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PREPARATION OF THE OPERATION OF THE SUPERCONDUCTING LOW-β INSERTION IN THE ISR

by

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Abstract

The low-β insertion described in Ref. 1 was installed in intersection 8 of the ISR in 1980, and has been operated successfully since.

This report describes the modifications to the scheme in Ref. 1 which were found to be necessary before operation as well as the new procedures which have been created to make the operation possible.

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Contents

INTRODUCTION

After the approval of the project of a superconducting low-β insertion (SL insertion) for the ISR in 1977, based on the scheme shown in Ref. 1, some modifications were made:

i) It was decided to install the SL insertion in intersection 8 instead of intersection 1, which had consequences on the luminosity balance.

ii) The end effects of the SL quadrupoles were taken into consideration and the matching of the insertion was remade accordingly.

iii) The calculation of the off-momentum closed orbits in the program AGS was improved[2], which necessitated the recalculation of the sextupole components in the insertion.

These modifications are described in the first chapter of this report.

The second chapter describes the new procedures and items specially created for the SL operation, they are:

i) A program which uses trajectory measurements and corrects locally the dipole defects of the insertion as well as its phase jump.

ii) A special data base for the program QPQQ which is used to tune the machine.

iii) An improved beam centring procedure.

iv) A collimator system adapted to the SL operation.

In the third chapter a new method of matching the ISR transfer line is described, which takes into account the actual betatron parameters in the injection septum.

1. MODIFICATIONS TO THE SCHEME OF REF.1

1.1 Effect of the displacement of the SL insertion from I1 to I8

The magnet parameters and the luminosity computed in Ref. 1 assumed the installation of the insertion in I1.

Installing the insertion in I8 did not change the SL magnet parameters. The betatron functions which are necessary for matching are in fact the same in all intersections of the ISR.

However, because of the modulation of the function β_h due to the horizontal mismatch of the insertion, the β_h values at the inflectors are different in the I8 case from what they were in the I1 case. This reduces the available aperture

in ring 1 and increases it in ring 2. The relevant β_h values are given in Table 1.

Table 1

Location of insertion	I1 (ring 1 & 2)	I8 (ring 1)	I8 (ring 2)
β_h(m) at the injection kicker on the injection orbit	65.5	111	8.3

The reduction of luminosity due to this change was expected to be about 7 %, the aperture balance being made as in Ref. 1, however this was considered to be the price to pay for the change of the initial design.

1.2 Modification due to the SL end effects

In Ref. 1 the SL quadrupoles and sextupole components were described as having a constant value inside the magnets and a zero value outside. In reality the value of these components decreases smoothly at the ends of the magnets[3]. The influence of this variation on the β_v^* function was examined some time ago[4] and was found to be negligible. However the main effect of this variation is the mismatch of the dispersion function which is introduced by the gradient decrease; the associated modulation of the off-momentum closed orbits reduces the stacking aperture by about 6 %. On the other hand the increase of β_v^* is about 8 % which is larger than previously[4] calculated, since the value of Q_v is closer to 9 for the present scheme.

1.2.1 Model to describe the end effects

The decrease of the gradient at the end of the magnet was extracted from Ref. 3. It is shown in Fig. 1 for two radial positions. The similarity of the two curves shows that this representation is valid in the useful aperture.

As the program AGS[5] only uses piece wise constant components, the end of the quadrupoles, whose length is 0.175 m in the hard edge model, has been replaced by six pieces, 0.055 m long, whose gradients divided by the central gradient gives the numbers:

0.927 0.841 0.688 0.459 0.210 0.05682

This is illustrated by Fig. 1. This representation garantees the value of the integrated gradient within 10^{-5} and provides transfer matrices which are very close to the matrices computed by means of a smooth curve as shown in Appendix 1. This representation will be referred to as "smooth edge" model.

1.2.2 Errors due to the hard edge approximation

One way to estimate these errors is to introduce the gradients computed in the hard edge approximation in the smooth edge model. The machine parameters are affected as shown in Table 2 for ring 2 (the situation is similar for ring 1).

Table 2

Tunes and their derivatives as well as luminosity parameters with insertion gradients computed for the hard edge model (Ring 2)

parameter	Q_h	Q'_h	Q''_h	Q_v	Q'_v	Q''_v	D_{max} (m)	β^*_v (m)	$\Delta p/p$ stacked (%)
hard edge	8.902	2.55	- 2.98	8.882	2.48	3.62	2.306	0.275	3.87
smooth edge	8.905	2.62	- 6.21	8.870	2.54	7.75	2.363	0.299	3.62

1.2.3 Rematching of the linear scheme

Taking the hard edge gradients as starting values, the previous matching procedure[1] was repeated using only the central part of the quadrupoles as variables and spreading the difference w.r.t. the starting value over the whole magnet.

In practice it was only necessary to do this once, since the solution obtained was quite acceptable, i.e.: good matching of the dispersion, values of the gradient stopbands equal to or lower than those of the hard edge solution (see Table 3 below). The results of the AGS calculations of the β functions, the dispersion and phase advances are shown in Tables 4.a and 4.c. The β functions inside the insertion are shown in Fig. 2.

Table 3

Half widths of the gradient stopbands and maximum value of the dispersion for the hard edge and smooth edge solutions

	δQ_h	δQ_v	D_{max} (m)	β^*_v (m)
hard edge solution, Ref. 1	0.112	0.008	2.296	0.293
smooth edge ring 1	0.112	0.0034	2.301	0.283
smooth edge ring 2	0.111	0.0060	2.302	0.286

1.2.4 The SL sextupoles for the smooth edge model

The maximisation of the stacking aperture by means of the F sextupoles in the SL quadrupoles was kept as a fundamental principle[1]. However as far as the D sextupoles are concerned, the principle of keeping β_v^* constant on the off-momentum orbits[1] has been discarded. Indeed, during the construction and testing of the sextupole windings, it was estimated to be more economic to take the F sextupole component which matches the orbit at the top of the stack as an upper limit, with the accepted consequence of an increase of β_v^* with positive momentum deviation. This results in a luminosity loss of about 4 % w.r.t. a solution with a constant β_v^*.

The decrease of the component at the end of the sextupole has not been computed. It was estimated to be steeper than that of the quadrupole. Thus the decrease of the sextupole component was spread over four of the end quadrupole pieces (see Fig. 1); however this did not significantly affect the variation of β_v^* with momentum or the stacking aperture. In the final scheme the sextupole component was nevertheless described this way for the homogeneity of the representation.

The F components were computed to match the off-momentum closed orbit at the top of the stack (i.e. for $\Delta p/p = 0.021$) and the D components were simply made to equal them. This is an iterative process which necessitated two iterations, starting with the values in Ref. 1. This computation was made with the corrected version of the routine MATRIX in the AGS program[2]

The detailed procedure is the following:

- Starting values were set for the K' of the sextupoles, the working line was adjusted by means of the K' and K" components of the main magnets of the ISR (computation made with the MA routine in the AGS[5] program).
- The insertion was turned off and the off momentum closed orbit position C_m, with the momentum deviation $(\Delta p/p)_m$ desired for matching, was computed.
- A trajectory with the same position and slope as C_m at the beginning of the insertion was tracked for $(\Delta p/p)_m$.
- The difference between this trajectory and C_m at the end of the insertion was made to vanish by adjusting the two F sextupole components.*

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* The program SEXT which computes the sextupole components was made by a summer student S. Olivieri in August 1979.

- The procedure was restarted with the new values of the sextupole components.

This is an iterative procedure which converges rather rapidly.

As a consequence of this orbit matching, it must be noted that the AGS[5] program finds the closed orbits faster when this matching is performed.

The values of the sextupole components are given in the summary of the AGS[5] outputs for the closed orbits at the top of the stack (Table 4 b and 4 d).

1.3 Modification of the compensation scheme for the AFM

The SL scheme in Ref. 1 was intended to be used with the superconducting solenoïd installed in I1. The vertical orbit distorsion due to the vertical kick given by the axial field of the solenoid was made local by means of two radial field compensators located at each end of the solenoid.

In I8 the SL insertion had to be used with the open axial field magnet (AFM). As no space was available to install a compensator between the AFM and the SL quadrupole (the AFM pole piece had to be machined to make the installation of the SL quadrupole possible in the outer arc part of the insertion), the compensator of the outer arc had to be put between the two SL quadupoles in the outer arc. Under these conditions it was advantageous to use the D quadrupoles themselves as compensators.

In order to explain this, let us consider a trajectory starting from the centre of the AFM with a zero slope. This trajectory reaches the D SL quadrupole with a certain vertical position and slope. The strength of the SL quadrupole is such that the maximum excursion of this trajectory occurs in it as shown in Appendix 2. Then the old radial field compensators AFC can be put almost anywhere between the SL quadrupoles and the next H magnet of the ISR to make the position of the trajectory equal to zero at the place of the H magnet. The latter has finally to be powered to give a kick opposite to the slope of the trajectory, which localises the vertical closed orbit distortion.

In practice one AFC is placed inside the doublet in the outer arc and the other one is placed in the free space between the F SL quadrupole and the F magnet of the ISR in the inner arc. Under these conditions the vertical excursion of the closed orbit is smaller than 1.5 mm in the superconducting quadrupoles as well as in the main magnets of the ISR close to the insertion.

This scheme is also convenient for $p\bar{p}$ operation because it provides the same vertical position of the p and $\bar{p}$ beams at the interaction point.

The excitation of the correctors used for this scheme are given in Table 5, as well as increments for a vertical displacement and a change of slope of the vertical closed orbit in I8.

Table 5

Excitation of the AFC's and H's at 26 GeV for the compensation of the vertical kick due to the AFM. Increments of the AFC's and H's for a vertical displacement of the closed orbit and a change of its slope at the interaction point. The kick of the AFM is 0.75 mrad at 26 GeV.

The upper number in each case is the kick in mrad at 26 GeV, the lower number is the intensity in percent of the maximum intensity. The reference axis for the slope is in the direction of the beam. For the H's and AFC's a positive kick corresponds to a positive excitation.

Compensation scheme for + 100 % AFM		-0.06564 -4.48	+0.04017 +3.15	+0.01972 +1.54	-0.06521 -4.46	-0.06568 -4.19	+0.03966 +3.11	+0.00929 +0.73	-0.05800 -3.96
Increments for displacement 1 mm upwards	Angle (mrad) Current (%)	0.02788 +1.91	0.33198 26.01	0.33146 25.97	-0.00523 -0.36	0.02790 1.91	0.33206 26.01	0.33297 26.08	-0.00455 -0.31
Increments for + 1 mrad slope change at intersection	Angle (mrad) Current (%)	-0.17770 -12.14	+0.07932 +5.51	-0.01570 -1.23	+0.1729 +11.81	-0.17763 -12.14	0.06882 +5.39	+0.01190 +0.93	+0.15376 +10.51

1.4 Expected performances of the new scheme compared to those given in Ref. 1

Three points influence the performance of the new scheme, they are:

i) The reduction of stacking aperture in ring 1 and its increase in ring 2 result in a luminosity loss of 7 %.

ii) The limitation of the D-sextupole strengths results in a loss of luminosity of 4 %.

iii) The decrease of β^* makes the luminosity increase by 1 %.

Thus the number given in Ref. 1 must be decreased by 10 %.

As the expected luminosity was in the range 1 to 3 10^{32} cm^{-2} s^{-1} depending on the conditions, the statement can be maintained that luminosities in excess of 10^{32} cm^{-2} s^{-1} with an acceptable background for the experiments may be obtained. This was effectivly achieved.

2. NEW PROCEDURES FOR SL OPERATION

These new procedures described below can be divided into four groups:

i) Change of the collimator system for limiting the proton losses in the superconducting quadrupoles.

ii) Adaptation of the tune control to the SL machine: this control has to be more precise than on the conventional ISR because of the increased sensitivity of the SL machine to vertical field perturbations. This concerns both the QPQQ program and the space charge compensation.

iii) Special procedure to obtain the first injection on the SL machine and to obtain injection currently with this machine.

iv) Centring and acceleration.

2.1 Changes to the ISR collimator system

The collimator system had to be adapted to provide maximum protection of the I8 insertion on the SL machine, without losing efficiency on the conventional machines FP, LB and TW.

The efficiency of a collimator configuration[6] can be evaluated with the programs TOUCH and MUSCAT (see Appendix 5). Betatron phase space plots in the vertical plane show that I8 is protected against any sort of proton losses. However, in the horizontal plane, the phase advances between the existing collimator locations (which should be roughly $\pi/2$ in both planes) are considerably perturbed by the horizontal betatron mismatch introduced by the insertion, and therefore new locations had to be found for some radial collimators, especially to provide a protection for SL7 and SL8.

In ring 2 it was sufficient to displace the farthest downstream collimator 340 (at $3\pi/2$ w.r.t. the primary collimators in I3) to the next straight section 344. This location was equally acceptable on the conventional ISR magnetic machines.

However, in ring 1 the β_h modulation in the collimator region is more visible than in ring 2. The phases of the radial collimators at 241 and 249 are no longer at π and $3\pi/2$ w.r.t. the primary collimators (see Fig. 3 a). To overcome this, a new radial collimator needed to be installed in the straight section 237. Even so, the use of the radial collimator 229 remains delicate, since a large part of the protons scattered by this (farthest downstream) collimator would be lost in the insertion on SL7. Therefore collimator 229 requires continuous attention, and must never be the strongest aperture limitation in the presence of high intensity beams. In the case of a sudden change of the closed orbit or during a coherent instability the beam could scrape itself superficially against the collimator block and the number of outscattered high energy protons would be large, making a quench in SL7 possible.

It was not considered justified to add collimators in the vicinity of I8 (the present collimator system is entirely located around I3), as this would dramatically increase the risk of scattering protons directly onto the superconducting quadrupoles. Furthermore, no equipment possibly causing scattered protons (scrapers, injection kicker, dump, etc.) is located between the present collimator system and the I8 insertion.

The phase space plots of the new configuration show that the superconducting magnets are protected w.r.t. injected pulses as follows:

- in the vertical plane perfectly well,
- in the horizontal plane the ISR vacuum chamber between I3 and I8 protects all magnets except SL7 in ring 1 and SL8 in ring 2, but the collimator system, when set up correctly, protects all magnets against the total loss of a single pulse.

The inner and vertical collimators are positioned by computer (program POCO[7]) around the injection orbit. The outer collimators presently need to be set up manually by "find beam" with a pulse from a position 3 mm further than the top of the stack, starting with the most downstream collimator.

MD tests have shown that, with the collimators in position, the superconducting magnets are protected from quenching during all operation with the exception of the total loss of a high intensity beam. In this event a beam current loss monitor triggers the beam dump. This loss monitor should be set to 1 A/10 seconds (normal value: 2 A/10 s).

2.2 Modification of the program QPQQ adjusting the tunes of the ISR

The program QPQQ computes increments for the currents in the 24 pole face windings of the main magnets of the ISR in order to achieve increments of the tunes and their derivatives.

In practice, these increments are obtained by multiplying a 24 x 10 matrix (10 tunes and derivatives, 24 pole face windings) by a vector constituted by the 10 tunes and derivatives requested. The matrix coefficients were measured some time ago[8] for the FP machine whose betatron parameters are close to those of the BASE machine, i.e. the machine to which the insertion is matched. Thus a good variation of the tunes will be obtained on the BASE machine by using the FP matrix.

In the SL machine the β_v's are the same as for the BASE machine but the β_h's are quite different. An alternative way of examining this is to compute the horizontal tune of the SL machine Q_h^* as a function of the horizontal tune of the BASE machine Q_h. This calculation is described in Ref. 9, giving:

$$\cos 2\pi Q_h^* = \cos \pi 2 \quad (Q_h + \phi) \quad / \cos 2\pi \; Q_h \qquad (1)$$

where Q_h is the half width of the gradient stopband associated with the mismatch of the insertion and ϕ is the sum of the phase advance due to the insertion and a term derived from the mismatch.

From equation (1) we can compute the values in Table 6.

Table 6

Horizontal tune of the SL machine Q*
as a function of the tune of the base machine Q_h

ΔQ_h^*	0	-0.050	-0.01	0.01	0.05	0.098
Q_h^*	8.9020	8.8520	8.8920	8.9120	8.952	9
Q_h	8.7502	8.7184	8.7444	8.7557	8.7733	8.7816
ΔQ_h	0	-0.0318	-0.0058	0.0055	0.0231	0.0314

The non linearity of Q_h^* versus Q_h is clear, Q_h^* is plotted as a function of Q_h on Fig. 4, where the significance of the gradient stopband is explained. The consequence of the non linearity above is that if Q_h is incremented, the associated increment of Q_h^* depends on the value of Q_h. In other words, an increment of Q_h^* made by QPQQ with FP coefficients will also create a variation of its derivatives of Q_h^* versus momentum for the SL machine[9].

A modification of the QPQQ matrix was made in the following way: using the AGS[5] program, increments of the multipole components in the main magnets were computed in order to achieve a variation of Q_h^* or of its derivatives; then these increments were added to the components in the main magnets of the FP machine and the associated difference in Q_h and its derivative were computed. In this way it was possible to compose Table 7 which could also be written in a matirx form:

$$[Q(FP)] = [M] \; [Q(SL)]$$

where $[Q]$ is a vertical vector containing Q and its derivatives.

Table 7

Theoretical conversion of SL increments into FP increments

Increments asked from QPQQ with working conditions FP		Increments wanted for the machine with the SL insertion
ΔQ_h	=	$0.535\,\Delta Q^*_h$
$\Delta Q'_{h\ \text{inner}}$	=	$-\ 7.2\,\Delta Q^*_h + 0.58\,\Delta Q'^*_{h\ \text{in}} + 0.0006\,\Delta Q''^*_h$
$\Delta Q'_{h\ \text{outer}}$	=	$-\ 6.4\,\Delta Q^*_h + 0.64\,\Delta Q'^*_{h\ \text{out}} + 0.0014\,\Delta Q'^*_{h\ \text{out}}$
$\Delta Q''_{h\ \text{inner}}$	=	$-189\ \Delta Q^*_h + 11\ \Delta Q'^*_{h\ \text{in}} + 0.77\ \Delta Q''^*_{h\ \text{in}}$
$\Delta Q''_{h\ \text{outer}}$	=	$-451\ \Delta Q^*_h - 30\ \Delta Q'^*_{h\ \text{out}} + 0.17\ \Delta Q'^*_{h\ \text{out}}$

Finally the multiplication of the FP QPQQ matrix by the matrix M provides the SL QPQQ matrix. This new matrix was checked experimentally and it was found that some terms had to be adjusted. The experimental results are given in Table 8 for finite increments of Q* and its derivatives, the non linearity of Q* versus Q can explain most of the discrepancies between Table 7 and Table 8.

Table 8

Measured coefficients for the conversion of SL tune increments into FP tune increments

Increments asked from QPQQ with working conditions FP		Increments wanted for the machine with the SL insertion
ΔQ_h	=	$0.7\,\Delta Q^*_h$
$\Delta Q'_{h\ \text{inner}}$	=	$-\ 10.0\,\Delta Q^*_h + 0.58\,\Delta Q'^*_{h\ \text{in}}$
$\Delta Q'_{h\ \text{outer}}$	=	$-\ 8.0\,\Delta Q^*_h + 0.64\,\Delta Q'^*_{h\ \text{out}}$
$\Delta Q''_{h\ \text{inner}}$	=	$-189\ \Delta Q^*_h + 2.0\ \Delta Q'^*_{h\ \text{in}} + 0.8\,\Delta Q''^*_{h\ \text{in}}$
$\Delta Q''_{h\ \text{outer}}$	=	$-451\ \Delta Q^*_h - 5.0\ \Delta Q'^*_{h\ \text{out}} + 0.8\,\Delta Q'^*_{h\ \text{out}}$

2.3 Space charge compensation

From the explanations in the above paragraph, it is obvious that the Q-shifts due to the space charge will be more important on the SL machine than in the conventional machines.

However, as the main magnets of the ISR are almost as regularly distributed as the space charge fields, the effect of the space charge can be compensated quasi locally by acting on the main magnets poleface winding currents. The relation between the beam profile (density vs. momentum) and poleface winding current increments then only depends on the current distribution in the vacuum chamber. Since the SL machine was designed to have the same theoretical off-momentum closed orbits as the FP machine outside the insertion, it seemed interesting to use the existing FP space charge compensation procedure equally on the SL machine. The program QCOMP[10], with a modification to select automatically the FP parameters, was found to give adequate results and required only some fine tuning of the parameters FH and FV which multiply the measured current profile before the calculation of the compensation:

FH was increased from + 0.97 (original value) to + 1.11

FV was decreased from - 1.26 (original value) to - 1.40

(the original values were chosen deliberately to undercompensate, which was not desired on the SL machine).

The results of the QCOMP calculations were incorporated into the S.C.C. program TUCO[11], which applies precalculated compensations automatically based on the beam current: it uses the position of top and the density of the stack as input parameters and assumes a rectangular distribution. The program TUCO has been used successfully on the SL machine, for the high intensity stacking tests and for the stacks used for acceleration to 31 GeV.

2.4 Beam centring

The compensation of the space charge described just above is also used during beam centring after stacking. On the conventional machine, precalculated increments were used in all cases. However, with the SL machine high precision of the working line handling is essential, therefore as the obtained beam currents and density profiles may be different from one run to the next, a procedure was created to calculate the poleface winding increments "on line" just before centring of the beam, using the QCOMP program with the SHIFT option[10]. Application of two steps of 5 mm gave good results and is now regularly used.

2.5 Local correction of the field defects in the insertion

For the running-in of the SL insertion, an essential problem was to inject circulating protons in this new machine.

For this purpose a special procedure was created as follows:

- The ISR was set up on the BASE machine which is obtained in the following way: the ELSA line having been made with the SL insertion, the latter is turned off. The working line then computed with this new machine is the BASE working line.
- The injection on the BASE machine being well adjusted, a single turn trajectory T_1 is measured as well as the closed orbit C_1 at injection.
- The insertion is turned on and a single turn trajectory T_2 is measured.
- Downstream of the insertion the difference between T_2 and T_1 is considered as a betatron oscillation around T_1. It is eliminated by two dipoles in both planes.
- When the difference between T_2 and T_1 is small enough, the injected pulse circulates; the position of the closed orbit C_2 is measured.
- A fine correction is finally made by cancelling the difference between C_1 and C_2 by means of the same dipoles as above.

This process has two advantages:

i) It ensures injection on the SL machine.

ii) It provides a closed orbit at injection as good as the closed orbit made on the base machine, so that the insertion is made invisible from the orbit point of view.

This worked perfectly well with the SL insertion in spite of the bad horizontal matching and made it possible to obtain circulating protons at the first run with the insertion. Fig. 5 shows measurements of the closed orbit distorsions measured without the insertion (BASE machine) and with the insertion after having applied INCO on the single turn measurements only (difference between T_2 and T_1 quoted above).

The procedure for using the program INCO can be found in Ref. 12.

The principle of the computations are given in Appendix 4.

2.6 Initial set up of the machine with the insertion

This initial set up had to be carried out with great care because injection attempts before the orbits and injection are properly turned could lead to losses in I8 making the magnets quench.

In order to overcome this problem the beam was not allowed at any time to cross the insertion on an unknown orbit.

At first the set up was made on the BASE machine as defined in § 2.5, identical to the conventional ISR: the working line was adjusted to equal that of the BASE machine with all the ISR magnets needed. The orbits were corrected and the injection line was carefully adjusted. The closed orbit at injection was measured and stored as well as a single turn trajectory. The collimators were positioned w.r.t. the thus measured injection orbit using the ß values of the SL machine.

The SL magnets were turned on, the stability of the injection was checked. The injected pulse was then allowed to cross the insertion once and INCO was applied to make the trajectory downstream from the insertion coincide with the orbit measured previously without the SL insertion. When INCO did not require any more correction the beam was allowed to circulate.

This procedure was effectively applied in ring 2 and worked perfectly well (Fig. 5).

In ring 1 the situation differs because I8 is very close to the injection kicker, which invalidates the above procedure. Therefore a second turn trajectory had to be measured and a special kicker was installed in I3 to prevent an injected pulse to cross I8 twice. This was more difficult and lengthy because the injection had to be adjusted frequently due to changes of the PS and the transfer line.

2.7 Fast injection procedure on a known closed orbit

Experience shows that the closed orbits on the SL machine are remarkably stable at 26 GeV/c, and in most cases the closed orbit measured in the previous run is a better estimation of the actual orbit than the closed orbit of the base machine. This fast procedure may however only be applied if no radical realignment work has been carried out since the previous run. The procedure is as follows:

The insertion is switched on together with the other magnets of the machine, and the special stoppers upstream of I8 (449 for ring 1 and 548 for ring 2) are closed to protect the insertion. The injection is tuned (program CINE[13]) and the collimators are positioned (program POCO[7]) w.r.t. the orbit measurement of the previous run, kept on disk. After taking out the stopper, circulating beam is obtained.

3. BETATRON MATCHING OF THE BEAM TRANSFER LINE TO THE ISR RING

This computation, which is of general interest, was developed for the SL operation because the betatron matching of the beam transfer line to the ISR ring had to be performed with precision; due to the horizontal beta modulation introduced by the insertion, the horizontal beam width is locally much larger than on the conventional machine, particularly in the ring 1 injection kicker and in the ring 2 septum magnet, and therefore it is essential to minimise the horizontal emittance through a good betatron matching to the PS.

As the beta values depend on the radial position of the orbit, it was necessary to calculate the beta values in the septum on the trajectory of the incoming beam, rather than to use the beta values on the central orbit or injection orbit. The AGS[5] program was modified to perform a reversed tracking, starting at the junction of the incoming beam trajectory and the ring orbit (i.e. in the injection kicker) back to the entrance of the septum at the nominal radial position of the incoming beam (- 100 mm w.r.t. the centre line). A trajectory associated with the momentum deviation of the injection orbit and making an angle exactly opposite to the one made by the kicker was traced through the relevant ISR magnets and then the transfer matrices were computed for the betatron oscillation along this trajectory. In this process the multipole components of the main magnets introduced in AGS to create the working line were used (this is only an approximation because this representation applies strictly only down to a position of about - 50 mm in the D magnets) and it was checked that the influence of the gradient and field defects in the QT magnet involved in this tracking was negligible. The obtained values were used as input in the matching program MATCH[14], which optimises the gradients of the six most downstream BT quadrupoles.

By using these quadrupole settings, rather than the standard values (so far used on all magnetic ISR machines) a horizontal blow-up of 20 % could be eliminated. This was confirmed by transverse Schottky measurements[15].

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15. J.P. Koutchouk, private communication.

A P P E N D I X 1

Analytic calculation of the transfer matrix for a transition region with a gradient decreasing to zero

Let s be the coordinate along the closed orbit and x the transverse displacement of the particles w.r.t. the closed orbit. x is determined by the differential equation:

$$x'' + K(s)\, x = 0 \qquad (1)$$

where K(s) takes the form:

$$K(s) = K_0 \left[1 + a(s/l)^2 + b(s/l)^3 + c(s/l)^4 \right] \qquad (2)$$

K_0 is the constant value inside the magnet; the parameters a, b and c describe the variation of K/K_0 from 1 for s = 0 to 0 for s = l, with K'(o) = 0. Imposing furthermore that:

$$K'(l) = 0 \quad \text{and} \int K(s)\, ds = K_0\, l_{ext}$$

we obtain, putting $R = l_{ext}/l$

$$a = 30R - 18 \qquad b = 32 - 60R \qquad c = 30R - 15$$

For the case of the SL quadrupoles l_{ext} was taken equal to 0.175 and l equal to 0.33. The associated function K(s) given by (2) with

$$a = -2.090909... \qquad b = 0.181818... \qquad c = 0.909090...$$

is shown in Fig. 1 and fits the computed variation well.

Equation (1) can be solved approximately by looking for a power series:

$$x(s) = x_0 + x_1 s + x_2 s^2 + \ldots + x_n s^n$$

where the x_i's are constants.

Putting this expansion in (1) gives:

$$2x_2 + 6x_3 s + \ldots + n(n-1)\, n_n s^{n-2} + \ldots + K_0 \cdot \left[1 + a(s/l)^2 + b(s/l)^3 + c(s/l)^4 \right] \cdot \left[x_0 + x_1 s + \ldots + x_n s^n \right] = 0 \qquad (3)$$

We now have to look for particular solutions since the elements m_{ij} of the transfer matrix are particular solutions of (1) such that:

$$m_{11}(o) = 1 \qquad m'_{11}(o) = 0 \qquad m_{12}(o) = 0 \qquad m'_{12}(o) = 1$$

Function m_{11}

The above initial conditions are $x_0 = 1$ $x_1 = 0$, then the other terms of the series in (3) are made to vanish:

constant terms: $2x_2 + K_0 = 0$ $\qquad x_2 = -K_0/2$

terms with s : $6x_3 = 0$ $\quad x_3 = 0$

terms with s^2 : $12x_4+K_0(x_2+ax_0/l^2) = 0$ $\quad x_4 = (K_0/12)(K_0/2-a/l^2)$

terms with s^3: $20x_5+K_0(x_2+ax_0/l^2) = 0$ $\quad x_5 = - K_0b/l^3$

terms with s^4: $30x_6+K_0(x_4+x_2a/l^2+x_1b/l^3+x_0c/l^4) = 0$

$$x_6 = (-K_0/30)(K^2_0/24-7aK_0/12l^2+c/l^4)$$

If the calculation is stopped here, the term in K_0l^2 of the expansion of the function K(s) is exactly obtained and we know that the error on the expansion is of the order of the next term which is $K^2_0l^4$. Thus we get:

$$m_{11}(s) = 1 - K_0l^2.\left[(s/l)^2 + a(s/l)^4/6 + b(s/l)^5/10 + c(s/l)^6/15 \right] /2$$
$$+ \text{ terms of order larger than } K^2_0l^4$$

making $s = l$, we obtain the approximate term of the matrix transfer of the transition region of length s:

$$m_{11} = 1 - K_0l^2.\left[1 + a/6 + b/10 + c/15 \right] /2 + \ldots$$
$$= 1 - K_0l^2 (R - 0.2)/2$$

for the SL case $R = 0.530303\ldots$, this gives $m_{11} = 0.9837$. We notice that the first term of the expansion looks like that of the expansion of the cosine function with a correction term smaller than 1 depending on a, b and c, thus the next term can be expected to be at the most $K^2_0l^4/24$ with a correction term, which means that the error on the value of m_{11} is of the order of $K^2_0l^4/24$ i.e. 10^{-4}. The accuracy of the gradient measurement is about 1°/oo and therefore m_{11} is known within about the same accuracy: in this respect the accuracy of 10^{-4} of the present computation is largely sufficient.

Function m_{12}

The above initial conditions are $x_0 = 0$ $\quad x_1 = 1$. Then the same equations as above can be used, they give:

$$m_{12}(s) = s \quad 1 - K_0l^2.\left[(s/l)^2/6 + a(s/l)^4/20 + b(s/l)^5/30 + c(s/l)^6/42 \right]$$

for $s = l$, we obtain:

$$m_{12} = l \left[1 - K_0l^2(1/6 + a/20 + b/30 + c/42) + \text{terms of order larger than } K_0{}^2l^4 \right]$$
$$= l \left[1 - K_0l^2(3R - 1/3)/14 + \ldots \right]$$

For the SL case $m_{12} = 0.3287$

The functions $m_{21}(s)$ and $m_{22}(s)$ are the respective derivatives of $m_{11}(s)$ and $M_{12}(s)$ which lead to:

$$m_{21} = - K_0l(1 + a/3 + b/4 + c/5) + \ldots = - K_0l_{ext} + \ldots$$
$$= - K_0lR$$

the first term of this expansion is exactly the same as the term which is obtained in the hard edge approximation. This is quite normal since it is the focusing term.

$$m_{22} = 1 - K_0 l^2(1/2 + a/4 + b/5 + c/6) + \ldots$$

$$= 1 - K_0 l^2(R - 1/5)/2 + \ldots$$

This expansion still looks like a cosine as for m_{11} but the correction term is different from the one above.

The determinant of the approximate transfer function is:

$$m_{11}\, m_{22} - m_{12}\, m_{21} = \left[1 - K_0 l^2(R + 1/5)/2\right].\left[1 - K_0 l^2(R - 1/5)/2\right] + l.\left[1 - K_0 l^2(3R - 1/3)/14\right].\left[K_0 l\, R\right]$$

$$= 1 + \text{terms of the order } K_0^2 l^4$$

which is consistent with the approximation of the expansions.

Comparison between the different transfer matrices of the quadrupole end

(vertical plane)

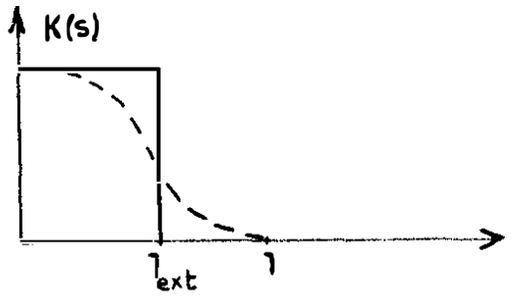
	m_{11}	m_{12}	m_{21}	m_{22}
Hard edge*	0.9937	0.3287	- 0.0716	0.9826
End in 6 pieces	0.9842	0.3287	- 0.0715	0.9922
Above calculation	0.9837	0.3287	- 0.0717	0.9926

* see Appendix 2

APPENDIX 2

Transfer matrix of a quadrupole end in the hard edge approximation

The gradient variation is shown below:



l is the length over which the gradient varies substantially (see Appendix 1), l_{ext} is such that:

$$K_o \, l_{ext} = \int_o^l K(s) \, ds$$

where K(s) is the actual gradient (see Appendix 1).

The transfer matrix from the origin to the point of abscissa s = l is obtained from the product:

$$\begin{pmatrix} l & l - l_{ext} \\ 0 & 1 \end{pmatrix} \times \begin{pmatrix} C & S \\ -KS & C \end{pmatrix}$$

where $C = 1 - \frac{Kl^2_{ext}}{2} + \ldots$

$$S = l_{ext} \left[1 - \frac{Kl^2_{ext}}{2} + \ldots \right]$$

The expansion of the matrix elements is, putting $R = \frac{l_{ext}}{l}$

$$m_{11} = 1 - \frac{Kl^2}{2} (R^2 - 2 + 2R) + \ldots$$

$$m_{12} = l \quad 1 - \frac{Kl^2R^2}{2} (3 - 2R) + \ldots$$

$$m_{21} = - KlR \left(1 - \frac{Kl^2R^2}{6} + \ldots \right.$$

$$m_{22} = 1 - \frac{Kl^2R^2}{2} + \ldots$$

APPENDIX 3

Maximum excursion of a trajectory in a focusing quadrupole

Let us consider a trajectory on the axis starting at a distance d of a quadripole, with a slope x'.

At the entrance of the quadrupole, the position and slope are respectively:

$$x'd \quad \text{and} \quad x'$$

The position inside the quadripole is:

$$dx' \cos \sqrt{K}\, s + \frac{x'}{\sqrt{K}} \sin \sqrt{K}\, s$$

where K is the gradient divided by the rigidity ($B\rho$) of the particle and s is the longitudinal coordinate with the origin at the beginning of the quadrupole.

The slope inside the quadrupole is:

$$- dx' \sqrt{K} \sin \sqrt{K}\, s + x' \cos \sqrt{K}\, s = x' \left(- d \sqrt{K} \sin \sqrt{K}\, s + \cos \sqrt{K}\, s\right)$$

The slope can be zero inside the quadripole, i.e. the trajectory can have an extremum x_m, if s_m exists smaller than l, the length of the quadripole, such that:

$$\operatorname{tg} \sqrt{K}\, s_m = \frac{1}{d \sqrt{K}}$$

Which can be expressed as:

$$s_m = \frac{1}{\sqrt{K}} \operatorname{Arctg} \frac{1}{d \sqrt{K}} \qquad l$$

For the case of a trajectory starting at the centre of the AFM, we have for the vertically focusing quadrupoles adjacent to the intersection point:

- in the outer arc:

$$d = 2.9 \text{ m} \quad K = 0.41 \text{ m}^{-2} \quad s_m = 0.77 \text{ m} \quad x_m = 3.29\, x'$$

- in the inner arc:

$$d = 3.97 \text{ m} \quad K = 0.365 \text{ m}^{-2} \quad s_m = 0.65 \text{ m} \quad x_m = 4.30\, x'$$

As both s_m are smaller than the quadrupole lengths which are 1.15 m, the extremum of the trajectories occur inside the quadrupoles. For the AFM, x' = $3.7\ 10^{-4}$ rad, hence the maximum vertical excursion of the orbit due to the AFM is smaller than 1.6 mm at 26 GeV.

APPENDIX 4

Computation of a local compensation of a dipole defect by means of two trajectory measurements

Let x_{1i} be the trajectory positions measured at the pick up stations in a reference (or unperturbed) machine. In the ISR this can be either a single turn measurement, which is a trajectory, or a closed orbit measurement.

Let us introduce a dipole defect at a certain position; the measured trajectory positions become x_{2i}.

If we assume that $x_{2i} - x_{1i}$ is a betatron oscillation around the reference trajectory, it is possible to find two dipoles A and B which give the kicks θ_A and θ_B such that

$$\theta_A \sqrt{\beta_A \beta_i} \sin(\mu_i - \mu_A) + \theta_B \sqrt{\beta_B \beta_i} \sin(\mu_i - \mu_B) + (x_{2i} - x_{1i}) = 0$$

which we will write for any i

$$A_i \theta_A + B_i \theta_B + x_i = 0 \qquad (1)$$

The best way to compute θ_A and θ_B is to make a "least square fit" of equation (1), which means that:

$$\sum_i \left[\theta_A \sqrt{\beta_A \beta_i} \sin(\mu_i - \mu_A) + \theta_B \sqrt{\beta_B \beta_i} \sin(\mu_i - \mu_B) + (x_{2i} - x_{1i})\right]^2 = S(\theta_A \theta_B)$$

is minimum. The condition that this function $S(\theta_A, \theta_B)$ is minimum is expressed by:

$$\frac{\partial S}{\partial \theta_A} = \frac{\partial S}{\partial \theta_B} = 0$$

The solution of this system is:

$$\theta_A = \frac{(\sum Bi^2)(\sum AiXi) - (\sum AiBi)(\sum BiXi)}{(\sum AiBi)^2 - (\sum Ai^2)(\sum Bi^2)}$$

$$\theta_B = \frac{(\sum Ai^2)(\sum BiXi) - (\sum AiBi)(\sum AiXi)}{(\sum AiBi)^2 - (\sum Ai^2)(\sum Bi^2)}$$

APPENDIX 5

1. Motion in the "phase space"

The amplitude y(s) of the betatron oscillation at the position s in a machine is given by:

$$y(s) = \sqrt{E\,\beta(s)}\,[\sin\ \mu(s) + \varphi]$$

where E and φ are constants depending on the value of x and its derivative at a given position. The amplitude function $\beta(s)$ and the phase advance $\mu(s)$ depends only on the machine geometry and on the normalized gradients (i.e. the gradients divided by the rigidity of the particles).

The normalized coordinate:

$$x(s) = y(s) / \sqrt{\beta(s)} = \sqrt{E}\ \sin\,[\mu(s) + \varphi]$$

is therefore a pure sinusoïdal function. Its derivative w.r.t. μ is

$$x'_{\mu}(s) = \sqrt{E}\,[\cos\ \mu(s) + \varphi]$$

If the betatron motion is represented in the phase plane $x\ x'_{\mu}$, the trajectories are circles of radius $\sqrt{E}$ and $dx'_{\mu}(s)/d\mu$ always has its sign opposite to that of x(s) which means that the motion of the point of coordinates x(s), $x'_{\mu}(s)$ occurs clockwise.

2. Representation of an aperture restriction

Let us consider two particles A and B with the same emittance E going from a point 1, to a point 2 where particles with an amplitude larger than x_2 (positive) are eliminated by the aperture restriction.

The motion is sketched in Fig. 5.

In this particular case particle B is eliminated at point 2.

The same representation as Fig. 2 b can be obtained by rotating this Figure anticlockwise by $\Delta\mu$, the phase advance between point 2 where the aperture restriction occurs and point 1 which is the origin of the motion.

Thus it is only necessary to specify the coordinates of the particles at point 1: the eliminated particles are obtained without considering the betatron motion as shown in Fig. 5 c.

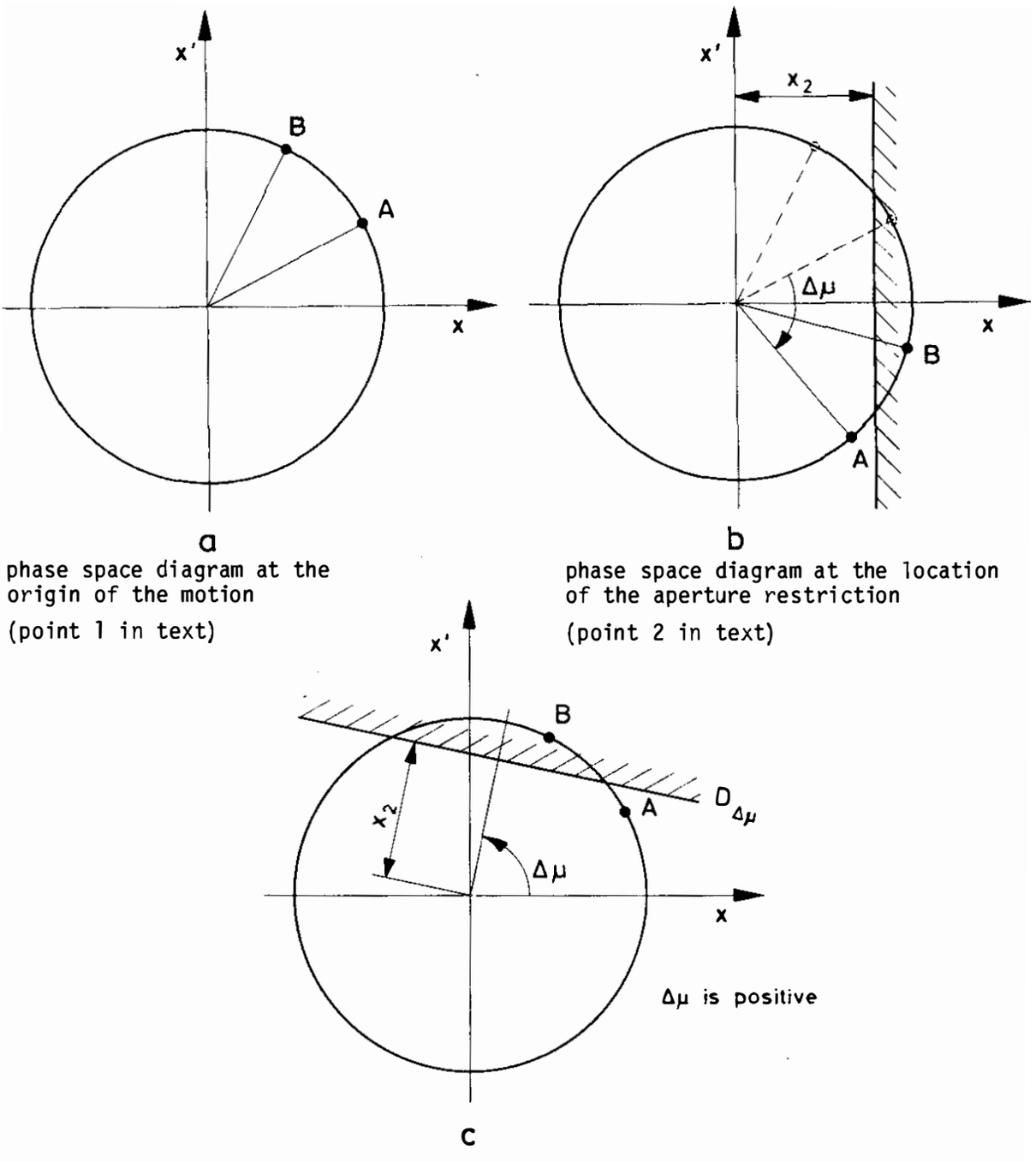


Fig. 5: Representation of an aperture restriction located at the phase $\Delta\mu$ w.r.t. the particles in the positions A and B.

For a given machine which has a continuous vacuum chamber, a straight line $D_{\Delta\mu}$ is associated with every point of the vacuum chamber at the phase $\Delta\mu$ w.r.t. an arbitrary origin. This ensemble has an innermost envelope. This envelope represents the aperture restriction over the number of turns for which it is traced.

3. Application to the case of two collimators

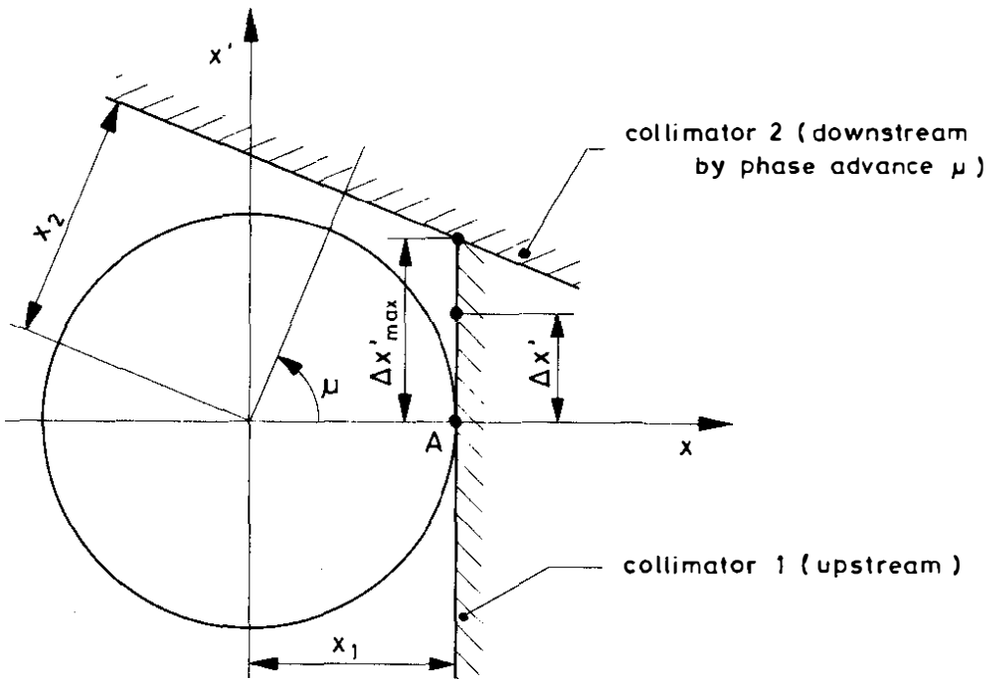


Figure 6

Let us take the origin of the phase at the upstream collimator; let us assume that there is no other aperture restriction. Collimator 1 is set as an aperture limitation defined by the distance x_1 from which the closed orbit under consideration is distant. Particles are deflected by collimator 1 so that their representing point is not A but is displaced vertically by $\Delta x'$. For any $\Delta x' < 0$ the deflected particles miss collimator 2. For $\Delta x' > 0$ there exists a value $\Delta x'_{max}$ below which the deflected particles miss collimator 2 and beyond which they are stopped (Fig. 6).

If we now consider an infinite number of turns of the particles, collimator 1 has to be set at all phases $\mu = n(2\pi Q)$ where n is any integer. The envelope of the straight lines representing collimator 1 is therefore the circle of radius x_1 which implies that a particle that has been deflected once will be stopped later on.

In such phase space plots the available aperture of a machine can be evaluated. The data are calculated by the program TOUCH (author K. Brand). This program calculates for a given part of a machine, or for a complete turn around the machine, the acceptance of the vacuum chamber for a given orbit.

The calculated acceptance is plotted in a phase space plot by the program MUSCAT (author T. Risselada). Aperture restrictions (for example collimators) may then be introduced and plotted in the same plot. The program may also be requested to calculate angular distributions of protons scattered by multiple scattering in a given collimator, scraper, septum, etc. and to plot their population in the phase space plot.

The circulating beam envelope is indicated by a circle with area equal to 9 times the beam emittance (this number is based on practical experience with collimator systems), and the collimators may be automatically set by the program against this circle. The orbit coordinates and betatron parameters are computed by the AGS program. This allows evaluation of a given collimator system on different machine optics and different $\Delta p/p$ values.

Table 4 a

Ring 1 - Summary of the AGS output for the central orbit (linear scheme)

SUPERCONDUCTING LOWBETA SCHEME 18 , RING 1 , ELSA LINE , STANDARD SPM , END EFF 1GRAGS 75.03 23/10/80 18.22.55

CIRCUMFERENCE = 942.63680 1 SUPERPERIODS STRAIGHT MAGNETS ALL VALUES AT EXIT OF ELEMENTS

NO	ELEM	L(M)	ANG(MR)	K(1/M2)	BETAV(M)	BETAH(M)	ALPHAV	ALPHAH	MUV/2PI	MUH/2PI	ALPHAP(M)	ALPHAP'
INITIAL					10.968	13.582	-1.707	.051	.89470	.98035	1.873	-.183
91	H817	.7827	0.0000	0.0000000	13.859	13.547	-1.986	-.007	.90481	.98954	1.730	-.183
113	F803.S1	1.2549	16.4979	-.0394832	31.501	49.304	.439	1.716	1.05271	1.09429	2.250	.001
114	801.1	.6450	0.0000	0.0000000	20.958	47.123	.403	1.664	1.05754	1.09642	2.251	.001
115		.0550	0.0000	-.0218000	20.915	46.937	.375	1.716	1.05796	1.09661	2.251	-.002
116		.0550	0.0000	-.0806000	20.879	46.737	.279	1.919	1.05838	1.09680	2.250	-.012
117		.0550	0.0000	-.1761000	20.860	46.502	.074	2.364	1.05880	1.09699	2.249	-.034
118		.0550	0.0000	-.2639000	20.868	46.205	-.231	3.027	1.05922	1.09717	2.246	-.067
119		.0550	0.0000	-.3226000	20.914	45.828	-.605	3.828	1.05964	1.09736	2.241	-.106
120		.0550	0.0000	-.3550000	21.004	45.359	-1.019	4.697	1.06005	1.09756	2.234	-.150
121	SLQ1.1	.1500	0.0000	-.3836000	21.495	43.579	-2.207	7.135	1.06118	1.09809	2.202	-.278
122	SLQ1.2	.1500	0.0000	-.3836000	22.372	41.102	-3.593	9.328	1.06307	1.09866	2.151	-.403
123		.0550	0.0000	-.3556000	22.793	40.039	-4.073	9.993	1.06366	1.09887	2.128	-.445
124		.0550	0.0000	-.3226000	23.266	38.909	-4.528	10.545	1.06304	1.09909	2.102	-.483
125		.0550	0.0000	-.2639000	23.786	37.728	-4.924	10.934	1.06341	1.09932	2.075	-.513
126		.0550	0.0000	-.1761000	24.344	36.515	-5.218	11.112	1.06377	1.09956	2.046	-.533
127		.0550	0.0000	-.0806000	24.927	35.294	-5.392	11.081	1.06413	1.09980	2.017	-.542
128		.0550	0.0000	-.0218000	25.526	34.084	-5.489	10.929	1.06448	1.10005	1.987	-.544
129	801.2	.5058	0.0000	0.0000000	31.391	23.932	-6.106	9.142	1.06732	1.10227	1.711	-.544
130	AFC1	.5057	0.0000	0.0000000	37.879	15.589	-6.723	7.355	1.06965	1.10704	1.436	-.544
131		.0550	0.0000	.0233000	38.619	14.792	-6.741	7.141	1.06988	1.10762	1.406	-.542
132		.0550	0.0000	.0861000	39.354	14.021	-6.620	6.882	1.07011	1.10822	1.377	-.536
133		.0550	0.0000	.1802000	40.063	13.282	-6.268	6.555	1.07033	1.10887	1.347	-.522
134		.0550	0.0000	.2821000	40.721	12.582	-5.692	6.177	1.07054	1.10959	1.319	-.501
135		.0550	0.0000	.3448000	41.307	11.924	-4.953	5.780	1.07076	1.11026	1.292	-.476
136		.0550	0.0000	.3801000	41.806	11.311	-4.113	5.385	1.07097	1.11101	1.267	-.450
137	SLQ3.1	.4000	0.0000	.4100000	42.338	8.004	2.811	3.062	1.07247	1.11778	1.127	-.254
138	SLQ3.2	.4000	0.0000	.4100000	37.502	6.194	9.014	1.560	1.07405	1.12692	1.061	-.076
139		.0550	0.0000	.3801000	36.475	6.031	9.656	1.404	1.07420	1.12836	1.058	-.054
140		.0550	0.0000	.3448000	35.383	5.884	10.185	1.265	1.07453	1.12983	1.055	-.034
141		.0550	0.0000	.2821000	34.242	5.751	10.553	1.152	1.07478	1.13133	1.054	-.017
142		.0550	0.0000	.1882000	33.072	5.629	10.715	1.071	1.07504	1.13287	1.053	-.006
143		.0550	0.0000	.0861000	31.896	5.514	10.674	1.024	1.07531	1.13444	1.053	-.001
144		.0550	0.0000	.0233000	30.730	5.403	10.515	.997	1.07559	1.13604	1.053	-.000
145	801.3	.2770	0.0000	0.0000000	25.184	4.879	9.509	.895	1.07717	1.14464	1.053	-.000
146	801PU	2.4627	0.0000	0.0000000	.365	2.710	.569	-.014	1.22820	1.26305	1.053	-.000
147	AFM.1	.1100	0.0000	0.0000000	.283	2.718	.169	-.055	1.28379	1.26950	1.053	-.000
148	X765.X8	.1100	0.0000	0.0000000	.290	2.735	-.230	-.095	1.34647	1.27592	1.053	-.000
149	AFM.2	3.8113	0.0000	0.0000000	54.778	8.822	-14.066	-1.502	1.54920	1.41730	1.053	-.000
150		.0550	0.0000	.0207000	56.333	8.989	-14.202	-1.532	1.54936	1.41828	1.053	.001
151		.0550	0.0000	.0767000	57.893	9.160	-14.156	-1.591	1.54951	1.41925	1.053	.006
152		.0550	0.0000	.1675000	59.431	9.341	-13.709	-1.699	1.54966	1.42019	1.053	.015
153		.0550	0.0000	.2511000	60.912	9.537	-13.135	-1.853	1.54981	1.42112	1.055	.030
154		.0550	0.0000	.3070000	62.308	9.751	-12.240	-2.043	1.54995	1.42203	1.057	.048
155		.0550	0.0000	.3384000	63.597	9.987	-11.189	-2.258	1.55009	1.42291	1.060	.067
156	SLQ5.1	.4000	0.0000	.3650000	68.873	12.560	-1.742	-4.297	1.55104	1.42866	1.118	.226
157	SLQ5.2	.4000	0.0000	.3650000	66.278	17.133	8.103	-7.359	1.55197	1.43304	1.242	.397
158		.0550	0.0000	.3384000	65.322	17.970	9.264	-7.870	1.55211	1.43354	1.265	.420
159		.0550	0.0000	.3070000	64.247	18.864	10.276	-8.381	1.55224	1.43401	1.288	.442
160		.0550	0.0000	.2511000	63.074	19.812	11.056	-8.862	1.55238	1.43447	1.313	.460
161		.0550	0.0000	.1675000	61.832	20.810	11.518	-9.275	1.55252	1.43490	1.339	.472
162		.0550	0.0000	.0767000	60.557	21.847	11.655	-9.597	1.55266	1.43531	1.365	.478
163		.0550	0.0000	.0207000	59.278	22.917	11.598	-9.857	1.55281	1.43570	1.391	.479
164	765.1	.4250	0.0000	0.0000000	49.833	32.070	10.627	-11.678	1.55405	1.43819	1.595	.479
165	765PU	.3650	0.0000	0.0000000	42.380	41.166	9.792	-13.241	1.55532	1.43979	1.770	.479
166		.0550	0.0000	-.0209000	41.312	42.632	9.619	-13.428	1.55553	1.44000	1.796	.477
167		.0550	0.0000	-.0771000	40.270	44.112	9.324	-13.675	1.55574	1.44020	1.822	.470
168		.0550	0.0000	-.1685000	39.272	45.584	8.840	-13.280	1.55596	1.44040	1.848	.453
169		.0550	0.0000	-.2526000	38.335	47.021	8.196	-12.841	1.55619	1.44059	1.872	.427
170		.0550	0.0000	-.3088000	37.474	48.399	7.462	-12.213	1.55642	1.44077	1.894	.395
171		.0550	0.0000	-.3404000	36.696	49.701	6.692	-11.452	1.55665	1.44095	1.915	.359
172	SLQ7.1	.1500	0.0000	-.3672000	35.009	52.768	4.583	-8.938	1.55732	1.44141	1.961	.252
173	SLQ7.2	.1500	0.0000	-.3672000	33.931	55.035	2.625	-6.129	1.55801	1.44186	1.991	.143
174		.0550	0.0000	-.3404000	33.678	55.654	1.982	-5.125	1.55827	1.44202	1.998	.106
175		.0550	0.0000	-.3088000	33.491	56.167	1.405	-4.198	1.55853	1.44217	2.002	.072
176		.0550	0.0000	-.2526000	33.363	56.586	.937	-3.430	1.55880	1.44233	2.006	.044
177		.0550	0.0000	-.1685000	33.277	56.935	.626	-2.914	1.55906	1.44248	2.008	.026
178		.0550	0.0000	-.0771000	33.216	57.243	.482	-2.681	1.55932	1.44263	2.009	.017
179		.0550	0.0000	-.0209000	33.165	57.535	.442	-2.622	1.55959	1.44279	2.010	.015
180	765.2	.4569	0.0000	0.0000000	32.768	59.960	.426	-2.665	1.56179	1.44403	2.016	.015
181	AFC3	.6670	0.0000	0.0000000	32.216	63.602	.402	-2.776	1.56506	1.44574	2.026	.015
182	AFQ1	1.5318	0.0000	0.0000000	31.070	72.429	.346	-2.986	1.57277	1.44934	2.049	.015
183	F763.S2	1.2549	16.4979	-.0394832	32.186	75.416	-1.253	.655	1.57915	1.45201	2.014	-.070
184	F763.S1	1.2549	16.4979	-.0394832	37.625	60.277	-3.170	4.136	1.58195	1.45475	1.876	-.150
185	761.1	.9543	0.0000	0.0000000	43.944	61.621	-3.451	3.887	1.58869	1.45707	1.733	-.150
186	P761	.6087	0.0000	0.0000000	48.253	56.987	-3.629	3.727	1.59079	1.45871	1.641	-.150
187	D759.S2	1.2521	16.4742	.0379240	54.611	51.152	-1.347	1.024	1.59463	1.46243	1.511	-.059
188	D759.S1	1.2521	16.4742	.0379240	54.732	51.650	1.252	-1.430	1.59824	1.46635	1.492	.028
189	757.1	.5318	0.0000	0.0000000	53.414	53.188	1.227	-1.461	1.59981	1.46796	1.507	.028
190	SLQ9	.3850	0.0000	-.0452200	52.831	53.961	.291	-.542	1.60096	1.46911	1.512	.002
191	757.2	.1753	0.0000	0.0000000	52.730	54.152	.287	-.547	1.60149	1.46962	1.513	.002
192	SCR757	.2844	0.0000	0.0000000	52.568	54.465	.281	-.553	1.60235	1.47046	1.513	.002
200	S749	.4314	0.0000	0.0000000	15.454	107.860	.721	2.122	1.65010	1.48689	2.277	.001
201	749.2	1.1608	0.0000	0.0000000	13.914	103.002	.606	2.063	1.66279	1.48865	2.279	.001
202	H749B	.5215	0.0000	0.0000000	13.308	100.865	.555	2.036	1.66889	1.48946	2.280	.001
203	Q16.1	.3850	0.0000	-.0020600	12.899	99.274	.507	2.095	1.67357	1.49007	2.280	-.000
222	SEP301	3.4080	0.0000	0.0000000	15.985	13.300	-.113	-1.012	1.96072	1.86199	2.272	-.000
223	SEP302	3.3960	0.0000	0.0000000	17.485	21.934	-.328	-1.528	1.99327	1.89384	2.272	-.000
224	733.2	.8135	0.0000	0.0000000	18.062	24.521	-.380	-1.652	2.00056	1.89942	2.272	-.000
225	Q17.1	.3850	0.0000	.0012700	18.360	25.820	-.395	-1.723	2.00392	1.90186	2.272	-.001
242	Q18.1	.3850	0.0000	-.0024900	14.914	111.065	.534	.121	2.10029	1.96924	2.301	-.001
247	FKI717.6	1.9950	0.0000	0.0000000	11.684	110.050	.084	.073	2.16507	1.97677	2.293	-.001
248	FKI717.4	1.9950	0.0000	0.0000000	11.692	109.795	-.088	.055	2.19237	1.97965	2.290	-.001
266	H701* I3	9.0073	0.0000	0.0000000	16.615	7.036	-.318	.272	2.44330	2.17626	2.244	-.001
381	601.2 I6	5.9533	0.0000	0.0000000	18.134	52.889	.283	.823	3.59585	3.49232	2.249	.001
456	501.1 I5	9.7897	0.0000	0.0000000	18.538	56.622	-.159	-.717	4.55532	4.43910	2.242	-.000
569	F403.S1	1.2549	16.4979	-.0394832	21.564	8.943	.751	.626	5.65708	5.62274	2.252	.001
570	401.1	.5879	0.0000	0.0000000	20.706	8.260	.708	.535	5.66151	5.63364	2.253	.001
571	Q14.3	.3850	0.0000	0.0000000	20.171	7.872	.681	.475	5.66451	5.64124	2.253	.001
572	401.2	.9533	7.0300	.0001400	18.936	7.109	.615	.325	5.67227	5.66158	2.257	.008
573	401.3	2.0000	-8.4500	-.0001700	16.778	6.425	.464	.016	5.69017	5.70939	2.264	-.001
574	401.4	.8000	-8.1900	-.0009000	16.090	6.495	.396	-.103	5.69793	5.72915	2.268	-.011
575	401.5	.8000	-9.3100	-.0022400	15.523	6.750	.312	-.216	5.70599	5.74842	2.246	-.024
576	401.6	1.4000	-12.5800	.0013000	14.746	7.677	.242	-.447	5.72073	5.77958	2.206	-.033
577	X305.X4	1.1000	8.7700	.0016400	14.271	8.866	.190	-.635	5.73281	5.80087	2.177	-.020
578	365.1	4.0000	47.2200	-.0001900	13.927	16.429	-.109	-1.255	5.77862	5.85459	2.108	.026
579	365.2	1.0000	1.4200	-.0001600	14.209	19.094	-.178	-1.409	5.78994	5.86358	2.214	.027
580	365.3	3.0004	-25.9100	-.0000100	15.924	28.951	-.393	-1.877	5.82100	5.88394	2.285	.001
581	365.4	.6870	0.0000	0.0000000	16.498	31.604	-.443	-1.984	5.82864	5.88756	2.255	.001
582	F363.S2	1.2549	16.4979	-.0394832	18.816	34.696	-1.442	-.429	5.84011	5.89353	2.197	-.094
657	301.VC I3	1.5412	0.0000	0.0000000	15.915	42.739	-.004	1.787	6.67210	6.50537	2.247	-.000
781	201.2 I2	5.9533	0.0000	0.0000000	14.429	64.801	.038	-1.260	7.86549	7.95093	2.253	.001
870	SOL101.5 I1	.3000	0.0000	0.0000000	13.651	12.857	-.157	-.767	8.81211	8.84406	2.249	-.000

DP/P	COSMU(H)	Q(H)	QPRIME(H)	BETAMAX(H)	COSMU(V)	Q(V)	QPRIME(V)	BETAMAX(V)	XMAX(H)	GAMMA TR.
0.0000	.81633	8.9020	-17.4698	116.5959	.73752	8.8820	-14.8490	68.8728	2.3008	8.9261

DP/P = 0.0000 AVERAGE X = 0.0000 AVERAGE ALPHAP = 1.8829 R.F. GAMMA TR. = 8.9261

Table 4 b

Ring 1 – Summary of the AGS output for the closed orbit at the top of the stack

NO	ELEM	DL/DX	DK/DX	D2K/DX2	BETAV(M)	BETAH(M)	ALPHAV	ALPHAH	MUV/2PI	MUH/2PI	XP/DPP	XP'/DPP
INITIAL					13.358	24.192	-1.976	-.535	.90723	.98893	1.881	-.182
91	H817	0.000	0.000000	0.00000	16.676	25.062	-2.264	-.577	.91558	.99399	1.738	-.182
113	F803.S1	0.000	-.029263	.00182	17.987	98.337	.526	3.753	1.06081	1.04570	2.241	.001
114	801.1	.228	0.000000	0.00000	17.338	93.559	.480	3.654	1.06762	1.04677	2.242	.001
115		0.000	-.017000	0.00000	17.287	93.151	.455	3.759	1.06813	1.04686	2.242	-.002
116		0.000	-.062000	0.00000	17.241	92.715	.374	4.168	1.06864	1.04696	2.241	-.012
117		0.000	-.130000	0.00000	17.210	92.207	.201	5.062	1.06914	1.04705	2.240	-.034
118		0.000	-.175000	0.00000	17.202	91.578	-.054	6.389	1.06965	1.04715	2.237	-.066
119		0.000	-.192000	0.00000	17.225	90.787	-.364	7.986	1.07016	1.04724	2.232	-.105
120		0.000	-.192000	0.00000	17.283	89.813	-.707	9.711	1.07067	1.04734	2.226	-.148
121	SLQ1.1	0.000	-.192000	0.00000	17.699	86.165	-1.734	14.535	1.07204	1.04761	2.194	-.275
122	SLQ1.2	0.000	-.192000	0.00000	18.330	81.142	-2.821	18.855	1.07337	1.04790	2.143	-.390
123		0.000	-.192000	0.00000	18.662	78.996	-3.213	20.164	1.07384	1.04801	2.120	-.440
124		0.000	-.192000	0.00000	19.036	76.717	-3.586	21.249	1.07431	1.04812	2.095	-.477
125		0.000	-.175000	0.00000	19.448	74.337	-3.910	22.012	1.07476	1.04824	2.068	-.507
126		0.000	-.130000	0.00000	19.891	71.897	-4.151	22.356	1.07521	1.04836	2.040	-.527
127		0.000	-.062000	0.00000	20.355	69.441	-4.293	22.285	1.07564	1.04848	2.010	-.535
128		0.000	-.017000	0.00000	20.832	67.007	-4.370	21.972	1.07607	1.04861	1.981	-.538
129	801.2	0.000	0.000000	0.00000	25.500	46.627	-4.858	18.320	1.07956	1.05005	1.709	-.538
130	AFC1	0.000	0.000000	0.00000	30.660	29.944	-5.346	14.669	1.08244	1.05220	1.437	-.538
131		0.000	.016000	0.00000	31.249	28.355	-5.359	14.236	1.08272	1.05250	1.407	-.536
132		0.000	.059000	0.00000	31.833	26.818	-5.261	13.714	1.08300	1.05282	1.378	-.529
133		0.000	.120000	0.00000	32.396	25.345	-4.970	13.065	1.08327	1.05316	1.349	-.516
134		0.000	.163000	0.00000	32.918	23.949	-4.511	12.322	1.08354	1.05351	1.321	-.495
135		0.000	.179000	0.00000	33.382	22.637	-3.918	11.515	1.08380	1.05389	1.295	-.471
136		0.000	.179000	0.00000	33.776	21.410	-3.244	10.775	1.08406	1.05428	1.270	-.444
137	SLQ3.1	0.000	.179000	0.00000	34.166	14.727	2.290	6.293	1.08592	1.05791	1.131	-.251
138	SLQ3.2	0.000	.179000	0.00000	30.271	10.899	7.236	3.482	1.08787	1.06299	1.067	-.075
139		0.000	.179000	0.00000	29.947	10.532	7.749	3.198	1.08817	1.06383	1.053	-.053
140		0.000	.179000	0.00000	28.571	10.194	8.172	2.948	1.08847	1.06465	1.061	-.033
141		0.000	.163000	0.00000	27.655	9.881	8.467	2.744	1.08878	1.06552	1.059	-.017
142		0.000	.120000	0.00000	26.717	9.587	8.597	2.598	1.08910	1.06642	1.059	-.006
143		0.000	.059000	0.00000	25.773	9.306	8.564	2.510	1.08944	1.06735	1.058	-.001
144		0.000	.016000	0.00000	24.838	9.033	8.437	2.455	1.08978	1.06830	1.058	.000
145	801.3	0.000	0.000000	0.00000	20.386	7.733	7.632	2.239	1.09174	1.07358	1.058	.000
146	801PU	0.000	0.000000	0.00000	.422	1.420	.475	.324	1.25049	1.20690	1.059	.000
147	AFM.1	3.700	0.000000	0.00000	.352	1.359	.155	.238	1.29657	1.21951	1.059	.000
148	X765.X8	0.000	0.000000	0.00000	.353	1.316	-.165	.153	1.34702	1.23262	1.059	.000
149	AFM.2	-3.700	0.000000	0.00000	43.831	11.451	-11.243	-2.812	1.55689	1.45236	1.060	.000
160		0.000	.018000	0.00000	45.073	11.763	-11.351	-2.868	1.55708	1.45311	1.060	.001
151		0.000	.067000	0.00000	46.320	12.084	-11.319	-2.962	1.55728	1.45385	1.060	.006
152		0.000	.135000	0.00000	47.549	12.418	-11.031	-3.121	1.55746	1.45456	1.060	.015
153		0.000	.184000	0.00000	48.734	12.779	-10.503	-3.344	1.55764	1.45526	1.062	.030
154		0.000	.202000	0.00000	49.850	13.156	-9.791	-3.617	1.55702	1.45593	1.064	.048
155		0.000	.202000	0.00000	50.882	13.571	-8.958	-3.926	1.55800	1.45659	1.067	.067
156	SLQ5.1	0.000	.202000	0.00000	55.134	17.834	-1.966	-6.935	1.55919	1.46072	1.125	.224
157	SLQ5.2	0.000	.202000	0.00000	53.134	25.102	6.367	-11.585	1.56035	1.46376	1.248	.394
158		0.000	.202000	0.00000	52.383	26.419	7.295	-12.370	1.56052	1.46410	1.270	.417
159		0.000	.202000	0.00000	51.535	27.822	8.106	-13.159	1.56069	1.46442	1.294	.439
160		0.000	.184000	0.00000	50.609	29.311	8.733	-13.907	1.56086	1.46473	1.319	.457
161		0.000	.135000	0.00000	49.628	30.876	9.107	-14.557	1.56103	1.46502	1.344	.469
162		0.000	.067000	0.00000	48.620	32.506	9.220	-15.074	1.56121	1.46530	1.370	.474
163		0.000	.018000	0.00000	47.608	34.187	9.177	-15.499	1.56139	1.46556	1.396	.476
164	765.1	0.000	0.000000	0.00000	40.130	48.636	8.416	-18.498	1.56294	1.46722	1.598	.476
165	765PU	0.000	0.000000	0.00000	34.225	63.079	7.763	-21.073	1.56451	1.46827	1.772	.476
166		0.000	-.018000	0.00000	33.379	65.915	7.626	-21.385	1.56477	1.46840	1.798	.474
167		0.000	-.067000	0.00000	32.553	67.772	7.389	-21.480	1.56503	1.46853	1.824	.466
168		0.000	-.136000	0.00000	31.762	70.120	6.998	-21.199	1.56530	1.46866	1.849	.449
169		0.000	-.185000	0.00000	31.021	72.416	6.477	-20.538	1.56558	1.46878	1.873	.424
170		0.000	-.203000	0.00000	30.341	74.624	5.884	-19.586	1.56587	1.46890	1.896	.392
171		0.000	-.203000	0.00000	29.728	76.715	5.261	-18.428	1.56616	1.46902	1.916	.356
172	SLQ7.1	0.000	-.203000	0.00000	28.410	81.680	3.555	-14.578	1.56698	1.46932	1.962	.251
173	SLQ7.2	0.000	-.203000	0.00000	27.584	85.914	1.966	-10.245	1.56784	1.46960	1.991	.143
174		0.000	-.203000	0.00000	27.396	86.455	1.442	-8.687	1.56815	1.46971	1.998	.106
175		0.000	-.203000	0.00000	27.264	87.332	.970	-7.243	1.56848	1.46981	2.003	.072
176		0.000	-.185000	0.00000	27.178	88.063	.585	-6.041	1.56880	1.46991	2.006	.044
177		0.000	-.136000	0.00000	27.128	88.683	.328	-5.232	1.56912	1.47001	2.008	.026
178		0.000	-.067000	0.00000	27.098	89.238	.209	-4.865	1.56944	1.47010	2.009	.017
179		0.000	-.018000	0.00000	27.077	89.768	.176	-4.776	1.56977	1.47020	2.010	.015
180	765.2	0.000	0.000000	0.00000	26.925	94.188	.158	-4.897	1.57246	1.47099	2.017	.015
181	AFC3	0.000	0.000000	0.00000	26.731	100.838	.133	-5.074	1.57642	1.47208	2.027	.015
182	AFQ1	0.000	0.000000	0.00000	26.413	117.064	.074	-5.480	1.58560	1.47433	2.050	.015
183	F763.S2	-.228	-.029263	.00182	27.938	123.516	-1.314	.397	1.59303	1.47597	2.016	-.069
184	F763.S1	0.000	-.029263	.00182	33.286	115.092	-3.033	6.178	1.59965	1.47763	1.879	-.148
185	761.1	.228	0.000000	0.00000	39.354	103.610	-3.326	5.853	1.60384	1.47902	1.737	-.148
186	P761	0.000	0.000000	0.00000	43.516	96.611	-3.512	5.646	1.60619	1.47999	1.647	-.148
187	D759.S2	.228	.016825	-.02806	49.476	88.392	-1.965	1.090	1.61042	1.48217	1.519	-.058
188	D759.S1	0.000	.016825	-.02806	50.568	90.925	.924	-3.193	1.61435	1.48441	1.501	.029
189	757.1	.228	0.000000	0.00000	49.595	94.356	.904	-3.259	1.61604	1.48532	1.516	.029
190	SLQ9	0.000	0.000000	0.00000	49.228	96.255	.053	-1.661	1.61728	1.48597	1.522	.003
191	757.2	0.000	0.000000	0.00000	49.210	96.838	.049	-1.668	1.61785	1.48626	1.523	.003
192	SCR757	0.000	0.000000	0.00000	49.184	97.790	.043	-1.679	1.61877	1.48672	1.523	.003
200	S749	0.000	-.150000	0.00000	16.435	208.806	.512	4.032	1.66668	1.49553	2.293	-.001
201	749.2	0.000	0.000000	0.00000	15.349	199.555	.423	3.936	1.67832	1.49644	2.292	-.001
202	H749B	0.000	0.000000	0.00000	14.929	195.472	.383	3.893	1.68381	1.49686	2.292	-.001
203	QT6.1	0.000	0.000000	0.00000	14.649	192.429	.342	4.011	1.68795	1.49717	2.291	-.003
222	SEP301	0.000	0.000000	0.00000	12.756	14.443	.081	-1.785	1.94637	1.91338	2.229	.000
223	SEP302	0.000	0.000000	0.00000	13.117	29.912	-.187	-2.770	1.98865	1.93950	2.229	.000
224	733.2	0.000	0.000000	0.00000	13.479	34.610	-.251	-3.006	1.99840	1.94353	2.230	.000
225	QT7.1	0.000	0.000000	0.00000	13.677	36.974	-.275	-3.135	2.00291	1.94524	2.230	.001
242	QT8.1	0.000	0.000000	0.00000	13.303	210.694	.243	-.227	2.12475	1.98553	2.301	.001
247	FKI717.6	0.000	0.000000	0.00000	12.938	213.202	-.173	-.253	2.18995	1.98945	2.307	.001
248	FKI717.4	0.000	0.000000	0.00000	13.946	214.231	-.332	-.263	2.21367	1.99094	2.309	.001
266	H701* I7	0.000	0.000000	0.00000	14.252	4.218	-.027	.510	2.42828	2.15996	2.245	-.001
381	601.2 I6	0.000	0.000000	0.00000	14.778	105.060	.016	1.739	3.63084	3.49648	2.250	.002
456	501.1 I5	.228	0.000000	0.00000	14.058	102.413	-.142	-1.934	4.58400	4.47229	2.240	-.000
569	F403.S1	0.000	-.029263	.00182	20.512	14.258	.537	1.817	5.70861	5.56388	2.260	.001
570	401.1	.228	0.000000	0.00000	19.902	12.226	.501	1.640	5.71325	5.57097	2.260	.001
571	QT4.3	0.000	0.000000	0.00000	19.526	11.008	.476	1.524	5.71635	5.57625	2.261	.001
572	401.2	0.000	-.001240	.00714	18.672	8.378	.419	1.235	5.72430	5.59208	2.266	.008
573	401.3	0.000	.000080	.00542	17.258	4.640	.288	.634	5.74207	5.64404	2.273	.001
574	401.4	0.000	-.000430	.01125	16.846	3.817	.227	.395	5.74954	5.67448	2.269	-.010
575	401.5	0.000	-.003180	.02852	16.545	3.374	.189	.158	5.75718	5.71025	2.256	-.032
576	401.6	0.000	.000590	.00087	16.206	3.534	.093	-.273	5.77079	5.77672	2.217	-.019
577	X365.X4	0.000	-.000150	-.00124	16.044	4.510	.054	-.615	5.78166	5.82136	2.189	.025
578	365.1	0.000	-.002100	-.00156	16.650	14.274	-.206	-1.823	5.82104	5.90112	2.201	.026
579	365.2	0.000	-.001370	.00321	17.128	18.219	-.272	-2.122	5.83047	5.91400	2.227	.000
580	365.3	0.000	.001450	.00203	19.324	33.649	-.460	-3.021	5.85684	5.93332	2.267	.000
581	365.4	0.000	0.000000	0.00000	19.986	37.942	-.503	-3.228	5.86240	5.93630	2.267	-.093
582	F363.S2	-.228	-.029263	.00182	22.660	43.873	-1.670	-1.402	5.87189	5.94123	2.208	
657	301.VC I3	0.000	0.000000	0.00000	15.863	69.728	-.131	3.246	6.72865	6.50918	2.266	-.001
781	201.2 I2	0.000	0.000000	0.00000	14.500	111.972	.158	+2.304	7.91228	7.97652	2.252	.000
870	SOL101.S I1	0.000	0.000000	0.00000	14.962	19.496	-.018	-1.928	8.86648	8.92197	2.261	-.001

DP/P	COSMU(H)	Q(H)	QPRIME(H)	BETAMAX(H)	COSMU(V)	Q(V)	QPRIME(V)	BETAMAX(V)	XMAX(H)	GAMMA TR.
.0210	.96035	8.9550	-31.8530	216.7590	.91767	8.9350	-13.8473	55.1337	.0487	8.8834

DP/P = .0210 AVERAGE X = .0399 AVERAGE ALPHAP = 1.9011 R.F. GAMMA TR. = 8.7515

DP/P = .0210 COSMU(H) = .96309 QH = 8.9566 (calcul par option VE)

ISRAGS 151080

Table 4 c

Ring 2 - Summary of the AGS output for the central orbit (linear scheme)

SUP. COND. LOWDETA SCHEME , R2 , I8 , STANDARD SFM , GL WITH END EFFECTS IGRAGE 75.03 24/10/80 17.34.50

CIRCUMFERENCE = 942.63610 1 SUPERPERIODS STRAIGHT MAGNETS ALL VALUES AT EXIT OF ELEMENTS

NO	ELEM	L(M)	ANG(MR)	K(1/M2)	BETAV(M)	BETAH(M)	ALPHAV	ALPHAH	MUV/2PI	MUH/2PI	ALPHAP(M)	ALPHAP'
INITIAL												
114	168.2 I2	5.9512	0.0000	0.0000000	23.528	64.909	.651	1.013	1.04990	1.15204	2.238	.001
					17.918	53.523	.291	.826	1.09670	1.16819	2.243	.001
153	GEP401	3.4080	0.0000	0.0000000	17.032	58.139	-.104	.096	1.57196	1.63994	2.279	-.001
154	GEP402	3.3960	0.0000	0.0000000	17.011	57.688	-.098	.037	1.60303	1.64928	2.277	-.001
155	232.2	.8135	0.0000	0.0000000	17.209	57.639	-.146	.023	1.61150	1.65153	2.276	-.001
156	QT7.1	.3850	0.0000	.0012700	17.327	57.635	-.160	-.012	1.61505	1.65259	2.276	.001
173	QT8.1	.3850	0.0000	-.0022470	11.919	18.937	.428	.761	1.72877	1.76858	2.291	-.002
177	H248	1.3130	0.0000	0.0000000	10.188	14.867	.105	.490	1.77646	1.79962	2.286	-.002
178	FKI248.4	1.9950	0.0000	0.0000000	10.165	13.244	-.093	.324	1.80786	1.82233	2.282	-.002
179	FKI248.6	1.9950	0.0000	0.0000000	10.932	12.285	-.291	.157	1.83816	1.84732	2.279	-.002
199	264.VC I3	1.5422	0.0000	0.0000000	18.509	56.759	-.145	-.727	2.05619	2.11508	2.238	-.000
320	F366.62	1.2549	16.4979	-.0394862	21.287	8.956	.743	.634	3.15882	3.29784	2.249	.001
321	368.1	.5874	0.0000	0.0000000	20.439	8.265	.700	.542	3.16330	3.30871	2.250	.001
322	QT4.2	.3850	0.0000	0.0000000	19.911	7.871	.672	.482	3.16634	3.31631	2.250	.001
323	368.2	.9512	7.0300	.0001400	18.695	7.097	.606	.332	3.17419	3.33662	2.255	.000
324	368.3	2.0000	-8.4500	-.0001700	16.573	6.392	.455	.021	3.19232	3.38460	2.262	-.001
325	368.4	.8000	-8.1900	-.0009000	15.900	6.154	.387	-.100	3.20016	3.40447	2.258	-.011
326	368.5	.8000	-9.3100	-.0022400	15.348	6.704	.303	-.213	3.20852	3.42387	2.249	-.024
327	368.6	1.4000	-12.5800	.0013000	14.600	7.624	.231	-.445	3.22322	3.45525	2.209	-.033
328	X400.X4	1.1000	8.7700	.0016400	14.148	8.809	.179	-.633	3.23541	3.47669	2.175	-.020
329	400.1	4.0000	47.2200	-.0001900	13.898	16.376	-.116	-1.257	3.28147	3.53067	2.187	.026
330	400.2	1.0000	1.4200	-.0001600	14.205	19.046	-.191	-1.412	3.29281	3.53969	2.214	.027
331	400.3	3.0000	-25.9100	-.0000100	16.000	20.929	-.407	-1.883	3.32469	3.56009	2.255	.001
332	400.4	.6896	0.0000	0.0000000	16.596	21.600	-.457	-1.991	3.33143	3.56372	2.256	.001
333	F402.S1	1.2549	16.4979	-.0394862	18.958	34.710	-1.463	-.436	3.34282	3.56969	2.197	-.093
409	464.1 I5	9.7871	0.0000	0.0000000	15.752	43.535	-.008	1.813	4.17445	4.18057	2.242	-.000
526	568.2 I6	5.9512	0.0000	0.0000000	14.591	65.452	.035	+1.287	5.36770	5.62698	2.256	.001
604	H664 I7	9.0122	0.0000	0.0000000	13.792	12.514	-.172	-.754	6.31531	6.51834	2.249	-.000
693	752.1	.7799	0.0000	0.0000000	11.003	13.342	-1.729	.033	7.28011	7.55773	1.873	-.182
694	H752	.7830	0.0000	0.0000000	13.933	13.337	-2.013	-.026	7.29018	7.56707	1.730	-.182
716	F766.S2	1.2549	16.4979	-.0394862	21.795	50.028	.454	1.722	7.43610	7.67187	2.255	.000
717	768.1	.6450	0.0000	0.0000000	21.232	47.839	.418	1.671	7.44087	7.67397	2.255	.000
718		.0550	0.0000	-.0218000	21.188	47.653	.390	1.724	7.44128	7.67415	2.255	-.002
719		.0550	0.0000	-.0806000	21.150	47.452	.293	1.930	7.44170	7.67434	2.254	-.012
720		.0550	0.0000	-.1762000	21.129	47.215	.085	2.382	7.44211	7.67452	2.253	-.034
721		.0550	0.0000	-.2642000	21.137	46.915	-.224	3.056	7.44252	7.67471	2.250	-.067
722		.0550	0.0000	-.3230000	21.183	46.534	-.603	3.871	7.44294	7.67490	2.246	-.107
723		.0550	0.0000	-.3560000	21.272	46.060	-1.023	4.754	7.44335	7.67508	2.239	-.151
724	SLQ2.1	.1500	0.0000	-.3840000	21.767	44.256	-2.288	7.233	7.44446	7.67561	2.226	-.279
725	SLQ2.2	.1500	0.0000	-.3840000	22.652	41.745	-3.632	9.464	7.44554	7.67617	2.155	-.404
726		.0550	0.0000	-.3560000	23.079	40.666	-4.118	10.141	7.44592	7.67638	2.132	-.446
727		.0550	0.0000	-.3230000	23.557	39.519	-4.579	10.703	7.44630	7.67660	2.106	-.484
728		.0550	0.0000	-.2642000	24.082	38.320	-4.980	11.099	7.44666	7.67682	2.079	-.515
729		.0550	0.0000	-.1762000	24.646	37.089	-5.278	11.280	7.44702	7.67706	2.050	-.535
730		.0550	0.0000	-.0806000	25.237	35.850	-5.454	11.249	7.44738	7.67730	2.020	-.544
731		.0550	0.0000	-.0218000	25.842	34.621	-5.552	11.095	7.44772	7.67754	1.990	-.546
732	768.2	.5058	0.0000	0.0000000	31.773	24.314	-6.175	9.282	7.45053	7.68032	1.714	-.546
733	AFC2	.5057	0.0000	0.0000000	38.333	15.844	-6.798	7.469	7.45283	7.68442	1.438	-.546
734		.0550	0.0000	.0233000	39.082	15.034	-6.815	7.253	7.45306	7.68499	1.408	-.549
735		.0550	0.0000	.0861000	39.825	14.251	-6.693	6.989	7.45328	7.68559	1.378	-.538
736		.0550	0.0000	.1862000	40.592	13.500	-6.337	6.657	7.45350	7.68622	1.349	-.523
737		.0550	0.0000	.2821000	41.207	12.789	-5.753	6.274	7.45373	7.68688	1.321	-.505
738		.0550	0.0000	.3448000	41.799	12.121	-5.006	5.871	7.45393	7.68759	1.294	-.478
739	SLQ4.1	.4000	0.0000	.3801000	42.303	11.498	-4.155	5.470	7.45413	7.68833	1.268	-.451
740	SLQ4.2	.4000	0.0000	.4100000	42.837	8.139	2.851	3.111	7.45501	7.69198	1.128	-.256
741		.0550	0.0000	.4100000	37.938	6.300	9.125	1.586	7.45717	7.70397	1.061	-.077
742		.0550	0.0000	.3801000	36.898	6.135	9.775	1.427	7.45741	7.70538	1.058	-.055
743		.0550	0.0000	.3448000	35.793	5.986	10.310	1.286	7.45765	7.70683	1.055	-.035
744		.0550	0.0000	.2821000	34.639	5.850	10.683	1.171	7.45790	7.70831	1.054	-.019
745		.0550	0.0000	.1882000	33.459	5.726	10.846	1.090	7.45815	7.70982	1.053	-.008
746		.0550	0.0000	.0861000	32.263	5.609	10.804	1.042	7.45842	7.71136	1.053	-.003
747	768.3	.2770	0.0000	.0233000	31.084	5.496	10.643	1.015	7.45870	7.71294	1.053	-.001
748	768PU	2.4601	0.0000	0.0000000	25.470	4.962	9.625	.912	7.46026	7.72139	1.052	-.001
749	AFM.1	.1100	0.0000	0.0000000	.364	2.708	.581	.004	7.61007	7.83848	1.049	-.001
750	X800.X8	.1100	0.0000	0.0000000	.280	2.712	.176	-.037	7.66603	7.84494	1.049	-.001
751	AFM.2	3.8139	0.0000	0.0000000	.286	2.729	-.228	-.077	7.72950	7.85138	1.049	-.001
752		.0550	0.0000	.0207000	55.502	8.686	-14.249	-1.486	7.93264	7.99481	1.043	-.001
753		.0550	0.0000	.0767000	57.077	8.851	-14.387	-1.516	7.93279	7.99581	1.043	-.000
754		.0550	0.0000	.1676000	58.657	9.021	-14.339	-1.575	7.93294	7.99679	1.043	.004
755		.0550	0.0000	.2512000	60.215	9.200	-13.978	-1.681	7.93309	7.99775	1.044	.014
756		.0550	0.0000	.3071000	61.716	9.393	-13.305	-1.833	7.93323	7.99869	1.045	.028
757		.0550	0.0000	.3384000	63.130	9.605	-12.397	-2.021	7.93337	7.99961	1.047	.046
758	SLQ6.1	.4000	0.0000	.3651000	64.435	9.839	-11.332	-2.233	7.93351	8.00051	1.050	.065
759	SLQ6.2	.4000	0.0000	.3651000	69.776	12.381	-1.758	-4.246	7.93445	8.00634	1.107	.222
760		.0550	0.0000	.3384000	67.140	16.900	8.219	-7.270	7.93587	8.01078	1.229	.392
761		.0550	0.0000	.3071000	66.171	17.727	9.394	-7.775	7.93550	8.01129	1.252	.415
762		.0550	0.0000	.2512000	65.081	18.609	10.420	-8.279	7.93564	8.01177	1.275	.436
763		.0550	0.0000	.1676000	63.891	19.546	11.210	-8.755	7.93577	8.01223	1.299	.454
764		.0550	0.0000	.0767000	62.632	20.531	11.679	-9.163	7.93591	8.01267	1.325	.466
765		.0550	0.0000	.0207000	61.339	21.557	11.817	-9.481	7.93605	8.01308	1.351	.472
766	800.1	.4250	0.0000	0.0000000	60.043	22.614	11.759	-9.739	7.93620	8.01348	1.377	.473
767	800PU	.3650	0.0000	0.0000000	50.466	31.657	10.773	-11.540	7.93743	8.01601	1.578	.473
768		.0550	0.0000	-.0209000	42.911	40.646	9.926	-13.087	7.93867	8.01763	1.751	.473
769		.0550	0.0000	-.0770000	41.823	42.096	9.751	-13.272	7.93888	8.01784	1.777	.471
770		.0550	0.0000	-.1662000	40.773	43.559	9.452	-13.319	7.93909	8.01804	1.802	.469
771		.0550	0.0000	-.2522000	39.760	45.013	8.962	-13.128	7.93931	8.01824	1.827	.447
772		.0550	0.0000	-.3083000	38.810	46.434	8.312	-12.695	7.93953	8.01843	1.851	.422
773		.0550	0.0000	-.3398000	37.937	47.797	7.569	-12.077	7.93976	8.01862	1.873	.390
774	SLQ8.1	.1500	0.0000	-.3666000	37.148	49.084	6.791	-11.328	7.93999	8.01880	1.894	.355
775	SLQ8.2	.1500	0.0000	-.3666000	35.435	52.120	4.658	-8.850	7.94065	8.01927	1.939	.249
776		.0550	0.0000	-.3398000	34.338	54.365	2.679	-6.081	7.94134	8.01972	1.969	.142
777		.0550	0.0000	-.3083000	34.079	55.980	2.029	-5.092	7.94159	8.01988	1.975	.105
778		.0550	0.0000	-.2522000	33.888	55.490	1.446	-4.178	7.94185	8.02003	1.980	.071
779		.0550	0.0000	-.1682000	33.755	55.908	.973	-3.420	7.94211	8.02019	1.983	.044
780		.0550	0.0000	-.0770000	33.665	56.257	.659	-2.912	7.94237	8.02035	1.985	.025
781		.0550	0.0000	-.0209000	33.600	56.564	.514	-2.602	7.94263	8.02050	1.986	.017
782	800.2	.4623	0.0000	0.0000000	33.546	56.856	.474	-2.625	7.94289	8.02066	1.987	.015
783	AFC4	.6670	0.0000	0.0000000	33.116	59.312	.457	-2.689	7.94510	8.02192	1.994	.015
784	AFQ2	1.5264	0.0000	0.0000000	32.523	62.961	.432	-2.781	7.94833	8.02366	2.004	.015
785	F802.S1	1.2549	16.4979	-.0394862	31.288	71.775	.377	-2.993	7.95595	8.02728	2.027	.015
786	F802.S2	1.2549	16.4979	-.0394862	32.340	74.821	-1.231	.616	7.96230	8.02997	1.993	-.069
787	804.1	.6059	0.0000	0.0000000	37.728	66.812	-3.151	4.074	7.96808	8.03273	1.856	-.148
788	P804	.9570	0.0000	0.0000000	41.653	63.968	-3.326	3.919	7.97051	8.03418	1.766	-.148
789	D806.S1	1.2521	16.4742	.0379247	48.285	56.701	-3.604	3.674	7.97391	8.03671	1.625	-.148
790	D806.S2	1.2521	16.4742	.0379247	54.572	50.979	-1.317	.986	7.97775	8.04045	1.496	-.058
791	808.1	.8422	0.0000	0.0000000	54.623	51.563	1.277	-1.462	7.98136	8.04338	1.478	.029
792	SLQ10	.3850	0.0000	-.0467000	52.506	54.070	1.237	-1.514	7.98387	8.04542	1.503	.029
793	808.2	.7084	0.0000	0.0000000	51.921	54.865	.287	-.548	7.98504	8.04804	1.508	.002
794	D810.S1	1.2521	16.4742	.0379247	51.525	55.654	.272	-.565	7.98722	8.05008	1.510	.002
795					47.886	60.539	2.576	-3.413	7.99119	8.05355	1.567	.091
800	A16.1	.7327	0.0000	0.0000000	15.784	110.464	.745	2.170	8.03008	8.06419	2.270	.002
801	S816	.4314	0.0000	0.0000000	15.159	108.601	.702	2.198	8.03452	8.06882	2.270	.002
802	B16.2	3.3773	0.0000	0.0000000	11.538	94.682	.370	1.974	8.07561	8.07012	2.276	.002
803	QT6.4	.3850	0.0000	-.0018730	11.271	93.144	.329	2.021	8.08099	8.07078	2.276	-.000
804	B16.3	3.9145	0.0000	0.0000000	10.239	78.159	-.060	1.807	8.14035	8.07808	2.276	-.000
805	H816	4.0935	0.0000	0.0000000	12.373	64.279	-.461	1.584	8.19959	8.08728	2.275	-.000
813	S824	.4314	0.0000	0.0000000	36.845	8.046	-.247	1.272	8.25485	8.14531	1.523	.000
871	SOL864.S I4	.3000	0.0000	0.0000000	16.877	7.027	-.315	.289	8.82652	8.75189	2.246	-.001

DP/P	COSMU(H)	B(H)	BPRIME(H)	BETAMAX(H)	COSMU(V)	B(V)	BPRIME(V)	BETAMAX(V)	XMAX(H)	GAMMA TR.
0.0000	.81634	8.9020	-17.5839	117.6030	.73750	8.8820	-14.8868	69.7756	2.3061	8.9264

DP/P = 0.0000 AVERAGE X = 0.0000 AVERAGE ALPHAP = 1.0028 R.F. GAMMA TR = 8.9264

Table 4 d

Ring 2 – Summary of the AGS output for the closed orbit at the top of the stack

NO	ELEM	DL/DX	DK/DX	D2K/DX2	BETAV(M)	BETAH(M)	ALPHAV	ALPHAH	MUV/2PI	MUH/2PI	XP/DPP	XP**2/DPP
INITIAL					17.796	121.642	.368	1.859	1.06965	1.11636	2.236	.001
114	168.2 I2	0.000	0.000000	0.00000	15.679	100.817	-.012	1.641	1.12762	1.12492	2.295	.001
153	SEP401	0.000	0.000000	0.00000	13.831	108.766	-.113	-.046	1.60456	1.61012	2.273	-.001
154	SEP402	0.000	0.000000	0.00000	15.441	109.184	-.361	-.077	1.64188	1.61508	2.270	-.001
155	232.2	0.000	0.000000	0.00000	16.077	109.315	-.421	-.065	1.61011	1.61627	2.269	-.001
156	QT7.1	0.000	0.000000	0.00000	16.409	109.402	-.441	-.141	1.65388	1.61683	2.269	.000
173	QT8.1	0.000	0.000000	0.00000	15.229	27.509	.452	1.745	1.75452	1.68278	2.286	-.001
177	H248	0.000	0.000000	0.00000	13.125	17.715	.195	1.267	1.79147	1.70632	2.283	-.001
178	FKI248.4	0.000	0.000000	0.00000	11.663	13.246	.037	.973	1.81620	1.72711	2.281	-.001
179	FKI248.6	0.000	0.000000	0.00000	12.830	9.948	-.121	.680	1.84121	1.75491	2.279	-.001
199	264.VC I3	0.000	0.000000	0.00000	14.592	99.167	-.260	-1.749	2.09118	2.09656	2.233	-.000
320	F366.S2	0.000	-.032402	-.00326	23.173	9.315	.603	1.326	3.20368	3.21262	2.247	.001
321	366.1	.228	0.000000	0.00000	22.985	7.859	.569	1.152	3.20778	3.22356	2.248	.001
322	QT9.2	0.000	0.000000	0.00000	22.056	7.015	.546	1.038	3.21053	3.23181	2.248	.001
323	368.2	0.000	-.001240	.00714	21.068	5.308	.493	.756	3.21756	3.25672	2.253	.008
324	368.3	0.000	.000080	.00542	19.344	3.466	.369	.165	3.23335	3.33392	2.260	-.001
325	368.4	0.000	-.000430	.01125	18.800	3.390	.311	-.070	3.24003	3.37141	2.255	-.011
326	368.5	0.000	-.003180	.02852	18.366	3.686	.232	-.300	3.24689	3.40773	2.242	-.024
327	368.6	0.000	.000590	.00087	17.781	5.118	.186	-.723	3.25922	3.45999	2.203	-.032
328	X400.X4	0.000	-.000150	-.00124	17.407	7.081	.154	-1.063	3.26918	3.48924	2.174	-.020
329	400.1	0.000	-.002100	-.00156	17.159	20.328	-.092	-2.245	3.30638	3.54328	2.185	.025
330	400.2	0.000	-.001370	.00321	17.405	25.110	-.154	-2.537	3.31559	3.55033	2.210	.026
331	400.3	0.000	-.001450	.00203	18.860	42.970	-.331	-3.416	3.34207	3.56488	2.249	.000
332	400.4	0.000	0.000000	0.00000	19.344	47.822	-.371	-3.619	3.34782	3.56730	2.249	.000
333	F402.S1	-.228	-.032402	-.00326	21.631	54.074	-1.488	-1.261	3.35769	3.57119	2.190	-.093
400	464.1 I5	.228	0.000000	0.00000	17.709	77.269	-.165	3.492	4.22810	4.13321	2.259	-.001
526	568.2 I6	0.000	0.000000	0.00000	14.182	119.754	.239	-2.375	5.39979	5.60472	2.228	.000
604	MG64 I7	0.000	0.000000	0.00000	14.989	16.158	.018	-1.652	6.36196	6.53870	2.244	-.002
693	752.1	.228	0.000000	0.00000	13.301	23.624	-1.935	-.393	7.33524	7.56888	1.864	-.181
694	H752	0.000	0.000000	0.00000	16.551	24.269	-2.215	-.431	7.34364	7.57409	1.722	-.181
716	F766.S2	0.000	-.032402	-.00326	17.552	86.329	.488	3.469	7.49370	7.62994	2.218	.001
717	768.1	.228	0.000000	0.00000	16.951	81.917	.443	3.372	7.49965	7.63116	2.219	.001
718		0.000	-.017000	0.00000	16.904	81.541	.418	3.463	7.50017	7.63126	2.219	-.002
719		0.000	-.063500	0.00000	16.862	81.141	.339	3.819	7.50069	7.63137	2.219	-.011
720		0.000	-.129000	0.00000	16.834	80.677	.170	4.601	7.50121	7.63148	2.217	-.033
721		0.000	-.175000	0.00000	16.829	80.107	-.080	5.761	7.50173	7.63159	2.215	-.065
722		0.000	-.192000	0.00000	16.855	79.397	-.384	7.158	7.50225	7.63170	2.210	-.104
723		0.000	-.192000	0.00000	16.915	78.526	-.720	8.665	7.50276	7.63181	2.203	-.147
724	SLQ2.1	0.000	-.192000	0.00000	17.282	75.285	-1.728	12.877	7.50416	7.63212	2.172	-.272
725	SLQ2.2	0.000	-.192000	0.00000	17.958	70.845	-2.799	16.643	7.50552	7.63244	2.122	-.394
726		0.000	-.192000	0.00000	18.286	68.951	-3.180	17.781	7.50600	7.63257	2.099	-.435
727		0.000	-.192000	0.00000	18.656	66.942	-3.546	18.723	7.50648	7.63270	2.074	-.472
728		0.000	-.175000	0.00000	19.064	64.846	-3.865	19.384	7.50694	7.63283	2.047	-.502
729		0.000	-.129000	0.00000	19.502	62.697	-4.102	19.678	7.50740	7.63297	2.019	-.521
730		0.000	-.063500	0.00000	19.961	60.536	-4.241	19.609	7.50784	7.63311	1.990	-.530
731		0.000	-.017000	0.00000	20.431	58.394	-4.319	19.330	7.50827	7.63326	1.961	-.532
732	768.2	0.000	0.000000	0.00000	25.046	40.481	-4.805	16.085	7.51183	7.63491	1.692	-.532
733	AFC2	0.000	0.000000	0.00000	30.152	25.654	-5.291	12.840	7.51476	7.63740	1.422	-.532
734		0.000	.016000	0.00000	30.735	24.463	-5.305	12.456	7.51505	7.63775	1.393	-.531
735		0.000	.059000	0.00000	31.313	23.118	-5.209	11.996	7.51533	7.63812	1.364	-.524
736		0.000	.120000	0.00000	31.871	21.830	-4.929	11.426	7.51561	7.63851	1.336	-.510
737		0.000	.163000	0.00000	32.388	20.609	-4.473	10.776	7.51588	7.63892	1.308	-.490
738		0.000	.179000	0.00000	32.848	19.462	-3.889	10.097	7.51615	7.63936	1.282	-.466
739		0.000	.179000	0.00000	33.240	18.388	-3.227	9.425	7.51641	7.63982	1.257	-.440
740	SLQ4.1	0.000	.179000	0.00000	33.651	12.536	2.220	5.520	7.51830	7.64406	1.120	-.249
741	SLQ4.2	0.000	.179000	0.00000	29.842	9.169	7.097	3.081	7.52028	7.65006	1.056	-.074
742		0.000	.179000	0.00000	29.033	8.843	7.603	2.835	7.52058	7.65104	1.052	-.053
743		0.000	.179000	0.00000	28.173	8.543	8.022	2.619	7.52089	7.65204	1.050	-.033
744		0.000	.163000	0.00000	27.275	8.265	8.314	2.441	7.52120	7.65308	1.049	-.017
745		0.000	.120000	0.00000	26.353	8.004	8.443	2.312	7.52153	7.65416	1.048	-.006
746		0.000	.059000	0.00000	25.426	7.754	8.412	2.232	7.52187	7.65527	1.048	-.001
747		0.000	.016000	0.00000	24.507	7.511	8.288	2.180	7.52222	7.65642	1.048	.000
748	768.3	0.000	0.000000	0.00000	20.139	6.362	7.500	1.968	7.52420	7.66280	1.048	.000
749	768PU	0.000	0.000000	0.00000	.441	1.315	.504	.084	7.67877	7.82467	1.048	.000
750	AFM.1	3.700	0.000000	0.00000	.365	1.306	.191	-.000	7.72300	7.83805	1.048	.000
751	X800.X8	0.000	0.000000	0.00000	.357	1.315	-.121	-.085	7.77233	7.85143	1.048	.000
752	AFM.2	-3.700	0.000000	0.00000	42.649	13.102	-10.968	-3.006	7.98864	8.03686	1.048	.000
753		0.000	.018000	0.00000	43.861	13.436	-11.074	-3.063	7.98884	8.03752	1.048	.001
754		0.000	.067000	0.00000	45.078	13.778	-11.039	-3.164	7.98903	8.03816	1.049	.006
755		0.000	.135000	0.00000	46.277	14.136	-10.764	-3.338	7.98923	8.03879	1.049	.015
756		0.000	.184000	0.00000	47.433	14.517	-10.250	-3.584	7.98941	8.03940	1.050	.030
757		0.000	.202000	0.00000	48.523	14.927	-9.559	-3.887	7.98960	8.03999	1.052	.047
758		0.000	.202000	0.00000	49.530	15.374	-8.748	-4.230	7.98977	8.04057	1.056	.066
759	SLQ6.1	0.000	.202000	0.00000	53.692	19.999	-1.455	-7.555	7.99100	8.04424	1.113	.222
760	SLQ6.2	0.000	.202000	0.00000	51.767	27.935	6.176	-12.668	7.99219	8.04696	1.235	.390
761		0.000	.202000	0.00000	51.037	29.375	7.080	-13.529	7.99236	8.04726	1.257	.413
762		0.000	.202000	0.00000	50.215	30.910	7.871	-14.394	7.99254	8.04755	1.280	.434
763		0.000	.184000	0.00000	49.315	32.538	8.483	-15.213	7.99271	8.04783	1.304	.452
764		0.000	.135000	0.00000	48.362	34.250	8.848	-15.922	7.99289	8.04809	1.329	.464
765		0.000	.067000	0.00000	47.382	36.032	8.958	-16.483	7.99307	8.04834	1.355	.469
766		0.000	.018000	0.00000	46.399	37.871	8.917	-16.942	7.99326	8.04858	1.381	.471
767	800.1	0.000	0.000000	0.00000	39.133	53.646	8.179	-20.175	7.99485	8.05008	1.581	.471
768	800PU	0.000	0.000000	0.00000	33.393	69.387	7.546	-22.951	7.99646	8.05103	1.753	.471
769		0.000	-.018000	0.00000	32.571	71.930	7.413	-23.286	7.99672	8.05116	1.779	.469
770		0.000	-.067000	0.00000	31.768	74.497	7.182	-23.382	7.99699	8.05128	1.804	.461
771		0.000	-.137000	0.00000	30.999	77.052	6.802	-23.067	7.99727	8.05139	1.829	.444
772		0.000	-.186000	0.00000	30.279	79.550	6.295	-22.335	7.99756	8.05150	1.853	.419
773		0.000	-.204000	0.00000	29.619	81.949	5.717	-21.284	7.99785	8.05161	1.875	.388
774		0.000	-.204000	0.00000	29.023	84.221	5.111	-20.010	7.99815	8.05172	1.896	.353
775	SL08.1	0.000	-.204000	0.00000	27.743	89.605	3.449	-15.779	7.99899	8.05199	1.941	.248
776	SL08.2	0.000	-.204000	0.00000	26.943	93.637	1.900	-11.026	7.99987	8.05225	1.970	.142
777		0.000	-.204000	0.00000	26.762	94.756	1.389	-9.320	8.00019	8.05234	1.977	.105
778		0.000	-.204000	0.00000	26.634	95.695	.929	-7.738	8.00052	8.05244	1.982	.072
779		0.000	-.186000	0.00000	26.553	96.424	.553	-6.421	8.00085	8.05253	1.985	.044
780		0.000	-.137000	0.00000	26.506	97.131	.302	-5.535	8.00110	8.05262	1.987	.026
781		0.000	-.067000	0.00000	26.479	97.718	.186	-5.133	8.00151	8.05271	1.988	.018
782		0.000	-.018000	0.00000	26.460	98.277	.153	-5.034	8.00184	8.05280	1.989	.015
783	800.2	0.000	0.000000	0.00000	26.327	102.989	.135	-5.158	8.00463	8.05353	1.995	.015
784	AFC4	0.000	0.000000	0.00000	26.163	109.989	.110	-5.337	8.00867	8.05453	2.006	.015
785	AFC2	0.000	0.000000	0.00000	25.919	126.905	.051	-5.746	8.01801	8.05658	2.030	.015
786	F802.S1	-.228	-.032402	-.00326	27.482	133.434	-1.321	.650	8.02557	8.05810	1.997	-.067
787	F802.S2	0.000	-.032402	-.00326	32.829	123.778	-3.026	6.887	8.03229	8.05964	1.862	-.140
788	804.1	.228	0.000000	0.00000	36.610	115.577	-3.214	6.550	8.03507	8.06044	1.774	-.146
789	PE04	0.000	0.000000	0.00000	43.045	103.208	-3.510	6.275	8.03891	8.06184	1.634	-.146
790	D806.S1	.228	.018068	-.02821	49.429	93.790	-1.486	1.397	8.04319	8.06388	1.508	-.056
791	D806.S2	0.000	.018068	-.02821	50.197	95.919	.884	-3.131	8.04715	8.06601	1.491	.030
792	808.1	-.228	0.000000	0.00000	48.733	101.274	.854	-3.226	8.04986	8.06737	1.517	.030
793	SL010	0.000	0.000000	0.00000	48.408	103.078	-.010	-1.450	8.05112	8.06797	1.523	.003
794	808.2	0.000	0.000000	0.00000	48.432	105.148	-.024	-1.472	8.05345	8.06905	1.525	.003
795	D810.S1	.228	.018068	-.02821	45.674	115.446	2.183	-6.917	8.05765	8.07087	1.585	.092
800	816.1	.228	0.000000	0.00000	17.123	216.677	.543	3.888	8.09585	8.07638	2.294	.002
801	S816	0.000	-.050000	0.00000	16.676	213.243	.494	4.073	8.09992	8.07670	2.295	.001
802	816.2	0.000	0.000000	0.00000	14.193	186.674	.242	3.794	8.13514	8.07939	2.299	.001
803	QTG 4	0.000	0.000000	0.00000	14.022	183.714	.203	3.892	8.13949	8.07972	2.299	-.000
804	816.3	0.000	0.000000	0.00000	13.570	154.589	-.088	3.548	8.18528	8.08342	2.297	-.000
805	M816	0.000	0.000000	0.00000	15.531	127.014	-.392	3.188	8.23077	8.08807	2.295	-.000
813	S824	0.000	0.000000	0.00000	39.854	14.163	.038	2.752	8.27788	8.11072	1.538	-.001
871	SOL8G4.S I4	0.000	0.000000	0.00000	13.697	5.888	-.030	.856	8.86142	8.70406	2.230	-.001

DP/P	COSMU(H)	Q(H)	QPRIME(H)	BETAMAX(H)	COSMU(V)	Q(V)	QPRIME(V)	BETAMAX(V)	XMAX(H)	GAMMA TR.
.0210	.96030	8.9550	-31.2766	222.4342	.91772	8.9350	-14.0177	58.5142	.0488	8.8933

DP/P = .0210 AVERAGE X = .0398 AVERAGE ALPHAP = 1.8969 R.F GAMMA TR. = 8.7703

DP/P = .0210 COSMU(H) = .96291 QH = 8.9565 (calcul par option VE)

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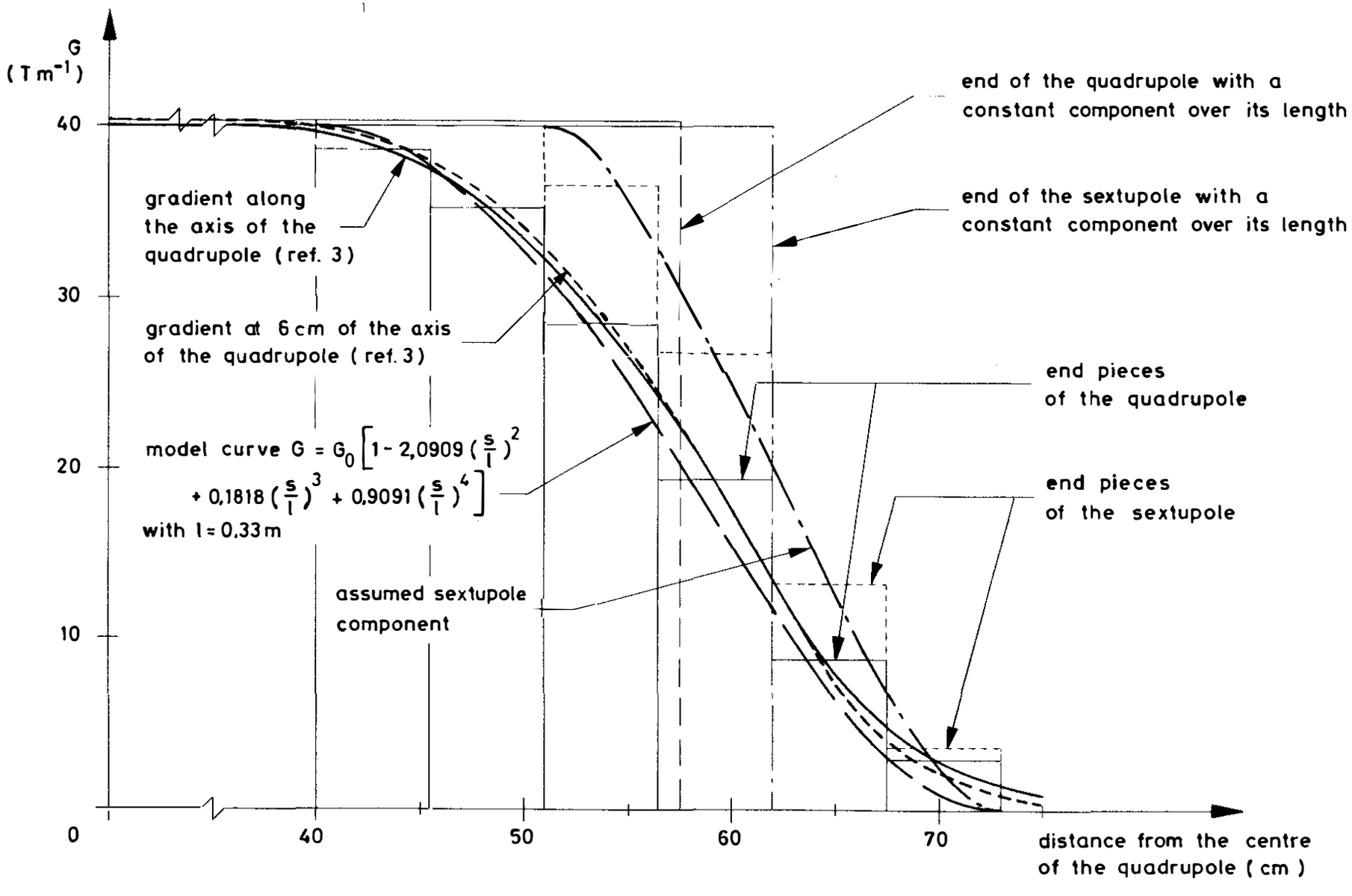


Fig. 1: Longitudinal variation of the gradient (computed Ref. 3, Fig. 11) and of the sextupole component (assumed) at the superconducting quadrupole ends. The step functions used for the AGS description are represented, the details are explained in paragraph 1.2.

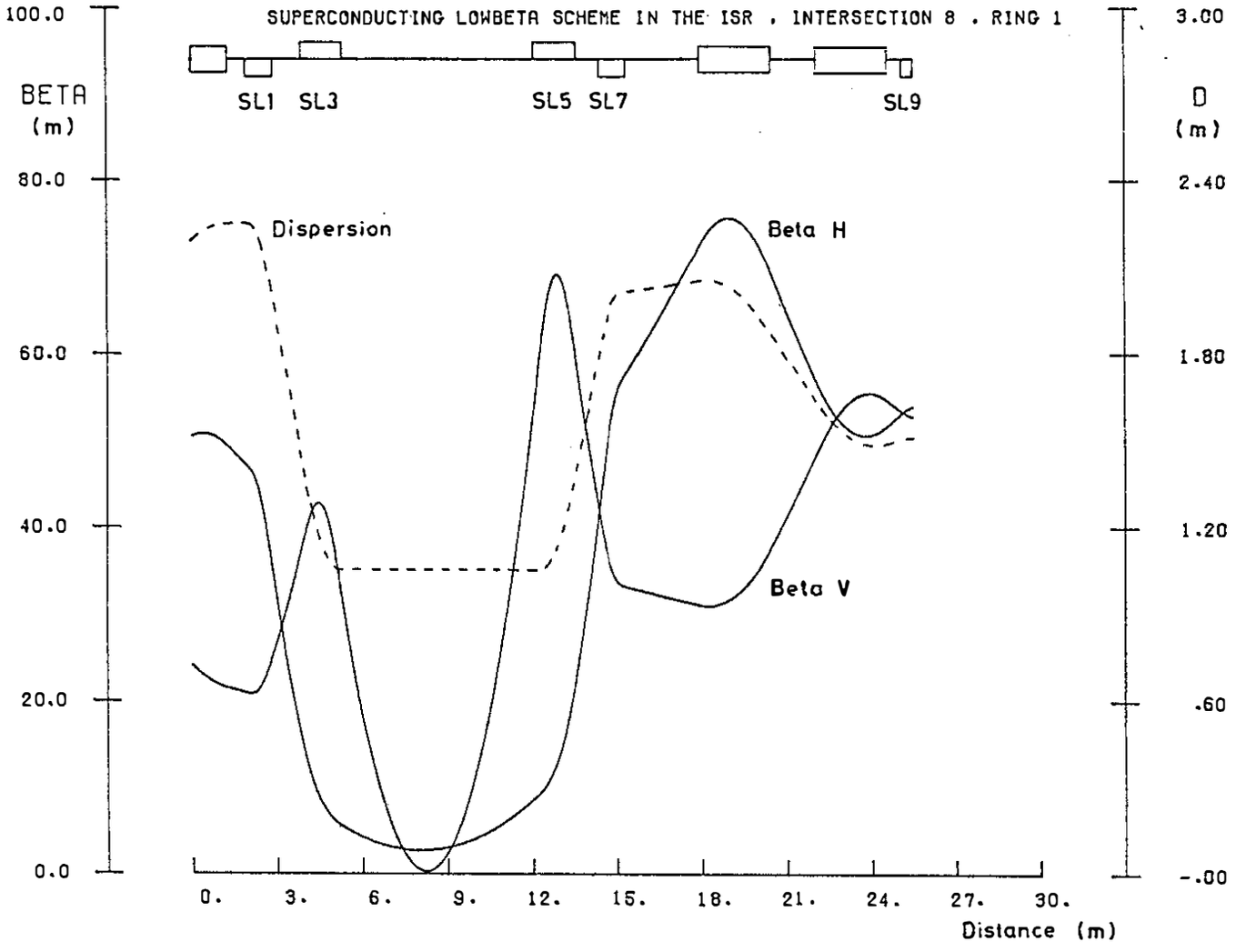
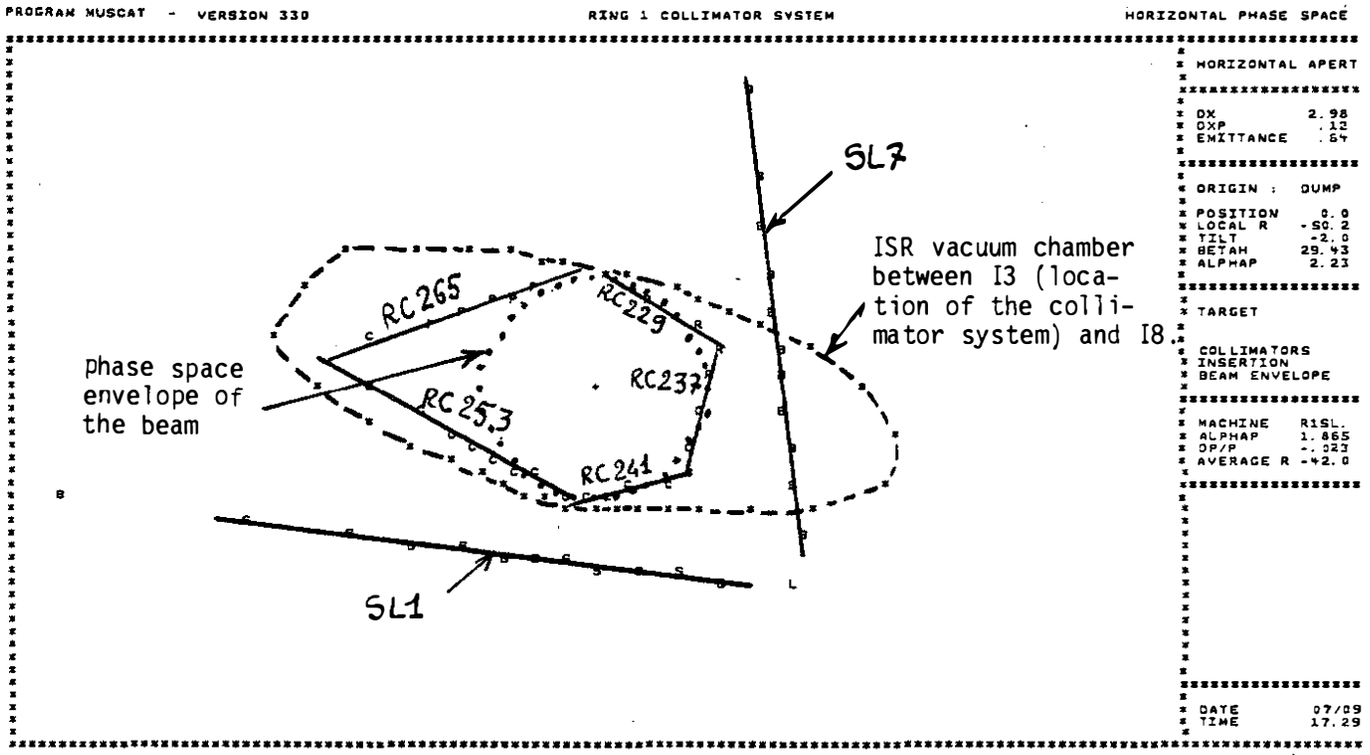
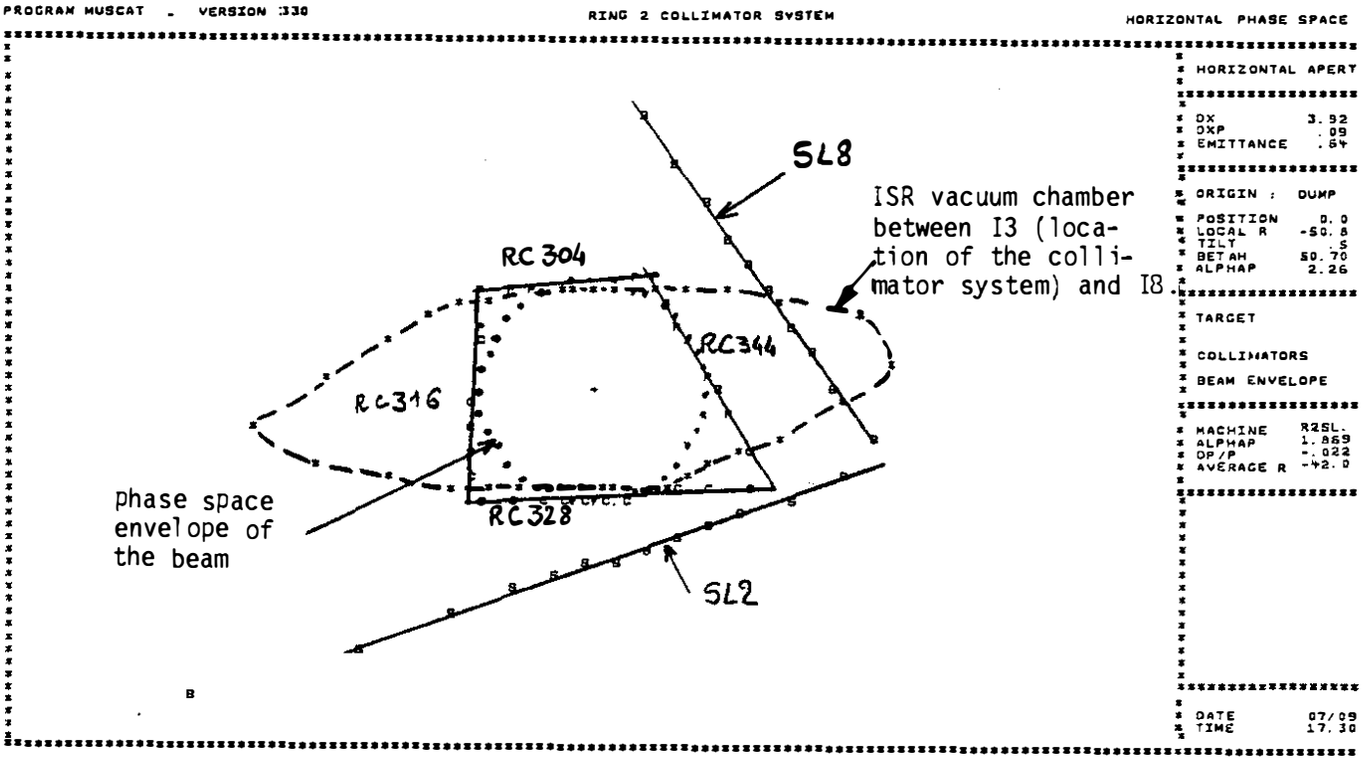


Fig. 2: Beta functions and dispersion inside the superconducting low-β insertion of the ISR in ring 1. SL1, 3, 5, 7 are superconducting quadrupoles, SL9 is a conventional quadrupole. Non referenced magnets are ISR main magnets.



a)



b)

Fig. 3: Phase-space plots on the injection orbit for evaluation of the protection of I8 by the collimator system and the vacuum chamber downstream from it.

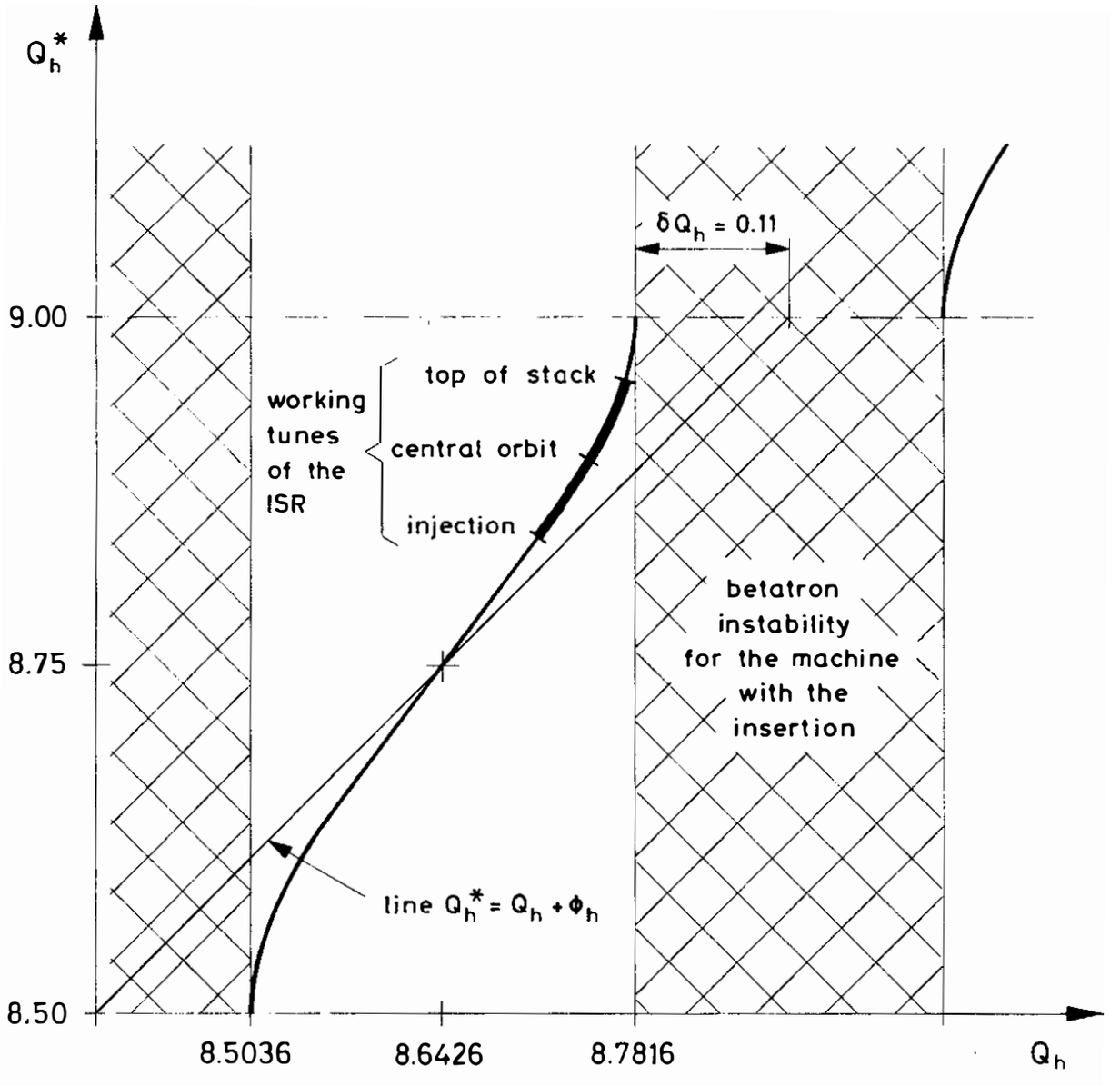


Fig. 4: Horizontal tune of the SL machine Q_h^* as a function of the tune of the base machine Q_h according to the formula

$$\cos 2\pi\, Q_h^* = \cos 2\pi\, (Q_h + \phi_h) \,/\, \cos 2\pi\, \delta\, Q_h .$$

Since Q_h is a smooth function of gradients, this picture shows the gradient stopbands due to the SL insertion.

$$\phi_h = 0.1074 \qquad \delta Q_h = 0.111$$

If the insertion were perfectly matched, δQ_h would be zero and we would have $Q_h^* = Q_h + \phi_h'$.

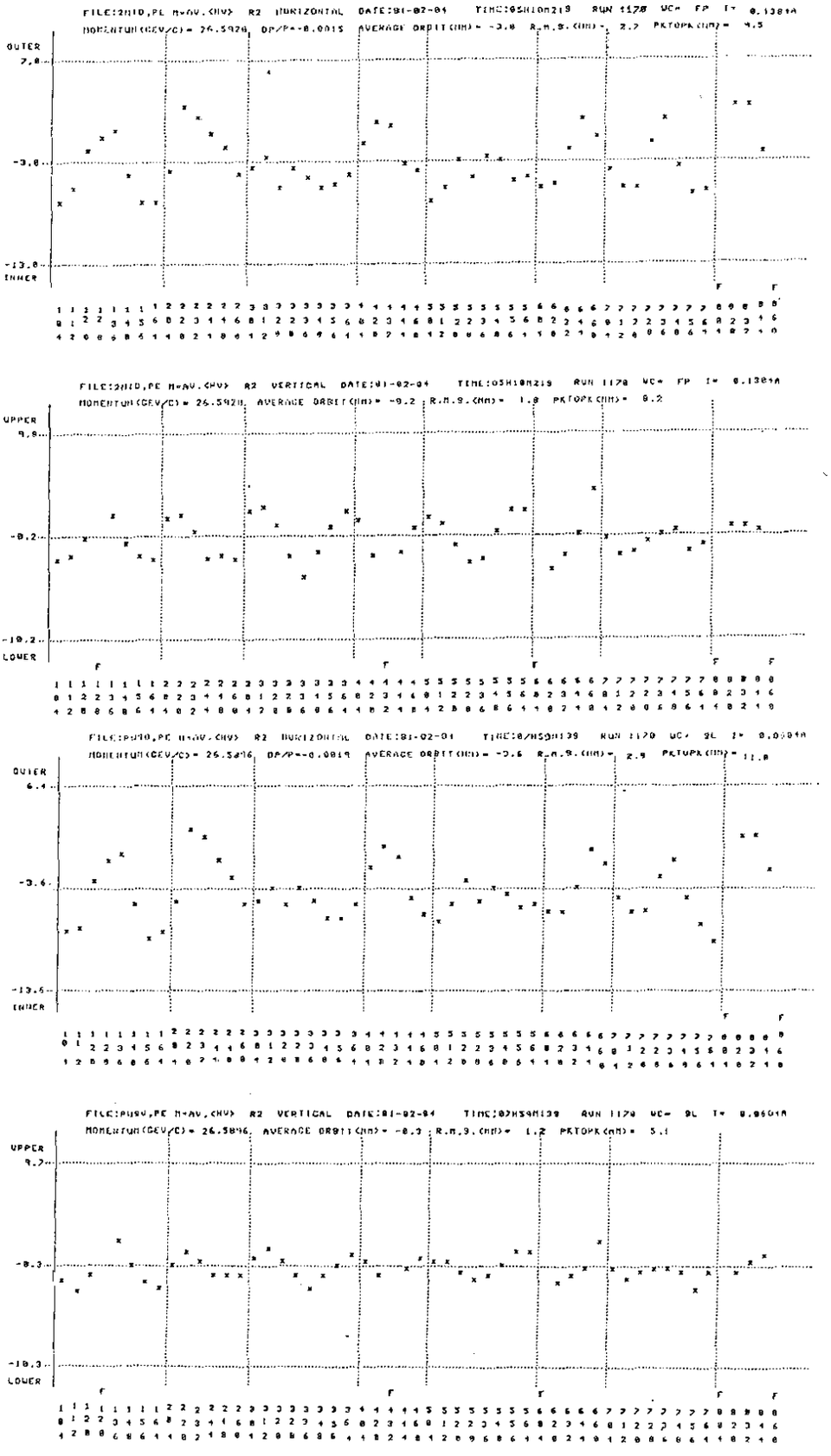


Fig. 5: Measurement of the position of the central closed orbit before turning on the SL insertion i.e. on the BASE machine (two upper plots) and after turning on the SL insertion and making a local compensation by INCO (two lower plots). Explanations in para. 2.5.