GEM TN-93-381

GEM Muon Review Meeting - SSCL

March 16, 1993

Abstract:

Agenda, attendees, and presentations of the GEM Muon Review Meeting held at the SSC Laboratory on March 16, 1993.

Agenda of the 3/16/93 GEM Muon Review

Time: 10:00 AM
Place: Dir #1 SSCL

10:00 General Remarks and Charge for the Review - Gary Sanders (10 min)

10:10 Overview of the Muon System - Marx (30 min)

10:40 Mechanical layout of system and support structure - Nimblett (30 min)

11:10 Chamber Design and Performance - Whitaker (45 min)

NOON Physics Lunch Roy Schwitters on SSC Schedule - Upstairs Conference Room

1:00 Electronics and Trigger - Atiya (30 min)

1:30 Alignment - Paradiso or Wuest (30 min)

2:00 Magnet FFS and Field knowledge requirements - Sullivan (30 min)

2:30 System Performance - McNeil (45 min)

3:15 System Implementation - Johnson (30 min)

3:45 Executive Session - Reviewers and Spokesmen, PM, Chief Engineer, Taylor, Marx

GEM muon Review 3/16/93

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Mike Marx

Over View
of
Muon System

MUON TDR OUTLINE

```
1  GEM Muon System Mission
        High Precision Measurement of Muons Low --> High Pt, eta < 2.5
        Robust, High Luminosity, Independent of tracker
        Provide trigger and Bunch Tag
   -->  Broad Range of Accessible Physics and Discovery Potential

2  GEM Muon System Description/Realization
        Measure Sagitta in Air behind Calorimeter
```

Press RETURN for more...

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```
    #4          22-JAN-1993 15:07:51.41                                TDRTXT
        Magnetic Field Shape
        Tracker Contribution at low and High Pt
        Calorimeter Contribution
        Description of Muon Detectors
                Chambers in 3 Superlayers
                        Precision, Number
                        Alignment, Positioning, Stability
                        Sectors, Global Alignment
                        Support Structure
                Non Bend Coordinate
                Trigger Elements
                Bunch Timing
        Upgrade Options
                External Chambers, FFS Augmentation, Vertex

3 System Element Description
        A Chambers
                Principle, Resolution (x,t)
                Parameters, Operation, Performance
```

Press RETURN for more...

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```
    #4          22-JAN-1993 15:07:51.41                                TDRTXT
                Technical Details
                Alignment Transfer
                Production, QC, Test
        B Electronics/Trigger/Timing/Readout..
        C Support Structure
                Design Details
                Performance/ Stability
                Sector Alignment
                Global Alignment
        D Magnet/FFS/Field

4 System Performance
        A Environment - Charged,neutrons,gammas,..
        B Rates and Occupancy
```

C Trigger Rates/Efficiency/False Triggers
D Resolution (including tracker,calorimeter and upgrade options)
E Pattern recognition
F Benchmark Process Performance (ZZ*,Z',High Pt top.....

Press RETURN for more...

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#4 22-JAN-1993 15:07:51.41 TDRTXT
5 System Implementation
A Chamber Production/Delivery/Test
B Support Structure Fabrication/Assembly
C Chamber Installation/Alignment/Commissioning
D Services (Gas,Power,Cooling....)
E Big Wheel Installation/Alignment/Commissioning

Status of the Muon TDR chapter 03/16/93 20:30

Section	Editor	Text	Fig. Capt.	Figures	References
4.1	M.Marx	Second Draft	Complete	Complete	Complete
4.2	F.Taylor/M.Marx	Second Draft	First Draft	4/4	First Draft
4.3.1.	S.Whitaker	First Draft	First Draft	22/24	First Draft
4.3.2.	M.Atiya	Second Draft	Second Draft	8/8	Not ready
4.3.3.	F.Nimblett	First Draft	First Draft	0/???	Not ready
4.3.4.	J.Paradiso	Second Draft	Second Draft	18/18	Second Draft
4.3.5.	L.Rosenson	First Draft	Not ready	0/???	First Draft
4.4.	R.McNeil	Second Draft (unfinished)	First Draft	13/20	First Draft
4.5.	C.Johnson	First Draft	First Draft	7/7	First Draft
4.6	H.Baker	First Draft			
4.7	R.Gustavson	First Draft			

P.S. Numbers 5/19 for Figures mean that 5 Figures from 19 are ready.

M. Mark
3/16/93

GEM MUON SYSTEM

- High Precision 500 GeV/c p_T — 5% @ $\eta \sim 0$, 12% @ $\eta \sim 2.5$

- Robust → High $\mathcal{L}$

  Does not <u>rely</u> on central tracker

  Can use <u>vertex</u> for robustness improvements

- Measure in <u>air</u> (good for low p_T)

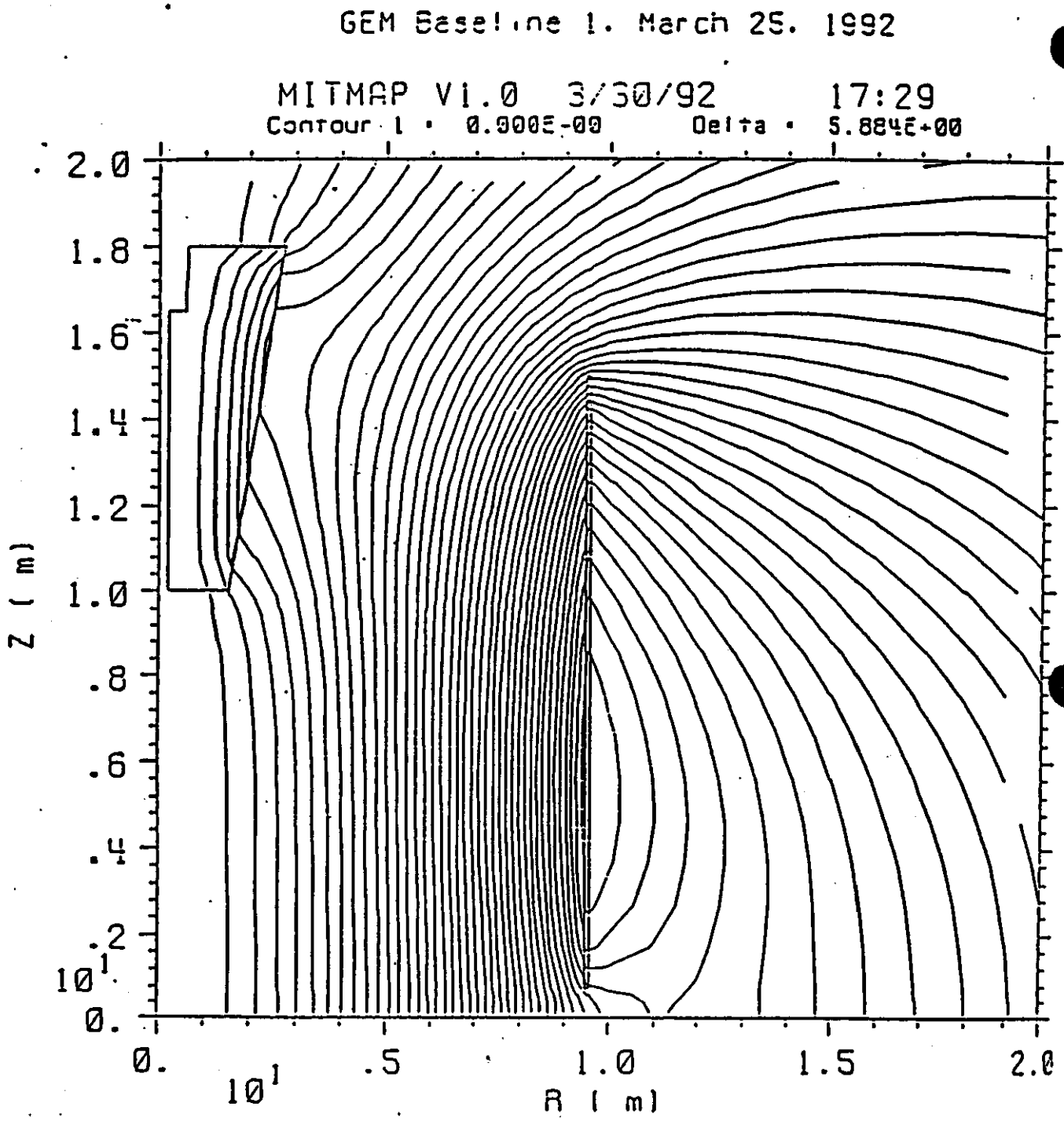
- Behind calorimeter (bad for low p_T)
  → shielded

MUON SYSTEM PROVIDES

- IDENTIFICATION
  (calorimeter)
- TRIGGER
  ($\Delta\phi$ or sagitta)
- TIMING + BEAM CROSSING TAG
- MOMENTUM RECONSTRUCTION
  500 GeV P_T 5% @ $\eta \sim 0$
  12% @ $\eta \sim 2.5$

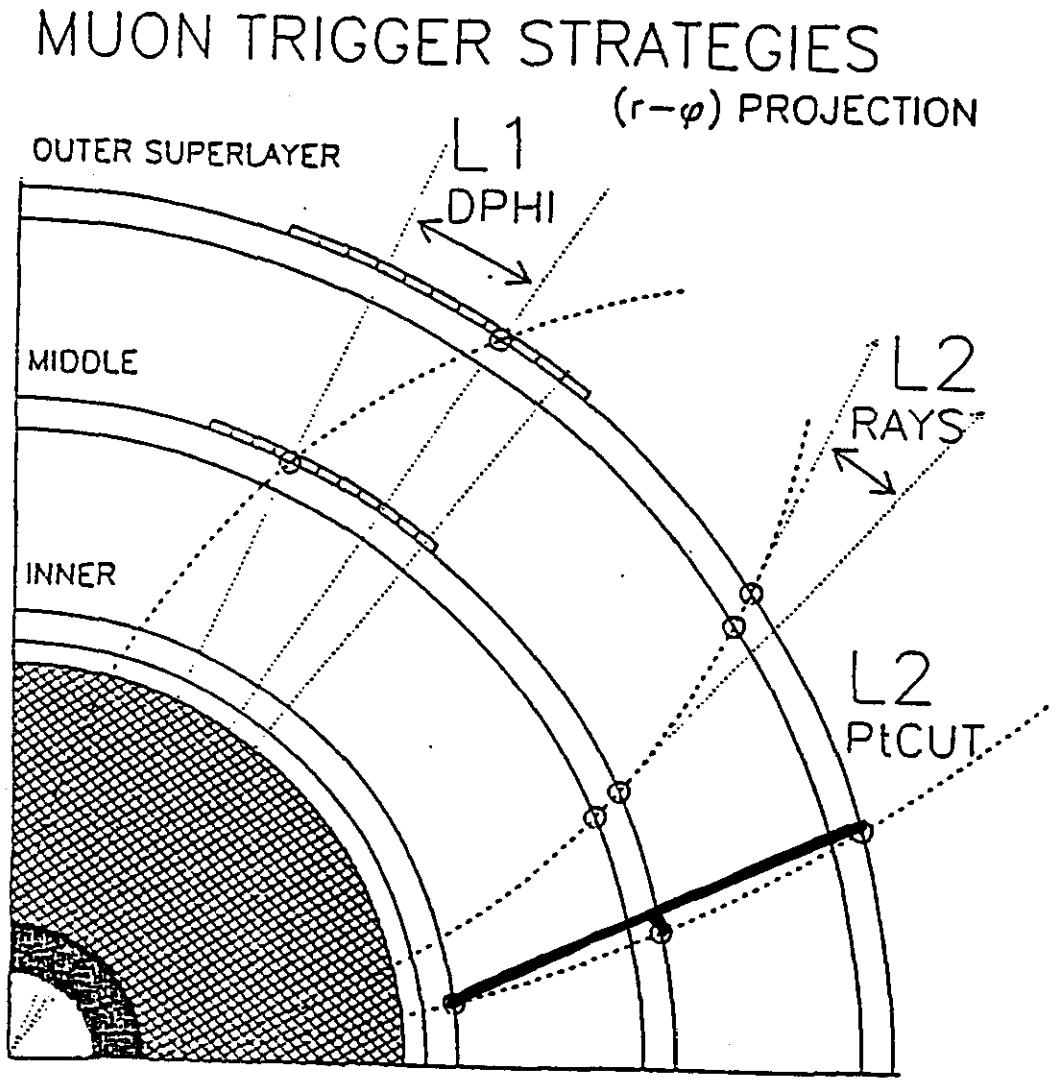
  GOOD COVERAGE $0 < \eta < 2.5$
  $\Delta\eta$ loss $\sim .4$

  GOOD EFFICIENCY
  Require 3/6 planes
  - E.M.
  - neutrons/photons



CONTOURS OF CONSTANT FLUX

Figure 1: Lines of constant magnetic flux in a meridional half-plane; the figure is rotationally symmetric about the horizontal axis and has mirror symmetry about $Z = 0$. Note: the beam axis, Z, is vertical while the transverse axis, R is horizontal. Both axes extend from 0 to 20 m and the field is in gauss. A sketch of the superconducting winding and the forward field shaper is also shown.



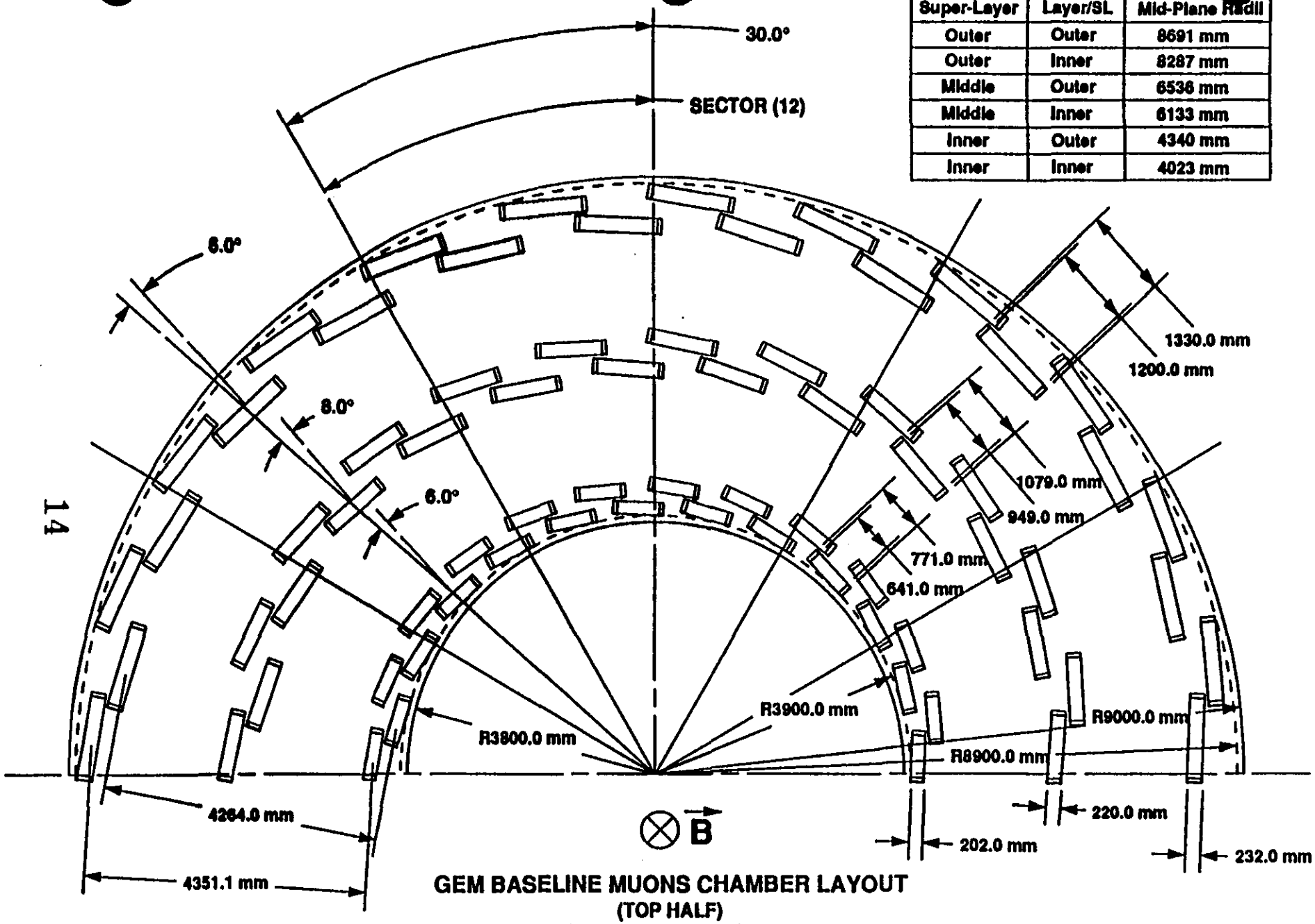
Measure sagitta

Fig. 5.1

$$s = \frac{.3BL^2}{8p_t}$$ 1.5mm @ 500 GeV

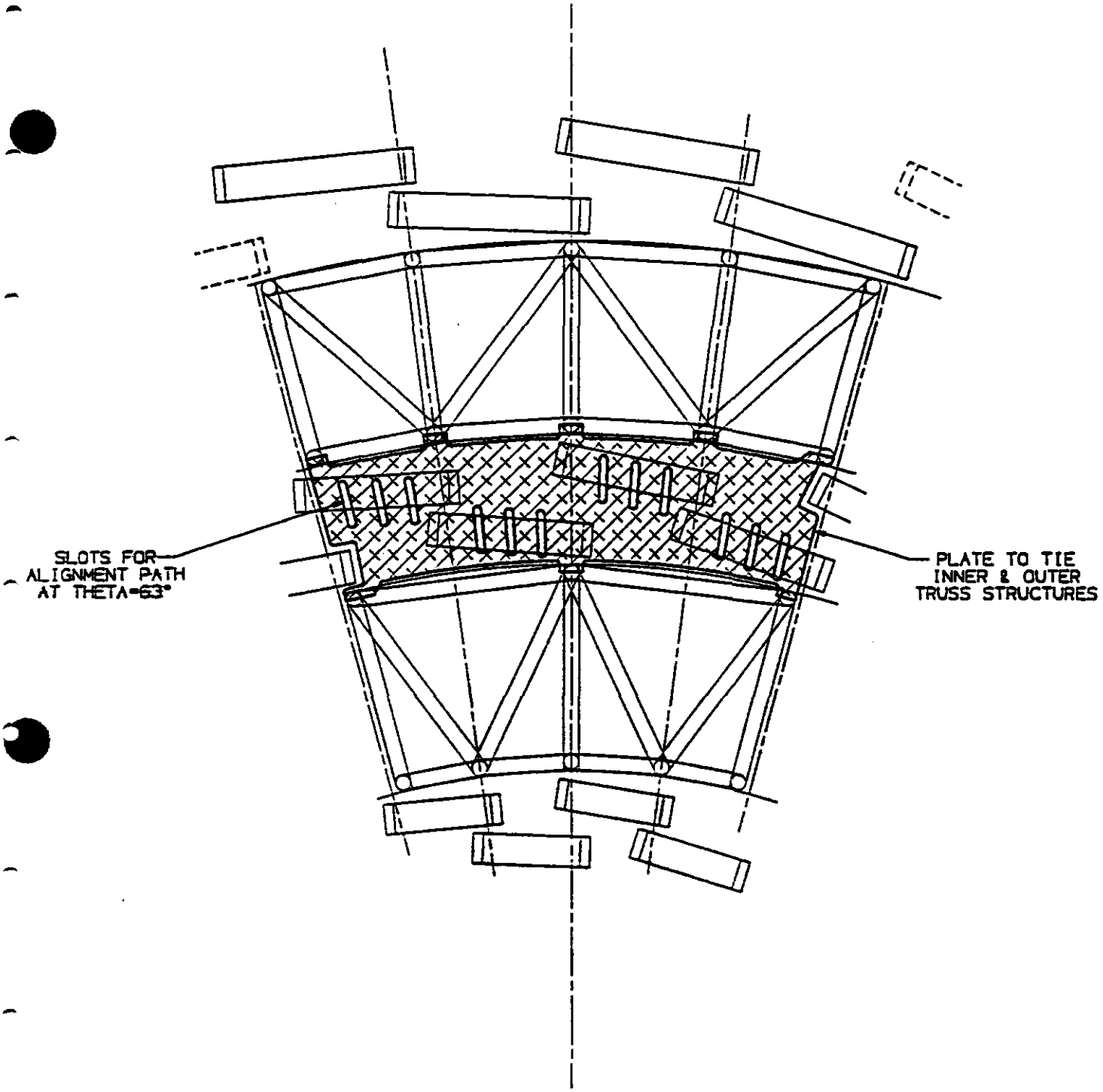
$\Delta s < 75\mu m$

Super-Layer	Layer/SL	Mid-Plane Radii
Outer	Outer	8691 mm
Outer	Inner	8287 mm
Middle	Outer	6536 mm
Middle	Inner	6133 mm
Inner	Outer	4340 mm
Inner	Inner	4023 mm

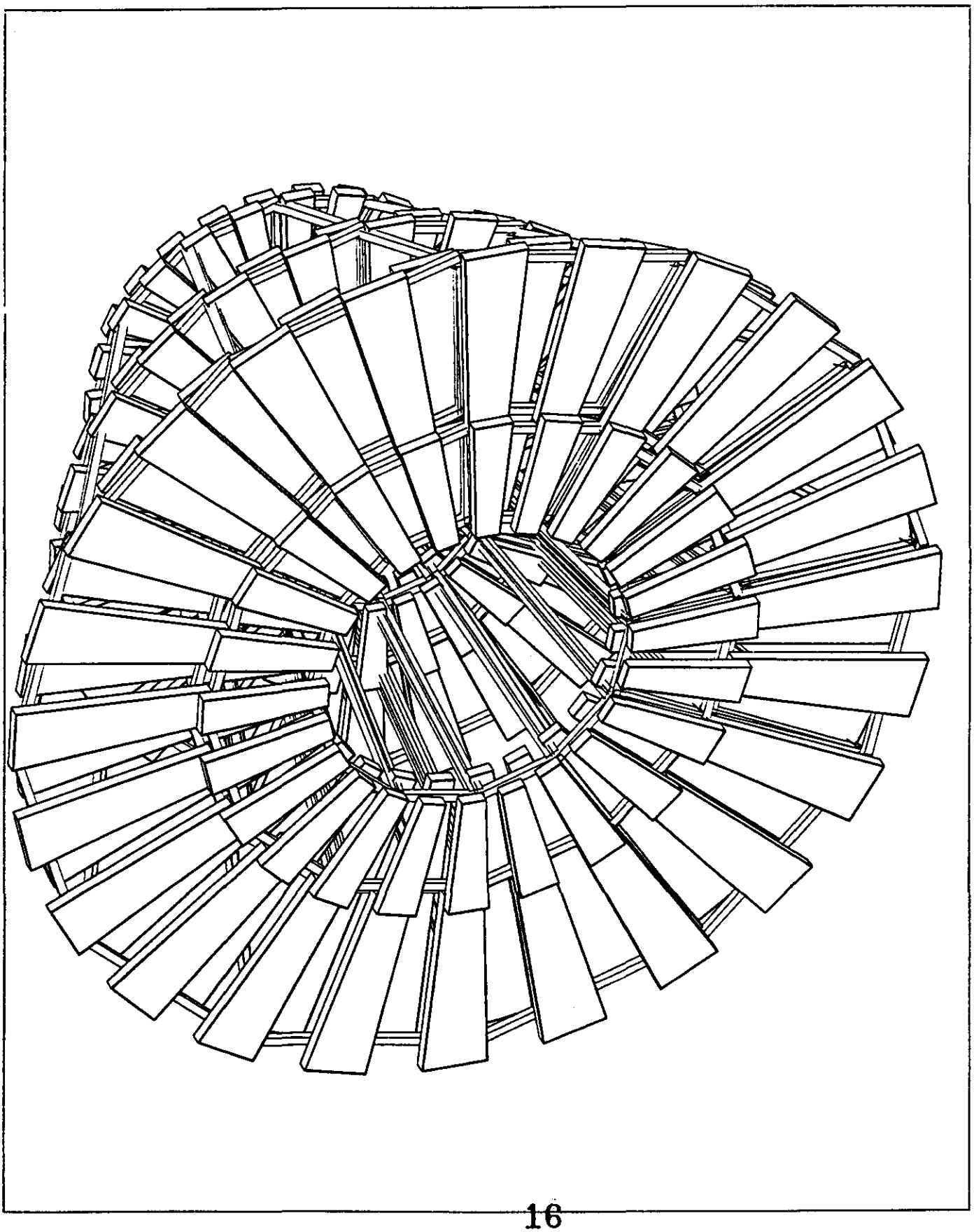


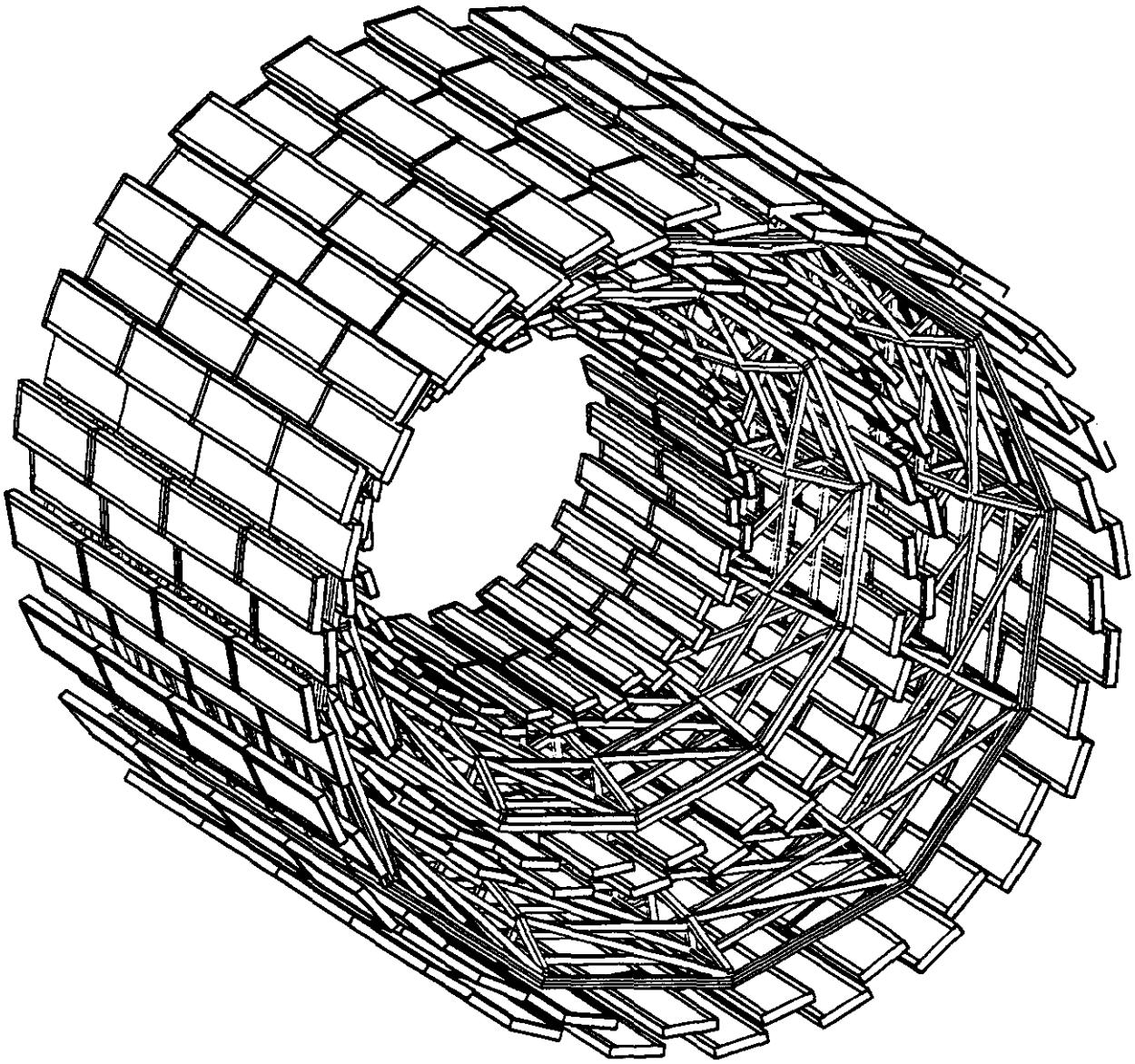
GEM BASELINE MUONS CHAMBER LAYOUT
(TOP HALF)
(CW TILTED, MAGNET END "A")

F. Nimblett
03 March 1993

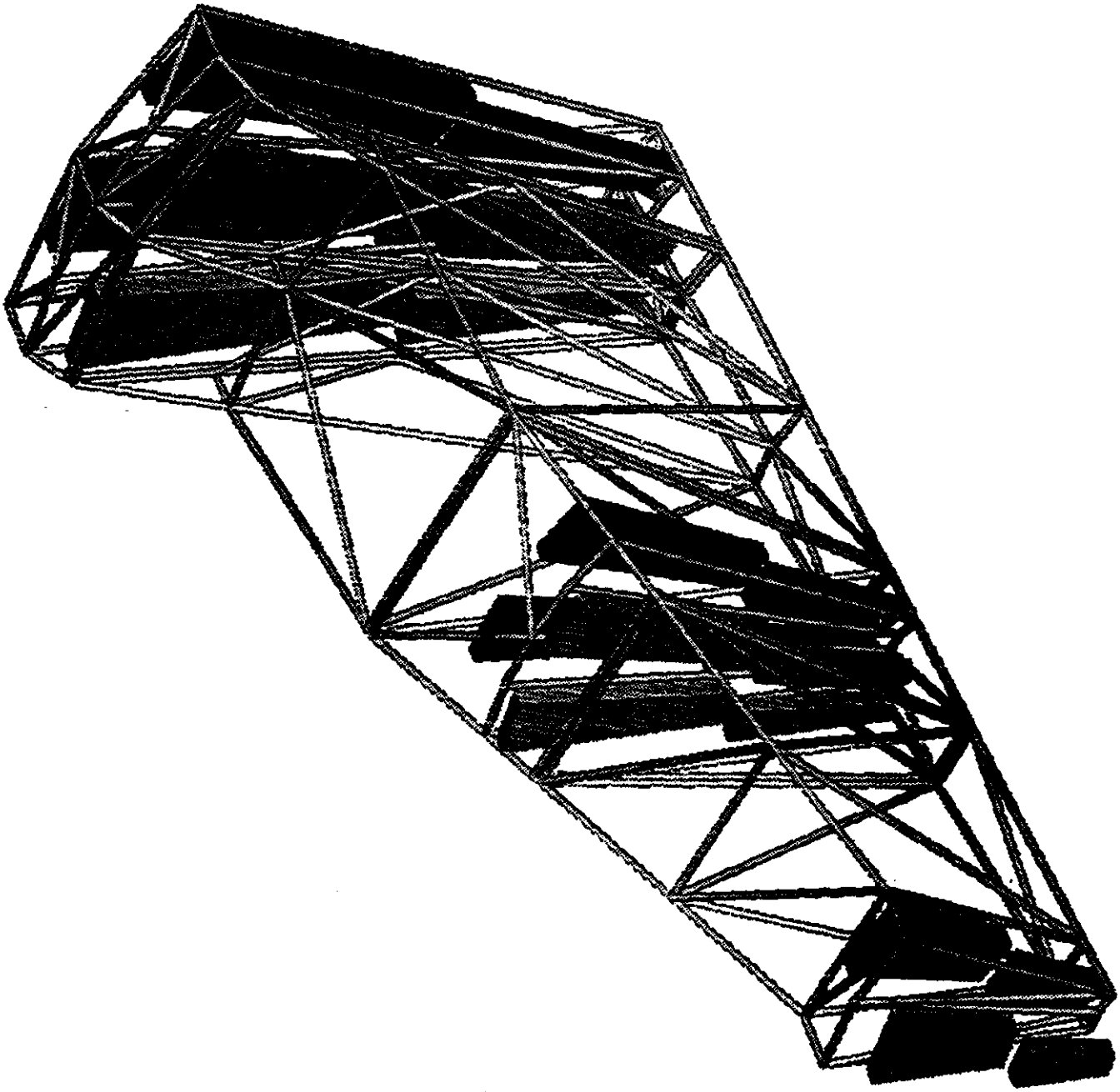


ALIGNMENT PATH
IN-LINE ALONG
"Z-AXIS"





84.
52.52.



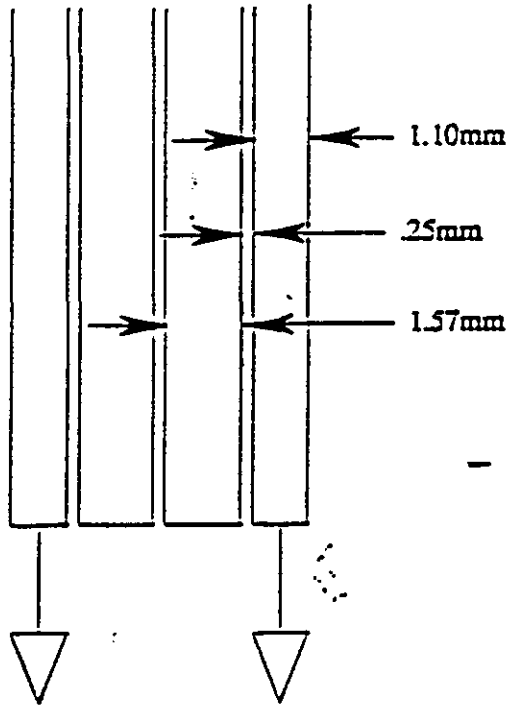


Figure 5a

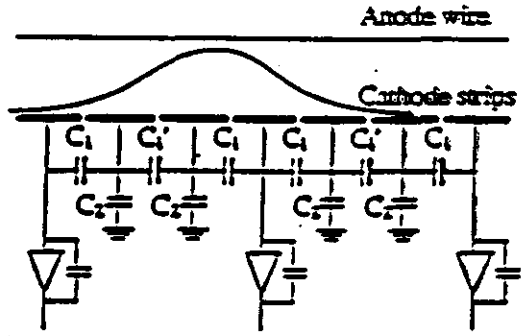
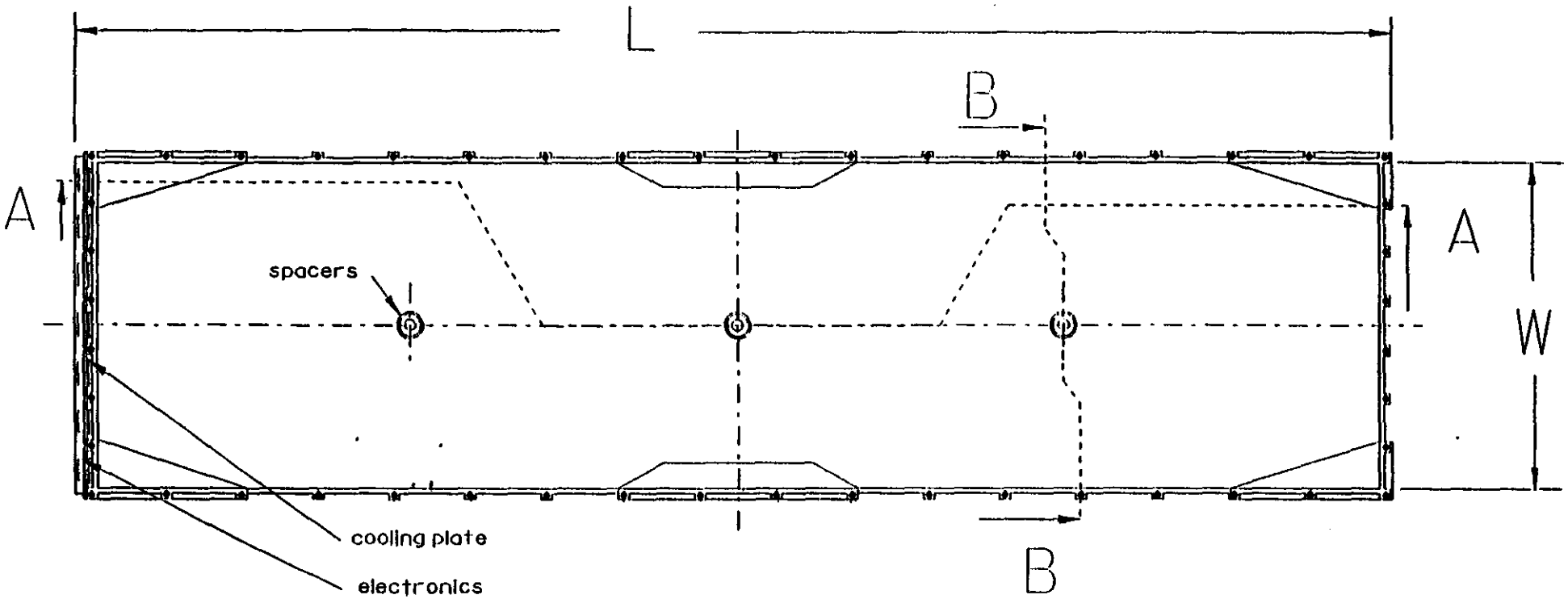


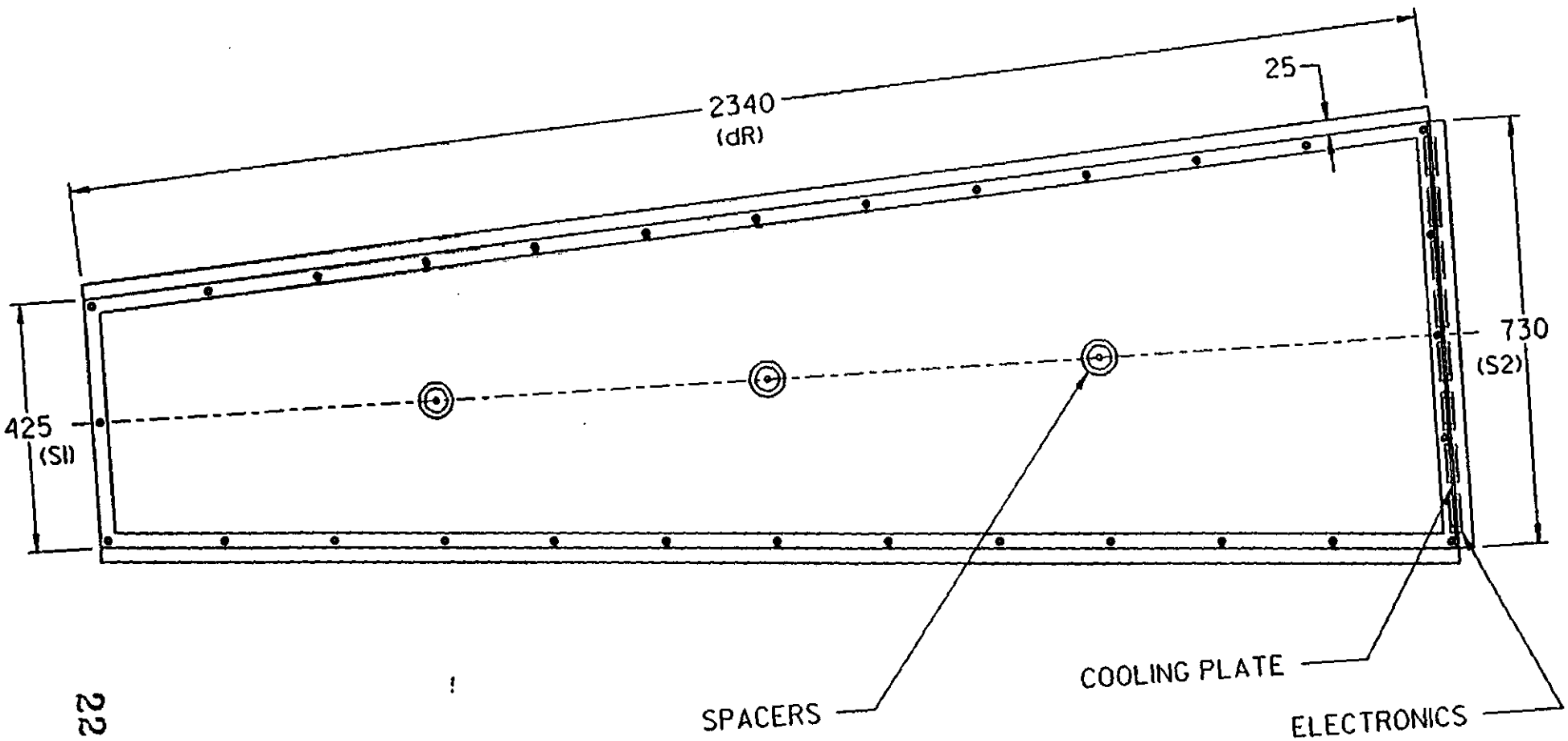
Figure 5b

4.3.1.2

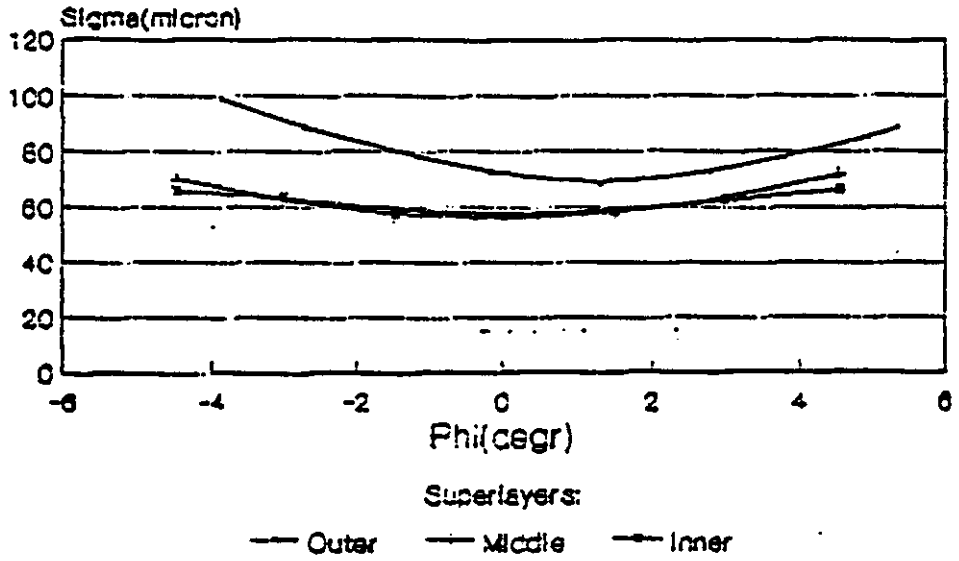

L
B
A
A
W
spacers
cooling plate
electronics
B

ENDCAP MODULE

MIDDLE MODULE 4A



Resolution vs Phi(degr)
Barrel



Resolution vs Theta(degr)
Barrel

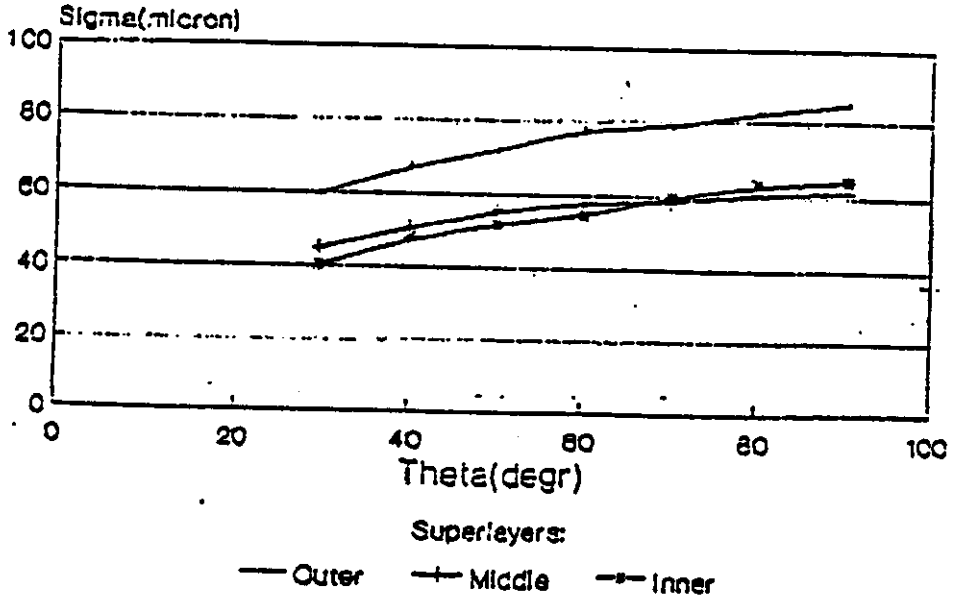


Fig. 4.3.1.4

Fig 4.4.4.1

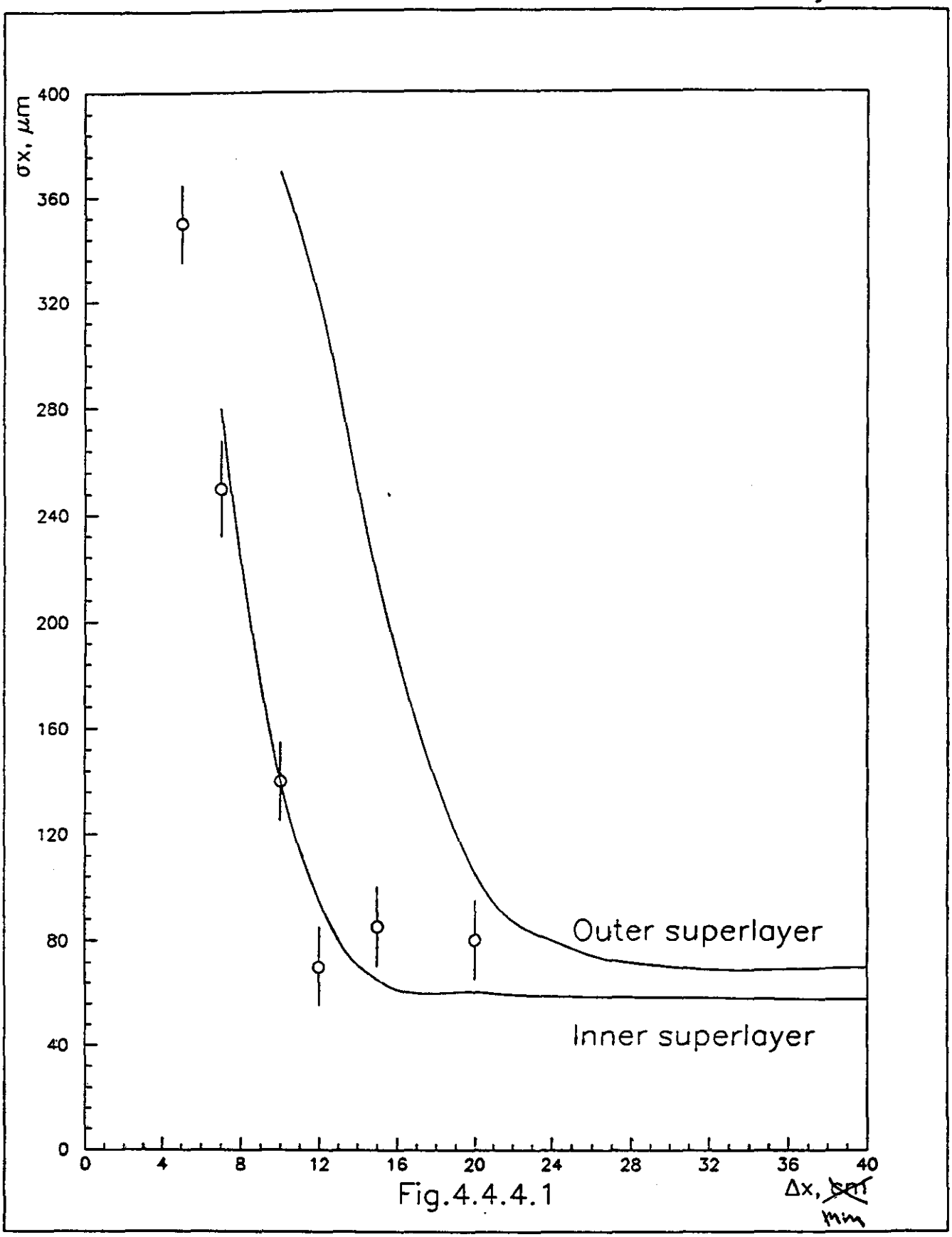
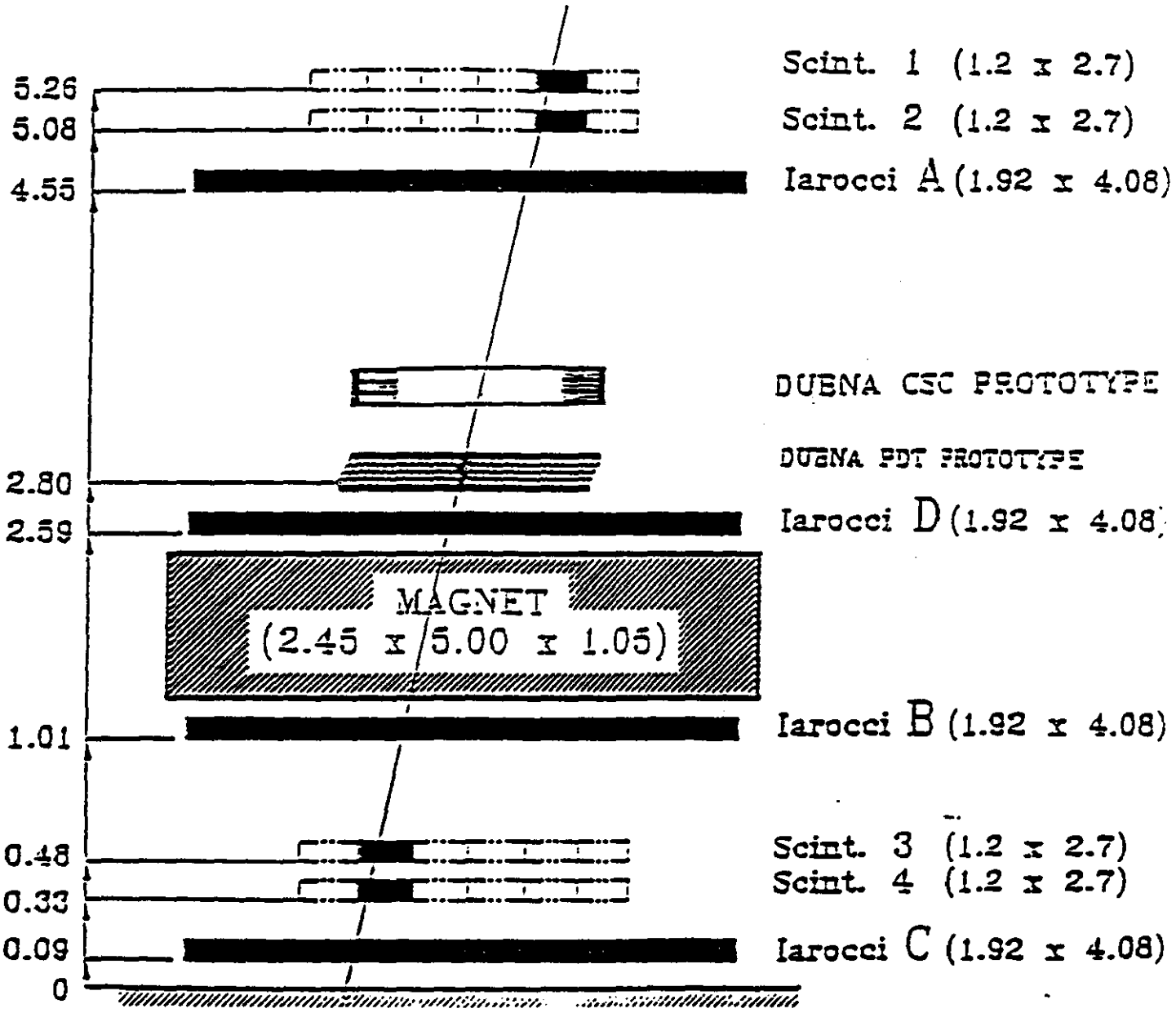


Fig.4.4.4.1

TTR TEST SETUP



All dimensions in m

Fig. 4.3.1.7

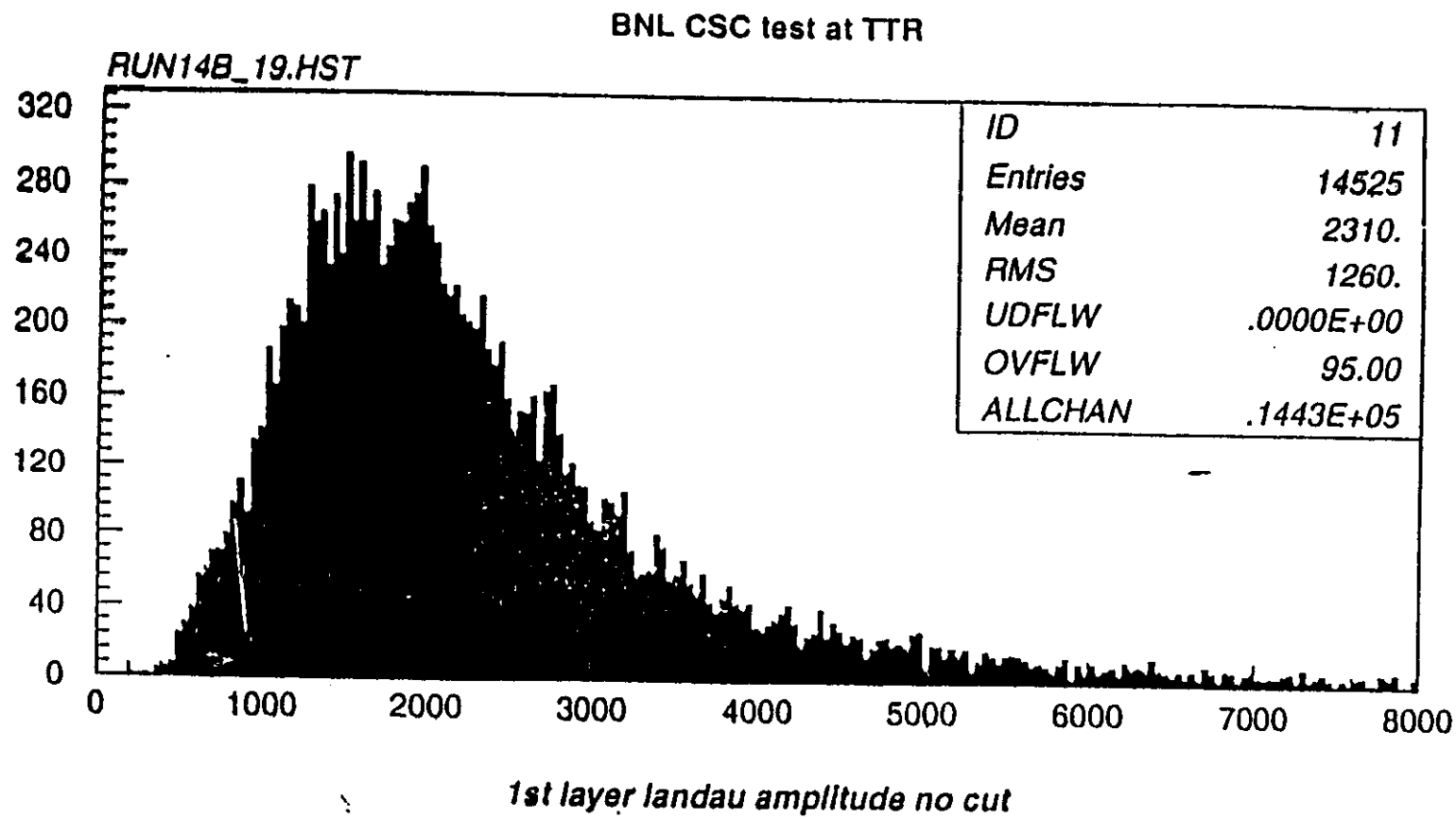
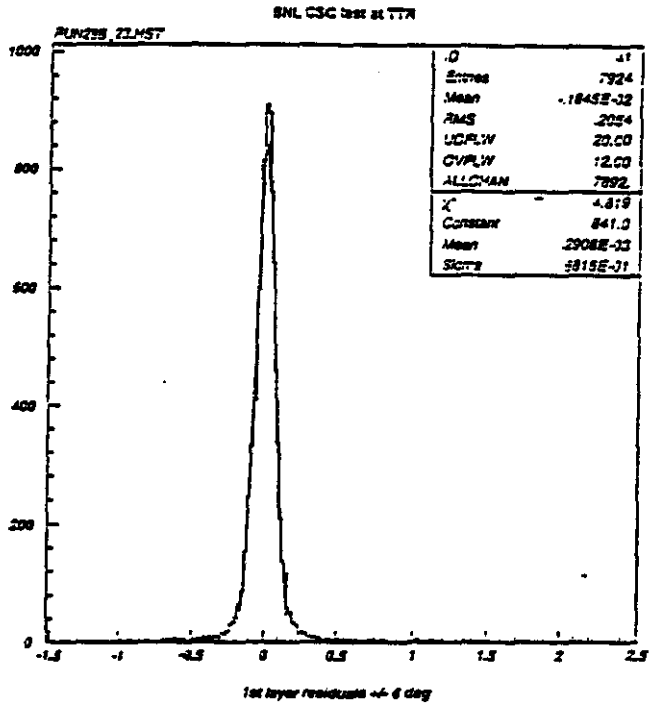
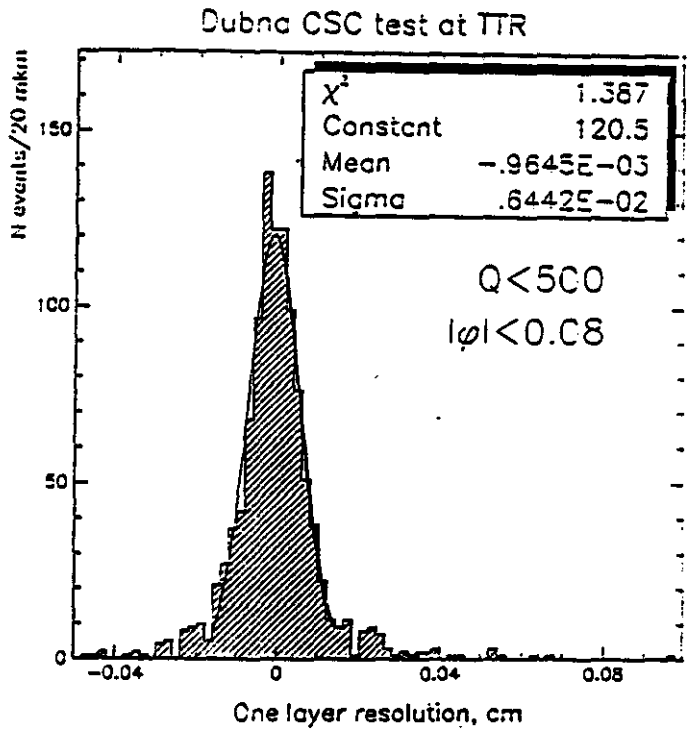

BNL CSC test at TTR
RUN14B_19.HST
ID 11
Entries 14525
Mean 2310.
RMS 1260.
UDFLW .0000E+00
OVFLW 95.00
ALLCHAN .1443E+05
320
280
240
200
160
120
80
40
0
0
1000
2000
3000
4000
5000
6000
7000
8000
1st layer landau amplitude no cut

Fig. 4.3.1.8


BNL CSC test at TTR
1st layer residuals +/- 6 deg


Dubna CSC test at TTR
N events/20 mkm
χ^2 1.387
Constant 120.5
Mean -.9645E-03
Sigma .64425E-02
Q<500
|φ|<0.08
One layer resolution, cm

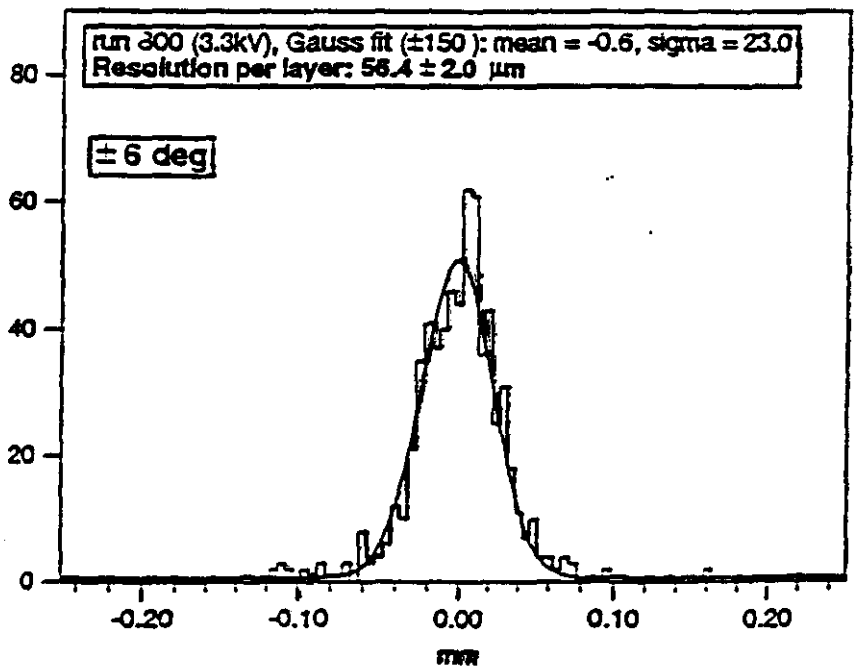

run 300 (3.3kV), Gauss fit (±150): mean = -0.6, sigma = 23.0
Resolution per layer: 56.4 ± 2.0 μm
± 6 deg
TTR

Fig. 4.3.1.10

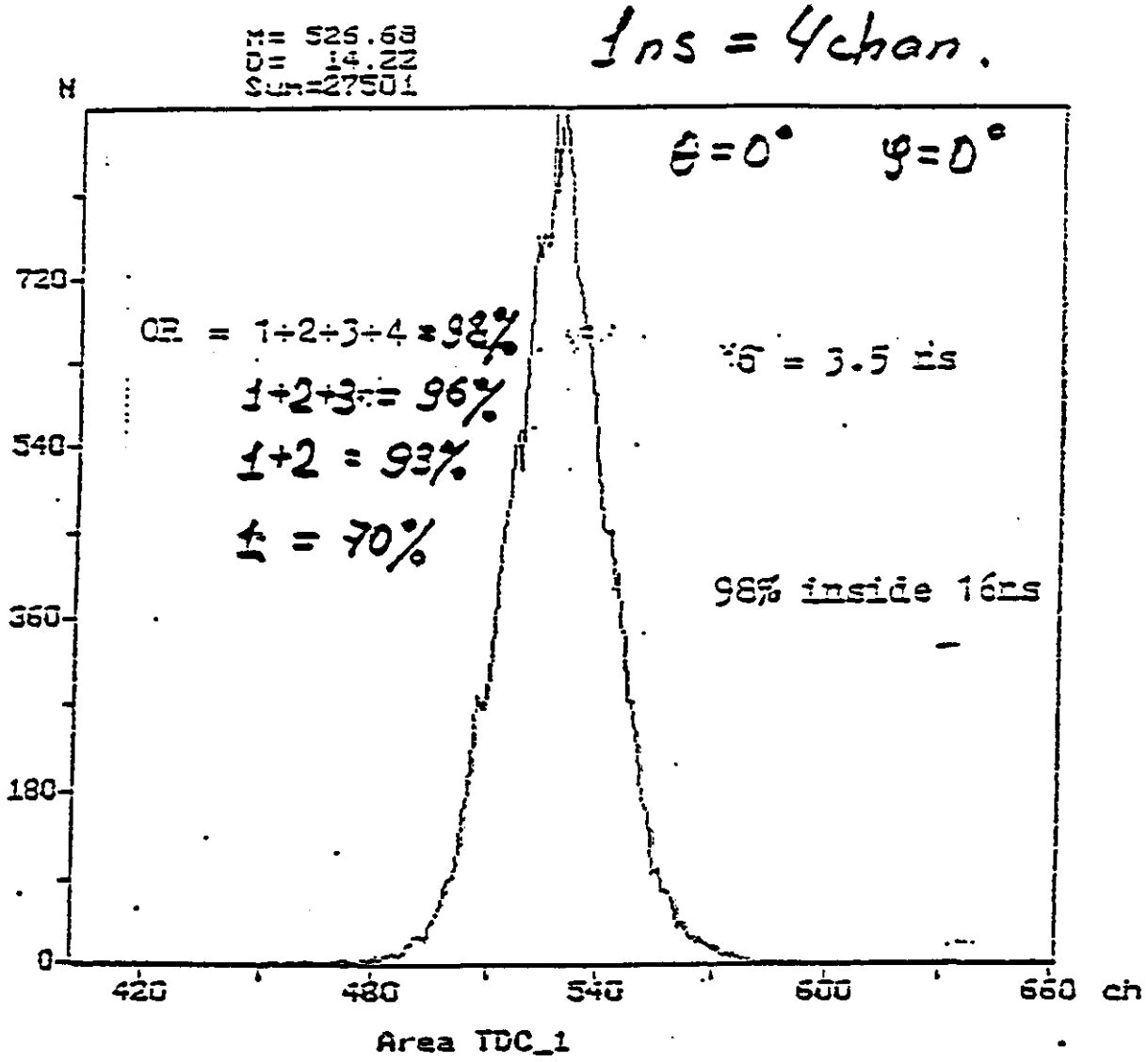
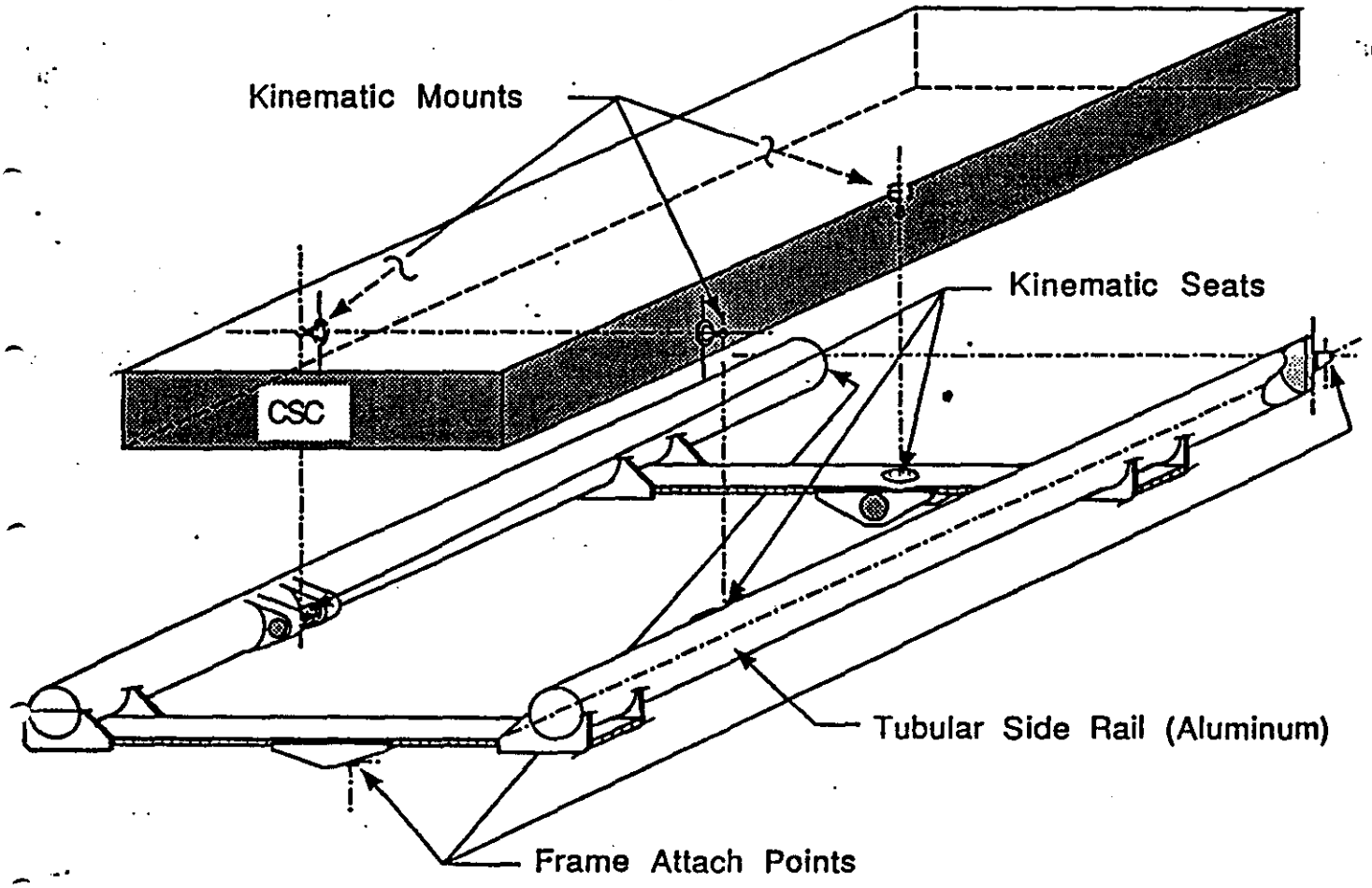
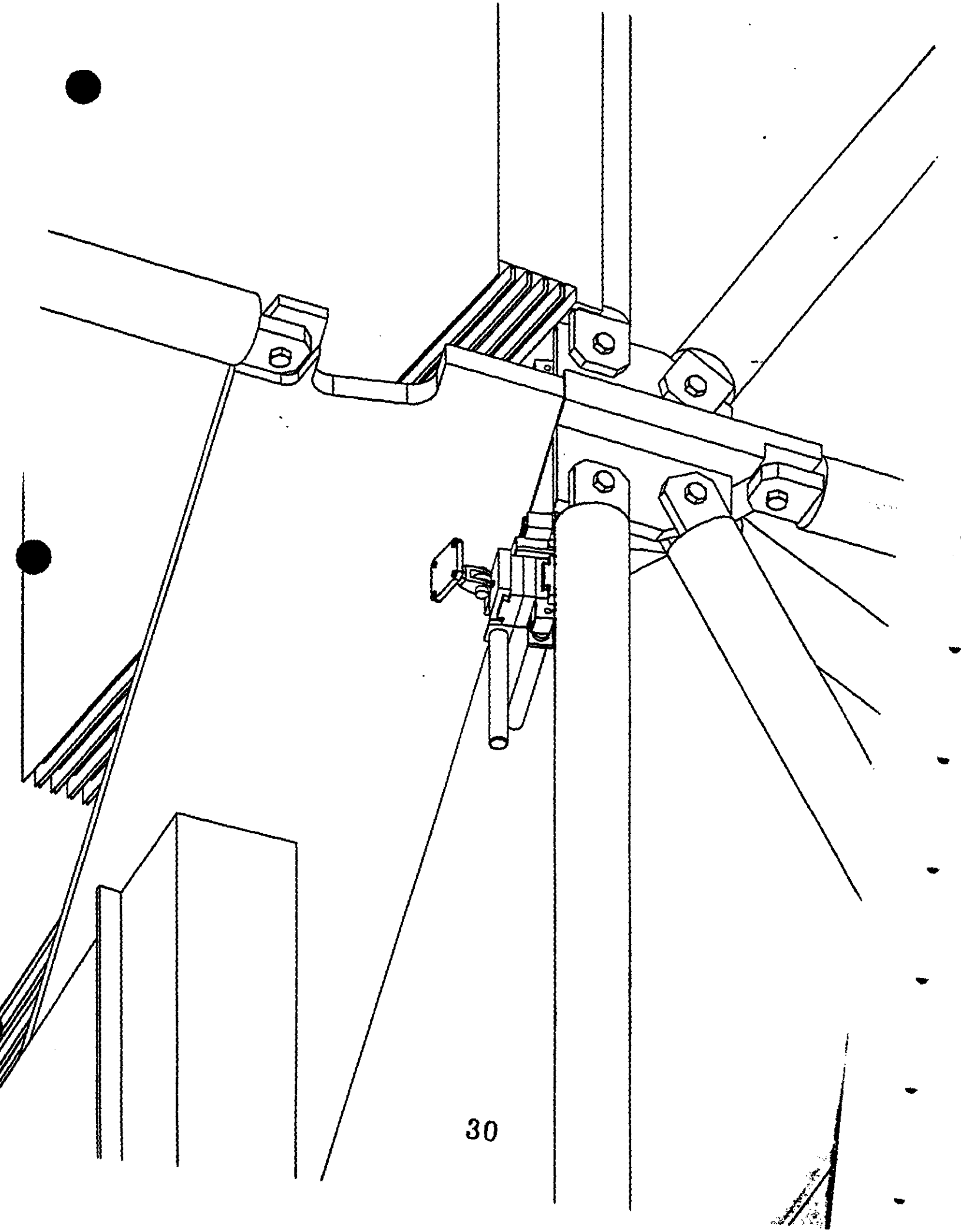
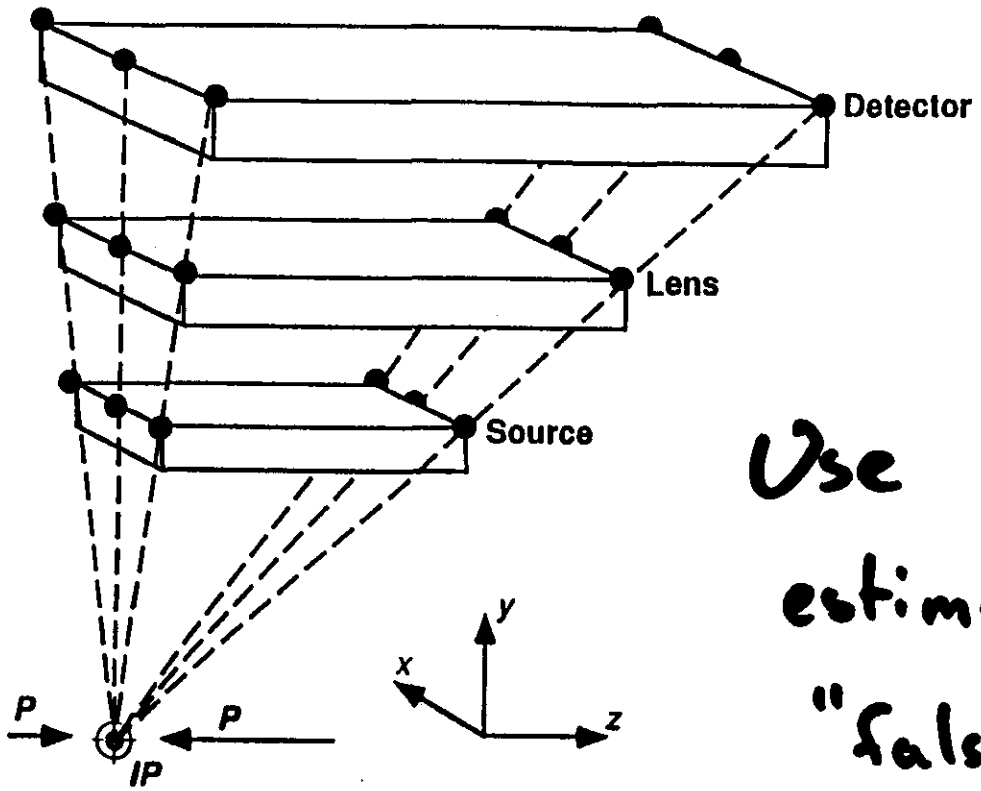

M= 526.68
D= 14.22
Sum=27501
1ns = 4chan.
N
θ=0° φ=0°
720
540
360
180
0
CE = 1÷2÷3÷4 = 98%
1÷2÷3 = 96%
1+2 = 93%
1 = 70%
σ = 3.5 ns
98% inside 16ns
420
480
540
600
660 ch
Area TDC_1

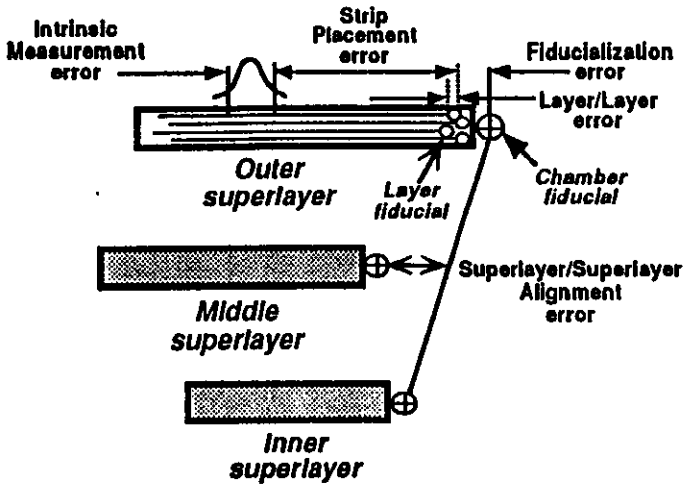
Fig. 4.3.1.12


Kinematic Mounts
Kinematic Seats
CSC
Tubular Side Rail (Aluminum)
Frame Attach Points

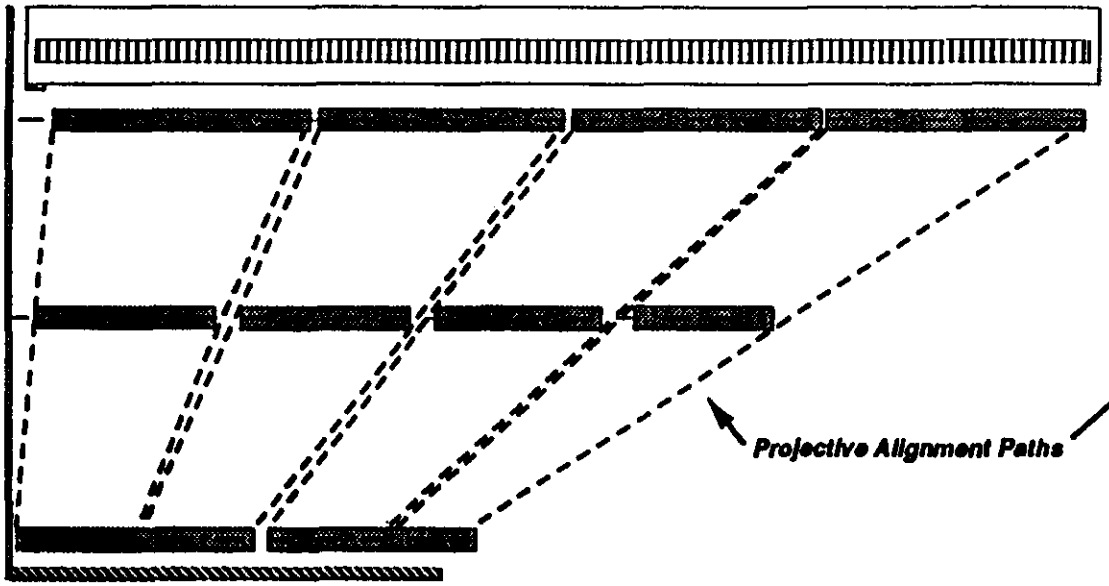


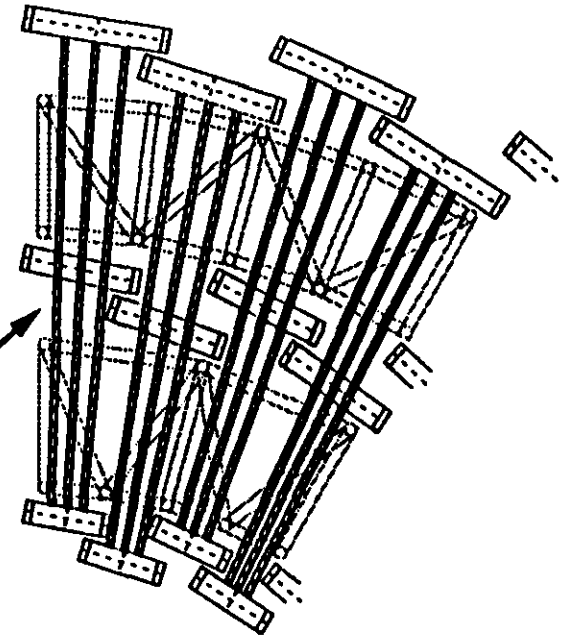


Use sensors to estimate "false sagitta" by interpolation



Error Source	RMS Value (μm)
Intrinsic chamber measurement	75
Multiple scattering (p = 500 GeV)	1
Strip to strip fiducial placement	17
Layer to layer placement	50
Fiducialization placement	10
Superlayer to superlayer alignment	25



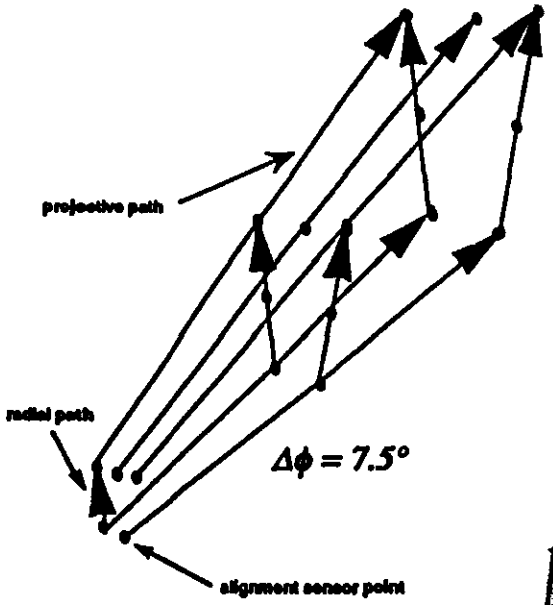


Local Alignment Monitors Needed:
Barrel Module ($\Delta\phi = 7.5°$) = 48
Assembly Sector ($\Delta\phi = 30°$) = 96
Net GEM Barrel = 2304

$\Delta\phi = 30° \rightarrow$ 4 Alignment Towers

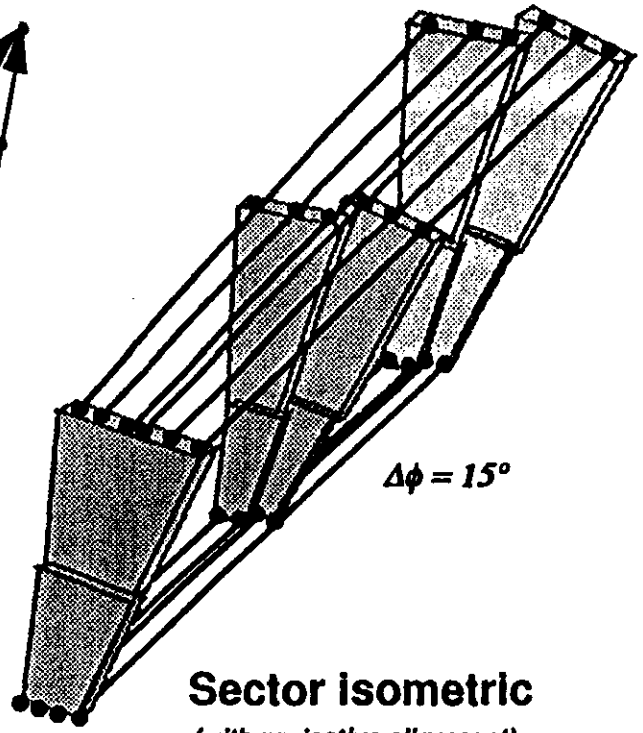
A) Side view ($r\theta$)

B) End view ($r\phi$)



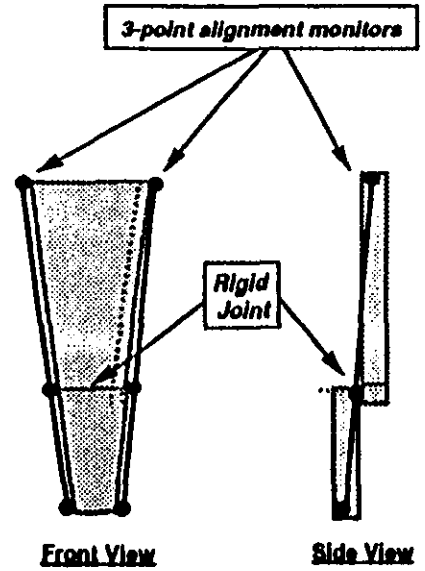
Tower alignment paths

(5 projective plus 5 radial coupling paths)



Sector isometric

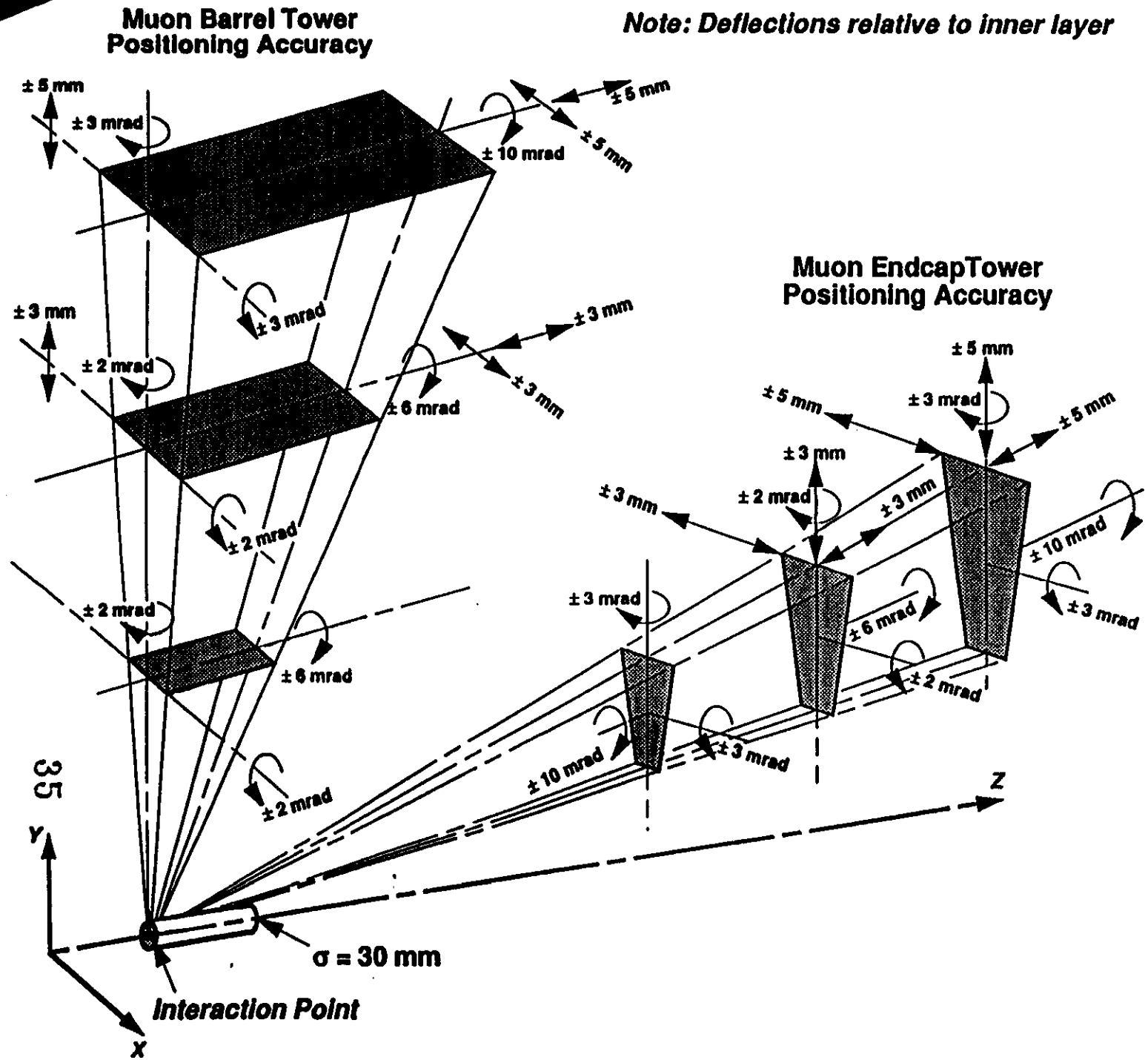
(with projective alignment)



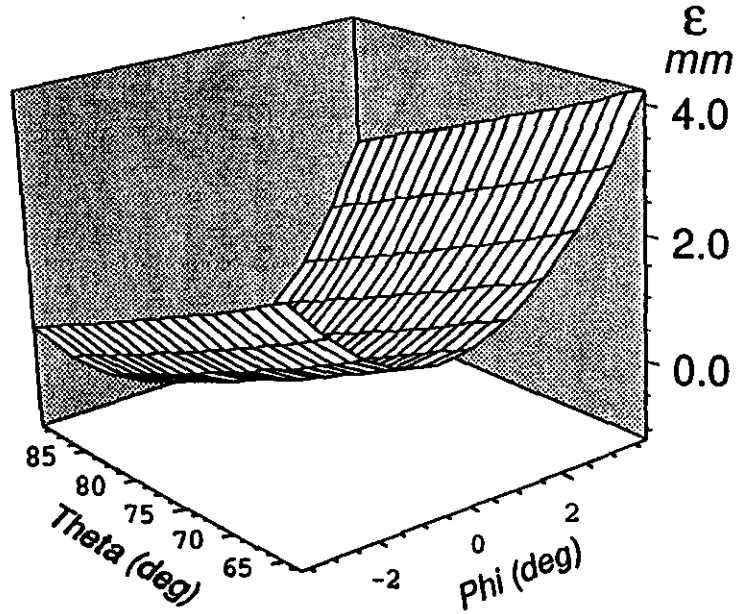
Front/side superlayer views

(with radial alignment paths)

No. of 3-point alignment monitors per GEM endcap = 480

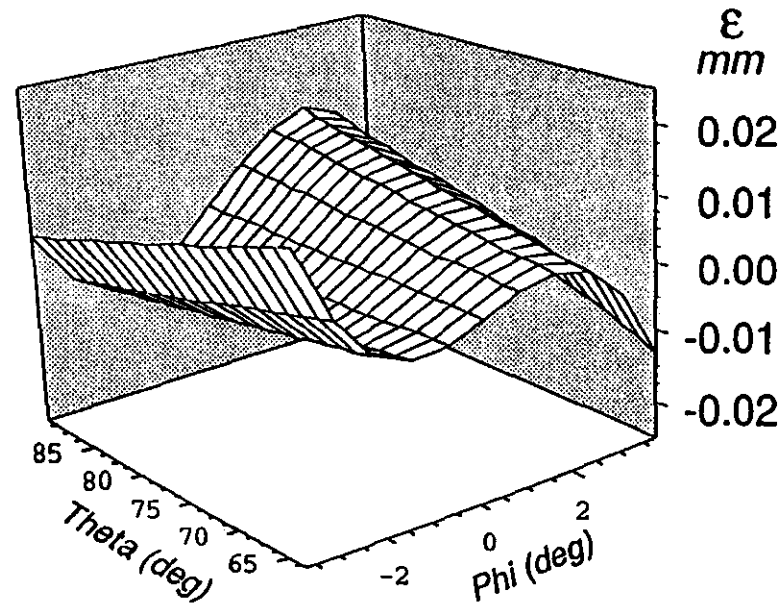

Muon Barrel Tower
Positioning Accuracy
Note: Deflections relative to inner layer
± 5 mm
± 3 mrad
± 10 mrad
± 5 mm
± 5 mm
± 3 mrad
± 3 mm
± 2 mrad
± 6 mrad
± 3 mm
± 3 mm
± 2 mrad
± 2 mrad
± 6 mrad
± 2 mrad
Muon EndcapTower
Positioning Accuracy
± 5 mm
± 5 mm
± 3 mrad
± 5 mm
± 3 mm
± 3 mm
± 2 mrad
± 3 mm
± 10 mrad
± 3 mrad
± 3 mrad
± 6 mrad
± 2 mrad
± 10 mrad
± 3 mrad
Z
Y
X
σ = 30 mm
Interaction Point

Sagitta Errors Before Alignment Correction



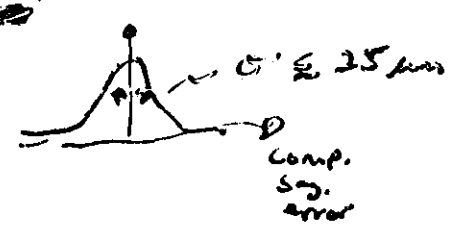
$\langle|\varepsilon|\rangle = 1.1\ mm$

Sagitta Residual After Alignment Correction



$\langle|\varepsilon|\rangle = 5.0\ \mu m$

→ Will add plot of residuals (error) with all known effects.

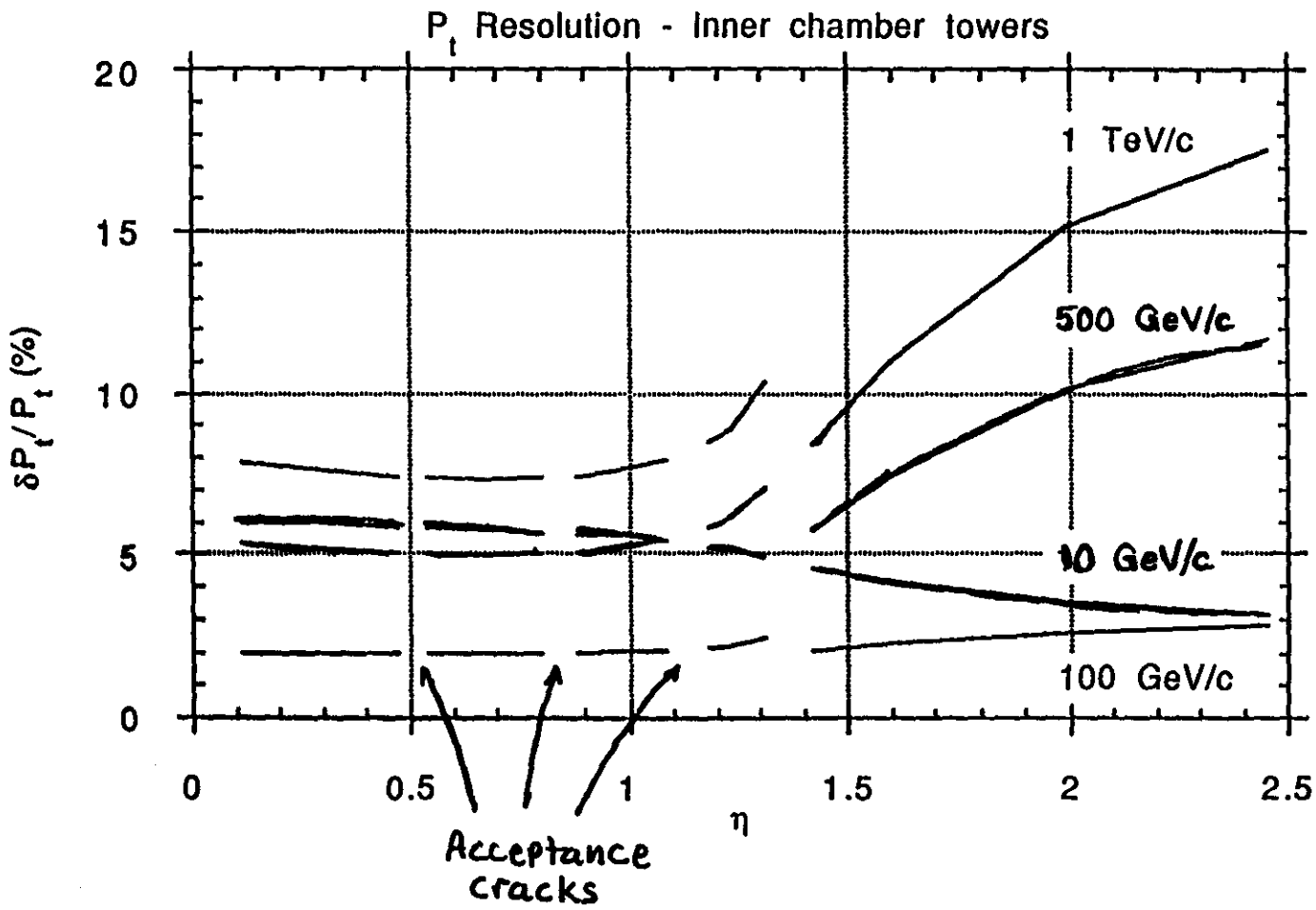


5. Muon Momentum resolution - including calorimeter effects (energy loss)

Baseline 2 GEM Muon System

standalone muon system performance - no vertex constraint, no inner tracker

FET 3/15/93



25

Track reconstruction eff vs η for different P_T
All 3 SL required

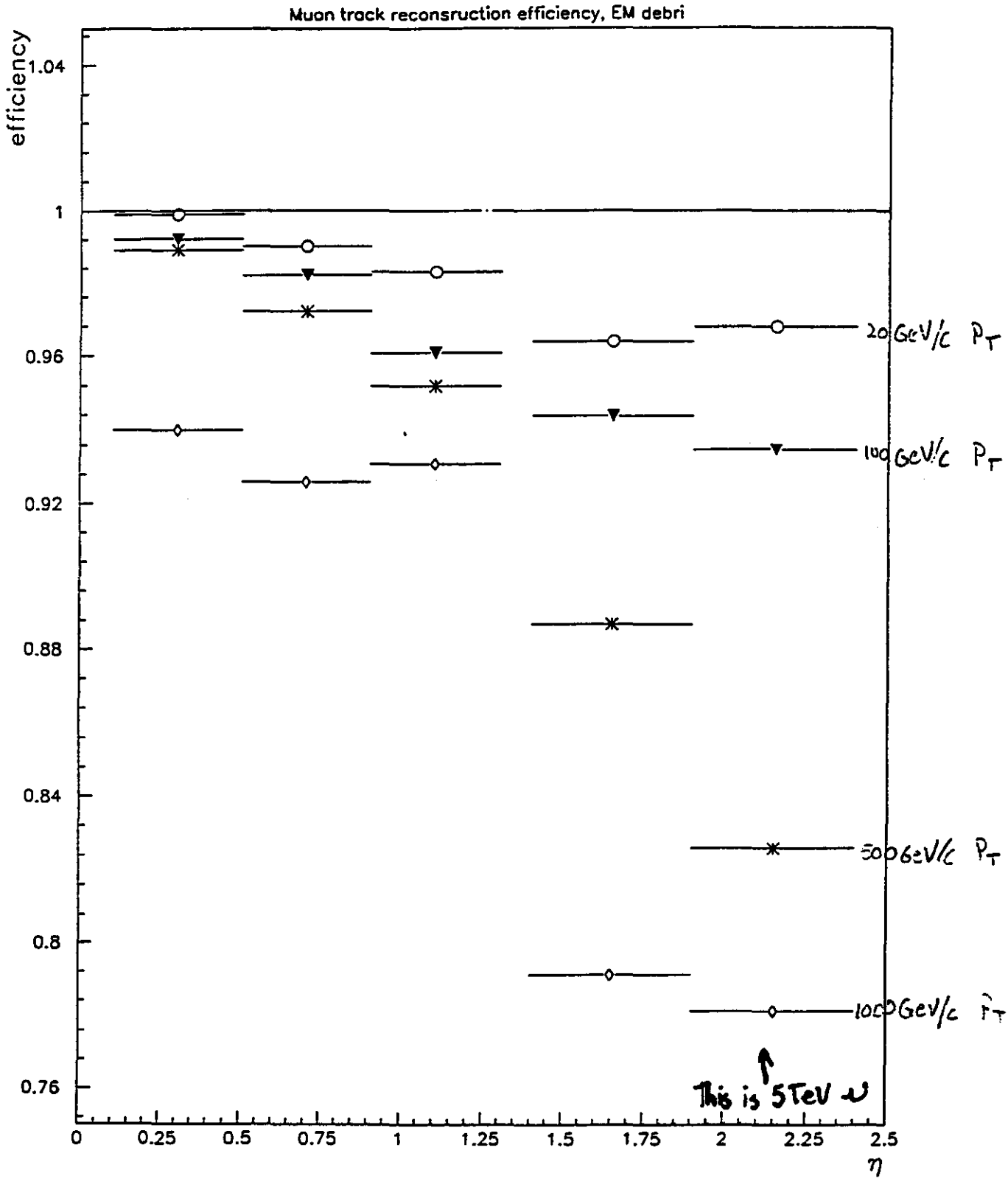
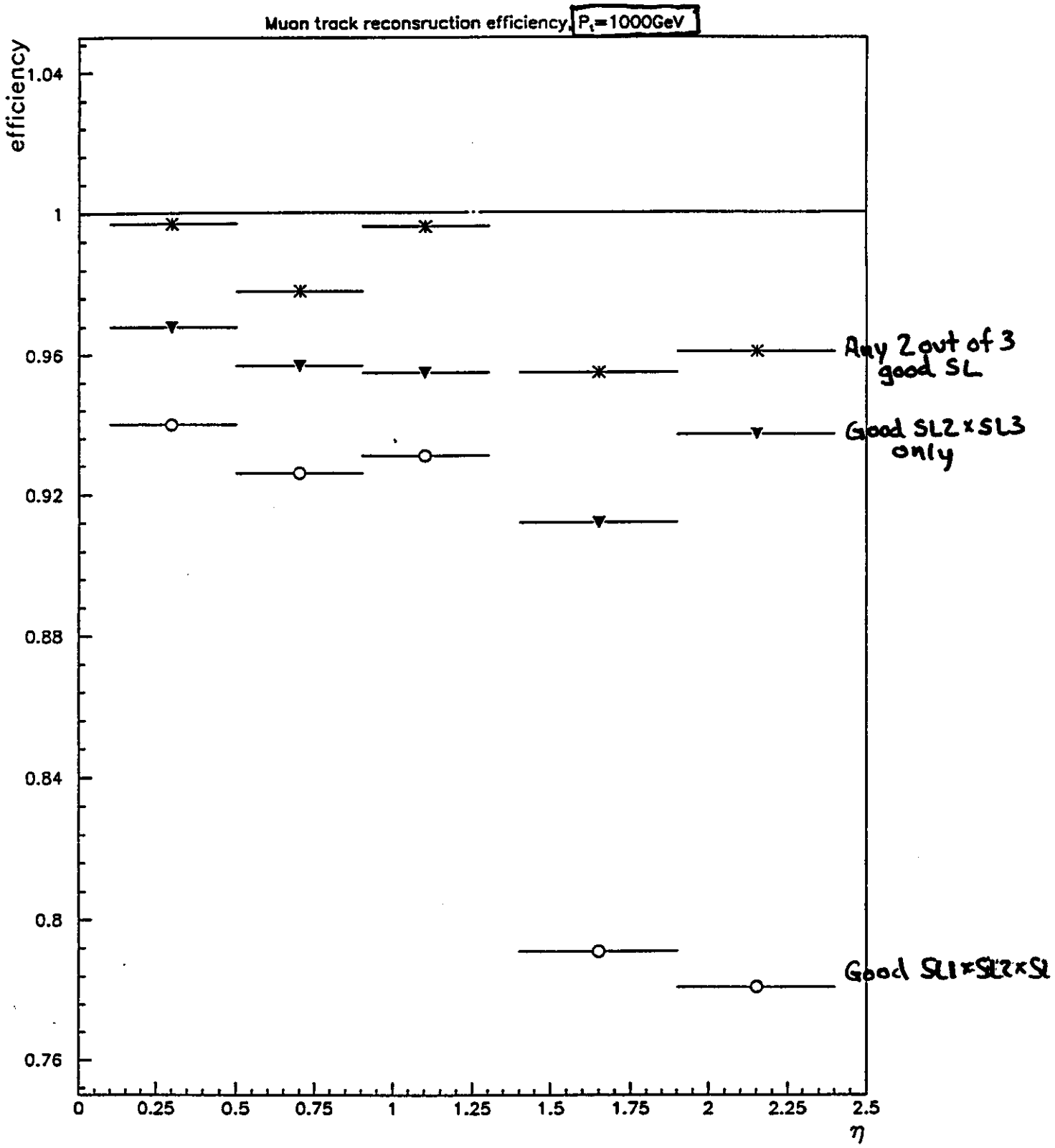


Figure 44.4.3c)

26

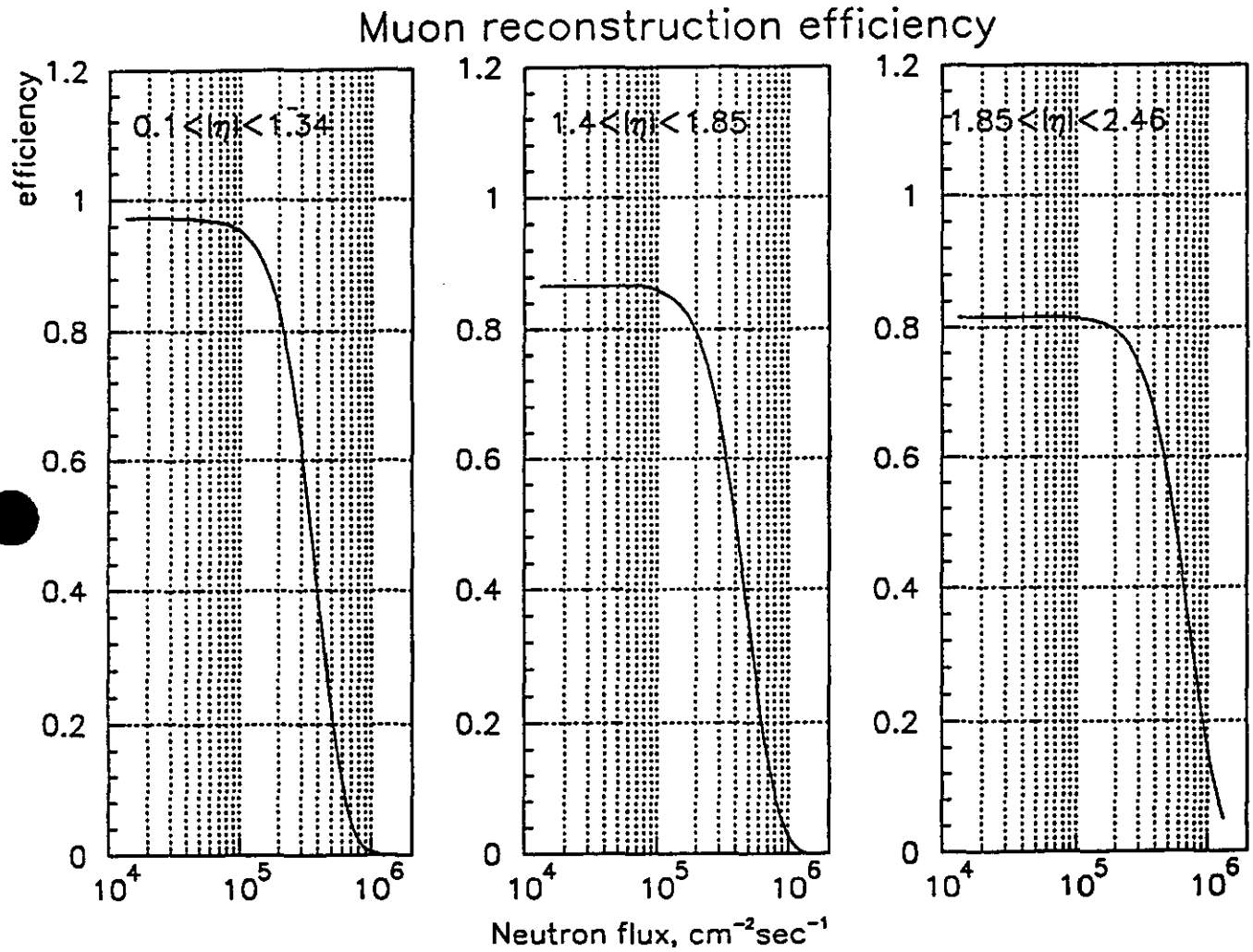
Track reconstruction eff for all 3SL good, and for 2 SL good



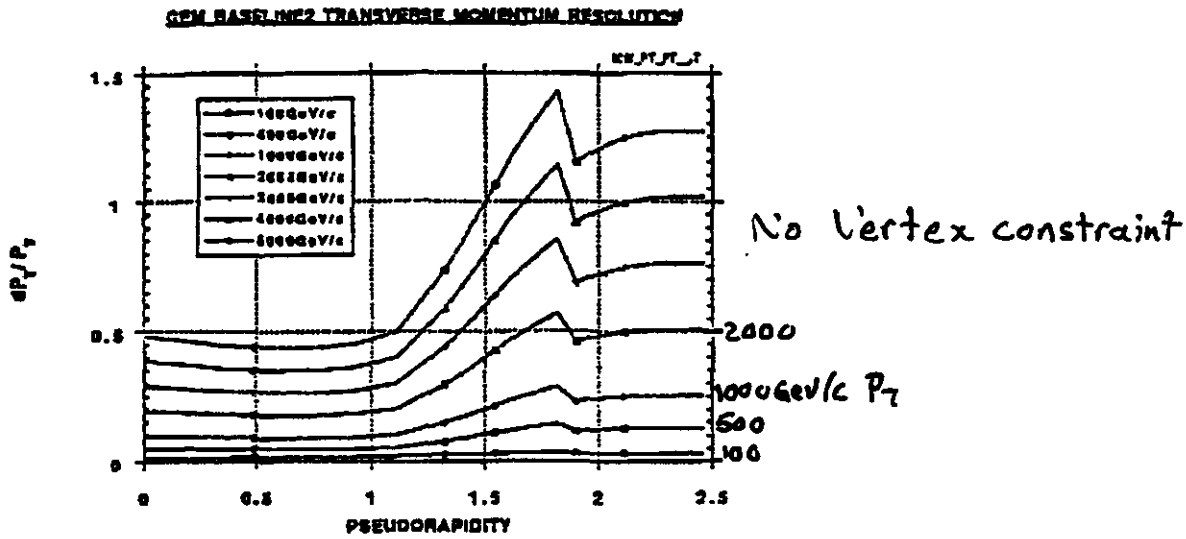
Muon Track reconstruction eff (all 3 SL) for 500 GeV/c P_T Muon as a function of n/γ fluence

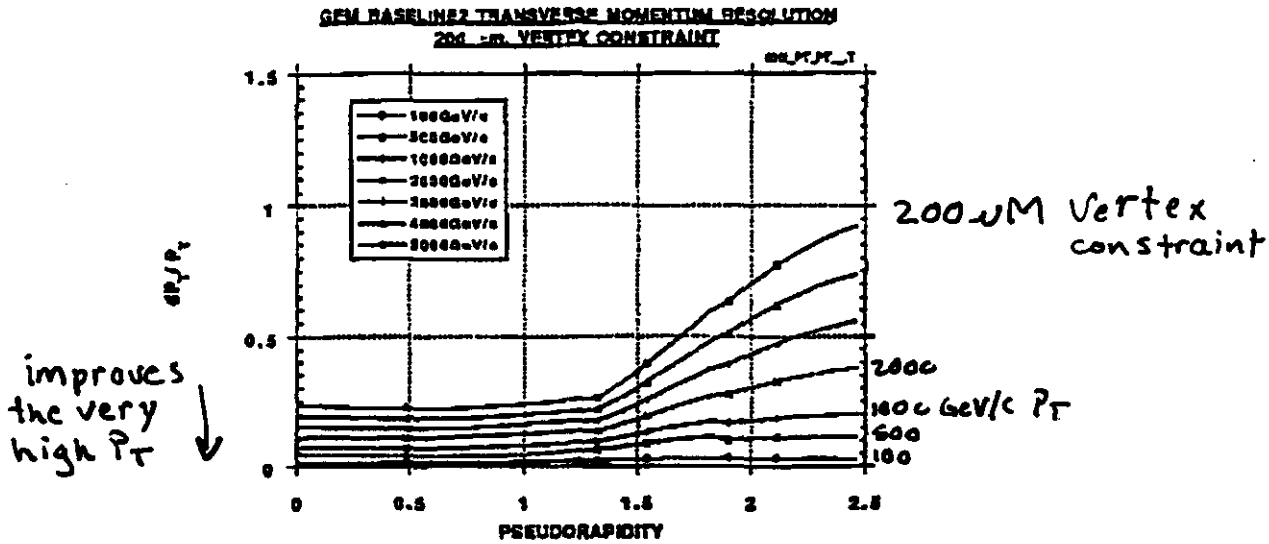
Δt_{INT} = 300 nsec

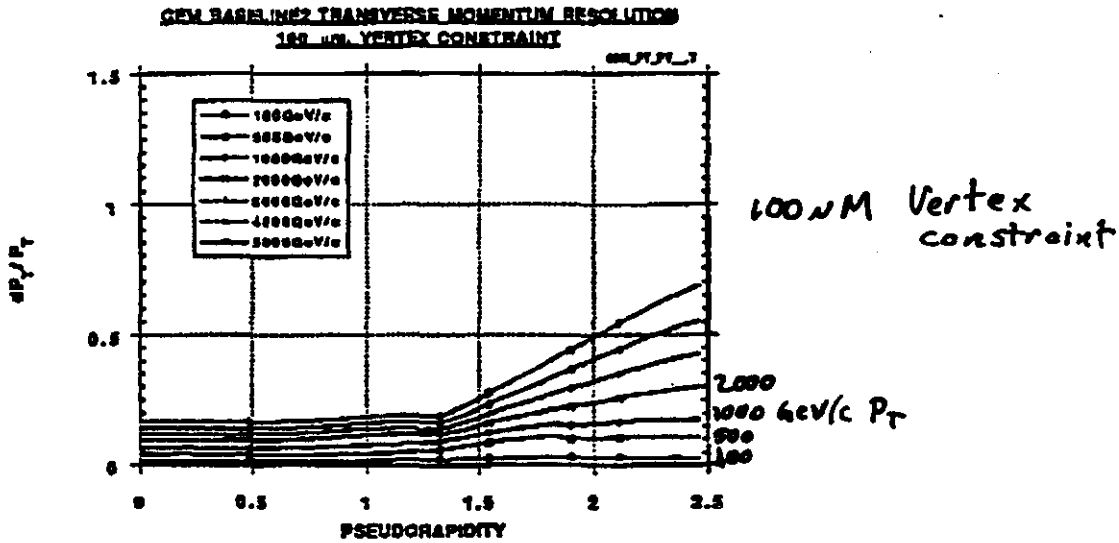
γ fluence 20% of n fluence
Thermal n fraction 50%

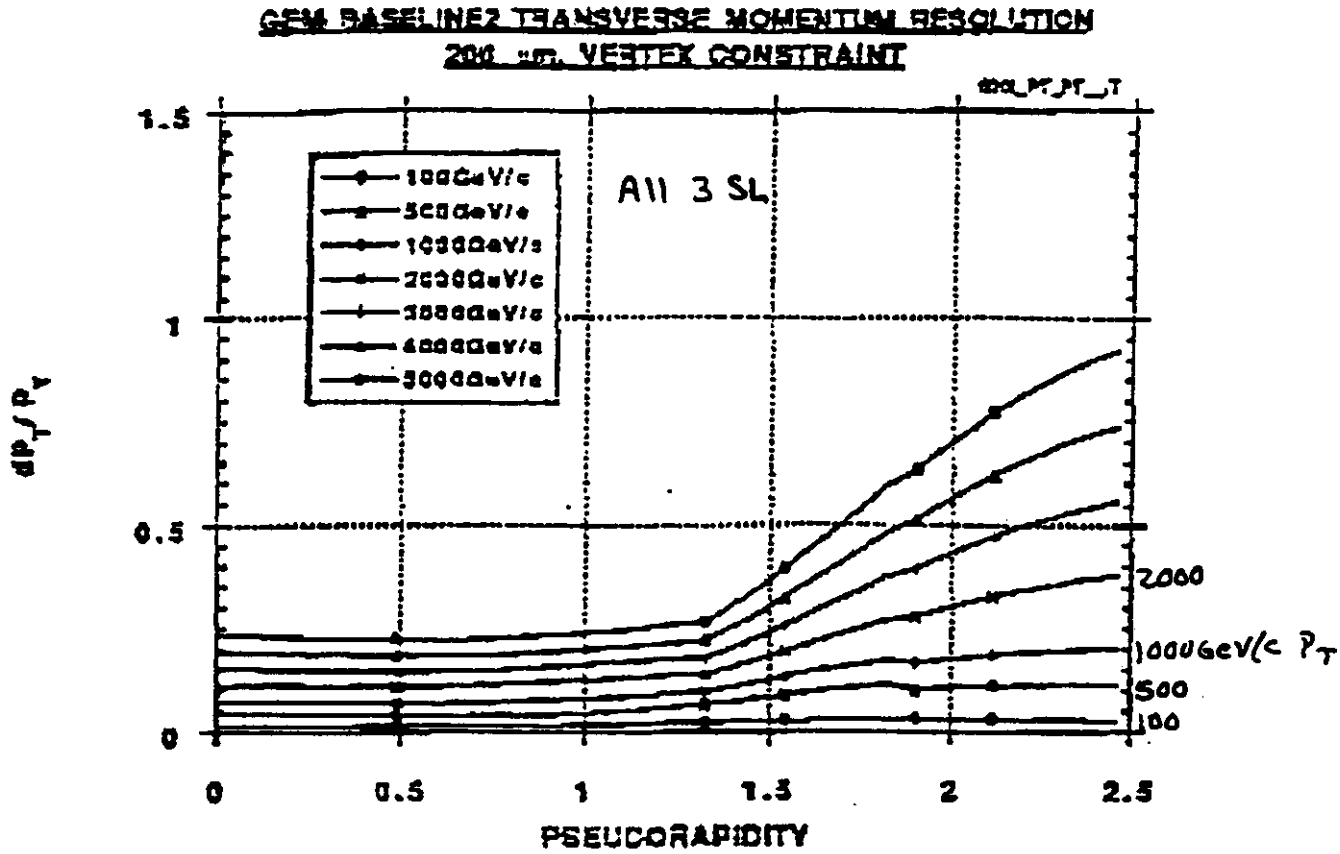


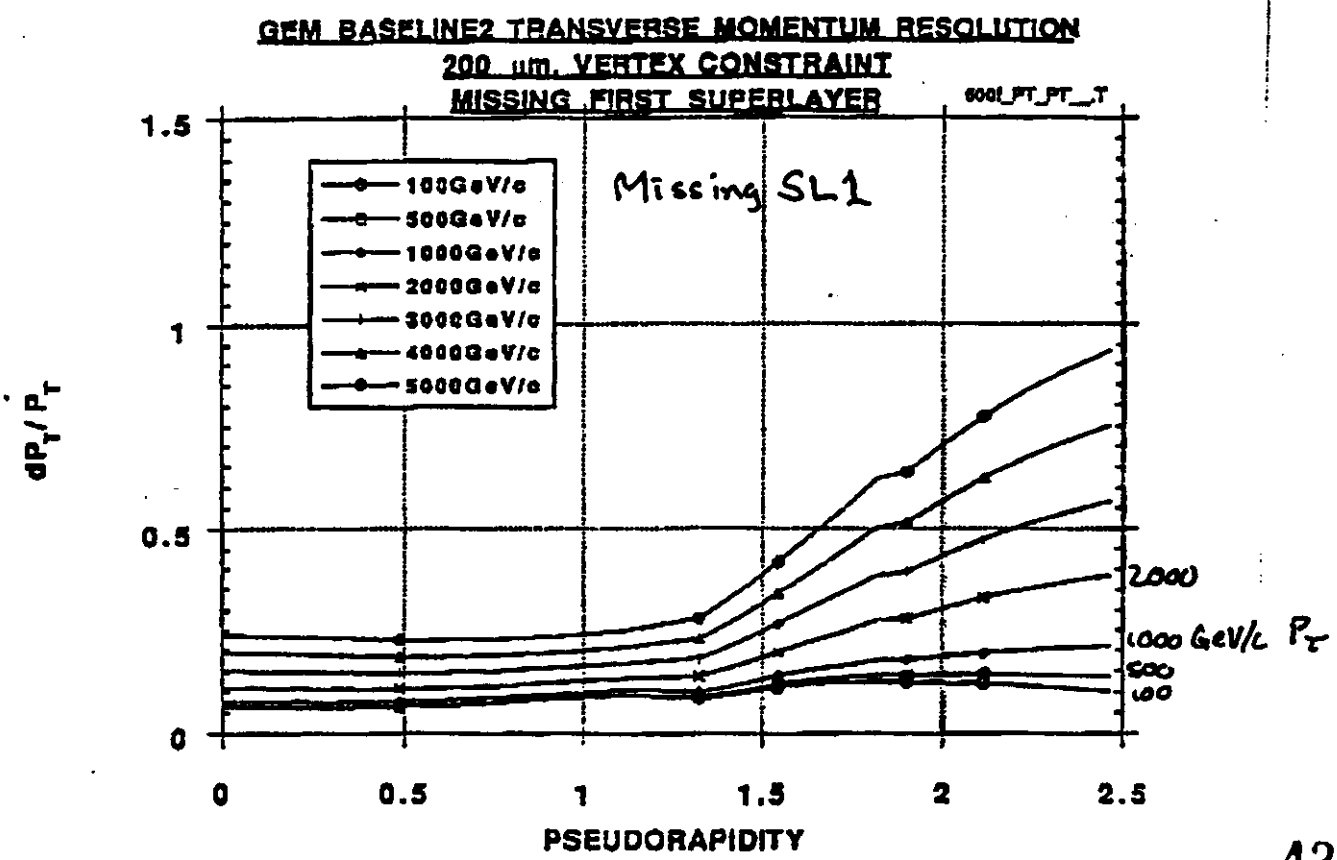
GEM Muon System can perform pattern recognition at 10^5 n/cm²s


GEM BASELINE2 TRANSVERSE MOMENTUM RESOLUTION
dP_T/P_T
PSEUDORAPIDITY
No Vertex constraint
2000
1000 GeV/c P_T
500
100

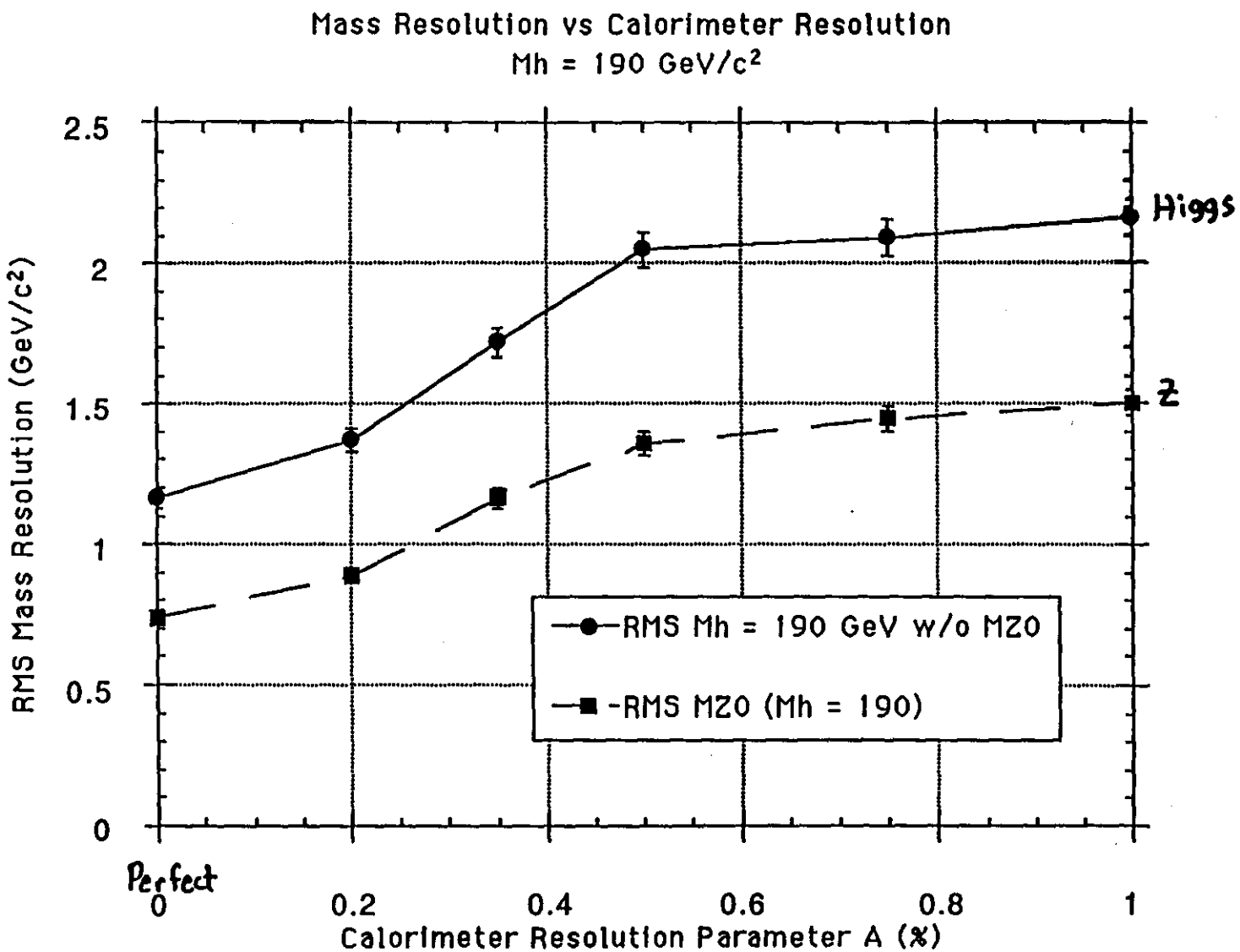

GEM BASELINE2 TRANSVERSE MOMENTUM RESOLUTION
200 μm VERTEX CONSTRAINT
dP_T/P_T
PSEUDORAPIDITY
200 μM Vertex constraint
improves the very high P_T
2000
1000 GeV/c P_T
500
100


GEM BASELINE2 TRANSVERSE MOMENTUM RESOLUTION
100 μm VERTEX CONSTRAINT
dP_T/P_T
PSEUDORAPIDITY
100 μM Vertex constraint
2000
1000 GeV/c P_T
500
100



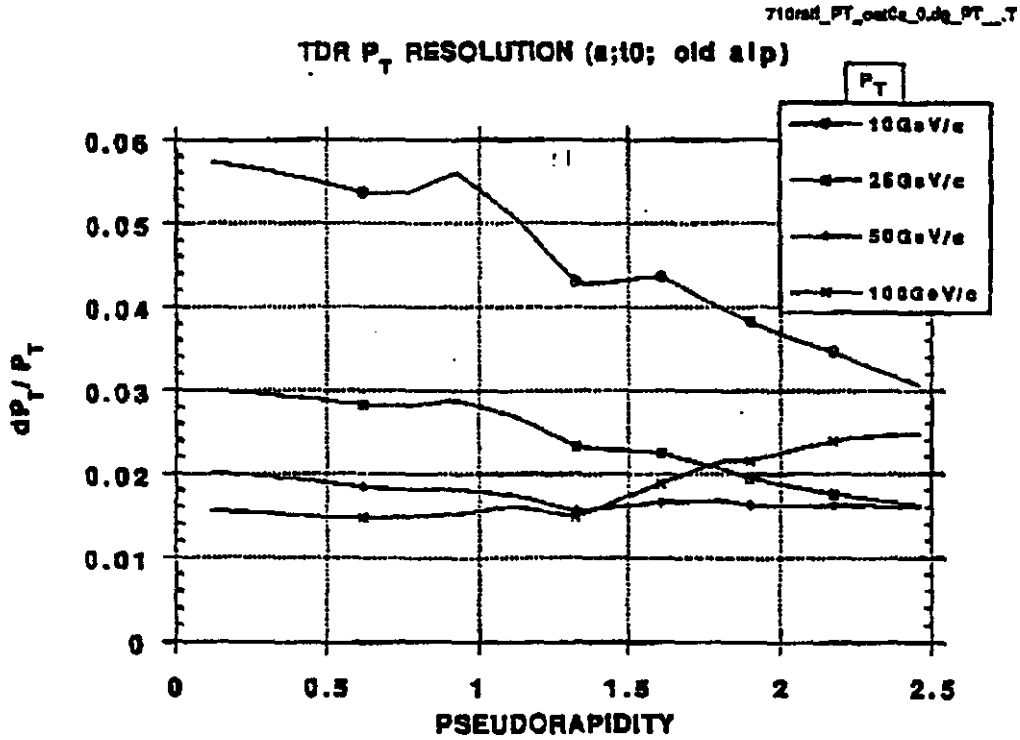


Lose substantial resolution at low P_T, not at high P_T

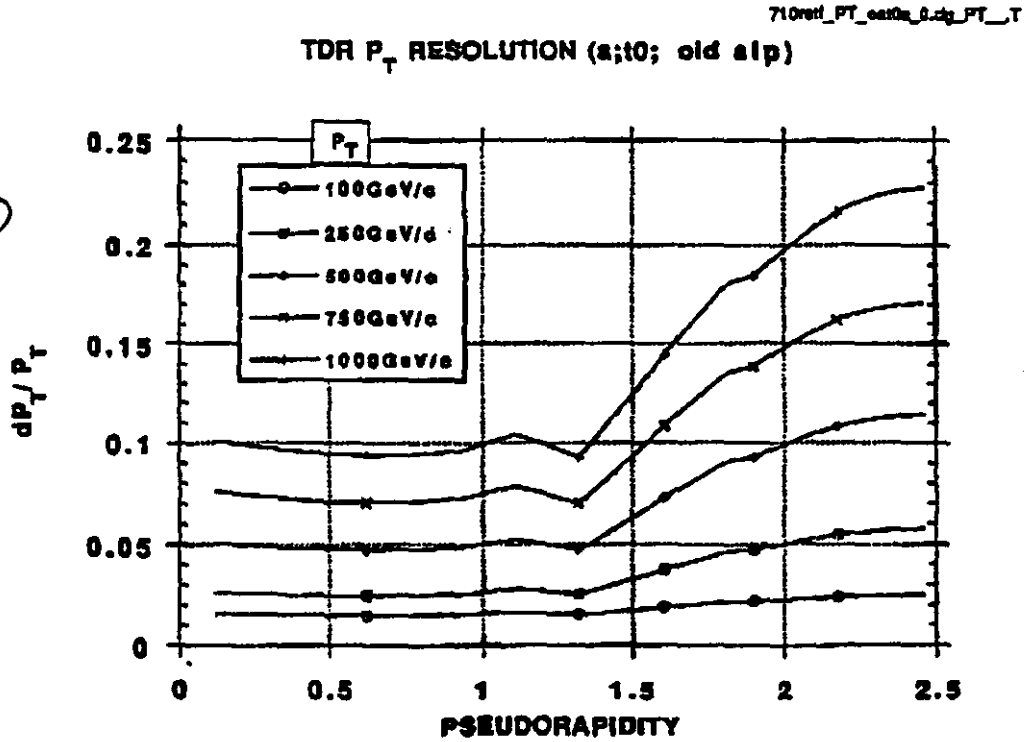

Mass Resolution vs Calorimeter Resolution
Mh = 190 GeV/c²
RMS Mass Resolution (GeV/c²)
2.5
2
1.5
1
0.5
0
Perfect
0
0.2
0.4
0.6
0.8
1
Calorimeter Resolution Parameter A (%)
Higgs
Z
RMS Mh = 190 GeV w/o MZO
RMS MZO (Mh = 190)

Baseline

Low P



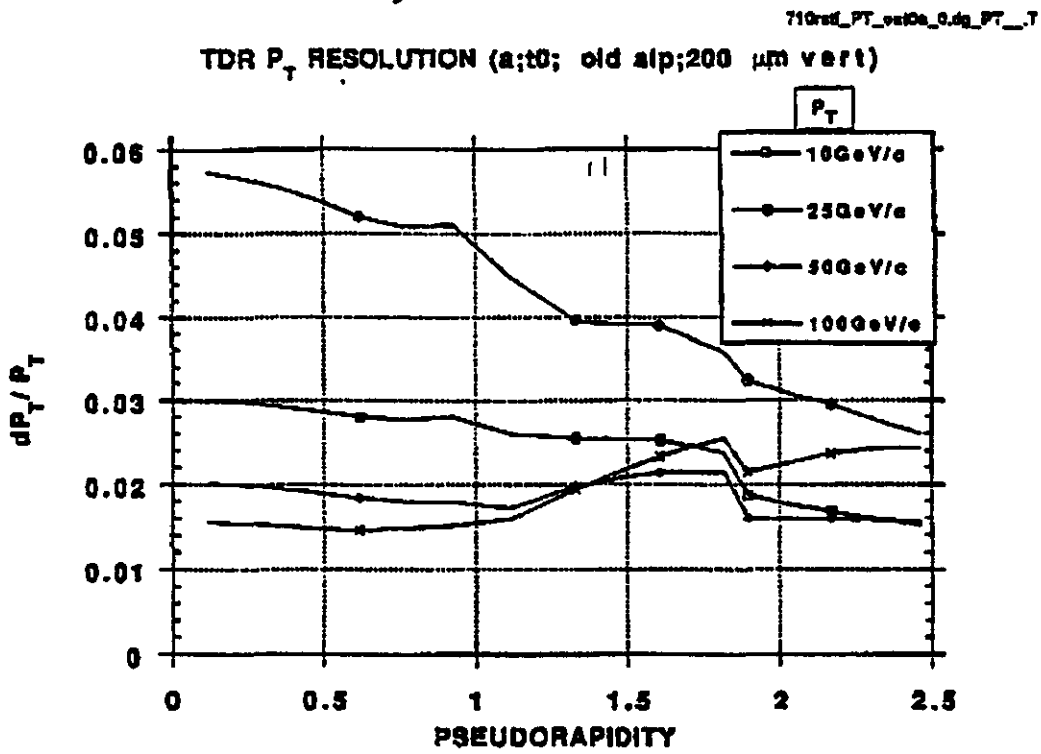
High P



Baseline +
200 μm VTX

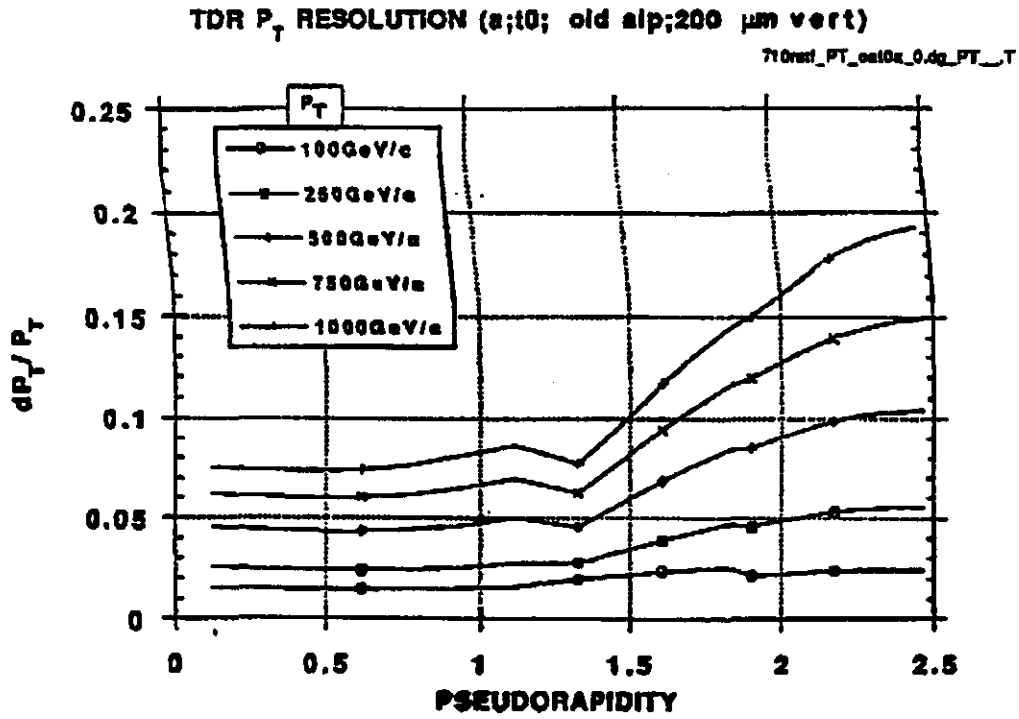
(3)

Low P



(3)

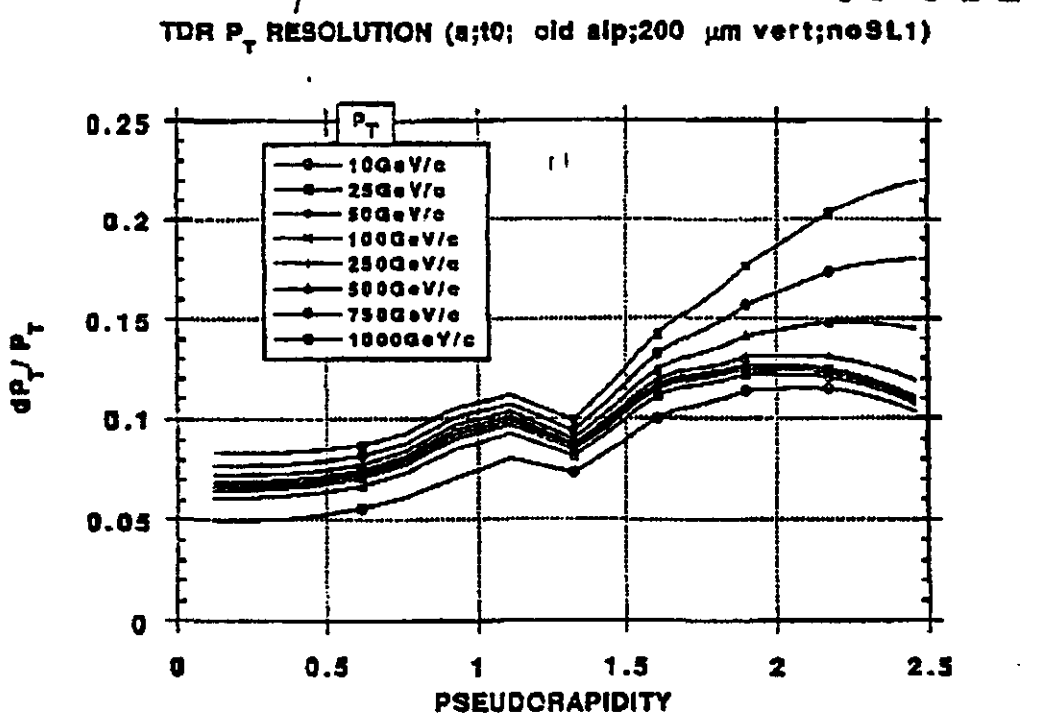
High P



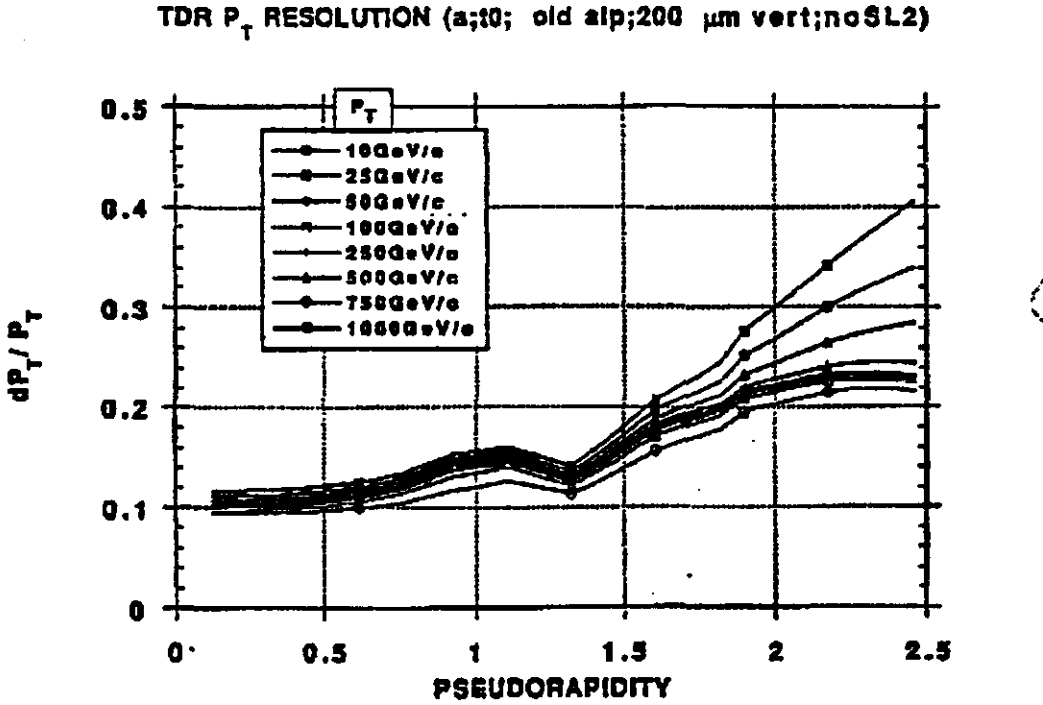
(4)

Missing SL
w/200μm VTX

SL1



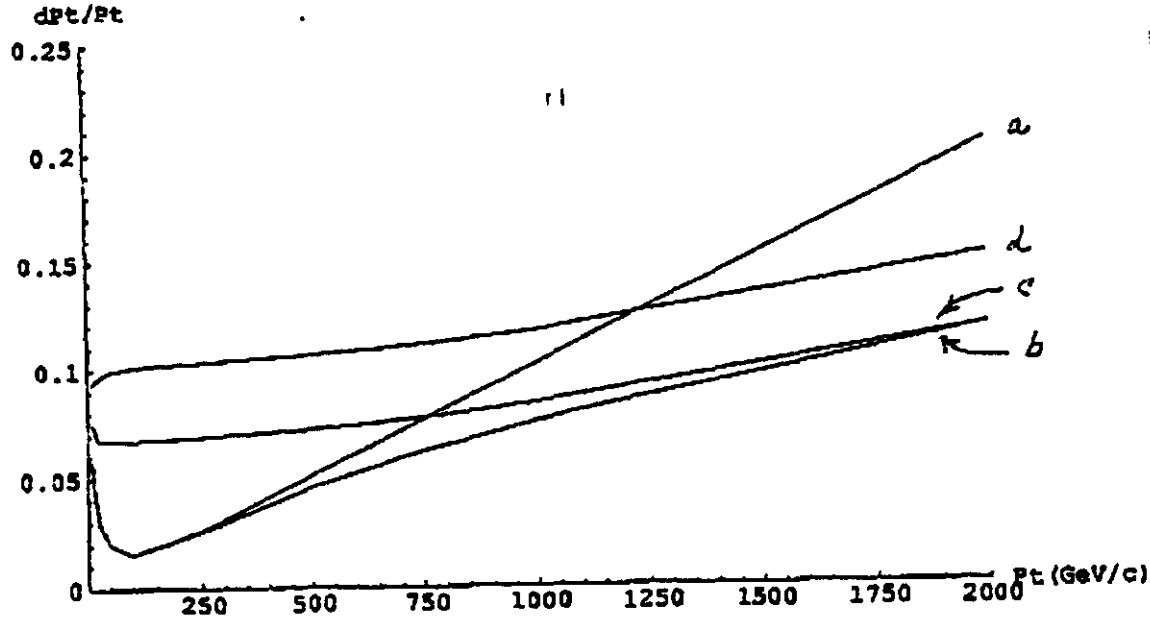
SL2



8

dPt/Pt at 90 deg.:
(a) Baseline
(b) Baseline +200 micron vertex
(c) (b) && missing first superlayer
(d) (b) && missing second superlayer

12



Frank Nimblett

Mechanical Layout

Endcap CSC Layout -- Baseline II Version b.6 -- Towers -- 8/6/6 09 March 1993

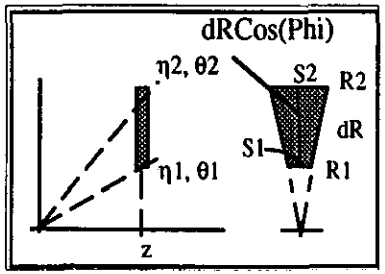
SW 18-Feb-93

Layout changed by F. Nimblett 03 March 1993

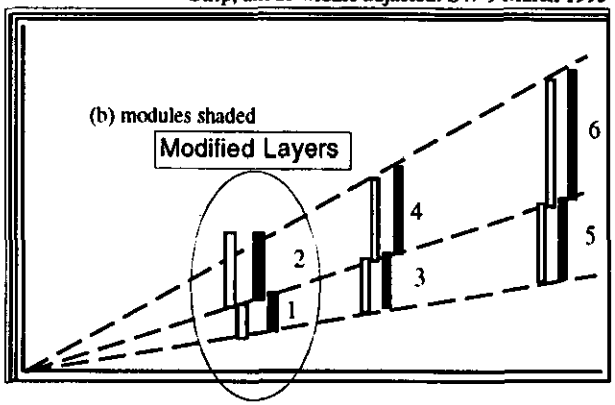
Strip, anode widths adjusted: SW 9 March 1993

core thickness (mm) =	20.00
in-tower intermd space (m) =	0.05
intertower space (m) =	0.15
anode ch modularity =	4
anode ch overlap =	1
strip ch modularity =	16
strip ch overlap =	3
neutron flux (Hz/cm^2) =	10,000
neutron efficiency =	0.005

Nomenclature:



Note: modules (a) occupy even-numbered sectors
modules (b) occupy odd-numbered sectors
Nsctrs/2 are type (a) and Nsctrs/2 are type (b)

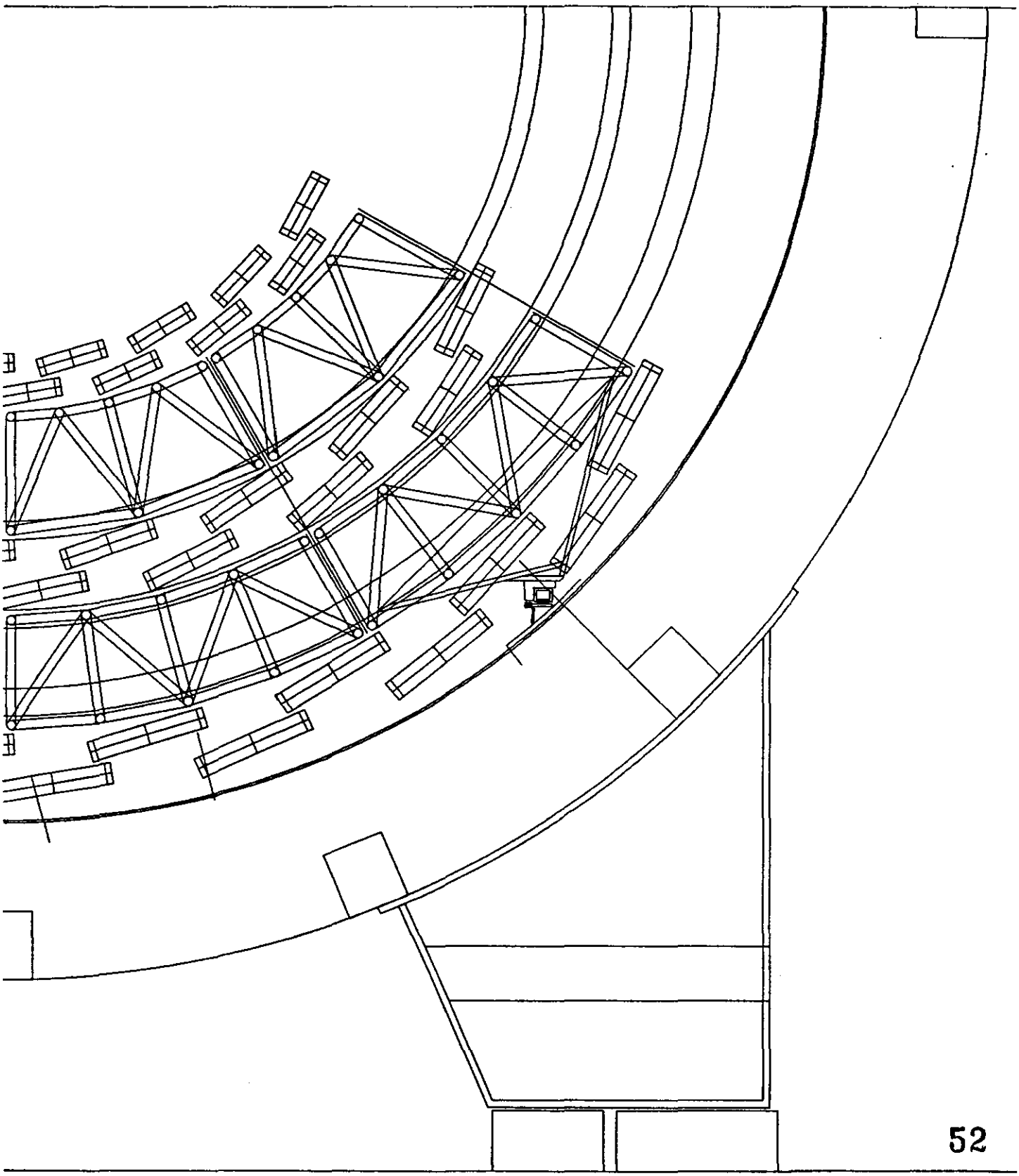


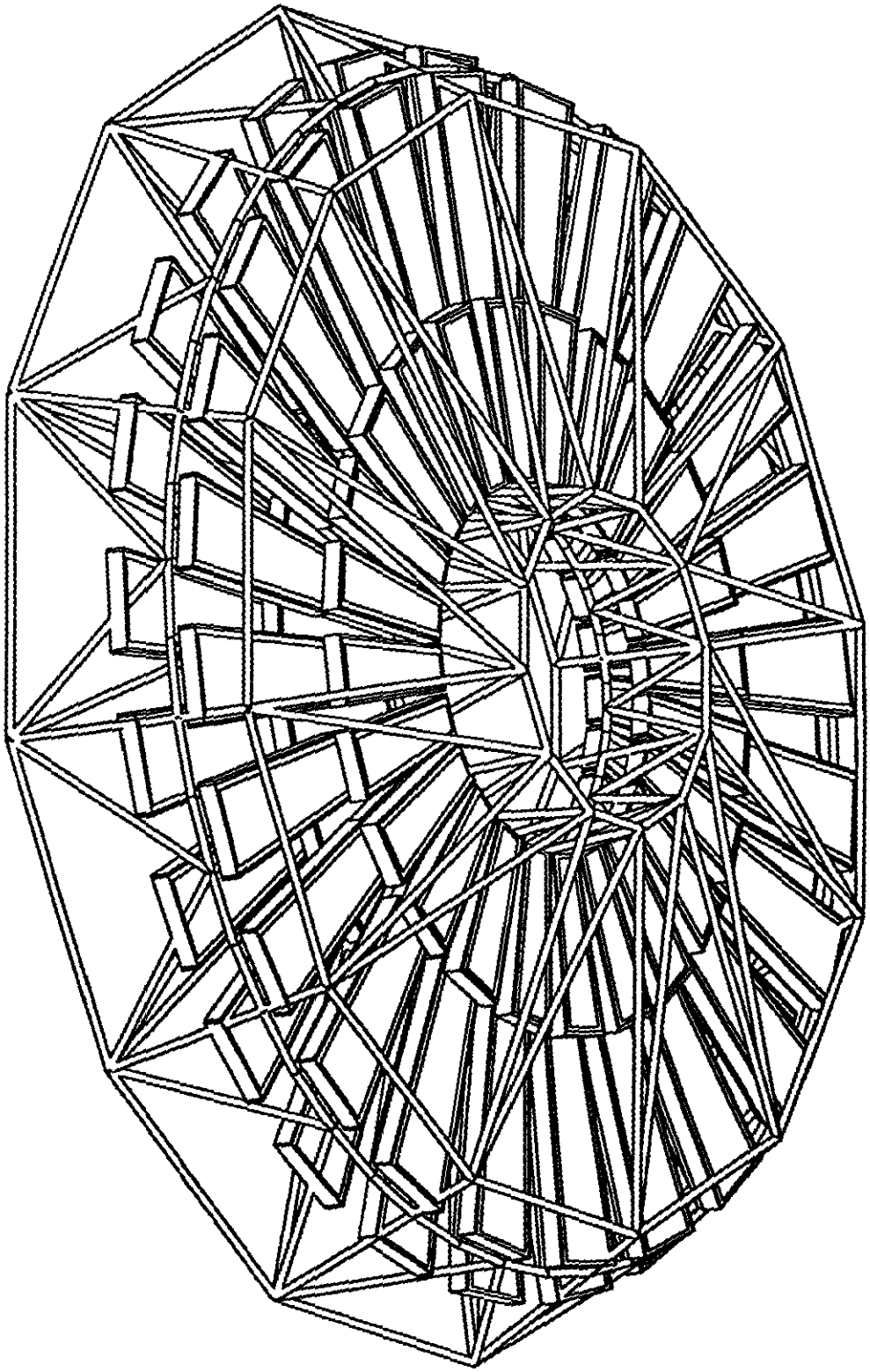
Mike Harris Arrangement + F. Nimblett Extend

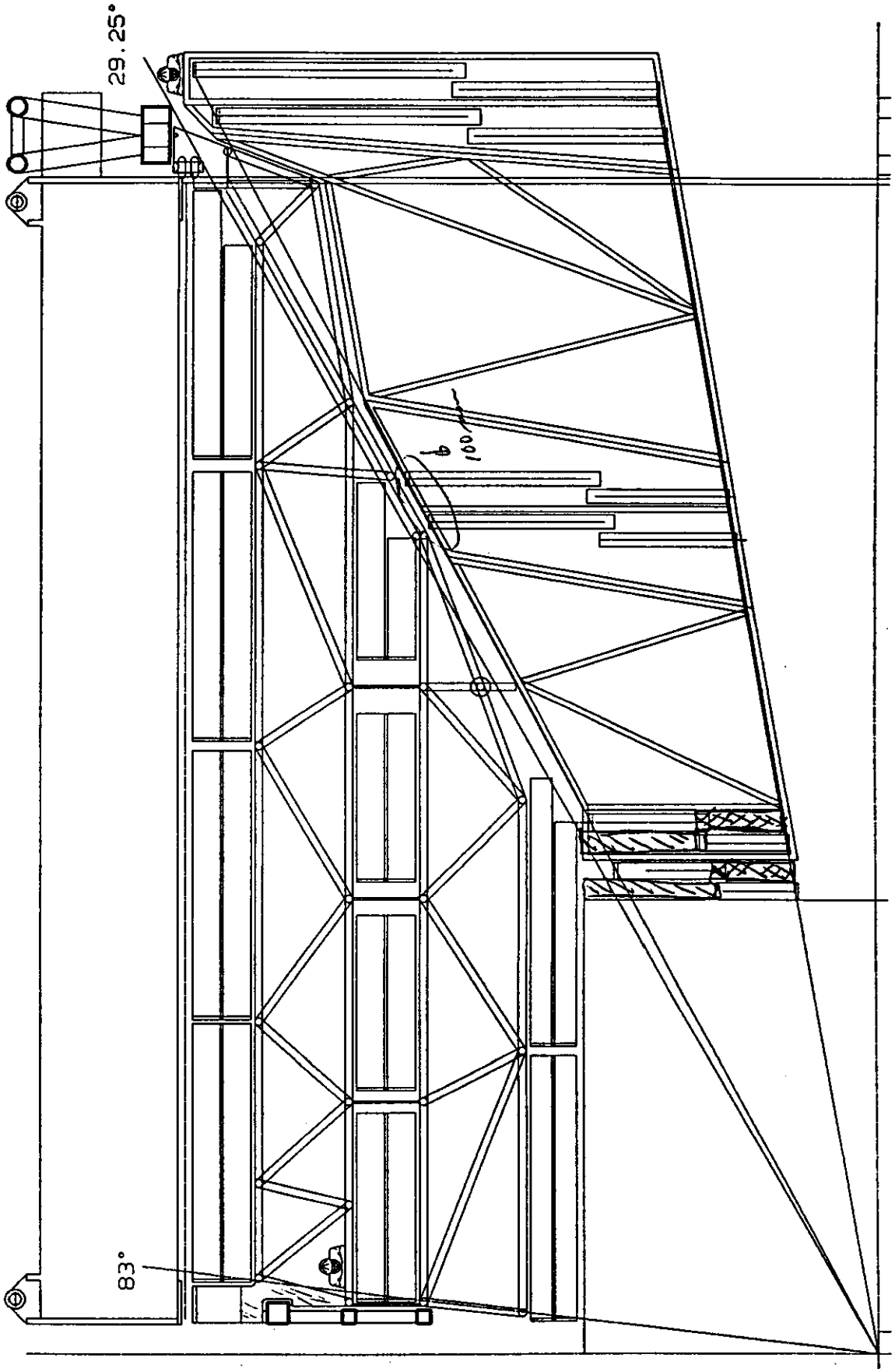
New Extended Layout (30° Coverage) F. Nimblett 17 Mar 93

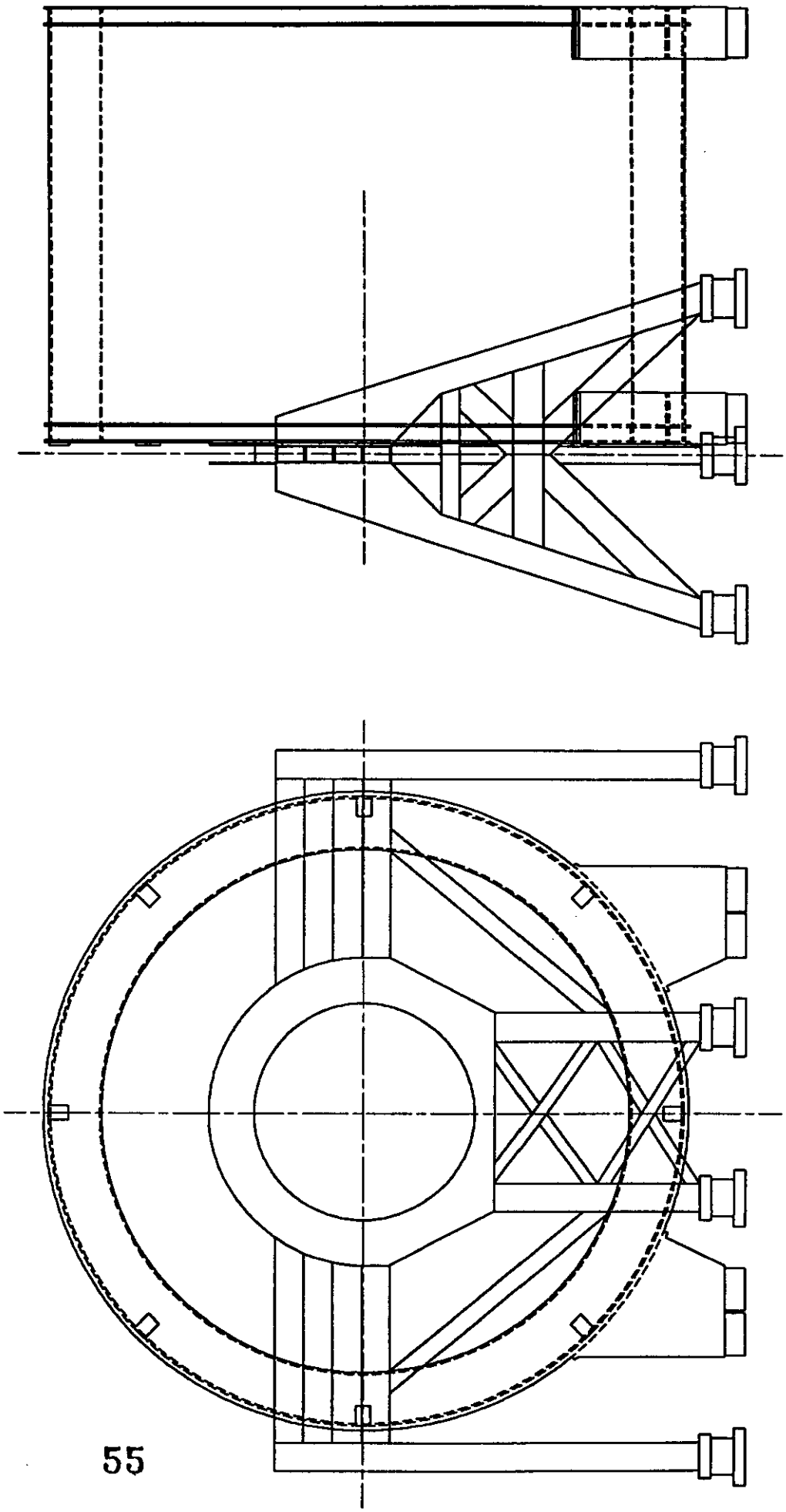
	ngaps	gas gap mm	modth m	zfr m	zba m	n1	θ1 deg	n2	θ2 deg	# sctrs	R1 m	R2 m	dR m	S1 m	S2 m	calc str wd mm	# strips /pl/sctr	nom'nl wire gp cm	calc wiregp cm	# r-ch /pl/sctr	Total ch counts: # str ch	# r ch	single strip occ ch. pt. /sec	neut. /sec	~worst case anode ch occ ch. pt /sec	neut /sec
Inner modules																										
1a)	8	5.0	0.220	6.270	6.490	2.46	9.75	1.84	18.05	24	1.0959	2.0789	0.9830	0.2965	0.5624	4.5	96	5.0	4.9	20	18,432	3,840	177	2,458	2,039	10,735
1b)	8	5.0	0.220	6.910	7.130	2.46	9.75	1.84	18.05	24	1.2059	2.2875	1.0816	0.3252	0.6168	4.9	96	5.0	4.5	24	18,432	4,608	214	2,704	2,051	11,774
2a)	8	5.0	0.220	6.000	6.220	1.86	17.63	1.25	31.88	24	1.9413	3.8000	1.8587	0.5169	1.0119	4.8	160	5.0	4.6	40	30,720	7,680	33	4,647	307	19,110
2b)	8	5.0	0.220	6.640	6.860	1.86	17.67	1.34	29.38	24	2.1497	3.8000	1.6503	0.5720	1.0112	4.9	160	5.0	4.6	36	30,720	6,912	36	4,126	333	19,790
Middle modules																										
3a)	6	7.0	0.182	10.650	10.832	2.46	9.75	1.84	18.05	48	1.8451	3.5000	1.6549	0.2558	0.4853	5.8	64	7.0	6.9	24	18,432	6,912	87	5,792	555	12,970
3b)	6	7.0	0.182	11.214	11.396	2.46	9.75	1.84	18.05	48	1.9419	3.6838	1.7418	0.2685	0.5094	6.1	64	7.0	6.2	28	18,432	8,064	96	6,096	526	13,613
4a)	6	7.0	0.182	10.882	11.064	1.86	17.72	1.40	27.71	48	3.5052	5.7622	2.2570	0.4744	0.7798	6.5	96	7.0	7.1	32	27,648	9,216	17	7,900	94	21,949
4b)	6	7.0	0.182	11.446	11.628	1.86	17.73	1.40	27.71	48	3.6889	6.0579	2.3689	0.4984	0.8185	6.9	96	7.0	6.6	36	27,648	10,368	18	8,291	92	23,046
Outer modules																										
5a)	6	10.0	0.200	15.950	16.150	2.46	9.75	1.84	18.05	48	2.7568	5.2295	2.4727	0.3813	0.7233	8.6	64	10.0	8.8	28	18,432	8,064	65	12,364	353	27,617
5b)	6	10.0	0.200	16.550	16.750	2.46	9.75	1.84	18.05	48	2.8599	5.4250	2.5652	0.3948	0.7489	8.9	64	10.0	9.2	28	18,432	8,064	69	12,826	380	28,593
6a)	6	10.0	0.200	16.200	16.400	1.86	17.73	1.40	27.71	48	5.2102	8.5588	3.3486	0.7042	1.1568	9.7	96	10.0	9.3	36	27,648	10,368	12	16,743	61	46,527
6b)	6	10.0	0.200	16.800	17.000	1.86	17.74	1.40	27.71	48	5.4056	8.8739	3.4682	0.7298	1.1980	10.0	96	10.0	9.6	36	27,648	10,368	13	17,341	66	48,196
																					Total =>	282,624		94,464		

total area of strip cathodes (m^2)	4592.8
total volume of chambers (m^3)	23.0
Total number of modules	480

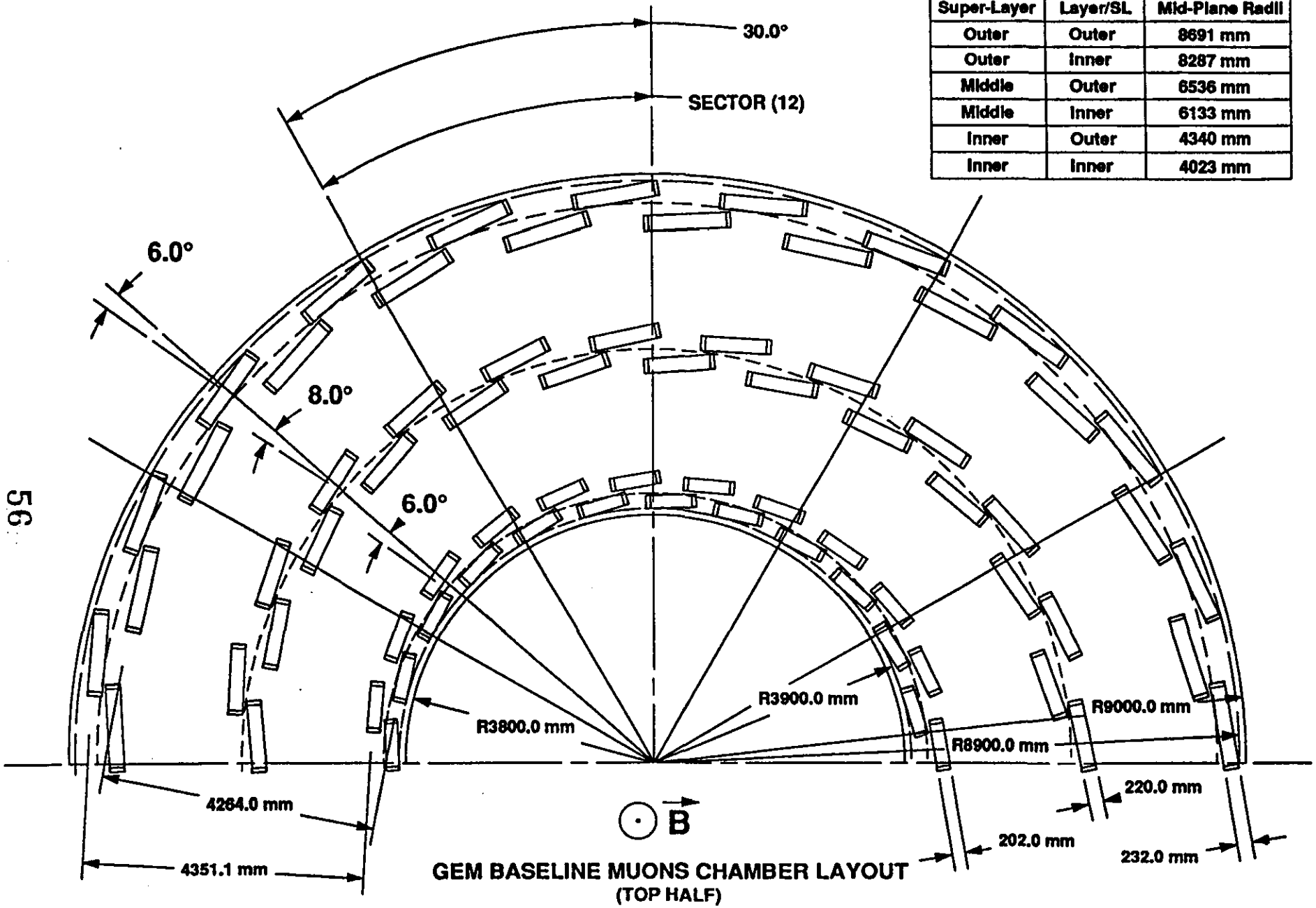





29.25°
83°



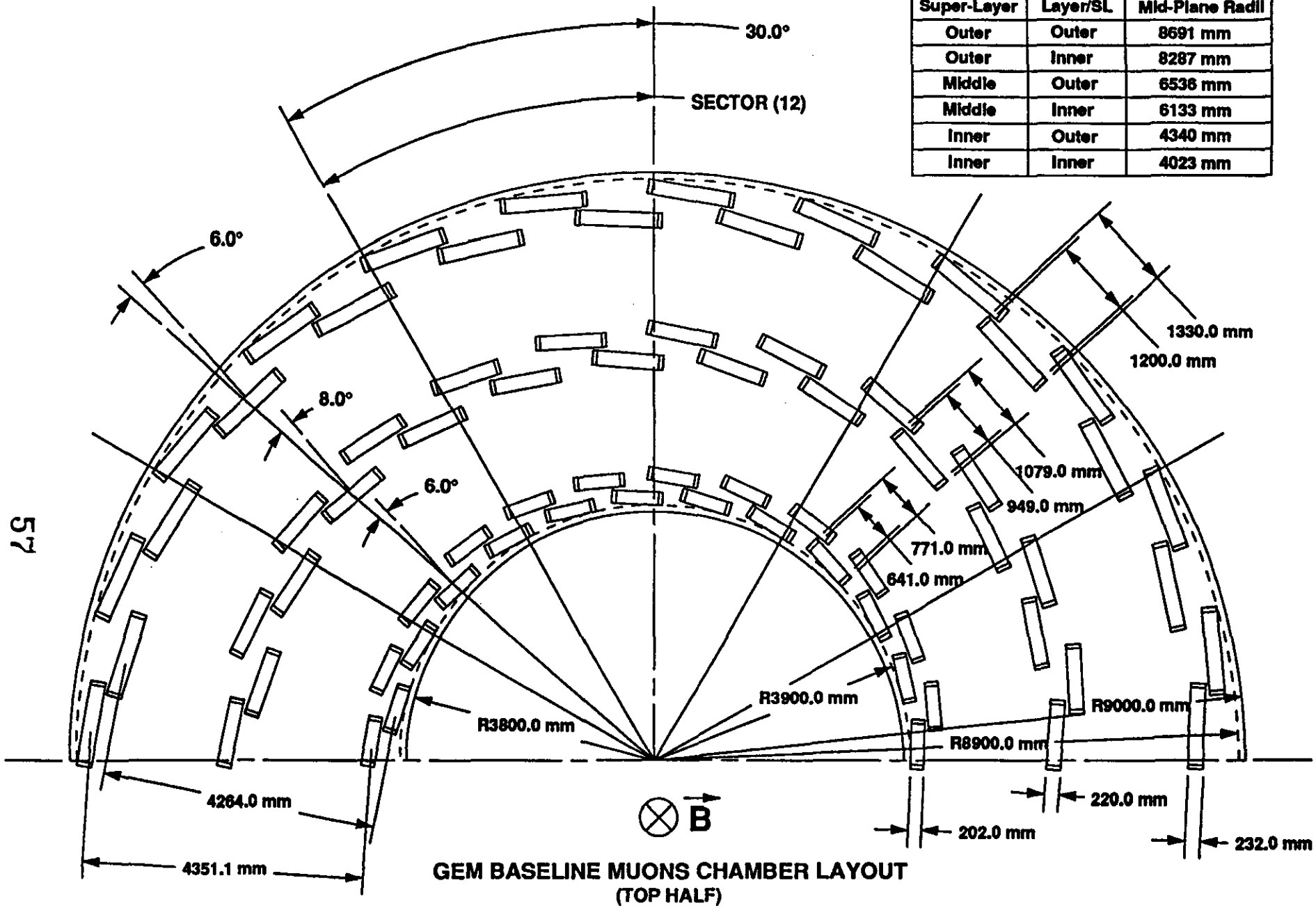
Super-Layer	Layer/SL	Mid-Plane Radii
Outer	Outer	8691 mm
Outer	Inner	8287 mm
Middle	Outer	6536 mm
Middle	Inner	6133 mm
Inner	Outer	4340 mm
Inner	Inner	4023 mm



GEM BASELINE MUONS CHAMBER LAYOUT
(TOP HALF)
(CCW TILTED MAGNET END)

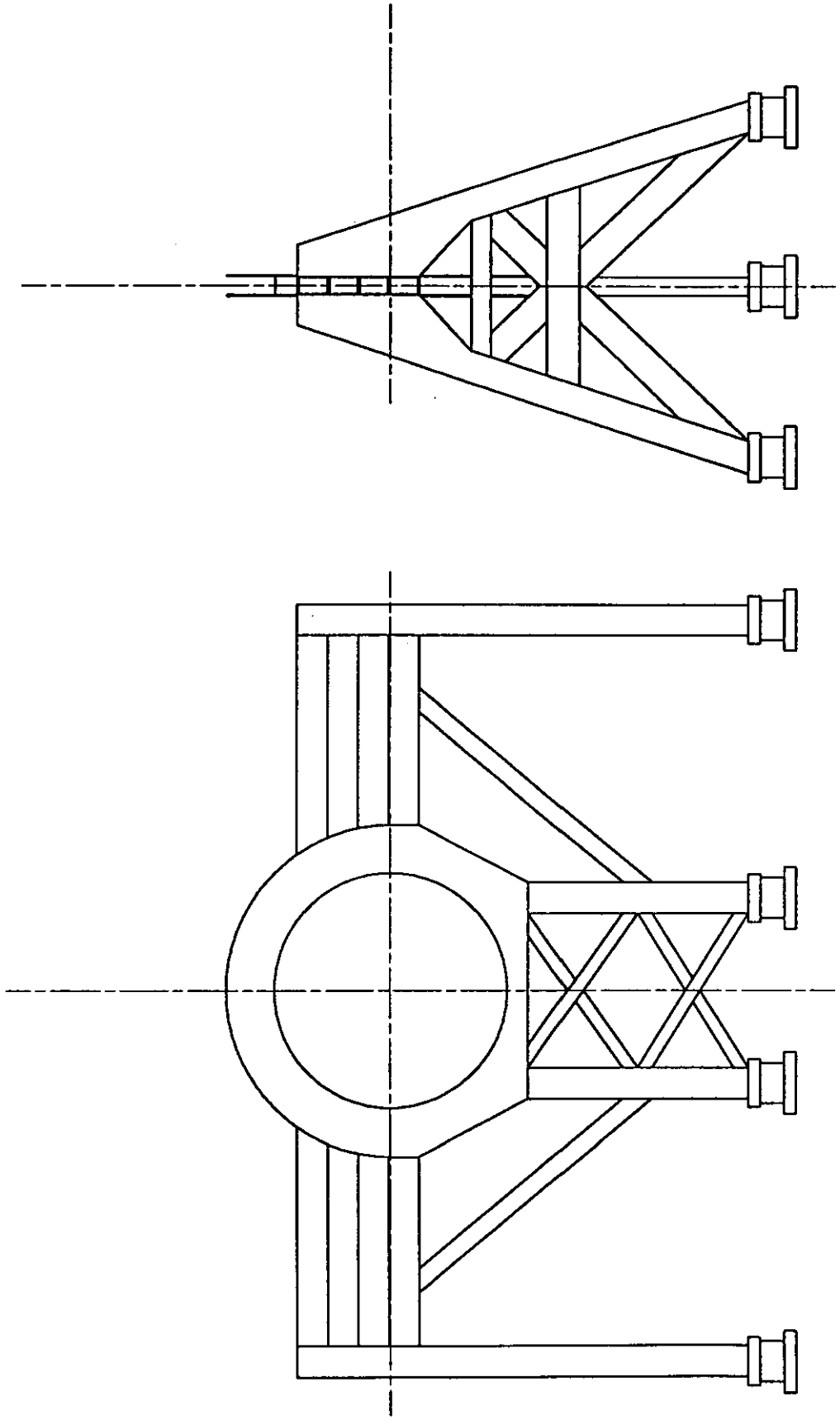
F. Nimblett
03 March 1993

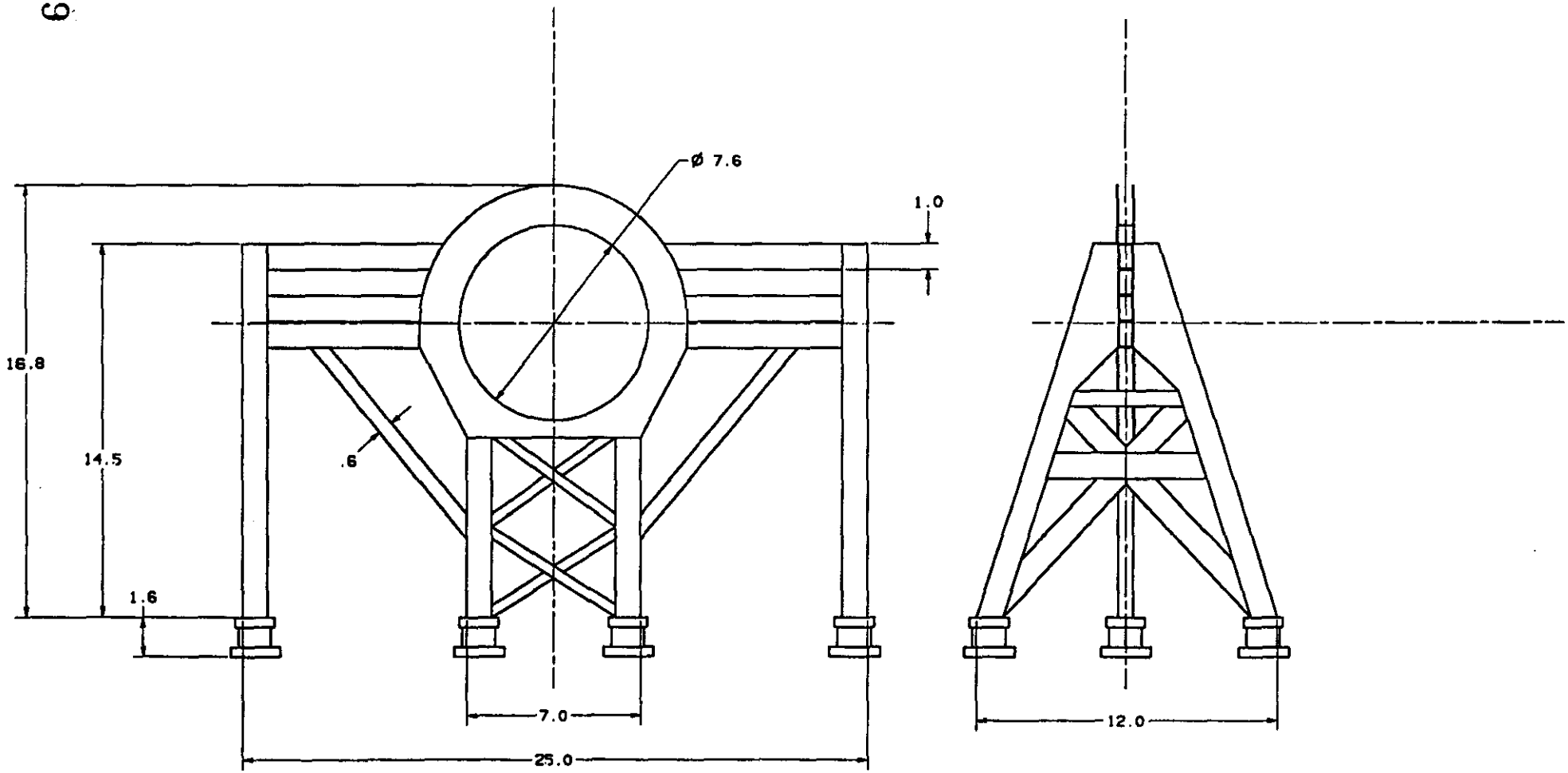
Super-Layer	Layer/SL	Mid-Plane Radii
Outer	Outer	8691 mm
Outer	Inner	8287 mm
Middle	Outer	6536 mm
Middle	Inner	6133 mm
Inner	Outer	4340 mm
Inner	Inner	4023 mm

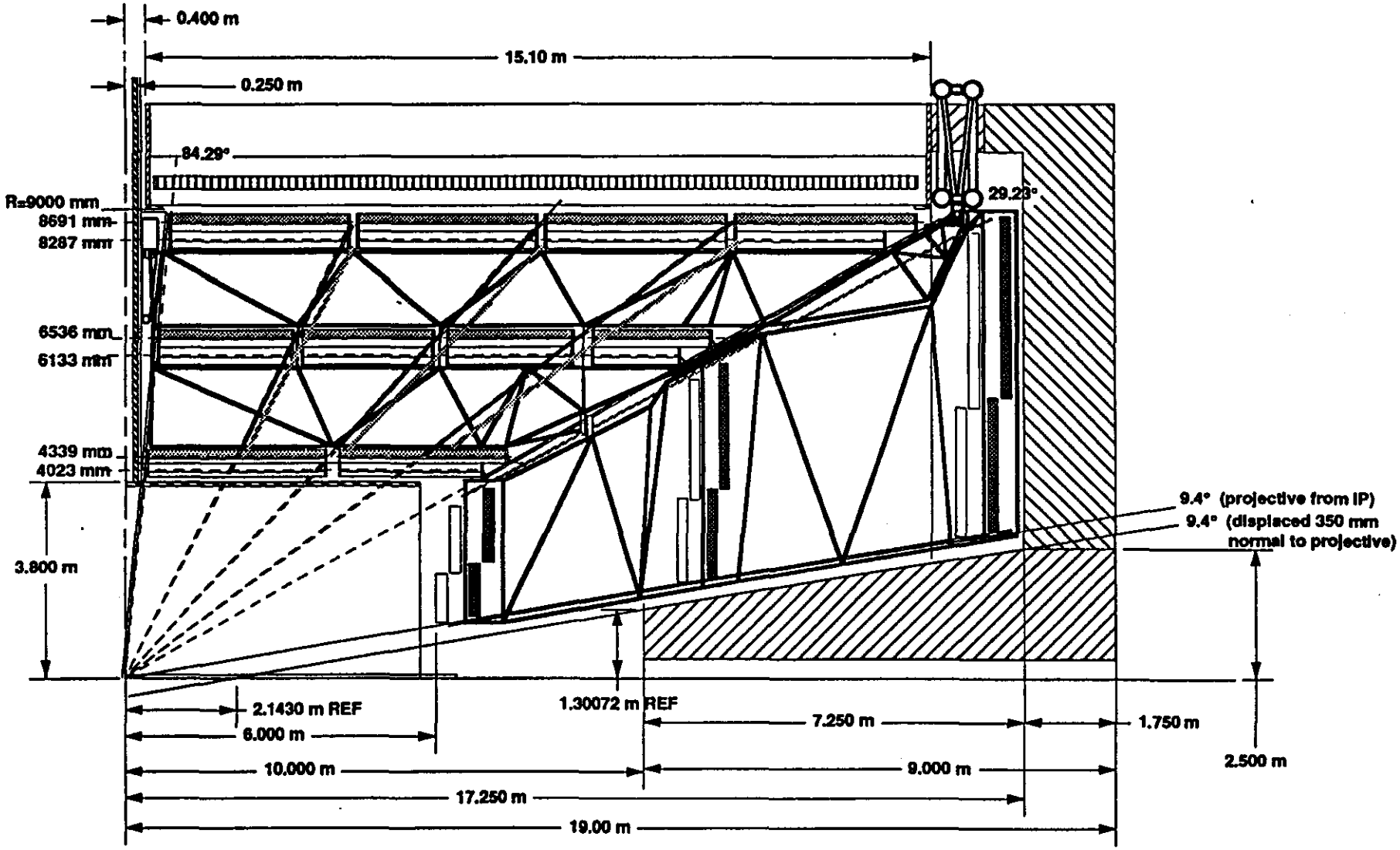


GEM BASELINE MUONS CHAMBER LAYOUT
(TOP HALF)
(CW TILTED, MAGNET END "A")

F. Nimblett
03 March 1993



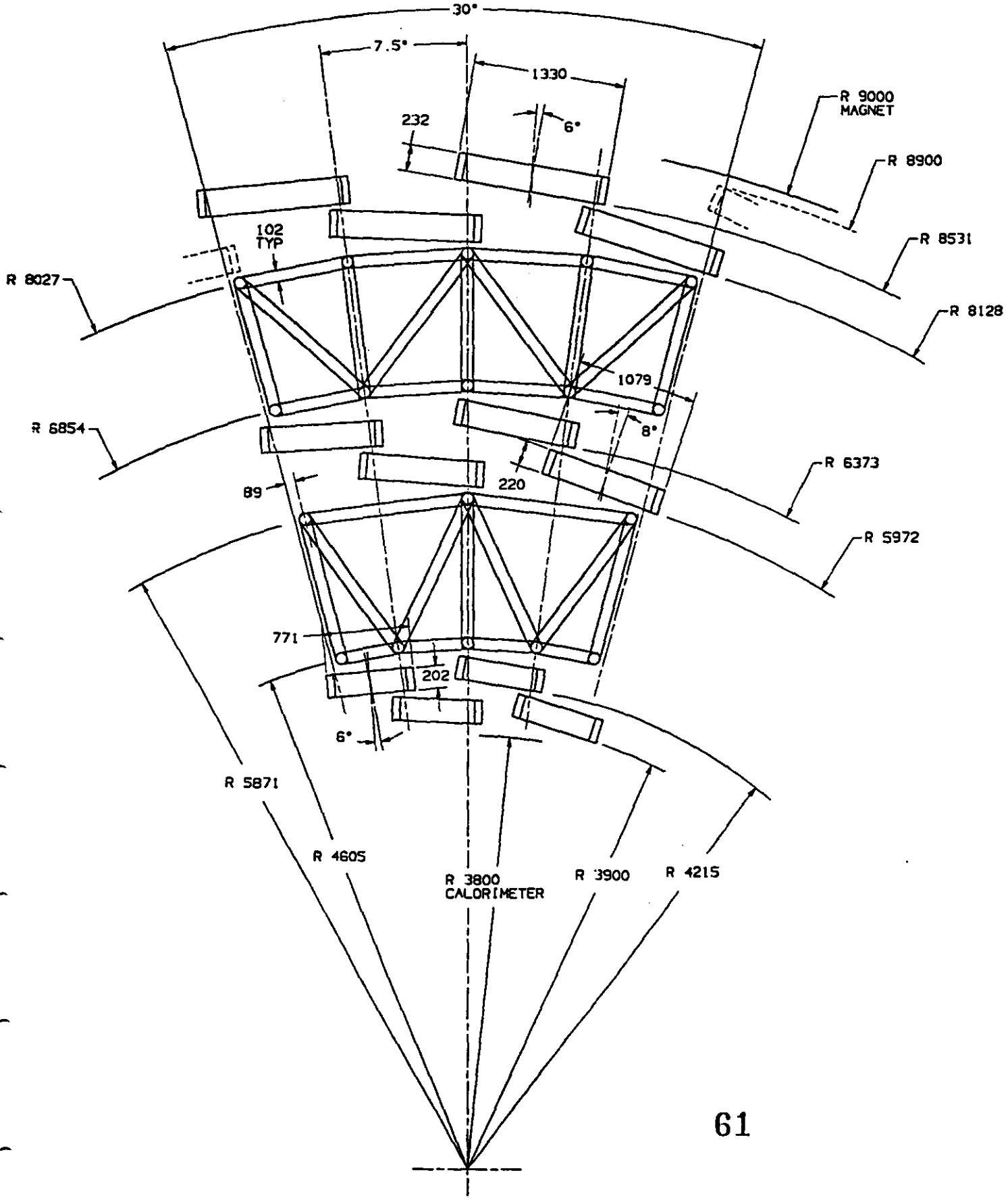

Ø 7.6
1.0
16.8
14.5
.6
1.6
7.0
25.0
12.0

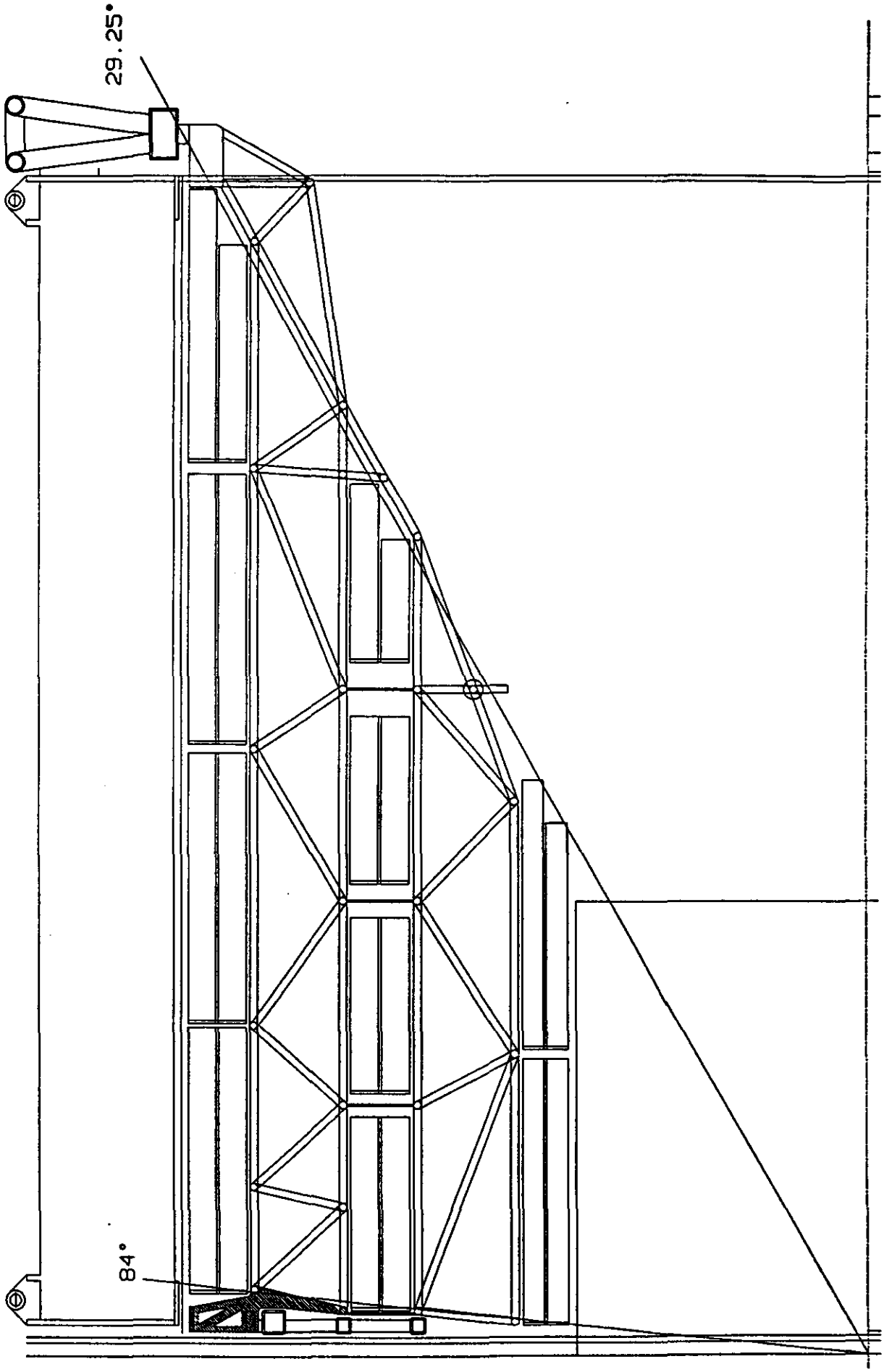


60

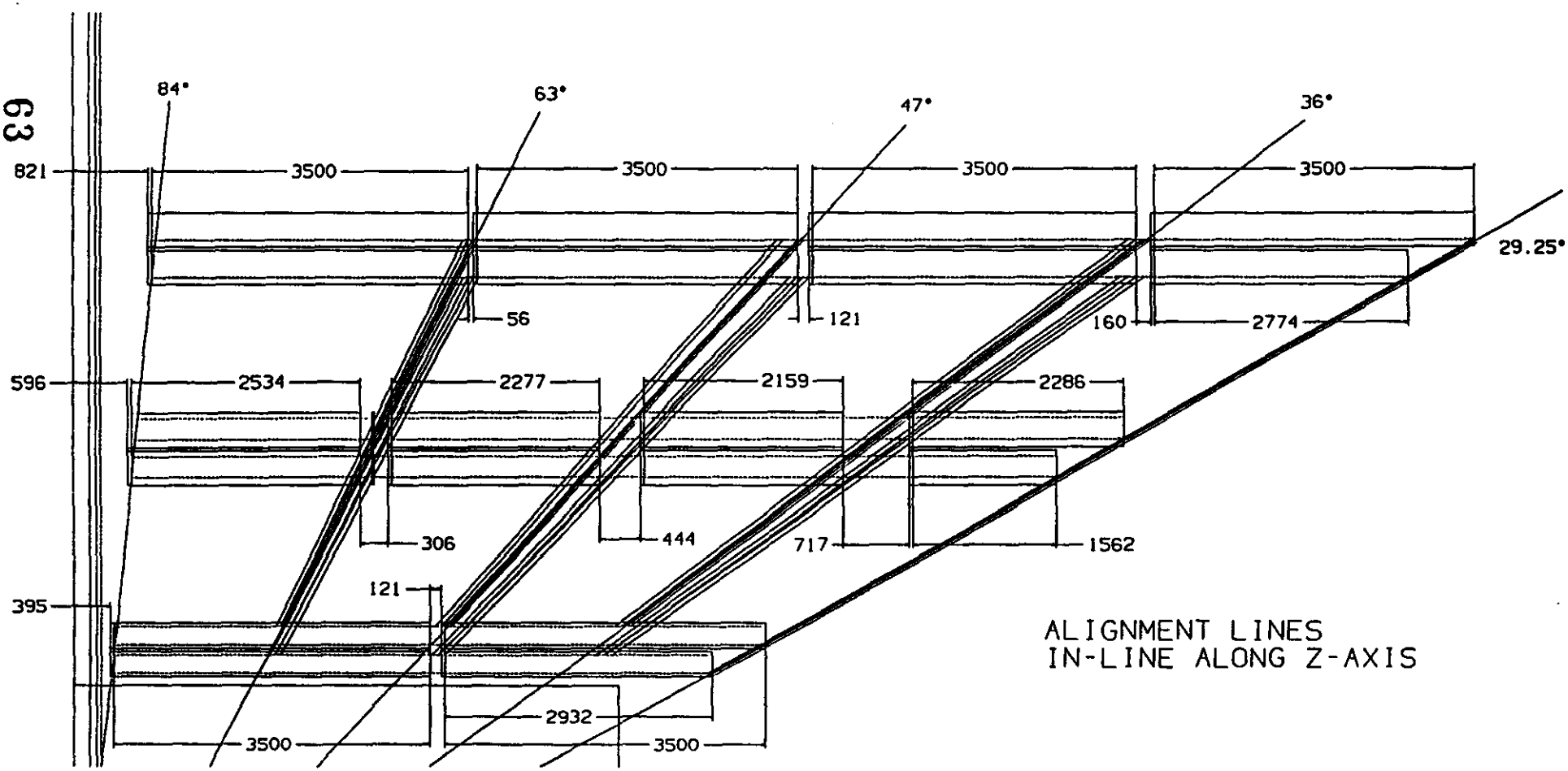
PROJECTIVE ALIGNMENT WITH RADIAL SUPPORT PLATES IN BARREL (NEW FFS)

F. Nimblett
13 March 1993

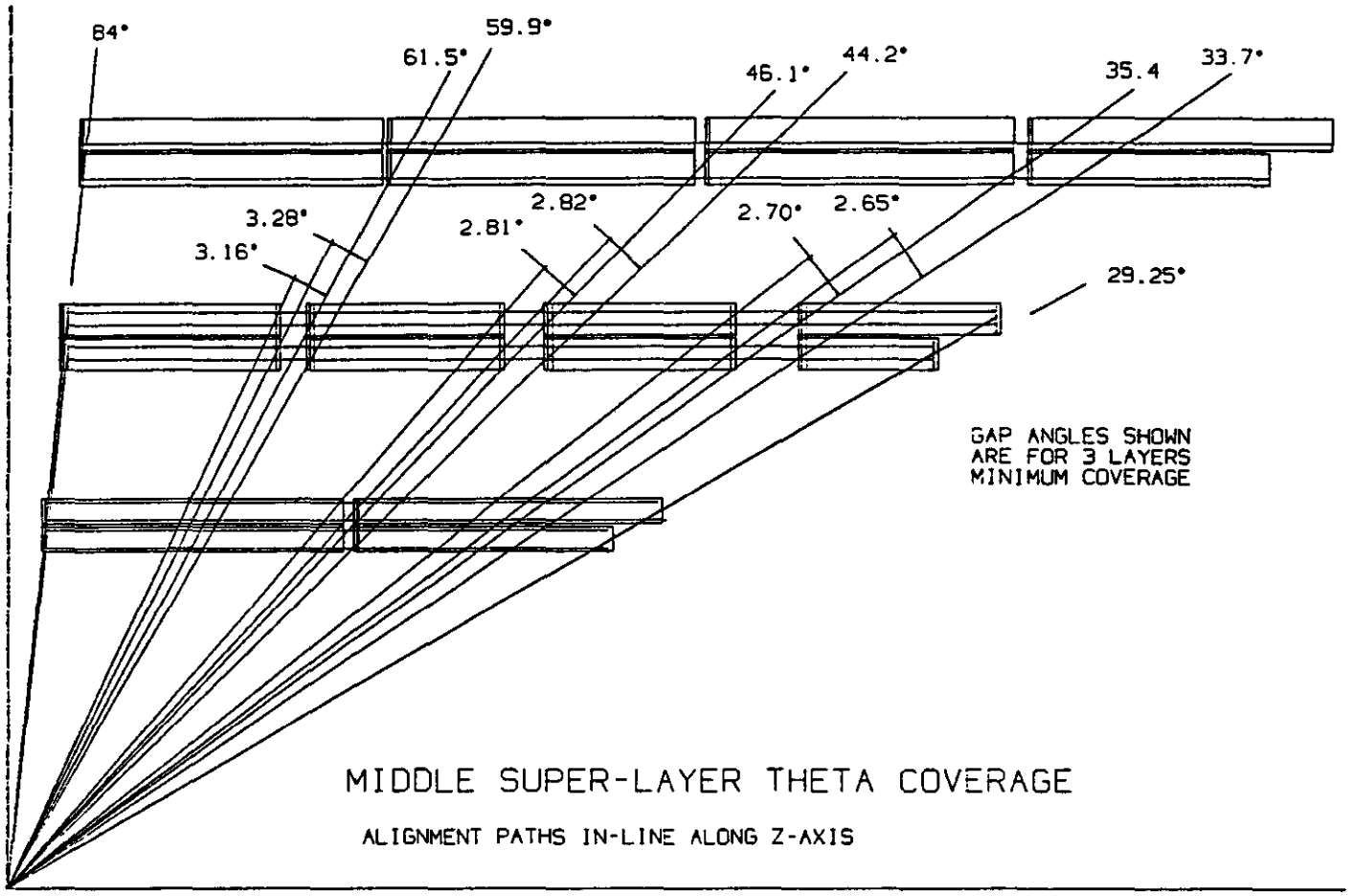

30°
7.5°
1330
232
6°
R 9000
MAGNET
R 8900
R 8531
R 8128
102
TYP
R 8027
1079
8°
R 6854
R 6373
220
89
R 5972
771
202
6°
R 5871
R 4605
R 3800
CALORIMETER
R 3900
R 4215

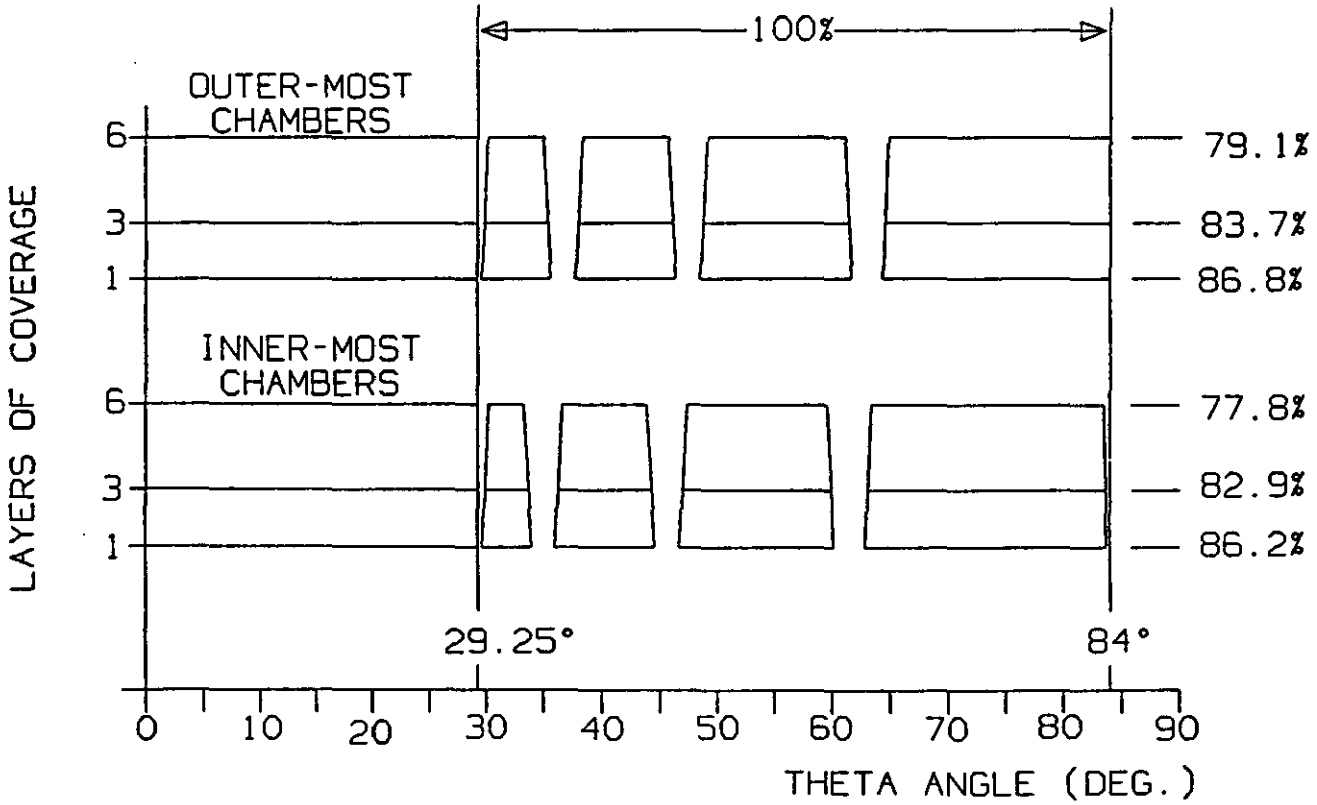

29.25°
84°

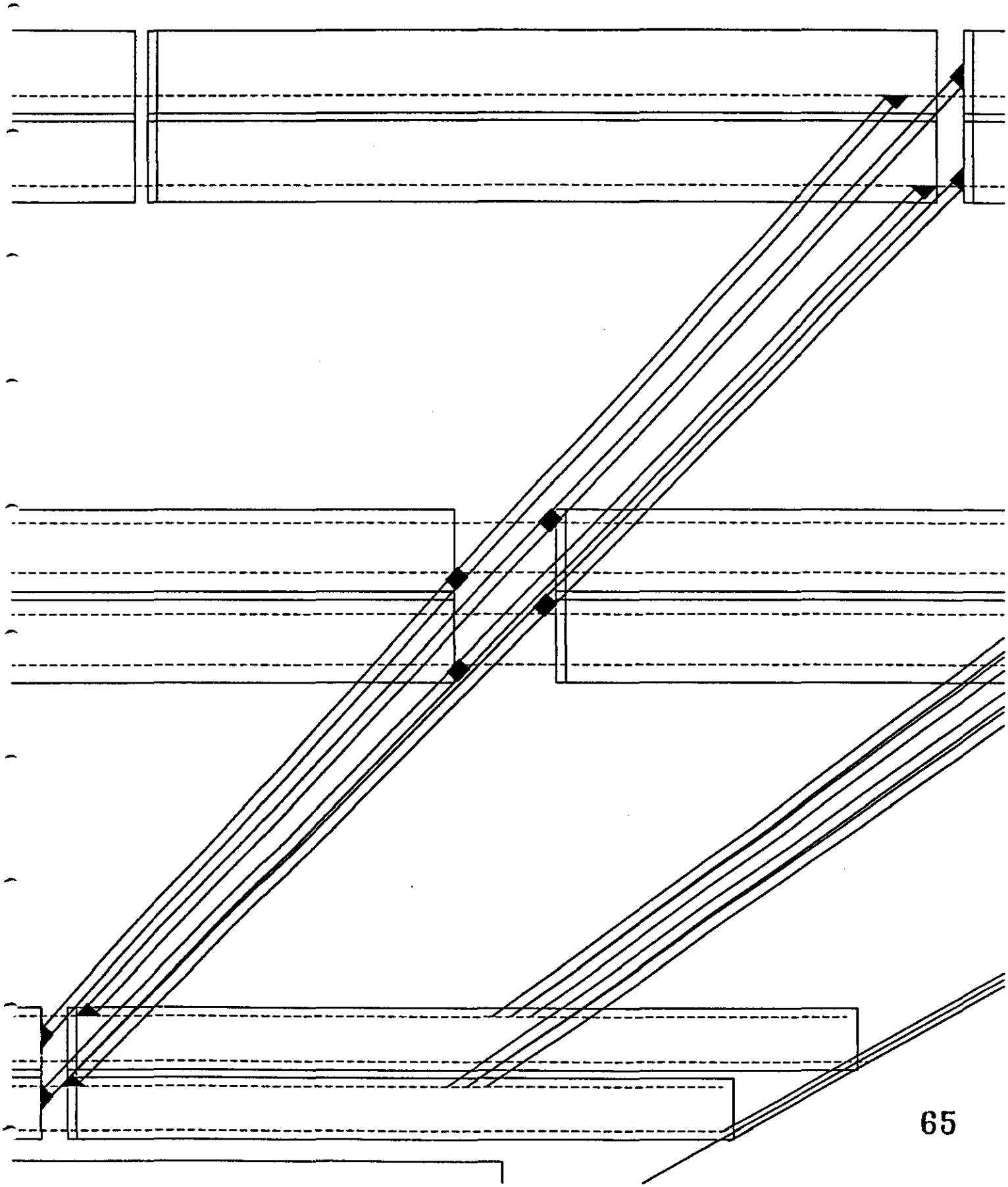
SUPER LAYER	LAYER	MID RADIUS (mm)
OUTER	OUTER	8691
	INNER	8287
MIDDLE	OUTER	6536
	INNER	6133
INNER	OUTER	4340
	INNER	4023

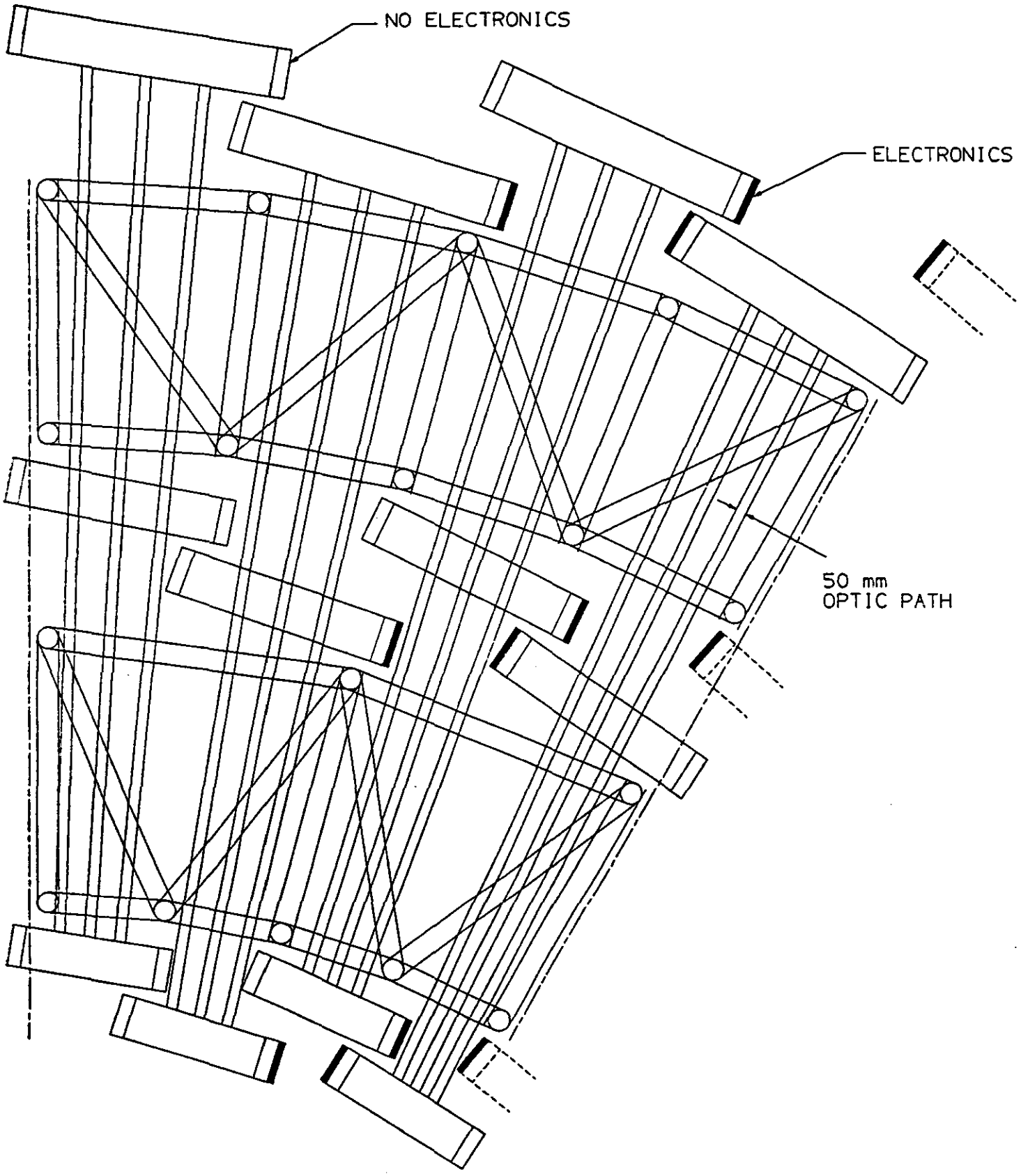


ALIGNMENT LINES
IN-LINE ALONG Z-AXIS

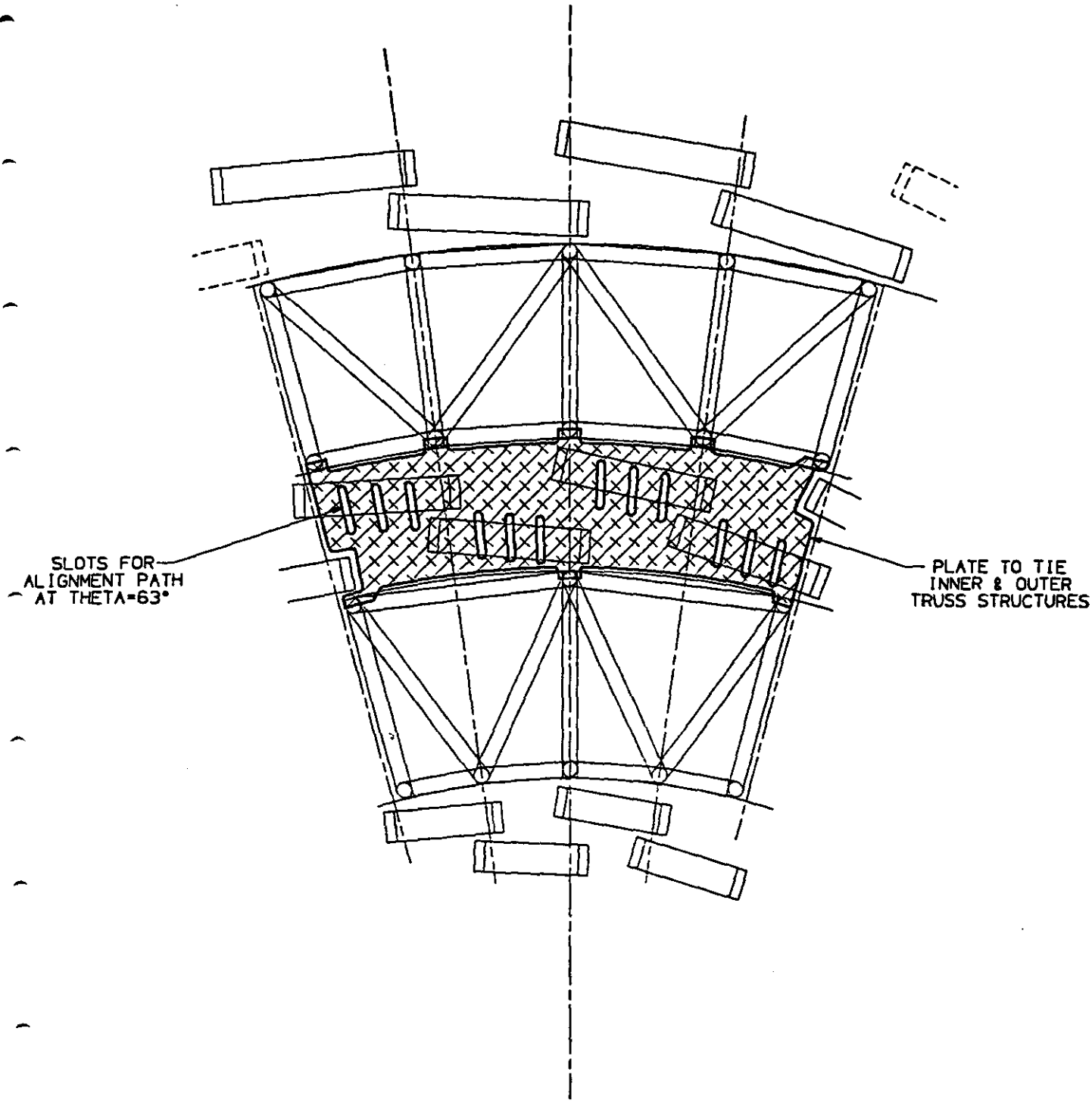

84°
61.5°
59.9°
46.1°
44.2°
35.4
33.7°
3.28°
3.16°
2.81°
2.82°
2.70°
2.65°
29.25°
GAP ANGLES SHOWN
ARE FOR 3 LAYERS
MINIMUM COVERAGE
MIDDLE SUPER-LAYER THETA COVERAGE
ALIGNMENT PATHS IN-LINE ALONG Z-AXIS


100%
OUTER-MOST
CHAMBERS
INNER-MOST
CHAMBERS
LAYERS OF COVERAGE
6
3
1
79.1%
83.7%
86.8%
77.8%
82.9%
86.2%
29.25°
84°
0
10
20
30
40
50
60
70
80
90
THETA ANGLE (DEG.)



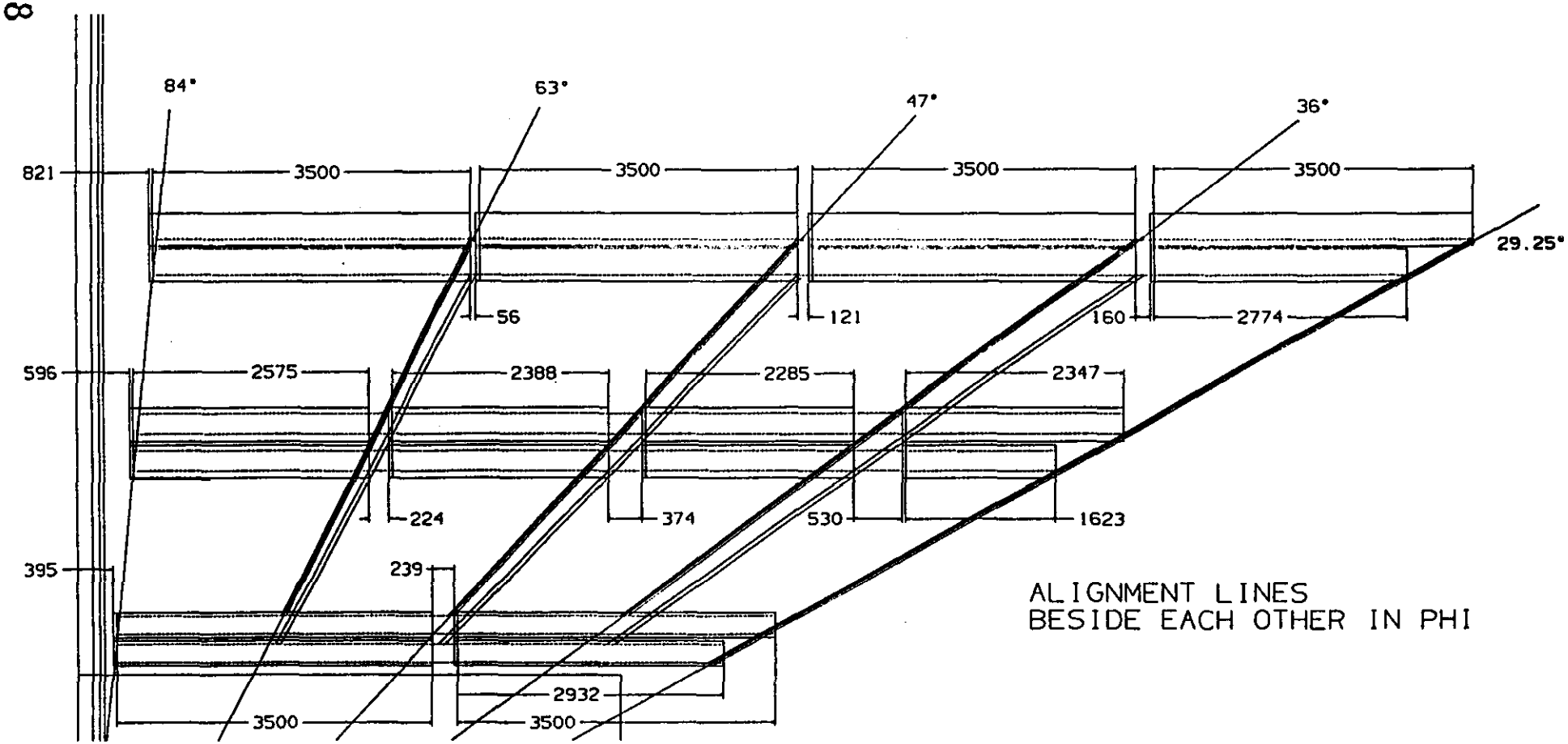


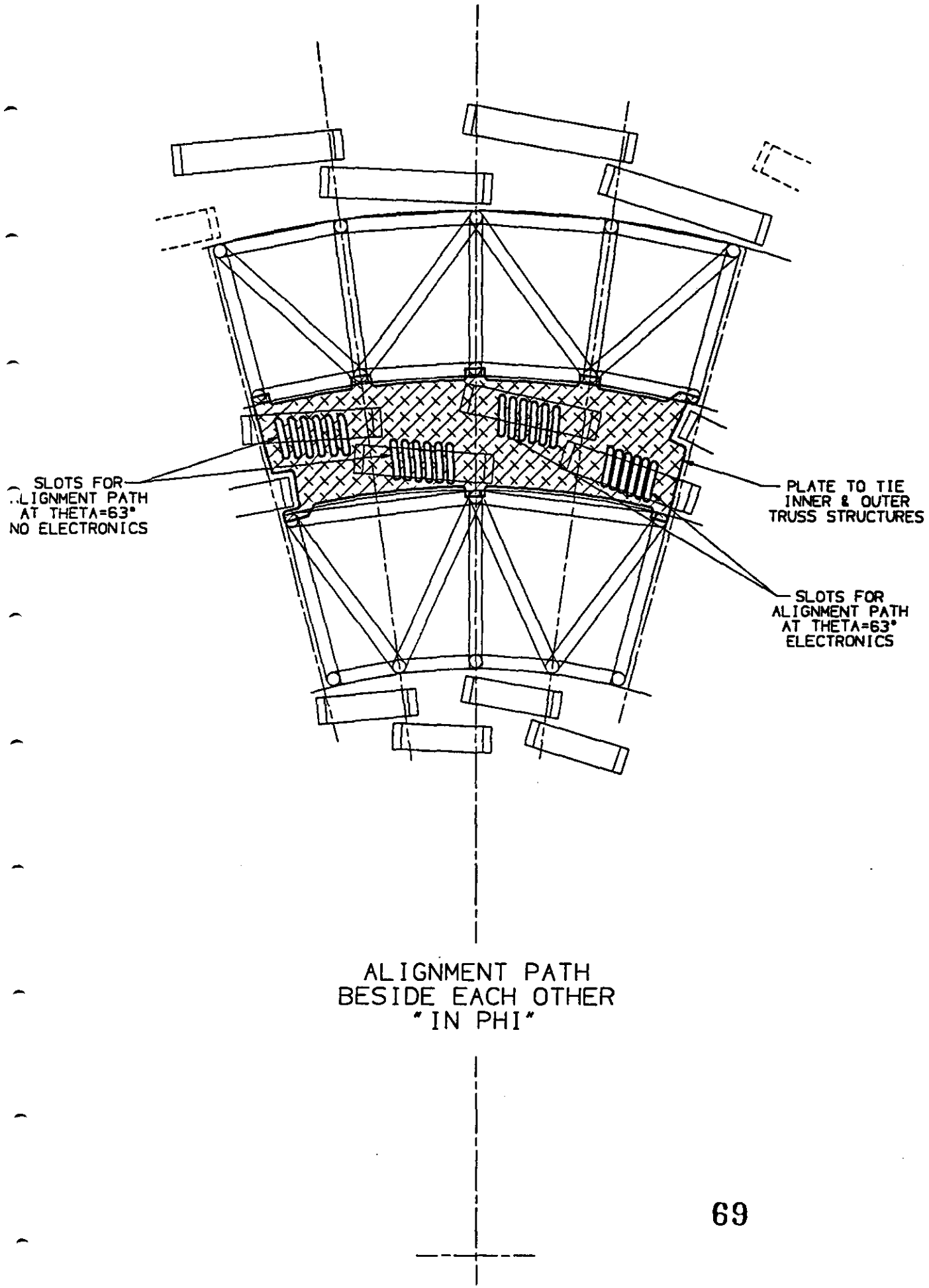
ALIGNMENT LINES
IN-LINE ALONG
Z-AXIS



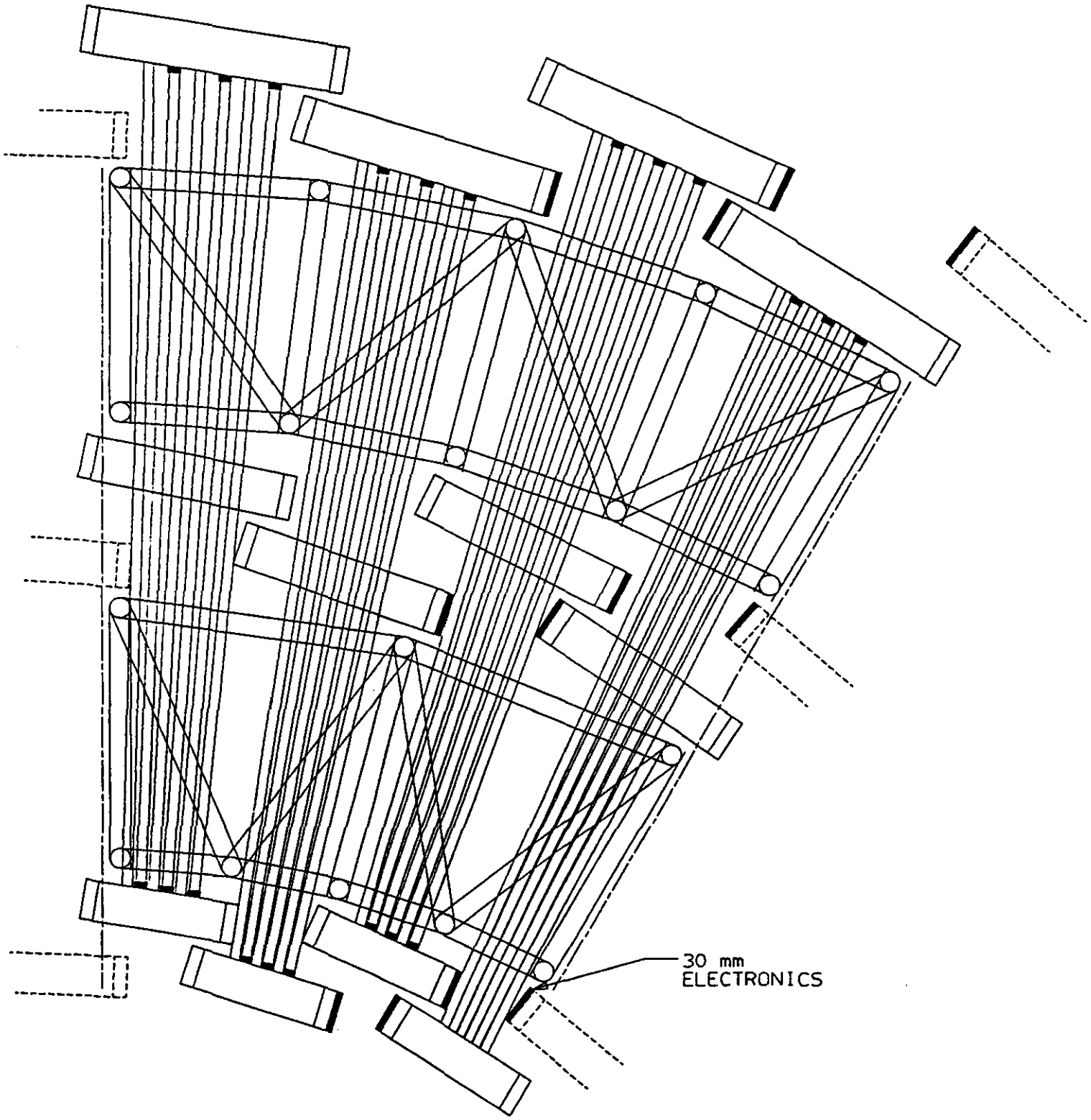
ALIGNMENT PATH
IN-LINE ALONG
"Z-AXIS"

SUPER LAYER	LAYER	MID RADIUS (mm)
OUTER	OUTER	8691
	INNER	8287
MIDDLE	OUTER	6536
	INNER	6133
INNER	OUTER	4340
	INNER	4023

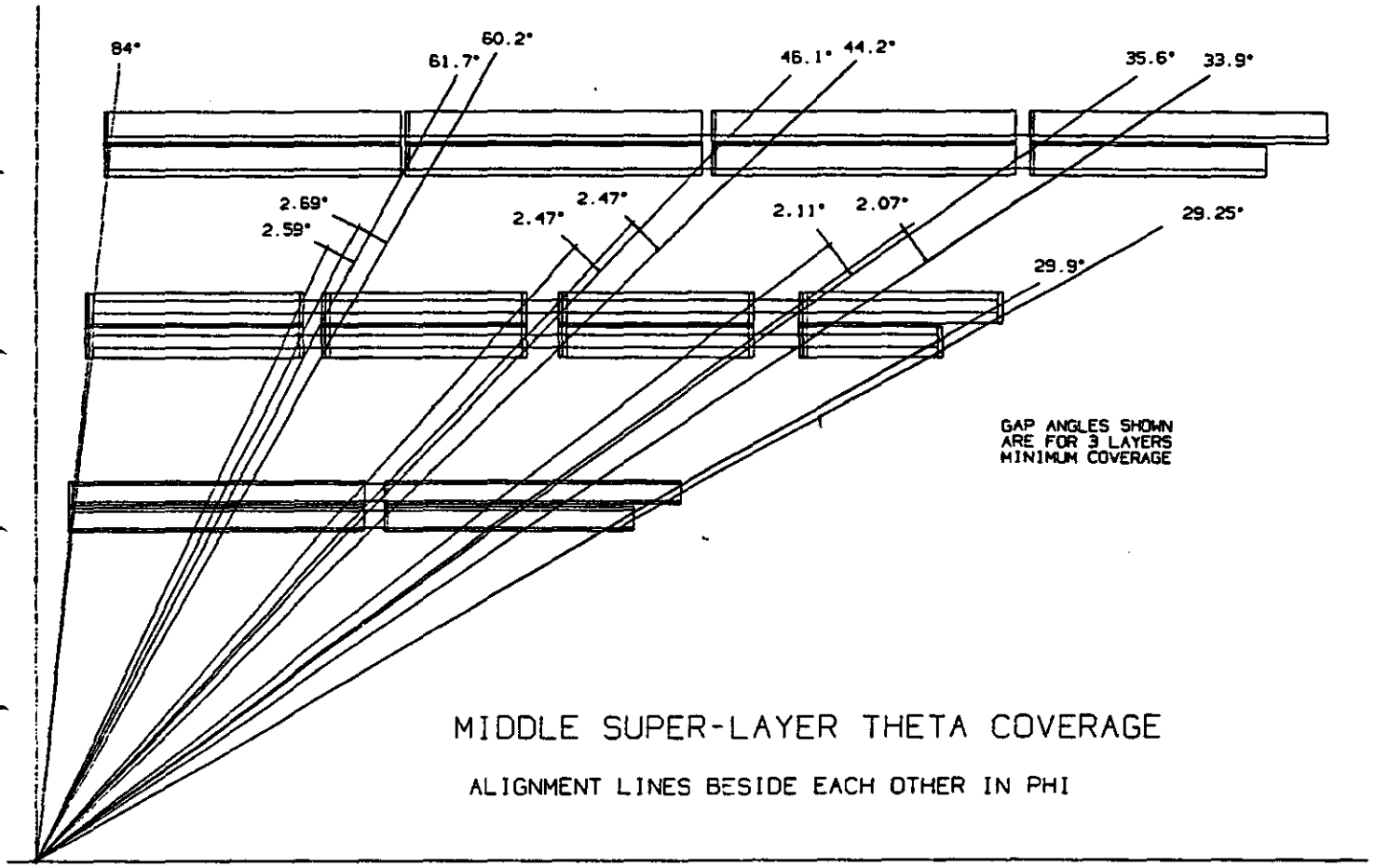


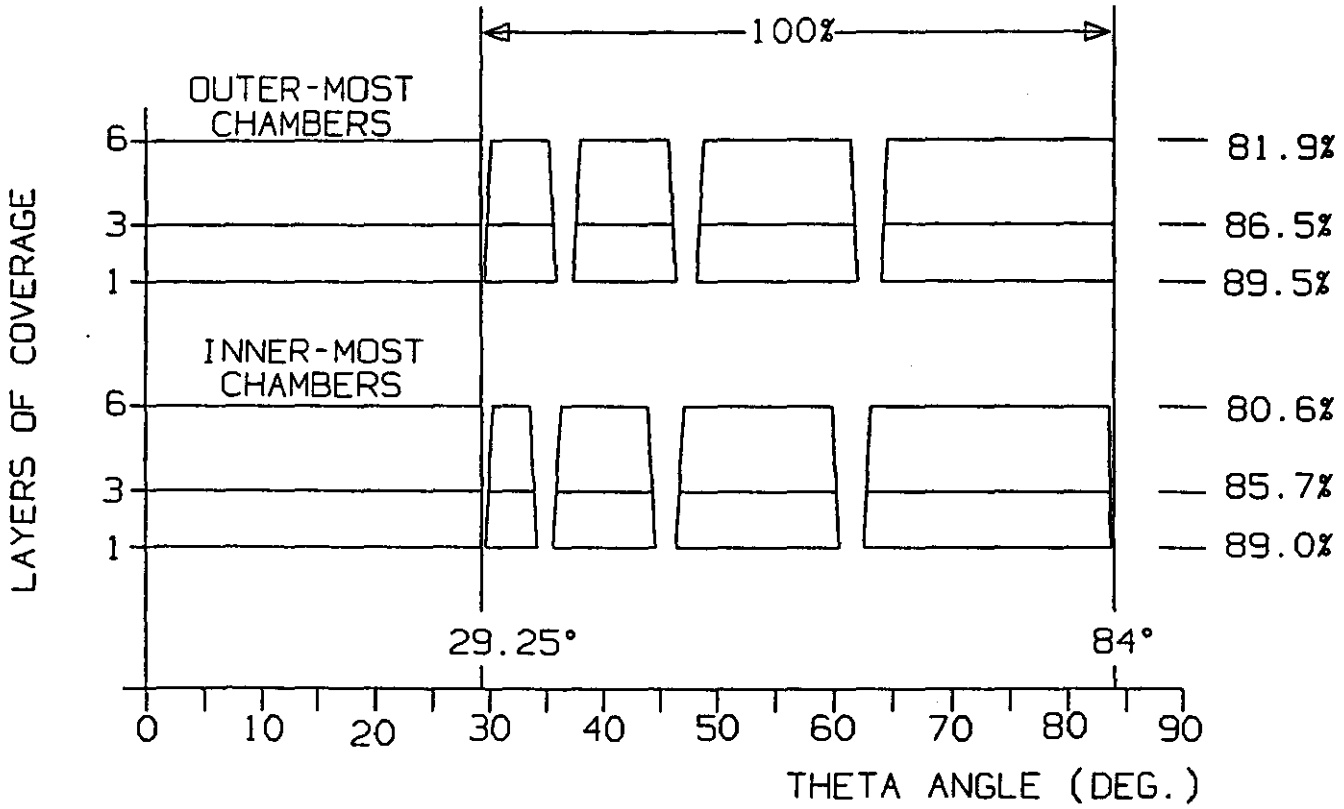


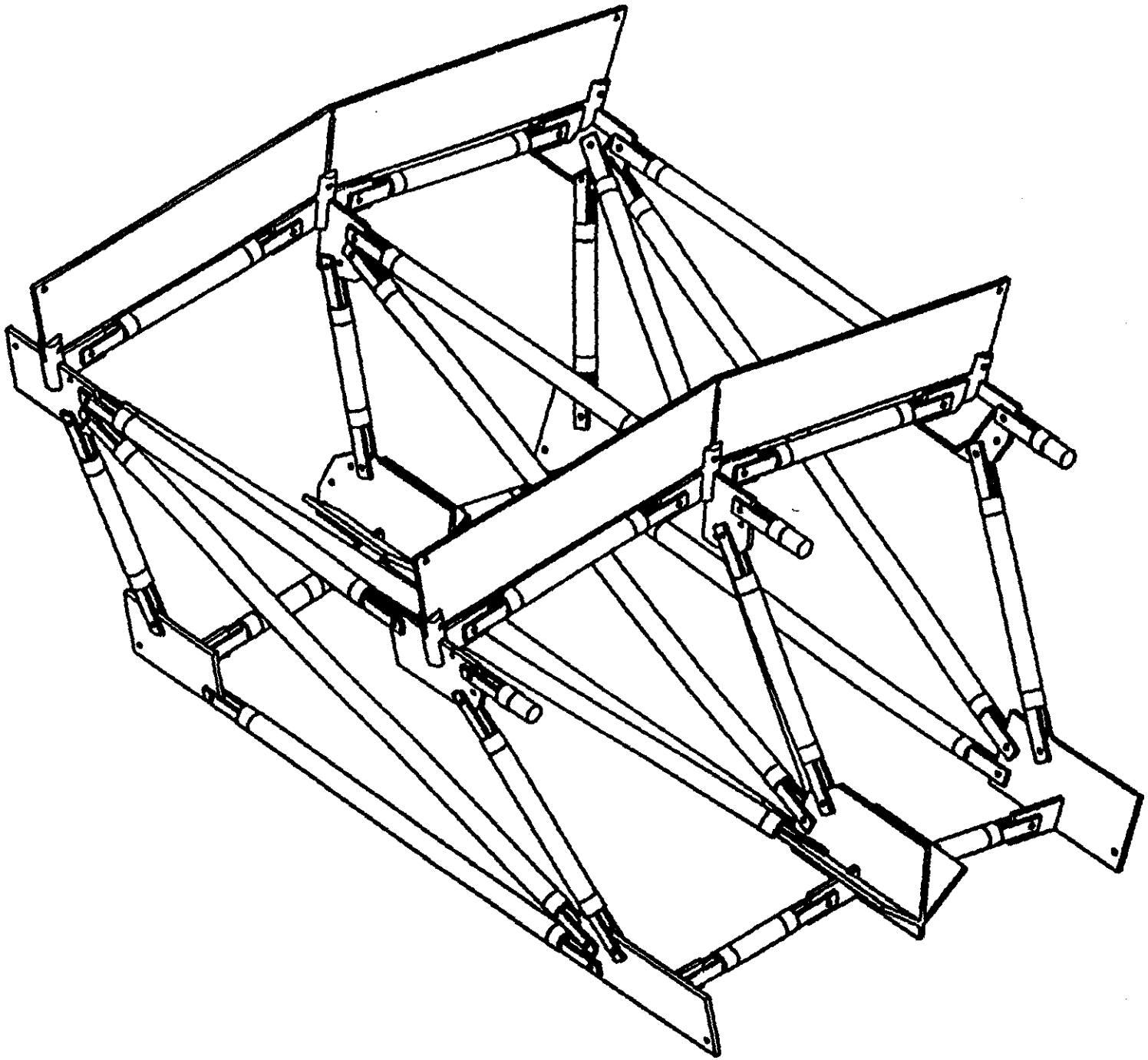
ALIGNMENT PATH
BESIDE EACH OTHER
"IN PHI"



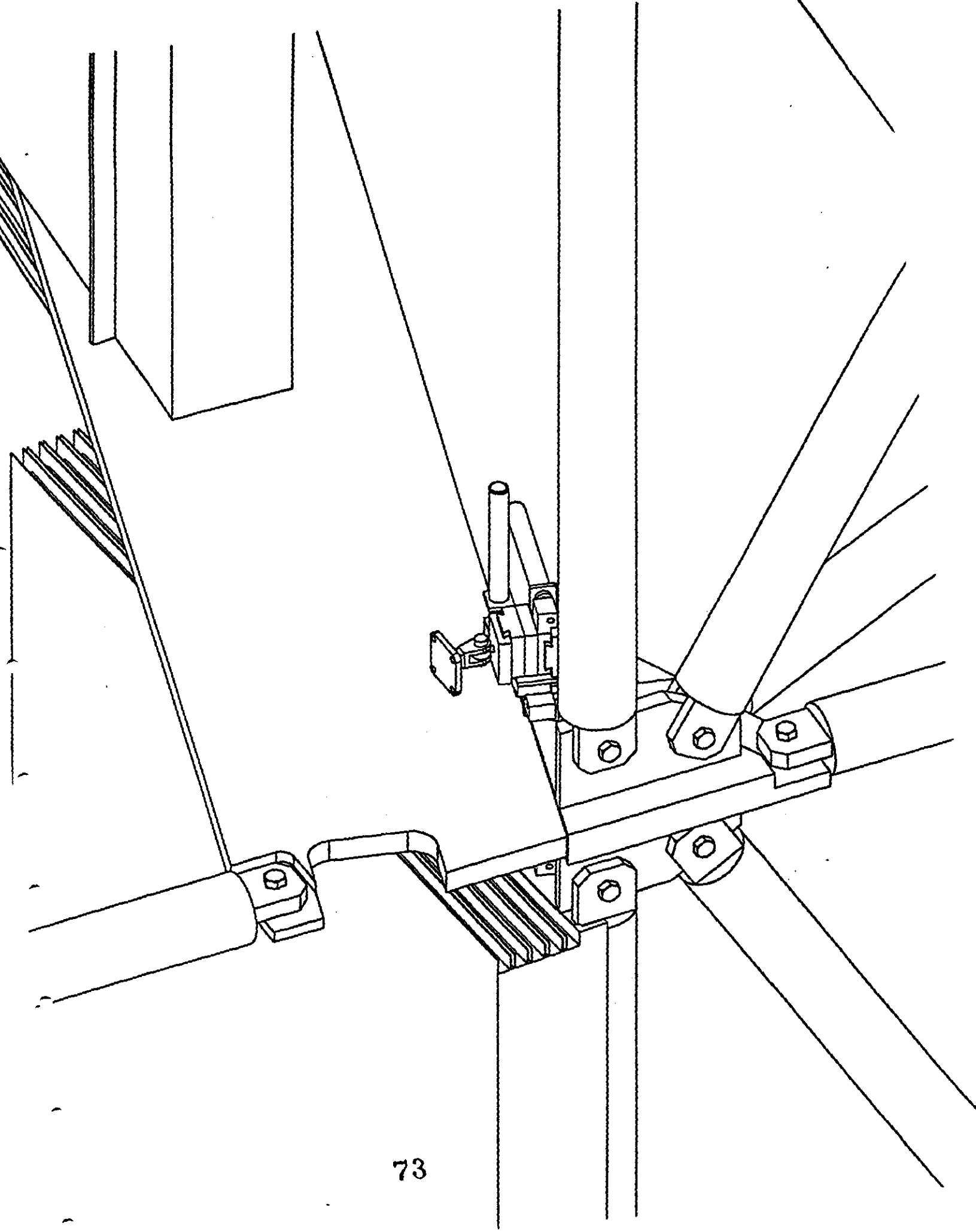
ALIGNMENT LINES
BESIDE EACH OTHER
"IN PHI"

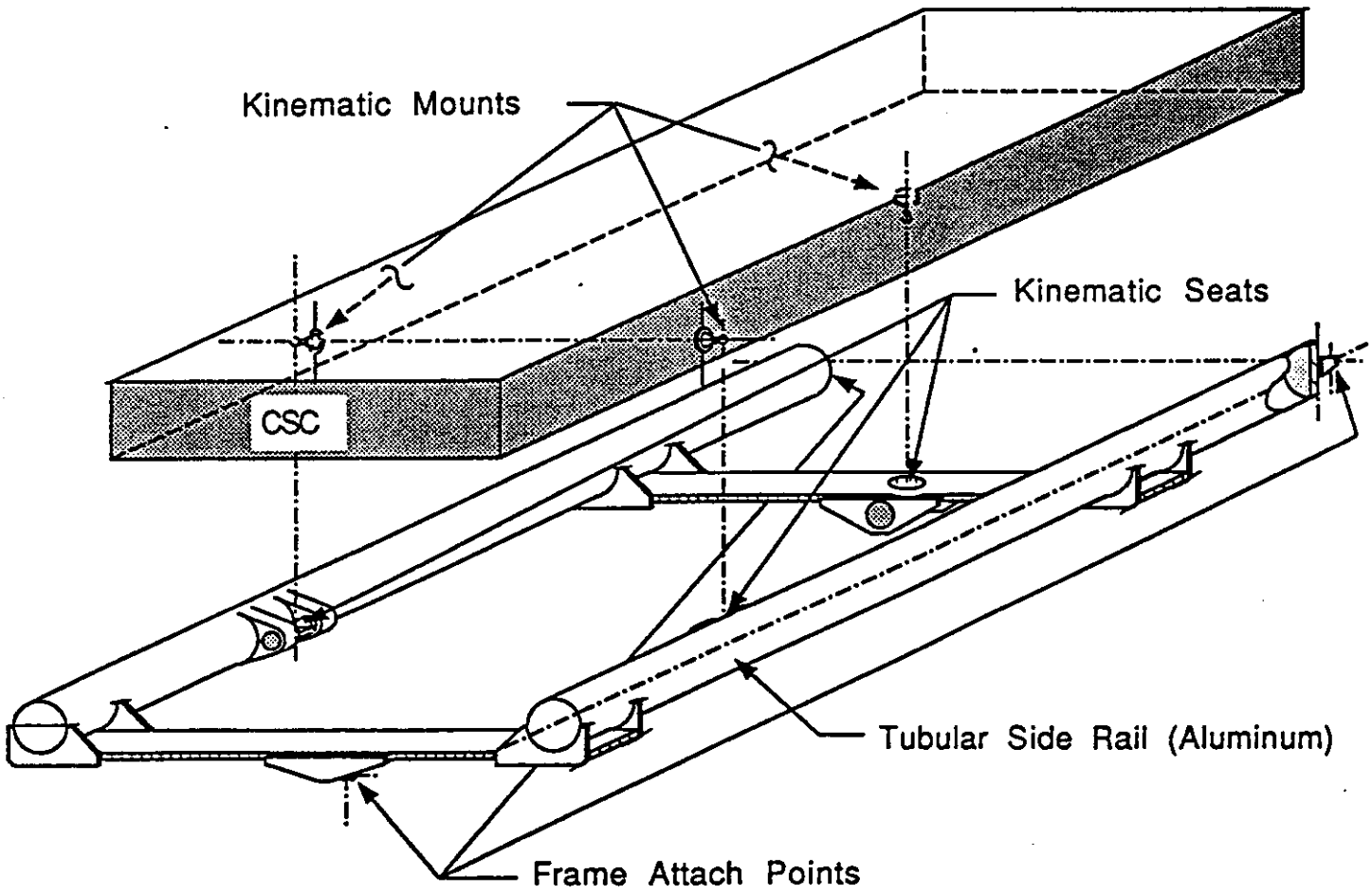

84°
61.7°
60.2°
46.1°
44.2°
35.6°
33.9°
2.69°
2.59°
2.47°
2.47°
2.11°
2.07°
29.25°
29.9°
GAP ANGLES SHOWN ARE FOR 3 LAYERS MINIMUM COVERAGE
MIDDLE SUPER-LAYER THETA COVERAGE
ALIGNMENT LINES BESIDE EACH OTHER IN PHI

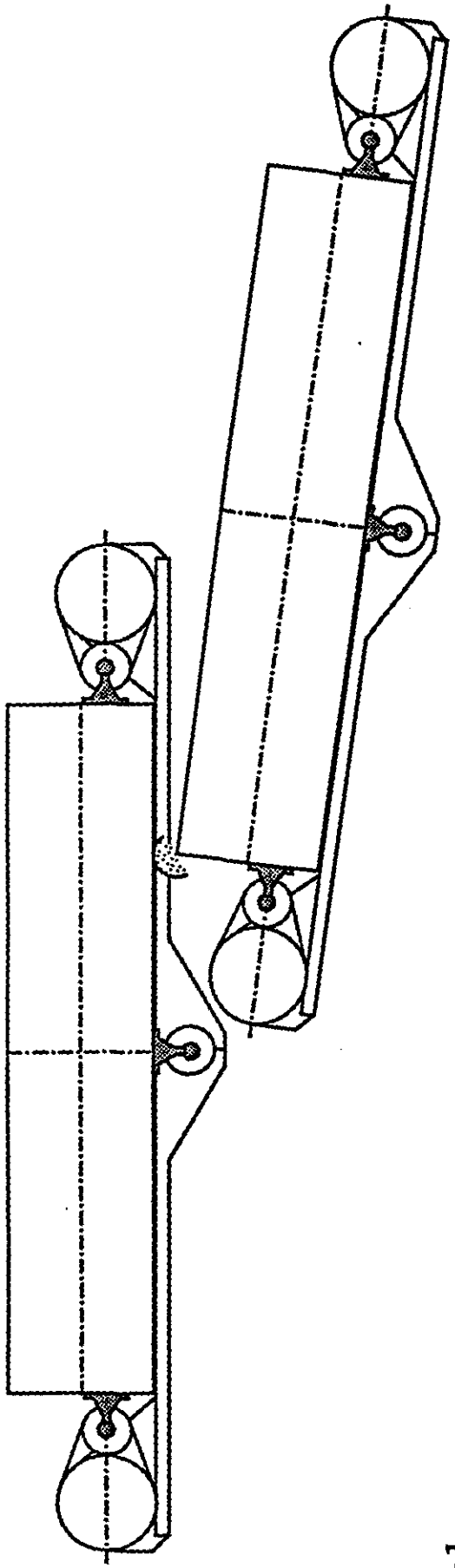

100%
OUTER-MOST CHAMBERS
INNER-MOST CHAMBERS
LAYERS OF COVERAGE
6
3
1
81.9%
86.5%
89.5%
80.6%
85.7%
89.0%
29.25°
84°
0
10
20
30
40
50
60
70
80
90
THETA ANGLE (DEG.)

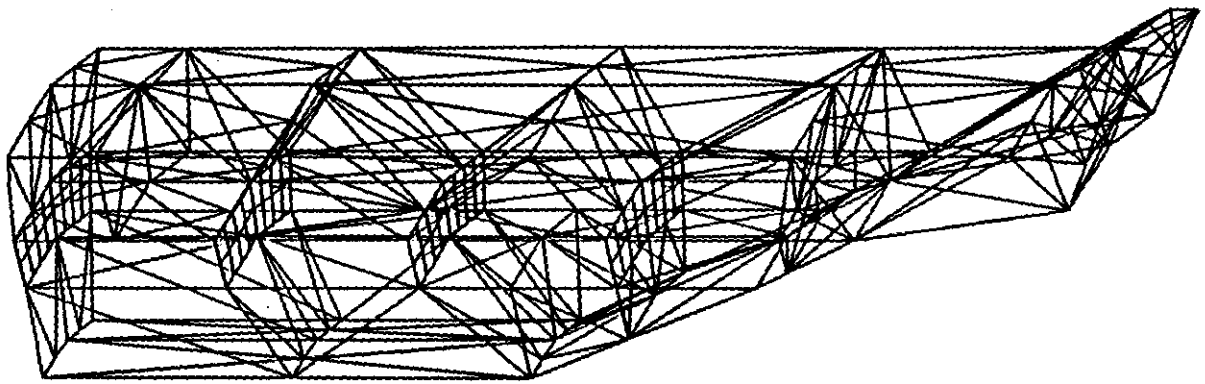


NAME: MUON_STRUCTU




Kinematic Mounts
Kinematic Seats
CSC
Tubular Side Rail (Aluminum)
Frame Attach Points





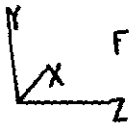
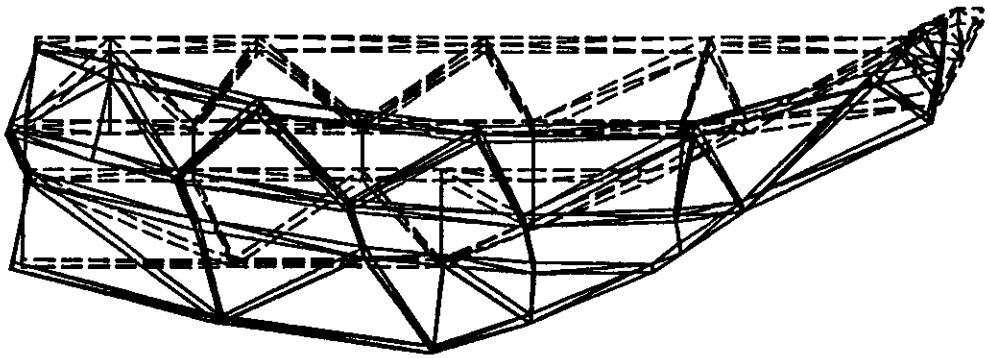


FIGURE 4.6 BARREL REGION MODULE

MAXIMUM DISPLACEMENT IS 0.26 INCHES



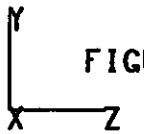


FIGURE 4.9A DEFORMATION OF BARREL REGION MODULE, 1G IN THE -Y

SSC BARREL REGION, SINGLE MODULE, 1/12 OF BARREL
1 G LOAD IN THE +X DIRECTION
1 G GRAVITY LOAD, -Y

MAXIMUM DISPLACEMENT IS 0.15 INCHES

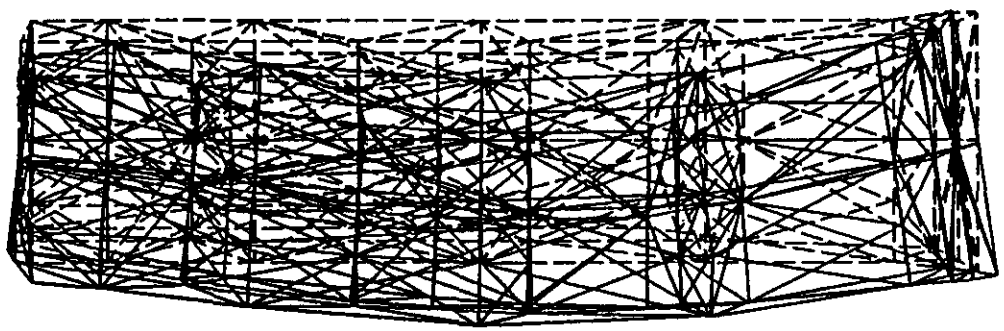
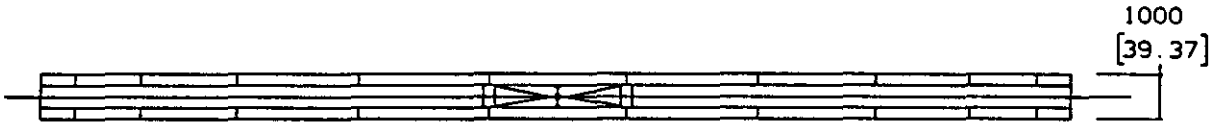
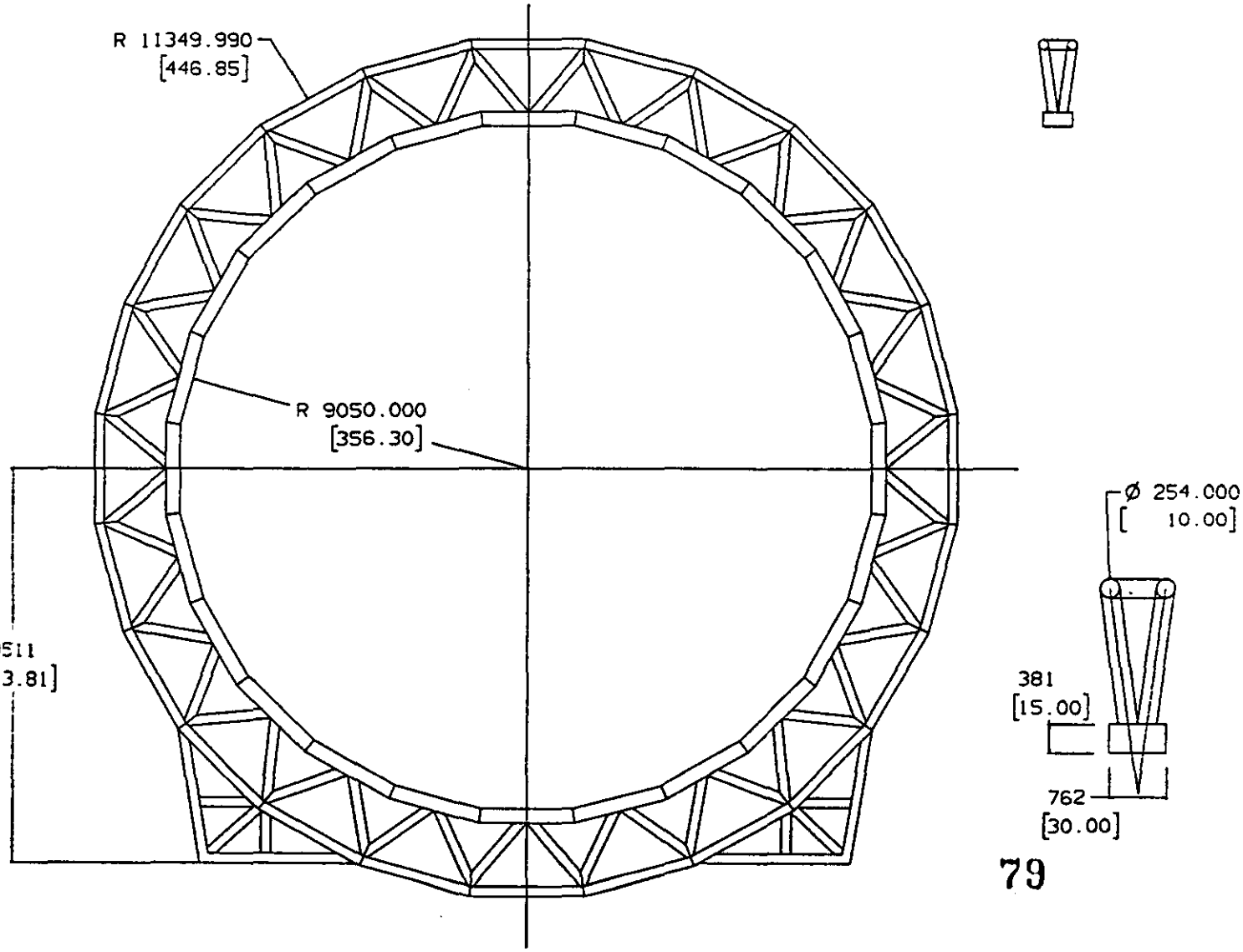


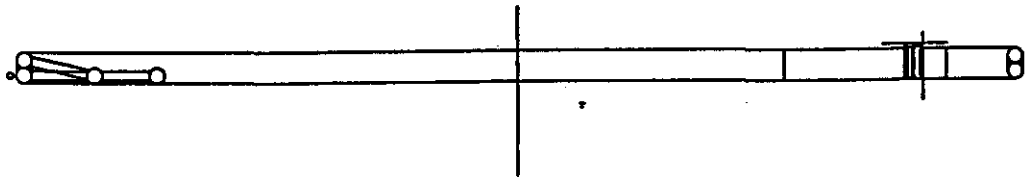
FIGURE 4.9B DEFORMATION OF BARREL REGION MODULE, 1G IN THE +X

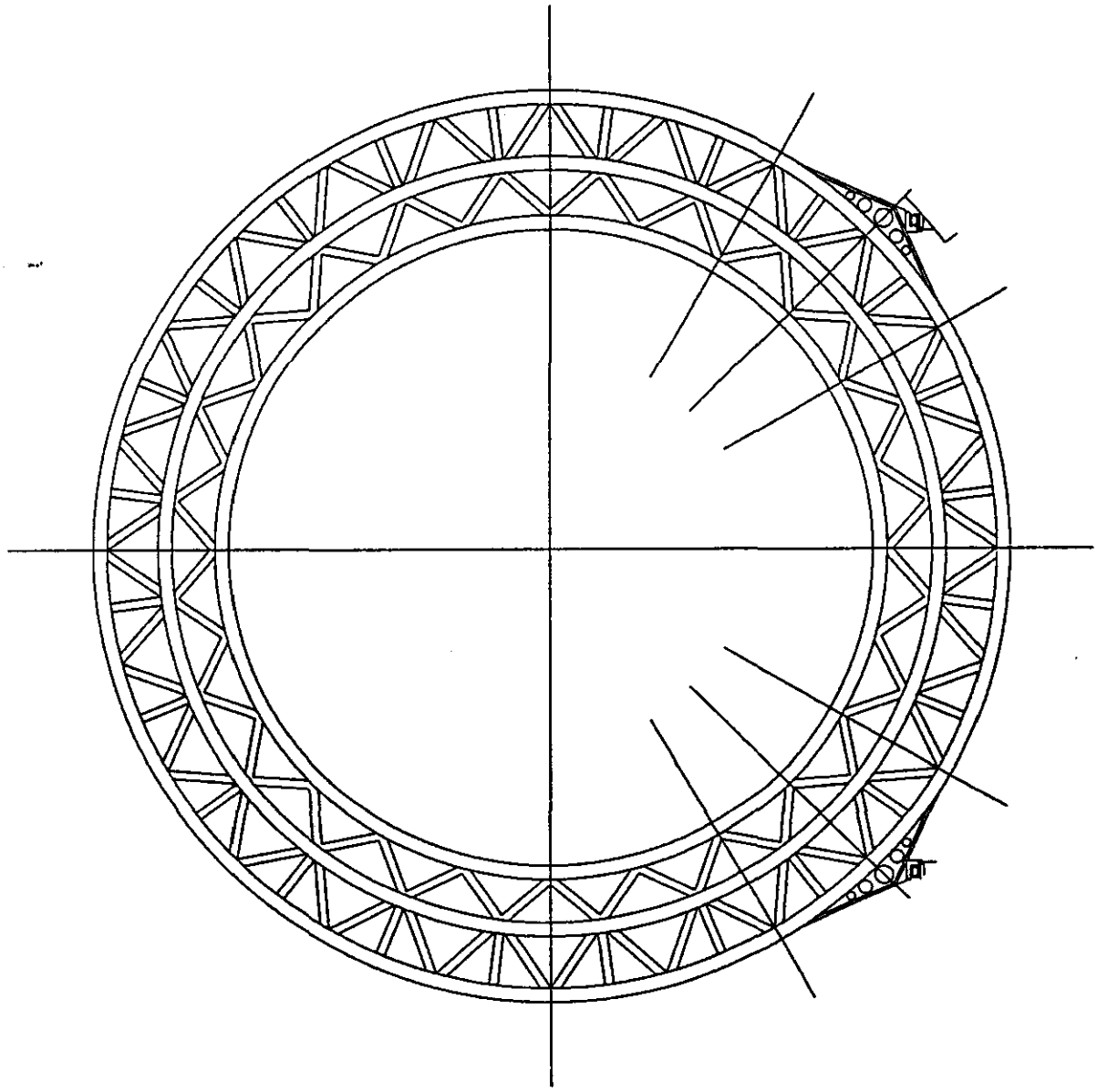
SSC BARREL REGION, SINGLE MODULE, 1/12 OF BARREL
1 G LOAD IN THE +X DIRECTION
1 G GRAVITY LOAD, +X

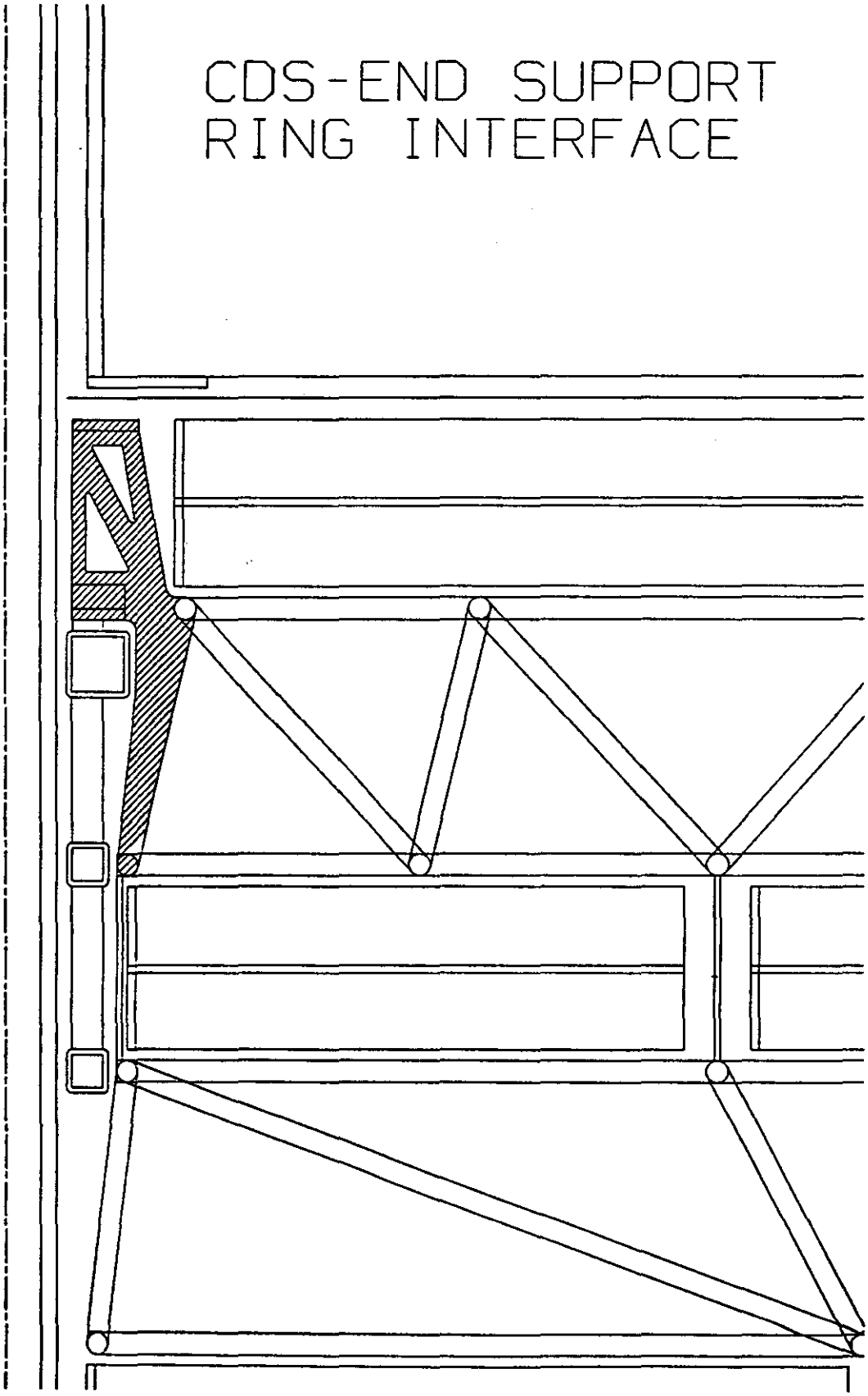
FFS SUPPORT RING

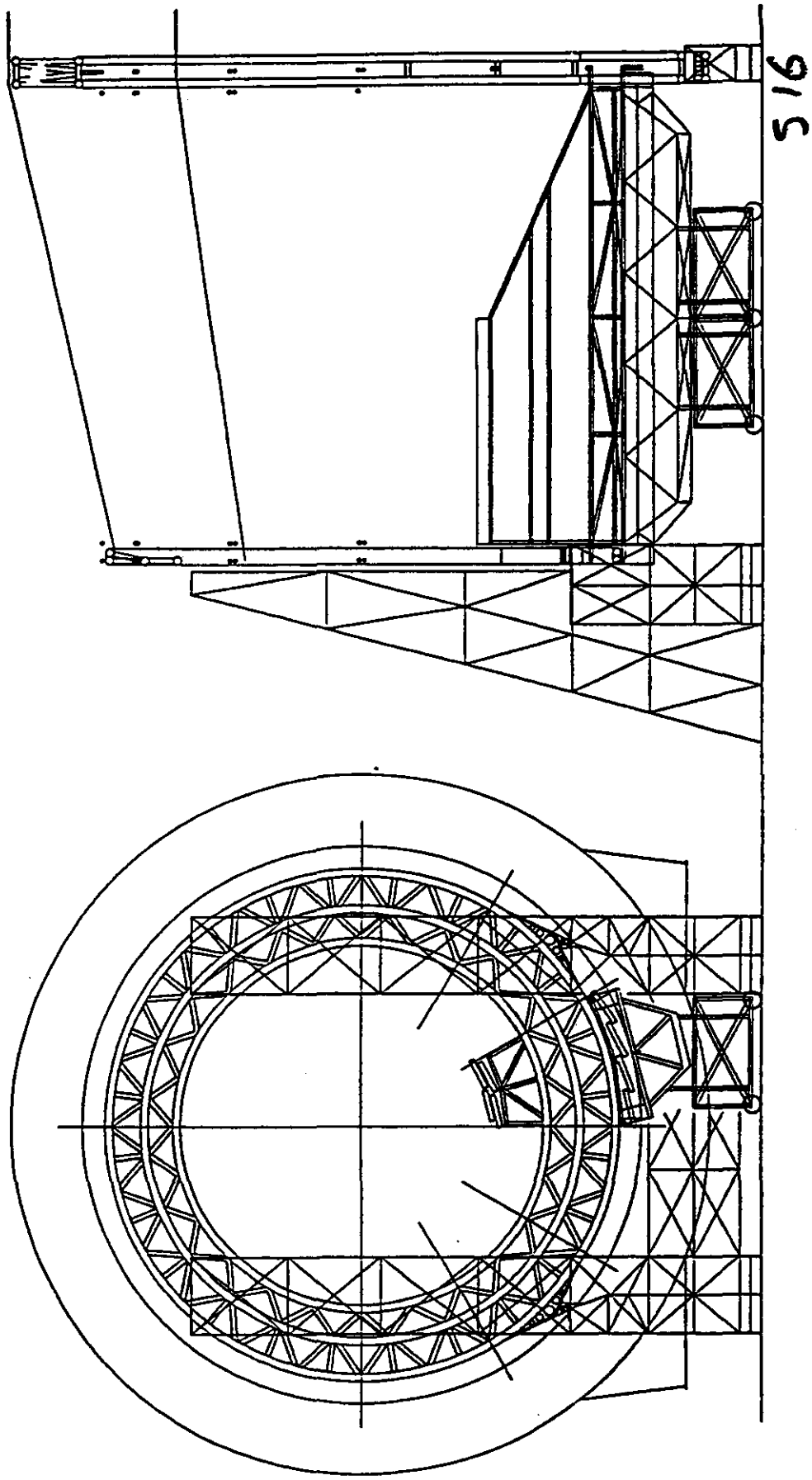









CDS-END SUPPORT
RING INTERFACE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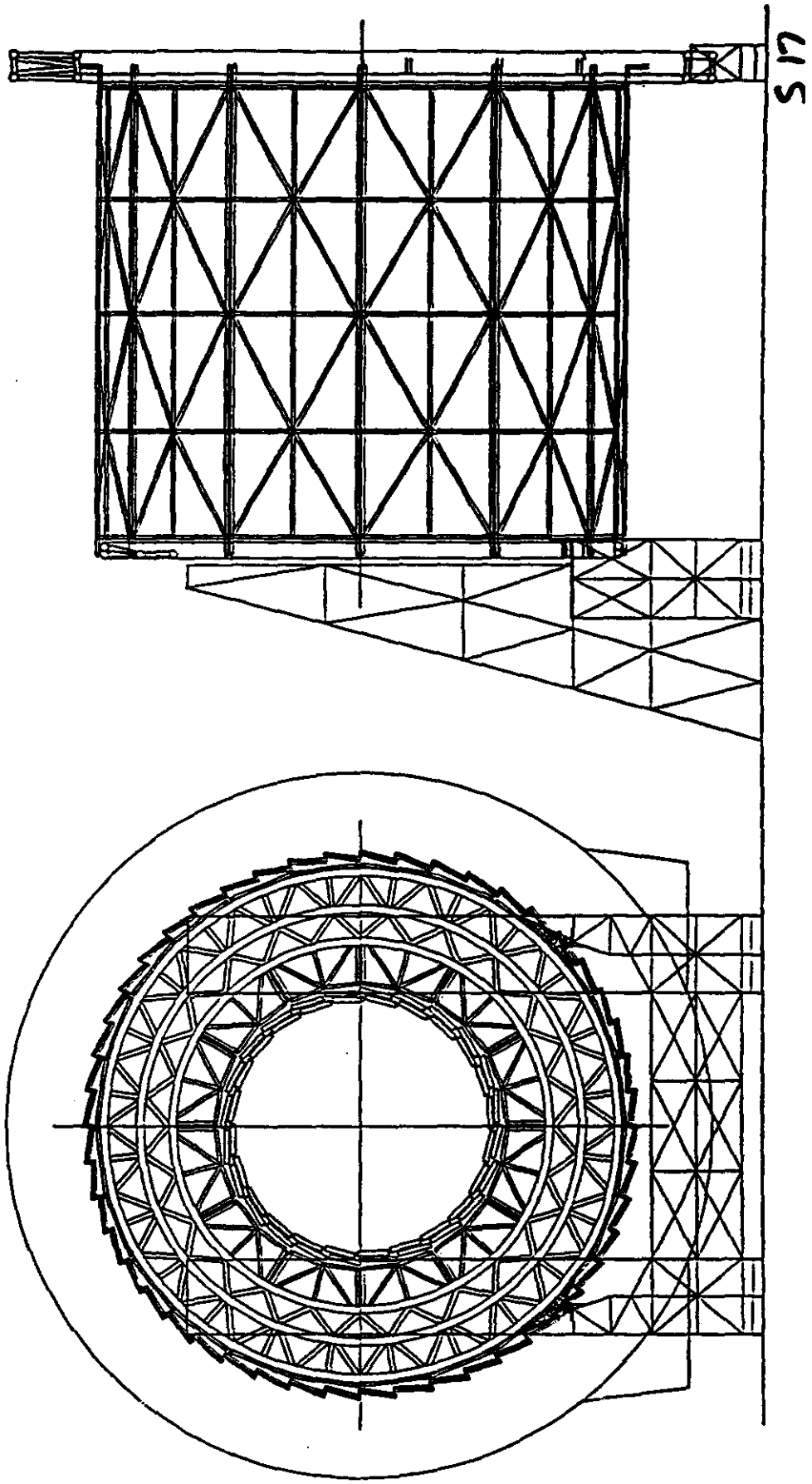
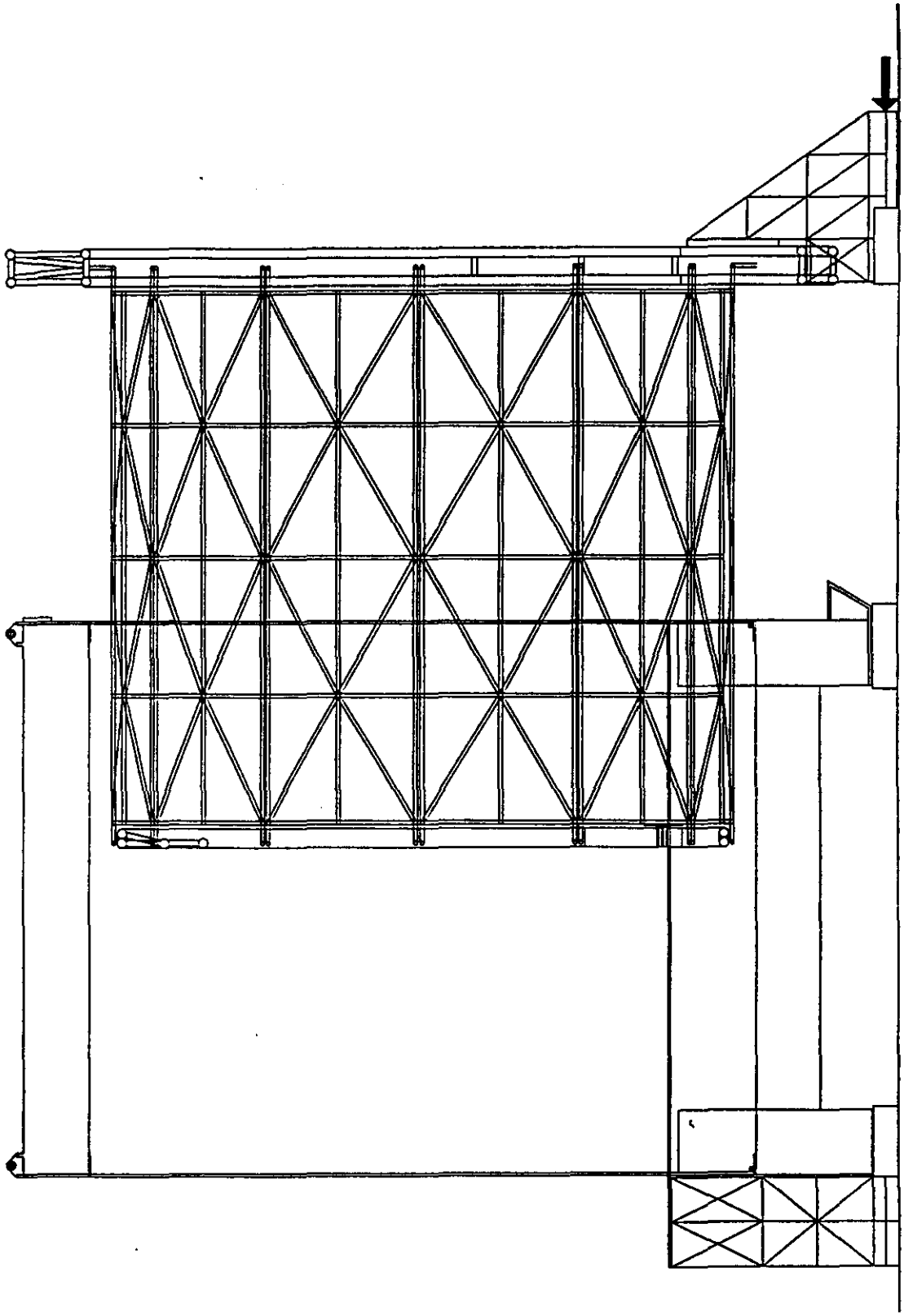
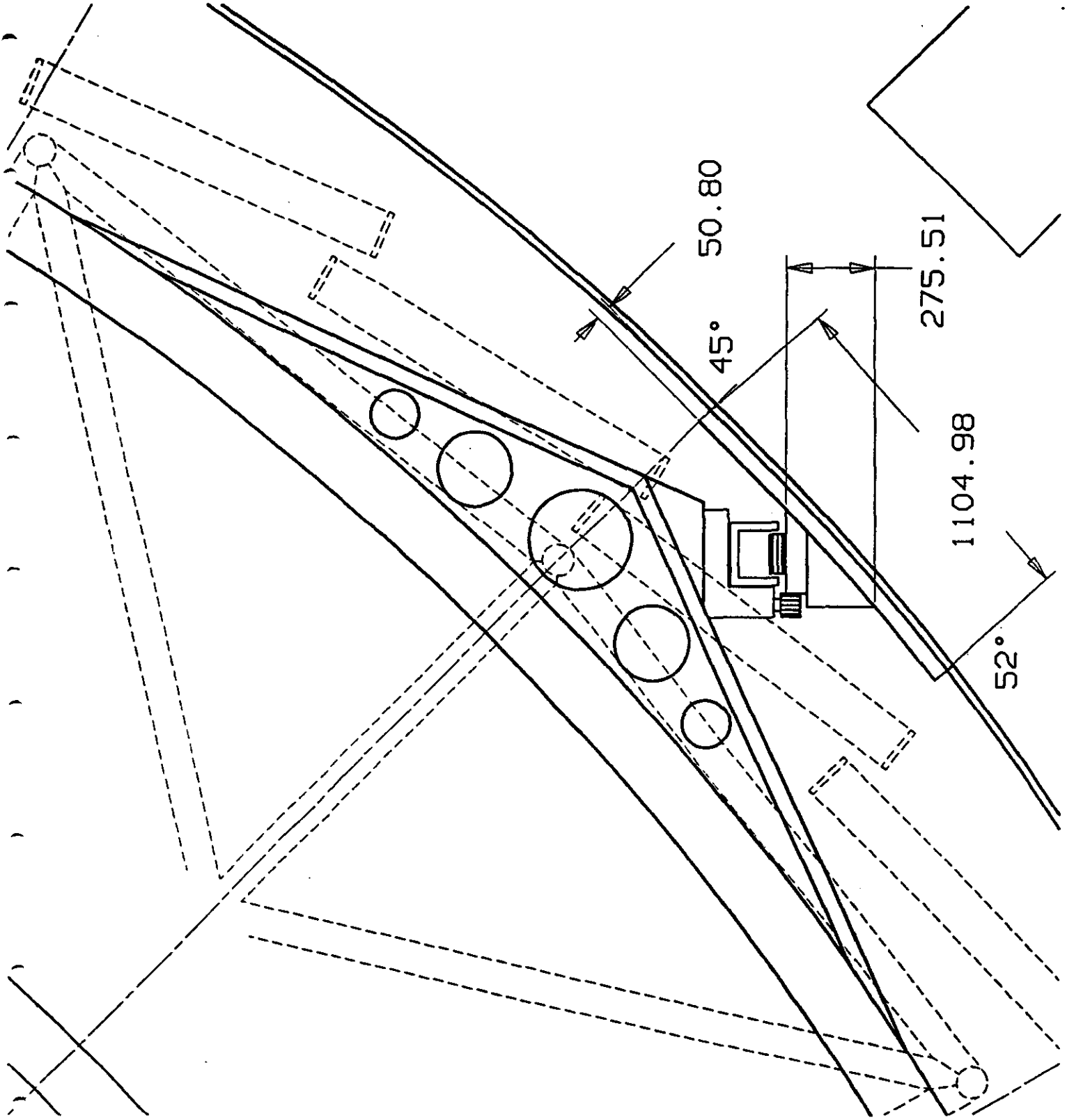
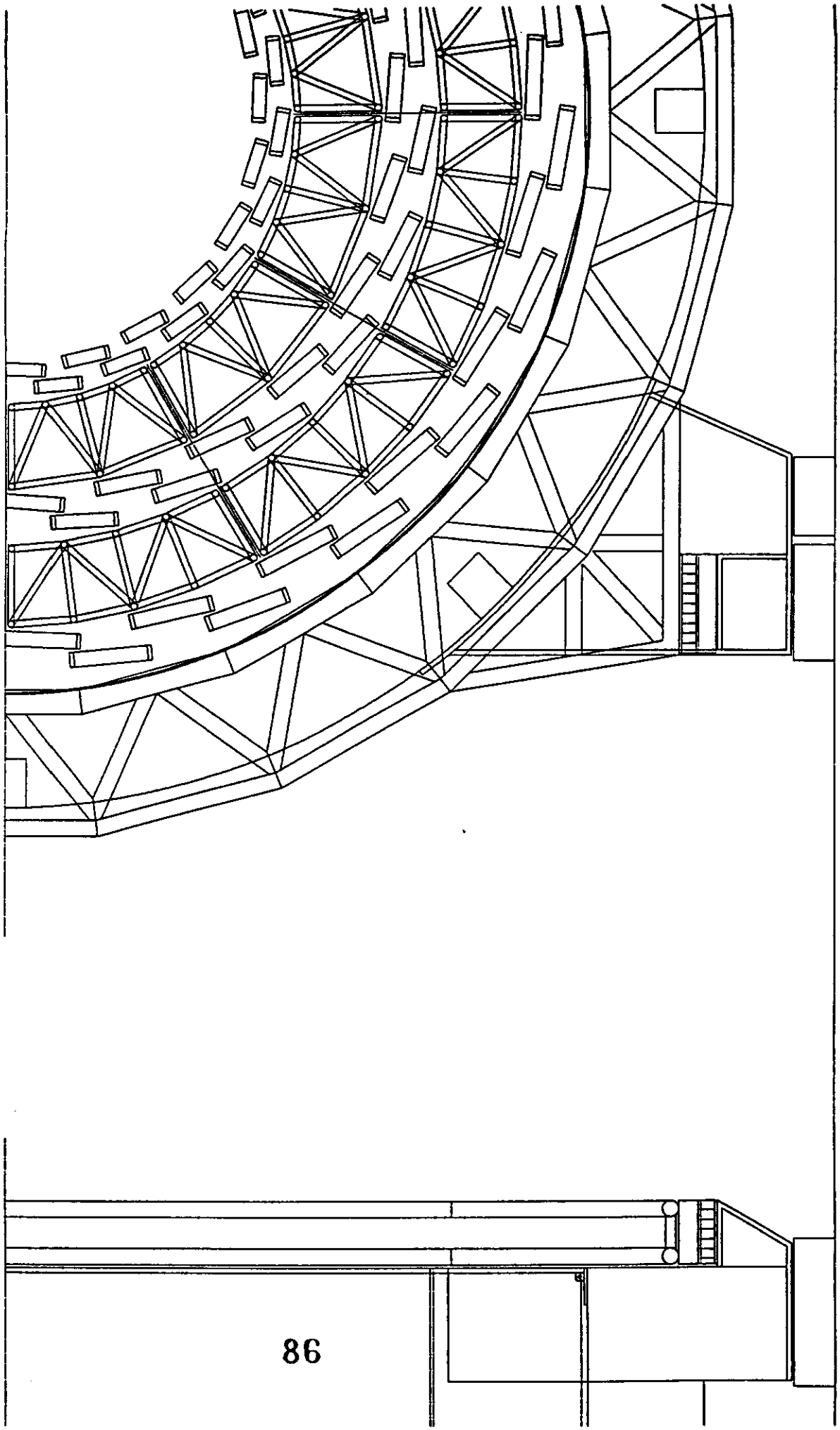
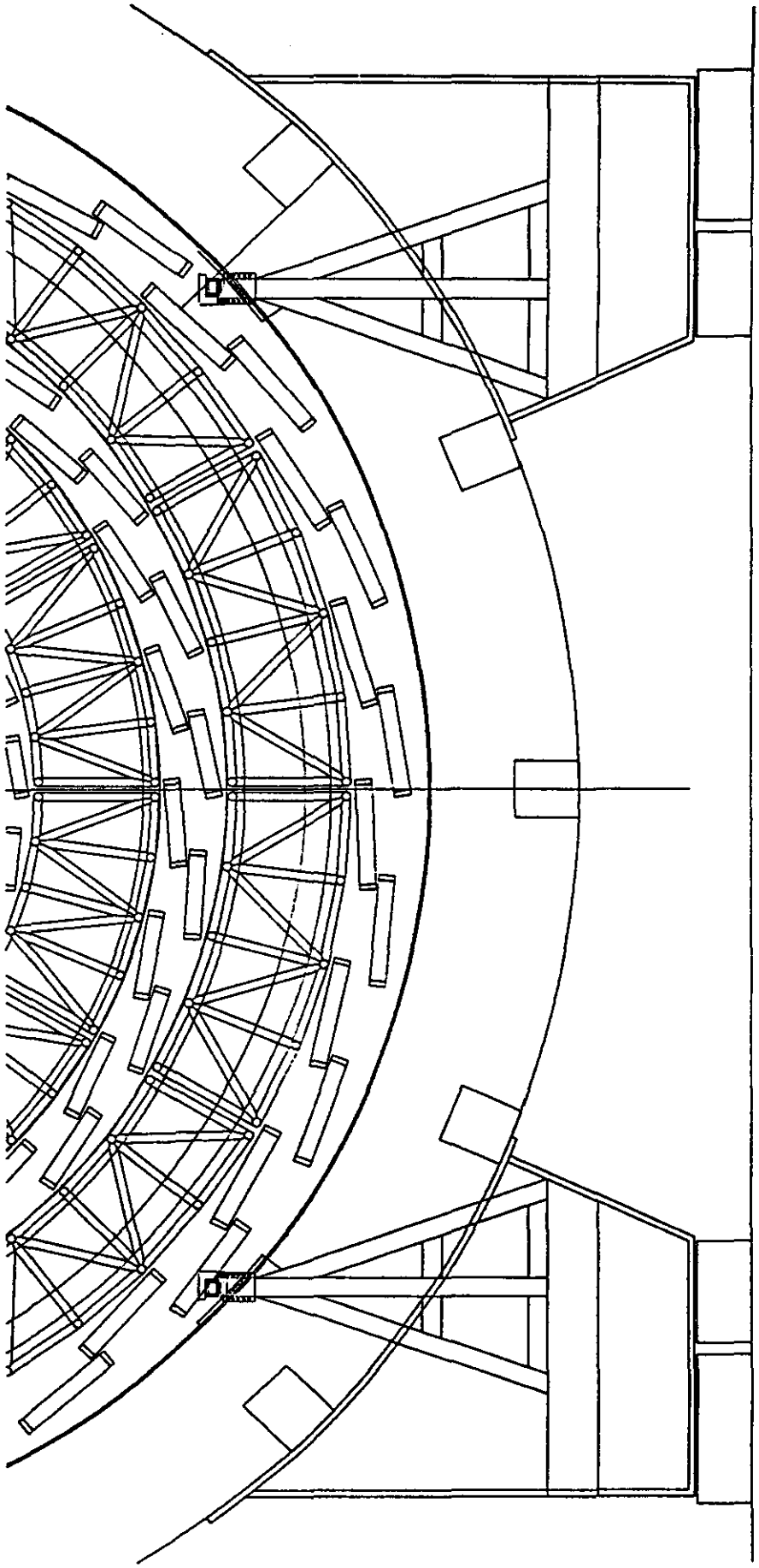
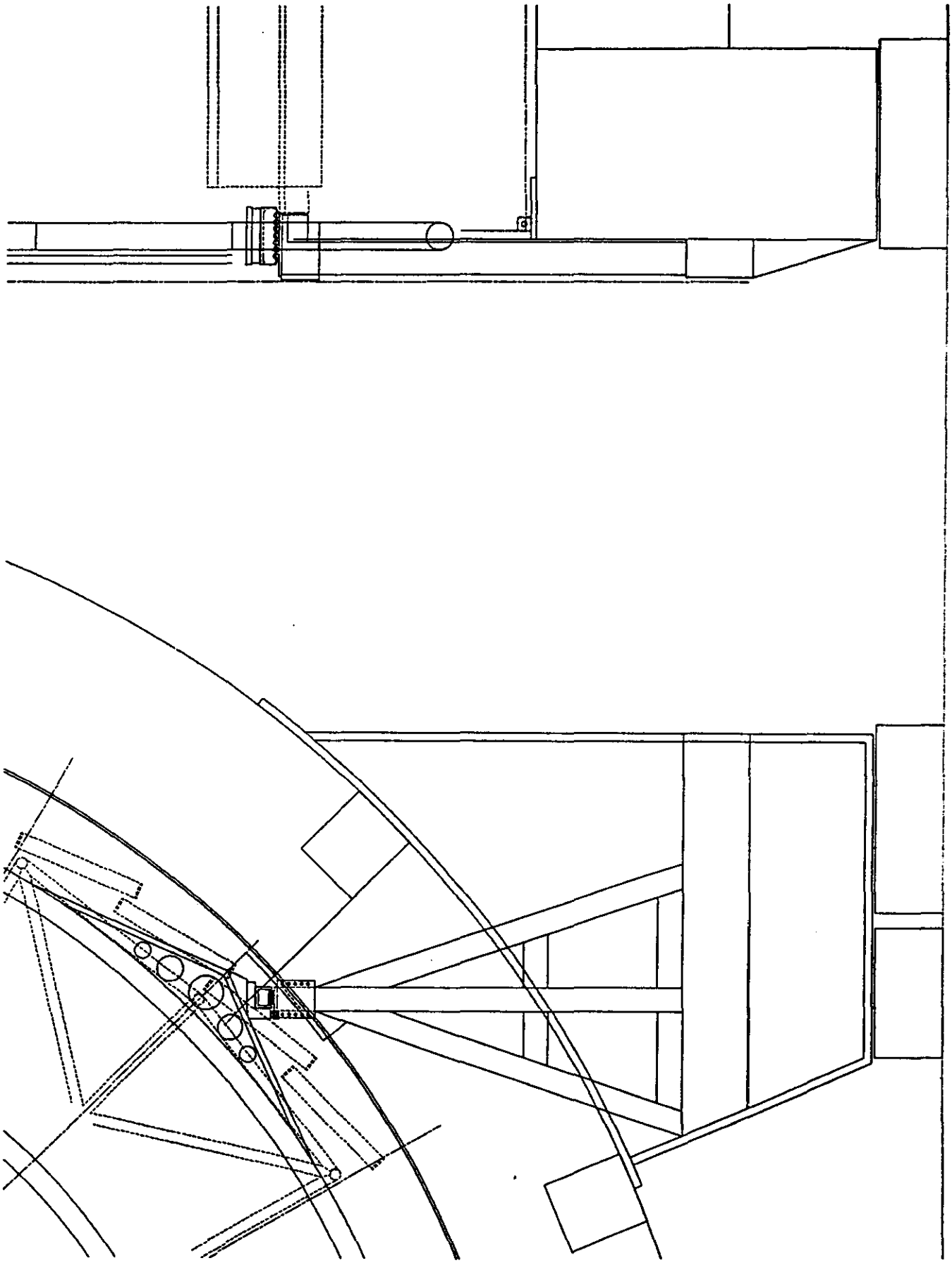

S17




50.80
45°
275.51
1104.98
52°

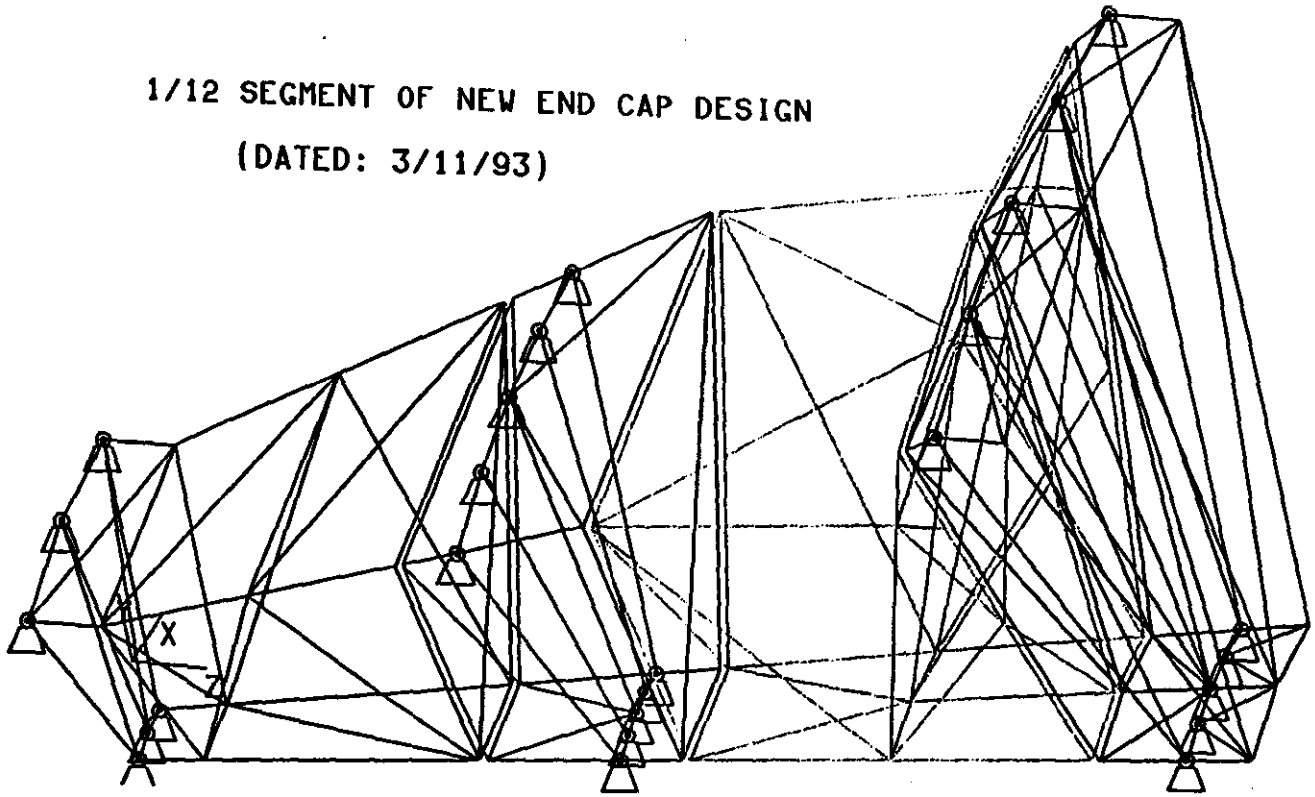


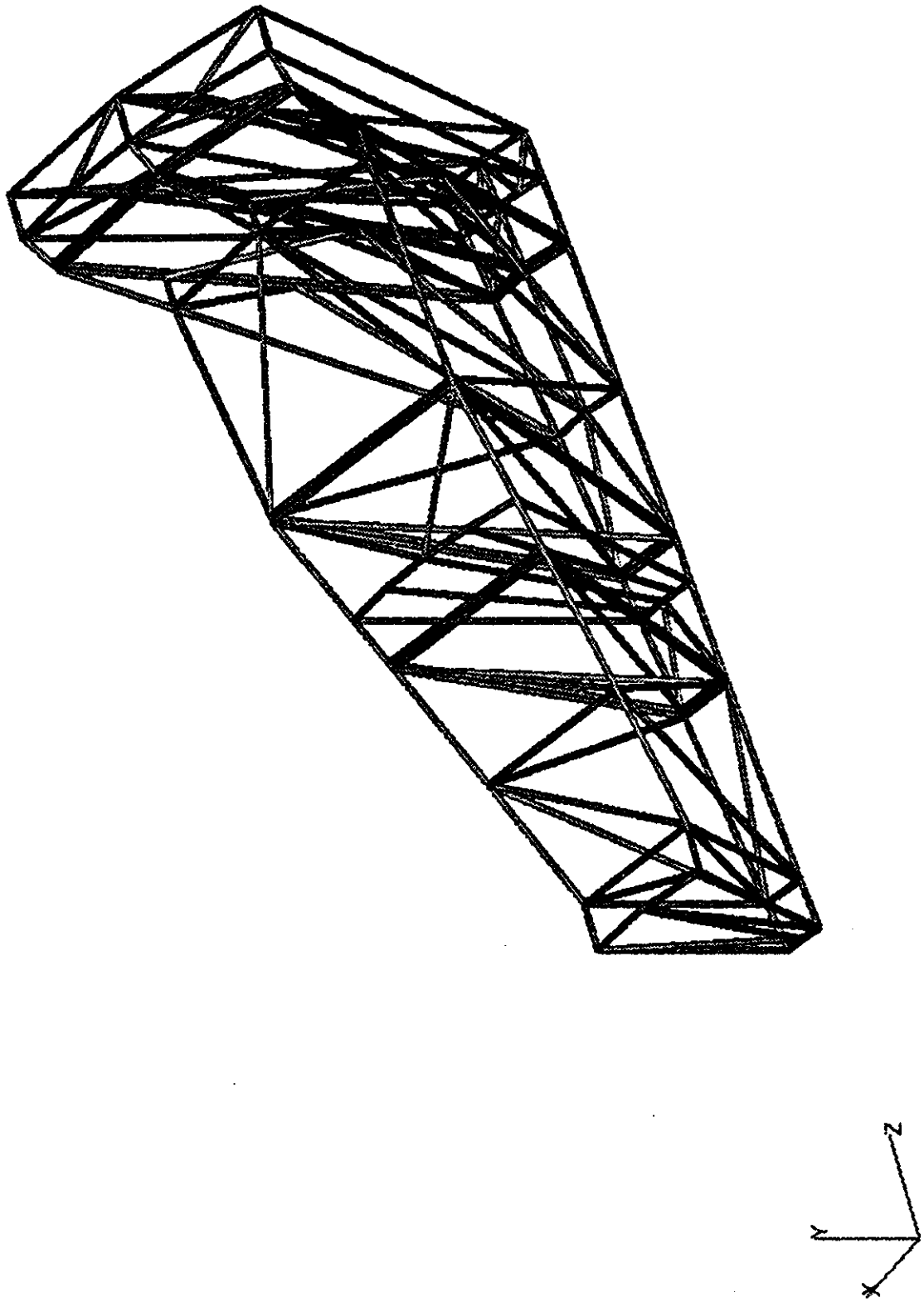


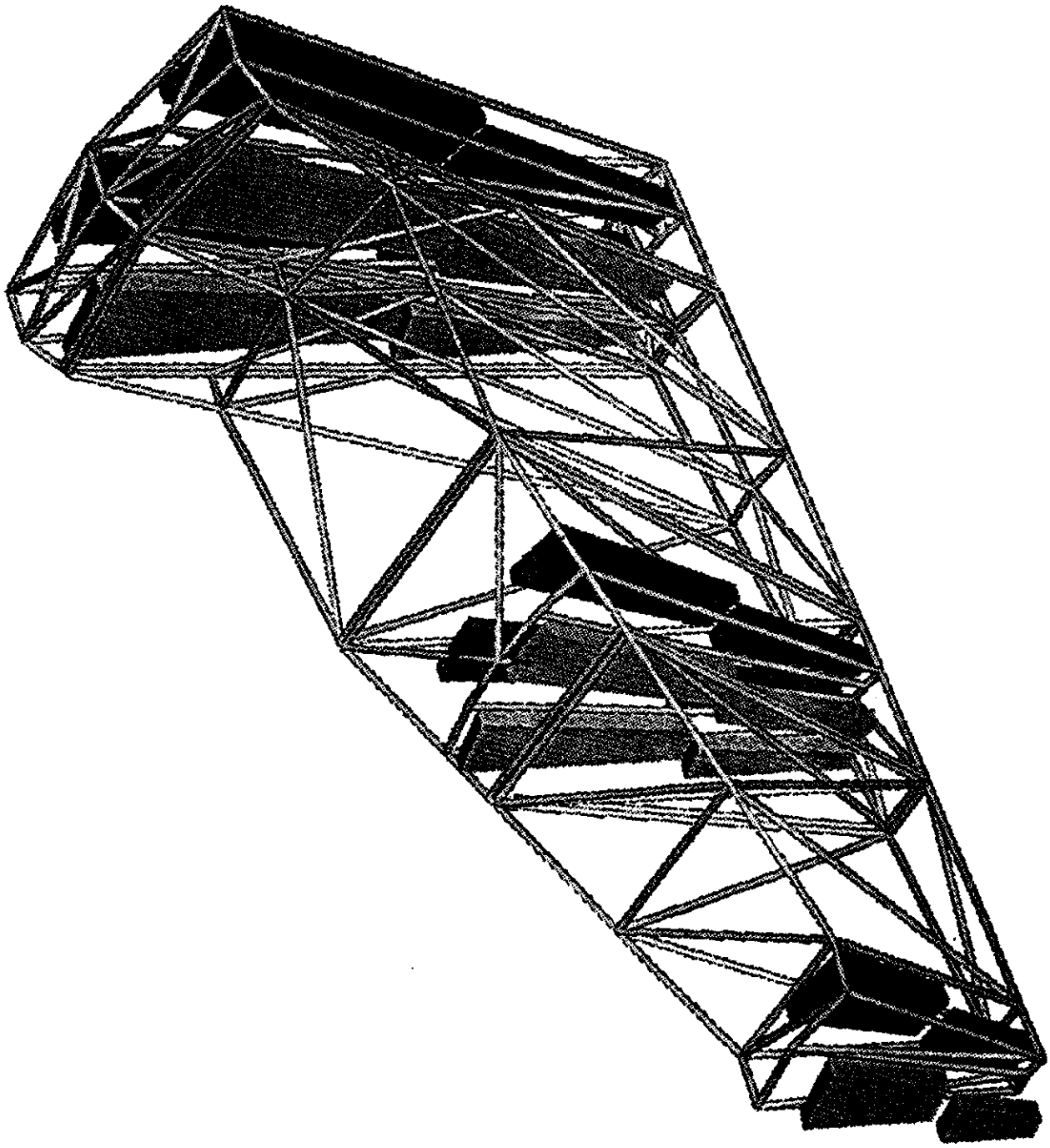


1/12 SEGMENT OF NEW END CAP DESIGN

(DATED: 3/11/93)




Z
Y
X



Gena Mitselmakher

Chamber Design

Gena MITSELMAKHER
GEM Muon System Review
March 16, 1993 SSCL

CSC CHAMBER DESIGN AND PERFORMANCE

CSC ADVANTAGES.

1. Intrinsic resolution of CSC technique is much better than GEM requirement, and measured to be less than 75 microns.

2. Both measurement strips and survey marks for alignment are done on the same board by the process of lithographic etching, so there is no loose in precision due to reference mark transfer.

3. Non-bend coordinate measurement with the precision of few centimeters comes from anode wire or coarse strip readout.

4. Fast timing and position information for use in the Level 1 trigger can be extracted from the CSC in a natural way using simple electronics. The assignment of the proper bunch crossing is 99% efficient for the six-layer chamber, filled with the fast gas.

5. CSC has good double track resolution. Spatial resolution in the presence of second track is simulated to be under 100 microns when tracks are separated by at least 7.5 mm; for smaller separation the resolution degrades but always remains below 450 microns.

6. The chamber can hanle particle rates as high as 500 cm-2s-1 with integration time of 300 ns and strip size of 300x0.5cm2, which is more than required for GEM conditions.

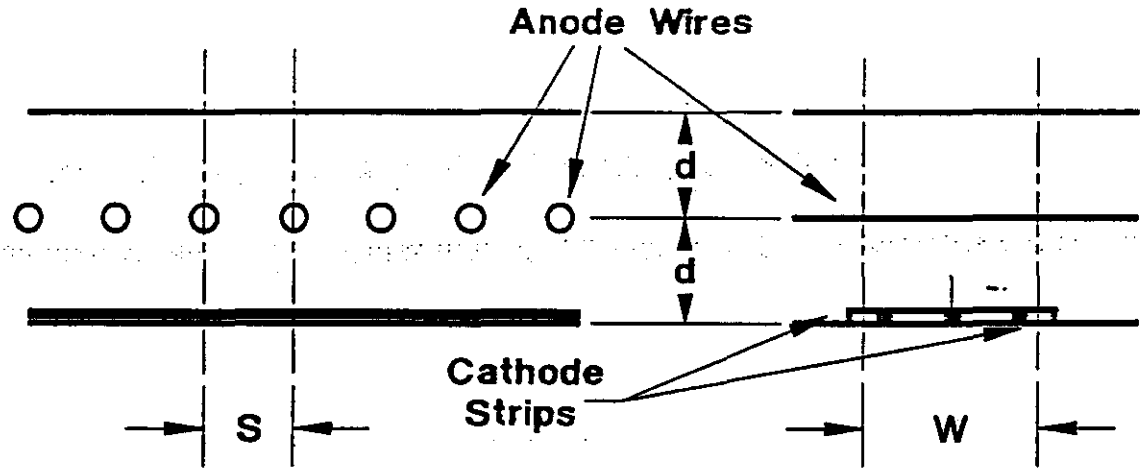
7. Since the CSC operates at the gas gain of 5x10**4, thus drawing a small anode current, the effects of the chamber aging are small.

8. The requirements for the gas mixing and delivery system are not tough, because the precise coordinate measurement does not depend crucially on the gas mixture.

9. The major component of the chamber - chathode strip boards - could be mass-produced in the industry, and the remaining steps of chamber assembly are well within capabilities of traditional facilities, which meets tight GEM construction time schedule.

431_1.EPS

4.3.1.1



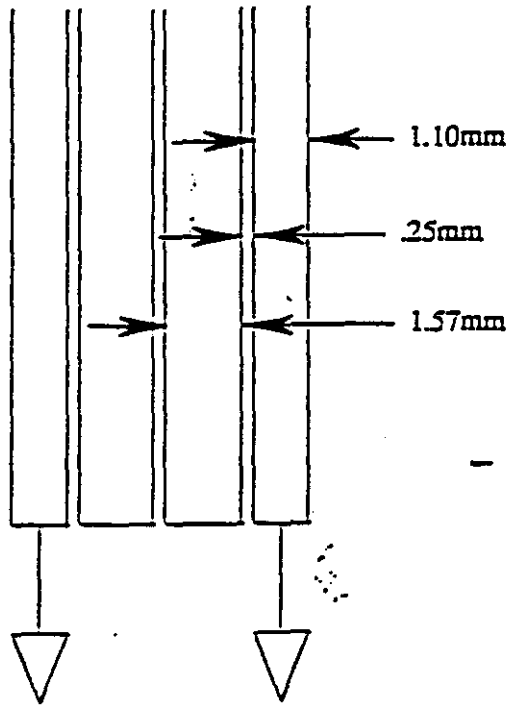


Figure 5a

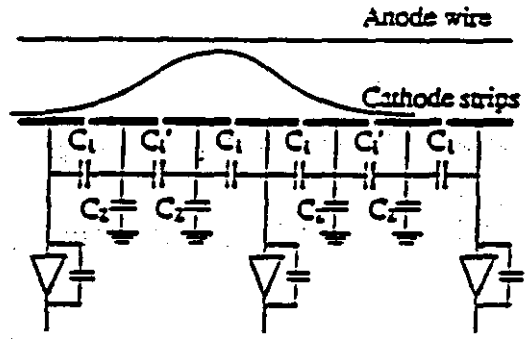


Figure 5b

4.3.1.2

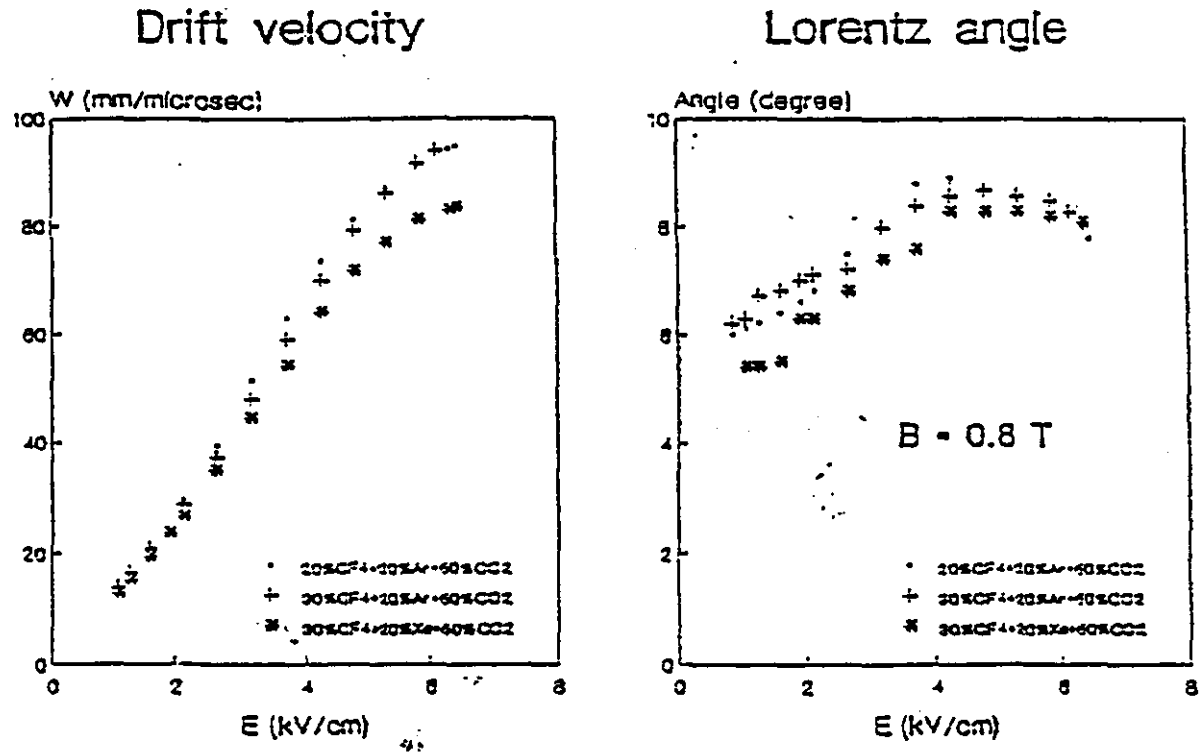
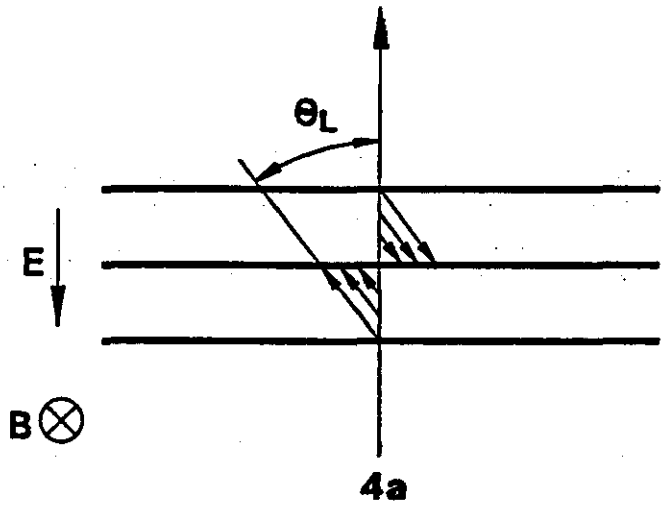


Fig. 2.14 Drift velocity and Lorentz angle for $Ar/CO_2/CF_4$ and $Xe/CO_2/CF_4$ gas mixtures.

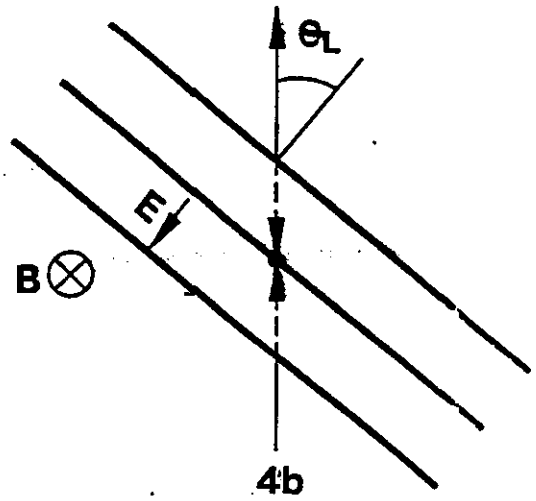
Fig. 4.3.1.3

431_3.EPS

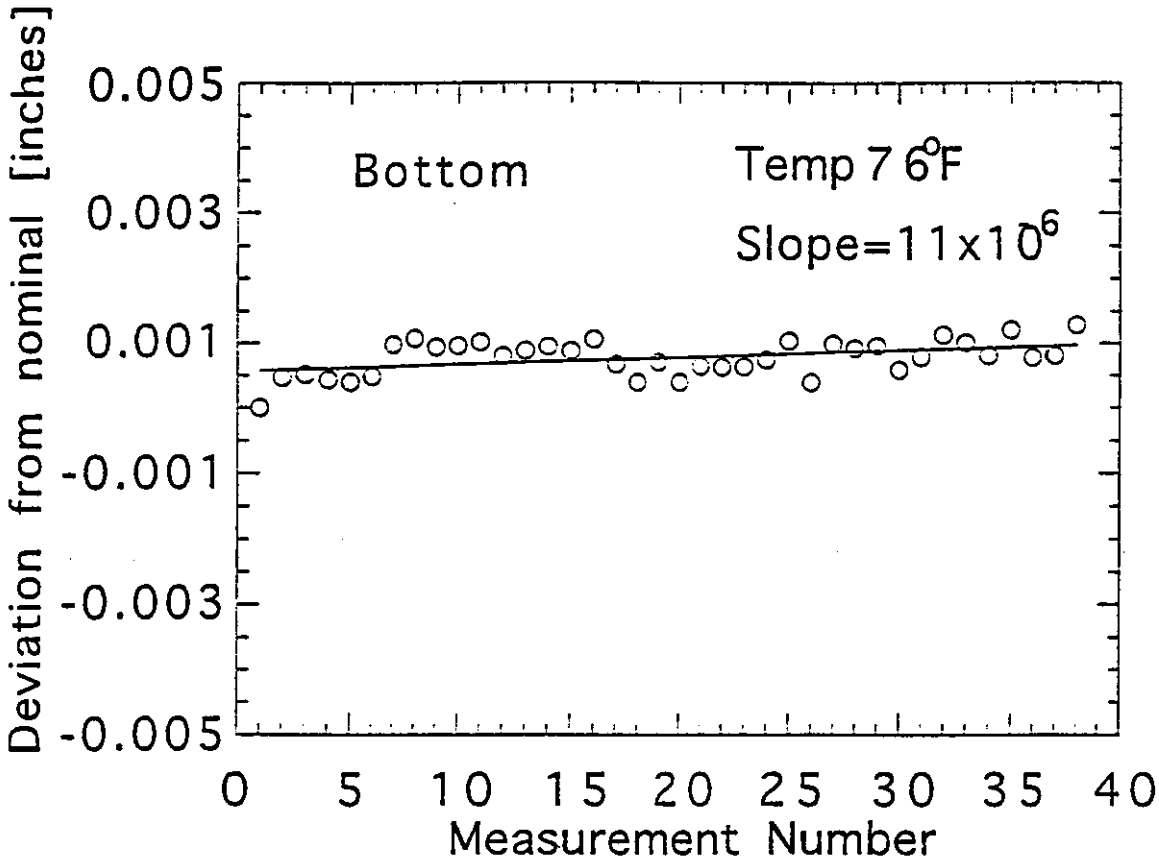
4.3.1.3

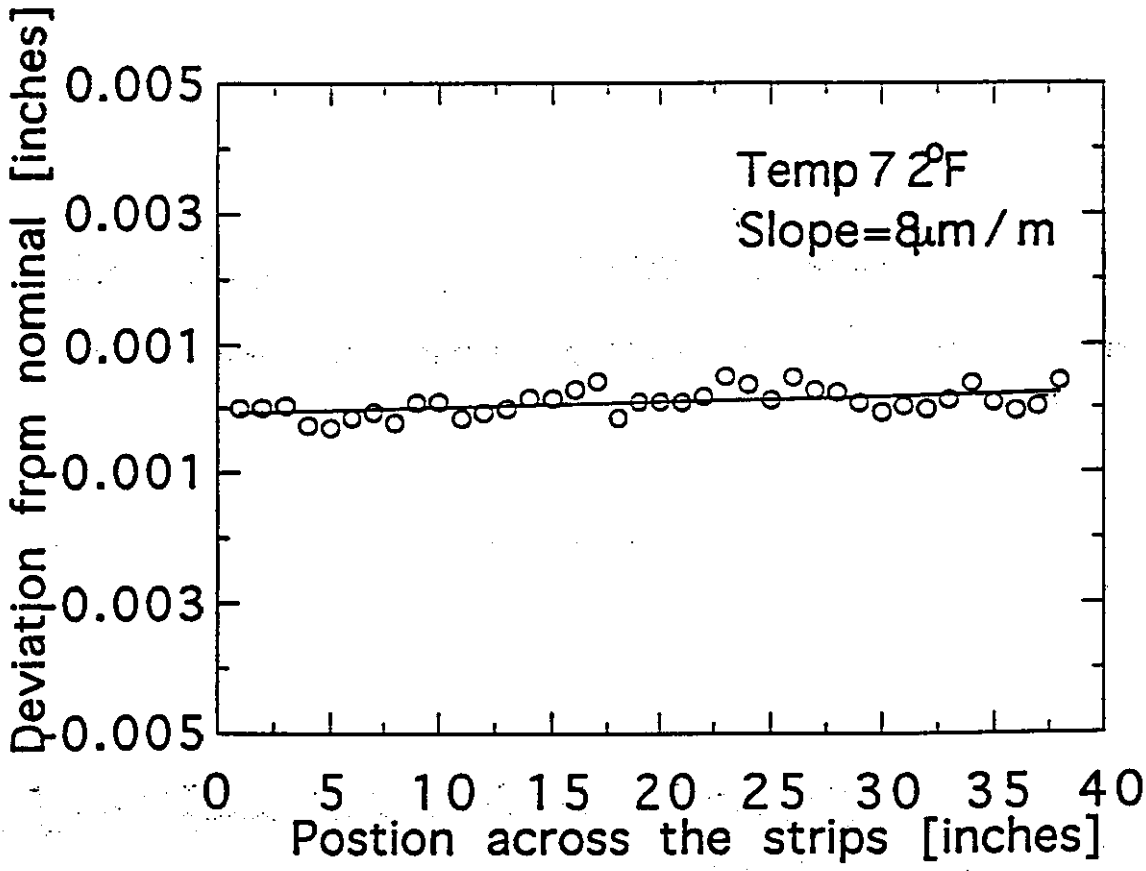


4a

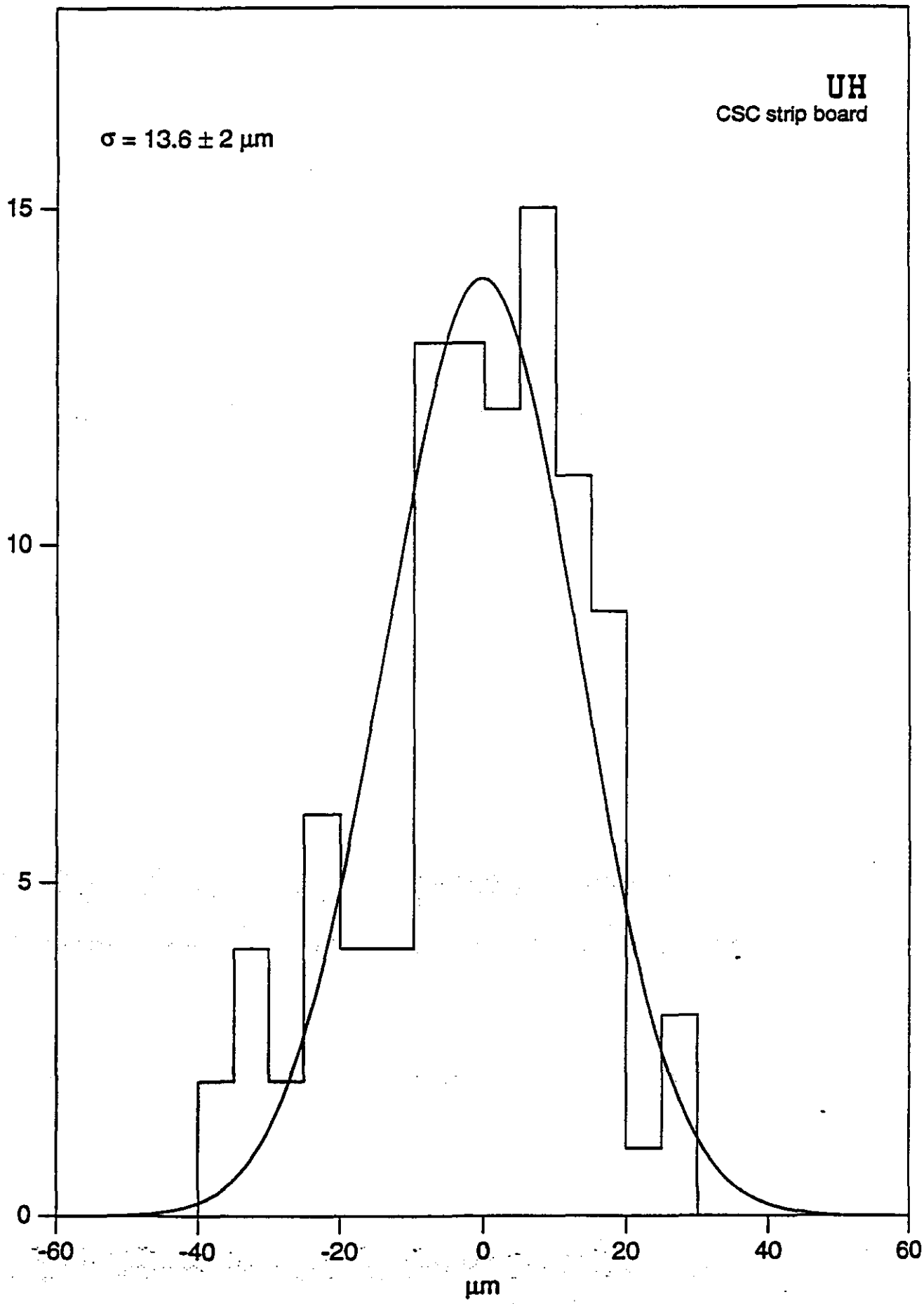


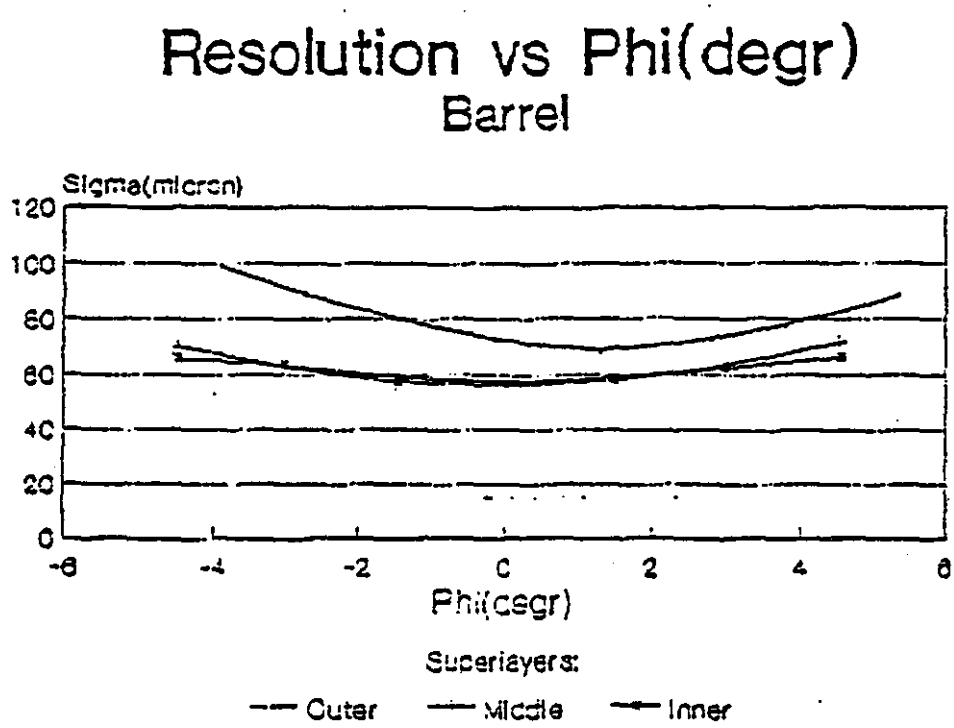
4b


Bottom
Temp 76°F
Slope=11x10^6
Deviation from nominal [inches]
0.005
0.003
0.001
-0.001
-0.003
-0.005
0 5 10 15 20 25 30 35 40
Measurement Number


Temp 72°F
Slope=8μm/m
Deviation from nominal [inches]
0.005
0.003
0.001
-0.001
-0.003
-0.005
0 5 10 15 20 25 30 35 40
Postion across the strips [inches]

F. 1.2.1.6


UH
CSC strip board
σ = 13.6 ± 2 μm
15
10
5
0
-60
-40
-20
0
20
40
60
μm


Resolution vs Phi(degr)
Barrel
Sigma(micron)
120
100
80
60
40
20
0
-6
-4
-2
0
2
4
6
Phi(degr)
Superlayers:
Outer
Middle
Inner

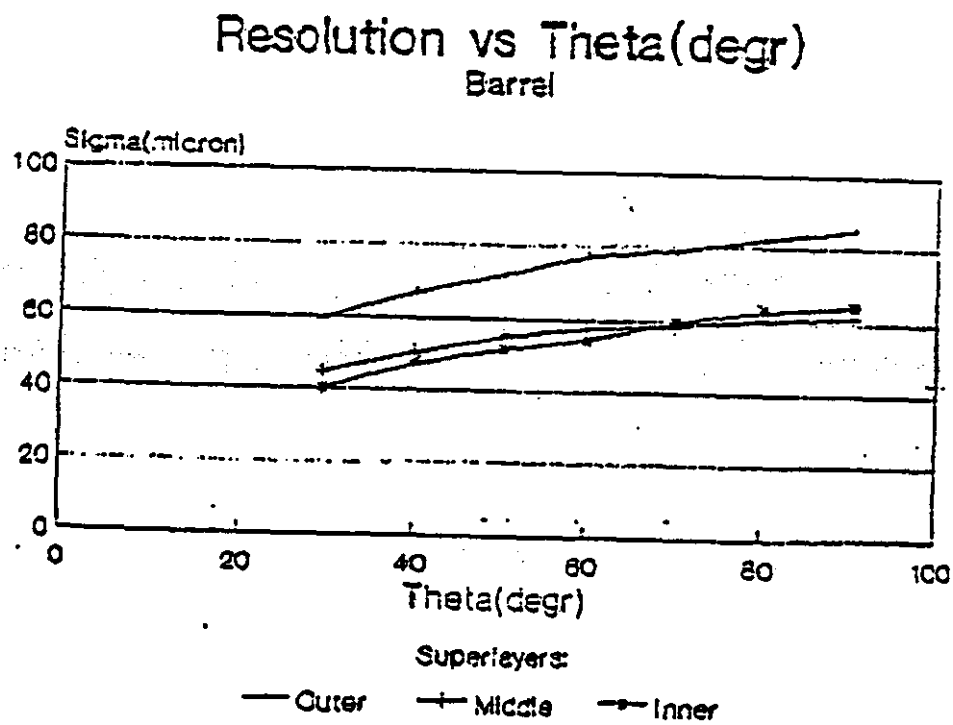
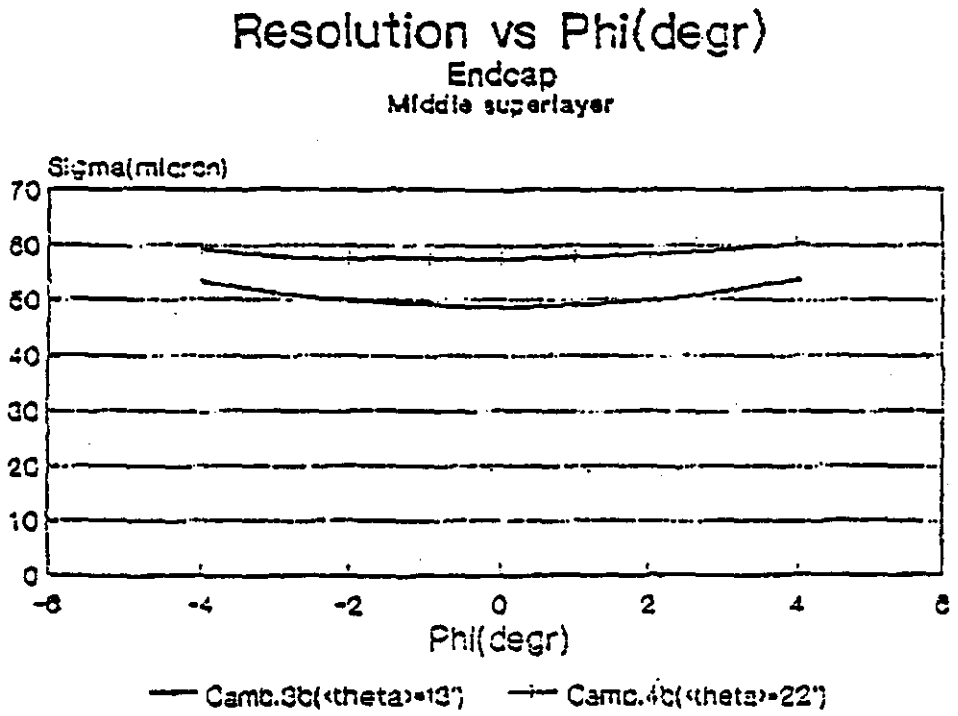

Resolution vs Theta(degr)
Barrel
Sigma(micron)
100
80
60
40
20
0
0
20
40
60
80
100
Theta(degr)
Superlayers:
Outer
Middle
Inner

Fig. 4.3.1.4


Resolution vs Phi(degr)
Endcap
Middle superlayer
Sigma(micron)
70
60
50
40
30
20
10
0
-6
-4
-2
0
2
4
6
Phi(degr)
Camc.3b(<theta>=13°)
Camc.4b(<theta>=22°)

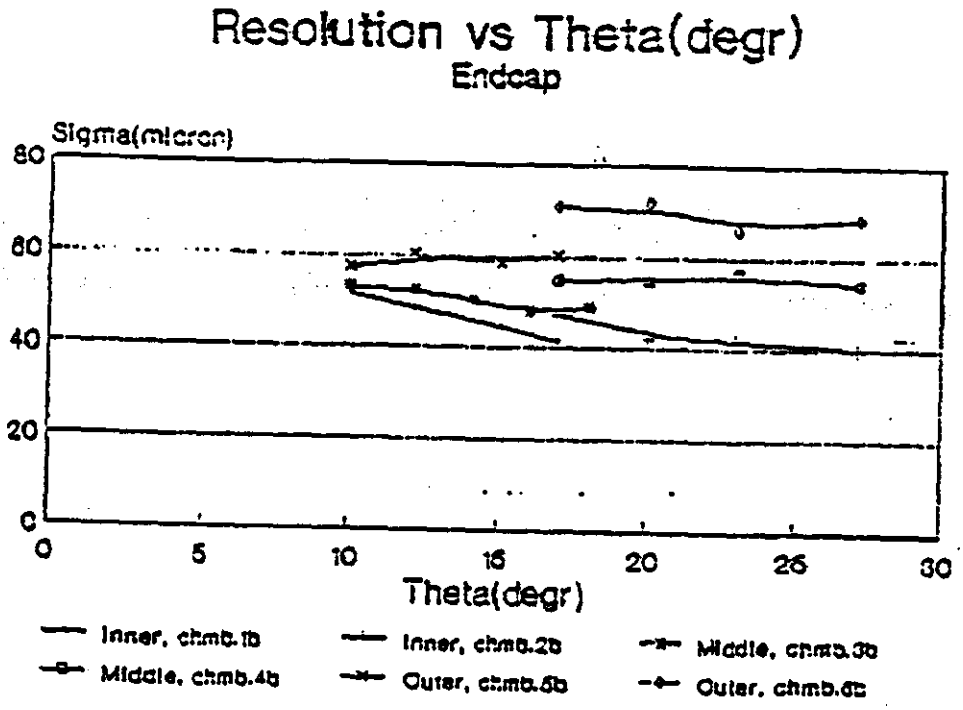
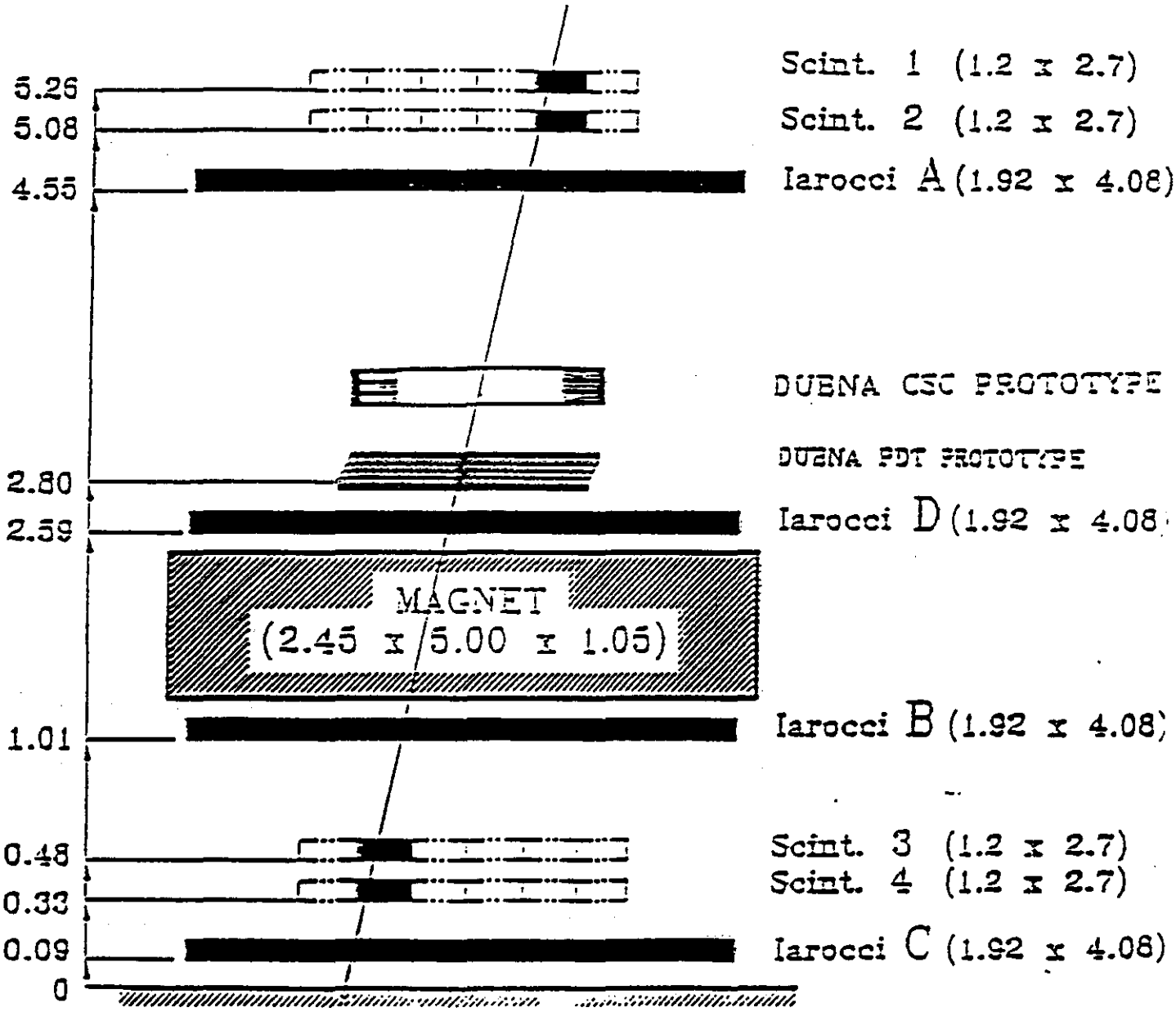

Resolution vs Theta(degr)
Endcap
Sigma(micron)
80
60
40
20
0
0
5
10
15
20
25
30
Theta(degr)
Inner, chmb.1b
Inner, chmb.2b
Middle, chmb.3b
Middle, chmb.4b
Outer, chmb.5b
Outer, chmb.6b

Fig 4.3.1.5

TTR TEST SETUP

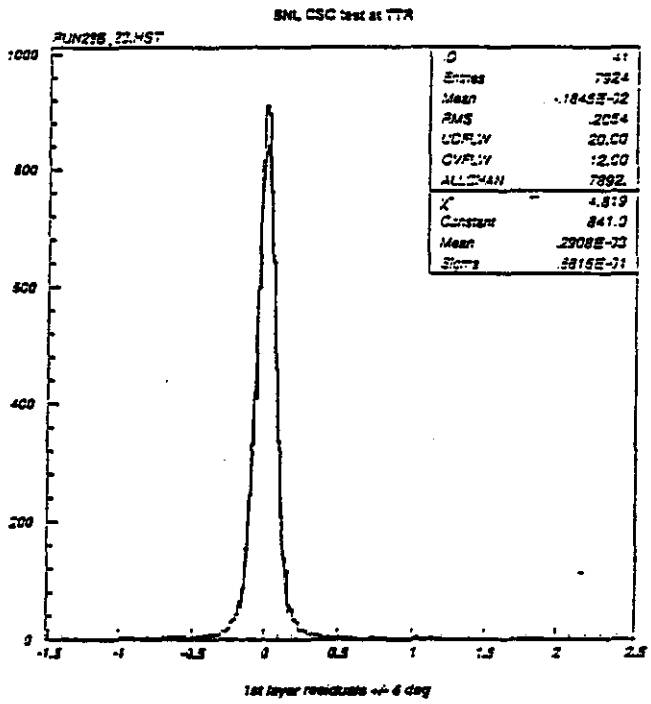


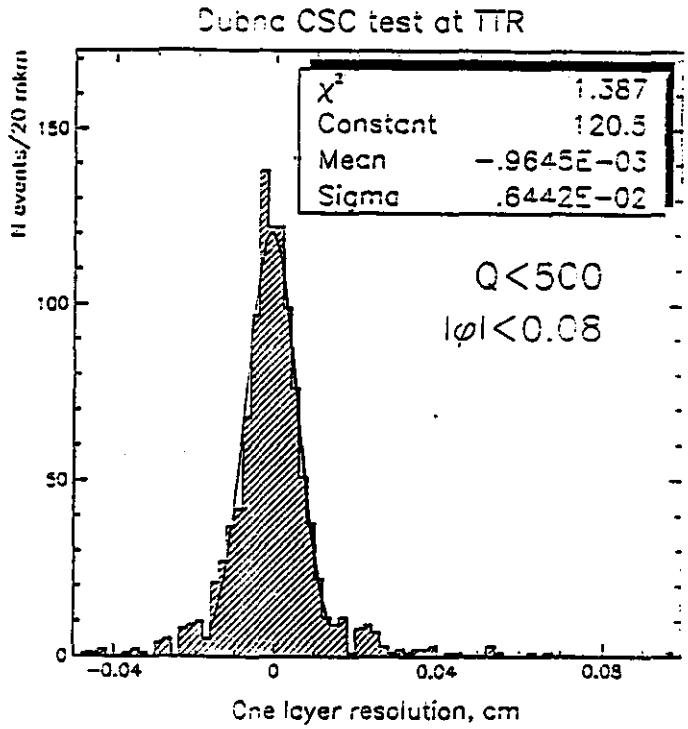
All dimensions in m

Fig. 4.3.1.7

The results of the CSC prototypes tests

Prototype	σ_x, $<2°$	$\sigma_x < 6°$
BNL $0.5 \times 0.5\,m^2$	46μ	66μ
BNL $1.8 \times 1.2\,m^2$	—	$<95\mu$
DUBNA $1.5 \times 1.0\,m^2$	60μ	64μ
HOUSTON $1.0 \times 0.5\,m^2$	38μ	56μ
PNPI $0.5 \times 0.5\,m^2$	43μ	—


SNL CSC test at TTR
1st layer residuals +/- 6 deg


Dubna CSC test at TTR
χ² 1.387
Constant 120.5
Mean −.9645E−03
Sigma .6442E−02
Q<500
|φ|<0.08
N events/20 mkm
One layer resolution, cm

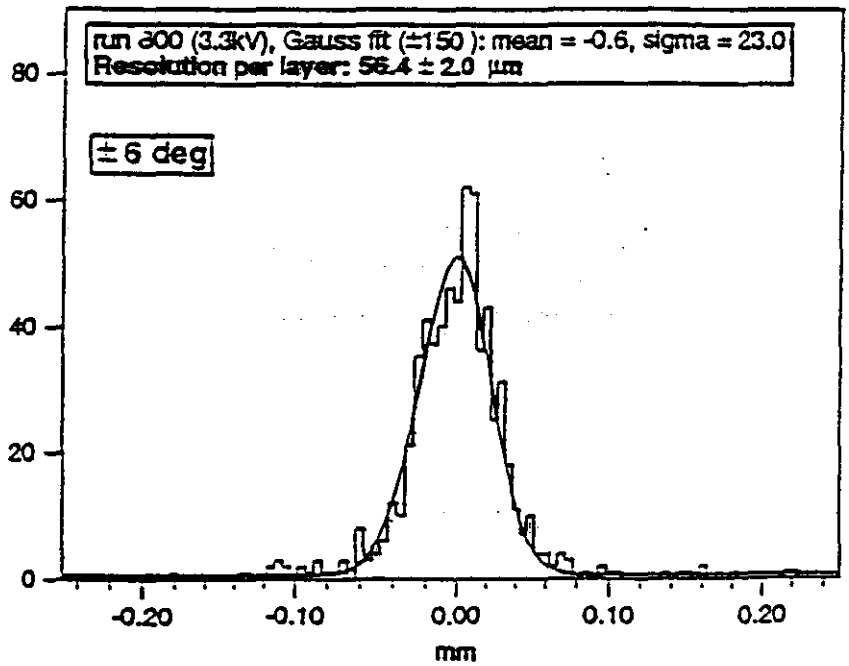

run 300 (3.3kV), Gauss fit (±150): mean = -0.6, sigma = 23.0
Resolution per layer: 56.4 ± 2.0 μm
± 6 deg
mm

Fig. 4.3.1.10

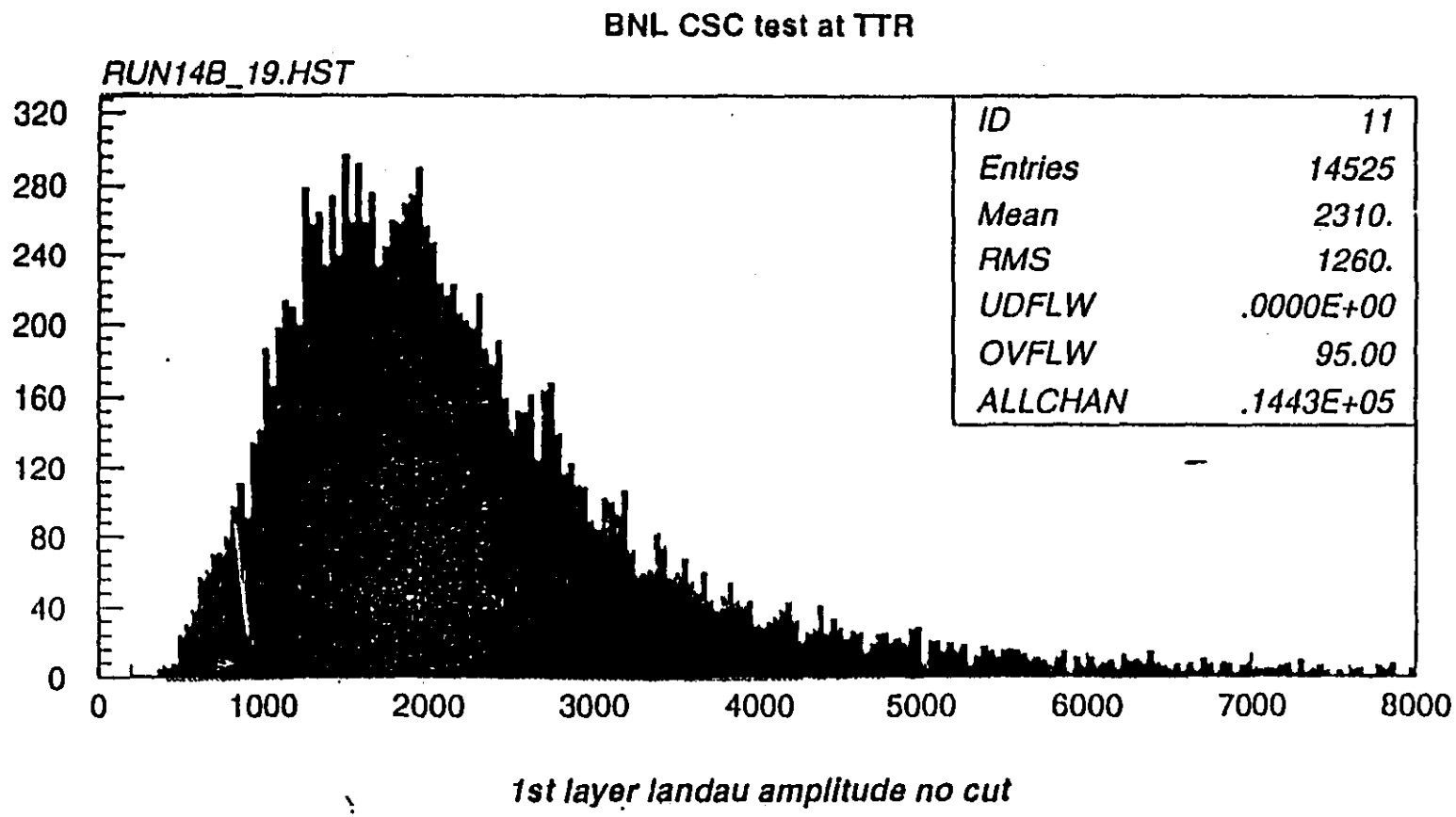

BNL CSC test at TTR
RUN14B_19.HST
ID 11
Entries 14525
Mean 2310.
RMS 1260.
UDFLW .0000E+00
OVFLW 95.00
ALLCHAN .1443E+05
320
280
240
200
160
120
80
40
0
0
1000
2000
3000
4000
5000
6000
7000
8000
1st layer landau amplitude no cut

Fig. 4.3.1.8

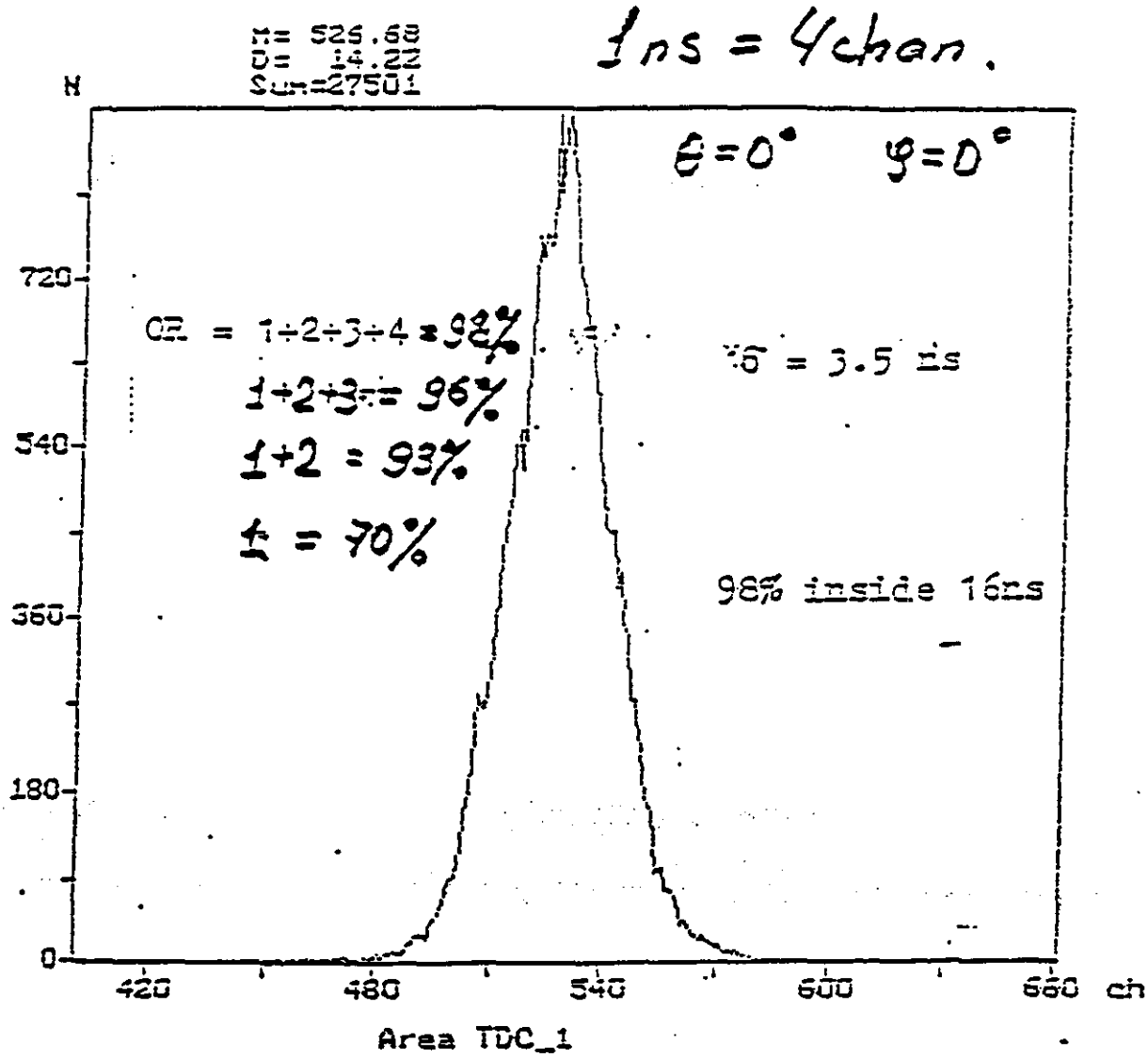

M= 526.68
D= 14.22
Sum=27501
1ns = 4chan.
N
θ=0°
φ=0°
720
540
360
180
0
CR = 1÷2÷3÷4 = 98%
1÷2÷3 = 96%
1+2 = 93%
1 = 70%
σ = 3.5 ns
98% inside 16ns
420
480
540
600
660
ch
Area TDC_1

Fig. 4.3.1.12

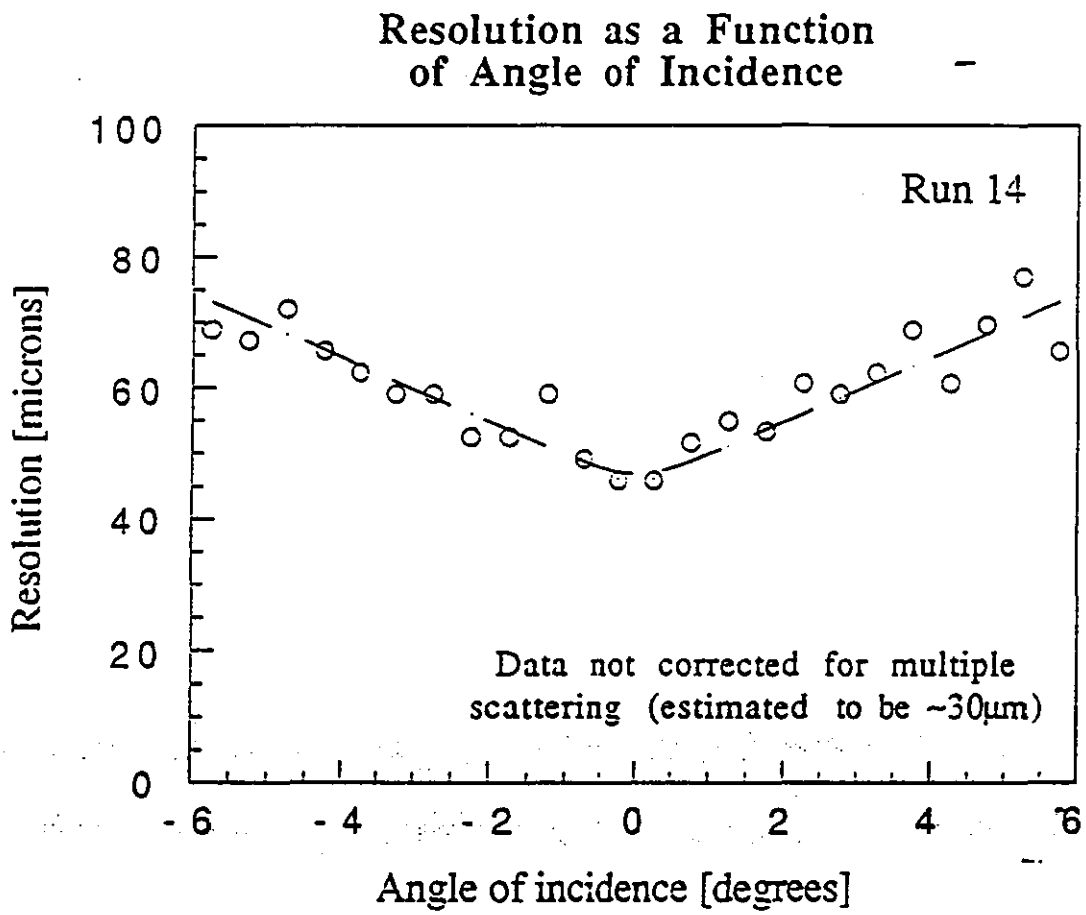
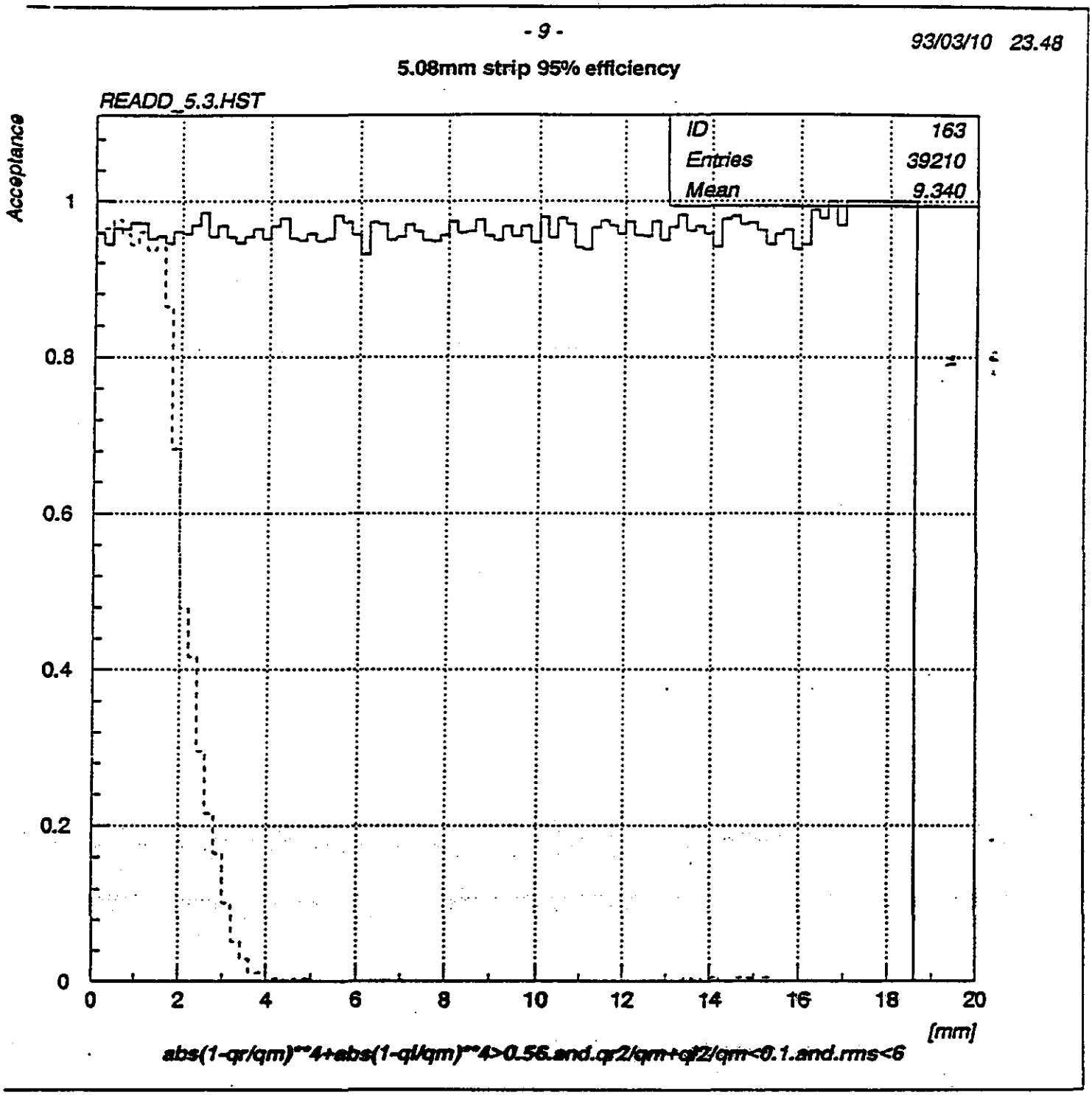
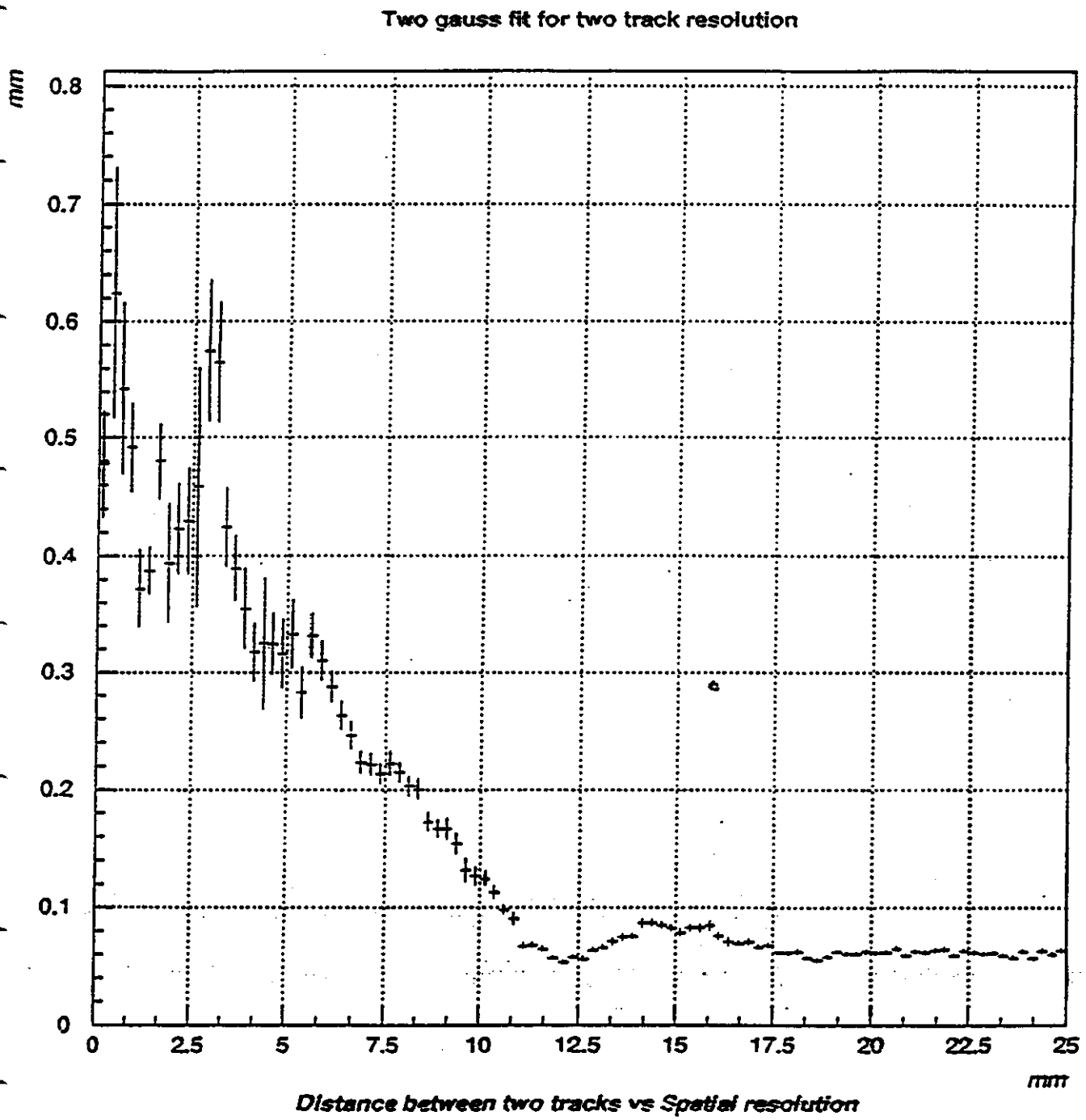
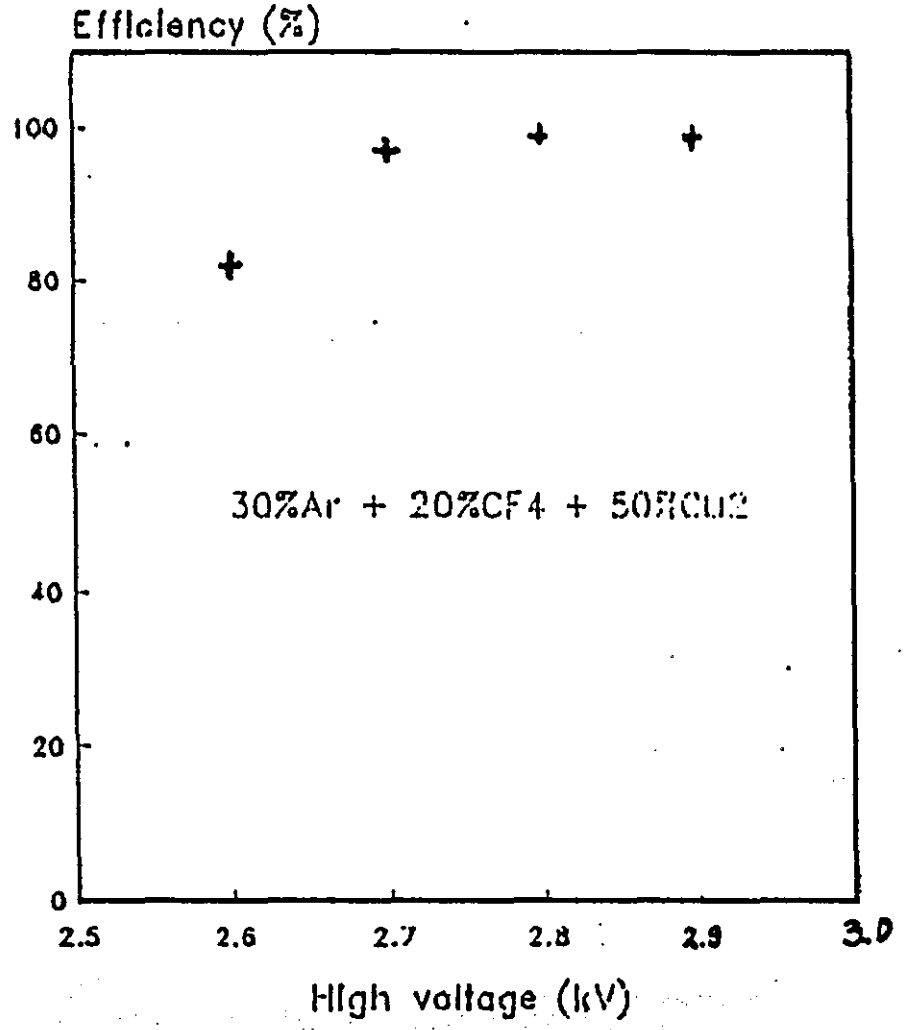

Resolution as a Function
of Angle of Incidence
Run 14
Data not corrected for multiple
scattering (estimated to be ~30μm)
Resolution [microns]
100
80
60
40
20
0
- 6
- 4
- 2
0
2
4
6
Angle of incidence [degrees]

Fig 24

4.3.1.11

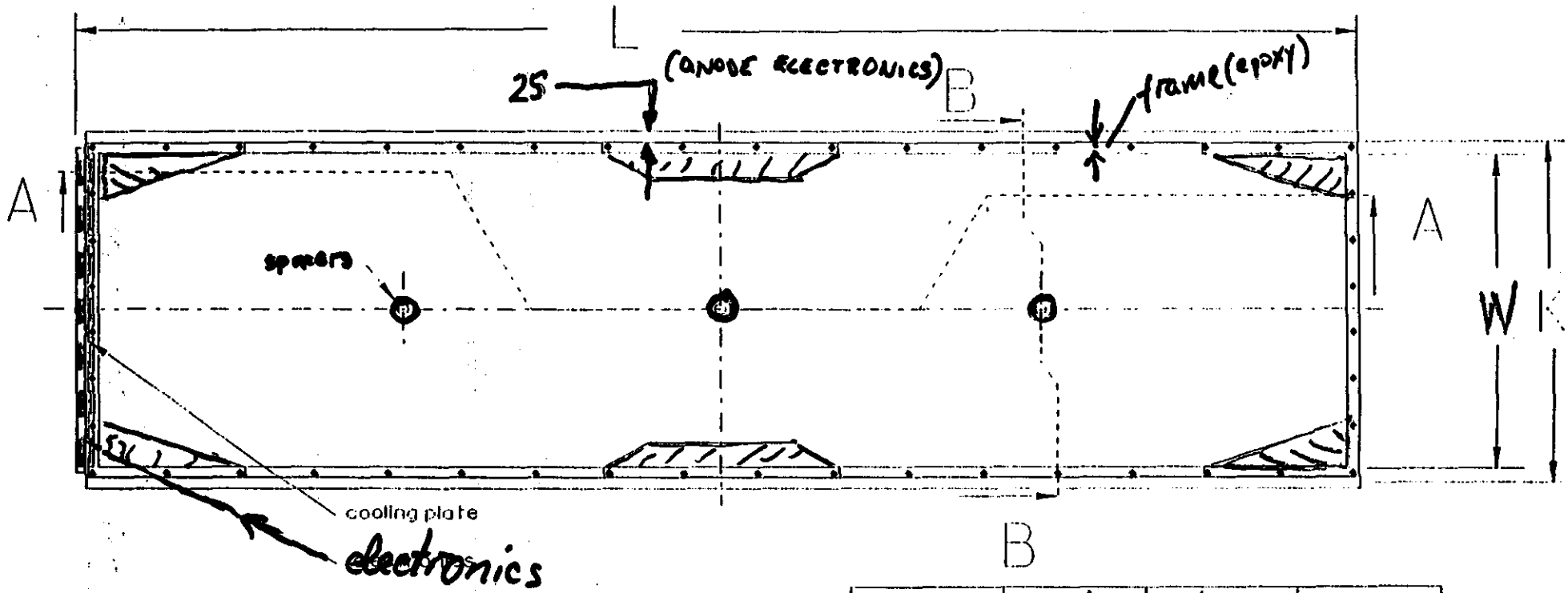

- 9 -
93/03/10 23.48
5.08mm strip 95% efficiency
READD_5.3.HST
ID 163
Entries 39210
Mean 9.340
Acceptance
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
14
16
18
20
[mm]
abs(1-qr/qm)**4+abs(1-ql/qm)**4>0.56.and.qr2/qm+ql2/qm<0.1.and.rms<6


Two gauss fit for two track resolution
mm
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
mm
Distance between two tracks vs Spatial resolution



99.8% efficiency

Fig. 4.3.1.9

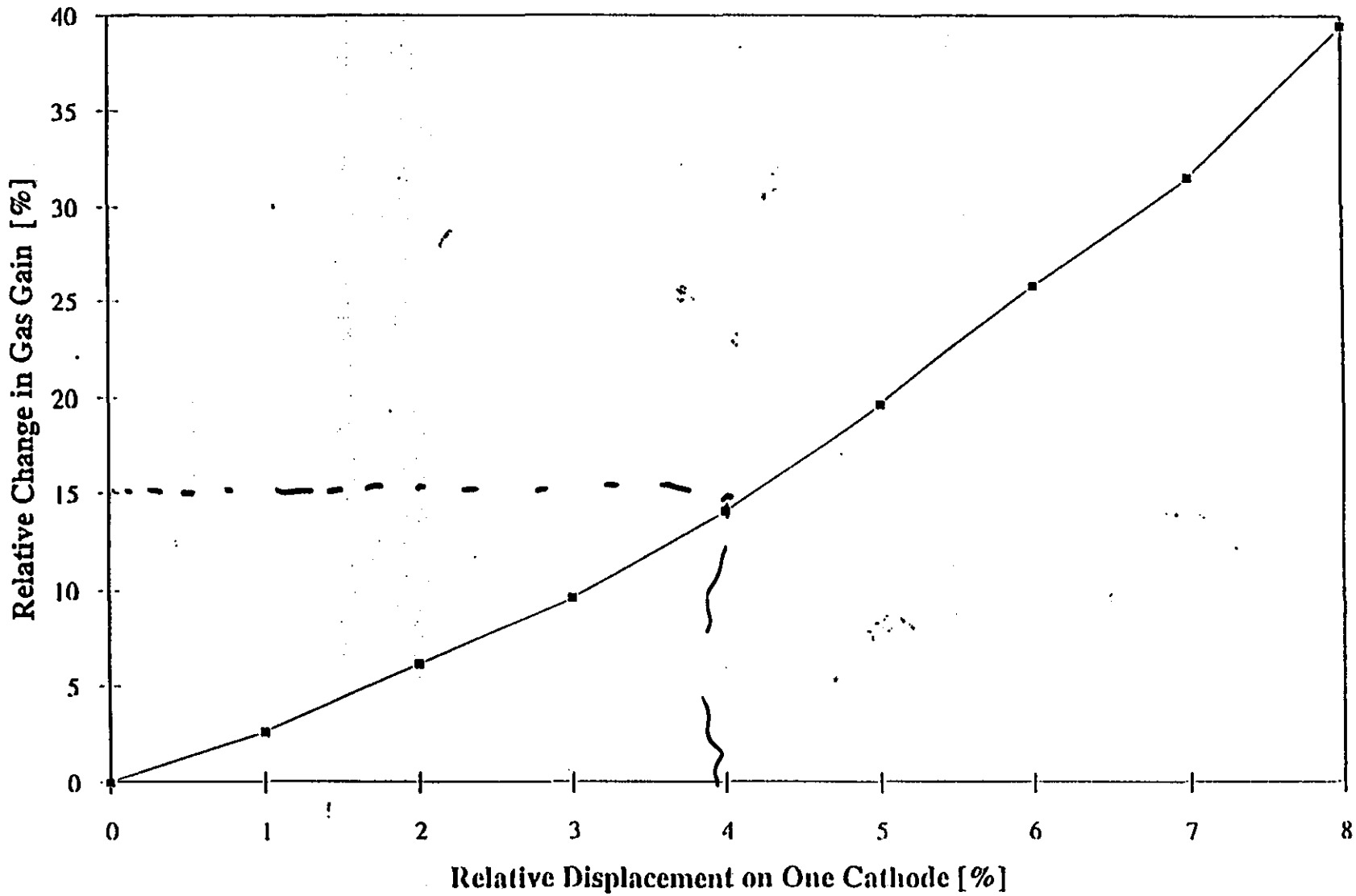


	K mm	W mm	h mm	S mm
INNER SUPERLAYER	770	640	2.5	5.71
MIDDLE SUPERLAYER	1080	950	4.0	8.48
OUTER SUPERLAYER	1330	1200	5.0	10.7

L is T.B.D.

I.GOLUTVIN
Y.KIRYUSHIN
03/03/1993

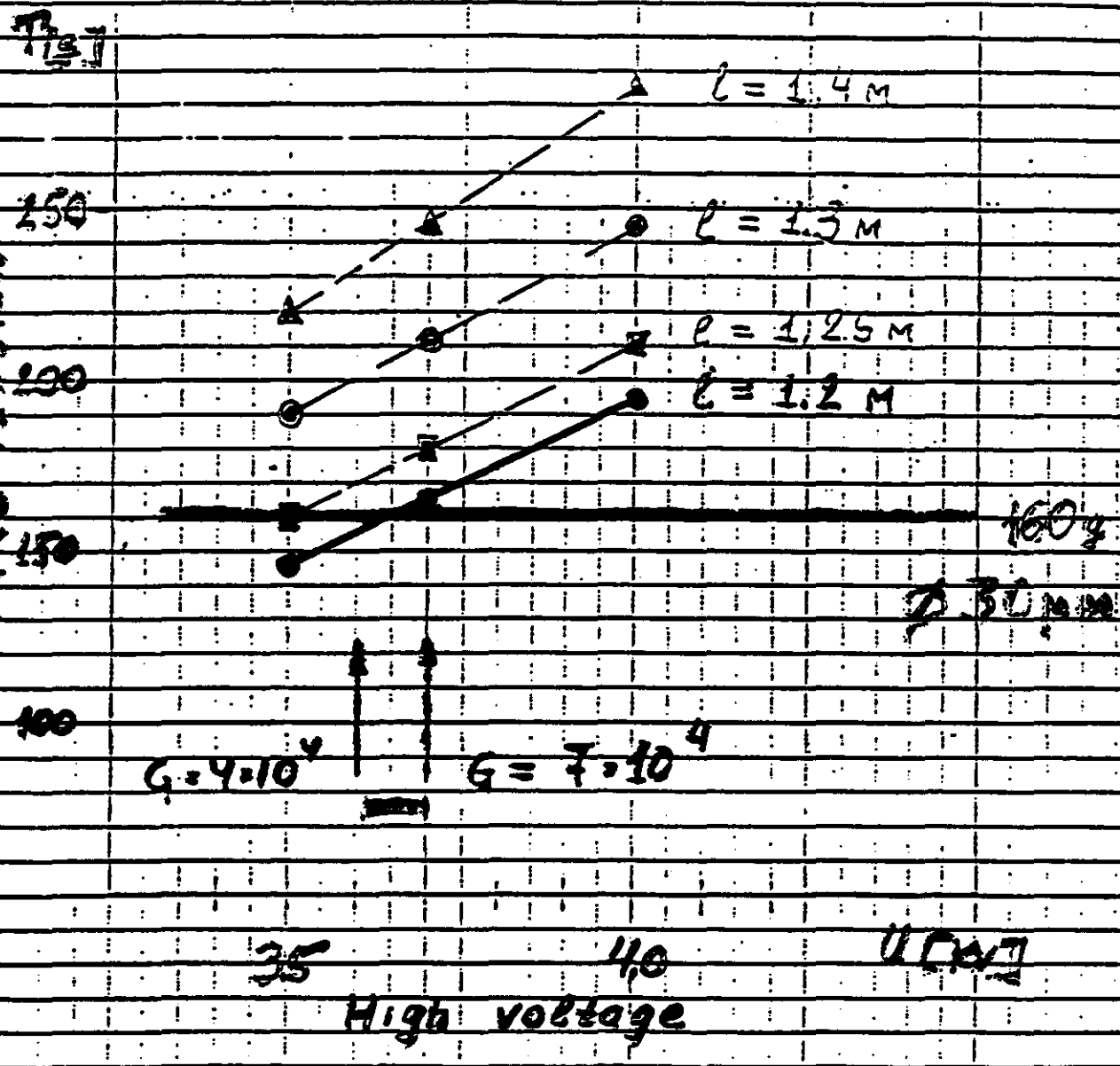
4.3.1.4



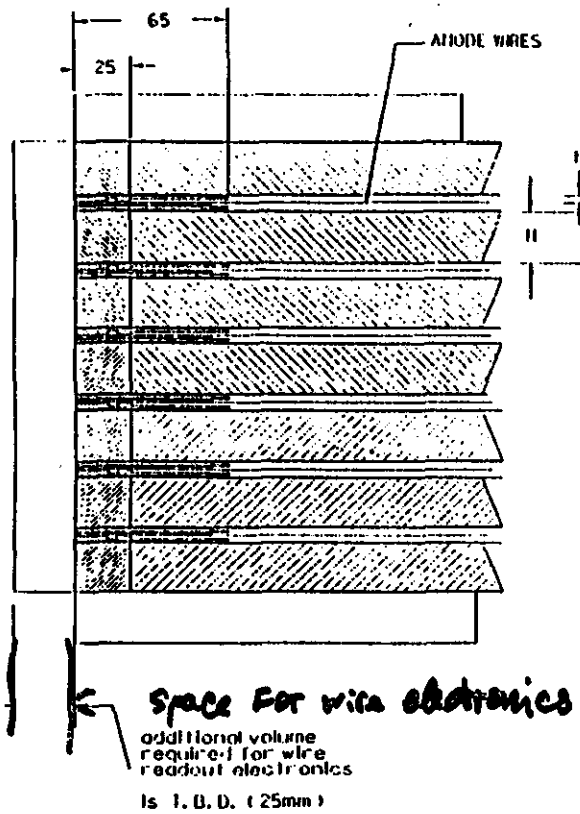
100 ÷ 150 μm tolerance

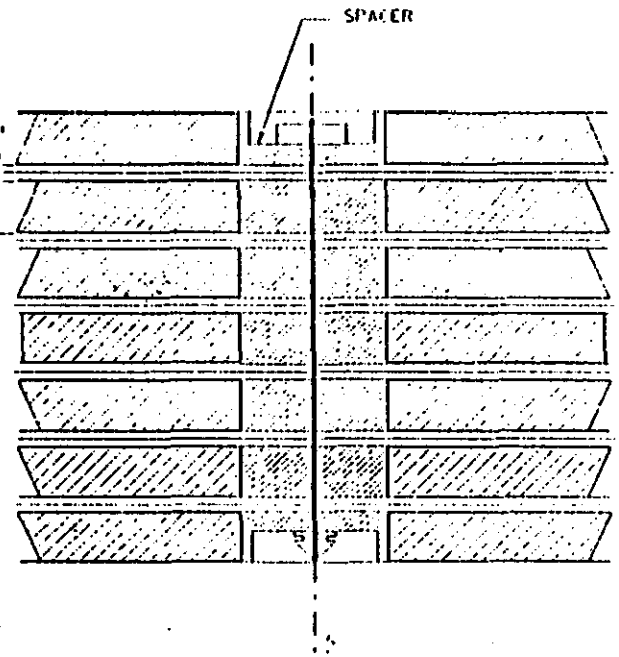
4.3.1.13

MAX ANODE WIRE LENGTH

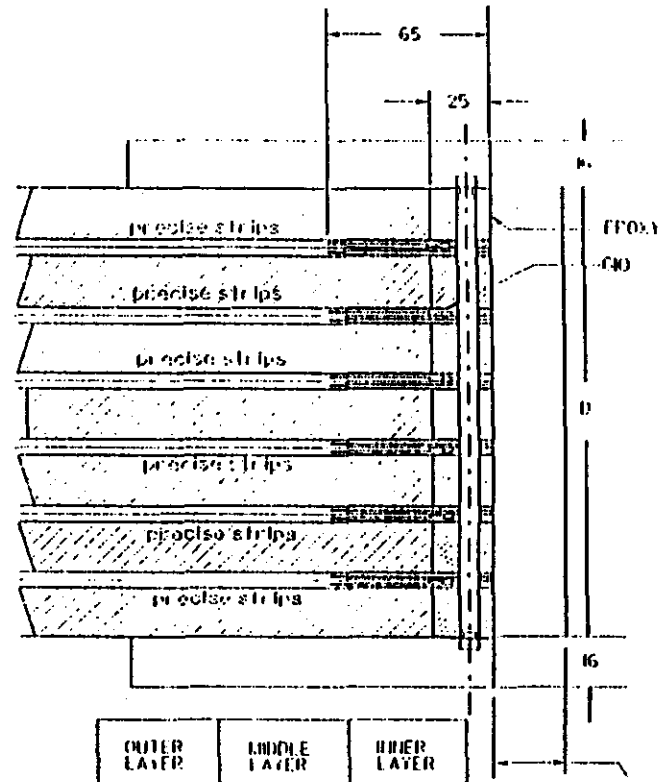


PRECISE STRIP READOUT
H = 50 mm
118





SECTION B-B
(ALONG STRIPS)



	OUTER LAYER	MIDDLE LAYER	INNER LAYER
h (mm)	5.0	4.0	2.5

H = 20 mm

additional volume required for distribution of the high voltage is T.B.D. (25mm)

I.GOLUTVIN
Y.FIRYUSHIN
03/03/1993

4.3.1.14

CSC material audit

	Mat.	Density g/cm³	cm/X₀	thick. cm	MASS kg	norm X₀
Hexel Core	Nomex	0.0288	1406	2×7	11.165	0.00995
Circuit Board	G10	1.7	19.4	0.05×14	32.873	0.0361
Skin Layer	Cu	8.96	1.47	0.0017×14	5.885	0.0162
Frames	G10	1.7	19.4	17.8	50.345	0.9175

Total mass = 100 kg

Mass / area = 36.24 kg/m²

X_0 through center = 0.0622

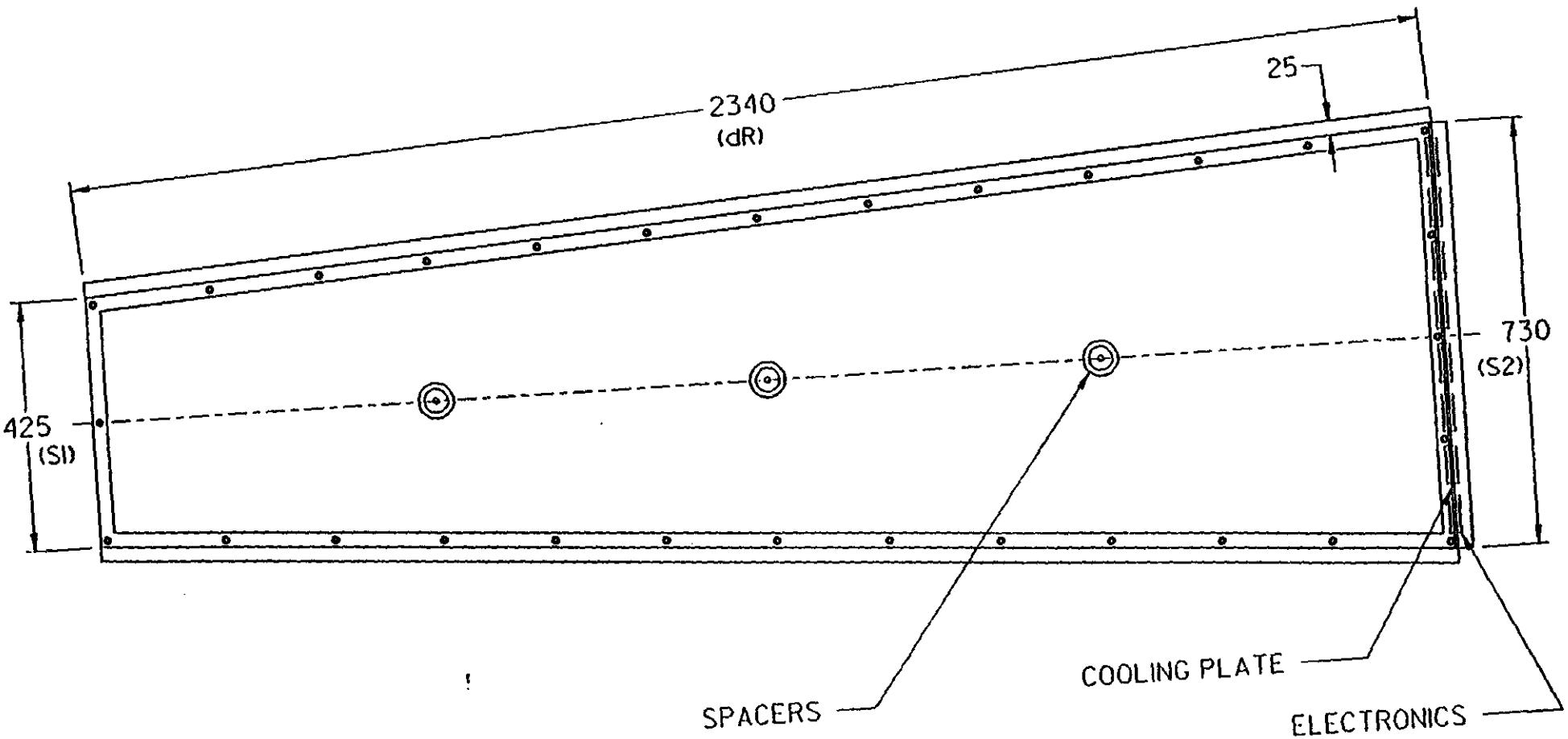
X_0 through frame = 0.9335

Total area = 2.76 m²

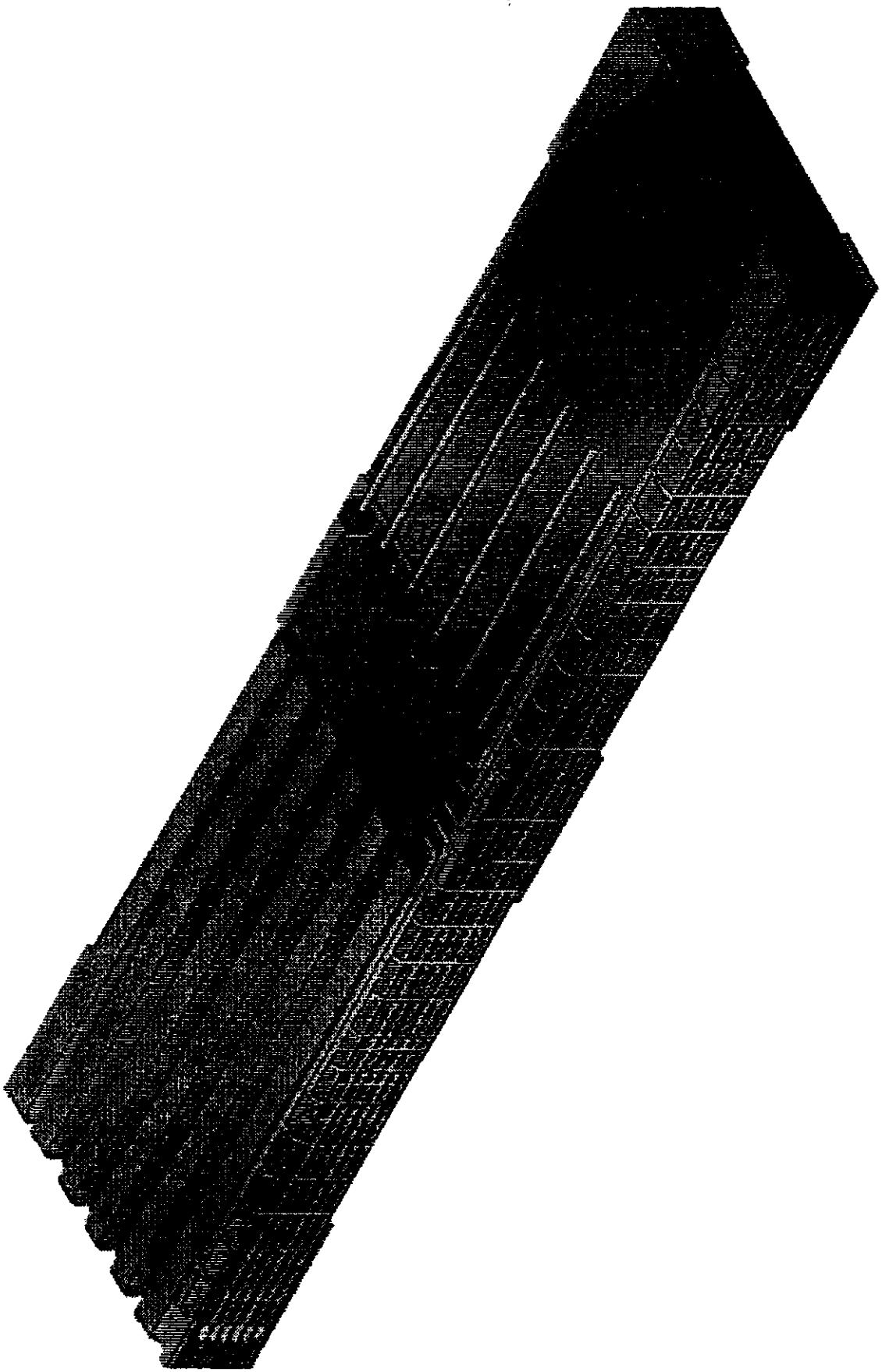
Frame area = 0.166 m² (6.03%

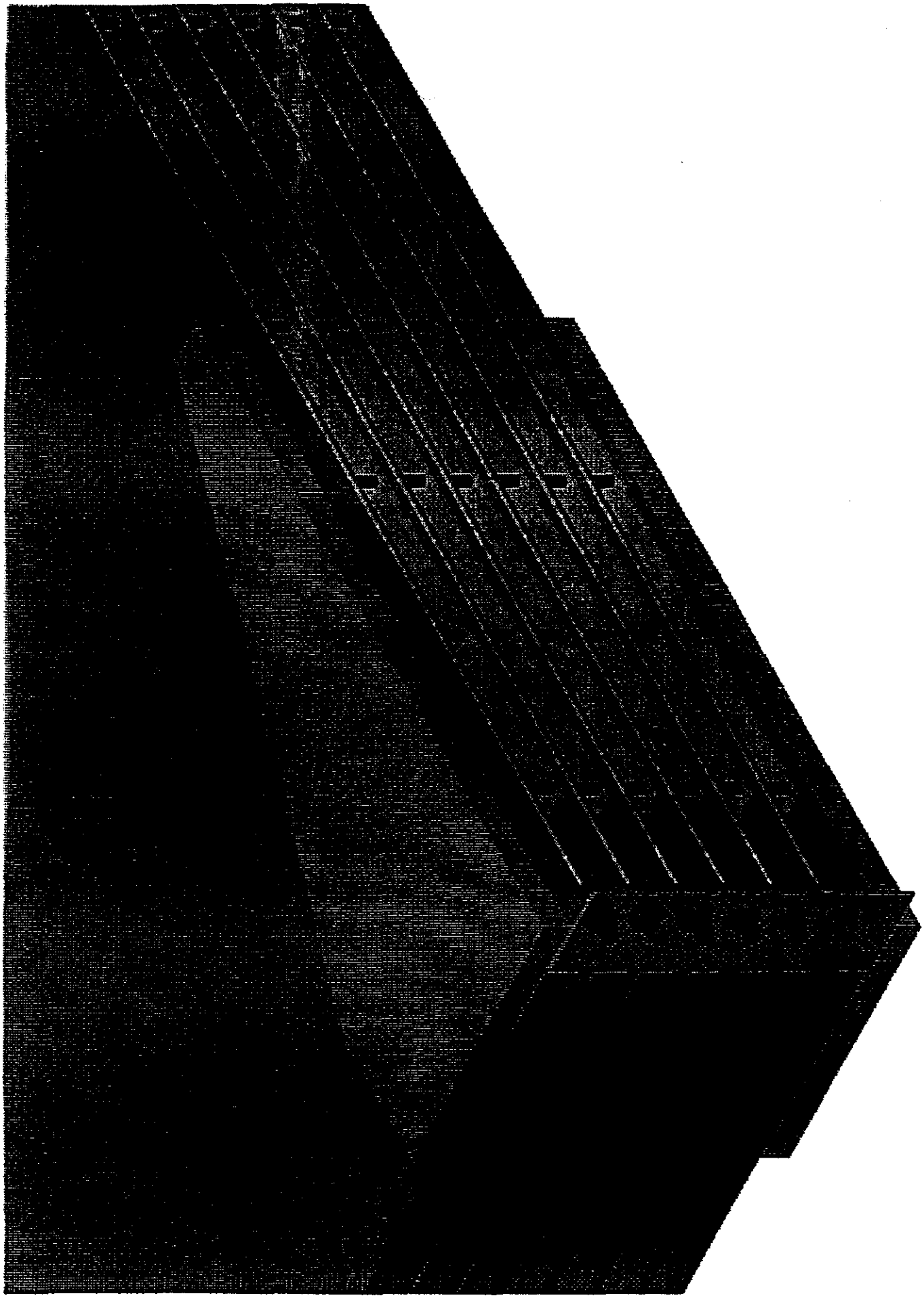
ENDCAP MODULE

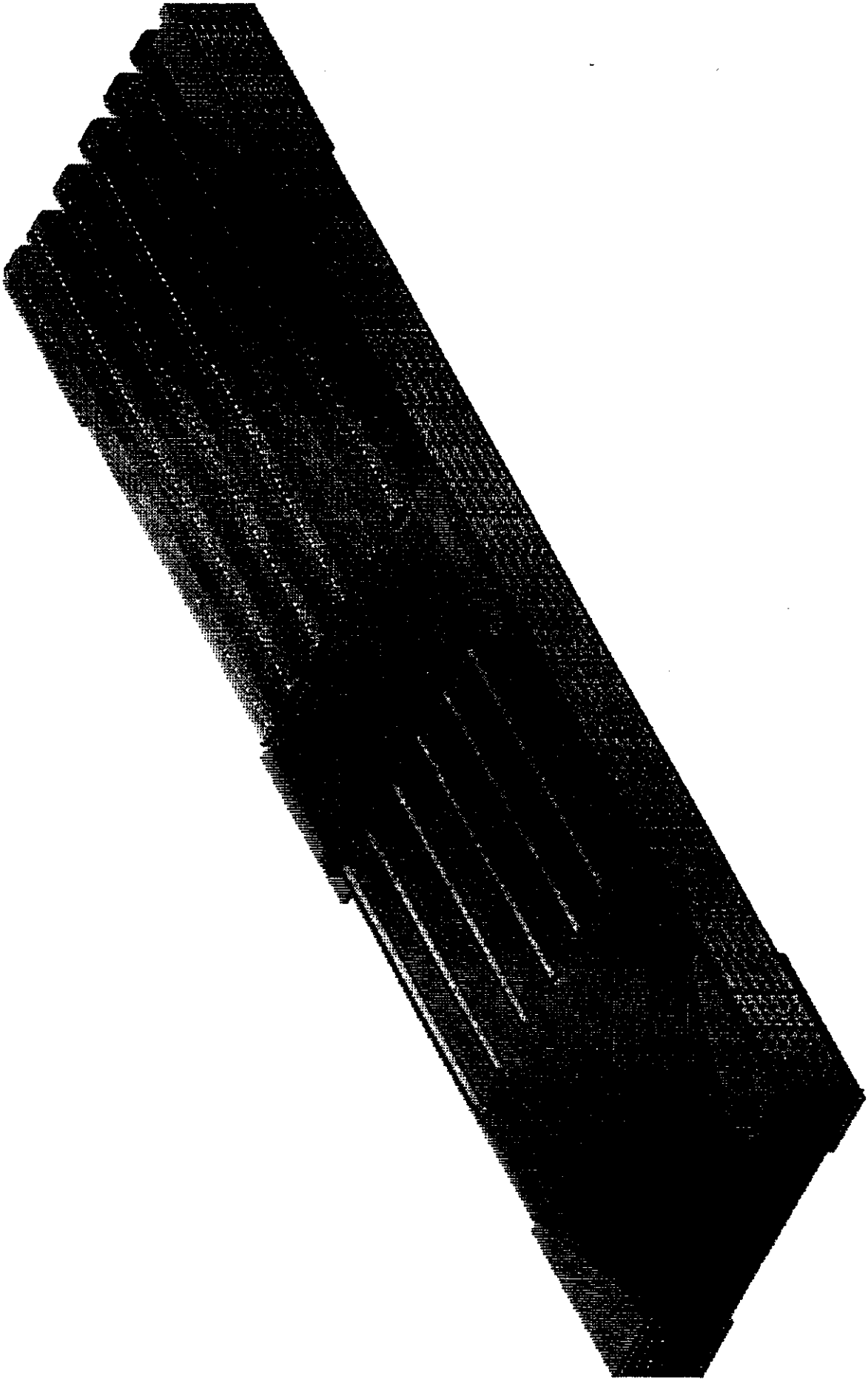
MIDDLE MODULE 4A



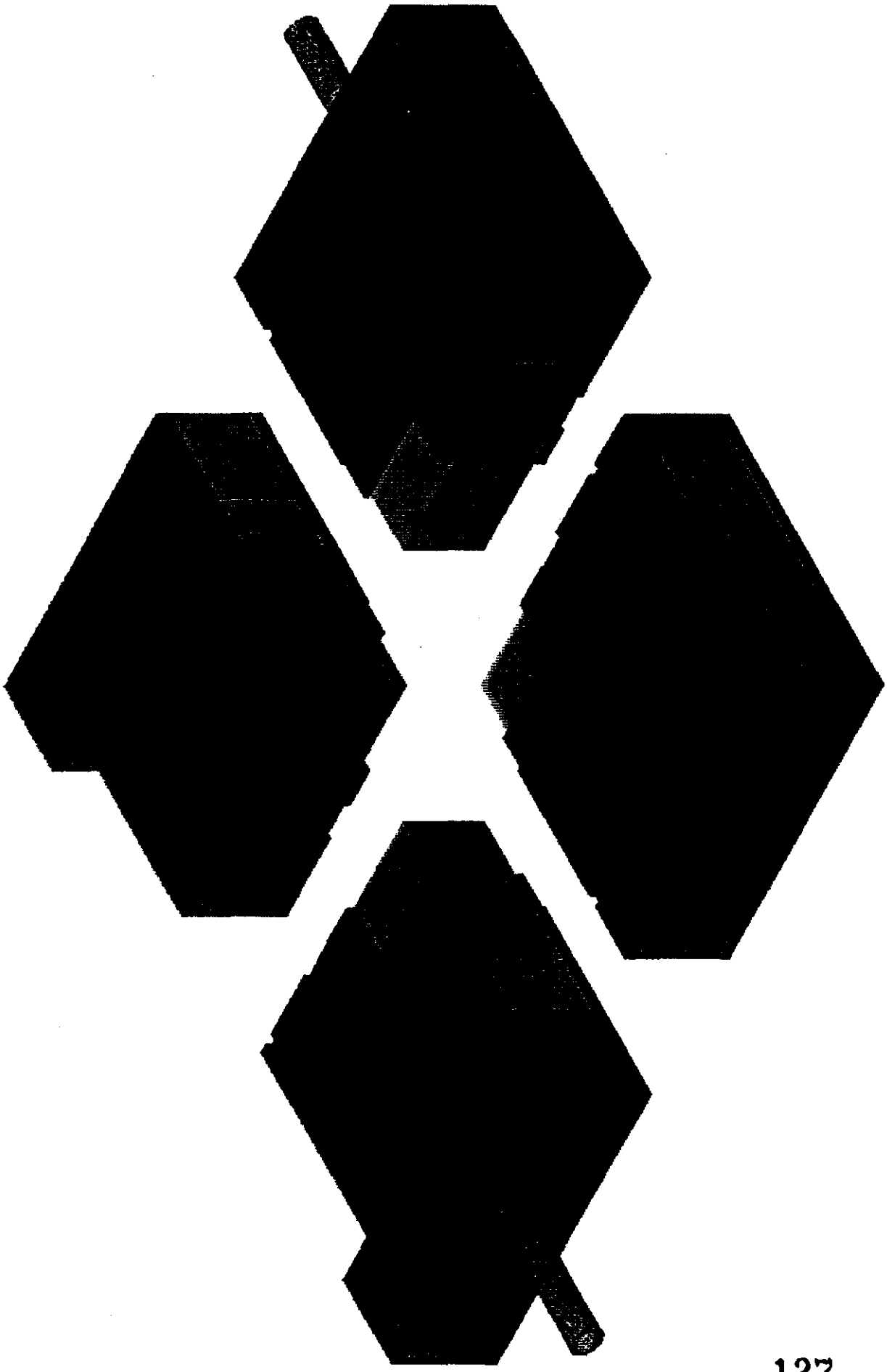
4.3.1.17

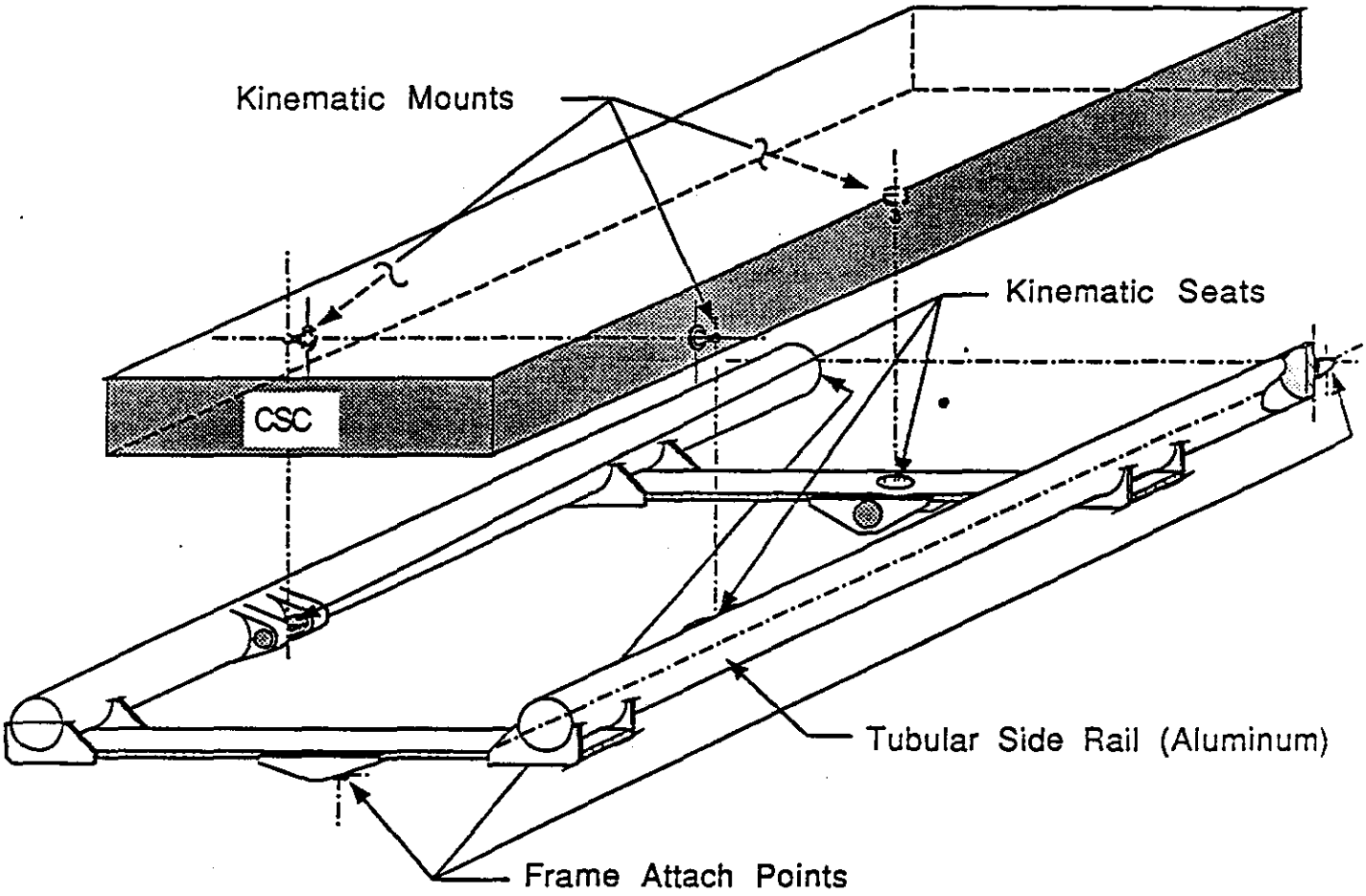


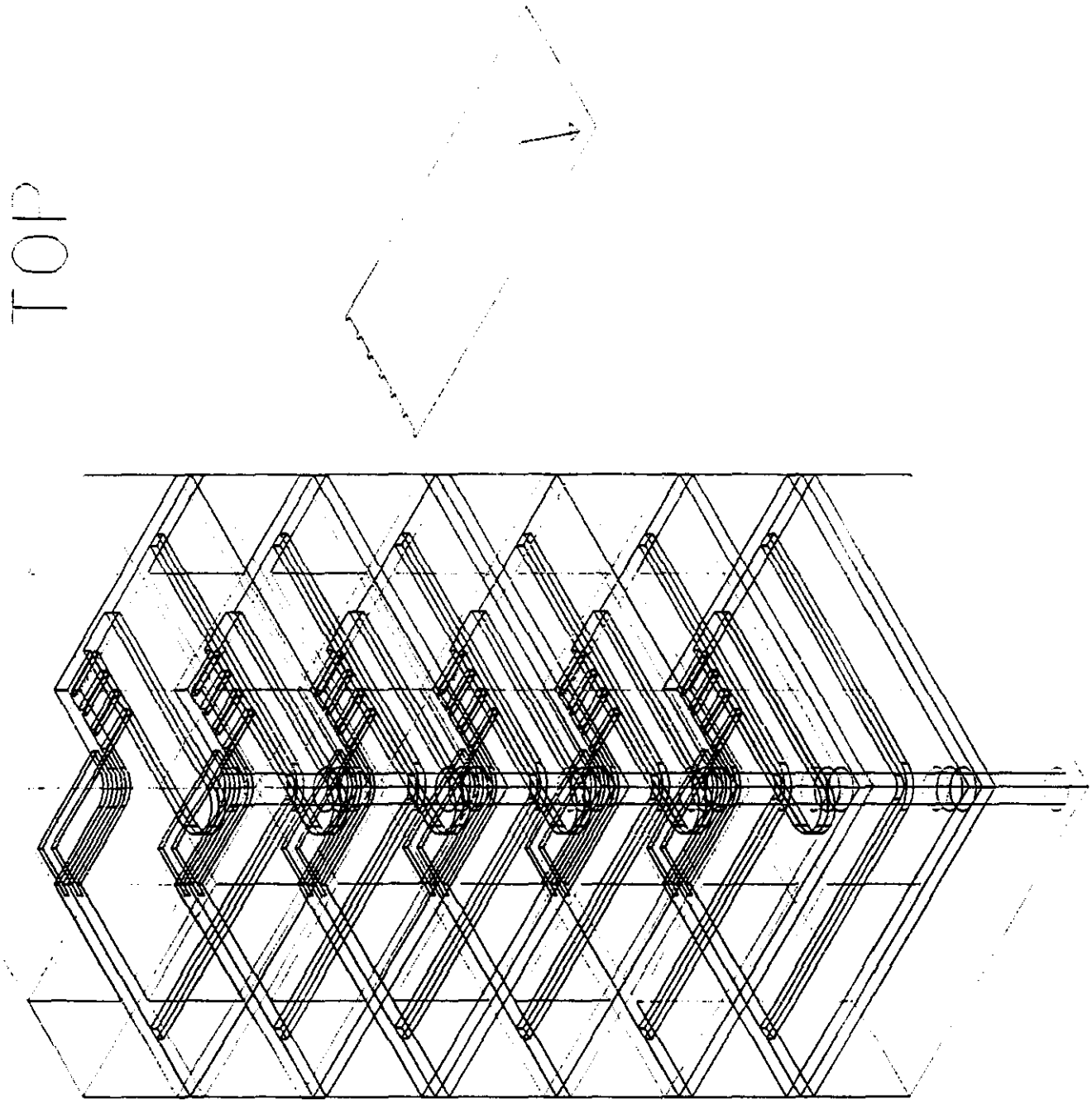


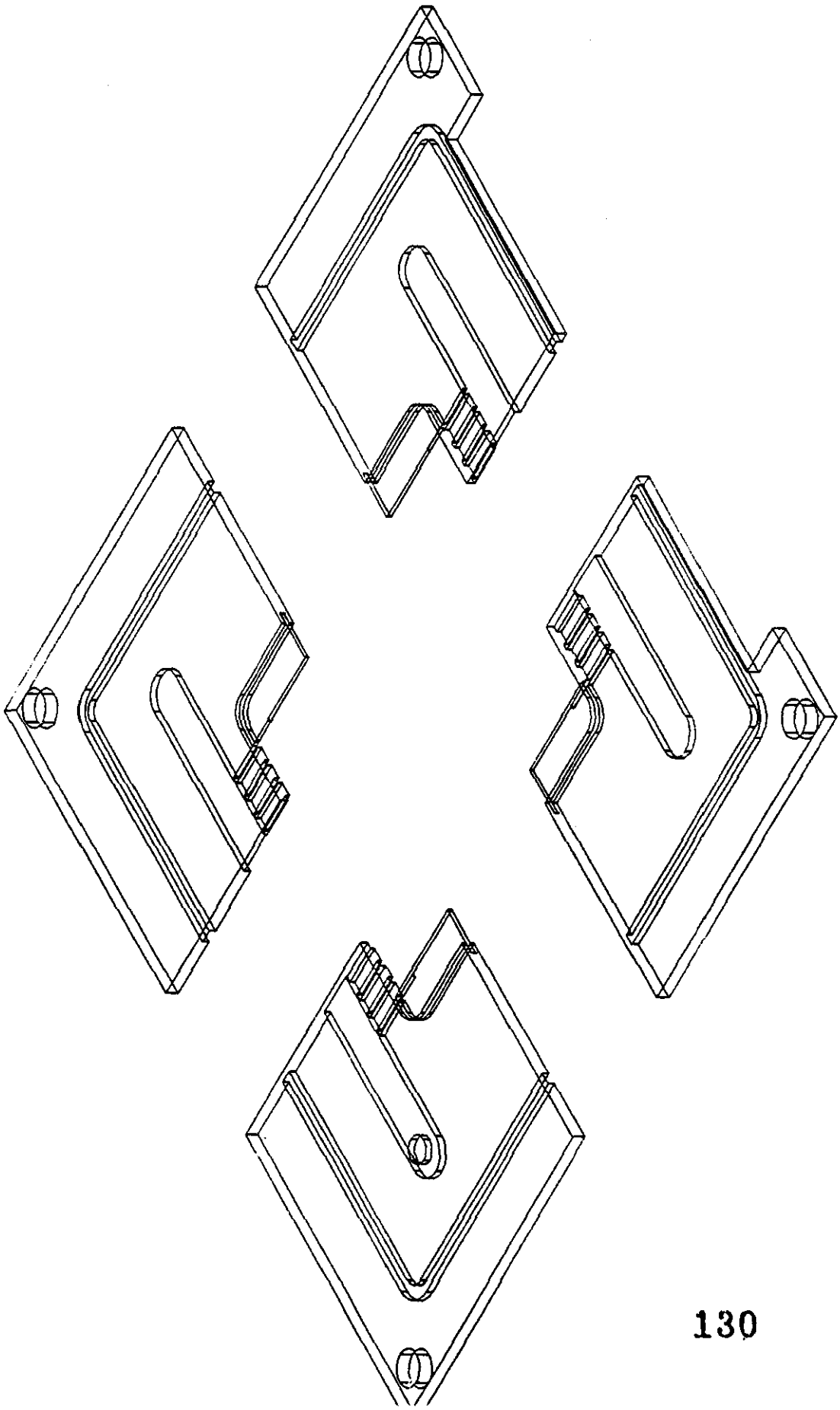


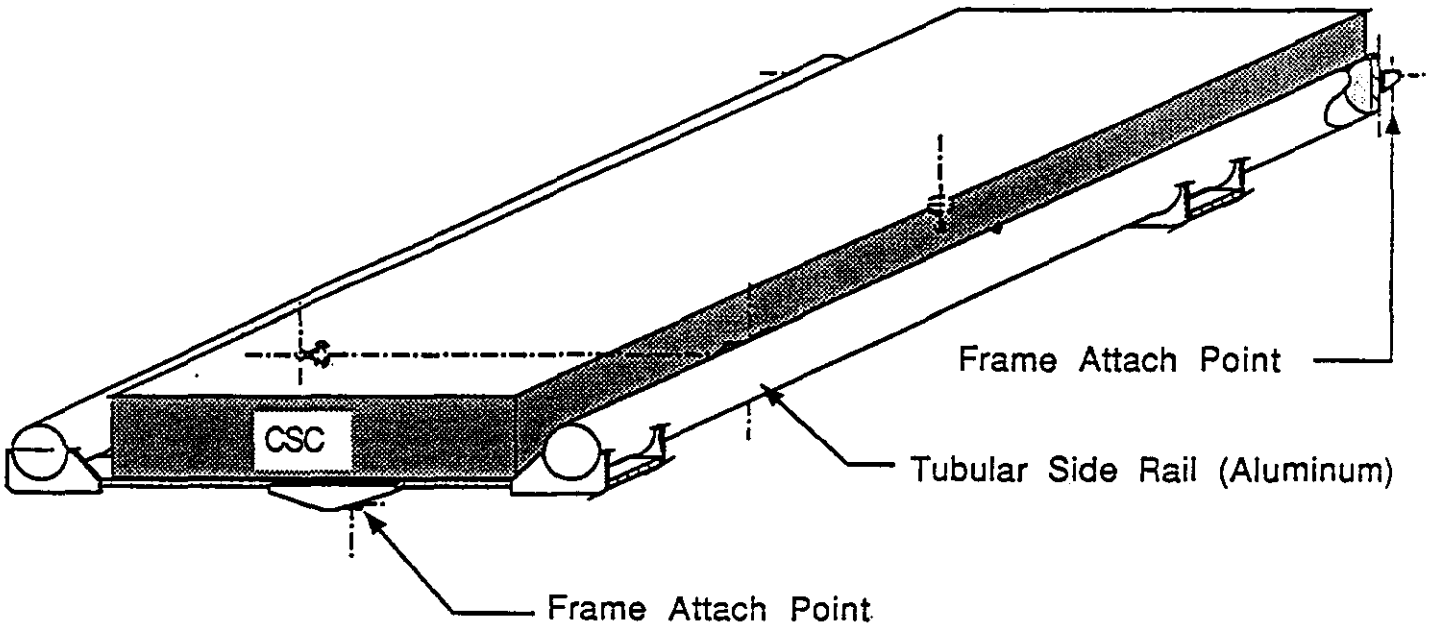
Unit # 2

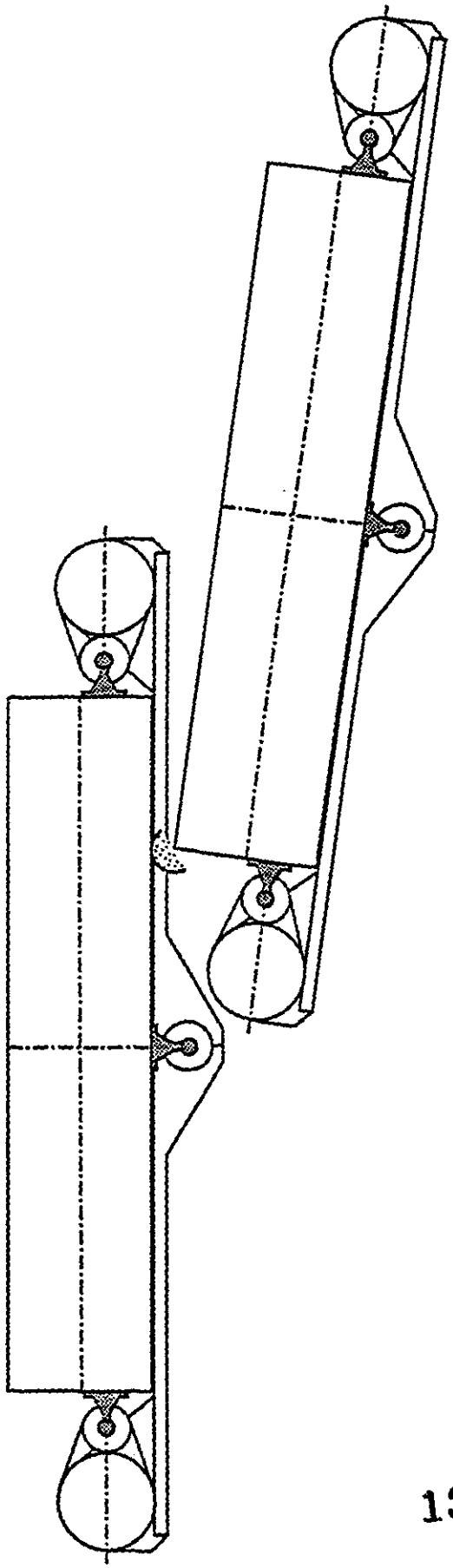


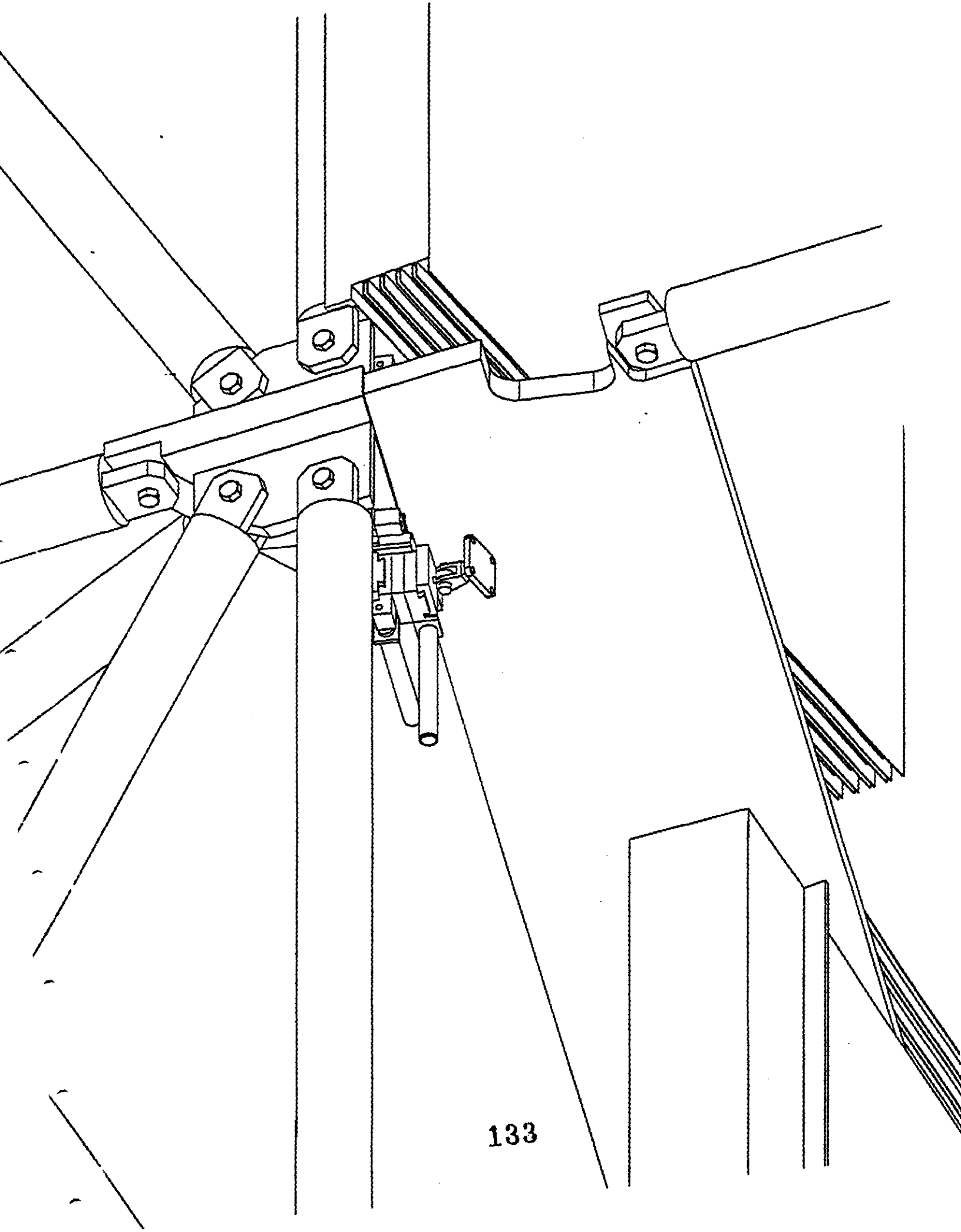

Kinematic Mounts
Kinematic Seats
CSC
Tubular Side Rail (Aluminum)
Frame Attach Points


TOP




CSC
Frame Attach Point
Tubular Side Rail (Aluminum)
Frame Attach Point





Remaining essential R&D

Results from our prototype program and R&D efforts thus far are very encouraging. The goals of our R&D program for the coming year will concentrate on the following points:

• verification of the detailed performance of a CSC in a magnetic field. We will build small detectors and test them in various magnetic field configurations to validate the Monte Carlo predictions of the Lorentz drift and geometric contributions to chamber resolution.

• development of preproduction modules. This effort will test construction techniques, the internal alignment of chambers within a module, and the electrical performance in an integrated six-chamber module.

• construction of a three-module tower with a truss support structure, as planned for the final muon system. This will test the structural support concept and validate the engineering calculations of structure rigidity and deformation. It will also provide a realistic test bed for the alignment systems proposed for the final system.

Maged Atiya

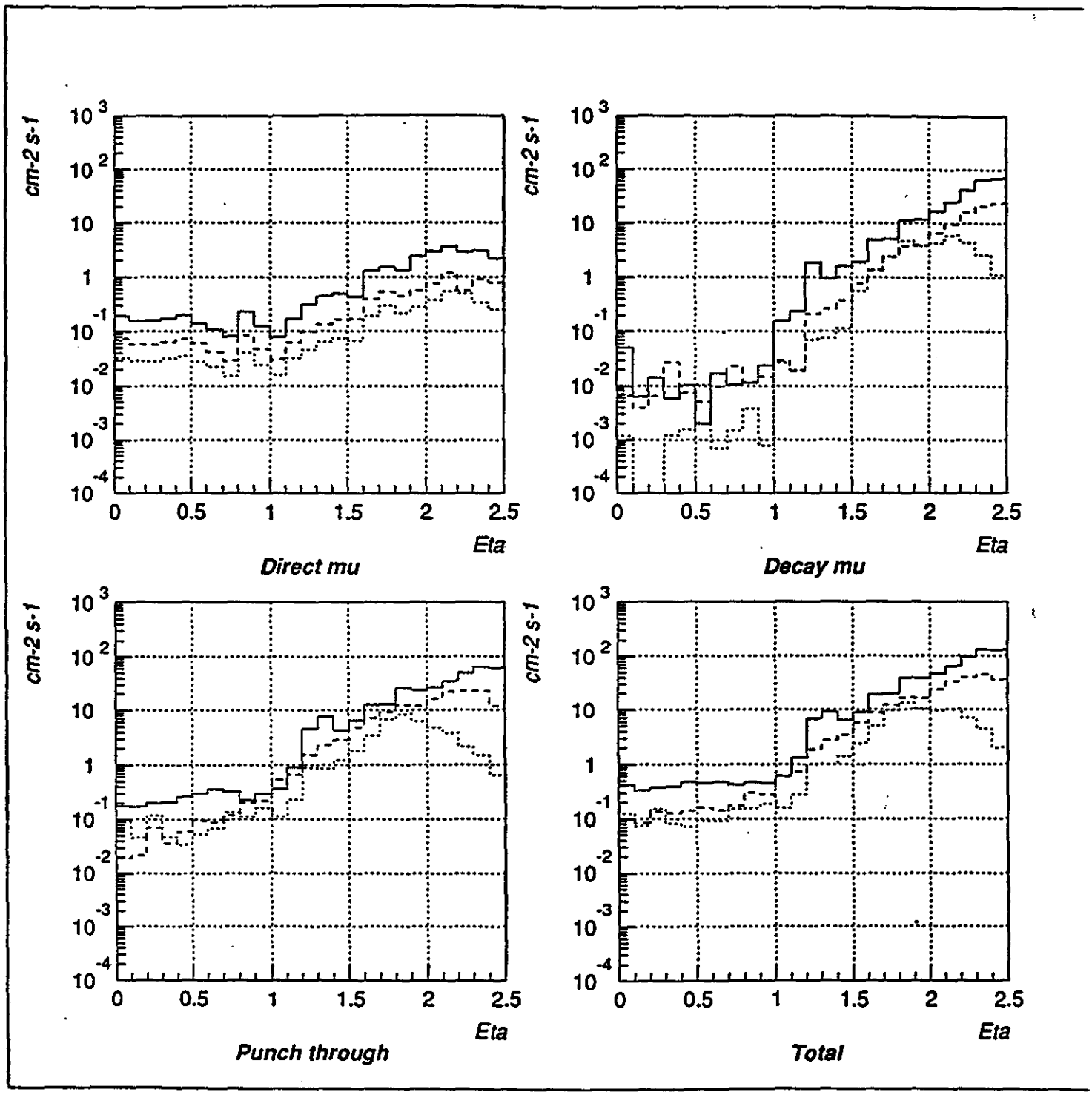
Electronics and Trigger

GEM MUON ELECTRONICS AND TRIGGER

BNL
BOSTON UNIVERSITY
CMU
HOUSTON
JINR (DUBNA)
BSU (MINSK)
MIT
PRINCETON
STONY BROOK

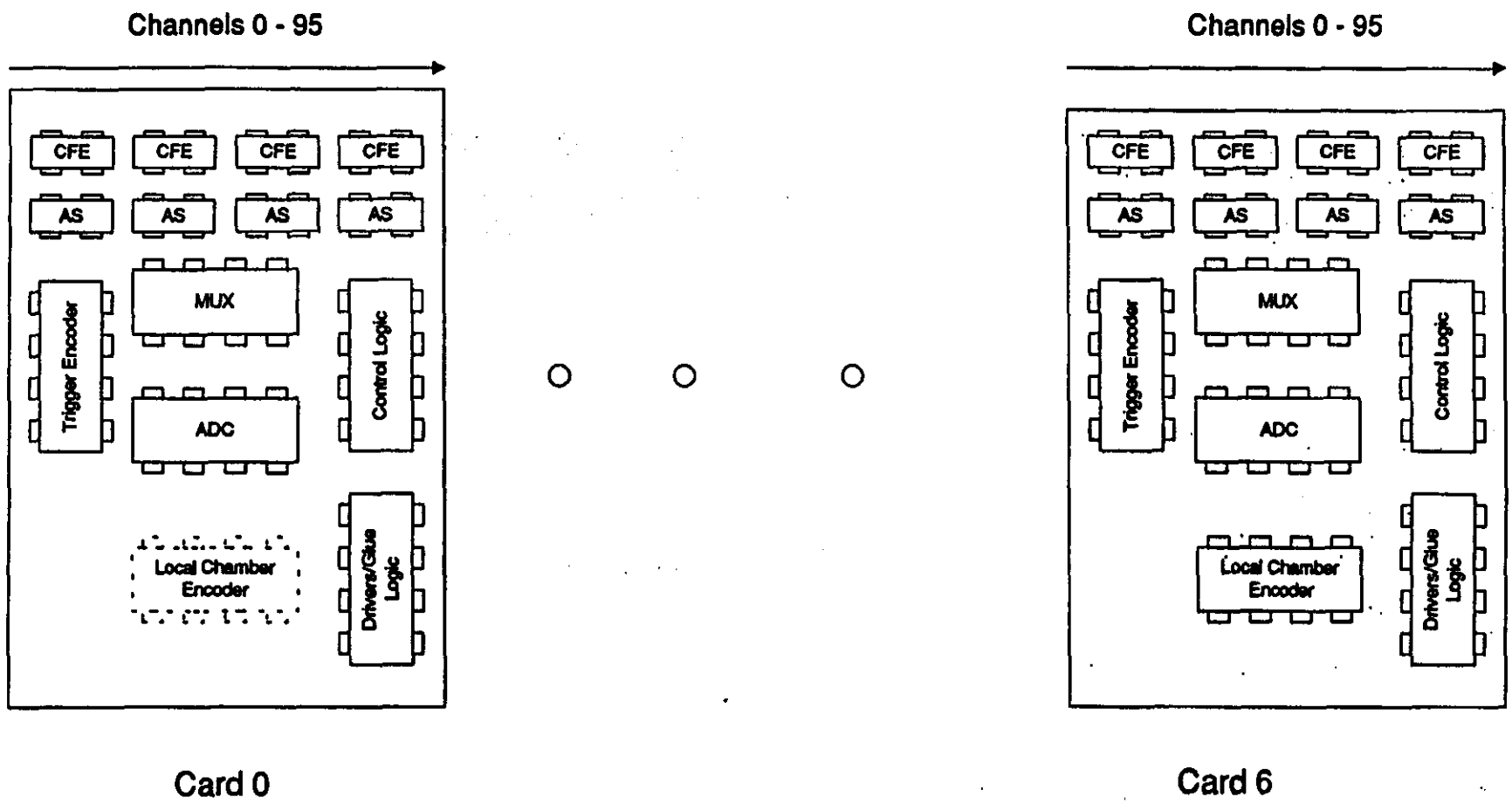
Electrical Specifications for the CSC Readout

Sys. Section	Parameter	Value	Notes
Readout	Equivalent Input Noise	$< 1500\ e^-$ rms	1
	Pulse Peaking Time	400 ± 100 ns	2
	Overall System Gain	0.4 fC/Count	3
	Dynamic Range	10 bits	4
	Cross Talk	< -50 db	
	Readout Rate	100 kHz	5
	Readout Latency	$< 100\ \mu$s	6
Trigger	Input Threshold	16 fC	7
	Timing Jitter	< 4 ns rms	8
	Time Walk	< 4 ns	9
General	Temperature Range	20 ± 5 °C	10
	Power Per Channel	< 100 mW	11
	Rad. Hardness: Ionizing	tbd	12
	Rad. Hardness: Neutrons	10^{14}cm^{-2}	13

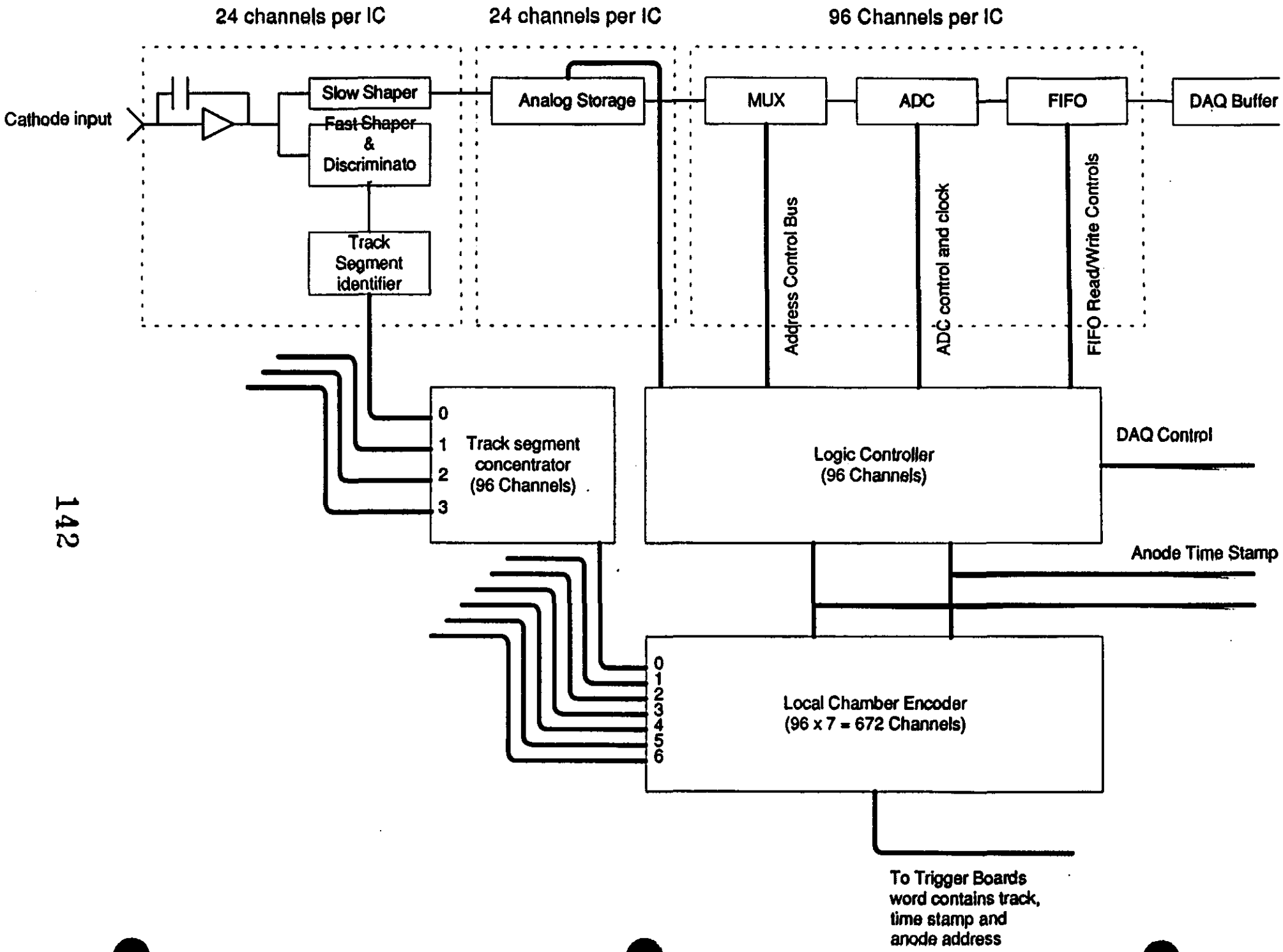

cm-2 s-1
Eta
Direct mu
Decay mu
Punch through
Total

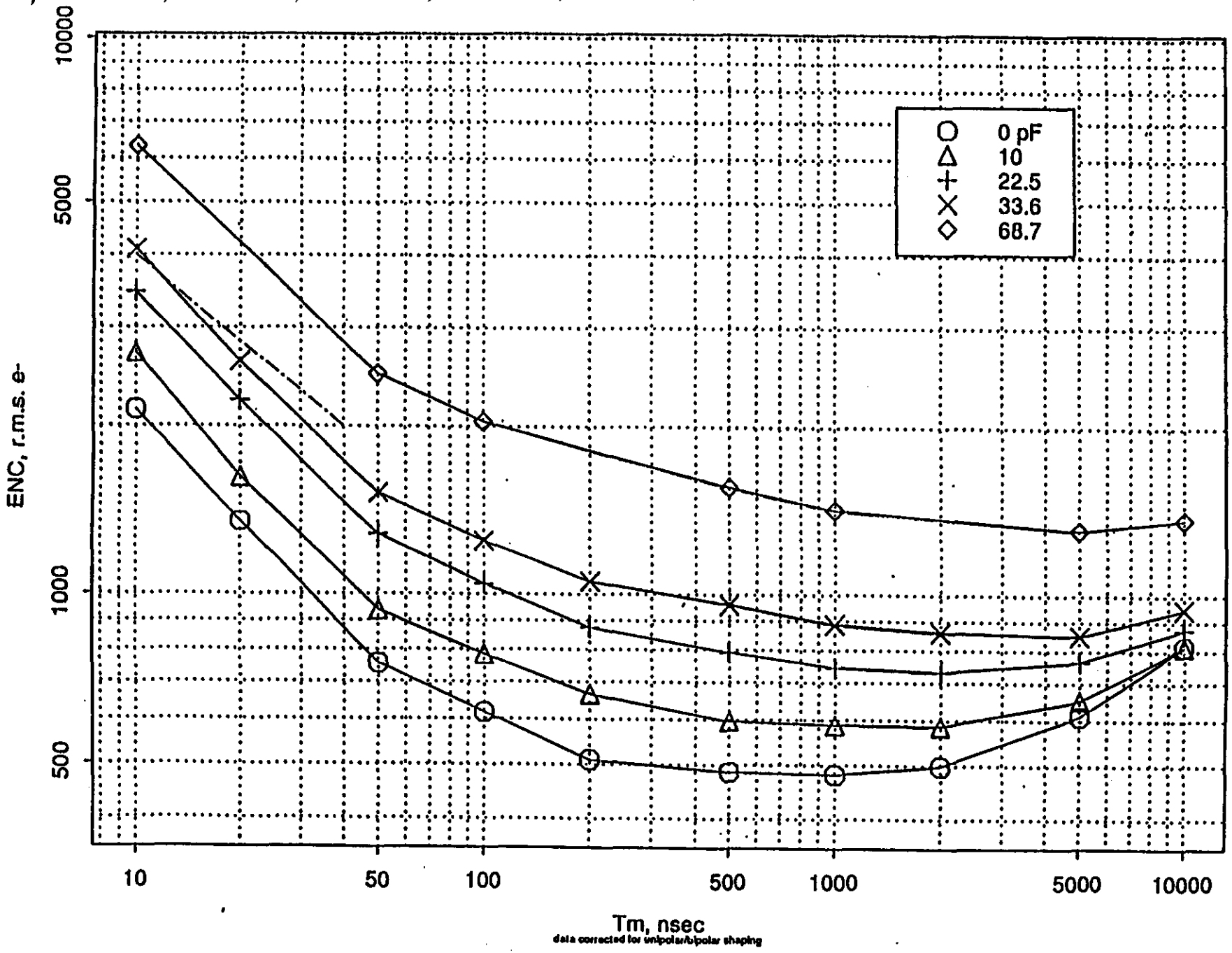
BARREL CHANNEL ACCOUNTING

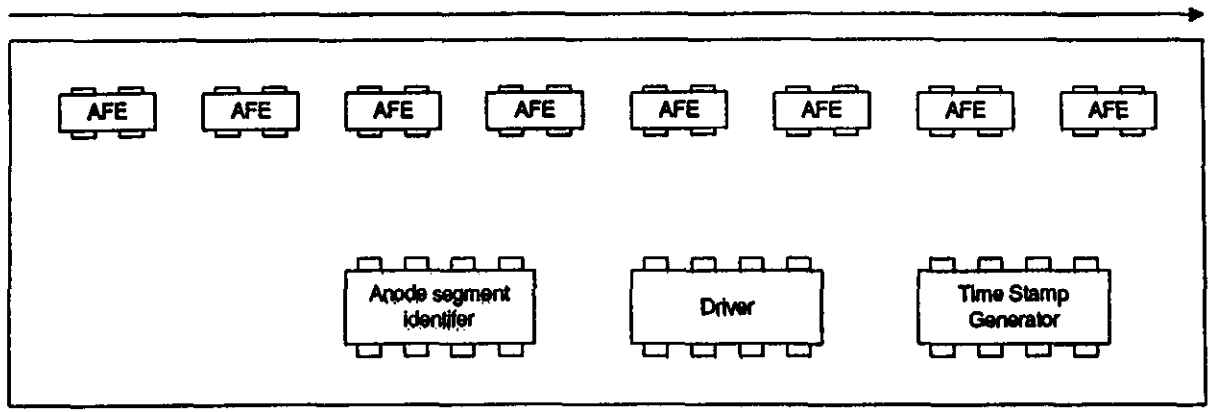
	SL1	SL2	SL3	
ETA SEGMENTS	4	8	8	
PHI SEGMENTS	48	48	48	
NUMBER /MODULES	192	384	384	960
NUMBER GAPS	6	6	6	
CATHODE CHANNELS/GAP	112	112	112	
TOTAL CATHODE	129024	258048	258048	645120
CHANNEL/ FE IC	24	24	24	
TOTAL FE IC'S	5376	10752	10752	26880
CHANNELS/ADC-MUX	96	96	96	
TOTAL ADC-MUX	1344	2688	2688	6720
CHANNELS/CATHODE RO BOARD	96	96	96	
TOTAL READOUT BOARDS	1344	2688	2688	6720
ANODE CHANNELS/GAP	32	32	32	
TOTAL ANODE	36864	73728	73728	184320
CHANNELS/ANODE READOUT BOARD	32	32	32	
TOTAL ANODE READOUT BOARDS	1152	2304	2304	5760
CHANNELS/LOCAL TRACK SEGMENTS	24	24	24	
CHANNELS/TRIGGER CABLE	672	672	672	
TOTAL TRIGGER CABLES	192	384	384	960



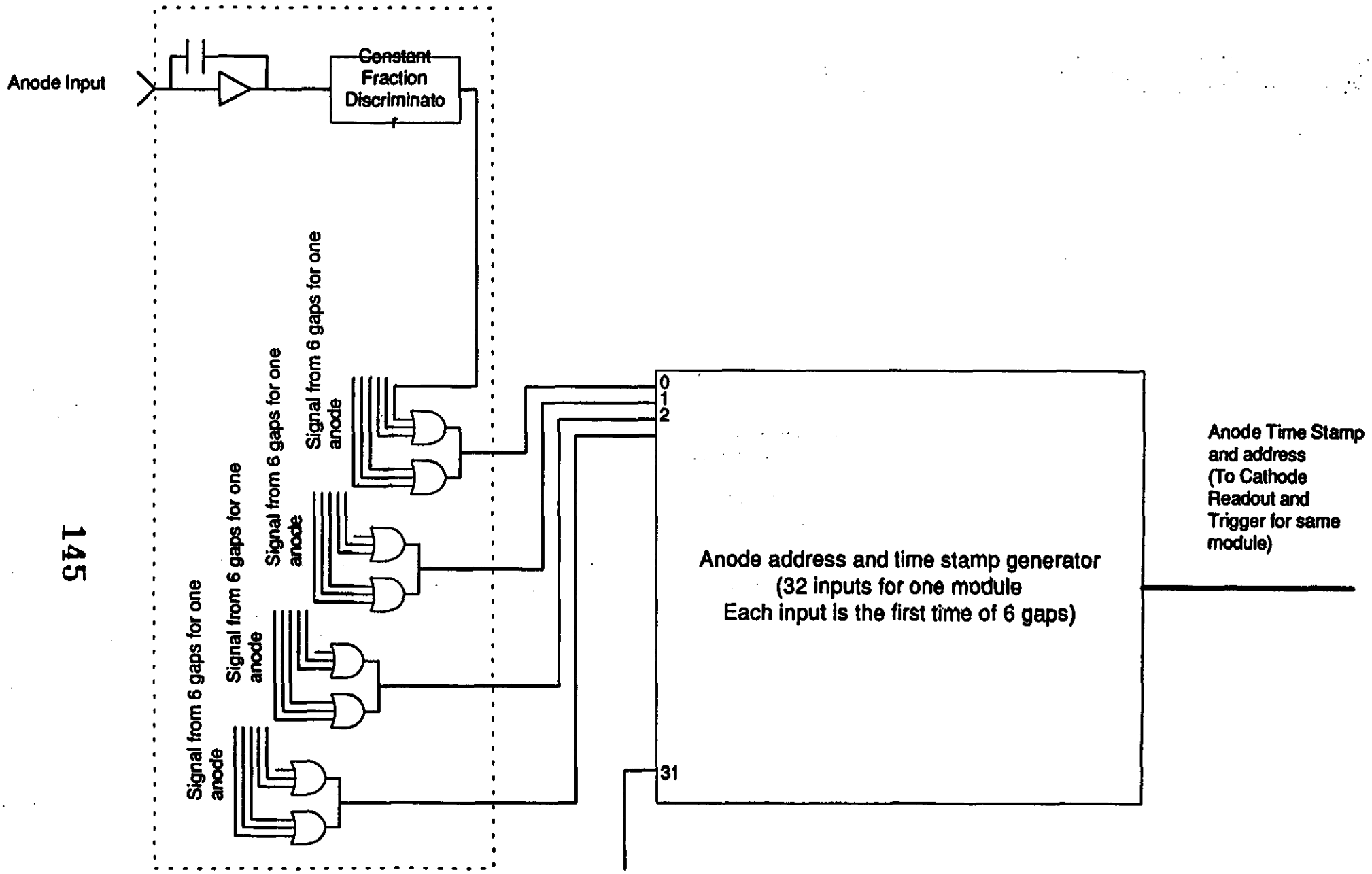
Single 6 gap module (672 channels)

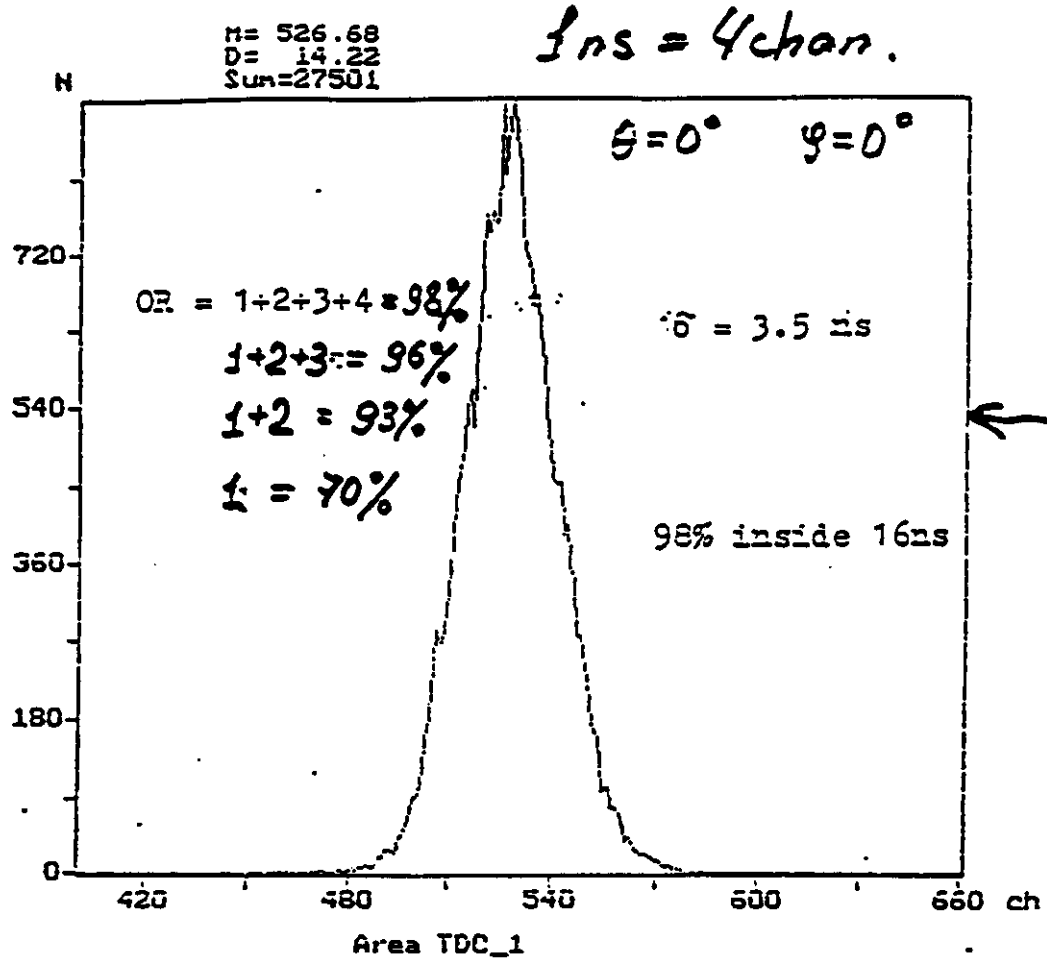

24 channels per IC
24 channels per IC
96 Channels per IC
Cathode input
Slow Shaper
Fast Shaper & Discriminato
Track Segment identifier
Analog Storage
MUX
ADC
FIFO
DAQ Buffer
Address Control Bus
ADC control and clock
FIFO Read/Write Controls
Track segment concentrator (96 Channels)
0
1
2
3
Logic Controller (96 Channels)
DAQ Control
Anode Time Stamp
Local Chamber Encoder (96 x 7 = 672 Channels)
0
1
2
3
4
5
6
To Trigger Boards word contains track, time stamp and anode address

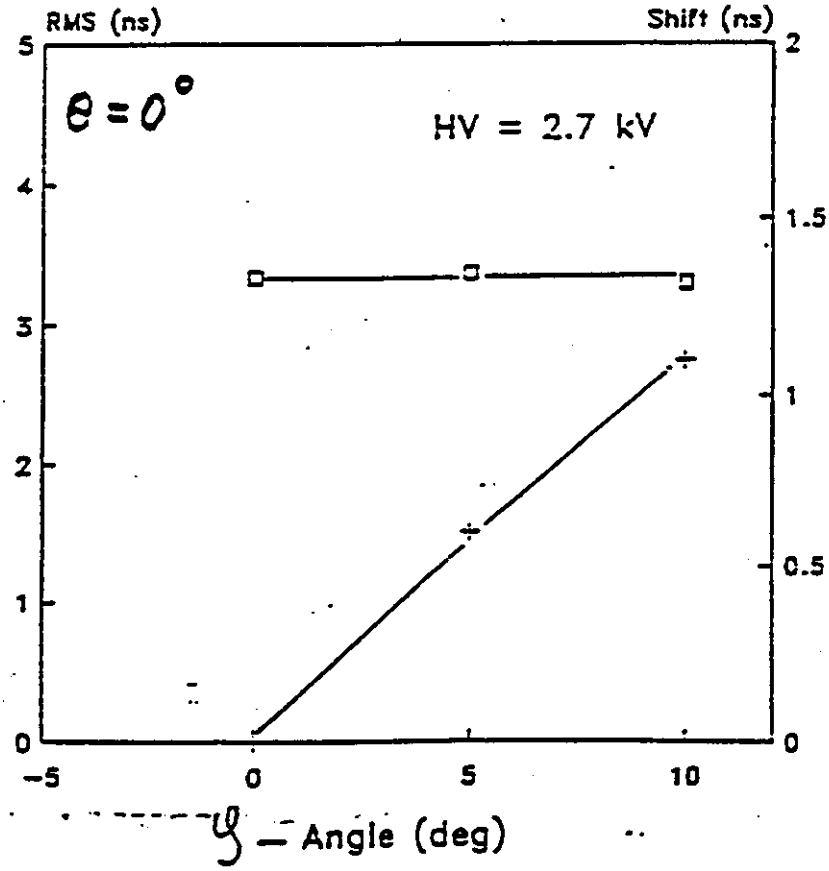

10000
5000
1000
500
ENC, r.m.s. e-
10
50
100
500
1000
5000
10000
Tm, nsec
data corrected for unipolar/bipolar shaping
0 pF
10
22.5
33.6
68.7



Single 6 gap module (192 channels)


24 channels per IC
Anode Input
Constant Fraction Discriminato
Signal from 6 gaps for one anode
Signal from 6 gaps for one anode
Signal from 6 gaps for one anode
Signal from 6 gaps for one anode
0
1
2
31
Anode address and time stamp generator
(32 inputs for one module
Each input is the first time of 6 gaps)
Anode Time Stamp and address (To Cathode Readout and Trigger for same module)





HV = 2.8 kV
σ = 3.5 ns

GEM Muon Trigger

Purpose & Means:

- Identify "true" muons according to their P_t.
  - P_t range : 10-50 GeV/c
  - η range : -2.5 to 2.5 Units

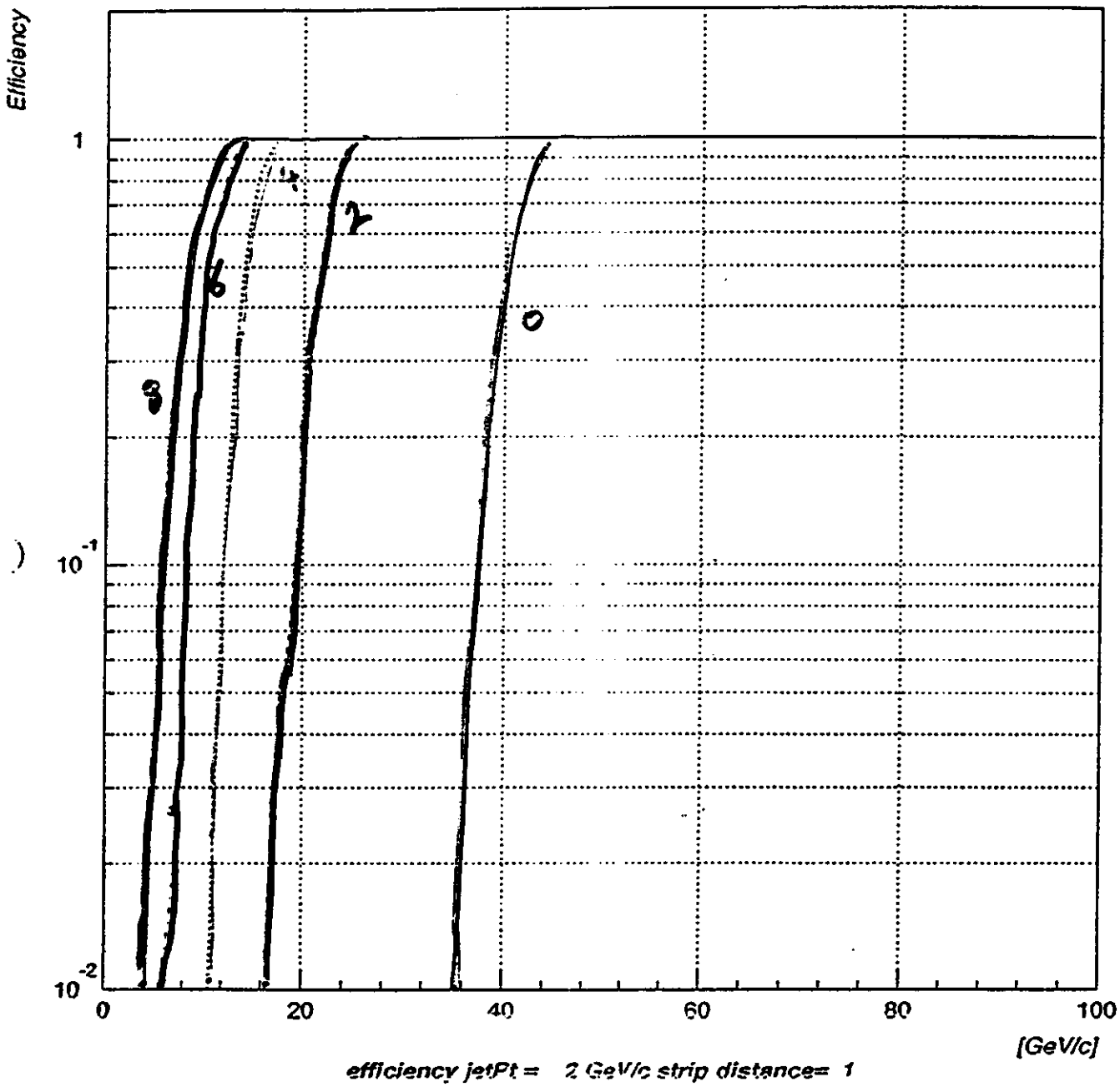
  This is attained by purely geometrical means:
  Sagitta of a 10 GeV/c muon is 7.5 cm.
  Multiple scattering and non-uniform field are a potential complication.

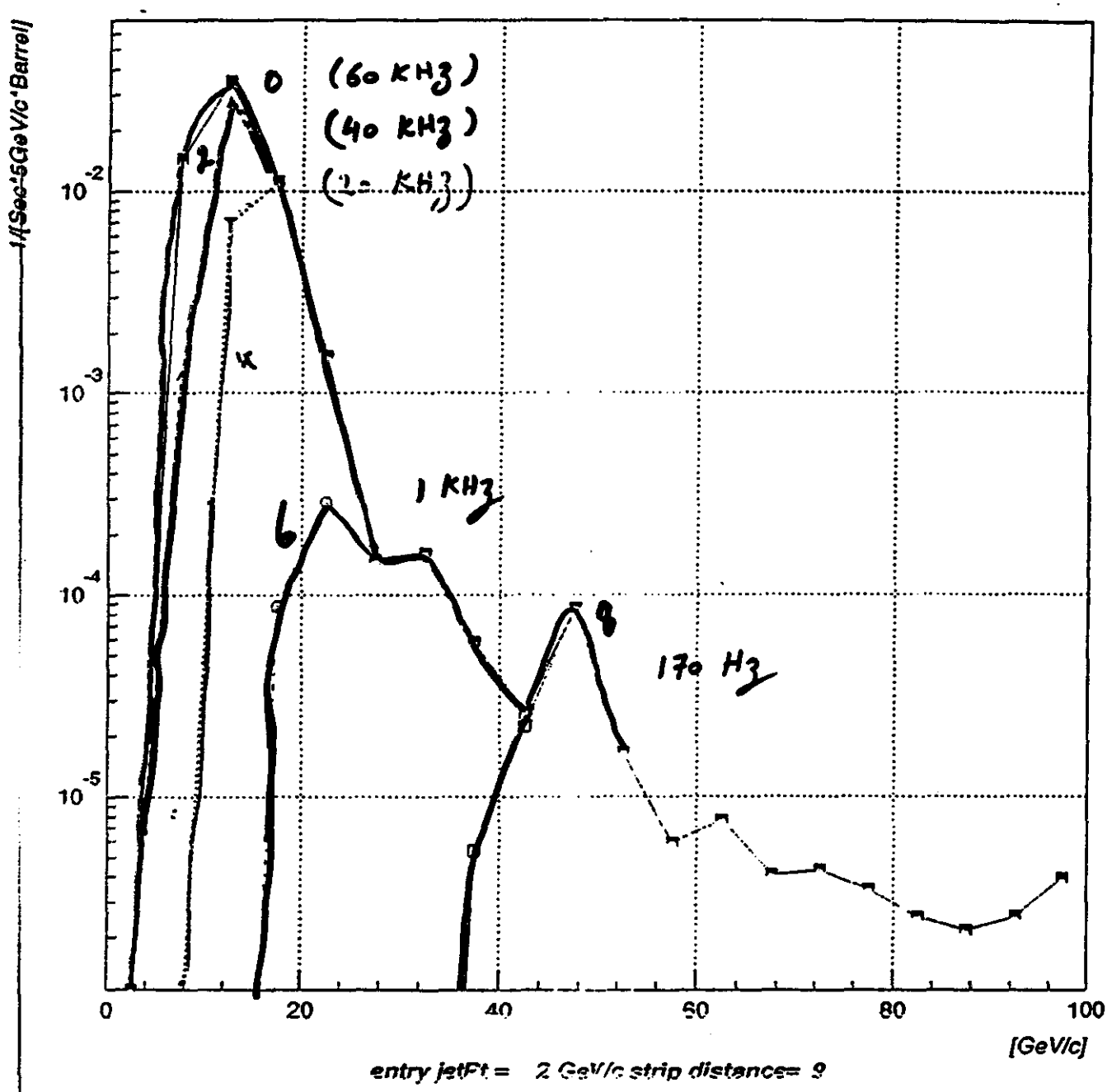
- Identify the beam crossing responsible for the generated trigger.

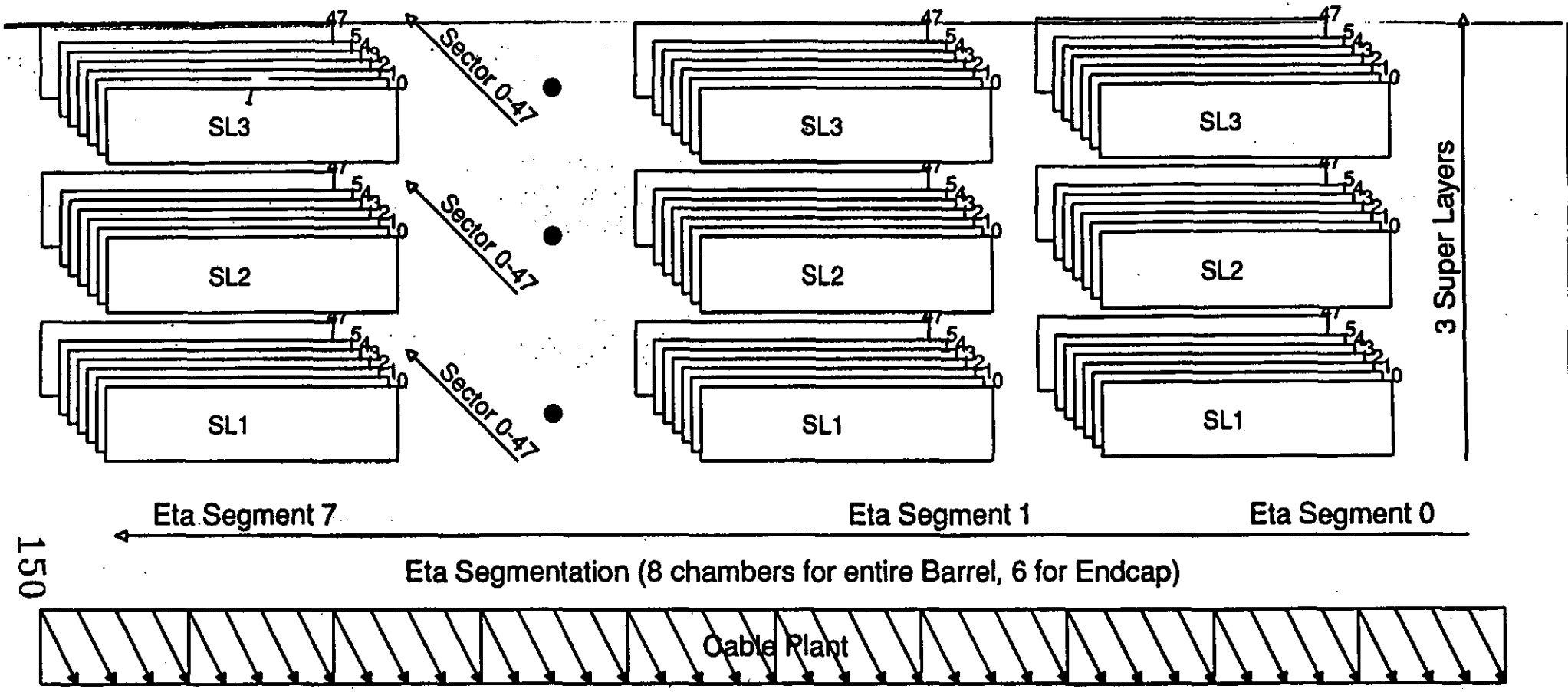
  This is attained by using the short drift time of the Cathode Strip Chamber anode wire.

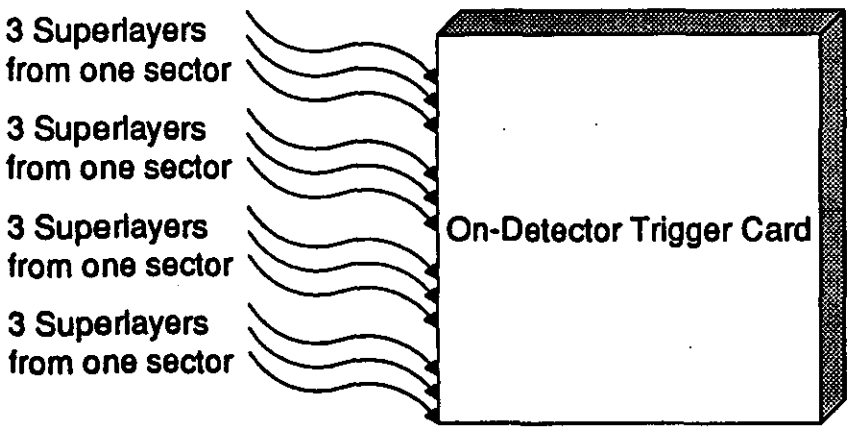
Objectives:

- Form the trigger in about 500 nsec.
- Reduce the number of connections.
- Allow programmability for P_t selection.
- Assist the DAQ in readout in order to reduce rate.


Efficiency
1
10^{-1}
10^{-2}
0
20
40
60
80
100
[GeV/c]
efficiency jetPt = 2 GeV/c strip distance= 1


1/[Sec*5GeV/c*Barrel]
10^-2
10^-3
10^-4
10^-5
0
20
40
60
80
100
[GeV/c]
(60 KHz)
(40 KHz)
1 KHz
170 Hz
entry jetPt = 2 GeV/c strip distance= 9





One Card per Super Sector

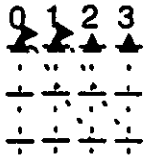
12 Super Sectors x 8 Eta Segments = 96 Cards for barrel and 72 for endcap

Barrel
1152 Cables =
96 Cards x 12 Cables =
48 sectors x 3 SuperLayers x 8 Eta Segments

Endcap
864 Cables =
72 Cards x 12 Cables =
48 sectors x 3 SuperLayers x 6 Eta Segments

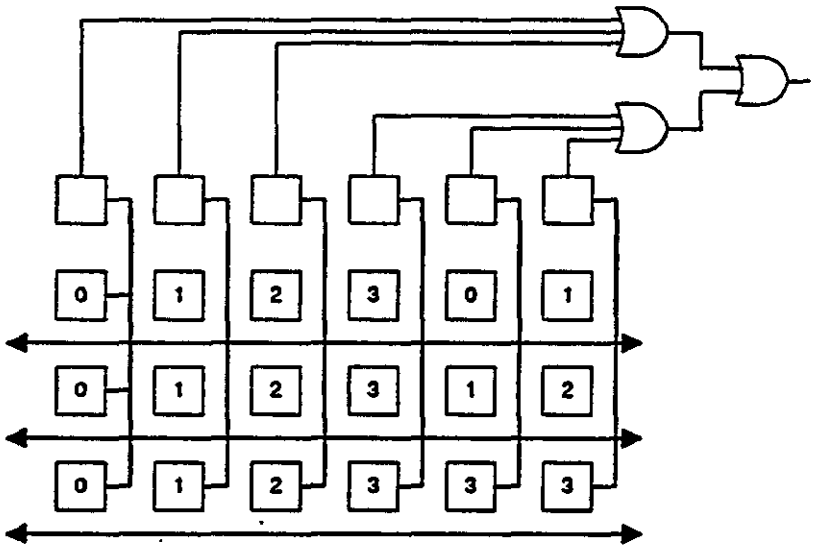
Structure of Muon Level 1 Trigger Hardware

Consider a situation with 6 allowable patterns

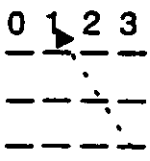


"Three out of Three" logic

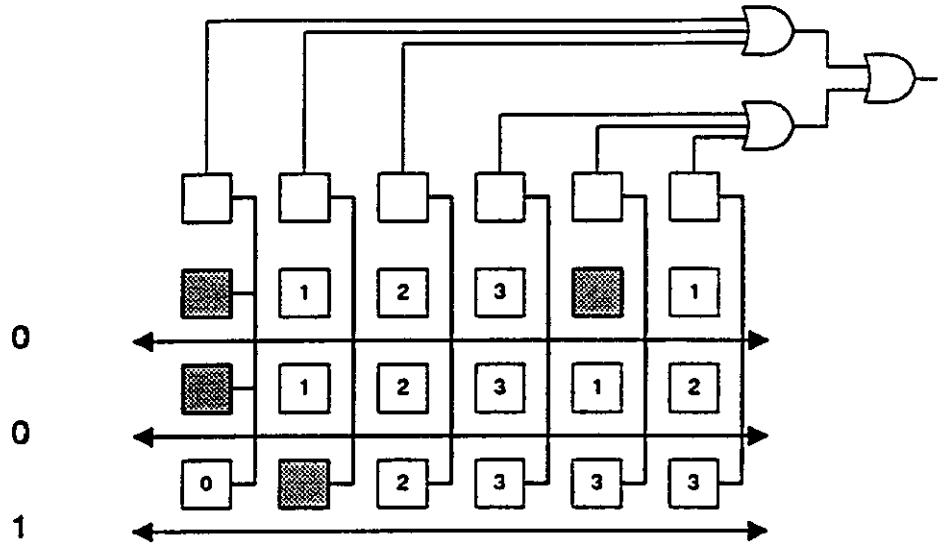
Data Buses

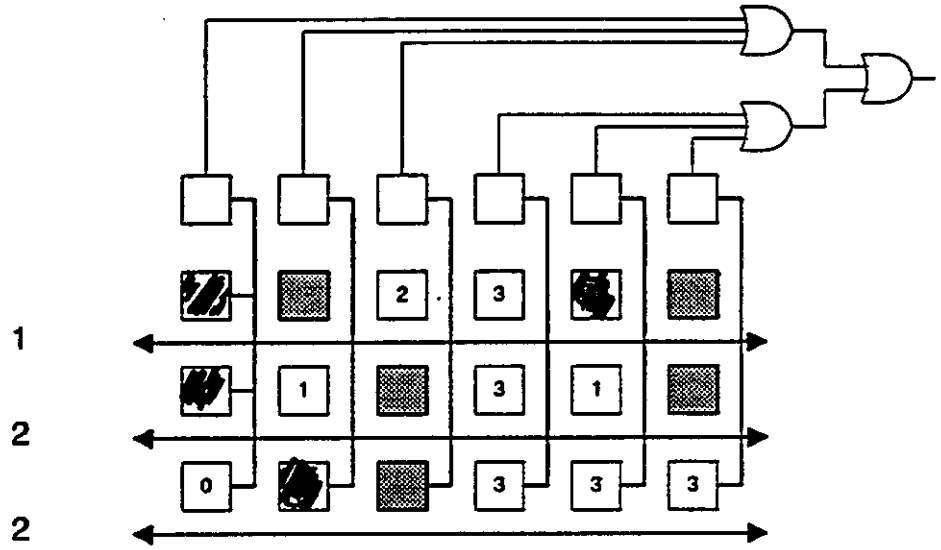


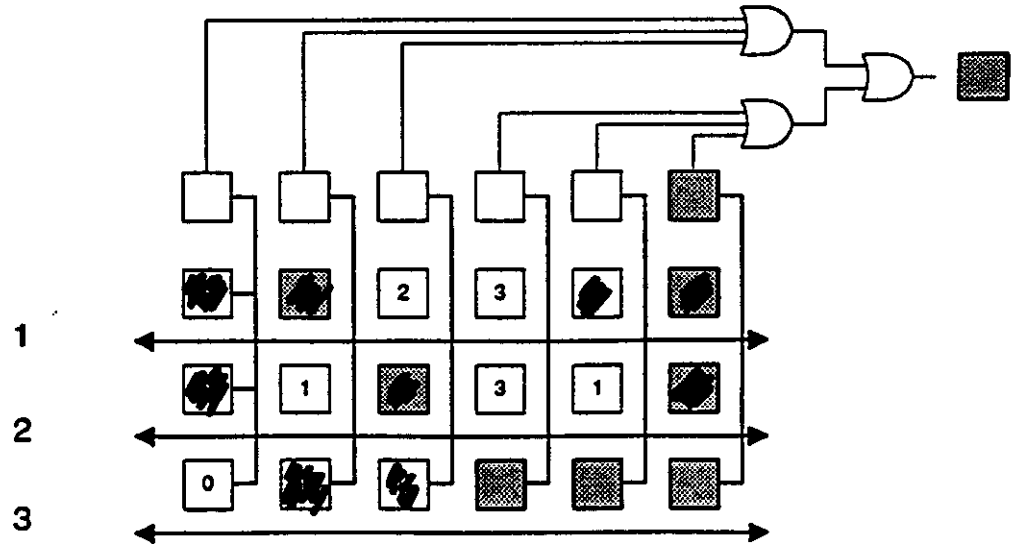
For Example:
A track with some extra hits

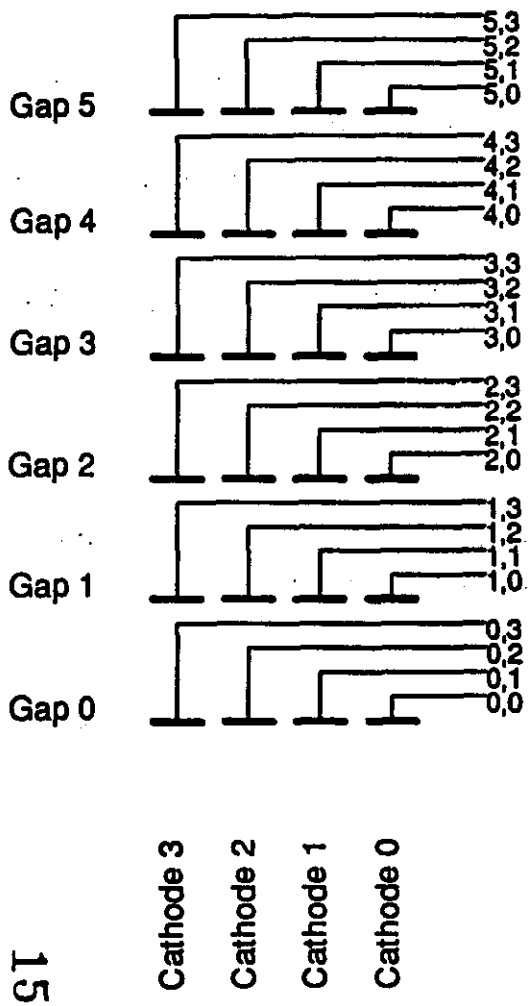


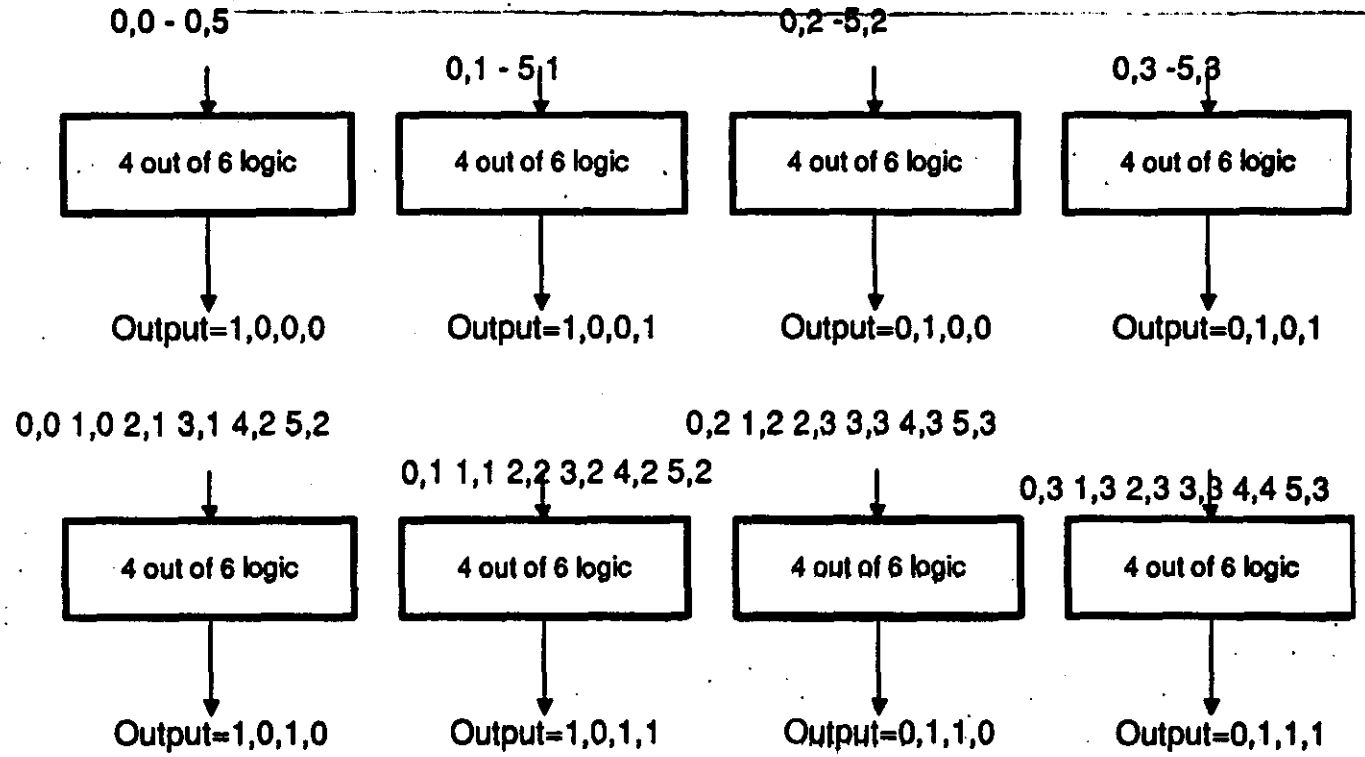
Hits
0,1
0,2
1,2,3


0
0
1
1 2 3 1
1 2 3 1 2
0 2 3 3 3

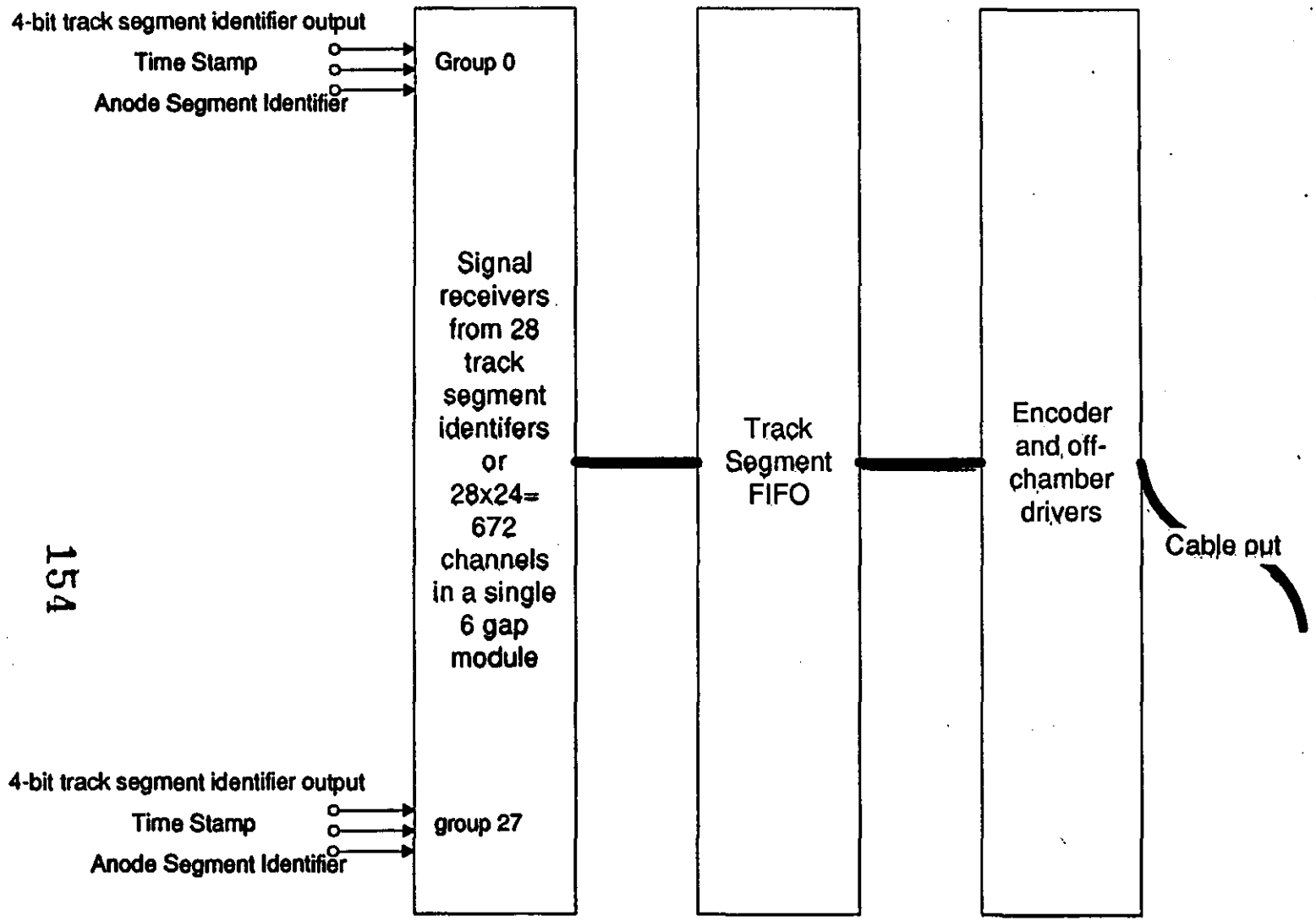

1
2
2
2 3
1 3 1
0 3 3 3


1
2
3
2 3
1 3 1
0


Gap 5
Gap 4
Gap 3
Gap 2
Gap 1
Gap 0
5,3
5,2
5,1
5,0
4,3
4,2
4,1
4,0
3,3
3,2
3,1
3,0
2,3
2,2
2,1
2,0
1,3
1,2
1,1
1,0
0,3
0,2
0,1
0,0
Cathode 3
Cathode 2
Cathode 1
Cathode 0


0,0 - 0,5
0,1 - 5,1
0,2 -5,2
0,3 -5,3
4 out of 6 logic
4 out of 6 logic
4 out of 6 logic
4 out of 6 logic
Output=1,0,0,0
Output=1,0,0,1
Output=0,1,0,0
Output=0,1,0,1
0,0 1,0 2,1 3,1 4,2 5,2
0,1 1,1 2,2 3,2 4,2 5,2
0,2 1,2 2,3 3,3 4,3 5,3
0,3 1,3 2,3 3,3 4,4 5,3
4 out of 6 logic
4 out of 6 logic
4 out of 6 logic
4 out of 6 logic
Output=1,0,1,0
Output=1,0,1,1
Output=0,1,1,0
Output=0,1,1,1

Etc.


4-bit track segment identifier output
Time Stamp
Anode Segment Identifier
Group 0
Signal receivers from 28 track segment identifers or 28x24= 672 channels in a single 6 gap module
4-bit track segment identifier output
Time Stamp
Anode Segment Identifier
group 27
Track Segment FIFO
Encoder and off-chamber drivers
Cable out

Trigger Numerology

Barrel

Superlayers	3		
Super Sectors	12		
Sectors	48		
Gaps/Superlayer	6	6	6
η Segments/Superlayer	4	8	8
Cathode Size (mm)	5.84	8.33	10.7
No Cathodes in trigger segment	2	2	2
No Channels/readout card	672	672	672
No trigger elements/readout card	336	336	336

EndCap

Superlayers	3		
Super Sectors	12		
Sectors	24	48	48
Gaps/Superlayer	8	6	6
η Segments/Superlayer	2x3	2x3	2x3
Cathode Size (mm) (radial)	5	5	5
No Cathodes in trigger segment	1	1	1

Associative Memory Scheme

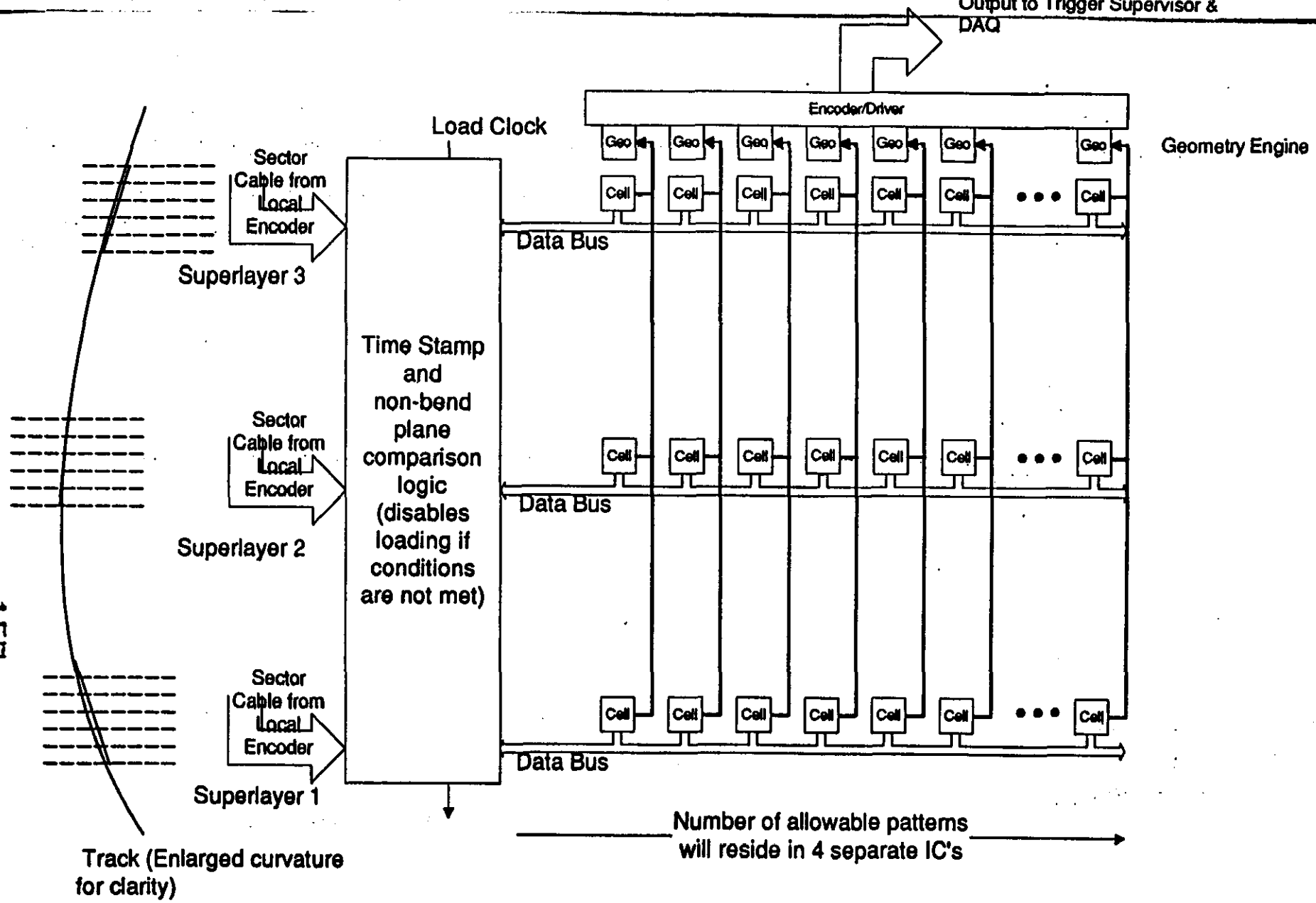
(Amendolia et. al., Dell'Orso et. al.)

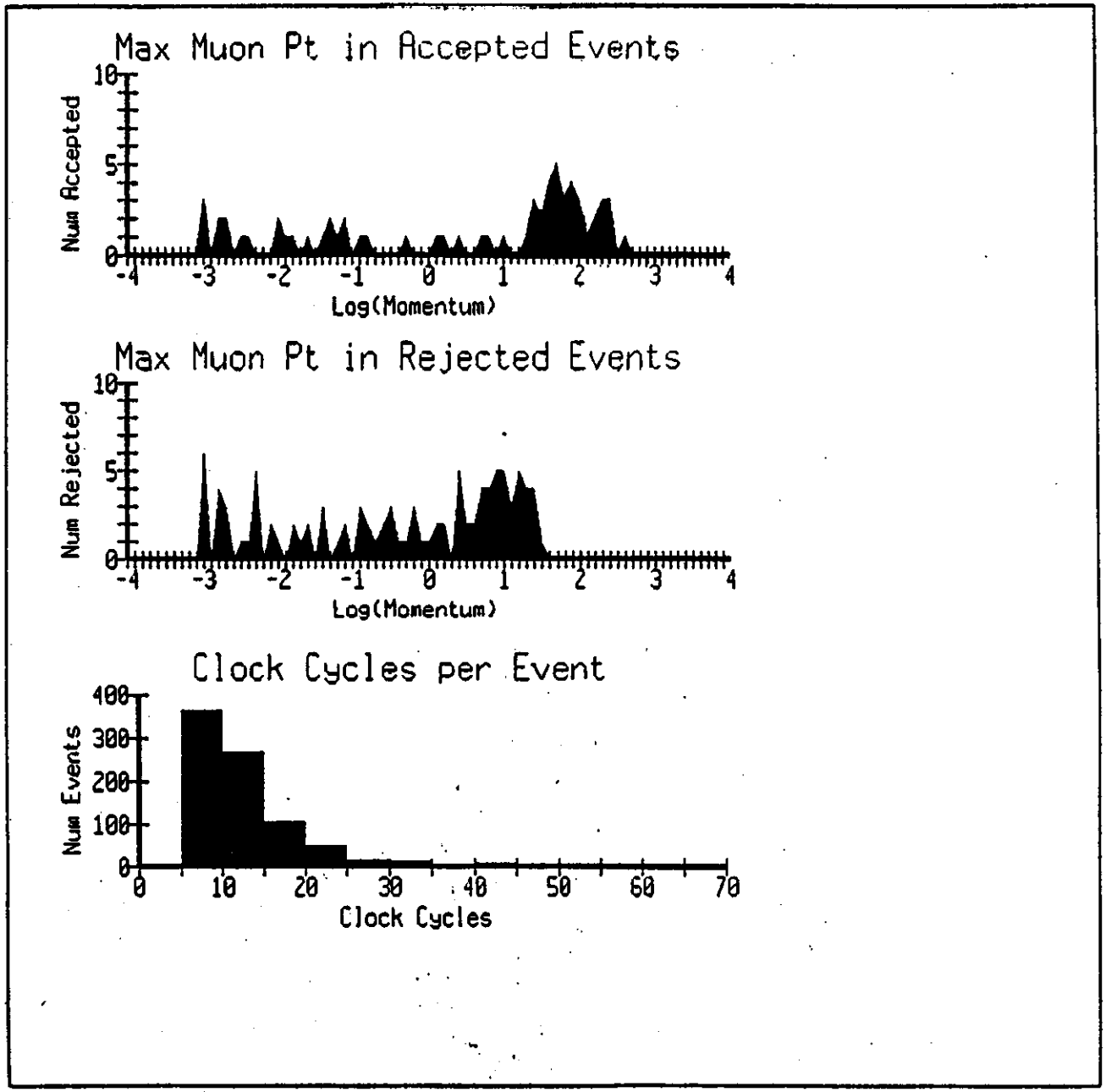
A content-addressable memory to recognize the appropriate trigger geometry patterns.

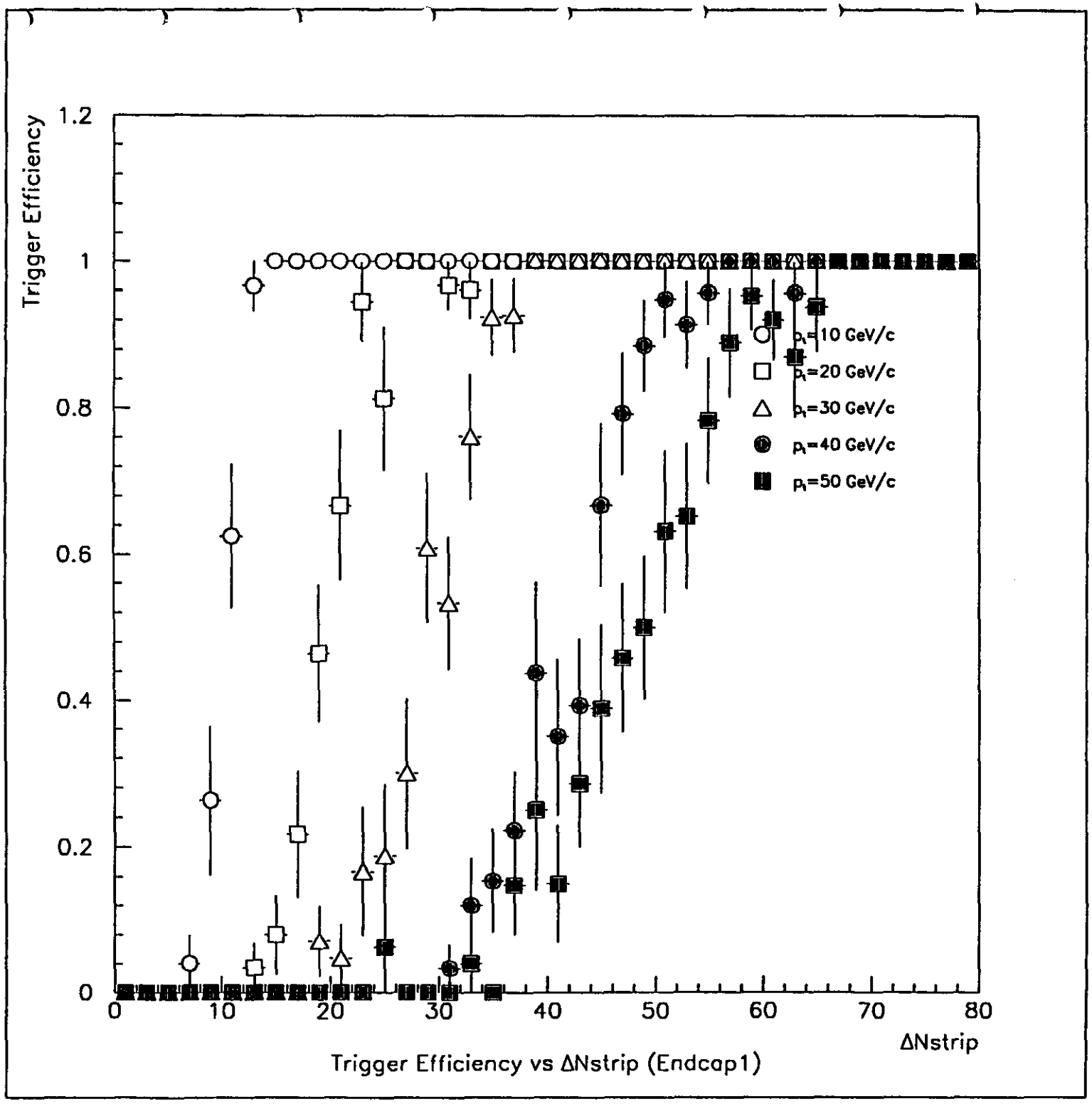
Pro	Con
Few Interconnects (encoded addressing)	Not "classically" pipe-lined
Programmable	Initial development necessary
Flexible	
Requires few services	

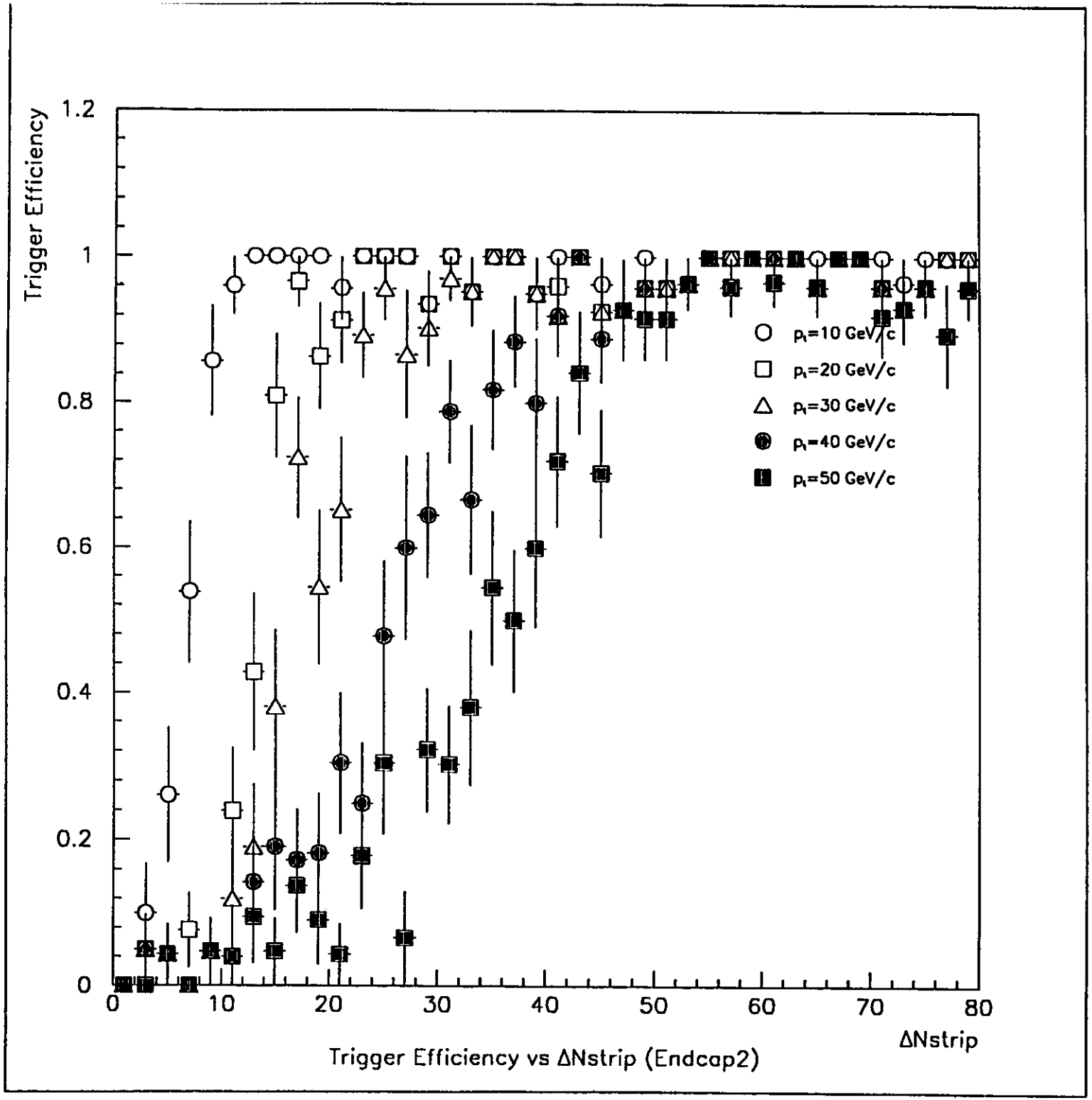
Number of patterns for baseline II

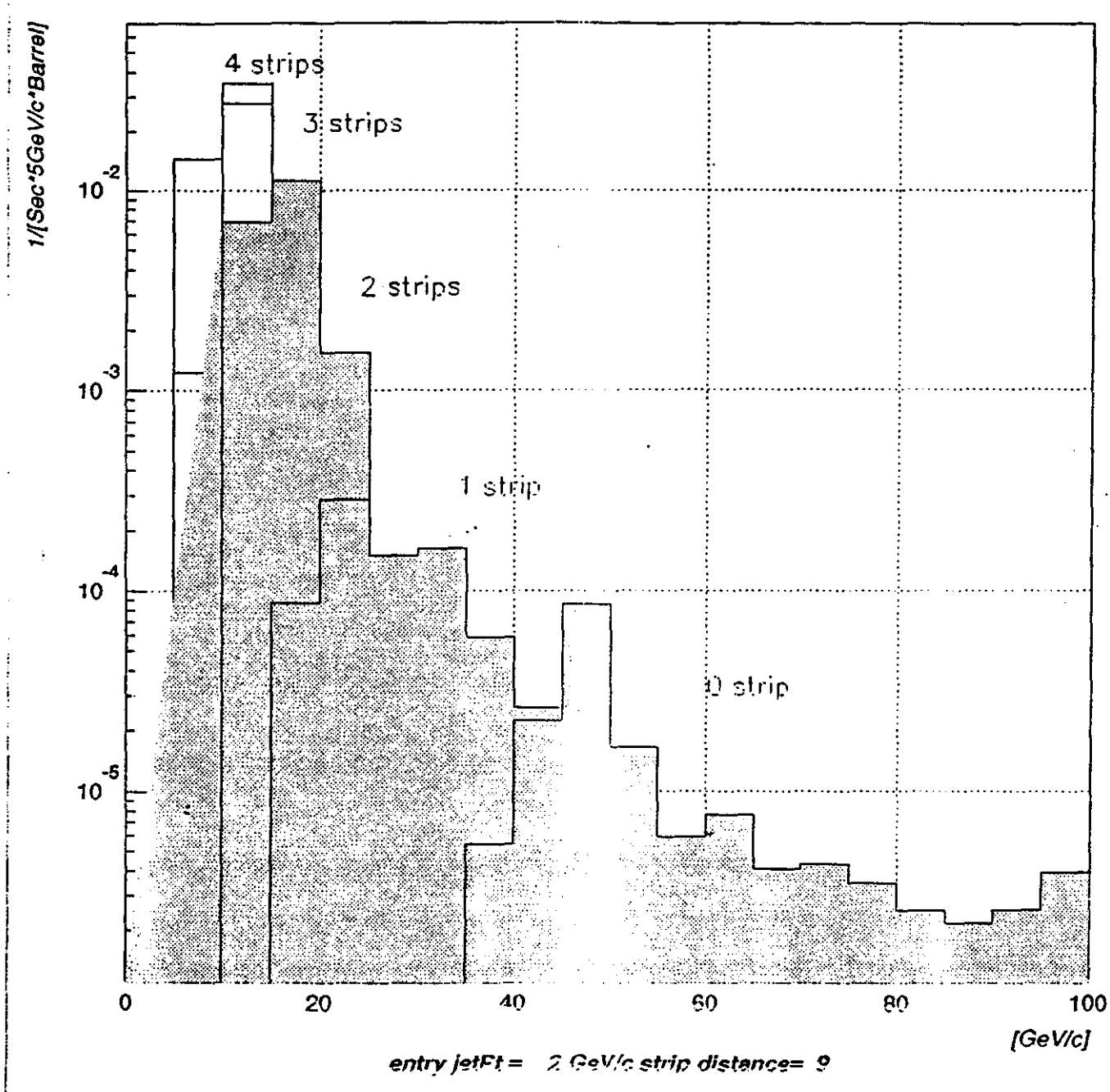
Minimum momentum Cut (GeV/c)	Number Patterns
10	1618
20	1090
30	793
40	610
50	503
60	448

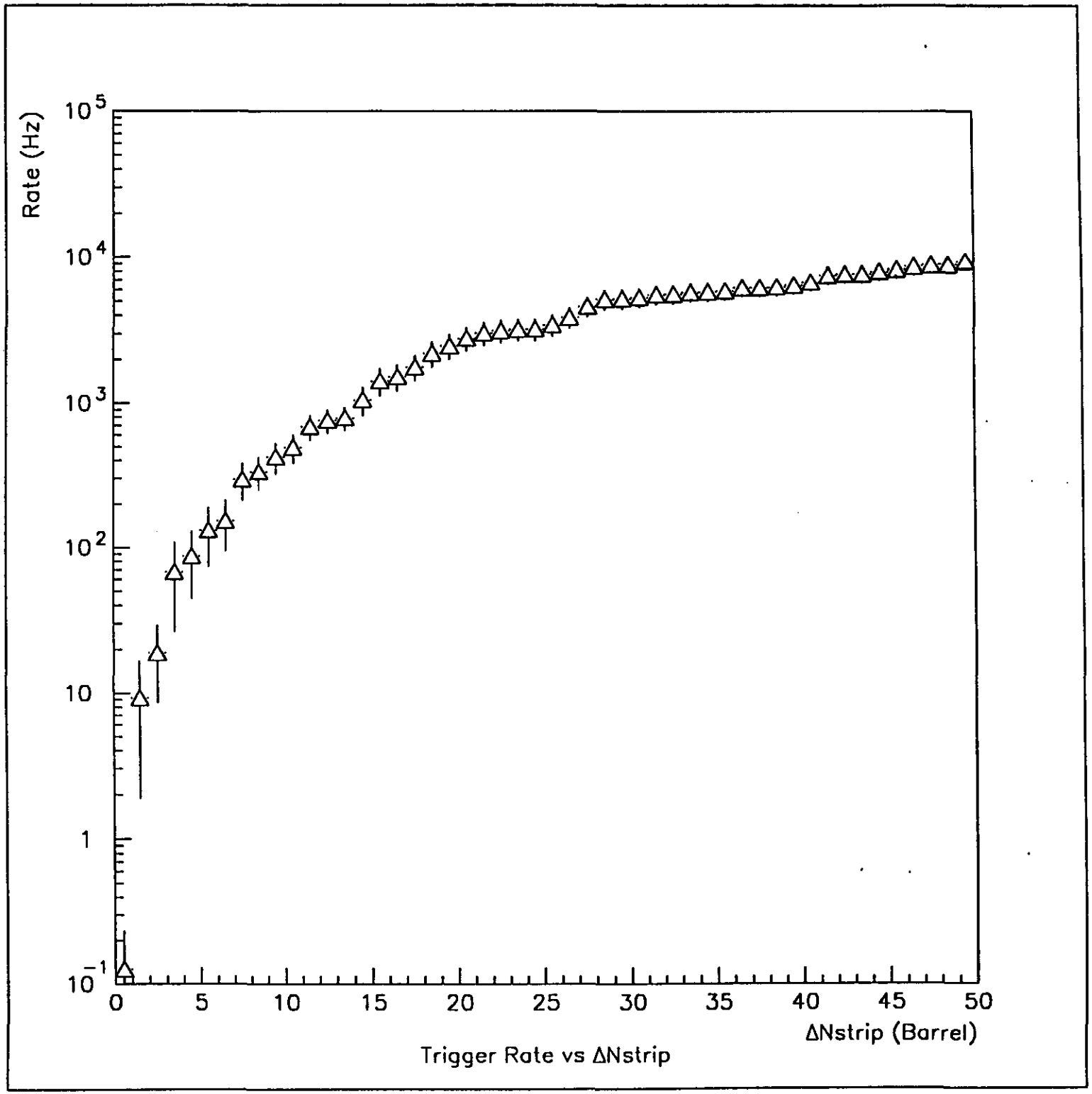

Output to Trigger Supervisor & DAQ
Encoder/Driver
Geometry Engine
Load Clock
Sector Cable from Local Encoder
Superlayer 3
Sector Cable from Local Encoder
Superlayer 2
Sector Cable from Local Encoder
Superlayer 1
Time Stamp and non-bend plane comparison logic (disables loading if conditions are not met)
Geo
Cell
Data Bus
Data Bus
Data Bus
Number of allowable patterns will reside in 4 separate IC's
Track (Enlarged curvature for clarity)

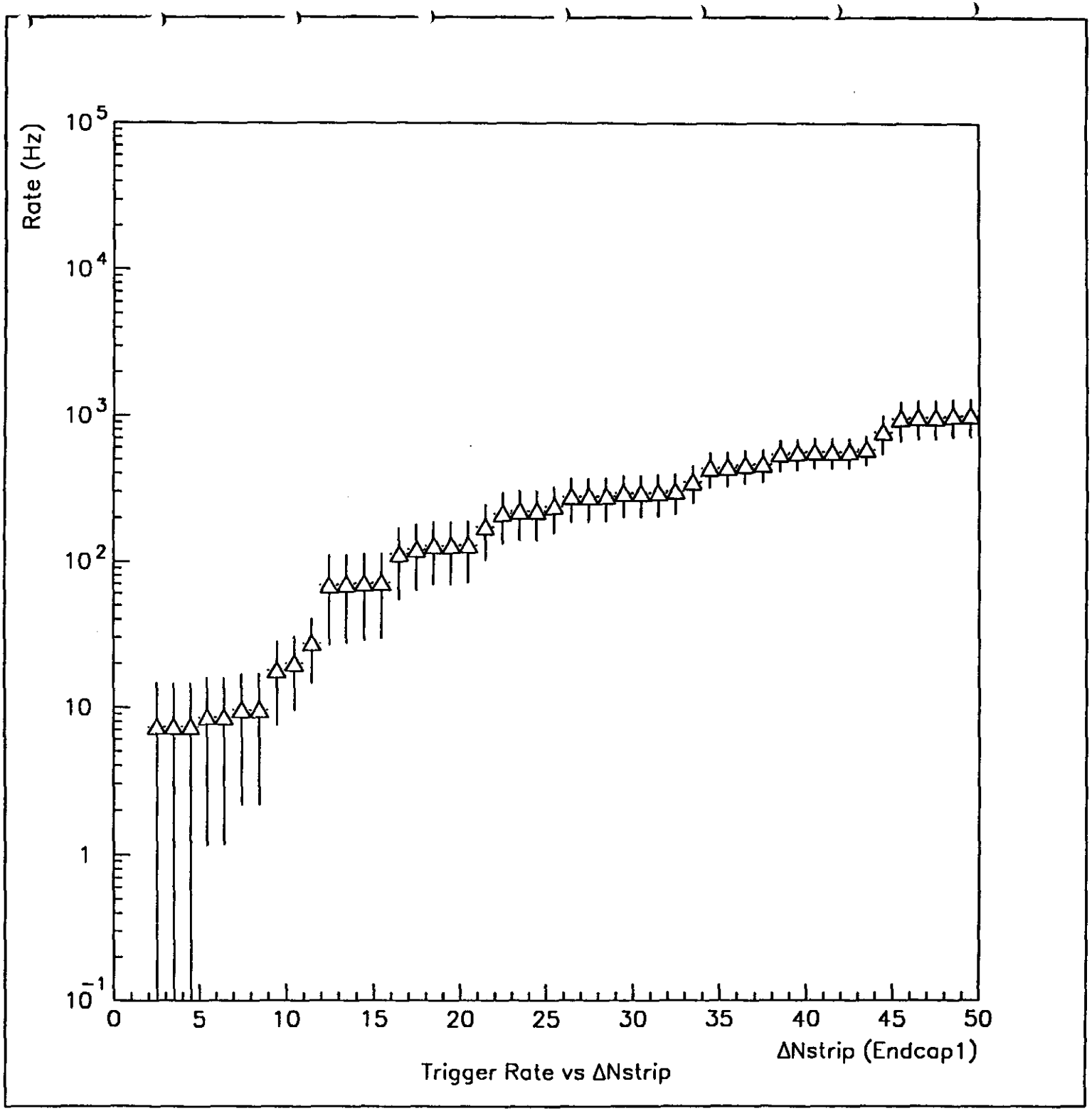

Max Muon Pt in Accepted Events
Num Accepted
10
5
0
-4
-3
-2
-1
0
1
2
3
4
Log(Momentum)
Max Muon Pt in Rejected Events
Num Rejected
10
5
0
-4
-3
-2
-1
0
1
2
3
4
Log(Momentum)
Clock Cycles per Event
Num Events
400
300
200
100
0
0
10
20
30
40
50
60
70
Clock Cycles

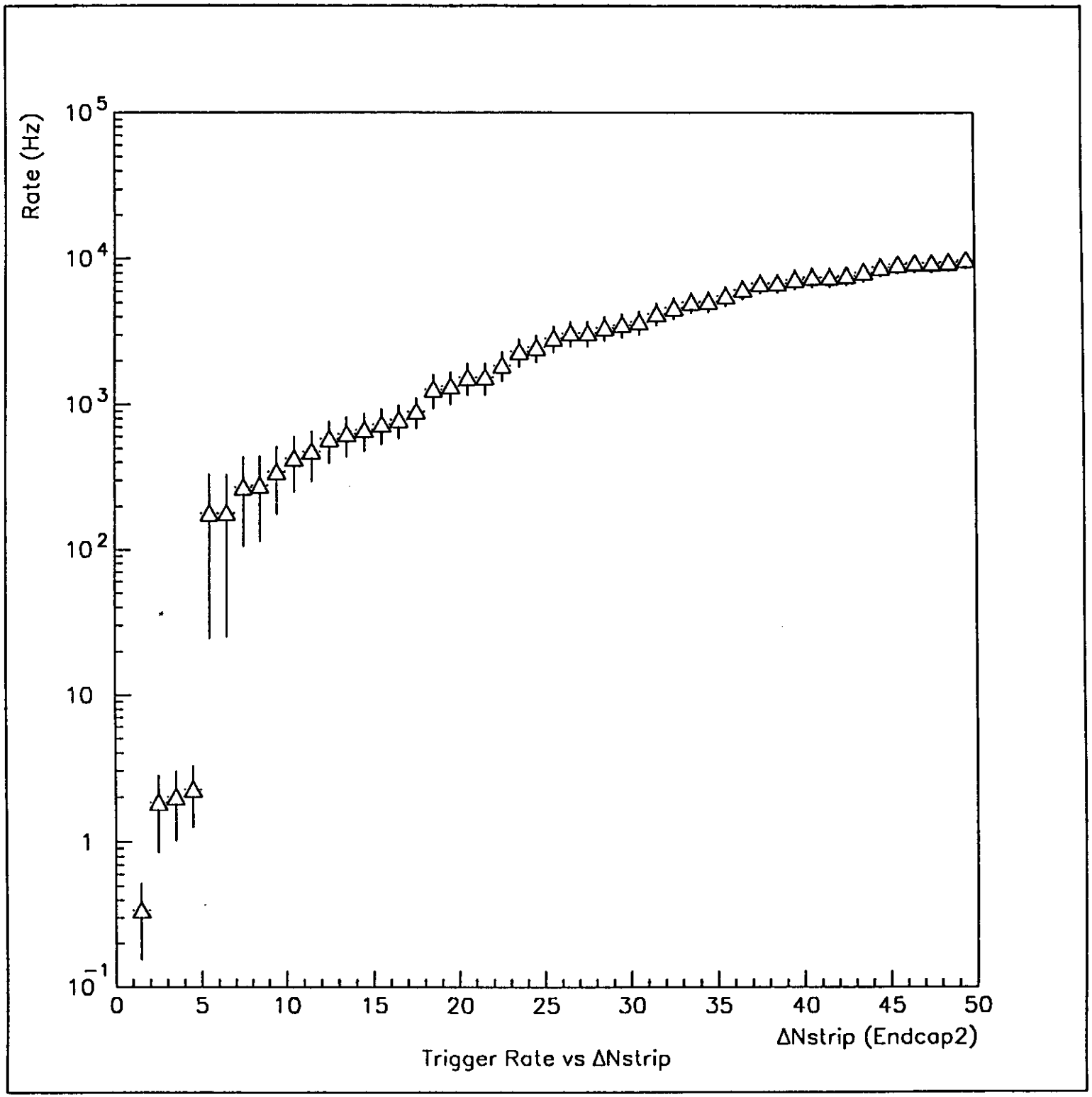

Trigger Efficiency
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
ΔNstrip
p_t=10 GeV/c
p_t=20 GeV/c
p_t=30 GeV/c
p_t=40 GeV/c
p_t=50 GeV/c
Trigger Efficiency vs ΔNstrip (Endcap1)

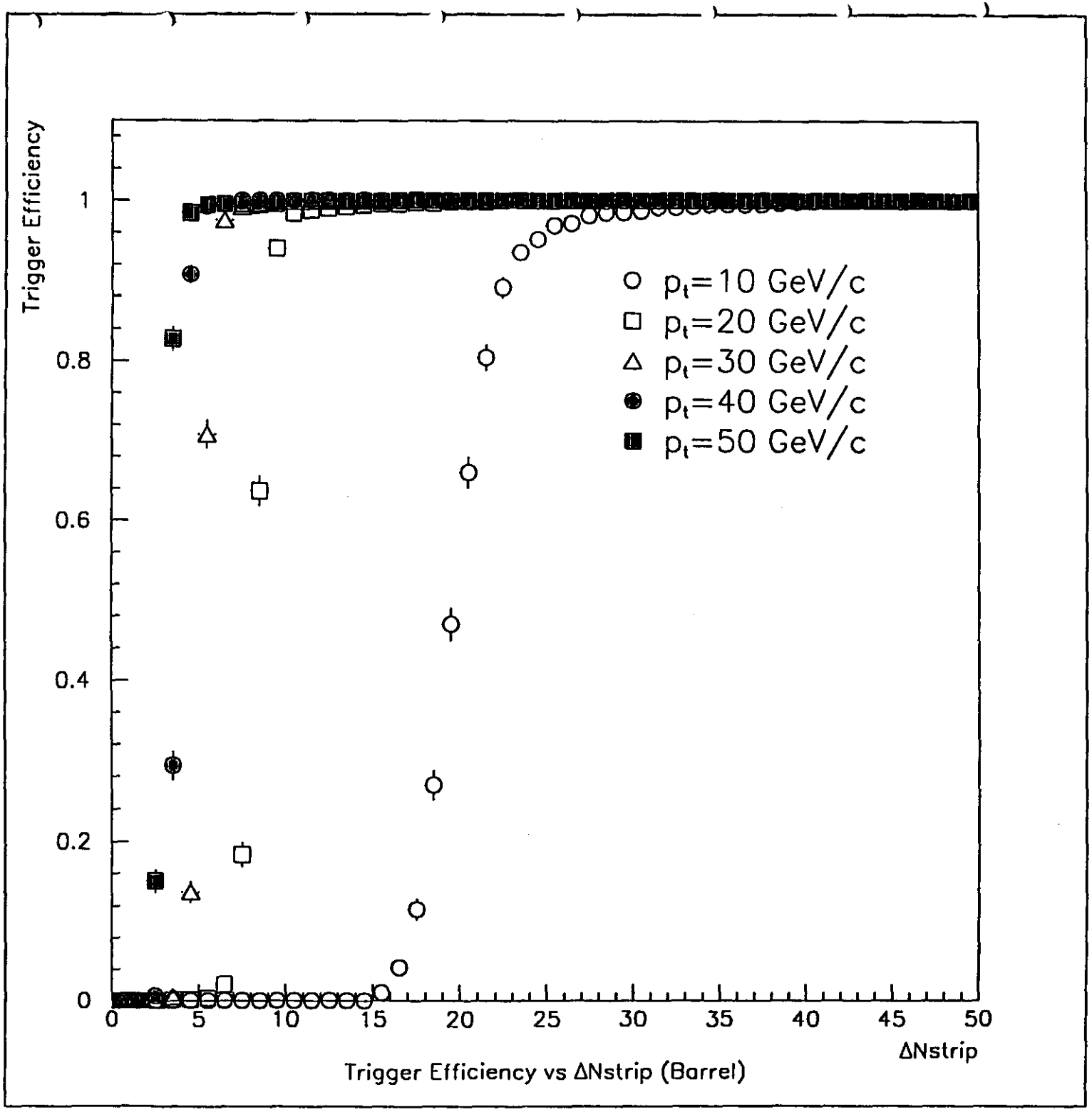

Trigger Efficiency
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
ΔNstrip
p_t=10 GeV/c
p_t=20 GeV/c
p_t=30 GeV/c
p_t=40 GeV/c
p_t=50 GeV/c
Trigger Efficiency vs ΔNstrip (Endcap2)

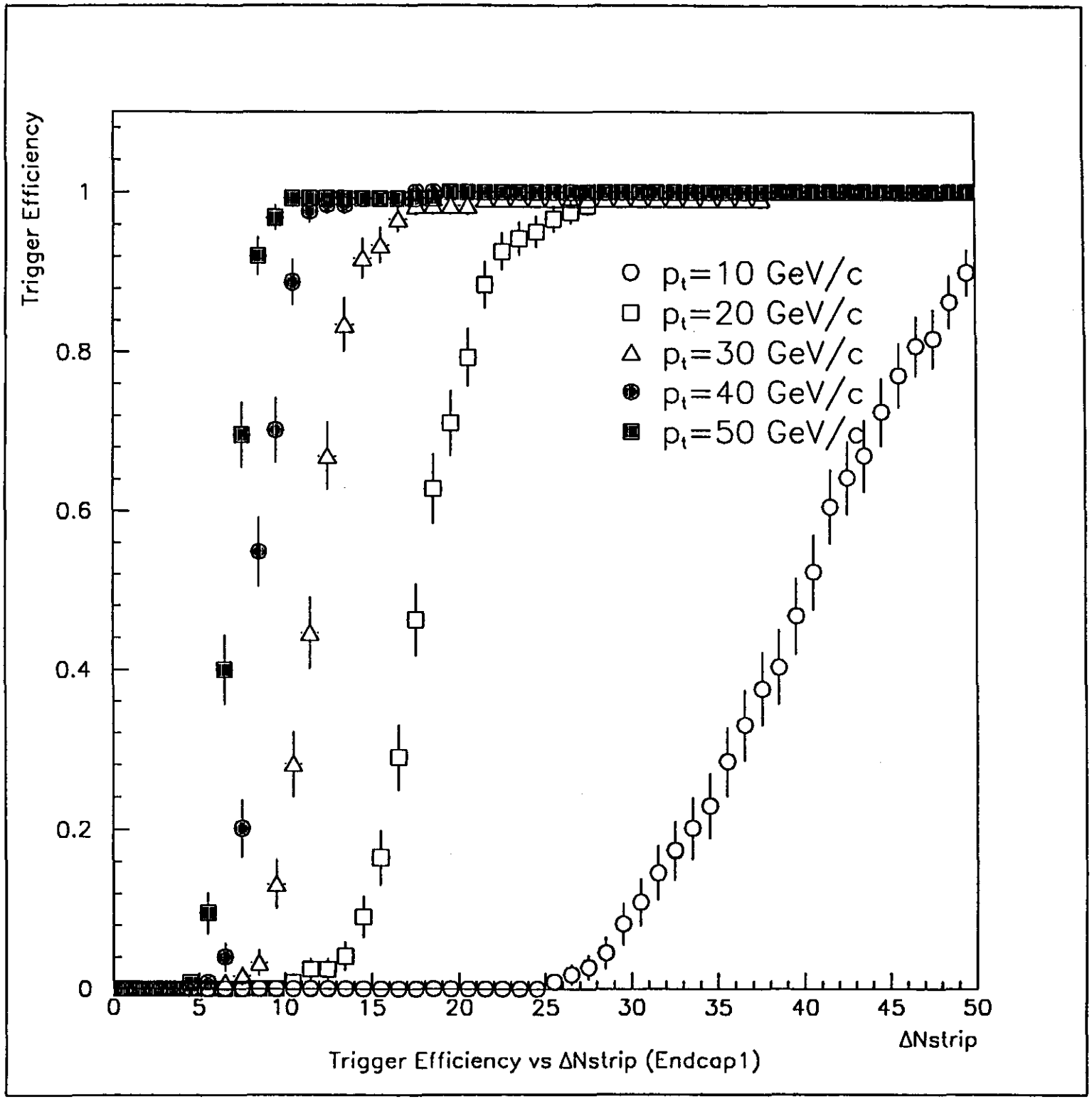

1/[Sec*5GeV/c*Barrel]
4 strips
3 strips
2 strips
1 strip
0 strip
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
20
40
60
80
100
[GeV/c]
entry jetPt = 2 GeV/c strip distance= 9

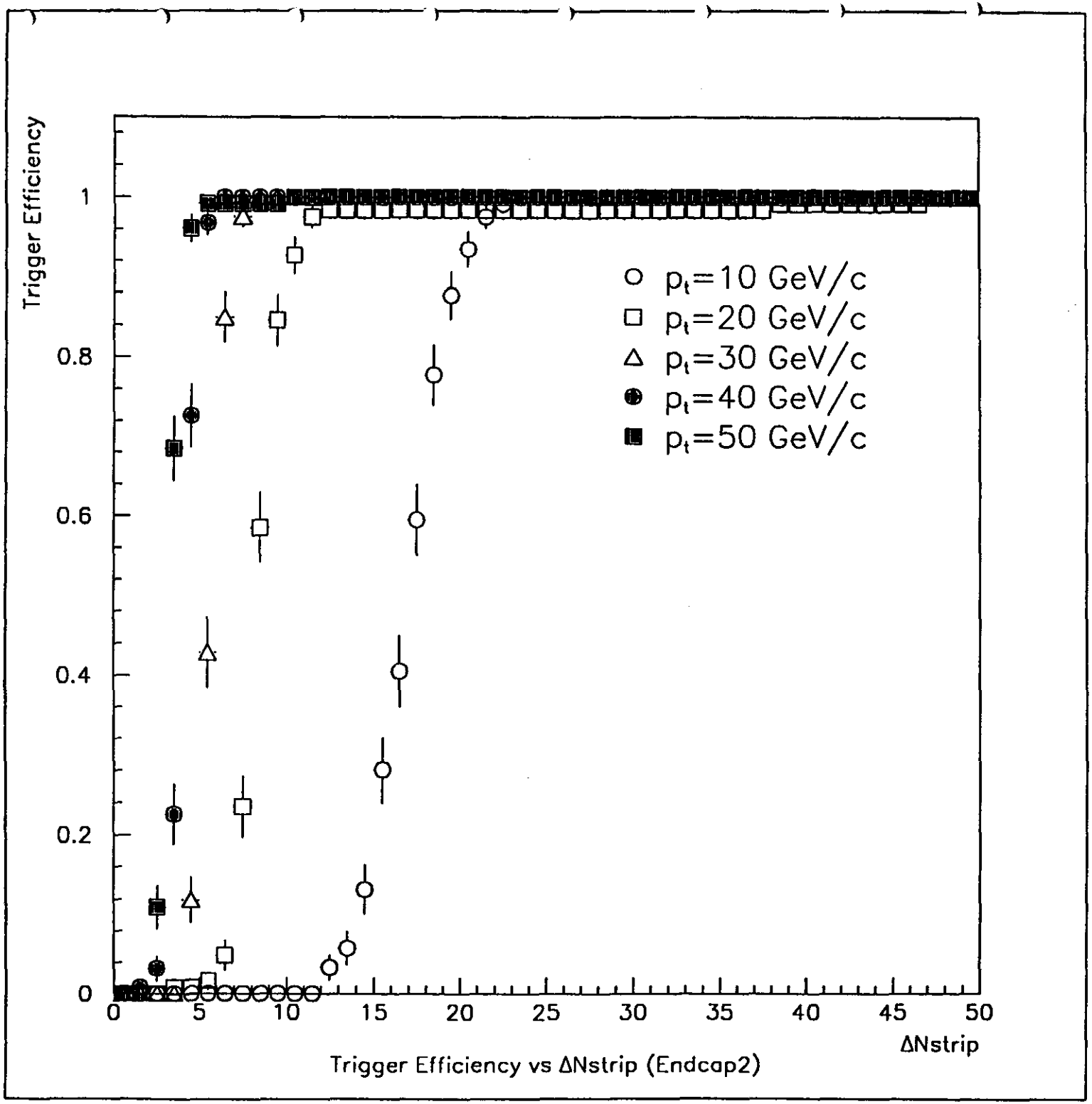

Rate (Hz)
10^5
10^4
10^3
10^2
10
1
10^{-1}
0
5
10
15
20
25
30
35
40
45
50
ΔNstrip (Barrel)
Trigger Rate vs ΔNstrip

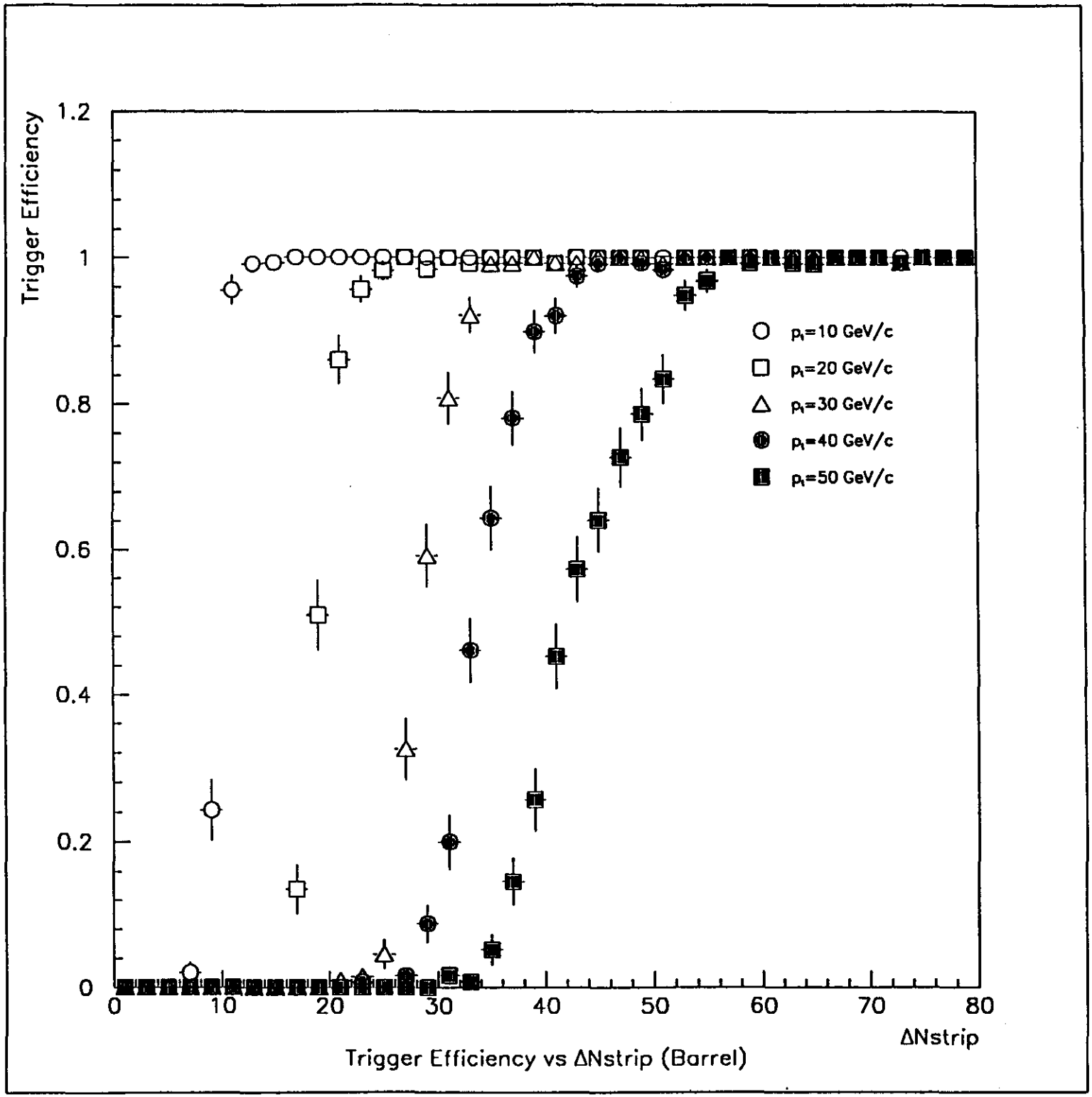

Rate (Hz)
10^5
10^4
10^3
10^2
10
1
10^{-1}
0
5
10
15
20
25
30
35
40
45
50
ΔNstrip (Endcap1)
Trigger Rate vs ΔNstrip


Rate (Hz)
10^5
10^4
10^3
10^2
10
1
10^{-1}
0
5
10
15
20
25
30
35
40
45
50
ΔNstrip (Endcap2)
Trigger Rate vs ΔNstrip


Trigger Efficiency
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
ΔNstrip
p_t=10 GeV/c
p_t=20 GeV/c
p_t=30 GeV/c
p_t=40 GeV/c
p_t=50 GeV/c
Trigger Efficiency vs ΔNstrip (Barrel)

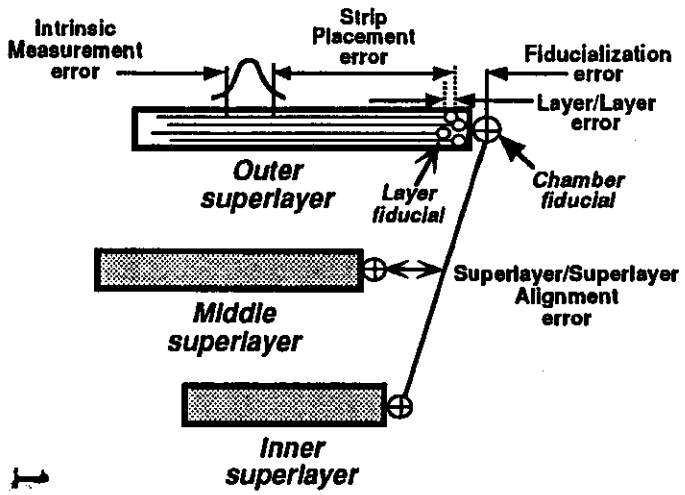

Trigger Efficiency
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
ΔNstrip
p_t=10 GeV/c
p_t=20 GeV/c
p_t=30 GeV/c
p_t=40 GeV/c
p_t=50 GeV/c
Trigger Efficiency vs ΔNstrip (Endcap1)


Trigger Efficiency
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
ΔNstrip
p_t=10 GeV/c
p_t=20 GeV/c
p_t=30 GeV/c
p_t=40 GeV/c
p_t=50 GeV/c
Trigger Efficiency vs ΔNstrip (Endcap2)

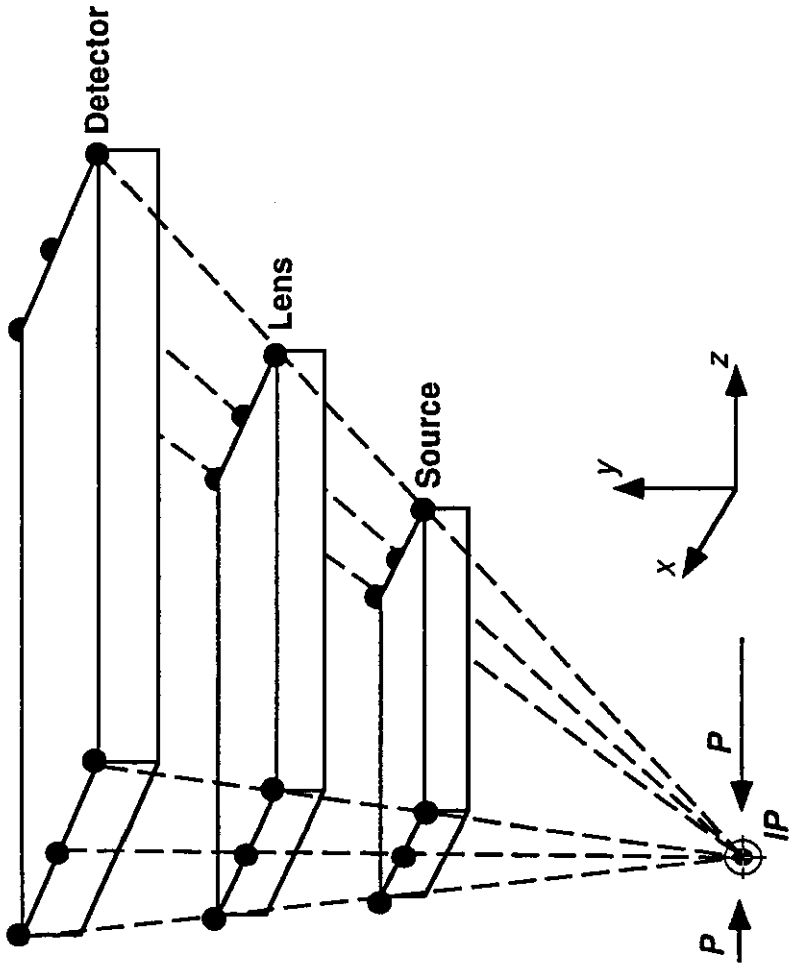

Trigger Efficiency
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
ΔNstrip
p_t=10 GeV/c
p_t=20 GeV/c
p_t=30 GeV/c
p_t=40 GeV/c
p_t=50 GeV/c
Trigger Efficiency vs ΔNstrip (Barrel)

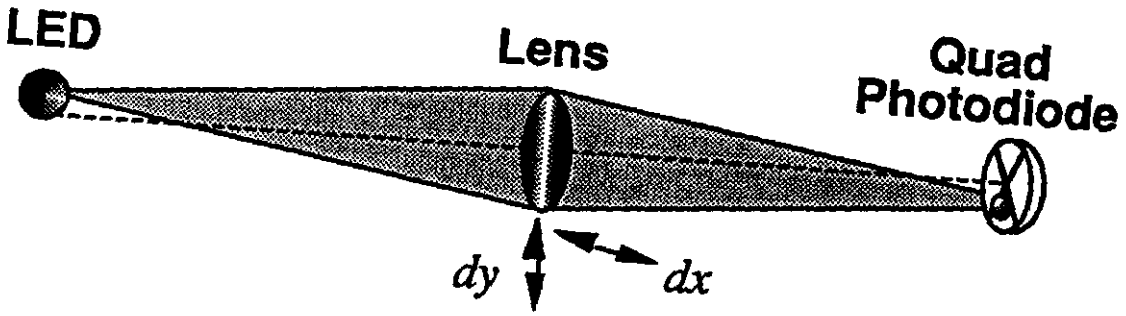
Joe Paradiso

Alignment

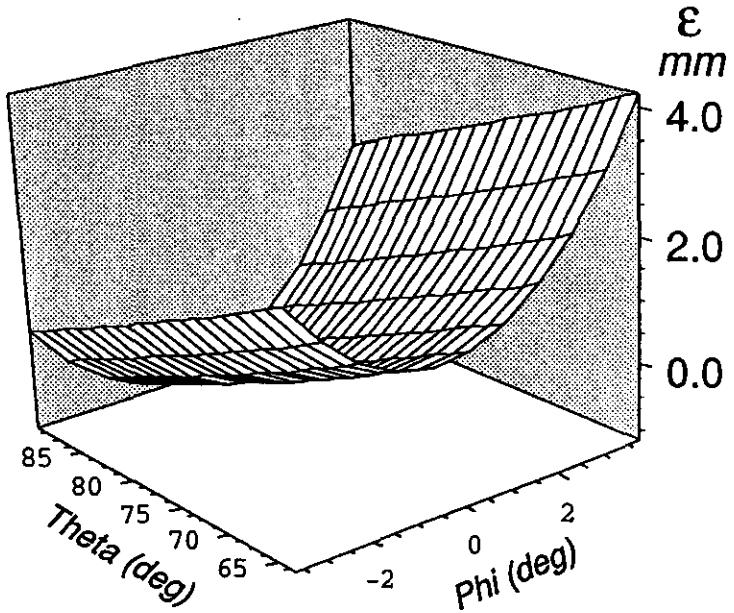


Error Source	RMS Value (μm)
Intrinsic chamber measurement	75
Multiple scattering (p = 500 GeV)	1
Strip to strip fiducial placement	17
Layer to layer placement	50
Fiducialization placement	10
Superlayer to superlayer alignment	25


Detector
Lens
Source
z
y
x
P
IP
P

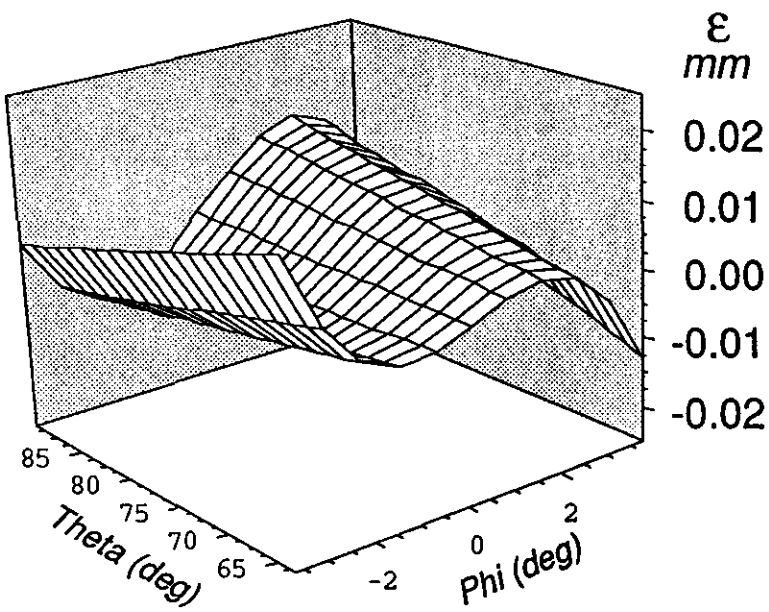

LED
Lens
Quad
Photodiode
dy
dx

Sagitta Errors Before Alignment Correction

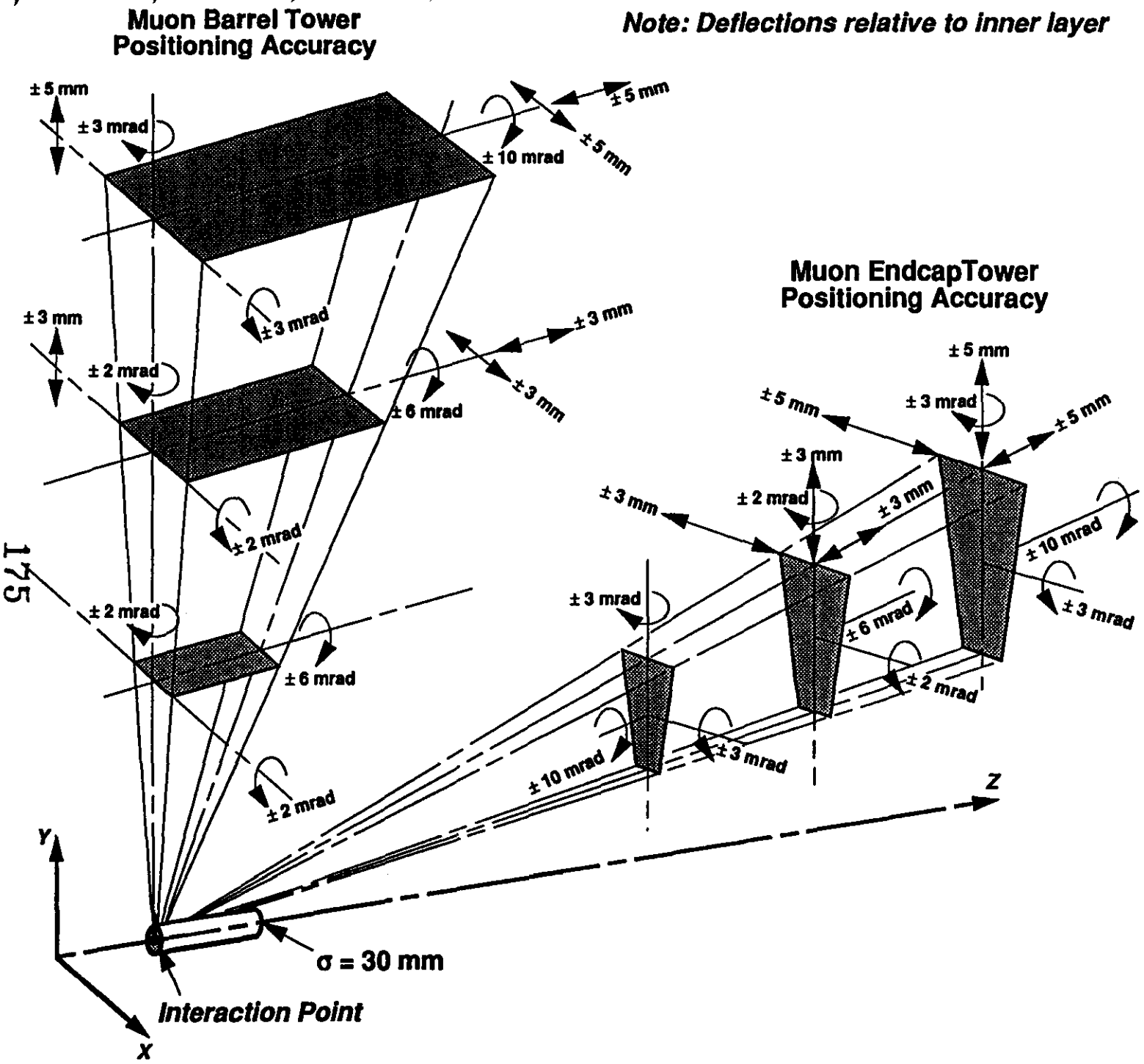


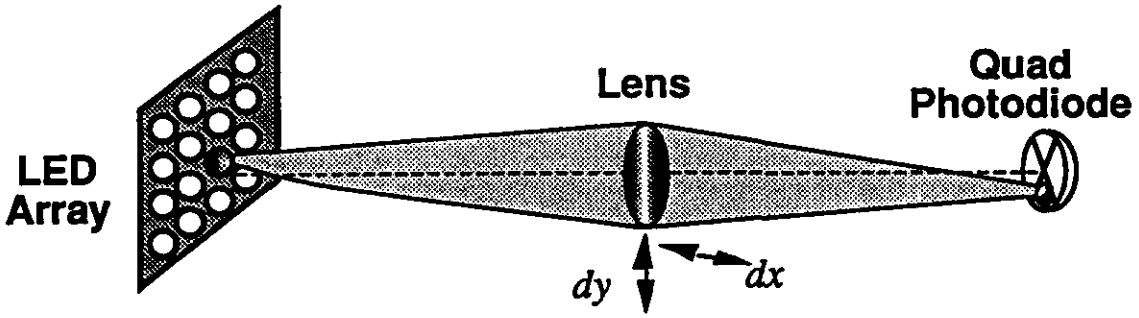
$\langle|\mathcal{E}|\rangle = 1.1\ mm$

Sagitta Residual After Alignment Correction

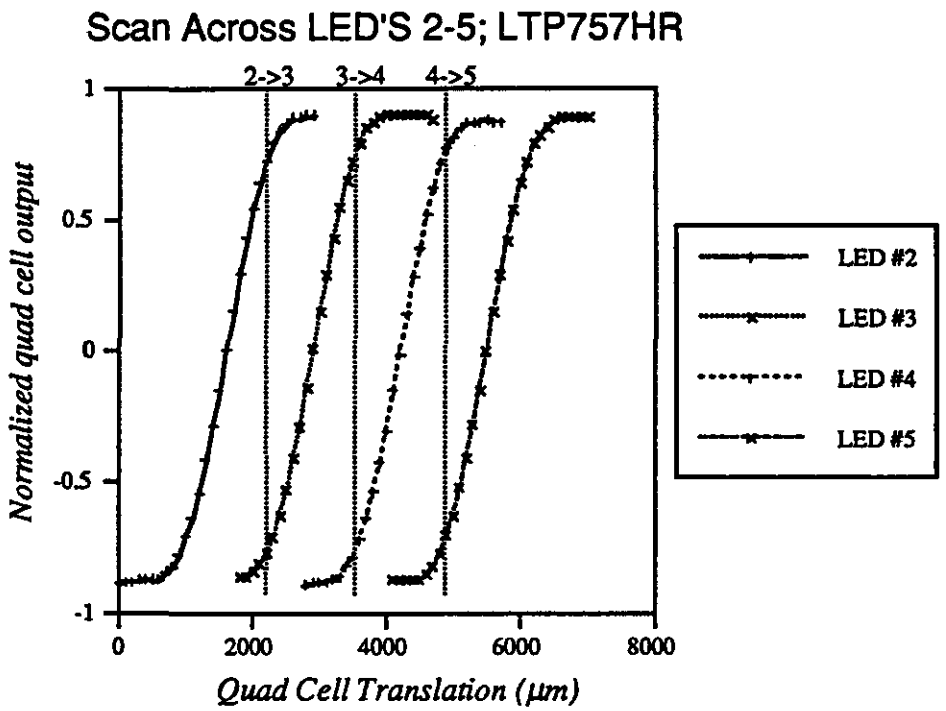


$\langle|\mathcal{E}|\rangle = 5.0\ \mu m$

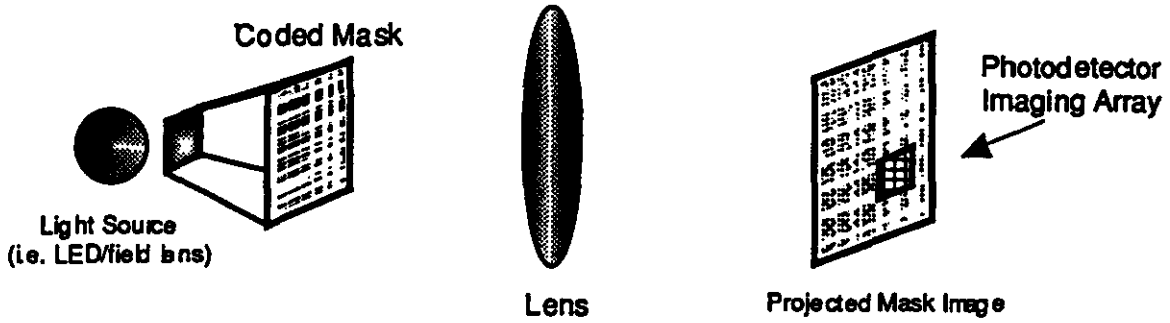

Muon Barrel Tower
Positioning Accuracy
Note: Deflections relative to inner layer
±5 mm
±3 mrad
±10 mrad
±5 mm
±5 mm
±3 mrad
±3 mm
±2 mrad
±6 mrad
±3 mm
±3 mm
±2 mrad
±2 mrad
±6 mrad
±2 mrad
Muon EndcapTower
Positioning Accuracy
±5 mm
±3 mrad
±5 mm
±5 mm
±3 mm
±2 mrad
±3 mm
±3 mm
±10 mrad
±3 mrad
±6 mrad
±2 mrad
±3 mrad
±10 mrad
±3 mrad
Z
Y
X
σ = 30 mm
Interaction Point



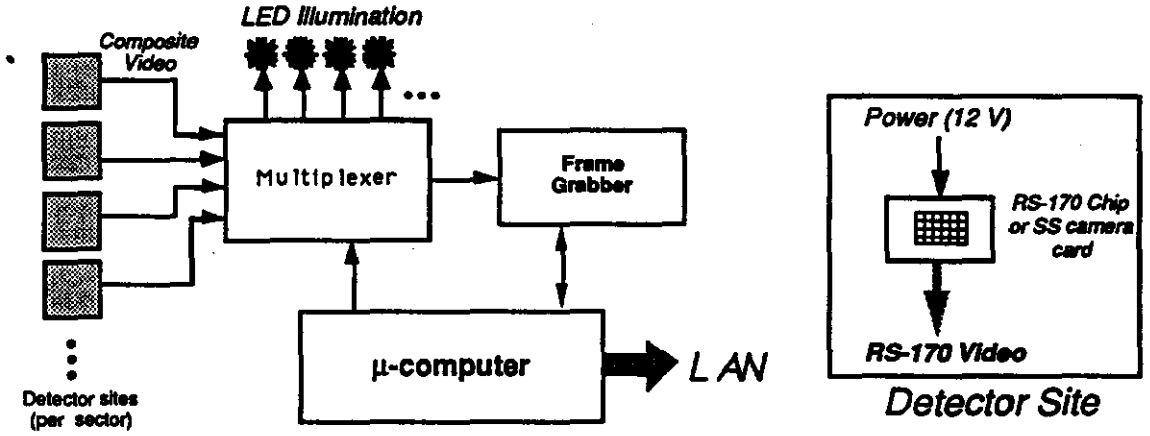
a) Multiple-LED Alignment System



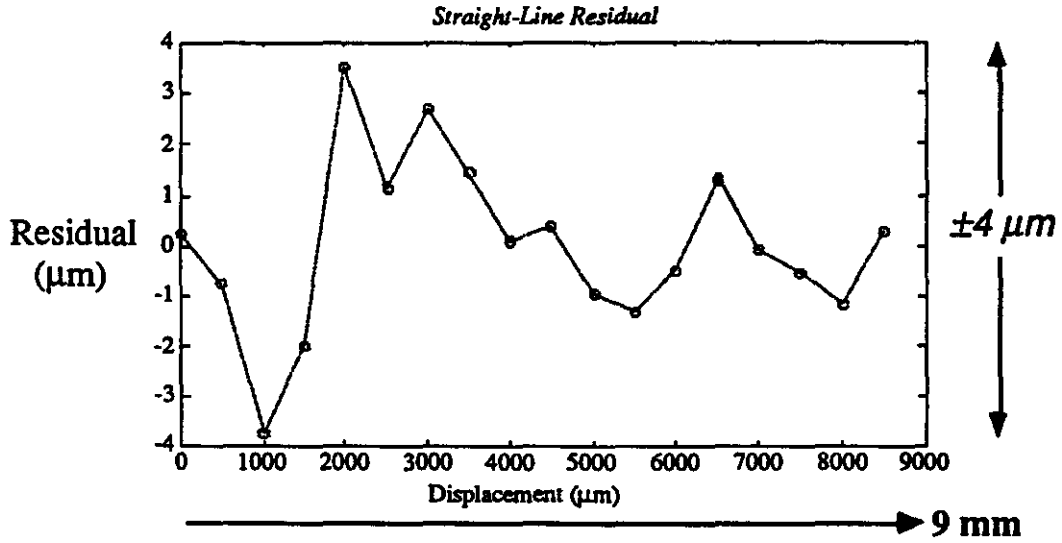
b) Test results for LED block w. 2.5 mm pitch



a) Wide-range video straightness monitor

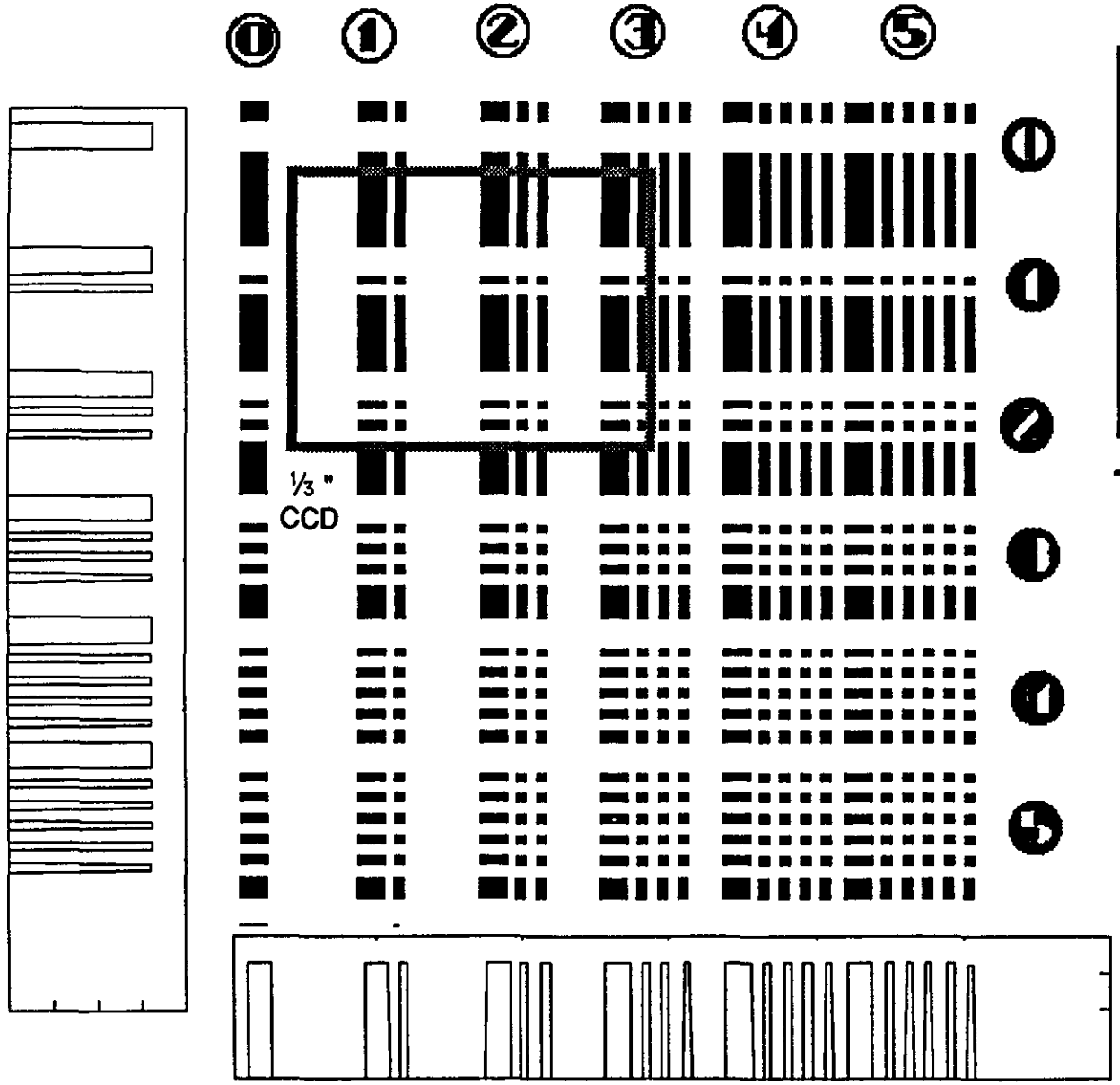


b) Implementation in GEM muon system



c) Preliminary test results

2D Barcode Mask



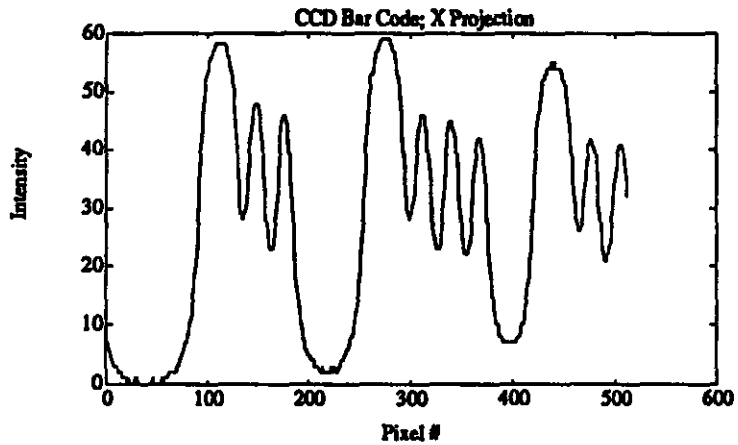
- Take x,y projections & separately match to code features
  - Converts 2D problem into 2 1D calculations!
  - Now nonotonic linear code; could binary-encode digits or use 2-digit numbers for *much* wider range!

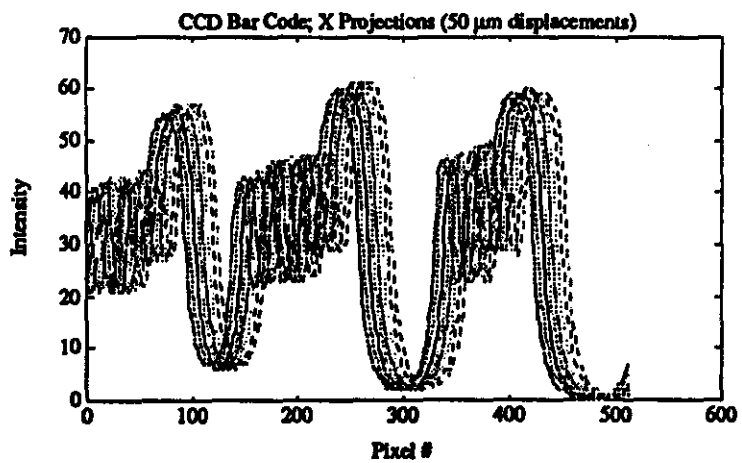
12 x 12 mm

- Current code hand-generated in Canvas (PICT oblect positions used to determine alignment), printed on Linotype.
  - Accurate pattern with direct postscript!
- Now on murky negative
  - Inexpensive (≈$20.) to put precisely on glass!

GEM

Pattern Analysis





50 μm Steps

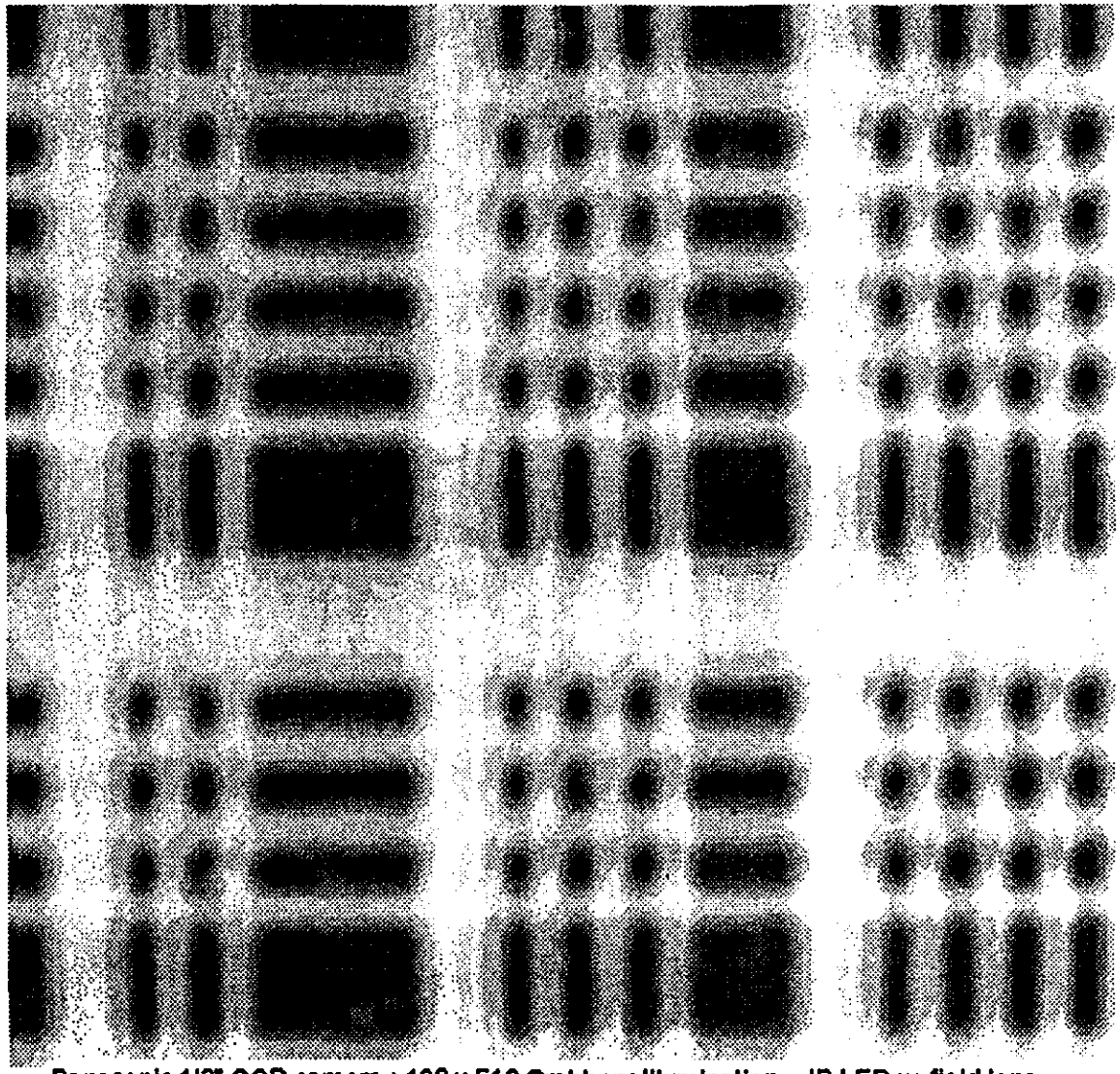
Analysis Sequence:

- **Take x,y projections of averaged frames.**
- **Find peaks (floating threshold)**
- **Parse barcode (identify cluster of peaks with digit)**
- **Centroid all peaks (fit quadratic)**
- **Fit peak positions in CCD projection with their expected place in the barcode (first linear least squares to get slope, then just average over offset (CCD - Bcode)**

This is quick & easy; correlation may be more precise...

GEM

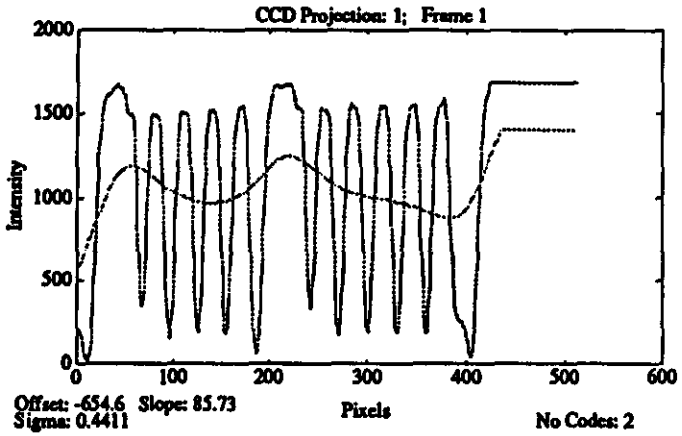
Sample Frame #1: IR LED w. Lens

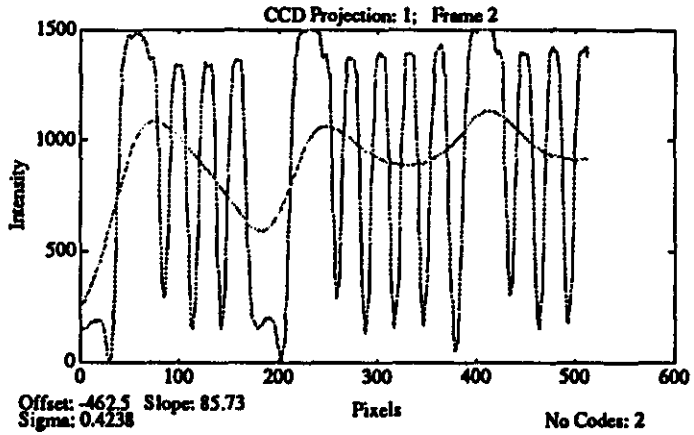


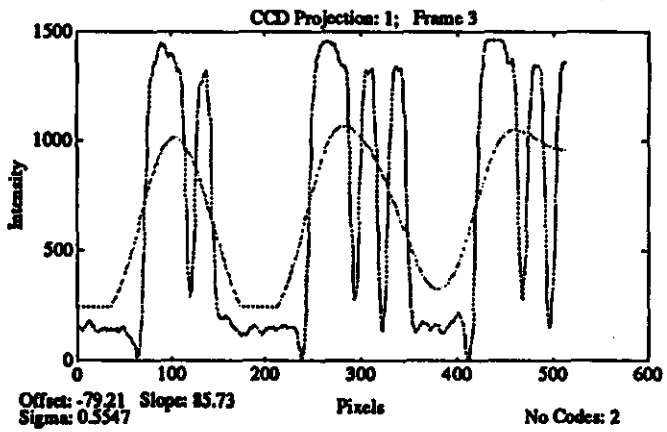
Panasonic 1/3" CCD camera : 480 x 512 Grabber : Illumination = IR LED w. field lens
Imaged over a 9 meter path through 1.5" lens aperture

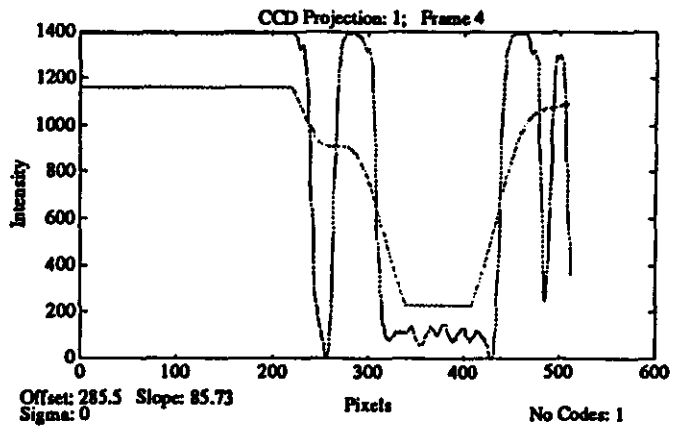
GEM

X projection data (9-meter path)







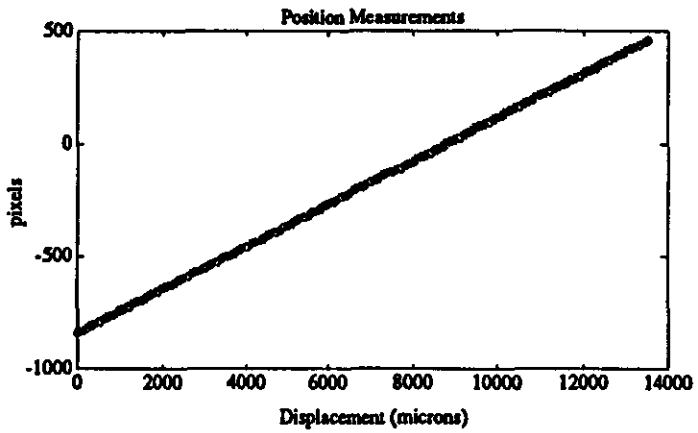


- 15 Frames averaged over 15 sec. (atmospheric dynamics at Hz-level)
- Low-pass filter serves as dynamic threshold.

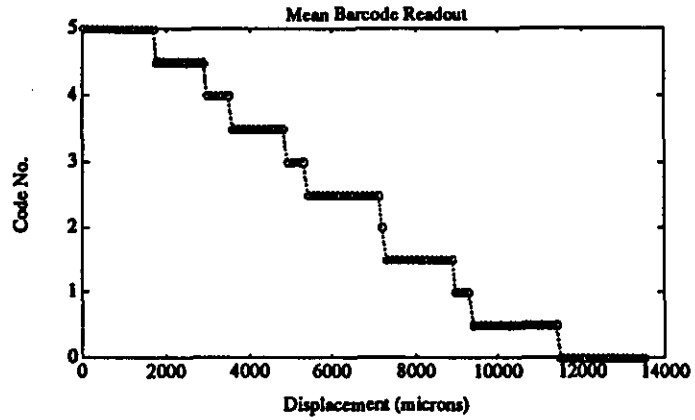
GEM

Scan Test; 100 μm shifts in X

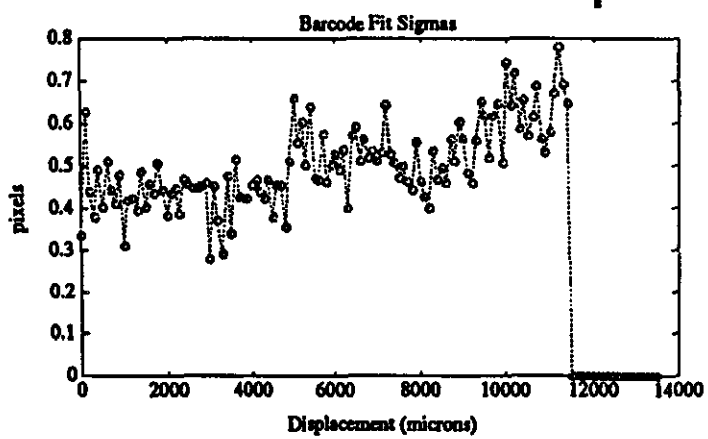
Measurement vs. Position



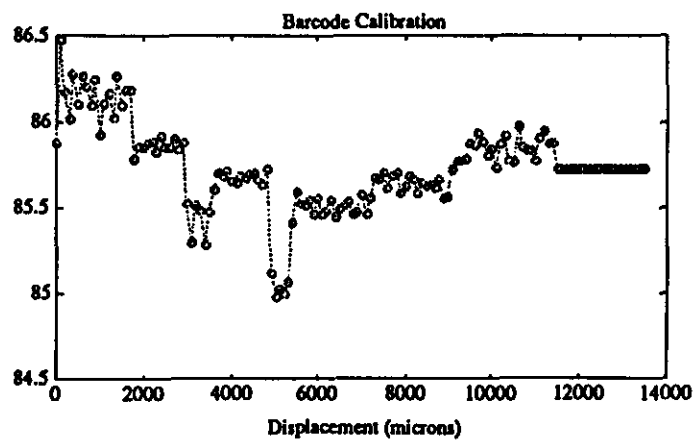
Average of Detected Bar Codes



Fit Residuals to Code Template



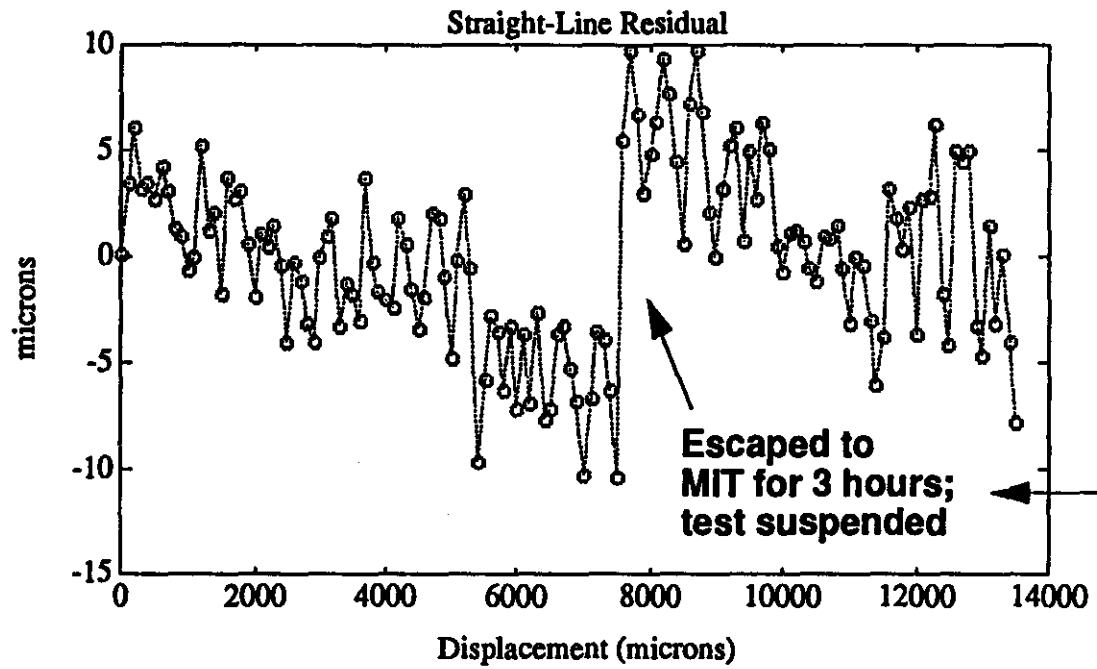
Calibration; CCD to Bar Code



- 15 Frames averaged for 15 sec. (atmospheric dynamics @ Hz-level)
- Measurements taken over 14 mm.

GEM

Scan Test; X Residual

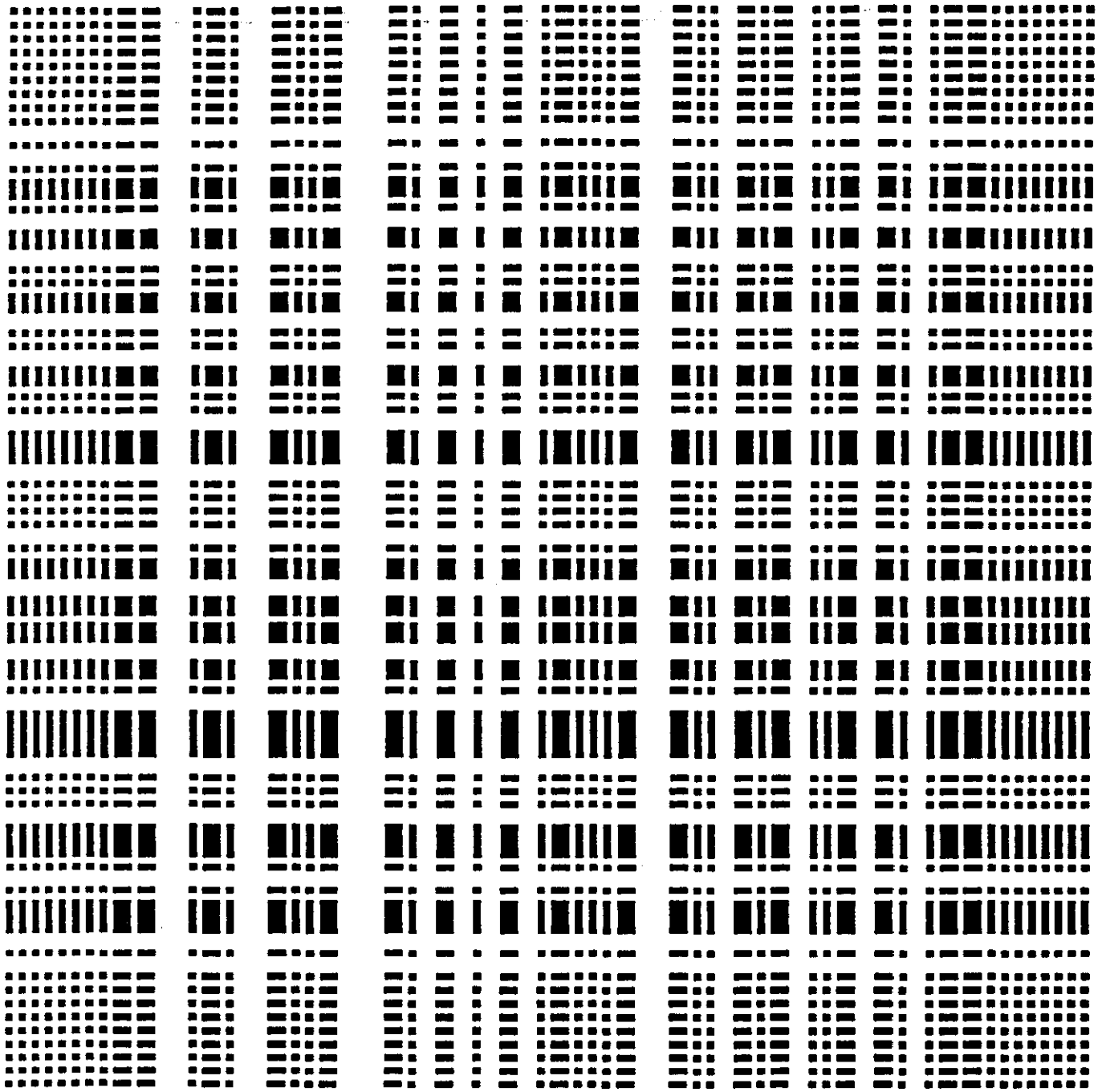


Air conditioning turned off; thermal drift!

Some systematic structure within ±10 μm
(i.e. film bent, flaws in film transfer, thermal effect)
True resolution at the 5 μm level?

- **15 Frames averaged for 15 sec. (atmospheric dynamics @ Hz-level)**
- **Measurements taken over 14 mm.**

GEM



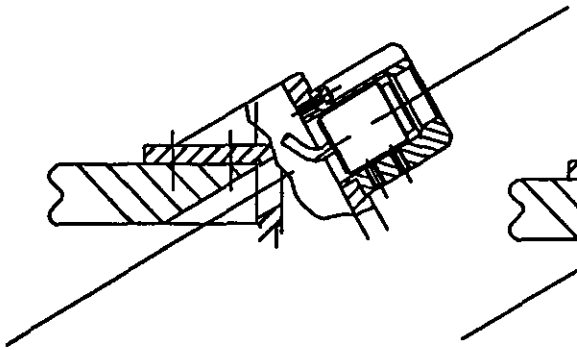
New Barcode

- Written in PostScript
- Binary-encoded digits
  - → Width of number encodes digit
  - → Absence/presence of bar encodes digit
- Digits scrambled for uniform feature density

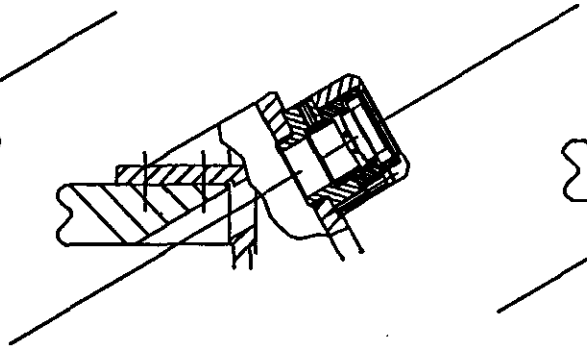
184 → Reduce this [8 x] → [2.4 x 2.4 cm] size

DETECTOR ASSEMBLY

(QUAD-CELL, PHOTOPOT, IMAGING ARRAY)

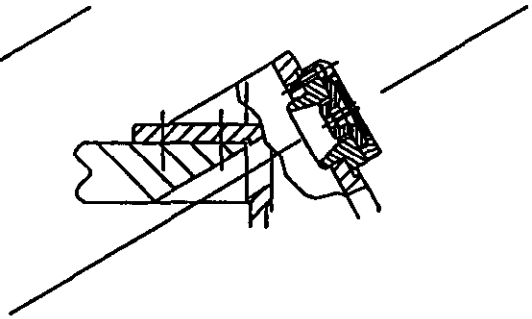


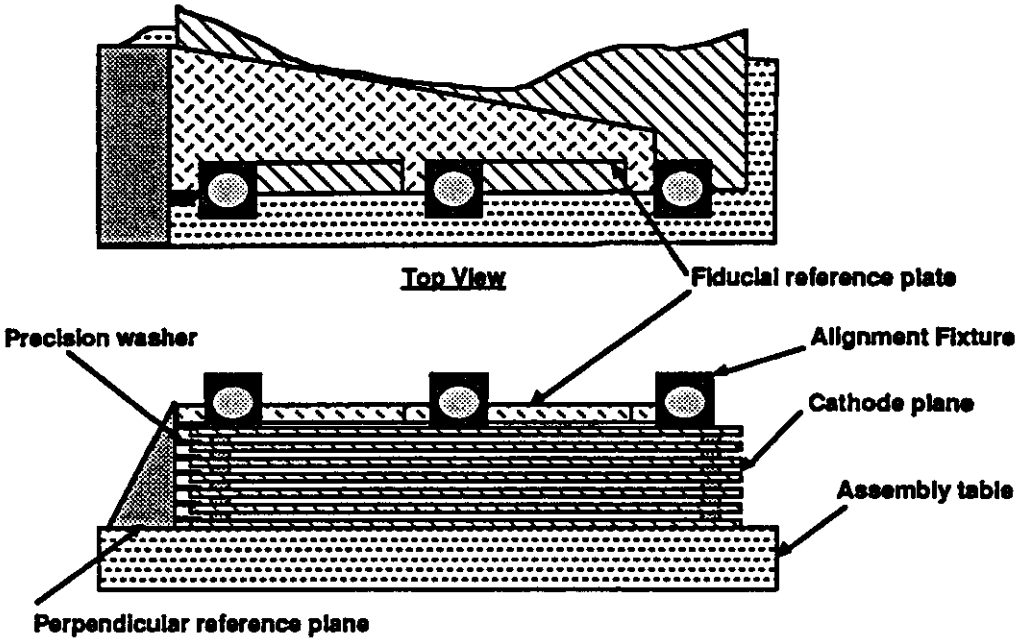
LENS ASSEMBLY



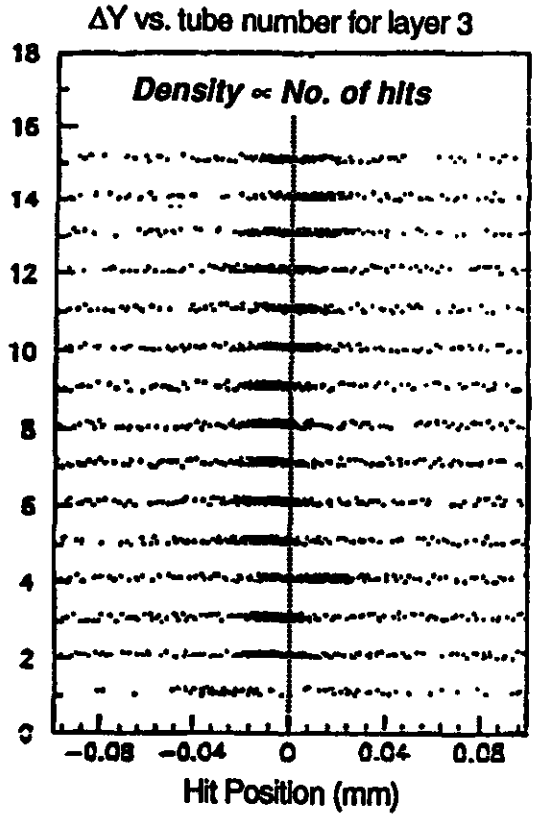
LIGHT SOURCE ASSEMBLY

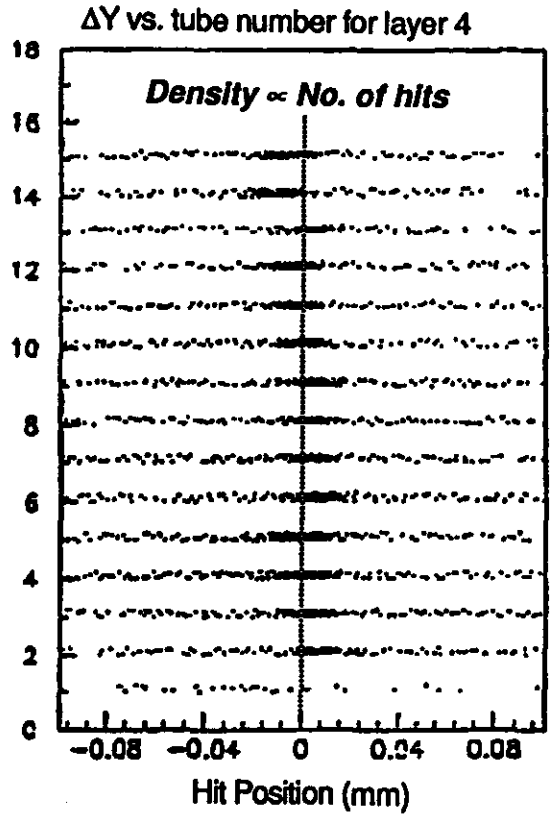
(LED, LED BLOCK, OR ILLUMINATED MASK)

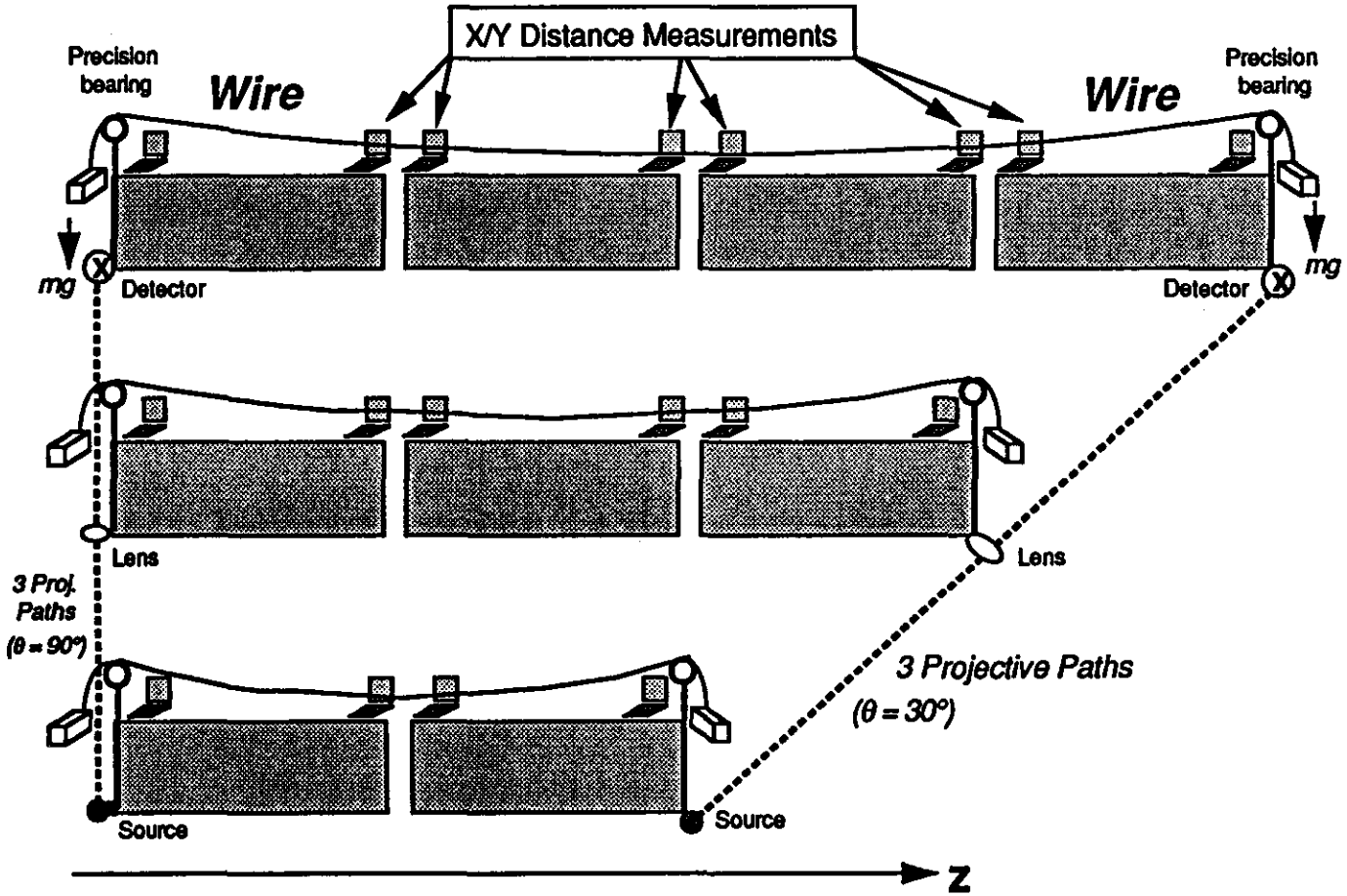


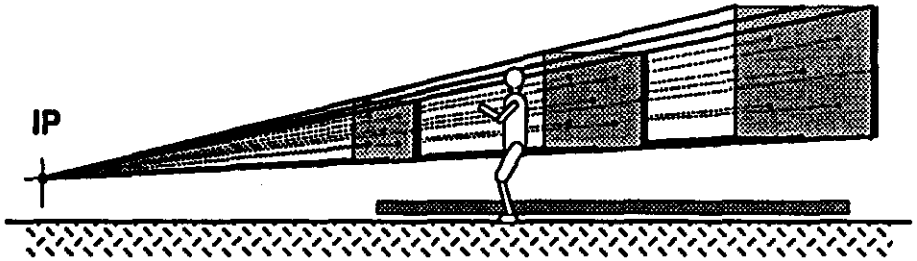

Top View
Fiducial reference plate
Precision washer
Alignment Fixture
Cathode plane
Assembly table
Perpendicular reference plane

End View

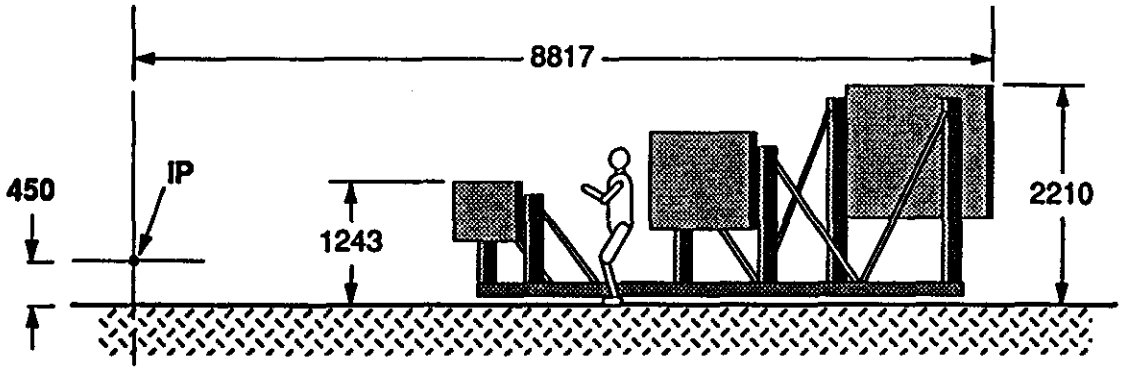

ΔY vs. tube number for layer 3
Density ∝ No. of hits
18
16
14
12
10
8
6
4
2
0
−0.08
−0.04
0
0.04
0.08
Hit Position (mm)


ΔY vs. tube number for layer 4
Density ∝ No. of hits
18
16
14
12
10
8
6
4
2
0
−0.08
−0.04
0
0.04
0.08
Hit Position (mm)

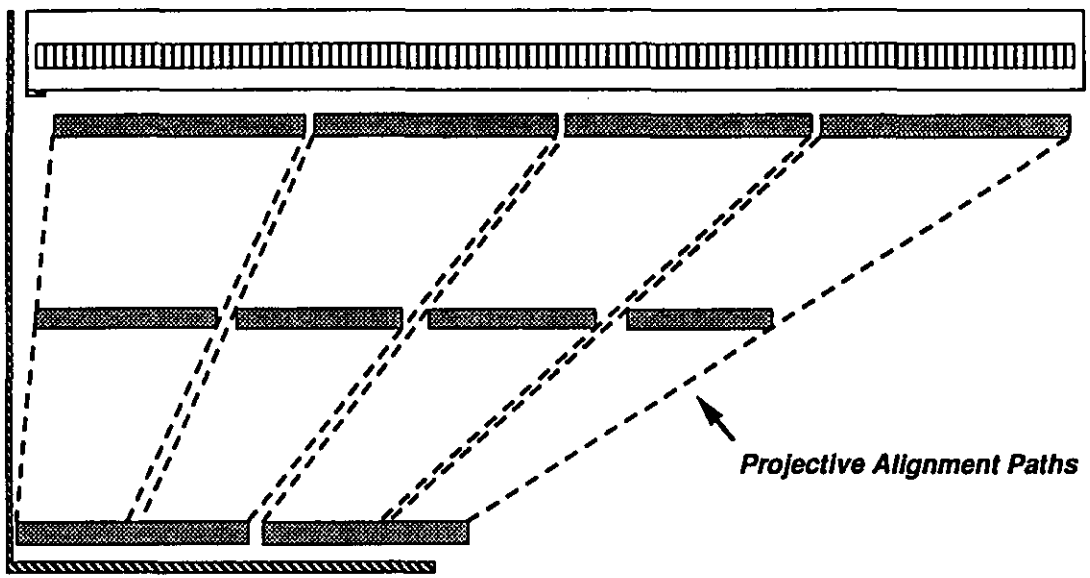

X/Y Distance Measurements
Precision bearing
Wire
Wire
Precision bearing
mg
Detector
Detector
mg
Lens
Lens
3 Proj. Paths (θ = 90°)
3 Projective Paths (θ = 30°)
Source
Source
z

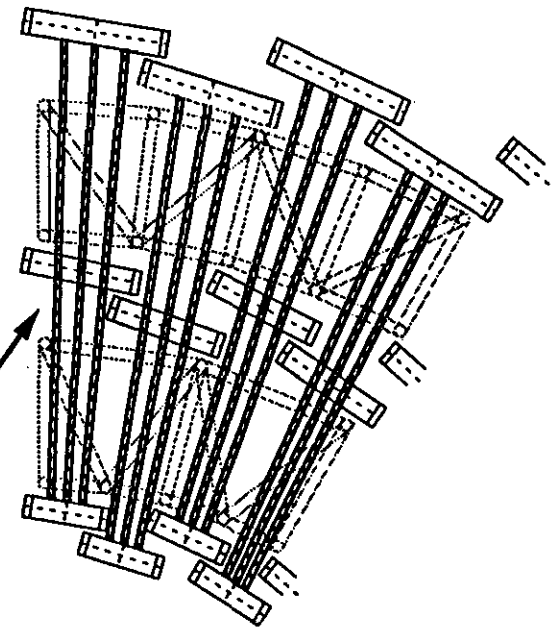


Proposed Projective Alignment Lines of Sight



Mechanical Design and Fixturing



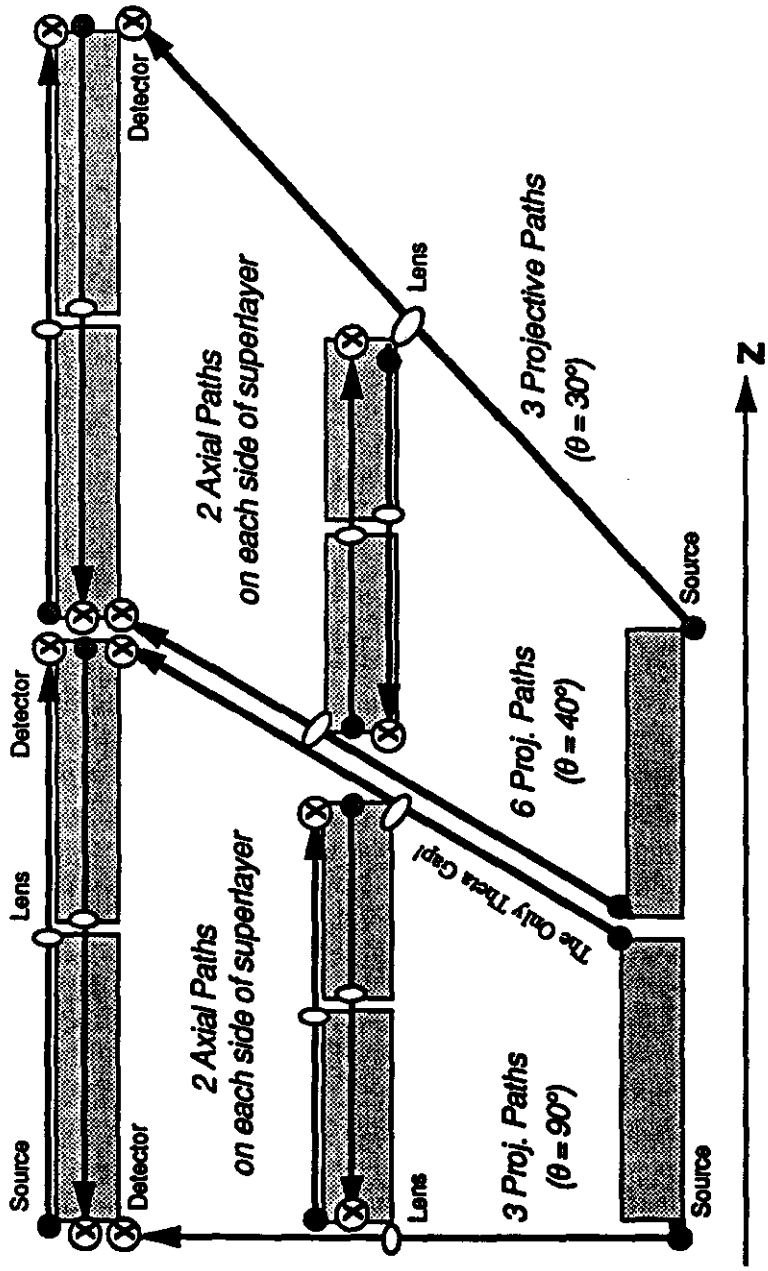


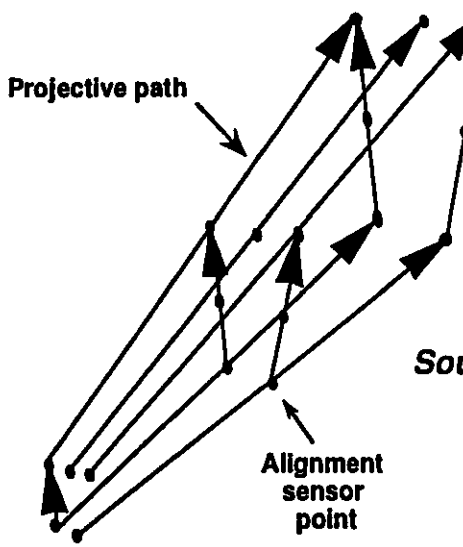
Local Alignment Monitors Needed:
Barrel Module ($\Delta\phi = 7.5°$) = 24
Assembly Sector ($\Delta\phi = 30°$) = 96
Net GEM Barrel = 2304

$\Delta\phi = 30° \rightarrow$ 4 Alignment Towers

A) Side view ($r\,\theta$)

B) End view ($r\,\phi$)

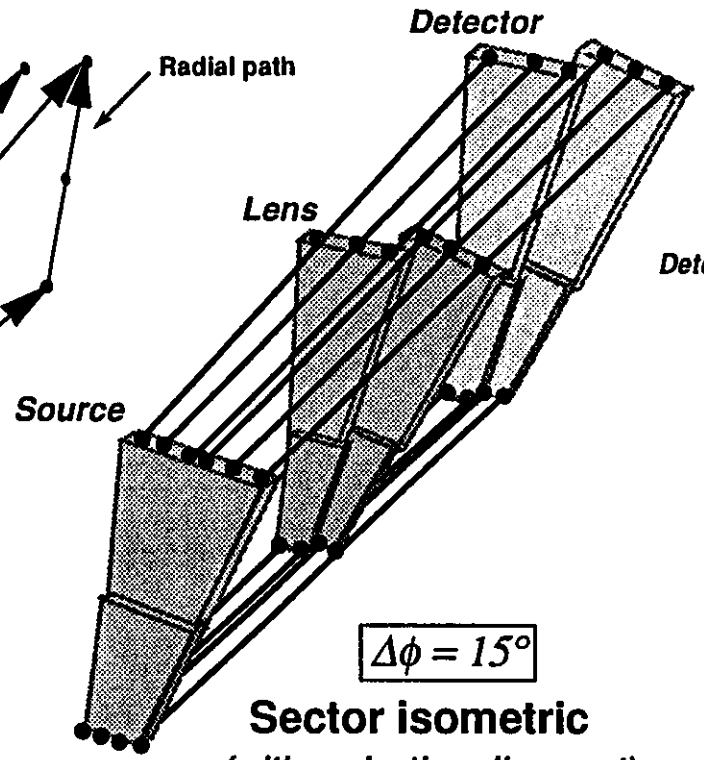

Source
Detector
Lens
Detector
2 Axial Paths
on each side of superlayer
Lens
3 Proj. Paths
(θ = 90°)
The Only Theta Gap!
6 Proj. Paths
(θ = 40°)
Source
2 Axial Paths
on each side of superlayer
Detector
Lens
3 Projective Paths
(θ = 30°)
Source
Z



$\Delta\phi = 7.5°$

Tower alignment paths

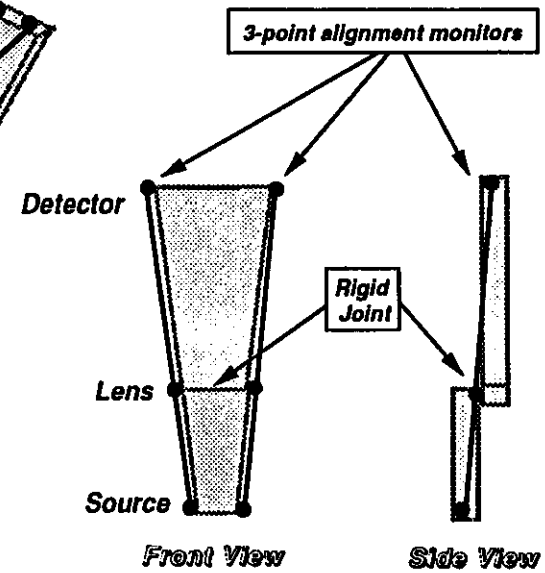
(5 projective plus 5 radial coupling paths)



$\Delta\phi = 15°$

Sector isometric

(with projective alignment)



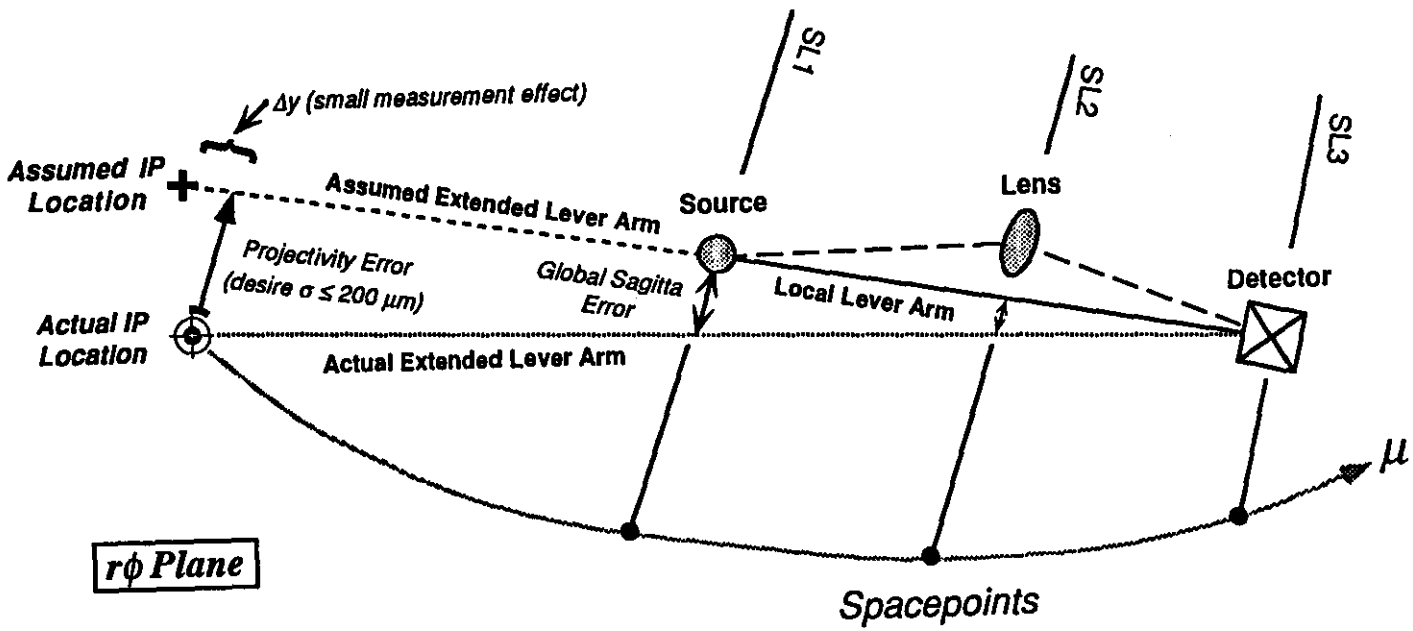
Front/side superlayer views

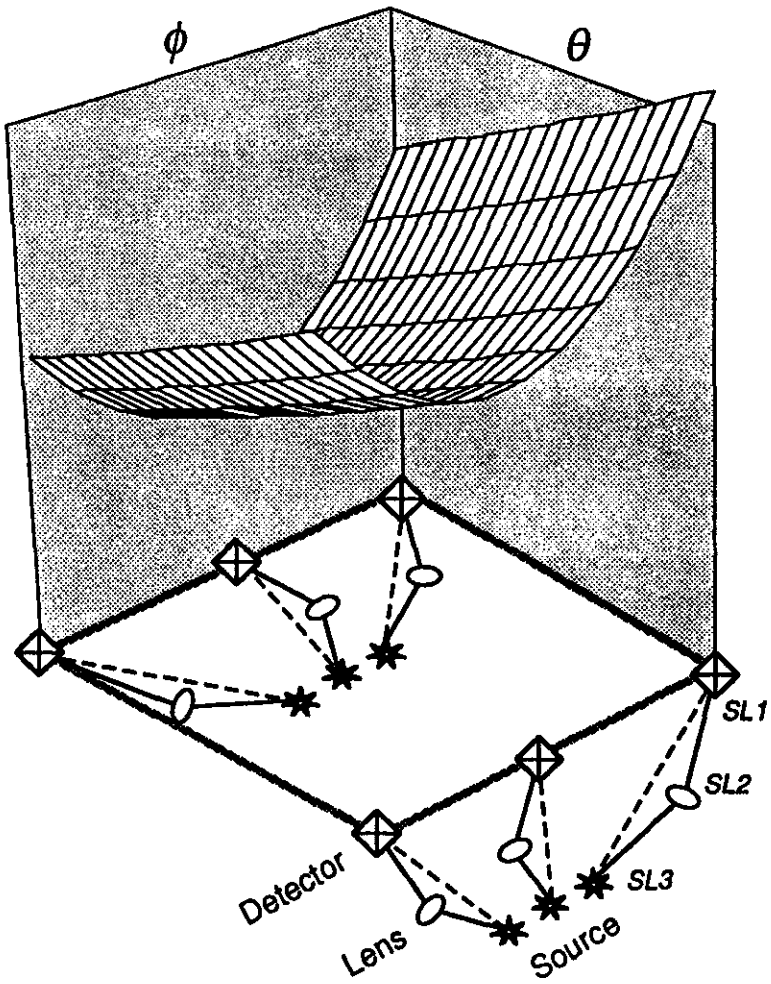
(with radial alignment paths)

No. of 3-point alignment monitors per GEM endcap = 480

	Error Source (positioning reqiurements)	Consequence	Interpretation
1	Dynamic Range of Local Alignment	±5 mm	Local position relative to bottom superlayer
2	Correction Range of False Sagitta	±3 mm	Local position relative to bottom superlayer
3	Projectivity of Local Alignment	±7 mm	Tolerance relative to IP line
4	Projectivity of Trigger Roads	±5 mm	Tolerance relative to IP line

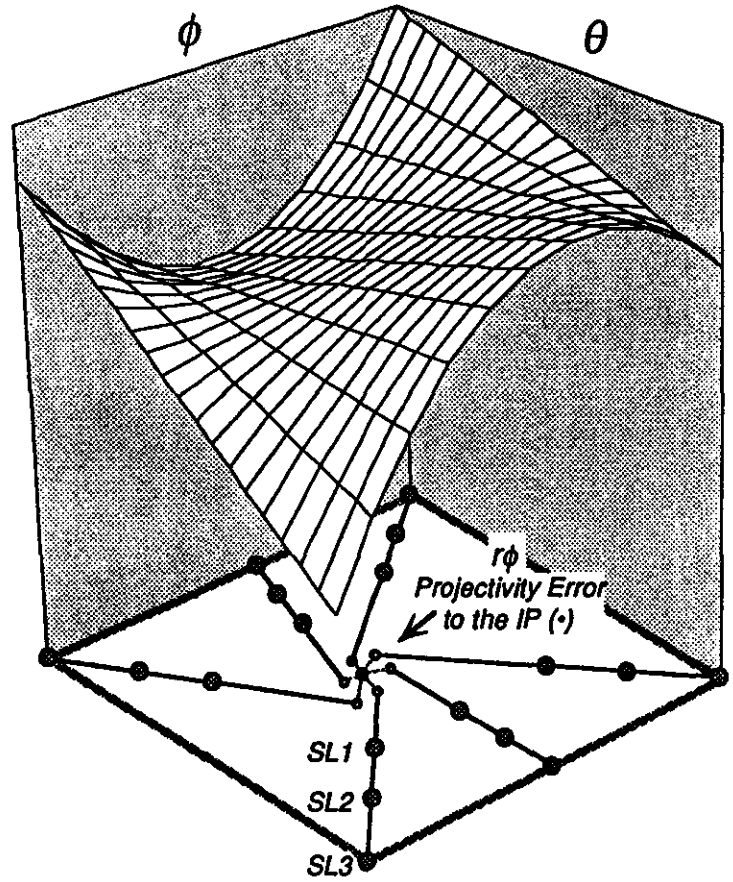
	Error Source (measurement accuracy)	Consequence	Interpretation
A	Muon Angle	3 mr	±5 mm chamber offset from IP line
B	Track Linking	≤1 mm	Preliminary estimate (mainly r-phi)
C	High Mass Momentum Resolution	200 μm	±175 μm (r-phi) chamber offset from IP line


Δy (small measurement effect)
Assumed IP Location
Assumed Extended Lever Arm
Source
Lens
Detector
SL1
SL2
SL3
Projectivity Error (desire σ ≤ 200 μm)
Global Sagitta Error
Local Lever Arm
Actual IP Location
Actual Extended Lever Arm
μ
rφ Plane
Spacepoints



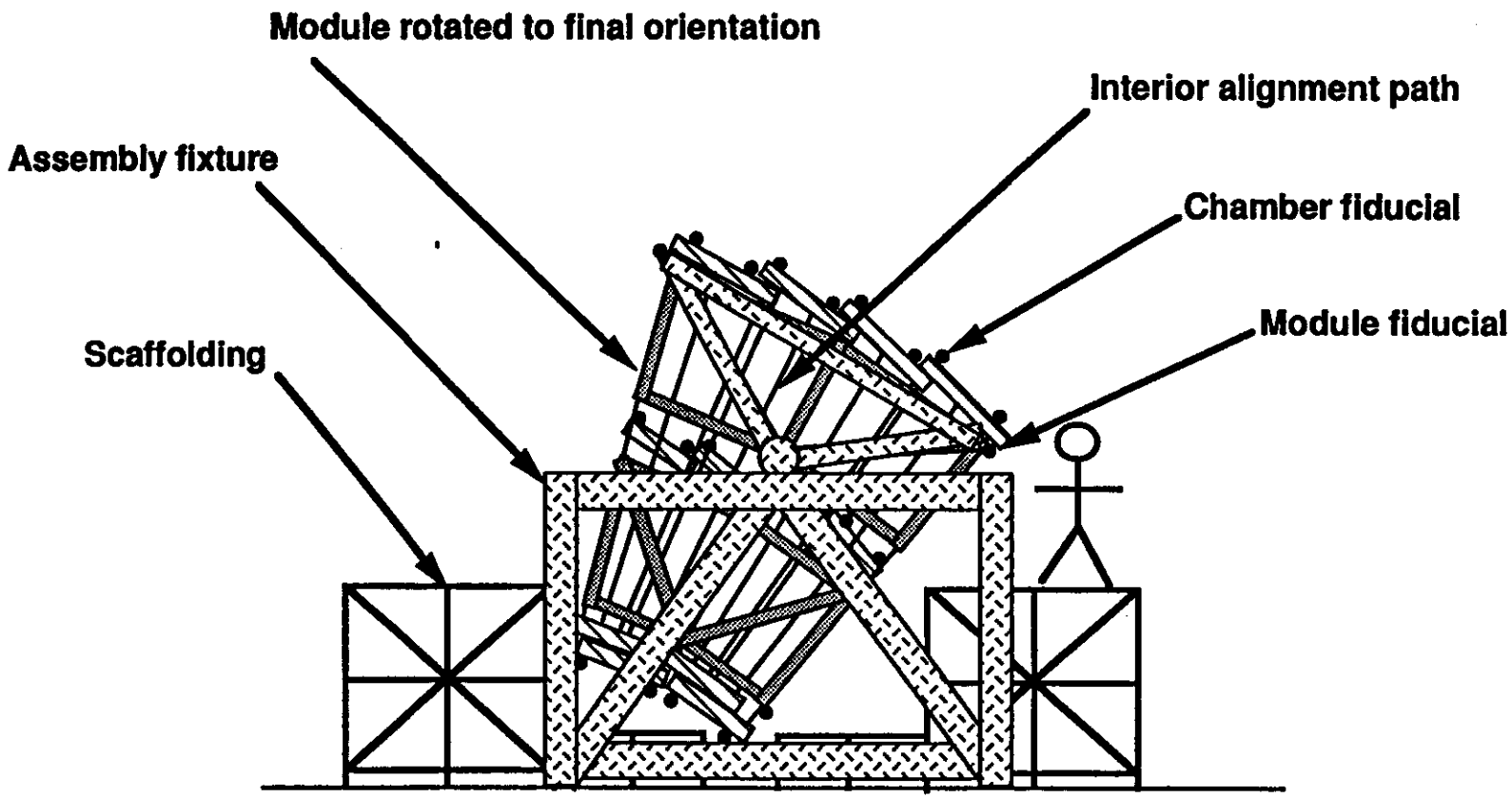
a) Local sagitta error correction function over alignment tower

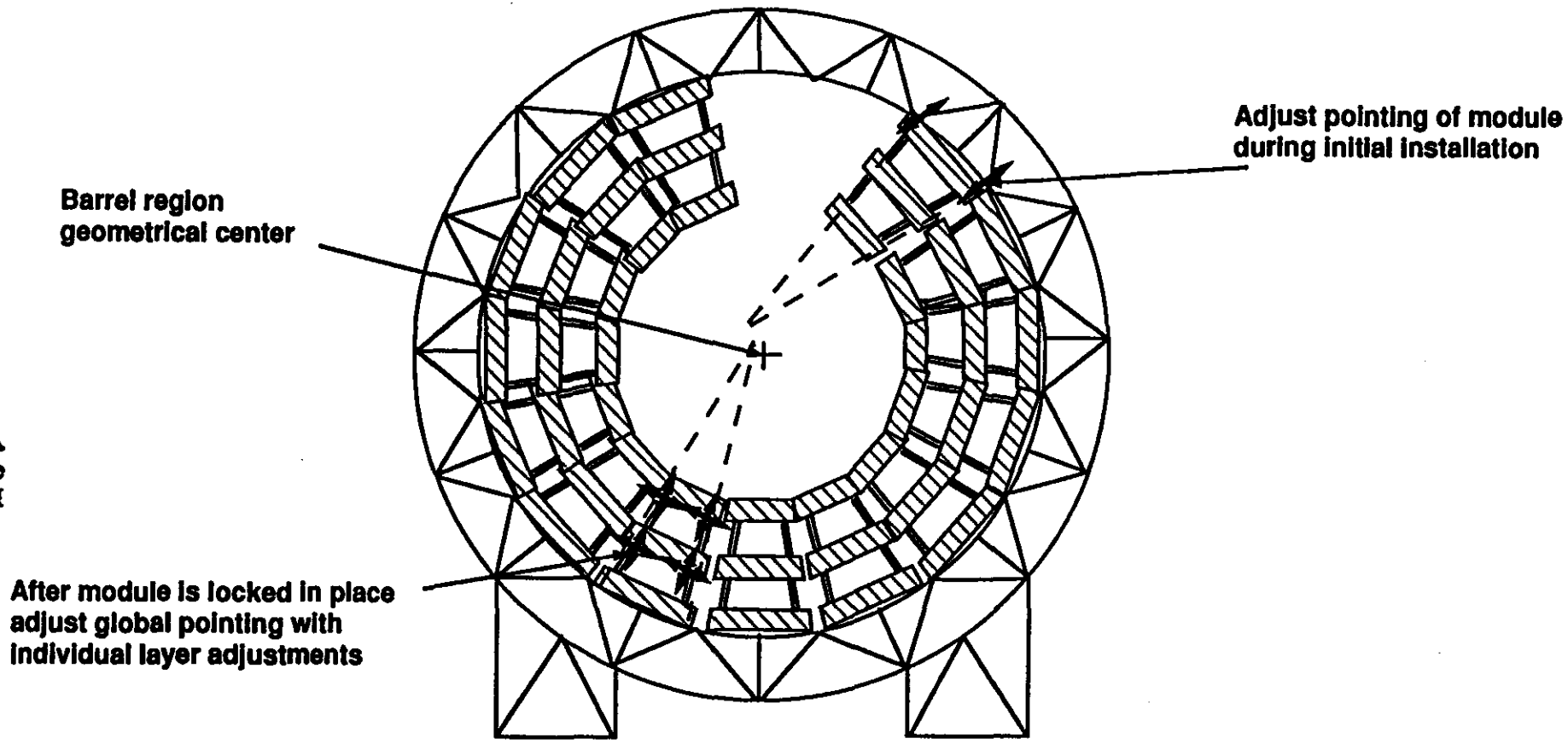
Interpolated from straightness monitor measurements



b) Tower projectivity correction function (rϕ) over alignment tower

Interpolated between straightness monitor axes
Fit to muon data


Module rotated to final orientation
Interior alignment path
Assembly fixture
Chamber fiducial
Module fiducial
Scaffolding


Barrel region
geometrical center
Adjust pointing of module
during initial installation
After module is locked in place
adjust global pointing with
individual layer adjustments

Roger McNeil

System Performance

GEM Muon System Performance

Outline

1. Introduction - Simulation Tools

2. Muon Backgrounds
   - Hadron Punchthrough / Charged particle rates
   - uncorrelated neutron/γ background
   - correlated electromagnetic showers

3. Trigger Performance - Covered by M. Atiya

4. Pattern Recognition Performance
   - em background
   - n/γ background

5. Momentum resolution
   - Vertex constraint
   - Loss of superlayer 1

6. Performance of Muon System on Physics
   - Acceptance * Eff for $H \to 4\mu$
   - Resolution $H \to 4\mu$

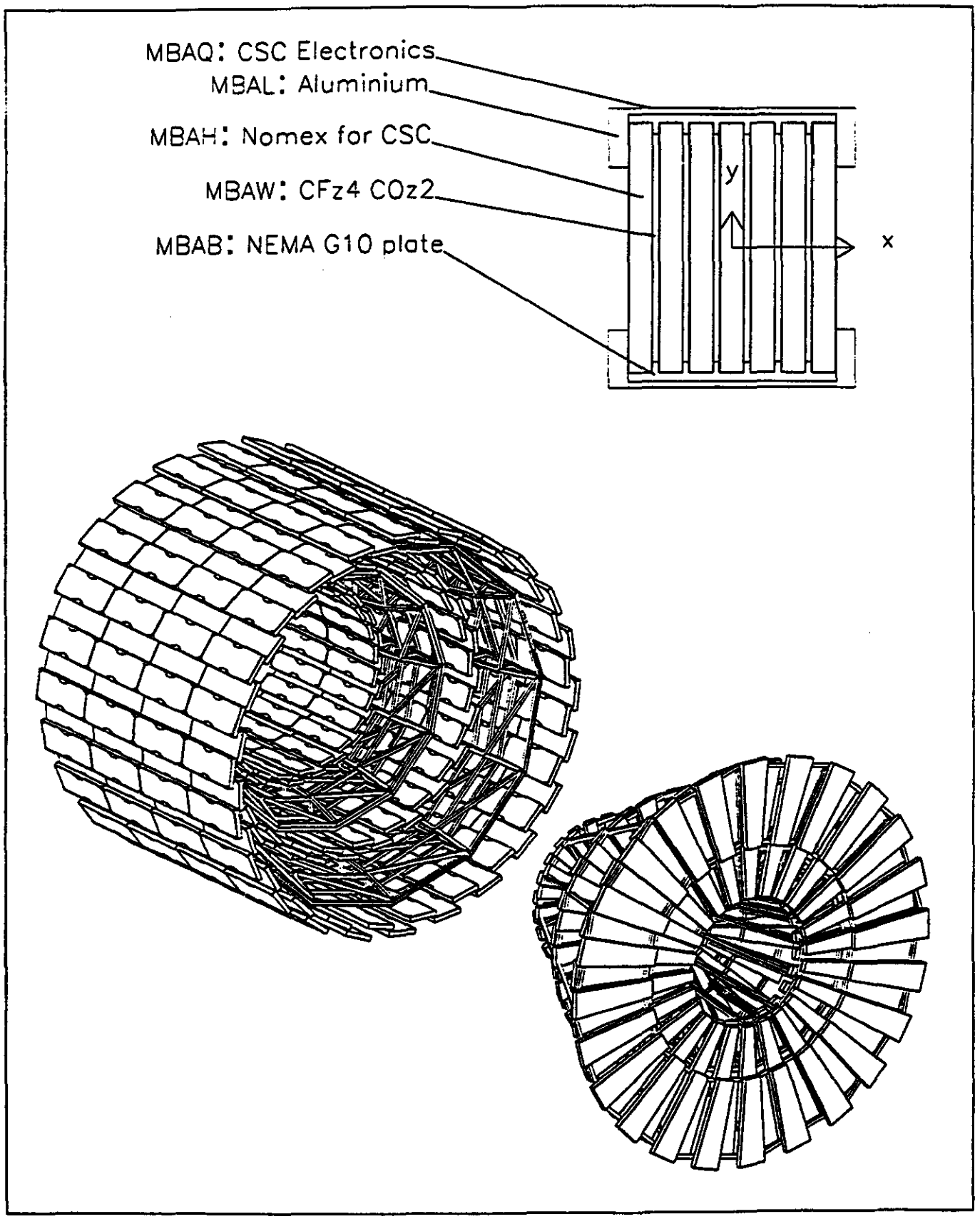
. Introduction - Simulation Tools

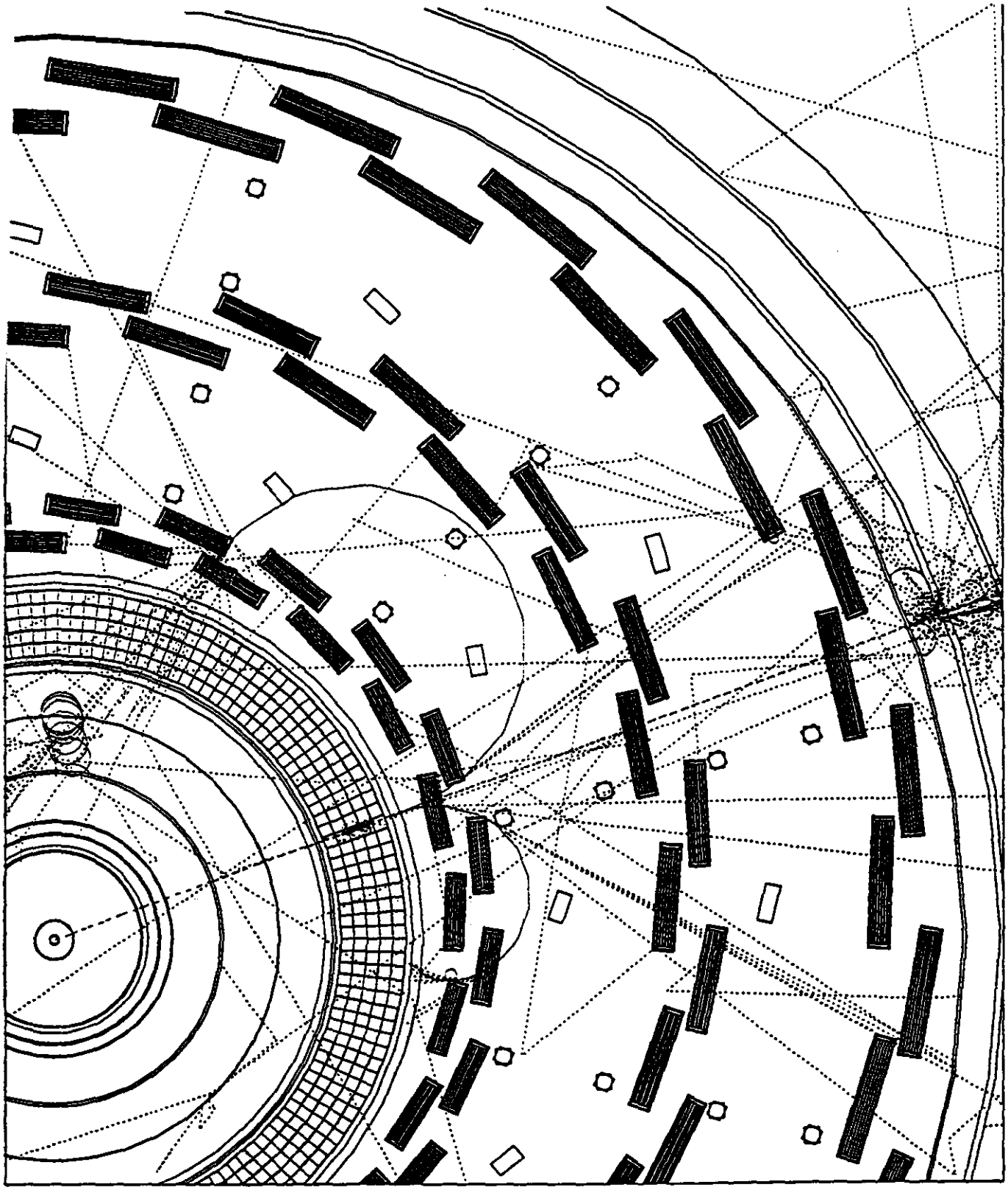
Muon system performance now being evaluated using full GEANT-based Hit-level Monte Carlo

SIGEM

SIGEM contains:

- Inner tracking detector
- Baseline 2 Calorimeter (correct depth, mat'ls - Homog mix)
- Baseline 2 Muon System Layout
- Muon system frames & support structures
- Detail layer geometry, mat'ls of CSC
- Non uniform B field - coil, cryo, FFS, etc.


MBAQ: CSC Electronics
MBAL: Aluminium
MBAH: Nomex for CSC
MBAW: CFz4 COz2
MBAB: NEMA G10 plate
y
x



2. Muon Backgrounds

Hadron Punchthrough - Calorimeter depth

Main sources of charged particles in muon system (exiting calorimeter)

- Prompt Muons from heavy quark decay
- Muons from decays of π/K in inner tracker

} Muon enters Calorimeter

- Hadron Punchthrough } hadron enters calorimeter

Calorimeter depth beyond that needed for resolution serves to suppress hadron punchthrough.

Criteria for gauging calorimeter depth:

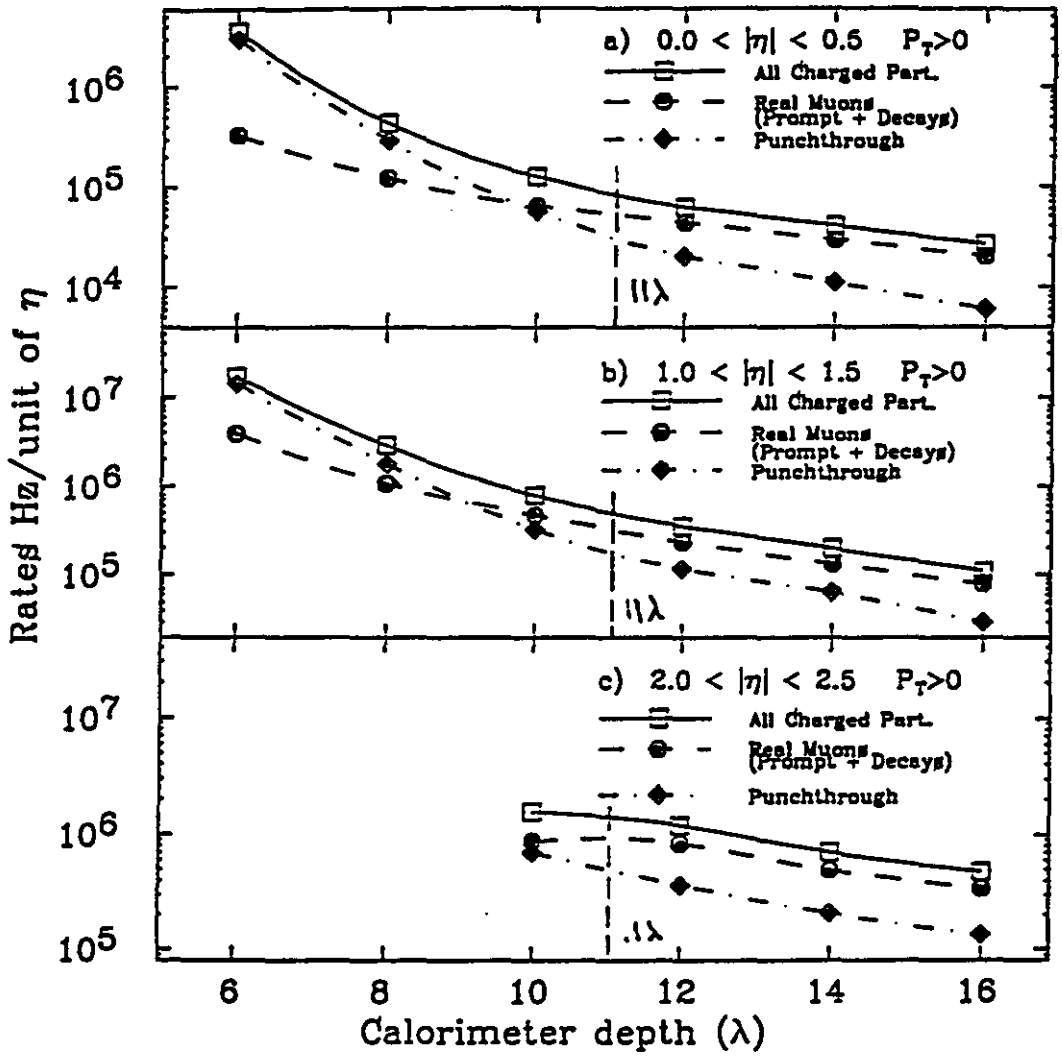
1. Overall rate of charged particles exiting calorimeter from hadron punchthrough should be much less than (factor of 2 used) than sum of rate from prompt and decay muons

2. Rate of charged particles above some P_T threshold [illegible] from punchthrough should be much less than rate from prompt muons + decay muons

3. Charged particle rate must be much less than CSC limiting rate - depends on design.
   $\ll 3\%$ occupancy

Overall Charged Particle rates in 3 rapidity intervals

Tracking volume: 95cm radius, 4.4m long



Criteria 1 satisfied at $\gtrsim 11\lambda$ $0 \leq |\eta| \leq 2.5$

In the forward region, rate dominated by <u>decays of π/K</u>

Summary of depth requirements

Criteria	Depth at eta=0	Depth at eta=1.3	2.5
1	11	11	11
2	10	10	10

Table 1. Depth Requirements imposed by Criteria 1 and 2

For $P_T > 10$ GeV/c and $\geq 10\lambda$. Prompt muons dominate rate everywhere.

Criteria 3

At high luminosity, $10^{34}\,cm^{-2}s^{-1}$, Max ± 3 strip (7-strip) barrel CSC occupancy is 0.27% ($\eta = 1.2$) for 11λ. $\Rightarrow$ Baseline Z Calorimeter depth $\eta=0$ 11λ, $\eta=1.2$ 12λ

In the far forward ($1.87 < |\eta| < 2.46$) region at $10^{34}\,cm^{-2}s^{-1}$

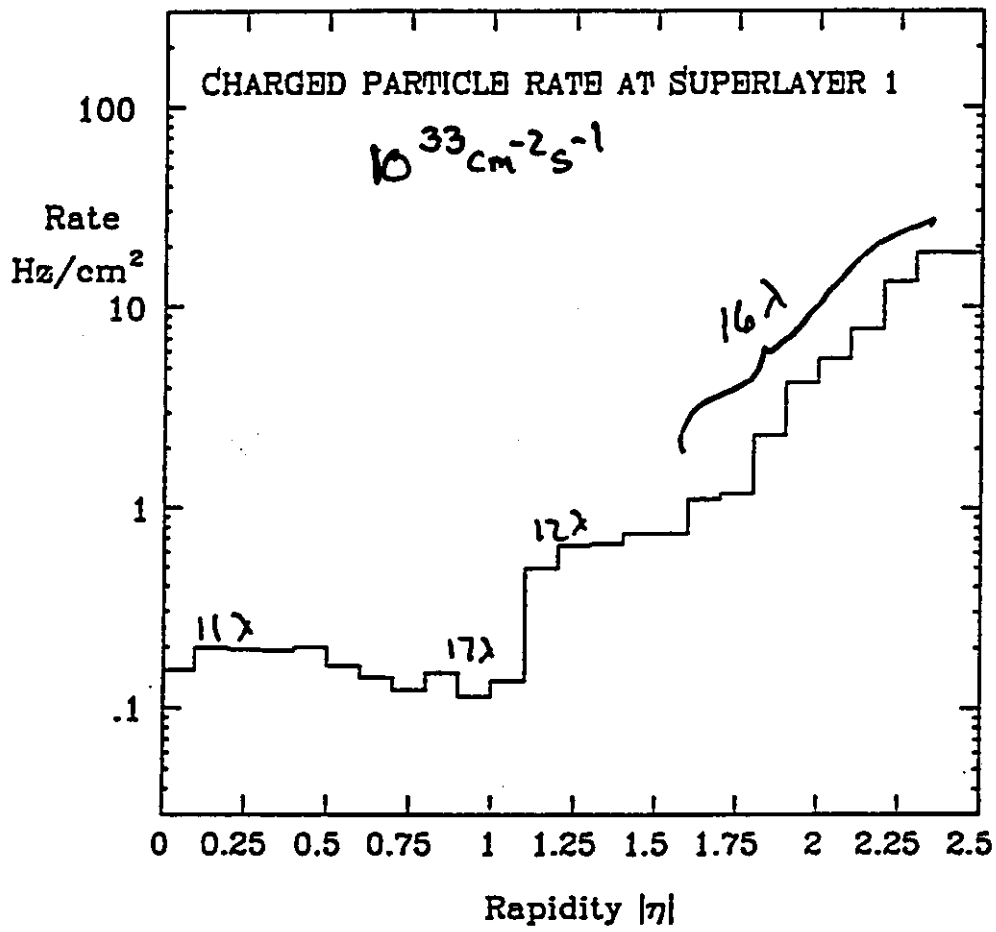
Calorimeter thickness	10	12	14	16
Rate per Strip (Hz) Strip size 93cm * 0.5cm	13100	10500	6640	4320
Single Strip Occupancy 300 nsec integration delay	0.39%	0.32%	0.20%	0.13%
3-strip Occupancy	1.20%	0.94%	0.63%	0.38%
7-strip Occupancy	2.7%	2.2%	1.4%	0.9%

Table 2. CSC strip Occupancy in the far forward region as a function of calorimeter depth at high luminosity.

Baseline Z Calorimeter depth $\eta > 1.6$ is 16λ

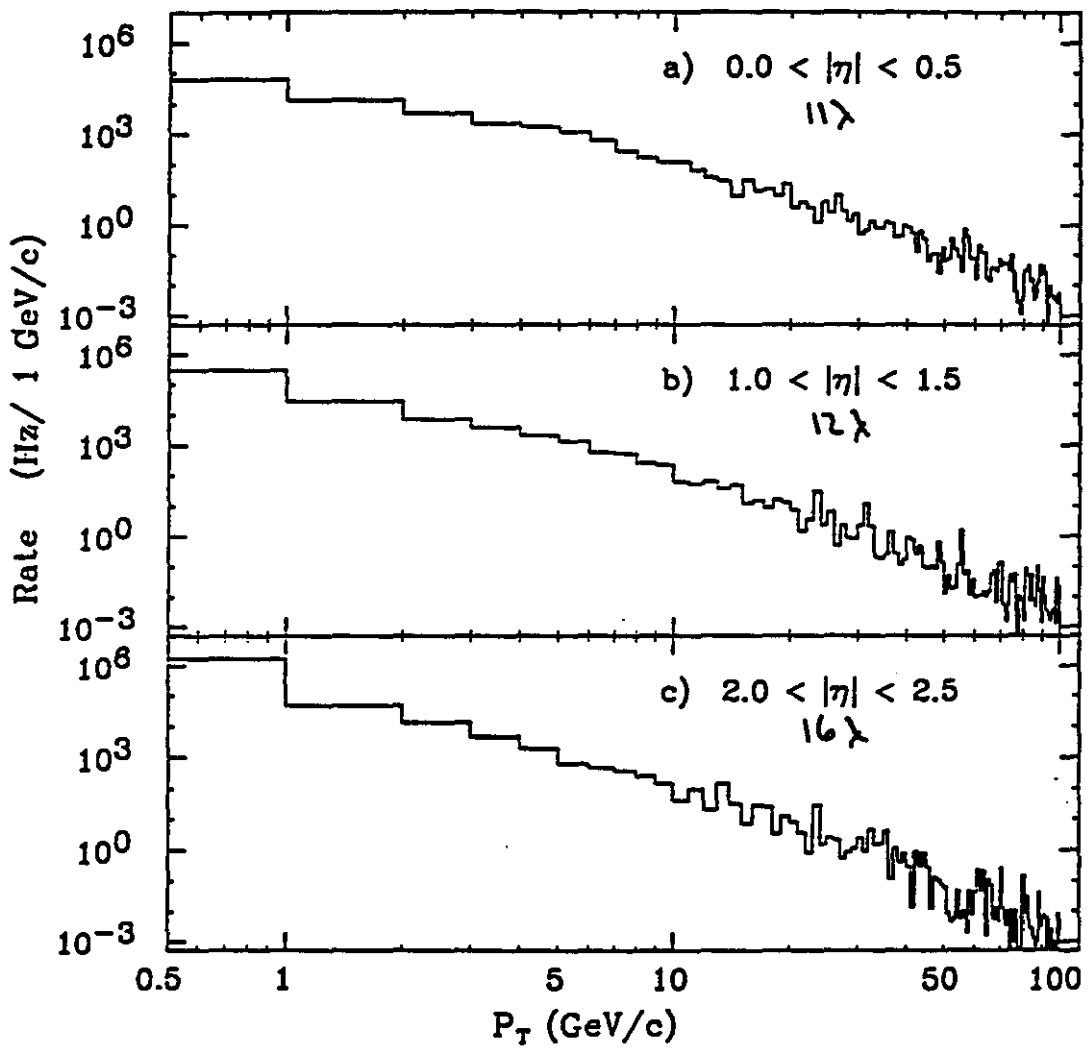
Charged particle rates in GEM muon system after baseline 2 Calorimeter

Fig 4.2.4.2



P_T of charged particles in GEM muon system

Fig 4.2.2.3



Requires sharp trigger thresholds

Uncorrelated neutron backgrounds

Occupancy in CSC from random n/γ hits is

$$R_{n/\gamma} \times \varepsilon_{n/\gamma} \times A_{channel} \times \Delta t_{INT\ Charge} = \text{Occupancy}$$

↑ fluence ↑ det Eff ↑ area ↑ integ time

An occupancy >3% leads to loss of reconstruction efficiency

neutron/γ detection efficiency

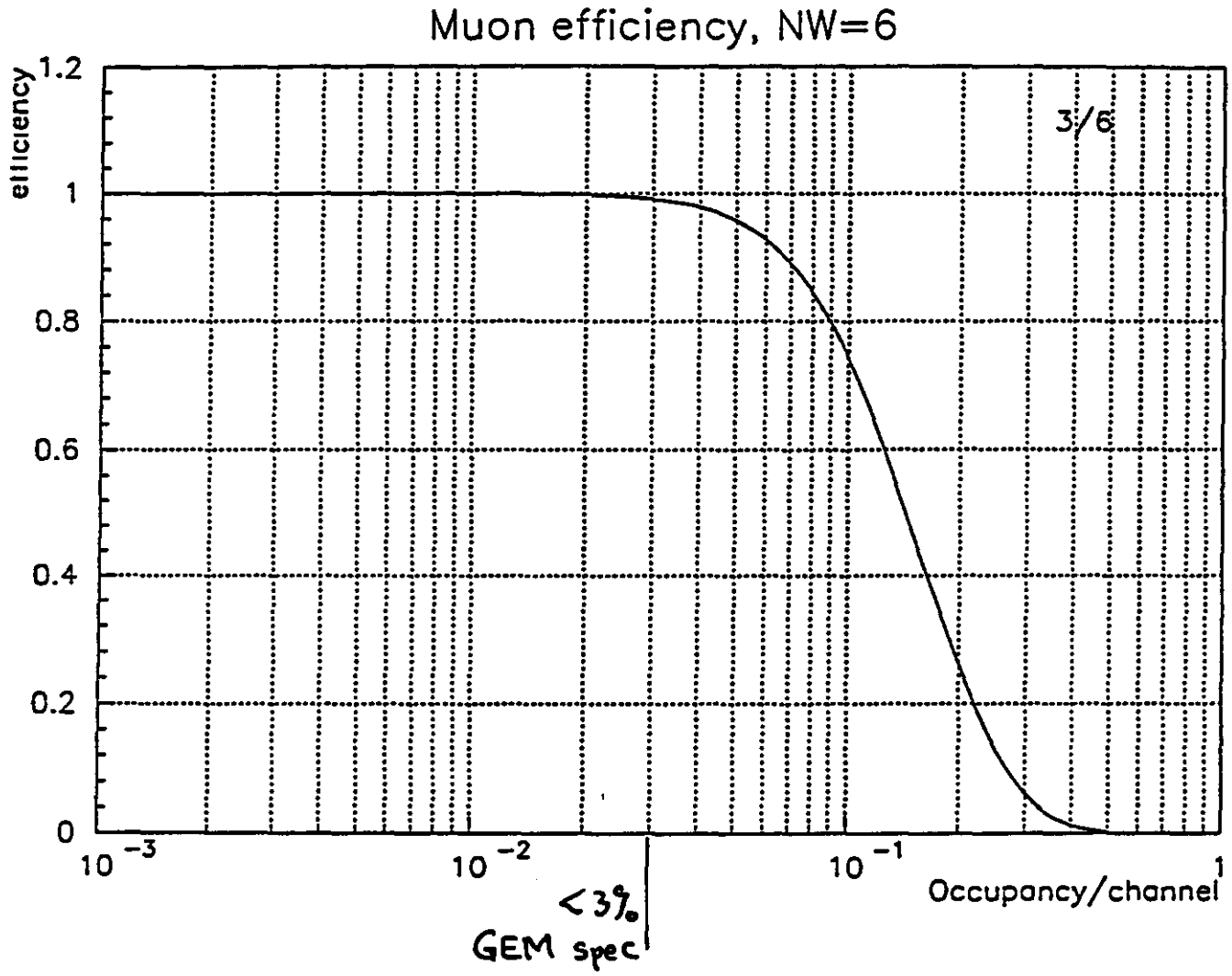
Table 3

Sensitivity of CSC to thermal and fast neutrons and gammas (in units of 10^(-3))

Superlayer	gas gap thick. Barrel/Endcap (mm)	sensitivity to: thermal neutrons	fast neutrons	gammas
Inner	5 / 5	0.8	0.4	8.
Middle	8 / 7	0.9	0.6	10.
Outer	10 / 10	1.0	0.8	12.

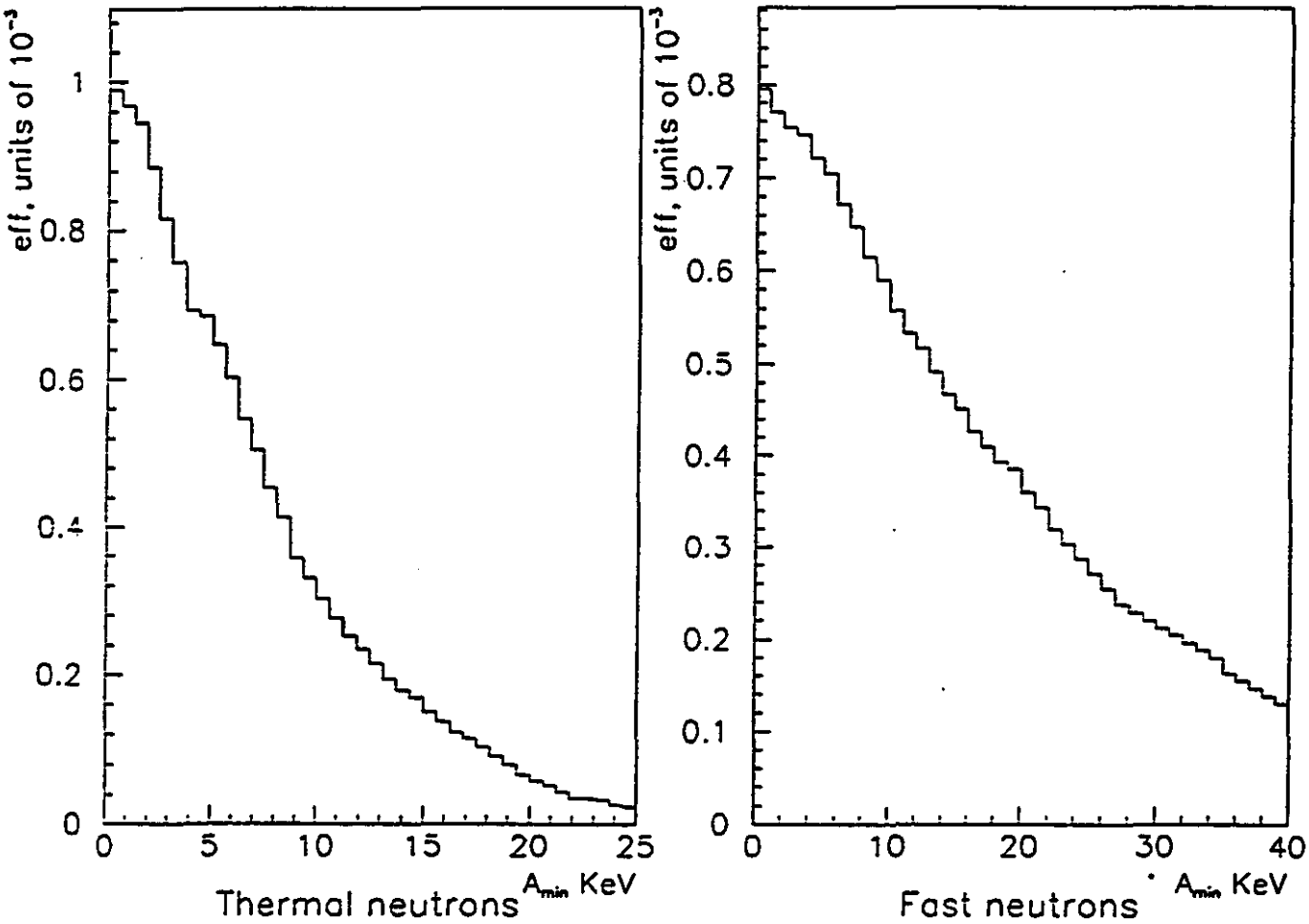
The Average neutron/gamma path length in gas gap is assummed to be in twice the gas gap.

In a given superlayer, the probability to have at least 3 uncompromise muon measurements out of 6 layers is a function of the chamber occupancy.



detection efficiency vs collected charge for outer SL

Fig 4.22.4



A MIP is a few keV.

Expected Occupancies in the barrel region

Conditions/parameters:

- 10^4 n/cm²-s uniform in η/ϕ 50% thermal, 50% fast
- 2×10^3 γ/cm²-s " " "
- Δt_{INT} = 300 nsec

Largest CSC chamber in outer barrel Superlayer
3.5m long strip pitch/gap = 10mm

Table 4

Rates in a single barrel CSC layer due to thermal/fast neutrons and gammas (in units of Hz/cm^2) and occupancies per one strip of barrel muon chambers for integration time equal 0.3 nsec. Neutron rate of 10^4Hz/cm^2 uniform was used and gamma rate of 2*10^3Hz/cm^2. Equal fraction of thermal and fast neutrons used.

Superlayer	CSC rates caused by:				Occupancy per one strip	7-strip Occup
	thermal neut	fast neut	gammas	total		
Inner	4	2	16	22	0.11%	0.77%
Middle	4	3	20	28	0.18%	1.3%
Outer	5	4	24	33	0.35%	2.5%

<3%, but not by much!

Muon- induced electromagnetic showers

Muons passing through mat'l produce showers δ-rays, γ, e^+e^-, hadrons

3 sources of material

- Calorimeter (final layers important)
- Muon system frames and structures
- Muon chamber mat'ls (G10, Gas, ...)

These mat'ls are in SIGEM

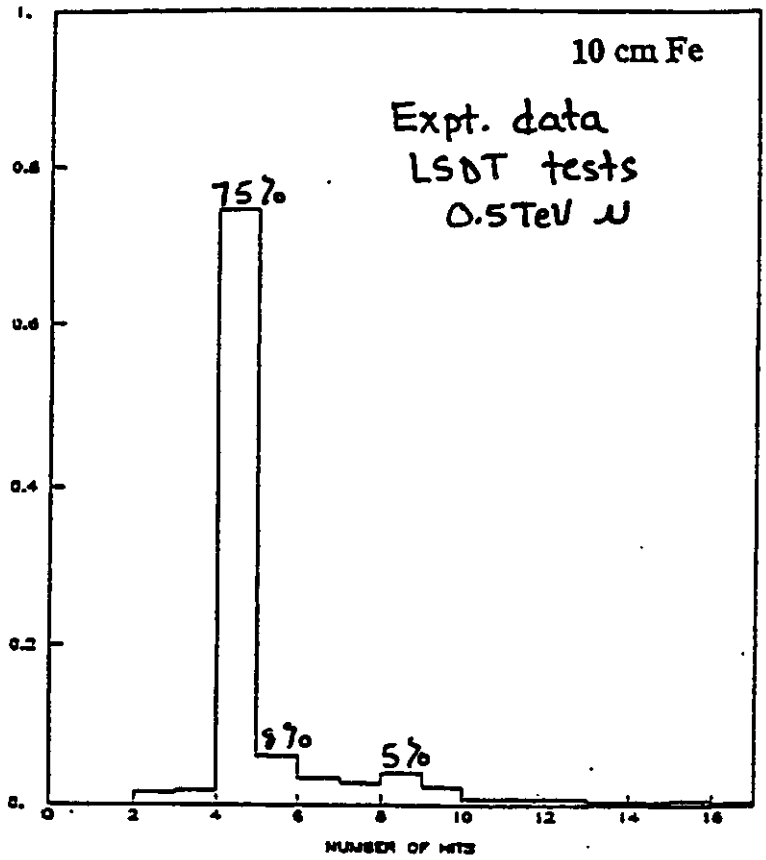
GEANT Simulation verified by experimental data

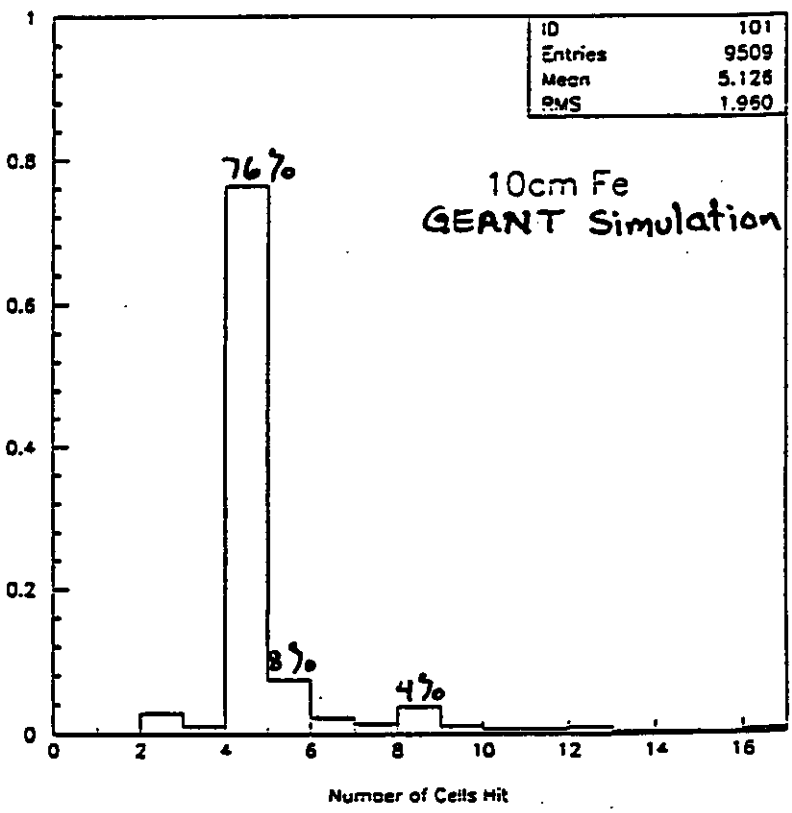
In barrel region, B field sweeps out charged em particles

Leave air gap to reduce em background

Baseline 2 Calorimeter ends R = 370 cm
Baseline 2 Muon system minimum R = 390 cm
~75% of em particles do not reach layer 1

FINAL Test Board - LCDT Test
UNIFORM X-DISTRIBUTION
ANODE WIRE
Y
X

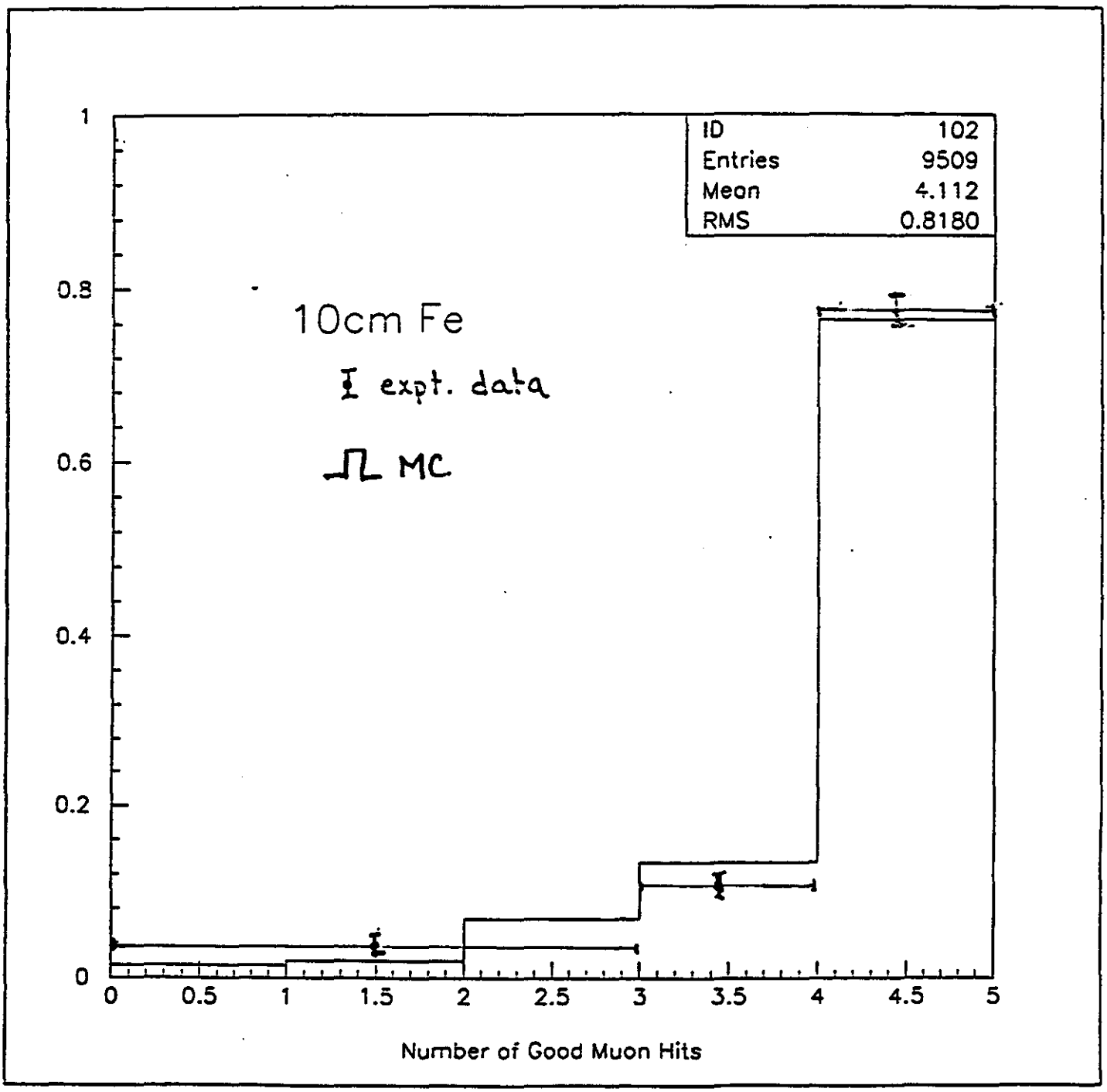

10 cm Fe
Expt. data
LSDT tests
0.5TeV ν
75%
8%
5%
NUMBER OF HITS


ID 101
Entries 9509
Mean 5.126
RMS 1.960
76%
10cm Fe
GEANT Simulation
8%
4%
Number of Cells Hit

Selection of single track events with all 4-cells hit. LSDT FNAL Test beam data vs GEANT Simulation

"Good" hit defn - data: hit within $\pm 4\sigma_{rec}$ of fit (80 μM)

MC : Muon closer to wire by >320 μM

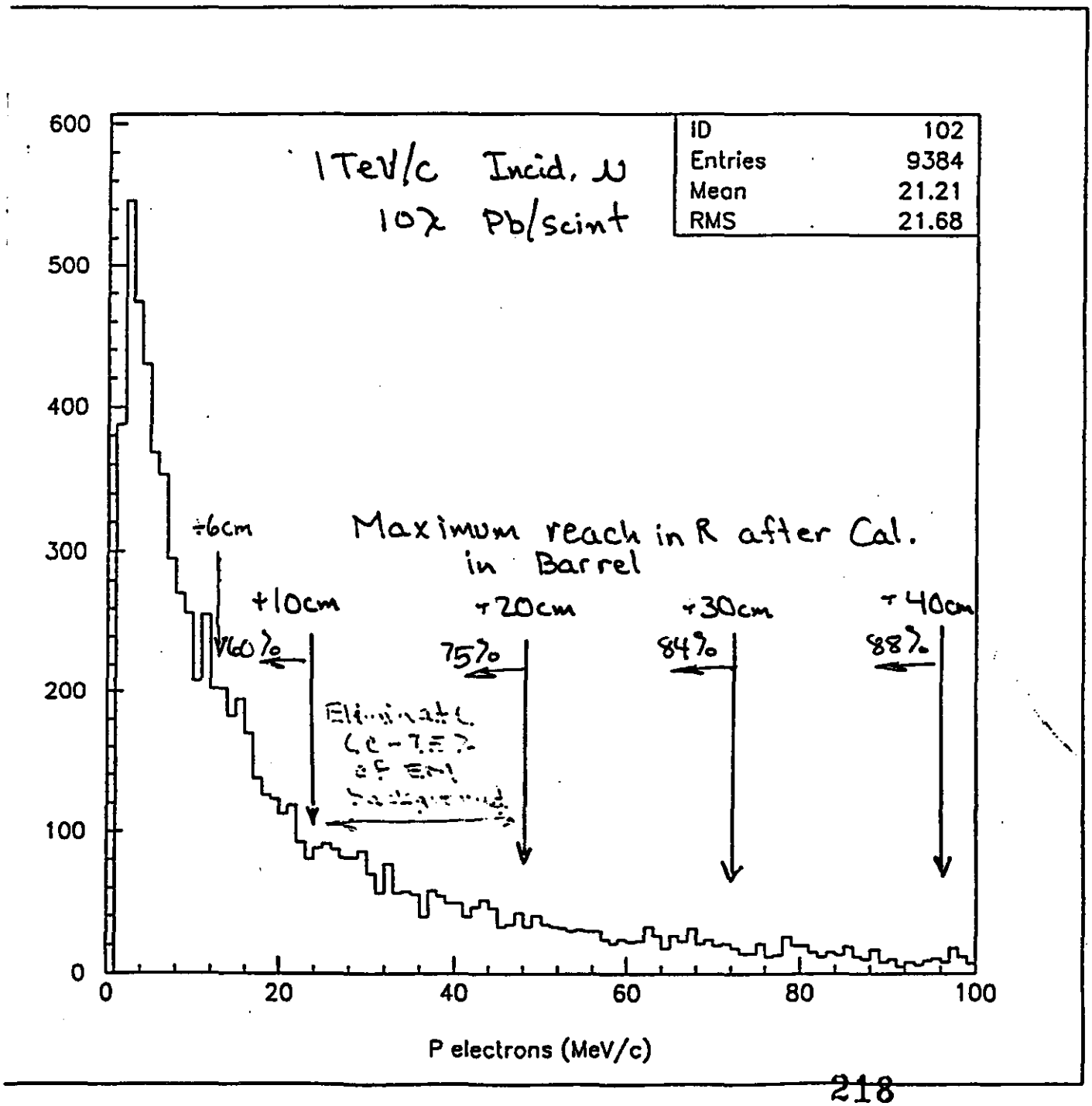


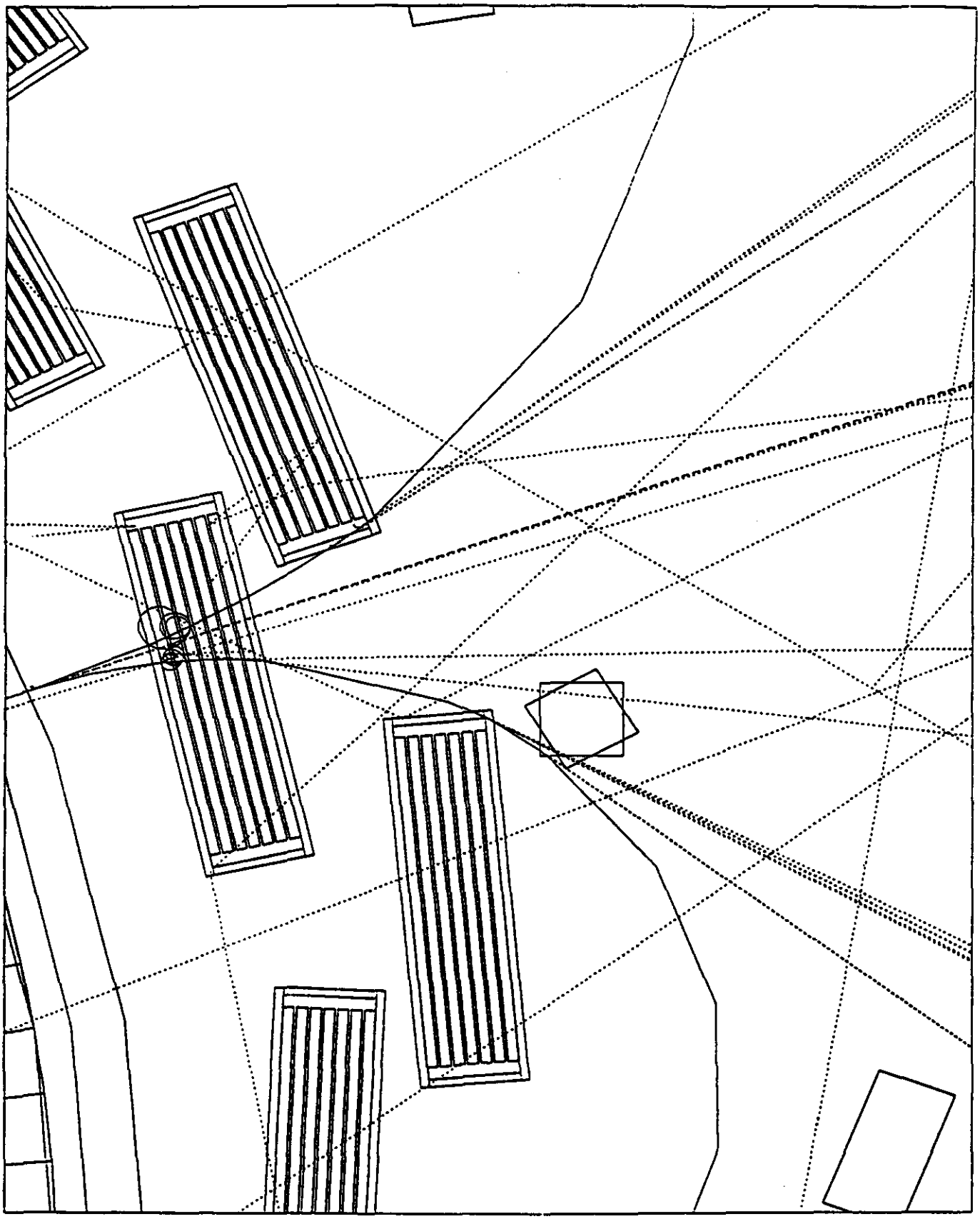
How Close can 1ST μ Layer be to Calorimeter?

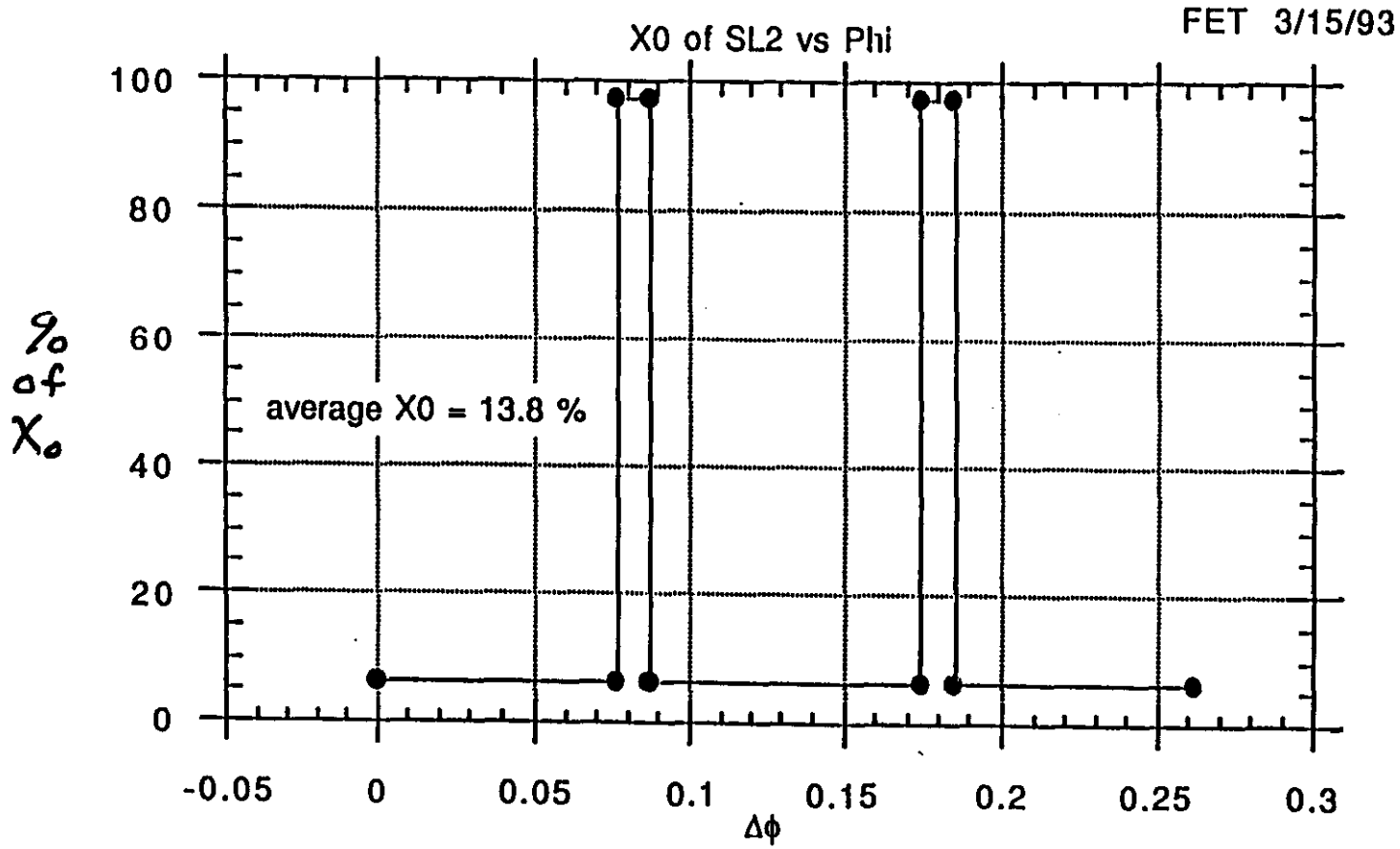
$$R = \frac{P_T}{0.3\,9\,B}$$

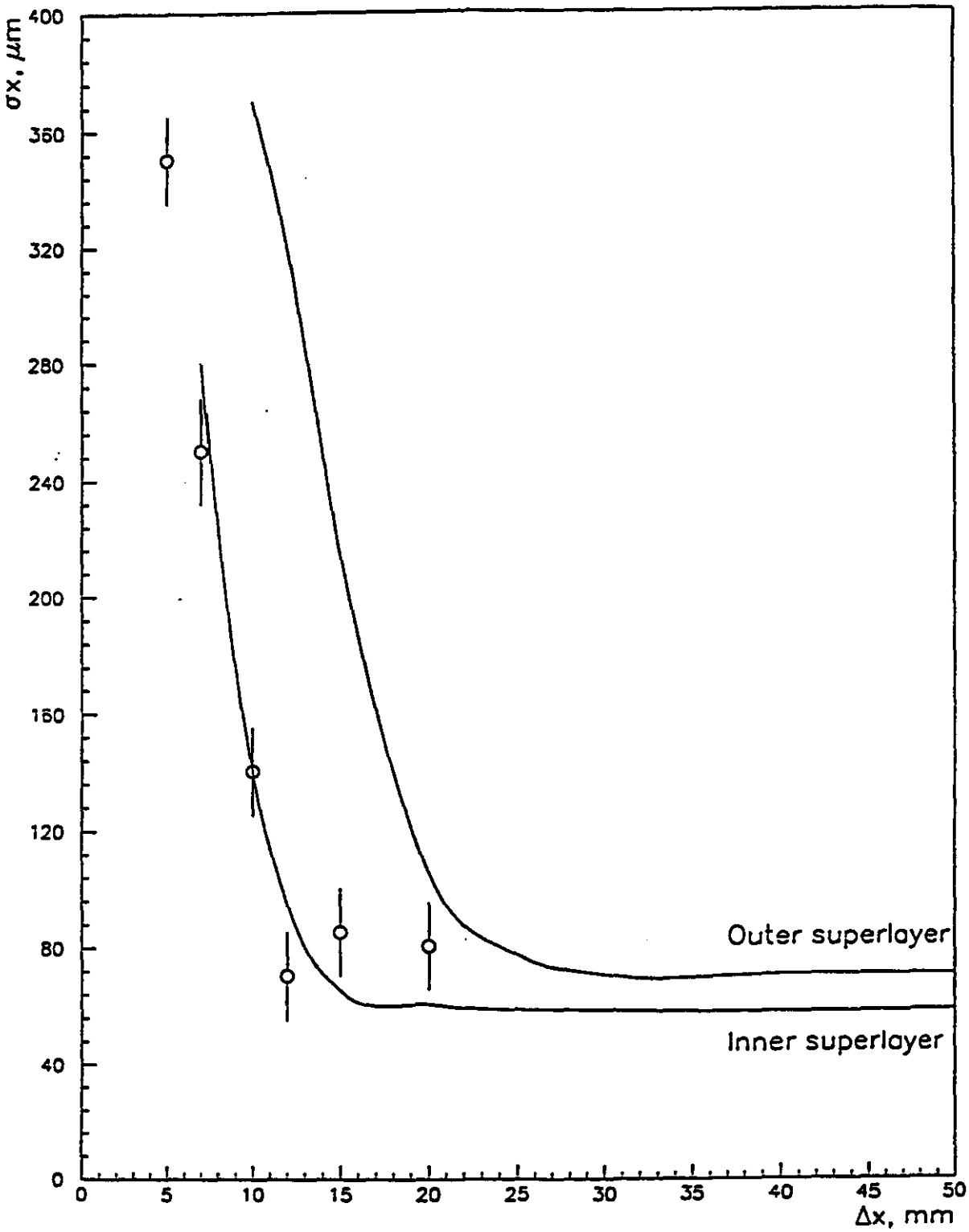
Put air gap to curl up low momentum particles

Low momentum particles exiting with muon
Avg 2-3 electrons per 1TeV/c μ






X0 of SL2 vs Phi
FET 3/15/93
average X0 = 13.8 %
% of X_0
100
80
60
40
20
0
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
Δφ


σx, μm
400
360
320
280
240
200
160
120
80
40
0
0
5
10
15
20
25
30
35
40
45
50
Δx, mm
Outer superlayer
Inner superlayer

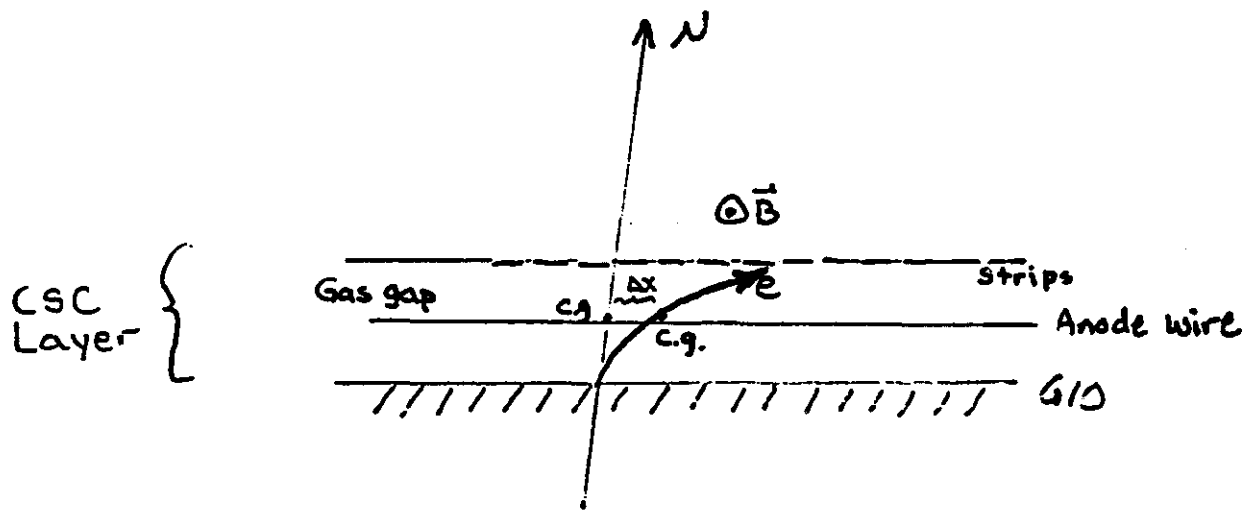
4.4.4.1

Precise position measurement requires fit to charge on strips

min 2-track separation for "good" position measurement

1.5 cm in SL1
2.4 cm in SL2
3.0 cm in SL3

Define Δx_{cN} from c.g. of tracks through gas gap



ΔX distribution in various superlayers for 1TeV/c P_T μ

EM debri, P_t=1000GeV 1000μ per barrel, endcap

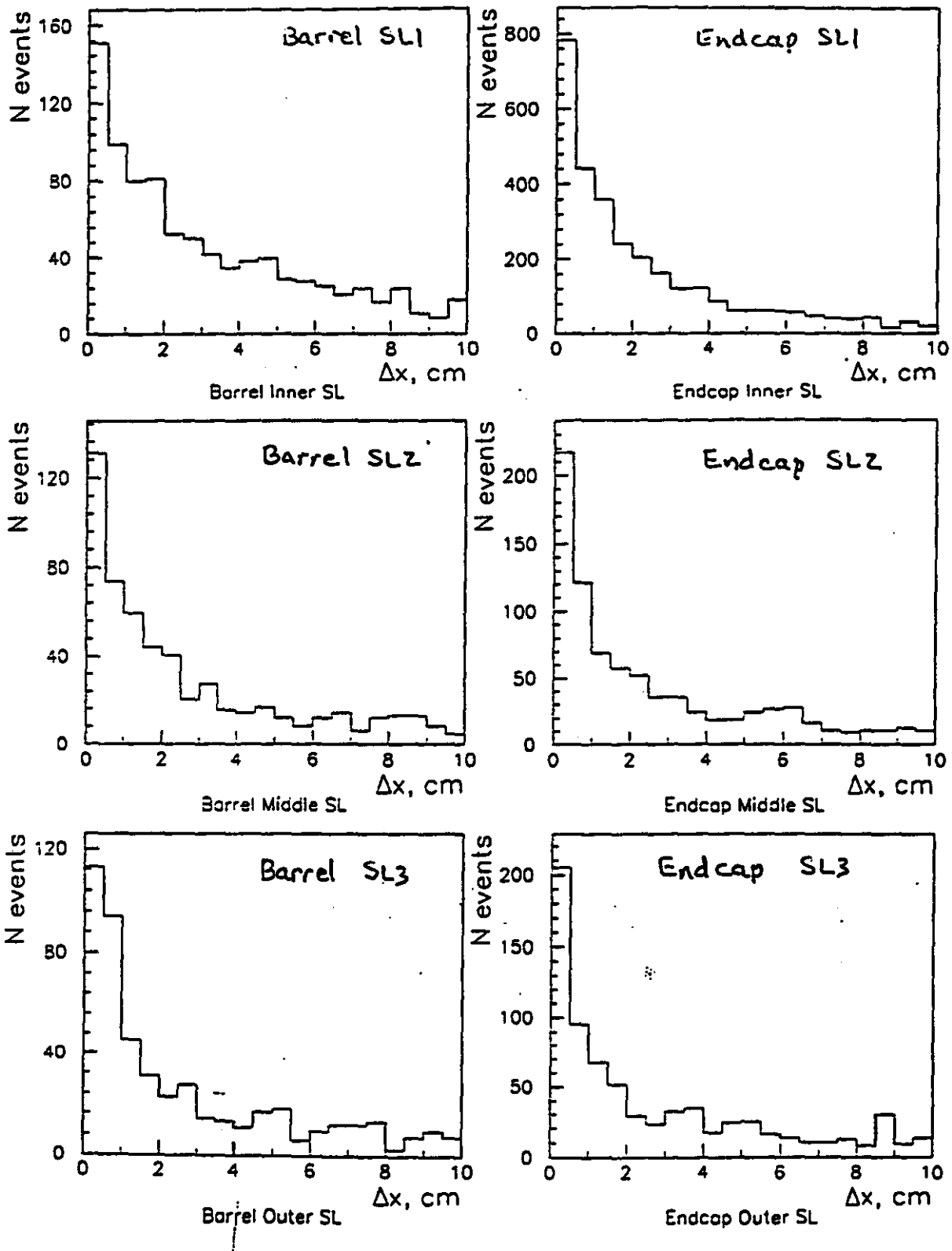


Fig 4.4.2.5

4

4. Pattern Recognition

Define track reconstruction efficiency:

Probability to have ≥ 3 "good" layers hit in each of the 3 superlayers

defined by 2-track separation

≥ 3 good layers one unambiguous track segment in each SL
suppress fake tracks, fitting errors

Extra handles we can use to recover some of ineff.

- Using charge information we can reject independently compromise layers
- Using info from 2 good SL can project into other bad SL and recover good hits
- Momentum resolution w/ vertex constraint and SL2,3 is not so bad at high P_T

Consider two backgrounds:

- correlated em particles
- uncorrelated n/γ background

Track reconstruction eff vs η for different P_T
All 3 SL required

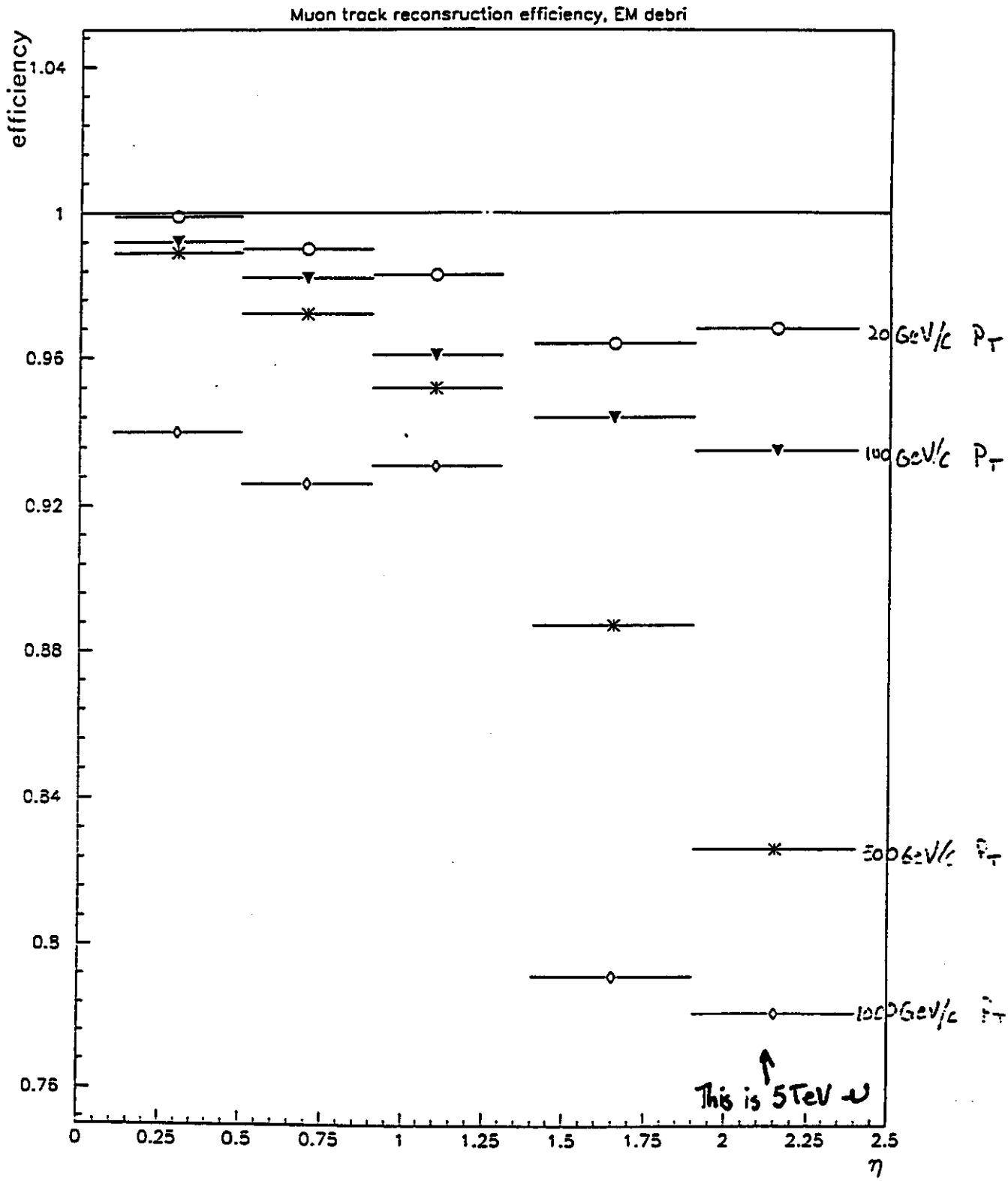
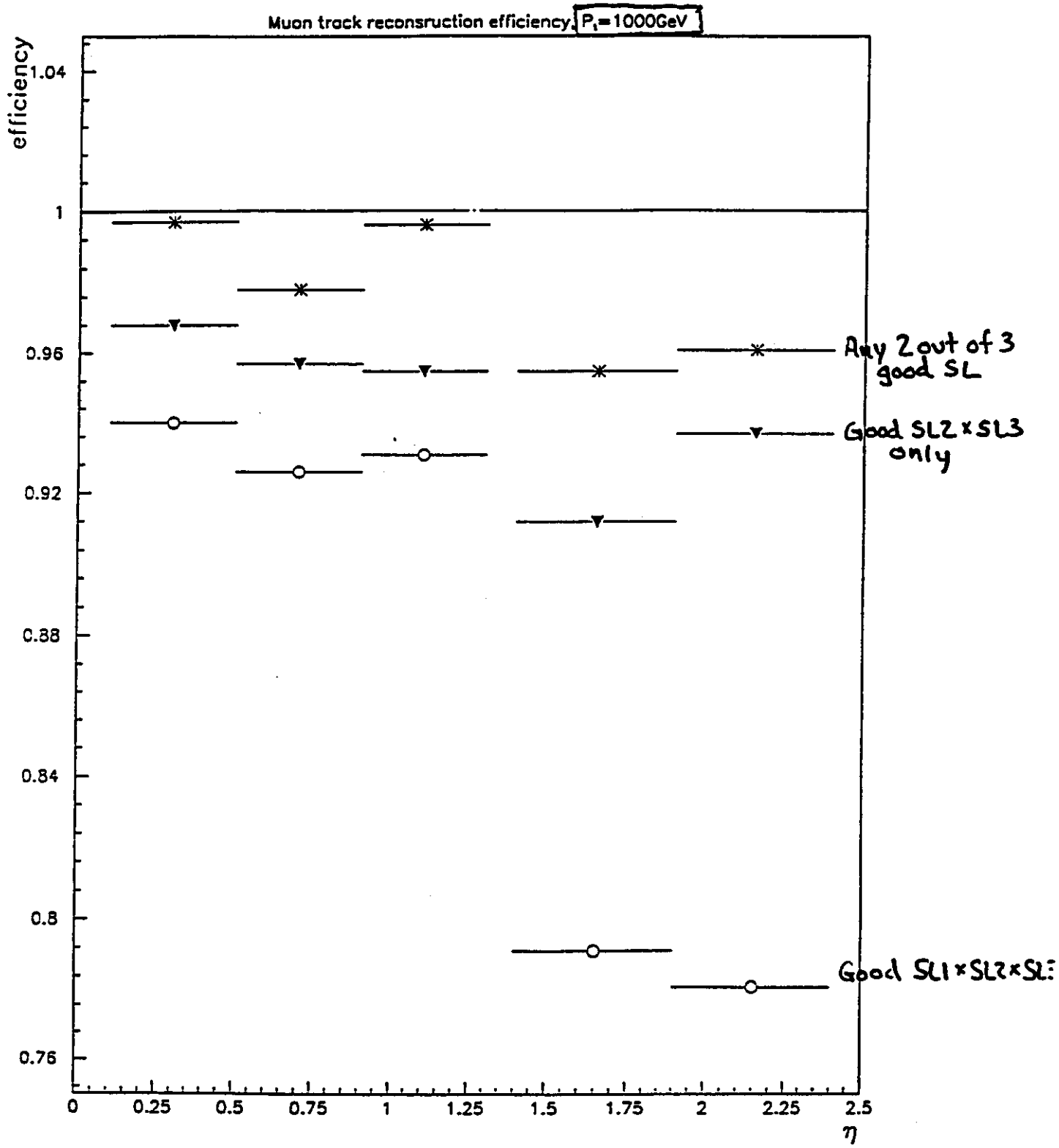


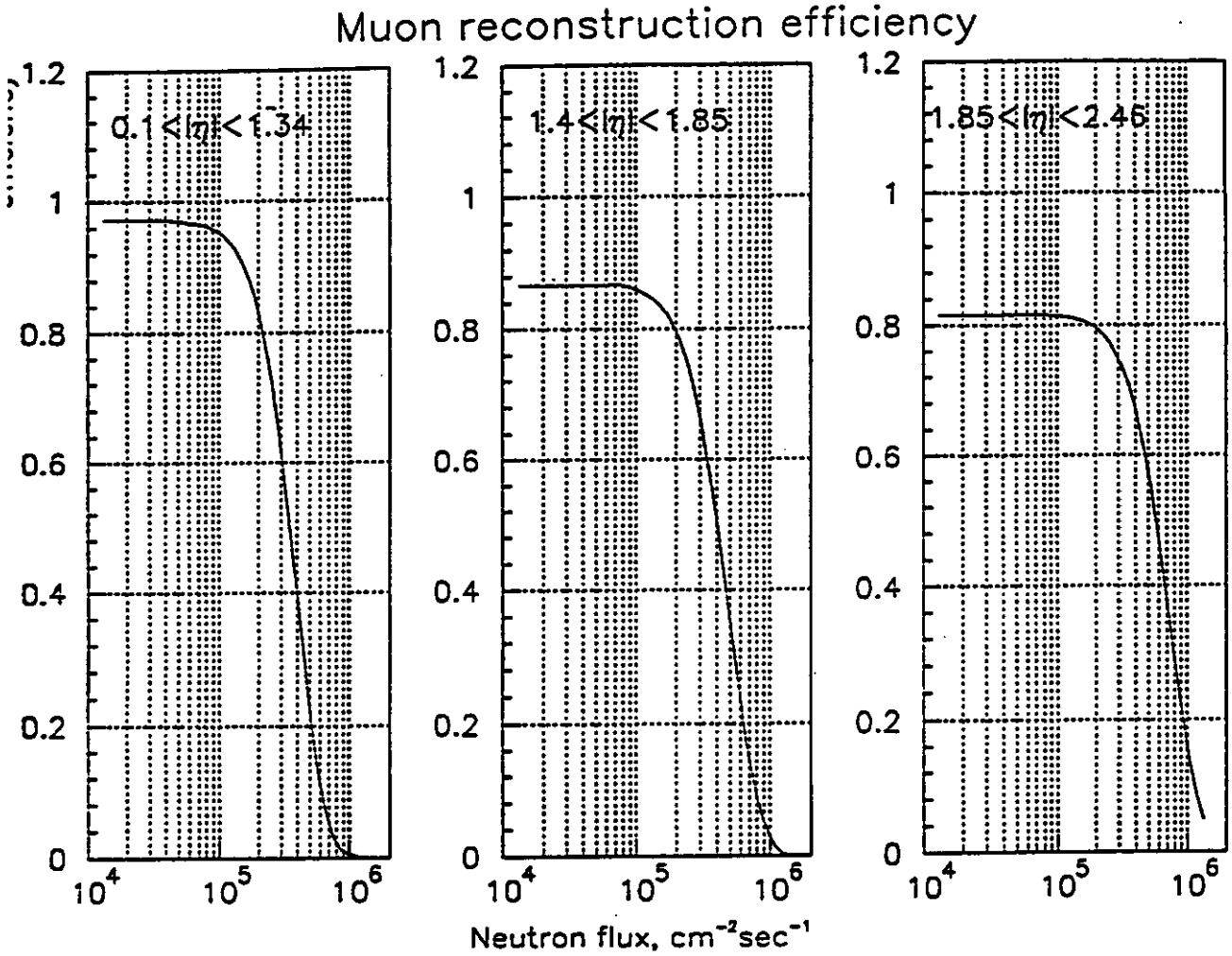
Figure 44.4 3 a)

Track reconstruction eff for all 3 SL good, and for 2 SL good



as a function of n/γ fluence

Δt_{INT} = 200 nsec γ fluence 20% of n fluence
Thermal n fraction 50%



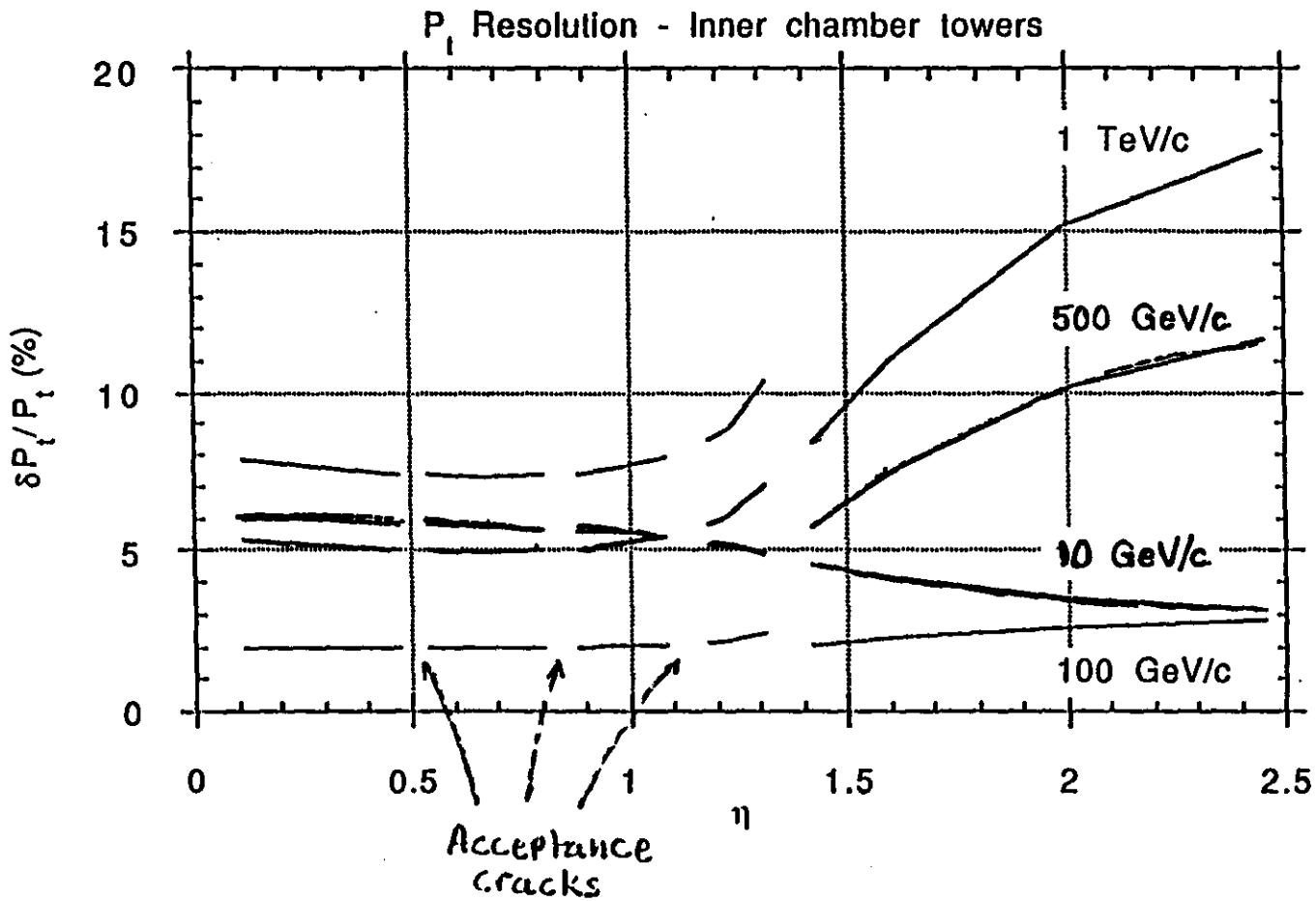
GEM Muon System can perform pattern recognition at 10^5 n/cm²s

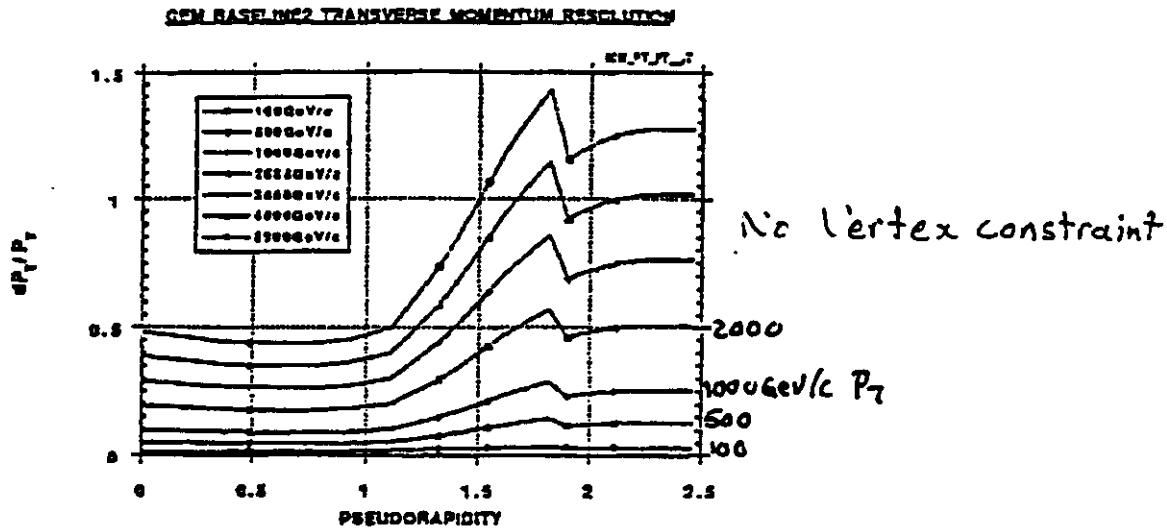
5. Muon Momentum resolution - including calorimeter effects (energy loss)

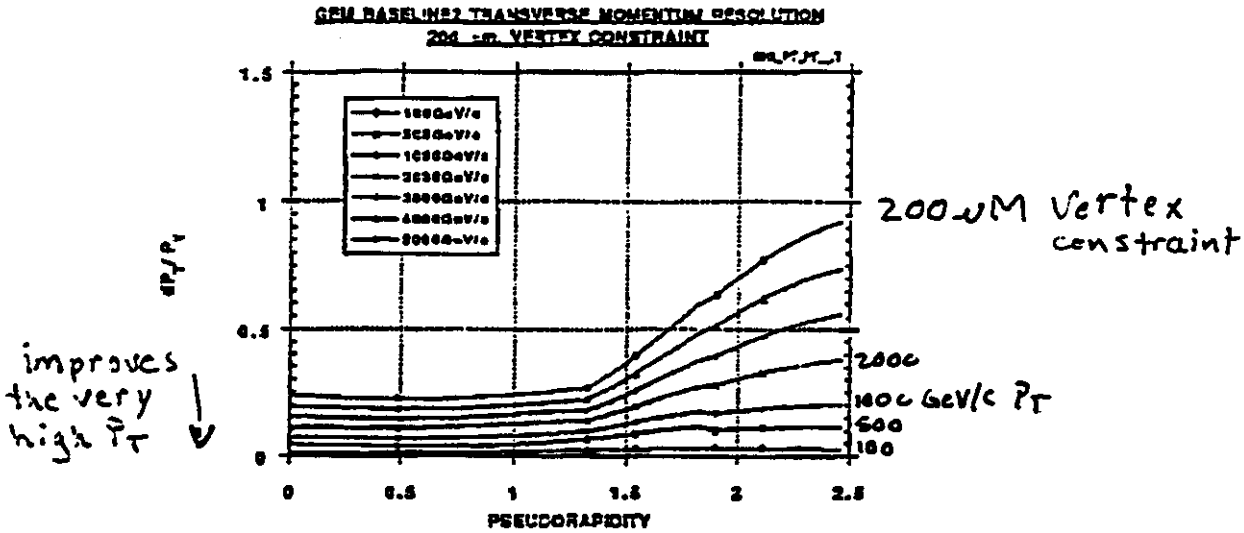
Baseline 2 GEM Muon System

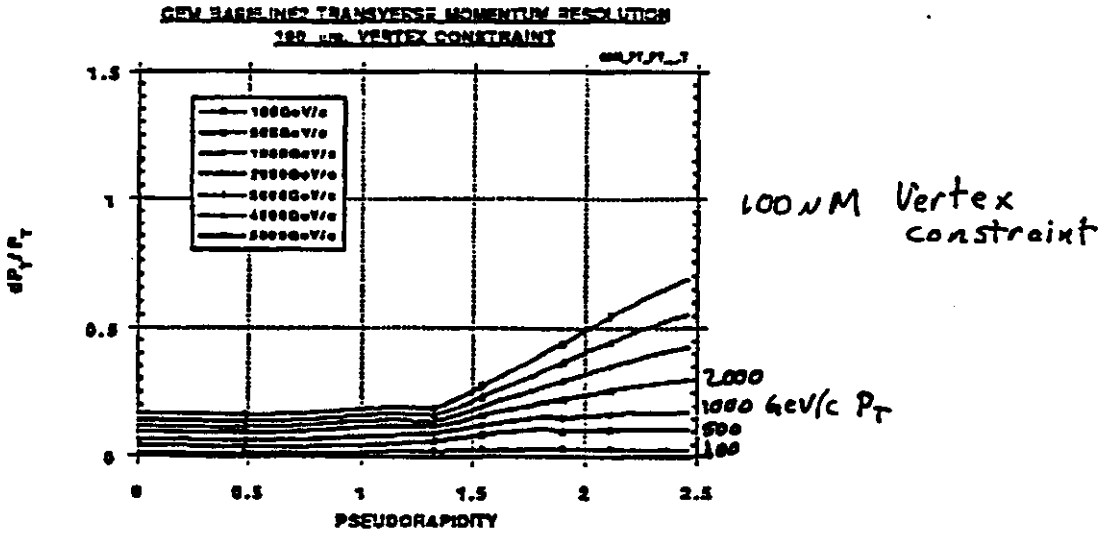
standalone muon system performance - no vertex constraint, no inner tracking

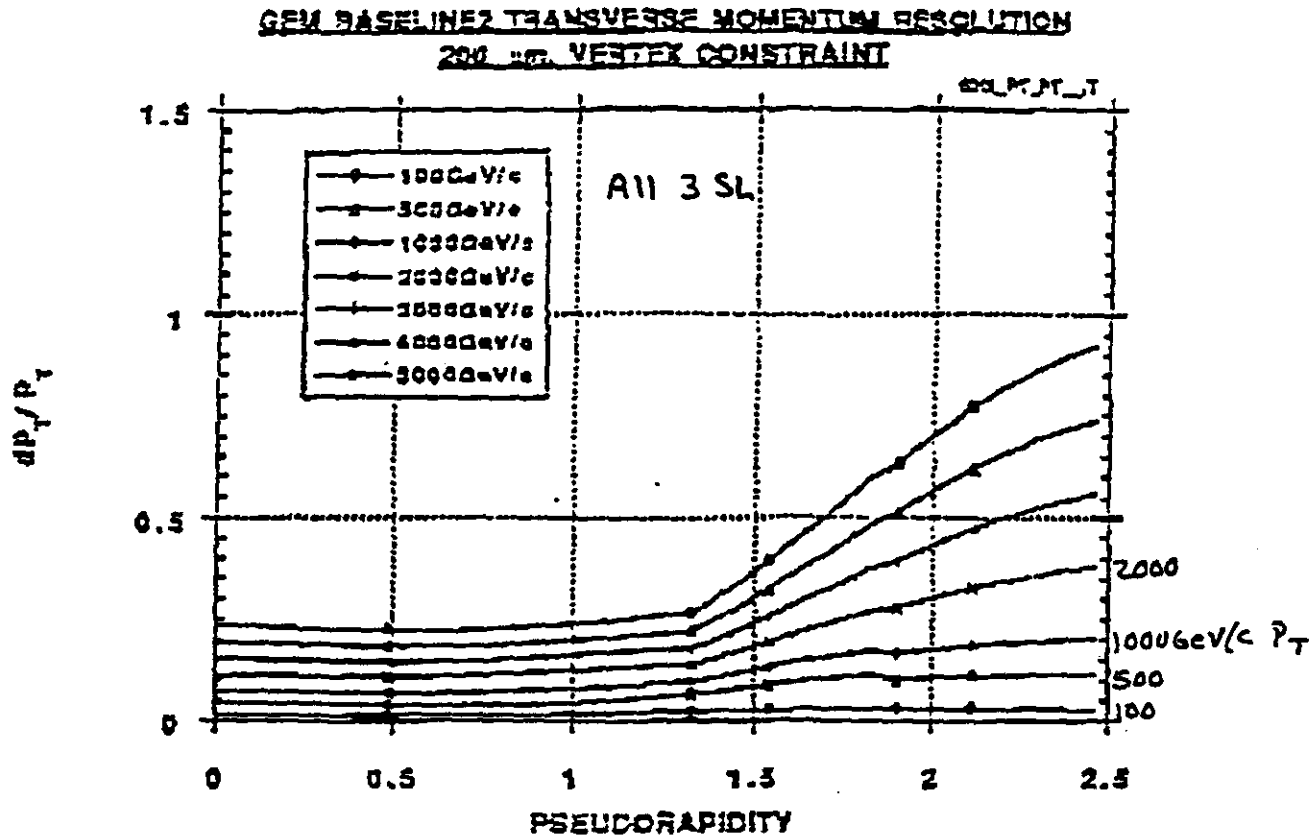
FET 3/15/93

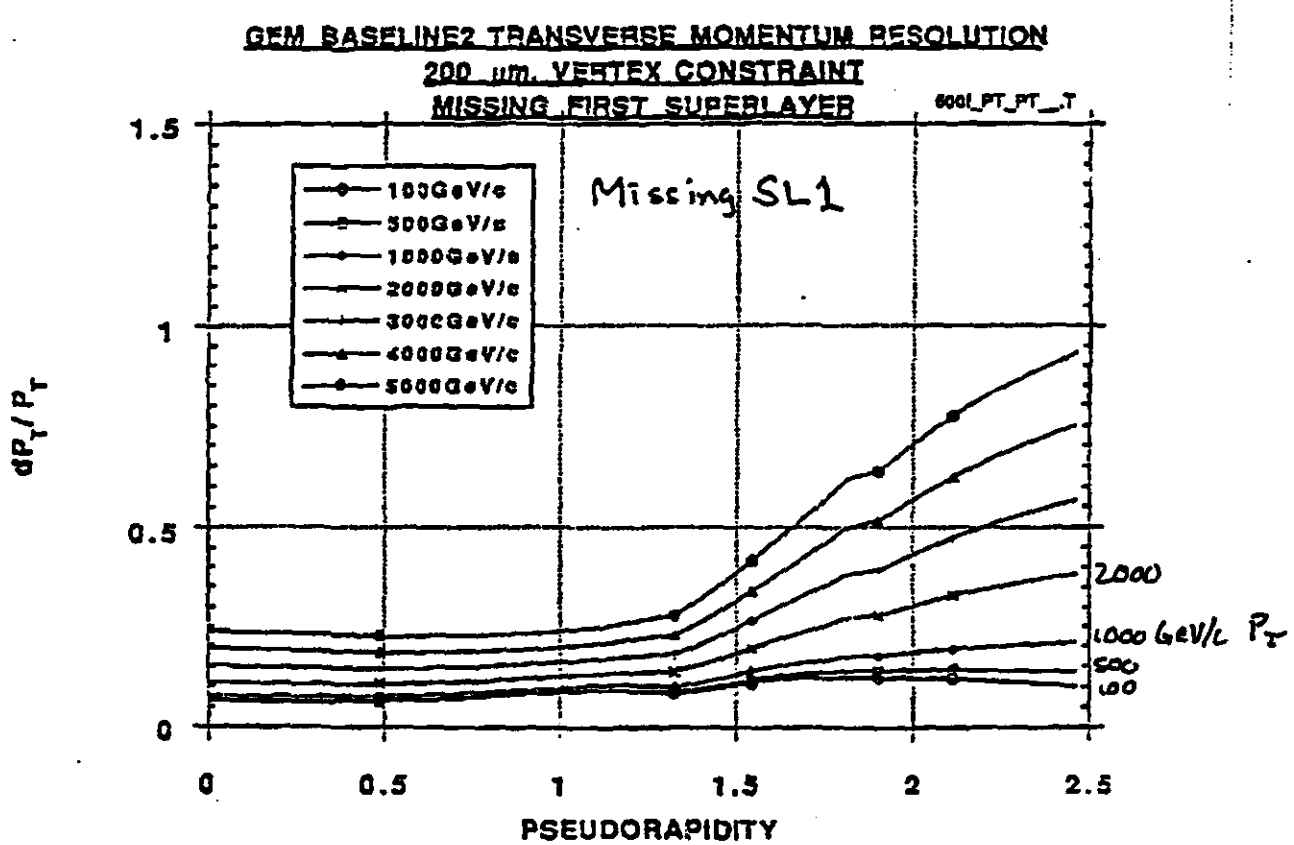



GEM BASELINE2 TRANSVERSE MOMENTUM RESOLUTION
dP_T/P_T
PSEUDORAPIDITY
No Vertex constraint
2000
1000 GeV/c P_T
500
100


GEM BASELINE2 TRANSVERSE MOMENTUM RESOLUTION
200 μm VERTEX CONSTRAINT
dP_T/P_T
PSEUDORAPIDITY
200 μM Vertex constraint
improves the very high P_T
2000
1000 GeV/c P_T
500
100


GEM BASELINE2 TRANSVERSE MOMENTUM RESOLUTION
100 μm VERTEX CONSTRAINT
dP_T/P_T
PSEUDORAPIDITY
100 μM Vertex constraint
2000
1000 GeV/c P_T
500
100





Lose substantial resolution at low P_T, not at high P_T

5. Performance of Muon System on Physics Benchmarks

Higgs $\rightarrow$ 4μ

Studied using SIGEM

- included acceptance cracks including $\eta > 2.46$
- included em background to μ

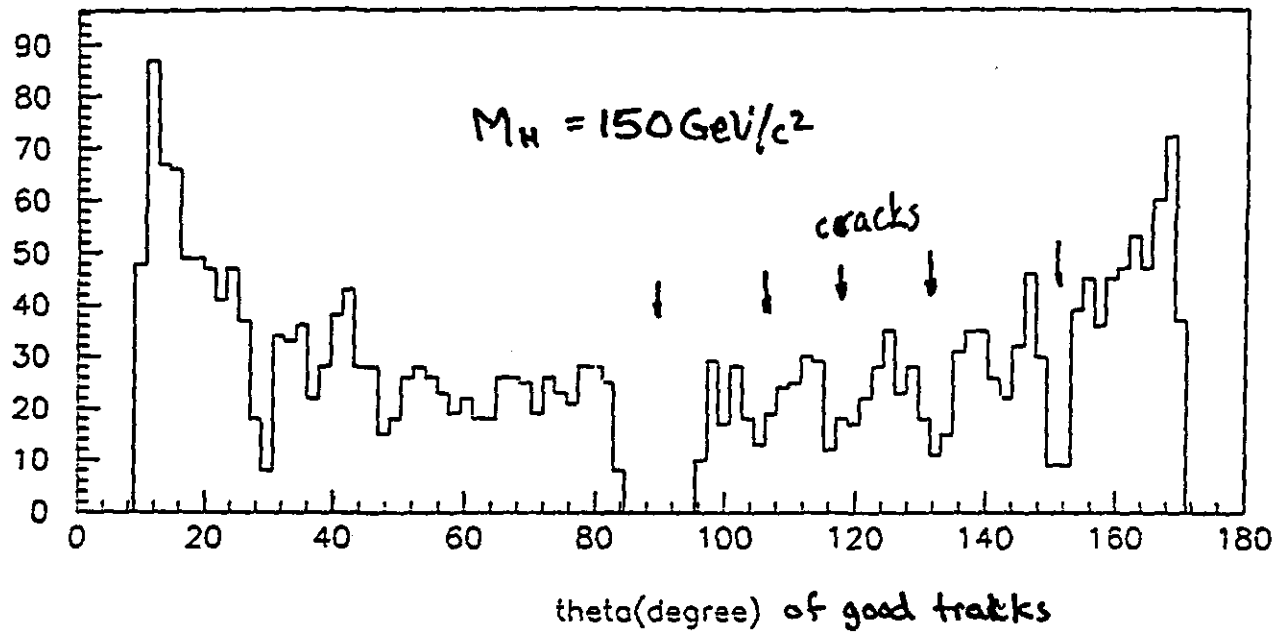
M_H = 150 GeV/c^2 and 400 GeV/c^2 simulated

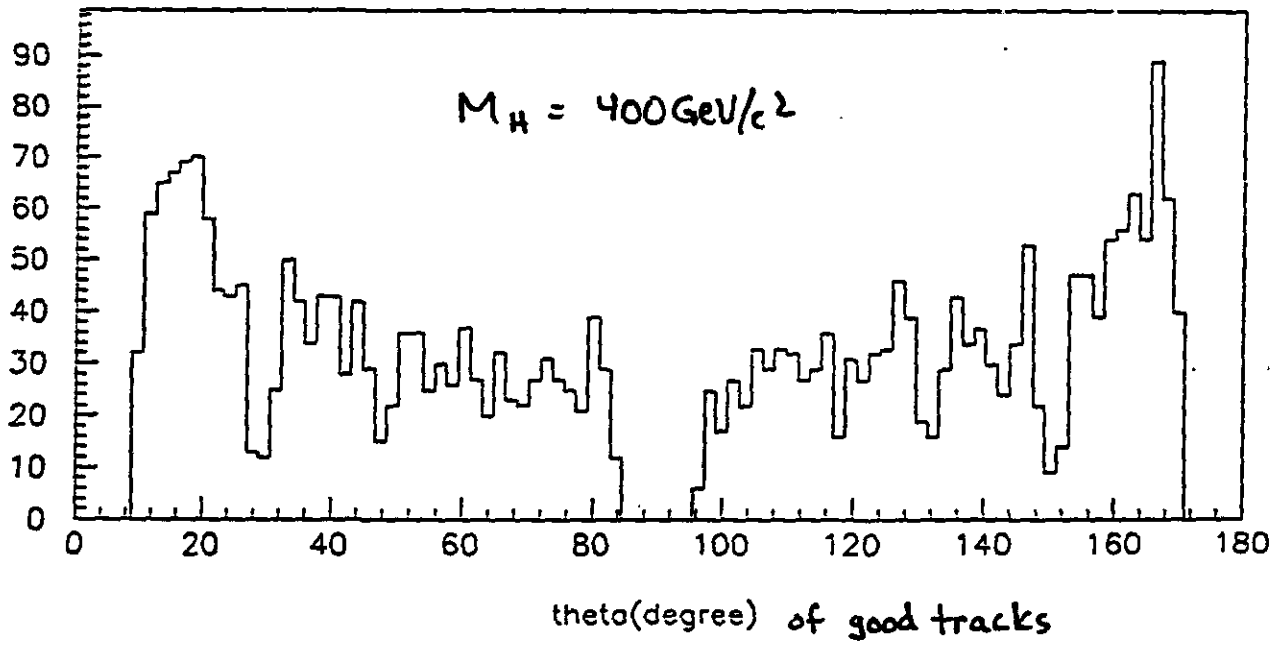
* All 3 SL, min 3 good layer in each SL

# of Good* μ tracks	M_H=150 GeV/c^2	M_H = 400 GeV/c^2	
0	8 %	2.1 %	
1	12.2 %	6.4 %	
2	21.1 %	19.5 %	Some recoverable
3	34.5 %	40.6 %	
4	24.1 %	31.2 %	Perfect

To be redone with $|\eta| < 2.46$ requirement imposed

93/03/16 07.42


M_H = 150 GeV/c²
cracks
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160
180
theta(degree) of good tracks

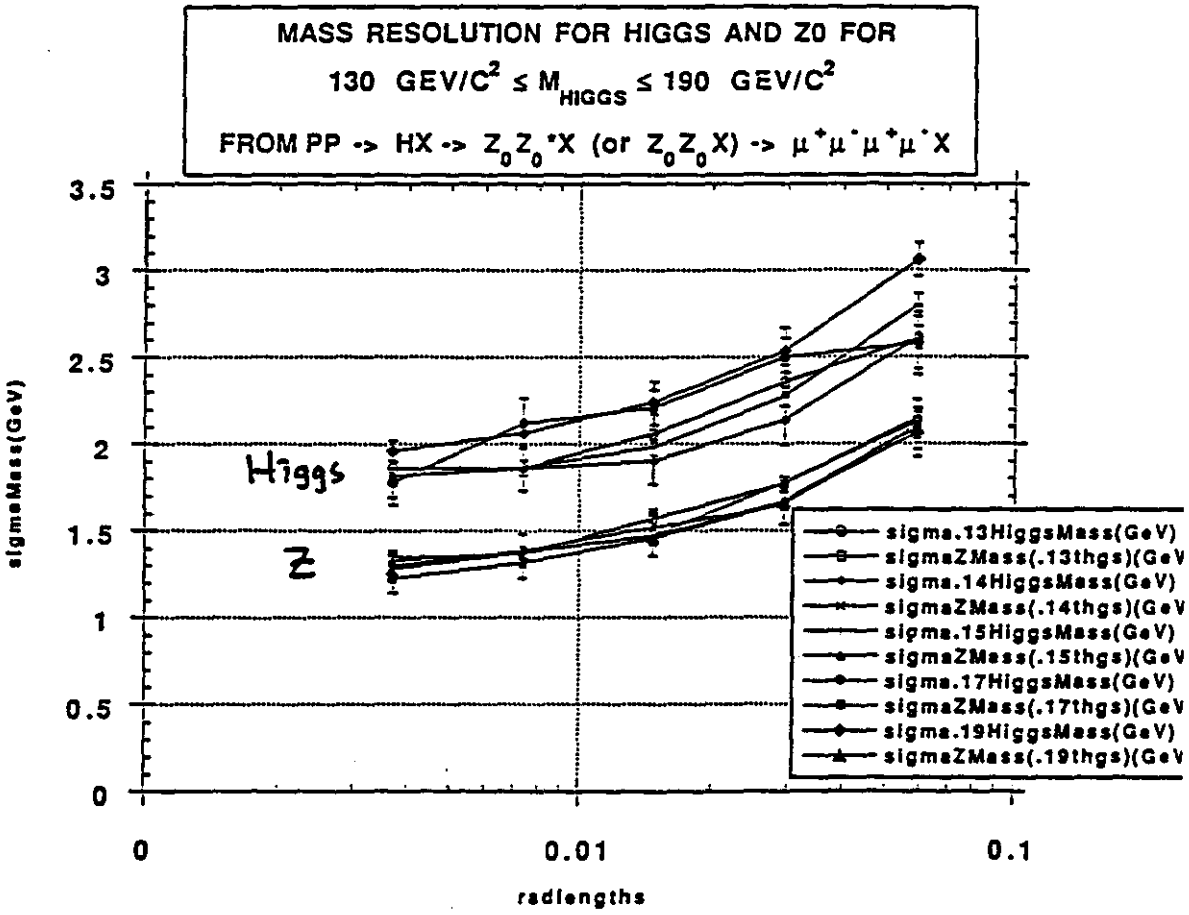

M_H = 400 GeV/c²
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160
180
theta(degree) of good tracks

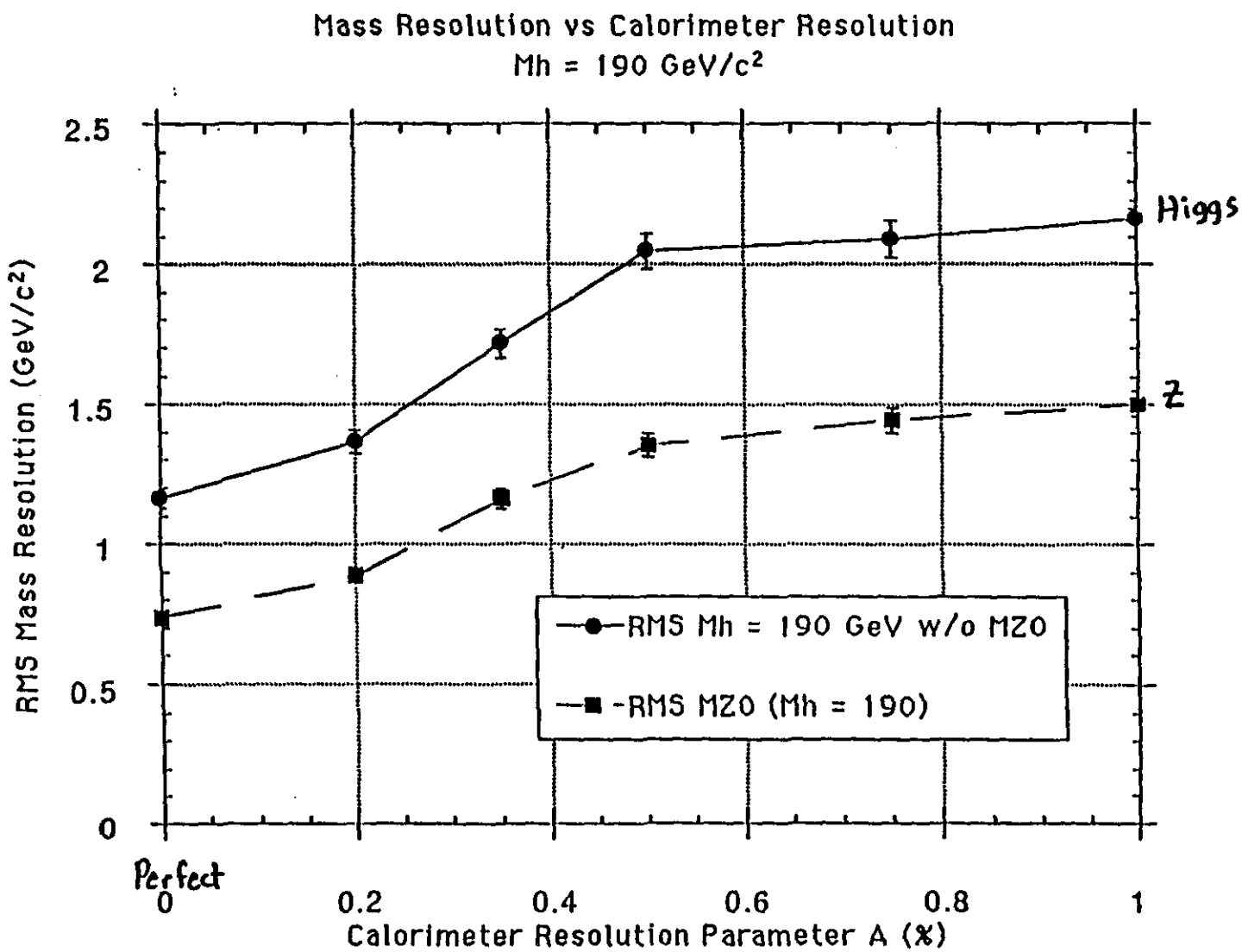
Higgs Mass reconstruction

Includes muon energy loss fluctuations
(Passive Calorimeter)

Is not a fit to SIGEM hits - this is underway

Need to [illegible]




Mass Resolution vs Calorimeter Resolution
Mh = 190 GeV/c²
RMS Mass Resolution (GeV/c²)
2.5
2
1.5
1
0.5
0
Perfect
0
0.2
0.4
0.6
0.8
1
Calorimeter Resolution Parameter A (%)
Higgs
Z
RMS Mh = 190 GeV w/o MZO
RMS MZO (Mh = 190)

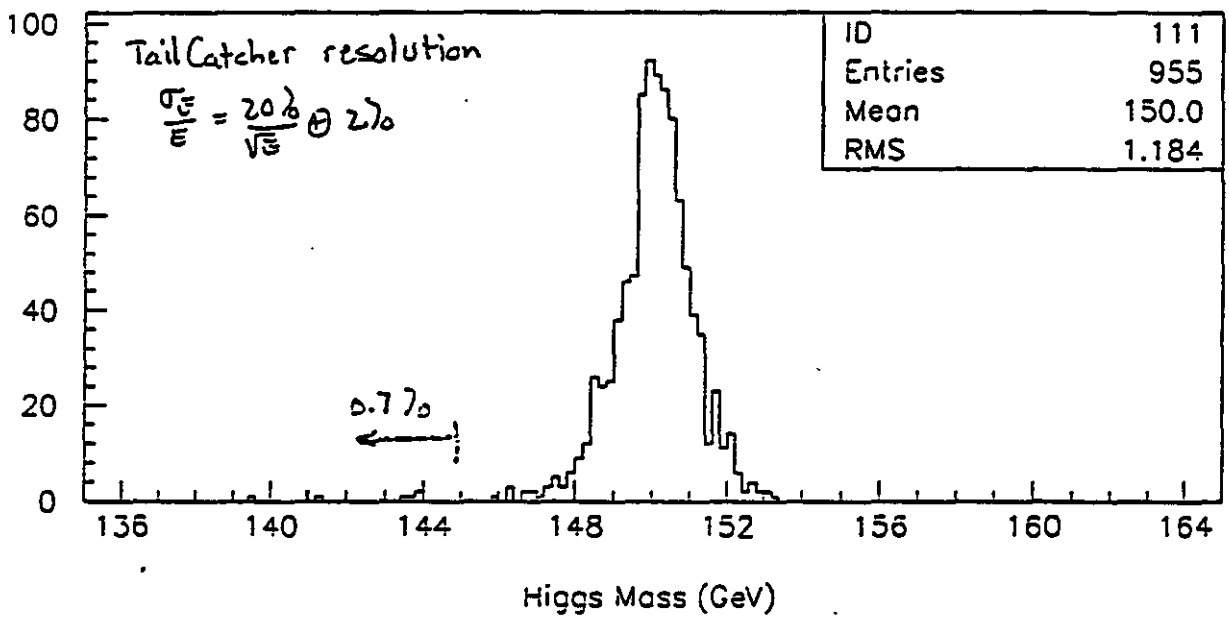
150 GeV/c² Higgs → 4 μ (only Muons simulated)

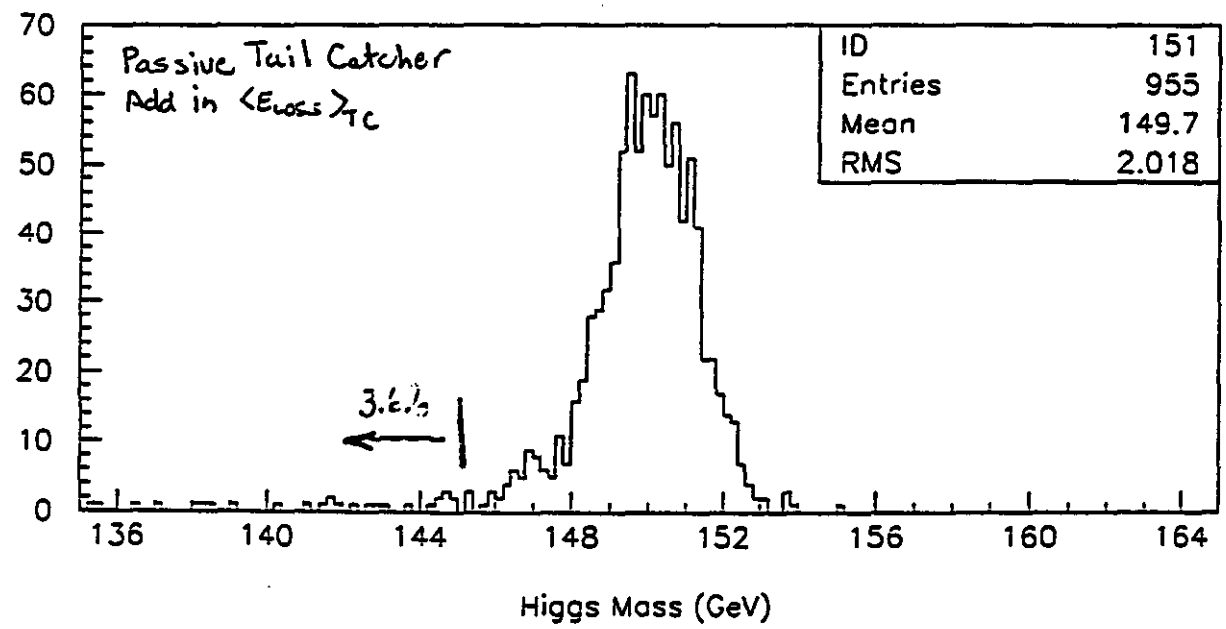
Baseline 2 Calorimeter

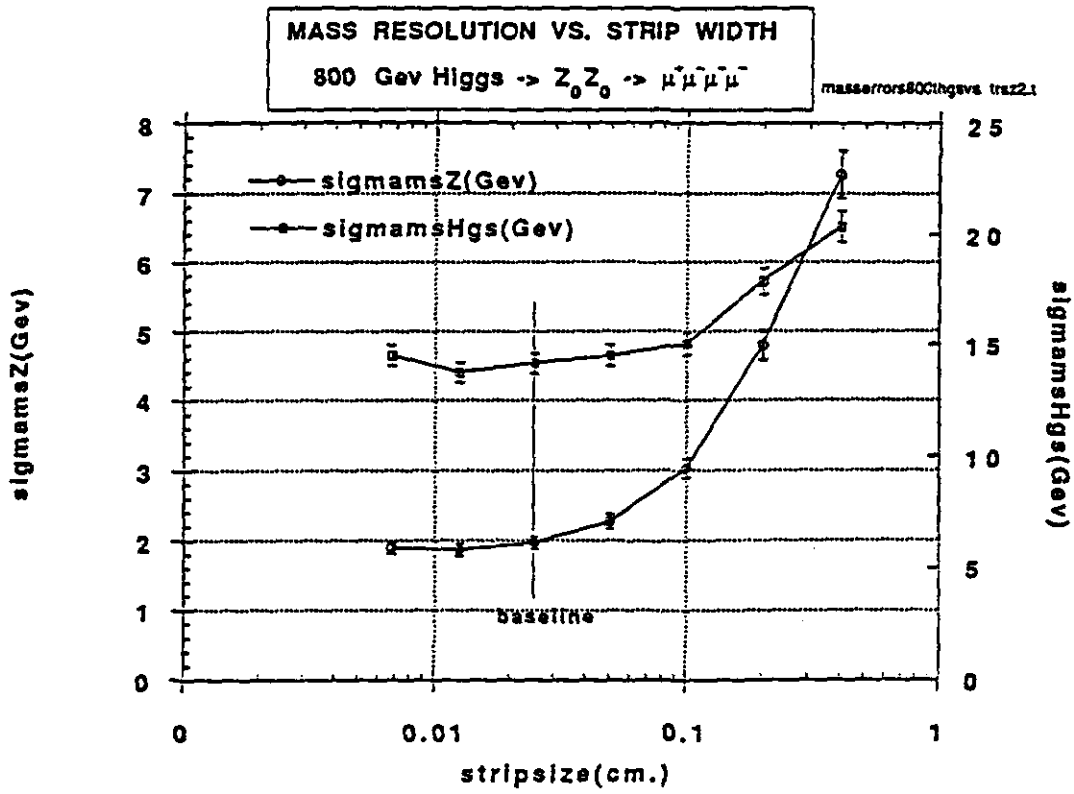
Assume Perfect Momentum reconstruction

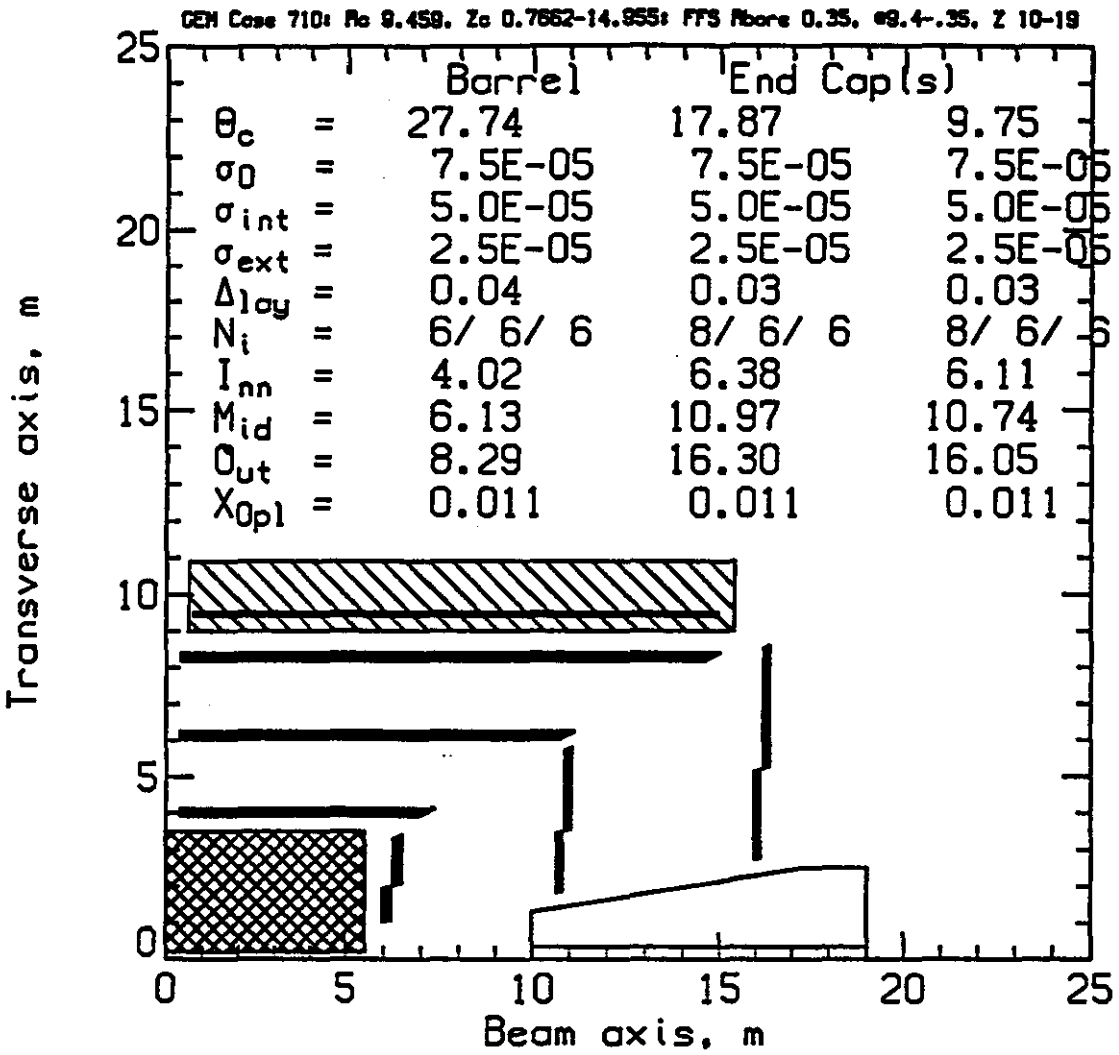
EM resolution $\frac{6\%}{\sqrt{E}} + \frac{.040\,\text{GeV}}{E}$

Liquid HAD resolution $\frac{20\%}{\sqrt{E}} + \frac{.160\,\text{GeV}}{E}$

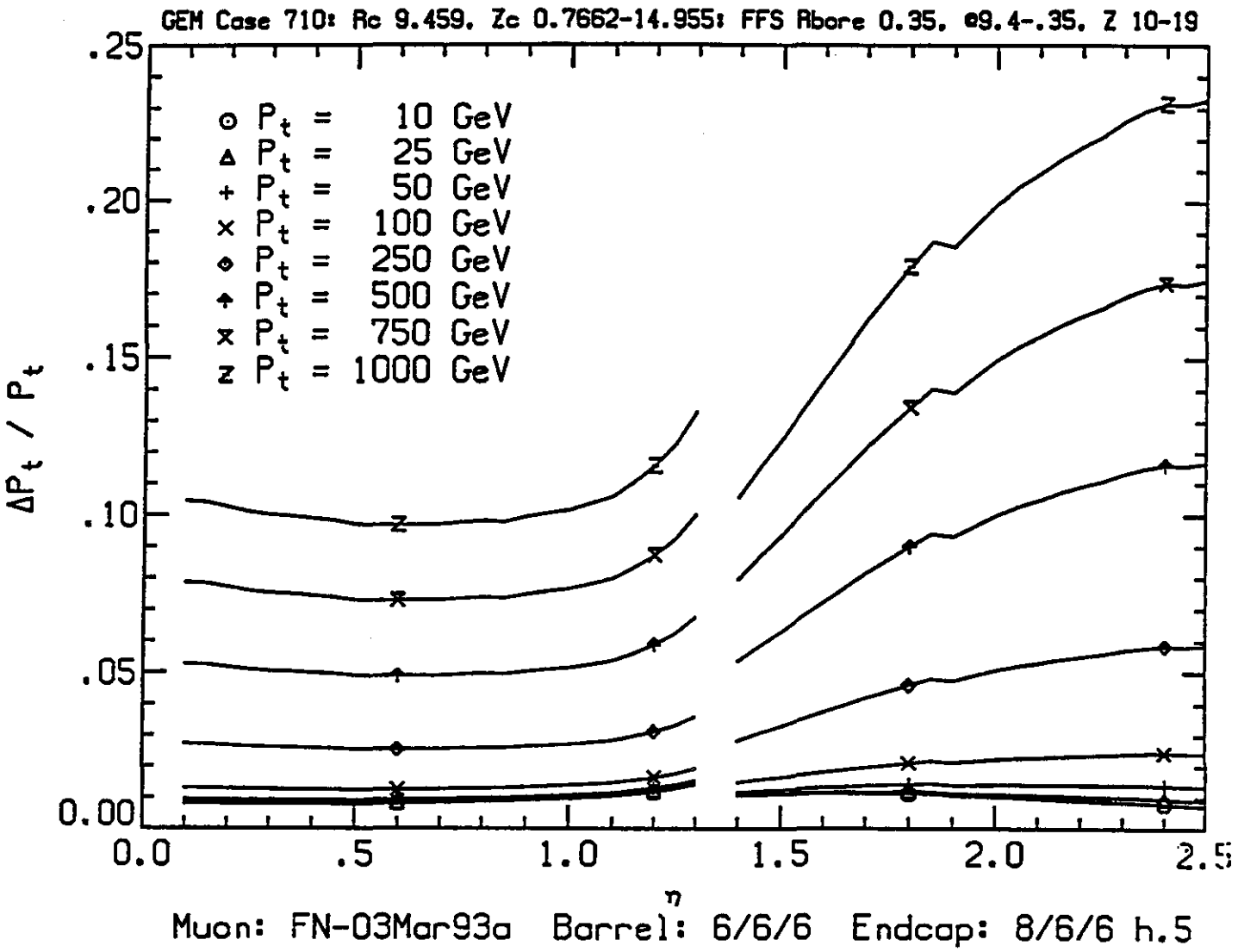


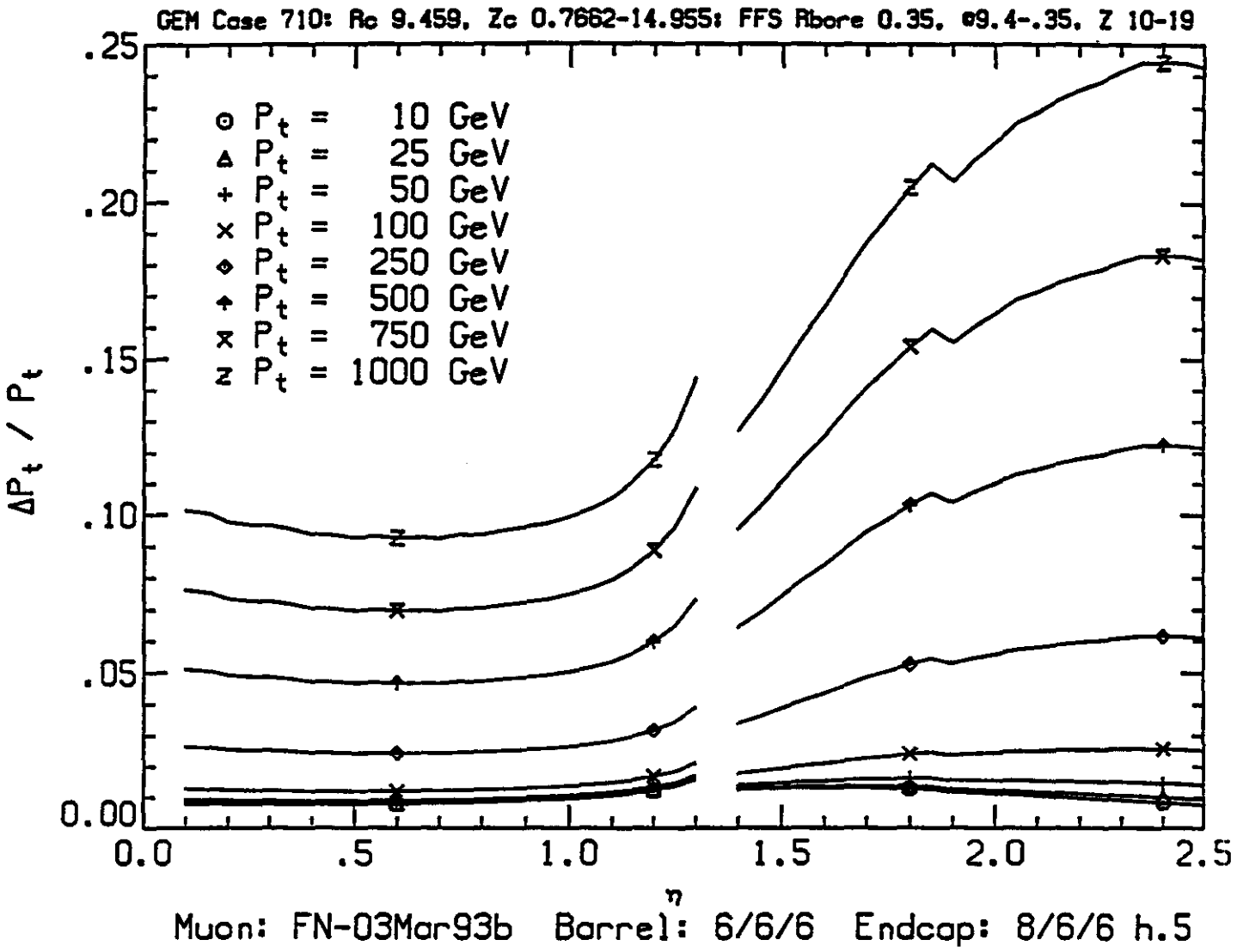


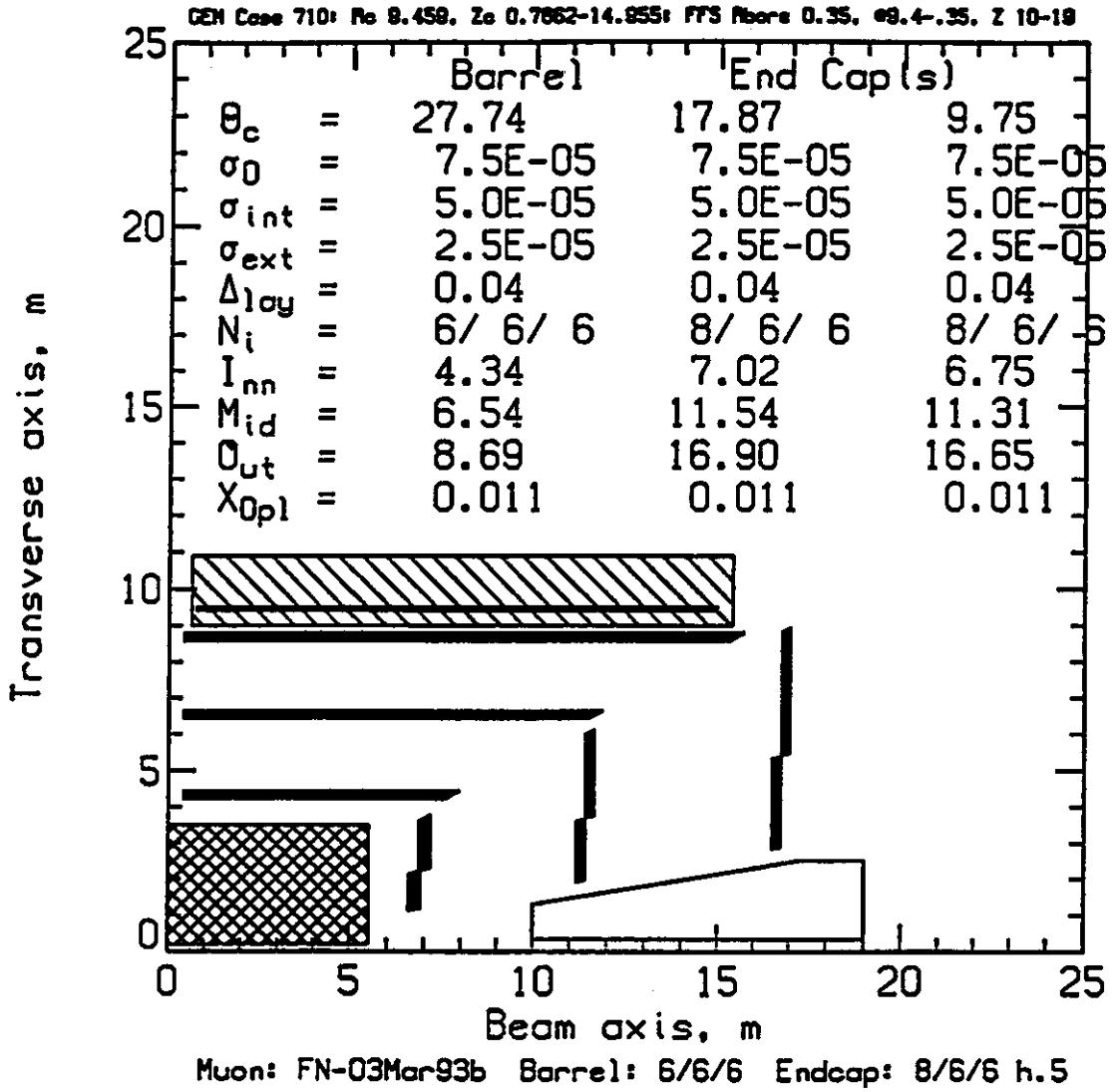

MASS RESOLUTION VS. STRIP WIDTH
800 Gev Higgs -> Z_0Z_0 -> $\mu^+\mu^-\mu^+\mu^-$
sigmamsZ(Gev)
sigmamsHgs(Gev)
baseline
sigmamsZ(Gev)
sigmamsHgs(Gev)
stripsize(cm.)
0
0.01
0.1
1
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25



Muon: FN-03Mar93a Barrel: 6/6/6 Endcap: 8/6/6 h.5


GEM Case 710: Rc 9.459, Zc 0.7662-14.955: FFS Rbore 0.35, ø9.4-.35, Z 10-19
⊙ Pt = 10 GeV
△ Pt = 25 GeV
+ Pt = 50 GeV
× Pt = 100 GeV
◇ Pt = 250 GeV
♠ Pt = 500 GeV
⧖ Pt = 750 GeV
z Pt = 1000 GeV
ΔPt / Pt
.25
.20
.15
.10
.05
0.00
0.0
.5
1.0
1.5
2.0
2.5
η
Muon: FN-03Mar93a Barrel: 6/6/6 Endcap: 8/6/6 h.5


GEM Case 710: Rc 9.459, Zc 0.7662-14.955: FFS Rbore 0.35, ø9.4-.35, Z 10-19
⊙ Pt = 10 GeV
△ Pt = 25 GeV
+ Pt = 50 GeV
× Pt = 100 GeV
◇ Pt = 250 GeV
♦ Pt = 500 GeV
⋇ Pt = 750 GeV
z Pt = 1000 GeV
ΔPt / Pt
.25
.20
.15
.10
.05
0.00
0.0
.5
1.0
1.5
2.0
2.5
η
Muon: FN-03Mar93b Barrel: 6/6/6 Endcap: 8/6/6 h.5


GEM Case 710: Rc 9.459, Zc 0.7862-14.955: FFS Rbore 0.35, ⊖9.4-.35, Z 10-19
Barrel
End Cap(s)
θc = 27.74 17.87 9.75
σ0 = 7.5E-05 7.5E-05 7.5E-05
σint = 5.0E-05 5.0E-05 5.0E-05
σext = 2.5E-05 2.5E-05 2.5E-05
Δlay = 0.04 0.04 0.04
Ni = 6/ 6/ 6 8/ 6/ 6 8/ 6/ 6
Inn = 4.34 7.02 6.75
Mid = 6.54 11.54 11.31
Out = 8.69 16.90 16.65
X0pl = 0.011 0.011 0.011
Transverse axis, m
Beam axis, m
0
5
10
15
20
25
Muon: FN-03Mar93b Barrel: 6/6/6 Endcap: 8/6/6 h.5

Coleman Johnson

System Implementation

SYSTEM IMPLEMENTATION

SECTION 4.5

- 4.5.1 Chamber Production
- 4.5.2 Quality Control and Assurance
- 4.5.3 Support Structure Fabrication and Installation
- 4.5.4 Chamber Installation
- 4.5.5 Alignment
- 4.5.6 Muon Chamber Services
- 4.5.7 Muon Chamber Commisioning
- 4.5.8 Access and Maintenance

CHAMBER PRODUCTION

Manufactured components assembled into chambers

- Critical components manufactured by industry
  etched cathode strip boards
  honeycomb panels manufactured with boards as face
  selected other spacer components
- Standard fittings, adhesives and connectors purchased
- Two or more factories assemble into chambers
  Two or more overseas
  Prototype factory in USA that could do mass prod.

cvjoooox-2
3/16/93

1) ETCHED CATHODE STRIP BOARDS:

a) Provided by GEM:

G-10 (o.5 mm thick) boards with Copper (17 microns thick) plated on one side, 6000 boards provided

specific pattern of strips

b) Required:

6000 etched cathode strip boards as follows:

1200 boards; 3.5 m by 0.77 m;
2400 boards; 3.5 m by 1.33 m;
2400 boards; 2.6 m by 0.95 m

c) Specifications:

Pitch of strips +/- 50 microns, not accumulative
space between strips +/- 50 microns
strips straight to +/- 50 microns

2) HONEYCOMB PANELS:

a) Provided by GEM:

6000 etched cathode strip boards
8000 G-10 boards with solid copper on one side

optional: additional material (NOMEX paper stock, epoxy, etc) estimated as provided by GEM or supplier

b) Required:

7000 honeycomb panels as follows:

6000 panels with one etched cathode strip board as a face and one board with solid copper as the other face, as follows:

1200 panels 3.5 m by 0.77 m;
2400 panels 3.5 m by 1.33 m;
2400 panels 2.5 m by 0.95 m

1000 panels with both faces of solid copper only as follows:

200 panels 3.5 m by 0.77 m;
400 panels 3.5 m by 1.33 m;
400 panels 2.5 m by 0.95 m

c) Specifications:

All panels 20 mm +/- 0.1 mm thick
all panels flat to 100 microns
all panels faces parallel to 50 microns

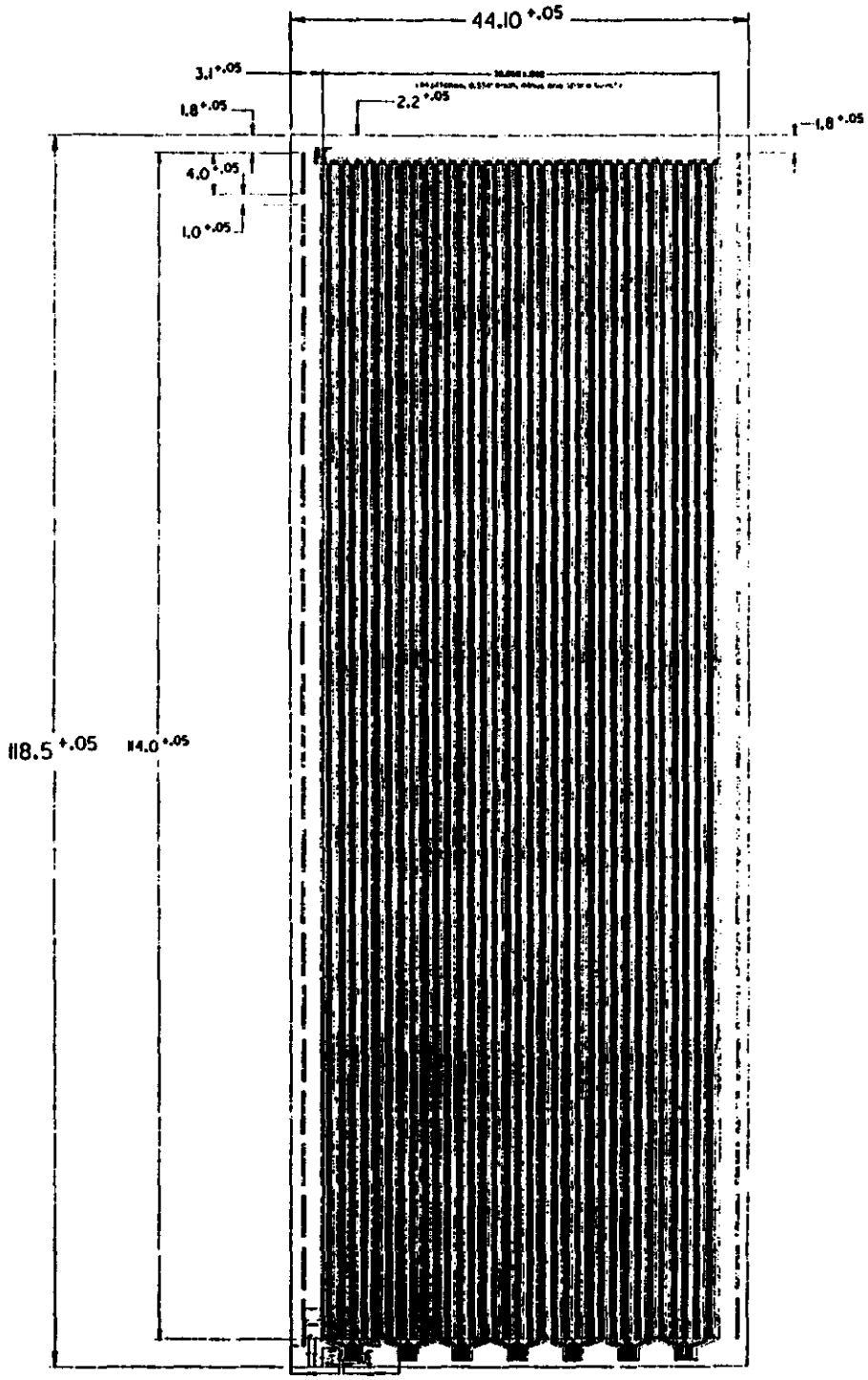
d) Details:

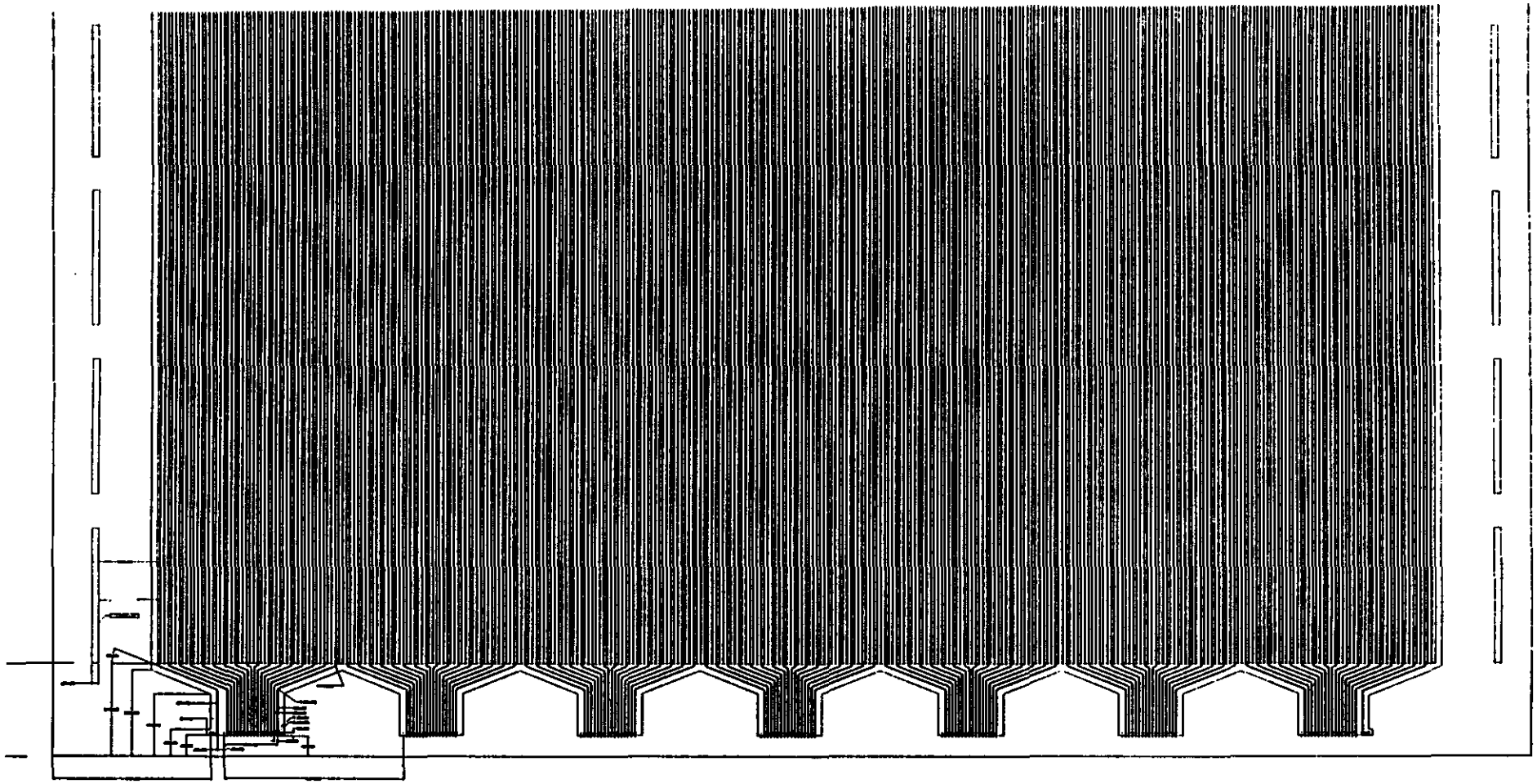
All panels will have 25 mm +5/-0 mm of the edge honeycomb cells filled with epoxy to form an edge seal and stiffener

3) SCHEDULE:

Provide delivery schedule for:

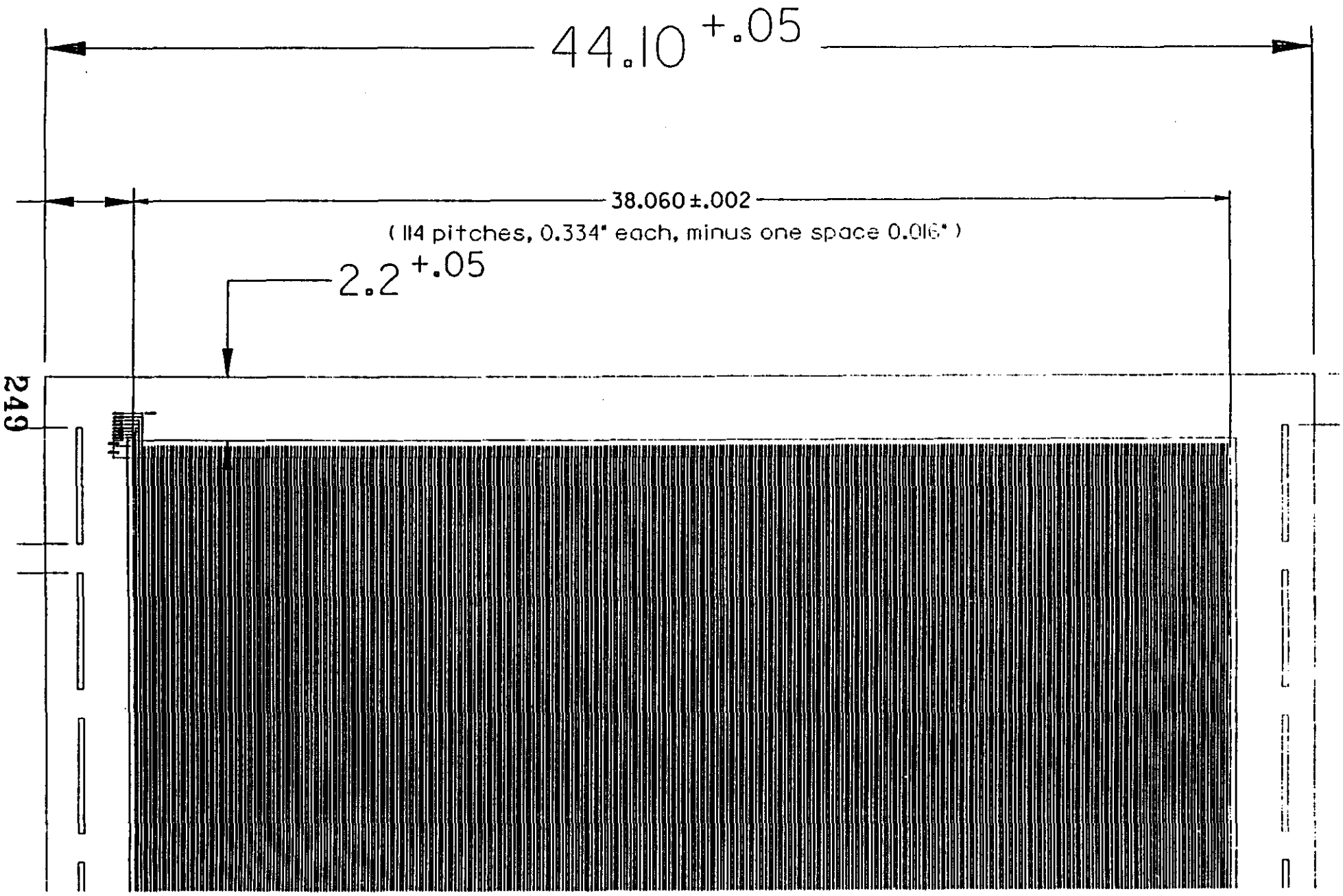
First 10 % of total order;
Second10 % of total order;
Third 10 % of total order;
Forth 10 % of total order;
Fifth 10 % of total order;
etc.

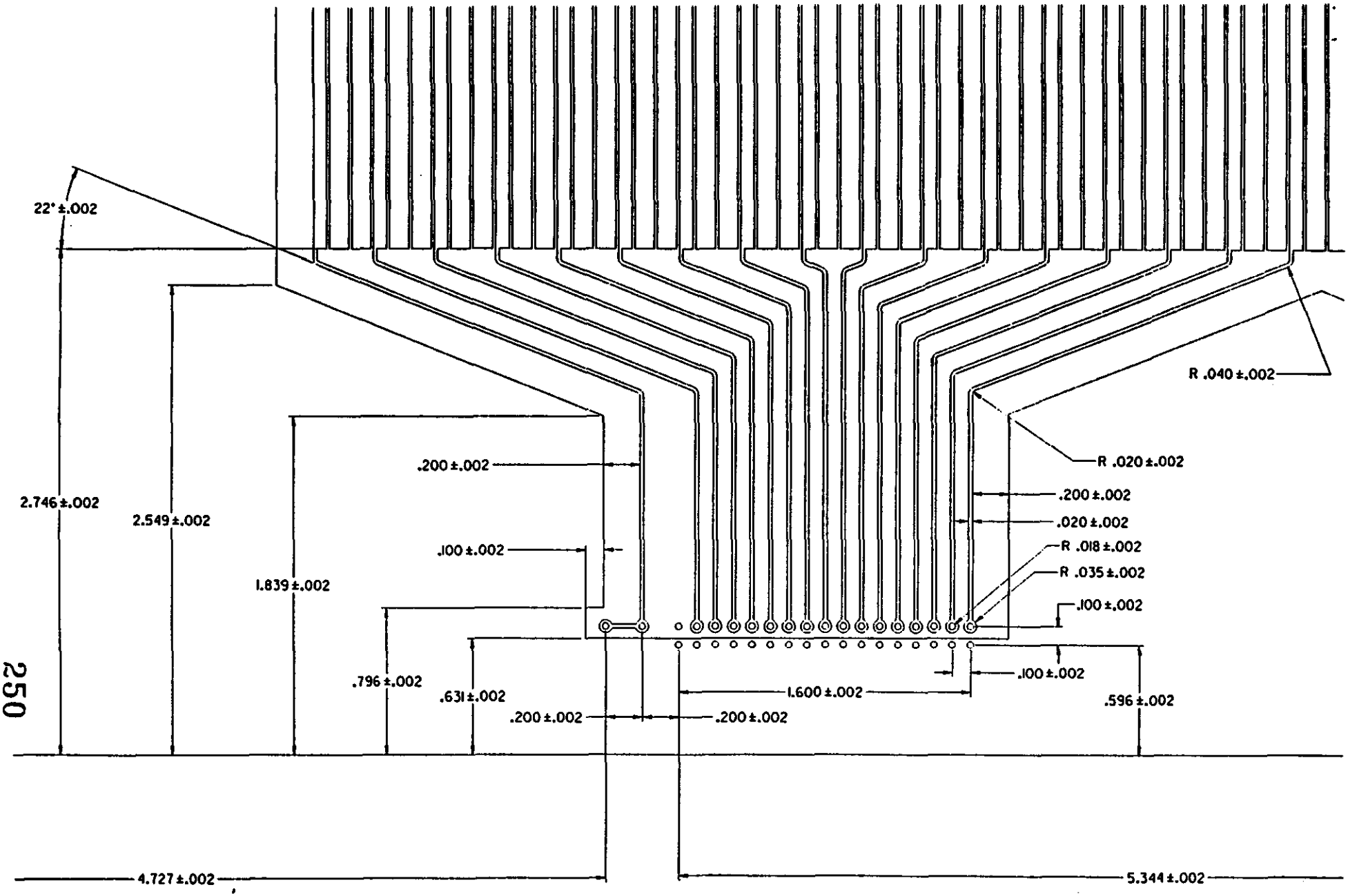

44.10 +.05
3.1 +.05
1.8 +.05
2.2 +.05
1.8 +.05
4.0 +.05
1.0 +.05
118.5 +.05
114.0 +.05



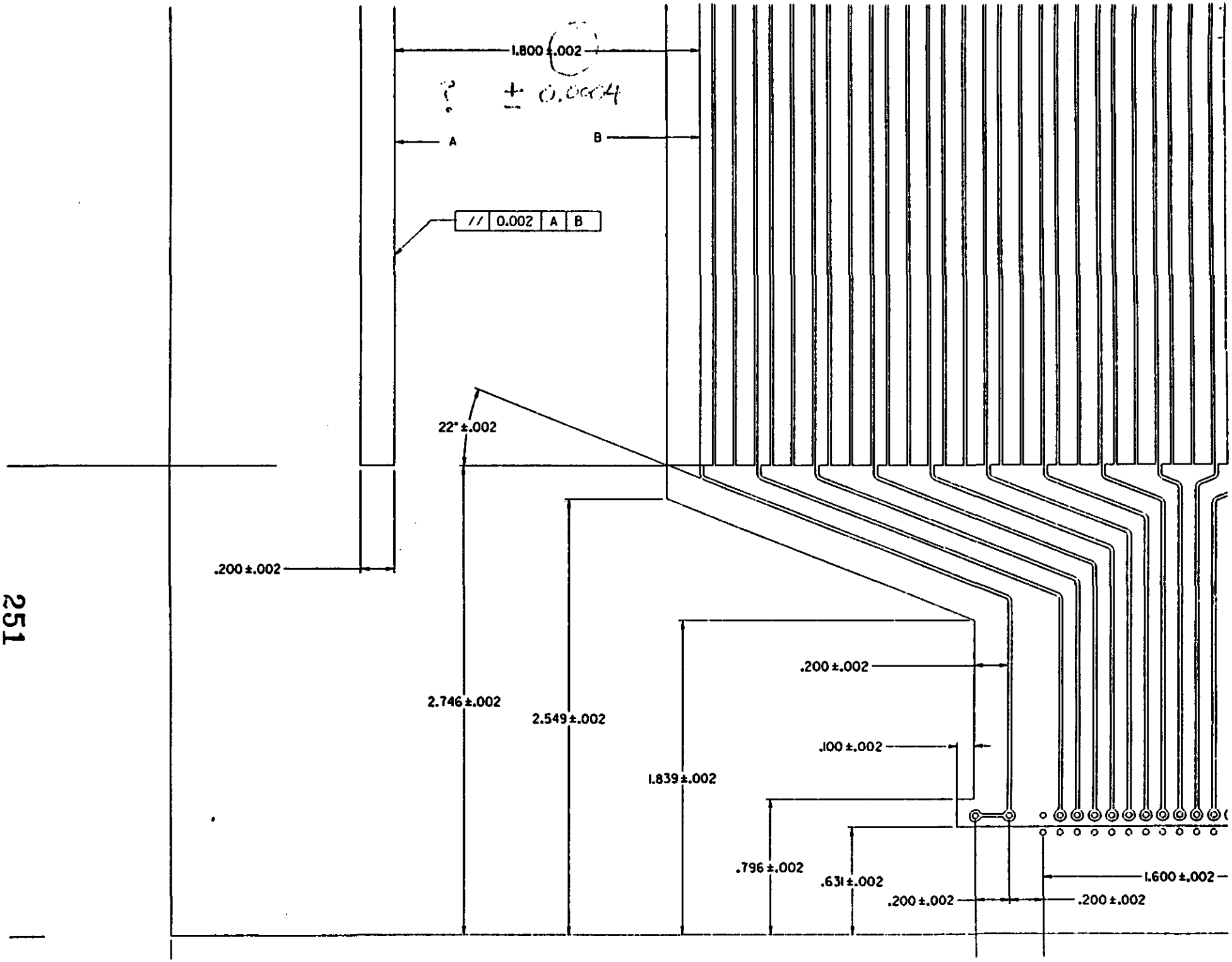
BOTTOM

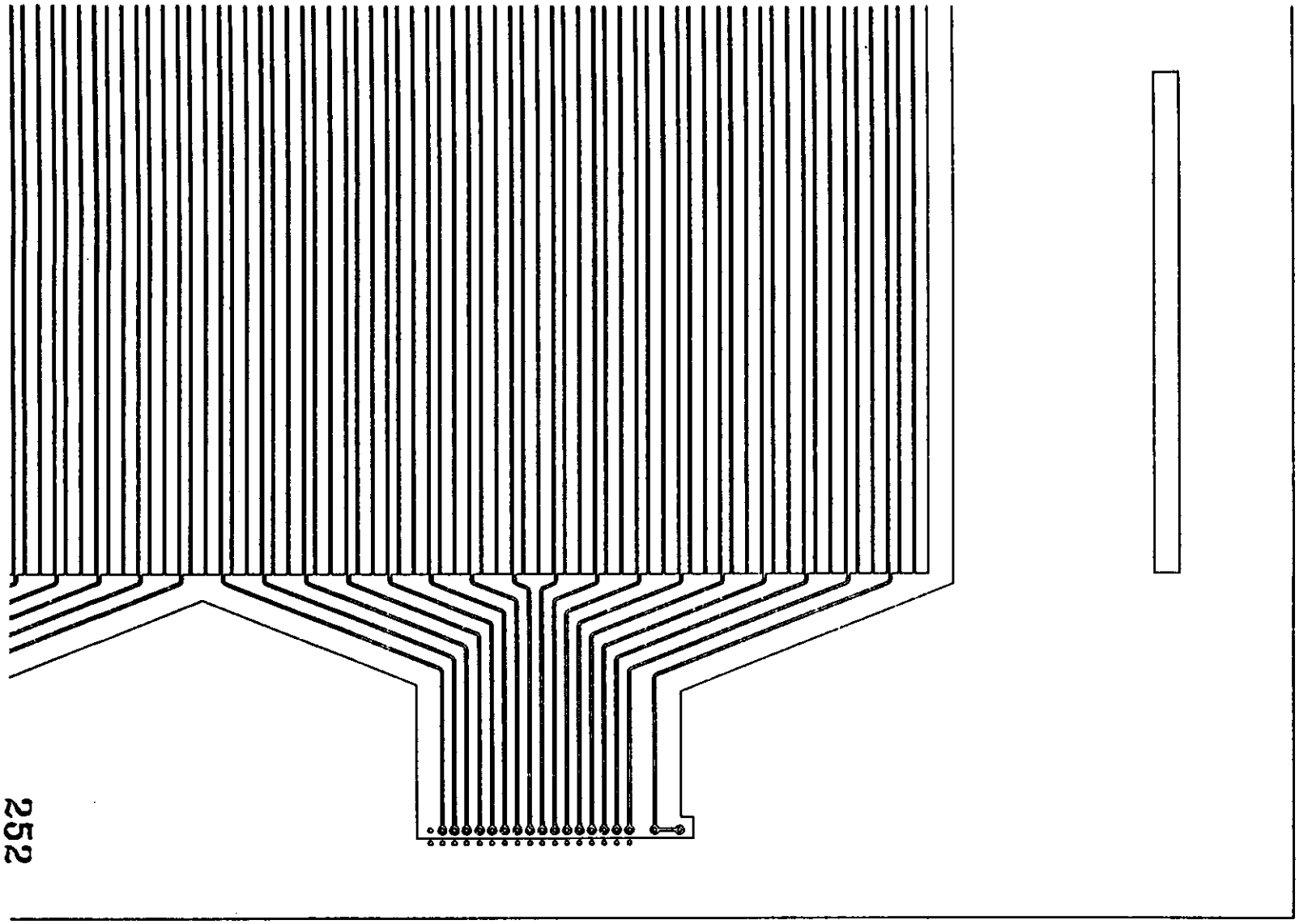
TOP


44.10 +.05
38.060 ±.002
(114 pitches, 0.334" each, minus one space 0.016")
2.2 +.05
249



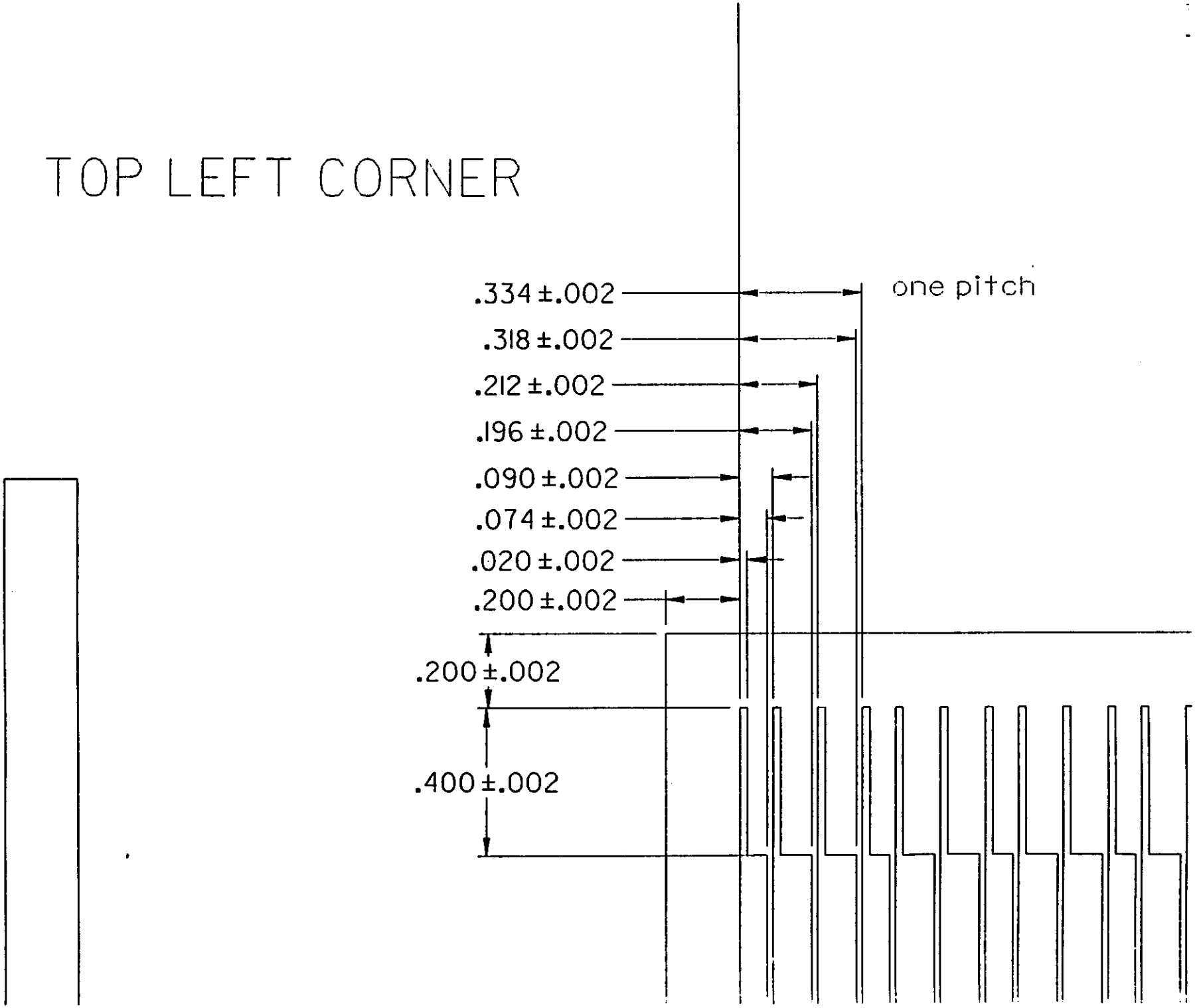
LEFT BOTTOM CORNER

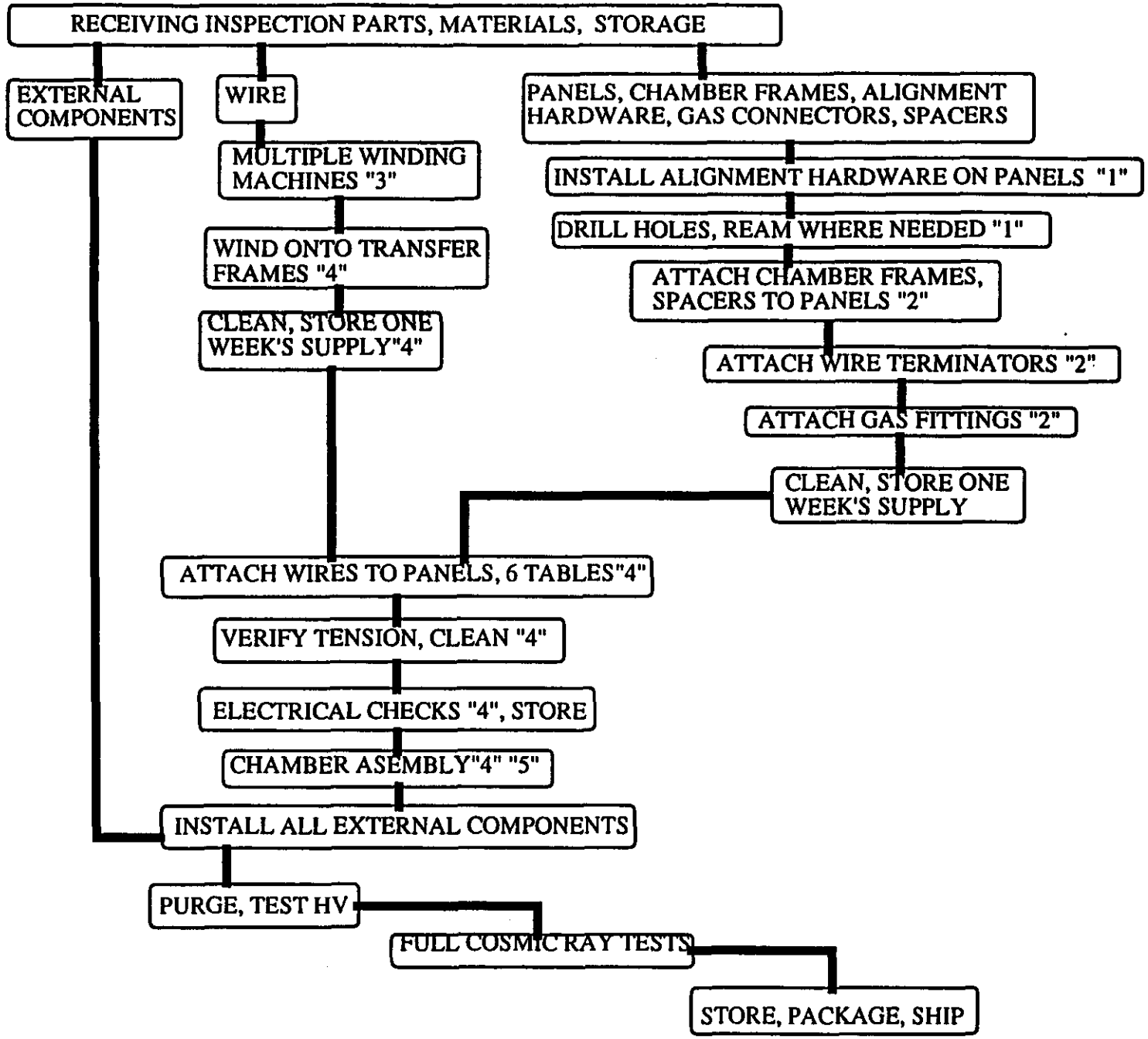

1.800 ±.002
? ± 0.004
A
B
// 0.002 A B
22° ±.002
.200 ±.002
2.746 ±.002
2.549 ±.002
.200 ±.002
.100 ±.002
1.839 ±.002
.796 ±.002
.631 ±.002
.200 ±.002
.200 ±.002
1.600 ±.002



RIGHT BOTTOM CORNER

TOP LEFT CORNER




RECEIVING INSPECTION PARTS, MATERIALS, STORAGE
EXTERNAL COMPONENTS
WIRE
PANELS, CHAMBER FRAMES, ALIGNMENT HARDWARE, GAS CONNECTORS, SPACERS
MULTIPLE WINDING MACHINES "3"
INSTALL ALIGNMENT HARDWARE ON PANELS "1"
DRILL HOLES, REAM WHERE NEEDED "1"
WIND ONTO TRANSFER FRAMES "4"
ATTACH CHAMBER FRAMES, SPACERS TO PANELS "2"
CLEAN, STORE ONE WEEK'S SUPPLY"4"
ATTACH WIRE TERMINATORS "2"
ATTACH GAS FITTINGS "2"
CLEAN, STORE ONE WEEK'S SUPPLY
ATTACH WIRES TO PANELS, 6 TABLES"4"
VERIFY TENSION, CLEAN "4"
ELECTRICAL CHECKS "4", STORE
CHAMBER ASEMBLY"4" "5"
INSTALL ALL EXTERNAL COMPONENTS
PURGE, TEST HV
FULL COSMIC RAY TESTS
STORE, PACKAGE, SHIP

Quality Control and Assurance

GEM complete oversight

- Manufacturers qualified, inspected
- Prototype factory develope sampling plan
- GEM on site inspection at assembly factories
- Functional testing before, after shipping
- Functional testing after sector assembly
- Functional testing after monolith assembly

SUPPORT STRUCTURE FABRICATION AND INSTALLATION

Sections fabricated in industry, assembled at IR 5

- Al pipe space frame manufactured by appropriate industry
  maximum amount of welding
  pinned and bolted joints where needed
  sections assembled, verified in factory
  dissassembled, shipped to IR 5, re assembled, verified
- Sectors assembled, loaded with chambers
- Sectors assembled into monolith support rings
- Monoliths transported into hall, installed

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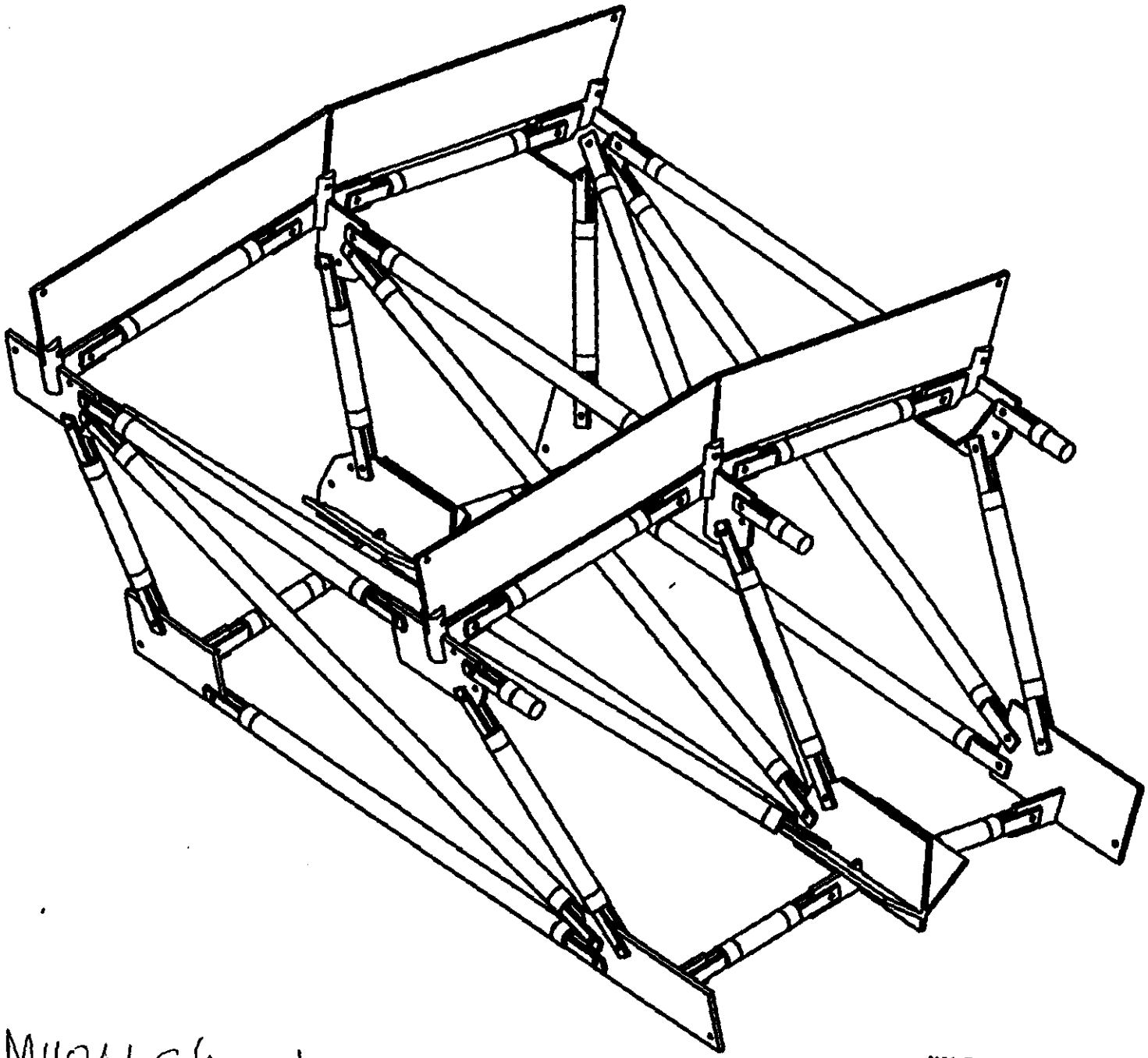

Muon chamber support structure

NAME: MUON_STRUCTU

- 4 5.3 - 1

CHAMBER INSTALLATION

Chambers will be function tested after each step

- Chamber receival, inspection, mounting harware
- Sector assembly
- Mololith assembly

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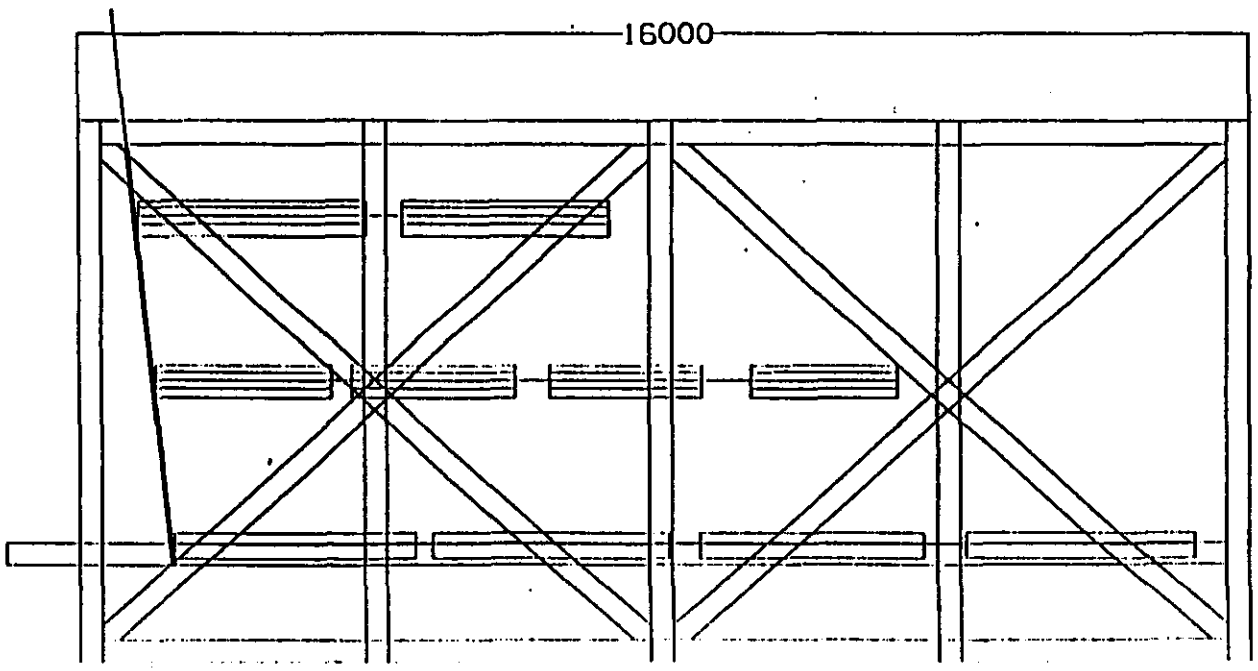
FIG 4.5.4.1 -1

SECTOR INSTALLATION FIXTURE



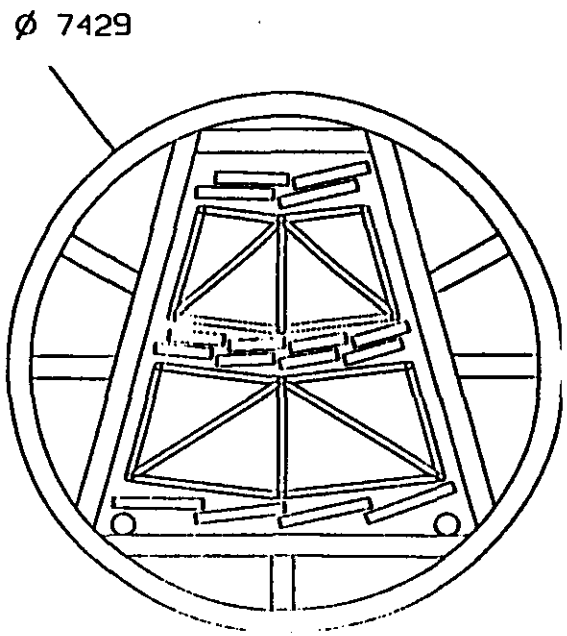


FIG 4.5.4.3-1
Initial module Assembly into
Monolith Ring structures

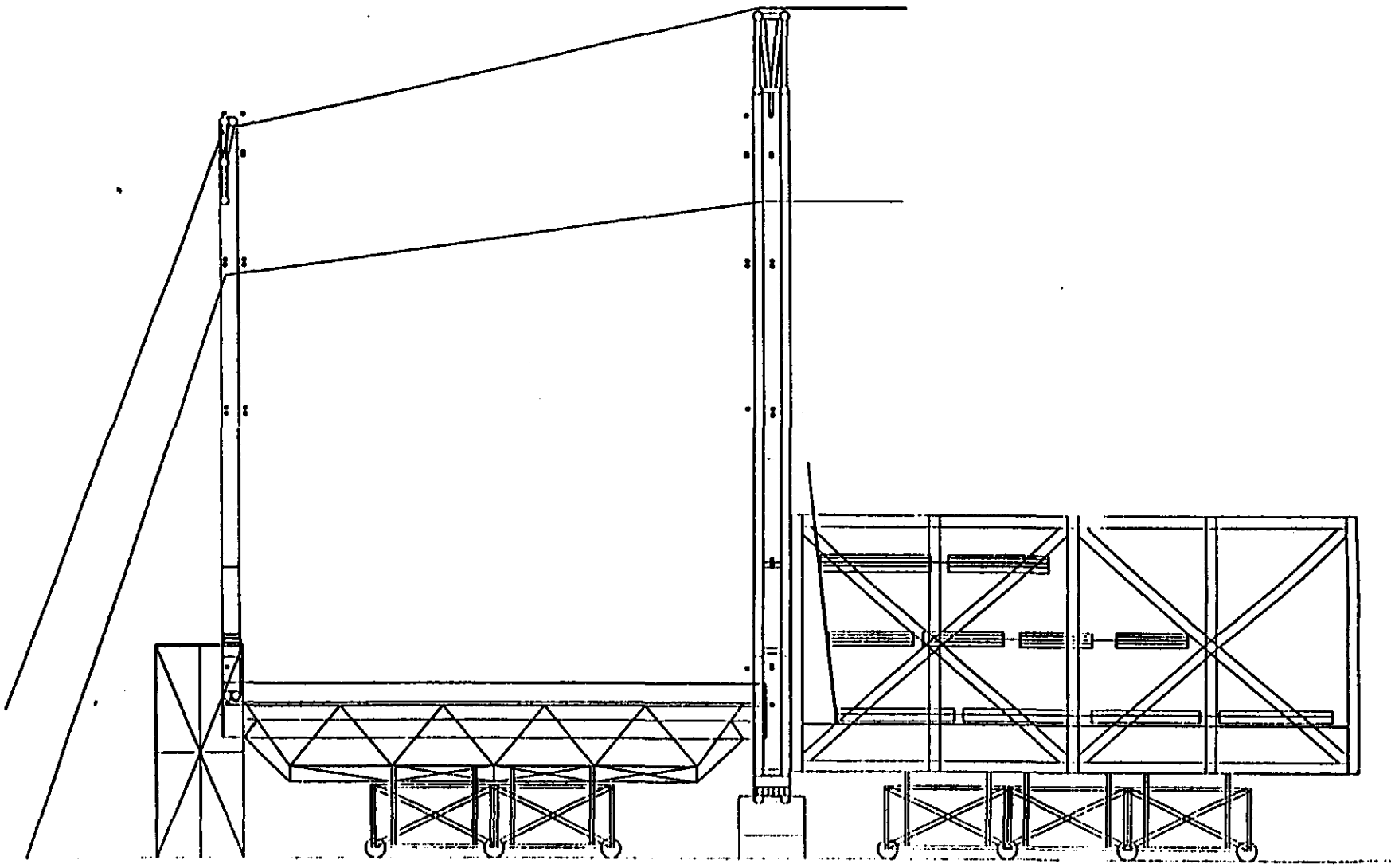
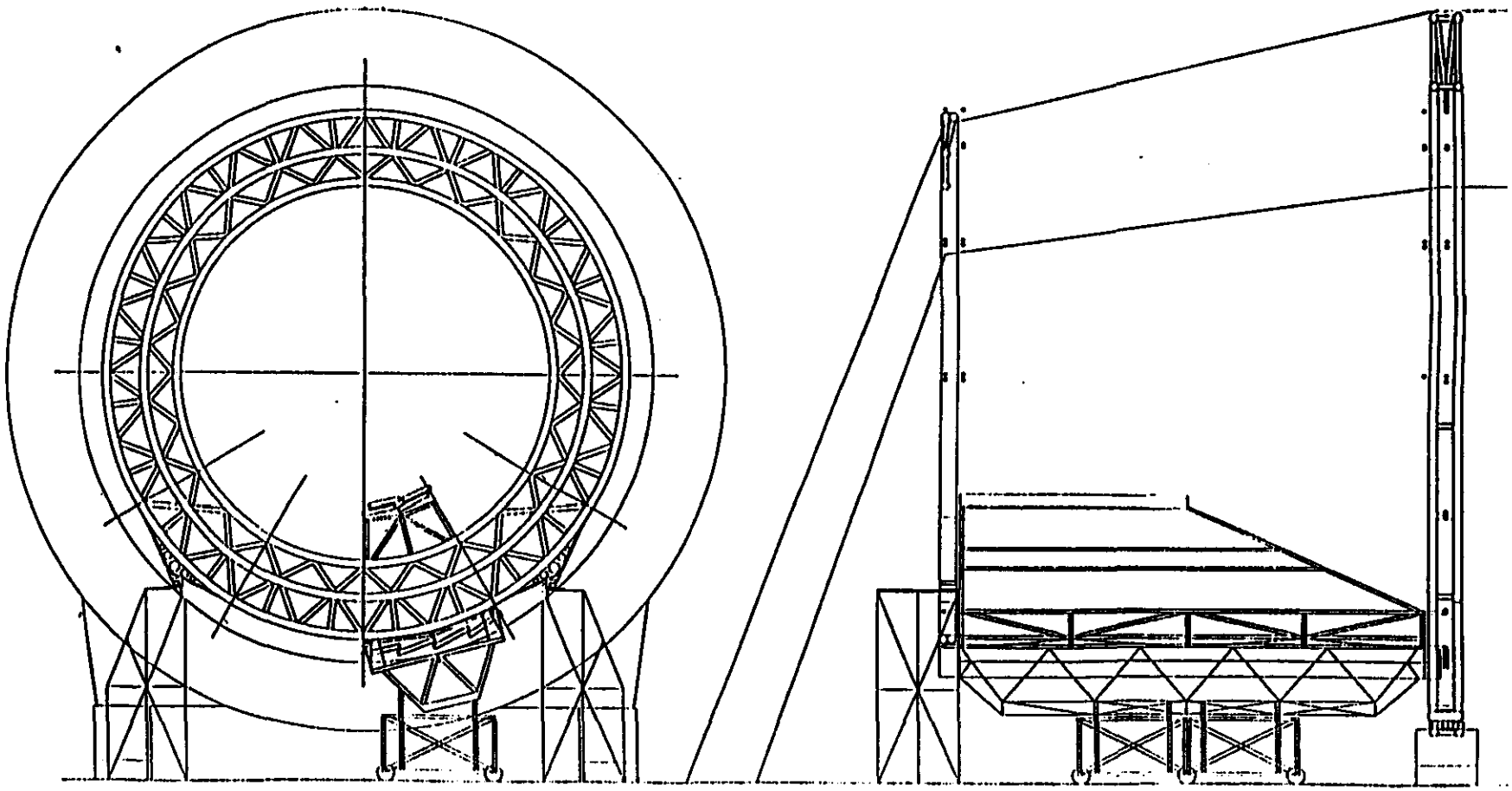
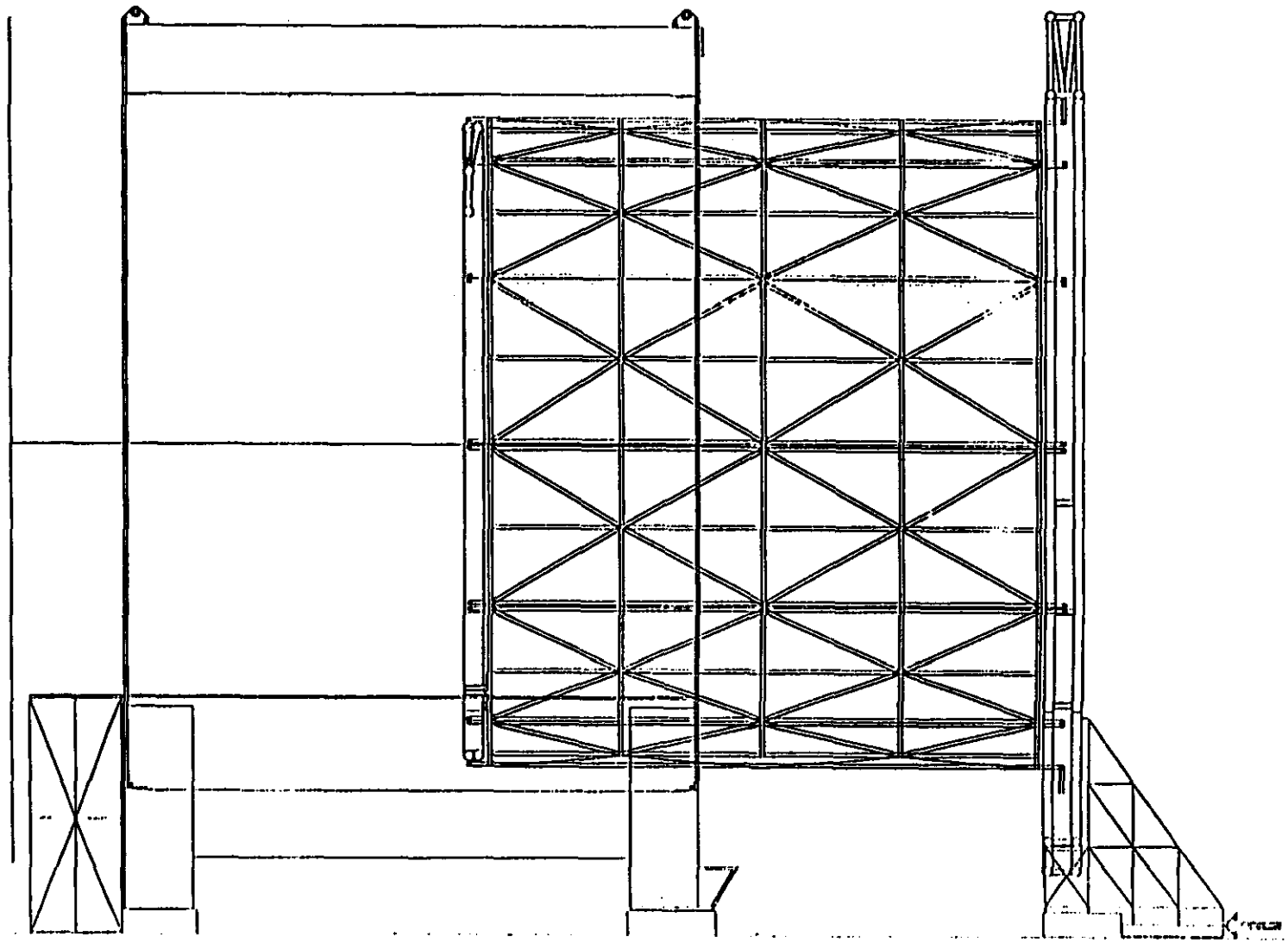


Fig 4.3.4.3-2

Initial Sections Assembled into monolith Rings



Barrel monolith installation
into magnet Half



Alignment

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MUON CHAMBER SERVICES

All services consolidated at sector level

- Gas system regulated at sector level
  mixing controls on surface
  local racks in utility shaft
  regulators at sector level
- Power distributed to sectors
  low voltage to mother boards
  high voltage to chamber gaps
- Water cooling to take out 100 mW per channel
- Cabling will be completed to pig tails at sector level
  sector pig tails collected to monolith pig tails
  flexibility to allow 10 meters of magnet motion

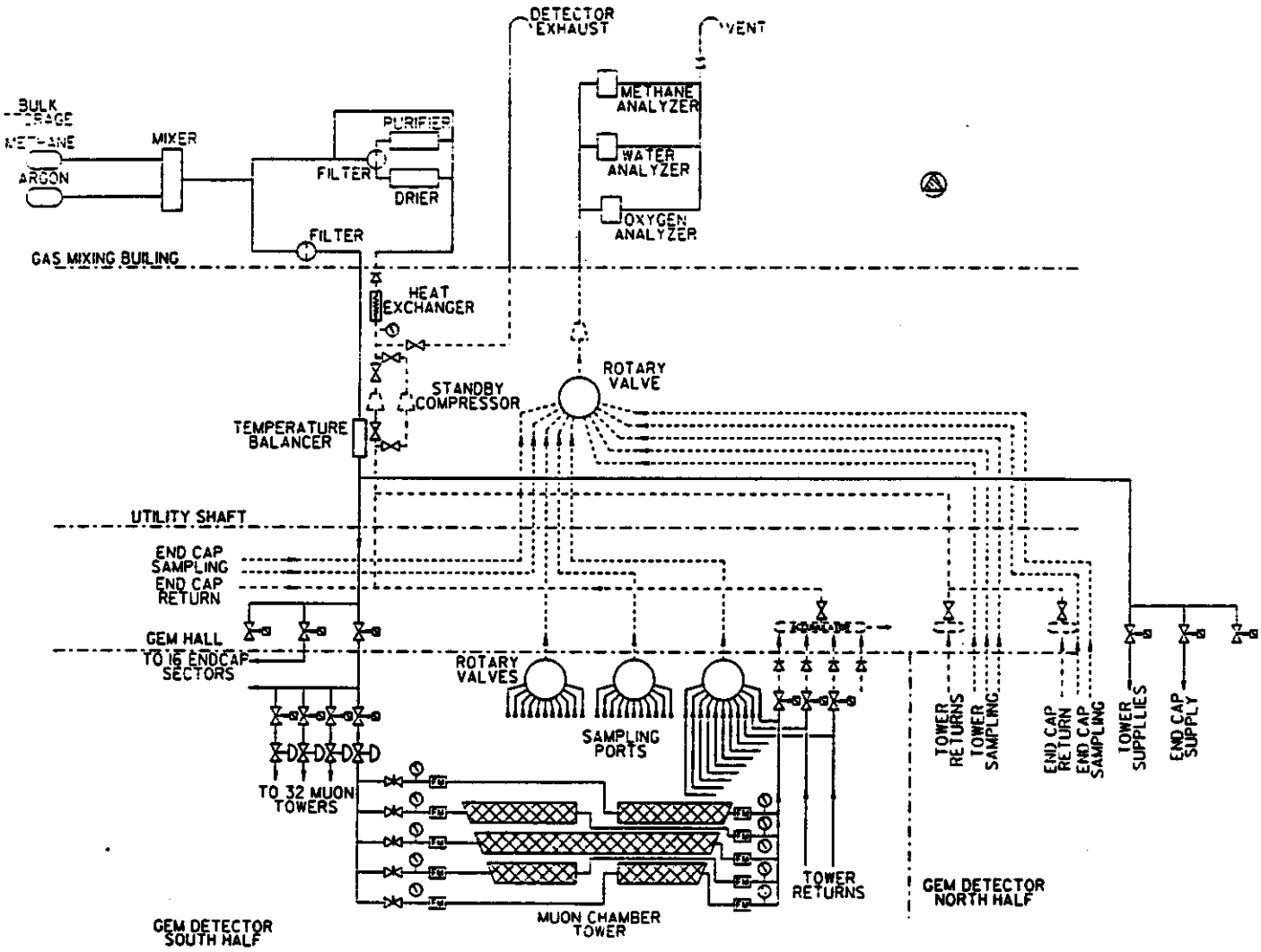
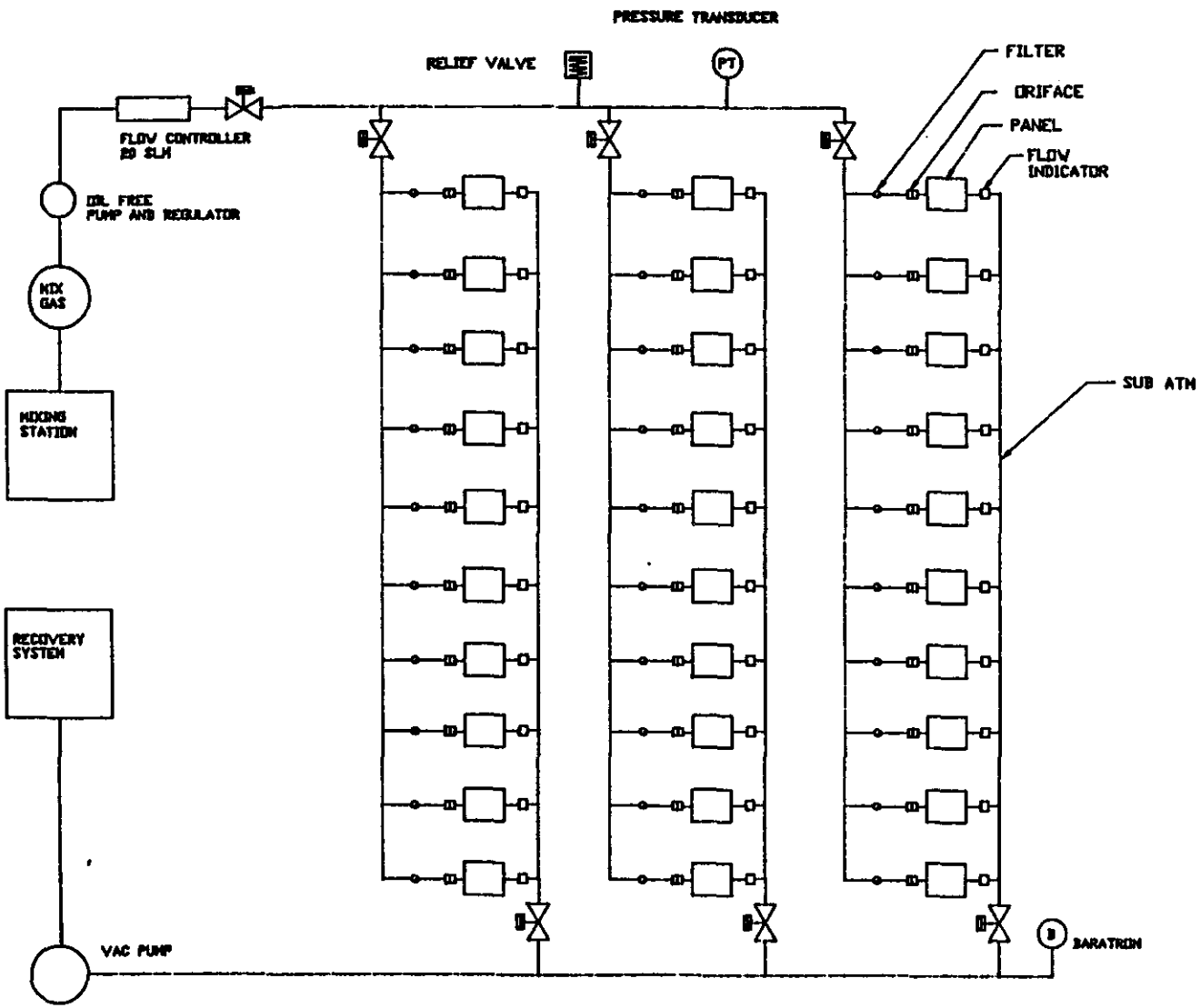
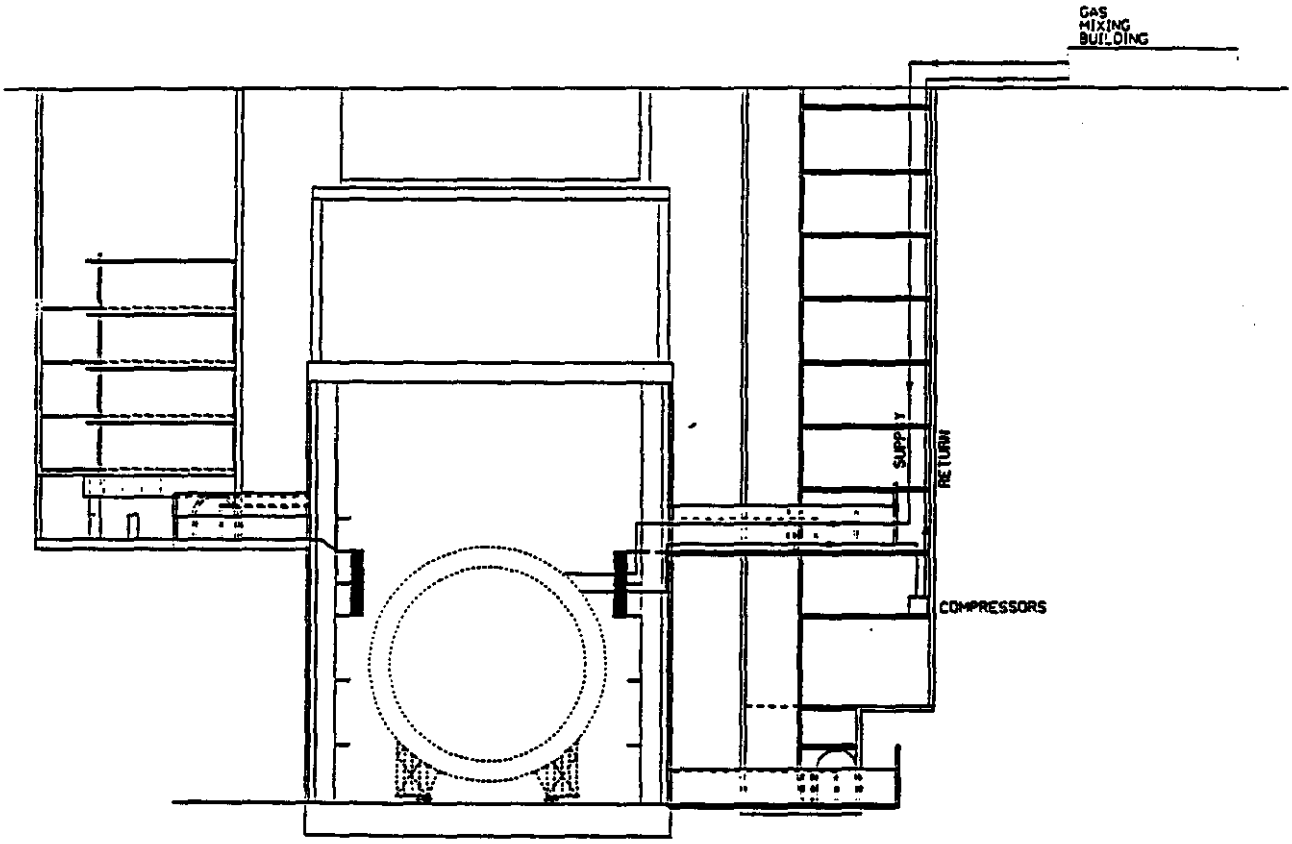

DETECTOR EXHAUST
VENT
METHANE ANALYZER
WATER ANALYZER
OXYGEN ANALYZER
BULK STORAGE
METHANE
ARGON
MIXER
PURIFIER
FILTER
DRIER
FILTER
GAS MIXING BUILING
HEAT EXCHANGER
ROTARY VALVE
STANDBY COMPRESSOR
TEMPERATURE BALANCER
UTILITY SHAFT
END CAP SAMPLING
END CAP RETURN
GEM HALL
TO 16 ENDCAP SECTORS
ROTARY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

FIG 4.5.6.1-2



ONE OF 48 SECTORS

MARCH 11 1993



GEM MUON DETECTOR
GAS SYSTEM

FIG 4.6.1-1

CHAMBER COMMISIONING

Chambers exercised at every assembly level

- Normal sequence of turn on testing
- Initial voltage testing with inert gas
  final verification with working gas
- Leak testing at every step

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ACCESS AND MAINTENANCE

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Summary of Comments

GEM MUON SUBSYSTEM POST REVIEW DISCUSSION

Gary Sanders Presiding

16 March 1993

Reviewer Comments

J. Antebi:
1. Aerospace organizations are generally expensive hardware manufacturers.
It was indicated that a financial savings is expected because a foreign aerospace concern is planned for chamber fabrication.
2. Three point kinematic mounting for the chambers is probably possible, but reproducibility of the position of the body on the mount is nontrivial. Careful engineering is required to accomplish this.
3. Chamber performance could be compromised by gravitational, moisture, thermal, or pressure effects without care to study each during the design phase.
It was indicated that an external bladder, which existed in a former chamber design, would ameliorate the effects of pressure excursions inside the chambers. Also, the chamber frame was responsible for maintaining wire tension high enough to avoid excess gravity-induced sag.
4. Stress relief may not be required for the support structure after fabrication.
It was indicated that opto-mechanical engineers had recommended stress relief as well as cautioned against the use of steel for the structure based on similar long term stability arguments.

M. White:
1. Access to chambers for removal of a wire is of paramount importance.
2. Rigorous testing of prototype chambers is essential to elimination of bothersome operational problems.
3. A graph of the **B** field superposed on the end cap chambers would clarify the description of the effectiveness of the FFS.

Executive Committee Comments

M. Harris:
1. Detector access and electronics placement have not been engineered sufficiently.
Possible improvements include reducing middle superlayer tilt angle to 6°, pairing chambers wherever possible, and thinning the CDS. Recommendation for implementation of these is not for the TDR but in May.
2. Acceptance of the system is low. For the TDR, an alternative alignment scheme should be defined as an option to reduce gaps between the chambers.
3. Pairing chambers together wherever possible was highly recommended.
4. A Safety Factor = 3 for the Δp in the chamber may not be adequate for Texas weather fluctuations.
M. Marx suggested the use of an external bladder to combat this problem.
5. The issue of copper shielding was confusing and should be treated more clearly.
6. The alignment of a tower to the beam line to $3\text{mm} \leq \delta \leq 5\text{mm}$ seems very stringent at this scale. No possibility to accomplish this has ever been shown.
7. C. Johnson's claim that ~90mm of inactive space exists on the end of the chambers is likely to increase acceptance loss. A clear schematic of this should be developed.

8. No scenario to deal with the end cap chambers design or assembly was shown. It is not clear that an acceptable program exists for end cap chamber manufacture.
It was indicated that a program for end cap chamber design exists.
9. A clear detection technology choice must be included in the TDR.

G. Sanders:
1. Questioned whether the rail design inside magnet vessel for introduction of the monolith was agreed to by the magnet group. A copy of a memo from J. Bowers, dated 12 November 1992, indicating the minimal impact on the vessel wall from this introduction using grease pads was promised to Sanders by M. Gamble. The use of grease may be unacceptable, however. Magnet evolution and the use of small rollers requires that this be reverified.
This feeling was shared by all and roller failures at CERN were mentioned. Sintered bronze hardware may be preferable.
2. Access and maintainability are obvious weak points of the current design.

B. Barish:
1. Inner superlayer chamber lengths of twice their current dimension should be considered.
It was indicated that a fabrication technology requirement prohibited this.
2. Chamber pairing should be strongly considered.

M. Gamble

Post-it™ brand fax transmittal memo 7671	# of pages ▸ 1
To Mike Gamble	From Joseph Antebi
Co. SSCL	Co. SGH
Dept. GEM	Phone # (617)643-2000
Fax # (214)708-6088	Fax # (617)643-2009

MEMORANDUM

Date: 17 March 1993

To: File

From: JA

Comm: 93069 SSCL Muon Detector Support

Additional comments since design review:

- Need to check deformation of magnet inner liner shell when subject to line loads from rail. In particular when structure is only partially in. Consider using more than 2 rails.

- To reduce chance of breakage of chamber wires, use anchorage which will maintain tension in wire constant, for example a belleville washer.

- With respect to using more than 3 point support for chambers, we have used multiple support for antenna reflector panels where the supports were used to slightly warp the panel a predetermined amount to improve its shape. This is an extra degree of freedom that can be used during alignment. Also, in the Keck telescope warping harnesses are used to improve the shape of mirrors.

Mike Gamble

Just a couple more comments since yesterday's meeting.

Thank you for your hospitality

Joe Antebi

Close - Out of Muon Review 3/16/93

Comments without attribution:

(1) Support Structure:

- Attention should be given to how well the joints are made.
- Aircraft manufacturing of the SS may be too expensive.
- Assembly procedure of EC has to be worked out. No details of the support fixturing needed.
- How well will the rollers inside the magnet work ? Support plate strong enough, and would grease pads be better ?
- How to access the muon system ? What to do about a broken wire ? How to get to the electronics ? Some plan has to be given in the TDR.
- Some discussion of options for better coverage. Close the gap at 61 ^{o} and 45 ^{o} and use axial alignment ? Needed is a quantitative analysis. [Alignment stays projective for TDR.]

(2) Chambers:

- The 3x safety factor for chamber over-pressure not enough. Consider going back to the gas bladder ?
- It seemed as though the inactive area of the cathode board was too large. Could a more efficient design be made with less than 95 mm lost?
- No details about the cable plant. How many and where ?
- What is the radiation length budget of the CSCs - including the support frames and electronics, etc. ? Need a complete layout of chamber electronics - several versions were presented - and none was complete !
- More detail on how to calibrate the system - electronics gain, alignment, etc. needed.
- Could we have the middle SL at 6° rather than 8° ?
- Could one large chamber in SL1 barrel spanning two towers be used ?
- Could we tie two chambers in SL2 together to reduce the number of alignment paths and simplify the design ?

(3) Alignment:

- What is the pointing specification of a tower to the IP (3 mm or 3 cm ?)

(4) TDR:

- Need section on access to the muon system.
- Need in one table the operating point parameters (gas, HV, T, P, alignment,...) and the
  their tolerances. Compile total error budget.
- Section on selection of technology - with cost comparisons and technical risks discussed.