GEM TN-93-440

GEM Muon Group Meeting - SSCL

July 12-13, 1993

Abstract;

Agenda, attendees, and presentations of the GEM Muon Group Meeting held at the SSC Laboratory on July 12-13, 1993.

Agenda July 12: Discussion of CSC chamber development

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1. Chamber performance, prototype results and plans

   Discussion (30 min) including:
   Large prototype status - Johnson, Golutvin
   Small prototypes plans - Mitselmakher, Prokofiev
   Electronics for prototypes - Polychronakos, Whitaker, Marlow
   BNL prototype results Balagura, Polychronakos, (30 min)

2. Chamber design

   Johnson - 15 min
   Golutvin - 15 min
   Polychronakos - 15 min
   Lau - 15 min
   Horvath - 15 min
   Discussion - 30 min.

3. Pannel,strip boards and frames prototyping and production prospects

   Johnson - 15 min.
   Pratuch - 10 min.
   Discussion - 20 min.

Agenda July 13: Discussion of alignment and FNAL test beam program

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1. Guidelines for GEM R&D program: goals, $, schedule

   G. Sanders

2. Progress on alignment: axial vs projective vs coverage

   J. Paradiso, A. Korytov, Yu. Gerstein

3. Pros and cons: monolith vs sector - physics considerations

   M. Marx - convenor

4. ATS plans

   C. Wuest

5. Plans for FNAL test beam program

   - scope and schedule
     C. Bromberg, et al.

   - proposal writing discussion/task assignments
     Group

6. Slow control system

   V. Glebov

7. Discussion and plans for next meeting

GEM Muon Meeting July 12, 13
SSCL

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Status of Dubna Prototypes

I. Golutvin

CONTENT:

- 0.3M × 3.0M 4 LAYER PROTOTYPE

- 1.1M × 3.0M 6 LAYER PROTOTYPE
  - LAYOUT
  - FACILITY
  - SCHEDULE

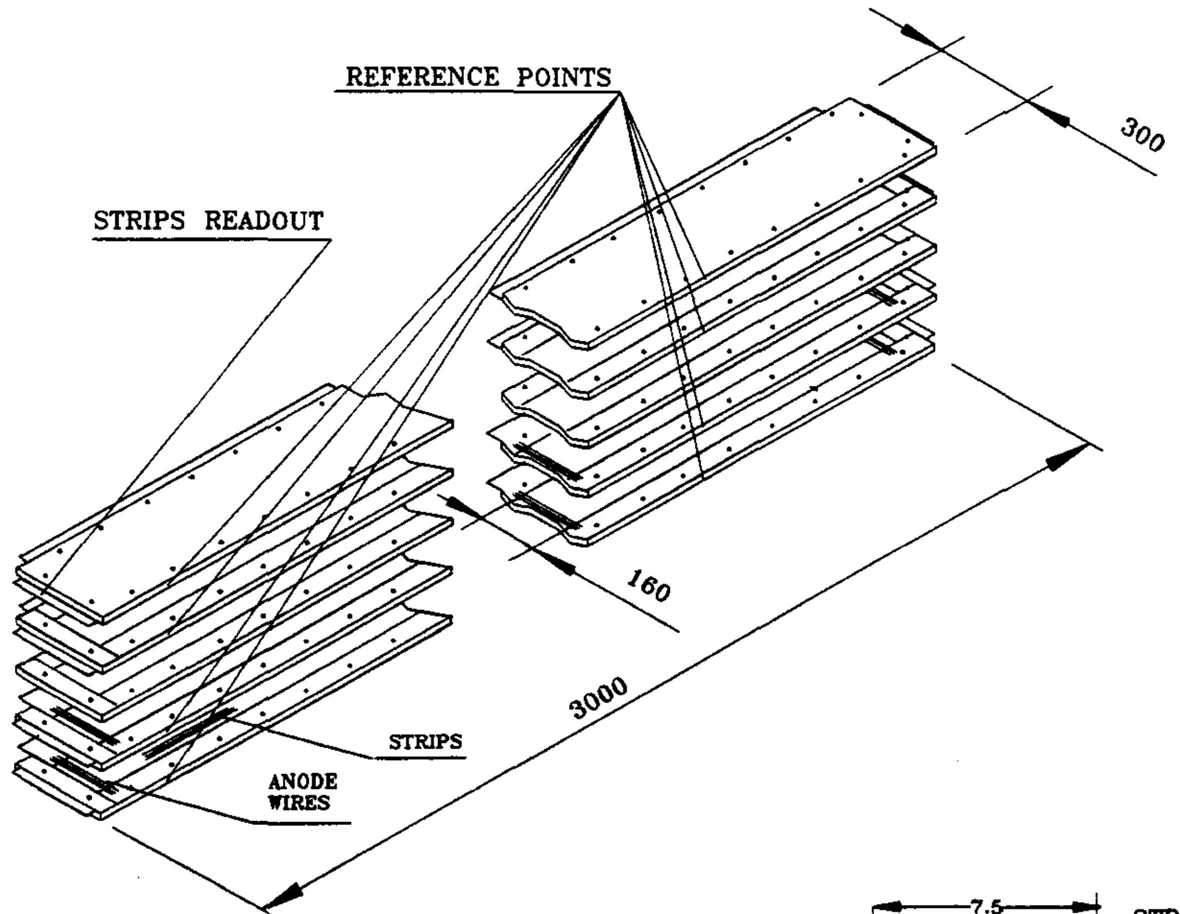
- MASS-PRODUCTION FACILITY DESIGN
  - TOOLS
  - AREA & CLEAN ROOMS

GOAL

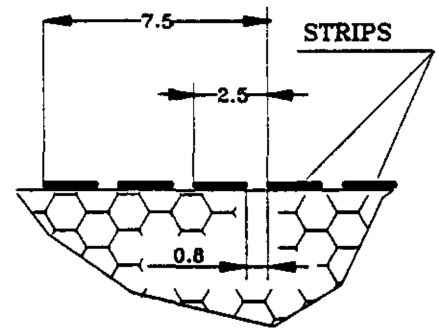
⇓

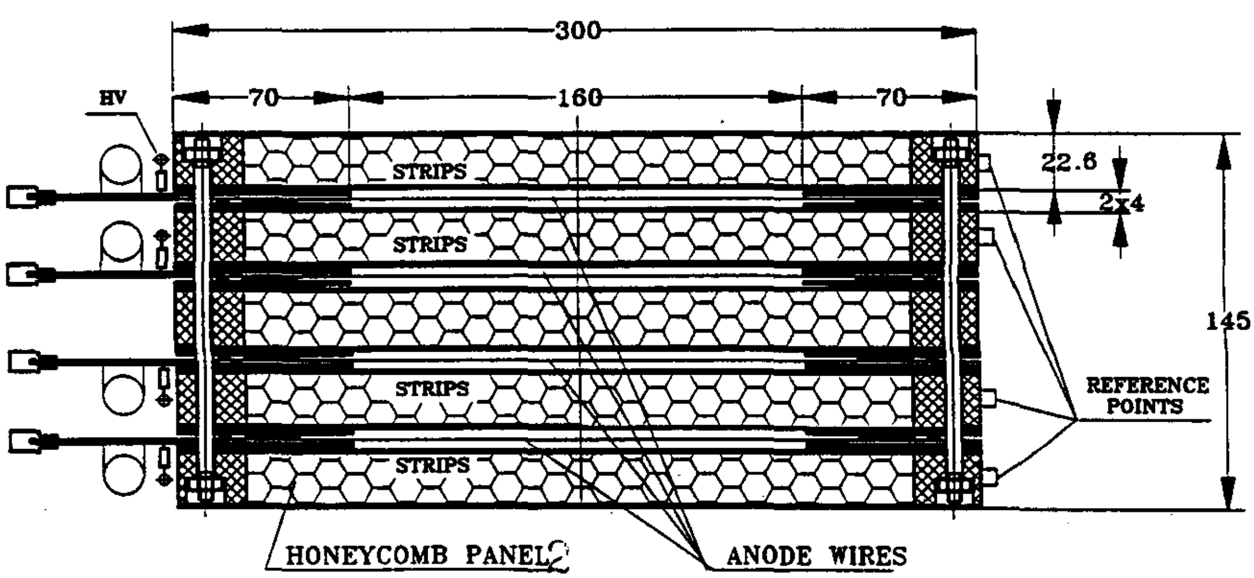
TO DESIGN THE TECHNOLOGY

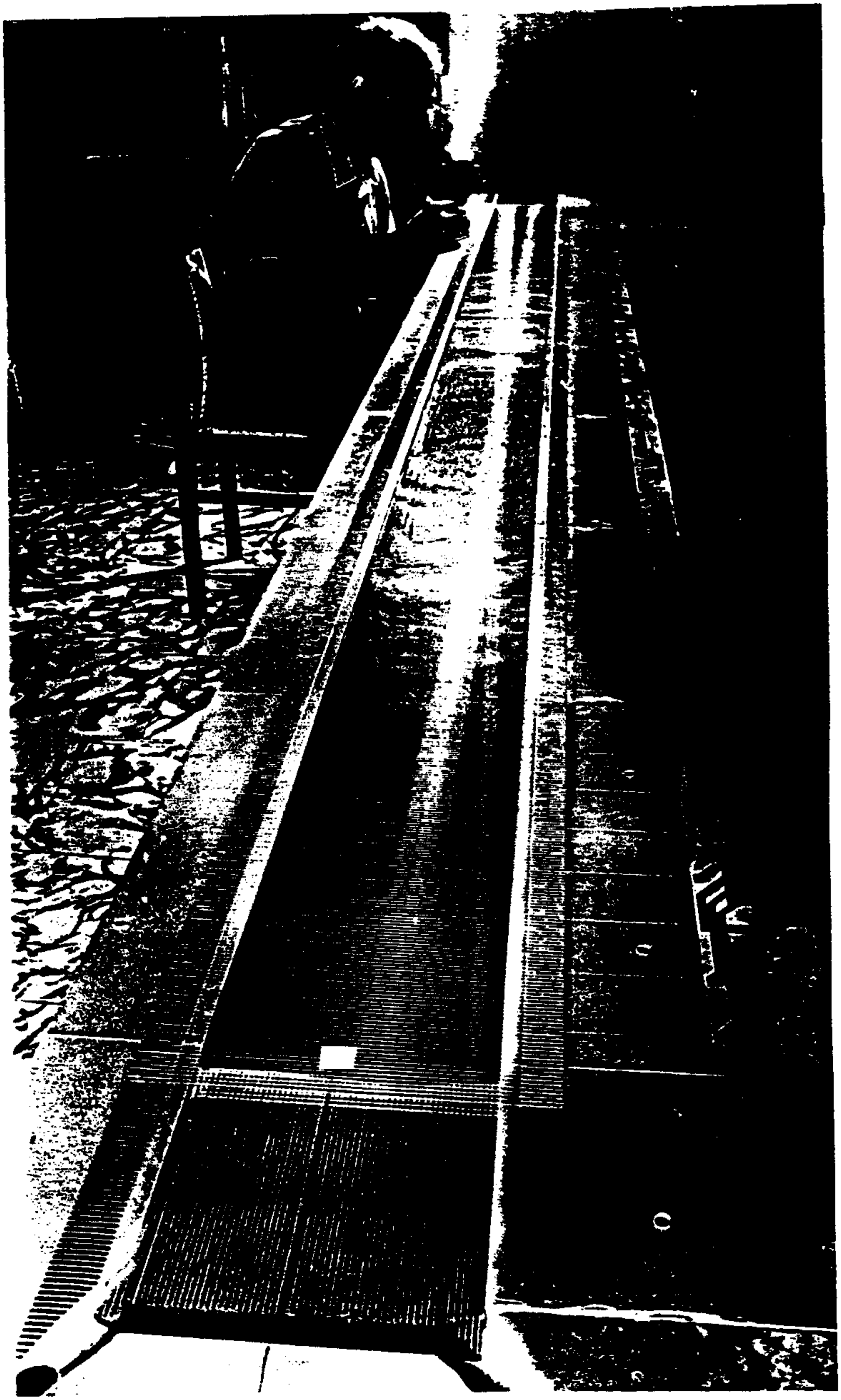
CSC 3m x 0.3m



CROSS SECTION
ALONG THE WIRE







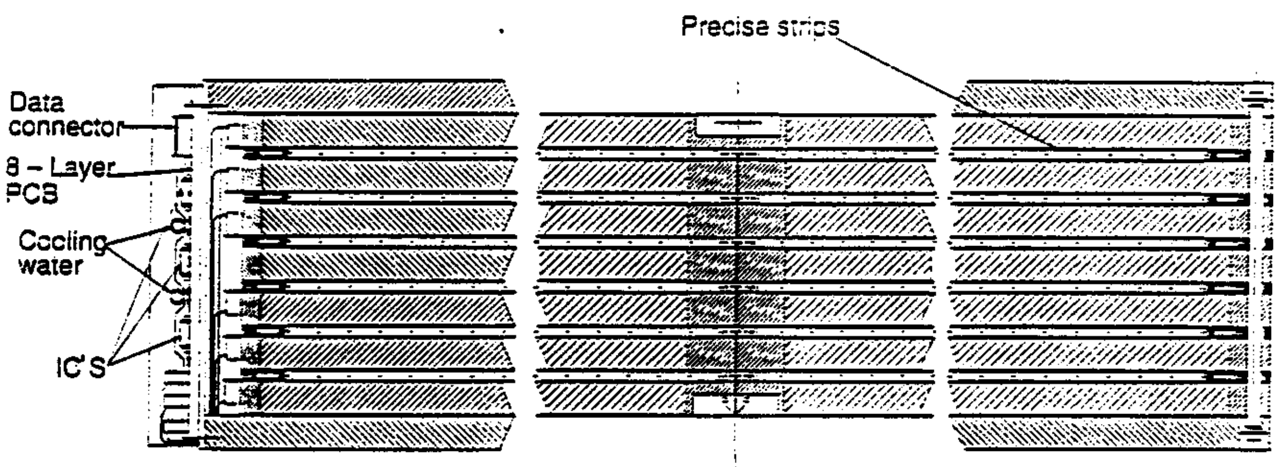
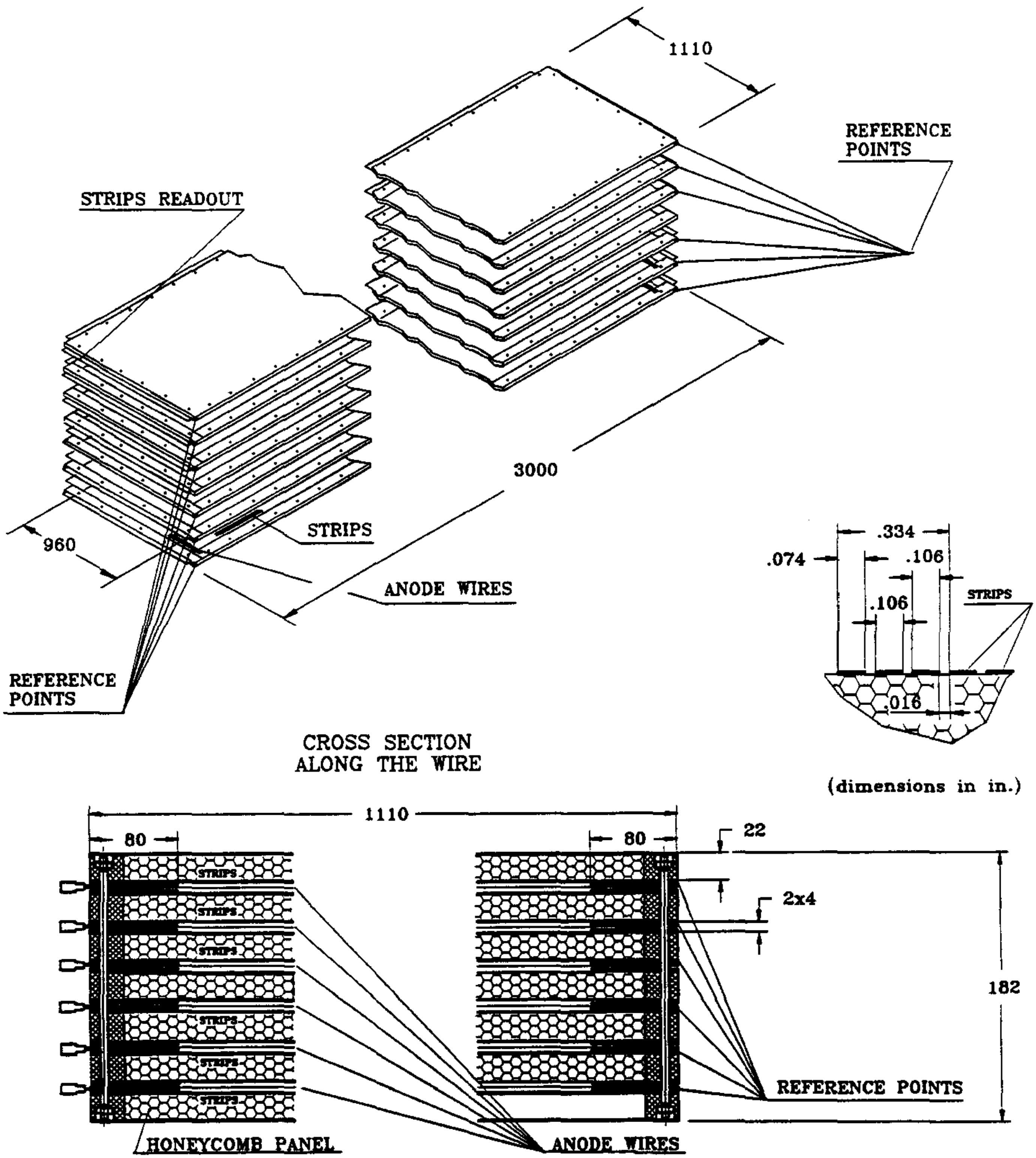


fig4_49

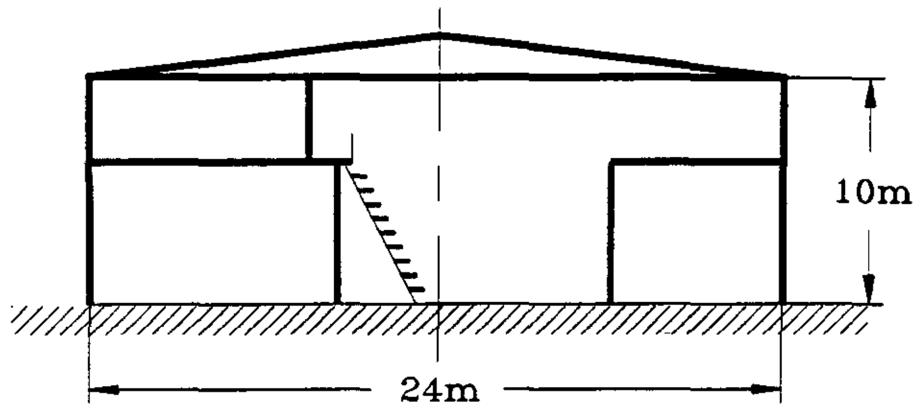
PRECISE STRIP READOUT

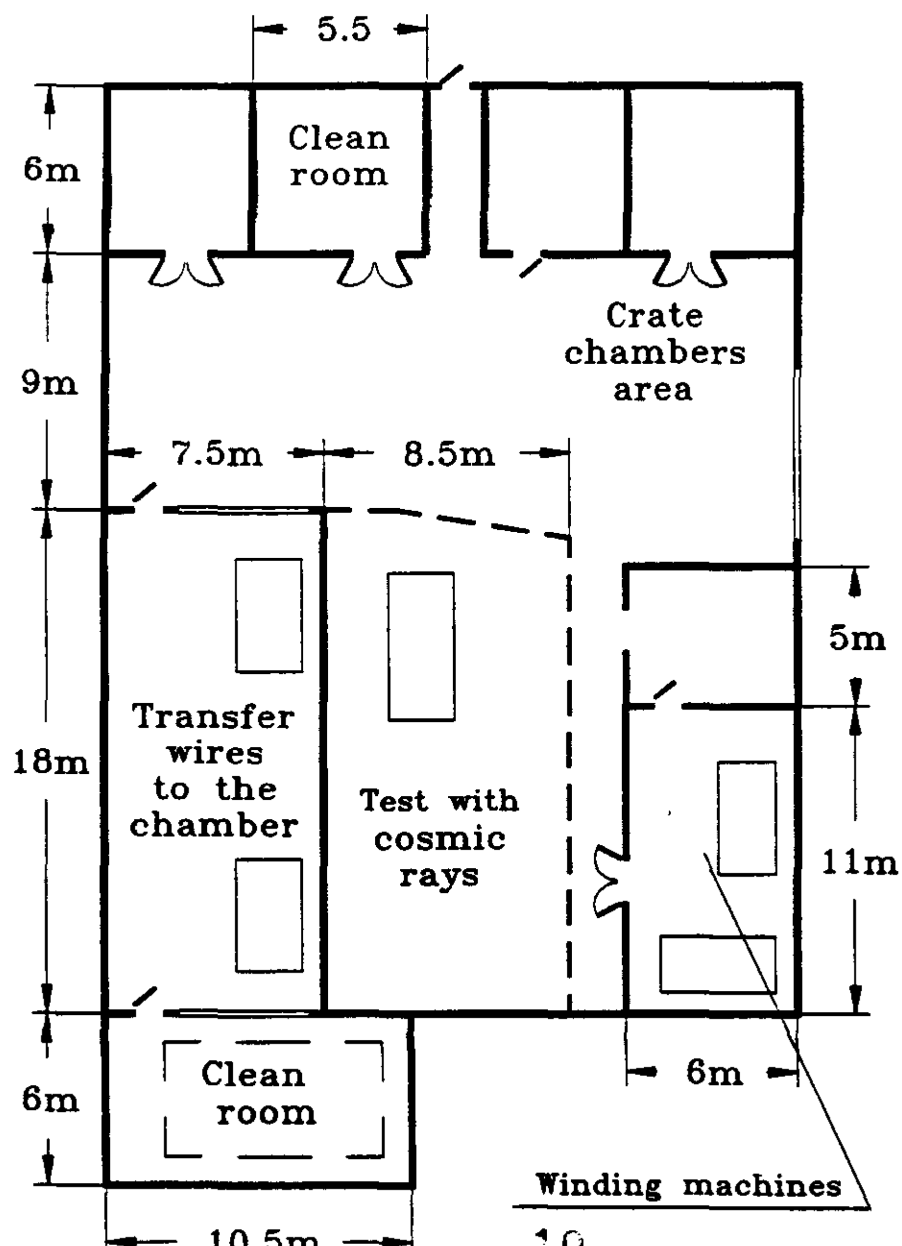
CSC 3m x 1.1m



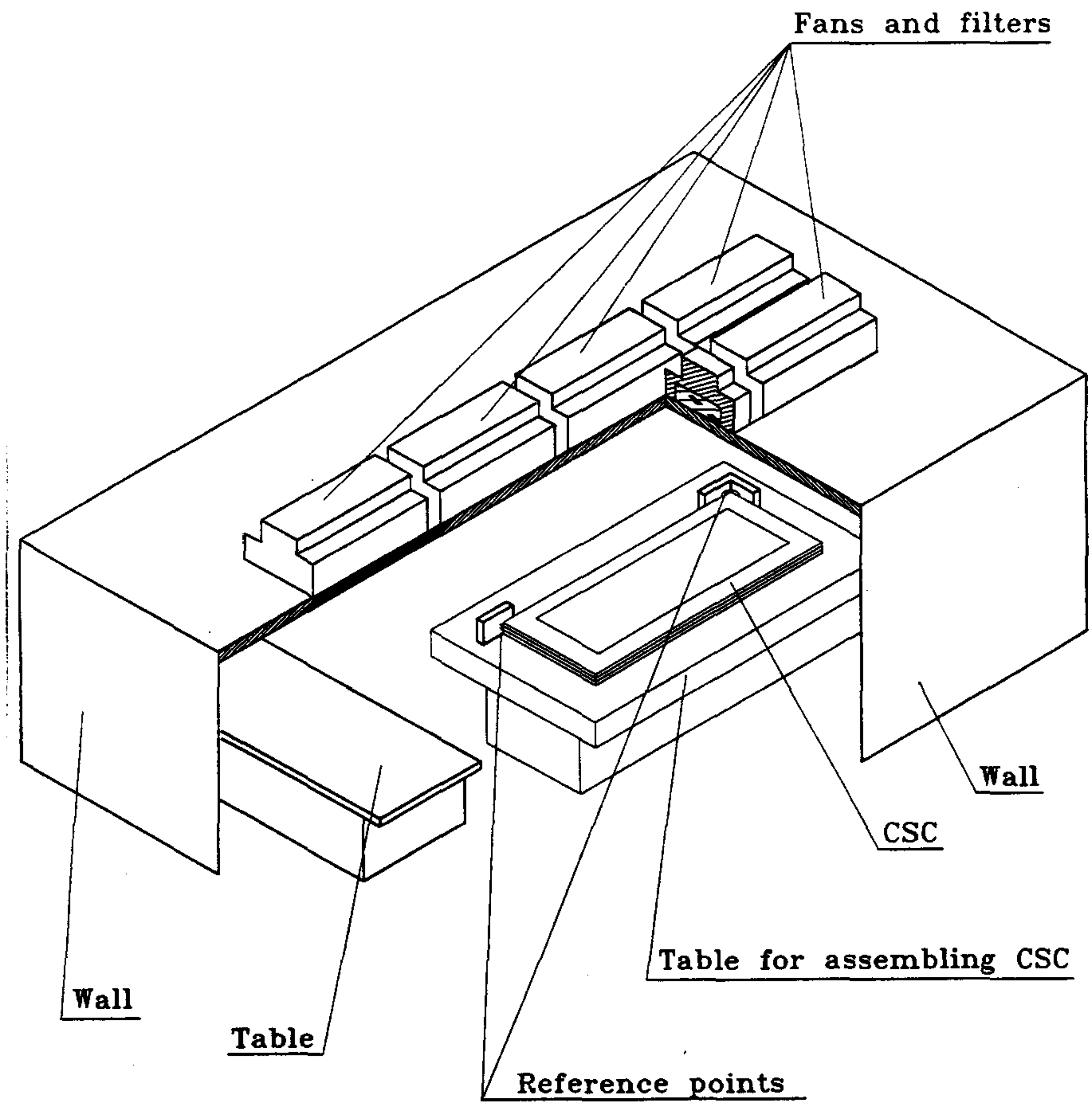
(dimensions in mm)

CSC PROTOTYPES PRODUCTION FACILITY





CLEAN ROOM



T = 20 C
HUMIDITY = 60%
AIR RATE CLEAN =10 000 dust part./cu.ft

CSC PROTOTYPE MILESTONES

* 1.	Panels preprocessing	**June 1993**
* 2.	Materials from SSCL received	**June 1993**
3.	Panels processing, precise gauges mounting, stripped boards gluing	2 August 1993
4.	Getting bars ready for gluing	13 August 1993
5.	Glue bars to panels	15 August 1993
6.	Drill holes	16 August 1993
* 7.	Test assembly of the panels	**17 August 1993**
8.	Assemble spacers and gas outlets	24 August 1993
9.	Cover strips with resistive mater.	25 August 1993
10.	Install anode wires	1 September 1993
11.	Mount Capacitors, resistors, connectors	2 September 1993
*12.	Assembled planes acceptance check	**3 September 1993**
13.	Get planes ready to assemble, clean	4 September 1993
*14.	Assemble chamber	**5 September 1993**
15.	Mount exterior parts	8 September 1993
*16.	Final test	**9-13 September 1993**
*17.	Packing	**14 September 1993**

Steps 4-6, 8-9, 10-13 go in parallel for all planes.
Key operations are shown in bold.

WHAT IS STILL NEEDED TO COMPLETE THE TASK?

- PARTS SHIPMENT EXPENSES
  SSC → DUBNA
- PROTOTYPE SHIPMENT EXPENSES
  DUBNA → SSC
- TRAVEL EXPENSES (CRUCIAL)

★ ELECTRONICS !!!

Appendix 1

From se.jinr.dubna.su POP3 server
Return-Path: <viz>
Received: by SE.jinr.dubna.su (4.1/SMI-4.1)
id AA18506; Tue, 15 Jun 93 17:42:55 MSK
Date: Tue, 15 Jun 93 17:42:55 MSK
From: viz (Victor Zhiltsov)
Message-Id: <9306151342.AA18506@SE.jinr.dubna.su>
To: golutvin@se
Subject: reply to M.Harris from Yu.Kiryshin
Status: RO

Dear Dr Harris,
In reply to your request of Dubna Muon Chamber Prototype Specifications:

>> 1. Facilities description

I. Building #1

- Panels preprocessing area:
  100 sq.m - equipped with two metal tables 4.5 x 2.4 sq.m (0.1mm);
  50 sq.m - equipped with crane, 0.5 tonns;
- wire arrays winding area:
  54 sq.m - equipped with two winding machines, and two tables;
- Clean room: 5.4 x 5.1 = 27.54 sq.m
- chamber testing area:
  54 sq.m - testing equipment for tests with cosmic rays;

* no temperature control;
** no humidity control;

II. Building #2

- Gluing area (two rooms):
  120 sq.m
  47 sq.m - the two room s are equipped with three metal tables 3.4 x 1.7 sq.m (0.3mm), and six wooden service tables;

* no temperature control;
** no humidity control;

In the new CSC fsctory building both temperature and humidity controls will be available.

>> 2. Materials specifications

List of Materials for Full-Scale SSCL-Dubna CSC Prototype:

1. honeycomb panel 7 pc (at Dubna)
2. strip cathodes 6 pc
3. cathode 3m x 1.2m 8 pc
4. G10 frames 48 pc
5. Conductive epoxy for strip cathode 0.5 kg
6. conductive epoxy for wires 2 kg
7. epoxy glue AW106 + AV953 15 kg
8. 5 minutes set epoxy glue (two 0.5 oz tubes) 10 pc
9. 5 hours set epoxy glue (two 2 oz tubes) 10 pc
10. capacitors CERA-MITE 0.001 uF/6 kV 250 pc
11. capacitors CERA-MITE 0.01 uF/6 kV 50 pc
12. resistors Allen-Bradley 1mOhm/0.5 W 250 pc
13. gold plated tungstein wire 30 mkm with Rhe 15 km
14. air-powered dispenser 1000D with accesories 2 pc
15. rubber seal 100 m
16. flat cable 3M (part # 3517 series/34) 50 m
17. flat cable connector 3M (part # 3514) 50 pc
18. printed board connector 3M (part # 3594) 50 pc
19. HV connector BNC - 5kV (male+female) 50 pc
20. LEMO connector (male+female) 20 pc
21. HV cable RG-59 100 m
22. set of shrinking tubes (1m long) 10 pc
23. wire for spacers, 0.8 mm diameter 5 m

24. red X corona dope (20 oz) 2 pc

>> 3. Fabrication Specifications and Sequience

Fabrication specification:

1. spacers
2. gas system prts
3. gauges
4. parts to mount amplifiers, HV supply, power supply
5. chamber assembly and fix parts
6. seal elements
7. screens
8. tranportation container
9. spacers installation tools
10. panels and bars gluing tools
11. drilling tools
12. gauges installation tools
13. tools for chamber assebly using gauges

Fabrication sequence

1. printed cirquit boards
2. preparation of the panels
3. mechanical parts assembly

>> 4. Assembly procedures

1. glue stripped electrodes onto the planes
2. assemble precise positionning monitors onto the planes
3. glue chamber frames to the panels
4. glue pc-boards to the chamber planes
5. drill holes in the planes
6. assemble spacers onto the planes
7. assemble resistors onto the stripped electrodes
8. clean cathodes and the chamber frames
9. wind wire areas on the on transfer frames
   (wire transition control, cleaning wires)
10. transfer wires from transfer frames to the chamber frames
    (wire tensioncontrol, cleaning the electrodes)
11. electrodes acceptance test
12. final cleaning of the electrodes
13. assemble and close the chamber
14. assemble exterrior mechanical parts
15. assemble ground conductors, signal and HV connectors, etc.
16. flush chamber with gas
17. chamber HV training
18. complete test with cosmic rays
19. crate chambers
20. shipping to SSCL

>> Testing procedures

A. test of single chambers of the module
  1. production quality test of each chamber
    1.1 cutting of anode wires
    1.2 soldering of HV parts (R,C)
    1.4 check of interstrip shortcirquits
    1.5 readout strips soldering, including cables and connectors
    1.6 wire tension check
    1.7 check of anode boards junction (Mechanical, HV, gas)
    1.8 seal surfaces quality check
    1.9 anode-cathode gap check
    1.10 spacers installation
  2. HV leaks check
     (fill chamber with N, apply HV=5kV, leakage current < 1 uA)
  3. clean assembly check
     (no noise (discharges) in chamber with Ar/CH4, HV=2.6kV.

chamber training, including disassembly and cleaning if needed)

B. Module check
1. gas leakage check of the module after assembly
2. strips misalignment measurement (with respect to outer gauge)
3. measurement of working voltage of the module
   (Ar/CFn/CO2 (30:20:50), measure space and time accuracy)
4. accumulation of statistics in working point (10e6 events)

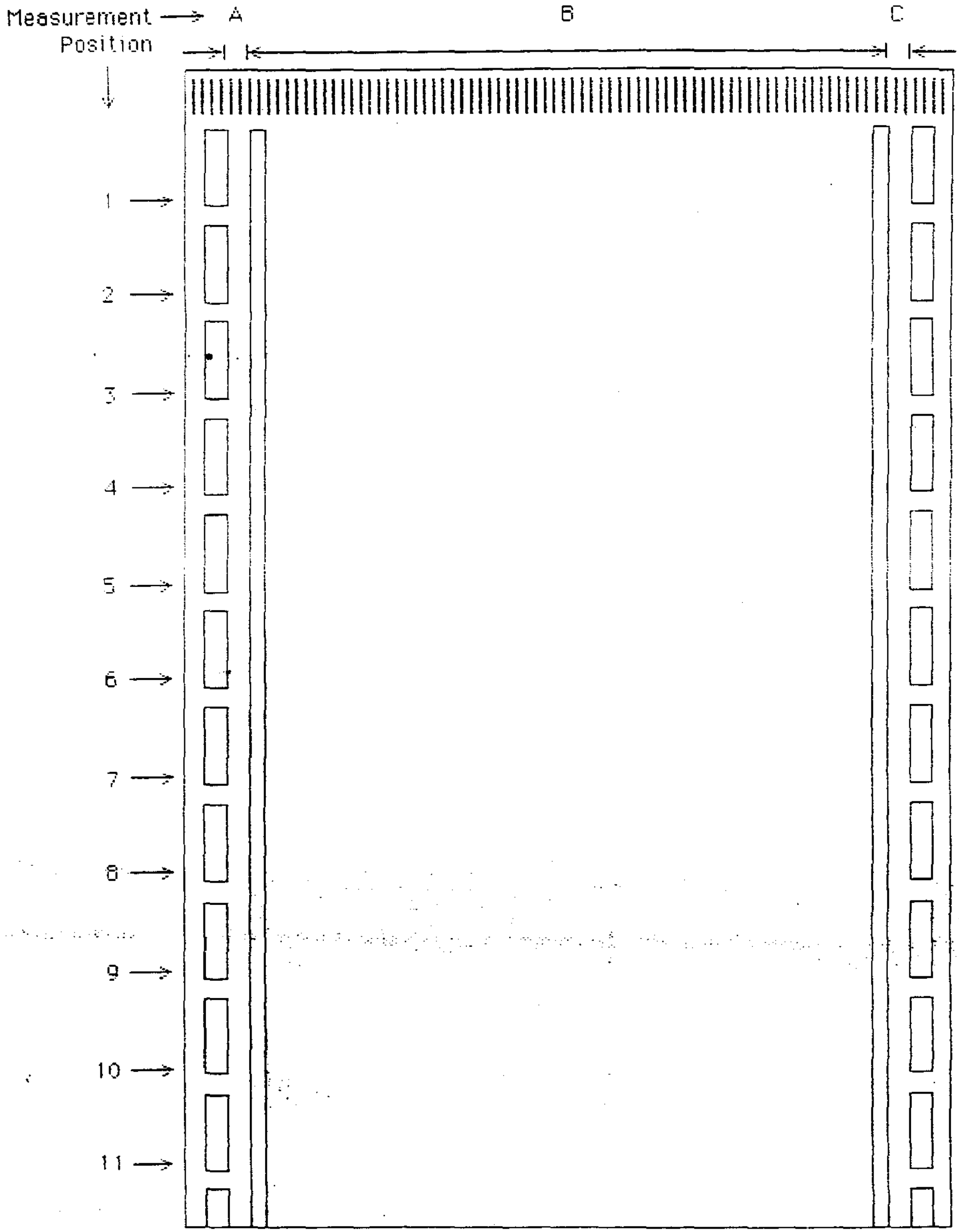
C. Passport (diskette)
1. gas leakage
2. strips misalignment
3. working voltage/current
4. 2-dimensional map of uniform cosmic rays exposition/noise
5. readout electronics calibration data (pedestal, linearity, noise, e

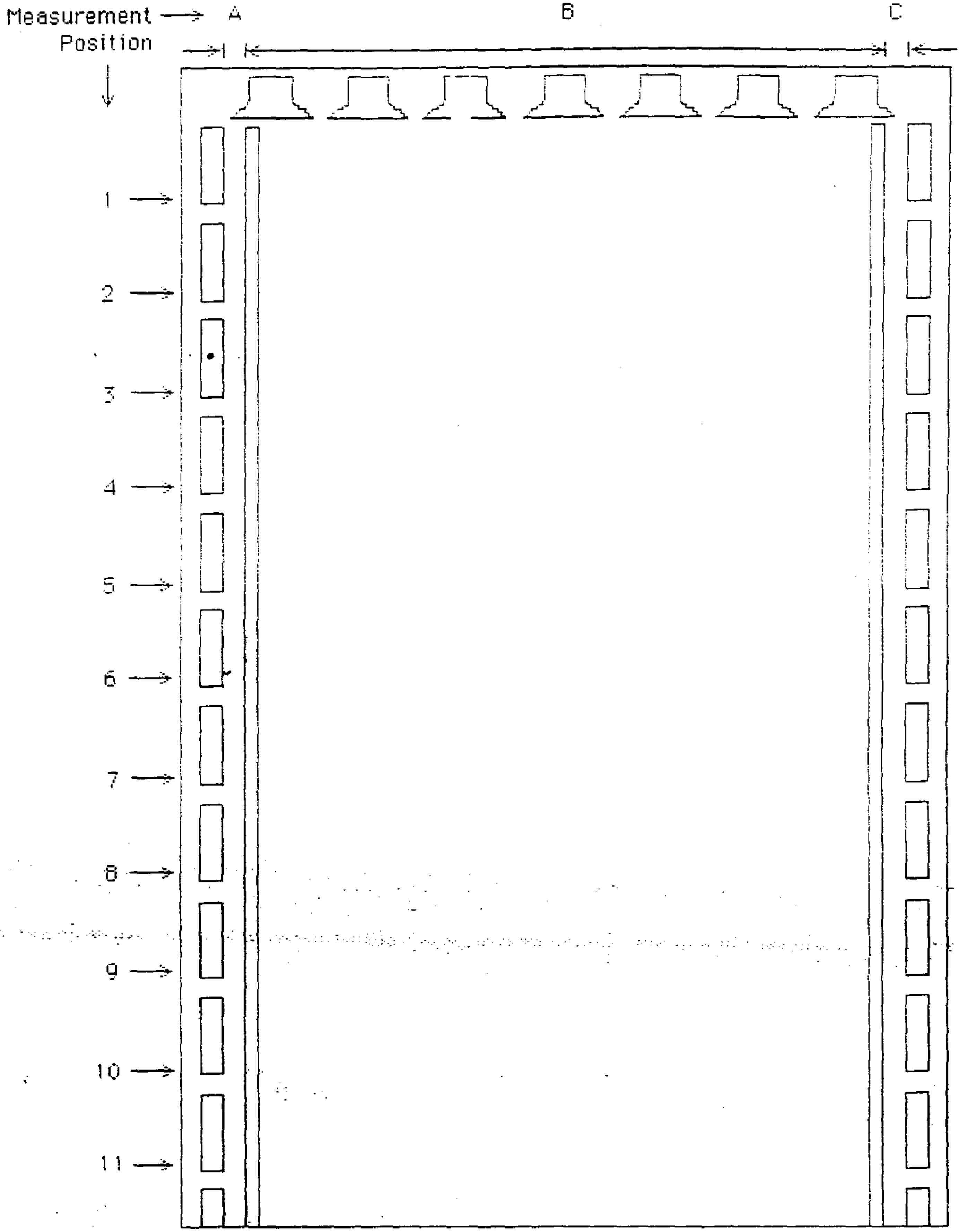
>> Schedule and personell

Schedule
1. Fabrication of technological equipment and CSC parts at workshop - 1 m
2. chamber assembly - 1.5 months
3. chamber testing - 0.5 months
4. shipping to SSCL - 0.5 months

Personnel
V.Rashevski
Yu. Victorov
A.Vishevski
V.Perelygin
S.Movchan
V.Karjavin
A.Ivanov
S.Selunin
V.Khabarov
A.Chvyrov
+ 12 technicians

With the best regards,
Yu. Kiryushin


Measurement
Position
A
B
C
1
2
3
4
5
6
7
8
9
10
11


Measurement Position
A
B
C
1
2
3
4
5
6
7
8
9
10
11

	Measurements for Readout Sheet					
Trial 1	6/30/93					
Note: Sheet was held flat horizontally, with an Aluminum bar perpendicular to the strips. Measurements are in inches.						
Measurement	A		B		C	
	Value	Dev	Value	Dev	Value	Dev
Position						
Nominal	1.8000		38.0600		1.8000	
1	1.7997	-0.0003	38.0638	0.0038	1.8001	0.0001
2	1.7996	-0.0004	38.0637	0.0037	1.7999	-0.0001
3	1.7997	-0.0003	38.0632	0.0032	1.7994	-0.0006
4	1.7995	-0.0005	38.0633	0.0033	1.8002	0.0002
5	1.7997	-0.0003	38.0632	0.0032	1.7993	-0.0007
6	1.7995	-0.0005	38.0631	0.0031	1.7998	-0.0002
7	1.7995	-0.0005	38.0633	0.0033	1.7997	-0.0003
8	1.7998	-0.0003	38.0630	0.0030	1.7998	-0.0002
9	1.7992	-0.0008	38.0623	0.0023	1.7994	-0.0006
10	1.7995	-0.0005	38.0611	0.0011	1.8000	0.0000
11	1.7994	-0.0006	38.0625	0.0025	1.8001	0.0001
Trial 2	7/1/93					
Note: This data is from measurements being made with two reference wires, as a check of the straightness of the traces. The sheet was held flat by two steel bars running parallel to the traces, in the spaces between the contrast line and the first trace.						
Measurement	A		B		C	
	Value	Deviation	Value	Deviation	Value	Deviation
Position						
Nominal	1.8000		38.0600		1.8000	
1	1.8000	0.0000	38.0626	0.0026	1.7995	-0.0005
2	1.7996	-0.0004	38.0628	0.0028	1.7996	-0.0004
3	1.7998	-0.0002	38.0625	0.0025	1.7993	-0.0007
4	1.7999	-0.0001	38.0626	0.0026	1.7993	-0.0007
5	1.7996	-0.0004	38.0623	0.0023	1.7991	-0.0009
6	1.7995	-0.0005	38.0629	0.0029	1.7995	-0.0005
7	1.7995	-0.0005	38.0632	0.0032	1.7994	-0.0006
8	1.7993	-0.0007	38.0618	0.0018	1.7995	-0.0005
9	1.7992	-0.0008	38.0590	-0.0010	1.7996	-0.0004
10	1.7997	-0.0003	38.0544	-0.0056	1.7996	-0.0004
11	1.7995	-0.0005	38.0495	-0.0105	1.7993	-0.0007
Notes: In the second trial, the sheet had an approx. 1cm bulge in the joint side. This would cause an apparent shortening in measurement B with minimum magnitude of 7 thousandths. Furthermore, a 500 mil lift of the edge of the sheet from the table outside of the hold down bars is needed to cause the discrepancy between trials of measurement C. It is likely that there was such a lift. There is confidence in the measurements of Trial 1, while sources of error have been found for Trial 2.						

	Measurements for Terminating Sheet					
Trial 1	6/30/93					
Note: Sheet was held flat horizontally, with an Aluminum bar perpendicular to the strips.						
Measurements are in inches.						
Measurement	A		B		C	
	Value	Deviation	Value	Deviation	Value	Deviation
Position						
Nominal	1.8000		38.0600		1.8000	
1	1.7992	-0.0008	38.0642	0.0042	1.8027	0.0027
2	1.7993	-0.0007	38.0632	0.0032	1.8028	0.0028
3	1.7991	-0.0009	38.0633	0.0033	1.8029	0.0029
4	1.7990	-0.0010	38.0635	0.0035	1.8025	0.0025
5	1.7994	-0.0006	38.0635	0.0035	1.8024	0.0024
6	1.7992	-0.0008	38.0644	0.0044	1.8025	0.0025
7	1.7989	-0.0011	38.0653	0.0053	1.8024	0.0024
8	1.7991	-0.0009	38.0649	0.0049	1.8019	0.0019
9	1.7989	-0.0011	38.0643	0.0043	1.8018	0.0018
10	1.7990	-0.0010	38.0644	0.0044	1.8015	0.0015
11	1.7987	-0.0013	38.0666	0.0066	1.8018	0.0018
Notes: These measurements were made with the procedure of the Trial 1 measurements of the Readout sheet, and the same confidence in our measurements apply.						

O. Prokofiev
7/12/93

PNPI prototype of CSC

1. Construction of small CSC
(20×20 cm² active area)
with geometric configuration
of Superlayers.

	L, mm	W mm
SL 1	2.54	5.71
SL 2	4.0	8.48
SL 3	5.0	10.7

spacing
$S = 2.5$ mm
$d_{Anode} = 30\,\mu m$

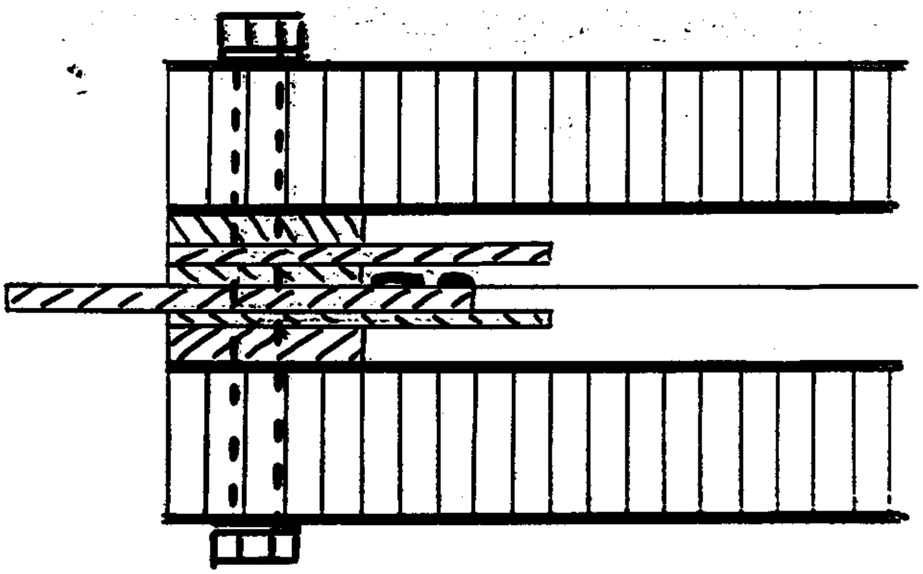
L - gap anode - cathode
W - pitch cathode strip readout

- parallel and radial strip configuratio[n]
- anode wire rotation for compensation
Lorentz effect in CSC
End-Cap configuration

Small chamber construction

PNPI has a special press-form for making frames:

20 × 20 cm² active area



Art-work:

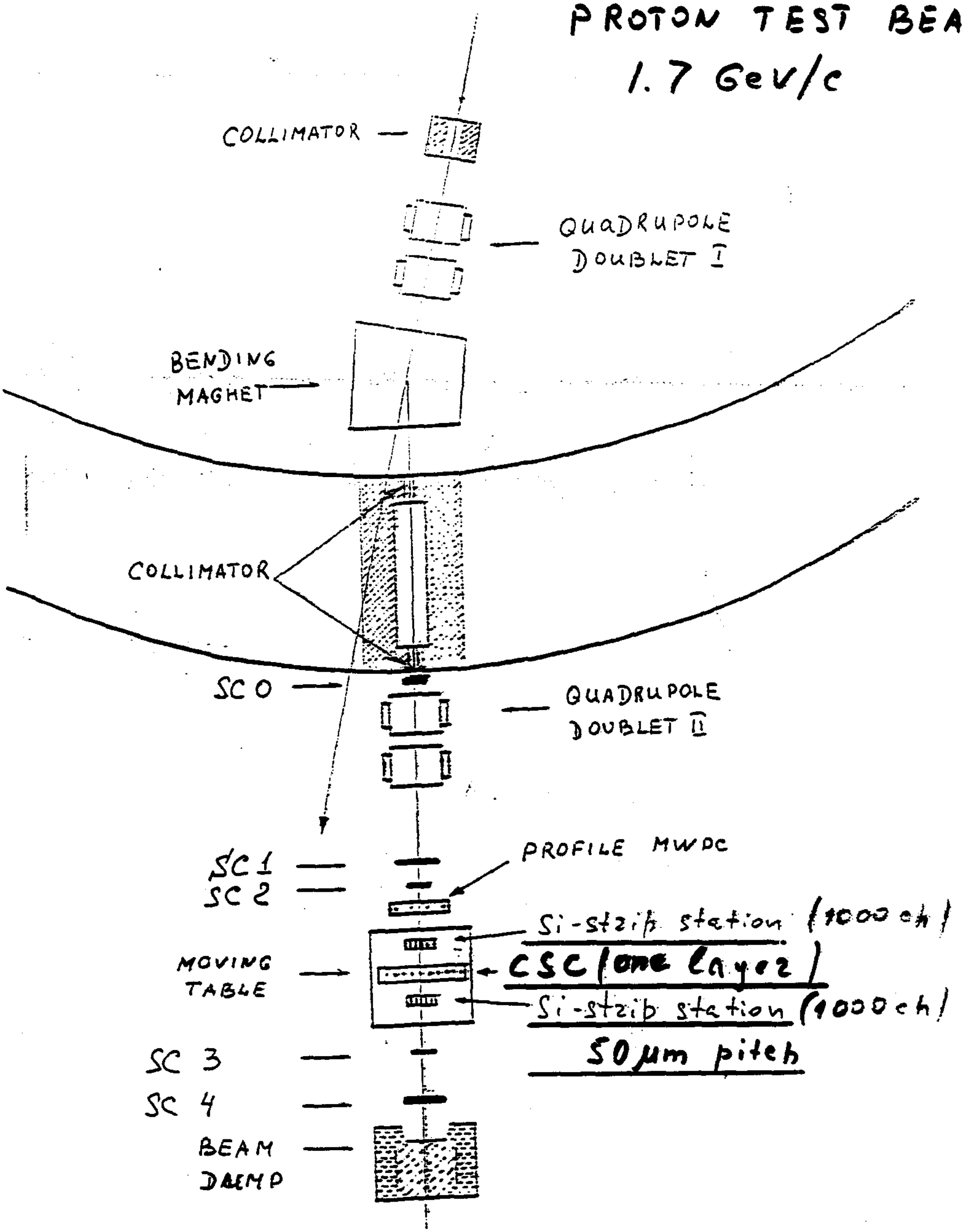
- Cathode strip (parallel)
  Barrel configuration
  W = 5.71 ; 8.48 ; 10.7 mm
- Radial strip (End Cap configuration)
- Anode plane $S' = 2.5$ mm
  perpendicular, rotated ≈ 8°

Studies :

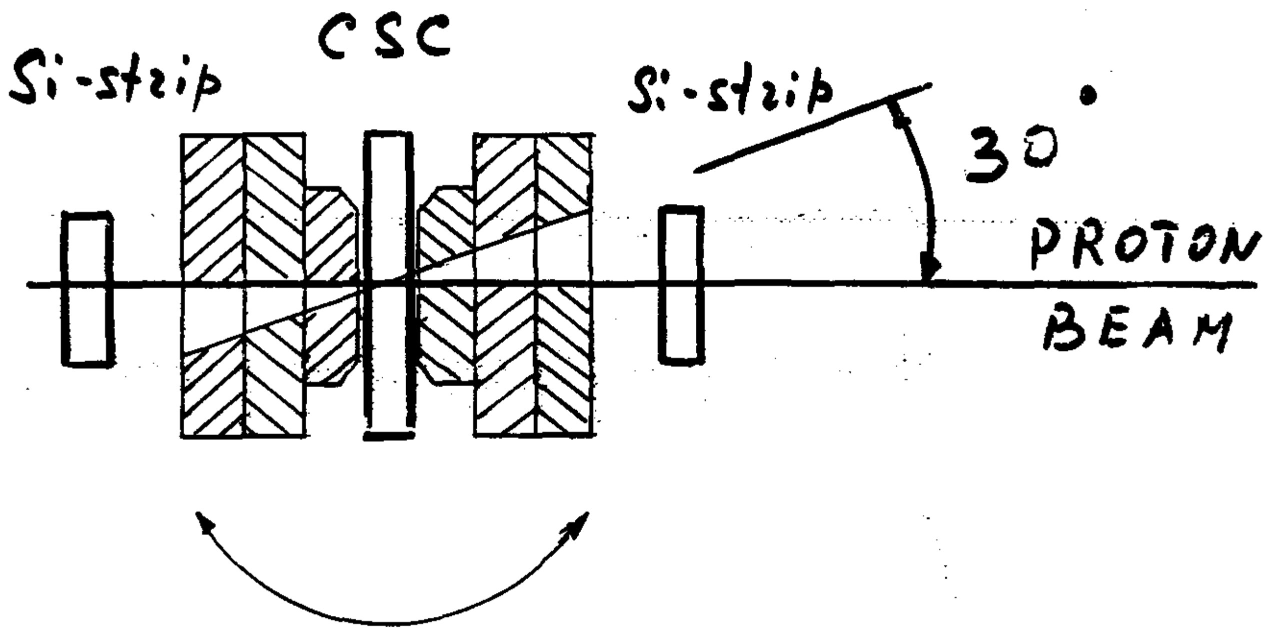
1. Intrinsic layer resolution for different chamber geometry
2. Timing. Beam crossing tag efficiency (6 layers) > 99 % at 16 ns gate
3. Magnetic field (End-Cap configuration)
4. Optimization chamber parameters.
   Cathode strip readout pitch
   GAP, spacing ...

- Proton test Beam
- Si strip station
- Magnet End-Cap configuration

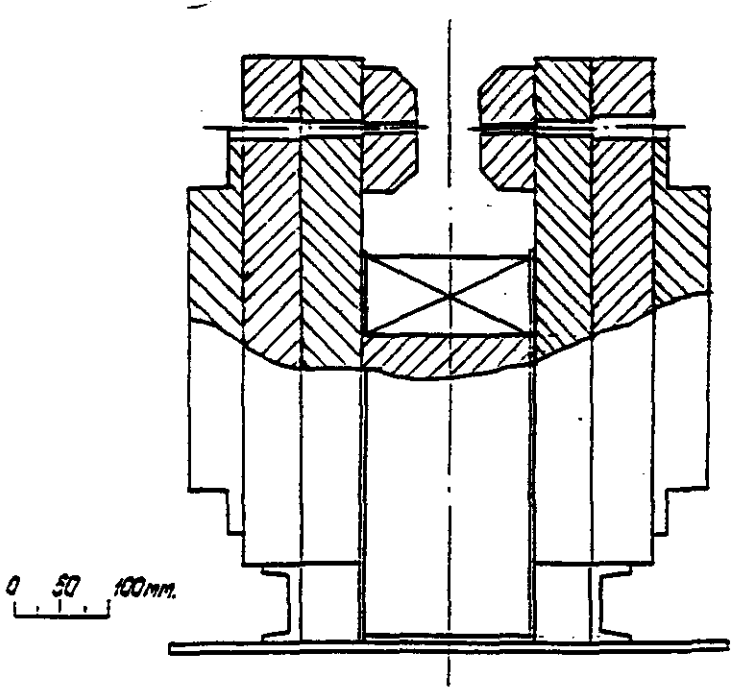
PROTON TEST BEAM
1.7 GeV/c

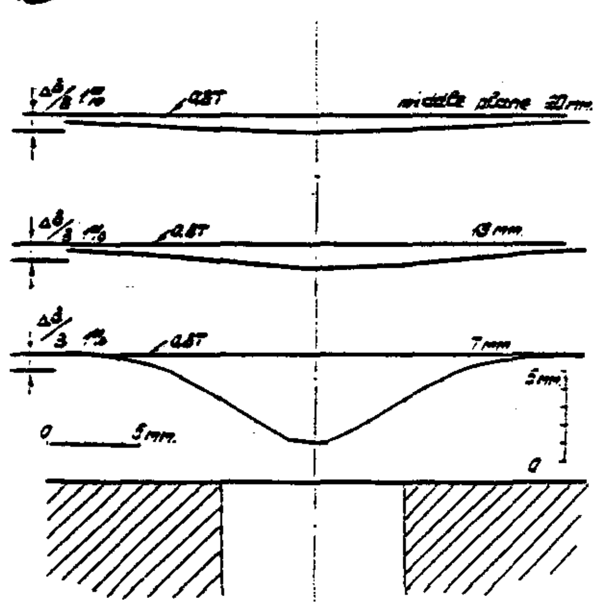


Test of CSC in magnetic field
$\vec{E} \parallel \vec{B}$



$$\frac{\Delta B}{B} \approx 0.1\% / mm$$





Status of CSC Readout Work at Princeton

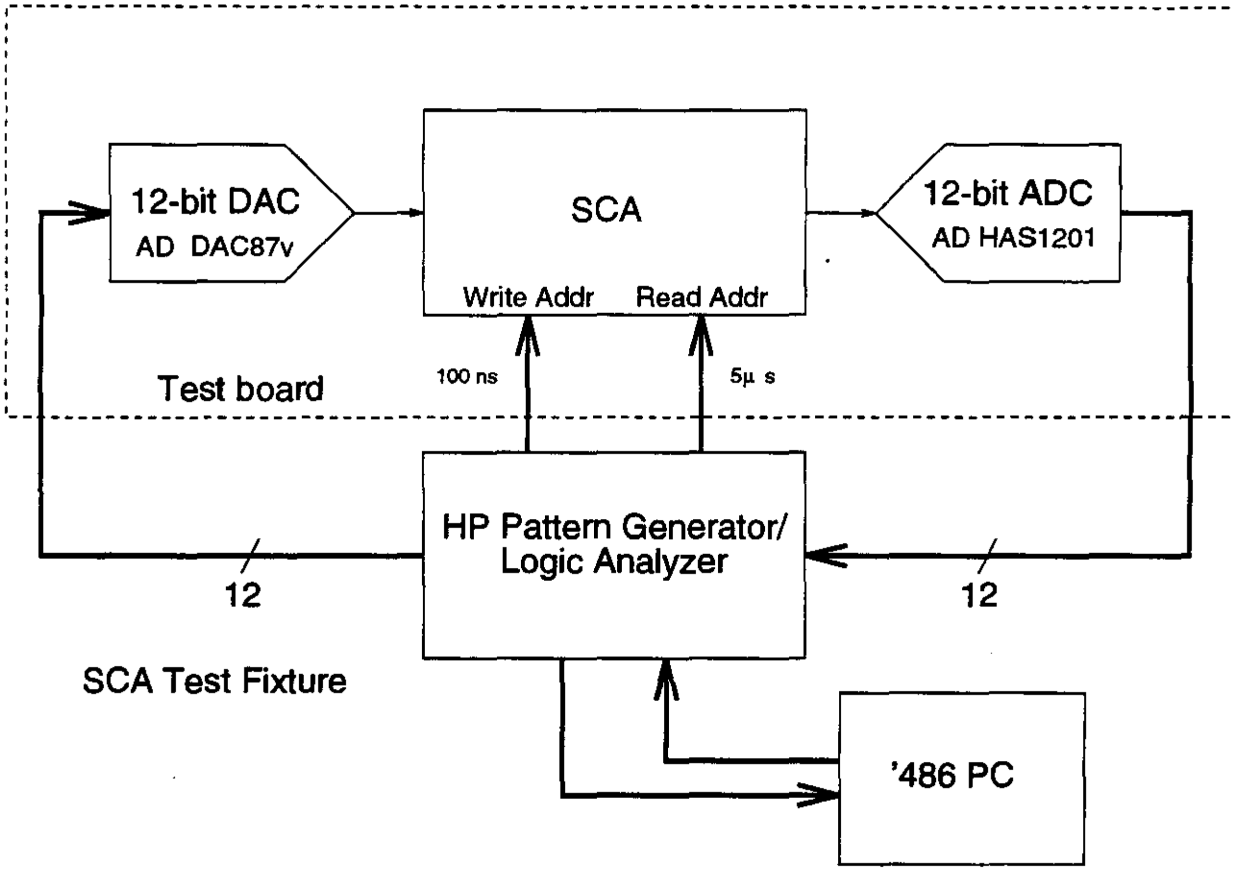
GEM Muon Meeting at the SSCL
July 12, 1993

Daniel R. Marlow
Princeton University

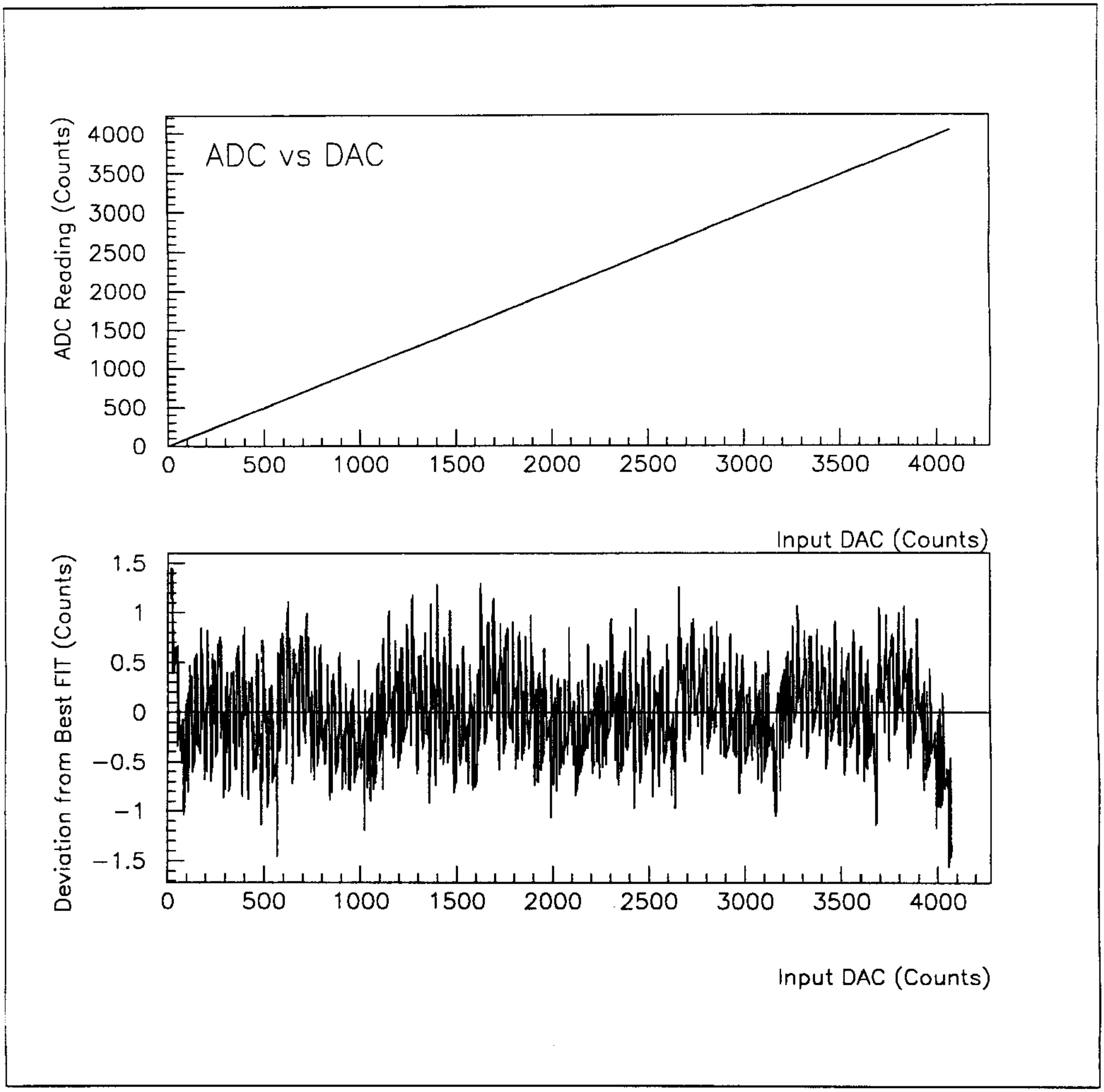
Muon CSC Electronics

- Work aimed toward production readout
- Pursuing SCA option, but work is directly relevant to T/H option.
- IC design by Bob Wixted
- Test fixture development by Stan Chidzik
- 2×2 mm^2 IC prototype fabricated using ORBIT 1.2 μm double-poly, double-metal CMOS
- First prototype
  - 3-channel $\times$ 24-sample 10 MHz SCA
  - CMOS comparator (building block for low-cost CF discriminator)

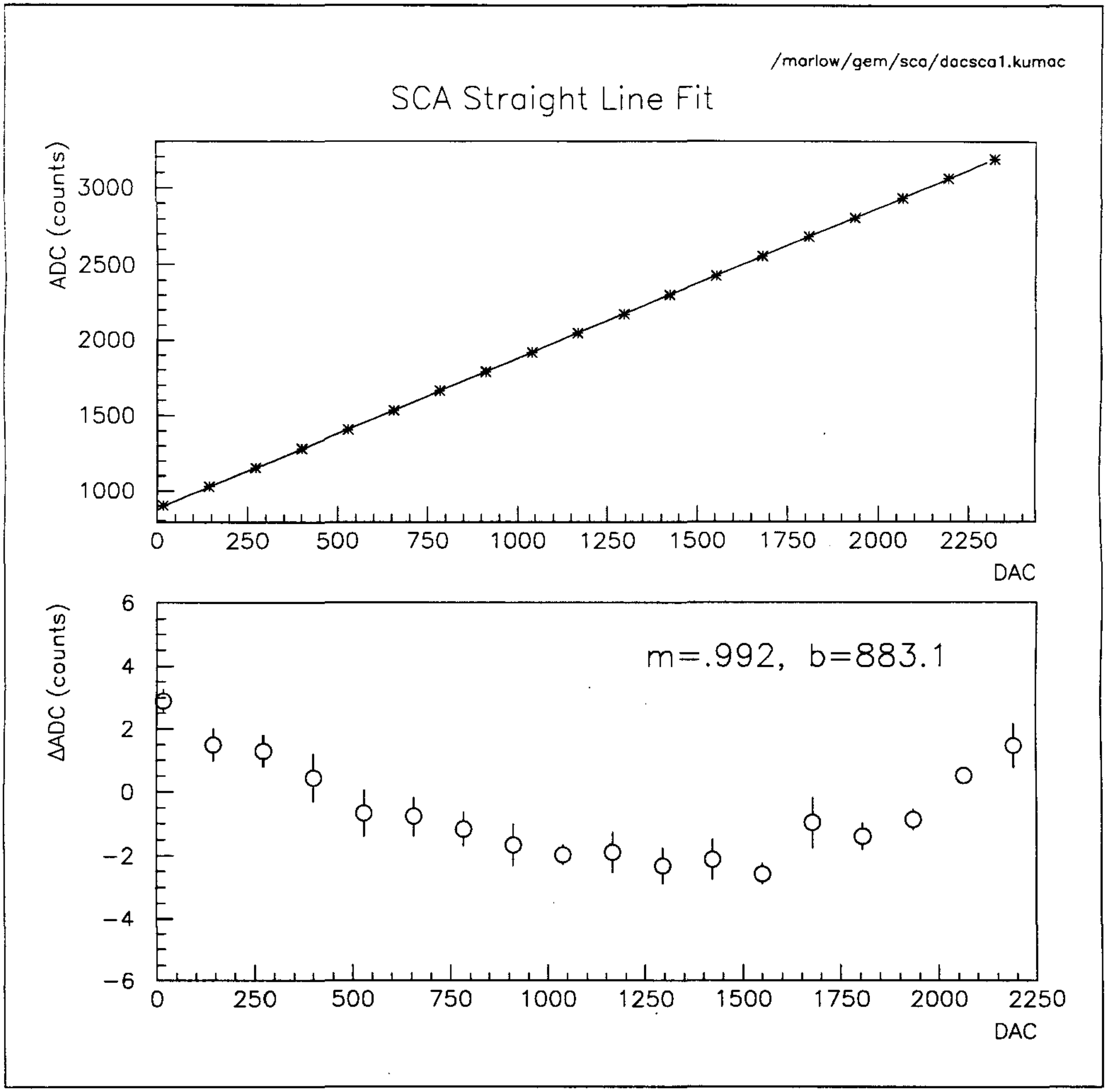
Test Setup

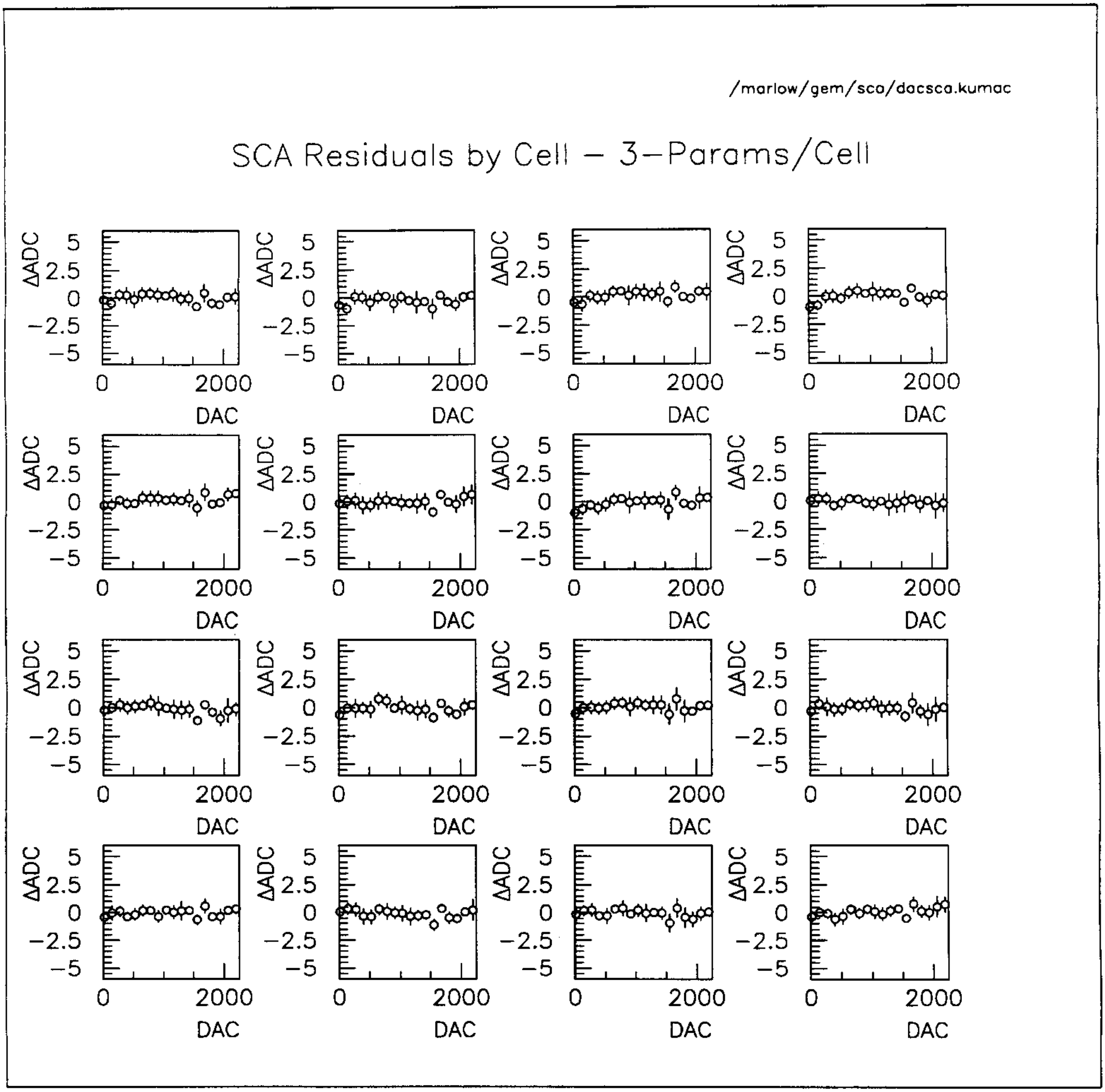


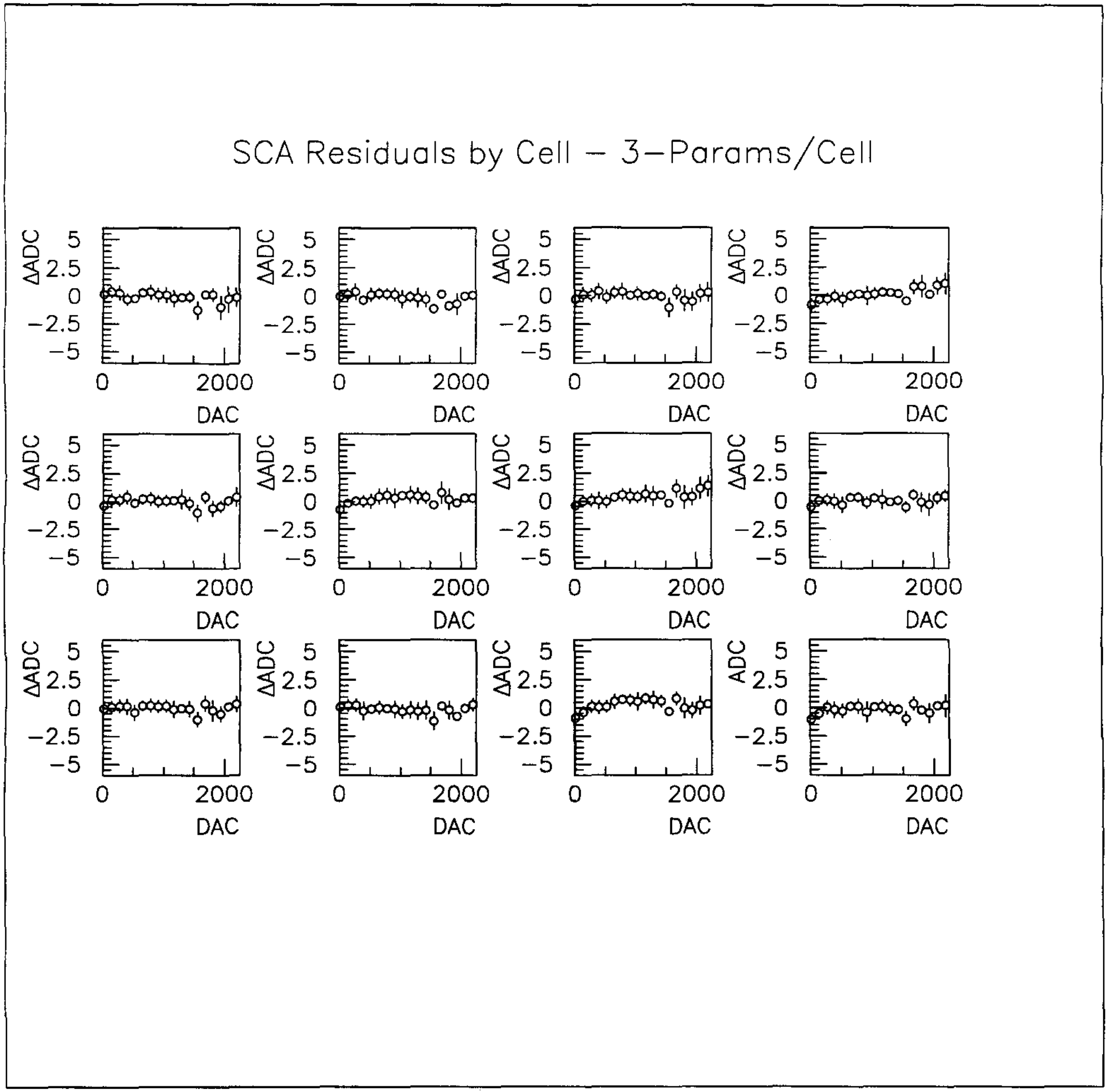
- Current tests use pattern generator to sequentially address the capacitors in the array. Readout follows same sequence and is not (yet) simulataneous with write.
- DAC settling time is 3 μs, so only "quasi-dynamic" tests are possible.

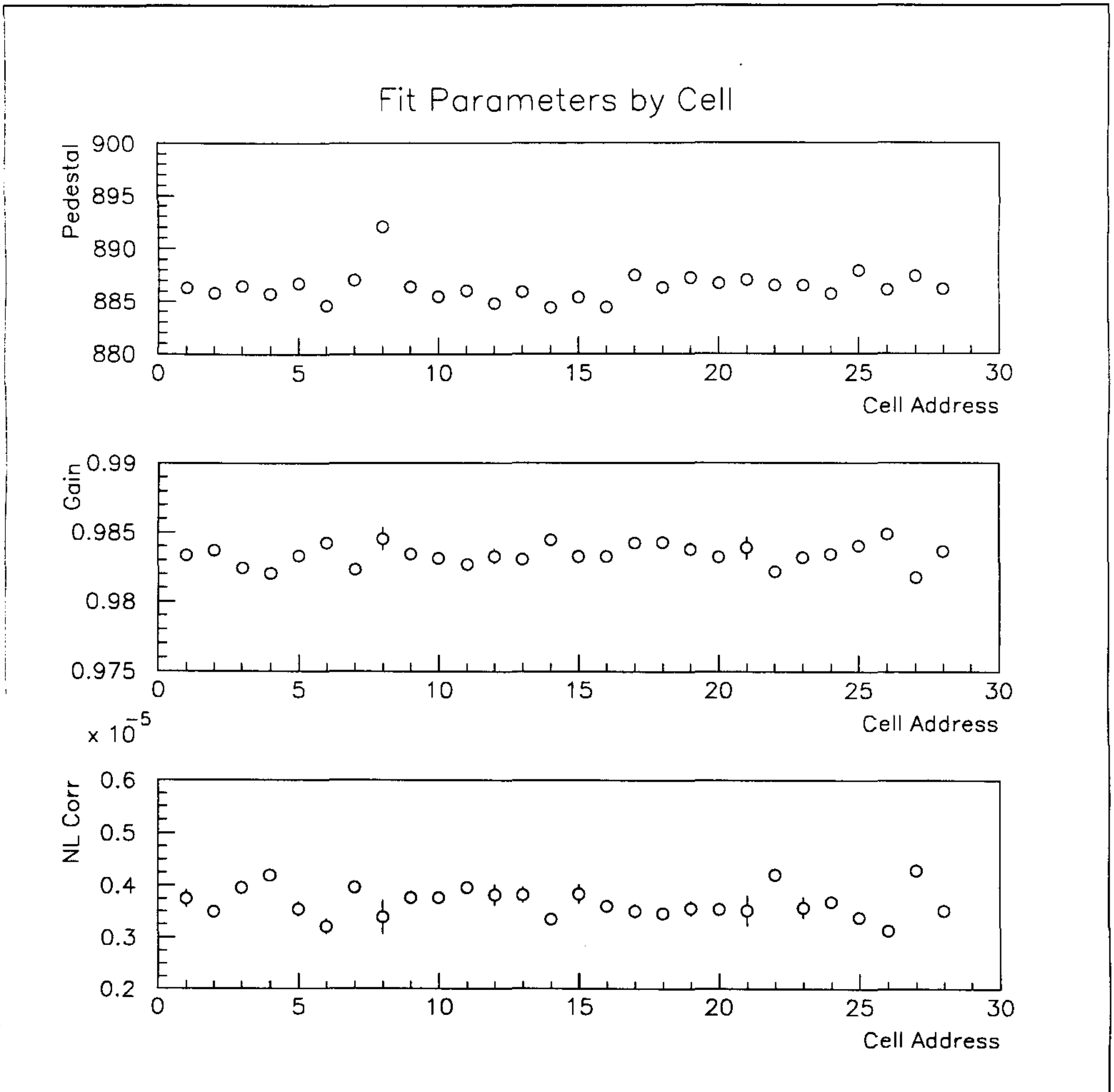


ADC vs DAC
ADC Reading (Counts)
4000
3500
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
3500
4000
Input DAC (Counts)
Deviation from Best FIT (Counts)
1.5
1
0.5
0
−0.5
−1
−1.5
Input DAC (Counts)


/marlow/gem/sca/dacsca1.kumac
SCA Straight Line Fit
ADC (counts)
3000
2500
2000
1500
1000
0
250
500
750
1000
1250
1500
1750
2000
2250
DAC
ΔADC (counts)
6
4
2
0
−2
−4
−6
m=.992, b=883.1
0
250
500
750
1000
1250
1500
1750
2000
2250
DAC

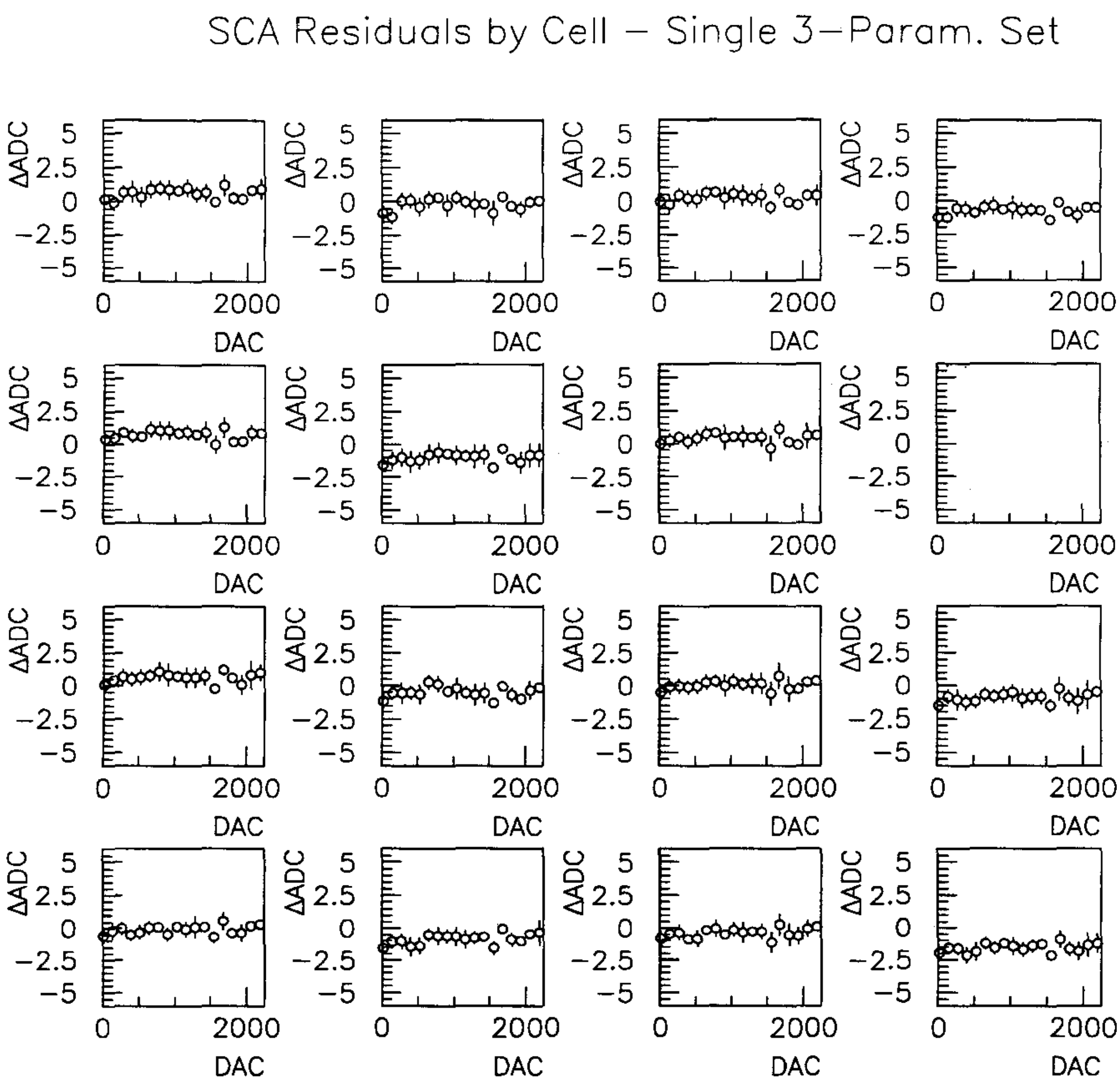

/marlow/gem/sca/dacsca.kumac
SCA Residuals by Cell – 3–Params/Cell
ΔADC
DAC
5
2.5
0
−2.5
−5
0
2000


SCA Residuals by Cell – 3–Params/Cell
ΔADC
DAC

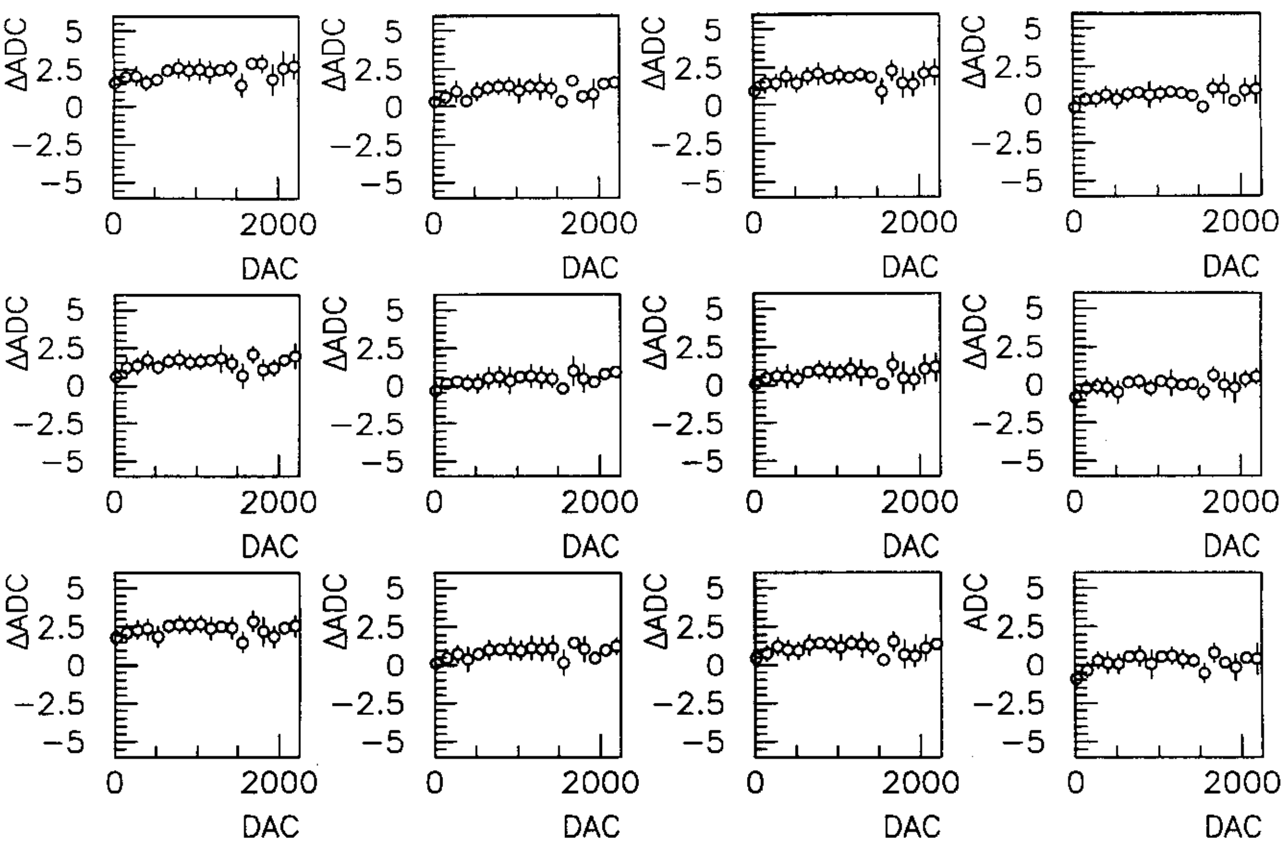


Fit Parameters by Cell
Pedestal
900
895
890
885
880
0 5 10 15 20 25 30
Cell Address
Gain
0.99
0.985
0.98
0.975
0 5 10 15 20 25 30
Cell Address
x 10^-5
NL Corr
0.6
0.5
0.4
0.3
0.2
0 5 10 15 20 25 30
Cell Address

/marlow/gem/sca/dacsca2.kumac



SCA Residuals by Cell – Single 3–Param. Set

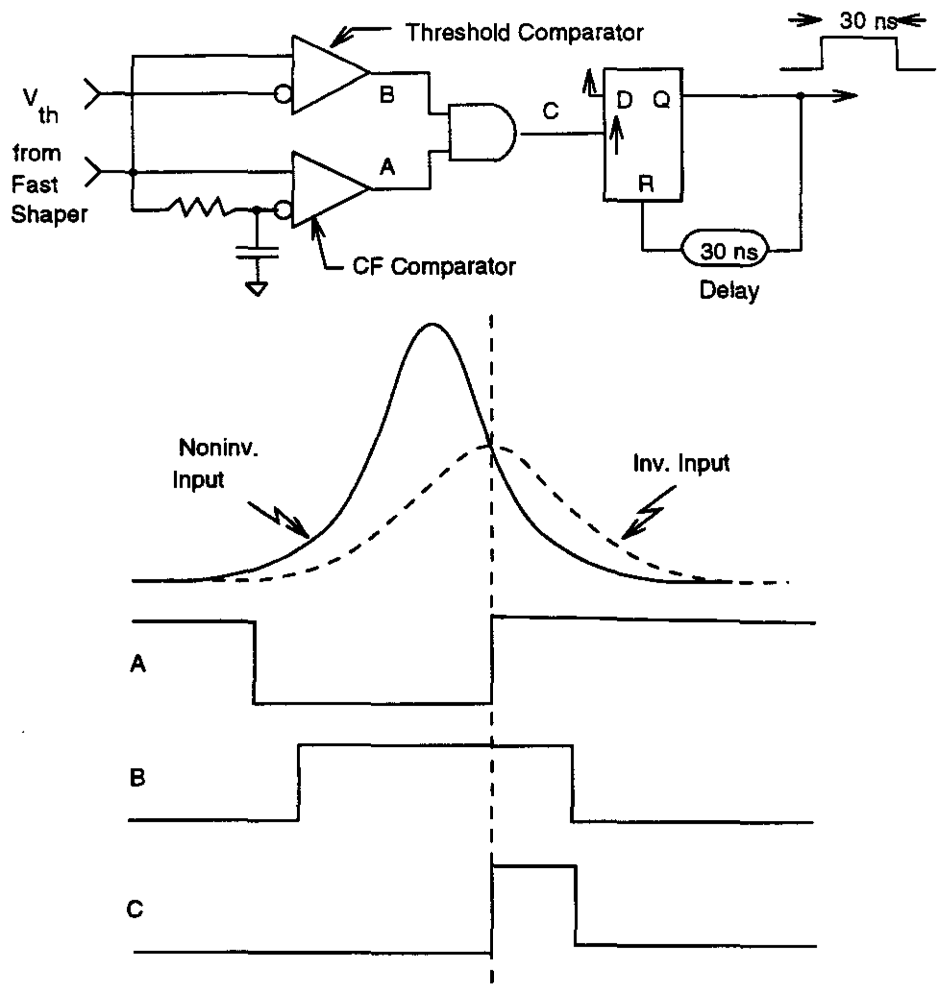


Conclusions & Future Work on SCA Evaluation

- Ten-bit operation appears to be readily achievable.
- Random noise and cell-gain variations are already at the 10-11 bit level.
- Cell pedestals are uniform to only $\sim$ 8 bits.
- Future Work
  - — Use FPGA-based logic to measure noise under simultaneous read/write operation.
  - — Work to understand cell pedestal variations.
  - — An improved test setup, using a 16-bit ADC, a faster DAC, and incorporating a number of "conveniences," is being developed.
  - — SCA's from other labs (ORNL, LBL) will be tested.
  - — Quantitative measurements of capacitor decay time will be made.
  - — Layout of the first "production" device for FNAL test electronics will commence late summer.

Constant Fraction Discriminator Tests

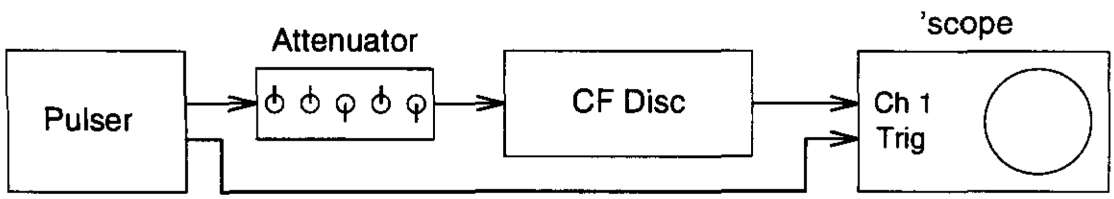
- Goal is to develop low-cost fully integrated CF discriminator to correct for pulse-height walk.
- Design is based on Turko and Smith concept



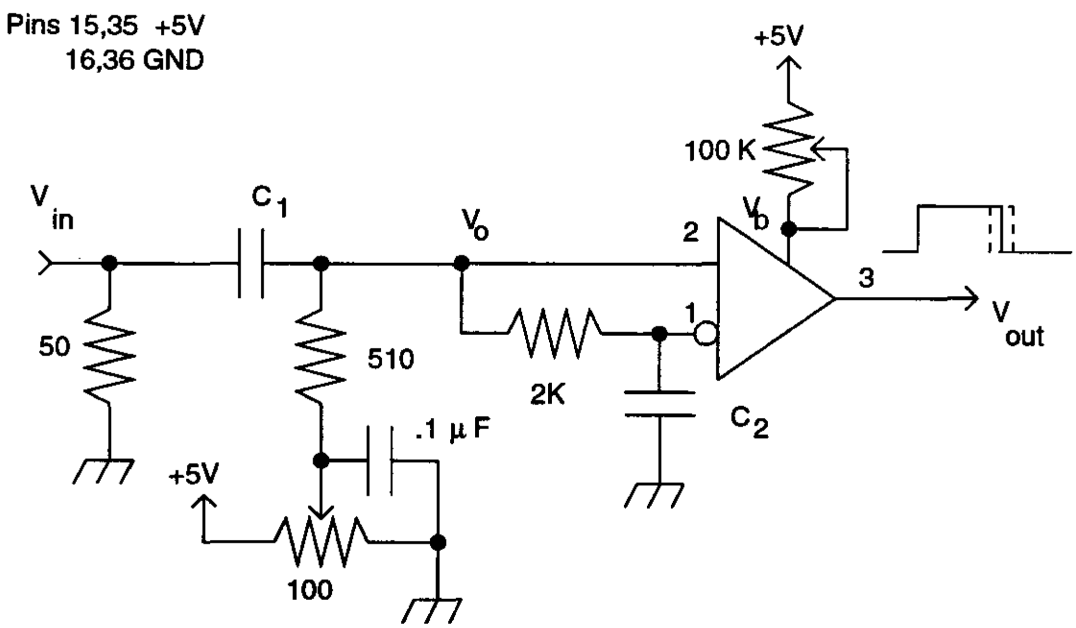
- Key building block is CMOS comparator.
- Current version requires external R's and C's, but these can be integrated.

Constant Fraction Discriminator Test Setup

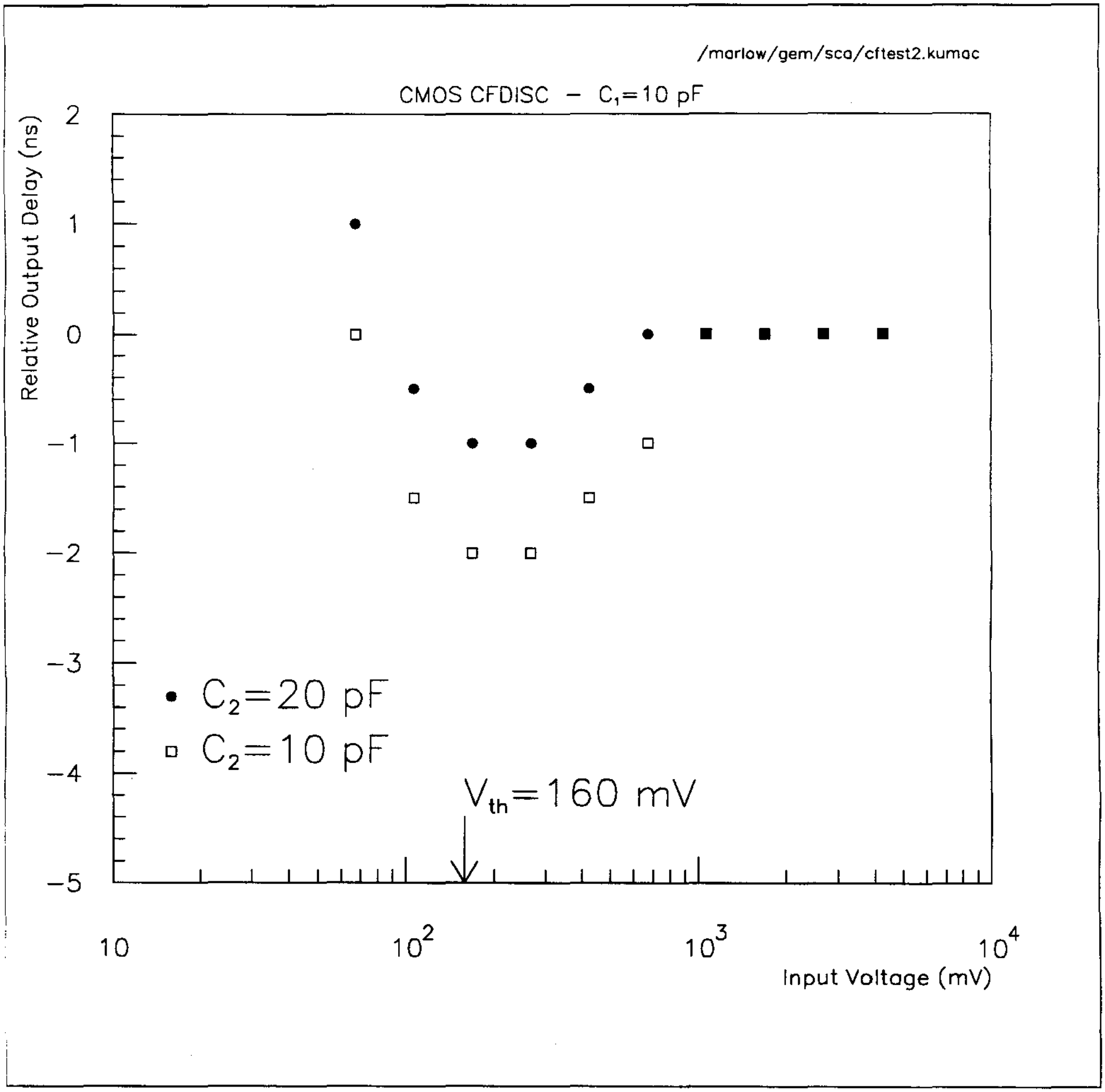
- Test setup is very simple.



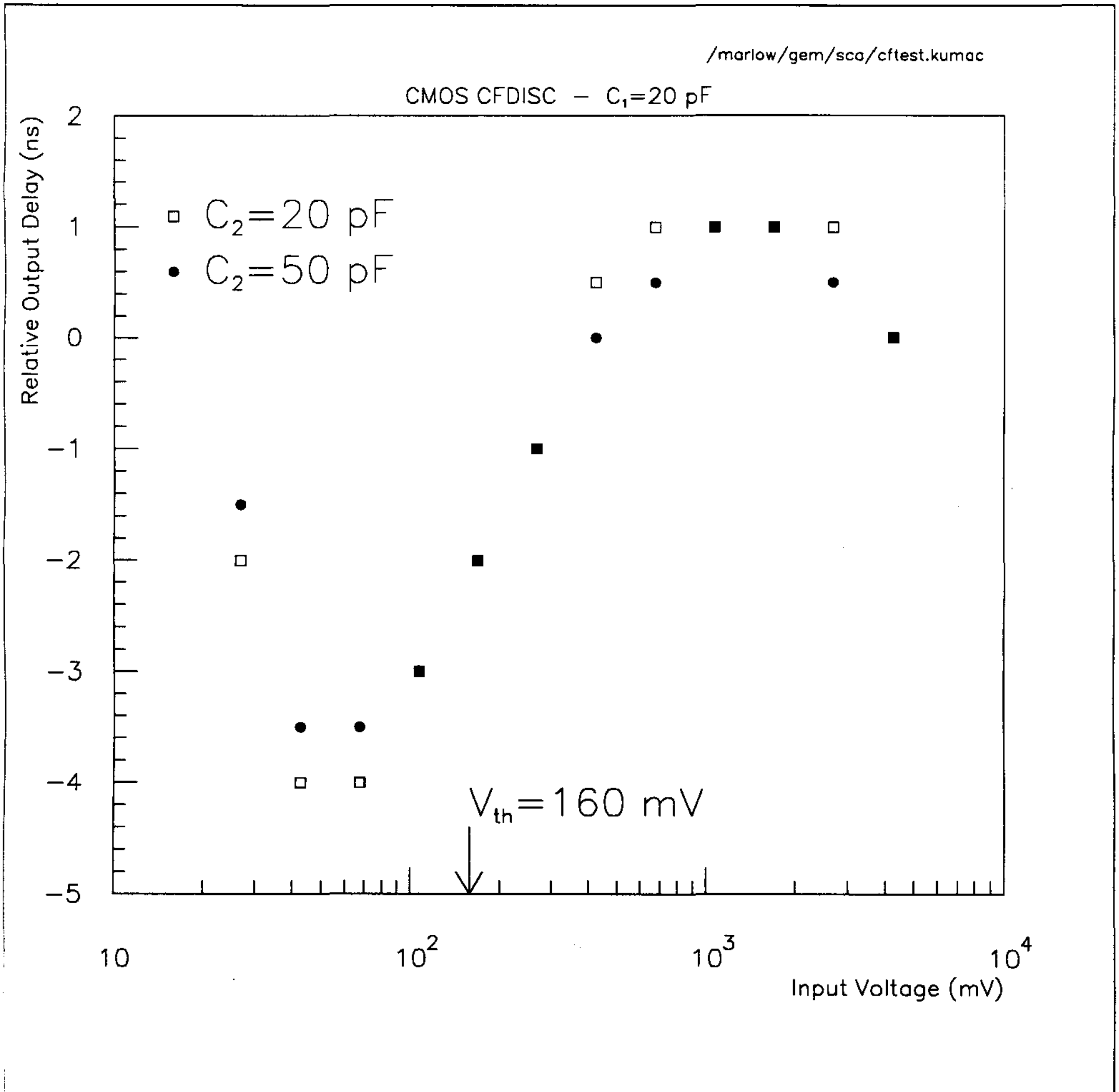
- Use simple *RC* differentiator to simulate pulse. (More realistic circuit needs to be developed.)



- Measure delay of *trailing* edge with respect to trigger as a function of V_{in}.

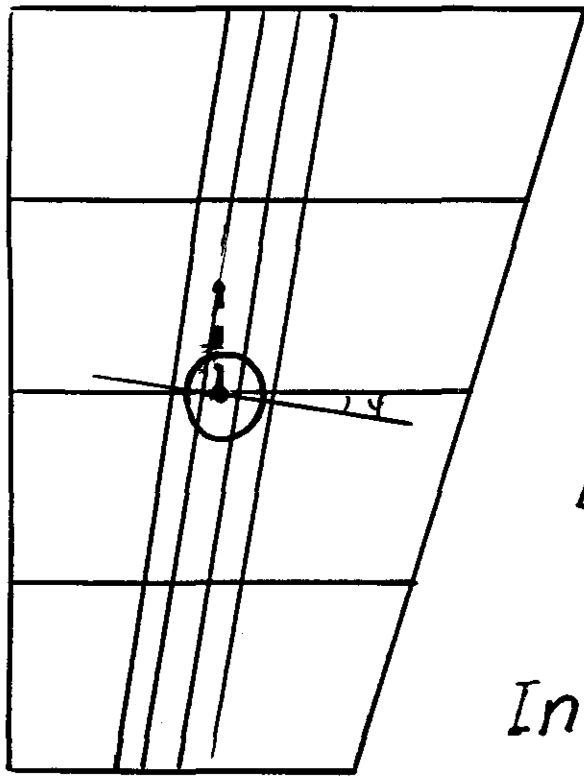


/marlow/gem/sca/cftest2.kumac
CMOS CFDISC – C1=10 pF
Relative Output Delay (ns)
2
1
0
−1
−2
−3
−4
−5
C2=20 pF
C2=10 pF
Vth=160 mV
10
10^2
10^3
10^4
Input Voltage (mV)


/marlow/gem/sca/cftest.kumac
CMOS CFDISC – C1=20 pF
C2=20 pF
C2=50 pF
Relative Output Delay (ns)
2
1
0
−1
−2
−3
−4
−5
Vth=160 mV
10
10^2
10^3
10^4
Input Voltage (mV)

Conclusions from Discriminator Tests

- The CMOS constant-fraction discriminator functions well and should easily meet GEM's requirements.
- Further tests with more realistic pulse shapes and with actual chamber pulses are needed.
- In the current design, there is a slight tendency to fire *early* on smaller pulses. This could be problematic and should be corrected.

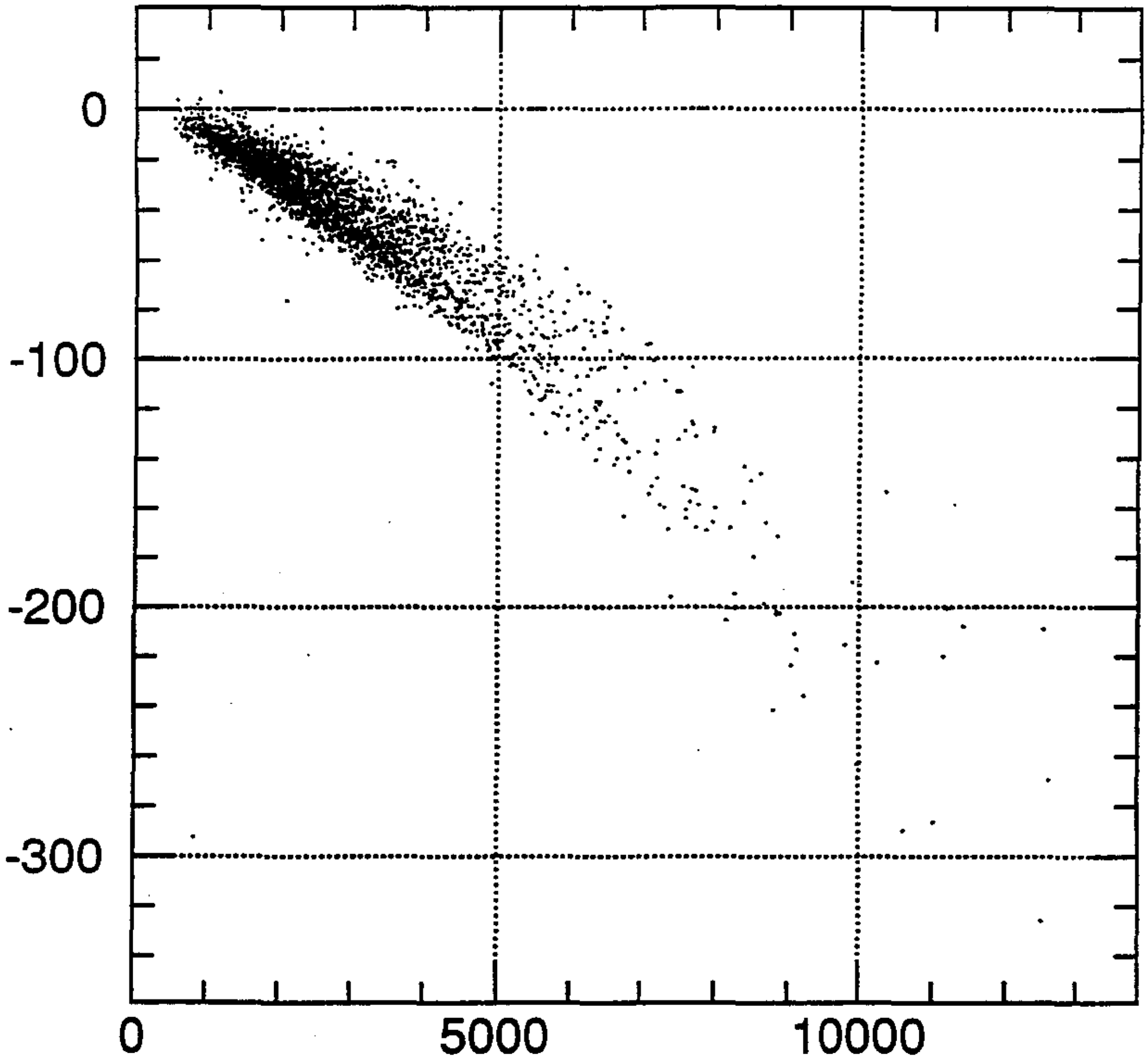


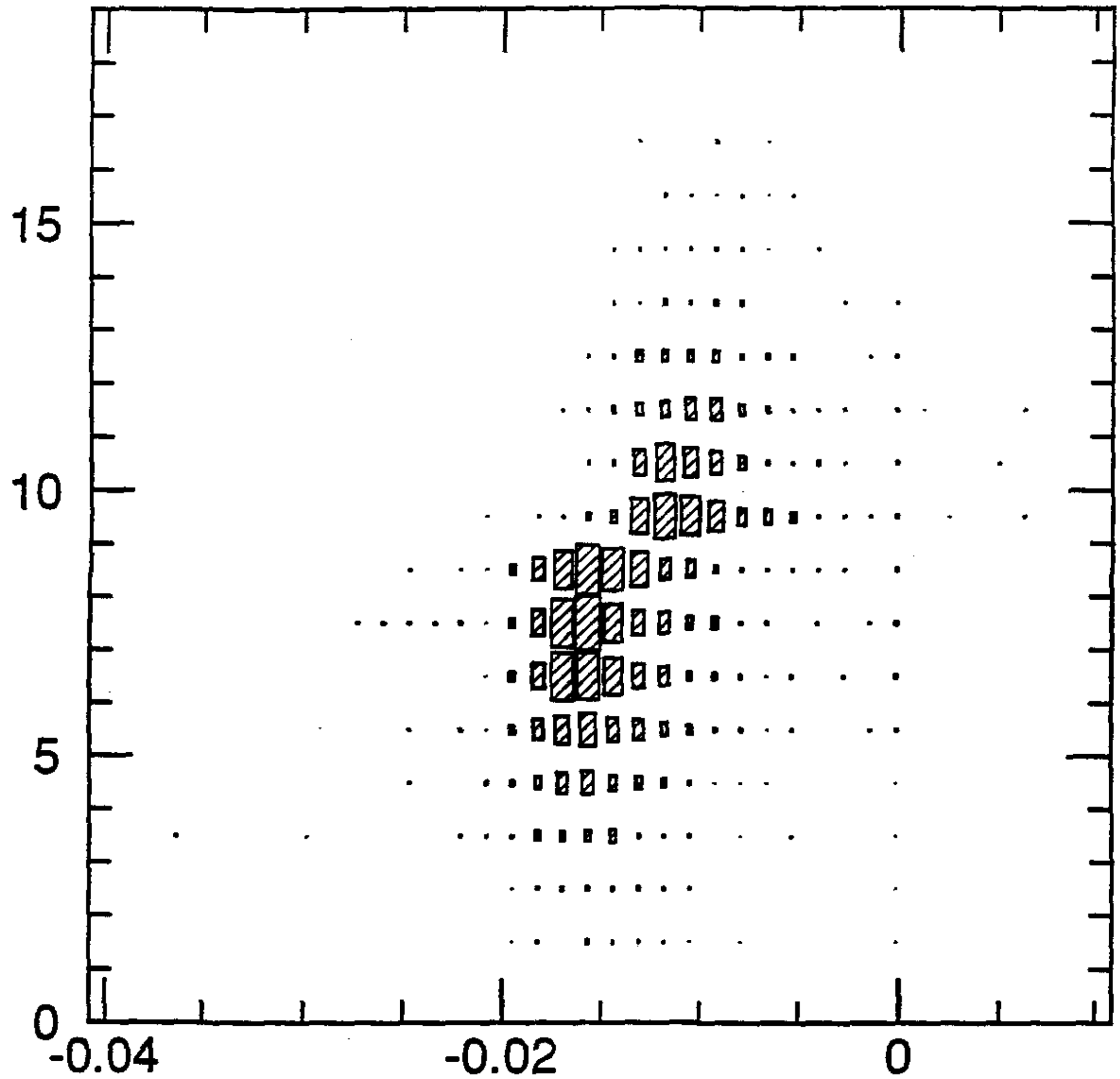
$$\varphi \sim \frac{9^\circ}{2}$$

$$\Delta X = \frac{2.5\,mm}{\sqrt{12}} \cdot \frac{9 \cdot \pi}{180 \cdot 2} = 56\,\mu m$$

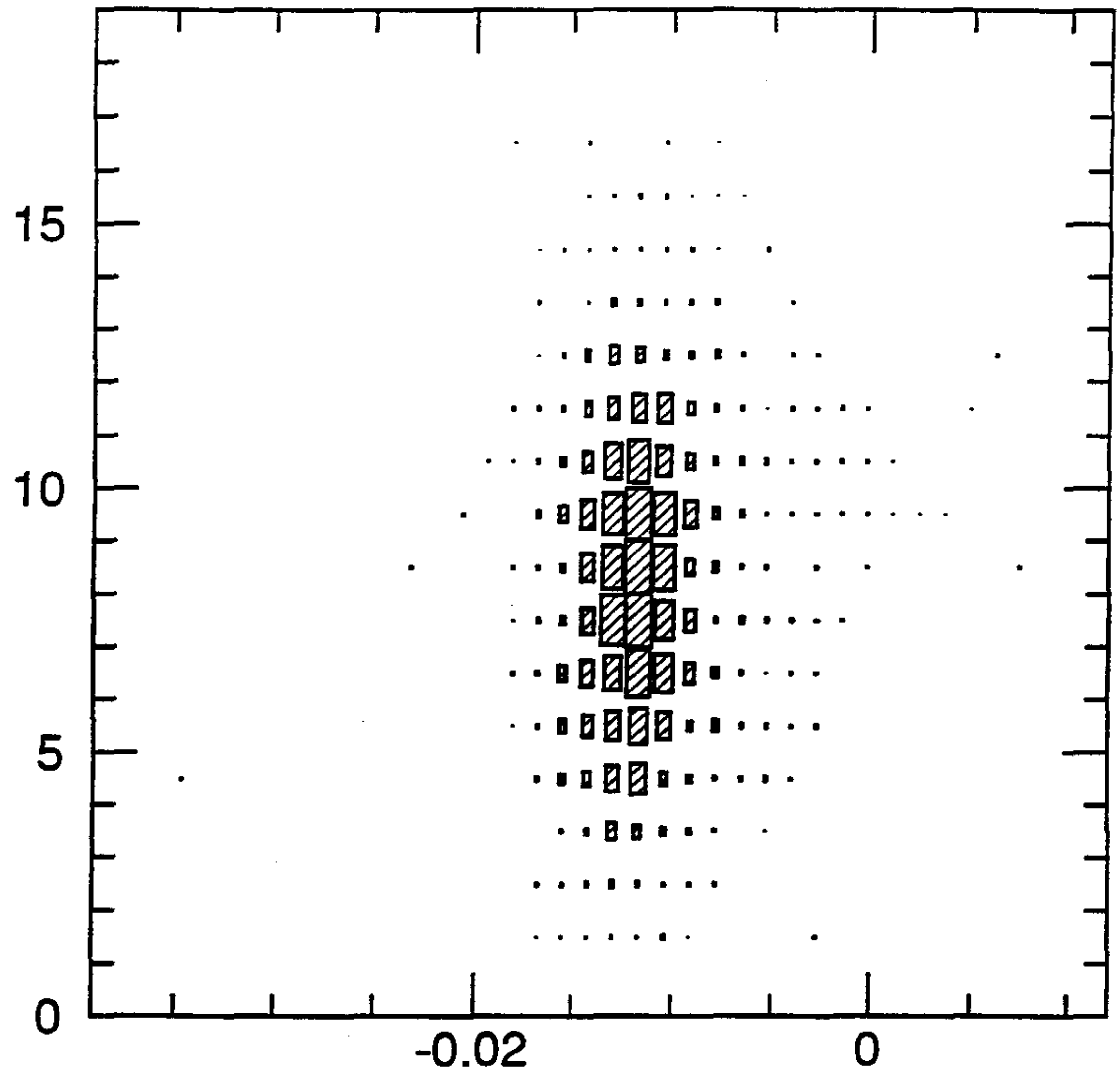
In our case

$$\varphi \sim \frac{9^\circ}{2} / 3 \longrightarrow \sim 20\,\mu m$$

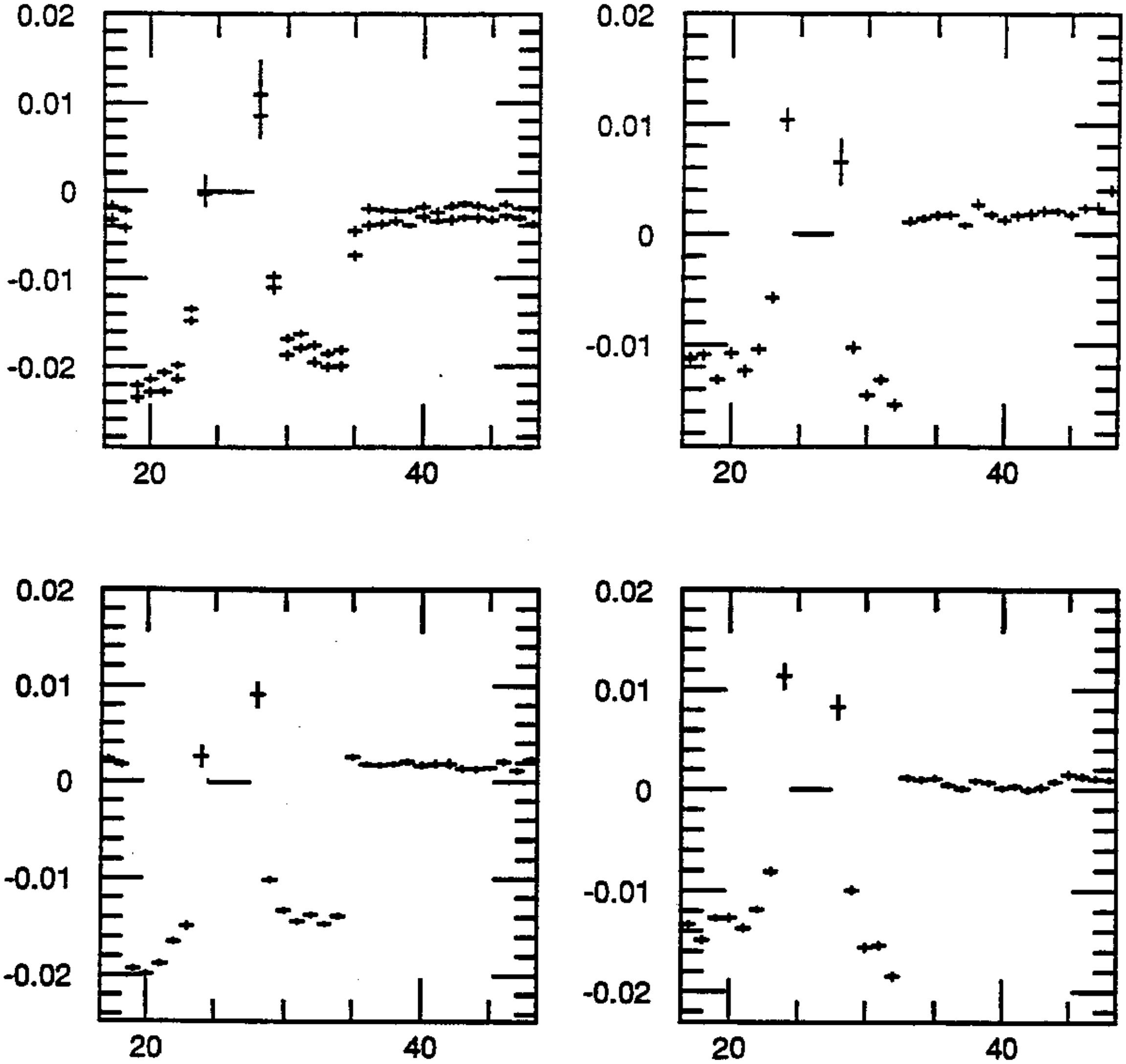

0
-100
-200
-300
0
5000
10000



15
10
5
0
-0.04
-0.02
0

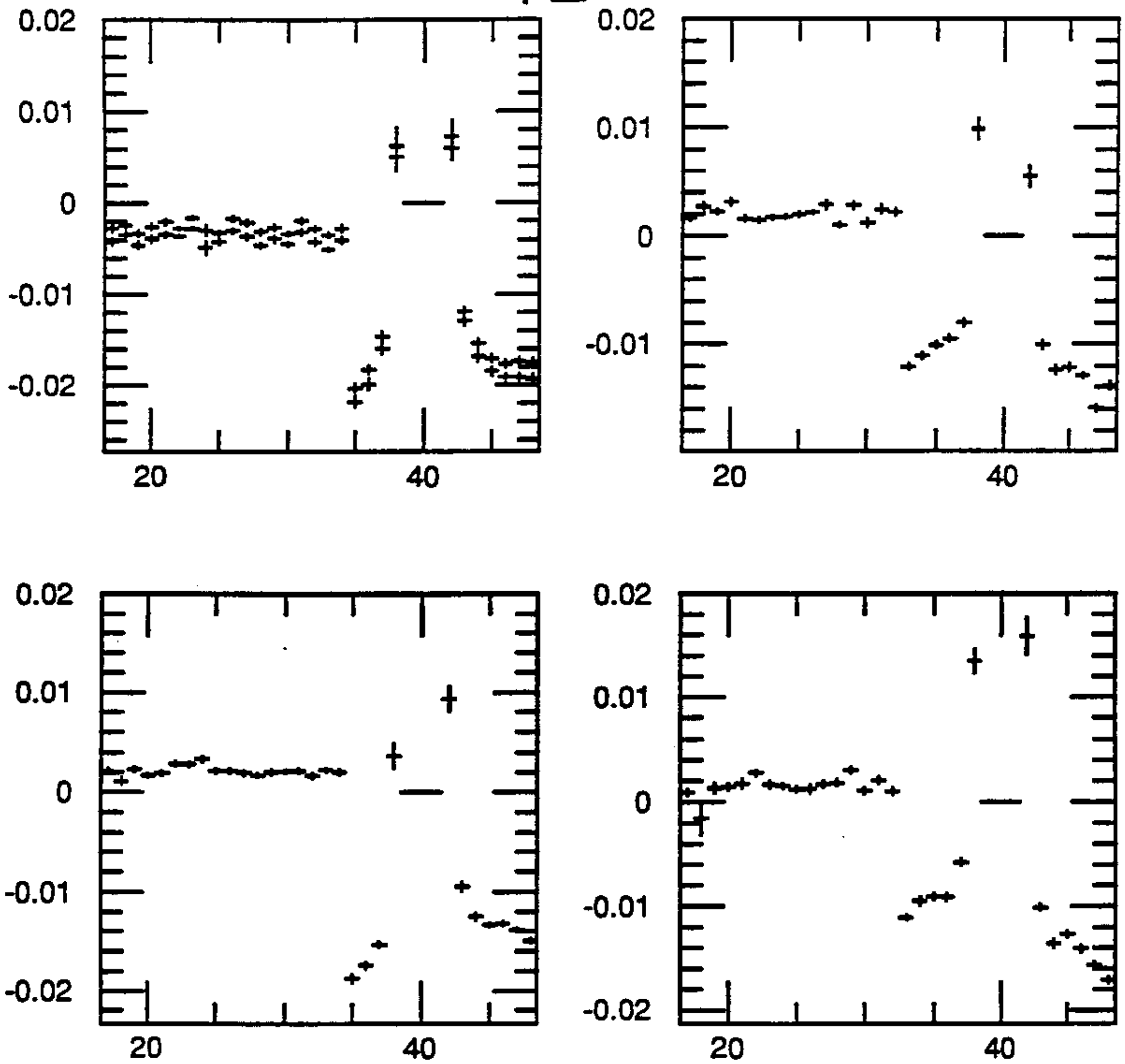

15
10
5
0
-0.02
0

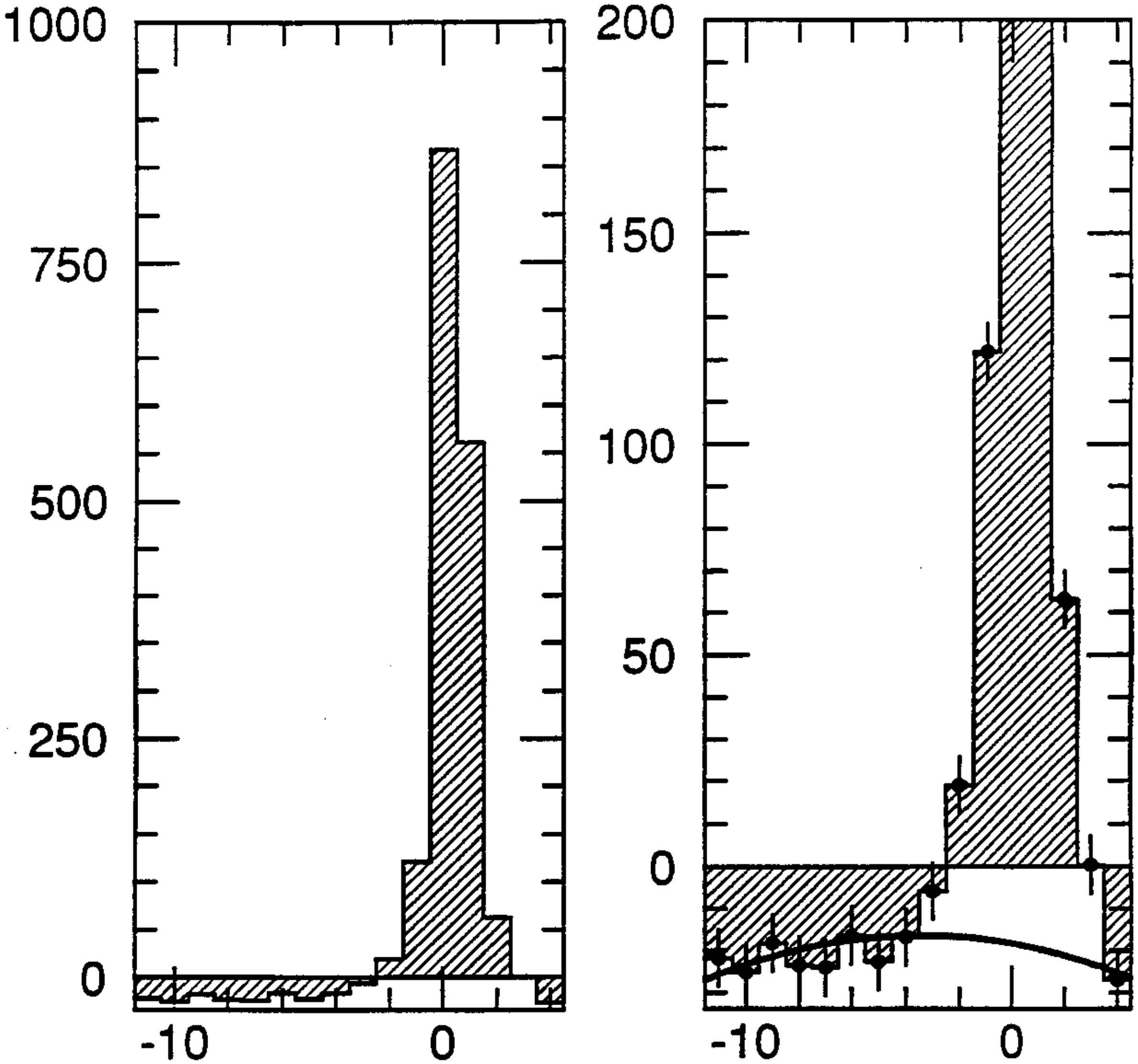
Strip_26



0.02
0.01
0
-0.01
-0.02
20
40
0.02
0.01
0
-0.01
20
40
0.02
0.01
0
-0.01
-0.02
20
40
0.02
0.01
0
-0.01
-0.02
20
40

Strip_40




1000
750
500
250
0
-10
0
200
150
100
50
0
-10
0

GEMUON Coleman Johnson 7-12-93

CHAMBER DESIGN

- Edge spacer frame update
- Summer workshop questions
- Intra chamber alignment transfer test prototype

PANEL PRODUCTION

- Cost summary

CHAMBER EDGE SPACER FRAME

gem

FUNCTIONS:

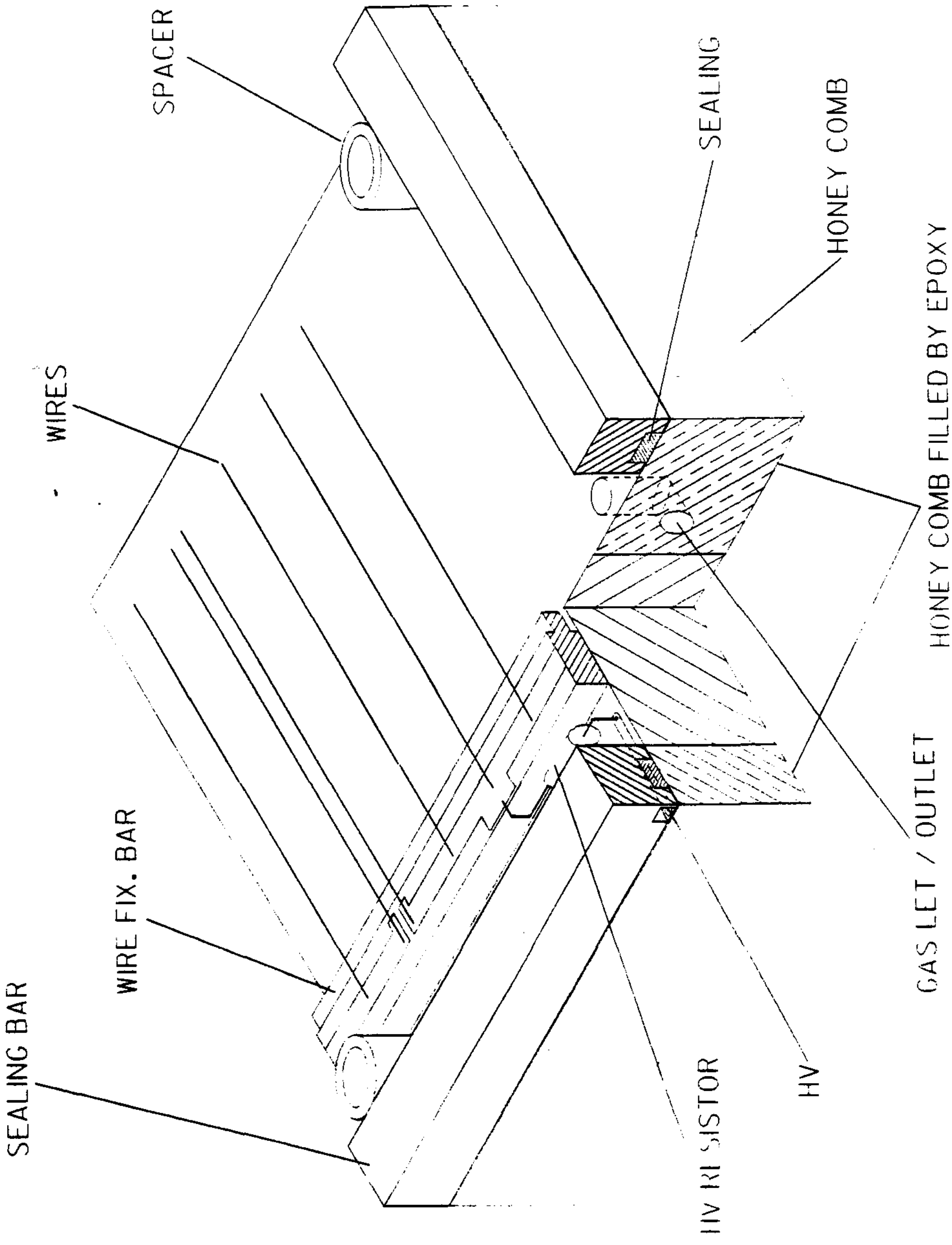
- Cathode-cathode spacing
- Cathode-anode spacing
- Wire support
- Gas seal
- Location for resistors, capacitors

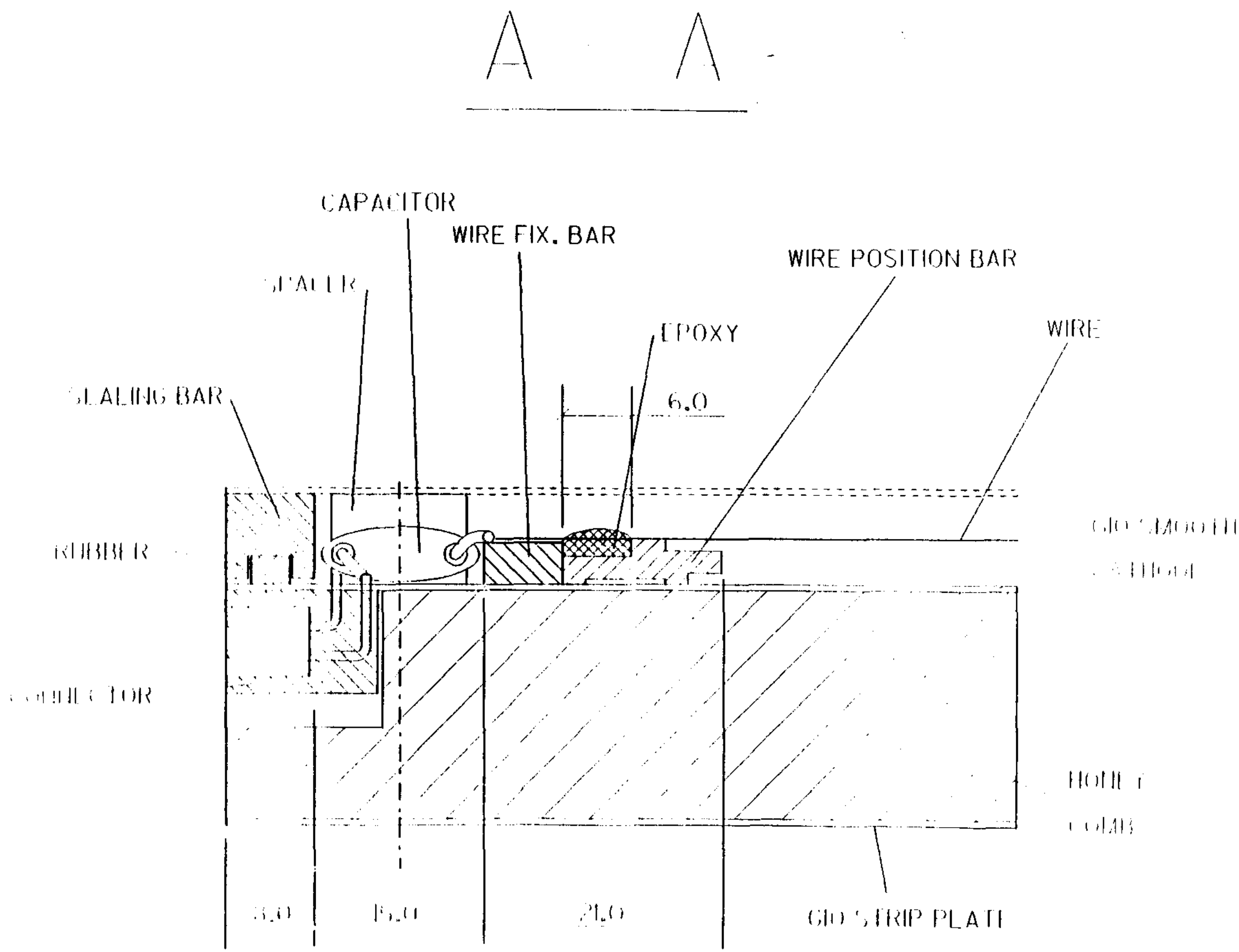
ONLY 2 REQUIRE ACCURATE DIMENSIONS:

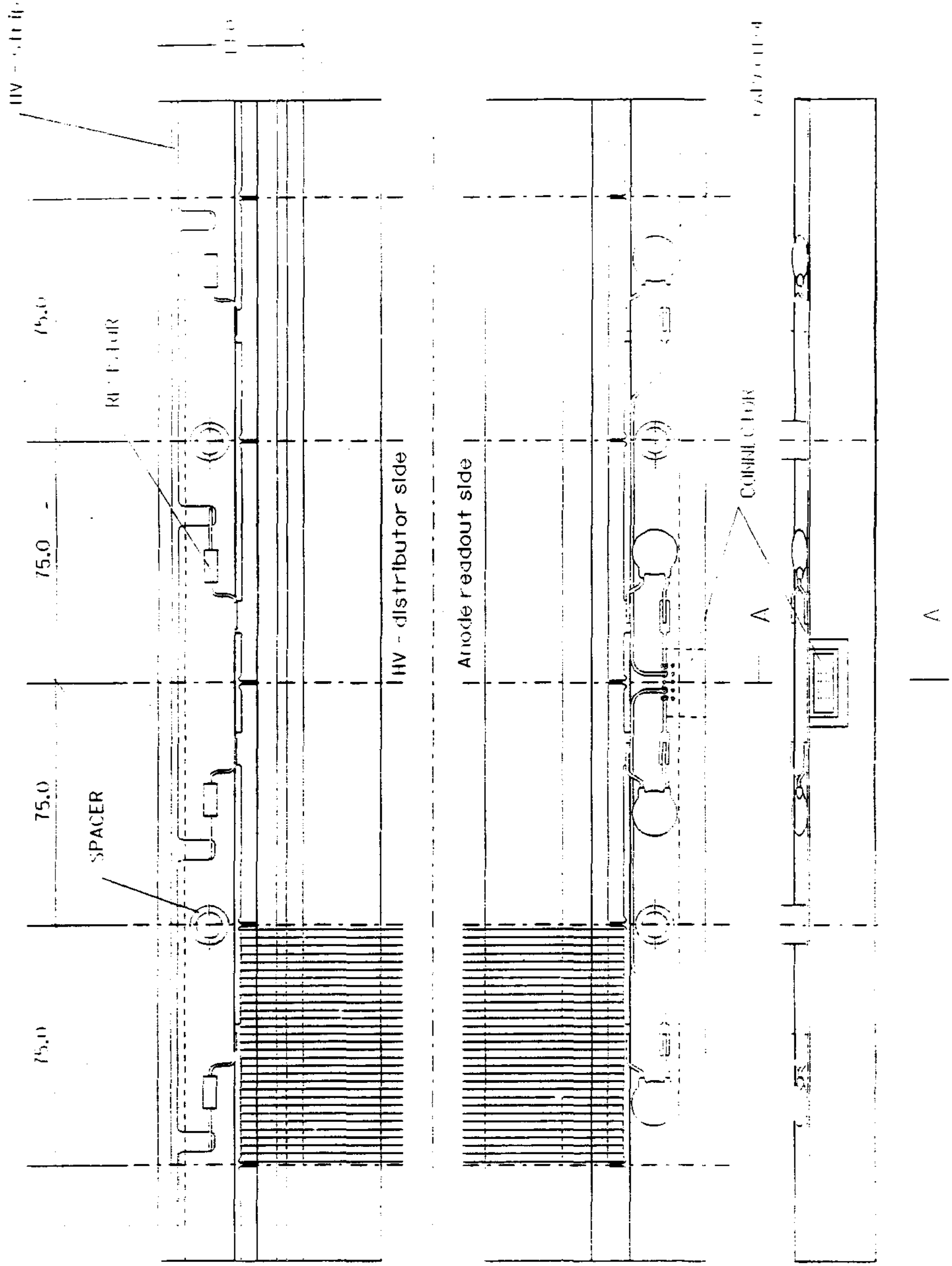
- Cathode-cathode spacing
- Cathode-anode spacing

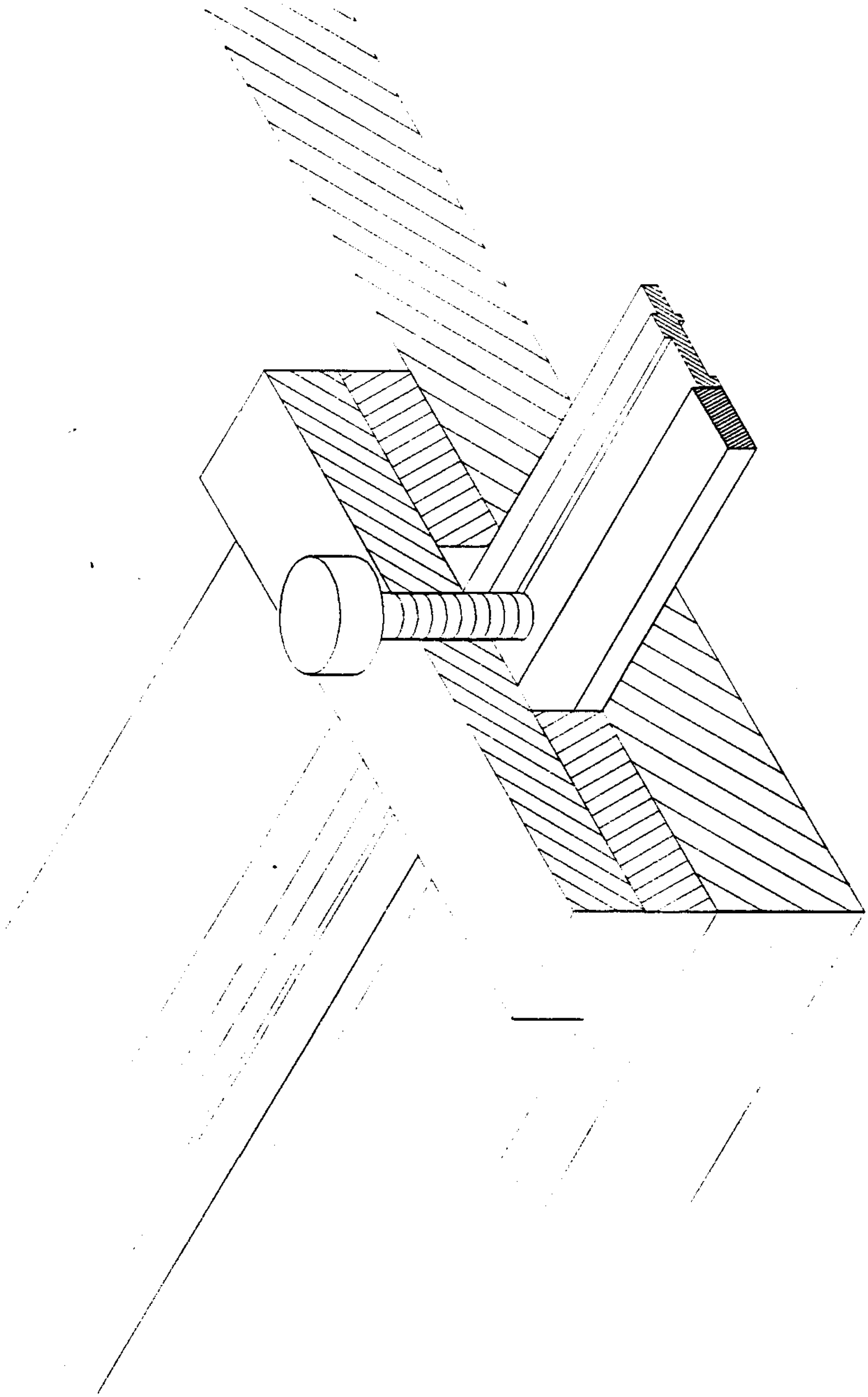
DESIRED PROPERTIES:

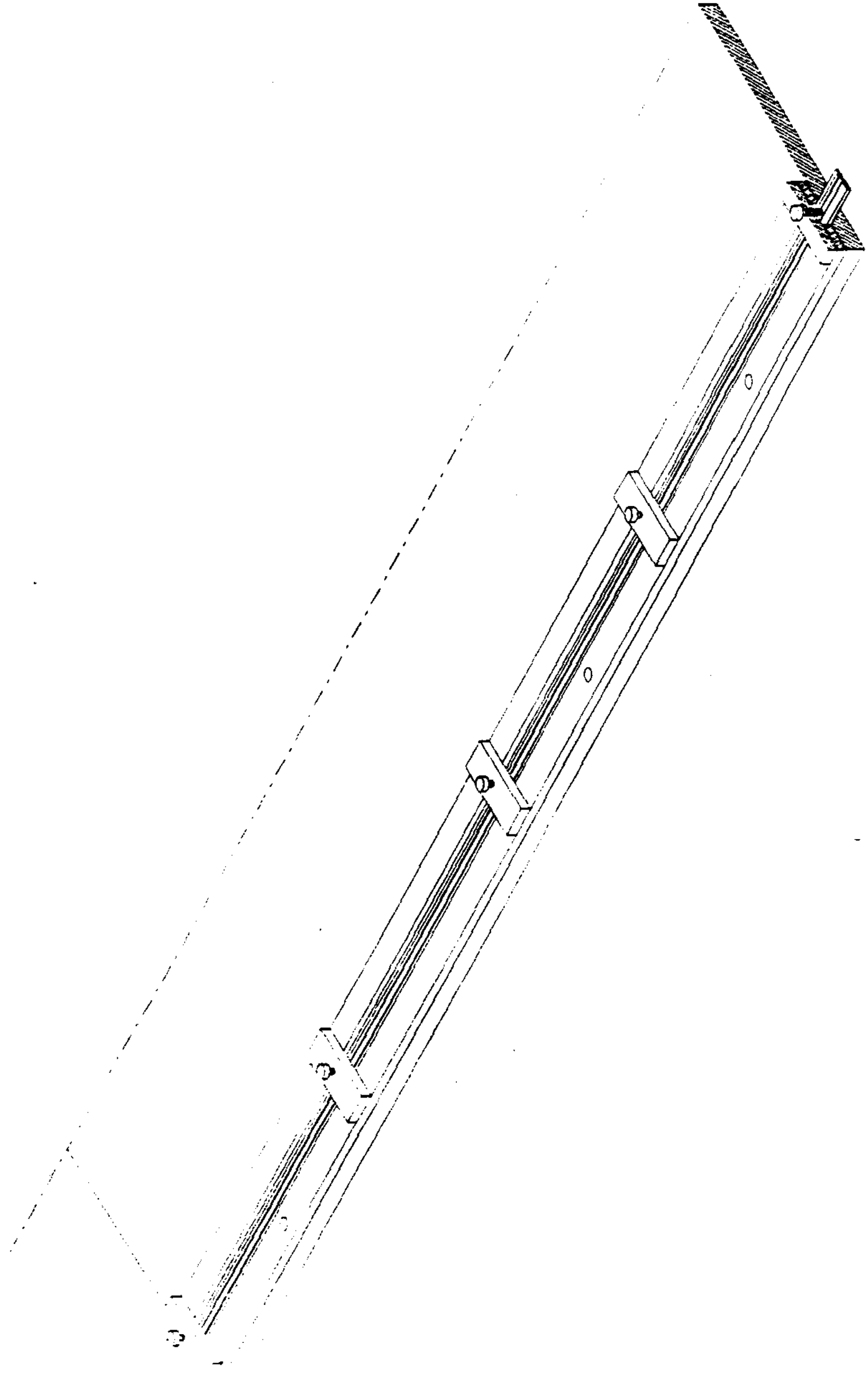
- Minimum material
- Minimize fabrication costs
- Minimize assembly costs


SPACER
WIRES
SEALING
HONEY COMB
HONEY COMB FILLED BY EPOXY
WIRE FIX. BAR
SEALING BAR
HV RESISTOR
HV
GAS LET / OUTLET

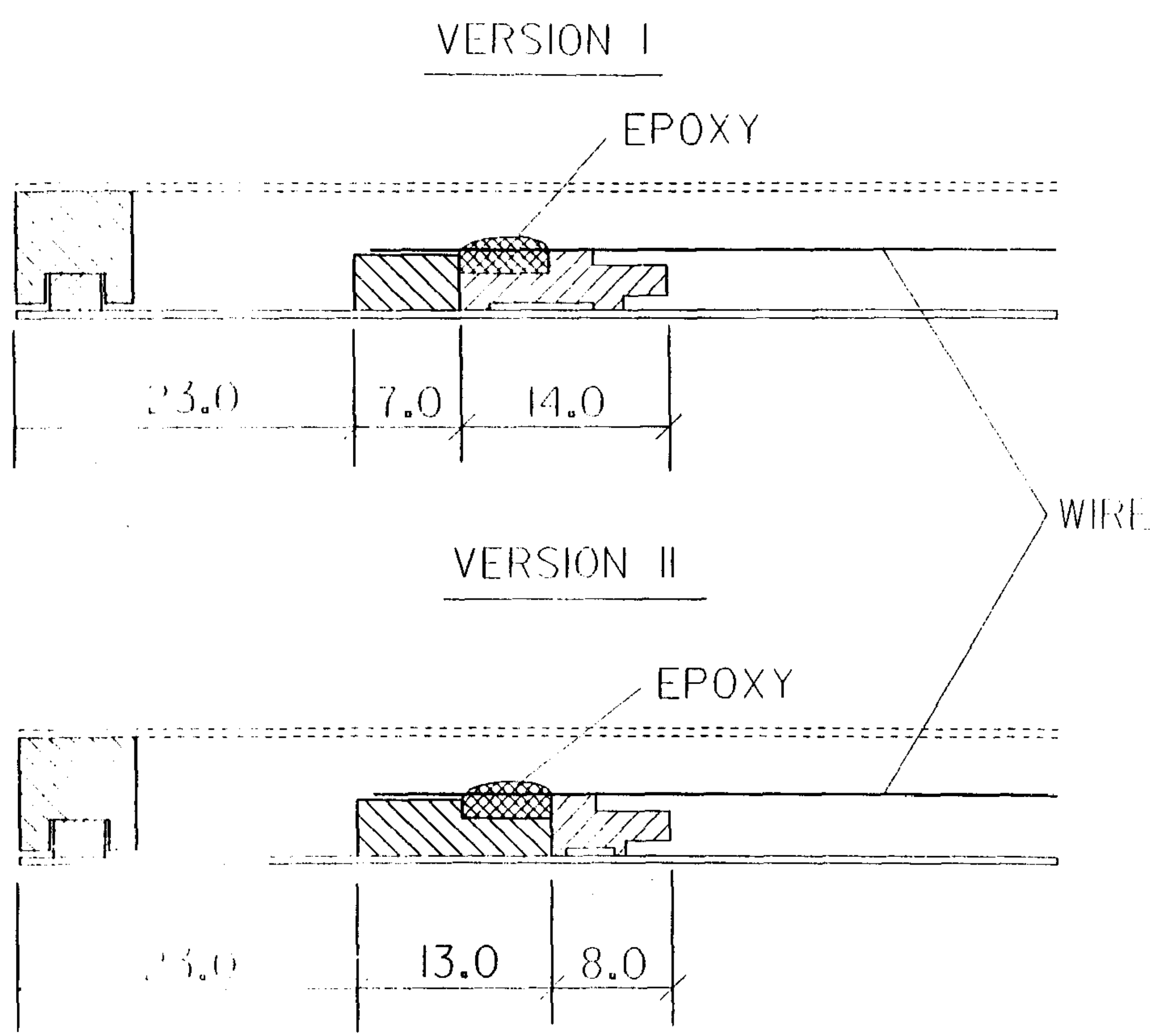

A A
CAPACITOR
WIRE FIX. BAR
WIRE POSITION BAR
EPOXY
WIRE
6.0
21.0


HV - distributor side
Anode readout side
SPACER
CONNECTOR
75.0
75.0
A
A





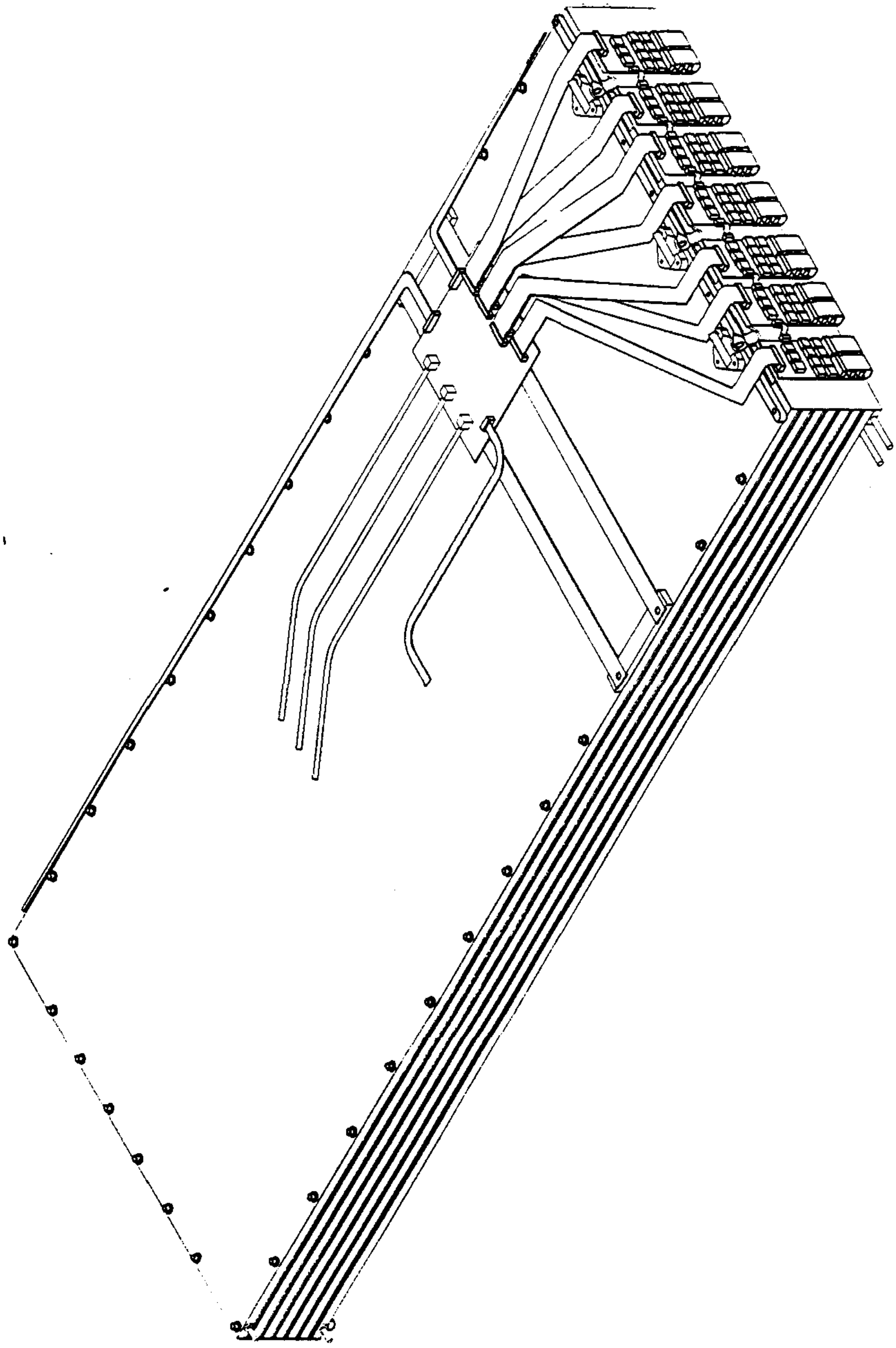
WIRE POSITION - FIXATION BARS'

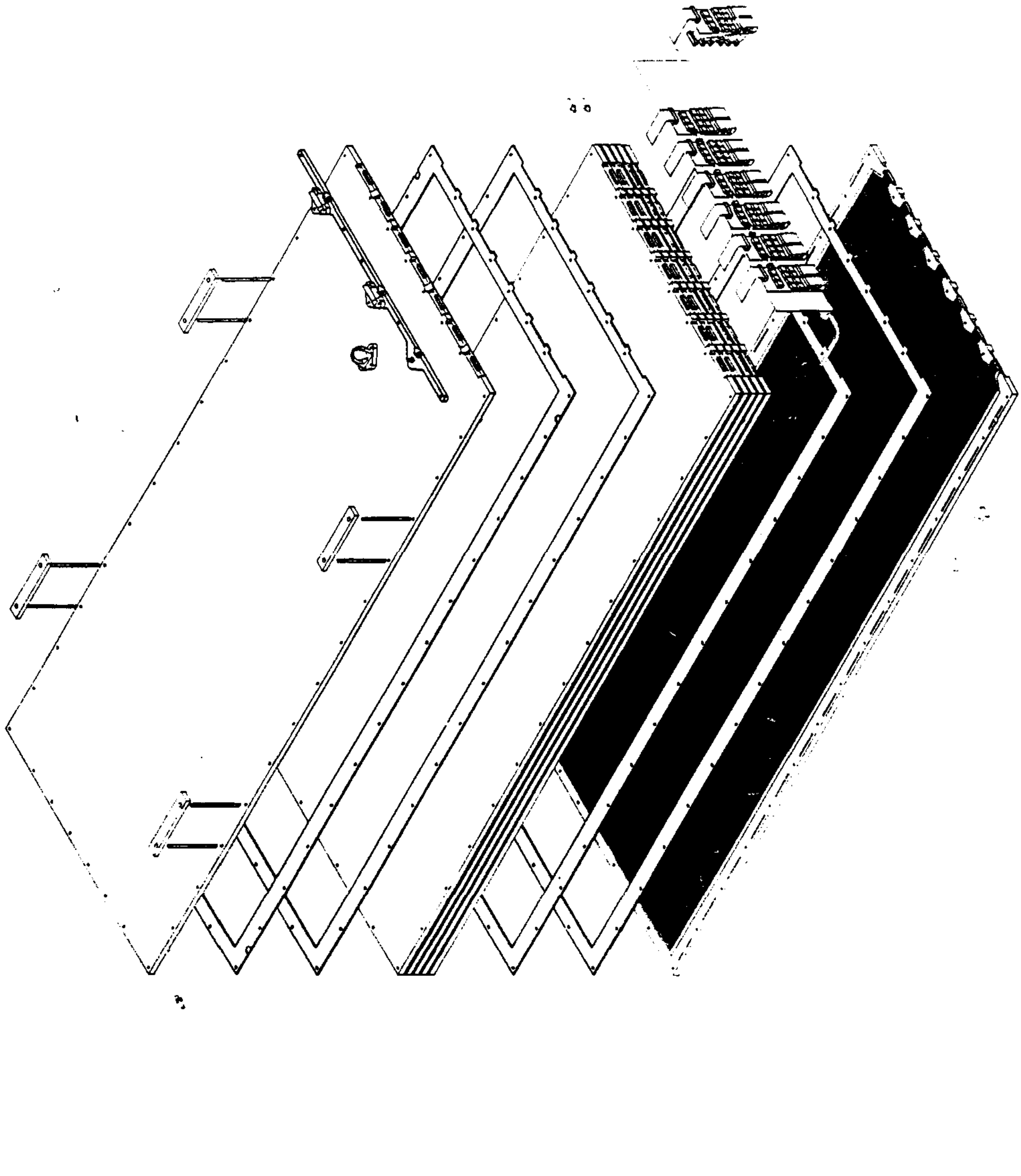


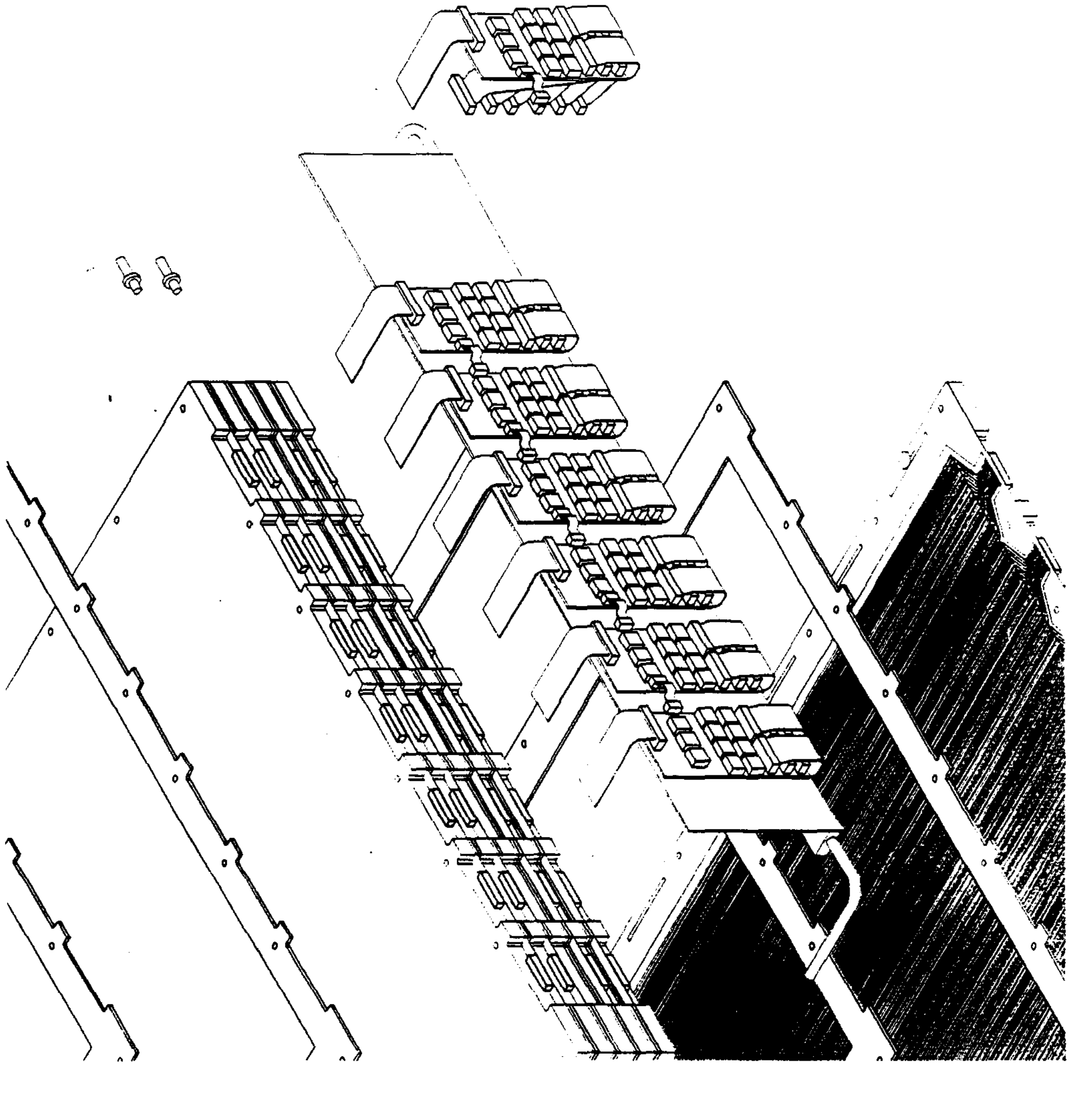
SUMMER WORKSHOP QUESTIONS

CHAMBER DETAILS TO BE STUDIED, TESTED, RESOLVED:

- HONEYCOMB PANEL
- EDGE FRAME
- BOLTS
- MID PLANE SPACERS
- ALIGNMENT DETAILS
- ON CHAMBER ELECTRONICS
- COOLING FOR ELECTRONICS
- ....
- ....







GEMUON SUMMER WORKSHOP QUESTIONS

DRAFT

1) HONEYCOMB PANEL:

a) unetched cathode side with anode readout connector;
b) precision strip cathode side with cathode readout connector;
c) honeycomb plate with edgefill and details;
d) gas inlet/outlet features

questions to be studied, tested, and resolved:

a) how to provide edge close outs, connector details, reinforcing for sealing, bolting, etc.
b) how to minimize density and total mass of close-out features
c) how to join layers of chambers together, bolts vrs adhesive bonding, effects on shear stiffness of final chamber, sag, etc., reinforcing for bolts, spacer tension wires, etc.
d) how to provide holes for support spacer wires, location, reinforcing, etc.
e) edge machining, raw honeycomb vrs edge filled, with or without face sheets bonded, etc.
f) cleaning, all holes, gas passages, etc.
g) soldering connectors to panel, reinforcing to withstand attachment forces, handling, etc.

2) EDGE FRAME:

a) provide wire position (both wire to wire and anode to cathode spacing) and fixation details;
b) provide wire anode circuit connections, distribution to connectors, etc.
c)provide location, isolation for resistors and capacitors
d) provide cathode to cathode dimension control
e) provide gas sealing details

questions to be studied, tested, and resolved:

a) detail component design to meet all functions and minimize mass and density of total system (compare three design concepts presented and others, evaluate, choose)
b) how should the frame elements be attached to the honeycomb panels? adhesive bond with controlled bond thickness, adhesive bond with line to line contact to control dimensions, casting in place, etc.
c) how should the anode wire connection copper pads be configured to allow staggering of wire groups from layer to layer in a given chamber? details of the required stagger? etc.
d) how should anode wires be fixed, electrically connected to frames? what kind of structural epoxy, how much; solder vrs conductive epoxy, etc.
e) what should the procedure, sequence be for attachment of resistors and capacitors? before wire attachment or after? above board or inside honeycomb/edgefill volume?
f) how to protect the high voltage distribution track, corona, surface leakage (dark current?) proximity to grounded bolts, etc. under gas seal?
g) how should we specify the cleaning processes and quality assurance testing, etc.

3) BOLTS

DRAFT

a) join honeycomb panels together to form chamber
b) ensure that elastic gas seal is intact
c) provide shear strength to chambers for sag
d) keep cathode planes in intimate contact with part of edge frame that determines cathode to cathode spacing.
e) possibly provide attachment to chamber mounting hardware
f) possibly provide attachment to chamber mounted electronics like mother boards
g) resist gas pressure

questions to be studied, tested, and resolved:

a) should bolts be inside of or outside of sealing location?
b)if bolts are inside of sealing location, how should the end be sealed, not compromise shear strength considerations, etc.
c) how should we define the bolting procedure, sequence, torques, etc.?

4) MID PLANE SPACERS

a) provide additional cathode to cathode spacing control, in compression
b) provide location for tensile element to ensure contact and resist gas pressure

questions to be studied, tested, and resolved:

a)study original Dubna design, new SSCL design, others, evaluate, choose
b) minimize lost readout area, volume
c) simplify fabrication
d) determine installation procedure constraints on design, when and how bonded into place, how to locate with respect to wires, etc.
e) how to prevent surface current leakage (dark current?) from high voltage anode wires to ground potential tensile element
f) how many do we need? how much performance degradation? etc.

5) ALIGNMENT DETAILS

a) provide means to transfer knowledge of precision strip locations outside of the given plane for layer to layer alignment in a specific chamber and transfer to straightness monitor systems

questions to be studied, tested, and resolved:

a) study various ideas for transferring etched pattern to a mechanical (washer/) external feature, registration, phi and theta directions?, attachment schemes, etc.
b) study possible external etched pattern concepts such as for the stretched wire concept (AK) identify limitations of photolithography process like minimum gaps achievable with accuracy, etc.
c) study details of straightness monitor hardware attachment to the chambers, machined grooves to indent lines of sight into chamber volume, etc.

6) ON CHAMBER ELECTRONICS

DRAFT

a) provide pre amplifiers to get signals from cathode strips to mother board for processing
b) marry information with adjacent pre amp boards for triggering information
c) provide pre amplifiers to get signals from anode wire sets to the mother board for processing
d) provide mother board to accept signals from both cathodes and anodes, process data, and send data and triggering information to control center
e) provide regulated low voltage to electronics
f) calibration functions
g) possibly provide high voltage system fault detection, circuit interruption
h) possibly provide calculations for straightness monitors
i) possibly provide input to and receive output from functional transducers like pressure, temperature, flow, etc.

questions to be studied, tested, and resolved:

a) study implications of the various locations for the first electronics, effects of cable lengths on signal to noise ratios, effects of access specific design features on the theta coverage, mounting, etc.
b) determine best shielding concept, compare woven with solid shields, feed thrus, straightness monitors, access for maintenance or replacement problems, support problems, grounding isolation concerns, etc.
c) study high voltage feed thru concerns
d) study effect of captured gas, dead air space, etc.
e) study overall temperature impact of closed shielding (see cooling, below)

7) COOLING FOR ELECTRONICS:

a) remove heat generated by the electronics
b) prevent any heat from distorting the chamber elements

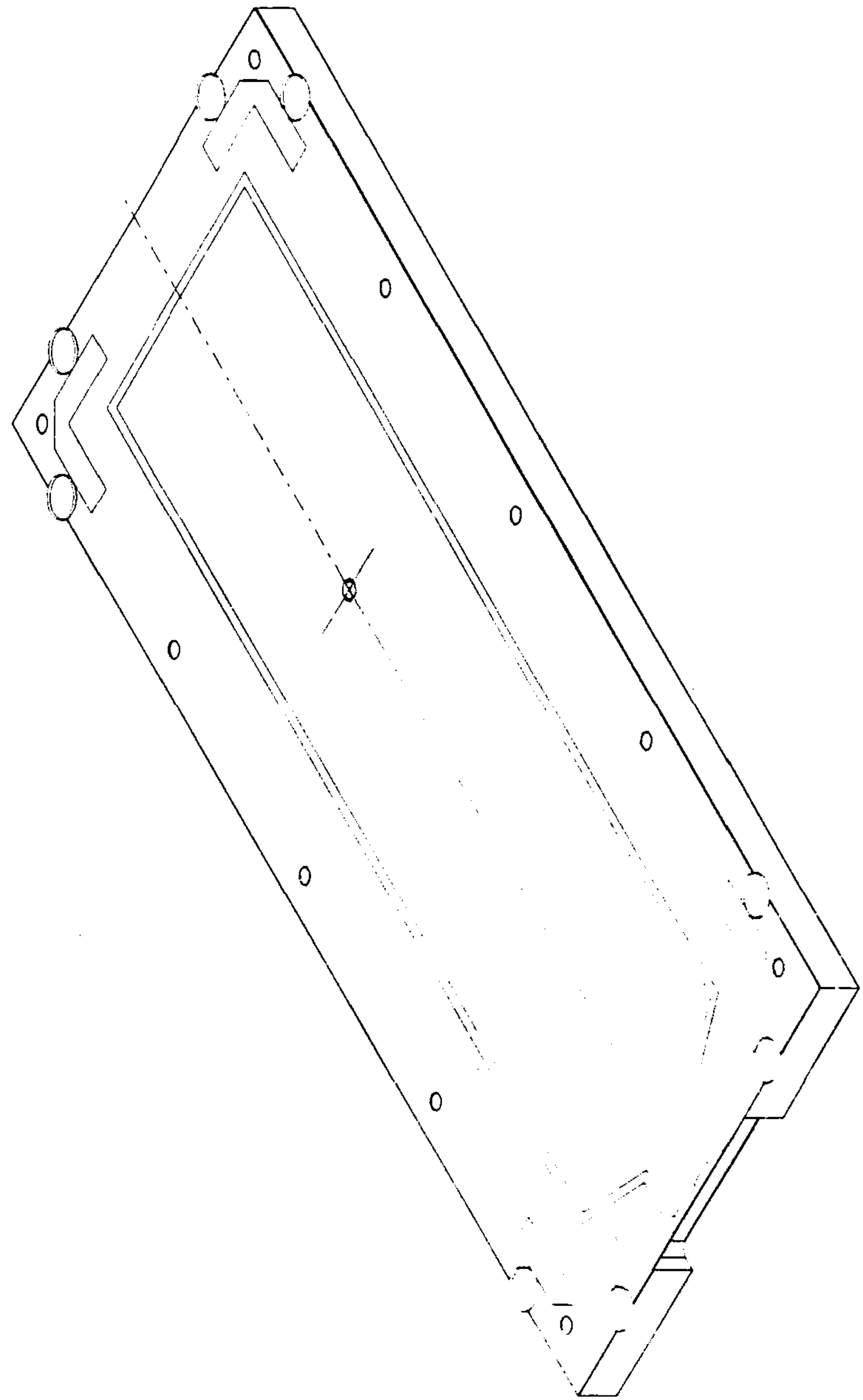
questions to be studied, tested, and resolved:

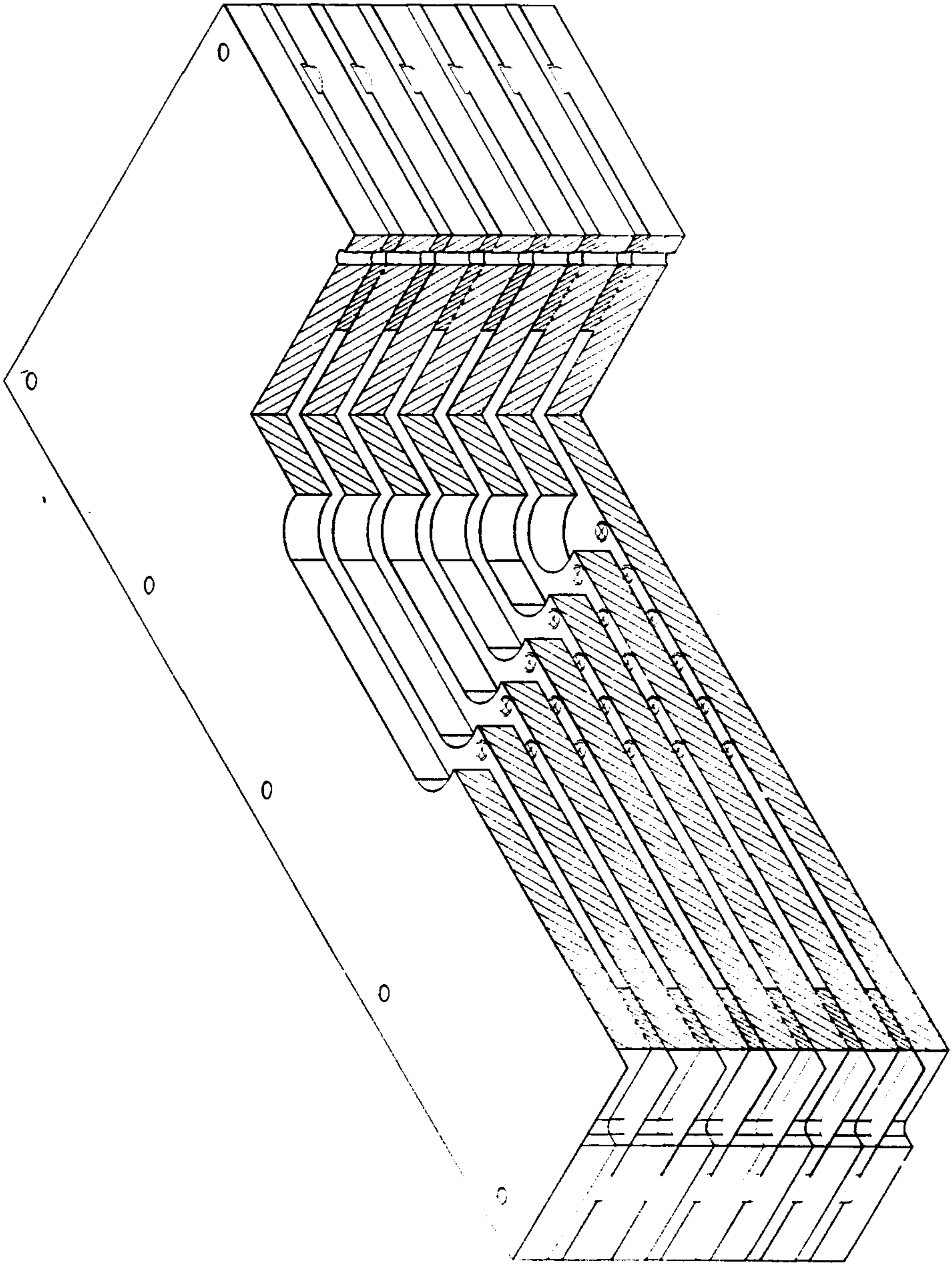
a) study ways to attach the electronics to the cooling system, make good thermal contact, etc.
b) ensure that attachment is consistent with maintenance access
c) study combinations of conductive and radiative cooling shields
d) consider the impact of the EM shielding on static air around heated electronics
e) study reliability impact of design features like soldered joints, feedthrus, etc.
f) study impact of pressure and flow controls on overall system design

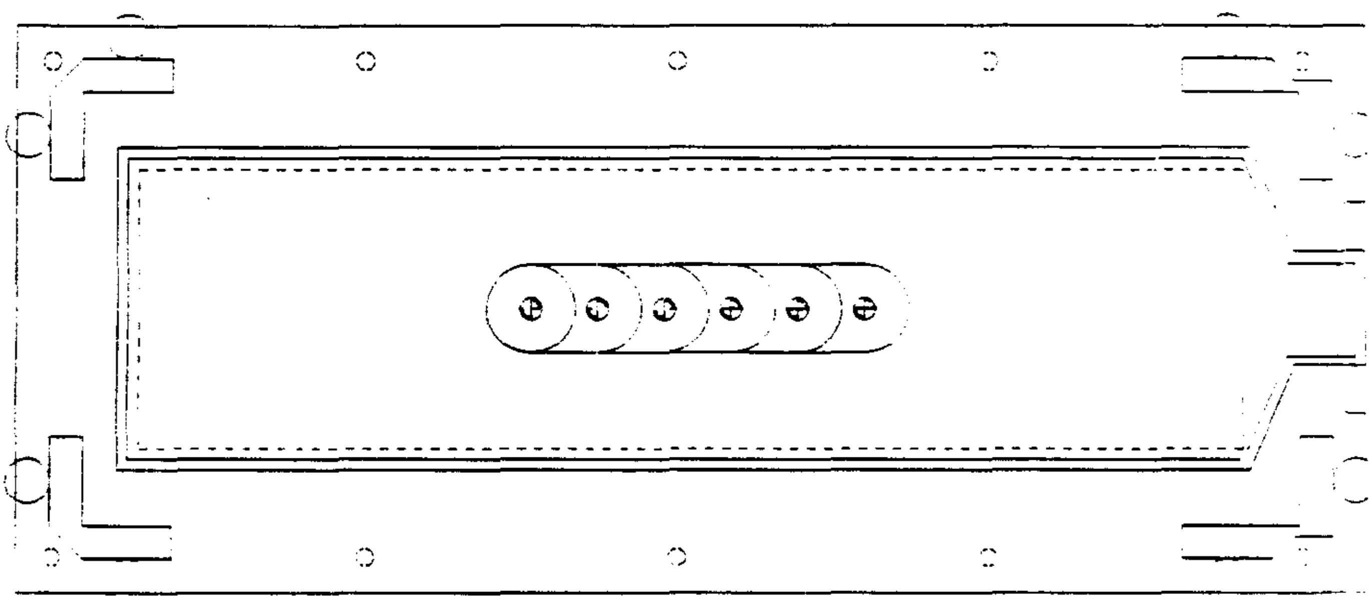
INTRA CHAMBER ALIGNMENT TRANSFER

TEST PROTOTYPE

- SSCL design concept
- Design coordinated with/transferred to LLNL
- Model to be constructed, tested at LLNL







COMMENTS ON CHAMBER LAYOUT

I. GOLUTVIN

07/12/93

Questions and Recommendations

1. Access to the muon system is claimed to require 3-4 months. The subpanel views this as undesirable and encourage the proponents to explore short-turn-around emergency access, perhaps through a small section of the muon end cap.

2. The 48-fold azimuthal segmentation may be unnecessarily fine. The subpanel requests that the proponents perform a cost-benefit analysis of the degree of segmentation. Reduced segmentation could lead to a lower overall cost and less material to produce multiple scattering and backgrounds.

3. The measurement and monitoring of the magnetic field requires more detailed study.

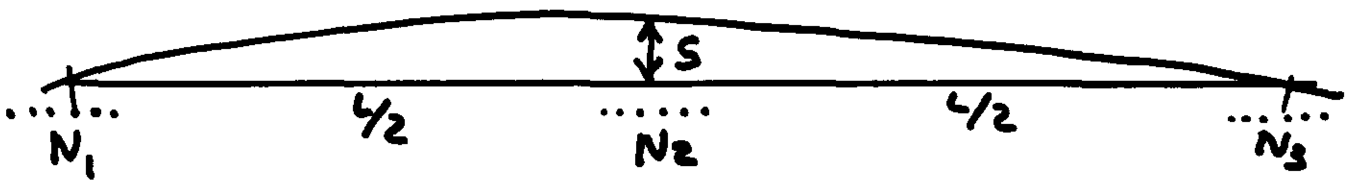
4. The proponents are encouraged to consider methods to improve the geometrical efficiency of the system within the angular region covered.

5. The proponents should proceed expeditiously towards a full-scale pre-production chamber.

1. WIDTH OF THE CHAMBERS IN THE MIDDLE SUPERLAYER

2. MATERIAL IN THE CSC

BASIC FORMULA:



$$\frac{\Delta p}{p} = \frac{\Delta s}{s} = \frac{27\, p\,(\frac{TeV}{c})}{BL^2\,(Tm)} \sqrt{\frac{\sigma_{s1}^2}{2} + \sigma_{s2}^2 + \frac{\sigma_{s3}^2}{2}} + \frac{0.1}{BL\,(Tm)} \sqrt{\frac{X_2}{X_0}}$$

$\sigma_{s1}, \sigma_{s2}, \sigma_{s3}$ - RESOLUTION OF SUPERLAYERS 1, 2, 3

$$\sigma_{si}^2 = \frac{\sigma_i^2}{N_i\, \epsilon_i}$$

σ_i - SINGLE LAYER RESOLUTION IN SUPERLAYER i

N_i - NUMBER OF LAYERS IN SUPERLAYER i $(N_i = 6)$

ϵ_i - SINGLE LAYER EFFICIENCY

$\frac{X_2}{X_0}$ - RAD. LENGTH OF SUPERLAYER 2

(1) RESOLUTION OF SUPERLAYER 2 SHOULD BE OPTIMIZED

$$\text{MIN} \left\{ \frac{\sigma_2^2}{N_2\, \epsilon_2} \right\}$$

(2) MULTIPLE SCATTERING IN SUPERLAYER 2 SHOULD BE MINIMIZED

$$\text{MIN} \left\{ \frac{X_2}{X_0} \right\}$$

DOMINATING REQUIREMENTS:

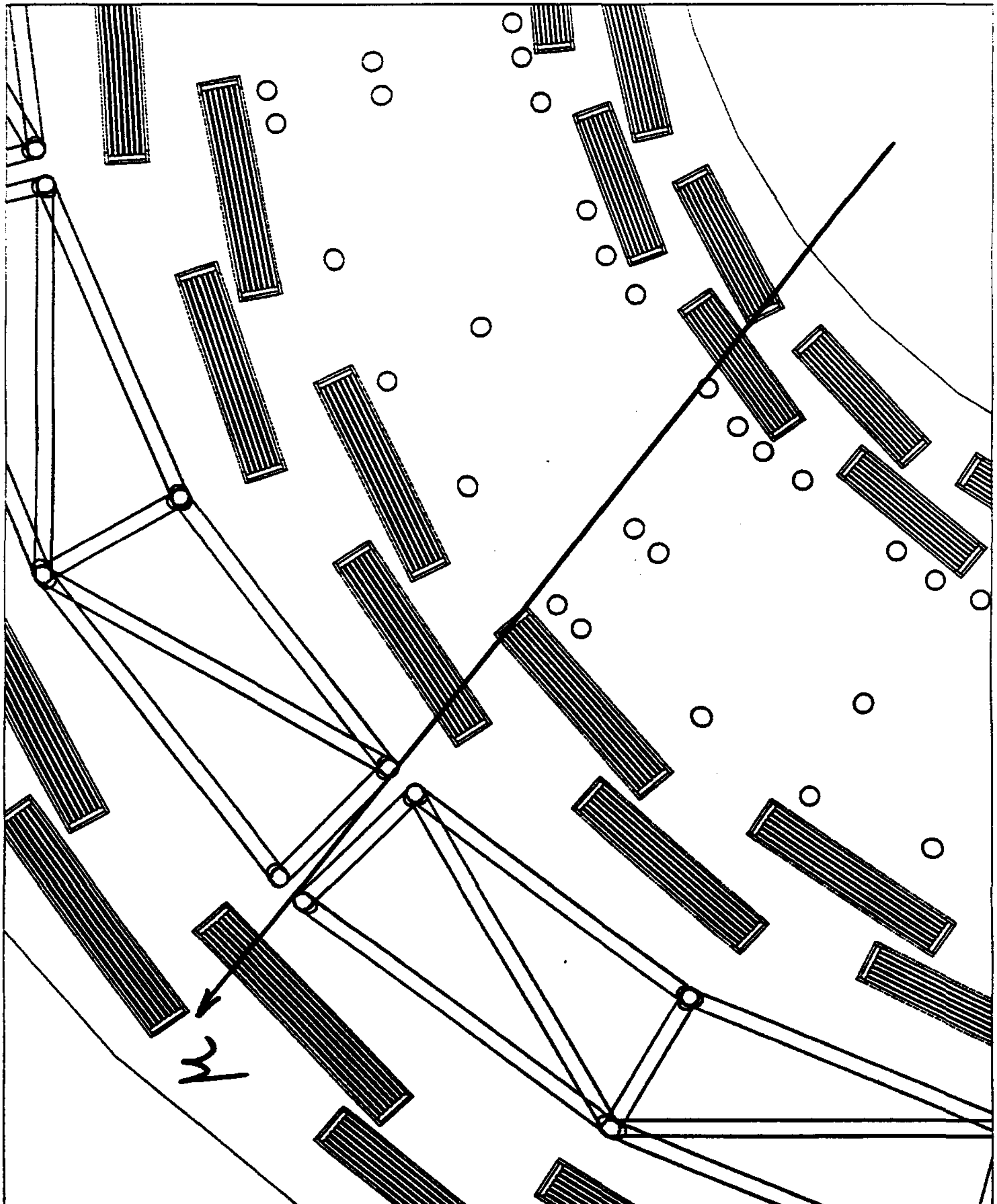
- MINIMUM NUMBER OF CHAMBERS IN THE MIDDLE SUPERLAYER
- MINIMUM NUMBER OF RAD. LENGTH IN THE CHAMBER AND IN THE FRAMES

DRIVING CONSTRAINS:

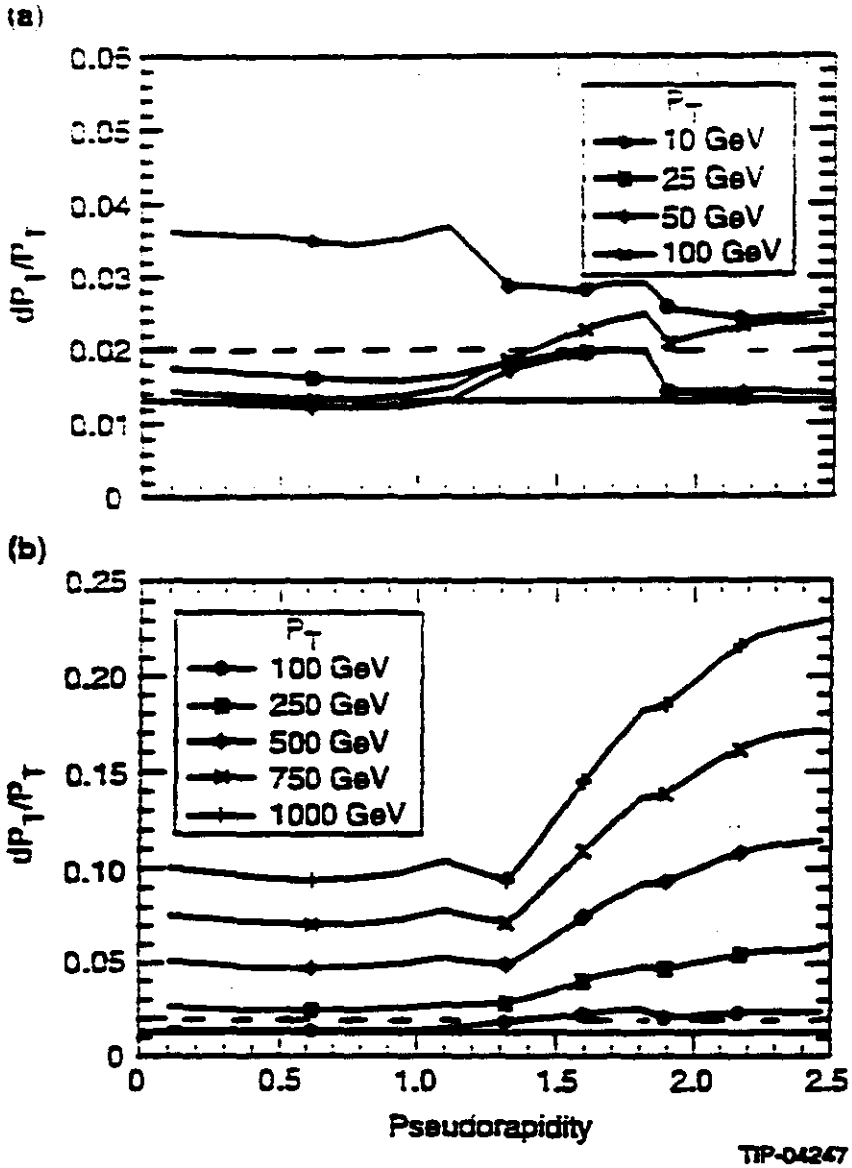
- MAXIMUM POSSIBLE LENGTH OF ANODE WIRES (L_w)
- ANGULAR RANGE IN THE MIDDLE CHAMBER ($\Delta\varphi$)

$$L_w = 120 \text{ cm}$$

$$\Delta\varphi = \pm 5^\circ$$



M



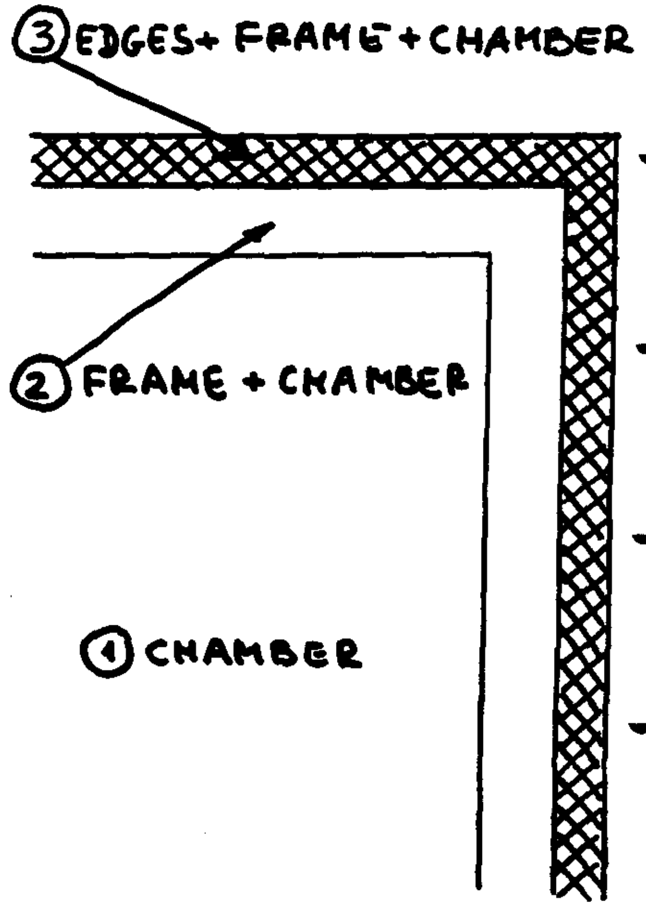


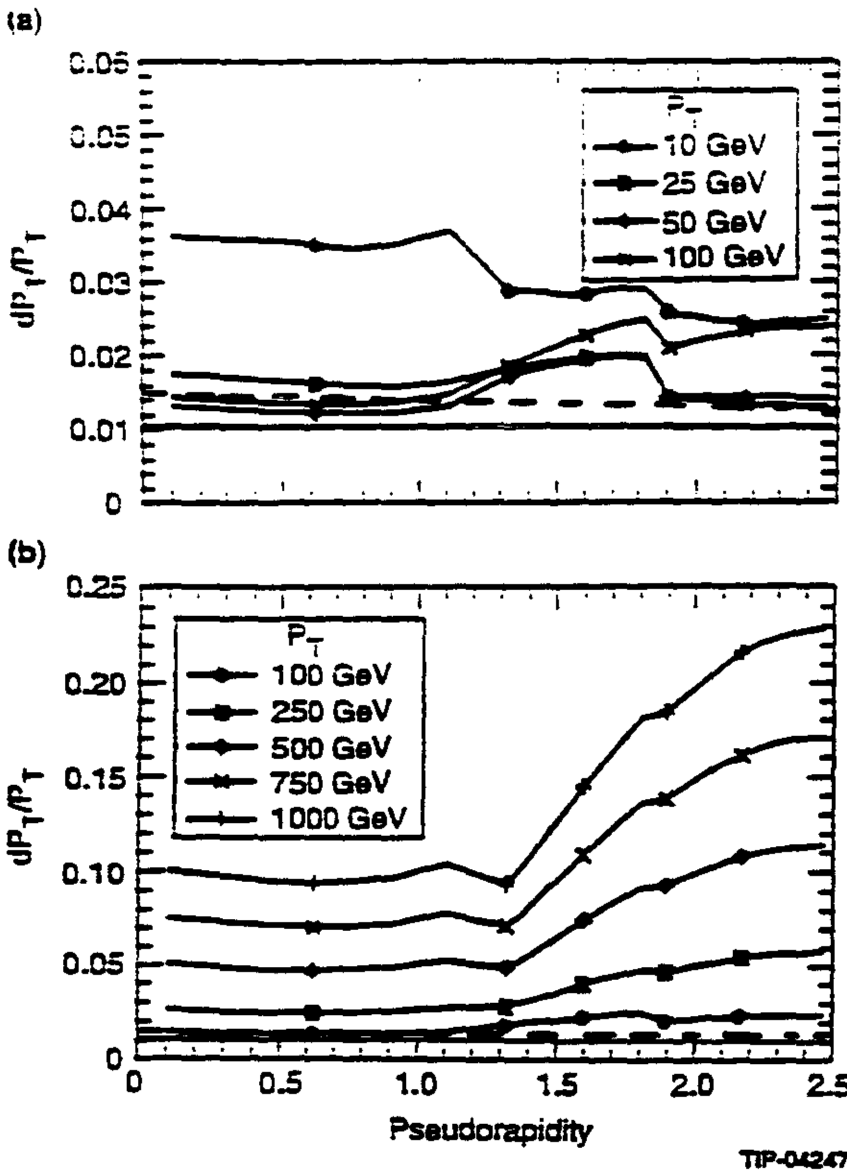
FIG. 4-19. Transverse momentum resolution for standalone three superlayer system:
a) $10 \leq p_T$ 100 GeV and
b) $100 \leq p_T \leq 1000$ GeV.

EDGES AND FRAMES ARE MADE OF EPOXY

① $0.063\ X_0$ $\qquad \left(\frac{\Delta p}{p}\right)_{MS} = 0.6\%$

② $0.21\ X_0$ $\qquad \left(\frac{\Delta p}{p}\right)_{MS} = 1.3\%$ ——

③ $0.66\ X_0$ $\qquad \left(\frac{\Delta p}{p}\right)_{MS} = 2\%$ ----



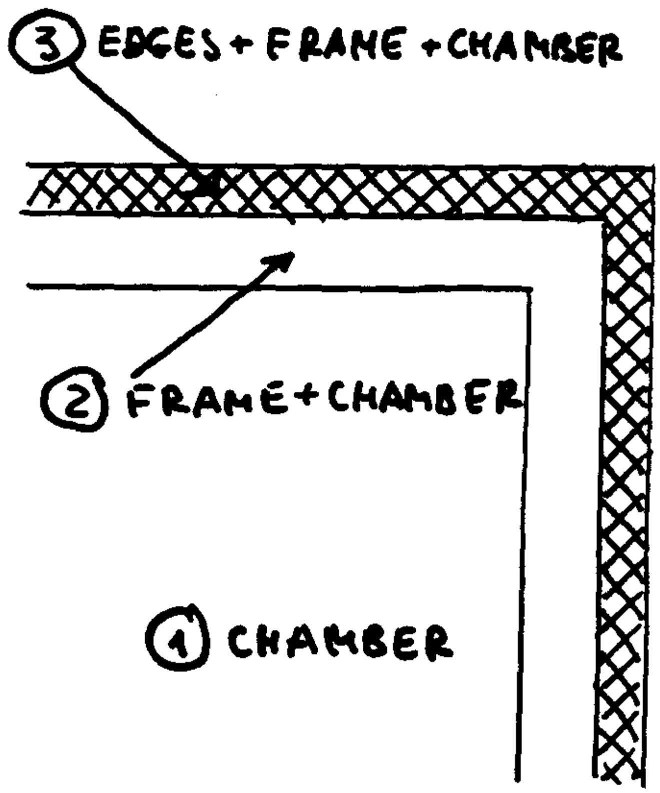


FIG. 4-19. Transverse momentum resolution for standalone three superlayer system:
a) $10 \le p_T$ 100 GeV and
b) $100 \le p_T \le 1000$ GeV.

EDGES AND FRAMES ARE MADE OF POLYMER CONCRETE

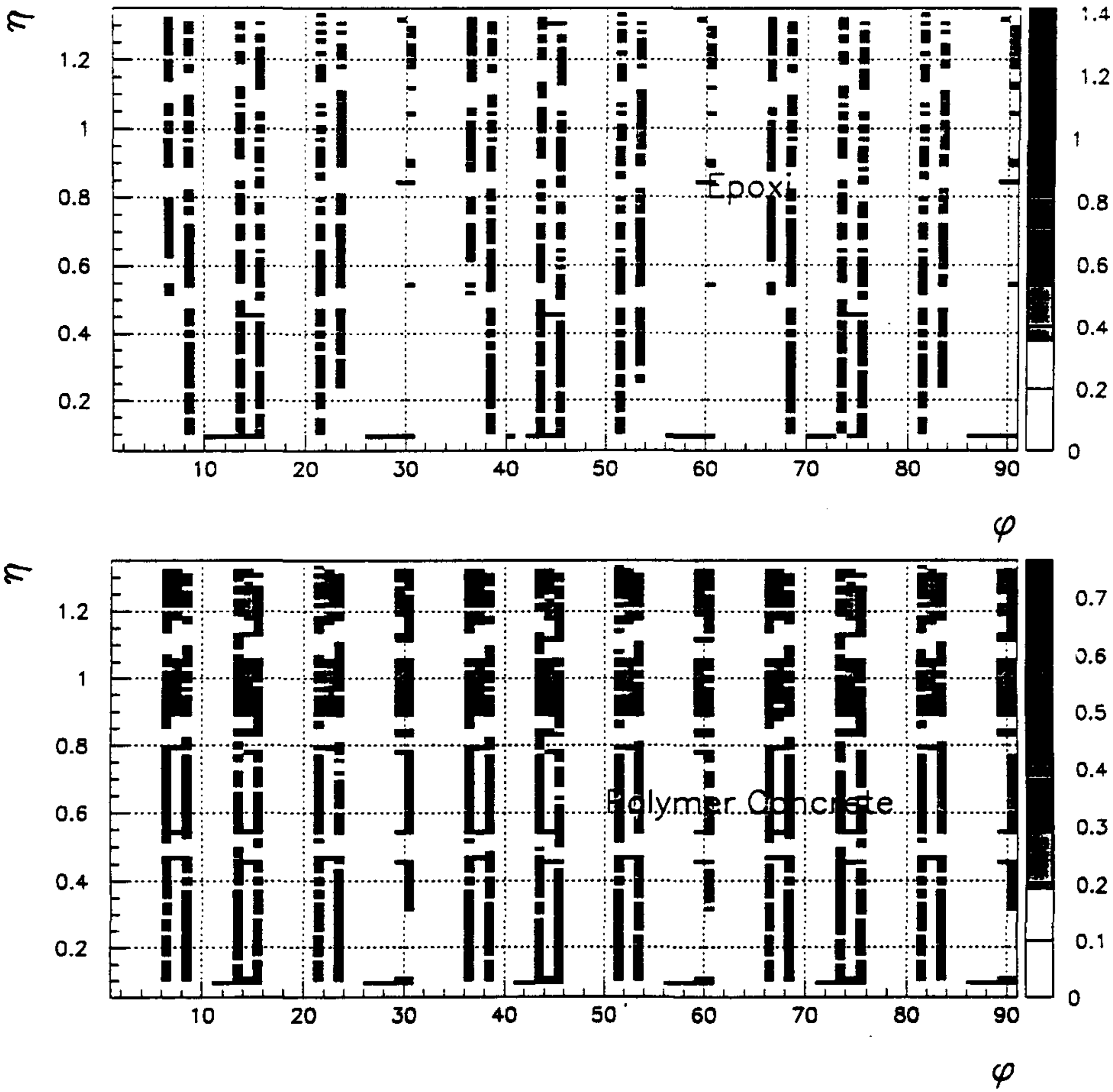
① $0.063\ X_0$ $\quad \left(\frac{\Delta p}{p}\right)_{MS} = 0.6\%$

② $0.14\ X_0$ $\quad \left(\frac{\Delta p}{p}\right)_{MS} = 1\%$ ——

③ $0.37\ X_0$ $\quad \left(\frac{\Delta p}{p}\right)_{MS} = 1.5\%$ - - - -

93/07/10 22.07

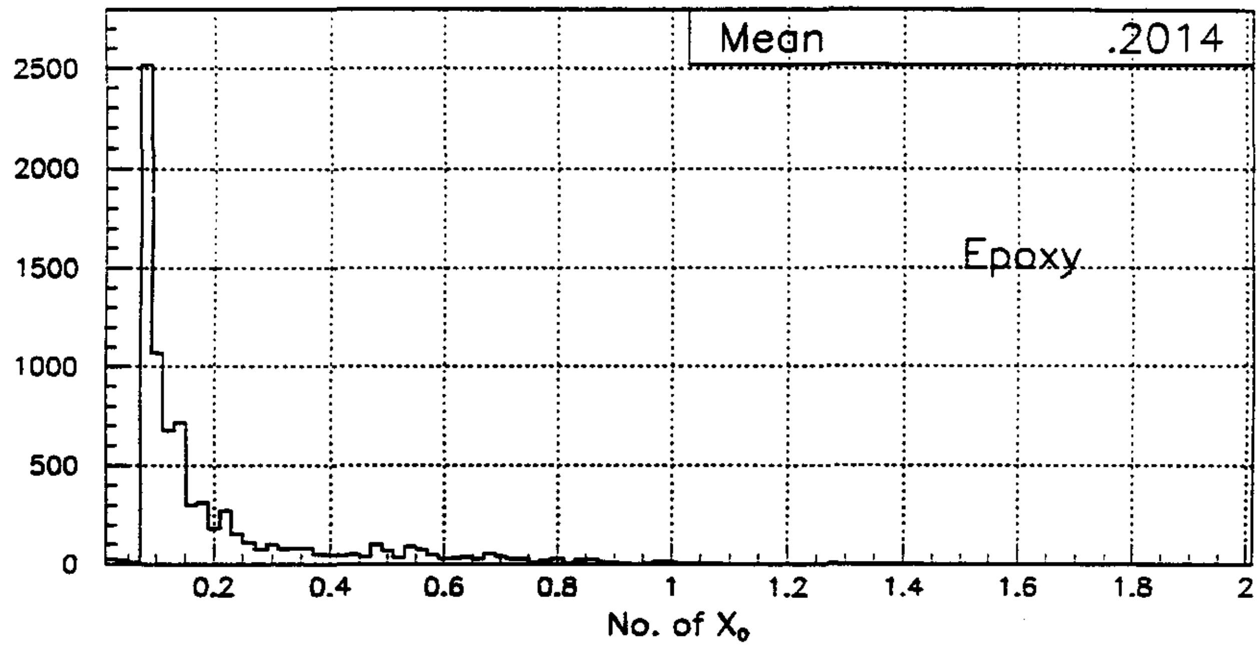
No. of X_0 in Barrel middle layer Y.Fisyak

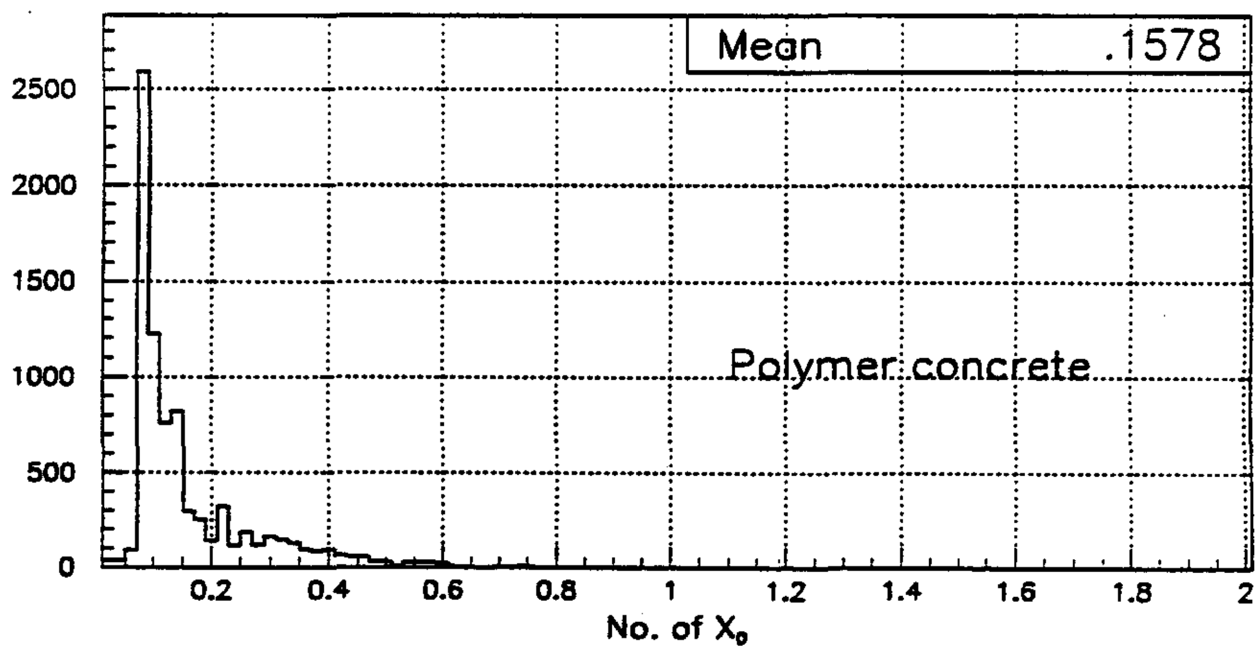


93/07/11 14.54

No. of X_0 seen by muon in 2-nd barrel superlayer

Y.Fisyak





CONCLUSIONS:

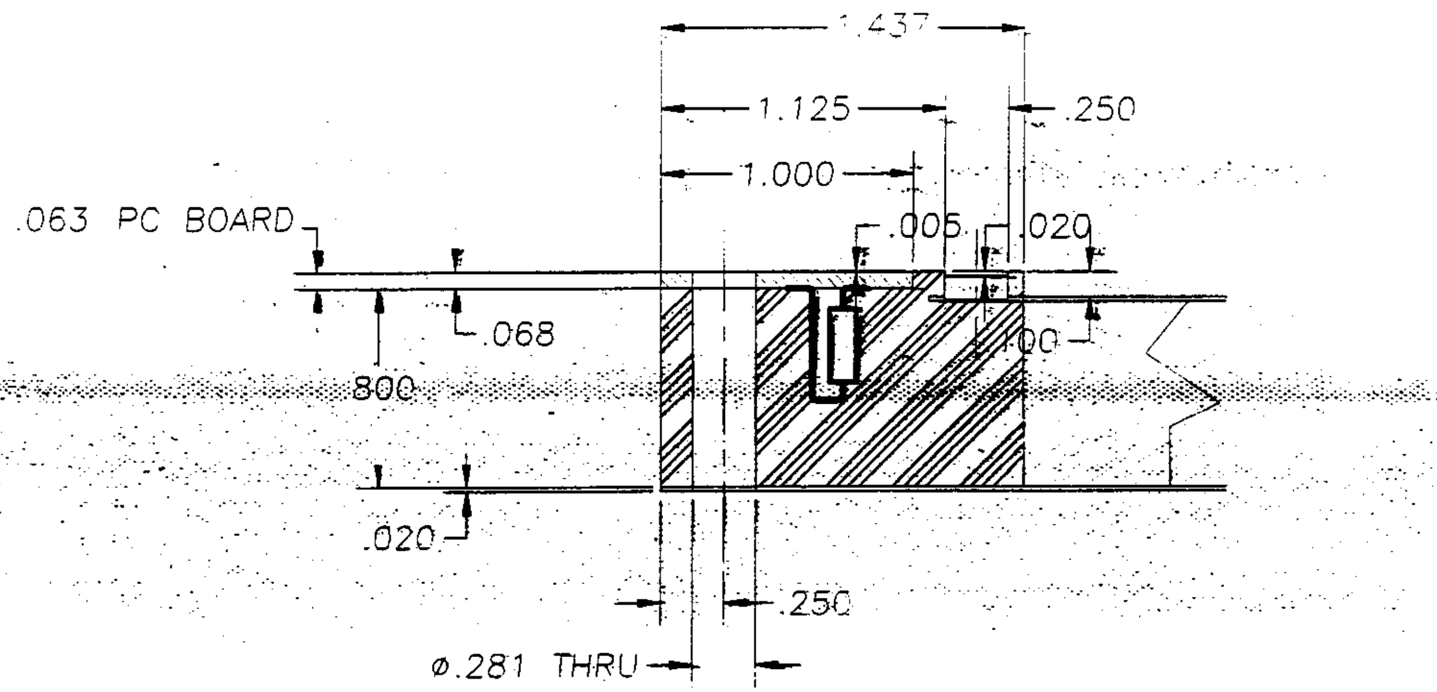
1. THERE IS NO CRUCIAL EFFECT OF MULTIPLE SCATTERING IN CSC FRAMES AND EDGES ON MUON MOMENTUM RESOLUTION: CHAMBERS OVERLAPPING DOES NOT MAKE A VITAL DETERIORATION

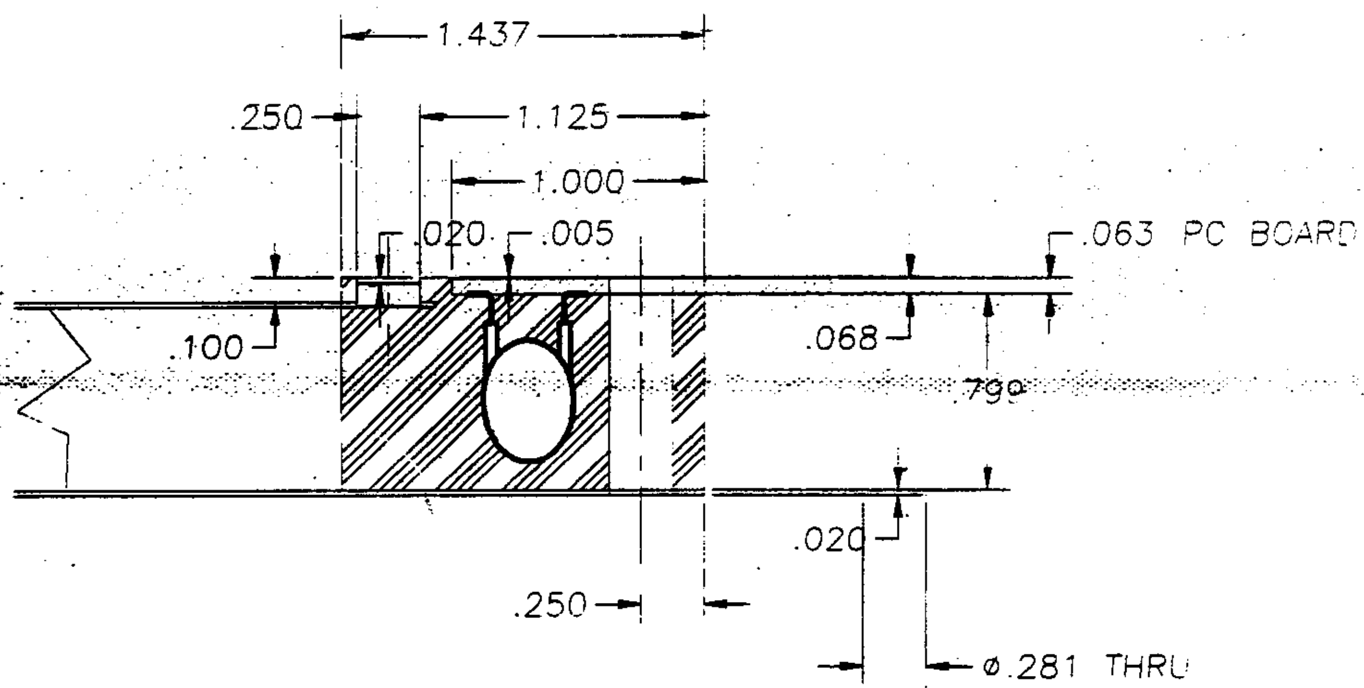
2. THERE IS NO NEED TO MINIMIZE THE WIDTH OF FRAMES AND EDGES

3. INCREASING THE WIRE LENGTH IN THE MIDDLE SUPERLAYER TO THE MAXIMUM POSSIBLE (120 cm) WILL DECREASE THE NUMBER OF FRAMES AND EDGES BY 25%

Presentation by:

Vinnie Polychronakos


1.437
1.125
.250
1.000
.063 PC BOARD
.005
.020
.068
.100
.800
.020
.250
ø.281 THRU


1.437
.250
1.125
1.000
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.005
.063 PC BOARD
.100
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.790
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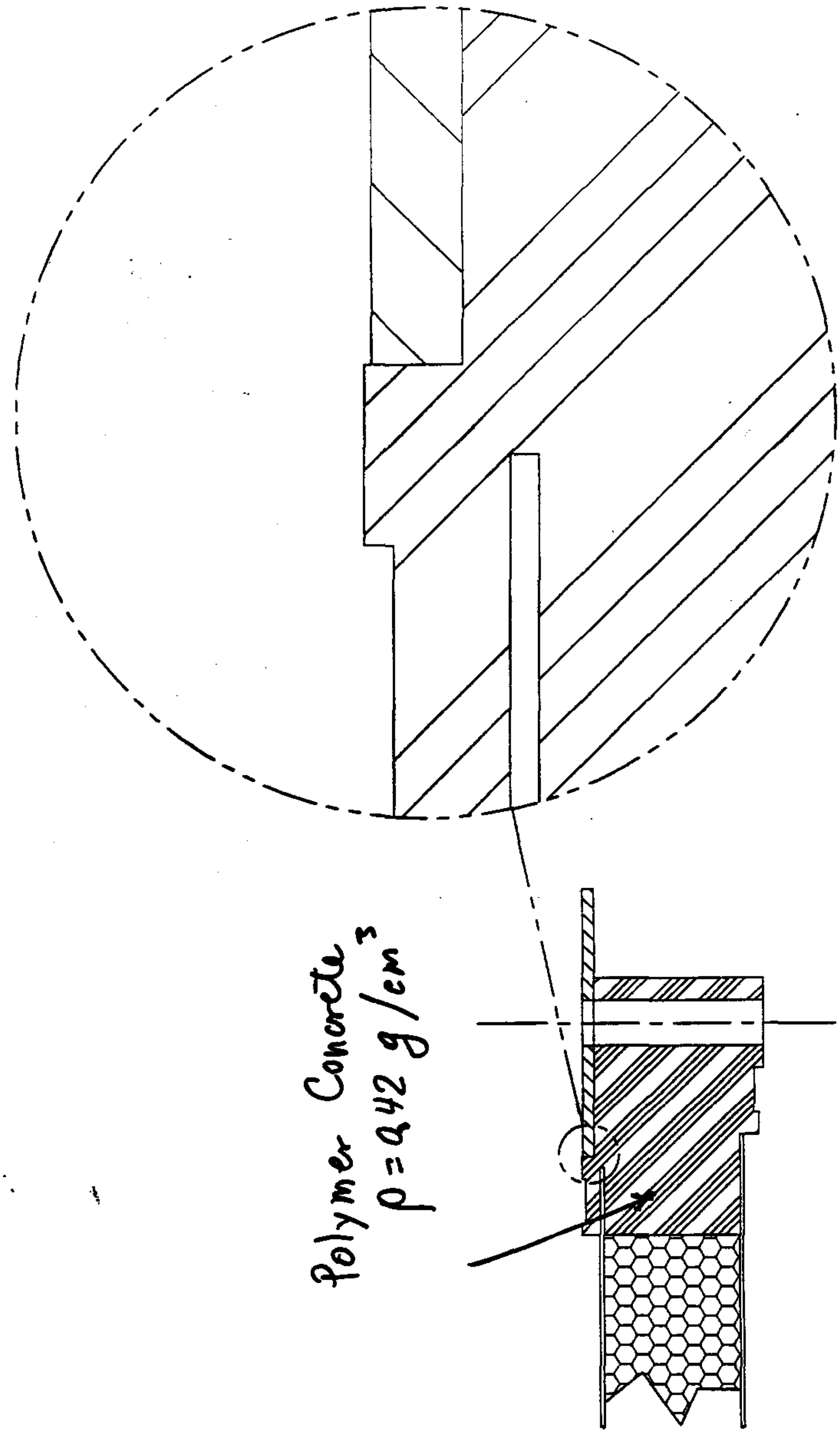
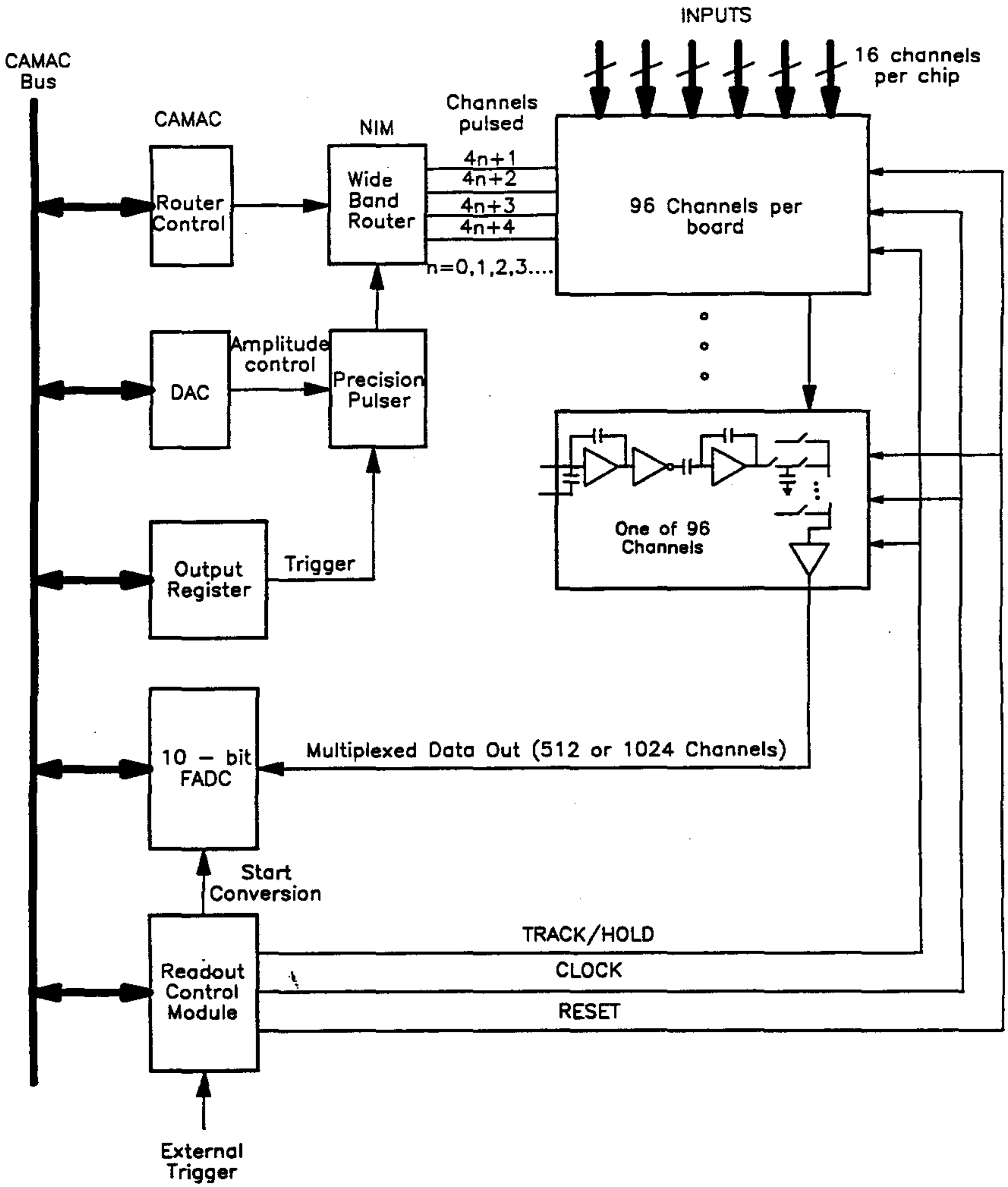
.250
ø.281 THRU


Polymer Concrete
ρ = 0.42 g/cm³

CSC Readout and Calibration Block Diagram
(Cathode Strips)



Gravity Sag of Sandwich Panel Assemblies

As Applied To
Precision Cathode Strip Chamber Structural Design

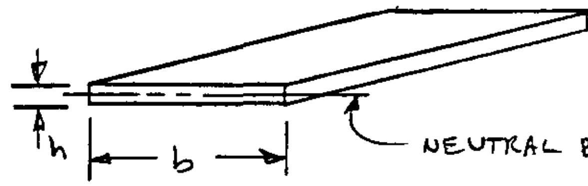
John Horvath

July 12, 1993

HOW TO CALCULATE THE STIFFNESS OF A STACK OF SLABS

STIFFNESS OF ONE SOLID SLAB
WITH RECTANGULAR CROSS-SECTION

$$I_{SLAB} = \frac{bh^3}{12}$$



NOTE:

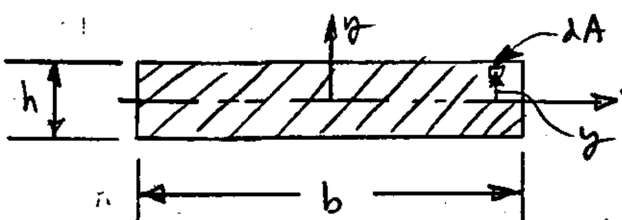
I_{SLAB} IS THE "AREA MOMENT OF INERTIA" OF THE CROSS-SECTION CALCULATED WITH RESPECT TO THE CENTROID OF THE SECTION.

THE DEFINITION OF "I" IS,

$$I = \int_{AREA} y^2 \, dA$$

WHERE y = DISTANCE FROM THE NEUTRAL PLANE TO ELEMENT dA

THE "INERTIA" OF A RECTANGULAR $b \times h$ CROSS-SECTION IS,



THE VERTICAL CO-ORDINATE OF THE CENTROID IS ALSO CALLED THE NEUTRAL PLANE

$$I = \int_{AREA} y^2 \, dArea = 2 \int_0^b \int_0^{\frac{h}{2}} y^2 \, dy \, dx$$

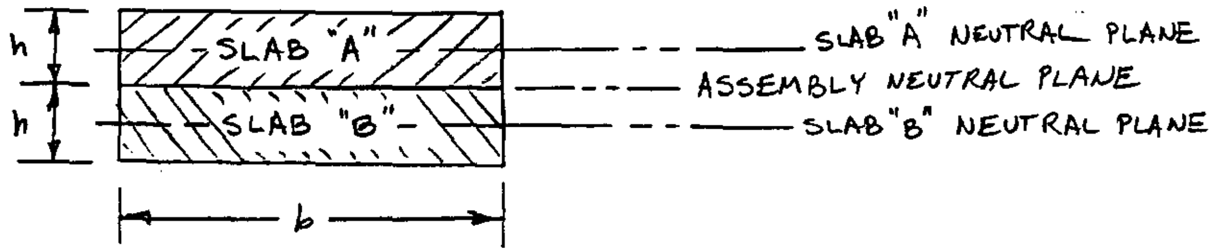
$$I = 2 \left[\int_0^{\frac{h}{2}} y^2 dy \; x \right]_0^b = 2 \left[\left[\frac{y^3}{3} \right]_0^{\frac{h}{2}} x \right]_0^b$$

$$I = 2 \frac{h^3 b}{(8)(3)}$$

$$\boxed{I_{RECTANGLE} = \frac{bh^3}{12}}$$

= MOMENT OF INERTIA OF <u>ONE</u> <u>RECTANGULAR</u> <u>SLAB</u>

SUPPOSE THERE ARE TWO SLABS "GLUED" TOGETHER (ASSUME BOTH ARE MADE OF THE SAME MATERIAL.)



INERTIA OF COMPONENTS:

$$I_{"A"} = \frac{bh^3}{12} \quad \text{(ABOUT SLAB "A" NEUTRAL PLANE)}$$

$$I_{"B"} = \frac{bh^3}{12} \quad \text{(ABOUT SLAB "B" NEUTRAL PLANE)}$$

INERTIA OF ASSEMBLY:

SINCE THE TWO SLABS ARE RIGIDLY "GLUED" TOGETHER, THE PARALLEL AXIS THEOREM MAY BE APPLIED.

$$I_{ASSEMBLY} = \sum I_o + \sum A y_{N.P.}^2$$

WHERE I_o IS THE INERTIA OF A COMPONENT ABOUT ITS NEUTRAL PLANE

A IS THE AREA OF A COMPONENT

AND $y_{N.P.}$ IS THE DISTANCE FROM THE ASSEMBLY NEUTRAL PLANE TO THE COMPONENT NEUTRAL PLANE.

THEREFORE,

$$I_{ASSEMBLY} = \frac{bh^3}{12} + \frac{bh^3}{12} + \left(\frac{h}{2}\right)^2 bh + \left(\frac{-h}{2}\right)^2 bh$$

$$I_{ASSEMBLY} = \frac{8bh^3}{12}$$ = MOMENT OF INERTIA OF GLUED ASSEMBLY (OF SLABS OF SAME MATERIAL)

CHECK: FOR THE ASSEMBLY AS ONE COMPONENT,

$$I_{ASSEMBLY} = \frac{b(2h)^3}{12} = \frac{8\,bh^3}{12}$$

FOR COMPARISON, 3/17

SUPPOSE THE TWO SLABS ARE <u>NOT</u> <u>GLUED</u>.

$$I_{ASSEMBLY} = \sum I_o$$

$$I_{ASSEMBLY} = \frac{bh^3}{12} + \frac{bh^3}{12}$$

$$I_{ASSEMBLY} = \frac{2\,bh^3}{12}$$

SUMMARY:

FOR TWO SLABS OF WIDTH "b" AND HEIGHT "h" STACKED TOGETHER,

IF ALLOWED TO SLIP (i.e. SHEAR IS ALLOWED)

$$I_{ASSEMBLY} = \frac{2\,bh^3}{12}$$

IF NOT ALLOWED TO SLIP (i.e. "IDEAL" ZERO-SHEAR GLUE)

$$I_{ASSEMBLY} = \frac{8\,bh^3}{12}$$

CSC OBSERVATIONS:

AS APPLIED TO CATHODE STRIP CHAMBERS, A "SLAB" IS ANALOGOUS TO A SANDWICH PANEL.

THE "GLUE" BOND THAT IS NECESSARY TO PREVENT SLIDING BETWEEN SLABS IS THE "GAP FRAME". IT BONDS TOGETHER THE SANDWICH PANELS.

THE STRUCTURAL PURPOSE OF THE GAP FRAME IS TO PREVENT SLIDING BETWEEN SANDWICH PANELS.

THE GAP FRAME MATERIAL AND GEOMETRIC DESIGN MUST RESIST SHEAR DEFORMATION.

STIFFNESS OF A STACK OF SLABS

FOR A STACK OF IDENTICAL SLABS OF THE SAME MATERIAL THAT ARE FASTENED TO PREVENT SLIDING,

$$I_{STACK} = n^3 I_{SLAB}$$

WHERE I_{STACK} = STACK STIFFNESS

I_{SLAB} = SLAB STIFFNESS

n = NUMBER OF SLABS

FOR SLABS FREE TO SLIDE ON EACH OTHER,

$$I_{STACK} = n I_{SLAB}$$

THE RATIO OF $\frac{I_{GLUED}}{I_{SEPARATE}}$ IS n^2

When a bending load is applied, the stack will deform as indicated in Fig. 10-13(*b*). Since the slabs were free to slide on one another, the ends do not remain even but become staggered. Each of the slabs behaves as an independent beam, and the total resistance to bending of *n*

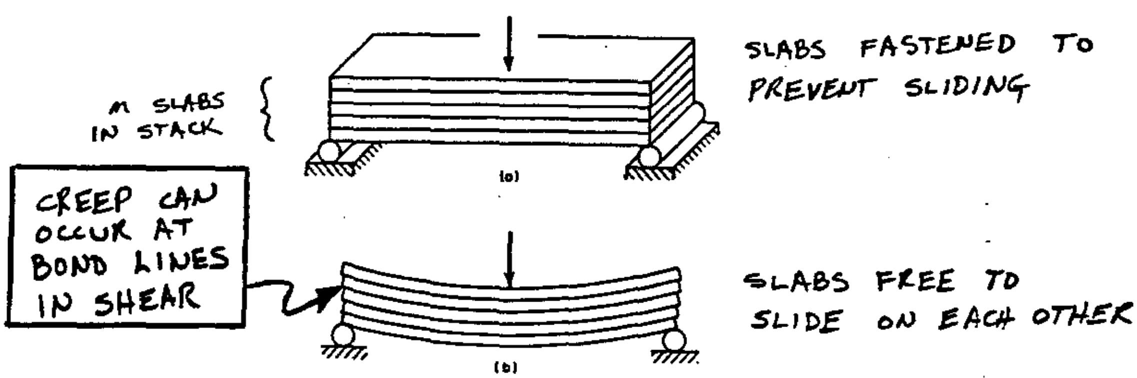
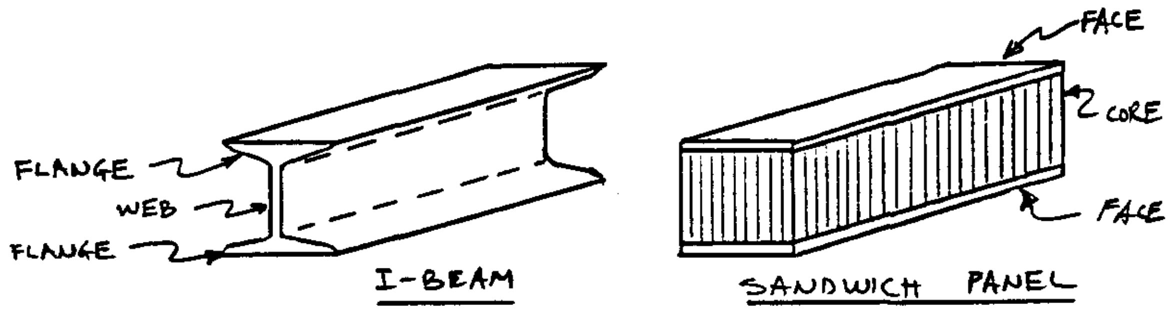


FIG. 10-13

slabs is approximately *n* times the resistance of one slab alone. If the experiment is repeated after the slabs have been fastened together so as to prevent their sliding on one another, the entire assembly would behave as a single beam having a thickness equal to *n* times the thickness of one slab. In the case of elastic action, the bending resistance of the assembly would be approximately n^3 times the bending resistance of one slab. From this simple experiment you can see the importance of a beam being able to resist longitudinal shear forces so that this "slipping" will not occur.

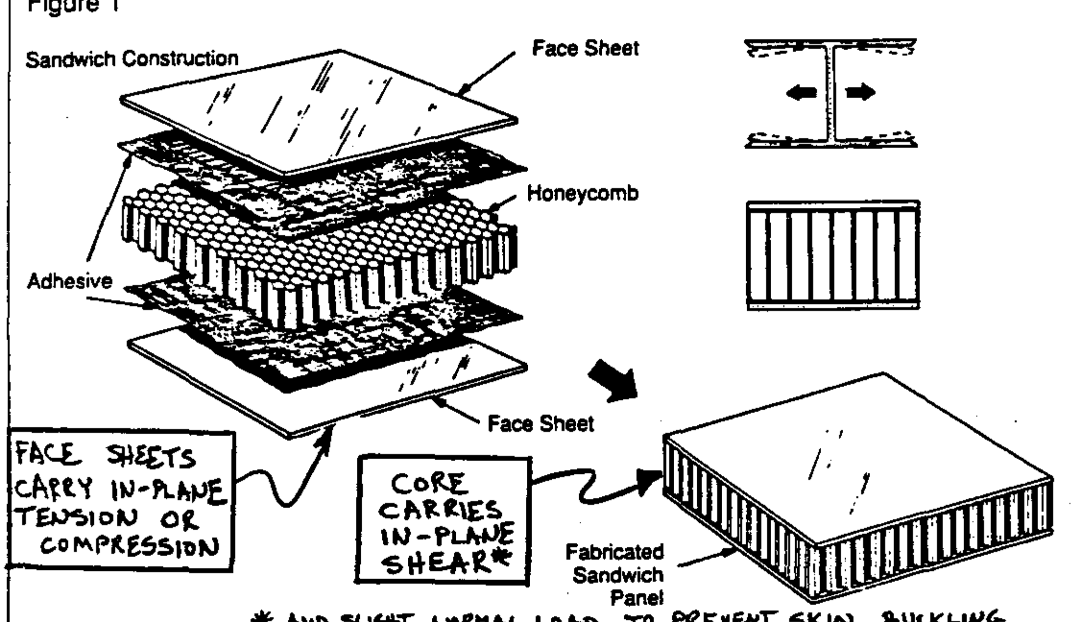
STIFFNESS OF A SANDWICH PANEL

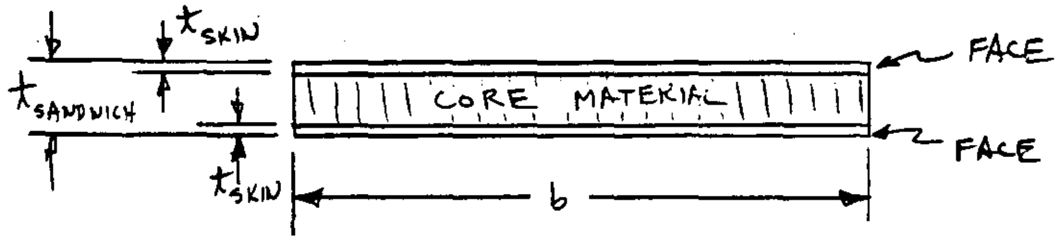
THE CORE OF A SANDWICH PANEL BEHAVES LIKE THE "WEB" OF AN I-BEAM, PREVENTING SLIDING BETWEEN TOP AND BOTTOM FLANGES.



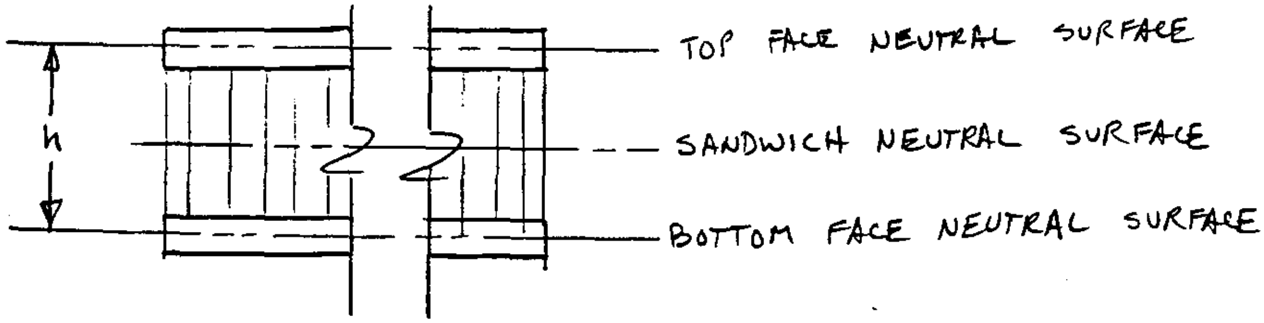
The facings of a sandwich panel used as a beam act similarly to the flanges of an I-beam by taking the bending loads — one facing in compression and the other in tension. Expanding this comparison further, the honeycomb core corresponds to the web of the I-beam. This core resists the shear loads, increases the stiffness of the structure by spreading the facings apart, but unlike the I-beam's web, gives continuous support to the flanges or facings. The core-to-skin adhesive rigidly joins the sandwich components and allows them to act as one unit with a high torsional and bending rigidity.

Figure 1





SINCE THE CORE MATERIAL IS "SOFT" COMPARED TO THE FACE MATERIAL, IT IS <u>IGNORED</u> IN THE INERTIA CALCULATION.



DEFINE "h" AS THE CENTROID DISTANCE BETWEEN THE FACES (DISTANCE BETWEEN NEUTRAL SURFACES)

$$I_{SANDWICH} = \sum I_0 + \sum A y^2$$

$$= \frac{b\,t_{SKIN}^3}{12} + \frac{b\,t_{SKIN}^3}{12} + b\,t_{SKIN}\left(\frac{h}{2}\right)^2 + b\,t_{SKIN}\left(\frac{-h}{2}\right)^2$$

$$= \frac{2\,b\,t_{SKIN}^3}{12} + \frac{2\,b\,t_{SKIN}\,h^2}{4}$$

$$\boxed{I_{SANDWICH} = \frac{b\,t_{SKIN}^3}{6} + \frac{b\,t_{SKIN}\,h^2}{2}}$$

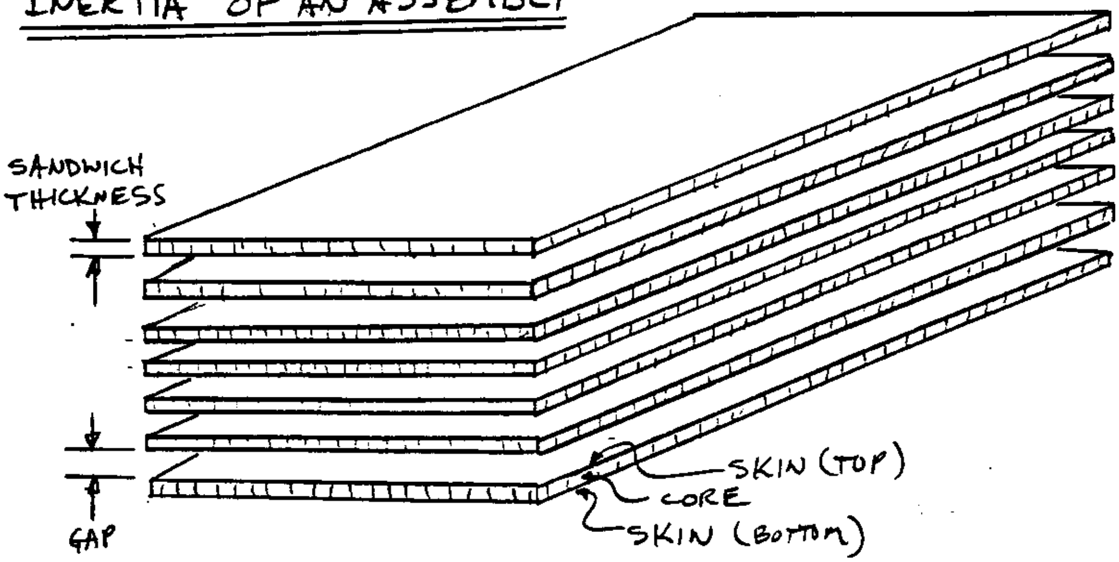
SINCE THE SKIN THICKNESS (t_{SKIN}) IS USUALLY SMALL, THE FIRST TERM CONTRIBUTES VERY LITTLE TO THE PANEL STIFFNESS.

THEREFORE INCREASING "t_{SKIN}" SHOULD HAVE A SMALL EFFECT ON STIFFNESS,

AND INCREASING "h" SHOULD HAVE A LARGER EFFECT.

ALSO, CORE MATERIAL SHEAR STIFFNESS IS NEEDED TO LINK SKINS, BUT ITS CORE WEIGHT IS <u>DEAD</u> <u>LOAD</u>.

"INERTIA" OF AN ASSEMBLY



ASSUME, 7 EQUALLY SPACED SANDWICH PANELS (DIMENSIONS AS SHOWN)

"IDEALLY" PREVENTED FROM SLIPPING BY PERFECT MASSLESS GLUE.

TREAT EACH SKIN (7 SANDWICHES × 2 SKINS/SANDWICH = 14 SKINS) AS A COMPONENT.

$$I_{ASSEMBLY} = \sum_{i=1}^{\#14} I_i + \sum_{i=1}^{\#14} A_i y_i^2$$

WHERE $I_i = \dfrac{b\, t_{SKIN}^3}{12}$

$$A_i = b\, t_{SKIN}$$

y_i = DISTANCE FROM NEUTRAL SURFACE OF ASSEMBLY TO NEUTRAL SURFACE OF THE i-th SKIN

THIS ARITHMETIC HAS BEEN PROGRAMMED INTO A SPREADSHEET MODEL.

THE SPREADSHEET CALCULATES $I_{ASSEMBLY}$ USING THE PARALLEL AXIS THEOREM, THE SAME AS ABOVE.

THE SPREADSHEET MODEL PROVIDES RAPID CALCULATION OF ASSEMBLY STIFFNESS AS A FUNCTION OF VARIOUS PARAMETER VALUES.

PARAMETRIC ANALYSIS

- STACK OF 7 SANDWICH PANELS
- SANDWICH PANEL THICKNESS = 20 mm (CONSTANT)

PARAMETERS:

- SANDWICH PANEL SKIN THICKNESS ($0.5\,mm \le t \le 10\,mm$)
- GAP BETWEEN SANDWICH PANELS ($0.0 \le GAP \le 20\,mm$)
- SLIP OR NO-SLIP (GLUED) BETWEEN PANELS

THE RESULTS OF THE ABOVE ANALYSES ARE PLOTTED ON THE FOLLOWING PAGE.

(EACH POINT ON THE GRAPH REPRESENTS ONE SPREADSHEET ANALYSIS RUN.)

CONCLUSIONS DRAWN FROM GRAPH:

THERE IS A FACTOR OF 39 INCREASE IN ASSEMBLY STIFFNESS BETWEEN A "SLIP" AND A "NO-SLIP" STACK OF 7 PANELS WITH 10 mm GAPS BETWEEN PANELS ($t_{SKIN} = 0.5\,mm$)

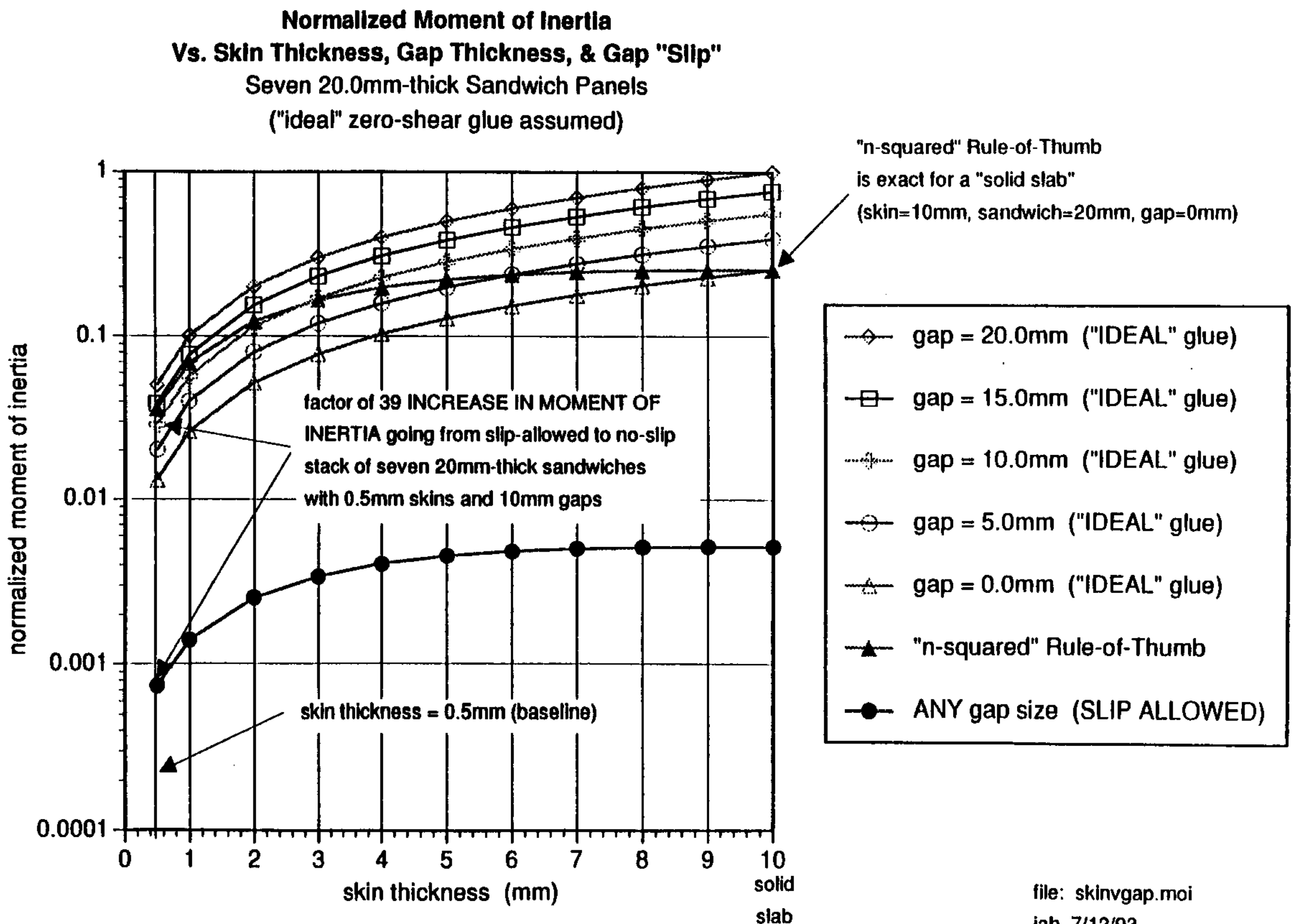
THE "RULE OF THUMB" GRAPH OF $I_{NO\text{-}SLIP} = n^2 I_{SLIP\text{-}ALLOWED}$

IS SEEN TO FALL ACROSS GRAPHS FOR VARIOUS GAP SIZES OF NO-SLIP ASSEMBLIES. THE "RULE OF THUMB" IS FOR A SOLID PANEL. SANDWICH PANELS BEHAVE DIFFERENTLY.

THE SPECIAL CASE OF A STACK OF 7 20mm-THICK SANDWICH PANELS WITH 10 mm SKINS AND GAP=0.0 REPRODUCES THE $I_{NO\text{-}SLIP} = n^2 I_{SLIP\text{-}ALLOWED}$ VALUE EXACTLY.

(TWO 10 mm SKINS ON A 20 mm SANDWICH IS A SOLID PANEL. GAP=0.0 IS A SOLID ASSEMBLY.)

IN GENERAL, THERE IS A DECREASING PAYOFF FOR INCREASING SKIN THICKNESS FOR A FIXED SANDWICH THICKNESS. (NOTE: STIFFNESS AXIS IS LOGARITHMIC.)



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GRAVITY SAG OF AN ASSEMBLY OF SANDWICH PANELS

THE CALCULATION OF STIFFNESS AS A FUNCTION OF SKIN THICKNESS IS NOT DIRECTLY APPLICABLE TO CHAMBER DESIGN.

STIFFNESS WOULD BE DIRECTLY APPLICABLE IF CHAMBER WEIGHT WAS AN INSIGNIFICANT FRACTION OF THE TOTAL LOAD ON THE CHAMBER.

FOR CATHODE STRIP CHAMBERS, THE WEIGHT OF THE STRUCTURAL COMPONENTS IS ABOUT 90% OF THE TOTAL LOAD. (NON-STRUCTURAL ELECTRONICS, UTILITIES AND ALIGNMENT HARDWARE COMPRISE THE REST.)

> SINCE INCREASING PANEL SKIN THICKNESS NOT ONLY INCREASES ASSEMBLY STIFFNESS, BUT ALSO INCREASES CHAMBER WEIGHT, THE IMPORTANT INDICATOR FOR CHAMBER STRUCTURAL DESIGN FOR STIFFNESS IS GRAVITY SAG.

THE FOLLOWING PAGE CONTAINS BEAM DEFLECTION EXPRESSIONS FOR VARIOUS SUPPORT LOCATIONS.

THE MOST CONSERVATIVE (LARGEST GRAVITY SAG) OCCURS FOR SIMPLE SUPPORTS AT THE EXTREME END POINTS.

(THE OPTIMUM LOCATIONS FOR SUPPORTING A UNIFORM BEAM ARE AT POINTS 0.223 L FROM THE ENDS. THIS IS CASE 4 ON THE CHART)

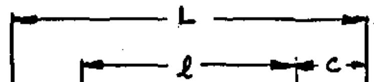
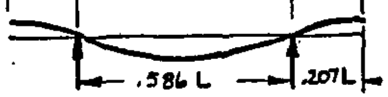
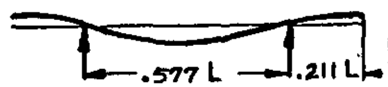
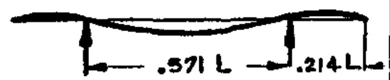
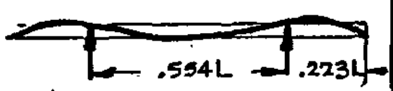
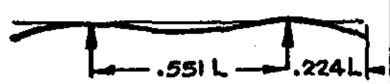
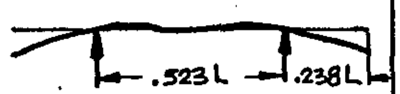
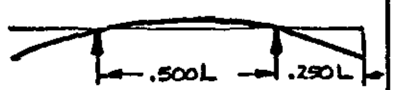
> THE GRAVITY SAG OF AN ASSEMBLY OF SANDWICH PANELS SUPPORTED AT THE EXTREME ENDS (MOST CONSERVATIVE CASE) HAS BEEN CALCULATED USING A SPREADSHEET.

NEW PARAMETERS ARE NOW INTRODUCED.

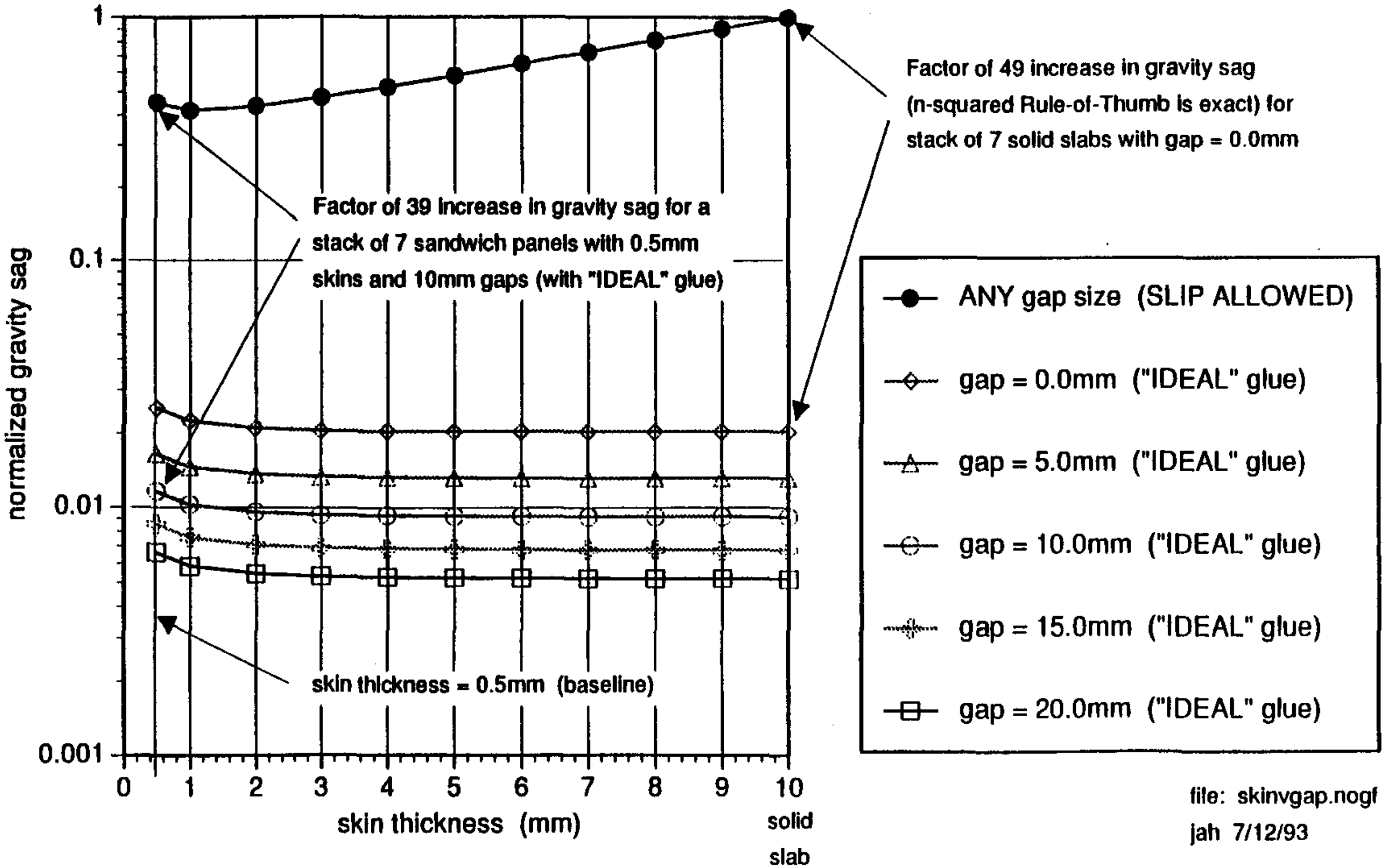
THE CROSS-SECTION INERTIA WAS A FUNCTION OF CROSS-SECTION DIMENSIONS ONLY.

THE BEAM GRAVITY SAG IS A FUNCTION OF THE CROSS-SECTION MOMENT OF INERTIA (PREVIOUSLY CALCULATED), MATERIAL MODULUS, MATERIAL DENSITY, BEAM LENGTH, AND SUPPORTS.

BEAM CALCULATIONS - SPECIAL CASES OF SYMETRICAL OVERHANGING BEAMS WITH UNIFORM LOAD w = UNIT LOAD (e.g. lbs/in)

SPECIAL CASE / CASE #		DISTANCE EACH WAY FROM CENTER TO INFLECTION POINT (POINT OF ZERO MOMENT) $=\sqrt{\frac{\ell^2}{4}-c^2}$	MOMENT AT CENTER $=\frac{w\left(c^2-\frac{\ell^2}{4}\right)}{2}$	MOMENT AT SUPPORTS (MAX. MOMENT) $=\frac{wc^2}{2}$ = MAX. MOMENT	DEFLECTION AT ENDS $=\frac{wc}{24EI}\left(3c^2(c+2\ell)-\ell^3\right)$ PLUS = DOWN MINUS = UP	DEFLECTION AT CENTER $=\frac{w\ell^2}{384EI}\left(5\ell^2-24c^2\right)$ PLUS = DOWN MINUS = UP
① EQUAL MOMENTS AT SUPPORTS & CENTER		.207 L	$.0214\ wL^2$	$.0214\ wL^2$	$-.00021\ \frac{wL^4}{EI}$	$.000615\ \frac{wL^4}{EI}$
② ZERO SLOPE AT ENDS		.196 L	$.0192\ wL^2$	$.0223\ wL^2$	$-.000078\ \frac{wL^4}{EI}$	$.000512\ \frac{wL^4}{EI}$
③ NO END DEFLECTION		.183 L	$.0177\ wL^2$	$.0230\ wL^2$	0	$.000446\ \frac{wL^4}{EI}$
④ END & CENTER DEFLECTIONS EQUAL. MINIMUM OVERALL DEFLECTION		.164 L	$.0135\ wL^2$	$.0248\ wL^2$	$.000268\ \frac{wL^4}{EI}$	$.000268\ \frac{wL^4}{EI}$
⑤ ZERO SLOPE AT SUPPORTS		.159 L	$.0126\ wL^2$	$.0252\ wL^2$	$.000317\ \frac{wL^4}{EI}$	$.000237\ \frac{wL^4}{EI}$
⑥ NO CENTER DEFLECTION		.106 L	$.0057\ wL^2$	$.0284\ wL^2$	$.000759\ \frac{wL^4}{EI}$	0
⑦ INFLECTION POINT AT CENTER MAX. DEFLECTION AT CENTER ZERO MOMENT AT CENTER		0	0	$.0312\ wL^2$	$.00113\ \frac{wL^4}{EI}$	$-.000162\ \frac{wL^4}{EI}$

Normalized Gravity Sag
Vs. Skin Thickness, Gap Thickness, & Gap "Slip"
Seven 20.0mm-thick Sandwich Panels
("IDEAL" massless zero-shear gap frame and glue assumed)

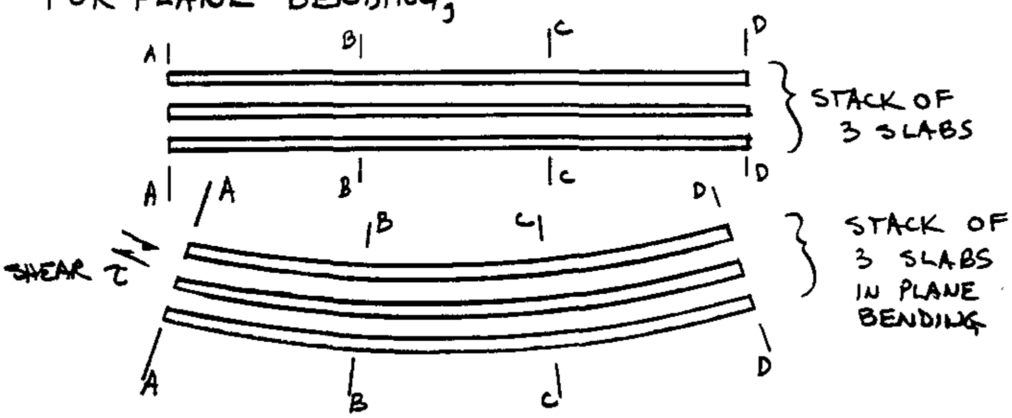


THE EFFECT OF GAP FRAMES ON DEFLECTION

IN THE PREVIOUS ANALYSIS THE STACK OF SANDWICH PANELS (WITH GAPS BETWEEN PANELS) WAS ASSUMED BONDED ACROSS THE GAPS WITH "IDEAL" MASSLESS GLUE.

IN MECHANICS, THIS BENDING ANALYSIS ASSUMPTION IS STATED AS "CROSS-SECTIONS REMAIN FLAT DURING BENDING."

FOR PLANE BENDING,

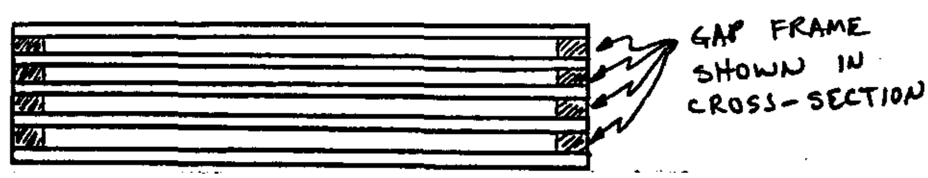


ALL CROSS-SECTION PLANES (A-A, B-B, ...) REMAIN FLAT DURING BENDING

TO ACHIEVE THIS LINKING BETWEEN SLABS THE GAPS MUST BE SPANNED AT SUFFICIENT LOCATIONS <u>AND</u> IN A MANNER THAT RESISTS THE SHEAR LOAD INDUCED BETWEEN SLABS.

SHEAR BETWEEN SLABS CAUSES THE ABOVE SECTION PLANES TO WARP. THIS RESULTS IN AN ADDITIONAL COMPONENT OF SAG CALLED "SHEAR DEFLECTION".

THE SANDWICH PANELS ARE LINKED TOGETHER INTO A "SANDWICH OF SANDWICHES" BY THE GAP FRAME. IDEALLY THE GAP FRAME SHOULD PREVENT SHEAR DEFORMATION (SLIPPING).



THE EFFECT OF GAP FRAME WIDTHS AND MATERIALS ON ASSEMBLY GRAVITY SAG IS CALCULATED USING ANOTHER SPREADSHEET AS FOLLOWS:

THE EFFECT OF GAP FRAMES (CONTINUED)

$$\text{"EFFECTIVE STIFFNESS"} = \frac{E\ I}{\text{WEIGHT / UNIT LENGTH}}$$

THE MODULUS OF ELASTICITY OF THE GAP FRAME MATERIAL IS A MATERIAL PROPERTY,

THE "MOMENT OF INERTIA" OF THE GAP FRAME IS A FUNCTION OF THE AMOUNT AND THE LOCATION OF THE GAP FRAME (GEOMETRIC DISTRIBUTION).

THE WEIGHT/UNIT LENGTH OF THE GAP FRAME MATERIAL IS A FUNCTION OF <u>BOTH</u> THE MATERIAL AND THE GEOMETRIC DISTRIBUTION.

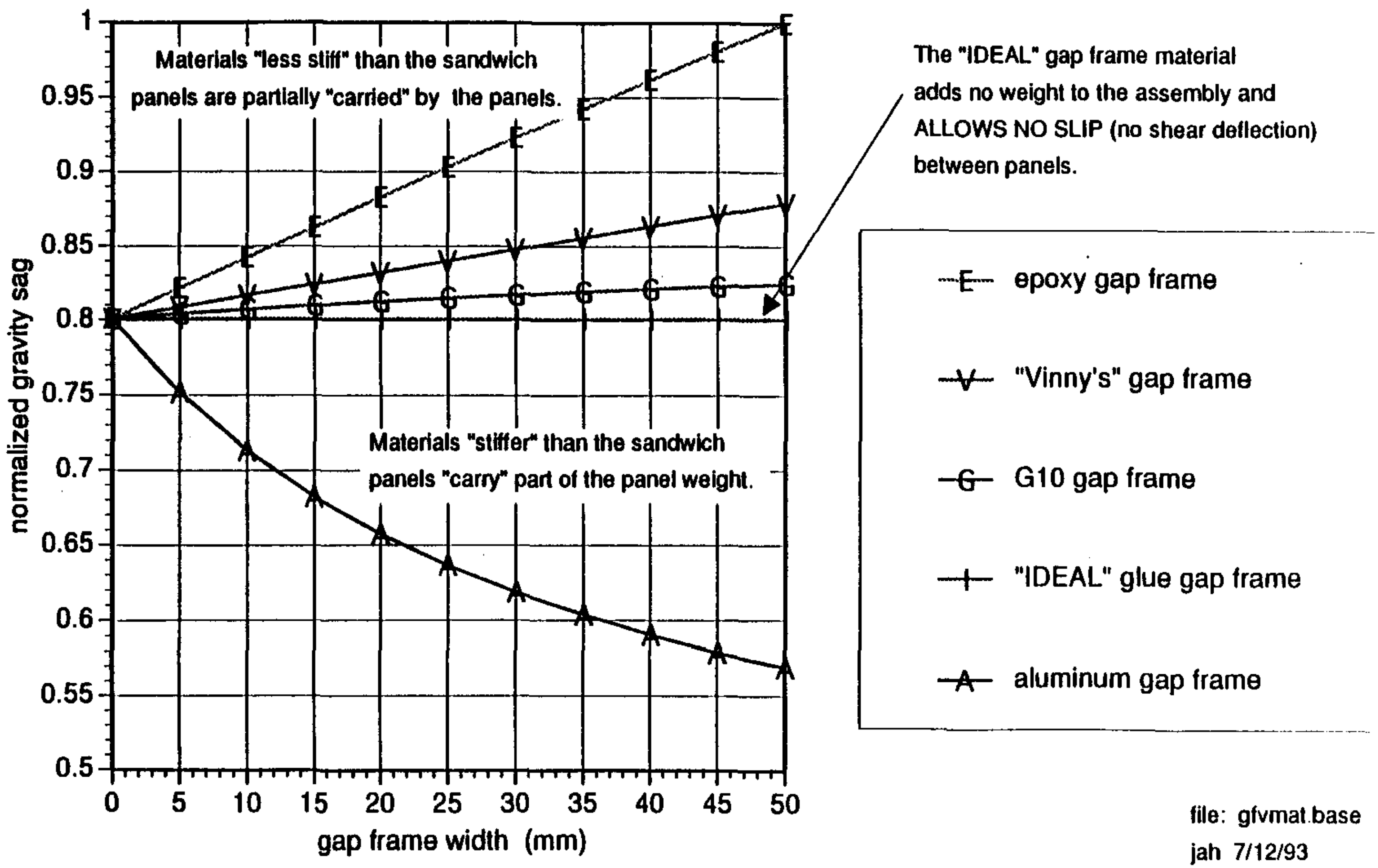
> THE GAP FRAME WILL "LOAD" THE SANDWICH "PANELS <u>IF</u> THE GAP FRAME EFFECTIVE STIFFNESS IS <u>LOWER</u> THAN THE SANDWICH PANEL E.S.
>
> THE GAP FRAME WILL "CARRY" PART OF THE SANDWICH PANEL WEIGHT IF THE GAP FRAME E.S. IS <u>HIGHER</u> THAN THE SANDWICH PANEL E.S.

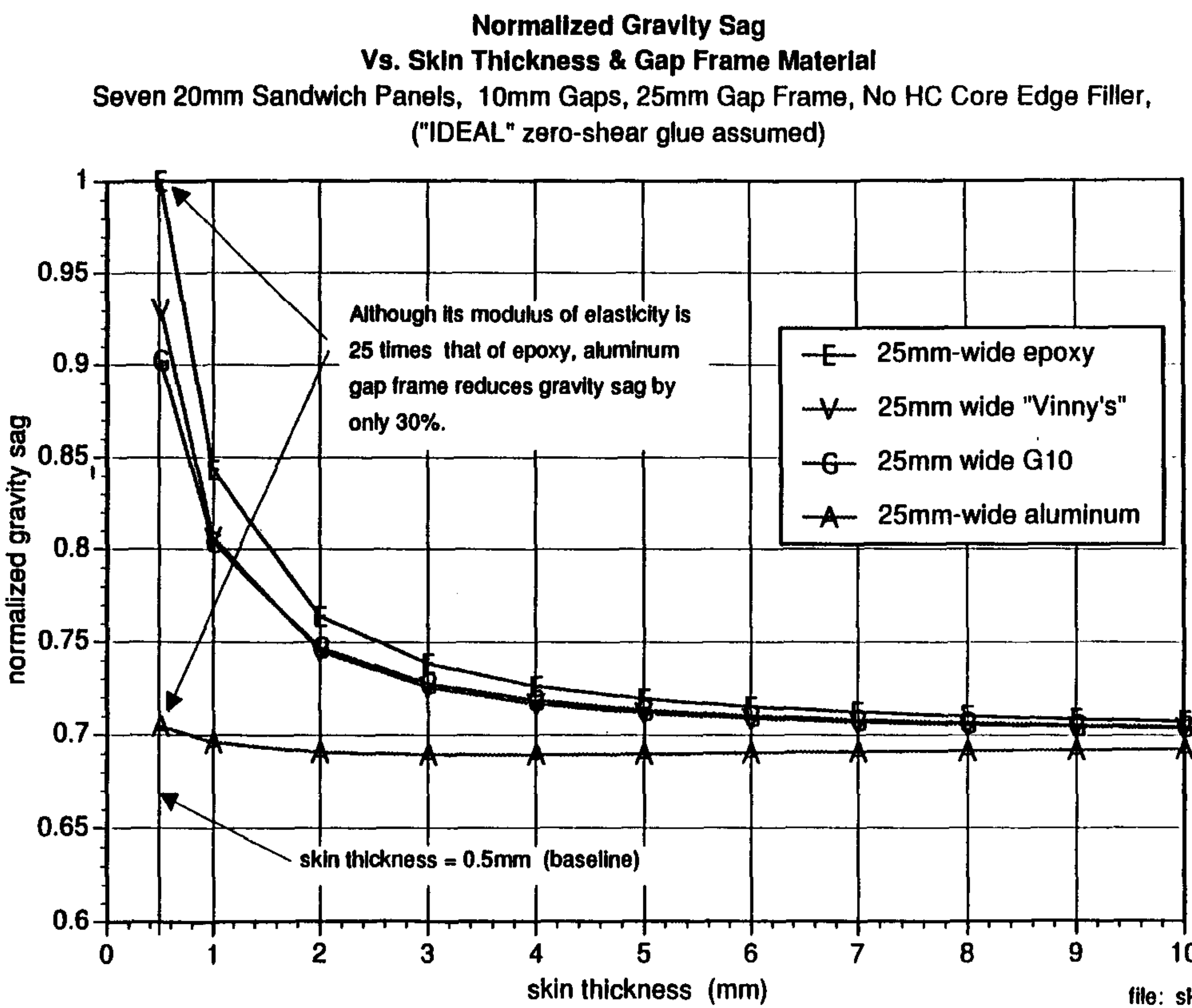
HOWEVER, THE ASSUMPTION THAT "CROSS-SECTIONS REMAIN FLAT" WILL NOT BE TRUE IF THE GAP FRAME ALLOWS SHEAR DEFORMATION TO OCCUR.

THE ABOVE ANALYSIS ASSUMES THAT EVEN THE MOST NARROW AND SOFT GAP FRAME WILL NOT SHEAR.

FOR SANDWICH ASSEMBLIES, THE EFFECT OF SHEAR DEFORMATION IN THE HONEYCOMB CORE MUST BE CONSIDERED, AS WELL AS THE GEOMETRY AND PROPERTIES OF THE GAP FRAMES.

Normalized Gravity Sag
Vs. Gap Frame Width & Gap Frame Material
Seven 20.0mm-thick Sandwich Panels, No Core Edge Filler,
Skin Thickness = 0.5mm, Gap Height = 10mm, NO SLIP ALLOWED





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jah 7/12/93

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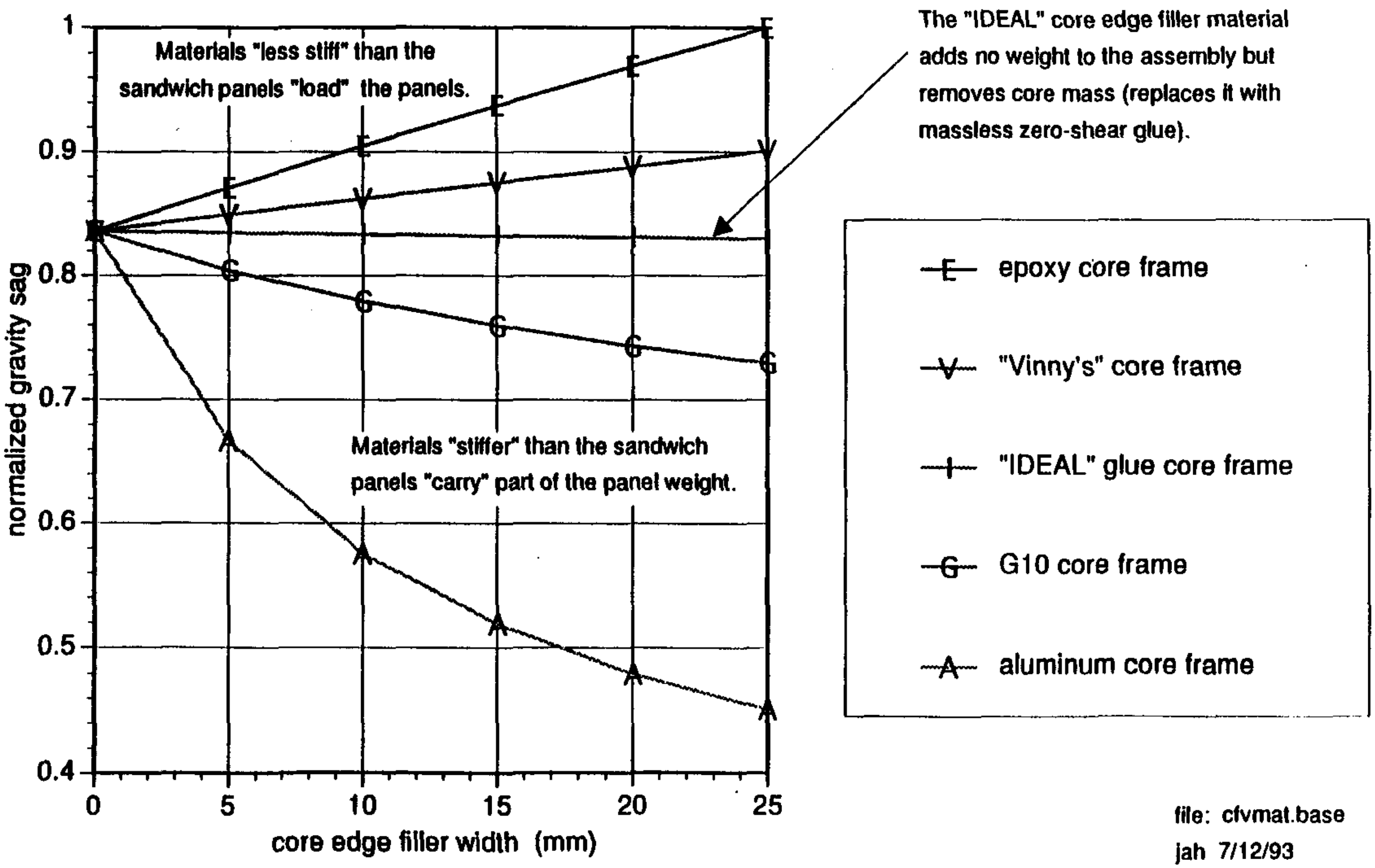
THE EFFECT OF SANDWICH CORE EDGE FILLER

CORE EDGE FILLER IS SIMPLY A SUBSTITUTE FOR THE SANDWICH CORE MATERIAL.

ITS EFFECT ON DEFLECTION IS PROPORTIONAL TO ITS RELATIVE "EFFECTIVE STIFFNESS" (AS DISCUSSED IN RELATION TO GAP FRAME EFFECTS).

THE ONLY MINOR DIFFERENCE IS THAT CORE EDGE FILLER DISPLACES HONEYCOMB MATERIAL. SINCE HONEYCOMB HAS ~~ZERO~~ MODULUS IN THE PLANE OF THE PANELS, LIGHT AND STIFF EDGE FILLERS SUCH AS G10 PROVIDE SOME BENEFIT, BUT ADD MASS.

Normalized Gravity Sag
Vs. Sandwich Core Edge Filler Width & Core Edge Filler Material
Seven 20.0mm-thick Sandwich Panels, 25mm-wide Epoxy Gap Frame,
Skin Thickness = 0.5mm, Gap Height = 10mm, NO SLIP ALLOWED



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jah 7/12/93

CONCLUSIONS

MAGNITUDE OF CHAMBER SAG IS HIGHLY DEPENDENT ON:

- CHAMBER SUPPORT LOCATION
- DESIGN OF GAP FRAME

GAP FRAME DESIGN WILL DETERMINE HOW CLOSE WE COME IN OBTAINING THE "PERFECT" SHEAR BOND BETWEEN SANDWICH PANELS, THUS MINIMIZING CHAMBER SAG:

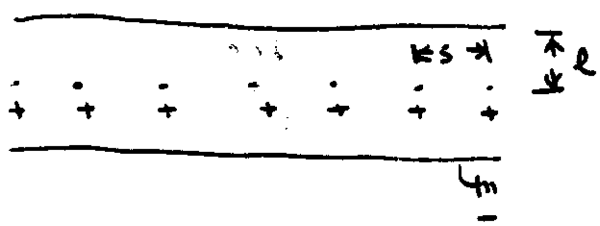
- GEOMETRY (THICKNESS, WIDTH, EXTENT AROUND PERIMETER OF PANEL)
- MATERIAL MECHANICAL PROPERTIES
- PANEL-TO-PANEL ATTACHMENT TECHNIQUE (BOLTS, ADHESIVE, ETC.)

Kwong Lau
7/12/93

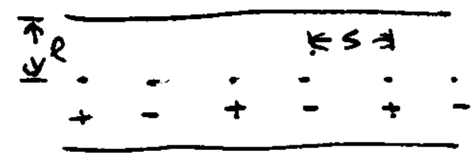
Some thoughts on Open Wire CSC

1. Electrostatic Instability

Two possible designs

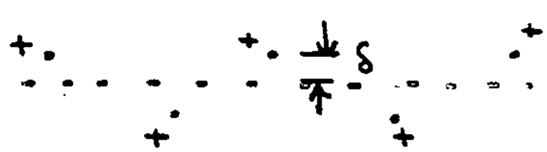


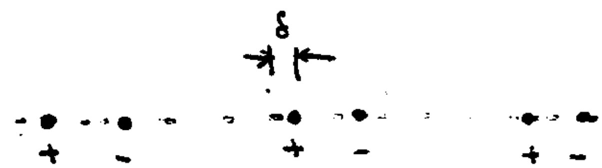
MWPC style



DC style

Lowest-order L_c estimate (a la Trippe : CERN 69-18(196





electrostatic force

$$F_e = \frac{\lambda^2}{2\pi\epsilon_0} \, 2\left\{ \frac{1}{s}\frac{2\delta}{s} + \frac{1}{3s}\frac{2\delta}{3s} \cdots \right\}$$

λ : charge per unit length

$$= \frac{\pi}{4} \, \frac{\lambda^2}{\epsilon_0} \, \frac{\delta}{s^2}$$

Same for both !!

Restoring force : $T \frac{d^2\delta}{dx^2}$

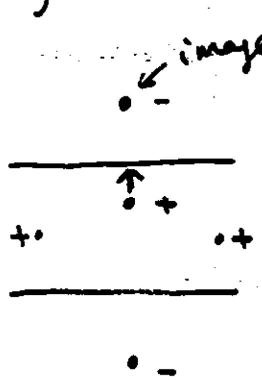
stable if $T \geq T_c = \frac{1}{4\pi\epsilon_0}\left(\frac{\lambda L}{s}\right)^2$, $T \leq T_M$

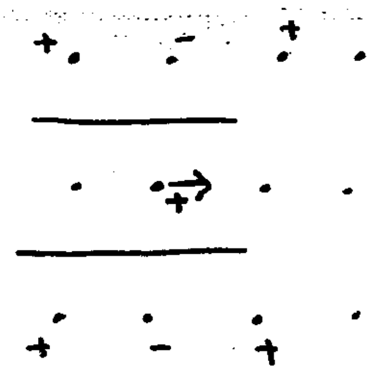
$\Rightarrow \quad L \leq L_c = \frac{s}{\lambda}\sqrt{4\pi\epsilon_0 T_M}$

For $s = \ell = 2.5$ mm
$T_M = 0.65\,N$ for 20 μm tungsten wires

$L_c \simeq 1.14$ m.

Other effects
e.g. cathode charge





De-stabilizing Stabilizing

2. Brief comparison

a. DC design is more stable electrostatically

b. stability in DC design can be improved further by using thicker field wires

c. $\vec{E}$ mostly along $\vec{B}$ in DC design: minimizes Lorentz-angle effects

d. Timing of DC design is "probably" worse, but should be adequate

3. Proposed Research Program

a. Construct a wide (1.5 m x ?) prototype to check resolution (stability)

b. Construct a small ( ) prototype to check Lorentz-angle effects and measure timing.

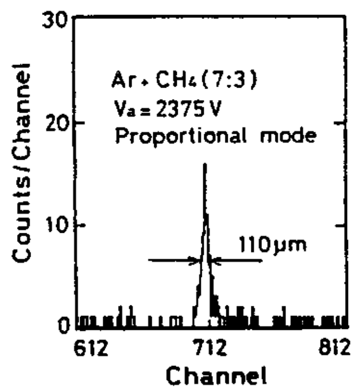


Fig. 2. Typical position spectrum obtained in the proportional mode.

the figure, the position resolution of the proportional mode reaches a value which is determined by the instrumental limitation due to the beam collimation and the electron noise. On the other hand, the position resolution of the SQS mode begins with a value higher than the instrumental limitation and goes to a serious value of about 1 mm. As for the avalanche size, the transition (displayed in fig. 3 as an arrow) from the proportional to the SQS mode as a function of high voltage can be observed in the position resolution data. The position resolution of the SQS mode is worse than that of the proportional mode. The fluctuation of the localization of the SQS discharge, however, can be considered to be less than 1 mm. Since the width of the SQS avalanche is considered to be less than 1 mm [2,5], the large fluctuation of the localization of the SQS discharge cannot depend on the avalanche width. Then, the fluctuation may be due mainly to that of the path of the SQS avalanche.

In addition to the standard quenching gas, so called second quenching gas, for example ethanol, methylal and so on, is considered to stabilize the SQS operation [8,9]. We measured the position resolution of the SQS

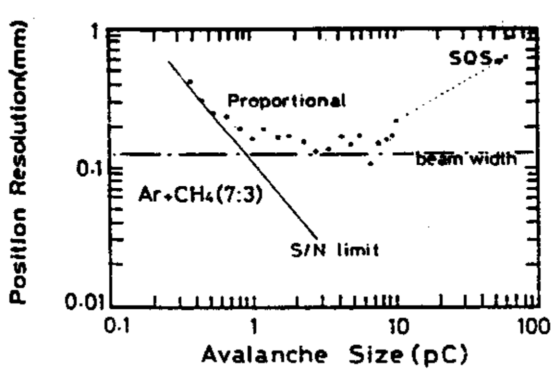


Fig. 3. Results of the measurement of the position resolution as a function of avalanche size.

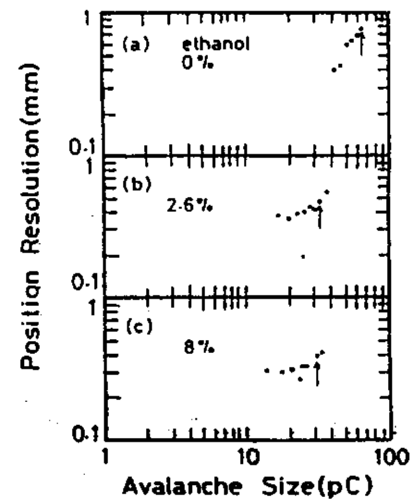


Fig. 4. Results of the measurement of the position resolution in the SQS mode. The counter gas was $Ar+CH_4$ (7:3) adding ethanol vapour of (a) 0%, (b) 2.6% and (c) 8%. Arrows in the figures show the 50% transition points.

mode in different concentrations of ethanol. In this measurement, the beam collimation was nearly 0.25 mm. Fig. 4 shows the results of the position resolution of the SQS mode. Arrows in fig. 4 show the 50% transition points. In this figure, the position resolution improves with higher concentrations of ethanol. From this result, the second quenching gas, ethanol, can be considered to suppress the fluctuation of the localization of the SQS discharge. In the practical use of the SQS discharge for position sensing, the second quenching gas promises stable counter operation and good resolution in an $Ar+CH_4$ gas mixture. Furthermore, ethanol can absorb the UV photons which play an important role in the transition mechanism of the SQS.

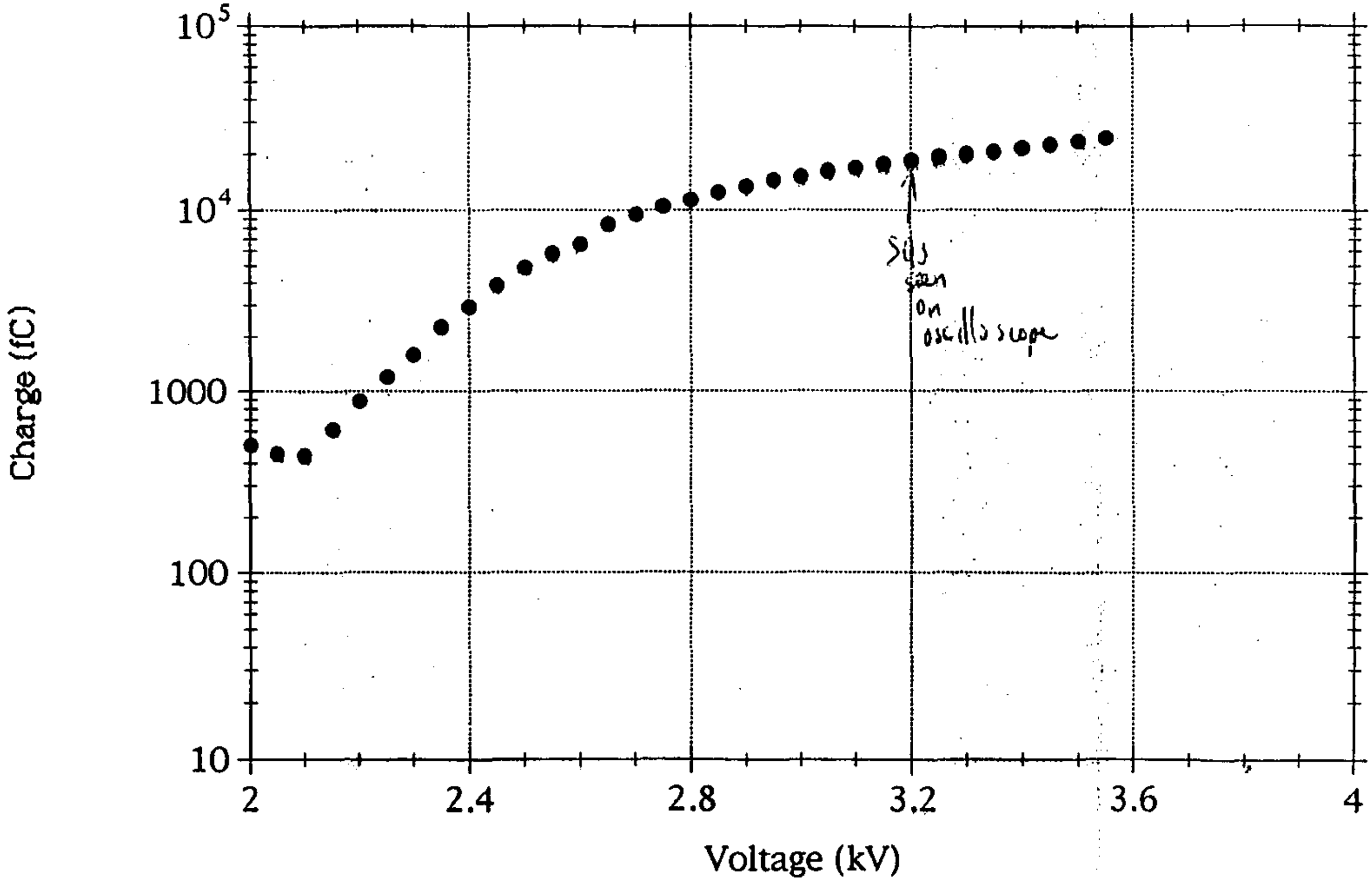
In our previous data [6], the double SQS mode was observed clearly and the position sensing was tried with this mode. In the present work, we could collect no meaningful events that arose from this mode. This may be due to the different cathode surface conditions in the two experiments. The double SQS mode is considered to be sensitive to the material and the condition of the cathode [5].

4. Conclusion

Position sensing has been investigated around the transition region from the proportional mode to the SQS mode. The position resolution of the proportional mode reaches to about 0.13 mm (FWHM) which is limited by the beam collimation. On the other hand, the position resolution of the SQS mode is worse than that of the proportional mode. The fluctuation of the localization of the SQS discharge, however, is less than 1 mm.

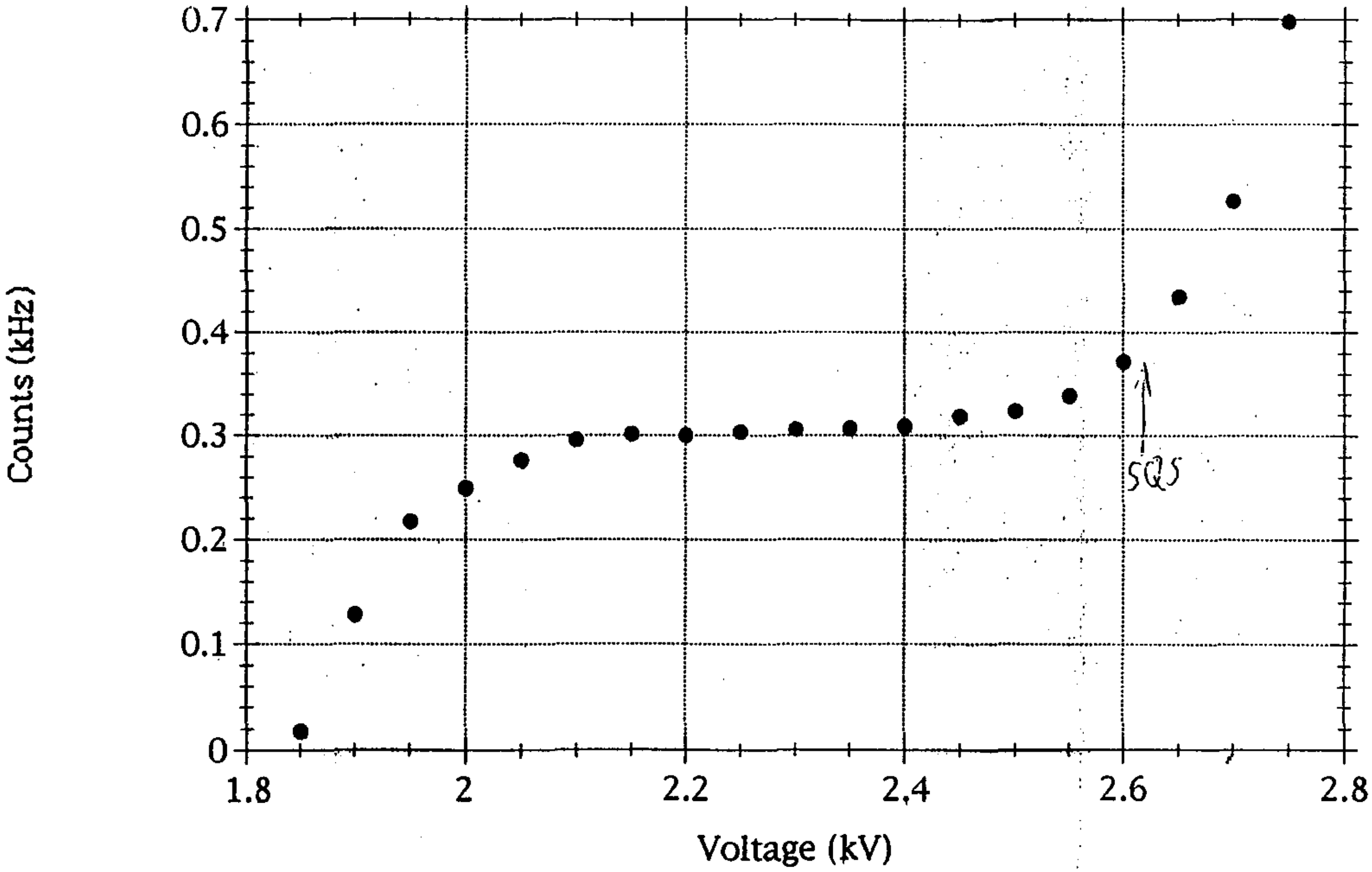
Charge Distribution of Gas I-B 100%
Source Fe55, SQS mode significant by 3.20 kV
30 micron wire chamber

No peak corresponding to streamer mode was seen



Rate Curve of Gas CF4 87%, I-B 13%
Threshold ~30mV, Source Fe55, Interval 100 s
SQS mode significant at 2.6 kV

30 μ chamber



HONEYCOMB PANELS

G-10

- GE: 60 x 144 in; 0.021 in; 0.5 oz Cu; $184.40
- min order 150

139

Bare honeycomb

- 48 x 96 x 0.75 in; $230
- 60 x 144 x 0.75 in; $678

Fabricate panels, including honeycomb material

- Hexcell 48 x 138 x 0.8 in ATF quality $1419.66
- 48 x 108 x 0.8 in Flat $2100
- Both plus tooling, setup charges

QUOTATION

HEXCEL

Telephone: (800) 284-3923
Fax: (817) 274-1121

HEXCEL CORPORATION
201 E. ABRAM STE 300
ARLINGTON TX 76010

Page: 1
Quote Nbr: A3C0406
Quote Date: 05/21/93
AE/CSR Nbr: 105/1R4
Cust. Ph: (214) 708-1188
Fax: (214) 708-6088

QUOTED TO: 82280-01

SUPER COLLIDER LABORATORY
ATTN: COLEMAN JOHNSON
9050 AUTOBAHN DR BLDG 2
DALLAS TX 75237-3946

TERMS: NET 30
FOB: Casa Grande, AZ
RFQ: FAX FROM NORRIS DATED 4/22
GOV'T CONTRACT:

ITEM	MATERIAL DESCRIPTION	UNIT OF MEASURE	QTY	UNIT PRICE	TOTAL
01	HRH-10-1/8-8.1 SHIPMENT: 10 Weeks After Receipt Of Order SPECIFICATIONS: D/S 4000 QUANTITY TOLERANCE: + 0% - 0% TQ: 1	Piece	10	$1,419.66	$14,196.60
02	HRH-10-1/8-8.1 SHIPMENT: 10 Weeks After Receipt Of Order SPECIFICATIONS: D/S 4000 QUANTITY TOLERANCE: + 0% - 0% TQ: 1	Piece	10	$1,397.82	$13,978.20
03	HRH-10-1/8-8.1 TOOLING FOR ITEM 01 SHIPMENT: 10 Weeks After Receipt Of Order SPECIFICATIONS: D/S 4000 QUANTITY TOLERANCE: + 0% - 0% TQ: 1	Lot	1	$2,446.23	$2,446.23
04	HRH-10-1/8-8.1 TOOLING FOR ITEM 2 SHIPMENT: 10 Weeks After Receipt Of Order SPECIFICATIONS: D/S 4000 QUANTITY TOLERANCE: + 0% - 0% TQ: 1	Lot	1	$2,446.23	$2,446.23

ATS Quality Panels

QUOTE TOTAL $33,067.26

Notes & Conditions:

1 DIMENSIONS AND TOLERANCE OF ITEM 01

QUOTATION

Quote Nbr: A3C0406
Quote Date: 05/21/93
AE/CSR Nbr: 105/1R4
Cust. Ph: (214) 708-1188
Fax: (214) 708-6088

Notes & Conditions: (Continued)

1 48 L +/-.125 X 138 W +/-.125 X 0.80 T +/-.045
DIMENSIONS AND TOLERANCE OF ITEM 02
28 L +/-.125 X 138 +/-.125 x 9.80 T +/- .045
SKINS: F185-7781 2 PLYS
ADHESIVE: MA 562 S
POTTING COMPD: EPOLITE 2402

THE PARTS ARE QUOTED PER REQUEST WITH THE FOLLOWING EXCEPTIONS:
1) THE L AND W DIMENSIONS ARE REVERSE OF THE RFQ DIMENSIONS.
2) RATHER THAN EPOXY FILLING THE OUTSIDE PERIMETER OF THE PANNEL, HEXCEL WILL USE A GLASS REINFORCED POLYESTER TUBE.

THANK YOU FOR THE OPPORTUNITY TO QUOTE.

05/21/93 09:27 MDowdle

DATE TIME Marla Dowdle
Customer Service Rep.

NOTE: This quote is valid for 60 days. Please read NOTES & CONDITIONS on reverse side.

QUOTATION

HEXCEL

HEXCEL CORPORATION
201 E. ABRAM STE 570
ARLINGTON TX 76010

Telephone: (800) 284-3923
Fax: (817) 274-1121

Page: 1
Quote Nbr: A2C0622
Quote Date: 10/29/92
AE/CSR Nbr: 105/1R8
Cust. Ph: (214) 708-1188

QUOTED TO: 82280-01

SUPER COLLIDER LABORATORY
ATTN: COLEMAN JOHNSON
9050 AUTOBAHN DR BLDG 2
DALLAS TX 75237-3946

TERMS: NET 30
FOB: Casa Grande, AZ
RFQ:
GOV'T CONTRACT: UNKNOWN

Final Production item 01, 05 only

ITEM	MATERIAL DESCRIPTION	UNIT OF MEASURE	QTY	UNIT PRICE	TOTAL
01	BONDED PANEL HRH-10-1/8-1.8 WITH .5 OZ./SF COPPER L 108.000 (+) 0.125 (-) 0.125 W 48.000 (+) 0.125 (-) 0.125 T 1.000 (+) 0.030 (-) 0.030 SPECIFICATIONS: HEXCEL BONDING CAPABILITIES QUANTITY TOLERANCE: + 0% - 0% TQ: 3 This item has been prepared as a ROUGH ORDER OF MAGNITUDE. HEXCEL reserves the right to submit a firm quotation before placement of an order.	Panel	2,100	$2,616.37	$5,494,377.00
02	BONDED PANEL HRH-10-1/8-1.8 WITH 1 OZ./SF COPPER L 108.000 (+) 0.125 (-) 0.125 W 48.000 (+) 0.125 (-) 0.125 T 1.000 (+) 0.030 (-) 0.030 SPECIFICATIONS: HEXCEL BONDING CAPABILITIES QUANTITY TOLERANCE: + 0% - 0% TQ: 3 This item has been prepared as a ROUGH ORDER OF MAGNITUDE. HEXCEL reserves the right to submit a firm quotation before placement of an order.	Panel	2,000	$3,751.59	$7,503,180.00
03	BONDED PANEL HFT-3/16-2.0 WITH .5 OZ./SF COPPER L 108.000 (+) 0.125 (-) 0.125 W 48.000 (+) 0.125 (-) 0.125 T 1.000 (+) 0.030 (-) 0.030 SPECIFICATIONS: HEXCEL BONDING CAPABILITIES QUANTITY TOLERANCE: + 0% - 0% TQ: 3 This item has been prepared as a ROUGH ORDER OF MAGNITUDE. HEXCEL reserves the right to submit a firm quotation before placement of an order.	Panel	2,100	$4,394.36	$9,228,156.00

HEXCEL

QUOTATION

Page: 2
Quote Nbr: A2C0622
Quote Date: 10/29/92
AE/CSR Nbr: 105/1R8
Cust. Ph: (214) 708-1188

ITEM	MATERIAL DESCRIPTION	UNIT OF MEASURE	QTY	UNIT PRICE	TOTAL
04	BONDED PANEL HFT-3/16-2.0 WITH 1 OZ./SF COPPER L 108.000 (+) 0.125 (-) 0.125 W 48.000 (+) 0.125 (-) 0.125 T 1.000 (+) 0.030 (-) 0.030 SPECIFICATIONS: HEXCEL BONDING CAPABILITIES QUANTITY TOLERANCE: + 0% - 0% TQ: 3 This item has been prepared as a ROUGH ORDER OF MAGNITUDE. HEXCEL reserves the right to submit a firm quotation before placement of an order.	Panel	2,000	$4,954.70	$9,909,400.00
05	NON-RECURRING ENGINEERING SPECIFICATIONS: N/A QUANTITY TOLERANCE: + 0% - 0% TQ: 3 This item has been prepared as a ROUGH ORDER OF MAGNITUDE. HEXCEL reserves the right to submit a firm quotation before placement of an order.	Lot	1	$100,000.00	$100,000.00
				QUOTE TOTAL	$32,235,113.00

Notes & Conditions:

1 QUOTE IS BASED ON THE ASSUMPTION THAT PULTRUSIONS WILL BE FLUSH WITH THE EDGE OF THE SKIN.

NON-RECURRING ENGINEERING SUBJECT TO FINAL DESIGN. NOT TO EXCEED PRICE QUOTED.

2 FREIGHT COLLECT

THANK YOU FOR THE OPPORTUNITY TO QUOTE.

10/29/92 15:39 Barbara Rust /GFD

DATE TIME Barbara Rust
Customer Service Rep.

NOTE: This quote is valid for 60 days. Please read NOTES & CONDITIONS on reverse side.

Barrel CSCs Materials Cost Estimate

Rev. 22

"6-6-6"

BASELINE

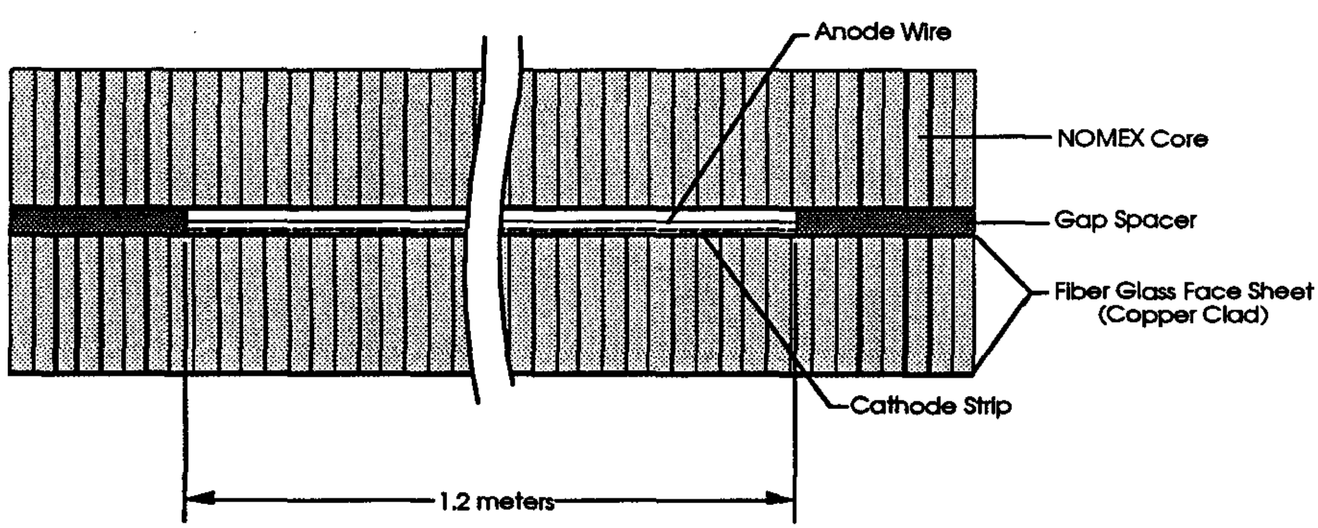
chamber type		Inner-1	Inner-2	Middle-1	Middle-2	Outer-1	Outer-2	Totals		
width (mm)		654	654	938	938	1200	1200			
length (mm)		3246	3471	2367	2567	3297	3500			
panel area (m^2)		2.123	2.270	2.220	2.408	3.956	4.200			
gaps/chamber		6	6	6	6	6	6			
chambers/sector		4	4	8	8	8	8			
sectors/barrel half		12	12	12	12	12	12			
total chambers		96	96	192	192	192	192	960		
total area (m^2)		1223	1308	2558	2774	4558	4838	17258		
wire (m/gap)		823.0	881.9	850.6	925.6	1534.6	1632.0		2.5 mm pitch, full chamber width	
wire (m/GEM)		592555	634935	1224633	1332690	2209766	2350080	8345060	*(25% wastage)*	
unit costs:										
wires	$/m	0.29	0.29	0.29	0.29	0.29	0.29		Quote from Luma	
circuit boards	$/m^2 of panel	20	20	20	20	20	20		End cap estimate	
cathodes, plain	$/m^2	5	5	5	5	5	5		End cap quote	
cathodes, strips	$/m^2	258	258	258	258	258	258		1/2 Actual Buckbee Mears cost	
manufactured panels		0.12725	0.12725	0.12725	0.12725	0.12725	0.12725		M. C. Gill "b" factor	
		450.71	450.71	450.71	450.71	450.71	450.71		M. C. Gill "a" factor	
	$/panel	869.42	898.44	888.62	925.63	1231.06	1279.11		M. C. Gill (Cost=a+b*area(in**2))	
	number req'd.	672	672	1344	1344	1344	1344	6720		
		401	[illegible]	400.28	384.40	311.19	304.55			$ / M^2
Total Costs:										
wires		$171,841	$184,131	$355,202	$386,538	$640,832	$681,523	$2,420,067		140.23
circuit boards		$48,911	$52,302	$102,309	$110,954	$182,311	$193,536	$690,322		40.00
J I N R spacers		$24,456	$26,151	$51,154	$55,477	$91,155	$96,768	$345,161	estimated as same as clr brds	20.00
cathodes, plain		$6,114	$6,538	$12,789	$13,869	$22,789	$24,192	$86,290		5.00
cathodes, strips		$315,476	$337,345	$659,893	$715,650	$1,175,905	$1,248,307	$4,452,578	$ / M (perimeter)	258.00
manufactured panels		$584,251	$603,755	$1,194,312	$1,244,042	$1,654,543	$1,719,118	$7,000,022	151.76	405.61
MATERIALS		$1,151,051	$1,210,221	$2,375,658	$2,526,530	$3,767,536	$3,963,445	$14,994,441		868.84

CSC Panel Fabrication Specs

Panel Definition: A 19 mm (nominal) honeycomb NOMEX core (1.8 lb/ cu. ft.; 0.25 in. cell) sandwiched between two .5 mm fiberglass (G-10 or FR-4; NEMA specs.) face sheets. The fiberglass face sheets are copper claded (17 μm thick; 1/2 oz. per sq. ft.) on the outward facing sides. The copper on one of the face sheets is etched to provide a precision cathode plane.

Specifications (prioritized)

1. Flatness
   100 μm over 1.2 m
2. Parallelism
   100 μm over 1.2 m
3. Net thickness (incl. face sheets)
   20 mm ± 250 μm
4. Squareness
   Diagonal measurements ± 250 μm of each other
5. Length and width dimensions
   Not set at this time.



Prototype Panel Manufacturer	Manufactured Precison			Cost
	Flatness (over 1.2 m)	Parallelism (over 1.2 m)	Thickness (Nom. 20mm)	(2 panels)
LLNL/M.C. Gill	100 µm*	100 µm	±250 µm	150 K$
Composite Optics	75 µm (side 1) 150 µm (side 2)	75 µm (side 1) 150 µm (side 2)	±250 µm	25 K$

* *Current Physics requirement: Anode to cathode spacing within ± 100 µm.*

Material Thickness Tolerances

Fiber Glass Face Sheets
- 10% or 20 mil ± 2 mil

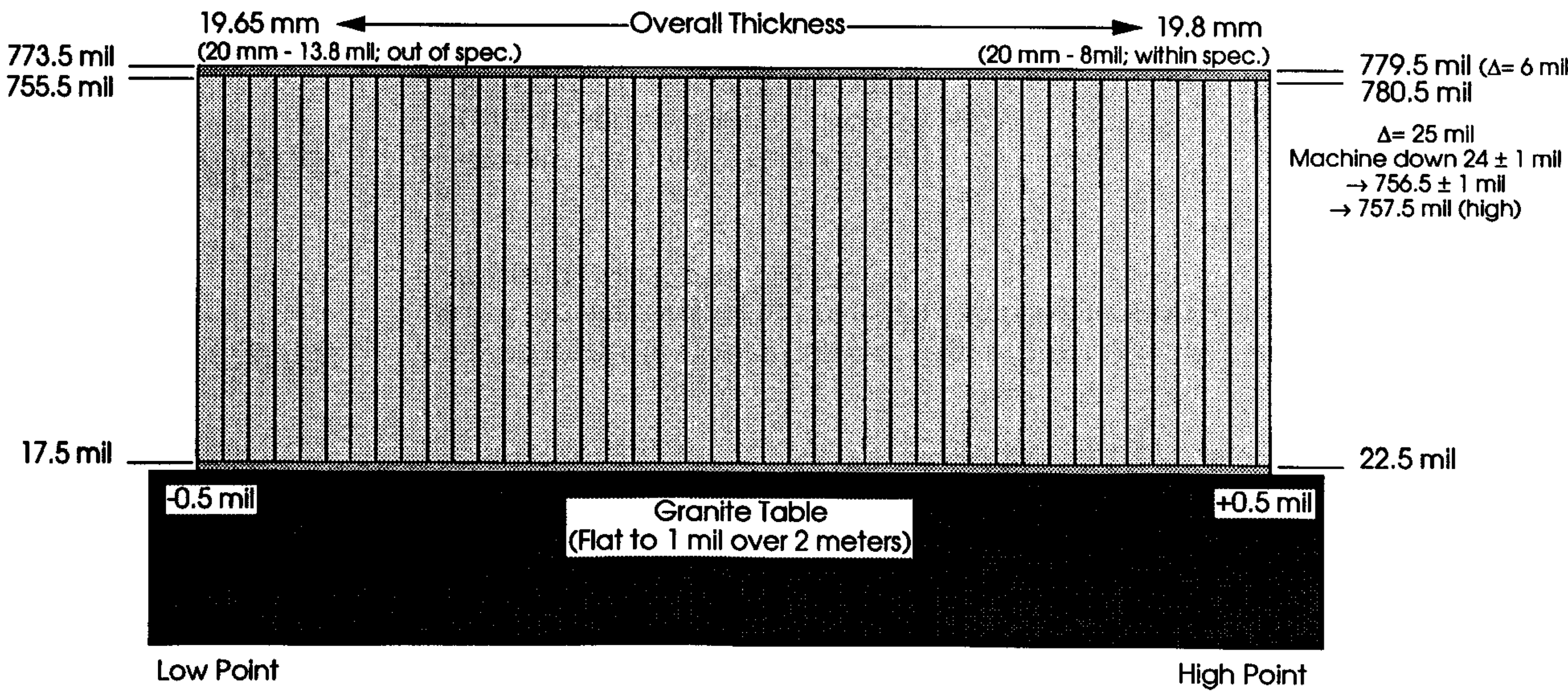
NOMEX Core
- 19 mm (748 mil) ± 10 mil

Panel Prototype Fabrication Process

Step 1: Fiber glass face sheet sucked down flat onto granite table and NOMEX core bonded to it via a room temperature curing epoxy.
Step 2: NOMEX core machined down (using Toshiba cutting tool) to a flatness of 2 mil over 1.2 m.
Step 3: Top fiber glass sheet bonded to NOMEX core.

Resulting Precision

Flatness (coarse Cathode) and Parallelism	6 mil over 1.2 m	Improve Fiber glass thickness tolerance and/or machine tolerance
Thickness	20 mm ± 14 mil	Improve NOMEX thickness tolerance

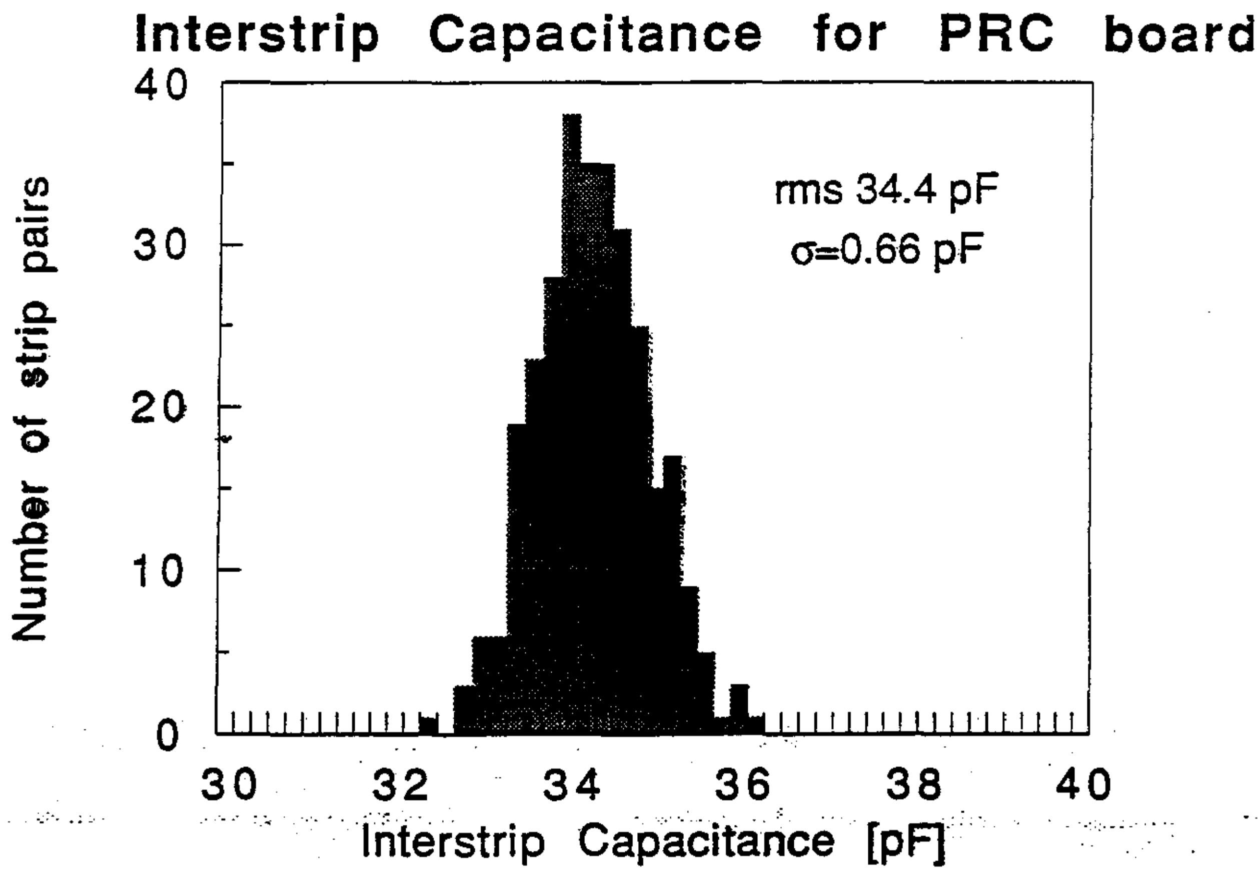


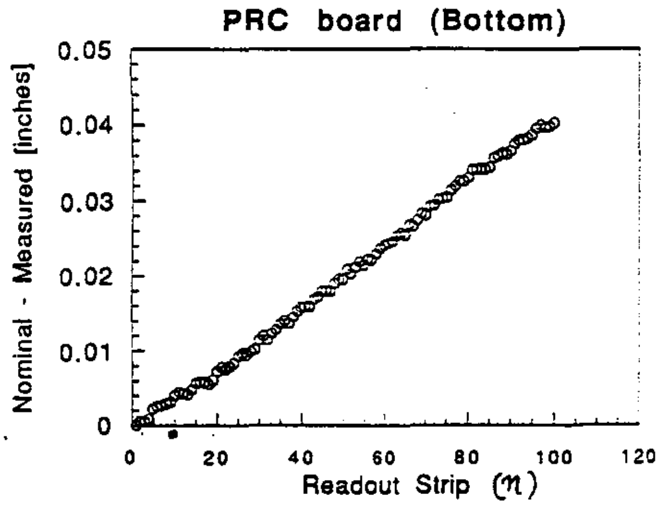
Concern: A seven-panel (6-gap) chamber sags 67 μm under its own weight leaving only 33 μm of manufacturing tolerance for the panel <u>and</u> gap frame assemblies.

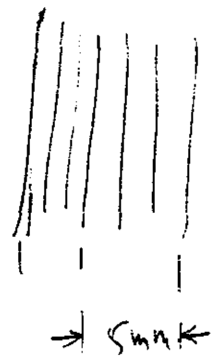
Solutions:

1. Review the physics requirement (and possibly loosen-up tolerances).
2. Stiffen-up the individual panels
   - Rib stiffeners across the panel width
   - Alternative face sheet materials which increase stiffness relative to mass.

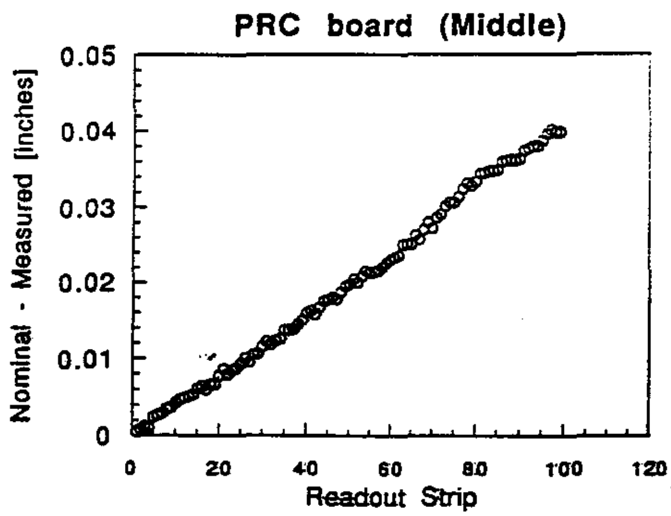
The strip board sample made by IPEAI, Beijing.

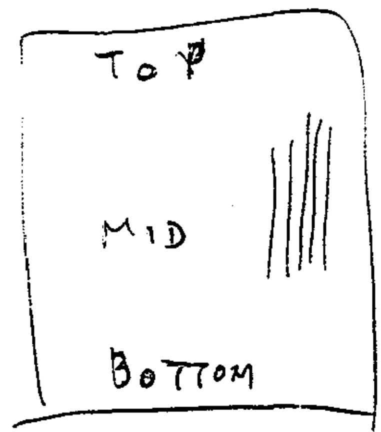


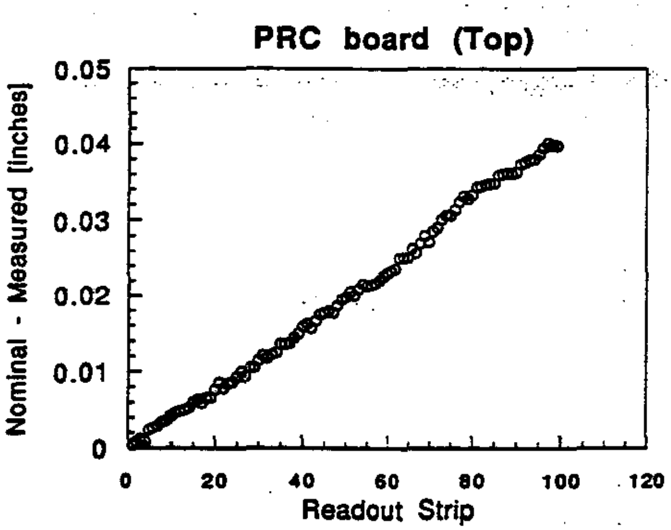




$Y = n \times 5 - Y_{measured}$

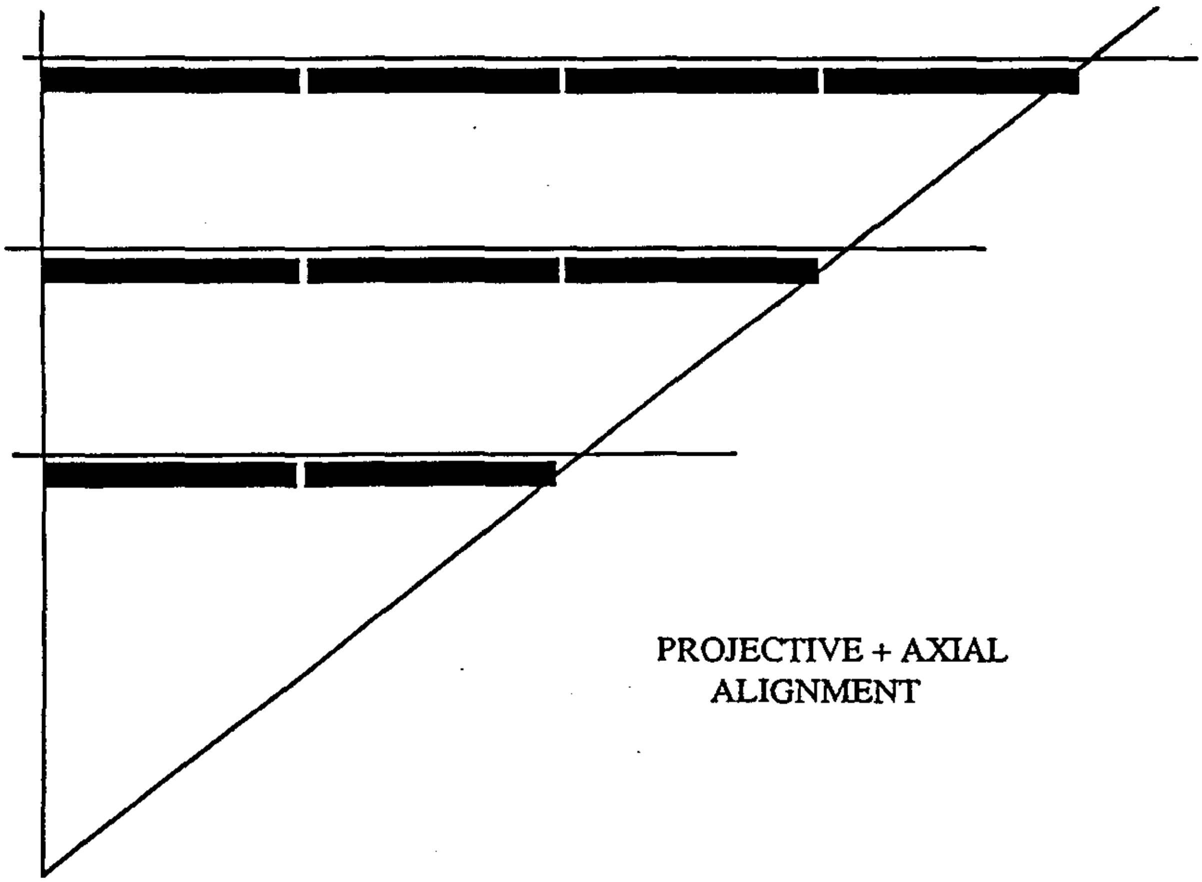






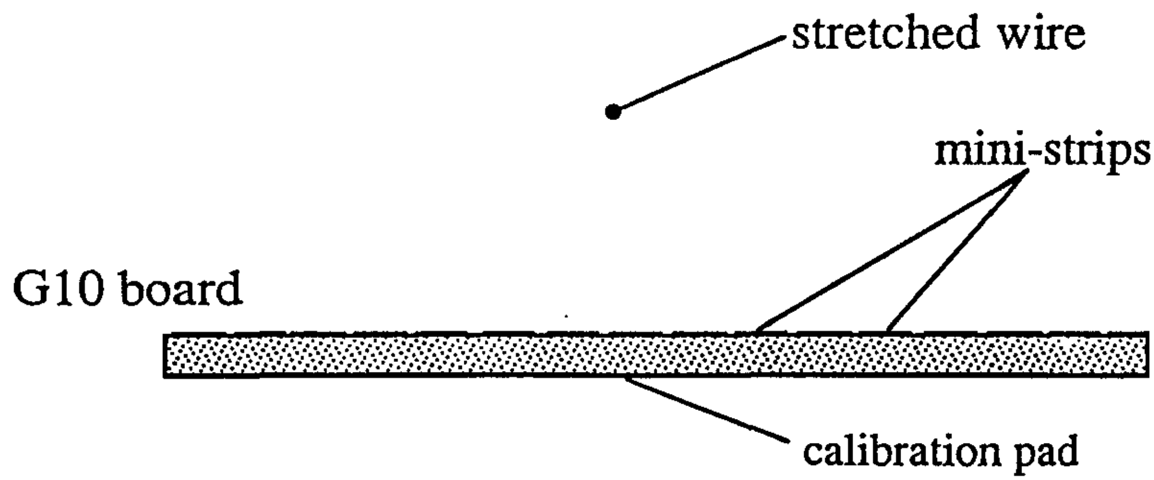
M.I.T.
June 29, 1993

Most Recent Results on Axial Alignment (Stretched Wire + mini-Strip Readout).



Reminder:

as was shown by J.Paradiso and A.Ostapchuk in detail, the axial alignment with a detector accuracy **~10 μm** is adequate to the GEM alignment goals.



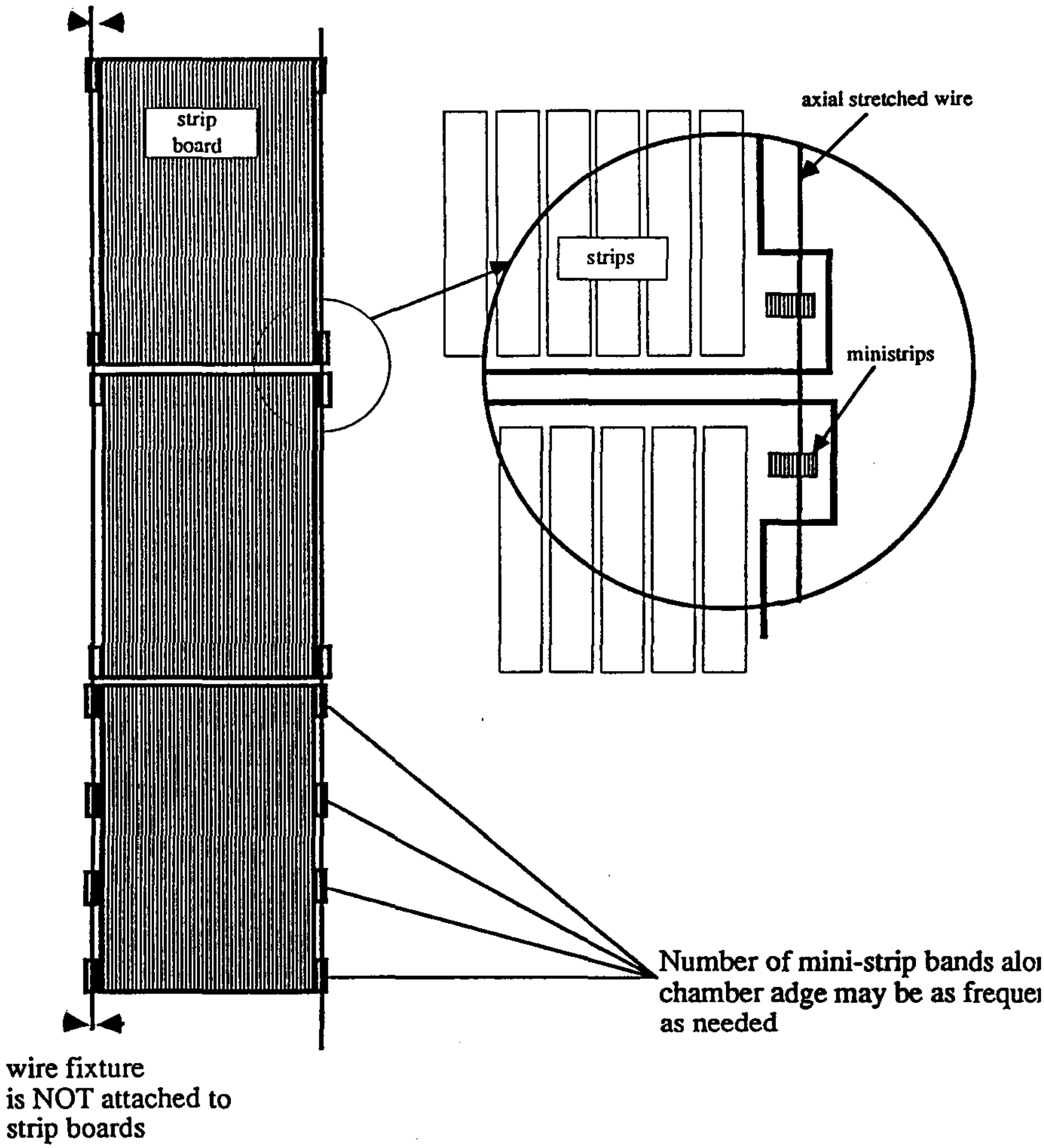
A pulse is fed to a stretched wire, as large as wanted.

Induced charges are picked up from mini-strips.

The induced charge shape is determined by pure electrostatics, peak of the distribution indicating the "horizontal" wire position and its width giving "vertical" displacement.

Narrow strips (~1 mm) allow to get
a high accuracy (<10 μm) over large range (~10 mm)
without special concerns about calibration, which is the main issue of a high accuracy + large range alignment.

Monte Carlo simulation showed that the scheme should work and not effected by many systematic errors, such as electronics calibration, wire tilts in both directions, cross-talks and so on (stochastic noise is not a concern at all).


strip board
strips
axial stretched wire
ministrips
Number of mini-strip bands alo
chamber adge may be as freque
as needed
wire fixture
is NOT attached to
strip boards

Experimental Set-Up:

A G10 board with 11 strips equipped with electronics.
Pitch = 1.016 mm (40 mil).
Etching was made at a standard firm
(standard electronic board tolerances, nothing special).

100 μm stretched wire (1 m long) over the board.

The board was fixed on a stage which could be moved by precise micrometers (2 μm min division).

Signal from ~ 2 V up to ~13 V was used for the wire.

Maximum pick-up charge on a strip was around 700 fC.
Electronics noise was ~ 5 fC (30,000 e, really lousy!)

Calibration was done by feeding a test pulse onto the underneath pad (trivial).

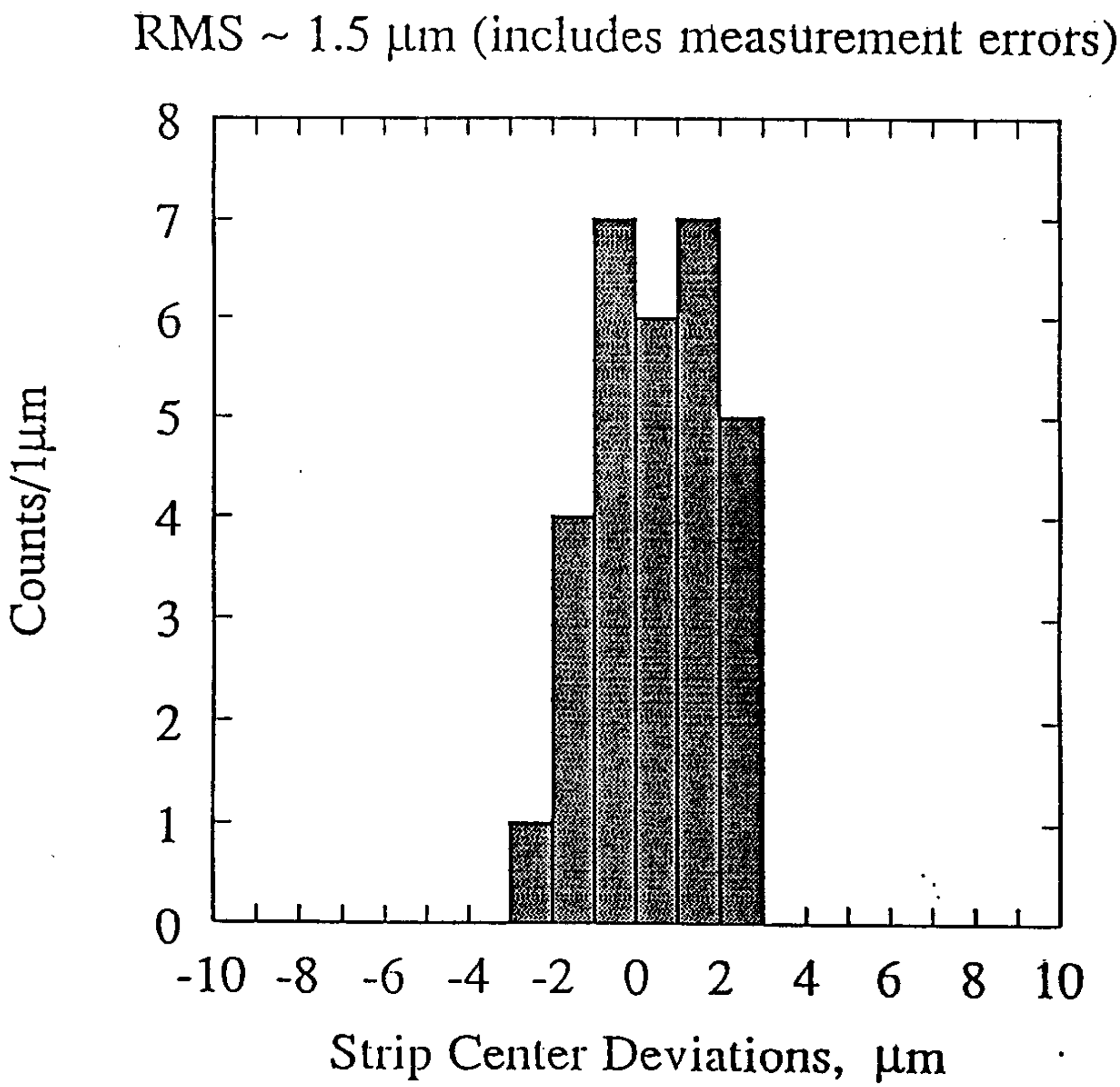
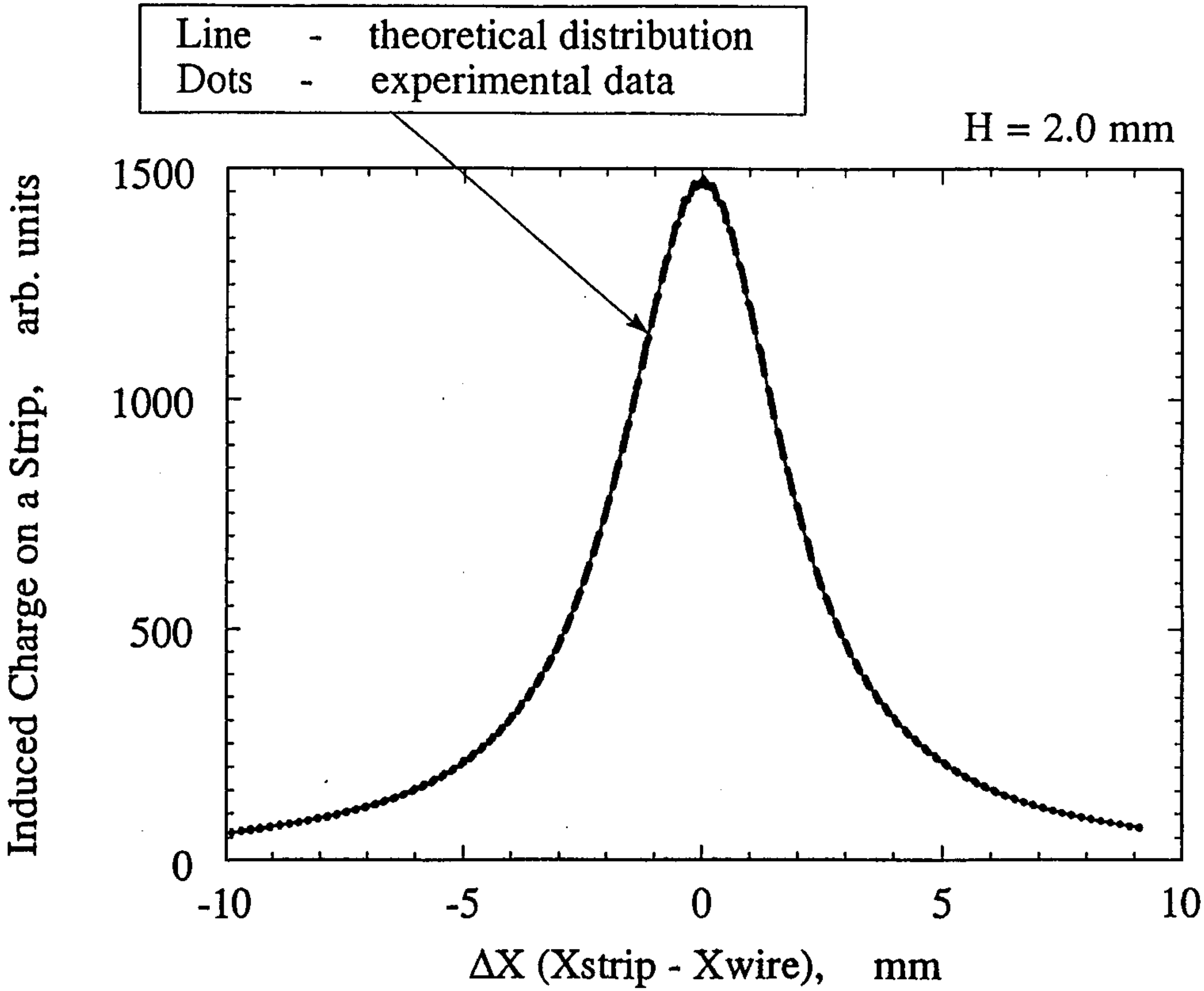
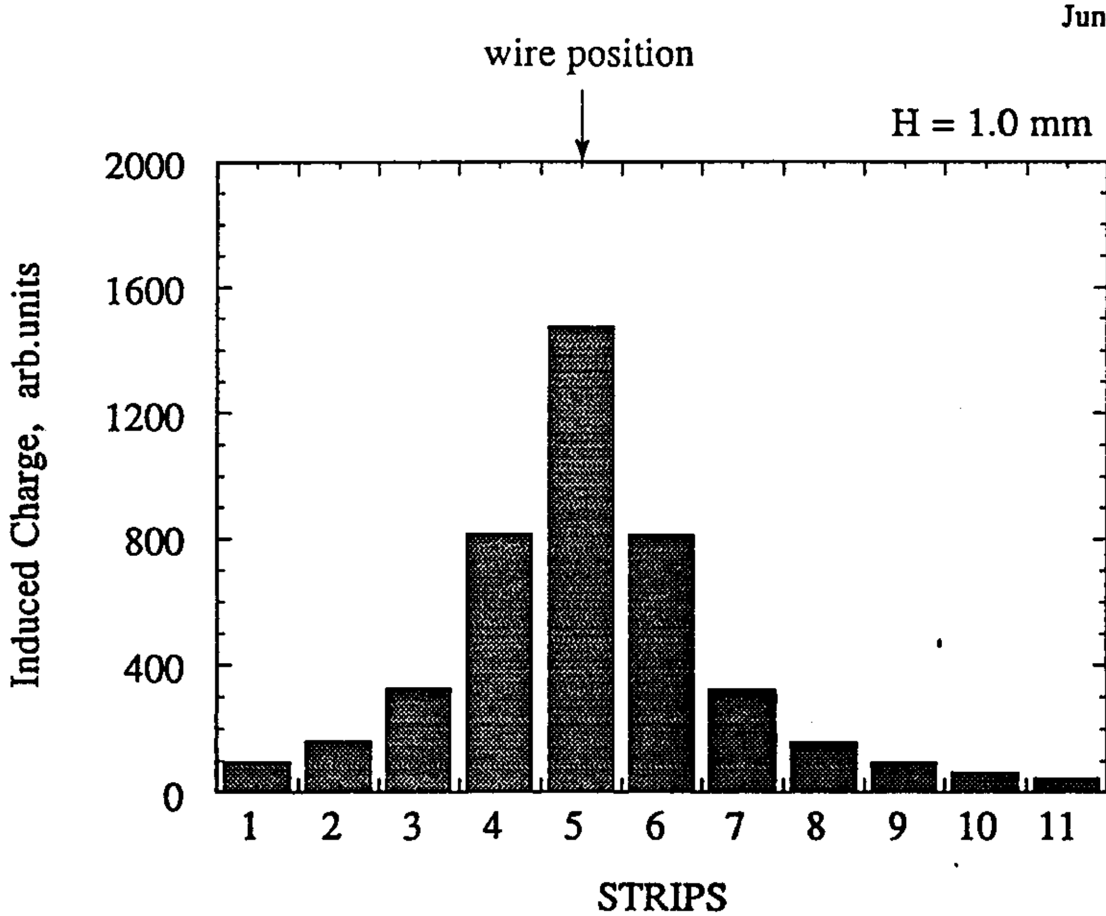


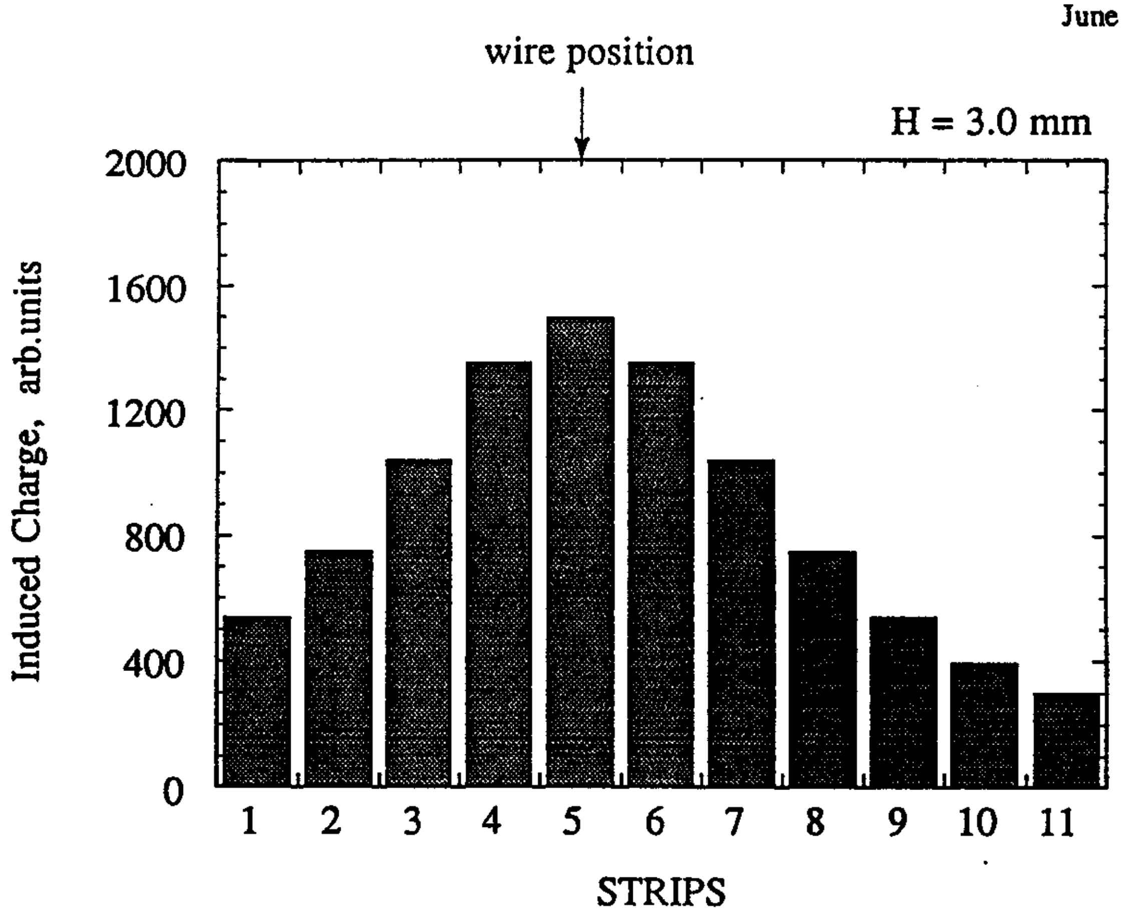
Fig.4. Pitch accuracy of strips etched on G10 board as measured with an optical microscope.


Line - theoretical distribution
Dots - experimental data
H = 2.0 mm
Induced Charge on a Strip, arb. units
1500
1000
500
0
-10
-5
0
5
10
ΔX (Xstrip - Xwire), mm

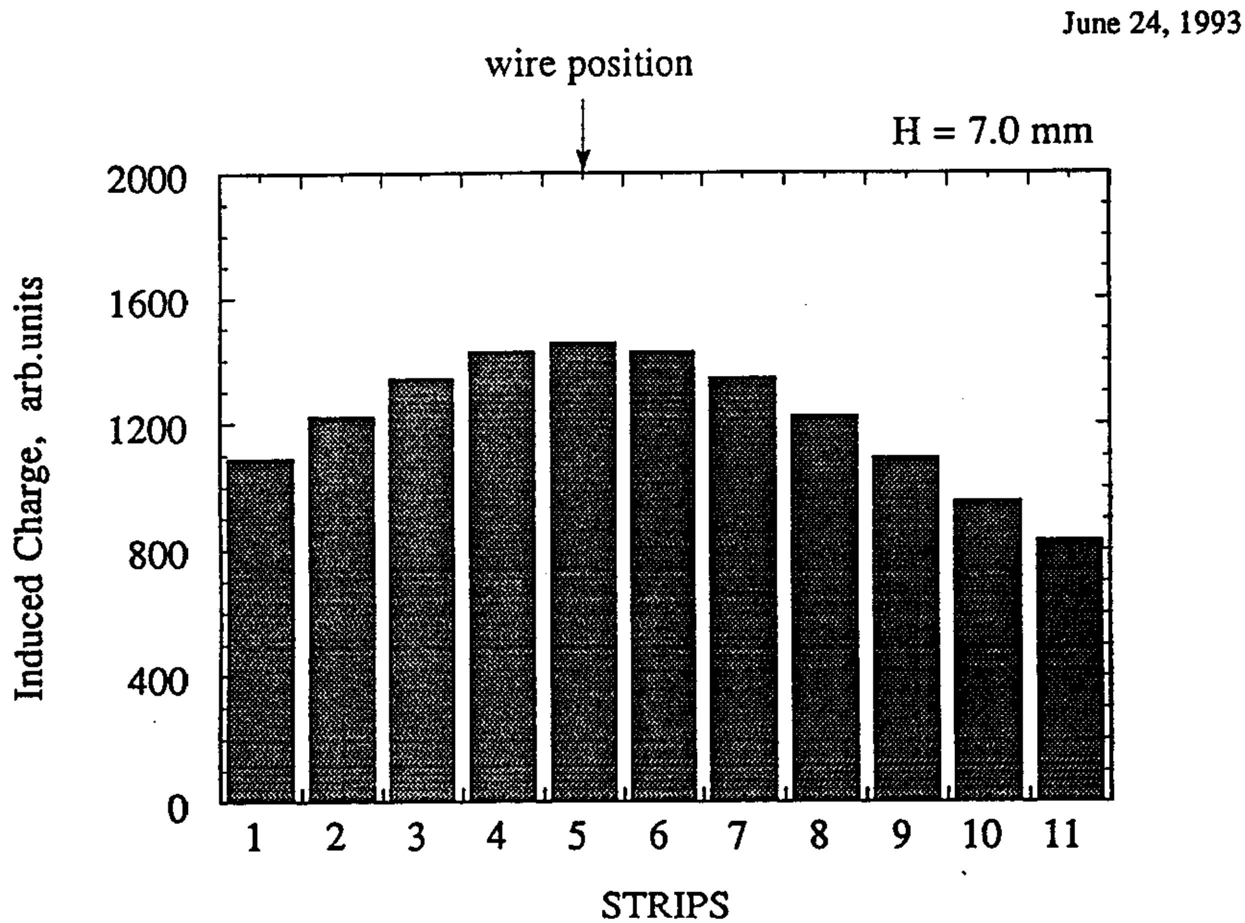
June 24, 1993

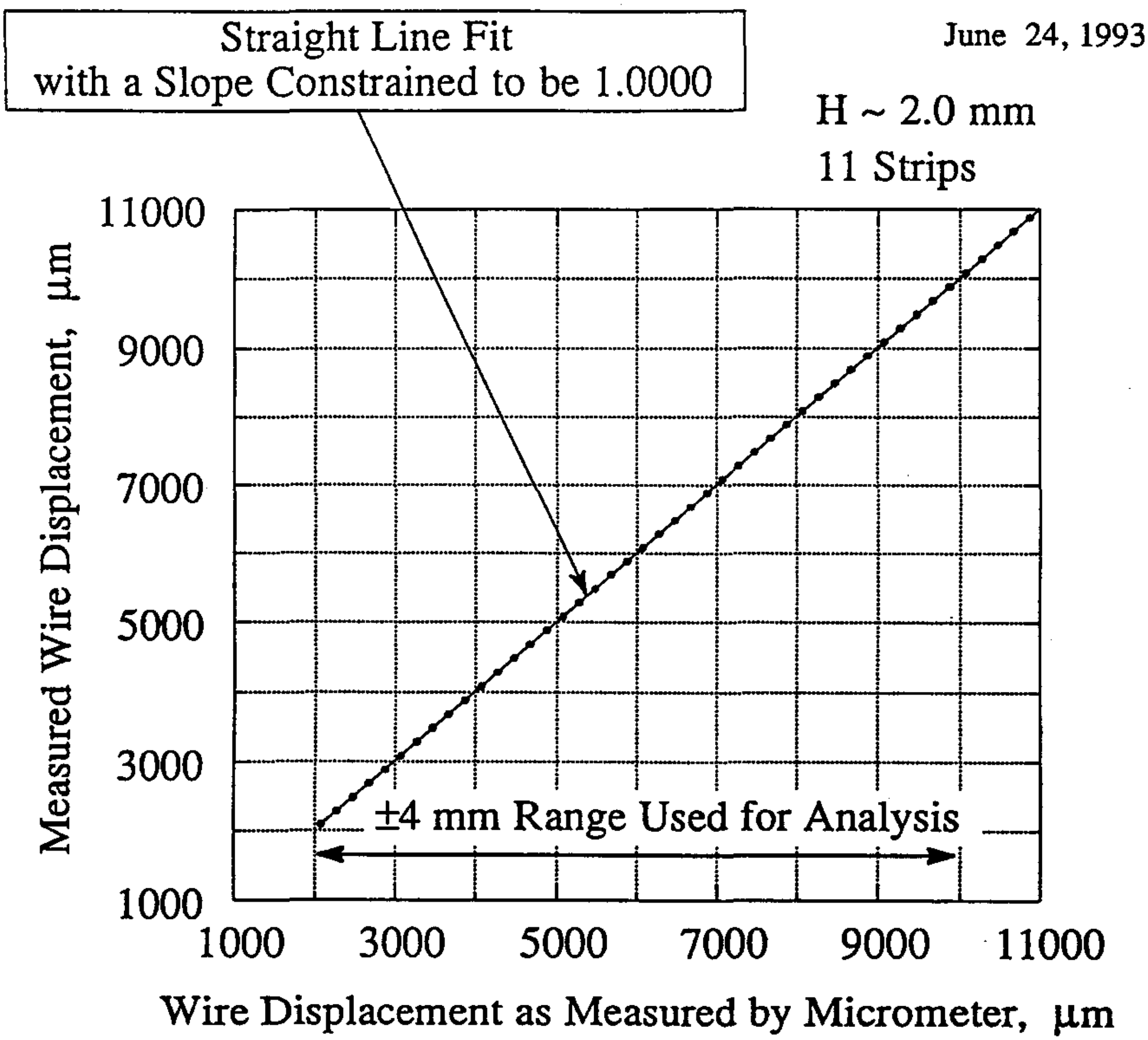

wire position
H = 1.0 mm
2000
1600
1200
800
400
0
Induced Charge, arb.units
1
2
3
4
5
6
7
8
9
10
11
STRIPS

June 24, 1993



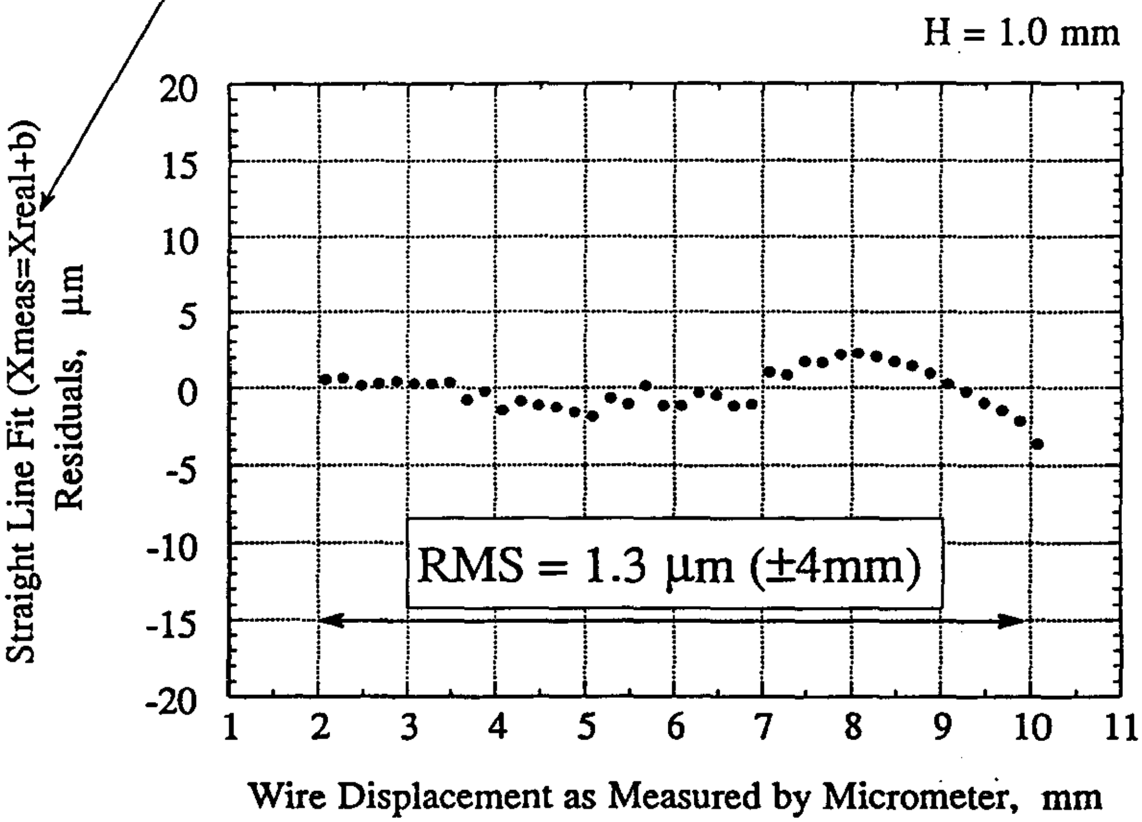
wire position
H = 3.0 mm
2000
1600
1200
800
400
0
Induced Charge, arb.units
1
2
3
4
5
6
7
8
9
10
11
STRIPS


June 24, 1993
wire position
H = 7.0 mm
2000
1600
1200
800
400
0
Induced Charge, arb.units
1
2
3
4
5
6
7
8
9
10
11
STRIPS


Straight Line Fit
with a Slope Constrained to be 1.0000
June 24, 1993
H ~ 2.0 mm
11 Strips
11000
9000
7000
5000
3000
1000
Measured Wire Displacement, µm
±4 mm Range Used for Analysis
1000
3000
5000
7000
9000
11000
Wire Displacement as Measured by Micrometer, µm

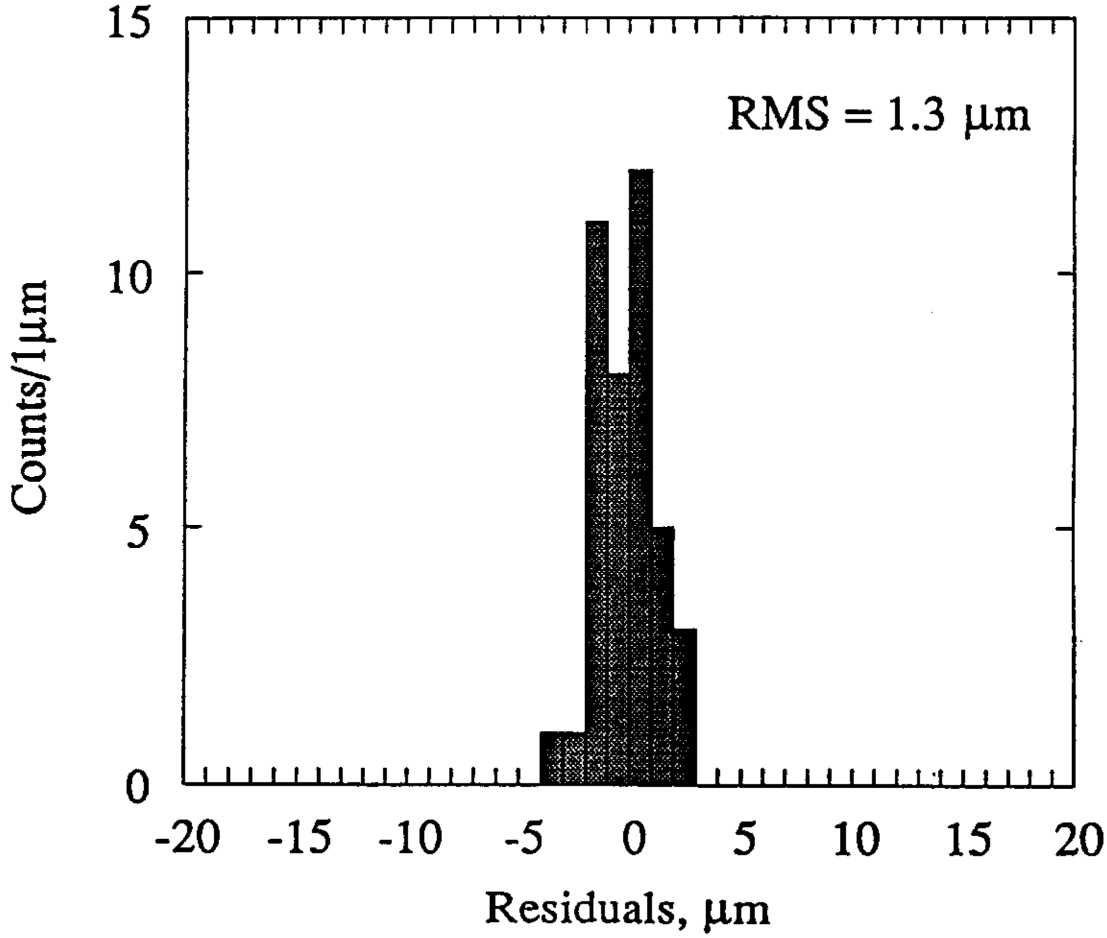
Note: slope is constrained to be 1.00000

June 24, 1993



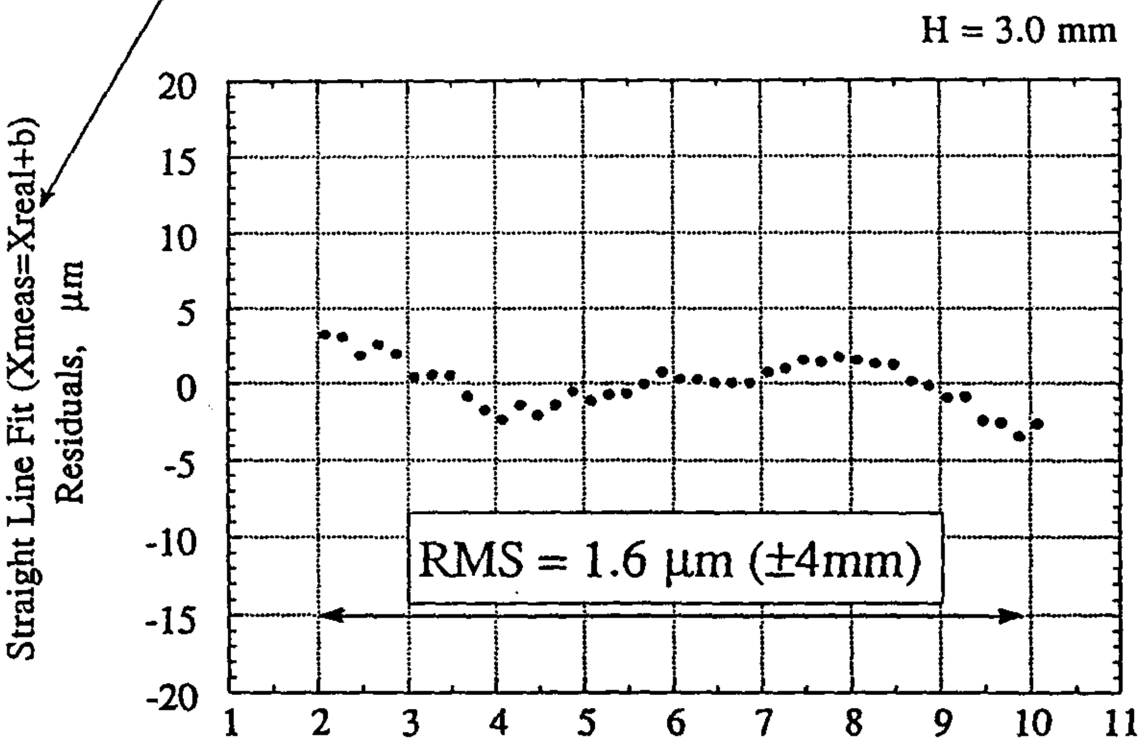
June 24, 1993

H = 1.0 mm



Note: slope is constrained to be 1.00000

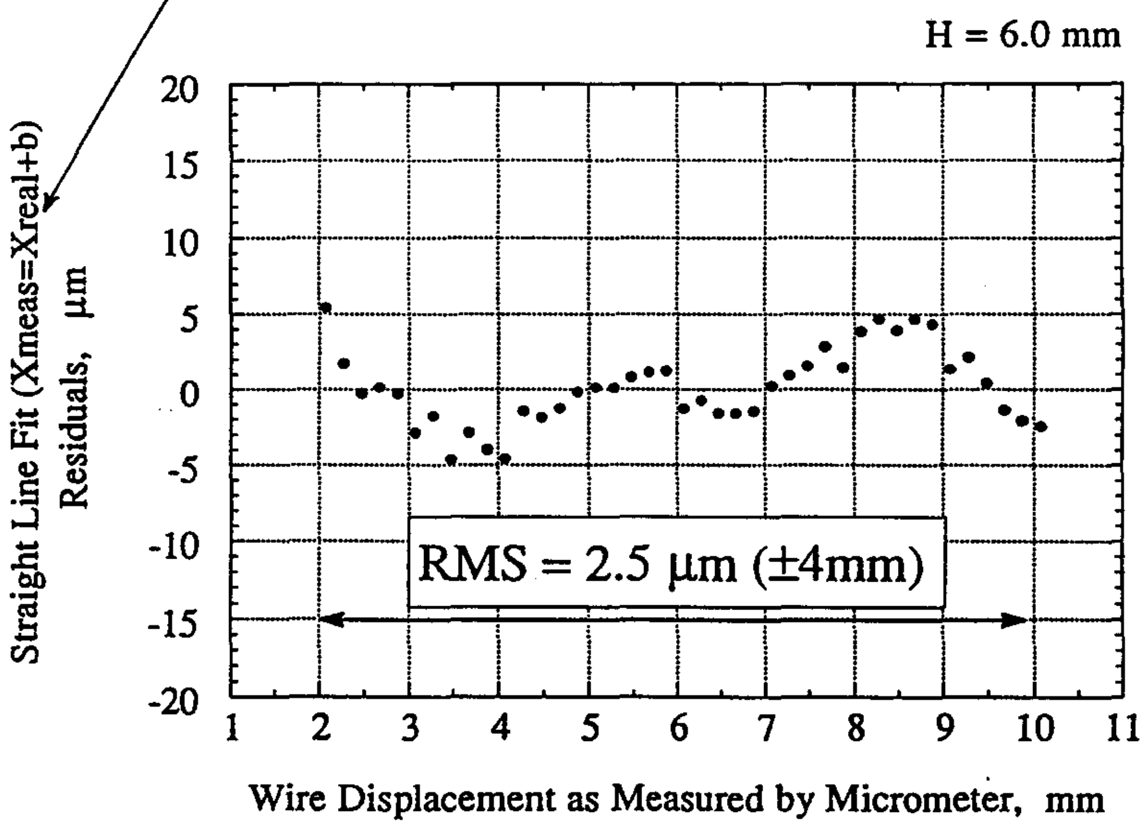
June 24, 1993



Wire Displacement as Measured by Micrometer, mm

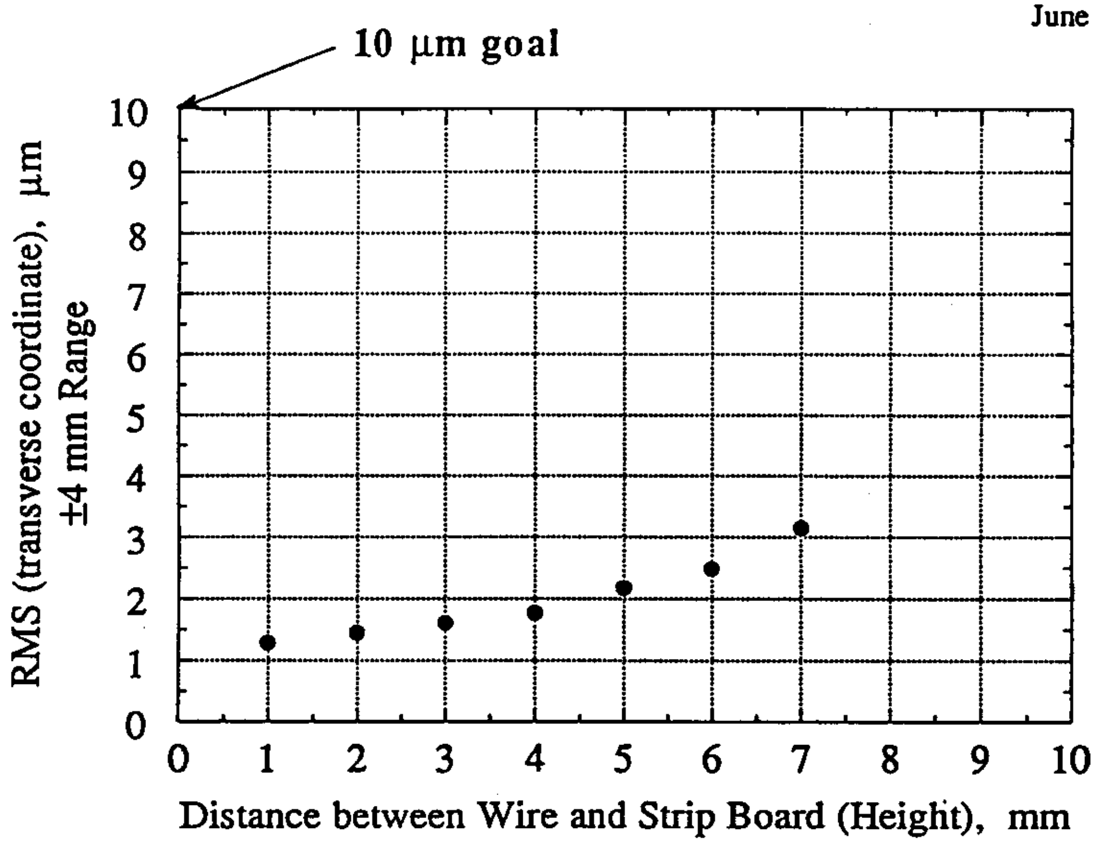
Note: slope is constrained to be 1.00000

June 24, 1993



RESULTS OBTAINED WITH 11 (1 mm wide) STRIPS

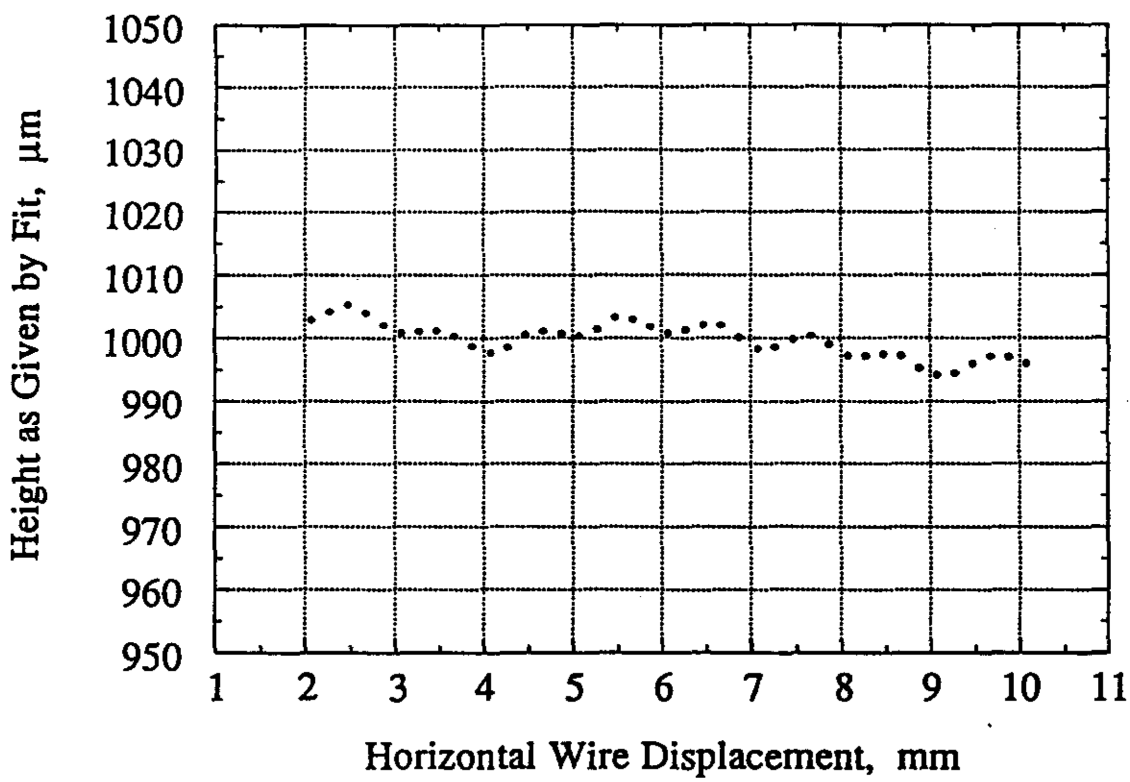
June 24, 1993

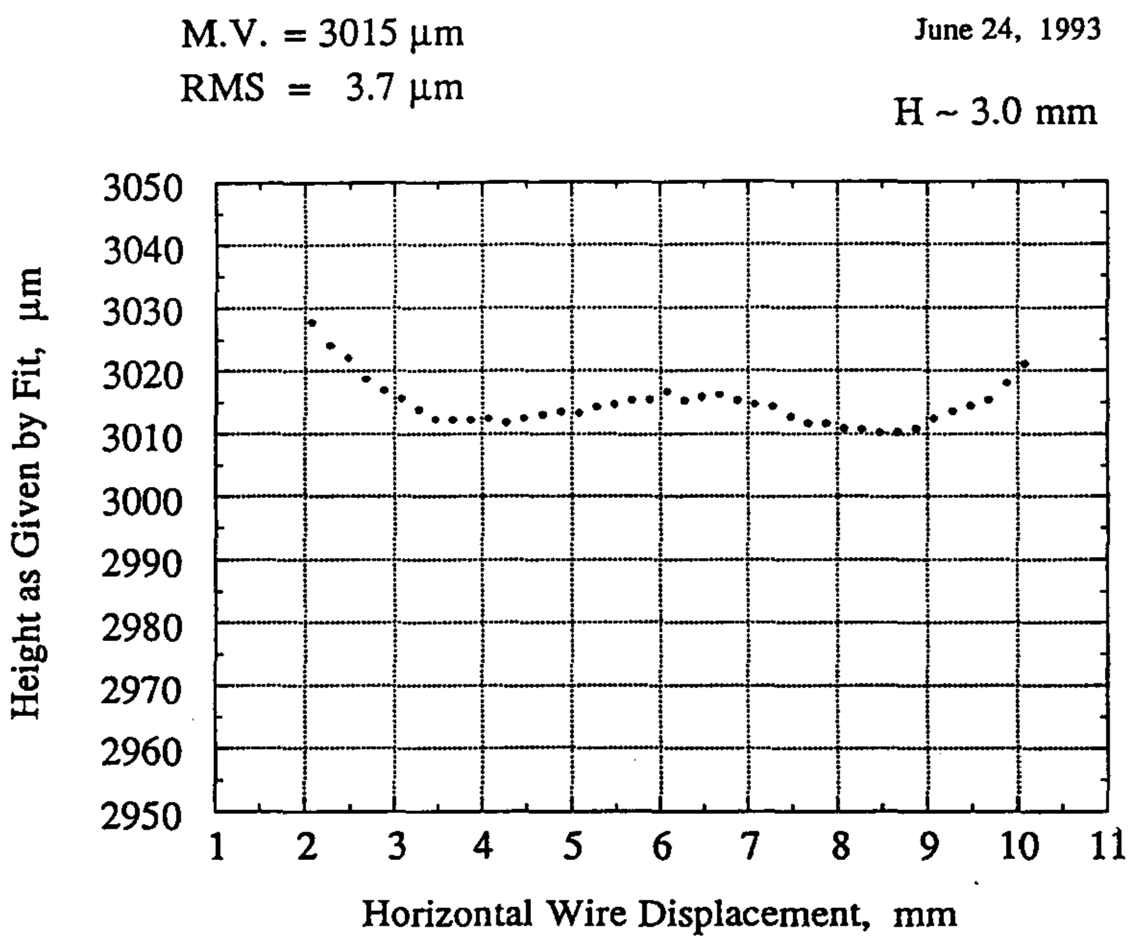


M.V. = 999.7 μm
RMS = 2.7 μm

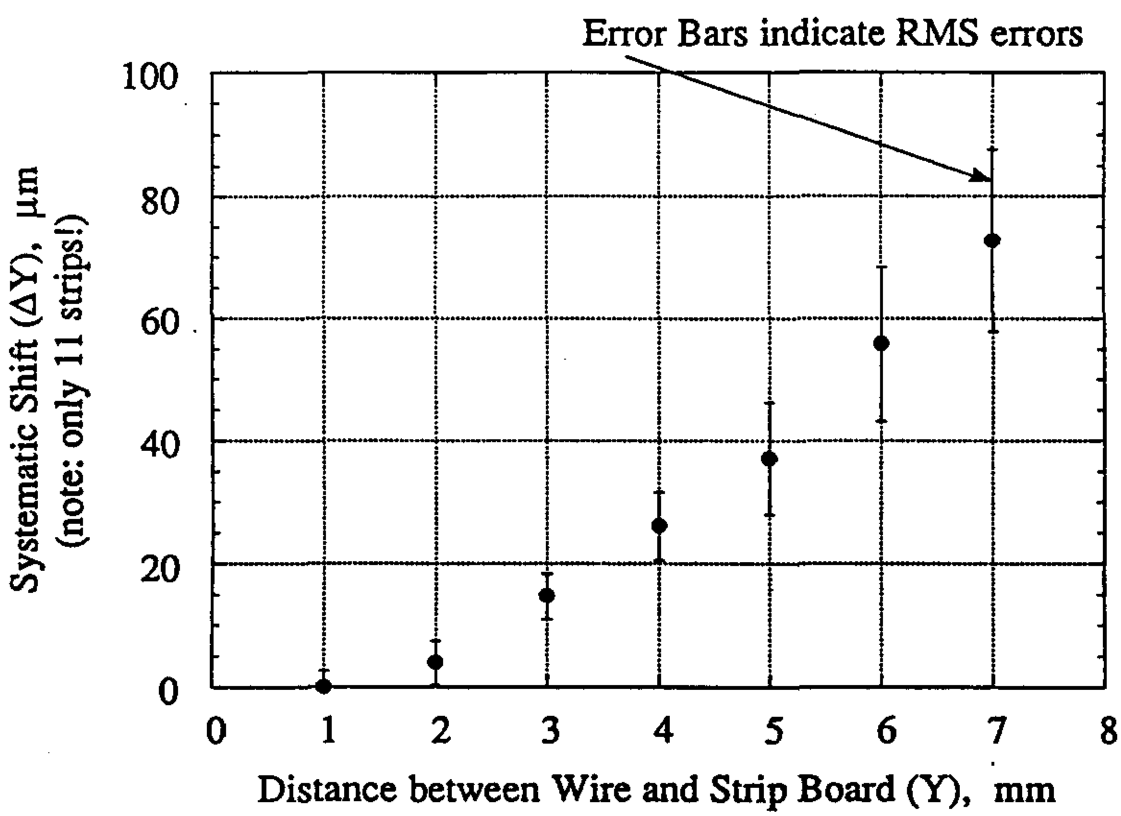
June 24, 1993

H ~ 1.0 mm




M.V. = 3015 µm
RMS = 3.7 µm
June 24, 1993
H ~ 3.0 mm
Height as Given by Fit, µm
3050
3040
3030
3020
3010
3000
2990
2980
2970
2960
2950
1
2
3
4
5
6
7
8
9
10
11
Horizontal Wire Displacement, mm

June 24, 1993


Error Bars indicate RMS errors
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
Systematic Shift (ΔY), μm
(note: only 11 strips!)
Distance between Wire and Strip Board (Y), mm

SUMMARY:

Regular Etching gives ~1 μm (or better) pitch accuracy.

Strip width has ~ 1 μm uniformity (over 3 cm range).

Using just 11 strips allowed to achieve 1-3 μm resolution over ±4 mm range (goal is ~10 μm).

Vertical accuracy is worse (~50 μm and should improve considerably with increasing the number of strips), but much better than 200-400 μm requirement.

PLANS:

1. Multiplex Readout.
Say, using an AMPLEX would allow to readout 16 strips with essentially one chip (cost estimations!).

2. Try a silicon carbide wire (it will sag by 300 μm only at 15 m length; 1-2% tension control is simple* and will allow to correct a sagita with a few μm accuracy).

3. Make a full scale prototype (15 m long wire and all accessories).

---

* As proposed by J.Paradiso, one of the possible options could use the same mini-strips: the wire can be vibrated with a peso-element at varying frequency while the resonance is detected by the mini-strips. However, even a simple weight may turn out to be adequate enough.

Alignment, BASED on the MEASUREMENTS of Particle Non-Bend Coordinate

(A. Ostapchuk)

- Introduction
- The method
- Realisation schemes
  - ↳ 100% z-readout
  - ↳ 10% z-readout
- Systematic effects
  - ↳ non-uniform magnetic field
  - ↳ chamber deformations
  - ↳ ...
- Conclusion

$$FS^{(6)}(x,z) = a_{00}^{(6)} + a_{10}^{(6)}x + a_{01}^{(6)}z + a_{11}^{(6)}xz + a_{20}^{(6)}x^2 + a_{21}^{(6)}x^2z$$

Different terms are different linear combinations of FS_i (measured values of false sagitta) and therefore they depend on different movements. So,

a_{00} is determined by shift along the x-axis;

a_{01} is determined by rotation around the y-axis;

a_{10} is determined by rotation around the x-axis;

a_{20} is determined by rotation around the z-axis;

We can apply the same interpolation procedure to the function NS(x,z) and get similar polynomials:

$$NS^{(4)}(x,z) = b_{00}^{(4)} + b_{10}^{(4)}x + b_{01}^{(4)}z + b_{11}^{(4)}xz$$

$$NS^{(6)}(x,z) = b_{00}^{(6)} + b_{10}^{(6)}x + b_{01}^{(6)}z + b_{11}^{(6)}xz + b_{20}^{(6)}x^2 + b_{21}^{(6)}x^2z$$

The coefficients of these polynomials depend on shifts and rotations of muon modules in different ways, but the shifts and rotations are the same in both cases! So, there must be correlations between coefficients a_{ij} and b_{ij}:

b_{10} is fully correlated with a_{01} (see Fig.18),

b_{01} is slightly correlated with a_{11} (see Fig.19);

and most interesting, if there are no torque deformations of muon modules,

b_{11} is fully correlated with a_{20} (Fig.20, but see Fig. 21).

The last correlation means we are able to correct rotation around z-axis using only four straightness monitors. This is the second application of monitor measurements of non-bending deflections.

9. Alignment requirements

We would like to stress the sharp distinction between placement and measurement accuracy requirements. The only requirement for monitor measurement accuracy is that it must be better than 25μm.

There are two types of placement or proper position requirements: 1) relative po-

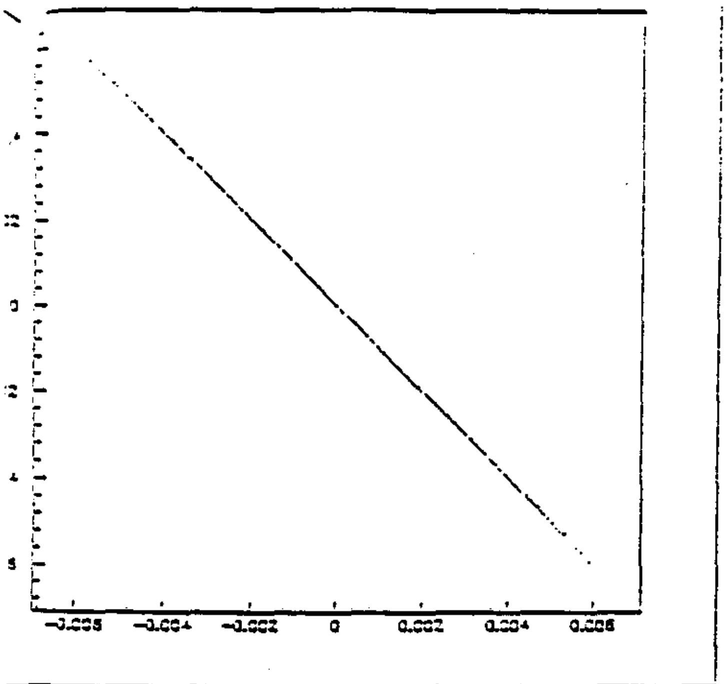


Fig.18 $b_{10} vs a_{01}$

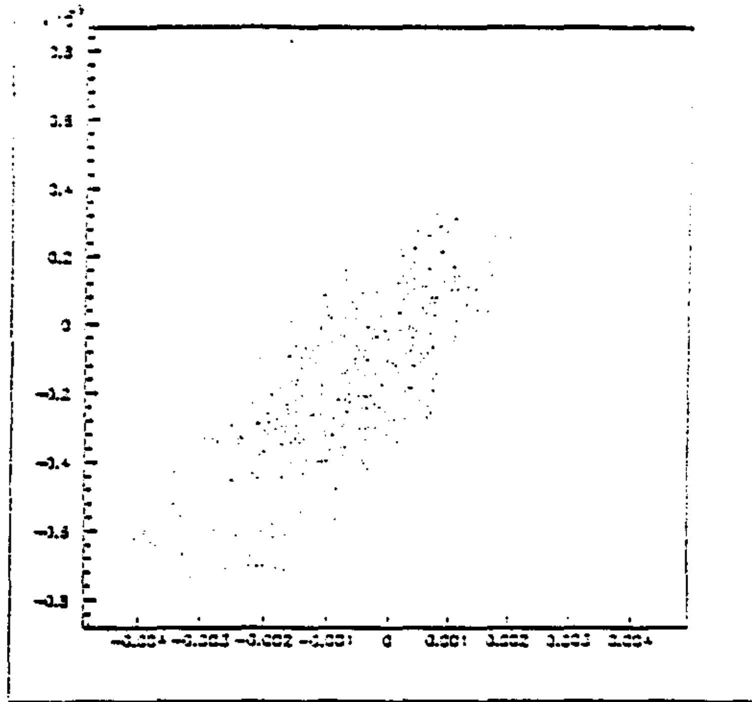


Fig.19 $b_{01} vs a_{11}$

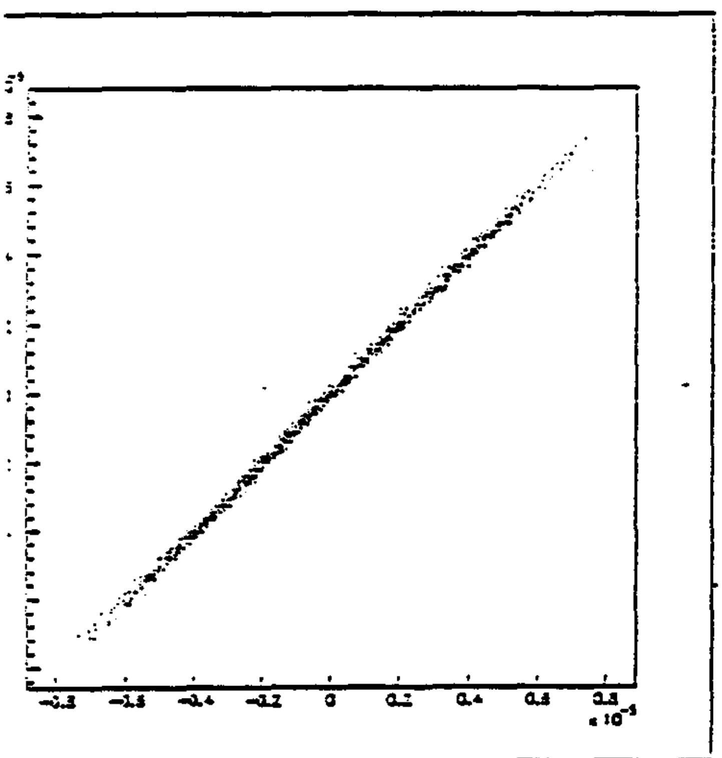


Fig.20 $b_{11} vs a_{02}$; No Torsion

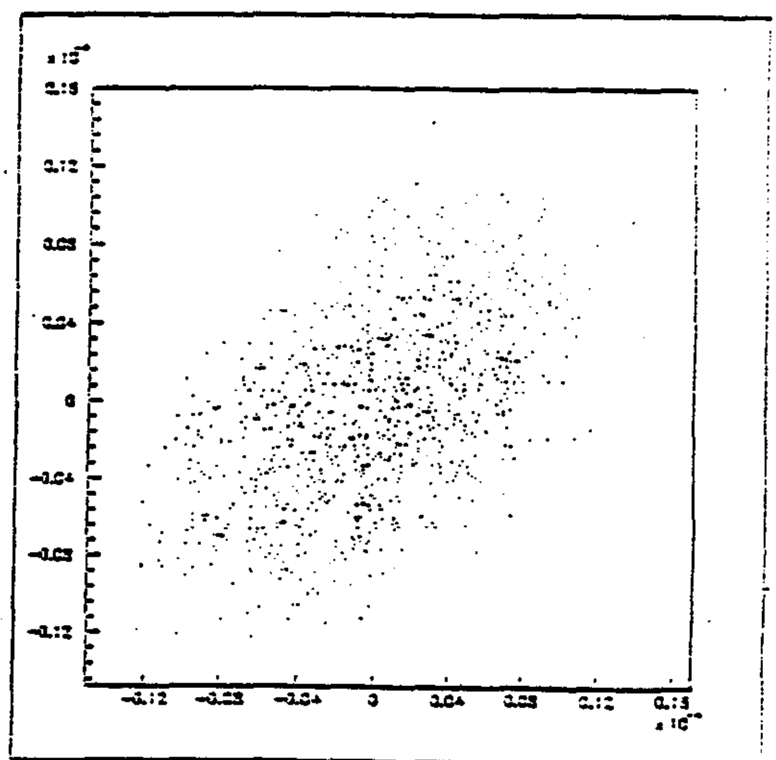


Fig.21 $b_{11} vs a_{02}$; Torsion: $\Psi_{torque} \leq \pm 3mrad$

- Chamber as a rigid body:

  D_x, D_y, D_z - displacements

  R_x, R_y, R_z - rotations

- False saggita $F(\theta, \varphi)$

  ↳ if disturbancies are small enough

$$F(\varphi,\theta) \simeq a_{00} + a_{10}\cdot tg\varphi + a_{01}\cdot tg\theta + a_{11}\cdot tg\varphi\, tg\theta + a_{20}\cdot tg^2\varphi$$

where:

$a_{00} = c\, D_x^{out} + (1-c)\, D_x^{inn} - D_x^{mid}$ ⇒ x shifts

$a_{10} = -c\, D_y^{out} - (1-c)\, D_y^{inn} + D_y^{mid}$ ⇒ y shifts

$a_{01} = -c\, R_y^{out}\cdot Y^{out} - (1-c)\, R_y^{inn}\cdot Y^{inn} + R_y^{mid}\cdot Y^{mid}$ → y rotations

$a_{11} = c\, R_x^{out}\, Y^{out} + (1-c)\, R_x^{inn}\, Y^{inn} - R_x^{mid}\, Y^{mid}$ → x rotations

$a_{20} = c\, R_z^{out}\, Y^{out} + (1-c)\, R_z^{inn}\, Y^{inn} - R_z^{mid}\, Y^{mid}$ → z rotations

and

$$c = \frac{Y^{mid} - Y^{inn}}{Y^{out} - Y^{inn}} = \frac{1}{2} \text{ if chambers equidistant}$$

- For non-bend coordinate: $N(\theta, \varphi)$

↳ same approach

↳ same D_i, R_i !

$$N(\theta,\varphi) \simeq b_{00} + b_{10}\, tg\varphi + b_{01}\, tg\theta + b_{11}\, tg\varphi\, tg\theta + b_{02}\, tg^2\theta$$

With b_{00} – z-shift, b_{01} – y-shift, b_{10} – y-rotation, b_{11} – z rotation, b_{02} – x rotation

↳ comparing with $F(\theta, \varphi)$

$a_{10} \equiv b_{01}$

$a_{01} \equiv -b_{10}$

$a_{11} \equiv b_{02}$

$a_{20} \equiv b_{11}$

↳ all coefficients exept

a_{00} – responsable for x-shift

- There is no saggita in non-bend direction

⇓

Only arise from:

- chamber misalignment
- Multiple scattering in the middle SL
- Non-uniform magnetic field
- Chamber deformations

↳ **METHOD:**

1. Obtain a set of $\varphi_i, \theta_i, N_i(\varphi_i, \theta_i)$
2. Fit the data by polinomial

$$N^{fit}(\varphi^{mes}, \theta^{mes}) = b_{00}^{fit} + b_{10}^{fit} tg\varphi^{mes} + b_{01}^{fit} tg\theta^{mes} + b_{11}^{fit} tg\varphi^{mes} tg\theta^{mes} + b_{02}^{fit} \cdot tg^2\theta^{mes}$$

3. Use relations $a_{ij} \Leftrightarrow b_{ij}$
4. Obtain missing a_{00} coefficient using one straitness monitor

- BUT: need z-resolution
  - ↳ Required resolution depends on statistics available

- Propose two realizations:
  - 100% readout - full Θ-range
  - 10% readout - 3 narrow Θ intervals

100% READOUT:

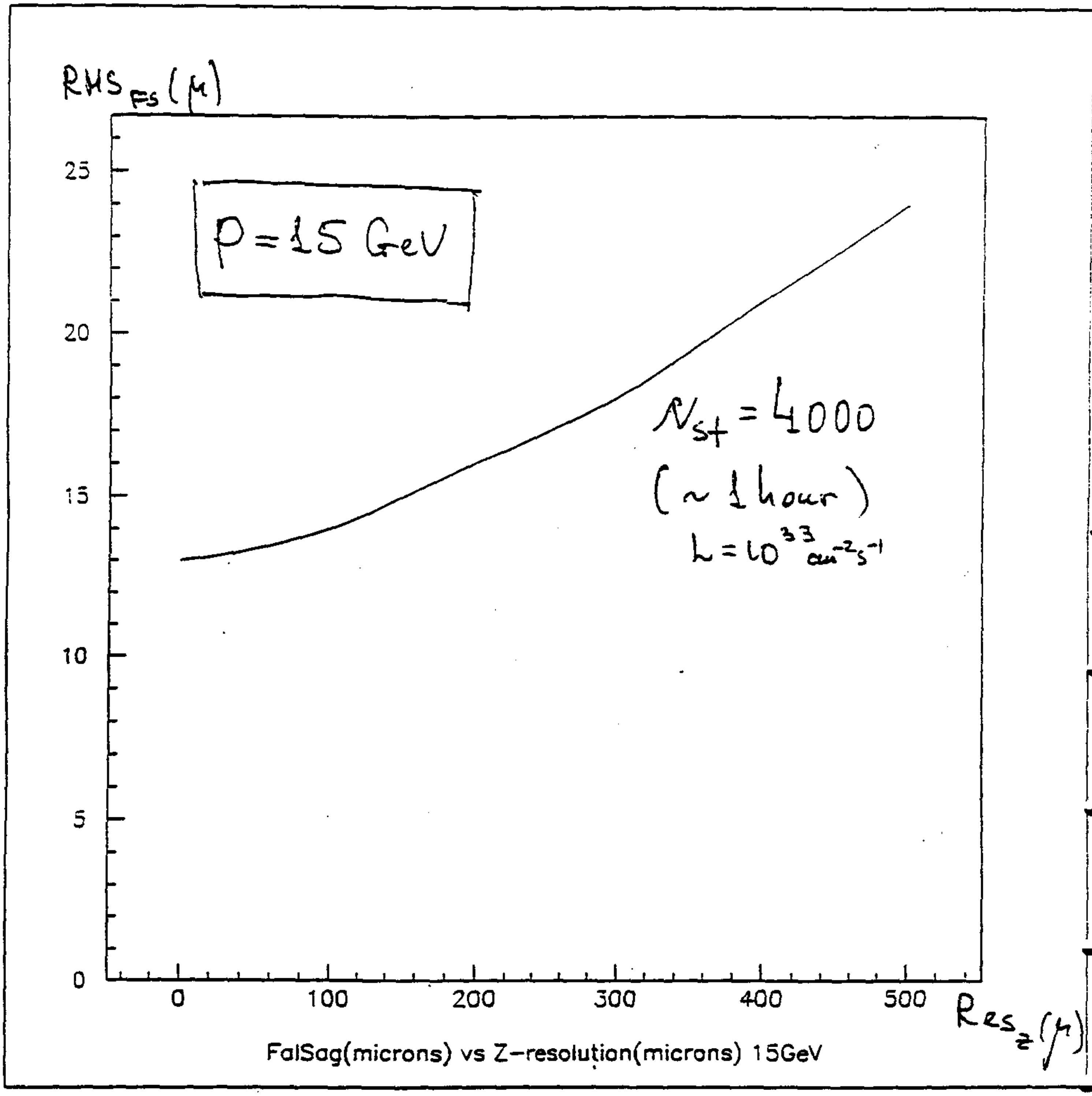
↳ wire spacing - 2.5 mm $\Rightarrow \sigma_z = \frac{2.5}{\sqrt{12}} = 700 \mu m$

↳ for two layers: $\sigma_z = 500 \mu m$ (factor of $\frac{1}{\sqrt{2}}$!

MC simulation

- $N_{stat} = 4000$
- $P_{min} = 15$ GeV
- multiply scattering
- limited size of interaction region
- coordinate resolution
- reasonable chamber distorsions

100% Readout


RMS FS (μ)
P = 15 GeV
N st = 4000
(~ 1 hour)
L = 10 33 cm-2 s-1
0
5
10
15
20
25
0
100
200
300
400
500
Res z (μ)
FalSag(microns) vs Z-resolution(microns) 15GeV

10% READOUT

if z-resolution of chambers

$\sigma_z \sim 100\text{-}200\ \mu m$

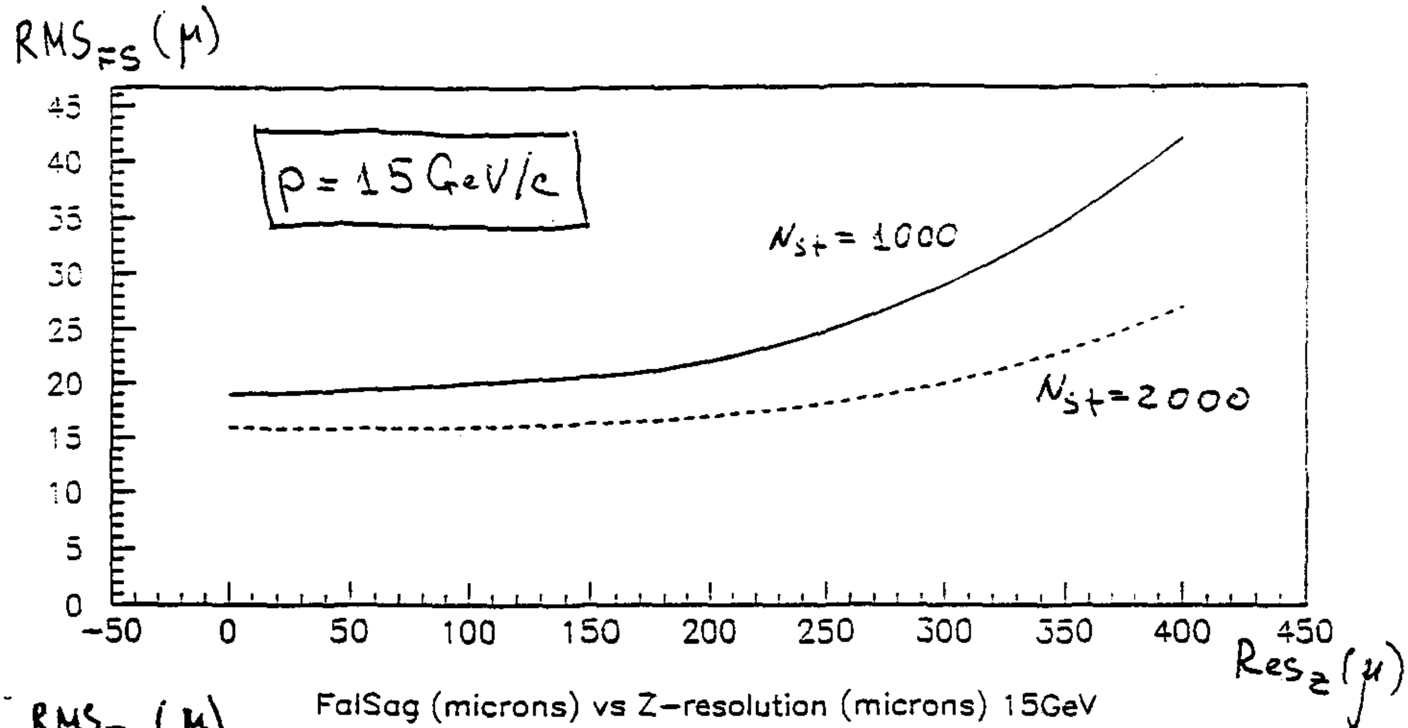
↳ 10000 particles $p > 15$ GeV → ENOUGH
(2 hour run @ 10^{33})

↳ 5000 particles $p > 25$ GeV → ENOUGH
(5 hour run @ 10^{33})

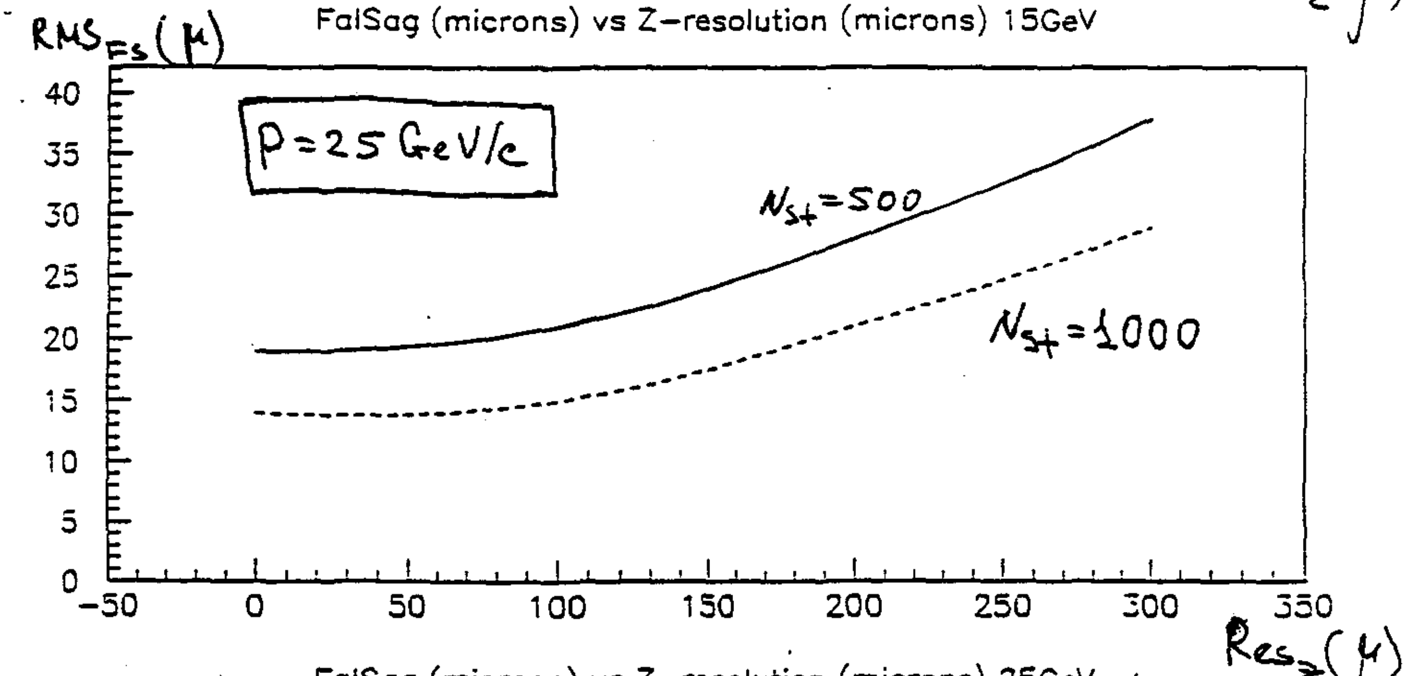
? ortogonal cathode strips ?

. . . . ?

Readout of 10% z-strips



FalSag (microns) vs Z–resolution (microns) 15GeV



FalSag (microns) vs Z–resolution (microns) 25GeV

Systematics

- non-uniform magnetic field
  GEM note TN-93-384, S. Timofeev
  ↳ BARREL: 0.23% → O'K
  ↳ ENDCAP: 10.5% → more study
  ↳ due to FFS

- Thermal expansion/contraction
  ↳ MC: $\Delta t \pm 10°C$ → O'K

- Torsion deformations:
  ↳ add $a_{21} tg^2\varphi \, tg\theta$ term to $F(\theta,\varphi)$
  $b_{12} tg\varphi \, tg^2\theta$ term to $N(\theta,\varphi)$ $a_{21} = b_{12}$
  ↳ MC: up to 3 mrad → O'K

- Non uniform anode wires ?
  ↳ more study!

- Anything else ?

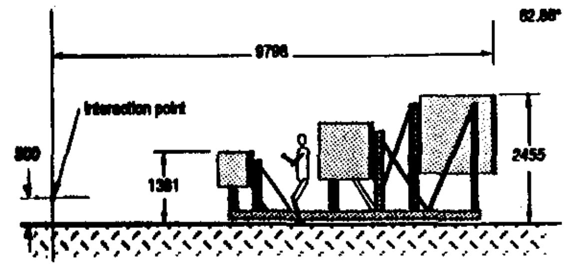
SUMMARY:

- As an alternative procedure:
  - ↳ eliminate gaps
  - ↳ reduce number of monitors
- As complementary procedure:
  - ↳ increase RELIABILITY !
- But:
  - ↳ requires several hour statistics
  - ↳ insensitive for fast change of chamber positions
  - ↳ hardware implementation?

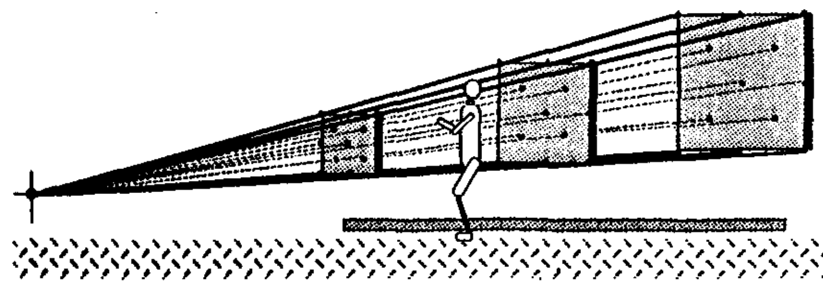
Alignment System R&D Program

Alignment Test Stand (ATS) Objectives

- Provide a "Test Bed" for proposed projective alignment hardware.
- Provide variable temperature conditions as would be seen in GEM.
- Measure the effects of air disturbances on the actual structure.
- Test actual hardware designs for chamber/structure interface.
- Develop alignment procedures, testing and certification.
- Demonstrate the physical constraints of the various alignment schemes.
- Test positioning actuators and kinematic mounting schemes.
- Test bed for using X rays for global alignment.



Mechanical Design and Fixturing



Projective Alignment Lines of Sight

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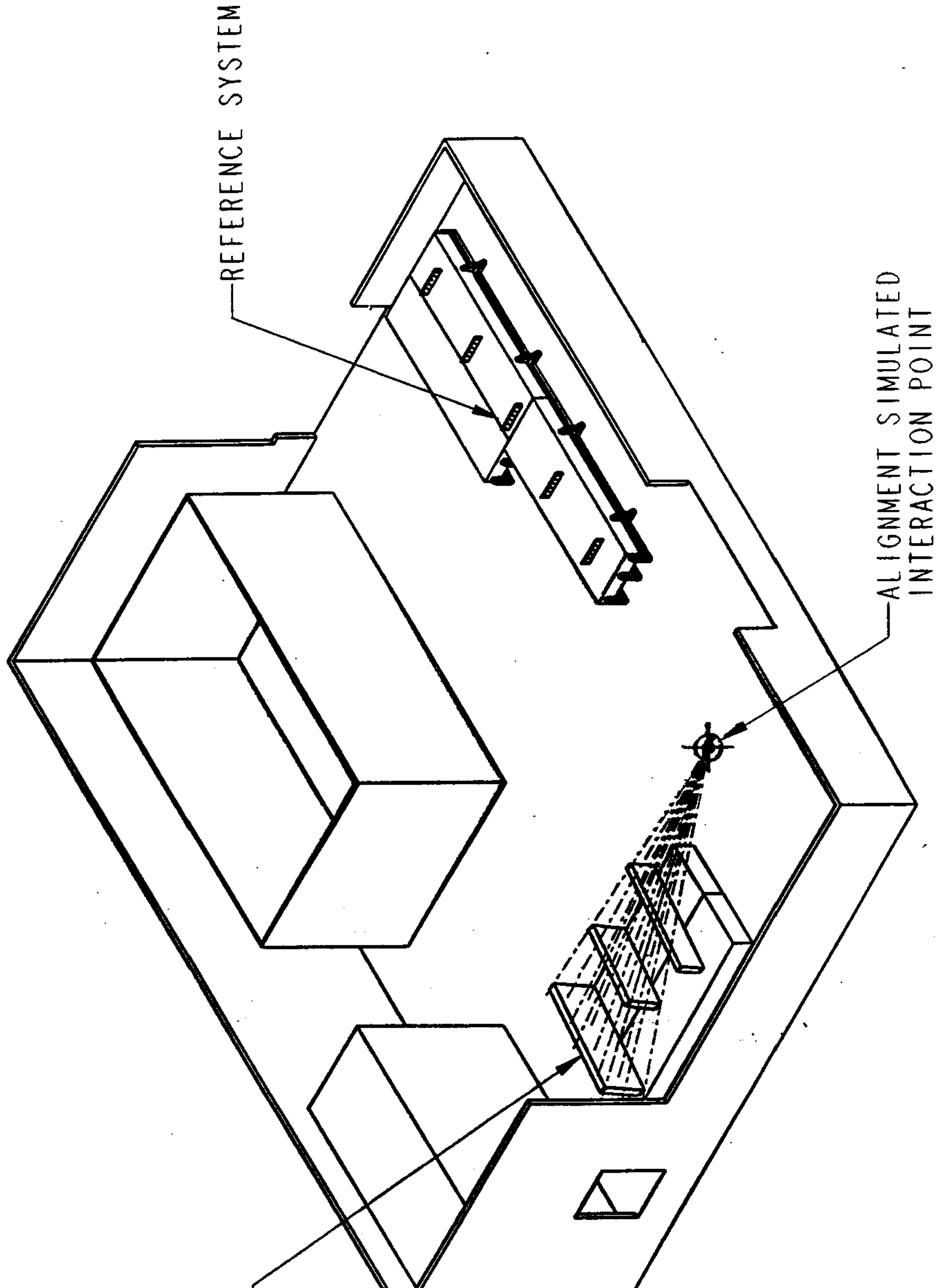
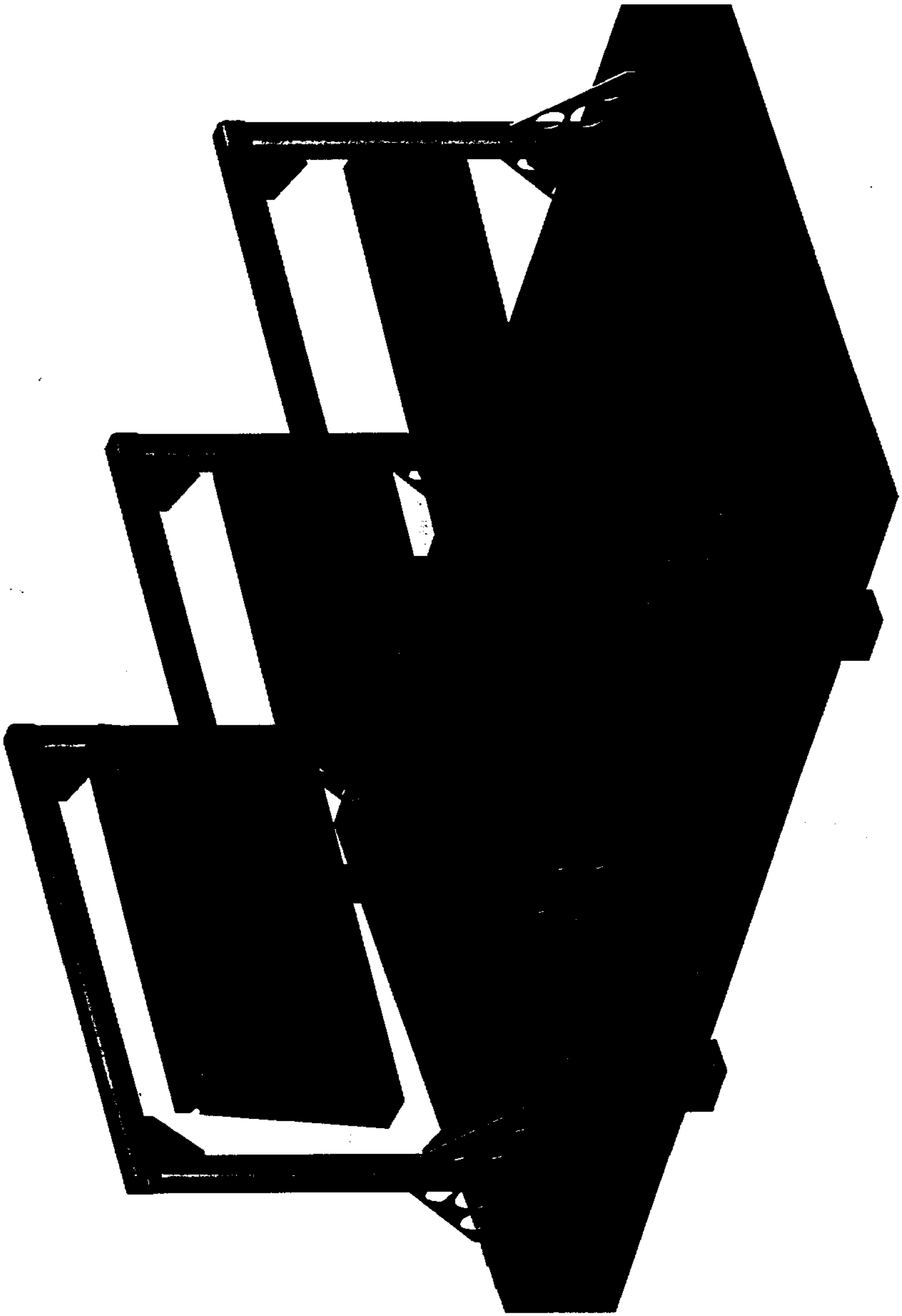
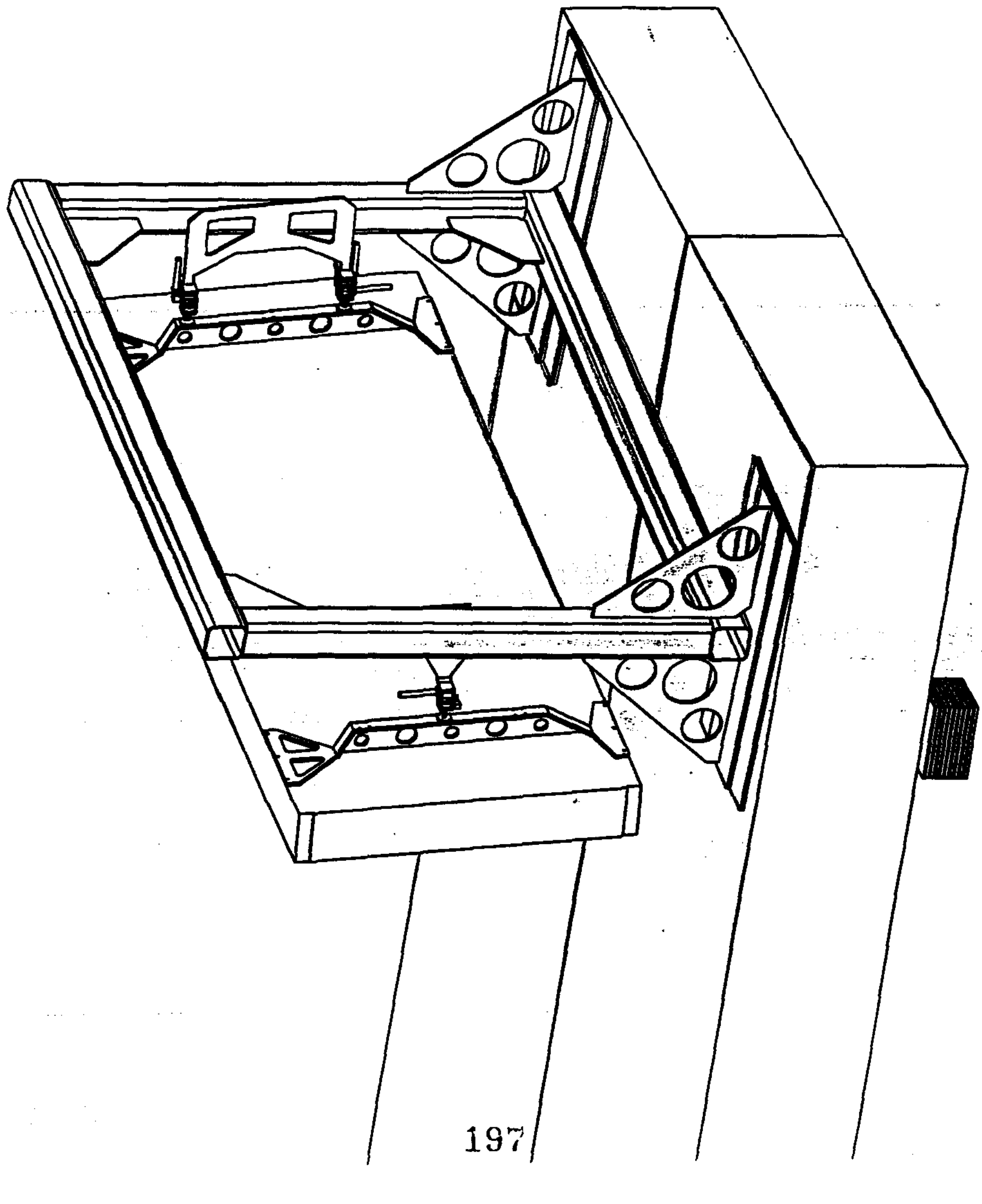
Alignment System R&D Program

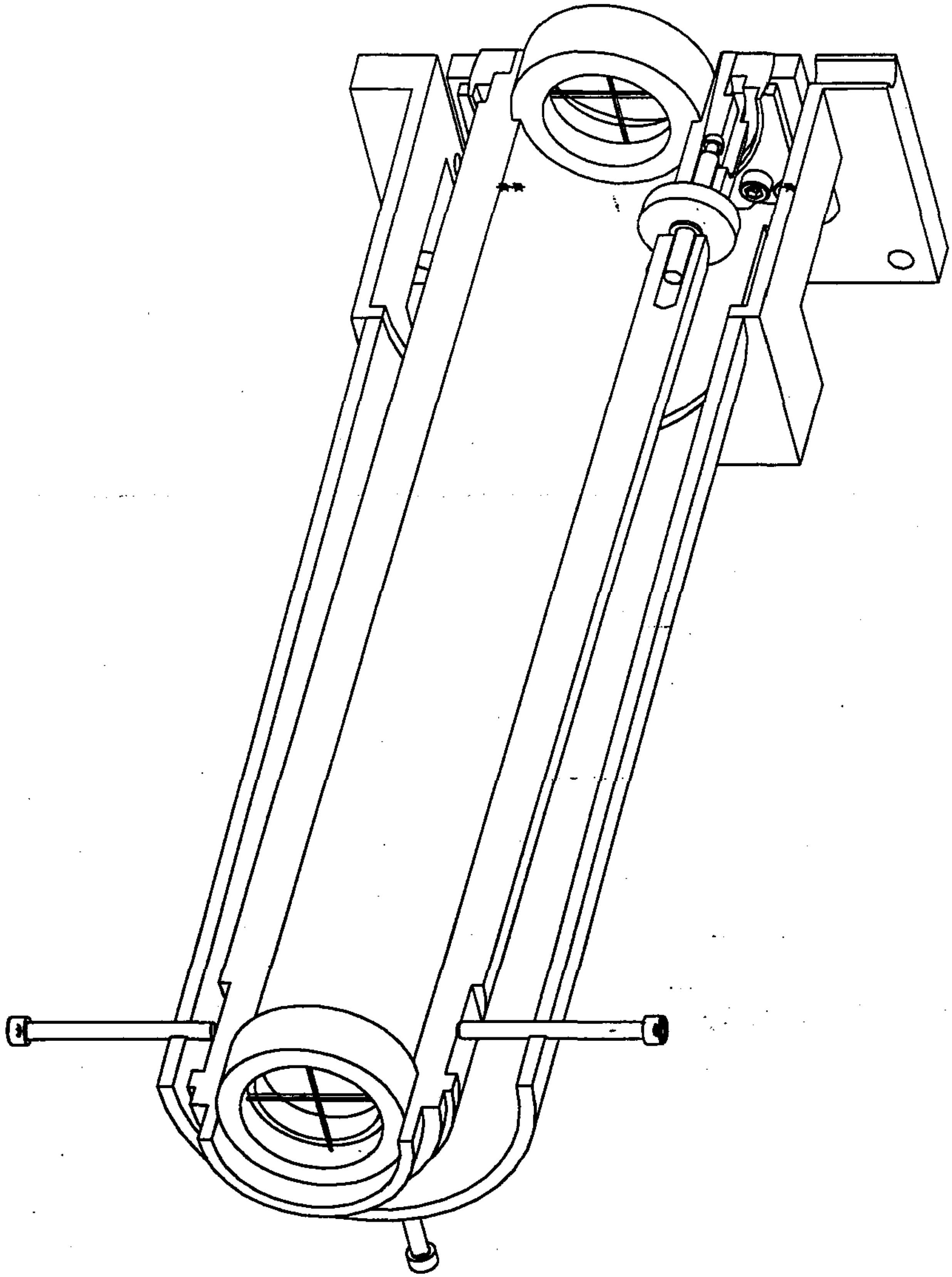
ATS Experimental Plan

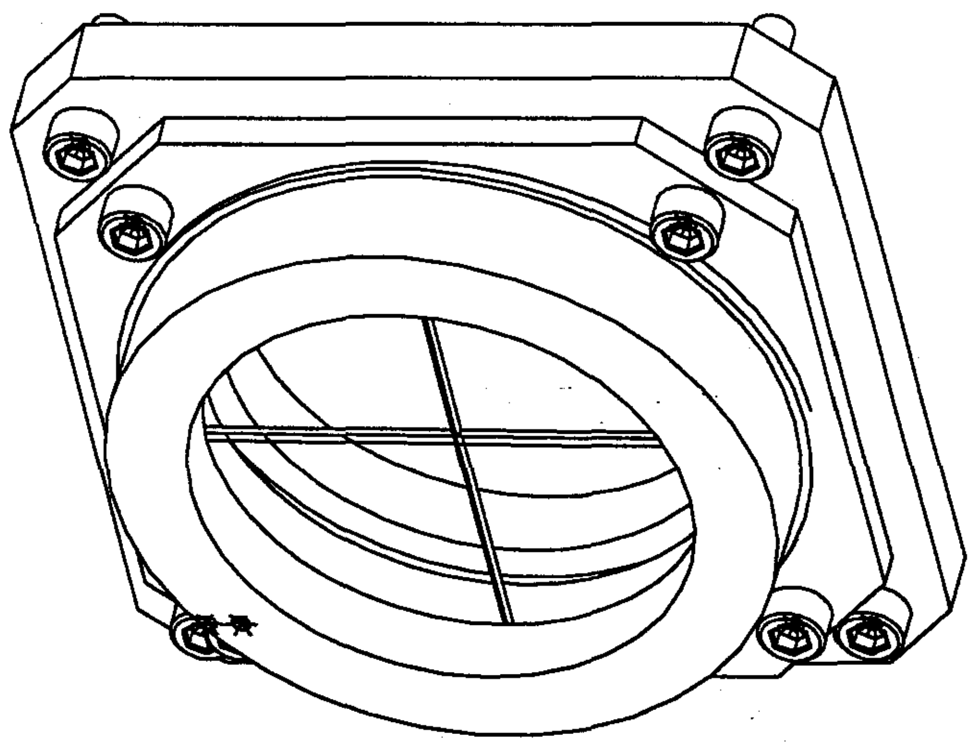
- Measure stability of alignment hardware for 3-point projective alignment scheme.
- Measure sensitivity of alignment hardware to temperature and atmospheric variations.
- Study procedures for installation of CSC mock chambers and chamber/structure interface hardware concepts.
- Study quadratic interpolation method by intentionally distorting chambers in controlled ways.
- Evaluation of remote actuator system, operation of remote position actuators and encoders, and development of alignment procedures.
- Vibration sensitivity measurement.
- Hardware optimization, including chamber interface hardware.
- Repeat tests for all straightness monitor technologies.


REFERENCE SYSTEM
ALIGNMENT SIMULATED
INTERACTION POINT
BARREL

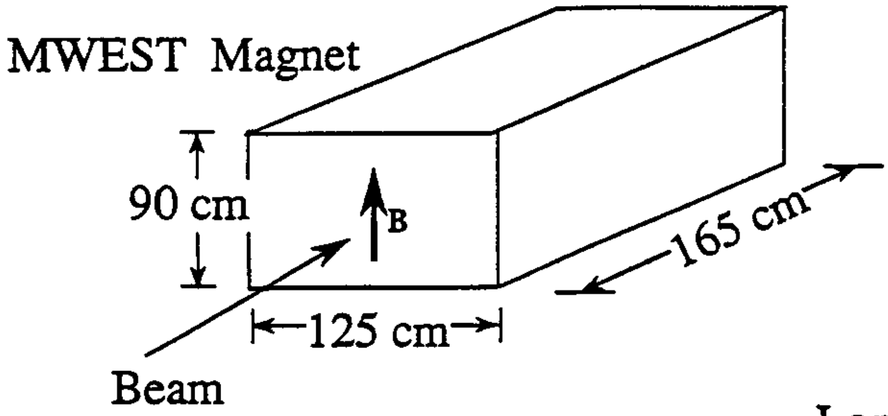






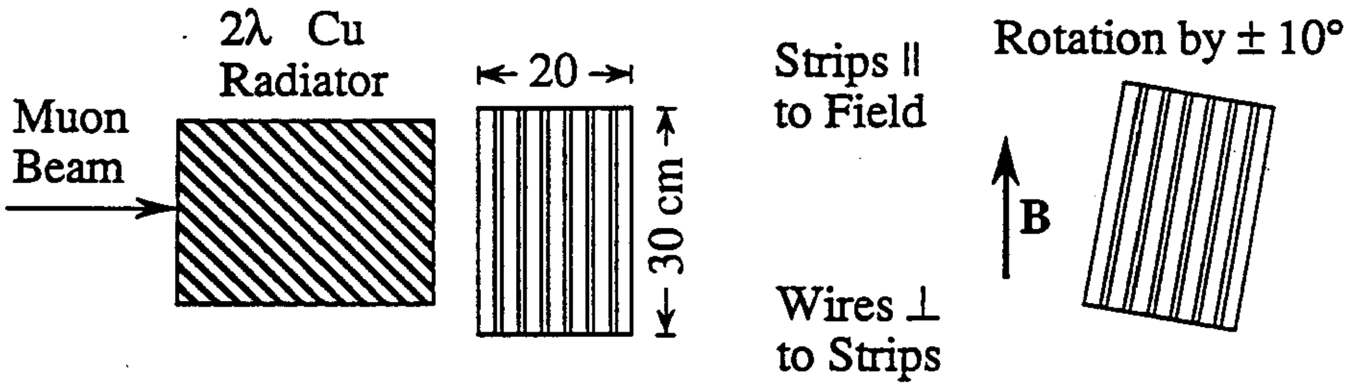


Cathode-Strip Chamber Tests
GEM Muon Detector

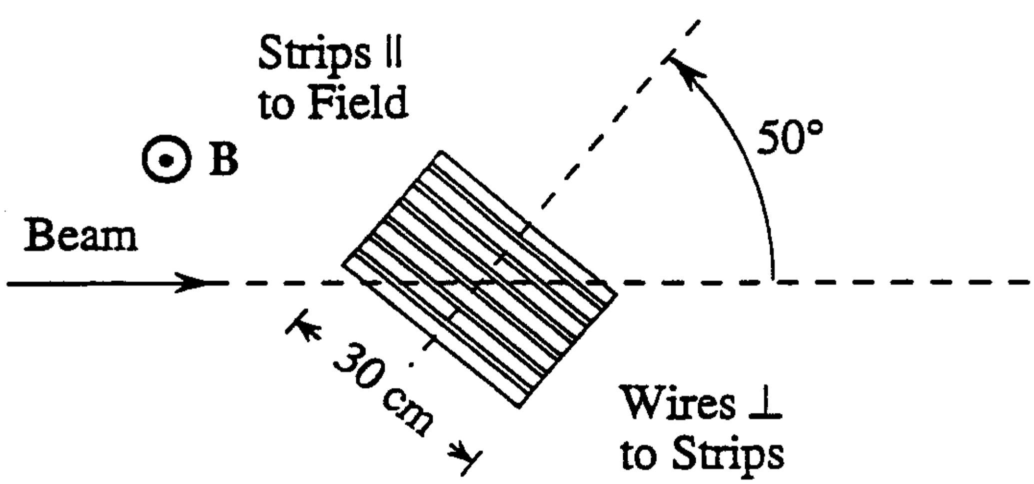


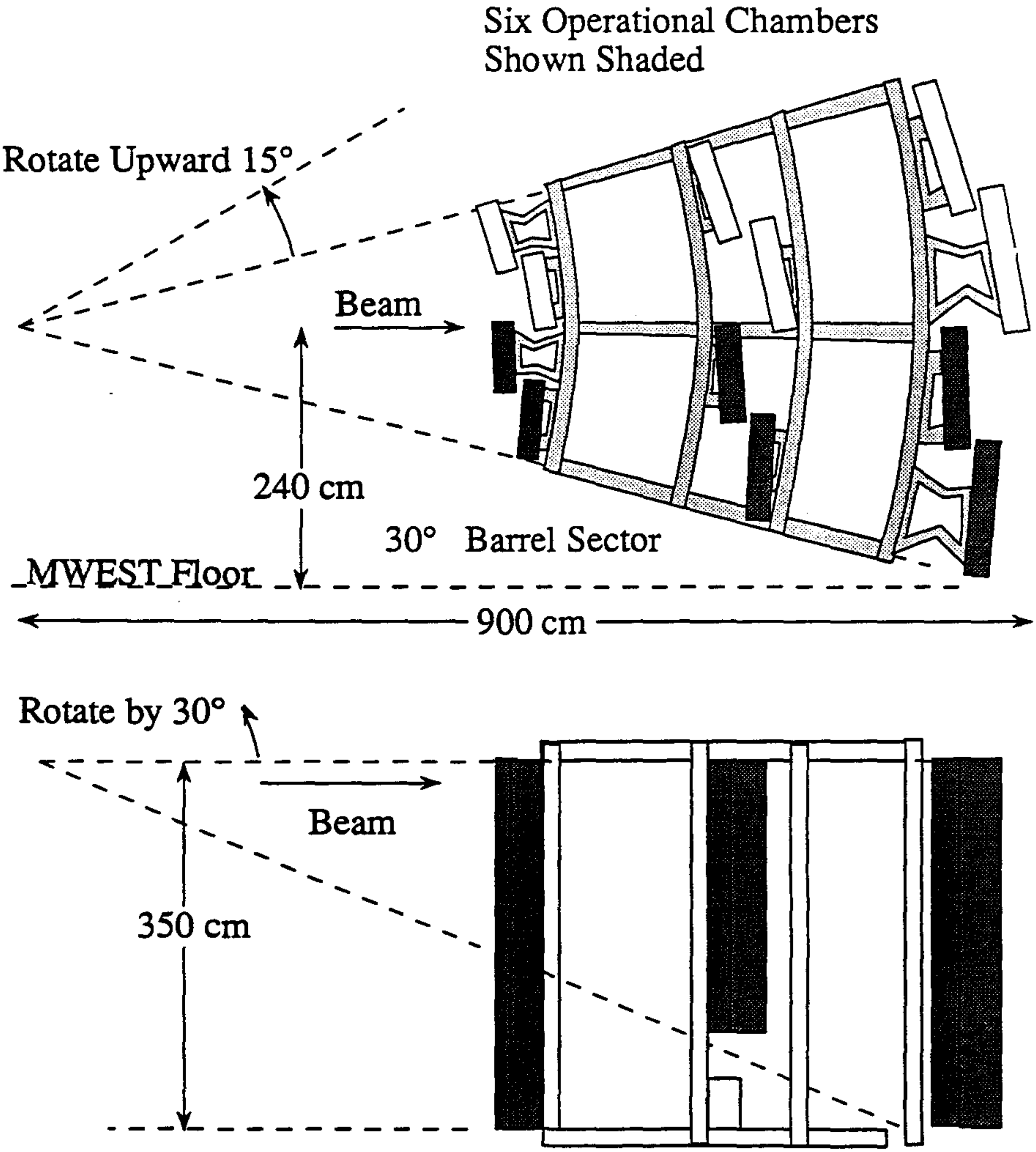
Six-Plane Chamber

Lorentz Angle and Resolution Studies



Resolution Studies from 0 to 50° Polar Angle




Six Operational Chambers
Shown Shaded
Rotate Upward 15°
Beam
240 cm
30° Barrel Sector
MWEST Floor
900 cm
Rotate by 30°
Beam
350 cm

VLADIMIR GLEBOV
SSCL, July 13, 1993

GEM Slow Control and Muon System Requirements

1. Information
2. Questions to be studied

GEM Slow Control and Monitoring System (SCMS)

GEM TDR:

"SCMS is a subsystem of the GCS to be implemented using the EPICS"

p. 8-14

EPICS - Experimental Physics and Industrial Control System

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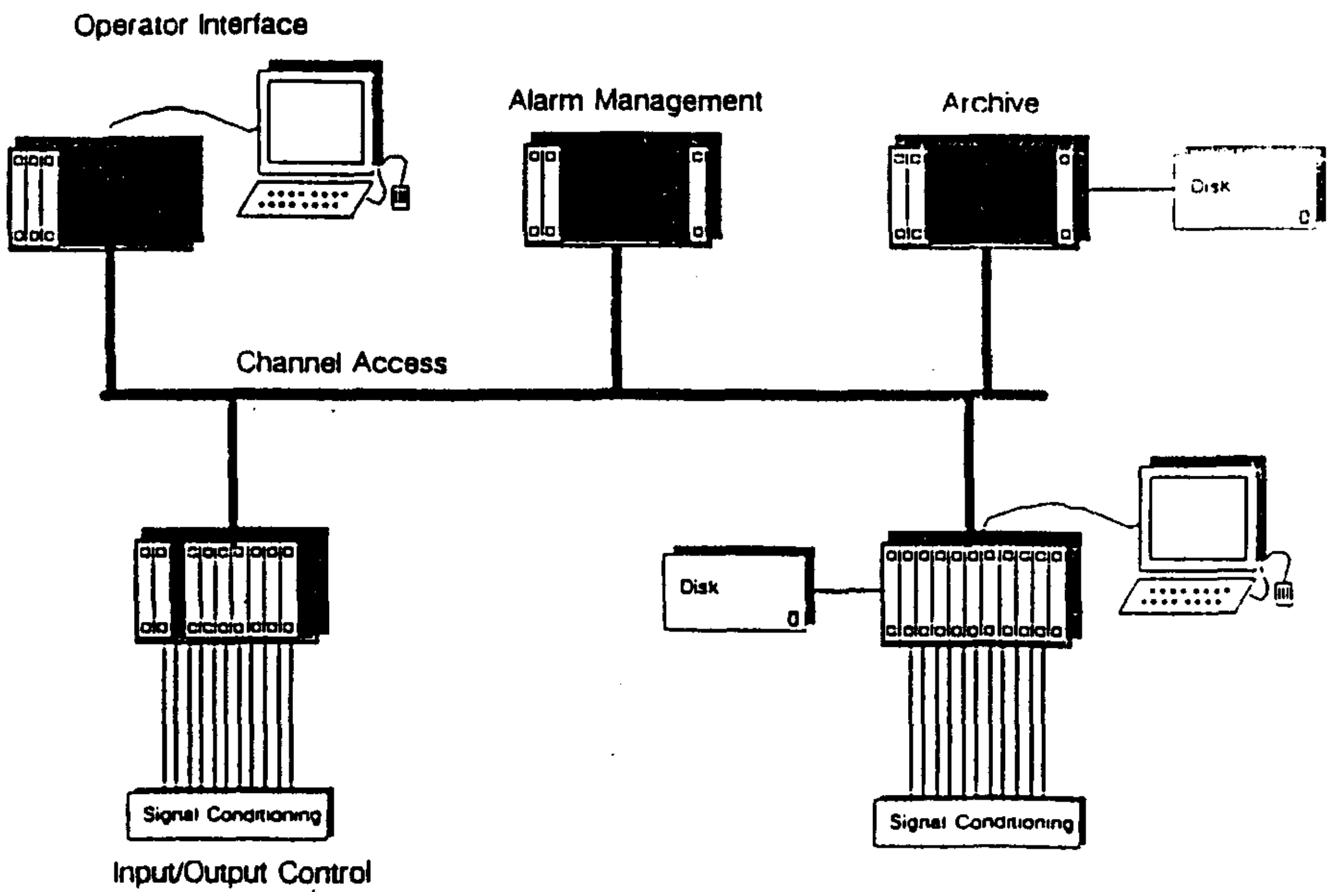
Modular Design



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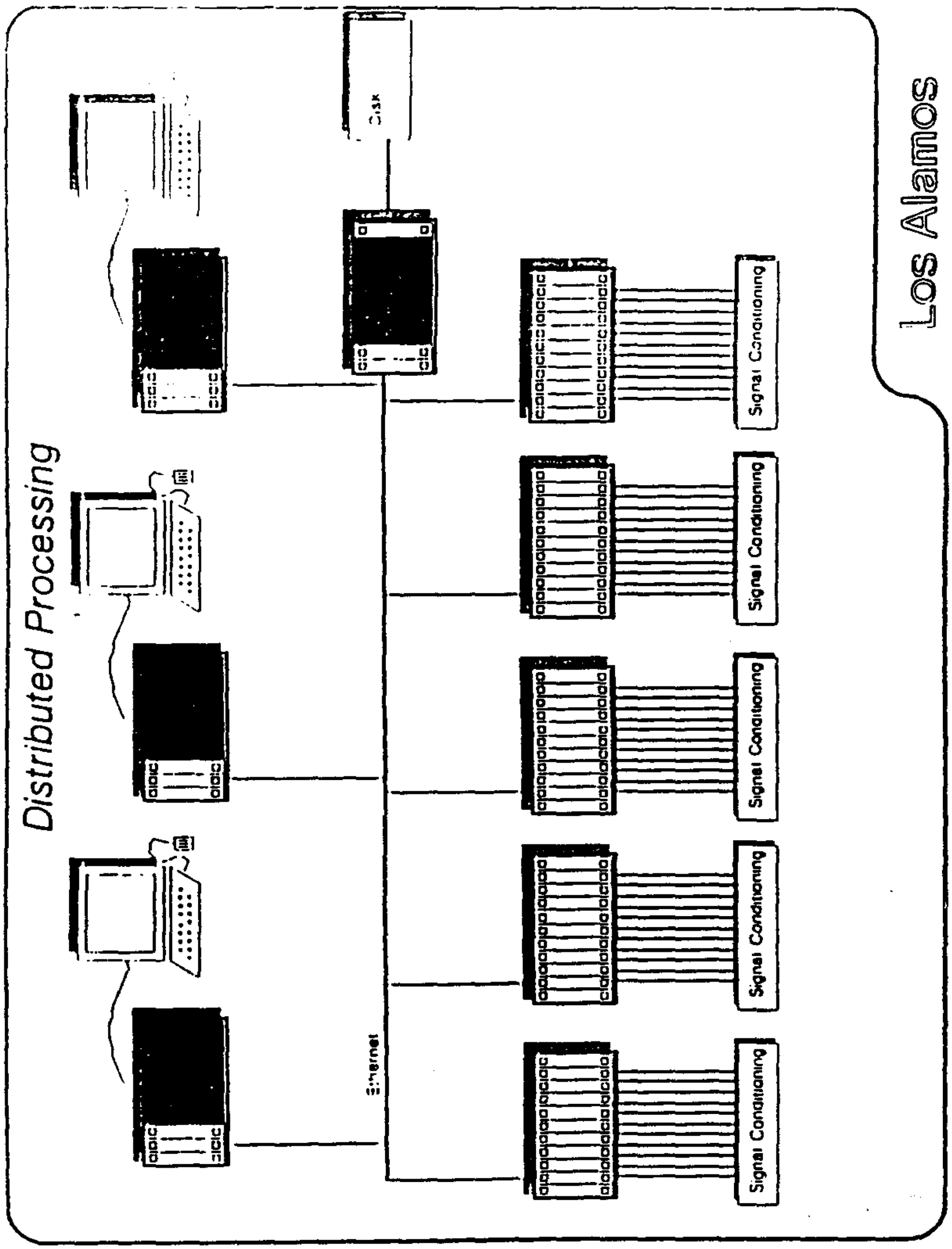
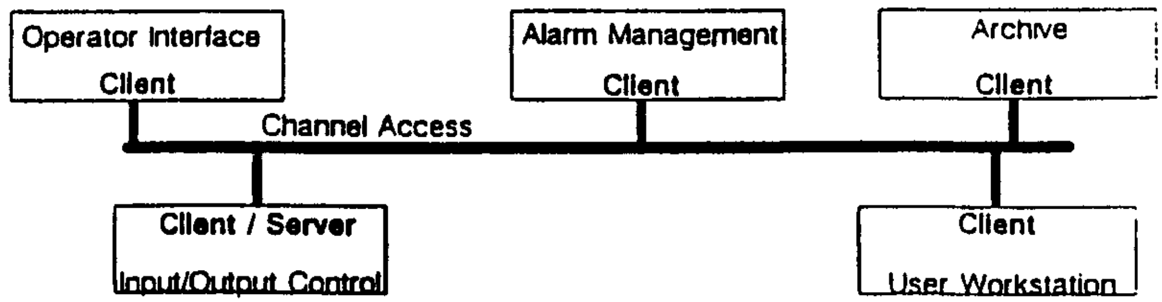

Distributed Processing
Los Alamos
Disk
Ethernet
Signal Conditioning
Signal Conditioning
Signal Conditioning
Signal Conditioning
Signal Conditioning

Channel Access



Client:

Provides read/write connections to any subsystem on the network with a channel access server.

Server:

Provides read/write connections to information in this node from anywhere on the network through the channel access client calls.

Platforms:

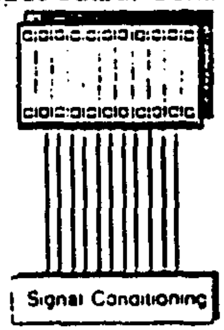
VxWorks - "C" interface
VMS - "C" and FORTRAN interface
UNIX - "C" and FORTRAN interface

Services Provided:

Dynamic Channel Location
Get (Correlated.Asyncnronous)
Put
Monitor (Correlated.Asynchronous)
Connection Monitoring
Automatic Reconnect
Data Conversions to Client Types
Network Transparency
Operating System Independence

Input/Output Controller

Input/Output Control



Hardware Components:
- 68020 Processor Board
- Ethernet Connection Board
- Input/Output Modules
- I/O Communication Modules

Acquired Software:
- VxWorks Operating System

Developed Software:
- Interactive Database Configuration Tool
- Database Access
- Database Scan Tasks
- Input/Output Drivers

Record Types Supported:
- Analog Input / Output
- Waveforms, Data Compression
- Discrete Input / Output
- Motors
- Timing
- Calculations, PID, Signal Select, Subroutine

I/O Bus Support
- VME
- VXI
- Allen-Bradley Serial Bus
- GPIB
- Bit-Bus
- CAMAC

Los Alamos

Operator Interface

Operator Interface

Operator Interface

Hardware Components:

SPARC Processor Board
Ethernet Connection Board
Graphic Generator Board
19" High Resolution Monitor
Keyboard
Mouse

Acquired Software:

UNIX Operating System
X Server
X Client
X Window manager

Developed Software:

Interactive Display Editor
Run-Time Display Generator
Channel Access

Graphical Elements:

Line. Arc. Oval. Rectangle
Monitors: Text. Indicator. Meter. Bar
Controllers: Text. Button. Slider
Plots: Stripchart. Value vs. Value. Waveform
Related Display Callup

Los Alamos

Archiver

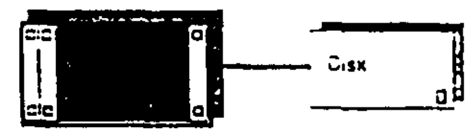
Hardware Components:
Sparc Processor Board
Ethernet Connection Board
SCSI Disk Interface
High Speed/High Density Disk

Acquired Software:
UNIX Operating System
SCSI Driver
Network File System

Developed Software:
Archive Configuration Tool
Archive User Interface
Run-Time Data Archiver

Data Collection
On Change
On Demand
Periodic
Timed
Triggered by Event
Pre-determined Disk Allocation
No Per Channel Quoatas

Data Analysis:
Data Correlation
Viewing Historic Data through Time
Plots (Time.yy) (x.yy) : (line)(mark)(point)
Fast Data Access
Spread Sheet Report Format
Encapsulated Postscript Plot Format



Los Alamos

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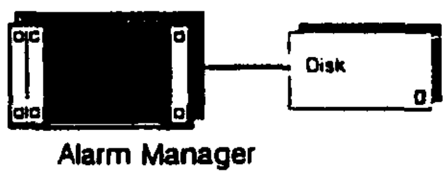
Alarm Manager

Plots (Time,yy) (x,yy) : (line)(mark)(point)
Fast Data Access
Spread Sheet Report Format
Encapsulated Postscript Plot Format

Los Alamos

Alarm Manager



Hardware Components:
- Sparc
- Ethernet Connection Board
- SCSI Disk Interface
- High Speed/High Density Disk

Acquired Software:
- UNIX Operating System
- SCSI Driver

Developed Software:
- Alarm Configuration Tool
- Alarm Access Routines
- Run-Time Alarm Manager

Alarm Monitoring
- Fault Tree Defintion
- Fault Tree Descent
- Fault Tree Status
- Alarm Annunciation
- Alarm Acknowledgement
- Alarm Log File
- Alarm Logger (Scroll Window)
- Disable Sub-trees
- Actions Configurable by Sub-tree

Los Alamos

EPICS status at the SSCL

1. 30 people at Accelerator Division
2. M. Botlo group (LEB)
3. Several people at SDC
4. GEM will have EPICS system soon (~ 2 weeks ???)

EPICS at TTR

V. Glebov

A. Morelos

G. Word

⋮

GEM Muon System

Subsystems:

- Muon chambers
- Muon alignment system
- Level 1 Muon Trigger
- High Voltage system
- Low Voltage system
- Muon gas system
- Servo-control for 3-point mounted chamber package.

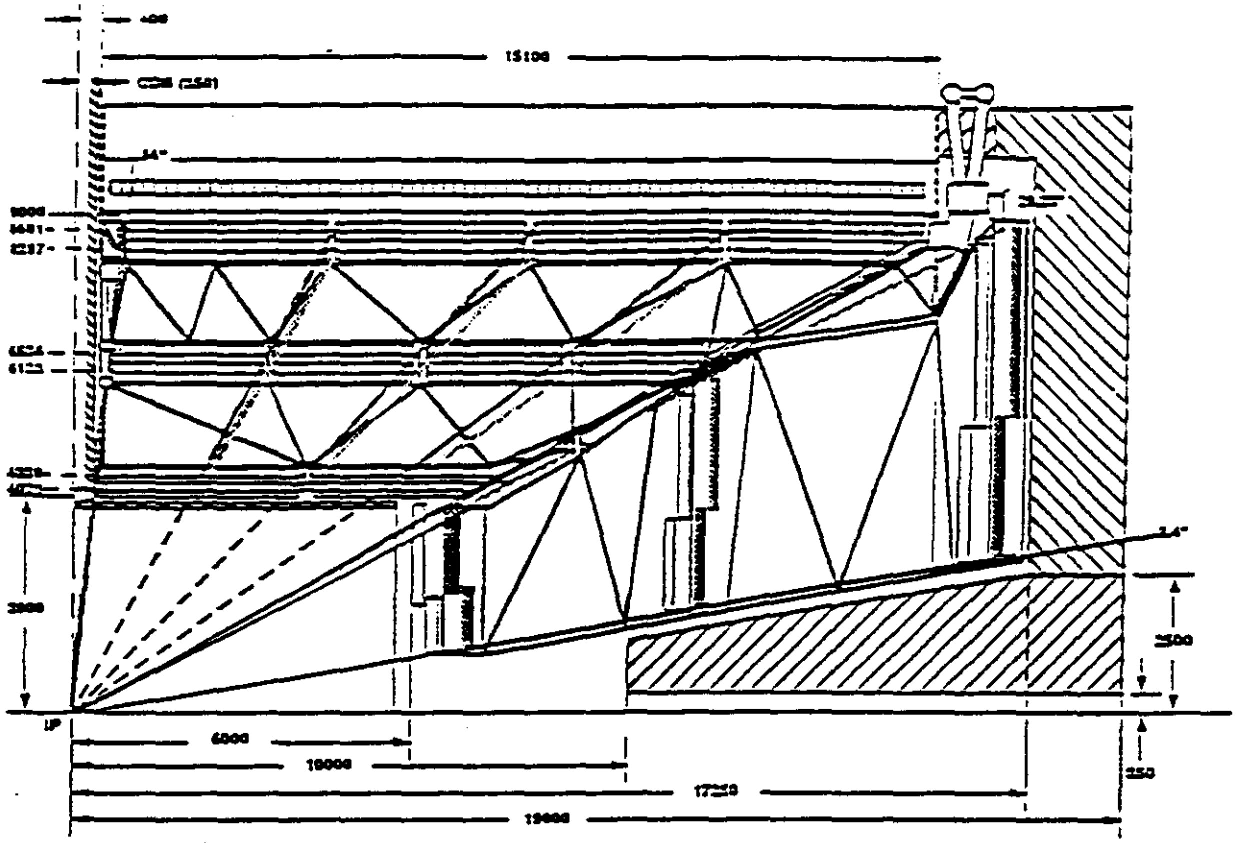


Figure 4.1.1a: Overview of GEM Muon Sytem (quadrant elevation view)

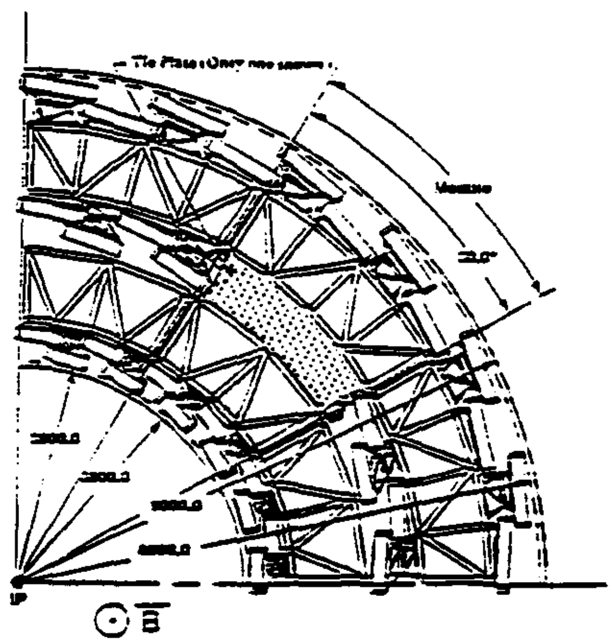


Figure 4.1b: Muon System End View (1/4 Section) View from North End of UG Hall

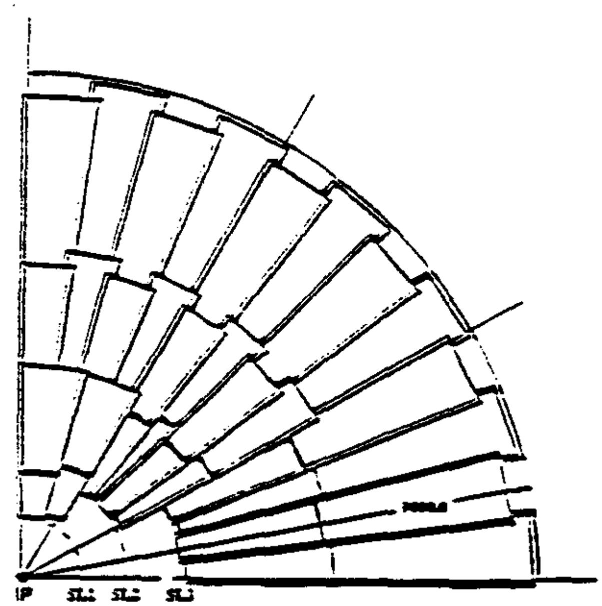


Figure 4.1c: Endcap Muon Chamber Layout (1/4 Section) View from IP

Fig. 4-1

Muon Chambers

Barrel	Endcaps	Total
960 CSC	480 CSC	1440 CSC

Muon Monitor Board on each chamber

Control:

1) Trigger condition
2) Gate width and delay
3) Threshold of the cathode amplifiers
4) Threshold of the anode amplifiers
5) Test pulse amplitude, width and delay

Monitor:

1) Voltage and current of LVPS
2) HV current in each plane of chamber
3) Gas input and output pressure
4) Gas input and output flow rate
5) Water input and output flow rate
6) Temperature on chamber, electronics and water cooling system

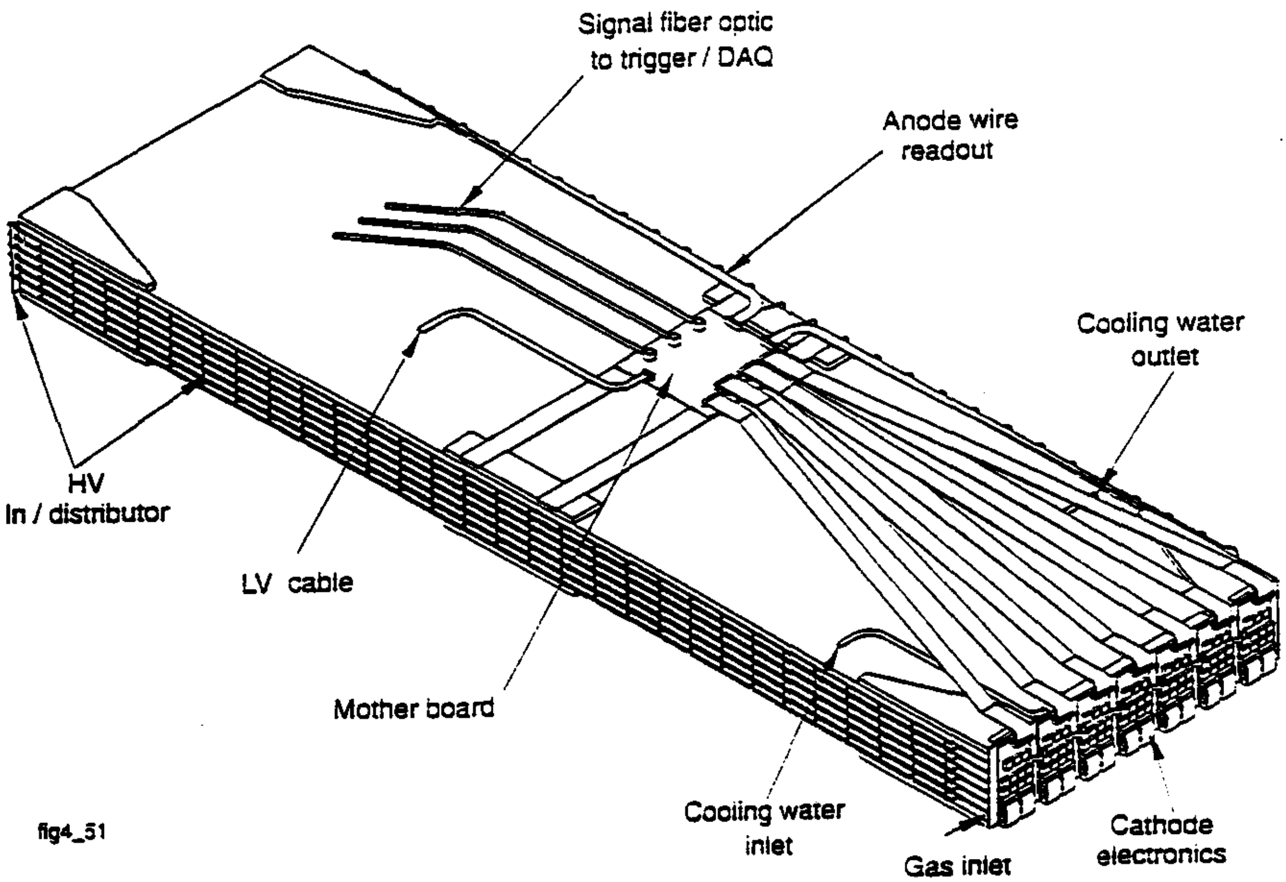

Signal fiber optic
to trigger / DAQ
Anode wire
readout
Cooling water
outlet
HV
In / distributor
LV cable
Mother board
Cooling water
inlet
Gas inlet
Cathode
electronics

fig4_51

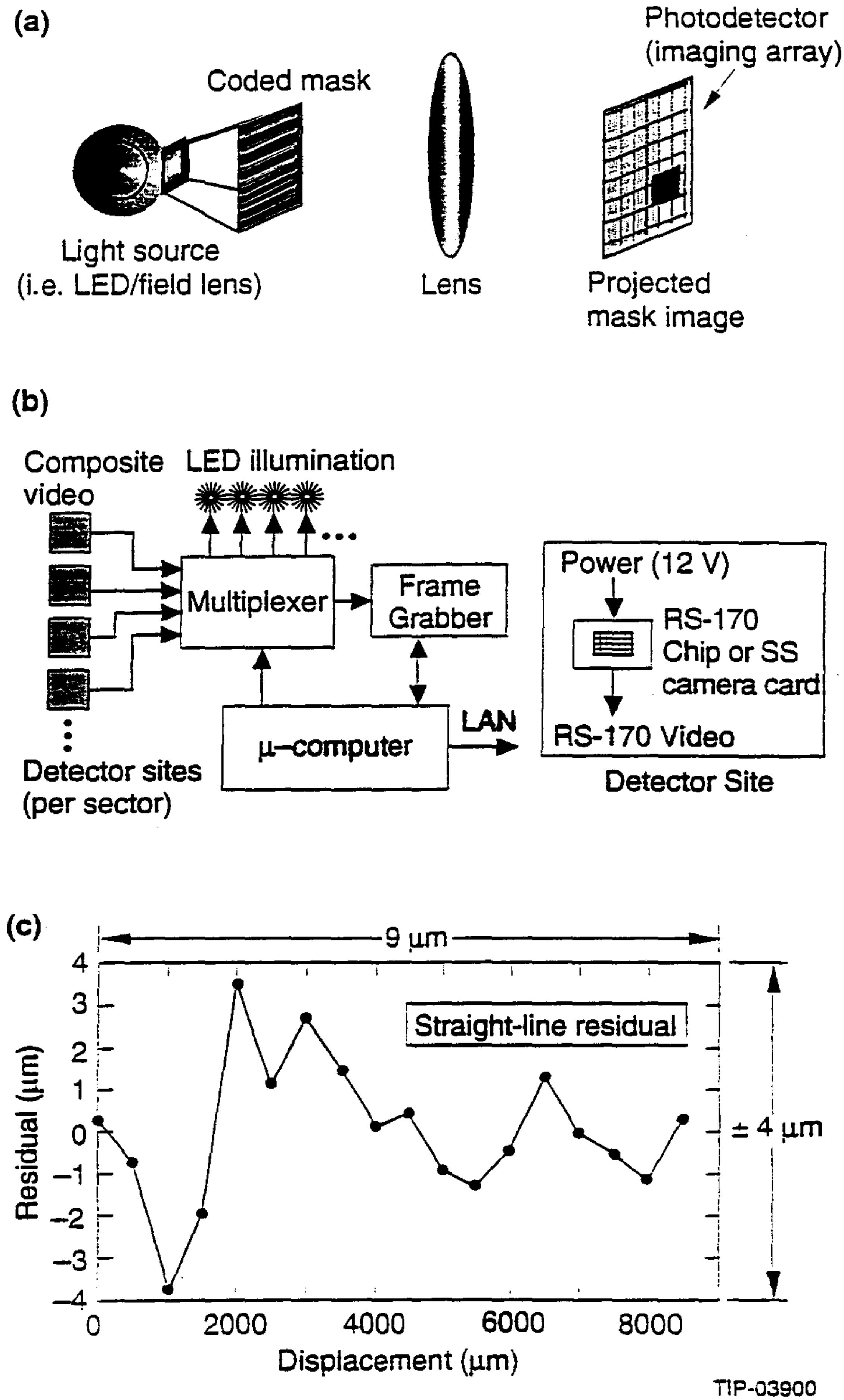
Muon Alignment System

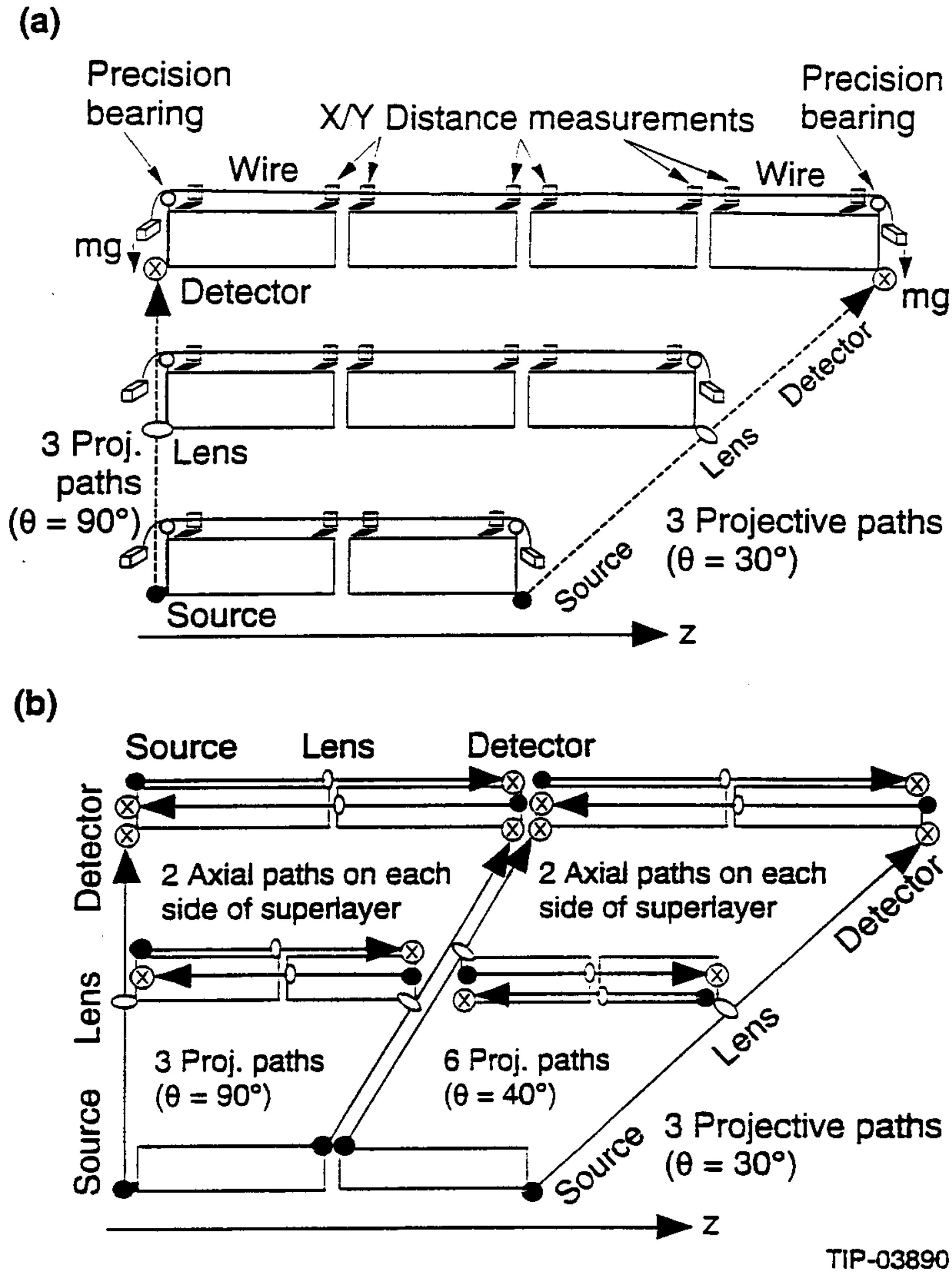
Requirement: 25 μm

Dynamically monitor the relative alignment by straightness monitor

Barrel	Endcaps
2304	960

One processor/multiplexer per $\Delta\phi = 30^\circ$ slice $\Rightarrow$ 24 DAQ Systems


(a)
Photodetector
(imaging array)
Coded mask
Light source
(i.e. LED/field lens)
Lens
Projected
mask image
(b)
Composite
video
LED illumination
Multiplexer
Frame
Grabber
Power (12 V)
RS-170
Chip or SS
camera card
μ–computer
LAN
RS-170 Video
Detector sites
(per sector)
Detector Site
(c)
9 μm
Straight-line residual
± 4 μm
Residual (μm)
Displacement (μm)
TIP-03900


(a)
Precision bearing
X/Y Distance measurements
Precision bearing
Wire
Wire
mg
Detector
mg
Detector
3 Proj. paths (θ = 90°)
Lens
Lens
3 Projective paths (θ = 30°)
Source
Source
z
(b)
Source
Lens
Detector
Detector
Lens
Source
2 Axial paths on each side of superlayer
2 Axial paths on each side of superlayer
Detector
3 Proj. paths (θ = 90°)
6 Proj. paths (θ = 40°)
Lens
Source
3 Projective paths (θ = 30°)
z
TIP-03890

Level 1 Muon Trigger

On-chamber electronics ⇒ Muon Monitor Board

Off-chamber electronics ⇒ GEM Rack Monitor

Level 1 Muon Trigger → ~ 8 crates

GEM Rack Monitor

1) Power supply voltages for each crate

2) Power supply currents for each crate

3) Temperatures of air and water

4) Water input and output flow rate

Level 1 Muon Trigger:

Downloading system

GEM High Voltage System

Single H.V. system for all of the GEM detectors

- Common Hardware
- Same Control System
- Same Control Software

DØ designed and produced such H.V. system

8 subsystems: LAr Cal., M.C., V.D., TRD ....

Current / Voltage ranges:

~100 V → 7 kV (+/-)

~10 nA → 1 mA

3650 HV channels

VME 6U crate, 48 H.V. chan./crate

68020 μProc., Full computer of set and read functions:

V_{set}, I_{oc}, V_{out}, I_{out}, V_{max}

Muon High Voltage System

1440 Chambers	8,832 Planes
⇓	⇓
1440 HV Channels	8,832 HV Channels
⇓	⇓
30 HV crates	184 HV crates

Muon HV Requirements

Superlayer :	SL1	SL2	SL3
Operating Voltage:	2.6kV	3.4kV	4.0kV
Max. Current :	$\sim 10\mu A$	$\sim 10\mu A$	$\sim 10\mu A$

GEM Low Voltage System

Single Low Voltage system for the GEM

- Common Hardware
- Same Control System
- Same Control Software

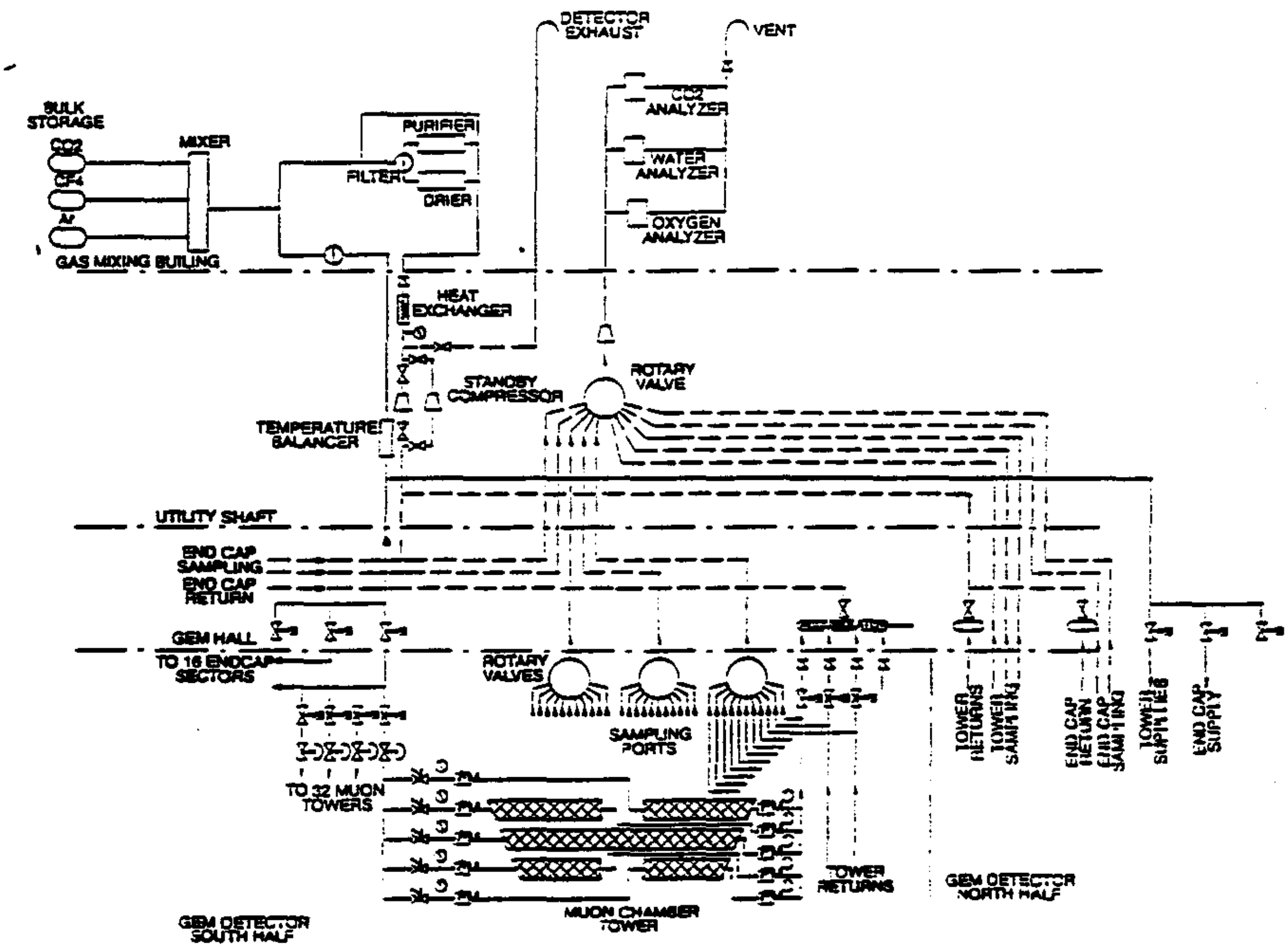
Similar to GEM Rack Monitor

1) Power supply voltages
2) Power supply currents
3) Temperatures
4) Water flow rate

Muon System:

LVPS for Muon Electronics

LVPS for Muon Alignment


DETECTOR EXHAUST
VENT
BULK STORAGE
CO2
CF4
Ar
MIXER
PURIFIER
FILTER
DRIER
CO2 ANALYZER
WATER ANALYZER
OXYGEN ANALYZER
GAS MIXING BUILING
HEAT EXCHANGER
STANDBY COMPRESSOR
ROTARY VALVE
TEMPERATURE BALANCER
UTILITY SHAFT
END CAP SAMPLING
END CAP RETURN
GEM HALL
TO 16 ENDCAP SECTORS
ROTARY VALVES
SAMPLING PORTS
TO 32 MUON TOWERS
TOWER RETURNS
TOWER SAMPLING
END CAP RETURN
END CAP SAMPLING
TOWER SUPPLIES
END CAP SUPPLY
TOWER RETURNS
GEM DETECTOR NORTH HALF
MUON CHAMBER TOWER
GEM DETECTOR SOUTH HALF

Chamber Interface Structure