOS     80 LNC 27 321         +PELLINEN                            (HELS)

DAUM     81 PL 100 B 439       +BARDSLEY+  (AMST+BRIS+CERN+CRAC+MPIM+RHEL)
IVANOV   81 PL 107 B 297       +KURDADZE,LELCHUK,SIDOROV,SKRINSKY,+ (NOVO)
    ALSO 82  PRIVATE COMM.     S.I.EIDELMAN                         (NOVO)
VASSERMA 81 PL 99 B 62         VASSERMAN,KURDADZE,SIDOROV,SKRINSKY+ (NOVO)

ARENTON  82 PR D 25 2241       +AYRES,DIEBOLD,MAY,SWALLOW+       (ANL+ILL)
PELLINEN 82 PS 25 599          A.PELLINEN, M.ROOS                   (HELS)

ARMSTRON 83 NP B 224 193       ARMSTRONG+  (BARI+BIRM+CERN+MILA+LPNP+PAVI)
BARATE   83 PL 121 B 449       +BAREYRE,ASTBURY,MCEWEN(SACL+LOIC+SHMP+IND)
KURDADZE 83 JETPL 38 306       +LELCHUK,ROOT+                       (NOVO)

DRUZHINI 84 PL 144 B 136       +GOLUBEV,IVANCHENKO,PERYSHKIN,REDKO,+(NOVO)

ALBRECHT 85 PL 153 B 343       +DRESCHER,HELLER+     (ARGUS COLLABORATION)
```

$h_1(1190)$ was $H(1190)$

$I^G(J^{PC}) = 0^-(1^{--})$

$h_1(1190)$ MASS (MeV)

```
M    C     1190.      60.                DANKOWYCH 81 SPEC   08 PI P,3 PI N
M   T     (1175.0)  APPROX               TORNQVIST 82 RVUE

M    C  USES THE MODEL OF BOWLER 75
M   T   FROM A UNITARIZED QUARK MODEL CALCULATION
```

$h_1(1190)$ WIDTH (MeV)

```
W    C      320.      50.                DANKOWYCH 81 SPEC   08 PI P,3 PI N
W   T      (365.0)  APPROX               TORNQVIST 82 RVUE

W    C  USES THE MODEL OF BOWLER 75
W   T   FROM A UNITARIZED QUARK MODEL CALCULATION
```

$h_1(1190)$ PARTIAL DECAY MODES

```
                                                              DECAY MASSES
P1      h1(1190) -> ρ π                                      769+ 135
```

$h_1(1190)$ BRANCHING RATIOS

$h_1(1190) \to (\rho\,\pi)$/total (P1)

```
R1          SEEN                       DANKOWYC  81 SPEC    8 PI P,3 PI N     |
R1          SEEN                       ATKINSON  84 OMEG    20-70GAM P,3 PI   |
```

REFERENCES FOR $h_1(1190)$

```
BOWLER   75 NP B97 227        +GAME,ATTCHISON,DAINTON           (OXF+DARE)

DANKOWYC 81 PRL 46 580        +BROCKMAN,EDWARDS+(TNTO+BNL+CARL+MCGI+OHIO)

TORNQVIS 82 NP B 203 268      TORNQVIST                             (HELS)

ATKINSON 84 NP B 231 15       ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
```

$b_1(1235)$ was $B(1235)$

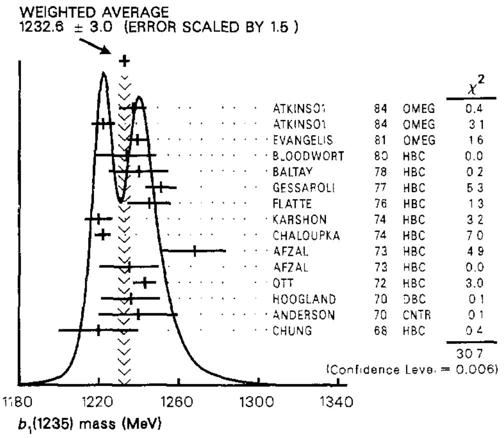
$I^G(J^{PC}) = 1^+(1^{+-})$

$b_1(1235)$ MASS (MeV)

```
M   W       (1228.)      (5.)             FRENKIEL  72 HBC  +- 0. PBAR PI,5 PI
M       360(1208.0)     (18.0)            GAVILLET  78 HBC  +  4.2 K-P,BACKWARD
M   T       (1243.0)   APPROX             TORNQVIST 82 RVUE
M           (1213.)      (5.)             ATKINSO3  84 OMEG   020-70GAM P       |
M           (1271.)     (11.)             COLLICK   84 SPEC +  200 PI+Z,Z PIOME |

M            1220.       20.              CHUNG     68 HBC   - 3.2,4.2 PI- P
M            1240.0      20.0             ANDERSON  70 CNTR   0 5-18 GAMMA P
M            1236.0      15.0             HOOGLAND  70 DBC   -  3.0 K- D
M  O   1163  1243.        6.              OTT       72 HBC  +  7.1 PI+ P
M            1235.       15.              AFZAL     73 HBC  +  11.7 PI+ P
M            1268.       16.              AFZAL     73 HBC  -  11.2 PI- P
M      1400  1222.        4.              CHALOUPKA 74 HBC   - 3.9 PI-P
M       600  1220.        7.              KARSHON   74 HBC  +  4.9 PI+P
M       890  1245.0      11.0             FLATTE    76 HBC   - 4.2 K-P,PI-OMEGA
M       450  1251.0       8.0             GESSAROLI 77 HBC   - 11 PI-P,PI- OME
M       225  1240.0      15.0             BALTAY    78 HBC  +  15 PI+P,P 4PI
M       105  1234.0      15.0             BLOODWORT 80 HBC   - 8.2 K- P
M            1239.        5.              EVANGELIS 81 OMEG  - 12 PI-P,OME PI P
M            1222.        6.              ATKINSO1  84 OMEG +- 25-55GAM P,OM PI |
M            1237.        7.              ATKINSO1  84 OMEG   025-55GAM P,OM PI |
M            . . . . . . . . . .
M   AVG      1232.6       3.0     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
                               (SEE IDEOGRAM BELOW)

M  O    FROM FIT OF THE MASS SPECTRUM
M   W   FIT REQUIRES AN ADDITIONAL JP=1- RESONANCE
M   W   AT 1256 MEV, WIDTH 129 MEV.
M   T   FROM A UNITARIZED QUARK MODEL CALCULATION
```



$b_1(1235)$ WIDTH (MeV)

```
W   W        (126.)     (10.)                FRENKIEL  72 HBC  +- 0. PBAR PI,5 PI
W       360 (163.0)     (50.8)               GAVILLET  78 HBC  +  4.2 K-P,BACKWARD
W   T        (118.0)   APPROX                TORNQVIST 82 RVUE
W            (231.)     (14.)                ATKINSO3  84 OMEG   020-70GAM P       |
W            (232.)     (29.)                COLLICK   84 SPEC +  200 PI+Z,Z PIOME |

W             150.       20.                 CHUNG     68 HBC   - 3.2,4.2 PI- P
W             132.0      20.0                HOOGLAND  70 DBC   -  3.0 K- D
W  O   1163   134.       23.       26.       OTT       72 HBC  +  7.1 PI+ P
W             120.       50.                 AFZAL     73 HBC  +  11.7 PI+ P
W             130.       50.                 AFZAL     73 HBC  -  11.2 PI- P
W      1400   135.       20.                 CHALOUPKA 74 HBC   - 3.9 PI-P
W       600   156.       22.                 KARSHON   74 HBC  +  4.9 PI+P
W       890   182.0      45.0                FLATTE    76 HBC   - 4.2 K-P,PI-OMEGA
W       450   155.0      32.0                GESSAROLI 77 HBC   - 11 PI-P,PI- OME
W       225   170.0      50.0                BALTAY    78 HBC  +  15 PI+P,P 4PI
W       105   150.0      50.0                BLOODWORT 80 HBC   - 8.2 K- P
W             170.       15.                 EVANGELIS 81 OMEG  - 12 PI-P,OME PI P
W            . . . . . . . . . .
W   AVG       150.0       7.3     AVERAGE

W  O    FROM FIT OF THE MASS SPECTRUM
W   W   SEE NOTE UNDER THE MASS ABOVE.
W   T   FROM A UNITARIZED QUARK MODEL CALCULATION
```

$b_1(1235)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$b_1(1235) \to \omega\pi$	783+ 140
P2	$b_1(1235) \to 2\pi^+2\pi^-$	140+ 140+ 140+ 140
P3	$b_1(1235) \to K\overline{K}$	494+ 494
P4	$b_1(1235) \to \pi\pi$	140+ 140
P5	$b_1(1235) \to \pi\phi$	135+1020
P6	$b_1(1235) \to \eta\pi$ (FORBIDDEN BY G)	549+ 140
P7	$b_1(1235) \to K\overline{K}\pi$	494+ 494+ 140
P8	$b_1(1235) \to \eta\rho$	549+ 769

$b_1(1235)$ PARTIAL WIDTHS (keV)

$b_1(1235) \to \pi^\pm\gamma$ (G3)

```
W3          230.0      60.0             COLLICK   84 SPEC +  200 PI+Z,Z PIOME  |
```

$b_1(1235)$ D-wave/S-wave RATIO IN $\omega\pi$ DECAY

```
DS             0.3      0.1             CHALOUPKA 74 HBC  -  3.9-7.5 PI-P
DS      600    0.35     0.25            KARSHON   74 HBC  +  4.9 PI+P
DS             0.21     0.08            CHUNG     75 HBC  +  7.1 PI+P
DS             0.4      0.1       0.1   GESSAROLI 77  HBC -  11 PI-P,PI- OME
DS             0.235    0.047           ATKINSO3  84 OMEG    20-70 GAM P       |
DS           . . . . . . . . . .
DS   AVG       0.260    0.035   AVERAGE
```

$b_1(1235)$ BRANCHING RATIOS

$b_1(1235) \to (4\pi)/(\omega\pi)$ (P2)/(P1)

```
R1          (0.5)  OR LESS                ABOLINS   63 HBC  +   3.5 PI+P
```

$b_1(1235) \to (K\bar{K})/(\omega\pi)$ (P3)/(P1)

```
R2          (0.02) OR LESS                DAHL      67 HBC  -   1.6-4.2 PI- P
R2          (0.10) OR LESS   CL=.90       BALTAY    67 HBC  +-  0.0 PBAR P
R2          (0.08) OR LESS   CL=.95       BIZZARRI  69 HBC  +-  0 PBAR P
```

$b_1(1235) \to (\pi\pi)/(\pi\omega)$ (P4)/(P1)

```
R3          (0.3)  OR LESS                ADERHOLZ  64 HBC      4.0 PI+P
R3          (0.15) OR LESS   CL=.90       OTT       72 HBC  +  7.1 PI+ P
```

$b_1(1235) \to (\pi\phi)/(\pi\omega)$ (P5)/(P1)

```
R4          (0.015)OR LESS                DAHL      67 HBC      1.6-4.2 PI- P
R4          (0.04) OR LESS   CL=.95       BIZZARRI  69 HBC  +-  0 PBAR P
```

$b_1(1235) \to (\eta\pi)/(\pi\omega)$ (P6)/(P1)

```
R5          (0.25) OR LESS   CL=.90       BALTAY    67 HBC  +-  0.0 PBAR P
```

$b_1(1235) \to ((K\bar{K})^{\pm}\pi^0)/(\pi\omega)$

```
R6          (0.08) OR LESS   CL=.90       BALTAY    67 HBC  +-  0.0 PBAR P
```

$b_1(1235) \to (K_S^0 K_S^0 \pi^{\pm})/(\pi\omega)$

```
R7          (0.02) OR LESS   CL=.90       BALTAY    67 HBC  +-  0.0 PBA- P
```

$b_1(1235) \to (K_S^0 K_L^0 \pi^{\pm})/(\pi\omega)$

```
R8          (0.06) OR LESS   CL=.90       BALTAY    67 HBC  +-  0.0 PBAR P
```

$b_1(1235) \to (\eta\rho)/(\pi\omega)$ (P8)/(P1)

```
R9          (0.10) OR LESS                ATKINSO2  84 OMEG   20-70 GAM P      |
```

REFERENCES FOR $b_1(1235)$

```
ABOLINS   63 PRL 11 381        ABOLINS,LANDER,MEHLHOP,XUONG,YAGER   (UCSD)
BONDAR    63 PL 5 209          BONDAR,DODD+   (AACHEN+BIRM+HAMB+LOIC+MPIM)

ADERHOLZ 64 PL 10 240          AACHEN+BERLIN+BIRM + BONN+HAMBUR+LOIC+MPIM
CARMONY   64 PRL 12 254        CARMONY,LANDER,RINDFLEISCH,XUONG,YAGER(UCB) JP

GOLDHABE 65 PRL 15 118         G GOLDHABER,S GOLDHABER,KADYK,SHEN     (LRL)

BALTAY    67 PRL 18 93         +SEVERIENS+YEH+ZANELLO             (COLU+BNL)
DAHL      67 PR 163 1377       +HARDY+HESS+KIRZ+MILLER                 (LRL)
LEE       67 PR 159 1156       +MOEBS,ROE,SINCLAIR,VANDERVELDE        (MICH)
SLATTERY 67 NC 50A 377         +KRAYBILL+FORMAN+FERBEL           (YALE+ROCH)

ASCOLI    68 PRL 20 1411       +CRAWLEY,MORTARA,SHAPIRO                (ILL)  JP
BOESEBEC 68 NP B 4 501         BOESEBECK,DEUTSCHMANN,+(AACHEN+BERLIN+CERN)
CASO      68 NC 54 A 983       +CONTE+CORDS+DIAZ+  (GENOVA+HAMB+MILA+SACL)
CHUNG     68 PR 165 1491       S.U.CHUNG,O.DAHL,J.KIRZ,D.H.MILLER     (LRL)

BIZZARRI 69 NP B 14 169        +FOSTER,GAVILLET,MONTANET,+       (CERN+CDEF)

ANDERSON 70 PR D 1 27          +GUSTAVSON,JOHNSON,+   (SLAC+CIT+UCSB+NEAS)
CASO      70 LNC 3 707         +CONTE,TOMASINI,CORDS+(GENO+HAMB+MILA+SACL)
CASON     70 PR D 1 851        +ANDREWS,BISWAS,GROVES,HARRINGTON,+  (NDAM)
EROFEEV   70 SJNP 11 450       +VETLITSKY,WLADIMIRSKY,GRIGOREV,+    (ITEP)
HONES     70 PR D 2 827        +CASON,BISWAS,HELLAND,KENNEY,MCGAHAN+(NDAM)
HOOGLAND 70 PL 33 B 631        SABRE COLLABOR.  (AMST+SACL+BGNA+REHO+EPOL)
MIYASHIT 70 PR D 1 771         MIYASHITA,VON KROGH,KOPELMAN,LIBBY   (COLO)
POLS      70 NP B 25 109       +BOECKMANN,CIRBA,+    (BONN+DURH+EPOL+TORI)
WERBROUC 70 LNC 4 1267         WERBROUCK,RINAUDO,+    (TORI+NIJM+BONN+LBL)JP

DEVONS    71 PRL 27 1614       +KOZLOWSKI,HORWITZ,+              (COLU+SYRA)

FRENKIEL 72 NP B 47 61         +GHESQUIERE,LILLESTOL,CHUNG,+   (CDEF+CERN)JP
OTT       72  LBL-1547         R.L.OTT  THESIS                          (LBL)JP
SISTERSO 72 NP B 48 493        SISTERSON,HARRISON,HEYDA,JOHNSON,+(HARVARD)

AFZAL     73 LNC 15 A 61       +BASSLER,+        (DURH+GENO+DESY+MILA+SACL)  JP
ARMENISE 73 NC 17 A 707        +FORINO,CARTACCI,+           (BARI+BGNA+FIRZ)
ARMENISE 73 LNC 8 425          +FORINO,CARTACCI,+           (BARI+BGNA+FIRZ)
ARNOLD    73 LNC 6 707         +ENGEL,ESCOUBES,KURTZ,LLORET,PATY,+  (STRB)
CASON     73 PR D 7 1971       +BISWAS,KENNEY,MADDEN,SANDER,SHEPHARD(NDAM)
CASON 1   73 NP B 64 14        +MADDEN,BISHOP,BISWAS,KENNEY,+       (NDAM)
CHUNG     73 PL 47 B 526       +PROTOPOPESCU,LYNCH,FLATTE,+ (BNL+LBL+UCSC)  JP
COHEN     73 PR D 8 23         +FERBEL,SLATTERY                  (ROCHESTER)

BALLAM    74 NP B76 375        +CHADWICK,BINGHAM,FRETTER+  (SLAC+LBL+MPIM)
CHALOUPK 74 PL 51B 407         CHALOUPKA,FERRANDO,LOSTY,MONTANET    (CERN)  JP
KARSHON   74 PR D10 3608       +MIKENBERG,EISENBERG,PITLUCK,RONAT+  (REHO)  JP

CHUNG     75 PR D11 2426       +PROTOPOPESCU,LYNCH,FLATTE,+ (BNL+LBL+UCSC)  JP
DUBOVIKO 75 SJNP 20 229        M.S.DUBOVIKOV,I.A.EROFEEV             (ITEP)  JP

FLATTE    76 PL 64 B 225       +GAY,BLOKZIJL,METZGER,+(CERN+AMST+NIJM+OXF)  JP

GESSAROL 77 NP B 126 382       GESSAROLI,+  (BGNA+FIRZ+GENO+MILA+OXF+PAVI)  JP

BALTAY    78 PR D 17 62        +CAUTIS,COHEN,CSORNA,SMITH,YEH,+(COLU+BING)
GAVILLET 78 PL 78 B 158        +DIONISI,GURTU,+        (CERN+AMST,NIJM+OXF)  JP

BLOODWOR 80 LNC 27 555         BLOODWORTH,+        (BIRM+CERN+GLAS+MSU+LPNP)

EVANGELI 81 NP B 178 197       EVANGELISTA+(BARI+BONN+CERN+DARE+LIVP+MILA)
WONG      81 PRL 46 974        +KEY,FRISKEN,CLINE,DEBONTE+(TNTO+YORK+PURD)

TORNQVIS 82 NP B 203 268       TORNQVIST                               (HELS)

ATKINSO1 84 PL 138 B 459       ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
ATKINSO2 84 NP B 242 269       ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
ATKINSO3 84 NP B 243 1         ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
COLLICK   84 PRL 53 2374       +HEPPELMANN,BERG,JONCKHEERE(MINN+ROCH+FNAL)
```

$f_0(1240)$ was $g_S(1240)$

$I^G(J^{PC}) = 0^-(0^{++})$

OMITTED FROM SUMMARY TABLE

```
SEEN IN PHASE SHIFT ANALYSIS OF KOS KOS SYSTEM.
NAMED G/S BY ETKIN 82.
NEEDS CONFIRMATION.
```

$f_0(1240)$ MASS (MeV)

```
M   A       1240.0      22.0              ETKIN      82 MPS    0 23 PI-P,KSKS N     |

M   A     FROM AN AMPLITUDE ANALYSIS OF THE KOS KOS SYSTEM. SYSTEMATIC
M   A     ERROR ADDED QUADRATICALLY BY US.
```

$f_0(1240)$ WIDTH (MeV)

```
W   A        140.0      22.0              ETKIN      82 MPS    0 23 PI-P,KSKS N     |

W   A     FROM AN AMPLITUDE ANALYSIS OF THE KOS KOS SYSTEM. SYSTEMATIC
W   A     ERROR ADDED QUADRATICALLY BY US.
```

$f_0(1240)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_0(1240) \to K\bar{K}$	498+ 498

REFERENCES FOR $f_0(1240)$

```
BAUBILLI 83 ZPHY C 17 309      BAUBILLIER+        (BIRM+CERN+GLAS+MSU+LPNP)
ETKIN     82 PR D 25 2446      +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)  JP
```

$\rho(1250)$

$I^G(J^{PC}) = 1^-(1^{--})$

OMITTED FROM SUMMARY TABLE

```
FORMERLY CALLED RHO PRIME.
EVIDENCE NOT COMPELLING.
```

$\rho(1250)$ MASS (MeV)

```
M          1256.       10.              FRENKIEL  72 HBC  +- 0.PBARP,OMEGA PI
M          1266.0       5.0             BARTALUCC 79 DASP   07 GAM P,E+E- P
M    A    (1250.)                       ASTON     80 OMEG    20-70G P,OME PI0
M    A    (1290.)     (40.)             BARBER    80 SPEC    3-5 G P,OMEG PI0
M          . . . . . . . . .
M    AVG   1264.0       4.5      AVERAGE

M    A   NOT SEPARATED FROM B1(1235),NOT PURE JP=1- EFFECT
```

$\rho(1250)$ WIDTH (MeV)

```
W           130.       20.              FRENKIEL  72 HBC  +- 0.PBARP,OMEGA PI
W           110.0      35.0             BARTALUCC 79 DASP   07 GAM P,E+E- P
W    A     (300.)                       ASTON     80 OMEG    20-70G P,OME PI0
W    A     (320.)    (100.)             BARBER    80 SPEC    3-5 G P,OMEG PI0
W          . . . . . . . . .
W    AVG    125.1      17.4      AVERAGE

W    A   NOT SEPARATED FROM B1(1235),NOT PURE JP=1- EFFECT
```

REFERENCES FOR $\rho(1250)$

```
ANDERSON 70 PR D 1 27          +GUSTAVSON,JOHNSON,+   (SLAC+CIT+UCSB+NEAS)

PODOLSKY 71  UCRL 20128        W.J.PODOLSKY,PH.D. THESIS               (LBL)

FRENKIEL 72 NP B 47 61         +GHESQUIERE,LILLESTOL,CHUNG,+   (CDEF+CERN)JP
WOLF      72 ITHACA N.Y. CONF. G.WOLF,P.213                            (SLAC)

CHUNG     73 PL 47 B 526       +PROTOPOPESCU,LYNCH,FLATTE,+ (BNL+LBL+UCSC)
BRAMON    73 LNC 8 659         A.BRAMON                            (FRASCATI)

BALLAM    74 NP B76 375        +CHADWICK,BINGHAM,FRETTER+  (SLAC+LBL+MPIM)
CHALOUPK 74 PL 51B 407         CHALOUPKA,FERRANDO,LOSTY,MONTANET    (CERN)
CONVERSI 74 PL 52B 493         +PAOLUZI,CERADINI,GRILLI+       (ROMA+FRAS)
ESTABROO 74 NP B79 301         P.ESTABROOKS,A.D.MARTIN               (DURH)
KARSHON   74 PR D10 3608       +MIKENBERG,EISENBERG,PITLUCK,RONAT+  (REHO)   JP

ALLES     75 NC 30A 136        ALLES-BORELLI,BERNARDINI+  (CERN+BGNA+FRAS)
CHUNG     75 PR D11 2426       +PROTOPOPESCU,LYNCH,FLATTE,+ (BNL+LBL+UCSC)
ESTABROO 75 NP B95 322         P.ESTABROOKS,A.D.MARTIN               (DURH)
FROGGATT 75 NP B91 454         C.D.FROGGATT,J.L.PETERSEN       (GLAS+NORD)
HYAMS     75 NP B100 205       +JONES,WEILHAMMER,BLUM,DIETL+   (CERN+MPIM)
```

```
BASSOMPI 76 PL 65 B 397        BASSOMPIERRE,BINDER,+      (MULH+STRB+TORI)

BUDNEV   77 PL 70 B 365        N.M.BUDNEV,V.M.BUDNEV,V.V.SEREBRYAKOV(NOVO)
COSTA    77 PL 67 B 213        COSTA DE BEAUREGARD,PHAM,PIRE,TRUONG (EPOL)
GESSAROL 77 NP B 126 382       GESSAROLI,+  (BGNA+FIRZ+GENO+MILA+OXF+PAVI)

BUKIN    78 PL  73 B 226       +VASSERMAN,KOOP,KURDADZE,SIDOROV,+   (NOVO)

BACCI    79 PL B 86 234        +DE ZORZI,PENSO,STELLA,+   (ROMA+BGNA+FRAS)
BARTALUC 79 NC 49 A 207        BARTALUCCI,BASINI,BERTOLUCCI+   (DESY+FRAS)

ASTON    80 PL 92 B 211        (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+PARIS+)
BARBER   80 ZPHY C 4 169       +DAINTON,BRODBECK,BROOKES,+(DARE+LANC+SHEF)

BARKOV   85 NP B 256 365       +CHILINGAROV,EIDELMAN,KHAZIN,LELCHUK+(NOVO)
```

$f_2(1270)$ was $f(1270)$

$I^G(J^{PC}) = 0^+(2^{++})$

$f_2(1270)$ MASS (MeV)

```
M          (1273.0)    (7.0)             ARMENISE  70 HBC      9 PI+ N -- MM P
M       600(1275.0)   (10.0)             OH        70 HBC     1.26 PI- P,P F2
M   E      (1273.0)    (6.0)             STUNTEBEC 70 HBC     8.PI-P,5.4 PI+D
M      2000(1261.0)   (10.0)             JACOBS    72 HBC      2.8 PI- P
M       10K  1269.      4.               APEL      75 CNTR    40 PI-P, N 2PI0    |
M  IH      (1269.)     (4.)              ESTABROOK 75 RVUE    17 PI-P,PI+PI-N
M  IG      (1275.)     (4.)              HYAMS     75 ASPK     17 PI-P,PI+PI-N
M   G      (1273.8)    (2.8)     (2.7)   BECKER    79 ASPK    17 PI- P POLARIZ

M            1276.      11.              RABIN     67 HBC     8.5 PI+ P
M  T   1960 1261.       5.               ARMENISE  68 DBC     5.1 PI+N,P PI+ -
M  T    360 1270.      10.               ARMENISE  68 DBC     5.1 PI+N,P PI0 0
M           1265.       8.               BOESEBECK 68 HBC     8 PI+ P
M    J      1268.0      6.0              JOHNSON   68 HBC      3.7-4.2 PI- P
M           1275.0     13.0              ARMENISE  70 HBC      9 PI+ N -- F2 P
M      5300 1277.0      4.0              FLATTE    71 HBC      7.0 PI+ P
M       600 1258.0     10.0              TAKAHASHI 72 HBC     8. PI- P,N 2PI
M      4600 1272.       4.               ENGLER    74 DBC      6. PI+N,PI+PI-P
M     16000 1284.0     10.0              DEUTSCHMA 76 HBC     16 PI+P
M           1282.0      5.0              CORDEN    79 OMEG    12-15PI-P, N 2PI
M           1281.0      7.0              GIDAL     81 SMK2    J/PSI DECAY
M        3K 1280.0     20.0              APEL      82 CNTR    25 PI-P, N 2PI0    |
M           1280.0      4.0              CASON     82 STRC    8 PI+P,PI+2PI0 P
M        3K 1284.0     30.0              BINON     83 GAM2    38 PI-P, N 2 ETA   |
M           1273.3      2.3              CHABAUD   83 ASPK    17 PI-P POLARIZ
M           1276.0      7.0              COURAU    84 DLCO    E+E-,E+E- PI+PI-   |
M           . . . . . . . . . .
M   AVG     1273.8      1.5     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)

M   G   INCLUDED IN CHABAUD 83 ANALYSIS
M   H   USES SAME DATA AS HYAMS 75
M  I    ERROR TAKES ACCOUNT OF SPREAD OF DIFFERENT PHASE-SHIFT SOLUTIONS
M    J  JOHNSON 68 INCLUDES BONDAR 63, LEE 64, DERADO 65, EISNER 67.
M  T    MASS ERRORS ENLARGED BY US TO WIDTH/SQRT(N),SEE K*(892) TYPED NOTE
```

$f_2(1270)$ WIDTH (MeV)

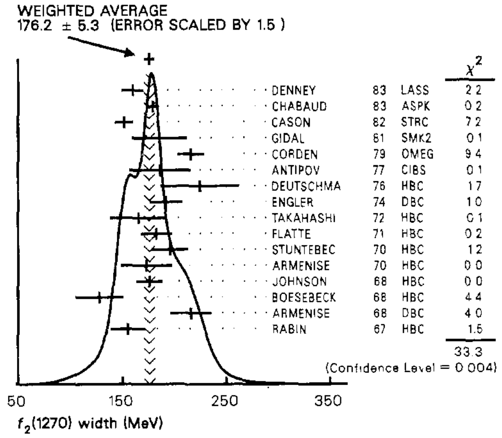
```
W          (131.0)   (25.0)              ARMENISE  70 HBC      9 PI+ N -- MM P
W  T   600 (120.0)   (20.0)              OH        70 HBC     1.26 PI- P,P F2
W     2000 (130.0)   (25.0)              JACOBS    72 HBC      2.8 PI- P
W      10K  190.      10.                APEL      75 CNTR    40 PI-P, N 2PI0    |
W  IH      (209.)    (10.)               ESTABROOK 75 RVUE    17 PI-P,PI+PI-N
W  IG      (188.)     (4.)               HYAMS     75 ASPK     17 PI-P,PI+PI-N
W   G      (183.2)    (8.3)      (7.9)   BECKER    79 ASPK    17 PI- P POLARIZ

W           155.      17.                RABIN     67 HBC     8.5 PI+ P
W  T  1960  216.      20.                ARMENISE  68 DBC     5.1 PI+N,P PI+ -
W           128.      23.                BOESEBECK 68 HBC     8 PI+ P
W    J      176.0     13.0               JOHNSON   68 HBC      3.7-4.2 PI- P
W  T        173.0     25.0               ARMENISE  70 HBC      9 PI+ N -- F2 P
W           196.0     18.0               STUNTEBEC 70 HBC     8.PI-P,5.4 PI+D
W     5300  183.0     15.0               FLATTE    71 HBC     7.PI+P,DELTA++F2
W  T   600  166.0     28.0               TAKAHASHI 72 HBC     8. PI- P,N 2PI
W     4600  192.      16.                ENGLER    74 DBC      6. PI+N,PI+P+-P
W    16000  225.0     38.0               DEUTSCHMA 76 HBC     16 PI+P
W  T   650  187.0     30.0               ANTIPOV   77 CIBS    25 PI-P,P 3PI
W           216.0     13.0               CORDEN    79 OMEG    12-15PI-P, N 2PI
W           186.0     27.0               GIDAL     81 SMK2    J/PSI DECAY
W       3K  196.0     10.0               APEL      82 CNTR    25 PI-P, N 2PI0    |
W           152.0      9.0               CASON     82 STRC    8 PI+P,PI+2PI0 P
W       3K  240.0     40.0               BINON     83 GAM2    38 PI-P, N 2 ETA   |
W           179.2      6.9       6.6     CHABAUD   83 ASPK    17 PI- P POLARIZ
W           160.0     11.0               DENNEY    83 LASS    10 PI+N /PI+ P     |
W           . . . . . . . . . .
W   AVG     176.2      5.3     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
                          (SEE IDEOGRAM BELOW)

W   G   INCLUDED IN CHABAUD 83 ANALYSIS
W   H   USES SAME DATA AS HYAMS 75
W  I    ERROR TAKES ACCOUNT OF SPREAD OF DIFFERENT PHASE-SHIFT SOLUTIONS
W    J  JOHNSON 68 INCLUDES BONDAR 63, LEE 64, DERADO 65, EISNER 67.
W  T    WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N),SEE K*(892) NOTE
```

$f_2(1270)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_2(1270) \rightarrow \pi\pi$	140+ 140
P2	$f_2(1270) \rightarrow 2\pi^+ 2\pi^-$	140+ 140+ 140+ 140
P3	$f_2(1270) \rightarrow \pi^+ \pi^- 2\pi^0$	140+ 140+ 135+ 135
P4	$f_2(1270) \rightarrow K\bar{K}$	498+ 498
P5	$f_2(1270) \rightarrow K\bar{K}\pi$	498+ 498+ 140
P6	$f_2(1270) \rightarrow \eta\pi\pi$	549+ 140+ 140
P7	$f_2(1270) \rightarrow \eta\eta$	549+ 549
P8	$f_2(1270) \rightarrow \gamma\gamma$	0+ 0



$f_2(1270)$ PARTIAL WIDTHS (keV)

$f_2(1270) \rightarrow \gamma\gamma$ (G8)

```
W8   A        2.3       0.8              BERGER     80 PLUT    E+ E-
W8 D          3.2       0.6              BRANDELIK  81 TASS    GAM GAM,2PI
W8 D          3.6       0.6              ROUSSARIE  81 SMK2    GAM GAM,2PI
W8 D          2.7       0.6              EDWARDS    82 CBAL    GAM GAM,2PI0
W8 DH        (2.9)     (0.8)     (0.7)   EDWARDS    82 CBAL    GAM GAM,2PI0
W8 D          2.3       0.5              FRAZER     83 JADE    E+E-,E+E- PI+PI-
W8 D          2.5       0.5              BEHREND    84 CELL    E+E-,E+E- PI+PI-
W8            2.70      0.21             COURAU     84 DLCO    E+E-,E+E- PI+PI-   |
W8 D          2.52      0.40             SMITH      84 SMK2    E+E-,E+E- K+K-     |
W8 D          2.85      0.60             BERGER     84 PLUT    E+E-,E+E- 2PI      |
W8 D         (3.2)     (0.4)             SENS       85 TPC     E+E-,E+E- 2PI      |
W8 DH        (3.6)     (0.5)             SENS       85 TPC     E+E-,E+E- 2PI      |
W8          . . . . . . . . . .
W8  AVG       2.70      0.14    AVERAGE

W8   A  USING MASS, WIDTH AND BR(F2(1270) TO 2PI) FROM PDG 1978
W8 D    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
W8  H   IF HELICITY=2 ASSUMPTION IS NOT MADE
```

$f_2(1270)$ BRANCHING RATIOS

$f_2(1270) \rightarrow (2\pi^+ 2\pi^-)/(\pi\pi)$ (P2)/(P1)

```
R1           0.047     0.013             OH         70 HBC     1.26 PI- P,P F2
R1     154   0.037     0.007             ANDERSON   73 DBC     6. PI+N,P F2
R1          (0.033)OR LESS  C.L.=.90 BUGG       73 DBC     8. PI+N,P F2
R1      70   0.051     0.025             EISENBERG  74 HBC     4.9 PI+P,DEL++F2
R1     285   0.043     0.007        .011 LOUIE      74 HBC     3.9 PI- P,N F2
R1     160   0.024     0.006             EMMS       75 DBC     4.  PI+N,P F2
R1          . . . . . . . . . .
R1  AVG      0.0340    0.0045  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

$f_2(1270) \rightarrow (\pi^+ \pi^- 2\pi^0)/(\pi\pi)$ (P3)/(P1)

```
R2   SHOULD BE TWICE R1 IF DECAY IS RHO-RHO (SEE ASCOLI 68)
R2     600   0.15      0.06              EISENBERG  74 HBC     4.9 PI+P,DEL++F2
R2          (0.07)                       EMMS       75 DBC     4.  PI+N,P F2
```

$f_2(1270) \rightarrow (K\bar{K})/(\pi\pi)$ (P4)/(P1)

```
R3          WE ONLY AVERAGE EXPERIMENTS WHICH EITHER TAKE INTO ACCOUNT F2-A2
R3          INTERFERENCE EXPLICITLY OR DEMONSTRATE THAT A2 PRODUCTION IS
R3          NEGLIGIBLE.
R3  W       (0.029)  (0.006)             WETZEL     76 OSPK    8.9 PI-P,KS KS
R3  BC      (0.047)  (0.005)             PAWLICKI   77 SPEC    6. PI N,K+ K- N
R3  AN      (0.028)  (0.005)             CASON      78 STRC    7. PI-P,KS KS N

R3  E       (0.047)  (0.012)             BEUSCH     67 OSPK    5,7,12 PI-P
R3     20    0.031    0.012              ADERHOLZ   69 HBC      8 PI+ P,K+K-PI-
R3           0.025    0.015              EMMS       75 DBC     4.  PI+N,P F2
R3           0.030    0.005              MARTIN     79 RVUE
R3   M       0.027    0.009              POLYCHRON  79 STRC    7. PI-P,KS KS N
R3   D       0.036    0.005              COSTA      80 OMEG    1-2.2 PI-P,K+K-N
R3           0.039    0.008              LOVERRE    80 HBC     4. PI-P,K K N
R3          (0.03) OR LESS  CL=.95      AGUILAR    81 HBC     4.2 K-P,LAM 2K
R3           0.045    0.009              CHABAUD    81 ASPK    17 PI-P POLARIZ
R3           0.037    0.008     0.021    ETKIN      82 MPS     23 PI-P,2KOS N
R3          . . . . . . . . . .
R3  AVG      0.0340   0.0027  AVERAGE

R3   C  THIS DETERMINATION HAS QUANTITATIVELY ACCOUNTED FOR BOTH F2'(1525)
R3   C  AND A2(1320) INTERFERENCE EFFECTS.
R3   M  TAKES INTO ACCOUNT THE F2(1270)-F2'(1525) INTERFERENCE
R3   N  BY EXTRAPOLATION TO THE PION POLE
R3  W   USING F2'(1525) WIDTH = 40 MEV
R3  A   INCLUDED IN POLYCHRONAKOS 79.
R3  B   INCLUDED IN MARTIN 79 REVIEW.
R3   D  RE-EVALUATED BY CHABAUD 83.W.
R3  E   + SYSTEMATIC ERRORS.
```

$f_2(1270) \rightarrow (K^0 K^- \pi^+ + \text{C.C.})/(\pi\pi)$ (P5)/(P1)

```
R4           (.004)OR LESS  CL=.95   EMMS       75 DBC     4.  PI+N,P F2
```

$f_2(1270) \rightarrow (\eta\pi\pi)/(\pi\pi)$ (P6)/(P1)

```
R5           (.010)OR LESS  CL=.95   EMMS       75 DBC     4.  PI+N,P F2
```

$f_2(1270) \rightarrow (\eta\eta)/(\pi\pi)$ (P7)/(P1)

```
R6              (.09) OR LESS  CL=.95   EISENBERG 74 HBC      4.9 PI+P,DEL++F2
R6              (.016)OR LESS  CL=.95   EMMS      75 DBC      4.  PI+N,P F2
R6              (.05) OR LESS  CL=.95   EDWARDS   82 CBAL     GAM GAM,4GAMMA
```

$f_2(1270) \rightarrow (\eta\eta)$/total (units 10^{-3}) (P7)

```
R7              5.2       1.7           BINON     83 GAM2    38 PI- P,4 GAMMA  |
R7              2.8       0.7           ALDE      85 GAM4    100PI- P,4 GAMMA  |
R7            . . . . . . . . . .
R7  AVG         3.15      0.84    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$f_2(1270) \rightarrow (\pi\pi)$/total (P1)

```
R10     600     0.8       0.04          OH        70 HBC    01.26 PI- P,P F2
R10     250     0.85      0.05          BEAUPRE   71 HBC    08 PI+ P,DEL++F2
R10IH          (0.82)    (0.01)         ESTABROOK 75 RVUE    17 PI-P,PI+PI-N
R10IG          (0.803)   (0.003)        HYAMS     75 ASPK     17 PI-P,PI+PI-N
R10             0.847     0.016         BECKER    79 ASPK    17 PI- P POLARIZ
R10             0.849     0.025         CHABAUD   83 ASPK    17 PI-P POLARIZ
R10           . . . . . . . . . .
R10 AVG         0.843     0.012   AVERAGE

R10 G   INCLUDED IN BECKER 79 ANALYSIS
R10 H   USES SAME DATA AS HYAMS 75
R10I    ERROR TAKES ACCOUNT OF SPREAD OF DIFFERENT PHASE-SHIFT SOLUTIONS
```

REFERENCES FOR $f_2(1270)$

```
SELOVE    62 PRL 9 272            SELOVE,HAGOPIAN,BRODY,BAKER,LEBOY    (PENN)
BONDAR    63 PL 5 153             BONDAR+    (AACHEN+BIRM+BONN+DESY+LOIC+MPIM)
GUIRAGOS  63 PRL 11 85            Z.G.T. GUIRAGOSSIAN                   (LRL)
HAGOPIAN  63 PRL 10 533           V HAGOPIAN,W SELOVE                  (PENN)
VEILLET   63 PRL 10 29            VEILLET,HENNESSY,BINGHAM,BLOCH+(EPOL+MILAN)

ADERHOLZ  64 PL 10 240            AACHEN+BERLIN+BERLIN+BONN+HAMBURG+LOIC+MPI  IJ
BRUYANT   64 PL 10 232            BRUYANT,GOLDBERG,HOLDER,FLEURY+ (CERN+EPOL) I
LEE       64 PRL 12 342           LEE,ROE,SINCLAIR,VANDERVELDE         (MICH)
SODICKSO  64 PRL 12 485           SODICKSON,WAHLIG,MANNELLI,FRISCH+     (MIT) I

BARMIN    65 SJNP 1 230           +DOLGOLENKO,ELENSKY,EROFEEV+  (ITEP MOSCOW) JP
BARMIN    65 SJNP 1 623           +DOLGOLENKO+EROFEEV+KRESTNIKOV+ (ITEP MOSC)
CHUNG     65 PRL 15 325           CHUNG,DAHL,HARDY,HESS,JACOBS,KIRZ     (LRL)
DERADO    65 PRL 14 872           DERADO,KENNEY,POIRIER,SHEPHARD (NOTRE DAME)
GUIRAGOS  65 PRL 11 85            Z G T GUIRAGOSSIAN                    (LRL)
WANGLER   65 PR  137 B 414        T P WANGLER,A R ERWIN,W WALKER  (WISCONSIN)

ACCENSI   66 PL 20 557            ACCENSI,ALLES-BORELLI,FRENCH,FRISK+  (CERN)
JACOBS    66 UCRL-16877           L.D.JACOBS,THESIS                     (LRL)
WAHLIG    66 PR  147  941         +SHIBATA,GORDON,FRISCH,MANNELLI  (MIT+PISA) J

BARLOW    67 NC 50A 701           +LILLESTOL+MONTANET+  (CERN+CDEF+IRAD+LIVP)
BEUSCH    67 PL 25 B 357          +FISCHER,GOBBI,ASTBURY+          (ETH+CERN)
DAHL      67 PR 163 1377          +HARDY+HESS+KIRZ+MILLER               (LRL)
EISNER    67 PR 164 1699          +JOHNSON+KLEIN+PETERS+SAHNI+YEN+   (PURDUE)
POIRIER   67 PR 163 1462          +BISWAS,CASON,DERADO,KENNEY+    (NDAM+PENN)
RABIN     67 THESIS               M. RABIN                          (RUTGERS)

ARMENISE  68 NC 54 A 999          +FORINO+CARTACCI+ (BARI+BGNA+FIRENZE+ORSAY)
ASCOLI    68 PRL 21 1712          G.ASCOLI,H.B.CRAWLEY,D.W.MORTARA,+    (ILL)
BOESEBEC  68 NP B 4 501           BOESEBECK,DEUTSCHMANN,+(AACHEN+BERLIN+CERN)
FOSTER    68 NP B 6 107           +GAVILLET+LABROSSE+MONTANET+    (CERN+CDEF)
JOHNSON   68 PR 176 1651          +POIRIER,BISWAS,GUTAY+     (NDAM+PURD+SLAC)
LAMSA     68 PR 166 1395          +CASON+BISWAS+DERADO+GROVES+    (NOTREDAME)
WHITEHEA  68 NC 53A 817           +MCEWEN,OTT,AITKEN+        (AERE+SHMP+LOUC)

ADERHOLZ  69 NP B 11 259          +BARTSCH,+          (AACH+BERL+CERN+JAGL+WARS)
AGUILAR   69 PL 29 B  241         M.AGUILAR-BENITEZ,J.BARLOW,+    (CERN+CDEF)
ARMENISE  69 LNC 2 501            +GHIDINI,FORINO,CARTACCI+  (BARI+BGNA+FIRZ)
CASO      69 NC 62 A 755          +CONTE,BENZ,+    (GENO+DESY+HAMB+MILA+SACL)
DONALD    69 NP B 11 551          +EDWARDS,BURAN,BETTINI,+   (LIVP+OSLO+PADO)

AGUILAR   70 PRL 25 58            AGUILAR-BENITEZ,BARNES,BASSANO,+ (BNL+SYRA)
ARMENISE  70 LNC 4  199           +GHIDINI,FORING,CARTACCI,+ (BARI+BGNA+FIRZ)
BADIER    70 NP B 22 512          +BONNET,DREVILLON,BAUBILLIER,+  (EPOL+IPNP)
OH        70 PR D 1 2494          +GARFINKEL,MORSE,WALKER,PRENTICE(WISC+TNTO)P
STUNTEBE  70 PL 32 B 391          STUNTEBECK,KENNEY,DEERY,BISWAS,CASON+(NDAM)

BARDADIN  71 PR D4 2711           BARDANIN-OTWINOWSKA,HOFMOKL,+        (WARS)
BEAUPRE   71 NP B 28 77           +DEUTSCHMANN,GRAESSLER,+   (AACH+BERL+CERN)
FARBER    71 NP B 29 237          +DE PINTO,BISWAS,CASON,DEERY,KENNEY,+(NDAM)
FLATTE    71 PL 34 B 551          +ALSTON-GARNJOST,BARBARO-GALTIERI,+   (LBL)

AGUILAR   72 PR D 6 29            AGUILAR-BENITEZ,CHUNG,EISNER,SAMIOS   (BNL)
BISWAS    72 PR D 5 1564          +CASON,HARRINGTON,KENNEY,SHEPHARD    (NDAM)
FOGLI     72 NC 8 A 670           FOGLI-MUCIACCIA,PICCIARELLI          (BARI)
GRAYER    72 PHIL.CONF.PROC. 5 +HYAMS,JONES,SCHLEIN,BLUM,DIETL+(CERN+MPIM)
JACOBS    72 PR D 6 1291          L.D.JACOBS                         (SACLAY)
KEMP      72 NC 8 A 611           +MAJOR,CONTRI,+  (DURH+GENO+MILA+EPOL+LPNP)
SCARROTT  72 LNC 3 271            SCARROTT,KEMP                      (DURHAM)
TAKAHASH  72 PR D 6 1266          TAKAHASHI,BARISH,+     (TOHO+PENN+NDAM+ANL)
WHITEHEA  72 NP B 48 365          WHITEHEAD,AULD,+      (AERE+RHEL+SHMP+LOUC)

ANDERSON  73 PRL 31 562           +ENGLER,KRAEMER,TOAF,DIAZ,+     (CARN+CASE)
BUGG      73 PR D 7 3264          +CONDO,HART,COHN,ENDORF,+  (TENN+ORNL+CINC)
CHARLESW  73 NP B 65 253          CHARLESWORTH,EMMS,BELL,+   (RHEL+BIRM+DURH)
HYAMS     73 NP B 64 134          +JONES,WEILHAMMER,BLUM,DIETL,+  (CERN+MPIM)
TOET      73 NP B 63 248          +THUAN,MAJOR,RINAUDO,+(NIJM+BONN+DURH+TORI)

EISENBER  74 PL 52B 239           EISENBERG,ENGLER,HABER,KARSHON+      (REHO)
ENGLER    74 PR D10 2070          +KRAEMER,TOAFF,WEISSER,DIAZ+    (CARN+CASE)
GRAYER    74 NP B 75 189          G.GRAYER,HYAMS,BLUM,DIETL,+     (CERN+MPIM)
HOLLOWAY  74 PR D9 1161           +HULD,JORDAN,KOETZ,BERNSTEIN+    (ILL+ILLC)
LOUIE     74 PL 48B 385           +ALITTI,GANDOIS,CHALOUPKA+      (SACL+CERN)

APEL      75 PL 57B 398           +AUGENSTEIN+     (KARL+PISA+SERP+WIEN+CERN)
EMMS      75 NP B96 155           +KINSON,STACEY,VOTRUBA+    (BIRM+DURH+RHEL)
ESTABROO  75 NP B95 322           P.ESTABROOKS,A.D.MARTIN              (DURH)
HYAMS     75 NP B100 205          +JONES,WEILHAMMER,BLUM,DIETL+   (CERN+MPIM)
PAWLICKI  75 PR D12 631           +AYRES,DIEBOLD,GREENE,KRAMER,WICKLUND (ANL)

DEUTSCHM  76 NP B 103 426         +KIRK,+(AACH+BERL+BONN+CERN+CRAC+HEID+WARS)
WETZEL    76 NP B 115 208         +FREUDENREICH,BEUSCH,+       (ETH+CERN+LOIC)

ALEXANDE  77 NP B 131 365         ALEXANDER,CORDEN,+    (TELA+BIRM+RHEL+LOWC)
ANTIPOV   77 NP B 119 45          +BUSNELLO,DAMGAARD,KIENZLE,+    (SERP+GEVA)
PAWLICKI  77 PR D 15 3196         +AYRES,COHEN,DIEBOLD,KRAMER,WICKLUND  (ANL)

BALTAY    78 PR D 17 62           +CAUTIS,COHEN,CSORNA,SMITH,YEH,+(COLU+BING)
CASON     78 PRL 41 271           +BAUMBAUGH,BISHOP,BISWAS,KENNEY,+(NDAM+ANL)

BECKER    79 NP B 151  46         +BLANAR,BLUM,CERRADA+ (MPIM+CERN+ZEEM+CRAC)
CORDEN    79 NP B 157 250         +DOWELL,GARVEY,JOBES,+(BIRM+RHEL+TELA+LOWC)
MARTIN    79 NP B 158 520         +OZMUTLU                             (DURH)
POLYCHRO  79 PR D 19 1317         POLYCHRONAKOS,CASON,BISHOP+      (NDAM+ANL)

BERGER    80  DESY 80/34          +GENZER+(AACH+BERG+DESY+HAMB+UMD+SIEG+WUPG)
COSTA     80 NP B 175 402         +       (BARI+BONN+CERN+GLAS+LIVP+MILA+WIEN)
GORLICH   80 NP B 174 16          +NICZYPORUK,ROZANSKA+ (CRAC+MPIM+CERN+ZEEM)
LOVERRE   80 ZPHY C 6 187         +ARMENTEROS,DIONISI+  (CERN+CDEF+MADR+STOH)

AGUILAR   81 ZPHY C 8 313         +ALBAJAR,ARMENTEROS,+ (CERN+CDEF+MADR+STOH)
BRANDELI  81 ZPHY C 10 117        BRANDELIK,BOERNER,+   (TASSO COLLABORATION)
CHABAUD   81 APP B 12 575         +NICZYPORUK,BECKER+         (CERN+CRAC+MPIM)
GIDAL     81 PL 107 B 153         +GOLDHABER,GUY,MILLIKAN,ABRAMS,+ (SLAC+LBL)
ROUSSARI  81 PL 105 B 304         ROUSSARIE,BURKE,ABRAMS,ALAM,+    (SLAC+LBL)

APEL      82 NP B 201 197         +AUGENSTEIN+     (KARL+PISA+SERP+WIEN+CERN)
CASON     82 PRL 48 1316          +BISWAS,BAUMBAUGH,BISHOP,CANNATA+(NDAM+ANL)
EDWARDS   82 PL 110 B 82          +PARTRIDGE,PECK,+ (CIT+HARV+PRIN+STAN+SLAC)
ETKIN     82 PR D 25 1786         +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)

ARMSTRON  83 NP B 224 193         ARMSTRONG+  (BARI+BIRM+CERN+MILA+LPNP+PAVI)
BINON     83 NC A 78 313          +DONSKOV,DUTEIL+         (BELG+LAPP+SERP+CERN)
    ALSO  83 SJNP 38 934          +GOUANERE,DOSNKOV+       (BELG+LAPP+SERP+CERN)
CASON     83 PR D 28 1586         +CANNATA,BAUMBAUGH,BISHOP,WATSON+(NDAM+ANL)
CHABAUD   83 NP B 223 1           +GORLICH,CERRADA+            (CERN+CRAC+MPIM)
DENNEY    83 PR D 28 2726         +CRANLEY,FIRESTONE,CHAPMAN+      (IOWA+MICH)
FRAZER    83 AACHEN CONF.         RAPPORTEUR TALK                       (UCSD)
JENNI     83 PR D 27 1031         +BURKE,TELNOV,ABRAMS,BLOCKER+     (SLAC+LBL)

BEHREND   84 ZPHY C 23 223        CELLO COLLAB(DESY+KARL+MPIM+LALO+LPNP+SACL)
COURAU    84 PL 147 B 227         +JOHNSON,SHERMAN,ATWOOD,BAILLON+ (CIT+SLAC)
SMITH     84 PR D 30 851          +BURKE,ABRAMS,BLOCKER,LEVI,+(SLAC+LBL+HARV)
BERGER    84 ZPHY C 26 199        +KLOVNING,BURGER+      (PLUTO COLLABORATION)

ALDE      85  CERN-EP/85-153      +BINON,BRICMAN,DUTEIL+(BELG+LAPP+SERP+CERN)
RYBICKI   85 ZPHY C 28 65         RYBICKI,SAKREJDA                      (CRAC)
SENS      85  SLAC-PUB-3754       PHYSICS IN COLLISION V CONFERENCE     (SLAC)
```

$a_1(1270)$ was $A_1(1270)$

$I^G(J^{PC}) = 1^-(1^{--})$

OUR LATEST MINIREVIEW ON THIS PARTICLE CAN BE FOUND IN THE 1984 EDITION.

$a_1(1270)$ MASS (MeV)

```
M   A      1270. TO 1350.            BOWLER    75 RVUE +- 7-40 PI+- P
M    B    (1382.)                    BASDEVANT 77 RVUE  - 25,40 PI- P
M   F     (1041.0)   (13.0)          GAVILLET  77 HBC  +  4.2 K- P,S 3PI
M    D     1240.0     80.0           DANKOWYCH 81 SPEC   08.45 PI-P,3PI N
M    D     1280.0     30.0           DAUM      81 CNTR    63,94 PI- P
M   E     (1230.0)   (30.0)          LONGACRE  82 RVUE
M   T     (1250.0)  APPROX           TORNQVIST 82 RVUE
M   UQ    (1056.)    (25.)           RUCKSTUHL 85 DLCO     E+E-,TAU+ TAU-    |
M          . . . . . . . . . .
M   AVG    1275.1     28.1     AVERAGE

M   A   USES DATA OF ANTIPOV 73,ASCOLI 74,OTTER 74,TABAK 74,THOMPSON 74.
M    B  USES ANTIPOV 73 DATA. WE SELECT SOLUTION B OF BASDEVANT 77.
M    D  USES THE MODEL OF BOWLER 75.
M   E   USES MULTICHANNEL AITCHISON-BOWLER MODEL.
M   E   USES DATA FROM GAVILLET 77, DAUM 80 AND DANKOWYCH 81.
M   F   PRODUCED IN K- BACKWARD SCATTERING.
M   Q   SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
M   T   FROM A UNITARIZED QUARK MODEL CALCULATION
M   U   FROM TAU --> A1 + NEUTRINO DECAYS.
```

$a_1(1270)$ WIDTH (MeV)

```
W   A       240. TO  280.            BOWLER    75 RVUE +- 7-40 PI+- P
W    B     (470.)                    BASDEVANT 77 RVUE  - 25,40 PI- P
W   F      (230.0)   (50.0)          GAVILLET  77 HBC  +  4.2 K- P,S 3PI
W    D      380.0    100.0           DANKOWYCH 81 SPEC   08.45 PI-P,3PI N
W    D      300.0     50.0           DAUM      81 CNTR    63,94 PI- P
W   E      (330.0)   (60.0)          LONGACRE  82 RVUE
W   T      (234.0)  APPROX           TORNQVIST 82 RVUE
W   UQ     (476.)    (143.)  (132.)  RUCKSTUHL 85 DLCO     E+E-,TAU+ TAU-    |
W           . . . . . . . . . .
W   AVG     316.0     44.7     AVERAGE

M   A   USES DATA OF ANTIPOV 73,ASCOLI 74,OTTER 74,TABAK 74,THOMPSON 74.
W    B  USES ANTIPOV 73 DATA. WE SELECT SOLUTION B OF BASDEVANT 77.
W    D  USES THE MODEL OF BOWLER 75.
W   E   USES MULTICHANNEL AITCHISON-BOWLER MODEL.
W   E   USES DATA FROM GAVILLET 77, DAUM 80 AND DANKOWYCH 81.
W   F   PRODUCED IN K- BACKWARD SCATTERING.
W   Q   SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
W   T   FROM A UNITARIZED QUARK MODEL CALCULATION
W   U   FROM TAU --> A1 + NEUTRINO DECAYS.
```

$a_1(1270)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$a_1(1270) \rightarrow \rho\pi$	769+ 140
P2	$a_1(1270) \rightarrow K\overline{K}$	494+ 498
P3	$a_1(1270) \rightarrow \pi(\pi\pi)_{S\text{-wave}}$	140+ 140+ 140
P4	$a_1(1270) \rightarrow \pi\gamma$	140+ 0

$a_1(1270)$ PARTIAL WIDTHS (keV)

$a_1(1270) \rightarrow \pi^{\pm}\gamma$ (G4)

W4	640.0	246.0	ZIELINSKI 84	SPEC	200 PI+Z,Z 3 PI

$a_1(1270)$ BRANCHING RATIOS

$a_1(1270) \rightarrow (\pi(\pi\pi)_{S\text{-wave}})/(\rho\pi)$ (P3)/(P1)

R4 E 0.003 0.003 LONGACRE 82 RVUE
R4 E USES MULTICHANNEL AITCHISON-BOWLER MODEL.
R4 E USES DATA FROM GAVILLET 77, DAUM 80 AND DANKOWYCH 81.

REFERENCES FOR $a_1(1270)$

BELLINI 63 NC 29 896 BELLINI,FIORINI,HERZ,NEGRI,RATTI (MILAN)

ADERHOLZ 64 PL 10 226 AACH+BERL+BIRM+BONN+DESY+HAMBURG+LOIC+MPIM
GOLDHABE 64 PRL 12 336 GOLDHABER,BROWN,KADYK,SHEN+ (LRL+UCB)
LANDER 64 PRL 13 346 A LANDER,ABOLINS,CARMONY,HENDRICKS + (UCSD) JP

ABOLINS 65 ATHENS(OHIO)CONF. +CARMONY,LANDER,XUONG,YAGER (LA JOLLA)I=1
ALITTI 65 PL 15 69 ALITTI,BATON,DELER,CRUSSARD+ (SACL+BGNA)

ALLARD 66 NC 46A 737 +DRIJARD+HENNESSY+ (ORSAY+MILAN+SACL+UCB)
DEUTSCHM 66 PL 20 82 DEUTSCHMANN,STEINBERG + (AACH+BERLIN+CERN)
HESS 66 UCRL-16832 R I HESS (THESIS, BERKELEY) (LRL)

ALLISON 67 PL 25B 619 +CRUZ+ (OXF+MPIM+BIRM+RHEL+GLAS+LOIC)
DAHL 67 PR 163 1377 +HARDY+HESS+KIRZ+MILLER (LRL)
DANYSZ 67 NC 51 A 801 DANYSZ+FRENCH+SIMAK (CERN)
JUHALA 67 PRL 19 1355 +LEACOCK+RHODE+KOPELMAN+ (IOWA+COLO)
SLATTERY 67 NC 50A 377 +KRAYBILL+FORMAN+FERBEL (YALE+ROCH) JP

ARMENISE 68 PL 26 B 336 +FORINO+CARTACCI+ (BARI+BGNA+FIRZ+ORSAY)
ASCOLI 68 PRL 21 113 +CRAWLEY,KRUSE,MORTARA,SCHAFER,+ (ILLINOIS)
BALLAM 68 PRL 21 934 +BRODY,CHADWICK,FRIES,GUIRAGOSSIAN+ (SLAC)JP
BOESEBEC 68 NP B 4 501 BOESEBECK,DEUTSCHMANN,+(AACHEN+BERLIN+CERN)
CASO 68 NC 54 A 983 +CONTE+CORDS+DIAZ+ (GENOVA+HAMB+MILA+SACL)
CHUNG 68 PR 165 1491 S.U.CHUNG,O.DAHL,J.KIRZ,D.H.MILLER (LRL)
CNOPS 68 PRL 21 1609 +HOUGH,COHN,BUGG+ (BNL+ORNL+UCND+TENN+PENN)
FRIDMAN 68 PR 167 1268 +MAURER,MICHALON,OUDET+ (HEID+STRASBOURG)
JUNKMANN 68 NP B8 471 +COCCONI+ (AACH+BERL+BONN+CERN+WARS)
KEY 68 PR 166 1430 +PRENTICE+COOPER+MANNER+ (TNTO+ANL+WISC)

ALEXANDE 69 PR 183 1168 G.ALEXANDER,A.FIRESTONE,G.GOLDHABER (LRL)
ALLABY 69 PL 29B 198 +BINON+DIDDENS+DUTEIL+KLOVNING+... (CERN)
ANDERSON 69 PRL 22 1390 +COLLINS,+ (BNL+CARN)
BERLINGH 69 PRL 23 42 BERLINGHIERI,FARBER,+ (ROCH)
DONALD 69 NP B 11 551 +EDWARDS,BURAN,BETTINI,+ (LIVP+OSLO+PADO)
FAYOLLE 69 NP B 13 40 +DE MONTAIGNAC,MORAND,STRACHMAN+ (PARIS)
JUHALA 69 PR 184 1461 +LEACOCK,RHODE,KOPELMAN,LIBBY,+ (ISU+COLO)
KENYON 69 PRL 23 146 +KINSON,SCARR,+ (BNL+UCND+ORNL)

ARMENISE 70 LNC 4 199 +GHIDINI,FORING,CARTACCI,+ (BARI+BGNA+FIRZ)
ASCOLI 70 PRL 25 962 +BROCKWAY,CRAWLEY,EISENSTEIN,HANFT,+ (ILL) JP
BRANDENB 70 NP B16 369 +BRENNER,IOFFREDO,JOHNSON,KIM+ (HARVARD)
CASO 70 LNC 3 707 +CORDS,COSTA+ (GENO+DESY+HAMB+MILA+SACL)
CRENNELL 70 PRL 24 781 +KARSHON,LAI,SCARR,SIMS (BNL)
GARELICK 70 PHILAD.CONF.P.205 D.A.GARELICK,REVIEW (NORTHEASTERN)
RABIN 70 PRL 24 925 +GALTIERI,DERENZO,FLATTE,FRIEDMAN+ (LRL)

ASCOLI 71 PRL 26 929 ILLINOIS+GENO+HAMB+MIL+SACL+HARV+TNTO+WISC
BEMPORAD 71 NP B 33 397 +BEUSCH,MELISSINOS,+ (CERN+ETH+LOIC+MILA)
BERGER 71 PHENOMENOLOGY IN PARTICLE PHYSICS, CALTECH 1971 (LRL)
RINAUDO 71 NC 5 A 239 +BOECKMANN,MAJOR+(TORI+BONN+DURH+NIJM+EPOL) JP

BERENYI 72 NP B 37 621 +PRENTICE,STEENBERG,YOON,WALKER (TNTO+WISC)
BLOODWOR 72 NP B 46 402 BLOODWORTH,JACKSON,PRENTICE,YOON (TORONTO)
DIEBOLD 72 BATAV.CONF.3P.17 R.DIEBOLD RAPPORTEUR TALK (ANL)
LAMSA 72 NP B 41 388 +EZELL,GAIDOS,WILLMANN (PURDUE)
MORSE 72 NP B 43 77 +OH,WALKER,JOHNSTON,YOON (WISC+TNTO)

ANTIPOV1 73 NP B 63 153 +ASCOLI,BUSNELLO,FOCACCI,+ (CERN+SERP) JP
ANTIPOV2 73 NP B 63 141 +ASCOLI,BUSNELLO,FOCACCI,+ (CERN+SERP) JP
ARNOLD 73 NC 17 A 393 +ENGEL,ESCOUBES,GEMESY,JANOSSY,+(STRB+BUDA)
ASCOLI 1 73 PR D 8 3894 +JONES,WEINSTEIN,WYLD (ILL)
ASCOLI 2 73 PRL 31 795 +CHAPIN,CUTLER,HOLLOWAY,KOESTER,KRUSE+(ILL) JP
ATHERTON 73 PL 43 B 249 +FRANEK,FRENCH,GHIDINI,HILPERT,+ (CERN)
READ 73 NP B 64 511 B.J.READ (DESY)

ASCOLI 74 PR D9 1963 +CUTLER,JONES,KRUSE,ROBERTS,WEINSTEIN+(ILL)
BOWLER 74 NP B74 493 +DAINTON,KADDOURA,AITCHISON (OXF)
KRUSE 74 PRL 32 1328 +ROBERTS,EDELSTEIN+ (ILL+CARN+NWES+ROCH) JP
LICHTMAN 74 NP B81 31 +BISWAS,CASON,KENNEY,MCGAHAN,+ (NDAM) JP
OTTER 74 NP B80 1 +RUDOLPH+ (AACH+BERL+BONN+CERN+HEID) JP
TABAK 74 BOSTON CONF. P.46 +RONAT,ROSENFELD,LASINSKI+ (LBL+SLAC) JP
THOMPSO1 74 PR D9 560 THOMPSON,GAIDOS,MCILWAIN,WILLMANN (PURD) JP
THOMPSO2 74 NP B69 381 THOMPSON,BADEWITZ,GAIDOS,MCILWAIN+ (PURD) JP

ABASHIAN 75 PRL 34 691 +BEAMER,BROSS,EISENSTEIN,+ (ILL+ANL+ISU)
AITCHISO 75 PL 59 B 288 I.J.R.AITCHISON, R.J.GOLDING (OXFORD)
ASCOLI 75 PR D 12 43 G.ASCOLI, H.W.WYLD (ILLINOIS)
BEUSCH 75 PL 55B 97 +POLGAR,FREUDENREICH+ (CERN+ETH+LOIC+MILA)
BOSETTI 75 NP B 101 304 +OTTER+(AACH+BERL+BONN+CERN+HEID+LOIC+WIEN)
BOWLER 75 NP B97 227 +GAME,AITCHISON,DAINTON (OXF+DARE)
DIAZ 75 PR 12 D 1272 +DIBIANCA,FICKINGER,DADO,ENGLER+(CASE+CARN) JP
EMMS 1 75 NP B93 1 +JONES,KINSON,BELL,DALE+ (BIRM+DURH+RHEL) JP
EMMS 2 75 PL 60 B 109 +JONES,KINSON,BELL,DALE+ (BIRM+DURH+RHEL) JP
HORNE 75 PR D11 996 +S.HAGOPIAN,V.HAGOPIAN,BENSINGER+(FSU+BRAN)
KANE 75 TENTH RENCONTRE DE MORIOND (MICH)
WAGNER 75 PL 58B 201 +TABAK,CHEW (LBL) JP

BAUBILLI 76 NP B 115 237 BAUBILLIER,RIVOAL,ARMENISE + (BARI+LPNP) JP
BENZ 76 NP B 115 385 +BRAUN +(AACHEN+BONN+HAMBURG+HEIDBERG+MPIM)
BRAYSHAW 76 PRL 36 73 D.BRAYSHAW (SLAC)

BALTAY 77 PRL 39 591 +CAUTIS,KALELKAR (COLUMBIA) JP
BASDEVAN 77 PR D 16 657 BASDEVANT,BERGER (FNAL+ANL) JP
CAUTIS 77 THESIS NEVIS 221 C.V.CAUTIS (COLUMBIA) JP
CERRADA 77 NP B 126 241 +BLOCKZIJL,HEINEN+ (AMST+CERN+NIJM+OXF) JP
FERRER 77 THESIS,LAL 1295 A.FERRER SORIA (ORSAY)
GAVILLET 77 PL 69 B 119 +BLOCKZIJL,ENGELEN+ (AMST+CERN+NIJM+OXF) JP
HABER 77 NP B 129 429 H.E.HABER,G.L.KANE (UNIV. OF MICHIGAN)
LONGACRE 77 PRL 38 1509 +AARON (NORTHEASTERN,BOSTON) JP
SCHULT 77 PR D 16 62 + WYLD (ILLINOIS) JP

ALEXANDE 78 PL 73 B 99 ALEXANDER,KNIES,+(DESY+AACH+HAMB+SIEG+WUPG)
BALTAY 78 PR D 17 62 +CAUTIS,COHEN,CSORNA,KALELKAR+ (COLU+BING)
BASDEVAN 78 PRL 40 994 BASDEVANT,BERGER (FNAL+ANL) JP
CORDEN 78 NP B 136 77 DOWELL,GARVEY,JOBES+ (BIRM+RHEL+TELA+LOWC) JP
FERRER 1 78 PL 74 B 287 +TREILLE,RIVET + (ORSAY+CERN+CDEF+LPNP)
FERRER 2 78 NP B 142 77 +TREILLE,RIVET + (ORSAY+CERN+CDEF+LPNP)
JAROS 78 PRL 40 1120 +ABRAMS,ALAM+ (SLAC+LBL+NWES+HAWA)
PERNEGR 78 NP B 134 436 +AEBISCHER+ (ETH+CERN+LOIC+MILA) JP
ROBERTS 78 PR D 18 59 +KRUSE,EDELSTEIN+ (ILL+CARN+NWES+ROCH) JP

CORDIER 79 PL B 81 389 +DELCOURT,ESCHSTRUTH,FULDA,+ (LALO)
KASPER 79 NP B 156 207 +CHAPMAN,DEROACH,GOLD,KLEIN,MARTIN+ (MELB)
MAZZUCAT 79 NP B 156 532 MAZZUCATO,PENNINGTON+ (CERN+ZEEM+NIJM+OXF)

DAUM 80 PL 89 B 281 +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL) JP
WAGNER 80 ZPHY C 3 193 +ALEXANDER+ (AACH+DESY+HAMB+SIEG+WUPP)

AARON 81 PR D 24 1207 +LONGACRE (NEAS+BNL)
DANKOWYC 81 PRL 46 580 +BROCKMAN,EDWARDS+(TNTO+BNL+CARL+MCGI+OHIO)
DAUM 81 NP B 182 269 +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
FOSTER 81 NP B 187 231 +BLOKZIJL,ARMENTEROS,+ (OXF+ZEEM+CERN+NIJM)

ARMSTRON 82 NP B 202 1 +BACCAR(AACH+BARI+BONN+CERN+GLAS+LIVP+MILA)
BELLINI 82 NP B 199 1 + (CERN+MILA+JINR+BGNA+HELS+PAVI+WARS+VIEN)
ETKIN 82 PR D 25 1786 +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)
GAVILLET 82 ZPHY C 16 119 +ARMENTEROS,AGUILAR+ (CERN+CDEF+PADO+ROMA)
LONGACRE 82 PR D 26 83 R.S.LONGACRE (BNL)
TORNQVIS 82 NP B 203 268 TORNQVIST (HELS)

LEEDOM 83 PR D 27 1426 +DE BONTE,GAIDOS,KEY,WONG+ (PURD+TNTO)

ZIELINSK 84 PR D 30 1855 +BERG,CHANDLEE,CIHANGIR,+ (ROCH+MINN+FNAL)
ZIELINSK 84 PRL 52 1195 +BERG,CHANDLEE,CIHANGIR,+ (ROCH+MINN+FNAL)
RUCKSTUH 85 CALT-68-1310 RUCKSTUHL,STROYNOWSKI,+ (CIT+SLAC+STAN)

$\eta(1275)$

$I^G(J^{PC}) = 0^-(0^{-+})$

OMITTED FROM SUMMARY TABLE

SEEN IN PHASE SHIFTS ANALYSIS OF THE ETA PI+ PI- SYSTEM WITH PI+ PI- IN AN S-WAVE (STANTON 79). WAIT CONFIRMATION.

$\eta(1275)$ MASS (MeV)

M	(1275.)	APPROX.	STANTON 79	CNTR	0 8.4PI-P,ETA 2PI

$\eta(1275)$ WIDTH (MeV)

W	(70.)	APPROX.	STANTON 79	CNTR	0 8.4PI-P,ETA 2PI

$\eta(1275)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\eta(1275) \rightarrow a_0(980)\ \pi$	983+ 140
P2	$\eta(1275) \rightarrow \eta\pi^+\pi^-$	549+ 140+ 140

$\eta(1275)$ BRANCHING RATIOS.

$\eta(1275) \rightarrow a_0(980)\ \pi$ (P1)

R1	LARGE	STANTON 79	CNTR	0 8.4PI-P,ETA 2PI

REFERENCES FOR $\eta(1275)$

STANTON 79 PRL 42 346 +BROCKMAN,DANKOWYCH,+ (OSU+CARL+MCGI+TNTO) JP

BARNES 82 PL 116 B 365 T.BARNES AND F.E.CLOSE (RHEL)
TANIMOTO 82 PL 116 B 198 M.TANIMOTO (BIEL)

ATKINSON 84 PL 138 B 459 ATKINSON+ (BONN+CERN+GLAS+LANC+MCHS+LPNP+)

$f_1(1285)$
was $D(1285)$

$I^G(J^{PC}) = 0^+(1^{-+})$

$f_1(1285)$ MASS (MeV)

M	S	500(1280.)	(3.)	THUN	72	MMS	13.4 PI- P
M		34(1271.0)	(10.0)	CORDEN	78	OMEG	12-15PI-P,K+K-PI
M	P	46(1275.0)	APPROX.	STANTON	79	CNTR	8.5PI-P,2GAM 2PI
M		1283.0	5.0	DAHL	67	HBC	1.6-4.2 PI- P
M		1290.	7.	D-ANDLAU	68	HBC	1.2 PBAR P, 5-6 PFS
M		1270.0	10.0	CAMPBELL	69	DBC	2.7 PI+ D
M		1285.	7.	LORSTAD	69	HBC	0.7 PB P, 4,5-BODY
M		1303.0	8.0	BARDADIN	71	HBC	8 PI+ P, P+6PI
M		1283.0	6.0	BOESEBECK	71	HBC	16.0 PI P,5 PI
M		150 1292.	10.	DEFOIX	72	HBC	0.7 PBAR P,7 PI
M		180 1286.	3.	DUBOC	72	HBC	1.2 PBAR P,2K4PI
M		210 1279.0	5.0	GRASSLER	77	HBC	16. PI-+ P
M		85 1295.0	12.0	CORDEN	78	OMEG	12-15PI-P, N 5PI
M		320 1282.0	2.0	NACASCH	78	HBC	.7+.76 PB P,KKBP
M		200 1288.0	9.0	GURTU	79	HBC	4.2 K- P,ETA 2PI

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M        31 1275.0       6.0              BROMBERG  80 SPEC     100 PI-P,2KPIX
M       103 1283.0       3.0              DIONISI   80 HBC      4. PI- P,K KB PI
M           1278.        4.               EVANGELIS 81 OMEG     12 PI-P,ETA3PIP
M   T      (1279.)    APPROX              TORNQVIST 82 RVUE
M           1285.0       2.0              PALANO    83 OMEG     85 PP PI+P,2KPIX
M       604 1270.0       2.0              ARMSTRONG 84 OMEG     85 PI+P,K KBARPI  |
M       353 1287.0       5.0              BITUKOV   84 SPEC     32 PI-P,K+K-PI0   |
M           1286.0       1.0              CHAUVAT   84 SPEC     ISR 31.5 PP       |
M           1285.0       2.0              CHUNG     85 SPEC   0 8 PI-P,K K PI N   |
M           . . . . . . . . . . .
M   AVG     1283.4       1.3      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.1)

M   P   FROM PHASE SHIFT ANALYSIS OF ETA PI+PI- SYSTEM.
M   S   SEEN IN THE MISSING MASS SPECTRUM
M   T   FROM A UNITARIZED QUARK MODEL CALCULATION
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$f_1(1285)$ WIDTH (MeV)

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                     ONLY EXPERIMENTS GIVING WIDTH ERROR LESS
                     THAN 20 MEV ARE KEPT FOR AVERAGING.

W   R        (35.0)   (10.0)           DAHL      67 HBC       1.6-4.2 PI- P
W   R        (60.)    (15.)            LORSTAD   69 HBC   0.7 PB P, 4,5-BODY
W   R   150  (28.)     (5.)            DEFOIX    72 HBC      0.7 PBAR P,7 P9
W   R   180  (46.)     (9.)            DUBOC     72 HBC      1.2 PBAR P,2K4PI
W   S   500  (37.)     (5.)            THUN      72 MMS      13.4 PI- P
W   P        (10.0)  APPROX.           STANTON   79 CNTR     8.5PI-P,2GAM 2PI

W             30.0     15.0            CAMPBELL  69 DBC       2.7 PI+ D
W             10.0     10.0            BOESEBECK 71 HBC      16.0 PI P,5 PI
W       210   24.0     18.0            GRASSLER  77 HBC      16. PI-+ P
W       320   28.3      6.7            NACASCH   78 HBC      .7+.76 PB P,KKBP
W       200   25.0     15.0            GURTU     79 HBC      4.2 K- P,ETA 2PI
W       103   29.0     10.0            DIONISI   80 HBC      4. PI- P,K KB PI
W             26.      12.             EVANGELIS 81 OMEG     12 PI-P,ETA3PIP
W             26.       5.             PALANO    83 OMEG     85 PP PI+P,2KPIX
W       604   32.0      3.0            ARMSTRONG 84 OMEG     85 PI+P,K KBARPI  |
W             24.0      3.0            CHAUVAT   84 SPEC     ISR 31.5 PP       |
W             22.0      2.0            CHUNG     85 SPEC   0 8 PI-P,K K PI N   |
W           . . . . . . . . . . .
W   AVG       24.9      1.6     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)

W   P   FROM PHASE SHIFT ANALYSIS OF ETA PI+PI- SYSTEM.
W   R   RESOLUTION NOT UNFOLDED
W   S   SEEN IN THE MISSING MASS SPECTRUM
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$f_1(1285)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_1(1285) \to K\bar{K}\pi$	498+ 498+ 135
P2	$f_1(1285) \to \pi\pi\rho$	135+ 135+ 769
P3	$f_1(1285) \to \eta\pi\pi$	549+ 135+ 135
P4	$f_1(1285) \to a_0(980)\ \pi$	983+ 135
P5	$f_1(1285) \to 2\pi^+2\pi^-$	140+ 140+ 140+ 140
P6	$f_1(1285) \to K^*(892)\ \bar{K}$	892+ 498
P7	$f_1(1285) \to 4\pi$	140+ 140+ 140+ 140

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
          P 1         P 3        P 7
 P 1 .1117+-.0266
 P 3    .2931  .4883+-.0586
 P 7   -.6152     -.9341  .4000+-.0711
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$f_1(1285)$ BRANCHING RATIOS

```
        THE F1(1285) BRANCHING RATIOS FIT IS MADE WITH THE ASSUMPTION THAT
        THE F1(1285) INTO 4PI DECAY IS ALWAYS VIA DECAY INTO I=1 PI PI
        PAIRS (E.G., RHO PI PI).
```

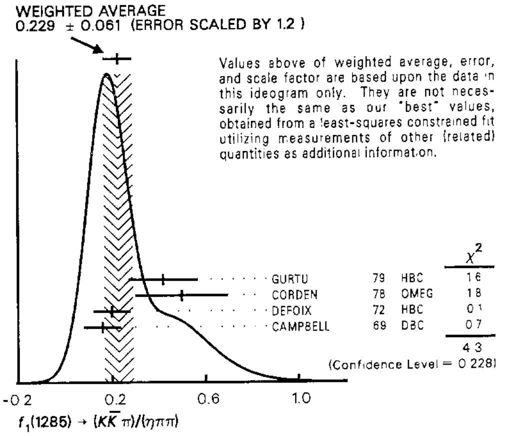
$f_1(1285) \to (\pi\pi\rho)/(K\bar{K}\pi)$ (P2)/(P1)

```
R1            (2.0)  OR LESS           DAHL      67 HBC       PI+-
R1   D        (4.0)  OR LESS           DONALD    69 HBC       1.2 PBAR P,5P+
R1   D         THIS IS FOR (RHO0 PI+ PI-)/(K KBAR PI0)
```

$f_1(1285) \to (K\bar{K}\pi)/(\eta\pi\pi)$ (P1)/(P3)

```
R2              0.16     0.08          CAMPBELL  69 DBC      2.7 PI+ D
R2 K            0.20     0.08          DEFOIX    72 HBC      0.7 PBAR P,7 PI
R2              0.5      0.2           CORDEN    78 OMEG     12-15PI-P
R2              0.42     0.15          GURTU     79 HBC      4.2 K- P
R2           . . . . . . . . . . .
R2   AVG        0.229    0.061   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
R2   FIT        0.229    0.053  FROM FIT
                         (SEE IDEOGRAM BELOW)

R2 K    K KBAR SYSTEM CHARACTERIZED BY THE I=1 THRESHOLD
R2 K    ENHANCEMENT (SEE UNDER A0(980)).
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$f_1(1285) \to (a_0(980)\ \pi)/(\eta\pi\pi)$ (P4)/(P3)

```
R3          SEEN                       DEFOIX    68 HBC      PBAR P
R3             1.0      0.3            GRASSLER  77 HBC    0 16. PI-+ P
R3             0.6      0.3      0.2   CORDEN    78 OMEG     12-15PI-P
R3             0.72     0.15           GURTU     79 HBC      4.2 K- P
R3          . . . . . . . . . . .
R3   AVG       0.74     0.12     AVERAGE
```

$f_1(1285) \to (2\pi^+2\pi^-\ (\text{including}\ \rho\pi\pi))/(\eta\pi^+\pi^-)$

```
R4                                                      (P5)/(2/3P3)
R4             0.46     0.15           GRASSLER  77 HBC      16. PI-+ P
R4             0.32     0.20           GURTU     79 HBC      4.2 K- P
R4          . . . . . . . . . . .
R4   AVG       0.41     0.12     AVERAGE
R4   FIT       0.41     0.12   FROM FIT
```

$f_1(1285) \to (K^*(892)\ \bar{K})/\text{total}$ (P6)

```
R5          NOT SEEN                   NACASCH   77 HBC      .7+.76 PB P,KKBP
```

$f_1(1285) \to (\rho^0\pi^+\pi^-)/(2\pi^+2\pi^-)$ (1/3P2)/(P5)

```
R6             1.0      0.4            GRASSLER  77 HBC      16 GEV PI+- P
```

$f_1(1285) \to (\rho\pi\pi)/(\eta\pi\pi)$ (P2)/(P3)

```
R7 C         (0.4)  OR LESS  CL=.95   CORDEN    78 OMEG     12-15PI-P
R7 C    NOTE THAT CORDEN 78 AND GRASSLER 77 ARE IN DISAGREEMENT.
```

REFERENCES FOR $f_1(1285)$

```
D-ANDLAU 65 PL  17 347          +BARLOW,ADAMSON,+      (CDEF+CERN+IRAD+LIVP)
MILLER   65 PRL 14 1074         +CHUNG,DAHL,HESS,HARDY,KIRZ,+       (LRL+UCB)

BARLOW   67 NC   50 A  701      +MONTANET,D-ANDLAU+    (CERN+CDEF+IRAD+LIVP)
DAHL     67 PR  163 1377        +HARDY+HESS+KIRZ+MILLER                (LRL)I  JP

D-ANDLAU 68 NP   B 5  693       +ASTIER,BARLOW+        (CDEF+CERN+IRAD+LIVP)I  JP
DEFOIX   68 PL  28 B 353        +RIVET,SIAUD,CONFORTO+      (CDEF+IPNP+CERN)

CAMPBELL 69 PRL 22 1204         +LICHTMAN,+                           (PURD)
DONALD   69 NP B 11 551         +EDWARDS,BURAN,BETTINI,+   (LIVP+OSLO+PADO)
LORSTAD  69 NP B 14 63          B.LORSTAD,D-ANDLAU,ASTIER,+      (CDEF+CERN)   JP
OTWINOWS 69 PL  29 B 529        S.OTWINOWSKI                        (WARSAW)

AMMAR    70 PR D2 430           +KROPAC,DAVIS,DERRICK+ (KANS+NWES+ANL+WISC)

BARDADIN 71 PR D4 2711          BARDADIN-OTWINOWSKA,HOFMOKL,MICHEJDA+(WARS)
BOESEBEC 71 PL 34 B 659                (AACH+BERL+BONN+CERN+CRAC+HEID+WARS)
GOLDBERG 71 LNC 1 627           +MAKOWSKI,TOUCHARD,DONALD,+       (IPN+LIVP)   JP

BERENYI  72 NP B 37 621         +PRENTICE,STEENBERG,YOON,WALKER (TNTO+WISC)
CHAPMAN  72 NP B 42 1           +CHURCH,LYS,MURPHY,RING,VANDER VELDE (MICH)
DEFOIX   72 NP B 44 125         +NASCIMENTO,BIZZARRI,+           (CDEF+CERN)
DUBOC    72 NP B 46 429         +GOLDBERG,MAKOWSKI,DONALD,+      (LPNP+LIVP)
THUN     72 PRL 28 1733         +BLIEDEN,FINOCCHIARO,BOWEN,+     (STON+NEAS)

VUILLEMI 75 LNC 14 165          VUILLEMIN,+       (LAUS+NEUC+LPNP+LIVP+GLAS)   JP
WELLS    75 NP B 101 333        +RADOJICIC,ROSCOE,LYONS,+                (OXF)

HANDLER  76 NP B 110 173        +PLANO,BRUCKER,KOLLER+      (RUTG+STEV+SETO)
VUILLEMI 76 NC 33A 133          VUILLEMIN+        (LAUS+NEUC+LPNP+LIVP+GLAS)

GRASSLER 77 NP B 121 189        +(AACHEN+BERLIN+BONN+CERN+CRACOW+HEID+WARS)

CORDEN   78 NP B 144 253        +CORBETT,ALEXANDER,+  (BIRM+RHEL+TELA+LOWC)   JP
IRVING   78 NP B 139 327        A.C.IRVING,H.R.SEPANGI                  (LIVP)
NACASCH  78 NP B 135 203        +DEFOIX,DOBRZYNSKI,+     (PARIS+MADRID+CERN)

GURTU    79 NP B 151 181        +GAVILLET,BLOKZIJL,+    (CERN+ZEEM+NIJM+OXF)
STANTON  79 PRL 42 346          +BROCKMAN,DANKOWYCH,+  (OSU+CARL+MCGI+TNTO)   JP

BROMBERG 80 PR D 22 1513        +HAGGERTY,ABRAMS,DZIERBA(CIT+FNAL+ILLC+IND)
DE BILLY 80 NP B 176 1          +BRIAND,DUBOC,LEVY+    (CURI+LAUS+NEUC+GLAS)   JP
DIONISI  80 NP B 169 1          +GAVILLET,ARMENTEROS+ (CERN+MADR+CDEF+STOH)

EVANGELI 81 NP B 178 197        EVANGELISTA+(BARI+BONN+CERN+DARE+LIVP+MILA)

GAVILLET 82 ZPHY C 16 119       +ARMENTEROS,AGUILAR+  (CERN+CDEF+PADO+ROMA)
TORNQVIS 82 NP B 203 268        TORNQVIST                               (HELS)

PALANO   83  CERN/EP 83-107     +ARMSTRONG,APOSTOLAKIS(ATEN+BARI+BIRM+CERN)
```

```
ARMSTRON 84 PL 146 B 273       +BLOODWORTH,BURNS,+    (ATHU+BARI+BIRM+CERN)  JP
ATKINSON 84 PL 138 B 459       ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
BITUKOV  84 PL 144 B 133       +DOROFEEV,DZHELYADIN,GOLOVKIN,KULIK,+(SERP)
CHAUVAT  84 PL 148 B 382       +MERITET,BONINO,ALITI+(CERN+UDCF+UCLA+SACL)

ASTON    85 PR D 32 2255       +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+CNRC)
CHUNG    85 PRL 55 779         +FERNOW,BOEHNLEIN+       (BNL+FLOR+IND+SMAS)  JP
```

$f_0(1300)$ was $\epsilon(1300)$

$I^G(J^{PC}) = 0^-(0^{--})$

OUR LATEST MINIREVIEW ON THIS PARTICLE CAN BE FOUND IN THE 1984 EDITION.

$f_0(1300)$ MASS (MeV)

```
M        (1256.0)                      FROGGATT  77 RVUE    PI+PI- CHANNEL
M        (1270.)  APPROX.              MARTIN    78 RVUE    PI+PI- CHANNEL
M        (1300.)  APPROX.              POLYCHRON 79 STRC    7. PI-P,KS KS N
M         1425.      15.               WICKLUND  80 SPEC    6. PI N,K+ K- N
M        (1394.)                       IRVING    81 RVUE    PI+PI-,K KBAR CH
M         1463.0      9.0              ETKIN1    82 MPS     23 PI-P,2K0S N
M  C      1470.0     22.4              ETKIN2    82 MPS     23 PI-P,2K0S N
M        (1237.)   APPROX              TORNQVIST 82 RVUE
M         1220.0     40.0              ALDE      85 GAM4    100PI- P,2 ETA    |
M        . . . . . . . . . .
M   AVERAGE MEANINGLESS (SCALE FACTOR = 3.6)

M  C    FIT INCLUDES INTERFERING F0(1240) RESONANCE. SYSTEMATIC
M  C    ERROR ADDED QUADRATICALLY BY US.
```

$f_0(1300)$ WIDTH (MeV)

```
W   E     (400.)  APPROX.              FROGGATT  77 RVUE    PI+PI- CHANNEL
W         (150.)  APPROX.              POLYCHRON 79 STRC    7. PI-P,KS KS N
W          160.      30.               WICKLUND  80 SPEC    6. PI N,K+ K- N
W P       (220.)                       IRVING    81 RVUE    PI+PI-,K KBAR CH
W          118.0    138.0      16.0    ETKIN1    82 MPS     23 PI-P,2K0S N
W  C       140.0     22.0              ETKIN2    82 MPS     23 PI-P,2K0S N    |
W        (1400.)   APPROX.             TORNQVIST 82 RVUE
W          320.0     40.0              ALDE      85 GAM4    100PI- P,2 ETA    |
W        . . . . . . . . . .
W   AVERAGE MEANINGLESS (SCALE FACTOR = 2.8)

W  C    FIT INCLUDES INTERFERING F0(1240) RESONANCE. SYSTEMATIC
W  C    ERROR ADDED QUADRATICALLY BY US.
W   E   WIDTH DEFINED AS DISTANCE BETWEEN 45 AND 135 DEGREES PHASE SHIFT.
W P     FROM POLE POSITION
```

$f_0(1300)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_0(1300) \rightarrow \pi\pi$	140+ 140
P2	$f_0(1300) \rightarrow K\overline{K}$	498+ 498
P3	$f_0(1300) \rightarrow \eta\eta$	549+ 549

$f_0(1300)$ BRANCHING RATIOS

$f_0(1300) \rightarrow (\pi\pi)/\text{total}$ (P1)

```
R1         (0.73)                      HYAMS     75 ASPK    17.2 PI-P,PI+PI-
R1          0.936     0.019     0.015  GORLICH   80 ASPK    17,18 PI-P POLAR
R1         (0.93)                      LOVERRE   80 HBC     4. PI- P,K K N
R1         (0.93) APPROX.              TORNQVIST 82 RVUE
```

$f_0(1300) \rightarrow (K\overline{K})/(\pi\pi)$ (P2)/(P1)

```
R2          0.08      0.01             COSTA     80 OMEG  0 10 PI-P,K+ K- N
```

REFERENCES FOR $f_0(1300)$

```
SAMIOS   62 PRL 9 139          +BACHMAN,LEA+          (BNL+CUNY+COLU+KNTY)

BLOKHINT 63 JETP 17 80         BLOKHINTSEVA,GREIBINNIK,ZHUKOV +    (DUBNA)
BOOTH    63 PR 132 2314        + ABASHIAN                            (LRL)
KIRZ     63 PR 130 2481        +SCHWARTZ + TRIPP                     (LRL)

BARISH   64 PR 135 B 416       BARISH,KURZ,PEREZ-MENDEZ,SOLOMON      (LRL)
CRAWFORD 64 PRL 13 421         +GROSSMAN,LLOYD,PRICE,FOWLER          (LRL)
DEL FABR 64 PRL 12 674         DEL FABRO,DE PRETIS,JONES+       (FRASCATI)
KALMUS   64 PRL 13  99         +KERNAN,PU,POWELL,DOWD      (LRL+WISCONSIN)

BATON    65 NC 36 1149         J.P.BATON, J.REGNIER               (SACLAY)
BIRGE    65 PR 139 B 1600      +ELY+GIDAL+KALMUS+CAMERINI+      (LRL+WISC)
BROWN    65 CORAL GABLES 219   BROWN+FAIER                  (NORTHWESTERN)
DURAND   65 PRL 14 329         L. DURAND AND Y.T. CHIU              (YALE)

BETTINI  66 NC 42A 695         +CRESTI,LIMENTANI,LORIA,PERUZZO+(PADO+PISA)
JACOBS   66 PRL 16 669         +SELOVE                               (LRL)
KOPELMAN 66 PL  22  118        +ALLEN,GODDEN,MARSHALL +   (COLORADO+IOWA)
LOVELACE 66 PL  22  332        LOVELACE,HEINZ,DONNACHIE             (CERN)

ANDERSON 67 PRL 18 89          +FUKUI+KESSLER+ (CHIC+ANL+CNRC+MCGILL+LOQM)
BEUSCH   67 PL 25 B 357        +FISCHER,GOBBI,ASTBURY+          (ETH+CERN)
CLEGG    67 PR 163 1664        A.B.CLEGG                       (LANCASTER)
CORBETT  67 PR 156 1451        +DAMERELL+MIDDLEMAS+NEWTON       (OXF+RHEL)
GUTAY    67 PRL 18 142         +JOHNSON+LOEFFLER+MCILWAIN+    (PURDUE+LRL)
JOHNSON  67 PR 163 1497        +GUTAY,EISNER,KLEIN,PETERS,SAHNI,YEN+(PURD)
MALAMUD  67 PRL 19 1056        E.MALAMUD + P.E.SCHLEIN              (UCLA)
WALKER   67 RMP 39 695         W.D.WALKER                      (WISCONSIN)
WALKER   67 PRL 18 630         +CARROLL,GARFINKEL,OH           (WISCONSIN)

BANDER   68 PR 168 1679        +SHAW,FULCO          (UC IRVINE+S.BARBARA)
BISWAS   68 PL 27 B 513        +CASON,JOHNSON,KENNEY,POIRIER+       (NDAM)
BRAUN    68 PRL 21 1275        BRAUN,CLINE,SCHERER             (WISCONSIN)
DUTTA-RO 68 PR 169 1357        B. DUTTA-ROY, I.R. LAPIDUS           (STEV)
EISENHAN 68 PRL 20 758         EISENHANDLER,MISTRY,MOSTEK +      (CORNELL)
FOSTER   68 NP B 6 107         +GAVILLET+LABROSSE+MONTANET+    (CERN+CDEF)
HYAMS    68 NP B7 1            +KOCH,POTTER,..VON LINDERN,LOREN(CERN+MPIM)
JONES    68 PR 166 1405        +CALDWELL+ZACHAROV+HARTING+BLEULER+  (CERN)
JOHNSON  68 PR 176 1651        +POIRIER,BISWAS,GUTAY+     (NDAM+PURD+SLAC)
LOVELACE 68 PL 28 B 264        C.LOVELACE                           (CERN)
MARATECK 68 PRL 21 1613        +HAGOPIAN,+  (PENN+LRL+COLO+PURD+TNTO+WISC)

BIZZARRI 69 NP B14 169(SEE P.190)+FOSTER,GAVILLET,GHESQUIERE+ (CERN+CDEF)
DAVISON  69 PR 180 1333        +BACASTOW,BARKAS,+                (UCR+UCB)
DEINET   69 PL 30 B 359        +MENZIONE,MULLER,STAUDENMAIER,+ (KARL+CERN)
ELY      69 PR 180 1319        +GIDAL,HAGOPIAN,+           (UCB+LOUC+WISC)
FELDMAN  69 PRL 22 316         +FRATI,GLEESON,HALPERN,NUSSBAUM,+    (PENN)
GUTAY    69 NP B 12 31         +CARMONY,CSONKA,LOEFFLER,MEIERE    (PURDUE)
HALL     69 NP B 12 573        +MURRAY,RIDDIFORD               (BIRMINGHAM)
HOPKINSO 69 NC 59 A 181        J.HOPKINSON,R.G.ROBERTS              (CERN)
MALAMUD  69 ARGONNE CONF.P.93 E.MALAMUD, P.SCHLEIN                  (UCLA)
MORGAN   69 NP B 10 261        D.MORGAN,G.SHAW                      (RHEL)
ROBERTS  69 PL 29 B 368        R.G. ROBERTS, F. WAGNER              (CERN)
SCHAREN1 69 ARGONNE CONF.306   SCHARENGUIVEL                      (PURDUE)
SCHAREN2 69 PR 186 1387        SCHARENGUIVEL(PURD+LRL+CERN+COLO+PENN+TNTO)
SMITH    69 PRL 23 335         G.A.SMITH, R.J.MANNING            (MSU+LRL)
SONDEREG 69  SEE BASDEVANT 72 SONDEREGGER,BONAMY                    (SACL)
STRUGALS 69 PL 29 B 518        +CHUVILO,FENYVES,+         (WARS+JINR+BUDA)
    ALSO 70 NP B 24 358        STRUGALSKI,CHUVILO,FENYVES,GEMESY,+ (DUBNA)
WAGNER   69 NC 64 A 189        F.WAGNER                             (CERN)

BARTSCH  70 NP B 22 1          +KEPPEL,GENSCH,MORRISON,+  (AACH+BERL+CERN)
BATON    70 PL 33 B 528        +LAURENS,REIGNIER                  (SACLAY)
BRODY    70 PRL 24 948         +GROVES,VANBERG,MAGLIC+(PENN+RUTG+UPNJ+ANL)
DIAZ     70 NP B 16 239        +GAVILLET,LABROSSE,MONTANET+    (CERN+CDEF)
HYAMS    70 PHILAD.CONF.P.41   +SCHLEIN,BEUSCH,+ (CERN+MPIM+ETH+LOIC+HAWA)
MAUNG    70 PL 33 B 521        +MASEK,MILLER,RUDERMAN,VERNON,+  (UCSD+LRL)
MORGAN 1 70 SPRINGER TRACTS MOD.PHYS.,VOL.55,P.1. MORGAN,PISUT(RHEL+CERN)
MORGAN 2 70 PR D 2 520         D.MORGAN,G.SHAW                      (RHEL)
NIELSEN  70 NP B 22 525        +LYNG-PETERSEN,PIETARINEN         (NORDITA)
OH       70 PR D 1 2494        +GARFINKEL,MORSE,WALKER,PRENTICE(WISC+TNTO)
SCHARENG 70 NP B 22 16         SCHARENGUIVEL,GUTAY,MILLER,+    (PURD+PENN)
SHIBATA  70 PRL 25 1227        +FRISCH,WAHLIG                        (MIT)

ALSTON-G 71 PL 36 B 152        ALSTON-GARNJOST,BARBARO-GALTIERI,+    (LBL)
BANAIGS  71 NP B 28 509        +BERGER,DUFLO,GOLDZAHL,COTTEREA+(SACL+CAEN)
BEAUPRE  71 NP B 28 77         +DEUTSCHMANN,GRAESSLER,+   (AACH+BERL+CERN)
BENSINGE 71 PL 36 B 134        BENSINGER,ERWIN,THOMPSON,W.D.WALKER  (WISC)
DUBAL    71 NP B 32 535        L.DUBAL,D.J.BROWN               (CNRC+CARL)
GUILLOU  71 NC 5 A 659         LE GUILLOU,MOREL,NAVELET             (CERN)
GUTAY    71 NP B 27 486        +SCHARENGUIVEL,FUCHS,GAIDOS,MILLER,+ (PURD)
HAMILTON 71 SPRINGER TRACTS MOD.PHYS.,VOL. 57,P.41 J.HAMILTON   (NORDITA)
KIM      71 PR D 4 265         +BANDER                               (UCI)
LYNG PET 71 PHYS.REPRTS 2 155 J.LYNG PETERSEN (REVIEW)              (CERN)

APEL     72 PL 41 B 542        +AUSLANDER,MULLER,BERTOLUCCI,+  (KARL+PISA)
BAILLON  72 PL 38 B 555        +CARNEGIE,KLUGE,LEITH,LYNCH,RATCLIFF+(SLAC)
BASDEVAN 72 PL 41 B 178        BASDEVANT,FROGGATT,PETERSEN          (CERN)
BRODY 1  72 PRL 28 1215        +GROVES,MAGLICH,NOREM,+    (PENN+RUTG+UPNJ)
BRODY 2  72 PRL 28 1217        H.BRODY                      (PENNSYLVANIA)
CARROLL  72 PRL 28 318         +DIAMOND,FIREBAUGH,MATTHEWS,+   (WISC+TNTO)
ELVEKJAE 72 NP B 43 445        F.ELVEKJAER                        (AARHUS)
FLATTE   72 PL 38 B 232        +ALSTON-GARNJOST,BARBARO-GALTIERI,    (LBL)
FRENKIEL 72 NP B 47 61         +GHESQUIERE,LILLESTOL,CHUNG,+   (CDEF+CERN)
GAIDOS   72 NP B 46 449        +MCILWAIN,THOMPSON,WILLMANN        (PURDUE)
PRASAD   72 PR D 6 3216        +BREHM            (UNIV.OF MASSACHUSETTS)
NIELSEN  72 NP B 49 586        H.NIELSEN,G.OADES             (NORD+AARHUS)
WHITEHEA 72 NP B 48 365        WHITEHEAD,AULD,+       (AERE+RHEL+SHMP+LOUC)
WILLIAMS 72 PR D 6 3178        P.K.WILLIAMS                          (FSU)
ZYLBERSZ 72 PL 38 B 457        ZYLBERSZTEJN,BASILE,BOURQUIN,+  (GEVA+SACL)

ANJOS    73 NP B 67 37         +D.LEVY,A.SANTORO                  (SACLAY)
BANAIGS1 73 PL 43 B 535        +COTTEREAU,FABBRI,+        (SACL+CAEN+FRAS)
BANAIGS2 73 NP B 67 1          +BERGER,GOLDZAHL,COTTEREAU,+    (SACL+CAEN)
BASDEVAN 73 AIX CONF.P.220     J.L.BASDEVANT RAPPORTEUR TALK    (PARIS VI)
BEIER    73 PRL 30 399         +BUCHHOLZ,MANN,PARKER,ROBERTS        (PENN)
BINNIE   73 PRL 31 1534        +CARR,DEBENHAM,DUANE,GARBUTT,+  (LOIC+SHMP)
BRAUN    73 PR D 8 3794        +D.CLINE                             (WISC)
HYAMS    73 NP B 64 134        +JONES,WEILHAMMER,BLUM,DIETL,+  (CERN+MPIM)
    FOR OTHER RESULTS ON SAME EXPERIMENT SEE GRAYER 74
OCHS     73 THESIS             THESIS                               (MPIM)
PILKUHN  73 NP B 65 460        +SCHMIDT,MARTIN,+      (KARL+CERN+LOUC+NIJM)
PROTOPOP 73 PR D 7 1280        PROTOPOPESCU,GARNJOST,GALTIERI,FLATTE+(LBL)
RISSER   73 PL 43 B 68         T.RISSER,M.D.SHUSTER                 (SACL)
SKUJA    73 PRL 31 653         +WAHLIG,RISSER,PRIPSTEIN,NELSON,+     (LBL)

BASDEVAN 74 NP B 72 413        BASDEVANT,FROGGATT,PETERSEN     (LPTP+NORD)
BONNIER  74 NP B 83 440        B.BONNIER,N.JOHANNESSON              (CERN)
CARROLL  74 PR D 10 1430       +MATTHEWS,WALKER+     (SLAC+DUKE+WISC+TNTO)
ENGLER   74 PR D 10 2070       +KRAEMER,TOAFF,WEISSER,DIAZ+    (CARN+CASE)
ESTABROO 74 NP B 79 301        P.ESTABROOKS,A.D.MARTIN              (DURH)
GRAYER   74 NP B 76 375        +HYAMS,JONES,BLUM,DIETL         (CERN+MPIM)
JONES    74 NP B 83 93         +ALLISON,SAXON                        (OXF)
MORGAN   74 PL 51 B 71         D.MORGAN                             (RHEL)
ORITO    74 PL 48 B 380        +FERRER,PAOLUZI,SANTONICO       (FRAS+ROMA)
PASCUAL  74 NP B 83 362        P.PASCUAL,F.J.YNDURAIN          (BARC+MADU)

BAR-NIR  75 NP B 87 109        +RISSER,SHUSTER            (CERN+UCSB+TELA)
BARRY    75 NP B 85 239        G.W.BARRY                            (PURD)
BASDEVAN 75 NP B 98 285        BASDEVANT,CHAPELLE,LOPEZ,SIGELLE     (LPTP)
DONOHUE  75 NC 25 A 409        J.T.DONOHUE,Y.LEROYER                (BORD)
ESTABROO 75 NP B 95 322        P.ESTABROOKS,A.D.MARTIN              (DURH)
FROGGATT 75 NP B 91 454        C.D.FROGGATT,J.L.PETERSEN       (GLAS+NORD)
FUJII    75 NP B 85 179        Y.FUJII,M.FUKUGITA                   (TOKY)
HYAMS    75 NP B 100 205       +JONES,WEILHAMMER,BLUM,DIETL+   (CERN+MPIM)
MORGAN   75 ARGONNE CONF. 45   D.MORGAN                             (RHEL)
RIESTER  75 NP B 96 407        +ARNOLD,ENGEL,PATY                   (STRB)
SHIMADA  75 NP B 100 225       T.SHIMADA                            (TOKY)
SRINIVAS 75 PR D 12 681        SRINIVASAN,HELLAND,LENNOX,KLEM+  (NDAM+ANL)

BANAIGS  76 NP B 105 52        +BERGER,GOLDZAHL,COTTEREAU+(SACL+CAEN+FRAS)I,JP
CASON    76 PRL 36 1485        +POLYCHRONAKOS,BISHOP,BISWAS,+  (NDAM+ANL)I J
CERRADA  76 PL 62 B 353        +GONZALEZ-ARROYO,RUBIO,YNDURAIN (CERN+MADR)
COMMON   76 NP B 103 109       A.K.COMMON                           (KENT)   JP
FLATTE   76 PL 63 B 228        S.M.FLATTE                           (CERN)
GRIVAZ   76 PL 61 B 400        +DAVIS,HALSTEINSLID,IRWIN,+(LALO+BERG+EPOL)
OWENS    76 NP B 112 514       +EISNER,CHUNG,PROTOPOPESCU       (CASE+BNL)
PAWLICKI 76 PRL 37 1666        +AYRES,COHEN,DIEBOLD,KRAMER,WICKLUND  (ANL)I,JP
WETZEL   76 NP B 115 208       +FREUDENREICH,BEUSCH,+      (ETH+CERN+LOIC)

FROGGATT 77 NP B 129 89        +PETERSEN             (GLASGOW+COPENHAGEN)
DAVID    77 PR D 16 2027       +VILLET,AYED,BAREYRE,BORGEAUD,+      (SACL)
MARTIN   77 NP B 121 514       +OZMUTLU,SQUIRES                   (DURHAM)
PAWLICKI 77 PR D 15 3196       +AYRES,COHEN,DIEBOLD,KRAMER,WICKLUND  (ANL)I J
ROSSELET 77 PR D 15 574        +EXTERMANN,FISHER,BERGER,BLOCH,+(GEVA+SACL)
```

```
AGUILAR  78 NP B 140 73       +CERRADA,+         (MADRID+BOMBAY+CERN+PARIS)
GELFAND  78 NP B 138 365      +DAGAN,LISSAUER,OREN,ABRAMS+      (TELA+UCB)
HOLMGREN 78 PL 77 B 304       +PENNINGTON                      (STOH+CERN)
MARTIN   78 ANP  114 1        A.D.MARTIN,M.R.PENNINGTON            (CERN)

ACHASOV  79 PL B 88 367       +DEVYANIN,SHESTAKOV                  (NOVO)
APEL     79 NP B 160 42       +AUSLANDER,MULLER,REHAK+        (KARL+PISA)
BECKER 1 79 NP B 150 301      +BLANAR,BLUM,CERRADA+ (MPIM+CERN+ZEEM+CRAC)
BECKER 2 79 NP B 151  46      +BLANAR,BLUM,CERRADA+ (MPIM+CERN+ZEEM+CRAC)
BORREANI 79 NP B 147 28       +FISHER,GUY,ELY,LEUTZ,+(TORI+RHEL+LBL+CERN)
CORDEN   79 NP B 157 250      +DOWELL,GARVEY,JOBES,+(BIRM+RHEL+TELA+LOWC)  JP
DONOHUE  79 NP B 158 123      +LEROYER                      (BORD+ANL+OXF)
ESTABROO 79 PR D 19 2678      P.ESTABROOKS                         (CARL)
GREENHUT 79 PR D 20 2326      +INTEMANN                            (SETO)
JAFFE  T 79 PR D 19 2105      R.L.JAFFE,F.E.LOW                     (MIT)
MARTIN   79 NP B 158 520      +OZMUTLU                             (DURH)I,JP
POLYCHRO 79 PR D 19 1317      POLYCHRONAKOS,CASON,BISHOP+      (NDAM+ANL)I,JP

ACHASOV  80 SJNP 32 566       +DEVYANIN,SHESTAKOV                  (NOVO)
BOHACIK  80 PR D 21 1342      J.BOHACIK,H.KUHNELT         (BRATISLAVA+WIEN)
COHEN    80 PR D 22 2595      +AYRES,DIEBOLD,KRAMER,PAWLICKI+       (ANL)I,JP
COSTA    80 NP B 175 402      +      (BARI+BONN+CERN+GLAS+LIVP+MILA+WIEN)
DE BILLY 80 NP B 176 1        +BRIAND,DUBOC,LEVY+   (CURI+LAUS+NEUC+GLAS)  JP
GORLICH  80 NP B 174 16       +NICZYPORUK,ROZANSKA+ (CRAC+MPIM+CERN+ZEEM)
GOTTESMA 80 PR D 22 1503      GOTTESMAN,JACOBS,+     (SYRA+BRAN+BNL+CINC)
LOVERRE  80 ZPHY C 6 187      +ARMENTEROS,DIONISI+  (CERN+CDEF+MADR+STOH)I,JP
WICKLUND 80 PRL 45 1469       +AYRES,COHEN,DIEBOLD,PAWLICKI         (ANL)

ACHASOV  81 PL 102 B 196      +DEVYANIN,SHESTAKOV                  (NOVO)
AGUILAR  81 ZPHY C 10 299     AGUILAR-BENITEZ,DONE,MARTIN     (MADR+DURH)
AGUILAR2 81 ZPHY C 8 313      +ALBAJAR,ARMENTEROS,+ (CERN+CDEF+MADR+STOH)
BOREANI  81 NP B 187 42       +GUY,MARCHETTO,MAURIZIO,+  (TORI+RHEL+CERN)
BISWAS   81 PRL 47 1378       +CASON,BAUMBAUGH,BISHOP,CANNATA,+(NDAM+ANL)
BRANDELI 81 ZPHY C 10 117     BRANDELIK+  (AACH+BONN+DESY+HAMB+LOIC+OXF+)
GIDAL    81 PL 107 B 153      +GOLDHABER,GUY,MILLIKAN,ABRAMS,+ (SLAC+LBL)
IRVING   81 ZPHY C 10 45      +MARTIN,DONE                    (LIVP+DURH)

ALEKSEEV 82 JETP 55 591       ALEKSEEVA,KARTAMYSHEV,MAKARIN+       (KIAE)
CASON    82 PRL 48 1316       +BISWAS,BAUMBAUGH,BISHOP,CANNATA+(NDAM+ANL)
ETKIN1   82 PR D 25 1786      +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)
ETKIN2   82 PR D 25 2446      +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)
SCHNITZE 82 PR B 117 96       H.SCHNITZER                          (BRAN)
TORNQVIS 82 PRL 49 624        N.A.TORNQVIST                        (HELS)

BAUBILLI 83 ZPHY C 17 309     BAUBILLIER+        (BIRM+CERN+GLAS+MSU+LPNP)
CASON    83 PR D 28 1586      +CANNATA,BAUMBAUGH,BISHOP,WATSON+(NDAM+ANL)
HITLIN   83 CORNELL CONF. 746 DAVID HITLIN, RAPPORTEUR'S TALK       (CIT)
MENNESSI 83 ZPHY C 16 241     G.MENNESSIER                         (MONP)
TORNQVIS 83 EMS CONFERENCE    N.A.TORNQVIST                        (HELS)

ACHASOV  84 ZPHY C 22 53      +DEVYANIN,SHESTAKOV                  (NOVO)
MORGAN   84 PL 137 B 411      +PENNINGTON                     (RHEL+DURH)

ALDE     85  CERN-EP/85-153   +BINON,BRICMAN,DUTEIL+(BELG+LAPP+SERP+CERN)
CLARK    85 PR D 32 1061      +BARLOW+    (FLOR+DUKE+TENN+ORNL+STON+SLAC)
RYBICKI  85 ZPHY C 28 65      RYBICKI,SAKREJDA                     (CRAC)
```

$\pi(1300)$

$I^G(J^{PC}) = 1^-(0^{-+})$

SEEN IN PARTIAL WAVE ANALYSIS OF THE
DIFFRACTIVELY PRODUCED 3PI SYSTEM.

$\pi(1300)$ MASS (MeV)

```
M    E     1273.0     50.0             AARON      81 RVUE
M           1342.     20.              BONESINI   81 OMEG      12 PI-P,3PI P
M          (1400.)   APPROX.           DAUM       81 SPEC      63,94 PI- P
M           1240.     30.              BELLINI    82 SPEC      40 PI-A,3PI A
M           1190.     30.              ZIELINSKI  84 SPEC      200 PI+Z,Z 3 PI    |
M          . . . . . . . . . . .
M   AVERAGE MEANINGLESS (SCALE FACTOR = 2.6)

M    E  USES MULTICHANNEL AITCHISON-BOWLER MODEL.
M    E  USES DATA FROM DAUM 80 AND DANKOWYCH 81.
```

$\pi(1300)$ WIDTH (MeV)

```
W    E      580.0    100.0             AARON      81 RVUE
W           220.      70.              BONESINI   81 OMEG      12 PI-P,3PI P
W          (600.)   APPROX.            DAUM       81 SPEC      63,94 PI- P
W           360.     120.              BELLINI    82 SPEC      40 PI-A,3PI A
W           440.      80.              ZIELINSKI  84 SPEC      200 PI+Z,Z 3 PI    |
W          . . . . . . . . . . .
W   AVERAGE MEANINGLESS (SCALE FACTOR = 1.8)

W    E  USES MULTICHANNEL AITCHISON-BOWLER MODEL.
W    E  USES DATA FROM DAUM 80 AND DANKOWYCH 81.
```

$\pi(1300)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\pi(1300) \rightarrow \rho\,\pi$	769+ 140
P2	$\pi(1300) \rightarrow f_0(1300)\ \pi$	1300+ 140
P3	$\pi(1300) \rightarrow \pi\,(\pi\,\pi)_{S\text{-wave}}$	140+ 140+ 140

$\pi(1300)$ BRANCHING RATIOS

$\pi(1300) \rightarrow (\pi\,(\pi\,\pi)_{S\text{-wave}}/(\rho\,\pi))$ (P3)/(P1)

```
R1 E          (2.12)                   AARON     81 RVUE
R1 E    USES MULTICHANNEL AITCHISON-BOWLER MODEL.
R1 E    USES DATA FROM DAUM 80 AND DANKOWYCH 81.
```

REFERENCES FOR $\pi(1300)$

```
DAUM     80 PL 80 B 281          +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)

AARON    81 PR D 24 1207         +LONGACRE                        (NEAS+BNL)
BELLINI  81 LISBON CONF. 413     +IVANSHIN,FRABETTI,+       (MILA+JINR+BGNA)
BONESINI 81 PL 103 B 75          +DONALD,+    (MILA+LIVP+DARE+CERN+BARI+BONN)
DANKOWYC 81 PRL 46 580           +BROCKMAN,EDWARDS+(TNTO+BNL+CARL+MCGI+OHIO)
DAUM     81 NP B 182 269         +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
EVANGELI 81 NP B 178 197         EVANGELISTA+(BARI+BONN+CERN+DARE+LIVP+MILA)

BELLINI  82 PRL 48 1697          +FRABETTI,IVANSHIN,LITKIN+ (MILA+BGNA+JINR)

LEEDOM   83 PR D 27 1426         +DE BONTE,GAIDOS,KEY,WONG+       (PURD+TNTO)

ZIELINSK 84 PR D 30 1855         +BERG,CHANDLEE,CIHANGIR,+  (ROCH+MINN+FNAL)
```

$a_2(1320)$ was $A_2(1320)$

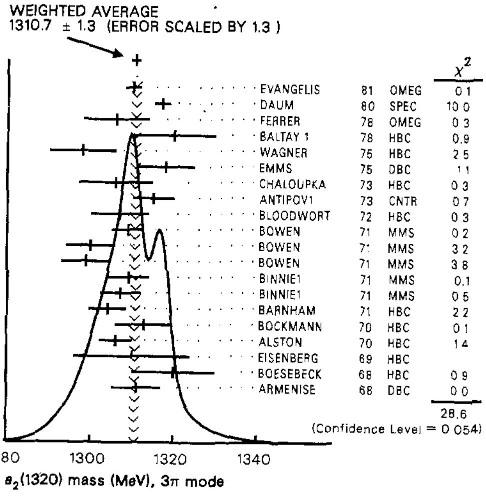
$I^G(J^{PC}) = 1^-(2^{++})$

ONLY EXPERIMENTS GIVING MASS ERROR LESS THAN 15
MEV ARE KEPT FOR AVERAGING.

$a_2(1320)$ MASS (MeV), 3π MODE

```
M        260 1311.0       6.0           ARMENISE  68 DBC     0 5.1 PI+D
M        120 1320.       10.            BOESEBECK 68 HBC     0 8 PI+ P
M            1310.0      14.0           EISENBERG 69 HBC   +  4.3,5.3 GAMMA P
M        941 1306.0       4.0           ALSTON    70 HBC   +  7.0 PI+P,3PI P
M        280 1313.0       7.0           BOCKMANN  70 HBC      05. PI+P
M        360 1304.0       4.5           BARNHAM   71 HBC   +  3.7 PI+ P,(3PI)+
M      10000 1307.        5.            BINNIE1   71 MMS    - PI-P NEAR A2 THR
M       5000 1309.        5.            BINNIE1   71 MMS    - PI-P NEAR A2 THR
M      28000 1299.0       6.0           BOWEN     71 MMS    - 5. PI- P
M      24000 1300.        6.0           BOWEN     71 MMS    + 5. PI+ P
M      17000 1309.0       4.0           BOWEN     71 MMS    - 7. PI- P
M        160 1307.        7.            BLOODWORT 72 HBC   +  5.45 PI+ P,P 3PI
M   P        1315.        5.            ANTIPOV1  73 CNTR -   25.,40. PI- P
M       1580 1306.        9.            CHALOUPKA 73 HBC  -   3.9 PI- P,P A2
M   P   1600 1318.        7.            EMMS      75 DBC      04.  PI+N,P A20
M   P   1200 1298.        8.            WAGNER    75 HBC      07.  PI+P,DEL++A2
M       1097 1320.0      10.0           BALTAY 1  78 HBC  +0  15 PI+P,P 4PI
M    P   490(1343.0)    (11.0)          BALTAY 1  78 HBC . 0  15 PI+P,DEL 3PI
M          (1285.0)     (9.0)           CORDEN 2  78 OMEG  -  12-15 PI-P,3PI N
M            1306.0       8.0           FERRER    78 OMEG  -  9 PI-P,P 3PI
M   P  25000 1317.0       2.0           DAUM      80 SPEC  -  63,94 PI- P= 3PI
M   P        1310.        2.            EVANGELIS 81 OMEG  -  12 PI-P,3PI P
M            . . . . . . . . . . .
M    AVG     1310.7       1.3     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
                         (SEE IDEOGRAM BELOW)

M   P    FROM A FIT TO JP=2+ RHO PI PARTIAL WAVE
```



$a_2(1320)$ MASS (MeV), $K^\pm K^0_S$ MODE

```
MK S   1500 1319.0       3.0            GRAYER     71 ASPK  - 17.2 PI-P,K-KS P
MK      730 1313.0       4.0            FOLEY      72 CNTR  - 20.3 PI- P,K- KS
MK     2724 1320.0       2.0            MARGULIES  76 SPEC  - 23.PI-P,K-KS
MK    11000 1312.0       4.0            CHABAUD    78 SPEC   -9.8 PI-P,K- KS P
MK     4730 1316.0       2.0            CHABAUD    78 SPEC  - 18.8PI-P,K- KS P
MK      350 1324.0       5.0            HYAMS      78 ASPK +  12.7 PI+P,K+KS P
MK P S      1318.        1.             MARTIN 1   78 SPEC   -10 PI P,KS K- P
MK     4000 1320.0       2.0            CHABAUD    80 SPEC  - 17PI-NUCLEI,KSK-
MK P W1000 1330.0       11.0            CLELAND    82 SPEC +  30 PI+P,KS K+ P
MK P W4700 1319.0        5.0            CLELAND    82 SPEC +  50 PI+P,KS K+ P
MK P W5200 1324.0        6.0            CLELAND    82 SPEC -  50 PI-P,KS K- P
MK          . . . . . . . . . . .
MK  AVG     1318.22      0.70    AVERAGE

MK S    SYSTEMATIC ERROR IN MASS SCALE SUBTRACTED
MK   W  NUMBER OF EVENTS EVALUATED BY US.
```

$a_2(1320)$ MASS (MeV), $\eta\pi$ MODE

```
M  E  1000 1323.       8.                KEY        73 OSPK -  6.PI-P,P PI-ETA
M  EM 6200(1324.)     (8.)               CONFORTO   73 OSPK -  6.PI-P,P MMS-
M     2561 1336.2      1.7               DELFOSSE   81 SPEC +  PI+-P,PI+-ETA P
M     1653 1330.7      2.4               DELFOSSE   81 SPEC -  PI+-P,PI+-ETA P
M          . . . . . . . . . .
M   AVG    1334.0      2.6     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.9)

M  E    ERROR INCLUDES 5 MEV SYSTEMATIC MASS-SCALE ERROR
M   M   MISSING MASS WITH ENRICHED MMS=ETA PI-, ETA = 2GAMMA
```

$a_2(1320)$ WIDTH (MeV), 3π MODE

```
W        260   96.0      16.0              ARMENISE  68 DBC    0 5.1 PI+D
W        941   79.0      12.0              ALSTON    70 HBC  + 7.0 PI+P,3PI P
W        360  111.4      18.0              BARNHAM   71 HBC  + 3.7 PI+ P,(3PI)+
W      10000 (100.)                        BINNIE1   71 MMS  - PI-P NEAR A2 THR
W       5000   72.       16.               BINNIE1   71 MMS  - PI-P NEAR A2 THR
W      28000  105.0       5.0              BOWEN     71 MMS  - 5. PI- P
W      24000   99.0       5.0              BOWEN     71 MMS  + 5. PI+ P
W      17000  103.0       5.0              BOWEN     71 MMS  - 7. PI- P
W   P         115.       15.               ANTIPOV1  73 CNTR -  25.,40. PI- P
W       1580   99.       15.               CHALOUPKA 73 HBC  -  3.9 PI- P,P A2
W   P   1600  112.       18.               EMMS      75 DBC   04.  PI+N,P A2D
W   P S1200  122.        14.               WAGNER    75 HBC   07.  PI+P,DEL++A2
W       1097  110.0      15.0              BALTAY 1  78 HBC +0 15 PI+P,P 4PI
W    P   490 (115.0)    (14.0)             BALTAY 1  78 HBC  0 15 PI+P,DEL 3PI
W            (150.0)    (20.0)             CORDEN 2  78 OMEG - 12-15 PI-P,3PI N
W   P 25000   96.0       9.0               DAUM      80 SPEC - 63,94 PI- P= 3PI
W   P         97.        5.                EVANGELIS 81 OMEG - 12 PI-P,3PI P
W             . . . . . . . . . .
W    AVG     100.6       2.2     AVERAGE

W    S  WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N),SEE K*(892) NOTE
W   P   FROM A FIT TO JP=2+ RHO PI PARTIAL WAVE
```

$a_2(1320)$ WIDTH (MeV), $K^{\pm}K^0_S$ MODE

```
WK    S1500  123.0      13.0               GRAYER    71 ASPK  - 17.2 PI-P,K-KS P
WK      730  113.0      19.0               FOLEY     72 CNTR  - 20.3 PI- P,K- KS
WK    S2724  105.0       8.0               MARGULIES 76 SPEC  - 23.PI-P,K-KS
WK      350  110.0      18.0               HYAMS     78 ASPK +  12.7 PI+P,K+KS P
WK    11000  126.0      11.0               CHABAUD   78 SPEC   -9.8 PI-P,K- KS P
WK     4730  101.0       8.0               CHABAUD   78 SPEC  - 18.8PI-P,K- KS P
WK P S       113.        4.                MARTIN 1  78 SPEC   -10 PI P,KS K- P
WK     4000  106.0       4.0               CHABAUD   80 SPEC  - 17PI-NUCLEI,KSK-
WK P W1000  121.0       51.0               CLELAND   82 SPEC +  30 PI+P,KS K+ P
WK P W4700  112.0       20.0               CLELAND   82 SPEC +  50 PI+P,KS K+ P
WK P W5200  120.0       25.0               CLELAND   82 SPEC -  50 PI-P,KS K- P
WK           . . . . . . . . . .
WK  AVG      109.8       2.4    AVERAGE

WK  P    FROM A FIT TO JP=2+ PARTIAL WAVE.
WK   S  WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N),SEE K* TYPED NOTE
WK   W  NUMBER OF EVENTS EVALUATED BY US.
```

$a_2(1320)$ WIDTH (MeV), $\eta\pi$ MODE

```
W      1000  108.       9.                KEY        73 OSPK -  6.PI-P,P PI-ETA
W    M 6200 (104.)     (9.)               CONFORTO   73 OSPK -  6.PI-P,P MMS-
W      2561  112.2      5.7               DELFOSSE   81 SPEC +  PI+-P,PI+-ETA P
W      1653  116.6      7.7               DELFOSSE   81 SPEC -  PI+-P,PI+-ETA P
W             . . . . . . . . . .
W    AVG     112.6      4.1    AVERAGE

W    M   MISSING MASS WITH ENRICHED MMS=ETA PI-, ETA = 2GAMMA
```

$a_2(1320)$ PARTIAL DECAY MODES

			DECAY MASSES
P1		$a_2(1320) \to \rho\pi$	769+ 140
P2		$a_2(1320) \to K\overline{K}$	494+ 498
P3		$a_2(1320) \to \eta\pi$	549+ 140
P4		$a_2(1320) \to \omega\pi\pi$	140+ 140+ 783
P5	S	$a_2(1320) \to \pi^+\pi^-\pi^0$(excluding$\rho\pi$)	140+ 140+ 135
P6	S	$a_2(1320) \to \pi^+\pi^-\pi^-$(excluding$\rho\pi$)	140+ 140+ 140
P7	S	$a_2(1320) \to \pi\gamma$	140+ 0
P8	S	$a_2(1320) \to \eta'\pi$	958+ 140
P9	S	$a_2(1320) \to \gamma\gamma$	0+ 0

```
P   S   SMALL, NOT USED IN THE FIT
```

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{(\delta P_i \delta P_i)}$, while the off-diagonal elements are the normalized correlation coefficients $(\delta P_i \delta P_j)/(\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above, only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
          P 1          P 2          P 3          P 4
 P 1 .7006+-.0225
 P 2   -.1065  .0487+-.0080
 P 3   -.0680     -.0451  .1448+-.0117
 P 4   -.8336     -.2037     -.3936  .1058+-.0250
```

$a_2(1320)$ PARTIAL WIDTHS (keV)

$a_2(1320) \to \pi^{\pm}\gamma$ (G7)

```
W7  M      (461.)   (110.)               MAY       77 SPEC +- 9.7 GAM N,A2 X
W7          295.      60.                CIHANGIR  82 SPEC +  200 PI+Z,Z A2
```

$a_2(1320) \to \gamma\gamma$ (G9)

```
W9 E G  22    0.77     0.32              EDWARDS   82 CBAL    E+ E-,PIO ETA
W9 F E  35    0.81     0.33              BEHREND   83 CELL    E+E-,E+E- 3 PI
W9 F E        0.84     0.17              FRAZER    83 JADE    E+E-,E+E- 3 PI
W9 E          1.06     0.26              BERGER    84 PLUT    E+E-,E+E- 3 PI
W9         . . . . . . . . . .
W9  AVG       0.87     0.12   AVERAGE

W  E    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
W  F    FROM RHO PI DECAY MODE
W   M   MODEL DEPENDENT
W   G   FROM ETA PIO DECAY MODE.
```

$a_2(1320)$ BRANCHING RATIOS

$a_2(1320) \to (K^- K^0_S)/(\rho\pi)$ (P2)/(P1)

```
R1  C       (0.054)  (0.022)             CHUNG     68 HBC   -  3.2 PI-P
R1  C       (0.06)   (0.03)              ABRAMOVIC 70 HBC   -  3.93 PI- P
R1  C       (0.07)   (0.03)              NEF       70 MMS   -  7.0 PI- P
R1  C  113  (0.097)  (0.018)             ALSTON    71 HBC   +  7.0 PI+ P
R1  C   50  (0.056)  (0.014)             CHALOUPKA 73 HBC   - 3.9 PI- P,P A2
R1            0.078    0.017             CHABAUD   78 RVUE
R1  C   INCLUDED IN CHABAUD 78 RVUE.
R1         . . . . . . . . . .
R1  FIT       0.070    0.012  FROM FIT
```

$a_2(1320) \to (\eta\pi)/(\rho\pi + K\overline{K} + \eta\pi)$ (P3)/(P1+P2+P3)

```
R2      34    0.15     0.04              BARNHAM   71 HBC  + 3.7 PI+ P
R2            0.13     0.04              ESPIGAT   72 HBC  +- 0.PBAR P,
R2         . . . . . . . . . .
R2  AVG       0.140    0.028   AVERAGE
R2  FIT       0.162    0.012  FROM FIT
```

$a_2(1320) \to (\eta\pi)/(\rho\pi)$ (P3)/(P1)

```
R3            0.22     0.09              CONTE     67 HBC   -  11.0 PI-P
R3      22    0.23     0.08              ASCOLI    68 HBC   -  5 PI-P
R3            0.12     0.08              CHUNG     68 HBC   -  3.2 PI-P
R3      15    0.25     0.09              BOCKMANN  70 HBC   +  5.0 PI+P
R3     167    0.246    0.042             ALSTON    71 HBC   +  7.0 PI+ P
R3     149    0.211    0.044             CHALOUPKA 73 HBC   - 3.9 PI- P,P A2
R3      52    0.22     0.05              ANTIPOV   73 CNTR  - 40. PI-P,P A2-
R3            0.18     0.05              FORINO    76 HBC     11 PI- P,ETA PI
R3         . . . . . . . . . .
R3  AVG       0.213    0.020   AVERAGE
R3  FIT       0.207    0.018  FROM FIT
```

$a_2(1320) \to (\eta'\pi)$/total (P8)

```
R4          (0.02) OR LESS  CL=.97   BARNHAM   71 HBC  +  3.7 PI+ P
```

$a_2(1320) \to (\eta'\pi)/(\rho\pi)$ (P8)/(P1)

```
R5            0.04     0.03      0.04  BOCKMANN  70 HBC    0 5.0 PI+ P
R5          (0.04) OR LESS             ALSTON    71 HBC  +   7.0 PI+ P
R5          (0.011)OR LESS  CL=.90     EISENSTEI 73 HBC  -  5.PI- P,P 6PI
```

$a_2(1320) \to (K\overline{K})/(\rho\pi + K\overline{K} + \eta\pi)$ (P2)/(P1+P2+P3)

```
R8      17    0.06     0.03              BARNHAM   71 HBC  + 3.7 PI+ P,KSK+P
R8  A       (0.020)  (0.004)             ESPIGAT   72 HBC  +- 0.PBAR P,
R8       8    0.03     0.02              DAMERI    72 HBC  -  11. PI- P
R8            0.05     0.02              TOET      73 HBC  +  5. PI+ P,P K+ KO
R8            0.09     0.04              TOET      73 HBC  0 5.PI+P,PI+P K KB
R8  A   NOT AVERAGED BECAUSE OF DISCREPANCY BETWEEN MASSES
R8  A   FROM  (K KBAR) AND (RHO PI)  MODES
R8         . . . . . . . . . .
R8  AVG       0.048    0.012   AVERAGE
R8  FIT       0.0545   0.0088 FROM FIT
```

$a_2(1320) \to (\pi^+\pi^-\pi^-)/(\rho^0\pi^-)$ (P6C)/(P1C)

```
R9          (0.23) OR LESS  CL=.90   ABRAMOVIC 70 HBC   -  3.93 PI- P
```

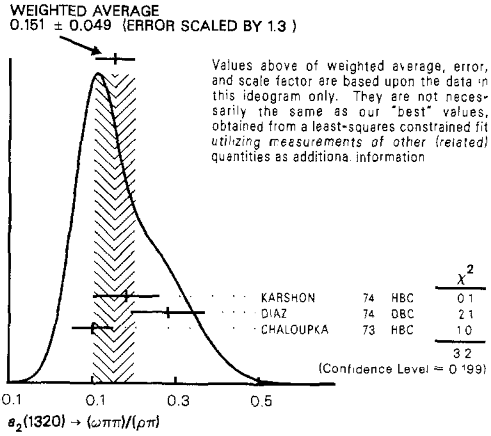
$a_2(1320) \to (\pi\gamma)$/total (P7)

```
R11R          0.005    0.005    0.003 EISENBERG 72 HBC     PHOTOPRODUCTION
R11R    PION EXCHANGE MODEL USED IN THIS ESTIMATION
```

$a_2(1320) \to (\omega\pi\pi)/(\rho\pi)$ (P4)/(P1)

```
R12         (0.19)   (0.08)              DEFOIX    73 HBC   0 0.7 PBAR P,7 PI
R12    279   0.10     0.05               CHALOUPKA 73 HBC  -  3.9 PI- P,P A2
R12     60   0.28     0.09               DIAZ      74 DBC   0 6.PI+N,P(5PI)0
R12  K 140  (0.29)   (0.08)              KARSHON   74 HBC   0 4.9 PI+P,DEL++A2
R12  K  60  (0.10)   (0.04)              KARSHON   74 HBC  +  4.9 PI+P,P A2+
R12  K       0.18     0.08               KARSHON   74 HBC   AVG OF ABOVE TWO
R12        . . . . . . . . . .
R12 AVG      0.151    0.049   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
R12 FIT      0.151    0.040  FROM FIT
                      (SEE IDEOGRAM BELOW)

R12  K  KARSHON 74 SUGGEST AN ADDITIONAL I=0 STATE, STRONGLY COUPLED
R12  K  TO OMEGA PI PI  COULD EXPLAIN DISCREPANCIES IN BRANCHING RATIOS
R12  K  AND MASSES. WE USE A CENTRAL VALUE AND A SYST. SPREAD.
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit *utilizing measurements of other (related)* quantities as additional information.

REFERENCES FOR $a_2(1320)$

ADERHOLZ 64 PL 10 226 (AACHEN+BERLIN+BIRM+BONN+HAMBURG+LOIC+MPIM)
CHUNG 64 PRL 12 621 +DAHL,HARDY,HESS,KALBFLEISCH,KIRZ (LRL)
GOLDHABE 64 DUBNA CONF 1 480 G GOLDHABER,S GOLDHABER,OHALLORAN,SHEN(LRL)
ALSO 64 PRL 12 336 G+S.GOLDHABER,BROWN,KADYK,TRILLING,+ (LBL)
LANDER 64 PRL 13 346 +ABOLINS,CARMONY,HENDRIKS,XUONG+ (LA JOLLA)

ABOLINS 65 ATHENS(OHIO)CONF. +CARMONY,LANDER,XUONG,YAGER (LA JOLLA)I=1
ADERHOLZ 65 PR 138 B 897 (AACHEN+BERL+BIRM+BONN+HAMB+LOIC+MPIM)
ALITTI 65 PL 15 69 ALITTI,BATON,DELER,CRUSSARD+ (SACLAY+BGNA) JP
CHUNG 65 PRL 15 325 +DAHL,HARDY,HESS,JACOBS,KIRZ,MILLER (LRL)
FORINO 65 PL 19 68 +GESSAROLI+ (BGNA+BARI+FIRZ+ORSA+SACL)
LEFEBVRE 65 PL 19 434 CERN MISSING MASS SPECTROMETER GROUP (CERN)
SEIDLITZ 65 PRL 15 217 L SEIDLITZ,O I DAHL,D H MILLER (LRL)

BARNES 66 PRL 16 41 BARNES,FOWLER,LAI,ORENSTEIN + (BNL+CUNY)
BENSON 66 MICH COO-1112-4 G.C.BENSON, THESIS (MICH)
ALSO 66 PRL 16 1177 G BENSON,LOVELL,MARQUIT,ROE + (MICH)
EHRLICH 66 PR 152 1194 R. EHRLICH,W.SELOVE,H.YUTA (PENN)
FERBEL 66 PL 21 111 FERBEL (ROCHESTER)
LEVRAT 66 PL 22 714 CERN MISSING MASS SPECTROMETER GROUP (CERN)

ARMENISE 67 PL 25B 53 ARMENISE,FORINO,+ (BARI+BGNA+FIRZ+ORSAY)
BALTAY 67 PL 25B 160 +KIRSCH+KUNG+YEH+RABIN (COLU+BNL+RUTGERS)
BARLOW 67 NC 50A 701 +LILLESTOL+MONTANET+ (CERN+CDEF+IRAD+LIVP)
BARTSCH 67 PL 25B 48 +DEUTSCHMANN+GROTE+COCCONI+(AACH+BERL+CERN)
BEUSCH 67 PL 25 B 357 +FISCHER,GOBBI,ASTBURY+ (ETH+CERN)
CASON 67 PRL 18 880 +LAMSA,BISWAS,DERADO,GROVES,+ (NOTREDAME)
CHIKOVAN 67 PL 25B 44 CERN MISSING MASS SPECTROMETER GROUP (CERN)
CHUNG 67 PRL 18 100 +DAHL,HARDY,HESS,KIRZ,MILLER (LRL)
ALSO 66 UCRL-16832 RICHARD I HESS--THESIS,BERKELEY (LRL)
COHN 67 NP B1 57 +MCCULLOCH+BUGG+CONDO (ORNL+UNIV.TENN.)
CONFORTO 67 NP B3 469 +MARECHAL,MONTANET+ (CERN+CDEF+IPN+LIVP)
CONTE 67 NC 51 A 175 +TOMASINI,CORDS+(GENOVA+HAMB+MILANO+SACLAY)
DAHL 67 PR 163 1377 +HARDY+HESS+KIRZ+MILLER (LRL)
DANYSZ 67 NC 51 A 801 DANYSZ+FRENCH+SIMAK (CERN)
SLATTERY 67 NC 50A 377 +KRAYBILL+FORMAN+FERBEL (YALE+ROCH) JP

ARMENISE 68 PL 26B 336 ARMENISE,FORINO,+ (BARI+BGNA+FIRZ+ORSAY)
ASCOLI 68 PRL 20 1321 +CRAWLEY,MORTARA,SHAPIRO,BRIDGES+(ILLINOIS) JP
BALLAM 68 PRL 21 934 +BRODY,CHADWICK,FRIES,GUIRAGOSSIAN+ (SLAC)
BENZ 68 PL 28 B 233 CERN MISSING MASS SPECTROMETER GROUP (CERN)
BOESEBEC 68 NP B 4 501 BOESEBECK,DEUTSCHMANN,+(AACHEN+BERLIN+CERN)
CASO 68 NC 54 A 983 +CONTE+CORDS+DIAZ+ (GENOVA+HAMB+MILAN+SACL)
CHUNG 68 PR 165 1491 S.U.CHUNG,O.DAHL,J.KIRZ,D.H.MILLER (LRL)
CRENNELL 68 PRL 20 1318 +KARSHON+KWAN LAI,SCARR,SKILLICORN (BNL)
DONALD 68 PL 26 B 327 +FRODESEN+BETTINI+ (LIVERPOOL+OSLO+PADUA)
FOSTER 68 NP B 8 174 +GAVILLET,LABROSSE,MONTANET,+ (CERN+CDEF)
FRIDMAN 68 PR 167 1268 +MAURER,MICHALON,OUDET+(HEID +STRASBOURG)
JUNKMANN 68 NP B8 471 +COCCONI,+ (AACH+BERL+BONN+CERN+WARS)
KEY 68 PR 166 1430 +PRENTICE+COOPER+MANNER+ (TNTO+ANL+WISC)
LAMSA 68 PR 166 1395 +CASON+BISWAS+DERADO+GROVES+ (NOTREDAME)
VON KROG 68 PL 27 B 253 +MIYASHITA,KOPELMAN,MARSHALL LIBBY (COLO)

ADERHOLZ 69 NP B 11 259 +BARTSCH,+ (AACH+BERL+CERN+JAGL+WARS)
AGUILAR1 69 PL 29 B 62 +BARLOW,JACOBS,DELLA NEGRA+(CERN+CDEF+LIVP)
AGUILAR2 69 PL 29 B 241 M.AGUILAR-BENITEZ,J.BARLOW,+ (CERN+CDEF)
ANDERSON 69 PRL 22 1390 +COLLINS,+ (BNL+CARN)
ARMENISE 69 LNC 2 501 +GHIDINI,FORINO,CARTACCI+ (BARI+BGNA+FIRZ)
CHIKOVAN 69 PL 28 B 526 CERN MISSING MASS SPECTROMETER GROUP (CERN) JP
CRENNELL 69 PRL 22 1327 +KARSHON,KWAN WU LAI,+ (BNL)IJP
DONALD 69 NP B 12 325 +EDWARDS,FOSTER,MOORE (LIVERPOOL)
EISENBER 69 PRL 23 1322 EISENBERG,HABER,BALLAM,CHADWICK+(REHO+SLAC)
VETLITSK 69 SJNP 9 596 VETLITSKY,GRIGOREYEV,GRISHIN,+ (ITEP)

ABRAMOVI 70 NP B 29 466 ABRAMOVICH,BLUMENFELD,BRUYANT,+ (CERN) JP
ALSTON 70 PL 33 B 607 +BARBARO,BUHL,DERENZO,EPPERSON,FLATTE+(LRL)
ASCOLI 70 PRL 25 962 +BROCKWAY,CRAWLEY,EISENSTEIN,HANFT,+ (ILL) JP
BASILE 70 LNC 4 838 +DALPIAZ,FRABETTI,MASSAM,+ (CERN+BGNA+STRB)
BAUD1 70 PL 31B 397 CERN BOSON SPECTROMETER GROUP (CERN)
BAUD2 70 PHILAD.CONF.P.311 CERN BOSON SPECTROMETER GROUP (CERN)
BAUD3 70 PL 31 B 401 CERN BOSON SPECTROMETER GROUP (CERN)
BOCKMANN 70 NP B 16 221 +MAJOR,POLS,+ (BONN+DURH+NIJM+EPOL+TORI)
BUTLER 70 UCRL 19845 THESIS (LRL)
CAROLL 70 PRL 25 1393 +FIREBAUGH,GARFINKEL,MORSE,OH,+ (WISC+TNTO)
CASO 70 LNC 3 707 +CONTE,TOMASINI,CORDS+(GENO+HAMB+MILA+SACL)
DIAZ 70 NP B 16 239 +GAVILLET,LABROSSE,MONTANET+ (CERN+CDEF)JP
DZIERBA 70 PR D 2 2544 +SHEPHARD,BISWAS,CASON,JOHNSON,KENNEY(NDAM)
GARFINKE 70 PL 33 B 536 GARFINKEL,AMMANN,CARMONY,YEN (PURD)JPC
JOHNSTON 70 NP B 24 253 +KEY,PRENTICE,YOON,GARFINKEL,+ (TNTO+WISC)
KRUSE 70 PHILAD.CONF.P.359 U.KRUSE, PARTIAL WAVE ANALYSIS (ILL) JP
NEF 70 THESIS+PRIV.COMM.CERN BOSON SPECTROMETER GROUP (CERN)
SUTHERLA 70 PHILAD.CONF.P.369 G.SUTHERLAND,INTERFERING RESONANCE(GLASGOW)

AGUILAR 71 PR D 4 2583 AGUILAR-BENITEZ,EISNER,KINSON (BNL)
ALSTON 71 PL 34 B 156 +BARBARO,BUHL,DERENZO,EPPERSON,FLATTE+(LRL)
BARNHAM 71 PRL 26 1494 +ABRAMS,BUTLER,COYNE,GOLDHABER,HALL,+ (LBL)
BEKETOV 71 SJNP 4 765 +SOMBKOWSKY,KONOWALOV,KRUTSCHININ,+ (ITEP) JP
BINNIE1 71 PL 36 B 257 +CAMILLERI,DUANE,FARUQI,BURTON,+(LOIC+SHMP)
BINNIE2 71 PL 36 B 537 +CAMILLERI,DUANE,FARUQI,BURTON,+(LOIC+SHMP)
BOWEN 71 PRL 26 1663 +FARLES,FAISSLER,BLIEDEN,+ (NEAS+STON)
CRENNEL 71 PL 35 B 185 +GORDON,KWAN-WU LAI,SCARR (BNL)
FARBER 71 NP B 29 237 +DE PINTO,BISWAS,CASON,DEERY,KENNEY,+(NDAM)
FOLEY 71 PRL 26 413 +LOVE,OZAKI,PLATNER,LINDENBAUM,+ (BNL+CUNY)
GRAYER 71 PL 34 B 333 +HYAMS,JONES,SCHLEIN,BLUM,DIETL+(CERN+MPIM)
LYNCH 71 UCRL 20022 AND 71 AMSTERDAM CONF. G.LYNCH (LBL)
RINAUDO 71 NC 5 A 239 +BOECKMANN,MAJOR+(TORI+BONN+DURH+NIJM+EPOL) JP

ANKENBRA 72 PRL 29 1688 ANKENBRANDT,BRABSON,CRITTENDEN,HEINZ,+(IND)
BERENYI 72 NP B 37 621 +PRENTICE,STEENBERG,YOON,WALKER (TNTO+WISC)
BLOODWOR 72 NP B 37 203 BLOODWORTH,JACKSON,PRENTICE,YOON (TNTO)
DAMERI 72 NC 9 A 1 +BORZATTA,GOUSSU,+ (GENO+MILA+SACL)
DIEBOLD 72 BATAVIA CONF. R.DIEBOLD RAPPORTEUR TALK (ANL)
EISENBER 72 PR D 5 15 EISENBERG,BALLAM,DAGAN,+ (REHO+SLAC+TELA)
ESPIGAT 72 NP B 36 93 +GHESQUIERE,LILLESTOL,MONTANET (CERN+CDEF)
FOLEY 72 PR D 6 747 +LOVE,OZAKI,PLATNER,LINDENBAUM,+ (BNL+CUNY)
LASSILA 72 PRL 28 1491 LASSILA,YOUNG (IOWA)
MORSE 72 NP B 43 77 +OH,WALKER,JOHNSTON,YOON (WISC+TNTO)

AMMANN 73 PR D 7 1345 +CARMONY,GARFINKEL,GUTAY,MILLER+(PURD+IUPU)
ANKEBRAN 73 PR D 8 2785 ANKEBRANDT,BRABSON,CRITTENDEN,HEINZ,+ (IND)
ANTIPOV 73 NP B 63 175 +ASCOLI,BUSNELLO,FOCACCI,+ (CERN+SERP) JP
ANTIPOV1 73 NP B 63 153 +ASCOLI,BUSNELLO,FOCACCI,+ (CERN+SERP) JP
ANTIPOV2 73 NP B 63 141 +ASCOLI,BUSNELLO,FOCACCI,+ (CERN+SERP) JP
CASON 73 NP B 64 14 +MADDEN,BISHOP,BISWAS,KENNEY,+ (NDAM)
CHALOUPK 73 PL 44 B 211 CHALOUPKA,DOBRZYNSKI,FERRANDO,LOSTY,+(CERN)
CONFORTO 73 PL 45 B 154 +MOBLEY,KEY,PERPOST,+ (EFI+FNAL+TNTO+WISC)
DEFOIX 73 PL 43 B 141 +DOBRZYNSKI,ESPIGAT,NASCIMENTO,+ (CDEF)
EISENSTE 73 PR D 7 278 EISENSTEIN,SCHULTZ,ASCOLI,IOFFREDO,+ (ILL)
KEY 73 PRL 30 503 +CONFORTO,MOBLEY,+ (TNTO+EFI+FNAL+WISC)
TOET 73 NP B 63 248 +THUAN,MAJOR,RINAUDO,+(NIJM+BONN+DURH+TORI)

DIAZ 74 PRL 32 260 +DIBIANCA,FICKINGER,ANDERSON,+ (CASE+CARN)
KARSHON 74 PRL 32 852 +MIKENBERG,PITLUCK,EISENBERG,RONAT+ (REHO)
OTTER 74 NP B80 1 +RUDOLPH+ (AACH+BERL+BONN+CERN+HEID) JP
THOMPSO1 74 PR D9 560 THOMPSON,GAIDOS,MCILWAIN,WILLMANN (PURD) JP
THOMPSO2 74 NP B69 381 THOMPSON,BADEWITZ,GAIDOS,MCILWAIN+ (PURD) JP

ABASHIAN 75 PRL 34 691 +BEAMER,BROSS,EISENSTEIN,+ (ILL+ANL+ISU)
EMMS 75 PL 58B 117 +JONES,KINSON,STACEY,BELL+ (BIRM+DURH+RHEL) JP
LOSTY 75 PL 56B 96 +CHALOUPKA,MONTANET,GANDOIS+ (CERN+SACL) JP
UNDERWOO 75 PR D11 2345 UNDERWOOD,CONFORTO,KEY+(EFI+FNAL+TNTO+WISC)
ALSO 73 CONFORTO, 73 KEY
WAGNER 75 PL 58B 201 +TABAK,CHEW (LBL) JP

FORINO 76 NC A 35 465 +GESSAROLI,+ BGNA+FIRZ+GENO+MILA+OXF+PAV
HANDLER 76 NP B 110 173 +PLANO,BRUCKNER,KOLLER,,+ (RUTG,STEV,SETO)
MARGULIE 76 PR D 14 667 +KRAMER,FOLEY,LOVE,LINDENBAUM,+ (BNL+CUNY)

CERRADA 77 NP B 126 241 +BLOCKZIJL,HEINEN,+ (AMST+CERN+NIJM+OXF)
MAY 77 PR D 16 1983 +ABRAMSON,ANDREWS,BUSNELLO,+ (ROCH+CORN)
PAWLICKI 77 PR D 15 3196 +AYRES,COHEN,DIEBOLD,KRAMER,WICKLUND (ANL)I J

BALTAY 1 78 PR D 17 62 +CAUTIS,COHEN,CSORNA,SMITH,YEH,+(COLU+BING)
BALTAY 2 78 PRL 40 87 +CAUTIS,KALELKAR (COLU) JP
CHABAUD 78 NP B 145 349 +HYAMS,JONES,WEILHAMMER,BLUM,+ (CERN+MPIM)
CORDEN 1 78 NP B 136 77 DOWELL,GARVEY,JOBES+ (BIRM+RHEL+TELA+LOWC) JP
CORDEN 2 78 NP B 138 235 +CORBETT,ALEXANDER,+ (BIRM+RHEL+TELA+LOWC)
FERRER 78 PL 74 B 287 +TREILLE,RIVET + (ORSAY+CERN+CDEF+LPNP)
HYAMS 78 NP B 146 303 +JONES,WEILHAMMER,BLUM,+ (CERN+MPIM+ATEN)
MARTIN 1 78 PL 74 B 417 +OZMUTLU+BALDI,BOHRINGER,DORSAZ+(DURH+GEVA) JP
MARTIN 2 78 NP B 140 158 +OZMUTLU,BALDI,BOHRINGER,DORSAZ+(DURH+GEVA)

CHABAUD 80 NP B 175 189 +HYAMS,PAPADOPOULOU,+ (CERN+MPIM+AMST)
DAUM 80 PL 89 B 276 +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL) JP

DAUM 81 NP B 182 269 +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
DELFOSSE 81 NP B 183 349 +GUISAN,MARTIN,MUHLEMANN,WEILL,+(GEVA+LAUS)
EVANGELI 81 NP B 178 197 EVANGELISTA+(BARI+BONN+CERN+DARE+LIVP+MILA)

BEHREND 82 PL 114 B 378 +D-AGOSTINI+(DESY+KARL+MPIM+LALO+LPNP+SACL)
CIHANGIR 82 PL 117 B 123 +BERG,BIEL,CHANDLEE,FERBEL+(FNAL+MINN+ROCH)
CLELAND 82 NP B 208 228 +DELFOSSE,DORSAZ,GLOOR(DURH+GEVA+LAUS+PITT)
EDWARDS 82 PL 110 B 82 +PARTRIDGE,PECK,+ (CIT+HARV+PRIN+STAN+SLAC)

BEHREND 83 PL 125 B 518 +D-AGOSTINI+(DESY+KARL+MPIM+LALO+LPNP+SACL)
FRAZER 83 AACHEN CONF. RAPPORTEUR TALK (UCSD)
JENNI 83 PR D 27 1031 +BURKE,TELNOV,ABRAMS,BLOCKER+ (SLAC+LBL)

BERGER 84 PL 149 B 427 +KLOVNING,BURGER+ (PLUTO COLLABORATION)

$f_2(1410)$

$I^G(J^{PC}) = 0^+(2^{+-})$

OMITTED FROM SUMMARY TABLE

THIS ENTRY LISTS PEAKS OF LOW STATISTICAL SIGNIFICANCE SEEN IN THE KS KS SYSTEM. J=2 FROM EVIDENCE IN THE D WAVE (DAUM 84). I=0 FROM ABSENCE OF CHARGED STATES.

$f_2(1410)$ MASS (MeV)

```
M  C        1439.0      5.0      6.0   BEUSCH    67 OSPK    5,7,12 PI-P,KSKS
M           1436.0     26.0     16.0   DAUM      84 CNTR    17-18 PI-P,K+ K-
M           1412.0      3.0            DAUM      84 CNTR    63PI-P,KSKS,K+K-
M  C    NOT SEEN BY WETZEL 76
M          . . . . . . . . .
M   AVERAGE MEANINGLESS (SCALE FACTOR = 4.3)
```

$f_2(1410)$ WIDTH (MeV)

```
W  C          43.0     17.0     18.0   BEUSCH    67 OSPK    5,7,12 PI-P,KSKS
W             81.0     56.0     29.0   DAUM      84 CNTR    17-18 PI-P,K+ K-
W             14.0      6.0            DAUM      84 CNTR    63PI-P,KSKS,K+K-
W  C    NOT SEEN BY WETZEL 76
W          . . . . . . . . .
W   AVERAGE MEANINGLESS (SCALE FACTOR = 1.6)
```

$f_2(1410)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_2(1410) \rightarrow K^0_S K^0_S$	498+ 498

REFERENCES FOR $f_2(1410)$

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BEUSCH    67 PL 25 B 357         +FISCHER,GOBBI,ASTBURY+          (ETH+CERN)

BEUSCH    70 EXPERIM.MESON SPECTROSCOPY,P.185,COLUMBIA U. PRESS (ETH+CERN)

BALOSHIN 76 SJNP 24 297          +BOLONKIN,VLADIMIRSKIJ,GRIGORJEV,+    (ITEP)
WETZEL    76 NP B 115 208        +FREUDENREICH,BEUSCH,+       (ETH+CERN+LOIC)

POLYCHRO 79 PR D 19 1317         POLYCHRONAKOS,CASON,BISHOP+      (NDAM+ANL)

CHABAUD   81 APP B 12 575        +NICZYPORUK,BECKER+        (CERN+CRAC+MPIM)JP

ETKIN     82 PR D 25 1786        +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)

CHABAUD   83 NP B 223 1          +GORLICH,CERRADA+          (CERN+CRAC+MPIM)JP
PALKA     83 THESIS 1230/PH      H.PALKA                              (CRAC)JP

DAUM      84 ZPHY C 23 339       +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)JP
TURNAU    84 ZPHY C 25 299       J.TURNAU                             (CRAC)
```

$f_1(1420)$
was $E(1420)$

$I^G(J^{PC}) = 0^+(1^{++})$

NOTE ON $f_1(1420)$ AND $\eta(1440)$

For this edition we continue to split the data on $f_1(1420)/\eta(1440)$ into two entries according to the proposed J^{PC} assignments.

The $J^{PC} = 1^{++}$ state (DIONISI 80, ARMSTRONG 84), now called $f_1(1420)$, appears to have a dominant decay mode into the $K^*(892)\overline{K}$ system.

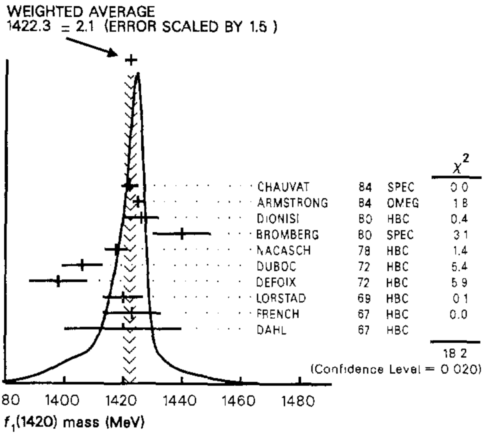
The state with $J^{PC} = 0^{-+}$ is now called $\eta(1440)$. Under this entry we group the results obtained in the early $\overline{p}p$ annihilation experiment at rest (BAILLON 67,83), in the study of the radiative decay of the J/ψ resonance (SCHARRE 80,81, EDWARDS 82, RICHMAN 85), and in a hadroproduction experiment (CHUNG 85). The $\eta(1440)$ is largely coupled to the $a_0(980)\pi$ decay channel, although the lack of a signal in the $\eta\pi\pi$ system (EDWARDS 83) is a source of concern.

The CHUNG 85 study of the $K\overline{K}\pi$ system is based on more than ten times the statistics of DIONISI 80. The $J^{PC} = 0^{-+}$ wave dominates the 1420-MeV mass region with little evidence for a 1^{++} resonance. The CHUNG 85 results may suggest that the $f_1(1420)$ is in fact the $\eta(1440)$.

$f_1(1420)$ MASS (MeV)

```
M            1420.       20.                DAHL      67 HBC    1.6-4.2 PI- P
M            1423.0      10.0               FRENCH    67 HBC     3-4 PBAR P
M        310 1420.        7.                LORSTAD   69 HBC    .7PB P,4,5-BODY
M        170 1398.       10.                DEFOIX    72 HBC    0.7 PBAR P,7 PI
M        280 1406.        7.                DUBOC     72 HBC    1.2 PBAR P,2K4PI
M            1417.5       4.                NACASCH   78 HBC     .7,.76 PBAR P
M  A         1440.0      10.0               BROMBERG  80 SPEC   100 PI-P,2KPIX
M        221 1426.0       6.0               DIONISI   80 HBC    4. PI-P,K K PI N
M   T       (1431.0)   APPROX               TORNQVIST 82 RVUE
M       1520 1425.0       2.0               ARMSTRONG 84 OMEG   85 PI+P,K KBARPI  |
M            1422.0       3.0               CHAUVAT   84 SPEC   ISR 31.5 PP       |
M            . . . . . . . . . . .
M   AVG      1422.3       2.1     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
                         (SEE IDEOGRAM BELOW)

M  A    MASS ERROR INCREASED TO ACCOUNT FOR A0(980) MASS CUT
M  A    UNCERTAINTIES
M   T   FROM A UNITARIZED QUARK MODEL CALCULATION
```



$f_1(1420)$ WIDTH (MeV)

```
W            60.0      20.0             DAHL      67 HBC     1.6-4.2 PI- P
W            45.       20.              FRENCH    67 HBC     3-4 PBAR P
W       310  60.       20.              LORSTAD   69 HBC    .7PB P,4,5-BODY
W       170  50.       10.              DEFOIX    72 HBC    0.7 PBAR P,7 PI
W       280  50.       12.              DUBOC     72 HBC    1.2 PBAR P,2K4PI
W            53.       20.0             NACASCH   78 HBC     .7,.76 PBAR P
W            62.0      14.0             BROMBERG  80 SPEC   100 PI-P,2KPIX
W       221  40.0      15.0             DIONISI   80 HBC    4. PI-P,K K PI N
W      1520  62.0       5.0             ARMSTRONG 84 OMEG   85 PI+P,K KBARPI  |
W            47.0      10.0             CHAUVAT   84 SPEC   ISR 31.5 PP       |
W            . . . . . . . . . . .
W   AVG      55.9       3.4     AVERAGE
```

$f_1(1420)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_1(1420) \rightarrow K\overline{K}^*(892)$	498+ 892
P2	$f_1(1420) \rightarrow K\overline{K}\pi$	498+ 498+ 140
P3	$f_1(1420) \rightarrow \pi\pi\rho$	140+ 140+ 769
P4	$f_1(1420) \rightarrow a_0(980)\ \pi$	983+ 140
P5	$f_1(1420) \rightarrow \eta\pi\pi$	549+ 140+ 140
P6	$f_1(1420) \rightarrow 4\pi$	140+ 140+ 140+ 140
P7	$f_1(1420) \rightarrow \gamma\gamma$	0+ 0

$f_1(1420)$ $\Gamma(I)*\Gamma(\gamma\gamma)/\Gamma(total)$ (keV)

$\Gamma(K\overline{K}\pi)*\Gamma(\gamma\gamma)/\Gamma(total)$

```
W7         (8.0)  OR LESS  CL=0.95  JENNI     83 SMK2   GAM GAM,KKBAR PI
```

$f_1(1420)$ BRANCHING RATIOS

$f_1(1420) \rightarrow (\overline{K}K^*(892)\ +\ C.C.)/(K\overline{K}\pi)$ (P1)/(P2)

```
R1          0.76      0.06             BROMBERG  80 SPEC   100 PI-P,2KPIX
R1          0.86      0.12             DIONISI   80 HBC    4. PI-P,K K PI N
R1         . . . . . . . . . . .
R1  AVERAGE MEANINGLESS
```

$f_1(1420) \rightarrow (\pi\pi\rho)/(K\overline{K}\pi)$ (P3)/(P2)

```
R2         (2.0)  OR LESS              DAHL      67 HBC   0  1.6-4.2 PI- P
R2         (0.3)  OR LESS  CL=.95      CORDEN    78 OMEG     12-15PI-P
```

$f_1(1420) \rightarrow (\eta\pi\pi)/(K\overline{K}\pi)$ (P5)/(P2)

```
R3         (1.5)  OR LESS  CL=.95      FOSTER    68 HBC   - 0.0 PBAR P
R3          1.5      0.8   '           DEFOIX    72 HBC     0.7 PBAR P
R3         (0.5)  OR LESS  CL=.95      CORDEN    78 OMEG    12-15PI-P
```

$f_1(1420) \rightarrow (a_0(980)\ \pi)/(\eta\pi\pi)$ (P4)/(P5)

```
R4          0.4      0.2               DEFOIX    72 HBC     0.7 PBAR P,7 PI
R4          NOT SEEN IN EITHER MODE CORDEN    78 OMEG     12-15PI-P
```

$f_1(1420) \rightarrow (4\pi)/(\overline{K}K^*(892)\ +\ C.C.)$ (P6)/(P1)

```
R5         (0.90)OR LESS CL=.95     DIONISI   80 HBC     4. PI-P,K K PI N
```

$f_1(1420) \rightarrow (K\overline{K}\pi)/(a_0(980)\ \pi\ +\ \overline{K}K^*(892)\ +\ C.C)$

```
R6                                                     (P2)/(P1+P4)
R6   C      0.65      0.27             DIONISI   80 HBC      4. PI-P
R6   C  CALCULATED USING,
R6   C  (A0(980) INTO K KB)/(A0(980) INTO ETA PI)=0.24+-0.07
```

$f_1(1420) \rightarrow (a_0(980)\ \pi)/(\overline{K}K^*(892))$ (P4)/(P1)

```
R7         (0.04) OR LESS  CL=.68     ARMSTRONG 84 OMEG    85 PI+P,KKBAR PI  |
```

REFERENCES FOR $f_1(1420)$

```
BARASH   67 PR 156  1399        BARASH,KIRSCH,MILLER,TAN           (COLUMBIA)
DAHL     67 PR 163 1377         +HARDY+HESS+KIRZ+MILLER                (LRL)I JP
    ALSO 65 PRL 14 1074         MILLER,CHUNG,DAHL,HESS,HARDY,KIRZ+(LRL+UCB)
FRENCH   67 NC 52A 438          +KINSON+MCDONALD+RIDDIFORD+      (CERN+BIRM)

FOSTER   68 NP B 8 174          +GAVILLET,LABROSSE,MONTANET,+    (CERN+CDEF)

BETTINI  69 NC 62 A 1038        +CRESTI,LIMENTANI,BERTANZA,BIGI+(PADO+PISA)IC
LORSTAD  69 NP B 14 63          B.LORSTAD,D-ANDLAU,ASTIER,+      (CDEF+CERN)  JP

DEVONS   71 PRL 27 1614         +KOZLOWSKI,HORWITZ,+             (COLU+SYRA)

CHAPMAN  72 NP B 42 1           +CHURCH,LYS,MURPHY,RING,VANDER VELDE (MICH)
DEFOIX   72 NP B 44 125         +NASCIMENTO,BIZZARRI,+           (CDEF+CERN)
DUBOC    72 NP B 46 429         +GOLDBERG,MAKOWSKI,DONALD,+      (LPNP+LIVP)

VUILLEMI 75 LNC 14 165          VUILLEMIN,+       (LAUS+NEUC+LPNP+LIVP+GLAS)  JP

HANDLER  76 NP B 110 173        +PLANO,BRUCKER,KOLLER+      (RUTG+STEV+SETO)
VUILLEMI 76 NC 33A 133          +VUILLEMIN,+      (LAUS+NEUC+LPNP+LIVP+GLAS)

GRASSLER 77 NP B 121 189        +(AACHEN+BERLIN+BONN+CERN+CRACOW+HEID+WARS)

CORDEN   78 NP B 144 253        +CORBETT,ALEXANDER,+  (BIRM+RHEL+TELA+LOWC)
IRVING   78 NP B 139 327        A.C.IRVING,H.R.SEPANGI                 (LIVP)
NACASCH  78 NP B 135 203        +DEFOIX,DOBRZYNSKI,+    (PARIS+MADRID+CERN)

STANTON  79 PRL 42 346          +BROCKMAN,DANKOWYCH,+  (OSU+CARL+MCGI+TNTO)  JP

BROMBERG 80 PR D 22 1513        +HAGGERTY,ABRAMS,DZIERBA(CIT+FNAL+ILLC+IND)
    ALSO 82  PRIVATE COMM.      C.BROMBERG                              (MSU)
DIONISI  80 NP B 169 1          +GAVILLET,ARMENTEROS+ (CERN+MADR+CDEF+STOH)I,JP
LACAZE   81 NP B 186 247        +NAVELET                               (SACL)

BAILLON  82 PARIS CONFERENCE    P.BAILLON                              (CERN)
GAVILLET 82 ZPHY C 16 119       +ARMENTEROS,AGUILAR+  (CERN+CDEF+PADO+ROMA)
EDWARDS  82 PRL 49 259          +PARTRIDGE,PECK+  (CIT+HARV+PRIN+STAN+SLAC)
    ALSO 83 PRL 50 219          EDWARDS+PARTRIDGE+(CIT+HARV+PRIN+STAN+SLAC)
TORNQVIS 82 NP B 203 268        TORNQVIST                              (HELS)

BAILLON  83  CERN/EP 83-82      P.BAILLON                              (CERN)
EDWARDS  83 PRL 51 859          +PARTRIDGE,PECK+  (CIT+HARV+PRIN+STAN+SLAC)
HITLIN   83 CORNELL CONF. 746 DAVID HITLIN, RAPPORTEUR'S TALK           (CIT)
JENNI    83 PR D 27 1031        +BURKE,TELNOV,ALAM,BOYARSKI+       (SLAC+LBL)
MENNESSI 83 ZPHY C 16 241       G.MENNESSIER                           (MONP)

ARMSTRON 84 PL 146 B 273        +BLOODWORTH,BURNS,+   (ATHU+BARI+BIRM+CERN)  JP
CHAUVAT  84 PL 148 B 382        +MERITET,BONINO,ALITI+(CERN+UDCF+UCLA+SACL)

ASTON    85 PR D 32 2255        +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+CNRC)
CHUNG    85 PRL 55 779          +FERNOW,BOEHNLEIN+       (BNL+FLOR+IND+SMAS)
```

$\eta(1440)$ was $\iota(1440)$

$I^G(J^{PC}) = 0^+(0^{-+})$

```
CALLED E BY BAILLON 67 AND IOTA BY SCHARRE 80.
SEE MINIREVIEW UNDER F1(1420).
```

$\eta(1440)$ MASS (MeV)

```
M           1425.       7.                BAILLON   67 HBC     0. PBAR P
M           1440.0     10.0      15.0     SCHARRE   80 SMK2    E+E-,J/PSI,E GAM
M       174 1440.0     20.0      15.0     EDWARDS   82 CBAL    J/PSI,ETA GAM
M           1421.0      2.0               CHUNG     85 SPEC  0 8 PI-P,K K PI N   |
M   D   340 1456.0      8.0               RICHMAN   85 SMK3    J/PSI,K0 K+ PI-G  |
M   D   402 1461.0      7.0               RICHMAN   85 SMK3    J/PSI,K+ K- PI0G  |
M   DX     (1420.0)   (25.0)              RICHMAN   85 SMK3    J/PSI,PI+PI-2GAM  |
M           . . . . . . . . . .
M    AVERAGE MEANINGLESS (SCALE FACTOR = 3.4)

M   D     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
M    X    THIS PEAK IN THE GAMMA RHO CHANNEL MAY NOT BE RELATED TO THE
M    X    ETA(1440).
```

$\eta(1440)$ WIDTH (MeV)

```
W              80.       10.               BAILLON   67 HBC     0. PBAR P
W              50.0      30.0      20.0    SCHARRE   80 SMK2    E+E-,J/PSI,E GAM
W        174   55.0      20.0      30.0    EDWARDS   82 CBAL    J/PSI,ETA GAM
W              60.0      10.0              CHUNG     85 SPEC  0 8 PI-P,K K PI N   |
W   D    340   95.0      18.0              RICHMAN   85 SMK3    J/PSI,K0 K+ PI-G  |
W   D    402  101.0      14.0              RICHMAN   85 SMK3    J/PSI,K+ K- PI0G  |
W   DX       (133.0)    (63.0)             RICHMAN   85 SMK3    J/PSI,PI+PI-2GAM  |
W              . . . . . . . . . .
W    AVG       75.7       7.5     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)

W   D     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
W    X    THIS PEAK IN THE GAMMA RHO CHANNEL MAY NOT BE RELATED TO THE
W    X    ETA(1440).
```

$\eta(1440)$ DECAY MODES

		DECAY MASSES
P1	$\eta(1440) \to K\overline{K}^*(892)$	498+ 892
P2	$\eta(1440) \to K\overline{K}\pi$	498+ 498+ 140
P3	$\eta(1440) \to \pi\pi\rho$	140+ 140+ 769
P4	$\eta(1440) \to a_0(980)\ \pi$	983+ 140
P5	$\eta(1440) \to \eta\pi\pi$	549+ 140+ 140
P6	$\eta(1440) \to 4\pi$	140+ 140+ 140+ 140
P7	$\eta(1440) \to \gamma\gamma$	0+ 0
P8	$\eta(1440) \to \rho^0\gamma$	769+ 0

$\eta(1440)$ $\Gamma(I)*\Gamma(\gamma\gamma)/\Gamma(\text{total})$ (keV)

$\Gamma(K\overline{K}\pi)*\Gamma(\gamma\gamma)/\Gamma(\text{total})$

```
W7          (8.0)  OR LESS  CL=0.95  JENNI      83 SMK2   GAM GAM,KKBAR PI
```

$\Gamma(\rho^0\gamma)*\Gamma(\gamma\gamma)/\Gamma(\text{total})$

```
W8          (1.5)  OR LESS  CL=0.95  ALTHOFF    84 TASS   E+E-,E+E-PI+PI-G  |
```

$\eta(1440)$ BRANCHING RATIOS

$\eta(1440) \to (\overline{K}K^*(892) + \text{C.C.})/(K\overline{K}\pi)$ (P1)/(P2)

```
R1               .50      .10              BAILLON   67 HBC     0.0 PBAR P
```

$\eta(1440) \to (\eta\pi\pi)/(K\overline{K}\pi)$ (P5)/(P2)

```
R3          (1.1)  OR LESS  CL=.90   SCHARRE    80 SMK2   E+E-,J/PSI,E GAM
R3          (0.5)  OR LESS  CL=.90   EDWARDS    83 CBAL   J/PSI,HADR GAM
```

$\eta(1440) \to (\overline{K}K^*(892) + \text{C.C.})/(a_0(980)\ \pi + \overline{K}K^*(892) + \text{C.C})$

```
R6                                                  (P1)/(P1+P4)
R6          (0.25) OR LESS  CL=.90   EDWARDS    82 CBAL    J/PSI,ETA GAM
```

REFERENCES FOR $\eta(1440)$

```
BAILLON  67 NC 50A  393         +EDWARDS+D-ANDLAU+ASTIER+  (CERN+CDEF+IRAD)

SCHARRE  80 PL 97 B 329         +TRILLING,ABRAMS,ALAM,BLOCKER+    (SLAC+LBL)

CHANOWIT 81 PRL 46 981          CHANOWITZ                               (LBL)
LIPKIN   81 PL 106 B 114        LIPKIN                                 (FNAL)
SCHARRE  81 BONN CONF. 163      D.L.SCHARRE                            (SLAC)
    ALSO 81 SANTA CRUZ CONF.    COYNE,EDWARDS,+   (PRIN+CIT+HARV+STAN+SLAC)
    ALSO 80 MORIOND II 83       ASCHMAN,PARTRIDGE+(PRIN+CIT+HARV+STAN+SLAC)

ALTHOFF  82 ZPHY C 16 13        +BOERNER,BURKHARDT+   (TASSO COLLABORATION)
BAILLON  82 PARIS CONFERENCE    P.BAILLON                              (CERN)
BARNES   82 PL 116 B 365        T.BARNES AND F.E.CLOSE                 (RHEL)
BARNES   82 NP B 198 360        +CLOSE,MONAGHAN                    (RHEL+OXF)
DONOGHUE 82 PL 112 B 409        J.F.DONOGHUE AND H.GOMM                (MASA)
EDWARDS  82 PRL 49 259          +PARTRIDGE,PECK+  (CIT+HARV+PRIN+STAN+SLAC)
    ALSO 83 PRL 50 219          EDWARSD+PARTRIDGE+(CIT+HARV+PRIN+STAN+SLAC)
MINAMI   82 PL 113 B 69         S.MINAMI                               (OSKC)
TANIMOTO 82 PL 116 B 198        M.TANIMOTO                             (BIEL)

BAILLON  83  CERN/EP 83-82      P.BAILLON                              (CERN)
EDWARDS  83 PRL 51 859          +PARTRIDGE,PECK+  (CIT+HARV+PRIN+STAN+SLAC)
JENNI    83 PR D 27 1031        +BURKE,TELNOV,ABRAMS,BLOCKER+     (SLAC+LBL)

ALTHOFF  84 PL 147 B 487                              (TASSO COLLABORATION)
LIPKIN   84 PL 135 B 215        +COHEN                         (REHO+CARACAS)

BARTEL   85  DESY 85-081          (DESY+HAMB+HEID+LANC+MCHS+UMD+RHEL+TOKY)
CHANOWIT 85  LBL-20091          M.S.CHANOWITZ                           (LBL)
CHUNG    85 PRL 55 779          +FERNOW,BOEHNLEIN+       (BNL+FLOR+IND+SMAS)  JP
FRANK    85 PL 158 B 442        +ISGUR,ODONNELL,WEINSTEIN              (TNTO)
RICHMAN  85  CALT-68-1260       20TH RENCONTRE DE MORIOND               (CIT)
```

$f_2'(1525)$ was $f'(1525)$

$I^G(J^{PC}) = 0^+(2^{++})$

$f_2'(1525)$ MASS (MeV)

```
M1   PRODUCED BY PION BEAM
M1    N     (1502.0)    (25.0)             CORDEN    79 OMEG    12-15PI-P, N 2PI
M1
M1    C       1506.0      7.5              PAWLICKI  77 SPEC    6.PI N,K+K-
M1            1492.0     29.0              GORLICH   80 ASPK    17 PI- P,POLARIZ
M1    D       1496.0     9.        8.      CHABAUD   81 ASPK    6  PI-P
M1            1497.0     8.        9.      CHABAUD   81 ASPK    18.4 PI-P
M1            . . . . . . . . . .
M1   AVG      1500.0      4.6    AVERAGE

M2   PRODUCED BY K+- BEAM
M2         (1515.0)     (7.0)              AMMAR     67 HBC      5.5 K-P,K KBAR
M2        46(1514.)     (4.)               COLLEY    72 HBC     10.K+ P,K+ K-
M2        47(1521.)     (7.)               VIDEAU    72 HBC     4.K- P,K KBAR
M2
M2       100 1519.       7.                AGUILAR   72 HBC     3.9,4.6 K-,K KB
M2       120 1527.0      3.0               BRANDENBU 76 ASPK    13.K-P,K+K-
M2       123 1522.0      6.0               BARREIRO  77 HBC     4.15 K-P,KS KS
M2       166 1528.       7.                EVANGELIS 77 OMEG    10 K- P
M2       650 1521.0      6.0               AGUILAR   81 HBC     4.2 K-P,LAM 2K
M2       572 1521.0      3.0               ALHARRAN  81 HBC     8.25 K-P,LAM 2K
M2           1529.0      3.0               ARMSTRONG 83 OMEG    18.5 K-P,K-K+LAM
M2           . . . . . . . . . .
M2   AVG     1524.9      1.5     AVERAGE

M     C  WITH A PHASE SHIFT ANALYSIS
M     C  MASS  ERRORS ENLARGED BY US BY FACTOR 1.5.
M     N  FROM AN AMPLITUDE ANALYSIS WHERE THE F2'(1525) WIDTH AND
M     N  ELASTICITY ARE IN COMPLETE DISAGREEMENT WITH VALUES
M     N  OBTAINED FROM KKBAR CHANNEL MAKING THE SOLUTION DUBIOUS.
M     D  CHABAUD 81 IS A RE-ANALYZES PAWLICKI 77 DATA.
```

$f_2'(1525)$ WIDTH (MeV)

```
W1  PRODUCED BY PION BEAM
W1   N      (165.0)   (42.0)             CORDEN     79 OMEG    12-15PI-P, N 2PI
W1          (150.0)   (83.0)    (50.0)   GORLICH    80 ASPK    17 PI- P,POLARIZ
W1
W1   L        66.0     15.0              PAWLICKI   77 SPEC    6.PI N,K+K-
W1   M        92.0     39.0      22.0    POLYCHRON  79 STRC    7. PI-P,KS KS N
W1   D        69.0     22.       16.     CHABAUD    81 ASPK    6  PI-P
W1           137.0     23.       21.     CHABAUD    81 ASPK    18.4 PI-P
W1          . . . . . . . . . . .
W1  AVG       83.7     16.0     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)

W2  PRODUCED BY K+- BEAM
W2           (35.0)   (25.0)             AMMAR      67 HBC      5.5 K-P, K KBAR
W2       46  (28.)    (15.)              COLLEY     72 HBC     10.K+ P,K+ K-
W2       47  (40.)    (10.)              VIDEAU     72 HBC     4.K- P,K KBAR
W2
W2      100   69.      22.               AGUILAR    72 HBC     3.9,4.6 K-P,K KB
W2      120   61.0      8.0              BRANDENBU  76 ASPK    13.K-P,K+K-
W2      123   62.0     19.0      14.0    BARREIRO   77 HBC     4.15 K-P,KS KS
W2      166   72.0     25.0              EVANGELIS  77 OMEG    10 K- P
W2      650   85.0     16.0              AGUILAR    81 HBC     4.2 K-P,LAM 2K
W2      572   80.0     14.0      11.0    ALHARRAN   81 HBC     8.25 K-P,LAM 2K
W2            83.0     15.0              ARMSTRONG  83 OMEG    18.5 K-P,K-K+LAM
W2          . . . . . . . . . . .
W2  AVG       70.3      5.1     AVERAGE

W    C  WITH A PHASE SHIFT ANALYSIS
W    C  WIDTH ERRORS ENLARGED BY US BY FACTOR 1.5.
W    M  FROM A FIT TO THE D WAVE WITH F2(1270)-F2'(1525) INTERFERENCE.
W    M  MASS FIXED AT 1516 MEV.
W    N  SEE NOTE N UNDER MASS.
W    D  CHABAUD 81 IS A RE-ANALYZES PAWLICKI 77 DATA.
```

$f_2'(1525)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_2'(1525) \to \pi\pi$	140+ 140
P2	$f_2'(1525) \to K\bar{K}$	498+ 498
P3	$f_2'(1525) \to K\bar{K}^*(892)$	494+ 892
P4	$f_2'(1525) \to \eta\eta$	549+ 549
P5	$f_2'(1525) \to \pi\pi\eta$	140+ 140+ 549
P6	$f_2'(1525) \to \pi K\bar{K}$	140+ 498+ 498
P7	$f_2'(1525) \to \pi^+\pi^+\pi^-\pi^-$	140+ 140+ 140+ 140
P8	$f_2'(1525) \to \gamma\gamma$	0+ 0

$f_2'(1525)$ PARTIAL WIDTHS (keV)

$f_2'(1525) \to \gamma\gamma$ (G8)

```
W8 B D        0.11      0.05             ALTHOFF    83 TASS    GAM GAM,2K        |

W8 B    USING BRANCHING RATIO F2'(1525) INTO K KBAR = 1.
W8   D  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$f_2'(1525)$ BRANCHING RATIOS

$f_2'(1525) \to (\pi\pi)$/total (P1)

```
R1 C         (0.0086) OR LESS         BEUSCH    75 OSPK    8.9 PI-P,K0 K0 N
R1           (0.063)OR LESS  CL=0.90  BRANDENBU 76 ASPK    13.K-P,K+K-
R1           (0.045)OR LESS  CL=0.95  BARREIRO  77 HBC     4.15 K-P,KS KS
R1 C          0.012     0.004         PAWLICKI  77 SPEC    6.PI N,K+K-
R1   N       (0.19)    (0.03)         CORDEN    79 OMEG    12-15PI-P, N 2PI
R1 C D        0.0075    0.0025        MARTIN    79 RVUE
R1            0.007     0.002         COSTA     80 OMEG    10 PI-P,K+ K- N
R1 C         (0.027)   (0.071)  (0.013)GORLICH  80 ASPK    17,18 PI-P POLAR
R1           (0.06) OR LESS  CL=.95   AGUILAR   81 HBC     4.2 K-P,LAM 2K
R1          . . . . . . . . . .
R1  AVG       0.0078    0.0015   AVERAGE

R1 C    ASSUMING THAT THE F2'(1525) IS PRODUCED BY AN OPE
R1      PRODUCTION MECHANISM.
R1   D  MARTIN 79 USES THE PAWLICKI 77 DATA WITH DIFFERENT INPUT
R1      VALUE OF THE F2(1270) INTO K KBAR BRANCHING RATIO.
R1   N  SEE NOTE N UNDER MASS.
```

$f_2'(1525) \to (\eta\eta)/(K\bar{K})$ (P4)/(P2)

```
R3           (0.50) OR LESS           BARNES    67 HBC      4.6, 5.0 K- P
```

$f_2'(1525) \to (\pi\pi\eta)/(K\bar{K})$ (P5)/(P2)

```
R4           (0.3)  OR LESS  CL=.67   AMMAR     67 HBC
R4           (0.41) OR LESS  CL=.95   AGUILAR   72 HBC     3.9,4.6 K- P
```

$f_2'(1525) \to (\pi K\bar{K} + K\bar{K}^*(892))/(K\bar{K})$ (P6+P3)/(P2)

```
R5           (0.4)  OR LESS  CL=.67   AMMAR     67 HBC
R5           (0.35) OR LESS  CL=.95   AGUILAR   72 HBC     3.9,4.6 K- P
```

$f_2'(1525) \to (\pi^+\pi^+\pi^-\pi^-)/(K\bar{K})$ (P7)/(P2)

```
R6           (0.32) OR LESS  CL=.95   AGUILAR   72 HBC     3.9,4.6 K- P
```

REFERENCES FOR $f_2'(1525)$

```
BARNES   65 PRL 15 322        +CULWICK,GUIDONI,KALBFLEISCH,GOZ+(BNL+SYRA)

CRENNELL 66 PRL  16  1025     + KALBFLEISCH,LAI,SCARR,SCHUMANN +    (BNL)I

ABRAMS   67 PRL 18 620        +KEHOE,GLASSER,SECHI-ZORN,WOLSKY (MARYLAND)
AMMAR    67 PRL  19  1071     +DAVIS,HWANG,DAGAN,DERRICK +     (NWES+ANL)  JP
BARNES   67 PRL  19  964      +DORNAN,GOLDBERG,LEITNER +   (BNL+SYRACUSE)ICJP

ALITTI   68 PRL 21 1705       +BARNES,CRENNELL,FLAMINIO,GOLDBERG,+  (BNL)

LORSTAD  69 NP B 14 63        B.LORSTAD,D-ANDLAU,ASTIER,+     (CDEF+CERN)
SCOTTER  69 NC 62 A 1057      +ERSKINE,PALER,+  (BIRM+GLAS+LOIC+MPIM+OXF)

AGUILAR  72 PR D 6 29         AGUILAR-BENITEZ,CHUNG,EISNER,SAMIOS   (BNL)
COLLEY   72 NP B 50 1         +JOBES,RIDDIFORD,GRIFFITHS,+     (BIRM+GLAS)
VIDEAU   72 PL 41 B 213       +VIDEAU,ROUGE,BARRELET,DEBRION,+(EPOL+SACL)

BEUSCH   75 PL 60 B 101       +BIRMAN,WEBSDALE,WETZEL            (CERN+ETH)

BRANDENB 76 NP B 104 413      BRANDENBURG,CARNEGIE,CASHMORE,DAVIER+(SLAC)

BARREIRO 77 NP B 121 237      +DIAZ,GAY,HEMINGWAY,+  (CERN+AMST+NIJM+OXF)
EVANGELI 77 NP B 127 384      EVANGELISTA,+   (BARI+BONN+CERN+DARE+GLAS+)
LAVEN    77 NP B 127 43       +OTTER,KLEIN,+   (AACH+BERL+CERN+LOIC+WIEN)
PAWLICKI 77 PR D 15 3196      +AYRES,COHEN,DIEBOLD,KRAMER,WICKLUND  (ANL)I JP

BECKER   79 NP B 151  46      +BLANAR,BLUM,CERRADA+ (MPIM+CERN+ZEEM+CRAC)
CORDEN   79 NP B 157 250      +DOWELL,GARVEY,JOBES,+(BIRM+RHEL+TELA+LOWC)  JP
MARTIN   79 NP B 158 520      +OZMUTLU                              (DURH)
POLYCHRO 79 PR D 19 1317      POLYCHRONAKOS,CASON,BISHOP+      (NDAM+ANL)

COSTA    80 NP B 175 402      +      (BARI+BONN+CERN+GLAS+LIVP+MILA+WIEN)
GORLICH  80 NP B 174 16       +NICZYPORUK,ROZANSKA+ (CRAC+MPIM+CERN+ZEEM)

AGUILAR  81 ZPHY C 8 313      +ALBAJAR,ARMENTEROS,+ (CERN+CDEF+MADR+STOH)
ALHARRAN 81 NP B 191 26       +BAUBILLIER,+    (BIRM+CERN+GLAS+MICH+LPNP)
CHABAUD  81 APP B 12 575      +NICZYPORUK,BECKER+         (CERN+CRAC+MPIM)

ARMSTRON 82 PL 110 B 77       +BAUBILLIER+(BARI+BIRM+CERN+MILA+LPNP+PAVI)
ETKIN    82 PR D 25 1786      +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)
LUKE     82  DESY 82 73       D.LUKE                                (DESY)

ALTHOFF  83 PL 121 B 216      +BRANDELIK,BOERNER+   (TASSO COLLABORATION)
ARMSTRON 83 NP B 224 193      ARMSTRONG+  (BARI+BIRM+CERN+MILA+LPNP+PAVI)
GRAY     83 PR D 27 307       +KALOGEROPOULOS,NANDY,ROY,ZENONE      (SYRA)
JENNI    83 PR D 27 1031      +BURKE,TELNOV,ABRAMS,BLOCKER+     (SLAC+LBL)
```

$f_1(1530)$ was $D(1530)$

$I^G(J^{PC}) = 0^+(1^{-+})$

NAMED D PRIME BY GAVILLET 82
NEEDS CONFIRMATION.

OMITTED FROM SUMMARY TABLE

$f_1(1530)$ MASS (MeV)

```
M     271 1526.0      6.0             GAVILLET  82 HBC    0 4.2 K-P,LAM KKPI
```

$f_1(1530)$ WIDTH (MeV)

```
W     271  107.0     15.0             GAVILLET  82 HBC    0 4.2 K-P,LAM KKPI
```

$f_1(1530)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_1(1530) \to K K^*(892)$	494+ 892

REFERENCES FOR $f_1(1530)$

```
GAVILLET 82 ZPHY C 16 119     +ARMENTEROS,AGUILAR+  (CERN+CDEF+PADO+ROMA)

BAILLON  83  CERN/EP 83-82    P.BAILLON                             (CERN)
```

$f_0(1590)$

$I^G(J^{PC}) = 0^+(0^{++})$

$f_0(1590)$ MASS (MeV)

```
M           1592.0     25.0           BINON     83 GAM2    038 PI-P,4 GAMMA    |
M           1568.0     33.0           BINON     84 GAM2     38 PI-P,ETA' ETA   |
M  A        1575.0     45.0           ALDE      85 GAM4    0100 PI-P,4 GAMMA   |
M  A        1605.0     35.0           ALDE      85 GAM4    0100 PI-P,8 GAMMA   |
M           . . . . . . . . . . .
M   AVG     1586.8     16.2     AVERAGE

M  A    FROM CENTRAL VALUE AND SPREAD OF TWO SOLUTIONS
```

$f_0(1590)$ WIDTH (MeV)

```
W            210.0     40.0              BINON      83 GAM2   038 PI-P,4 GAMMA    |
M            260.0     60.0              BINON      84 GAM2    38 PI-P,ETA' ETA   |
W   A        265.0     65.0              ALDE       85 GAM4   0100 PI-P,4 GAMMA   |
W   A        320.0     80.0              ALDE       85 GAM4   0100 PI-P,8 GAMMA   |
W            . . . . . . . . . .
W    AVG     286.9     50.4      AVERAGE

M 'A    FROM CENTRAL VALUE AND SPREAD OF TWO SOLUTIONS
```

$f_0(1590)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_0(1590) \rightarrow \eta\eta$	549+ 549
P2	$f_0(1590) \rightarrow \eta\eta'$	549+ 958
P3	$f_0(1590) \rightarrow \pi^0\pi^0$	135+ 135
P4	$f_0(1590) \rightarrow K\overline{K}$	498+ 498

$f_0(1590)$ BRANCHING RATIOS

$f_0(1590) \rightarrow (\eta\eta)$/total (P1)

```
R1          LARGE                        BINON      83 GAM2   038 PI-P,4 GAMMA    |
```

$f_0(1590) \rightarrow (\eta\eta')/(\eta\eta)$ (P2)/(P1)

```
R2            2.7        0.8             BINON      84 GAM2   038 PI-P,4 GAMMA    |
```

$f_0(1590) \rightarrow (\pi^0\pi^0)/(\eta\eta)$ (P3)/(P1)

```
R3           (0.3)   OR LESS             BINON      83 GAM2   038 PI-P,4 GAMMA    |
```

$f_0(1590) \rightarrow (K\overline{K})/(\eta\eta)$ (P4)/(P1)

```
R4           (0.6)   OR LESS             BINON      83 GAM2   038 PI-P,4 GAMMA    |
```

REFERENCES FOR $f_0(1590)$

```
BINON    83 NC A 78 313       +DONSKOV,DUTEIL+       (BELG+LAPP+SERP+CERN)IGJP
BINON    84 NC A 80 363       +BRICMAN,DONSKOV+      (BELG+LAPP+SERP+CERN)
ALDE     85  CERN-EP/85-153   +BINON,BRICMAN,DUTEIL+(BELG+LAPP+SERP+CERN)IGJP
```

$\rho(1600)$

$I^G(J^{PC}) = 1^+(1^{--})$

OUR LATEST MINIREVIEW ON THIS PARTICLE CAN BE FOUND IN THE 1984 EDITION.

$\rho(1600)$ MASS (MeV)

```
M  PI+ PI- MODE
M   H     (1590.)    (20.)           HYAMS      73 ASPK  0 17 PI-P,N PI+PI-
M  P       1610.      30.            FROGGATT   77 RVUE  0 17 PI-P,PI+PI-N
M  P      (1575.)                    MARTIN     78 RVUE  0 17 PI-P,PI+PI-N
M    R     1600.0     10.0           ATIYA      79 SPEC    50 GAM C,2PI
M          1598.0     24.0     22.0  BECKER     79 ASPK  0 17 PI- P POLARIZ
M   P     (1659.)    (25.)           LANG       79 RVUE  0
M    M     1590.      20.            ASTON 1    80 OMEG    20-70GAM P,2 PI
M          1550.      70.            ABE        84 HYBR    20 GAM P,PI+PI-P   |
M  K KBAR MODE
M     1600 1582.      36.            CLELAND    82 SPEC +- 50 PI P,KS K+-P
M  MIXED MODES
M  G       1580.      20.            BUON       82 DM1     E+E-,HADRONS
M          . . . . . . . . . . .
M   AVG    1595.2      7.3    AVERAGE

M  2(PI+ PI-) MODE
M      400 1430.      50.            BINGHAM    72 HBC   0 9.3 GAM P,P 4PI
M    M     1550.      60.            CONVERSI   74 OSPK  0 E+ E-,2(PI+PI-)
M      160 1550.      50.            SCHACHT    74 STRC  0 5.5-9 G P,P 4PI
M      340 1450.     100.            SCHACHT    74 STRC  0 9-18 G P,P 4PI
M   D   65(1570.)    (60.)           ALEXANDER  75 HBC   0 7.5 GAM P,P 4PI
M   C     (1500.)                    ATIYA      79 SPEC    50 GAM C,4 PI+-
M   A     (1666.)    (39.)           BACCI      80 FRAG    E+ E-, 2(PI+PI-)
M       34(1780.)                    KILLIAN    80 SPEC    11 E-P,2(PI+PI-)
M    M     1520.      30.            ASTON 1    81 OMEG    20-70GAM P,4 PI
M  O       1654.      25.            DIBIANCA   81 DBC   0 PI+D,PP2(PI+PI-)
M  A       1570.      20.            CORDIER    82 DM1     E+E-,2(PI+PI-)
M   B     (1540.)                    PENSO      82 RVUE    E+ E-, 2(PI+PI-)
M          . . . . . . . . . .
M   AVERAGE MEANINGLESS (SCALE FACTOR = 2.1)

M  PI+ PI- PI0 PI0 MODE
M          1660.      30.            ATKINSO2  85 OMEG    20-70 GAM P         |

M   A   SIMPLE RELATIV. BREIT-WIGNER FIT WITH MODEL DEPENDENT WIDTH
M   B   ASSUMING RHO+F0(1300) DECAY MODE INTERFERES WITH
M   B   A1(1270)+PI BACKGROUND
M   C   PARAMETERS ROUGHLY ESTIMATED,NOT FROM A FIT
M   D   SKEW MASS DISTRIBUTION COMPENSATED BY ROSS-STODOLSKY FACTOR
M   H   INCLUDED IN BECKER 79 ANALYSIS
M    M  SIMPLE RELATIV. BREIT WIGNER FIT WITH CONSTANT WIDTH
M  O    ONE PEAK FIT RESULT.
M  P    FROM PHASE SHIFT ANALYSIS OF HYAMS 73 DATA
M    R  AN ADDITIONAL 40 MEV UNCERTAINTY IN BOTH THE MASS AND WIDTH
M    R  IS PRESENT DUE TO THE CHOICE OF THE BACKGROUND SHAPE.
M  G    FROM GLOBAL FIT OF RHO,OMEGA,PHI AND THEIR RADIAL EXCITATIONS TO
M  G    CHANNELS OMEGA PI+PI-,K+K-,KS KL,KS K+- PI-+.
```

$\rho(1600)$ WIDTH (MeV)

```
W  PI+ PI- MODE
W   H      (180.)     (50.)           HYAMS      73 ASPK  0 17 PI-P,N PI+PI-
W  P        300.      100.            FROGGATT   77 RVUE  0 17 PI-P,PI+PI-N
W  P       (340.)                     MARTIN     78 RVUE  0 17 PI-P,PI+PI-N
W    R      283.0      14.0           ATIYA      79 SPEC    50 GAM C,2PI
W           175.0      98.0     53.0  BECKER     79 ASPK  0 17 PI- P POLARIZ
W   P      (232.)     (34.)           LANG       79 RVUE  0
W    M      230.0      80.0           ASTON 1    80 OMEG    20-70 GAM P,2PI
W           280.       30.      80.   ABE        84 HYBR    20 GAM P,PI+PI-P   |
W  K KBAR MODE
W     1600  265.      120.            CLELAND    82 SPEC +- 50 PI P,KS K+-P
W  MIXED MODES
W  G        340.       80.            BUON       82 DM1     E+E-,HADRONS
W           . . . . . . . . . . .
W   AVG     279.9      12.8     AVERAGE

W  2(PI+ PI-) MODE
W       400 650.      100.            BINGHAM    72 HBC   0 9.3 GAM P,P 4PI
W    M      360.      100.            CONVERSI   74 OSPK  0 E+ E-,2(PI+PI-)
W  E    160 400.      120.            SCHACHT    74 STRC  0 5.5-9 G P,P 4PI
W  E    340 850.      200.            SCHACHT    74 STRC  0 9-18 G P,P 4PI
W   D    65 (340.)    (160.)          ALEXANDER  75 HBC   0 7.5 GAM P,P 4PI
W   C       (600.)                    ATIYA      79 SPEC    50 GAM C,4 PI+-
W   A       (700.)    (160.)          BACCI      80 FRAG    E+ E-, 2(PI+PI-)
W        34 (100.)                    KILLIAN    80 SPEC    11 E-P,2(PI+PI-)
W   B       (230.)                    PENSO      80 RVUE    E+ E-, 2(PI+PI-)
W    M      400.       50.            ASTON 1    81 OMEG    20-70GAM P,4 PI
W  O        400.      146.            DIBIANCA   81 DBC   0 PI+D,PP2(PI+PI-)
W  A        510.       40.            CORDIER    82 DM1     E+E-,2(PI+PI-)
W           . . . . . . . . . .
W   AVERAGE MEANINGLESS (SCALE FACTOR = 1.4)

W  PI+ PI- PI0 PI0 MODE
W           300.       50.            ATKINSO2  85 OMEG    20-70 GAM P         |

W   A   SIMPLE RELATIV. BREIT-WIGNER FIT WITH MODEL DEPENDENT WIDTH
M   B   ASSUMING RHO+F0(1300) DECAY MODE INTERFERES WITH
M   B   A1(1270)+PI BACKGROUND
W   C   PARAMETERS ROUGHLY ESTIMATED,NOT FROM A FIT
W   D   SKEW MASS DISTRIBUTION COMPENSATED BY ROSS-STODOLSKY FACTOR
W  E    WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N),SEE K*(892) NOTE
W   H   INCLUDED IN BECKER 79 ANALYSIS
W    M  SIMPLE RELATIV. BREIT WIGNER FIT WITH CONSTANT WIDTH
W  O    ONE PEAK FIT RESULT.
W  P    FROM PHASE SHIFT ANALYSIS OF HYAMS 73 DATA
W    R  AN ADDITIONAL 40 MEV UNCERTAINTY IN BOTH THE MASS AND WIDTH
W    R  IS PRESENT DUE TO THE CHOICE OF THE BACKGROUND SHAPE.
W  G    FROM GLOBAL FIT OF RHO,OMEGA,PHI AND THEIR RADIAL EXCITATIONS TO
W  G    CHANNELS OMEGA PI+PI-,K+K-,KS KL,KS K+- PI-+.
```

$\rho(1600)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\rho(1600) \rightarrow \rho\pi^+\pi^-$	769+ 140+ 140
P2	$\rho(1600) \rightarrow 4\pi^\pm$	140+ 140+ 140+ 140
P3	$\rho(1600) \rightarrow \rho\rho$	769+ 769
P4	$\rho(1600) \rightarrow \pi\pi$	140+ 140
P5	$\rho(1600) \rightarrow \overline{K}K$	494+ 494
P6	$\rho(1600) \rightarrow \pi\omega$	140+ 783
P7	$\rho(1600) \rightarrow \rho^0\pi^0\pi^0$	769+ 135+ 135
P8	$\rho(1600) \rightarrow e^+e^-$	.511+.511
P9	$\rho(1600) \rightarrow \rho^\pm\pi^\mp\pi^0$	769+ 140+ 135
P10	$\rho(1600) \rightarrow \overline{K}K^*(892)$ + C.C.	494+ 892
P11	$\rho(1600) \rightarrow \pi\pi\eta$	140+ 140+ 549
P12	$\rho(1600) \rightarrow \rho\pi\pi$	769+ 140+ 140

$\rho(1600)$ PARTIAL WIDTHS (keV)

$\rho(1600) \rightarrow e^+e^-$ (G8)

```
W8  D        (7.5)     (1.5)           DELCOUR2  81 DM1     E+ E-, 2(PI+PI-)

W8  D   MODEL DEPENDENT, NOT INDEPENDENT OF DELCOUR2 81 WIDTH TIMES E+E-
W8  D   BRANCHING RATIO BELOW
```

$\rho(1600)$ BRANCHING RATIOS

$\rho(1600) \rightarrow (\rho\pi^+\pi^-)/(4\pi^\pm)$ (P1)/(P2)

```
R1 S         (0.80)                    BINGHAM   72  HBC    9.3 GAM P,P 4PI
R1      500   0.7       0.1            SCHACHT   74 STRC    5.5-18 G P,P 4PI
R1           (1.0)  APPROX.            DELCOUR2  81 DM1     E+E-,2(PI+PI-)
R1 S    THE PI PI SYSTEM IS IN S-WAVE
```

$\rho(1600) \rightarrow (\pi^+\pi^-)/(4\pi^\pm)$ (P4)/(P2)

```
R3  S        (0.2)  OR LESS            BINGHAM   72  HBC    9.3 GAM P,P 2PI
R3  E        (0.14) OR LESS            DAVIER    73 STRC    6-18 G P,P 4PI
R3            0.13      0.05           ASTON 1   80 OMEG    20-70 GAM P,2PI
R3  S   2 SIGMA UPPER LIMIT
R3  E   UPPER LIMIT IS ESTIMATE
```

$\rho(1600) \rightarrow (\overline{K}K)/(4\pi^\pm)$ (P5)/(P2)

```
R4           (0.04) OR LESS  CL=0.95   BINGHAM   72  HBC  0 9.3 GAM P
R4   D        0.015     0.010          DELCOUR2  81 DM1     E+E-,KBAR K
R4   D  ASSUMING RHO(1600) AND OMEGA RAD.EXIT. TO BE DEGENERATE IN MASS.
```

$\rho(1600) \rightarrow (\pi^+\pi^-)/\text{total}$ (P4)

```
R5  E       (0.15) OR LESS              EISENBERG 73 HBC      5 PI+ P,DEL++2PI
R5  H       (0.25)   (0.05)             HYAMS     73 ASPK     17 PI-P,N PI+PI-
R5           0.20     0.05              MONTANET  73 HBC      PBAR P AT REST
R5 C        (0.20) OR LESS              COSTA 2   77 RVUE     E+E-,2 PI + 4 PI
R5  P       (0.30)   (0.05)             FROGGATT  77 RVUE     17 PI-P,PI+PI-N
R5 P        (0.15)TO 0.30               MARTIN    78 RVUE     17 PI-P,PI+PI-N
R5           0.287    0.043     0.042 BECKER    79 ASPK     17 PI- P POLARIZ
R5          . . . . . . . . .
R5  AVERAGE MEANINGLESS (SCALE FACTOR = 1.3)

R5 C    ESTIMATE USING UNITARITY,TIME REVERSAL INVARIANCE,BREIT WIGNER
R5  E   ESTIMATED USING OPE MODEL.
R5  H   INCLUDED IN BECKER 79 ANALYSIS
R5 P    FROM PHASE SHIFT ANALYSIS OF HYAMS 73 DATA
```

$\rho(1600) \rightarrow (\rho^0\pi^0\pi^0)/(\rho^\pm\pi^\mp\pi^0)$ (P7)/(P9)

```
R6          (0.15) OR LESS              ATKINSON  82 OMEG   0 20-70GAM P,4PI P
R6          (0.10) OR LESS              ATKINSO2  85 OMEG     20-70 GAM P
```

$\rho(1600) \rightarrow (\pi^+\pi^- + \text{neutrals})/(4\pi^\pm)$ (P7+....)/(P2)

```
R7  U       (2.6)    (0.4)              BALLAM    74 HBC      9.3 GAMMA P
R7  U   UPPER LIMIT. BACKGROUND NOT SUBTRACTED
```

$\rho(1600) \rightarrow (\pi\pi\eta)/(4\pi^\pm)$ (P11)/P2

```
R8          (0.1)  APPROX.              ASTON 1   80 OMEG     20-70 GAM P
R8           0.123    0.027             DELCOURT  82 DM1      E+E-,PI+PI-MM
```

$\rho(1600) \rightarrow (\bar{K}K^*(892) + \text{C.C.})/(4\pi^\pm)$ (P10)/(P2)

```
R9   D       0.15     0.03              DELCOUR2  81 DM1      E+E-,KBAR K PI
R9   D  ASSUMING RHO(1600) AND OMEGA RAD.EXIT. TO BE DEGENERATE IN MASS.
```

$\rho(1600) \rightarrow (\bar{K}K)/(\bar{K}K^*(892) + \text{C.C.})$ (P5)/P10)

```
R10          0.052    0.026             BUON      82 DM1      E+E-,HADRONS
```

$\rho(1600)$ $\Gamma(\text{I})^*\Gamma(e^+e^-)/\Gamma(\text{total})$ (keV)

```
    THIS COMBINATION OF A PARTIAL WIDTH WITH THE PARTIAL WIDTH INTO
    E+E- AND WITH THE TOTAL WIDTH IS OBTAINED FROM THE CROSS-SECTION
    INTO CHANNEL(I) IN E+E- ANNIHILATION.
```

$\Gamma(4\pi^\pm)^*\Gamma(e^+e^-)/\Gamma(\text{total})$ (G2)*(G8)/TOTAL

```
G2           2.83     0.42              BACCI     80 FRAG     E+ E-, 2(PI+PI-)
G2 P        (0.4)                       PENSO     80 RVUE     E+ E-, 2(PI+PI-)
G2           2.6      0.2               DELCOUR2  81 DM1      E+ E-, 2(PI+PI-)
G2          . . . . . . . . .
G2  AVG      2.64     0.18    AVERAGE

G2 P    ASSUMING RHO F0(1300) DECAY MODE INTERFERES WITH A1(1270) PI
G2 P    BACKGROUND.
```

$\Gamma(\bar{K}K)^*\Gamma(e^+e^-)/\Gamma(\text{total})$ (G5)*(G8)/TOTAL

```
G5  M       (0.035)  (0.029)            BIZOT     80 DM1      E+ E-
```

$\Gamma(\bar{K}K^*(892) + \text{C.C.})^*\Gamma(e^+e^-)/\Gamma(\text{total})$ (G10)*(G8)/TOTAL

```
G10 M       (0.305)  (0.071)            BIZOT     80 DM1      E+ E-
```

$\Gamma(\rho\pi\pi)^*\Gamma(e^+e^-)/\Gamma(\text{total})$ (G12)*(G8)/TOTAL

```
G12 M       (3.510)  (0.090)            BIZOT     80 DM1      E+ E-

G   M   MODEL DEPENDENT
```

REFERENCES FOR $\rho(1600)$

```
ALVENSLE 71 PRL 26 273          ALVENSLEBEN,BECKER,BERTRAM,CHEN,+(DESY+MIT) G
BRAUN    71 NP B30 213          +FRIDMAN, GERBER, GIVERNAUD,+  (STRASBOURB) G
BULOS    71 PRL 26 149          +BUSZA,KEHOE,BENISTON,+  (SLAC+UMD+IBM+LBL) G

BACCI    72 PL 38B 551          +PENSO,SALVINI,STELLA,BALDINI-CE(ROMA+FRAS) JPC
BARBARIN 72 LNC 3 689           BARBARINO,CERADINI,+   (FRAS+ROMA+PADO+UMD)IGJP
BARTOLI  72 PR D 6 2374         +FELICETTI,OGREN,+          (FRAS+ROMA+NAPL)IGJP
BINGHAM  72 PL 41B 635          +RABIN,ROSENFELD,SMADJA,YOST+(LBL,UCB,SLAC)IGJP
BRAMON   72 LNC 3 693           +GRECO (THEORETICAL PAPER)          (FRASCATI)
DIEBOLD  72 BATAVIA CONF.       R.DIEBOLD  RAPPORTEUR TALK                (ANL)
EISENBER 72 PR D 5 15           EISENBERG,BALLAM,DAGAN,+    (REHO+SLAC+TELA)
LAYSSAC  72 NC 10A 407          J.LAYSSAC,F.M.RENARD                     (MONP)
SMADJA   72 PHIL.CONF.PROC349 +BINGHAM,FRETTER,BALLAM,CHADWICK+(LBL+SLAC)

CERADINI 73 PL 43 B 341         +CONVERSI,EKSTRAND,GRILLI,+(ROMA+FRAS+PADO)IGJP
CHUNG    73 PL 47 B 526         +PROTOPOPESCU,LYNCH,FLATTE+    (BNL+LBL+USC)
DAVIER   73 NP B 58 31          +DERADO,FRIES,LIU,MOZLEY,ODIAN,PARK,+(SLAC)
EISENBER 73 PL 43 B 149         EISENBERG,KARSHON,MIKENBERG,PITLUCK,+(REHO)
HYAMS    73 NP B 64 134         +JONES,WEILHAMMER,BLUM,DIETL,+  (CERN+MPIM)
KREUZER  73 PR D 8 1431         H.J.KREUZER,A.N.KAMAL    (UNIV. OF ALBERTA)
OCHS     73 THESIS              THESIS                                   (MPIM)
MONTANET 73 ERICE SCHOOL 518    L.MONTANET                               (CERN)
PARK     73 NP B 58 45          J.C.H.PARK                               (MPIM)  JP

BALLAM   74 NP B76 375          +CHADWICK,BINGHAM,FRETTER+  (SLAC+LBL+MPIM)
BERNABEI 74 LNC 11 261          +D.ANGELO,SPILLANTINI,VALENTE   (ROMA+FRAS)
CHALOUPK 74 PL 51 B 407         CHALOUPKA,FERRANDO,LOSTY,MONTANET     (CERN)
CONVERSI 74 PL 52B 493          +PAOLUZI,CERADINI,GRILLI+        (ROMA+FRAS)
ESTABROO 74 NP B79 301          P.ESTABROOKS,A.D.MARTIN                  (DURH)
FERBEL   74 PR D9 824           T.FERBEL AND P.SLATTERY                  (ROCH)
GRAYER   74 NP B 75 189         G.GRAYER,HYAMS,BLUM,DIETL,+      (CERN+MPIM)
HIRSHFEL 74 NP B74 211          A.C.HIRSHFELD,G.KRAMER                   (HAMB)
SCHACHT  74 NP B81 205          +DERADO,FRIES,PARK,YOUNT                 (MPIM)

ALEXANDE 75 PL 57B 487          ALEXANDER,BENARY,GANDSMAN,LISSAUER+  (TELA)
ALLES    75 NC 30A 136          ALLES-BORELLI,BERNARDINI+  (CERN+BGNA+FRAS)
CHUNG    75 PR D 11 2436        +PROTOPOPESCU,LYNCH,FLATTE+   (BNL+LBL+USC)
ESTABROO 75 NP B95 322          P.ESTABROOKS,A.D.MARTIN .                (DURH)
FROGGATT 75 NP B91 454          C.D.FROGGATT,J.L.PETERSEN        (GLAS+NORD)
HYAMS    75 NP B100 205         +JONES,WEILHAMMER,BLUM,DIETL+    (CERN+MPIM)
LANG     75 PL 58B 450          C.B.LANG,I.S.STEFANESCU                  (KARL)
LANGACKE 75 PR D 13 697         P.LANGACKER,G.SEGRE                      (PENN)
LEE      75 STANFORD CONF.213 WONYONG LEE                              (COLU)
ROOS     75 NP B 97 165         M.ROOS                                   (HELS)

BASSOMPI 76 PL 65 B 397         BASSOMPIERRE,BINDER,+       (MULH+STRB+TORI)
COMMON   76 NP B 103 109        A.K.COMMON                               (KENT)  JP
JOHNSON  76 PL 63 B 95          +MARTIN,PENNINGTON                  (DURH+CERN)  JP

BUDNEV   77 PL 70 B 365         N.M.BUDNEV,V.M.BUDNEV,V.V.SEREBRYAKOV(NOVO)
COSTA 1  77 PL 67 B 213         COSTA DE BEAUREGARD,PHAM,PIRE,TRUONG (EPOL)
COSTA 2  77 PL 71 B 345         COSTA DE BEAUREGARD,PIRE,T.N.TRUONG  (EPOL)
FROGGATT 77 NP B 129 89         C.D.FROGGATT,J.L.PETERSEN        (GLAS+BOHR)
GESSAROL 77 NP B 126 382        GESSAROLI+   (BGNA+FIRZ+GENO+MILA+OXF+PAVI)

GENSINI  78 PR D 17 1368        PAOLO M GENSINI                          (SLAC)
MARTIN   78 ANP  114 1          A.D.MARTIN,M.R.PENNINGTON                (CERN)

ATIYA    79 PRL 43 1691         +HOLMES,KNAPP,LEE,SETO,+    (COLU+ILL+FNAL)
BACCI    79 PL B 86 234         +DE ZORZI,PENSO,STELLA,+   (ROMA+BGNA+FRAS)
BECKER   79 NP B 151  46        +BLANAR,BLUM,CERRADA+ (MPIM+CERN+ZEEM+CRAC)
CORDEN   79 NP B 157 250        +DOWELL,GARVEY,JOBES,+(BIRM+RHEL+TELA+LOWC)   JP
CORDIER  79 PL 81 B 389         +DELCOURT,ESCHSTRUTH,FULDA+              (LALO)
COSME    79 NP B 152 215        +DUDELZAK,GRELAUD,JEAN-MARIE,JULLIAN+ (IPN)
LANG     79 PR D 19 956         C.B.LANG,A.MAS-PARAREDA                  (GRAZ)
RICHARD  79 FERMILAB SYMP.469 F.RICHARD                                (LALO)

ASTON 1  80 PL 92 B 215         (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+PARIS+)
ASTON 2  80 NP B 174 269        (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+PARIS+)
BARBER   80 ZPHY C 4 169        +DAINTON,BRODBECK,BROOKES,+(DARE+LANC+SHEF)
BACCI    80 PL 95 B 139         +DE ZORZI,PENSO,BALDINI-CELIO,+ (ROMA+FRAS)
BIZOT    80 MADISON CONF. 546 +BISELLO,BUON,CORDIER,DELCOURT,+(LALO+USTL)
HEYN     80 ZPHY C 7 169        M.F.HEYN,C.B.LANG                        (GRAZ)
KILLIAN  80 PR D 21 3005        +TREADWELL,AHRENS,BERKELMAN,CASSEL,+ (CORN)
O-DONNEL 80 PR D 22 711         P.J.O-DONNELL                         (TORONTO)
PENSO    80 PL 95 B 143         G.PENSO,TRAN N.TRUONG               (ROMA+EPOL)

ASTON 1  81 NP B 189 15         (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+PARIS+)
ASTON 2  81 PL 104 B 231        (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+PARIS+)
DELCOURT 81 PL 99 B 257         +BISELLO,BIZOT,BUON,CORDIER,MANE      (ORSAY)
DELCOUR2 81 BONN CONF. 205      B.DELCOURT                              (ORSAY)
    ALSO 82 PL 109B 129         CORDIER,+                               (ORSAY)
DIBIANCA 81 PR D 23 595         +FICKINGER,MALKO,DADO,ENGELER,+ (CASE+CARN)

ATKINSON 82 PL 108 B 55         + (BONN+CERN+GLAS+LANC+MCHS+CURI+RHEL+SHEF)
BUON     82 PL 118 B 221        +BISELLO,BIZOT,CORDIER,DELCOURT+(LALO+MONP)
CORDIER  82 PL 109 B 129        +BISELLO,BIZOT,BUON,DELCOURT             (LALO)
DELCOURT 82 PL 113 B 93         +BISELLO,BIZOT,BUON,CORDIER,MANE       (LALO)
CLELAND  82 NP B 208 228        +DELFOSSE,DORSAZ,GLOOR(DURH+GEVA+LAUS+PITT)
PENSO    82 NC 68 A 213         +PENSO,TRAN N.TRUONG                (ROMA+EPOL)
SHAMBROO 82 PR D 26 1           +WILSON,ANDERSON,FRANCIS+(HARV+EFI+ILL+OXF)

AUGUSTIN 83  LAL/83-21          +AYACH,BISELLO,BALDINI+     (LALO+PADO+FRAS)
ATKINSO1 83 NP B 229 269        ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
ATKINSO2 83 PL 127 B 132        ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)

ABE      84 PRL 53 751          SLAC HYBRID FACILITY PHOTON COLLABORATION
ATKINSO1 84 NP B 231 1          ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
ATKINSO2 84 NP B 231 15         ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)

ATKINSO2 85 ZPHY C 26 499       ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
BARKOV   85 NP B 256 365        +CHILINGAROV,EIDELMAN,KHAZIN,LELCHUK+(NOVO)
```

$\omega_3(1670)$
was $\omega(1670)$

$I^G(J^{PC}) = 0^-(3^{--})$

$\omega_3(1670)$ MASS (MeV)

```
M          1636.      20.                 ARMENISE  68 DBC      5.1 PI+N,P(3PI)0
M   Q      1695.0     20.0                BARNES    69 HBC    0 4.6 K-P,OMEG2PI
M          1670.      20.                 KENYON    69 DBC      8.  PI+N,P(3PI)0
M     200  1679.      17.                 MATTHEWS  71 DBC      7.0 PI+N,P(3PI)0
M     500  1678.      14.                 DIAZ      74 DBC      6.  PI+N,P(3PI)0
M   Q 200  1660.      13.                 DIAZ      74 DBC      6.  PI+N,P(5PI)0
M  P  600  1669.      11.                 WAGNER    75 HBC      7. PI+P,DEL++3PI
M   E 110(1700.0)  APPROX.                CERRADA   77 HBC      4.2 K-P,LAM 3PI
M  P E 430 1673.0     12.0                BALTAY    78 HBC      15 PI+P,DEL 3PI
M          1650.0    12.0                 CORDEN    78 OMEG     8-12 PI- P,N 3PI
M      60  1685.0     20.0                BAUBILLIE 79 HBC      8.2K- P,BACKWARD
M          . . . . . . . . .
M   AVG    1667.9      4.6    AVERAGE

M   E  PHASE ROTATION SEEN FOR JP 3- (RHO PI) WAVE.
M  P   FROM A FIT TO I=0, JP=3- RHO PI PARTIAL WAVE
M   Q  FROM (OMEGA PI PI) MODE
```

$\omega_3(1670)$ WIDTH (MeV)

```
W            112.       60.               ARMENISE  68 DBC      5.1 PI+N,P(3PI)0
W   Q        (90.)     (20.)              BARNES    69 HBC    0 4.6 K-P,OMEG2PI
W            100.       40.               KENYON    69 DBC      8.  PI+N,P(3PI)0
W   S 200    155.       40.               MATTHEWS  71 DBC      7.0 PI+N,P(3PI)0
W     500    167.       40.               DIAZ      74 DBC      6.  PI+N,P(3PI)0
W   Q 200    122.       39.               DIAZ      74 DBC      6.  PI+N,P(5PI)0
W  P S 600   173.       28.               WAGNER    75 HBC      7. PI+P,DEL++3PI
W  P E 430   173.0      16.0              BALTAY    78 HBC      15 PI+P,DEL 3PI
W            253.0      39.0              CORDEN    78 OMEG     8-12 PI- P,N 3PI
W   S  60    160.0      80.0              BAUBILLIE 79 HBC      8.2K- P,BACKWARD
W            . . . . . . . . .
W   AVG      166.1      12.0    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)

W   E  PHASE ROTATION SEEN FOR JP 3- (RHO PI) WAVE.
W  P   FROM A FIT TO I=0, JP=3- RHO PI PARTIAL WAVE
W   S  WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N),SEE K*(892) NOTE
W   Q  FROM (OMEGA PI PI ) MODE
```

$\omega_3(1670)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\omega_3(1670) \rightarrow 3\pi$ (including $\rho\pi$)	135+ 135+ 135
P2	$\omega_3(1670) \rightarrow 5\pi$ (including $\omega\pi^+\pi^-$)	135+ 135+ 135+ 135
P3	$\omega_3(1670) \rightarrow \rho\pi$	769+ 135
P4	$\omega_3(1670) \rightarrow \omega\pi\pi$	783+ 135+ 135
P5	$\omega_3(1670) \rightarrow b_1(1235)\ \pi$	1234+ 135

$\omega_3(1670)$ BRANCHING RATIOS

$\omega_3(1670) \rightarrow (5\pi)/(3\pi)$

```
                                                                  (P2)/(P1)
R1     200     0.97      0.28              DIAZ       74 DBC     6.  PI+N,P(5PI)0
```

$\omega_3(1670) \rightarrow (\rho\,\pi)/(3\pi)$

```
                                                                  (P3)/(P1)
R2     200    (0.70) OR MORE               MATTHEWS   71 DBC     7.0 PI+N,P(3PI)0
```

$\omega_3(1670) \rightarrow (\omega\,\pi\,\pi)/(\rho\,\pi)$

```
                                                                  (P4)/(P3)
R3     100     0.71      0.27              DIAZ       74 DBC     6.  PI+N,P(5PI)0
```

$\omega_3(1670) \rightarrow (b_1(1235)\ \pi)/(\rho\,\pi)$

```
                                                                  (P5)/(P3)
R4           POSSIBLY SEEN                 DIAZ       74 DBC     6.  PI+N,P(5PI)0
```

$\omega_3(1670) \rightarrow (b_1(1235)\ \pi)/(\omega\,\pi\,\pi)$

```
                                                                  (P5)/(P4)
R5             1.0       0.0       0.25  BAUBILLIE 79 HBC     8.2K- P,BACKWARD
```

REFERENCES FOR $\omega_3(1670)$

```
ARMENISE 68 PL 26B 336        +GHIDINI,FORINO+ (BARI+BGNA  +FIRZ  +ORSAY)

BARNES   69 PRL 23 142        +CHUNG,EISNER,FLAMINIO,+               (BNL)
KENYON   69 PRL 23 146        +KINSON,SCARR,+               (BNL+UCND+ORNL)

ARMENISE 70 LNC 4 199         +GHIDINI,FORINO,CARTACCI,+ (BARI+BGNA+FIRZ)

MATTHEWS 71 PR D 3 2561       +PRENTICE,YOON,CARROLL,+         (TNTO+WISC)
MATTHEW1 71 LNC 1 361         +PRENTICE,YOON,CARROLL,+         (TNTO+WISC)

DIAZ     74 PRL 32 260        +DIBIANCA,FICKINGER,ANDERSON,+  (CASE+CARN)

WAGNER   75 PL 58B 201        +TABAK,CHEW                            (LBL)JP

CERRADA  77 NP B 126 241      +BLOCKZIJL,HEINEN,+    (AMST+CERN+NIJM+OXF)JP

BALTAY   78 PRL 40 87         +CAUTIS,KALELKAR                      (COLU)JP
CORDEN   78 NP B 138 235      +CORBETT,ALEXANDER,+  (BIRM+RHEL+TELA+LOWC)

BAUBILLI 79 PL B 89 131       BAUBILLIER+        (BIRM+CERN+GLAS+MSU+LPNP)
```

$\pi_2(1680)$ was $A_3(1680)$

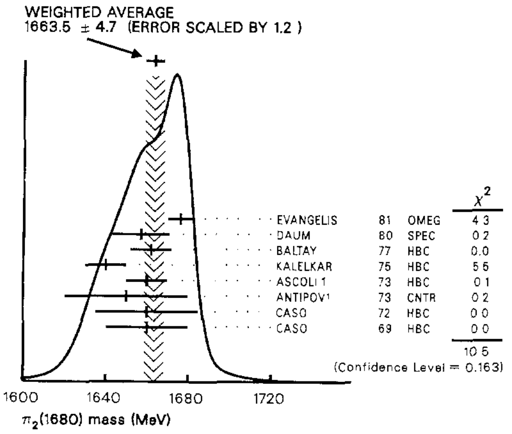
$I^G(J^{PC}) = 1^-(2^{-+})$

OUR LATEST MINIREVIEW ON THIS PARTICLE CAN BE FOUND IN THE 1984 EDITION.

$\pi_2(1680)$ MASS (MeV)

```
M            1660.0     20.0                CASO      69 HBC   -  11 PI-P, PI-F2
M        260 1660.      25.                 CASO      72 HBC   +  11.7 PI+ P
M    P       1650.      30.                 ANTIPOV1  73 CNTR  -  25.,40. PI- P
M    P       1660.      10.                 ASCOLI 1  73 HBC   -  5-25 PI- P,P PI2
M  P E      (1600.)    (10.)                THOMPSON  74 HBC   +  13. PI+ P,P PI2+
M        575 1640.      10.                 KALELKAR  75 HBC   +  15 PI+P,P PI+F2
M    P    2M 1662.0     10.0                BALTAY    77 HBC   0  15 PI+ P,P 3PI
M    R      (1650.0)                        PERNEGR   78 CNTR  -  9+13+15,PI- NUC.
M  P D       1657.0     14.0                DAUM      80 SPEC  -  63-94 PI- P, 3PI
M   L       (1710.0)   (20.0)               DAUM      81 SPEC  -  63,94 PI- P
M  P         1676.       6.                 EVANGELIS 81 OMEG  -  12 PI-P,3PI P
M            . . . . . . . . . .
M   AVG      1663.5      4.7    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
                         (SEE IDEOGRAM BELOW)

M    D      CLEAR PHASE ROTATION SEEN IN  (2-S),(2-P),(2-D) WAVES.
M    D      WE QUOTE CENTRAL VALUE AND SPREAD OF SINGLE-RESONANCE
M    D      FITS TO THREE CHANNELS.
M    E   EVIDENCE FOR A ROTATION OF THE PHASE CLAIMED.
M    L   FROM A TWO RESONANCE FIT TO FOUR 2-0+ WAVES. THIS SHOULD NOT BE
M    L   AVERAGED WITH ALL THE SINGLE RESONANCE FITS.
M  P     FROM A FIT TO JP=2-S (F2(1270) PI) PARTIAL WAVE
M    R   CLEAR PHASE ROTATION SEEN IN (2-S) AND (2-P) WAVES
```



$\pi_2(1680)$ WIDTH (MeV)

```
W        297  240.0      50.0               ARMENISE  69 DBC  +   5.1 PI+D,3PI++-
W            (130.)                         CASO      69 HBC  -   11 PI- P
W            (150.0)                        CASO      69 HBC  - 11.0 PI-P,PI- F2
W  P          200. TO 400.                  CASO      72 HBC  + 11.7 PI+ P
W        260  190.      100.                CASO      72 HBC  + 11.7 PI+ P
W  P          300.       50.                ANTIPOV1  73 CNTR - 25.,40. PI- P
W  P          270.       60.                ASCOLI 1  73 HBC  - 5-25 PI- P,P PI2
W  P E       (310.)     (40.)               THOMPSON  74 HBC  + 13. PI+ P,P PI2+
W        575  240.       30.                KALELKAR  75 HBC  + 15 PI+P,P PI+F2
W  P    2000  285.0      60.0               BALTAY    77 HBC  0 15 PI+ P,P 3PI
W    R       (400.0)                        PERNEGR   78 CNTR - 9+13+15,PI- NUC.
W  P D        219.0      20.0               DAUM      80 SPEC - 63-94 PI- P, 3PI
W    L        312.0      50.0               DAUM      81 SPEC - 63,94 PI- P
W  P          260.       20.                EVANGELIS 81 OMEG - 12 PI-P,3PI P
W             . . . . . . . . . .
W   AVG       248.3      11.2     AVERAGE

W    D        SEE NOTE D UNDER MASS.
W    E   EVIDENCE FOR A ROTATION OF THE PHASE CLAIMED.
W    L   FROM A TWO RESONANCE FIT TO FOUR 2-0+ WAVES. THIS SHOULD NOT BE
W    L   AVERAGED WITH ALL THE SINGLE RESONANCE FITS.
W  P     FROM A FIT TO JP=2- F2(1270) PI PARTIAL WAVE
W    R   CLEAR PHASE ROTATION SEEN IN (2-S) AND (2-P) WAVES
```

$\pi_2(1680)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\pi_2(1680) \rightarrow 3\pi^0$	135+ 135+ 135
P2	$\pi_2(1680) \rightarrow \rho\,\pi$	135+ 769
P3	$\pi_2(1680) \rightarrow \eta\,\pi$	135+ 549
P4	$\pi_2(1680) \rightarrow 5\pi$	140+ 140+ 140+ 140+
P5	$\pi_2(1680) \rightarrow K\overline{K}^*(892)$	498+ 892
P6	$\pi_2(1680) \rightarrow K\overline{K}\pi$	498+ 498+ 135
P7	$\pi_2(1680) \rightarrow K\overline{K}$	498+ 498
P8	$\pi_2(1680) \rightarrow f_2(1270)\ \pi$	1274+ 135
P9	$\pi_2(1680) \rightarrow \omega\,\pi\,\pi$	783+ 135+ 135
P10	$\pi_2(1680) \rightarrow 3\pi$	140+ 140+ 140
P11	$\pi_2(1680) \rightarrow f_0(1300)\ \pi$	1300+ 140

$\pi_2(1680)$ BRANCHING RATIOS

$\pi_2(1680) \rightarrow (\pi^\pm\rho^0)/(\pi^\pm\pi^+\pi^-)$

```
                                                                   (P2C)/(P1C)
R2          (0.3)  OR LESS              BARTSCH   68 HBC  +   8. PI+ P,3PI P
R2          (0.4)  OR LESS              FERBEL    68 RVUE +-
R2    L      0.29     0.05              DAUM      81 SPEC    63,94 PI- P
R2    L  FROM A TWO RESONANCE FIT TO FOUR 2-0+ WAVES.
```

$\pi_2(1680) \rightarrow (\pi^\pm f_2(1270))/(\pi^\pm\pi^+\pi^-)$

```
                                                                    (P8)/(P1C)
R3                    (WITH F2(1270) INTO PI+ PI-)
R3          (0.59)                      BARTSCH   68 HBC  +   8. PI+ P,3PI P
R3           0.35     0.20              BALTAY    68 HBC  +  7-8.5 PI+P
R3           0.76     0.24      0.34    ARMENISE  69 DBC  +   5.1 PI+D,3PI+--
R3    L      0.61     0.04              DAUM      81 SPEC    63,94 PI- P
R3    A  FOR JP=1+
R3    B  FOR JP=0-
R3    L  FROM A TWO RESONANCE FIT TO FOUR 2-0+ WAVES.
R3          . . . . . . . . . .
R3   AVG     0.603    0.050   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$\pi_2(1680) \rightarrow (\pi^\pm\eta)/(\pi^\pm\pi^+\pi^-)$

```
                                                                    (P3)/(P1C)
R5                    (ALL ETA DECAYS)
R5          (0.09) OR LESS              BALTAY    68 HBC  +  7-8.5 PI+P
R5          (0.10) OR LESS              CRENNELL  70 HBC   -  6. PI- P,F2 PI
```

$\pi_2(1680) \rightarrow (\pi^\pm 2\pi^+ 2\pi^-)/(\pi^\pm\pi^+\pi^-)$

```
                                                                   (P4C)/(P1C)
R6          (0.1)  OR LESS              BALTAY    68 HBC  +  7,8.5 PI+ P
R6          (0.10) OR LESS              CRENNELL  70 HBC   -  6. P+- P,F2 P+
```

$\pi_2(1680) \rightarrow (\pi^\pm f_0(1300))/(\pi^\pm\pi^+\pi^-)$

```
                                                                   (P11)/(P1C)
R11                   (WITH F0(1300) INTO PI+ PI-)
R11   L      0.10     0.05              DAUM      81 SPEC    63,94 PI- P
R11   L  FROM A TWO RESONANCE FIT TO FOUR 2-0+ WAVES.
```

$\pi_2(1680) \rightarrow (K\overline{K}^*(892))/(\pi^\pm f_2(1270))$

```
                                                                     (P5)/(P8)
R13M         0.075    0.025             ARMSTRONG 82 OMEG -  16 PI-P,K+K-PI-P
R13M     FROM A PARTIAL WAVE ANALYSIS OF K+ K- PI- SYSTEM
```

D-wave/S-wave RATIO FOR $\pi_2(1680) \rightarrow f_2(1270)\ \pi$

```
R14   L      0.22     0.10              DAUM      81 SPEC    63,94 PI- P
R14   L  FROM A TWO RESONANCE FIT TO FOUR 2-0+ WAVES.
```

REFERENCES FOR $\pi_2(1680)$

```
FORINO   65 PL 19 68          +GESSAROLI+      (BGNA+BARI+FIRZ+ORSA+SACL)

FOCACCI  66 PRL  17  890      CERN MISSING MASS SPECTROMETER GROUP (CERN)
LEVRAT   66 PL  22  714       CERN MISSING MASS SPECTROMETER GROUP (CERN)
LUBATTI  66 THESIS BERKELEY   H.J.LUBATTI                           (LRL)1-2-
VETLITSK 66 PL  21  579       VETLITSKY,GUSZAVIN,KLIGER,ZOLGANOV+  (ITEP)

DANYSZ   67 NC 51 A 801       DANYSZ+FRENCH+SIMAK                  (CERN)
DUBAL    67 NP B3 435         CERN MISSING MASS SPECTROMETER GROUP (CERN)
  ALSO   68 THESIS 1456       L.DUBAL                            (GENEVE)

BALTAY   68 PRL 20 887        +KUNG+YEH+FERBEL+     (COLU+ROCH+RUTG+YALE)I=1
BARTSCH  68 NP B 7 345        +KEPPEL,KRAUS,+             (AACH+BERL+CERN) JP
CASO     68 NC 54 A 983       +CONTE+CORDS+DIAZ+  (GENOVA+HAMB+MILA+SACL)
FERBEL   68 PHILA.CONF.335    T.FERBEL                        (ROCHESTER)
IOFFREDO 68 PRL 21 1212       +BRANDENBURG,BRENNER,EISENSTEIN+  (HARVARD)
LAMSA    68 PR 166 1395       +CASON+BISWAS+DERADO+GROVES+    (NOTREDAME)
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```
ARMENISE 69 LNC 2 501            +GHIDINI,FORINO,CARTACCI+  (BARI+BGNA+FIRZ)
BARNES   69 PRL 23 142           +CHUNG,EISNER,FLAMINIO,+              (BNL)
CASO     69 LNC 2 437            +CONTE,TOMASINI,CANTORE+   (GENO+MILA+SACL)

BRANDENB 70 NP B16 369           +BRENNER,IOFFREDO,JOHNSON,KIM+    (HARVARD)
CRENNELL 70 PRL 24 781           +KARSHON,LAI,SCARR,SIMS               (BNL)
CHIEN    70 PHILAD.CONF.P.275 C.Y.CHIEN, REVIEW            (JOHNS HOPKINS)
MIYASHIT 70 PR D 1 771           MIYASHITA,VON KROGH,KOPELMAN,LIBBY   (COLO)

BEKETOV  71 SJNP 4 765           +SOMBKOWSKY,KONOWALOV,KRUTSCHININ,+  (ITEP)  JP
PALER    71 PRL 26 1675          +BADEWITZ,BARTON,MILLER,PALFREY,TEBES(PURD)

ALEXANDE 72 NP B 45 29           ALEXANDER,BAR-NIR,BENARY,DAGAN,+     (TELA)
ARMENISE 72 LNC 4 201            +FORINO,CARTACCI,+         (BARI+BGNA+FIRZ)
CASO     72 NP B 36 349          +MADDOCK,BASSLER+(DURH+GENO+DESY+MILA+SACL)
HARRISON 72 PRL 28 775           +HEYDA,JOHNSON,KIM,LAW,MUELLER,+     (HARV)
SALZBERG 72 NP B 41 397          +HARRISON,HEYDA,JOHNSON,KIM,LAW,+    (HARV)

ANTIPOV1 73 NP B 63 153          +ASCOLI,BUSNELLO,FOCACCI,+      (CERN+SERP)  JP
ANTIPOV2 73 NP B 63 141          +ASCOLI,BUSNELLO,FOCACCI,+      (CERN+SERP)  JP
ASCOLI 1 73 PR D 7 669           INTERNAT. COLLABORATION              (ILL+)  JP
ASCOLI 2 73 PR D 8 3894          +JONES,WEINSTEIN,WYLD                 (ILL)  JP

ASCOLI   74 PR D9 1963           +CUTLER,JONES,KRUSE,ROBERTS,WEINSTEIN+(ILL)
LICHTMAN 74 NP B81 31            +BISWAS,CASON,KENNEY,MCGAHAN,+       (NDAM)
OTTER    74 NP B80 1             +RUDOLPH+         (AACH+BERL+BONN+CERN+HEID)  JP
TABAK    74 BOSTON CONF.         +RONAT,ROSENFELD,LASINSKI+        (LBL+SLAC)  JP
THOMPSON 74 PRL 32 331           +BADEWITZ,GAIDOS,MCILWAIN,PALER,+    (PURD)  JP
    ALSO 74 NP B69 381           THOMPSON,BADEWITZ,GAIDOS,MCILWAIN+   (PURD)  JP

BEKETOV  75 SJNP 20 379          +ZOMBKOVSKII,KAIDALON,KONOVALOV+     (ITEP)
EMMS     75 PL 60 B 109          +JONES,KINSON,BELL,DALE+   (BIRM+DURH+RHEL)  JP
HORNE    75 PR D11 996           +S.HAGOPIAN,V.HAGOPIAN,BENSINGER+(FSU+BRAN)
KALELKAR 75 THESIS(NEVIS 207) M.S.KALELKAR                            (COLU)
WAGNER   75 PL 58B 201           +TABAK,CHEW                           (LBL)  JP

BALTAY   77 PRL 39 591           +CAUTIS,KALELKAR                 (COLUMBIA)  JP
CAUTIS   77  THESIS NEVIS 221 C.V.CAUTIS                          (COLUMBIA)  JP
CERRADA  77 NP B 126 241         +BLOCKZIJL,HEINEN,+    (AMST+CERN+NIJM+OXF)  JP

BALTAY   78 PR D 17 52           +CAUTIS,COHEN,CSORNA,KALELKAR+  (COLU+BING)
CORDEN   78 NP B 136 77          DOWELL,GARVEY,JOBES+  (BIRM+RHEL+TELA+LOWC)  JP
PERNEGR  78 NP B 134 436         +AEBISCHER+            (ETH+CERN+LOIC+MILA)
ROBERTS  78 PR D 18 59           +KRUSE,EDELSTEIN+      (ILL+CARN+NWES+ROCH)

DAUM     80 PL 89 B 285          +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)  JP

DAUM     81 NP B 182 269         +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
EVANGELI 81 NP B 178 197         EVANGELISTA+(BARI+BONN+CERN+DARE+LIVP+MILA)
    ALSO 81 NP B 186 594         (ERRATUM)

ARMSTRON 82 NP B 202 1           +BACCAR(AACH+BARI+BONN+CERN+GLAS+LIVP+MILA)
BELLINI  82 NP B 199 1           + (CERN+MILA+JINR+BGNA+HELS+PAVI+WARS+VIEN)

CHEN     83 PR D 28 2304         +FENKER+(ARIZ+FNAL+FLOR+NDAM+TUFT+VAND+VPI)
LEEDOM   83 PR D 27 1426         +DE BONTE,GAIDOS,KEY,WONG+      (PURD+TNTO)
```

$\phi(1680)$

$I^G(J^{PC}) = 0^-(1^{--})$

```
                   FORMERLY CALLED PHIPRIME.
   FIRST IDENTIFIED USING DALITZ PLOT ANALYSIS OF E+E- INTO K K*(892)
   (BIZOT 80, DELCOURT 81) WE LIST BELOW CANDIDATES FOR THE OMEGA AND
   PHI RADIAL EXCITATIONS UNTIL THEY ARE WELL ESTABLISHED.
```

$\phi(1680)$ MASS (MeV)

```
M  K KBAR MODE
M    B      1690.      10.              ASTON     81 OMEG    25-70 GAM P,K+K-
M  C        1680.      10.              BUON      82 DM1     E+E-,HADRONS
M  D        1677.      12.              MANE      82 DM1     E+E-,KS K PI
M           1760.      20.              ATKINSO1  85 OMEG    20-70 GAM PKKBAR   |
M           . . . . . . . . . .
M   AVERAGE MEANINGLESS (SCALE FACTOR = 2.2)

M  PIONS MODE
M         (1652.0)    (17.0)            COSME     79 OSPK  0 E+ E-,3PI
M       21 1679.       34.              ESPOSITO  80 FRAM    E+E-,3 PI
M  D        1657.      13.              CORDIER   81 DM1     E+E-,OMEGA 2PI
M   A     (1670.)     (20.)             ATKINSO2  83 OMEG    20-70 GAM P,3 PI
M           . . . . . . . . . . .
M   AVERAGE MEANINGLESS

M    B  JP NOT UNAMBIGUOUSLY 1-
M  C    FROM GLOBAL FIT OF RHO,OMEGA,PHI AND THEIR RADIAL EXCITATIONS TO
M  C    CHANNELS OMEGA PI+PI-,K+K-,KS KL,KS K+-PI-+. ASSUME MASS 1570 MEV
M  C    AND WIDTH 510 MEV FOR RHO RAD. EXIT.,MASS 1570 AND WIDTH 500 MEV
M  C    FOR OMEGA RADIAL EXCITATION.
M  D    FIT TO ONE CHANNEL ONLY, NEGLECTING INTERFERENCE WITH OMEGA,
M  D    RHO(1600)
M   A   MAY BE PHI OR OMEGA RADIAL EXCITATION. INTERPRETATION COMPLICATED.
```

$\phi(1680)$ WIDTH (MeV)

```
W  K KBAR MODE
W    B       100.      40.              ASTON     81 OMEG    25-70 GAM P,K+K-
W  C         185.      22.              BUON      82 DM1     E+E-,HADRONS
W  D         102.      36.              MANE      82 DM1     E+E-,KS K PI
W             80.      40.              ATKINSO1  85 OMEG    20-70 GAM PKKBAR   |
W           . . . . . . . . . . .
W   AVERAGE MEANINGLESS (SCALE FACTOR = 1.7)

W  PIONS MODE
W          (42.0)    (17.0)             COSME     79 OSPK  0 E+ E-,3PI
W       21  99.       49.               ESPOSITO  80 FRAM    E+E-,3 PI
W  D        136.      46.               CORDIER   81 DM1     E+E-,OMEGA 2PI
W   A      (160.)    (20.)              ATKINSO2  83 OMEG    20-70 GAM P,3 PI
W           . . . . . . . . . . .
W   AVERAGE MEANINGLESS

W    B  JP NOT UNAMBIGUOUSLY 1-
W  C    SEE NOTE C UNDER MASS.
W  D    FIT TO ONE CHANNEL ONLY, NEGLECTING INTERFERENCE WITH OMEGA,
W  D    RHO(1600)
W   A   MAY BE PHI OR OMEGA RADIAL EXCITATION. INTERPRETATION COMPLICATED.
```

$\phi(1680)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\phi(1680) \to \omega\pi\pi$	783+ 140+ 140
P2	$\phi(1680) \to 3\pi$	140+ 140+ 135
P3	$\phi(1680) \to K\overline{K}$	494+ 494
P4	$\phi(1680) \to K^*(892)\ \overline{K}\ +\ \text{C.C.}$	892+ 494
P5	$\phi(1680) \to K^0_S K\pi$	498+ 494+ 140
P6	$\phi(1680) \to e^+e^-$	.511+.511

$\phi(1680)$ BRANCHING RATIOS

$\phi(1680) \to (\omega\pi^+\pi^-)/(K^*(892)\ \overline{K}\ +\ \text{C.C.})$ (P1)/(P4)

```
R1          (0.10) OR LESS            BUON      82 DM1     E+E-
```

$\phi(1680) \to (K\overline{K})/(K^*(892)\ \overline{K}\ +\ \text{C.C.})$ (P3)/(P4)

```
R2            0.07       0.01         BUON      82 DM1     E+E-
```

$\phi(1680) \to (K^*(892)\ \overline{K})/(K^0_S K^\pm\pi^\mp)$ (P4)/(P5)

```
R3        DOMINANT                    MANE      82 DM1     E+E-,KS K+- PI-+
```

$\phi(1680) \to (3\pi)$/total (P2)

```
R4        SEEN                        ATKINSO2  83 OMEG   20-70 GAM P,3 PI   |
```

$\phi(1680)$ $\Gamma(\mathrm{I})^*\Gamma(e^+e^-)/\Gamma(\text{total})$ (keV)

```
      THIS COMBINATION OF A PARTIAL WIDTH WITH THE PARTIAL WIDTH INTO
      E+E- AND WITH THE TOTAL WIDTH IS OBTAINED FROM THE INTEGRATED
      CROSS SECTION INTO CHANNEL(I) IN E+E- ANNIHILATION.
      WE ONLY LIST DATA NOT HAVING BEEN USED TO DETERMINE THE PARTIAL
      WIDTH G(I) OR THE BRANCHING RATIO G(I)/TOTAL.
```

$\Gamma(\omega\pi\pi)^*\Gamma(e^+e^-)/\Gamma(\text{total})$ (G1)*(G6)/TOTAL

```
G1  M       (0.017)APPROX             BIZOT     80 DM1   0 E+ E-
```

$\Gamma(K\overline{K})^*\Gamma(e^+e^-)/\Gamma(\text{total})$ (G3)*(G6)/TOTAL

```
G3  M       (0.053)  (0.035)          BIZOT     80 DM1   0 E+ E-
```

$\Gamma(K^*(892)\ \overline{K}\ +\ \text{C.C.})^*\Gamma(e^+e^-)/\Gamma(\text{total})$ (G4)*(G6)/TOTAL

```
G4  M       (0.413)  (0.033)          BIZOT     80 DM1   0 E+ E-

G   M   MODEL DEPENDENT
```

REFERENCES FOR $\phi(1680)$

```
COSME     79 NP B 152 215        +DUDELZAK,GRELAUD,JEAN-MARIE,JULLIAN+(IPNP)

ASTON     80 NP B 174 269        (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+IPNP +)
BIZOT     80 MADISON CONF. 546 +BISELLO,BUON,CORDIER,DELCOURT,+(LALO+USTL)
ESPOSITO  80 LNC 28 195          +MARINI,PATTERI,NIGRO+(FRAS+NAPL+PADO+ROMA)

ASTON     81 PL 104 B 231        (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+PARIS+)
CORDIER   81 PL 106 B 155        +BISELLO,BIZOT,BUON,DELCOURT,MANE   (ORSAY)
DELCOURT  81 PL 99 B 257         +BISELLO,BIZOT,BUON,CORDIER,MANE    (ORSAY)
MANE      81 PL 99 B 261         +BISELLO,BIZOT,BUON,CORDIER,DELCOURT(ORSAY)

BUON      82 PL 118 B 221        +BISELLO,BIZOT,CORDIER,DELCOURT+(LALO+MONP)
MANE      82 PL 112 B 178        +BISELLO,BIZOT,BUON,DELCOURT,FAYARD,+(LALO)

AUGUSTIN  83  LAL/83-21          +AYACH,BISELLO,BALDINI+    (LALO+PADO+FRAS)
ATKINSO1  83 NP B 229 269        ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
ATKINSO2  83 PL 127 B 132        ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)

ATKINSO1  84 NP B 231 1          ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
ATKINSO2  84 NP B 231 15         ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)

ATKINSO1  85 ZPHY C 27 233       ATKINSON+  (BONN+CERN+GLAS+LANC+MCHS+LPNP+)
```

$\rho_3(1690)$
was $g(1690)$

$I^G(J^{PC}) = 1^+(3^{--})$

$\rho_3(1690)$ MASS (MeV)

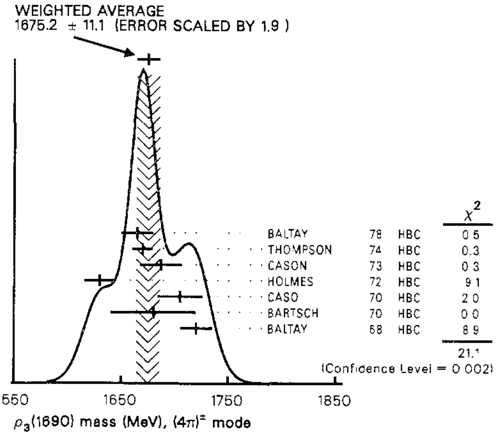
```
     WE ONLY INCLUDE HIGH STATISTICS EXPERIMENTS IN THE AVERAGE FOR THE
     2PI AND KKBAR MODES.

M     2PI MODE
M
M          1670.0     30.0          GOLDBERG  65 HBC    0 6 PI+D, 8 PI-P
M         (1683.)    (13.)          ARMENISE  68 DBC    0 5.1 PI+ D
M         (1737.0)   (23.0)         ARMENISE  70 DBC    0 9 PI+ N
M      122 1650.0     35.0          BARTSCH   70 HBC  +  8 PI+ P,2 PI
M          1687.      21.           STUNTEBEC 70 HDBC  0 8. PI-P,5.4 PI+D
M          1678.      12.           MATTHEWS  71 DBC   0  7. PI+ N
M  E   600 1690.       7.           ENGLER    74 DBC    0 6. PI+N,PI+PI-P
M  G       1693.       8.           GRAYER    74 ASPK   0 17 PI-P,PI+PI-N
M  GI     (1692.)    (12.)          ESTABROOK 75 RVUE    17 PI-P,PI+PI-N
M   I     (1722.)     (3.)          HYAMS     75 ASPK   0 17 PI-P,PI+PI-N
M  E   175 1678.0     12.0          ANTIPOV   77 CIBS  0 25 PI-P,P 3PI
M      476 1679.0     11.0          BALTAY    78 HBC   0 15 PI+P,PI+PI-
M    M    (1734.0)   (10.0)         CORDEN    79 OMEG    12-15PI-P, N 2PI
M          1677.      14.           EVANGELIS 81 OMEG  - 12 PI-P,2PI P
M
M  E    MASS ERRORS ENLARGED BY US TO WIDTH/SQRT(N),SEE K*(892) TYPED NOTE
M  G    USES SAME DATA AS HYAMS 75
M   I   FROM PHASE-SHIFT ANALYSIS
M   I   ERROR TAKES ACCOUNT OF SPREAD OF DIFFERENT PHASE-SHIFT SOLUTIONS
M    M  FROM A PHASE SHIFT SOLUTION CONTAINING A F2'(1525) WIDTH
M    M  TWO TIMES LARGER THAN THE K KBAR RESULT.
```

```
M      K KBAR + K KBAR PI MODE
M
M           1690.0      16.0               ADERHOLZ  69 HBC  +   8 PI+ P,KKBARPI
M           1692.        6.                BLUM      75 ASPK   018.4 PI-P,N K+K-
M   P S  6K 1698.       12.                MARTIN 1  78 SPEC    10 PI P,KS K- P
M           1699.0       5.0               ALPER     80 CNTR  0 62 PI-P,K+ K- N
M    L     (1694.0)     (8.0)              COSTA     80 OMEG    10. PI-P,K+ K- N
M
M    L   THEY CANNOT DISTINGUISH BETWEEN RHO3(1690) AND OMEGA3(1670).
M   P    FROM A FIT TO JP=3- PARTIAL WAVE.
M    S   SYSTEMATIC ERROR ON MASS SCALE SUBTRACTED
M
M           . . . . . . . . . . .
M   AVG     1690.9       2.6      AVERAGE

M      (4PI)+- MODE
M
M           1720.       15.                BALTAY    68 HBC  +   7, 8.5 PI+ P
M       144 1680.0      40.0               BARTSCH   70 HBC  +  8 PI+ P,4 PI
M    F  102(1689.0)    (20.0)              BARTSCH   70 HBC  +  8 PI+ P,2 RHO
M           1705.0      21.0               CASO      70 HBC   - 11.2PI-P,RHO 2PI
M           1630.       15.                HOLMES    72 HBC  +  10.-12. K+ P
M           1687.       20.                CASON     73 HBC  -  8.,18.5 PI- P
M    F     (1685.)     (14.)               CASON     73 HBC  -  8.,18.5 PI- P
M    F    66(1733.)     (9.)               KLIGER    74 HBC   - 4.5 PI-P,P 4PI
M           1670.       10.                THOMPSON  74 HBC  +  13 PI+ P
M       177 1665.0      15.0               BALTAY    78 HBC  +  15 PI+P,P 4PI
M    A     (1694.)      (6.)               EVANGELI  81 OMEG  - 12 PI-P,(4PI)-P
M    B     (1718.)     (10.)               EVANGELI  81 OMEG  - 12 PI-P,(4PI)-P
M    C     (1673.)      (9.)               EVANGELI  81 OMEG  - 12 PI-P,(4PI)-P
M           . . . . . . . . . . .
M   AVG     1675.2      11.1      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.9)
                                  (SEE IDEOGRAM BELOW)

M   A   FROM RHO- RHO0 MODE, NOT INDEPENDENT OF (B), (C)
M   B   FROM (A2)- PI0 MODE, NOT INDEPENDENT OF (A), (C)
M   C   FROM (A2)0 PI- MODE, NOT INDEPENDENT OF (A), (B)
M   F   FROM (RHO+- RHO0) MODE
```



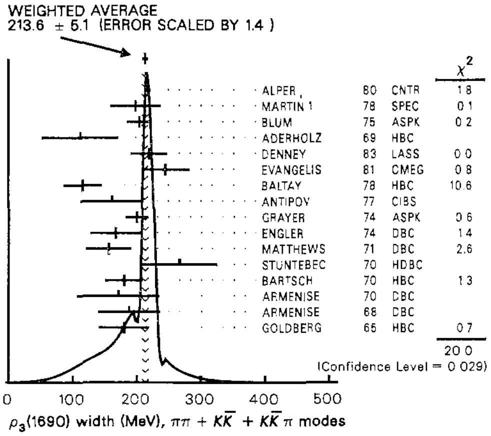
```
M      OMEGA PI  MODE
M
M           1654.       24.                BARNHAM   70 HBC  +  10 K+ P,OMEGA PI
M           1686.        9.                THOMPSON  74 HBC  +  13 PI+ P
M           1666.0      14.0               GESSAROLI 77 HBC     11 PI-P,OMEGA PI
M           1690.       15.                EVANGELIS 81 OMEG  - 12 PI-P,OME PI P
M           . . . . . . . . . . .
M   AVG     1680.1       6.6      AVERAGE
```

$\rho_3(1690)$ WIDTH (MeV)

```
        WE ONLY INCLUDE HIGH STATISTICS EXPERIMENTS IN THE AVERAGE FOR THE
        2PI AND KKBAR MODES.

W      2PI MODE
W
W           180.0       40.0               GOLDBERG  65 HBC    0 6 PI+D, 8 PI-P
W           188.        49.                ARMENISE  68 DBC    0 5.1 PI+ D
W           171.0       65.0               ARMENISE  70 DBC    0 9 PI+ D
W       122 180.0       30.0               BARTSCH   70 HBC  +  8 PI+ P,2 PI
W           267.        72.       46.      STUNTEBEC 70 HDBC  0 8. PI-P,5.4 PI+D
W           156.        36.                MATTHEWS  71 DBC   0  7. PI+ N
W       600 167.        40.                ENGLER    74 DBC    0 6. PI+N,PI+PI-P
W   G       200.        18.                GRAYER    74 ASPK   0 17 PI-P,PI+PI-N
W   GI     (240.)      (30.)               ESTABROOK 75 RVUE     17 PI-P,PI+PI-N
W    I     (267.)      (30.)               HYAMS     75 ASPK   0 17 PI-P,PI+PI-N
W   T   175 162.0       50.0               ANTIPOV   77 CIBS  0 25 PI-P,P 3PI
W       476 116.0       30.0               BALTAY    78 HBC   0 15 PI+P,PI+PI-
W          (206.0)    OR MORE  CL=.84      BECKER    79 ASPK  0 17 PI- P POLARIZ
W     M    (322.0)     (35.0)              CORDEN    79 OMEG    12-15PI-P, N 2PI
W           246.        37.                EVANGELIS 81 OMEG  - 12 PI-P,2PI P
W           220.        29.                DENNEY    83 LASS    10 PI+N /PI+ P     |
W
W    I   FROM PHASE-SHIFT ANALYSIS
W    I   ERROR TAKES ACCOUNT OF SPREAD OF DIFFERENT PHASE-SHIFT SOLUTIONS
W   G    USES SAME DATA AS HYAMS 75 AND BECKER 79
W     M  FROM A PHASE SHIFT SOLUTION CONTAINING A F2'(1525) WIDTH
W     M  TWO TIMES LARGER THAN THE K KBAR RESULT.
W   T    WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N),SEE K*(892) NOTE
```

```
W      K KBAR + K KBAR PI MODE
W
W           112.0       60.0               ADERHOLZ  69 HBC  +   8 PI+ P,KKBARPI
W           205.        20.                BLUM      75 ASPK   018.4 PI-P,N K+K-
W   P  6000 199.        40.                MARTIN 1  78 SPEC    10 PI P,KS K- P
W           219.0        4.0               ALPER     80 CNTR  0 62 PI-P,K+ K- N
W    L     (186.0)     (11.0)              COSTA     80 OMEG    10. PI-P,K+ K- N
W
W    L   THEY CANNOT DISTINGUISH BETWEEN RHO3(1690) AND OMEGA3(1670).
W   P        FROM A FIT TO JP=3- PARTIAL WAVE.
W
W           . . . . . . . . . . .
W   AVG     213.6        5.1      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
                                  (SEE IDEOGRAM BELOW)
```



```
W      (4PI)+- MODE
W
W           100.        35.                BALTAY    68 HBC  +   7, 8.5 PI+ P
W       144 135.0       30.0               BARTSCH   70 HBC  +  8 PI+ P,4 PI
W        90 (180.0)    (30.0)              BARTSCH   70 HBC  +  8 PI+ P,A2 PI
W    F  102 (160.0)    (30.0)              BARTSCH   70 HBC  +  8 PI+ P,2 RHO
W           130.        30.                HOLMES    72 HBC  +  10.-12. K+ P
W           169.        70.       48.      CASON     73 HBC  -  8.,18.5 PI- P
W    F     (125.)      (83.)     (35.)     CASON     73 HBC  -  8.,18.5 PI- P
W    F   66 (150.)                         KLIGER    74 HBC   - 4.5 PI-P,P 4PI
W           106.        25.                THOMPSON  74 HBC  +  13 PI+ P
W       177 105.0       30.0               BALTAY    78 HBC  +  15 PI+P,P 4PI
W    A     (123.)      (13.)               EVANGELI  81 OMEG  - 12 PI-P,(4PI)-P
W    B     (230.)      (28.)               EVANGELI  81 OMEG  - 12 PI-P,(4PI)-P
W    C     (184.)      (33.)               EVANGELI  81 OMEG  - 12 PI-P,(4PI)-P
W           . . . . . . . . . . .
W   AVG     117.8       12.9      AVERAGE

W   A   FROM RHO- RHO0 MODE, NOT INDEPENDENT OF (B), (C)
W   B   FROM (A2)- PI0 MODE, NOT INDEPENDENT OF (A), (C)
W   C   FROM (A2)0 PI- MODE, NOT INDEPENDENT OF (A), (B)
W   F   FROM (RHO+- RHO0) MODE

W      OMEGA PI  MODE
W
W           130.        73.       43.      BARNHAM   70 HBC  +  10 K+ P,OMEGA PI
W            89.        25.                THOMPSON  74 HBC  +  13 PI+ P
W           160.0       56.0               GESSAROLI 77 HBC     11 PI-P,OMEGA PI
W           190.        65.                EVANGELIS 81 OMEG  - 12 PI-P,OME PI P
W           . . . . . . . . . . .
W   AVG     112.9       20.6      AVERAGE
```

$\rho_3(1690)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\rho_3(1690) \to \pi\pi$	140+ 140
P2	$\rho_3(1690) \to 4\pi(\text{including } \pi^0\text{'S})$	140+ 140+ 140+ 140
P3	$\rho_3(1690) \to K\bar{K}\pi$	498+ 498+ 140
P4	$\rho_3(1690) \to K\bar{K}$	498+ 498
P5	$\rho_3(1690) \to \pi\pi\rho\,(\text{excluding } 2\rho \text{ and } a_2\pi)$	140+ 140+ 769
P6	$\rho_3(1690) \to a_2(1320)\ \pi$	1318+ 140
P7	$\rho_3(1690) \to \omega\pi$	140+ 783
P8	$\rho_3(1690) \to 2\rho$	769+ 769
P9	$\rho_3(1690) \to \phi\pi$	1020+ 140
P10	$\rho_3(1690) \to \eta\pi$	549+ 140
P11	$\rho_3(1690) \to \pi^{\pm}\pi^{+}\pi^{-}\pi^{0}$	140+ 140+ 140+ 140

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
          P 1         P 2         P 3         P 4
P 1 .2380+-.0129
P 2   -.7561  .7090+-.0189
P 3    .1510    -.7415  .0378+-.0122
P 4   -.1452    -.0478    -.0230  .0151+-.0031
```

$\rho_3(1690)$ BRANCHING RATIOS

$\rho_3(1690) \rightarrow (2\pi)$/total (P1)

```
R1   P        0.22     0.04              MATTHEWS  71 HDBC  0  7. PI+N,PI-P
R1   G       (0.245)  (0.006)            ESTABROOK 75 RVUE    17 PI-P,PI+PI-N
R1            0.259    0.018     0.019   BECKER    79 ASPK  0 17 PI- P POLARIZ
R1            0.23     0.02              CORDEN    79 OMEG    12-15PI-P, N 2PI
R1         . . . . . . . . . .
R1   AVG      0.243    0.013    AVERAGE
R1   FIT      0.238    0.013   FROM FIT

R1   G   FROM PHASE-SHIFT ANALYSIS OF HYAMS 75 DATA
R1   H   INCLUDED IN BECKER 79 ANALYSIS
R1   P   OPE MODEL USED IN THIS ESTIMATION
```

$\rho_3(1690) \rightarrow (2\pi)/(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$ (P1)/(P11)

```
R2           (0.12) OR LESS              BALLAM    71 HBC  -   16. PI- P
R2           (0.2)  OR LESS              HOLMES    72 HBC  +  10.-12. K+ P
R2            0.35     0.11              CASON     73 HBC  -  8.,18.5 PI- P
```

$\rho_3(1690) \rightarrow (2\pi)/(4\pi)$ (P1)/(P2)

```
R3            0.30     0.10              BALTAY    78 HBC   0 15 PI+P,P 4PI
R3         . . . . . . . . . .
R3   FIT      0.336    0.026   FROM FIT
```

$\rho_3(1690) \rightarrow (K\bar{K})/(2\pi)$ (P4)/(P1)

```
R4            0.191    0.040     0.037   GORLICH   80 ASPK  0 17,18 PI-P POLAR
R4         . . . . . . . . . .
R4   FIT      0.063    0.014   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$\rho_3(1690) \rightarrow (K\bar{K}\pi)/(2\pi)$ (P3)/(P1)

```
R5 A          0.16     0.05              BARTSCH   70 HBC  +  8. PI+ P
R5 A     INCREASED BY US TO CORRESPOND TO RHO3(1690) INTO (2PI)=.24
R5         . . . . . . . . . .
R5   FIT      0.159    0.051   FROM FIT
```

$\rho_3(1690) \rightarrow (\rho\,2\pi)/(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$ (P5+P6+P8)/(P11)

```
R6            CONSISTENT WITH 1.         CASO      68 HBC  -   11 PI- P
R6           (1.)     (0.15)             BARTSCH   70 HBC  +  8. PI+ P
R6            0.88     0.15              BALLAM    71 HBC  -   16. PI- P
R6            0.96     0.21              BALTAY    78 HBC  +  15 PI+P,P 4PI
R6         . . . . . . . . . .
R6   AVG      0.91     0.12    AVERAGE
```

$\rho_3(1690) \rightarrow (2\rho)/(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$ (P8)/(P11)

```
R7           (0.7)    (0.15)             BARTSCH   70 HBC  +  8. PI+ P
R7       66  (0.56)                      KLIGER    74 HBC   - 4.5 PI-P,P 4PI
R7   T       (0.13)   (0.09)             THOMPSON  74 HBC  +  13 PI+ P
R7            0.12     0.11              BALTAY    78 HBC  +  15 PI+P,P 4PI
R7   T   RHO RHO AND A2(1320) PI MODES ARE INDISTINGUISHABLE
```

$\rho_3(1690) \rightarrow (2\rho)/(\rho\,2\pi)$ (P8)/(P5+P6+P8)

```
R8            0.48     0.16              CASO      68 HBC  -   11 PI- P
```

$\rho_3(1690) \rightarrow (\pi\,a_2)/(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$ (P6)/(P11)

```
R9           (0.6)                       BALTAY    68 HBC  +   7,8.5 PI+P
R9           (0.6)    (0.15)             BARTSCH   70 HBC  +  8. PI+ P
R9            NOT SEEN                   CASON     73 HBC  -  8.,18.5 PI- P
R9   T       (0.36)   (0.14)             THOMPSON  74 HBC  +  13 PI+P
R9            0.66     0.08              BALTAY    78 HBC  +  15 PI+P,P 4PI
R9   T   RHO RHO AND A2(1320) PI MODES ARE INDISTINGUISHABLE
```

$\rho_3(1690) \rightarrow (\pi\,\omega)/(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$ (P7)/(P11)

```
R10           0.25     0.10              BALTAY    68 HBC  +   7-8.5 PI+P
R10           0.25     0.10              JOHNSTON  68 HBC   -  7.0 PI- P
R10           0.12     0.07              BALLAM    71 HBC  -   16. PI- P
R10          (0.09) OR LESS              KLIGER    74 HBC   - 4.5 PI-P,P 4PI
R10           0.33     0.07              THOMPSON  74 HBC  +  13 PI+ P
R10          (0.11) OR LESS  CL=0.95     BALTAY    78 HBC  +  15 PI+P,P 4PI
R10        . . . . . . . . . .
R10 AVG       0.233    0.050   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

$\rho_3(1690) \rightarrow (\pi\,\phi)/(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$ (P9)/(P11)

```
R11          (0.11) OR LESS              BALTAY    68 HBC  +   7,8.5 PI+P
```

$\rho_3(1690) \rightarrow (\pi^{\pm}2\pi^{+}2\pi^{-}\pi^{0})/(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$

```
R12          (0.15) OR LESS              BALTAY    68 HBC  +   7,8.5 PI+ P
```

$\rho_3(1690) \rightarrow (\pi\,\eta)/(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$ (P10)/(P11)

```
R13          (0.02) OR LESS              THOMPSON  74 HBC  +  13 PI+ P
```

$\rho_3(1690) \rightarrow (K\bar{K})$/total (P4)

```
R14  B        0.013    0.004             MARTIN 2  78 SPEC   -10 PI P,KS K- P
R14           0.013    0.003             COSTA     80 OMEG  0 10 PI-P,K+ K- N
R14  B   FROM SQRT(P1*P4)=0.056+-0.034 ASSUMING (2PI)/TOTAL=P1=0.24
R14        . . . . . . . . . .
R14 AVG       0.0130   0.0024   AVERAGE
R14 FIT       0.0151   0.0031 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$\rho_3(1690) \rightarrow (\pi\,\omega)/(\pi\,\omega + 2\rho)$ (P7)/(P7+P8)

```
R16           0.22     0.08              CASON     73 HBC  -  8.,18.5 PI- P
```

REFERENCES FOR $\rho_3(1690)$

```
BELLINI  65 NC 40 A 948        BELLINI,DI CORATO,DUIMIO,FIORINI   (MILANO)
DEUTSCHM 65 PL 18 351          M.DEUTSCHMANN ET AL    (AACHEN+BERLIN+CERN)
FORINO   65 PL 19 65           FORINO,GESSAROLI +   (BOLOGNA+ORSAY+SACLAY)
GOLDBERG 65 PL 17 354          GOLDBERG+ (CERN+EPOL+ORSAY+MILANO+CEA-SACL)

EHRLICH  66 PR 152 1194        R. EHRLICH,W.SELOVE,H.YUTA   (PENNSYLVANIA)
FOCACCI  66 PRL  17  890       CERN MISSING MASS SPECTROMETER GROUP (CERN)
LEVRAT   66 PL  22  714        CERN MISSING MASS SPECTROMETER GROUP (CERN)
SEGUINOT 66 PL 19 712          CERN MISSING MASS SPECTROMETER GROUP (CERN)

ABRAMS   67 PRL 18 620         +KEHOE+GLASSER+SECHI-ZORN+WOLSKY (MARYLAND)
DANYSZ   67 PL 24B 309         +FRENCH+KINSON+SIMAK+      (CERN+LIVERPOOL)
DUBAL    67 NP B3 435          +FOCACCI+KIENZLE+LECHANOINE+LEVRAT+  (CERN)
   ALSO  68 THESIS 1456        L.DUBAL                            (GENEVE)
FRENCH   67 NC 52A 442         +KINSON+MCDONALD+RIDDIFORD+     (CERN+BIRM)

ARMENISE 68 NC 54 A 999        +FORINO+CARTACCI+(BARI+BGNA +FIRENZE+ORSAY)I
BALTAY   68 PRL 20 887         +KUNG+YEH+FERBEL+     (COLU+ROCH+RUTG+YALE)I=1
BISWAS   68 PRL 21 50          +CASON,DZIERBA,GROVES,KENNEY,+        (NDAM)
BOESEBEC 68 NP B 4 501         BOESEBECK,DEUTSCHMANN,+(AACHEN+BERLIN+CERN)
CASO     68 NC 54 A 983        +CONTE+CORDS+DIAZ+  (GENOVA+HAMB+MILA+SACL)
CRENNELL 68 PL 28 B 136        +KARSHON,LAI,SCARR,SKILLICORN          (BNL)
JOHNSTON 68 PRL 20 1414        +PRENTICE,STEENBERG,YOON     (TORONTO+WISC)IJP

ADERHOLZ 69 NP B 11 259        +BARTSCH,+        (AACH+BERL+CERN+JAGL+WARS)
ANDERSON 69 PRL 22 1390        +COLLINS,BLIEDEN+                 (BNL+CARN)
BARISH   69 PR 184  1375       +SELOVE,BISWAS,CASON,+      (PENN+NDAM+ROCH)
CASO     69 NC 62 A 755        +CONTE,BENZ,+    (GENO+DESY+HAMB+MILA+SACL)
VETLITSK 69 SJNP 9 461         +GUZHAVIN,KLIGER,KOLGANOV,LEBEDEV+    (ITEP)

ARMENISE 70 LNC 4  199         +GHIDINI,FORINO,CARTACCI,+ (BARI+BGNA+FIRZ)
BARNHAM  70 PRL 24 1083        +COLLEY,JOBES,KENYON,PATHAK,RIDDIFORD(BIRM)
BARTSCH  70 NP B 22 109        +KRAUS,TSANOS,GROTE,KOTZAN+(AACH+BERL+CERN)
CASO     70 LNC 3 707          +CONTE,TOMASINI,CORDS+(GENO+HAMB+MILA+SACL)
KRAMER   70 PRL 25 396         +BARTON,GUTAY,LICHTMAN,MILLER,+     (PURDUE)
MAURER   70  THESIS NO.588     G.MAURER                       (STRASBOURG)
STUNTEBE 70 PL 32 B 391        STUNTEBECK,KENNEY,DEERY,BISWAS,CASON+(NDAM)

BALLAM   71 PR D 3 2606        +CHADWICK,GUIRAGOSSIAN,JOHNSON,+      (SLAC)
BRAUN    71 NP B 30 213        +FRIDMAN,GERBER,GIVERNAUD,KAHN,+      (STRB)
GRAYER   71 PL 35 B 610        +HYAMS,JONES,SCHLEIN,BLUM,+     (CERN+MPIM)JP3-
MATTHEWS 71 NP B 331           +PRENTICE,YOON,CARROLL,+        (TNTO+WISC)JP3-

ARMENISE 72 LNC 4 205          +FORINO,CARTACCI,+          (BARI+BGNA+FIRZ)
    ALSO 75 LNC 14 177         +FOGLI-MUCIACCIA,FORINO+    (BARI+BGNA+FIRZ)  JP
BOWEN    72 PRL 29 890         +EARLES,FAISSLER,BLIEDEN,+       (NEAS+STON)
CLAYTON  72 NP B 47 81         +MASON,MUIRHEAD,RIGOPOULOS,+     (LIVP+PATR)
GRAYER   72 PHIL.CONF.PROC. 5  +HYAMS,JONES,SCHLEIN,BLUM,DIETL+(CERN+MPIM)
HOLMES   72 PR D 6 3336        +FERBEL,SLATTERY,WERNER               (ROCH)

ARNOLD   73 LNC 6 707          +ENGEL,ESCOUBES,KURTZ,LLORET,PATY,+  (STRB)
CASON    73 PR D 7 1971        +BISWAS,KENNEY,MADDEN,SANDER,SHEPHARD(NDAM)
CASON 1  73 NP B 64 14         +MADDEN,BISHOP,BISWAS,KENNEY,+        (NDAM)
HYAMS    73 NP B 64 134        +JONES,WEILHAMMER,BLUM,DIETL,+  (CERN+MPIM)
ROBERTSO 73 PR D 7 2554        ROBERTSON,WALKER,DAVIS          (DUKE+WISC)

DUBOVIKO 74 SJNP 19 568        DUBOVIKOV,MATSYUK,NILOV,SOKOLOV       (ITEP)
ENGLER   74 PR D10 2070        +KRAEMER,TOAFF,WEISSER,DIAZ+    (CARN+CASE)
GRAYER   74 NP B 75 189        G.GRAYER,HYAMS,BLUM,DIETL,+     (CERN+MPIM)
KLIGER   74 SJNP 19 428        +BEKETOV,GRECHKO,GUZHAVIN,DUBOVIKOV+ (ITEP)
OREN     74 NP B71 189         +COOPER,FIELDS,RHINES,WHITMORE,+  (ANL+OXF)
THOMPSON 74 NP B69 220         +GAIDOS,MCILWAIN,MILLER,MULERA,+      (PURD)

BLUM     75 PL 57B 403         +CHABAUD,DIETL,GARELICK,GRAYER+ (CERN+MPIM) JP
ESTABROO 75 NP B95 322         P.ESTABROOKS,A.D.MARTIN               (DURH)
HYAMS    75 NP B100 205        +JONES,WEILHAMMER,BLUM,DIETL+   (CERN+MPIM)
KALELKAR 75 THESIS(NEVIS 207)  M.S.KALELKAR                       (COLU)I=1

ANTIPOV  77 NP B 119 45        +BUSNELLO,DAMGAARD,KIENZLE+     (CERN+SERP)
GESSAROL 77 NP B 126 382       GESSAROLI,+  (BGNA+FIRZ+GENO+MILA+OXF+PAVI)

BALTAY   78 PR D 17 62         +CAUTIS,COHEN,CSORNA,SMITH,YEH,+(COLU+BING)
FORINO   78 NP B 139 413       +CARTACCI,+  (BGNA+FIRZ+GENO+MILA+OXF+PAVI)  JP
MARTIN 1 78 PL 74 B 417        +OZMUTLU+BALDI,BOHRINGER,DORSAZ+(DURH+GEVA)
MARTIN 2 78 NP B 140 158       +OZMUTLU,BALDI,BOHRINGER,DORSAZ+(DURH+GEVA)
MARTIN 3 78 ANP  114 1         A.D.MARTIN,M.R.PENNINGTON             (CERN)

BECKER   79 NP B 151  46       +BLANAR,BLUM,CERRADA+ (MPIM+CERN+ZEEM+CRAC)
CORDEN   79 NP B 157 250       +DOWELL,GARVEY,JOBES,+(BIRM+RHEL+TELA+LOWC)  JP
EVANGELI 79 NP B 154 381       + (BARI+BONN+CERN+DARE+GLAS+LIVP+MILA+WIEN)

ALPER    80 PL 94 B 422        +BECKER,+    (AMST+CERN+CRAC+MPIM+OXF+RHEL)
COSTA    80 NP B 175 402       +        (BARI+BONN+CERN+GLAS+LIVP+MILA+WIEN)
GORLICH  80 NP B 174 16        +NICZYPORUK,ROZANSKA+ (CRAC+MPIM+CERN+ZEEM)

EVANGELI 81 NP B 178 197       EVANGELISTA+(BARI+BONN+CERN+DARE+LIVP+MILA)

BARNETT  83 PL 120 B 455       +BLOCKUS,BURKA,CHIEN,CHRISTIAN+        (JHU)

DENNEY   83 PR D 28 2726       +CRANLEY,FIRESTONE,CHAPMAN+      (IOWA+MICH)
```

$X(1700)$ was $\eta(1700)$

OMITTED FROM SUMMARY TABLE

$I^G(J^{PC}) = \text{even}^{+}(?^{?+})$

```
ENHANCEMENT SEEN IN THE ETA PI PI SYSTEM
PRODUCED IN THE RADIATIVE DECAY OF THE J/PSI(3097).
MAY CONTAIN SIGNIFICANT SUB-STRUCTURE. RELATION TO
OTHER ENHANCEMENTS SEEN IN RADIATIVE J/PSI DECAY
UNCLEAR (SEE HITLIN 83).
TENTATIVELY CALLED X(1700) BY US.
```

$X(1700)$ MASS (MeV)

```
M           1700.0      45.               EDWARDS   83 CBAL    J/PSI,ETA 2PIGAM
```

$X(1700)$ WIDTH (MeV)

```
W            520.      110.               EDWARDS   83 CBAL    J/PSI,ETA 2PIGAM
```

REFERENCES FOR $X(1700)$

```
EDWARDS  83 PRL 51 859         +PARTRIDGE,PECK+  (CIT+HARV+PRIN+STAN+SLAC)
HITLIN   83 CORNELL CONF.      D. HITLIN                              (CIT)
```

$f_2(1720)$ was $\theta(1690)$

$I^G(J^{PC})=0^+(2^{++})$

```
NAMED THETA BY EDWARDS 82
SEEN IN J/PSI INTO GAMMA F2(1720), THEREFORE C=+.
F2(1720) DECAYS INTO 2ETA, THEREFORE IG=0+.
JP=2+ IS PREFERRED OVER 0+, HIGHER SPINS NOT
STUDIED.
MASS AND WIDTH DETERMINATION COMPLICATED BY OVERLAP WITH F2'(1525)
IN MASS SPECTRA. POSSIBLE CONNECTION OF THIS STATE WITH STRUCTURE
SEEN IN J/PSI TO GAMMA RHO RHO AND IN J/PSI TO GAMMA ETA PI PI
IS UNCLEAR (SEE BURKE 82, HITLIN 83).  RECENT RESULTS (BALTRUSAITIS 85)
INDICATE THAT THE RHO RHO ENHANCEMENT IS JP=0-, HENCE UNRELATED TO THE
F2(1720).
```

$f_2(1720)$ MASS (MeV)

```
M   E    (1640.)    (50.)              EDWARDS   82 CBAL  0 J/PSI,GAM 2ETA    |
M         1708.0     30.0              FRANKLIN  82 SMK2    E+E-,GAM K+ K-
M         1670.      50.               BLOOM     83 CBAL  0 J/PSI,GAM 2ETA    |
M         1720.      10.               PERRIER   84 SMK3    J/PSI,GAM K+ K-   |
M         1713.      15.               PERRIER   84 SMK3    J/PSI,GAM PI+PI-  |
M         . . . . . . . . . .
M   AVG   1716.0      7.9     AVERAGE

M   E   FROM FIT NEGLECTING NEARBY F2'(1525). REPLACED BY BLOOM 83.
```

$f_2(1720)$ WIDTH (MeV)

```
W   E     (220.)   (100.)     (70.)    EDWARDS   82 CBAL  0 J/PSI,GAM 2ETA    |
W          156.0     60.0              FRANKLIN  82 SMK2    E+E-,GAM K+ K-
W          160.      80.               BLOOM     83 CBAL  0 J/PSI,GAM 2ETA    |
W          130.      20.               PERRIER   84 SMK3    J/PSI,GAM K+ K-   |
W         . . . . . . . . . .
W   AVG    134.1     18.5     AVERAGE

W   E   FROM FIT NEGLECTING NEARBY F2'(1525). REPLACED BY BLOOM 83.
```

$f_2(1720)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_2(1720) \to \eta\eta$	549+ 549
P2	$f_2(1720) \to K\overline{K}$	498+ 498
P3	$f_2(1720) \to \rho\rho$	769+ 769
P4	$f_2(1720) \to \omega\omega$	783+ 783
P5	$f_2(1720) \to \pi\pi$	140+ 140

REFERENCES FOR $f_2(1720)$

```
ALTHOFF  82 ZPHY C 16 13        +BOERNER,BURKHARDT+   (TASSO COLLABORATION)
BARNES   82 PL 116 B 365        T.BARNES AND F.E.CLOSE                (RHEL)
BARNES   82 NP B 198 360        +CLOSE,MONAGHAN                   (RHEL+OXF)
BURKE    82 PRL 49 632          +TRILLING,ABRAMS,ALAM,BLOCKER,+  (LBL+SLAC)
EDWARDS  82 PRL 48 458          +PARTRIDGE,PECK,+ (CIT+HARV+PRIN+STAN+SLAC)
FRANKLIN 82  SLAC-254           M.E.B.FRANKLIN                        (SLAC)
TANIMOTO 82 PL 116 B 198        M.TANIMOTO                            (BIEL)

ALTHOFF  83 PL 121 B 216        +BRANDELIK,BOERNER+   (TASSO COLLABORATION)
BARNETT  83 PL 120 B 455        +BLOCKUS,BURKA,CHIEN,CHRISTIAN+        (JHU)
BLOOM    83 ARNS 33 143         BLOOM,PECK                        (SLAC+CIT)
HITLIN   83 CORNELL CONF.746    D.HITLIN                               (CIT)
PERRIER  84  SLAC-PUB-3436      J.PERRIER                        (UCSC+SLAC)

BALTRUSA 85  SLAC-PUB-3682      BALTRUSAITIS,       (CIT+UCSC+ILL+SLAC+WASH)
```

$f_0(1730)$ was $S(1730)$

$I^G(J^{PC})=0^+(0^{-+})$

OMITTED FROM SUMMARY TABLE

```
NAMED S* PRIME BY ETKIN 82
SEEN IN PHASE SHIFT ANALYSIS OF KOS KOS SYSTEM.
NEEDS CONFIRMATION.
```

$f_0(1730)$ MASS (MeV)

```
M  A S    1730.0     22.0              ETKIN2    82 MPS   0 23 PI-P,KSKS N    |
M         1742.0     15.0              WILLIAMS  84 MPSF    200PI-N,KSKS X    |
M         . . . . . . . . . .
M   AVERAGE MEANINGLESS

M  A    FROM AN AMPLITUDE ANALYSIS OF THE KOS KOS SYSTEM.
M    S  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$f_0(1730)$ WIDTH (MeV)

```
W  A       200.0    156.0       9.0    ETKIN1    82 MPS   0 23 PI-P,KSKS N
W           57.0     38.0              WILLIAMS  84 MPSF    200PI-N,KSKS X    |
W         . . . . . . . . . .
W   AVG     82.0     54.3     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)

W  A    FROM AN AMPLITUDE ANALYSIS OF THE KOS KOS SYSTEM.
```

$f_0(1730)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_0(1730) \to K\overline{K}$	498+ 498

REFERENCES FOR $f_0(1730)$

```
ETKIN1   82 PR D 25 1786      +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)JP
ETKIN2   82 PR D 25 2446      +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)

WILLIAMS 84 PR D 30 877       +DIAMOND+(VAND+NDAM+TUFT+ARIZ+FNAL+FSU+VPI)
```

$\pi(1770)$

$I^G(J^{PC})=1^-(0^{--})$

OMITTED FROM SUMMARY TABLE

```
SEEN IN PARTIAL WAVE ANALYSIS OF THE DIFFRACTIVELY
PRODUCED 3PI SYSTEM.
NEEDS CONFIRMATION.
```

$\pi(1770)$ MASS (MeV)

```
M     1100 1770.      30.            BELLINI   82 SPEC -  40 PI-A,3PI A
```

$\pi(1770)$ WIDTH (MeV)

```
W     1100  310.      50.            BELLINI   82 SPEC -  40 PI-A,3PI A
```

$\pi(1770)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\pi(1770) \to f_0(1300)\ \pi$	1300+ 140
P2	$\pi(1770) \to \rho\pi$	769+ 140

$\pi(1770)$ BRANCHING RATIOS

$\pi(1770) \to (f_0(1300)\ \pi)$/total (P1)

```
R1        DOMINANT                   BELLINI   82 SPEC -  40 PI-A,3PI A
```

$\pi(1770) \to (\rho\pi)$/total (P2)

```
R2        NOT SEEN                   BELLINI   82 SPEC -  40 PI-A,3PI A
```

REFERENCES FOR $\pi(1770)$

```
BELLINI  82 PRL 48 1697        +FRABETTI,IVANSHIN,LITKIN+ (MILA+BGNA+JINR)
```

$f_2(1810)$ was $f(1810)$

$I^G(J^{PC})=0^+(2^{++})$

OMITTED FROM SUMMARY TABLE

```
FORMERLY CALLED X(1850).
FROM AN AMPLITUDE ANALYSIS OF THE K+K- SYSTEM SEEN
IN PI- P INTO K+ K- N AT 10 GEV/C. NOT CONFIRMED
BY ETKIN 82. SEEN ALSO IN PI+PI- TO 2PI0 AMPLITUDE
ANALYSIS (CASON 82),BUT NOT SEEN IN THE PARTIAL
WAVE ANALYSIS OF THE PI+PI- SYSTEM.
NEEDS CONFIRMATION.
```

$f_2(1810)$ MASS (MeV)

```
M   A     1857.0     35.0      24.0    COSTA     80 OMEG  0 10 PI-P,K+ K- N
M         1799.0     15.0              CASON     82 STRC  0 8 PI+P,PI+2PI0 P
M         . . . . . . . . . .
M   AVERAGE MEANINGLESS (SCALE FACTOR = 1.8)

M   A  ERROR INCREASED BY SPREAD OF TWO SOLUTIONS.
```

$f_2(1810)$ WIDTH (MeV)

```
W   A      185.0    102.0     139.0    COSTA     80 OMEG  0 10 PI-P,K+ K- N
W          280.0     42.0      35.0    CASON     82 STRC  0 8 PI+P,PI+2PI0 P
W         . . . . . . . . . .
W   AVERAGE MEANINGLESS

W   A  ERROR INCREASED BY SPREAD OF TWO SOLUTIONS.
```

$f_2(1810)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_2(1810) \to K^+K^-$	494+ 494
P2	$f_2(1810) \to \pi\pi$	140+ 140

$f_2(1810)$ BRANCHING RATIOS

$f_2(1810) \rightarrow (K^+ K^-)$/total (P1)

```
R1          SEEN                     COSTA      80 OMEG  0 10 PI-P,K+ K- N
```

$f_2(1810) \rightarrow (\pi\ \pi)$/total (P2)

```
R2            0.44      0.03         CASON      82 STRC  0 8 PI+P,PI+2PI0 P
```

REFERENCES FOR $f_2(1810)$

```
COSTA    80 NP B 175 402      +       (BARI+BONN+CERN+GLAS+LIVP+MILA+WIEN)

CASON    82 PRL 48 1316       +BISWAS,BAUMBAUGH,BISHOP,CANNATA+(NDAM+ANL)
ETKIN    82 PR D 25 1786      +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)

CASON    83 PR D 28 1586      +CANNATA,BAUMBAUGH,BISHOP,WATSON+(NDAM+ANL)
```

$\phi_J(1850)$ was $\phi(1850)$

$$I^G(J^{PC}) = 0^?(?^{??})$$

SEEN IN THE K KBAR AND K KBAR PI MASS DISTRIBUTIONS.

$\phi_J(1850)$ MASS (MeV)

```
M       123 1850.0      10.0             ALHARRAN  81 HBC      8.25 K-P,LAM 2K
M       430 1870.0      30.0      20.0   ARMSTRONG 82 OMEG     18.5 K-P,K-K+LAM
M           . . . . . . . . . .
M   AVG     1852.8       9.3      AVERAGE
```

$\phi_J(1850)$ WIDTH (MeV)

```
W       123   80.0      40.0      30.0   ALHARRAN  81 HBC      8.25 K-P,LAM 2K
W       430  160.0      90.0      50.0   ARMSTRONG 82 OMEG     18.5 K-P,K-K+LAM
W           . . . . . . . . . .
W   AVG       96.0      32.0      AVERAGE
```

$\phi_J(1850)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\phi_J(1850) \rightarrow K\overline{K}$	494+ 494
P2	$\phi_J(1850) \rightarrow K^*(892)\ \overline{K}$ + C.C.	892+ 494

$\phi_J(1850)$ BRANCHING RATIOS

$\phi_J(1850) \rightarrow (K^*(892)\ \overline{K}$ + C.C.)/$(K\overline{K})$ (P2)/(P1)

```
R1             0.8       0.4             ALHARRAN  81 OMEG     8.25 K-P,LAM 2K
```

REFERENCES FOR $\phi_J(1850)$

```
ASTON    80 PL 92 B 219       (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+PARIS+)

ALHARRAN 81 PL 101 B 357      +AMIRZADEH,+      (BIRM+CERN+GLAS+MICH+LPNP)

ARMSTRON 82 PL 110 B 77       +BAUBILLIER+(BARI+BIRM+CERN+MILA+LPNP+PAVI)JP
CORDIER  82 PL 110 B 335      +BISELLO,BIZOT,BUON,DELCOURT,FAYARD,+(LALO)
```

$X(1935)$ was $S(1935)$

$$I^G(J^{PC}) = ?^?(?^{??})$$

FOR A SUMMARY OF THE X(1935) MESON SEE NAKAMURA 84 AND OUR 1984 EDITION.

OMITTED FROM SUMMARY TABLE

$X(1935)$ MASS (MeV)

```
M       X(1935) CHANNEL NBAR N
M   C     (1940.)     (8.)               CLINE     70 HBC   0  .25-.74 PBAR P
M   B     (1968.)                        BENVENUTI 71 HBC   0  .1 - .8 PBAR P
M  S       1932.       2.                CARROLL   74 CNTR    S CHAN.PBAR P,D
M   C     (1942.)     (5.)               D-ANDLAU  75 HBC   0 .175-.750 PBAR P
M   Z     (1934.4)    (2.6)     (1.4)    KALOGERO  75 DBC   - PBAR N ANNIH
M  S       1935.9      1.0               CHALOUPKA 76 HBC   0 PBAR P TOT,ELAS
M          1939.0      3.0               BRUCKNER  77 SPEC  0 .4-.85 PBAR P
M          1935.5      1.0               SAKAMOTO  79 HBC   0 .37-.73 PB P
M          1930.0      2.0               ASTON     80 OMEG    GAM P,P PBAR X
M   A     (1949.)    (10.)               DEFOIX    80 HBC   0 PBAR P,5PI
M    M     1939.0      2.0               HAMILTO2  80 CNTR  0 S CHAN,PBAR P
M
M       PRODUCTION EXPERIMENTS
M       36(1940.0)    (1.0)              DAUM      80 CNTR  0 93 P P,PB P + X
M         . . . . . . . . . . .
M   AVERAGE MEANINGLESS (SCALE FACTOR = 1.7)

M   A   FROM ENERGY DEPENDENCE OF 5PI CROSS-SECTION.IG=1- FROM OBSERVATION
M   A   OF OMEGA RHO DECAY. P=+ AND J>1. A2(1320) PI PI ALSO SEEN.
M   B   SEEN AS A BUMP IN THE PBAR P - KS KL  CROSS SECTION WITH JPC=1--.
M       NOT SEEN BY CARSON 72 WITH EQUAL STATISTICS.
M   C   FROM ENERGY DEPENDENCE OF FAR BACKWARD ELASTIC SCATTERING.
M       SOME INDICATION OF ADDITIONAL STRUCTURE.
M    M  I=0 FAVORED,J=0 OR 1,SEEN IN TOTAL PBAR P TOTAL CROSS-SECTION,
M    M  PRIMARLY FROM ANNIH. REACTIONS.  NOT SEEN IN PBAR D TOTAL AND
M    M  ANNIH. CROSS SECTIONS.
M   N   SEEN IN 3 CHARGED MODE. NOT SEEN BY BOWEN 73 WITH 6X STATISTICS.
M   S   NARROW BUMP SEEN IN TOTAL PBAR P,D CROSS-SECTIONS.ISOSPIN UNCERTAIN
M       NOT SEEN IN PBAR P CEX BY GARNJOST 75,CHALOUPKA 76. INTEGRATED
M       CROSS-SECTION 3X LARGER THAN BRUCKNER 77.
M   Z   NOT SEEN BY ALBERI 79 WITH COMPARABLE STATISTICS.
```

$X(1935)$ WIDTH (MeV)

```
W       X(1935) CHANNEL NBAR N
W   C     (49.)       (9.)               CLINE     70 HBC   0  .25-.74 PBAR P
W   B     (35.)                          BENVENUTI 71 HBC   0  .1 - .8 PBAR P
W  S        9.         4.        3.      CARROLL   74 CNTR    S CHAN.PBAR P,D
W   C     (57.5)      (5.)               D-ANDLAU  75 HBC   0 .175-.750 PBAR P
W   Z     (11.)      (11.)      (4.)     KALOGERO  75 DBC   - PBAR N ANNIH
W  S        8.8        4.3       3.2     CHALOUPKA 76 HBC   0 PBAR P TOT,ELAS
W          (4.0)   OR LESS               BRUCKNER  77 SPEC  0 .4-.85 PBAR P
W           2.8        1.4               SAKAMOTO  79 HBC   0 .37-.73 PB P
W          12.0        7.0               ASTON     80 OMEG    GAM P,P PBAR X
W   A     (80.)      (20.)               DEFOIX    80 HBC   0 PBAR P,5PI
W    M     22.0        6.0               HAMILTO2  80 CNTR  0 S CHAN,PBAR P
W
W       PRODUCTION EXPERIMENTS
W          (6.0)   APPROX.               DAUM      80 CNTR    93 P P,PB P + X
W         . . . . . . . . . .
W   AVERAGE MEANINGLESS (SCALE FACTOR = 1.9)

W   SEE FOOTNOTES UNDER X(1935) MASS ABOVE
```

$X(1935)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$X(1935) \rightarrow \overline{p}p$	938+ 938

REFERENCES FOR $X(1935)$

```
CLINE    68 PRL 21 1268       +ENGLISH,REEDER,TERRELL,TWITTY  (WISCONSIN)

CLINE    70  PREPRINT         D.CLINE,J.ENGLISH,D.D.REEDER         (WISC)J
  ALSO   70 KIEV CONF.        ASTIER RAPPORTEUR TALK

BENVENUT 71 PRL 27 283        BENVENUTI,CLINE,RUTZ,REEDER,SCHERER  (WISC)
PINSKI   71 PRL 27 1548       STEPHEN S. PINSKY             (UTAH+ARGONNE)

BIZZARRI 72 PR D 6 160        +GUIDONI,MARZANO,CASTELLI,+     (ROMA+TRST)
BOWEN 1  72 PRL 29 890        +EARLES,FAISSLER,BLIEDEN,+      (NEAS+STON)

BOWEN    73 PRL 30 332        +EARLES,FAISSLER,BLIEDEN,+      (NEAS+STON)
BURNS    73 PR D 8 1286       +CONDON,DONAHUE,MANDELKERN,PRICE,+    (UCI)
KIENZLE  73 PR D 7 3520       W.KIENZLE                            (CERN)

BURNS    74 NC 20A 463        +CONDON,MANDELKERN,PRICE,SCHULTZ      (UCI)
CARROLL  74 PRL 32 247        +CHIANG,KYCIA,LI,MAZUR,MICHAEL,+      (BNL)

ABASHIAN 75 PRL 34 691        +BEAMER,BROSS,EISENSTEIN,+    (ILL+ANL+ISU)
D-ANDLAU 75 PL 58B 223        +COHEN-GANOUNA,LALOUM,LUTZ,PETRI(CDEF+PISA)JP
DEFOIX   75 PALERMO  CONF.    B.FRENCH, RAPPORTEURS TALK           (CDEF)
DONNACHI 75 NC 26 A 317       A.DONNACHIE,P.R.THOMAS         (MANCHESTER)
GARNJOST 75 PRL 35 1685       +KENNEY,POLLARD,ROSS,TRIPP,+     (LBL+MHCO)
KALOGERO 75 PRL 34 1047       KALOGEROPOULOS,TZANAKOS              (SYRA)
WEINGART 75 PRL 34 1201       WEINGARTEN,OKUBO                     (ROCH)

ABASHIAN 76 PR D 13 5         +WATSON,GELFAND,BUTTRAM,+(ILL+ANL+CHIC+ISU)
DEFOIX   76 STOCK.SYMP.NBAR-N +LADRON DE GUEVARA,ANGELINI,+   (CDEF+PISA)
DOVER    76 PL 62 B 293       +KAHANA                               (BNL)
CHALOUPK 76 PL 61 B 487       CHALOUPKA,+ (CERN+LIVP+MONS+PADO+ROMA+TRST)

BENKHEIR 77 PL B 68 483       BENKHEIRI,BOUCROT,+   (CERN+CDEF+EPOL+LALO)
BRUCKNER 77 PL 67 B 222       +GRANZ,INGHAM,KILIAN,LYNEN+(MPIH+HEID+CERN)
MONTANET 77 BOSTON CONF. 260  L.MONTANET                           (CERN)
ROSSI    77 PL 70 B 255       G.C.ROSSI,G.VENEZIANO                (CERN)

CARTER   78 NP B 132 176      A.A.CARTER                         (LOQM)JP
CUTTS    78 PR D 17 16        +GOOD,GRANNIS,GREEN,LEE,PITTMAN+(STON+WISC)
PENNINGT 78 NP B 137 77       M.R. PENNINGTON                      (CERN)

ALBERI   79 PL 83 B 247       +ALVEAR,CASTELLI,POROPAT+  (TRST+CERN+IFRJ)
ALSTON-G 79 PRL 43 1901       ALSTON-GARNJOST,HAMILTON+    (LBL+MTHO+BNL)
CARROLL  79 PR D 19 1950      +CHIANG,KYCIA,LI,LITTENBERG,+    (BNL+ROCH)
DELCOURT 79 PL B 86 395       +DERADO,BERTRAND,BISELLO,BIZOT,BUON,+(LALO)
GIBBARD  79 PRL 42 1593       +AHRENS,BERKELMAN,CASSEL,DAY,HARDING+(CORN)
KLUYVER  79 ZPHY C 2 351      J.C. KLUYVER                         (AMST)
RICHARD  79 BATAVIA CONF. 469 F. RICHARD                           (LALO)
SAKAMOTO 79 NP B 158 410      +HASHIMOTO,SAI,YAMAMOTO+             (TOKY)

ALLEN    80 BRESSANONE 175    5TH EUROPEAN SYMPOSIUM ON N-NBAR INTS.
ASTON    80 PL 93 B 517       (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+PARIS+)
BIONTA   80 PRL 46 970        +CARROLL,EDELSTEIN,+   (BNL+CARN+FNAL+SMAS)
CHUNG    80 PRL 45 1611       +ETKIN,BENSINGER,+(BNL+BRAN+CUNY+SMAS+MASA)
DAUM     80 PL 90 B 475       +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
DEFOIX   80 NP B 162 12       +DOBRZYNSKI,ANGELINI,BIGI,+     (CDEF+PISA)
    ALSO 80 NP B 162 41       ESPIGAT,DEFOIX,DOBRZYNSKI+      (CDEF+PISA)
HAMILTO1 80 PRL 44 1179       HAMILTON,PUN,TRIPP,LAZARUS,+ (LBL+BNL+MTHO)
HAMILTO2 80 PRL 44 1182       HAMILTON,PUN,TRIPP,LAZARUS,+ (LBL+BNL+MTHO)
KAMAE    80 PRL 44 1439       +AIHARA,CHIBA,FUJII,IWASAKI,+   (TOKY+HIRO)

DAUM     81 PL 100 B 439      +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
GANGULI  81 NP B 183 295      +CERRADA,DEFOIX,+(TIFR+CERN+CDEF+MADR+PISA)
JASTRZEM 81 PR D 23 2784      JASTRZEMBSKI,MANDELKERN,+    (TEMP+UCI+UNM)
LOWENSTE 81 PR D 23 2788      LOWENSTEIN,PEASLEE,+     (BNL+DOE+MSU+SYRA)

SUMIYOSH 82 PRL 49 628        +CHIBA,FUJII,IKEDA,TAKADA,+ (TOKY+KEK+TSUK)

BARNETT  83 PR D 27 493       +BLOCKUS,BURKA,CHIEN,CHRISTIAN+       (JHU)
BENSINGE 83 PR D 27 1417      BENSINGER,CHUNG    (BRAN+BNL+CINC+FSU+SMAS)

NAKAMURA 84 PR D 29 349       +AIHARA,CHIBA,FUJII,FUKUMA,+    (TOKY+HIRO)

BODENKAM 85 NP B 255 717      BODENKAMP,FRIES,BEHREND,HESSE+  (KARL+DESY)
BRANDO   85 PL 158 B 505      +DAFTARI+      (SYRA+PENN+BNL+MSU+UMD+TEMP)
TIMMERS  85 PR D 31 99        +VAN DER SANDEM,DE SWART             (NIJM)
```

$f_4(2030)$ was $h(2030)$

$I^G(J^{PC}) = 0^+(4^{++})$

$f_4(2030)$ MASS (MeV)

```
M      700 2020.     30.             APEL       75 CNTR     40.  PI-P,N 2PIO
M          2050.     25.             BLUM       75 ASPK     18.4 PI-P,N K+K-
M  T      (1922.0)  (14.0)           ANTIPOV    77 CIBS   0 25 PI-P,P 3PI
M  M      (1935.0)  (13.0)           CORDEN     79 OMEG     12-15PI-P, N 2PI
M         (1988.0)   (7.0)           EVANGELIS  79 OMEG     10. PI-P,K+ K- N
M    M    (2040.0)  (10.0)           ROZANSKA   80 SPRK     18.PI-P,P PB N
M  M      (1978.0)   (5.0)           ALPER      80 CNTR     62 PI-P,K+ K- N
M  N       2015.0    28.0            CASON      82 STRC   0 8 PI+P,PI+2PIO P
M  E       2031.0    36.0            ETKIN      82 MPS    0 23 PI-P,2KOS N
M  N   40K 2020.0    20.0            BINON      84 SPEC   0 38 PI-P,N 2PIO
M          2000.0    60.0            ALDE       85 GAM4     100PI- P,2 ETA    |
M          . . . . . . . . .
M   AVG    2025.9    11.5      AVERAGE

M    M  I=0,JP=4+ FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE
M  T    WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N),SEE K* TYPED NOTE
M  E    ETKIN 82 QUOTES ERRORS +25/-36 MEV. WE USE +-36 MEV IN THE AVERAGE.
M  N    FROM AMPLITUDE ANALYSIS OF REACTION PI+PI- TO 2PIO
```

$f_4(2030)$ WIDTH (MeV)

```
W      700  180.      60.            APEL       75 CNTR     40.  PI-P,N 2PIO
W           225.     120.     70.    BLUM       75 ASPK     18.4 PI-P,N K+K-
W  T       (107.0)   (56.0)          ANTIPOV    77 CIBS   0 25 PI-P,P 3PI
W  M       (263.0)   (57.0)          CORDEN     79 OMEG     12-15PI-P, N 2PI
W          (100.0)   (28.0)          EVANGELIS  79 OMEG     10. PI-P,K+ K- N
W    M     (140.0)   (15.0)          ROZANSKA   80 SPRK     18.PI-P,P PB N
W  M       (243.0)   (16.0)          ALPER      80 CNTR     62 PI-P,K+ K- N
W  N        186.0    103.0    58.0   CASON      82 STRC   0 8 PI+P,PI+2PIO P
W  E        305.0    119.0           ETKIN      82 MPS    0 23 PI-P,2KOS N
W  N    40K 240.0     40.0           BINON      84 SPEC   0 38 PI-P,N 2PIO
W           190.0     14.0           DENNEY     83 LASS     10 PI+N /PI+ P    |
W           400.0    100.0           ALDE       85 GAM4     100PI- P,2 ETA    |
W           . . . . . . . . .
W   AVG     199.4     12.5     AVERAGE

W    M  I=0,JP=4+ FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE
W  E    ETKIN 82 QUOTES ERRORS +36/-119 MEV. WE USE +-119 MEV.
W  N    FROM AMPLITUDE ANALYSIS OF REACTION PI+PI- TO 2PIO
```

$f_4(2030)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_4(2030) \to \pi\pi$	140+ 140
P2	$f_4(2030) \to K\overline{K}$	498+ 498
P3	$f_4(2030) \to \eta\eta$	549+ 549

$f_4(2030)$ BRANCHING RATIOS

$f_4(2030) \to (\pi\pi)$/total (P1)

```
R1          0.17      0.02           CORDEN     79 OMEG     12-15PI-P, N 2PI
R1          0.16      0.03           CASON      82 STRC   0 8 PI+P,PI+2PIO P
R1          . . . . . . . . .
R1  AVG     0.167     0.017    AVERAGE
```

$f_4(2030) \to (K\overline{K})/(\pi\pi)$ (P2)/(P1)

```
R2          0.04      0.02      0.01 ETKIN      82 MPS    0 23 PI-P,2KOS N
```

$f_4(2030) \to (\eta\eta)$/total (units 10^{-3}) (P3)

```
R3          2.2       1.0            ALDE       85 GAM4     100 PI-P,4 GAMMA  |
```

REFERENCES FOR $f_4(2030)$

```
WAGNER   74 LONDON CONF.      F. WAGNER, RAPPORTEURS TALK          (MPIM)

APEL     75 PL 57B 398        +AUGENSTEIN+     (KARL+PISA+SERP+WIEN+CERN)JP
BLUM     75 PL 57B 403        +CHABAUD,DIETL,GARELICK,GRAYER+ (CERN+MPIM)JP

ANTIPOV  77 NP B 119 45       +BUSNELLO,DAMGAARD,KIENZLE+     (CERN+SERP)

CORDEN   79 NP B 157 250      +DOWELL,GARVEY,JOBES,+(BIRM+RHEL+TELA+LOWC)JP
EVANGELI 79 NP B 154 381      + (BARI+BONN+CERN+DARE+GLAS+LIVP+MILA+WIEN)

ALPER    80 PL 94 B 422       +BECKER,+    (AMST+CERN+CRAC+MPIM+OXF+RHEL)
ROZANSKA 80 NP B 162 505      +BLUM,DIETL,GRAYER,LORENZ+      (MPIM+CERN)

GOTTESMA 81 PR D 22 1503      GOTTESMAN,JACOBS,+     (SYRA+BRAN+BNL+CINC)

CASON    82 PRL 48 1316       +BISWAS,BAUMBAUGH,BISHOP,CANNATA+(NDAM+ANL)
ETKIN    82 PR D 25 1786      +FOLEY,LAI,LINDENBAUM+ (BNL+CUNY+TUFT+VAND)

CASON    83 PR D 28 1586      +CANNATA,BAUMBAUGH,BISHOP,WATSON+(NDAM+ANL)
DENNEY   83 PR D 28 2726      +CRANLEY,FIRESTONE,CHAPMAN+     (IOWA+MICH)

BINON    84 LNC 39 41         +DONSKOV,DUTEIL,GOUANERE+  (SERP+BELG+LAPP)

ALDE     85  CERN-EP/85-153   +BINON,BRICMAN,DUTEIL+(BELG+LAPP+SERP+CERN)
```

$a_4(2040)$ was $\delta(2040)$

$I^G(J^{PC}) = 1^-(4^{++})$

OMITTED FROM SUMMARY TABLE

SEEN IN PARTIAL WAVE ANALYSIS OF THE K KBAR AND
PI+PI-PIO SYSTEMS.
NEEDS CONFIRMATION.

$a_4(2040)$ MASS (MeV)

```
M   Y     (1903.0)  (10.0)          BALDI     78 SPEC -  10 PI-P,P KS K-
M    M     2030.0    50.0           CORDEN    78 OMEG  0 15 PI- P,3 PI N
M    C     2040.0    30.0           CLELAND   82 SPEC +- 50 PI P,KS K+-P
M          . . . . . . . . . .
M   AVG    2037.4    25.7     AVERAGE

M    M  JP=4+ IS FAVORED , THOUGH 2+ CANNOT BE EXCLUDED.
M   Y   FROM A FIT TO THE Y(8,0) MOMENT. LIMITED BY PHASE SPACE.
M    C   FROM AN AMPLITUDE ANALYSIS
M
```

$a_4(2040)$ WIDTH (MeV)

```
W   Y      (166.0)  (43.0)          BALDI     78 SPEC -  10PI-P,P KS K-
W    M      510.0   200.0           CORDEN    78 OMEG  0 15 PI- P,3 PI N
W    C      380.0   150.0           CLELAND   82 SPEC +- 50 PI P,KS K+-P
W          . . . . . . . . . .
W   AVG     426.8   120.0     AVERAGE

W    M  JP=4+ IS FAVORED , THOUGH 2+ CANNOT BE EXCLUDED.
W   Y   FROM A FIT TO THE Y(8,0) MOMENT. LIMITED BY PHASE SPACE.
W    C   FROM AN AMPLITUDE ANALYSIS
W
```

$a_4(2040)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$a_4(2040) \to K\overline{K}$	494+ 494
P2	$a_4(2040) \to \pi^+\pi^-\pi^0$	140+ 140+ 135

$a_4(2040)$ BRANCHING RATIOS

$a_4(2040) \to (K\overline{K})$/total (P1)

```
R1       SEEN                     BALDI     78 SPEC +- 10 PI-P,KS K- P
```

$a_4(2040) \to (\pi^+\pi^-\pi^0)$/total (P2)

```
R2       SEEN                     CORDEN    78 OMEG  0 15 PI- P,3 PI N
```

REFERENCES FOR $a_4(2040)$

```
BALDI    78 PL 74 B 413      +BOHRINGER,DORSAZ,HUNGERBULER,+    (GENEVA)JP
CORDEN   78 NP B 136 77      DOWELL,GARVEY,JOBES+  (BIRM+RHEL+TELA+LOWC)JP

DELFOSSE 81 NP B 183 349     +DORSAZ,EXTERMANN,GLOOR,WEILL,+ (GEVA+LAUS)

CLELAND  82 NP B 208 228     +DELFOSSE,DORSAZ,GLOOR(DURH+GEVA+LAUS+PITT)
```

$a_3(2050)$ was $A(2050)$

$I^G(J^{PC}) = 1^-(3^{++})$

OMITTED FROM SUMMARY TABLE

FORMERLY CALLED A4 OR PI.
NEEDS CONFIRMATION.

$a_3(2050)$ MASS (MeV)

```
M      208 2080.     40.            KALELKAR  75 HBC  +  15PI+P,P PI+RHO3
M         (2100.)   APPROX          ANTIPOV   77 CIBS -  25PI-P,P PI-RHO3
M         (2214.)    (15.)          BALTAY    77 HBC   0 15PI-P,DEL++3PI
```

$a_3(2050)$ WIDTH (MeV)

```
W      208  340.     80.            KALELKAR  75 HBC  +  15PI+P,P PI+RHO3
W          (500.)   APPROX.         ANTIPOV   77 CIBS -  25PI-P,P PI-RHO3
W          (355.)    (21.)          BALTAY    77 HBC   0 15PI-P,DEL++3PI
```

$a_3(2050)$ PARTIAL DECAY MODES

		DECAY MASSES
F1	$a_3(2050) \to 3\pi$	140+ 140+ 140
F2	$a_3(2050) \to \rho_3(1690)\ \pi$	1691+ 140

$a_3(2050)$ BRANCHING RATIOS

$a_3(2050) \rightarrow (\rho_3(1690)\ \pi)/(3\pi)$ (P2)/(P1)

```
R1        DOMINANT                   KALELKAR  75 HBC  +  15 PI+P,P 3PI
```

REFERENCES FOR $a_3(2050)$

```
HUSON    68 PL 28 B 208        +LUBATTI,BELLINI,BINGHAM,+  (ORSA+MILA+LBL)

BEMPORAD 71 NP B 33 397        +DUFEY,CODLING,+       (CERN+ETH+LOIC+MILA)

CLAYTON  72 NP B 47 81         +MASON,MUIRHEAD,RIGOPOULOS,+    (LIVP+PATR)

BASTIEN  73 UPPSALA CONF. 73   +DUNN,HARRIS,LUBATTI,BINGHAM,+   (SEAT+UCB)

OREN     74 NP B71 189         +COOPER,FIELDS,RHINES,WHITMORE,+  (ANL+OXF)

DEUTSCHM 75 NP B99 397         DEUTSCHMANN,+       (ABBCCHW COLLABORATION)
KALELKAR 75 THESIS(NEVIS 207) M.S.KALELKAR                          (COLU)

ANTIPOV  77 NP B 119 45        +BUSNELLO,DAMGAARD,KIENZLE+     (CERN+SERP)
BALTAY   77 PRL 39 591         +CAUTIS,KALELKAR                (COLUMBIA)JP

HARRIS   81 ZPHY C 9 275       +DUNN,LUBATTI,MORIYASU,PODOLSKY+ (SEAT+UCB)
CAUTIS   77 THESIS NEVIS 221 C.V.CAUTIS                        (COLUMBIA)JP

BALTAY   78 PR D 17 52         +CAUTIS,COHEN,CSORNA,KALELKAR+  (COLU+BING)
```

$\pi_2(2100)$ was $A(2100)$

$I^G(J^{PC}) = 1^-(2^{--})$

OMITTED FROM SUMMARY TABLE

```
FORMERLY CALLED PI.
SEEN IN THE (RHO PI), (F0(1300) PI), AND
(F2(1270) PI) JP = 2- WAVES OF THE DIFFRACTIVELY
PRODUCED 3PI SYSTEM. NEEDS CONFIRMATION.
```

$\pi_2(2100)$ MASS (MeV)

```
M    L     2100.     150.             DAUM      81 CNTR    63,94 PI- P,3PI
M    L  FROM A TWO RESONANCE FIT TO FOUR 2-0- WAVES.
```

$\pi_2(2100)$ WIDTH (MeV)

```
W    L      651.      50.             DAUM      81 CNTR    63,94 PI- P,3PI
W    L  FROM A TWO RESONANCE FIT TO FOUR 2-0+ WAVES.
```

$\pi_2(2100)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\pi_2(2100) \rightarrow 3\pi$	140+ 140+ 140
P2	$\pi_2(2100) \rightarrow \rho\pi$	769+ 140
P3	$\pi_2(2100) \rightarrow f_2(1270)\ \pi$	1274+ 140
P4	$\pi_2(2100) \rightarrow f_0(1300)\ \pi$	1300+ 140

$\pi_2(2100)$ BRANCHING RATIOS

$\pi_2(2100) \rightarrow (\rho\pi)/(3\pi)$ (P2)/(P1)

```
R1   L         0.19      0.05             DAUM      81 CNTR    63,94 PI- P
```

$\pi_2(2100) \rightarrow (f_2(1270)\ \pi)/(3\pi)$ (P3)/(P1)

```
R2   L         0.36      0.09             DAUM      81 CNTR    63,94 PI- P
```

$\pi_2(2100) \rightarrow (f_0(1300)\ \pi)/(3\pi)$ (P4)/(P1)

```
R3   L         0.45      0.07             DAUM      81 CNTR    63,94 PI- P
```

D-wave/S-wave RATIO FOR $\pi_2(2100) \rightarrow f_2(1270)\ \pi$

```
R4   L         0.39      0.23             DAUM      81 CNTR    63,94 PI- P
R    L  FROM A TWO RESONANCE FIT TO FOUR 2-0+ WAVES.
```

REFERENCES FOR $\pi_2(2100)$

```
DAUM     81 NP B 182 269       +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
```

$\rho(2150)$

$I^G(J^{PC}) = 1^-(1^{--})$

OMITTED FROM SUMMARY TABLE

```
THIS ENTRY WAS PREVIOUSLY CALLED T1(2190).
CONTAINS ONLY RESULTS FROM FORMATION EXPERIMENTS, FOR
PRODUCTION EXPERIMENTS SEE THE NBAR N(1200-3600) ENTRY.
SEE ALSO F2(2150), RHO3(2250), F4(2300), RHO5(2350)

   OUR LATEST MINIREVIEW ON THIS PARTICLE CAN BE FOUND IN THE 1984 EDITION.
```

$\rho(2150)$ MASS (MeV)

```
M        PBAR P INTO PI PI
M
M    P    (2100.0)  APPROX.          MARTIN A  80 RVUE
M    P    (2170.0)  APPROX.          MARTIN B  80 RVUE
M
M        S CHANNEL NUCLEON ANTINUCLEON
M
M  B       2190.      10.            ABRAMS    70 CNTR    S CHANNEL PBAR N
M    I     2193.       2.            ALSPECTOR 73 CNTR    S CHANNEL PBAR P
M  E I     2155.0     15.0           COUPLAND  77 CNTR  0 .7-2.4PB-P,PB-P
M    I    (2190.0)  APPROX.          CUTTS     78 CNTR    .97-3. PB P,NB N
M          . . . . . . . . . .
M   AVERAGE MEANINGLESS

M    P  I=1,JP=1- FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PI0 PI0
M  B    SEEN AS BUMP IN I=1 STATE. SEE ALSO COOPER 68.
M  B    PEASLEE 75 CONFIRM PBAR P RESULTS OF ABRAMS 70,NO NARROW STRUCTURE
M  E    FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
M    I  ISOSPINS 0 AND 1 NOT SEPARATED
```

$\rho(2150)$ WIDTH (MeV)

```
W        PBAR P INTO PI PI
W
W    P     (200.0)  APPROX.          MARTIN A  80 RVUE
W    P     (250.0)  APPROX.          MARTIN B  80 RVUE
W
W        S CHANNEL NUCLEON ANTINUCLEON
W
W  B        (85.)   APPROX.          ABRAMS    70 CNTR    S CHANNEL PBAR N
W    I       98.       8.            ALSPECTOR 73 CNTR    S CHANNEL PBAR P
W  E I      135.0     75.0           COUPLAND  77 CNTR  0 .7-2.4PB-P,PB-P
W    P  I=1,JP=1- FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PI0 PI0
W          . . . . . . . . . .
W   AVERAGE MEANINGLESS

W  B    SEE NOTE B ABOVE.
W  E    FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
W    I  ISOSPINS 0 AND 1 NOT SEPARATED
```

REFERENCES FOR $\rho(2150)$

```
ABRAMS   67 PRL 18 1209        +COOL,GIACOMELLI,KYCIA,LEONTIC,LI,+   (BNL)

COOPER   68 PRL 20 1059        +HYMAN,MANNER,MUSGRAVE,VOYVODIC       (ANL)

BRICMAN  69 PL 29 B 451        +FERRO-LUZZI,BIZARD,+      (CERN+CAEN+SACL)

ABRAMS   70 PR D 1 1917        +COOL,GIACOMELLI,KYCIA,LEONTIC,LI,+   (BNL)

BACON    71 NP B 32 66         +BUTTERWORTH,MILLER,PHELAN,+    (RHEL+LIVP)
FIELDS   71 PRL 27 1749        +COOPER,RHINES,ALLISON            (ANL+OXF)
YOH      71 PRL 26 922         +BARISH,CAROLL,LOBKOVICZ+    (CIT+BNL+ROCH)

ALEXANDE 72 NP B 45 29         ALEXANDER,BAR-NIR,BEVARY,DAGAN,+     (TELA)
DONALD   72 PL 40 B 586        +GALLETLY,EDWARDS,DE BILLY,+    (LIVP+LPNP)

ALSPECTO 73 PRL 30 511         ALSPECTOR,COHEN,CVIJANOVICH,+   (RUTG+UPNJ)
BACON    73 PR D 7 577         +BUTTERWORTH,                   (RHEL+LIVP)
BETTINI  73 NC 15 A 563        +GARNJOST,BIGI,+        (PADO+LBL+PISA+TORI)
DONALD   73 NP B 61 333        +EDWARDS,GIBBINS,BRIAND,DUBOC,+ (LIVP+LPNP)
NICHOLSO 73 PR D 7 2572        NICHOLSON,DELORME,CARROLL,+  (CIT+ROCH+BNL)

BERTANZA 74 NC 23A 209         +BIGI,CASALI,LARICCIA,+    (PISA+PADO+TORI)
HYAMS    74 NP B 73 202        +JONES,WEILHAMMER,BLUM,+        (CERN+MPIM)

DONNACHI 75 NC 26 A 317        A.DONNACHIE,P.R.THOMAS          (MANCHESTER)
EISENHAN 75 NP B 96 109        EISENHANDLER,GIBSON,+ (LOQM+LIVP+DARE+RHEL)
HANDLER  75 NP B101 35         +JACQUES,JONES,PANDOULAS,- (RUTG+STEV+ALBA)
HUESMAN  75 NC 25A  91         +GARNJOST,ROSS,+        (LBL+PADO+PISA+TORI)
PEASLEE  75 PL 57B 189         +DEMARZO,GUERRIERO,+    (CANB+BARI+BROW+MIT)

GAY      76 NC 31 A 593        +JEANNERET,BOGDANSKI,+(NEUC+LAUS+LIVP+LPNP)
ZEMANY   76 NP B 103 537       +MING MA,MOUNTZ,SMITH                 (MSU)

CARTER 1 77 PL 67 B 117        +COUPLAND,EISENHANDLER,ASTBURY,+(LOQM+RHEL)JP
CARTER 2 77 PL 67 B 122        A.A.CARTER                           (LOQM)JP
CARTER 3 77 NP B 127 202       +COUPLAND,ATKINSON,ARNISON+(LOQM+DARE+RHEL)
COUPLAND 77 PL 71 B 460        +EISENHANDLER,GIBSON,ASTBURY,+  (LOQM+RHEL)
JONES    77 NP B 119 476       M.D.JONES,R.J.PLANO                  (RUTG)
MONTANET 77 BOSTON CONF. 260   L.MONTANET                           (CERN)

CARTER 1 78 NP B 132 176       A.A.CARTER                           (LOQM)JP
CARTER 2 78 NP B 141 467       A.A.CARTER                           (LOQM)
CUTTS    78 PR D 17 16         +GOOD,GRANNIS,GREEN,LEE,PITTMAN+(STON+WISC)

MARTIN   79 PL 86 B 93         A.D. MARTIN,M.R. PENNINGTON          (DURH)

MARTIN A 80 NP B 169 216       A.D. MARTIN,M.R. PENNINGTON          (DURH)JP
MARTIN B 80 NP B 176 355       B.R.MARTIN,D.MORGAN             (LOUC+RHEL)JP
```

$f_2(2150)$ was $\epsilon(2150)$

OMITTED FROM SUMMARY TABLE

$I^G(J^{PC}) = 0^+(2^{++})$

THIS ENTRY WAS PREVIOUSLY CALLED T0.
CONTAINS ONLY RESULTS FROM FORMATION EXPERIMENTS,
FOR PRODUCTION EXPERIMENTS SEE THE NBARN(1200-3600)
ENTRY. SEE ALSO RHO(2150), RHO3(2250), F4(2300),
RHO5(2350).

$f_2(2150)$ MASS (MeV)

```
M       PBAR P INTO PI PI
M
M    L    (2150.0)  APPROX.            DULUDE2   78 OSPK    1.-2.PB P,PIOPIO
M    P    (2150.0)  APPROX.            MARTIN A  80 RVUE
M    P    (2170.0)  APPROX.            MARTIN B  80 RVUE

M    L  IG=0+,JP=2+ FROM PARTIAL WAVE AMPLITUDE ANALYSIS
M    P  I=0,JP=2+ FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PIO PIO

M       S CHANNEL PBAR P OR NBAR N
M
M    I     2193.       2.              ALSPECTOR 73 CNTR    S CHANNEL PBAR P
M  E I     2155.0     15.0             COUPLAND  77 CNTR  0 .7-2.4PB-P,PB-P
M    I    (2190.0)  APPROX.            CUTTS     78 CNTR    .97-3. PB P,NB N
M          . . . . . . . . . .
M   AVERAGE MEANINGLESS

M  E    FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
M    I  ISOSPINS 0 AND 1 NOT SEPARATED
```

$f_2(2150)$ WIDTH (MeV)

```
W       PBAR P INTO PI PI
W
W    L     (250.0)  APPROX.            DULUDE2   78 OSPK    1.-2.PB P,PIOPIO
W    P     (250.0)  APPROX.            MARTIN A  80 RVUE
W    P     (250.0)  APPROX.            MARTIN B  80 RVUE

W    L  IG=0+,JP=2+ FROM PARTIAL WAVE AMPLITUDE ANALYSIS
W    P  I=0,JP=2+ FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PIO PIO

W       S CHANNEL PBAR P OR NBAR N
W
W    I      98.        8.              ALSPECTOR 73 CNTR    S CHANNEL PBAR P
W  E I     135.0      75.0             COUPLAND  77 CNTR  0 .7-2.4PB-P,PB-P
W          . . . . . . . . . .
W   AVERAGE MEANINGLESS

W  E    FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
W    I  ISOSPINS 0 AND 1 NOT SEPARATED
```

$f_2(2150)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_2(2150) \rightarrow \pi\pi$	140+ 140

REFERENCES FOR $f_2(2150)$

```
FIELDS    71 PRL 27 1749        +COOPER,RHINES,ALLISON            (ANL+OXF)
YOH       71 PRL 26 922         +BARISH,CAROLL,LOBKOVICZ+    (CIT+BNL+ROCH)

DONALD    72 PL 40 B 586        +GALLETLY,EDWARDS,DE BILLY,+    (LIVP+LPNP)

ALSPECTO  73 PRL 30 511         ALSPECTOR,COHEN,CVIJANOVICH,+   (RUTG+UPNJ)
BACON     73 PR D 7 577         +BUTTERWORTH,                   (RHEL+LIVP)
DONALD    73 NP B 61 333        +EDWARDS,GIBBINS,BRIAND,DUBOC,+ (LIVP+LPNP)
NICHOLSO  73 PR D 7 2572        NICHOLSON,DELORME,CARROLL,+  (CIT+ROCH+BNL)

GAY       76 NC 31 A 593        +JEANNERET,BOGDANSKI,+(NEUC+LAUS+LIVP+LPNP)

COUPLAND  77 PL 71 B 460        +EISENHANDLER,GIBSON,ASTBURY,+  (LOQM+RHEL)

CUTTS     78 PR D 17 16         +GOOD,GRANNIS,GREEN,LEE,PITTMAN+(STON+WISC)
DULUDE1   78 PL 79 B 329        +LANOU,MASSIMO,PEASLEE+     (BROW+MIT+BARI)  JP
DULUDE2   78 PL 79 B 335        +LANOU,MASSIMO,PEASLEE+     (BROW+MIT+BARI)  JP

MARTIN    79 PL 86 B 93         A.D. MARTIN,M.R. PENNINGTON           (DURH)

BOWCOCK   80 LNC 28 21          J.E.BOWCOCK,D.C.HODGSON               (BIRM)
MARTIN A  80 NP B 169 216       A.D. MARTIN,M.R. PENNINGTON           (DURH)  JP
MARTIN B  80 NP B 176 355       B.R.MARTIN,D.MORGAN              (LOUC+RHEL)  JP
```

$X(2220)$ was $\xi(2220)$

OMITTED FROM SUMMARY TABLE

$I^G(J^{PC}) = 0^?(\text{even}^{+-})$

CALLED XI(2220) BY EINSWEILER 83.
THIS STATE HAS BEEN SEEN AT SPEAR IN THE K KBAR
SYSTEMS (K+ K- AND KOS KOS) PRODUCED IN THE RADIATIVE
DECAY OF J/PSI(3097).
NOT SEEN IN THE DM2 EXPERIMENT AT DCI (JEAN-MARIE 85)
NEEDS CONFIRMATION. NOT SEEN IN UPSILON
RADIATIVE DECAYS NOR IN B INCLUSIVE DECAY
(BEHRENDS 84).

$X(2220)$ MASS (MeV)

```
M    A     (2220.)    (25.)             EINSWEILE 83 SMK3    E+E-,HADRONS GAM  |
M    A   93(2230.)    (15.)             BALTRUSAI 86 SMK3    E+E-, K+ K- GAM   |
M    A   23(2232.)    (10.)             BALTRUSAI 86 SMK3    E+E-,KOS KOS GAM  |
M    A   SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$X(2220)$ WIDTH (MeV)

```
W    A        (30.)     (25.)             EINSWEILE 83 SMK3    E+E-,HADRONS GAM  |
W    A    93  (26.)     (26.)     (23.)   BALTRUSAI 86 SMK3    E+E-, K+ K- GAM   |
W    A    23  (18.)     (25.)     (18.)   BALTRUSAI 86 SMK3    E+E-,KOS KOS GAM  |
W    A   SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

REFERENCES FOR $X(2220)$

```
EINSWEIL 83 BRIGHTON CONF.348 K.F.EINSWEILER+MARKIII COLLABORATION (SLAC)
HITLIN   83 CORNELL CONF.746  D.HITLIN                              (CIT)

BEHRENDS 84 PL 137 B 277      +  (ROCH+RUTG+SYRA+VAND+CORN+ITHA+HARV+OSU)
GODFREY  84 PL 141 B 439      +KOKOSKI,ISGUR                       (TNTO)
SHATZ    84 PL 138 B 209      M.P.SHATZ                             (CIT)
WILLEY   84 PRL 52 585        R.S.WILLEY                           (PITT)

BALTRUSA 86 PRL 56 107        BALTRUSAITIS        (CIT+UCSC+ILL+SLAC+WASH)
JEAN-MAR 85  LAL 85-34        JEAN-MARIE                           (LALO)
YAOUANC  85 ZPHY C 28 309     +OLIVER,PENE,RAYNAL,ONO         (ORSA+TOKY)
```

$f_2(2240)$ was $g_T(2240)$

OMITTED FROM SUMMARY TABLE

$I^G(J^{PC}) = 0^-(2^{+-})$

THIS ENTRY CONTAINS VARIOUS STATES OBSERVED IN
PARTIAL WAVE ANALYSES OF THE PHI PHI SYSTEM.
NEEDS CONFIRMATION.

$f_2(2240)$ MASS (MeV)

```
M1   D     (2160.0)   (50.0)             ETKIN     82 MPS   0 16 PI-P,2PHI N
M1          2120.0     20.0    120.0     LINDENBAU 84 RVUE
M1   D  D-WAVE/S-WAVE RATIO IS 0.02 APPROXIMATELY

M2          2320.0     40.0              ETKIN     82 MPS   0 16 PI-P,2PHI N
M2          2220.0     90.0     20.0     LINDENBAU 84 RVUE
M2          2231.0     10.0              BOOTH     85 OMEG    85 PI-BE,2PHI BE  |
M2          . . . . . . . . . . .
M2  AVG   · 2235.7     20.6     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.2)

M3          2360.0     20.0              LINDENBAU 84 RVUE
M3          2392.0     10.0              BOOTH     85 OMEG    85 PI-BE,2PHI BE  |
M3          . . . . . . . . . . .
M3  AVG     2385.6     12.8     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
```

$f_2(2240)$ WIDTH (MeV)

```
W1          (310.0)   (70.0)             ETKIN     82 MPS   0 16 PI-P,2PHI N
W1           300.0    150.0     50.0     LINDENBAU 84 RVUE

W2          (220.0)   (70.0)             ETKIN     82 MPS   0 16 PI-P,2PHI N
W2           200.0     50.0              LINDENBAU 84 RVUE
W2           133.0     50.0              BOOTH     85 OMEG    85 PI-BE,2PHI BE  |
W2          . . . . . . . . . . .
W2  AVG      166.5     35.4     AVERAGE

W3           150.0    150.0     50.0     LINDENBAU 84 RVUE
W3           198.0     50.0              BOOTH     85 OMEG    85 PI-BE,2PHI BE  |
W3          . . . . . . . . . . .
W3  AVG      188.4     44.7     AVERAGE
```

$f_2(2240)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_2(2240) \rightarrow \phi\phi$	1020+1020

REFERENCES FOR $f_2(2240)$

```
ETKIN    82 PRL 49 1620       +FOLEY,LONGACRE,LINDENBAUM,CHAN+ (BNL+CUNY)I JP
   ALSO  83 BRIGHTON CONF.    LINDENBAUM                       (BNL+CUNY)I JP

BOOTH    84 NP B 242 51       +BALLANCE,CARROLL,DONALD,+ (LIVP+GLAS+CERN)
LINDENBA 84 CNPP 13 285       S.LINDENBAUM                          (CUNY)

BOOTH    85  CERN/EP 85-138   +CARROLL,DONALD,EDWARDS+   (LIVP+GLAS+CERN)
```

$\rho_3(2250)$ was $\rho(2250)$

OMITTED FROM SUMMARY TABLE

$I^G(J^{PC}) = 1^+(3^{--})$

CONTAINS ONLY RESULTS FROM FORMATION EXPERIMENTS,
FOR PRODUCTION EXPERIMENTS SEE THE NBARN(1200-3600)
ENTRY. SEE ALSO RHO(2150), F2(2150), F4(2300),
RHO5(2350).

$\rho_3(2250)$ MASS (MeV)

```
M       PBAR P INTO PI PI OR K KB
M
M  J      (2150.0)  APPROX.            CARTER 1  77 CNTR  0 .7-2.4PB P,PIPI
M    K    (2140.0)  APPROX.            CARTER 2  78 CNTR  0 .7-2.4PB P,K-K+
M    P    (2300.0)  APPROX.            MARTIN A  80 RVUE
M    P    (2250.0)  APPROX.            MARTIN B  80 RVUE
```

```
M  J      I=1,JP=3- FROM AMPLITUDE ANALYSIS.
M    K    I=0,1.JP=3- FROM BARRELET ZERO ANALYSIS.
M    P    I=1,JP=3- FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PIO PIO

M         S CHANNEL NUCLEON ANTINUCLEON
M
M  B        2190.      10.                 ABRAMS    70 CNTR    S CHANNEL PBAR N
M    I      2193.       2.                 ALSPECTOR 73 CNTR    S CHANNEL PBAR P
M  E I      2155.0     15.0                COUPLAND  77 CNTR  0 .7-2.4PB-P,PB-P
M    I     (2190.0)  APPROX.               CUTTS     78 CNTR    .97-3. PB P,NB N
M           . . . . . . . . . .
M   AVERAGE MEANINGLESS

M  B      SEEN AS BUMP IN I=1 STATE. SEE ALSO COOPER 68.
M  B      PEASLEE 75 CONFIRM PBAR P RESULTS OF ABRAMS 70,NO NARROW STRUCTURE
M  E      FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
M    I    ISOSPINS 0 AND 1 NOT SEPARATED
```

$\rho_3(2250)$ WIDTH (MeV)

```
W         PBAR P INTO PI PI OR K KB
W
W  J        (200.0)  APPROX.               CARTER 1  77 CNTR  0 .7-2.4PB P,PIPI
W    K      (150.0)  APPROX.               CARTER 2  78 CNTR  0 .7-2.4PB P,K-K+
W    P      (200.0)  APPROX.               MARTIN A  80 RVUE
W    P      (250.0)  APPROX.               MARTIN B  80 RVUE

W  J      I=1,JP=3- FROM AMPLITUDE ANALYSIS.
W    K    I=0,1.JP=3- FROM BARRELET ZERO ANALYSIS.
W    P    I=1,JP=3- FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PIO PIO

W         S CHANNEL NUCLEON ANTINUCLEON
W
W  B         (85.)   APPROX.               ABRAMS    70 CNTR    S CHANNEL PBAR N
W    I        98.       8.                 ALSPECTOR 73 CNTR    S CHANNEL PBAR P
W  E I       135.0     75.0                COUPLAND  77 CNTR  0 .7-2.4PB-P,PB-P
W           . . . . . . . . . .
W   AVERAGE MEANINGLESS

W  B      SEE NOTE B ABOVE.
W  E      FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
W    I    ISOSPINS 0 AND 1 NOT SEPARATED
```

REFERENCES FOR $\rho_3(2250)$

```
ABRAMS   67 PRL 18 1209         +COOL,GIACOMELLI,KYCIA,LEONTIC,LI,+   (BNL)

COOPER   68 PRL 20 1059         +HYMAN,MANNER,MUSGRAVE,VOYVODIC       (ANL)

ABRAMS   70 PR D 1 1917         +COOL,GIACOMELLI,KYCIA,LEONTIC,LI,+   (BNL)

FIELDS   71 PRL 27 1749         +COOPER,RHINES,ALLISON            (ANL+OXF)
YOH      71 PRL 26 922          +BARISH,CAROLL,LOBKOVICZ+    (CIT+BNL+ROCH)

ALSPECTO 73 PRL 30 511          ALSPECTOR,COHEN,CVIJANOVICH,+   (RUTG+UPNJ)
BETTINI  73 NC 15 A 563         +GARNJOST,BIGI,+        (PADO+LBL+PISA+TORI)
DONNACHI 73 LNC 7 285           A.DONNACHIE,P.R.THOMAS         (MANCHESTER)
NICHOLSO 73 PR D 7 2572         NICHOLSON,DELORME,CARROLL,+  (CIT+ROCH+BNL)

BERTANZA 74 NC 23A 209          +BIGI,CASALI,LARICCIA,+    (PISA+PADO+TORI)

ZEMANY   76 NP B 103 537        +MING MA,MOUNTZ,SMITH                 (MSU)

CARTER 1 77 PL 67 B 117         +COUPLAND,EISENHANDLER,ASTBURY,+(LOQM+RHEL)JP
CARTER 2 77 PL 67 B 122         A.A.CARTER                           (LOQM)JP
CARTER 3 77 NP B 127 202        +COUPLAND,ATKINSON,ARNISON+(LOQM+DARE+RHEL)
COUPLAND 77 PL 71 B 460         +EISENHANDLER,GIBSON,ASTBURY,+  (LOQM+RHEL)
MONTANET 77 BOSTON CONF. 260    L.MONTANET                           (CERN)

CARTER 1 78 NP B 132 176        A.A.CARTER                           (LOQM)JP
CARTER 2 78 NP B 141 467        A.A.CARTER                           (LOQM)
CUTTS    78 PR D 17 16          +GOOD,GRANNIS,GREEN,LEE,PITTMAN+(STON+WISC)

MARTIN   79 PL 86 B 93          A.D. MARTIN,M.R. PENNINGTON          (DURH)

MARTIN A 80 NP B 169 216        A.D. MARTIN,M.R. PENNINGTON          (DURH)JP
MARTIN B 80 NP B 176 355        B.R.MARTIN,D.MORGAN             (LOUC+RHEL)JP
```

$f_4(2300)$ was $\epsilon(2300)$

$I^G(J^{PC})=0^+(4^{++})$

OMITTED FROM SUMMARY TABLE

```
THIS ENTRY WAS PREVIOUSLY CALLED UD(2350).
CONTAINS ONLY RESULTS FROM FORMATION EXPERIMENTS,
FOR PRODUCTION EXPERIMENTS SEE THE NBARN(1200-3600)
ENTRY. SEE ALSO RHO(2150), F2(2150), RHO3(2250),
RHO5(2350).
```

$f_4(2300)$ MASS (MeV)

```
M         PBAR P INTO PI PI OR KB K
M
M  J       (2310.0)  APPROX.               CARTER 1  77 CNTR  0 .7-2.4PB P,PIPI
M    K     (2340.0)  APPROX.               CARTER 2  78 CNTR  0 .7-2.4PB P,K-K+
M          (2330.0)  APPROX.               DULUDE2   78 OSPK    1.-2.PB P,PIOPIO
M    P     (2300.0)  APPROX.               MARTIN A  80 RVUE
M    P     (2300.0)  APPROX.               MARTIN B  80 RVUE

M  J      I=0,JP=4+ FROM AMPLITUDE ANALYSIS.
M    K    I=0,JP=4+ FROM BARRELET ZERO ANALYSIS
M    P    I=0,JP=4+ FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PIO PIO

M         S CHANNEL PBAR P OR NBAR N
M
M           2375.      10.                 ABRAMS    70 CNTR    S CHANNEL NBAR N
M   I      (2359.)     (2.)                ALSPECTOR 73 CNTR    S CHANNEL PBAR P
M  EI      (2345)     (15.0)               COUPLAND  77 CNTR  0 .7-2.4PB-P,PB-P
M   I      (2380.0)  APPROX.               CUTTS     78 CNTR    .97-3. PB P,NB N

M  E      FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
M   I     ISOSPINS 0 AND 1 NOT SEPARATED
```

$f_4(2300)$ WIDTH (MeV)

```
W         PBAR P INTO PI PI OR KB K
W
W  J        (210.0)  APPROX.               CARTER 1  77 CNTR  0 .7-2.4PB P,PIPI
W    K      (150.0)  APPROX.               CARTER 2  78 CNTR  0 .7-2.4PB P,K-K+
W    P      (200.)   APPROX.               MARTIN A  80 RVUE

W  J      I=0,JP=4+ FROM AMPLITUDE ANALYSIS.
W    K    I=0,JP=4+ FROM BARRELET ZERO ANALYSIS
W    P    I=0,JP=4+ FROM SIMULTANEOUS ANAL. OF P PBAR --> PI-PI+ AND PIO PIO

W         S CHANNEL PBAR P OR NBAR N
W
W           (190.)   APPROX.               ABRAMS    70 CNTR    S CHANNEL NBAR N
W   I       (165.)    (18.)      (8.)      ALSPECTOR 73 CNTR    S CHANNEL PBAR P
W  EI       (135.0)  (150.0)    (65.0)     COUPLAND  77 CNTR  0 .7-2.4PB-P,PB-P

W  E      FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
W   I     ISOSPINS 0 AND 1 NOT SEPARATED
```

REFERENCES FOR $f_4(2300)$

```
BRICMAN  69 PL 29 B 451         +FERRO-LUZZI,BIZARD,+       (CERN+CAEN+SACL)

ABRAMS   70 PR D 1 1917         +COOL,GIACOMELLI,KYCIA,LEONTIC,LI,+   (BNL)

FIELDS   71 PRL 27 1749         +COOPER,RHINES,ALLISON            (ANL+OXF)
YOH      71 PRL 26 922          +BARISH,CAROLL,LOBKOVICZ+    (CIT+BNL+ROCH)

EASTMAN  72 NP B 51 29          +MING MA,OH,PARKER,SMITH,SPRAFKA      (MSU)

ALSPECTO 73 PRL 30 511          ALSPECTOR,COHEN,CVIJANOVICH,+   (RUTG+UPNJ)
DONNACHI 73 LNC 7 285           A.DONNACHIE,P.R.THOMAS         (MANCHESTER)
NICHOLSO 73 PR D 7 2572         NICHOLSON,DELORME,CARROLL,+  (CIT+ROCH+BNL)

HYAMS    74 NP B 73 202         +JONES,WEILHAMMER,BLUM,+        (CERN+MPIM)
MING MA  74 NP B68 214          +MOUNTZ,ZEMANY,SMITH                 (MICH)

DONNACHI 75 NC 26 A 317         A.DONNACHIE,P.R.THOMAS         (MANCHESTER)
EISENHAN 75 NP B 96 109         EISENHANDLER,GIBSON,+ (LOQM+LIVP+DARE+RHEL)

CARTER 1 77 PL 67 B 117         +COUPLAND,EISENHANDLER,ASTBURY,+(LOQM+RHEL)JP
CARTER 2 77 PL 67 B 122         A.A.CARTER                           (LOQM)JP
CARTER 3 77 NP B 127 202        +COUPLAND,ATKINSON,ARNISON+(LOQM+DARE+RHEL)
COUPLAND 77 PL 71 B 460         +EISENHANDLER,GIBSON,ASTBURY,+  (LOQM+RHEL)
MONTANET 77 BOSTON CONF. 260    L.MONTANET                           (CERN)

CARTER 1 78 NP B 132 176        A.A.CARTER                           (LOQM)JP
CARTER 2 78 NP B 141 467        A.A.CARTER                           (LOQM)
CUTTS    78 PR D 17 16          +GOOD,GRANNIS,GREEN,LEE,PITTMAN+(STON+WISC)
DULUDE1  78 PL 79 B 329         +LANOU,MASSIMO,PEASLEE+      (BROW+MIT+BARI)JP
DULUDE2  78 PL 79 B 335         +LANOU,MASSIMO,PEASLEE+      (BROW+MIT+BARI)JP

MARTIN   79 PL 86 B 93          A.D. MARTIN,M.R. PENNINGTON          (DURH)

BOWCOCK  80 LNC 28 21           J.E.BOWCOCK,D.C.HODGSON              (BIRM)
MARTIN A 80 NP B 169 216        A.D. MARTIN,M.R. PENNINGTON          (DURH)JP
MARTIN B 80 NP B 176 355        B.R.MARTIN,D.MORGAN             (LOUC+RHEL)JP
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$\rho_5(2350)$ was $\rho(2350)$

$I^G(J^{PC})=1^+(5^{--})$

OMITTED FROM SUMMARY TABLE

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THIS ENTRY WAS PREVIOUSLY CALLED U1(2400).
CONTAINS ONLY RESULTS FROM FORMATION EXPERIMENTS,
FOR PRODUCTION EXPERIMENTS SEE THE NBARN(1200-3600)
ENTRY. SEE ALSO RHO(2150), F2(2150), RHO3(2250),
F4(2300).
```

$\rho_5(2350)$ MASS (MeV)

```
M         PBAR P INTO PI PI OR KB K
M  J       (2480.0)  APPROX.               CARTER 1  77 CNTR  0 .7-2.4PB P,PIPI
M    K     (2500.0)  APPROX.               CARTER 2  78 CNTR  0 .7-2.4PB P,K-K+
M    P     (2250.0)  APPROX.               MARTIN A  80 RVUE
M    P     (2300.0)  APPROX.               MARTIN B  80 RVUE

M  J      I=1,JP=5- FROM AMPLITUDE ANALYSIS.
M    K    I=0,1.JP=5- FROM BARRELET ZERO ANALYSIS.
M    P    I=1,JP=5- FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PIO PIO

M         S CHANNEL NUCLEON ANTINUCLEON
M
M  A        2350.      10.                 ABRAMS    70 CNTR    S CHANNEL NBAR N
M   N      (2360.0)   (25.0)               OH        70 HDBC  -OPBAR(P,N),K*K2PI
M   I      (2359.)     (2.)                ALSPECTOR 73 CNTR    S CHANNEL PBAR P
M  EI      (2345.0)   (15.0)               COUPLAND  77 CNTR  0 .7-2.4PB-P,PB-P
M   I      (2380.0)  APPROX.               CUTTS     78 CNTR    .97-3. PB P,NB N

M  A      FOR I=1 NBAR N
M  E      FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
M   I     ISOSPINS 0 AND 1 NOT SEPARATED
M   N     NO EVIDENCE FOR THIS BUMP SEEN IN THE PBAR P DATA OF CHAPMAN 71
M   N     NARROW STATE NOT CONFIRMED BY OH 73 WITH MORE DATA.
```

$\rho_5(2350)$ WIDTH (MeV)

```
W         PBAR P INTO PI PI OR KB K
W  J        (210.0)  APPROX.               CARTER 1  77 CNTR  0 .7-2.4PB P,PIPI
W    K      (150.0)  APPROX.               CARTER 2  78 CNTR  0 .7-2.4PB P,K-K+
W    P      (300.0)  APPROX.               MARTIN A  80 RVUE
W    P      (250.0)  APPROX.               MARTIN B  80 RVUE

W  J      I=1,JP=5- FROM AMPLITUDE ANALYSIS.
W    K    I=0,1.JP=5- FROM BARRELET ZERO ANALYSIS.
W    P    I=1,JP=5- FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PIO PIO
```

W		S CHANNEL NUCLEON ANTINUCLEON						
W								
W		(140.)	APPROX.		ABRAMS	67	CNTR	S CHANNEL PBAR N
W	N	(60.0)	OR LESS		OH	70	HDBC	-OPBAR(P,N),K*K2PI
W	I	(165.)	(18.)	(8.)	ALSPECTOR	73	CNTR	S CHANNEL PBAR P
W	EI	(135.0)	(150.0)	(65.0)	COUPLAND	77	CNTR	0 .7-2.4PB-P,PB-P

W E FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
W I ISOSPINS 0 AND 1 NOT SEPARATED
W N NO EVIDENCE FOR THIS BUMP SEEN IN THE PBAR P DATA OF CHAPMAN 71
W N NARROW STATE NOT CONFIRMED BY OH 73 WITH MORE DATA.

REFERENCES FOR $\rho_5(2350)$

ABRAMS 67 PRL 18 1209 +COOL,GIACOMELLI,KYCIA,LEONTIC,LI,+ (BNL)

BRICMAN 69 PL 29 B 451 +FERRO-LUZZI,BIZARD,+ (CERN+CAEN+SACL)
CASO 69 LNC 3 707 +CONTE,BENZ,+ (GENO+DESY+HAMB+MILA+SACL)

ABRAMS 70 PR D 1 1917 +COOL,GIACOMELLI,KYCIA,LEONTIC,LI,+ (BNL)
OH 70 PRL 24 1257 +PARKER,EASTMAN,SMITH,SPRAFKA,MA (MSU)

CHAPMAN 71 PR D4 1275 +GREEN,LYS,MURPHY,RING,+ (MICH)
FIELDS 71 PRL 27 1749 +COOPER,RHINES,ALLISON (ANL+OXF)
YOH 71 PRL 26 922 +BARISH,CAROLL,LOBKOVICZ+ (CIT+BNL+ROCH)

EASTMAN 72 NP B 51 29 +MING MA,OH,PARKER,SMITH,SPRAFKA (MSU)
MING MA 72 NP B 51 77 +EASTMAN,OH,PARKER,SMITH,SPRAFKA (MSU)
OH 72 NP B 51 57 +EASTMAN,MING MA,PARKER,SMITH,+ (MSU)

ALSPECTO 73 PRL 30 511 ALSPECTOR,COHEN,CVIJANOVICH,+ (RUTG+UPNJ)
NICHOLSO 73 PR D 7 2572 NICHOLSON,DELORME,CARROLL,+ (CIT+ROCH+BNL)

HYAMS 74 NP B 73 202 +JONES,WEILHAMMER,BLUM,+ (CERN+MPIM)
MING MA 74 NP B68 214 +MOUNTZ,ZEMANY,SMITH (MICH)

DONNACHI 75 NC 26 A 317 A.DONNACHIE,P.R.THOMAS (MANCHESTER)
EISENHAN 75 NP B 96 109 EISENHANDLER,GIBSON,+ (LOQM+LIVP+DARE+RHEL)

CARTER 1 77 PL 67 B 117 +COUPLAND,EISENHANDLER,ASTBURY,+(LOQM+RHEL)JP
CARTER 2 77 PL 67 B 122 A.A.CARTER (LOQM)JP
CARTER 3 77 NP B 127 202 +COUPLAND,ATKINSON,ARNISON+(LOQM+DARE+RHEL)
COUPLAND 77 PL 71 B 460 +EISENHANDLER,GIBSON,ASTBURY,+ (LOQM+RHEL)
MONTANET 77 BOSTON CONF. 260 L.MONTANET (CERN)

CARTER 1 78 NP B 132 176 A.A.CARTER (LOQM)JP
CARTER 2 78 NP B 141 467 A.A.CARTER (LOQM)
CUTTS 78 PR D 17 16 +GOOD,GRANNIS,GREEN,LEE,PITTMAN+(STON+WISC)

MARTIN 79 PL 86 B 93 A.D. MARTIN,M.R. PENNINGTON (DURH)

BOWCOCK 80 LNC 28 21 J.E.BOWCOCK,D.C.HODGSON (BIRM)
MARTIN A 80 NP B 169 216 A.D. MARTIN,M.R. PENNINGTON (DURH)JP
MARTIN B 80 NP B 176 355 B.R.MARTIN,D.MORGAN (LOUC+RHEL)JP

$a_6(2450)$
was $\delta(2450)$

$I^G(J^{PC}) = 1^-(6^{--})$

SEEN IN PARTIAL WAVE ANALYSIS OF THE K KBAR SYSTEM. NEEDS CONFIRMATION.

OMITTED FROM SUMMARY TABLE

$a_6(2450)$ MASS (MeV)

M	C	2450.	130.	CLELAND	82	SPEC	+- 50 PI P,KS K+-P

M C FROM AN AMPLITUDE ANALYSIS

$a_6(2450)$ WIDTH (MeV)

W	C	400.	250.	CLELAND	82	SPEC	+- 50 PI P,KS K+-P

M C FROM AN AMPLITUDE ANALYSIS

$a_6(2450)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$a_6(2450) \to K\bar{K}$	498+ 498

REFERENCES FOR $a_6(2450)$

CLELAND 82 NP B 208 228 +DELFOSSE,DORSAZ,GLOOR(DURH+GEVA+LAUS+PITT)

$f_6(2510)$
was $r(2510)$

$I^G(J^{PC}) = 0^+(6^{++})$

SEEN IN PI0 PI0.
NEEDS CONFIRMATION.

OMITTED FROM SUMMARY TABLE

$f_6(2510)$ MASS (MeV)

M	2510.0	30.0	BINON	84	SPEC	0 38 PI-P,N 2PI0

$f_6(2510)$ WIDTH (MeV)

W	240.0	60.0	BINON	84	SPEC	0 23 PI-P,N 2PI0

$f_6(2510)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$f_6(2510) \to \pi\pi$	135+ 135

REFERENCES FOR $f_6(2510)$

BINON 84 LNC 39 41 +DONSKOV,DUTEIL,GOUANERE+ (SERP+BELG+LAPP) JP

$e^+e^-(1100-2200)$

$I^G(J^{PC}) = ?^?(1^{--})$

OMITTED FROM SUMMARY TABLE

THIS ENTRY CONTAINS NON-STRANGE VECTOR MESONS COUPLED TO E+ E-(PHOTON) BETWEEN PHI AND J/PSI MASS REGION. SEE ALSO RHO(1250), RHO(1600),AND PHI(1680).

$e^+e^-(1100-2200)$ MASSES AND WIDTHS (MeV)

M		(1097.0)	(16.0)	(19.0)	BARTALUCC	79	OSPK	7 GAM P,E+ E- P
W		(31.0)	(24.0)	(20.0)	BARTALUCC	79	OSPK	7 GAM P,E+ E- P
M		(1830.0)	APPROX.		PETERSON	78	SPEC	GAM P,K+ K- P
W		(120.0)	APPROX.		PETERSON	78	SPEC	GAM P,K+ K- P
M	C	(2130.)	APPROX.		ESPOSIT1	78	FRAM	E+E-,K*(892)+..
W	C	(30.)	APPROX.		ESPOSIT1	78	FRAM	E+E-,K*(892)+..
M	A	(1820.)	APPROX.		SPINETTI	79	RVUE	E+E-,4 PI+- 2GAM
W	A	(30.)	APPROX.		SPINETTI	79	RVUE	E+E-,4 PI+- 2GAM

A INTEGRATED CROSS-SECTION OF BACCI 77, BARBIELLINI 77, ESPOSITO 77.
C NOT SEEN BY DELCOURT 79.

REFERENCES FOR $e^+e^-(1100-2200)$

BACCI 75 PL 58 B 481 +BIDOLI,PENSO,STELLA,BALDINI,+ (ROMA+FRAS)

BACCI 76 PL 64 B 356 +BIDOLI,PENSO,STELLA,BALDINI,+ (ROMA+FRAS)

BACCI 77 PL B 68 393 +DE ZORZI,PENSO,STELLA,BALDINI,+(ROMA+FRAS)
BARBIELL 77 PL B 68 397 BARBIELLINI,BARLETTA,+(FRAS+NAPL+PISA+SANI)
BARTALUC 77 NC A 39 374 BARTALUCCI BERTOLUCCI,BRADASCHIA(DESY+FRAS)
ESPOSITO 77 PL B 68 389 +FELICETTI,MARINI,+ (FRAS+NAPL+PADO+ROMA)

AMBROSIO 78 PL 80 B 141 +CERRITO,BEMPORAD,BROSCO,+ (NAPL+PISA+ROMA)
BALDINI 78 PL 78 B 167 +BATTISTONI,CAPON,BACCI,DEZORZI+(FRAS+ROMA)
ESPOSIT1 78 LNC 22 305 ESPOSITO,FELICETTI+ (FRAS+NAPL+PADO+ROMA)
ESPOSIT2 78 LNC 23 604 ESPOSITO,FELICETTI+ (FRAS+NAPL+PADO+ROMA)
PETERSON 78 PR D 18 3955 +DIXON,EHRLICH,GALIK,LARSON+ (CORN+HARV)

BARTALUC 79 NC 49 A 207 BARTALUCCI,BASINI,BERTOLUCCI+ (DESY+FRAS)
DELCOURT 79 BATAVIA CONF.499 +BERTRAND,BISELLO,BIZOT,BUON,CORDIER+(LALO)
ESPOSITO 79 LNC 25 5 +MARINI,PALLOTTA+ (FRAS+UMD+PADO+ROMA)
SPINETTI 79 BATAVIA CONF.506 M. SPINETTI (FRAS)

BALDINI 81 LNC 30 337 +BATTISTONI,CAPON,BACCI,DEZORZI+(FRAS+ROMA)

$\bar{N}N(1200-3600)$

OMITTED FROM SUMMARY TABLE

THIS ENTRY CONTAINS VARIOUS HIGH MASS, NON-STRANGE STRUCTURES COUPLED TO THE BARYON-ANTIBARYON SYSTEM AS WELL AS QUASI-NUCLEAR BOUND STATES BELOW THRESHOLD.

SEE ALSO X(1935), RHO(2150), F2(2150), RHO3(2250), F4(2300), RHO5(2350). EVIDENCE FOR STRUCTURES COUPLED TO THE ANTIHYPERON NUCLEON (OR C.C.) SYSTEM IS LISTED UNDER K(2200).

$\bar{N}N(1200-3600)$ MASSES AND WIDTHS (MeV)

M	W G	1210.	5.0		RICHTER	83	CNTR	0 STOPPED PBARS
M	W G	(1395.)			PAVLOPOUL	78	CNTR	STOPPED PBARS
M		1637.1	5.6	7.3	ADIELS	84	CNTR	PBAR HELIUM
M	W G	1638.	3.0		RICHTER	83	CNTR	0 STOPPED PBARS
M		1644.0	5.6	7.3	ADIELS	84	CNTR	PBAR HELIUM
M	W G	(1646.)			PAVLOPOUL	78	CNTR	STOPPED PBARS
M	W G	(1684.)			PAVLOPOUL	78	CNTR	STOPPED PBARS
M		1687.1	5.0	4.3	ADIELS	84	CNTR	PBAR HELIUM

Meson Full Listings

$\bar{N}N(1200-3600)$, $X(1900-3600)$

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M  W G     1694.        2.0                 RICHTER   83 CNTR  0 STOPPED PBARS

M  W G     1771.        1.0                 RICHTER   83 CNTR  0 STOPPED PBARS
   W     OBSERVED WIDTHS CONSISTENT WITH EXPERIMENTAL RESOLUTION.
     G   THEY LOOKED FOR RADIATIVE TRANSITIONS TO BOUND P PBAR STATES,
     G   MONO-ENERGETIC GAMMA RAYS DETECTED.

M   ZD    (1794.5)    (1.4)                 GRAY      71 DBC  -  0.PBAR D
W   ZD       (8.)   OR LESS  CL=.95         GRAY      71 DBC  -  0.PBAR D
     D  DECAYS TO FOUR OR MORE PIONS,I=1.
    Z   NOT SEEN BY AMSLER 80.

M   Z     (1897.)     (1.)                  KALOGERO  75 DBC  -  PBAR N ANNIH
W   Z       (25.)     (6.)                  KALOGERO  75 DBC  -  PBAR N ANNIH
    Z   NOT SEEN BY ALBERI 79, AMSLER 80.

M  B      (1897.0)   (17.0)                 ABASHIAN  76 STRC    8PI-P,P 3PI
W  B       (110.0)   (82.0)                 ABASHIAN  76 STRC    8PI-P,P 3PI
   B    PRODUCED BACKWARDS.

M    R    (1920.0)  APPROX.                 EVANGELIS 79 OMEG    10,16 PI-P,PB P
W          (190.0)  APPROX.                 EVANGELIS 79 OMEG    10,16 PI-P,PB P
     R  I=1,JP=1- FROM A MASS DEPENDENT PARTIAL WAVE ANALYSIS TAKING
     R  SOLUTION A.

M          1940.      20.                   TANIMORI  85 CNTR    .4-.8 PPBAR,M+M-  |
W           (40.)  OR LESS                  TANIMORI  85 CNTR    .4-.8 PPBAR,M+M-  |

M    I     1949.      10.                   DEFOIX    80 HBC   0 0-1.2 PB P,5 PI
W    I      80.       20.                   DEFOIX    80 HBC   0 0-1.2 PB P,5 PI
     I  ISOSPIN = 1 FAVORED

M   Z  153(2020.0)    (3.0)                 BENKHEIRI 77 OMEG  0 9,12PI-P,PPPBPI-
W   Z  153  (24.0)   (12.0)                 BENKHEIRI 77 OMEG  0 9,12PI-P,PPPBPI-
    Z   NOT SEEN BY BIONTA 80, CARROLL 80, HAMILTON 80, BANKS 81, CHUNG 81,
    Z   BARNETT 83.
M    T    (2020.0)  APPROX.                 EVANGELIS 79 OMEG    10,16 PI-P,PB P
W          (160.0)  APPROX.                 EVANGELIS 79 OMEG    10,16 PI-P,PB P
     T  I=0,JP=2+ FROM A MASS DEPENDENT PARTIAL WAVE ANALYSIS TAKING
     T  SOLUTION A.

M   Z     (2022.0)    (6.0)                 AZOOZ     83 HYBR +  6 PBARP,PNBAR3PI
W   Z       (14.0)   (13.0)                 AZOOZ     83 HYBR +  6 PBARP,PNBAR3PI

M         2023.0      5.0                   BODENKAMP 83 SPEC  0 GAM P, PBAR P P  |
W           27.0     12.0                   BODENKAMP 83 SPEC  0 GAM P, PBAR P P  |

M   Z     (2026.0)    (5.0)                 AZOOZ     83 HYBR -  4 PBARP,PBARN3PI
W   Z       (20.0)   (11.0)                 AZOOZ     83 HYBR -  4 PBARP,PBARN3PI

M  K       2080.      10.                   KREYMER   80 STRC  D 13 PI-D,PPBN(N)
W  K        110.      20.                   KREYMER   80 STRC  D 13 PI-D,PPBN(N)
   K    NEUTRON SPECTATOR. SEE ALSO NPPBPI-(P) CHANNEL FOLLOWING.

M  L      2090.0     20.0                   KREYMER   80 STRC    13 PI-D,NPPBPI-P
W  L       170.0     50.0                   KREYMER   80 STRC    13 PI-D,NPPBPI-P
   L    PROTON  SPECTATOR. SEE ALSO PPBN(N) CHANNEL ABOVE.

M    R    (2110.0)  APPROX.                 EVANGELIS 79 OMEG    10,16 PI-P,PB P
W    R     (330.0)  APPROX.                 EVANGELIS 79 OMEG    10,16 PI-P,PB P
     R  I=1,JP=3- FROM A MASS DEPENDENT PARTIAL WAVE ANALYSIS TAKING
     R  SOLUTION A.

M    N    2110.0     10.0                   ROZANSKA  80 SPRK    18.PI-P,P PB N
W    N     190.0     10.0                   ROZANSKA  80 SPRK    18.PI-P,P PB N
     N  I=1,JP=3- FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE

M    S    (2141.)                           DONALD    73 HBC   0 S CHANNEL PBAR P
W    S      (14.)                           DONALD    73 HBC   0 S CHANNEL PBAR P
     S  SEEN IN FINAL STATE (OMEGA PI+ PI-)

M    M    2180.0     10.0                   ROZANSKA  80 SPRK    18.PI-P,P PB N
W    M     270.0     10.0                   ROZANSKA  80 SPRK    18.PI-P,P PB N
     M  I=0,JP=2+ FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE

M   K     (2190.0)                          KALBFLEIS 69 HBC    0 S-CHANNEL PBARP
W   K      BETWEEN 20 AND 80 MEV            KALBFLEIS 69 HBC    0 S-CHANNEL PBARP
    K   SEEN IN PBAR P TO RHO0 RHO0 PI0. IG=1-.
    K   NOT SEEN BY BACON 73, DONALD 73.
    K   NOT SEEN BY ZEMANY 76 IN RHO0 RHO0 PI-.

M   Z   58(2204.0)    (5.0)                 BENKHEIRI 77 OMEG -  9,12PI-P,PPPBPI-
W   Z   58  (16.)   OR LESS                 BENKHEIRI 77 OMEG -  9,12PI-P,PPPBPI-
    Z   NOT SEEN BY BIONTA 80, BANKS 81, CHUNG 81, BARNETT 83.

M   A     (2207.)    (13.)                  ALLES-BOR 67 HBC    0 5.7 PBAR P
W   A       (62.)    (52.)                  ALLES-BOR 67 HBC    0 5.7 PBAR P
    A   ALLES-BORELLI 67 SEE NEUTRAL MODE ONLY (PI+PI-PI0)

M         2210.0     79.0      21.0         EVANGEL2  79 OMEG    10. PI-P,K+ K- N
W         (203.0)  APPROX.                  EVANGEL2  79 OMEG    10. PI-P,K+ K- N

M    R    (2260.0)  APPROX.                 EVANGELIS 79 OMEG    10,16 PI-P,PB P
W    R     (440.0)  APPROX.                 EVANGELIS 79 OMEG    10,16 PI-P,PB P
     R  I=0,JP=4+ FROM A MASS DEPENDENT PARTIAL WAVE ANALYSIS TAKING
     R  SOLUTION A.

M         2307.0      6.0                   ALPER     80 CNTR  0 62 PI-P,K+ K- N
W          245.0     20.0                   ALPER     80 CNTR  0 62 PI-P,K+ K- N

M    M    2380.0     10.0                   ROZANSKA  80 SPRK    18.PI-P,P PB N
W    M     380.0     20.0                   ROZANSKA  80 SPRK    18.PI-P,P PB N
     M  I=0,JP=4+ FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE

M    M    (2450.0)   (10.0)                 ROZANSKA  80 SPRK    18.PI-P,P PB N
W    M     (280.0)   (20.0)                 ROZANSKA  80 SPRK    18.PI-P,P PB N
     M  I=1,JP=5- FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE

M  J      (2480.0)   (30.0)                 CARTER    77 CNTR  0 .7-2.4PB P,PIPI
W  J       (210.0)   (25.0)                 CARTER    77 CNTR  0 .7-2.4PB P,PIPI
   J    I=1,JP=5- FROM AMPLITUDE ANALYSIS OF PBAR P INTO PI PI.

M    K    (2500.0)  APPROX.                 CARTER    78 CNTR  0 .7-2.4PB P,K-K+
W    K     (150.0)  APPROX.                 CARTER    78 CNTR  0 .7-2.4PB P,K-K+
     K  I=0,1.JP=5- FROM BARRELET ZERO ANALYSIS.

M         (2710.0)   (20.0)                 ROZANSKA  80 SPRK    18.PI-P,P PB N
W          (170.0)   (40.0)                 ROZANSKA  80 SPRK    18.PI-P,P PB N

M  V      (2850.0)    (5.0)                 BRAUN     76 DBC  -  5.5PBAR D,N NBP+
W  V        (39.)   OR LESS                 BRAUN     76 DBC  -  5.5PBAR D,N NBP+
   V    DECAYS TO NBAR N AND NBAR N PI. NOT SEEN BY BARNETT 83.

M  W      (3080.)    (20.)                  ALEXANDER 72 HBC   0 6.94 PBAR P
W  W       (220.)    (70.)                  ALEXANDER 72 HBC   0 6.94 PBAR P
   W    DECAYS TO 3PI+ 3PI-
   W    NOT SEEN BY KALELKAR 75 WITH 1.5 TIMES MORE DATA

M  X      (3370.)    (10.)                  ALEXANDER 72 HBC   0 6.94 PBAR P
W  X       (150.)    (40.)                  ALEXANDER 72 HBC   0 6.94 PBAR P
   X    DECAYS TO 4PI+ 4PI-

M  Y      (3390.)    (20.)                  ALEXANDER 72 HBC   0 6.94 PBAR P
W  Y       (220.)   (100.)                  ALEXANDER 72 HBC   0 6.94 PBAR P
   Y    DECAYS TO 3PI+ 3PI-
   Y    NOT SEEN BY KALELKAR 75 WITH 1.5 TIMES MORE DATA

M  Z      (3600.)    (20.)                  ALEXANDER 72 HBC   0 6.94 PBAR P
W  Z       (140.)    (20.)                  ALEXANDER 72 HBC   0 6.94 PBAR P
   Z    DECAYS TO 4PI+ 4PI-
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REFERENCES FOR $\bar{N}N(1200-3600)$

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ALLES-BO 67 NC 50 A 776         ALLES-BORELLI,FRENCH,FRISK,+    (CERN+BONN)G=

KALBFLEI 69 PL 29 B  259        G.KALBFLEISCH,R.STRAND,V.VANDERBURG   (BNL)

ALEXANDE 70 PRL 25 63           +BAR-NIR,DAGAN,GIDAL,GRUNHAUS+   (TEL-AVIV)
KALBFLEI 70 PHILAD.CONF.P.409 G.KALBFLEISCH AND D.MILLER REVIEWS      (BNL)

GRAY     71 PRL 26 1491          +HAGERT,KALOGEROPOULOS                (SYRA)

ALEXANDE 72 NP B 45 29          ALEXANDER,BAR-NIR,BEVARY,DAGAN,+       (TELA)
BOGDANOV 72 PRL 28 1418         BOGDANOVA,DALKAROV,SHAPIRO             (ITEP)
BUGG     72 PR D 6 3047         +CONDO,HART,COHN,ENDORF,+  (TENN+ORNL+CINC)
CLAYTON  72 NP B 47 81          +MASON,MUIRHEAD,RIGOPOULOS,+    (LIVP+PATR)

BOWEN    73 PRL 30 332          +EARLES,FAISSLER,BLIEDEN,+      (NEAS+STON)
DONALD   73 NP B 61 333         +EDWARDS,GIBBINS,BRIAND,DUBOC,+ (LIVP+LPNP)
GRAY     73 PRL 30 1091         +PAPADOPOULOU,KARAGEROPOULOS,+  (ATEN+SYRA)
NICHOLSO 73 PR D 7 2572         NICHOLSON,DELORME,CARROLL,+  (CIT+ROCH+BNL)

HYAMS    74 NP B 73 202         +JONES,WEILHAMMER,BLUM,+        (CERN+MPIM)

DONNACHI 75 NC 26 A 317         A.DONNACHIE,P.R.THOMAS         (MANCHESTER)
EISENHAN 75 NP B 96 109         EISENHANDLER,GIBSON,+ (LOQM+LIVP+DARE+RHEL)
KALOGERO 75 PRL 34 1047         KALOGEROPOULOS,TZANAKOS                (SYRA)

ABASHIAN 76 PR D 13 5           +WATSON,GELFAND,BUTTRAM+(ILL+ANL+CHIC+IOWA)
BRAUN    76 PL B 60 481         +BRICK,FRIDMAN,GERBER,JUILLOT,MAURER+(STRB)
ZEMANY   76 NP B 103 537        +MING MA,MOUNTZ,SMITH                   (MSU)

BENKHEIR 77 PL B 68 483         BENKHEIRI,BOUCROT,+   (CERN-CDEF+EPOL+LALO)
CARTER   77 PL 67 B 117         +COUPLAND,EISENHANDLER,ASTBURY,+(LOQM+RHEL)JP
EVANGELI 77 PL B 72 139         EVANGELISTA+    (BARI+BONN+CERN+DARE+GLAS+)

BALTAY   78 PR D 17 62          +CAUTIS,COHEN,CSORNA,KALELKAR+  (COLU+BING)
CARTER   78 NP B 141 467        A.A.CARTER                             (LOQM)
PAVLOPOU 78 PL 72 B 415         PAVLOPOULOS+      (KARL+BASL+CERN+STOH+STRB)
PENNINGT 78 NP B 137 77         M.R. PENNINGTON                        (CERN)

ALBERI   79 PL 83 B 247         +ALVEAR,CASTELLI,POROPAT+  (TRST+CERN+IFRJ)
ALSTON-G 79 PRL 43 1901         ALSTON-GARNJOST,HAMILTON+     (LBL+MTHO+BNL)
ARMSTRON 79 PL B 85 304         ARMSTRONG+ (AACH+BARI+BONN+CERN+GLAS+LIVP+)
BENKHEIR 79 PL 81 B 380         BENKHEIRI,BOUCROT,+   (EPOL+LALO+CDEF+CERN)
BOWCOCK  79  PREP. BIRMINGH.    J.E.BOWCOCK,D.C.HODGSON                (BIRM)
CARROLL  79 PR D 19 1950        +CHIANG,KYCIA,LI,LITTENBERG,+    (BNL+ROCH)
DELCOURT 79 PL B 86 395         +DERADO,BERTRAND,BISELLO,BIZOT,BUON,+(LALO)
EVANGELI 79 NP B 153 253        + (BARI+BONN+CERN+DARE+GLAS+LIVP+MILA+WIEN)
EVANGEL2 79 NP B 154 381        + (BARI+BONN+CERN+DARE+GLAS+LIVP+MILA+WIEN)
GIBBARD  79 PRL 42 1593         +AHRENS,BERKELMAN,CASSEL,DAY,HARDING+(CORN)
MARTIN   79 PL B 86 93          A.D. MARTIN,M.R. PENNINGTON            (DURH)

ALPER    80 PL 94 B 422         +BECKER,+     (AMST+CERN+CRAC+MPIM+OXF+RHEL)
AMSLER   80 PRL 44 853          +AUERBACH,MANDELKERN,+         (UNM+TEMP+UCI)
BIONTA   80 PRL 44 909          +CARROLL,EDELSTEIN,+   (BNL+CARN+FNAL+SMAS)
BIONTA 2 80 PRL 46 970          +CARROLL,EDELSTEIN,+   (BNL+CARN+FNAL+SMAS)
CARROLL  80 PRL 44 1572         +CHIANG,JOHNSON,CESTER,WEBB,+    (BNL+PRIN)
CHUNG    80 PRL 45 1611         +ETKIN,BENSINGER,+(BNL+BRAN+CUNY+SMAS+MASA)
DEFOIX   80 NP B 162 12         +DOBRZYNSKI,ANGELINI,BIGI,+      (CDEF+PISA)
HAMILTON 80 PRL 44 1179         +PUN,TRIPP,LAZARUS,NICHOLSON (LBL+BNL+MTHO)
KREYMER  80 PR D 22 36          +BAGGETT,FIEGUTH,ALAM,+(IND+PURD+SLAC+VAND)
ROZANSKA 80 NP B 162 505        +BLUM,DIETL,GRAYER,LORENZ+       (MPIM+CERN)

BANKS    81 PL 100 B 191        +BOOTH,CAMPBELL,ARMSTRONG,+      (LIVP+CERN)
CHUNG    81 PRL 46 395          +BENSINGER,+         (BNL+BRAN+CINC+FSU+SMAS)

AJALTOUN 82 NP B 209 301        AJALTOUNI,BACHMAN+    (CERN+NEUC+EPOL+CDEF)

AZOOZ    83 PL 122 B 471        +BUTTERWORTH(LOIC+RHEL+SACL+SLAC+TOHO+TUFT)
BARNETT  83 PR D 27 493         +BLOCKUS,BURKA,CHIEN,CHRISTIAN+         (JHU)
BENSINGE 83 PR D 27 1417        BENSINGER,CHUNG    (BRAN+BNL+CINC+FSU+SMAS)
BODENKAM 83 PL 133 B 275        BODENKAMP,FRIES,BEHREND,FENNER+ (KARL+DESY)
RICHTER  83 PL 126 B 284        +ADIELS              (BASL+KARL+STOH+STRB+THES)

ADIELS   84 PL 138 B 235        +BACKENSTOSS+     (BASL+KARL+STOH+STRB+THES)
AZOOZ    84 NP B 244 277        +BUTTERWORTH(LOIC+RHEL+SACL+SLAC+TOHO+TUFT)

ANGELOPO 85 PL 159 B 210        ANGELOPOULOS+      (ATHU+UCI+UNM+PENN+TEMP)
BODENKAM 85 NP B 255 717        BODENKAMP,FRIES,BEHREND,HESSE+  (KARL+DESY)
TANIMORI 85 PRL 55 1835         +FUJII,KAGEYAMA,NAKAMURA,SAI+   (TOKY+TSUK)
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$X(1900-3600)$

OMITTED FROM SUMMARY TABLE   THIS ENTRY CONTAINS VARIOUS HIGH-MASS NON-STRANGE PEAKS.

The high-mass region is covered nearly continuously by evidence for peaks of various widths and decay modes. As a satisfactory grouping into particles is not yet possible, we list all the $Y = 0$ bumps coupled neither to $\bar{N}N$ nor to $e^{+}e^{-}$, and having $M > 1900$ MeV, together, ordered by increasing mass. Note that ANTIPOV 72 ($\pi^{-}p \rightarrow p\,MM^{-}$ at 25 and 40 GeV/c) see no narrow bumps.

$X(1900-3600)$ MASSES AND WIDTHS (MeV)

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M  G      1870.0     40.0            ALDE      85 GAM4  0100 PI-P,2 ETA
W  G       250.0     30.0            ALDE      85 GAM4  0100 PI-P,2 ETA
   G   SEEN IN J=2 WAVE IN ONE OF THE TWO AMBIGUOUS SOLUTIONS.

M     100(1898.)    (18.)            THOMPSON  74 HBC  +  13 PI+ P,2RHO
W     100 (108.)    (41.)    (27.)   THOMPSON  74 HBC  +  13 PI+ P,2RHO

M     100(1900.)    (40.)            BOESEBECK 68 HBC  +   8 PI+ P,PI+ PIO
W     100 (216.)   (105.)            BOESEBECK 68 HBC  +   8 PI+ P,PI+ PIO

M        (1970.)    (10.)            CHLIAPNIK 80 HBC   0 32 K+ P,2KS 2PI
W        (1970.)    (10.)            CHLIAPNIK 80 HBC   0 32 K+ P,2KS 2PI

M      30(1973.0)   (15.0)           CASO      70 HBC   - 11.2PI-P,RHO 2PI
W      30  (80.0)                    CASO      70 HBC   - 11.2PI-P,RHO 2PI

M   K  40(1975.0)   (12.0)           KRAMER    70 HBC  +  13.1 PI+ P,2PI
W   K  40  (52.0)  OR LESS  CL=.90   KRAMER    70 HBC  +  13.1 PI+ P,2PI
    K  2PI PEAK OF KRAMER NOT SEEN IN SAME EXP WITH MORE DATA(THOMPSON 74)

M      50(2070.)                     TAKAHASHI 72 HBC     8. PI-P,N 2PI
W      50 (160.)                     TAKAHASHI 72 HBC     8. PI-P,N 2PI

M  F      2100.0     40.0            ALDE      85 GAM4  0100 PI-P,2 ETA
W  F       250.0     40.0            ALDE      85 GAM4  0100 PI-P,2 ETA
   F   SEEN IN J=0 WAVE IN ONE OF THE TWO AMBIGUOUS SOLUTIONS.

M  A   24(2145.)    (10.)            AJINENKO  80 HBC  +  32 K+P,PHI PI+ X
M  AW  10(2100.)    (20.)            BARTH     82 BEBC +  70 K+P,PHI PI+ P
W  AW  24  (25.)   OR LESS           AJINENKO  80 HBC  +  32 K+P,PHI PI+ X
   A   ASTON 81 SEES NO PEAK, HAS 850 EVENTS IN AJINENKO+BARTH BINS.
   A   ARESTOV 80 SEES NO PEAK.
    W  COMPATIBLE WITH ESTIMATED EXPERIMENTAL RESOLUTION

M  E     (2157.0)   (10.0)           KRAMER    70 HBC  +  13.1 PI+ P,2PI
W  E       (68.0)   (22.0)           KRAMER    70 HBC  +  13.1 PI+ P,2PI
   E   EVIDENCE OF KRAMER 70 DISAPPEARED WITH MORE STATISTICS(THOMPSON 74)

M        (2190.0)   (10.0)           CLAYTON   67 HBC  +- 2.5PBAR,A2+OMEGA

M   C    (2207.0)   (22.0)           CASO      70 HBC   - 11.2PI- P,NOTE C
W   C     (130.0)                    CASO      70 HBC   - 11.2PI- P,NOTE C
    C  SEEN IN RHO- PI+ PI- (OMEGA AND ETA ANTISELECTED IN 4PI SYSTEM)

M        (2300.0)  (100.0)           ATKINSON  84 OMEG +-020-70GAM P,RHO F
W         (250.0)  APPROX.           ATKINSON  84 OMEG +-020-70GAM P,RHO F

M  B  126(2340.)    (20.)            BALTAY    75 HBC  +  15 PI+P,P5PI
W  B  126 (180.)    (60.)            BALTAY    75 HBC  +  15 PI+P,P5PI
   B   DOMINANT DECAY INTO RHO0 RHO0 PI+. BALTAY 78 FINDS CONFIRMATION
   B   IN 2PI+PI-2PI0 EVENTS WHICH CONTAIN RHO+ RHO0 PI0 AND 2RHO+PI-.

M        (2500.0)   (32.0)           ANDERSON  69 MMS   -  16 PI- P,BACKW9
W          (87.0)                    ANDERSON  69 MMS   -  16 PI- P,BACKW9

M     550(2620.)    (20.)            BAUD      69 MMS   -  8.-10. PI- P
W     550  (85.)    (30.)            BAUD      69 MMS   -  8.-10. PI- P

M        (2676.0)   (27.0)           CASO      70 HBC   - 11.2PI- P,NOTE C
W         (150.0)                    CASO      70 HBC   - 11.2PI- P,NOTE C
    C  SEEN IN RHO- PI+ PI- (OMEGA AND ETA ANTISELECTED IN 4PI SYSTEM)

M        (2747.)    (32.)            DENNEY    83 LASS    10 PI+N /PI+ P
W         (195.)    (75.)            DENNEY    83 LASS    10 PI+N /PI+ P

M     640(2800.)    (20.)            BAUD      69 MMS   -  8.-10. PI- P
W     640  (46.)    (10.)            BAUD      69 MMS   -  8.-10. PI- P

M  C   15(2820.)    (10.)            SABAU     71 HBC  +  8. PI+ P
W  C   15  (50.)    (10.)            SABAU     71 HBC  +  8. PI+ P
   C   SEEN IN (K KBAR PI PI)+ MASS DISTRIBUTION

M     230(2880.)    (20.)            BAUD      69 MMS   -  8.-10. PI- P
W     230  (15.)   OR LESS           BAUD      69 MMS   -  8.-10. PI- P

M  Y   43(3013.)     (5.)            YOST      71 HBC  +  11.PI+ P,P(8PI)+
W  Y   43  (40.)   OR LESS           YOST      71 HBC  +  11.PI+ P,P(8PI)
   Y   4.3 S.D. EFFECT  . DECAY TO 7PIONS
   Y   NOT SEEN BY KALELKAR 75 WITH 5 TIMES MORE DATA

M        (3025.0)   (20.0)           BAUD      70 MMS   - 10.5-13 PI- P
W          (25.0)  APPROX.           BAUD      70 MMS   - 10.5-13 PI- P

M        (3075.0)   (20.0)           BAUD      70 MMS   - 10.5-13 PI- P
W          (25.0)  APPROX.           BAUD      70 MMS   - 10.5-13 PI- P

M        (3145.0)   (20.0)           BAUD      70 MMS   - 10.5-15 PI- P
W          (10.0)  OR LESS           BAUD      70 MMS   - 10.5-15 PI- P

M        (3475.0)   (20.0)           BAUD      70 MMS   - 14-15.5 PI- P
W          (30.0)  APPROX.           BAUD      70 MMS   - 14-15.5 PI- P

M        (3535.0)   (20.0)           BAUD      70 MMS   - 14-15.5 PI- P
W          (30.0)  APPROX.           BAUD      70 MMS   - 14-15.5 PI- P
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REFERENCES FOR $X(1900-3600)$

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CLAYTON  67 HEIDBG.CONF.P.57  +MASON,MUIRHEAD,FILIPPAS+(LIVERPOOL+ATHENS)

BOESEBEC 68 NP B 4 501        BOESEBECK,DEUTSCHMANN,+(AACHEN+BERLIN+CERN)

ANDERSON 69 PRL 22 1390       +COLLINS,+                       (BNL+CARN)
BAUD     69 PL  30B 129       CERN BOSON SPECTROMETER GROUP       (CERN)

BAUD     70 PL 31 B 549       CERN BOSON SPECTROMETER GROUP       (CERN)
CASO     70 LNC 3 707         +CONTE,TOMASINI,CORDS+(GENO+HAMB+MILA+SACL)
KRAMER   70 PRL 25 396        +BARTON,GUTAY,LICHTMAN,MILLER,+   (PURDUE)

SABAU    71 LNC 1 514         +URETSKY                        (BUCH+ANL)
YOST     71 PR D 3 642        +MORRIS,ALBRIGHT,BRUCKER,LANNUTTI    (FSU)

TAKAHASH 72 PR D 6 1266       TAKAHASHI,BARISH,+     (TOHO+PENN+NDAM+ANL)

THOMPSON 74 NP B69 220        +GAIDOS,MCILWAIN,MILLER,MULERA,+    (PURD)

BALTAY   75 PRL 35 891        +CAUTIS,COHEN,KALELKAR,PISELLO,+(COLU+BING)
KALELKAR 75 THESIS(NEVIS 207) M.S.KALELKAR                        (COLU)
KEMP     75 NC 27 A 155       +LOTTS,CONTRI,TEODORO+(DURH+GENO+MILA+LPNP)

BALTAY   78 PR D 17 52        +CAUTIS,COHEN,CSORNA,KALELKAR+ (COLU+BING)
BLANAR   79 PR D 20 615       +BOYER,EARLES,FAISSLER,GARELICK+    (NEAS)
CLINE    79 PRL 43 1771       +DE BONTE,GAIDOS,LEEDOM,KEY,+  (PURD+TNTO)

AJINENKO 80 PL 95 B 451       +CHLIAPNIKOV,+         (SERP+BELG+MONS+SACL)
CHLIAPNI 80 ZPHY C 3 285      CHLIAPNIKOV,GERDYUKOV,+     (SERP+BRUX+MONS)

ASTON    81 NP B 189 205      (BONN+CERN+EPOL+GLAS+LANC+MCHS+ORSA+RHEL++)

BARTH    82 PL 117 B 267      +DREVERMANN+(BELG+CERN+GENO+MONS+NIJM+SERP)

ATKINSON 83  CERN-EP/83-106   + (BONN+CERN+GLAS+LANC+MCHS+IPNP+RHEL+SHEF)
DENNEY   83 PR D 28 2726      +CRANLEY,FIRESTONE,CHAPMAN+    (IOWA+MICH)J=7-

ATKINSON 84 NP B 239 1        + (BONN+CERN+GLAS+LANC+MCHS+IPNP+RHEL+SHEF)
DOVER    84 PL 146 B 103      C.B.DOVER                           (ORSA)

ALDE     85  CERN-EP/85-153   +BINON,BRICMAN,DUTEIL+(BELG+LAPP+SERP+CERN)
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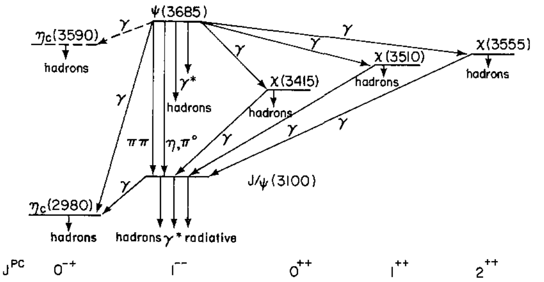
THE CHARMONIUM SYSTEM



The current state of knowledge of the charmonium system and transitions, as interpreted by the charmonium model. Uncertain states and transitions are indicated by dashed lines. The notation γ^* refers to decay processes involving intermediate virtual photons, including decays to e^+e^- and $\mu^+\mu^-$.

$\eta_c(2980)$

$I^G(J^{PC}) = 0^+(0^{-+})$

```
                OBSERVED IN THE INCLUSIVE GAMMA SPECTRUM GENERATED FROM
                PSI(3685) DECAY, THEREFORE C=+. FROM THE 4PI DECAY G=+,
THEREFORE I=0.  FROM ANGULAR DISTRIBUTION IN J/PSI TO ETA/C, ETA/C TO
PHI PHI, JP=0- (BALTRUSAITIS 84).
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$\eta_c(2980)$ MASS (MeV)

```
M  M    18 2982.      8.             HIMEL     80 SMK2    E+ E-
M   M     (2980.)    (9.)            PARTRIDGE 80 CBAL    E+ E-
M  B      (2976.)    (8.)            BALTRUSAI 84 SMK3   J/PSI, 2 PHI GAM
M       75(2977.)    (4.)            BALTRUSAI 85 SMK3   J/PSI,ETA 2PI G
M  A       2980.2     1.6            BALTRUSAI 85 SMK3   J/PSI,ETAC GAMMA
M          2984.      5.             GAISER    85 CBAL   J/PSI,GAMMA X
M          . . . . . . . . . .
M   AVG    2980.6     1.5    AVERAGE

M  M    MASS ADJUSTED BY US TO CORRESPOND TO J/PSI(3097) MASS = 3097.
M  B    ETA/C TO PHI PHI
M  A    AVERAGE OF SEVERAL DECAY MODES.
```

$\eta_c(2980)$ WIDTH (MeV)

```
W       18  (40.)   OR LESS  CL=.90  HIMEL     80 SMK2    E+ E-
W           (20.)   OR LESS  CL=.90  PARTRIDGE 80 CBAL    E+ E-
W  A    75   11.       16.           BALTRUSAI 85 SMK3   J/PSI,ETA 2PI G
W            11.5      4.5           GAISER    85 CBAL   J/PSI,GAMMA X
W          . . . . . . . . . .
W   AVG      11.5 .    4.3   AVERAGE

W  A    AVERAGE OF SEVERAL DECAY MODES.
```

η_c(2980) PARTIAL DECAY MODES

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P         HADRONIC DECAYS
P         ---------------
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P11	$\eta_c(2980) \rightarrow 2(\pi^+\pi^-)$	140+ 140+ 140+ 140
P12	$\eta_c(2980) \rightarrow p\overline{p}$	938+ 938
P13	$\eta_c(2980) \rightarrow \pi^+\pi^- p\overline{p}$	140+ 140+ 938+ 938
P14	$\eta_c(2980) \rightarrow K\overline{K}\pi$	498+ 498+ 140
P15	$\eta_c(2980) \rightarrow \pi^+\pi^- K^+K^-$	140+ 140+ 494+ 494
P16	$\eta_c(2980) \rightarrow \eta\pi^+\pi^-$	549+ 140+ 140
P17	$\eta_c(2980) \rightarrow \phi\phi$	1020+1020
P18	$\eta_c(2980) \rightarrow K^*(892)\ \overline{K}^*(892)$	892+ 892
P19	$\eta_c(2980) \rightarrow \rho\rho$	769+ 769
P20	$\eta_c(2980) \rightarrow \omega\omega$	783+ 783
P21	$\eta_c(2980) \rightarrow a_0(980)\ \pi$	983+ 140
P22	$\eta_c(2980) \rightarrow a_2(1320)\ \pi$	1318+ 140
P23	$\eta_c(2980) \rightarrow f_2(1270)\ \eta$	1274+ 549
P24	$\eta_c(2980) \rightarrow \eta' 2\pi$	958+ 140+ 140
P25	$\eta_c(2980) \rightarrow \eta 2K$	549+ 498+ 498
P26	$\eta_c(2980) \rightarrow K^*(892)\ K^-\pi^+ +$ C.C.	892+ 498+ 140

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P         RADIATIVE DECAYS
P         ---------------
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P31	$\eta_c(2980) \rightarrow \gamma\gamma$	0+ 0

η_c(2980) BRANCHING RATIOS

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R         HADRONIC DECAYS
R         ---------------
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$\eta_c(2980) \rightarrow (2(\pi^+\pi^-))$/total (P11)

```
R1 A           0.013     0.009     0.006 HIMEL      80 SMK2    PSI3685,ETAC GAM
R1 E           0.013     0.006           BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
R1          . . . . . . . . . .
R1  AVG        0.0130    0.0047   AVERAGE
```

$\eta_c(2980) \rightarrow (\overline{p}\,p)$/total (P12)

```
R2 A           0.002     0.002     0.001 HIMEL      80 SMK2    PSI3685,ETAC GAM
R2 E           0.0011    0.0006          BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
R2          . . . . . . . . . .
R2  AVG       0.00122   0.00056   AVERAGE
```

$\eta_c(2980) \rightarrow (\pi^+\pi^- p\overline{p})$/total (P13)

```
R3            (0.012)OR LESS  CL=.90   HIMEL      80 SMK2    PSI3685,ETAC GAM
```

$\eta_c(2980) \rightarrow (K\overline{K}\pi)$/total (P14)

```
R4 A B         0.105     0.056     0.042 HIMEL      80 SMK2    PSI3685,ETAC GAM
R4 C          (0.071)OR LESS  CL=.90   PARTRIDGE 80 CBAL    J/PSI,ETA/C GAM   |
R4 E           0.048     0.017           BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
R4          . . . . . . . . . .
R4  AVG        0.054     0.018    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$\eta_c(2980) \rightarrow (\pi^+\pi^- K^+K^-)$/total (P15)

```
R5 A           0.009     0.014     0.006 HIMEL      80 SMK2    PSI3685,ETAC GAM
R5 E           0.021     0.007           BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
R5          . . . . . . . . . .
R5  AVG        0.0171    0.0057   AVERAGE
```

$\eta_c(2980) \rightarrow (\eta 2\pi)$/total (P16)

```
R6 C     18    0.036     0.024           PARTRIDGE 80 CBAL    J/PSI,ETA/C GAM   |
R6 E           0.054     0.020           BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
R6          . . . . . . . . . .
R6  AVG        0.047     0.015    AVERAGE
```

$\eta_c(2980) \rightarrow (\phi\phi)$/total (P17)

```
R7 C S   16    0.0080    0.0032          BALTRUSAI  84 SMK3    J/PSI, 2 PHI GAM  |
```

$\eta_c(2980) \rightarrow (K^*(892)\ \overline{K}^*(892))$/total (P18)

```
R8 E           0.009     0.005           BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
```

$\eta_c(2980) \rightarrow (\rho\rho)$/total (P19)

```
R9 E          (0.014)OR LESS  CL=.9    BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
```

$\eta_c(2980) \rightarrow (\omega\omega)$/total (P20)

```
R10E          (0.0031)OR LESS  CL=.9   BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
```

$\eta_c(2980) \rightarrow (a_0(980)\ \pi)$/total (P21)

```
R11E F        (0.02) OR LESS  CL=.9    BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
```

$\eta_c(2980) \rightarrow (a_2(1320)\ \pi)$/total (P22)

```
R12E          (0.02)  OR LESS  CL=.9   BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
```

$\eta_c(2980) \rightarrow (f_2(1270)\ \eta)$/total (P23)

```
R13E          (0.011)OR LESS  CL=.9    BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
```

$\eta_c(2980) \rightarrow (\eta' 2\pi)$/total (P24)

```
R14E           0.041     0.017           BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
```

$\eta_c(2980) \rightarrow (\eta 2K)$/total (P25)

```
R15E          (0.031)OR LESS CL=.9     BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |
```

$\eta_c(2980) \rightarrow (K^*(892)\ K^-\pi^+ +$ C.C.)/total (P25)

```
R16E           0.02      0.007           BALTRUSAI  85 SMK3    J/PSI,ETAC GAMMA  |

R         RADIATIVE DECAYS
R         ---------------
```

$\eta_c(2980) \rightarrow (\gamma\gamma)$/total (units 10^{-4}) (P31)

```
R31C          (18.)   OR LESS  CL=.90   BLOOM      83 CBAL    J/PSI,ETA/C GAM   |
R31            (5.5)  OR LESS  CL=.90   BAGLIN     85 SPEC    PBAR P,E+ E-      |

R  A    ESTIMATED USING BR ( PSI(3685) INTO ETA/C(2980) GAMMA) = .0043
R  A    THE ERRORS DO NOT CONTAIN THE UNCERTAINTY IN THE PSI(3685) DECAY.
R    B  NOT SEEN BY PARTRIDGE IN K+ K- PIO.
R   C   USING BR(J/PSI INTO ETA/C GAMMA) = 0.0127+-0.0036
R  E    BALTRUSAITIS 85 USES BR(J/PSI INTO ETA/C GAMMA)=0.0127+-0.0036
R   F   WE ARE ASSUMING BR(A0(980) INTO ETA PI) LARGER THAN 0.5
R    S  STATISTICAL AND SYSTEMATIC ERRORS ADDED IN QUADRATURE.
```

REFERENCES FOR η_c(2980)

```
BLOOM    79 FERMILAB SYMP.92  E.D.BLOOM          (CIT+HARV+PRIN+SLAC+STAN)

HIMEL    80 PRL 45 1146       +TRILLING,ABRAMS,ALAM+        (SLAC+LBL+UCB)
PARTRIDG 80 PRL 45 1150       PARTRIDGE,PECK+    (CIT+HARV+PRIN+STAN+SLAC)

BLOOM    83 ARNS 33 143       BLOOM,PECK                        (SLAC+CIT)

BALTRUSA 84 PRL 52 2126       BALTRUSAITIS+      (CIT+UCSC+ILL+SLAC+WASH)JP

BAGLIN   85  CERN-PRE-85        (LAPP+CERN+GENO+LYON+OSLO+ROMA+STRB+TORI)
BALTRUSA 85  SLAC-PUB-3704    BALTRUSAITIS+      (CIT+UCSC+ILL+SLAC+WASH)
    ALSO 86  PRIVATE COMM.    R. PARTRIDGE                          (UCSC)
GAISER   85  SLAC-PUB-2899    +BLOOM,BULOS+      (CIT+HARV+PRIN+STAN+SLAC)
```

$J/\psi(3097)$

$I^G(J^{PC}) = 0^-(1^{--})$

J/ψ(3097) MASS (MeV)

```
                     WE USE INDEPENDENT MEASUREMENTS OF THE J/PSI(3097)
                     MASS, THE PSI(3685) MASS AND THE MASS DIFFERENCE TO
                     PERFORM A CONSTRAINED FIT.

M           (3100.)                       AUBERT     74 SPEC    28. PP(E+E-)
M    L      (3105.)     (3.)              AUGUSTIN   74 SMAG         E+E-
M            3103.       6.               BEMPORAD   75 FRAB         E+E-
M   O        3095.       4.               BOYARSKI   75 SMAG         E+E-
M   S        3089.5     31.               CRIEGEE    75 PLUT         E+E-
M            3098.       6.               PREPOST    75 SPEC    13.-21.GAMMA D
M            3096.0     30.0              SNYDER     76 SPEC    400 P BE,E+E-
M   F        3097.0      1.               BRANDELIK  79 DASP    E+ E-
M        502 3096.93     0.09             ZHOLENTZ   80 OLYA    E+E- COLL.BEAMS
M        38K 3098.4      2.0              LEMOIGNE   82 GOLI    190 PI-BE,2MU
M   D    190 3096.92     0.29             BAGLIN     85 SPEC    PBAR P,E+ E-      |
M            . . . . . . . . . .
M    AVG     3096.933    0.086   AVERAGE
M    FIT     3096.93     0.09   FROM FIT

M   F    FROM A SIMULTANEOUS FIT TO E+ E-,MU+ MU- AND HADRONIC CHANNELS
M   F    ASSUMING G(E+ E-) = G(MU+ MU-)
M
M    L   BOYARSKI 75 IS A REEVALUATION OF AUGUSTIN 74 BASED
M    L   ON A RECALIBRATION OF THE SPEAR BEAM ENERGY.
M
M   O    MASS, WIDTH, PARTIAL WIDTHS, AND BRANCHING RATIOS ALL OBTAINED
M   O    FROM ONE OVERALL FIT TO DATA OF THIS EXPERIMENT.
M
M   S    ERROR OF ABOUT 1 PER CENT FROM THE UNCERTAINTY IN CALIBRATION OF
M   S    THE BEAM ENERGY.
M
M   D     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

J/ψ(3097) WIDTH (keV)

```
W            69.        15.               BOYARSKI   75 SMAG         E+E-
W            68.        26.               BALDINI1   75 FRAG         E+E-
W            60         25                ESPOSITO   75 FRAM         E+E-
W   F        58.        13.               BRANDELIK  79 DASP    E+ E-
W   F    FROM A SIMULTANEOUS FIT TO E+ E-,MU+ MU- AND HADRONIC CHANNELS
W   F    ASSUMING G(E+ E-) = G(MU+ MU-)
W            . . . . . . . . . .
W    AVG     63.0        8.6     AVERAGE
```

J/ψ(3097) PARTIAL DECAY MODES

		DECAY MASSES
P1	$J/\psi(3097) \rightarrow e^+e^-$	.511+.511
P2	$J/\psi(3097) \rightarrow \mu^+\mu^-$	106+ 106
P3	$J/\psi(3097) \rightarrow$ hadrons	
P4	$J/\psi(3097) \rightarrow$ virtual $\gamma \rightarrow$ hadrons	

```
P         HADRONIC DECAYS
P         ---------------
```

P6	$J/\psi(3097) \rightarrow \pi^+\pi^-$	140+ 140
P7	$J/\psi(3097) \rightarrow \pi^+\pi^-\pi^0$	140+ 140+ 135
P8	$J/\psi(3097) \rightarrow 2(\pi^+\pi^-)$	140+ 140+ 140+ 140
P9	$J/\psi(3097) \rightarrow 2(\pi^+\pi^-)\ \pi^0$	140+ 140+ 140+ 140+
P10	$J/\psi(3097) \rightarrow 3(\pi^+\pi^-)$	
P11	$J/\psi(3097) \rightarrow 3(\pi^+\pi^-)\ \pi^0$	
P12	$J/\psi(3097) \rightarrow 4(\pi^+\pi^-)\ \pi^0$	

P13	$J/\psi(3097) \to K^+K^-$	494+ 494
P14	$J/\psi(3097) \to K_S^0 K_S^0$	498+ 498
P15	$J/\psi(3097) \to K\bar{K}\pi$	498+ 498+ 140
P16	$J/\psi(3097) \to \pi^+\pi^-K^+K^-$	140+ 140+ 494+ 494
P17	$J/\psi(3097) \to 2(\pi^+\pi^-)\ K^+K^-$	
P18	$J/\psi(3097) \to \pi^+\pi^-\pi^0K^+K^-$	140+ 140+ 135+ 494+
P19	$J/\psi(3097) \to 2(K^+K^-)$	494+ 494+ 494+ 494
P20	$J/\psi(3097) \to \rho\pi$	769+ 140
P21	$J/\psi(3097) \to \rho^0\pi^0$	769+ 135
P22	$J/\psi(3097) \to \rho\eta$	769+ 549
P23	$J/\psi(3097) \to \rho\eta'$	769+ 958
P24	$J/\psi(3097) \to \omega\pi\pi$	783+ 140+ 140
P26	$J/\psi(3097) \to \omega 4\pi$	783+ 140+ 140+ 140+
P27	$J/\psi(3097) \to \omega K\bar{K}$	783+ 498+ 498
P28	$J/\psi(3097) \to \omega f_2(1270)$	783+1274
P29	$J/\psi(3097) \to \omega f_2'(1525)$	783+1525
P30	$J/\psi(3097) \to \omega\eta$	783+ 549
P31	$J/\psi(3097) \to \omega\eta'$	783+ 958
P32	$J/\psi(3097) \to \omega\pi^0$	783+ 135
P33	$J/\psi(3097) \to \phi\pi^0$	1020+ 135
P34	$J/\psi(3097) \to \phi\pi\pi$	1020+ 140+ 140
P35	$J/\psi(3097) \to \phi 2(\pi^+\pi^-)$	1020+ 140+ 140+ 140+
P36	$J/\psi(3097) \to \phi K\bar{K}$	1020+ 498+ 498
P37	$J/\psi(3097) \to \phi\eta$	1020+ 549
P38	$J/\psi(3097) \to \phi\eta'$	1020+ 958
P39	$J/\psi(3097) \to \phi f_2(1270)$	1020+1274
P40	$J/\psi(3097) \to \phi f_2'(1525)$	1020+1525
P41	$J/\psi(3097) \to \phi f_0(975)$	1020+ 975
P42	$J/\psi(3097) \to a_2(1320)\ \pi$	1318+ 140
P43	$J/\psi(3097) \to a_2(1320)\ \rho$	1318+ 769
P44	$J/\psi(3097) \to K\bar{K}^*(892)\ +\ \mathrm{C.C.}$	498+ 892
P45	$J/\psi(3097) \to K\bar{K}_2^*(1430)\ +\ \mathrm{C.C.}$	498+1425
P46	$J/\psi(3097) \to K^*(892)\ \bar{K}^*(892)$	892+ 892
P47	$J/\psi(3097) \to K_2^*(1430)\ \bar{K}_2^*(1430)$	1425+1425
P48	$J/\psi(3097) \to K^*(892)\ \bar{K}_2^*(1430)\ +\ \mathrm{C.C.}$	892+1425
P49	$J/\psi(3097) \to \pi b_1(1235)$	140+1234
P50	$J/\psi(3097) \to p\bar{p}$	938+ 938
P52	$J/\psi(3097) \to p\bar{p}\pi^0$	938+ 938+ 135
P53	$J/\psi(3097) \to p\bar{n}\pi^-$	938+ 940+ 140
P54	$J/\psi(3097) \to p\bar{p}\pi^+\pi^-$	938+ 938+ 140+ 140
P55	$J/\psi(3097) \to p\bar{p}\pi^+\pi^-\pi^0$	938+ 938+ 140+ 140+
P56	$J/\psi(3097) \to p\bar{p}\eta$	938+ 938+ 549
P57	$J/\psi(3097) \to p\bar{p}\rho$	938+ 938+ 769
P58	$J/\psi(3097) \to p\bar{p}\omega$	938+ 938+ 783
P59	$J/\psi(3097) \to p\bar{p}\eta'$	938+ 938+ 958
P60	$J/\psi(3097) \to \Lambda\bar{\Lambda}$	1116+1116
P61	$J/\psi(3097) \to \Lambda\bar{\Sigma}$	1116+1192
P62	$J/\psi(3097) \to \Xi\bar{\Xi}$	1315+1315
P63	$J/\psi(3097) \to \Sigma\bar{\Sigma}$	1192+1192
P64	$J/\psi(3097) \to n\bar{n}$	940+ 940
P65	$J/\psi(3097) \to n\bar{n}\pi^+\pi^-$	940+ 940+ 140+ 140
P66	$J/\psi(3097) \to \Delta(1232)^{++}\bar{\Delta}(1232)^{--}$	1232+1232
P67	$J/\psi(3097) \to \Sigma(1385)^{\mp}\bar{\Sigma}(1385)^{\pm}$	1385+1385
P68	$J/\psi(3097) \to \Sigma(1385)^{\mp}\bar{\Sigma}^{\pm}$	1385+ 135
P69	$J/\psi(3097) \to \bar{p}N(1440-1535)^+$	938+1440
P70	$J/\psi(3097) \to \Delta(1232)^{++}\bar{p}\pi^-$	1232+ 938+ 140
P71	$J/\psi(3097) \to \Lambda\bar{\Sigma}^{\pm}\pi^{\mp}$	1116+ 135+ 140
P72	$J/\psi(3097) \to pK^-\bar{\Lambda}$	938+ 494+1116
P73	$J/\psi(3097) \to pK^-\bar{\Sigma}^0$	938+ 494+1192
P74	$J/\psi(3097) \to pK^-\Sigma(1385)^0$	938+ 494+1385
P75	$J/\psi(3097) \to K_S^0 K_L^0$	498+ 498

```
P       RADIATIVE DECAYS
P       ----------------
```

P80	$J/\psi(3097) \to \gamma\gamma$	0+ 0
P81	$J/\psi(3097) \to 3\gamma$	0+ 0+ 0
P82	$J/\psi(3097) \to \pi^0\gamma$	135+ 0
P83	$J/\psi(3097) \to \eta\gamma$	549+ 0
P84	$J/\psi(3097) \to \eta'\gamma$	958+ 0
P85	$J/\psi(3097) \to \eta_c(2980)\ \gamma$	2981+ 0
P86	$J/\psi(3097) \to f_2(1270)\ \gamma$	1274+ 0
P87	$J/\psi(3097) \to f_2'(1525)\ \gamma$	1525+ 0
P88	$J/\psi(3097) \to f_1(1285)\ \gamma$	1283+ 0
P89	$J/\psi(3097) \to \eta(1440)\ \gamma$	1440+ 0
P90	$J/\psi(3097) \to p\bar{p}\gamma$	938+ 938+ 0
P91	$J/\psi(3097) \to f_2(1720)\ \gamma$	1720+ 0
P92	$J/\psi(3097) \to X(2220)\ \gamma$	2220+ 0
P93	$J/\psi(3097) \to pp\pi^+\pi^-\gamma$	938+ 938+ 140+ 140-
P94	$J/\psi(3097) \to \rho\rho\gamma$	769+ 769+ 0
P95	$J/\psi(3097) \to 2\pi^+2\pi^-\gamma$	140+ 140+ 140+ 140+
P96	$J/\psi(3097) \to \eta\pi\pi\gamma$	549+ 140+ 140+ 0
P97	$J/\psi(3097) \to \omega\omega\gamma$	0+ 783+ 783
P98	$J/\psi(3097) \to \phi\phi\gamma$	1020+1020+ 0

$J/\psi(3097)$ PARTIAL WIDTHS

$J/\psi(3097) \to e^+e^-$ (keV) (G1)

```
W1            4.8      0.6             BOYARSKI  75 SMAG          E+E-
W1   B       (4.6)     (.8)            BALDINI1  75 FRAG          E+E-
W1            4.6      1.0             ESPOSITO  75 FRAM          E+E-
W1   B   ASSUMING EQUAL PARTIAL WIDTHS FOR (E+E-) AND (MU+MU-)
W1   F       (4.4)    (0.6)            BRANDELIK 79 DASP    E+ E-
W1   F   FROM A SIMULTANEOUS FIT TO E+ E-,MU+ MU- AND HADRONIC CHANNELS
W1   F   ASSUMING G(E+ E-) = G(MU+ MU-)
W1         . . . . . . . . . . .
W1   AVG      4.75     0.51    AVERAGE
```

$J/\psi(3097) \to \mu^+\mu^-$ (keV) (G2)

```
W2            4.8      0.6             BOYARSKI  75 SMAG          E-E-
W2            5.0      1.0             ESPOSITO  75 FRAM          E-E-
W2         . . . . . . . . . . .
W2   AVG      4.85     0.51    AVERAGE
```

$J/\psi(3097) \to$ hadrons (keV) (G3)

```
W3           59.      14.              BOYARSKI  75 SMAG          E+E-
W3           59.      24.              BALDINI1  75 FRAG          E+E-
W3           50.      25.              ESPOSITO  75 FRAM          E+E-
W3         . . . . . . . . . . .
W3   AVG     57.3     10.9     AVERAGE
```

$J/\psi(3097) \to \gamma \to$ hadrons (keV) (G4)

```
W4 C         12.       2.              BOYARSKI  75 SMAG          E+E-
W4 C     INCLUDED IN W3
```

$J/\psi(3097) \to \gamma\gamma$ (eV) (G70)

```
W70          (5.4)  OR LESS CL=0.90    BRANDELIK 79 DASP    E+ E-
```

$J/\psi(3097)$ BRANCHING RATIOS

```
         FOR THE BRANCHING RATIOS R1 - R4, SEE ALSO THE PARTIAL
         WIDTHS ABOVE, AND (PARTIAL WIDTHS)*R1 BELOW.
```

$J/\psi(3097) \to (e^+e^-)$/total (P1)/(P1+P2+P3)

```
R1            0.069    0.009           BOYARSKI  75 SMAG          E+E-
```

$J/\psi(3097) \to (\mu^+\mu^-)$/total (P2)/(P1+P2+P3)

```
R2            0.069    0.009           BOYARSKI  75 SMAG          E+E-
```

$J/\psi(3097) \to$ (hadrons)/total (P3)/(P1+P2+P3)

```
R3            0.86     0.02            BOYARSKI  75 SMAG          E+E-
```

$J/\psi(3097) \to (\gamma \to$ hadrons)/total (P4)

```
R4 C           .17      .02            BOYARSKI  75 SMAG          E+E-
R4 C     INCLUDED IN R3
```

$J/\psi(3097) \to (e^+e^-)/(\mu^+\mu^-)$ (P1)/(P2)

```
R5            1.00     0.05            BOYARSKI  75 SMAG          E+E-
R5            0.93     0.10            FORD      75 SPEC          E+E-
R5             .91      .15            ESPOSITO  75 FRAM          E+E-
R5         . . . . . . . . . . .
R5   AVG      0.980    0.043   AVERAGE
```

```
R       HADRONIC DECAYS
R       ---------------
```

$J/\psi(3097) \to (\pi^+\pi^-)$/total (units 10^{-4}) (P6)

```
R6         1    1.6      1.6           VANNUCCI  77 SMAG          E+E-
R6         5    1.0      0.5           BRANDELIK 78 DASP          E+E-
R6   S    84    1.58     0.25          BALTRUSA3 85 SMK3     E+E-,HADRONS
R6   S   SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
R6         . . . . . . . . . . .
R6   AVG        1.47     0.23    AVERAGE
```

$J/\psi(3097) \to (\pi^+\pi^-\pi^0)$/total (P7)

```
R7       168    0.015    0.002         FRANKLIN  83 SMK2     E+E-,HADRONS
R7              0.0149   0.0022        EINSWEILE 83 SMK3     E+E-,HADRONS
R7         . . . . . . . . . . .
R7   AVG        0.0150   0.0015  AVERAGE
```

$J/\psi(3097) \to (2(\pi^+\pi^-))$/total (P8)

```
R8        76     .004     .001         JEAN-MARI 76 SMAG          E+E-
```

$J/\psi(3097) \to (2(\pi^+\pi^-)\ \pi^0)$/total (P9)

```
R9       675     .04      .01          JEAN-MARI 76 SMAG          E+E-
R9      1500    0.0364   0.0052        BURMESTER 77 PLUT          E+E-
R9       147    0.0317   0.0042        FRANKLIN  83 SMK2     E+E-,HADRONS
R9         . . . . . . . . . . .
R9   AVG        0.0342   0.0031  AVERAGE
```

$J/\psi(3097) \to (3(\pi^+\pi^-)$/total (P10)

```
R10       32     .004     .002         JEAN-MARI 76 SMAG          E+E-
```

$J/\psi(3097) \to (3(\pi^+\pi^-)\ \pi^0)$/total (P11)

```
R11      181     .029     .007         JEAN-MARI 76 SMAG          E+E-
R11       11    0.028    0.009         FRANKLIN  83 SMK2     E+E-,HADRONS
R11        . . . . . . . . . . .
R11  AVG        0.0286   0.0055  AVERAGE
```

$J/\psi(3097) \to (4(\pi^+\pi^-)\ \pi^0)$/total (P12)

```
R12       13     .009     .003         JEAN-MARI 76 SMAG          E+E-
```

$J/\psi(3097) \to (K^+ K^-)$/total (units 10^{-4}) (P13)

```
R13       2    2.0       1.6             VANNUCCI  77 SMAG    E+E-,K+K-
R13       6    2.2       0.9             BRANDELIK 79 DASP    E+E-,K+K-
R13S    110    2.39      0.33            BALTRUSA3 85 SMK3    E+E-,K+K-
R13S    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
R13          . . . . . . . . .
R13 AVG        2.35      0.30    AVERAGE
```

$J/\psi(3097) \to (K^0_S K^0_S)$/total (units 10^{-4}) (P14)

```
R14C        (0.052)OR LESS CL=0.90   BALTRUSAI 85 SMK3    E+E-,HADRONS
R14C    FORBIDDEN BY CP.
```

$J/\psi(3097) \to (K \overline{K} \pi)$/total (units 10^{-4}) (P15)

```
R15     126    78.0      21.0            VANNUCCI  77 SMAG    E+E-,KS K+- PI-+
R15      25    55.2      12.0            FRANKLIN  83 SMK2    E+E-,K+ K- PI0
R15          . . . . . . . . .
R15 AVG        60.8      10.4    AVERAGE
```

$J/\psi(3097) \to (\pi^+ \pi^- K^+ K^-)$/total (P16)

```
R16     205    0.0072    0.0023          VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (2(\pi^+ \pi^-)\ K^+ K^-)$/total (P17)

```
R17      30    0.0031    0.0013          VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (\pi^+ \pi^- \pi^0 K^+ K^-)$/total (P18)

```
R18     309    0.012     0.003           VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to 2(K^+ K^-)$/total (P19)

```
R19            0.0007    0.0003          VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (\rho \pi)$/total (P20)

```
R20     543    0.010     0.002           BARTEL 1  76 CNTR        E+E-
R20     153    0.013     0.003           JEAN-MARI 76 SMAG        E+E-
R20     183    0.016     0.004           ALEXANDER 78 PLUT    E+ E-
R20            0.0133    0.0021          BRANDELIK 78 DASP    E+E-,PI+PI-GAMMA
R20     150    0.013     0.003           FRANKLIN  83 SMK2    E+E-,HADRONS
R20            0.0133    0.0015          BALTRUS2  85 SMK3    E+E-,PI0PI+PI-
R20          . . . . . . . . . . .
R20 AVG       0.01270   0.00091  AVERAGE
```

$J/\psi(3097) \to (\rho^0 \pi^0)/(\rho \pi)$ (P21)/P(20)

```
R21            0.39      0.11            BARTEL 1  76 CNTR        E+E-
R21            0.37      0.09            JEAN-MARI 76 SMAG        E+E-
R21            0.35      0.08            ALEXANDER 78 PLUT    E+ E-
R21            0.32      0.08            BRANDELIK 78 DASP    E+E-,PI+PI-GAMMA
R21           (0.36)    (0.03)           SCHARRE   79 SMAG    E+E-
R21          . . . . . . . . . .
R21 AVG        0.352     0.044   AVERAGE
```

$J/\psi(3097) \to (\rho \eta)$/total (units 10^{-3}) (P22)

```
R22            0.18      0.04            BALTRUS2  85 SMK3    E+E-,PI+PI-ETA
```

$J/\psi(3097) \to (\rho \eta')$/total (units 10^{-3}) (P23)

```
R23           (0.1)      OR LESS         BALTRUS2  85 SMK3    E+E-,4PI ETA
```

$J/\psi(3097) \to (\omega \pi^+ \pi^-)$/total (units 10^{-3}) (P24)

```
R24     215    7.8       1.6             BURMESTER 77 PLUT        E+E-
R24     348    6.8       1.9             VANNUCCI  77 SMAG        E+E-
R24          . . . . . . . . . .
R24 AVG        7.4       1.2     AVERAGE
```

$J/\psi(3097) \to (\omega \pi \pi)/(2(\pi^+ \pi^-)\ \pi^0)$ (P24)/(P9)

```
R25K J        (0.3)                      JEAN-MARI 76 SMAG    E+E-
R25  J  FINAL STATE 2(PI+ PI-)PI0
R25K    UNDER THE ASSUMPTION THAT PI PI IS ISOSPIN 0
```

$J/\psi(3097) \to (\omega\, 2\pi^+ 2\pi^-)$/total (P26)

```
R26     140    0.0085    0.0034          VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (\omega K \overline{K})$/total (P27)

```
R27      22    0.0016    0.0010          FELDMAN   77 SMAG        E+E-
```

$J/\psi(3097) \to (\omega f_2(1270))$/total (P28)

```
R28      81    0.0019    0.0008          VANNUCCI  77 SMAG        E+E-
R28      70    0.0040    0.0016          BURMESTER 77 PLUT        E+E-
R28          . . . . . . . . . . .
R28 AVG       0.00232   0.00084  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

$J/\psi(3097) \to (\omega f'_2(1525))$/total (units 10^{-4}) (P29)

```
R29           (1.6)  OR LESS  CL=0.90  VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (\omega \eta)$/total (units 10^{-3}) (P30)

```
R30            1.9       0.4             BALTRUS2  85 SMK3    E+E-,3PI ETA
```

$J/\psi(3097) \to (\omega \eta')$/total (units 10^{-3}) (P31)

```
R31            0.39      0.13            BALTRUS2  85 SMK3    3PI RHO GAMMA
R31            0.43      0.20    0.23    BALTRUS2  85 SMK3    PI0PI+PI-ETA2PI
R31          . . . . . . . . . . .
R31 AVG        0.40      0.11    AVERAGE
```

$J/\psi(3097) \to (\omega \pi^0)$/total (units 10^{-3}) (P32)

```
R32            0.67      0.13            BALTRUS2  85 SMK3    PI0PI+PI- PI0
```

$J/\psi(3097) \to (\phi \pi^0)$/total (units 10^{-3}) (P33)

```
R33           (0.013)    OR LESS         BALTRUS2  85 SMK3    E+E-, K+K-PI0
```

$J/\psi(3097) \to (\phi \pi^+ \pi^-)$/total (P34)

```
R34      23    0.0021    0.0009          FELDMAN   77 SMAG        E+E-
```

$J/\psi(3097) \to (\phi\, 2(\pi^+ \pi^-))$/total (P35)

```
R35           (0.0015)OR LESS  CL=0.90 VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (\phi K \overline{K})$/total (P36)

```
R36      14    0.0018    0.0008          FELDMAN   77 SMAG        E+E-
```

$J/\psi(3097) \to (\phi \eta)$/total (units 10^{-3}) (P37)

```
R37       5    1.0       0.6             VANNUCCI  77 SMAG        E+E-
R37            0.69      0.11            BALTRUS2  85 SMK3    K+K-NEUTRALS
R37            0.64      0.17            BALTRUS2  85 SMK3    E+E-,K+K-ETA
R37            0.61      0.16            BALTRUS2  85 SMK3    E+E-,K+K-3PI
R37          . . . . . . . . . . .
R37 AVG        0.665     0.079   AVERAGE
```

$J/\psi(3097) \to (\phi \eta')$/total (units 10^{-3}) (P38)

```
R38           (1.3)    OR LESS  CL=0.90 VANNUCCI  77 SMAG        E+E-
R38            0.39      0.12            BALTRUS2  85 SMK3    K+K-RHO0 GAMMMA
R38            0.365     0.064           BALTRUS2  85 SMK3    K+K-ETA PI+PI-
R38          . . . . . . . . . . .
R38 AVG        0.371     0.056   AVERAGE
```

$J/\psi(3097) \to (\phi f_2(1270))$/total (units 10^{-4}) (P39)

```
R39           (3.7)  OR LESS  CL=0.90  VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (\phi f'_2(1525))$/total (units 10^{-4}) (P40)

```
R40B      6    8.0       5.0             VANNUCCI  77 SMAG        E+E-
R40B     46    3.4       1.3             GIDAL     81 SMK2        E+E-
R40B    ASSUMES F2'(1525) INTO K KBAR IS 100 PER CENT.
R40          . . . . . . . . . .
R40 AVG        3.7       1.3     AVERAGE
```

$J/\psi(3097) \to (\phi f_0(975))$/total (units 10^{-4}) (P41)

```
R41      50    2.6       0.6             GIDAL     81 SMK2        E+E-
```

$J/\psi(3097) \to (\pi^\pm a_2)$/total (P42)

```
R42           (0.0043)OR LESS  CL=0.90 BRAUNSCHW 76 DASP        E+E-
```

$J/\psi(3097) \to (\rho a_2(1320))$/total (P43)

```
R43      36    0.0084    0.0045          VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (K \overline{K}^*(892)\ +\ \text{C.C.})$/total (units 10^{-4}) (P44)

```
R44      39   82.        24.             BRAUNSCHW 76 DASP    E+E-,K+- K*BAR-+
R44      48   64.        12.             VANNUCCI  77 SMAG    E+E-,K+- K*BAR-+
R44      45   54.        12.             VANNUCCI  77 SMAG    E+E-,K0  K*BAR0
R44      24   52.8       11.4            FRANKLIN  83 SMK2    E+E-,K+- K*BAR-+
R44A         100.        13.             BALTRUS2  85 SMK3    E+E-,K-K*+
R44B         120.        15.             BALTRUS2  85 SMK3    E+E-,K-K*+
R44C          78.        13.             BALTRUS2  85 SMK3    E+E-,K0 K*0
R44A    FROM  K*+ K- + C.C.   TO FINAL STATE K+- KS PI-+ AND ISOSPIN INV.
R44B    FROM  K*+ K- + C.C    TO FINAL STATE K+  K- PI0  AND ISOSPIN INV.
R44C    FROM  K*0 K0BAR + C.C TO FINAL STATE K+- KS PI+- AND ISOSPIN INV.
R44          . . . . . . . . . . .
R44 AVG       74.6       9.3      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)
```

$J/\psi(3097) \to (K \overline{K}^*_2(1430))$/total (P45)

```
R45          (0.0066)OR LESS  CL=0.90  BRAUNSCHW 76 DASP    E+E-,K+-K2*BAR-+
R45          (0.004) OR LESS  CL=0.90  VANNUCCI  77 SMAG    E+E-,K0 K2*BAR0
```

$J/\psi(3097) \to (K^*(892)^0 \overline{K}^*(892)^0)$/total (P46)

```
R46          (0.0005)OR LESS  CL=0.90  VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (K^*_2(1430)^0 \overline{K}^*_2(1430)^0)$/total (P47)

```
R47          (0.0029)OR LESS  CL=0.90  VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (K^*(892)^0 \overline{K}^*_2(1430)^0\ +\ \text{C.C.})$/total (P48)

```
R48      40    0.0067    0.0026          VANNUCCI  77 SMAG        E+E-
```

$J/\psi(3097) \to (b_1(1235)^\pm \pi^\mp)$/total (P49)

```
R49      87    0.0029    0.0007          BURMESTER 77 PLUT        E+E-
```

$J/\psi(3097) \to (\overline{p} p)$/total (units 10^{-3}) (P50)

```
R50            2.0       0.5             BESCH     78 BONA        E+E-
R50   A 331    2.2       0.2             PERUZZI   78 SMAG        E+E-
R50     133    2.5       0.4             BRANDELIK 79 DASP    E+ E-
R50S   1420    2.16      0.17            EATON     84 SMK2    E+E-,HADRONS GAM
R50S    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R50   A ASSUMING ANGULAR DISTRIBUTION (1.+COS(THETA)**2)
R50          . . . . . . . . . .
R50 AVG        2.20      0.12    AVERAGE
```

$J/\psi(3097) \to (\overline{p} p)/(\mu^+ \mu^-)$ (P50)/(P2)

```
R51   A  20    .051      .02             WIIK      75 PLUT        E+E-
R51   A ASSUMING ANGULAR DISTRIBUTION (1.+COS(THETA)**2)
```

$J/\psi(3097) \to (p \overline{p} \pi^0)$/total (units 10^{-3}) (P52)

```
R52     109    1.00      0.15            PERUZZI   78 SMAG    E+E-,P PB
R52            1.4       0.4             BRANDELIK 79 DASP    E+ E-
R52S    685    1.13      0.13            EATON     84 SMK2    E+E-,HADRONS GAM
R52S    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R52          . . . . . . . . . . .
R52 AVG        1.093     0.095   AVERAGE
```

$J/\psi(3097) \to (p \overline{n} \pi^-)$/total (units 10^{-3}) (P53)

```
R53     194    2.16      0.29            PERUZZI   78 SMAG    E+E-,P PI-
R53B    204    2.04      0.27            PERUZZI   78 SMAG    E+E-,P PI+
R53      32    1.7       0.7             BESCH     81 BONA        E+E-
R53B      5    1.6       1.2             BESCH     81 BONA        E+E-
R53S   1288    2.02      0.24            EATON     84 SMK2    E+E-,P PI-
R53S  B1191    1.93      0.24            EATON     84 SMK2    E+E-,P PI+
R53S    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R53B    FROM ANTI-CHANNEL (PBAR N PI+)
R53          . . . . . . . . . . .
R53 AVG        2.01      0.13    AVERAGE
```

$J/\psi(3097) \to (p \overline{p} \pi^+ \pi^-)$/total (units 10^{-3}) (P54)

```
R54     533    5.5       0.6             PERUZZI   78 SMAG    E+E-,P PB 1-2PI
R54      48    3.8       1.6             BESCH     81 BONA        E+E-
R54S   1435    6.46      0.46            EATON     84 SMK2    E+E-,HADRONS GAM
R54S    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R54          . . . . . . . . . . .
R54 AVG        5.99      0.48    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$J/\psi(3097) \to (p\bar{p}\pi^+\pi^-\pi^0)$/total (units 10^{-3}) (P55)

```
R55      INCLUDING P PBAR PI+PI- GAMMA AND EXCLUDING OMEGA,ETA,ETA'
R55      39    1.6       0.6             PERUZZI   78 SMAG    E+E-,P PB 2PI
R55S    364    3.36      0.71            EATON     84 SMK2    E+E-,HADRONS
R55S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R55          . . . . . . . . . . .
R55 AVG        2.33      0.87    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.9)
```

$J/\psi(3097) \to (p\bar{p}\eta)$/total (units 10^{-3}) (P56)

```
R56     197    2.3       0.4             PERUZZI   78 SMAG    E+E-,P PB 0-2PI
R56            2.5       1.2             BRANDELIK 79 DASP    E+ E-
R56S    826    2.03      0.20            EATON     84 SMK2    E+E-,HADRONS GAM
R56S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R56          . . . . . . . . . . .
R56 AVG        2.09      0.18    AVERAGE
```

$J/\psi(3097) \to (p\bar{p}\rho)$/total (units 10^{-3}) (P57)

```
R57          (0.31) OR LESS  CL=.90  EATON     84 SMK2    E+E-,HADRONS GAM
```

$J/\psi(3097) \to (p\bar{p}\omega)$/total (units 10^{-3}) (P58)

```
R58      77    1.6       0.3             PERUZZI   78 SMAG    E+E-,P PB 1-2PI
R58S    486    1.10      0.25            EATON     84 SMK2    E+E-,HADRONS GAM
R58S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R58          . . . . . . . . . . .
R58 AVG        1.30      0.25    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$J/\psi(3097) \to (p\bar{p}\eta')$/total (units 10^{-3}) (P59)

```
R59      19    1.8       0.6             PERUZZI   78 SMAG    E+E-,P PB 1-2PI
R59S     19    0.68      0.29            EATON     84 SMK2    E+E-,HADRONS GAM
R59S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R59          . . . . . . . . . . .
R59 AVG        0.89      0.44    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)
```

$J/\psi(3097) \to (\Lambda\bar{\Lambda})$/total (units 10^{-3}) (P60)

```
R60     196    1.1       0.2             PERUZZI   78 SMAG    E+E-,L X,LBAR L
R60       5    2.6       1.6             BESCH     81 BONA         E+E-
R60S    365    1.58      0.21            EATON     84 SMK2    E+E-,HADRONS GAM
R60S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R60          . . . . . . . . . . .
R60 AVG        1.34      0.24    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)
```

$J/\psi(3097) \to (\Lambda\bar{\Sigma})$/total (units 10^{-3}) (P61)

```
R61          (0.15) OR LESS  CL=0.90 PERUZZI   78 SMAG    E+E-,LAMBDA X
```

$J/\psi(3097) \to (\Xi\bar{\Xi})$/total (units 10^{-3}) (P62)

```
R62      71    3.2       0.8             PERUZZI   78 SMAG    E+E-,L LBAR
R62S    194    2.28      0.44            EATON     84 SMK2    E+E-,HADRONS GAM
R62S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R62          . . . . . . . . . . .
R62 AVG        2.49      0.39    AVERAGE
```

$J/\psi(3097) \to (\Sigma\bar{\Sigma})$/total (units 10^{-3}) (P63)

```
R63      52    3.9       1.2             PERUZZI   78 SMAG    E+E-,SIGO SIGBO
R63       3    7.2       7.8             BESCH     81 BONA    E+E-,SIG+ SIGB-
R63S     90    4.74      0.90            EATON     84 SMK2    E+E-,SIGO SIGBO
R63S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R63          . . . . . . . . . . .
R63 AVG        4.46      0.72    AVERAGE
```

$J/\psi(3097) \to (n\bar{n})$/total (units 10^{-2}) (P64)

```
R64            0.18      0.09            BESCH     78 BONA         E+E-
```

$J/\psi(3097) \to (n\bar{n}\pi^+\pi^-)$/total (units 10^{-3})

```
R65                                                              (P65)
R65       5    3.8       3.6             BESCH     81 BONA         E+E-
```

$J/\psi(3097) \to (\Delta(1232)^{++}\bar{\Delta}(1232)^{--})$/total (units 10^{-3})

```
R66                                                      (P66)
R66S    233    1.10      0.29            EATON     84 SMK2    E+E-,HADRONS GAM
R66S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \to (\Sigma(1385)^{\mp}\bar{\Sigma}(1385)^{\pm})$/total (units 10^{-3})

```
R67                                                      (P67)
R67S     56    0.86      0.32            EATON     84 SMK2    E+E-,SIGMA*-
R67S     68    1.03      0.48            EATON     84 SMK2    E+E-,SIGMA*+
R67S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US,SEE TEXT SEC.IV.C.2.
R67          . . . . . . . . . . .
R67 AVG        0.91      0.27    AVERAGE
```

$J/\psi(3097) \to (\Sigma(1385)^{\mp}\bar{\Sigma}^{\pm})$/total (units 10^{-3}) (P68)

```
R68S     26    0.29      0.17            EATON     84 SMK2    E+E-,SIGMA*-
R68S     28    0.31      0.19            EATON     84 SMK2    E+E-,SIGMA*+
R68S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US,SEE TEXT SEC.IV.C.2.
R68          . . . . . . . . . . .
R68 AVG        0.30      0.13    AVERAGE
```

$J/\psi(3097) \to (\bar{p}N(1440-1535)^{+})$/total (units 10^{-3}) (P69)

```
R69S    189    0.93      0.35            EATON     84 SMK2    E+E-,HADRONS GAM
R69S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \to (\Delta(1232)^{++}\bar{p}\pi^-)$/total (units 10^{-3}) (P70)

```
R70S    332    1.58      0.46            EATON     84 SMK2    E+E-,HADRONS GAM
R70S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \to (\Lambda\bar{\Sigma}^{\pm}\pi^{\mp})$/total (units 10^{-3}) (P71)

```
R71S    135    1.53      0.56            EATON     84 SMK2    E+E-,HADRONS+PI-
R71S    118    1.38      0.52            EATON     84 SMK2    E+E-,HADRONS-PI+
R71S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US,SEE TEXT SEC.IV.C.2.
R71          . . . . . . . . . . .
R71 AVG        1.45      0.38    AVERAGE
```

$J/\psi(3097) \to (pK^-\bar{\Lambda})$/total (units 10^{-3}) (P72)

```
R72S    307    0.89      0.16            EATON     84 SMK2    E+E-,HADRONS GAM
R72S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \to (pK^-\bar{\Sigma}^0)$/total (units 10^{-3}) (P73)

```
R73S     90    0.29      0.08            EATON     84 SMK2    E+E-,HADRONS GAM
R73S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \to (pK^-\Sigma(1385)^0)$/total (units 10^{-3}) (P74)

```
R74S     89    0.51      0.32            EATON     84 SMK2    E+E-,HADRONS GAM
R74S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \to (K^0_S K^0_L)$/total (units 10^{-4}) (P75)

```
R75S     74    1.01      0.18            BALTRUSA3 85 SMK3    E+E-,KS KL
R75S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

```
R        RADIATIVE DECAYS
R        ----------------
```

$J/\psi(3097) \to (2\gamma)$/total (units 10^{-3}) (P80)

```
R80          (0.5)  OR LESS  CL=0.90 BARTEL    77 CNTR         E+E-
```

$J/\psi(3097) \to (3\gamma)$/total (units 10^{-3}) (P81)

```
R81          (0.055)OR LESS  CL=0.90 PARTRIDGE 80 CBAL    E+E-,3 GAMMA
```

$J/\psi(3097) \to (\pi^0\gamma)$/total (units 10^{-3}) (P82)

```
R82      10    0.073     0.047           BRANDELIK 79 DASP    E+ E-
R82            0.036     0.013           BLOOM     83 CBAL    E+ E-,3 GAMMA
R82          . . . . . . . . . . .
R82 AVG        0.039     0.013   AVERAGE
```

$J/\psi(3097) \to (\eta\gamma)$/total (units 10^{-3}) (P83)

```
R83      21    1.3       0.4             BARTEL    77 CNTR    E+E-,3 GAMMA
R83            0.82      0.10            BRANDELIK 79 DASP    E+ E-
R83S           0.88      0.14            BLOOM     83 CBAL    E+ E-,3 GAMMA
R83S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R83          . . . . . . . . . . .
R83 AVG        0.859     0.080   AVERAGE
```

$J/\psi(3097) \to (\eta'\gamma)$/total (units 10^{-3}) (P84)

```
R84           (3.2)  OR LESS  CL=.90  MURTAS    76 FRAG         E+E-
R84      57   (2.4)     (0.7)            BARTEL 1  76 CNTR    E+E-,2 GAMMA RHO
R84       6    2.9       1.1             BRANDELIK 79 DASP    E+E-,3 GAMMA
R84B          (3.8)     (1.3)            SCHARRE   79 SMAG    E+E-, GAMMA X
R84           (3.4)     (0.7)            SCHARRE   79 SMAG    E+E-,2 PI 2GAMMA
R84S           4.1       0.7             BLOOM     83 CBAL    E+E-,3G+HADR GAM
R84S           4.6       0.8             EINSWEILE 83 SMK3    E+E-,HADRONS GAM
R84S           4.7       1.0             EINSWEILE 83 SMK3    E+E-,HADRONS GAM
R84B     FROM THE INCLUSIVE GAMMA DECAY SPECTRUM
R84S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R84          . . . . . . . . . . .
R84 AVG        4.17      0.43    AVERAGE
```

$J/\psi(3097) \to (\eta_c(2980)\ \gamma)$/total (P85)

```
R85      16    SEEN                      BALTRUSAI 84 SMK3    J/PSI,2PHI GAMMA
R85            0.0127    0.0036          GAISER    85 CBAL    J/PSI,GAMMA X
```

$J/\psi(3097) \to (f_2(1270)\ \gamma)$/total (units 10^{-3}) (P86)

```
R86      35    2.0       0.7             ALEXANDER 78 PLUT  0 E+E-
R86  T   30    1.2       0.6             BRANDELIK 78 DASP    E+E-,PI+PI-GAMMA
R86S    178    1.48      0.39            EDWARDS1  82 CBAL    E+E-,2 PI0 GAMMA
R86S           1.7       0.3             EINSWEILE 83 SMK3    E+E-,HADRONS GAM
R86          . . . . . . . . . . .
R86 AVG        1.60      0.21    AVERAGE

R86  T   RE-STATED BY US TO TAKE ACCOUNT OF SPREAD OF E1,M2,E3 TRANSITIONS.
R86S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$J/\psi(3097) \to (f_2'(1525)\ \gamma)$/total (units 10^{-3}) (P87)

```
R87       3   (0.23) OR LESS  CL=0.90 ALEXANDE2 78 PLUT    E+E-,K+K- GAMMA
R87  I    4   (0.34) OR LESS  CL=0.90 BRANDELIK 79 DASP    E+E-,PI+PI-GAMMA
R87A           0.18      0.10            FRANKLI2  83 SMK2    J/PSI,K KBAR GAM
R87S  A        0.16      0.05            EINSWEILE 83 SMK3    E+E-,HADRONS GAM
R87A     USING BRANCHING RATIO (F2'(1525) INTO K KBAR) = 1.0
R87  I   ASSUMING ISOTROPIC PRODUCTION AND DECAY OF THE F2'(1525)
R87  I   AND ISOSPIN.
R87S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$J/\psi(3097) \to (f_1(1285)\ \gamma)$/total (P88)

```
R88  D       (0.006)OR LESS  CL=.90  SCHARRE   80 SMK2    E+E-
R88  D   USING BR(F1(1285) INTO K KBAR PI)=0.12
```

$J/\psi(3097) \to (\eta(1440)\ \gamma)$/total (P89)

```
R89C B         0.0043    0.0017          SCHARRE   80 SMK2    E+E-
R89S B         0.0040    0.0012          EDWARDS3  82 CBAL    J/PSI,ETA GAM
R89S B         0.0050    0.0009          RICHMAN   85 SMK3    J/PSI,K K PI GAM
R89          . . . . . . . . . . .
R89 AVG        0.00459   0.00066 AVERAGE

R89  B   INCLUDES UNKNOWN BRANCHING FRACTION ETA(1440) INTO K KBAR PI.
R89C     CORRECTED FOR SPIN-ZERO HYPOTHESIS FOR ETA(1440).
R89S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \to (p\bar{p}\gamma)$/total (units 10^{-3}) (P90)

```
R90          (0.11) OR LESS  CL=0.90 PERUZZI   78 SMAG    E+E-,P PB SHOWER
R90S     49    0.38      0.10            EATON     84 SMK2    E+E-,HADRONS GAM
R90S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \to (f_2(1720)\ \gamma)$/total (units 10^{-4}) (P91)

```
R91 A         (3.8)     (1.6)            EDWARDS2  82 CBAL    E+E-,ETA ETA GAM
R91S B         4.8       1.1             EINSWEILE 83 SMK3    E+E-,K+K- GAMMA
R91S B         6.0       3.4             FRANKLI2  83 SMK2    E+E-,K+K- GAMMA
R91 A    INCLUDES UNKNOWN BRANCHING FRACTION TO ETA ETA.
R91  B   INCLUDES UNKNOWN BRANCHING FRACTION TO K+K-.
R91S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R91          . . . . . . . . . . .
R91 AVG        4.9       1.0     AVERAGE
```

$J/\psi(3097) \to (X(2220)\ \gamma)$/total (units 10^{-5}) (P92)

```
R92S B   93    8.4       3.8       3.2   BALTRUSA4 85 SMK3    J/PSI, K+ K- GAM
R92S B   23   13.        7.        6.    BALTRUSA4 85 SMK3    J/PSI, KS KS GAM
R92  B   INCLUDES UNKNOWN BRANCHING FRACTION INTO K KBAR.
R92S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R92          . . . . . . . . . . .
R92 AVG        9.4       3.1     AVERAGE
```

$J/\psi(3097) \to (p\bar{p}\pi^+\pi^-\gamma)$/total (units 10^{-3}) (P93)

```
R93          (0.79) OR LESS  CL=.90  EATON     84 SMK2
```

$J/\psi(3097) \to (\rho^0\rho^0\gamma)$/total (units 10^{-3}) (P94)

```
R94S M         1.25      0.53            BURKE     82 SMK2    E+E-,HADRONS GAM
R94  M   RHO RHO MASS LESS THAN 2.0 GEV.
R94S     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \rightarrow (2\pi^+ 2\pi^- \gamma)$/total (units 10^{-3}) (P95)

```
R95S M       4.85     1.28             BURKE     82 SMK2    E+E-,HADRONS GAM
R95  M  4PI MASS LESS THAN 2.5 GEV.
R95S    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097) \rightarrow (\eta\,\pi\,\pi\,\gamma)$/total (units 10^{-3}) (P96)

```
R96S M       5.9      1.2              EDWARDS   83 CBAL    J/PSI,ETA PI+PI-
R96S M       7.8      2.7              EDWARDS   83 CBAL    J/PSI,ETA 2PI0
R96  M  BROAD ENHANCEMENT AT 1700 MEV.
R96S    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R96         . . . . . . . . .
R96 AVG      6.2      1.1      AVERAGE
```

$J/\psi(3097) \rightarrow (\omega\,\omega\,\gamma)$/total (units 10^{-3}) (P97)

```
R97S         1.76     0.46             BALTRUSAI 85 SMK3    E+E-,HADRONS GAM  |
R97S    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$J/\psi(3097)$ $\Gamma(\mathrm{I})^*\Gamma(e^+e^-)/\Gamma(\mathrm{total})$ (keV)

```
        THIS COMBINATION OF A PARTIAL WIDTH WITH THE PARTIAL WIDTH
        INTO E-E- AND WITH THE TOTAL WIDTH IS OBTAINED FROM THE INTEGRATED
        CROSS-SECTION INTO CHANNEL(I) IN THE E+E- ANNIHILATION.
```

$\Gamma(e^+e^-)^*\Gamma(e^+e^-)/\Gamma(\mathrm{total})$

```
G1 S          .32      .07             BALDINI1  75 FRAG        E+E-
G1            .34      .14             BEMPORAD  75 FRAB        E+E-
G1 S          .34      .09             ESPOSITO  75 FRAM        E+E-
G1 S          .36      .10             FORD      75 SPEC        E+E-
G1           0.35     0.02             BRANDELIK 79 DASP        E+E-
G1          . . . . . . . . .
G1  AVG      0.348    0.018    AVERAGE
```

$\Gamma(\mu^+\mu^-)^*\Gamma(e^+e^-)/\Gamma(\mathrm{total})$

```
G2            .31      .09             BEMPORAD  75 FRAB        E+E-
G2            .51      .09             DASP1     75 DASP        E+E-
G2 S          .38      .05             ESPOSITO  75 FRAM        E+E-
G2 S          .46      .10             LIBERMAN  75 SPEC        E+E-
G2          . . . . . . . . .
G2  AVG      0.401    0.037    AVERAGE
```

$\Gamma(\mathrm{hadronic})^*\Gamma(e^+e^-)/\Gamma(\mathrm{total})$

```
G3 S         4.        .8              BALDINI1  75 FRAG        E+E-
G3 S         3.9       .8              ESPOSITO  75 FRAM        E+E-
G3          . . . . . . . . .
G3  AVG      3.95     0.57     AVERAGE

G  S    DATA REDUNDANT WITH BRANCHING RATIOS OR PARTIAL WIDTHS ABOVE
```

REFERENCES FOR $J/\psi(3097)$

```
CHRISTEN 70 PRL 25 1523          CHRISTENSON,HICKS,LEDERMAN+ (COLU+BNL+CERN)

ABRAMS   74 PRL 33 1453          +BRIGGS,AUGUSTIN,BOYARSKI+         (LBL+SLAC)
ASH      74 LNC 11 705           +ZORN,BARTOLI+    (FRAS+UMD+NAPL+PADO+ROMA)
AUBERT   74 PRL 33 1404          +BECKER,BIGGS,BURGER,CHEN,EVERHART(MIT+BNL)
AUGUSTIN 74 PRL 33 1406          +BOYARSKI,ABRAMS,BRIGGS+           (SLAC+LBL)
BACCI    74 PRL 33 1408          +BARTOLI,BARBARINO,BARBIELLINI+  (FRASCATI)
    ALSO 74 PRL 33 1649          FOR ERRATA
BALDINI- 74 LNC 11 711           BALDINI-CELIO,BACCI+          (FRASCATI+ROMA)
BARBIELL 74 LNC 11 718           BARBIELLINI,BEMPORAD+ (FRAS+NAPL+PISA+ROMA)
BRAUNSCH 74 PL 53B 393           BRAUNSCHWEIG+    (AACHEN+HAMB+MUNICH+TOKYO)

ANDREWS  75 PRL 34 231           +HARVEY,LOBKOWICZ,MAY,NORDBERG  (ROCH+CORN)
AUBERT   75 NP B 89 1            +BECKER,BIGGS,BURGER,GLENN,+       (MIT+BNL)
BACCI    75 LNC 12 269           +PENSO,STELLA,BALDINI-CELIO,+   (ROMA+FRAS)
BALDINI1 75 PL 58B 471           BALDINI-CELIO,BOZZO,CAPON,BACCI+(FRAS+ROMA)
BALDINI2 75 PL 58B 475           BALDINI-CELIO,CAPON,DEL FABBRO+ (FRAS+ROMA)
BEMPORAD 75 STANFORD SYMP.113 C.BEMPORAD                   (PISA+FRASCATI)
BLANAR   75 PRL 35 346           +BOYER,FAISSLER,GARELICK,GETTNER,+   (NEAS)
BOYARSKI 75 PRL 34 1357          +BREIDENBACH,BULOS,FELDMAN,+      (SLAC+LBL)JPC
BRAUNSCH 75 PL 53B 491           BRAUNSCHWEIG+    (AACHEN+HAMB+MUNICH+TOKYO)
BUSSER   75 PL 56 B 482          +BLUMENFELD,BANNER,+  (CERN+COLU+ROCK+SACL)
CAMERINI 75 PRL 35 483           +LEARNED,PREPOST,ASH,ANDERSON,+ (WISC+SLAC)
CRIEGEE  75 PL 53B 489           +DEHNE,FRANKE,HORLITZ,KRECHLOCK+     (DESY)
DAKIN    75 PL 56 B 405          +KREISLER,BOLON,HEILE+       (MASA+MIT+SLAC)
DASP1    75 PL 56B 491           BRAUNSCHWEIG,KONIGS,+ (AACH+DESY+MPIM+TOKY)
DASP2    75 PL 57B 297           BRAUNSCHWEIG,KONIGS,+ (AACH+DESY+MPIM+TOKY)
ESPOSITO 75 LNC 14 73            +BARTOLI,BISELLO,+    (FRAS+NAPL+PADO+ROMA)
FORD     75 PRL 34 604           +BERON,HILGER,HOFSTADTER+         (SLAC+PENN)
GITTELMA 75 PRL 35 1616          GITTELMAN+HANSON+LARSON+LOH+         (CORN)
GRECO    75 PL 56B 367           +PANCHERI-SRIVASTAVA,SRIVASTAVA      (FRAS)
HEINTZE  75 STANFORD SYMP.97  J.HEINTZE                        (HEIDELBERG)
JACKSON  75 NIM 128 13           J.D.JACKSON,D.SCHARRE                 (LBL)
KNAPP1   75 PRL 34 1040          +LEE,BRONSTEIN+   (COLU+HAWA+CORN+ILL+FNAL)
KNAPP2   75 PRL 34 1044          +LEE,BRONSTEIN+   (COLU+HAWA+CORN+ILL+FNAL)
LIBERMAN 75 STANFORD SYMP.55  A.D.LIBERMAN                       (STANFORD)
MARTIN   75 PRL 34 288           +BOLON,DAKIN,FELDMAN,HANSON+(MIT+MASA+SLAC)
PREPOST  75 STANFORD SYMP.241 R.PREPOST                         (WISCONSIN)
SIMPSON  75 PRL 35 699           +BERON,FORD,HILGER,HOFSTADTER,+ (STAN+PENN)
WIIK     75 STANFORD SYMP.69  B.H.WIIK                               (DESY)
YENNIE   75 PRL 34 239           D.R.YENNIE                        (CORNELL)

ANTIPOV  76 TBILISI CONF.N 8  +BESSUBOV,BUDANOV,BUSHNIN,DENISOV,+  (SERP)
BARTEL 1 76 PL 64 B 483          +DUINKER,OLSSON,STEFFEN,HEINTZE+(DESY+HEID)
BRAUNSCH 76 PL 63 B 487          BRAUNSCHWEIG,+   (AACH+DESY+HAMB+MPIM+TOKY)
BUSSER   76 NP B 113 189         +BLUMENFELD,BANNER,+  (CERN+COLU+ROCK+SACL)
JEAN-MAR 76 PRL 36 291.          +ABRAMS,BOYARSKI,BREIDENBACH,+   (SLAC+LBL)IG
MURTAS   76 TBILISI CONF. N60 G.P.MURTAS                             (FRAS)
PIERRE   76 TBILISI CONF. N46 F.PIERRE                           (SLAC+LBL)
SNYDER   76 PRL 36 1415          +HOM,LEDERMAN,APPEL,KAPLAN+(COLU+FNAL+STON)

BARTEL   77 PL 66 B 489          +DUINKER,OLSSON,HEINTZE,+       (DESY+HEID)
BIDDICK  77 PRL 38 1324          +BURNETT+     (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
BURMESTE 77 PL 72 B 135          BURMESTER,CRIEGEE,+   (DESY+HAMB+SIEG+WUPP)
CORDEN   77 PL 68 B 96           +DOWELL,+   (BIRM+CERN+MPIM+NEUC+EPOL+RHEL)
FELDMAN  77 PL 33 C 285          +PERL                               (LBL+SLAC)
VANNUCCI 77 PR D 15 1814         +ABRAMS,ALAM,BOYARSKI,+           (SLAC+LBL)
YAMADA   77 HAMB. CONF. P. 69 YAMADA                             (DESY+TOKY)

ALEXANDE 78 PL 72 B 493          ALEXANDER,CRIEGEE,+   (DESY+HAMB+SIEG+WUPP)
BESCH    78 PL 78 B 347          +EISERMANN,KOWALSKI,V EYSS+(BONN+DESY+MANZ)
BRANDELI 78 PL 74 B 292          BRANDELIK,CORDS+ (AACH+DESY+HAMB+MPIM+TOKY)
PERUZZI  78 PR D 17 2901         +PICCOLO,ALAM,BOYARSKI,GOLDHABER+(SLAC+LBL)

BRANDELI 79 ZPHY C 1 233         BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
KIRK     79 PRL 42 619           +GOODMAN,ALVERSON,+(FNAL+HARV+ILL+OXF+TUFT)
SCHARRE  79  SLAC-PUB-2321       D.L. SCHARRE                     (SLAC+LBL)
    ALSO 79  LBL 9502             ABRAMS,ALAM,BLOCKER,BOYARSKI,+  (SLAC+LBL)

PARTRIDG 80 PRL 44 712           PARTRIDGE,PECK,+  (CIT+HARV+PRIN+SLAC+STAN)
SCHARRE  80 PL 97 B 329          +TRILLING,ABRAMS,ALAM,BLOCKER+   (SLAC+LBL)
ZHOLENTZ 80 PL 96 B 214          +KURDADZE,LELCHUK,MISHNEV,NIKITIN+   (NOVO)
    ALSO 81 YAD.PHYS. 34 1471 ZHOLENTZ ET AL.                        (NOVO)

BESCH    81 ZPHY C 8 1           +EISERMANN,LOHR,KOWALSKI,+ (BONN+DESY+MANZ)
GIDAL    81 PL 107 B 153         +GOLDHABER,GUY,MILLIKAN,ABRAMS+  (SLAC+LBL)

BURKE    82 PRL 49 632           +TRILLING,ABRAMS,ALAM,BLOCKER+   (SLAC+LBL)
EDWARDS1 82 PR D 25 3065         +PARTRIDGE,PECK,+ (CIT+HARV+PRIN+STAN+SLAC)
EDWARDS2 82 PRL 48 458           +PARTRIDGE,PECK,+ (CIT+HARV+PRIN+STAN+SLAC)
    ALSO 83 BLOOM 83
EDWARDS3 82 PRL 49 259           +PARTRIDGE,PECK+  (CIT+HARV+PRIN+STAN+SLAC)
LEMOIGNE 82 PL 113 B 509         +BARATE,ASTBURY,MCEWEN+(SACL+LOIC+SHMP+IND)

BARATE   83 PL 121 B 449         +BAREYRE,ASTBURY,MCEWEN(SACL+LOIC+SHMP+IND)
BLOOM    83 ARNS 33 143          BLOOM,PECK                       (SLAC+CIT)
EDWARDS  83 PRL 51 859           +PARTRIDGE,PECK+  (CIT+HARV+PRIN+STAN+SLAC)
EINSWEIL 83 BRIGHTON CONF.348 K.F.EINSWEILER-MARKIII COLLABORATION (SLAC)
FRANKLIN 83  SLAC-PUB-3092       +FRANKLIN,FELDMAN,ABRAMS,ALAM+   (LBL+SLAC)
FRANKLI2 83 SLAC-254 THESIS      M.E.B.FRANKLIN                       (STAN)

BALTRUSA 84 PRL 52 2126          BALTRUSAITIS+      (CIT+UCSC+ILL+SLAC+WASH)
EATON    84 PR D 29 804          +GOLDHABER,ABRAMS,ALAM,BOYARSKI+ (LBL+SLAC)

BAGLIN   85  CERN-PRE-85           (LAPP+CERN+GENO+LYON+OSLO+ROMA+STRB+TORI)
BALTRUSA 85 PRL 55 1723          BALTRUSAITIS+      (CIT+UCSC+ILL+SLAC+WASH)
BALTRUS2 85 PR D 32 2883         BALTRUSAITIS+      (CIT+UCSC+ILL+SLAC+WASH)
BALTRUS3 85 PR D 32 566          BALTRUSAITIS+      (CIT+UCSC+ILL+SLAC+WASH)
BALTRUS4 85  SLAC-PUB-3786       BALTRUSAITIS+      (CIT+UCSC+ILL+SLAC+WASH)
GAISER   85  SLAC-PUB-2899       +BLOOM,BULOS+     (CIT+HARV+PRIN+STAN+SLAC)
RICHMAN  85  CALT-68-1260        20TH RENCONTRE DE MORIOND               (CIT)
```

$\chi_0(3415)$ was $\chi(3415)$

$I^G(J^{PC}) = 0^+(0^{++})$

```
OBSERVED IN THE RADIATIVE DECAY OF PSI(3685) INTO
CHI0(3415) GAMMA. THEREFORE C=+. THE OBSERVED DECAY
INTO PI+ PI- OR K+ K- IMPLIES G=+, JP=0+,2+,... .
THE ANGULAR DISTRIBUTION IS CONSISTENT WITH J=0. JP ABNORMAL
EXCLUDED BY PI+ PI- AND K+ K- DECAYS. JP=0+ PREFERRED (FELDMAN 77).
```

$\chi_0(3415)$ MASS (MeV)

```
M          2(3407.0)    (8.0)          WIIK      75 DASP    E+E-,J/PSI 2 GAM
M  D         3415.0      9.0           BIDDICK   77 CNTR    E+E-,MONOCHR.GAM
M  D         3422.0     10.0           BARTEL    78 CNTR    E+E-,J/PSI 2 GAM
M  D M       3416.0      6.0           TANENBAUM 78 SMAG    E+ E-             |
M  D E       3414.8      1.1           HIMEL     79 SMK2    E+E-,HADRONS
M           . . . . . . . . . .
M   AVG      3414.9      1.1     AVERAGE

M  D    MASS VALUE SHIFTED BY US BY AMOUNT APPROPRIATE FOR
M  D                PSI(3685) MASS=3686 AND PSI(3097) MASS=3097.
M    E  SYSTEMATIC ERROR ADDED LINEARLY BY US
M    M  FROM A SIMULTANEOUS FIT TO RADIATIVE AND HADRONIC DECAY CHANNELS
M    M              SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$\chi_0(3415)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\chi_0(3415) \rightarrow \pi^+\pi^-$	140+ 140
P2	$\chi_0(3415) \rightarrow K^+K^-$	494+ 494
P3	$\chi_0(3415) \rightarrow 2(\pi^+\pi^-)$	140+ 140+ 140+ 140
P4	$\chi_0(3415) \rightarrow 3(\pi^+\pi^-)$	
P5	$\chi_0(3415) \rightarrow \pi^+\pi^-K^+K^-$	140+ 140+ 494+ 494
P6	$\chi_0(3415) \rightarrow J/\psi(3097)\ \gamma$	3097+ 0
P7	$\chi_0(3415) \rightarrow \gamma\gamma$	0+ 0
P8	$\chi_0(3415) \rightarrow \pi^+\pi^-p\overline{p}$	140+ 140+ 938+ 938
P9	$\chi_0(3415) \rightarrow \rho^0\pi^+\pi^-$	769+ 140+ 140
P10	$\chi_0(3415) \rightarrow K^*(892)^0K^\pm\pi^\mp$	892+ 494+ 140
P11	$\chi_0(3415) \rightarrow p\overline{p}$	938+ 938

$\chi_0(3415)$ BRANCHING RATIOS

$\chi_0(3415) \rightarrow (\gamma\,\gamma)$/total (P7)

```
R1 T        (0.0015)OR LESS  CL=0.90 YAMADA    77 DASP    E+ E-,3 GAMMA      |
```

$\chi_0(3415) \rightarrow 2(\pi^+\pi^-)$/total (P3)

```
R2 T         0.038     0.008            TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_0(3415) \rightarrow (\pi^+\pi^-K^+K^-)$/total (P5)

```
R3 T         0.029     0.008            TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_0(3415) \rightarrow 3(\pi^+\pi^-)$/total (P4)

```
R4 T         0.015     0.005            TANENBAUM 78 SMAG PSI(3685)TO GAM CHI
```

$\chi_0(3415) \rightarrow (\pi^+\pi^-)$/total (P1)

```
R5 T         0.008     0.003            TANENBAUM 78 SMAG PSI(3685)TO GAM CHI
R5 T         0.007     0.003            BRANDEL2  79 DASP PSI(3685)TO GAM CHI
R5          . . . . . . . . .
R5  AVG      0.0075    0.0021  AVERAGE
```

$\chi_0(3415) \rightarrow (K^+ K^-)$/total (P2)

```
R6 T          0.009    0.004          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI
R6 T          0.006    0.003          BRANDEL2  79 DASP PSI(3685)TO GAM CHI
R6         . . . . . . . . . .
R6  AVG       0.0071   0.0024  AVERAGE
```

$\chi_0(3415) \rightarrow (\pi^+ \pi^- p \bar{p})$/total (P8)

```
R7 T          0.005    0.002          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI
```

$\chi_0(3415) \rightarrow (J/\psi(3097)\ \gamma)$/total (P6)

```
R8 T          0.021    0.021          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
R8 T          0.018    0.009          BARTEL    78 CNTR PSI(3685)TO GAM CHI  |
R8 T          0.032    0.021          BRANDEL2  79 DASP PSI(3685)TO GAM CHI  |
R8 T         (0.059)OR LESS  CL=0.90  HIMEL     80 SMK2 PSI(3685)TO GAM CHI  |
R8 T S  17    0.0063   0.0018         OREGLIA   82 CBAL PSI(3685)TO GAM CHI  |
R8         . . . . . . . . . . .
R8  AVG       0.0070   0.0023  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$\chi_0(3415) \rightarrow (\rho^0 \pi^+ \pi^-)$/total (P9)

```
R9 T          0.016    0.005          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI
```

$\chi_0(3415) \rightarrow (K^*(892)^0 K^{\pm} \pi^{\mp})$/total (P10)

```
R10T          0.012    0.005          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_0(3415) \rightarrow (p \bar{p})$/total (units 10^{-2}) (P11)

```
R11T         (0.09) OR LESS  CL=0.90  BRANDEL2  79 DASP PSI(3685)TO GAM CHI  |

R    S  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R  T    CALCULATED USING PSI(3685) TO (GAMMA CHI0(3415))/TOTAL=0.094         |
R  T    THE ERRORS DO NOT CONTAIN THE UNCERTAINTY IN THE PSI(3685) DECAY.
```

REFERENCES FOR $\chi_0(3415)$

```
FELDMAN  75 PRL 35 821          +JEAN-MARIE,SADOULET,VANNUCCI,+  (LBL+SLAC)
    ALSO 75 PRL 35 1189  (ERRATA)
TANENBAU 75 PRL 35 1323         TANENBAUM,WHITAKER,ABRAMS,+      (LBL+SLAC)
WIIK     75 STANFORD SYMP.69    B.H.WIIK                             (DESY)

BIDDICK  77 PRL 38 1324         +BURNETT+    (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
FELDMAN  77 PL 33 C 285         +PERL                            (LBL+SLAC)
YAMADA   77 HAMB. CONF. P. 69 YAMADA                            (DESY+TOKY)

BARTEL   78 PL 79 B 492         DITTMANN,DUINKER,OLSSON,O?NEILL+(DESY+HEID)
TANENBAU 78 PR D 17 1731        TANENBAUM,ALAM,BOYARSKI,+        (SLAC+LBL)
    ALSO 82  PRIVATE COMM.      G.H.TRILLING                      (LBL+UCB)

BRANDEL1 79 ZPHY C 1 233        BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
BRANDEL2 79 NP B 160 426        BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
HIMEL    79 THESIS  SLAC-223    T.M.HIMEL                            (SLAC)
    ALSO 82  PRIVATE COMM.      G.H.TRILLING                      (LBL+UCB)
KIRK     79 PRL 42 619          +GOODMAN,ALVERSON,+(FNAL+HARV+ILL+OXF+TUFT)

HIMEL    80 PRL 44 920          +ABRAMS,ALAM,BLOCKER,+           (LBL+SLAC)

OREGLIA  82 PR D 25 2259        +PARTRIDGE,BLOOM,-(SLAC+CIT+HARV+PRIN+STAN)
```

$\chi_1(3510)$ was $\chi(3510)$

$I^G(J^{PC}) = 0^+(1^{++})$

```
                        FORMERLY CALLED PC.
                        OBSERVED IN THE RADIATIVE SEQUENTIAL DECAY
                        OF THE PSI(3685) INTO CHI1(3510) GAMMA, CHI1(3510)
     INTO J/PSI(3097) GAMMA. THEREFORE, C=+.  THE LACK OF DECAYS INTO
     PI+ PI- OR K+K- IS SUGGESTIVE OF JP = ABNORMAL. THE DECAYS INTO
     4PI AND 6PI IMPLY G=+, THUS I=0.  J=0,2 EXCLUDED BY ANGULAR
     DISTRIBUTION IN THE (GAMMA J/PSI) DECAY. JP=1+ PREFERRED
     (FELDMAN 77, OREGLIA 82)
```

$\chi_1(3510)$ MASS (MeV)

```
M        40(3500.)    (10.)            TANENBAUM 75 SMAG         HADRONS GAM
M         7(3507.0)    (7.0)           WIIK      75 DASP    E+E-,J/PSI 2 GAM
M          (3510.0)   (20.0)           BARTEL    76 CNTR    E+E-,J/PSI 2 GAM
M  D    367 3513.0      7.0            BIDDICK   77 CNTR    E+E-,MONOCHR.GAM
M  D        3507.0      3.0            BARTEL    78 CNTR    E+E-,J/PSI 2 GAM
M  D M      3505.0      6.0            TANENBAUM 78 SMAG    E+ E-              |
M        21 3509.0     11.0            BRANDEL2  79 DASP    E+E-,J/PSI 2GAM
M        15(3520.)                     LEMOIGNE  79 GOLI    150 PI-BE,2MU
M  D    254 3510.1      1.1            HIMEL     80 SMK2    E+E-,J/PSI 2 GAM
M  P     91 3507.4      1.7            LEMOIGNE  82 GOLI    190 PI-BE,GAM2MU
M  E        3510.4      0.6            OREGLIA   82 CBAL    E+E-,J/PSI 2 GAM
M  F        3511.4      0.5            BAGLIN    85 SPEC    PBAR P,E+ E-       |
M           . . . . . . . . . . .
M   AVG     3510.67     0.51   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)

M  D    MASS VALUE SHIFTED BY US BY AMOUNT APPROPRIATE FOR
M  D                  PSI(3685) MASS=3686 AND PSI(3097) MASS=3097
M  E    ASSUMING PSI(3685) MASS=3686 AND PSI(3097) MASS=3097.
M    F  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
M    M  FROM A SIMULTANEOUS FIT TO RADIATIVE AND HADRONIC DECAY CHANNELS
M    M                 SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
M  P    J/PSI MASS CONSTRAINED TO 3097.
```

$\chi_1(3510)$ WIDTH (MeV)

```
W             (0.97) OR LESS  CL=0.90  BAGLIN    85 SPEC    PBAR P,E+ E-       |
```

$\chi_1(3510)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\chi_1(3510) \rightarrow J/\psi(3097)\ \gamma$	3097+ 0
P2	$\chi_1(3510) \rightarrow \pi^+ \pi^-$	140+ 140
P3	$\chi_1(3510) \rightarrow K^+ K^-$	494+ 494
P4	$\chi_1(3510) \rightarrow \gamma \gamma$	0+ 0
P5	$\chi_1(3510) \rightarrow 2(\pi^+ \pi^-)$	140+ 140+ 140+ 140
P6	$\chi_1(3510) \rightarrow 3(\pi^+ \pi^-)$	
P7	$\chi_1(3510) \rightarrow \pi^+ \pi^- K^+ K^-$	140+ 140+ 494+ 494
P8	$\chi_1(3510) \rightarrow \pi^+ \pi^- p \bar{p}$	140+ 140+ 938+ 938
P9	$\chi_1(3510) \rightarrow \rho^0 \pi^+ \pi^-$	769+ 140+ 140
P10	$\chi_1(3510) \rightarrow K^*(892)^0 K^{\pm} \pi^{\mp}$	892+ 494+ 140
P11	$\chi_1(3510) \rightarrow p \bar{p}$	938+ 938

$\chi_1(3510)$ BRANCHING RATIOS

$\chi_1(3510) \rightarrow (J/\psi(3097)\ \gamma)$/total (P1)

```
R1 T         (0.58)   (0.17)          BIDDICK   77 CNTR PSI(3685)TO GAM CHI  |
R1 T          0.29     0.05           BARTEL    78 CNTR PSI(3685)TO GAM CHI  |
R1 T          0.28     0.09           TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
R1 T          0.19     0.05           BRANDEL2  79 DASP PSI(3685)TO GAM CHI  |
R1 T          0.28     0.07           HIMEL     80 SMK2 PSI(3685)TO GAM CHI  |
R1 T   943    0.274    0.046          OREGLIA   82 CBAL PSI(3685)TO GAM CHI  |
R1         . . . . . . . . . .
R1  AVG       0.258    0.025   AVERAGE
```

$\chi_1(3510) \rightarrow (\pi^+ \pi^- + K^+ K^-)$/total (P2+P3)

```
R2 T         (0.0017)OR LESS          FELDMAN   77 SMAG PSI(3685)TO GAM CHI  |
R2 T         (0.0038)OR LESS CL=0.90  BRANDEL2  79 DASP PSI(3685)TO GAM CHI  |
```

$\chi_1(3510) \rightarrow (\gamma \gamma)$/total (P4)

```
R3 T         (0.0015)OR LESS CL=0.90  YAMADA    77 DASP    E+ E-,3 GAMMA     |
```

$\chi_1(3510) \rightarrow 2(\pi^+ \pi^-)$/total (P5)

```
R4 T          0.017    0.005          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_1(3510) \rightarrow (\pi^+ \pi^- K^+ K^-)$/total (P7)

```
R5 T          0.009    0.004          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_1(3510) \rightarrow 3(\pi^+ \pi^-)$/total (P6)

```
R6 T          0.022    0.009          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_1(3510) \rightarrow (\pi^+ \pi^- p \bar{p})$/total (P8)

```
R7 T          0.0014   0.0009         TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_1(3510) \rightarrow (\rho^0 \pi^+ \pi^-)$/total (P9)

```
R8 T          0.0040   0.0035         TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_1(3510) \rightarrow (K^*(892)^0 K^{\pm} \pi^{\mp})$/total (P10)

```
R9 T          0.0032   0.0021         TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_1(3510) \rightarrow (p \bar{p})$/total (units 10^{-4}) (P11)

```
R11T        (12.0)   OR LESS CL=0.90  BRANDEL2  79 DASP PSI(3685)TO GAM CHI  |
R11          (0.5)  OR LARGE CL=0.95  BAGLIN    85 SPEC    PBAR P,E+ E-      |

R  T    ESTIMATED USING PSI(3685) TO (GAMMA PC)/TOTAL=0.087                  |
R  T    THE ERRORS DO NOT CONTAIN THE UNCERTAINTY IN THE PSI(3685) DECAY.
```

REFERENCES FOR $\chi_1(3510)$

```
DASP     75 PL 57B 407          BRAUNSCHWEIG,KONIGS,+ (AACH+DESY+MPIM+TOKY)
FELDMAN  75 STANFORD SYMP.39    G.J.FELDMAN                          (SLAC)
HEINTZE  75 STANFORD SYMP.97    J.HEINTZE                      (HEIDELBERG)
SIMPSON  75 PRL 35 699          +BERON,FORD,HILGER,HOFSTADTER,+ (STAN+PENN)
TANENBAU 75 PRL 35 1323         TANENBAUM,WHITAKER,ABRAMS,+      (LBL+SLAC)
WIIK     75 STANFORD SYMP.69    B.H.WIIK                             (DESY)

BARTEL   76 TBILISI CONF.N75    +DUINKER,OLSSON,HEINTZE,+       (DESY+HEID)

BIDDICK  77 PRL 38 1324         +BURNETT+    (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
FELDMAN  77 PL 33 C 285         +PERL                            (LBL+SLAC)
YAMADA   77 HAMB. CONF. P. 69 YAMADA                            (DESY+TOKY)

BARTEL   78 PL 79 B 492         +DITTMANN,DUINKER,OLSSON,ONEILL+(DESY-HEID)
TANENBAU 78 PR D 17 1731        TANENBAUM,ALAM,BOYARSKI,+        (SLAC+LBL)
    ALSO 82  PRIVATE COMM.      G.H.TRILLING                      (LBL+UCB)

BRANDEL1 79 ZPHY C 1 233        BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
BRANDEL2 79 NP B 160 426        BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
KIRK     79 PRL 42 619          +GOODMAN,ALVERSON,+(FNAL+HARV+ILL+OXF+TUFT)
LEMOIGNE 79 FERMILAB CONF.524 +ABOLINS,BARATE,+       (SACL+LOIC+SHMP+IND)

HIMEL    80 PRL 44 920          +ABRAMS,ALAM,BLOCKER,+           (LBL-SLAC)
    ALSO 82  PRIVATE COMM.      G.H.TRILLING                      (LBL+UCB)

LEMOIGNE 82 PL 113 B 509        +BARATE,ASTBURY,MCEWEN+(SACL+LOIC+SHMP+IND)
OREGLIA  82 PR D 25 2259        +PARTRIDGE,BLOOM,+(SLAC+CIT+HARV+PRIN+STAN)
   ALSO  82  PRIVATE COMM.      M. OREGLIA                            (EFI)

BARATE   83 PL 121 B 449        +BAREYRE,ASTBURY,MCEWEN(SACL+LOIC+SHMP+IND)

BAGLIN   85  CERN-PRE-85          (LAPP+CERN+GENO+LYON+OSLO+ROMA+STRB+TORI)
```

Meson Full Listings

$\chi_2(3555)$, $\eta_c(3590)$

$\chi_2(3555)$ was $\chi(3555)$

$I^G(J^{PC}) = 0^+(2^{-+})$

```
OBSERVED IN RADIATIVE DECAY OF PSI(3685) INTO
CHI2(3555) GAMMA. THEREFORE C=+. THE OBSERVED
DECAY INTO 4PI AND 6PI IMPLY G=+, THUS I=0.
J=0 IS EXCLUDED BY THE ANGULAR DISTRIBUTION IN THE HADRONIC
DECAYS. JP ABNORMAL EXCLUDED BY PI+ PI- AND K+ K- DECAYS.
JP=2+ PREFERRED (FELDMAN 77, OREGLIA 82).
```

$\chi_2(3555)$ MASS (MeV)

```
M          (3550.0)   (10.0)          TRILLING  76 SMAG   E+E-,HADRONS GAM
M         4(3543.0)   (10.0)          WHITAKER  76 SMAG   E+E-,J/PSI 2 GAM
M  D   360 3563.0      7.0            BIDDICK   77 CNTR   E+E-,MONOCHR.GAM
M  D       3553.0      4.0            BARTEL    78 CNTR   E+E-,J/PSI 2 GAM
M  D M     3553.0      6.0            TANENBAUM 78 SMAG   E+ E-              |
M       15 3551.0     11.0            BRANDEL2  79 DASP   E+E-,J/PSI 2GAM
M  D    69 3557.       1.5            HIMEL     80 SMK2   E+E-,J/PSI 2 GAM
M  P    66 3553.4      2.2            LEMOIGNE  82 GOLI   190 PI-BE,GAM2MU
M  E       3555.9      0.7            OREGLIA   82 CBAL   E+E-,J/PSI 2 GAM
M  F       3556.8      0.6            BAGLIN    85 SPEC   PBAR P,E+ E-       |
M          . . . . . . . . . .
M   AVG    3556.31     0.42     AVERAGE

M  D    MASS VALUE SHIFTED BY US BY AMOUNT APPROPRIATE FOR
M  D                PSI(3685) MASS=3686 AND PSI(3097) MASS=3097.
M  E    ASSUMING PSI(3685) MASS=3686 AND PSI(3097) MASS=3097.
M    F  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
M    M  FROM A SIMULTANEOUS FIT TO RADIATIVE AND HADRONIC DECAY CHANNELS
M    M              SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
M  P    J/PSI MASS CONSTRAINED TO 3097
```

$\chi_2(3555)$ WIDTH (MeV)

```
W            2.9      1.8      1.1  BAGLIN     85 SPEC    PBAR P,E+ E-       |
```

$\chi_2(3555)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\chi_2(3555) \to \pi^+\pi^-$	140+ 140
P2	$\chi_2(3555) \to K^+K^-$	494+ 494
P3	$\chi_2(3555) \to 2(\pi^+\pi^-)$	140+ 140+ 140+ 140
P4	$\chi_2(3555) \to 3(\pi^+\pi^-)$	
P5	$\chi_2(3555) \to \pi^+\pi^-K^+K^-$	140+ 140+ 494+ 494
P6	$\chi_2(3555) \to J/\psi(3097)\ \gamma$	3097+ 0
P7	$\chi_2(3555) \to \gamma\gamma$	0+ 0
P8	$\chi_2(3555) \to \pi^+\pi^-p\overline{p}$	140+ 140+ 938+ 938
P9	$\chi_2(3555) \to \rho^0\pi^+\pi^-$	769+ 140+ 140
P10	$\chi_2(3555) \to K^*(892)^0K^\pm\pi^\mp$	892+ 494+ 140
P11	$\chi_2(3555) \to p\overline{p}$	938+ 938
P12	$\chi_2(3555) \to J/\psi(3097)\ \pi^+\pi^-\pi^0$	3097+ 140+ 140+ 135

$\chi_2(3555)$ BRANCHING RATIOS

$\chi_2(3555) \to (\gamma\gamma)$/total (P7)

```
R1 T      (0.0006)OR LESS  CL=0.90 YAMADA    77 DASP    E+ E-,3 GAMMA
```

$\chi_2(3555) \to 2(\pi^+\pi^-)$/total (P3)

```
R2 T       0.022    0.005          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_2(3555) \to (\pi^+\pi^-K^+K^-)$/total (P5)

```
R3 T       0.019    0.005          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_2(3555) \to 3(\pi^+\pi^-)$/total (P4)

```
R4 T       0.011    0.008          TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_2(3555) \to (\pi^+\pi^- + K^+K^-)$/total (P1+P2)

```
R5 T       0.0025   0.0010         TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_2(3555) \to (\pi^+\pi^-p\overline{p})$/total (P8)

```
R6 T       0.0033   0.0013         TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_2(3555) \to (J/\psi(3097)\ \gamma)$/total (P6)

```
R7 T      (0.28)   (0.13)          BIDDICK   77 CNTR PSI(3685)TO GAM CHI  |
R7 T       0.13     0.03           BARTEL    78 CNTR PSI(3685)TO GAM CHI  |
R7 T       0.11     0.13     0.07  SPITZER   78 PLUT PSI(3685)TO GAM CHI  |
R7 T       0.13     0.08           TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
R7 T       0.18     0.05           BRANDEL2  79 DASP PSI(3685)TO GAM CHI  |
R7 T       0.14     0.04           HIMEL     80 SMK2 PSI(3685)TO GAM CHI  |
R7 T   479 0.162    0.028          OREGLIA   82 CBAL PSI(3685)TO GAM CHI  |
R7        . . . . . . . . . .
R7  AVG    0.148    0.017   AVERAGE
```

$\chi_2(3555) \to (\rho^0\pi^+\pi^-)$/total (P9)

```
R8 T       0.0067   0.0040         TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_2(3555) \to (K^*(892)^0K^\pm\pi^\mp)$/total (P10)

```
R9 T       0.0047   0.0028         TANENBAUM 78 SMAG PSI(3685)TO GAM CHI  |
```

$\chi_2(3555) \to (\pi^+\pi^-)$/total (units 10^{-3}) (P1)

```
R10T    4    1.9      1.0            BRANDEL1  79 DASP PSI(3685)TO GAM CHI  |
```

$\chi_2(3555) \to (K^+K^-)$/total (units 10^{-3}) (P2)

```
R11T    2    1.5      1.1            BRANDEL1  79 DASP PSI(3685)TO GAM CHI  |
```

$\chi_2(3555) \to (p\overline{p})$/total (units 10^{-3}) (P11)

```
R12T        (0.9)  OR LESS CL=0.90   BRANDEL2  79 DASP PSI(3685)TO GAM CHI  |
R12          7.6      4.0      2.0   BAGLIN    85 SPEC    PBAR P,E+ E-      |
```

$\chi_2(3555) \to (J/\psi(3097)\ \pi^+\pi^-\pi^0)$/total (P12)

```
R13         (0.015)OR LESS  CL=.90   BARATE    81 SPEC    190 PI-BE,2PI2MU

R  T    ESTIMATED USING PSI(3685) TO (GAMMA CHI2(3555))/TOTAL=0.078        |
R  T    THE ERRORS DO NOT CONTAIN THE UNCERTAINTY IN THE PSI(3685) DECAY.
```

REFERENCES FOR $\chi_2(3555)$

```
FELDMAN  75 PRL 35 821          +JEAN-MARIE,SADOULET,VANNUCCI,+  (LBL+SLAC)
   ALSO  75 PRL 35 1189  (ERRATA)
TANENBAU 75 PRL 35 1323         TANENBAUM,WHITAKER,ABRAMS,+      (LBL+SLAC)

TRILLING 76 STANFORD SYMP.437 G. H. TRILLING                          (LBL)
WHITAKER 76 PRL 37 1596       +TANENBAUM,ABRAMS,ALAM,BOYARSKI,+(SLAC+LBL)

BIDDICK  77 PRL 38 1324       +BURNETT+    (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
FELDMAN  77 PL 33 C 285       +PERL                             (LBL+SLAC)
YAMADA   77 HAMB. CONF. P. 69 YAMADA                           (DESY+TOKY)

BARTEL   78 PL 79 B 492       DITTMANN,DUINKER,OLSSON,O?NEILL+(DESY+HEID)
SPITZER  78 KYOTO SUM.INST.47 H. SPITZER                            (HAMB)
TANENBAU 78 PR D 17 1731      TANENBAUM,ALAM,BOYARSKI,+        (SLAC+LBL)
   ALSO  82  PRIVATE COMM.    G.H.TRILLING                       (LBL+UCB)

BRANDEL1 79 ZPHY C 1 233      BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
BRANDEL2 79 NP B 160 426      BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
KIRK     79 PRL 42 619        +GOODMAN,ALVERSON,+(FNAL+HARV+ILL+OXF+TUFT)

HIMEL    80 PRL 44 920        +ABRAMS,ALAM,BLOCKER,+           (LBL+SLAC)
   ALSO  82  PRIVATE COMM.    G.H.TRILLING                       (LBL+UCB)

BARATE   81 PR D 24 2994      +ASTBURY,MCEWEN,+ (SACL+LOIC+SHMP+CERN+IND)

LEMOIGNE 82 PL 113 B 509      +BARATE,ASTBURY,MCEWEN+(SACL+LOIC+SHMP+IND)
OREGLIA  82 PR D 25 2259      +PARTRIDGE,BLOOM,+(SLAC+CIT+HARV+PRIN+STAN)
   ALSO  82  PRIVATE COMM.    M. OREGLIA                             (EFI)

BARATE   83 PL 121 B 449      +BAREYRE,ASTBURY,MCEWEN(SACL+LOIC+SHMP+IND)

BAGLIN   85  CERN-PRE-85        (LAPP+CERN+GENO+LYON+OSLO+ROMA+STRB+TORI)
```

$\eta_c(3590)$

$I^G(J^{PC}) = ?^?(?^{?+})$

OMITTED FROM SUMMARY TABLE

```
OUR LATEST MINIREVIEW ON THIS PARTICLE
CAN BE FOUND IN THE 1984 EDITION.
NEEDS CONFIRMATION.
```

$\eta_c(3590)$ MASS (MeV)

```
M    A     3594.0     5.0            EDWARDS   82 CBAL    E+E-,GAM INCL
M    A  ASSUMING MASS OF PSI(3685) = 3686 MEV.
```

$\eta_c(3590)$ WIDTH (MeV)

```
W            (8.0)  OR LESS  CL=.95  EDWARDS   82 CBAL    E+E-,GAM INCL
```

$\eta_c(3590)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\eta_c(3590) \to$ hadrons	

$\eta_c(3590)$ BRANCHING RATIOS

$\eta_c(3590) \to$ hadrons (P1)

```
R1         SEEN                      EDWARDS   82 CBAL    E+E-,GAM INCL
```

REFERENCES FOR $\eta_c(3590)$

```
BARTEL   78 PL 79 B 492        +DITTMANN,DUINKER,OLSSON,+      (DESY+HEID)

PORTER   81 SLAC SUM.CONF.355 +EDWARDS,+        (CIT+HARV+PRIN+STAN+SLAC)

EDWARDS  82 PRL 48 70          +PARTRIDGE,PECK,+ (CIT+HARV+PRIN+STAN+SLAC)
OREGLIA  82 PR D 25 2259       +PARTRIDGE,BLOOM,+(SLAC+CIT+HARV+PRIN+STAN)
```

$\psi(3685)$

$I^G(J^{PC}) = 0^-(1^{--})$

$\psi(3685)$ MASS (MeV)

```
                  WE USE INDEPENDENT MEASUREMENTS OF THE J/PSI(3097)
                  MASS, THE PSI(3685) MASS, AND THE MASS DIFFERENCE TO
                  PERFORM A CONSTRAINED FIT.

M  S       3680.3     37.              CRIEGEE   75 PLUT         E+E-
M   R     (3684.)     (5.)             LUTH      75 SMAG         E+E-
M          3684.       9.              PREPOST   75 SPEC     21. GAMMA D
M      140(3683.0)    (6.0)            LEMOIGNE  79 GOLI   0 150 PI-BE,2MU
M  F       3686.       3.              BRANDEL1  79 DASP     E+ E-
M      413 3686.00     0.10            ZHOLENTZ  80 OLYA     E+E- COLL.BEAMS
M          . . . . . . . . . .
M   AVG    3686.000    0.100   AVERAGE
M   FIT    3686.00     0.10   FROM FIT

M  F    FROM A SIMULTANEOUS FIT TO E+ E-,MU+ MU- AND HADRONIC CHANNELS
M  F    ASSUMING G(E+ E-) = G(MU+ MU-)
M   R   REDUNDANT WITH DATA IN MASS DIFFERENCE BELOW
M   S   ERROR OF ABOUT 1 PER CENT FROM THE UNCERTAINTY IN CALIBRATION OF
M   S   THE BEAM ENERGY.
```

$\psi(3685)$ − $J/\psi(3097)$ MASS DIFFERENCE (MeV)

```
DM          588.7       .8             LUTH      75 SMAG
DM  R      (589.07)   (0.13)           ZHOLENTZ  80 OLYA     E+E-
DM          589.7      1.2             LEMOIGNE  82 GOLI     190 PI-BE,2MU
DM          . . . . . . . . . .
DM  AVG     589.01     0.67    AVERAGE
DM  FIT     589.06     0.13   FROM FIT

DM  R   REDUNDANT WITH DATA IN MASS ABOVE
```

$\psi(3685)$ WIDTH (keV)

```
W           228.       56.             LUTH      75 SMAG
W  F        202.       57.             BRANDEL1  79 DASP     E+ E-
W  F    FROM A SIMULTANEOUS FIT TO E+ E-,MU+ MU- AND HADRONIC CHANNELS
W  F    ASSUMING G(E+ E-) = G(MU+ MU-)
W           . . . . . . . . . .
W   AVG     215.2      39.9    AVERAGE
```

$\psi(3685)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\psi(3685) \to e^+e^-$	.511+.511
P2	$\psi(3685) \to \mu^+\mu^-$	106+ 106
P3	$\psi(3685) \to$ hadrons	
P4	$\psi(3685) \to$ virtual $\gamma \to$ hadrons	
P	DECAYS INTO J/PSI(3097) + ANYTHING	
P	--------------------------------	
P11	$\psi(3685) \to J/\psi(3097)$ + anything	
P12	$\psi(3685) \to J/\psi(3097)$ + neutrals	
P13	$\psi(3685) \to J/\psi(3097)\ \pi^+\pi^-$	3097+ 140+ 140
P14	$\psi(3685) \to J/\psi(3097)\ \pi^0\pi^0$	3097+ 135+ 135
P15	$\psi(3685) \to J/\psi(3097)\ \eta$	3097+ 549
P16	$\psi(3685) \to J/\psi(3097)\ \gamma\gamma$	3097+ 0+ 0
P17	$\psi(3685) \to J/\psi(3097)\ \pi^0$	3097+ 135
P17	SMALL -- NOT USED IN FIT	
P	HADRONIC DECAYS	
P	---------------	
P21	$\psi(3685) \to \pi^+\pi^-$	140+ 140
P22	$\psi(3685) \to \rho\pi$	769+ 140
P23	$\psi(3685) \to K^+K^-$	494+ 494
P24	$\psi(3685) \to 2(\pi^+\pi^-)$	140+ 140+ 140+ 140
P25	$\psi(3685) \to 2(\pi^+\pi^-)\ \pi^0$	140+ 140+ 140+ 140
P26	$\psi(3685) \to \pi^+\pi^-K^+K^-$	140+ 140+ 494+ 494
P27	$\psi(3685) \to \overline{p}\underline{p}$	938+ 938
P28	$\psi(3685) \to \Lambda\overline{\Lambda}$	1116+1116
P29	$\psi(3685) \to \Xi\overline{\Xi}$	1321+1321
P31	$\psi(3685) \to \pi^+\pi^-p\overline{p}$	140+ 140+ 938+ 938
P32	$\psi(3685) \to 3(\pi^+\pi^-)$	
P33	$\psi(3685) \to \rho^0\pi^+\pi^-$	769+ 140+ 140
P34	$\psi(3685) \to K^*(892)^0K^\pm\pi^\mp$	892+ 494+ 140
P35	$\psi(3685) \to \overline{p}p\pi^0$	938+ 938+ 135
P36	$\psi(3685) \to \pi^+\pi^-\pi^0$	140+ 140+ 135
P37	$\psi(3685) \to 3(\pi^+\pi^-)\ \pi^0$	
P38	$\psi(3685) \to K^+K^-\pi^0$	494+ 494+ 135
P39	$\psi(3685) \to K^\pm K^*(892)^\mp$	494+ 892
P	RADIATIVE DECAYS	
P	----------------	
P51	$\psi(3685) \to \gamma\gamma$	0+ 0
P52	$\psi(3685) \to \pi^0\gamma$	135+ 0
P53	$\psi(3685) \to \eta\gamma$	549+ 0
P54	$\psi(3685) \to \eta'\gamma$	958+ 0
P56	$\psi(3685) \to \chi_0(3415)\ \gamma$	3415+ 0
P58	$\psi(3685) \to \chi_1(3510)\ \gamma$	3510+ 0
P59	$\psi(3685) \to \chi_2(3555)\ \gamma$	3556+ 0
P60	$\psi(3685) \to \chi_1(3510)$ + anything	
P61	$\psi(3685) \to \eta_c(2980)\ \gamma$	2981+ 0
P62	$\psi(3685) \to \eta(1440)\ \gamma$	1440+ 0
P63	$\psi(3685) \to \eta_c(3590)\ \gamma$	3594+ 0

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{(\delta P_i \delta P_i)}$, while the off-diagonal elements are the normalized correlation coefficients $(\delta P_i \delta P_j)/(\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

	$J/\psi\ \pi^+\pi^-$	$J/\psi\ \pi^0\pi^0$	$J/\psi\ \eta$	J/ψ + OTHER	NON-J/ψ
$J/\psi\ \pi^+\pi^-$	.4106+-.0821				
$J/\psi\ \pi^0\pi^0$	.8343	.2176+-.0522			
$J/\psi\ \eta$	.0155	.0130	.0265+-.0036		
J/ψ − OTHER	.4864	.0643	-.0298	.0373+-.0464	
NON-J/ψ	-.9819	-.8192	-.0273	-.5935	.3081+-.1510

$\psi(3685)$ PARTIAL WIDTHS

$\psi(3685) \to e^+e^-$ (keV) (G1)

```
W1 F          2.1        .3            LUTH      75 SMAG         E+E-
W1 F          2.        0.3            BRANDEL1  79 DASP     E+ E-
W1 F    FROM A SIMULTANEOUS FIT TO E+ E-,MU+ MU- AND HADRONIC CHANNELS
W1 F    ASSUMING G(E+ E-) = G(MU+ MU-)
W1          . . . . . . . . . .
W1  AVG       2.05      0.21    AVERAGE
```

$\psi(3685) \to$ hadrons (keV) (G3)

```
W3          224.       56.             LUTH      75 SMAG         E+E-
```

$\psi(3685) \to \gamma\gamma$ (eV) (G51)

```
W51          43. OR LESS CL=0.90       BRANDEL1  79 DASP     E+ E-
```

$\psi(3685)$ BRANCHING RATIOS

$\psi(3685) \to (e^+e^-)$/total (P1)

```
R1 L          .0088     .0013          FELDMAN   77 RVUE         E+E-
R1 L    FROM AN OVERALL FIT ASSUMING EQUAL PARTIAL WIDTHS FOR (E+E-)
R1 L    AND (MU+MU-). FOR A MEASUREMENT OF THE RATIO SEE THE ENTRY R4 BELOW
R1 L    INCLUDES LUTH 75,HILGER 75,BURMESTER 77
```

$\psi(3685) \to (\mu^+\mu^-)$/total (P2)

```
R2 H          .0077     .0017          HILGER    75 SPEC         E+E-
R2 H    RE-STATED BY US USING (J/PSI(3097)+ANYTHING)/TOTAL =0.55
```

$\psi(3685) \to$ (hadrons)/total (P3)

```
R3   P        .981      .003           LUTH      75 SMAG         E+E-
R3   P  INCLUDES CASCADE DECAY INTO J/PSI(3097)
```

$\psi(3685) \to (\mu^+\mu^-)/(e^+e^-)$ (P2)/(P1)

```
R4            .89       .16            BOYARSKI  75 SMAG         E+E-
```

$\psi(3685) \to (\gamma \to$ hadrons)/total (P4)

```
R5 C          .029      .004           LUTH      75 SMAG         E+E-
R5 C    INCLUDED IN R3
```

```
R      DECAYS INTO J/PSI(3097) + ANYTHING
R      --------------------------------
```

$\psi(3685) \to (J/\psi(3097)$ + anything)/total (P11)

```
R10           .57       .08            ABRAMS    75 SMAG         E+E-
R10          0.51      0.12            BRANDEL1  79 DASP     E+ E-
R10         . . . . . . . . . .
R10 AVG      0.552     0.067    AVERAGE
R10 FIT      0.69      0.15   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 3.1)
```

$\psi(3685) \to (J/\psi(3097)$+neutrals)/($J/\psi(3097)$+anything) (P12)/(P11)

```
R11           .41       .02            TANENBAUM 76 SMAG         E+E-
R11         . . . . . . . . . .
R11 FIT      0.395     0.027  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.4)
```

$\psi(3685) \to (J/\psi(3097)\ \pi\pi)$/total (P13+P14)

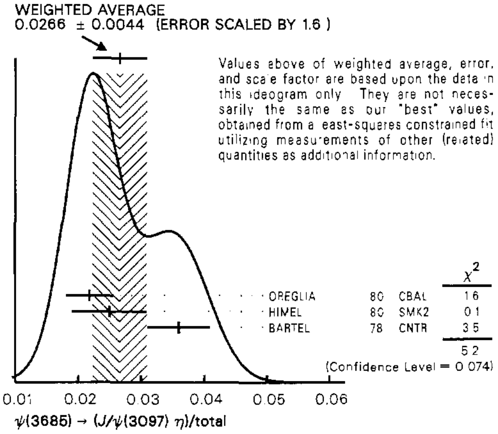
```
R12          0.48      0.06            ABRAMS1   75 SMAG     E+E-,JPSI PI+PI-
R12          0.51      0.087           ABRAMS1   75 SMAG     E+E-,JPSI 2PI0
R12          0.54      0.09            WIIK      75 DASP     E+E-,JPSI PI+PI-
R12          0.54      0.18            WIIK      75 DASP     E+E-,JPSI 2PI0
R12         . . . . . . . . . .
R12 AVG      0.503     0.042    AVERAGE
R12 FIT      0.411     0.082  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.7)
```

$\psi(3685) \to (J/\psi(3097)\ \pi^0\pi^0)/(J/\psi(3097)\ \pi^+\pi^-)$ (P14)/(P13)

```
R14 H       (.64)    (.15)          HILGER    75 SPEC          E+E-
R14          0.53     0.06          TANENBAUM 76 SMAG          E+E-
R14 H   IGNORING THE (J/PSI ETA) AND (J/PSI GAMMA GAMMA) DECAYS
R14         . . . . . . . . . .
R14 FIT      0.530    0.070  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

$\psi(3685) \to (J/\psi(3097)\ \eta)$/total (P15)

```
R15 S   44   (.043)   (.008)        TANENBAUM 76 SMAG          E+E-
R15    164   0.036    0.005         BARTEL    78 CNTR      E+E-
R15 S   17  (0.035)  (0.009)        BRANDEL2  79 DASP      E+E-,PSI 2GAM
R15    166   0.025    0.006         HIMEL     80 SMK2      E+E-
R15  D 386   0.0218   0.0038        OREGLIA   80 CBAL      E+E-,PSI 2GAM
R15         . . . . . . . . . .
R15 AVG      0.0266   0.0044  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
R15 FIT      0.0265   0.0036 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
                      (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$\psi(3685) \to (J/\psi(3097)\ \pi^0)$/total (P17)

```
R16      7   0.0015   0.0006        HIMEL     80 SMK2      E+E-
R16  D  23   0.0009   0.0003        OREGLIA   80 CBAL      PSI3685,PSI 2GAM
R16         . . . . . . . . . .
R16 AVG      0.00102  0.00027  AVERAGE
```

```
R      HADRONIC DECAYS
R      ---------------
```

$\psi(3685) \to (\pi^+\pi^-)$/total (units 10^{-4}) (P21)

```
R20         (0.5)  OR LESS  CL=0.90 FELDMAN   77 SMAG          E+E-
R20          0.8      0.5           BRANDEL1  79 DASP      E+ E-
```

$\psi(3685) \to (2(\pi^+\pi^-)\ \pi^0)$/total (P25)

```
R22           .0035    .0015        ABRAMS    75 SMAG          E+E-
R22     42   0.003    0.0008        FRANKLIN  83 SMK2      E+E-,HADRONS
R22         . . . . . . . . . .
R22 AVG      0.00311  0.00071  AVERAGE
```

$\psi(3685) \to (K^+K^-)$/total (units 10^{-4}) (P23)

```
R23         (0.5)  OR LESS  CL=0.90 FELDMAN   77 SMAG          E+E-
R23          1.0      0.7           BRANDEL1  79 DASP      E+ E-
```

$\psi(3685) \to (\pi^+\pi^-K^+K^-)$/total (P26)

```
R24K         0.0016   0.0004        TANENBAUM 78 SMAG          E+E-
R24K    ASSUMING ENTIRELY STRONG DECAY
```

$\psi(3685) \to (\overline{p}\,p)$/total (units 10^{-4}) (P27)

```
R25          2.3      0.7           FELDMAN   77 SMAG          E+E-
R25      4   1.4      0.8           BRANDEL1  79 DASP      E+ E-
R25         . . . . . . . . . .
R25 AVG      1.91     0.53     AVERAGE
```

$\psi(3685) \to (\rho\,\pi)$/total (units 10^{-4}) (P22)

```
R26  N      (10.)   OR LESS  CL=.90  ABRAMS    75 SMAG          E+E-
R26         (10.)   OR LESS CL=0.90  BARTEL    76 CNTR          E+E-
R26      1  (0.83)  OR LESS CL=0.90  FRANKLIN  83 SMK2      E+E-,HADRONS
R26  N  FINAL STATE RHOO PIO
```

$\psi(3685) \to 2(\pi^+\pi^-)$/total (P24)

```
R27          0.00045  0.0001        TANENBAUM 78 SMAG          E+E-
```

$\psi(3685) \to (\Lambda\,\overline{\Lambda})$/total (P28)

```
R28          (0.0004)OR LESS  CL=0.90 FELDMAN   77 SMAG          E+E-
```

$\psi(3685) \to (\Xi^-\overline{\Xi}^+)$/total (P29)

```
R29          (0.0002)               FELDMAN   77 SMAG          E+E-
```

$\psi(3685) \to (\pi^+\pi^-p\,\overline{p})$/total (units 10^{-3}) (P31)

```
R31S         0.8      0.2           TANENBAUM 78 SMAG      E+ E-
R31S    ASSUMING ENTIRELY STRONG DECAY
```

$\psi(3685) \to 3(\pi^+\pi^-)$/total (units 10^{-3}) (P32)

```
R32S         0.15     0.1           TANENBAUM 78 SMAG      E+ E-
```

$\psi(3685) \to (\rho^0\pi^+\pi^-)$/total (units 10^{-3}) (P33)

```
R33          0.42     0.15          TANENBAUM 78 SMAG      E+ E-
```

$\psi(3685) \to (K^*(892)^0K^\pm\pi^\mp)$/total (units 10^{-3}) (P34)

```
R34          0.67     0.25          TANENBAUM 78 SMAG      E+ E-
```

$\psi(3685) \to (p\,\overline{p}\,\pi^0)$/total (units 10^{-4}) (P35)

```
R35      9   1.4      0.5           FRANKLIN  83 SMK2      E+E-,HADRONS
```

$\psi(3685) \to (\pi^+\pi^-\pi^0)$/total (units 10^{-5}) (P36)

```
R36      4   8.5      4.6           FRANKLIN  83 SMK2      E+E-,HADRONS
```

$\psi(3685) \to (3(\pi^+\pi^-)\pi^0)$/total (P37)

```
R37      6    .0035    .0016        FRANKLIN  83 SMK2      E+E-,HADRONS
```

$\psi(3685) \to (K^+K^-\pi^0)$/total (units 10^{-5}) (P38)

```
R38      1  (2.96) OR LESS CL=0.90  FRANKLIN  83 SMK2      E+E-,HADRONS
```

$\psi(3685) \to (K^\pm K^*(892)^\mp)$/total (units 10^{-5}) (P39)

```
R39      0  (1.79) OR LESS CL=0.90  FRANKLIN  83 SMK2      E+E-,HADRONS
```

```
R      RADIATIVE DECAYS
R      ----------------
```

$\psi(3685) \to (\pi^0\gamma)$/total (P52)

```
R42  U      (.0054)R LESS  CL=.95   LIBERMAN  75 SPEC          E+E-
R42         (.01) OR LESS  CL=.90   WIIK      75 DASP          E+E-
```

$\psi(3685) \to (\eta\,\gamma)$/total (units 10^{-2}) (P53)

```
R43         (0.02)OR LESS  CL=0.90  YAMADA    77 DASP      E+ E-,3 GAMMA
```

$\psi(3685) \to (\eta'\gamma)$/total (units 10^{-2}) (P54)

```
R44C        (0.11) OR LESS  CL=0.90 BARTEL    76 CNTR          E+E-
R44  R      (0.6)  OR LESS  CL=0.90 BRAUNSCHW 77 DASP          E+E-
```

$\psi(3685) \to (\chi_0(3415)\ \gamma)$/total (units 10^{-2}) (P56)

```
R55  A       7.5      2.6           WHITAKER  76 SMAG          E+E-
R55  A       7.2      2.3           BIDDICK   77 CNTR      E+E-,MONOCHR.GAM
R55D A       9.9      0.9           GAISER    85 CBAL      E+E-,MONOCHR.GAM
R55         . . . . . . . . . .
R55 AVG      9.35     0.80     AVERAGE
```

$\psi(3685) \to (\chi_1(3510)\ \gamma)$/total (units 10^{-2}) (P58)

```
R58  B       7.1      1.9           BIDDICK   77 CNTR      E+E-,MONOCHR.GAM
R58D G       9.0      0.9           GAISER    85 CBAL      E+E-,MONOCHR.GAM
R58         . . . . . . . . . .
R58 AVG      8.65     0.81     AVERAGE
```

$\psi(3685) \to (\chi_2(3555)\ \gamma)$/total (units 10^{-2}) (P59)

```
R59  B       7.0      2.0           BIDDICK   77 CNTR      E+E-,MONOCHR.GAM
R59D F       8.0      0.9           GAISER    85 CBAL      E+E-,MONOCHR.GAM
R59         . . . . . . . . . .
R59 AVG      7.83     0.82     AVERAGE
```

$\psi(3685) \to (\eta_c(2980)\ \gamma)$/total (units 10^{-2}) (P61)

```
R60          0.28     0.06          GAISER    85 CBAL      E+E-,MONOCHR.GAM
```

$\psi(3685) \to (\eta(1440)\ \gamma)$/total (units 10^{-3}) (P62)

```
R61  E      (0.12) OR LESS  CL=.90  SCHARRE   80 SMAG      E+E-
```

$\psi(3685) \to (\eta_c(3590)\ \gamma)$/total (units 10^{-2}) (P63)

```
R62         (0.2) TO  1.3   CL=.95  EDWARDS   82 CBAL      E+E-,MONOCHR.GAM
```

```
R     A  ANGULAR DISTRIBUTION (1+COS**2) ASSUMED
R     B  VALID FOR ISOTROPIC DISTRIBUTION OF THE PHOTON
R  C     THE VALUE IS NORMALIZED TO THE BRANCHING RATIO FOR PSI(3685)
R  C     INTO (J/PSI(3097) ETA)/TOTAL.
R     D  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
R     E  INCLUDES UNKNOWN BRANCHING FRACTION ETA(1440) INTO K KBAR PI.
R     F  ANGULAR DISTRIBUTION (1-0.052*COS**2) ASSUMED
R     G  ANGULAR DISTRIBUTION (1-0.189*COS**2) ASSUMED
R     U  RE-STATED BY US USING (MU+MU-)/TOTAL = .0077
R     R  RE-STATED BY US USING TOTAL DECAY WIDTH 228 KEV.
R    S   LOW STATISTICS DATA REMOVED FROM AVERAGE.
```

$\psi(3685)$ $\Gamma(I)*\Gamma(e^+e^-)/\Gamma(\text{total})$ (keV)

```
THIS COMBINATION OF A PARTIAL WIDTH WITH THE PARTIAL WIDTH
INTO E+E- AND WITH THE TOTAL WIDTH IS OBTAINED FROM THE INTEGRATED
CROSS-SECTION INTO CHANNEL(I) IN THE E+E- ANNIHILATION.
WE ONLY LIST DATA NOT HAVING BEEN USED TO DETERMINE THE PARTIAL
WIDTH G(I) OR THE BRANCHING RATIO G(I)/TOTAL.
```

Γ(hadronic)$*\Gamma(e^+e^-)/\Gamma$(total)

```
G3           2.2       .4           ABRAMS    75 SMAG          E+E-
```

REFERENCES FOR $\psi(3685)$

```
ABRAMS   74 PRL 33 1453         +BRIGGS,AUGUSTIN,BOYARSKI+       (LBL+SLAC)

ABRAMS   75 STANFORD SYMP.25    G.S.ABRAMS                             (LBL)
ABRAMS1  75 PRL 34 1181         +BRIGGS,CHINOWSKY,FRIEDBERG,+    (LBL+SLAC)
AUBERT   75 PRL 33 1624         +BECKER,BIGGS,BURGER,GLENN+       (MIT+BNL)
BOYARSKI 75 PALERMO CONF. 54    +BREIDENBACH,BULOS,ABRAMS,BRIGGS+(SLAC+LBL)
CAMERINI 75 PRL 35 483          +LEARNED,PREPOST,ASH,ANDERSON,+ (WISC+SLAC)
CRIEGEE  75 PL 53B 489          +DEHNE,FRANKE,HORLITZ,KRECHLOCK+     (DESY)
DASP3    75 PL 57B 407          BRAUNSCHWEIG,KONIGS,+ (AACH+DESY+MPIM+TOKY)
FELDMAN  75 PRL 35 821          +JEAN-MARIE,SADOULET,VANNUCCI,+  (LBL+SLAC)
GRECO    75 PL 56B 367          +PANCHERI-SRIVASTAVA,SRIVASTAVA      (FRAS)
```

```
JACKSON  75 NIM 128 13          J.D.JACKSON,D.SCHARRE                (LBL)
HILGER   75 PRL 35 625          +BERON,FORD,HOFSTADTER,HOWELL,+ (STAN+PENN)
LIBERMAN 75 STANFORD SYMP.55    A.D.LIBERMAN                    (STANFORD)
LUTH     75 PRL 35 1124         +BOYARSKI,LYNCH,BREIDENBACH,+    (SLAC+LBL)JPC
PREPOST  75 STANFORD SYMP.241 R.PREPOST                        (WISCONSIN)
SIMPSON  75 PRL 35 699          +BERON,FORD,HILGER,HOFSTADTER,+ (STAN+PENN)
WIIK     75 STANFORD SYMP.69    B.H.WIIK                            (DESY)

BARTEL   76 PL 64 B 483         +DUINKER,OLSSON,STEFFEN,HEINTZE+(DESY+HEID)
SNYDER   76 PRL 36 1415         +HOM,LEDERMAN,APPEL,KAPLAN+(COLU+FNAL+STON)
TANENBAU 76 PRL 36 402          TANENBAUM,ABRAMS,BOYARSKI,BULOS,+(SLAC+LBL)IG
WHITAKER 76 PRL 37 1596         +TANENBAUM,ABRAMS,ALAM,BOYARSKI,+(SLAC+LBL)

BIDDICK  77 PRL 38 1324         +BURNETT+     (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
BRAUNSCH 77 PL 67 B 249         BRAUNSCHWEIG,+    (AACH+DESY+HAMB+MPIM+TOKY)
BURMESTE 77 PL 66 B 395         BURMESTER,CRIEGEE,+    (DESY+HAMB+SIEG+WUPP)
FELDMAN  77 PL 33 C 285         +PERL                           (LBL+SLAC)
YAMADA   77 HAMB. CONF. P. 69 YAMADA                            (DESY+TOKY)

BARTEL   78 PL 79 B 492         DITTMANN,DUINKER,OLSSON,O?NEILL+(DESY+HEID)
TANENBAU 78 PR D 17 1731        TANENBAUM,ALAM,BOYARSKI,+        (SLAC+LBL)

BRANDEL1 79 ZPHY C 1 233        BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
BRANDEL2 79 NP B 160 426        BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
LEMOIGNE 79 FERMILAB CONF.524 +ABOLINS,BARATE,+        (SACL+LOIC+SHMP+IND)

HIMEL    80 PRL 44 920          +ABRAMS,ALAM,BLOCKER,+          (LBL+SLAC)
OREGLIA  80 PRL 45 959          +PARTRIDGE+        (SLAC+CIT+HARV+PRIN+STAN)
PARTRIDG 80 PRL 45 1150         PARTRIDGE,PECK+    (CIT+HARV+PRIN+STAN+SLAC)
SCHARRE  80 PL 97 B 329         +TRILLING,ABRAMS,ALAM,BLOCKER+   (SLAC+LBL)
ZHOLENTZ 80 PL 96 B 214         +KURDADZE,LELCHUK,MISHNEV,NIKITIN+    (NOVO)
    ALSO 81 YAD.PHYS. 34 1471 ZHOLENTZ ET AL.                         (NOVO)

BARATE   81 PR D 24 2994        +ASTBURY,MCEWEN,+ (SACL+LOIC+SHMP+CERN+IND)

EDWARDS  82 PRL 48 70           +PARTRIDGE,PECK,+ (CIT+HARV+PRIN+STAN+SLAC)
LEMOIGNE 82 PL 113 B 509        +BARATE,ASTBURY,MCEWEN+(SACL+LOIC+SHMP+IND)

BARATE   83 PL 121 B 449        +BAREYRE,ASTBURY,MCEWEN(SACL+LOIC+SHMP+IND)
FRANKLIN 83 PRL 51 963          +FRANKLIN,FELDMAN,ABRAMS,ALAM+   (LBL+SLAC)
FRANKL12 83 SLAC-254 THESIS     M.E.B.FRANKLIN                        (STAN)

GAISER   85  SLAC-PUB-2899      +BLOOM,BULOS+      (CIT+HARV+PRIN+STAN+SLAC)
```

ψ(3770)

$I^G(J^{PC}) = ?^?(1^{--})$

ψ(3770) MASS (MeV)

```
M  E       3772.0    (6.0)           RAPIDIS   77 SMAG  0 E+E-
M  E       3770.     (6.0)           BACINO    78 DLCO  0 E+E-
M  E       3764.0    (5.0)           SCHINDLER 80 SMAG    E+ E-
M  E    ERRORS INCLUDE SYSTEMATIC COMMON TO ALL EXPERIMENTS
M          . . . . . . . . . .
M   MASS   3769.9      2.5      FROM PSI(3685) MASS AND MASS DIFFERENCE
M                               BELOW
```

ψ(3770) − ψ(3685) MASS DIFFERENCE (MeV)

```
DM           88.0      3.0           RAPIDIS   77 SMAG    E+E-
DM S         86.0      2.0           BACINO    78 DLCO    E+E-
DM S    SPEAR PSI PRIME MASS (3684) SUBTRACTED (SEE SCHINDLER 80)
DM           80.0      2.0           SCHINDLER 80 SMAG    E+ E-
DM         . . . . . . . . . .
DM  AVG      83.9      2.4      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)
```

ψ(3770) WIDTH (MeV)

```
W            28.0      5.0           RAPIDIS   77 SMAG  0 E+E-
W            24.0      5.0           BACINO    78 DLCO  0 E+E-
W            24.0      5.0           SCHINDLER 80 SMAG    E+ E-
W          . . . . . . . . . .
W   AVG      25.3      2.9      AVERAGE
```

ψ(3770) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\psi(3770) \to e^+e^-$	.511+.511
P2	$\psi(3770) \to D\overline{D}$	1869+1869

ψ(3770) PARTIAL WIDTHS (keV)

$\psi(3770) \to e^+e^-$ (G1)

```
W1 R          0.37     0.09          RAPIDIS   77 SMAG  0 E+E-
W1            0.18     0.06          BACINO    78 DLCO  0 E+E-
W1            0.276    0.050         SCHINDLER 80 SMAG    E+ E-
W1 R    SEE ALSO R2 BELOW
W1         . . . . . . . . . .
W1  AVG       0.257    0.046    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

ψ(3770) BRANCHING RATIOS

$\psi(3770) \to (D\overline{D})$/total (P2)

```
R1          DOMINANT                 PERUZZI   77 SMAG    E+E-,D DBAR
```

$\psi(3770) \to (e^+e^-)$/total (units 10^{-5}) (P1)

```
R2            1.3      0.2           RAPIDIS   77 SMAG  0 E+E-
```

REFERENCES FOR ψ(3770)

```
PERUZZI  77 PRL 39 1301      +PICCOLO,FELDMAN,PERL,+(SLAC,LBL,NWES+HAWA)
RAPIDIS  77 PRL 39 526       +GOBBI,LUKE,PERL,+(STAN+SLAC+LBL+NWES+HAWA)

BACINO   78 PRL 40 671       +BAUMGARTEN,BIRKWOOD,+ (SLAC+STAN+UCLA+UCI)

SCHINDLE 80 PR D 21 2716     SCHINDLER,SIEGRIST,ALAM,BOYARSKI-(SLAC+LBL)
```

ψ(4030)

$I^G(J^{PC}) = ?^?(1^{--})$

NOTE ON ψ(4030) AND ψ(4160)

Although these peaks are clearly separated from each other in the DASP experiment (BRANDELIK 78, 79) and are confirmed with much fewer statistics by PLUTO (BURMESTER 77), the existence of two resonances is in doubt. The SPEAR MARK-I data (SIEGRIST 82) show only one broad structure between 3.9 and 4.1 GeV, upon which there may be a sharp rise at 4.0 GeV. Part of the discrepancy between the experiments may come from the radiative corrections which tend to enhance any structure seen. A deviation from a naive Breit-Wigner-like structure is expected at 4.02 GeV, where the $D^*\overline{D}^*$ threshold opens up.

It is difficult to accommodate within a conventional charmonium model two resonances with large e^+e^- coupling in this region. A $3S$ state is expected near 4.10 GeV (RICHARDSON 79), while the slightly heavier $2D$ state should couple only very weakly to e^+e^-, even when relativistic or coupled-channel effects are included (HEIKKILA 84). Therefore an identification of ψ(4160) as the $2D$ state is hardly possible. Thus, if there really are two peaks, one must have a new type of state, e.g., a "hybrid" $c\overline{c}g$ state (ONO 84). New data in this region would be most welcome.

ψ(4030) MASS (MeV)

```
M          4028.0      2.5           GOLDHABER 77 SMAG          E+E-
M          4040.0     10.0           BRANDELIK 78 DASP    E+E-
M          . . . . . . . . . .
M   AVG    4028.7      2.8      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

ψ(4030) WIDTH (MeV)

```
W            52.0     10.0           BRANDELIK 78 DASP    E+E-
```

ψ(4030) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\psi(4030) \to D\overline{D}$	1869+1869
P2	$\psi(4030) \to D^*(2010)\ \overline{D}$ + C.C.	2007+1865
P3	$\psi(4030) \to D^*(2010)\ \overline{D}^*(2010)$	2007+2007
P4	$\psi(4030) \to J/\psi(3097)$ + hadrons	
P5	$\psi(4030) \to e^+e^-$	.511+.511
P6	$\psi(4030) \to \mu^+\mu^-$	106+ 106

ψ(4030) PARTIAL WIDTHS (keV)

$\psi(4030) \to e^+e^-$ (G5)

```
W5            0.75     0.15          BRANDELIK 78 DASP    E+ E-
```

Meson Full Listings

$\psi(4030)$, $\psi(4160)$, $\psi(4415)$, BOTTOMONIUM

$\psi(4030)$ BRANCHING RATIOS

$\psi(4030) \rightarrow (D^0 \overline{D}^0)/(D^*(2010)^0 \overline{D}^0 + \mathrm{C.C.})$ (P1)/(P2)

```
R1   P       0.05     0.03             GOLDHABER 77 SMAG  0 E+ E-
```

$\psi(4030) \rightarrow (D^*(2010)^0 \overline{D}^*(2010)^0)/(D^*(2010)^0 \overline{D}^0 + \mathrm{C.C.})$

```
R2                                                        (P3)/(P2)
R2   P      32.0     12.0              GOLDHABER 77 SMAG  0 E+ E-

R    P  PHASE-SPACE FACTOR (P**3) EXPLICITLY REMOVED.
```

$\psi(4030) \rightarrow (J/\psi(3097) +$ hadrons)/total (P4)

```
R3          LOOKED FOR                 BURMESTER 77 PLUT         E+E-
```

$\psi(4030) \rightarrow (e^+ e^-)$/total (units 10^{-5}) (P5)

```
R4            (1.0) APPROX.            FELDMAN   77 SMAG    E+ E-
```

REFERENCES FOR $\psi(4030)$

```
AUGUSTIN 75 PRL 34 764        +BOYARSKI,ABRAMS,BRIGGS+          (SLAC+LBL)
BACCI    75 PL 58B 481        +BIDOLI,PENSO,STELLA,+           (ROMA+FRAS)
BOYARSKI 75 PRL 34 762        +BREIDENBACH,ABRAMS,BRIGGS,+      (SLAC+LBL)
ESPOSITO 75 PL 58B 478        +FELICETTI,PERUZZI,+  (FRAS+NAPL+PADO+ROMA)

PERUZZI  76 PRL 37 569        +PICCOLO,FELDMAN,NGUYEN,WISS,+    (SLAC+LBL)

BURMESTE 77 PL 66 B 395       +CRIEGEE,DEHNE+         (DESY+HAMB+SIEG+WUPP)
GOLDHABE 77 PL 69 B 503       GOLDHABER,WISS,ABRAMS,ALAM,LUTH,+(LBL+SLAC)
FELDMAN  77 PL 33 C 285       +PERL                             (LBL+SLAC)
LUTH     77 PL 70 B 120       +PIERRE,ABRAMS,ALAM,BOYARSKI,+    (LBL+SLAC)

BRANDELI 78 PL 76 B 361       BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)
    ALSO 79 ZPHY C 1 233      BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)

KIRKBY   79 FERMILAB SYMP.107 J. KIRKBY RAPPORTEUR                  (SLAC)
RICHARDS 79 PL 82 B 272       J.L.RICHARDSON                        (SLAC)

SIEGRIST 82 PR D 26 969       +SCHWITTERS,ALAM,CHINOWSKY,+      (SLAC+LBL)

HEIKKILA 84 PR D 29 110       +TORNQVIST,ONO                   (HELS+TOKY)
ONO      84 ZPHY C 26 307     SEIJI ONO                             (ORSA)
```

$\psi(4160)$

$I^G(J^{PC}) = ?^?(1^{--})$

SEE NOTE UNDER PSI(4030)

$\psi(4160)$ MASS (MeV)

```
M         4159.0     20.0              BRANDELIK 78 DASP    E+E-
```

$\psi(4160)$ WIDTH (MeV)

```
W           78.0     20.0              BRANDELIK 78 DASP    E+E-
```

$\psi(4160)$ PARTIAL DECAY MODES

```
                                                       DECAY MASSES
P1     ψ(4160) → e+e-                                  .511+.511
```

$\psi(4160)$ PARTIAL WIDTHS (keV)

$\psi(4160) \rightarrow e^+ e^-$ (G1)

```
W1          0.77     0.23              BRANDELIK 78 DASP    E+ E-
```

REFERENCES FOR $\psi(4160)$

```
BURMESTE 77 PL 66 B 395       +CRIEGEE,DEHNE+         (DESY+HAMB+SIEG+WUPP)

BRANDELI 78 PL 76 B 361       BRANDELIK,CORDS+ (AACH+DESY+HAMB+MPIM+TOKY)

KIRKBY   79 FERMILAB SYMP.107 J. KIRKBY RAPPORTEUR                  (SLAC)

ONO      84 ZPHY C 26 307     SEIJI ONO                             (ORSA)
```

$\psi(4415)$

$I^G(J^{PC}) = ?^?(1^{--})$

$\psi(4415)$ MASS (MeV)

```
M         4414.      7.                SIEGRIST  76 SMAG           E+E-
M        (4400.)   APPROX.             KNIES     77 PLUT  D E+E-,MU+ MU-
M         4417.0    10.0               BRANDELIK 78 DASP     E+E-
M         . . . . . . . . . .
M   AVG   4415.0     5.7        AVERAGE
```

$\psi(4415)$ WIDTH (MeV)

```
W           33.      10.               SIEGRIST  76 SMAG         E+E-
W           66.0     15.0              BRANDELIK 78 DASP    E+E-
W         . . . . . . . . .
W   AVG     43.2     15.2      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)
```

$\psi(4415)$ PARTIAL DECAY MODES

```
                                                       DECAY MASSES
P1     ψ(4415) → e+e-                                  .511+.511
```

$\psi(4415)$ PARTIAL WIDTHS (keV)

$\psi(4415) \rightarrow e^+ e^-$ (G1)

```
W1          0.44     0.14              SIEGRIST  76 SMAG    E+ E-
W1          0.49     0.13              BRANDELIK 78 DASP    E+ E-
W1        . . . . . . . . .
W1  AVG     0.467    0.095     AVERAGE
```

$\psi(4415)$ BRANCHING RATIOS

$\psi(4415) \rightarrow$ hadrons/total

```
R2          DOMINANT                   SIEGRIST  76 SMAG         E+E-
```

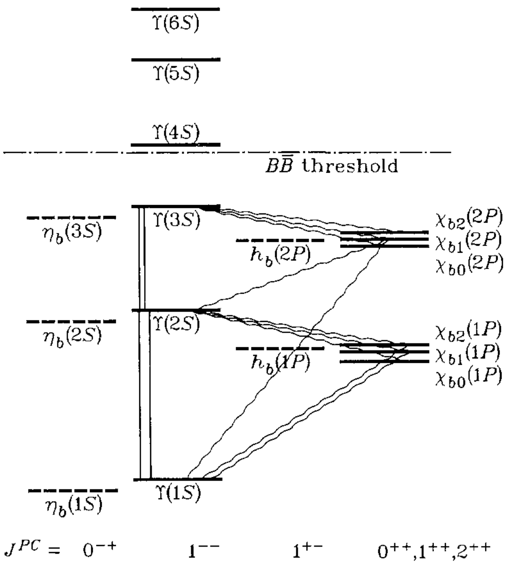
REFERENCES FOR $\psi(4415)$

```
SIEGRIST 76 PRL 36 700        +ABRAMS,BOYARSKI,BREIDENBACH,+    (LBL+SLAC)

BURMESTE 77 PL 66 B 395       +CRIEGEE,DEHNE+         (DESY+HAMB+SIEG+WUPP)
KNIES    77 HAMBURG SYMP.93   G.KNIES HAMBURG TALK ON PLUTO COLLAB.(DESY)
LUTH     77 PL 70 B 120       +PIERRE,ABRAMS,ALAM,BOYARSKI,+    (LBL+SLAC)

BRANDELI 78 PL 76 B 361       BRANDELIK,CORDS+ (AACH+DESY+HAMB+MPIM+TOKY)
```

THE BOTTOMONIUM SYSTEM



The level scheme of the $b\overline{b}$ states with the names as adopted in this issue of the Review of Particle Properties. Singlet states are called η_b and h_b, triplet states Υ and χ_{bJ}. In parentheses it is sufficient to give the radial quantum number and the orbital angular momentum to specify the states with all their quantum numbers. E.g., $h_b(2P)$ means 2^1P_1 with $n = 2, L = 1, S = 0, J = 1$, $PC = +-$. If found, D-wave states would be called $\eta_b(nD)$, $h_b(nD)$, $\Upsilon_J(nD)$, and $\chi_{bJ}(nD)$, with $J = 1,2,3$ and $n = 1,2,3,4, \cdots$. The figure also shows the observed hadronic transitions as solid lines and the observed radiative transitions as photonic lines.

NOTE ON WIDTH DETERMINATIONS OF THE Υ STATES

As is the case for $J/\psi(3097)$ and $\psi(3685)$, the full widths of the bound $b\bar{b}$ states Υ(1S), Υ(2S), and Υ(3S) are not directly measurable, since they are much smaller than the energy resolution of the e^+e^- storage rings where these states are produced. The common indirect method to determine Γ starts from

$$\Gamma = \Gamma_{\ell\ell}/B_{\ell\ell}\,, \tag{1}$$

where $\Gamma_{\ell\ell}$ is one leptonic partial width and $B_{\ell\ell}$ is the corresponding branching fraction ($\ell = e$, μ, or τ). One then assumes e-μ-τ universality and uses

$$\Gamma_{\ell\ell} = \Gamma_{ee}\,, \tag{2}$$

$$B_{\ell\ell} = \text{average of } B_{ee},\ B_{\mu\mu}, \text{ and } B_{\tau\tau}\,.$$

The electronic partial width Γ_{ee} is also not directly measureable at e^+e^- storage rings, only the combination $\Gamma_{ee}\Gamma_{\text{had}}/\Gamma$, where Γ_{had} is the hadronic partial width and

$$\Gamma_{\text{had}} + 3\Gamma_{ee} = \Gamma\,. \tag{3}$$

This combination is obtained experimentally from the energy-integrated hadronic cross section

$$\int_{\text{resonance}} \sigma(e^+e^- \to \Upsilon \to \text{hadrons})\, dE$$

$$= \frac{6\pi}{M^2}\,\frac{\Gamma_{ee}\Gamma_{\text{had}}}{\Gamma} \times C_r\,, \tag{4}$$

where M is the Υ mass and C_r is the radiative correction. The knowledge of the $B_{\ell\ell}$ then allows one to extract Γ_{ee} using Eq. (3):

$$\Gamma_{ee} = \frac{\Gamma_{ee}\Gamma_{\text{had}}/\Gamma}{(1 - 3B_{\ell\ell})}\,. \tag{5}$$

The Listings give experimental results only on B_{ee}, $B_{\mu\mu}$, $B_{\tau\tau}$, and Γ_{ee}. The Γ_{ee} entries are checked (within statistical errors) or re-evaluated for the proper $(1 - 3B_{\ell\ell})$ correction in Eq. (5). The full widths of Υ(1S), Υ(2S), and Υ(3S) are then calculated from the averages for Γ_{ee} and $B_{\ell\ell}$, using Eqs. (1) and (2). We no longer list Γ evaluations of individual experiments. Also note that the procedure adopted here relies only on experimental results and not on model assumptions like $\Gamma_{ggg}[\Upsilon(2S)]/\Gamma_{ee}[\Upsilon(2S)] = \Gamma_{ggg}[\Upsilon(1S)]/\Gamma_{ee}[\Upsilon(1S)]$, where Γ_{ggg} is the partial width for three-gluon decay. This assumption was made in, e.g., MAGERAS 81, NICZYPORUKZ 81, and in former editions of this Review.

Υ(9460) or Υ(1S)

$I^G(J^{PC}) = ?^?(1^{--})$

Υ(9460) MASS (MeV)

```
M          9460.6     0.4             ARTAMONO  84 REDE    E+E- -->HADRONS
M    Q     9459.97    0.13            MAC KAY   84 REDE    E+E- -->HADRONS
M          . . . . . . . . . .
M    AVG   9460.03    0.19    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)

M    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

Υ(9460) WIDTH (keV)

```
W    B       43.1     3.1

W    B  OUR EVAL. FROM W2,R1,R2,R3 BELOW ASSUMING E-MU-TAU UNIVERSALITY
```

Υ(9460) PARTIAL DECAY MODES

```
                                                        DECAY MASSES
P1        Υ(9460) → μ+μ-                                106+ 106
P2        Υ(9460) → e+e-                                .511+.511
P3        Υ(9460) → τ+τ-                                1784+1784

P         HADRONIC DECAYS
P         ---------------
P11       Υ(9460) → ρπ                                  769+ 140
P12       Υ(9460) → J/ψ(3097) + anything
```

Υ(9460) PARTIAL WIDTHS (keV)

Υ(9460) → e^+e^- (G2)

```
W2            1.33     0.14           BERGER    79 PLUT    E+E- -->HADRONS
W2            1.08     0.25           BOCK      80 CNTR    E+E- -->HADRONS
W2   Q        1.23     0.14           ALBRECHT  82 DASP    E+E- -->HADRONS
W2   Q        1.13     0.12           NICZYPOR  82 LENA    E+E- ->HADRONS
W2   Q        1.15     0.11           TUTS      83 CUSB    E+E- ->HADRONS
W2   Q        1.30     0.09           GILES     84 CLEO    E+E- -->HADRONS
W2         . . . . . . . . .
W2   AVG      1.224    0.050   AVERAGE

W2   Q  SYSTEMATIC ERRORS ADDED QUADRATICALLY BY US.
```

Υ(9460) BRANCHING RATIOS

Υ(9460) → $(\mu^+\mu^-)$/total (P1)

```
R1           0.022    0.020           BERGER    79 PLUT    E+E- -->MU+MU-
R1           0.014    0.034    0.014  BOCK      80 CNTR    E+E- -->MU+MU-
R1   Q       0.032    0.013           ALBRECHT  82 DASP    E+E- -->MU+MU-
R1   Q       0.038    0.015           NICZYPOR  82 LENA    E+E- -->MU+MU-
R1   Q       0.027    0.004           ANDREWS   83 CLEO    E+E- -->MU+MU-
R1   Q       0.027    0.004           TUTS      83 CUSB    E+E- -->MU+MU-
R1   Q       0.029    0.004           BESSON    84 CLEO    Y2S-->PI+PI- 2MU
R1         . . . . . . . . . .
R1   AVG     0.0278   0.0022  AVERAGE
```

Υ(9460) → (e^+e^-)/total (P2)

```
R2           0.051    0.030           BERGER    80 PLUT    E+E- -->E+E-
R2   Q       0.028    0.005           ALBRECHT  84 ARG     Y2S->PI+PI-E+E-
R2   Q       0.028    0.004           BESSON    84 CLEO    Y2S->PI+PI-E+E-
R2         . . . . . . . . . .
R2   AVG     0.0282   0.0031  AVERAGE
```

Υ(9460) → $(\tau^+\tau^-)$/total (P3)

```
R3   Q       0.034    0.006           GILES     83 CLEO    E+E- -->TAU+TAU-
R3 A Q       0.0307   0.0051          ALBRECH3  85 ARG     Y2S-->PI+PI-2TAU
R3         . . . . . . . . . .
R3   AVG     0.0321   0.0039  AVERAGE

R3 A    USING BR(Y1S->EE)=BR(Y1S->MUMU)=0.029, NOT USED FOR TOTAL
R3 A    WIDTH EVALUATION.
```

Υ(9460) → $(\rho\pi)$/total (P11)

```
R11          (.0021)OR LESS CL=0.90  NICZYPOR  83 LENA
```

Υ(9460) → $(J/\psi(3097)$ + anything)/total (P12)

```
R12          (.02)  OR LESS CL=0.90  NICZYPOR  83 LENA

R    Q  SYSTEMATIC ERRORS ADDED QUADRATICALLY BY US.
```

REFERENCES FOR Υ(9460)

```
COBB     77 PL 72 B 273     +IWATA,FABJAN,GOLDBERG+(BNL+CERN+SYRA+YALE)
HERB     77 PRL 39 252      +HOM,LEDERMAN,APPEL,ITO,+  (COLU+FNAL+STON)
INNES    77 PRL 39 1240     +APPEL,BROWN,HERB,HOM,FISK+(COLU+FNAL+STON)

BERGER   78 PL 76 B 243     +ALEXANDER,DAUM,+(AACH+DESY+HAMB+SIEG+WUPG)
BIENLEIN 78 PL 78 B 360     +GLAWE,BOCK,BLANAR,+  (DESY+HAMB+HEID+MPIM)
DARDEN   78 PL 76 B 246     C.W.DARDEN+                 (DASP2 COLLAB.)
GARELICK 78 PR D 18 945     +GAUTHIER,HICKS,OLIVER,+   (NEAS+WASH+TUFT)
KAPLAN   78 PRL 40 435      +APPEL,HERB,HOM,LEDERMAN,+ (STON+FNAL+COLU)
YOH      78 PRL 41 684      +HERB,HOM,LEDERMAN,UENO,+  (COLU+FNAL+STON)
```

```
ANGELIS   79 PL 87 B 398        +BESCH,BLUMENFELD,+    (CERN+COLU+OXF+ROCK)
BADIER    79 PL 86 B 98         +BOUCROT,BURGUN+ (SACL+CERN+CDEF+EPOL+LALO)
BERGER    79 ZPHY C 1 343       +ALEXANDER+      (AACH+DESY+HAMB+SIEG+WUPG)
DARDEN    79 PL 80 B 419        C.W.DARDEN+                  (DASP2 COLLAB.)

ALBRECHT  80 PL 93 B 500        H.ALBRECHT+                  (DASP2 COLLAB.)
ANDREWS   80 PRL 44 1108        + (CORN+HARV+ITHA+LEMO+ROCH+RUTG+SYRA+VAND)
BERGER    80 PL 93 B 497        +LACKAS,RAUPACH,+(AACH+DESY+HAMB+SIEG+WUPP)
BOCK      80 ZPHY C 6 125       +BLANAR,BLUM,BIENLEIN+(HEID+MPIM+DESY+HAMB)
BOHRINGE  80 PRL 44 1111        BOHRINGER,COSTANTINI,FINOCCHIARO(COLU+STON)
KOURKOUM  80 PL 91 B 481        KOURKOUMELIS+(ATHU+NTUA+BNL+CERN+SYRA+YALE)

MAGERAS   81 PRL 46 1115        +BOHRINGER,FINOCCHIARO+(COLU+STON+LSU+MPIM)
MUELLER   81 PRL 46 1181        + (RUTG+SYRA+LEMO+VAND+CORN+ITHA+HARV+ROCH)
NICZYPOR  81 PRL 46 92          NICZYPORUK,CHEN,VOGEL,WEGENER+(LENA COLLAB)

ALBRECHT  82 PL 116 B 383       H.ALBRECHT+                  (DASP2 COLLAB.)
ARTAMONO  82 PL 118 B 225       +BARU,BLINOV,BONDAR,BUKIN,GROSHEV+    (NOVO)
NICZYPOR  82 ZPHY C 15 299      NICZYPORUK,FOLGER,BIENLEIN+    (LENA COLLAB)

ANDREWS   83 PRL 50 807         +  (CORN+ITHA+HARV+OSU+ROCH+RUTG+SYRA+VAND)
GILES     83 PRL 50 877         +  (HARV+OSU+ROCH+RUTG+SYRA+VAND+CORN+ITHA)
NICZYPOR  83 ZPHY C 17 197      + (CRAC+ERLA+DESY+NIJM+PITT+SACL+TELA+WURZ)
TUTS      83 CORNELL CONF.P.248                   P.M.TUTS(CUSB COLLAB.)

ALBRECHT  84 PL 134 B 137       H.ALBRECHT+                  (ARGUS COLLAB.)
ARTAMONO  84 PL 137 B 272       ARTAMONOV+BARU+BLINOV+BONDAR+ (NOVOSIBIRSK)
BESSON    84 PR D 30 1433       +GREEN+HICKS+NAMJOSHI+SANNAS+(CLEO COLLAB.)
GILES     84 PR D 29 1285       +HASSARD+HEMPSTEAD+KINOSHITA+(CLEO COLLAB.)
MAC KAY   84 PR D 29 2483       +CUSB COLL.+ (HARV+CORN+COLU+LSU+MPIM+ALBA)

ALBRECH3  85 PL 154 B 452       H.ALBRECHT+                  (ARGUS COLLAB.)
```

$\chi_{b0}(9860)$ or $\chi_{b0}(1P)$

$I^G(J^{PC}) = ?^?(0\ \text{preferred}^{++})$

```
OBSERVED IN RADIATIVE DECAY OF THE
UPSILON(10023), THEREFORE C=+.
BRANCHING RATIO REQUIRES E1 TRANSITION, M1 IS
STRONGLY DISFAVOURED, THEREFORE P=+.
```

χ_{b0}(9860) MASS (MeV)

```
M  U Q   (9872.8)    (5.1)           KLOPFENS  83 CUSB    Y2S->GAMMA X
M  U Q    9864.1      7.1            HAAS1     84 CLEO    Y2S->CONV.GAM X
M  U Q    9858.3      3.1            NERNST    85 CBAL    Y2S->GAMMA X
M  U Q    9860.0      1.5            ALBRECH2  85 ARG     Y2S->CONV.GAM X
M         . . . . . . . . . .
M   AVG   9859.8      1.3      AVERAGE

M  U   FROM GAMMA ENERGY BELOW, ASSUMING UPSILON(10023) MASS = 10023.4 MEV
M    Q SYSTEMATIC ERRORS ADDED QUADRATICALLY BY US
```

γ ENERGY IN Υ(10023) DECAY (MeV)

```
DM   Q    (149.4)    (5.1)           KLOPFENS  83 CUSB    Y2S->GAMMA X
DM   Q     158.0      7.1            HAAS1     84 CLEO    Y2S->CONV.GAM X
DM   Q     163.8      3.1            NERNST    85 CBAL    Y2S->GAMMA X
DM   Q     162.1      1.5            ALBRECH2  85 ARG     Y2S->CONV.GAM X
DM        . . . . . . . . . .
DM  AVG    162.3      1.3      AVERAGE

DM   Q SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

χ_{b0}(9860) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\chi_{b0}(9860) \to \Upsilon(9460)\ \gamma$	9460+ 0

χ_{b0}(9860) BRANCHING RATIOS

χ_{b0}(9860) → (Υ(9460) γ)/total (P1)

```
R1          (0.11) OR LESS  CL=.90   PAUSS     83 CUSB    Y2S->2 GAM L+L-
R1          (0.06) OR LESS  CL=.90   WALK      85 CBAL    Y2S->2 GAM L+L-
```

REFERENCES FOR χ_{b0}(9860)

```
KLOPFENS 83 PRL 51 160          KLOPFENSTEIN+HORSTKOTTE+      (CUSB COLLAB.)
PAUSS    83 PL 130 B 439        +DIETL,EIGEN+     (MPIM+COLU+CORN+LSU+STON)

HAAS1    84 PRL 52 799          +JENSEN+KAGAN+KASS+BEHRENDS+ (CLEO COLLAB.)

ALBRECH2 85 PL 160 B 331        H.ALBRECHT+                  (ARGUS COLLAB.)
NERNST   85 PRL 54 2195         +ANTREASYAN+ASCHMAN+ (CRYSTAL BALL COLLAB.)
WALK     85  SLAC-PUB-3820      +ZSCHORSCH+          (CRYSTAL BALL COLLAB.)
```

$\chi_{b1}(9895)$ or $\chi_{b1}(1P)$

$I^G(J^{PC}) = ?^?(1\ \text{preferred}^{++})$

```
OBSERVED IN RADIATIVE DECAY OF THE
UPSILON(10023), THEREFORE C=+.
BRANCHING RATIO REQUIRES E1 TRANSITION, M1 IS
STRONGLY DISFAVOURED, THEREFORE P=+.
```

χ_{b1}(9895) MASS (MeV)

```
M  U Q    9894.4      3.0            KLOPFENS  83 CUSB    Y2S->GAMMA X
M         9892.0      3.0            PAUSS     83 CUSB    Y2S->2 GAM L+L-
M  U Q    9893.6      1.3            HAAS1     84 CLEO    Y2S->CONV.GAM X
M  U Q    9892.0      2.5            NERNST    85 CBAL    Y2S->GAMMA X
M  U Q    9890.8      1.1            ALBRECH2  85 ARG     Y2S->CONV.GAM X
M  U Q    9890.8      1.6            WALK      85 CBAL    Y2S->2 GAM L+L-
M         . . . . . . . . . .
M   AVG   9891.89     0.68     AVERAGE

     Q SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
M  U   FROM GAMMA ENERGY BELOW ASSUMING UPSILON(10023) MASS = 10023.4 MEV
```

γ ENERGY IN Υ(10023) DECAY (MeV)

```
DM   Q     128.1      3.0            KLOPFENS  83 CUSB    Y2S->GAMMA X
DM   Q     130.6      3.0            PAUSS     83 CUSB    Y2S->2 GAM L+L-
DM   Q     129.0      1.3            HAAS1     84 CLEO    Y2S->CONV.GAM X
DM   Q     130.6      2.5            NERNST    85 CBAL    Y2S->GAMMA X
DM   Q     131.7      1.1            ALBRECH2  85 ARG     Y2S->CONV.GAM X
DM   Q     131.7      1.6            WALK      85 CBAL    Y2S->2 GAM L+L-
DM        . . . . . . . . . .
DM  AVG    130.65     0.68     AVERAGE

DM   Q SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

χ_{b1}(9895) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\chi_{b1}(9895) \to \Upsilon(9460)\ \gamma$	9460+ 0

χ_{b1}(9895) BRANCHING RATIOS

χ_{b1}(9895) → (Υ(9460) γ)/total (P1)

```
R1             0.47      0.18            KLOPFENS  83 CUSB    Y2S->2 GAM L+L-
R1   Q         0.32      0.09            WALK      85 CBAL    Y2S->2 GAM L+L-
R1          . . . . . . . . . .
R1  AVG        0.350     0.080     AVERAGE

R1   Q SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

REFERENCES FOR χ_{b1}(9895)

```
KLOPFENS 83 PRL 51 160          KLOPFENSTEIN+HORSTKOTTE+      (CUSB COLLAB.)
PAUSS    83 PL 130 B 439        +DIETL,EIGEN+     (MPIM+COLU+CORN+LSU+STON)

HAAS1    84 PRL 52 799          +JENSEN+KAGAN+KASS+BEHRENDS+ (CLEO COLLAB.)

ALBRECH2 85 PL 160 B 331        H.ALBRECHT+                  (ARGUS COLLAB.)
NERNST   85 PRL 54 2195         +ANTREASYAN+ASCHMAN+ (CRYSTAL BALL COLLAB.)
WALK     85  SLAC-PUB-3820      +ZSCHORSCH+          (CRYSTAL BALL COLLAB.)
```

$\chi_{b2}(9915)$ or $\chi_{b2}(1P)$

$I^G(J^{PC}) = ?^?(2\ \text{preferred}^{+-})$

```
OBSERVED IN RADIATIVE DECAY OF THE
UPSILON(10023), THEREFORE C=+.
BRANCHING RATIO REQUIRES E1 TRANSITION, M1 IS
STRONGLY DISFAVOURED, THEREFORE P=+.
```

χ_{b2}(9915) MASS (MeV)

```
M  U Q    9914.6      2.0            KLOPFENS  83 CUSB    Y2S->GAMMA X
M         9914.0      4.0            PAUSS     83 CUSB    Y2S->2 GAM L+L-
M  U Q    9913.3      1.2            HAAS1     84 CLEO    Y2S->CONV.GAM X
M  U Q    9912.4      2.3            NERNST    85 CBAL    Y2S->GAMMA X
M  U Q    9912.2      1.0            ALBRECH2  85 ARG     Y2S->CONV.GAM X
M  U Q    9915.8      1.7            WALK      85 CBAL    Y2S->2 GAM L+L-
M         . . . . . . . . . .
M   AVG   9913.29     0.63     AVERAGE

M    Q SYSTEMATIC ERRORS ADDED QUADRATICALLY BY US
M  U   FROM GAMMA ENERGY BELOW ASSUMING UPSILON(10023) MASS = 10023.4 MEV
```

γ ENERGY IN $\Upsilon(10023)$ DECAY (MeV)

```
DM   Q      108.2     2.0          KLOPFENS  83 CUSB    Y2S->GAMMA X
DM          108.8     4.0          PAUSS     83 CUSB    Y2S->2 GAM L+L-
DM   Q      109.5     1.2          HAAS1     84 CLEO    Y2S->CONV.GAM X    |
DM   Q      110.4     2.3          NERNST    85 CBAL    Y2S->GAMMA X       |
DM   Q      110.6     1.0          ALBRECH2  85 ARG     Y2S->CONV.GAM X    |
DM   Q      107.0     1.7          WALK      85 CBAL    Y2S->2 GAM L+L-    |
DM          . . . . . . . . . .
DM   AVG    109.51    0.63     AVERAGE

DM   Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$\chi_{b2}(9915)$ PARTIAL DECAY MODES

```
                                                      DECAY MASSES
```

P1 $\chi_{b2}(9915) \rightarrow \Upsilon(9460)\ \gamma$ 9460+ 0

$\chi_{b2}(9915)$ BRANCHING RATIOS

$\chi_{b2}(9915) \rightarrow (\Upsilon(9460)\ \gamma)$/total (P1)

```
R1           0.20      0.05        KLOPFENS  83 CUSB    Y2S->2GAM L+L-
R1   Q       0.27      0.08        WALK      85 CBAL    Y2S->2 GAM L+L-    |
R1          . . . . . . . . . .
R1   AVG     0.220     0.042   AVERAGE

R1   Q     SYSTEMATIC ERRORS ADDED QUADRATICALLY BY US
```

REFERENCES FOR $\chi_{b2}(9915)$

```
KLOPFENS 83 PRL 51 160        KLOPFENSTEIN+HORSTKOTTE+     (CUSB COLLAB.)
PAUSS    83 PL 130 B 439      +DIETL,EIGEN+      (MPIM+COLU+CORN+LSU+STON)

HAAS1    84 PRL 52 799        +JENSEN+KAGAN+KASS+BEHRENDS+ (CLEO COLLAB.)

ALBRECH2 85 PL 160 B 331      H.ALBRECHT+                  (ARGUS COLLAB.)
NERNST   85 PRL 54 2195       +ANTREASYAN+ASCHMAN+ (CRYSTAL BALL COLLAB.)
WALK     85  SLAC-PUB-3820    +ZSCHORSCH+          (CRYSTAL BALL COLLAB.)
```

$\boxed{\begin{array}{c}\Upsilon(10023)\\ \text{or}\ \ \Upsilon(2S)\end{array}}$

$I^G(J^{PC}) = ?^?(1^{--})$

$\Upsilon(10023)$ MASS (GeV)

```
M           10.0238   0.0005       ARTAMONO  84 REDE    E+E- ->HADRONS
M           10.0231   0.0004       BARBER    84 REDE    E+E- ->HADRONS
M          . . . . . . . . . .
M    AVG   10.02337  0.00034   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$\Upsilon(10023)$ WIDTH (keV)

```
W  B        30.0      7.3                                                  |

W  B    OUR EVAL. FROM W2,R1,R3 BELOW ASSUMING E-MU-TAU UNIVERSALITY
```

$\Upsilon(10023)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Upsilon(10023) \rightarrow \mu^+\mu^-$	106+ 106
P2	$\Upsilon(10023) \rightarrow e^+e^-$	.511+.511
P3	$\Upsilon(10023) \rightarrow \tau^+\tau^-$	1784+1784
P4	$\Upsilon(10023) \rightarrow \Upsilon(9460)\ \pi^+\pi^-$	9460+ 140+ 140
P5	$\Upsilon(10023) \rightarrow \Upsilon(9460)\ \pi^0\pi^0$	9460+ 135+ 135
P6	$\Upsilon(10023) \rightarrow \Upsilon(9460)\ \eta$	9460+ 549
P7	$\Upsilon(10023) \rightarrow \chi_{b2}(9915)\ \gamma$	9915+ 0
P8	$\Upsilon(10023) \rightarrow \chi_{b1}(9895)\ \gamma$	9895+ 0
P9	$\Upsilon(10023) \rightarrow \chi_{b0}(9860)\ \gamma$	9860+ 0

$\Upsilon(10023)$ PARTIAL WIDTHS (keV)

$\Upsilon(10023) \rightarrow e^+e^-$ (G2)

```
W2 A         0.39      0.16        BOCK      80 CNTR    E+E- ->HADRONS
W2   Q       0.56      0.09        NICZYPO1  81 LENA    E+E- ->HADRONS
W2 A Q       0.58      0.12        ALBRECHT  82 DASP    E+E- ->HADRONS     |
W2   Q       0.56      0.06        TUTS      83 CUSB    E+E- ->HADRONS     |
W2   Q       0.52      0.05        GILES     84 CLEO    E+E- ->HADRONS     |
W2          . . . . . . . . . .
W2  AVG      0.537     0.033   AVERAGE

W2   Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
W2 A    USING B.R. UPSILON(10023) INTO (MU+MU-)/TOTAL FROM AVG BELOW
```

$\Upsilon(10023)$ BRANCHING RATIOS

$\Upsilon(10023) \rightarrow (\mu^+\mu^-)$/total (P1)

```
R1          (0.038)OR LESS CL=0.90    NICZYPO1  81 LENA    E+E-,MU+MU-
R1   Q       0.019     0.006          TUTS      83 CUSB    E+E-,MU+MU-     |
R1   Q       0.018     0.009          HAAS2     84 CLEO    E+E-,MU+MU-     |
R1   Q       0.0157    0.0090         ALBRECH1  85 ARG     E+E-,MU+MU-     |
R1          . . . . . . . . . .
R1   AVG     0.0180    0.0044   AVERAGE
```

$\Upsilon(10023) \rightarrow (\tau^+\tau^-)$/total (P3)

```
R3   Q       0.017     0.016          HAAS2     84 CLEO     E+E- -->TAU+TAU-  |
```

$\Upsilon(10023) \rightarrow (\Upsilon(9460)\ \pi^+\pi^-)$/total (P4)

```
R4       7   0.21      0.07           NICZYPO2  81 LENA    E+E--->L+L-PI+PI-
R4   Q       0.179     0.023          ALBRECHT  84 ARG     PI+PI- MISS.MASS  |
R4   Q       0.191     0.013          BESSON    84 CLEO    PI+PI- MISS.MASS  |
R4           0.189     0.026          FONSECA   84 CUSB    E+E--->L+L-PI+PI- |
R4           0.169     0.040          GELPHMAN  85 CBAL    E+E--->E+E-PI+PI- |
R4          . . . . . . . . . .
R4   AVG     0.1875    0.0099   AVERAGE
```

$\Upsilon(10023) \rightarrow (\Upsilon(9460)\ \pi^0\pi^0)$/total (P5)

```
R5           0.103     0.023          FONSECA   84 CUSB    E+E--->L+L-PIOPIO |
R5   Q       0.085     0.024          HELLER    84 ARG     E+E--->L+L-PIOPIO |
R5           0.080     0.015          GELPHMAN  85 CBAL    E+E--->L+L-PIOPIO |
R5          . . . . . . . . . .
R5   AVG     0.086     0.011    AVERAGE
```

$\Upsilon(10023) \rightarrow (\Upsilon(9460)\ \eta)$/total (P6)

```
R6          (0.002)OR LESS CL=0.90    FONSECA   84 CUSB                      |
R6          (0.010)OR LESS CL=0.90    BESSON    84 CLEO                      |
```

$\Upsilon(10023) \rightarrow (\chi_{b2}(9915)\ \gamma)$/total (P7)

```
R7           0.061     0.014          KLOPFENS  83 CUSB    E+E- -->GAMMA X
R7   Q       0.102     0.028          HAAS1     84 CLEO    E+E--->CONV.GAM X |
R7   Q       0.058     0.012          NERNST    85 CBAL    E+E- -->GAMMA X   |
R7   Q       0.098     0.032          ALBRECH2  85 ARG     E+E--->CONV.GAM X |
R7          . . . . . . . . . .
R7   AVG     0.0657    0.0087   AVERAGE
```

$\Upsilon(10023) \rightarrow (\chi_{b1}(9895)\ \gamma)$/total (P8)

```
R8           0.059     0.014          KLOPFENS  83 CUSB    E+E- -->GAMMA X
R8   Q       0.080     0.023          HAAS1     84 CLEO    E+E--->CONV.GAM X |
R8   Q       0.065     0.014          NERNST    85 CBAL    E+E- -->GAMMA X   |
R8   Q       0.091     0.028          ALBRECH2  85 ARG     E+E--->CONV.GAM X |
R8          . . . . . . . . . .
R8   AVG     0.0673    0.0086   AVERAGE
```

$\Upsilon(10023) \rightarrow (\chi_{b0}(9860)\ \gamma)$/total (P9)

```
R9          (0.035)   (0.014)         KLOPFENS  83 CUSB    E+E- -->GAMMA X
R9   Q       0.044     0.025          HAAS1     84 CLEO    E+E--->CONV.GAM X |
R9   Q       0.036     0.012          NERNST    85 CBAL    E+E- -->GAMMA X   |
R9   Q       0.064     0.021          ALBRECH2  85 ARG     E+E--->CONV.GAM X |
R9          . . . . . . . . . .
R9   AVG     0.0431    0.0096   AVERAGE

R    Q  SYSTEMATIC ERRORS ADDED QUADRATICALLY BY US
```

REFERENCES FOR $\Upsilon(10023)$

```
COBB     77 PL 72 B 273       -IWATA,FABJAN,GOLDBERG+(BNL+CERN+SYRA+YALE)
HERB     77 PRL 39 252        +HOM,LEDERMAN,APPEL,ITO,+  (COLU+FNAL+STON)
INNES    77 PRL 39 1240       +APPEL,BROWN,HERB,HOM,FISK+(COLU+FNAL+STON)

BIENLEIN 78 PL 78 B 360       +GLAWE,BOCK,BLANAR,+  (DESY+HAMB+HEID+MPIM)
DARDEN   78 PL 78 B 364       C.W.DARDEN+                  (DASP2 COLLAB.)
KAPLAN   78 PRL 40 435        +APPEL,HERB,HOM,LEDERMAN,+ (STON+FNAL+COLU)
YOH      78 PRL 41 684        +HERB,HOM,LEDERMAN,UENO,+  (COLU+FNAL+STON)

UENO     79 PRL 42 486        +BROWN,HERB,HOM,FISK,ITO,+ (FNAL+COLU+STON)

ANDREWS  80 PRL 44 1108       + (CORN+HARV+ITHA+LEMO+ROCH+RUTG+SYRA+VAND)
ARESTOV  80 IHEP 80-165       +BOGOLJUBSKI,+                        (SERP)
BOCK     80 ZPHY C 6 125      +BLANAR,BLUM,BIENLEIN+(HEID+MPIM+DESY+HAMB)
BOHRINGE 80 PRL 44 1111       BOHRINGER,COSTANTINI,FINOCCHIARO(COLU+STON)
KOURKOUM 80 PL 91 B 481       KOURKOUMELIS+(ATHU+NTUA+BNL+CERN+SYRA+YALE)

MAGERAS  81 PRL 46 1115       +BOHRINGER,FINOCCHIARO+(COLU+STON+LSU+MPIM)
MUELLER  81 PRL 46 1181       + (RUTG+SYRA+LEMO+VAND+CORN+ITHA+HARV+ROCH)
NICZYPO1 81 PL 99 B 169       NICZYPORUK,CHEN,VOGEL,WEGENER+(LENA COLLAB)
NICZYPO2 81 PL 100 B 95       NICZYPORUK,CHEN,FOLGER,LURZ,+ (LENA COLLAB)

ALBRECHT 82 PL 116 B 383      +HOFMANN,SCHUBERT(DESY+DORT+HEID+LUND+ITEP)
GREEN    82 PRL 49 617        +(RUTG+SYRA+VAND+CORN+ITHACA+HARV+OSU+ROCH)

ANDREWS  83 PRL 50 807        +  (CORN+ITHA+HARV+OSU+ROCH+RUTG+SYRA+VAND)
KLOPFENS 83 PRL 51 160        KLOPFENSTEIN,HAN+ (STON+COLU+CORN+LSU+MPIM)
TUTS     83 CORNELL CONF.P.284                     P.M.TUTS(CUSB COLLAB.)

ALBRECHT 84 PL 134 B 137      H.ALBRECHT+                  (ARGUS COLLAB.)
ARTAMONO 84 PL 137 B 272      +BARU,BLINOV,BONDAR,BUKIN,GROSHEV+    (NOVO)
BARBER   84 PL 135 B 498      +(DESY,ARGUS COLLAB+CRYSTAL BALL COLLABOR.)
BESSON   84 PR D 30 1433      +GREEN+HICKS+NAMJOSHI+SANNES+(CLEO COLLAB.)
FONSECA  84 NP B 242 31       +MAGERAS+SON+DIETL+EIGEN+     (CUSB COLLAB.)
GILES    84 PR D 29 1285      +HASSARD+HEMPSTEAD+KINOSHITA+(CLEO COLLAB.)
HAAS1    84 PRL 52 799        +JENSEN+KAGAN+KASS+BEHRENDS+ (CLEO COLLAB.)
HAAS2    84 PR D 30 1996      +JENSEN+KAGAN+KASS+BEHRENDS+ (CLEO COLLAB.)
HELLER   84 THESIS            R.HELLER, UNIV.HEIDELBERG    (ARGUS COLLAB.)

ALBRECH1 85 ZPHY C 28 45      H.ALBRECHT+                  (ARGUS COLLAB.)
ALBRECH2 85 PL 160 B 331      H.ALBRECHT+                  (ARGUS COLLAB.)
GELPHMAN 85 PR D 11 2893      +LURZ+ANTREASYAN+     (CRYSTAL BALL COLLAB.)
NERNST   85 PRL 54 2195       +ANTREASYAN+ASCHMAN+ (CRYSTAL BALL COLLAB.)
```

$\chi_{b0}(10235)$ or $\chi_{b0}(2P)$

OMITTED FROM SUMMARY TABLE

$I^G(J^{PC}) = ?^?(0\ \text{preferred}^{++})$

OBSERVED IN RADIATIVE DECAY OF THE
UPSILON(10355), THEREFORE C=+.
BRANCHING RATIO REQUIRES E1 TRANSITION, M1 IS
STRONGLY DISFAVOURED, THEREFORE P=+.
NEEDS CONFIRMATION.

$\chi_{b0}(10235)$ MASS (GeV)

```
M    U       10.2327   .0050

M    U  FROM GAMMA ENERGY BELOW ASSUMING UPSILON(10355) MASS = 10355.5 MEV
```

γ ENERGY IN $\Upsilon(10355)$ DECAY (MeV)

```
DM   Q       122.1      5.0            TUTS      83 CUSB    E+E- ->GAMMA X     |

DM   Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

$\chi_{b0}(10235)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\chi_{b0}(10235) \rightarrow \Upsilon(9460)\ \gamma$	9460+ 0
P2	$\chi_{b0}(10235) \rightarrow \Upsilon(10023)\ \gamma$	10023+ 0

REFERENCES FOR $\chi_{b0}(10235)$

EIGEN 82 PRL 49 1616 +BOHRINGER,HERB+ (MPIM+COLU+CORN+STON+LSU)
HAN 82 PRL 49 1612 +HORSTKOTTE,IMLAY+(COLU+STON+CORN+LSU+MPIM)

TUTS 83 CORNELL CONF.P.284 P.M.TUTS(CUSB COLLAB.)

$\chi_{b1}(10255)$ or $\chi_{b1}(2P)$

$I^G(J^{PC}) = ?^?(1\ \text{preferred}^{++})$

OBSERVED IN RADIATIVE DECAY OF THE
UPSILON(10355), THEREFORE C=+.
BRANCHING RATIO REQUIRES E1 TRANSITION, M1 IS
STRONGLY DISFAVOURED, THEREFORE P=+.

$\chi_{b1}(10255)$ MASS (GeV)

```
M  U         10.2560   .0020          EIGEN     82 CUSB    E+E-->2 GAM L+L-   |
M  U Q       10.2536   .0030          TUTS      83 CUSB    E+E- ->GAMMA X     |
M           . . . . . . . . .
M   AVG      10.2553   0.0017  AVERAGE

M  U   FROM GAMMA ENERGY BELOW ASSUMING UPSILON(10355) MASS = 10355.5 MEV.
M    Q SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

γ ENERGY IN $\Upsilon(10355)$ DECAY (MeV)

```
DM            99.0      2.0           EIGEN     82 CUSB    E+E-->2 GAM L+L-
DM    Q      101.4      3.0           TUTS      83 CUSB    E+E- ->GAMMA X
DM          . . . . . . . . .
DM   AVG      99.7      1.7     AVERAGE

DM    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$\chi_{b1}(10255)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\chi_{b1}(10255) \rightarrow \Upsilon(9460)\ \gamma$	9460+ 0
P2	$\chi_{b1}(10255) \rightarrow \Upsilon(10023)\ \gamma$	10023+ 0

REFERENCES FOR $\chi_{b1}(10255)$

EIGEN 82 PRL 49 1616 +BOHRINGER,HERB+ (MPIM+COLU+CORN+STON+LSU)
HAN 82 PRL 49 1612 +HORSTKOTTE,IMLAY+(COLU+STON+CORN+LSU+MPIM)

TUTS 83 CORNELL CONF.P.284 P.M.TUTS(CUSB COLLAB.)

$\chi_{b2}(10270)$ or $\chi_{b2}(2P)$

$I^G(J^{PC}) = ?^?(2\ \text{preferred}^{++})$

OBSERVED IN RADIATIVE DECAY OF THE
UPSILON(10355), THEREFORE C=+.
BRANCHING RATIO REQUIRES E1 TRANSITION, M1 IS
STRONGLY DISFAVOURED, THEREFORE P=+.

$\chi_{b2}(10270)$ MASS (GeV)

```
M  U         10.2712   .0030          EIGEN     82 CUSB    E+E-->2 GAM L+L-
M  U Q       10.2710   .0020          TUTS      83 CUSB    E+E- ->GAMMA X     |
M           . . . . . . . . . .
M   AVG      10.2711   0.0017  AVERAGE

M  U   FROM GAMMA ENERGY BELOW ASSUMING UPSILON(10355) MASS = 10355.5 MEV.
M    Q SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

γ ENERGY IN $\Upsilon(10355)$ DECAY (MeV)

```
DM            84.0      3.0           EIGEN     82 CUSB    E+E-->2 GAM L+L-
DM    Q       84.2      2.0           TUTS      83 CUSB    E+E- ->GAMMA X     |
DM          . . . . . . . . .
DM   AVG      84.1      1.7     AVERAGE

DM    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$\chi_{b2}(10270)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\chi_{b2}(10270) \rightarrow \Upsilon(9460)\ \gamma$	9460+ 0
P2	$\chi_{b2}(10270) \rightarrow \Upsilon(10023)\ \gamma$	10023+ 0

REFERENCES FOR $\chi_{b2}(10270)$

EIGEN 82 PRL 49 1616 +BOHRINGER,HERB+ (MPIM+COLU+CORN+STON+LSU)
HAN 82 PRL 49 1612 +HORSTKOTTE,IMLAY+(COLU+STON+CORN+LSU+MPIM)

TUTS 83 CORNELL CONF. P.284 P.M.TUTS(CUSB COLLAB.)

$\Upsilon(10355)$ or $\Upsilon(3S)$

$I^G(J^{PC}) = ?^?(1^{--})$

$\Upsilon(10355)$ MASS (GeV)

```
M            10.3555   0.0005         ARTAMONO  84 REDE    E+E- ->HADRONS
```

$\Upsilon(10355)$ WIDTH (keV)

```
W    B       12.0      10.0      4.0                                         |

W    B  OUR EVAL. FROM W2,R1 BELOW ASSUMING E-MU-UNIVERSALRTY
```

$\Upsilon(10355)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Upsilon(10355) \rightarrow \mu^+\mu^-$	106+ 106
P2	$\Upsilon(10355) \rightarrow e^+e^-$	.511+.511
P3	$\Upsilon(10355) \rightarrow \pi^+\pi^-\Upsilon(9460)$	140+ 140+9460
P4	$\Upsilon(10355) \rightarrow \pi^+\pi^-\Upsilon(10023)$	140+ 140+10023
P5	$\Upsilon(10355) \rightarrow \chi_{b2}(10270)\ \gamma$	10271+ 0
P6	$\Upsilon(10355) \rightarrow \chi_{b1}(10255)\ \gamma$	10254+ 0
P7	$\Upsilon(10355) \rightarrow \chi_{b0}(10235)\ \gamma$	10233+ 0

$\Upsilon(10355)$ PARTIAL WIDTHS (keV)

$\Upsilon(10355) \rightarrow (e^+e^-)$ (G2)

```
W2   Q        0.39      0.04          TUTS      83 CUSB    E+E- ->HADRONS     |
W2   Q        0.42      0.05          GILES     84 CLEO    E+E- ->HADRONS     |
W2          . . . . . . . . . .
W2  AVG       0.402     0.031   AVERAGE

W2   Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

Υ(10355) BRANCHING RATIOS

Υ(10355) → $(\mu^+\mu^-)$/total (P1)

```
R1  Q1096   0.033    0.015          ANDREWS   83 CLEO    E+E- ->MU+MU-
```

Υ(10355) → (Υ(9460) $\pi^+\pi^-$)/total (P3)

```
R3   Q  22   0.049    0.010          GREEN     82 CLEO    Y3S->PI+PI-L+L-
R3      26   0.039    0.013          MAGERAS   82 CUSB    Y3S->PI+PI-L+L-
R3        . . . . . . . . . .
R3  AVG      0.0453   0.0079  AVERAGE
```

Υ(10355) → (Υ(10023) $\pi^+\pi^-$)/total (P4)

```
R4       5   0.031    0.020          MAGERAS   82 CUSB    Y3S->PI+PI-L+L-
```

Υ(10355) → $(\chi_{b2}(10270)\ \gamma)$/total (P5)

```
R5           0.127    0.041          TUTS      83 CUSB    E+E- ->GAMMA X
```

Υ(10355) → $(\chi_{b1}(10255)\ \gamma)$/total (P6)

```
R6           0.156    0.042          TUTS      83 CUSB    E+E- ->GAMMA X
```

Υ(10355) → $(\chi_{b0}(10235)\ \gamma)$/total (P7)

```
R7           0.076    0.035          TUTS      83 CUSB    E+E- ->GAMMA X

R    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

REFERENCES FOR Υ(10355)

```
COBB     77 PL 72 B 273        +IWATA,FABJAN,GOLDBERG+(BNL+CERN+SYRA+YALE)
HERB     77 PRL 39 252         +HOM,LEDERMAN,APPEL,ITO,+  (COLU+FNAL+STON)
INNES    77 PRL 39 1240        +APPEL,BROWN,HERB,HOM,FISK+(COLU+FNAL+STON)

KAPLAN   78 PRL 40 435         +APPEL,HERB,HOM,LEDERMAN,+ (STON+FNAL+COLU)
YOH      78 PRL 41 684         +HERB,HOM,LEDERMAN,UENO,+  (COLU+FNAL+STON)

UENO     79 PRL 42 486         +BROWN,HERB,HOM,FISK,ITO,+ (FNAL+COLU+STON)

ANDREWS  80 PRL 44 1108        + (CORN+HARV+ITHA+LEMO+ROCH+RUTG+SYRA+VAND)
BOHRINGE 80 PRL 44 1111        BOHRINGER,COSTANTINI,FINOCCHIARO(COLU+STON)

GREEN    82 PRL 49 617         +(RUTG+SYRA+VAND+CORN+ITHACA+HARV+OSU+ROCH)
HAN      82 PRL 49 1612        +HORSTKOTTE,IMLAY+(COLU+STON+CORN+LSU+MPIM)
MAGERAS  82 PL 118 B 453       +HERB,IMLAY+      (COLU+CORN+LSU+MPIM+STON)
PETERSON 82 PL 114 B 277       +GIANNINI,LEE-FRANZINI+(COLU+STON+LSU+MPIM)

ANDREWS  83 PRL 50 807         +  (CORN+ITHA+HARV+OSU+ROCH+RUTG+SYRA+VAND)
TUTS     83 CORNELL CONF.P.284                      P.M.TUTS(CUSB COLLAB.)

ARTAMONO 84 PL 137 B 272       ARTAMONOV+BARU+BLINOV+BUNDAR+ (NOVOSIBIRSK)
GILES    84 PR D 29 1285       +HASSARD+HEMPSTEAD+KINOSHITA+(CLEO COLLAB.)
```

Υ(10575)
or Υ(4S)

$I^G(J^{PC}) = ?^?(1^{--})$

Υ(10575) MASS (GeV)

```
M  A Q     10.5775   0.0058          BESSON    85 CLEO    E+E- ->HADRONS
M  B Q     10.5774   0.0058          LOVELOCK  85 CUSB    E+E- ->HADRONS
M         . . . . . . . . . .
M   AVG    10.5775   0.0041   AVERAGE

M    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
M  A    SYS.ERR.=0.004 INCREASED FOR AVERAGING PURPOSE, SEE PROCEDURES C2
M  B    NO SYSTEMATIC ERROR GIVEN, WE ASSUME IT EQUAL TO BESSON 85
```

Υ(10575) WIDTH (MeV)

```
W    Q     20.0      4.5             BESSON    85 CLEO    E+E- ->HADRONS
W          25.       2.5             LOVELOCK  85 CUSB    E+E- ->HADRONS
W         . . . . . . . . . . .
W   AVG    23.8      2.2      AVERAGE

W    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

Υ(10575) PARTIAL DECAY MODES

```
                                                        DECAY MASSES
```

P1 Υ(10575) → e^+e^- .511+.511

Υ(10575) PARTIAL WIDTHS (keV)

Υ(10575) → (e^+e^-) (G1)

```
W1   Q      0.192    0.039           BESSON    85 CLEO    E+E- ->HADRONS
W1          0.283    0.037           LOVELOCK  85 CUSB    E+E- ->HADRONS
W1        . . . . . . . . . .
W1  AVG     0.240    0.045    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)

W1   Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

REFERENCES FOR Υ(10575)

```
ANDREWS  80 PRL 45 219        + (CORN+HARV+ITHA+LEMO+ROCH+RUTG+SYRA+VAND)
FINOCCHI 80 PRL 45 222        FINOCCHIARO,GIANNINI,BOHRINGER,+(COLU+STON)

BESSON   85 PRL 54 381        +GREEN+NAMJOSHI+SANNES+SKUBIC+(CLEO COLLAB)
LOVELOCK 85 PRL 54 377        +HORSTKOTTE+KLOPFENSTEIN+     (CUSB COLLAB)
```

Υ(10860)
or Υ(5S)

$I^G(J^{PC}) = ?^?(1^{--})$

Υ(10860) MASS (GeV)

```
M    Q     10.868    0.008           BESSON    85 CLEO    E+E- ->HADRONS
M          10.845    0.020           LOVELOCK  85 CUSB    E+E- ->HADRONS
M         . . . . . . . . . .
M   AVG    10.8648   0.0079   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)

M    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

Υ(10860) WIDTH (MeV)

```
W    Q     112.0     29.0            BESSON    85 CLEO    E+E- ->HADRONS
W          110.0     15.0            LOVELOCK  85 CUSB    E+E- ->HADRONS
W         . . . . . . . . . . .
W   AVG    110.4     13.3     AVERAGE

W    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

Υ(10860) PARTIAL DECAY MODES

```
                                                        DECAY MASSES
```

P1 Υ(10860) → e^+e^- .511+.511

Υ(10860) PARTIAL WIDTHS (keV)

Υ(10860) → (e^+e^-) (G1)

```
W1   Q      0.22     0.09            BESSON    85 CLEO    E+E- ->HADRONS
W1          0.365    0.070           LOVELOCK  85 CUSB    E+E- ->HADRONS
W1        . . . . . . . . . .
W1  AVG     0.310    0.070    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)

W1   Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

REFERENCES FOR Υ(10860)

```
BESSON   85 PRL 54 381        +GREEN+NAMJOSHI+SANNES+SKUBIC+(CLEO COLLAB)
LOVELOCK 85 PRL 54 377        +HORSTKOTTE+KLOPFENSTEIN+     (CUSB COLLAB)
```

Υ(11020)
or Υ(6S)

$I^G(J^{PC}) = ?^?(1^{--})$

Υ(11020) MASS (GeV)

```
M    Q     11.019    0.009           BESSON    85 CLEO    E+E- ->HADRONS
M          11.020    0.030           LOVELOCK  85 CUSB    E+E- ->HADRONS
M         . . . . . . . . . .
M   AVG    11.0191   0.0086   AVERAGE

M    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

Υ(11020) WIDTH (MeV)

```
W    Q     61.0      26.0            BESSON    85 CLEO    E+E- ->HADRONS
W          90.0      20.0            LOVELOCK  85 CUSB    E+E- ->HADRONS
W         . . . . . . . . . . .
W   AVG    79.2      15.9     AVERAGE

W    Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.
```

Υ(11020) PARTIAL DECAY MODES

```
                                                        DECAY MASSES
```

P1 Υ(11020) → e^+e^- .511+.511

Meson Full Listings

Υ(11020), $K^{\pm}$, K^0, $K^*(892)$

Υ(11020) PARTIAL WIDTHS (keV)

Υ(11020) → (e^+e^-) (G1)

```
W1   Q        0.095    0.046              BESSON    85 CLEO    E+E- ->HADRONS
W1            0.156    0.040              LOVELOCK  85 CUSB    E+E- ->HADRONS
W1           . . . . . . . . .
W1  AVG       0.130    0.030   AVERAGE

W1   Q  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

REFERENCES FOR Υ(11020)

```
BESSON   85 PRL 54 381        +GREEN+NAMJOSHI+SANNES+SKUBIC+(CLEO COLLAB)
LOVELOCK 85 PRL 54 377        +HORSTKOTTE+KLOPFENSTEIN+     (CUSB COLLAB)
```

$S=\pm 1$, $C=0$, $B=0$ MESON STATES

$K^{\pm}$

$I(J^P) = \frac{1}{2}(0^-)$

SEE STABLE PARTICLE FULL LISTINGS

K^0

$I(J^P) = \frac{1}{2}(0^-)$

SEE STABLE PARTICLE FULL LISTINGS

$K^*(892)$

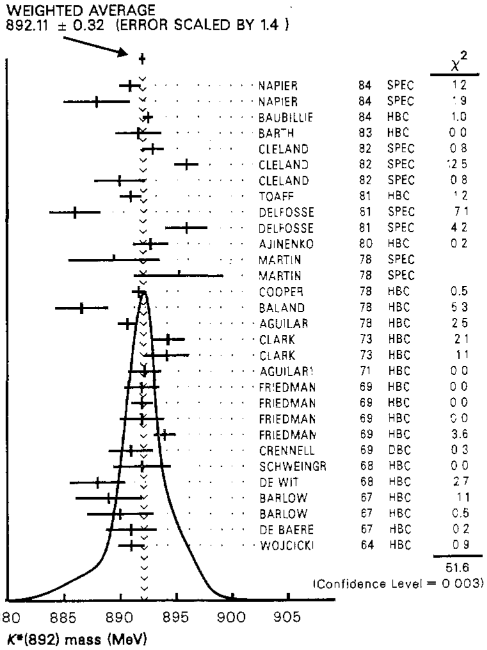
$I(J^P) = \frac{1}{2}(1^-)$

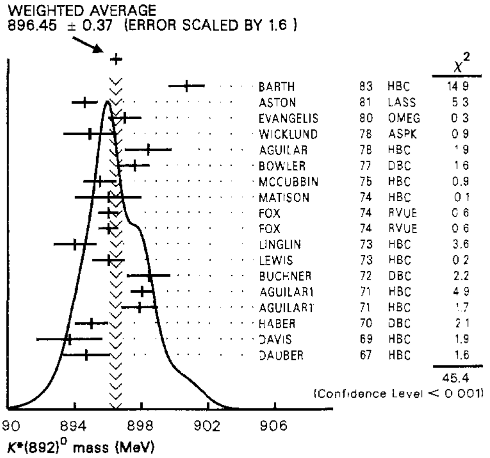
K^*(892) MASS (MeV)

```
M   CHARGED ONLY. THIS IS WHAT APPEARS ON MESON SUMMARY TABLE
M   W  1700  891.0       1.2                WOJCICKI  64 HBC    -  1.7 K-P(K0 PI-)
M     D 620  891.        2.3                DE BAERE  67 HBC   +  3.5 K+P (K0 PI+)
M       720  890.        3.0                BARLOW    67 HBC   +- 1.2 PBARP(K0 PI)
M       600  889.        3.0                BARLOW    67 HBC   +- 1.2 PBARP(K PI)
M     D 540  888.        2.5                DE WIT    68 HBC    - 3.0 K-P
M     D 341  892.0       2.6                SCHWEINGR 68 HBC    -  5.5 K-P(K0 PI-)
M      1000  891.0       2.0                CRENNELL  69 DBC    -  3.9 K-N (K0PI-)
M      2886  894.        1.0                FRIEDMAN  69 HBC    -  2.1 K-P(K0 PI-)
M       728  892.        2.                 FRIEDMAN  69 HBC    - 2.45 K-P(K0 PI-)
M      3229  892.        1.0                FRIEDMAN  69 HBC    - 2.6  K-P(K0 PI-)
M     D1027  892.        1.6                FRIEDMAN  69 HBC    - 2.7  K-P(K0 PI-)
M      4404  892.2       1.5                AGUILAR1  71 HBC    -  3.9,4.6 K- P
M     D 765  894.2       2.0                CLARK     73 HBC    - 3.13 K-P(K0 PI-)
M   W D1150  894.3       1.5                CLARK     73 HBC   -  3.3 K-P,P PI- K0
M    I 9000 (891.9)     (0.7)               PALER     75 HBC    - 14.3 K-P,K*- X+
M      1800  890.7       0.9                AGUILAR   78 HBC   +- .76 PB P,K KS PI
M      1225  886.6       2.4                BALAND    78 HBC   +- 12 PB P,INCLUSIV
M      6706  891.7       0.6                COOPER    78 HBC   +- .76 PB P,INCLUSV
M   X        895.3       4.0                MARTIN    78 SPEC +  10 K+-P,KS PI P
M   X        889.5       4.1                MARTIN    78 SPEC -  10 K+-P,KS PI P
M            892.8       1.6                AJINENKO  80 HBC  +  32 K+P
M       380  896.0       1.9                DELFOSSE  81 SPEC +  K+-P,K+- PID P
M       187  886.0       2.3                DELFOSSE  81 SPEC -  K+-P,K+- PID P
M      4100  891.0       1.0                TOAFF     81 HBC  -  6.5 K-P,K0 PI- P
M   W D 800  890.0       2.3                CLELAND   82 SPEC +  30 K+P,KS PI+P
M   W D3200  896.0       1.1                CLELAND   82 SPEC +  50 K+P,KS PI+P
M   W D3600  893.0       1.0                CLELAND   82 SPEC  - 50 K+P,KS PI-P
M      3700  891.7       2.1                BARTH     83 HBC  +  70 K+P,K0 PI+ X
M      5840  892.6       0.5                BAUBILLIE 84 HBC  -  8.25 K-P,K0PI-P
M            888.0       3.0                NAPIER    84 SPEC +  200 PI-P,2K0 X
M            891.0       1.0                NAPIER    84 SPEC  -200 PI-P,2K0 X
M            . . . . . . . . . .
M    AVG     892.11      0.32    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
                         (SEE IDEOGRAM BELOW)
```

```
M   NEUTRAL ONLY.
M     D1040  894.7       1.4                DAUBER    67 HBC    02.0 K-P(K-PI+)
M       10K  893.7       2.0                DAVIS     69 HBC    0 12. K+P(K+PI-)
M   W  4300  895.0       1.0                HABER     70 DBC    0 3. K-N (K-PI+)
M     D2934  897.9       1.1                AGUILAR1  71 HBC    0 3.9,4.6 K- P
M     D5362  898.0       0.7                AGUILAR1  71 HBC    0 3.9,4.6 K- P
M     D1700  898.4       1.3                BUCHNER   72 DBC    04.6 K+ N,K+ PI-
M      3186  896.0       1.0                LEWIS     73 HBC    02.1-2.7 K+P
M    C       894.0       1.3                LINGLIN   73 HBC    02-13 K+P,K+PI-
M       10K  896.0       0.6                FOX       74 RVUE   0 2 K-P,K-PI+N
M            896.0       0.6                FOX       74 RVUE   0 2 K+N,K+PI-P
M    C       896.        2.                 MATISON   74 HBC    012 K+P,K+PI-
M      3600  895.5       1.0                MCCUBBIN  75 HBC    0 3.6 K-P,K-PI+N
M    I  22K (897.1)     (0.7)               PALER     75 HBC    014.3 K-P,K*D X0
M            897.6       0.9                BOWLER    77 DBC    05.4 K+D,K+PI-P P
M      1180  898.4       1.4                AGUILAR   78 HBC   0 .76 PB P,K KS PI
M    P      (895.7)     (0.3)               ESTABROOK 78 ASPK   013 K+-P,K+-PI+-
M            894.9       1.6                WICKLUND  78 ASPK  0 3,4,6 PI+-PN
M    C      (892.8)     (1.3)               LANG      79 RVUE  0
M       28K  897.        1.                 EVANGELIS 80 OMEG  0 10 PI-P
M            894.6        .8                ASTON     81 LASS  0 11 K-P,K- PI+ N
M      5900  900.7       1.1                BARTH     83 HBC   0 70 K+P,K+ PI- X
M            . . . . . . . . . .
M    AVG     896.45      0.37    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
                         (SEE IDEOGRAM BELOW)
```

```
M    C  FROM POLE EXTRAPOLATION.
M    D  MASS ERRORS ENLARGED BY US TO   GAMMA/SQRT(N). SEE TYPED NOTE.
M   I   INCLUSIVE REACTION. COMPLICATED BACKGROUND AND PHASE-SPACE EFFECTS
M  P    FROM PHASE SHIFT ANALYSIS OF 155000 EVENTS.
M  W    NUMBER OF EVENTS IN PEAK REEVALUATED BY US
M  X    SYSTEMATIC ERROR ADDED
```





NOTE ON K^*(892) MASSES AND MASS DIFFERENCES

Unrealistically small errors are reported by some experiments. We use simple "realistic" tests for the minimum errors on the determination of mass and width from a sample of N events:

$$\delta_{\min}(m) = \frac{\Gamma}{\sqrt{N}}, \quad \delta_{\min}(\Gamma) = 4\frac{\Gamma}{\sqrt{N}}.$$

(For a detailed discussion, see the 1971 edition of this note.) We consistently increase unrealistic errors before averaging.

$K^*(892)^0$ − $K^*(892)^\pm$ MASS DIFFERENCE (MeV)

```
D  W   283    6.3      4.1                BARASH    67 HBC      0 PBAR P
D   SD1400   (6.5)    (5.0)               FICENEC1  68 HBC       1.3 K- P
D   SD1600   (9.5)    (5.0)               FICENEC2  68 HBC       2.7 K- P
D     7338    5.7      1.7                AGUILAR1  71 HBC   -0 3.9,4.6 K- P
D     2980    7.7      1.7                AGUILAR   78 HBC  +- .76 PB P,K KS PI
D             . . . . . . . . . .
D   AVG       6.7      1.2      AVERAGE

D    D  MASS ERRORS ENLARGED BY US TO   GAMMA/SQRT(N). SEE TYPED NOTE.
D   S   DATA WITH MASS ERROR OF 3 MEV OR MORE NOT AVERAGED
D  W    NUMBER OF EVENTS IN PEAK REEVALUATED BY US
```

$K^*(892)$ WIDTH (MeV)

```
W  CHARGED ONLY. THIS IS WHAT APPEARS ON MESON SUMMARY TABLE
W  W D1700   46.0     5.0                 WOJCICKI  64 HBC   -   1.7 K-P(KO PI-)
W    D 620   56.0     9.0                 DE BAERE  67 HBC  +    3.5 K+P(KO PI+)
W      720   43.      9.0                 BARLOW    67 HBC  +- 1.2 PBARP(KO PI)
W    D 600   53.      9.0                 BARLOW    67 HBC  +- 1.2 PBARP(K PI)
W    D 540   44.0     8.0                 DE WIT    68 DBC   -   3. K- D
W    D2886   53.      4.0                 FRIEDMAN  69 HBC   -   2.1 K-P(KO PI-)
W    D 728   49.      7.3                 FRIEDMAN  69 HBC   -   2.45K-P(KO PI-)
W    D3229   46.      3.2                 FRIEDMAN  69 HBC   -   2.6 K-P(KO PI-)
W    D1027   49.      6.1                 FRIEDMAN  69 HBC   -   2.7 K-P(KO PI-)
W    D4404   54.3     3.3                 AGUILAR1  71 HBC   -   3.9,4.6 K- P
W    D 765   46.3     6.7                 CLARK     73 HBC  -  3.13K-P,P PI- KO
W  W D1150   48.2     5.7                 CLARK     73 HBC  -  3.3 K-P,P PI- KO
W   I 9000  (52.1)   (2.2)                PALER     75 HBC   - 14.3 K-P,K*- X+
W     1800   45.8     3.6                 AGUILAR   78 HBC  +- .76 PB P,K KS PI
W     1225   43.0     8.4                 BALAND    78 HBC  +- 12 PB P,INCLUSIV
W    D6706   52.0     2.5                 COOPER    78 HBC  +- .76 PB P,INCLUSV
W            50.9     2.3                 MARTIN    78 SPEC +  10 K+-P,KS PI P
W            50.5     5.6                 AJINENKO  80 HBC  +  32 K+P
W      380   62.6     3.8                 DELFOSSE  81 SPEC +  K+-P,K+- PIO P
W      187   50.5     3.9                 DELFOSSE  81 SPEC -  K+-P,K+- PIO P
W     4100   51.0     2.0                 TOAFF     81 HBC  -  6.5 K-P,KO PI- P
W  W D 800   64.0     9.2                 CLELAND   82 SPEC +  30 K+P,KS PI+P
W  W D3200   62.0     4.4                 CLELAND   82 SPEC +  50 K+P,KS PI+P
W  W D3600   55.0     4.0                 CLELAND   82 SPEC  - 50 K+P,KS PI-P
W     3700   42.8     7.1                 BARTH     83 HBC  +  70 K+P,KO PI+ X
W     5840   49.0     2.0                 BAUBILLIE 84 HBC  -  8.25 K-P,KOPI-P
W            54.0     9.0                 NAPIER    84 SPEC +  200 PI-P,2KO X
W            56.0     4.0                 NAPIER    84 SPEC   -200 PI-P,2KO X
W           . . . . . . . . . .
W   AVG      51.13    0.84    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)


W  NEUTRAL ONLY.
W    D1040   44.      5.5                 DAUBER    67 HBC    0  2.0 K- P
W    D 10K   53.2     2.1                 DAVIS     69 HBC    0 12. K+P(K+PI-)
W  W D4300   54.0     3.3                 HABER     70 DBC    0 3. K-N (K-PI+)
W     2934   55.8     4.2        3.4      AGUILAR1  71 HBC    0 3.9,4.6 K- P
W    D5362   48.5     2.7                 AGUILAR1  71 HBC    0 3.9,4.6 K- P
W    D1700   51.4     5.0                 BUCHNER   72 DBC    04.6 K+ N,K+ PI-P
W    D3186   46.0     3.3                 LEWIS     73 HBC    02.1-2.7 K+P
W   C       (46.5)   (1.5)                LINGLIN   73 HBC    02-13 K+P,K+PI-
W      10K   47.      2.                  FOX       74 RVUE   0 2 K-P,K-PI+N
W            51.      2.                  FOX       74 RVUE   0 2 K+N,K+PI-P
W   C       (47.)    (3.)                 MATISON   74 HBC    012 K+P,K+PI-
W     3600   48.      3.         2.       MCCUBBIN  75 HBC    0 3.6 K-P,K-PI+N
W   I  22K  (50.6)   (2.5)                PALER     75 HBC    014.3 K-P,K*0 X0
W            48.9     2.5                 BOWLER    77 DBC    05.4 K+D,K+PI-P P
W     1180   45.9     4.8                 AGUILAR   78 HBC   0 .76 PB P,K KS PI
W   P       (52.9)   (0.4)                ESTABROOK 78 ASPK   013 K+-P,K+-PI+-
W            51.2     1.7                 WICKLUND  78 ASPK  0 3,4,6 PI+-PN
W   C       (40.1)   (6.0)                LANG      79 RVUE  0
W      28K   54.      2.                  EVANGELIS 80 OMEG  0 10 PI-P
W            49.8     1.2                 ASTON     81 LASS  0 11 K-P,K- PI+ N
W     5900   46.5     4.3                 BARTH     83 HBC   0 70 K+P,K+ PI- X
W           . . . . . . . . . .
W   AVG      50.24    0.65    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)

W    C  FROM POLE EXTRAPOLATION.
W    D  WIDTH ERRORS ENLARGED BY US TO 4*GAMMA/SQRT(N). SEE TYPED NOTE.
W   I   INCLUSIVE REACTION. COMPLICATED BACKGROUND AND PHASE-SPACE EFFECTS
W  P    FROM PHASE SHIFT ANALYSIS OF 155000 EVENTS.
W  W    NUMBER OF EVENTS IN PEAK REEVALUATED BY US
```

$K^*(892)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K^*(892) \rightarrow K\pi$	494+ 140
P2	$K^*(892) \rightarrow K\pi\pi$	494+ 140+ 140
P3	$K^*(892)^\pm \rightarrow K^\pm\gamma$	494+ 0
P4	$K^*(892)^0 \rightarrow K^0\gamma$	498+ 0

$K^*(892)$ PARTIAL WIDTHS (keV)

$K^*(892)^\pm \rightarrow (K^\pm\gamma)$ (G3)

```
W3            48.0      11.0              BERG      83 SPEC -   156 K-A,K PI A
W3            51.0       5.0              CHANDLEE  83 SPEC +   200 K+A,K PI A
W3          . . . . . . . . . .
W3  AVG       50.5       4.6      AVERAGE
```

$K^*(892)^0 \rightarrow (K^0\gamma)$ (G4)

```
W4      584  116.5       9.9              CARLSMITH 86 SPEC  0 KOL A,KOS PIO A
```

$K^*(892)$ BRANCHING RATIOS

$K^*(892) \rightarrow (K\pi\pi)/(K\pi)$ (P2)/(P1)

```
R1        0   (0.002)OR LESS            WOJCICKI2 64 HBC   -  1.7 K-P
R1        0   (0.0007)R LESS  CL=0.95   JONGEJANS 78 HBC      4 K-P,P KO 2PI
```

$K^*(892)^\pm \rightarrow (K^\pm\gamma)$/total (units 10^{-3}) (P3)

```
R2            (1.6)  OR LESS  CL=.95    BEMPORAD  72 CNTR +  10.-16. K+A,COUL
```

$K^*(892)^0 \rightarrow (K^0\gamma)$/total (units 10^{-3}) (P4)

```
R3              1.5      0.7            CARITHERS 75 CNTR  0 8-16KBARO A,COUL
```

REFERENCES FOR $K^*(892)$

```
ALSTON   61 PRL 6 300          ALSTON,ALVAREZ,EBERHARD,GOOD,GRAZIANO+(LRL)

ALEXANDE 62 PRL 8 447          ALEXANDER,KALBFLEISCH,MILLER,G SMITH  (LRL)
COLLEY   62 CERN CONF 315      D COLLEY,N GELFAND +    (COLUMBIA+RUTGERS)

CHADWICK 63 PL 6 309           CHADWICK,CRENNELL,DAVIES,BETTINI+(OXF+PADO)
GOLDHABE 63 ATHENS CONF 92     SULAMITH GOLDHABER                    (LRL)

WOJCICKI 64 PR 135 B 484       STANLEY G WOJCICKI                    (LRL)

ADELMAN  65 ATHENS 527         STUART LEE ADELMAN              (CAVENDISH)
FERRO-LU 65 NC 36 1101         FERRO-LUZZI,GEORGE,HENRI,JONGEJANS   (CERN)
FERRO-LU 65 NC 39 417          FERRO-LUZZI,GEORGE,GOLDSCHMIDT-CLER+ (CERN)
GELSEMA  65 THESIS             E.S.GELSEMA (SEE ALSO PL 10 341)(AMSTERDAM)
WANGLER  65 PR 137 B 414       WANGLER,ERWIN,WALKER            (WISCONSIN)

BARASH   67 PR  156  1399      BARASH,KIRSCH,MILLER,TAN         (COLUMBIA)
BARLOW   67 NC  50 A  701      +MONTANET,D-ANDLAU+   (CERN+CDEF+IRAD+LIVP)
BOMSE    67 PR 158 1298        +BORENSTEIN+COLE+GILLESPIE+  (JOHN HOPKINS)
CONFORTO 67 NP B3 469          +MARECHAL,MONTANET+CERN+CDEF+IPN+LIVERPOOL
DAUBER   67 PR 153 1403        +SCHLEIN,SLATER,TICHO                (UCLA)
DE BAERE 67 NC 51 A 401        +GOLDSCHMIDT-CLERMONT,HENRI+    (BRUX+CERN)
FRENCH   67 NC 42A 442         +KINSON+MCDONALD+RIDDIFORD+     (CERN+BIRM)
GEORGE   67 NC 49A 9           +GOLDSCHMIDT-CLERMONT+HENRI+    (CERN+BRUX)
SALLSTRO 67 NC 49A 348         SALLSTROM+OTTER+EKSPONG         (STOCKHOLM)

DE WIT   68  THESIS            S. DE WIT                       (AMSTERDAM)
FICENEC1 68 PR 169 1034        +HULSIZER+SWANSON+TROWER              (ILL)
FICENEC2 68 PR 175 1725        FICENEC, GORDON, TROWER          (ILLINOIS)
KANG     68 PR 176 1587        Y.W.KANG                             (IOWA)
SCHWEING 68 PR 166 1317        SCHWEINGRUBER,DERRICK,FIELDS+    (ANL+NWES)

CRENNELL 69 PRL 22  487        +KARSHON,LAI,ONEALL,SCARR             (BNL)
DAVIS    69 PRL 23 1071        +DERENZO,FLATTE,ALSTON,LYNCH,SOLMITZ  (LRL)
DE BAERE 69 NC 61 A 397        +GOLDSCHMIDT-CLERMONT,HENRI,+   (BELG+CERN)
FRIEDMAN 69  UCRL-18860        J.FRIEDMAN,PH.D. THESIS               (LRL)
JUHALA   69 PR 184  1461       +LEACOCK,RHODE,KOPELMAN,LIBBY,+ (ISU+COLO)
LIND     69 NP B 14 1          +ALEXANDER,FIRESTONE,FU,GOLDHABER     (LRL) JP

ATHERTON 70 NP B 16 416        +FRANEK,FRENCH,FRISK,BEDNAR+    (CERN+PRAG)
HABER    70 NP B 17 289        +SHAPIRA,ALEXANDER+   (REHO+SACL+BGNA+EPOL)

AGUILAR  71 PRL 26 466         +BARNES,BASSANO,EISNER,KINSON,SAMIOS  (BNL)
AGUILAR1 71 PR D 4 2583        +EISNER,KINSON                        (BNL)
BARNHAM  71 NP B 28 171        +COLLEY,JOBES,GRIFFITHS,HUGHES,+(BIRM+GLAS)
BUCHNER  71 NP B 29 381        +DEHM,GOEBEL,GOLDSCHMIDT,+ (MPIM+CERN+BELG)
CORDS    71 PR D 4 1974        +CARMONY,ERWIN,MEIERE,+    (PURD+UCD+IUPU)
MERCER   71 NP B32 381         +ANTICH,CALLAHAN,CHIEN,COX,+ (JOHN HOPKINS)
YUTA     71 PRL 26 1502        +DERRICK,ENGELMANN,MUSGRAVE       (ANL+EFI)

ABRAMOVI 72 NP B 39 189        ABRAMOVICH,CHALOUPKA,CHUNG,HILPERT,+ (CERN)
BINGHAM  72 NP B 41 1          +           (INTERNATIONAL K+ COLLABORATION)
BEMPORAD 72 NP B 51 1          +BEUSCH,FREUDENREICH,+      (CERN+ETH+LOIC)
BRUNET   72 NP B 37 114        +DANYSZ,GOLDSACK,+    (CDEF+SACL+LOIC+LOWC)
BUCHNER  72 NP B 45 333        +DEHM,CHARRIERE,CORNET,+   (MPIM+CERN+BRUX)
CRENNELL 72 PR D 6 1220        +GORDON,KWAN-WU LAI,SCARR             (BNL)
DEUTSCHM 72 NP B 36 373        DEUTSCHMANN,+           (ABCLV COLLABORATION)
ENGELMAN 72 PR D 5 2162        ENGELMANN,MUSGRAVE,FORMAN,+       (ANL+EFI)
ROUGE    72 NP B 46 29         +VIDEAU,VOLTE,DE BRION,+        (EPOL+SACL)
TIECKE   72 NP B 39 596        +GRIJNS,HEINEN,DE GROOT,+       (NIJM+AMST)

BERTHON  73 NP B 63 54         +MONTANET,PAUL,BERTRANET,+      (CERN+SACL)
CHARRIER 73 NP B 51 317        CHARRIERE,DRIJARD,DE BAERE,+    (CERN+BELG)
CLARK    73 NP B 54 432        +LYONS,RADOJICIC                   (OXFORD)
LEWIS    73 NP B 60 283        +ALLEN,JACOBS,DANYSZ,BORG,+(LOWC+LOIC+CDEF)
LINGLIN  73 NP B 55 408        D.LINGLIN                            (CERN)
WALUCH   73 PR D 8 2837        +FLATTE,FRIEDMAN                      (LBL)

FOX      74 NP B80 403         G.C.FOX,M.L.GRISS                     (CIT)
MATISON  74 PR D9 1872         +GALTIERI,GARNJOST,FLATTE,FRIEDMAN,+  (LBL)

BRANDENB 75 PL 59 B 405        BRANDENBURG,CARNEGIE,CASHMORE,DAVIER+(SLAC)
CARITHER 75 PRL 35 349         CARITHERS,MUHLEMANN,UNDERWOOD,+ (ROCH+MCGI)
MCCUBBIN 75 NP B86 13          N.A.MCCUBBIN,L.LYONS                  (OXF)
PALER    75 NP B96 1           +TOVEY,SHAH,SPIRO,CHAURAND+(RHEL+SACL+EPOL)

KIRK     76 NP B 116 99        +KLEIN,COUNIHAN,+(AACH+BERL+CERN+LOIC+WIEN)

BOWLER   77 NP B 126 31        +DAINTON,DRAKE,WILLIAMS            (OXFORD)

AGUILAR  78 NP B 141 101       +FERNANDEZ,COOPER,+   (MADR+TIFR+CERN+CDEF)
BALAND   78 NP B 140 220       +GRARD,JOHNSON,+ (MONS+BELG+CERN+LOIC+LALO)
BALDI    78 NP B 134 365       +BOHRINGER,DORSAZ,HUNGERBUHLER+      (GEVA)
COOPER   78 NP B 136 365       +GURTU,DOBRZYNSKI,+   (TIFR+CERN+CDEF+MADR)
ENGELEN  78 NP B 134 14        +JONGEJANS,HEMINGWAY,+ (NIJM+ZEEM+CERN+OXF)
ESTABROO 78 NP B 133 490       ESTABROOKS,CARNEGIE,+ (MONT+CARL+DURH+SLAC)
    ALSO 78 PR D 17 658        ESTABROOKS,CARNEGIE+  (MONT+CARL+DURH+SLAC)
JONGEJAN 78 NP B 139 383       JONGEJANS,CERRADA,+    (ZEEM+CERN+NIJM+OXF)
MARTIN   78 NP B 134 392       +SHIMADA,BALDI,BOHRINGER,DORSAZ+(DURH+GEVA)
WICKLUND 78 PR D 17 1197       +AYRES,DIEBOLD,GREENE,KRAMER,PAWLICKI (ANL)

LANG     79 PR D 19 956        C.B.LANG,A.MAS-PARAREDA              (GRAZ)

AJINENKO 80 ZPHY 5 177         +BARTH,DUJARDIN,+     (SERP+LIBH+MONS+SACL)
EVANGELI 80 NP B 165 383       + (BARI+BONN+CERN+DARE+GLAS+LIVP+MILA+WIEN)

ASTON    81 PL 106 B 235       +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA) JP
BERG     81 PL 98 B 119        +CHANDLEE,BIEL,HEPPELMANN,+(ROCH+FNAL+MINN)
DELFOSSE 81 NP B 183 349       +GUISAN,MARTIN,MUHLEMANN,WEILL,+(GEVA+LAUS)
TOAFF    81 PR D 23 1500       +MUSGRAVE,AMMAR,DAVIS,ECKLUND,+  (ANL+KANS)

CLELAND  82 NP B 208 189       +DELFOSSE,DORSAZ,GLOOR(DURH+GEVA+LAUS+PITT)

BARTH    83 NP B 223 296       +DREVERMANN+(BRUX+CERN+GENO+MONS+NIJM+SERP)
BERG     83  THESIS            D.BERG                               (ROCH)
CHANDLEE 83  COO 3065 354      +BERG,CIHANGIR,COLLICK+    (ROCH+FNAL+MINN)
```

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BAUBILLI 84 ZPHY C 26 37       BAUBILLIER+       (BIRM+CERN+GLAS+MICH+LPNP)
NAPIER   84 PL 149 B 514       +CHEN+ (TUFT+ARIZ+FNAL+FLOR+NDAM+VAND+VIRG)

CARLSMIT 86 PRL 56 18          CARLSMITH,BERNSTEIN,PEYAUD,TURLAY(EFI+SACL)
```

$K_1(1280)$ was $Q(1280)$

$I(J^P) = \frac{1}{2}(1^+)$

OUR LATEST MINIREVIEW ON THIS PARTICLE CAN BE FOUND IN THE 1984 EDITION.

$K_1(1280)$ MASS (MeV)

```
M1  PRODUCED BY BEAMS OTHER THAN K MESONS
M1 A      1242.0      9.0     10.0   ASTIER    69 HBC    0 PBAR P
M1 A   THIS IS THE C MESON.
M1      45(1300.)                    CRENNELL  67 HBC    0 6 PI- P,LK2PI
M1      40(1300.)                    CRENNELL  72 HBC    0 4.5PI-P,LK2PI
M1     310(1294.)    (10.)           RODEBACK  81 HBC     4 PI-P,LAM K 2PI

M2  PRODUCED BY K-, BACKWARDS SCATTERING, HYPERON EXCHANGE
M2     700 1275.0     10.0           GAVILLET  78 HBC  +  4.2 K-P,XI-KPIPI

M3  PRODUCED BY K BEAMS
M3        (1260.)                    DAVIS     72 HBC  +  12. K+ P
M3        (1234.)    (12.)           FIRESTONE 72 DBC  +  12. K+ D
M3        (1300.)   APPROX.          BRANDENB  76 ASPK +- 13 K+-P,(KPIPI)P
M3  E     (1289.0)   (25.0)          CARNEGIE  77 ASPK +- 13 K+-P,P KPIPI
M3        (1270.0)  APPROX.          OTTER     76 HBC  -  10-14-16K-P
M3        (1300.0)  APPROX.          VERGEEST  79 HBC  +- 4.2 K-P,K PI PI
M3         1270.      10.            DAUM      81 CNTR -  63 K-P,K 2PI P
M3  T     (1276.0)  APPROX           TORNQVIST 82 RVUE
M3
M3  E   FROM A MODEL DEPENDENT FIT WITH GAUSSIAN BACKGROUND TO
M3  E   BRANDENBURG 76 DATA.
M3  T   FROM A UNITARIZED QUARK MODEL CALCULATION
```

$K_1(1280)$ WIDTH (MeV)

```
W1  PRODUCED BY BEAMS OTHER THAN K MESONS
W1         127.0      7.0     25.0   ASTIER    69 HBC    0 PBAR P
W1     45  (60.)                     CRENNELL  67 HBC    0 6 PI- P
W1     40  (60.)                     CRENNELL  72 HBC    0 4.5PI-P,LK2PI
W1    310  (66.)     (15.)           RODEBACK  81 HBC     4 PI-P,LAM K 2PI

W2  PRODUCED BY K-, BACKWARDS SCATTERING, HYPERON EXCHANGE
W2    700   75.0     15.0            GAVILLET  78 HBC  +  4.2 K-P,XI-KPIPI

W3  PRODUCED BY K BEAMS
W3        (120.)                     DAVIS     72 HBC  +  12. K+ P
W3        (188.)     (21.)           FIRESTONE 72 DBC  +  12. K+ D
W3        (200.)   APPROX.           BRANDENB  76 ASPK +- 13 K+-P,(KPIPI)P
W3  E     (150.00)  (71.0)           CARNEGIE  77 ASPK +- 13 K+-P,P KPIPI
W3        (150.0)  APPROX.           VERGEEST  79 HBC  +- 4.2 K-P,K PI PI
W3          90.       8.             DAUM      81 CNTR -  63 K-P,K 2PI P
W3
W3  E   SEE NOTE E ABOVE.
```

$K_1(1280)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_1(1280) \rightarrow K^*(892)\ \pi$	892+ 140
P2	$K_1(1280) \rightarrow K\,\rho$	498+ 769
P3	$K_1(1280) \rightarrow K\,\pi$	498+ 140
P4	$K_1(1280) \rightarrow K\,\eta$	498+ 549
P5	$K_1(1280) \rightarrow K\,\omega$	498+ 783
P6	$K_1(1280) \rightarrow K\,\pi\,\pi$	498+ 140+ 140
P7	$K_1(1280) \rightarrow K_0^*(1350)\ \pi$	1350+ 140
P8	$K_1(1280) \rightarrow K\,f_0(1300)$	498+1300

$K_1(1280)$ PARTIAL WIDTHS (MeV)

$K_1(1280) \rightarrow K^*(892)\ \pi$ (G1)

```
W1             2.0       2.0          CARNEGIE1 77 ASPK +- 13 K+-P,(KPIPI)P
W1            14.0      11.0          MAZZUCATO 79 HBC  +  4.2 K-P,XI-KPIPI
W1          . . . . . . . . .
W1  AVG        2.4       2.0     AVERAGE
```

$K_1(1280) \rightarrow K\ \rho$ (G2)

```
W2            75.0       6.0          CARNEGIE1 77 ASPK +- 13 K+-P,(KPIPI)P
W2            57.0       5.0          MAZZUCATO 79 HBC  +  4.2 K-P,XI-KPIPI
W2          . . . . . . . . .
W2  AVG       64.4       8.9     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.3)
```

$K_1(1280) \rightarrow K\ \omega$ (G5)

```
W5            24.0       3.0          CARNEGIE1 77 ASPK +- 13 K+-P,(KPIPI)P
W5             4.0       4.00         MAZZUCATO 79 HBC  +  4.2 K-P,XI-KPIPI
W5          . . . . . . . . .
W5  AVG       16.8       9.6     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 4.0)
```

$K_1(1280) \rightarrow K_0^*(1350)\ \pi$ (G7)

```
W7            26.0       6.0          CARNEGIE1 77 ASPK +- 13 K+-P,(KPIPI)P
```

$K_1(1280) \rightarrow f_0(1300)\ K$ (G8)

```
W8            22.0       5.0          CARNEGIE1 77 ASPK +- 13 K+-P,(KPIPI)P
```

$K_1(1280)$ BRANCHING RATIOS

$K_1(1280) \rightarrow (K^*(892)\ \pi)$/total (P1)

```
R1 F         0.16      0.05            DAUM      81 CNTR    63 K-P,K 2PI P
```

$K_1(1280) \rightarrow (K\ \rho)$/total (P2)

```
R2 F         0.42      0.06            DAUM      81 CNTR    63 K-P,K 2PI P
R2         DOMINANT                    RODEBACK  81 HBC     4 PI-P,LAM K 2PI
```

$K_1(1280) \rightarrow (K\ \omega)$/total (P5)

```
R3 F         0.11      0.02            DAUM      81 CNTR    63 K-P,K 2PI P
```

$K_1(1280) \rightarrow (K_0^*(1350)\ \pi)$/total (P7)

```
R4 F         0.28      0.04            DAUM      81 CNTR    63 K-P,K 2PI P
```

$K_1(1280) \rightarrow (K\ f_0(1300))$/total (P8)

```
R5 F         0.03      0.02            DAUM      81 CNTR    63 K-P,K 2PI P
```

$K_1(1280) \rightarrow (K\ \omega)/(K\ \rho)$ (P5)/(P2)

```
R6          (0.30) OR LESS  CL=.95     RODEBACK  81 HBC     4 PI-P,LAM K 2PI
```

D-wave/S-wave RATIO FOR $K_1(1280) \rightarrow K^*(892)\ \pi$

```
R9 F         1.0       0.7             DAUM      81 CNTR    63 K-P,K 2PI P

R  F    AVERAGE FROM LOW AND HIGH T DATA.
```

REFERENCES FOR $K_1(1280)$

```
ARMENTER 64 DUBNA CONF 1 577  ARMENTEROS,EDWARDS,D-ANDLAU +    (CERN+CDEF)
    ALSO 64 DUBNA CONF 1 617  R ARMENTEROS (RAPPORTEUR)
ARMENTER 64 PL 9 207          ARMENTEROS,EDWARDS,D-ANDLAU,+    (CERN+CDEF)
    ALSO 66 PR  145  1095     BARASH,KIRSCH,MILLER,TAN          (COLUMBIA)

ALMEIDA  65 PL 16 184         ALMEIDA,ATHERTON,BYER,DORNAN,FORSON+ (CAVE)

SHEN     66 PRL  17  726      +BUTTERWORTH,FU,GOLDHABERS,TRILLING   (LRL)
    ALSO 66  PRIVATE COMM.   GERSON GOLDHABER                      (LRL)

BASSOMPI 67 PL 26B 30         BASSOMPIERRE,GOLDSCHMIDT+  (CERN+BRUX+BIRM)IJP
BERLINGH 67 PRL 18 1087       BERLINGHIERI+FARBER+FERBEL+FORMAN    (ROCH)IJP
CRENNELL 67 PRL 19  44        +KALBFLEISCH,LAI,SCARR,SCHUMANN       (BNL)I
DE BAERE 67 NC 49A 374        +DEBAISIEUX+FAST+FILIPPAS+       (CERN+BRUX)
    ALSO PRIVATE COMMUNICATION BY B. JONGEJANS
GOLDHABE 67 PRL 19 976        G.GOLDHABER                           (LBL)

BARTSCH  68 NP B8 9           +COCCONI,+         (AACH+BERL+CERN+LOIC+VIEN)
BOMSE    68 PRL 20 1519       +BORENSTEIN,CALLAHAN,COLE,COX,+  (JOHNHOPK)  1+
DENEGRI  68 PRL 20 1194       +CALLAHAN+ETTLINGER+GILLESPIE+   (JOHNHOPK)  1+

ALEXANDE 69 NP B 13 503       G.ALEXANDER,FIRESTONE,GOLDHABER,+     (LRL)
ANDREWS  69 PRL 22 731        +LACH,LUDLAM,SANDWEISS,BERGER,+  (YALE+LRL)
ASTIER   69 NP B 10 65        +MARECHAL,MONTANET,+  (CDEF+CERN+IPNP+LIVP)IJP
BARBARO  69 PRL 22 1207       BARBARO-GALTIERI,DAVIS,FLATTE,+       (LRL)
BETTINI  69 NC 62 A 1038      +CRESTI,LIMENTANI,BERTAUZA,BIGI+(PADO+PISA)I
BISHOP   69 NP B 9 403        +GOSHAW,ERWIN,WALKER                 (WISC)
CHIEN    69 PL 29B 433        +MALAMUD,MELLEMA,RUDNICK,SCHLEIN+    (UCLA)
CHUNG    69 PR 182 1443       +EISNER+BALI+LUERS                    (BNL)
COLLEY   69 NC A 59 519       +EASTWOOD,+  (BIRM+GLAS+LOIC+MPIM+OXF+RHEL)
ERWIN    69 NP B 9 364        +WALKER,GOSHAW,WEINBERG     (WISC+PRIN+VAND)
FRIEDMAN 69  UCRL-18860       J.FRIEDMAN,PH.D. THESIS               (LRL)
WERNER   69 PR 188 2023       +AMMAR,DAVIS,KROPAC,YARGER,CHO,+ (NWES+ANL) 1+

ABRAMS   70 PR D 1 2433       +EISENSTEIN,KIM,MARSHALL,O-HALLORAN,+ (ILL)
ANTICH   70 NP B 20 201       +CARSON,CHIEN,COX,DENEGRI,ETTLINGER,+ (JHU)  1+
BOWLER   70 PL 31 B 318       M.G.BOWLER                         (OXFORD)
FARBER   70 PR D 1 78         +FERBEL,SLATTERY,YUTA                (ROCH)  1+

BARNHAM  71 NP B25 49         +COLLEY,GRIFFITHS,ALPER, +  (BIRM+GLAS+OXF)
DENEGRI  71 NP B 28 13        +ANTICH,CALLAHAN,CARSON,CHIEN,COX,+   (JHU)  1+
FORMAN   71 PR D 3 2610       +GELFAND,LEARY,MOSER,SEIDL,WOLFSON    (EFI)
GARFINKE 71 PRL 26 1505       GARFINKEL,HOLLAND,CARMONY,LANDER+(PURD+UCD)  1+

ANDERSON 72 PR D 6 1823       +FRANKLIN,GODDEN,KOPELMAN,LIBBY,TAN  (COLO)
BINGHAM  72 NP B 48 589       +EISENSTEIN,GRARD,HERQUET,+      (CERN+BRUX)
BRANDENB 72 NP B 45 397       BRANDENBURG,BRODY,JOHNSON,LEITH,LOOS+(SLAC)
BRANDENB 72 PRL 28 932        BRANDENBURG,JOHNSON,LEITH,LOOS,LUSTE+(SLAC)
CRENNELL 72 PR D 6 1220       +GORDON,KWAN-WU LAI,SCARR             (BNL)
DAVIS    72 PR D 5 2688       +ALSTON,BARBARO,FLATTE,FRIEDMAN,LYNCH+(LBL)
FIRESTON 72 PR D 5 505        FIRESTONE,GOLDHABER,LISSAUER,TRILLING (LBL)
FIRESTON172 NP B 47 348       A.FIRESTONE                           (CIT)
FRATI    72 PR D 6 2361       +HALPERN,HARGIS,SNAPE,CARNAHAN,+(PENN+CINC)
HAATUFT  72 NP B 48 78        +ARNOLD,HAGUENAUER,+  (BERG+STRB+EPOL+MADR)

BARLOUTA 73 NP B 59 374       +DREVILLON,SHAH,+           (SACL+EPOL+RHEL)  JP
BINGHAM  73 NP B 52 31        +FARWEL,+         (LBL+ORSAY+BNL+SACLAY+MILAN)  JP
DE JONGH 73 NP B 58 110       +CORNET,CHARRIERE,+   (BRUX+MONS+CERN+MPIM)
JONES    73 NP B 52 383       G.T.JONES                            (CERN)  JP
LEWIS    73 NP B 60 283       +ALLEN,JACOBS,DANYSZ,BORG,+(LOWC+LOIC+CDEF)
WERNER   73 PR D 7 1275       +SLATTERY,FERBEL                (ROCHESTER)

ANGELOPO 74 NC 20A 49         ANGELOPOULOS,FILIPPAS+(ATHU+ATEN+LIVP+VIEN)  JP
BOWLER   74 NP B74 493        +DAINTON,KADDOURA,AITCHISON           (OXF)
DAVIDSON 74 PR D9 77          +CHAPMAN,GREEN,LYS,ROE               (MICH)
DEUTSCHM 74 PL 49B 388        DEUTSCHMANN,+     (AACH+BERL+CERN+LOIC+VIEN)  JP

ANTIPOV  75 NP B86 381        +ASCOLI,BUSNELLO,KIENZLE+   (SERP+CERN+ILL)  JP
BOWLER   75 NP B97 227        +GAME,AITCHISON,DAINTON          (OXF+DARE)
DORE     75 LNC 13 265        +GUIDONI,LAAKSO,MARINI,CONFORTO+(ROMA+RHEL)
DREVILLO 75 PL 55 B 245       DREVILLON,BORENSTEIN+       (EPOL+BOHR+CDEF)  JP
DUNWOODI 75 NP B91 189        DUNMOODIE,GRANT+       (CERN+BELG+MONS+MPIM)  JP
OTTER1   75 NP B84 333        + (AACH+BERL+CERN+LOIC+VIEN+ATHU+ATEN+LIVP)  JP
OTTER2   75 NP B93 365        +RUDOLPH,RUMPF+  (AACH+BERL+CERN+LOIC+VIEN)  JP
OTTER3   75 NP B96 29         +RUDOLPH,SEYFERT+(AACH+BERL+CERN+LOIC+VIEN)I,JP
TOVEY    75 NP B95 109        +HANSEN,BORENSTEIN,BORG+    (RHEL+EPOL+SACL)I,JP

BASDEVAN 76 PRL 37 977        BASDEVANT,BERGER                  (FNAL+ANL)
BOAL     76 PR D 14 2998      +EDWARDS,KAMAL,TORGESON             (ALBERTA)
BOWLER   76 JPG 3 775         M.G.BOWLER                         (OXFORD)
BRANDENB 76 PRL 26 703        BRANDENBURG,CARNEGIE,CASHMORE,DAVIER+(SLAC)  JP
OTTER    76 NP B 106 77       + (AACH+BERL+CERN+LOIC+VIEN+LPNP+RHEL+SACL)  JP
VERGEEST 76 PL 62 B 471       +ENGELEN,JONGEJANS,+    (AMST+CERN+NIJM+OXF)  JP

CARNEGIE 77 NP B 127 509      +CASHMORE,DAVIER,DUNWOODIE,LASINSKI+ (SLAC)
CARNEGIE177 PL B 68 287       +CASHMORE,DUNWOODIE,LASINSKI,+       (SLAC)

BEUSCH   78 PL 74 B 282       +BIRMAN,KONIGS,OTTER,+       (CERN+AACH+ETH)  JP
GAVILLET 78 PL 76 B 517       +DIAZ,DIONISI,+         (AMST+CERN+NIJM+OXF)  JP
WOHL     78 NP B 132 401      +PALER,CHAURAND,+          (LPNP+RHEL+SACLAY)
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BASDEVAN 79 PR D 19 246         BASDEVANT,BERGER                       (ANL)
MAZZUCAT 79 NP B 156 532        MAZZUCATO,PENNINGTON+  (CERN+ZEEM+NIJM+OXF)
VERGEEST 79 NP B 158 265        +JONGEJANS,DIONISI,+   (NIJM+AMST+CERN+OXF)

BACON    80 NP B 162 189        +BARREY,BUTTERWORTH,ANSORGE,+   (LOIC+CAVE)
DIONISI  80 NP B 169 1          +GAVILLET,ARMENTEROS+ (CERN+MADR+CDEF+STOH)
ETKIN    80 PR D 22 42          +FOLEY,LINDENBAUM,KRAMER,+        (BNL+CUNY)JP
IRVING   80 JPG 6 153           A.C.IRVING                            (LIVP)
RADFORD  80 NP B 167 181        RADFORD,BRANDENBURG                    (MIT)

DAUM     81 NP B 187 1          +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
OTTER    81 NP B 181 1            (AACH+BERL+LOIC+VIEN+BIRM+BELG+CERN+MONS)
RODEBACK 81 ZPHY C 9 9          +SJOGREN,ARMENTEROS,+ (CERN+CDEF+MADR+STOH)

BAUBILLI 82 NP B 202 21         BAUBILLIER+         (BIRM+CERN+GLAS+MSU+LPNP)
FERNANDE 82 ZPHY C 16 95        FERNANDEZ,AGUILAR+    (MADR+CERN+CDEF+STOH)JP
GAVILLET 82 ZPHY C 16 119       +ARMENTEROS,AGUILAR+  (CERN+CDEF+PADO+ROMA)
TORNQVIS 82 NP B 203 268        TORNQVIST                             (HELS)
```

$K_0^*(1350)$ was $\kappa(1350)$

$I(J^P) = \frac{1}{2}(0^+)$

OUR LATEST MINIREVIEW ON THIS PARTICLE CAN BE FOUND IN THE 1984 EDITION.

$K_0^*(1350)$ MASS (MeV)

```
M    C     (1425.)   APPROX.          ESTABROOK 78 ASPK    13 K+- P
M          (1450.0)  APPROX.          MARTIN    78 SPEC    10 K+-P,KS PI P
M    P     (1278.)    (50.)           LANG      79 RVUE  0
M          (1400.)   APPROX.          ASTON     81 LASS  0 11 K-P,K- PI+ N
M    T     (1350.)                    TORNQVIST 82 RVUE    13 K+- P
M          (1430.)   APPROX.          BAUBILLIE 84 HBC  -  8.25 K-P,K0PI-P   |

M    C   FROM ELASTIC K PI PARTIAL WAVE ANALYSIS.
M    P   POLE EXTRAPOLATION USING FIRESTONE 72 AND MATISON 74 DATA.
M    T   FROM A UNITARIZED QUARK MODEL CALCULATION
```

$K_0^*(1350)$ WIDTH (MeV)

```
W    C       200-300 APPROX.          ESTABROOK 78 ASPK    13 K+- P
W    P      (540.)   (106.)           LANG      79 RVUE  0
W           (250.)   APPROX.          ASTON     81 LASS  0 11 K-P,K- PI+ N
W    T      (430.)   OR MORE          TORNQVIST 82 RVUE    13 K+- P
W           (200.)   APPROX.          BAUBILLIE 84 HBC  -  8.25 K-P,K0PI-P   |

W    C   FROM ELASTIC K PI PARTIAL WAVE ANALYSIS.
W    P   POLE EXTRAPOLATION USING FIRESTONE 72 AND MATISON 74 DATA.
W    T   FROM A UNITARIZED QUARK MODEL CALCULATION
```

$K_0^*(1350)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_0^*(1350) \to K\pi$	498+ 135
P2	$K_0^*(1350) \to K\eta$	498+ 549
P3	$K_0^*(1350) \to K\eta'$	498+ 958

$K_0^*(1350)$ BRANCHING RATIOS

$K_0^*(1350) \to (K\pi)$/total (P1)

```
R1            (0.85) APPROX.          ASTON     81 LASS  0 11 K-P,K- PI+ N
R1   T        (0.93) APPROX.          TORNQVIST 82 RVUE    13 K+-P

R1   T   FROM A UNITARIZED QUARK MODEL CALCULATION
```

REFERENCES FOR $K_0^*(1350)$

```
TRIPPE   68 PL 28 B 203         +CHIEN,MALAMUD,MELLEMA,SCHLEIN,+      (UCLA)

CRENNELL 69 PRL 22 487          +KARSHON,LAI,O.NEALL,SCARR             (BNL)
DODD     69 PR 177 1994         +JOLDERSMA,PALMER,SAMIOS               (BNL)
GOLDBERG 69 PL 30 B 434         SABRE COLLABOR.  (SACL+AMST+BGNA+REHO+EPOL)
SCHLEIN  69 ARGONNE CONF. 446 P.SCHLEIN                               (UCLA)

FIRESTON 71 PRL 26 1460         A.FIRESTONE,G.GOLDHABER,D.LISSAUER     (LRL)
MERCER   71 NP B32 381          +ANTICH,CALLAHAN,CHIEN,COX,+ (JOHN HOPKINS)
YUTA     71 PRL 26 1502         +DERRICK,ENGELMANN,MUSGRAVE        (ANL+EFI)

AGUILAR  72 PR D 6 11           AGUILAR-BENITEZ,CHUNG,EISNER           (BNL)
BINGHAM  72 NP B 41 1           +             (INTERNATIONAL K+ COLLABORATION)
BUCHNER  72 NP B 45 333         +DEHM,CHARRIERE,CORNET,+   (MPIM+CERN+BRUX)
CHUNG    72 PRL 29 1570         +EISNER,AGUILAR-BENITEZ                (BNL)
CRENNELL 72 PR D 6 1220         +GORDON,KWAN-WU LAI,SCARR              (BNL)
DIEBOLD  72 BATAV.CONF. V.3 17R.DIEBOLD  RAPPORTEUR TALK               (ANL)
ENGELMAN 72 PR D 5 2162         ENGELMANN,MUSGRAVE,FORMAN,+        (ANL+EFI)
FIRESTON 72 PR D 5 2188         +GOLDHABER, LISSAUER, TRILLING         (LBL)PWA
FRATI    72 PR D 6 2361         +HALPERN,HARGIS,SNAPE,CARNAHAN,+(PENN+CINC)
MATISON  72 LBL 1537 (THESIS) REVISED VERSION WILL GO TO PHYS.REV.   LBL
ROUGE    72 NP B 46 29          +VIDEAU,VOLTE,DE BRION,+          (EPOL+SACL)

CORDS    73 NP B 54 109         +CARMONY,LANDER,MEIERE,+    (PURD+UCD+IUPU)
GALTIERI 73  LBL 1772           +MATISON,GARNJOST,FLATTE,FRIEDMAN+     (LBL)
LINGLIN  73 NP B 55 408         D.LINGLIN                             (CERN)
YUTA     73 NP B 52 70          +ENGELMANN,MUSGRAVE,FORMAN,+       (ANL+EFI)

FOX      74 NP B80 403          G.C.FOX,M.L.GRISS                      (CIT)
MATISON  74 PR D9 1872          +GALTIERI,GARNJOST,FLATTE,FRIEDMAN,+  (LBL)
MORGAN   74 PL 51B 71           D.MORGAN                              (RHEL)

BAKER    75 NP B99 211          +BANERJEE,CAMPBELL,ALLEN,MARCH+ (LOIC+LOWC)
LAUSCHER 75 NP B86 189          +OTTER,WIECZOREK,+   (ABCLV COLLABORATION)
MORGAN   75 ARGONNE CONF. 45  D.MORGAN                              (RHEL)

CHIEN    76 NP B 106 355        +FEIOCK,LUCAS,PEVSNER,ZOANIS   (BALTIMORE)

BOWLER   77 NP B 126  31        +DAINTON,DRAKE,WILLIAMS             (OXFORD)
SPIRO    77 NP B 125 162        +BARLOUTAUD,COMBER,PALER,+ (SACL+RHEL-EPOL)

BALDI    78 NP B 134 365        +BOHRINGER,DORSAZ,HUNGERBUHLER+       (GEVA)
ENGELEN  78 NP B 134 14         +JONGEJANS,HEMINGWAY,+ (NIJM+ZEEM+CERN+OXF)
ESTABROO 78 NP B 133 490        ESTABROOKS,CARNEGIE,+ (MONT+CARL+DURH+SLAC)
MARTIN   78 NP B 134 392        +SHIMADA,BALDI,BOHRINGER,DORSAZ+(DURH+GEVA)

ESTABROO 79 PR D 19 2678        P.ESTABROOKS                          (CARL)
LANG     79 PR D 19 956         C.B.LANG,A.MAS-PARAREDA               (GRAZ)

ASTON    81 PL 106 B 235        +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA)JP
TOAFF    81 PR D 23 1500        +MUSGRAVE,AMMAR,DAVIS,ECKLUND,+  (ANL+KANS)

TORNQVIS 82 PRL 49 624          N.A.TORNQVIST                         (HELS)

BAUBILLI 84 ZPHY C 26 37        BAUBILLIER+       (BIRM+CERN+GLAS+MICH+LPNP)
```

$K_1(1400)$ was $Q(1400)$

$I(J^P) = \frac{1}{2}(1^+)$

$K_1(1400)$ MASS (MeV)

```
M          (1420.)                    DAVIS     72 HBC  +  12. K- P
M          (1368.)    (18.)           FIRESTONE 72 DBC  +  12. K- D
M          (1400.)   APPROX.          BRANDENB  76 ASPK +- 13 K+-P,(KPIPI)P
M    E     (1404.0)   (10.0)          CARNEGIE  77 ASPK +- 13 K+-P,P KPIPI
M          (1400.0)  APPROX.          VERGEEST  79 HBC  +- 4.2 K-P,K PI PI
M           1415.      15.            ETKIN     80 MPS   0 6 K-P,K0 PI+ PI-
M           1410.      25.            DAUM      81 CNTR -  63 K-P,K 2PI P
M           1392.      18.            BAUBILLIE 82 HBC   0 8.25 K-P,KS 2PIN
M    T     (1350.)   APPROX           TORNQVIST 82 RVUE
M           . . . . . . . . . .
M    AVG    1406.3     10.5     AVERAGE

M    E   FROM A MODEL DEPENDENT FIT WITH GAUSSIAN BACKGROUND TO
M    E   BRANDENBURG 76 DATA.
M    T   FROM A UNITARIZED QUARK MODEL CALCULATION
```

$K_1(1400)$ WIDTH (MeV)

```
W           (80.)                     DAVIS     72 HBC  +  12. K+ P
W          (241.)     (30.)           FIRESTONE 72 DBC  +  12. K+ D
W          (160.)    APPROX.          BRANDENB  76 ASPK +- 13 K+-P,(KPIPI)P
W    E     (142.0)    (16.0)          CARNEGIE  77 ASPK +- 13 K+-P,P KPIPI
W          (200.0)   APPROX.          VERGEEST  79 HBC  +- 4.2 K-P,K PI PI
W           180.       10.            ETKIN     80 MPS   0 6 K-P,K0 PI+ PI-
W           195.       25.            DAUM      81 CNTR -  63 K-P,K 2PI P
W           276.       65.            BAUBILLIE 82 HBC   0 8.25 K-P,KS 2PIN
W           . . . . . . . . . .
W    AVG    183.9       9.2     AVERAGE

W    E   SEE NOTE E ABOVE.
```

$K_1(1400)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_1(1400) \to K^*(892)\ \pi$	892+ 140
P2	$K_1(1400) \to K\rho$	498+ 769
P3	$K_1(1400) \to K\pi$	498+ 140
P4	$K_1(1400) \to K\eta$	498+ 549
P5	$K_1(1400) \to K\omega$	498+ 783
P6	$K_1(1400) \to K\pi\pi$	498+ 140+ 140
P7	$K_1(1400) \to K_0^*(1350)\ \pi$	1350+ 140
P8	$K_1(1400) \to K f_0(1300)$	498+1300

$K_1(1400)$ PARTIAL WIDTHS (MeV)

$K_1(1400) \to K^*(892)\ \pi$ (G1)

```
W1            117.0      10.0         CARNEGIE1 77 ASPK +- 13 K+-P,(KPIPI)P
```

$K_1(1400) \to K\rho$ (G2)

```
W2              2.0       1.0         CARNEGIE1 77 ASPK +- 13 K+-P,(KPIPI)P
```

$K_1(1400) \to K\omega$ (G5)

```
W5             23.0      12.0         CARNEGIE1 77 ASPK +- 13 K+-P,(KPIPI)P
```

$K_1(1400)$ BRANCHING RATIOS

$K_1(1400) \to (K^*(892)\ \pi)$/total (P1)

```
R1 F           0.94      0.06         DAUM      81 CNTR    63 K-P,K 2PI P
```

$K_1(1400) \to (K\rho)$/total (P2)

```
R2 F           0.03      0.03         DAUM      81 CNTR    63 K-P,K 2PI P
```

$K_1(1400) \to (K\omega)$/total (P5)

```
R3 F           0.01      0.01         DAUM      81 CNTR    63 K-P,K 2PI P
```

$K_1(1400) \to (K_0^*(1350)\ \pi)$/total

```
                                                         (P7)
R4 F          (0.00) APPROX.          DAUM     81 CNTR   63 K-P,K 2PI P
```

$K_1(1400) \to (K\ f_0(1300)\ \pi)$/total

```
                                                         (P8)
R5 F           0.02     0.02          DAUM     81 CNTR   63 K-P,K 2PI P
```

D-wave/S-wave RATIO FOR $K_1(1400) \to K^*(892)\ \pi$

```
R9 F           0.04     0.01          DAUM     81 CNTR   63 K-P,K 2PI P

R  F    AVERAGE FROM LOW AND HIGH T DATA.
```

REFERENCES FOR $K_1(1400)$

```
ARMENTER 64 DUBNA CONF 1 577  ARMENTEROS,EDWARDS,D-ANDLAU +   (CERN+CDEF)
    ALSO 64 DUBNA CONF 1 617  R ARMENTEROS (RAPPORTEUR)
ARMENTER 64 PL 9 207          ARMENTEROS,EDWARDS,D-ANDLAU,+   (CERN+CDEF)
    ALSO 66 PR  145  1095     BARASH,KIRSCH,MILLER,TAN         (COLUMBIA)

ALMEIDA  65 PL 16 184         ALMEIDA,ATHERTON,BYER,DORNAN,FORSON+ (CAVE)

SHEN     66 PRL  17  726      +BUTTERWORTH,FU,GOLDHABERS,TRILLING   (LRL)
    ALSO 66  PRIVATE COMM.   GERSON GOLDHABER                       (LRL)

BASSOMPI 67 PL 26B 30         BASSOMPIERRE,GOLDSCHMIDT+  (CERN+BRUX+BIRM)IJP
BERLINGH 67 PRL 18 1087       BERLINGHIERI+FARBER+FERBEL+FORMAN    (ROCH)IJP
CRENNELL 67 PRL 19  44        +KALBFLEISCH,LAI,SCARR,SCHUMANN       (BNL)I
DE BAERE 67 NC 49A 374        +DEBAISIEUX+FAST+FILIPPAS+       (CERN+BRUX)
    ALSO PRIVATE COMMUNICATION BY B. JONGEJANS
GOLDHABE 67 PRL 19 976        G.GOLDHABER                           (LBL)

BARTSCH  68 NP B8 9           +COCCONI,+        (AACH+BERL+CERN+LOIC+VIEN)
BOMSE    68 PRL 20 1519       +BORENSTEIN,CALLAHAN,COLE,COX,+  (JOHNHOPK)  1+
DENEGRI  68 PRL 20 1194       +CALLAHAN+ETTLINGER+GILLESPIE+   (JOHNHOPK)  1+

ALEXANDE 69 NP B 13 503       G.ALEXANDER,FIRESTONE,GOLDHABER,+     (LRL)
ANDREWS  69 PRL 22 731        +LACH,LUDLAM,SANDWEISS,BERGER,+  (YALE+LRL)
ASTIER   69 NP B 10 65        +MARECHAL,MONTANET,+  (CDEF+CERN+IPNP+LIVP)IJP
BARBARO  69 PRL 22 1207       BARBARO-GALTIERI,DAVIS,FLATTE,+       (LRL)
BETTINI  69 NC 62 A 1038      +CRESTI,LIMENTANI,BERTAUZA,BIGI+(PADO+PISA)I
BISHOP   69 NP B 9 403        +GOSHAW,ERWIN,WALKER                 (WISC)
CHIEN    69 PL 29B 433        +MALAMUD,MELLEMA,RUDNICK,SCHLEIN+    (UCLA)
CHUNG    69 PR 182 1443       +EISNER+BALI+LUERS                    (BNL)
COLLEY   69 NC A 59 519       +EASTWOOD,+  (BIRM+GLAS+LOIC+MPIM+OXF+RHEL)
ERWIN    69 NP B 9 364        +WALKER,GOSHAW,WEINBERG    (WISC+PRIN+VAND)
FRIEDMAN 69  UCRL-18860       J.FRIEDMAN,PH.D. THESIS               (LRL)
WERNER   69 PR 188 2023       +AMMAR,DAVIS,KROPAC,YARGER,CHO,+ (NWES+ANL) 1+

ABRAMS   70 PR D 1 2433       +EISENSTEIN,KIM,MARSHALL,O-HALLORAN,+ (ILL)
ANTICH   70 NP B 20 201       +CARSON,CHIEN,COX,DENEGRI,ETTLINGER,+ (JHU)  1+
BOWLER   70 PL 31 B 318       M.G.BOWLER                         (OXFORD)
FARBER   70 PR D 1 78         +FERBEL,SLATTERY,YUTA                (ROCH)  1+

BARNHAM  71 NP B25 49         +COLLEY,GRIFFITHS,ALPER, +  (BIRM+GLAS+OXF)
DENEGRI  71 NP B 28 13        +ANTICH,CALLAHAN,CARSON,CHIEN,COX,+   (JHU)  1+
FORMAN   71 PR D 3 2610       +GELFAND,LEARY,MOSER,SEIDL,WOLFSON    (EFI)
GARFINKE 71 PRL 26 1505       GARFINKEL,HOLLAND,CARMONY,LANDER+(PURD+UCD)  1+

ANDERSON 72 PR D 6 1823       +FRANKLIN,GODDEN,KOPELMAN,LIBBY,TAN  (COLO)
BINGHAM  72 NP B 48 589       +EISENSTEIN,GRARD,HERQUET,+      (CERN+BRUX)
BRANDENB 72 NP B 45 397       BRANDENBURG,BRODY,JOHNSON,LEITH,LOOS+(SLAC)
BRANDENB 72 PRL 28 932        BRANDENBURG,JOHNSON,LEITH,LOOS,LUSTE+(SLAC)
CRENNELL 72 PR D 6 1220       +GORDON,KWAN-WU LAI,SCARR             (BNL)
DAVIS    72 PR D 5 2688       +ALSTON,BARBARO,FLATTE,FRIEDMAN,LYNCH+(LBL)
FIRESTON 72 PR D 5 505        FIRESTONE,GOLDHABER,LISSAUER,TRILLING (LBL)
FIRESTON172 NP B 47 348       A.FIRESTONE                           (CIT)
FRATI    72 PR D 6 2361       +HALPERN,HARGIS,SNAPE,CARNAHAN,+(PENN+CINC)
HAATUFT  72 NP B 48 78        +ARNOLD,HAGUENAUER,+  (BERG+STRB+EPOL+MADR)

BARLOUTA 73 NP B 59 374       +DREVILLON,SHAH,+          (SACL+EPOL+RHEL)  JP
BINGHAM  73 NP B 52 31        +FARWEL,+       (LBL+ORSAY+BNL+SACLAY+MILAN)  JP
DE JONGH 73 NP B 58 110       +CORNET,CHARRIERE,+   (BRUX+MONS+CERN+MPIM)
JONES    73 NP B 52 383       G.T.JONES                            (CERN)  JP
LEWIS    73 NP B 60 283       +ALLEN,JACOBS,DANYSZ,BORG,+(LOWC+LOIC+CDEF)
WERNER   73 PR D 7 1275       +SLATTERY,FERBEL                (ROCHESTER)

ANGELOPO 74 NC 20A 49         ANGELOPOULOS,FILIPPAS+(ATHU+ATEN+LIVP+VIEN)  JP
BOWLER   74 NP B74 493        +DAINTON,KADDOURA,AITCHISON           (OXF)
DAVIDSON 74 PR D9 77          +CHAPMAN,GREEN,LYS,ROE               (MICH)
DEUTSCHM 74 PL 49B 388        DEUTSCHMANN,+    (AACH+BERL+CERN+LOIC+VIEN)  JP

ANTIPOV  75 NP B86 381        +ASCOLI,BUSNELLO,KIENZLE+    (SERP+CERN+ILL)  JP
BOWLER   75 NP B97 227        +GAME,AITCHISON,DAINTON          (OXF+DARE)
DORE     75 LNC 13 265        +GUIDONI,LAAKSO,MARINI,CONFORTO+(ROMA+RHEL)
DREVILLO 75 PL 55 B 245       DREVILLON,BORENSTEIN+      (EPOL+BOHR+CDEF)  JP
DUNWOODI 75 NP B91 189        DUNWOODIE,GRANT+      (CERN+BELG+MONS+MPIM)  JP
OTTER1   75 NP B84 333        + (AACH+BERL+CERN+LOIC+VIEN+ATHU+ATEN+LIVP)  JP
OTTER2   75 NP B93 365        +RUDOLPH,RUMPF+  (AACH+BERL+CERN+LOIC+VIEN)  JP
OTTER3   75 NP B96 29         +RUDOLPH,SEYFERT+(AACH+BERL+CERN+LOIC+VIEN)I,JP
TOVEY    75 NP B95 109        +HANSEN,BORENSTEIN,BORG+   (RHEL+EPOL+SACL)I,JP

BASDEVAN 76 PRL 37 977        BASDEVANT,BERGER                 (FNAL+ANL)
BOAL     76 PR D 14 2998      +EDWARDS,KAMAL,TORGESON           (ALBERTA)
BOWLER   76 JPG 3 775         M.G.BOWLER                         (OXFORD)
BRANDENB 76 PRL 26 703        BRANDENBURG,CARNEGIE,CASHMORE,DAVIER+(SLAC)  JP
OTTER    76 NP B 106 77       + (AACH+BERL+CERN+LOIC+VIEN+LPNP+RHEL+SACL)  JP
VERGEEST 76 PL 62 B 471       +ENGELEN,JONGEJANS,+   (AMST+CERN+NIJM+OXF)  JP

CARNEGIE 77 NP B 127 509      +CASHMORE,DAVIER,DUNWOODIE,LASINSKI+ (SLAC)
CARNEGIE177 PL B 68 287       +CASHMORE,DUNWOODIE,LASINSKI,+       (SLAC)

BEUSCH   78 PL 74 B 282       +BIRMAN,KONIGS,OTTER,+       (CERN+AACH+ETH)  JP
GAVILLET 78 PL 76 B 517       +DIAZ,DIONISI,+        (AMST+CERN+NIJM+OXF)  JP
WOHL     78 NP B 132 401      +PALER,CHAURAND,+       (LPNP+RHEL+SACLAY)

BASDEVAN 79 PR D 19 246       BASDEVANT,BERGER                      (ANL)
MAZZUCAT 79 NP B 156 532      MAZZUCATO,PENNINGTON+  (CERN+ZEEM+NIJM+OXF)
VERGEEST 79 NP B 158 265      +JONGEJANS,DIONISI,+   (NIJM+AMST+CERN+OXF)

BACON    80 NP B 162 189      +BARREY,BUTTERWORTH,ANSORGE,+   (LOIC+CAVE)
DIONISI  80 NP B 169 1        +GAVILLET,ARMENTEROS+ (CERN+MADR+CDEF+STOH)
ETKIN    80 PR D 22 42        +FOLEY,LINDENBAUM,KRAMER,+       (BNL+CUNY)  JP
IRVING   80 JPG 6 153         A.C.IRVING                           (LIVP)
RADFORD  80 NP B 167 181      RADFORD,BRANDENBURG                   (MIT)

DAUM     81 NP B 187 1        +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
OTTER    81 NP B 181 1          (AACH+BERL+LOIC+VIEN+BIRM+BELG+CERN+MONS)
RODEBACK 81 ZPHY C 9 9        +SJOGREN,ARMENTEROS,+ (CERN+CDEF+MADR+STOH)

BAUBILLI 82 NP B 202 21       BAUBILLIER+        (BIRM+CERN+GLAS+MSU+LPNP)
FERNANDE 82 ZPHY C 16 95      FERNANDEZ,AGUILAR+     (MADR+CERN+CDEF+STOH)
TORNQVIS 82 NP B 203 268      TORNQVIST                            (HELS)
```

$K^*(1410)$

$I(J^P) = \frac{1}{2}(1^-)$

OMITTED FROM SUMMARY TABLE

```
SEEN IN PARTIAL WAVE ANALYSIS OF THE K0 PI+ PI-
SYSTEM.
```

$K^*(1410)$ MASS (MeV)

```
M          1500.     30.             ETKIN     80 MPS   0 6K-P,K0 PI+ PI-
M          1474.     25.             BAUBILLIE 82 HBC   0 8.25K-P,KS 2PI N
M  D       1412.0     9.2            ASTON     84 LASS  0 11K-P,K0 2PI N     |
M          . . . . . . . . . .
M   AVG    1425.6    20.4      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.5)

M  D    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$K^*(1410)$ WIDTH (MeV)

```
W           500.    100.             ETKIN     80 MPS   0 6K-P,K0 PI+ PI-
W           275.     65.             BAUBILLIE 82 HBC   0 8.25K-P,KS 2PI N
W  D        196.0    22.0            ASTON     84 LASS  0 11K-P,K0 2PI N     |
W           . . . . . . . . . .
W   AVG     216.4    45.0      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.2)

W  D    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$K^*(1410)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K^*(1410) \to K\pi$	494+ 140
P2	$K^*(1410) \to K^*(892)\ \pi$	892+ 140
P3	$K^*(1410) \to K\rho$	494+ 769

$K^*(1410)$ BRANCHING RATIOS

$K^*(1410) \to (K\ \rho)/(K^*(892)\ \pi)$

```
                                                              (P3)/(P2)
R1          (0.17) OR LESS  CL=.95   ASTON     84 LASS  0 11 K-P,K0 2PI N   |
```

$K^*(1410) \to (K\ \pi)/(K^*(892)\ \pi)$

```
                                                              (P1)/(P2)
R2          (0.16) OR LESS  CL=.95   ASTON     84 LASS  0 11 K-P,K0 2PI N   |
```

REFERENCES FOR $K^*(1410)$

```
ETKIN    80 PR D 22 42        +FOLEY,LINDENBAUM,KRAMER,+       (BNL+CUNY)JP
BAUBILLI 82 NP B 202 21       BAUBILLIER+       (BIRM+CERN+GLAS+MSU+LPNP)
ASTON    84 PL 149 B 258      +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA)JP
```

$K_2^*(1430)$
was $K^*(1430)$

$I(J^P) = \frac{1}{2}(2^-)$

```
WE CONSIDER THAT PHASE-SHIFT ANALYSES PROVIDE
MORE RELIABLE DETERMINATIONS OF THE MASS AND
WIDTH.
```

$K_2^*(1430)$ MASS (MeV)

```
M1  CHARGED ONLY, WITH FINAL STATE K PI
M1    D  39 1423.       11.0           BASSANO   67 HBC   - 4.6-5.0K-P,K0PI-
M1    D  63 1427.0      12.0           SCHWEINGR 68 HBC   -  5.5 K- P (K PI)
M1      220 1416.0      10.0           CRENNELL  69 DBC   -  3.9 K-N (K0PI-)
M1    D  60 1414.       13.0           LIND      69 HBC   +  9. K+ P(K0 PI+)
M1     1400 1420.0       3.1           AGUILAR1  71 HBC   -  3.9,4.6 K- P
M1 W D 225 1425.         8.0           BARNHAM   71 HBC   + K+ P,K0 PI+ P
M1    B     1428.0       4.6           MARTIN    78 SPEC + 10 K+-P,KS PI P H
M1    B     1423.8       4.6           MARTIN    78 SPEC - 10 K+-P,KS PI P H
M1    D 579(1448.5)     (5.0)          DELFOSSE  81 SPEC +  K+-P,K+- PI0 P
M1    D 292(1431.8)     (5.6)          DELFOSSE  81 SPEC -  K+-P,K+- PI0 P
M1      935 1423.0       5.0           TOAFF     81 HBC   - 6.5 K-P,K0 PI- P
M1 W D 400 1436.         5.5           CLELAND   82 SPEC +  30 K+P,KS PI+P
M1 W D1500 1430.         3.2           CLELAND   82 SPEC +  50 K+P,KS PI+P
M1 W D1200 1430.         3.2           CLELAND   82 SPEC  - 50 K+P,KS PI-P
M1     1587 1420.        4.            BAUBILLIE 84 HBC   -  8.25 K-P,K0PI-P    |
M1          . . . . . . . . . .
M1  AVG     1425.6       1.5     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)

M4  NEUTRAL ONLY
M4     2200 1421.1       2.6           DAVIS     69 HBC    0 12. K+ P(K+PI-)
M4     1800 1419.1       3.7           AGUILAR1  71 HBC    0 3.9,4.6 K- P
M4      600 1416.        6.            CORDS     71 DBC   D 9. K+ N,K+ PI- P
M4     1100 1427.        3.            BUCHNER   72 DBC   0 4.6 K+ N,K+ PI-P
M4   C      1420.1       4.3           LINGLIN   73 HBC   0 2-13 K+P,K+PI-
M4      800 1421.6       4.2           MCCUBBIN  75 HBC    0 3.6 K-P,K-PI+N
M4  E      (1423.0)     (3.0)          ETKIN     76 SPEC   06.K-P,K0 PI+PI-
M4      300 1420.0       7.0           HENDRICKX 76 DBC     8.25 K+N,K+PI
M4 P        1440.0      10.0           BOWLER    77 DBC   0 5.5 K+D,K PI P P
M4  P      (1434.0)     (2.0)          ESTABROOK 78 ASPK  0 13K+-P,P K PI
M4          1450.       30.            ETKIN     80 SPEC  0 6.K-P,K0 PI+PI-N
M4          1428.        3.            ASTON     81 LASS  0 11 K-P,K- PI+ N
M4  P      (1471.)     (12.)           BAUBILLIE 82 HBC   0 8.25 K-P,KS 2PIN
M4 F        1433.       12.            ASTON     84 LASS  0 11 K-P,K0 2PI N     |
M4          . . . . . . . . . .
M4  AVG     1423.3       1.5     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

```
M    B   SYSTEMATIC ERROR ADDED BY US.
M     C  FROM POLE EXTRAPOLATION, USING WORLD K+P DST
M     D  ERRORS ENLARGED BY US TO   GAMMA/SQRT(N). SEE TYPED NOTE ON K*(892)
M   E    SEE MORE RECENT PARTIAL WAVE ANALYSIS (ETKIN 80)
M  P     FROM PHASE SHIFT OR PARTIAL WAVE ANALYSIS.
M  W     NUMBER OF EVENTS IN PEAK REEAVALUATED BY US
M  F     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$K_2^*(1430)$ WIDTH (MeV)

```
W1  CHARGED ONLY, WITH FINAL STATE K PI
W1     1400   94.7      15.1     12.5    AGUILAR1   71 HBC   -  3.9,4.6 K- P
W1            96.5       3.8             MARTIN     78 SPEC +  10 K+-P,KS PI P
W1            97.7       4.0             MARTIN     78 SPEC -  10 K+-P,KS PI P
W1    D 579  118.9      20.0             DELFOSSE   81 SPEC +  K+-P,K+- PI0 P
W1    D 292   96.0      22.5             DELFOSSE   81 SPEC -  K+-P,K+- PI0 P
W1      935   85.0      16.0             TOAFF      81 HBC  -  6.5 K-P,K0 PI- P
W1 W D 400   109.       22.              CLELAND    82 SPEC +  30 K+P,KS PI+P
W1 W D1500   124.       12.8             CLELAND    82 SPEC +  50 K+P,KS PI+P
W1 W D1200   113.       12.8             CLELAND    82 SPEC  - 50 K+P,KS PI-P
W1     1587  102.       10.              BAUBILLIE  84 HBC  -  8.25 K-P,K0PI-P    |
W1           . . . . . . . . . . .
W1  AVG       99.0       2.4     AVERAGE

W4  NEUTRAL ONLY
W4     2200  101.       10.              DAVIS      69 HBC    0 12. K+ P (K PI)
W4     1800  116.6      10.3     15.5    AGUILAR1   71 HBC    0 3.9,4.6 K- P
W4    D1100  109.       14.0             BUCHNER    72 DBC   0 4.6 K+ N,K+ PI-P
W4  C        (61.0)    (14.0)            LINGLIN    73 HBC   0 2-13 K+P,K+PI-
W4      800  116.       18.              MCCUBBIN   75 HBC    0 3.6 K-P,K-PI+N
W4 P        (170.0)    (20.0)            BOWLER     77 DBC   0 5.5 K+D,K PI P P
W4  P        (98.0)     (5.0)            ESTABROOK  78 ASPK  0 13K+-P,P K PI
W4 P         140.       30.              ETKIN      80 SPEC  0 6.K-P,K0 PI+PI-N
W4            98.        8.              ASTON      81 LASS  0 11 K-P,K- PI+ N
W4  P       (143.)     (34.)             BAUBILLIE  82 HBC   0 8.25 K-P,KS 2PIN
W4 F         131.       31.              ASTON      84 LASS  0 11 K-P,K0 2PI N    |
W4           . . . . . . . . . . .
W4  AVG      106.0       4.9     AVERAGE

W    C   FROM POLE EXTRAPOLATION, USING WORLD K+P DST
W     D  ERRORS ENLARGED BY US TO 4*GAMMA/SQRT(N). SEE K*(892) TYPED NOTE.
W  P     FROM PHASE SHIFT OR PARTIAL WAVE ANALYSIS.
W  W     NUMBER OF EVENTS IN PEAK REEAVALUATED BY US
W  F     SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$K_2^*(1430)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_2^*(1430) \to K\pi$	494+ 140
P2	$K_2^*(1430) \to K^*(892)\ \pi$	892+ 140
P3	$K_2^*(1430) \to K\rho$	494+ 769
P4	$K_2^*(1430) \to K\omega$	494+ 783
P5	$K_2^*(1430) \to K\eta$	494+ 549
P6	$K_2^*(1430) \to K^*(892)\ \pi\pi$	892+ 140+ 140
P7	$K_2^*(1430) \to K\omega\pi$	494+ 783+ 140
P8	$K_2^*(1430) \to K\gamma$	494+ 0

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{(\delta P_i \delta P_i)}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1          P 2         P 3         P 4         P 5         P 6
 P 1 .4490+-.0266
 P 2    .1249   .2356+-.0177
 P 3    .0359       .5676   .0862+-.0081
 P 4   -.2093      -.2008      -.1486  .0431+-.0155
 P 5   -.4935      -.4172      -.3104     -.0918  .0517+-.0286
 P 6   -.4366      -.3951      -.2959     -.0955     -.1533  .1345+-.0269
```

$K_2^*(1430)$ PARTIAL WIDTHS (keV)

$K_2^*(1430) \to K\gamma$ (G8)

```
W8          240.      45.                CIHANGIR  82 SPEC +  200 PI+Z,Z A2
```

$K_2^*(1430)$ BRANCHING RATIOS

$K_2^*(1430) \to (K\pi)/\text{total}$ (P1)

```
R1 P            0.49      0.02           ESTABROOK 78 ASPK +-  13K+-P,P K PI
R1 P            0.43      0.01           ASTON     81 LASS  0 11 K-P,K- PI+ N
R1 P    FROM PHASE SHIFTS ANALYSIS.
R1             . . . . . . . . . . .
R1  AVG         0.442     0.024   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.7)
R1  FIT         0.449     0.027  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 3.2)
```

$K_2^*(1430) \to (K^*(892)\ \pi)/(K\pi\ +\ K\pi\pi)$ (P2)/(P1+P2+P3)

```
R2  QR         (0.45)    (0.13)          BADIER    65 HBC   -  3.0 K-P
R2  Q          (0.47)    (0.10)          BASSANO   67 HBC   -0 4.6, 5.0 K- P
```

$K_2^*(1430) \to (K\rho)/(K\pi\ +\ K\pi\pi)$ (P3)/(P1+P2+P3)

```
R3  QR         (0.14)    (0.07)          BADIER    65 HBC   -  3.0 K-P
R3  Q          (0.14)    (0.10)          BASSANO   67 HBC   -0 4.6, 5.0 K- P
```

$K_2^*(1430) \to (K^*(892)\ \pi)/(K\pi)$ (P2)/(P1)

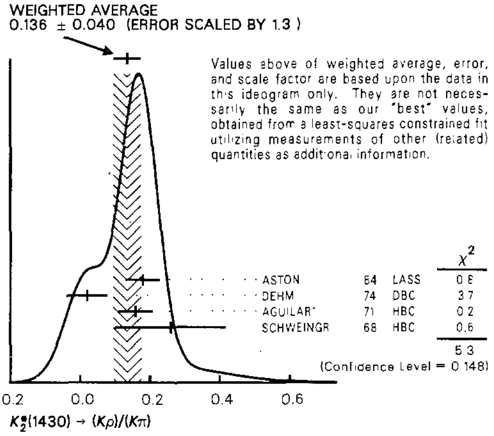
```
R4              0.65      0.20           SHEN      66 HBC    0  N* PRODUCED
R4  Q          (0.63)    (0.20)          SHEN      66 HBC  +    NO N* PRODUCED
R4              0.52      0.12           SCHWEINGR 68 HBC    0 4.1+5.5 K- P
R4  Q   84     (0.93)    (0.11)          BISHOP    69 HBC       3.5 K+ P
R4              0.47      0.08           AGUILAR1  71 HBC       3.9,4.6 K- P
R4 AQ  150     (0.65)    (0.25)          ANTIPOV   75 ASPK  - 40 K-P,K*- P
R4              0.54      0.16           DEHM      74 DBC   0 4.6 K+ N
R4              0.62      0.19           LAUSCHER  75 HBC    010,16 K-P,K-PI+N
R4              0.44      0.09           ASTON     84 LASS  0 11 K-P,K0 2PI N    |
R4 A    K*(892) PI SIGNAL FROM PARTIAL WAVE ANALYSIS OF (K-PI+PI-) SYSTEM
R4             . . . . . . . . . . .
R4  AVG         0.495     0.048   AVERAGE
R4  FIT         0.525     0.047  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$K_2^*(1430) \to (K\omega)/(K\pi)$ (P4)/(P1)

```
R5   R          0.19      0.16           BADIER    65 HBC   -  3.0 K-P
R5             (0.08) OR LESS            SHEN      66 HBC      4.6 K+P
R5             (0.2)  OR LESS            BASSOMPIE 69 HBC  +   5 K+ P
R5              0.13      0.07           BASSOMPIE 69 HBC    0 5 K+ P
R5              0.05      0.04           AGUILAR1  71 HBC       3.9-4.6 K- P
R5             (0.2)  OR LESS  CL=.95    CHUNG     74 HBC   - 7.3 K-P,K*- P
R5             . . . . . . . . . . .
R5  AVG         0.075     0.034   AVERAGE
R5  FIT         0.096     0.036  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$K_2^*(1430) \to (K\rho)/(K\pi)$ (P3)/(P1)

```
R6             (0.09) OR LESS            CHUNG     65 HBC  + 0  3.9-4.2 PI- P
R6              0.26      0.16           SCHWEINGR 68 HBC    0 4.1+5.5 K- P
R6             (0.2)  OR LESS            BASSOMPIE 69 HBC  +   5 K+ P
R6             (0.3)  OR LESS            BASSOMPIE 69 HBC    0 5 K+ P
R6  Q   15     (0.11)    (0.06)          BISHOP    69 HBC       3.5 K+ P
R6              0.16      0.05           AGUILAR1  71 HBC       3.9,4.6 K- P
R6              0.02      0.10     0.02  DEHM      74 DBC   0 4.6 K+ N
R6              0.18      0.05           ASTON     84 LASS  0 11 K-P,K0 2PI N    |
R6             . . . . . . . . . . .
R6  AVG         0.136     0.040   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
R6  FIT         0.192     0.021  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
                          (SEE IDEOGRAM BELOW)
R6  S   USES RESULTS OF OTTER 75 (SEE R7 BELOW). WE DO NOT AVERAGE THIS
R6  S   STATISTICALLY REDUNDANT RATIO, BUT KEEP THE LAUSCHER 75 RESULT
R6  S   FOR R4 ABOVE.
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$K_2^*(1430) \to (K\rho)/(K^*(892)\ \pi)$ (P3)/(P2)

```
R7             (0.39) OR LESS            BASSOMPIE 67 HBC  +    5. K+ P
R7             (0.40) OR LESS  CL=.90    FIELD     67 HBC   - 3.8 K- P
R7 P   130      0.13      0.09           OTTER     75 HBC    08,10,16 K-P,K* N
R7 AN          (0.03)    (0.03)          ANTIPOV   75 ASPK  - 40 K-P,K*- P
R7 P            0.36      0.10           VERGEEST  76 HBC   0 4.2 K-P,P K0PIPI
R7 P           (0.33) APPROX.            ETKIN     80 SPEC  0 6.K-P,K0 PI+PI-N
R7              0.39      0.03           DAUM      81 CNTR     63 K-P,K 2PI P
R7              0.38      0.09           BAUBILLIE 82 HBC   0 8.25 K-P,KS 2PIN
R7             (0.20)     APPROX.        FERNANDEZ 82 HBC    -4 PI-P,LAM K 2PI
R7              0.42      0.08           ASTON     84 LASS  0 11 K-P,K0 2PI N    |
R7             . . . . . . . . . . .
R7  AVG         0.370     0.035   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
R7  FIT         0.366     0.029  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
                          (SEE IDEOGRAM BELOW)
R7  N   K RHO MODE NOT OBSERVED
R7 A    FROM PARTIAL WAVE ANALYSIS OF (K-PI+PI-) SYSTEM
R7 P    FROM PARTIAL WAVE ANALYSIS OF (K0 PI+ PI-) SYSTEM
```

$K_2^*(1430) \to (K\omega)/(K^*(892)\ \pi)$ (P4)/(P2)

```
R8  Q          (0.10)    (0.04)          FIELD     67 HBC   - 3.8 K- P
```

$K_2^*(1430) \to (K\eta)/(K^*(892)\ \pi)$ (P5)/(P2)

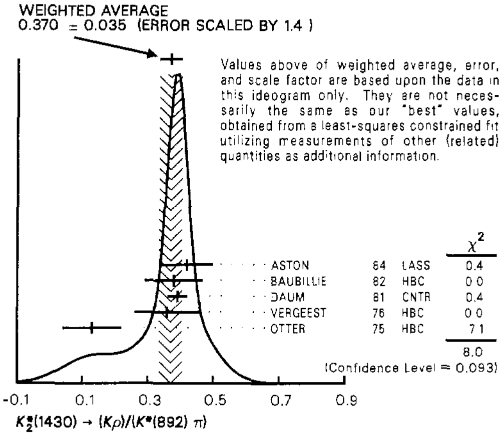
```
R9  Q          (0.07)    (0.04)          FIELD     67 HBC   - 3.8 K- P
```

$K_2^*(1430) \to (K\eta)/(K\pi)$ (P5)/(P1)

```
R10  R          0.05      0.06           BADIER    65 HBC   -  3.0 K-P
R10  R         (0.065)OR LESS            BASSOMPIE 69 HBC      5.0 K+P
R10            (0.02) OR LESS            BISHOP    69 HBC      3.5 K+ P
R10            (0.04) OR LESS  CL=.95    AGUILAR1  71 HBC      3.9-4.6 K- P
R10            . . . . . . . . . . .
R10 FIT         0.115     0.067  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$K_2^*(1430) \to (K^*(892)\ \pi\pi)/\text{total}$ (P6)

```
R11T            0.12      0.04           GOLDBERG  76 HBC  -  3 K-P,P K0PIPIPI
R11            . . . . . . . . . . .
R11 FIT         0.135     0.027  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1:2)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$K_2^*(1430) \to (K^*(892)\ \pi\pi)/(K\pi)$ (P6)/(P1)

```
R12T R        0.21     0.08              JONGEJANS 78 HBC  -  4K-P,P KOOPIPIPI
R12          . . . . . . . . . . .
R12 FIT       0.300    0.069  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$K_2^*(1430) \to (K\,\omega\,\pi)$/total (units 10^{-3}) (P7)

```
R13      0   (0.72) OR LESS  CL=0.95  JONGEJANS 78 HBC     4 K-P,P KO 4PI

R   Q   FOLLOWING SUGGESTION BY AGUILAR 70, WE DO NOT MAKE USE OF MEASURE-
R   Q   MENTS WHERE THE (K PI PI) BACKGROUND SUBTRACTION IS DIFFICULT DUE
R   Q   TO THE NEARBY K1(1400) REGION.
R    R  RESTATED BY US.
R  T    ASSUMING PI PI SYSTEM HAS ISOSPIN 1, WHICH IS SUPPORTED BY
R  T    THE DATA
```

REFERENCES FOR $K_2^*(1430)$

```
BADIER   65 PL 19 612          BADIER,DEMOULIN,GOLDBERG+  (EPOL+SACL+AMST)
CHUNG    65 PRL  15  325       +DAHL,HARDY,HESS,JACOBS,KIRZ,MILLER   (LRL)
FOCARDI  65 PL 16 351          FOCARDI,MINGUZZI RANZI,SERRA+(BOLOGNA+SACL)

SHEN     66 PRL  17  726       +BUTTERWORTH,FU,GOLDHABERS,TRILLING   (LRL)
    ALSO 66  PRIVATE COMM.    GERSON GOLDHABER                      (LRL)

BASSANO  67 PRL  19  968       +GOLDBERG,GOZ,BARNES,LEITNER+(BNL+SYRACUSE)
BASSOMPI 67 PL 26B 30          BASSOMPIERRE,GOLDSCHMIDT+  (CERN+BRUX+BIRM)IJP
CRENNELL 67 PRL 19  44         +KALBFLEISCH,LAI,SCARR,SCHUMANN       (BNL)
DAHL     67 PR 163 1377        +HARDY+HESS+KIRZ+MILLER               (LRL)
    ALSO 65 PRL 14 401         HARDY,CHUNG,DAHL,HESS,KIRZ,MILLER     (LRL)
DE BAERE 67 NC 51 A 401        +GOLDSCHMIDT-CLERMONT,HENRI+    (BRUX+CERN)
FIELD    67 PL 24B 638         +HENDRICKS+PICCIONI+YAGER         (LAJOLLA)
GOLDHABE 67 PRL 19  972        G.GOLDHABER,FIRESTONE,SHEN            (LRL)

ADERHOLZ 68 NP B 5  567        +DEUTSCHMANN+  (AACH+BERL+CERN+LOIC+VIENNA)
    ALSO 66 PL 22 357          BARTSCH,DEUTSCHMANN,MORRISON+   (ABCL(IC)V)
ANTICH   68 PRL 21 1842       +CALLAHAN,CARSON,COX,DENEGRI,+         (JHU)
DUBAL    68 THESIS   1456      L.DUBAL                            (GENEVE)
KANG     68 PR 176 1587        Y.W.KANG                             (IOWA)
SCHWEING 68 PR 166 1317        SCHWEINGRUBER,DERRICK,FIELDS+    (ANL+NWES)
   ALSO  67  THESIS            F.L.SCHWEINGRUBER   (NORTHWESTERN,EVANSTON)

BASSOMPI 69 NP  B13 189        BASSOMPIERE,GOLDSCHMIDT-CLERM.+ (CERN+BRUX) JP
BISHOP   69 NP B 9 403         +GOSHAW,ERWIN,WALKER                 (WISC)
CRENNELL 69 PRL 22  487        +KARSHON,LAI,ONEALL,SCARR             (BNL)
DAVIS    69 PRL 23 1071        +DERENZO,FLATTE,ALSTON,LYNCH,SOLMITZ  (LRL)
DE BAERE 69 NC 61 A 397        +GOLDSCHMIDT-CLERMONT,HENRI,+   (BELG+CERN)
FRIEDMAN 69  UCRL-18860        J.FRIEDMAN,PH.D. THESIS               (LRL)
LIND     69 NP B 14 1          +ALEXANDER,FIRESTONE,FU,GOLDHABER     (LRL) JP

ABRAMS   70 PR D 1 2433        +EISENSTEIN,KIM,MARSHALL,O.HALLORAN,+ (ILL)
AGUILAR  70 PRL 25 1362        AGUILAR-BENITEZ,BASSANO,EISNER,+ (BNL+PURD)

AGUILAR1 71 PR D 4 2583        +EISNER,KINSON                        (BNL)
BARNHAM  71 NP B 28 171        +COLLEY,JOBES,GRIFFITHS,HUGHES,+(BIRM+GLAS)
CORDS    71 PR D 4 1974        +CARMONY,ERWIN,MEIERE,+      (PURD+UCD+IUPU)

BUCHNER  72 NP B 45 333        +DEHM,CHARRIERE,CORNET,+   (MPIM+CERN+BRUX)
CRENNELL 72 PR D 6 1220        +GORDON,KWAN-WU LAI,SCARR             (BNL)
DEUTSCHM 72 NP B 36 373        DEUTSCHMANN,+           (ABCLV COLLABORATION)
ENGELMAN 72 PR D 5 2162        ENGELMANN,MUSGRAVE,FORMAN,+       (ANL+EFI)
FRATI    72 PR D 6 2361        +HALPERN,HARGIS,SNAPE,CARNAHAN,+(PENN+CINC)
ROUGE    72 NP B 46 29         +VIDEAU,VOLTE,DE BRION,+        (EPOL+SACL)
TIECKE   72 NP B 39 596        +GRIJNS,HEINEN,DE GROOT,+       (NIJM+AMST)

CHARRIER 73 NP B 51 317        CHARRIERE,DRIJARD,DE BAERE,+    (CERN+BELG)
    ALSO 75  PRIVATE COMM.     GOLDSCHMIDT-CLERMONT                 (CERN)
CLARK    73 NP B 54 432        +LYONS,RADOJICIC                   (OXFORD)
DE JONGH 73 NP B 58 110        +CORNET,CHARRIERE,+  (BRUX+MONS+CERN+MPIM)
LINGLIN  73 NP B 55 408        D.LINGLIN                            (CERN)
WALUCH   73 PR D 8 2837        +FLATTE,FRIEDMAN                      (LBL)

CHUNG    74 PL 51B 413         +EISNER,PROTOPOPESCU,SAMIOS,STRAND    (BNL)
DEHM     74 NP B75 47          +GOEBEL,WITTEK,WOLF,+ (MPIM+BRUX+MONS+CERN)

ANTIPOV  75 NP B86 381         +ASCOLI,BUSNELLO,KIENZLE+   (SERP+CERN+ILL)
LAUSCHER 75 NP B86 189         +OTTER,WIECZOREK,+    (ABCLV COLLABORATION)JP
MCCUBBIN 75 NP B86 13          N.A.MCCUBBIN,L.LYONS                  (OXF)
OTTER    75 NP B84 333         + (AACH+BERL+CERN+LOIC+VIEN+ATHU+ATEN+LIVP)

ETKIN    76 PRL 36 1482        +FOLEY,GOLDMAN,LINDENBAUM,KIM,+  (BNL+CUNY)
GOLDBERG 76 LNC 17 253         J.GOLDBERG                          (HAIFA)
HENDRICK 76 NP B 112 189       +VIGNAUD,BURLAUD,+    (MONS+SACL+LPNP+BELG)
KIRK     76 NP B 116 99        +KLEIN,COUNIHAN,+(AACH+BERL+CERN+LOIC+WIEN)
VERGEEST 76 PL 62 B 471        +ENGELEN,JONGEJANS,+   (AMST+CERN+NIJM+OXF)JP

BOWLER   77 NP B 126  31       +DAINTON,DRAKE,WILLIAMS              (OXFORD)

BALDI    78 NP B 134 365       +BOHRINGER,DORSAZ,HUNGERBUHLER+        (GEVA)
BOHM     78 PRL 41 1761        +VAN DALEN,+ (AACH,UCR+CERN+HARV+MUNI+NWES)
ENGELEN  78 NP B 134 14        +JONGEJANS,HEMINGWAY,+ (NIJM+ZEEM+CERN+OXF)
ESTABROO 78 NP B 133 490       ESTABROOKS,CARNEGIE,+ (MONT+CARL+DURH+SLAC)
    ALSO 78 PR D 17 658        ESTABROOKS,CARNEGIE+  (MONT+CARL+DURH+SLAC)
JONGEJAN 78 NP B 139 383       JONGEJANS,CERRADA,+     (ZEEM+CERN+NIJM+OXF)
MARTIN   78 NP B 134 392       +SHIMADA,BALDI,BOHRINGER,DORSAZ+(DURH+GEVA)

ETKIN    80 PR D 22 42         +FOLEY,LINDENBAUM,KRAMER,+        (BNL+CUNY)JP

ASTON    81 PL 106 B 235       +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA)JP
DAUM     81 NP B 187 1         +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
DELFOSSE 81 NP B 183 349       +GUISAN,MARTIN,MUHLEMANN,WEILL,+(GEVA+LAUS)
TOAFF    81 PR D 23 1500       +MUSGRAVE,AMMAR,DAVIS,ECKLUND,+  (ANL+KANS)

BAUBILLI 82 NP B 202 21        BAUBILLIER+        (BIRM+CERN+GLAS+MSU+LPNP)
CIHANGIR 82 PL 117 B 123       +BERG,BIEL,CHANDLEE,FERBEL+(FNAL+MINN+ROCH)
CLELAND  82 NP B 208 189       +DELFOSSE,DORSAZ,GLOOR(DURH+GEVA+LAUS+PITT)
FERNANDE 82 ZPHY C 16 95       FERNANDEZ,AGUILAR+    (MADR+CERN+CDEF+STOH)

ASTON    84 NP 247 B 261       +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA)
BAUBILLI 84 ZPHY C 26 37       BAUBILLIER+       (BIRM+CERN+GLAS+MICH+LPNP)
```

$K(1460)$ was $K(1400)$

$I(J^P) = \frac{1}{2}(0^-)$

OMITTED FROM SUMMARY TABLE

```
FORMERLY CALLED K PRIME.
OBSERVED IN K PI PI PARTIAL-WAVE ANALYSIS.
NOT SEEN BY VERGEEST 79.
WAIT CONFIRMATION.
```

$K(1460)$ MASS (MeV)

```
M  A      (1400.)   APPROX.            BRANDENBU 76 ASPK +- 13 K+-P,KPIPI
M         (1460.)   APPROX.            DAUM      81 CNTR -  63 K-P,K 2PI P

M  A      COUPLED MAINLY TO K F0(1300). DECAY INTO K*(892) PI SEEN.
M
```

$K(1460)$ WIDTH (MeV)

```
W  A       (250.)   APPROX.            BRANDENBU 76 ASPK +- 13 K+-P,KPIPI
W          (260.)   APPROX.            DAUM      81 CNTR -  63 K-P,K 2PI P

W  A      COUPLED MAINLY TO K F0(1300). DECAY INTO K*(892) PI SEEN.
```

$K(1460)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K(1460) \to K^*(892)\ \pi$	892+ 140
P2	$K(1460) \to K\rho$	494+ 769
P3	$K(1460) \to K_0^*(1350)\ \pi$	1350+ 140

$K(1460)$ PARTIAL WIDTHS (MeV)

$K(1460) \to K^*(892)\ \pi$ (G1)

```
W1         (109.)   APPROX.           DAUM       81 CNTR    63 K-P,K 2PI P
```

$K(1460) \to K\rho$ (G2)

```
W2          (34.)   APPROX.           DAUM       81 CNTR    63 K-P,K 2PI P
```

$K(1460) \to K_0^*(1350)\ \pi$ (G3)

```
W3         (117.)   APPROX.           DAUM       81 CNTR    63 K-P,K 2PI P
```

REFERENCES FOR $K(1460)$

```
BRANDENB 76 PRL 36 1239       BRANDENBURG,CARNEGIE,CASHMORE,DAVIER+(SLAC)JP

VERGEEST 79 NP B 158 265      +JONGEJANS,DIONISI,+   (NIJM+AMST+CERN+OXF)

DAUM     81 NP B 187 1        +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)

BARNES   82 PL 116 B 365      T.BARNES AND F.E.CLOSE                (RHEL)
TANIMOTO 82 PL 116 B 198      M.TANIMOTO                            (BIEL)
```

$K_2(1580)$ was $L(1580)$

$I(J^P) = \frac{1}{2}(2^-)$

OMITTED FROM SUMMARY TABLE

```
SEEN IN PARTIAL WAVE ANALYSIS OF THE K-PI+PI-
SYSTEM. (OTTER 78).
NEEDS CONFIRMATION.
```

$K_2(1580)$ MASS (MeV)

```
M        (1580.)   APPROX.           OTTER     79        -   10,14,16 K- P
```

$K_2(1580)$ WIDTH (MeV)

```
W         (110.)   APPROX.         OTTER      79       -  10,14,16 K- P
```

$K_2(1580)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_2(1580) \rightarrow K^*(892)\ \pi$	892+ 140
P2	$K_2(1580) \rightarrow K_2^*(1430)\ \pi$	1425+ 140

$K_2(1580)$ BRANCHING RATIOS

$K_2(1580) \rightarrow (K^*(892)\ \pi)$/total (P1)

```
W1        SEEN                     OTTER      79 HBC  -  10,14,16 K- P
```

$K_2(1580) \rightarrow (K_2^*(1430)\ \pi)$/total (P2)

```
W2        POSSIBLY SEEN            OTTER      79 HBC  -  10,14,16 K- P
```

REFERENCES FOR $K_2(1580)$

```
OTTER     79 NP B 147 1          +RUDOLPH,+         (AACH+BERL+CERN+LOIC+WIEN)JP
```

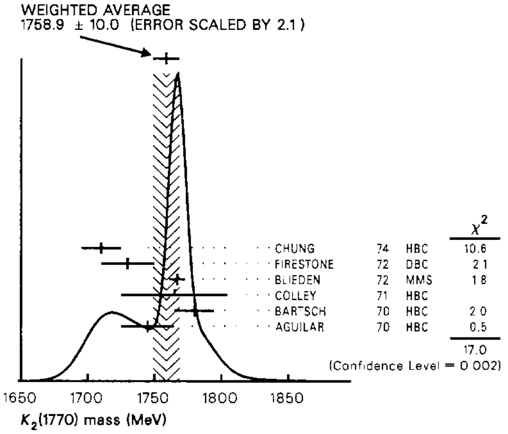
$K_2(1770)$ was $L(1770)$

$I(J^P) = \frac{1}{2}(2^-)$

OUR LATEST MINIREVIEW ON THIS PARTICLE CAN BE FOUND IN THE 1984 EDITION.

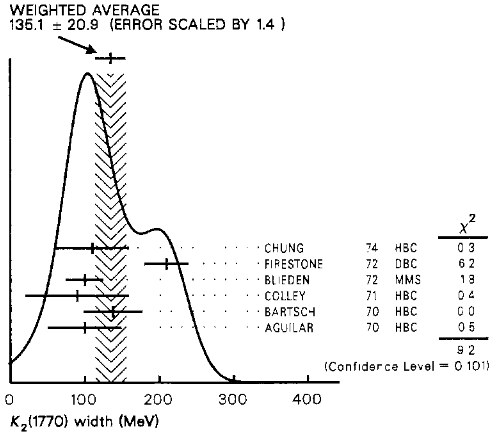
$K_2(1770)$ MASS (MeV)

```
M            1745.0     20.0                 AGUILAR   70 HBC   -  4.6 K- P
M            1780.0     15.0                 BARTSCH   70 HBC   -  10.1 K- P
M           (1760.0)   (15.0)                LUDLAM    70 HBC   -  12.6 K- P
M   X        1765.0     40.0                 COLLEY    71 HBC  + 10.K+P,K 2PI
M           (1740.0)                         DENEGRI   71 DBC   - 12.6 K-D,K 2PI D
M            1767.       6.                  BLIEDEN   72 MMS  -  11.-16. K- P
M   P    306 1730.      20.                  FIRESTONE 72 DBC  +  12. K+ D
M         60 1710.      15.                  CHUNG     74 HBC   - 7.3K-P,K-OMEGA P
M           (1820.)   APPROX.                DAUM      81 CNTR -  63 K-P,K 2PI P
M           (1730.)   APPROX.                ARMSTRONG 83 OMEG -  18.5 K-P,3K P
M            . . . . . . . . .
M    AVG     1758.9     10.0      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.1)
                           (SEE IDEOGRAM BELOW)

M   P    PRODUCED IN CONJUNCTION WITH EXCITED DEUTERON.
M   X    SYSTEMATIC ERRORS ADDED CORRESP. TO SPREAD OF DIFFERENT FITS.
```



$K_2(1770)$ WIDTH (MeV)

```
W            100.0      50.0                 AGUILAR   70 HBC   -  4.6 K- P
W            138.0      40.0                 BARTSCH   70 HBC   -  10.1 K- P
W           (50.0)     (40.0)     (20.0)     LUDLAM    70 HBC   -  12.6 K- P
W   X         90.       70.                  COLLEY    71 HBC  +  10.K+P,K 2PI
W           (130.0)                          DENEGRI   71 DBC   - 12.6 K-D,K 2PI D
W            100.       26.                  BLIEDEN   72 MMS  -  11.-16. K- P
W   P    306 210.       30.                  FIRESTONE 72 DBC  +  12. K+ D
W         60 110.       50.                  CHUNG     74 HBC   - 7.3K-P,K-OMEGA P
W           (200.)    APPROX.                DAUM      81 CNTR -  63 K-P,K 2PI P
W           (220.)    APPROX.                ARMSTRONG 83 OMEG -  18.5 K-P,3K P
W            . . . . . . . . .
W    AVG     135.1      20.9      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
                           (SEE IDEOGRAM BELOW)

W   P    PRODUCED IN CONJUNCTION WITH EXCITED DEUTERON
W   X    SYSTEMATIC ERRORS ADDED CORRESP. TO SPREAD OF DIFFERENT FITS.
```



$K_2(1770)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_2(1770) \rightarrow K\pi\pi$	498+ 135+ 135
P2	$K_2(1770) \rightarrow K_2^*(1430)\ \pi$	135+1425
P3	$K_2(1770) \rightarrow K\pi\pi\pi$	498+ 135+ 135+ 135
P4	$K_2(1770) \rightarrow K^*(892)\ \pi$	892+ 135
P5	$K_2(1770) \rightarrow K^*(892)\ \rho$	892+ 769
P6	$K_2(1770) \rightarrow K^*(892)\ \omega$	892+ 783
P7	$K_2(1770) \rightarrow K^*(892)\ \pi\pi$	892+ 135+ 135
P8	$K_2(1770) \rightarrow K\omega$	498+ 783
P9	$K_2(1770) \rightarrow K f_2(1270)$	498+1274
P10	$K_2(1770) \rightarrow K\phi$	494+1020

$K_2(1770)$ BRANCHING RATIOS

$K_2(1770) \rightarrow (K_2^*(1430)\ \pi)\ /\ (K\pi\pi)$ (P2)/(P1)

```
R1                    (K2*(1430) INTO K PI)
R1           (1.0)                           BARBARD   69 HBC  +   12.0 K+ P
R1            0.2      0.2                   AGUILAR   70 HBC   -  4.6 K- P
R1           (1.0)  OR  LESS                 BARTSCH   70 HBC   -  10.1 K- P
R1           (1.0)  OR LESS                  COLLEY    71 HBC      10. K+ P
R1   P       (1.0)  APPROX.                  FIRESTONE 72 DBC  +  12. K+ D
R1           (0.6)  APPROX.                  DAUM      81 CNTR    63 K-P,K 2PI P
R1   P   PRODUCED IN CONJUNCTION WITH EXCITED DEUTERON
R1    R  FOR DISCUSSION OF THE EXPERIMENTAL EVIDENCE ON OTHER DECAY
R1    R  MODES SEE HUGHES 71,SLATTERY 71,EISNER 74.
```

$K_2(1770) \rightarrow (K\omega)$/total (P8)

```
R2          SEEN                             CHUNG     74 HBC  -  7.3K-P,K-OMEGAP
R2          SEEN                             OTTER     81 HBC  +- 8.25,10,16 K+-P
```

$K_2(1770) \rightarrow (K^*(892)\ \pi)/(K\pi\pi)$ (P4)/(P1)

```
R3           (0.24) APPROX.                  DAUM      81 CNTR    63 K-P,K 2PI P
```

$K_2(1770) \rightarrow (K f_2(1270))/(K\pi\pi)$ (P9)/(P1)

```
R4                    (F2(1270) INTO PI PI)
R4           (0.16) APPROX.                  DAUM      81 CNTR    63 K-P,K 2PI P
```

$K_2(1770) \rightarrow (K\phi)$/total (P10)

```
R5          SEEN                             ARMSTRONG 83 OMEG -  18.5 K-P,K-PHI
```

Meson Full Listings

$K_2(1770)$, $K_3^*(1780)$

REFERENCES FOR $K_2(1770)$

BARTSCH 66 PL 22 357 +DEUTSCHMANN,+ (AACH+BERL+CERN+LOIC+VIEN)

BERLINGH 67 PRL 18 1087 BERLINGHIERI+FARBER+FERBEL+FORMAN+ (ROCH)I
CARMONY 67 PRL 18 615 D.CARMONY,T.HENDRICKS,L.LANDER (LA JOLLA)
JOBES 67 PL 26B 49 +BASSOMPIERRE,DE BAERE + (BIRM+CERN+BRUX)

BARTSCH 68 NP B8 9 +COCCONI,+ (AACH+BERL+CERN+LOIC+VIEN)
DENEGRI 68 PRL 20 1194 +CALLAHAN+ETTLINGER+GILLESPIE+ (JHU)

ANDREWS 69 PRL 22 731 +LACH,LUDLAM,SANDWEISS,BERGER,+ (YALE+LRL)
BARBARO 69 PRL 22 1207 BARBARO-GALTIERI,DAVIS,FLATTE,+ (LRL)
COLLEY 69 NC A 59 519 +EASTWOOD,+ (BIRM+GLAS+LOIC+MPIM+OXF+RHEL)

AGUILAR 70 PRL 25 54 AGUILAR-BENITEZ,BARNES,BASSANO,CHUNG,+(BNL)
BARTSCH 70 PL 33 B 186 +DEUTSCHMANN,+ (AACH+BERL+CERN+LOIC+VIEN)
LUDLAM 70 PR D 2 1234 +SANDWEISS,SLAUGHTER (YALE)

COLLEY 71 NP B 26 71 +JOBES,KENYON,PATHAK,HUGHES,+ (BIRM+GLAS)
DENEGRI 71 NP B 28 13 +ANTICH,CALLAHAN,CARSON,CHIEN,COX,+ (JHU)JP

ANDERSON 72 PR D 6 1823 +FRANKLIN,GODDEN,KOPELMAN,LIBBY,TAN (COLO)
BLIEDEN 72 PL 39 B 668 +FINOCCHIARO,BOWEN,EARLES,+ (STON+NEAS)
FIRESTON 72 PR D 5 505 FIRESTONE,GOLDHABER,LISSAUER,TRILLING (LBL)

BARLOUTA 73 NP B 59 374 +DREVILLON,SHAH,+ (SACL+EPOL+RHEL)
BINGHAM 73 NP B 52 31 +FARWEL,+ (LBL+ORSAY+BNL+SACLAY+MILAN)
CHARRIER 73 NP B 51 317 CHARRIERE,DRIJARD,DE BAERE,+ (CERN+BELG)

CHUNG 74 PL 51B 412 +EISNER,PROTOPOPESCU,SAMIOS,STRAND (BNL)
DEUTSCHM 74 PL 49B 388 DEUTSCHMANN,+ (AACH+BERL+CERN+LOIC+VIEN)JP
EISNER 74 BOSTON CONF R.L.EISNER REVIEW TALK (BNL)

ANTIPOV 75 NP B86 381 +ASCOLI,BUSNELLO,KIENZLE+ (SERP+CERN+ILL)JP
OTTER 75 NP B93 365 +RUDOLPH,RUMPF+ (AACH+BERL+CERN+LOIC+VIEN)JP

OTTER 79 NP B 147 1 +RUDOLPH,+ (AACH+BERL+CERN+LOIC+WIEN)JP

DAUM 81 NP B 187 1 +HERTZBERGER+(AMST+CERN+CRAC+MPIM+OXF+RHEL)
OTTER 81 NP B 181 1 (AACH+BERL+LOIC+VIEN+BIRM+BELG+CERN+MONS)

ARMSTRON 83 NP B 221 1 ARMSTRONG+ (BARI+BIRM+CERN+MILA+LPNP+PAVI)

$K_3^*(1780)$ was $K^*(1780)$

$I(J^P) = \frac{1}{2}(3^-)$

OUR LATEST MINIREVIEW ON THIS PARTICLE CAN BE FOUND IN THE 1984 EDITION.

$K_3^*(1780)$ MASS (MeV)

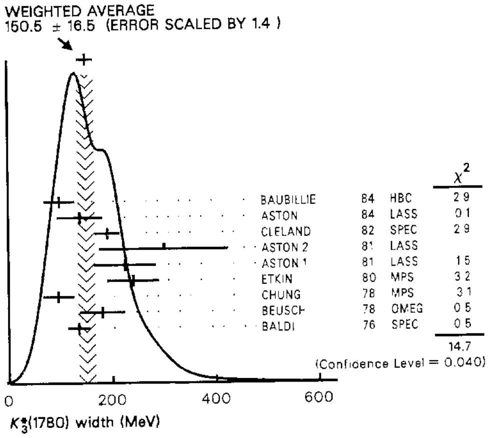
M	M		1779.0	11.0		BALDI	76	SPEC	+ 10 K+P,K0 PI+P
M	A		1776.	26.		BRANDENB	76	ASPK	013 K+-P,K+-PI-+
M			1812.0	28.0		BEUSCH	78	OMEG	10K-P,K0 PI+PI-N
M			1786.0	8.0		CHUNG	78	MPS	0 K-P,K-PI+N 6 GEV
M			1850.	50.		ETKIN	80	MPS	0 6 K-P,K0 PI+ PI-
M	J		1786.	15.		ASTON 1	81	LASS	0 11 K-P,K- PI+ N
M	K		1753.	25.	18.	ASTON 2	81	LASS	0 11 K-P,K- PI+ N
M		190	1762.0	9.0		TOAFF	81	HBC	- 6.5 K-P,K0 PI- P
M			1790.0	15.0		BAUBILLIE	82	HBC	0 8.25 K-P,KS2PIN
M		2060	1784.0	9.0		CLELAND	82	SPEC	+- 50 K+P,KS PI+-P
M	F		1790.0	28.0		ASTON	84	LASS	0 11 K-P,K0 2PI N
M		300	1780.0	9.0		BAUBILLIE	84	HBC	- 8.25 K-P,K0PI-P
M			. . . . .	. . . . .					
M	AVG		1780.0	3.6	AVERAGE				

M A CONFIRMED BY PHASE SHIFT ANALYSIS OF ESTABROOKS 77,YIELDS JP=3-
M J FROM A FIT TO Y(6,0) MOMENT.
M K FROM ENERGY INDEPENDENT PWA.
M M FROM A FIT TO Y(6,2) MOMENT. JP=3- FOUND.
M F SYSTEMATIC ERROR ADDED QUADRATICALLY BY US

$K_3^*(1780)$ WIDTH (MeV)

W	M		135.0	22.0		BALDI	76	SPEC	+ 10 K+P,K0 PI+P
W	E		(270.)	(70.)		BRANDENB	76	ASPK	013 K+-P,K+-PI-+
W	D		181.0	44.0		BEUSCH	78	OMEG	10K-P,K0 PI+PI-N
W			96.0	31.0		CHUNG	78	MPS	0 K-P,K-PI+N 6 GEV
W			240.	50.		ETKIN	80	MPS	0 6 K-P,K0 PI+ PI-
W	J		225.	60.		ASTON 1	81	LASS	011 K-P,K- PI+ N
W	K		300.	170.	80.	ASTON 2	81	LASS	0 11 K-P,K- PI+ N
W		190	(80.)	APPROX.		TOAFF	81	HBC	- 6.5 K-P,K0 PI- P
W			(130.0)	APPROX		BAUBILLIE	82	HBC	0 8.25 K-P,KS2PIN
W		2060	191.0	24.0		CLELAND	82	SPEC	+- 50 K+P,KS PI+-P
W	F		138.0	44.0		ASTON	84	LASS	0 11 K-P,K0 2PI N
W		300	99.0	30.0		BAUBILLIE	84	HBC	- 8.25 K-P,K0PI-P
W			. . . . .	. . . . .					
W	AVG		150.5	16.5	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4) (SEE IDEOGRAM BELOW)				

W D ERRORS ENLARGED BY US TO 4*GAMMA/SQRT(N). SEE K*(892) TYPED NOTE.
W E ESTABROOKS 77 FIND THAT BRANDENBURG 76 DATA ARE CONSISTENT
W E WITH 175 MEV WIDTH.NOT AVERAGED.
W J FROM A FIT TO Y(6,0) MOMENT.
W K FROM ENERGY INDEPENDENT PWA.
W M FROM A FIT TO Y(6,2) MOMENT. JP=3- FOUND.
W F SYSTEMATIC ERROR ADDED QUADRATICALLY BY US.



$K_3^*(1780)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_3^*(1780) \rightarrow K\pi$	494+ 140
P2	$K_3^*(1780) \rightarrow K^*(892)\ \pi$	892+ 140
P3	$K_3^*(1780) \rightarrow K\rho$	494+ 769
P4	$K_3^*(1780) \rightarrow K_2^*(1430)\ \pi$	1425+ 140
P5	$K_3^*(1780) \rightarrow K\pi\pi$	494+ 140+ 140
P6	$K_3^*(1780) \rightarrow K^*(892)\ \rho$	1275+ 769

$K_3^*(1780)$ BRANCHING RATIOS

$K_3^*(1780) \rightarrow (K\pi)$/total (P1)

R4		0.19	0.02	ESTABROO	78	ASPK	0 13 K+-P,K PI
R4		0.16	0.01	ASTON 2	81	LASS	0 11 K-P,K- PI+ N
R4		. . . . .	. . . . .				
R4	AVG	0.166	0.012	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)			

$K_3^*(1780) \rightarrow (K\rho)/(K^*(892)\ \pi)$ (P3)/(P2)

R5	(0.77) OR LESS	CL=.95	ASTON	84	LASS	0 11 K-P,K0 2PI N

$K_3^*(1780) \rightarrow (K_2^*(1430)\ \pi)/(K^*(892)\ \pi)$ (P4)/(P2)

R6	(1.78) OR LESS	CL=.95	ASTON	84	LASS	0 11 K-P,K0 2PI N

$K_3^*(1780) \rightarrow (K^*(892)\ \pi)/(K\pi)$ (P2)/(P1)

R7	1.09	0.26	ASTON	84	LASS	0 11 K-P,K0 2PI N

REFERENCES FOR $K_3^*(1780)$

CARMONY 71 PRL 27 1160 +CORDS,CLOPP,ERWIN,MEIERE,+ (PURD+UCD+IUPU)
FIRESTON 71 PL 36 B 513 FIRESTONE,GOLDHABER,LISSAUER,TRILLING (LBL)

AGUILAR 73 PRL 30 672 +CHUNG,EISNER,PROTOPOPESCU,SAMIOS,+ (BNL)
WALUCH 73 PR D 8 2837 +FLATTE,FRIEDMAN (LBL)

BALDI 76 PL 63 B 344 +BOEHRINGER,DORSAZ,HUNGERBUHLER,+ (GENEVA)JP
BRANDENB 76 PL 60 B 478 BRANDENBURG,CARNEGIE,CASHMORE,DAVIER+(SLAC)JP
SPIRO 76 PL 60 B 389 +BARLOUTAUD,PALER,CHAURAND+(SACL+RHEL+EPOL)JP

BOWLER 77 NP B 126 31 +DAINTON,DRAKE,WILLIAMS (OXFORD)JP
CARMONY 77 PR D 16 1251 +CLOPP,LANDER,MEIERE,YEN,+ (PURD+UCD+IUPU)
GRASSLER 77 NP B 125 189 +KLUGOW,+ (AACHEN+BERLIN+CERN+LOIC+VIENNA)

BEUSCH 78 PL 74 B 282 +BIRMAN,KONIGS,OTTER,+ (CERN+AACH+ETH)JP
CHUNG 78 PRL 40 355 +ETKIN,FLAMINO+ (BNL+BRAN+CUNY+MASA+PENN)JP
ESTABROO 78 NP B 133 490 ESTABROOKS,CARNEGIE,+ (MONT+CARL+DURH+SLAC)JP
ALSO 78 PR D 17 658 ESTABROOKS,CARNEGIE+ (MONT+CARL+DURH+SLAC)

CLELAND 80 PL 97B 465 +DORSAZ,MARTIN,NEF,+ (PITT+GEVA+LAUS+DURH)JP
ENGELEN 80 NP B 167 61 +JONGEJANS,DIONISI+ (NIJM+AMST+CERN+OXF)JP
ETKIN 80 PR D 22 42 +FOLEY,LINDENBAUM,KRAMER,+ (BNL+CUNY)JP

ASTON 1 81 PL 99 B 502 +DUNWOODIE,DURKIN,FIEGUTH+ (SLAC+CARL+OTTA)JP
ASTON 2 81 PL 106 B 235 +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA)JP
TOAFF 81 PR D 23 1500 +MUSGRAVE,AMMAR,DAVIS,ECKLUND,+ (ANL+KANS)

BAUBILLI 82 NP B 202 21 BAUBILLIER+ (BIRM+CERN+GLAS+MSU+LPNP)
CLELAND 82 NP B 208 189 +DELFOSSE,DORSAZ,GLOOR(DURH+GEVA+LAUS+PITT)

ASTON 84 NP 247 B 261 +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA)
BAUBILLI 84 ZPHY C 26 37 BAUBILLIER+ (BIRM+CERN+GLAS+MICH+LPNP)

$K^*(1790)$

$I(J^P) = \frac{1}{2}(1^-)$

OMITTED FROM SUMMARY TABLE

```
SEEN IN PARTIAL WAVE ANALYSIS OF THE K0 PI+PI-
OR K- PI+ SYSTEMS.
```

$K^*(1790)$ MASS (MeV)

```
M          1650   APPROX.                ESTABROOK 78 ASPK  0 13K+-P,K+-PI+- N
M          1800.        70.              ETKIN     80 MPS   0 6 K-P,K0 PI+PI-N
M          1700   APPROX.                ASTON     81 LASS  0 11 K-P,K- PI+ N
M   D      1786.0       9.0              ASTON     84 LASS  0 11K-P,K0 2PI N     |
M          . . . . . . . . . . .
M    AVG   1786.2       8.9     AVERAGE

M   D   SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$K^*(1790)$ WIDTH (MeV)

```
W       250-300   APPROX.                ESTABROOK 78 ASPK  0 13K+-P,K+-PI+- N
W          170.         30.              ETKIN     80 MPS   0 6 K-P,K0 PI+PI-N
W          (200) APPROX.                 ASTON     81 LASS  0 11 K-P,K- PI+ N
W   D      195.0       22.0              ASTON     84 LASS  0 11K-P,K0 2PI N     |
W          . . . . . . . . . . .
W    AVG   186.3       17.7     AVERAGE

W   D   SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$K^*(1790)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K^*(1790) \rightarrow K\pi$	494+ 140
P2	$K^*(1790) \rightarrow K^*(892)\ \pi$	892+ 140
P3	$K^*(1790) \rightarrow K\rho$	494+ 769

$K^*(1790)$ BRANCHING RATIOS

$K^*(1790) \rightarrow (K\rho)/(K^*(892)\ \pi)$ (P3)/(P2)

```
R1        3.4      1.3           ASTON     84 LASS  0 11 K-P,K0 2PI N   |
```

$K^*(1790) \rightarrow (K\pi)/(K^*(892)\ \pi)$ (P1)/(P2)

```
R2        2.8      1.1           ASTON     84 LASS  0 11 K-P,K0 2PI N   |
```

$K^*(1790) \rightarrow (K\rho)/(K\pi)$ (P3)/(P1)

```
R3        1.2      0.4           ASTON     84 LASS  0 11 K-P,K0 2PI N   |
```

REFERENCES FOR $K^*(1790)$

ESTABROO 78 NP B 133 490 ESTABROOKS,CARNEGIE,+ (MONT+CARL+DURH+SLAC)JP

ETKIN 80 PR D 22 42 +FOLEY,LINDENBAUM,KRAMER,+ (BNL+CUNY)JP

ASTON 81 PL 106 B 235 +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA)JP

ASTON 84 PL 149 B 258 +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA)JP

$K(1830)$

$I(J^P) = \frac{1}{2}(0^-)$

OMITTED FROM SUMMARY TABLE

```
SEEN IN PARTIAL WAVE ANALYSIS OF K- PHI SYSTEM.
NEEDS CONFIRMATION.
```

$K(1830)$ MASS (MeV)

```
M         (1830.0)  APPROX            ARMSTRONG 83 OMEG -  18.5 K-P,3K P
```

$K(1830)$ WIDTH (MeV)

```
W          (250.0)  APPROX            ARMSTRONG 83 OMEG -  18.5 K-P,3K P
```

$K(1830)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K(1830) \rightarrow K\phi$	494+1020

REFERENCES FOR $K(1830)$

ARMSTRON 83 NP B 221 1 ARMSTRONG+ (BARI+BIRM+CERN+MILA+LPNP+PAVI)JP

$K_4^*(2060)$ was $K^*(2060)$

$I(J^P) = \frac{1}{2}(4^+)$

$K_4^*(2060)$ MASS (MeV)

```
M      488 2115.     46.               CARMONY   77 HBC   0 9 K+D,K+ PIONS
M   C     (2092.)   (21.)              ASTON 1   81 LASS   011.K-P,K- PI+ N
M    D     2070.    100.      40.      ASTON 2   81 LASS   011.K-P,K- PI+ N
M      650 2088.     20.               BAUBILLIE 82 HBC  -  8.25 K-P,KS PI-P
M  W B 400 2039.     10.               CLELAND   82 SPEC +- 50 K+P,KS PI--P
M          . . . . . . . . . .
M   AVERAGE MEANINGLESS (SCALE FACTOR = 1.8)

M    B  FROM A FIT TO 8 MOMENTS.
M  W    NUMBER OF EVENTS EVALUATED BY US.
M    C  FROM A FIT TO Y(5,0), Y(7,0) AND Y(8,0) MOMENTS.
M    D  FROM ENERGY INDEPENDENT PWA.
```

$K_4^*(2060)$ WIDTH (MeV)

```
W           300.     200.              CARMONY   77 HBC   0 9 K+D,K+ PIONS
W   C      (205.)    (70.)    (55.)    ASTON 1   81 LASS   011.K-P,K- PI+ N
W    D      240.     500.     100.     ASTON 2   81 LASS   011.K-P,K- PI+ N
W      650  170.     100.      50.     BAUBILLIE 82 HBC  -  8.25 K-P,KS PI-P
W  W B 400  189.      35.              CLELAND   82 SPEC +- 50 K+P,KS PI+-P
W          . . . . . . . . . . .
W   AVERAGE MEANINGLESS

W    B  FROM A FIT TO 8 MOMENTS.
W  W    NUMBER OF EVENTS EVALUATED BY US.
W    C  FROM A FIT TO Y(5,0), Y(7,0) AND Y(8,0) MOMENTS.
W    D  FROM ENERGY INDEPENDENT PWA.
```

$K_4^*(2060)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_4^*(2060) \rightarrow K\pi$	494+ 140
P2	$K_4^*(2060) \rightarrow K^*(892)\ \pi\pi$	892+ 140+ 140
P3	$K_4^*(2060) \rightarrow \rho K\pi$	769+ 498+ 140
P4	$K_4^*(2060) \rightarrow \omega K\pi$	783+ 498+ 140
P5	$K_4^*(2060) \rightarrow K^*(892)\ \pi\pi\pi$	892+ 140+ 140- 135

$K_4^*(2060)$ BRANCHING RATIOS

$K_4^*(2060) \rightarrow (K\pi)/\text{total}$ (P1)

```
R1          0.07     0.01        ASTON 2   81 LASS  0 11 K-P,K- PI+ N
```

$K_4^*(2060) \rightarrow (K^*(892)\ \pi\pi)/\text{total}$ (P2)

```
R2        SEEN                   BAUBILLIE 82 HBC  -  8.25K-P,KS 3PI P
```

$K_4^*(2060) \rightarrow (\rho K\pi)/\text{total}$ (P3)

```
R3        SEEN                   BAUBILLIE 82 HBC  -  8.25K-P,KS 3PI P
```

$K_4^*(2060) \rightarrow (\omega K\pi)/\text{total}$ (P4)

```
R4        SEEN                   BAUBILLIE 82 HBC  -  8.25K-P,KS 3PI P
```

$K_4^*(2060) \rightarrow (K^*(892)\ \pi\pi\pi)/\text{total}$ (P5)

```
R5        POSSIBLY SEEN          BAUBILLIE 82 HBC  -  8.25K-P,KS 3PI P
```

REFERENCES FOR $K_4^*(2060)$

CARMONY 71 PRL 27 1160 +CORDS,CLOPP,ERWIN,MEIERE,+ (PURD+UCD+IND)

CARMONY 77 PR D 16 1251 +CLOPP,LANDER,MEIERE,YEN,+ (PURD+UCD+IUPU)

BROMBERG 80 PR D 22 1513 +HAGGERTY,ABRAMS,DZIERBA(CIT+FNAL+ILLC+IND)
CLELAND 80 PL 97B 465 +DORSAZ,MARTIN,NEF,+ (PITT+GEVA+LAUS+DURH)JP

ASTON 1 81 PL 99 B 502 +DUNWOODIE,DURKIN,FIEGUTH+ (SLAC+CARL+OTTA)JP
ASTON 2 81 PL 106 B 235 +CARNEGIE,DUNWOODIE,DURKIN+(SLAC+CARL+OTTA)JP
BAUBILLI 82 PL 118 B 447 BAUBILLIER,BURNS+ (BIRM+CERN+GLAS+MSU+LPNP)
CLELAND 82 NP B 208 189 +DELFOSSE,DORSAZ,GLOOR(DURH-GEVA+LAUS+PITT)

$K_2(2250)$ was $K(2250)$

$I(J^P) = \frac{1}{2}(2^-)$

OMITTED FROM SUMMARY TABLE

FORMERLY CALLED K*.
THIS ENTRY CONTAINS VARIOUS PEAKS IN STRANGE MESON SYSTEMS REPORTED IN THE 2100-2300 MEV REGION AS WELL AS ENHANCEMENTS SEEN IN ANTIHYPERON NUCLEON SYSTEM, EITHER IN THE MASS SPECTRA OR IN THE JP=2- WAVE.

$K_2(2250)$ MASS (MeV)

```
M        20(2240.)    (20.)            LISSAUER  70 HBC      9. K+ P
M   C      (2200.)   APPROX.           SLATTERY  71 RVUE     8-13 K+ P
M        37(2147.)     (4.)            CHLIAPNIK 79 HBC   +  K+P TO LAM-BAR P
M     Q     2235.      50.             BAUBILLIE 81 HBC   -  8. K-P,LAM PBAR
M     Q     2260.      20.             CLELAND   81 SPEC -- 50 K+P,LAM PBAR
M     Q     2200.0     40.0            ARMSTRONG 83 OMEG  -  18 K-P,LAM PBAR
M           . . . . . . . . . .
M    AVG    2246.5     16.8      AVERAGE

M   C   COMPILATION OF (ANTIHYP.-NUCLEON) MASS IN K+ P 8.-13.  GEV/C
M     Q  JP=2- FROM MOMENTS ANALYSIS.
```

$K_2(2250)$ WIDTH (MeV)

```
W        20  (80.)    (20.)            LISSAUER  70 HBC      9. K+ P
W   C       (200.)   APPROX.           SLATTERY  71 RVUE     8-13 K+ P
W        37  (40.)   APPROX.           CHLIAPNIK 79 HBC   +  K+P TO LAM-BAR P
W     Q     (200.)   APPROX.           BAUBILLIE 81 HBC   -  8. K-P,LAM PBAR
W     Q      210.      30.             CLELAND   81 SPEC +- 50 K+P,LAM PBAR
W     Q      150.0     30.0            ARMSTRONG 83 OMEG  -  18 K-P,LAM PBAR
W           . . . . . . . . . .
W    AVG     180.0     30.0      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)

W   C   COMPILATION OF (ANTIHYP.-NUCLEON) MASS IN K+ P 8.-13.  GEV/C
W     Q  JP=2- FROM MOMENTS ANALYSIS.
```

$K_2(2250)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_2(2250) \rightarrow K\pi\pi$	498+ 135+ 135
P2	$K_2(2250) \rightarrow \Lambda\overline{p}$	1116+ 938

REFERENCES FOR $K_2(2250)$

```
ALEXANDE 68 PRL 20 755          ALEXANDER,FIRESTONE,GOLDHABER,SHEN    (LRL)

LISSAUER 70 NP B 18 491         +ALEXANDER,FIRESTONE,GOLDHABER        (LBL)

SLATTERY 71  UR-875-332(PREP) P.SLATTERY,A REVIEW OF STRANGE MESONS(ROCH)

CHLIAPNI 79 NP B 158 253        CHLIAPNIKOV,GERDYUKOV+     (CERN+BELG+MONS)

BAUBILLI 81 NP B 183 1          BAUBILLIER,+      (BIRM+CERN+GLAS+MSU+LPNP)  JP
CLELAND  81 NP B 184 1          +NEF,MARTIN,+          (PITT+GEVA+LAUS+DURH)  JP

ARMSTRON 83 NP B 227 365        ARMSTRONG+  (BARI+BIRM+CERN+MILA+LPNP+PAVI)
```

$K_3(2320)$ was $K(2320)$

$I(J^P) = \frac{1}{2}(3^+)$

THIS ENTRY CONTAINS ENHANCEMENTS SEEN IN THE JP=3+ WAVE OF THE ANTIHYPERON NUCLEON SYSTEM

OMITTED FROM SUMMARY TABLE

$K_3(2320)$ MASS (MeV)

```
M     P     2320.0     30.0            CLELAND   81 SPEC +- 50 K+P,LAM PBAR
M     P     2330.0     40.0            ARMSTRONG 83 OMEG  - 18 K-P,LAM PBAR
M           . . . . . . . . . .
M    AVG    2323.6     24.0      AVERAGE

M     P   JP=3+ FROM MOMENTS ANALYSIS
```

$K_3(2320)$ WIDTH (MeV)

```
W     P     (250.0)  APPROX.           CLELAND   81 SPEC +- 50 K+P,LAM PBAR
W     P      150.0     30.0            ARMSTRONG 83 OMEG  - 18 K-P,LAM PBAR

W     P   JP=3+ FROM MOMENTS ANALYSIS
```

$K_3(2320)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$K_3(2320) \rightarrow \Lambda\overline{p}$	1116+ 938

REFERENCES FOR $K_3(2320)$

```
CLELAND  81 NP B 184 1          +NEF,MARTIN,+          (PITT+GEVA+LAUS+DURH)

ARMSTRON 83 NP B 227 365        ARMSTRONG+  (BARI+BIRM+CERN+MILA+LPNP+PAVI)
```

$K_4(2500)$ was $K(2500)$

$I(J^P) = \frac{1}{2}(4^-)$

THIS ENTRY CONTAINS ENHANCEMENTS SEEN IN THE JP=4- WAVE OF THE ANTIHYPERON NUCLEON SYSTEM

OMITTED FROM SUMMARY TABLE

$K_4(2500)$ MASS (MeV)

```
M     R     2490.0     20.0            CLELAND   81 SPEC +- 50 K+P,LAM PBAR

M     R   JP=4- FROM MOMENTS ANALYSIS
```

$K_4(2500)$ WIDTH (MeV)

```
W     R     (250.0)  APPROX.           CLELAND   81 SPEC +- 50 K+P,LAM PBAR

W     R   JP=4- FROM MOMENTS ANALYSIS
```

REFERENCES FOR $K_4(2500)$

```
CLELAND  81 NP B 184 1          +NEF,MARTIN,+          (PITT+GEVA+LAUS+DURH)
```

$C = \pm 1$, $B = 0$ MESON STATES

$D^{\pm}$

$I(J^P) = \frac{1}{2}(0^-)$

SEE STABLE PARTICLE FULL LISTINGS

D^0

$I(J^P) = \frac{1}{2}(0^-)$

SEE STABLE PARTICLE FULL LISTINGS

$D^*(2010)^{\pm}$

$I(J^P) = \frac{1}{2}(1^-)$

$D^*(2010)^{\pm}$ MASS (MeV)

```
M   G      (2008.)      (3.)            GOLDHABE  77 SMAG +- E+E-
M   P      (2008.6)     (1.0)           PERUZZI   77 SMAG +- E+E-
M          . . . . . . . . . .
M   MASS   2010.1       0.7    FROM DO MASS (TRILLING 81 RVUE) AND
M                              MASS DIFFERENCE BELOW

M   G   FROM SIMULTANEUS FIT TO D*(2010)+, D*(2010)0, D+, AND DO, NOT
M   G   INDEPENDENT OF FELDMAN 77 MASS DIFFERENCE BELOW.
M   P   PERUZZI 77 MASS NOT INDEPENDENT OF FELDMAN 77 MASS DIFFERENCE
M   P   BELOW AND PERUZZI 77 DO MASS VALUE.
```

$D^*(2010)^+ - D^0$ MASS DIFFERENCE (MeV)

```
DM        30  145.3      0.5            FELDMAN   77 SMAG   D*+ TO DO PI+
DM         2  145.2      0.6            BLIETSCHA 79 BEBC   NEUTRINO P
DM           (145.5)  APPROX.           AVERY     80 SPEC   GAMMA A
DM        60  145.5      0.3            FITCH     81 SPEC   PI- A
DM        14  145.5      0.5            YELTON    82 SMK2   29 E+E-,K-PI+
DM        16  145.8      1.5            AHLEN     83 HRS    D*+ TO DO PI+
DM        12  145.1      1.8            BAILEY    83 SPEC   D*+- TO DO PI+-
DM        28  145.5      0.3            BAILEY    83 SPEC   D*+- TO DO PI+-
DM        14  145.1      0.5            BAILEY    83 SPEC   D*+- TO DO PI+-
DM   D        145.46     0.08           ALBRECHT  85 ARG    D*+- TO DO PI+      |
DM           . . . . . . . . . . .
DM  AVG       145.451    0.072    AVERAGE

DM   D  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$D^*(2010)^+$ − $D^*(2010)^0$ MASS DIFFERENCE (MeV)

```
EM   P        2.6       1.8              PERUZZI   77 SMAG +- E+E-
EM   P  NOT INDEPENDENT OF FELDMAN 77 MASS DIFFERENCE ABOVE, PERUZZI 77
EM   P  D0 MASS, AND GOLDHABER 77 D*(2010)0 MASS.
EM          . . . . . . . . . .
EM  DMASS     2.9       1.3   FROM (D*+)-(D0) AND (D*0)-(D0)
EM                            MASS DIFFERENCES
```

$D^*(2010)^\pm$ WIDTH (MeV)

```
W       30   (2.0)  OR LESS  CL=.90   FELDMAN    77 SMAG     D*+ TO D0 PI+
W            (2.2)  OR LESS           YELTON     82 SMK2     29 E+E-,K-PI+PI-
```

$D^*(2010)^\pm$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$D^*(2010)^+ \to D^0\pi^+$	1865+ 140
P2	$D^*(2010)^+ \to D^+\gamma$	1869+ 0
P3	$D^*(2010)^+ \to D^+\pi^0$	1869+ 135

```
P       D*(2010)- MODES ARE CHARGE CONJUGATES OF ABOVE MODES
```

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i = \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1         P 2         P 3
 P 1 .4892+-.0832
 P 2   -.7652  .1708+-.1087
 P 3    .0000     -.6438  .3400+-.0700
```

$D^*(2010)^\pm$ BRANCHING RATIOS

$D^*(2010)^+ \to (D^0\pi^+)$/total (P1)

```
R1 G          0.6       0.15            GOLDHABE  77 SMAG +  E+E-
R1            0.44      0.10            COLES     82 SMK2    E+ E-          |
R1 G    ASSUMING THAT ISOSPIN IS CONSERVED IN THE DECAY
R1          . . . . . . . . . .
R1  AVG       0.489     0.083   AVERAGE
R1  FIT       0.489     0.083  FROM FIT
```

$D^*(2010)^+ \to (D^+\gamma)$/total (P2)

```
R2  C        (0.22)    (0.12)           COLES     82 SMK2    E+ E-          |
R2  C  NOT INDEPENDENT OF R1 AND R3 MEASUREMENT.
R2          . . . . . . . . . .
R2  FIT       0.17      0.11   FROM FIT
```

$D^*(2010)^+ \to (D^+\pi^0)$/total (P3)

```
R3            0.34      0.07            COLES     82 SMK2    E+ E-          |
R3          . . . . . . . . . .
R3  FIT       0.340     0.070  FROM FIT
```

REFERENCES FOR $D^*(2010)^\pm$

```
PERUZZI  76 PRL 37 569          +PICCOLO,FELDMAN,NGUYEN,WISS,+   (SLAC+LBL)

FELDMAN  77 PRL 38 1313         +PERUZZI,PICCOLO,ABRAMS,ALAM+    (SLAC+LBL)
PERUZZI  77 PRL 39 1301         +PICCOLO,FELDMAN,PERL,+(SLAC,LBL,NWES+HAWA)
GOLDHABE 77 PL 69 B 503         +WISS,ABRAMS,ALAM,BOYARSKI,+      (LBL+SLAC)

BLIETSCH 79 PL 86 B 108         BLIETSCHAU,+      (AACH+BONN+CERN+MPIM+OXF)

AVERY    80 PRL 44 1309         +WISS,BINKLEY,ATIYA,+        (ILL+FNAL+COLU)

FITCH    81 PRL 46 761          +DEVAUX,CAVAGLIA,MAY,+ (PRIN+SACL+TORI+BNL)
TRILLING 81 PRPL 75 57          G.H.TRILLING                      (LBL+UCB)

BEBEK    82 PRL 49 610          +(HARV+OSU+ROCH+RUTG+SYRA+VAND+CORN+ITHACA)
COLES    82 PR D26 2190         +ABRAMS,BLOCKER,BLONDEL+          (LBL+SLAC)
YELTON   82 PRL 49 430          +FELDMAN,GOLDHABER,+    (SLAC+LBL+UCB+HARV)

AHLEN    83 PRL 51 1147         +AKERLOF+       (ANL+IND+LBL+MICH+PURD+SLAC)
ALTHOFF  83 PL 126 B 493        +FISCHER,BURKHARDT+    (TASSO COLLABORATION)
BAILEY   83 PL 132 B 230        +BARDSLEY+  (AMST+BRIS+CERN+CRAC+MPIM+RHEL)

ALBRECHT 85 PL 150 B 235        +DRESCHER,HELLER+      (ARGUS COLLABORATION)
```

$D^*(2010)^0$

$I(J^P) = \frac{1}{2}(1^-)$

```
J CONSISTENT WITH 1, VALUE 0 RULED OUT (NGUYEN 77).
```

$D^*(2010)^0$ MASS (MeV)

```
M   G     (2006.)     (1.5)             GOLDHABE  77 SMAG    E+E-
M   G   FROM SIMULTANEUS FIT TO D*(2010)+, D*(2010)0, D+, AND D0.
M          . . . . . . . . . .
M   MASS   2007.2       2.1   FROM D0 MASS (TRILLING 81 RVUE) AND
M                             MASS DIFFERENCE BELOW
```

$D^*(2010)^0$ − D^0 MASS DIFFERENCE (MeV)

```
DM G         142.7       1.7             GOLDHABE  77 SMAG  0 E+E-
DM           142.2       2.0             SADROZIN  80 CBAL  0 D*0 TO D0 PI0
DM G    FROM SIMULTANEOUS FIT TO D*(2010)+, D*(2010)0, D+, AND D0.
DM           . . . . . . . . . .
DM  AVG      142.5       1.3    AVERAGE
```

$D^*(2010)^0$ WIDTH (MeV)

```
W             (5.)   OR LESS             GOLDHAB2  76 SMAG    E+E- TO D*D*
```

$D^*(2010)^0$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$D^*(2010)^0 \to D^0\pi^0$	1865+ 135
P2	$D^*(2010)^0 \to D^0\gamma$	1865+ 0

```
P       D*(2010)BAR0 MODES ARE CHARGE CONJUGATES OF ABOVE MODES
```

$D^*(2010)^0$ BRANCHING RATIOS

$D^*(2010)^0 \to (D^0\gamma)/(D^0\pi^0 + D^0\gamma)$ (P2)/(P1+P2)

```
R1   G          0.45      0.15             GOLDHABE  77 SMAG    E+E-
R1              0.47      0.12             COLES     82 SMK2    E+ E-         |
R1              0.53      0.13             BARTEL    85 JADE    E+ E-,HADRONS |
R1   G  WE QUOTE THE NORMAL FIT VALUE FROM TABLE 1. THE ISO-SPIN
R1   G  CONSTRAINED FIT IS NOW KNOWN TO GIVE A D0 GAMMA FRACTION WHICH IS
R1   G  TOO LARGE. SEE DETAILS IN FOOTNOTE 21 OF FELDMAN 77 REVIEW.
R1            . . . . . . . . . .
R1  AVG         0.485     0.076   AVERAGE
```

REFERENCES FOR $D^*(2010)^0$

```
GOLDHAB1 76 PRL 37 255         GOLDHABER,PIERRE,ABRAMS,ALAM,+   (LBL+SLAC)
GOLDHAB2 76 SLAC CONF. 379     G.GOLDHABER (AVAIL. AS LBL-5534) (LBL+SLAC)

GOLDHABE 77 PL 69 B 503        GOLDHABER,ABRAMS,ALAM+           (LBL+SLAC)
FELDMAN  77 BANFF SUM.INST 75  G.J.FELDMAN                          (SLAC)
NGUYEN   77 PRL 39 262         +WISS,ABRAMS,ALAM,BOYARSKI,+     (LBL+SLAC)

SADROZIN 80 MADISON CONF. 681  SADROZINSKI,+     (PRIN+CIT+HARV+SLAC+STAN)

TRILLING 81 PRPL 75 57         G.H.TRILLING                      (LBL+UCB)
COLES    82 PR D26 2190        +ABRAMS,BLOCKER,BLONDEL+         (LBL+SLAC)

BARTEL   85 PL 161B 197        +DIETRICH,AMBRUS+      (JADE COLLABORATION)
```

$D^*(2420)^0$

$I(J^P) = \frac{1}{2}(?^?)$

OMITTED FROM SUMMARY TABLE

```
SEEN IN D*(2010)+ PI-
JP=0+ RULED OUT
```

$D^*(2420)^0$ MASS (MeV)

```
M          2420.        6.              ALBRECHT  85  ARG    E+E-,D*+ PI- X  |
```

$D^*(2420)^0$ WIDTH (MeV)

```
W            70.       21.              ALBRECHT  85  ARG    E+E-,D*+ PI- X  |
```

$D^*(2420)^0$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$D^*(2420)^0 \to D^*(2010)^+\pi^-$	2010+ 140

Meson Full Listings

$D^*(2420)^0$, $D_s^\pm$, $D_s^*(2110)$, $B^\pm$, B^0, $B^*(5325)$, EXOTICS

$D^*(2420)^0$ BRANCHING RATIOS

$D^*(2420)^0 \rightarrow (D^*(2010)^+ \pi^-)$/total (P1)

```
R1          SEEN                      ALBRECHT  85  ARG     E+E-,D*+ PI- X    |
```

REFERENCES FOR $D^*(2420)^0$

```
ALBRECHT 85  DESY 85-119                              (ARGUS COLLABORATION)
```

$D_s^\pm$ was $F^\pm$

$I(J^P) = 0(0^-)$

SEE STABLE PARTICLE FULL LISTINGS

$D_s^*(2110)$ was $F^*(2140)$

$I(J^P) = ?(?^?)$

OMITTED FROM SUMMARY TABLE

$D_s^*(2110)$ MASS (MeV)

```
M  D        2113.       8.
M  D     OUR EVALUATION FROM D/S MASS= 1972 MEV AND DM AVERAGE BELOW
```

$D_s^*(2110)^+ - D_s^+$ MASS DIFFERENCE (MeV)

```
DM             110.      46.              BRANDELIK 79 DASP +- E+E-,D/S GAMMA
DM    D  60    139.5     12.8             AIHARA    84 TPC  + -E+E-,HADRONS     |
DM    D        144.0     11.4             ALBRECHT  84 ARG     E+E-,D/S GAMMA   |
DM        8    143.0     18.0             ASRATYAN  85 HLBC    FNAL 15FT,NU-H2  |
DM             . . . . . . . . . . .
DM   AVG       141.3      7.6      AVERAGE
M     D  SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

$D_s^*(2110)$ PARTIAL DECAY MODES

```
                                                            DECAY MASSES
```

P1 $D_s^*(2110) \rightarrow D_s \gamma$ 1971+ 0

$D_s^*(2110)$ BRANCHING RATIOS

$D_s^*(2110) \rightarrow (D_s \gamma)$/total (P1)

```
R1      SEEN BY ALL FOUR GROUPS QUOTED ABOVE FOR DM                        |
```

REFERENCES FOR $D_s^*(2110)$

```
BRANDELI 77 PL 70 B 132        BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)

BRANDELI 78 PL 76 B 361        BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)

BRANDELI 79 PL 80 B 412        BRANDELIK,CORDS,+(AACH+DESY+HAMB+MPIM+TOKY)

AIHARA   84 PRL 53 2465        +ALSTON+  (LBL+UCLA+UCR+JHU+MASA+TOKY+YALE)
ALBRECHT 84 PL 146 B 111       + (DESY+DORT+HEID+IPPC+KANS+LUND+ITEP+USCC)

ASRATYAN 85 PL 156 B 441       +FEDOTOV,AMMOSOV,BURTOVOY+       (ITEP+SERP)
```

$B = \pm 1$ MESON STATES

$B^\pm$

$I(J^P) = ?(?^?)$

SEE STABLE PARTICLE FULL LISTINGS

B^0

$I(J^P) = ?(?^?)$

SEE STABLE PARTICLE FULL LISTINGS

$B^*(5325)$

$I(J^P) = ?(?^?)$

OMITTED FROM SUMMARY TABLE

$B^*(5325)$ MASS (MeV)

```
M  D  1400 5325.0     5.0            HAN       85 CUSB  0 E+E-,GAMMA E X    |
M  D    FROM B MASS 5272.3+-2.5 MEV AND MASS DIFFERENCE BELOW
```

$B^*(5325) - B$ MASS DIFFERENCE (MeV)

```
DM D  1400   52.0     4.5            HAN       85 CUSB  0 E+E-,GAMMA E X    |
M  D    SYSTEMATIC ERROR ADDED QUADRATICALLY BY US
```

REFERENCES FOR $B^*(5325)$

```
HAN      85 PRL 55 36        +KLOPFENSTEIN,MAGERAS+ (COLU+LSU+MPIM+STON)
```

EXOTIC MESON STATES

EXOTICS

OMITTED FROM SUMMARY TABLE

THE PURPOSE OF THIS ENTRY IS TO PROVIDE A LIST OF REFERENCES FOR EXOTIC MESON SEARCHES (SEE THE SECTION ON THE NONRELATIVISTIC QUARK MODEL IN THE MISCELLANEOUS SECTION OF THIS REVIEW), AS WELL AS THEORETICALLY BASED SUGGESTIONS FOR EXPERIMENTS. NOTE THAT LIPKIN 73 PROPOSES EXPERIMENTS WHICH ARE CONCLUSIVE EVEN IF NEGATIVE RESULTS ARE OBTAINED.

REFERENCES FOR EXOTICS

```
                                 REPORTS ON SEARCHES

ROSENFEL 68 PHILA.CONF.P.455  A.H.ROSENFELD                            (LRL)

DODD     69 PR 177 1991       +JOLDERSMA, PALMER, SAMIOS               (BNL)

CHO      70 PL 32 B 409       +DERRICK,JOHNSON,MUSGRAVE,+ (ANL+NWES+KANS)
GIACOMEL 70 PL  33 B 373      G.GIACOMELLI +   (BGNA+SACL+AMST+REHO+EPOL)
LYS      70 PR D 2 2525       J.LYS+                                  (MICH)
ROSNER   70 EXP.MESON SPECTROSCOPY,ED. C.BALTAY AND A.H.ROSENFELD,P.499

BUHL     72 NP B 37 421       +CLINE,TERRELL                     (WISCONSIN)

COHEN    73 NP B 53 1         +FERBEL,SLATTERY,WERNER            (ROCHESTER)
DURUSOY  73 PL 45 B 517       +BAUBILLIER,GEORGE,ARMENISE,+    (LPNP+BARI)

ALAM     74 PL 53B 207        +BRABSON,GALLOWAY,+    (IND+PURD+SLAC+VAND)
COHEN    74  BOSTON           D.COHEN  REVIEW TALK                    (COLU)
OREN     74 NP B71 189        +COOPER,FIELDS,RHINES,WHITMORE,+  (ANL+OXF)
BALTAY   75 PL 57B 293        +CAUTIS,COHEN,KALELKAR,PISELLO,+(COLU+BING)
DAVIS    75 NP B96 426        +AMMAR,KROPAC,YARGER,+       (KANS+CCAC+ANL)

BRUNDIER 76 PL 64 B 107       BRUNDIERS,BRUN,FLURI,+  (FREIBURG+SACL+ETH)

BOUCROT  77 NP B 121 251      +NAVACH,RIVET,+        (LALO+CERN+CDEF+EPOL)
HOOGLAND 77 NP B 126 109      +GRAYER,HYAMS,BLUM,DITL,+  (AMST+CERN+MPIM)
HOOGLAND 77 NP B 126 109      +GRAYER,HYAMS,BLUM,DITL,+  (AMST+CERN+MPIM)
MOSER    77 NP B 129 28       F.L.MOSER                                (EFI)

ALAM     78 PRL 40 1685       +BAGGETT,BAGLIN,BONAMY+(IND+PURD+SLAC+VAND)
ARMSTRON 78 PL 77 B 447       ARMSTRONG,FRAME,HUGHES,BIENLEIN+(GLAS+DESY)

LEMOIGNE 79 BATAVIA CONF.524  +ABOLINS,BARATE+        (SACL+LOIC+SHMP+IND)

KOOIJMAN 80 PRL 45 316        +ARENTON,AYRES,DIEBOLD,MAY+         (ANL+EFI)

AGUILAR  81 ZPHY C 6 109      +ALBAJAR,SJOGREN,+     (CERN+CDEF+MADR+STOH)
APEL     81 NP B 193 269      +AUGENSTEIN,BERTOLUCCI,DONSKOV,+(SERP+CERN)
BIONTA   81 PRL 46 970        +CARROLL,EDELSTEIN,+   (BNL+CARN+FNAL+SMAS)
EVANGELI 81 NP B 178 197      EVANGELISTA+(BARI+BONN+CERN+DARE+LIVP+MILA)
FRAME    81 PL 107 B 301      +HUGHES,COLLEY,ARMSTRONG,+ (GLAS+BIRM+CERN)
IRVING   81 NP B 193 1        +LOVERRE,AGUILAR,+     (CERN+CDEF+MADR+STOH)

DOVER    84 PL 146 B 103      C.B.DOVER                               (ORSA)
JENKINS  84 PR D 30 1409      +DIAMOND,KIRSCH,+  (FSU+BRAN+BNL+CINC+SMAS)
KITAZOE  84 ZPHY C 24 143     +WADA,KABURAGI,KAWAGUCHI,MORII,+ (KOBE+MIT)

                              SUGGESTIONS FOR SEARCHES

ROSNER   68 PRL 21 950,1468   J.L.ROSNER                          (TEL-AVIV)

ROSNER   70 EXP.MESON SPECTROSCOPY,ED. C.BALTAY AND A.H.ROSENFELD,P.499

FAIMAN   73 PL 43 B 307       D.FAIMAN,G.GOLDHABER,Y.ZARMI            (CERN)
LIPKIN   73 PR D 7 2262       H.J.LIPKIN                       (ARGONNE+FNAL)

HOLMGREN 78 PL 77 B 304       +PENNINGTON                        (STOH+CERN)

ARENTON  82 PR D 25 2241      +AYRES,DIEBOLD,MAY,SWALLOW+         (ANL+ILL)

ACHASOV  85 ZPHY C 27 99      +DEVYANIN,SHESTAKOV                     (NOVO)
```

NOTE ON N AND Δ RESONANCES

I. Introduction

(by G. Höhler, University of Karlsruhe)

The excited states of the nucleon have been studied in a large number of formation and production experiments. Production experiments are not suitable for accurate determination of resonance parameters but will be essential in searching for the many predicted nucleon resonances that decouple from the πN channel.[1]

The masses, widths, and elasticities of the N and Δ resonances in the Baryon Summary Table come almost entirely from partial-wave analyses of πN total, elastic, and charge-exchange scattering data (see Sec. II, below). Similar methods have been used to get the $N\eta$, ΛK, and ΣK branching fractions. Other branching fractions come from isobar-model analyses of $\pi N \rightarrow N\pi\pi$ data (Sec. III). Finally, some $N\gamma$ branching fractions have been determined from photoproduction experiments (Sec. IV).

Table 1 lists all the N and Δ entries in the Baryon Listings and gives our evaluation of the status of each, both overall and channel by channel. Only the established resonances (overall status 3 or 4 stars) appear in the Baryon Summary Table. A resonance is considered to be well established only if it has been seen in at least two independent analyses and if its partial wave does not behave erratically or have large errors. Good reason for a cautious attitude is the fact that some recent data[2,3] differ appreciably from earlier data and from predictions of the analyses.

The Baryon Listings give, in addition to the usual Breit-Wigner parameters, the locations and the residues of the poles of the resonant partial waves on the second sheet of the complex energy plane as obtained from πN partial-wave analyses and from the isobar-model analyses of $\pi N \rightarrow N\pi\pi$.

The Listings are much shortened by the omission of many now-obsolete results, nearly all which were published before 1975. There also used to be separate entries for bumps seen in production experiments — bumps with masses in the 1440-MeV region, the 1520-MeV region, etc. — but these have been removed. All the omitted material may be found in our 1982 edition.[4]

There are two recent extensive reviews of nucleon resonances.[5,6]

Further progress in understanding the N and Δ resonances depends on investigations of three different types.

Table 1. The status of the N and Δ resonances. Only those with an overall status of *** or **** are included in the main Baryon Summary Table.

			Status as seen in --						
Particle	$L_{2I\cdot 2J}$	Overall status	$N\pi$	$N\eta$	ΛK	ΣK	$\Delta\pi$	$N\rho$	$N\gamma$
$N(939)$	P_{11}	****							
$N(1440)$	P_{11}	****	****	*			***	*	***
$N(1520)$	D_{13}	****	****	*			****	****	****
$N(1535)$	S_{11}	****	****	****			*	**	***
$N(1540)$	P_{13}	*					*	*	
$N(1650)$	S_{11}	****	****	*	***	**	***	*	***
$N(1675)$	D_{15}	****	****	*	*		****	*	***
$N(1680)$	F_{15}	****	****				****	****	****
$N(1700)$	D_{13}	***	***	*	**	*	**	*	**
$N(1710)$	P_{11}	***	***	*	**	*	**	*	***
$N(1720)$	P_{13}	****	****	*	**	*	*	*	*
$N(1960)$	?	*							
$N(1990)$	F_{17}	**	**	*	*	*			*
$N(2000)$	F_{15}	**	**	*	*	*			
$N(2080)$	D_{13}	**	**	*	*				*
$N(2090)$	S_{11}	*	*						
$N(2100)$	P_{11}	*	*						
$N(2190)$	G_{17}	****	****	*	*	*			*
$N(2200)$	D_{15}	**	**	*	*				
$N(2220)$	H_{19}	****	****	*					
$N(2250)$	G_{19}	****	****	*					
$N(2600)$	I_{111}	***	***						
$N(2700)$	K_{113}	**	**						
$N(\sim 3000)$									
$\Delta(1232)$	P_{33}	****	****	F					****
$\Delta(1550)$	P_{31}	*		o			*	*	*
$\Delta(1600)$	P_{33}	**	**	r			**	*	**
$\Delta(1620)$	S_{31}	****	****	b			****	****	***
$\Delta(1700)$	D_{33}	****	****		i	*	***	**	***
$\Delta(1900)$	S_{31}	***	***		d	*		*	*
$\Delta(1905)$	F_{35}	****	****		d	*	**	*	***
$\Delta(1910)$	P_{31}	****	****		e	*	*	*	*
$\Delta(1920)$	P_{33}	***	***		n	*	*		*
$\Delta(1930)$	D_{35}	***	***	F		*			*
$\Delta(1940)$	D_{33}	*	*	o					
$\Delta(1950)$	F_{37}	****	****	r		*	***	*	***
$\Delta(2000)$	F_{35}	**		b				**	
$\Delta(2150)$	S_{31}	*	*		i				
$\Delta(2200)$	G_{37}	*	*		d				
$\Delta(2300)$	H_{39}	**	**		d				
$\Delta(2350)$	D_{35}	*	*		e				
$\Delta(2390)$	F_{37}	*	*		n				
$\Delta(2400)$	G_{39}	**	**						
$\Delta(2420)$	H_{311}	****	****						*
$\Delta(2750)$	I_{313}	**	**						
$\Delta(2950)$	K_{315}	**	**						
$\Delta(\sim 3000)$									

****	Good, clear, and unmistakable.
***	Good, but in need of clarification or not absolutely certain.
**	Not established; needs confirmation.
*	Evidence weak; could disappear.

(1) ***New accurate data***: Much new data is coming from groups working at LAMPF,[7] and there is also some new accurate data from the Leningrad group.[8] These groups are also preparing to measure spin-rotation data, the first such in the resonance region. Very unfortunately, however, none of this work extends above a mass of about 1500 MeV, and to our knowledge there are no plans anywhere for new measurements at higher masses. The recently published results of an older high-statistics measurement of $\pi^+ p$ backward differential cross sections from 1.3 to 2.5 GeV/c[3] disagree significantly with previous high-statistics experiments and thus also with predictions from partial-wave analyses.[5]

(2) ***New partial-wave analyses***: Existing solutions will need to be adjusted to get a good fit to the new data.[9] However, this is only the first step of an iterative procedure. A unique and *reliable* result can be obtained only if, in addition, rather strong analyticity constraints are imposed on the amplitudes. The CMU-LBL and Karlsruhe groups have computer programs for this purpose, but new fits has not yet been made due to lack of manpower.

(3) ***New theoretical investigations***: The relation between the resonance parameters determined from partial-wave analyses and the quantities derived from lattice calculations and various models needs clarifying. Until this difficult problem is solved, the uncertainties involved in comparing theoretical predictions with the parameters listed in our Table should be kept much in mind.

References for section I

1. R. Koniuk and N. Isgur, Phys. Rev. **D21**, 1868 (1980).
2. πN Newsletter No. 1 (1984), eds. G. Höhler and B.M.K. Nefkens.
3. D.J. Candlin et al., Nucl. Phys. **B244**, 23 (1984).
4. Particle Data Group, Phys. Lett. **111B** (1982).
5. G. Höhler, *Pion-Nucleon Scattering*, Landolt-Börnstein Vol. **I/9b** (1983), ed. H. Schopper, Springer Verlag.
6. A.J.G. Hey and R.L. Kelly, Phys. Reports **96**, 71 (1983).
7. A. Mokhtari et al., Phys. Rev. Lett. **55**, 359 (1985). See also B.M.K. Nefkens in *Proceedings of the Xth International Conference on Few Body Problems*, Vol. I (Karlsruhe, 1983), ed. B. Zeitnitz, p. 193c. This group also has preliminary data on $\pi^- p$ charge-exchange cross sections and polarization parameters.
8. V.V. Abaev et al., Z. Phys. **C** (in press).
9. R.A. Arndt et al., Phys. Rev. **D32**, 1085 (1985).

II. Two-body partial-wave analyses and determination of resonance parameters

(by G. Höhler, University of Karlsruhe)

πN partial-wave analysis: Even if $\pi N \rightarrow \pi N$ scattering data were measured with infinite accuracy, it would not be possible in the inelastic region to determine a unique set of partial waves from the data alone. It is essential to add theoretical constraints, and unitarity, analyticity, and isospin invariance are chosen in order to avoid the biases that a specific model or parametrization might introduce.

Atkinson et al.,[1] continuing earlier work, investigated to what extent amplitudes are restricted by just unitarity if the $d\sigma/d\Omega$ and P angular distributions for $\pi^+ p$ elastic scattering are given at one energy with very high precision. They found a variety of solutions differing from one another substantially in some of the lower partial waves and strongly in the tail of high partial waves. They concluded that cutting off the partial-wave expansion sharply (which was done in many early and in some recent analyses[2,3]) is not justified.

In QCD, isospin is not exactly conserved in strong interactions because the masses of the up and down quarks are different. The only well-established experimental evidence for a violation is in the Δ(1232) region, where one is expected because the Δ^{++} and Δ^0 masses are different. Other reported violations turned out to be caused by errors in the data or the analysis.[4]

The uniqueness problem remains even if one includes data for all three reactions plus unitarity and isospin invariance; it is still necessary to add analyticity constraints. Many analyses have used as input predictions for the forward amplitudes, which follow from total-cross-section data, the optical theorem, and forward dispersion relations, but this is still not nearly enough.

Constraints based on Mandelstam's 2-variable analyticity have so far been used successfully only in the CMU-LBL[5] and Karlsruhe-Helsinki[6,7] analyses. In both, long tails of high partial waves were admitted, but only some global results for these waves should be taken seriously, not the value of a particular high wave. The resonance masses, widths, and elasticities in the Baryon Summary Table are mainly determined by these two analyses, whose partial-wave amplitudes are shown in Fig. 1. More detailed figures and speed plots may be found in Ref. 8.

Results from other recent analyses should be considered preliminary as long as the compatibility with analyticity constraints and the effect of the neglect of higher partial waves have not been investigated (see Sec. 2.1 in Ref. 7).

Substantial progress may be expected when final results of several experiments now in progress are available.[9] The analysis will be simplified and improved if predictions for the tail of high partial waves, based on new evaluations of the nearby parts of the Mandelstam double spectral function,[10] are used. R. Koch[11] included these predictions in getting a smooth interpola-

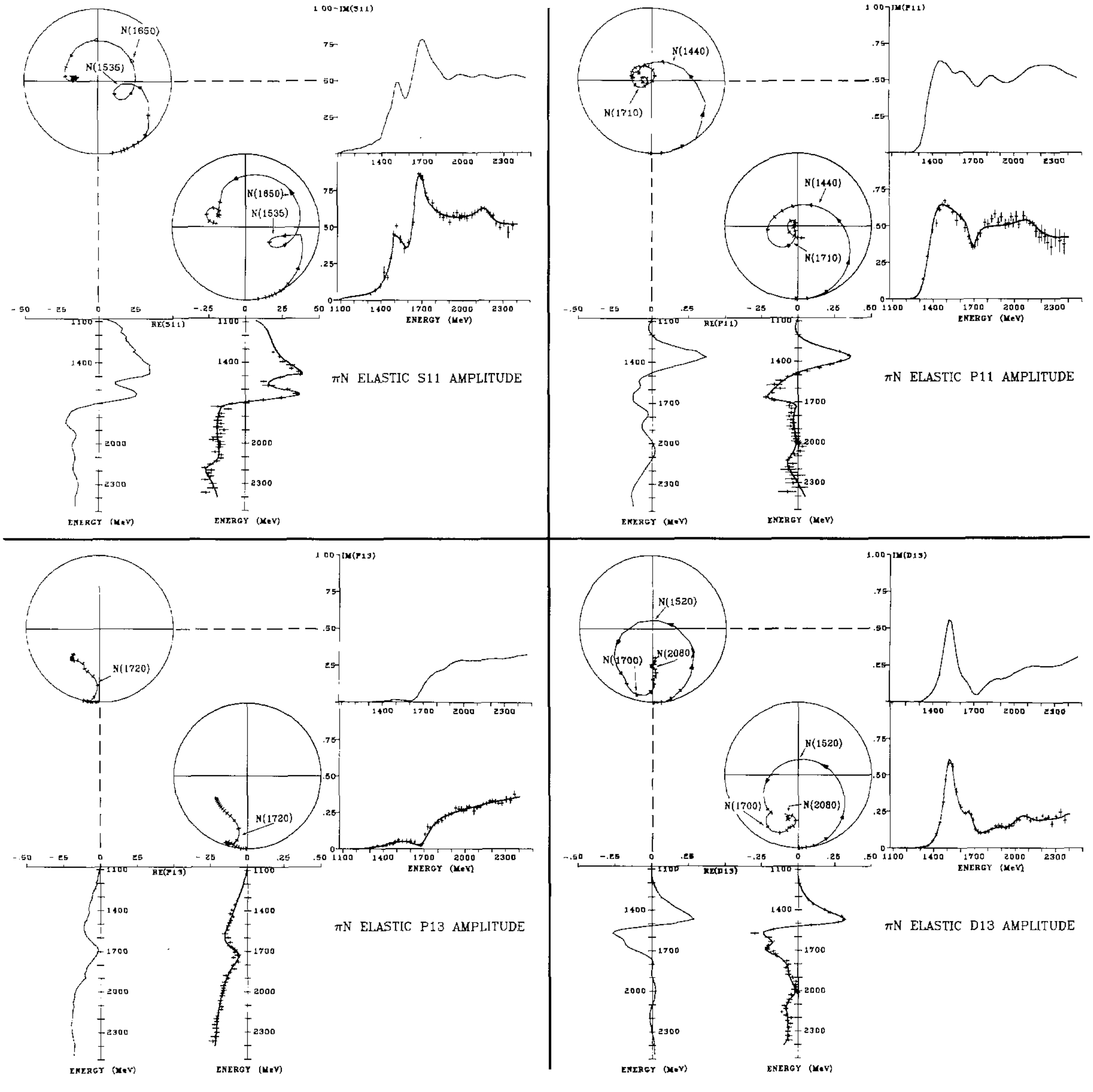


Fig. 1(a). The $L_{2I,2J} = S_{11}, P_{11}, P_{13}$, and D_{13} partial-wave amplitudes for πN elastic scattering. The upper plot for each amplitude is from HOEHLER 79 and the lower one is from CUTKOSKY 80. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots (in the projections of the CUTKOSKY 80 amplitudes, the "data points" are results of energy-independent fits, and the curves are from an energy-dependent fit to join them).

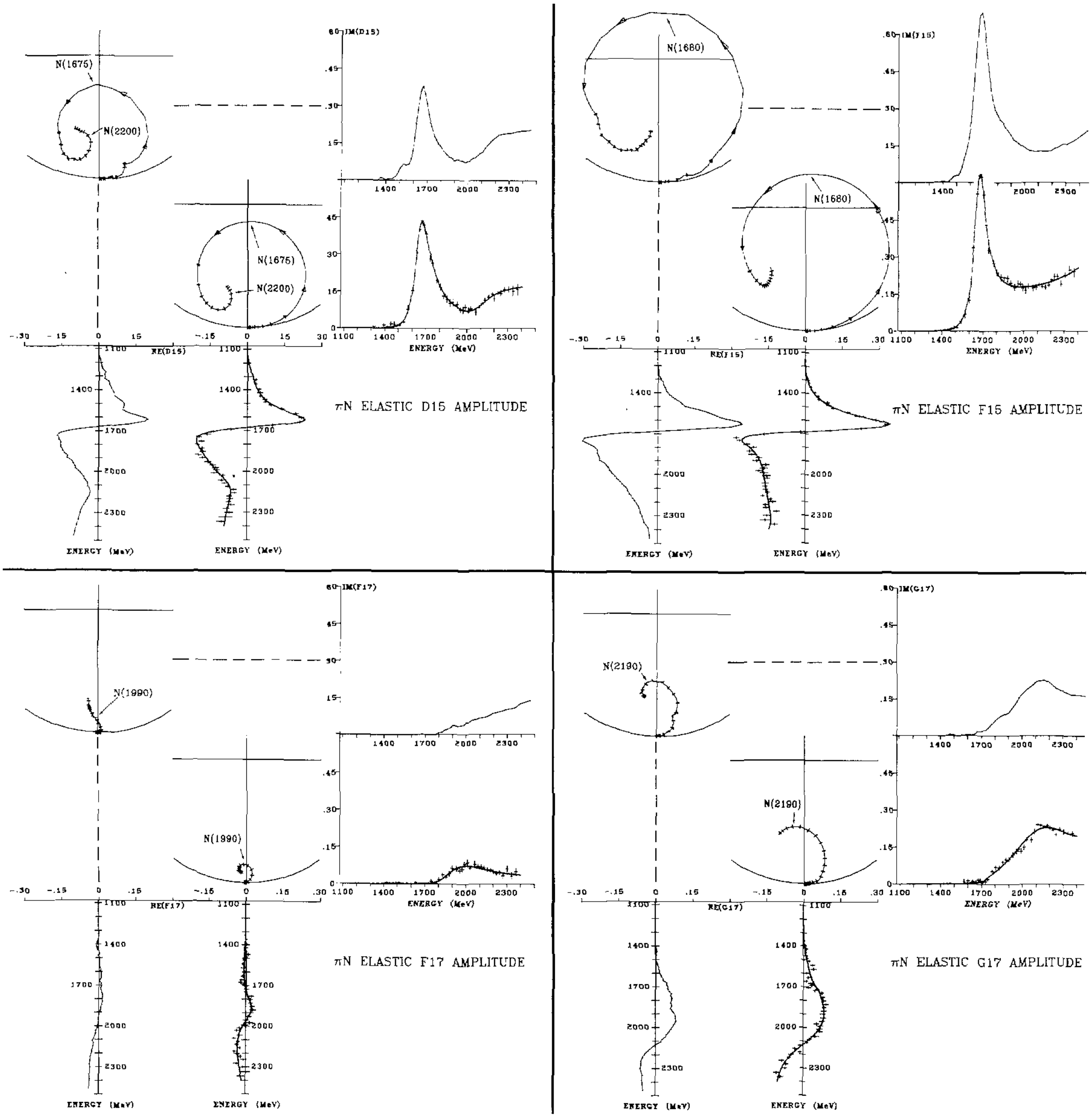


Fig. 1(b). The $L_{2I\cdot 2J} = D_{15}$, F_{15}, F_{17}, and G_{17} partial-wave amplitudes for πN elastic scattering. The upper plot for each amplitude is from HOEHLER 79 and the lower one is from CUTKOSKY 80. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots (in the projections of the CUTKOSKY 80 amplitudes, the "data points" are results of energy-independent fits, and the curves are from an energy-dependent fit to join them).

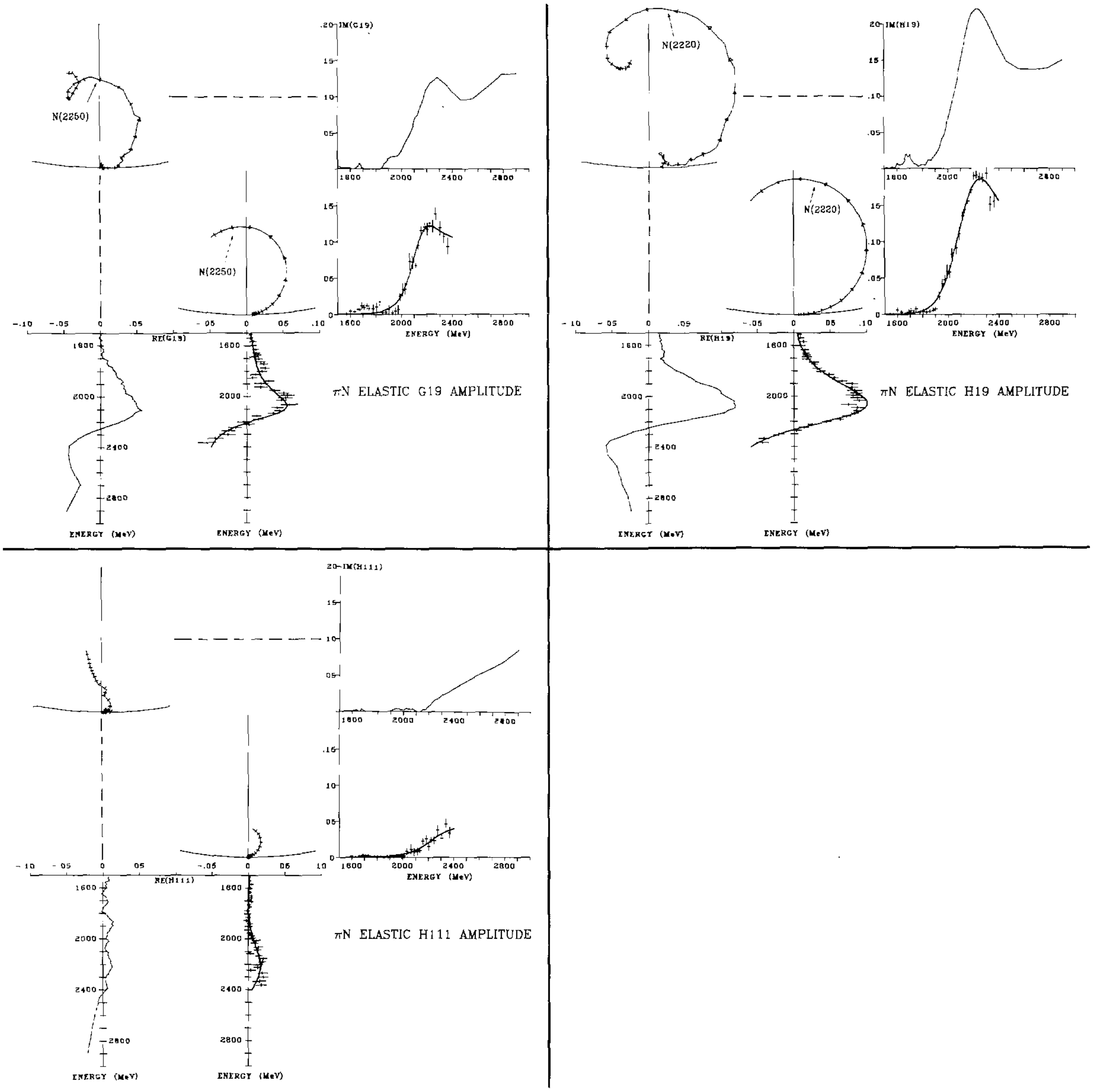


Fig. 1(c). The $L_{2I\cdot 2J} = G_{19}$, H_{19}, and H_{111} partial-wave amplitudes for πN elastic scattering. The upper plot for each amplitude is from HOEHLER 79 and the lower one is from CUTKOSKY 80. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots (in the projections of the CUTKOSKY 80 amplitudes, the "data points" are results of energy-independent fits, and the curves are from an energy-dependent fit to join them).

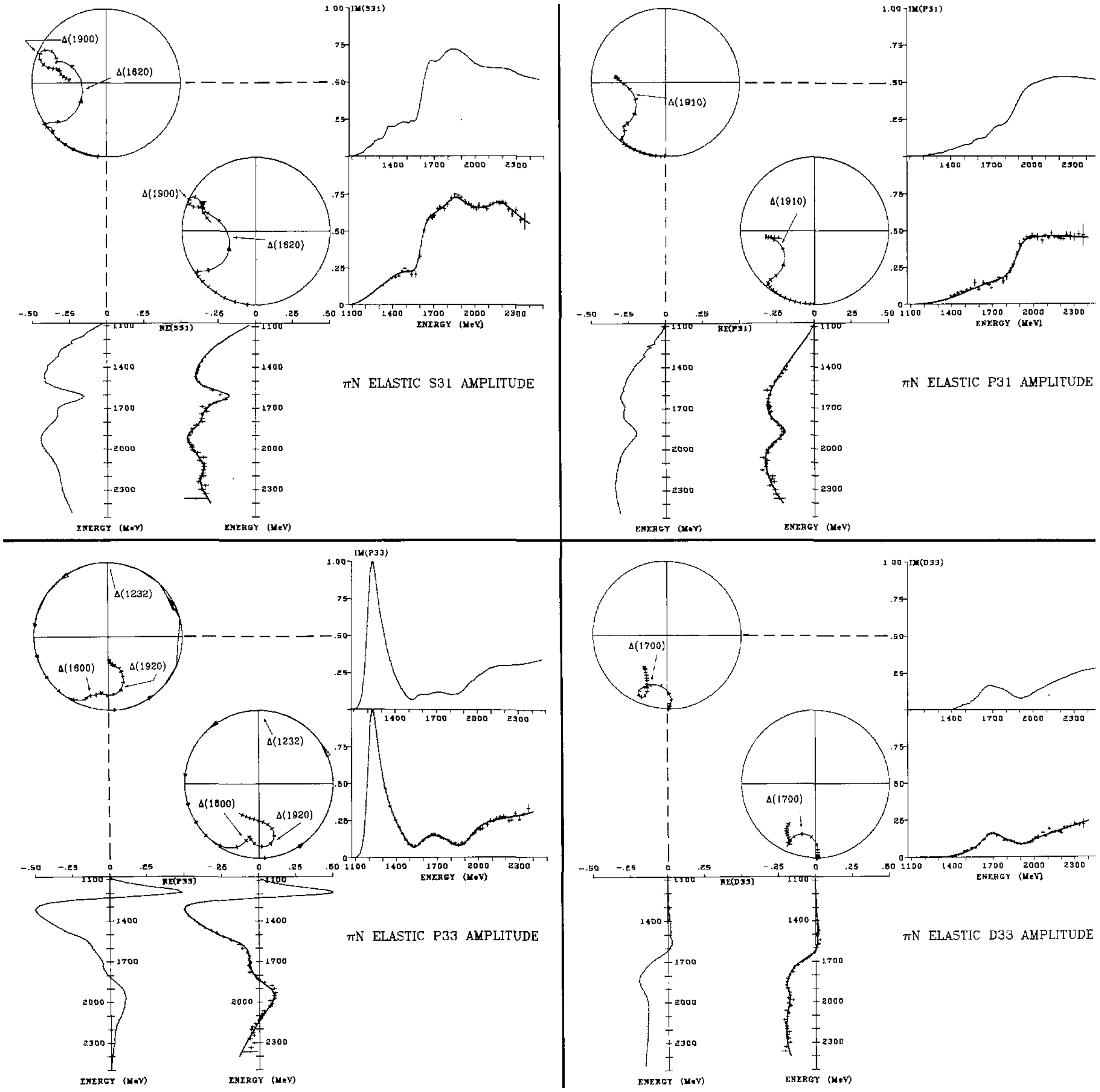


Fig. 1(d). The $L_{2I\cdot 2J} = S_{31}$, P_{31}, P_{33}, and D_{33} partial-wave amplitudes for πN elastic scattering. The upper plot for each amplitude is from HOEHLER 79 and the lower one is from CUTKOSKY 80. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots (in the projections of the CUTKOSKY 80 amplitudes, the "data points" are results of energy-independent fits, and the curves are from an energy-dependent fit to join them).

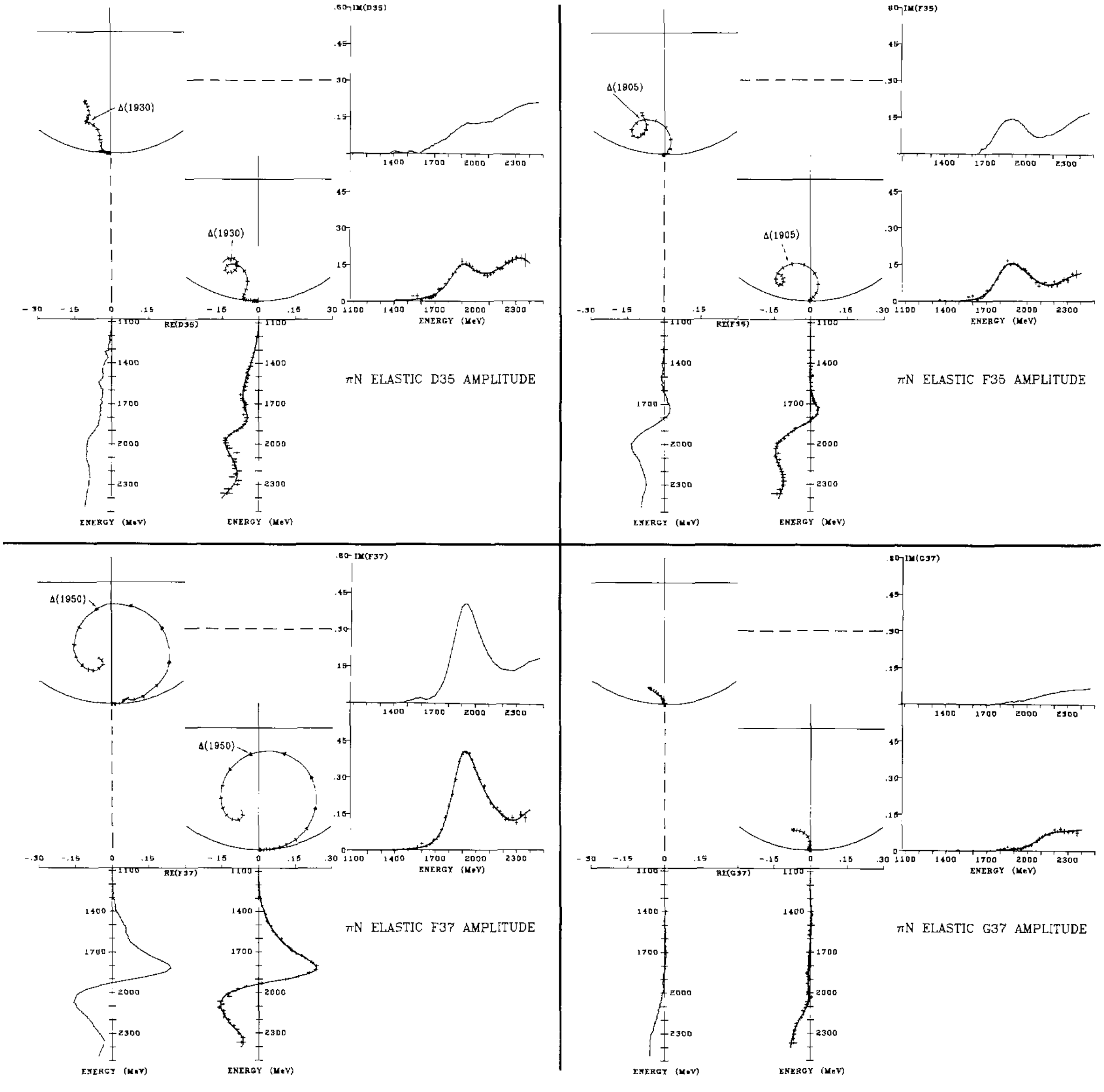


Fig. 1(e). The $L_{2I\cdot 2J} = D_{35}$, F_{35}, F_{37}, and G_{37} partial-wave amplitudes for πN elastic scattering. The upper plot for each amplitude is from HOEHLER 79 and the lower one is from CUTKOSKY 80. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots (in the projections of the CUTKOSKY 80 amplitudes, the "data points" are results of energy-independent fits, and the curves are from an energy-dependent fit to join them).

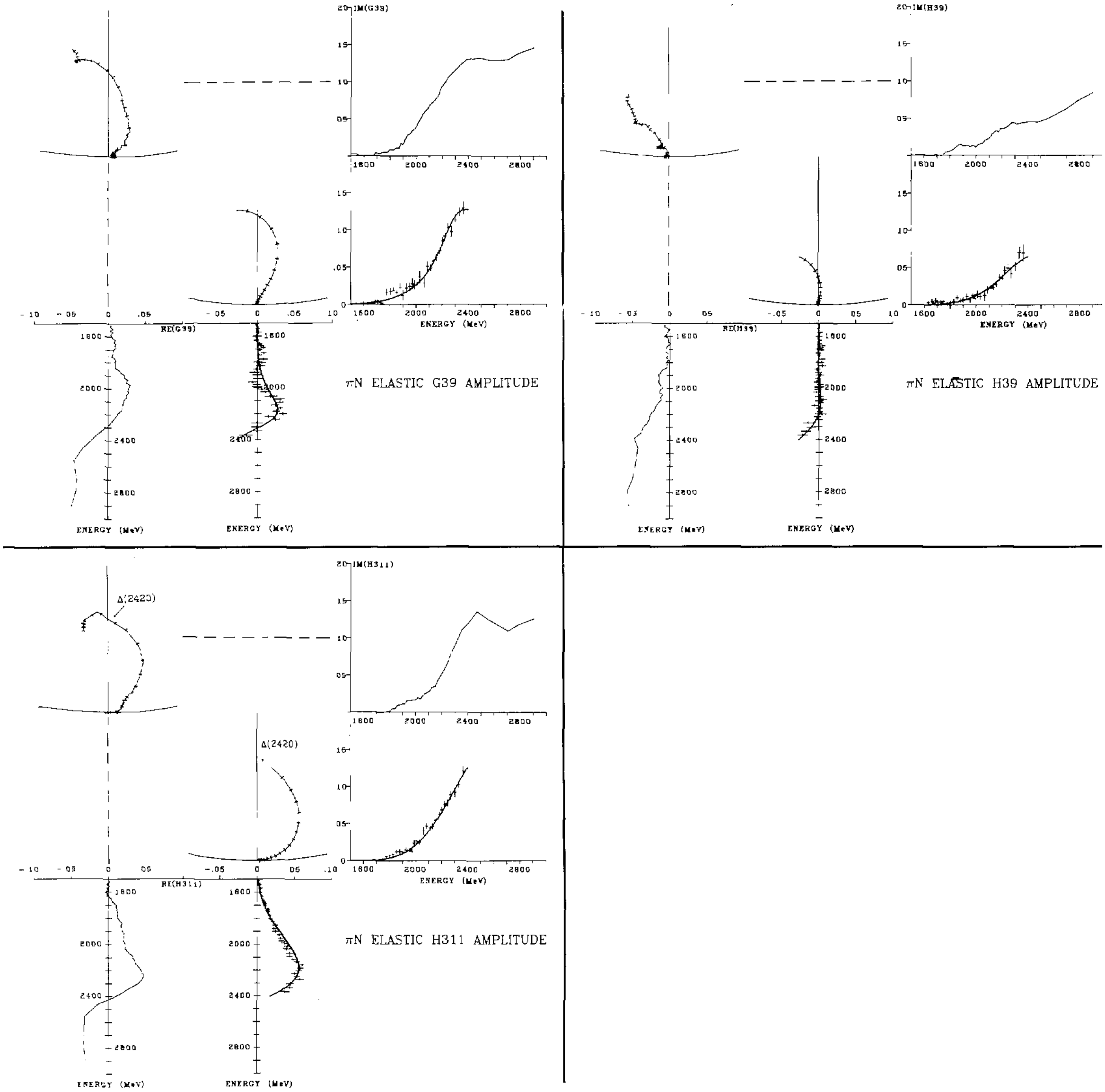


Fig. 1(f). The $L_{2I\cdot 2J} = G_{39}$, H_{39}, and H_{311} partial-wave amplitudes for πN elastic scattering. The upper plot for each amplitude is from HOEHLER 79 and the lower one is from CUTKOSKY 80. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots (in the projections of the CUTKOSKY 80 amplitudes, the "data points" are results of energy-independent fits, and the curves are from an energy-dependent fit to join them).

tion of the earlier Karlsruhe solution for D and higher partial waves constrained by the condition that the partial-wave dispersion relations be satisfied. Koch's solution improves the information on the shape of the resonance structures and has been used for a determination of the pole parameters.[12]

In a second paper,[13] Koch presented real parts of partial waves up to 500 MeV/c from a projection of fixed-t dispersion relations (an exact version of the approach of Ref. 14). Agreement with the results of the quite different application of analyticity constraints in the first paper is in general good, which justifies the use of Mandelstam analyticity in partial-wave analysis. A smooth solution, taking the S and P waves from Ref. 13 and the D and higher waves from Ref. 11, is being prepared. The solution will be checked by calculating the zero trajectories and should be a good starting solution in the analysis of new data.

The data are still too poor for a good test of predictions for the highest resonances (masses > 2.2 GeV). Evidence for resonances in this range has been reported by Koch[6] and by Hendry.[15] See also Ref. 7.

***Determination of resonance parameters*:** Since a dynamical theory of πN scattering does not yet exist, the resonance parameters are not uniquely defined. One can fit a partial-wave amplitude with a phenomenological ansatz consisting of a generalized Breit-Wigner form plus a background term, and most of the earlier analyses, including the first CMU-LBL analysis and the KH 78 analysis,[6] used a prescription of this type. A more sophisticated multichannel coupled resonance scheme was used in the more recent work of the CMU-LBL group.[5] The parameters listed in the Baryon Summary Table were obtained using these methods.

A difficulty that becomes more and more important as the energy increases is that some "background terms" such as diffraction and ρ-exchange make contributions to the partial waves that resemble highly inelastic resonances (see Sec. 2.4.1.1 in Ref. 7). The energy dependences are different, but at high energies the speed with which an amplitude traverses the complex plane cannot be accurately determined due to insufficient data. Furthermore, it is a dynamical question whether this background is part of the resonance mechanism.

If the resonances are ordered according to the shapes of their Argand plots, one finds a continuous transition from textbook-type resonances to tiny wiggles superimposed on a huge background. The Baryon Summary Table lists all objects that have a "resonance-like" shape of the Argand diagram and a maximum of the speed. It is up to the reader to decide which of these objects are "resonances" in the framework of his or her model.

The above discussion shows that a comparison of the resonance masses listed in the Baryon Summary Table with predictions from lattice calculations or from quark-shell, bag, Skyrmion, or other models is quite uncertain, especially where mass differences are small, since the models cannot yet describe the scattering process and take into account the background.

A cautionary example has been given by Blankleider and Walker,[16] who used separable potentials for the reactions $\pi N \to \pi N$, $\pi N \to \pi\Delta$, and $\pi\Delta \to \pi\Delta$ and got excellent fits to the P_{11}, D_{13}, D_{15}, and S_{31} waves without explicitly introducing the lowest 4-star resonances in these waves. Since various parameters have been fitted, the authors do not claim that their mechanism explains the resonances. But the opening of an inelastic channel contributes to the shape of a resonant amplitude, as may also be seen from the partial wave dispersion relation (or from the discussion by Ball and Frazer[17]). This effect is disregarded in the usual extraction of resonance parameters from models.

The Baryon Listings contain a second set of resonance parameters, the locations and residues of the resonance poles on the second sheet of the s plane. These may be determined in a (more or less) model-independent way. Table 2 summarizes some of the recent results.[2(b),5,12] Note, however, that Fonda et al.[18] were able to fit the resonant P_{33} amplitude *without a pole*. A theoretical assumption that excludes parametrizations of this type is needed.

Remarkably, there exist families of resonances in which the splittings of the pole positions are comparable with the errors; i.e., degeneracy is not excluded.[7] For example, all six isospin-1/2 partial waves from S_{11} to F_{15} have a well-established resonance with a pole near $\sqrt{s}$ = (1665-60i) MeV, and at least six of the seven possible isospin-3/2 resonances from S_{31} to F_{37} have a pole near (1880-120i) MeV.

We have not included in the Listings the zeros of the partial-wave amplitudes given in Ref. 2(b) because a zero in the neighborhood of a resonance pole gives only information on the background. However, zero trajectories of the invariant and transversity amplitudes may be of fundamental importance (see Sect. 2.4.3 in Ref. 7).

***Inelastic 2-body reactions*:** Partial-wave analyses of the inelastic 2-body reactions $\pi N \to N\eta$, ΛK, and ΣK are similar to $\pi N \to \pi N$ analyses. However, since the data are far less complete and accurate, energy-dependent parametrizations must be used.

Table 2. Recent determinations of pole parameters of 3- and 4-star N and Δ resonances. Cutkosky et al.[5] and Arndt et al.[2(b)] have taken into account inelastic channels in the isobar approximation. In general, a resonance has a pole in several sheets of the energy plane. The parameters here are of the pole reached most directly from the physical region. In certain cases, this condition is ambiguous because a strong inelastic channel ($\Delta\pi$, $N\eta$, $N\rho$, etc.) opens within the width of the resonance. If theoreticians working on quark or bag models use the parameters, they should keep in mind that their models do not include the effects caused by the opening of inelastic channels.[16] In particular, they should not try to describe the two poles given by Arndt et al.[2(b)] for the $N(1440)\ P_{11}$. A splitting of this resonance was claimed earlier from an analysis of the elastic data alone, but this was not tenable (see the remark in Sec. 2.1.8 of Ref. 7). The pole parameters determined by M. Sararu[12] for a selection of resonances follow from Koch's smoothed version[11] of the Karlsruhe solution without taking into account data for inelastic scattering.

	Pole position (MeV)		Residue		
Resonance	Re W	$-2\times\mathrm{Im}\,W$	$\lvert r \rvert$ (MeV)	θ (°)	Ref.†
$N(1440)\ P_{11}$	1375 ± 30	180 ± 40	52 ± 5	-100 ± 35	C
	1355	200	62	-108	A
	1416	156	118	-4	
$N(1520)\ D_{13}$	1510 ± 5	114 ± 10	35 ± 2	-12 ± 5	C
	1508	124	40	-9	A
$N(1535)\ S_{11}$	1510 ± 50	260 ± 80	120 ± 40	$+15\pm45$	C
	1464	150	40	-44	A
$N(1650)\ S_{11}$	1640 ± 20	150 ± 30	60 ± 10	-75 ± 25	C
	1656	108	34	-54	A
$N(1675)\ D_{15}$	1660 ± 10	140 ± 10	31 ± 5	-30 ± 10	C
	1658	136	32	-20	A
$N(1680)\ F_{15}$	1667 ± 5	110 ± 10	34 ± 2	-25 ± 5	C
	1668	110	33	-18	A
	1671	122	25	-20	S
$N(1700)\ D_{13}$	1660 ± 30	90 ± 40	6 ± 3	0 ± 50	C
	1676	48	2	$+43$	A
$N(1710)\ P_{11}$	1690 ± 20	80 ± 20	8 ± 2	$+175\pm35$	C
	(not seen)				A
$N(1720)\ P_{13}$	1680 ± 30	120 ± 40	8 ± 2	-160 ± 30	C
	1690	66	3.7	-138	A
	1670	188	8	-127	S
$N(2190)\ G_{17}$	2100 ± 50	400 ± 160	25 ± 10	-30 ± 50	C
	2056	580	40	-18	S
$N(2220)\ H_{19}$	2160 ± 80	480 ± 100	45 ± 20	-45 ± 25	C
	2130	340	19	-47	S
$N(2250)\ G_{19}$	2150 ± 50	360 ± 100	20 ± 6	-50 ± 20	C
$N(2600)\ I_{1\,11}$	2589	460			S
$\Delta(1232)\ P_{33}$	1210 ± 1	100 ± 2	53 ± 2	-47 ± 1	C
	1211	102	56	-30	A
	1209	100			S
$\Delta(1620)\ S_{31}$	1600 ± 15	120 ± 20	15 ± 2	-110 ± 20	C
	1592	108	13	-117	A
$\Delta(1700)\ D_{33}$	1675 ± 25	220 ± 40	13 ± 3	-20 ± 25	C
	1674	336	32	-24	A
	1680	226	14	$+34$	S
$\Delta(1900)\ S_{31}$	1870 ± 40	180 ± 50	10 ± 3	$+20\pm40$	C
$\Delta(1905)\ F_{35}$	1830 ± 40	280 ± 60	25 ± 8	-50 ± 20	C
	1872	228	23	-13	A
	1850	220	10	-11	S
$\Delta(1910)\ P_{31}$	1880 ± 30	200 ± 40	20 ± 4	-90 ± 30	C
	1883	392	27	-89	S
$\Delta(1920)\ P_{33}$	1900 ± 80	300 ± 100	24 ± 4	-150 ± 30	C
	(not seen)				A
$\Delta(1930)\ D_{35}$	1890 ± 50	260 ± 60	18 ± 6	-20 ± 40	C
$\Delta(1950)\ F_{37}$	1890 ± 15	260 ± 40	50 ± 7	-33 ± 8	C
	1864	216	50	-20	A
	1890	242	32	-22	S
$\Delta(2420)\ H_{3\,11}$	2360 ± 100	420 ± 100	18 ± 6	-30 ± 40	C

†C = Cutkosky et al.,[5] A = Arndt et al.,[2(b)] and S = Sararu.[12]

The best results, which give resonance masses and widths as well as couplings, follow from the $\pi^- p \rightarrow \Lambda K^0$ data of the Rutherford group.[19] In one analysis, the nonresonant and high waves were represented by a reggeized K^* exchange term.[19,20] In another analysis, a Lagrangian model was used for the long-range forces.[21] In general, agreement with the $\pi N \rightarrow \pi N$ analyses is good, but there are discrepancies for the $P_{11}\ N(1710)$ and $D_{15}\ N(1675)$ widths and for the $D_{15}\ N(2200)$ mass.

In an analysis of the less accurate $\pi^- p \rightarrow n\eta$ data,[22] the partial waves were parametrized as Breit-Wigner resonances without background. The resonance spectrum was assumed and the data were used to determine the $n\eta$ couplings. For resonances with relatively large couplings, the masses and widths were varied in a second step.

The results derived from the bubble-chamber data for $\pi^+ p \rightarrow \Sigma^+ K^+$ [23] have large uncertainties. Values of the resonance masses were assumed and Breit-Wigner forms and an empirical ansatz for the background were used for partial waves up to F waves (the G waves are probably not negligible at 1.7 GeV/c). The recent addition of precise data from 1820 to 2350 MeV[24] has allowed an improved analysis.[25] The solution found is unique. Above 2 GeV, all the resonances with two or more stars are seen, but none of the 1-star states is supported.

In a recent note,[26] Isgur has pointed out that distortions of resonance couplings can occur in cases such as $\pi N \rightarrow \Delta \rightarrow \Sigma K$ if the threshold is just below the resonance mass.

A possible new resonance, an $N(1960)$, has been detected in the final state $\Sigma(1385)^- K^+$ in neutron carbon reactions.[27] If confirmed, the small width (27 ± 15 MeV) indicates an exotic nature.

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III. The $\pi N \rightarrow N\pi\pi$ reaction

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Dalitz plots reveal that the $\pi N \rightarrow N\pi\pi$ reaction is dominated by the formation of N and Δ resonances which decay into quasi-2-body channels. This observation prompts the analysis of this reaction by isobar models in which the partial-wave amplitudes are represented by a coherent sum over quasi-2-body channels, such as $\pi N \rightarrow \Delta(1232)\pi$, $\pi N \rightarrow N\rho$, $\pi N \rightarrow N(\pi\pi)_S$, and $\pi N \rightarrow N(1440)\pi$, where $(\pi\pi)_S$ is the strong isospin-0, S-wave $\pi\pi$ interaction. The resulting fitted amplitudes contain valuable information about the couplings of the N and Δ resonances to the quasi-2-body channels.

While the analyses determine the relative phases of the quasi-2-body amplitudes, their overall phase is arbitrary. In this edition, all couplings are expressed according to the "baryon-first" convention,[1] with the overall phase determined by choosing the coupling sign of the S_{31} $\Delta(1620)$ to the $\Delta\pi$ channel to be negative. Experimentally, this coupling is strong in all analyses performed thus far. Furthermore, quark-model calculations for this coupling are simplified by the absence of other low-mass S_{31} resonances. Further details of the isobar-model formalism and a definition of the couplings are given in our 1982 edition.[2]

The Baryon Summary Table includes branching fractions for the $N\pi\pi$ quasi-2-body channels. For this edition, these branching fractions were re-evaluated (a number of the branching fractions have been changed considerably) based upon the results of five energy-independent partial-wave analyses (IPWA), one of which is new. The Listings give the results from these five. Further details of the four older analyses are also discussed in our 1982 edition.

LONGACRE 75 and 78 (LBL-SLAC)[3] are resonance analyses of the partial-wave solution of Herndon et al.,[4] which was obtained from an isobar-model analysis of 170,000 $\pi^- p \rightarrow n\pi^-\pi^+$, $\pi^- p \rightarrow p\pi^-\pi^0$, and $\pi^+ p \rightarrow p\pi^+\pi^0$ events between 1300 and 1990 MeV c.m. energy. The $\Delta(1232)\pi$, $N\rho$, and $N(\pi\pi)_S$ channels were included. The couplings and T-matrix poles of nine N and five Δ resonances are given in the Listings.

LONGACRE 77 (Saclay)[5] is a similar analysis of 91,000 events between 1360 and 1760 MeV. This work, unlike that of Herndon et al.,[4] included a nonzero range in the centrifugal barrier term that enters into the isobar-model parametrization. The importance of a nonzero range has been discussed by Dolbeau et al.[1] Several waves (especially $N\rho$ waves) that were small in the LBL-SLAC solution[4] contribute significantly in this analysis, mainly because of the choice of a nonzero-range barrier. The Listings include couplings and pole positions for ten N and six Δ resonances, including a $P_{13}N(1540)$ and a $P_{31}\Delta(1550)$, which this analysis suggested for the first time.

NOVOSELLER 78 (Cal Tech)[6] is an analysis between 1630 and 1990 MeV based in part on the analysis of Herndon et al.[4] Starting with the LBL-SLAC solution as input, a solution was generated without the unitarity constraints imposed by Herndon et al.[4] Another solution was generated in a similar manner by including in the fit a high-partial-wave background derived from single-pion exchange. The most important contribution from this background is in the D-wave $N\rho$ channel of the G_{17} wave. It was concluded that the contribution from the $N\pi\pi$ channel, with the two pions in the isospin-2 Swave, is small below 1970 MeV. It also was concluded that the solution of Herndon et al.[4] may be questionable for the P_{11}, P_{13}, and F_{35} waves above 1700 MeV because of inconsistencies in the solutions obtained under different fitting conditions.

BARNHAM 80 (Imperial College)[7] is an analysis of 44,000 $\pi^+p \to p\pi^+\pi^0$ and $\pi^+p \to n\pi^+\pi^+$ events between 1400 and 1700 MeV. The analysis included $\Delta(1232)\pi$, $N\rho$, and $N(1440)\pi$ channels, and used a zero-range barrier. Evidence was found for the $P_{31}\Delta(1550)$ seen by LONGACRE 77, and for significant decay of the $P_{33}\Delta(1600)$ into $N(1440)\pi$, a mode first considered by this analysis. The Listings include couplings for four Δ resonances.

MANLEY 84 (VPI&SU)[8] is a major new analysis of 241,000 $\pi^-p \to n\pi^-\pi^+$, $\pi^-p \to p\pi^-\pi^0$, $\pi^+p \to p\pi^+\pi^0$, and $\pi^+p \to n\pi^+\pi^+$ events between 1320 and 1930 MeV. The main channels considered were $\Delta(1232)\pi$, $N\rho$, $N(\pi\pi)_S$, and $N(1440)\pi$. Also investigated, however, were the channels $N(1520)\pi$, $N(1535)\pi$, and $N(1675)\pi$. Actual resonance parameters have not been published, so the Listings include only the signs and sizes (large or small) of the couplings. The analysis used a nonzero-range centrifugal barrier factor, and for the first time investigated the importance of partial waves with $L > 3$ (G waves).

The analysis found evidence for a large D-wave $N\rho$ decay in the G_{17} wave, possibly associated with the $G_{17}N(2190)$. Unlike earlier analyses, essentially all inelasticity in the P_{31} wave was accounted for by decay into $N(1440)\pi$. A large $N(1440)\pi$ decay for the $P_{33}\Delta(1600)$ was found, as did BARNHAM 80. No evidence was found for the $P_{13}N(1540)$ and $P_{31}\Delta(1550)$ claimed by LONGACRE 77 and BARNHAM 80. In agreement with LONGACRE 75, no evidence was found for an $N\pi\pi$ decay of the $D_{35}\Delta(1930)$, even though πN elastic analyses predict a large inelastic decay for this resonance. Also in agreement with LONGACRE 75, a large F-wave $\Delta(1232)\pi$ decay was found for the $F_{37}\Delta(1950)$, although the resonant phases determined by the two analyses differ by about 60°. It was pointed out[8] that this conflict could be resolved if the large P-wave $N\rho$ decay observed by LONGACRE 75 and MANLEY 84 in the F_{35} wave were associated with a second resonance, an $F_{35}\Delta(2000)$, above the $F_{35}\Delta(1905)$. This higher mass F_{35} resonance is of interest because it is predicted by the Isgur-Karl quark model;[9] failure to observe it in πN elastic analyses is not surprising since it should couple weakly to the πN channel.

This analysis also found tentative evidence for several new resonances, including a P_{13} and an F_{15} at about 1850 MeV, and an S_{11}, a P_{11}, and a D_{13} at about 1900 MeV. (Since no actual masses or other parameters have been published, these resonances are not included in the Listings.)

Table 3 gives a compilation, adapted in part from MANLEY 84, of the signs of the $\pi N \to N\pi\pi$ couplings. Only those decay channels found to be significant in at least one analysis are included.

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Table 3. The signs of the $\pi N \rightarrow N\pi\pi$ couplings according to four analyses. Letter subscripts give the final-state orbital angular momenta. The ρ states are labeled by twice the total final-state spin, $2S$. A "0" indicates a negligibly small coupling. A question mark indicates the sign is indeterminant or questionable because the resonant amplitude is rotated more than 70° away from the imaginary axis. An asterisk at the right indicates the coupling sign is considered to be well established by Manley 84.

Resonance	Decay channel	Long-acre 75,78[3]	Long-acre 77[5]	Barn-ham 80[7]	Manley 84[8]	
$N(1440)\ P_{11}$	$(\Delta\pi)_P$	+	+		+	*
	$(N\rho_1)_P$	−	−?		0	
	$(N\rho_3)_P$	0	+		0	
	$N(\pi\pi)_S$	−?	−		+	
$N(1520)\ D_{13}$	$(\Delta\pi)_S$	−	−		−	*
	$(\Delta\pi)_D$	−	−		−	*
	$(N\rho_3)_S$	−	−?		−	*
	$N(\pi\pi)_S$	−	−?		0	
$N(1535)\ S_{11}$	$(\Delta\pi)_D$	+?	0		0	
	$(N\rho_1)_S$	−	−?		−	*
	$N(\pi\pi)_S$	+	+		+	*
$N(1540)\ P_{13}$	$(\Delta\pi)_P$		−?		0	
	$(N\rho_1)_P$		+		0	
$N(1650)\ S_{11}$	$(\Delta\pi)_D$	−	+		+	*
	$(N\rho_1)_S$	−?	+?		−	
	$(N\rho_3)_D$	0	+		+?	
	$N(\pi\pi)_S$	+	0		+	
$N(1675)\ D_{15}$	$(\Delta\pi)_D$	+	+		+	*
	$(N\rho_3)_D$	0	−		−	
	$N(\pi\pi)_S$	0	+		0	
$N(1680)\ F_{15}$	$(\Delta\pi)_P$	−	−		−	*
	$(\Delta\pi)_F$	+	+		+	*
	$(N\rho_3)_P$	−	−		−	*
	$(N\rho_3)_F$	0	−		−	
	$N(\pi\pi)_S$	+	+		+	*
$N(1700)\ D_{13}$	$(\Delta\pi)_S$	−	0		−?	
	$(\Delta\pi)_D$	+	−?		+	
	$(N\rho_3)_S$	+	−?		0	
	$N(\pi\pi)_S$	+	0		+	
$N(1710)\ P_{11}$	$(\Delta\pi)_P$	+	−		−	
	$(N\rho_1)_P$	−	+		+	
	$(N\rho_3)_P$	0	+		0	
	$N(\pi\pi)_S$	−?	−		−?	
$N(1720)\ P_{13}$	$(\Delta\pi)_P$	0	−		0	
	$(N\rho_1)_P$	+	−		0	
	$(N\rho_3)_P$	0	+		0	
	$N(\pi\pi)_S$	0	−		0	
$\Delta(1550)\ P_{31}$	$(\Delta\pi)_P$		−	?	0	
	$(N\rho_3)_P$		−	?	0	
$\Delta(1600)\ P_{33}$	$(\Delta\pi)_P$	+	+	+	+	*
	$(\Delta\pi)_F$	0	−?	?	0	
	$(N\rho_1)_P$	0	+	?	0	
	$(N\rho_3)_P$	0	+	?	0	
	†$(N^*\pi)_P$			+	+	*
$\Delta(1620)\ S_{31}$	$(\Delta\pi)_D$	−	−	−	−	*
	$(N\rho_1)_S$	+	+	+	+	*
	$(N\rho_3)_D$	0	−	?	−	
$\Delta(1700)\ D_{33}$	$(\Delta\pi)_S$	+	+	+	+	*
	$(\Delta\pi)_D$	+?	+	?	+	*
	$(N\rho_1)_D$	0	0	+	0	
	$(N\rho_3)_S$	−	+?	?	+	
$\Delta(1905)\ F_{35}$	$(\Delta\pi)_P$	0			+	
	$(\Delta\pi)_F$	+			+	*
$\Delta(1910)\ P_{31}$	$(\Delta\pi)_P$		+		0	
	$(N\rho_3)_P$		+		0	
	†$(N^*\pi)_P$				+	
$\Delta(1950)\ F_{37}$	$(\Delta\pi)_F$	+			+	*
	$(N\rho_3)_F$	+?			0	
$\Delta(2000)\ F_{35}$	$(N\rho_3)_P$	+			+	*

†The N^* here is the P_{11} $N(1440)$.

IV. Photoproduction and Compton scattering

(by R.L. Crawford, University of Glasgow)

The γN couplings of the N and Δ resonances are obtained from partial-wave analyses of single-pion photoproduction on protons and neutrons and of Compton scattering on protons. The definitions of the couplings and a discussion of the methods used in the analyses may be found in our 1976 edition.[1] The large amount of pion photoproduction data, including many measurements from single and double polarization experiments, has permitted accurate measurement of many of the couplings and determination of the signs of many more. Recently, photon couplings in the second and third resonance regions have also been obtained from accurate measurements of proton Compton-scattering differential cross sections; the results, with a few exceptions, agree with those from photoproduction. All these analyses rely heavily upon $\pi N \rightarrow \pi N$ analyses for information on the existence, masses, and widths of the resonances. The only photoproduction analyses that quote resonance masses and widths as well as couplings are BERENDS 75, BERENDS 77, BARBOUR 78, and CRAWFORD 80. These results are of interest since they give access to the charge +1 states of the resonances. In particular, the mass of the $\Delta(1232)^+$ seems to be as well determined as those of the Δ^{++} and Δ^0 seen in elastic πN scattering.

There are three main methods of analysis.

(*a*) *The simple isobar model*: The simple isobar model is an energy-dependent partial-wave analysis (DPWA) in which the partial waves are parametrized as Breit-Wigner resonances plus background. The model is relatively simple but is flexible enough to give good fits. However, there are possible problems about the uniqueness of the solutions obtained, and it is not clear how the form of the parametrization distorts the solutions.

The Listings give the results of the isobar analyses of TAKEDA 80 and BRATASHEVSKIJ 80 (photoproduction), and of ISHII 80 and WADA 84 (Compton scattering). The two photoproduction analyses use small data sets. The large-scale isobar analysis of METCALF 74 is now obsolete and has been omitted.

(*b*) *Fixed-t dispersion relations* (*FTDR*): Here only the imaginary parts of the production amplitudes are parametrized, and the real parts are calculated from them using fixed-t dispersion relations. The resonance dominance of the imaginary parts permits a relatively simple parametrization scheme, and there are fewer ambiguity problems than in the isobar model. However, it is less flexible than the isobar model and gives poorer fits, and it can only be used properly in a large-scale analysis over a wide energy range.

The Listings give the results from the FTDR analyses of AZNAURYAN 77, BARBOUR 78, ARAI 80, CRAWFORD 80, FUJII 81, and AWAJI 81. NOELLE 78 is a hybrid analysis using FTDR in a coupled-channel isobar calculation.

*(c) **Energy-independent analyses (IPWA)***: These evaluate the partial-wave amplitudes by fitting at essentially single energies. At low energies, Watson's theorem is used to fix the complex phases of many of the partial waves. This allows a unique solution but becomes difficult above the first resonance region due to the onset of inelasticity. BERENDS 77 is the only true IPWA that has been extended into the second resonance region. CRAWFORD 83 is an IPWA that depends on the CRAWFORD 80 FTDR analysis to give stable solutions, and is thus not independent of the energy-dependent analysis.

New data in the Listings: Reflecting the decline in interest in baryon physics, there is only one new analysis in the Listings. WADA 84 is an isobar-model analysis of Compton scattering on protons using data on differential cross sections in the second and third resonance regions. Most of the couplings agree well with previously determined values from photoproduction. The exceptions are $A^p_{1/2}$ for the $P_{11}\,N(1440)$ and the $P_{33}\,\Delta(1600)$, which disagree badly with other measurements, particularly with those from photoproduction. However, these results should not yet be taken seriously since the quality of the photoproduction data is much higher and restricts the values of the couplings more strongly than do the Compton scattering data. Also, WADA 84 does not fit the couplings of all the resonances in the energy range of the analysis. Many of the more important couplings are not varied but are given values from the photoproduction analysis of AWAJI 81. Fitting all the couplings might give results for them all that are compatible with the photoproduction results.

The Baryon Summary Table now gives the $N\gamma$ branching fractions for the resonances whose couplings are considered to have an unambiguous sign. These branching fractions have been calculated from the couplings given by the most reliable analyses in the Listings using the partial width

$$\Gamma_\gamma = \frac{k^2}{\pi}\,\frac{2M_N}{M_R(2J+1)}\left[\,|A_{1/2}|^2 + |A_{3/2}|^2\,\right],$$

where M_N and M_R are the masses of the nucleon and resonance, J is the resonance spin, and k is the c.m. decay momentum.

Resonance couplings in the Listings: The Listings omit a number of analyses that now must be considered to be obsolete. These are ROSSI 73, HEMMI1 73, HEMMI2 73, BENEVENTANO 74, METCALF 74, KRIVETS 75 (all isobar model), MOORHOUSE 73, DEVENISH 73, KNIES 74, MOORHOUSE 74, DEVENISH2 74, CRAWFORD 75, and BARBOUR 76 (all FTDR). They may all be found in our 1982 edition.[7]

The errors quoted for the couplings in the Listings are calculated in different ways in the different analyses. They are therefore not comparable and should be used with care. FELLER 76, AZNAURYAN 77, and ARAI 80 obtain errors using the sensitivity of the "best possible" χ^2 to the value of each coupling. BARBOUR 78, CRAWFORD 80, and CRAWFORD 83 attempt to assess the effects of the systematic errors caused by the different possible parametrization schemes, especially those for the background, and quote errors that reflect this. AWAJI 81 gives errors which also include a contribution from the uncertainty in the πN elasticity used to calculate the couplings from the partial waves.

In general, it is likely that the systematic differences between the analyses caused by the different parametrization schemes are more indicative than are the individual errors quoted in each analysis.

Table 4 gives a compilation of the couplings from BARBOUR 78, ARAI 80, CRAWFORD 80, FUJII 81, AWAJI 81, and CRAWFORD 83. The errors given are a combination of the statistical errors quoted in the analyses and the systematic differences between them. The Table is unchanged from the previous edition except that two values are quoted for $A_{1/2}$ of the $S_{31}\,\Delta(1620)$ to take account of the large spread in values obtained for this coupling. This can be attributed to imaginary background in the partial wave, which is treated differently, or ignored, in the different analyses. The second value uses only the Glasgow analyses (BARBOUR 78, CRAWFORD 80, and CRAWFORD 83). The Glasgow FTDR analyses obtain stable and acceptable values for the mass and width of this resonance, and it is thus reasonable to infer that the coupling obtained is accurate.

Table 4. A compilation of measured γN decay couplings. Sources are given in the text.

(a) Proton-target couplings

Resonance	Helicity	Couplings ($\mathrm{GeV}^{-1/2} \times 10^{-3}$)	Status
$N(1440)\,P_{11}$	1/2	-69 ± 7	good
$N(1520)\,D_{13}$	1/2	-22 ± 10	good
	3/2	$+167 \pm 10$	good
$N(1535)\,S_{11}$	1/2	$+73 \pm 14$	good
$N(1650)\,S_{11}$	1/2	$+48 \pm 16$	good
$N(1675)\,D_{15}$	1/2	$+19 \pm 12$	good, nonzero
	3/2	$+19 \pm 12$	good, nonzero
$N(1680)\,F_{15}$	1/2	-17 ± 10	good, nonzero
	3/2	$+127 \pm 12$	good
$N(1700)\,D_{13}$	1/2	-22 ± 13	good, small
	3/2	0 ± 19	fair, small
$N(1710)\,P_{11}$	1/2	$+5 \pm 16$	fair, small
$N(1720)\,P_{13}$	1/2	$+52 \pm 39$	poor
	3/2	-35 ± 24	fair
$N(1990)\,F_{17}$	1/2	$+24 \pm 30$	poor
	3/2	$+31 \pm 55$	bad
$\Delta(1232)\,P_{33}$	1/2	-141 ± 5	very good
	3/2	-258 ± 11	very good
$\Delta(1550)\,P_{31}$	1/2	$+16 \pm 16$	doubtful
$\Delta(1600)\,P_{33}$	1/2	-20 ± 29	poor, small
	3/2	$+1 \pm 22$	fair, small
$\Delta(1620)\,S_{31}$	1/2	$+19 \pm 16$	fair
	(1/2	$+30 \pm 10$	good -- see text)
$\Delta(1700)\,D_{33}$	1/2	$+116 \pm 17$	good
	3/2	$+77 \pm 28$	fair
$\Delta(1900)\,S_{31}$	1/2	$+10 \pm$?	?
$\Delta(1905)\,F_{35}$	1/2	$+27 \pm 13$	good
	3/2	-47 ± 19	fair
$\Delta(1910)\,P_{31}$	1/2	-12 ± 30	poor
$\Delta(1920)\,P_{33}$	1/2	$+40 \pm$?	?
	3/2	$+23 \pm$?	?
$\Delta(1930)\,D_{35}$	1/2	-30 ± 40	poor
	3/2	-10 ± 35	poor
$\Delta(1950)\,F_{37}$	1/2	-73 ± 14	good
	3/2	-90 ± 13	good

(b) Neutron-target couplings

Resonance	Helicity	Couplings ($\mathrm{GeV}^{-1/2} \times 10^{-3}$)	Status
$N(1440)\,P_{11}$	1/2	$+37 \pm 19$	fair
$N(1520)\,D_{13}$	1/2	-65 ± 13	good
	3/2	-144 ± 14	good
$N(1535)\,S_{11}$	1/2	-76 ± 32	fair
$N(1650)\,S_{11}$	1/2	-17 ± 37	poor
$N(1675)\,D_{15}$	1/2	-47 ± 23	fair
	3/2	-69 ± 19	fair
$N(1680)\,F_{15}$	1/2	$+31 \pm 13$	good
	3/2	-30 ± 14	good
$N(1700)\,D_{13}$	1/2	0 ± 56	bad
	3/2	-2 ± 44	bad
$N(1710)\,P_{11}$	1/2	-5 ± 23	fair, small
$N(1720)\,P_{13}$	1/2	-2 ± 26	fair, small
	3/2	-43 ± 94	very bad
$N(1990)\,F_{17}$	1/2	-49 ± 45	poor
	3/2	-122 ± 55	poor

The E/M ratio of the $P_{33}\Delta(1232)$: There is continuing interest in the E_2/M_1 ratio of the $\Delta(1232)$. In the simplest form of the quark model, it is predicted to be zero,[2] but in more recent models this is not the case,[3] an effect attributed to tensor quark-quark forces giving D-wave components in the wave functions. Tanabe and Ohta[4] have evaluated the ratio using a phenomenological model, derived from the work of Olsson,[5] which includes nonresonant background not usually included when extracting the $\Delta \rightarrow N\gamma$ couplings. Effectively, this work defines renormalized couplings that are evaluated by fitting the model to the partial waves from the IPWA of BERENDS 75. The couplings obtained are $A_{1/2} = -0.093 \pm 0.005\ \mathrm{GeV}^{-1/2}$ and $A_{3/2} = -0.142 \pm 0.009\ \mathrm{GeV}^{-1/2}$. These are not included in the Listings since it is not clear that they are the same quantities as are given there. The E_2/M_1 ratio obtained is $+0.037 \pm 0.004$. A more recent, unpublished analysis, also based on the approach of Olsson and using IPWA of the first resonance region, has been carried out by Davidson, Mukhopadhyay, and Wittman.[6] The values obtained are $A_{1/2} = -0.125 \pm 0.003\ \mathrm{GeV}^{-1/2}$, $A_{3/2} = -0.229 \pm 0.006\ \mathrm{GeV}^{-1/2}$, and $E_2/M_1 = -0.015 \pm 0.002$.

It should be noted that the errors in the compiled values of $A_{1/2}$ and $A_{3/2}$ in Table 4 do not accurately reflect the precision with which E_2/M_1 is given in the Listings, since the errors contain components, such as in overall normalization, that do not contribute to this ratio. Calculation of E_2/M_1 from the individual entries and then combining them gives -0.013 ± 0.005.

References for section IV

1. Particle Data Group, Rev. Mod. Phys. **48**, S157 (1976).
2. C.M. Becchi and G. Morpurgo, Phys. Lett. **17**, 352 (1965).
3. N. Isgur, G. Karl, and R. Koniuk, Phys. Rev. **D25**, 2394 (1983); G. Kälbermann and J.M. Eisenberg, Phys. Rev. **D28**, 71 (1983); J. Dey and M. Dey, Phys. Lett. **138B**, 200 (1984); and D. Drechsel and M.M. Giannini, Phys. Lett. **143B**, 329 (1984).
4. H. Tanabe and K. Ohta, Phys. Rev. **C31**, 1876 (1985).
5. M.G. Olsson, Nucl. Phys. **B78**, 55 (1974).
6. R. Davidson, N.C. Mukhopadhyay, and R. Wittman, Preprint, Rensselaer Polytechnic Inst., New York (1985).
7. Particle Data Group, Phys. Lett. **111B** (1982).

V. Electroproduction

The excitation of the N and Δ resonances has been investigated using pion and η electroproduction data. However, the level of activity in this field is presently low, and the interested reader is referred to our 1982 edition[1] and to an extensive review.[2]

Since 1982, additional information has been obtained from π^+ electroproduction about the switching in dominance of the helicity 3/2 and 1/2 amplitudes of the D_{13} $N(1520)$ and F_{15} $N(1680)$ as Q^2 moves from the photoproduction limit.[3] In η electroproduction,[4] the Q^2 dependence of the S_{11} $N(1535)$ cross section has been examined for Q^2 up to 3 GeV^2. It is found that the slow decrease of production of the S_{11} compared to that of the D_{13} $N(1520)$ continues to these values of Q^2. Both these features of electroproduction are already well known and have been described in the reviews mentioned above.

References for section V

1. Particle Data Group, Phys. Lett. **111B** (1982).
2. F. Foster and G. Hughes, Rep. Prog. Phys. **46**, 1445 (1983).
3. H. Breuker et al., Zeit. Physik **C13**, 113 (1982).
4. F.W. Brasse et al., Zeit. Physik **C22**, 33 (1984).

VI. Production experiments

Partial-wave analyses of course separate partial waves, whereas a peak in a cross section or an invariant mass distribution usually cannot be disentangled from background and analyzed for its quantum numbers; and more than one resonance may be contributing to the peak. We used to have separate entries in the Baryon Listings for bumps seen in production experiments in the 1440-MeV region, the 1520-MeV region, etc., but these have been removed. They last appeared in our 1982 edition.[1]

Reference for section VI

1. Particle Data Group, Phys. Lett. **111B** (1982).

N BARYONS ($S=0$, $I=1/2$)

$\boxed{p}$

$I(J^P)=\frac{1}{2}(\frac{1}{2}^+)$

SEE STABLE PARTICLES.

$\boxed{n}$

$I(J^P)=\frac{1}{2}(\frac{1}{2}^+)$

SEE STABLE PARTICLES.

$\boxed{N(1440)\ P_{11}}$

$I(J^P)=\frac{1}{2}(\frac{1}{2}^+)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

IN ADDITION, RESULTS IN THIS REGION FROM PRODUCTION EXPERIMENTS, WHICH USED TO BE LISTED SEPARATELY AS THE NEXT ENTRY, HAVE BEEN ENTIRELY REMOVED. THEY TOO MAY BE FOUND IN OUR 1982 EDITION.

$N(1440)$ MASS (MeV)

```
M    A     1415. OR 1390.            LONGACRE  75 IPWA    PI N TO 2PI N
M    A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M         (1460.0)                   BERENDS   77 IPWA    PI-N PHOTOPROD.
M    B    (1380.0)                   LONGACRE  77 IPWA    PI N TO 2PI N
M    B  ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M    B  POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M         (1417.0)                   BARBOUR   78 DPWA    PI-N PHOTOPROD.
M    C    (1472.0)                   BAKER     79 DPWA  0 PI- P TO ETA N
M         (1450.0)   (30.0)          CUTKOSKY  79 IPWA    PI N TO PI N
M          1410.0     12.0           HOEHLER   79 IPWA    PI N TO PI N
M         (1411.0)                   CRAWFORD  80 DPWA    PI N PHOTOPROD.
M          1440.0     30.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1440)$ WIDTH (MeV)

```
W    A      180. OR  200.            LONGACRE  75 IPWA    PI N TO 2PI N
W         (279.0)                    BERENDS   77 IPWA    PI-N PHOTOPROD.
W    B    (200.0)                    LONGACRE  77 IPWA    PI N TO 2PI N
W         (331.0)                    BARBOUR   78 DPWA    PI-N PHOTOPROD.
W    C    (113.0)                    BAKER     79 DPWA  0 PI- P TO ETA N
W         (370.0)   (80.0)           CUTKOSKY  79 IPWA    PI N TO PI N
W          135.0     10.0            HOEHLER   79 IPWA    PI N TO PI N
W         (334.0)                    CRAWFORD  80 DPWA    PI N PHOTOPROD.
W          340.0     70.0            CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1440)$ REAL PART OF POLE POSITION (MeV)

```
RE   B     1360.0 OR 1333.0          LONGACRE  77 IPWA    PI N TO 2PI N
RE         1381.0 OR 1379.0          LONGACRE  78 IPWA    PI N TO 2PI N
RE        (1369.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
RE         1375.0     30.0           CUTKOSKY  80 IPWA    PI N TO PI N
RE   F    (1359.)                    ARNDT     85 DPWA    PI N TO PI N
RE   F  ARNDT 84 FIND A SECOND P11 POLE AT (1410, -80) MEV.
```

$N(1440)$ −2*IMAG PART OF POLE POSITION (MeV)

```
IM   B      167.0 OR 234.0           LONGACRE  77 IPWA    PI N TO 2PI N
IM          209.0 OR 210.0           LONGACRE  78 IPWA    PI N TO 2PI N
IM         (178.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
IM          180.0     40.0           CUTKOSKY  80 IPWA    PI N TO PI N
IM   F     (200.)                    ARNDT     85 DPWA    PI N TO PI N
```

$N(1440)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER        (-9.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
RER         -9.0      31.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1440)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR        (-48.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
IMR         -51.0      7.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1440)$ ABSOLUTE VALUE OF POLE RESIDUE (MeV)

```
ABS          52.0      5.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1440)$ PHASE OF POLE RESIDUE (RADIANS)

```
PH           -1.75      0.61              CUTKOSKY  80 IPWA     PI N TO PI N
```

$N(1440)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1440) \rightarrow N\pi$	938+ 140
P2	$N(1440) \rightarrow N\eta$	940+ 549
P3	$N(1440) \rightarrow \Lambda K$	1116+ 498
P4	$N(1440) \rightarrow N\pi\pi$	938+ 140+ 140
P5	$N(1440) \rightarrow \Delta(1232)\ \pi$, P-wave	1232+ 140
P6	$N(1440) \rightarrow N\rho$, S=1/2, P-wave	938+ 769
P7	$N(1440) \rightarrow N\rho$, S=3/2, P-wave	938+ 769
P8	$N(1440) \rightarrow N(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P9	$N(1440) \rightarrow p\gamma$, helicity=1/2	938+ 0
P10	$N(1440) \rightarrow n\gamma$, helicity=1/2	940+ 0

$N(1440)$ BRANCHING RATIOS

$N(1440) \rightarrow (N\pi)$/total (P1)

```
R1           (0.65)    (0.05)             CUTKOSKY  79 IPWA     PI N TO PI N
R1            0.51      0.05              HOEHLER   79 IPWA     PI N TO PI N
R1            0.68      0.04              CUTKOSKY  80 IPWA     PI N TO PI N
```

$N(1440)$ in $N\pi \rightarrow N\eta$ SQRT(P1*P2)

```
R2  D       (+0.328)                      FELTESSE  75 DPWA  0 1488 TO 1745 MEV
R2  D   AN ALTERNATIVE WHICH CANNOT BE DISTINGUISHED FROM THIS IS TO HAVE
R2  D   A P13 RESONANCE WITH M=1530, W=79, AND COUPLING=+.271
R2  C   BAKER 79 FINDS A COUPLING OF THE N(1440) TO THE N ETA CHANNEL
R2  C   NEAR (BUT SLIGHTLY BELOW) THRESHOLD.

R       NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R              IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R              THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R              SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

$N(1440)$ in $N\pi \rightarrow \Delta(1232)\ \pi$, P-wave SQRT(P1*P5)

```
R3  A        +0.30 OR +0.37               LONGACRE  75 IPWA     PI N TO 2PI N
R3  B       (+0.41)                       LONGACRE  77 IPWA     PI N TO 2PI N
R3  B   LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R3  E        - (LARGE)                    MANLEY    84 IPWA     PI N TO 2PI N
R3  E   MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
```

$N(1440)$ in $N\pi \rightarrow N\rho$, S=1/2, P-wave SQRT(P1*P6)

```
R4  A         0.0  OR +0.23               LONGACRE  75 IPWA     PI N TO 2PI N
R4  B       (-0.11)                       LONGACRE  77 IPWA     PI N TO 2PI N
R4           (0.0)                        MANLEY    84 IPWA     PI N TO 2PI N
```

$N(1440)$ in $N\pi \rightarrow N\rho$, S=3/2, P-wave SQRT(P1*P7)

```
R5  B       (+0.18)                       LONGACRE  77 IPWA     PI N TO 2PI N
R5  B   LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R5           (0.0)                        MANLEY    84 IPWA     PI N TO 2PI N
```

$N(1440)$ in $N\pi \rightarrow N(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P8)

```
R6  A        -0.18 OR -0.23               LONGACRE  75 IPWA     PI N TO 2PI N
R6  B       (-0.18)                       LONGACRE  77 IPWA     PI N TO 2PI N
R6           + (LARGE)                    MANLEY    84 IPWA     PI N TO 2PI N
```

$N(1440)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(1440) \rightarrow p\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1           -0.087     0.006             FELLER    76 DPWA     PI N PHOTOPROD.
A1           -0.038     0.013             AZNAURYAN 77 DPWA     PI0 PHTPRD,SOL 1
A1           -0.019     0.011             AZNAURYAN 77 DPWA     PI0 PHTPRD,SOL 2
A1          (-0.076)                      BERENDS   77 IPWA     PI-N PHOTOPROD.
A1           -0.075     0.015             BARBOUR   78 DPWA     PI-N PHOTOPROD.
A1  N       (-0.125)                      NOELLE    78          PI-N PHOTOPROD.
A1  N   CONVERTED TO OUR CONVENTIONS USING M=1.486, W=.613 FROM NOELLE 78.
A1           -0.069     0.004             ARAI      80 DPWA     PI N PHOTO FIT 1
A1           -0.066     0.004             ARAI      80 DPWA     PI N PHOTO FIT 2
A1           -0.079     0.009             BRATASHEV 80 DPWA     PI N PHOTOPROD.
A1           -0.068     0.015             CRAWFORD  80 DPWA     PI N PHOTOPROD.
A1           -0.0584    0.0148            ISHII     80 DPWA     P COMPTON SCAT
A1           -0.063     0.008             AWAJI     81 DPWA     PI N PHOTOPROD.
A1           -0.069     0.018             CRAWFORD  83 IPWA     PI N PHOTOPROD.
A1  P       (-0.129)                      WADA      84 DPWA     COMPTON SCATT.
A1  P   INCONSISTENT WITH OTHER ANALYSES -- SEE MINI-REVIEW.
```

$N(1440) \rightarrow n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A2           +0.059     0.016             BARBOUR   78 DPWA     PI-N PHOTOPROD.
A2  N        (0.062)                      NOELLE    78          PI-N PHOTOPROD.
A2            0.023     0.009             ARAI      80 DPWA     PI N PHOTO FIT 1
A2            0.019     0.012             ARAI      80 DPWA     PI N PHOTO FIT 2
A2            0.056     0.015             CRAWFORD  80 DPWA     PI N PHOTOPROD.
A2           -0.029     0.035             TAKEDA    80 DPWA     PI N PHOTOPROD.
A2            0.037     0.010             AWAJI     81 DPWA     PI N PHOTOPROD.
A2            0.030     0.003             FUJII     81 DPWA     PI N PHOTOPROD.
```

REFERENCES FOR $N(1440)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
FELTESSE 75 NP B93 242        +AYED,BAREYRE,BORGEAUD,DAVID,ERNWEIN+(SACL)IJP
LONGACRE 75 PL 55B 415        +ROSENFELD,LASINSKI,SMADJA+     (LBL+SLAC)IJP
FELLER   76 NP B104 219       +FUKUSHIMA,HORIKAWA,KAJIKAWA+  (NAGO+OSAK)IJP
AZNAURYA 77  EFI-264(57)-77   +AKOPOV,BAGDASARYAN                 (YERE)IJP
BERENDS  77 NP B136 317       F A BERENDS,A DONNACHIE        (LEID+MCHS)IJP
LONGACRE 77 NP B122 493       LONGACRE,DOLBEAU                    (SACL)IJP
    ALSO 76 NP B108 365       DOLBEAU,TRIANTIS,NEVEU,CADIET       (SACL)IJP
BARBOUR  78 NP B141 253       BARBOUR,CRAWFORD,PARSONS            (GLAS)
LONGACRE 78 PR D17 1795       +LASINSKI,ROSENFELD,SMADJA+     (LBL+SLAC)
NOELLE   78 PTP 60 778        P NOELLE                            (NAGO)
BAKER    79 NP B156 93        +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+ (RHEL)IJP
CUTKOSKY 79 PR D20 2839       +FORSYTH,HENDRICK,KELLY         (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                              +KAISER,KOCH,PIETARINEN             (KARL)IJP
    ALSO 80  TORONTO CONF 3   R KOCH                              (KARL)IJP
ARAI     80  TORONTO CONF 93  I ARAI                              (TOKY)
    ALSO 82 NP B194 251       I ARAI, H FUJII                     (TOKY)
BRATASHE 80 NP B166 525       BRATASHEVSKIJ,GORBENKO,DEREBCHINSKIJ+(KHAR)
CRAWFORD 80  TORONTO CONF 107 R L CRAWFORD                        (GLAS)
CUTKOSKY 80  TORONTO CONF 19  +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
ISHII    80 NP B165 189       ISHII,EGAWA,KATO,MIYACHI+      (KYOT+TOKY)
TAKEDA   80 NP B168 17        TAKEDA,ARAI,FUJII,IKEDA,IWASAKI+    (TOKY)
AWAJI    81  BONN CONF 352    R KAJIKAWA (TALK)                   (NAGO)
    ALSO 82 NP B197 365       FUJII,HAYASHII,IWATA,KAJIKAWA+      (NAGO)
FUJII    81 NP B187 53        FUJII,HAYASHII,IWATA,KAJIKAWA+      (TOKY)
CRAWFORD 83 NP B211 1         R L CRAWFORD, W T MORTON            (GLAS)
MANLEY   84 PR D30 904        MANLEY,ARNDT,GORADIA,TEPLITZ         (VPI)
WADA     84 NP B247 313       +EGAWA,IMANISHI,ISHII,KATO,UKAI+    (INUS)
ARNDT    85 PR D32 1085       R A ARNDT, J M FORD, L D ROPER       (VPI)
```

$N(1520)\ D_{13}$

$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

IN ADDITION, RESULTS IN THIS REGION FROM PRODUCTION EXPERIMENTS, WHICH USED TO BE LISTED SEPARATELY AS THE NEXT ENTRY, HAVE BEEN ENTIRELY REMOVED. THEY TOO MAY BE FOUND IN OUR 1982 EDITION.

$N(1520)$ MASS (MeV)

```
M   A     1524. OR 1520.              LONGACRE  75 IPWA     PI N TO 2PI N
M   A   THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M        (1510.0)                     BERENDS   77 IPWA     PI-N PHOTOPROD.
M   B    (1510.0)                     LONGACRE  77 IPWA     PI N TO 2PI N
M   B   ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M   B   POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M        (1503.0)                     BARBOUR   78 DPWA     PI-N PHOTOPROD.
M        (1525.0)   (15.0)            CUTKOSKY  79 IPWA     PI N TO PI N
M         1519.0      4.0             HOEHLER   79 IPWA     PI N TO PI N
M        (1504.0)                     CRAWFORD  80 DPWA     PI N PHOTOPROD.
M         1525.0     10.0             CUTKOSKY  80 IPWA     PI N TO PI N
```

$N(1520)$ WIDTH (MeV)

```
W   A      120. OR  150.              LONGACRE  75 IPWA     PI N TO 2PI N
W         (105.0)                     BERENDS   77 IPWA     PI-N PHOTOPROD.
W   B     (110.0)                     LONGACRE  77 IPWA     PI N TO 2PI N
W         (135.0)                     BARBOUR   78 DPWA     PI-N PHOTOPROD.
W         (183.0)                     BAKER     79 DPWA   0 PI- P TO ETA N
W         (125.0)   (25.0)            CUTKOSKY  79 IPWA     PI N TO PI N
W          114.0      7.0             HOEHLER   79 IPWA     PI N TO PI N
W         (124.0)                     CRAWFORD  80 DPWA     PI N PHOTOPROD.
W          120.0     15.0             CUTKOSKY  80 IPWA     PI N TO PI N
```

$N(1520)$ REAL PART OF POLE POSITION (MeV)

```
RE  B     1508.0 OR 1505.0            LONGACRE  77 IPWA     PI N TO 2PI N
RE        1514.0 OR 1511.0            LONGACRE  78 IPWA     PI N TO 2PI N
RE       (1510.0)                     CUTKOSKY  79 IPWA     PI N TO PI N
RE        1510.0      5.0             CUTKOSKY  80 IPWA     PI N TO PI N
RE       (1510.)                      ARNDT     85 DPWA     PI N TO PI N
```

$N(1520)$ −2*IMAG PART OF POLE POSITION (MeV)

```
IM  B      109.0 OR 107.0             LONGACRE  77 IPWA     PI N TO 2PI N
IM         146.0 OR 137.0             LONGACRE  78 IPWA     PI N TO 2PI N
IM        (114.0)                     CUTKOSKY  79 IPWA     PI N TO PI N
IM         114.0     10.0             CUTKOSKY  80 IPWA     PI N TO PI N
IM        (122.)                      ARNDT     85 DPWA     PI N TO PI N
```

$N(1520)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER        (34.0)                     CUTKOSKY  79 IPWA     PI N TO PI N
RER         34.0      2.0             CUTKOSKY  80 IPWA     PI N TO PI N
```

$N(1520)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR        (-8.0)                     CUTKOSKY  79 IPWA     PI N TO PI N
IMR         -7.0      3.0             CUTKOSKY  80 IPWA     PI N TO PI N
```

Baryon Full Listings

N(1520), *N*(1535)

N(1520) PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1520) \to N\pi$	938+ 140
P2	$N(1520) \to N\eta$	940+ 549
P3	$N(1520) \to \Lambda K$	1116+ 498
P4	$N(1520) \to N\pi\pi$	938+ 140+ 140
P5	$N(1520) \to \Delta(1232)\ \pi$, *S*-wave	1232+ 140
P6	$N(1520) \to \Delta(1232)\ \pi$, *D*-wave	1232+ 140
P7	$N(1520) \to N\rho$, S=1/2, *D*-wave	938+ 769
P8	$N(1520) \to N\rho$, S=3/2, *S*-wave	938+ 769
P9	$N(1520) \to N\rho$, S=3/2, *D*-wave	938+ 769
P10	$N(1520) \to N(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P11	$N(1520) \to p\gamma$, helicity=1/2	938+ 0
P12	$N(1520) \to p\gamma$, helicity=3/2	938+ 0
P13	$N(1520) \to n\gamma$, helicity=1/2	940+ 0
P14	$N(1520) \to n\gamma$, helicity=3/2	940+ 0

N(1520) BRANCHING RATIOS

$N(1520) \to (N\pi)$/total (P1)

R1		(0.56)	(0.06)	CUTKOSKY	79	IPWA	PI N TO PI N
R1		0.54	0.03	HOEHLER	79	IPWA	PI N TO PI N
R1		0.58	0.03	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1520)$ in $N\pi \to N\eta$ SQRT(P1*P2)

R2		+0.011 OR +0.058		FELTESSE	75	DPWA	0 1488 TO 1745 MEV
R2		(0.02)		BAKER	79	DPWA	0 PI- P TO ETA N

R NOTE: SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.

$N(1520)$ in $N\pi \to \Delta(1232)\ \pi$, *S*-wave SQRT(P1*P5)

R3	A	-0.27 OR -0.24		LONGACRE	75	IPWA	PI N TO 2PI N
R3	B	(-0.26)		LONGACRE	77	IPWA	PI N TO 2PI N
R3	B	LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.					
R3	C	- (LARGE)		MANLEY	84	IPWA	PI N TO 2PI N
R3	C	MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.					

$N(1520)$ in $N\pi \to \Delta(1232)\ \pi$, *D*-wave SQRT(P1*P6)

R4	A	-0.24 OR -0.30		LONGACRE	75	IPWA	PI N TO 2PI N
R4	B	(-0.21)		LONGACRE	77	IPWA	PI N TO 2PI N
R4	B	LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.					
R4	C	- (LARGE)		MANLEY	84	IPWA	PI N TO 2PI N
R4	C	MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.					

$N(1520)$ in $N\pi \to N\rho$, S=3/2, *S*-wave SQRT(P1*P8)

R5	A	-0.32 OR -0.24		LONGACRE	75	IPWA	PI N TO 2PI N
R5	B	(-0.35)		LONGACRE	77	IPWA	PI N TO 2PI N
R5	B	LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.					
R5	C	- (LARGE)		MANLEY	84	IPWA	PI N TO 2PI N
R5	C	MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.					

$N(1520)$ in $N\pi \to N(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P10)

R6	A	0.0 OR -0.17		LONGACRE	75	IPWA	PI N TO 2PI N
R6	B	(-0.13)		LONGACRE	77	IPWA	PI N TO 2PI N

N(1520) PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(1520) \to p\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A1		-0.005	0.005	FELLER	76	DPWA	PI N PHOTOPROD.
A1		-0.003	0.003	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 1
A1		-0.030	0.002	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 2
A1		(-0.021)		BERENDS	77	IPWA	PI-N PHOTOPROD.
A1		-0.016	0.008	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A1	N	(-0.008)		NOELLE	78		PI-N PHOTOPROD.
A1	N	CONVERTED TO OUR CONVENTIONS USING M=1.528, W=.187 FROM NOELLE 78.					
A1		-0.032	0.005	ARAI	80	DPWA	PI N PHOTO FIT 1
A1		-0.032	0.004	ARAI	80	DPWA	PI N PHOTO FIT 2
A1		-0.031	0.009	BRATASHEV	80	DPWA	PI N PHOTOPROD.
A1		-0.019	0.007	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A1		-0.0430	0.0063	ISHII	80	DPWA	P COMPTON SCAT
A1		-0.007	0.004	AWAJI	81	DPWA	PI N PHOTOPROD.
A1		-0.028	0.014	CRAWFORD	83	IPWA	PI N PHOTOPROD.
A1		(-0.012)		WADA	84	DPWA	COMPTON SCATT.

$N(1520) \to p\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A2		+0.164	0.008	FELLER	76	DPWA	PI N PHOTOPROD.
A2		+0.182	0.006	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 1
A2		+0.133	0.002	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 2
A2		(+0.075)		BERENDS	77	IPWA	PI-N PHOTOPROD.
A2		+0.157	0.007	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A2	N	(0.206)		NOELLE	78		PI-N PHOTOPROD.
A2		0.178	0.003	ARAI	80	DPWA	PI N PHOTO FIT 1
A2		0.162	0.003	ARAI	80	DPWA	PI N PHOTO FIT 2
A2		0.166	0.005	BRATASHEV	80	DPWA	PI N PHOTOPROD.
A2		0.167	0.010	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A2		0.1695	0.0014	ISHII	80	DPWA	P COMPTON SCAT
A2		0.168	0.013	AWAJI	81	DPWA	PI N PHOTOPROD.
A2		0.156	0.022	CRAWFORD	83	IPWA	PI N PHOTOPROD.
A2		(0.168)		WADA	84	DPWA	COMPTON SCATT.

$N(1520) \to n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A3		-0.055	0.014	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A3	N	(-0.060)		NOELLE	78		PI-N PHOTOPROD.
A3		-0.076	0.006	ARAI	80	DPWA	PI N PHOTO FIT 1
A3		-0.071	0.011	ARAI	80	DPWA	PI N PHOTO FIT 2
A3		-0.056	0.011	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A3		-0.050	0.014	TAKEDA	80	DPWA	PI N PHOTOPROD.
A3		-0.066	0.013	AWAJI	81	DPWA	PI N PHOTOPROD.
A3		-0.067	0.004	FUJII	81	DPWA	PI N PHOTOPROD.

$N(1520) \to n\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A4		-0.141	0.015	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A4	N	(-0.127)		NOELLE	78		PI-N PHOTOPROD.
A4		-0.147	0.008	ARAI	80	DPWA	PI N PHOTO FIT 1
A4		-0.148	0.009	ARAI	80	DPWA	PI N PHOTO FIT 2
A4		-0.144	0.015	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A4		-0.118	0.011	TAKEDA	80	DPWA	PI N PHOTOPROD.
A4		-0.124	0.009	AWAJI	81	DPWA	PI N PHOTOPROD.
A4		-0.158	0.003	FUJII	81	DPWA	PI N PHOTOPROD.

REFERENCES FOR *N*(1520)

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).
FOR VERY EARLY REFERENCES, SEE RMP 37, 633 (1965).

FELTESSE 75 NP B93 242 +AYED,BAREYRE,BORGEAUD,DAVID,ERNWEIN+(SACL)IJP
LONGACRE 75 PL 55B 415 +ROSENFELD,LASINSKI,SMADJA+ (LBL+SLAC)IJP
FELLER 76 NP B104 219 +FUKUSHIMA,HORIKAWA,KAJIKAWA+ (NAGO+OSAK)IJP
AZNAURYA 77 EFI-264(57)-77 -AKOPOV,BAGDASARYAN (YERE)IJP
BERENDS 77 NP B136 317 F A BERENDS,A DONNACHIE (LEID+MCHS)IJP
LONGACRE 77 NP B122 493 LONGACRE,DOLBEAU (SACL)IJP
ALSO 76 NP B108 365 DOLBEAU,TRIANTIS,NEVEU,CADIET (SACL)IJP
BARBOUR 78 NP B141 253 BARBOUR,CRAWFORD,PARSONS (GLAS)
LONGACRE 78 PR D17 1795 +LASINSKI,ROSENFELD,SMADJA+ (LBL+SLAC)
NOELLE 78 PTP 60 778 P NOELLE (NAGO)
BAKER 79 NP B156 93 +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+ (RHEL)IJP
CUTKOSKY 79 PR D20 2839 +FORSYTH,HENDRICK,KELLY (CARN+LBL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
ARAI 80 TORONTO CONF 93 I ARAI (TOKY)
ALSO 82 NP B194 251 I ARAI, H FUJII (TOKY)
BRATASHE 80 NP B166 525 BRATASHEVSKIJ,GORBENKO,DEREBCHINSKIJ+(KHAR)
CRAWFORD 80 TORONTO CONF 107 R L CRAWFORD (GLAS)
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
ISHII 80 NP B165 189 ISHII,EGAWA,KATO,MIYACHI+ (KYOT-TOKY)
TAKEDA 80 NP B168 17 TAKEDA,ARAI,FUJII,IKEDA,IWASAKI+ (TOKY)
AWAJI 81 BONN CONF 352 R KAJIKAWA (TALK) (NAGO)
ALSO 82 NP B197 365 FUJII,HAYASHII,IWATA,KAJIKAWA+ (NAGO)
FUJII 81 NP B187 53 FUJII,HAYASHII,IWATA,KAJIKAWA+ (TOKY)
CRAWFORD 83 NP B211 1 R L CRAWFORD, W T MORTON (GLAS)
MANLEY 84 PR D30 904 MANLEY,ARNDT,GORADIA,TEPLITZ (VPI)
WADA 84 NP B247 313 +EGAWA,IMANISHI,ISHII,KATO,UKAI+ (INUS)
ARNDT 85 PR D32 1085 R A ARNDT, J M FORD, L D ROPER (VPI)

N(1535) S_{11}

$I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

N(1535) MASS (MeV)

M	A	1520. OR 1510.		LONGACRE	75	IPWA	PI N TO 2PI N
M	A	THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.					
M		(1500.0)		BERENDS	77	IPWA	PI-N PHOTOPROD.
M		1547.0	6.0	BHANDARI	77	DPWA	0 USES ETA N CUSP
M	B	(1520.0)		LONGACRE	77	IPWA	PI N TO 2PI N
M	B	ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE					
M	B	POSITION WHICH IS FROM SOLUTIONS S1 AND C1.					
M		(1511.0)		BARBOUR	78	DPWA	PI-N PHOTOPROD.
M		(1540.0)	(20.0)	CUTKOSKY	79	IPWA	PI N TO PI N
M		1526.0	7.0	HOEHLER	79	IPWA	PI N TO PI N
M		(1513.0)		CRAWFORD	80	DPWA	PI N PHOTOPROD.
M		1550.0	40.0	CUTKOSKY	80	IPWA	PI N TO PI N

N(1535) WIDTH (MeV)

W	A	75. OR 100.		LONGACRE	75	IPWA	PI N TO 2PI N
W		(57.0)		BERENDS	77	IPWA	PI-N PHOTOPROD.
W		139.0	33.0	BHANDARI	77	DPWA	0 USES ETA N CUSP
W	B	(135.0)		LONGACRE	77	IPWA	PI N TO 2PI N
W		(132.0)		BARBOUR	78	DPWA	PI-N PHOTOPROD.
W		(180.0)		BAKER	79	DPWA	0 PI- P TO ETA N
W		(270.0)	(50.0)	CUTKOSKY	79	IPWA	PI N TO PI N
W		120.0	20.0	HOEHLER	79	IPWA	PI N TO PI N
W		(136.0)		CRAWFORD	80	DPWA	PI N PHOTOPROD.
W		240.0	80.0	CUTKOSKY	80	IPWA	PI N TO PI N

N(1535) REAL PART OF POLE POSITION (MeV)

RE		1519.0	4.0	BHANDARI	77	DPWA	0 USES ETA N CUSP
RE	B	1525.0 OR 1527.0		LONGACRE	77	IPWA	PI N TO 2PI N
RE		1496.0 OR 1499.0		LONGACRE	78	IPWA	PI N TO 2PI N
RE		(1465.0)		CUTKOSKY	79	IPWA	PI N TO PI N
RE		1510.0	50.0	CUTKOSKY	80	IPWA	PI N TO PI N
RE		(1461.)		ARNDT	85	DPWA	PI N TO PI N

N(1535) −2*IMAG PART OF POLE POSITION (MeV)

IM		140.0	32.0	BHANDARI	77	DPWA	0 USES ETA N CUSP
IM	B	135.0 OR 123.0		LONGACRE	77	IPWA	PI N TO 2PI N
IM		103.0 OR 105.0		LONGACRE	78	IPWA	PI N TO 2PI N
IM		(256.0)		CUTKOSKY	79	IPWA	PI N TO PI N
IM		260.0	80.0	CUTKOSKY	80	IPWA	PI N TO PI N
IM		(140.)		ARNDT	85	DPWA	PI N TO PI N

$N(1535)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER         20.0      21.0              BHANDARI  77 DPWA  0 USES ETA N CUSP
RER        (48.0)                       CUTKOSKY  79 IPWA    PI N TO PI N
RER        116.0      46.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1535)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR         13.0       8.0              BHANDARI  77 DPWA  0 USES ETA N CUSP
IMR       (-67.0)                       CUTKOSKY  79 IPWA    PI N TO PI N
IMR         31.0      92.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1535)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1535) \rightarrow N\pi$	938+ 140
P2	$N(1535) \rightarrow N\eta$	940+ 549
P3	$N(1535) \rightarrow \Lambda K$	1116+ 498
P4	$N(1535) \rightarrow N\pi\pi$	938+ 140+ 140
P5	$N(1535) \rightarrow \Delta(1232)\ \pi$, D-wave	1232+ 140
P6	$N(1535) \rightarrow N\rho$, S=1/2, S-wave	938+ 769
P7	$N(1535) \rightarrow N\rho$, S=3/2, D-wave	938+ 769
P8	$N(1535) \rightarrow N(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P9	$N(1535) \rightarrow p\gamma$, helicity=1/2	938+ 0
P10	$N(1535) \rightarrow n\gamma$, helicity=1/2	940+ 0

$N(1535)$ BRANCHING RATIOS

$N(1535) \rightarrow (N\pi)$/total (P1)

```
R1          0.297     0.026             BHANDARI  77 DPWA  0 USES ETA N CUSP
R1         (0.45)    (0.06)             CUTKOSKY  79 IPWA    PI N TO PI N
R1          0.38      0.04              HOEHLER   79 IPWA    PI N TO PI N
R1          0.50      0.10              CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1535)$ in $N\pi \rightarrow N\eta$ SQRT(P1*P2)

```
R2         (+0.48)                      FELTESSE  75 DPWA  0 1488 TO 1745 MEV
R2         (+0.33)                      BAKER     79 DPWA  0 PI- P TO ETA N

R       NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R              IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R              THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R              SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

$N(1535)$ in $N\pi \rightarrow \Delta(1232)\ \pi$, D-wave SQRT(P1*P5)

```
R3    A     0.0  OR -0.06               LONGACRE  75 IPWA    PI N TO 2PI N
R3    B    (0.00)                       LONGACRE  77 IPWA    PI N TO 2PI N
```

$N(1535)$ in $N\pi \rightarrow N\rho$, S=1/2, S-wave SQRT(P1*P6)

```
R4    A    -0.12 OR -0.09               LONGACRE  75 IPWA    PI N TO 2PI N
R4    B   (-0.10)                       LONGACRE  77 IPWA    PI N TO 2PI N
R4    C     - (SMALL)                   MANLEY    84 IPWA    PI N TO 2PI N      |
R4    C  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.           |
```

$N(1535)$ in $N\pi \rightarrow N(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P8)

```
R5    A     0.1  OR +0.09               LONGACRE  75 IPWA    PI N TO 2PI N
R5    B    (+0.08)                      LONGACRE  77 IPWA    PI N TO 2PI N
R5    C     + (SMALL)                   MANLEY    84 IPWA    PI N TO 2PI N      |
R5    C  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.           |
```

$N(1535) \rightarrow (p\gamma)$/total (P9)

```
R6    D     0.0020    0.0007            DEANS     72 MPWA    P ETA PHOTOPROD.
R6    D  BR=(DEANS72 RADIATIVE WIDTH)/(NOMINAL FULL WIDTH=210 MEV)
R6    D  THE HICKS73 ENTRY UNDER R7 IS A MORE RECENT RESULT BY SAME GROUP.
```

$N(1535)$ in $p\gamma \rightarrow p\eta$ SQRT(P9*P2)

```
R7         (0.0366)                     HICKS     73 MPWA    GAM P-ETA P
```

$N(1535)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(1535) \rightarrow p\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1         +0.070     0.004             FELLER    76 DPWA    PI N PHOTOPROD.
A1         +0.046     0.007             AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A1         +0.101     0.012             AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A1        (+0.034)                      BERENDS   77 IPWA    PI-N PHOTOPROD.
A1         +0.082     0.019             BARBOUR   78 DPWA    PI-N PHOTOPROD.
A1    N   (0.046)                       NOELLE    78         PI-N PHOTOPROD.
A1    N  CONVERTED TO OUR CONVENTIONS USING M=1.548, W=.073 FROM NOELLE 78.
A1          0.083     0.007             ARAI      80 DPWA    PI N PHOTO FIT 1
A1          0.080     0.007             ARAI      80 DPWA    PI N PHOTO FIT 2
A1          0.029     0.007             BRATASHEV 80 DPWA    PI N PHOTOPROD.
A1          0.065     0.016             CRAWFORD  80 DPWA    PI N PHOTOPROD.
A1          0.0704    0.0091            ISHII     80 DPWA    P COMPTON SCAT
A1          0.077     0.021             AWAJI     81 DPWA    PI N PHOTOPROD.
A1          0.053     0.015             CRAWFORD  83 IPWA    PI N PHOTOPROD.
A1         (0.055)                      WADA      84 DPWA    COMPTON SCATT.     |
```

$N(1535) \rightarrow n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A2         -0.112     0.034             BARBOUR   78 DPWA    PI-N PHOTOPROD.
A2    N   (-0.048)                      NOELLE    78         PI-N PHOTOPROD.
A2         -0.075     0.019             ARAI      80 DPWA    PI N PHOTO FIT 1
A2         -0.075     0.018             ARAI      80 DPWA    PI N PHOTO FIT 2
A2         -0.098     0.026             CRAWFORD  80 DPWA    PI N PHOTOPROD.
A2         -0.011     0.017             TAKEDA    80 DPWA    PI N PHOTOPROD.
A2          0.035     0.014             AWAJI     81 DPWA    PI N PHOTOPROD.
A2         -0.062     0.003             FUJII     81 DPWA    PI N PHOTOPROD.
```

REFERENCES FOR $N(1535)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS    72 PN 3 217          +JACOBS, LYONS, HICKS             (SFLA+CARN)
HICKS    73 PR D7 2614        +DEANS,JACOBS,LYONS+        (CARN+ORNL+SFLA)IJP
FELTESSE 75 NP B93 242        +AYED,BAREYRE,BORGEAUD,DAVID,ERNWEIN+(SACL)IJP
LONGACRE 75 PL 55B 415        +ROSENFELD,LASINSKI,SMADJA+      (LBL+SLAC)IJP
FELLER   76 NP B104 219       +FUKUSHIMA,HORIKAWA,KAJIKAWA+   (NAGO+OSAK)IJP
AZNAURYA 77  EFI-264(57)-77   +AKOPOV,BAGDASARYAN                   (YERE)IJP
BERENDS  77 NP B136 317       F A BERENDS,A DONNACHIE          (LEID+MCHS)IJP
BHANDARI 77 PR D15 192        R BHANDARI,Y-A CHAO                   (CARN)IJP
LONGACRE 77 NP B122 493       LONGACRE,DOLBEAU                      (SACL)IJP
    ALSO 76 NP B108 365       DOLBEAU,TRIANTIS,NEVEU,CADIET         (SACL)IJP
BARBOUR  78 NP B141 253       BARBOUR,CRAWFORD,PARSONS              (GLAS)
LONGACRE 78 PR D17 1795       +LASINSKI,ROSENFELD,SMADJA+      (LBL+SLAC)
NOELLE   78 PTP 60 778        P NOELLE                              (NAGO)
BAKER    79 NP B156 93        +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+  (RHEL)IJP
CUTKOSKY 79 PR D20 2839       +FORSYTH,HENDRICK,KELLY           (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                              +KAISER,KOCH,PIETARINEN               (KARL)IJP
    ALSO 80  TORONTO CONF 3   R KOCH                                (KARL)IJP
ARAI     80  TORONTO CONF 93  I ARAI                                (TOKY)
    ALSO 82 NP B194 251       I ARAI, H FUJII                       (TOKY)
BRATASHE 80 NP B166 525       BRATASHEVSKIJ,GORBENKO,DEREBCHINSKIJ+(KHAR)
CRAWFORD 80  TORONTO CONF 107 R L CRAWFORD                          (GLAS)
CUTKOSKY 80  TORONTO CONF 19  +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
ISHII    80 NP B165 189       ISHII,EGAWA,KATO,MIYACHI+        (KYOT+TOKY)
TAKEDA   80 NP B168 17        TAKEDA,ARAI,FUJII,IKEDA,IWASAKI+      (TOKY)
AWAJI    81  BONN CONF 352    R KAJIKAWA (TALK)                     (NAGO)
    ALSO 82 NP B197 365       FUJII,HAYASHII,IWATA,KAJIKAWA+        (NAGO)
FUJII    81 NP B187 53        FUJII,HAYASHII,IWATA,KAJIKAWA+        (TOKY)
CRAWFORD 83 NP B211 1         R L CRAWFORD, W T MORTON              (GLAS)
MANLEY   84 PR D30 904        MANLEY,ARNDT,GORADIA,TEPLITZ           (VPI)
WADA     84 NP B247 313       +EGAWA,IMANISHI,ISHII,KATO,UKAI+      (INUS)
ARNDT    85 PR D32 1085       R A ARNDT, J M FORD, L D ROPER         (VPI)
```

$N(1540)$ P_{13}

$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

THIS RESONANCE HAS NOT BEEN SEEN IN PI N --> PI N ANALYSES, AND ITS EXISTENCE IS THUS DOUBTFUL.

$N(1540)$ MASS (MeV)

```
M     A     (1540.0)                    LONGACRE  77 IPWA    PI N TO 2PI N
M     A  ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M     A  POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
```

$N(1540)$ WIDTH (MeV)

```
W     A      (200.0)                    LONGACRE  77 IPWA    PI N TO 2PI N
```

$N(1540)$ REAL PART OF POLE POSITION (MeV)

```
RE    A     1535.0 OR 1482.0            LONGACRE  77 IPWA    PI N TO 2PI N
```

$N(1540)$ −2*IMAG PART OF POLE POSITION (MeV)

```
IM    A      207.0 OR 314.0             LONGACRE  77 IPWA    PI N TO 2PI N
```

$N(1540)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1540) \rightarrow N\pi$	938+ 140
P2	$N(1540) \rightarrow \Delta(1232)\ \pi$, P-wave	1232+ 140
P3	$N(1540) \rightarrow N\rho$, S=1/2, P-wave	938+ 769
P4	$N(1540) \rightarrow N\rho$, S=3/2, P-wave	938+ 769
P5	$N(1540) \rightarrow N(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P6	$N(1540) \rightarrow p\gamma$	938+ 0

$N(1540)$ BRANCHING RATIOS

```
R       NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R              IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R              THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R              SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

$N(1540)$ in $N\pi \rightarrow \Delta(1232)\ \pi$, P-wave SQRT(P1*P2)

```
R1    A     (-0.11)                     LONGACRE  77 IPWA    PI N TO 2PI N
```

$N(1540)$ in $N\pi \rightarrow N\rho$, S=1/2, P-wave SQRT(P1*P3)

```
R2    A     (+0.08)                     LONGACRE  77 IPWA    PI N TO 2PI N
```

$N(1540)$ in $N\pi \rightarrow N\rho$, S=3/2, P-wave SQRT(P1*P4)

```
R3    A      (0.00)                     LONGACRE  77 IPWA    PI N TO 2PI N
```

$N(1540)$ in $N\pi \rightarrow N(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P5)

```
R4    A      (0.00)                     LONGACRE  77 IPWA    PI N TO 2PI N
```

$N(1540)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

```
  FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-
REVIEW PRECEDING THE BARYON LISTINGS.
```

$N(1540) \to p\,\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1          -0.014    0.028             CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

$N(1540) \to p\,\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A2           0.009    0.027             CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

REFERENCES FOR $N(1540)$

```
LONGACRE 77 NP B122 493       LONGACRE,DOLBEAU                       (SACL)IJP
   ALSO 76 NP B108 365        DOLBEAU,TRIANTIS,NEVEU,CADIET          (SACL)IJP
CRAWFORD 83 NP B211 1         R L CRAWFORD, W T MORTON               (GLAS)
```

$N(1650)$ S_{11}

$I(J^P)=\frac{1}{2}(\frac{1}{2}^-)$ Status: * * * *

```
MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE
BEEN OMITTED.  THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS
111B).
```

$N(1650)$ MASS (MeV)

```
M         (1675.0)                    KNASEL    75 DPWA  0 PI- P TO K0 LAM
M    A     1675. OR 1660.             LONGACRE  75 IPWA    PI N TO 2PI N
M    A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M    B    (1700.0)    (5.0)           BAKER     77 IPWA  0 PI- P TO K LAM.
M    B    (1680.0)                    BAKER     77 DPWA  0 PI- P TO K LAM.
M    B  THE TWO ENTRIES FOR BAKER 77 ARE FOR AN IPWA USING THE BARRELET
M    B  ZERO METHOD AND A CONVENTIONAL ENERGY-DEPENDENT ANALYSIS.
M    C    (1700.0)                    LONGACRE  77 IPWA    PI N TO 2PI N
M    C  ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M    C  POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M         (1680.0)                    BAKER     78 DPWA  0 PI- P TO K LAM
M         (1694.0)                    BARBOUR   78 DPWA    PI-N PHOTOPROD.
M         (1640.0)   (30.0)           CUTKOSKY  79 IPWA    PI N TO PI N
M          1670.0      8.0            HOEHLER   79 IPWA    PI N TO PI N
M         (1688.0)                    CRAWFORD  80 DPWA    PI N PHOTOPROD.
M          1650.0     30.0            CUTKOSKY  80 IPWA    PI N TO PI N
M         (1672.0)                    MUSETTE   80 IPWA  0 PI- P TO K LAM
M         (1680.0)                    SAXON     80 DPWA  0 PI- P TO K LAM
```

$N(1650)$ WIDTH (MeV)

```
W          (170.0)                    KNASEL    75 DPWA  0 PI- P TO K0 LAM
W    A      150. OR  130.             LONGACRE  75 IPWA    PI N TO 2PI N
W    B     (130.0)   (10.0)           BAKER     77 IPWA  0 PI- P TO K LAM.
W    B      (90.0)                    BAKER     77 DPWA  0 PI- P TO K LAM.
W    C     (170.0)                    LONGACRE  77 IPWA    PI N TO 2PI N
W           (90.0)                    BAKER     78 DPWA  0 PI- P TO K LAM
W          (193.0)                    BARBOUR   78 DPWA    PI-N PHOTOPROD.
W          (140.0)   (40.0)           CUTKOSKY  79 IPWA    PI N TO PI N
W           180.0     20.0            HOEHLER   79 IPWA    PI N TO PI N
W          (183.0)                    CRAWFORD  80 DPWA    PI N PHOTOPROD.
W           150.0     40.0            CUTKOSKY  80 IPWA    PI N TO PI N
W          (179.0)                    MUSETTE   80 IPWA  0 PI- P TO K LAM
W          (120.0)                    SAXON     80 DPWA  0 PI- P TO K LAM
```

$N(1650)$ REAL PART OF POLE POSITION (MeV)

```
RE   C      1699.0 OR 1698.0          LONGACRE  77 IPWA    PI N TO 2PI N
RE          1648.0 OR 1651.0          LONGACRE  78 IPWA    PI N TO 2PI N
RE         (1639.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
RE          1640.0     20.0           CUTKOSKY  80 IPWA    PI N TO PI N
RE         (1660.)                    ARNDT     85 DPWA    PI N TO PI N      |
```

$N(1650)$ -2*IMAG PART OF POLE POSITION (MeV)

```
IM   C      174.0 OR 173.0            LONGACRE  77 IPWA    PI N TO 2PI N
IM          117.0 OR 119.0            LONGACRE  78 IPWA    PI N TO 2PI N
IM         (140.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
IM          150.0     30.0            CUTKOSKY  80 IPWA    PI N TO PI N
IM         (122.)                     ARNDT     85 DPWA    PI N TO PI N      |
```

$N(1650)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER          (3.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
RER          16.0      25.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1650)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR        (-58.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
IMR         -58.0      12.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1650)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1650) \to N\,\pi$	938+ 140
P2	$N(1650) \to N\,\eta$	940+ 549
P3	$N(1650) \to \Lambda K$	1116+ 498
P4	$N(1650) \to \Sigma K$	1189+ 494
P5	$N(1650) \to N\,\pi\,\pi$	938+ 140+ 140
P6	$N(1650) \to \Delta(1232)\ \pi$, D-wave	1232+ 140
P7	$N(1650) \to N\,\rho$, S=1/2, S-wave	938+ 769
P8	$N(1650) \to N\,\rho$, S=3/2, D-wave	938+ 769
P9	$N(1650) \to N\,(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P10	$N(1650) \to N(1440)\ \pi$, S-wave	1440+ 140
P11	$N(1650) \to p\,\gamma$, helicity=1/2	938+ 0
P12	$N(1650) \to n\,\gamma$, helicity=1/2	940+ 0

$N(1650)$ BRANCHING RATIOS

$N(1650) \to (N\,\pi)$/total (P1)

```
R1          (0.60)   (0.05)          CUTKOSKY  79 IPWA    PI N TO PI N
R1           0.61     0.04           HOEHLER   79 IPWA    PI N TO PI N
R1           0.65     0.10           CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1650)$ in $N\,\pi \to N\,\eta$ SQRT(P1*P2)

```
R2   E     (-0.09)                   BAKER     79 DPWA  0 PI- P TO ETA N
R2   E  THIS COUPLING WAS FIXED DURING FITTING, BUT THE NEGATIVE SIGN
R2   E  RELATIVE TO N(1535) IS WELL DETERMINED.
```

$N(1650)$ in $N\,\pi \to \Lambda K$ SQRT(P1*P3)

```
R3          (0.12)                   KNASEL    75 DPWA  0 PI- P TO K0 LAM
R3   B     (-0.23)   (0.01)          BAKER     77 IPWA  0 PI- P TO K LAM.
R3   B     (-0.25)                   BAKER     77 DPWA  0 PI- P TO K LAM.
R3   F     (-0.25)                   BAKER     78 DPWA  0 PI- P TO K LAM
R3   F  THE (UNDETERMINED) OVERALL PHASE OF ALL COUPLINGS HAS BEEN
R3   F  CHANGED TO AGREE WITH PREVIOUS CONVENTIONS. SUPERSEDED BY SAXON 80.
R3         (-0.22)                   SAXON     80 DPWA  0 PI- P TO K LAM
R3         (-0.22)                   BELL      83 DPWA 0  PI- P TO LAM K0
```

$N(1650)$ in $N\,\pi \to \Sigma K$ SQRT(P1*P4)

```
R4   D       0.066 TO 0.137          DEANS     75 DPWA    PI N TO K SIGMA
R4   D  RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.
R4          (0.20)                   KNASEL    75 DPWA  0
R4         (-0.254)                  LIVANOS   80 DPWA    PI P TO K SIGMA

R       NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
               IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
               THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
               SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI
```

$N(1650)$ in $N\,\pi \to \Delta(1232)\ \pi$, D-wave SQRT(P1*P6)

```
R5   A      +0.16 OR +0.15           LONGACRE  75 IPWA    PI N TO 2PI N
R5   C     (+0.29)                   LONGACRE  77 IPWA    PI N TO 2PI N
R5   C  LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R5   G        + (LARGE)              MANLEY    84 IPWA    PI N TO 2PI N     |
R5   G  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.        |
```

$N(1650)$ in $N\,\pi \to N\,\rho$, S=1/2, S-wave SQRT(P1*P7)

```
R6   A       0.23 OR -0.16           LONGACRE  75 IPWA    PI N TO 2PI N
R6   C     (+0.17)                   LONGACRE  77 IPWA    PI N TO 2PI N
R6         (-)                       MANLEY    84 IPWA    PI N TO 2PI N     |
```

$N(1650)$ in $N\,\pi \to N\,\rho$, S=3/2, D-wave SQRT(P1*P8)

```
R7   C     (+0.29)                   LONGACRE  77 IPWA    PI N TO 2PI N
R7   C  LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R7            (LARGE)                MANLEY    84 IPWA    PI N TO 2PI N     |
```

$N(1650)$ in $N\,\pi \to N\,(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P9)

```
R8   A      +0.23 OR +0.25           LONGACRE  75 IPWA    PI N TO 2PI N
R8   C      (0.00)                   LONGACRE  77 IPWA    PI N TO 2PI N
R8         (+)                       MANLEY    84 IPWA    PI N TO 2PI N     |
```

$N(1650)$ in $N\,\pi \to N(1440)\ \pi$, S-wave SQRT(P1*P10)

```
R9         (+)                       MANLEY    84 IPWA    PI N TO 2PI N     |
```

$N(1650)$ in $p\,\gamma \to p\,\eta$ SQRT(P11*P2)

```
R10         (0.0101)                 HICKS     73 MPWA    GAM P-ETA P
```

$N(1650)$ in $p\,\gamma \to \Lambda K$ SQRT(P11*P3.

```
R11         (0.002)OR LESS           ORITO2    69 CNTR    K LAM PHOTOPRO
R11         (0.0072)                 SCHORSCH  70 DPWA    K LAM PHOTOPRO.
R11         (0.0060)                 DEANS     72 MPWA    GAM P-K LM,SOL D
```

$N(1650)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

```
  FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-
REVIEW PRECEDING THE BARYON LISTINGS.
```

$N(1650) \to p\,\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1          +0.068    0.009          FELLER    76 DPWA    PI N PHOTOPROD.
A1          +0.004    0.004          AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A1          +0.003    0.004          AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A1          +0.048    0.017          BARBOUR   78 DPWA    PI-N PHOTOPROD.
A1           0.065    0.005          ARAI      80 DPWA    PI N PHOTO FIT 1
A1           0.061    0.005          ARAI      80 DPWA    PI N PHOTO FIT 2
A1           0.031    0.017          CRAWFORD  80 DPWA    PI N PHOTOPROD.
A1           0.050    0.010          AWAJI     81 DPWA    PI N PHOTOPROD.
A1           0.033    0.015          CRAWFORD  83 IPWA    PI N PHOTOPROD.
A1          (0.091)                  WADA      84 DPWA    COMPTON SCATT.    |
```

$N(1650) \rightarrow n\gamma$, helicity=1/2 ($GeV^{-1/2}$)

```
A2      -0.045    0.024          BARBOUR   78 DPWA    PI-N PHOTOPROD.
A2       0.010    0.020          ARAI      80 DPWA    PI N PHOTO FIT 1
A2       0.008    0.019          ARAI      80 DPWA    PI N PHOTO FIT 2
A2      -0.068    0.040          CRAWFORD  80 DPWA    PI N PHOTOPROD.
A2      -0.011    0.011          TAKEDA    80 DPWA    PI N PHOTOPROD.
A2      -0.008    0.004          AWAJI     81 DPWA    PI N PHOTOPROD.
A2       0.004    0.004          FUJII     81 DPWA    PI N PHOTOPROD.
```

REFERENCES FOR $N(1650)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
ORITO2   69 INS J 113          S ORITO (THESIS)                          (TOKY)
SCHORSCH 70 NP  B25 179        +TIETGE,WEILNBOECK                        (MPIM)
DEANS    72 PR D6 1906         DEANS,JACOBS, LYONS,MONTGOMERY          (SFLA)IJP
HICKS    73 PR D7 2614         +DEANS,JACOBS,LYONS+           (CARN+ORNL+SFLA)IJP
DEANS    75 NP B96 90          +MITCHELL,MONTGOMERY,+              (SFLA+ALAH)IJP
KNASEL   75 PR D11 1           +LINDQUIST,NELSON+        (CHIC+WUSL+OSU+ANL)IJP
LONGACRE 75 PL 55B 415         +ROSENFELD,LASINSKI,SMADJA+          (LBL+SLAC)IJP
FELLER   76 NP B104 219        +FUKUSHIMA,HORIKAWA,KAJIKAWA+      (NAGO+OSAK)IJP
AZNAURYA 77  EFI-264(57)-77    +AKOPOV,BAGDASARYAN                     (YERE)IJP
BAKER    77 NP B126 365        +BLISSET,BLOODWORTH,BROOME,HART+        (RHEL)IJP
LONGACRE 77 NP B122 493        LONGACRE,DOLBEAU                        (SACL)IJP
    ALSO 76 NP B108 365        DOLBEAU,TRIANTIS,NEVEU,CADIET           (SACL)IJP
BAKER    78 NP B141 29         +BLISSET,BLOODWORTH,BROOME+         (RL+CAMB)IJP
BARBOUR  78 NP B141 253        BARBOUR,CRAWFORD,PARSONS                (GLAS)
LONGACRE 78 PR D17 1795        +LASINSKI,ROSENFELD,SMADJA+         (LBL+SLAC)
BAKER    79 NP B156 93         +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+  (RHEL)IJP
CUTKOSKY 79 PR D20 2839        +FORSYTH,HENDRICK,KELLY            (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                               +KAISER,KOCH,PIETARINEN                 (KARL)IJP
    ALSO 80  TORONTO CONF 3    R KOCH                                  (KARL)IJP
ARAI     80  TORONTO CONF 93   I ARAI                                  (TOKY)
    ALSO 82 NP B194 251        I ARAI, H FUJII                         (TOKY)
CRAWFORD 80  TORONTO CONF 107 R L CRAWFORD                             (GLAS)
CUTKOSKY 80  TORONTO CONF 19   +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
LIVANOS  80  TORONTO CONF 35   +BATON,COUTURES,KOCHOWSKI,NEVEU         (SACL)IJP
MUSETTE  80 NC 57A 37          M MUSETTE                               (BRUX)IJP
SAXON    80 NP B162 522        +BAKER,BELL,BLISSETT,BLOODWORTH+(RHEL+BRIS)IJP
TAKEDA   80 NP B168 17         TAKEDA,ARAI,FUJII,IKEDA,IWASAKI+        (TOKY)
AWAJI    81  BONN CONF 352     R KAJIKAWA (TALK)                       (NAGO)
    ALSO 82 NP B197 365        FUJII,HAYASHII,IWATA,KAJIKAWA+          (NAGO)
FUJII    81 NP B187 53         FUJII,HAYASHII,IWATA,KAJIKAWA+          (TOKY)
BELL     83 NP B222 389        +BLISSET,BROOME,DALEY,HART,LINTERN,+      (RL)IJP
CRAWFORD 83 NP B211 1          R L CRAWFORD, W T MORTON                (GLAS)
MANLEY   84 PR D30 904         MANLEY,ARNDT,GORADIA,TEPLITZ             (VPI)
WADA     84 NP B247 313        +EGAWA,IMANISHI,ISHII,KATO,UKAI+        (INUS)
ARNDT    85 PR D32 1085        R A ARNDT, J M FORD, L D ROPER           (VPI)
```

$N(1675)$ D_{15}

$I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

IN ADDITION, RESULTS IN THIS REGION FROM PRODUCTION EXPERIMENTS, WHICH USED TO BE LISTED SEPARATELY IN AN ENTRY FOLLOWING THE N(1700), HAVE BEEN ENTIRELY REMOVED. THEY TOO MAY BE FOUND IN OUR 1982 EDITION.

$N(1675)$ MASS (MeV)

```
M    A     1660. OR 1660.             LONGACRE  75 IPWA     PI N TO 2PI N
M    A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M    B    (1650.0)                    LONGACRE  77 IPWA     PI N TO 2PI N
M    B  ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M    B  POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M         (1680.0)                    BARBOUR   78 DPWA     PI-N PHOTOPROD.
M         (1680.0)   (15.0)           CUTKOSKY  79 IPWA     PI N TO PI N
M          1679.0      8.0            HOEHLER   79 IPWA     PI N TO PI N
M         (1685.0)                    CRAWFORD  80 DPWA     PI N PHOTOPROD.
M          1675.0     10.0            CUTKOSKY  80 IPWA     PI N TO PI N
M         (1670.0)                    SAXON     80 DPWA   0 PI- P TO K LAM
```

$N(1675)$ WIDTH (MeV)

```
W    A      145. OR  150.             LONGACRE  75 IPWA     PI N TO 2PI N
W    B     (130.0)                    LONGACRE  77 IPWA     PI N TO 2PI N
W          (192.0)                    BARBOUR   78 DPWA     PI-N PHOTOPROD.
W           (88.0)                    BAKER     79 DPWA   0 PI- P TO ETA N
W          (180.0)   (30.0)           CUTKOSKY  79 IPWA     PI N TO PI N
W           120.0     15.0            HOEHLER   79 IPWA     PI N TO PI N
W          (191.0)                    CRAWFORD  80 DPWA     PI N PHOTOPROD.
W           160.0     20.0            CUTKOSKY  80 IPWA     PI N TO PI N
W           (40.0)                    SAXON     80 DPWA   0 PI- P TO K LAM
```

$N(1675)$ REAL PART OF POLE POSITION (MeV)

```
RE   B      1649.0 OR 1650.0          LONGACRE  77 IPWA     PI N TO 2PI N
RE          1663.0 OR 1668.0          LONGACRE  78 IPWA     PI N TO 2PI N
RE         (1663.0)                   CUTKOSKY  79 IPWA     PI N TO PI N
RE          1660.0     10.0           CUTKOSKY  80 IPWA     PI N TO PI N
RE         (1661.)                    ARNDT     85 DPWA     PI N TO PI N
```

$N(1675)$ -2*IMAG PART OF POLE POSITION (MeV)

```
IM   B      127.0 OR 127.0            LONGACRE  77 IPWA     PI N TO 2PI N
IM          146.0 OR 171.0            LONGACRE  78 IPWA     PI N TO 2PI N
IM         (150.0)                    CUTKOSKY  79 IPWA     PI N TO PI N
IM          140.0      10.0           CUTKOSKY  80 IPWA     PI N TO PI N
IM         (142.)                     ARNDT     85 DPWA     PI N TO PI N
```

$N(1675)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER         (33.0)                    CUTKOSKY  79 IPWA     PI N TO PI N
RER          27.0       5.0           CUTKOSKY  80 IPWA     PI N TO PI N
```

$N(1675)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR        (-11.0)                    CUTKOSKY  79 IPWA     PI N TO PI N
IMR         -16.0       5.0           CUTKOSKY  80 IPWA     PI N TO PI N
```

$N(1675)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1675) \rightarrow N\pi$	938+ 140
P2	$N(1675) \rightarrow N\eta$	940+ 549
P3	$N(1675) \rightarrow \Lambda K$	1116+ 498
P4	$N(1675) \rightarrow \Sigma K$	1189+ 494
P5	$N(1675) \rightarrow N\pi\pi$	938+ 140+ 140
P6	$N(1675) \rightarrow \Delta(1232)\ \pi$, D-wave	1232+ 140
P7	$N(1675) \rightarrow \Delta(1232)\ \pi$, G-wave	1232+ 140
P8	$N(1675) \rightarrow N\rho$, S=1/2, D-wave	938+ 769
P9	$N(1675) \rightarrow N\rho$, S=3/2, D-wave	938+ 769
P10	$N(1675) \rightarrow N\rho$, S=3/2, G-wave	938+ 769
P11	$N(1675) \rightarrow N(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P12	$N(1675) \rightarrow N(1520)\ \pi$, P-wave	1520+ 140
P13	$N(1675) \rightarrow p\gamma$, helicity=1/2	938+ 0
P14	$N(1675) \rightarrow p\gamma$, helicity=3/2	938+ 0
P15	$N(1675) \rightarrow n\gamma$, helicity=1/2	940+ 0
P16	$N(1675) \rightarrow n\gamma$, helicity=3/2	940+ 0

$N(1675)$ BRANCHING RATIOS

$N(1675) \rightarrow (N\pi)$/total (P1)

```
R1         (0.35)   (0.06)            CUTKOSKY  79 IPWA     PI N TO PI N
R1          0.38     0.03             HOEHLER   79 IPWA     PI N TO PI N
R1          0.38     0.05             CUTKOSKY  80 IPWA     PI N TO PI N
```

$N(1675)$ in $N\pi \rightarrow N\eta$ SQRT(P1*P2)

```
R2          0.0 OR  +0.009            FELTESSE  75 DPWA   0 1488 TO 1745 MEV
R2         (-0.07)                    BAKER     79 DPWA   0 PI- P TO ETA N
```

$N(1675)$ in $N\pi \rightarrow \Lambda K$ SQRT(P1*P3)

```
R3          -0.034    0.006           DEVENISH  74          0 FIXED T DISP REL
R3      COUPLING TO LAMBDA K NOT REQUIRED IN THE ANALYSES OF BAKER 77 AND
R3      BAKER 78
R3   C     (+0.036)                   SAXON     80 DPWA   0 PI- P TO K LAM
R3   C  SUPERSEDES BAKER 78.  COUPLING PHASE IS NEAR 90 DEGREES.
R3         (-0.01)                    BELL      83 DPWA 0  PI- P TO LAM K0
```

$N(1675)$ in $N\pi \rightarrow \Sigma K$ SQRT(P1*P4)

```
R4   D     LESS THAN 0.003            DEANS     75 DPWA     PI N TO K SIGMA
R4   D  RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.  DEANS 75 DISAGREES
R4   D  WITH PI+ P TO K+ SIGMA+ DATA OF WINNIK 77 AROUND 1920 MEV.

R       NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R              IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R              THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R              SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

$N(1675)$ in $N\pi \rightarrow \Delta(1232)\ \pi$, D-wave SQRT(P1*P6)

```
R5   A       +0.45 OR +0.50           LONGACRE  75 IPWA     PI N TO 2PI N
R5   B     (+0.46)                    LONGACRE  77 IPWA     PI N TO 2PI N
R5   B  LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R5   E     (+0.5)                     NOVOSELLE 78 IPWA     PI N TO 2PI N
R5   E  BW FIT TO LONGACRE 75 IPWA.
R5   F       +  (LARGE)               MANLEY    84 IPWA     PI N TO 2PI N
R5   F  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
```

$N(1675)$ in $N\pi \rightarrow N\rho$, S=3/2, D-wave SQRT(P1*P9)

```
R6   B     (-0.15)                    LONGACRE  77 IPWA     PI N TO 2PI N
R6   B  LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R6           -  (SMALL)               MANLEY    84 IPWA     PI N TO 2PI N
```

$N(1675)$ in $N\pi \rightarrow N(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P11)

```
R7   B     (+0.03)                    LONGACRE  77 IPWA     PI N TO 2PI N
```

$N(1675)$ in $N\pi \rightarrow N(1520)\ \pi$, P-wave SQRT(P1*P12)

```
R8         (-0.15)                    MANLEY    84 IPWA     PI N TO 2PI N
```

$N(1675)$ PHOTON DECAY AMPLITUDES ($GeV^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(1675) \rightarrow p\gamma$, helicity=1/2 ($GeV^{-1/2}$)

```
A1          +0.034    0.004           FELLER    76 DPWA     PI N PHOTOPROD.
A1          +0.034    0.003           AZNAURYAN 77 DPWA     PI0 PHTPRD,SOL 1
A1          +0.071    0.002           AZNAURYAN 77 DPWA     PI0 PHTPRD,SOL 2
A1          +0.022    0.010           BARBOUR   78 DPWA     PI-N PHOTOPROD.
A1           0.006    0.005           ARAI      80 DPWA     PI N PHOTO FIT 1
A1           0.006    0.004           ARAI      80 DPWA     PI N PHOTO FIT 2
A1           0.023    0.015           CRAWFORD  80 DPWA     PI N PHOTOPROD.
A1           0.034    0.005           AWAJI     81 DPWA     PI N PHOTOPROD.
A1           0.021    0.011           CRAWFORD  83 IPWA     PI N PHOTOPROD.
```

$N(1675) \to p\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A2	+0.019	0.009	FELLER	76	DPWA	PI N PHOTOPROD.
A2	+0.010	0.010	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 1
A2	+0.002	0.021	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 2
A2	+0.015	0.006	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A2	0.030	0.004	ARAI	80	DPWA	PI N PHOTO FIT 1
A2	0.029	0.004	ARAI	80	DPWA	PI N PHOTO FIT 2
A2	0.003	0.012	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A2	0.024	0.008	AWAJI	81	DPWA	PI N PHOTOPROD.
A2	0.015	0.009	CRAWFORD	83	IPWA	PI N PHOTOPROD.

$N(1675) \to n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A3	-0.066	0.020	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A3	-0.039	0.017	ARAI	80	DPWA	PI N PHOTO FIT 1
A3	-0.025	0.027	ARAI	80	DPWA	PI N PHOTO FIT 2
A3	-0.059	0.015	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A3	-0.021	0.011	TAKEDA	80	DPWA	PI N PHOTOPROD.
A3	-0.057	0.024	AWAJI	81	DPWA	PI N PHOTOPROD.
A3	-0.033	0.004	FUJII	81	DPWA	PI N PHOTOPROD.

$N(1675) \to n\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A4	-0.073	0.014	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A4	-0.066	0.026	ARAI	80	DPWA	PI N PHOTO FIT 1
A4	-0.071	0.022	ARAI	80	DPWA	PI N PHOTO FIT 2
A4	-0.059	0.020	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A4	-0.030	0.012	TAKEDA	80	DPWA	PI N PHOTOPROD.
A4	-0.077	0.018	AWAJI	81	DPWA	PI N PHOTOPROD.
A4	-0.069	0.004	FUJII	81	DPWA	PI N PHOTOPROD.

REFERENCES FOR $N(1675)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

DEVENISH 74 NP B81 330 DEVENISH,FROGGATT,MARTIN (DESY+NORD+LOUC)
DEANS 75 NP B96 90 +MITCHELL,MONTGOMERY,+ (SFLA+ALAH)IJP
FELTESSE 75 NP B93 242 +AYED,BAREYRE,BORGEAUD,DAVID,ERNWEIN+(SACL)IJP
LONGACRE 75 PL 55B 415 +ROSENFELD,LASINSKI,SMADJA+ (LBL+SLAC)IJP
FELLER 76 NP B104 219 +FUKUSHIMA,HORIKAWA,KAJIKAWA+ (NAGO+OSAK)IJP
AZNAURYA 77 EFI-264(57)-77 +AKOPOV,BAGDASARYAN (YERE)IJP
LONGACRE 77 NP B122 493 LONGACRE,DOLBEAU (SACL)IJP
ALSO 76 NP B108 365 DOLBEAU,TRIANTIS,NEVEU,CADIET (SACL)IJP
BAKER 77 NP B126 365 +BLISSET,BLOODWORTH,BROOME,HART+ (RHEL)IJP
WINNIK 77 NP B128 66 +TOAFF,REVEL,GOLDBERG,BERNY (HAIF)I
BARBOUR 78 NP B141 253 BARBOUR,CRAWFORD,PARSONS (GLAS)
LONGACRE 78 PR D17 1795 +LASINSKI,ROSENFELD,SMADJA+ (LBL+SLAC)
NOVOSELL 78 NP B137 509 D E NOVOSELLER (CIT)IJP
ALSO 78 NP B137 445 D E NOVOSELLER (CIT)IJP
BAKER 79 NP B156 93 +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+ (RHEL)IJP
CUTKOSKY 79 PR D20 2839 +FORSYTH,HENDRICK,KELLY (CARN+LBL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
ARAI 80 TORONTO CONF 93 I ARAI (TOKY)
ALSO 82 NP B194 251 I ARAI, H FUJII (TOKY)
CRAWFORD 80 TORONTO CONF 107 R L CRAWFORD (GLAS)
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
SAXON 80 NP B162 522 +BAKER,BELL,BLISSETT,BLOODWORTH+(RHEL+BRIS)IJP
TAKEDA 80 NP B168 17 TAKEDA,ARAI,FUJII,IKEDA,IWASAKI+ (TOKY)
AWAJI 81 BONN CONF 352 R KAJIKAWA (TALK) (NAGO)
ALSO 82 NP B197 365 FUJII,HAYASHII,IWATA,KAJIKAWA+ (NAGO)
FUJII 81 NP B187 53 FUJII,HAYASHII,IWATA,KAJIKAWA+ (TOKY)
BELL 83 NP B222 389 +BLISSET,BROOME,DALEY,HART,LINTERN,+ (RL)IJP
CRAWFORD 83 NP B211 1 R L CRAWFORD, W T MORTON (GLAS)
MANLEY 84 PR D30 904 MANLEY,ARNDT,GORADIA,TEPLITZ (VPI)
ARNDT 85 PR D32 1085 R A ARNDT, J M FORD, L D ROPER (VPI)

$N(1680)$ F_{15}

$I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

IN ADDITION, RESULTS IN THIS REGION FROM PRODUCTION EXPERIMENTS, WHICH USED TO BE LISTED SEPARATELY IN AN ENTRY FOLLOWING THE N(1700), HAVE BEEN ENTIRELY REMOVED. THEY TOO MAY BE FOUND IN OUR 1982 EDITION.

$N(1680)$ MASS (MeV)

M		(1685.0)		KNASEL	75	DPWA	0	PI- P TO K0 LAM
M	A	1680. OR 1670.		LONGACRE	75	IPWA		PI N TO 2PI N
M	A	THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.						
M	B	(1660.0)		LONGACRE	77	IPWA		PI N TO 2PI N
M	B	ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE						
M	B	POSITION WHICH IS FROM SOLUTIONS S1 AND C1.						
M		(1680.0)		BARBOUR	78	DPWA		PI-N PHOTOPROD.
M		(1680.0)	(15.0)	CUTKOSKY	79	IPWA		PI N TO PI N
M		1684.0	3.0	HOEHLER	79	IPWA		PI N TO PI N
M		(1682.0)		CRAWFORD	80	DPWA		PI N PHOTOPROD.
M		1680.0	10.0	CUTKOSKY	80	IPWA		PI N TO PI N

$N(1680)$ WIDTH (MeV)

W		(155.0)		KNASEL	75	DPWA	0	PI- P TO K0 LAM
W	A	125. OR 130.		LONGACRE	75	IPWA		PI N TO 2PI N
W	B	(150.0)		LONGACRE	77	IPWA		PI N TO 2PI N
W		(119.0)		BARBOUR	78	DPWA		PI-N PHOTOPROD.
W		(120.0)	(25.0)	CUTKOSKY	79	IPWA		PI N TO PI N
W		128.0	8.0	HOEHLER	79	IPWA		PI N TO PI N
W		(121.0)		CRAWFORD	80	DPWA		PI N PHOTOPROD.
W		120.0	10.0	CUTKOSKY	80	IPWA		PI N TO PI N

$N(1680)$ REAL PART OF POLE POSITION (MeV)

RE	B	1656.0 OR 1653.0		LONGACRE	77	IPWA	PI N TO 2PI N
RE		1688.0 OR 1674.0		LONGACRE	78	IPWA	PI N TO 2PI N
RE		(1666.0)		CUTKOSKY	79	IPWA	PI N TO PI N
RE		1667.0	5.0	CUTKOSKY	80	IPWA	PI N TO PI N
RE		(1680.)		ARNDT	85	DPWA	PI N TO PI N

$N(1680)$ −2*IMAG PART OF POLE POSITION (MeV)

IM	B	145.0 OR 143.0		LONGACRE	77	IPWA	PI N TO 2PI N
IM		132.0 OR 137.0		LONGACRE	78	IPWA	PI N TO 2PI N
IM		(112.0)		CUTKOSKY	79	IPWA	PI N TO PI N
IM		110.0	10.0	CUTKOSKY	80	IPWA	PI N TO PI N
IM		(120.)		ARNDT	85	DPWA	PI N TO PI N

$N(1680)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	(31.0)		CUTKOSKY	79	IPWA	PI N TO PI N
RER	31.0	2.0	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1680)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	(-15.0)		CUTKOSKY	79	IPWA	PI N TO PI N
IMR	-14.0	3.0	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1680)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1680) \to N\pi$	938+ 140
P2	$N(1680) \to N\eta$	940+ 549
P3	$N(1680) \to \Lambda K$	1116+ 498
P4	$N(1680) \to \Sigma K$	1189+ 494
P5	$N(1680) \to N\pi\pi$	938+ 140+ 140
P6	$N(1680) \to \Delta(1232)\ \pi$, P-wave	1232+ 140
P7	$N(1680) \to \Delta(1232)\ \pi$, F-wave	1232+ 140
P8	$N(1680) \to N\rho$, S=1/2, F-wave	938+ 769
P9	$N(1680) \to N\rho$, S=3/2, P-wave	938+ 769
P10	$N(1680) \to N\rho$, S=3/2, F-wave	938+ 769
P11	$N(1680) \to N(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P12	$N(1680) \to p\gamma$, helicity=1/2	938+ 0
P13	$N(1680) \to p\gamma$, helicity=3/2	938- 0
P14	$N(1680) \to n\gamma$, helicity=1/2	940+ 0
P15	$N(1680) \to n\gamma$, helicity=3/2	940+ 0

$N(1680)$ BRANCHING RATIOS

$N(1680) \to (N\pi)$/total (P1)

R1	(0.62)	(0.06)	CUTKOSKY	79	IPWA	PI N TO PI N
R1	0.65	0.02	HOEHLER	79	IPWA	PI N TO PI N
R1	0.62	0.05	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1680)$ in $N\pi \to N\eta$ SQRT(P1*P2)

R2	NOT SEEN	BAKER	79	DPWA	0	PI- P TO ETA N

$N(1680) \to (N\eta)$/total (P2)

R3	C	(0.0004)		BOTKE	69	MPWA	T POLE + RESON.
R3	C	(0.003)	(0.002)	DEANS	69	MPWA	T POLE + RESON.
R3	C	0.0005 OR 0.001		CARRERAS	70	MPWA	T POLE + RESON.
R3	C	PARAMETRIZATION USED COULD BE IN DANGER OF DOUBLE COUNTING					

$N(1680) \to (N\eta)/(N\pi)$ (P2)/(P1)

R4	(0.027)OR LESS	HEUSCH	66	RVUE +	PI0, ETA PHOTO

$N(1680)$ in $N\pi \to \Lambda K$ SQRT(P1*P3)

R5	-0.009	0.009	DEVENISH	74	0	FIXED T DISP REL
R5	(0.01)		KNASEL	75 DPWA	0	PI- P TO K0 LAM
R5	COUPLING TO LAMBDA K NOT REQUIRED IN THE ANALYSES OF BAKER 77,					
R5	SAXON 80, OR BELL 83.					

$N(1680)$ in $N\pi \to \Sigma K$ SQRT(P1*P4)

R6	D	LESS THAN 0.001	DEANS	75	DPWA	PI N TO K SIGMA
R6	D	RANGE GIVEN IS FROM 3 OF 4 BEST SOLUTIONS, NOT PRESENT IN SLTN.1.				
R6	D	DEANS 75 DISAGREES WITH PI+ P TO K+ SIGMA+ DATA OF WINNIK 77				
R6	D	AROUND 1920 MEV.				

R NOTE: SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.

$N(1680)$ in $N\pi \to \Delta(1232)\ \pi$, P-wave SQRT(P1*P6)

R7	A	-0.26 OR -0.25	LONGACRE	75	IPWA	PI N TO 2PI N
R7	B	(-0.27)	LONGACRE	77	IPWA	PI N TO 2PI N
R7	B	LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.				
R7	E	(-0.38)	NOVOSELLE	78	IPWA	PI N TO 2PI N
R7	E	BW FIT TO LONGACRE 75 IPWA.				
R7	F	- (LARGE)	MANLEY	84	IPWA	PI N TO 2PI N
R7	F	MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.				

$N(1680)$ in $N\pi \to \Delta(1232)\ \pi$, F-wave SQRT(P1*P7)

R8	A	0. OR +0.08	LONGACRE	75	IPWA	PI N TO 2PI N
R8	B	(+0.07)	LONGACRE	77	IPWA	PI N TO 2PI N
R8	E	(+0.05)	NOVOSELLE	78	IPWA	PI N TO 2PI N
R8	F	+ (SMALL)	MANLEY	84	IPWA	PI N TO 2PI N
R8	F	MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.				

$N(1680)$ in $N\pi \rightarrow N\rho$, S=3/2, *P*-wave SQRT(P1*P9)

```
R9    A       -0.27 OR -0.30             LONGACRE  75 IPWA    PI N TO 2PI N
R9    B     (-0.23)                      LONGACRE  77 IPWA    PI N TO 2PI N
R9    B  LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R9    E     (-0.34)                      NOVOSELLE 78 IPWA    PI N TO 2PI N
R9    F        -  (LARGE)                MANLEY    84 IPWA    PI N TO 2PI N
R9    F  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
```

$N(1680)$ in $N\pi \rightarrow N\rho$, S=3/2, *F*-wave SQRT(P1*P10)

```
R10   B     (-0.15)                      LONGACRE  77 IPWA    PI N TO 2PI N
R10   B  LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R10            -  (SMALL)                MANLEY    84 IPWA    PI N TO 2PI N
```

$N(1680)$ in $N\pi \rightarrow N(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P11)

```
R11   A       +0.28 OR +0.30             LONGACRE  75 IPWA    PI N TO 2PI N
R11   B     (+0.31)                      LONGACRE  77 IPWA    PI N TO 2PI N
R11   B  LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R11   E     (+0.42)                      NOVOSELLE 78 IPWA    PI N TO 2PI N
R11   F        +  (LARGE)                MANLEY    84 IPWA    PI N TO 2PI N
R11   F  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
```

$N(1680)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(1680) \rightarrow p\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1          -0.009    0.002          FELLER     76 DPWA    PI N PHOTOPROD.
A1          -0.007    0.002          AZNAURYAN  77 DPWA    PIO PHTPRD,SOL 1
A1          -0.010    0.001          AZNAURYAN  77 DPWA    PIO PHTPRD,SOL 2
A1          -0.005    0.015          BARBOUR    78 DPWA    PI-N PHOTOPROD.
A1          -0.028    0.003          ARAI       80 DPWA    PI N PHOTO FIT 1
A1          -0.026    0.003          ARAI       80 DPWA    PI N PHOTO FIT 2
A1          -0.018    0.014          CRAWFORD   80 DPWA    PI N PHOTOPROD.
A1          -0.009    0.006          AWAJI      81 DPWA    PI N PHOTOPROD.
A1          -0.017    0.018          CRAWFORD   83 IPWA    PI N PHOTOPROD.
```

$N(1680) \rightarrow p\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A2          +0.121    0.010          FELLER     76 DPWA    PI N PHOTOPROD.
A2          +0.112    0.002          AZNAURYAN  77 DPWA    PIO PHTPRD,SOL 1
A2          +0.114    0.002          AZNAURYAN  77 DPWA    PIO PHTPRD,SOL 2
A2          +0.138    0.021          BARBOUR    78 DPWA    PI-N PHOTOPROD.
A2           0.115    0.003          ARAI       80 DPWA    PI N PHOTO FIT 1
A2           0.122    0.003          ARAI       80 DPWA    PI N PHOTO FIT 2
A2           0.141    0.014          CRAWFORD   80 DPWA    PI N PHOTOPROD.
A2           0.115    0.008          AWAJI      81 DPWA    PI N PHOTOPROD.
A2           0.132    0.010          CRAWFORD   83 IPWA    PI N PHOTOPROD.
```

$N(1680) \rightarrow n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A3          +0.037    0.010          BARBOUR    78 DPWA    PI-N PHOTOPROD.
A3           0.026    0.005          ARAI       80 DPWA    PI N PHOTO FIT 1
A3           0.028    0.014          ARAI       80 DPWA    PI N PHOTO FIT 2
A3           0.044    0.012          CRAWFORD   80 DPWA    PI N PHOTOPROD.
A3           0.025    0.010          TAKEDA     80 DPWA    PI N PHOTOPROD.
A3           0.017    0.014          AWAJI      81 DPWA    PI N PHOTOPROD.
A3           0.032    0.003          FUJII      81 DPWA    PI N PHOTOPROD.
```

$N(1680) \rightarrow n\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A4          -0.038    0.018          BARBOUR    78 DPWA    PI-N PHOTOPROD.
A4          -0.024    0.009          ARAI       80 DPWA    PI N PHOTO FIT 1
A4          -0.029    0.017          ARAI       80 DPWA    PI N PHOTO FIT 2
A4          -0.033    0.015          CRAWFORD   80 DPWA    PI N PHOTOPROD.
A4          -0.035    0.012          TAKEDA     80 DPWA    PI N PHOTOPROD.
A4          -0.033    0.013          AWAJI      81 DPWA    PI N PHOTOPROD.
A4          -0.023    0.005          FUJII      81 DPWA    PI N PHOTOPROD.
```

REFERENCES FOR $N(1680)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).
FOR VERY EARLY REFERENCES, SEE RMP 37, 633 (1965).

```
HEUSCH   66 PRL 17 1019        C A HEUSCH, C Y PRESCOTT, R F DASHEN  (CIT)
BOTKE    69 PR 180 1417        J C BOTKE                            (UCSB)
DEANS    69 PR 185 1797        S DEANS, J WOOTEN                    (SFLA)
CARRERAS 70 NP 163 35          B CARRERAS, A DONNACHIE         (DARE-MCHS)
DEVENISH 74 NP B81 330         DEVENISH,FROGGATT,MARTIN   (DESY+NORD+LOUC)
DEANS    75 NP B96 90          +MITCHELL,MONTGOMERY,+         (SFLA+ALAH)IJP
KNASEL   75 PR D11 1           +LINDQUIST,NELSON+       (CHIC+WUSL+OSU+ANL)IJP
LONGACRE 75 PL 55B 415         +ROSENFELD,LASINSKI,SMADJA+     (LBL+SLAC)IJP
FELLER   76 NP B104 219        +FUKUSHIMA,HORIKAWA,KAJIKAWA+  (NAGO+OSAK)IJP
AZNAURYA 77  EFI-264(57)-77    +AKOPOV,BAGDASARYAN                  (YERE)IJP
BAKER    77 NP B126 365        +BLISSET,BLOODWORTH,BROOME,HART+     (RHEL)IJP
LONGACRE 77 NP B122 493        LONGACRE,DOLBEAU                     (SACL)IJP
    ALSO 76 NP B108 365        DOLBEAU,TRIANTIS,NEVEU,CADIET        (SACL)IJP
WINNIK   77 NP B128 66         +TOAFF,REVEL,GOLDBERG,BERNY          (HAIF)I
BARBOUR  78 NP B141 253        BARBOUR,CRAWFORD,PARSONS             (GLAS)
LONGACRE 78 PR D17 1795        -LASINSKI,ROSENFELD,SMADJA+     (LBL+SLAC)
NOVOSELL 78 NP B137 509        D E NOVOSELLER                        (CIT)IJP
    ALSO 78 NP B137 445        D E NOVOSELLER                        (CIT)IJP
BAKER    79 NP B156 93         +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+  (RHEL)IJP
CUTKOSKY 79 PR D20 2839        +FORSYTH,HENDRICK,KELLY         (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                               +KAISER,KOCH,PIETARINEN              (KARL)IJP
    ALSO 80  TORONTO CONF 3    R KOCH                               (KARL)IJP
ARAI     80  TORONTO CONF 93   I ARAI                               (TOKY)
    ALSO 82 NP B194 251        I ARAI, H FUJII                      (TOKY)
CRAWFORD 80  TORONTO CONF 107 R L CRAWFORD                          (GLAS)
CUTKOSKY 80  TORONTO CONF 19   -FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
SAXON    80 NP B162 522        +BAKER,BELL,BLOODWORTH+        (RHEL+BRIS)IJP
TAKEDA   80 NP B168 17         TAKEDA,ARAI,FUJII,IKEDA,IWASAKI+     (TOKY)
AWAJI    81  BONN CONF 352     R KAJIKAWA (TALK)                    (NAGO)
    ALSO 82 NP B197 365        FUJII,HAYASHII,IWATA,KAJIKAWA+       (NAGO)
FUJII    81 NP B187 53         FUJII,HAYASHII,IWATA,KAJIKAWA+       (TOKY)
BELL     83 NP B222 389        +BLISSET,BROOME,DALEY,HART,LINTERN,+   (RL)IJP
CRAWFORD 83 NP B211 1          R L CRAWFORD, W T MORTON             (GLAS)
MANLEY   84 PR D30 904         MANLEY,ARNDT,GORADIA,TEPLITZ          (VPI)
ARNDT    85 PR D32 1085        R A ARNDT, J M FORD, L D ROPER        (VPI)
```

$N(1700)$ D_{13}

$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$ Status: * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

IN ADDITION, RESULTS IN THIS REGION FROM PRODUCTION EXPERIMENTS, WHICH USED TO BE LISTED SEPARATELY AS THE NEXT ENTRY, HAVE BEEN ENTIRELY REMOVED. THEY TOO MAY BE FOUND IN OUR 1982 EDITION.

THE VARIOUS PARTIAL-WAVE ANALYSES DO NOT AGREE VERY WELL.

$N(1700)$ MASS (MeV)

```
M     A      1710. OR 1710.             LONGACRE  75 IPWA    PI N TO 2PI N
M     A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M     B    (1670.0)   (10.0)            BAKER     77 IPWA  0 PI- P TO K LAM.
M     C    (1690.0)                     BAKER     77 DPWA  0 PI- P TO K LAM.
M     B  THE TWO ENTRIES FOR BAKER 77 ARE FOR AN IPWA USING THE BARRELET
M     C  ZERO METHOD AND A CONVENTIONAL ENERGY-DEPENDENT ANALYSIS.
M     D    (1660.0)                     LONGACRE  77 IPWA    PI N TO 2PI N
M     D  ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M     D  POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M            1690. TO 1710.             BAKER     78 DPWA  0 PI- P TO K LAM
M          (1719.0)                     BARBOUR   78 DPWA    PI-N PHOTOPROD.
M     E    (1880.0)                     BAKER     79 DPWA  0 PI- P TO ETA N
M     E  THE HIGH MASS FOUND BY BAKER 79 MAY BE INFLUENCED BY THE N(2080).
M          (1670.0)   (25.0)            CUTKOSKY  79 IPWA    PI N TO PI N
M           1731.0     15.0             HOEHLER   79 IPWA    PI N TO PI N
M          (1709.0)                     CRAWFORD  80 DPWA    PI N PHOTOPROD.
M           1675.0     25.0             CUTKOSKY  80 IPWA    PI N TO PI N
M          (1650.0)                     SAXON     80 DPWA  0 PI- P TO K LAM
```

$N(1700)$ WIDTH (MeV)

```
W     A       100. OR  300.             LONGACRE  75 IPWA    PI N TO 2PI N
W     B      (90.0)   (25.0)            BAKER     77 IPWA  0 PI- P TO K LAM.
W     C     (100.0)                     BAKER     77 DPWA  0 PI- P TO K LAM.
W     D     (600.0)                     LONGACRE  77 IPWA    PI N TO 2PI N
W              70. TO  100.             BAKER     78 DPWA  0 PI- P TO K LAM
W           (126.0)                     BARBOUR   78 DPWA    PI-N PHOTOPROD.
W     E      (87.0)                     BAKER     79 DPWA  0 PI- P TO ETA N
W            (80.0)   (40.0)            CUTKOSKY  79 IPWA    PI N TO PI N
W            110.0     30.0             HOEHLER   79 IPWA    PI N TO PI N
W           (166.0)                     CRAWFORD  80 DPWA    PI N PHOTOPROD.
W             90.0     40.0             CUTKOSKY  80 IPWA    PI N TO PI N
W            (70.0)                     SAXON     80 DPWA  0 PI- P TO K LAM
```

$N(1700)$ REAL PART OF POLE POSITION (MeV)

```
RE    D     1616.0 OR 1613.0            LONGACRE  77 IPWA    PI N TO 2PI N
RE          1710.0 OR 1678.0            LONGACRE  78 IPWA    PI N TO 2PI N
RE         (1660.0)                     CUTKOSKY  79 IPWA    PI N TO PI N
RE          1660.0     30.0             CUTKOSKY  80 IPWA    PI N TO PI N
RE         (1670.)                      ARNDT     85 DPWA    PI N TO PI N
```

$N(1700)$ −2*IMAG PART OF POLE POSITION (MeV)

```
IM    D      577.0 OR 575.0             LONGACRE  77 IPWA    PI N TO 2PI N
IM           607.0 OR 567.0             LONGACRE  78 IPWA    PI N TO 2PI N
IM           (76.0)                     CUTKOSKY  79 IPWA    PI N TO PI N
IM            90.0     40.0             CUTKOSKY  80 IPWA    PI N TO PI N
IM           (80.)                      ARNDT     85 DPWA    PI N TO PI N
```

$N(1700)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER          (4.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
RER           6.0      3.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1700)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR         (-0.3)                      CUTKOSKY  79 IPWA    PI N TO PI N
IMR           0.0      5.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1700)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1700) \rightarrow N\pi$	938+ 140
P2	$N(1700) \rightarrow N\eta$	940+ 549
P3	$N(1700) \rightarrow \Lambda K$	1116+ 498
P4	$N(1700) \rightarrow \Sigma K$	1189+ 494
P5	$N(1700) \rightarrow \Delta(1232)\ \pi$, *S*-wave	1232+ 140
P6	$N(1700) \rightarrow \Delta(1232)\ \pi$, *D*-wave	1232+ 140
P7	$N(1700) \rightarrow N\rho$, S=1/2, *D*-wave	938+ 769
P8	$N(1700) \rightarrow N\rho$, S=3/2, *S*-wave	938+ 769
P9	$N(1700) \rightarrow N\rho$, S=3/2, *D*-wave	938+ 769
P10	$N(1700) \rightarrow N(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P11	$N(1700) \rightarrow p\gamma$, helicity=1/2	938+ 0
P12	$N(1700) \rightarrow p\gamma$, helicity=3/2	938+ 0
P13	$N(1700) \rightarrow n\gamma$, helicity=1/2	940+ 0
P14	$N(1700) \rightarrow n\gamma$, helicity=3/2	940+ 0

$N(1700)$ BRANCHING RATIOS

$N(1700) \rightarrow (N\pi)/\text{total}$ (P1)

```
R1          (0.10)    (0.02)         CUTKOSKY  79 IPWA    PI N TO PI N
R1           0.08      0.03          HOEHLER   79 IPWA    PI N TO PI N
R1           0.11      0.05          CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1700)$ in $N\pi \rightarrow N\eta$ SQRT(P1*P2)

```
R2          (0.065)                  BAKER     79 DPWA  0 PI- P TO ETA N
```

$N(1700)$ in $N\pi \rightarrow \Lambda K$ SQRT(P1*P3)

```
R3           +0.026    0.019         DEVENISH  74         0 FIXED T DISP REL
R3   B      (-0.03)   (0.004)        BAKER     77 IPWA  0 PI- P TO K LAM.
R3   C      (-0.03)                  BAKER     77 DPWA  0 PI- P TO K LAM.
R3   F      (-0.04)                  BAKER     78 DPWA  0 PI- P TO K LAM
R3   F  THE (UNDETERMINED) OVERALL PHASE OF ALL COUPLINGS HAS BEEN
R3   F  CHANGED TO AGREE WITH PREVIOUS CONVENTIONS. SUPERSEDED BY SAXON 80.
R3          (-0.012)                 SAXON     80 DPWA  0 PI- P TO K LAM
R3          (-0.012)                 BELL      83 DPWA 0  PI- P TO LAM K0
```

$N(1700)$ in $N\pi \rightarrow \Sigma K$ SQRT(P1*P4)

```
R4   G     LESS THAN 0.017           DEANS     75 DPWA    PI N TO K SIGMA
R4   G  RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.
R4           NOT SEEN                LIVANOS   80 DPWA    PI P TO K SIGMA

R       NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R              IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R              THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R              SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

$N(1700)$ in $N\pi \rightarrow \Delta(1232)\ \pi$, S-wave SQRT(P1*P5)

```
R5   A      -0.15 OR -0.16           LONGACRE  75 IPWA    PI N TO 2PI N
R5   D      (0.00)                   LONGACRE  77 IPWA    PI N TO 2PI N
R5             (SMALL)               MANLEY    84 IPWA    PI N TO 2PI N     |
```

$N(1700)$ in $N\pi \rightarrow \Delta(1232)\ \pi$, D-wave SQRT(P1*P6)

```
R6   A      +0.10 OR +0.14           LONGACRE  75 IPWA    PI N TO 2PI N
R6   D     (-0.12)                   LONGACRE  77 IPWA    PI N TO 2PI N
R6           + (SMALL)               MANLEY    84 IPWA    PI N TO 2PI N     |
```

$N(1700)$ in $N\pi \rightarrow N\rho$, S=3/2, S-wave SQRT(P1*P8)

```
R7   A       0.  OR  +0.07           LONGACRE  75 IPWA    PI N TO 2PI N
R7   D     (-0.07)                   LONGACRE  77 IPWA    PI N TO 2PI N
```

$N(1700)$ in $N\pi \rightarrow N(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P10)

```
R8   A      +0.2  OR +0.2            LONGACRE  75 IPWA    PI N TO 2PI N
R8   D      (0.00)                   LONGACRE  77 IPWA    PI N TO 2PI N
R8           + (SMALL)               MANLEY    84 IPWA    PI N TO 2PI N     |
```

$N(1700)$ in $p\gamma \rightarrow \Lambda K$ SQRT((P11+P12)*P3)

```
R9          (0.0077)                 DEANS     72 MPWA    GAM P-K LM,SOL D
```

$N(1700)$ PHOTON DECAY AMPLITUDES ($\text{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(1700) \rightarrow p\gamma$, helicity=1/2 ($\text{GeV}^{-1/2}$)

```
A1          -0.014    0.025          FELLER    76 DPWA    PI N PHOTOPROD.
A1          +0.078    0.008          AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A1          +0.038    0.005          AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A1          -0.033    0.021          BARBOUR   78 DPWA    PI-N PHOTOPROD.
A1          -0.028    0.007          ARAI      80 DPWA    PI N PHOTO FIT 1
A1          -0.029    0.006          ARAI      80 DPWA    PI N PHOTO FIT 2
A1          -0.024    0.019          CRAWFORD  80 DPWA    PI N PHOTOPROD.
A1          -0.002    0.013          AWAJI     81 DPWA    PI N PHOTOPROD.
A1          -0.016    0.014          CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

$N(1700) \rightarrow p\gamma$, helicity=3/2 ($\text{GeV}^{-1/2}$)

```
A2           0.0      0.014          FELLER    76 DPWA    PI N PHOTOPROD.
A2          -0.066    0.007          AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A2          -0.048    0.007          AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A2          -0.014    0.025          BARBOUR   78 DPWA    PI-N PHOTOPROD.
A2          -0.002    0.005          ARAI      80 DPWA    PI N PHOTO FIT 1
A2           0.014    0.005          ARAI      80 DPWA    PI N PHOTO FIT 2
A2          -0.017    0.014          CRAWFORD  80 DPWA    PI N PHOTOPROD.
A2           0.029    0.014          AWAJI     81 DPWA    PI N PHOTOPROD.
A2          -0.009    0.012          CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

$N(1700) \rightarrow n\gamma$, helicity=1/2 ($\text{GeV}^{-1/2}$)

```
A3          +0.050    0.042          BARBOUR   78 DPWA    PI-N PHOTOPROD.
A3          -0.052    0.030          ARAI      80 DPWA    PI N PHOTO FIT 1
A3          -0.055    0.030          ARAI      80 DPWA    PI N PHOTO FIT 2
A3           0.052    0.035          CRAWFORD  80 DPWA    PI N PHOTOPROD.
A3           0.006    0.024          AWAJI     81 DPWA    PI N PHOTOPROD.
A3          -0.002    0.013          FUJII     81 DPWA    PI N PHOTOPROD.
```

$N(1700) \rightarrow n\gamma$, helicity=3/2 ($\text{GeV}^{-1/2}$)

```
A4          +0.035    0.030          BARBOUR   78 DPWA    PI-N PHOTOPROD.
A4          -0.037    0.036          ARAI      80 DPWA    PI N PHOTO FIT 1
A4          -0.035    0.024          ARAI      80 DPWA    PI N PHOTO FIT 2
A4           0.041    0.030          CRAWFORD  80 DPWA    PI N PHOTOPROD.
A4          -0.033    0.017          AWAJI     81 DPWA    PI N PHOTOPROD.
A4           0.018    0.018          FUJII     81 DPWA    PI N PHOTOPROD.
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REFERENCES FOR $N(1700)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS     72 PR D6 1906          DEANS,JACOBS, LYONS,MONTGOMERY       (SFLA)IJP
DEVENISH  74 NP B81 330          DEVENISH,FROGGATT,MARTIN    (DESY+NORD+LOUC)
DEANS     75 NP B96 90           +MITCHELL,MONTGOMERY,+           (SFLA+ALAH)IJP
LONGACRE  75 PL 55B 415          +ROSENFELD,LASINSKI,SMADJA+       (LBL+SLAC)IJP
FELLER    76 NP B104 219         +FUKUSHIMA,HORIKAWA,KAJIKAWA+    (NAGO+OSAK)IJP
AZNAURYA  77  EFI-264(57)-77     +AKOPOV,BAGDASARYAN                       (YERE)IJP
BAKER     77 NP B126 365         +BLISSET,BLOODWORTH,BROOME,HART+          (RHEL)IJP
LONGACRE  77 NP B122 493         LONGACRE,DOLBEAU                          (SACL)IJP
   ALSO   76 NP B108 365         DOLBEAU,TRIANTIS,NEVEU,CADIET             (SACL)IJP
BAKER     78 NP B141 29          +BLISSET,BLOODWORTH,BROOME+           (RL+CAMB)IJP
BARBOUR   78 NP B141 253         BARBOUR,CRAWFORD,PARSONS                  (GLAS)
LONGACRE  78 PR D17 1795         +LASINSKI,ROSENFELD,SMADJA+           (LBL+SLAC)
BAKER     79 NP B156 93          +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+  (RHEL)IJP
CUTKOSKY  79 PR D20 2839         +FORSYTH,HENDRICK,KELLY              (CARN+LBL)IJP
HOEHLER   79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                                 +KAISER,KOCH,PIETARINEN                   (KARL)IJP
   ALSO   80  TORONTO CONF 3     R KOCH                                    (KARL)IJP
ARAI      80  TORONTO CONF 93    I ARAI                                    (TOKY)
   ALSO   82 NP B194 251         I ARAI, H FUJII                           (TOKY)
CRAWFORD  80  TORONTO CONF 107   R L CRAWFORD                              (GLAS)
CUTKOSKY  80  TORONTO CONF 19    +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
LIVANOS   80  TORONTO CONF 35    +BATON,COUTURES,KOCHOWSKI,NEVEU           (SACL)IJP
SAXON     80 NP B162 522         +BAKER,BELL,BLISSETT,BLOODWORTH+(RHEL-BRIS)IJP
AWAJI     81  BONN CONF 352      R KAJIKAWA (TALK)                         (NAGO)
   ALSO   82 NP B197 365         FUJII,HAYASHII,IWATA,KAJIKAWA+            (NAGO)
FUJII     81 NP B187 53          FUJII,HAYASHII,IWATA,KAJIKAWA-            (TOKY)
BELL      83 NP B222 389         +BLISSET,BROOME,DALEY,HART,LINTERN,+    (RL)IJP
CRAWFORD  83 NP B211 1           R L CRAWFORD, W T MORTON                  (GLAS)
MANLEY    84 PR D30 904          MANLEY,ARNDT,GORADIA,TEPLITZ               (VPI)
ARNDT     85 PR D32 1085         R A ARNDT, J M FORD, L D ROPER             (VPI)
```

$N(1710)$ P_{11}

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

THE VARIOUS PARTIAL-WAVE ANALYSES DO NOT AGREE VERY WELL.

$N(1710)$ MASS (MeV)

```
M        (1670.0)                       KNASEL    75 DPWA  0 PI- P TO K0 LAM
M    A     1730. OR 1710.               LONGACRE  75 IPWA    PI N TO 2PI N
M    A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M    B    (1625.0)   (10.0)             BAKER     77 IPWA  0 PI- P TO K LAM.
M    C    (1650.0)                      BAKER     77 DPWA  0 PI- P TO K LAM.
M    B  THE TWO ENTRIES FOR BAKER 77 ARE FOR AN IPWA USING THE BARRELET
M    C  ZERO METHOD AND A CONVENTIONAL ENERGY-DEPENDENT ANALYSIS.
M    D    (1720.0)                      LONGACRE  77 IPWA    PI N TO 2PI N
M    D  ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M    D  POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M          1650. TO 1680.               BAKER     78 DPWA  0 PI- P TO K LAM
M        (1721.0)                       BARBOUR   78 DPWA    PI-N PHOTOPROD.
M        (1690.0)                       BAKER     79 DPWA  0 PI- P TO ETA N
M        (1710.0)    (60.0)             CUTKOSKY  79 IPWA    PI N TO PI N
M          1723.0       9.0             HOEHLER   79 IPWA    PI N TO PI N
M        (1692.0)                       CRAWFORD  80 DPWA    PI N PHOTOPROD.
M          1700.0      50.0             CUTKOSKY  80 IPWA    PI N TO PI N
M        (1730.0)                       SAXON     80 DPWA  0 PI- P TO K LAM
```

$N(1710)$ WIDTH (MeV)

```
W          (174.0)                      KNASEL    75 DPWA  0 PI- P TO K0 LAM
W    A      165.  OR  75.               LONGACRE  75 IPWA    PI N TO 2PI N
W    B     (160.0)    (6.0)             BAKER     77 IPWA  0 PI- P TO K LAM.
W    C      (95.0)                      BAKER     77 DPWA  0 PI- P TO K LAM.
W    D     (120.0)                      LONGACRE  77 IPWA    PI N TO 2PI N
W            90. TO  150.               BAKER     78 DPWA  0 PI- P TO K LAM
W          (167.0)                      BARBOUR   78 DPWA    PI-N PHOTOPROD.
W           (97.0)                      BAKER     79 DPWA  0 PI- P TO ETA N
W          (100.0)    (50.0)            CUTKOSKY  79 IPWA    PI N TO PI N
W           120.0      15.0             HOEHLER   79 IPWA    PI N TO PI N
W          (200.0)                      CRAWFORD  80 DPWA    PI N PHOTOPROD.
W            90.0      30.0             CUTKOSKY  80 IPWA    PI N TO PI N
W          (550.0)                      SAXON     80 DPWA  0 PI- P TO K LAM
W          (540.0)                      BELL      83 DPWA 0  PI- P TO LAM K0
```

$N(1710)$ REAL PART OF POLE POSITION (MeV)

```
RE   D     1720.0 OR 1711.0             LONGACRE  77 IPWA    PI N TO 2PI N
RE         1708.0 OR 1712.0             LONGACRE  78 IPWA    PI N TO 2PI N
RE        (1692.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
RE         1690.0      20.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1710)$ −2*IMAG PART OF POLE POSITION (MeV)

```
IM   D      123.0 OR 115.0              LONGACRE  77 IPWA    PI N TO 2PI N
IM           17.0 OR 22.0               LONGACRE  78 IPWA    PI N TO 2PI N
IM          (88.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
IM           80.0      20.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1710)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER         (-9.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
RER          -8.0       2.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1710)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR          (0.1)                      CUTKOSKY  79 IPWA    PI N TO PI N
IMR           1.0       5.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(1710)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1710) \to N\pi$	938+ 140
P2	$N(1710) \to N\eta$	940+ 549
P3	$N(1710) \to \Lambda K$	1116+ 498
P4	$N(1710) \to \Sigma K$	1189+ 494
P5	$N(1710) \to N\pi\pi$	938+ 140+ 140
P6	$N(1710) \to \Delta(1232)\,\pi$, P-wave	1232+ 140
P7	$N(1710) \to N\rho$, S=1/2, P-wave	938+ 769
P8	$N(1710) \to N\rho$, S=3/2, P-wave	938+ 769
P9	$N(1710) \to N(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P10	$N(1710) \to p\gamma$, helicity=1/2	938+ 0
P11	$N(1710) \to n\gamma$, helicity=1/2	940+ 0

$N(1710)$ BRANCHING RATIOS

$N(1710) \to (N\pi)$/total (P1)

R1		(0.19)	(0.05)	CUTKOSKY	79	IPWA	PI N TO PI N
R1		0.12	0.04	HOEHLER	79	IPWA	PI N TO PI N
R1		0.20	0.04	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1710)$ in $N\pi \to N\eta$ SQRT(P1*P2)

R2		(0.22)		BAKER	79	DPWA	0 PI- P TO ETA N

$N(1710)$ in $N\pi \to \Lambda K$ SQRT(P1*P3)

R3		(0.10)		KNASEL	75	DPWA	0 PI- P TO K0 LAM
R3	B	(-0.05)	(0.03)	BAKER	77	IPWA	0 PI- P TO K LAM.
R3	C	(-0.10)		BAKER	77	DPWA	0 PI- P TO K LAM.
R3	E	(-0.12)		BAKER	78	DPWA	0 PI- P TO K LAM
R3	E	THE (UNDETERMINED) OVERALL PHASE OF ALL COUPLINGS FROM BAKER 78					
R3	E	HAS BEEN CHANGED TO AGREE WITH PREVIOUS CONVENTIONS. SUPERSEDED					
R3	E	BY SAXON 80.					
R3		(+0.14)		SAXON	80	DPWA	0 PI- P TO K LAM
R3		(-0.16)		BELL	83	DPWA	0 PI- P TO LAM K0

$N(1710)$ in $N\pi \to \Sigma K$ SQRT(P1*P4)

R4	F	0.075 TO 0.203		DEANS	75	DPWA	PI N TO K SIGMA
R4	F	RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.					
R4		(-0.034)		LIVANOS	80	DPWA	PI P TO K SIGMA

R NOTE: SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.

$N(1710)$ in $N\pi \to \Delta(1232)\,\pi$ SQRT(P1*P6)

R5	A	0.13 OR +0.20		LONGACRE	75	IPWA	PI N TO 2PI N
R5	D	(-0.17)		LONGACRE	77	IPWA	PI N TO 2PI N
R5		(-)		MANLEY	84	IPWA	PI N TO 2PI N

$N(1710)$ in $N\pi \to N\rho$, S=1/2, P-wave SQRT(P1*P7)

R6	A	-0.32 OR -0.20		LONGACRE	75	IPWA	PI N TO 2PI N
R6	D	(-0.19)		LONGACRE	77	IPWA	PI N TO 2PI N
R6		(-)		MANLEY	84	IPWA	PI N TO 2PI N

$N(1710)$ in $N\pi \to N\rho$, S=3/2, P-wave SQRT(P1*P8)

R7	D	(+0.31)		LONGACRE	77	IPWA	PI N TO 2PI N

$N(1710)$ in $N\pi \to N(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P9)

R8	A	-0.18 OR -0.28		LONGACRE	75	IPWA	PI N TO 2PI N
R8	D	(-0.26)		LONGACRE	77	IPWA	PI N TO 2PI N

$N(1710)$ in $p\gamma \to p\eta$ SQRT(P10*P2)

R9		(0.0075)		HICKS	73	MPWA	GAM P-ETA P

$N(1710)$ in $p\gamma \to \Lambda K$ SQRT(P10*P3)

R10		(0.0027)		ORITO2	69	CNTR	K LAM PHOTOPRO
R10		(0.0088)		SCHORSCH	70	DPWA	K LAM PHOTOPRO.
R10		(0.0104)		DEANS	72	MPWA	GAM P-K LM,SOL D

$N(1710)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(1710) \to p\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A1	+0.053	0.019	FELLER	76	DPWA	PI N PHOTOPROD.
A1	+0.001	0.039	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A1	-0.009	0.006	ARAI	80	DPWA	PI N PHOTO FIT 1
A1	-0.012	0.005	ARAI	80	DPWA	PI N PHOTO FIT 2
A1	0.015	0.025	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A1	0.028	0.009	AWAJI	81	DPWA	PI N PHOTOPROD.
A1	0.006	0.018	CRAWFORD	83	IPWA	PI N PHOTOPROD.

$N(1710) \to n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A2	-0.028	0.045	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A2	0.005	0.013	ARAI	80	DPWA	PI N PHOTO FIT 1
A2	0.011	0.021	ARAI	80	DPWA	PI N PHOTO FIT 2
A2	-0.017	0.020	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A2	0.000	0.018	AWAJI	81	DPWA	PI N PHOTOPROD.
A2	-0.001	0.003	FUJII	81	DPWA	PI N PHOTOPROD.

REFERENCES FOR $N(1710)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

ORITO2 69 INS J 113 S ORITO (THESIS) (TOKY)
SCHORSCH 70 NP B25 179 -TIETGE,WEILNBOECK (MPIM)
DEANS 72 PR D6 1906 DEANS,JACOBS, LYONS,MONTGOMERY (SFLA)IJP
HICKS 73 PR D7 2614 +DEANS,JACOBS,LYONS+ (CARN+ORNL+SFLA)IJP
DEANS 75 NP B96 90 +MITCHELL,MONTGOMERY,+ (SFLA+ALAH)IJP
KNASEL 75 PR D11 1 +LINDQUIST,NELSON+ (CHIC+WUSL+OSU+ANL)IJP
LONGACRE 75 PL 55B 415 +ROSENFELD,LASINSKI,SMADJA+ (LBL+SLAC)IJP
FELLER 76 NP B104 219 +FUKUSHIMA,HORIKAWA,KAJIKAWA+ (NAGO+OSAK)IJP
BAKER 77 NP B126 365 +BLISSET,BLOODWORTH,BROOME,HART+ (RHEL)IJP
LONGACRE 77 NP B122 493 LONGACRE,DOLBEAU (SACL)IJP
ALSO 76 NP B108 365 DOLBEAU,TRIANTIS,NEVEU,CADIET (SACL)IJP
BAKER 78 NP B141 29 +BLISSET,BLOODWORTH,BROOME+ (RL+CAMB)IJP
BARBOUR 78 NP B141 253 BARBOUR,CRAWFORD,PARSONS (GLAS)
LONGACRE 78 PR D17 1795 +LASINSKI,ROSENFELD,SMADJA+ (LBL+SLAC)
BAKER 79 NP B156 93 +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+ (RHEL)IJP
CUTKOSKY 79 PR D20 2839 +FORSYTH,HENDRICK,KELLY (CARN+LBL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
ARAI 80 TORONTO CONF 93 I ARAI (TOKY)
ALSO 82 NP B194 251 I ARAI, H FUJII (TOKY)
CRAWFORD 80 TORONTO CONF 107 R L CRAWFORD (GLAS)
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
LIVANOS 80 TORONTO CONF 35 +BATON,COUTURES,KOCHOWSKI,NEVEU (SACL)IJP
SAXON 80 NP B162 522 +BAKER,BELL,BLISSETT,BLOODWORTH+(RHEL+BRIS)IJP
AWAJI 81 BONN CONF 352 R KAJIKAWA (TALK) (NAGO)
ALSO 82 NP B197 365 FUJII,HAYASHII,IWATA,KAJIKAWA+ (NAGO)
FUJII 81 NP B187 53 FUJII,HAYASHII,IWATA,KAJIKAWA+ (TOKY)
BELL 83 NP B222 389 +BLISSET,BROOME,DALEY,HART,LINTERN,+ (RL)IJP
CRAWFORD 83 NP B211 1 R L CRAWFORD, W T MORTON (GLAS)
MANLEY 84 PR D30 904 MANLEY,ARNDT,GORADIA,TEPLITZ (VPI)

$N(1720)$ P_{13}

$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$ Status: ****

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

$N(1720)$ MASS (MeV)

M		(1850.0)		KNASEL	75	DPWA	0 PI- P TO K0 LAM
M	A	1695. OR 1720.		LONGACRE	75	IPWA	PI N TO 2PI N
M	A	THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.					
M	B	(1640.0)	(10.0)	BAKER	77	IPWA	0 PI- P TO K LAM.
M	C	(1710.0)		BAKER	77	DPWA	0 PI- P TO K LAM.
M	B	BAKER 77 IS BASED ON AN IPWA USING THE BARRELET ZERO METHOD.					
M	D	(1750.0)		LONGACRE	77	IPWA	PI N TO 2PI N
M	D	ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE					
M	D	POSITION WHICH IS FROM SOLUTIONS S1 AND C1.					
M		1710. TO 1790.		BAKER	78	DPWA	0 PI- P TO K LAM
M		(1809.0)		BARBOUR	78	DPWA	PI-N PHOTOPROD.
M		(1740.0)	(80.0)	CUTKOSKY	79	IPWA	PI N TO PI N
M		1710.0	20.0	HOEHLER	79	IPWA	PI N TO PI N
M		(1785.0)		CRAWFORD	80	DPWA	PI N PHOTOPROD.
M		1700.0	50.0	CUTKOSKY	80	IPWA	PI N TO PI N
M		(1690.0)		SAXON	80	DPWA	0 PI- P TO K LAM

$N(1720)$ WIDTH (MeV)

W		(327.0)		KNASEL	75	DPWA	0 PI- P TO K0 LAM
W	A	115. OR 150.		LONGACRE	75	IPWA	PI N TO 2PI N
W	B	(200.0)	(50.0)	BAKER	77	IPWA	0 PI- P TO K LAM.
W	C	(500.0)		BAKER	77	DPWA	0 PI- P TO K LAM.
W	D	(130.0)		LONGACRE	77	IPWA	PI N TO 2PI N
W		300. TO 400.		BAKER	78	DPWA	0 PI- P TO K LAM
W		(285.0)		BARBOUR	78	DPWA	PI-N PHOTOPROD.
W		(447.0)		BAKER	79	DPWA	0 PI- P TO ETA N
W		(210.0)	(80.0)	CUTKOSKY	79	IPWA	PI N TO PI N
W		190.0	30.0	HOEHLER	79	IPWA	PI N TO PI N
W		(308.0)		CRAWFORD	80	DPWA	PI N PHOTOPROD.
W		125.0	70.0	CUTKOSKY	80	IPWA	PI N TO PI N
W		(120.0)		SAXON	80	DPWA	0 PI- P TO K LAM

$N(1720)$ REAL PART OF POLE POSITION (MeV)

RE	D	1745.0 OR 1748.0		LONGACRE	77	IPWA	PI N TO 2PI N
RE		1716.0 OR 1716.0		LONGACRE	78	IPWA	PI N TO 2PI N
RE		(1702.0)		CUTKOSKY	79	IPWA	PI N TO PI N
RE		1680.0	30.0	CUTKOSKY	80	IPWA	PI N TO PI N
RE		(1705.)		ARNDT	85	DPWA	PI N TO PI N

$N(1720)$ -2*IMAG PART OF POLE POSITION (MeV)

IM	D	135.0 OR 123.0		LONGACRE	77	IPWA	PI N TO 2PI N
IM		124.0 OR 126.0		LONGACRE	78	IPWA	PI N TO 2PI N
IM		(158.0)		CUTKOSKY	79	IPWA	PI N TO PI N
IM		120.0	40.0	CUTKOSKY	80	IPWA	PI N TO PI N
IM		(80.)		ARNDT	85	DPWA	PI N TO PI N

$N(1720)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	(-6.0)		CUTKOSKY	79	IPWA	PI N TO PI N
RER	-8.0	2.0	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1720)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	(-8.0)		CUTKOSKY	79	IPWA	PI N TO PI N
IMR	-3.0	4.0	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1720)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1720) \rightarrow N\pi$	938+ 140
P2	$N(1720) \rightarrow N\eta$	940+ 549
P3	$N(1720) \rightarrow \Lambda K$	1116+ 498
P4	$N(1720) \rightarrow \Sigma K$	1189+ 494
P5	$N(1720) \rightarrow N\pi\pi$	938+ 140+ 140
P6	$N(1720) \rightarrow \Delta(1232)\ \pi$, P-wave	1232+ 140
P7	$N(1720) \rightarrow N\rho$, S=1/2, P-wave	938+ 769
P8	$N(1720) \rightarrow N\rho$, S=3/2, P-wave	938+ 769
P9	$N(1720) \rightarrow N(\pi\pi)_{S\text{-wave}}$	938+ 140+ 140
P10	$N(1720) \rightarrow p\gamma$, helicity=1/2	938+ 0
P11	$N(1720) \rightarrow p\gamma$, helicity=3/2	938+ 0
P12	$N(1720) \rightarrow n\gamma$, helicity=1/2	940+ 0
P13	$N(1720) \rightarrow n\gamma$, helicity=3/2	940+ 0

$N(1720)$ BRANCHING RATIOS

$N(1720) \rightarrow (N\pi)$/total (P1)

R1		(0.19)	(0.05)	CUTKOSKY	79	IPWA	PI N TO PI N
R1		0.14	0.03	HOEHLER	79	IPWA	PI N TO PI N
R1		0.10	0.04	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1720)$ in $N\pi \rightarrow N\eta$ SQRT(P1*P2)

R2		(-0.08)		BAKER	79	DPWA	0 PI- P TO ETA N

$N(1720)$ in $N\pi \rightarrow \Lambda K$ SQRT(P1*P3)

R3	B	(-0.06)	(0.02)	BAKER	77	IPWA	0 PI- P TO K LAM.
R3	C	(-0.09)		BAKER	77	DPWA	0 PI- P TO K LAM.
R3	E	(-0.09)		BAKER	78	DPWA	0 PI- P TO K LAM
R3	E	THE (UNDETERMINED) OVERALL PHASE OF ALL COUPLINGS FROM HAS BEEN					
R3	E	CHANGED TO AGREE WITH PREVIOUS CONVENTIONS. SUPERSEDED BY SAXON 80.					
R3		(-0.11)		SAXON	80	DPWA	0 PI- P TO K LAM
R3		(-0.09)		BELL	83	DPWA	0 PI- P TO LAM K0

$N(1720)$ in $N\pi \rightarrow \Sigma K$ SQRT(P1*P4)

R4	F	0.051 TO 0.087		DEANS	75	DPWA	PI N TO K SIGMA
R4	F	RANGE GIVEN IS FROM FOUR BEST SOLUTIONS. DEANS 75 DISAGREES WITH					
R4	F	PI+ P TO K+ SIGMA+ DATA OF WINNIK 77 AROUND 1920 MEV.					

R NOTE: SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.

$N(1720)$ in $N\pi \rightarrow \Delta(1232)\pi$, P-wave SQRT(P1*P6)

R5	D	(-0.17)		LONGACRE	77	IPWA	PI N TO 2PI N

$N(1720)$ in $N\pi \rightarrow N\rho$, S=1/2, P-wave SQRT(P1*P7)

R6	A	+0.35 OR +0.40		LONGACRE	75	IPWA	PI N TO 2PI N
R6	D	(-0.26)		LONGACRE	77	IPWA	PI N TO 2PI N

$N(1720)$ in $N\pi \rightarrow N\rho$, S=3/2, P-wave SQRT(P1*P8)

R7	D	(+0.15)		LONGACRE	77	IPWA	PI N TO 2PI N

$N(1720)$ in $N\pi \rightarrow N(\pi\pi)_{S\text{-wave}}$ SQRT(P1*P9)

R8	D	(-0.19)		LONGACRE	77	IPWA	PI N TO 2PI N

$N(1720)$ in $p\gamma \rightarrow p\eta$ SQRT((P10+P11)*P2)

R9		(0.0052)		HICKS	73	MPWA	GAM P-ETA P

$N(1720)$ in $p\gamma \rightarrow \Lambda K$ SQRT((P10+P11)*P3)

R10		(0.0082)		DEANS	72	MPWA	GAM P-K LM,SOL D

$N(1720)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(1720) \rightarrow p\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A1	+0.122	0.018	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 1
A1	+0.054	0.012	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 2
A1	+0.111	0.047	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A1	0.051	0.009	ARAI	80	DPWA	PI N PHOTO FIT 1
A1	0.071	0.010	ARAI	80	DPWA	PI N PHOTO FIT 2
A1	0.038	0.050	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A1	-0.004	0.007	AWAJI	81	DPWA	PI N PHOTOPROD.
A1	0.044	0.066	CRAWFORD	83	IPWA	PI N PHOTOPROD.

$N(1720) \rightarrow p\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A2	+0.034	0.015	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 1
A2	0.000	0.016	AZNAURYAN	77	DPWA	PI0 PHTPRD,SOL 2
A2	-0.063	0.032	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A2	-0.058	0.010	ARAI	80	DPWA	PI N PHOTO FIT 1
A2	-0.011	0.011	ARAI	80	DPWA	PI N PHOTO FIT 2
A2	-0.014	0.040	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A2	-0.040	0.016	AWAJI	81	DPWA	PI N PHOTOPROD.
A2	-0.024	0.006	CRAWFORD	83	IPWA	PI N PHOTOPROD.

$N(1720) \rightarrow n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A3	+0.007	0.020	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A3	-0.019	0.033	ARAI	80	DPWA	PI N PHOTO FIT 1
A3	0.001	0.038	ARAI	80	DPWA	PI N PHOTO FIT 2
A3	-0.003	0.034	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A3	0.002	0.005	AWAJI	81	DPWA	PI N PHOTOPROD.

$N(1720) \rightarrow n\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A4	+0.051	0.051	BARBOUR	78	DPWA	PI-N PHOTOPROD.
A4	-0.139	0.039	ARAI	80	DPWA	PI N PHOTO FIT 1
A4	-0.134	0.044	ARAI	80	DPWA	PI N PHOTO FIT 2
A4	0.018	0.028	CRAWFORD	80	DPWA	PI N PHOTOPROD.
A4	-0.015	0.019	AWAJI	81	DPWA	PI N PHOTOPROD.

REFERENCES FOR $N(1720)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

DEANS	72	PR D6 1906	DEANS,JACOBS, LYONS,MONTGOMERY	(SFLA)IJP
HICKS	73	PR D7 2614	+DEANS,JACOBS,LYONS+	(CARN+ORNL+SFLA)IJP
DEANS	75	NP B96 90	+MITCHELL,MONTGOMERY,+	(SFLA+ALAH)IJP
KNASEL	75	PR D11 1	+LINDQUIST,NELSON+	(CHIC-WUSL+OSU+ANL)IJP
LONGACRE	75	PL 55B 415	+ROSENFELD,LASINSKI,SMADJA+	(LBL+SLAC)IJP
AZNAURYA	77	EFI-264(57)-77	+AKOPOV,BAGDASARYAN	(YERE)IJP
BAKER	77	NP B126 365	+BLISSET,BLOODWORTH,BROOME,HART+	(RHEL)IJP
LONGACRE	77	NP B122 493	LONGACRE,DOLBEAU	(SACL)IJP
ALSO	76	NP B108 365	DOLBEAU,TRIANTIS,NEVEU,CADIET	(SACL)IJP
WINNIK	77	NP B128 66	+TOAFF,REVEL,GOLDBERG,BERNY	(HAIF)I
BAKER	78	NP B141 29	+BLISSET,BLOODWORTH,BROOME+	(RL+CAMB)IJP
BARBOUR	78	NP B141 253	BARBOUR,CRAWFORD,PARSONS	(GLAS)
LONGACRE	78	PR D17 1795	+LASINSKI,ROSENFELD,SMADJA+	(LBL+SLAC)
BAKER	79	NP B156 93	+BROWN,CLARK,DAVIES,DEPAGTER,EVANS+	(RHEL)IJP
CUTKOSKY	79	PR D20 2839	+FORSYTH,HENDRICK,KELLY	(CARN+LBL)IJP
HOEHLER	79	HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1	+KAISER,KOCH,PIETARINEN	(KARL)IJP
ALSO	80	TORONTO CONF 3	R KOCH	(KARL)IJP
ARAI	80	TORONTO CONF 93	I ARAI	(TOKY)
ALSO	82	NP B194 251	I ARAI, H FUJII	(TOKY)
CRAWFORD	80	TORONTO CONF 107	R L CRAWFORD	(GLAS)
CUTKOSKY	80	TORONTO CONF 19	+FORSYTH,BABCOCK,KELLY,HENDRICK	(CARN+LBL)IJP
SAXON	80	NP B162 522	+BAKER,BELL,BLISSETT,BLOODWORTH+	(RHEL+BRIS)IJP
AWAJI	81	BONN CONF 352	R KAJIKAWA (TALK)	(NAGO)
ALSO	82	NP B197 365	FUJII,HAYASHII,IWATA,KAJIKAWA+	(NAGO)
BELL	83	NP B222 389	+BLISSET,BROOME,DALEY,HART,LINTERN,+	(RL)IJP
CRAWFORD	83	NP B211 1	R L CRAWFORD, W T MORTON	(GLAS)
ARNDT	85	PR D32 1085	R A ARNDT, J M FORD, L D ROPER	(VPI)

$N(1960)$

$I(J^P) = \frac{1}{2}(\ \ )$ Status: *

OMITTED FROM SUMMARY TABLE

A NARROW PEAK IN SIGMA(1385)- K+ DIFFRACTIVELY PRODUCED BY NEUTRONS ON QUASI-FREE NUCLEONS OF CARBON. THE SPIN-PARITY IS ONE OF 5/2-, 7/2-, ETC.

$N(1960)$ MASS (MeV)

M	1956.	8.	6.	ALEEV	84	BIS2	0 SIG(1385)- K+

$N(1960)$ WIDTH (MeV)

W	27.	15.		ALEEV	84	BIS2	0 SIG(1385)- K+

REFERENCES FOR $N(1960)$

ALEEV	84	ZPHY C25 205	+	(JINR+BERL+LEBD+MOSU+PRAG+SOFI+TBLI)

$N(1990)$ F_{17}

$I(J^P) = \frac{1}{2}(\frac{7}{2}^-)$ Status: * *

OMITTED FROM SUMMARY TABLE

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

THE VARIOUS ANALYSES DO NOT AGREE VERY WELL WITH ONE ANOTHER.

$N(1990)$ MASS (MeV)

M	(1999.0)		BARBOUR	78	DPWA	PI-N PHOTOPROD.
M	(1970.0)	(80.0)	CUTKOSKY	79	IPWA	PI N TO PI N
M	2005.0	150.0	HOEHLER	79	IPWA	PI N TO PI N
M	(2018.0)		CRAWFORD	80	DPWA	PI N PHOTOPROD.
M	1970.0	50.0	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1990)$ WIDTH (MeV)

W	(216.0)		BARBOUR	78	DPWA	PI-N PHOTOPROD.
W	(325.0)	(150.0)	CUTKOSKY	79	IPWA	PI N TO PI N
W	350.0	100.0	HOEHLER	79	IPWA	PI N TO PI N
W	(295.0)		CRAWFORD	80	DPWA	PI N PHOTOPROD.
W	350.0	120.0	CUTKOSKY	80	IPWA	PI N TO PI N

$N(1990)$ REAL PART OF POLE POSITION (MeV)

RE	(1899.0)		CUTKOSKY	79 IPWA	PI N TO PI N
RE	1900.0	30.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(1990)$ −2*IMAG PART OF POLE POSITION (MeV)

IM	(208.0)		CUTKOSKY	79 IPWA	PI N TO PI N
IM	260.0	60.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(1990)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	(3.0)		CUTKOSKY	79 IPWA	PI N TO PI N
RER	5.0	4.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(1990)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	(-6.0)		CUTKOSKY	79 IPWA	PI N TO PI N
IMR	-8.0	4.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(1990)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(1990) \to N\pi$	938+ 140
P2	$N(1990) \to N\eta$	940+ 549
P3	$N(1990) \to \Lambda K$	1116+ 498
P4	$N(1990) \to \Sigma K$	1189+ 494
P5	$N(1990) \to N\pi\pi$	938+ 140+ 140
P6	$N(1990) \to p\gamma$, helicity=1/2	938+ 0
P7	$N(1990) \to p\gamma$, helicity=3/2	938+ 0
P8	$N(1990) \to n\gamma$, helicity=1/2	940+ 0
P9	$N(1990) \to n\gamma$, helicity=3/2	940+ 0

$N(1990)$ BRANCHING RATIOS

$N(1990) \to (N\pi)$/total (P1)

R1		(0.06)	(0.02)	CUTKOSKY	79 IPWA	PI N TO PI N
R1		0.04	0.02	HOEHLER	79 IPWA	PI N TO PI N
R1		0.06	0.02	CUTKOSKY	80 IPWA	PI N TO PI N

$N(1990)$ in $N\pi \to N\eta$ SQRT(P1*P2)

R2		(-0.043)		BAKER	79 DPWA	0 PI- P TO ETA N

$N(1990)$ in $N\pi \to \Lambda K$ SQRT(P1*P3)

R3		-0.021	0.033	DEVENISH	74	0 FIXED T DISP REL
R3		NOT SEEN		SAXON	80 DPWA	0 PI- P TO K LAM
R3		(+0.01)		BELL	83 DPWA	0 PI- P TO LAM K0

$N(1990)$ in $N\pi \to \Sigma K$ SQRT(P1*P4)

R4		(0.06)		LANGBEIN	73 IPWA	PI N-K SIG,SOL 1
R4	A	0.010 TO 0.023		DEANS	75 DPWA	PI N TO K SIGMA
R4	A	RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.				

$N(1990)$ in $N\pi \to N\pi\pi$ SQRT(P1*P5)

R5		NOT SEEN		LONGACRE	75 IPWA	PI N TO 2PI N
R5		NOT SEEN		MANLEY	84 IPWA	PI N TO 2PI N

$N(1990)$ in $p\gamma \to p\eta$ SQRT((P6+P7)*P2)

R6		(0.0045)		HICKS	73 MPWA	GAM P-ETA P

$N(1990)$ in $p\gamma \to \Lambda K$ SQRT((P6+P7)*P3)

R7		(0.0034)		DEANS	72 MPWA	GAM P-K LM,SOL D

$N(1990)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(1990) \to p\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A1	(0.040)		BARBOUR	78 DPWA	PI-N PHOTOPROD.
A1	0.001	0.040	CRAWFORD	80 DPWA	PI N PHOTOPROD.
A1	0.030	0.029	AWAJI	81 DPWA	PI N PHOTOPROD.

$N(1990) \to p\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A2	(+0.004)		BARBOUR	78 DPWA	PI-N PHOTOPROD.
A2	0.004	0.025	CRAWFORD	80 DPWA	PI N PHOTOPROD.
A2	0.086	0.060	AWAJI	81 DPWA	PI N PHOTOPROD.

$N(1990) \to n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A3	(-0.069)		BARBOUR	78 DPWA	PI-N PHOTOPROD.
A3	-0.078	0.030	CRAWFORD	80 DPWA	PI N PHOTOPROD.
A3	(-0.001)		AWAJI	81 DPWA	PI N PHOTOPROD.

$N(1990) \to n\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A4	(-0.072)		BARBOUR	78 DPWA	PI-N PHOTOPROD.
A4	-0.116	0.045	CRAWFORD	80 DPWA	PI N PHOTOPROD.
A4	(-0.178)		AWAJI	81 DPWA	PI N PHOTOPROD.

REFERENCES FOR $N(1990)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

DEANS	72 PR D6 1906	DEANS,JACOBS, LYONS,MONTGOMERY	(SFLA)IJP
HICKS	73 PR D7 2614	+DEANS,JACOBS,LYONS+	(CARN+ORNL+SFLA)IJP
LANGBEIN	73 NP B53 251	LANGBEIN,WAGNER	(MUNI)IJP
DEVENISH	74 NP B81 330	DEVENISH,FROGGATT,MARTIN	(DESY+NORD+LOUC)
DEANS	75 NP B96 90	+MITCHELL,MONTGOMERY,+	(SFLA+ALAH)IJP
LONGACRE	75 PL 55B 415	+ROSENFELD,LASINSKI,SMADJA+	(LBL+SLAC)IJP
BARBOUR	78 NP B141 253	BARBOUR,CRAWFORD,PARSONS	(GLAS)
BAKER	79 NP B156 93	+BROWN,CLARK,DAVIES,DEPAGTER,EVANS+	(RHEL)IJP
CUTKOSKY	79 PR D20 2839	+FORSYTH,HENDRICK,KELLY	(CARN+LBL)IJP
HOEHLER	79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1	+KAISER,KOCH,PIETARINEN	(KARL)IJP
ALSO	80 TORONTO CONF 3	R KOCH	(KARL)IJP
CRAWFORD	80 TORONTO CONF 107	R L CRAWFORD	(GLAS)
CUTKOSKY	80 TORONTO CONF 19	+FORSYTH,BABCOCK,KELLY,HENDRICK	(CARN+LBL)IJP
SAXON	80 NP B162 522	+BAKER,BELL,BLISSETT,BLOODWORTH+	(RHEL+BRIS)IJP
AWAJI	81 BONN CONF 352	R KAJIKAWA (TALK)	(NAGO)
ALSO	82 NP B197 365	FUJII,HAYASHII,IWATA,KAJIKAWA+	(NAGO)
BELL	83 NP B222 389	+BLISSET,BROOME,DALEY,HART,LINTERN,+	(RL)IJP
CRAWFORD	83 NP B211 1	R L CRAWFORD, W T MORTON	(GLAS)
MANLEY	84 PR D30 904	MANLEY,ARNDT,GORADIA,TEPLITZ	(VPI)

$N(2000)$ F_{15}

$I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$ Status: * *

OMITTED FROM SUMMARY TABLE

OLDER RESULTS HAVE BEEN RETAINED SIMPLY BECAUSE THERE IS LITTLE INFORMATION AT ALL ABOUT THIS STATE.

$N(2000)$ MASS (MeV)

M		(2175.0)		ALMEHED	72 IPWA	
M		(1930.0)		DEANS	72 MPWA	GAM P-K LM,SOL D
M	A	(1970.0)		LANGBEIN	73 IPWA	PI N-K SIG,SOL 2
M	A	NOT SEEN IN SOLUTION 1 OF LANGBEIN 73.				
M		(2025.0)		AYED	76 IPWA	
M		1882.0	10.0	HOEHLER	79 IPWA	PI N TO PI N

$N(2000)$ WIDTH (MeV)

W		(150.0)		ALMEHED	72 IPWA	
W		(112.0)		DEANS	72 MPWA	GAM P-K LM,SOL D
W	A	(170.0)		LANGBEIN	73 IPWA	PI N-K SIG,SOL 2
W		(157.0)		AYED	76 IPWA	
W		95.0	20.0	HOEHLER	79 IPWA	PI N TO PI N

$N(2000)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(2000) \to N\pi$	938+ 140
P2	$N(2000) \to N\eta$	940+ 549
P3	$N(2000) \to \Lambda K$	1116+ 498
P4	$N(2000) \to \Sigma K$	1189+ 494
P5	$N(2000) \to p\gamma$, helicity=1/2	938+ 0
P6	$N(2000) \to p\gamma$, helicity=3/2	938+ 0
P7	$N(2000) \to n\gamma$, helicity=1/2	940+ 0
P8	$N(2000) \to n\gamma$, helicity=3/2	940+ 0

$N(2000)$ BRANCHING RATIOS

$N(2000) \to (N\pi)$/total (P1)

R1		(0.25)		ALMEHED	72 IPWA	
R1		(0.08)		AYED	76 IPWA	
R1		0.04	0.02	HOEHLER	79 IPWA	PI N TO PI N

$N(2000)$ in $N\pi \to N\eta$ SQRT(P1*P2)

R2		(+0.03)		BAKER	79 DPWA	0 PI- P TO ETA N

$N(2000)$ in $N\pi \to \Lambda K$ SQRT(P1*P3)

R3		NOT SEEN		SAXON	80 DPWA	0 PI- P TO K LAM

$N(2000)$ in $N\pi \to \Sigma K$ SQRT(P1*P4)

R4	A	(0.05)		LANGBEIN	73 IPWA	PI N-K SIG,SOL 2
R4	B	(0.022)		DEANS	75 DPWA	PI N TO K SIGMA
R4	B	VALUE GIVEN IS FROM SOLUTION 1, NOT PRESENT IN SOLUTIONS 2,3,4.				

$N(2000)$ in $p\gamma \to \Lambda K$ SQRT((P5+P6)*P3)

R5		(0.0022)		DEANS	72 MPWA	GAM P-K LM,SOL D

REFERENCES FOR $N(2000)$

ALMEHED	72 NP B40 157	+LOVELACE	(RUTG)IJP
DEANS	72 PR D6 1906	DEANS,JACOBS, LYONS,MONTGOMERY	(SFLA)IJP
LANGBEIN	73 NP B53 251	LANGBEIN,WAGNER	(MUNI)IJP
DEANS	75 NP B96 90	+MITCHELL,MONTGOMERY,+	(SFLA+ALAH)IJP

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AYED       76 CEA-N-1921          AYED (THESIS)                        (SACL)IJP
MA         76 PR D13 3027         E MA,G L SHAW                    (OREG-UCI)IJP
BAKER      79 NP B156 93          +BROWN,CLARK,DAVIES,DEPAGTER,EVANS-  (RHEL)IJP
HOEHLER    79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                                  +KAISER,KOCH,PIETARINEN              (KARL)IJP
   ALSO 80  TORONTO CONF 3        R KOCH                               (KARL)IJP
SAXON      80 NP B162 522         +BAKER,BELL,BLISSETT,BLOODWORTH+(RHEL-BRIS)IJP
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$N(2080)$ D_{13}

$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$ Status: * *

OMITTED FROM SUMMARY TABLE

THERE IS SOME EVIDENCE THAT TWO RESONANCES EXIST IN THIS WAVE BETWEEN 1800 AND 2200 MEV (SEE CUTKOSKY 80). THE SOLUTION OF HOEHLER 79 IS QUITE DIFFERENT.

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

$N(2080)$ MASS (MeV)

```
M     A    (1830.0)   (50.0)           CUTKOSKY  79 IPWA    PI N TO PI N
M     B    (2100.0)   (80.0)           CUTKOSKY  79 IPWA    PI N TO PI N
M    AB  CUTKOSKY 79 FIND A LOWER MASS D13 RESONANCE, AS WELL AS ONE IN THIS
M    AB  MASS REGION. BOTH ARE LISTED HERE, AND LABELED A AND B.
M           2081.0     20.0            HOEHLER   79 IPWA    PI N TO PI N
M     C     1880.0    100.0            CUTKOSKY  80 IPWA    PI N TO PI N
M     D     2060.0     80.0            CUTKOSKY  80 IPWA    PI N TO PI N
M    CD  CUTKOSKY 80 AGAIN FINDS A LOWER MASS D13 RESONANCE, AS WELL AS ONE
M    CD  IN THIS MASS REGION.  BOTH ARE LISTED HERE, LABELED C AND D.
M          (1900.0)                    SAXON     80 DPWA  0 PI- P TO K LAM
M          (1920.0)                    BELL      83 DPWA 0  PI- P TO LAM K0
```

$N(2080)$ WIDTH (MeV)

```
W     A     (125.0)   (50.0)           CUTKOSKY  79 IPWA    PI N TO PI N
W     B     (300.0)  (100.0)           CUTKOSKY  79 IPWA    PI N TO PI N
W            265.0     40.0            HOEHLER   79 IPWA    PI N TO PI N
W     C      180.0     60.0            CUTKOSKY  80 IPWA    PI N TO PI N
W     D      300.0    100.0            CUTKOSKY  80 IPWA    PI N TO PI N
W           (240.0)                    SAXON     80 DPWA  0 PI- P TO K LAM
W           (320.0)                    BELL      83 DPWA 0  PI- P TO LAM K0
```

$N(2080)$ REAL PART OF POLE POSITION (MeV)

```
RE    A    (1818.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
RE    B    (2053.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
RE    C     1880.0    100.0            CUTKOSKY  80 IPWA    PI N TO PI N
RE    D     2050.0     70.0            CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(2080)$ -2*IMAG PART OF POLE POSITION (MeV)

```
IM    A     (122.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
IM    B     (308.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
IM    C      160.0     80.0            CUTKOSKY  80 IPWA    PI N TO PI N
IM    D      200.0     80.0            CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(2080)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER   A       (3.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
RER   B      (24.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
RER   C       -2.0     14.0            CUTKOSKY  80 IPWA    PI N TO PI N
RER   D       30.0     20.0            CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(2080)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR   A      (-3.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
IMR   B     (-10.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
IMR   C       10.0      5.0            CUTKOSKY  80 IPWA    PI N TO PI N
IMR   D        0.0     52.0            CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(2080)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(2080) \to N\pi$	938+ 140
P2	$N(2080) \to N\eta$	940+ 549
P3	$N(2080) \to \Lambda K$	1116+ 498
P4	$N(2080) \to \Sigma K$	1189+ 494
P5	$N(2080) \to N\pi\pi$	938+ 140+ 140
P6	$N(2080) \to p\gamma$, helicity=1/2	938+ 0
P7	$N(2080) \to p\gamma$, helicity=3/2	938+ 0
P8	$N(2080) \to n\gamma$, helicity=1/2	940+ 0
P9	$N(2080) \to n\gamma$, helicity=3/2	940+ 0

$N(2080)$ BRANCHING RATIOS

$N(2080) \to (N\pi)$/total (P1)

```
R1    A     (0.06)    (0.03)           CUTKOSKY  79 IPWA    PI N TO PI N
R1    B     (0.13)    (0.05)           CUTKOSKY  79 IPWA    PI N TO PI N
R1           0.06      0.02            HOEHLER   79 IPWA    PI N TO PI N
R1    C      0.10      0.04            CUTKOSKY  80 IPWA    PI N TO PI N
R1    D      0.14      0.07            CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(2080)$ in $N\pi \to N\eta$ SQRT(P1*P2)

```
R2          NOT SEEN                   BAKER     79 DPWA  0 PI- P TO ETA N
```

$N(2080)$ in $N\pi \to \Lambda K$ SQRT(P1*P3)

```
R3         (+0.03)                     SAXON     80 DPWA  0 PI- P TO K LAM
R3         (+0.04)                     BELL      83 DPWA 0  PI- P TO LAM K0
```

$N(2080)$ in $N\pi \to \Sigma K$ SQRT(P1*P4)

```
R4   E       0.014 TO 0.037            DEANS     75 DPWA    PI N TO K SIGMA
R4   E   RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.  DISAGREES WITH PI- P TO
R4   E   K+ SIGMA+ DATA OF WINNIK 77 AROUND 1920 MEV.
```

$N(2080)$ in $p\gamma \to p\eta$ SQRT((P6+P7)*P2)

```
R5          (0.0037)                   HICKS     73 MPWA    GAM P-ETA P
```

$N(2080)$ in $p\gamma \to \Lambda K$ SQRT((P6+P7)*P3)

```
R6          (0.0070)                   DEANS     72 MPWA    GAM P-K LM,SOL D
```

$N(2080)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(2080) \to p\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1           0.026     0.052           DEVENISH  74 DPWA    PI N PHOTOPROD.
A1          -0.020     0.008           AWAJI     81 DPWA    PI N PHOTOPROD.
```

$N(2080) \to p\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A2           0.128     0.057           DEVENISH  74 DPWA    PI N PHOTOPROD.
A2           0.017     0.011           AWAJI     81 DPWA    PI N PHOTOPROD.
```

$N(2080) \to n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A3           0.053     0.083           DEVENISH  74 DPWA    PI N PHOTOPROD.
A3           0.007     0.013           AWAJI     81 DPWA    PI N PHOTOPROD.
```

$N(2080) \to n\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A4           0.100     0.141           DEVENISH  74 DPWA    PI N PHOTOPROD.
A4          -0.053     0.034           AWAJI     81 DPWA    PI N PHOTOPROD.
```

REFERENCES FOR $N(2080)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS      72 PR D6 1906          DEANS,JACOBS, LYONS,MONTGOMERY       (SFLA)IJP
HICKS      73 PR D7 2614          +DEANS,JACOBS,LYONS+        (CARN+ORNL-SFLA)IJP
DEVENISH   74 PL 52B 227          DEVENISH,LYTH,RANKIN        (DESY+LANC-BONN)IJP
DEANS      75 NP B96 90           +MITCHELL,MONTGOMERY,+          (SFLA-ALAH)IJP
WINNIK     77 NP B128 66          +TOAFF,REVEL,GOLDBERG,BERNY          (HAIF)I
BAKER      79 NP B156 93          +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+  (RHEL)IJP
CUTKOSKY   79 PR D20 2839         +FORSYTH,HENDRICK,KELLY          (CARN-LBL)IJP
HOEHLER    79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                                  +KAISER,KOCH,PIETARINEN              (KARL)IJP
   ALSO 80  TORONTO CONF 3        R KOCH                               (KARL)IJP
CUTKOSKY   80  TORONTO CONF 19    +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
SAXON      80 NP B162 522         +BAKER,BELL,BLISSETT,BLOODWORTH+(RHEL-BRIS)IJP
AWAJI      81  BONN CONF 352      R KAJIKAWA (TALK)                    (NAGO)
   ALSO 82 NP B197 365            FUJII,HAYASHII,IWATA,KAJIKAWA+       (NAGO)
BELL       83 NP B222 389         +BLISSET,BROOME,DALEY,HART,LINTERN,+   (RL)IJP
```

$N(2090)$ S_{11}

$I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

ANY STRUCTURE IN THIS WAVE ABOVE 1800 MEV IS LISTED HERE. A FEW EARLY RESULTS THAT ARE NOW OBSOLETE HAVE BEEN OMITTED.

$N(2090)$ MASS (MeV)

```
M           1880.0     20.0            HOEHLER   79 IPWA    PI N TO PI N
M           2180.0     80.0            CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(2090)$ WIDTH (MeV)

```
W             95.0     30.0            HOEHLER   79 IPWA    PI N TO PI N
W            350.0    100.0            CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(2090)$ REAL PART OF POLE POSITION (MeV)

```
RE          1937.0 OR 1949.0           LONGACRE  78 IPWA    PI N TO 2PI N
RE          2150.0     70.0            CUTKOSKY  80 IPWA    PI N TO PI N
```

$N(2090)$ −2*IMAG PART OF POLE POSITION (MeV)

IM	139.0 OR 131.0		LONGACRE	78 IPWA	PI N TO 2PI N
IM	350.0	100.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2090)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	40.0	20.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2090)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	0.0	60.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2090)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(2090) \to N\pi$	938+ 140
P2	$N(2090) \to \Lambda K$	1116+ 498

$N(2090)$ BRANCHING RATIOS

$N(2090) \to (N\pi)$/total (P1)

R1	0.09	0.05	HOEHLER	79 IPWA	PI N TO PI N
R1	0.18	0.08	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2090)$ in $N\pi \to \Lambda K$ SQRT(P1*P2)

R2	NOT SEEN		SAXON	80 DPWA	0 PI- P TO K LAM

REFERENCES FOR $N(2090)$

LONGACRE 78 PR D17 1795 +LASINSKI,ROSENFELD,SMADJA+ (LBL+SLAC)
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
SAXON 80 NP B162 522 +BAKER,BELL,BLISSETT,BLOODWORTH+(RHEL+BRIS)IJP

$N(2100)$ P_{11}

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

$N(2100)$ MASS (MeV)

M	2050.0	20.0	HOEHLER	79 IPWA	PI N TO PI N
M	2125.0	75.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2100)$ WIDTH (MeV)

W	200.0	30.0	HOEHLER	79 IPWA	PI N TO PI N
W	260.0	100.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2100)$ REAL PART OF POLE POSITION (MeV)

RE	2120.0	40.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2100)$ −2*IMAG PART OF POLE POSITION (MeV)

IM	240.0	80.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2100)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	11.0	7.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2100)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	8.0	6.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2100)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(2100) \to N\pi$	938+ 140

$N(2100)$ BRANCHING RATIOS

$N(2100) \to (N\pi)$/total (P1)

R1	0.10	0.04	HOEHLER	79 IPWA	PI N TO PI N
R1	0.12	0.03	CUTKOSKY	80 IPWA	PI N TO PI N

REFERENCES FOR $N(2100)$

HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
KOCH 80 TORONTO CONF 3 R KOCH (KARL)IJP
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP

$N(2190)$ G_{17}

$I(J^P) = \frac{1}{2}(\frac{7}{2}^-)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

$N(2190)$ MASS (MeV)

M	(2117.0)		BARBOUR	78 DPWA	PI-N PHOTOPROD.
M	2140.0	40.0	HENDRY	78 MPWA	PI N TO PI N
M	(2140.0)		BAKER	79 DPWA	0 PI- P TO ETA N
M	(2150.0)	(100.0)	CUTKOSKY	79 IPWA	PI N TO PI N
M	2140.0	12.0	HOEHLER	79 IPWA	PI N TO PI N
M	(2098.0)		CRAWFORD	80 DPWA	PI N PHOTOPROD.
M	2200.0	70.0	CUTKOSKY	80 IPWA	PI N TO PI N
M	(2180.0)		SAXON	80 DPWA	0 PI- P TO K LAM

$N(2190)$ WIDTH (MeV)

W	(220.0)		BARBOUR	78 DPWA	PI-N PHOTOPROD.
W	270.0	50.0	HENDRY	78 MPWA	PI N TO PI N
W	(319.0)		BAKER	79 DPWA	0 PI- P TO ETA N
W	(300.0)	(100.0)	CUTKOSKY	79 IPWA	PI N TO PI N
W	390.0	30.0	HOEHLER	79 IPWA	PI N TO PI N
W	(238.0)		CRAWFORD	80 DPWA	PI N PHOTOPROD.
W	500.0	150.0	CUTKOSKY	80 IPWA	PI N TO PI N
W	(80.0)		SAXON	80 DPWA	0 PI- P TO K LAM

$N(2190)$ REAL PART OF POLE POSITION (MeV)

RE	(2111.0)		CUTKOSKY	79 IPWA	PI N TO PI N
RE	2100.0	50.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2190)$ −2*IMAG PART OF POLE POSITION (MeV)

IM	(308.0)		CUTKOSKY	79 IPWA	PI N TO PI N
IM	400.0	160.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2190)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	(24.0)		CUTKOSKY	79 IPWA	PI N TO PI N
RER	22.0	14.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2190)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	(-12.0)		CUTKOSKY	79 IPWA	PI N TO PI N
IMR	-13.0	20.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2190)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(2190) \to N\pi$	938+ 140
P2	$N(2190) \to N\eta$	940+ 549
P3	$N(2190) \to \Lambda K$	1116+ 494
P4	$N(2190) \to \Sigma K$	1189+ 494
P5	$N(2190) \to N\pi\pi$	938+ 140+ 140
P6	$N(2190) \to N\rho$, S=3/2, D-wave	938+ 769
P7	$N(2190) \to p\gamma$, helicity=1/2	938+ 0
P8	$N(2190) \to p\gamma$, helicity=3/2	938+ 0
P9	$N(2190) \to n\gamma$, helicity=1/2	940+ 0
P10	$N(2190) \to n\gamma$, helicity=3/2	940+ 0

$N(2190)$ BRANCHING RATIOS

$N(2190) \to (N\pi)$/total (P1)

R1	0.16	0.04	HENDRY	78 MPWA	PI N TO PI N
R1	(0.16)	(0.07)	CUTKOSKY	79 IPWA	PI N TO PI N
R1	0.14	0.02	HOEHLER	79 IPWA	PI N TO PI N
R1	0.12	0.06	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2190)$ in $N\pi \to N\eta$ SQRT(P1*P2)

R2	(+0.052)	BAKER	79 DPWA	0	PI- P TO ETA N

$N(2190)$ in $N\pi \to \Lambda K$ SQRT(P1*P3)

R3	(-0.02)	SAXON	80 DPWA	0	PI- P TO K LAM
R3	(-0.02)	BELL	83 DPWA	0	PI- P TO LAM K0

$N(2190)$ in $N\pi \to \Sigma K$ SQRT(P1*P4)

R4 A	0.014 TO 0.019	DEANS	75 DPWA		PI N TO K SIGMA

R4 A RANGE GIVEN IS FROM FOUR BEST SOLUTIONS. DISAGREES WITH PI+ P TO
R4 A K+ SIGMA+ DATA OF WINNIK 77 AROUND 1920 MEV.

$N(2190)$ in $N\pi \to N\rho$, $S=3/2$, D-wave SQRT(P1*P6)

R5	- (LARGE)	MANLEY	84 IPWA	PI N TO 2PI N

$N(2190)$ in $p\gamma \to p\eta$ SQRT((P7+P8)*P2)

R6	(0.0094)	HICKS	73 MPWA	GAM P-ETA P

$N(2190)$ in $p\gamma \to \Lambda K$ SQRT((P7+P8)*P3)

R7	(0.0161)	DEANS	72 MPWA	GAM P-K LM,SOL D

$N(2190)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$N(2190) \to p\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A1	(-0.030)	BARBOUR	78 DPWA	PI-N PHOTOPROD.
A1	(-0.055)	CRAWFORD	80 DPWA	PI N PHOTOPROD.

$N(2190) \to p\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A2	(+0.180)	BARBOUR	78 DPWA	PI-N PHOTOPROD.
A2	(0.081)	CRAWFORD	80 DPWA	PI N PHOTOPROD.

$N(2190) \to n\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

A3	(-0.085)	BARBOUR	78 DPWA	PI-N PHOTOPROD.
A3	(-0.042)	CRAWFORD	80 DPWA	PI N PHOTOPROD.

$N(2190) \to n\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

A4	(-0.007)	BARBOUR	78 DPWA	PI-N PHOTOPROD.
A4	(-0.126)	CRAWFORD	80 DPWA	PI N PHOTOPROD.

REFERENCES FOR $N(2190)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

DEANS 72 PR D6 1906 DEANS,JACOBS, LYONS,MONTGOMERY (SFLA)IJP
HICKS 73 PR D7 2614 +DEANS,JACOBS,LYONS+ (CARN+ORNL+SFLA)IJP
WINNIK 77 NP B128 66 +TOAFF,REVEL,GOLDBERG,BERNY (HAIF)I
BARBOUR 78 NP B141 253 BARBOUR,CRAWFORD,PARSONS (GLAS)
HENDRY 78 PRL 41 222 A W HENDRY (IND+LBL)IJP
-- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
BAKER 79 NP B156 93 +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+ (RHEL)IJP
CUTKOSKY 79 PR D20 2839 +FORSYTH,HENDRICK,KELLY (CARN+LBL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
CRAWFORD 80 TORONTO CONF 107 R L CRAWFORD (GLAS)
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
SAXON 80 NP B162 522 +BAKER,BELL,BLISSETT,BLOODWORTH+(RHEL+BRIS)IJP
HENDRY 81 ANP 136 1 A W HENDRY (IND)
BELL 83 NP B222 389 +BLISSET,BROOME,DALEY,HART,LINTERN,+ (RL)IJP
CRAWFORD 83 NP B211 1 R L CRAWFORD, W T MORTON (GLAS)
MANLEY 84 PR D30 904 MANLEY,ARNDT,GORADIA,TEPLITZ (VPI)
ALSO 84 PRL 52 2122 MANLEY (VPI)

$N(2200)$ D_{15}

$I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$ Status: * *

OMITTED FROM SUMMARY TABLE

THE MASS IS NOT WELL DETERMINED. A FEW EARLY RESULTS HAVE BEEN OMITTED.

$N(2200)$ MASS (MeV)

M	2228.0	30.0	HOEHLER	79 IPWA		PI N TO PI N
M	2180.0	80.0	CUTKOSKY	80 IPWA		PI N TO PI N
M	(1920.0)		SAXON	80 DPWA	0	PI- P TO K LAM
M	(1900.0)		BELL	83 DPWA	0	PI- P TO LAM K0

$N(2200)$ WIDTH (MeV)

W	310.0	50.0	HOEHLER	79 IPWA		PI N TO PI N
W	400.0	100.0	CUTKOSKY	80 IPWA		PI N TO PI N
W	(220.0)		SAXON	80 DPWA	0	PI- P TO K LAM
W	(130.0)		BELL	83 DPWA	0	PI- P TO LAM K0

$N(2200)$ REAL PART OF POLE POSITION (MeV)

RE	2100.0	60.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2200)$ -2*IMAG PART OF POLE POSITION (MeV)

IM	360.0	80.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2200)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	0.0	17.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2200)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	-20.0	10.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2200)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(2200) \to N\pi$	938+ 140
P2	$N(2200) \to N\eta$	940+ 549
P3	$N(2200) \to \Lambda K$	1116+ 498

$N(2200)$ BRANCHING RATIOS

$N(2200) \to (N\pi)$/total (P1)

R1	0.07	0.02	HOEHLER	79 IPWA	PI N TO PI N
R1	0.10	0.03	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2200)$ in $N\pi \to N\eta$ SQRT(P1*P2)

R2	(0.066)	BAKER	79 DPWA	0	PI- P TO ETA N

$N(2200)$ in $N\pi \to \Lambda K$ SQRT(P1*P3)

R3	(-0.05)	SAXON	80 DPWA	0	PI- P TO K LAM
R3	(-0.03)	BELL	83 DPWA	0	PI- P TO LAM K0

REFERENCES FOR $N(2200)$

ALMEHED 72 NP B40 157 +LOVELACE (LUND+RUTG)IJP
AYED 76 CEA-N-1921 AYED (THESIS) (SACL)IJP
MA 76 PR D13 3027 E MA,G L SHAW (OREG+UCI)IJP
BAKER 77 NP B126 365 +BLISSET,BLOODWORTH,BROOME,HART+ (RHEL)IJP
BAKER 79 NP B156 93 +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+ (RHEL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
SAXON 80 NP B162 522 +BAKER,BELL,BLISSETT,BLOODWORTH+(RHEL+BRIS)IJP
BELL 83 NP B222 389 +BLISSET,BROOME,DALEY,HART,LINTERN,+ (RL)IJP

$N(2220)$ H_{19}

$I(J^P) = \frac{1}{2}(\frac{9}{2}^+)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

$N(2220)$ MASS (MeV)

M	2300.0	100.0	HENDRY	78 MPWA		PI N TO PI N
M	(2050.0)		BAKER	79 DPWA	0	PI- P TO ETA N
M	(2250.0)		CUTKOSKY	79 IPWA		PI N TO PI N
M	2205.0	10.0	HOEHLER	79 IPWA		PI N TO PI N
M	2230.0	80.0	CUTKOSKY	80 IPWA		PI N TO PI N

$N(2220)$ WIDTH (MeV)

W	450.0	150.0	HENDRY	78 MPWA	PI N TO PI N
W	(450.0)		CUTKOSKY	79 IPWA	PI N TO PI N
W	365.0	30.0	HOEHLER	79 IPWA	PI N TO PI N
W	500.0	150.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2220)$ REAL PART OF POLE POSITION (MeV)

RE	(2180.0)		CUTKOSKY	79 IPWA	PI N TO PI N
RE	2160.0	80.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2220)$ -2*IMAG PART OF POLE POSITION (MeV)

IM	(400.0)		CUTKOSKY	79 IPWA	PI N TO PI N
IM	480.0	100.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2220)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	(37.0)		CUTKOSKY	79 IPWA	PI N TO PI N
RER	32.0	20.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2220)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	(-21.0)		CUTKOSKY	79 IPWA	PI N TO PI N
IMR	-32.0	20.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2220)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(2220) \to N\pi$	938+ 140
P2	$N(2220) \to N\eta$	940+ 549
P3	$N(2220) \to \Lambda K$	1116+ 498

$N(2220)$ BRANCHING RATIOS

$N(2220) \to (N\pi)$/total (P1)

R1	0.12	0.04	HENDRY	78 MPWA	PI N TO PI N
R1	(0.20)		CUTKOSKY	79 IPWA	PI N TO PI N
R1	0.18	0.015	HOEHLER	79 IPWA	PI N TO PI N
R1	0.15	0.03	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2220)$ in $N\pi \to N\eta$ SQRT(P1*P2)

R2	(0.034)	BAKER	79 DPWA	0 PI- P TO ETA N

$N(2220)$ in $N\pi \to \Lambda K$ SQRT(P1*P3)

R3	NOT SEEN	SAXON	80 DPWA	0 PI- P TO K LAM
R3	NOT REQUIRED	BELL	83 DPWA 0	PI- P TO LAM KO

REFERENCES FOR $N(2220)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

HENDRY	78	PRL 41 222	A W HENDRY	(IND+LBL)IJP
		-- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.		
BAKER	79	NP B156 93	+BROWN,CLARK,DAVIES,DEPAGTER,EVANS+	(RHEL)IJP
CUTKOSKY	79	PR D20 2839	+FORSYTH,HENDRICK,KELLY	(CARN+LBL)IJP
HOEHLER	79	HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1	+KAISER,KOCH,PIETARINEN	(KARL)IJP
ALSO	80	TORONTO CONF 3	R KOCH	(KARL)IJP
CUTKOSKY	80	TORONTO CONF 19	+FORSYTH,BABCOCK,KELLY,HENDRICK	(CARN+LBL)IJP
SAXON	80	NP B162 522	+BAKER,BELL,BLISSETT,BLOODWORTH+	(RHEL+BRIS)IJP
HENDRY	81	ANP 136 1	A W HENDRY	(IND)
BELL	83	NP B222 389	+BLISSET,BROOME,DALEY,HART,LINTERN,+	(RL)IJP

$N(2250)$ G_{19}

$I(J^P) = \frac{1}{2}(\frac{9}{2}^-)$ Status: * * * *

$N(2250)$ MASS (MeV)

M	2200.0	100.0	HENDRY	78 MPWA	PI N TO PI N
M	(2200.0)		CUTKOSKY	79 IPWA	PI N TO PI N
M	2268.0	15.0	HOEHLER	79 IPWA	PI N TO PI N
M	2250.0	80.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2250)$ WIDTH (MeV)

W	350.0	100.0	HENDRY	78 MPWA	PI N TO PI N
W	(330.0)		CUTKOSKY	79 IPWA	PI N TO PI N
W	300.0	40.0	HOEHLER	79 IPWA	PI N TO PI N
W	480.0	120.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2250)$ REAL PART OF POLE POSITION (MeV)

RE	(2169.0)		CUTKOSKY	79 IPWA	PI N TO PI N
RE	2150.0	50.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2250)$ -2*IMAG PART OF POLE POSITION (MeV)

IM	(290.0)		CUTKOSKY	79 IPWA	PI N TO PI N
IM	360.0	100.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2250)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	(15.0)		CUTKOSKY	79 IPWA	PI N TO PI N
RER	13.0	7.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2250)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	(-7.0)		CUTKOSKY	79 IPWA	PI N TO PI N
IMR	-15.0	6.0	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2250)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(2250) \to N\pi$	938+ 140
P2	$N(2250) \to N\eta$	940+ 549
P3	$N(2250) \to \Lambda K$	1116+ 498

$N(2250)$ BRANCHING RATIOS

$N(2250) \to (N\pi)$/total (P1)

R1	0.09	0.02	HENDRY	78 MPWA	PI N TO PI N
R1	(0.10)		CUTKOSKY	79 IPWA	PI N TO PI N
R1	0.10	0.02	HOEHLER	79 IPWA	PI N TO PI N
R1	0.10	0.02	CUTKOSKY	80 IPWA	PI N TO PI N

$N(2250)$ in $N\pi \to N\eta$ SQRT(P1*P2)

R2	(-0.043)	BAKER	79 DPWA	0 PI- P TO ETA N

$N(2250)$ in $N\pi \to \Lambda K$ SQRT(P1*P3)

R3	NOT SEEN	SAXON	80 DPWA	0 PI- P TO K LAM
R3	(-0.02)	BELL	83 DPWA 0	PI- P TO LAM KO

REFERENCES FOR $N(2250)$

AYED	76	CEA-N-1921	AYED (THESIS)	(SACL)IJP
HENDRY	78	PRL 41 222	A W HENDRY	(IND+LBL)IJP
		-- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.		
BAKER	79	NP B156 93	+BROWN,CLARK,DAVIES,DEPAGTER,EVANS+	(RHEL)IJP
CUTKOSKY	79	PR D20 2839	+FORSYTH,HENDRICK,KELLY	(CARN+LBL)IJP
HOEHLER	79	HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1	+KAISER,KOCH,PIETARINEN	(KARL)IJP
ALSO	80	TORONTO CONF 3	R KOCH	(KARL)IJP
CUTKOSKY	80	TORONTO CONF 19	+FORSYTH,BABCOCK,KELLY,HENDRICK	(CARN+LBL)IJP
SAXON	80	NP B162 522	+BAKER,BELL,BLISSETT,BLOODWORTH+	(RHEL+BRIS)IJP
HENDRY	81	ANP 136 1	A W HENDRY	(IND)
BELL	83	NP B222 389	+BLISSET,BROOME,DALEY,HART,LINTERN,+	(RL)IJP

$N(2600)$ $I_{1\,11}$

$I(J^P) = \frac{1}{2}(\frac{11}{2}^-)$ Status: * * *

$N(2600)$ MASS (MeV)

M	2700.0	100.0	HENDRY	78 MPWA	PI N TO PI N
M	2577.0	50.0	HOEHLER	79 IPWA	PI N TO PI N

$N(2600)$ WIDTH (MeV)

W	900.0	100.0	HENDRY	78 MPWA	PI N TO PI N
W	400.0	100.0	HOEHLER	79 IPWA	PI N TO PI N

$N(2600)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$N(2600) \to N\pi$	938+ 140

$N(2600)$ BRANCHING RATIOS

$N(2600) \to (N\pi)$/total (P1)

R1	0.08	0.02	HENDRY	78 MPWA	PI N TO PI N
R1	0.05	0.01	HOEHLER	79 IPWA	PI N TO PI N

REFERENCES FOR $N(2600)$

HENDRY	78	PRL 41 222	A W HENDRY	(IND+LBL)IJP
		-- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.		
HOEHLER	79	HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1	+KAISER,KOCH,PIETARINEN	(KARL)IJP
ALSO	80	TORONTO CONF 3	R KOCH	(KARL)IJP
HENDRY	81	ANP 136 1	A W HENDRY	(IND)

$N(2700)$ $K_{1\,13}$

$I(J^P) = \frac{1}{2}(\frac{13}{2}^+)$ Status: * *

OMITTED FROM SUMMARY TABLE

$N(2700)$ MASS (MeV)

M	3000.0	100.0	HENDRY	78 MPWA	PI N TO PI N
M	2612.0	45.0	HOEHLER	79 IPWA	PI N TO PI N

$N(2700)$ WIDTH (MeV)

W	900.0	150.0	HENDRY	78 MPWA	PI N TO PI N
W	350.0	50.0	HOEHLER	79 IPWA	PI N TO PI N

$N(2700)$ PARTIAL DECAY MODES

```
                                                     DECAY MASSES
P1      N(2700) -> N pi                             938+ 140
```

$N(2700)$ BRANCHING RATIOS

$N(2700) \rightarrow (N\pi)$/total (P1)

```
R1          0.07     0.02           HENDRY    78 MPWA    PI N TO PI N
R1          0.04     0.01           HOEHLER   79 IPWA    PI N TO PI N
```

REFERENCES FOR $N(2700)$

```
HENDRY   78 PRL 41 222         A W HENDRY                          (IND+LBL)IJP
            -- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                               +KAISER,KOCH,PIETARINEN                (KARL)IJP
    ALSO 80  TORONTO CONF 3    R KOCH                                 (KARL)IJP
HENDRY   81 ANP 136 1          A W HENDRY                              (IND)
```

~3000 MeV REGION — $I=1/2$ FORMATION EXPERIMENTS

WE LIST HERE MISCELLANEOUS HIGH-MASS CANDIDATES FOR ISOSPIN-1/2 RESONANCES FOUND IN PARTIAL-WAVE ANALYSES. SO FAR, NO ANALYSIS OF THIS REGION HAS USED ALL THE AVAILABLE DATA OR INCORPORATED ANALYTICITY CONSTRAINTS.

OUR 1982 EDITION ALSO HAD AN N(3030), AN N(3245), AN N(3690), AND AN N(3755). NOTHING HAS BEEN HEARD FROM THEM SINCE THE 1960'S, AND UNDER THE AUTHORITY GRANTED UNTO US BY THE STATUTE OF LIMITATIONS WE DECLARE THEM TO BE DEAD. THE LAST THREE WERE NARROW PEAKS SEEN IN PRODUCTION EXPERIMENTS. THE N(3030) WAS DEDUCED FROM TOTAL-CROSS-SECTION AND 180-DEG-ELASTIC-CROSS-SECTION MEASUREMENTS; PLACED IN THE BARYON SUMMARY TABLE IN THE ANYTHING-GOES 1960'S, IT REMAINED THERE DUE TO INATTENTION UNTIL THE 1984 EDITION.

$N(\sim 3000)$ MASS (MeV)

```
M          3500.0     200.0           HENDRY    78 MPWA    PI N  L115
M          3800.0     200.0           HENDRY    78 MPWA    PI N  M117
M          4100.0     200.0           HENDRY    78 MPWA    PI N  N119
M         (2600.0)                    KOCH      80 IPWA    PI N  D13
M         (3100.0)                    KOCH      80 IPWA    PI N  L115
M         (3500.0)                    KOCH      80 IPWA    PI N  M117
M          3500.0 TO 4000.0           KOCH      80 IPWA    PI N  N119
```

$N(\sim 3000)$ WIDTH (MeV)

```
W          1300.0     200.0           HENDRY    78 MPWA    PI N  L115
W          1600.0     200.0           HENDRY    78 MPWA    PI N  M117
W          1900.0     300.0           HENDRY    78 MPWA    PI N  N119
```

$N(\sim 3000)$ PARTIAL DECAY MODES

```
                                                     DECAY MASSES
P1      N(~3000) -> N pi                            938+ 140
```

$N(\sim 3000)$ BRANCHING RATIOS

$N(\sim 3000) \rightarrow (N\pi)$/total (P1)

```
R1          0.055    0.02           HENDRY    78 MPWA    PI N  L115
R1          0.040    0.015          HENDRY    78 MPWA    PI N  M117
R1          0.030    0.015          HENDRY    78 MPWA    PI N  N119
```

REFERENCES FOR $N(\sim 3000)$

```
HENDRY   78 PRL 41 222         A W HENDRY                          (IND+LBL)IJP
            -- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
KOCH     80  TORONTO CONF 3    R KOCH                                 (KARL)IJP
HENDRY   81 ANP 136 1          A W HENDRY                              (IND)IJP
```

Δ BARYONS $(S=0,\ I=3/2)$

$\Delta(1232)$ P_{33}

$I(J^P)=\frac{3}{2}(\frac{3}{2}^+)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1977 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

IN ADDITION, RESULTS IN THIS REGION FROM PRODUCTION EXPERIMENTS, WHICH USED TO BE LISTED SEPARATELY AS THE NEXT ENTRY, HAVE BEEN ENTIRELY REMOVED. THEY TOO MAY BE FOUND IN OUR 1982 EDITION.

$\Delta(1232)$ MASS (MeV)

```
M             1233.0       2.0            HOEHLER   79 IPWA    PI N TO PI N
M             1232.0       3.0            CUTKOSKY  80 IPWA    PI N TO PI N

M++           1231.1       0.2            PEDRONI   78 DPWA ++ PI N 70-370 MEV
M++           1230.9       0.3            KOCH      80 IPWA ++ PI N TO PI N
M++           1230.6       0.2            ZIDELL    80 DPWA ++ PI N  0-350 MEV

M+           (1231.8)                     BERENDS   75 IPWA +  GAM P TO PI NUC
M+           (1231.2)                     BARBOUR   78 DPWA    PI-N PHOTOPROD.
M+            1234.9       1.4            MIROSHNIC 79      +  FIT PHOTOPROD.
M+           (1231.6)                     CRAWFORD  80 DPWA    PI N PHOTOPROD.

M0            1233.8       0.2            PEDRONI   78 DPWA  0 PI N 70-370 MEV
M0            1233.6       0.5            KOCH      80 IPWA  0 PI N TO PI N
M0            1232.5       0.3            ZIDELL    80 DPWA  0 PI N  0-350 MEV
```

$\Delta(1232)$ WIDTH (MeV)

```
W              116.0       5.0            HOEHLER   79 IPWA    PI N TO PI N
W              120.0       5.0            CUTKOSKY  80 IPWA    PI N TO PI N

W++            111.3       0.5            PEDRONI   78 DPWA ++ PI N 70-370 MEV
W++            111.0       1.0            KOCH      80 IPWA ++ PI N TO PI N
W++            113.2       0.3            ZIDELL    80 DPWA ++ PI N  0-350 MEV

W+            (111.0)                     BARBOUR   78 DPWA    PI-N PHOTOPROD.
W+             131.1       2.4            MIROSHNIC 79      +  FIT PHOTOPROD.
W+            (111.2)                     CRAWFORD  80 DPWA    PI N PHOTOPROD.

W0             117.9       0.9            PEDRONI   78 DPWA  0 PI N 70-370 MEV
W0             113.0       1.5            KOCH      80 IPWA  0 PI N TO PI N
W0             121.3       0.4            ZIDELL    80 DPWA  0 PI N  0-350 MEV
```

$\Delta(1232)^0$ − $\Delta(1232)^{++}$ MASS DIFFERENCE (MeV)

```
D    A       (2.7)     (0.3)             PEDRONI   78 DPWA    PI N 70-370 MEV
D    A   REDUNDANT WITH DATA IN MASS LISTING.
D    A   USING PI+-D AS WELL, PEDRONI 78 DETERMINE (M- - M++)+(M0 - M+)/3 =
D    A   4.6+-0.2 MEV.
```

$\Delta(1232)^0$ − $\Delta(1232)^{++}$ WIDTH DIFFERENCE (MeV)

```
WD   A       (6.6)     (1.0)             PEDRONI   78 DPWA    PI N 70-370 MEV
WD   A   REDUNDANT WITH DATA IN MASS LISTING.
```

$\Delta(1232)$ REAL PART OF POLE POSITION (MeV)

```
RE          1210.0      1.0               CUTKOSKY  80 IPWA    PI N TO PI N
RE         (1210.)                        ARNDT     85 DPWA    PI N TO PI N      |

R++  B      1209.6      0.5               VASAN     76      ++ FIT CARTER 73
R++  B   FROM FITS TO COULOMB-BARRIER-CORRECTED CARTER 73 PHASE SHIFT.
R++  C      1210.5 TO 1210.8              VASAN     76      ++ FIT CARTER 73
R++  C   FROM FITS TO CARTER 73 NUCLEAR PHASE SHIFT WITHOUT COULOMB BARRIER
R++  C   CORRECTIONS.
R++  D     (1210.4)    (0.17)             ZIDELL    78      ++ FIT ZIDELL 78
R++  D   FIT TO ZIDELL 78 NUCLEAR PHASE SHIFT WITHOUT COULOMB
R++  D   BARRIER CORRECTIONS.
R++  E      1210.70     0.16              ZIDELL    80 DPWA ++ PI N  0-350 MEV
R++  E   FIT TO ZIDELL 80 NUCLEAR PHASE SHIFTS.  THE ACCURACY CLAIMED ON THE
R++  E   REAL PART IS CONSIDERABLY BETTER THAN IS ALLOWED BY UNCERTAINTIES
R++  E   IN THE BEAM MOMENTUM.

RE+         1208.0      2.0               CAMPBELL  76      +  FIT PHOTOPROD.
RE+         1206.9+-0.9 TO 1210.5+-1.8 MIROSHNIC 79      +  FIT PHOTOPROD.

RE0  B      1210.75     0.6               VASAN     76       0 FIT CARTER 73
RE0  C     (1210.2)                       VASAN     76       0 FIT CARTER 73
RE0  D     (1209.5)    (0.41)             ZIDELL    78       0 FIT ZIDELL 78
RE0  E      1210.30     0.36              ZIDELL    80 DPWA  0 PI N  0-350 MEV
```

$\Delta(1232)$ −IMAG PART OF POLE POSITION (MeV)

```
IM            50.0      1.0               CUTKOSKY  80 IPWA    PI N TO PI N
IM           (50.)                        ARNDT     85 DPWA    PI N TO PI N      |

I++  B        50.4      0.5               VASAN     76      ++ FIT CARTER 73
I++  C        49.9 TO  50.0               VASAN     76      ++ FIT CARTER 73
I++  D      (49.745)   (0.14)             ZIDELL    78      ++ FIT ZIDELL 78
I++  E        49.61     0.12              ZIDELL    80 DPWA ++ PI N  0-350 MEV
```

IM+		53.0	2.0	CAMPBELL 76		+	FIT PHOTOPROD.
IM+		55.6+-1.0 TO 58.3+-1.1		MIROSHNIC 79		+	FIT PHOTOPROD.
IMO	B	52.8	0.6	VASAN 76		0	FIT CARTER 73
IMO	C	52.9 TO 53.1		VASAN 76		0	FIT CARTER 73
IMO	D	(52.45)	(0.2)	ZIDELL 78		0	FIT ZIDELL 78
IMO	E	54.0	0.26	ZIDELL 80	DPWA	0	PI N 0-350 MEV

Δ(1232) ABSOLUTE VALUE OF ELASTIC POLE RESIDUE

(MEV)

ABS		53.0	2.0	CUTKOSKY 80	IPWA		PI N TO PI N
A++	B	52.4 TO 53.2		VASAN 76		++	FIT CARTER 73
A++	C	52.1 TO 52.4		VASAN 76		++	FIT CARTER 73
AB0	B	54.8 TO 55.0		VASAN 76		++	FIT CARTER 73
AB0	C	55.2 TO 55.3		VASAN 76		--	FIT CARTER 73

Δ(1232) PHASE OF ELASTIC POLE RESIDUE (RADIANS)

PH		-0.82	0.02	CUTKOSKY 80	IPWA		PI N TO PI N
P++	B	-0.822 TO -0.833		VASAN 76		++	FIT CARTER 73
P++	C	-0.823 TO -0.830		VASAN 76		++	FIT CARTER 73
PH0	B	-0.840 TO -0.847		VASAN 76		++	FIT CARTER 73
PH0	C	-0.848 TO -0.856		VASAN 76		++	FIT CARTER 73

Δ(1232) PHASE OF M1+(3/2) PHOTOPRODUCTION

MULTIPOLE AMPLITUDE POLE RESIDUE

M1P INFORMATION ON THE PHASE (AND MAGNITUDE) OF THE M1+(3/2) MULTIPOLE
M1P AMPLITUDE POLE RESIDUE IS CONTAINED IMPLICITLY IN THE PAPER OF
M1P MIROSHNICHENKO 79. THEY FIND THAT THE PHASE IS CONSISTENT WITH
M1P BEING EQUAL TO THAT OF THE ELASTIC POLE RESIUDE.

Δ(1232) MAGNETIC MOMENT (NUCLEAR MAGNETONS)

MM	+4.7 TO +6.7	NEFKENS 78	PI P TO PI P GAM

Δ(1232) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Delta(1232) \to N\pi$	938+ 140
P2	$\Delta(1232) \to N\pi\pi$	938+ 140+ 140
P3	$\Delta(1232) \to N\gamma$	938+ 0
P4	$\Delta(1232) \to N\gamma$, helicity=1/2	938+ 0
P5	$\Delta(1232) \to N\gamma$, helicity=3/2	938+ 0

Δ(1232) BRANCHING RATIOS

$\Delta(1232)^0 \to (N\pi)$/total (P1)

R1	(1.0)	HOEHLER 79	IPWA	PI N TO PI N
R1	(1.0)	CUTKOSKY 80	IPWA	PI N TO PI N

Δ(1232) PHOTON DECAY AMPLITUDES $(\mathrm{GeV}^{-1/2})$

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$\Delta(1232) \to N\gamma$, helicity=1/2 $(\mathrm{GeV}^{-1/2})$

A1		-0.141	0.004	FELLER 76	DPWA	PI N PHOTOPROD.
A1		-0.136	0.002	AZNAURYAN 77	DPWA	PIO PHTPRD,SOL 1
A1		-0.139	0.002	AZNAURYAN 77	DPWA	PIO PHTPRD,SOL 2
A1		-0.142	0.007	BARBOUR 78	DPWA	PI-N PHOTOPROD.
A1	N	(-0.140)		NOELLE 78		PI-N PHOTOPROD.
A1	N	CONVERTED TO OUR CONVENTIONS USING M=1.232, W=.110 FROM NOELLE 78.				
A1		-0.147	0.001	ARAI 80	DPWA	PI N PHOTO FIT 1
A1		-0.145	0.001	ARAI 80	DPWA	PI N PHOTO FIT 2
A1		-0.136	0.006	CRAWFORD 80	DPWA	PI N PHOTOPROD.
A1		-0.138	0.004	AWAJI 81	DPWA	PI N PHOTOPROD.
A1		-0.145	0.015	CRAWFORD 83	IPWA	PI N PHOTOPROD.

$\Delta(1232) \to N\gamma$, helicity=3/2 $(\mathrm{GeV}^{-1/2})$

A2		-0.256	0.003	FELLER 76	DPWA	PI N PHOTOPROD.
A2		-0.255	0.002	AZNAURYAN 77	DPWA	PIO PHTPRD,SOL 1
A2		-0.256	0.002	AZNAURYAN 77	DPWA	PIO PHTPRD,SOL 2
A2		-0.271	0.010	BARBOUR 78	DPWA	PI-N PHOTOPROD.
A2	N	(-0.247)		NOELLE 78		PI-N PHOTOPROD.
A2		-0.264	0.002	ARAI 80	DPWA	PI N PHOTO FIT 1
A2		-0.261	0.002	ARAI 80	DPWA	PI N PHOTO FIT 2
A2		-0.247	0.010	CRAWFORD 80	DPWA	PI N PHOTOPROD.
A2		-0.259	0.006	AWAJI 81	DPWA	PI N PHOTOPROD.
A2		-0.263	0.026	CRAWFORD 83	IPWA	PI N PHOTOPROD.

REFERENCES FOR Δ(1232)

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

BERENDS 75 NP B84 342 BERENDS,DONNACHIE (LEID+MCHS)
CAMPBELL 76 PR D14 2431 CAMPBELL,SHAW,BALL (BOIS+UCI+UTAH)IJP
FELLER 76 NP B104 219 +FUKUSHIMA,HORIKAWA,KAJIKAWA+ (NAGO+OSAK)IJP
VASAN 76 NP B106 535 S S VASAN (CARN)IJP
ALSO 76 NP B106 526 S S VASAN (CARN)IJP
AZNAURYA 77 EFI-264(57)-77 +AKOPOV,BAGDASARYAN (YERE)IJP
BARBOUR 78 NP B141 253 BARBOUR,CRAWFORD,PARSONS (GLAS)
NEFKENS 78 PR D18 3911 +ARMAN,BALLAGH,GLODIS,HADDOCK+ (UCLA+CATH)IJP
NOELLE 78 PTP 60 778 P NOELLE (NAGO)
PEDRONI 78 NP A300 321 +GABATHULER,DOMINGO,HIRT+ (SIN+GREN+KARL++)IJP
ZIDELL 78 LNC 21 140 V S ZIDELL,R A ARNDT,L D ROPER (VPI)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
MIROSHNI 79 SJNP 29 94 MIROSHNICHENKO,NIKIFOROV,SANIN+ (KHAR)IJP
ARAI 80 TORONTO CONF 93 I ARAI (TOKY)
ALSO 82 NP B194 251 I ARAI, H FUJII (TOKY)
CRAWFORD 80 TORONTO CONF 107 R L CRAWFORD (GLAS)
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
KOCH 80 NP A336 331 R KOCH, E PIETARINEN (KARL)IJP
ZIDELL 80 PR D21 1255 V S ZIDELL,R A ARNDT,L D ROPER (VPI)IJP
AWAJI 81 BONN CONF 352 R KAJIKAWA (TALK) (NAGO)
ALSO 82 NP B197 365 FUJII,HAYASHII,IWATA,KAJIKAWA+ (NAGO)
CRAWFORD 83 NP B211 1 R L CRAWFORD, W T MORTON (GLAS)
ARNDT 85 PR D32 1085 R A ARNDT, J M FORD, L D ROPER (VPI)

Δ(1550) P_{31}

$I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

THIS RESONANCE HAS NOT BEEN SEEN IN PI N --> PI N ANALYSES, AND ITS EXISTENCE IS THUS DOUBTFUL.

Δ(1550) MASS (MeV)

M	A	(1550.0)	LONGACRE 77	IPWA		PI N TO 2PI N
M	A	ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE				
M	A	POSITION WHICH IS FROM SOLUTIONS S1 AND C1.				
M		(1525.0)	BARNHAM 80	IPWA	++	PI N TO 2PI N
M		(1506.0)	CRAWFORD 80	DPWA		PI N PHOTOPROD.

Δ(1550) WIDTH (MeV)

W	A	(110.0)	LONGACRE 77	IPWA		PI N TO 2PI N
W		(40.0)	BARNHAM 80	IPWA	++	PI N TO 2PI N
W		(137.0)	CRAWFORD 80	DPWA		PI N PHOTOPROD.

Δ(1550) REAL PART OF POLE POSITION (MeV)

RE	A	1554.0 OR 1553.0	LONGACRE 77	IPWA	PI N TO 2PI N

Δ(1550) −2*IMAG PART OF POLE POSITION (MeV)

IM	A	105.0 OR 104.0	LONGACRE 77	IPWA	PI N TO 2PI N

Δ(1550) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Delta(1550) \to N\pi$	938+ 140
P2	$\Delta(1550) \to \Delta(1232)\,\pi$, P-wave	1232+ 140
P3	$\Delta(1550) \to N\rho$, S=3/2, P-wave	938+ 769
P4	$\Delta(1550) \to N\gamma$, helicity=1/2	938+ 0

Δ(1550) BRANCHING RATIOS

R NOTE: SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.

$\Delta(1550)$ in $N\pi \to \Delta(1232)\,\pi$, P-wave SQRT(P1*P2)

R1	A	(-0.11)		LONGACRE 77	IPWA		PI N TO 2PI N
R1		0.13	0.05	BARNHAM 80	IPWA	++	PI N TO 2PI N

$\Delta(1550)$ in $N\pi \to N\rho$, S=3/2, P-wave SQRT(P1*P3)

R2	A	(-0.08)		LONGACRE 77	IPWA		PI N TO 2PI N
R2		0.17	0.05	BARNHAM 80	IPWA	++	PI N TO 2PI N

Δ(1550) PHOTON DECAY AMPLITUDES $(\mathrm{GeV}^{-1/2})$

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$\Delta(1550) \to N\gamma$, helicity=1/2 $(\mathrm{GeV}^{-1/2})$

A1	(0.013)		CRAWFORD 80	DPWA	PI N PHOTOPROD.
A1	0.016	0.016	CRAWFORD 83	IPWA	PI N PHOTOPROD.

REFERENCES FOR Δ(1550)

LONGACRE 77 NP B122 493 LONGACRE,DOLBEAU (SACL)IJP
ALSO 76 NP B108 365 DOLBEAU,TRIANTIS,NEVEU,CADIET (SACL)IJP
BARNHAM 80 NP B168 243 BARNHAM,GLICKMAN,MIER-JEDRZEJOWICZ+ (LOIC)
CRAWFORD 80 TORONTO CONF 107 R L CRAWFORD (GLAS)
CRAWFORD 83 NP B211 1 R L CRAWFORD, W T MORTON (GLAS)

$\Delta(1600)\ P_{33}$ $I(J^P)=\frac{3}{2}(\frac{3}{2}^+)$ Status: * *

OMITTED FROM SUMMARY TABLE

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

THE AGREEMENT AMONG THE VARIOUS ANALYSES IS NOT VERY GOOD.

Δ(1600) MASS (MeV)

```
M    A     1900. OR 1640.           LONGACRE  75 IPWA    PI N TO 2PI N
M    A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M   B     (1560.0)                  LONGACRE  77 IPWA    PI N TO 2PI N
M   B   ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M   B   POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M         (1640.0)   (50.0)         CUTKOSKY  79 IPWA    PI N TO PI N
M          1522.0     13.0          HOEHLER   79 IPWA    PI N TO PI N
M         (1690.0)                  BARNHAM   80 IPWA ++ PI N TO 2PI N
M          1600.0     50.0          CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1600) WIDTH (MeV)

```
W    A      205. OR  300.           LONGACRE  75 IPWA    PI N TO 2PI N
W   B     (180.0)                   LONGACRE  77 IPWA    PI N TO 2PI N
W         (370.0)    (70.0)         CUTKOSKY  79 IPWA    PI N TO PI N
W          220.0      40.0          HOEHLER   79 IPWA    PI N TO PI N
W         (250.0)                   BARNHAM   80 IPWA ++ PI N TO 2PI N
W          300.0     100.0          CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1600) REAL PART OF POLE POSITION (MeV)

```
RE  B      1541.0 OR 1542.0         LONGACRE  77 IPWA    PI N TO 2PI N
RE         1609.0 OR 1610.0         LONGACRE  78 IPWA    PI N TO 2PI N
RE        (1547.0)                  CUTKOSKY  79 IPWA    PI N TO PI N
RE         1550.0     40.0          CUTKOSKY  80 IPWA    PI N TO PI N
RE        (1581.)                   ARNDT     85 DPWA    PI N TO PI N
```

Δ(1600) −2*IMAG PART OF POLE POSITION (MeV)

```
IM  B       178.0 OR 178.0          LONGACRE  77 IPWA    PI N TO 2PI N
IM          323.0 OR 325.0          LONGACRE  78 IPWA    PI N TO 2PI N
IM        (230.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
IM         200.0      60.0          CUTKOSKY  80 IPWA    PI N TO PI N
IM        (300.)                    ARNDT     85 DPWA    PI N TO PI N
```

Δ(1600) REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER       (-18.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
RER        -15.0       6.0          CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1600) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR       (-11.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
IMR          8.0       8.0          CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1600) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Delta(1600) \to N\pi$	938+ 140
P2	$\Delta(1600) \to \Sigma K$	1189+ 494
P3	$\Delta(1600) \to \Delta(1232)\ \pi$, P-wave	1232+ 140
P4	$\Delta(1600) \to \Delta(1232)\ \pi$, F-wave	1232+ 140
P5	$\Delta(1600) \to N\rho$, S=1/2, P-wave	938+ 769
P6	$\Delta(1600) \to N\rho$, S=3/2, P-wave	938+ 769
P7	$\Delta(1600) \to N\rho$, S=3/2, F-wave	938+ 769
P8	$\Delta(1600) \to N(1440)\ \pi$, P-wave	1440+ 140
P9	$\Delta(1600) \to N\gamma$, helicity=1/2	938+ 0
P10	$\Delta(1600) \to N\gamma$, helicity=3/2	938+ 0

Δ(1600) BRANCHING RATIOS

$\Delta(1600) \to (N\pi)$/total (P1)

```
R1          (0.20)   (0.04)         CUTKOSKY  79 IPWA    PI N TO PI N
R1           0.21     0.06          HOEHLER   79 IPWA    PI N TO PI N
R1           0.18     0.04          CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1600)$ in $N\pi \to \Sigma K$ SQRT(P1*P2)

```
R2  C          0.006 TO 0.042       DEANS     75 DPWA    PI N TO K SIGMA
R2  C   RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.
R2  C   DEANS75 DISAGREES WITH PI+ P TO K+ SIGMA+ DATA OF WINNIK77
R2  C   AROUND 1920 MEV.
```

```
R       NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R              IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R              THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R              SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

$\Delta(1600)$ in $N\pi \to \Delta(1232)\ \pi$, P-wave SQRT(P1*P3)

```
R3   A       +0.36 OR +0.30         LONGACRE  75 IPWA    PI N TO 2PI N
R3   B     (+0.34)                  LONGACRE  77 IPWA    PI N TO 2PI N
R3   B  LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R3   D       (0.3)                  NOVOSELLE 78 IPWA    PI N TO 2PI N
R3   D  BW FIT TO LONGACRE 75 IPWA, PHASE IS NEAR -90 DEGREES.
R3   E       (0.27)                 NOVOSELLE 78 IPWA    PI N TO 2PI N
R3   E  BW FIT TO NOVOSELLER 78 IPWA, PHASE IS NEAR -90 DEGREES. THIS FIT
R3   E  ASSUMES THE MASS IS NEAR 1900 MEV.
R3          +0.24      0.05         BARNHAM   80 IPWA ++ PI N TO 2PI N
R3   F       +  (LARGE)             MANLEY    84 IPWA    PI N TO 2PI N
R3   F  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
```

$\Delta(1600)$ in $N\pi \to \Delta(1232)\ \pi$, F-wave SQRT(P1*P4)

```
R4   B     (-0.07)                  LONGACRE  77 IPWA    PI N TO 2PI N
```

$\Delta(1600)$ in $N\pi \to N\rho$, S=1/2, P-wave SQRT(P1*P5)

```
R5   B     (+0.10)                  LONGACRE  77 IPWA    PI N TO 2PI N
```

$\Delta(1600)$ in $N\pi \to N\rho$, S=3/2, P-wave SQRT(P1*P6)

```
R6   B     (+0.10)                  LONGACRE  77 IPWA    PI N TO 2PI N
```

$\Delta(1600)$ in $N\pi \to N(1440)\ \pi$, P-wave SQRT(P1*P8)

```
R7          +0.23      0.04         BARNHAM   80 IPWA ++ PI N TO 2PI N
R7   F       +  (LARGE)             MANLEY    84 IPWA    PI N TO 2PI N
R7   F  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
```

Δ(1600) PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$\Delta(1600) \to N\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1           0.0       0.020        FELLER    76 DPWA    PI N PHOTOPROD.
A1          +0.006     0.018        AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A1          -0.119     0.014        AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A1           0.000     0.030        BARBOUR   78 DPWA    PI-N PHOTOPROD.
A1           0.005     0.020        CRAWFORD  80 DPWA    PI N PHOTOPROD.
A1          -0.046     0.013        AWAJI     81 DPWA    PI N PHOTOPROD.
A1          -0.039     0.030        CRAWFORD  83 IPWA    PI N PHOTOPROD.
A1   P     (-0.200)                 WADA      84 DPWA    COMPTON SCATT.
A1   P  INCONSISTENT WITH OTHER ANALYSES -- SEE MINI-REVIEW.
```

$\Delta(1600) \to N\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A2           0.0       0.015        FELLER    76 DPWA    PI N PHOTOPROD.
A2          -0.133     0.042        AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A2          -0.088     0.037        AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A2           0.000     0.045        BARBOUR   78 DPWA    PI-N PHOTOPROD.
A2          -0.009     0.020        CRAWFORD  80 DPWA    PI N PHOTOPROD.
A2           0.025     0.031        AWAJI     81 DPWA    PI N PHOTOPROD.
A2          -0.013     0.014        CRAWFORD  83 IPWA    PI N PHOTOPROD.
A2          (0.023)                 WADA      84 DPWA    COMPTON SCATT.
```

REFERENCES FOR Δ(1600)

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS     75 NP B96 90          +MITCHELL,MONTGOMERY,+          (SFLA+ALAH)IJP
LONGACRE  75 PL 55B 415         +ROSENFELD,LASINSKI,SMADJA+      (LBL+SLAC)IJP
FELLER    76 NP B104 219        +FUKUSHIMA,HORIKAWA,KAJIKAWA+   (NAGO+OSAK)IJP
AZNAURYA  77  EFI-264(57)-77    +AKOPOV,BAGDASARYAN                  (YERE)IJP
LONGACRE  77 NP B122 493        LONGACRE,DOLBEAU                     (SACL)IJP
    ALSO  76 NP B108 365        DOLBEAU,TRIANTIS,NEVEU,CADIET        (SACL)IJP
WINNIK    77 NP B128 66         +TOAFF,REVEL,GOLDBERG,BERNY          (HAIF)I
BARBOUR   78 NP B141 253        BARBOUR,CRAWFORD,PARSONS             (GLAS)
LONGACRE  78 PR D17 1795        +LASINSKI,ROSENFELD,SMADJA+      (LBL+SLAC)
NOVOSELL  78 NP B137 509        D E NOVOSELLER                        (CIT)IJP
    ALSO  78 NP B137 445        D E NOVOSELLER                        (CIT)IJP
CUTKOSKY  79 PR D20 2839        +FORSYTH,HENDRICK,KELLY          (CARN+LBL)IJP
HOEHLER   79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                                +KAISER,KOCH,PIETARINEN              (KARL)IJP
    ALSO  80  TORONTO CONF 3    R KOCH                               (KARL)IJP
BARNHAM   80 NP B168 243        BARNHAM,GLICKMAN,MIER-JEDRZEJOWICZ+  (LOIC)
CRAWFORD  80  TORONTO CONF 107  R L CRAWFORD                         (GLAS)
CUTKOSKY  80  TORONTO CONF 19   +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
AWAJI     81  BONN CONF 352     R KAJIKAWA (TALK)                    (NAGO)
    ALSO  82 NP B197 365        FUJII,HAYASHII,IWATA,KAJIKAWA+       (NAGO)
CRAWFORD  83 NP B211 1          R L CRAWFORD, W T MORTON             (GLAS)
MANLEY    84 PR D30 904         MANLEY,ARNDT,GORADIA,TEPLITZ          (VPI)
WADA      84 NP B247 313        +EGAWA,IMANISHI,ISHII,KATO,UKAI+     (INUS)
ARNDT     85 PR D32 1085        R A ARNDT, J M FORD, L D ROPER        (VPI)
```

$\Delta(1620)\ S_{31}$ $I(J^P)=\frac{3}{2}(\frac{1}{2}^-)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

Δ(1620) MASS (MeV)

```
M    A     1625. OR 1600.           LONGACRE  75 IPWA    PI N TO 2PI N
M    A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M   B     (1580.0)                  LONGACRE  77 IPWA    PI N TO 2PI N
M   B   ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M   B   POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M         (1662.0)                  BARBOUR   78 DPWA    PI-N PHOTOPROD.
M         (1620.0)   (20.0)         CUTKOSKY  79 IPWA    PI N TO PI N
M          1610.0      7.0          HOEHLER   79 IPWA    PI N TO PI N
```

```
M          (1620.0)                     BARNHAM   80 IPWA ++ PI N TO 2PI N
M    C     (1712.8)    (6.0)            CHEW      80 BPWA ++ PI+P TO PI+P
M    D     (1786.7)    (2.0)            CHEW      80 BPWA ++ PI+P TO PI+P
M    CD  CHEW 80 REPORTS TWO S31 RESONANCES AT SOMEWHAT HIGHER MASSES THAN
M    CD  OTHER ANALYSES.  THEY ARE LISTED HERE, AS C AND D.  PROBLEMS WITH
M    CD  THIS ANALYSIS ARE DISCUSSED IN SEC.2.1.11 OF HOEHLER 83.
M          (1657.0)                     CRAWFORD  80 DPWA    PI N PHOTOPROD.
M           1620.0     20.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1620)$ WIDTH (MeV)

```
W     A     160. OR  150.               LONGACRE  75 IPWA    PI N TO 2PI N
W    B     (120.0)                      LONGACRE  77 IPWA    PI N TO 2PI N
W          (180.0)                      BARBOUR   78 DPWA    PI-N PHOTOPROD.
W          (140.0)   (20.0)             CUTKOSKY  79 IPWA    PI N TO PI N
W           139.0     18.0              HOEHLER   79 IPWA    PI N TO PI N
W          (120.0)                      BARNHAM   80 IPWA ++ PI N TO 2PI N
W    C     (228.3)   (18.0)             CHEW      80 BPWA ++ PI+P TO PI+P
W    D      (30.0)    (6.4)             CHEW      80 BPWA ++ PI+P TO PI+P
W          (161.0)                      CRAWFORD  80 DPWA    PI N PHOTOPROD.
W           140.0     20.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1620)$ REAL PART OF POLE POSITION (MeV)

```
RE   B      1575.0 OR 1572.0            LONGACRE  77 IPWA    PI N TO 2PI N
RE          1583.0 OR 1583.0            LONGACRE  78 IPWA    PI N TO 2PI N
RE         (1597.0)                     CUTKOSKY  79 IPWA    PI N TO PI N
RE          1600.0     15.0             CUTKOSKY  80 IPWA    PI N TO PI N
RE         (1599.)                      ARNDT     85 DPWA    PI N TO PI N
```

$\Delta(1620)$ -2*IMAG PART OF POLE POSITION (MeV)

```
IM   B       119.0 OR 128.0             LONGACRE  77 IPWA    PI N TO 2PI N
IM           143.0 OR 149.0             LONGACRE  78 IPWA    PI N TO 2PI N
IM          (120.0)                     CUTKOSKY  79 IPWA    PI N TO PI N
IM           120.0     20.0             CUTKOSKY  80 IPWA    PI N TO PI N
IM          (120.)                      ARNDT     85 DPWA    PI N TO PI N
```

$\Delta(1620)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER          (-6.0)                     CUTKOSKY  79 IPWA    PI N TO PI N
RER           -5.0      5.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1620)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR         (-15.0)                     CUTKOSKY  79 IPWA    PI N TO PI N
IMR          -14.0      3.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1620)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Delta(1620) \to N\pi$	938+ 140
P2	$\Delta(1620) \to N\pi\pi$	938+ 140+ 140
P3	$\Delta(1620) \to \Delta(1232)\ \pi$, D-wave	1232+ 140
P4	$\Delta(1620) \to N\rho$, S=1/2, S-wave	938+ 769
P5	$\Delta(1620) \to N\rho$, S=3/2, D-wave	938+ 769
P6	$\Delta(1620) \to N(1440)\ \pi$, S-wave	1440+ 140
P7	$\Delta(1620) \to N\gamma$, helicity=1/2	938+ 0

$\Delta(1620)$ BRANCHING RATIOS

$\Delta(1620) \to (N\pi)$/total (P1)

```
R1             (0.25)   (0.04)          CUTKOSKY  79 IPWA    PI N TO PI N
R1              0.35     0.06           HOEHLER   79 IPWA    PI N TO PI N
R1   C         (0.60)                   CHEW      80 BPWA ++ PI+P TO PI+P
R1   D         (0.36)                   CHEW      80 BPWA ++ PI+P TO PI+P
R1              0.25     0.03           CUTKOSKY  80 IPWA    PI N TO PI N

R        NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R               IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R               THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R               SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

$\Delta(1620)$ in $N\pi \to \Delta(1232)\ \pi$, D-wave SQRT(P1*P3)

```
R2   A      -0.40 OR -0.40              LONGACRE  75 IPWA    PI N TO 2PI N
R2   B     (-0.39)                      LONGACRE  77 IPWA    PI N TO 2PI N
R2   B   LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R2          -0.33     0.06              BARNHAM   80 IPWA ++ PI N TO 2PI N
R2   E       -  (LARGE)                 MANLEY    84 IPWA    PI N TO 2PI N
R2   E   MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
```

$\Delta(1620)$ in $N\pi \to N\rho$, S=1/2, S-wave SQRT(P1*P4)

```
R3   A        0.18 OR +0.28             LONGACRE  75 IPWA    PI N TO 2PI N
R3   B     (+0.08)                      LONGACRE  77 IPWA    PI N TO 2PI N
R3           +0.40     0.10             BARNHAM   80 IPWA ++ PI N TO 2PI N
R3   E       +  (LARGE)                 MANLEY    84 IPWA    PI N TO 2PI N
R3   E   MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
```

$\Delta(1620)$ in $N\pi \to N\rho$, S=3/2, D-wave SQRT(P1*P5)

```
R4   B     (-0.13)                      LONGACRE  77 IPWA    PI N TO 2PI N
R4           -  (SMALL)                 MANLEY    84 IPWA    PI N TO 2PI N
```

$\Delta(1620)$ in $N\pi \to N(1440)\ \pi$, S-wave SQRT(P1*P6)

```
R5            0.11     0.05             BARNHAM   80 IPWA ++ PI N TO 2PI N
```

$\Delta(1620)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$\Delta(1620) \to N\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1          -0.005    0.016           FELLER     76 DPWA    PI N PHOTOPROD.
A1          -0.014    0.030           AZNAURYAN  77 DPWA    PI0 PHTPRD,SOL 1
A1           0.000    0.014           AZNAURYAN  77 DPWA    PI0 PHTPRD,SOL 2
A1          +0.034    0.028           BARBOUR    78 DPWA    PI-N PHOTOPROD.
A1          -0.022    0.007           ARAI       80 DPWA    PI N PHOTO FIT 1
A1          -0.026    0.008           ARAI       80 DPWA    PI N PHOTO FIT 2
A1           0.021    0.020           CRAWFORD   80 DPWA    PI N PHOTOPROD.
A1           0.126    0.021           TAKEDA     80 DPWA    PI N PHOTOPROD.
A1           0.010    0.015           AWAJI      81 DPWA    PI N PHOTOPROD.
A1           0.035    0.010           CRAWFORD   83 IPWA    PI N PHOTOPROD.
A1          (0.066)                   WADA       84 DPWA    COMPTON SCATT.
```

REFERENCES FOR $\Delta(1620)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
LONGACRE 75 PL 55B 415          +ROSENFELD,LASINSKI,SMADJA+       (LBL+SLAC)IJP
FELLER   76 NP B104 219         +FUKUSHIMA,HORIKAWA,KAJIKAWA+   (NAGO+OSAK)IJP
AZNAURYA 77  EFI-264(57)-77     +AKOPOV,BAGDASARYAN                   (YERE)IJP
LONGACRE 77 NP B122 493         LONGACRE,DOLBEAU                      (SACL)IJP
    ALSO 76 NP B108 365         DOLBEAU,TRIANTIS,NEVEU,CADIET         (SACL)IJP
BARBOUR  78 NP B141 253         BARBOUR,CRAWFORD,PARSONS              (GLAS)
LONGACRE 78 PR D17 1795         +LASINSKI,ROSENFELD,SMADJA+       (LBL+SLAC)
CUTKOSKY 79 PR D20 2839         +FORSYTH,HENDRICK,KELLY           (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                                +KAISER,KOCH,PIETARINEN               (KARL)IJP
    ALSO 80  TORONTO CONF 3     R KOCH                                (KARL)IJP
ARAI     80  TORONTO CONF 93    I ARAI                                (TOKY)
    ALSO 82 NP B194 251         I ARAI, H FUJII                       (TOKY)
BARNHAM  80 NP B168 243         BARNHAM,GLICKMAN,MIER-JEDRZEJOWICZ+   (LOIC)
CHEW     80  TORONTO CONF 123 D M CHEW                                 (LBL)IJP
CRAWFORD 80  TORONTO CONF 107 R L CRAWFORD                            (GLAS)
CUTKOSKY 80  TORONTO CONF 19    +FORSYTH,BABCOCK,KELLY,HENDRICK   (CARN+LBL)IJP
TAKEDA   80 NP B168 17          TAKEDA,ARAI,FUJII,IKEDA,IWASAKI+      (TOKY)
AWAJI    81  BONN CONF 352      R KAJIKAWA (TALK)                     (NAGO)
    ALSO 82 NP B197 365         FUJII,HAYASHII,IWATA,KAJIKAWA+        (NAGO)
CRAWFORD 83 NP B211 1           R L CRAWFORD, W T MORTON              (GLAS)
HOEHLER  83 LANDOLT-BORNSTEIN VOL I-9B2        G HOEHLER              (KARL)
MANLEY   84 PR D30 904          MANLEY,ARNDT,GORADIA,TEPLITZ           (VPI)
WADA     84 NP B247 313         +EGAWA,IMANISHI,ISHII,KATO,UKAI+      (INUS)
ARNDT    85 PR D32 1085         R A ARNDT, J M FORD, L D ROPER         (VPI)
```

$\boxed{\Delta(1700)\ D_{33}}$

$I(J^P) = \frac{3}{2}(\frac{3}{2}^-)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

$\Delta(1700)$ MASS (MeV)

```
M     A     1725. OR 1680.              LONGACRE  75 IPWA    PI N TO 2PI N
M     A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M    B     (1600.0)                     LONGACRE  77 IPWA    PI N TO 2PI N
M    B   ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M    B   POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M          (1629.0)                     BARBOUR   78 DPWA    PI-N PHOTOPROD.
M          (1730.0)   (30.0)            CUTKOSKY  79 IPWA    PI N TO PI N
M           1680.0     70.0             HOEHLER   79 IPWA    PI N TO PI N
M          (1650.0)                     BARNHAM   80 IPWA ++ PI N TO 2PI N
M     C    (1718.4)   (13.1)   (13.0)   CHEW      80 BPWA ++ PI+P TO PI+P
M     C  PROBLEMS WITH THIS ANALYSIS ARE DISCUSSED IN SEC.2.1.11 OF
M     C  HOEHLER 83.
M          (1622.0)                     CRAWFORD  80 DPWA    PI N PHOTOPROD.
M           1710.0     30.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1700)$ WIDTH (MeV)

```
W     A      190. OR  240.              LONGACRE  75 IPWA    PI N TO 2PI N
W    B      (200.0)                     LONGACRE  77 IPWA    PI N TO 2PI N
W           (216.0)                     BARBOUR   78 DPWA    PI-N PHOTOPROD.
W           (300.0)  (100.0)            CUTKOSKY  79 IPWA    PI N TO PI N
W            230.0     80.0             HOEHLER   79 IPWA    PI N TO PI N
W           (160.0)                     BARNHAM   80 IPWA ++ PI N TO 2PI N
W     C     (193.3)   (26.0)            CHEW      80 BPWA ++ PI+P TO PI+P
W           (209.0)                     CRAWFORD  80 DPWA    PI N PHOTOPROD.
W            280.0     80.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1700)$ REAL PART OF POLE POSITION (MeV)

```
RE   B      1600.0 OR 1594.0            LONGACRE  77 IPWA    PI N TO 2PI N
RE          1681.0 OR 1672.0            LONGACRE  78 IPWA    PI N TO 2PI N
RE         (1691.0)                     CUTKOSKY  79 IPWA    PI N TO PI N
RE          1675.0     25.0             CUTKOSKY  80 IPWA    PI N TO PI N
RE         (1668.)                      ARNDT     85 DPWA    PI N TO PI N
```

$\Delta(1700)$ -2*IMAG PART OF POLE POSITION (MeV)

```
IM   B       208.0 OR 201.0             LONGACRE  77 IPWA    PI N TO 2PI N
IM           245.0 OR 241.0             LONGACRE  78 IPWA    PI N TO 2PI N
IM          (292.0)                     CUTKOSKY  79 IPWA    PI N TO PI N
IM           220.0     40.0             CUTKOSKY  80 IPWA    PI N TO PI N
IM          (320.)                      ARNDT     85 DPWA    PI N TO PI N
```

Δ(1700) REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER         (24.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
RER          12.0       3.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1700) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR         (-2.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
IMR          -4.0       5.0             CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1700) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(1700) → $N\pi$	938+ 140
P2	Δ(1700) → ΣK	1189+ 494
P3	Δ(1700) → $N\pi\pi$	938+ 140+ 140
P4	Δ(1700) → Δ(1232) π, S-wave	1232+ 140
P5	Δ(1700) → Δ(1232) π, D-wave	1232+ 140
P6	Δ(1700) → $N\rho$, S=1/2, D-wave	938+ 769
P7	Δ(1700) → $N\rho$, S=3/2, S-wave	938+ 769
P8	Δ(1700) → $N\rho$, S=3/2, D-wave	938+ 769
P9	Δ(1700) → $N\gamma$, helicity=1/2	938+ 0
P10	Δ(1700) → $N\gamma$, helicity=3/2	938+ 0

Δ(1700) BRANCHING RATIOS

Δ(1700) → ($N\pi$)/total (P1)

```
R1          (0.12)   (0.04)             CUTKOSKY  79 IPWA    PI N TO PI N
R1           0.20     0.03              HOEHLER   79 IPWA    PI N TO PI N
R1   C      (0.16)                      CHEW      80 BPWA ++ PI+P TO PI+P
R1           0.12     0.03              CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1700) in $N\pi$ → ΣK SQRT(P1*P2)

```
R2  D        0.001 TO 0.011             DEANS     75 DPWA    PI N TO K SIGMA
R2  D    RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.
R2  D    DEANS75 DISAGREES WITH PI+ P TO K+ SIGMA+ DATA OF WINNIK77
R2  D    AROUND 1920 MEV.
R2           (.002)                     LIVANOS   80 DPWA    PI P TO K SIGMA

R        NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R               IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R               THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R               SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

Δ(1700) in $N\pi$ → Δ(1232) π, S-wave SQRT(P1*P4)

```
R3   A      +0.25 OR +0.24              LONGACRE  75 IPWA    PI N TO 2PI N
R3  B      (+0.30)                      LONGACRE  77 IPWA    PI N TO 2PI N
R3  B    LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R3          +0.18     0.04              BARNHAM   80 IPWA ++ PI N TO 2PI N
R3   E     (+)                          MANLEY    84 IPWA    PI N TO 2PI N    |
R3   E   MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.          |
```

Δ(1700) in $N\pi$ → Δ(1232) π, D-wave SQRT(P1*P5)

```
R4   A       0.  OR  +0.10              LONGACRE  75 IPWA    PI N TO 2PI N
R4  B      (+0.05)                      LONGACRE  77 IPWA    PI N TO 2PI N
R4           0.14     0.04              BARNHAM   80 IPWA ++ PI N TO 2PI N
R4   E     (+)                          MANLEY    84 IPWA    PI N TO 2PI N    |
R4   E   MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.          |
```

Δ(1700) in $N\pi$ → $N\rho$, S=1/2, D-wave SQRT(P1*P6)

```
R5          +0.17     0.05              BARNHAM   80 IPWA ++ PI N TO 2PI N
```

Δ(1700) in $N\pi$ → $N\rho$, S=3/2, S-wave SQRT(P1*P7)

```
R6   A       0.20 OR -0.30              LONGACRE  75 IPWA    PI N TO 2PI N
R6  B      (+0.04)                      LONGACRE  77 IPWA    PI N TO 2PI N
R6         (+)                          MANLEY    84 IPWA    PI N TO 2PI N    |
```

Δ(1700) in $N\pi$ → $N\rho$, S=3/2, D-wave SQRT(P1*P8)

```
R7           0.18     0.07              BARNHAM   80 IPWA ++ PI N TO 2PI N
```

Δ(1700) PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Δ(1700) → $N\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1          +0.072    0.033             FELLER    76 DPWA    PI N PHOTOPROD.
A1          +0.147    0.013             AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A1          +0.136    0.013             AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A1          +0.130    0.037             BARBOUR   78 DPWA    PI-N PHOTOPROD.
A1           0.112    0.006             ARAI      80 DPWA    PI N PHOTO FIT 1
A1           0.130    0.006             ARAI      80 DPWA    PI N PHOTO FIT 2
A1           0.123    0.022             CRAWFORD  80 DPWA    PI N PHOTOPROD.
A1           0.089    0.033             AWAJI     81 DPWA    PI N PHOTOPROD.
A1           0.111    0.017             CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

Δ(1700) → $N\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A2          +0.087    0.023             FELLER    76 DPWA    PI N PHOTOPROD.
A2          +0.053    0.003             AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A2          +0.022    0.003             AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A2          +0.098    0.036             BARBOUR   78 DPWA    PI-N PHOTOPROD.
A2           0.047    0.007             ARAI      80 DPWA    PI N PHOTO FIT 1
A2           0.050    0.007             ARAI      80 DPWA    PI N PHOTO FIT 2
A2           0.102    0.015             CRAWFORD  80 DPWA    PI N PHOTOPROD.
A2           0.060    0.015             AWAJI     81 DPWA    PI N PHOTOPROD.
A2           0.107    0.015             CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

REFERENCES FOR Δ(1700)

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS    75 NP B96 90          +MITCHELL,MONTGOMERY,+            (SFLA-ALAH)IJP
LONGACRE 75 PL 55B 415         +ROSENFELD,LASINSKI,SMADJA+        (LBL-SLAC)IJP
FELLER   76 NP B104 219        +FUKUSHIMA,HORIKAWA,KAJIKAWA+    (NAGO+OSAK)IJP
AZNAURYA 77  EFI-264(57)-77    +AKOPOV,BAGDASARYAN                    (YERE)IJP
LONGACRE 77 NP B122 493        LONGACRE,DOLBEAU                       (SACL)IJP
    ALSO 76 NP B108 365        DOLBEAU,TRIANTIS,NEVEU,CADIET          (SACL)IJP
WINNIK   77 NP B128 66         +TOAFF,REVEL,GOLDBERG,BERNY            (HAIF)I
BARBOUR  78 NP B141 253        BARBOUR,CRAWFORD,PARSONS               (GLAS)
LONGACRE 78 PR D17 1795        +LASINSKI,ROSENFELD,SMADJA+        (LBL+SLAC)
CUTKOSKY 79 PR D20 2839        +FORSYTH,HENDRICK,KELLY            (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                               +KAISER,KOCH,PIETARINEN                (KARL)IJP
    ALSO 80  TORONTO CONF 3    R KOCH                               · (KARL)IJP
ARAI     80  TORONTO CONF 93   I ARAI                                 (TOKY)
    ALSO 82 NP B194 251        I ARAI, H FUJII                        (TOKY)
BARNHAM  80 NP B168 243        BARNHAM,GLICKMAN,MIER-JEDRZEJOWICZ+    (LOIC)
CHEW     80  TORONTO CONF 123 D M CHEW                                 (LBL)IJP
CRAWFORD 80  TORONTO CONF 107 R L CRAWFORD                            (GLAS)
CUTKOSKY 80  TORONTO CONF 19   +FORSYTH,BABCOCK,KELLY,HENDRICK    (CARN+LBL)IJP
LIVANOS  80  TORONTO CONF 35   +BATON,COUTURES,KOCHOWSKI,NEVEU        (SACL)IJP
AWAJI    81  BONN CONF 352     R KAJIKAWA (TALK)                      (NAGO)
    ALSO 82 NP B197 365        FUJII,HAYASHII,IWATA,KAJIKAWA+         (NAGO)
CRAWFORD 83 NP B211 1          R L CRAWFORD, W T MORTON               (GLAS)
HOEHLER  83 LANDOLT-BORNSTEIN VOL I-9B2       G HOEHLER               (KARL)
MANLEY   84 PR D30 904         MANLEY,ARNDT,GORADIA,TEPLITZ            (VPI)
ARNDT    85 PR D32 1085        R A ARNDT, J M FORD, L D ROPER          (VPI)
```

Δ(1900) S_{31}

$I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$ Status: * * *

Δ(1900) MASS (MeV)

```
M         (1850.0)   (35.0)             CUTKOSKY  79 IPWA    PI N TO PI N
M          1908.0     30.0              HOEHLER   79 IPWA    PI N TO PI N
M         (1918.5)   (23.0)             CHEW      80 BPWA ++ PI+P TO PI+P
M         (1803.0)                      CRAWFORD  80 DPWA    PI N PHOTOPROD.
M          1890.0     50.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1900) WIDTH (MeV)

```
W          (130.0)   (40.0)             CUTKOSKY  79 IPWA    PI N TO PI N
W           140.0     40.0              HOEHLER   79 IPWA    PI N TO PI N
W           (93.5)   (54.0)             CHEW      80 BPWA ++ PI+P TO PI+P
W          (137.0)                      CRAWFORD  80 DPWA    PI N PHOTOPROD.
W           170.0     50.0              CUTKOSKY  80 IPWA    PI N TO.PI N
```

Δ(1900) REAL PART OF POLE POSITION (MeV)

```
RE         2029.0 OR 2025.0             LONGACRE  78 IPWA    PI N TO 2PI N    |
RE        (1844.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
RE         1870.0     40.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1900) −2*IMAG PART OF POLE POSITION (MeV)

```
IM          164.0 OR 163.0              LONGACRE  78 IPWA    PI N TO 2PI N    |
IM         (142.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
IM          180.0     50.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1900) REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER          (7.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
RER           9.0      4.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1900) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR         (-1.0)                      CUTKOSKY  79 IPWA    PI N TO PI N
IMR           3.0      7.0              CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1900) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(1900) → $N\pi$	938+ 140
P2	Δ(1900) → ΣK	1189+ 494
P3	Δ(1900) → $N\rho$, S=3/2, D-wave	938+ 769
P4	Δ(1900) → N(1440) π, S-wave	1440+ 140
P5	Δ(1900) → $N\gamma$, helicity=1/2	938+ 0

Δ(1900) BRANCHING RATIOS

Δ(1900) → ($N\pi$)/total (P1)

```
R1          (0.08)   (0.03)             CUTKOSKY  79 IPWA    PI N TO PI N
R1           0.08     0.04              HOEHLER   79 IPWA    PI N TO PI N
R1          (0.28)                      CHEW      80 BPWA ++ PI+P TO PI+P
R1           0.10     0.03              CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1900) in $N\pi \to \Sigma K$ SQRT(P1*P2)

```
R2          (0.11)                  LANGBEIN  73 IPWA    PI N-K SIG,SOL 1
R2          (0.12)                  LANGBEIN  73 IPWA    PI N-K SIG,SOL 2
R2  A       (0.076)                 DEANS     75 DPWA    PI N TO K SIGMA
R2  A   VALUE GIVEN IS FROM SOLUTION 1, NOT PRESENT IN SOLUTIONS 2,3,4.
```

Δ(1900) in $N\pi \to N\rho$, S=3/2, *D*-wave SQRT(P1*P3)

```
R3           (LARGE)                MANLEY    84 IPWA    PI N TO 2PI N
```

Δ(1900) in $N\pi \to N(1440)\ \pi$, *S*-wave SQRT(P1*P4)

```
R4          + (LARGE)               MANLEY    84 IPWA    PI N TO 2PI N
```

Δ(1900) PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Δ(1900) → $N\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1          -0.006 TO -0.025        CRAWFORD  80 DPWA    PI N PHOTOPROD.
A1           0.029    0.008         AWAJI     81 DPWA    PI N PHOTOPROD.
A1          -0.004    0.016         CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

REFERENCES FOR Δ(1900)

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
LANGBEIN 73 NP B53 251          LANGBEIN,WAGNER                      (MUNI)IJP
DEANS    75 NP B96 90           +MITCHELL,MONTGOMERY,+           (SFLA+ALAH)IJP
LONGACRE 78 PR D17 1795         +LASINSKI,ROSENFELD,SMADJA+      (LBL+SLAC)
CUTKOSKY 79 PR D20 2839         +FORSYTH,HENDRICK,KELLY          (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                                +KAISER,KOCH,PIETARINEN              (KARL)IJP
    ALSO 80  TORONTO CONF 3     R KOCH                               (KARL)IJP
CHEW     80  TORONTO CONF 123   D M CHEW                              (LBL)IJP
CRAWFORD 80  TORONTO CONF 107   R L CRAWFORD                         (GLAS)
CUTKOSKY 80  TORONTO CONF 19    +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
AWAJI    81  BONN CONF 352      R KAJIKAWA (TALK)                    (NAGO)
    ALSO 82 NP B197 365         FUJII,HAYASHII,IWATA,KAJIKAWA+       (NAGO)
CRAWFORD 83 NP B211 1           R L CRAWFORD, W T MORTON             (GLAS)
MANLEY   84 PR D30 904          MANLEY,ARNDT,GORADIA,TEPLITZ          (VPI)
```

Δ(1905) F_{35}

$I(J^P) = \frac{3}{2}(\frac{5}{2}^-)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

CUTKOSKY 80 ALSO FINDS WEAK EVIDENCE FOR A HIGHER MASS F35 RESONANCE IN ADDITION TO THIS STATE. BOTH RESONANCES ARE LISTED HERE FOR NOW.

Δ(1905) MASS (MeV)

```
M   A     1870. OR 1830.            LONGACRE  75 IPWA    PI N TO 2PI N
M   A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M        (1892.0)                   BARBOUR   78 DPWA    PI-N PHOTOPROD.
M        (1920.0)   (30.0)          CUTKOSKY  79 IPWA    PI N TO PI N
M         1905.0     20.0           HOEHLER   79 IPWA    PI N TO PI N
M        (1787.0)    (6.0)   (5.7)  CHEW      80 BPWA ++ PI+P TO PI+P
M        (1880.0)                   CRAWFORD  80 DPWA    PI N PHOTOPROD.
M   B     1910.0     30.0           CUTKOSKY  80 IPWA    PI N TO PI N
M   C     2200.0    125.0           CUTKOSKY  80 IPWA    PI N TO PI N
M   BC CUTKOSKY 80 FINDS A HIGHER MASS F35 RESONANCE AS WELL AS THE ONE IN
M   BC THIS MASS REGION.  THEY ARE LISTED HERE AS B AND C.
```

Δ(1905) WIDTH (MeV)

```
W   A      255. OR  220.            LONGACRE  75 IPWA    PI N TO 2PI N
W         (159.0)                   BARBOUR   78 DPWA    PI-N PHOTOPROD.
W         (340.0)   (80.0)          CUTKOSKY  79 IPWA    PI N TO PI N
W          260.0     20.0           HOEHLER   79 IPWA    PI N TO PI N
W          (66.0)   (24.0)  (16.0)  CHEW      80 BPWA ++ PI+P TO PI+P
W         (193.0)                   CRAWFORD  80 DPWA    PI N PHOTOPROD.
W   B      400.0    100.0           CUTKOSKY  80 IPWA    PI N TO PI N
W   C      400.0    125.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1905) REAL PART OF POLE POSITION (MeV)

```
RE        1813.0 OR 1808.0          LONGACRE  78 IPWA    PI N TO 2PI N
RE       (1865.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
RE  B     1830.0     40.0           CUTKOSKY  80 IPWA    PI N TO PI N
RE  C     2150.0    100.0           CUTKOSKY  80 IPWA    PI N TO PI N
RE       (1830.)                    ARNDT     85 DPWA    PI N TO PI N
```

Δ(1905) −2*IMAG PART OF POLE POSITION (MeV)

```
IM         193.0 OR 187.0           LONGACRE  78 IPWA    PI N TO 2PI N
IM        (266.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
IM  B      280.0     60.0           CUTKOSKY  80 IPWA    PI N TO PI N
IM  C      350.0    100.0           CUTKOSKY  80 IPWA    PI N TO PI N
IM        (180.)                    ARNDT     85 DPWA    PI N TO PI N
```

Δ(1905) REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER        (20.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
RER  B      16.0      8.0           CUTKOSKY  80 IPWA    PI N TO PI N
RER  C     -14.0     13.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1905) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR        (-5.0)                   CUTKOSKY  79 IPWA    PI N TO PI N
IMR  B     -19.0      8.0           CUTKOSKY  80 IPWA    PI N TO PI N
IMR  C       8.0     22.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1905) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(1905) → $N\pi$	938+ 140
P2	Δ(1905) → ΣK	1189+ 494
P3	Δ(1905) → $N\pi\pi$	938+ 140+ 140
P4	Δ(1905) → Δ(1232) π, *P*-wave	1232+ 140
P5	Δ(1905) → Δ(1232) π, *F*-wave	1232+ 140
P6	Δ(1905) → $N\rho$, S=1/2, *F*-wave	938+ 769
P7	Δ(1905) → $N\rho$, S=3/2, *P*-wave	938+ 769
P8	Δ(1905) → $N\rho$, S=3/2, *F*-wave	938+ 769
P9	Δ(1905) → $N\gamma$, helicity=1/2	938+ 0
P10	Δ(1905) → $N\gamma$, helicity=3/2	938+ 0

Δ(1905) BRANCHING RATIOS

Δ(1905) → $(N\pi)$/total (P1)

```
R1          (0.15)    (0.02)        CUTKOSKY  79 IPWA    PI N TO PI N
R1           0.15      0.02         HOEHLER   79 IPWA    PI N TO PI N
R1          (0.11)                  CHEW      80 BPWA ++ PI+P TO PI+P
R1   B       0.08      0.03         CUTKOSKY  80 IPWA    PI N TO PI N
R1   C       0.07      0.04         CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1905) in $N\pi \to \Sigma K$ SQRT(P1*P2)

```
R2  D        0.021 TO 0.054         DEANS     75 DPWA    PI N TO K SIGMA
R2  D   RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.
R2          (-0.013)                LIVANOS   80 DPWA    PI P TO K SIGMA

R       NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R              IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R              THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R              SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

Δ(1905) in $N\pi \to$ Δ(1232) π, *P*-wave SQRT(P1*P4)

```
R3           + (SMALL)              MANLEY    84 IPWA    PI N TO 2PI N
```

Δ(1905) in $N\pi \to$ Δ(1232) π, *F*-wave SQRT(P1*P5)

```
R4   A       +0.12 OR +0.20         LONGACRE  75 IPWA    PI N TO 2PI N
R4   E      (+0.17)                 NOVOSELLE 78 IPWA    PI N TO 2PI N
R4   E  BW FIT TO LONGACRE 75 IPWA.
R4   F      (+0.06)                 NOVOSELLE 78 IPWA    PI N TO 2PI N
R4   F  BW FIT TO NOVOSELLER 78 IPWA.
R4   G      (+)                     MANLEY    84 IPWA    PI N TO 2PI N
R4   G  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
R4   G  MANLEY 84 SUGGEST THAT THE LARGE N RHO DECAY SEEN IN PREVIOUS
R4   G  ANALYSES IS PREDOMINANTLY FROM A HIGHER MASS F35 RESONANCE.
R4   G  SEE LISTINGS FOR DELTA(2000) F35.
```

Δ(1905) in $N\pi \to N\rho$, S=3/2, *P*-wave SQRT(P1*P7)

```
R5   A       +0.28 OR +0.33         LONGACRE  75 IPWA    PI N TO 2PI N
R5   E      (+0.26)                 NOVOSELLE 78 IPWA    PI N TO 2PI N
R5   H       +0.11 TO +0.33         NOVOSELLE 78 IPWA    PI N TO 2PI N
R5   H  BW FIT TO NOVOSELLER 78 IPWA, PHASE IS NEAR 90 DEGREES.
```

Δ(1905) PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Δ(1905) → $N\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1          -0.001    0.012         AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A1          +0.063    0.018         AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A1          +0.033    0.018         BARBOUR   78 DPWA    PI-N PHOTOPROD.
A1           0.022    0.010         ARAI      80 DPWA    PI N PHOTO FIT 1
A1           0.031    0.009         ARAI      80 DPWA    PI N PHOTO FIT 2
A1           0.024    0.014         CRAWFORD  80 DPWA    PI N PHOTOPROD.
A1           0.043    0.020         AWAJI     81 DPWA    PI N PHOTOPROD.
A1           0.021    0.010         CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

Δ(1905) → $N\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A2          -0.094    0.027         AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A2          -0.101    0.018         AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A2          -0.055    0.019         BARBOUR   78 DPWA    PI-N PHOTOPROD.
A2          -0.029    0.007         ARAI      80 DPWA    PI N PHOTO FIT 1
A2          -0.045    0.006         ARAI      80 DPWA    PI N PHOTO FIT 2
A2          -0.072    0.035         CRAWFORD  80 DPWA    PI N PHOTOPROD.
A2          -0.025    0.023         AWAJI     81 DPWA    PI N PHOTOPROD.
A2          -0.056    0.028         CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

REFERENCES FOR Δ(1905)

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS    75 NP B96 90           +MITCHELL,MONTGOMERY,+           (SFLA+ALAH)IJP
LONGACRE 75 PL 55B 415          +ROSENFELD,LASINSKI,SMADJA+       (LBL+SLAC)IJP
AZNAURYA 77  EFI-264(57)-77     +AKOPOV,BAGDASARYAN                   (YERE)IJP
```

```
BARBOUR  78 NP B141 253        BARBOUR,CRAWFORD,PARSONS              (GLAS)
LONGACRE 78 PR D17 1795        +LASINSKI,ROSENFELD,SMADJA+       (LBL+SLAC)
NOVOSELL 78 NP B137 509        D E NOVOSELLER                       (CIT)IJP
   ALSO  78 NP B137 445        D E NOVOSELLER                       (CIT)IJP
CUTKOSKY 79 PR D20 2839        +FORSYTH,HENDRICK,KELLY          (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                               +KAISER,KOCH,PIETARINEN              (KARL)IJP
   ALSO  80  TORONTO CONF 3    R KOCH                               (KARL)IJP
ARAI     80  TORONTO CONF 93   I ARAI                               (TOKY)
   ALSO  82 NP B194 251        I ARAI, H FUJII                      (TOKY)
CHEW     80  TORONTO CONF 123  D M CHEW                              (LBL)IJP
CRAWFORD 80  TORONTO CONF 107  R L CRAWFORD                         (GLAS)
CUTKOSKY 80  TORONTO CONF 19   +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
LIVANOS  80  TORONTO CONF 35   +BATON,COUTURES,KOCHOWSKI,NEVEU      (SACL)IJP
AWAJI    81  BONN CONF 352     R KAJIKAWA (TALK)                    (NAGO)
   ALSO  82 NP B197 365        FUJII,HAYASHII,IWATA,KAJIKAWA+       (NAGO)
CRAWFORD 83 NP B211 1          R L CRAWFORD, W T MORTON             (GLAS)
MANLEY   84 PR D30 904         MANLEY,ARNDT,GORADIA,TEPLITZ          (VPI)
   ALSO  84 PRL 52 2122        MANLEY                                (VPI)
ARNDT    85 PR D32 1085        R A ARNDT, J M FORD, L D ROPER        (VPI)
```

$\Delta(1910)$ P_{31}

$I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

$\Delta(1910)$ MASS (MeV)

```
M   A     (1790.0)                          LONGACRE  77 IPWA    PI N TO 2PI N
M   A   ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE
M   A   POSITION WHICH IS FROM SOLUTIONS S1 AND C1.
M         (1899.0)                          BARBOUR   78 DPWA    PI-N PHOTOPROD.
M         (1920.0)   (50.0)                 CUTKOSKY  79 IPWA    PI N TO PI N
M          1888.0     20.0                  HOEHLER   79 IPWA    PI N TO PI N
M   B     (1715.2)   (21.0)                 CHEW      80 BPWA ++ PI+P TO PI+P
M   C     (1778.4)    (9.0)                 CHEW      80 BPWA ++ PI+P TO PI+P
M   D     (1960.1)   (21.0)                 CHEW      80 BPWA ++ PI+P TO PI+P
M   E     (2121.4)   (13.0)   (14.3)        CHEW      80 BPWA ++ PI+P TO PI+P
M  BC   CHEW 80 REPORTS FOUR RESONANCES IN THE P31 WAVE.  ALL ARE LISTED
M  DE   HERE LABELED B-E.  PROBLEMS WITH THIS ANALYSIS ARE DISCUSSED IN
M  DE   SEC.2.1.11 OF HOEHLER 83.
M         (1921.0)                          CRAWFORD  80 DPWA    PI N PHOTOPROD.
M          1910.0     40.0                  CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1910)$ WIDTH (MeV)

```
W   A      (170.0)                          LONGACRE  77 IPWA    PI N TO 2PI N
W          (230.0)                          BARBOUR   78 DPWA    PI-N PHOTOPROD.
W          (300.0)  (100.0)                 CUTKOSKY  79 IPWA    PI N TO PI N
W           280.0     50.0                  HOEHLER   79 IPWA    PI N TO PI N
W   B       (93.3)   (55.0)                 CHEW      80 BPWA ++ PI+P TO PI+P
W   C       (23.0)   (29.0)                 CHEW      80 BPWA ++ PI+P TO PI+P
W   D      (152.9)   (60.0)                 CHEW      80 BPWA ++ PI+P TO PI+P
W   E      (172.2)   (37.0)                 CHEW      80 BPWA ++ PI+P TO PI+P
W          (351.0)                          CRAWFORD  80 DPWA    PI N PHOTOPROD.
W           225.0     50.0                  CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1910)$ REAL PART OF POLE POSITION (MeV)

```
RE  A      1792.0 OR 1801.0                 LONGACRE  77 IPWA    PI N TO 2PI N
RE        (1871.0)                          CUTKOSKY  79 IPWA    PI N TO PI N
RE         1880.0     30.0                  CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1910)$ -2*IMAG PART OF POLE POSITION (MeV)

```
IM  A       172.0 OR 165.0                  LONGACRE  77 IPWA    PI N TO 2PI N
IM         (200.0)                          CUTKOSKY  79 IPWA    PI N TO PI N
IM          200.0     40.0                  CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1910)$ REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER         (-0.6)                          CUTKOSKY  79 IPWA    PI N TO PI N
RER          0.0      10.0                  CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1910)$ IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR        (-18.0)                          CUTKOSKY  79 IPWA    PI N TO PI N
IMR         -20.0      4.0                  CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1910)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Delta(1910) \to N\pi$	938+ 140
P2	$\Delta(1910) \to \Sigma K$	1189+ 494
P3	$\Delta(1910) \to N\pi\pi$	938+ 140+ 140
P4	$\Delta(1910) \to \Delta(1232)\ \pi$, P-wave	1232+ 140
P5	$\Delta(1910) \to N\rho$, S=3/2, P-wave	938+ 769
P6	$\Delta(1910) \to N(1440)\ \pi$, P-wave	1440+ 140
P7	$\Delta(1910) \to N\gamma$, helicity=1/2	938+ 0

$\Delta(1910)$ BRANCHING RATIOS

$\Delta(1910) \to (N\pi)$/total (P1)

```
R1          (0.19)   (0.04)          CUTKOSKY  79 IPWA    PI N TO PI N
R1           0.24     0.06           HOEHLER   79 IPWA    PI N TO PI N
R1 *B       (0.18)                   CHEW      80 BPWA ++ PI+P TO PI+P
R1 *C       (0.20)                   CHEW      80 BPWA ++ PI+P TO PI+P
R1 *D       (0.17)                   CHEW      80 BPWA ++ PI+P TO PI+P
R1 *E       (0.40)                   CHEW      80 BPWA ++ PI+P TO PI+P
R1           0.19     0.03           CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1910)$ in $N\pi \to \Sigma K$ SQRT(P1*P2)

```
R2  F        0.082 TO 0.184          DEANS     75 DPWA    PI N TO K SIGMA
R2  F   RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.
R2         (-0.019)                  LIVANOS   80 DPWA    PI P TO K SIGMA

R       NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
               IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
               THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
               SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

$\Delta(1910)$ in $N\pi \to \Delta(1232)\ \pi$, P-wave SQRT(P1*P4)

```
R3  A      (+0.06)                   LONGACRE  77 IPWA    PI N TO 2PI N
```

$\Delta(1910)$ in $N\pi \to N\rho$, S=3/2, P-wave SQRT(P1*P5)

```
R4  A      (+0.29)                   LONGACRE  77 IPWA    PI N TO 2PI N
R4   G     (+0.17)                   NOVOSELLE 78 IPWA    PI N TO 2PI N
R4   G  EVIDENCE FOR THIS COUPLING IS WEAK, SEE NOVOSELLER 78. THIS
R4   G  COUPLING ASSUMES THE MASS IS NEAR 1820 MEV.
```

$\Delta(1910)$ in $N\pi \to N(1440)\ \pi$, P-wave SQRT(P1*P6)

```
R5   H        + (LARGE)              MANLEY    84 IPWA    PI N TO 2PI N
R5   H  MANLEY 84 FINDS THIS DECAY MODE ACCOUNTS FOR ALL THE INELASTICITY.
```

$\Delta(1910)$ PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

$\Delta(1910) \to N\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1               +0.040    0.013          AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 1
A1               +0.039    0.012          AZNAURYAN 77 DPWA    PI0 PHTPRD,SOL 2
A1               -0.035    0.021          BARBOUR   78 DPWA    PI-N PHOTOPROD.
A1               -0.012    0.005          ARAI      80 DPWA    PI N PHOTO FIT 1
A1               -0.031    0.004          ARAI      80 DPWA    PI N PHOTO FIT 2
A1               -0.005    0.030          CRAWFORD  80 DPWA    PI N PHOTOPROD.
A1                0.025    0.011          AWAJI     81 DPWA    PI N PHOTOPROD.
A1                0.014    0.030          CRAWFORD  83 IPWA    PI N PHOTOPROD.
```

REFERENCES FOR $\Delta(1910)$

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS    75 NP B96 90          +MITCHELL,MONTGOMERY,+           (SFLA+ALAH)IJP
AZNAURYA 77  EFI-264(57)-77    +AKOPOV,BAGDASARYAN                  (YERE)IJP
LONGACRE 77 NP B122 493        LONGACRE,DOLBEAU                     (SACL)IJP
   ALSO  76 NP B108 365        DOLBEAU,TRIANTIS,NEVEU,CADIET        (SACL)IJP
BARBOUR  78 NP B141 253        BARBOUR,CRAWFORD,PARSONS             (GLAS)
NOVOSELL 78 NP B137 509        D E NOVOSELLER                        (CIT)IJP
   ALSO  78 NP B137 445        D E NOVOSELLER                        (CIT)IJP
CUTKOSKY 79 PR D20 2839        +FORSYTH,HENDRICK,KELLY          (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                               +KAISER,KOCH,PIETARINEN              (KARL)IJP
   ALSO  80  TORONTO CONF 3    R KOCH                               (KARL)IJP
ARAI     80  TORONTO CONF 93   I ARAI                               (TOKY)
   ALSO  82 NP B194 251        I ARAI, H FUJII                      (TOKY)
CHEW     80  TORONTO CONF 123  D M CHEW                              (LBL)IJP
CRAWFORD 80  TORONTO CONF 107  R L CRAWFORD                         (GLAS)
CUTKOSKY 80  TORONTO CONF 19   +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
LIVANOS  80  TORONTO CONF 35   +BATON,COUTURES,KOCHOWSKI,NEVEU      (SACL)IJP
AWAJI    81  BONN CONF 352     R KAJIKAWA (TALK)                    (NAGO)
   ALSO  82 NP B197 365        FUJII,HAYASHII,IWATA,KAJIKAWA+       (NAGO)
CRAWFORD 83 NP B211 1          R L CRAWFORD, W T MORTON             (GLAS)
HOEHLER  83 LANDOLT-BORNSTEIN VOL I-9B2      G HOEHLER              (KARL)
MANLEY   84 PR D30 904         MANLEY,ARNDT,GORADIA,TEPLITZ          (VPI)
```

$\Delta(1920)$ P_{33}

$I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$. Status: * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

$\Delta(1920)$ MASS (MeV)

```
M         (1960.0)   (80.0)              CUTKOSKY  79 IPWA    PI N TO PI N
M          1868.0     10.0               HOEHLER   79 IPWA    PI N TO PI N
M   A     (1955.0)   (13.0)              CHEW      80 BPWA ++ PI+P TO PI+P
M   B     (2065.0)   (13.6)   (12.9)     CHEW      80 BPWA ++ PI+P TO PI+P
M   AB  CHEW 80 REPORTS TWO P33 RESONANCES IN THIS MASS REGION.  BOTH ARE
M   AB  LISTED HERE, LABELED A AND B.  PROBLEMS WITH THIS ANALYSIS ARE
M   AB  DISCUSSED IN SEC.2.1.11 OF HOEHLER 83.
M          1920.0     80.0               CUTKOSKY  80 IPWA    PI N TO PI N
```

$\Delta(1920)$ WIDTH (MeV)

```
W          (300.0)  (100.0)              CUTKOSKY  79 IPWA    PI N TO PI N
W           220.0     80.0               HOEHLER   79 IPWA    PI N TO PI N
W   A       (88.3)   (35.0)              CHEW      80 BPWA ++ PI+P TO PI+P
W   B       (62.0)   (44.0)              CHEW      80 BPWA ++ PI+P TO PI+P
W           300.0    100.0               CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(1920) REAL PART OF POLE POSITION (MeV)

```
RE        (1933.0)                        CUTKOSKY  79 IPWA     PI N TO PI N
RE         1900.0    80.0                 CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1920) −2*IMAG PART OF POLE POSITION (MeV)

```
IM        (280.0)                         CUTKOSKY  79 IPWA     PI N TO PI N
IM         300.0    100.0                 CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1920) REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER       (-10.0)                         CUTKOSKY  79 IPWA     PI N TO PI N
RER        -21.0      7.0                 CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1920) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR       (-27.0)                         CUTKOSKY  79 IPWA     PI N TO PI N
IMR        -12.0     11.0                 CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1920) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(1920) → $N\pi$	938+ 140
P2	Δ(1920) → ΣK	1189+ 494
P3	Δ(1920) → Δ(1232) π, P-wave	1232+ 140
P4	Δ(1920) → N(1440) π, P-wave	1440+ 140
P5	Δ(1920) → $N\gamma$, helicity=1/2	938+ 0
P6	Δ(1920) → $N\gamma$, helicity=3/2	938+ 0

Δ(1920) BRANCHING RATIOS

Δ(1920) → ($N\pi$)/total (P1)

```
R1          (0.17)    (0.04)              CUTKOSKY  79 IPWA     PI N TO PI N
R1           0.14      0.04               HOEHLER   79 IPWA     PI N TO PI N
R1   A      (0.24)                        CHEW      80 BPWA  ++ PI+P TO PI+P
R1   B      (0.18)                        CHEW      80 BPWA  ++ PI+P TO PI+P
R1           0.20      0.05               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1920) in $N\pi$ → ΣK SQRT(P1*P2)

```
R2   C       0.048 TO 0.120               DEANS     75 DPWA     PI N TO K SIGMA
R2   C   RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.
R2          (-0.049)                      LIVANOS   80 DPWA     PI P TO K SIGMA
```

Δ(1920) in $N\pi$ → Δ(1232) π, P-wave SQRT(P1*P3)

```
R3          (+)                           MANLEY    84 IPWA     PI N TO 2PI N    |
```

Δ(1920) in $N\pi$ → N(1440) π, P-wave SQRT(P1*P4)

```
R4          (+)                           MANLEY    84 IPWA     PI N TO 2PI N    |
```

Δ(1920) PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Δ(1920) → $N\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1           0.040     0.014              AWAJI     81 DPWA     PI N PHOTOPROD.
```

Δ(1920) → $N\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A2           0.023     0.017              AWAJI     81 DPWA     PI N PHOTOPROD.
```

REFERENCES FOR Δ(1920)

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS    75 NP B96 90           +MITCHELL,MONTGOMERY,+             (SFLA+ALAH)IJP
CUTKOSKY 79 PR D20 2839         +FORSYTH,HENDRICK,KELLY             (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                                +KAISER,KOCH,PIETARINEN                 (KARL)IJP
    ALSO 80  TORONTO CONF 3     R KOCH                                  (KARL)IJP
CHEW     80  TORONTO CONF 123   D M CHEW                                 (LBL)IJP
CUTKOSKY 80  TORONTO CONF 19    +FORSYTH,BABCOCK,KELLY,HENDRICK     (CARN+LBL)IJP
LIVANOS  80  TORONTO CONF 35    +BATON,COUTURES,KOCHOWSKI,NEVEU         (SACL)IJP
AWAJI    81  BONN CONF 352      R KAJIKAWA (TALK)                       (NAGO)
    ALSO 82 NP B197 365         FUJII,HAYASHII,IWATA,KAJIKAWA+          (NAGO)
HOEHLER  83 LANDOLT-BORNSTEIN VOL I-9B2     G HOEHLER                   (KARL)
MANLEY   84 PR D30 904          MANLEY,ARNDT,GORADIA,TEPLITZ             (VPI)
```

Δ(1930) D_{35}

$I(J^P) = \frac{3}{2}(\frac{5}{2}^-)$ Status: * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

THE AGREEMENT AMONG THE VARIOUS ANALYSES IS NOT VERY GOOD.

Δ(1930) MASS (MeV)

```
M         (2024.0)                        BARBOUR   78 DPWA     PI-N PHOTOPROD.
M         (1930.0)    (20.0)              CUTKOSKY  79 IPWA     PI N TO PI N
M          1901.0      15.0               HOEHLER   79 IPWA     PI N TO PI N
M         (1910.0)    (15.0)    (17.2)    CHEW      80 BPWA  ++ PI+P TO PI+P
M         (2000.0)                        CRAWFORD  80 DPWA     PI N PHOTOPROD.
M          1940.0      30.0               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1930) WIDTH (MeV)

```
W          (462.0)                        BARBOUR   78 DPWA     PI-N PHOTOPROD.
W          (280.0)    (90.0)              CUTKOSKY  79 IPWA     PI N TO PI N
W           195.0      60.0               HOEHLER   79 IPWA     PI N TO PI N
W           (74.8)    (17.0)    (16.0)    CHEW      80 BPWA  ++ PI+P TO PI+P
W          (442.0)                        CRAWFORD  80 DPWA     PI N PHOTOPROD.
W           320.0      60.0               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1930) REAL PART OF POLE POSITION (MeV)

```
RE        (1908.0)                        CUTKOSKY  79 IPWA     PI N TO PI N
RE         1890.0      50.0               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1930) −2*IMAG PART OF POLE POSITION (MeV)

```
IM         (226.0)                        CUTKOSKY  79 IPWA     PI N TO PI N
IM          260.0      60.0               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1930) REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER         (13.0)                        CUTKOSKY  79 IPWA     PI N TO PI N
RER          17.0       7.0               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1930) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR          (2.0)                        CUTKOSKY  79 IPWA     PI N TO PI N
IMR          -6.0      12.0               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1930) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(1930) → $N\pi$	938+ 140
P2	Δ(1930) → ΣK	1189+ 494
P3	Δ(1930) → $N\pi\pi$	938+ 140+ 140
P4	Δ(1930) → $N\gamma$, helicity=1/2	938+ 0
P5	Δ(1930) → $N\gamma$, helicity=3/2	938+ 0

Δ(1930) BRANCHING RATIOS

Δ(1930) → ($N\pi$)/total (P1)

```
R1          (0.12)    (0.03)              CUTKOSKY  79 IPWA     PI N TO PI N
R1           0.04      0.03               HOEHLER   79 IPWA     PI N TO PI N
R1          (0.11)                        CHEW      80 BPWA  ++ PI+P TO PI+P
R1           0.14      0.04               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1930) in $N\pi$ → ΣK SQRT(P1*P2)

```
R2   A       0.018 TO 0.035               DEANS     75 DPWA     PI N TO K SIGMA
R2   A   RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.
R2          (-0.031)                      LIVANOS   80 DPWA     PI P TO K SIGMA
```

Δ(1930) in $N\pi$ → $N\pi\pi$ SQRT(P1*P3)

```
R3        NOT SEEN                        LONGACRE  75 IPWA     PI N TO 2PI N    |
R3        NOT SEEN                        MANLEY    84 IPWA     PI N TO 2PI N    |
```

Δ(1930) PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Δ(1930) → $N\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1          -0.062     0.064              BARBOUR   78 DPWA     PI-N PHOTOPROD.
A1          -0.038     0.047              CRAWFORD  80 DPWA     PI N PHOTOPROD.
A1           0.009     0.009              AWAJI     81 DPWA     PI N PHOTOPROD.
```

Δ(1930) → $N\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A2          +0.019     0.054              BARBOUR   78 DPWA     PI-N PHOTOPROD.
A2          -0.023     0.080              CRAWFORD  80 DPWA     PI N PHOTOPROD.
A2          -0.025     0.011              AWAJI     81 DPWA     PI N PHOTOPROD.
```

REFERENCES FOR Δ(1930)

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS    75 NP B96 90           +MITCHELL,MONTGOMERY,+          (SFLA+ALAH)IJP
LONGACRE 75 PL 55B 415          +ROSENFELD,LASINSKI,SMADJA+      (LBL+SLAC)IJP
BARBOUR  78 NP B141 253         BARBOUR,CRAWFORD,PARSONS            (GLAS)
CUTKOSKY 79 PR D20 2839         +FORSYTH,HENDRICK,KELLY          (CARN+LBL)IJP
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                                +KAISER,KOCH,PIETARINEN             (KARL)IJP
    ALSO 80  TORONTO CONF 3     R KOCH                              (KARL)IJP
CHEW     80  TORONTO CONF 123 D M CHEW                               (LBL)IJP
CRAWFORD 80  TORONTO CONF 107 R L CRAWFORD                          (GLAS)
CUTKOSKY 80  TORONTO CONF 19  +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
LIVANOS  80  TORONTO CONF 35  +BATON,COUTURES,KOCHOWSKI,NEVEU      (SACL)IJP
AWAJI    81  BONN CONF 352    R KAJIKAWA (TALK)                     (NAGO)
    ALSO 82 NP B197 365         FUJII,HAYASHII,IWATA,KAJIKAWA+      (NAGO)
CRAWFORD 83 NP B211 1           R L CRAWFORD, W T MORTON            (GLAS)
MANLEY   84 PR D30 904          MANLEY,ARNDT,GORADIA,TEPLITZ         (VPI)
```

Δ(1940) D_{33}

$I(J^P)=\frac{3}{2}(\frac{3}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

Δ(1940) MASS (MeV)

```
M          1940.0     100.0              CUTKOSKY  80 IPWA     PI N TO PI N
M         (2058.1)    (34.5)             CHEW      80 BPWA ++ PI+P TO PI+P
```

Δ(1940) WIDTH (MeV)

```
W          200.0      100.0              CUTKOSKY  80 IPWA     PI N TO PI N
W         (198.4)     (45.5)             CHEW      80 BPWA ++ PI+P TO PI+P
```

Δ(1940) REAL PART OF POLE POSITION (MeV)

```
RE         1900.0     100.0              CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1940) −2*IMAG PART OF POLE POSITION (MeV)

```
IM         200.0      60.0               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1940) REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER         -6.0       5.0               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1940) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR          6.0       5.0               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1940) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(1940) → $N\pi$	938+ 140
P2	Δ(1940) → $N\gamma$, helicity=1/2	938+ 0
P3	Δ(1940) → $N\gamma$, helicity=3/2	938+ 0

Δ(1940) BRANCHING RATIOS

Δ(1940) → ($N\pi$)/total (P1)

```
R1          0.05      0.02               CUTKOSKY  80 IPWA     PI N TO PI N
R1         (0.18)                        CHEW      80 BPWA ++ PI+P TO PI+P
```

Δ(1940) PHOTON DECAY AMPLITUDES ($GeV^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Δ(1940) → $N\gamma$, helicity=1/2 ($GeV^{-1/2}$)

```
A1         -0.036     0.058              AWAJI     81 DPWA     PI N PHOTOPROD.
```

Δ(1940) → $N\gamma$, helicity=3/2 ($GeV^{-1/2}$)

```
A2         -0.031     0.012              AWAJI     81 DPWA     PI N PHOTOPROD.
```

REFERENCES FOR Δ(1940)

```
CHEW     80  TORONTO CONF 123 D M CHEW                               (LBL)IJP
CUTKOSKY 80  TORONTO CONF 19  +FORSYTH,BABCOCK,KELLY,HENDRICK  (CARN+LBL)IJP
AWAJI    81  BONN CONF 352    R KAJIKAWA (TALK)                     (NAGO)
   ·ALSO 82 NP B197 365       FUJII,HAYASHII,IWATA,KAJIKAWA+        (NAGO)
```

Δ(1950) F_{37}

$I(J^P)=\frac{3}{2}(\frac{7}{2}^-)$ Status: ****

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

IN ADDITION, RESULTS IN THIS REGION FROM PRODUCTION EXPERIMENTS, WHICH USED TO BE LISTED SEPARATELY AS THE NEXT ENTRY, HAVE BEEN ENTIRELY REMOVED. THEY TOO MAY BE FOUND IN OUR 1982 EDITION.

Δ(1950) MASS (MeV)

```
M     A      1930. OR 1925.              LONGACRE  75 IPWA     PI N TO 2PI N
M     A  THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.
M          (1912.0)                      BARBOUR   78 DPWA     PI-N PHOTOPROD.
M          (1950.0)   (20.0)             CUTKOSKY  79 IPWA     PI N TO PI N
M           1913.0      8.0              HOEHLER   79 IPWA     PI N TO PI N
M          (1855.0)   (11.0)    (10.0)   CHEW      80 BPWA ++ PI+P TO PI+P
M          (1902.0)                      CRAWFORD  80 DPWA     PI N PHOTOPROD.
M           1950.0     15.0              CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1950) WIDTH (MeV)

```
W     A      235. OR  240.               LONGACRE  75 IPWA     PI N TO 2PI N
W            (198.0)                     BARBOUR   78 DPWA     PI-N PHOTOPROD.
W            (340.0)  (60.0)             CUTKOSKY  79 IPWA     PI N TO PI N
W             224.0    10.0              HOEHLER   79 IPWA     PI N TO PI N
W            (157.2)  (22.0)    (19.0)   CHEW      80 BPWA ++ PI+P TO PI+P
W            (225.0)                     CRAWFORD  80 DPWA     PI N PHOTOPROD.
W             340.0    50.0              CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1950) REAL PART OF POLE POSITION (MeV)

```
RE          1924.0 OR 1924.0             LONGACRE  78 IPWA     PI N TO 2PI N
RE         (1892.0)                      CUTKOSKY  79 IPWA     PI N TO PI N
RE          1890.0     15.0              CUTKOSKY  80 IPWA     PI N TO PI N
RE         (1858.)                       ARNDT     85 DPWA     PI N TO PI N
```

Δ(1950) −2*IMAG PART OF POLE POSITION (MeV)

```
IM          258.0 OR 258.0               LONGACRE  78 IPWA     PI N TO 2PI N
IM         (248.0)                       CUTKOSKY  79 IPWA     PI N TO PI N
IM          260.0      40.0              CUTKOSKY  80 IPWA     PI N TO PI N
IM         (238.)                        ARNDT     85 DPWA     PI N TO PI N
```

Δ(1950) REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER         (43.0)                       CUTKOSKY  79 IPWA     PI N TO PI N
RER          42.0       7.0              CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1950) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR         (-24.0)                      CUTKOSKY  79 IPWA     PI N TO PI N
IMR          -27.0      7.0              CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1950) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(1950) → $N\pi$	938+ 140
P2	Δ(1950) → ΣK	1189+ 494
P3	Δ(1950) → Δ(1232) π, F-wave	1232+ 140
P4	Δ(1950) → Δ(1232) π, H-wave	1232+ 140
P5	Δ(1950) → $N\rho$, S=1/2, F-wave	938+ 769
P6	Δ(1950) → $N\rho$, S=3/2, F-wave	938+ 769
P7	Δ(1950) → N(1680) π, P-wave	1680+ 140
P8	Δ(1950) → $N\gamma$, helicity=1/2	938+ 0
P9	Δ(1950) → $N\gamma$, helicity=3/2	938+ 0

Δ(1950) BRANCHING RATIOS

Δ(1950) → ($N\pi$)/total (P1)

```
R1         (0.40)    (0.02)              CUTKOSKY  79 IPWA     PI N TO PI N
R1          0.38      0.02               HOEHLER   79 IPWA     PI N TO PI N
R1         (0.44)                        CHEW      80 BPWA ++ PI+P TO PI+P
R1          0.39      0.04               CUTKOSKY  80 IPWA     PI N TO PI N
```

Δ(1950) in $N\pi\rightarrow\Sigma K$ SQRT(P1*P2)

```
R2  B       0.022 TO 0.040               DEANS     75 DPWA     PI N TO K SIGMA
R2  B   RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.
R2  B   DEANS75 AND LANGBEIN73 DISAGREE WITH PI+ P TO K+ SIGMA+ DATA OF
R2  B   WINNIK77 AROUND 1920 MEV.
```

```
R        NOTE:  SIGNS OF COUPLINGS FROM PI N INTO N PI PI ANALYSES CHANGED
R               IN 1986 EDITION TO AGREE WITH BARYON-FIRST CONVENTION WITH
R               THE OVERALL PHASE AMBIGUITY RESOLVED BY CHOOSING A NEGATIVE
R               SIGN FOR DELTA(1620) S31 COUPLING TO DELTA(1232) PI.
```

Δ(1950) in $N\pi \rightarrow \Delta(1232)\ \pi$, *F*-wave SQRT(P1*P3)

```
R3   A        +0.25 OR +0.32           LONGACRE  75 IPWA    PI N TO 2PI N
R3   C        (0.21)                   NOVOSELLE 78 IPWA    PI N TO 2PI N
R3   C  BW FIT TO LONGACRE 75 IPWA, PHASE IS NEAR -60 DEGREES.
R3   D        (0.38)                   NOVOSELLE 78 IPWA    PI N TO 2PI N
R3   D  BW FIT TO NOVOSELLER 78 IPWA, PHASE IS NEAR -60 DEGREES.
R3            + (LARGE)                MANLEY    84 IPWA    PI N TO 2PI N
R3      MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
```

Δ(1950) in $N\pi \rightarrow N\rho$, S=3/2, *F*-wave SQRT(P1*P6)

```
R4   A         0.18 OR +0.24           LONGACRE  75 IPWA    PI N TO 2PI N
R4   E        (0.24)                   NOVOSELLE 78 IPWA    PI N TO 2PI N
R4   E  BW FIT TO LONGACRE 75 IPWA, PHASE IS NEAR 120 DEGREES.
R4   F        (0.43)                   NOVOSELLE 78 IPWA    PI N TO 2PI N
R4   F  BW FIT TO NOVOSELLER 78 IPWA, PHASE IS NEAR 120 DEGREES.
```

Δ(1950) in $N\pi \rightarrow N(1680)\ \pi$, *P*-wave SQRT(P1*P7)

```
R5           (+0.20)                   MANLEY    84 IPWA    PI N TO 2PI N
```

Δ(1950) PHOTON DECAY AMPLITUDES ($\mathrm{GeV}^{-1/2}$)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Δ(1950) → $N\gamma$, helicity=1/2 ($\mathrm{GeV}^{-1/2}$)

```
A1           -0.078     0.008           AZNAURYAN 77 DPWA    PIO PHTPRD,SOL 1
A1           -0.132     0.015           AZNAURYAN 77 DPWA    PIO PHTPRD,SOL 2
A1           -0.058     0.013           BARBOUR   78 DPWA    PI-N PHOTOPROD.
A1           -0.091     0.005           ARAI      80 DPWA    PI N PHOTO FIT 1
A1           -0.083     0.005           ARAI      80 DPWA    PI N PHOTO FIT 2
A1           -0.067     0.014           CRAWFORD  80 DPWA    PI N PHOTOPROD.
A1           -0.068     0.007           AWAJI     81 DPWA    PI N PHOTOPROD.
```

Δ(1950) → $N\gamma$, helicity=3/2 ($\mathrm{GeV}^{-1/2}$)

```
A2           -0.160     0.016           AZNAURYAN 77 DPWA    PIO PHTPRD,SOL 1
A2           -0.169     0.015           AZNAURYAN 77 DPWA    PIO PHTPRD,SOL 2
A2           -0.075     0.020           BARBOUR   78 DPWA    PI-N PHOTOPROD.
A2           -0.101     0.005           ARAI      80 DPWA    PI N PHOTO FIT 1
A2           -0.100     0.005           ARAI      80 DPWA    PI N PHOTO FIT 2
A2           -0.082     0.017           CRAWFORD  80 DPWA    PI N PHOTOPROD.
A2           -0.094     0.016           AWAJI     81 DPWA    PI N PHOTOPROD.
```

REFERENCES FOR Δ(1950)

FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

```
DEANS     75 NP B96 90         +MITCHELL,MONTGOMERY,+         (SFLA+ALAH)IJP
LONGACRE  75 PL 55B 415        +ROSENFELD,LASINSKI,SMADJA+     (LBL+SLAC)IJP
AZNAURYA  77  EFI-264(57)-77   +AKOPOV,BAGDASARYAN                 (YERE)IJP
WINNIK    77 NP B128 66        +TOAFF,REVEL,GOLDBERG,BERNY         (HAIF)I
BARBOUR   78 NP B141 253       BARBOUR,CRAWFORD,PARSONS            (GLAS)
LONGACRE  78 PR D17 1795       +LASINSKI,ROSENFELD,SMADJA+     (LBL+SLAC)
NOVOSELL  78 NP B137 509       D E NOVOSELLER                       (CIT)IJP
    ALSO  78 NP B137 445       D E NOVOSELLER                       (CIT)IJP
CUTKOSKY  79 PR D20 2839       +FORSYTH,HENDRICK,KELLY         (CARN+LBL)IJP
HOEHLER   79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                               +KAISER,KOCH,PIETARINEN             (KARL)IJP
    ALSO  80  TORONTO CONF 3   R KOCH                              (KARL)IJP
ARAI      80  TORONTO CONF 93  I ARAI                              (TOKY)
    ALSO  82 NP B194 251       I ARAI, H FUJII                     (TOKY)
CHEW      80  TORONTO CONF 123 D M CHEW                             (LBL)IJP
CRAWFORD  80  TORONTO CONF 107 R L CRAWFORD                        (GLAS)
CUTKOSKY  80  TORONTO CONF 19  +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
AWAJI     81  BONN CONF 352    R KAJIKAWA (TALK)                   (NAGO)
    ALSO  82 NP B197 365       FUJII,HAYASHII,IWATA,KAJIKAWA+      (NAGO)
CRAWFORD  83 NP B211 1         R L CRAWFORD, W T MORTON            (GLAS)
MANLEY    84 PR D30 904        MANLEY,ARNDT,GORADIA,TEPLITZ         (VPI)
    ALSO  84 PRL 52 2122       MANLEY                               (VPI)
ARNDT     85 PR D32 1085       R A ARNDT, J M FORD, L D ROPER       (VPI)
```

Δ(2000) F_{35}

$I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$ Status: * *

OMITTED FROM SUMMARY TABLE

Δ(2000) MASS (MeV)

```
M    ABOUT 2000.                       MANLEY    84 IPWA    PI N TO 2PI N
```

Δ(2000) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(2000) → $N\pi$	938+ 140
P2	Δ(2000) → $N\rho$, S=3/2, *P*-wave	938+ 769

Δ(2000) BRANCHING RATIOS

Δ(2000) in $N\pi \rightarrow N\rho$, S=3/2, *P*-wave SQRT(P1*P2)

```
R1   A        + (LARGE)                MANLEY    84 IPWA    PI N TO 2PI N
R1   A  MANLEY 84 CONSIDER THIS COUPLING SIGN TO BE WELL DETERMINED.
R1   A  THIS RESONANCE HAS NOT BEEN SEEN IN PI N --> PI N ANALYSES.
R1   A  THUS, ITS COUPLING TO THE N PI CHANNEL IS EXPECTED TO BE WEAK.
```

REFERENCES FOR Δ(2000)

```
MANLEY    84 PR D30 904        MANLEY,ARNDT,GORADIA,TEPLITZ         (VPI)
    ALSO  84 PRL 52 2122       MANLEY                               (VPI)
```

Δ(2150) S_{31}

$I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

Δ(2150) MASS (MeV)

```
M           2150.0     100.0           CUTKOSKY  80 IPWA    PI N TO PI N
M    A     (2047.4)    (27.0)          CHEW      80 BPWA ++ PI+P TO PI+P
M    B     (2203.2)     (8.4)          CHEW      80 BPWA ++ PI+P TO PI+P
M    AB  CHEW 80 REPORTS TWO S31 RESONANCES IN THIS MASS REGION LABELED
M    AB  A AND B.  PROBLEMS WITH THIS ANALYSIS ARE DISCUSSED IN SEC.2.1.11
M    AB  HOEHLER 83.
```

Δ(2150) WIDTH (MeV)

```
W            200.0     100.0           CUTKOSKY  80 IPWA    PI N TO PI N
W    A      (121.6)    (62.0)          CHEW      80 BPWA ++ PI+P TO PI+P
W    B      (120.5)    (45.0)          CHEW      80 BPWA ++ PI+P TO PI+P
```

Δ(2150) REAL PART OF POLE POSITION (MeV)

```
RE          2140.0      80.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(2150) −2*IMAG PART OF POLE POSITION (MeV)

```
IM           200.0      80.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(2150) REAL PART OF ELASTIC POLE RESIDUE (MeV)

```
RER            4.0      10.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(2150) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

```
IMR           -6.0       6.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(2150) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(2150) → $N\pi$	938+ 140

Δ(2150) BRANCHING RATIOS

Δ(2150) → $(N\pi)$/total (P1)

```
R1             0.08      0.02          CUTKOSKY  80 IPWA    PI N TO PI N
R1   A        (0.41)                   CHEW      80 BPWA ++ PI+P TO PI+P
R1   B        (0.37)                   CHEW      80 BPWA ++ PI+P TO PI+P
```

REFERENCES FOR Δ(2150)

```
CHEW      80  TORONTO CONF 123 D M CHEW                             (LBL)IJP
CUTKOSKY  80  TORONTO CONF 19  +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
HOEHLER   83 LANDOLT-BORNSTEIN VOL I-9B2       G HOEHLER           (KARL)
```

Δ(2200) G_{37}

$I(J^P) = \frac{3}{2}(\frac{7}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

THE AGREEMENT AMONG THE VARIOUS ANALYSES IS NOT VERY GOOD.

Δ(2200) MASS (MeV)

```
M           2280.0      80.0           HENDRY    78 MPWA    PI N TO PI N
M          (2200.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
M           2215.0      60.0           HOEHLER   79 IPWA    PI N TO PI N
M           2200.0      80.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(2200) WIDTH (MeV)

```
W            400.0     150.0           HENDRY    78 MPWA    PI N TO PI N
W           (350.0)                    CUTKOSKY  79 IPWA    PI N TO PI N
W            400.0     100.0           HOEHLER   79 IPWA    PI N TO PI N
W            450.0     100.0           CUTKOSKY  80 IPWA    PI N TO PI N
```

Δ(2200) REAL PART OF POLE POSITION (MeV)

RE	(2094.0)		CUTKOSKY	79	IPWA	PI N TO PI N
RE	2100.0	50.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2200) −2*IMAG PART OF POLE POSITION (MeV)

IM	(294.0)		CUTKOSKY	79	IPWA	PI N TO PI N
IM	340.0	80.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2200) REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	(2.0)		CUTKOSKY	79	IPWA	PI N TO PI N
RER	3.0	5.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2200) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	(-7.0)		CUTKOSKY	79	IPWA	PI N TO PI N
IMR	-8.0	3.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2200) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(2200) → $N\pi$	938+ 140

Δ(2200) BRANCHING RATIOS

Δ(2200) → ($N\pi$)/total (P1)

R1	0.09	0.02	HENDRY	78	MPWA	PI N TO PI N
R1	(0.05)		CUTKOSKY	79	IPWA	PI N TO PI N
R1	0.05	0.02	HOEHLER	79	IPWA	PI N TO PI N
R1	0.06	0.02	CUTKOSKY	80	IPWA	PI N TO PI N

REFERENCES FOR Δ(2200)

HENDRY 78 PRL 41 222 A W HENDRY (IND+LBL)IJP
-- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
CUTKOSKY 79 PR D20 2839 +FORSYTH,HENDRICK,KELLY (CARN+LBL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
HENDRY 81 ANP 136 1 A W HENDRY (IND)

Δ(2300) H_{39}

$I(J^P) = \frac{3}{2}(\frac{9}{2}^-)$ Status: * *

OMITTED FROM SUMMARY TABLE

Δ(2300) MASS (MeV)

M	2450.0	100.0	HENDRY	78	MPWA	PI N TO PI N
M	2217.0	80.0	HOEHLER	79	IPWA	PI N TO PI N
M	(2204.5)	(3.4)	CHEW	80	BPWA	++ PI+P TO PI+P
M	2400.0	125.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2300) WIDTH (MeV)

W	500.0	200.0	HENDRY	78	MPWA	PI N TO PI N
W	300.0	100.0	HOEHLER	79	IPWA	PI N TO PI N
W	(32.3)	(1.0)	CHEW	80	BPWA	++ PI+P TO PI+P
W	425.0	150.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2300) REAL PART OF POLE POSITION (MeV)

RE	2370.0	80.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2300) −2*IMAG PART OF POLE POSITION (MeV)

IM	420.0	160.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2300) REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	9.0	4.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2300) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	-3.0	5.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2300) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(2300) → $N\pi$	938+ 140

Δ(2300) BRANCHING RATIOS

Δ(2300) → ($N\pi$)/total (P1)

R1	0.08	0.02	HENDRY	78	MPWA	PI N TO PI N
R1	0.03	0.02	HOEHLER	79	IPWA	PI N TO PI N
R1	(0.05)		CHEW	80	BPWA	++ PI+P TO PI+P
R1	0.06	0.02	CUTKOSKY	80	IPWA	PI N TO PI N

REFERENCES FOR Δ(2300)

HENDRY 78 PRL 41 222 A W HENDRY (IND+LBL)IJP
-- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
CHEW 80 TORONTO CONF 123 D M CHEW (LBL)IJP
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
HENDRY 81 ANP 136 1 A W HENDRY (IND)

Δ(2350) D_{35}

$I(J^P) = \frac{3}{2}(\frac{5}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

Δ(2350) MASS (MeV)

M	2305.0	26.0	HOEHLER	79	IPWA	PI N TO PI N
M	2400.0	125.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2350) WIDTH (MeV)

W	300.0	70.0	HOEHLER	79	IPWA	PI N TO PI N
W	400.0	150.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2350) REAL PART OF POLE POSITION (MeV)

RE	2400.0	125.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2350) −2*IMAG PART OF POLE POSITION (MeV)

IM	400.0	150.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2350) REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	5.0	17.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2350) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	-14.0	10.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2350) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(2350) → $N\pi$	938+ 140

Δ(2350) BRANCHING RATIOS

Δ(2350) → ($N\pi$)/total (P1)

R1	0.04	0.02	HOEHLER	79	IPWA	PI N TO PI N
R1	0.20	0.10	CUTKOSKY	80	IPWA	PI N TO PI N

REFERENCES FOR Δ(2350)

HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP

Δ(2390) F_{37}

$I(J^P)=\frac{3}{2}(\frac{7}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

Δ(2390) MASS (MeV)

M	2425.0	60.0	HOEHLER	79	IPWA	PI N TO PI N
M	2350.0	100.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2390) WIDTH (MeV)

W	300.0	80.0	HOEHLER	79	IPWA	PI N TO PI N
W	300.0	100.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2390) REAL PART OF POLE POSITION (MeV)

RE	2350.0	100.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2390) −2*IMAG PART OF POLE POSITION (MeV)

IM	260.0	100.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2390) REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	0.0	13.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2390) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	-12.0	6.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2390) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(2390) → $N\pi$	938+ 140

Δ(2390) BRANCHING RATIOS

Δ(2390) → $(N\pi)$/total (P1)

R1	0.07	0.04	HOEHLER	79	IPWA	PI N TO PI N
R1	0.08	0.04	CUTKOSKY	80	IPWA	PI N TO PI N

REFERENCES FOR Δ(2390)

HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP

Δ(2400) G_{39}

$I(J^P)=\frac{3}{2}(\frac{9}{2}^-)$ Status: **

OMITTED FROM SUMMARY TABLE

Δ(2400) MASS (MeV)

M	2200.0	100.0	HENDRY	78	MPWA	PI N TO PI N
M	2468.0	50.0	HOEHLER	79	IPWA	PI N TO PI N
M	2300.0	100.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2400) WIDTH (MeV)

W	450.0	200.0	HENDRY	78	MPWA	PI N TO PI N
W	480.0	100.0	HOEHLER	79	IPWA	PI N TO PI N
W	330.0	100.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2400) REAL PART OF POLE POSITION (MeV)

RE	2260.0	60.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2400) −2*IMAG PART OF POLE POSITION (MeV)

IM	320.0	160.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2400) REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	7.0	4.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2400) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	-3.0	3.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2400) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(2400) → $N\pi$	938+ 140

Δ(2400) BRANCHING RATIOS

Δ(2400) → $(N\pi)$/total (P1)

R1	0.10	0.03	HENDRY	78	MPWA	PI N TO PI N
R1	0.06	0.03	HOEHLER	79	IPWA	PI N TO PI N
R1	0.05	0.02	CUTKOSKY	80	IPWA	PI N TO PI N

REFERENCES FOR Δ(2400)

AYED 76 CEA-N-1921 AYED (THESIS) (SACL)IJP
HENDRY 78 PRL 41 222 A W HENDRY (IND+LBL)IJP
-- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDR
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN (KARL)IJP
ALSO 80 TORONTO CONF 3 R KOCH (KARL)IJP
CUTKOSKY 80 TORONTO CONF 19 +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
HENDRY 81 ANP 136 1 A W HENDRY (IND)

Δ(2420) H_{311}

$I(J^P)=\frac{3}{2}(\frac{11}{2}^+)$ Status: * * * *

MOST OF THE RESULTS PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN OMITTED. THEY MAY BE FOUND IN OUR 1982 EDITION (PHYSICS LETTERS 111B).

IN ADDITION, RESULTS IN THIS REGION FROM PRODUCTION EXPERIMENTS, WHICH USED TO BE LISTED SEPARATELY AS THE NEXT ENTRY, HAVE BEEN ENTIRELY REMOVED. THEY TOO MAY BE FOUND IN OUR 1982 EDITION.

Δ(2420) MASS (MeV)

M	2400.0	60.0	HENDRY	78	MPWA	PI N TO PI N
M	2416.0	17.0	HOEHLER	79	IPWA	PI N TO PI N
M	(2358.0)	(9.0)	CHEW	80	BPWA ++	PI+P TO PI+P
M	2400.0	125.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2420) WIDTH (MeV)

W	460.0	100.0	HENDRY	78	MPWA	PI N TO PI N
W	340.0	28.0	HOEHLER	79	IPWA	PI N TO PI N
W	(202.2)	(45.0)	CHEW	80	BPWA ++	PI+P TO PI+P
W	450.0	150.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2420) REAL PART OF POLE POSITION (MeV)

RE	2360.0	100.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2420) −2*IMAG PART OF POLE POSITION (MeV)

IM	420.0	100.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2420) REAL PART OF ELASTIC POLE RESIDUE (MeV)

RER	16.0	8.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2420) IMAG PART OF ELASTIC POLE RESIDUE (MeV)

IMR	-9.0	11.0	CUTKOSKY	80	IPWA	PI N TO PI N

Δ(2420) PARTIAL DECAY MODES

		DECAY MASSES
P1	Δ(2420) → $N\pi$	938+ 140
P2	Δ(2420) → ΣK	1197+ 494

Δ(2420) BRANCHING RATIOS

Δ(2420) → (N π)/total

```
                                                              (P1)
R1        0.11     0.02           HENDRY    78 MPWA    PI N TO PI N
R1        0.08     0.015          HOEHLER   79 IPWA    PI N TO PI N
R1       (0.22)                   CHEW      80 BPWA ++ PI+P TO PI+P
R1        0.08     0.03           CUTKOSKY  80 IPWA    PI N TO PI N
```

REFERENCES FOR Δ(2420)

```
         FOR EARLY REFERENCES, SEE PHYSICS LETTERS 111B (1982).

HENDRY   78 PRL 41 222        A W HENDRY                      (IND+LBL)IJP
         -- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                              +KAISER,KOCH,PIETARINEN             (KARL)IJP
    ALSO 80  TORONTO CONF 3   R KOCH                              (KARL)IJP
CHEW     80  TORONTO CONF 123 D M CHEW                             (LBL)IJP
CUTKOSKY 80  TORONTO CONF 19  +FORSYTH,BABCOCK,KELLY,HENDRICK (CARN+LBL)IJP
HENDRY   81 ANP 136 1         A W HENDRY                           (IND)
```

Δ(2750) I_{313}

$I(J^P) = \frac{3}{2}(\frac{13}{2}^-)$ Status: * *

OMITTED FROM SUMMARY TABLE

Δ(2750) MASS (MeV)

```
M        2650.0    100.0          HENDRY    78 MPWA    PI N TO PI N
M        2794.0     80.0          HOEHLER   79 IPWA    PI N TO PI N
```

Δ(2750) WIDTH (MeV)

```
W         500.0    100.0          HENDRY    78 MPWA    PI N TO PI N
W         350.0    100.0          HOEHLER   79 IPWA    PI N TO PI N
```

Δ(2750) PARTIAL DECAY MODES

```
                                                    DECAY MASSES
P1       Δ(2750) → N π                              938+ 140
```

Δ(2750) BRANCHING RATIOS

Δ(2750) → (N π)/total

```
                                                              (P1)
R1        0.05     0.01           HENDRY    78 MPWA    PI N TO PI N
R1        0.04     0.015          HOEHLER   79 IPWA    PI N TO PI N
```

REFERENCES FOR Δ(2750)

```
HENDRY   78 PRL 41 222        A W HENDRY                      (IND+LBL)IJP
         -- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                              +KAISER,KOCH,PIETARINEN             (KARL)IJP
    ALSO 80  TORONTO CONF 3   R KOCH                              (KARL)IJP
HENDRY   81 ANP 136 1         A W HENDRY                           (IND)
```

Δ(2950) K_{315}

$I(J^P) = \frac{3}{2}(\frac{15}{2}^+)$ Status: * *

OMITTED FROM SUMMARY TABLE

Δ(2950) MASS (MeV)

```
M        2850.0    100.0          HENDRY    78 MPWA    PI N TO PI N
M        2990.0    100.0          HOEHLER   79 IPWA    PI N TO PI N
```

Δ(2950) WIDTH (MeV)

```
W         700.0    200.0          HENDRY    78 MPWA    PI N TO PI N
W         330.0    100.0          HOEHLER   79 IPWA    PI N TO PI N
```

Δ(2950) PARTIAL DECAY MODES

```
                                                    DECAY MASSES
P1       Δ(2950) → N π                              938+ 140
```

Δ(2950) BRANCHING RATIOS

Δ(2950) → (N π)/total

```
                                                              (P1)
R1        0.03     0.01           HENDRY    78 MPWA    PI N TO PI N
R1        0.04     0.02           HOEHLER   79 IPWA    PI N TO PI N
```

REFERENCES FOR Δ(2950)

```
HENDRY   78 PRL 41 222        A W HENDRY                      (IND+LBL)IJP
         -- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
HOEHLER  79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                              +KAISER,KOCH,PIETARINEN             (KARL)IJP
    ALSO 80  TORONTO CONF 3   R KOCH                              (KARL)IJP
HENDRY   81 ANP 136 1         A W HENDRY                           (IND)
```

~3000 MeV REGION – I=3/2 FORMATION EXPERIMENTS

WE LIST HERE MISCELLANEOUS HIGH-MASS CANDIDATES FOR ISOSPIN-3/2 RESONANCES FOUND IN PARTIAL-WAVE ANALYSES. SO FAR, NO ANALYSIS OF THIS REGION HAS USED ALL THE AVAILABLE DATA OR INCORPORATED ANALYTICITY CONSTRAINTS.

OUR 1982 EDITION ALSO HAD A DELTA(2850) AND A DELTA (3230). NOTHING HAS BEEN HEARD FROM THEM IN 10 YEARS, AND UNDER THE AUTHORITY GRANTED UNTO US BY THE STATUTE OF LIMITATIONS, WE DECLARE THEM TO BE DEAD. THE EVIDENCE FOR THEM WAS DEDUCED FROM TOTAL-CROSS-SECTION AND 180-DEG-ELASTIC-CROSS-SECTION MEASUREMENTS. PLACED IN THE BARYON SUMMARY TABLE IN THE ANYTHING-GOES 1960'S, THEY REMAINED THERE DUE TO INATTENTION UNTIL THE 1984 EDITION.

Δ(~3000) MASS (MeV)

```
M        2850.0    150.0          HENDRY    78 MPWA    PI N  I311
M        3200.0    200.0          HENDRY    78 MPWA    PI N  K313
M        3300.0    200.0          HENDRY    78 MPWA    PI N  L317
M        3700.0    200.0          HENDRY    78 MPWA    PI N  M319
M        4100.0    300.0          HENDRY    78 MPWA    PI N  N321
M       (3300.0)                  KOCH      80 IPWA    PI N  L317
M       (3500.0)                  KOCH      80 IPWA    PI N  M315
M     IN ADDITION, KOCH 80 REPORT SOME EVIDENCE FOR AN S31 DELTA(2700)
M     AND A P33 DELTA(2800).
```

Δ(~3000) WIDTH (MeV)

```
W         700.0    200.0          HENDRY    78 MPWA    PI N  I311
W        1000.0    300.0          HENDRY    78 MPWA    PI N  K313
W        1100.0    300.0          HENDRY    78 MPWA    PI N  L317
W        1300.0    400.0          HENDRY    78 MPWA    PI N  M319
W        1600.0    500.0          HENDRY    78 MPWA    PI N  N321
```

Δ(~3000) PARTIAL DECAY MODES

```
                                                    DECAY MASSES
P1       Δ(~3000) → N π                             938+ 140
```

Δ(~3000) BRANCHING RATIOS

Δ(~3000) → (N π)/total

```
                                                              (P1)
R1        0.06     0.02           HENDRY    78 MPWA    PI N  I311
R1        0.045    0.02           HENDRY    78 MPWA    PI N  K313
R1        0.03     0.01           HENDRY    78 MPWA    PI N  L317
R1        0.025    0.01           HENDRY    78 MPWA    PI N  M319
R1        0.018    0.01           HENDRY    78 MPWA    PI N  N321
```

REFERENCES FOR Δ(~3000)

```
HENDRY   78 PRL 41 222        A W HENDRY                      (IND+LBL)IJP
         -- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
KOCH     80  TORONTO CONF 3   R KOCH                              (KARL)IJP
HENDRY   81 ANP 136 1         A W HENDRY                           (IND)
```

NOTE ON THE S = +1 BARYON SYSTEM

The evidence for strangeness +1 baryon resonances was reviewed in our 1976 edition,[1] and more recently by Kelly[2] and by Oades.[3] Two new partial-wave analyses[4] have appeared since our 1984 edition. Both claim that the P_{13} and perhaps other waves resonate. However, the results permit no definite conclusion — the same story heard for 15 years. The standards of proof must simply be much more severe here than in a channel in which many resonances are already known to exist. The general prejudice against baryons not made of three quarks and the lack of any experimental activity in this area make it likely that it will be another 15 years before the issue is decided.

References

1. Particle Data Group, Rev. Mod. Phys. **48**, S188 (1976).
2. R.L. Kelly, in *Proceedings of the Meeting on Exotic Resonances* (Hiroshima, 1978), ed. I. Endo et al.
3. G.C. Oades, in *Low and Intermediate Energy Kaon-Nucleon Physics* (1981), ed. E. Ferrari and G. Violini.
4. K. Hashimoto, Phys. Rev. **C29**, 1377 (1984); and R.A. Arndt and L.D. Roper, Phys. Rev. **D31**, 2230 (1985).

Z BARYONS ($S = +1$)

$Z_0(1780)$ P_{01}

$I(J^P) = 0(\frac{1}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

WILSON 72, GIACOMELLI 74, AND NAKAJIMA 82 FIND SOME SOLUTIONS WITH RESONANT-LIKE BEHAVIOR IN THE P01 PARTIAL WAVE. THE EFFECT SEEN IN THE I=0 TOTAL CROSS SECTION, IF A RESONANCE, MUST HAVE SPIN=1/2, BECAUSE THE INELASTIC CROSS SECTION IS VERY SMALL AND THE TOTAL CROSS SECTION IS ABOUT 4*PI/K**2.

$Z_0(1780)$ MASS (MeV)

```
M          1780.0     10.0              COOL      70 CNTR +  K+P, D TOTAL
M   A      SEEN                         DOWELL    70 CNTR     K+P,D TOTAL
M   A      SEE ALSO DISCUSSION OF LYNCH 70.
M   B     (1800.0)                      WILSON    72 PWA     K+N P01-WAVE
M   B   ESTIMATE OF PARAMETERS FROM BW + QUADRATIC BACKGROUND FIT TO P01.
M    C    (1750.0)                      CARROLL   73 CNTR    KN I=0 TCS,FIT 1
M    C    (1825.0)                      CARROLL   73 CNTR    KN I=0 TCS,FIT 2
M    C  FIT 1=FIT OF SINGLE L=1 BW+BACKGROUND TO I=0 TCS FROM 0.4-1.1 GEV/C
M    C  FIT 2=FIT OF L=1 AND L=2 BWS TO SAME DATA,SEE Z0(1865) FOR L=2 PART
M         (1740.0)                      GIACOMEL  74 PWA    0.38-1.51 GEV/C
M         (1778.0)                      NAKAJIMA  82 PWA     KN 0.2-1.6 GEV/C
```

$Z_0(1780)$ WIDTH (MeV)

```
W          (565.0)                      COOL      70 CNTR +  K+P, D TOTAL
W   B      (300.0)                      WILSON    72 PWA     K+N P01-WAVE
W    C     (600.0)                      CARROLL   73 CNTR    KN I=0 TCS,FIT 1
W    C     (845.0)                      CARROLL   73 CNTR    KN I=0 TCS,FIT 2
W          (300.0)                      GIACOMEL  74 PWA     D.38-1.51 GEV/C
W          (662.0)                      NAKAJIMA  82 PWA     KN 0.2-1.6 GEV/C
```

$Z_0(1780)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$Z_0(1780) \rightarrow N K$	940+ 494

$Z_0(1780)$ BRANCHING RATIOS

$Z_0(1780) \rightarrow (N K)$/total (P1)

```
R1          (0.95)                 COOL      70 CNTR +  K+P, D TOTAL
R1  B       (0.85)                 WILSON    72 PWA     K+N P01-WAVE
R1   C      (0.75)                 CARROLL   73 CNTR    IF J=1/2,FIT 1
R1   C      (0.91)                 CARROLL   73 CNTR    IF J=1/2,FIT 2
R1          (0.85)                 GIACOMEL  74  PWA    .38-1.51 GEV/C
R1          (0.56)                 NAKAJIMA  82 PWA     KN 0.2-1.6 GEV/C
```

REFERENCES FOR $Z_0(1780)$

```
COOL     70 DUKE CONF 47       R L COOL                                (BNL)
    ALSO 69 PL 30B 564         ABRAMS,COOL,GIACOMELLI,KYCIA,LI +       (BNL)
    ALSO 70 PR D1 1887         COOL,GIACOMELLI,KYCIA,LEONTIC,LI +      (BNL)
DOWELL   70 DUKE 53            J D DOWELL                             (BIRM)
WILSON   72 NP B42 445         +GRIFFITHS,HIRATA +    (BGNA+GLAS+ROMA+TRST)
CARROLL  73 PL 45B 531         +KYCIA,LI,MICHAEL,MOCKETT,RAHM+         (BNL)I
GIACOMEL 74 NP B71 138         GIACOMELLI,+           (BGNA+GLAS+ROMA+TRST)IJP
NAKAJIMA 82 PL 112B 80         +KIM,KOBAYASHI,MASAIKE,MURAKAMI,+       (KEK)IJP

                               PAPERS NOT REFERRED TO IN DATA LISTINGS

LYNCH    70 DUKE 9             G LYNCH (REVIEWER)                      (LRL)
HIRATA   71 NP B30 157         +GOLDHABER,HALL,SEEGER,TRILLING,WOHL   (LBL)IJP
BOWEN    73 PR D7 22           +JENKINS,KALBACH,PETERSEN +       (ARIZ+MICH)
JOHNSON  74 PL 50B 343         JOHNSON,VLASSOPULOS               (CERN+DURH)
CAMERON  75 PALERMO CONF.      +CAPILUPPI+          (BGNA+EDIN+GLAS+PISA+RHEL)IJP
BIGI     76 NP B110 25         +CAMERON+            (BGNA+EDIN+GLAS+PISA+RHEL)IJP
ROIESNEL 79 PR D20 1646        C ROIESNEL                              (MIT)
MARTIN   80 TORONTO CONF. 355 B R MARTIN,G C OADES               (LOUC+AARH)
OADES    81 ROME CONF. 53      LOW + INTERMEDIATE ENERGY KN PHYSICS (AARH)
CORDEN   82 PR D25 720         +COX,KELSEY,LAWRENCE,WATKINS+     (BIRM+LPNP)
```

SEE OUR 1982 EDITION (PHYS. LETT. 111B) FOR A NUMBER OF OTHER REFERENCES TO EXPERIMENTAL WORK IN THIS REGION.

$Z_0(1865)$ D_{03}

$I(J^P) = 0(\frac{3}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

THIS EFFECT IS STRONGLY ASSOCIATED WITH THE K* N THRESHOLD. SEE ALSO THE Z0(1780).

$Z_0(1865)$ MASS (MeV)

```
M         (1860.0)   (15.0)         CARTER    67 THEO    DISPERSION REL.
M         (1868.0)   (10.0)         COOL      70 CNTR    K+P, D TOTAL
M         (1830.0)                  AARON     73 MPWA    I=0 KN .6-1.6G/C
M   A     (1840.0)                  CARROLL   73 CNTR    KN I=0 TCS,FIT 2
M   A   FIT2=FIT OF L=1 AND L=2 BWS TO I=0 TCS FROM 0.4-1.1 GEV/C.
M   A   SEE Z0(1780) FOR FIT 1 AND L=1 PART OF FIT 2.
M         (1907.0)                  NAKAJIMA  82 PWA     KN 0.2-1.6 GEV/C
```

$Z_0(1865)$ WIDTH (MeV)

```
W          (200.0)   (50.0)         CARTER    67 THEO
W          (160.0)   (30.0)         COOL      70 CNTR
W          (100.0)                  AARON     73 MPWA    I=0 KN .6-1.6G/C
W   A       (75.0)                  CARROLL   73 CNTR    KN I=0 TCS,FIT 2
W          (291.0)                  NAKAJIMA  82 PWA     KN 0.2-1.6 GEV/C
```

$Z_0(1865)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$Z_0(1865) \rightarrow N K$	940+ 494
P2	$Z_0(1865) \rightarrow N K^*(892)$	938+ 892

$Z_0(1865)$ BRANCHING RATIOS

$Z_0(1865) \rightarrow (N K)$/total (P1)

```
R1          (0.155)  (0.025)        CARTER    67 THEO    IF J=3/2
R1          (0.115)  (0.025)        COOL      70 CNTR    IF J=3/2
R1   A      (0.085)                 CARROLL   73 CNTR    IF J=3/2,FIT 2
R1          (0.35)                  NAKAJIMA  82 PWA     KN 0.2-1.6 GEV/C
```

$Z_0(1865) \rightarrow (N K^*(892))$/total (P2)

```
R2            MAIN INELASTIC DECAY  HIRATA    68 HBC
```

REFERENCES FOR $Z_0(1865)$

```
CARTER   67 PRL 18 801         A A CARTER                              (CAVE)
HIRATA   68 PRL 21 1485        HIRATA, WOHL, GOLDHABER, TRILLING       (LRL)
COOL     70 PR D1 1887         COOL,GIACOMELLI,KYCIA,LEONTIC,LI +      (BNL)
    ALSO 66 PRL 17 102         +GIACOMELLI,KYCIA,LEONTIC,LI,LUNDBY,+ (BNL) I
    ALSO 69 PL 30B 564         ABRAMS,COOL,GIACOMELLI,KYCIA,LI +       (BNL)
AARON    73 PR D7 1401         AARON,RICH,HOGAN,SRIVASTAVA     (LASL+NEAS)IJP
CARROLL  73 PL 45B 531         +KYCIA,LI,MICHAEL,MOCKETT,RAHM+         (BNL)I
NAKAJIMA 82 PL 112B 80         +KIM,KOBAYASHI,MASAIKE,MURAKAMI,+       (KEK)IJP
```

```
                                PAPERS NOT REFERRED TO IN DATA LISTINGS

HIRATA    70 DUKE   429         +GOLDHABER,SEEGER,TRILLING,WOHL       (LRL)
AARON     71 PRL 26 407         +AMADO+SILBAR                (NEAS+PENN+LASL)IJP
HIRATA-1  71 NP B33 445         +GOLDHABER,HALL,SEEGER,TRILLING,WOHL  (LBL)
GIACOMEL  72 NP B37 577         GIACOMELLI,+           (BGNA+GLAS+ROMA+TRST)
WILSON    72 NP B42 445         -GRIFFITHS,HIRATA +    (BGNA+GLAS+ROMA+TRST)
HASHIMOT  84 PR C29 1377        HASHIMOTO                         (VPI+KYOT)
```

$Z_1(1725)$ P_{11} — $I(J^P) = 1(\frac{1}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

```
    BOTH HASHIMOTO 84 AND ARNDT 85 SEE EVIDENCE FOR A RESONANCE IN THE
    P11-WAVE (HASHIMOTO GIVES NO PARAMETERS).
```

$Z_1(1725)$ REAL PART OF POLE POSITION (MeV)

```
RE        (1725.)                       ARNDT     85 DPWA    K+ P ELASTIC      |
```

$Z_1(1725)$ −IMAGINARY PART OF POLE POSITION (MeV)

```
IM        (61.)                         ARNDT     85 DPWA    K+ P ELASTIC      |
```

REFERENCES FOR $Z_1(1725)$

```
HASHIMOT 84 PR C29 1377     HASHIMOTO                           (VPI+KYOT)
ARNDT    85 PR D31 2230     ARNDT,ROPER                              (VPI)
```

$Z_1(1900)$ P_{13} — $I(J^P) = 1(\frac{3}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

```
    THIS EFFECT IS STRONGLY ASSOCIATED WITH THE K-DELTA THRESHOLD.
```

$Z_1(1900)$ MASS (MeV)

```
M   A     (1932.0)                   AYED      70 IPWA    P13,SOL.I
M   A     (1899.0)                   AYED      70 IPWA    P13,SOL.II
M   A     (2030.0)                   AYED      70 IPWA    S11,SOL.III
M   A      THREE SOLNS IN ORDER OF DECREASING SIGNIFICANCE. THOUGH AYED 70
M   A      GIVE PARAMETERS,THEY CONCLUDE RESONANT INTERPRETATION DOUBTFUL.
M    B    (1830.0)                   BARNETT   70 IPWA    P13,SOLN III
M    B     RESONANCE SIGNAL BARELY ABOVE BACKGROUND DUE TO THE LARGE ERRORS
M    B     IN THE AMPLITUDES RESULTING FROM THE ANALYSIS
M          1900.0     10.0           COOL      70 CNTR ++ K+P TOTAL
M         (1880.0)                   ALBROW    71 IPWA ++  SOL. GAMMA
M   C     (1890.0)                   KATO      71 IPWA    SOL  I(FIT BW)
M   C     (2040.0)                   KATO      71 IPWA    SOL II(FIT BW)
M   C   KATO 71 ESTIMATE RESONANCE PARAMETERS -- UPDATED PHASE SHIFTS
M   C   PUBLISHED IN MILLER 72.
M         (1931.0)                   NAKAJIMA  82 PWA     KN 0.2-1.6 GEV/C
```

$Z_1(1900)$ WIDTH (MeV)

```
W   A     (520.0)                    AYED      70 IPWA    K+P
W   A     (397.0)                    AYED      70 IPWA    K+P
W   A     (557.0)                    AYED      70 IPWA    K+P
W    B    (120.0)                    BARNETT   70 IPWA    P13,SOLN III
W         (240.0)                    COOL      70 CNTR ++ K+- TOTAL
W         (190.0)                    ALBROW    71 IPWA ++ SOL. GAMMA
W   C     (280.0)                    KATO      71 IPWA    SOL  I(FIT BW)
W   C     (260.0)                    KATO      71 IPWA    SOL II(FIT BW)
W         (347.0)                    NAKAJIMA  82 PWA     KN 0.2-1.6 GEV/C
```

$Z_1(1900)$ REAL PART OF POLE POSITION

```
RE  D     (1787.0)                   ARNDT     74 DPWA    K+ P ELASTIC
RE  D   SUPERSEDED BY ARNDT 78.
RE        (1796.0)                   ARNDT     78 DPWA    K+ P
RE  E     (1780.)                    ARNDT     85 DPWA    K+ P ELASTIC      |
RE  E   ARNDT 85 BELIEVE THAT THEIR 1978 RESULT MAY BE MORE ACCURATE.      |
```

$Z_1(1900)$ −IMAGINARY PART OF POLE POSITION

```
IM  D     (100.0)                    ARNDT     74 DPWA    K+ P ELASTIC
IM        (101.0)                    ARNDT     78 DPWA    K+ P
IM  E     (140.)                     ARNDT     85 DPWA    K+ P ELASTIC      |
```

$Z_1(1900)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$Z_1(1900) \to N K$	938+ 494
P2	$Z_1(1900) \to \Delta(1232)\ K$	1232+ 494

$Z_1(1900)$ BRANCHING RATIOS

$Z_1(1900) \to (N K)$/total (P1)

```
R1          (0.10) OR LESS          CARTER    67 THEO    DISPERSION REL.
R1   A      (0.16)                  AYED      70 IPWA
R1   A      (0.20)                  AYED      70 IPWA
R1   A      (0.17)                  AYED      70 IPWA
R1    B     (0.12)                  BARNETT   70 IPWA    P13,SOLN III
R1          (0.12) (ASSUMING J=3/2) COOL      70 CNTR ++ K+P TOTAL
R1          (0.15)                  ALBROW    71 IPWA ++ SOL. GAMMA
R1   C      (0.22)                  KATO      71 IPWA    SOL  I(FIT BW)
R1   C      (0.27)                  KATO      71 IPWA    SOL II(FIT BW)
R1          (0.24)                  NAKAJIMA  82 PWA     KN 0.2-1.6 GEV/C
```

$Z_1(1900) \to (\Delta(1232)\ K)$/total (P2)

```
R2             MAIN INELASTIC DECAY    BLAND     67 HBC  ++
R2       NO EVIDENCE, SPEED HAS MINIM. GRIFFITHS 72 HBC     K+P .9-1.5 GEV/C
```

REFERENCES FOR $Z_1(1900)$

```
BLAND     67 PRL 18 1077        +BOWLER,BROWN,G+S GOLDHABER,SEEGER,-  (LRL)
CARTER    67 PRL 18 801         A A CARTER                           (CAVE)

AYED      70 PL 32B 404         +BAREYRE, FELTESSE, VILLET        (SACL)IJP
BARNETT   70 U MD,RPT 70-101    BARNETT,GOLDMAN,LAASANEN,STEINBERG (UMD)IJP
     ALSO 70 DUKE 443           BARNETT,GOLDMAN,LAASANEN,STEINBERG (UMD)IJP
COOL      70 PR D1 1887         +GIACOMELLI, KYCIA, LEONTIC, LI, +  (BNL) I
     ALSO 66 PRL 17 102         COOL,GIACOMELLI,KYCIA,LEONTIC,LI +  (BNL)

ALBROW    71 NP  B30 273        +ANDERSON,ALMEHED,...,UDO,WAGNER  (CERN)IJP
     ALSO 70 DUKE  375          ERNE,SENS,WAGNER                  (CERN)IJP
KATO      71 MORIOND            +KOEHLER,...,YOKOSAWA,BURLESON (ANL-NWES)IJP
     ALSO 70 DUKE 367           A YOKOSAWA                         (ANL)IJP
     ALSO 70 PRL 24 615         KATO,KOEHLER,NOVEY,YOKOSAWA+   (ANL+NWES)IJP

GRIFFITH  72 NP B38 365         +HIRATA,HUGHES +       (BGNA+GLAS+ROMA+TRST)
MILLER    72 NP B37 401         +NOVEY,YOKOSAWA,CUTKOSKY -  (ANL+CARN-NWES)IJP
ARNDT     74 PRL 33 987         ARNDT,HACKMAN,ROPER,STEINBERG  (VPI+UMD)IJP
ARNDT     78 PR D18 3278        ARNDT,ROPER,STEINBERG          (VPI+UMD)
NAKAJIMA  82 PL 112B 80         +KIM,KOBAYASHI,MASAIKE,MURAKAMI,+  (KEK)IJP
ARNDT     85 PR D31 2230        ARNDT,ROPER                          (VPI)

     REVIEW TALKS AND PAPERS ---
LEVISETT  69 LUND CONF 341      R LEVI SETTI  (RAPPORTEUR)          (CHIC)
GOLDHABE  70 DUKE   407         G GOLDHABER (REVIEWER)               (LRL)
DOWELL    72  NAL REVIEW        REVIEW TALK IN BARYON SESSION       (BIRM)
LOVELACE  72  NAL REVIEW        RAPPORTEUR'S TALK                   (RUTG)
DOWELL    73 PURDUE CONF. 157   DOWELL                              (BIRM)
CUTKOSKY  74 LONDON CONF II-54  CUTKOSKY                            (CARN)
KELLY     75 ANL-HEP-CP-75-58   REVIEW TALK IN BARYON SESSION        (LBL)
URBAN     75 PL 60B 77          URBAN                                (LBL)
MARTIN    76 OXFORD CONF. 409   RAPPORTEUR'S TALK                   (LOUC)
KELLY     78 HUPD-7813 44       MTG. ON EXOTIC RESONANCES, HIROSHIMA (LBL)
OADES     81 ROME CONF. 53      LOW - INTERMEDIATE ENERGY KN PHYSICS (AARH)

       SEE ALSO OUR 1982 EDITION (PHYS. LETT. 111B) FOR A LARGE NUMBER OF
       OTHER REFERENCES TO THEORETICAL AND EXPERIMENTAL WORK IN THIS REGION
```

$Z_1(2150)$ — $I(J^P) = 1(\ \ )$ Status: *

OMITTED FROM SUMMARY TABLE

```
    UNTIL THERE IS FURTHER CLARIFICATION, WE PLACE TOGETHER HERE A SMALL
    BUMP SEEN LONG AGO IN THE K+ P TOTAL CROSS SECTION AND POLE PARAMETERS
    FOR A POSSIBLE D15 RESONANCE FOUND IN A PARTIAL-WAVE ANALYSIS.
```

$Z_1(2150)$ MASS (MeV)

```
M         2150.0     20.0            ABRAMS    70 CNTR ++ K+P TOTAL
```

$Z_1(2150)$ WIDTH (MeV)

```
W         (175.0)                    ABRAMS    70 CNTR +  K+P TOTAL
```

$Z_1(2150)$ REAL PART OF POLE POSITION (MeV)

```
RE        (2161.)                    ARNDT     85 DPWA    K+ P ELASTIC      |
```

$Z_1(2150)$ −IMAGINARY PART OF POLE POSITION (MeV)

```
IM        (160.)                     ARNDT     85 DPWA    K+ P ELASTIC      |
```

$Z_1(2150)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$Z_1(2150) \to N K$	938+ 494

$Z_1(2150)$ BRANCHING RATIOS

$Z_1(2150) \to (N K)$/total (P1)

```
R1      J IS NOT KNOWN, THE FOLLOWING IS (J+1/2)*P1
R1          (0.04)                   ABRAMS    70 CNTR +  K+P TOTAL
```

REFERENCES FOR $Z_1(2150)$

```
ABRAMS   70 PR  D1 1917        +COOL,GIACOMELLI,KYCIA,LEONTIC,LI +   (BNL)
    ALSO 67 PRL 19 257         ABRAMS,COOL,GIACOMELLI,KYCIA,LEONTIC+ (BNL)
ARNDT    85 PR D31 2230        ARNDT,ROPER                           (VPI)
```

$Z_1(2500)$ BUMPS

$I(J^P) = 1(\ \ )$ Status: *

OMITTED FROM SUMMARY TABLE

```
    A SMALL BUMP IN THE TOTAL CROSS SECTION AT 2.7 GEV/C.
```

$Z_1(2500)$ MASS (MeV)

```
M          2500.0    20.0              ABRAMS    70 CNTR ++ K+P TOTAL
```

$Z_1(2500)$ WIDTH (MeV)

```
W          (160.0)                     ABRAMS    70 CNTR ++ K+P TOTAL
```

$Z_1(2500)$ PARTIAL DECAY MODES

```
                                                          DECAY MASSES
P1       Z1(2500) -> N K                                  938+ 494
```

$Z_1(2500)$ BRANCHING RATIOS

$Z_1(2500) \rightarrow (N\,K)$/total (P1)

```
R1       J IS NOT KNOWN, THE FOLLOWING IS (J+1/2)*P1
R1             (0.03)                  ABRAMS    70 CNTR ++ K+P TOTAL
```

REFERENCES FOR $Z_1(2500)$

```
ABRAMS   70 PR  D1 1917        +COOL,GIACOMELLI,KYCIA,LEONTIC,LI +   (BNL)
    ALSO 67 PRL 19 257         ABRAMS,COOL,GIACOMELLI,KYCIA,LEONTIC+ (BNL)
```

NOTE ON Λ AND Σ RESONANCES

I. Introduction

There is actually a new result or two on Λ and Σ resonances for this edition. There are new results on the Σ(1385) and Λ(1405), leftovers from the old 4.2 GeV/c $K^- p$ experiment.[1] There are two modest additions to the set of scattering data, mentioned in Sec. II below. There is some recent work on the nature of the low-energy $\bar{K}N$ system bearing on the interpretation of the Λ(1405), and this difficult object is also being got at by studying radiative annihilation of the K^- hydrogen atom (see the Listings for references). Generally, however, the field remains at a standstill. It can only be revived if one of the lower energy accelerators becomes a kaon factory.

Table 1 is an attempt to evaluate the status, both overall and channel by channel, of each Λ and Σ resonance in the full Baryon Listings; the evaluations are of course partly subjective. A blank indicates there is no evidence at all; either the relevant couplings are small or the resonance does not really exist. The main Baryon Summary Table includes only the established resonances (overall status 3 or 4 stars). A number of the 1- and 2-star entries may eventually disappear, but there are certainly many resonances yet to be discovered underlying the established ones.

Table 1. The status of the Λ and Σ resonances. Only those with an overall status of *** or **** are included in the main Baryon Table.

			Status as seen in --			
Particle	$L_{I\cdot 2J}$	Overall status	$N\bar{K}$	$\Lambda\pi$	$\Sigma\pi$	Other channels
Λ(1116)	P_{01}	****				$N\pi$ (weakly)
Λ(1405)	S_{01}	****	****	F	****	
Λ(1520)	D_{03}	****	****	o	****	$\Lambda\pi\pi$, $\Lambda\gamma$
Λ(1600)	P_{01}	***	***	r	**	
Λ(1670)	S_{01}	****	****	b	****	$\Lambda\eta$
Λ(1690)	D_{03}	****	****	i	****	$\Lambda\pi\pi$, $\Sigma\pi\pi$
Λ(1800)	S_{01}	***	***	d	**	$N\bar{K}^*$, $\Sigma(1385)\pi$
Λ(1800)	P_{01}	***	***	d	**	$N\bar{K}^*$
Λ(1820)	F_{05}	****	****	e	****	$\Sigma(1385)\,\pi$
Λ(1830)	D_{05}	****	***	n	****	$\Sigma(1385)\,\pi$
Λ(1890)	P_{03}	****	****	F	**	$N\bar{K}^*$, $\Sigma(1385)\pi$
Λ(2000)		*		o	*	$\Lambda\omega$, $N\bar{K}^*$
Λ(2020)	F_{07}	*	*	r	*	
Λ(2100)	G_{07}	****	****	b	***	$\Lambda\omega$, $N\bar{K}^*$
Λ(2110)	F_{05}	***	**	i	*	$\Lambda\omega$, $N\bar{K}^*$
Λ(2325)	D_{03}	*	*	d		$\Lambda\omega$
Λ(2350)		***	***	d	*	
Λ(2585)		**	**	e		
				n		
Σ(1193)	P_{11}	****				$N\pi$ (weakly)
Σ(1385)	P_{13}	****		****	****	
Σ(1480)		*	*	*	*	
Σ(1560)		**		**	**	
Σ(1580)	D_{13}	**	*	*		
Σ(1620)	S_{11}	**	**	*	*	
Σ(1660)	P_{11}	***	***	*	**	
Σ(1670)	D_{13}	****	****	****	****	several others
Σ(1690)		**	*	**	*	$\Lambda\pi\pi$
Σ(1750)	S_{11}	***	***	**	*	$\Sigma\eta$
Σ(1770)	P_{11}	*				
Σ(1775)	D_{15}	****	****	****	***	several others
Σ(1840)	P_{13}	*	*	**	*	
Σ(1880)	P_{11}	**	**	**		$N\bar{K}^*$
Σ(1915)	F_{15}	****	***	****	***	$\Sigma(1385)\pi$
Σ(1940)	D_{13}	***	*	***	**	quasi-2-body
Σ(2000)	S_{11}	*		*		$N\bar{K}^*$, $\Lambda(1520)\pi$
Σ(2030)	F_{17}	****	****	****	**	several others
Σ(2070)	F_{15}	*	*		*	
Σ(2080)	P_{13}	**		**		
Σ(2100)	G_{17}	*		*	*	
Σ(2250)		***	***	*	*	
Σ(2455)		**	*			
Σ(2620)		**	*			
Σ(3000)		*	*	*		
Σ(3170)		*				multi-body

****	Good, clear, and unmistakable.
***	Good, but in need of clarification or not absolutely certain.
**	Not established; needs confirmation.
*	Evidence weak; could disappear.

None of the Λ's and Σ's proposed in the last decade couple strongly to the main 2-body decay channels $N\bar{K}$, $\Lambda\pi$, and $\Sigma\pi$, and thus they seldom appear in cross sections or invariant mass distributions. However, when the reactions $\bar{K}N \rightarrow \bar{K}N$, $\bar{K}N \rightarrow \Lambda\pi$, and $\bar{K}N \rightarrow \Sigma\pi$ are analyzed, some of the partial-wave amplitudes traverse small, more-or-less resonance-like circles. The question in each case is: Is this really a resonance, or is it an idle meander? Is the effect even real, or is it the result of imperfect data and analysis?

Baryon Full Listings

Λ's and Σ's

What follows is the review, slightly revised, from our 1984 edition: it summarizes "recent" progress and problems. (For another brief overview, see Tripp.[2]) In the Listings, some obsolete results, nearly all from before 1975, have been removed. This has been done only for the established Λ's and Σ's, where the addition of much improved data to partial-wave analyses has really made obsolete the older results. Where little new has been learned in the last decade, or where the situation is uncertain, nothing has been removed.

II. Formation experiments

(by G.P. Gopal, Rutherford Appleton Laboratory)

Partial-wave analyses have been made mainly for the $N\bar{K}$, $\Lambda\pi$, and $\Sigma\pi$ channels, but there are also a few results for the ΞK, $\Lambda\omega$, and some quasi-2-body channels. Early analyses usually covered only the range of a single bubble chamber experiment. Although the amplitudes from analyses in neighboring mass ranges often did not join smoothly, they did give fairly reliable information about the strongly coupled resonances. More recent analyses have used the Breit-Wigner forms of the dominant resonances as input to provide constraints in determining the overall amplitudes and thus in learning about the less prominent resonances. Besides covering wider ranges, some of the more ambitious of the analyses at the lower energies have treated several channels simultaneously, so that unitarity constraints are automatically satisfied and only a single mass and width is obtained for each resonance.

In the mid and late 1970's, much new data became available. Results from several large K^-p bubble chamber experiments were published,[3-6] and other bubble chamber experiments studied K^-n reactions[7] and K_L^0p reactions.[8] Counter experiments measured the $K^-p \rightarrow \bar{K}^0n$ total and differential cross sections at low energies,[9] the K^-p polarizations down to 1630 MeV for the first time,[10] the K^-p polarizations from 1700 to 1900 MeV with an order of magnitude increase in statistics,[11] the K^-n elastic angular distributions from 1600 to 1800 MeV[12] and from 1900 to 2300 MeV,[13] and the 180° K^-p and 0° $\Sigma^-\pi^+$ differential cross sections from 1550 to 1900 MeV.[14]

More recently, there have been new measurements of K^-n elastic scattering between 1600 and 1740 MeV.[15] Also, new total and differential cross-section data on K^-p, $\bar{K}^0n$, $\Sigma^{\pm}\pi^{\mp}$, and $\Lambda\pi^0$ between 1437 and 1486 MeV have become available.[16] They clearly show the onset of P-wave amplitudes by 1450 MeV, which brings into question analyses of low energy data that assumed only S waves were significant. Finally, there are new $\Sigma^{\pm}\pi^{\mp}$ differential cross-section and polarization distributions in a region where data were sparse, from 1650 to 1715 MeV.[17]

We now compare the more recent analyses with each other and with the data. Some of the data have yet to be incorporated into any analysis.

The $N\bar{K}$ channel: The most recent analysis[18] is an update of the old Rutherford Lab-Imperial College (RLIC 77) analysis.[19] As before, it is a conventional energy-dependent analysis with the added constraint that the masses and widths of the resonances had to be consistent with those determined in the inelastic channels analyzed previously — $\Lambda\pi$, $\Sigma\pi$, $\Lambda(1520)\pi$, $\Sigma(1385)\pi$. and $N\bar{K}^*(892)$. The analysis also goes closer to threshold, covering 1470 to 2170 MeV. It does not include the data from a number of the more recent experiments mentioned above. As before, angular distributions (a total of 5110 data points) were fit directly. The new amplitudes differ little from the RLIC 77 amplitudes. However, the K^-n data removed some of the uncertainties in the Σ resonances.

The LBL-Mt. Holyoke-CERN analysis[20] covers the narrower range of 1500 to 1940 MeV and also includes most of the new data. It is an energy-dependent analysis using a unitary background parametrized in terms of scattering lengths. The cusp effects at the $\Lambda\eta$ and $\Sigma\eta$ thresholds are included by introducing a square-root singularity in the energy variation of the widths of the appropriate resonances. This group's own high-statistics charge-exchange data[9] (which do not agree with bubble chamber measurements) all but kill the less well-established resonances.

The University College, London (UCL) K-matrix energy-dependent analysis[21] covers from 1540 to 2000 MeV. The $N\bar{K}$ amplitudes are consistent with those of the other analyses over most of this range. However, at the low end there are major differences, due to the absence of constraints from the $\Lambda(1520)$, which lies just outside the range covered. The K^-n angular distributions and K^-p polarization measurements are not fit very well.

The above analyses, all below 2200 MeV, are complemented by the College de France-Saclay (CdF-S) energy-dependent analysis[6] covering from 2070 to 2440 MeV. Besides the conventional polynomial parametrization of the background amplitudes, also tried is a parametrization using constraints imposed by the duality hypothesis (that s-channel backgrounds come exclusively from the t-channel Pomeron exchange amplitude). With 30 fewer free parameters, the results are consistent with the conventional approach.

The Σπ channel: There is very little agreement, particularly about the lower partial waves, between the two multichannel analyses.[19,21] The low-energy $K_L^0 p \rightarrow \Sigma^0 \pi^+$ data[8] are better explained by the RLIC 77 amplitudes than by the UCL amplitudes. At the high end, there is good continuity between the RLIC 77 amplitudes and those from the single-channel analysis of the CdF-S collaboration[6] covering from 2070 to 2440 MeV. The Λ(1520) and Λ(2110) resonances, which lie outside the range covered by the UCL analysis, clearly provide strong constraints.

The Λπ channel: This isospin-1 channel has been the subject of many energy-dependent and -independent analyses (for example, RLIC 77,[19] UCL,[21] Baillon-Litchfield,[22] de Bellefon-Berthon,[23] and Van Horn[24]). However, even the widespread use of the method of Barrelet zeroes has not helped to resolve the Σ spectrum — probably because most Σ resonances simply do not couple strongly to the $N\overline{K}$ initial state.

Quasi-2-body channels: The RLIC group has made energy-dependent analyses of the Λ(1520)π, Σ(1385)π, and $N\overline{K}^*$(892) channels over the widest ranges for which data are available. The data were extracted from the appropriate 3-particle final states by making 4-variable fits to an incoherent superposition of quasi-2-body final states and 3-particle Lorentz-invariant phase space. The quality of the fits suggests a maximum model-dependent systematic uncertainty of 10%. The Λω channel has been analyzed from threshold to 2440 MeV by the CdF-S collaboration.[6]

Sign conventions for resonance couplings: In terms of the isospin-0 and -1 elastic scattering amplitudes A_0 and A_1, the amplitude for $K^- p \rightarrow \overline{K}^0 n$ scattering is $\pm(A_1 - A_0)/2$, where the sign depends on conventions used in conjunction with the Clebsch-Gordan coefficients (such as, is the baryon or the meson the "first" particle). If this reaction is partial-wave analyzed and if the overall phase is chosen so that, say, the D_{15} Σ(1775) amplitude at resonance points along the positive imaginary axis (points "up"), then any Σ at resonance will point "up" and any Λ at resonance will point "down" (along the negative imaginary axis). Thus the phase at resonance determines the isospin. The above ignores background amplitudes in the resonating partial waves.

That is the basic idea. In a similar but somewhat more complicated way, the phases of the $\overline{K}N \rightarrow \Lambda\pi$ and $\overline{K}N \rightarrow \Sigma\pi$ amplitudes for a resonating wave help determine the SU(3) multiplet to which the resonance belongs. Again, a convention has to be adopted for some overall arbitrary phases: which way is "up"? Our convention is that of Levi-Setti[25] and is shown in Fig. 1, which also compares experimental results with

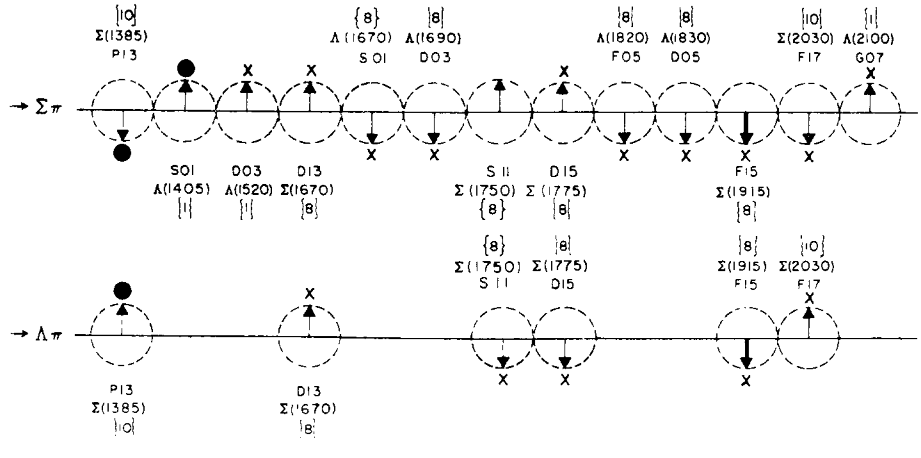

Fig. 1. The signs of the imaginary parts of resonating amplitudes in the $\overline{K}N \rightarrow \Lambda\pi$ and Σπ channels. The signs of the Σ(1385) and Λ(1405), marked with a •, are set by convention, and then the others are determined relative to them. The signs required by the SU(3) assignments of the resonances are shown with an arrow, and the experimentally determined signs are shown with an ×.

theoretical predictions for the signs of several resonances. In the Listings, a + or − sign in front of a measurement of an inelastic resonance coupling indicates the sign (the *absence* of a sign means that the sign is not determined, *not* that it is positive). For more details, see Appendix II of our 1982 edition.[26]

Argand plots: Figure 2 shows some representative Argand plots of partial-wave amplitudes. For the $N\overline{K}$ channel we show the amplitudes from RLIC 77[19] and from LBL-Mt. Holyoke-CERN,[20] and for the $\Lambda\pi$ and $\Sigma\pi$ channels we show those from RLIC 77[19] and from UCL.[21]

Errors on masses and widths: The errors quoted on resonance parameters from partial-wave analyses are often only statistical, and the parameters can change by more than these errors when a different parametrization of the waves is used. Furthermore, the different analyses use more or less the same data, so it is not really appropriate to treat the different determinations of the resonance parameters as independent or to average them together. In any case, the spread of the masses, widths, and branching fractions from the different analyses is certainly a better indication of the uncertainties than are the quoted errors. In the Baryon Summary Table, usually a range reflecting the spread of the values is given rather than a particular value with error.

For three states, the Λ(1520), the Λ(1820), and the Σ(1775), there is enough information to make an overall fit to the various branching fractions. It is then necessary to use the quoted errors, but the errors obtained from the fit should not be taken seriously.

III. Production experiments

Partial-wave analyses of course separate partial waves, whereas a peak in a cross section or an invariant mass distribution usually cannot be disentangled from background and analyzed for its quantum numbers; and more than one resonance may be contributing to the peak. Results from partial-wave analyses and from production experiments are generally kept separate in the Listings, and in the Baryon Summary Table results from production experiments are used only for the low-mass states. The Σ(1385) and Λ(1405) of course lie below the $\overline{K}N$ threshold and everything about them comes from production experiments; and production and formation experiments agree quite well in the case of Λ(1520) and results have been combined. There is some disagreement between production and formation experiments in the 1600-1700-MeV region: see the Note on the Σ(1670).

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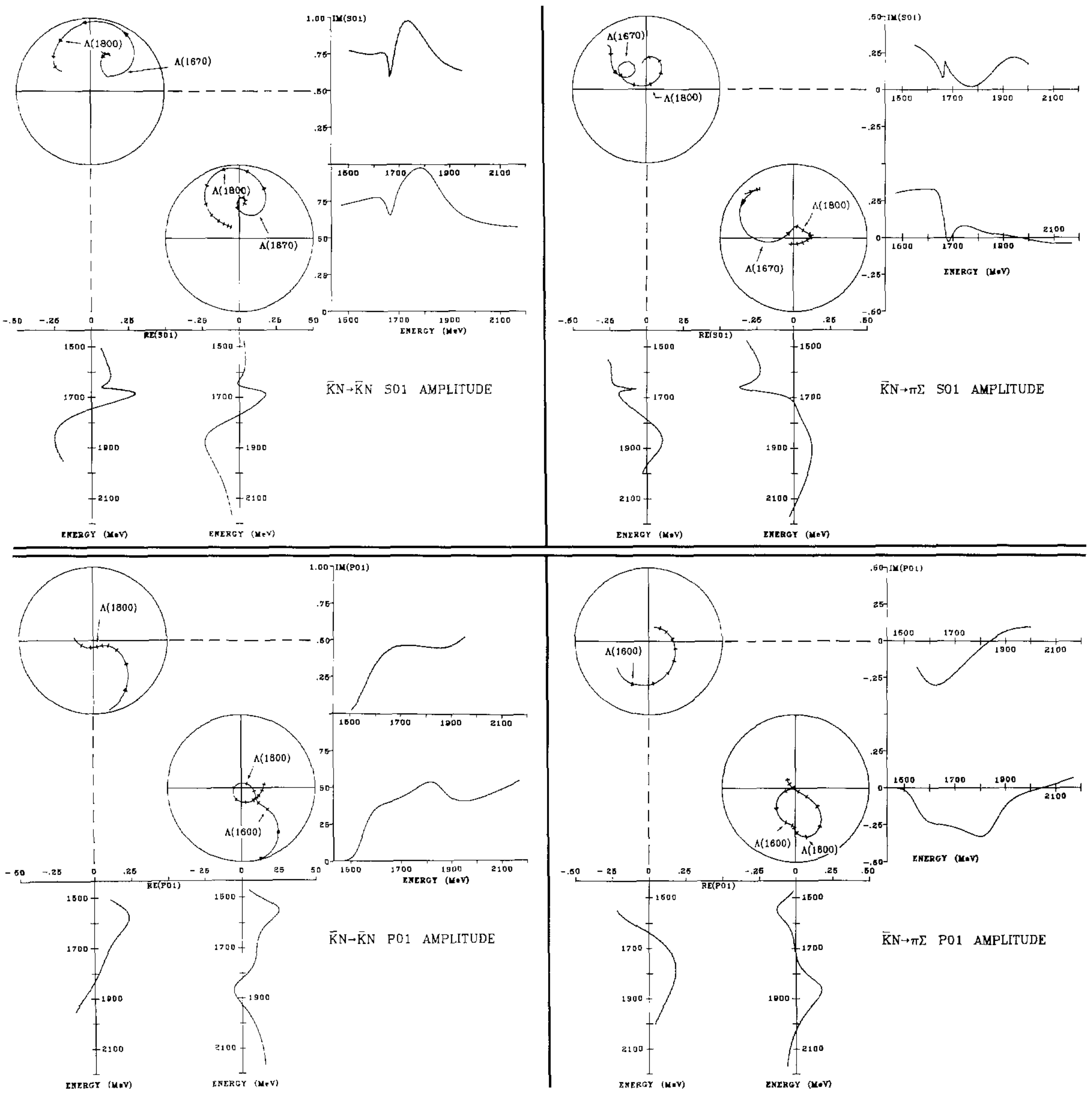


Fig. 2(a). The $L_{I\cdot 2J} = S_{01}$ and P_{01} partial-wave amplitudes for $\overline{K}N$ scattering in the elastic and $\Sigma\pi$ channels. The lower plot for each amplitude is from RLIC 77, the upper plots for the elastic amplitudes are from ALSTON 78, and the upper plots for the $\Sigma\pi$ amplitudes are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions [the S_{01} Λ(1405) is of course below threshold and is not shown]. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.

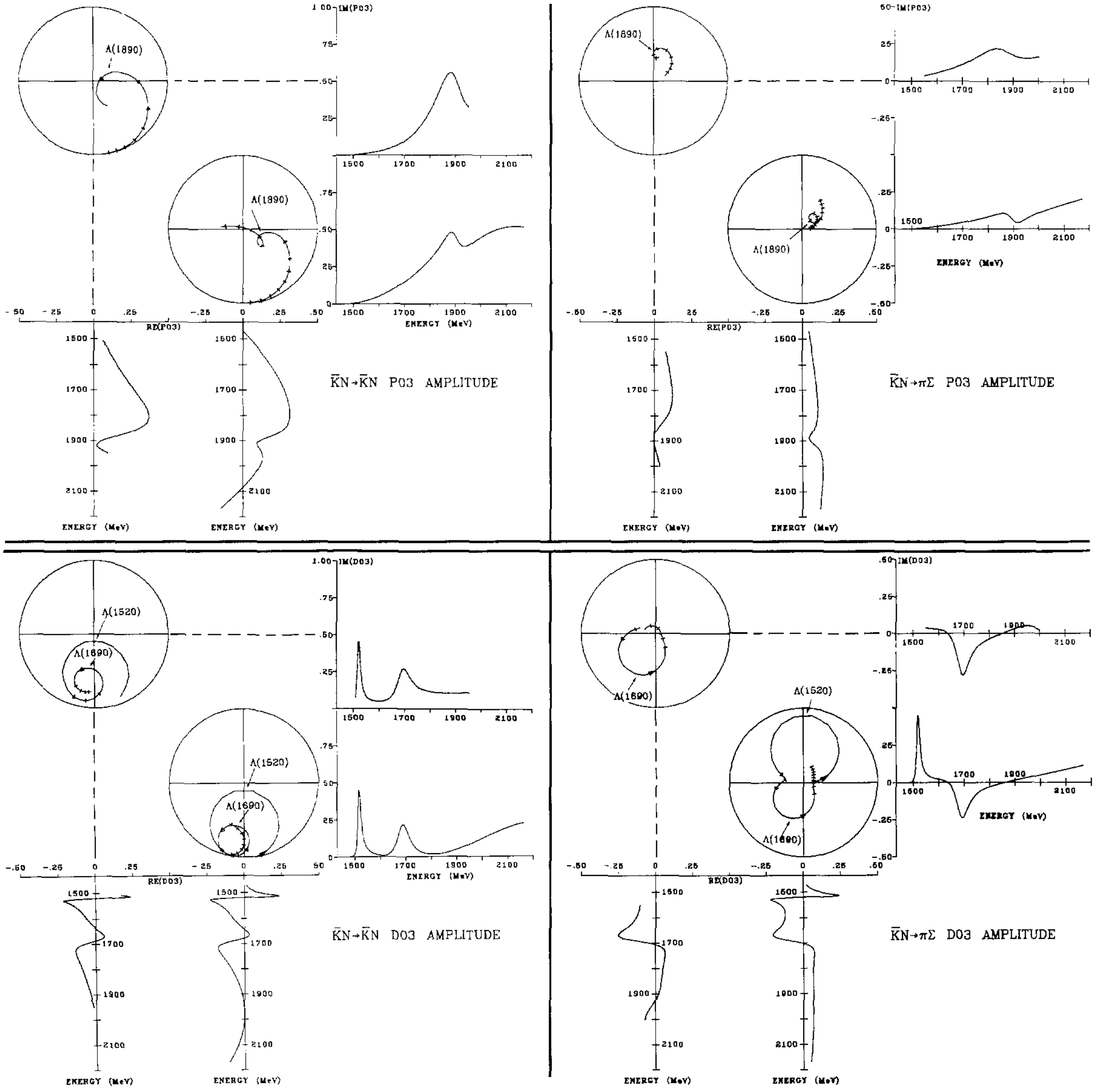


Fig. 2(b). The $L_{I\cdot 2J} = P_{03}$ and D_{03} partial-wave amplitudes for $\overline{K}N$ scattering in the elastic and $\Sigma\pi$ channels. The lower plot for each amplitude is from RLIC 77, the upper plots for the elastic amplitudes are from ALSTON 78, and the upper plots for the $\Sigma\pi$ amplitudes are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.

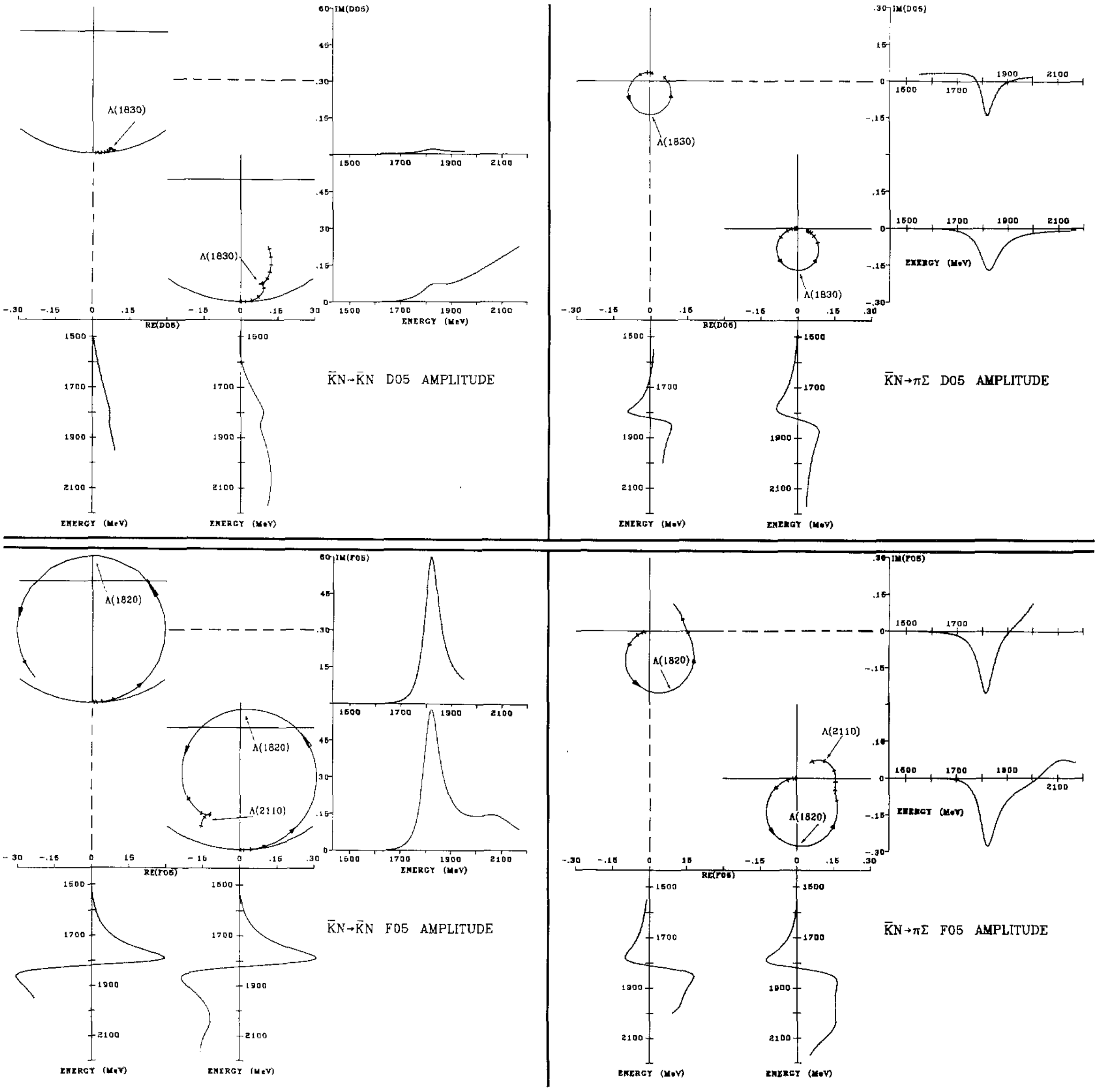


Fig. 2(c). The $L_{I\cdot 2J} = D_{05}$ and F_{05} partial-wave amplitudes for $\bar{K}N$ scattering in the elastic and $\Sigma\pi$ channels. The lower plot for each amplitude is from RLIC 77, the upper plots for the elastic amplitudes are from ALSTON 78, and the upper plots for the $\Sigma\pi$ amplitudes are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.

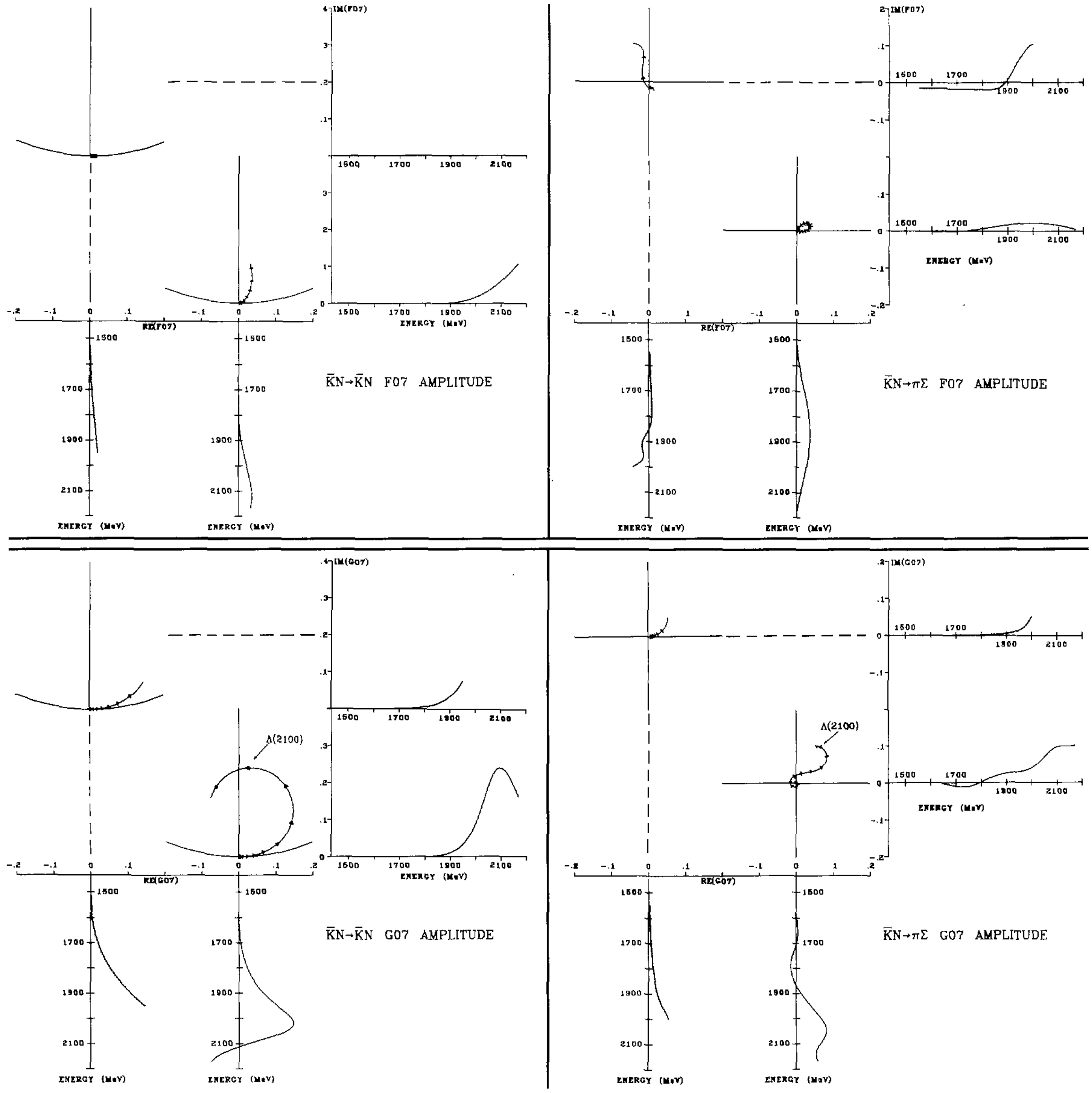
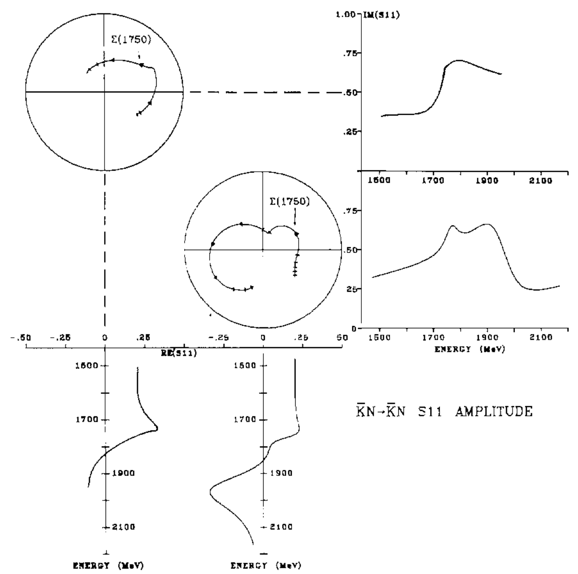
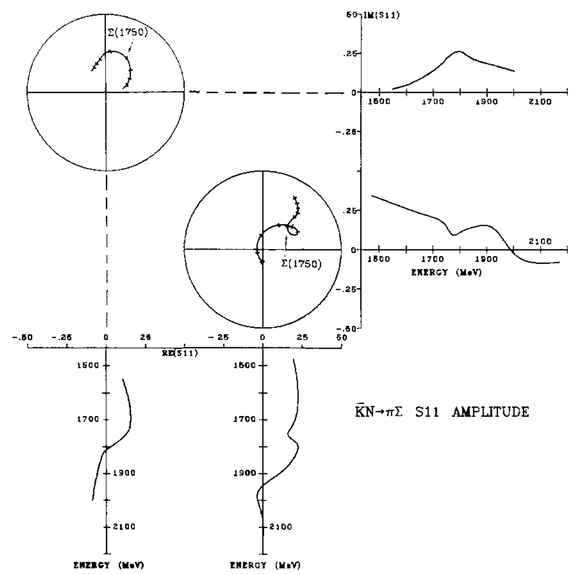


Fig. 2(d). The $L_{I\cdot 2J} = F_{07}$ and G_{07} partial-wave amplitudes for $\overline{K}N$ scattering in the elastic and $\Sigma\pi$ channels. The lower plot for each amplitude is from RLIC 77, the upper plots for the elastic amplitudes are from ALSTON 78, and the upper plots for the $\Sigma\pi$ amplitudes are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonance is shown at its nominal position. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.





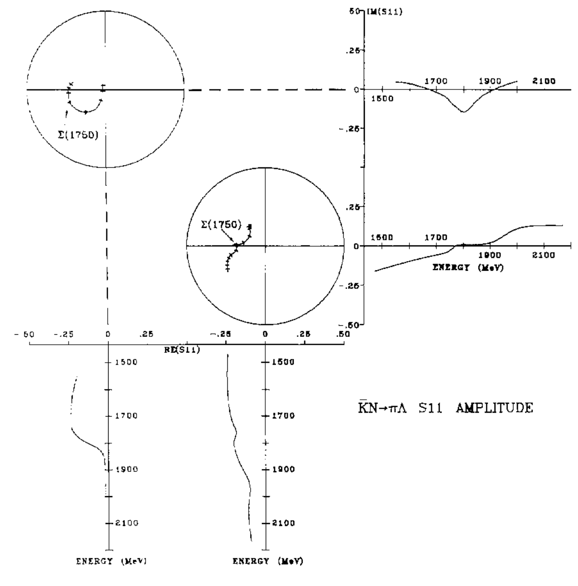
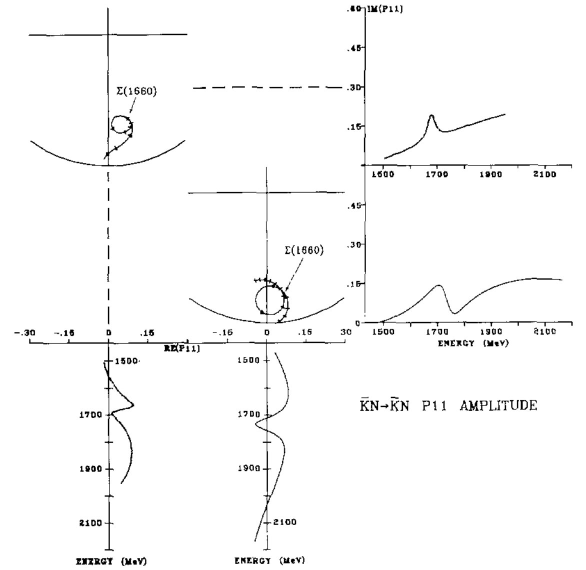
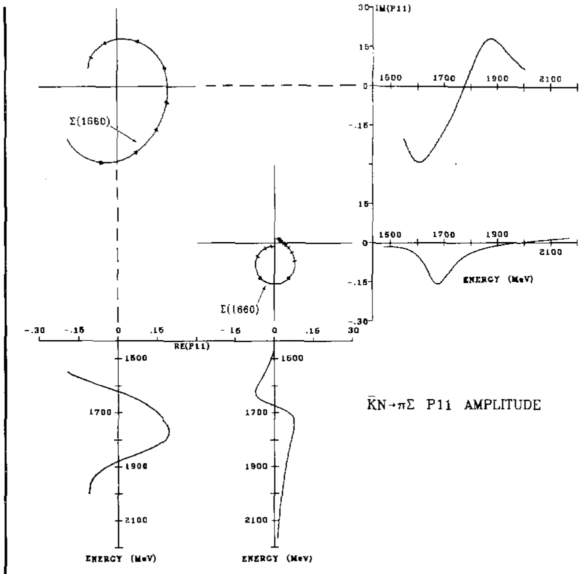


Fig. 2(e). The $L_{I \cdot 2J} = S_{11}$ partial-wave amplitudes for $\overline{K}N$ scattering in the elastic, $\Lambda\pi$, and $\Sigma\pi$ channels. The lower plot for each amplitude is from RLIC 77, the upper plot for the elastic amplitude is from ALSTON 78, and the upper plots for the $\Lambda\pi$ and $\Sigma\pi$ channels are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonance is shown at its nominal position. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.





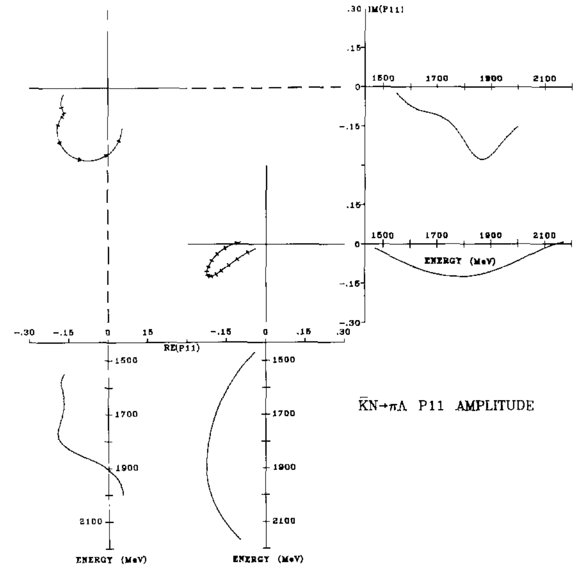
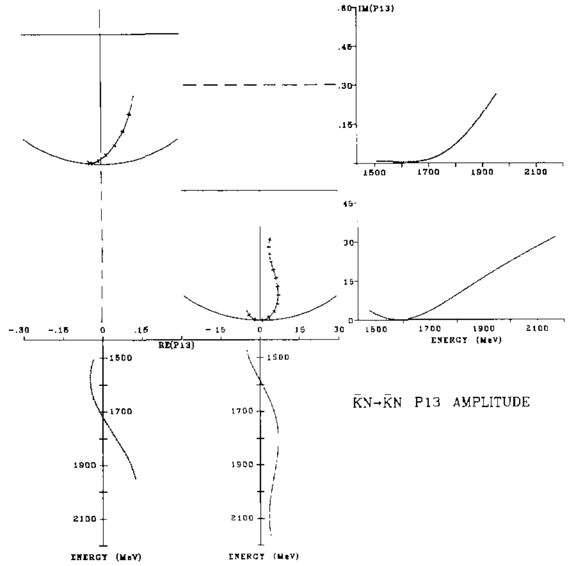
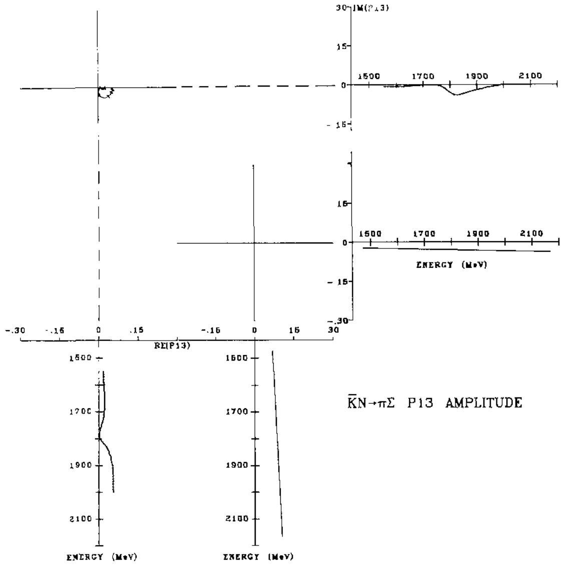


Fig. 2(f). The $L_{I\cdot 2J} = P_{11}$ partial-wave amplitudes for $\overline{K}N$ scattering in the elastic, Λπ, and Σπ channels. The lower plot for each amplitude is from RLIC 77, the upper plot for the elastic amplitude is from ALSTON 78, and the upper plots for the Λπ and Σπ channels are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonance is shown at its nominal position. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.





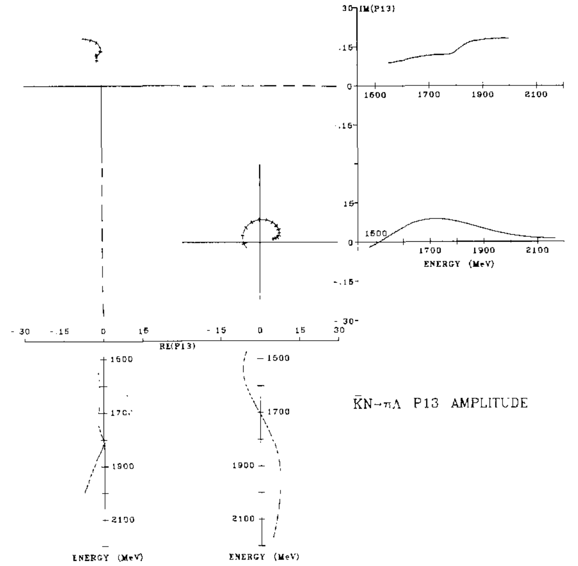
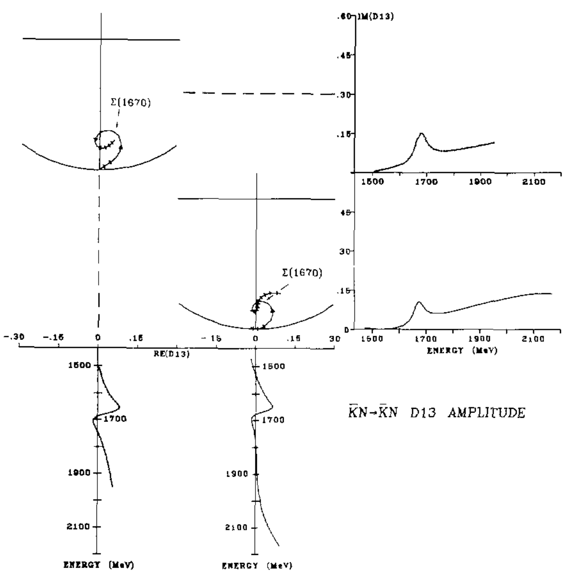
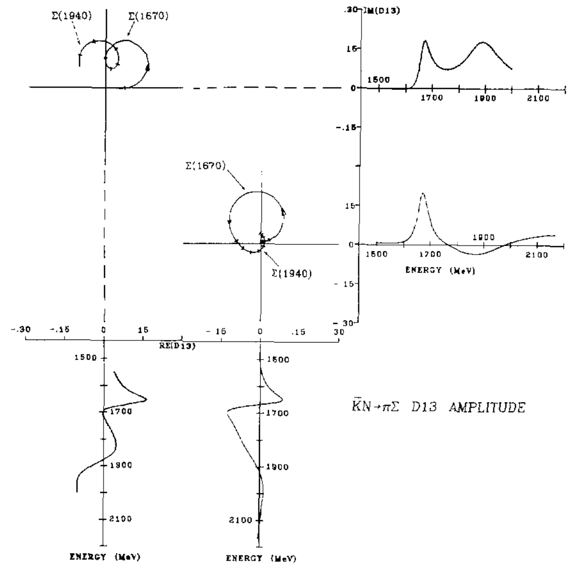


Fig. 2(g). The $L_{I\cdot 2J} = P_{13}$ partial-wave amplitudes for $\overline{K}N$ scattering in the elastic, $\Lambda\pi$, and $\Sigma\pi$ channels. The lower plot for each amplitude is from RLIC 77, the upper plot for the elastic amplitude is from ALSTON 78, and the upper plots for the $\Lambda\pi$ and $\Sigma\pi$ channels are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV [the $\Sigma(1385)$ is of course below threshold and is not shown]. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.





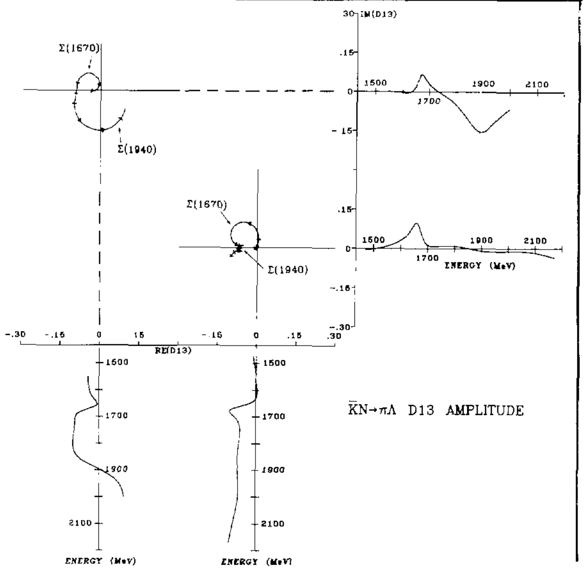


Fig. 2(h). The $L_{I\cdot 2J} = D_{13}$ partial-wave amplitudes for $\overline{K}N$ scattering in the elastic, Λπ, and Σπ channels. The lower plot for each amplitude is from RLIC 77, the upper plot for the elastic amplitude is from ALSTON 78, and the upper plots for the Λπ and Σπ channels are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonances are shown at their nominal positions. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.

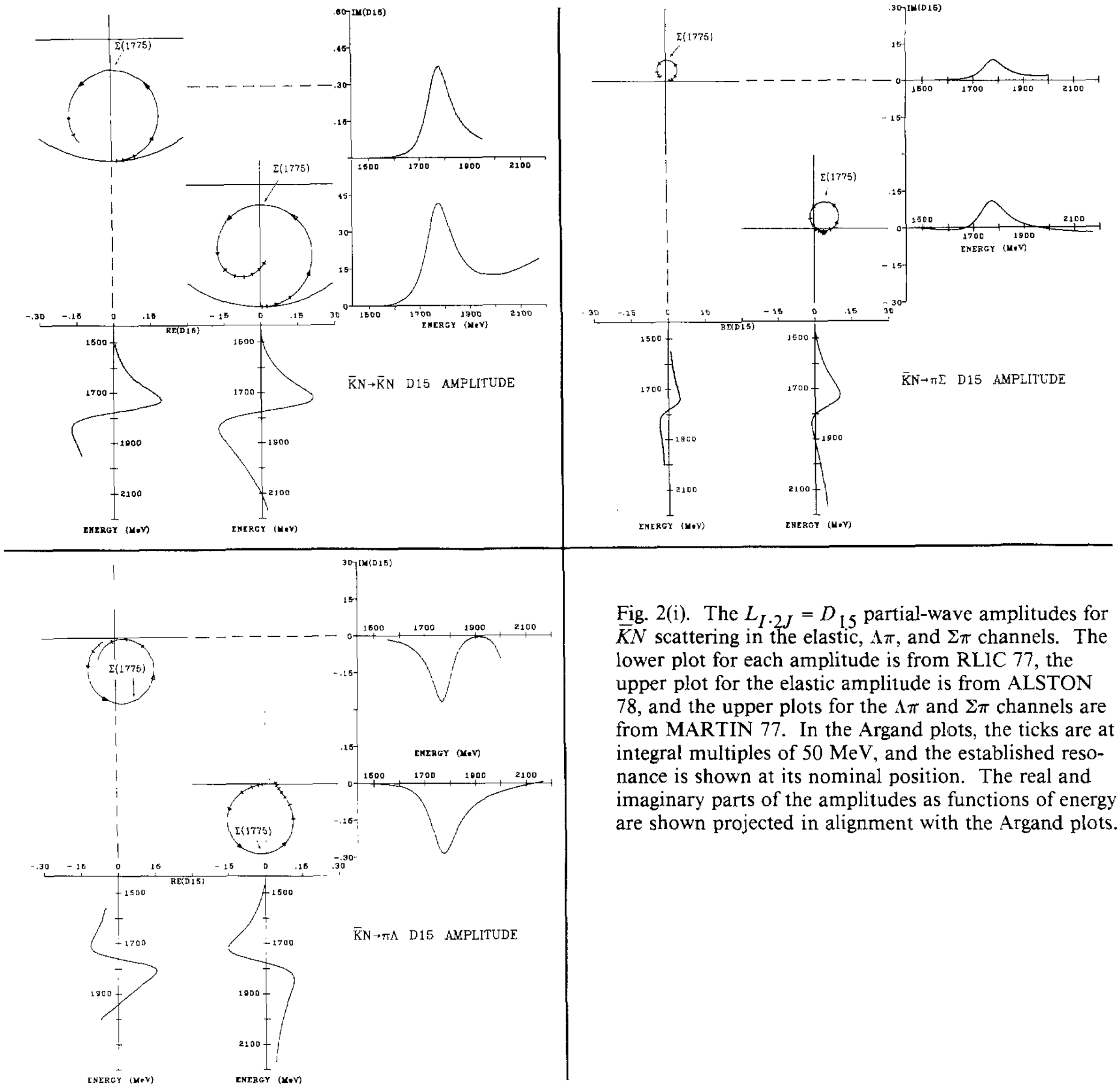
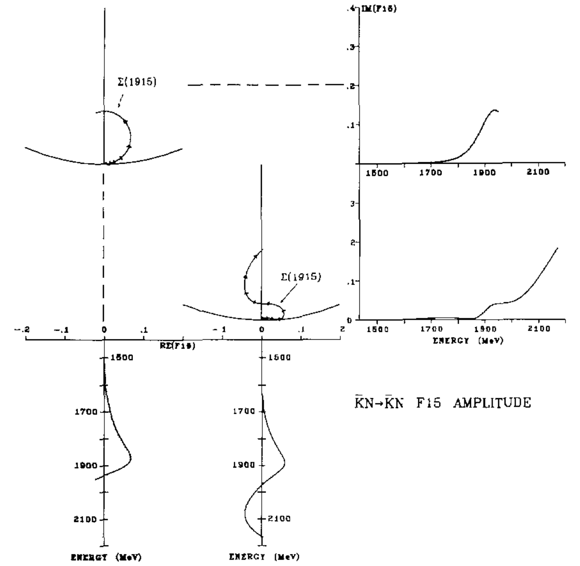
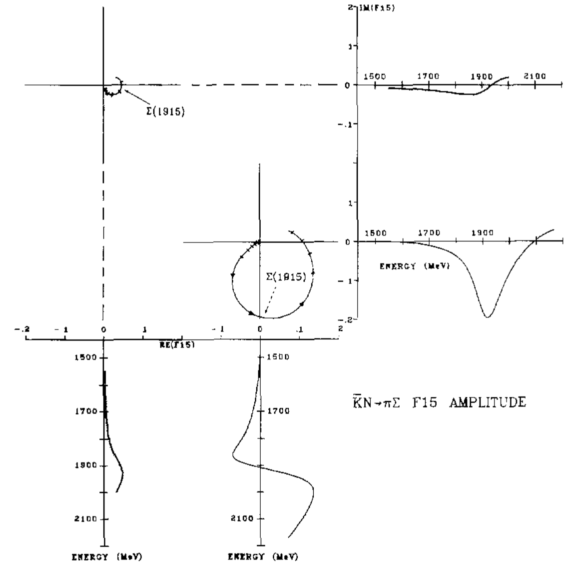


Fig. 2(i). The $L_{I\cdot 2J} = D_{15}$ partial-wave amplitudes for $\overline{K}N$ scattering in the elastic, $\Lambda\pi$, and $\Sigma\pi$ channels. The lower plot for each amplitude is from RLIC 77, the upper plot for the elastic amplitude is from ALSTON 78, and the upper plots for the $\Lambda\pi$ and $\Sigma\pi$ channels are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonance is shown at its nominal position. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.





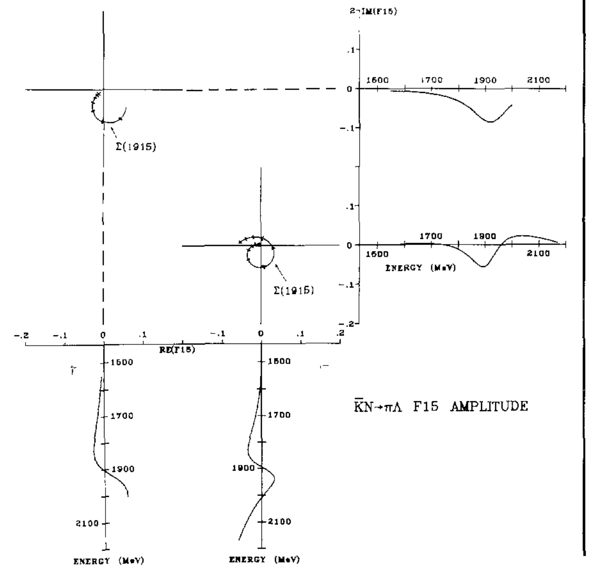
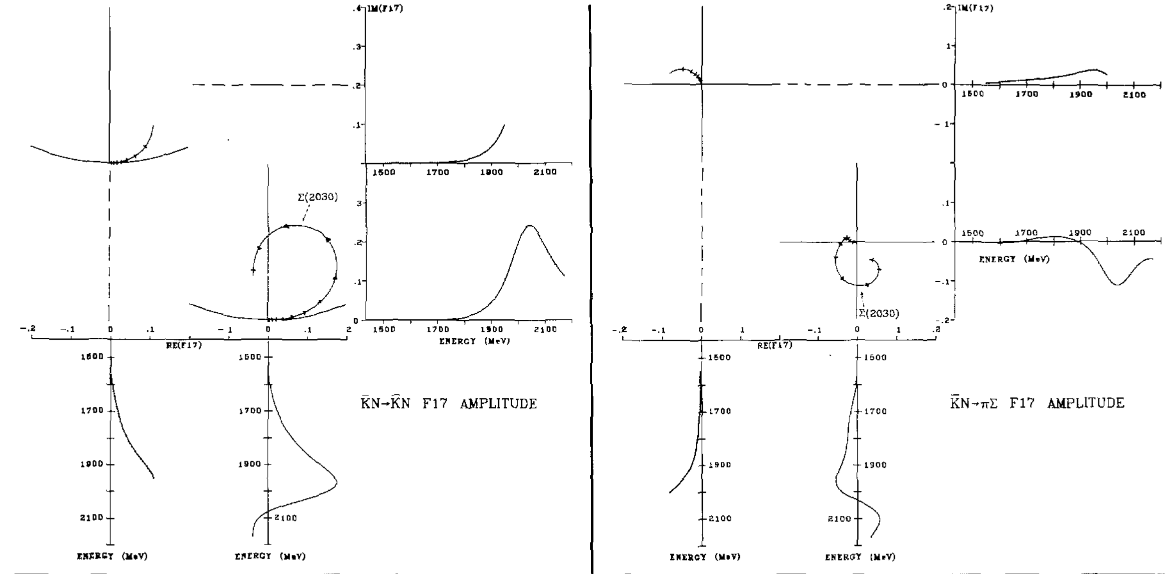
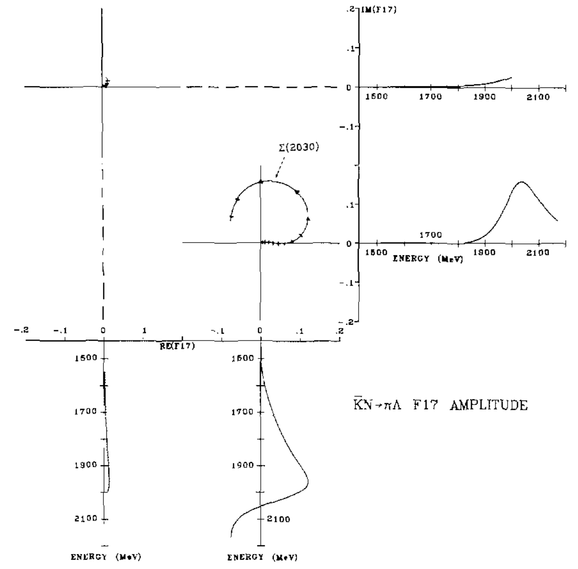


Fig. 2(j). The $L_{I\cdot 2J} = F_{15}$ partial-wave amplitudes for $\overline{K}N$ scattering in the elastic, $\Lambda\pi$, and $\Sigma\pi$ channels. The lower plot for each amplitude is from RLIC 77, the upper plot for the elastic amplitude is from ALSTON 78, and the upper plots for the $\Lambda\pi$ and $\Sigma\pi$ channels are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonance is shown at its nominal position. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.



K̄N→K̄N F17 AMPLITUDE

K̄N→πΣ F17 AMPLITUDE



K̄N→πΛ F17 AMPLITUDE

Fig. 2(k). The $L_{I\cdot 2J} = F_{17}$ partial-wave amplitudes for $\overline{K}N$ scattering in the elastic, $\Lambda\pi$, and $\Sigma\pi$ channels. The lower plot for each amplitude is from RLIC 77, the upper plot for the elastic amplitude is from ALSTON 78, and the upper plots for the $\Lambda\pi$ and $\Sigma\pi$ channels are from MARTIN 77. In the Argand plots, the ticks are at integral multiples of 50 MeV, and the established resonance is shown at its nominal position. The real and imaginary parts of the amplitudes as functions of energy are shown projected in alignment with the Argand plots.

Λ BARYONS ($S=-1$, $I=0$)

Λ

$I(J^P)=0(\frac{1}{2}^+)$ Status: * * * *

SEE STABLE PARTICLES.

Λ(1405) S_{01}

$I(J^P)=0(\frac{1}{2}^-)$ Status: * * * *

PRODUCTION EXPERIMENTS

THIS RESONANCE IS IDENTIFIED WITH THE VIRTUAL BOUND STATE IN THE N-KBAR SYSTEM FOUND IN THE ANALYSIS OF LOW ENERGY K- P INTERACTIONS. WE LIST THOSE RESULTS SEPARATELY IN THE NEXT ENTRY. WE USE ONLY PRODUCTION EXPERIMENTS FOR GETTING THE MASS AND WIDTH FOR THE BARYON SUMMARY TABLE.

Λ(1405) MASS (MeV) (PROD. EXP.)

```
M          (1405.0)                    ALSTON    61 HBC     K-P 1.15 GEV/C
M          (1410.0)                    ALEXANDER 62 HBC     PI-P 2.1 GEV/C
M          (1405.0)                    ALSTON    62 HBC     K-P 1.2-.5 GEV/C
M          (1382.0)    (8.0)           ENGLER    65 HDBC    PI-P, PI+D 1.68
M           1400.0     24.0            MUSGRAVE  65 HBC     PBAR P 3-4 GEV/C
M       67  1400.0      5.0            BIRMINGHA 66 HBC     K-P 3.5
M      120  1405.0      5.0            GALTIERI  68 DBC     K-D 2.1-2.7GEV/C
M      400     ABOUT 1405.0            THOMAS    73 HBC     PI- P 1.69 GEV/C
M    A 700(1391.0)     (1.0)           HEMINGWAY 85 HBC     K-P 4.2 GEV
M    A  HEMINGWAY 85 FINDS SIGMA PI MASS DISTRIBUTION IS ASYMMETRIC AND
M    A  BREIT-WIGNER FIT IS POOR.
M           . . . . . . . . . . .
M   AVG     1402.4      3.5      AVERAGE
```

Λ(1405) WIDTH (MeV) (PROD. EXP.)

```
W          (20.0)                      ALSTON    61 HBC
W           35.0        5.0            ALEXANDER 62 HBC
W          (50.0)                      ALSTON    62 HBC
W          (89.0)     (20.0)           ENGLER    65 HDBC
W           60.0       20.0            MUSGRAVE  65 HBC
W       67  50.0       10.0            BIRMINGHA 66 HBC     K-P 3.5
W      120  35.0        8.0            GALTIERI  68 DBC     K-D 2.1-2.7GEV/C
W      400  45.0 TO 55.0               THOMAS    73 HBC     PI- P 1.69 GEV/C
W    A 700  (32.0)     (1.0)           HEMINGWAY 85 HBC     K-P 4.2 GEV
W           . . . . . . . . . . .
W   AVG      38.1       3.9      AVERAGE
```

Λ(1405) PARTIAL DECAY MODES (PROD. EXP.)

		DECAY MASSES
P1	$\Lambda(1405) \to \Sigma\pi$	1189- 140
P2	$\Lambda(1405) \to N\overline{K}$	938- 494

Λ(1405) BRANCHING RATIOS

$\Lambda(1405) \to (N\overline{K})/(\Sigma\pi)$ (P2)/(P1)

```
R1          (0.03) OR LESS          HEMINGWAY 85 HBC     K-P 4.2 GEV/C
```

REFERENCES FOR Λ(1405) (PROD. EXP.)

```
ALSTON    61 PRL 6 698           +ALVAREZ,EBERHARD,GOOD,GRAZIANO, +     (LRL) I
ALEXANDE  62 PRL 8 447           ALEXANDER,KALBFLEISCH,MILLER,SMITH     (LRL) I
ALSTON    62 CERN CONF 311       +ALVAREZ,FERRO-LUZZI,ROSENFELD, +      (LRL) I
ENGLER    65 PRL 15 224          +FISK,KRAEMER,MELTZER,WESTGARD,+ (CARN+BNL) IJ
MUSGRAVE  65 NC 35 735           +PETMEZAS,+       (BIRM+CERN+EPOL+LOIC+SACL)
BIRMINGH  66 PR 152 1148                            (BIRM+GLAS+LOIC+OXF+RHEL)
GALTIERI  68 PRL 21 573          BARBARO-GALTIERI,CHADWICK +       (LRL+SLAC)
THOMAS    73 NP B56 15           +ENGLER,FISK,KRAEMER                  (CMU)  J
HEMINGWA  85 NP B253 742         R J HEMINGWAY                        (CERN)  J
```

1405 MeV REGION: EXTRAPOLATIONS BELOW THRESHOLD

$I(J^P)=0(\frac{1}{2}^-)$

THERE IS A RATHER EXTENSIVE LITERATURE ON THE LOW-ENERGY KBAR-N SYSTEM, ONLY A SMALL PART OF WHICH IS LISTED HERE. FOR A REVIEW OF THE STATUS OF THE LAMBDA(1405), SEE DALITZ 80. FOR RECENT MODELS OF THE LOW-ENERGY KBAR-N SYSTEM, SEE KIANG 84 AND VAN DIJK 84. FOR ANALYSIS OF THE RADIATIVE ANNIHILATION OF THE KAONIC HYDROGEN ATOM AND THE LAMBDA(1405), SEE DAREWYCH 85 AND BURKHARDT 85. FURTHER REFERENCES MAY BE FOUND IN THESE PAPERS.

Λ(1405) MASS (MeV)

```
M          1410.7     (1.0)          KIM       65 HBC     0-EFF-RANGE FIT
M          1409.6     (1.7)          SAKITT    65 HBC     0-EFF-RANGE FIT
M                          DATA OF SAKITT ARE USED IN FIT BY KITTEL.
M          1407.5     (1.2)          KITTEL    66 HBC     0-EFF-RANGE FIT
M          1403.0     (3.0)          KIM       67 HBC     K MATRIX FIT(KP)
M          1416.0     (4.0)          MARTIN    69 HBC     CONST. K MATRIX
M         (1421.0)                   MARTIN    70 RVUE    CONST. K MATRIX
M     A   (1406.0)                   CHAO      73 DPWA    0-RNG. FIT.SOL B
M     A  SEE ALSO THE ACCOMPANYING PAPER OF THOMAS 73.
```

Λ(1405) WIDTH (MeV)

```
W           37.0      (3.2)          KIM       65 HBC
W           28.2      (4.1)          SAKITT    65 HBC
W           34.1      (4.1)          KITTEL    66 HBC
W           50.0      (5.0)          KIM       67 HBC     K MATRIX FIT(KP)
W           29.0      (6.0)          MARTIN    69 HBC     CONST. K MATRIX
W          (20.0)                    MARTIN    70 RVUE    CONST. K MATRIX
W     B    (55.0)                    CHAO      73 DPWA    0-RNG. FIT.SOL B
W     B  ASYMMETRIC SHAPE, W/2=41 MEV BELOW RESONANCE, 14 MEV ABOVE.
```

REFERENCES FOR Λ(1405) (EXTRAPOLATIONS)

```
KIM      65 PRL 14 29          J K KIM                                (COLU)IJP
SAKITT   65 PR 139 B719        +DAY,GLASSER,SEEMAN,FRIEDMAN, +    (UMD+LRL)IJP
KITTEL   66 PL 21 349          W KITTEL, G OTTER, I WACEK             (VIEN)IJP
KIM      67 PRL 19 1074        J KIM                                   (YALE)JP
MARTIN   69 PR 183 1352        B R MARTIN, M SAKITT                 (LOUC+BNL)
MARTIN   70 NP B16 479         A D MARTIN, G G ROSS                   (DURH)IJP
CHAO     73 NP B56 46          CHAO,KRAEMER,THOMAS,MARTIN (RHEL+CARN+LOUC)IJP
    ALSO 73 NP B56 15          THOMAS,ENGLER,FISK,KRAEMER              (CARN)IJ
DALITZ   80 IN LOW AND INTERMEDIATE ENERGY KAON-NUCLEON PHYSICS      (OXF)
KIANG    84 PR C30 1638        +KUMAR,NOGAMI,VAN DIJK              (DALH+MCMS)
VAN DIJK 84 PR D30 937         W VAN DIJK                               (MCMS)
BURKHARD 85 NP A440 653        BURKHARDT,LOWE,ROSENTHAL     (NOTT+BIRM+WMIU)
DAREWYCH 85 PR D32 1765        +KONIUK,ISGUR                       (YORK+TNTO)

                               PAPERS NOT REFERRED TO IN DATA LISTINGS

ABRAMS   65 PR 139 B454        G S ABRAMS, B SECHI-ZORN                (UMD)IJP
DONALD   66 PL 22 711          + EDWARDS, LYS, NISAR, MOORE            (LIVP)
KADYK    66 PRL 17 599         +OREN, G+S GOLDHABER, TRILLING          (LRL)IJP
DALITZ   67 PR 153 1617        DALITZ, WONG, RAJASEKARAN           (OXF+BOMB)
DALITZ   70 DUKE-HR 70 03      R D DALITZ                               (OXF)
CLINE    71 PRL 26 1194        D CLINE,R LAUMANN,J MAPP                (WISC)
MARTIN   71 PL 35B 62          A D MARTIN,B R MARTIN,ROSS (DURH+LOUC-RHEL)
DOBSON   72 PR D6 3256         P N DOBSON,R MCELHANEY                  (HAWA)
GALTIERI 72 LBL 555            A BARBARO-GALTIERI                       (LBL)
RAJASEKA 72 PR D5 610          RAJASEKARAN                             (TIFR)
    ALSO EARLIER PAPERS CITED  IN RAJASEKARAN 72.
SHAW     73 PURDUE CONF. 417   SHAW                                    (UCI)IJP
OADES    77 NC 42A 462         G C OADES,G RASCHE                (AARH+ZURI)IJP
```

Λ(1520) D_{03}

$I(J^P)=0(\frac{3}{2}^-)$ Status: * * * *

THE MEASUREMENTS OF THE MASS, WIDTH, AND ELASTICITY THAT WERE PUBLISHED BEFORE 1975 ARE NOW OBSOLETE AND HAVE BEEN REMOVED. THEY WERE LAST LISTED IN OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

PRODUCTION AND FORMATION EXPERIMENTS AGREE QUITE WELL WITH EACH OTHER, SO THE TWO ARE LISTED TOGETHER HERE.

THE DECAY MODE LAMBDA PI PI IS LARGELY DUE TO SIGMA(1385) PI. ONLY THE VALUES OF (SIGMA(1385) PI)/(LAMBDA 2PI) GIVEN BY MAST 72 AND CORDEN 75 ARE BASED ON REAL 3-BODY PARTIAL-WAVE ANALYSES (THE OLDER RESULTS USED CRUDER METHODS). THE DISCREPANCY BETWEEN THE TWO RESULTS IS ESSENTIALLY DUE TO THE DIFFERENT HYPOTHESES MADE CONCERNING THE SHAPE OF THE (PI PI)S-WAVE STATE.

Λ(1520) MASS (MeV)

```
M      2000 1519.4      0.3            CORDEN    75 DBC     K- D 1.4-1.8GV/C
M        4K 1519.7      0.3            CAMERON   77 HBC     K-P 0.96-1.36GEV
M           1519.0      1.0            RLIC      77 DPWA    KBAR N MULTICHNL
M           1520.0      0.5            ALSTON    78 DPWA    KBAR N ELASTIC
M        5K 1517.8      1.2            BARLAG    79 HBC     K-P AT 4.2 GEV/C
M       300 1517.3      1.5            BARBER    80 SPEC    GAM P TO K+ Y*
M           1519.0      1.0            GOPAL     80 DPWA    KBAR N ELASTIC
M           . . . . . . . . . . .
M   AVG     1519.50     0.18     AVERAGE
```

Λ(1520) WIDTH (MeV)

```
W      2000    15.5     1.6            CORDEN    75 DBC     K- D 1.4-1.8GV/C
W        4K    16.3     0.5            CAMERON   77 HBC     K-P 0.96-1.36GEV
W              15.0     0.5            RLIC      77 DPWA    KBAR N MULTICHNL
W              15.4     0.5            ALSTON    78 DPWA    KBAR N ELASTIC
W   A   677    14.0     3.0            BARLAG    79 HBC     K-P AT 4.2 GEV/C
W   A     FROM BEST-RESOLUTION SAMPLE OF LAMBDA PI PI EVENTS ONLY.
W       300    16.3     3.3            BARBER    80 SPEC    GAM P TO K+ Y*
W              16.0     1.0            GOPAL     80 DPWA    KBAR N ELASTIC
W           . . . . . . . . . . .
W   AVG        15.59    0.27     AVERAGE
```

Λ(1520) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda(1520) \rightarrow N\overline{K}$	938+ 494
P2	$\Lambda(1520) \rightarrow \Sigma\pi$	1189+ 140
P3	$\Lambda(1520) \rightarrow \Lambda\pi\pi$	1116+ 140+ 140
P4	$\Lambda(1520) \rightarrow \Lambda\gamma$	1116+ 0
P5	$\Lambda(1520) \rightarrow \Sigma^0\gamma$	1192+ 0
P6	$\Lambda(1520) \rightarrow \Sigma\pi\pi$	1192+ 140+ 140
P7	$\Lambda(1520) \rightarrow \Sigma(1385)\ \pi$	1385+ 140
P8	$\Lambda(1520) \rightarrow \Sigma(1385)\ \pi(\rightarrow \Lambda\pi\pi)$	1116+ 140+ 140
P9	$\Lambda(1520) \rightarrow \Lambda(\pi\pi)_{S\text{-wave}}$	1520+ 140+ 140

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$ For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
         P 1         P 2          P 3          P 4          P 5          P 6
 P 1 .4475+-.0066
 P 2   -.6724   .4214+-.0067
 P 3   -.2834     -.3058   .0952+-.0043
 P 4   -.0895     -.0870     -.0370  .0079+-.0014
 P 5   -.2280     -.2217     -.0942     -.0180  .0195+-.0034
 P 6   -.0342     -.0333     -.0141     -.0027     -.0069  .0086+-.0005
```

Λ(1520) BRANCHING RATIOS

$\Lambda(1520) \rightarrow (\Sigma\pi)/(N\overline{K})$ (P2)/(P1)

```
R1             1.72      0.78             MUSGRAVE  65 HBC
R1             0.96      0.20             DAHL      67 HBC      PI-P 1.6-4 GEV/C
R1             0.73      0.11             DAUBER    67 HBC      K-P AT 2.GEV/C
R1             1.06      0.14             SCHEUER   68 DBC    0 K-N 3 GEV/C
R1             0.82      0.08             BURKHARDT 69 HBC      K-P .8-1.2 GEV/C
R1            (1.06)    (0.12)            BERTHON   74 HBC    0 QUASI 2 BODY CS
R1   B         0.98      0.03             RLIC      77 DPWA     KBAR N MULTICHNL
R1   B  N KBAR TO SIGMA PI AMPLITUDE AT RESONANCE IS +0.46 +/- 0.01.
R1          . . . . . . . . . . .
R1   AVG       0.951     0.044   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)
R1   FIT       0.942     0.026  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$\Lambda(1520) \rightarrow (\Lambda\pi\pi)/(N\overline{K})$ (P3)/(P1)

```
R2             0.17      0.05             DAHL      67 HBC      PI-P 1.6-4 GEV/C
R2             0.21      0.18             DAUBER    67 HBC      K-P AT 2.GEV/C
R2             0.19      0.04             SCHEUER   68 DBC    0 K-N 3 GEV/C
R2             0.22      0.03             BURKHARDT 69 HBC      K-P .8-1.2 GEV/C
R2            (0.2)                       KIM       71 DPWA     K-MATRIX ANAL.
R2            (0.27)    (0.13)            BERTHON   74 HBC    0 QUASI 2 BODY CS
R2          . . . . . . . . . . .
R2   AVG       0.202     0.021   AVERAGE
R2   FIT       0.213     0.011  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$\Lambda(1520) \rightarrow (\Sigma\pi)/(\Lambda\pi\pi)$ (P2)/(P3)

```
R3             4.5       1.0              ARMENTERO 65 HBC
R3             3.3       1.1              BIRMINGHA 66 HBC      K-P 3.5
R3             3.9       1.0              UHLIG     67 HBC      K-P .9-1.0 GEV/C
R3          . . . . . . . . . . .
R3   AVG       3.94      0.59    AVERAGE
R3   FIT       4.43      0.23   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$\Lambda(1520) \rightarrow (\Lambda\gamma)/\text{total}$ (%) (P4)

```
R4     238     0.80      0.14             MAST      68 HBC    0 USING ELAST=.45
R4          . . . . . . . . . . .
R4   FIT       0.79      0.14   FROM FIT
```

$\Lambda(1520) \rightarrow (\Sigma^0\gamma)/\text{total}$ (%) (P5)

```
R5   C         2.0       0.35             MAST      68 HBC      SEE NOTE S
R5   C     RATIOS CALCULATED FROM R4, ASSUMING SU(3). NEEDED TO CONSTRAIN
R5   C     ALL THE LAMBDA(1520) BRANCHING RATIOS TO BE UNITY.
R5          . . . . . . . . . . .
R5   FIT       1.95      0.34   FROM FIT
```

$\Lambda(1520) \rightarrow (N\overline{K})/\text{total}$ (P1)

```
R6             0.448     0.014            CORDEN    75 DBC      K- D 1.4-1.8GV/C
R6            (0.42)                      MAST      76 HBC    0 K- P CEX
R6   D        (0.47)    (0.01)            RLIC      77 DPWA     KBAR N MULTICHNL
R6   D  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R6             0.45      0.03             ALSTON    78 DPWA     KBAR N ELASTIC
R6             0.47      0.02             GOPAL     80 DPWA     KBAR N ELASTIC
R6          . . . . . . . . . . .
R6   AVG       0.455     0.011   AVERAGE
R6   FIT       0.4475    0.0066 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

$\Lambda(1520) \rightarrow (\Sigma\pi)/\text{total}$ (P2)

```
R7             0.55      0.09             WATSON    63 HBC      K-P ALL CHANNELS
R7             0.418     0.017            GALTIERI  69 HBC    0 K-P .28-.45GEV/C
R7            (0.46)                      KIM       71 DPWA     K-MATRIX ANAL.
R7             0.426     0.014            CORDEN    75 DBC      K- D 1.4-1.8GV/C
R7          . . . . . . . . . . .
R7   AVG       0.425     0.011   AVERAGE
R7   FIT       0.4214    0.0067 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

$\Lambda(1520) \rightarrow (\Sigma\pi\pi)/\text{total}$ (P6)

```
R8             0.010     0.0015           GALTIERI  69 HBC    0 K-P .28-.45GEV/C
R8   E         0.0085    0.0006           MAST2     73 MPWA     K-P TO 2PI SIG
R8   E  BASED ON ASSUMED ELASTICITY OF 0.46.
R8   F         0.007     0.002            CORDEN    75 DBC      K- D 1.4-1.8GV/C
R8   F  MUCH OF THE SIGMA PI PI DECAY PROCEEDS VIA SIGMA(1385) PI.
R8          . . . . . . . . . . .
R8   AVG      0.00858   0.00054  AVERAGE
R8   FIT      0.00857   0.00054 FROM FIT
```

$\Lambda(1520) \rightarrow (\Sigma(1385)\ \pi \rightarrow \Lambda\pi\pi)/\Lambda\pi\pi$

```
R9                                                          (P8)/(P3)
R9          MORE THAN   0.10             CLINE     69 DBC      K-D TO 2PI LAM N
R9   G         0.39      0.10             BURKHARDT 71 HBC      LAM. 3PI PROD.
R9   G  CENTRAL BIN(1514-1524) GIVES .74+-.10 -- OTHER BINS LOWER BY 2-5SIG
R9   H        (1.0)                       CHAN      72 IPWA     K-P TO LAM 2PI
R9   H  ONLY THE SIGMA(1385) DS03 SEEMS TO CONTRIBUTE.
R9   I         0.82      0.10             MAST      73 IPWA     K-P TO 2PI LAM
R9   I  BOTH SIGMA(1385) DS03 AND SIGMA (PI PI) DP03 CONTRIBUTE.
R9             0.58      0.22             CORDEN    75 DBC      K- D 1.4-1.8GV/C
```

$\Lambda(1520) \rightarrow (\Sigma(1385)\ \pi)/\text{total}$ (P7)

```
R10            0.041     0.005            CHAN      72 HBC      K-P TO LAM 2PI
```

$\Lambda(1520) \rightarrow (\Lambda\pi\pi)/\text{total}$ (P3)

```
R11  J         0.11      0.01             MAST      73 IPWA     K-P TO 2PI LAM
R11  J  BASED ON ASSUMED ELASTICITY OF 0.46+/-0.02.
R11            0.091     0.006            CORDEN    75 DBC      K- D 1.4-1.8GV/C
R11         . . . . . . . . . . .
R11 AVG        0.0960    0.0084  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
R11 FIT        0.0952    0.0043 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$\Lambda(1520) \rightarrow (\Lambda(\pi\pi)_{S\text{-wave}})/\text{total}$ (P9)

```
R12            0.20      0.08             CORDEN    75 DBC      K- D 1.4-1.8GV/C
```

REFERENCES FOR Λ(1520)

```
FERRO-LU 62 PRL 8 28            M FERRO-LUZZI,R D TRIPP,M B WATSON    (LRL)IJP
GALTIERI 63 PL 6 296            A BARBARO-GALTIERI,A HUSSAIN,RD TRIPP (LRL)
WATSON   63 PR 131 2248         M B WATSON, M FERRO-LUZZI, R D TRIPP  (LRL)IJP
ALMEIDA  64 PL 9 204            S P ALMEIDA, G R LYNCH               (CERN)
ARMENTER 65 PL 19 338           ARMENTEROS,F-LUZZI, +      (CERN+HEID+SACL)
MUSGRAVE 65 NC 35 735           +PETMEZAS,+       (BIRM+CERN+EPOL+LOIC+SACL)
BIRMINGH 66 PR 152 1148                           (BIRM+GLAS+LOIC+OXF+RHEL)
DAHL     67 PR 163 1377         DAHL,HARDY,HESS,KIRZ,MILLER           (LRL)
DAUBER   67 PL 24B 525          +MALAMUD,SCHLEIN,SLATER,STORK        (UCLA)
UHLIG    67 PR 155 1448         +CHARLTON,CONDON,GLASSER,YODH,+   (UMD+NRL)
MAST     68 PRL 21 1715         MAST,ALSTON,BANGERTER,GALTIERI+       (LRL)
SCHEUER  68 NP B8 503           SABRE COLLAB.    (SACL+AMST+BGNA+REHO+EPOL)
BURKHARD 69 NP B14 106          +FILTHUTH,KLUGE+        (HEID+EFI+CERN+SACL)
CLINE    69 LNC 2 407           +LAUMANN,MAPP                        (WISC)
GALTIERI 69 LUND 352            BARBARO-GALTIERI,BANGERTER,MAST,TRIPP (LRL)
    ALSO 70 DUKE 95             R D TRIPP                             (LRL)
BERLEY   70 PR D1 1996          +YAMIN,KOFLER,MANN,MEISNER+ (BNL+MASA+YALE)IJP
BURKHARDT71 NP  B27 64          +FILTHUTH,KLUGE,OBERLACK++ (HEID+CERN+SACL)
COLLEY   71 NP  B31 61          +COX,EASTWOOD,FRY+..  (BIRM+EDIN+GLAS+LOIC)
KIM      71 PRL 27 356          J K KIM                              (HARV)IJP
    ALSO 70 DUKE 161            J K KIM                              (HARV)IJP
CHAN     72 PRL 28 256          +BUT.-SHAFER,HERTZBACH,KOFLER++ (MASA+YALE)
MAST     73 PR D7 5             +ALSTON-GARNJOST,BANGERTER,+          (LBL)IJP
MAST2    73 PR D7 3212          +BANGERTER,ALSTON-GARNJOST,+          (LBL)IJP
BERTHON  74 NC 21A 146          BERTHON,TRISTRAM,+     (CDEF+RHEL+SACL+STRB)
GOLOWICH 74 PR D10 3861         E GOLOWICH                           (SLAC)
CORDEN   75 NP B84 306          CORDEN,COX,DARTNELL,KENYON,ONEALE,+  (BIRM)
MAST     76 PR D14 13           MAST,ALSTON-GARNJOST,BANGERTER+       (LBL)
CAMERON  77 NP B131 399         +FRANEK,GOPAL,KALMUS,MCPHERSON+ (RHEL+LOIC)IJP
RLIC     77 NP B119 362         GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182          +KENNEY,POLLARD,ROSS+       (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007         ALSTON-GARNJOST,KENNEY,+    (LBL+MTHO+CERN)IJP
BARLAG   79 NP B149 220         +BLOKZIJL,JONGEJANS+    (AMST+CERN+NIJM+OXF)
BARBER   80 ZPHY C7 17          +DAINTON,LEE,MARSHALL+      (DARE+LANC+SHEF)
GOPAL    80  TORONTO CONF 159 G P GOPAL                              (RHEL)IJP
```

$\boxed{\Lambda(1600)\ P_{01}}$

$I(J^P) = 0(\frac{1}{2}^+)$ Status: * * *

SEE THE NOTE FOR THE LAMBDA(1800, JP=1/2+) P01. SOMEWHERE IN THIS REGION THERE IS PROBABLY ONE, AND PERHAPS TWO, P01 STATES.

Λ(1600) MASS (MeV)

```
M    A      (1570.0)                      KIM       71 DPWA     K-MATRIX ANAL.
M    A  POSSIBLE EFFECT IN SIGMA PI AND N KBAR CHANNELS.
M            1620.0     10.0              LANGBEIN  72 IPWA     MULTICHANNEL
M            1596.0     (6.0)             KANE      74 DPWA     K-P TO PI SIG
M     B      1646.0      7.0              CARROLL   76 DPWA     I=0 TOTAL CS
M     B  TOTAL CROSS SECTION BUMP WITH (J+1/2)X=0.04.
M     C      1572. OR 1617.               MARTIN    77 DPWA     KBAR N MULTICHNL
M     C  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M     C  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M            1573.0     25.0              RLIC      77 DPWA     KBAR N MULTICHNL
M            1703.0    100.0              ALSTON    78 DPWA     KBAR N ELASTIC
M            1568.0    (20.0)             GOPAL     80 DPWA     KBAR N ELASTIC
```

Λ(1600) WIDTH (MeV)

```
W    A       (50.0)                       KIM       71 DPWA     K-MATRIX ANAL.
W             60.0      10.0              LANGBEIN  72 IPWA     MULTICHANNEL
W            175.0     (20.0)             KANE      74 DPWA     K-P TO PI SIG
W     B      (20.0)                       CARROLL   76 DPWA     I=0 TOTAL CS
W     C      247. OR 271.                 MARTIN    77 DPWA     KBAR N MULTICHNL
W            147.0      50.0              RLIC      77 DPWA     KBAR N MULTICHNL
W            593.0     200.0              ALSTON    78 DPWA     KBAR N ELASTIC
W            116.0     (20.0)             GOPAL     80 DPWA     KBAR N ELASTIC
```

Λ(1600) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda(1600) \rightarrow N\overline{K}$	938+ 494
P2	$\Lambda(1600) \rightarrow \Sigma\pi$	1189+ 140

Λ(1600) BRANCHING RATIOS

Λ(1600) → $(N\overline{K})$/total (P1)

```
R1            0.25      0.15            LANGBEIN  72 IPWA     MULTICHANNEL
R1   C        0.30 OR   0.29            MARTIN    77 DPWA     KBAR N MULTICHNL
R1   D       (0.24)    (0.04)           RLIC      77 DPWA     KBAR N MULTICHNL
R1   D  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1            0.14      0.05            ALSTON    78 DPWA     KBAR N ELASTIC
R1            0.23     (0.04)           GOPAL     80 DPWA     KBAR N ELASTIC
```

Λ(1600) in $N\overline{K}$ → $\Sigma\pi$ SQRT(P1*P2)

```
R2            0.28      0.09            LANGBEIN  72 IPWA     MULTICHANNEL
R2           -0.33     (0.11)           KANE      74 DPWA     K-P TO PI SIG
R2         NOT SEEN                     HEPP2     76 DPWA -0 K- NUC TO SIG PI
R2   C       -0.39 OR -0.39             MARTIN    77 DPWA     KBAR N MULTICHNL
R2           -0.16      0.04            RLIC      77 DPWA     KBAR N MULTICHNL
```

REFERENCES FOR Λ(1600)

```
KIM       71 PRL 27 356         J K KIM                                (HARV)IJP
    ALSO 70 DUKE 161            J K KIM                                (HARV)IJP
LANGBEIN 72 NP B47 477          +WAGNER                                (MPIM)IJP
KANE     74  LBL-2452           D F KANE                                (LBL)IJP
CARROLL  76 PRL 37 806          +CHIANG,KYCIA,LI,MAZUR,MICHAEL+         (BNL)I
HEPP2    76 PL 65B 487          +BRAUN,GRIMM,STROBELE,THOL+(CERN+HEID+MPIM)IJP
MARTIN   77 NP B127 349         MARTIN,PIDCOCK,MOORHOUSE          (LOUC+GLAS)IJP
    ALSO 77 NP B126 266         MARTIN,PIDCOCK                         (LOUC)
    ALSO 77 NP B126 285         MARTIN,PIDCOCK                         (LOUC)IJP
RLIC     77 NP B119 362         GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182          +KENNEY,POLLARD,ROSS+        (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007         ALSTON-GARNJOST,KENNEY,+     (LBL+MTHO+CERN)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                                (RHEL)IJP
```

Λ(1670) S_{01}

$I(J^P) = 0(\frac{1}{2}^-)$ Status: * * * *

THE MEASUREMENTS OF THE MASS, WIDTH, AND ELASTICITY THAT WERE PUBLISHED BEFORE 1974 ARE NOW OBSOLETE AND HAVE BEEN REMOVED. THEY WERE LAST LISTED IN OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

Λ(1670) MASS (MeV)

```
M           1679.0     (1.0)            KANE      74 DPWA     K-P TO PI SIG
M           1665.0     (5.0)            PREVOST   74 DPWA 0-  K-N TO S(1385)PI
M           1675.0     (2.0)            HEPP2     76 DPWA -0  K- NUC TO SIG PI
M    A     (1664.0)                     MARTIN    77 DPWA     KBAR N MULTICHNL
M    A  MARTIN 77 OBTAINS IDENTICAL RESONANCE PARAMETERS FROM THE
M    A  T-MATRIX POLE AND FROM A B-W FIT.
M           1670.0     (5.0)            RLIC      77 DPWA     KBAR N MULTICHNL
M           1671.0     (3.0)            ALSTON    78 DPWA     KBAR N ELASTIC
M           1667.0     (5.0)            GOPAL     80 DPWA     KBAR N ELASTIC
M           1670.8     (1.7)            KOISO     85 DPWA     K- P TO SIGMA PI   |
```

Λ(1670) WIDTH (MeV)

```
W             40.0     (3.0)            KANE      74 DPWA     K-P TO PI SIG
W             19.0     (5.0)            PREVOST   74 DPWA 0-  K-N TO S(1385)PI
W             46.0     (5.0)            HEPP2     76 DPWA -0  K- NUC TO SIG PI
W    A       (12.0)                     MARTIN    77 DPWA     KBAR N MULTICHNL
W             45.0    (10.0)            RLIC      77 DPWA     KBAR N MULTICHNL
W             29.0     (5.0)            ALSTON    78 DPWA     KBAR N ELASTIC
W             29.0     (5.0)            GOPAL     80 DPWA     KBAR N ELASTIC
W             34.1     (3.7)            KOISO     85 DPWA     K- P TO SIGMA PI   |
```

Λ(1670) PARTIAL DECAY MODES

		DECAY MASSES
P1	Λ(1670) → $N\overline{K}$	938+ 494
P2	Λ(1670) → $\Lambda\eta$	1116+ 549
P3	Λ(1670) → $\Sigma\pi$	1189+ 140
P4	Λ(1670) → $\Sigma(1385)\ \pi$	1385+ 140

Λ(1670) BRANCHING RATIOS

Λ(1670) → $(N\overline{K})$/total (P1)

```
R1   A       (0.15)                     MARTIN    77 DPWA     KBAR N MULTICHNL
R1   B       (0.20)    (0.03)           RLIC      77 DPWA     KBAR N MULTICHNL
R1   B  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1            0.17     (0.03)           ALSTON    78 DPWA     KBAR N ELASTIC
R1            0.18     (0.03)           GOPAL     80 DPWA     KBAR N ELASTIC
```

Λ(1670) in $N\overline{K}$ → $\Lambda\eta$ SQRT(P1*P2)

```
R2   C        0.20  OR 0.23             BERLEY    65 HBC    0
R2   C   THE FIRST VALUE ASSUMES THE BRANCHING RATIO INTO LAMBDA ETA IS
R2   C SMALL, THE SECOND THAT IT IS LARGE.  BECAUSE THE RESONANCE IS NEAR
R2   C THE LAMBDA ETA THRESHOLD, THE BRANCHING RATIO AFFECTS THE MOMENTUM
R2   C DEPENDENCE OF THE TOTAL WIDTH, AND THUS ALSO THE RESONANCE PARA-
R2   C METERS OBTAINED BY FITTING TO THE DATA.
R2           (0.26)                     ARMENT-3  69 HBC    0
R2           (0.24)                     KIM       71 DPWA     K-MATRIX ANAL.
R2           +0.20     (0.05)           BAXTER    73 DPWA  0 K- P TO NEUTRALS
```

Λ(1670) in $N\overline{K}$ → $\Sigma\pi$ SQRT(P1*P3)

```
R3           -0.27     (0.02)           KANE      74 DPWA     K-P TO PI SIG
R3           -0.23     (0.03)           LONDON    75 HLBC  0  K- P TO SIGO PIO
R3           -0.29     (0.03)           HEPP2     76 DPWA -0  K- NUC TO SIG PI
R3   A      (-0.13)                     MARTIN    77 DPWA     KBAR N MULTICHNL
R3           -0.31     (0.03)           RLIC      77 DPWA     KBAR N MULTICHNL
R3           -0.26     (0.02)           KOISO     85 DPWA     K- P TO SIGMA PI   |
```

Λ(1670) in $N\overline{K}$ → $\Sigma(1385)\ \pi$ SQRT(P1*P4)

```
R4           -0.18      0.05            PREVOST   74 DPWA 0- K-N TO S(1385)PI
```

REFERENCES FOR Λ(1670)

```
BERLEY   65 PRL 15 641          +CONNOLLY, HART, RAUM, STONEHILL, +   (BNL)IJP
BIRMINGH 66 PR 152 1148                         (BIRM+GLAS+LOIC+OXF+RHEL)
ARMENT-1 68 NP B8 195           ARMENTEROS, BAILLON, +      (CERN+HEID+SACL)IJP
ARMENT-2 68 NP B8 223           ARMENTEROS, BAILLON, +      (CERN+HEID+SACL)IJP
ARMENT-3 69 LUND PAPER 229      ARMENTEROS, BAILLON, +      (CERN+HEID+SACL)IJP
    VALUES ARE QUOTED IN LEVI SETTI 69.
ARMENT-4 69 NP B14 91           ARMENTEROS, BAILLON, +      (CERN+HEID+SACL)IJP
BERLEY   69 PL 30B 430          + HART, RAHM, WILLIS, YAMAMOTO         (BNL)IJP
LEVISETT 69 LUND 339            R LEVI SETTI  (RAPPORTEUR)             (CHIC)
GALTIERI 70 DUKE 173            A BARBARO GALTIERI                     (LRL)IJP
CONFORTO 71 NP  B34  41         +LEVI SETTI,LASINSKI..OBERLACK++ (EFI+HEID)IJP
KIM      71 PRL 27 356          J K KIM                               (HARV)IJP
    ALSO 70 DUKE 161            J K KIM                               (HARV)IJP
LANGBEIN 72 NP B47 477          +WAGNER                               (MPIM)IJP
BAXTER   73 NP B67 125          BAXTER,BUCKINGHAM,CORBETT,DUNN,+       (OXF)IJP
HART     73 PURDUE CONF. 311    +RICE,BACASTOW,FUNG,+  (TENN+UCR+MASA+BUFF)IJP
KANE     74  LBL-2452           D F KANE                               (LBL)IJP
PREVOST  74 NP B69 246          PREVOST,BARLOUTAUD,+        (SACL+CERN+HEID)
LONDON   75 NP B85 289          LONDON,YU,BOYD,+  (BNL+CERN+EPOL+ORSA+TORI)
HEPP2    76 PL 65B 487          +BRAUN,GRIMM,STROBELE,THOL+(CERN+HEID+MPIM)IJP
MARTIN   77 NP B127 349         MARTIN,PIDCOCK,MOORHOUSE         (LOUC+GLAS)IJP
    ALSO 77 NP B126 266         MARTIN,PIDCOCK                        (LOUC)
    ALSO 77 NP B126 285         MARTIN,PIDCOCK                        (LOUC)IJP
RLIC     77 NP B119 362         GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182          +KENNEY,POLLARD,ROSS+        (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007         ALSTON-GARNJOST,KENNEY,+     (LBL+MTHO+CERN)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                               (RHEL)IJP
KOISO    85 NP A433 619         +SAI,YAMAMOTO,KOFLER                 (TOKY+MASA)
```

Λ(1690) D_{03}

$I(J^P) = 0(\frac{3}{2}^-)$ Status: * * * *

THE MEASUREMENTS OF THE MASS, WIDTH, AND ELASTICITY THAT WERE PUBLISHED BEFORE 1974 ARE NOW OBSOLETE AND HAVE BEEN REMOVED. THEY WERE LAST LISTED IN OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

Λ(1690) MASS (MeV)

```
M           1689.0     (1.0)            KANE      74 DPWA     K-P TO PI SIG
M           1692.0     (4.0)            CARROLL   76 DPWA     I=0 TOTAL CS
M           1690.0     (3.0)            HEPP2     76 DPWA -0  K- NUC TO SIG PI
M    A      1687. OR 1689.              MARTIN    77 DPWA     KBAR N MULTICHNL
M    A  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M    A  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M    A  ANOTHER 3/2- LAMBDA AT 1966 MEV IS ALSO SUGGESTED BY MARTIN 77,
M    A  BUT IS VERY UNCERTAIN.
M           1690.0     (5.0)            RLIC      77 DPWA     KBAR N MULTICHNL
M           1692.0     (5.0)            ALSTON    78 DPWA     KBAR N ELASTIC
M           1690.0     (5.0)            GOPAL     80 DPWA     KBAR N ELASTIC
M           1695.7     (2.6)            KOISO     85 DPWA     K- P TO SIGMA PI   |
```

Λ(1690) WIDTH (MeV)

```
W             60.0     (4.0)            KANE      74 DPWA     K-P TO PI SIG
W            (38.0)                     CARROLL   76 DPWA     I=0 TOTAL CS
W             82.0     (8.0)            HEPP2     76 DPWA -0  K- NUC TO SIG PI
W    A        62. OR 62.                MARTIN    77 DPWA     KBAR N MULTICHNL
W             60.0     (5.0)            RLIC      77 DPWA     KBAR N MULTICHNL
W             64.0    (10.0)            ALSTON    78 DPWA     KBAR N ELASTIC
W             61.0     (5.0)            GOPAL     80 DPWA     KBAR N ELASTIC
W             67.2     (5.6)            KOISO     85 DPWA     K- P TO SIGMA PI   |
```

Λ(1690) PARTIAL DECAY MODES

		DECAY MASSES
P1	Λ(1690) → $N\overline{K}$	938+ 494
P2	Λ(1690) → $\Sigma\pi$	1189+ 140
P3	Λ(1690) → $\Lambda\pi\pi$	1116+ 140+ 140
P4	Λ(1690) → $\Sigma\pi\pi$	1192+ 140+ 140
P5	Λ(1690) → $\Sigma(1385)\ \pi$, S-wave	1385+ 140
P6	Λ(1690) → $\Lambda\eta$	1116+ 549

Λ(1690) BRANCHING RATIOS

THE SUM OF ALL THE QUOTED BRANCHING RATIOS IS MORE THAN 1.0. THE TWO-BODY RATIOS ARE FROM PARTIAL-WAVE ANALYSES, AND THUS PROBABLY ARE MORE RELIABLE THAN THE THREE-BODY RATIOS, WHICH ARE DETERMINED FROM BUMPS IN CROSS SECTIONS. OF THE LATTER, THE SIGMA PI PI BUMP LOOKS MORE SIGNIFICANT (THE ERROR GIVEN FOR THE LAMBDA PI PI RATIO LOOKS UNREASONABLY SMALL). HARDLY ANY OF THE SIGMA PI PI DECAY CAN BE VIA SIGMA(1385), FOR THEN NINE TIMES AS MUCH LAMBDA PI PI DECAY WOULD BE REQUIRED.

$\Lambda(1690) \rightarrow (N\bar{K})$/total (P1)

```
R1   A       0.28 OR  0.26         MARTIN    77 DPWA    KBAR N MULTICHNL
R1   B      (0.24)   (0.03)        RLIC      77 DPWA    KBAR N MULTICHNL
R1   B  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1           0.22    (0.03)        ALSTON    78 DPWA    KBAR N ELASTIC
R1           0.23    (0.03)        GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Lambda(1690)$ in $N\bar{K} \rightarrow \Sigma\pi$ SQRT(P1*P2)

```
R2          -0.28    (0.02)        KANE      74 DPWA    K-P TO PI SIG
R2          -0.28    (0.03)        LONDON    75 HLBC  0 K- P TO SIG0 PI0
R2          -0.29    (0.03)        HEPP2     76 DPWA -0 K- NUC TO SIG PI
R2   A      -0.30 OR -0.28         MARTIN    77 DPWA    KBAR N MULTICHNL
R2          -0.25    (0.03)        RLIC      77 DPWA    KBAR N MULTICHNL
R2          -0.34    (0.02)        KOISO     85 DPWA    K- P TO SIGMA PI
```

$\Lambda(1690)$ in $N\bar{K} \rightarrow \Lambda\pi\pi$ SQRT(P1*P3)

```
R3  C       (0.25)   (0.02)        BARTLEY   68 HDBC  0 LAM 2PI CROS SEC
R3  C   ONLY CROSS-SECTION DATA USED. ENHANCEMENT NOT SEEN BY PREVOST 71,
```

$\Lambda(1690)$ in $N\bar{K} \rightarrow \Sigma\pi\pi$ SQRT(P1*P4)

```
R4          (0.21)                 ARMENT-2  68 HDBC  0 K-N TO SIG PI PI
```

$\Lambda(1690)$ in $N\bar{K} \rightarrow \Lambda\eta$ SQRT(P1*P6)

```
R5           0.00    (0.03)        BAXTER    73 DPWA  0 K- P TO NEUTRALS
```

$\Lambda(1690)$ in $N\bar{K} \rightarrow \Sigma(1385)\pi$, S-wave SQRT(P1*P5)

```
R6          +0.27     0.04         PREVOST   74 DPWA 0- K-N TO S(1385)PI
```

REFERENCES FOR Λ(1690)

```
ARMENT-1 68 NP B8 195         ARMENTEROS, BAILLON, +     (CERN+HEID+SACL)IJP
ARMENT-2 68 NP B8 216         ARMENTEROS, BAILLON, +     (CERN+HEID+SACL) I
ARMENT-3 68 NP B8 223         ARMENTEROS, BAILLON, +     (CERN+HEID+SACL)IJP
BARTLEY  68 PRL 21 1111       +CHU,DOWD,GREENE,+          (TUFT+FSU+BRAN) I
BUGG     68 PR 168 1466       +GILMORE, KNIGHT, +        (BIRM+CAVE+RHEL) I
    ALSO 67 PRL 18 62         DAVIES,DOWELL,+            (BIRM+CAVE+RHEL) I
CONFORTO 68 NP B8 265         +HARMSEN, LASINSKI, +           (CHIC+HEID)IJP
ARMENT-4 69 NP B14 91         ARMENTEROS, BAILLON, +     (CERN+HEID+SACL)IJP
BERLEY   69 PL 30B 430        + HART, RAHM, WILLIS, YAMAMOTO        (BNL)IJP
BERTANZA 69 PR 177 2036       +BIGI,CARRARA,CASALI, +    (PISA+BNL+YALE)IJP
GALTIERI 70 DUKE 173          A BARBARO GALTIERI                    (LRL)IJP
CONFORTO 71 NP  B34  41       +LEVI SETTI,LASINSKI..OBERLACK+  (EFI+HEID)IJP
KIM      71 PRL 27 356        J K KIM                              (HARV)IJP
    ALSO 70 DUKE 161          J K KIM                              (HARV)IJP
PREVOST  71  AMSTERDAM CONF   + CHS COLLABORATION        (CERN+HEID+SACL)
LANGBEIN 72 NP B47 477        +WAGNER                              (MPIM)IJP
BAXTER   73 NP B67 125        BAXTER,BUCKINGHAM,CORBETT,DUNN,+      (OXF)IJP
HART     73 PURDUE CONF. 311  +RICE,BACASTOW,FUNG,+  (TENN+UCR+MASA+BUFF)IJP
KANE     74  LBL-2452         D F KANE                              (LBL)IJP
PREVOST  74 NP B69 246        PREVOST,BARLOUTAUD,+       (SACL+CERN+HEID)
LONDON   75 NP B85 289        LONDON,YU,BOYD,+  (BNL+CERN+EPOL+ORSA+TORI)
CARROLL  76 PRL 37 806        +CHIANG,KYCIA,LI,MAZUR,MICHAEL+       (BNL)I
HEPP2    76 PL 65B 487        +BRAUN,GRIMM,STROBELE,THOL+(CERN+HEID+MPIM)IJP
MARTIN   77 NP B127 349       MARTIN,PIDCOCK,MOORHOUSE        (LOUC+GLAS)IJP
    ALSO 77 NP B126 266       MARTIN,PIDCOCK                       (LOUC)
    ALSO 77 NP B126 285       MARTIN,PIDCOCK                       (LOUC)IJP
RLIC     77 NP B119 362       GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182        +KENNEY,POLLARD,ROSS+      (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007       ALSTON-GARNJOST,KENNEY,+   (LBL+MTHO+CERN)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                            (RHEL)IJP
KOISO    85 NP A433 619       +SAI,YAMAMOTO,KOFLER            (TOKY+MASA)
```

Λ(1800) S_{01}

$I(J^P) = 0(\frac{1}{2}^-)$ Status: * * *

THE S01 AMPLITUDE SHOWS A RATHER CLEAR SECOND RESONANCE BEHAVIOR IN THE 1700-1900 MEV REGION. THERE ARE MAJOR DISAGREEMENTS ABOUT THE MASS, WIDTH, AND COUPLINGS.

Λ(1800) MASS (MeV)

```
M         (1872.0)   (10.0)          BRICMAN   70 DPWA    TOT, ELAS, CHEX
M         (1780.0)                   KIM       71 DPWA    K-MATRIX ANAL.
M          1830.0    (20.0)          LANGBEIN  72 IPWA    MULTICHANNEL
M    A     1767. OR 1842.            MARTIN    77 DPWA    KBAR N MULTICHNL
M    A  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M    A  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1825.0    (20.0)          RLIC      77 DPWA    KBAR N MULTICHNL
M          1725.0    (20.0)          ALSTON    78 DPWA    KBAR N ELASTIC
M          1841.0    (10.0)          GOPAL     80 DPWA    KBAR N ELASTIC
```

Λ(1800) WIDTH (MeV)

```
W          (100.0)   (20.0)          BRICMAN   70 DPWA    TOT, ELAS, CHEX
W           (40.0)                   KIM       71 DPWA    K-MATRIX ANAL.
W            70.0    (15.0)          LANGBEIN  72 IPWA    MULTICHANNEL
W    A      435. OR 473.             MARTIN    77 DPWA    KBAR N MULTICHNL
W           230.0    (20.0)          RLIC      77 DPWA    KBAR N MULTICHNL
W           185.0    (20.0)          ALSTON    78 DPWA    KBAR N ELASTIC
W           228.0    (20.0)          GOPAL     80 DPWA    KBAR N ELASTIC
```

Λ(1800) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda(1800) \rightarrow N\bar{K}$	938+ 494
P2	$\Lambda(1800) \rightarrow \Sigma\pi$	1189+ 140
P3	$\Lambda(1800) \rightarrow \Sigma(1385)\ \pi$	1385+ 140
P4	$\Lambda(1800) \rightarrow N K^*(892)$, S1-wave	940+ 892
P5	$\Lambda(1800) \rightarrow N K^*(892)$, D3-wave	940+ 892

Λ(1800) BRANCHING RATIOS

$\Lambda(1800) \rightarrow (N\bar{K})$/total (P1)

```
R1          (0.18)   (0.02)        BRICMAN   70 DPWA   TOT, ELAS, CHEX
R1          (0.80)                 KIM       71 DPWA   K-MATRIX ANAL.
R1           0.35    (0.15)        LANGBEIN  72 IPWA   MULTICHANNEL
R1   A       1.21 OR  0.70         MARTIN    77 DPWA   KBAR N MULTICHNL
R1   B      (0.37)   (0.05)        RLIC      77 DPWA   KBAR N MULTICHNL
R1   B  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1           0.28    (0.05)        ALSTON    78 DPWA   KBAR N ELASTIC
R1           0.36    (0.04)        GOPAL     80 DPWA   KBAR N ELASTIC
```

$\Lambda(1800)$ in $N\bar{K} \rightarrow \Sigma\pi$ SQRT(P1*P2)

```
R2          (0.24)                 KIM       71 DPWA   K-MATRIX ANAL.
R2   A      -0.74 OR -0.43         MARTIN    77 DPWA   KBAR N MULTICHNL
R2          -0.08    (0.05)        RLIC      77 DPWA   KBAR N MULTICHNL
```

$\Lambda(1800)$ in $N\bar{K} \rightarrow \Sigma(1385)\ \pi$ SQRT(P1*P3)

```
R3   C      +0.056    0.028        CAMERON   78 DPWA 0 K-P TO S(1385)PI
R3   C  SIGN CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION.
```

$\Lambda(1800)$ in $N\bar{K} \rightarrow N K^*(892)$, S1-wave SQRT(P1*P4)

```
R4   D      -0.17     0.03         CAMERON2  78 DPWA   K-P TO K*N
R4   D  THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R4   D  CONVENTION.
```

$\Lambda(1800)$ in $N\bar{K} \rightarrow N K^*(892)$, D3-wave SQRT(P1*P5)

```
R5          -0.13     0.04         CAMERON2  78 DPWA   K-P TO K*N
```

REFERENCES FOR Λ(1800)

```
BRICMAN  70 PL 33B 511        C BRICMAN, M FERRO-LUZZI, J P LAGNAUX(CERN)IJP
KIM      71 PRL 27 356        J K KIM                              (HARV)IJP
    ALSO 70 DUKE 161          J K KIM                              (HARV)IJP
LANGBEIN 72 NP B47 477        +WAGNER                              (MPIM)IJP
MARTIN   77 NP B127 349       MARTIN,PIDCOCK,MOORHOUSE        (LOUC+GLAS)IJP
    ALSO 77 NP B126 266       MARTIN,PIDCOCK                       (LOUC)
    ALSO 77 NP B126 285       MARTIN,PIDCOCK                       (LOUC)IJP
RLIC     77 NP B119 362       GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182        +KENNEY,POLLARD,ROSS+      (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007       ALSTON-GARNJOST,KENNEY,+   (LBL+MTHO+CERN)IJP
CAMERON  78 NP B143 189       +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)IJP
CAMERON2 78 NP B146 327       +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                            (RHEL)IJP
```

Λ(1800) P_{01}

$I(J^P) = 0(\frac{1}{2}^+)$ Status: * * *

THE EVIDENCE FOR THIS STATE IS SOMEWHAT CONFUSED. IT WAS FIRST SUGGESTED IN A PARTIAL-WAVE ANALYSIS OF N KBAR DATA BY THE BEHAVIOUR OF THE P01 AMPLITUDE WHEN IT WAS PARAMETRIZED AS A TWO-STRAIGHT-LINE BACKGROUND (ARMENTEROS 68).

ALMOST ALL THE RECENT ANALYSES CONTAIN A P01 STATE, AND SOMETIMES TWO, BUT THE MASSES, WIDTHS, AND BRANCHING RATIOS VARY GREATLY. SEE ALSO THE LAMBDA(1600) P01 LISTING.

Λ(1800) MASS (MeV)

```
M         (1745.0)                   ARMENTERO 68 HBC    0 ELASTIC, CH EXCH
M         (1740.0)                   BAILEY    69 DPWA   0 ELASTIC, CH EXCH
M         (1800.0)                   ARMENTERO 70 HBC    0 ELASTIC, CH EX
M         (1750.0)                   ARMENTERO 70 HBC    0 SIGMA PI
M    A    (1690.0)   (10.0)          GALTIERI  70 HBC    0 SIG PI,EDPWA
M    A    ERROR STATIST. ONLY- NO ERROR DUE TO PARTICULAR P.W.ANAL. INCLUDED
M         (1755.0)                   KIM       71 DPWA     K-MATRIX ANAL.
M          1780.0     20.0           LANGBEIN  72 IPWA     MULTICHANNEL
M          1746.0     10.0           PREVOST   74 DPWA 0-  K-N TO S(1385)PI
M          1735.0      5.0           CARROLL   76 DPWA     I=0 TOTAL CS
M     B    1861. OR 1953.            MARTIN    77 DPWA     KBAR N MULTICHNL
M     B  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M     B  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1853.0     20.0           RLIC      77 DPWA     KBAR N MULTICHNL
M          1841.0    (20.0)          GOPAL     80 DPWA     KBAR N ELASTIC
```

Λ(1800) WIDTH (MeV)

```
W          (147.0)                   ARMENTERO 68 HBC    0
W          (300.0)                   BAILEY    69 DPWA   0 ELASTIC, CH EXCH
W           (30.0)                   ARMENTERO 70 HBC    0 ELASTIC, CH EX
W           (70.0)                   ARMENTERO 70 HBC    0 SIGMA PI
W    A      (22.0)                   GALTIERI  70 HBC    0 SIG PI,EDPWA
W           (35.0)                   KIM       71 DPWA     K-MATRIX ANAL.
W           120.0     10.0           LANGBEIN  72 IPWA     MULTICHANNEL
W            46.0     20.0           PREVOST   74 DPWA 0-  K-N TO S(1385)PI
W           (28.0)                   CARROLL   76 DPWA     I=0 TOTAL CS
W     B     535. OR 585.             MARTIN    77 DPWA     KBAR N MULTICHNL
W           166.0     20.0           RLIC      77 DPWA     KBAR N MULTICHNL
W            90.0     20.0           CAMERON2  78 DPWA     K-P TO K*(892) N
W           164.0    (20.0)          GOPAL     80 DPWA     KBAR N ELASTIC
```

Λ(1800) PARTIAL DECAY MODES

```
                                                      DECAY MASSES
P1     Λ(1800) → N K̄                                   938+ 494
P2     Λ(1800) → Σπ                                   1189+ 140
P3     Λ(1800) → Σ(1385) π                            1385+ 140
P4     Λ(1800) → N K*(892), P1-wave                    940+ 892
P5     Λ(1800) → N K*(892), P3-wave                    940+ 892
```

Λ(1800) BRANCHING RATIOS

$\Lambda(1800) \rightarrow (N\bar{K})$/total (P1)

```
R1            (0.4)                   ARMENTERO 68 DPWA  0 ELASTIC, CH EXCH
R1            (0.55)                  BAILEY    69 DPWA  0 ELASTIC, CH EXCH
R1            (0.15)                  ARMENTERO 70 DPWA  0 ELASTIC, CH EXCH
R1            (0.30)                  KIM       71 DPWA    K-MATRIX ANAL.
R1             0.36     0.05          LANGBEIN  72 IPWA    MULTICHANNEL
R1   B         0.52 OR  0.49          MARTIN    77 DPWA    KBAR N MULTICHNL
R1   C        (0.21)   (0.04)         RLIC      77 DPWA    KBAR N MULTICHNL
R1   C  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1             0.24    (0.04)         GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Lambda(1800)$ in $N\bar{K} \rightarrow \Sigma\pi$ SQRT(P1*P2)

```
R2   D        (+0.20)                 ARMENTERO 70 DPWA  0 K-P TO SIGMA PI
R2   D  PUBLISHED SIGN CHANGED TO AGREE WITH LUND 1969 CONVENTION (SEE NOTE
R2   D  ON LAMBDA AND SIGMA RESONANCES).
R2   A        (-0.13)   (0.03)        GALTIERI  70 DPWA  0 K-P TO SIGMA PI
R2            (0.17)                  KIM       71 DPWA    K-MATRIX ANAL.
R2            (0.01) OR LESS          LANGBEIN  72 IPWA    MULTICHANNEL
R2   B        +0.25 OR +0.23          MARTIN    77 DPWA    KBAR N MULTICHNL
R2            -0.24     0.04          RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Lambda(1800)$ in $N\bar{K} \rightarrow \Sigma(1385)\ \pi$ SQRT(P1*P3)

```
R3            +0.18     0.10          PREVOST   74 DPWA 0- K-N TO S(1385)PI
```

$\Lambda(1800)$ in $N\bar{K} \rightarrow N K^{*}(892)$, $P1$-wave SQRT(P1*P4)

```
R4   E        -0.14     0.03          CAMERON2  78 DPWA    K-P TO K*N
R4   E  THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R4   E  CONVENTION.
```

$\Lambda(1800)$ in $N\bar{K} \rightarrow N K^{*}(892)$, $P3$-wave SQRT(P1*P5)

```
R5            +0.35     0.06          CAMERON2  78 DPWA    K-P TO K*N
```

REFERENCES FOR Λ(1800)

```
ARMENTER 68 NP B8 195          ARMENTEROS, BAILLON, +     (CERN+HEID+SACL)IJP
BAILEY   69 THESIS UCRL-50617 DAVID SAAL BAILEY                      (LLL)IJP
ARMENTER 70 DUKE CONF 123      ARMENTEROS, BAILLON, +          (CERN+HEID)IJP
GALTIERI 70 DUKE CONF 173      A BARBARO-GALTIERI                    (LRL)IJP
KIM      71 PRL 27 356         J K KIM                              (HARV)IJP
   ALSO  70 DUKE 161           J K KIM                              (HARV)IJP
LANGBEIN 72 NP B47 477         +WAGNER                              (MPIM)IJP
PREVOST  74 NP B69 246         PREVOST,BARLOUTAUD,+       (SACL+CERN+HEID)
CARROLL  76 PRL 37 806         +CHIANG,KYCIA,LI,MAZUR,MICHAEL+        (BNL)I
MARTIN   77 NP B127 349        MARTIN,PIDCOCK,MOORHOUSE        (LOUC+GLAS)IJP
   ALSO  77 NP B126 266        MARTIN,PIDCOCK                       (LOUC)
   ALSO  77 NP B126 285        MARTIN,PIDCOCK                       (LOUC)IJP
RLIC     77 NP B119 362        GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
CAMERON2 78 NP B146 327        +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                            (RHEL)IJP
```

Λ(1820) F_{05}

$I(J^P) = 0(\frac{5}{2}^-)$ Status: * * * *

FOR MOST RESULTS PUBLISHED BEFORE 1973 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

MOST OF THE QUOTED ERRORS ARE STATISTICAL ONLY. THE SYSTEMATIC ERRORS DUE TO THE PARTICULAR PARAMETRIZATIONS USED IN THE P.W.A. ARE NOT INCLUDED. FOR THIS REASON WE DO NOT CALCULATE WEIGHTED AVERAGES FOR THE MASS AND WIDTH.

Λ(1820) MASS (MeV)

```
M          1821.0     (2.0)           KANE      74 DPWA    K-P TO PI SIG
M         (1830.0)                    DECLAIS   77 DPWA    KBAR N TO KBAR N
M    A     1817. OR 1819.             MARTIN    77 DPWA    KBAR N MULTICHNL
M    A  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M    A  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1822.0     (2.0)           RLIC      77 DPWA    KBAR N MULTICHNL
M          1819.0     (2.0)           ALSTON    78 DPWA    KBAR N ELASTIC
M          1823.0     (3.0)           GOPAL     80 DPWA    KBAR N ELASTIC
```

Λ(1820) WIDTH (MeV)

```
W            87.0     (3.0)           KANE      74 DPWA    K-P TO PI SIG
W           (82.0)                    DECLAIS   77 DPWA    KBAR N TO KBAR N
W    A       76. OR 76.               MARTIN    77 DPWA    KBAR N MULTICHNL
W            81.0     (5.0)           RLIC      77 DPWA    KBAR N MULTICHNL
W            72.0     (5.0)           ALSTON    78 DPWA    KBAR N ELASTIC
W            77.0     (5.0)           GOPAL     80 DPWA    KBAR N ELASTIC
```

Λ(1820) PARTIAL DECAY MODES

```
                                                      DECAY MASSES
P1     Λ(1820) → N K̄                                   938- 494
P2     Λ(1820) → Σπ                                   1189- 140
P3     Λ(1820) → Σππ                                  1192+ 140- 140
P4     Λ(1820) → Λη                                   1116+ 549
P5     Λ(1820) → Σ(1385) π, P-wave                    1385+ 140
P6     Λ(1820) → Σ(1385) π, F-wave                    1385+ 140
```

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above. only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1        P 2        P 3        P 4        P 5        P 6

 P 1 .5940+-.0304
 P 2   -.2306  .1320+-.0288
 P 3   -.2081     .0481  .1046+-.0293
 P 4   -.3697    -.5263    -.5507  .1468+-.0447
 P 5   -.0910     .0210     .0190    -.1571  .0155+-.0086
 P 6   -.0568     .0131     .0118    -.1198     .0052  .0071+-.0063
```

Λ(1820) BRANCHING RATIOS

ERRORS QUOTED BY EXPERIMENTERS DO NOT INCLUDE UNCERTAINTY DUE TO PARAMETRIZATION USED IN THE P.W.A. THEY SHOULD BE INCREASED.

$\Lambda(1820) \rightarrow (N\bar{K})$/total (P1)

```
R1            (0.51)                  DECLAIS   77 DPWA    KBAR N TO KBAR N
R1   A         0.59 OR  0.58          MARTIN    77 DPWA    KBAR N MULTICHNL
R1   B        (0.57)   (0.02)         RLIC      77 DPWA    KBAR N MULTICHNL
R1   B  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1             0.60     0.03          ALSTON    78 DPWA    KBAR N ELASTIC
R1             0.58    (0.02)         GOPAL     80 DPWA    KBAR N ELASTIC
R1          . . . . . . . . . . . .
R1   FIT       0.594    0.030   FROM FIT
```

$\Lambda(1820)$ in $N\bar{K} \rightarrow \Sigma\pi$ SQRT(P1*P2)

```
R2            -0.28    (0.01)         KANE      74 DPWA    K-P TO PI SIG
R2   A        -0.25 OR -0.25          MARTIN    77 DPWA    KBAR N MULTICHNL
R2            -0.28     0.03          RLIC      77 DPWA    KBAR N MULTICHNL
R2          . . . . . . . . . . . .
R2   FIT       0.280    0.030   FROM FIT
```

$\Lambda(1820)$ in $N\bar{K} \rightarrow \Lambda\eta$ SQRT(P1*P4)

```
R3            -0.096    0.040    0.020 RADER     73 MPWA
R3          . . . . . . . . . . . .
R3   FIT       0.096    0.026   FROM FIT
```

$\Lambda(1820) \rightarrow (\Sigma(1385)\ \pi)$/total (P5)

```
R4             0.20     0.05          BIRGE     65 HBC   0 K-P TO LAM PI PI
R4          . . . . . . . . . . . .
R4   FIT       0.105    0.029   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5)
```

$\Lambda(1820) \rightarrow (\Sigma\pi\pi)$/total (P3)

```
R5   C     NO CLEAR SIGNAL            ARMENT-4  68 HDBC  0 K-N TO SIG PI PI
R5   C  THERE IS A SUGGESTION OF A BUMP, ENOUGH TO BE CONSISTENT WITH
R5   C  WHAT IS EXPECTED FROM SIGMA(1385) TO SIGMA PI DECAY -- ABOUT 0.02.
R5          . . . . . . . . . . . .
R5   FIT       0.147    0.045   FROM FIT
```

$\Lambda(1820)$ in $N\bar{K} \rightarrow \Sigma(1385)\ \pi$, P-wave SQRT(P1*P5)

```
R6            +0.27     0.03          PREVOST   74 DPWA 0- K-N TO S(1385)PI
R6   D        -0.167    0.054         CAMERON   78 DPWA  0 K-P TO S(1385)PI
R6   D  THE SIGN HERE AND IN R7 IS CHANGED TO BE IN ACCORD WITH THE
R6   D  BARYON-FIRST CONVENTION.
R6          . . . . . . . . . . . .
R6   AVG MOD   0.246    0.044    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)
R6   FIT       0.249    0.034   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5)
```

$\Lambda(1820)$ in $N\bar{K} \rightarrow \Sigma(1385)\ \pi$, F-wave SQRT(P1*P6)

```
R7   D        +0.065    0.029         CAMERON   78 DPWA  0 K-P TO S(1385)PI
R7          . . . . . . . . . . . .
R7   FIT       0.065    0.029   FROM FIT
```

REFERENCES FOR Λ(1820)

```
CHAMBERL 62 PR 125 1696        CHAMBERLAIN,CROWE,KEEFE,KERTH, +       (LRL) I
GALTIERI 63 PL 6 296           A BARBARO-GALTIERI,A HUSSAIN,R D TRIPP(LRL)IJ
SODICKSO 64 PR 133 B757        SODICKSON,MANNELLI,FRISCH,WAHLIG  (MIT+BNL) J
BIRGE    65 ATHENS CONF  296   +ELY,KALMUS,KERNAN,LOUIE,SAHOURIA, +  (LRL)IJP
HOLLEY   65 UCRL-16274 THESIS W R HOLLEY                              (LRL) J
BIRMINGH 66 PR 152 1148                             (BIRM+GLAS+LOIC+OXF+RHEL)
COOL     66 PRL 16 1228        +GIACOMELLI,KYCIA,LEONTIC,LUNDBY +     (BNL)I
GELFAND  66 PRL 17 1224        +HARMSEN,LEVI-SETTI,PREDAZZI+     (EFI+ANL)
ARMENTER 67 NP B3 592          ARMENTEROS,FERRO-LUZZI+     (CERN+HEID+SACL)IJP
ARMENT-1 67 PL 24B 198         ARMENTEROS, F LUZZI, +      (CERN+HEID+SACL)IJP
ARMENT-2 67 ZPHY 202 486       ARMENTEROS, F LUZZI, +      (CERN+HEID+SACL)IJP
BELL     67 PRL 19 936         R B BELL                               (LRL)IJP
ARMENT-3 68 NP B8 195          ARMENTEROS, BAILLON, +      (CERN+HEID+SACL)IJP
ARMENT-4 68 NP B8 216          ARMENTEROS, BAILLON, +      (CERN+HEID+SACL) I
BUGG     68 PR 168 1466        +GILMORE, KNIGHT,      +    (RHEL+BIRM+CAVE) I
CONFORTO 68 NP B8 265          +HARMSEN, LASINSKI, +            (CHIC+HEID)IJP
LASINSKI 68 PR 163 1792        LASINSKI, LEVI SETTI, PREDAZZI        (CHIC) JP
```

```
BRICMAN  70 PL 31B 152          +FERRO LUZZI, PERREAU,+    (CERN+CAEN+SACL)
BRICMAN1 70 PL 33B 511          +FERRO-LUZZI,LAGNAUX                 (CERN)
COOL     70 PR D1 1887          +GIACOMELLI, KYCIA, LEONTIC, LI, +    (BNL) I
GALTIERI 70 DUKE CONF 173       A BARBARO-GALTIERI                    (LRL)IJP
CONFORTO 71 NP  B34  41         +LEVI SETTI,LASINSKI..OBERLACK+  (EFI+HEID)IJP
KIM      71 PRL 27 356          J K KIM                              (HARV)IJP
    ALSO 70 DUKE 161            J K KIM                              (HARV)IJP
PREVOST  71  AMSTERDAM CONF     + CHS COLLABORATION        (CERN+HEID+SACL)
KANE     72 PR D5 1583          D F KANE                              (LBL)IJP
LANGBEIN 72 NP B47 477          +WAGNER                              (MPIM)IJP
RADER    73 NC 16A 178          +BARLOUTAUD,+    (SACL+HEID+CERN+RHEL+CDEF)
KANE     74  LBL-2452           D F KANE                              (LBL)IJP
PREVOST  74 NP B69 246          PREVOST,BARLOUTAUD,+       (SACL+CERN+HEID)
DECLAIS  77  CERN 77-16         +DUCHON,LOUVEL,PATRY,SEGUINOT+  (CAEN+CERN)IJP
MARTIN   77 NP B127 349         MARTIN,PIDCOCK,MOORHOUSE        (LOUC+GLAS)IJP
    ALSO 77 NP B126 266         MARTIN,PIDCOCK                       (LOUC)
    ALSO 77 NP B126 285         MARTIN,PIDCOCK                       (LOUC)IJP
RLIC     77 NP B119 362         GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182          +KENNEY,POLLARD,ROSS+      (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007         ALSTON-GARNJOST,KENNEY,+   (LBL+MTHO+CERN)IJP
CAMERON  78 NP B143 189         +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                              (RHEL)IJP
```

Λ(1830) D_{05}

$I(J^P) = 0(\frac{5}{2}^-)$ Status: * * * *

FOR RESULTS PUBLISHED BEFORE 1973 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

THE BEST EVIDENCE FOR THIS RESONANCE COMES FROM THE SIGMA PI CHANNEL.

Λ(1830) MASS (MeV)

```
M          1825.0     (1.0)             KANE       74 DPWA    K-P TO PI SIG
M     A    1817. OR 1818.               MARTIN     77 DPWA    KBAR N MULTICHNL
M     A  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M     A  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1825.0    (10.0)             RLIC       77 DPWA    KBAR N MULTICHNL
M          1831.0    (10.0)             GOPAL      80 DPWA    KBAR N ELASTIC
```

Λ(1830) WIDTH (MeV)

```
W           119.0     (3.0)             KANE       74 DPWA    K-P TO PI SIG
W     A      56. OR 56.                 MARTIN     77 DPWA    KBAR N MULTICHNL
W            94.0    (10.0)             RLIC       77 DPWA    KBAR N MULTICHNL
W           100.0    (10.0)             GOPAL      80 DPWA    KBAR N ELASTIC
```

Λ(1830) PARTIAL DECAY MODES

		DECAY MASSES
P1	Λ(1830) → $N\bar{K}$	938+ 494
P2	Λ(1830) → $\Sigma\pi$	1189+ 140
P3	Λ(1830) → Σ(1385) π, D-wave	1385+ 140
P4	Λ(1830) → $\Lambda\eta$	1116+ 549

Λ(1830) BRANCHING RATIOS

Λ(1830) → ($N\bar{K}$)/total (P1)

```
R1    A      0.04 OR  0.04              MARTIN     77 DPWA    KBAR N MULTICHNL
R1    B     (0.04)   (0.03)             RLIC       77 DPWA    KBAR N MULTICHNL
R1    B  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1           0.02    (0.02)             ALSTON     78 DPWA    KBAR N ELASTIC
R1           0.08    (0.03)             GOPAL      80 DPWA    KBAR N ELASTIC
```

Λ(1830) in $N\bar{K}$ → $\Sigma\pi$ SQRT(P1*P2)

```
R2          -0.15    (0.01)             KANE       74 DPWA    K-P TO PI SIG
R2    A     -0.17 OR -0.17              MARTIN     77 DPWA    KBAR N MULTICHNL
R2          -0.17    (0.03)             RLIC       77 DPWA    KBAR N MULTICHNL
```

Λ(1830) in $N\bar{K}$ → $\Lambda\eta$ SQRT(P1*P4)

```
R3           -0.044    0.020            RADER      73 MPWA
```

Λ(1830) in $N\bar{K}$ → Σ(1385) π, D-wave SQRT(P1*P3)

```
R4           +0.13     0.03             PREVOST    74 DPWA 0- K-N TO S(1385)PI
R4    C      +0.141    0.014            CAMERON    78 DPWA  0 K-P TO S(1385)PI
R4    C  CAMERON  78 UPPER LIMIT ON G-WAVE DECAY IS 0.03.  THE SIGN HERE IS
R4    C  CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION.
```

REFERENCES FOR Λ(1830)

```
ARMENTER 67 PL 24B 198          ARMENTEROS, F-LUZZI, +     (CERN+HEID+SACL)IJP
BELL     67 PRL 19 936          R B BELL                              (LRL)IJP
ARMENTER 68 NP B8 195           ARMENTEROS, BAILLON, +     (CERN+HEID+SACL)IJP
CONFORTO 68 NP B8 265           -HARMSEN, LASINSKI, +           (CHIC+HEID)IJP
    IS SUPERSEDED BY CONFORTO 71.
BRICMAN1 70 PL 33B 511          +FERRO-LUZZI,LAGNAUX                 (CERN)
GALTIERI 70 DUKE CONF 173       A BARBARO-GALTIERI                    (LRL)IJP
CONFORTO 71 NP  B34  41         +LEVI SETTI,LASINSKI..OBERLACK++ (EFI+HEID)IJP
KIM      71 PRL 27 356          J K KIM                              (HARV)IJP
    ALSO 70 DUKE 161            J K KIM                              (HARV)IJP
KANE     72 PR D5 1583          D F KANE                              (LBL)IJP
LANGBEIN 72 NP B47 477          +WAGNER                              (MPIM)IJP
RADER    73 NC 16A 178          +BARLOUTAUD,+    (SACL+HEID+CERN+RHEL+CDEF)
KANE     74  LBL-2452           D F KANE                              (LBL)IJP
PREVOST  74 NP B69 246          PREVOST,BARLOUTAUD,-       (SACL+CERN+HEID)
MARTIN   77 NP B127 349         MARTIN,PIDCOCK,MOORHOUSE        (LOUC+GLAS)IJP
    ALSO 77 NP B126 266         MARTIN,PIDCOCK                       (LOUC)
    ALSO 77 NP B126 285         MARTIN,PIDCOCK                       (LOUC)IJP
RLIC     77 NP B119 362         GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182          +KENNEY,POLLARD,ROSS+      (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007         ALSTON-GARNJOST,KENNEY,+   (LBL+MTHO+CERN)IJP
CAMERON  78 NP B143 189         +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                              (RHEL)IJP
```

Λ(1890) P_{03}

$I(J^P) = 0(\frac{3}{2}^+)$ Status: * * * *

FOR RESULTS PUBLISHED BEFORE 1974 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

THE JP=3/2+ ASSIGNMENT IS CONSISTENT WITH ALL AVAILABLE DATA (INCLUDING POLARIZATION) AND RECENT PARTIAL-WAVE ANALYSES. THE DOMINANT INELASTIC MODES REMAIN UNKNOWN.

Λ(1890) MASS (MeV)

```
M          1894.0     10.0              HEMINGWA  75 DPWA  0 K- P TO KBAR N
M     A   (1900.0)                      NAKKASYA  75 DPWA  0 K-P TO LAM. OMG.
M     A  FOUND IN ONE OF TWO BEST SOLUTIONS.
M          SEEN                         BACCARI   77 IPWA  0 K-P TO LAM. OMG.
M     B    1856. OR 1868.               MARTIN    77 DPWA    KBAR N MULTICHNL
M     B  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M     B  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1900.0      5.0              RLIC      77 DPWA    KBAR N MULTICHNL
M          1908.0     10.0              ALSTON    78 DPWA    KBAR N ELASTIC
M          1897.0     (5.0)             GOPAL     80 DPWA    KBAR N ELASTIC
```

Λ(1890) WIDTH (MeV)

```
W           107.0     10.0              HEMINGWA  75 DPWA  0 K- P TO KBAR N
W     A    (100.0)                      NAKKASYA  75 DPWA  0 K-P TO LAM. OMG.
W     B     191. OR 193.                MARTIN    77 DPWA    KBAR N MULTICHNL
W            72.0     10.0              RLIC      77 DPWA    KBAR N MULTICHNL
W           119.0     20.0              ALSTON    78 DPWA    KBAR N ELASTIC
W            74.0    (10.0)             GOPAL     80 DPWA    KBAR N ELASTIC
```

Λ(1890) PARTIAL DECAY MODES

		DECAY MASSES
P1	Λ(1890) → $N\bar{K}$	938+ 494
P2	Λ(1890) → $\Sigma\pi$	1189+ 140
P3	Λ(1890) → $\Lambda\omega$	1116+ 783
P4	Λ(1890) → Σ(1385) π, P-wave	1385+ 140
P5	Λ(1890) → Σ(1385) π, F-wave	1385+ 140
P6	Λ(1890) → $N K^*(892)$, $P1$-wave	940+ 892

Λ(1890) BRANCHING RATIOS

Λ(1890) → ($N\bar{K}$)/total (P1)

```
R1           0.24      0.04             HEMINGWA  75 DPWA  0 K- P TO KBAR N
R1    B      0.36 OR  0.34              MARTIN    77 DPWA    KBAR N MULTICHNL
R1    C     (0.18)   (0.02)             RLIC      77 DPWA    KBAR N MULTICHNL
R1    C  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1           0.34      0.05             ALSTON    78 DPWA    KBAR N ELASTIC
R1           0.20     (0.02)            GOPAL     80 DPWA    KBAR N ELASTIC
```

Λ(1890) → ($\Sigma\pi$)/total (P2)

```
R2          (0.03) OR LESS              LANGBEIN  72 IPWA    MULTICHANNEL
```

Λ(1890) in $N\bar{K}$ → $\Sigma\pi$ SQRT(P1*P2)

```
R3    B     +0.15 OR +0.14              MARTIN    77 DPWA    KBAR N MULTICHNL
R3          -0.09      0.03             RLIC      77 DPWA    KBAR N MULTICHNL
```

Λ(1890) in $N\bar{K}$ → $\Lambda\omega$ SQRT(P1*P3)

```
R4    A     (0.032)                     NAKKASYA  75 DPWA  0 K-P TO LAM. OMG.
```

Λ(1890) in $N\bar{K}$ → Σ(1385) π, P-wave SQRT(P1*P4)

```
R5         LESS THAN 0.03               CAMERON   78 DPWA  0 K-P TO S(1385)PI
```

Λ(1890) in $N\bar{K}$ → Σ(1385) π, F-wave SQRT(P1*P5)

```
R6    D     -0.126    0.055             CAMERON   78 DPWA  0 K-P TO S(1385)PI
R6    D  SIGN CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION.
```

Λ(1890) in $N\bar{K}$ → $N K^*(892)$, $P1$-wave SQRT(P1*P6)

```
R7    E     -0.07     0.03              CAMERON2  78 DPWA    K-P TO K*N
R7    E  THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R7    E  CONVENTION.  UPPER LIMITS ON THE P3 AND F3 WAVES ARE EACH 0.03.
```

REFERENCES FOR Λ(1890)

```
ARMENTER 67 NP B3 592           ARMENTEROS, F-LUZZI, +     (CERN+HEID+SACL)IJP
ARMENTERO68 NP B8 195           ARMENTEROS, BAILLON, +     (CERN+HEID+SACL)IJP
BUGG     68 PR 168 1466         +GILMORE, KNIGHT, +        (RHEL+BIRM+CAVE) I
CONFORTO 68 NP B8 265           +HARMSEN, LASINSKI, +           (CHIC+HEID)IJP
GALTIERI 68 PRL 21 573          BARBARO-GALTIERI, MATISON, +    (LRL+SLAC)
LEVISETT 69 LUND 339            R LEVI SETTI  (RAPPORTEUR)            (EFI)
BRICMAN  70 PL 31B 152          +FERRO LUZZI, PERREAU,+    (CERN+CAEN+SACL)
BRICMAN1 70 PL 33B 511          +FERRO LUZZI LAGNAUX                 (CERN)
```

```
ALBROW   71 NP  B29 413          +ANDERSON,BOSNJAKOVIC,DAUM,ERNZ,+    (CERN)
CONFORTO 71 NP  B34  41          +LEVI SETTI,LASINSKI..OBERLACK++ (EFI+HEID)IJP
KIM      71 PRL 27 356           J K KIM                              (HARV)IJP
   ALSO  70 DUKE 161             J K KIM                              (HARV)IJP
LANGBEIN 72 NP B47 477           +WAGNER                              (MPIM)IJP
LEA      73 NP B56 77            +MARTIN,MOORHOUSE+    (RHEL+LOUC+GLAS+AARH)IJP
HEMINGWA 75 NP B91 12            HEMINGWAY,EADES,HARMSEN+   (CERN+HEID+MPIM)IJP
NAKKASYA 75 NP B93 85            A NAKKASYAN                          (CERN)IJP
BACCARI  77 NC 41A 96            +POULARD,REVEL,TALLINI+         (SACL+CDEF)IJP
MARTIN   77 NP B127 349          MARTIN,PIDCOCK,MOORHOUSE        (LOUC+GLAS)IJP
   ALSO  77 NP B126 266          MARTIN,PIDCOCK                       (LOUC)
   ALSO  77 NP B126 285          MARTIN,PIDCOCK                       (LOUC)IJP
RLIC     77 NP B119 362          GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182           +KENNEY,POLLARD,ROSS+       (LBL+MTHO+CERN)IJP
   ALSO  77 PRL 38 1007          ALSTON-GARNJOST,KENNEY,+    (LBL+MTHO+CERN)IJP
CAMERON  78 NP B143 189          +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)IJP
CAMERON2 78 NP B146 327          +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159    G P GOPAL                            (RHEL)IJP
```

Λ(2000)

$I(J^P) = 0(\ \ )$ Status: *

OMITTED FROM SUMMARY TABLE

WE LIST HERE ALL THE AMBIGUOUS RESONANCE POSSIBLITIES WITH A MASS AROUND 2 GEV. THE PROPOSED QUANTUM NUMBERS ARE D3 (GALTIERI 70 IN SIGMA PI), D3+F5, P3+D5, OR P1+D3 (BRANDSTETTER 72 IN LAMBDA OMEGA), AND S1 (CAMERON2 78 IN N K*). THE FIRST TWO OF THE ABOVE ANALYSES SHOULD NOW BE CONSIDERED OBSOLETE.

Λ(2000) MASS (MeV)

```
M          (2010.0)   (30.0)             GALTIERI  70 DPWA  0 K-P TO SIGMA PI
M     A     1935. TO 1971.               BRANDSTE  72 DPWA  0 K-P TO LAM. OMG.
M     A     1951. TO 2034.               BRANDSTE  72 DPWA  0 K-P TO LAM. OMG.
M     A  PARAMETERS QUOTED ARE RANGES FROM THREE BEST FITS, THE LOWER
M     A  (HIGHER) MASS STATE PROBABLY HAS J.LE.3/2(5/2).
M           2030.0     30.0              CAMERON2  78 DPWA    K-P TO K*(892) N
```

Λ(2000) WIDTH (MeV)

```
W           (130.0)   (50.0)             GALTIERI  70 DPWA  0 K-P TO SIGMA PI
W     A      180. TO  240. (LWR. MASS)   BRANDSTE  72 DPWA  0 K-P TO LAM. OMG.
W     A       73. TO  154. (HGR. MASS)   BRANDSTE  72 DPWA  0 K-P TO LAM. OMG.
W            125.0     25.0              CAMERON2  78 DPWA    K-P TO K*(892) N
```

Λ(2000) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda(2000) \to N\overline{K}$	938+ 494
P2	$\Lambda(2000) \to \Sigma\pi$	1189+ 140
P3	$\Lambda(2000) \to \Lambda\omega$	1116+ 783
P4	$\Lambda(2000) \to NK^*(892)$, $S1$-wave	940+ 892
P5	$\Lambda(2000) \to NK^*(892)$, $D3$-wave	940+ 892

Λ(2000) BRANCHING RATIOS

Λ(2000) in $N\overline{K} \to \Sigma\pi$ SQRT(P1*P2)

```
R1            (-0.20)   (0.04)           GALTIERI  70 DPWA  0 K-P TO SIGMA PI
```

Λ(2000) in $N\overline{K} \to \Lambda\omega$ SQRT(P1*P3)

```
R2    A        0.17  TO 0.25 (LWR.)      BRANDSTE  72 DPWA  0 K-P TO LAM. OMG.
R2    A        0.04  TO 0.15 (HGR.)      BRANDSTE  72 DPWA  0 K-P TO LAM. OMG.
```

Λ(2000) in $N\overline{K} \to NK^*(892)$, $S1$-wave SQRT(P1*P4)

```
R3    B       -0.12      0.03            CAMERON2  78 DPWA    K-P TO K*N
R3    B  THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R3    B  CONVENTION.
```

Λ(2000) in $N\overline{K} \to NK^*(892)$, $D3$-wave SQRT(P1*P5)

```
R4            +0.09      0.03            CAMERON2  78 DPWA    K-P TO K*N
```

REFERENCES FOR Λ(2000)

```
GALTIERI 70 DUKE CONF 173      A BARBARO-GALTIERI                  (LRL)IJP
BRANDSTE 72 NP B39 13          BRANDSTETTER,BUTTERWORTH,+ (RHEL+CDEF+SACL)
CAMERON2 78 NP B146 327        +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP

                               PAPERS NOT REFERRED TO IN DATA LISTINGS

NAKKASYA 75 NP B93 85          A NAKKASYAN                        (CERN)IJP
```

Λ(2020) F_{07}

$I(J^P) = 0(\frac{7}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

EFFECTS IN THIS PARTIAL WAVE HAVE BEEN OBSERVED AT DIFFERENT ENERGIES IN TWO CHANNELS. IN LITCHFIELD 71, NEED FOR THE STATE RESTS SOLELY ON POSSIBLY INCONSISTENT POLARIZATION MEASUREMENT AT 1.784 GEV/C. HEMINGWAY 75 ANALYSIS OF N KBAR DOES NOT REQUIRE THIS STATE. RLIC 77 DO NOT NEED IT IN EITHER N KBAR OR SIGMA PI. WITH NEW K- NEUTRON ANGULAR DISTRIBUTIONS INCLUDED, DECLAIS 77 SEE THIS STATE. HOWEVER, THIS AND OTHER NEW DATA ARE INCLUDED IN GOPAL 80 AND THIS STATE IS NOT REQUIRED. BACARI 77 WEAKLY SUPPORTS THIS STATE.

Λ(2020) MASS (MeV)

```
M          (2020.0)   (20.0)             GALTIERI  70 DPWA  0 K-P TO SIGMA PI
M          (2100.0)   (30.0)             LITCHFIE  71 DPWA    K-P TO KBAR N
M          (2140.0)                      BACCARI   77 DPWA  0 K-P TO LAM. OMG.
M          (2117.0)                      DECLAIS   77 DPWA    KBAR N TO KBAR N
```

Λ(2020) WIDTH (MeV)

```
W           (160.0)   (30.0)             GALTIERI  70 DPWA  0 K-P TO SIGMA PI
W           (120.0)   (30.0)             LITCHFIE  71 DPWA    K-P TO KBAR N
W           (128.0)                      BACCARI   77 DPWA  0 K-P TO LAM. OMG.
W           (167.0)                      DECLAIS   77 DPWA    KBAR N TO KBAR N
```

Λ(2020) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda(2020) \to N\overline{K}$	938+ 494
P2	$\Lambda(2020) \to \Sigma\pi$	1189+ 140
P3	$\Lambda(2020) \to \Lambda\omega$	1116+ 783

Λ(2020) BRANCHING RATIOS

Λ(2020) → $(N\overline{K})$/total (P1)

```
R1             (0.05)   (0.02)           LITCHFIE  71 DPWA    K-P TO KBAR N
R1             (0.05)                    DECLAIS   77 DPWA    KBAR N TO KBAR N
```

Λ(2020) in $N\overline{K} \to \Sigma\pi$ SQRT(P1*P2)

```
R2            (-0.15)   (0.02)           GALTIERI  70 DPWA  0 K-P TO SIGMA PI
```

Λ(2020) in $N\overline{K} \to \Lambda\omega$ SQRT(P1*P3)

```
R3             LESS THAN 0.05            BACCARI   77 DPWA  0 K-P TO LAM. OMG.
```

REFERENCES FOR Λ(2020)

```
GALTIERI 70 DUKE CONF 173      A BARBARO-GALTIERI                  (LRL)IJP
LITCHFIE 71 NP  B30 125        LITCHFIELD,...-LESQUOY,+.. (RHEL+CDEF+SACL)IJP
BACCARI  77 NC 41A 96          +POULARD,REVEL,TALLINI+       (SACL+CDEF)IJP
DECLAIS  77  CERN 77-16        +DUCHON,LOUVEL,PATRY,SEGUINOT-  (CAEN+CERN)IJP

                               PAPERS NOT REFERRED TO IN DATA LISTINGS

HEMINGWA 75 NP B91 12          HEMINGWAY,EADES,HARMSEN+  (CERN+HEID+MPIM)IJP
```

Λ(2100) G_{07}

$I(J^P) = 0(\frac{7}{2}^-)$ Status: * * * *

FOR MOST RESULTS PUBLISHED BEFORE 1973 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

THIS ENTRY ONLY INCLUDES RESULTS FROM PARTIAL-WAVE ANALYSES. PARAMETERS OF PEAKS SEEN IN CROSS SECTIONS AND INVARIANT-MASS DISTRIBUTIONS AROUND 2100 MEV ARE GIVEN IN A SEPARATE ENTRY BELOW.

Λ(2100) MASS (MeV)

```
M           2115.0     (10.0)            KANE      74 DPWA    K-P TO PI SIG
M           2105.0     (10.0)            HEMINGWAY 75 DPWA  0 K- P TO KBAR N
M     A     2110. OR 2089.               NAKKASYA  75 DPWA  0 K-P TO LAM. OMG.
M     A  QUOTED PARAMETERS CORRESPOND TO THE TWO BEST SOLUTIONS FOUND.
M     A  EACH HAS THE LAMBDA(2100) AND ONE ADDITIONAL RESONANCE (P3 OR F5).
M          (2094.0)                      BACCARI   77 DPWA  0 K-P TO LAM. OMG.
M          (2094.0)                      DECLAIS   77 DPWA    KBAR N TO KBAR N
M           2110.0     (10.0)            RLIC      77 DPWA    KBAR N MULTICHNL
M           2106.0     (30.0)            BELLEFON  78 DPWA  0 KBAR N TO KBAR N
M           2104.0     (10.0)            GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Lambda(2100)$ WIDTH (MeV)

```
W             152.0    (15.0)             KANE      74 DPWA    K-P TO PI SIG
W             241.0    (30.0)             HEMINGWAY 75 DPWA  0 K- P TO KBAR N
W     A       244. OR  302.               NAKKASYA  75 DPWA  0 K-P TO LAM. OMG.
W             (98.0)                      BACCARI   77 DPWA  0 K-P TO LAM. OMG.
W            (250.0)                      DECLAIS   77 DPWA    KBAR N TO KBAR N
W             250.0    (30.0)             RLIC      77 DPWA    KBAR N MULTICHNL
W             157.0    (40.0)             BELLEFON  78 DPWA  0 KBAR N TO KBAR N
```

$\Lambda(2100)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda(2100) \rightarrow N\overline{K}$	938+ 494
P2	$\Lambda(2100) \rightarrow \Sigma\pi$	1189+ 140
P3	$\Lambda(2100) \rightarrow \Xi K$	1321+ 498
P4	$\Lambda(2100) \rightarrow \Lambda\omega$	1116+ 783
P5	$\Lambda(2100) \rightarrow \Lambda\eta$	1116+ 549
P6	$\Lambda(2100) \rightarrow N\,K^{*}(892)$, $D3$-wave	940+ 892
P7	$\Lambda(2100) \rightarrow N\,K^{*}(892)$, $G1$-wave	940+ 892

$\Lambda(2100)$ BRANCHING RATIOS

$\Lambda(2100) \rightarrow (N\overline{K})$/total (P1)

```
R1             0.31    (0.03)             HEMINGWA  75 DPWA  0 K- P TO KBAR N
R1            (0.29)                      DECLAIS   77 DPWA    KBAR N TO KBAR N
R1   C        (0.30)   (0.03)             RLIC      77 DPWA    KBAR N MULTICHNL
R1   C  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1             0.24    (0.06)             BELLEFON  78 DPWA  0 KBAR N TO KBAR N
R1             0.34    (0.03)             GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Lambda(2100)$ in $N\overline{K} \rightarrow \Sigma\pi$ SQRT(P1*P2)

```
R2            +0.11    (0.01)             KANE      74 DPWA    K-P TO PI SIG
R2            +0.12    (0.04)             RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Lambda(2100)$ in $N\overline{K} \rightarrow \Xi K$ SQRT(P1*P3)

```
R3            (0.05)                      TRIPP     67 RVUE  0 K-P TO XI K
R3            (0.003)                     MULLER    69 DPWA  0
R3             0.035    0.018             LITCHFIE  71 DPWA    K-P TO XI K
```

$\Lambda(2100)$ in $N\overline{K} \rightarrow \Lambda\omega$ SQRT(P1*P4)

```
R4   A         0.122 OR 0.154             NAKKASYA  75 DPWA  0 K-P TO LAM. OMG.
R4  D         (-0.070)                    BACCARI   77 DPWA  0 GD37-WAVE
R4  D         (+0.011)                    BACCARI   77 DPWA  0 GG17-WAVE
R4  D         (+0.008)                    BACCARI   77 DPWA  0 GG37-WAVE
R4  D   NOTE THAT THE 3 ENTRIES FOR BACCARI77 ARE FOR 3 DIFFERENT WAVES.
```

$\Lambda(2100)$ in $N\overline{K} \rightarrow \Lambda\eta$ SQRT(P1*P5)

```
R5            -0.050    0.020             RADER     73 MPWA
```

$\Lambda(2100)$ in $N\overline{K} \rightarrow N\,K^{*}(892)$, $D3$-wave SQRT(P1*P6)

```
R6            -0.21     0.04              CAMERON2  78 DPWA    K-P TO K*N
```

$\Lambda(2100)$ in $N\overline{K} \rightarrow N\,K^{*}(892)$, $G1$-wave SQRT(P1*P7)

```
R7   E        -0.04     0.03              CAMERON2  78 DPWA    K-P TO K*N
R7   E  THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R7   E  CONVENTION.  THE UPPER LIMIT ON THE G3-WAVE IS 0.03.
```

REFERENCES FOR $\Lambda(2100)$

```
WOHL     66 PRL 17 107        C G WOHL, F T SOLMITZ, M L STEVENSON  (LRL)IJP
TRIPP    67 NP B3 10          + LEITH, +      (LRL+SLAC+  CERN+HEID+SACL)
BURGUN   68 NP B8 447         +MEYER,PAULI, +              (SACL+CDEF+RHEL)
DAUM     68 NP B7 19          +ERNE, LAGNAUX, SENS, STEUER, UDO    (CERN)JP
MULLER   69 THESIS,UCRL 19372 R A MULLER                            (LRL)
BERTHON1 70 NP B24 417        +VRANA, BUTTERWORTH, +     (CDEF+RHEL+SACL)IJP
GALTIERI 70 DUKE CONF 173     A BARBARO-GALTIERI                    (LRL)IJP
LITCHFIE 71 NP  B30 125       LITCHFIELD,...+LESQUOY,+   (RHEL+CDEF+SACL)IJP
BRANDSTE 72 NP B39 13         BRANDSTETTER+...+TALLINI   (RHEL+CDEF+SACL)IJP
KANE     72 PR D5 1583        D F KANE                              (LBL)IJP
RADER    73 NC 16A 178        +BARLOUTAUD,+    (SACL+HEID+CERN+RHEL+CDEF)
KANE     74  LBL-2452         D F KANE                              (LBL)IJP
HEMINGWA 75 NP B91 12         HEMINGWAY,EADES,HARMSEN+   (CERN+HEID+MPIM)IJP
NAKKASYA 75 NP B93 85         A NAKKASYAN                          (CERN)IJP
BACCARI  77 NC 41A 96         +POULARD,REVEL,TALLINI+         (SACL+CDEF)IJP
DECLAIS  77  CERN 77-16       +DUCHON,LOUVEL,PATRY,SEGUINOT+  (CAEN+CERN)IJP
RLIC     77 NP B119 362       GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
BELLEFON 78 NC 42A 403        +BERTHON,BILLOIR,BRUNET+        (CDEF+SACL)IJP
CAMERON2 78 NP B146 327       +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                            (RHEL)IJP
```

2100 MeV REGION — PRODUCTION AND σ_{TOTAL} EXPTS

$I(J^P) = 0(\quad)$ Status: * * * *

SEE THE NOTE TO THE G07 LAMBDA(2100), IN FRONT OF THIS ENTRY. HERE WE LIST ONLY PARAMETERS OF PEAKS IN CROSS SECTIONS AND INVARIANT-MASS DISTRIBUTIONS. THE CROSS-SECTION PEAKS ARE AT LEAST DOMINANTLY ASSOCIATED WITH THE LAMBDA(2100), BUT MAY CONTAIN A SMALL CONTRIBUTION FROM THE SUGGESTED BUT NOT ESTABLISHED OTHER RESONANCES IN THIS REGION.

$\Lambda(2100)$ MASS (MeV) (PROD. EXP.)

```
M          (2097.0)     (6.0)             BOCK      65 HBC     PBAR P 5.7 GEV/C
M           2100.0      (7.0)             BUGG      68 CNTR    K-P, D TOTAL
M           2121.0      (5.0)             BRICMAN   70 CNTR  0 TOTAL AND CH EX
M           2107.0     (10.0)             COOL      70 CNTR    K-P, D TOTAL
M          (2135.0)    (20.0)             LU        70 CNTR  0 GAMMA P TO K+ Y*
```

$\Lambda(2100)$ WIDTH (MeV) (PROD. EXP.)

```
W            (24.0)    (14.0)    (24.0)   BOCK      65 HBC     INTO KBAR N (PI)
W            140.0     (15.0)             BUGG      68 CNTR
W            147.0     (15.0)             BRICMAN   70 CNTR  0 TOTAL AND CH EX
W            185.0                        COOL      70 CNTR    K-P, D TOTAL
W            (40.0)                       LU        70 CNTR  0 GAMMA P TO K+ Y*
```

$\Lambda(2100)$ PARTIAL DECAY MODES (PROD. EXP.)

		DECAY MASSES
P1	$\Lambda(2100) \rightarrow N\overline{K}$	938+ 494
P2	$\Lambda(2100) \rightarrow N\overline{K}\pi$	938+ 498+ 140
P3	$\Lambda(2100) \rightarrow \Lambda\eta$	1116+ 549
P4	$\Lambda(2100) \rightarrow \Lambda\omega$	1116+ 783

$\Lambda(2100)$ BRANCHING RATIOS (PROD. EXP.)

$\Lambda(2100) \rightarrow (N\overline{K})$/total (P1)

```
R1        THESE VALUES OF ELASTICITIES ASSUME J=7/2 --
R1            0.305                       BUGG      68 CNTR
R1            0.24     (0.02)             BRICMAN   70 CNTR  0 TOTAL AND CH EX
R1            0.4                         COOL      70 CNTR    K-P, D TOTAL
```

$\Lambda(2100) \rightarrow (N\overline{K}\pi)$/total (P2)

```
R2               SEEN                     BOCK      65 HBC
```

$\Lambda(2100)$ in $N\overline{K} \rightarrow \Lambda\eta$ SQRT(P1*P3)

```
R3          (0.09) OR LESS                FLATTE 2  67 HBC   0 K-P TO LAM ETA
```

$\Lambda(2100) \rightarrow (\Lambda\omega)$/total (P4)

```
R4          (0.1)  OR LESS                FLATTE 1  67 HBC   0 K-P TO LAM OMEGA
```

REFERENCES FOR $\Lambda(2100)$ (PROD. EXP.)

```
BOCK     65 PL 17 166         +COOPER,FRENCH,KINSON, +         (CERN+SACL)
COOL     66 PRL 16 1228       +GIACOMELLI,KYCIA,LEONTIC,LI,LUNDBY,+ (BNL) I
   SUPERSEDED BY COOL 70.
FLATTE 1 67 PR 155 1517       S M FLATTE                            (LRL)
FLATTE 2 67 PR 163 1441       S M FLATTE, C G WOHL                  (LRL)
BUGG     68 PR 168 1466       +GILMORE,KNIGHT, +         (RHEL+BIRM+CAVE) I
BRICMAN  70 PL 31B 152        +FERRO LUZZI, PERREAU,+    (CERN+CAEN+SACL)
COOL     70 PR D1 1887        +GIACOMELLI, KYCIA, LEONTIC, LI, +    (BNL) I
LU       70 PR D2 1846        +GREENBERG, HUGHES, MINEHART, MORI,+ (YALE)
```

$\Lambda(2110)$ F_{05}

$I(J^P) = 0(\frac{5}{2}^-)$ Status: * * *

FOR RESULTS PUBLISHED BEFORE 1974 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

THIS RESONANCE IS IN THE BARYON SUMMARY TABLE, BUT THE EVIDENCE FOR IT COULD BE IMPROVED.

$\Lambda(2110)$ MASS (MeV)

```
M            2112.0      7.0              KANE      74 DPWA    K-P TO PI SIG
M     A     (2103.0)                      NAKKASYA  75 DPWA  0 K-P TO LAM. OMG.
M     A   FOUND IN ONE OF TWO BEST SOLUTIONS.
M           (2137.0)                      BACCARI   77 DPWA  0 K-P TO LAM. OMG.
M            2140.0    (20.0)             BELLEFON  77 DPWA  0 K- P TO SIG PI
M            2100.0    (50.0)             RLIC      77 DPWA    KBAR N MULTICHNL
M            2106.0    (50.0)             BELLEFON  78 DPWA  0 KBAR N TO KBAR N
M            2125.0    (25.0)             CAMERON2  78 DPWA    K-P TO K*(892) N
M            2092.0    (25.0)             GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Lambda(2110)$ WIDTH (MeV)

```
W             190.0    (30.0)             KANE      74 DPWA    K-P TO PI SIG
W     A      (391.0)                      NAKKASYA  75 DPWA  0 K-P TO LAM. OMG.
W            (132.0)                      BACCARI   77 DPWA  0 K-P TO LAM. OMG.
W             140.0    (20.0)             BELLEFON  77 DPWA  0 K- P TO SIG PI
W             200.0    (50.0)             RLIC      77 DPWA    KBAR N MULTICHNL
W             251.0    (50.0)             BELLEFON  78 DPWA  0 KBAR N TO KBAR N
W             160.0    (30.0)             CAMERON2  78 DPWA    K-P TO K*(892) N
W             245.0    (25.0)             GOPAL     80 DPWA    KBAR N ELASTIC
```

Λ(2110) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda(2110) \to N\bar{K}$	938+ 494
P2	$\Lambda(2110) \to \Sigma\pi$	1189+ 140
P3	$\Lambda(2110) \to \Lambda\omega$	1116+ 783
P4	$\Lambda(2110) \to \Sigma(1385)\ \pi$, P-wave	1385+ 140
P5	$\Lambda(2110) \to N K^*(892)$, $F1$-wave	940+ 892

Λ(2110) BRANCHING RATIOS

Λ(2110) in $N\bar{K}$ → $\Sigma\pi$ SQRT(P1*P2)

R1		+0.20	(0.03)	KANE	74	DPWA		K-P TO PI SIG
R1		+0.14	(0.01)	BELLEFON	77	DPWA	0	K- P TO SIG PI
R1		(+0.10)	(0.03)	RLIC	77	DPWA		KBAR N MULTICHNL

Λ(2110) → ($N\bar{K}$)/total (P1)

R2	B	(0.07)	(0.03)	RLIC	77	DPWA		KBAR N MULTICHNL
R2	B	(N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.						
R2	C	0.27	(0.06)	BELLEFON	78	DPWA	0	KBAR N TO KBAR N
R2	C	THE PUBLISHED ERROR OF 0.6 WAS A MISPRINT.						
R2		0.07	(0.03)	GOPAL	80	DPWA		KBAR N ELASTIC

Λ(2110) in $N\bar{K}$ → $\Lambda\omega$ SQRT(P1*P3)

R3	A	(0.112)		NAKKASYA	75	DPWA	0	K-P TO LAM. OMG.
R3		LESS THAN 0.05		BACCARI	77	DPWA	0	K-P TO LAM. OMG.

Λ(2110) in $N\bar{K}$ → $\Sigma(1385)\ \pi$, P-wave SQRT(P1*P4)

R4	D	+0.071	0.025	CAMERON	78	DPWA	0	K-P TO S(1385)PI
R4	D	CAMERON 78 UPPER LIMIT ON F-WAVE DECAY IS 0.03. THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION.						

Λ(2110) in $N\bar{K}$ → $N K^*(892)$, $F1$-wave SQRT(P1*P5)

R5	E	-0.17	0.04	CAMERON2	78	DPWA		K-P TO K*N
R5	E	THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION. UPPER LIMITS ON THE P3 AND F3-WAVES ARE EACH 0.03.						

REFERENCES FOR Λ(2110)

BERTHON1 70 NP B24 417 +VRANA,BUTTERWORTH,+ (CDEF+RHEL+SACL)IJP
LITCHFIE 71 NP B30 125 LITCHFIELD,...+LESQUOY,+.. (RHEL+CDEF+SACL)IJP
KANE 72 PR D5 1583 D F KANE (LBL)IJP
KANE 74 LBL-2452 D F KANE (LBL)IJP
NAKKASYA 75 NP B93 85 A NAKKASYAN (CERN)IJP
BACCARI 77 NC 41A 96 +POULARD,REVEL,TALLINI+ (SACL+CDEF)IJP
BELLEFON 77 NC 37A 175 DE BELLEFON,BERTHON,BILLOIR+ (CDEF+SACL)IJP
RLIC 77 NP B119 362 GOPAL,ROSS,VAN HORN,MCPHERSON+ (LOIC+RHEL)IJP
BELLEFON 78 NC 42A 403 +BERTHON,BILLOIR,BRUNET+ (CDEF+SACL)IJP
CAMERON 78 NP B143 189 +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)IJP
CAMERON2 78 NP B146 327 +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP
GOPAL 80 TORONTO CONF 159 G P GOPAL (RHEL)IJP

Λ(2325) D_{03}

$I(J^P)=0(\frac{3}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

BACCARI 77 FIND THIS STATE WITH JP EITHER 3/2- OR 3/2+ IN A DPWA OF K- P TO LAMBDA OMEGA FROM 2070 TO 2436 MEV. A SUBSEQUENT SEMI-ENERGY-INDEPENDENT PWA FROM THRESHOLD TO 2436 MEV SELECTS 3/2-. BELLEFON 78 (SAME GROUP) ALSO SEE THIS STATE IN A DPWA OF K- P ELASTIC AND CHARGE-EXCHANGE DATA IN THE SAME ENERGY RANGE, AND FIND JP=3/2- OR 3/2+. THEY AGAIN PREFER JP=3/2-, BUT ONLY ON THE BASIS OF MODEL DEPENDENT CONSIDERATIONS.

Λ(2325) MASS (MeV)

M	2327.0	20.0	BACCARI	77	DPWA	0	K-P TO LAM. OMG.
M	2342.0	30.0	BELLEFON	78	DPWA	0	KBAR N TO KBAR N

Λ(2325) WIDTH (MeV)

W	160.0	40.0	BACCARI	77	IPWA	0	K-P TO LAM. OMG.
W	177.0	40.0	BELLEFON	78	DPWA	0	KBAR N TO KBAR N

Λ(2325) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Lambda(2325) \to N\bar{K}$	938+ 494
P2	$\Lambda(2325) \to \Lambda\omega$	1116+ 783

Λ(2325) BRANCHING RATIOS

Λ(2325) in $N\bar{K}$ → $\Lambda\omega$ SQRT(P1*P2)

R1	A	0.06	0.02	BACCARI	77	IPWA	0	DS33-WAVE
R1	A	0.05	0.02	BACCARI	77	DPWA	0	DD13-WAVE
R1	A	0.08	0.03	BACCARI	77	DPWA	0	DD33-WAVE
R1	A	NOTE THAT THE 3 ENTRIES FOR BACCARI77 ARE FOR 3 DIFFERENT WAVES.						

Λ(2325) → ($N\bar{K}$)/total (P1)

R2		0.19	0.06	BELLEFON	78	DPWA	0	KBAR N TO KBAR N

REFERENCES FOR Λ(2325)

BACCARI 77 NC 41A 96 +POULARD,REVEL,TALLINI+ (SACL+CDEF)IJP
BELLEFON 78 NC 42A 403 +BERTHON,BILLOIR,BRUNET+ (CDEF+SACL)IJP

Λ(2350) BUMPS

$I(J^P)=0(\frac{9}{2}^+)$ Status: * * *

DAUM 68 FAVORS JP=7/2- OR 9/2+. BRICMAN 70 FAVORS 9/2+. LASINSKI 71 SUGGESTS THREE STATES IN THIS REGION USING A POMERON - RESONANCES MODEL. THERE ARE NOW ALSO THREE FORMATION EXPERIMENTS FROM THE COLLEGE DE FRANCE-SACLAY GROUP WHICH WE INCLUDE HERE, BELEFON 77, BACCARI 77, AND BELLEFON 78, WHICH FIND 9/2+ IN DPWAS OF KBAR N TO SIGMA PI, LAMBDA OMEGA, AND KBAR N.

Λ(2350) MASS (MeV) (PROD. EXP.)

M	2340.0	(7.0)	BUGG	68	CNTR		K-P, D TOTAL
M	2358.0	(6.0)	BRICMAN	70	CNTR	0	TOTAL AND CH EX
M	2344.0	(15.0)	COOL	70	CNTR		K-P, D TOTAL
M	(2360.0)	(20.0)	LU	70	CNTR	0	GAMMA P TO K+ Y*
M	(2372.0)		BACCARI	77	DPWA	0	K-P TO LAM. OMG.
M	2365.0	20.0	BELLEFON	77	DPWA	0	K- P TO SIG PI
M	2370.0	50.0	BELLEFON	78	DPWA	0	KBAR N TO KBAR N

Λ(2350) WIDTH (MeV) (PROD. EXP.)

W	140.0	(20.0)	BUGG	68	CNTR		K-P, D TOTAL
W	324.0	(30.0)	BRICMAN	70	CNTR	0	TOTAL AND CH EX
W	(190.0)		COOL	70	CNTR		K-P, D TOTAL
W	(55.0)		LU	70	CNTR	0	GAMMA P TO K+ Y*
W	(257.0)		BACCARI	77	DPWA	0	K-P TO LAM. OMG.
W	110.0	20.0	BELLEFON	77	DPWA	0	K- P TO SIG PI
W	204.0	50.0	BELLEFON	78	DPWA	0	KBAR N TO KBAR N

Λ(2350) PARTIAL DECAY MODES (PROD. EXP.)

		DECAY MASSES
P1	$\Lambda(2350) \to N\bar{K}$	938+ 494
P2	$\Lambda(2350) \to \Sigma\pi$	1189+ 140
P3	$\Lambda(2350) \to \Lambda\omega$	1116+ 783

Λ(2350) BRANCHING RATIOS (PROD. EXP.)

Λ(2350) → ($N\bar{K}$)/total (P1)

R1	0.12	0.04	BELLEFON	78	DPWA	0	KBAR N TO KBAR N

Λ(2350) in $N\bar{K}$ → $\Sigma\pi$ SQRT(P1*P2)

R2	-0.11	0.02	BELLEFON	77	DPWA	0	K- P TO SIG PI

Λ(2350) in $N\bar{K}$ → $\Lambda\omega$ SQRT(P1*P3)

R3	LESS THAN 0.05		BACCARI	77	DPWA	0	K-P TO LAM. OMG.

Λ(2350) → ($N\bar{K}$)/total (J+1/2)*(P1)

R4	J IS NOT DETERMINED IN THESE EXPTS. THE FOLLOWING IS (J+1/2)*P1						
R4	*(0.57)*		*BUGG*	*68*	*CNTR*		*K-P, D TOTAL*
R4	1.1	0.25	BRICMAN	70	CNTR	0	TOTAL AND CH EX
R4	(1.0)		COOL	70	CNTR		K-P, D TOTAL

REFERENCES FOR Λ(2350) (PROD. EXP.)

BUGG 68 PR 168 1466 +GILMORE,KNIGHT, + (RHEL+BIRM+CAVE) I
DAUM 68 NP B7 19 +ERNE, LAGNAUX, SENS, STEUER, UDO (CERN)JP
BRICMAN 70 PL 31B 152 +FERRO LUZZI, PERREAU,+ (CERN+CAEN+SACL)
COOL 70 PR D1 1887 +GIACOMELLI, KYCIA, LEONTIC, LI, + (BNL) I
LU 70 PR D2 1846 +GREENBERG, HUGHES, MINEHART, MORI,+ (YALE)
BACCARI 77 NC 41A 96 +POULARD,REVEL,TALLINI+ (SACL+CDEF)IJP
BELLEFON 77 NC 37A 175 DE BELLEFON,BERTHON,BILLOIR+ (CDEF+SACL)IJP
BELLEFON 78 NC 42A 403 +BERTHON,BILLOIR,BRUNET+ (CDEF+SACL)IJP

PAPERS NOT REFERRED TO IN DATA LISTINGS

COOL 66 PRL 16 1228 +GIACOMELLI,KYCIA,LEONTIC,LI,LUNDBY,+ (BNL) I
SUPERSEDED BY COOL 70.
LASINSKI 71 NP B29 125 T A LASINSKI (EFI)IJP
BELLEF02 75 NC 28A 289 DE BELLEFON,BERTHON,BILLOIR+ (CDEF+SACL)
PRESENTLY LISTED UNDER SIGMA(2250), BUT ISOSPIN UNDETERMINED.

Λ(2585) BUMPS

$I(J^P)=0(\ \ )$ Status: * *

OMITTED FROM SUMMARY TABLE

Λ(2585) MASS (MeV) (PROD. EXP.)

M	2585.0	45.0	ABRAMS	70	CNTR		K-P, D TOTAL
M	(2530.0)	(25.0)	LU	70	CNTR	0	GAMMA P TO K+ Y*

Λ(2585) WIDTH (MeV) (PROD. EXP.)

```
W          (300.0)                          ABRAMS     70 CNTR    K-P, D TOTAL
W          (150.0)                          LU         70 CNTR  D GAMMA P TO K+ Y*
```

Λ(2585) PARTIAL DECAY MODES (PROD. EXP.)

		DECAY MASSES
P1	Λ(2585) → $N\bar{K}$	938+ 494

Λ(2585) BRANCHING RATIOS (PROD. EXP.)

Λ(2585) → ($N\bar{K}$)/total (P1)

```
R1          J IS NOT KNOWN.  THE FOLLOWING IS (J+1/2)*P1.
R1            (1.0)                      ABRAMS    70 CNTR    K-P, D TOTAL
R1   A        (0.12)   (0.12)            BRICMAN   70 CNTR    TOTAL AND CH EX
R1   A    RESONANCE AT END OF REGION ANALYZED -- NO CLEAR SIGNAL.
```

REFERENCES FOR Λ(2585) (PROD. EXP.)

```
COOL      66 PRL 16 1228        +GIACOMELLI,KYCIA,LEONTIC,LUNDBY +    (BNL)I
   SUPERSEDED BY ABRAMS 70.
ABRAMS    70 PR D1 1917         +COOL, GIACOMELLI, KYCIA, LEONTIC, +  (BNL) I
BRICMAN   70 PL 31B 152         +FERRO LUZZI, PERREAU,+    (CERN+CAEN+SACL)
LU        70 PR D2 1846         +GREENBERG, HUGHES, MINEHART, MORI,+ (YALE)
```

Σ BARYONS ($S=-1$, $I=1$)

Σ^+

$I(J^P)=1(\frac{1}{2}^+)$ Status: ∗∗∗∗

SEE STABLE PARTICLES.

Σ^-

$I(J^P)=1(\frac{1}{2}^+)$ Status: ∗∗∗∗

SEE STABLE PARTICLES.

Σ^0

$I(J^P)=1(\frac{1}{2}^+)$ Status: ∗∗∗∗

SEE STABLE PARTICLES.

Σ(1385) P_{13}

$I(J^P)=1(\frac{3}{2}^-)$ Status: ∗∗∗∗

EARLY MEASUREMENTS OF THE MASS AND WIDTH FOR COMBINED CHARGE STATES HAVE BEEN REMOVED. THEY MAY BE FOUND IN OUR 1984 EDITION (REV. MOD. PHYS. 56, NO. 2, PART II, APRIL 1984).

WE NO LONGER USE EVERY PUBLISHED VALUE, BUT AVERAGE ONLY THE MOST SIGNIFICANT DETERMINATIONS. NEITHER DO WE AVERAGE RESULTS FROM INCLUSIVE EXPERIMENTS WITH LARGE BACKGROUNDS OR RESULTS WHICH ARE NOT ACCOMPANIED BY AT LEAST A DISCUSSION ON EXPERIMENTAL RESOLUTION. NEVERTHELESS SYSTEMATIC DIFFERENCES BETWEEN EXPERIMENTS REMAIN (SEE THE IDEOGRAMS INSERTED IN THE LISTINGS BELOW). THESE DIFFERENCES COULD ARISE FROM INTERFERENCE EFFECTS THAT CHANGE WITH PRODUCTION MECHANISM AND/OR BEAM MOMENTUM. THEY CAN ALSO BE ACCOUNTED FOR IN PART BY DIFFERENCES IN THE PARAMETRIZATIONS EMPLOYED (SEE BORENSTEIN 74 FOR A DISCUSSION ON THIS POINT). THUS BORENSTEIN 74 USE A BREIT-WIGNER WITH ENERGY INDEPENDENT WIDTH, SINCE A P-WAVE WAS FOUND TO GIVE UNSATISFACTORY FITS. CAMERON 78 USE THE SAME FORM. ON THE OTHER HAND HOLMGREN 77 OBTAIN A GOOD FIT TO THEIR LAMBDA PI MASS SPECTRUM WITH A P-WAVE BREIT-WIGNER, BUT INCLUDE THE PARTIAL WIDTH FOR THE SIGMA PI DECAY MODE IN THE PARAMETRIZATION. AGUILAR-BENITEZ 81 GIVE MASSES AND WIDTHS FOR FIVE DIFFERENT BREIT-WIGNER SHAPES. THE RESULTS VARY CONSIDERABLY (ONLY THE BEST-FIT S-WAVE RESULTS ARE GIVEN HERE).

Σ(1385) MASS (MeV)

```
MO A   240 1385.1      2.5               THOMAS    73 HBC   0 PI-P TO PIOKOLM
MO A    ERROR ENLARGED TO GAMMA/SQRT(N). SEE NOTE ON K* MASS IN 1984 ED.
MO B  3100 1380.0      2.0               BORENSTE  74 HBC   0 K-P TO(1385)+PIS
MO B    FROM FIT TO LAM PIO MASS SPECTRUM (IN LAM PI+ PI- PIO EVENTS) WITH
MO B    WO FIXED AT 34 MEV.
MO  C  500(1389.0)    (3.0)              BAUBILLIE 79 HBC   0 K-P AT 8.25 GEV
MO  C   FROM FIT TO INCLUSIVE LAMBDA PIO SPECTRUM WITH WIDTH FIXED AT
MO  C   40 MEV.
MO    5722 1384.1      0.8               AGUILAR   81 HBC  +  K-P 4.2, LAM 3PI
MO         . . . . . . . . . .
MO  AVG    1383.7      1.0     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)

M+ A   154(1376.0)    (3.9)              ELY       61 HLBC +  K-P 1.11 GEV/C
M+     170(1375.0)    (3.9)              COOPER    64 HBC  +  K-P 1.45 GEV/C
M+     859 1381.0      1.6               HUWE      64 HBC  +  K-P 1.22 GEV/C
M+     750 1382.0      1.0               ARMENTERO 65 HBC  +  K-P .9-1.2 GEV/C
M+ A   250(1384.3)    (1.9)              SMITH     65 HBC  +  K-P 1.8 GEV/C
M+ A   250(1382.6)    (2.1)              SMITH     65 HBC  +  K-P 1.95 GEV/C
M+ A    62(1383.0)    (8.0)              BIRMINGHA 66 HBC  +  K-P 3.5 GEV/C
M+     135(1378.0)    (5.0)              LONDON    66 HBC  +  K-P 2.24 GEV/C
M+    1260 1384.4      1.0               SIEGEL    67 HBC  +  K-P AT 2.1 GEV/C
M+      46(1390.0)    (6.0)              AGUILAR   70 HBC  +  K-P 4 GEV/SIG.PI
M+     400 1382.0      2.0               AGUILAR   72 HBC  +  K-P TO LAM+PIS
M+    2300 1383.5      0.85              HABIBI    73 HBC  +  K-P TO 2PI LAM
M+  D 3740(1382.0)    (1.0)              BERTHON   74 HBC  +  K-P 1263-1843MEV
M+  D   ERRORS STATISTICAL ONLY. RESOLUTION NOT UNFOLDED.
M+    6846 1381.0      1.0               BORENSTE  74 HBC  +  K-P TO(1385)+PIS
M+  E      (1380.0)   (2.0)              BARDADIN  75 HBC  +  K- P 14.3 GEV/C
M+ FE  22K(1385.0)    (3.0)              BARREIRO  77 HBC  +  K-P AT 4.2 GEV
M+ F    INCLUDES DATA OF HOLMGREN 77.
M+  G 2594(1385.0)    (1.0)              HOLMGREN  77 HBC  +  K-P AT 4.2 GEV
M+  G   SUPERSEDED BY AGUILAR 81.
M+    6900 1381.9      0.3               CAMERON   78 HBC  +  K-P 0.96-1.36GEV
M+  E   7K(1381.0)    (2.0)              BAUBILLIE 79 HBC  +  K-P AT 8.25 GEV
M+      2K(1391.0)    (2.0)              CAUTIS    79 HYBR +  PI+/K-P 11.5 GEV
M+  E  100(1390.0)    (2.0)              SUGAHARA  79 HBC  +  PI-P AT 6 GEV/C
M+     600(1385.1)    (1.2)              BAKER     80 HYBR +  PI+P 7 GEV/C
M+     750(1383.2)    (1.0)              BAKER     80 HYBR +  K-P 7 GEV/C
M+    5256 1384.5      0.5               AGUILAR   81 HBC  +  K-P 4.2, LAM 2PI
M+    9361 1383.0      0.4               AGUILAR   81 HBC  +  K-P 4.2, LAM 3PI
M+    1897 1384.1      0.7               BAUBILLI  84 HBC  +  K-P, 8.25 GEV/C
M+
M+  E   FROM FIT TO INCLUSIVE LAMBDA PI SPECTRUM.
M+ A    ERROR ENLARGED TO GAMMA/SQRT(N). SEE NOTE ON K* MASS IN 1984 ED.
M+         . . . . . . . . . .
M+  AVG    1382.79     0.38    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.0)
                       (SEE IDEOGRAM BELOW)
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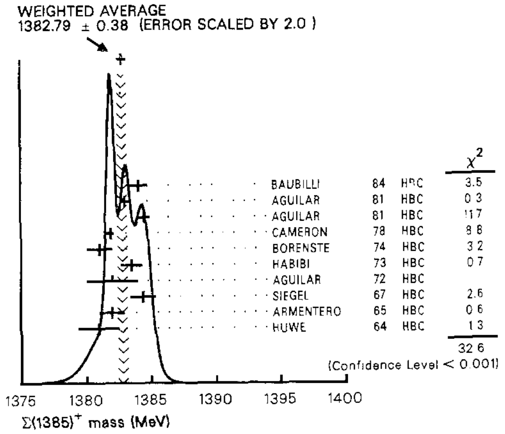

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M-      93(1382.0)    (3.0)              DAHL      61 DBC  -  K-D 0.45 GEV/C
M- A   224(1376.0)    (4.4)              ELY       61 HLBC -  K-P 1.11 GEV/C
M-     200(1392.0)    (6.2)              COOPER    64 HBC  -  K-P 1.45 GEV/C
M- A  1086 1385.3      1.9               HUWE      64 HBC  -  K-P 1.15-1.30GEV
M-    1380 1384.0      1.0               ARMENTERO 65 HBC  -  K-P .9-1.2 GEV/C
M- A   120(1391.5)    (2.6)              SMITH     65 HBC  -  K-P 1.8 GEV/C
M- A    58(1399.8)    (2.2)              SMITH     65 HBC  -  K-P 1.95 GEV/C
M-      15(1389.0)    (9.0)              LONDON    66 HBC  -  K-P AT 2.24 GEV
M-     370 1390.7      2.0               SIEGEL    67 HBC  -  K-P AT 2.1 GEV/C
M-    1900 1390.7      1.2               HABIBI    73 HBC  -  K-P TO 2PI LAM
M- A   630 1387.1      1.9               THOMAS    73 HBC  -  PI-P TO PI-K+LM
M-  D 3060(1389.0)    (1.0)              BERTHON   74 HBC  -  K-P 1263-1843MEV
M-  D   ERRORS STATISTICAL ONLY. RESOLUTION NOT UNFOLDED.
M-    2303 1383.0      2.0               BORENSTE  74 HBC  -  K-P TO(1385)+PIS
M-  E      (1383.0)   (2.0)              BARDADIN  75 HBC  -  K- P 14.3 GEV/C
M- FE  12K(1387.0)    (3.0)              BARREIRO  77 HBC  -  K-P AT 4.2 GEV
M- F    INCLUDES DATA OF HOLMGREN 77
M-  G  193(1391.0)    (3.0)              HOLMGREN  77 HBC  -  K-P AT 4.2 GEV
M-  G   SUPERSEDED BY AGUILAR 81.
M-    9720 1387.6      0.3               CAMERON   78 HBC  -  K-P 0.96-1.36GEV
M-  E 4.5K(1383.0)    (1.0)              BAUBILLIE 79 HBC  -  K-P AT 8.25 GEV
M-  E  150(1380.0)    (6.0)              SUGAHARA  79 HBC  -  PI-P AT 6 GEV/C
M-     620 1388.3      1.7               AGUILAR   81 HBC  +  K-P 4.2, LAM 2PI
M-    3346 1384.9      0.8               AGUILAR   81 HBC  +  K-P 4.2, LAM 3PI
M-
M-  E   FROM FIT TO INCLUSIVE LAMBDA PI SPECTRUM.
M- A    ERROR ENLARGED TO GAMMA/SQRT(N). SEE NOTE ON K* MASS IN 1984 ED.
M-         . . . . . . . . . .
M-  AVG    1387.18     0.55    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.2)
                       (SEE IDEOGRAM BELOW)
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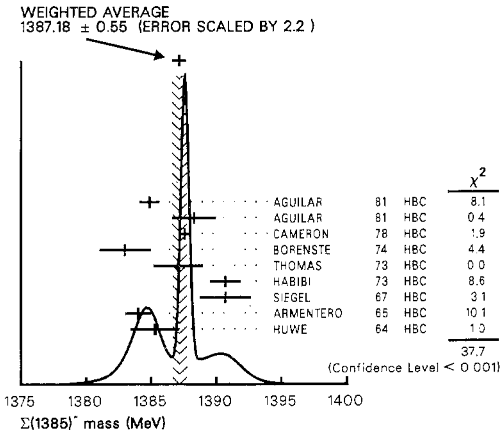


$\Sigma(1385)^- - \Sigma(1385)^+$ MASS DIFFERENCE (MeV)

```
D-+ R        (0.0)     (4.2)             ELY        61 HLBC +- K-P 1.11 GEV/C
D-+ R       (17.0)     (7.0)             COOPER     64 HBC  +- K-P 1.45 GEV/C
D-+ R        (4.3)     (2.2)             HUWE       64 HBC  +- K-P 1.22 GEV/C
D-+ R        (2.0)     (1.5)             ARMENTERO  65 HBC  +- K-P .9-1.2 GEV/C
D-+ R        (7.2)     (2.1)             SMITH      65 HBC  +- K-P 1.8 GEV/C
D-+ R       (17.2)     (2.0)             SMITH      65 HBC  +- K-P 1.95 GEV/C
D-+ R       (11.0)     (9.0)             LONDON     66 HBC  +- K-P 2.24 GEV/C
D-+           9.0       6.0              LONDON     66 HBC  +- LAMBDA 3PI EVTS
D-+ R        (6.3)     (2.0)             SIEGEL     67 HBC  +- K-P AT 2.1 GEV/C
D-+ R        (7.2)     (1.4)             HABIBI     73 HBC  +- K-P TO 2PI LAM
D-+ R      BETWEEN -2 AND +6 CL=.95      BORENSTE   74 HBC  +- K-P TO(1385)+PIS
D-+
D-+ R   REDUNDANT WITH DATA IN MASS LISTINGS.
```

$\Sigma(1385)^0 - \Sigma(1385)^+$ MASS DIFFERENCE (MeV)

```
D0+ R      BETWEEN -4 AND +4 CL=.95      BORENSTE   74 HBC  +0 K-P TO(1385)+PIS
D0+ R   REDUNDANT WITH DATA IN MASS LISTINGS.
```

$\Sigma(1385)^- - \Sigma(1385)^0$ MASS DIFFERENCE (MeV)

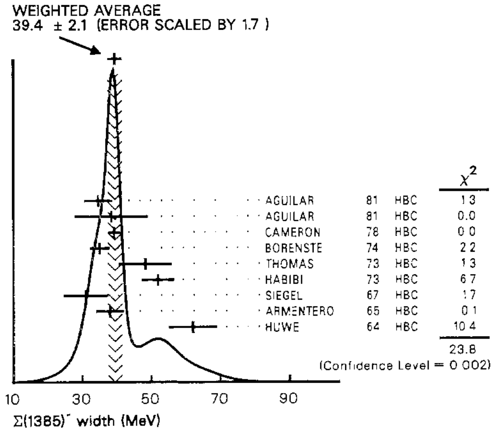
```
D-0 R        (2.0)     (2.4)             THOMAS     73 HBC  -0 PI-P TO PI-K+LM
D-0 R   REDUNDANT WITH DATA IN MASS LISTINGS.
```

Σ(1385) WIDTH (MeV)

```
W0      106  (30.0)     (9.0)            CURTIS     63 OSPK  0 PI-P 1.5 GEV/C
W0 M    240   39.3      10.2             THOMAS     73 HBC   0 PI-P TO PI0K0LM
W0 M     ERROR ENLARGED TO 4*GAMMA/SQRT(N). SEE NOTE ON K* MASS IN 1984 ED.
W0  N 3100  (53.0)     (8.0)             BORENSTE   74 HBC   0 K-P TO(1385)+PIS
W0  N    CONSISTENT WITH W0=W+=W-.
W0     5722   34.8       5.6             AGUILAR    81 HBC  +  K-P 4.2, LAM 3PI  |
W0             . . . . . . . . . .
W0  AVG       35.8       4.9     AVERAGE

W+ M    154  (48.0)    (16.0)            ELY        61 HLBC +  K-P 1.11 GEV/C
W+ M    170  (51.0)    (16.0)            COOPER     64 HBC  +  K-P 1.45 GEV/C
W+ M    859   46.5       6.4             HUWE       64 HBC  +  K-P 1.15-1.30GEV
W+ M    750   32.0       4.7             ARMENTERO  65 HBC  +  K-P .95-1.20 GEV
W+ M    250  (30.3)     (7.5)            SMITH      65 HBC  +  K-P 1.8 GEV/C
W+ M    250  (33.1)     (8.3)            SMITH      65 HBC  +  K-P 1.95 GEV/C
W+ M     62  (25.0)    (32.0)            BIRMINGHA  66 HBC  +  K-P 3.5 GEV/C
W+ M   1260   36.0       4.0             SIEGEL     67 HBC  +  K-P AT 2.1 GEV/C
W+ M     46  (33.0)    (20.0)            AGUILAR    70 HBC  +  K-P 4 GEV/SIG.PI
W+      400   32.5       6.0             AGUILAR    72 HBC  +  K-P TO LAM+PIS
W+ M   2300   38.3       3.2             HABIBI     73 HBC  +  K-P TO 2PI LAM
W+  D 3740  (48.0)      (3.0)            BERTHON    74 HBC  +  K-P 1263-1843MEV
W+  D    ERRORS STATISTICAL ONLY. RESOLUTION NOT UNFOLDED.
W+ P  6846    34.0       1.6             BORENSTE   74 HBC  +  K-P TO(1385)+PIS
W+ P  RESULTS FROM LAM PI+ PI- AND LAM PI+ PI- PI0 COMBINED BY US.
W+  E        (40.0)     (3.2)            BARDADIN   75 HBC  +  K- P 14.3 GEV/C
W+ FE  22K  (43.0)      (5.0)            BARREIRO   77 HBC  +  K-P AT 4.2 GEV
W+ F     INCLUDES DATA OF HOLMGREN 77
W+  G 2594  (34.0)      (2.0)            HOLMGREN   77 HBC  +  K-P AT 4.2 GEV
W+    6900   35.5        1.9             CAMERON    78 HBC  +  K-P 0.96-1.36GEV
W+  E   7K  (37.0)      (2.0)            BAUBILLIE  79 HBC  +  K-P AT 8.25 GEV
W+      2K  (30.0)      (4.0)            CAUTIS     79 HYBR +  PI+/K-P 11.5 GEV
W+  E  100  (30.0)      (6.0)            SUGAHARA   79 HBC  +  PI-P AT 6 GEV/C
W+     600  (40.0)      (3.0)            BAKER      80 HYBR +  PI+P 7 GEV/C
W+     750  (37.0)      (2.0)            BAKER      80 HYBR +  K-P 7 GEV/C
W+    5256   35.1        1.7             AGUILAR    81 HBC  +  K-P 4.2, LAM 2PI  |
W+    9361   37.5        2.0             AGUILAR    81 HBC  +  K-P 4.2, LAM 3PI  |
W+    1897   37.2        2.0             BAUBILLI   84 HBC  +  K-P, 8.25 GEV/C   |
W+
W+  E    FROM FIT TO INCLUSIVE LAMBDA PI SPECTRUM.
W+ M     ERROR ENLARGED TO 4*GAMMA/SQRT(N). SEE NOTE ON K* MASS IN 1984 ED.
W+             . . . . . . . . . .
W+  AVG       35.80      0.75    AVERAGE

W-           (40.0)                      DAHL       61 DBC  -  K-D 0.45 GEV/C
W- M    224  (66.0)    (18.0)            ELY        61 HLBC -  K-P 1.11 GEV/C
W- M    200  (88.0)    (24.0)            COOPER     64 HBC  -  K-P 1.45 GEV/C
W-     1086   62.0       7.0             HUWE       64 HBC  -  K-P 1.15-1.30GEV
W- M   1382   38.0       4.1             ARMENTERO  65 HBC  -  K-P .95-1.20 GEV
W- M    120  (29.2)    (10.6)            SMITH      65 HBC  -  K-P 1.80 GEV/C
W- M     58  (17.1)     (8.9)            SMITH      65 HBC  -  K-P 1.95 GEV/C
W- M    370   31.0       6.5             SIEGEL     67 HBC  -  K-P AT 2.1 GEV/C
W- M   1900   51.9       4.8             HABIBI     73 HBC  -  K-P TO 2PI LAM
W- M    630   48.2       7.7             THOMAS     73 HBC  -  PI-P TO PI-K0LM
W-  D 3060  (40.0)      (3.0)            BERTHON    74 HBC  -  K-P 1263-1843MEV
W-  D    ERRORS STATISTICAL ONLY. RESOLUTION NOT UNFOLDED.
W- P  2303    35.0       3.0             BORENSTE   74 HBC  -  K-P TO(1385)+PIS
W- P  RESULTS FROM LAM PI+ PI- AND LAM PI+ PI- PI0 COMBINED BY US.
W-  E        (47.0)     (6.0)            BARDADIN   75 HBC  -  K- P 14.3 GEV/C
W- FE  12K  (45.0)      (5.0)            BARREIRO   77 HBC  -  K-P AT 4.2 GEV
W- F     INCLUDES DATA OF HOLMGREN 77
W-  G  193  (35.0)     (10.0)            HOLMGREN   77 HBC  -  K-P AT 4.2 GEV
W-    9720   39.2        1.7             CAMERON    78 HBC  -  K-P 0.96-1.36GEV
W-  E 4.5K  (44.0)      (4.0)            BAUBILLIE  79 HBC  -  K-P AT 8.25 GEV
W-  E  150  (58.0)      (4.0)            SUGAHARA   79 HBC  -  PI-P AT 6 GEV/C
W-     620   38.4       10.7             AGUILAR    81 HBC  +  K-P 4.2, LAM 2PI  |
W-    3346   34.6        4.2             AGUILAR    81 HBC  +  K-P 4.2, LAM 3PI  |
W-
W-  E    FROM FIT TO INCLUSIVE LAMBDA PI SPECTRUM.
W- M     ERROR ENLARGED TO 4*GAMMA/SQRT(N). SEE NOTE ON K* MASS IN 1984 ED.
W-             . . . . . . . . . .
W-  AVG       39.4       2.1      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)
                                  (SEE IDEOGRAM BELOW)
```



Σ(1385) REAL PART OF POLE POSITION (MeV)

```
RE+        1379.0      1.0            LICHTENB  74       +  EXTRAP HABIBI73
RE-        1383.0      1.0            LICHTENB  74       -  EXTRAP HABIBI73
```

Σ(1385) −IMAGINARY PART OF POLE POSITION (MeV)

```
IM+          17.5     1.5             LICHTENB  74       +  EXTRAP HABIBI73
IM-          22.5     1.5             LICHTENB  74       -  EXTRAP HABIBI73
```

Σ(1385) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(1385) \rightarrow \Lambda\pi$	1116+ 140
P2	$\Sigma(1385) \rightarrow \Sigma\pi$	1189+ 140
P3	$\Sigma(1385) \rightarrow \Lambda\gamma$	1116+ 0
P4	$\Sigma(1385) \rightarrow N\bar{K}$	938+ 494
P5	$\Sigma(1385) \rightarrow \Sigma\gamma$	1197+ 0

Σ(1385) BRANCHING RATIOS

$\Sigma(1385) \rightarrow (\Sigma\pi)/(\Lambda\pi)$ (P2)/(P1)

```
R1           (0.04)    (0.04)          BASTIEN    61 HBC  +-
R1           (0.04) OR LESS            ALSTON     62 HBC  +-0K-P 1.15 GEV/C
R1            0.09      0.04           HUWE       64 HBC  +- K-P 1.2-1.7 GEV
R1            0.163     0.041          ARMENTERO  65 HBC  +- K-P .95-1.20 GEV
R1            0.08      0.06           LONDON     66 HBC  +  K-P 2.24 GEV/C
R1            0.13      0.04           PAN        69 HBC  +  PI+ P - K Y PI
R1            0.13      0.04           COLLEY     71 DBC  -0 K-N 1.5 GEV PROD
R1            0.16      0.07           AGUILAR    72 HBC  +  K-P 3.9,4.6 GEV
R1            0.18      0.04           MAST2      73 MPWA +- K-P - 2PI SIG/LM
R1            0.10      0.05           THOMAS     73 HBC  -  PI-P TO PI K Y
R1            0.16      0.03           BERTHON    74 HBC  +  K-P 1263-1843MEV
R1            0.11      0.02           BERTHON    74 HBC  -  K-P 1263-1843MEV
R1            0.21      0.05           BORENSTE   74 HBC  +  K-P TO(1385)+PIS
R1            0.20      0.06           DIONISI    78 HBC  +- K-P TO Y* K KBAR
R1          . . . . . . . . . .
R1  AVG       0.135     0.011    AVERAGE
```

$\Sigma(1385) \rightarrow (\Lambda\gamma)/\text{total}$ (P3)

```
R2        1  (0.17)  (0.17)          MEISNER   72 HBC  0  1 EVENT ONLY
```

$\Sigma(1385)$ in $N\bar{K} \rightarrow \Lambda\pi$ SQRT(P1*P4)

```
R3 S          -0.586    0.319        DEVENISH  74        0 FIXED T DISP REL
R3 S    EXTRAPOLATION OF PARAMETRIZED AMPLITUDE BELOW THRESHOLD.
```

$\Sigma(1385) \rightarrow (\Lambda\gamma)/(\Lambda\pi)$ (P3)/(P1)

```
R4            (0.06) OR LESS  CL=.90   COLAS     75 HLBC  0 K-P 575-970 MEV
```

$\Sigma(1385) \rightarrow (\Sigma\gamma)/(\Lambda\pi)$ (P5)/(P1)

```
R5            (0.05) OR LESS  CL=.90   COLAS     75 HLBC  0 K-P 575-970 MEV
```

REFERENCES FOR Σ(1385)

```
ALSTON   60 PRL 5 520         +ALVAREZ,EBERHARD,GOOD,GRAZIANO, +    (LRL) I
BASTIEN  61 PRL 6 702         P BASTIEN,M FERRO-LUZZI,A H ROSENFELD (LRL)
BERGE    61 PRL 6 557         +BASTIEN,DAHL,FERRO-LUZZI,KIRZ, +     (LRL)
DAHL     61 PRL 6 142         +HORWITZ,MILLER,MURRAY,WHITE          (LRL)
ELY      61 PRL 7 461         +FUNG,GIDAL,PAN,POWELL,WHITE          (LRL) J
MARTIN   61 PRL 6 283         +LEIPUNER,CHINOWSKY,SHIVELY, +   (BNL+YALE)
ALSTON   62 CERN CONF 311     +ALVAREZ,FERRO-LUZZI,ROSENFELD, +     (LRL)
COLLEY   62 PR 128 1930       +GELFAND,NAUENBERG, +          (COLU+RUTG) JP
CURTIS   63 PR 132 1771       +COFFIN,MEYER,TERWILLIGER            (MICH) J
COOPER   64 PL 8 365          +FILTHUTH,FRIDMAN,MALAMUD, +    (CERN+AMST)
HUWE     64 UCRL-11291 THESIS D O HUWE                              (LRL) JP
    ALSO 69 PR 180 1824       D O HUWE                              (LRL)
ARMENTER 65 PL 19 75          ARMENTEROS, +               (CERN+HEID+SACL)
BALTAY   65 PR 140 B1027      +SANDWEISS,TAFT,CULWICK,KOPP, +  (YALE+BNL)
MUSGRAVE 65 NC 35 735         +PETMEZAS,+       (BIRM+CERN+EPOL+LOIC+SACL)
SMITH    65 THESIS (UCLA)     L T SMITH                            (UCLA)
BIRMINGH 66 PR 152 1148                         (BIRM+GLAS+LOIC+OXF+RHEL)
LONDON   66 PR 143 1034       +RAU,SAMIOS,YAMAMOTO,GOLDBERG,+  (BNL+SYRA) J
SIEGEL   67 UCRL 18041 THESIS D M SIEGEL                            (LRL)
PAN      69 PRL 23 808        +FORMAN                              (PENN) I
AGUILAR  70 PRL 25 58         +BARNES, BASSANO, CHUNG, EISNER,+(BNL+SYRA)
ATHERTON 71 NP B29 477        +CELNIKIER,CLAYTON,FRENCH,FRISK,+    (CERN)
COLLEY   71 NP  B31 61        +COX,EASTWOOD,FRY+..  (BIRM+EDIN+GLAS+LOIC)
AGUILAR  72 PR 06 29          AGUILAR-BENITEZ,CHUNG,EISNER,SAMIOS   (BNL)
MEISNER  72 NC 12A 62         G MEISNER                (U NC GREENSBORO+LBL)
AMMANN   73 PR D7 1345        +CARMONY,GARFINKEL,GUTAY,+      (PURD+IUPU)
MAST2    73 PR D7 3212        +BANGERTER,ALSTON-GARNJOST,+          (LBL)IJP
    ALSO 73 PR D7 5           MAST,BANGERTER,ALSTON-GARNJOST,+      (LBL)IJP
HABIBI   73 NEVIS 199(THESIS) M HABIBI                             (COLU)
    ALSO 73 PURD73, PG. 387   BALTAY,BRIDGEWATER,COOPER,+     (COLU+BING)
THOMAS   73 NP B56 15         THOMAS,ENGLER,FISK,KRAEMER           (CARN) JP
BERTHON  74 NC 21A 146        BERTHON,TRISTRAM,+     (CDEF+RHEL+SACL+STRB)
BORENSTE 74 PR D9 3006        BORENSTEIN,KALBFLEISCH,STRAND,+  (BNL+MICH)
DEVENISH 74 NP B81 330        DEVENISH,FROGGATT,MARTIN   (DESY+NORD+LOUC)
LICHTENB 74 PR D10 3865       D B LICHTENBERG                       (IND)
    ALSO 74 PRIV. COMM.       D B LICHTENBERG                       (IND)
ATHERTO1 75 NC 25A 1          ATHERTON,BAR-NIR,FRENCH              (CERN)
BARDADIN 75 NP B98 418        BARDADIN-OTWINOWSKA+         (SACL+EPOL+RHEL)
COLAS    75 NP B91 253        COLAS,FARWELL,FERRER,SIX             (ORSA)
BARREIRO 77 NP B126 319       +BERGE,GANGULI,BLOKZIJL+   (CERN+AMST+NIJM)
HOLMGREN 77 NP B119 261       +AGUILAR-BENITEZ,KLUYVER+  (CERN+AMST+NIJM)
ALSTON   78 PR D18 182        ALSTON-GARNJOST,KENNEY+     (LBL+MHCO+CERN)
CAMERON  78 NP B143 189       +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)
DIONISI  78 PL 78B 154        +ARMENTEROS,DIAZ       (CERN+AMST+NIJM+OXF)
BANERJEE 79 ZPHY C3 1         +GANGULI,MALHOTRA,RAGHAVAN,SUDHAKAR  (TIFR)
BAUBILLI 79 NP B148 18        BAUBILLIER+          (BIRM+CERN+GLAS+MSU+LPNP)
CAUTIS   79 NP B156 507       +BALLAM,BOUCHEZ,CARROLL,CHADWICK+    (SLAC)
SUGAHARA 79 NP B156 237       +OCHIAI,FUKUI,COOPER+        (KEK+OSKC+KINK)
BAKER    80 NP B166 207       +CHIMA,DORNAN,GIBBS,HALL,MILLER+     (LOIC)
AGUILAR  81 AFIS A77 144      M AGUILAR-BENITEZ, J SALICIO         (MADR)
BAUBILLI 84 ZPHY C23 213      BAUBILLIER+          (BIRM+CERN+GLAS+MSU+LPNP)

                              PAPERS NOT REFERRED TO IN DATA LISTINGS

MALAMUD  64 PL 10 145         E MALAMUD, P E SCHLEIN          (CERN+UCLA) JP
SHAFER   64 PR 134 B1372      J B SHAFER, D O HUWE                  (LRL) JP
HUNGERBU 74 PR D10 2051       HUNGERBUHLER,MAJKA,+   (YALE+FNAL+BNL+PITT)
WALTER   79 ZPHY C3 89        +BECKER+     (BERL+AACH+CERN+SERP+SACL+VIEN)
AGUILAR  80 ZPHY C6 109       AGUILAR-BENITEZ+         (MADR+STOH+CERN+CDEF)
BALAND   80 ZPHY C3 187       +POIRET+(MONS+SERP+SACL+ALMA-ATA+MOSU+BELG)
BIAGI    81 ZPHY C9 305       +        (BRIS+CAMB+GEVA+HEID+LAUS+LOQM+RHEL)
```

Σ(1480) BUMPS

$I(J^P) = 1(\ \ )$ Status: *

OMITTED FROM SUMMARY TABLE

PEAKS ARE SEEN IN LAMBDA PI AND SIGMA PI SPECTRA IN THE REACTION PI+P TO K+ PI Y AT 1.7 GEV/C. ALSO THE Y POLARIZATION OSCILLATES IN THE SAME REGION.

SEE MILLER 70 FOR A DISCUSSION OF THIS STATE. HE SUGGESTS A POSSIBLE ALTERNATE EXPLANATION IN TERMS OF A REFLECTION OF N(1675) DECAY TO LAMBDA K. HOWEVER, SUCH AN EXPLANATION FOR THE K+ SIGMA+ PI0 CHANNEL SEEMS UNLIKELY (SEE PAN 70) IN TERMS OF KNOWN DELTA(1650) DECAY INTO SIGMA K. IN ADDITION SUCH REFLECTIONS WOULD ALSO HAVE TO ACCOUNT FOR THE OSCILLATION OF THE Y POLARIZATION IN THE 1480 MASS REGION.

HANSON 71, WITH FEWER DATA THAN PAN 70, CAN NEITHER CONFIRM NOR DENY THE EXISTENCE OF THIS STATE. MAST 75 SEES NO STRUCTURE IN THIS MASS REGION IN K- P TO LAMBDA PI0.

ENGELEN 81 PERFORM A MULTI-CHANNEL ANALYSIS OF K-P --> K0 PI- P AT 4.2 GEV/C. THEY OBSERVE A 3.5 STD. DEV. SIGNAL AT 1480 MEV IN P K0BAR WHICH CANNOT BE EXPLAINED AS A REFLECTION OF ANY COMPETING CHANNEL.

Σ(1480) MASS (MeV) (PROD. EXP.)

```
M          1479.0     10.0              PAN       70 HBC  +  PI+P TO K PI LAM
M          1465.0     15.0              PAN       70 HBC  +  PI+P TO K PI SIG
M          1485.0     10.0              CLINE     73 MPWA    K- D TO LM PI- P
M      120(1480.0)                      ENGELEN   80 HBC  +  K-P TO K0 PI- P
```

Σ(1480) WIDTH (MeV) (PROD. EXP.)

```
W            31.0      15.0             PAN       70 HBC  +  PI+P TO K PI LAM
W            30.0      20.0             PAN       70 HBC  +  PI+P TO K PI SIG
W            40.0      20.0             CLINE     73 MPWA    K- D TO LM PI- P
W      120   80.0      20.0             ENGELEN   80 HBC  +  K-P TO K0 PI- P
```

Σ(1480) PARTIAL DECAY MODES (PROD. EXP.)

		DECAY MASSES
P1	$\Sigma(1480) \rightarrow N\bar{K}$	938+ 494
P2	$\Sigma(1480) \rightarrow \Lambda\pi$	1116+ 140
P3	$\Sigma(1480) \rightarrow \Sigma\pi$	1189+ 140

Σ(1480) BRANCHING RATIOS (PROD. EXP.)

$\Sigma(1480) \rightarrow (\Sigma\pi)/(\Lambda\pi)$ (P3)/(P2)

```
R1           0.82   . 0.51          PAN        70 HBC  +
```

$\Sigma(1480) \rightarrow (p\bar{K}^0)/(\Lambda\pi)$ (P1)/(P2)

```
R2           0.36     0.25          PAN        70 HBC  +
```

$\Sigma(1480) \rightarrow (N\bar{K})/\text{total}$ (P1)

```
R3          SMALL                   CLINE      73 MPWA    K- D TO LM PI- P
```

REFERENCES FOR Σ(1480) (PROD. EXP.)

```
PAN      70 PR D2, 49         +FORMAN,KO,HAGOPIAN,SELOVE            (PENN)
CLINE    73 LNC 6 205         CLINE,LAUMANN,MAPP                    (WISC)IJP
ENGELEN  80 NP B167 61        +HEINEN,KITTEL,METZGER+(NIJM+AMST+CERN+OXF)

                              PAPERS NOT REFERRED TO IN DATA LISTINGS

YU-LI PA 69 PRL 23 806        YU-LI PAN, F L FORMAN                 (PENN) I
YU-LI PA 69 PRL 23 808        YU-LI PAN, F L FORMAN                 (PENN) I
MILLER   70 DUKE 229          D H MILLER        (REVIEW TALK)       (PURD)
HANSON   71 PR D4 1296        +KALMUS,LOUIE                          (LBL) I
MAST     75 PR D11 3078       +ALSTON-GARNJOST,BANGERTER+            (LBL)
```

Σ(1560) BUMPS

$I(J^P) = 1(\ \ )$ Status: * *

OMITTED FROM SUMMARY TABLE

THIS ENTRY LISTS PEAKS REPORTED IN MASS SPECTRA AROUND 1560 MEV WITHOUT IMPLYING THAT THEY ARE NECESSARILY RELATED.

DIONISI 78 OBSERVE A 6 STD. DEVIATION ENHANCEMENT AT 1553 MEV IN THE CHARGED (LAMBDA/SIGMA PI) MASS SPECTRA FROM K-P --> LAMBDA/SIGMA PI K KBAR AT 4.2 GEV/C. IN A CERN ISR EXPERIMENT, LOCKMAN 78 REPORT A NARROW 6 STD. DEVIATION ENHANCEMENT AT 1572 MEV IN THE LAMBDA PI+/PI- SYSTEMS FROM THE REACTION P P --> LAMBDA PI+ PI- + ANYTHING AT C.M. ENERGIES OF 53 AND 62 GEV.

THESE ENHANCEMENTS ARE UNLIKELY TO BE ASSOCIATED WITH THE SIGMA(1580) (WHICH HAS NOT BEEN CONFIRMED BY SEVERAL RECENT EXPERIMENTS -- SEE THE LISTINGS BELOW).

CARROLL 76 OBSERVE A BUMP AT 1550 MEV (AS WELL AS AT 1580 MEV) IN THE K-N I=1 TOTAL CROSS SECTION, BUT UNCERTAINTIES IN CROSS SECTION MEASUREMENTS OUTSIDE THE MASS RANGE OF THE EXPERIMENT PRECLUDE ESTIMATING ITS SIGNIFICANCE.

SEE ALSO MEADOWS 80 FOR A REVIEW OF THIS STATE.

Σ(1560) MASS (MeV) (PROD. EXP.)

```
M       121 1553.0      7.0             DIONISI   78 HBC  +- K-P TO Y* K KBAR
M        40 1572.0      4.0             LOCKMAN   78 SPEC +- PP TO L PI PI X
```

Σ(1560) WIDTH (MeV) (PROD. EXP.)

```
W       121   79.0     30.0             DIONISI   78 HBC  +- K-P TO Y* K KBAR
W  A     40   15.0      6.0             LOCKMAN   78 SPEC +- PP TO L PI PI X
W  A     OBSERVED WIDTH CONSISTENT WITH EXPERIMENTAL RESOLUTION.
```

Σ(1560) PARTIAL DECAY MODES (PROD. EXP.)

		DECAY MASSES
P1	$\Sigma(1560) \rightarrow \Lambda\pi$	1116+ 140
P2	$\Sigma(1560) \rightarrow \Sigma\pi$	1189+ 140

Σ(1560) BRANCHING RATIOS (PROD. EXP.)

$\Sigma(1560) \rightarrow \Sigma\pi/(\Sigma\pi + \Lambda\pi)$ (P2)/(P1+P2)

```
R1           0.35     0.12          DIONISI   78 HBC  +- K-P TO Y* K KBAR
```

$\Sigma(1560) \rightarrow (\Lambda\pi)/\text{total}$ (P1)

```
R2          SEEN                    LOCKMAN   78 SPEC +- PP TO L PI PI X
```

REFERENCES FOR Σ(1560) (PROD. EXP.)

```
DIONISI  78 PL 78B 154          +ARMENTEROS,DIAZ+       (CERN+AMST+NIJM+OXF)I
LOCKMAN  78  CEN DPHPE 78-01    +MEYER,RANDER,POSTER,SCHLEIN+    (UCLA+SACL)

                                PAPERS NOT REFERRED TO IN DATA LISTINGS

CARROLL  76 PRL 37 806          +CHIANG,KYCIA,LI,MAZUR,MICHAEL+         (BNL)I
MEADOWS  80 TORONTO CONF. 283 B T MEADOWS                               (CINC)
```

Σ(1580) D_{13}

$I(J^P) = 1(\frac{3}{2}^-)$ Status: * *

OMITTED FROM SUMMARY TABLE

OBSERVED IN K- N I=1 TOTAL CS WITHOUT JP ASSIGNMENT AT BNL (LI 73, CARROLL 73, CARROLL 76) AND IN PWA OF K- P --> LAMBDA PI FOR CM ENERGIES=1560-1600 MEV BY LITCHFIELD 74. LITCHFIELD 74 FINDS JP=3/2-. NOT SEEN BY ENGLER 78 OR BY CAMERON 78 (WITH LARGER STATISTICS) IN KLONG P TO PI+ LAMBDA AND PI+ SIGMA0.

Σ(1580) MASS (MeV)

```
M  A        1582.0      4.0              LITCHFIEL 74 DPWA  0 K- P TO LAM PI
M    B      1583.0      4.0              CARROLL   76 DPWA    I=1 TOTAL CS
M           . . . . . . . . . .
M   AVG     1582.5      2.8     AVERAGE
```

Σ(1580) WIDTH (MeV)

```
W  A         11.0       4.0              LITCHFIEL 74 DPWA  0 K- P TO LAM PI
W    B      (15.0)                       CARROLL   76 DPWA    I=1 TOTAL CS
```

Σ(1580) PARTIAL DECAY MODES

```
                                                        DECAY MASSES
P1       Σ(1580) → N K̄                                   938+ 494
P2       Σ(1580) → Λ π                                  1116+ 140
P3       Σ(1580) → Σ π                                  1189+ 140
```

Σ(1580) BRANCHING RATIOS

$\Sigma(1580) \rightarrow (N\overline{K})$/total (P1)

```
R1 A        +0.03      0.01             LITCHFIEL 74 DPWA    KBAR N MULTICHNL
R1 A    MAIN EFFECT OBSERVED BY LITCHFIELD 74 IS IN PI LAMBDA FINAL STATE,
R1 A    KBAR N AND SIGMA PI COUPLINGS ALSO ESTIMATED FROM MULTICHANNEL FIT
R1 A    INCLUDING TOTAL CROSS SECTION DATA (LI 73).
R1   B  TOTAL CROSS SECTION BUMP WITH (J+1/2)X=.06   SEEN BY CARROLL 76
```

$\Sigma(1580)$ in $N\overline{K} \rightarrow \Lambda\pi$ SQRT(P1*P2)

```
R2 A        +0.10      0.02             LITCHFIEL 74 DPWA  0 K- P TO LAM PI
R2         NOT SEEN                     CAMERON   78 HBC  +  KL P TO PI+ LAM
R2         NOT SEEN                     ENGLER    78  HBC +  KL P TO PI+ LAM
```

$\Sigma(1580)$ in $N\overline{K} \rightarrow \Sigma\pi$ SQRT(P1*P3)

```
R3 A        +0.03      0.04             LITCHFIEL 74 DPWA    KBAR N MULTICHNL
R3         NOT SEEN                     CAMERON   78 HBC  +  KL P TO PI+ SIG0
R3         NOT SEEN                     ENGLER    78  HBC +  KL P TO PI+ SIG0
```

REFERENCES FOR Σ(1580)

```
LITCHFIE 74 PL 51B 509          LITCHFIELD                           (CERN)IJP
CARROLL  76 PRL 37 806          +CHIANG,KYCIA,LI,MAZUR,MICHAEL+         (BNL)I
ENGLER   76 PL 63B 231          +KEYES,KRAEMER,SCHLERETH,TANAKA+ (CARN+ANL)I
CAMERON  78 NP B132 189         +CAPILUPPI+        (BGNA+EDIN+GLAS+PISA+RHEL)I
ENGLER   78 PR D18 3061         +KEYES,KRAEMER,TANAKA,CHO,+       (CARN+ANL)

                                PAPERS NOT REFERRED TO IN DATA LISTINGS

CARROLL  73 APS BRKLY MTG 208 CARROLL,CHIANG,KYCIA,LI,MAZUR,MICHAEL+(BNL)I
LI       73 PURDUE CONF. 283  LI                                        (BNL)I
```

Σ(1620) S_{11}

$I(J^P) = 1(\frac{1}{2}^-)$ Status: * *

OMITTED FROM SUMMARY TABLE

THE S11 STATE AT 1697 MEV REPORTED BY VANHORN 75 IS INTERMEDIATE IN MASS BETWEEN THE SIGMA(1620) AND SIGMA(1750). WE TENTATIVELY LIST IT UNDER SIGMA(1750). CARROLL 76 SEES TWO BUMPS IN THE I=1 TOTAL CROSS SECTIONS NEAR THIS MASS.

PRODUCTION EXPERIMENTS ARE LISTED SEPARATELY IN THE NEXT ENTRY.

Σ(1620) MASS (MeV)

```
M        (1620.0)                   KIM       71 DPWA    K-MATRIX ANAL.
M         1630.0    (10.0)          LANGBEIN  72 IPWA    MULTICHANNEL
M   'A    1608.0      5.0           CARROLL   76 DPWA    I=1 TOTAL CS
M    B    1633.0     10.0           CARROLL   76 DPWA    I=1 TOTAL CS
M   C    (1600.0)    (6.0)          MORRIS    78 DPWA -  K- N TO LAM PI-
M   C   AN EQUALLY GOOD FIT IS OBTAINED WITHOUT INCLUDING THIS RESONANCE.
```

Σ(1620) WIDTH (MeV)

```
W          (40.0)                   KIM       71 DPWA    K-MATRIX ANAL.
W           65.0    (20.0)          LANGBEIN  72 IPWA    MULTICHANNEL
W    A     (15.0)                   CARROLL   76 DPWA    I=1 TOTAL CS
W    B     (10.0)                   CARROLL   76 DPWA    I=1 TOTAL CS
W   C      (87.0)   (19.0)          MORRIS    78 DPWA -  K- N TO LAM PI-
```

Σ(1620) PARTIAL DECAY MODES

```
                                                        DECAY MASSES
P1       Σ(1620) → N K̄                                   938+ 494
P2       Σ(1620) → Σ π                                  1189+ 140
P3       Σ(1620) → Λ π                                  1116+ 135
```

Σ(1620) BRANCHING RATIOS

$\Sigma(1620) \rightarrow (N\overline{K})$/total (P1)

```
R1          (0.05)                  KIM       71 DPWA    K-MATRIX ANAL.
R1 D         0.05  OR LESS          WONG      71 DPWA    K-+P--LAM+PI
R1 D   K-MATRIX FIT(NEGLECTS 3-BODY CHANNELS) REQUIRES NO RESONANCE
R1           0.22     (0.02)        LANGBEIN  72 IPWA    MULTICHANNEL
R1   A  TOTAL CROSS SECTION BUMP WITH (J+1/2)X=.06   SEEN BY CARROLL 76
R1   B  TOTAL CROSS SECTION BUMP WITH (J+1/2)X=.04   SEEN BY CARROLL 76
```

$\Sigma(1620)$ in $N\overline{K} \rightarrow \Sigma\pi$ SQRT(P1*P2)

```
R2          (0.08)                  KIM       71 DPWA    K-MATRIX ANAL.
R2           0.40     (0.06)        LANGBEIN  72 IPWA    MULTICHANNEL
R2         NOT SEEN                 HEPP2     76 DPWA -0 K- NUC TO SIG PI
```

$\Sigma(1620)$ in $N\overline{K} \rightarrow \Lambda\pi$ SQRT(P1*P3)

```
R3          (0.15)                  KIM       71 DPWA    K-MATRIX ANAL.
R3          NOT SEEN                BAILLON   75 IPWA    KBAR N TO LAM PI
R3   C      (0.12)    (0.02)        MORRIS    78 DPWA -  K- N TO LAM PI-
```

REFERENCES FOR Σ(1620)

```
KIM      71 PRL 27 356          J K KIM                              (HARV)IJP
   ALSO  70 DUKE 161            J K KIM                              (HARV)IJP
WONG     71 NC 2A 353           N S WONG                             (YALE)IJP
LANGBEIN 72 NP B47 477          +WAGNER                              (MPIM)IJP
BAILLON  75 NP B94 39           P BAILLON, P J LITCHFIELD       (CERN+RHEL)IJP
CARROLL  76 PRL 37 806          +CHIANG,KYCIA,LI,MAZUR,MICHAEL+         (BNL)I
HEPP2    76 PL 65B 487          +BRAUN,GRIMM,STROBELE,THOL+(CERN+HEID+MPIM)IJP
MORRIS   78 PR D17 55           +ALBRIGHT,COLLERAINE,KIMEL,LANNUTTI   (FSU)IJP

                                PAPERS NOT REFERRED TO IN DATA LISTINGS

VANHORN  75 NP B87 145          A J VAN HORN                          (LBL)IJP
   ALSO  75 NP B87 157          A J VAN HORN                          (LBL)IJP
```

1620 MeV REGION – PRODUCTION EXPERIMENTS

$I(J^P) = 1(\ \ )$

FORMATION EXPERIMENTS ARE LISTED SEPARATELY IN THE PREVIOUS ENTRY.

THIS RESONANCE NEEDS CONFIRMATION. THE RESULTS OF CRENNELL 69 AT 3.9 GEV/C ARE NOT CONFIRMED BY THE SABRE COLLABORATION AT 3.0 GEV/C (SABRE 70). HOWEVER IN AN EXPERIMENT AT 4.5 GEV/C, AMMANN 70 SEE A PEAK AT 1642 MEV WHICH ON THE BASIS OF BRANCHING RATIOS THEY DO NOT ASSOCIATE WITH THE SIGMA(1670). SEE MILLER 70 FOR A REVIEW OF THESE CONFLICTS.

Σ(1620) MASS (MeV) (PROD. EXP.)

```
M   A      (1616.0)     (8.0)           CRENNELL  68 DBC  +- K-D 3.9 GEV/C
M   A     EVENTS OF CRENNELL 68 ARE IN THE LARGER SAMPLE OF CRENNELL 69.
M      20 1618.0       3.0              BLUMENFEL 69 HBC  +  KO LONG + PROTON
M          1619.0      8.0              CRENNELL  69 DBC  -- K-N TO LAM 3PI
M          1642.0     12.0              AMMANN    70 DBC     K-N 4.5 GEV/C
```

Σ(1620) WIDTH (MeV) (PROD. EXP.)

```
W   A        (66.0)    (16.0)           CRENNELL  68 DBC  -- SEE NOTE N ABOVE
W      20     30.0      10.0            BLUMENFEL 69 HBC  +
W             72.0      22.0      15.0  CRENNELL  69 DBC  +-
W             55.0      24.0            AMMANN    70 DBC     K-N 4.5 GEV/C
```

Σ(1620) PARTIAL DECAY MODES (PROD. EXP.)

```
                                                        DECAY MASSES
P1       Σ(1620) → N K̄                                   938+ 494
P2       Σ(1620) → Λ π                                  1116+ 140
P3       Σ(1620) → Σ(1385) π                            1385+ 140
P4       Σ(1620) → Λ π π                                1116+ 140+ 140
P5       Σ(1620) → Σ π                                  1189+ 140
P6       Σ(1620) → Λ(1405) π                            1405+ 140
```

$\Sigma(1620)$ BRANCHING RATIOS (PROD. EXP.)

$\Sigma(1620) \rightarrow (\Lambda \pi \pi)/(\Lambda \pi)$ (P4)/(P3)

```
R1       14   (2.5)  APPROX            BLUMENFEL 69 HBC  +
```

$\Sigma(1620) \rightarrow (N \bar{K})/(\Lambda \pi)$ (P1)/(P2)

```
R2           (0.0)    (0.1)            CRENNELL  68 DBC  +
R2            0.4      0.4             AMMANN    70 DBC      K-P 4.5 GEV/C
```

$\Sigma(1620) \rightarrow (\Lambda \pi)$/total (P2)

```
R3            LARGE                    CRENNELL  68 DBC  +-
```

$\Sigma(1620) \rightarrow (\Sigma(1385)\ \pi)/(\Lambda \pi)$ (P3)/(P2)

```
R4           (0.2)    (0.1)            CRENNELL  68 DBC  +-
R4           (0.3)  OR LESS  CL=.95    AMMANN    70 DBC      K-P 4.5 GEV/C
```

$\Sigma(1620) \rightarrow (\Sigma \pi)/(\Lambda \pi)$ (P5)/(P2)

```
R5           (1.1)(95 PC UPPER LIMIT) AMMANN    70 DBC      K-N 4.5 GEV/C
```

$\Sigma(1620) \rightarrow (\Lambda(1405)\ \pi)/(\Lambda \pi)$ (P6)/(P2)

```
R6            0.7      0.4             AMMANN    70 DBC      K-P 4.5 GEV/C
```

REFERENCES FOR $\Sigma(1620)$ (PROD. EXP.)

```
CRENNELL 68 PRL 21 648           -DELANEY, FLAMINIO, KARSHON, +   (BNL+CUNY) I
BLUMENFE 69 PL 29B 58            BLUMENFELD, KALBFLEISCH               (BNL) I
CRENNELL 69 LUND PAPER 183       +KARSHON, LAI, ONEIL, SCARR, +   (BNL+CUNY) I
   RESULTS ARE QUOTED IN LEVI SETTI 69.
AMMANN   70 PRL 24 327           - GARFINKEL, CARMONY, GUTAY,+    (PURD+IND)
    ALSO 73 PR D7 1345           AMMANN,CARMONY,GARFINKEL,       (PURD+IUPU)

                                 PAPERS NOT REFERRED TO IN DATA LISTINGS

ARMENTER 68 NP B8 183            ARMENTEROS,BAILLON +        (CERN+HEID+SACL)
LEVISETT 69 LUND CONF            R LEVI SETTI    (RAPPORTEUR)            (EFI)
TRIPP    69 UCRL 19361           R D TRIPP                               (LRL)
ARMENTER 70 DUKE 123             ARMENTEROS,BAILLON +        (CERN+HEID+SACL)
MILLER   70 DUKE 229             D H MILLER   (REVIEW TALK)             (PURD)
SABRE    70 NP B16 201           SABRE COLLAB.    (SACL+AMST+BGNA+REHO+EPOL)
HUNGERBU 74 PR D10 2051          HUNGERBUHLER,MAJKA,+   (YALE+FNAL+BNL+PITT)
```

$\Sigma(1660)$ P_{11}

$I(J^P) = 1(\frac{1}{2}^-)$ Status: * * *

```
FOR RESULTS PUBLISHED BEFORE 1974 (THEY ARE NOW OBSOLETE), SEE OUR
1982 EDITION (PHYSICS LETTERS 111B).  ALL THE REFERENCES HAVE BEEN
RETAINED.
```

$\Sigma(1660)$ MASS (MeV)

```
M          1670.0    (20.0)              KANE      74 DPWA    K-P TO PI SIG
M    A    (1660.0)   (30.0)              BAILLON   75 IPWA    KBAR N TO LAM PI
M    A  FROM SOLUTION 1 OF BAILLON 75, NOT PRESENT IN SOLUTION 2
M    B    (1671.0)    (2.0)              PONTE     75 DPWA  0 K- P TO LAM PI
M    B   FROM SOLUTION 2 OF PONTE 75, NOT PRESENT IN SOLUTION 1.
M          1668.0    (25.0)              VANHORN   75 DPWA  0 K- P TO LAM PIO
M     C    1565. OR 1597.                MARTIN    77 DPWA    KBAR N MULTICHNL
M     C  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M     C  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1676.0    (15.0)              RLIC      77 DPWA    KBAR N MULTICHNL
M          1679.0    (10.0)              ALSTON    78 DPWA    KBAR N ELASTIC
M          1670.0    (10.0)              GOPAL     80 DPWA    KBAR N ELASTIC
M     D    1665.1    (11.2)              KOISO     85 DPWA    K-P TO SIGMA PI    |
M     D  BUT THE EVIDENCE IS WEAK.                                               |
```

$\Sigma(1660)$ WIDTH (MeV)

```
W           250.0   (110.0)              KANE      74 DPWA    K-P TO PI SIG
W    A      (80.0)   (40.0)              BAILLON   75 IPWA    KBAR N TO LAM PI
W    B      (81.0)   (10.0)              PONTE     75 DPWA  0 K- P TO LAM PI
W           230.0   (165.0)    (60.0)    VANHORN   75 DPWA  0 K- P TO LAM PIO
W     C     202. OR 217.                 MARTIN    77 DPWA    KBAR N MULTICHNL
W           120.0    (20.0)              RLIC      77 DPWA    KBAR N MULTICHNL
W            38.0    (10.0)              ALSTON    78 DPWA    KBAR N ELASTIC
W           152.0    (20.0)              GOPAL     80 DPWA    KBAR N ELASTIC
W     D      81.5    (22.2)              KOISO     85 DPWA    K-P TO SIGMA PI    |
```

$\Sigma(1660)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(1660) \rightarrow N \bar{K}$	938+ 494
P2	$\Sigma(1660) \rightarrow \Sigma \pi$	1189+ 140
P3	$\Sigma(1660) \rightarrow \Lambda \pi$	1116+ 140

$\Sigma(1660)$ BRANCHING RATIOS

$\Sigma(1660)$ in $N \bar{K} \rightarrow \Sigma \pi$ SQRT(P1*P2)

```
R1           -0.11    (0.01)             KANE      74 DPWA    K-P TO PI SIG
R1         NOT SEEN                      HEPP2     76 DPWA -0 K- NUC TO SIG PI
R1    C      -0.34 OR -0.37              MARTIN    77 DPWA    KBAR N MULTICHNL
R1           -0.16    (0.03)             RLIC      77 DPWA    KBAR N MULTICHNL
R1    D      -0.13    (0.04)             KOISO     85 DPWA    K-P TO SIGMA PI    |
```

$\Sigma(1660) \rightarrow (N \bar{K})$/total (P1)

```
R2    C      0.27 OR  0.29               MARTIN    77 DPWA    KBAR N MULTICHNL
R2    E     LESS THAN 0.04               RLIC      77 DPWA    KBAR N MULTICHNL
R2    E  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R2           0.10     (0.05)             ALSTON    78 DPWA    KBAR N ELASTIC
R2           0.12     (0.03)             GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Sigma(1660)$ in $N \bar{K} \rightarrow \Lambda \pi$ SQRT(P1*P3)

```
R3   A     (-0.04)    (0.02)             BAILLON   75 IPWA    KBAR N TO LAM PI
R3   B     (+0.16)    (0.01)             PONTE     75 DPWA  0 K- P TO LAM PI
R3           0.12     (0.12)    (0.04)   VANHORN   75 DPWA  0 K- P TO LAM PIO
R3    C     -0.10 OR -0.11               MARTIN    77 DPWA    KBAR N MULTICHNL
R3          LESS THAN 0.04               RLIC      77 DPWA    KBAR N MULTICHNL
```

REFERENCES FOR $\Sigma(1660)$

```
ARMENTER 70 DUKE 123            ARMENTEROS, BAILLON, +           (CERN+HEID)IJP
KIM      71 PRL 27 356          J K KIM                                (HARV)IJP
    ALSO 70 DUKE 161            J K KIM                                (HARV)IJP
HART     73 PURDUE CONF. 311    +RICE,BACASTOW,FUNG,+  (TENN+UCR+MASA+BUFF)IJP
LEA      73 NP B56 77           +MARTIN,MOORHOUSE+    (RHEL+LOUC+GLAS+AARH)IJP
KANE     74  LBL-2452           D F KANE                                (LBL)IJP
BAILLON  75 NP B94 39           P BAILLON, P J LITCHFIELD        (CERN+RHEL)IJP
PONTE    75 PR D12 2597         +HERTZBACH,BUTTON-SHAFER+   (MASA+TENN+UCR)IJP
VANHORN  75 NP B87 145          A J VAN HORN                            (LBL)IJP
    ALSO 75 NP B87 157          A J VAN HORN                            (LBL)IJP
HEPP2    76 PL 65B 487          +BRAUN,GRIMM,STROBELE,THOL+(CERN+HEID+MPIM)IJP
MARTIN   77 NP B127 349         MARTIN,PIDCOCK,MOORHOUSE         (LOUC+GLAS)IJP
    ALSO 77 NP B126 266         MARTIN,PIDCOCK                         (LOUC)
    ALSO 77 NP B126 285         MARTIN,PIDCOCK                         (LOUC)IJP
RLIC     77 NP B119 362         GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182          +KENNEY,POLLARD,ROSS+       (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007         ALSTON-GARNJOST,KENNEY,+    (LBL+MTHO+CERN)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                                (RHEL)IJP
KOISO    85 NP A433 619         +SAI,YAMAMOTO,KOFLER             (TOKY+MASA)
```

NOTE ON THE $\Sigma(1670)$

***Production experiments*:** The measured $\Sigma\pi/\Sigma\pi\pi$ branching ratio for produced $\Sigma(1670)$'s is strongly dependent on momentum transfer. This was first discovered by EBERHARD 69, who suggested that there exist two Σ resonances with the same mass and quantum numbers: one with a large $\Sigma\pi\pi$ [mainly $\Lambda(1405)\pi$] decay mode produced peripherally, and the other with a large $\Sigma\pi$ decay mode produced at larger angles. These results were confirmed by AGUILAR-BENITEZ 70, ASPELL 74, ESTES 74, and TIMMERMANS 76. The most likely quantum numbers for both the $\Sigma\pi$ and the $\Lambda(1405)\pi$ states are D_{13}. There is also possibly a third Σ, the $\Sigma(1690)$ in the Listings, the main evidence for which is a large $\Lambda\pi/\Sigma\pi$ branching ratio. These topics have been reviewed by EBERHARD 73 and by MILLER 70.

***Formation experiments*:** Two states are also observed near this mass in formation experiments. One of these, the D_{13} $\Sigma(1670)$, has the same quantum numbers as those observed in production and has a large $\Sigma\pi/\Sigma\pi\pi$ branching ratio. It may well be the $\Sigma(1670)$ produced at larger angles (see TIMMERMANS 76). The other state, the P_{11} $\Sigma(1660)$, has different quantum numbers from those seen in production, and its $\Sigma\pi/\Sigma\pi\pi$ branching ratio is unknown. Thus its relation to the produced $\Sigma(1670)$'s remains obscure.

Σ(1670) D_{13}

$I(J^P) = 1(\frac{3}{2}^-)$ Status: * * * *

FOR MOST RESULTS PUBLISHED BEFORE 1974 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

RESULTS FROM PRODUCTION EXPERIMENTS ARE LISTED SEPARATELY IN THE NEXT ENTRY.

Σ(1670) MASS (MeV)

```
M           1670.0     (2.0)               KANE      74 DPWA    K-P TO PI SIG
M           1685.0    (20.0)               BAILLON   75 IPWA    KBAR N TO LAM PI
M   A      (1671.0)    (3.0)               PONTE     75 DPWA  0 K- P TO LAM PI
M   A    FROM SOLUTION 1 OF PONTE 75.
M   B      (1655.0)    (2.0)               PONTE     75 DPWA  0 K- P TO LAM PI
M   B    FROM SOLUTION 2 OF PONTE 75.
M           1659.0    (12.0)     (5.0)     VANHORN   75 DPWA  0 K- P TO LAM PIO
M          (1650.0)                        BELLEFON  76 IPWA  0 K- P TO LAM PI
M           1670.0     (6.0)               HEPP2     76 DPWA -0 K- NUC TO SIG PI
M    C      1667. OR 1668.                 MARTIN    77 DPWA    KBAR N MULTICHNL
M    C   THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M    C   PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M           1670.0     (5.0)               RLIC      77 DPWA    KBAR N MULTICHNL
M           1679.0    (10.0)               ALSTON    78 DPWA    KBAR N ELASTIC
M           1682.0     (5.0)               GOPAL     80 DPWA    KBAR N ELASTIC
M           1665.1     (4.1)               KOISO     85 DPWA    K- P TO SIGMA PI  |
```

Σ(1670) WIDTH (MeV)

```
W             79.0     (6.0)               KANE      74 DPWA    K-P TO PI SIG
W             85.0    (25.0)               BAILLON   75 IPWA    KBAR N TO LAM PI
W   A        (44.0)   (11.0)               PONTE     75 DPWA  0 K- P TO LAM PI
W   B        (76.0)    (5.0)               PONTE     75 DPWA  0 K- P TO LAM PI
W             32.0    (11.0)               VANHORN   75 DPWA  0 K- P TO LAM PIO
W            (80.0)                        BELLEFON  76 IPWA  0 K- P TO LAM PI
W             56.0     (3.0)               HEPP2     76 DPWA -0 K- NUC TO SIG PI
W    C        46. OR 46.                   MARTIN    77 DPWA    KBAR N MULTICHNL
W             50.0     (5.0)               RLIC      77 DPWA    KBAR N MULTICHNL
W             56.0    (20.0)               ALSTON    78 DPWA    KBAR N ELASTIC
W             79.0    (10.0)               GOPAL     80 DPWA    KBAR N ELASTIC
W             65.0     (7.3)               KOISO     85 DPWA    K- P TO SIGMA PI  |
```

Σ(1670) PARTIAL DECAY MODES

		DECAY MASSES
P1	Σ(1670) → $N\bar{K}$	938+ 494
P2	Σ(1670) → $\Lambda\pi$	1116+ 140
P3	Σ(1670) → $\Sigma\pi$	1189+ 140
P4	Σ(1670) → $\Lambda\pi\pi$	1116+ 140+ 140
P5	Σ(1670) → $\Sigma\pi\pi$	1192+ 140+ 140
P6	Σ(1670) → Σ(1385) π, *S*-wave	1385+ 140
P7	Σ(1670) → Λ(1405) π	1405+ 140
P8	Σ(1670) → Λ(1520) π	1520+ 140

Σ(1670) BRANCHING RATIOS

Σ(1670) → $(N\bar{K})$/total (P1)

```
R1    C        0.07 OR  0.07               MARTIN    77 DPWA    KBAR N MULTICHNL
R1    D       (0.08)   (0.03)              RLIC      77 DPWA    KBAR N MULTICHNL
R1    D  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1             0.11    (0.03)              ALSTON    78 DPWA    KBAR N ELASTIC
R1             0.10    (0.03)              GOPAL     80 DPWA    KBAR N ELASTIC
```

Σ(1670) → $(\Lambda\pi\pi)$/total (P4)

```
R2            (0.11) OR LESS               ARMENTE3  68 HBC     K-P (P1=.09)
```

Σ(1670) → $(\Sigma\pi\pi)$/total (P5)

```
R3  E         (0.14) OR LESS               ARMENTE3  68 HBC     K-P AND D-P1=.09
R3  E    RATIO ONLY FOR (SIG2PI) SYSTEM IN I=1, WHICH CANNOT BE SIGMA(1385)
```

Σ(1670) → (Λ(1405) π)/total (P7)

```
R4            (0.06) OR LESS               ARMENTE3  68 HBC     K-P AND D-P1=.09
```

Σ(1670) in $N\bar{K} \to \Lambda\pi$ SQRT(P1*P2)

```
R5            +0.018    0.060              DEVENISH  74       0 FIXED T DISP REL
R5            +0.06    (0.02)              BAILLON   75 IPWA    KBAR N TO LAM PI
R5  A         (0.08)   (0.01)              PONTE     75 DPWA  0 K- P TO LAM PI
R5  B         (0.17)   (0.01)              PONTE     75 DPWA  0 K- P TO LAM PI
R5            +0.09    (0.02)              VANHORN   75 DPWA  0 K- P TO LAM PIO
R5           (+0.05)                       BELLEFON  76 IPWA  0 K- P TO LAM PI
R5   C        +0.08 OR +0.08               MARTIN    77 DPWA    KBAR N MULTICHNL
R5            +0.10    (0.02)              RLIC      77 DPWA    KBAR N MULTICHNL
R5   F         0.17    (0.03)              MORRIS    78 DPWA -  K- N TO LAM PI-
R5   F         0.13    (0.02)              MORRIS    78 DPWA -  K- N TO LAM PI-
R5   F   RESULTS ARE WITH AND WITHOUT AN S11 SIG(1620) IN THE FIT.
```

Σ(1670) in $N\bar{K} \to \Sigma\pi$ SQRT(P1*P3)

```
R6            +0.21    (0.03)              KANE      74 DPWA    K-P TO PI SIG
R6            +0.20    (0.01)              HEPP2     76 DPWA -0 K- NUC TO SIG PI
R6   C        +0.18 OR +0.17               MARTIN    77 DPWA    KBAR N MULTICHNL
R6            +0.21    (0.02)              RLIC      77 DPWA    KBAR N MULTICHNL
R6            +0.20    (0.02)              KOISO     85 DPWA    K- P TO SIGMA PI  |
```

Σ(1670) in $N\bar{K} \to$ Σ(1385) π, *S*-wave SQRT(P1*P6)

```
R7  G         (0.17)   (0.02)              SIMS      68 DBC  -  LAM 2PI CROS.SEC
R7  G    SIMS 68 USES ONLY CROSS-SECT. DATA. RESULT USED AS UPPER LIMIT ONLY
R7            +0.11     0.03               PREVOST   74 DPWA 0- K-N TO S(1385)PI
```

Σ(1670) → (Λ(1405)π)*($N\bar{K}$)/total2** (P7*P1)

```
R8             (0.03) OR LESS              BERLEY    69 HBC   0 K-P .6-.82 GEV/C
R8   H          0.007   (0.002)            BRUCKER   70 DBC  -  K-N TO SIG 2PI
R8   H  ASSUMING LAMBDA(1405) PI CROSS SECTION BUMP DUE ONLY TO 3/2- RESON.
```

Σ(1670) → (Λ(1405) π)/(Σ(1385) π) (P7)/(P6)

```
R9              0.23    (0.08)             BRUCKER   70 DBC  -  K-N TO SIG 2PI
```

Σ(1670) in $N\bar{K} \to$ Λ(1520) π SQRT(P1*P8)

```
R10  I          0.081    0.016             CAMERON   77 DPWA  0 P-WAVE DECAY
R10  I  CAMERON77 UPPER LIMIT ON F-WAVE DECAY IS 0.03
R10  I  ASSUMES LAMBDA(1520) ELASTICITY=.46.
```

REFERENCES FOR Σ(1670)

```
BASTIEN1 63 PRL 10 188 P L8BASTIEN, J P BERGE                       (LRL) IJ
BASTIEN2 63 UCRL-10779 THESIS P L BASTIEN                           (LRL) IJ
T-ZADEH  63 PRL 11 470         TAHER-ZADEH,PROWSE,SCHLEIN,SLATER,+  (UCLA) JP
BERLEY   64 DUBNA CONF I 565   +CONNOLLY,HART,RAHM,STONEHILL, +      (BNL)IJP
SCHLEIN  66 UCLA-1016          P E  SCHLEIN, T G  TRIPPE            (UCLA) JP
SMART    66 PRL 17 556         W M SMART,A KERNAN,G E KALMUS,R P ELY (LRL)IJP
ARMENTER 67 NP B3 592          ARMENTEROS,FERRO-LUZZI+    (CERN+HEID+SACL)
ARMENTER 68 NP B8 195          ARMENTEROS,BAILLON +       (CERN+HEID+SACL)IJP
ARMENTE1 68 NP B8 183          ARMENTEROS,BAILLON +       (CERN+HEID+SACL)IJP
ARMENTE2 68 NP B8 223          ARMENTEROS+BAILLON +       (CERN+HEID+SACL)IJP
ARMENTE3 68 PL 28B 521         ARMENTEROS,BAILLON +       (CERN+HEID+SACL)I
SIMS     68 PRL 21 1413        SIMS,ALBRIGHT,BARTLEY,MEER+ (FSU+TUFT+BRAN)
ARMENTE4 69 NP B10 459         ARMENTEROS,BAILLON,MINTEN +     (CERN+SACL) J
ARMENT-5 69 NP B14 91          ARMENTEROS, BAILLON, +     (CERN+HEID+SACL)IJP
BERLEY   69 PL 30B 430         BERLEY,HART,RAHM,WILLIS,YAMAMOTO      (BNL)
ARMENTER 70 DUKE 123           ARMENTEROS, BAILLON, +          (CERN+HEID)
BRUCKER  70 DUKE 155           -HARRISON,SIMS,ALBRIGHT,CHANDLER++     (FSU)I
GALTIERI 70 DUKE 173           A BARBARO GALTIERI                    (LRL)IJP
BUDGEN   71 LNC 2  85          D BUDGEN                             (DURH)IJP
KIM      71 PRL 27 356         J K KIM                              (HARV)IJP
    ALSO 70 DUKE 161           J K KIM                              (HARV)IJP
PREVOST  71  AMSTERDAM CONF    + CHS COLLABORATION        (CERN+HEID+SACL)
LANGBEIN 72 NP B47 477         +WAGNER                              (MPIM)IJP
BAXTER   73 NP B67 125         BAXTER,BUCKINGHAM,CORBETT,DUNN,+      (OXF)IJP
HART     73 PURDUE CONF. 311   +RICE,BACASTOW,FUNG,+  (TENN+UCR+MASA+BUFF)IJP
DEVENISH 74 NP B81 330         DEVENISH,FROGGATT,MARTIN   (DESY+NORD+LOUC)
KANE     74  LBL-2452          D F KANE                              (LBL)IJP
PREVOST  74 NP B69 246         PREVOST,BARLOUTAUD,+       (SACL+CERN+HEID)
BAILLON  75 NP B94 39          P BAILLON, P J LITCHFIELD      (CERN+RHEL)IJP
PONTE    75 PR D12 2597        +HERTZBACH,BUTTON-SHAFER+   (MASA+TENN+UCR)IJP
VANHORN  75 NP B87 145         A J VAN HORN                          (LBL)IJP
    ALSO 75 NP B87 157         A J VAN HORN                          (LBL)IJP
BELLEFON 76 NP B109 129        DE BELLEFON,BERTHON                  (CDEF)IJP
HEPP2    76 PL 65B 487         +BRAUN,GRIMM,STROBELE,THOL+(CERN+HEID+MPIM)IJP
CAMERON  77 NP B131 399        +FRANEK,GOPAL,KALMUS,MCPHERSON+ (RHEL+LOIC)IJP
MARTIN   77 NP B127 349        MARTIN,PIDCOCK,MOORHOUSE       (LOUC+GLAS)IJP
    ALSO 77 NP B126 266        MARTIN,PIDCOCK                       (LOUC)
    ALSO 77 NP B126 285        MARTIN,PIDCOCK                       (LOUC)IJP
RLIC     77 NP B119 362        GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182         +KENNEY,POLLARD,ROSS+       (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007        ALSTON-GARNJOST,KENNEY,+    (LBL+MTHO+CERN)IJP
MORRIS   78 PR D17 55          +ALBRIGHT,COLLERAINE,KIMEL,LANNUTTI   (FSU)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                             (RHEL)IJP
KOISO    85 NP A433 619        +SAI,YAMAMOTO,KOFLER            (TOKY-MASA)
```

Σ(1670) BUMPS

$I(J^P) = 1(\ \ )$

FORMATION EXPERIMENTS ARE LISTED SEPARATELY IN THE PRECEDING ENTRY.

PROBABLY THERE ARE TWO STATES AT SAME MASS WITH SAME QUANTUM NUMBERS, ONE DECAYING INTO SIGMA PI AND LAMBDA PI, THE OTHER INTO LAMBDA(1405) PI. SEE THE NOTE PRECEDING THE PRECEDING ENTRY.

Σ(1670) MASS (MeV) (PROD. EXP.)

```
M         (1685.0)                       ALEXANDER 62 HBC  -0 PI-P 2-2.2 GEV/C
M          1660.0      10.0              ALVAREZ   63 HBC  +  K-P 1.51 GEV/C
M         (1665.0)     (5.0)             BUGG      68 CNTR    K-P, D TOTAL C.S
M   A   70(1661.0)     (9.0)             PRIMER    68 HBC  +  K-P 4.6-5. GEV/C
M   A      SEE BARNES 69 FOR NEW ANALYSIS OF DATA (3 TIMES MORE DATA)
M          1670.0       6.0              AGUILAR   70 HBC     SIG.PI K-P 4 GEV
M          1668.0      10.0              AGUILAR   70 HBC     SIG.2PI K-P 4GEV
M          1665.0       1.0              APSELL    74 HBC     K- P 2.87 GEV/C
M     1200 1688+/-2. OR 1683+/-5.        BERTHON   74 HBC   0 QUASI 2 BODY CS
M    B     1670.0       4.0              CARROLL   76 DPWA    I=1 TOTAL CS
M    B   TOTAL CROSS SECTION BUMP WITH (J+1/2)X=.23
M    C     1675.0      10.0              HEPP1     76 DBC  -  K-N 1.6-1.75 GEV
M    C   ENHANCEMENTS IN SIG P1 AND SIG P1 P1 CHANNEL CROSS SECTIONS.
M          1655. TO 1677.                TIMMERMA  76 HBC  +  K- P 4.2 GEV/C
M   D  150(1668.0)    (10.0)             FERRER    81 OMEG -  PI-P 9,12 GEV/C
M   D    BACKWARD PRODUCTION IN LAMBDA PI- K+ FINAL STATE.
```

Σ(1670) WIDTH (MeV) (PROD. EXP.)

```
W            (45.0)                      ALEXANDER 62 HBC  -0
W             40.0     10.0              ALVAREZ   63 HBC  +
W            (30.0)   (15.0)             BUGG      68 CNTR
W   A    70  (60.0)   (20.0)             PRIMER    68 HBC  +  K-P 4.6-5. GEV/C
W            110.0     12.0              AGUILAR   70 HBC     SIG.PI K-P 4 GEV
W            135.0     40.0     30.0     AGUILAR   70 HBC     SIG.2PI K-P 4GEV
W             67.0      2.4              APSELL    74 HBC     K- P 2.87 GEV/C
W    B       (52.0)                      CARROLL   76 DPWA    I=1 TOTAL CS
W             48. TO 63.                 TIMMERMA  76 HBC  +  K- P 4.2 GEV/C
W   D   150  (90.0)   (20.0)             FERRER    81 OMEG -  PI-P 9,12 GEV/C
```

Σ(1670) PARTIAL DECAY MODES (PROD. EXP.)

		DECAY MASSES
P1	$\Sigma(1670) \rightarrow N\bar{K}$	938+ 494
P2	$\Sigma(1670) \rightarrow \Lambda\pi$	1116+ 140
P3	$\Sigma(1670) \rightarrow \Sigma\pi$	1189+ 140
P4	$\Sigma(1670) \rightarrow \Lambda\pi\pi$	1116+ 140+ 140
P5	$\Sigma(1670) \rightarrow \Sigma\pi\pi$	1192+ 140+ 140
P6	$\Sigma(1670) \rightarrow \Sigma(1385)\ \pi$	1385+ 140
P7	$\Sigma(1670) \rightarrow \Lambda(1405)\ \pi$	1405+ 140

Σ(1670) BRANCHING RATIOS (PROD. EXP.)

$\Sigma(1670) \rightarrow (N\bar{K})/(\Sigma\pi)$ (P1)/(P3)

```
R1       0   (0.19) OR LESS          ALVAREZ   63 HBC  +  K-P 1.15 GEV/C
R1           (0.5)+- 0.25 OR MORE    SMITH     63 HBC  -0
R1           (0.6)  OR LESS          LONDON    66 HBC  +  K-P 2.25 GEV/C
R1           (0.025)                 BUGG      68 CNTR  0 ASSUMING J=3/2
R1       0   (0.24) OR LESS          PRIMER    68 HBC  +  K-P 4.6-5. GEV/C
R1           (0.26) OR LESS          BARNES    69 HBC  +  K-P 3.9-5 GEV/C
R1           (0.2)  OR LESS          AGUILAR   70 HBC
R1           (0.10) OR LESS          BERTHON   74 HBC   0 QUASI 2 BODY CS
R1           (0.03) OR LESS          TIMMERMA  76 HBC  +  K- P 4.2 GEV/C
```

$\Sigma(1670) \rightarrow (\Lambda\pi)/(\Sigma\pi)$ (P2)/(P3)

```
R2     130   (1.20)                  ALVAREZ   63 HBC  +  K-P 1.15 GEV/C
R2           (1.2)                   SMITH     63 HBC  -0
R2            0.15       0.07        HUWE      64 HBC  +
R2            0.6   OR LESS          LONDON    66 HBC  +  K-P 2.25 GEV/C
R2      33    0.11       0.06        BUTTON-S  68 HBC  +  K-P AT 1.7 GEV/C
R2  A    0   (0.0)                   PRIMER    68 HBC  +  K-P 3.9-5 GEV/C
R2  A   PRIMER 68 ASSUMED THIS DECAY TO BE ALL SIGMA(1690) - SEE BARNES 69
R2  A   FOR NEWW INTERPRATATION OF DATA.(3 TIMES MORE DATA) -
R2            0.45       0.15        BARNES    69 HBC  +  K-P 3.9-5 GEV/C
R2           (0.55)    (0.11)        BERTHON   74 HBC   0 QUASI 2 BODY CS
R2            0.76       0.09        ESTES     74 HBC   0 K-P,2.1+2.6GEV/C
R2           (0.45)+/- 0.07 OR LESS  TIMMERMA  76 HBC  +  K- P 4.2 GEV/C
```

$\Sigma(1670) \rightarrow (\Lambda\pi\pi)/(\Sigma\pi)$ (P4)/(P3)

```
R3      90   (0.56)                  ALVAREZ   63 HBC  +  K-P 1.15 GEV/C
R3           (0.17)                  SMITH     63 HBC  -0
R3           (0.6)  OR LESS          LONDON    66 HBC  + K-P AT 2.25 GEV/C
```

$\Sigma(1670) \rightarrow (\Sigma\pi\pi)/(\Sigma\pi)$ (P5)/(P3)

```
R4     180   (0.56)                  ALVAREZ   63 HBC  +  K-P 1.15 GEV/C
R4         LARGEST AT SMALL ANGLES   ESTES     74 HBC   0 K-P,2.1+2.6GEV/C
R4    C      (0.2)OR LESS            HEPP1     76 DBC  -  K-N 1.6-1.75 GEV
```

$\Sigma(1670) \rightarrow (\Lambda(1405)\ \pi)/(\Sigma\pi)$ (P7)/(P3)

```
R5      50    3.0        1.6         LONDON    66 HBC  +  K-P 2.25 GEV/C
R5  A   17   (0.58)    (0.20)        PRIMER    68 HBC  +  K-P 4.6-5. GEV/C
R5         LARGEST AT SMALL ANGLES   ESTES     74 HBC  +- K-P 2.1+2.6GEV/C
R5 DE      1.8+/-0.3 TO 0.02+/-0.07  TIMMERMA  76 HBC  +  K-P 4.2 GEV/C
R5  E   DEPENDING ON PRODUCTION ANGLE
```

$\Sigma(1670) \rightarrow (\Sigma\pi)/(\Sigma\pi\pi)$ (P3)/(P5)

```
R6            0.4   OR LESS          BIRMINGHA 66 HBC  +  K-P AT 3.5 GEV/C
R6            0.30       0.15        LONDON    66 HBC  +  K-P 2.25 GEV/C
R6  F      BETWEEN 2.5 AND 0.24      EBERHARD  69 HBC     K-P AT 2.6 GEV/C
R6  F   DEPENDING ON THE PRODUCTION ANGLE
R6 G       VARIES WITH PROD. ANGLE   APSELL    74 HBC  +  K-P 2.87 GEV/C
R6           (1.39)    (0.16)        BERTHON   74 HBC   0 QUASI 2 BODY CS
R6 G    APSELL 74, ESTES 74 AND TIMMERMANS 76 FIND STRONG BRANCHING RATIO
R6 G    DEPENDENCE ON PRODUCTION ANGLE, AS IN EARLIER PROD. EXPERIMENTS.
```

$\Sigma(1670) \rightarrow (\Lambda(1405)\ \pi)/(\Sigma\pi\pi)$ (P7)/(P5)

```
R7            0.90       0.10      0.16 EBERHARD  65 HBC  +  K-P 2.45 GEV/C
R7            1.00       0.02        APSELL    74 HBC     K- P 2.87 GEV/C
R7            0.97       0.08        TIMMERMA  76  HBC    K- P 4.2 GEV/C
```

$\Sigma(1670) \rightarrow (\Lambda(1405)\ \pi)/(\Sigma(1385)\ \pi)$ (P7)/(P6)

```
R8           (0.8)  OR LESS          EBERHARD  65 HBC  +  K-P 2.45 GEV/C
```

$\Sigma(1670) \rightarrow (\Lambda\pi\pi)/(\Sigma\pi\pi)$ (P4)/(P5)

```
R9            0.35       0.2         BIRMINGHA 66 HBC  +  K-P AT 3.5 GEV/C
```

$\Sigma(1670) \rightarrow (\Lambda\pi)/(\Sigma\pi\pi)$ (P2)/(P5)

```
R10          (0.2)  OR LESS          BIRMINGHA 66 HBC  +  K-P AT 3.5 GEV/C
```

$\Sigma(1670) \rightarrow (\Lambda\pi)/(\Lambda\pi\ +\ \Sigma\pi)$ (P2)/(P2+P3)

```
R11          (0.6)  OR LESS          AGUILAR   70 HBC
```

$\Sigma(1670) \rightarrow (\Sigma(1385)\ \pi)/(\Sigma\pi)$ (P6)/(P3)

```
R12          (0.21)+/- 0.05 OR LESS  TIMMERMA  76  HBC    K- P 4.2 GEV/C
```

Σ(1670) QUANTUM NUMBERS (PROD. EXP.)

```
Q1                  JP=3/2+          LEVEQUE   65 HBC     SIGMA(1405) PI
Q3                  JP=3/2-          EBERHARD  67 HBC  +  SIGMA(1405) PI
Q4      400         JP=3/2-          BUTTON-SH 68 HBC  +- INTO SIGZERO PI
```

REFERENCES FOR Σ(1670) (PROD. EXP.)

```
ALEXANDE 62 CERN CONF 320     ALEXANDER,JACOBS,KALBFLEISCH,MILLER,+ (LRL) I
ALVAREZ  63 PRL 10 184        +ALSTON,FERRO-LUZZI,HUWE, +           (LRL) I
SMITH    63 ATHENS CONF 67    G A SMITH                             (LRL)
HUWE     64 PR 180 1824(1969) D O HUWE                              (LRL)
EBERHARD 65 PRL 14 466        +SHIVELY,ROSS,SIEGAL,FICENEC, +   (LRL+ILL) I
BIRMINGH 66 PR 152 1148                    (BIRM+GLAS+LOIC+OXF+RHEL)
LONDON   66 PR 143 1034       +RAU,SAMIOS,YAMAMOTO,GOLDBERG,+  (BNL+SYRA) IJ
BUGG     68 PR 168 1466       +GILMORE,KNIGHT,DAVIES+    (BIRM+CAVE+RHEL)I
BUTTON-S 68 PRL 21 1123       J BUTTON-SHAFER                  (MASA+LRL) JP
PRIMER   68 PRL 20 610        +GOLDBERG,JAEGER,BARNES,DORNAN + (SYRA+BNL)
BARNES   69 BNL 13823         +CHUNG,EISNER,FLAMINIO+          (BNL+SYRA)
EBERHARD 69 PRL 22 200        +FRIEDMAN,PRIPSTEIN,ROSS              (LRL)
AGUILAR  70 PRL 25 58         +BARNES, BASSANO, CHUNG, EISNER,+(BNL+SYRA)
APSELL   74 PR D10 1419       APSELL,FORD,GOUREVITCH+(BRAN+UMD+SYRA+TUFT)I
BERTHON  74 NC 21A 146        BERTHON,TRISTRAM,+    (CDEF+RHEL+SACL+STRB)
ESTES    74 LBL-3827 (THESIS) R D ESTES                             (LBL)
CARROLL  76 PRL 37 806        +CHIANG,KYCIA,LI,MAZUR,MICHAEL+       (BNL)I
HEPP1    76 NP B115 82        +BRAUN,GRIMM,STROBELE,THOL+(CERN+HEID+MPIM)I
TIMMERMA 76 NP B112 77        TIMMERMANS,ENGELEN+    (NIJM+CERN+AMST+OXF) JP
FERRER   81 NP B178 373       +TREILLE,RIVET,VOLTE+ (CERN+CDEF+EPOL+LALO)

                              PAPERS NOT REFERRED TO IN DATA LISTINGS

LEVEQUE  65 PL 18 69          +             (SACL+EPOL+GLAS+LOIC+OXF+RHEL) JP
LEE      66 PRL 17 45         Y Y LEE, D D REEDER, R W HARTUNG     (WISC) JP
EBERHARD 67 PR 163 1446       +PRIPSTEIN,SHIVELY,KRUSE,SWANSON  (LRL+ILL)IJP
MILLER   70 DUKE 229          D H MILLER   (REVIEW TALK)             (PURD)
EBERHARD 73 PURDUE CONF. 247  P EBERHARD                            (LBL)IJP
HUNGERBU 74 PR D10 2051       HUNGERBUHLER,MAJKA,+   (YALE+FNAL+BNL+PITT)
```

Σ(1690) BUMPS

$I(J^P) = 1(\ \ )$ Status: * *

OMITTED FROM SUMMARY TABLE

SEE THE NOTE PRECEDING THE SIGMA(1670) LISTINGS. SEEN IN PRODUCTION EXPERIMENTS ONLY, MAINLY IN LAMBDA PI.

Σ(1690) MASS (MeV) (PROD. EXP.)

```
M        30(1715.0)    (12.0)            COLLEY    67 HBC  +  K-P 6 GEV/C
M    A   60(1694.0)    (24.0)            PRIMER    68 HBC  +  K-P 4.6-5 GEV/C
M    A    SEE SIGMA(1670) LISTING-AGUILAR 70 WITH THREE TIMES THE DATA OF
M    A    PRIMER 68  SHOW THAT THEY HAVE NO EVIDENCE FOR SIGMA(1690)
M     B    (1700.0)    (6.0)             SIMS      68 HBC  -  K-N TO LAM PI PI
M     B   THIS ANALYSIS, WHICH IS DIFFICULT AND REQUIRES SEVERAL ASSUMPTIONS
M     B   AND SHOWS NO UNAMBIGUOUS SIGMA(1690) SIGNAL, SUGGESTS JP=5/2+.
M     B   SUCH A Y* WOULD LEAD ALL PREVIOUSLY KNOWN Y* TRAJECTORIES.
M        15(1698.0)    (20.0)            ADERHOLZ  69 HBC  +  PI+P 8 GEV/C
M        46(1682.0)     (2.0)            BLUMENFEL 69 HBC  +  KO LONG + PROTON
M          (1700.0)    (20.0)            MOTT      69 HBC  +  K-P 5.5 GEV/C
M    C   70(1698.0)    (20.0)            GODDARD   79 HBC  +  PI+P 10.3 GEV/C
M    C    FROM (LAMBDA PI+) K+ FINAL STATE. J>1/2 NOT REQUIRED BY DATA.
M    D   40(1707.0)    (20.0)            GODDARD   79 HBC  +  PI+P 10.3 GEV/C
M    D    FROM (LAMBDA PI+) (K PI)+ FINAL STATE. J>1/2 INDICATED, BUT LARGE
M    D    BACKGROUND PRECLUDES DEFINITE CONCLUSION.
```

Σ(1690) WIDTH (MeV) (PROD. EXP.)

```
W        30 (100.0)    (35.0)            COLLEY    67 HBC  +
W    A   60 (105.0)    (35.0)            PRIMER    68 HBC  +
W     B      (62.0)    (14.0)            SIMS      68 HBC  -  SEE NOTE N ABOVE
W        15 (142.0)    (40.0)            ADERHOLZ  69 HBC  +  PI+P 8 GEV/C
W        46  (25.0)    (10.0)            BLUMENFEL 69 HBC  +
W           (130.0)    (25.0)            MOTT      69 HBC  +
W    C   70 (240.0)    (60.0)            GODDARD   79 HBC  +  PI+P 10.3 GEV/C
W    D   40 (130.0)   (100.0)    (60.0)  GODDARD   79 HBC  +  PI+P 10.3 GEV/C
```

Σ(1690) PARTIAL DECAY MODES (PROD. EXP.)

		DECAY MASSES
P1	$\Sigma(1690) \rightarrow N\bar{K}$	938+ 494
P2	$\Sigma(1690) \rightarrow \Lambda\pi$	1116+ 140
P3	$\Sigma(1690) \rightarrow \Sigma\pi$	1189+ 140
P4	$\Sigma(1690) \rightarrow \Sigma(1385)\ \pi$	1385+ 140
P5	$\Sigma(1690) \rightarrow \Lambda\pi\pi$ (including P4)	1116+ 140+ 140

Σ(1690) BRANCHING RATIOS (PROD. EXP.)

$\Sigma(1690) \rightarrow (N\bar{K})/(\Lambda\pi)$ (P1)/(P2)

```
R1      18     0.4        0.25           COLLEY    67 HBC  +  6/30 EVENTS
R1            (0.2)  OR LESS             MOTT      69 HBC  +
R1          SMALL                        GODDARD   79 HBC  +  PI+P 10.2 GEV/C
```

$\Sigma(1690) \rightarrow (\Sigma\pi)/(\Lambda\pi)$ (P3)/(P2)

```
R2             0.3        0.3            COLLEY    67 HBC  +  4/30 EVENTS
R2            (0.4)  OR LESS  CL=.90     MOTT      69 HBC  +
R2          SMALL                        GODDARD   79 HBC  +  PI+P 10.2 GEV/C
```

$\Sigma(1690) \rightarrow (\Sigma(1385)\ \pi)/(\Lambda\pi)$ (P4)/(P2)

```
R3            (0.5)  OR LESS             MOTT      69 HBC  +
```

$\Sigma(1690) \rightarrow (\Lambda\pi\pi)/(\Lambda\pi)$ (P5)/(P2)

```
R4             0.5        0.25           COLLEY    67 HBC  +  15/30 EVENTS
R4             2.0        0.6            BLUMENFEL 69 HBC  +  31/15 EVENTS
R4          . . . . . . . . . .
R4  AVG        0.72       0.53     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.3)
```

$\Sigma(1690) \rightarrow (\Sigma(1385)\ \pi)/(\Lambda\pi\pi)$ (P4)/(P5)

```
R5            SMALL                      COLLEY    67 HBC  +
R5            LARGE                      SIMS      68 HBC  -  K-N TO L2PI
```

REFERENCES FOR Σ(1690) (PROD. EXP.)

```
COLLEY   67 PL 24B 489                   (BIRM+GLAS+LOIC+MUNI+OXF+RHEL) I
DERRICK  67 PRL 18 266       +FIELDS, LOKEN, AMMAR,              (ANL+NWES) I
    REPLACED BY MOTT 69.
PRIMER   68 PRL 20 610       +GOLDBERG, JAEGER, BARNES, + (SYRACUSE+BNL) I
SIMS     68 PRL 21 1413      +ALBRIGHT, +                   (FSU+TUFT+BRAN) I
```

```
ADERHOLZ 69 NP B11 259        +BARTSCH,SCHULTE+(AACH+BERL+CERN+CRAL-WARS)I
BLUMENFE 69 PL 29B 58         B J BLUMENFELD, G R KALBFLEISCH        (BNL) I
MOTT     69 PR 177 1966       +AMMAR, DAVIS, KROPAC, +          (NWES+ANL) I
GODDARD  79 PR D19 1350       +KEY,LUSTE,PRENTICE,YOON,GORDON+ (TNTO+BNL)I,J

                              PAPERS NOT REFERRED TO IN DATA LISTINGS

AGUILAR  70 PRL 25 58         AGUILAR-BENITEZ,BARNES,BASSANO+  (BNL-SYRA)
COOPER   70 NP B23 605        +MANNER,MUSGRAVE,POLLARD,VOYVODIC     (ANL)I
```

$\Sigma(1750)$ S_{11}

$I(J^P) = 1(\frac{1}{2}^-)$ Status: * * *

FOR MOST RESULTS PUBLISHED BEFORE 1974 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

THERE IS EVIDENCE FOR THIS STATE IN MANY PARTIAL-WAVE ANALYSES, BUT WITH RATHER WIDE VARIATIONS IN THE MASS, WIDTH AND COUPLINGS. THE LATEST ANALYSES INDICATED SIGNIFICANT COUPLINGS TO N KBAR AND LAMBDA PI, AS WELL AS SIGMA ETA WHOSE THRESHOLD IS NEARBY AT 1746 MEV (JONES 74).

$\Sigma(1750)$ MASS (MeV)

```
M        (1785.0)   (12.0)              CHU       74 DBC   - FIT SIG- ETA CS
M   A    (1760.0)    (5.0)              JONES     74 HBC   0 FIT SIGO ETA CS
M   A  S-WAVE BW FIT TO THRSHLD C.S., NO BKGND. ERRORS STATISTICAL ONLY
M        (1739.0)   (10.0)              PREVOST   74 DPWA 0- K-N TO S(1385)PI
M  B     (1780.0)   (30.0)              BAILLON   75 IPWA    KBAR N TO LAM PI
M  B   FROM SOLUTION 1 OF BAILLON 75.
M  C     (1700.0)   (30.0)              BAILLON   75 IPWA    KBAR N TO LAM PI
M  C   FROM SOLUTION 2 OF BAILLON 75.
M        (1697.0)   (20.0)    (10.0)    VANHORN   75 DPWA  0 K- P TO LAM PIO
M        (1730.0)                       BELLEFON  76 IPWA  0 K- P TO LAM PI
M   D     1715.0     10.0               CARROLL   76 DPWA    I=1 TOTAL CS
M   D  A TOTAL CROSS SECTION BUMP WITH (J+1/2)X=0.30.
M   E     1800. OR 1813.                MARTIN    77 DPWA    KBAR N MULTICHNL
M   E  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M   E  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M         1770.0     15.0               RLIC      77 DPWA    KBAR N MULTICHNL
M         1770.0     10.0               ALSTON    78 DPWA    KBAR N ELASTIC
M         1756.0    (10.0)              GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Sigma(1750)$ WIDTH (MeV)

```
W          (89.0)   (33.0)              CHU       74 DBC   - FIT SIG- ETA CS
W   A      (92.0)    (7.0)              JONES     74 HBC   0 FIT SIG+ETA CS
W         (108.0)   (20.0)              PREVOST   74 DPWA 0- K-N TO S(1385)PI
W  B      (140.0)   (30.0)              BAILLON   75 IPWA    KBAR N TO LAM PI
W  C      (160.0)   (50.0)              BAILLON   75 IPWA    KBAR N TO LAM PI
W          (66.0)   (14.0)    (12.0)    VANHORN   75 DPWA  0 K- P TO LAM PIO
W         (110.0)                       BELLEFON  76 IPWA  0 K- P TO LAM PI
W   D      (10.0)                       CARROLL   76 DPWA    I=1 TOTAL CS
W   E      117. OR 119.                 MARTIN    77 DPWA    KBAR N MULTICHNL
W           60.0     10.0               RLIC      77 DPWA    KBAR N MULTICHNL
W          161.0     20.0               ALSTON    78 DPWA    KBAR N ELASTIC
W           64.0    (10.0)              GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Sigma(1750)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(1750) \to N\bar{K}$	938+ 494
P2	$\Sigma(1750) \to \Sigma\eta$	1192+ 549
P3	$\Sigma(1750) \to \Lambda\pi$	1116+ 135
P4	$\Sigma(1750) \to \Sigma\pi$	1189+ 140
P5	$\Sigma(1750) \to \Sigma(1385)\ \pi$	1385+ 140
P6	$\Sigma(1750) \to \Lambda(1520)\ \pi$	1520+ 140

$\Sigma(1750)$ BRANCHING RATIOS

$\Sigma(1750) \to (N\bar{K})$/total (P1)

```
R1  E       0.06 OR  0.05               MARTIN    77 DPWA    KBAR N MULTICHNL
R1  F      (0.15)   (0.03)              RLIC      77 DPWA    KBAR N MULTICHNL
R1  F  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1          0.33     0.05               ALSTON    78 DPWA    KBAR N ELASTIC
R1          0.14    (0.03)              GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Sigma(1750)$ in $N\bar{K} \to \Sigma\eta$ SQRT(P1*P2)

```
R2         SEEN                         CLINE     69 DBC   - THRESHOLD BUMP
R2  A      (0.23)   (0.01)              JONES     74 HBC   0 FIT SIG+ETA CS
```

$\Sigma(1750)$ in $N\bar{K} \to \Lambda\pi$ SQRT(P1*P3)

```
R3        (-0.120)  (0.077)             DEVENISH  74       0 FIXED T DISP REL
R3  B     (-0.12)   (0.02)              BAILLON   75 IPWA    KBAR N TO LAM PI
R3  C     (-0.13)   (0.03)              BAILLON   75 IPWA    KBAR N TO LAM PI
R3        (-0.13)   (0.04)              VANHORN   75 DPWA  0 K- P TO LAM PIO
R3        (-0.12)                       BELLEFON  76 IPWA  0 K- P TO LAM PI
R3   E     -0.10 OR -0.09               MARTIN    77 DPWA    KBAR N MULTICHNL
R3         (0.04)   (0.03)              RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1750)$ in $N\bar{K} \to \Sigma\pi$ SQRT(P1*P4)

```
R4         (0.13)   (0.02)              LANGBEIN  72 IPWA    MULTICHANNEL
R4   E     +0.06 OR +0.06               MARTIN    77 DPWA    KBAR N MULTICHNL
R4         -0.09     0.05               RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1750)$ in $N\bar{K} \to \Sigma(1385)\ \pi$ SQRT(P1*P4)

```
R5         +0.18     0.15               PREVOST   74 DPWA 0  K-N TO S(1385)PI
```

$\Sigma(1750)$ in $N\bar{K} \to \Lambda(1520)\ \pi$ SQRT(P1*P6)

```
R6  G       0.032    0.021              CAMERON   77 DPWA  0 P-WAVE DECAY
R6  G  ASSUMES LAMBDA(1520) ELASTICITY=.46
```

REFERENCES FOR $\Sigma(1750)$

```
FERRO-LU 66 BERKELEY CONF 183 M FERRO LUZZI  (RAPPORTEUR)           (CERN)
CLINE    67 PL 25B 41         CLINE, OLSSON                         (WISC)IJP
MEYER    67 HEIDELBERG C 117  J MEYER  (RAPPORTEUR)                 (SACL)IJP
ARMENTER 68 NP B8 183         ARMENTEROS, BAILLON, +      (CERN+HEID+SACL)IJP
ARMENTER 69 LUND CONF PAPER   ARMENTEROS, BAILLON, +      (CERN+HEID+SACL)IJP
ARMENTER 70 DUKE 123          ARMENTEROS, BAILLON, +           (CERN+HEID)IJP
HARRISON 70 FSU-HEP 70 3 1    W C HARRISON (THESIS)                 (FSU)
CONFORTO 71 NP  B34  41       +LEVI SETTI,LASINSKI..OBERLACK+- (EFI+HEID)IJP
KIM      71 PRL 27 356        J K KIM                               (HARV)IJP
    ALSO 70 DUKE 161          J K KIM                               (HARV)IJP
LANGBEIN 72 NP B47 477        +WAGNER                               (MPIM)IJP
BAXTER   73 NP B67 125        BAXTER,BUCKINGHAM,CORBETT,DUNN,+       (OXF)IJP
CHU      74 NC 20A 35         CHU,BARTLEY,+  (SUNY PLATTSBURGH+TUFT+BRAN)IJP
JONES    74 NP B73 141        JONES                                 (CHIC)IJP
DEVENISH 74 NP B81 330        DEVENISH,FROGGATT,MARTIN   (DESY+NORD-LOUC)
PREVOST  74 NP B69 246        PREVOST,BARLOUTAUD,+       (SACL+CERN+HEID)
BAILLON  75 NP B94 39         P BAILLON, P J LITCHFIELD        (CERN+RHEL)IJP
VANHORN  75 NP B87 145        A J VAN HORN                           (LBL)IJP
    ALSO 75 NP B87 157        A J VAN HORN                           (LBL)IJP
BELLEFON 76 NP B109 129       DE BELLEFON,BERTHON                   (CDEF)IJP
CARROLL  76 PRL 37 806        +CHIANG,KYCIA,LI,MAZUR,MICHAEL+        (BNL)I
CAMERON  77 NP B131 399       +FRANEK,GOPAL,KALMUS,MCPHERSON+ (RHEL+LOIC)IJP
MARTIN   77 NP B127 349       MARTIN,PIDCOCK,MOORHOUSE         (LOUC+GLAS)IJP
    ALSO 77 NP B126 266       MARTIN,PIDCOCK                        (LOUC)
    ALSO 77 NP B126 285       MARTIN,PIDCOCK                        (LOUC)IJP
RLIC     77 NP B119 362       GOPAL,ROSS,VAN HORN,MCPHERSON-  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182        +KENNEY,POLLARD,ROSS+       (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007       ALSTON-GARNJOST,KENNEY,+    (LBL+MTHO+CERN)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                             (RHEL)IJP
```

$\Sigma(1770)$ P_{11}

$I(J^P) = 1(\frac{1}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

EVIDENCE FOR THIS STATE NOW RESTS SOLELY ON SOLUTION 1 OF BAILLON 75 - BUT THE LAMBDA PI PARTIAL-WAVE AMPLITUDES OF THIS SOLUTION ARE IN DISAGREEMENT WITH AMPLITUDES FROM MOST OTHER LAMBDA PI ANALYSES.

$\Sigma(1770)$ MASS (MeV)

```
M   A    (1772.0)                       KANE      72 DPWA    K-P TO SIGMA PI
M   A  STATE IS NOT REQUIRED IN KANE 74 WHICH SUPERSEDES KANE 72.
M    B    1770.0     20.0               BAILLON   75 IPWA    KBAR N TO PI LAM
M    B FROM SOLUTION 1 OF BAILLON 75, NOT PRESENT IN SOLUTION 2.
M   C    (1738.0)   (10.0)              RLIC      77 DPWA    KBAR N MULTICHNL
M   C  STATE REQUIRED TO FIT I=1 TOTAL X-SECTION OF CARROLL 76 IN KBAR N
M   C  CHANNEL. NEW K-P POLARIZATION AND K- NEUTRON DIFFERENTIAL X-SECTION
M   C  DATA MORE CONSISTENT WITH SIGMA(1660) P11 IN GOPAL 80 ANALYSIS.
```

$\Sigma(1770)$ WIDTH (MeV)

```
W   A      (80.0)                       KANE      72 DPWA    K-P TO SIGMA PI
W    B      80.0     30.0               BAILLON   75 IPWA    KBAR N TO PI LAM
W   C      (72.0)   (10.0)              RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1770)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(1770) \to N\bar{K}$	938+ 494
P2	$\Sigma(1770) \to \Lambda\pi$	1116+ 140
P3	$\Sigma(1770) \to \Sigma\pi$	1189+ 140

$\Sigma(1770)$ BRANCHING RATIOS

$\Sigma(1770) \to (N\bar{K})$/total (P1)

```
R1  C      (0.14)   (0.04)              RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1770)$ in $N\bar{K} \to \Lambda\pi$ SQRT(P1*P2)

```
R2   B     -0.08     0.02               BAILLON   75 IPWA    KBAR N TO PI LAM
R2         LESS THAN 0.04               RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1770)$ in $N\bar{K} \to \Sigma\pi$ SQRT(P1*P3)

```
R3  A     (-0.108)                      KANE      72 DPWA    K-P TO SIGMA PI
R3         LESS THAN 0.04               RLIC      77 DPWA    KBAR N MULTICHNL
```

REFERENCES FOR $\Sigma(1770)$

```
KANE     72 PR D5 1583        D F KANE                               (LBL)
BAILLON  75 NP B94 39         P BAILLON, P J LITCHFIELD        (CERN+RHEL)IJP
RLIC     77 NP B119 362       GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP

                              PAPERS NOT REFERRED TO IN DATA LISTINGS

KANE     74  LBL-2452         D F KANE                               (LBL)IJP
CARROLL  76 PRL 37 806        +CHIANG,KYCIA,LI,MAZUR,MICHAEL,+       (BNL)I
```

$\Sigma(1775)\ D_{15}$

$I(J^P) = 1(\frac{5}{2}^-)$ Status: * * * *

```
FOR MOST RESULTS PUBLISHED BEFORE 1974 (THEY ARE NOW OBSOLETE), SEE
OUR 1982 EDITION (PHYSICS LETTERS 111B).  ALL THE REFERENCES HAVE BEEN
RETAINED.
```

Σ(1775) MASS (MeV)

```
M          1772.0     (6.0)            KANE      74 DPWA     K-P TO PI SIG
M          1775.0     10.0             BAILLON   75 IPWA     KBAR N TO LAM PI
M          1774.0     10.0             VANHORN   75 DPWA   0 K- P TO LAM PI0
M         (1765.0)                     BELLEFON  76 IPWA   0 K- P TO LAM PI
M    A     1772. OR 1777.              MARTIN    77 DPWA     KBAR N MULTICHNL
M    A  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M    A  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1774.0      5.0             RLIC      77 DPWA     KBAR N MULTICHNL
M          1777.0      5.0             ALSTON    78 DPWA     KBAR N ELASTIC
M          1778.0     (5.0)            GOPAL     80 DPWA     KBAR N ELASTIC
```

Σ(1775) WIDTH (MeV)

```
W           154.0    (10.0)            KANE      74 DPWA     K-P TO PI SIG
W           125.0     15.0             BAILLON   75 IPWA     KBAR N TO LAM PI
W           146.0     18.0             VANHORN   75 DPWA   0 K- P TO LAM PI0
W          (120.0)                     BELLEFON  76 IPWA   0 K- P TO LAM PI
W    A      102. OR 103.               MARTIN    77 DPWA     KBAR N MULTICHNL
W           130.0     10.0             RLIC      77 DPWA     KBAR N MULTICHNL
W           116.0     10.0             ALSTON    78 DPWA     KBAR N ELASTIC
W           137.0    (10.0)            GOPAL     80 DPWA     KBAR N ELASTIC
W          . . . . . . . . . .
W   AVG     125.9      6.0      AVERAGE
```

Σ(1775) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(1775) \to N\bar{K}$	938+ 494
P2	$\Sigma(1775) \to \Lambda\pi$	1116+ 135
P3	$\Sigma(1775) \to \Lambda(1520)\ \pi$	1520+ 140
P4	$\Sigma(1775) \to \Sigma(1385)\ \pi$, D-wave	1385+ 140
P5	$\Sigma(1775) \to \Sigma\pi$	1189+ 140
P6	$\Sigma(1775) \to \Sigma\eta$	1192+ 549
P7	$\Sigma(1775) \to \Sigma\pi\pi$	1192+ 140+ 140

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

	P 1	P 2	P 3	P 4	P 5	P 6
P 1	.4520+-.0333					
P 2	-.1658	.1497+-.0139				
P 3	-.7170	.1184	.1869+-.0259			
P 4	-.5842	.0969	.4174	.0790+-.0099		
P 5	-.2374	.0394	.1695	.1387	.0374+-.0121	
P 6	-.1406	-.4778	-.3639	-.1568	-.3887	.0950+-.0270

Σ(1775) BRANCHING RATIOS

```
ERRORS QUOTED BY EXPERIMENTERS DO NOT INCLUDE UNCERTAINTY DUE
TO PARAMETRIZATION USED IN THE P.W.A.  THEY SHOULD BE INCREASED.
```

$\Sigma(1775) \to (N\bar{K})$/total (P1)

```
R1   A       0.37 OR  0.36            MARTIN    77 DPWA    KBAR N MULTICHNL
R1   B      (0.41)   (0.03)           RLIC      77 DPWA    KBAR N MULTICHNL
R1   B  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1           0.37     0.03            ALSTON    78 DPWA    KBAR N ELASTIC
R1           0.40    (0.02)           GOPAL     80 DPWA    KBAR N ELASTIC
R1         . . . . . . . . . .
R1  FIT      0.452    0.033  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.9)
```

$\Sigma(1775)$ in $N\bar{K} \to \Lambda\pi$ SQRT(P1*P2)

```
R2          -0.259    0.048           DEVENISH  74        0 FIXED T DISP REL
R2          -0.25     0.02            BAILLON   75 IPWA     KBAR N TO LAM PI
R2          -0.28     0.04     0.05   VANHORN   75 DPWA   0 K- P TO LAM PI0
R2         (-0.30)                    BELLEFON  76 IPWA   0 K- P TO LAM PI
R2   A      -0.29 OR -0.28            MARTIN    77 DPWA     KBAR N MULTICHNL
R2          -0.28     0.03            RLIC      77 DPWA     KBAR N MULTICHNL
R2         . . . . . . . . . .
R2  AVG MOD  0.261    0.015   AVERAGE
R2  FIT      0.260    0.014  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

$\Sigma(1775)$ in $N\bar{K} \to \Lambda(1520)\ \pi$ SQRT(P1*P3)

```
R3           0.27     0.03            ARMENTERO 65 HBC    0 K-P TO Y*1520 PI
R3           0.31     0.02            BARLETTA  72 DPWA   0 K-P TO Y*1520 PI
R3   C      -0.305    0.010           CAMERON   77 DPWA   0 K-P TO L(1520)PI
R3   C  LISTED RATE COMBINES P- AND F-WAVE DECAYS AND ASSUMES LAMBDA(1520)
R3   C  ELASTICITY=.46. THE CAMERON 77 RESULTS FOR THE SEPARATE P- AND
R3   C  F-WAVE DECAYS ARE -0.303+/-.010 AND -0.037+/-.014, RESPECTIVELY.
R3   C  THE SIGNS ARE CHANGED HERE TO BE IN ACCORD WITH THE BARYON-FIRST
R3   C  CONVENTION.
R3         . . . . . . . . . .
R3  AVG MOD  0.3031   0.0086  AVERAGE
R3  FIT      0.291    0.015  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.7)
```

$\Sigma(1775)$ in $N\bar{K} \to \Sigma(1385)\ \pi$, D-wave SQRT(P1*P4)

```
R4          (0.24)   (0.03)           ARMENT-2  67 HBC    0 K-P TO LAM PI PI
R4  D       (0.32)   (0.06)           SIMS      68 DBC    - K-N TO LAM PI PI
R4  D   SIMS 68 USES ONLY CROSS-SECT. DATA. RESULT USED AS UPPER LIMIT ONLY
R4          +0.20     0.02            PREVOST   74 DPWA 0- K-N TO S(1385)PI
R4   C      -0.184    0.011           CAMERON   78 DPWA   0 K-P TO S(1385)PI
R4   C  CAMERON  78 UPPER LIMIT ON G-WAVE DECAY IS 0.03.
R4         . . . . . . . . . .
R4  AVG MOD  0.1877   0.0096  AVERAGE
R4  FIT      0.1889   0.0096 FROM FIT
```

$\Sigma(1775)$ in $N\bar{K} \to \Sigma\pi$ SQRT(P1*P5)

```
R5           0.09    (0.01)           KANE      74 DPWA     K-P TO PI SIG
R5   A      +0.08 OR +0.08            MARTIN    77 DPWA     KBAR N MULTICHNL
R5          +0.13     0.02            RLIC      77 DPWA     KBAR N MULTICHNL
R5         . . . . . . . . . .
R5  FIT      0.130    0.020  FROM FIT
```

$\Sigma(1775) \to (\Lambda\pi)/(N\bar{K})$ (P2)/(P1)

```
R6           0.33     0.05            UHLIG     67 HBC    0 K-P,.9 GEV/C
R6         . . . . . . . . . .
R6  FIT      0.331    0.042  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

$\Sigma(1775) \to (\Lambda(1520)\pi)/(N\bar{K})$ (P3)/(P1)

```
R7           0.28     0.05            UHLIG     67 HBC    0 K-P,.9 GEV/C
R7         . . . . . . . . . .
R7  FIT      0.413    0.082  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 2.5)
```

$\Sigma(1775) \to (\Sigma(1385)\pi)/(N\bar{K})$ (P4)/(P1)

```
R8           0.25     0.09            UHLIG     67 HBC    0 K-P,.9 GEV/C
R8         . . . . . . . . . .
R8  FIT      0.175    0.031  FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.4)
```

$\Sigma(1775) \to (\Sigma\pi\pi)$/total (P7)

```
R9   E      (0.12)                    ARMENT-2  68 HDBC -0 K-N TO SIG PI PI
R9   E   FOR ABOUT 3/4 OF THIS, THE SIGMA PI SYSTEM HAS I=0 AND IS ALMOST
R9   E ENTIRELY LAMBDA(1520).  FOR THE REST, THE SIGMA PI HAS I=1.  THIS
R9   E IS ABOUT WHAT IS EXPECTED FROM THE KNOWN RATE SIGMA(1775) TO
R9   E SIGMA(1385) PI, AS SEEN IN LAMBDA PI PI.
```

REFERENCES FOR Σ(1775)

```
GALTIERI 63 PL 6 296           A BARBARO-GALTIERI,A HUSSAIN,R D TRIPP(LRL)IJ
ARMENTER 65 PL 19 338          ARMENTEROS, +              (CERN+HEID+SACL)IJP
BELL 1   66 PRL 16 203         R B BELL, R W BIRGE, Y-L PAN, R T PU  (LRL)IJP
BELL 2   66 UCRL-16936 THESIS R B BELL                               (LRL)IJP
FENSTER  66 PRL 17 841         +GELFAND,HARMSEN,L-SETTI,+  (CHIC+ANL+CERN)IJP
    -- FENSTER 66 IS SUPERSEDED BY BARLETTA 72
ARMENTER 67 PL 24B 198         ARMENTEROS,FERRO-LUZZI+    (CERN+HEID+SACL)IJP
ARMENT-2 67 ZEIT.PHYS.202 486 ARMENTEROS,FERRO-LUZZI+     (CERN+HEID+SACL)
UHLIG    67 PR 155 1448        +CHARLTON,CONDON,GLASSER,YODH,+   (UMD+NRL)
ARMENT-1 68 NP B8 195          ARMENTEROS, BAILLON, +     (CERN+HEID+SACL)IJP
ARMENT-2 68 NP B8 216          ARMENTEROS, BAILLON, +     (CERN+HEID+SACL) I
BUGG     68 PR 168 1466        +GILMORE,KNIGHT,DAVIES+    (BIRM+CAVE+RHEL)I
CONFORTO 68 NP B8 265          +HARMSEÑ, LASINSKI, +           (CHIC+HEID)IJP
    SUPERSEDED BY CONFORTO 71.
SIMS     68 PRL 21 1413        SIMS,ALBRIGHT,BARTLEY,MEER+ (FSU+TUFT+BRAN)
SMART    68 PR 169 1330        W M SMART                             (LRL)IJP
BRICMAN1 70 PL 33B 511         +FERRO-LUZZI,LAGNAUX                 (CERN)
COOL     70 PR D1 1887         +GIACOMELLI, KYCIA, LEONTIC, LI, +   (BNL) I
GALTIERI 70 DUKE CONF 173      A BARBARO-GALTIERI                    (LRL)IJP
HARRISON 70 FSU-HEP 70 3 1     W C HARRISON (THESIS)                (FSU)
CONFORTO 71 NP  B34  41        +LEVI SETTI,LASINSKI..OBERLACK++ (EFI+HEID)IJP
KIM      71 PRL 27 356         J K KIM                              (HARV)IJP
    ALSO 70 DUKE 161           J K KIM                              (HARV)IJP
PREVOST  71  AMSTERDAM CONF    + CHS COLLABORATION         (CERN+HEID+SACL)
BARLETTA 72 NP B40 45          W A BARLETTA                         (EFI) IJP
KANE     72 PR D5 1583         D F KANE                              (LBL)IJP
LANGBEIN 72 NP B47 477         +WAGNER                              (MPIM)IJP
DEVENISH 74 NP B81 330         DEVENISH,FROGGATT,MARTIN    (DESY+NORD+LOUC)
KANE     74  LBL-2452          D F KANE                              (LBL)IJP
PREVOST  74 NP B69 246         PREVOST,BARLOUTAUD,+        (SACL+CERN+HEID)
BAILLON  75 NP B94 39          P BAILLON, P J LITCHFIELD        (CERN+RHEL)IJP
VANHORN  75 NP B87 145         A J VAN HORN                          (LBL)IJP
    ALSO 75 NP B87 157         A J VAN HORN                          (LBL)IJP
BELLEFON 76 NP B109 129        DE BELLEFON,BERTHON                  (CDEF)IJP
CAMERON  77 NP B131 399        +FRANEK,GOPAL,KALMUS,MCPHERSON+ (RHEL+LOIC)IJP
MARTIN   77 NP B127 349        MARTIN,PIDCOCK,MOORHOUSE         (LOUC+GLAS)IJP
    ALSO 77 NP B126 266        MARTIN,PIDCOCK                       (LOUC)
    ALSO 77 NP B126 285        MARTIN,PIDCOCK                       (LOUC)IJP
RLIC     77 NP B119 362        GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182         +KENNEY,POLLARD,ROSS+       (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007        ALSTON-GARNJOST,KENNEY,+    (LBL+MTHO+CERN)IJP
CAMERON  78 NP B143 189        +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                             (RHEL)IJP
```

$\Sigma(1840)\ P_{13}$

$I(J^P) = 1(\frac{3}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

```
FOR THE TIME BEING, WE LIST ALL RESONANCE CLAIMS IN THE P13-WAVE IN
THE 1700-1900 MEV MASS REGION TOGETHER UNDER THIS HEADING.
```

Σ(1840) MASS (MeV)

```
M          1840.0    (10.0)            LANGBEIN  72 IPWA    MULTICHANNEL
M    A    (1720.0)   (30.0)            BAILLON   75 IPWA    KBAR N TO LAM PI
M    A  FROM SOLUTION 1 OF BAILLON 75, NOT PRESENT IN SOLUTION 2.
M          1925.0   (200.0)            VANHORN   75 DPWA  0 K- P TO LAM PI0
M     B    1798. OR 1802.              MARTIN    77 DPWA    KBAR N MULTICHNL
M     B  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M     B  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
```

Baryon Full Listings

$\Sigma(1840)$, $\Sigma(1880)$, $\Sigma(1915)$

$\Sigma(1840)$ WIDTH (MeV)

```
W          120.0    (10.0)             LANGBEIN  72 IPWA    MULTICHANNEL
W   A     (120.0)   (30.0)             BAILLON   75 IPWA    KBAR N TO LAM PI
W           65.0    (50.0)    (20.0)   VANHORN   75 DPWA  0 K- P TO LAM PI0
W    B      93. OR 93.                 MARTIN    77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1840)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(1840) \rightarrow N\bar{K}$	938+ 494
P2	$\Sigma(1840) \rightarrow \Sigma\pi$	1189+ 140
P3	$\Sigma(1840) \rightarrow \Lambda\pi$	1116+ 135

$\Sigma(1840)$ BRANCHING RATIOS

$\Sigma(1840) \rightarrow (N\bar{K})$/total (P1)

```
R1          0.37     (0.13)            LANGBEIN  72 IPWA    MULTICHANNEL
R1   B      0.0 OR 0.0                 MARTIN    77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1840)$ in $N\bar{K} \rightarrow \Sigma\pi$ SQRT(P1*P2)

```
R2          0.15     (0.04)            LANGBEIN  72 IPWA    MULTICHANNEL
R2   B     -0.04 OR -0.04              MARTIN    77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1840)$ in $N\bar{K} \rightarrow \Lambda\pi$ SQRT(P1*P3)

```
R3          0.20     (0.04)            LANGBEIN  72 IPWA    MULTICHANNEL
R3         +0.122     0.078            DEVENISH  74       0 FIXED T DISP REL
R3   A    (+0.11)    (0.02)            BAILLON   75 IPWA    KBAR N TO LAM PI
R3         +0.06     (0.04)            VANHORN   75 DPWA  0 K- P TO LAM PI0
R3   B     +0.03 OR +0.03              MARTIN    77 DPWA    KBAR N MULTICHNL
```

REFERENCES FOR $\Sigma(1840)$

```
LANGBEIN 72 NP B47 477        +WAGNER                              (MPIM)IJP
DEVENISH 74 NP B81 330        DEVENISH,FROGGATT,MARTIN    (DESY+NORD+LOUC)
BAILLON  75 NP B94 39         P BAILLON, P J LITCHFIELD         (CERN+RHEL)IJP
VANHORN  75 NP B87 145        A J VAN HORN                          (LBL)IJP
    ALSO 75 NP B87 157        A J VAN HORN                          (LBL)IJP
MARTIN   77 NP B127 349       MARTIN,PIDCOCK,MOORHOUSE         (LOUC+GLAS)IJP
    ALSO 77 NP B126 266       MARTIN,PIDCOCK                        (LOUC)
    ALSO 77 NP B126 285       MARTIN,PIDCOCK                        (LOUC)IJP
```

$\Sigma(1880)$ P_{11}

$I(J^P) = 1(\frac{1}{2}^+)$ Status: * *

OMITTED FROM SUMMARY TABLE

A RESONANCE IS SUGGESTED BY SEVERAL PARTIAL-WAVE ANALYSES ACROSS THIS REGION, BUT WITH WIDE VARIATIONS IN THE MASS AND OTHER PARAMETERS. WE LIST HERE ALL CLAIMS WHICH LIE WELL ABOVE THE SIGMA(1770).

$\Sigma(1880)$ MASS (MeV)

```
M          1882.0     40.0             SMART     68 DPWA -0 K- N TO LAM PI
M         (1850.0)                     BAILEY    69 DPWA  0 ELASTIC, CH EXCH
M          ABOUT 1850.0                ARMENTERO 70 IPWA -0 ELASTIC, CH EXCH
M          1950.0     50.0             GALTIERI  70 DPWA -0 K- N TO LAM PI
M          1920.0     30.0             LITCHFIEL 70 DPWA -0 K- N TO LAM PI
M    A    (1898.0)                     LEA       73 DPWA    MULTICHNL K-MTRX
M    A  ONLY UNCONSTRAINED STATES FROM TABLE 1 OF LEA73 ARE IN LISTINGS.
M   B     (1960.0)   (30.0)            BAILLON   75 IPWA    KBAR N TO LAM PI
M   B   FROM SOLUTION 1 OF BAILLON 75, NOT PRESENT IN SOLUTION 2.
M          1985.0     50.0             VANHORN   75 DPWA  0 K- P TO LAM PI0
M    C     1847. OR 1863.              MARTIN    77 DPWA    KBAR N MULTICHNL
M    C  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M    C  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1870.0     10.0             CAMERON2  78 DPWA    K-P TO K*(892) N
M          1826.0    (20.0)            GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Sigma(1880)$ WIDTH (MeV)

```
W           222.0    150.0             SMART     68 DPWA -0 K- N TO LAM PI
W          (200.0)                     BAILEY    69 DPWA  0 ELASTIC, CH EXCH
W          ABOUT 30.0                  ARMENTERO 70 IPWA -0 ELASTIC, CH EXCH
W           200.0     50.0             GALTIERI  70 DPWA -0 K- N TO LAM PI
W           170.0     40.0             LITCHFIEL 70 DPWA -0 K- N TO LAM PI
W    A     (222.2)                     LEA       73 DPWA    MULTICHNL K-MTRX
W   B      (260.0)   (40.0)            BAILLON   75 IPWA    KBAR N TO LAM PI
W           220.0    140.0             VANHORN   75 DPWA  0 K- P TO LAM PI0
W    C      216. OR 220.               MARTIN    77 DPWA    KBAR N MULTICHNL
W            80.0     10.0             CAMERON2  78 DPWA    K-P TO K*(892) N
W            86.0    (15.0)            GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Sigma(1880)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(1880) \rightarrow N\bar{K}$	938+ 494
P2	$\Sigma(1880) \rightarrow \Lambda\pi$	1116+ 135
P3	$\Sigma(1880) \rightarrow \Sigma\pi$	1197+ 140
P4	$\Sigma(1880) \rightarrow NK^*(892)$, $P1$-wave	940+ 892
P5	$\Sigma(1880) \rightarrow NK^*(892)$, $P3$-wave	940+ 892

$\Sigma(1880)$ BRANCHING RATIOS

$\Sigma(1880) \rightarrow (N\bar{K})$/total (P1)

```
R1         (0.22)                      BAILEY    69 DPWA  0 ELASTIC, CH EXCH
R1         (0.20)                      ARMENTERO 70 IPWA -0 ELASTIC, CH EXCH
R1   A     (0.31)                      LEA       73 DPWA    MULTICHNL K-MTRX
R1   C      0.27 OR  0.27              MARTIN    77 DPWA    KBAR N MULTICHNL
R1          0.06     (0.02)            GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Sigma(1880)$ in $N\bar{K} \rightarrow \Lambda\pi$ SQRT(P1*P2)

```
R2         -0.11      0.03             SMART     68 DPWA -0 K- N TO LAM PI
R2         -0.09      0.04             GALTIERI  70 DPWA -0 K- N TO LAM PI
R2         -0.14      0.03             LITCHFIEL 70 DPWA -0 K- N TO LAM PI
R2   A    (-0.30)                      LEA       73 DPWA    MULTICHNL K-MTRX
R2         -0.169     0.119            DEVENISH  74       0 FIXED T DISP REL
R2  B     (-0.12)    (0.02)            BAILLON   75 IPWA    KBAR N TO LAM PI
R2         +0.05      0.07      0.02   VANHORN   75 DPWA  0 K- P TO LAM PI0
R2   C     -0.24 OR -0.24              MARTIN    77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1880)$ in $N\bar{K} \rightarrow \Sigma\pi$ SQRT(P1*P3)

```
R3   A    NOT SEEN                     LEA       73 DPWA    MULTICHNL K-MTRX
R3   C     +0.30 OR +0.29              MARTIN    77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1880)$ in $N\bar{K} \rightarrow NK^*(892)$, $P1$-wave SQRT(P1*P4)

```
R4   D     -0.05      0.03             CAMERON2  78 DPWA    K-P TO K*N
R4   D  THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R4   D  CONVENTION.
```

$\Sigma(1880)$ in $N\bar{K} \rightarrow NK^*(892)$, $P3$-wave SQRT(P1*P5)

```
R5         +0.11      0.03         .   CAMERON2  78 DPWA    K-P TO K*N
```

REFERENCES FOR $\Sigma(1880)$

```
SMART    68 PR 169 1330        W M SMART                               (LRL)IJP
BAILEY   69 THESIS UCRL-50617 DAVID SAAL BAILEY                        (LLL)IJP
ARMENTER 70 DUKE CONF 123      ARMENTEROS, BAILLON, +             (CERN+HEID)IJP
GALTIERI 70 DUKE CONF 173      A BARBARO-GALTIERI                      (LRL)IJP
LITCHFIE 70 NP B22 269         P J LITCHFIELD                         (RHEL)IJP
LEA      73 NP B56 77          +MARTIN,MOORHOUSE+     (RHEL+LOUC+GLAS+AARH)IJP
DEVENISH 74 NP B81 330         DEVENISH,FROGGATT,MARTIN   (DESY+NORD+LOUC)
BAILLON  75 NP B94 39          P BAILLON, P J LITCHFIELD          (CERN+RHEL)IJP
VANHORN  75 NP B87 145         A J VAN HORN                            (LBL)IJP
    ALSO 75 NP B87 157         A J VAN HORN                            (LBL)IJP
MARTIN   77 NP B127 349        MARTIN,PIDCOCK,MOORHOUSE           (LOUC+GLAS)IJP
    ALSO 77 NP B126 266        MARTIN,PIDCOCK                         (LOUC)
    ALSO 77 NP B126 285        MARTIN,PIDCOCK                         (LOUC)IJP
CAMERON2 78 NP B146 327        +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                               (RHEL)IJP
```

$\Sigma(1915)$ F_{15}

$I(J^P) = 1(\frac{5}{2}^+)$ Status: * * * *

FOR RESULTS PUBLISHED BEFORE 1974 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

THIS RESONANCE WAS FIRST SEEN IN THE TOTAL-CROSS-SECTION MEASUREMENTS OF COOL 66. IN THIS ENTRY, HOWEVER, WE LIST ONLY THE RESULTS FROM PARTIAL-WAVE ANALYSES. SEE THE NEXT ENTRY FOR THE PARAMETERS OF PEAKS SEEN AROUND 1900-1950 MEV IN CROSS SECTIONS AND INVARIANT-MASS DISTRIBUTIONS. WE MAKE THIS SEPARATION BECAUSE ONLY THE PARTIAL-WAVE ANALYSES ISOLATE THE F15-WAVE. SEE ALSO THE NOTE TO THE NEXT ENTRY.

$\Sigma(1915)$ MASS (MeV)

```
M          1920.0    (5.0)             KANE      74 DPWA    K-P TO PI SIG
M          1920.0    30.0              BAILLON   75 IPWA    KBAR N TO LAM PI
M          1914.0    10.0              HEMINGWA  75 DPWA  0 K- P TO KBAR N
M          1920.0    15.0      20.0    VANHORN   75 DPWA  0 K- P TO LAM PI0
M         (1915.0)                     BELLEFON  76 IPWA  0 K- P TO LAM PI
M    A     1900.0     4.0              CORDEN    76 DPWA  - K- N TO PI- LAM
M    A  PREFERRED SOLUTION 3, SEE CORDEN 76 FOR OTHER POSSIBLILITES.
M    A  CORDEN 76 INCLUDES THE DATA OF COX 70 AS A SUBSAMPLE
M    B     1894.0     5.0              CORDEN1   77         - K- N TO PI SIG
M    B     1909.0     5.0              CORDEN1   77         - K- N TO PI SIG
M    B  THE 2 ENTRIES FOR CORDEN177 ARE FROM 2 DIFFERENT ACCEPTABLE SLTNS.
M       NOT SEEN                       DECLAIS   77 DPWA    KBAR N TO KBAR N
M    C     1925. OR 1933.              MARTIN    77 DPWA    KBAR N MULTICHNL
M    C  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M    C  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1920.0    10.0              RLIC      77 DPWA    KBAR N MULTICHNL
M          1937.0    20.0              ALSTON    78 DPWA    KBAR N ELASTIC
```

$\Sigma(1915)$ WIDTH (MeV)

```
W          162.0    (25.0)             KANE      74 DPWA    K-P TO PI SIG
W           70.0     20.0              BAILLON   75 IPWA    KBAR N TO LAM PI
W           85.0     15.0              HEMINGWA  75 DPWA  0 K- P TO KBAR N
W          102.0     18.0              VANHORN   75 DPWA  0 K- P TO LAM PI0
W          (60.0)                      BELLEFON  76 IPWA  0 K- P TO LAM PI
W    A      75.0     14.0              CORDEN    76 DPWA  - K- N TO PI- LAM
W    B     107.0     14.0              CORDEN1   77         - K- N TO PI SIG
W    B      85.0     13.0              CORDEN1   77         - K- N TO PI SIG
W    C     171. OR 173.                MARTIN    77 DPWA    KBAR N MULTICHNL
W          130.0     10.0              RLIC      77 DPWA    KBAR N MULTICHNL
W          161.0     20.0              ALSTON    78 DPWA    KBAR N ELASTIC
```

$\Sigma(1915)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(1915) \to N\bar{K}$	938+ 494
P2	$\Sigma(1915) \to \Lambda\pi$	1116+ 140
P3	$\Sigma(1915) \to \Sigma\pi$	1189+ 140
P4	$\Sigma(1915) \to \Sigma(1385)\ \pi$, P-wave	1385+ 140
P5	$\Sigma(1915) \to \Sigma(1385)\ \pi$, F-wave	1385+ 140

$\Sigma(1915)$ BRANCHING RATIOS

$\Sigma(1915) \to (N\bar{K})$/total (P1)

```
R1          0.11    (0.04)          HEMINGWA  75 DPWA  0 K- P TO KBAR N
R1   C      0.08 OR  0.08           MARTIN    77 DPWA    KBAR N MULTICHNL
R1   D     (0.05)   (0.03)          RLIC      77 DPWA    KBAR N MULTICHNL
R1   D  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1          0.14    (0.05)          ALSTON    78 DPWA    KBAR N ELASTIC
R1   E      0.03    (0.02)          GOPAL     80 DPWA    KBAR N ELASTIC
R1   E  MASS AND WIDTH FIXED TO RLIC 77 VALUES DUE TO LOW ELASTICITY.
```

$\Sigma(1915)$ in $N\bar{K} \to \Lambda\pi$ SQRT(P1*P2)

```
R2         -0.087   (0.056)         DEVENISH  74       0 FIXED T DISP REL
R2         -0.06    (0.02)          BAILLON   75 IPWA    KBAR N TO LAM PI
R2         -0.09    (0.02)          VANHORN   75 DPWA  0 K- P TO LAM PI0
R2        (-0.10)                   BELLEFON  76 IPWA  0 K- P TO LAM PI
R2   A     -0.10     0.01           CORDEN    76 DPWA  - K- N TO PI- LAM
R2   C     -0.09 OR -0.09           MARTIN    77 DPWA    KBAR N MULTICHNL
R2         -0.09    (0.03)          RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1915)$ in $N\bar{K} \to \Sigma\pi$ SQRT(P1*P3)

```
R3         -0.16    (0.03)          KANE      74 DPWA    K-P TO PI SIG
R3   B     -0.17     0.01           CORDEN1   77       - K- N TO PI SIG
R3   B     -0.15     0.02           CORDEN1   77       - K- N TO PI SIG
R3   C     -0.05 OR -0.05           MARTIN    77 DPWA    KBAR N MULTICHNL
R3         -0.19    (0.03)          RLIC      77 DPWA    KBAR N MULTICHNL
R3         . . . . . . . . . . .
R3  AVG MOD  0.1660   0.0089  AVERAGE
```

$\Sigma(1915)$ in $N\bar{K} \to \Sigma(1385)\ \pi$, P-wave SQRT(P1*P4)

```
R4         LESS THAN 0.01           CAMERON   78 DPWA  0 K-P TO S(1385)PI
```

$\Sigma(1915)$ in $N\bar{K} \to \Sigma(1385)\ \pi$, F-wave SQRT(P1*P5)

```
R5   F     +0.039    0.009          CAMERON   78 DPWA  0 K-P TO S(1385)PI
R5   F  THE SIGN IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R5   F  CONVENTION.
```

REFERENCES FOR $\Sigma(1915)$

```
SMART    66 PRL 17 556          W M SMART,A KERNAN,G E KALMUS,R P ELY (LRL)IJP
ARMENTER 67 PL 24B 198          ARMENTEROS,FERRO-LUZZI+    (CERN+HEID+SACL)
ARMENTE1 67 NP B3 592           ARMENTEROS,FERRO-LUZZI+    (CERN+HEID+SACL)
CONFORTO 68 NP B8 265           +HARMSEN, LASINSKI, +           (CHIC+HEID)
SMART    68 PR 169 1330         W M SMART                            (LRL)IJP
BERTHON  70 NP B20 476          +RANGAN, VRANA,         +  (CDEF+RHEL+SACL)IJP
BERTHON1 70 NP B24 417          +VRANA, BUTTERWORTH, +     (CDEF+RHEL+SACL)IJ
BRICMAN1 70 PL 33B 511          +FERRO-LUZZI,LAGNAUX                (CERN)
COX      70 NP B19 61           +ISLAM, COLLEY, +     (BIRM+EDIN+GLAS+LOIC)IJP
GALTIERI 70 DUKE CONF 173       A BARBARO-GALTIERI                   (LRL)IJP
LITCHFIE 70 NP B22 269          P J LITCHFIELD                      (RHEL)IJP
CONFORTO 71 NP  B34  41         +LEVI SETTI,LASINSKI..OBERLACK++ (EFI+HEID)IJP
LITCHFIE 71 NP  B30 125         LITCHFIELD,...+LESQUOY,+.. (RHEL+CDEF+SACL)IJP
KANE     72 PR D5 1583          D F KANE                             (LBL)IJP
DEVENISH 74 NP B81 330          DEVENISH,FROGGATT,MARTIN   (DESY+NORD+LOUC)
KANE     74  LBL-2452           D F KANE                             (LBL)IJP
BAILLON  75 NP B94 39           P BAILLON, P J LITCHFIELD       (CERN+RHEL)IJP
HEMINGWA 75 NP B91 12           HEMINGWAY,EADES,HARMSEN+   (CERN+HEID+MPIM)IJP
VANHORN  75 NP B87 145          A J VAN HORN                         (LBL)IJP
    ALSO 75 NP B87 157          A J VAN HORN                         (LBL)IJP
BELLEFON 76 NP B109 129         DE BELLEFON,BERTHON                 (CDEF)IJP
CORDEN   76 NP B104 382         +COX,DARTNELL,KENYON,ONEALE,SUMOROK+ (BIRM)IJP
CORDEN1  77 NP B125 61          +COX,KENYON,ONEALE,STUBBS,SUMOROK+   (BIRM)IJP
DECLAIS  77  CERN 77-16         +DUCHON,LOUVEL,PATRY,SEGUINOT+  (CAEN+CERN)IJP
MARTIN   77 NP B127 349         MARTIN,PIDCOCK,MOORHOUSE        (LOUC+GLAS)IJP
    ALSO 77 NP B126 266         MARTIN,PIDCOCK                      (LOUC)
    ALSO 77 NP B126 285         MARTIN,PIDCOCK                      (LOUC)IJP
RLIC     77 NP B119 362         GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
ALSTON   78 PR D18 182          +KENNEY,POLLARD,ROSS+       (LBL+MTHO+CERN)IJP
    ALSO 77 PRL 38 1007         ALSTON-GARNJOST,KENNEY,+    (LBL+MTHO+CERN)IJP
CAMERON  78 NP B143 189         +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                             (RHEL)IJP
```

1915 MeV REGION – PRODUCTION AND σ_{TOTAL} EXP'TS

$I(J^P) = 1(\quad)$

SEE THE NOTES TO THE SIGMA(1915) AND SIGMA(1940), WHICH IMMEDIATELY PRECEDE AND FOLLOW THIS ENTRY. HERE WE LIST ONLY PARAMETERS OF PEAKS SEEN IN CROSS SECTIONS AND INVARIANT-MASS DISTRIBUTIONS. THE CROSS-SECTION PEAKS ARE ALMOST CERTAINLY ASSOCIATED WITH THE F15 SIGMA(1915) SEEN IN PARTIAL-WAVE ANALYSES. THE INVARIANT-MASS PEAKS SEEM MORE LIKELY TO BE ASSOCIATED WITH THE D13 SIGMA(1940).

$\Sigma(1915)$ MASS (MeV) (PROD. EXP.)

```
M         CROSS-SECTION PEAKS --
M          1905.0      5.0          BUGG      68 CNTR    K-P, D TOTAL
M          1906.0      6.0          BRICMAN   70 CNTR  0 TOTAL AND CH EX
M          1912.0     10.0          COOL      70 CNTR    K-P, D TOTAL
M         INVARIANT-MASS-DISTRIBUTION PEAKS --
M         (1942.0)    (9.0)         BOCK      65 HBC     PBAR P 5.7 GEV/C
M          1940.0     11.0          AGUILAR   70 HBC   + 3.9-4.6 GEV/C K-
M       42 1979.0     14.0          BRIEFEL   77 HBC   + XI K MODE 2.9K-P
M   A  200(1910.0)   (17.0)         FERRER    81 OMEG  - PI-P 9,12 GEV/C
M   A   BACKWARD PRODUCTION IN LAMBDA PI- K+ FINAL STATE.
M         ELASTIC DCS --
M    B     1931.0    9.0            DADO      72 HBC   0 K-P ELSTC DCS
M    B  G7 INDICATED BY LEGENDRE COEFFS.,G9 NOT RULED OUT.
```

$\Sigma(1915)$ WIDTH (MeV) (PROD. EXP.)

```
W         CROSS-SECTION PEAKS --
W           60.0      10.0          BUGG      68 CNTR
W           50.0      12.0          BRICMAN   70 CNTR  0 TOTAL AND CH EX
W          (30.0)                   COOL      70 CNTR    K-P, D TOTAL
W         INVARIANT-MASS-DISTRIBUTION PEAKS --
W          (36.0)    (20.0)   (36.0) BOCK     65 HBC
W           90.0      20.0          AGUILAR   70 HBC   + 3.9-4.6 GEV/C K-
W       42  69.0      32.0          BRIEFEL   77 HBC   + XI K MODE 2.9K-P
W   A  200 (87.0)    (25.0)         FERRER    81 OMEG  - PI-P 9,12 GEV/C
W         ELASTIC DCS --
W    B      70.0      14.0          DADO      72 HBC   0 K-P ELSTC DCS
```

$\Sigma(1915)$ PARTIAL DECAY MODES (PROD. EXP.)

		DECAY MASSES
P1	$\Sigma(1915) \to N\bar{K}$	938+ 494
P2	$\Sigma(1915) \to \Lambda\pi$	1116+ 135
P3	$\Sigma(1915) \to \Sigma\pi$	1189+ 140
P4	$\Sigma(1915) \to \Xi K$	1315+ 494

$\Sigma(1915)$ BRANCHING RATIOS (PROD. EXP.)

$\Sigma(1915) \to (N\bar{K})$/total (P1)

```
R1          THESE VALUES OF ELASTICITIES ASSUME J=5/2 --
R1          0.06                    BUGG      68 CNTR    ASSUMING J=5/2
R1          0.07     0.02           BRICMAN   70 CNTR  0 TOTAL AND CH EX
R1          0.07                    COOL      70 CNTR    K-P, D TOTAL
R1   B  THIS ELASTICITY ASSUMES J=7/2
R1   B      0.62     0.08           DADO      72 HBC   0 K-P ELSTC DCS
R1         . . . . . . . . . . .
R1  AVG     0.10     0.13    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 6.7)
```

$\Sigma(1915) \to (N\bar{K})/(\Sigma\pi)$ (P1)/(P3)

```
R2         (0.37) OR LESS           BARNES    69 HBC   + 1 STAN. DEV.
```

$\Sigma(1915) \to (\Lambda\pi)/(\Sigma\pi)$ (P2)/(P3)

```
R3         (0.28) OR LESS           BARNES    69 HBC   + 1 STAN. DEV.
```

$\Sigma(1915) \to (\Xi K)$/total (P4)

```
R4      42   SEEN                   BRIEFEL   77 HBC   + K-P 2.87 GEV
```

REFERENCES FOR $\Sigma(1915)$ (PROD. EXP.)

```
BOCK     65 PL 17 166           +COOPER,FRENCH,KINSON, +       (CERN+SACL) I
COOL     66 PRL 16 1228         +GIACOMELLI,KYCIA,LEONTIC,LI,LUNDBY,+ (BNL) I
   SUPERSEDED BY COOL 70.
BUGG     68 PR 168 1466         +GILMORE,KNIGHT,DAVIES+    (BIRM+CAVE+RHEL)I
PRIMER   68 PRL 20 610          +GOLDBERG,JAEGER,BARNES,DORNAN + (SYRA+BNL)
   SUPERSEDED BY BARNES 69 AND AGUILAR-BENITEZ 70.
BARNES   69 PRL 22 479          +FLAMINIO,MONTANET,SAMIOS +       (BNL+SYRA)
AGUILAR  70 PRL 25 58           AGUILAR-BENITEZ, BARNES, +        (BNL+SYRA)
BRICMAN  70 PL 31B 152          +FERRO LUZZI, PERREAU,+    (CERN+CAEN+SACL)
COOL     70 PR D1 1887          +GIACOMELLI, KYCIA, LEONTIC, LI, +   (BNL) I
DADO     72 PRL 29 1695         +BIRMAN,GOLDBERG,WEISS               (HAIF)JP
BRIEFEL  77 PR D16 2706         +GOUREVITCH,CHANG+    (BRAN+UMD+SYRA+TUFT)
FERRER   81 NP B178 373         +TREILLE,RIVET,VOLTE+ (CERN+CDEF+EPOL+LALO)
```

$\boxed{\Sigma(1940)\ D_{13}}$

$I(J^P) = 1(\tfrac{3}{2}^-)$ Status: * * *

FOR RESULTS PUBLISHED BEFORE 1974 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

SOME, NOT ALL, PARTIAL-WAVE ANALYSES SUGGEST A STATE IN THIS REGION. IT IS PERHAPS ASSOCIATED WITH THE BUMPS SEEN IN PRODUCTION EXPERIMENTS NEAR THIS MASS (SEE THE PRECEDING ENTRY). THIS STATE IS NOT REQUIRED IN K- NEUTRON TO (PI SIGMA)- ANALYSIS OF GOYAL 77. KBAR N ANALYSIS (GOPAL 80) WITH K- NEUTRON ELASTIC DATA DOES NOT REQUIRE THIS STATE.

$\Sigma(1940)$ MASS (MeV)

```
M          1935.0    (80.0)         KANE      74 DPWA    K-P TO PI SIG
M          1940.0     20.0          LITCHFI2  74 DPWA  0 K-P TO L(1520)PI
M          1950.0     20.0          LITCHFI3  74 DPWA  0 K-P TO KBAR DEL
M          1950.0     30.0          BAILLON   75 IPWA    KBAR N TO LAM PI
M          1949.0     40.0     60.0 VANHORN   75 DPWA  0 K- P TO LAM PI0
M   A     (1940.0)                  BELLEFON  76 IPWA  0 K- P TO LAM PI
M   A   SLIGHT BUMP IN MODULUS OF F7-WAVE.
M    B     1886. OR 1893.           MARTIN    77 DPWA    KBAR N MULTICHNL
M    B  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M    B  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M          1920.0     50.0          RLIC      77 DPWA    KBAR N MULTICHNL
```

Σ(1940) WIDTH (MeV)

```
W          330.0     (80.0)            KANE      74 DPWA    K-P TO PI SIG
W           60.0      20.0             LITCHFI2  74 DPWA  0 K-P TO L(1520)PI
W           70.0      30.0     20.0    LITCHFI3  74 DPWA  0 K-P TO KBAR DEL
W          150.0      75.0             BAILLON   75 IPWA    KBAR N TO LAM PI
W          160.0      70.0     40.0    VANHORN   75 DPWA  0 K- P TO LAM PIO
W     B    157. OR 159.                MARTIN    77 DPWA    KBAR N MULTICHNL
W          300.0      80.0             RLIC      77 DPWA    KBAR N MULTICHNL
W          170.0      25.0             CAMERON2  78 DPWA    K-P TO K*(892) N
```

Σ(1940) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(1940) \rightarrow N\overline{K}$	938+ 494
P2	$\Sigma(1940) \rightarrow \Lambda\pi$	1116+ 140
P3	$\Sigma(1940) \rightarrow \Sigma\pi$	1189+ 140
P4	$\Sigma(1940) \rightarrow \Lambda(1520)\ \pi$, P-wave	1520+ 135
P5	$\Sigma(1940) \rightarrow \Lambda(1520)\ \pi$, F-wave	1520+ 135
P6	$\Sigma(1940) \rightarrow \Delta(1232)\ \overline{K}$, S-wave	1232+ 494
P7	$\Sigma(1940) \rightarrow \Delta(1232)\ \overline{K}$, D-wave	1232+ 494
P8	$\Sigma(1940) \rightarrow \Sigma(1385)\ \pi$, S-wave	1385+ 140
P9	$\Sigma(1940) \rightarrow N\,K^*(892)$, $S3$-wave	940+ 892

Σ(1940) BRANCHING RATIOS

$\Sigma(1940) \rightarrow (N\overline{K})$/total (P1)

```
R1    B        0.14 OR  0.13           MARTIN    77 DPWA    KBAR N MULTICHNL
R1            LESS THAN 0.04           RLIC      77 DPWA    KBAR N MULTICHNL
R1       NO SIGNAL FOR THIS STATE WITH X LARGER THAN ABOUT 0.03 IN THE
R1       ANALYSIS OF HEMINGWAY 75.
```

$\Sigma(1940)$ in $N\overline{K} \rightarrow \Lambda\pi$ SQRT(P1*P2)

```
R2            -0.153    0.070          DEVENISH  74       0 FIXED T DISP REL
R2            -0.04     0.02           BAILLON   75 IPWA    KBAR N TO LAM PI
R2            -0.05     0.03     0.02  VANHORN   75 DPWA  0 K-P TO LAM PIO
R2    B       -0.15 OR -0.14           MARTIN    77 DPWA    KBAR N MULTICHNL
R2            -0.06     0.03           RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1940)$ in $N\overline{K} \rightarrow \Sigma\pi$ SQRT(P1*P3)

```
R3            -0.14    (0.04)          KANE      74 DPWA    K-P TO PI SIG
R3    B       +0.16 OR +0.16           MARTIN    77 DPWA    KBAR N MULTICHNL
R3            -0.08     0.04           RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(1940)$ in $N\overline{K} \rightarrow \Lambda(1520)\ \pi$, P-wave SQRT(P1*P4)

```
R4    C       -0.11     0.04           LITCHFI2  74 DPWA  0 K-P TO L(1520)PI
R4    C  ASSUMES LAMBDA(1520) ELASTICITY=.45,SIGN RLTV. TO SIG(2030) DECAY.
R4    D       LESS THAN 0.03           CAMERON   77 DPWA  0 K-P TO L(1520)PI
R4    D  ASSUMES LAMBDA(1520) ELASTICITY=.46.
```

$\Sigma(1940)$ in $N\overline{K} \rightarrow \Lambda(1520)\ \pi$, F-wave SQRT(P1*P5)

```
R5    C       -0.08     0.04           LITCHFI2  74 DPWA  0 K-P TO L(1520)PI
R5    D        0.062     0.021         CAMERON   77 DPWA  0 K-P TO L(1520)PI
```

$\Sigma(1940)$ in $N\overline{K} \rightarrow \Delta(1232)\ \overline{K}$, S-wave SQRT(P1*P6)

```
R6    E       -0.16     0.05           LITCHFI3  74 DPWA  0 K-P TO KBAR DEL
R6    E  SIGN RELATIVE TO SIGMA(2030) DECAY
```

$\Sigma(1940)$ in $N\overline{K} \rightarrow \Delta(1232)\ \overline{K}$, D-wave SQRT(P1*P7)

```
R7    E       -0.14     0.05           LITCHFI3  74 DPWA  0 K-P TO KBAR DEL
```

$\Sigma(1940)$ in $N\overline{K} \rightarrow \Sigma(1385)\ \pi$, S-wave SQRT(P1*P8)

```
R8    F       +0.066    0.025          CAMERON   78 DPWA  0 K-P TO S(1385)PI
R8    F  SIGN CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION.
```

$\Sigma(1940)$ in $N\overline{K} \rightarrow N\,K^*(892)$, $S3$-wave SQRT(P1*P9)

```
R9    G       -0.09     0.02           CAMERON2  78 DPWA    K-P TO K*N
R9    G  UPPER LIMITS ON THE D1 AND D3-WAVES ARE EACH 0.03.
```

REFERENCES FOR Σ(1940)

```
GALTIERI 70 DUKE CONF 173     A BARBARO-GALTIERI                  (LRL)IJP
LITCHFIE 70 NP B22 269        P J LITCHFIELD                     (RHEL)IJP
KANE     72 PR D5 1583        D F KANE                            (LBL)IJP
LEA      73 NP B56 77         +MARTIN,MOORHOUSE+    (RHEL+LOUC+GLAS+AARH)IJP
DEVENISH 74 NP B81 330        DEVENISH,FROGGATT,MARTIN   (DESY+NORD+LOUC)
KANE     74  LBL-2452         D F KANE                            (LBL)IJP
LITCHFI2 74 NP B74 19         LITCHFIELD,HEMINGWAY,BAILLON,+  (CERN+HEID)IJP
LITCHFI3 74 NP B74 39         LITCHFIELD,HEMINGWAY,BAILLON,+  (CERN+HEID)IJP
BAILLON  75 NP B94 39         P BAILLON, P J LITCHFIELD       (CERN+RHEL)IJP
HEMINGWA 75 NP B91 12         HEMINGWAY,EADES,HARMSEN+   (CERN+HEID+MPIM)IJP
VANHORN  75 NP B87 145        A J VAN HORN                        (LBL)IJP
    ALSO 75 NP B87 157        A J VAN HORN                        (LBL)IJP
BELLEFON 76 NP B109 129       DE BELLEFON,BERTHON                (CDEF)IJP
CAMERON  77 NP B131 399       +FRANEK,GOPAL,KALMUS,MCPHERSON+ (RHEL+LOIC)IJP
GOYAL    77 PR D16 2746       +SODHI                             (DELH)
MARTIN   77 NP B127 349       MARTIN,PIDCOCK,MOORHOUSE        (LOUC+GLAS)IJP
    ALSO 77 NP B126 266       MARTIN,PIDCOCK                     (LOUC)
    ALSO 77 NP B126 285       MARTIN,PIDCOCK                     (LOUC)IJP
RLIC     77 NP B119 362       GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
CAMERON  78 NP B143 189       +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)IJP
CAMERON2 78 NP B146 327       +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP
```

Σ(2000) S_{11}

$I(J^P) = 1(\frac{1}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

WE LIST HERE ALL REPORTED S11 STATES LYING ABOVE THE SIGMA(1750).

Σ(2000) MASS (MeV)

```
M           2004.0    40.0             VANHORN   75 DPWA  0 K-P TO LAM PIO
M     A     1755. OR 1834.             MARTIN    77 DPWA    KBAR N MULTICHNL
M     A  THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M     A  PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M           1955.0    15.0             RLIC      77 DPWA    KBAR N MULTICHNL
M           1944.0   (15.0)            GOPAL     80 DPWA    KBAR N ELASTIC
```

Σ(2000) WIDTH (MeV)

```
W            116.0    40.0             VANHORN   75 DPWA  0 K-P TO LAM PIO
W     A     413. OR 450.               MARTIN    77 DPWA    KBAR N MULTICHNL
W            170.0    40.0             RLIC      77 DPWA    KBAR N MULTICHNL
W            215.0   (25.0)            GOPAL     80 DPWA    KBAR N ELASTIC
```

Σ(2000) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(2000) \rightarrow N\overline{K}$	938+ 494
P2	$\Sigma(2000) \rightarrow \Lambda\pi$	1116+ 135
P3	$\Sigma(2000) \rightarrow \Sigma\pi$	1197+ 140
P4	$\Sigma(2000) \rightarrow \Lambda(1520)\ \pi$	1520+ 140
P5	$\Sigma(2000) \rightarrow N\,K^*(892)$, $S1$-wave	940+ 892
P6	$\Sigma(2000) \rightarrow N\,K^*(892)$, $D3$-wave	940+ 892

Σ(2000) BRANCHING RATIOS

$\Sigma(2000) \rightarrow (N\overline{K})$/total (P1)

```
R1    A        0.62 OR  0.57           MARTIN    77 DPWA    KBAR N MULTICHNL
R1    B       (0.44)   (0.05)          RLIC      77 DPWA    KBAR N MULTICHNL
R1    B  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1             0.51    (0.05)          GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Sigma(2000)$ in $N\overline{K} \rightarrow \Lambda\pi$ SQRT(P1*P2)

```
R2           NOT SEEN                  BAILLON   75 IPWA    KBAR N TO LAM PI
R2            +0.07     0.02     0.01  VANHORN   75 DPWA  0 K-P TO LAM PIO
R2    A       -0.19 OR -0.18           MARTIN    77 DPWA    KBAR N MULTICHNL
R2             0.08     0.03           RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(2000)$ in $N\overline{K} \rightarrow \Sigma\pi$ SQRT(P1*P3)

```
R3    A       +0.26 OR +0.24           MARTIN    77 DPWA    KBAR N MULTICHNL
R3            +0.20     0.04           RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(2000)$ in $N\overline{K} \rightarrow \Lambda(1520)\ \pi$ SQRT(P1*P4)

```
R4    C       +0.081    0.021          CAMERON   77 DPWA  0 P-WAVE DECAY
R4    C  ASSUMES LAMBDA(1520) ELASTICITY=0.46.  THE SIGN IS CHANGED HERE TO
R4    C  BE IN ACCORD WITH THE BARYON-FIRST CONVENTION.
```

$\Sigma(2000)$ in $N\overline{K} \rightarrow N\,K^*(892)$, $S1$-wave SQRT(P1*P5)

```
R5    D       +0.10     0.02           CAMERON2  78 DPWA    K-P TO K*N
R5    D  THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R5    D  CONVENTION.
```

$\Sigma(2000)$ in $N\overline{K} \rightarrow N\,K^*(892)$, $D3$-wave SQRT(P1*P6)

```
R6            -0.07     0.03           CAMERON2  78 DPWA    K-P TO K*N
```

REFERENCES FOR Σ(2000)

```
BAILLON  75 NP B94 39         P BAILLON, P J LITCHFIELD       (CERN+RHEL)IJP
VANHORN  75 NP B87 145        A J VAN HORN                        (LBL)IJP
    ALSO 75 NP B87 157        A J VAN HORN                        (LBL)IJP
CAMERON  77 NP B131 399       +FRANEK,GOPAL,KALMUS,MCPHERSON+ (RHEL+LOIC)IJP
MARTIN   77 NP B127 349       MARTIN,PIDCOCK,MOORHOUSE        (LOUC+GLAS)IJP
    ALSO 77 NP B126 266       MARTIN,PIDCOCK                     (LOUC)
    ALSO 77 NP B126 285       MARTIN,PIDCOCK                     (LOUC)IJP
RLIC     77 NP B119 362       GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
CAMERON2 78 NP B146 327       +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                          (RHEL)IJP
```

$\Sigma(2030)$ F_{17}

$I(J^P) = 1(\frac{7}{2}^+)$ Status: * * * *

FOR MOST RESULTS PUBLISHED BEFORE 1974 (THEY ARE NOW OBSOLETE), SEE OUR 1982 EDITION (PHYSICS LETTERS 111B). ALL THE REFERENCES HAVE BEEN RETAINED.

THIS ENTRY ONLY INCLUDES RESULTS FROM PARTIAL-WAVE ANALYSES. PARAMETERS OF PEAKS SEEN IN CROSS SECTIONS AND INVARIANT-MASS DISTRIBUTIONS AROUND 2030 MEV MAY BE FOUND IN OUR 1984 EDITION, REV. MOD. PHYS. 56 (APRIL 1984, PART II).

Σ(2030) MASS (MeV)

```
M          2020.0     (6.0)          KANE       74 DPWA     K-P TO PI SIG
M          2025.0     10.0           LITCHFI1   74 DPWA   0 K-P TO L(1820)PI
M          2035.0     10.0           LITCHFI2   74 DPWA   0 K-P TO L(1520)PI
M          2020.0     30.0           LITCHFI3   74 DPWA   0 K-P TO KBAR DEL
M          2035.0     15.0           BAILLON    75 IPWA     KBAR N TO LAM PI
M          2038.0     10.0           HEMINGWA   75 DPWA   0 K- P TO KBAR N
M          2042.0     11.0           VANHORN    75 DPWA   0 K-P TO LAM PIO
M         (2030.0)                   BELLEFON   76 IPWA   0 K- P TO LAM PI
M    A     2030.0      3.0           CORDEN     76 DPWA   - K- N TO PI- LAM
M    A  PREFERRED SOLUTION 3, SEE CORDEN 76 FOR OTHER POSSIBILITIES.
M          2038.0     10.0           CORDEN2    77        - K- N TO K* N
M          2027. TO 2057.            GOYAL      77 DPWA   - K- N TO SIG PI
M          2040.0      5.0           RLIC       77 DPWA     KBAR N MULTICHNL
M          2036.0     (5.0)          GOPAL      80 DPWA     KBAR N ELASTIC
```

Σ(2030) WIDTH (MeV)

```
W           111.0     (5.0)          KANE       74 DPWA     K-P TO PI SIG
W            70. TO  125.            LITCHFI1   74 DPWA   0 K-P TO L(1820)PI
W           160.0     20.0           LITCHFI2   74 DPWA   0 K-P TO L(1520)PI
W           200.0     30.0           LITCHFI3   74 DPWA   0 K-P TO KBAR DEL
W           180.0     20.0           BAILLON    75 IPWA     KBAR N TO LAM PI
W           172.0     15.0           HEMINGWA   75 DPWA   0 K- P TO KBAR N
W           178.0     13.0           VANHORN    75 DPWA   0 K-P TO LAM PIO
W          (160.0)                   BELLEFON   76 IPWA   0 K- P TO LAM PI
W    A      201.0      9.0           CORDEN     76 DPWA   - K- N TO PI- LAM
W           137.0     40.0           CORDEN2    77        - K- N TO K* N
W          (260.0)                   DECLAIS    77 DPWA     KBAR N TO KBAR N
W           126. TO  195.            GOYAL      77 DPWA   - K- N TO SIG PI
W           190.0     10.0           RLIC       77 DPWA     KBAR N MULTICHNL
W           172.0    (10.0)          GOPAL      80 DPWA     KBAR N ELASTIC
```

Σ(2030) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(2030) \to N\overline{K}$	938+ 494
P2	$\Sigma(2030) \to \Lambda\pi$	1116+ 135
P3	$\Sigma(2030) \to \Sigma\pi$	1189+ 140
P4	$\Sigma(2030) \to \Xi K$	1321+ 498
P5	$\Sigma(2030) \to \Lambda(1820)\ \pi$, P-wave	1820+ 135
P6	$\Sigma(2030) \to \Lambda(1520)\ \pi$, D-wave	1520+ 135
P7	$\Sigma(2030) \to \Lambda(1520)\ \pi$, G-wave	1520+ 135
P8	$\Sigma(2030) \to \Delta(1232)\ \overline{K}$, F-wave	1232+ 494
P9	$\Sigma(2030) \to \Delta(1232)\ \overline{K}$, H-wave	1232+ 494
P10	$\Sigma(2030) \to \Sigma(1385)\ \pi$, F-wave	1385+ 140
P11	$\Sigma(2030) \to N K^*(892)$, $F1$-wave	940+ 892
P12	$\Sigma(2030) \to N K^*(892)$, $F3$-wave	940+ 892

Σ(2030) BRANCHING RATIOS

$\Sigma(2030) \to (N\overline{K})$/total (P1)

```
R1           0.18      0.03          HEMINGWA  75 DPWA  0 K- P TO KBAR N
R1          (0.15)                   DECLAIS   77 DPWA    KBAR N TO KBAR N
R1   B      (0.24)    (0.02)         RLIC      77 DPWA    KBAR N MULTICHNL
R1   B  (N KBAR)/TOTAL FROM RLIC 77 IS SUPERSEDED BY GOPAL 80.
R1           0.19     (0.03)         GOPAL     80 DPWA    KBAR N ELASTIC
```

$\Sigma(2030)$ in $N\overline{K} \to \Lambda\pi$ SQRT(P1*P2)

```
R2          +0.195     0.053         DEVENISH  74       0 FIXED T DISP REL
R2          +0.18      0.02          BAILLON   75 IPWA    KBAR N TO LAM PI
R2          +0.20      0.01          VANHORN   75 DPWA  0 K-P TO LAM PIO
R2          (0.20)                   BELLEFON  76 IPWA  0 K- P TO LAM PI
R2   A      +0.20      0.01          CORDEN    76 DPWA  - K- N TO PI- LAM
R2          +0.18      0.02          RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(2030)$ in $N\overline{K} \to \Sigma\pi$ SQRT(P1*P3)

```
R3          -0.10     (0.01)         KANE      74 DPWA    K-P TO PI SIG
R3   C      -0.09      0.01          CORDEN1   77       - K- N TO PI SIG
R3   C      -0.06      0.01          CORDEN1   77       - K- N TO PI SIG
R3   C  THE 2 ENTRIES FOR CORDEN177 ARE FROM 2 DIFFERENT ACCEPTABLE SLTNS.
R3  D      (-0.085)   (0.02)         GOYAL     77 DPWA  - K- N TO SIG PI
R3  D   THIS COUPLING IS EXTRACTED FROM UNNORMALIZED DATA.
R3          -0.15      0.03          RLIC      77 DPWA    KBAR N MULTICHNL
```

$\Sigma(2030)$ in $N\overline{K} \to \Xi K$ SQRT(P1*P4)

```
R4          (0.05) OR LESS           TRIPP     67 RVUE  0 K-P TO XI K
R4          (0.05) OR LESS           BURGUN    68 DPWA  0 K-P TO XI K
R4          (0.023)                  MULLER    69 DPWA  0
```

$\Sigma(2030)$ in $N\overline{K} \to \Lambda(1820)\ \pi$, P-wave SQRT(P1*P5)

```
R5   E       0.18      0.04          LITCHFI1  74 DPWA  0 K-P TO L(1820)PI
R5   E  ASSUMES LAMBDA(1820) ELASTICITY=.6
R5           0.14      0.02          CORDEN2   75 DBC   - KBAR PI- NUCLEON
R5         . . . . . . . . .
R5  AVG      0.148     0.018   AVERAGE
```

$\Sigma(2030)$ in $N\overline{K} \to \Lambda(1520)\ \pi$, D-wave SQRT(P1*P6)

```
R6   F       0.14      0.03          LITCHFI2  74 DPWA  0 K-P TO L(1520)PI
R6   F  ASSUMES LAMBDA(1520) ELASTICITY=.45
R6  G       (0.10)    (0.03)         CORDEN2   75 DBC   - KBAR PI- NUCLEON
R6  G   UPPER LIMIT
R6   H      +0.114     0.010         CAMERON   77 DPWA  0 K-P TO L(1520)PI
R6   H  ASSUMES LAMBDA(1520) ELASTICITY=.46.  THE SIGN IS CHANGED HERE TO
R6   H  BE IN ACCORD WITH THE BARYON-FIRST CONVENTION.
R6         . . . . . . . . . .
R6  AVG      0.1166    0.0095  AVERAGE
```

$\Sigma(2030)$ in $N\overline{K} \to \Lambda(1520)\ \pi$, G-wave SQRT(P1*P7)

```
R7   F       0.02      0.02          LITCHFI2  74 DPWA  0 K-P TO L(1520)PI
R7   H      +0.146     0.010         CAMERON   77 DPWA  0 K-P TO L(1520)PI
R7         . . . . . . . . . .
R7  AVG      0.121     0.050   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 5.6)
```

$\Sigma(2030)$ in $N\overline{K} \to \Delta(1232)\ \overline{K}$, F-wave SQRT(P1*P8)

```
R8           0.16      0.03          LITCHFI3  74 DPWA  0 K-P TO KBAR DEL
R8  G       (0.17)    (0.03)         CORDEN2   75 DBC   - KBAR PI- NUCLEON
R8  G   UPPER LIMIT
```

$\Sigma(2030)$ in $N\overline{K} \to \Delta(1232)\ \overline{K}$, H-wave SQRT(P1*P9)

```
R9           0.00      0.02          LITCHFI3  74 DPWA  0 K-P TO KBAR DEL
```

$\Sigma(2030)$ in $N\overline{K} \to \Sigma(1385)\ \pi$, F-wave SQRT(P1*P10)

```
R10  I      +0.153     0.026         CAMERON   78 DPWA  0 K-P TO S(1385)PI
R10  I  THE SIGN IS CHANGED HERE TO BE IN ACCORD WITH THE BARYON-FIRST
R10  I  CONVENTION.
```

$\Sigma(2030)$ in $N\overline{K} \to N K^*(892)$, $F1$-wave SQRT(P1*P11)

```
R11         -0.02      0.01          CORDEN2   77         K-D TO K*N
R11  J      +0.06      0.03          CAMERON2  78 DPWA    K-P TO K*N
R11  J  THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R11  J  CONVENTION.
R11        . . . . . . . . . .
R11 AVG MOD  0.024     0.012   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
```

$\Sigma(2030)$ in $N\overline{K} \to N K^*(892)$, $F3$-wave SQRT(P1*P12)

```
R12         -0.12      0.02          CORDEN2   77         K-D TO K*N
R12  K      +0.04      0.03          CAMERON2  78 DPWA    K-P TO K*N
R12  K  THE UPPER LIMIT ON THE G3-WAVE IS 0.03.
R12        . . . . . . . . . .
R12 AVG MOD  0.095     0.037   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.2)
```

REFERENCES FOR Σ(2030)

```
WOHL     66 PRL 17 107         C G WOHL, F T SOLMITZ, M L STEVENSON  (LRL)IJP
TRIPP    67 NP B3 10           + LEITH, +      (LRL+SLAC+  CERN+HEID+SACL)
BURGUN   68 NP B8 447          +MEYER,PAULI,TALLINI +     (SACL+CDEF+RHEL)
DAUM     68 NP B7 19           +ERNE,LAGNAUX,SENS,STEUER,UDO         (CERN)JP
SMART    68 PR 169 1336        W M SMART                              (LRL)IJP
MULLER   69 THESIS,UCRL 19372 R A MULLER                              (LRL)
BERTHON  70 NP B20 476         +RANGAN, VRANA,      +     (CDEF+RHEL+SACL)IJP
BERTHON1 70 NP B24 417         +VRANA, BUTTERWORTH, +     (CDEF+RHEL+SACL)IJP
COX      70 NP B19 61          +ISLAM, COLLEY, +     (BIRM+EDIN+GLAS+LOIC)IJP
GALTIERI 70 DUKE CONF 173      A BARBARO-GALTIERI                     (LRL)IJP
LITCHFIE 70 NP B22 269         P J LITCHFIELD                        (RHEL)IJP
CAMPBELL 71 NP B25 75          +MORTON, NEGUS, GOYAL, MILLER   (GLAS+LOIC)IJP
LITCHFIE 71 NP  B30 125        LITCHFIELD,...+LESQUOY,+.. (RHEL+CDEF+SACL)IJP
KANE     72 PR D5 1583         D F KANE                               (LBL)IJP
DEVENISH 74 NP B81 330         DEVENISH,FROGGATT,MARTIN   (DESY+NORD+LOUC)
KANE     74  LBL-2452          D F KANE                               (LBL)IJP
LITCHFI1 74 NP B74 12          LITCHFIELD,HEMINGWAY,BAILLON,+  (CERN+HEID)IJP
LITCHFI2 74 NP B74 19          LITCHFIELD,HEMINGWAY,BAILLON,+  (CERN+HEID)IJP
LITCHFI3 74 NP B74 39          LITCHFIELD,HEMINGWAY,BAILLON,+  (CERN+HEID)IJP
BAILLON  75 NP B94 39          P BAILLON, P J LITCHFIELD       (CERN+RHEL)IJP
CORDEN2  75 NP B92 365         +COX,DARTNELL,KENYON,ONEALE,SUMOROK+ (BIRM)IJP
HEMINGWA 75 NP B91 12          HEMINGWAY,EADES,HARMSEN+   (CERN+HEID+MPIM)IJP
VANHORN  75 NP B87 145         A J VAN HORN                           (LBL)IJP
    ALSO 75 NP B87 157         A J VAN HORN                           (LBL)IJP
BELLEFON 76 NP B109 129        DE BELLEFON,BERTHON                   (CDEF)IJP
CORDEN   76 NP B104 382        +COX,DARTNELL,KENYON,ONEALE,SUMOROK+ (BIRM)IJP
CAMERON  77 NP B131 399        +FRANEK,GOPAL,KALMUS,MCPHERSON+ (RHEL+LOIC)IJP
CORDEN1  77 NP B125 61         +COX,KENYON,ONEALE,STUBBS,SUMOROK+   (BIRM)IJP
CORDEN2  77 NP B121 365        +COX,KENYON,ONEALE,STUBBS,SUMOROK+   (BIRM)IJP
DECLAIS  77  CERN 77-16        +DUCHON,LOUVEL,PATRY,SEGUINOT+  (CAEN+CERN)IJP
GOYAL    77 PR D16 2746        D P GOYAL,A V SODHI                   (DELH)IJP
RLIC     77 NP B119 362        GOPAL,ROSS,VAN HORN,MCPHERSON+  (LOIC+RHEL)IJP
CAMERON  78 NP B143 189        +FRANEK,GOPAL,BACON,BUTTERWORTH+(RHEL+LOIC)IJP
CAMERON2 78 NP B146 327        +FRANEK,GOPAL,KALMUS,MCPHERSON,+(RHEL+LOIC)IJP
GOPAL    80  TORONTO CONF 159 G P GOPAL                              (RHEL)IJP
```

$\Sigma(2070)$ F_{15}

$I(J^P) = 1(\frac{5}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

THIS STATE SUGGESTED BY BERTHON 70 NOW FINDS CONFIRMATION IN GOPAL 80 WITH NEW K-P POLARIZATION AND K- NEUTRON ANGULAR DISTRIBUTIONS. THE VERY BROAD STATE SEEN IN KANE 72 IS NOT REQUIRED IN THE LATER (KANE 74) ANALYSIS OF PI SIGMA.

Σ(2070) MASS (MeV)

```
M        (2070.0)    (10.0)          BERTHON1  70 DPWA -  K- P TO SIG PI
M        (2057.0)                    KANE      72 DPWA    K-P TO SIGMA PI
M         2051.0     (25.0)          GOPAL     80 DPWA    KBAR N ELASTIC
```

Σ(2070) WIDTH (MeV)

```
W         (140.0)    (20.0)          BERTHON1  70 DPWA -  K- P TO SIG PI
W         (906.0)                    KANE      72 DPWA    K-P TO SIGMA PI
W          300.0     (30.0)          GOPAL     80 DPWA    KBAR N ELASTIC
```

Σ(2070) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(2070) \to N\overline{K}$	938+ 494
P2	$\Sigma(2070) \to \Sigma\pi$	1189+ 140

Σ(2070) BRANCHING RATIOS

$\Sigma(2070)$ in $N\overline{K} \to \Sigma\pi$ SQRT(P1*P2)

```
R1         (+0.12)   (0.02)           BERTHON1  70 DPWA -  K- P TO SIG PI
R1         (+0.104)                   KANE      72 DPWA    K-P TO SIGMA PI
```

$\Sigma(2070) \to (N\overline{K})$/total (P1)

```
R2            0.08    (0.03)          GOPAL     80 DPWA    KBAR N ELASTIC
```

REFERENCES FOR Σ(2070)

```
BERTHON1 70 NP B24 417        +VRANA,BUTTERWORTH,+       (CDEF+RHEL+SACL)IJP
KANE     72 PR D5 1583        D F KANE                               (LBL)
GOPAL    80  TORONTO CONF 159 G P GOPAL                          (RHEL)IJP
```

Σ(2080) P_{13}

$I(J^P) = 1(\frac{3}{2}^+)$ Status: * *

OMITTED FROM SUMMARY TABLE

SUCH A RESONANCE IS SUGGESTED BY SOME BUT NOT ALL PARTIAL-WAVE ANALYSES ACROSS THIS REGION.

Σ(2080) MASS (MeV)

```
M          (2082.0)    (4.0)          COX       70 DPWA -  K- N TO LAM PI
M          (2070.0)   (30.0)          LITCHFIEL 70 DPWA -0 K- N TO LAM PI
M     A     2120.0     40.0           BAILLON   75 IPWA    KBAR N TO LAM PI
M     A  FROM SOLUTION 1 OF BAILLON 75.
M     B     2140.0     40.0           BAILLON   75 IPWA    KBAR N TO LAM PI
M     B  FROM SOLUTION 2 OF BAILLON 75.
M           2140.0     30.0           BELLEFO1  75 DPWA  0 K- P TO LAM PI0
M    C      2070. TO 2120.            BELLEFON  76 IPWA  0 K- P TO LAM PI
M    C   SUPERSEDES BELLEFO1 75.
M     D     2091.0      7.0           CORDEN    76 DPWA  - K- N TO PI- LAM
M     D  PREFERRED SOLUTION 3, SEE CORDEN 76 FOR OTHER POSSIBLILITES,
M     D  INCLUDING A D15 AT THIS MASS.
M     D  CORDEN 76 INCLUDES THE DATA OF COX 70 AS A SUBSAMPLE.
```

Σ(2080) WIDTH (MeV)

```
W            (87.0)   (20.0)          COX       70 DPWA -  K- N TO LAM PI
W           (250.0)   (40.0)          LITCHFIEL 70 DPWA -0 K- N TO LAM PI
W     A      240.0     50.0           BAILLON   75 IPWA    KBAR N TO LAM PI
W     B      200.0     50.0           BAILLON   75 IPWA    KBAR N TO LAM PI
W            180.0     20.0           BELLEFO1  75 DPWA  0 K- P TO LAM PI0
W    C      (100.0)                   BELLEFON  76 IPWA  0 K- P TO LAM PI
W     D      186.0     48.0           CORDEN    76 DPWA  - K- N TO PI- LAM
```

Σ(2080) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(2080) \to N\overline{K}$	938+ 494
P2	$\Sigma(2080) \to \Lambda\pi$	1116+ 140

Σ(2080) BRANCHING RATIOS

$\Sigma(2080)$ in $N\overline{K} \to \Lambda\pi$ SQRT(P1*P2)

```
R1         (-0.16)   (0.03)           COX       70 DPWA -  K- N TO LAM PI
R1         (-0.09)   (0.03)           LITCHFIEL 70 DPWA -0 K- N TO LAM PI
R1    A     -0.13     0.04            BAILLON   75 IPWA    KBAR N TO LAM PI
R1    B     -0.13     0.04            BAILLON   75 IPWA    KBAR N TO LAM PI
R1          +0.19     0.03            BELLEFO1  75 DPWA  0 K- P TO LAM PI0
R1   C     (-0.10)                    BELLEFON  76 IPWA  0 K- P TO LAM PI
R1    D     -0.10     0.03            CORDEN    76 DPWA  - K- N TO PI- LAM
```

REFERENCES FOR Σ(2080)

```
COX      70 NP B19 61         +ISLAM, COLLEY, +    (BIRM+EDIN+GLAS+LOIC)IJP
LITCHFIE 70 NP B22 269        P J LITCHFIELD                     (RHEL)IJP
BAILLON  75 NP B94 39         P BAILLON, P J LITCHFIELD     (CERN+RHEL)IJP
BELLEFO1 75 NP B90 1          DE BELLEFON,BERTHON,BRUNET+   (CDEF+SACL)IJP
BELLEFON 76 NP B109 129       DE BELLEFON,BERTHON                (CDEF)IJP
CORDEN   76 NP B104 382       +COX,DARTNELL,KENYON,ONEALE,SUMOROK+ (BIRM)IJP
```

Σ(2100) G_{17}

$I(J^P) = 1(\frac{7}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

Σ(2100) MASS (MeV)

```
M          (2060.0)   (20.0)          GALTIERI  70 DPWA  0 K-P TO LAMBDA PI
M          (2120.0)   (30.0)          GALTIERI  70 DPWA  0 K-P TO SIGMA PI
```

Σ(2100) WIDTH (MeV)

```
W            (70.0)   (30.0)          GALTIERI  70 DPWA  0 K-P TO LAMBDA PI
W           (135.0)   (30.0)          GALTIERI  70 DPWA  0 K-P TO SIGMA PI
```

Σ(2100) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma(2100) \to N\overline{K}$	938+ 494
P2	$\Sigma(2100) \to \Lambda\pi$	1116+ 135
P3	$\Sigma(2100) \to \Sigma\pi$	1189+ 140

Σ(2100) BRANCHING RATIOS

$\Sigma(2100)$ in $N\overline{K} \to \Lambda\pi$ SQRT(P1*P2)

```
R1         (-0.07)   (0.02)           GALTIERI  70 DPWA  0 K-P TO LAMBDA PI
```

$\Sigma(2100)$ in $N\overline{K} \to \Sigma\pi$ SQRT(P1*P3)

```
R2         (+0.13)   (0.02)           GALTIERI  70 DPWA  0 K-P TO SIGMA PI
```

REFERENCES FOR Σ(2100)

```
GALTIERI 70 DUKE CONF 173     A BARBARO-GALTIERI                  (LRL)IJP
```

Σ(2250) BUMPS

$I(J^P) = 1(\ \ )$ Status: * * *

THE PARTIAL-WAVE ANALYSIS RESULTS ARE TOO WEAK TO WARRANT SEPARATING THEM FROM THE PRODUCTION AND CROSS-SECTION EXPERIMENTS. LASINSKI 71 IN KBAR N, USING A POMERON+RESONANCES MODEL, AND BELLEFON1 76, BELLEFON 77, AND BELLEFON 78 (COLLEGE DE FRANCE-SACLAY GROUP) IN DPWA'S OF KBAR N TO LAMBDA PI, SIGMA PI, AND KBAR N, RESPECTIVELY, SUGGEST THE PRESENCE OF TWO RESONANCES AROUND THIS MASS VALUE.

Σ(2250) MASS (MeV) (PROD. EXP.)

```
M          (2245.0)                    BLANPIED  65 CNTR    GAMMA P TO K+ Y*
M          (2299.0)    (6.0)           BOCK      65 HBC     PBAR P 5.7 GEV/C
M           2250.0      7.0            BUGG      68 CNTR    K-P, D TOTAL
M           2280.0     14.0            AGUILAR   70 HBC  +  K- 3.9-4.6 GEV/C
M           2237.0     11.0            BRICMAN   70 CNTR  0 TOTAL AND CH EX
M           2255.0     10.0            COOL      70 CNTR    K-P, D TOTAL
M          (2250.0)   (20.0)           LU        70 CNTR  0 GAMMA P TO K+ Y*
M    A     (2260.0)   (30.0)           BELLEFO1  75 DPWA    D5-WAVE
M    A     (2215.0)   (10.0)           BELLEFO1  75 DPWA    G9 OR H11-WAVE
M    A   EVIDENCE FOR 2 RESONANCES IN THIS LAMBDA PI DPWA
M     B     2300.0     30.0            BELLEFO2  75 HBC   0 K- P TO XI*0 K0
M     C     2251.0     30.0     20.0   VANHORN   75 DPWA  0 K-P TO LAM PI0
M     C    VANHORN72 VALUE FROM A DPWA THAT FINDS JP=5/2+.
M    D     (2260.0)                    BELLEFON  76 IPWA  0 D5-WAVE
M    D     (2215.0)                    BELLEFON  76 IPWA  0 G9-WAVE
M    D   SUPERSEDES BELLEFO1 75.
M           2275.0     20.0            BELLEFON  77 DPWA  0 D5-WAVE
M           2215.0     20.0            BELLEFON  77 DPWA  0 G9-WAVE
M           2270.0     50.0            BELLEFON  78 DPWA  0 D5-WAVE
M           2210.0     30.0            BELLEFON  78 DPWA  0 G9-WAVE
```

Σ(2250) WIDTH (MeV) (PROD. EXP.)

```
W           (150.0)                    BLANPIED  65 CNTR    GAMMA P TO K+ Y*
W            (21.0)   (17.0)   (21.0)  BOCK      65 HBC     PBAR P 5.7 GEV/C
W            230.0     20.0            BUGG      68 CNTR    K-P, D TOTAL
W            100.0     20.0            AGUILAR   70 HBC  +  K- 3.9-4.6 GEV/C
W            164.0     50.0            BRICMAN   70 CNTR  0 TOTAL AND CH EX
W           (170.0)                    COOL      70 CNTR    K-P, D TOTAL
W           (125.0)                    LU        70 CNTR  0 GAMMA P TO K+ Y*
W    A      (100.0)   (20.0)           BELLEFO1  75 DPWA    D5-WAVE
W    A       (60.0)   (40.0)   (20.0)  BELLEFO1  75 DPWA    G9 OR H11-WAVE
W     B      130.0     20.0            BELLEFO2  75 HBC   0 K- P TO XI*0 K0
W     C      192.0     30.0            VANHORN   75 DPWA  0 K-P TO LAM PI0
W    D      (100.0)                    BELLEFON  76 IPWA  0 D5-WAVE
W    D      (140.0)                    BELLEFON  76 IPWA  0 G9-WAVE
W             70.0     20.0            BELLEFON  77 DPWA  0 D5-WAVE
W             60.0     20.0            BELLEFON  77 DPWA  0 G9-WAVE
W            120.0     40.0            BELLEFON  78 DPWA  0 D5-WAVE
W             80.0     20.0            BELLEFON  78 DPWA  0 G9-WAVE
```

Σ(2250) PARTIAL DECAY MODES (PROD. EXP.)

```
                                                  DECAY MASSES
P1      Σ(2250) → N K̄                              938+ 494
P2      Σ(2250) → Λ π                             1116+ 135
P3      Σ(2250) → Σ π                             1189+ 140
P4      Σ(2250) → N K̄ π                            938+ 498+ 140
P5      Σ(2250) → Ξ(1530) K                       1533+ 498
```

Σ(2250) BRANCHING RATIOS (PROD. EXP.)

Σ(2250) → $(N\bar{K})$/total (P1)

```
R1          0.08       0.02        BELLEFON  78 DPWA  0 D5-WAVE
R1          0.02       0.01        BELLEFON  78 DPWA  0 G9-WAVE
```

Σ(2250) in $N\bar{K} \to \Lambda\pi$ SQRT(P1*P2)

```
R2         -0.18 (FOR JP=9/2-)     GALTIERI  70 DPWA    K-P TO LAMBDA PI
R2  A     (+0.12)    (0.03)        BELLEFO1  75 DPWA    D5-WAVE
R2  A     (-0.09)    (0.02)        BELLEFO1  75 DPWA    G9 OR H11-WAVE
R2   C     -0.16      0.03         VANHORN   75 DPWA  0 K-P TO LAM PI0
R2  D     (+0.11)                  BELLEFON  76 IPWA  0 D5-WAVE
R2  D     (-0.10)                  BELLEFON  76 IPWA  0 G9-WAVE
```

Σ(2250) in $N\bar{K} \to \Sigma\pi$ SQRT(P1*P3)

```
R3         +0.07 (FOR JP=9/2-)     GALTIERI  70 DPWA    K-P TO SIGMA PI
R3         +0.06      0.02         BELLEFON  77 DPWA  0 D5-WAVE
R3         -0.03      0.02         BELLEFON  77 DPWA  0 G9-WAVE
```

Σ(2250) → $(N\bar{K})/(\Sigma\pi)$ (P1)/(P3)

```
R4         (0.18) OR LESS          BARNES    69 HBC  +  1 STAN DEV LIMIT
```

Σ(2250) → $(\Lambda\pi)/(\Sigma\pi)$ (P2)/(P3)

```
R5         (0.18) OR LESS          BARNES    69 HBC  +  1 STAN DEV LIMIT
```

Σ(2250) in $N\bar{K} \to \Xi(1530)^0 K^0$ SQRT(P1*P5)

```
R6  B       0.09      0.02         BELLEFO2  75 HBC   0 K- P TO XI*0 K0
R6  B  SEEN IN DD5-WAVE IN NEUTRAL CHANNEL ONLY, ISOSPIN UNDETERMINED.
```

Σ(2250) → $(N\bar{K})$/total (J+1/2)*(P1)

```
R7       J IS NOT DETERMINED IN THESE EXPTS.  THE FOLLOWING IS (J+1/2)*P1.
R7         (0.47)                  BUGG      68 CNTR
R7         (0.16)    (0.12)        BRICMAN   70 CNTR  0 TOTAL AND CH EX
R7         (0.42)                  COOL      70 CNTR    K-P, D TOTAL
```

REFERENCES FOR Σ(2250) (PROD. EXP.)

```
BLANPIED 65 PRL 14 741         +GREENBERG,HUGHES,KITCHING, +    (YALE+CEA)
BOCK     65 PL  17 166         +COOPER,FRENCH,KINSON, +        (CERN+SACL)
BUGG     68 PR  168 1466       +GILMORE,KNIGHT, +         (RHEL+BIRM+CAVE) I
BARNES   69 PRL 22 479         +FLAMINIO,MONTANET,SAMIOS +      (BNL+SYRA)
AGUILAR  70 PRL 25 58          AGUILAR-BENITEZ, BARNES, +       (BNL+SYRA)
BRICMAN  70 PL  31B 152        +FERRO LUZZI, PERREAU,+    (CERN+CAEN+SACL)
COOL     70 PR  D1 1887        +GIACOMELLI, KYCIA, LEONTIC, LI, +    (BNL) I
GALTIERI 70 DUKE CONF 173      A BARBARO-GALTIERI                   (LRL)IJP
LU       70 PR  D2 1846        +GREENBERG, HUGHES, MINEHART, MORI,+ (YALE)
BELLEFO1 75 NP  B90 1          DE BELLEFO2,BERTHON,BRUNET+     (CDEF+SACL)IJP
BELLEFO2 75 NC  28A 289        DE BELLEFO2,BERTHON,BILLOIR+    (CDEF+SACL)
VANHORN  75 NP  B87 145        A J VAN HORN                         (LBL)IJP
    ALSO 75 NP  B87 157        A J VAN HORN                         (LBL)IJP
BELLEFON 76 NP  B109 129       DE BELLEFON,BERTHON                 (CDEF)IJP
BELLEFON 77 NC  37A 175        DE BELLEFON,BERTHON,BILLOIR+    (CDEF+SACL)IJP
BELLEFON 78 NC  42A 403        +BERTHON,BILLOIR,BRUNET+        (CDEF+SACL)IJP

                               PAPERS NOT REFERRED TO IN DATA LISTINGS

COOL     66 PRL 16 1228        +GIACOMELLI,KYCIA,LEONTIC,LI,LUNDBY,+ (BNL) I
   SUPERSEDED BY COOL 70.
DAUBER   66 PL  23 154         +SCHLEIN, SLATER, STORK, TICHO   (UCLA+LRL) J
   SUGGESTS J=9/2 RESONANT BEHAVIOR IN SIGMA- PI+, BUT APPEARS
         INCONSISTENT WITH PARAMETERS OF COOL 66.
DAUM     68 NP  B7 19          +ERNE, LAGNAUX, SENS, STEUER, UDO    (CERN)JP
LASINSKI 71 NP   B29  125      T A LASINSKI                         (EFI)IJP
HEMINGWA 75 NP  B91 12         HEMINGWAY,EADES,HARMSEN+   (CERN+HEID+MPIM)IJP
```

Σ(2455) BUMPS

$I(J^P) = 1(\ \ )$ Status: * *

OMITTED FROM SUMMARY TABLE

```
THERE IS ALSO SOME SLIGHT EVIDENCE FOR Y* STATES IN THIS MASS REGION
FROM THE REACTION GAMMA + P TO K+ + MISSING MASS -- SEE GREENBERG 68.
```

Σ(2455) MASS (MeV) (PROD. EXP.)

```
M            2455.0      7.0              BUGG      68 CNTR    K-P, D TOTAL
M            2455.0     10.0              ABRAMS    70 CNTR    K-P, D TOTAL
M            . . . . . . . . .
M    AVG     2455.0      5.7      AVERAGE
```

Σ(2455) WIDTH (MeV) (PROD. EXP.)

```
W             100.0     20.0              BUGG      68 CNTR
W             140.0                       ABRAMS    70 CNTR    K-P, D TOTAL
```

Σ(2455) PARTIAL DECAY MODES (PROD. EXP.)

```
                                                  DECAY MASSES
P1      Σ(2455) → N K̄                              938+ 494
```

Σ(2455) BRANCHING RATIOS (PROD. EXP.)

Σ(2455) → $(N\bar{K})$/total (P1)

```
R1        J IS NOT KNOWN.  THE FOLLOWING IS (J+1/2)*P1.
R1           (0.3)                   BUGG      68 CNTR
R1            0.39                   ABRAMS    70 CNTR    K-P, D TOTAL
R1  A        (0.05)    (0.05)        BRICMAN   70 CNTR  0 TOTAL AND CH EX
R1  A     FIT OF TOTAL CROSS SECTION GIVEN BY BRICMAN 70 IS POOR IN
R1  A     THIS REGION.
```

REFERENCES FOR Σ(2455) (PROD. EXP.)

```
BUGG     68 PR  168 1466       +GILMORE,KNIGHT, +          (RHEL+BIRM+CAVE) I
ABRAMS   70 PR  D1 1917        +COOL, GIACOMELLI, KYCIA, LEONTIC, +  (BNL) I
BRICMAN  70 PL  31B 152        +FERRO LUZZI, PERREAU,+    (CERN+CAEN+SACL)
                               PAPERS NOT REFERRED TO IN DATA LISTINGS

ABRAMS   67 PRL 19 678         +COOL,GIACOMELLI,KYCIA,LEONTIC,LI, +  (BNL)
   SUPERSEDED BY ABRAMS 70.
GREENBER 68 PRL 20 221         GREENBERG, HUGHES, LU, MINEHART, +   (YALE)
```

Σ(2620) BUMPS

$I(J^P) = 1(\ \ )$ Status: * *

OMITTED FROM SUMMARY TABLE

Σ(2620) MASS (MeV) (PROD. EXP.)

```
M          2620.0     15.0          ABRAMS    70 CNTR    K-P, D TOTAL
M          2542.0     22.0          DIBIANCA  75 DBC     XI K PI
```

Σ(2620) WIDTH (MeV) (PROD. EXP.)

```
W          (175.0)                  ABRAMS    70 CNTR    K-P, D TOTAL
W           221.0     81.0          DIBIANCA  75 DBC     XI K PI
```

Σ(2620) PARTIAL DECAY MODES (PROD. EXP.)

```
                                                  DECAY MASSES
P1      Σ(2620) → N K̄                              938+ 494
```

Σ(2620) BRANCHING RATIOS (PROD. EXP.)

Σ(2620) → $(N\bar{K})$/total (P1)

```
R1        J IS NOT KNOWN.  THE FOLLOWING IS (J+1/2)*P1.
R1          (0.32)                  ABRAMS    70 CNTR    K-P, D TOTAL
R1           0.36      0.12         BRICMAN   70 CNTR  0 TOTAL AND CH EX
```

REFERENCES FOR Σ(2620) (PROD. EXP.)

```
ABRAMS   67 PRL 19 678         +COOL,GIACOMELLI,KYCIA,LEONTIC,LI, +  (BNL)
   SUPERSEDED BY ABRAMS 70.
ABRAMS   70 PR  D1 1917        +COOL, GIACOMELLI, KYCIA, LEONTIC, +  (BNL) I
BRICMAN  70 PL  31B 152        +FERRO LUZZI, PERREAU,+    (CERN+CAEN+SACL)

DIBIANCA 75 NP  B98 137        DIBIANCA,ENDORFR                     (CARN)
```

Σ(3000) BUMPS

$I(J^P) = 1(\ \ )$ Status: *

OMITTED FROM SUMMARY TABLE

```
ENHANCEMENT IN LAMBDA PI AND KBAR N INVARIANT MASS SPECTRA AND IN
MISSING MASS OF NEUTRALS RECOILING AGAINST K0.
```

Σ(3000) MASS (MeV) (PROD. EXP.)

```
M          (3000.0)                 EHRLICH   66 HBC   0 PI-P 7.91 GEV/C
```

Σ(3000) PARTIAL DECAY MODES (PROD. EXP.)

```
                                                  DECAY MASSES
P1      Σ(3000) → N K̄                              938+ 494
P2      Σ(3000) → Λ π                             1116+ 140
```

REFERENCES FOR $\Sigma(3000)$ (PROD. EXP.)

```
EHRLICH  66 PR 152 1194      R EHRLICH, W SELOVE, H YUTA      (PENN+BNL) I
```

$\Sigma(3170)$ BUMPS

$I(J^P) = 1(\ \ )$ Status: *

OMITTED FROM SUMMARY TABLE

```
SEEN BY AMIRZADEH 79 AS A NARROW 6.5 STD. DEV. ENHANCEMENT IN THE
REACTION K-P --> Y* PI- USING DATA FROM TWO INDEPENDENT HIGH
STATISTICS BUBBLE CHAMBER EXPERIMENTS AT 8.25 AND 6.5 GEV/C.  THE
DOMINANT DECAY MODES ARE INTO MULTI-BODY, MULTI-STRANGE FINAL STATES
AND THE PRODUCTION IS VIA I=3/2 BARYON EXCHANGE.  I=1 IS FAVORED.

NOT SEEN IN A K- P EXPERIMENT IN LASS AT 11 GEV/C (ASTON 85).
```

$\Sigma(3170)$ MASS (MeV) (PROD. EXP.)

```
M       35 3170.0      5.0            AMIRZAD   79 HBC  +  K-P TO Y* PI-
```

$\Sigma(3170)$ WIDTH (MeV) (PROD. EXP.)

```
W  A    35  (20.0)  OR LESS            AMIRZAD   79 HBC  +  K-P TO Y* PI-
W  A    OBSERVED WIDTH CONSISTENT WITH EXPERIMENTAL RESOLUTION.
```

$\Sigma(3170)$ PARTIAL DECAY MODES (PROD. EXP.)

DECAY MASSES

P1 $\Sigma(3170) \to \Lambda K \bar{K} + \pi$'s

P2 $\Sigma(3170) \to \Sigma K \bar{K} + \pi$'s

P3 $\Sigma(3170) \to \Xi K + \pi$'s

$\Sigma(3170)$ BRANCHING RATIOS (PROD. EXP.)

$\Sigma(3170) \to (\Lambda K \bar{K} + \pi$'s)/total (P1)

```
R1        SEEN                        AMIRZAD   79 HBC  +  K-P TO Y* PI-
```

$\Sigma(3170) \to (\Sigma K \bar{K} + \pi$'s)/total (P2)

```
R2        SEEN                        AMIRZAD   79 HBC  +  K-P TO Y* PI-
```

$\Sigma(3170) \to (\Xi K + \pi$'s)/total (P3)

```
R3        SEEN                        AMIRZAD   79 HBC  +  K-P TO Y* PI-
```

REFERENCES FOR $\Sigma(3170)$ (PROD. EXP.)

```
AMIRZAD  79 PL 89B 125         AMIRZADEH+  (BIRM+CERN+GLAS+MSU+LPNP+CAMB+)I
   ALSO  80 TORONTO CONF. 263  J B KINSON+ (BIRM+CERN+GLAS+MSU+LPNP+CAMB+)I
ASTON    85 PR D32 2270        + LASS COLLABORATION  (SLAC+CARL+CNRC+CINC)
```

NOTE ON Ξ RESONANCES

Not much is known about Ξ resonances. This is because (1) they can only be produced as a part of a final state, and so the analysis is more complicated than if direct formation were possible, (2) they are produced with small cross sections (typically a few μb), and (3) the final states are topologically complicated and difficult to study with electronic techniques. Thus our early information about Ξ resonances came entirely from bubble chamber experiments, where the numbers of events are small, and the best information is still from bubble chamber experiments.

The accompanying table gives our evaluation of the present status of the Ξ resonances. Until fairly recently only the $\Xi(1530)$ was really well established. However, the late 1970's saw a major improvement with results from the large K^-p bubble chamber experiment at 4.2 GeV/c (GAY 76, HEMINGWAY 77). The $\Xi(1820)$ and $\Xi(2030)$ were firmly established as narrow states (widths of about 20 MeV), and the spin of the $\Xi(1820)$ was found to be 3/2 (TEODORO 78).

Table 1. The status of the Ξ resonances. Only those with an overall status of *** or **** are included in the Baryon Summary Table.

			Status as seen in --				
Particle	$L_{2I \cdot 2J}$	Overall status	$\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	Other channels
$\Xi(1318)$	P_{11}	****					
$\Xi(1530)$	P_{13}	****	****				
$\Xi(1630)$		*	*				
$\Xi(1680)$		**		*	**		
$\Xi(1820)$	13	***	*	***	**	***	
$\Xi(1940)$		**	**			**	
$\Xi(2030)$	1	***		**	***		
$\Xi(2120)$		*		*			
$\Xi(2250)$		**					3-body decays
$\Xi(2370)$	1	**					3-body decays
$\Xi(2500)$		*		*	*		3-body decays

****	Good, clear, and unmistakable.
***	Good, but in need of clarification or not absolutely certain.
**	Not established; needs confirmation.
*	Evidence weak; could disappear.

Since then, however, not much has changed, although there is some improved evidence for the $\Xi(2250)$ and the $\Xi(2370)$. There is probably at least one other Ξ in the 1850-2000-MeV region, and there are indications of several others above 2000 MeV. Indeed, there should be many Ξ resonances below 2500 MeV, and the broad (and not completely established) $\Xi(1940)$ could well be a mixture of several of them. For now we are forced to group together differing observations and await new results. The differences among experiments are shown in ideograms in the Listings; the wait for new results is almost certain to be a long one.

In the last few years, results from experiments using electronic methods have appeared. BIAGI 81 used the CERN hyperon beam to study inclusive $\Lambda\bar{K}$ and $\Xi\pi$ mass spectra from 102 and 135 GeV/c Ξ^- incident on hydrogen and deuterium. They saw a large $\Xi(1820)$ signal in $\Lambda\bar{K}$ as well as a peak at about 1700 MeV, which might be associated with the threshold enhancement seen by DIONISI 78. The $\Xi(1940)$ appears as a broad bump in the $\Xi\pi$ mass spectrum, and there is a very clean $\Xi(1530)$ signal. And Brookhaven multiparticle spectrometer measurements of $K^-p \to K^+$ anything at 5 GeV/c (JENKINS 83) have seen all the established Ξ resonances and also the less well-established $\Xi(2250)$, $\Xi(2370)$, and $\Xi(2500)$.

For a detailed review, see Meadows.[1]

References

1. B.T. Meadows, in *Proceedings of the IVth International Conference on Baryon Resonances* (Toronto, 1980), ed. N. Isgur, p. 283.

Ξ BARYONS ($S=-2$, $I=1/2$)

Ξ^-

$I(J^P)=\frac{1}{2}(\frac{1}{2}\ )$

SEE STABLE PARTICLES.

Ξ^0

$I(J^P)=\frac{1}{2}(\frac{1}{2}\ )$

SEE STABLE PARTICLES.

$\Xi(1530)$ P_{13}

$I(J^P)=\frac{1}{2}(\frac{3}{2}^+)$ Status: ****

THIS IS THE ONLY XI RESONANCE WHOSE PROPERTIES ARE ALL REASONABLY WELL KNOWN. SPIN-PARITY 3/2+ IS FAVORED BY THE DATA.

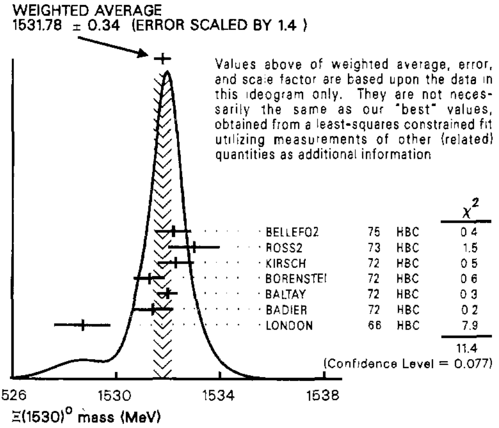
WE DO NOT USE DETERMINATIONS OF THE MASS AND WIDTH HERE UNLESS THEY ARE ACCOMPANIED BY SOME DISCUSSION OF SYSTEMATICS AND RESOLUTION.

$\Xi(1530)$ MASS (MeV)

```
M   MIXED CHARGES
M      20(1535.0)                   BERTANZA  62 HBC  -0 K-P 2.3 GEV/C
M      55(1529.0)    (5.0)          PJERROU   62 HBC  -0 K-P 1.8 GEV/C
M        (1532.0)    (2.0)          BADIER    64 HBC  -0 K-P 3 GEV/C

M-  NEGATIVE CHARGE ONLY
M-     38 1535.7      3.2           LONDON    66 HBC  -  K-P 2.24 GEV/C
M-    334(1534.7)    (1.1)          BALTAY    72 HBC  -  K-P 1.75 GEV
M-    185 1536.2      1.6           KIRSCH    72 HBC  -  K-P 2.87GEV/C
M-        1535.3      2.0           ROSS2     73 HBC  -  XI KBAR PI (PI)
M-     48(1540.0)    (3.0)          BERTHON   74 HBC  -  QUASI 2 BODY CS
M-        1534.5      1.2           BELLEFO2  75 HBC  -  K-P TO XI- K PI
M-        . . . . . . . . .
M-  AVG   1535.18     0.84    AVERAGE
M-  FIT   1534.97     0.63   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

MO  NEUTRAL CHARGE ONLY
MO     76 1528.7      1.1           LONDON    66 HBC   0 K-P 2.24 GEV/C
MO     59 1531.4      0.8           BADIER    72 HBC   0 K-P AT 3.95GEV/C
MO   1262 1532.0      0.4           BALTAY    72 HBC   0 K-P 1.75 GEV
MO    324 1531.3      0.6           BORENSTEI 72 HBC   0 K-P 2.2GEV/C
MO    286 1532.3      0.7           KIRSCH    72 HBC   0 K-P 2.87GEV/C
MO        1533.0      1.0           ROSS2     73 HBC     XI KBAR PI (PI)
MO     97(1533.6)    (1.4)          BERTHON   74 HBC   0 QUASI 2 BODY CS
MO        1532.2      0.7           BELLEFO2  75 HBC   0 K-P TO XI- K PI
MO     80(1527.0)    (6.0)          SIXEL     79 HBC   0 INCL. K-P 10 GEV
MO    100(1535.0)    (4.0)          SIXEL     79 HBC   0 INCL. K-P 16 GEV
MO  A 2700(1532.1)   (0.6)          BAUBILLIE 81 HBC   0 K-P AT 8.25 GEV
MO  A   FIT TO INCLUSIVE SPECTRUM.  RESOLUTION (5 MEV) NOT UNFOLDED.
MO    450(1530.0)    (1.0)          BIAGI     81 SPEC -  HYPERON BEAM
MO   1244(1532.1)    (0.4)          ASTON     85 LASS    K-P 11 GEV/C
MO        . . . . . . . . .
MO  AVG   1531.78     0.34    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
MO  FIT   1531.80     0.31   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)
                             (SEE IDEOGRAM BELOW)
```



Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our "best" values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information

$\Xi(1530)^-$ − $\Xi(1530)^0$ MASS DIFFERENCE (MeV)

```
D            5.7       3.0                PJERROU   65 HBC  -0 1.8-1.95 GEV/C
D   B       (7.0)     (4.0)               LONDON    66 HBC  -0 2.24 GEV/C
D            2.0       3.2                MERRILL   66 HBC  -0 1.7-2.7 GEV/C
D            2.7       1.0                BALTAY    72 HBC  -0 K-P 1.75 GEV
D   B       (3.9)     (1.8)               KIRSCH    72 HBC  -0 K- P 2.87 GEV/C
D   B      REDUNDANT WITH DATA IN MASS LISTING.
D          . . . . . . . . .
D   AVG      2.92      0.91     AVERAGE
D   FIT      3.17      0.64   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)
```

$\Xi(1530)$ WIDTH (MeV)

```
W   MIXED CHARGES
W       20  (35.0)  OR LESS             BERTANZA  62 HBC  -0 K-P 2.3 GEV/C

W-  NEGATIVE CHARGE ONLY
W-           7.8       3.5       7.8    BALTAY    72 HBC  -  K-P 1.75 GEV
W-          16.2       4.6              KIRSCH    72 HBC  -  XI- PI0,XI0 PI-
W-           8.3       3.6              ROSS2     73 HBC  -  XI KBAR PI (PI)
W-           9.6       2.8              BELLEFO2  75 HBC  -  K-P TO XI- K PI
W-        . . . . . . . . .
W-  AVG     10.1       1.9      AVERAGE

WO  NEUTRAL CHARGE ONLY
WO           7.0       2.0              SCHLEIN   63 HBC   0 1.8, 1.95 GEV/C
WO           7.0       7.0              BERGE     66 HBC   0 1.5-1.7 GEV/C
WO           8.5       3.5              LONDON    66 HBC   0 2.24 GEV/C
WO          11.0       2.0              BADIER    72 HBC   0 K-P AT 3.95GEV/C
WO           9.0       0.7              BALTAY    72 HBC   0 K-P 1.75 GEV
WO           8.4       1.4              BORENSTEI 72 HBC   0 XI- PI+ MODE
WO          11.0       1.8              KIRSCH    72 HBC   0 XI- PI+
WO           9.1       2.4              ROSS2     73 HBC   0 XI KBAR PI (PI)
WO           9.5       1.2              BELLEFO2  75 HBC   0 K-P TO XI- K PI
WO  C   80  (19.0)    (6.0)             SIXEL     79 HBC   0 INCL. K-P 10 GEV
WO  C  100  (14.0)    (5.0)             SIXEL     79 HBC   0 INCL. K-P 16 GEV
WO  C     EXPERIMENTAL RESOLUTION OF 15 MEV NOT UNFOLDED.
WO  D 2700  (12.8)    (1.0)             BAUBILLIE 81 HBC   0 K-P AT 8.25 GEV
WO  D    FIT TO INCLUSIVE SPECTRUM.  RESOLUTION (5 MEV) NOT UNFOLDED.
WO        . . . . . . . . .
WO  AVG      9.14      0.48     AVERAGE
```

$\Xi(1530)$ REAL PART OF POLE POSITION (MeV)

```
REO        1531.6     0.4               LICHTENB  74        0 EXTRAP HABIBI73
RE-        1534.4     1.1               LICHTENB  74      -  EXTRAP HABIBI73
```

$\Xi(1530)$ IMAGINARY PART OF POLE POSITION (MeV)

```
IMO          4.45      0.35             LICHTENB  74        0 EXTRAP HABIBI73
IM-          3.9       1.75      3.9    LICHTENB  74      -  EXTRAP HABIBI73
```

$\Xi(1530)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi(1530) \rightarrow \Xi\pi$	1321+ 140
P2	$\Xi(1530) \rightarrow \Xi\gamma$	1321+ 0

$\Xi(1530)$ BRANCHING RATIOS

$\Xi(1530)$ → $(\Xi\gamma)$/total (P2)

```
R1           (0.04) OR LESS  CL=.90   KALBFLEI  75 HBC  -  K-P AT 2.18 GEV
```

REFERENCES FOR $\Xi(1530)$

```
BERTANZA 62 PRL 9 180           +BRISSON,CONNOLLY,GOLDBERG,GRAY,+(BNL+SYRA) IJ
PJERROU  62 PRL 9 114           +PROWSE,SCHLEIN,SLATER,STORK,TICHO   (UCLA) I
SCHLEIN  63 PRL 11 167          +CARMONY,PJERROU,SLATER,STORK,TICHO  (UCLA)IJP
BADIER   64 DUBNA I 593         +DEMOULIN,GOLDBERG, +      (EPOL+SACL+AMST) I
PJERROU  65 PRL 14 275          +SCHLEIN,SLATER,SMITH,STORK,TICHO    (UCLA)
BERGE    66 PR 147 945          +EBERHARD,HUBBARD,MERRILL,B-SHAFER,+  (LRL) I
LONDON   66 PR 143 1034         +RAU,SAMIOS,YAMAMOTO,GOLDBERG,+  (BNL+SYRA) IJ
MERRILL  66 UCRL-16455 THESIS D W MERRILL                            (LRL) JP
BADIER   72 NP B37 429          +BARRELET,CHARLTON,VIDEAU             (EPOL)
BALTAY   72 PL 42B 129          +BRIDGEWATER,COOPER,GERSHWIN,+  (COLU+BING)
    ALSO 73 NEVIS 199 THESIS    HABIBI                                (COLU)
BORENSTE 72 PR D5 1559          BORENSTEIN,DANBURG,KALBFLEISCH++ (BNL+MICH) I
KIRSCH   72 NP B40 349          SCHMIDT+CHANG,HEMINGWAY(BRAN+UMD+SYRA+TUFT) I
ROSS2    73 PURDUE CONF. 355    ROSS,LLOYD,RADOJICIC                   (OXF)
BERTHON  74 NC 21A 146          BERTHON,TRISTRAM,+    (CDEF+RHEL+SACL+STRB)
LICHTENB 74 PR D10 3865         D B LICHTENBERG                        (IND)
    ALSO 74 PRIV. COMM.         D B LICHTENBERG                        (IND)
BELLEFO2 75 NC 28A 289          DE BELLEFON,BERTHON,BILLOIR+    (CDEF+SACL)
KALBFLEI 75 PR D11 987          KALBFLEISCH,STRAND,CHAPMAN       (BNL+MICH)
SIXEL    79 NP B159 125         +BOTTCHER,KLEIN+ (AACH+BERL+CERN+LOIC+VIEN)
BAUBILLI 81 NP B192 1           BAUBILLIER+        (BIRM+CERN+GLAS+MSU+LPNP)
BIAGI    81 ZPHY C9 305         +      (BRIS+CAMB+GEVA+HEID+LAUS+LOQM+RHEL)
ASTON    85 PR D32 2270         + LASS COLLABORATION  (SLAC+CARL+CNRC+CINC)

                                PAPERS NOT REFERRED TO IN DATA LISTINGS

SHAFER   66 PR 142 883          BUTTON-SHAFER,LINDSEY,MURRAY,SMITH   (LRL) JP
HUNGERBU 74 PR D10 2051         HUNGERBUHLER,MAJKA,+   (YALE+FNAL+BNL+PITT)
BRIEFEL  75 PR D12 1859         +GOUREVITCH,KIRSCH+    (BRAN+UMD+SYRA+TUFT)
BRIEFEL  77 PR D16 2706         +GOUREVITCH,CHANG+     (BRAN+UMD+SYRA+TUFT)
MAZZUCAT 81 NP B178 1           MAZZUCATO,PENNINO+     (AMST+CERN+NIJM+OXF)
```

Ξ(1630)

$I(J^P) = \frac{1}{2}(\ \ )$ Status: *

OMITTED FROM SUMMARY TABLE

SEEN ONLY IN THE XI PI CHANNEL.

BARTSCH 69 SEE A SMALL, BROAD ENHANCEMENT NEAR 1650 MEV - IT IS NOT CLEAR THAT IT IS THE SAME PHENOMENON AS BRIEFEL 77, WHO FIND CS=2.6+-0.9 MICROBARNS AT 2.87 GEV/C INCIDENT K- MOMENTUM.

BORENSTEIN 72 SEE NO EFFECT IN THIS REGION. THEY FIND CS<2 MICROBARNS AT 2.18 GEV/C.

ROSS 72 ARGUE THAT THE EFFECT THEY SEE IS NOT THE SAME AS THAT SEEN BY BRIEFEL 77 (WHOSE PRELIMINARY RESULTS WERE REPORTED IN BMST 70), AND FIND CS=2+-1 MICROBARNS AT 3.3 GEV/C.

BELLEFON 75 FIND A CS OF AROUND 10 MICROBARNS NEAR 2 GEV/C, BUT LESS THAN 3 MICROBARNS AROUND 2.3 GEV/C.

NOT SEEN BY HASSALL 81 IN A HIGH STATISTICS BUBBLE CHAMBER EXPERIMENT (46 EVENTS/MICROBARN) AT 6.5 GEV/C.

Ξ(1630) MASS (MeV)

```
M        29 1606.0       6.0                ROSS      72 HBC   0 K-P AT 3.1-3.7
M        34 1633.0      12.0                BELLEFO2  75 HBC   0 K-P TO XI- K PI
M        31 1624.0       3.0                BRIEFEL   77 HBC   0 K-P 2.87 GEV/C
```

Ξ(1630) WIDTH (MeV)

```
W        29   21.0       7.0                ROSS      72 HBC   0 XI-PI+ K*0(890)
W        34   40.0      15.0                BELLEFO2  75 HBC   0 K-P TO XI- K PI
W   A    31  (22.5)                         BRIEFEL   77 HBC   0 K-P 2.87 GEV/C
W   A    GOODNESS OF FIT INSENSITIVE TO VALUES BETWEEN 15 AND 30 MEV.
```

Ξ(1630) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi(1630) \to \Xi\pi$	1321+ 140

SEEN IN K- P TO XI- PI+ K0 AND XI- PI0 K+.

REFERENCES FOR Ξ(1630)

```
ROSS      72 PL 38B 177          +BURAN,LLOYD,MULVEY,RADOJICIC          (OXF) I
BELLEFO2  75 NC 28A 289          DE BELLEFON,BERTHON,BILLOIR+    (CDEF+SACL)
BRIEFEL   77 PR D16 2706         +GOUREVITCH,CHANG+        (BRAN+UMD+SYRA+TUFT)
    ALSO  70 DUKE CONF. 317      BMST                      (BRAN+UMD+SYRA+TUFT)

                                 PAPERS NOT REFERRED TO IN DATA LISTINGS

APSELL    69 PRL 23 884          +                         (BRAN+UMD+SYRA+TUFT)
    SUPERSEDED BY BMST 70.
BARTSCH   69 PL 28B 439          +                    (AACH+BERL+CERN+LOIC+VIEN)
KALBFLEI  70 DUKE CONF 331       G R KALBFLEISCH                          (BNL) I
BORENSTE  72 PR D5 1559          BORENSTEIN,DANBURG,KALBFLEISCH++ (BNL+MICH) I
SCHMIDT   73 PURDUE CONF. 363    SCHMIDT                                 (BRAN)
HUNGERBU  74 PR D10 2051         HUNGERBUHLER,MAJKA,+      (YALE+FNAL+BNL+PITT)
BRIEFEL   75 PR D12 1859         +GOUREVITCH,KIRSCH+       (BRAN+UMD+SYRA+TUFT)
HASSALL   81 NP B189 397         +ANSORGE,CARTER,NEALE,RUSHBROOKE+(CAMB+MSU)
```

Ξ(1680)

$I(J^P) = \frac{1}{2}(\ \ )$ Status: * *

OMITTED FROM SUMMARY TABLE

SEEN BY DIONISI 78 AS A THRESHOLD ENHANCEMENT IN BOTH THE NEUTRAL AND NEGATIVELY CHARGED SIGMA KBAR MASS SPECTRA FROM THE REACTIONS K-P --> (SIGMA KBAR) K PI AT 4.2 GEV/C. THE DATA FROM THE SIGMA KBAR CHANNELS ALONE CANNOT DISTINGUISH BETWEEN A RESONANCE INTERPRETATION AND A LARGE SCATTERING LENGTH.

WEAKER EVIDENCE FOR AN ENHANCEMENT AT THE SAME MASS IS SEEN IN THE CORRESPONDING LAMBDA KBAR CHANNELS AND A COUPLED CHANNEL ANALYSIS YIELDS RESULTS CONSISTENT WITH A NEW XI.

THE HYPERON BEAM EXPERIMENT OF BIAGI 81 OBSERVE AN ENHANCEMENT AT 1700 MEV IN THE DIFFRACTIVELY PRODUCED LAMBDA K- SYSTEM. A PEAK IS ALSO OBSERVED IN THE LAMBDA K0 MASS SPECTRUM AT 1660 MEV WHICH IS CONSISTENT WITH A RESONANCE OF MASS 1720 MEV DECAYING INTO SIGMA0 K0, WITH THE GAMMA FROM THE SIGMA0 DECAY NOT DETECTED.

Ξ(1680) MASS (MeV)

```
M0  NEUTRAL CHARGE
M0  A  175(1699.0)    (5.0)             DIONISI   78 HBC   0 K-P AT 4.2 GEV/C
M0  A   FROM FIT TO SIGMA+ K- SPECTRUM
M0  B  183(1684.0)    (5.0)             DIONISI   78 HBC   0 K-P AT 4.2 GEV/C
M0  B   FROM COUPLED CHANNEL ANALYSIS OF SIGMA+ K- AND LAMBDA K0 SPECTRA

M-  NEGATIVE CHARGE
M-  C   45(1694.0)    (6.0)             DIONISI   78 HBC  -  K-P AT 4.2 GEV/C
M-  C   FROM COUPLED CHANNEL ANALYSIS OF SIGMA0 K- AND LAMBDA K- SPECTRA
M-  D  150(1700.0)   (10.0)             BIAGI     81 SPEC -  HYPERON BEAM
M-  D   FIT TO INCLUSIVE SPECTRUM FROM XI-N --> LAM K- X
```

Ξ(1680) WIDTH (MeV)

```
W0  NEUTRAL CHARGE
W0  A  175  (44.0)   (23.0)             DIONISI   78 HBC   0 K-P AT 4.2 GEV/C
W0  B  183  (20.0)    (4.0)             DIONISI   78 HBC   0 K-P AT 4.2 GEV/C

W-  NEGATIVE CHARGE
W-  C   45  (26.0)    (6.0)             DIONISI   78 HBC  -  K-P AT 4.2 GEV/C
W-  D  150  (47.0)   (14.0)             BIAGI     81 SPEC -  HYPERON BEAM
```

Ξ(1680) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi(1680) \to \Sigma\overline{K}$	1192+ 498
P2	$\Xi(1680) \to \Lambda\overline{K}$	1116+ 498
P3	$\Xi(1680) \to \Xi\pi$	1315+ 135
P4	$\Xi(1680) \to \Xi(1530)\ \pi$	1533+ 135
P5	$\Xi(1680) \to \Xi\pi\pi$ (including $\Xi(1530)\ \pi$)	1315+ 135+ 135

Ξ(1680) BRANCHING RATIOS

$\boldsymbol{\Xi(1680) \to (\Sigma\overline{K})/(\Lambda\overline{K})}$ (P1)/(P2)

```
R1  E      (2.7)    (0.9)               DIONISI   78 HBC   0 K-P AT 4.2 GEV/C
R1  E   NEUTRAL CHARGE
R1  F      (3.1)    (1.4)               DIONISI   78 HBC  -  K-P AT 4.2 GEV/C
R1  F   NEGATIVE CHARGE
```

$\boldsymbol{\Xi(1680) \to (\Xi\pi)/(\Sigma\overline{K})}$ (P3)/(P1)

```
R2         (0.09) OR LESS               DIONISI   78 HBC   0 K-P AT 4.2 GEV/C
```

$\boldsymbol{\Xi(1680) \to (\Xi^-\pi^+\pi^0)/(\Sigma\overline{K})}$ (P5)/(P1)

```
R3         (0.04) OR LESS               DIONISI   78 HBC   0 K-P AT 4.2 GEV/C
```

$\boldsymbol{\Xi(1680) \to (\Xi^-\pi^+\pi^-)/(\Sigma\overline{K})}$ (P5)/(P1)

```
R4         (0.03) OR LESS               DIONISI   78 HBC  -  K-P AT 4.2 GEV/C
```

$\boldsymbol{\Xi(1680) \to (\Xi(1530)\ \pi)/(\Sigma\overline{K})}$ (P4)/(P1)

```
R5         (0.06) OR LESS               DIONISI   78 HBC  -  K-P AT 4.2 GEV/C
```

REFERENCES FOR Ξ(1680)

```
DIONISI  78 PL 80B 145       +DIAZ,ARMENTEROS+       (CERN+AMST+NIJM+OXF)I,JP
BIAGI    81 ZPHY C9 305      +       (BRIS+CAMB+GEVA+HEID+LAUS+LOQM+RHEL)
```

Ξ(1820)

$I(J^P) = \frac{1}{2}(\frac{3}{2}\ )$ Status: * * *

WE LIST HERE EVERYTHING REPORTED IN THE MASS RANGE 1750-1875 MEV.

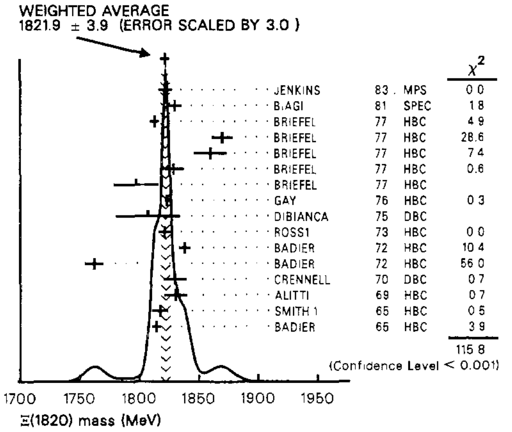
The clearest evidence for the Ξ(1820) comes from GAY 76, who saw an 8-standard-deviation peak in ΛK^- and smaller signals in $\Xi(1530)\pi$ and $\Sigma\overline{K}$. The peak is narrow ($\Gamma = 21 \pm 7$ MeV), whereas earlier (and much smaller) experiments found widths of up to 100 MeV (see the Listings below). A spin-parity analysis of the GAY 76 data, but with more events (TEODORO 78), favors spin 3/2 but cannot make a parity discrimination.

BIAGI 81 used the CERN hyperon beam to study Ξ^- interactions in hydrogen and deuterium. The diffractively produced ΛK^- system has a broad peak ($\Gamma = 72 \pm 20$ MeV) at 1830 MeV on top of a substantial background. There is also a smaller peak in the inclusive ΛK_S^0 spectrum.

Neither GAY 76 nor BIAGI 81 saw a peak in the $\Xi\pi$ channel. It is possible that $\Xi\pi$ peaks seen in this region by some of the lower momentum experiments were at least partly due to the Ξ(1940), with a shape distorted by the limited phase space available (SMITH 65). Furthermore, some of the early experiments were forced to add several different channels together to overcome poor statistics (CRENNELL 70, BADIER 71).

Ξ(1820) MASS (MeV)

```
M          (1770.0)                        HALSTEINS 63 FBC  -0 K-FR 3.5 GEV/C
M        30 1814.0      4.0                BADIER    65 HBC   0 LAMBDA KOBAR
M        29 1817.0      7.0                SMITH 1   65 HBC  -0 LAMBDA KBAR
M        40 1830.0     10.0                ALITTI    69 HBC  -  LAM, SIG KBAR
M   A    25 1830.0     10.0                CRENNELL  70 DBC  -0 3.6, 3.9 GEV/C
M   A    FROM FIT TO INCLUSIVE XI PI, XI PI PI AND LAMBDA K- SPECTRA
M    B     (1826.0)   (12.0)               CRENNELL  70 DBC  -0 3.6, 3.9 GEV/C
M    B   FROM FIT TO INCLUSIVE XI PI AND XI PI PI SPECTRA ONLY
M   C    28 1762.0      8.0                BADIER    72 HBC  -0 XI PI,XI2PI,K Y
M   C    38 1838.0      5.0                BADIER    72 HBC   -0XI PI,XI2PI,K Y
M   C    BADIER 72 ADDS ALL CHANNELS AND DIVIDES PEAK IN LOWER AND HIGHER
M   C    MASS REGIONS. THE DATA CAN ALSO BE FITTED WITH A SINGLE BREIT-
M   C    WIGNER OF MASS 1800 AND WIDTH 150 MEV.
M     D  30 1821.0      5.0                ROSS1     73 HBC  -0 LAMBDA K-/KBARO
M     D  LESS SIGNIFICANT ENHANCEMENTS SEEN IN XI(1530) PI (M=1825,W=100)
M     D  AND SIGMA KBAR (M=1810+-9,W=16+-11).
M           1807.0     27.0                DIBIANCA  75 DBC  -0 XI 2PI, XI* PI
M       130 1823.0      2.0                GAY       76 HBC  -  K- P AT 4.2 GEV
M        74 1797.0     19.0                BRIEFEL   77 HBC   0 XI PI (2.87 K-P)
M        68 1829.0      9.0                BRIEFEL   77 HBC  -0 XI(1530) PI
M        39 1860.0     14.0                BRIEFEL   77 HBC  -  SIGMA- KOBAR
M        44 1870.0      9.0                BRIEFEL   77 HBC   0 LAMBDA KOBAR
M        57 1813.0      4.0                BRIEFEL   77 HBC  -  LAMBDA K-
M     E 300 1830.0      6.0                BIAGI     81 SPEC -  HYPERON BEAM
M     E  FIT TO INCLUSIVE SPECTRUM FROM XI-N --> LAM K- X
M           1822.0      6.0                JENKINS   83 MPS  -  K- P TO K+ MM
M           . . . . . . . . . . .
M  AVG      1821.9      3.9      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 3.0)
                                 (SEE IDEOGRAM BELOW)
```

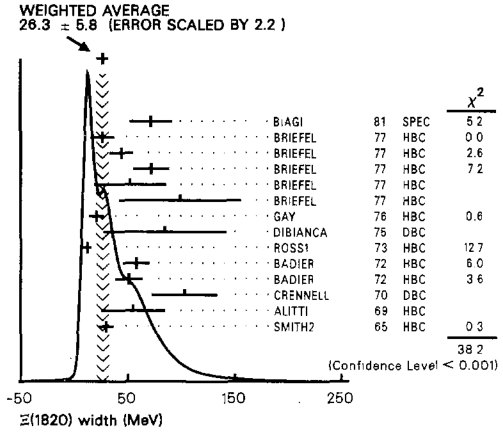


Ξ(1820) WIDTH (MeV)

```
W             (80.0)  OR LESS              HALSTEINS 63 FBC  -0 K-FR 3.5 GEV/C
W             (12.0)    (4.0)              BADIER    65 HBC   0 LAMBDA KOBAR
W              30.0      7.0               SMITH2    65 HBC  -0 LAMBDA KBAR
W              55.0     40.0      20.0     ALITTI    69 HBC  -  LAM, SIG KBAR
W   A         103.0     38.0      24.0     CRENNELL  70 DBC  -0 3.6, 3.9 GEV/C
W    B        (48.0)   (36.0)    (19.0)    CRENNELL  70 DBC  -0 3.6, 3.9 GEV/C
W   C          51.0     13.0               BADIER    72 HBC  -0 LOWER MASS
W   C          58.0     13.0               BADIER    72 HBC  -0 HIGHER MASS
W     D   30   12.0      4.0               ROSS1     73 HBC  -0 LAMBDA K-/KBARO
W              85.0     58.0               DIBIANCA  75 DBC  -0 XI 2PI, XI* PI
W        130   21.0      7.0               GAY       76 HBC  -  K- P AT 4.2 GEV
W         74   99.0     57.0               BRIEFEL   77 HBC   0 XI PI (2.87 K-P)
W         68   52.0     34.0               BRIEFEL   77 HBC  -0 XI(1530) PI
W         39   72.0     17.0               BRIEFEL   77 HBC  -  SIGMA- KOBAR
W         44   44.0     11.0               BRIEFEL   77 HBC   0 LAMBDA KOBAR
W         57   26.0     11.0               BRIEFEL   77 HBC  -  LAMBDA K-
W      E 300   72.0     20.0               BIAGI     81 SPEC -  HYPERON BEAM
W             . . . . . . . . . . .
W   AVG        26.3      5.8     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.2)
                                 (SEE IDEOGRAM BELOW)
```

Ξ(1820) PARTIAL DECAY MODES

		DECAY MASSES
P1	Ξ(1820) → $\Lambda \overline{K}$	1116+ 498
P2	Ξ(1820) → $\Xi \pi$	1321+ 140
P3	Ξ(1820) → $\Sigma \overline{K}$	1197+ 498
P4	Ξ(1820) → Ξ(1530) π	1533+ 140
P5	Ξ(1820) → $\Xi \pi \pi$ (excluding Ξ(1530) π)	1321+ 140+ 140



FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

```
        P 1      P 2      P 3      P 4
 P 1   .4974+-.0871
 P 2  -.761    .1889+-.0529
 P 3   .133   -.508    .1463+-.0477
 P 4  -.822    .581   -.501    .1674+-.0647
```

Ξ(1820) BRANCHING RATIOS

Ξ(1820) → ($\Lambda \overline{K}$)/total (P1)

```
R1             0.30      0.15              ALITTI    69 HBC  -  K-P 3.9-5.0 GEV
R1           . . . . . . . . . . .
R1   FIT       0.497     0.087   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.8)
```

Ξ(1820) → ($\Xi \pi$)/total (P2)

```
R2             0.10      0.10              ALITTI    69 HBC  -  K-P 3.9-5.0 GEV
R2           . . . . . . . . . . .
R2   FIT       0.189     0.053   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
```

Ξ(1820) → ($\Xi \pi$)/($\Lambda \overline{K}$) (P2)/(P1)

```
R21            0.20      0.20              BADIER    65 HBC   0 K-P AT 3 GEV
R21           (0.36) OR LESS  CL=.95       GAY       76 HBC  -  K- P AT 4.2 GEV
R21          . . . . . . . . . . .
R21  FIT       0.38      0.16    FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5)
```

Ξ(1820) → ($\Xi \pi$)/(Ξ(1530) π) (P2)/(P4)

```
R22            1.5       0.6       0.4     APSELL    70 HBC   0 K-P AT 2.87 GEV
R22          . . . . . . . . . . .
R22  FIT       1.13      0.36    FROM FIT
```

Ξ(1820) → ($\Sigma \overline{K}$)/total (P3)

```
R3            (0.02) OR LESS               TRIPP     67 RVUE
R3             0.30      0.15              ALITTI    69 HBC  -  K-P 3.9-5.0 GEV
R3           . . . . . . . . . . .
R3   FIT       0.146     0.048   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

Ξ(1820) → ($\Sigma \overline{K}$)/($\Lambda \overline{K}$) (P3)/(P1)

```
R31            0.24      0.10              GAY       76 HBC  -  K- P AT 4.2 GEV
R31          . . . . . . . . . . .
R31  FIT       0.29      0.10    FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)
```

Ξ(1820) → (Ξ(1530) π)/total (P4)

```
R4             0.30      0.15              ALITTI    69 HBC  -  K-P 3.9-5.0 GEV
R4   F        (0.25) OR LESS               DAUBER    69 HBC     K-P 2.7 GEV/C
R4   F   USES IN PART THE SAME DATA AS SMITH 65
R4    G       NOT SEEN                     HASSALL   81 HBC     K-P 6.5 GEV/C
R4                SEEN                     ASTON     85 LASS    K-P 11 GEV/C      |
R4    G  INCLUDING XI PI PI
R4           . . . . . . . . . . .
R4   FIT       0.167     0.065   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.6)
```

Ξ(1820) → (Ξ(1530) π)/($\Lambda \overline{K}$) (P4)/(P1)

```
R41            0.26      0.13              SMITH1    65 HBC  -0 K-P 2.45-2.70GEV
R41            1.0       0.3               GAY       76 HBC  -  K- P AT 4.2 GEV
R41          . . . . . . . . . . .
R41  AVG       0.38      0.27     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.3)
R41  FIT       0.34      0.18    FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.7)
```

Baryon Full Listings

$\Xi(1820)$, $\Xi(1940)$

$\Xi(1820) \to (\Xi\pi\pi)/(\Lambda\bar{K})$ (P5)/(P1)

```
R51           (0.1)  OR MORE            SMITH1    65 HBC  -0 K-P 2.45-2.70GEV
```

$\Xi(1820) \to (\Xi\pi\pi)/(\Xi(1530)\ \pi)$ (P5)/(P4)

```
R52 H         (0.3)    (0.5)            APSELL    70 HBC   0 K-P AT 2.87 GEV
R52 H   OR LESS. UPPER LIMIT FOR THE 3-BODY DECAY
R52          CONSISTENT WITH ZERO       GAY       76 HBC  -  K-P AT 4.2 GEV
```

$\Xi(1820) \to (\Xi\pi\pi$ (including $\Xi(1530)\ \pi))/(\Lambda\bar{K})$

```
R53                                                    (P4+P5)/(P1)
R53  I        (0.14) OR LESS            BADIER    65 HBC   0 1 STD.DEV.LIMIT
R53  I  FOR THE DECAY MODE (XI- PI+ PI0) ONLY
```

REFERENCES FOR $\Xi(1820)$

```
HALSTEIN 63 SIENA CONF 173   HALSTEINSLID,+   (BERG+CERN+EPOL+RHEL+LOUC) I
BADIER   65 PL 16 171        +DEMOULIN,GOLDBERG, +      (EPOL+SACL+AMST) I
SMITH1   65 PRL 14 25        +LINDSEY,BUTTON-SHAFER,MURRAY          (LRL)IJP
SMITH2   65 ATHENS CONF 251  G A SMITH, J S LINDSEY                 (LRL)
TRIPP    67 NP B3 10         + LEITH, +         (LRL+SLAC+CERN+HEID+SACL)
    USES DATA OF SMITH1.

ALITTI   69 PRL 22 79        +BARNES,FLAMINIO,METZGER, +      (BNL+SYRA) I
DAUBER   69 PR 179 1262      +BERGE, HUBBARD, MERRILL, MULLER      (LRL)
APSELL   70 PRL 24 777       +                     (BRAN+UMD+SYRA+TUFT) I
CRENNELL 70 PR D1 847        +KARSHON, LAI, ONEALL, SCARR, SCHUMANN(BNL)
BADIER   72 NP B37 429       +BARRELET,CHARLTON,VIDEAU             (EPOL)
ROSS1    73 PURDUE CONF. 345 ROSS,LLOYD,RADOJICIC                  (OXF)

DIBIANCA 75 NP B98 137       DIBIANCA,ENDORF                       (CARN)
GAY      76 PL 62B 477       +ARMENTEROS,BERGE,GAVILLET+(AMST+CERN+NIJM)IJ
BRIEFEL  77 PR D16 2706      +GOUREVITCH,CHANG+     (BRAN+UMD+SYRA+TUFT)
    ALSO 70 DUKE CONF. 317   BMST                   (BRAN+UMD+SYRA+TUFT)
BIAGI    81 ZPHY C9 305      +       (BRIS+CAMB+GEVA+HEID+LAUS+LOQM+RHEL)
HASSALL  81 NP B189 397      +ANSORGE,CARTER,NEALE,RUSHBROOKE+(CAMB+MSU)
JENKINS  83 PRL 51 951       +ALBRIGHT,DIAMOND,+(FSU+BRAN+LBL+CINC+SMAS)
ASTON    85 PR D32 2270      + LASS COLLABORATION  (SLAC+CARL+CNRC+CINC)

                             PAPERS NOT REFERRED TO IN DATA LISTINGS

SMITH    64 PRL 13 61        +LINDSEY,MURRAY,BUTTON-SHAFER+        (LRL) IJP
MERRILL  68 PR 167 1202      D W MERRILL, J BUTTON-SHAFER          (LRL)
APSELL   69 PRL 23 884       +                      (BRAN+UMD+SYRA+TUFT)
    SUPERSEDED BY BRIEFEL 77.
SCHMIDT  73 PURDUE CONF. 363 SCHMIDT                               (BRAN)
BRIEFEL  75 PR D12 1859      +GOUREVITCH,KIRSCH+    (BRAN+UMD+SYRA+TUFT)
TEODORO  78 PL 77B 451       +DIAZ,DIONISI,BLOKZIJL+(AMST+CERN+NIJM+OXF)  JP
```

$\Xi(1940)$

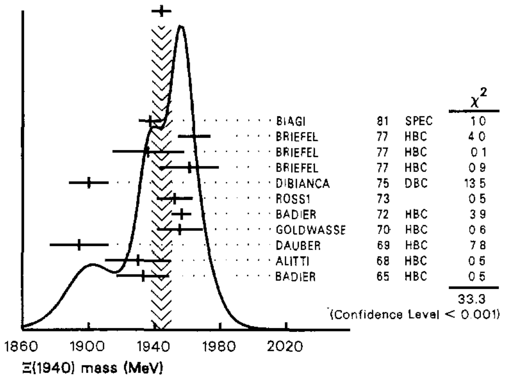
$I(J^P) = \frac{1}{2}(\ \ )$ Status: * *

OMITTED FROM SUMMARY TABLE

WE LIST UNDER XI(1940) EVERYTHING REPORTED IN THE MASS RANGE 1875-2000 MEV.

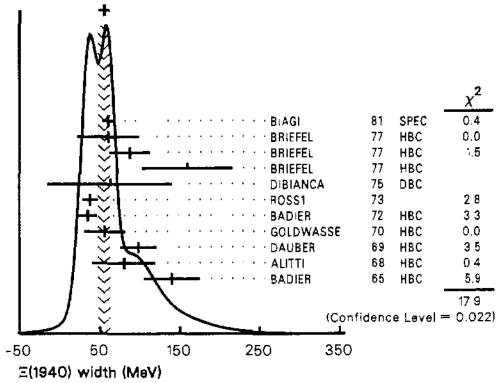
$\Xi(1940)$ MASS (MeV)

```
M      35 1933.0     16.0            BADIER    65 HBC   0 XI- PI+
M      27 1930.0     20.0            ALITTI    68 HBC   0 XI- PI+
M      66 1894.0     18.0            DAUBER    69 HBC  -  XI PI
M      21 1955.0     14.0            GOLDWASSE 70 HBC  -  XI PI
M      29 1956.0      6.0            BADIER    72 HBC     XI PI,XI2PI,K Y
M      25 1952.0     11.0            ROSS1     73         (XI PI)-
M         1900.0     12.0            DIBIANCA  75 DBC     XI PI
M     139 1961.0     18.0            BRIEFEL   77 HBC   0 XI-PI+(2.87 K-P)
M      44 1936.0     22.0            BRIEFEL   77 HBC  -  XI0PI-(2.87 K-P)
M      56 1964.0     10.0            BRIEFEL   77 HBC  -0 XI(1530) PI
M   A 150 1937.0      7.0            BIAGI     81 SPEC  0 HYPERON BEAM
M   A  FIT TO INCLUSIVE SPECTRUM FROM XI-N --> XI- PI+ X
                    (SEE IDEOGRAM BELOW)
```



$\Xi(1940)$ WIDTH (MeV)

```
W      35  140.0      35.0           BADIER    65 HBC   0 XI- PI+
W      27   80.0      40.0           ALITTI    68 HBC   0 XI- PI+
W      66   98.0      23.0           DAUBER    69 HBC  -  XI PI
W      21   56.0      26.0           GOLDWASSE 70 HBC  -  XI PI
W      29   35.0      11.0           BADIER    72 HBC     XI PI,XI2PI,K Y
W           38.0      10.0           ROSS1     73         (XI PI)-
W           63.0      78.0           DIBIANCA  75 DBC     XI PI
W     139  159.0      57.0           BRIEFEL   77 HBC   0 XI-PI+(2.87 K-P)
W      44   87.0      26.0           BRIEFEL   77 HBC  -  XI0PI-(2.87 K-P)
W      56   60.0      39.0           BRIEFEL   77 HBC  -0 XI(1530) PI
W   A 150   60.0       8.0           BIAGI     81 SPEC  0 HYPERON BEAM
                 (SEE IDEOGRAM BELOW)
```



$\Xi(1940)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi(1940) \to \Xi\pi$	1321+ 140
P2	$\Xi(1940) \to \Xi(1530)\ \pi$	1533+ 140
P3	$\Xi(1940) \to \Xi\pi\pi$ (excluding $\Xi(1530)\ \pi$)	1321+ 140+ 140
P4	$\Xi(1940) \to \Xi^0\pi^-$	1315+ 140
P5	$\Xi(1940) \to \Xi^-\pi^0$	1321+ 135
P6	$\Xi(1940) \to \Sigma\bar{K}$	1197+ 498

$\Xi(1940)$ BRANCHING RATIOS

THE XI(1940) IS SEEN MAINLY IN XI PI AND SOME IN XI(1530) PI. IT HAS BEEN LOOKED FOR IN OTHER CHANNELS BUT ONLY OBSERVED BY HASSALL 81 WHO SEE A 3SIGMA EFFECT IN SIGMA KBAR.

$\Xi(1940) \to (\Xi\pi)/(\Xi(1530)\ \pi)$ (P1)/(P2)

```
R1           2.8      0.7      0.6   APSELL    70 HBC   0
```

$\Xi(1940) \to (\Xi\pi\pi)/(\Xi(1530)\ \pi)$ (P3)/(P2)

```
R2           0.0      0.3            APSELL    70 HBC   0
```

$\Xi(1940) \to (\Xi^0\pi^-)/(\Xi^-\pi^0)$ (P4)/(P5)

```
R3     25    2.6      6.0      1.6   ROSS1     73            (XI PI)-
```

$\Xi(1940) \to (\Sigma\bar{K})/\mathrm{total}$ (P6)

```
R4     17   POSSIBLY SEEN            HASSALL   81 HBC  -  K-P AT 6.5 GEV/C
```

REFERENCES FOR $\Xi(1940)$

```
BADIER   65 PL 16 171        +DEMOULIN,GOLDBERG, +      (EPOL+SACL+AMST) I
ALITTI   68 PRL 21 1119      +FLAMINIO,METZGER,RADOJICIC,+    (BNL+SYRA) I
DAUBER   69 PR 179 1262      +BERGE, HUBBARD, MERRILL, MULLER      (LRL) I
APSELL   70 PRL 24 777       +                     (BRAN+UMD+SYRA+TUFT) I
GOLDWASS 70 PR D1 1960       E L GOLDWASSER, P F SCHULTZ       (ILLINOIS)
BADIER   72 NP B37 429       +BARRELET,CHARLTON,VIDEAU             (EPOL)
ROSS1    73 PURDUE CONF. 345 ROSS,LLOYD,RADOJICIC                  (OXF)

DIBIANCA 75 NP B98 137       DIBIANCA,ENDORF                       (CARN)
BRIEFEL  77 PR D16 2706      +GOUREVITCH,CHANG+     (BRAN+UMD+SYRA+TUFT)
    ALSO 70 DUKE CONF. 317   BMST                   (BRAN+UMD+SYRA+TUFT)
BIAGI    81 ZPHY C9 305      +       (BRIS+CAMB+GEVA+HEID+LAUS+LOQM+RHEL)
HASSALL  81 NP B189 397      +ANSORGE,CARTER,NEALE,RUSHBROOKE+(CAMB+MSU)

                             PAPERS NOT REFERRED TO IN DATA LISTINGS

APSELL   69 PRL 23 884       +                      (BRAN+UMD+SYRA+TUFT)
    SUPERSEDED BY BMST  70.
SCHMIDT  73 PURDUE CONF. 363 SCHMIDT                               (BRAN)
BRIEFEL  75 PR D12 1859      +GOUREVITCH,KIRSCH+    (BRAN+UMD+SYRA+TUFT)
```

Ξ(2030)

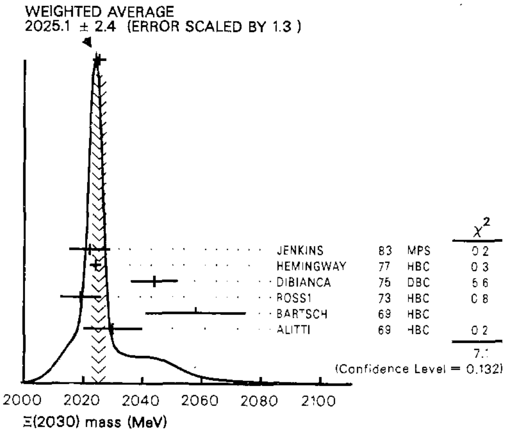
$I(J^P)=\frac{1}{2}(\geqslant\frac{5}{2}\ )$ Status: * * *

```
THE EVIDENCE FOR THIS STATE HAS BEEN MUCH IMPROVED BY HEMINGWAY 77, WHO
SEE AN 8 STD. DEV. ENHANCEMENT IN SIGMA KBAR AND A WEAKER COUPLING TO
LAMBDA KBAR. ALITTI 68 AND HEMINGWAY 77 OBSERVE NO SIGNALS IN THE
XI PI PI (OR XI(1530) PI) CHANNEL, IN CONTRAST TO DIBIANCA 75. THE
DECAY INTO LAMBDA/SIGMA KBAR PI REPORTED BY BARTSCH 69 IS ALSO NOT
CONFIRMED BY HEMINGWAY 77.

A MOMENTS ANALYSIS OF THE HEMINGWAY 77 DATA INDICATES THAT THE SPIN
IS GREATER THAN OR EQUAL TO 5/2 AT A LEVEL OF 3 STD. DEVIATIONS.
```

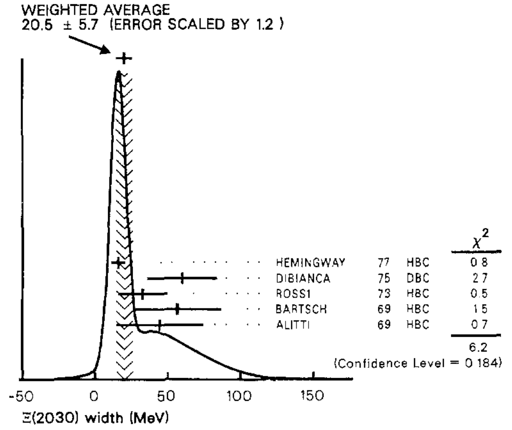
Ξ(2030) MASS (MeV)

```
M      42 2030.0     10.0             ALITTI    69 HBC  -  K-P 3.9-5 GEV/C
M      40 2058.0     17.0             BARTSCH   69 HBC  -0 K-P 10 GEV/C
M      15 2019.0      7.0             ROSS1     73 HBC  -0 SIGMA KBAR
M         2044.0      8.0             DIBIANCA  75 DBC  -0 XI 2PI, XI* PI
M     200 2024.0      2.0             HEMINGWAY 77 HBC  -  K-P AT 4.2 GEV
M         2022.0      7.0             JENKINS   83 MPS  -  K- P TO K+ MM
M         . . . . . . . . . .
M   AVG   2025.1      2.4    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
                      (SEE IDEOGRAM BELOW)
```



Ξ(2030) WIDTH (MeV)

```
W           45.0     40.0     20.0  ALITTI    69 HBC  -  K-P 3.9-5 GEV/C
W           57.0     30.0           BARTSCH   69 HBC  -0 K-P 10 GEV/C
W      15   33.0     17.0           ROSS1     73 HBC  -0 SIGMA KBAR
W           60.0     24.0           DIBIANCA  75 DBC  -0 XI 2PI, XI* PI
W     200   16.0      5.0           HEMINGWAY 77 HBC  -  K-P AT 4.2 GEV
W           . . . . . . . . . .
W   AVG     20.5      5.7     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
                     (SEE IDEOGRAM BELOW)
```



Ξ(2030) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi(2030) \rightarrow \Xi\pi$	1321+ 140
P2	$\Xi(2030) \rightarrow \Lambda\overline{K}$	1116+ 498
P3	$\Xi(2030) \rightarrow \Sigma\overline{K}$	1197+ 498
P4	$\Xi(2030) \rightarrow \Xi(1530)\ \pi$	1533+ 140
P5	$\Xi(2030) \rightarrow \Xi\pi\pi$ (excluding $\Xi(1530)\ \pi$)	1321+ 140+ 140
P6	$\Xi(2030) \rightarrow \Lambda\overline{K}\pi$	1116+ 498+ 140
P7	$\Xi(2030) \rightarrow \Sigma\overline{K}\pi$	1189+ 498+ 140

Ξ(2030) BRANCHING RATIOS

$\Xi(2030) \rightarrow (\Xi\pi)/$(modes P1 to P4) (P1)/(P1+P2+P3+P4)

```
R1          (0.30) OR LESS          ALITTI    69 HBC  -  1 STD DEV LIMIT
```

$\Xi(2030) \rightarrow (\Xi\pi)/(\Sigma\overline{K})$ (P1)/(P3)

```
R11         (0.19) OR LESS  CL=.95  HEMINGWAY 77 HBC  -  K-P AT 4.2 GEV
```

$\Xi(2030) \rightarrow (\Lambda\overline{K})/$(modes P1 to P4) (P2)/(P1+P2+P3+P4)

```
R2           0.25    0.15           ALITTI    69 HBC  -  K-P 3.9-5 GEV/C
```

$\Xi(2030) \rightarrow (\Lambda\overline{K})/(\Sigma\overline{K})$ (P2)/(P3)

```
R21          0.22     0.09          HEMINGWAY 77 HBC  -  K-P AT 4.2 GEV
```

$\Xi(2030) \rightarrow (\Sigma\overline{K})/$(modes P1 to P4) (P3)/(P1+P2+P3+P4)

```
R3           0.75    0.20           ALITTI    69 HBC  -  K-P 3.9-5 GEV/C
```

$\Xi(2030) \rightarrow (\Xi(1530)\ \pi)/$(modes P1 to P4) (P4)/(P1+P2+P3+P4)

```
R4          (0.15) OR LESS          ALITTI    69 HBC  -  1 STD DEV LIMIT
```

$\Xi(2030) \rightarrow (\Xi\pi\pi$ including $\Xi(1530)\ \pi)/(\Sigma\overline{K})$

```
R41                                                  (P4+P5)/(P3)
R41   A     (0.11) OR LESS  CL=.95  HEMINGWAY 77 HBC  -  K-P AT 4.2 GEV
R41   A  FOR THE DECAY MODE (XI- PI+ PI-) ONLY
```

$\Xi(2030) \rightarrow (\Lambda\overline{K}\pi)/$total (P6)

```
R6          SEEN                    BARTSCH   69 HBC     K-P AT 10 GEV
```

$\Xi(2030) \rightarrow (\Lambda\overline{K}\pi)/(\Sigma\overline{K})$ (P6)/(P3)

```
R61         (0.32) OR LESS  CL=.95  HEMINGWAY 77 HBC  -  K-P AT 4.2 GEV
```

$\Xi(2030) \rightarrow (\Sigma\overline{K}\pi)/$total (P7)

```
R7          SEEN                    BARTSCH   69 HBC     K-P AT 10 GEV
```

$\Xi(2030) \rightarrow (\Sigma\overline{K}\pi)/(\Sigma\overline{K})$ (P7)/(P3)

```
R71   B     (0.04) OR LESS  CL=.95  HEMINGWAY 77 HBC  -  K-P AT 4.2 GEV
R71   B  FOR THE DECAY MODE (SIGMA+- K- PI-+) ONLY
```

REFERENCES FOR Ξ(2030)

```
ALITTI   69 PRL 22 79          +BARNES,FLAMINIO,METZGER, +       (BNL+SYRA) I
BARTSCH  69 PL 28B 439         +                   (AACH+BERL+CERN+LOIC+VIEN)
ROSS1    73 PURDUE CONF. 345   ROSS,LLOYD,RADOJICIC                     (OXF)

DIBIANCA 75 NP B98 137         DIBIANCA,ENDORF                         (CARN)
HEMINGWA 77 PL 68B 197         HEMINGWAY,ARMENTEROS+  (AMST+CERN+NIJM+OXF) IJ
    ALSO 76 PL 62B 477         GAY,ARMENTEROS,BERGE+       (AMST+CERN+NIJM)
JENKINS  83 PRL 51 951         +ALBRIGHT,DIAMOND,+(FSU+BRAN+LBL+CINC+SMAS)
```

Ξ(2120)

$I(J^P)=\frac{1}{2}(\quad)$ Status: *

OMITTED FROM SUMMARY TABLE

```
THIS EFFECT IS REPORTED IN GAY 76 AS A FOUR STANDARD DEVIATION
ENHANCEMENT IN LAMBDA K-. AN ANALYSIS OF THE SAME DATA BY HEMINGWAY 77,
BUT WITH ADDITIONAL STATISTICS, POINTS OUT THAT THE SIGNIFICANCE OF THE
ENHANCEMENT IS GREATLY REDUCED IF A RESTRICTIVE FOUR-MOMENTUM CUT
(U-CUT) IS MADE. THIS SUGGESTS AN ANOMALOUS PRODUCTION MECHANISM IF THE
STATE IS GENUINE.

CHLIAPNIKOV 79 REPORT A BUMP OF 18 EVENTS AT 2137 MEV IN AN INCLUSIVE
LAMBDABAR K+ SPECTRUM FROM K+P INTERACTIONS AT 32 GEV/C.  THE K+ ARE
NOT UNIQUELY IDENTIFIED. BUMPS WITH LOWER NUMBERS OF EVENTS ARE ALSO
REPORTED AT 2240, 2830, AND 2540 MEV.
```

Ξ(2120) MASS (MeV)

```
M         2123.0      7.0           GAY         76 HBC  -  K- P AT 4.2 GEV
M       18(2137.0)   (4.0)          CHLIAPNIK 79 HBC  +  LAMBDABAR K+
```

Ξ(2120) WIDTH (MeV)

```
W          25.0      12.0           GAY         76 HBC  -  K- P AT 4.2 GEV
W       18  (20.0)   OR LESS        CHLIAPNIK 79 HBC  +  LAMBDABAR K+
```

Ξ(2120) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi(2120) \to \Lambda \overline{K}$	1116+ 498

Ξ(2120) BRANCHING RATIOS

$\Xi(2120) \to (\Lambda \overline{K})$/total (P1)

R1	SEEN	GAY	76	HBC	-	K- P AT 4.2 GEV

REFERENCES FOR Ξ(2120)

GAY 76 PL 62B 477 +ARMENTEROS,BERGE,GAVILLET+(AMST+CERN+NIJM)I
HEMINGWA 77 PL 68B 197 HEMINGWAY,ARMENTEROS+ (AMST+CERN+NIJM+OXF)
CHLIAPNI 79 NP B158 253 CHLIAPNIKOV,GERDYUKOV+ (SERP+BELG+MONS)

Ξ(2250)

$I(J^P) = \frac{1}{2}(\quad)$ Status: * *

OMITTED FROM SUMMARY TABLE

THE EVIDENCE FOR THIS STATE IS MIXED. BARTSCH 69 SEE A BUMP OF NOT MUCH STATISTICAL SIGNIFICANCE IN LAMBDA-KBAR-PI, SIGMA-KBAR-PI, AND XI-PI-PI MASS SPECTRA. GOLDWASSER 70 SEE A NARROWER BUMP IN XI-PI-PI AT A HIGHER MASS. NOT SEEN BY HASSALL 81 WITH 45 EVENTS/MICROBARN AT 6.5 GEV/C. SEEN BY JENKINS 83.

Ξ(2250) MASS (MeV)

M	35	2244.0	52.0	BARTSCH	69	HBC		K-P 10 GEV/C
M	18	2295.0	15.0	GOLDWASSE	70	HBC	-	K-P 5.5 GEV/C
M		2214.0	5.0	JENKINS	83	MPS	-	K- P TO K+ MM

Ξ(2250) WIDTH (MeV)

W	130.0	80.0	BARTSCH	69	HBC		
W	LESS THAN	30.0	GOLDWASSE	70	HBC	-	K-P 5.5 GEV/C

Ξ(2250) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi(2250) \to \Xi \pi \pi$	1321+ 140+ 140
P2	$\Xi(2250) \to \Lambda \overline{K} \pi$	1116+ 498+ 140
P3	$\Xi(2250) \to \Sigma \overline{K} \pi$	1197+ 498+ 140

REFERENCES FOR Ξ(2250)

BARTSCH 69 PL 28B 439 + (AACH+BERL+CERN+LOIC+VIEN)
GOLDWASS 70 PR D1 1960 E L GOLDWASSER, P F SCHULTZ (ILL)
JENKINS 83 PRL 51 951 +ALBRIGHT,DIAMOND,+(FSU+BRAN+LBL+CINC+SMAS)

PAPERS NOT REFERRED TO IN DATA LISTINGS

HASSALL 81 NP B189 397 +ANSORGE,CARTER,NEALE,RUSHBROOKE+(CAMB+MSU)

Ξ(2370)

$I(J^P) = \frac{1}{2}(\quad)$ Status: * *

OMITTED FROM SUMMARY TABLE

SEEN BY AMIRZADEH 80 AND HASSALL 81 IN THE CHARGED AND NEUTRAL LAMBDA/SIGMA KBAR PI MASS SPECTRA FROM THE REACTIONS K-P --> XI(1530) K AND XI(1530) K PI. AMIRZADEH 80 ALSO OBSERVE A SMALL EFFECT AT THE SAME MASS IN THE OMEGA- K MASS SPECTRUM. KINSON 80 RE-ANALYSE THE DATA OF AMIRZADEH 80 BUT WITH 50 PER CENT MORE STATISTICS.

Ξ(2370) MASS (MeV)

M		2392.0	27.0	DIBIANCA	75	DBC		XI 2PI
M	94	2373.0	8.0	AMIRZAD	80	HBC	-0	K-P AT 8.25 GEV
M	50	(2370.0)		HASSALL	81	HBC	-0	K-P AT 6.5 GEV/C
M		2356.0	10.0	JENKINS	83	MPS	-	K- P TO K+ MM
M		. . . . . .	. . . . .					
M	AVG	2367.7	7.0	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)				

Ξ(2370) WIDTH (MeV)

W		75.0	69.0	DIBIANCA	75	DBC		XI 2PI
W	94	80.0	25.0	AMIRZAD	80	HBC	-0	K-P AT 8.25 GEV
W	50	(80.0)		HASSALL	81	HBC	-0	K-P AT 6.5 GEV/C
W		. . . . . .	. . . . .					
W	AVG	79.4	23.5	AVERAGE				

Ξ(2370) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi(2370) \to \Lambda \overline{K} \pi$ (including P4+P6)	1116+ 498+ 140
P2	$\Xi(2370) \to \Sigma \overline{K} \pi$ (including P5+P6)	1197+ 498+ 140
P3	$\Xi(2370) \to \Omega^- K$	1672+ 498
P4	$\Xi(2370) \to \Lambda \overline{K}^*(892)$	1116+ 892
P5	$\Xi(2370) \to \Sigma \overline{K}^*(892)$	1197+ 892
P6	$\Xi(2370) \to \Sigma(1385)\ \overline{K}$	1385+ 498

Ξ(2370) BRANCHING RATIOS

$\Xi(2370) \to (\Lambda \overline{K} \pi)$/total (P1)

R1		SEEN		AMIRZAD	80	HBC	-0	K-P AT 8.25 GEV	

$\Xi(2370) \to (\Sigma \overline{K} \pi)$/total (P2)

R2		SEEN		AMIRZAD	80	HBC	-0	K-P AT 8.25 GEV

$\Xi(2370) \to (\Lambda/\Sigma \overline{K} \pi)$/total (P1+P2)

R3	50	SEEN		HASSALL	81	HBC	-0	K-P AT 6.5 GEV/C

$\Xi(2370) \to (\Omega^- K)$/total (P3)

R4		0.09	0.04	KINSON	80	HBC	-	K-P AT 8.25 GEV

$\Xi(2370) \to (\Lambda/\Sigma \overline{K}^*(892))$/total (P4+P5)

R5		0.22	0.13	KINSON	80	HBC	-	K-P AT 8.25 GEV

$\Xi(2370) \to (\Sigma(1385)\ \overline{K})$/total (P6)

R6		0.12	0.08	KINSON	80	HBC	-	K-P AT 8.25 GEV

REFERENCES FOR Ξ(2370)

DIBIANCA 75 NP B98 137 DIBIANCA,ENDORF (CARN)
AMIRZAD 80 PL 90B 324 AMIRZADEH+ (BIRM+CERN+GLAS+MSU+LPNP)I
KINSON 80 TORONTO CONF. 263 J B KINSON+ (BIRM+CERN+GLAS+MSU+LPNP)I
HASSALL 81 NP B189 397 +ANSORGE,CARTER,NEALE,RUSHBROOKE+(CAMB+MSU)
JENKINS 83 PRL 51 951 +ALBRIGHT,DIAMOND,+(FSU+BRAN+LBL+CINC+SMAS)

Ξ(2500)

$I(J^P) = \frac{1}{2}(\quad)$ Status: *

OMITTED FROM SUMMARY TABLE

THE ALITTI 69 PEAK MIGHT BE INSTEAD THE XI(2370) OR MIGHT BE NEITHER THE XI(2370) NOR THE XI(2500).

Ξ(2500) MASS (MeV)

M	30	2430.0	20.0	ALITTI	69	HBC	-	K-P 4.6-5 GEV/C
M	45	2500.0	10.0	BARTSCH	69	HBC	-0	K-P 10 GEV/C
M		2505.0	10.0	JENKINS	83	MPS	-	K- P TO K+ MM

Ξ(2500) WIDTH (MeV)

W	150.0	60.0	40.0	ALITTI	69	HBC	-
W	59.0	27.0		BARTSCH	69	HBC	-0

Ξ(2500) PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Xi(2500) \to \Xi \pi$	1321+ 140
P2	$\Xi(2500) \to \Lambda \overline{K}$	1116+ 498
P3	$\Xi(2500) \to \Sigma \overline{K}$	1197+ 498
P4	$\Xi(2500) \to \Xi(1530)\ \pi$	1533+ 140
P5	$\Xi(2500) \to \Lambda$ (or Σ) $\overline{K} \pi$	1116+ 498+ 140
P6	$\Xi(2500) \to \Xi \pi \pi$	1321+ 140+ 140

Ξ(2500) BRANCHING RATIOS

$\Xi(2500) \to (\Xi \pi)$/(modes P1 to P4) (P1)/(P1+P2+P3+P4)

R1	(0.5)	OR LESS	ALITTI	69	HBC		1 STD DEV LIMIT

$\Xi(2500) \to (\Lambda \overline{K})$/(modes P1 to P4) (P2)/(P1+P2+P3+P4)

R2	0.5	0.2	ALITTI	69	HBC	-	

$\Xi(2500) \to (\Sigma \overline{K})$/(modes P1 to P4) (P3)/(P1+P2+P3+P4)

R3	0.5	0.2	ALITTI	69	HBC	-	

$\Xi(2500) \to (\Xi(1530)\ \pi)$/(modes P1 to P4) (P4)/(P1+P2+P3+P4)

R4	(0.2)	OR LESS	ALITTI	69	HBC		1 STD DEV LIMIT

$\Xi(2500) \to (\Lambda$ (or Σ) $\overline{K} \pi)$/total (P5)

R5	SEEN		BARTSCH	69	HBC	-0

$\Xi(2500) \to (\Xi \pi \pi)$/total (P6)

R6	SEEN		BARTSCH	69	HBC	-0

REFERENCES FOR Ξ(2500)

ALITTI 69 PRL 22 79 +BARNES,FLAMINIO,METZGER, + (BNL+SYRA) I
BARTSCH 69 PL 28B 439 + (AACH+BERL+CERN+LOIC+VIEN)
JENKINS 83 PRL 51 951 +ALBRIGHT,DIAMOND,+(FSU+BRAN+LBL+CINC+SMAS)

Ω BARYONS ($S=-3$, $I=0$)

Ω^-

$I(J^P)=0(\ )$ Status: ****

SEE STABLE PARTICLES.

CHARMED BARYONS

Λ_c^+

$I(J^P)=0(\ )$

SEE STABLE PARTICLES.

$\Sigma_c(2450)$

$I(J^P)=1(\ )$ Status: **

OMITTED FROM SUMMARY TABLE

THE SIGMA/C DECAYS TO LAMBDA/C PI, AND THE SCHISM IN MASSES HERE REFLECTS THAT IN MEASUREMENTS OF THE LAMBDA/C MASS (THE HIGHER MASSES ARE PRESENTLY FAVORED). THE IMPRESSIVE AGREEMENT ON THE SIGMA/C-LAMBDA/C MASS DIFFERENCE STRONGLY INDICATES THIS TO BE THE CASE, RATHER THAN THAT TWO STATES (THE SIGMA/C AND Y*/C) ARE BEING OBSERVED.

THIS PARTICLE IS AT ABOUT THE 2-AND-1/2-STAR LEVEL. A DEFINITIVE EXPERIMENT IS NEEDED.

$\Sigma_c(2450)$ MASS (MeV)

M	1	2426.0	12.0	CAZZOLI	75	HBC	++	NU P IN BNL 7-FT
M	9	(2460.0)		KNAPP	76	SPEC	-	GAMMA BE
M	1	(2439.0)	OR MORE	BARISH	77	DBC	++	NU D IN 12-FT
M	6	2425.0	10.0	BALTAY	79	HLBC	++	NU NE-H IN 15-FT
M	1	2457.0	4.0	CALICCHIO	80	HBC	+	NU P IN BEBC-TST
M	1	2454.0	5.0	BOSETTI	82	HBC	++	NU P IN BEBC
M	1	(2480.0)		ADAMOVICH	84	EMUL	++	GAMMA NUC--OMEGA

$\Sigma_c(2450)$ − Λ_c^+ MASS DIFFERENCE (MeV)

D	1	166.0	15.0	CAZZOLI	75	HBC	++	NU P IN BNL 7-FT
D	6	168.0	3.0	BALTAY	79	HLBC	++	NU NE-H IN 15-FT
D	1	168.0	3.0	CALICCHIO	80	HBC	+	NU P IN BEBC-TST
D	1	166.0	1.0	BOSETTI	82	HBC	++	NU P IN BEBC

$\Sigma_c(2450)$ PARTIAL DECAY MODES

		DECAY MASSES
P1	$\Sigma_c(2450) \rightarrow \Lambda_c^+\pi$	2282+ 140

REFERENCES FOR $\Sigma_c(2450)$

CAZZOLI 75 PRL 34 1125 +CNOPS,CONNOLLY,LOUTTIT,MURTAGH, + (BNL)
KNAPP 76 PRL 37 882 +LEE,LEUNG,SMITH, + (COLU+HAWA+ILL+FNAL)
BARISH 77 PR D15 1 +DERRICK,DOMBECK,MUSGRAVE, + (ANL+PURD)
BALTAY 79 PRL 42 1721 +CAROUMBALIS,FRENCH,HIBBS, + (COLU+BNL)I
CALICCHI 80 PL 93B 521 + (BARI+BIRM+BRUX+CERN+EPOL+RHEL+SACL+LOUC)
BOSETTI 82 PL 109B 234 +GRAESSLER, + (AACH+BONN+CERN+MPIM+OXF)
ADAMOVIC 84 PL 140B 119 ADAMOVICH+ (BGNA+CERN+FIRZ+GENO+MADR+LEBD+)

THEORY AND REVIEW

DERUJULA 75 PR D12 147 +GEORGI,GLASHOW (HARV)
LEE 77 PR D15 157 +QUIGG,ROSNER (FNAL)
TRILLING 81 PRPL 75 57 G H TRILLING (LBL)

Ξ_c^+ was A^+

$I(J^P)=$

OMITTED FROM SUMMARY TABLE

SEE STABLE PARTICLES.

Ω_c^0 was T^0

$I(J^P)=$

OMITTED FROM SUMMARY TABLE

SEE STABLE PARTICLES.

BOTTOM (BEAUTY) BARYON

Λ_b^0

$I(J^P)=$

OMITTED FROM SUMMARY TABLE

SEE STABLE PARTICLES.

NOTE ON DIBARYON RESONANCES

(by L.D. Roper, V.irginia Polytechnic Institute and State University)

Probably the first modern theoretical discussion of dibaryon resonances was by Oakes.[1] The first experimental hints were in a Λp invariant mass distribution by Dahl et al.,[2] and in the ${}^1D_2$ state in a pp partial-wave analysis by Arndt.[3] [The notation is ${}^{(2S+1)}L_J$, where S, L, and J are the spin, orbital, and total angular momenta. The Pauli principle restricts two nucleons to the following states:

$$I=0:\ ({}^3S_1,{}^3D_1),{}^1P_1,{}^3D_2,({}^3D_3,{}^3G_3),{}^1F_3,{}^3G_4$$

$$I=1:\ {}^1S_0,{}^3P_0,{}^3P_1,({}^3P_2,{}^3F_2),{}^1D_2,{}^3F_3,\cdots\ .$$

Here the states that couple together (same J^P) are grouped together in parentheses. Similarly, only certain states are allowed for $\Lambda\Lambda$, etc.]

Interest in dibaryons rose dramatically in 1977 when strong energy dependence was unexpectedly observed in pp polarization experiments at Argonne.[4] At about the same time, Hoshizaki claimed to have found dibaryon resonances in a pp partial-wave analysis,[5] and Jaffe gave a detailed theoretical treatment of multiquark states.[6] There is now a vast literature on dibaryon resonances.

However, there is still disagreement about what "dibaryon resonances" are. There is little doubt there are distinct structures in NN partial-wave amplitudes that look very much like ordinary highly inelastic resonances, such as are seen in πN scattering. The question is whether these structures are caused by resonance poles in the complex energy plane or by some other structure of the scattering amplitude.

One of the arguments about dibaryon resonances is whether they are calculable in terms of quark theory or should instead be calculated using some hadron interaction theory without reference to the underlying quarks. Both approaches have had successes and failures, so possibly both will make contributions to unraveling the mysteries of dibaryon resonances.

The idea that dibaryon resonances are "pseudoresonances"[7] has taken some new turns. The idea is that box diagrams (e.g., involving $N\Delta$ in NN scattering) create resonance-like loops in the Argand diagram without resonance poles actually existing. The problem with believing this is whether poles would be created when one unitarizes the box-diagram calculations in order to calculate physical scattering amplitudes. Kloet and Tjon[8] have recently shown that a model exists in which, indeed, this is the case. However, resonance hunters should definitely report pole positions rather than looping Argand diagrams in the future. All who suggest that the NN $^1D_2$ and $^3F_3$ resonance-like structures are resonances or are instead due to some other dynamics must take their case to the world collection of NN scattering data in the form of a detailed partial-wave analysis, and should report the existence or nonexistence of resonance poles.

Closely related to the work described above is that of Ueda,[9] in which Faddeev πNN dynamics is fitted to the NN partial-wave amplitudes. Although the fit is not good, the approximately correct structure is present. The interesting point is that poles do occur on the "resonance" sheets in the complex energy plane. Ueda claims this work is important because many claims for resonance poles assume that the poles exist, but the Faddeev approach does not make such prior assumptions.

VerWest[10] recently reported separable potential model fits to the $^1D_2$ and $^3F_3$ NN amplitudes and claims some solutions had no resonance poles, but Kloet and Tjon[11] have shown that these potential model fits all do, indeed, have resonance poles.

Dinucleon resonances also communicate with the γd and πd channels. There is not much γd data, and the multipole analysis does not tell much about which dibaryons might be involved. In the πd channel, uncertainties abound, and partial-wave analyses yield poor fits compared to NN analyses. In addition to NN analyses, results from analyses of $\pi d \rightarrow \pi d$, $\pi d \rightarrow \pi pn$, $pp \rightarrow \pi d$, and $\gamma d \rightarrow pn$ scattering are listed below. Most of these strongly indicate the existence of dibaryon resonances in the $^1D_2$ and $^3F_3$ NN states, and some indicate possible resonances in the $^1S_0$, $^3S_1$, $^3P_1$, $^3P_2$, $^3D_3$, $^1F_3$, $^1G_4$, and other states.

Since our last edition, many more papers have been published about dibaryon resonances. There are eleven new references for dinucleons and one for strange dibaryons giving values for the resonance-pole (or Breit-Wigner) parameters. Many of the new references are fits to πd partial-wave amplitudes, in which the couplings to dibaryons appear to be larger than in NN amplitudes.

Some notable papers in which narrow (width < 20 MeV) dibaryon production peaks are seen are: (1) Siemiarczuk et al.[12] for the $dp \rightarrow (np)p$ and $dp \rightarrow p\pi X$ reactions; (2) Bairamov et al.[13] for $pC \rightarrow npX$; (3) Zelinski et al.[14] for $^4\text{He}\,p \rightarrow dppn$; and (4) Tatischeff et al.[15] for $p\,^3\text{He} \rightarrow dX$ and $^3\text{He}\,p \rightarrow dX$ reactions.

However, Katayama et al.[16] claims to have done an experiment similar to that of Siemiarczuk et al. and sees no peaks; and Combes et al.[17] sees no narrow dibaryon resonances in $dd \rightarrow dX$. Tatischeff[15] suggests that the reason some experiments do not see these narrow peaks is that they appear as small bumps on a large background and may not be observable except at the maxima of the production cross sections.

Since our last edition, only one paper has appeared giving data on strange dibaryon states. It appears that the strangeness -1 dominant resonance is in the $^3S_1$ state, an SU(3) partner of the deuteron. Dalitz,[18] in an excellent review, concludes that the $S = -1$ $^3S_1$ resonance pole probably exists. However, May et al.[19] sees no enhancements in the Σ^+n, Σ^0p, or Λp invariant mass spectra in $K^-d \rightarrow \pi^-X$; and Arenton et al.[20] sees none in the Λp spectrum in $pp \rightarrow \Lambda pK^+$.

In the Listings below, we separate the determinations of pole positions and Breit-Wigner parameters. To be a resonance, the pole must occur on the lower half of the second sheet for the elastic channel; it may be a bound state or resonance for inelastic channels.

In summary, this reviewer feels that the evidence, both experimental and theoretical, for the $^1D_2$ and $^3F_3$ dinucleon resonances is now very strong. The theoretical calculations almost all now agree that resonance poles occur in the *NN* amplitudes. The disagreement among production experiments is inherent in the difficulties of such experiments; overlapping highly inelastic resonances are very difficult to see in final states.

For more detailed reviews of dibaryons, expressing a wide variety of opinions, see Hoshizaki,[21] Bugg,[22] Kamae,[23] Vinh Mau,[24] Kroll,[25] Locher,[26] Svarc,[27] and Yokasawa.[28]

Experimentalists wishing to look for strange dibaryons should peruse the recent paper by Aerts and Dover.[29]

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DIBARYONS

$S=0$ DIBARYONS

BARYON NUMBER 2, STRANGENESS 0 STATES

IN THIS SECTION WE USE THE FOLLOWING ABBREVIATIONS FOR TYPES OF ANALYSES--

AB	ALPHA P -> D P P N (ALPHA BREAKUP) (NN INVARIANT MASS)
DB	D P -> P P N (DEUTERON BREAKUP) (NN INVARIANT MASS)
DBX	D P -> P PI+ X (DEUTERON BREAKUP) (X MISSING MASS)
GD	GAMMA D -> P X CROSS SECTIONS
HPDX	HE3 P -> D X (X MISSING MASS)
GDPN	GAMMA D -> P N PARTIAL-WAVE ANALYSIS RESONANCE PARAMETRIZATION
NN	FIT TO NN ELASTIC PARTIAL-WAVE ANALYSIS RESULTS
NNF	FIT TO NN FORWARD AMPLITUDES
NPT	NP TOTAL CROSS SECTION BREIT-WIGNER FIT
PCPP	PI C12 -> P P X (MASS OF PP)
PID	PI- D ELASTIC PARTIAL-WAVE ANALYSIS RESONANCE PARAMETRIZATION
PIDC	PI D DIFFERENTIAL CROSS SECTION BREIT-WIGNER FIT
PIDI	PI D -> PI P N AMPLITUDE ANALYSIS RESONANCE PARAMETRIZATION
PIDF	PI D FORWARD AMPLITUDE CALCULATION
PIDP	PI D -> P P PARTIAL-WAVE ANALYSIS RESONANCE PARAMETRIZATION
PIPR	N N -> N N PI DECK + RESONANCE FIT TO CROSS SECTIONS AND A PARAMETERS
PNI	P N -> P P PI- CROSS SECTIONS BREIT-WIGNER FIT
PPPD	P P -> PI+ D PARTIAL-WAVE ANALYSIS RESONANCE PARAMETRIZATION

$NN(2170)$ $I=1$, ${}^1D_2$

Status: * *

OMITTED FROM SUMMARY TABLE

B=2, S=0, ${}^1D_2$ -- BREIT-WIGNER MASS (MeV)

```
BREIT-WIGNER MASS APPROXIMATELY EQUALS RE(POLE POSITION).

M         (2170.0)                   HOSHIZAKI 79 NN   1D2 ASSUMED BCDGRND
M         (2180.0)                   ARVIEUX   80 PID  1D2
M    A    (2185.0)                   KAMO      80 PPPD 1D2
M         (2170.0)                   HOFTIEZE  81 PIDI 1D2
M    B    (2140.0)                   KANAI     81 PID  1D2 SOL. B AND C
M          2140. TO 2160.            DAKHNO    82 PNI  1D2
M    C    (2116.0)                   UEDA      82 NN   1D2 FADDEEV ''FIT''
M    D    (2200.0)                   LOCHER    83 PID  1D2
M    E     2263. TO 2340.            BAKKER    84 NN   1D2 P MATRIX ANAL.
M          2176.0     6.0            STRAKOVSK 84 PIDP 1D2
M    F    (2176.0)                   HIROSHIGE 85 PID  1D2 USES LYON AMPL.
M
M    A  KAMO 80 DID NOT TRY FITS WITH FEWER THAN SIX RESONANCES.
M    B  KANAI 81 FIT WITH NO RESONANCES WAS VERY POOR AND DID NOT TRY
M    B  OTHER FITS WITH FEWER THAN FOUR RESONANCES.
M    C  UEDA 82 REPORTS AS ''MASS'' BUT DOES NOT EXPLAIN HOW CALCULATED
M    C  FROM POLE POSITION.
M    D  RESONANCE FIT TO VECTOR POLARIZATION.
M    E  ACTUALLY P-MATRIX POLE POSITION.
M    F  3P2 STATE IN PI D SYSTEM.
```

B=2, S=0, $^1D_2$ -- BREIT-WIGNER WIDTH (MeV)

```
        BREIT-WIGNER WIDTH APPROXIMATELY EQUALS 2 TIMES IM(POLE POSITION).

W           100. TO 150.             HOSHIZAKI 79 NN   1D2 ASSUMED BCKGRND
W    A     (134.0)                   KAMO      80 PPPD 1D2
W           (75.0)                   HOFTIEZE  81 PIDI 1D2
W    B      (56.0)                   KANAI     81 PID  1D2 SOL. B
W    B      (54.0)                   KANAI     81 PID  1D2 SOL. C
W            50. TO 100.             DAKHNO    82 PNI
W    C      (61.0)                   UEDA      82 NN   1D2 FADDEEV ''FIT''
W    G      (50.0)                   FERREIRA  83 PIDF 1D2
W    F      (85.0)                   LOCHER    83 PID  1D2
W           100. TO 200.             GRACH     84 NN   1D2 P MATRIX ANAL.
W           107.0      23.0          STRAKOVSK 84 PIDP 1D2
W    F     (124.)                    HIROSHIGE 85 PID  1D2 USES LYON AMPL.
W
W    G  RESONANCE MASS FIXED.
```

B=2, S=0, $^1D_2$ -- BREIT-WIGNER ELASTICITY

```
        BREIT-WIGNER ELASTICITY APPROXIMATELY EQUALS
        ABS(RESIDUE OF POLE)/IM(POLE POSITION).

R1           (0.1)                   HOSHIZAKI 79 NN   1D2
R1            0.3 TO 0.5             GRACH     84 NN   1D2
```

B=2, S=0, $^1D_2$ -- BREIT-WIGNER π^-d INELASTICITY

```
        BREIT-WIGNER ELASTICITY APPROXIMATELY EQUALS
        ABS(RESIDUE OF POLE)/IM(POLE POSITION).

R2           (0.26)                  KANAI     81 PID  1D2
R2   D       (0.29)                  LOCHER    83 PID  1D2
R2   G       (0.09)                  FERREIRA  83 PID  1D2
R2   H       (0.29)                  SMITH     84 PID  1D2
R2   F       (0.49)                  HIROSHIGE 85 PID  1D2 USES LYON AMPL.
R2
R2   H  FADDEEV + RESONANCE FIT TO VECTOR ANALYZING POWER; VARIED ONLY
R2   H  ELASTICITY; MASSES AND WIDTHS FIXED AT LOCHRER'S VALUES.
```

B=2, S=0, $^1D_2$ -- Re(POLE POSITION) (MeV)

```
        RE(POLE POSITION) APPROXIMATELY EQUALS BREIT-WIGNER MASS.

RE         (2045.0)                  BHANDARI  81 NN   1D2 K-MATRIX FIT
RE         (2135.0)                  BHANDARI  81 NN   1D2 M-MATRIX FIT
RE         (2150.0)                  EDWARDS   81 NN   1D2 K-MATRIX FIT
RE   I     (2153.0)                  KLOET     81 NN   1D2 POT. MODEL FIT
RE   J     (2110.0)                  UEDA      82 NN   1D2 FADDEEV ''FIT''
RE   K      2120. TO 2150.           BHANDARI  83 NN   1D2 M-MATRIX FIT
RE   J      2149. TO 2150.           KLOET     83 NN   1D2 COUP. CHAN. FIT
RE   E      2150. TO 2170.           GRACH     84 NN   1D2
RE
RE   I  KLOET 81 DOES NOT SHOW GOODNESS OF FIT TO 1D2.
RE   J  NOT A GOOD FIT TO PARTIAL-WAVE AMPLITUDES.
RE   K  BHANDARI 83 CLAIMS 1D2 IS AN N-DELTA BOUND STATE.
```

B=2, S=0, $^1D_2$ -- Im(POLE POSITION) (MeV)

```
        IM(POLE POSITION) APPROXIMATELY EQUALS ONE-HALF BREIT-WIGNER WIDTH.

IM         (110.0)                   BHANDARI  81 NN   1D2 K-MATRIX FIT
IM          (90.0)                   BHANDARI  81 NN   1D2 M-MATRIX FIT
IM          (56.0)                   EDWARDS   81 NN   1D2 K-MATRIX FIT
IM   I      (46.0)                   KLOET     81 NN   1D2 POT. MODEL FIT
IM   J      (54.0)                   UEDA      82 NN   1D2 FADDEEV ''MDFIT
IM   K       80. TO 100.             BHANDARI  83 NN   1D2 M-MATRIX FIT
IM   J       39. TO  45.             KLOET     83 NN   1D2 COUP. CHAN. FIT
```

B=2, S=0, $^1D_2$ -- |RESIDUE|/Im(POLE POSITION)

```
        ABS(RES)/IM(POLE POSITION) APPROXIMATELY EQUALS BREIT-WIGNER
        ELASTICITY.

RES          (0.175)                 BHANDARI  81 NN   1D2 K-MATRIX FIT
RES          (0.2)                   BHANDARI  81 NN   1D2 M-MATRIX FIT
RES          (0.29)                  EDWARDS   81 NN   1D2 K-MATRIX FIT
RES  K        0.1 TO 0.3             BHANDARI  83 NN   1D2 M-MATRIX FIT
```

$NN(2250)$ $I=1$, $^3F_3$

Status: * *

OMITTED FROM SUMMARY TABLE

B=2, S=0, $^3F_3$ -- BREIT-WIGNER MASS (MeV)

```
M    L     (2390.0)                  GREIN     78 NNF  3F3
M          (2220.0)                  HOSHIZAKI 78 NN   3F3 ASSUMED BCKGRND
M    M      2260. (FIXED)            IKEDA     80 GDPN 3F3 SOL. A
M           2296.0      11.0         IKEDA     80 GDPN 3F3 SOL. A'
M           2307.0      12.0         IKEDA     80 GDPN 3F3 SOL. B''
M    A     (2185.0)                  KAMO      80 PPPD 3F3
M    B     (2260.0)                  KANAI     81 PID  3F3 SOL. B AND C
M           2251. TO 2266.           BHANDARI  82 NN   3F3
M           2220. TO 2260.           DAKHNO    82 PNI  3F3(OR 3D3/3G3)
M    L     (2310.0)                  GREIN     82 NNF  3F3
M    N      2200.0      10.0         SHAMU     82 NPT  3F3
M    C     (2155.0)                  UEDA      82 NN   3F3 FADDEEV ''FIT''
M          (2236.0)                  JAUCH     84 PIPR 3F3
M           2170.0       5.0         STRAKOVSK 84 PIDP 3F3
M    O      2240.0       5.0         TATISCHEF 85 HPDX 3F3
M
M    L  GREIN 78 AND GREIN 82 SEE NO 1D2 RESONANCE.
M    M  IKEDA 80 GIVES TWO OTHER SOLUTIONS WITH POORER FITS TO DATA.
M    N  THIS IS AN N P RESONANCE.
M           . . . . . . . . . . .
M   AVG     2218.4      22.9      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 7.4)
```

B=2, S=0, $^3F_3$ -- BREIT-WIGNER WIDTH (MeV)

```
W    L     (290.0)                   GREIN     78 NNF  3F3
W            50. TO 100.             HOSHIZAKI 78 NN   3F3 ASSUMED BCKGRND
W    M      200. (FIXED)             IKEDA     80 GDPN 3F3 SOL. A
W           177.0       32.0         IKEDA     80 GDPN 3F3 SOL. A'
W           213.0       54.0         IKEDA     80 GDPN 3F3 SOL. B''
W    A      (81.0)                   KAMO      80 PPPD 3F3
W    B     (181.0)                   KANAI     81 PID  3F3 SOL. B
W    B     (171.0)                   KANAI     81 PID  3F3 SOL. C
W             70. TO 100.            BHANDARI  82 NN   3F3
W           100. TO 200.             DAKHNO    82 PNI  3F3(OR 3D3/3G3)
W    N      134.0        9.0         SHAMU     82 NPT  3F3
W    C      (60.0)                   UEDA      82 NN   3F3 FADDEEV ''FIT''
W    G      (75.0)                   FERREIRA  83 PIDF 3F3
W          (120.0)                   JAUCH     84 PIPR 3F3
W           142.0        9.0         STRAKOVSK 84 PIDP 3F3
W    O       16.0        3.0         TATISCHEF 85 HPDX 3F3
```

B=2, S=0, $^3F_3$ -- BREIT-WIGNER ELASTICITY

```
R1           (0.2)                   HOSHIZAKI 78 NN   3F3
R1   P        0.11 TO 0.13           BHANDARI  82 NN   3F3
R1   Q        0.096      0.012       SHAMU     82 NPT  3F3
R1   G       (0.05)                  FERREIRA  83 PIDF 3F3
R1           (0.21)                  JAUCH     84 PIPR 3F3

R1   P BHANDARI 82 REPORTS R(PI D)=0.2 TO 0.3 AND R(N DELTA)=0.6 TO 0.7.
R1   Q THIS NP VALUE IS EQUIVALENT TO (0.19+-0.02) FOR PP.
```

B=2, S=0, $^3F_3$ -- Re(POLE POSITION) (MeV)

```
RE         (2190.0)                  BHANDARI  81 NN   3F3 K-MATRIX FIT
RE         (2215.0)                  BHANDARI  81 NN   3F3 M-MATRIX FIT
RE         (2185.0)                  EDWARDS   81 NN   3F3 K-MATRIX FIT
RE         (2175.0)                  KLOET     81 NN   3F3 POT. MODEL FIT
RE          2218. TO 2200.           BHANDARI  82 NN   3F3 BREIT-WIG. FIT
RE   J     (2134.0)                  UEDA      82 NN   3F3 FADDEEV ''FIT''
RE   J     (2211.0)                  VERWEST   82 NN   3F3 POT. MODEL FIT
RE   R      2210. TO 2220.           BHANDARI  83 NN   3F3 M-MATRIX FIT
RE   J      2148. TO 2149.           KLOET     83 NN   3F3 COUP. CHAN. FIT
RE   S      2162. TO 2173.           KLOET     83 NN   3F3 COUP. CHAN. FIT

RE   R  BHANDARI 83 CLAIMS 3F3 IS NOT AN N-DELTA BOUND STATE.
RE   S  KLOET 83 FOUND TWO NEARBY 3F3 POLES.
```

B=2, S=0, $^3F_3$ -- Im(POLE POSITION) (MeV)

```
IM          (65.0)                   BHANDARI  81 NN   3F3 K-MATRIX FIT
IM          (70.0)                   BHANDARI  81 NN   3F3 M-MATRIX FIT
IM          (70.0)                   EDWARDS   81 NN   3F3 K-MATRIX FIT
IM          (43.0)                   KLOET     81 NN   3F3 POT. MODEL FIT
IM           45. TO 60.              BHANDARI  82 NN   3F3 BREIT-WIG. FIT
IM   J      (52.0)                   UEDA      82 NN   3F3 FADDEEV ''FIT''
IM   J      (35.0)                   VERWEST   82 NN   3F3 POT. MODEL FIT
IM   R       60. TO 80.              BHANDARI  83 NN   3F3 M-MATRIX FIT
IM   J       33. TO 38.              KLOET     83 NN   3F3 COUP. CHAN. FIT
IM   S       43. TO 48.              KLOET     83 NN   3F3 COUP. CHAN. FIT
```

B=2, S=0, $^3F_3$ -- |RESIDUE|/Im(POLE POSITION)

```
RES          (0.15)                  BHANDARI  81 NN   3F3 K-MATRIX FIT
RES          (0.15)                  BHANDARI  81 NN   3F3 M-MATRIX FIT
RES          (0.30)                  EDWARDS   81 NN   3F3 K-MATRIX FIT
RES           0.08 TO 0.13           BHANDARI  82 NN   3F3 BREIT-WIG. FIT
RES  R        0.1 TO 0.2             BHANDARI  83 NN       M-MATRIX FIT
```

OTHER NN

Status: *

OMITTED FROM SUMMARY TABLE

B=2, S=0 MISCELL. -- BREIT-WIGNER MASS (MeV)

```
M          (2170.0) (10.0)           ALADASHVI 76 DB   PP INVARIANT MASS
M          (2250.0)                  GREIN     80 NNF  3S1 OR 3D3
M          (2190.0)                  HASHIMOTO 80 NN   1F3 ASSUMED BCKGRND
M          (2352.0)    (69.0)        IKEDA     80 GDPN 3S1 SOL. A
M           2380. (FIXED)            IKEDA     80 GDPN 3S1 SOL. A'
M          (2290.0)    (14.0)        IKEDA     80 GDPN 3P2 SOL. C
M           2380. (FIXED)            IKEDA     80 GDPN 3S1 SOL. C
M          (2377.0)    (17.0)        IKEDA     80 GDPN 3D3 SOL. B''
M    A     (2100.0)                  KAMO      80 PPPD 1S0
M    A     (2117.0)                  KAMO      80 PPPD 3P2
M    A     (2148.0)                  KAMO      80 PPPD 3F2
M    A     (2159.0)                  KAMO      80 PPPD 3P1
M          (2230.0)                  ARGAN     81 GD
M    B     (2290.0)                  KANAI     81 PID  3P2 SOL. B
M    B     (2300.0)                  KANAI     81 PID  3P2 SOL. C
M    B     (2510.0)                  KANAI     81 PID  1G4 SOL. B
M    B     (2530.0)                  KANAI     81 PID  1S0 SOL. C
```

```
M         (2250.0)                        GREIN      82 NNF  3S1 OR 3D3
M         (2362.0)                        AKEMOTO    83 PIDC Q=0
M         (2429.0)                        AKEMOTO    83 PIDC Q=0
M         (2722.0)                        AKEMOTO    83 PIDC Q=0
M    D    (2480.0)                        LOCHER     83 PID  1G4
M    G    (2060.0)                        FERREIRA   83 PIDF 3P1
M    T    (1961.0)     (2.0)              BAIRAMOV   84 PCPP Q=2
M          2016.0       3.0               BAIRAMOV   84 PCPP Q=2
M    E     2179. TO 2190.                 BAKKER     84 NN   1S0 P MATRIX ANAL.
M    E     2021. TO 2236.                 BAKKER     84 NN   3S1 P MATRIX ANAL.
M    E     2268. TO 2272.                 BAKKER     84 NN   1P1 P MATRIX ANAL.
M    E     2324. TO 2329.                 BAKKER     84 NN   3P1 P MATRIX ANAL.
M          2179.0       1.0               STRAKOVSK  84 PIDP 3P1
M    E     2160. TO 2170.                 VESELOV    84 NN   3S1 P MATRIX FIT
M          2035.0      15.0               ZIELINSKI  84 AB   Q=2
M          2137.0      15.0               ZIELINSKI  84 AB   Q=2
M          2030.0      20.0               SIEMIARCZ  85 DBX  Q=0
M          2143.0      20.0               SIEMIARCZ  85 DBX  Q=0
M          2020.0      10.0               SIEMIARCZ  85 DB   Q=1
M          2130.0      10.0               SIEMIARCZ  85 DB   Q=1
M          2384.0      20.0               SIEMIARCZ  85 DBX  Q=1
M    O     2192.0       3.0               TATISCHEF  85 HPDX 3P1
M    O     2124.0       3.0               TATISCHEF  85 HPDX 3P2
M
M    T  DISAPPEARS FOR PLAB > 300 MEV/C
```

B=2, S=0 MISCELL. -- BREIT-WIGNER WIDTH (MeV)

```
W          (50.0)                         ALADASHVI 76 DB   PP INVARIANT MASS
W         (100.0)                         GREIN     80 NNF  3S1 OR 3D3
W          (50.0)                         HASHIMOTO 80 NN   1F3 ASSUMED BCKGRND
W         (342.0)    (69.0)               IKEDA     80 GDPN 3S1 SOL. A
W          200. (FIXED)                   IKEDA     80 GDPN 3S1 SOL. A'
W         (263.0)    (55.0)               IKEDA     80 GDPN 3P2 SOL. C
W          200. (FIXED)                   IKEDA     80 GDPN 3S1 SOL. C
W         (214.0)    (52.0)               IKEDA     80 GDPN 3D3 SOL. B''
W    A    (315.0)                         KAMO      80 PPPD 1S0
W    A     (58.0)                         KAMO      80 PPPD 3P2
W    A      (5.0)                         KAMO      80 PPPD 3F2
W    A     (51.0)                         KAMO      80 PPPD 3P1
M          (40.0)                         ARGAN     81 GD
W    B    (139.0)                         KANAI     81 PID  3P2 SOL. B
W    B    (150.0)                         KANAI     81 PID  3P2 SOL. C
W    B    (122.0)                         KANAI     81 PID  1G4 SOL. B
W    B     (66.0)                         KANAI     81 PID  1S0 SOL. C
W         (317.0)                         AKEMOTO   83 PIDC Q=0
W         (103.0)                         AKEMOTO   83 PIDC Q=0
W         (223.0)                         AKEMOTO   83 PIDC Q=0
M    G     (50.0)                         FERREIRA  83 PIDF 3P1
M    D    (150.0)                         LOCHER    83 PID  1G4
M    T     (11.0)     (4.0)               BAIRAMOV  84 PCPP Q=2
M           30.0      14.0                BAIRAMOV  84 PCPP Q=2
M           86.0       2.0                STRAKOVSK 84 PIDP 3P1
M           30.0      23.0                ZIELINSKI 84 AB   Q=2
M           59.0      20.0                ZIELINSKI 84 AB   Q=2
M           64.0      20.0                SIEMIARCZ 85 DBX  Q=0
M           62.0      20.0                SIEMIARCZ 85 DBX  Q=0
M           45.0      20.0                SIEMIARCZ 85 DB   Q=1
M           20.0      10.0                SIEMIARCZ 85 DB   Q=1
M           80.0      20.0                SIEMIARCZ 85 DBX  Q=1
M           25.0       6.0                TATISCHEF 85 HPDX 3P1
M           25.0       2.0                TATISCHEF 85 HPDX 3P2
```

B=2, S=0 MISCELL. -- BREIT-WIGNER ELASTICITY

```
R1         (0.12)                         HASHIMOTO 80 NN   1F3 ASSUMED BCKGRND
R1   D     (0.13)                         LOCHER    83 PID  1G4
R1   H     (0.06)                         SMITH     84 PID  1G4
```

REFERENCES FOR B=2, S=0 STATES

```
ALADASHV 76 NP A274 486      ALADASHVILI,GLAGOLEV+        (JINR+WARS+WINR)
GREIN    78 NP B137 173      W GREIN,P KROLL                   (KARL+WUPP)
HOSHIZAK 78 PTP 60 1796      N HOSHIZAKI                            (KYOT)
HOSHIZAK 79 PTP 61 129       N HOSHIZAKI                            (KYOT)
ARVIEUX  80 NP A350 205      J ARVIEUX,A S RIN AT         (GREN+REHO+SACL)
GREIN    80 PL 96B 176       W GREIN,A KRONIG,P KROLL           (SIN+WUPP)
HASHIMOT 80 PTP 64 1693      K HASHIMOTO,N HOSHIZAKI                (KYOT)
IKEDA    80 NP B172 509      +ARAI,FUJII,FUJII,IWASAKI+  (TOKY+KEK+INUS)
KAMO     80 LNC 29 289       H KAMO,W WATARI                        (OSAK)
    ALSO 80 PTP 64 2144      KAMO,WATARI,YONEZAWA              (OSAK+HIRO)
ARGAN    81 PRL 46 96        +AUDIT,DE BOTTON,FAURE,MARTIN,+        (SACL)
BHANDARI 81 PRL 46 1111      +ARNDT,ROPER,VERWEST               (VPI+TAMU)
EDWARDS  81 PR D23 1978      B J EDWARDS                             (ANL)
HOFTIEZE 81 PR C23 407       +BAKER,CLEMENT,DRAGOSET+   (RICE+HOUS+BONN)
KANAI    81 PTP 65 266       +MINAKA,NAKAMURA+      (TMU+KAGO+TWAS+SAGA)
KLOET    81 PL 106B 24       W M KLOET,J A TJON                (RUTG+UTRE)
BHANDARI 82 LNC 34 65        R BHANDARI                              (VPI)
DAKHNO   82 PL 114B 409      +KRAVTSOV,LOBACHEV,MAKAROV,MEDVEDEV+ (LENI)
    ALSO 82 SJNP 36 83       +KRAVTSOV,LOBACHEV,MAKAROV,MEDVEDEV+ (LENI)
GREIN    82 NP A377 505      W GREIN,P KROLL                    (SIN+WUPP)
SHAMU    82 PR D25 2008      +SOGA,SHILTS,LISOWSKI             (WMIU+LASL)
UEDA     82 PL 119B 281      T UEDA                                 (OSAK)
VERWEST  82 PR C25 482       B J VERWEST                            (TAMU)
AKEMOTO  83 PRL 50 400       +BABA,ENDO,HIMENIYA,INOUE+        (HIRO+UOEH)
BHANDARI 83 PR D27 296       R BHANDARI                              (VPI)
    ALSO 83 LNC 38 251       R BHANDARI                             (NMSU)
FERREIRA 83 JPG 9 169        E FERREIRA, G A P MUNGUIA              (PUCB)
KLOET    83 NP A392 271      W M KLOET,T A TJON                     (ITPU)
LOCHER   83 PL 121B 227      M P LOCHER, M E SAINO                   (SIN)
BAIRAMOV 84 SJNP 39 26       +BUDAGOV,DVORNIK,LOMAKIN,MILOV+        (JINR)
BAKKER   84 NP A424 563      BAKKER,GRACH,NARODETSKII          (VRIJ+ITEP)
GRACH    84 SJNP 39 56       GRACH,NARODETSKII,SHMATIKOV            (ITEP)
    ALSO 84 ZPHY C21 229     GRACH,NARODETSKII,SHMATIKOV            (ITEP)
JAUCH    84 PL 143B 509      W JAUCH,A KONIG,P KROLL                (WUPP)
SMITH    84 PR C29 2206      +MATHIE,BOSCHITZ,OTTERMANN+       (KARL+SIN+)
STRAKOVS 84 SJNP 40 273      I STRAKOVSKII,A KRAVTSOV,M RYSKIN      (LENI)
    ALSO 84 JPG 9 L187       A KRAVTSOV,M TYSKIN,I STRAKOVSKII      (LENI)
VESELOV  84 SJNP 39 456      A VESELOV, I GRACH, I NARODETSKII      (ITEP)
ZIELINSK 84 SJNP 40 306      ZIELINSKI,SOBCHAK,STEPANYAK,+         (WINR+)
    ALSO 84 ZPHY A317 335    GLAGOLEV,LEBEDEV,SHURAVLEVA+          (JINR+)
HIROSHIG 85 PL 150B 41       HIROSHIGE,WATARI,TAKABAYASHI+     (OSKC+HIRO)
SIEMIARC 85 PL 137B 434      SIEMIARCZUK,ZIELINSKI             (WINR+WARS)
    ALSO 83 PL 128B 367      SIEMIARCZUK,STEPANIAK,ZIELINSKI        (WINR)
TATISCHE 85 PL 154B 107      B TATISCHEFF                            (IPN)
    ALSO 84 PRL 52 2022      +BERTHET,COMBES,DIDELEZ,FRASCARIA+     (IPN+)
```

PAPERS NOT REFERRED TO IN DATA LISTINGS

```
HIDAKA   77 PL 70B 479       +BERETVAS,NIELD,SPINKA+                  (ANL)
FRASCARI 80 PL 91B 345       +BRISSAUD,DIDELEZ,PERRIN+   (IPN+GREN+NEUC)
KUBODERA 80 JPG 6 171        +LOCHER,MYHRER,THOMAS       (SIN+NORD+TRIU)
ARGAN    81 PRL 46 96        +AUDIT,DEBOTTON,FAURE,MARTIN            (SACL)
ARVIEUX  81 PL 103B 99       J ARVIEUX                          (GREN+SACL)
BOLGER   81 PRL 46 167       +BOSCHITZ,PROBSTLE,SMITH     (KARL+SIN+ERLA+)
GREIN    81 JPG 7 1355       W GREIN,M LOCHER                          (SIN)
HOLT     81 PRL 47 472       +SPECHT,STEPHENSON,ZEIDMAN+        (ANL+LASL+)
KLOET    81 NP A364 346      W KLOET,R SILBAR                   (RUTG+LASL)
MINEHART 81 PRL 46 1185      +BOSWELL,DAVIS,DAY,MCCARTHY+       (VIRG+LASL)
MIZUTANI 81 PL 107B 177      +FAYARD,LAMOT,NAHABETIAN           (LYON+REGE)
RINAT    81 PL 104B 182      A RINAT,J ARVIEUX             (GREN+REHO+SACL)
TAMAS    81 NP A358 347      G TAMAS                                  (SACL)
LISOWSKI 82 PRL 49 255       +SHAMU,AUCHAMPAUGH,KING,MOORE+           (LASL)
ABLEEV   83 NP A393 491      +ABDUSHUKUROV,AVRAMENKO,DIMITROV+        (JINR)
ARNDT    83 PR D28 97        +ROPER,BRYAN,CLARK,VERWEST+   (VPI+TAMU+MSU)
KLOET    83 PR C27 430       W M KLOET,T A TJON                       (ITPU)
BYSTRICK 84 NC 82 385        +DEREGEL,LEHAR,+         (SACL+GEVA+TRST+MONT)
COMBES   84 NP A431 703      +BERTHET,+          (IPN+SACL+STRB+FRAS+CAEN)
KATAYAMA 84 NP A423 410      +KAJITA,KOISO,KUBOTA,SAI,SAKAMOTO+       (TOKY)
SVARC    85 NP A434 329C     A SVARC                                   (SIN)
```

$S=-1$ DIBARYON

BARYON NUMBER 2, STRANGENESS −1 STATES

```
IN THIS SECTION WE USE THE FOLLOWING ABBREVIATIONS FOR TYPES
OF ANALYSES--

BB        BARYON-BARYON SCATTERING COMBINED AMPLITUDE ANALYSIS
LNIM      LAMBDA-N INVARIANT MASS
LPIM      LAMBDA-P INVARIANT MASS
LPPIM     LAMBDA-P-PI INVARIANT MASS
SPIM      SIGMA-P INVARIANT MASS
KPID      K(-)P -> PI X AND PI D -> K X (X MISSING MASS)
```

$\Lambda N(2130)$ $I=1/2$, $^3S_1$

Status: * *

OMITTED FROM SUMMARY TABLE

B=2, S=−1 -- BREIT-WIGNER MASS (MeV)

```
     BREIT-WIGNER MASS APPROXIMATELY EQUALS RE(POLE POSITION).

M    A     2098.0       6.0          COHN      64 LNIM      Q=0
M    B    (2126.0)                   CLINE     68 LPIM 3S1 Q=1
M    B    (2130.0)                   ALEXANDER 69 LPIM      Q=1
M    C    (2130.0)                   JAIN      69 LPIM      Q=1
M    B    ´2128.7       0.2          TAN       69 LPIM      Q=1
M    B    (2138.8)    (0.7)          TAN       69 LPIM      Q=1
M    B    (2129.0)                   EASTWOOD  71 LPIM      Q=1
M    D     2127.0       1.0          SIMS      71 LPIM LNIM Q=0,1
M    E     2125.2       2.5          SHAHBAZI  73 LPIM      Q=1
M    E    (2251.4)    (3.9)          SHAHBAZI  73 LPIM      Q=1
M    F    (2115.0)                   SODHI     75 LPIM      Q=1
M    B     2129.0       0.4          BRAUN     77 LPIM      Q=1
M    G    (2130.0)                   GOYAL     78 LPIM      Q=1
M    H    (2320.0)                   GOYAL     80 SPIM      Q=0
M         (2255.5)    (0.4)          SHAHBAZIA 82 LPIM      Q=1 FIT 1
M         (2257.4)    (2.3)         ´SHAHBAZIA 82 LPIM      Q=1 FIT 2
M         (2350.8)    (2.4)          SHAHBAZIA 82 LPIM      Q=1 FIT 1
M         (2358.4)    (1.3)          SHAHBAZIA 82 LPIM      Q=1 FIT 2
M    I    (2495.2)    (8.7)          SHAHBAZIA 82 LPPIM     Q=0,1
M          2129.8       2.0          PIGOT     85 KPID      Q=1

M    A  SIGMA- D TO LAMBDA N X.
M    B  K- D TO PI- LAMBDA P.
M    C  GOYAL 71 RAISES DOUBTS ABOUT THE EXPERIMENTAL PROCEDURE USED
M    C  IN JAIN 69.  JAIN STUDIED K- EMULSION TO LAMBDA P.
M    D  K- D TO PI- LAMBDA P, PI- LAMBDA PI+ N, AND PI- LAMBDA PI0 P.
M    E  N P TO LAMBDA P X FOR P IN CARBON 12.
M    F  K- D TO PI- PI0 LAMBDA P.
M    G  GOYAL 78 SEES ANOTHER UNCERTAIN PEAK AT 2195-2210 MEV.
M    G  K- D TO 2PI- PI+ LAMBDA P.
M    H  K- D TO PI+ PI- SIGMA- P.
M    I  SIMULTANEOUS FIT TO INVARIANT MASS AND LAMBDA-P ELASTIC
M    I  NEUTRON CARBON INTERACTION AT 7.0 GEV/C
```

B=2, S=−1 -- BREIT-WIGNER WIDTH (MeV)

```
     BREIT-WIGNER WIDTH APPROXIMATELY EQUALS 2 TIMES IM(POLE POSITION).

W    A      20.0       10.0          COHN      64 LPIM      Q=0
W    B      10. OR LESS              CLINE     68 LPIM 3S1 Q=1
W    C     (20.0)                    JAIN      69 LPIM      Q=1
W    B       7.0        0.6          TAN       69 LPIM      Q=1
W    B      (9.1)      (2.4)         TAN       69 LPIM      Q=1
W    B     (10.)                     EASTWOOD  71 LPIM      Q=1
W    D       8.0        1.0          SIMS      71 LPIM      Q=1
W    E      20.6        5.2          SHAHBAZI  73 LPIM      Q=1 2125 PEAK
W    E     (21.1)      (5.4)         SHAHBAZI  73 LPIM      Q=1 2251 PEAK
W    F    (150.0)                    SODHI     75 LPIM      Q=1
W    B       5.9        1.6          BRAUN     77 LPIM      Q=1
W    H     (25.0)                    GOYAL     80 SPIM      Q=0
W          (15.6)      (0.8)         SHAHBAZIA 82 LPIM      Q=1 FIT 1
W          (18.1)      (1.1)         SHAHBAZIA 82 LPIM      Q=1 FIT 2
W          (44.2)      (2.2)         SHAHBAZIA 82 LPIM      Q=1 FIT 1
W          (77.2)      (6.6)         SHAHBAZIA 82 LPIM      Q=1 FIT 2
W    I    (204.7)      (5.6)         SHAHBAZIA 82 LPPIM     Q=0,1
W           16.7        2.8          PIGOT     85 KPID      Q=1
```

B=2, S=−1 −− Re(POLE POSITION) (MeV)

```
      RE(POLE POSITION) APPROXIMATELY EQUALS BREIT-WIGNER MASS.

RE   J    (2132.0)                        NAGELS    79 BB   3S1 Q=1
RE   J    (2137.0)                        NAGELS    79 BB   3S1 Q=0
RE   B    (2129.0)                        DOSCH     80 LPIM 3S1 Q=1
RE        (2127.0)                        TAKAHASHI 80 BB   3S1 Q=0,1,2
RE        (2148.0)                        TAKAHASHI 80 BB   1P  Q=0,1,2
RE
RE   J  NAGELS 79 REPORTS POLE POSITION FOR TWO DIFFERENT 3S1 CHARGE
RE   J  STATES.
```

B=2, S=−1 −− Im(POLE POSITION) (MeV)

```
      IM(POLE POSITION) APPROXIMATELY EQUALS ONE-HALF BREIT-WIGNER WIDTH.

IM   J      (2.4)                         NAGELS    79 BB   3S1 Q=1
IM   J      (2.6)                         NAGELS    79 BB   3S1 Q=0
IM   B      (5.0)                         DOSCH     80 LPIM 3S1 Q=1
IM          (9.0)                         TAKAHASHI 80 BB   3S1 Q=0,1,2
IM          (8.0)                         TAKAHASHI 80 BB   1P  Q=0,1,2
```

REFERENCES FOR B=2, S=−1 STATES

```
COHN      64 PRL 22 668        H O COHN,K H BHATT,W M BUGG      (ORNL+TENN)
CLINE     68 PRL 20 1452       D CLINE,R LAUMANN,J MAPP               (WISC)
ALEXANDE  69 PRL 22 483        ALEXANDER,HALL,JEW,KALMUS,KERNAN  (LBL+UCR)
JAIN      69 PR 187 1816       P L JAIN                               (BUFF)
TAN       69 PRL 23 395        T H TAN                                (SLAC)
EASTWOOD  71 PR D3 2603        +FRY,HEATHCOTE,ISLAN+ (BIRM+EDIN+GLAS+LOIC)
SIMS      71 PR D3 1162        +O'NEAL,ALBRIGHT,BRUCKER,LANUTTI        (FSU)
SHAHBAZI  73 NP B53 19         B SHAHBAZIAN,A TIMONINA                (JINR)
SODHI     75 NP B97 403        A SODHI,D GOYAL                        (DELH)
BRAUN     77 NP B124 45        +GRIMM,HEPP,STROEBELE,THOEL+      (HEID+MPIM)
GOYAL     78 PR D18 948        D GOYAL,A SODHI                        (DELH)
NAGELS    79 PR D20 1633       M NAGELS,T RIJKEN,J DESWART            (NIJM)
DOSCH     80 ZPHY C3 249       H DOSCH,I STAMATESCU                   (HEID)
GOYAL     80 PTP 64 700        D GOYAL,J MISRA                        (DELH)
TAKAHASH  80 NP A336 347       TAKAHASHI,IWAMURA,KIMURA,KUME          (TOKY)
SHAHBAZI  82 NP A374 73C       SHAHBAZIAN,TEMNIKOV,TIMONINA           (JINR)
PIGOT     85 NP B249 172       +DE BRION,CAILLET,CHEZE+    (ROMA+SACL+VAND)

                               PAPERS NOT REFERRED TO IN DATA LISTINGS

PIROUE    64 PL 11 164         P A PIROUE                             (PRIN)
ALEXANDE  68 PR 173 1452       +KASHORN,SHAPIRA+                 (REHO+HEID)
BUNNEL    70 PR D2 98          +DERRICK,FIELDS,HYMAN,KEYES        (NWES+ANL)
GOYAL     71 PR D3 1259        D P GOYAL                              (DELH)
KADYK     71 NP B27 13         +ALEXANDER,CHAN,GAPOSCHKIN,TRILLING     (LBL)
DOSCH     78 PR D18 4071       H G DOSCH,V HEPP                       (HEID)
MIZUNO    79 PTP 62 1691       T  MIZUNO                              (TOKY)
ROOSEN    79 NC B49 217        +VANDERVELDE-WILQUET,WICKENS+     (LOUC+BRUX)
D'AGOSTI  81 PL 104B 330                                   (ROMA+SACL+VAND)
KIMURA    81 PTP 65 649        M KIMURA,Y IWAMURA,Y TAKAHASHI         (TOKY)
TOKER     81 NP A362 405       G TOKER,A GAL,J EISENBERG         (HEBR+TELA)
AERTS     85 NP B253 116       A T M AERTS,C B DOVER              (CERN+IPN)
```

S=−2 DIBARYON

OMITTED FROM SUMMARY TABLE

BARYON NUMBER 2, STRANGENESS −2 STATES

```
      IN THIS SECTION WE USE THE FOLLOWING ABBREVIATIONS FOR MEASURED
      QUANTITIES--

      LLIM      LAMBDA-LAMBDA INVARIANT MASS
      LLPI      LAMBDA-LAMBDA-PI INVARIANT MASS
      XPIM      XI-P INVARIANT MASS
```

B=2, S=−2 −− MASS (MeV)

```
M    A    (2367.0)    (4.0)          BEILLIERE 72 LLIM Q=0 GAUSSIAN FIT
M    B    (2365.3)    (9.6)          SHAHBAZIA 73 LLIM Q=0
M    C    (2480.0)                   GOYAL     80 XPIM Q=0
M
M    A  K- D TO XI- P K0.
M    B  N P TO LAMBDA LAMBDA X AND PI- P TO LAMBDA LAMBDA X FOR P IN C12.
M    C  GOYAL 80 ALSO SEES A SHOULDER AT 2360 MEV.
```

B=2, S=−2 −− WIDTH (MeV)

```
W    A      (15.0)    (4.0)          BEILLIERE 72 LLIM Q=0 GAUSSIAN FIT
W    B      (47.0)   (15.7)          SHAHBAZIA 73 LLIM Q=0
```

REFERENCES FOR B=2, S=−2 STATES

```
BEILLIER 72 PL 39B 671        BEILLIERE,MAYEUR+     (BRUX+CERN+TUFT+LOUC)
SHAHBAZI 73 NP B53 19         B SHAHBAZIAN,A TIMONINA                (JINR)
GOYAL    80 PR D21 607        D GOYAL,J MISRA,A SODHI                (DELH)
SHAHBAZI 82 NP A374 73C       SHAHBAZIAN,TEMNIKOV,TIMONINA           (JINR)

                              PAPERS NOT REFERRED TO IN DATA LISTINGS

CARROLL  78 PRL 41 777        +CHIANG,JOHNSON,KYCIA,KI,+         (BNL+PRIN)
D'AGOSTI 82 NP B209 1                              (INFN+SACL+VAND+CERN)
AERTS    85 NP B253 116       A T M AERTS,C B DOVER              (CERN+IPN)
WALCHER  85 NP A434 343C      T WALCHER                              (MPIH)
```

ACCESSING AND USING PARTICLE PHYSICS DATABASES

A number of publicly accessible computer databases containing particle physics information now exist at various institutions. Some of these databases are for literature searching, allowing the user to locate papers of interest, while others contain actual numerical data. The following discussion gives some idea of what is available and how to get started accessing and using these databases. The two locations covered are SLAC and Rutherford Appleton Laboratory (RAL).

The SLAC Particle Physics Databases

The databases of interest at SLAC are: (1) HEP, a literature-searching guide for all particle physics journal articles, preprints, reports, theses, etc., indexed by the standard bibliographic quantities; (2) DATAGUIDE, an adjunct to HEP, which indexes papers containing experimental data by accelerator, detector, beam momentum, reactions and particles studied; (3) PARTICLES (formerly RPP), containing the Full Listings from this Review of Particle Properties, indexed by particle and particle property; (4) REACTIONS, containing numerical data (e.g., cross sections, polarizations, etc.) on reactions; and (5) EXPERIMENTS, a guide to current and past particle physics experiments, indexed similarly to the HEP and DATAGUIDE databases.

All these databases are managed by the SPIRES database management system, which runs interactively under VM/CMS on SLAC's IBM 3081 computer. To enter SPIRES, once you are logged onto the computer, key in SPIRES. You can then obtain information about the database you are interested in by typing in, say, EXPLAIN PARTICLES. To actually access the database, enter, for example, SELECT PARTICLES. You may then find out what terms are available for searching on by keying in SHOW INDICES. To see the form of the contents of a particular index, say the PP (particle property) index of the PARTICLES database, key in BROWSE PP; this will give you an idea of what kinds of expressions appear in this index, and thus will suggest what form you should use in your search. Then to do an actual search for information, say for the RPP Full Listings on the η meson mass, you would key in a command like FIND PP ETA MASS, followed by the command TYPE; this would print out the Listings for the η mass. At any time, you may get help by typing in such commands as EXPLAIN EXPLAIN, EXPLAIN SHOW INDICES, EXPLAIN BROWSE, EXPLAIN FIND, EXPLAIN TYPE, etc. When you are finished searching, key in EXIT, which gets you out of SPIRES.

Anyone who has an account on the SLAC computing system can access these databases online. If you do not have an account and cannot find anyone who does (at main laboratories, ask at the library), please contact SLAC directly. More information on how to access and search the databases can be found in the report "A User's Guide to Particle Physics Computer-Searchable Databases on the SLAC-SPIRES System," LBL-19173, available from the Particle Data Group, Bldg. 50 — Room 308, Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA. An extensive wall poster, "A Guide to VM SPIRES," is available from the Library, SLAC, P.O. Box 4349, Stanford, CA 94305, USA. You may also contact Alan Rittenberg at LBL (CMS-id AXRVX, tel. 415-486-4723, or 451-4723 on FTS), or Louise Addis at SLAC (CMS-id ADDIS, tel. 415-854-3300, ext. 2411).

The Durham-RAL Particle Physics Databases

These databases contain compilations of current and past experimental particle physics data (e.g., reaction cross sections), and are available for interactive searching under CMS on both the Rutherford Appleton and CERN central computers. The topics included are: (1) two-body (and quasi-two-body) reactions; (2) hadron and photon one- and two-particle inclusive distributions; (3) lepton-produced inclusive data (i.e., deep inelastic scattering, structure functions, etc.); and (4) data from e^+e^- annihilations. The databases also contain complete bibliographic information on these and other related topics, status information of current particle physics experiments, and the Full Listings from this Review of Particle Properties. To insure that the databases are up to date, experimentalists are urged to send their data to the compilers immediately on completion.

The databases can easily used by anyone having network access to the RAL computer (PSS address 23422351919169, then RLIB) or to CERN; a guest account (PDG password HEPDATA) is available at RAL for those who do not have their own CMS account. An EXEC file, HEPDATA, on the UDISK gives direct access to the databases, and contains an extensive built-in HELP facility to assist the unfamiliar user. Data are retrieved using a simple keyword-based search, and can be displayed in either tabular or (at RAL) graphical form.

For more information, or a guide to the service, please contact Mike Whalley at Durham University, England (CMS-id MRW; tel. 0385-64971, ext. 591), or Dick Roberts at RAL (CMS-id RGR; tel. 0235-21900, ext. 5259).

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