GEM TN-92-80

GEM Muon Group Meeting - Tucson

March 8, 1992

Abstract:

Agenda, attenders, and transparencies of the GEM Muon group meeting held at Tucson on March 8, 1992. Agenda: (1) Review of the new baseline; (2) Status of the trigger; (3) Status of engineering design; (4) R&D short term goals and schedule; (5) cost review preparation; and (6) Long range plans - EDR and beyond.

TO: Muon Group
FROM: Frank Taylor
SUBJECT: Muon Meeting at Tucson Sunday 3/8/92

Agenda:
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(1) Review of the new baseline	9:00 to 11:00
- general layout (Taylor)	9:00 to 9:15
- momentum resolution (Sullivan/Taylor/Rosenson)	9:15 to 10:00
- channel counts, weights, costs (Nimblett)	10:00 to 10:15
- hadron punchthrough versus calorimeter thickness (Atiya)	10:15 to 10:40
- neutron background estimates (Atiya)	10:40 to 10:50
- proposed neutron tests (Osborne)	10:50 to 11:00
(2) Status of the trigger	11:00 to 12:30
- barrel (Atiya/Pless)	11:00 to 11:30
- endcaps (Polychronakos)	11:30 to 12:00
- Discussion	12:00 to 12:30
(3) Status of engineering design	1:30 to 3:00
- support structure for barrel and endcaps (Nimblett)	1:30 to 2:00
- alignment concept (Paradiso)	2:00 to 2:30
- barrel solid angle coverage (Nimblett)	2:30 to 2:45
- endcap solid angle coverage (Whitaker)	2:45 to 3:00
(4) R&D short term goals and schedule	3:00 to 5:00
- status reports from R&D proponents	
o CSC (Polychronakos/Whitaker)	3:00 to 3:20
o RPC (Pless)	3:20 to 3:40
o LSDT (Osborne/Korytov)	3:40 to 4:00
o PDT (Miller/Golutvin)	4:00 to 4:20
- TTR goals and schedule (Stocker/McFarlane/Yost)	4:20 to 4:40
- Discussion	4:40 to 5:00
(5) Cost review preparation (Nimblett)	5:00 to 5:10
(6) Long range plans - EDR and beyond (Nimblett/Taylor/Group)	5:10 to 5:30

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GEM MUON SYSTEM BASELINE 3/8/92

Resolution design criterion:

pt = 500 GeV/c

$\delta pt/pt \approx 5\ \%$ for $\eta \approx 0$
$\delta pt/pt \approx 10\ \%$ for $\eta \approx 2.5$

Forced design changes: fig. of merit $BL^2/\sigma_{\text{resolu}}$ (ch. align)

(1) Larger bore magnet:

radius of cryostat increased from 8.3 m to 9.0 m

(2) Longer lever arm in forward direction:

Z-postion of last EC ch. increased from 14.4 m to 16.5 m
Coil halfs separated by 1.5 m

(3) More compact calorimeter:

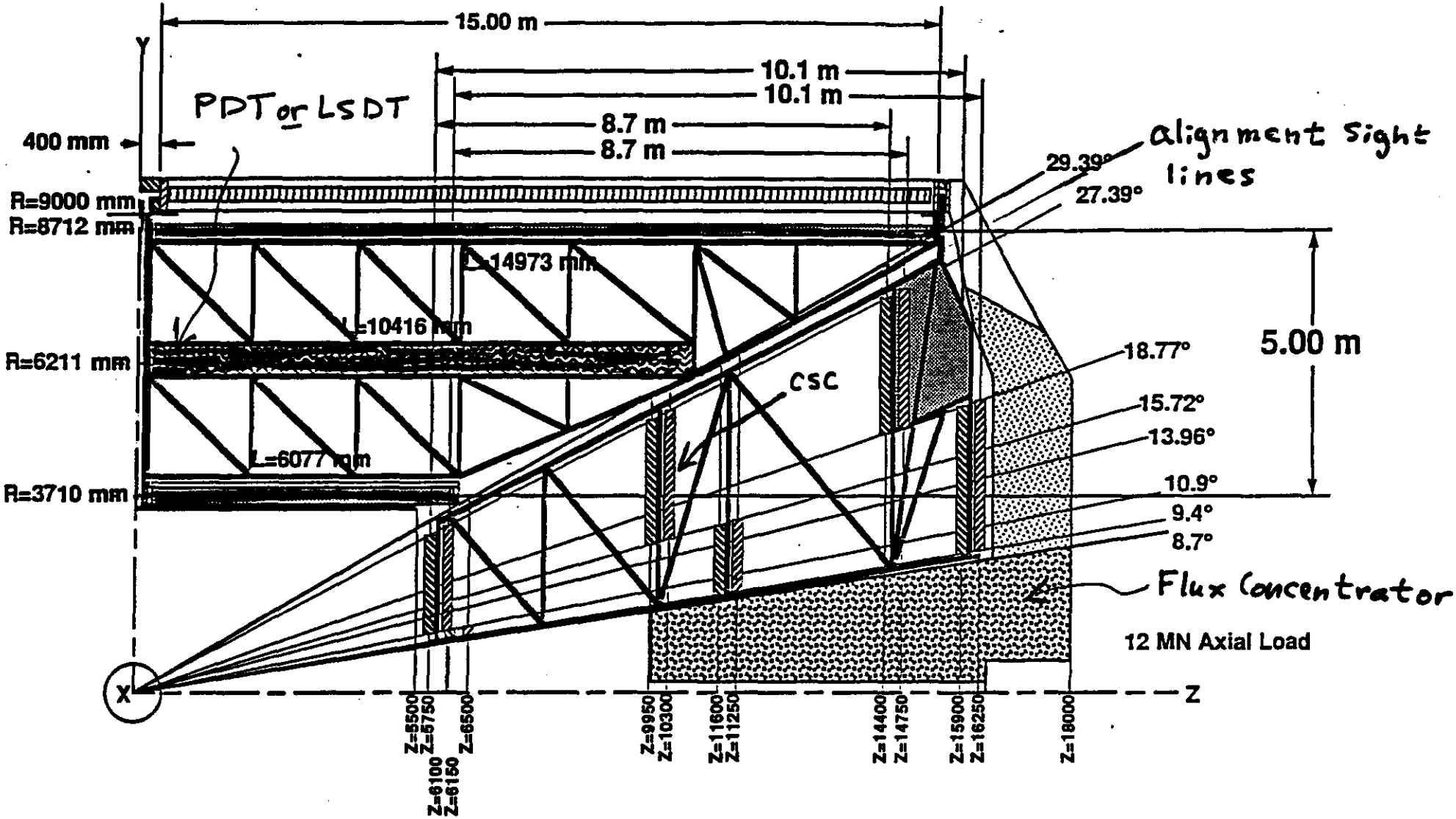
outer radius decreased from 4 m to 3.5 m
length decreased from 6 m to 5.5 m

(4) Field shaping in forward direction:

solid iron flux concentrator from 10 m to 18 m

(5) Very good position measurement needed:

σ layer $\approx$ 100 µm to 75 µm (chamber layer resolution)
σ internal $\approx$ 50 µm (alignment of chamber wires/strips)
σ external $\approx$ 25 µm (alignment of superlayer-to-superlayer)



GEM PDT 18/7 (8/8/4) Barrel or LSDT

Fig. 2.1

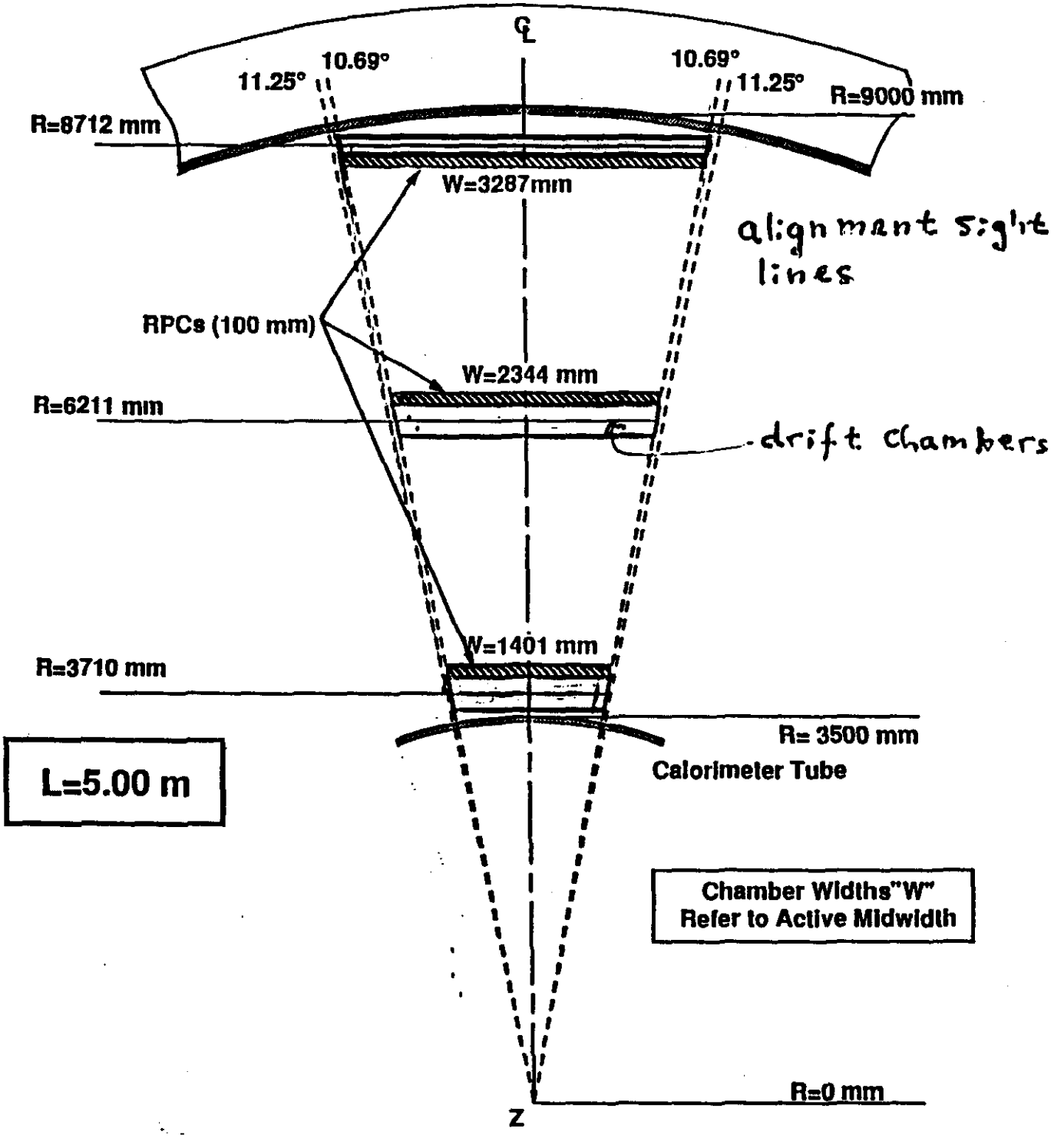
CSC Endcap (Modules A& B)

(Calorimeter 7m OD x11m Long)

(Extended Forward Field Shaper 18000mm Long)

(100 mm RPCs O/O/I)(Magnet half displaced along Z)

F. Nimblett
Draper Lab.
GEM920306



PDT 18/7 (8/8/4)

95% Acceptance

(Barrel Region Endview)

Fig. 2.4

F. Nimblett
GEM 920306

ANGULAR ACCEPTANCE VS INNER MUON CHAMBER CLEARANCE

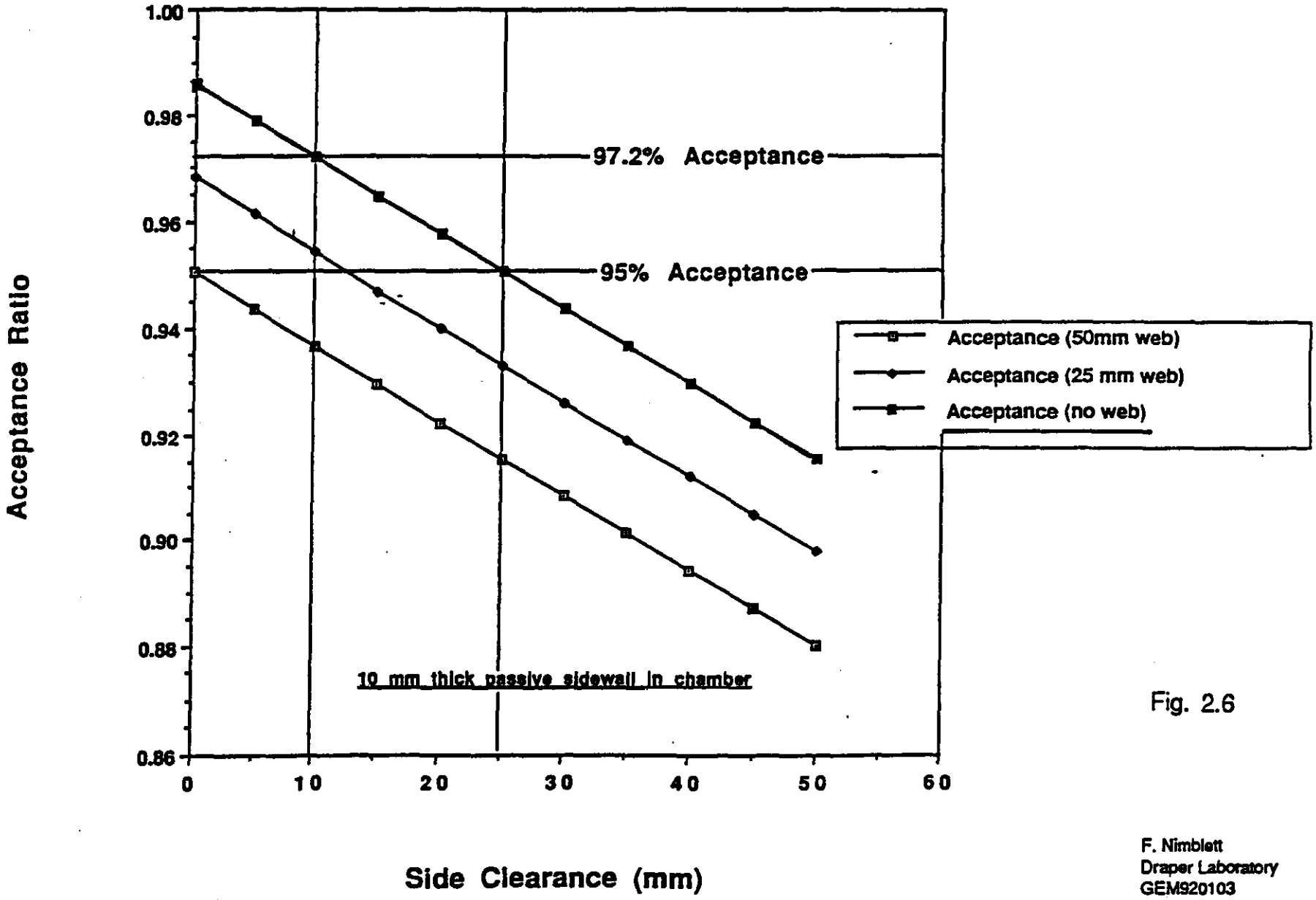


Fig. 2.6

F. Nimblett
Draper Laboratory
GEM920103

GEM

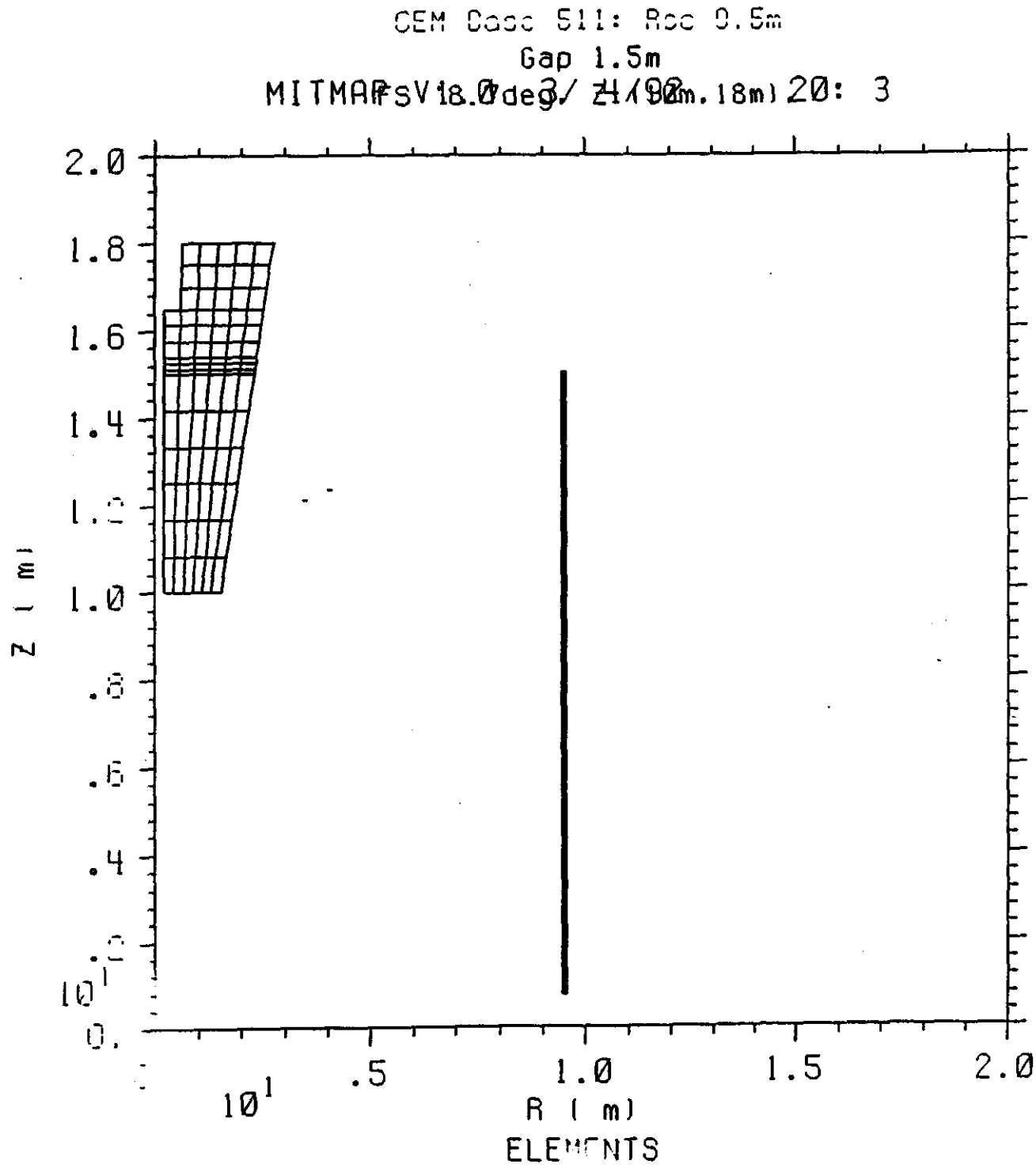
Collaboration Meeting

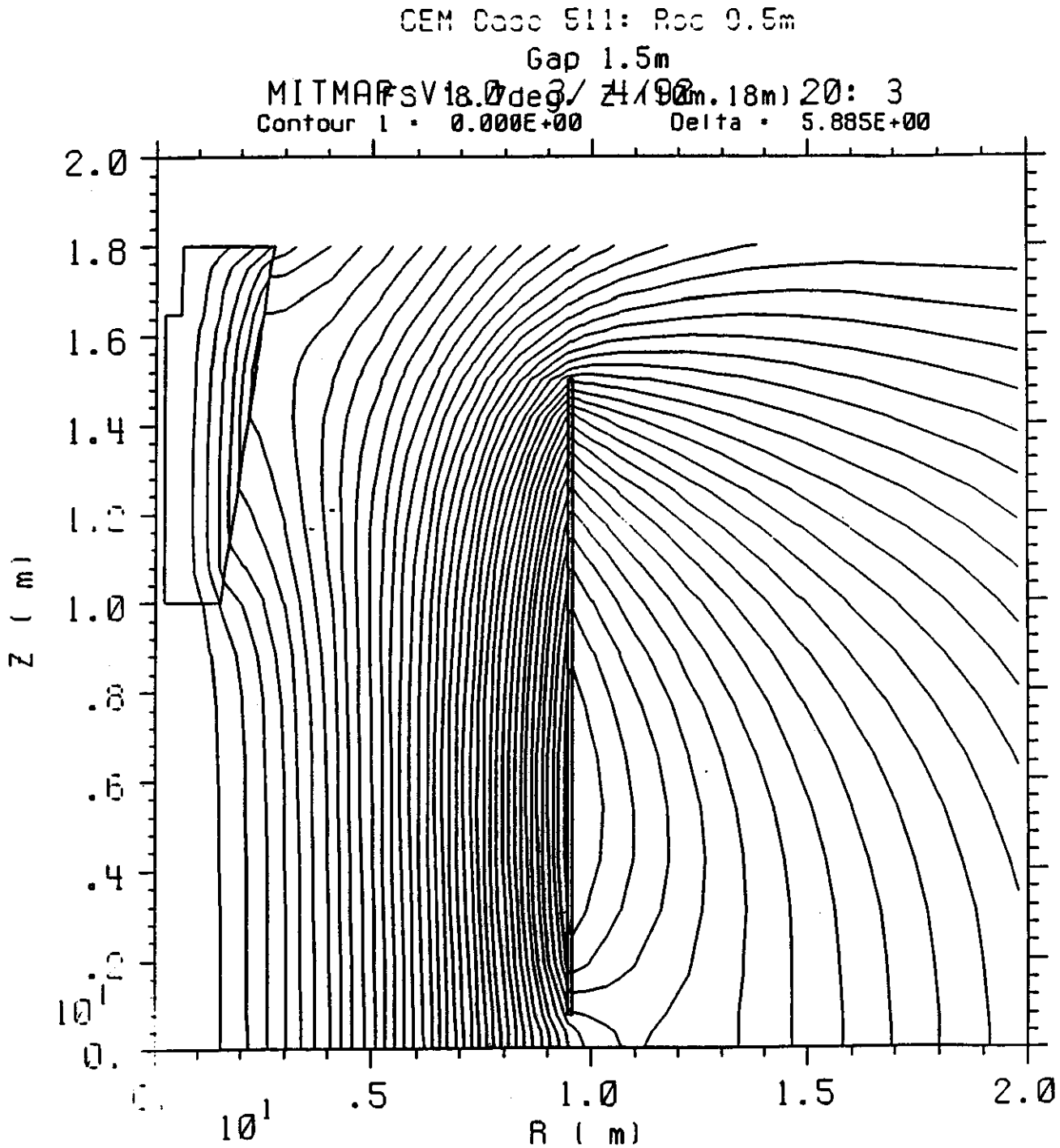
March 7–11, 1992

J.D. Sullivan
MIT/PFC NW16-166, (617)253-7537

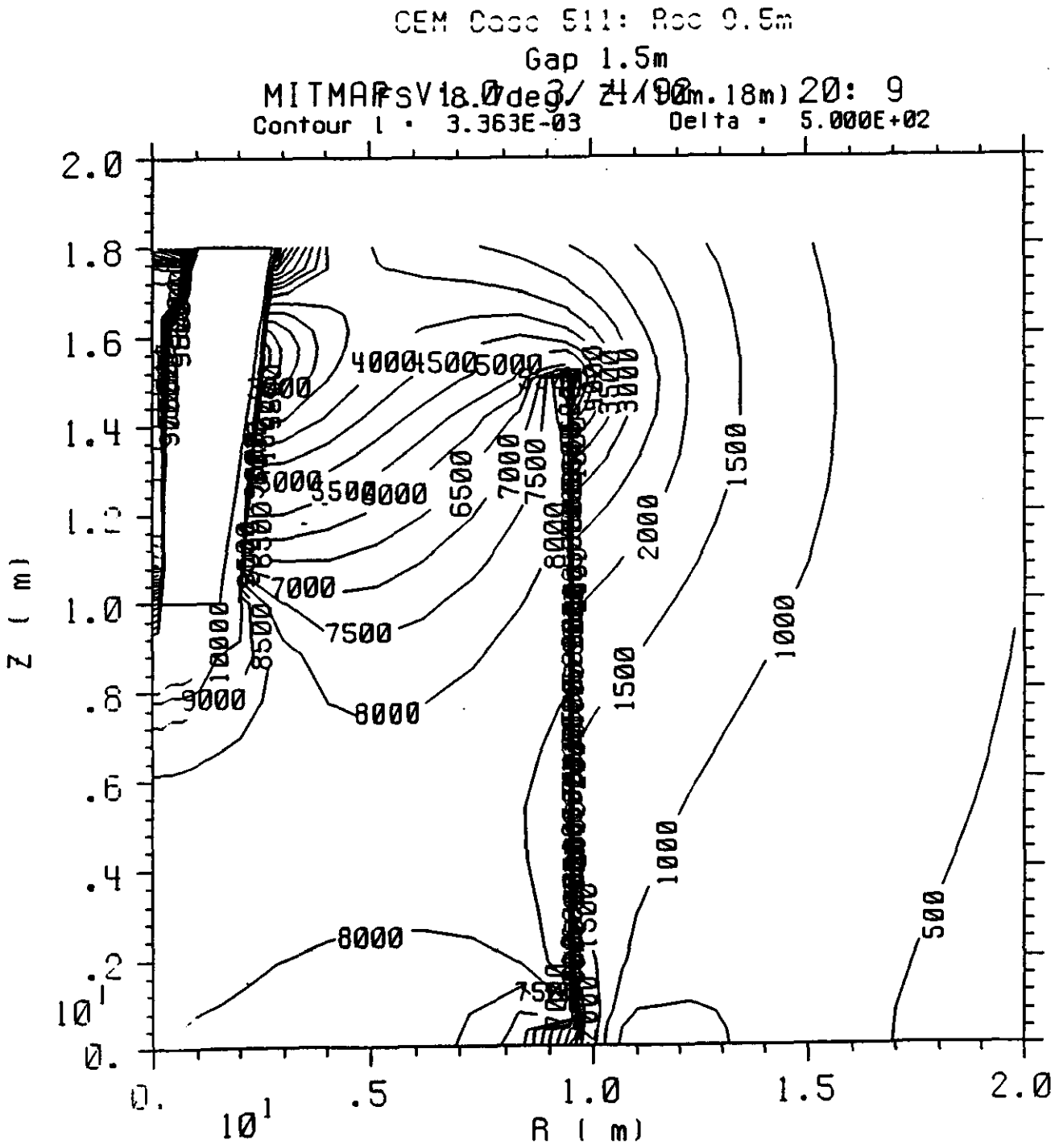
Magnet and Flux Concentrator Geometry:

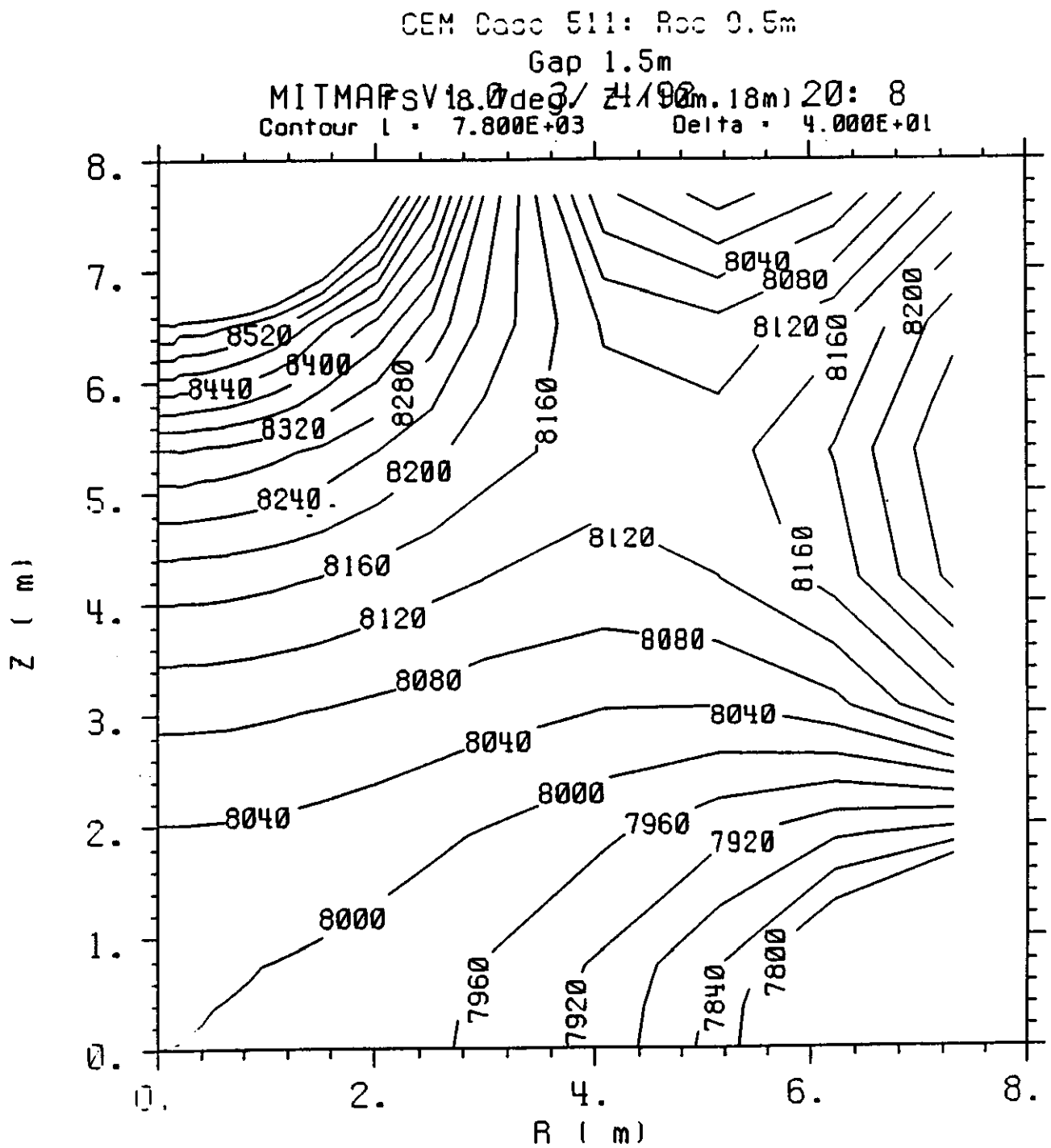
Coil	
mean radius	9.5 m
length	14.25 m
center gap	1.5 m
axial extent	0.75–15.0 m
Cryostat	
ID	18 m
OD	19.8 m
axial extent	0.6–15.4 m
Flux concentrator	
ID	0.4 m
OD	8.7° cone
axial extent	10–18 m
notch	
ID	1.17–1.25 m
axial extent	16.5–18 m
support structure	> 16.5 m


CEM Case 511: Rsc 0.5m
Gap 1.5m
MITMAPsV1.0 3/ 4/92 20: 3
2.0
1.8
1.6
1.4
1.0
.8
.6
.4
0.
Z (m)
.5
1.0
1.5
2.0
R (m)
ELEMENTS

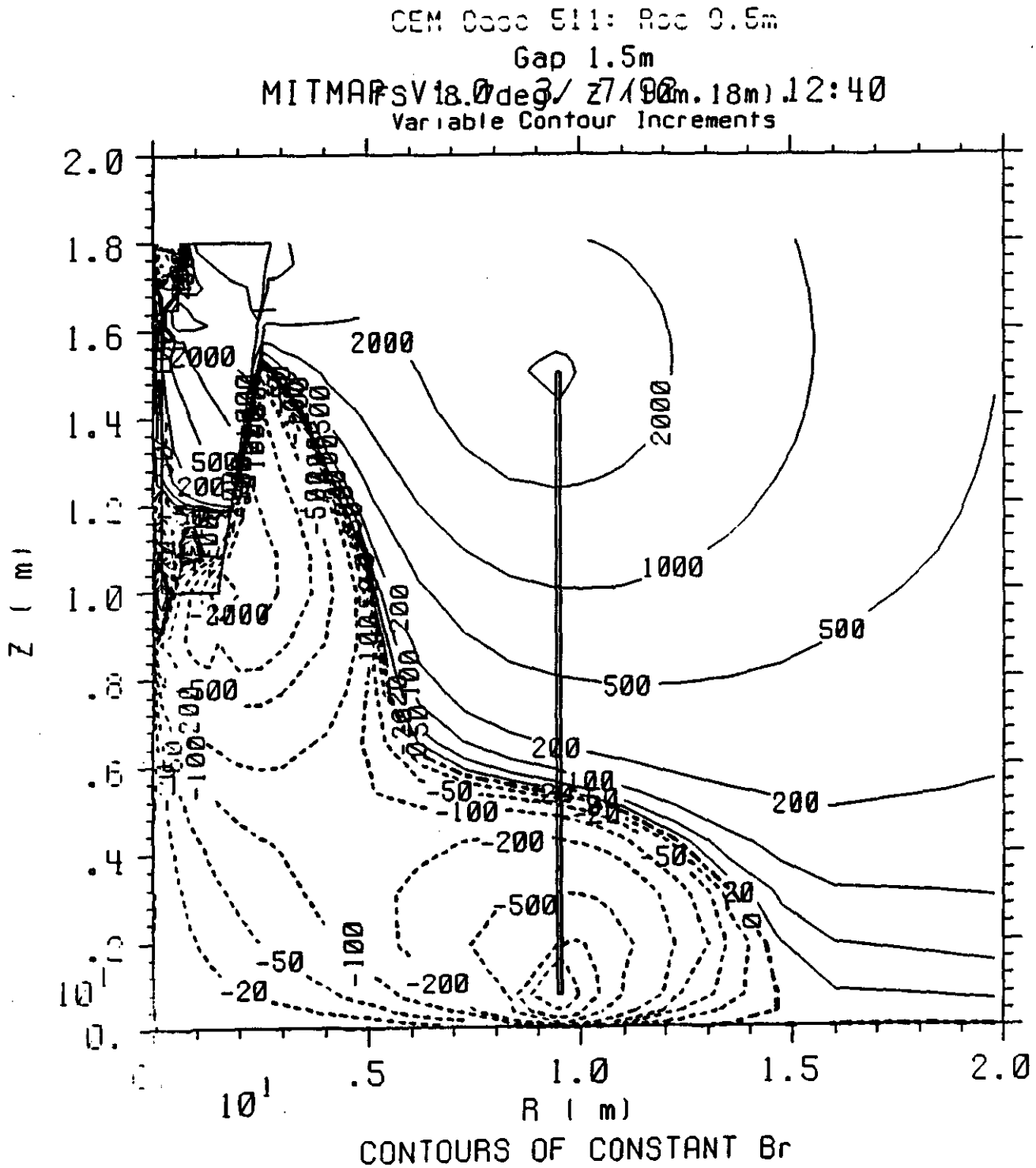


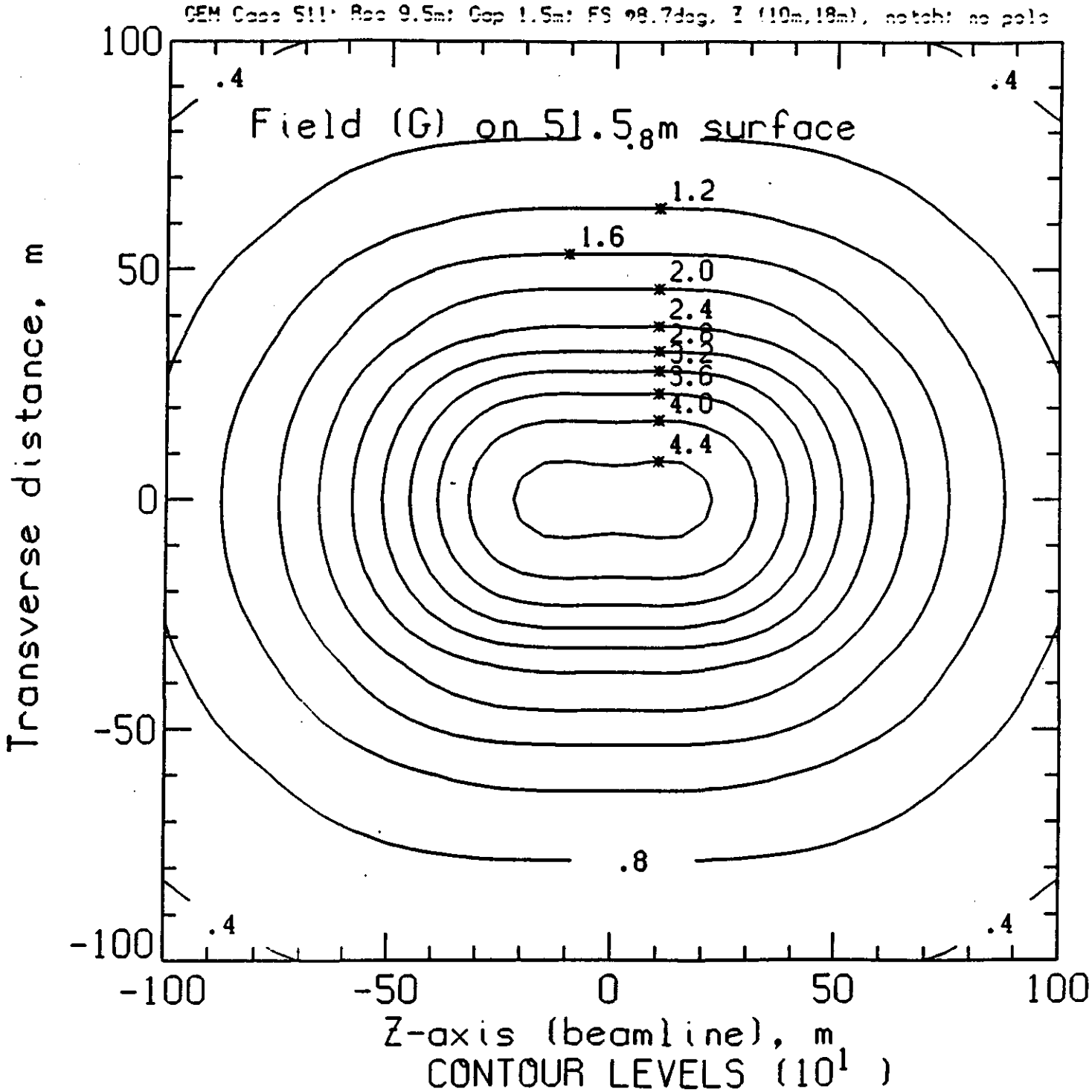
CONTOURS OF CONSTANT FLUX


CEM Case 511: Rsc 9.5m
Gap 1.5m
MITMAP V1.0 3/ 4/92 20: 9
Contour 1 = 3.363E-03
Delta = 5.000E+02
Z (m)
R (m)
10^1
CONTOURS OF CONSTANT B



CONTOURS OF CONSTANT B


CEM Case 511: Rsc 0.5m
Gap 1.5m
MITMAP V1.0 3/ 7/92 12:40
Variable Contour Increments
Z (m)
R (m)
2.0
1.8
1.6
1.4
1.0
.8
.6
.4
0.
.5
1.0
1.5
2.0
2000
1000
500
200
100
-50
-100
-200
-500
-20
CONTOURS OF CONSTANT Br


CEM Case 511: Rac 9.5m: Gap 1.5m: FS 98.7deg, I (10m,18m), notch: no pole
Field (G) on 51.5.8m surface
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
.8
.4
Transverse distance, m
Z-axis (beamline), m
CONTOUR LEVELS (10^1)
100
50
0
-50
-100

Muon Resolution Studies:

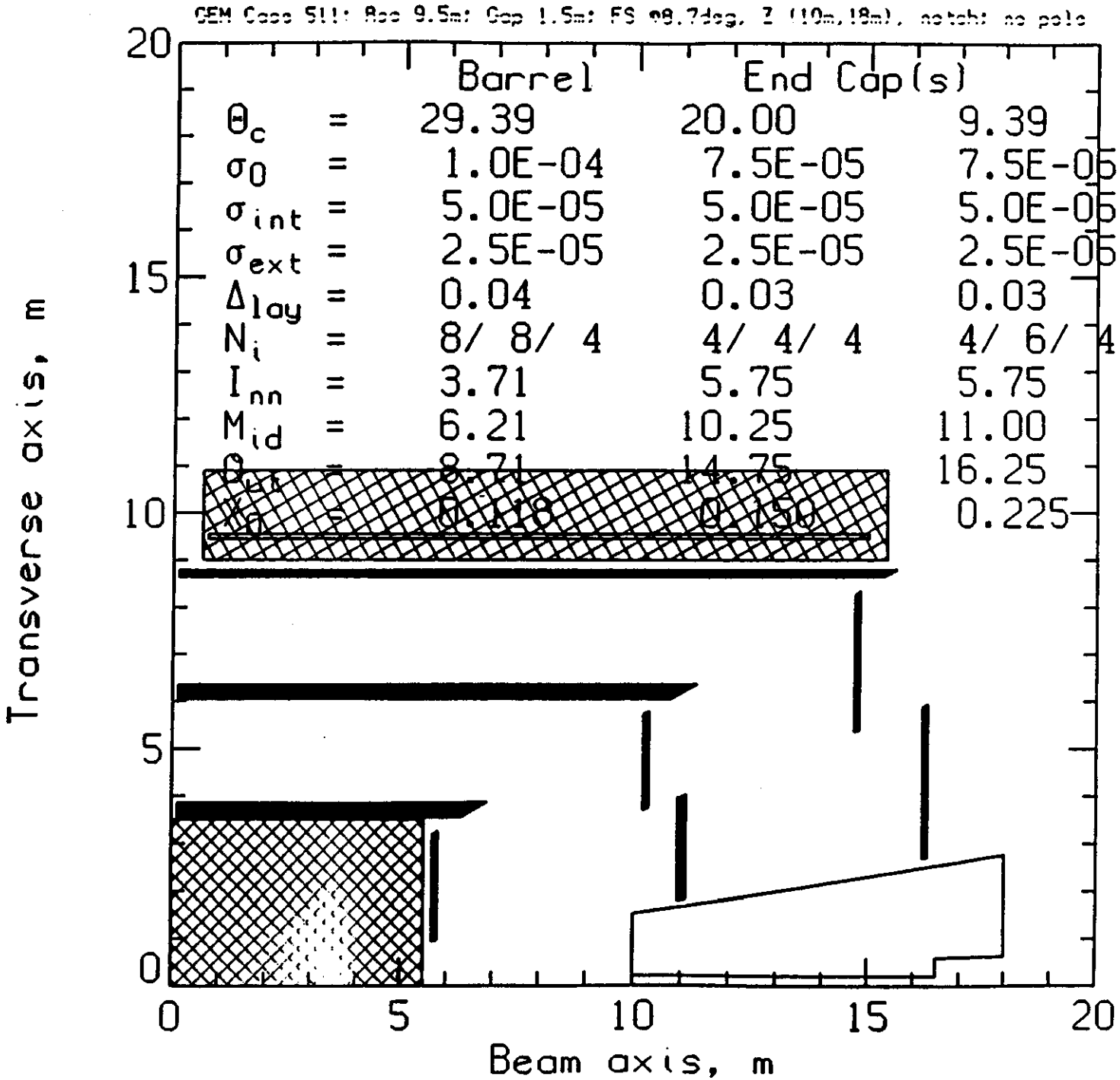
GOALS:

- $\Delta S/S = 0.05$ at $\eta = 0.0$ and
- $\Delta S/S = 0.10$ at $\eta = 2.5$.

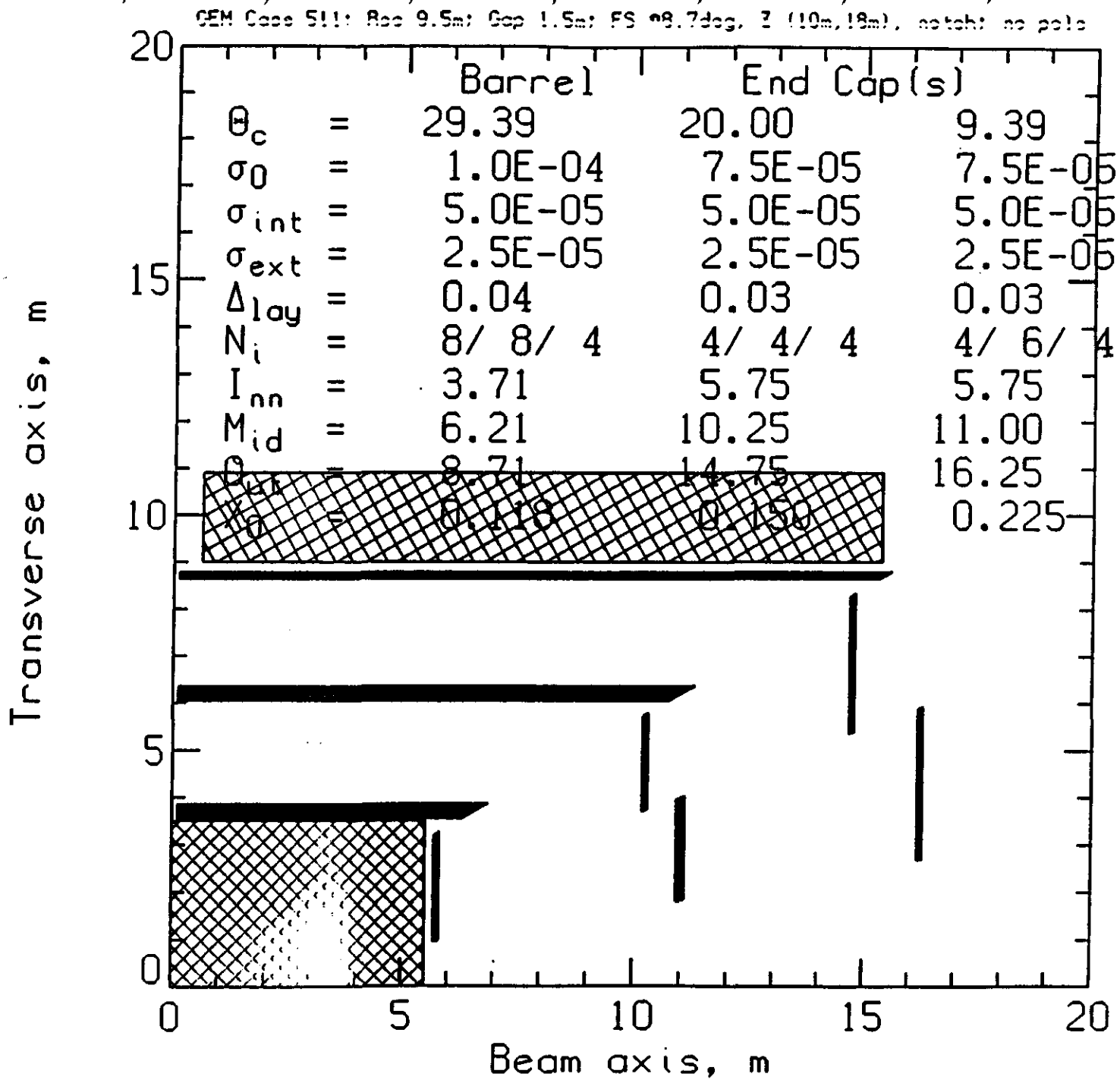
CONCLUSIONS:

Barrel 3.5 m OD for central detectors;
100 μm chambers in 8-8-4 superlayers

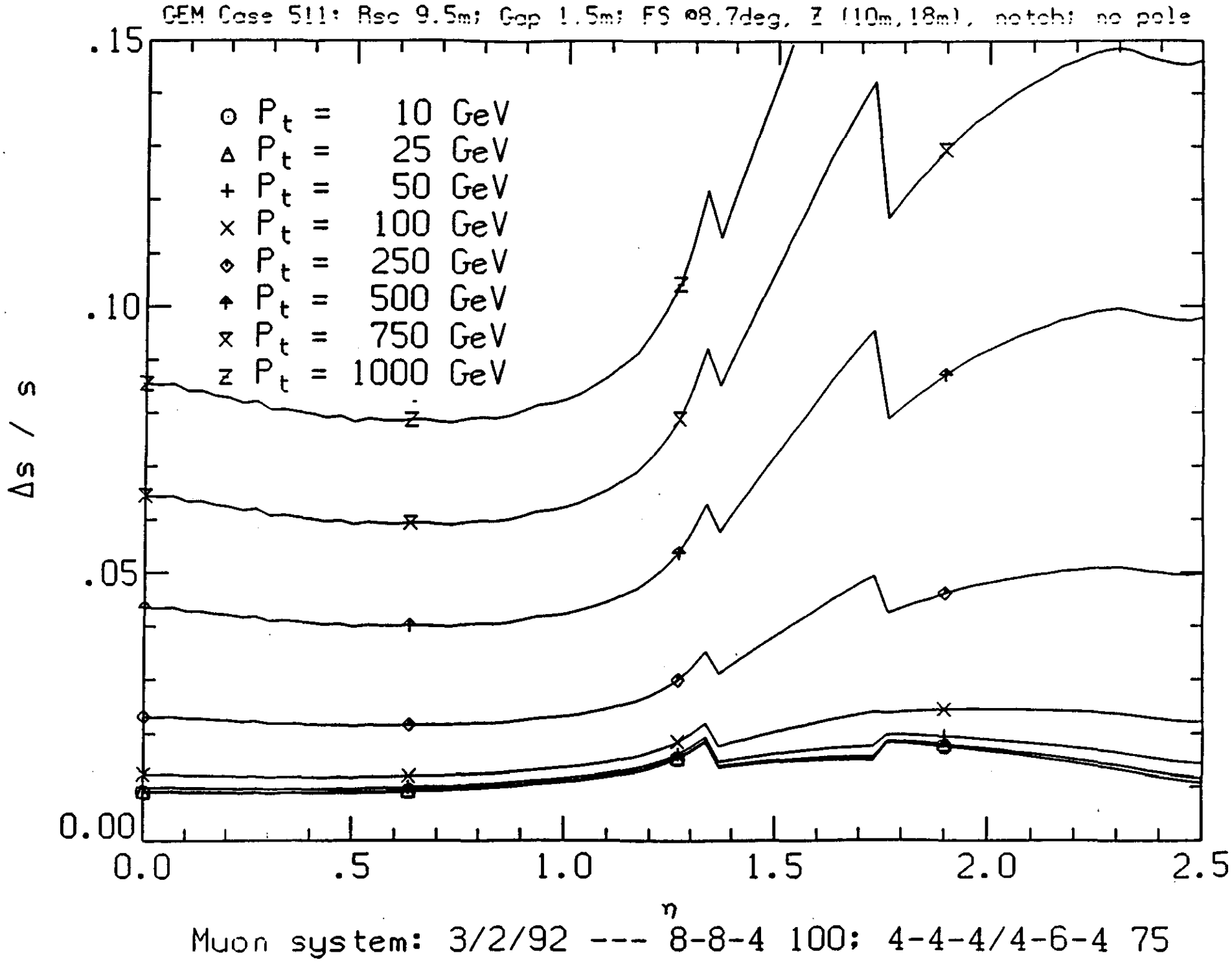
End Cap 5.5 m axial limit for central detectors;
75 μm chambers in 4-4-4/4-6-4 superlayers
split at 20° with outermost at 14.75/16.25 m

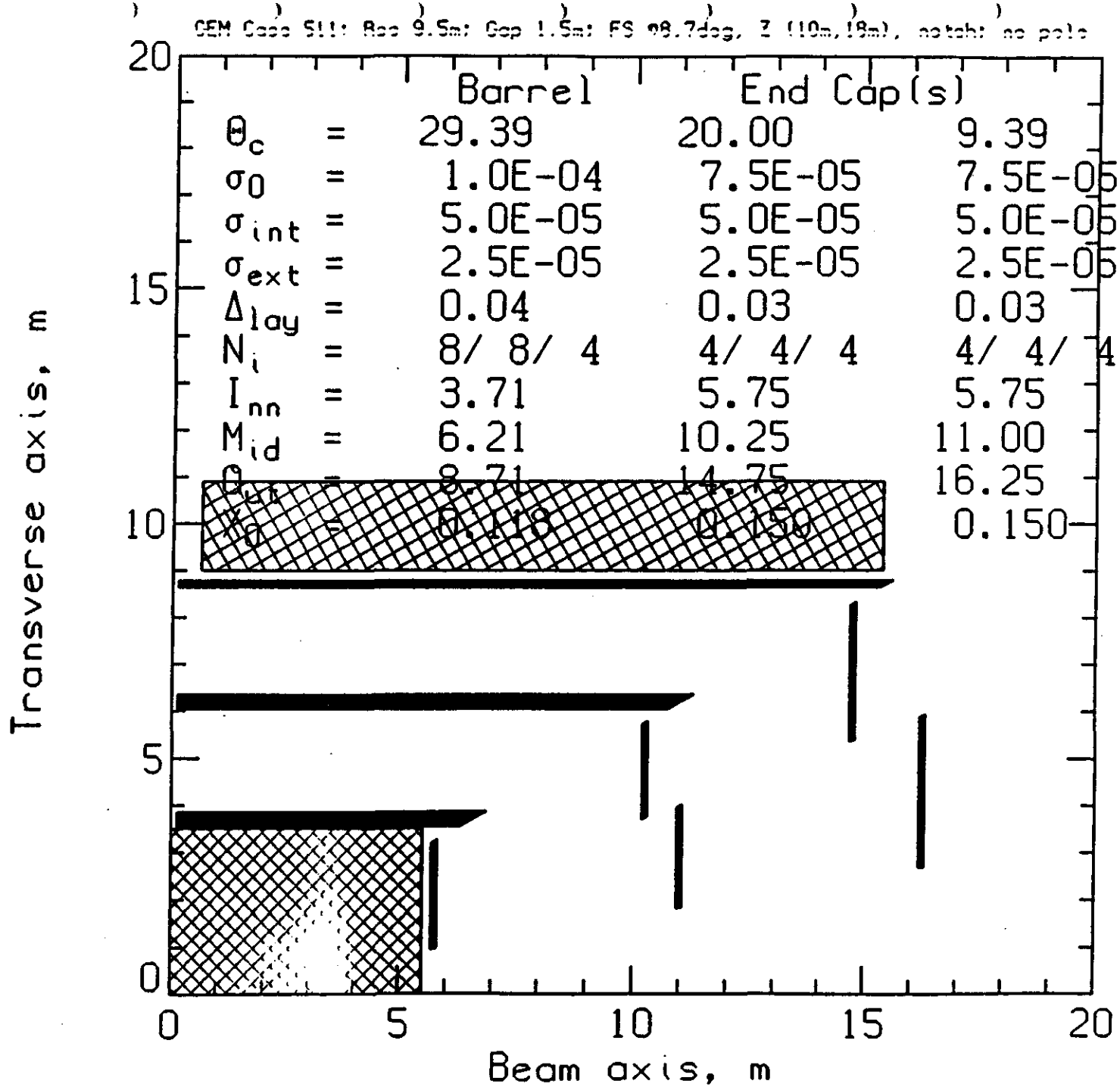


Muon system: 3/2/92 --- 8-8-4 100; 4-4-4/4-6-4 75

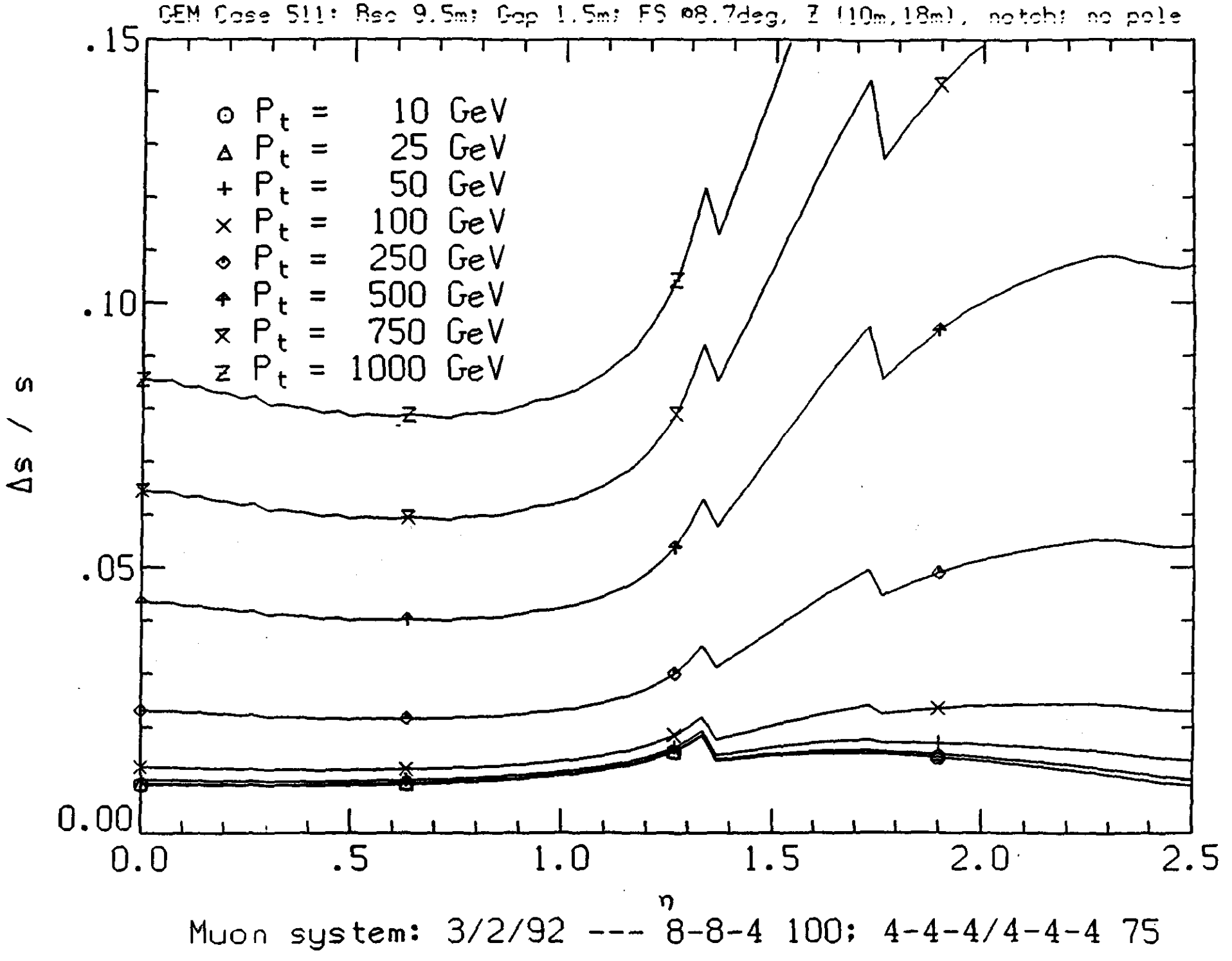


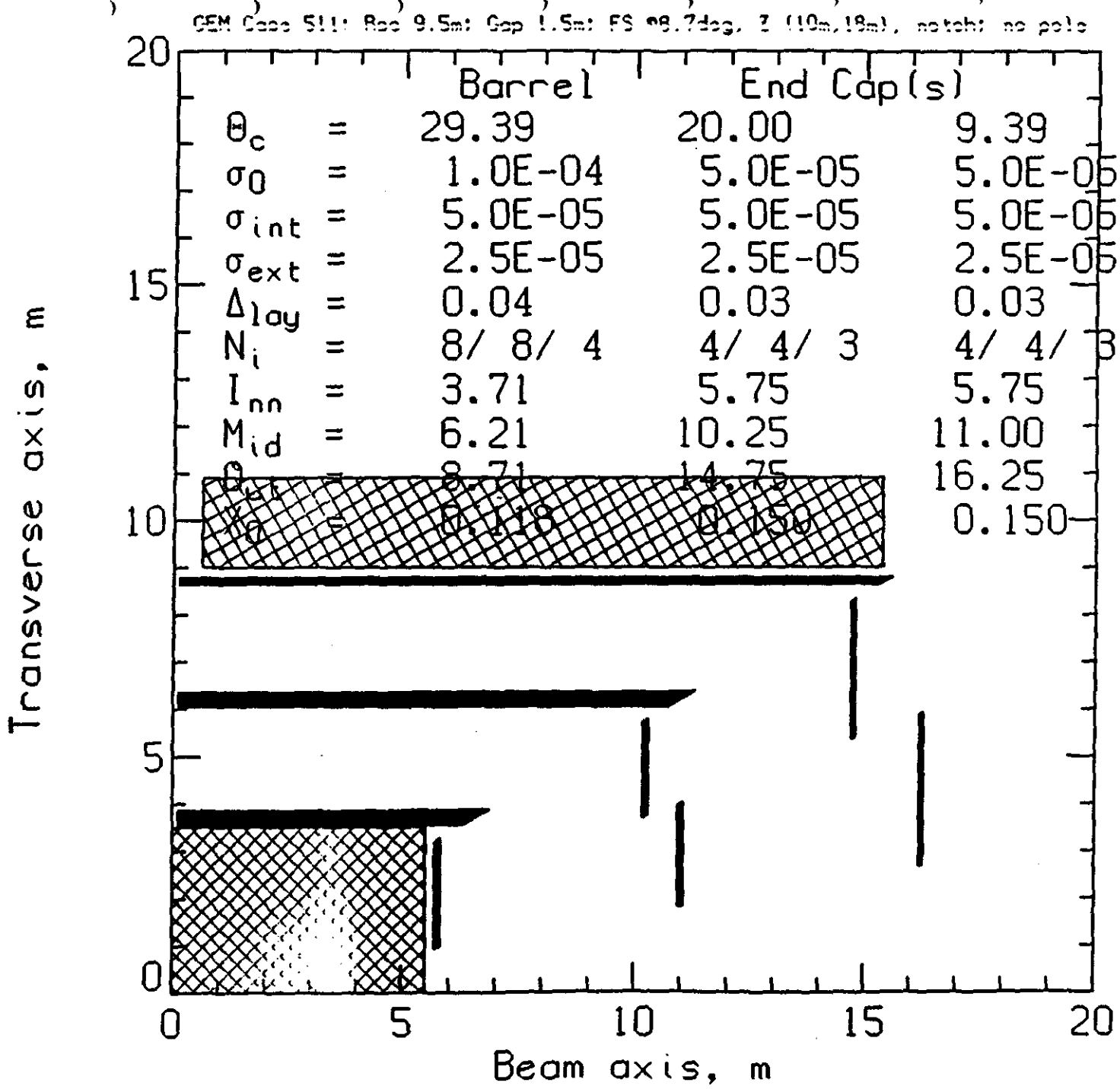
Muon system: 3/2/92 --- 8-8-4 100: 4-4-4/4-6-4 75


GEM Case 511: Rsc 9.5m; Gap 1.5m; FS @8.7deg, Z (10m,18m), notch; no pole
⊙ P_t = 10 GeV
△ P_t = 25 GeV
+ P_t = 50 GeV
× P_t = 100 GeV
◇ P_t = 250 GeV
↑ P_t = 500 GeV
⧖ P_t = 750 GeV
z P_t = 1000 GeV
.15
.10
.05
0.00
Δs / s
0.0
.5
1.0
1.5
2.0
2.5
η
Muon system: 3/2/92 --- 8-8-4 100; 4-4-4/4-6-4 75

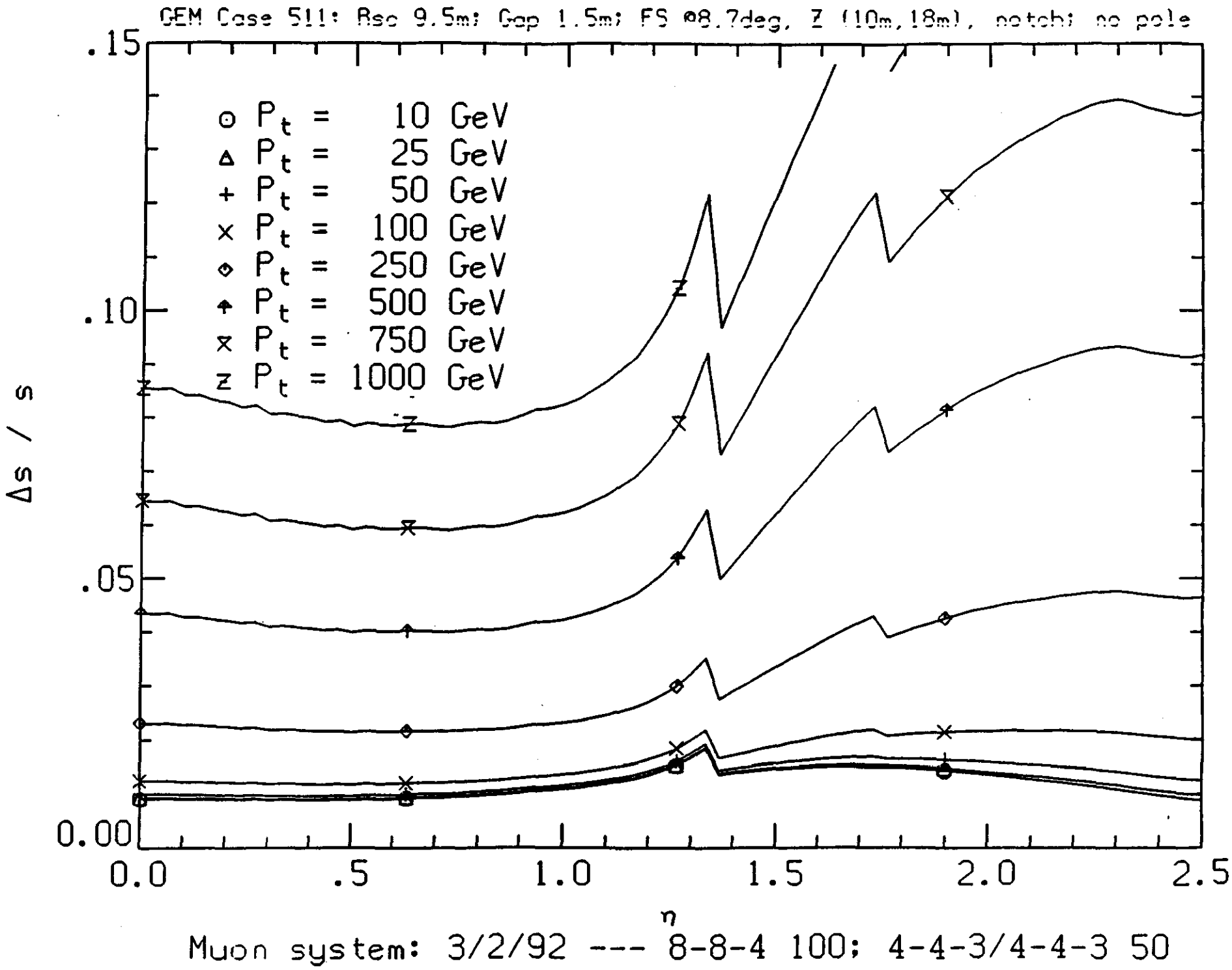


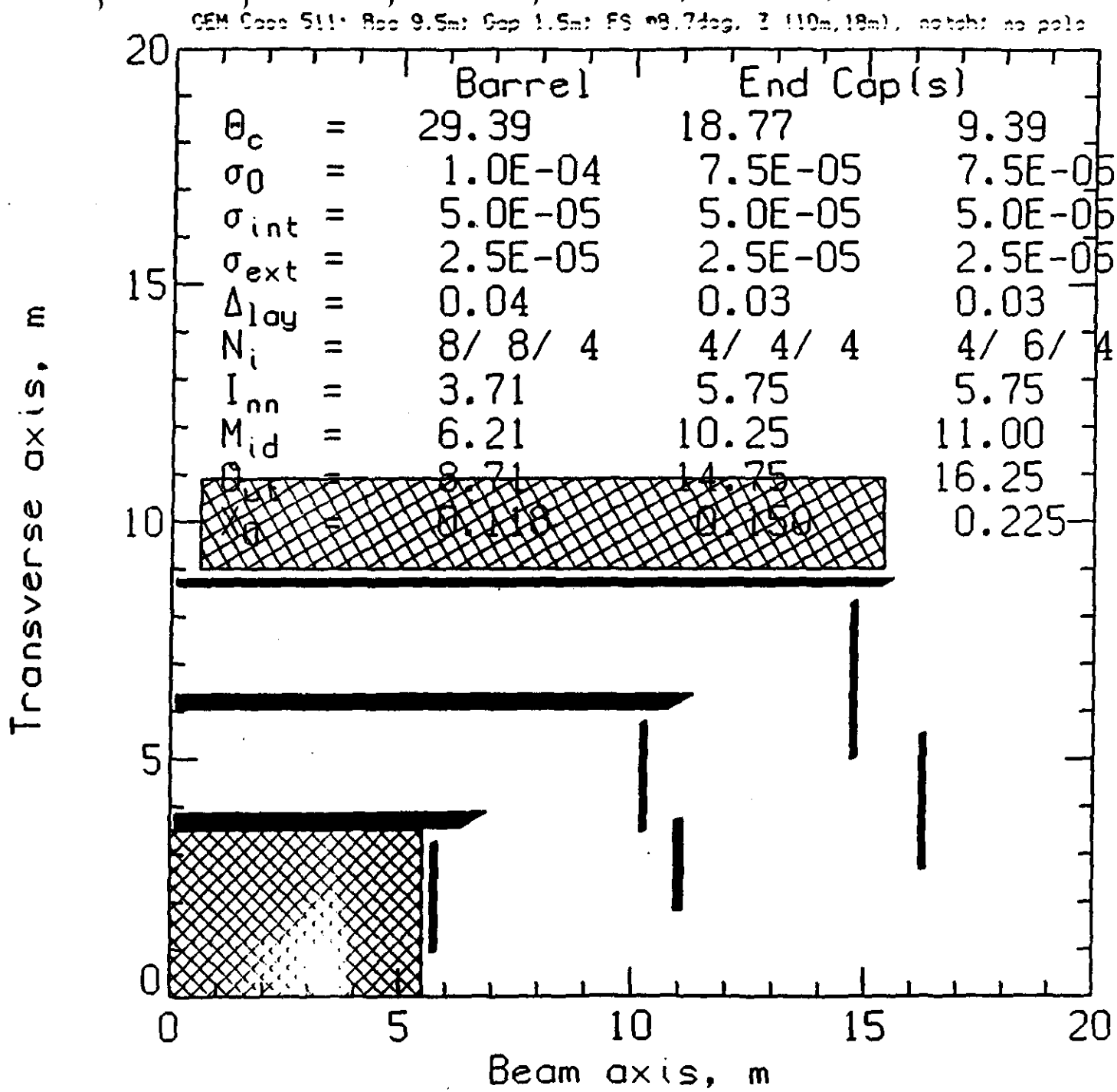
Muon system: 3/2/92 --- 8-8-4 100; 4-4-4/4-4-4 75


CEM Case 511: Rsc 9.5m; Gap 1.5m; FS ø8.7deg, Z (10m,18m), notch: no pole
⊙ P_t = 10 GeV
△ P_t = 25 GeV
+ P_t = 50 GeV
× P_t = 100 GeV
◇ P_t = 250 GeV
↑ P_t = 500 GeV
⧖ P_t = 750 GeV
z P_t = 1000 GeV
.15
.10
.05
0.00
Δs / s
0.0
.5
1.0
1.5
2.0
2.5
η
Muon system: 3/2/92 --- 8-8-4 100; 4-4-4/4-4-4 75

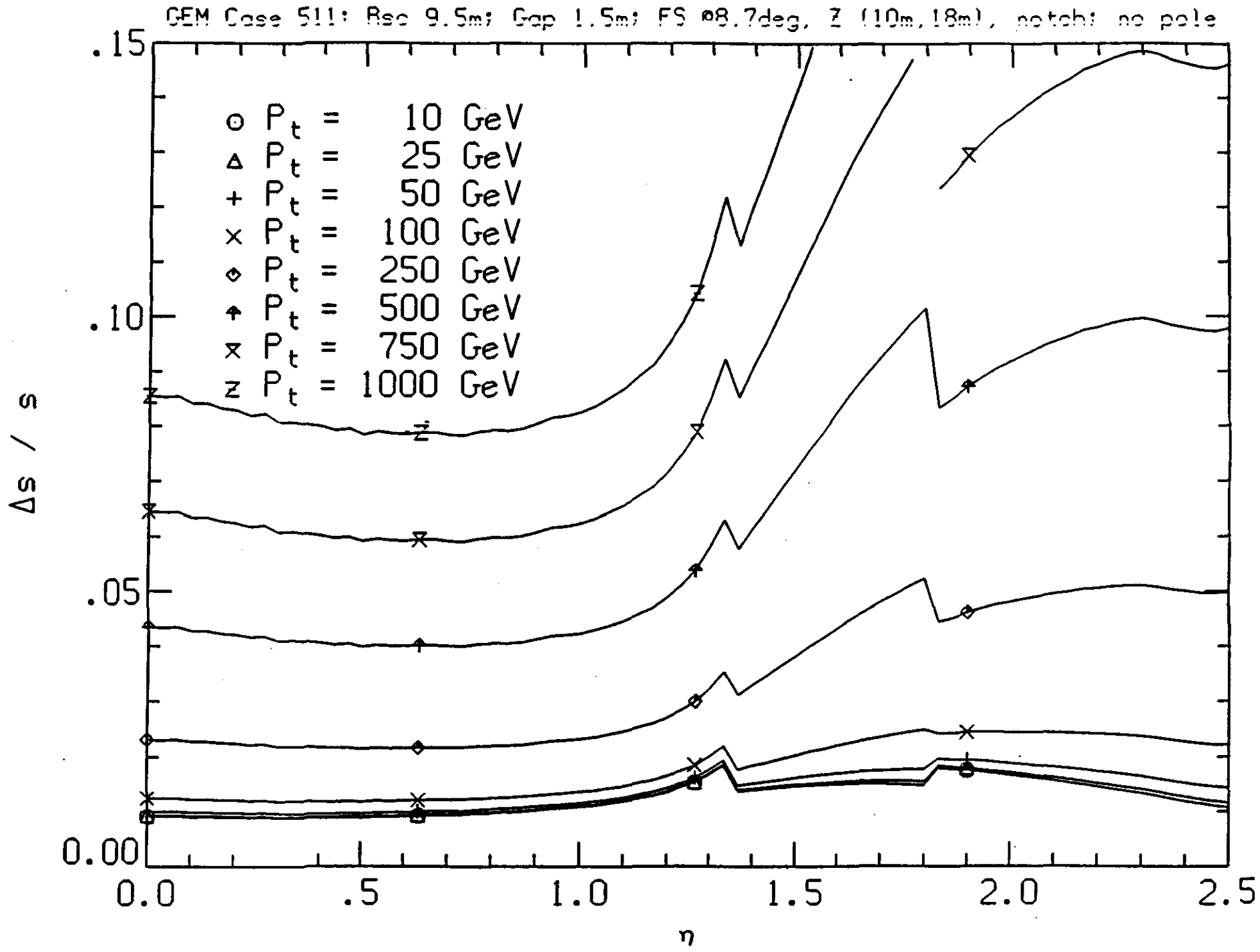


Muon system: 3/2/92 --- 8-8-4 100; 4-4-3/4-4-3 50

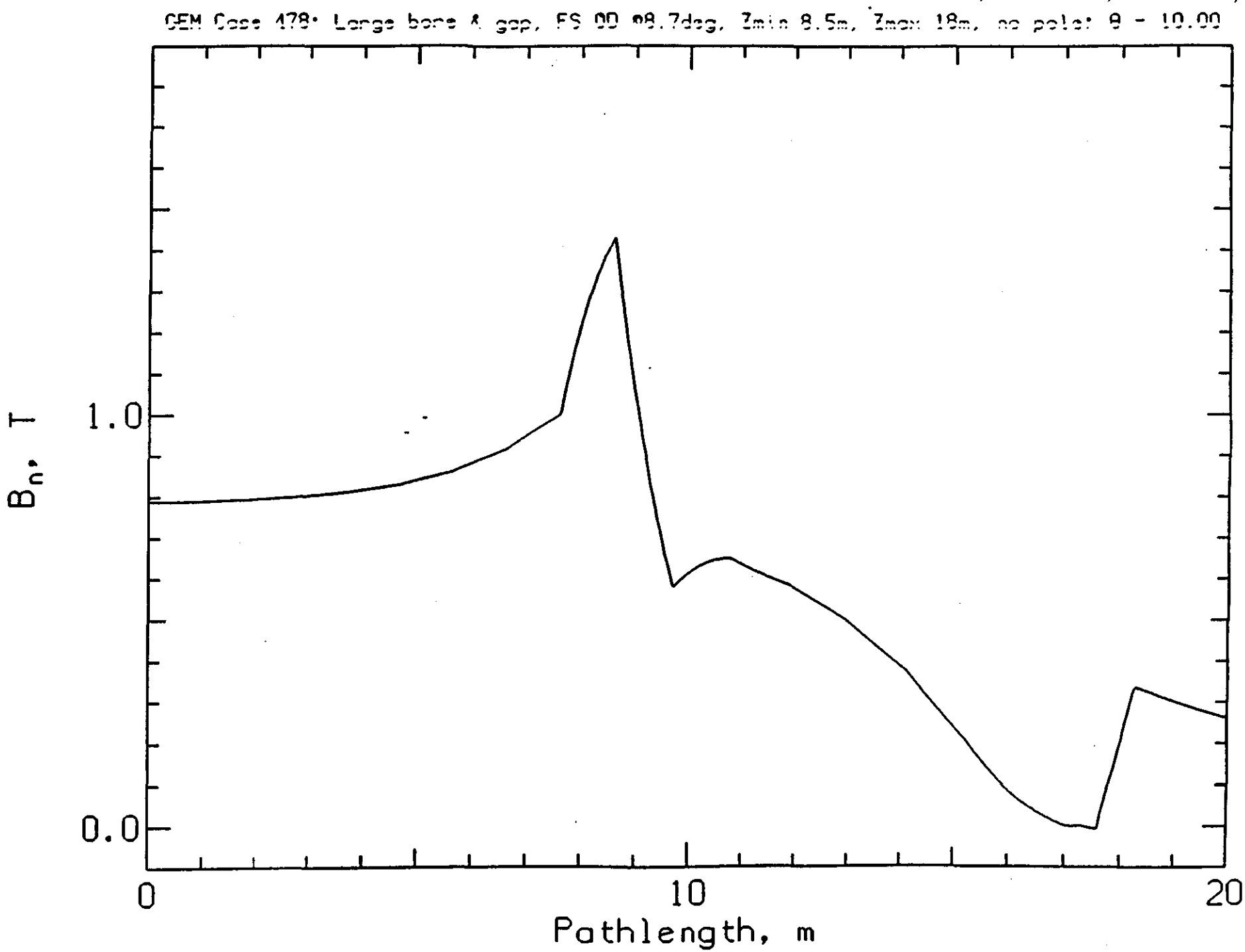

GEM Case 511: Rsc 9.5m; Gap 1.5m; FS @8.7deg, Z (10m,18m), notch; no pole
⊙ P_t = 10 GeV
△ P_t = 25 GeV
+ P_t = 50 GeV
× P_t = 100 GeV
◇ P_t = 250 GeV
↑ P_t = 500 GeV
⧖ P_t = 750 GeV
z P_t = 1000 GeV
.15
.10
.05
0.00
Δs / s
0.0
.5
1.0
1.5
2.0
2.5
η
Muon system: 3/2/92 --- 8-8-4 100; 4-4-3/4-4-3 50

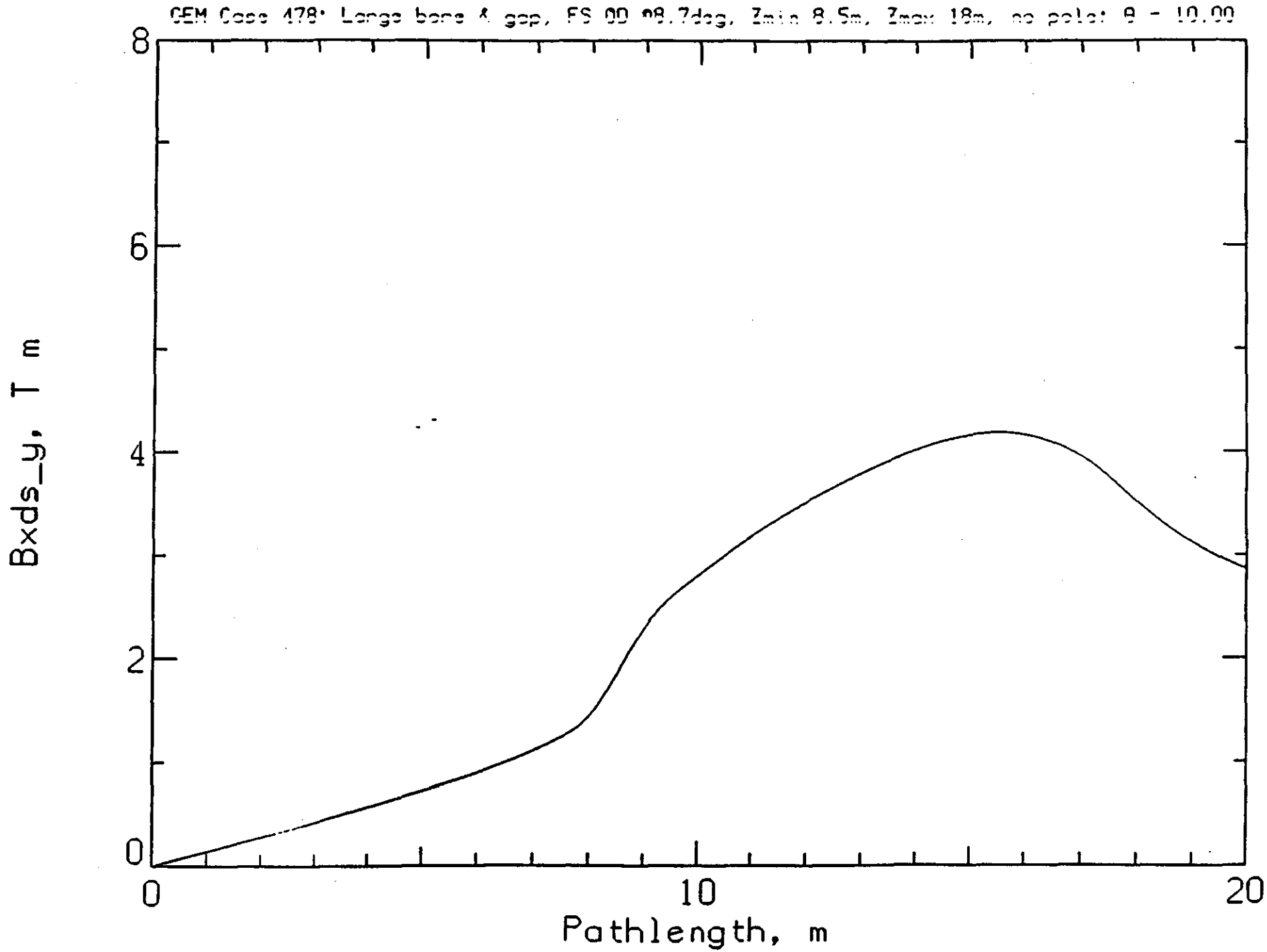


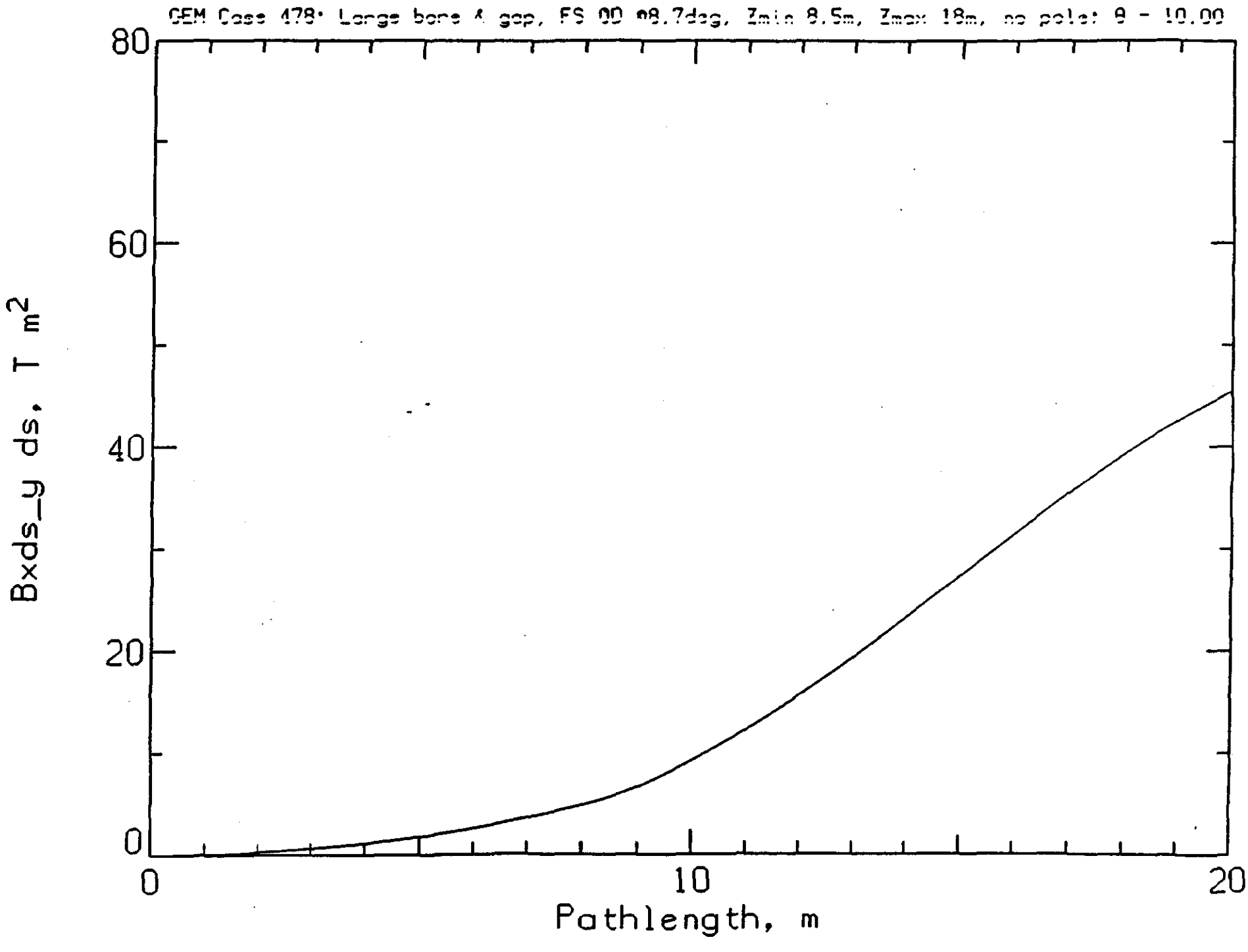
Muon system: 3/5/92 --- 8-8-4 100: 4-4-4/4-6-4 75

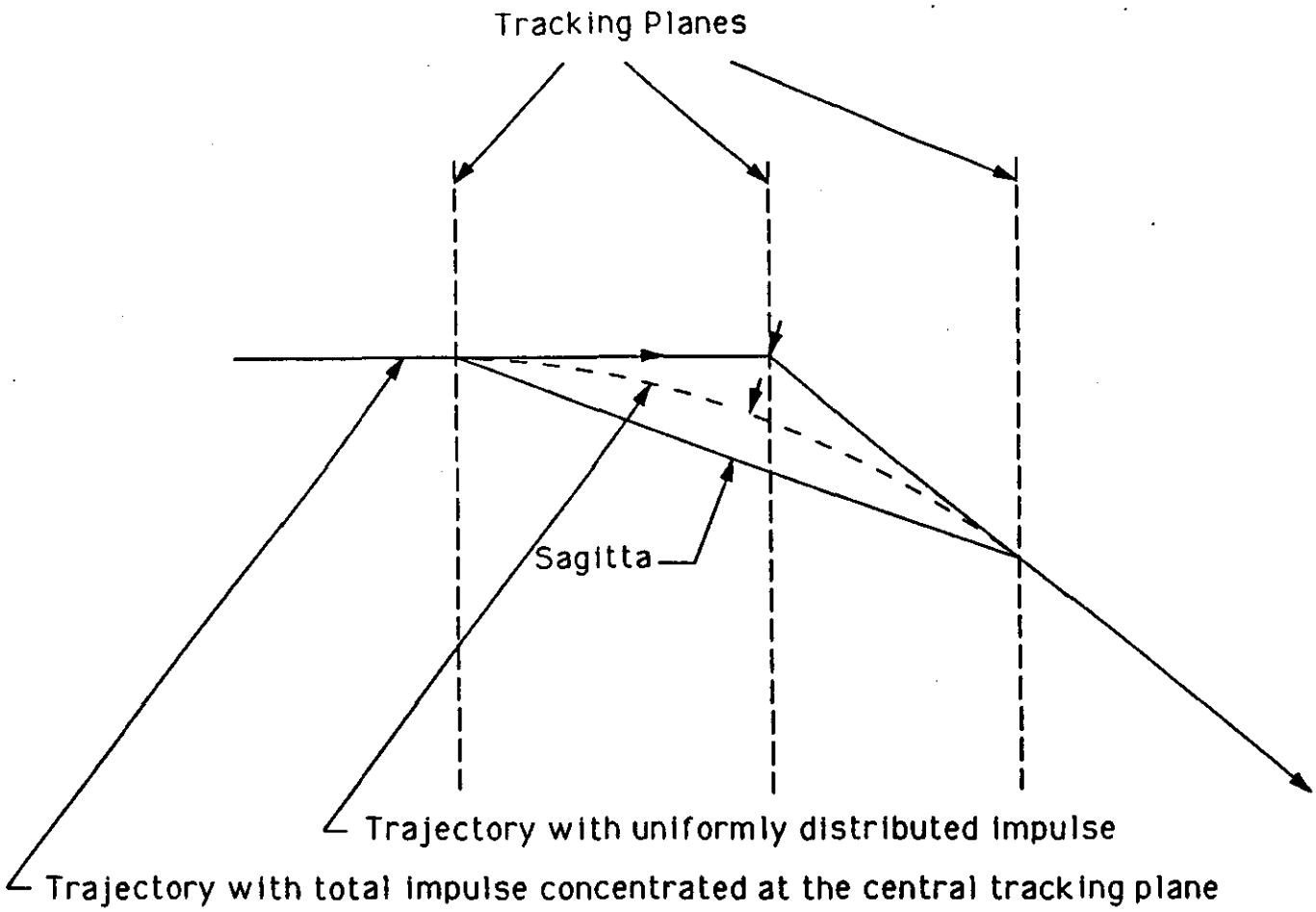


Muon system: 3/5/92 --- 8-8-4 100; 4-4-4/4-6-4 75


GEM Case 478: Large bore & gap, FS OD @8.7deg, Zmin 8.5m, Zmax 18m, no pole: 0 - 10.00
B_n, T
1.0
0.0
0
10
20
Pathlength, m


CEM Case 478: Large bore & gap, FS OD 98.7deg, Zmin 8.5m, Zmax 18m, no pole: 9 - 10.00
Bxds_y, T m
Pathlength, m
0
2
4
6
8
0
10
20

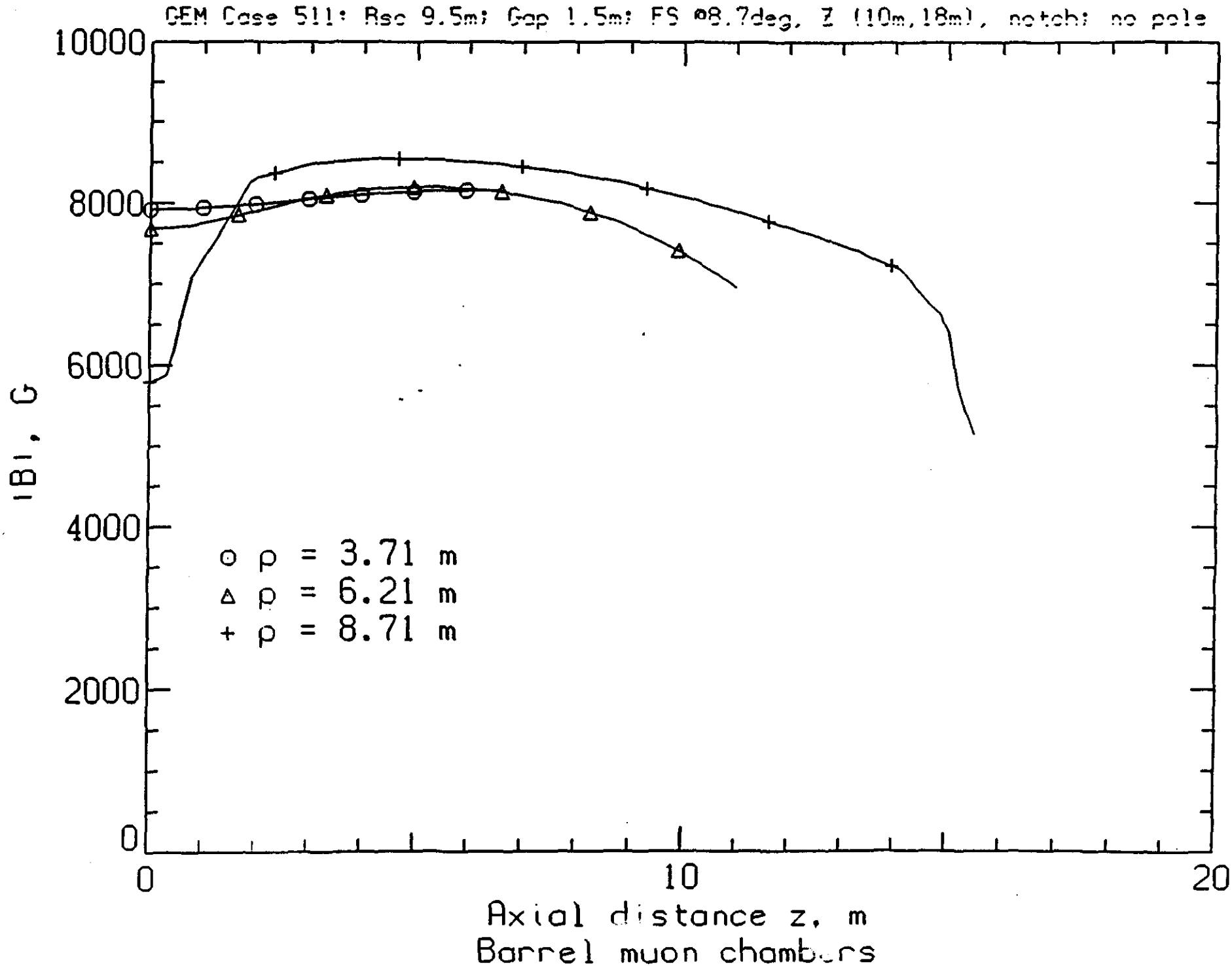

GEM Case 478: Large bore 4 gap, FS 00 @8.7deg, Zmin 8.5m, Zmax 18m, no pole: 0 - 10.00
80
60
40
20
0
Bxds_y ds, T m2
0
10
20
Pathlength, m

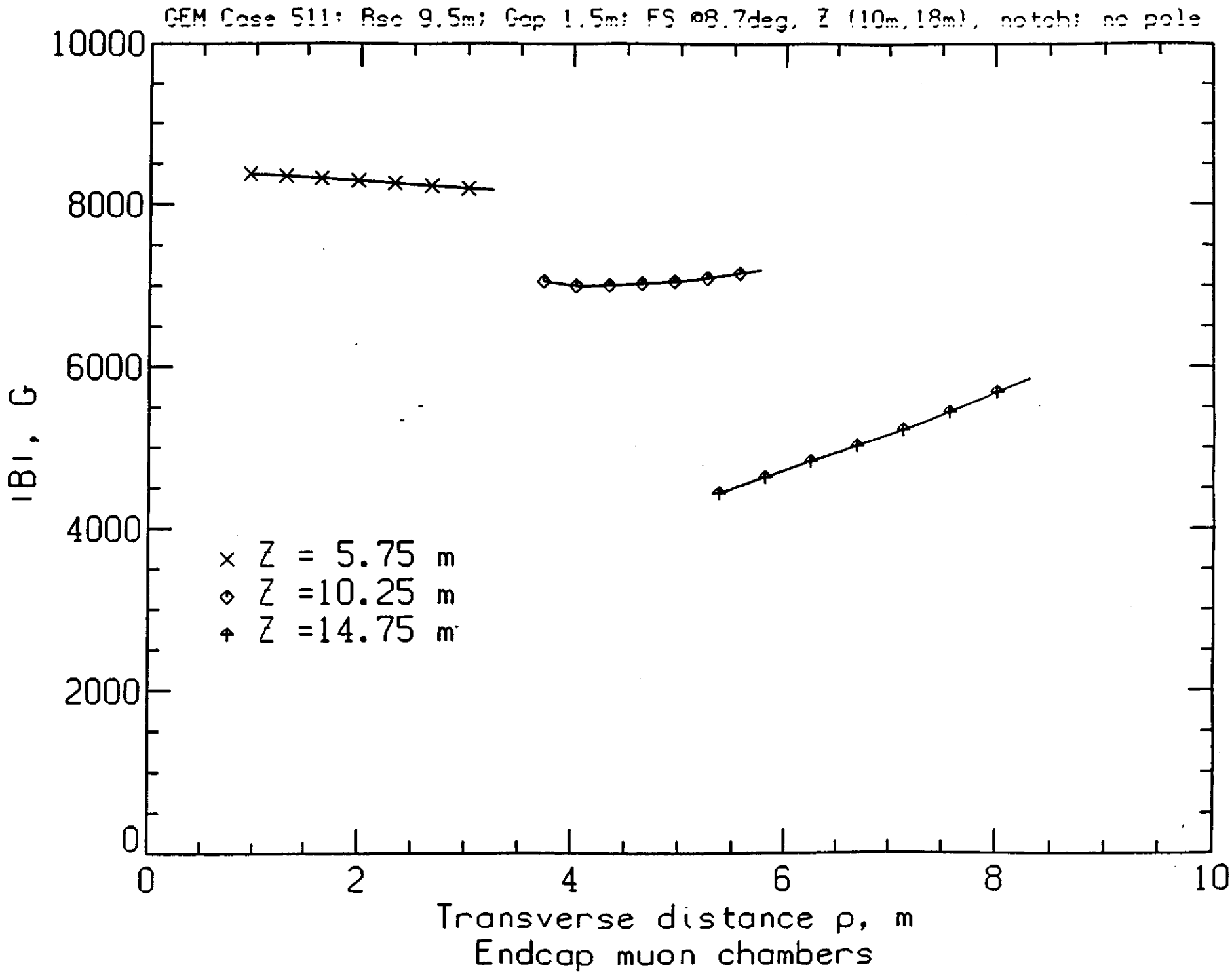


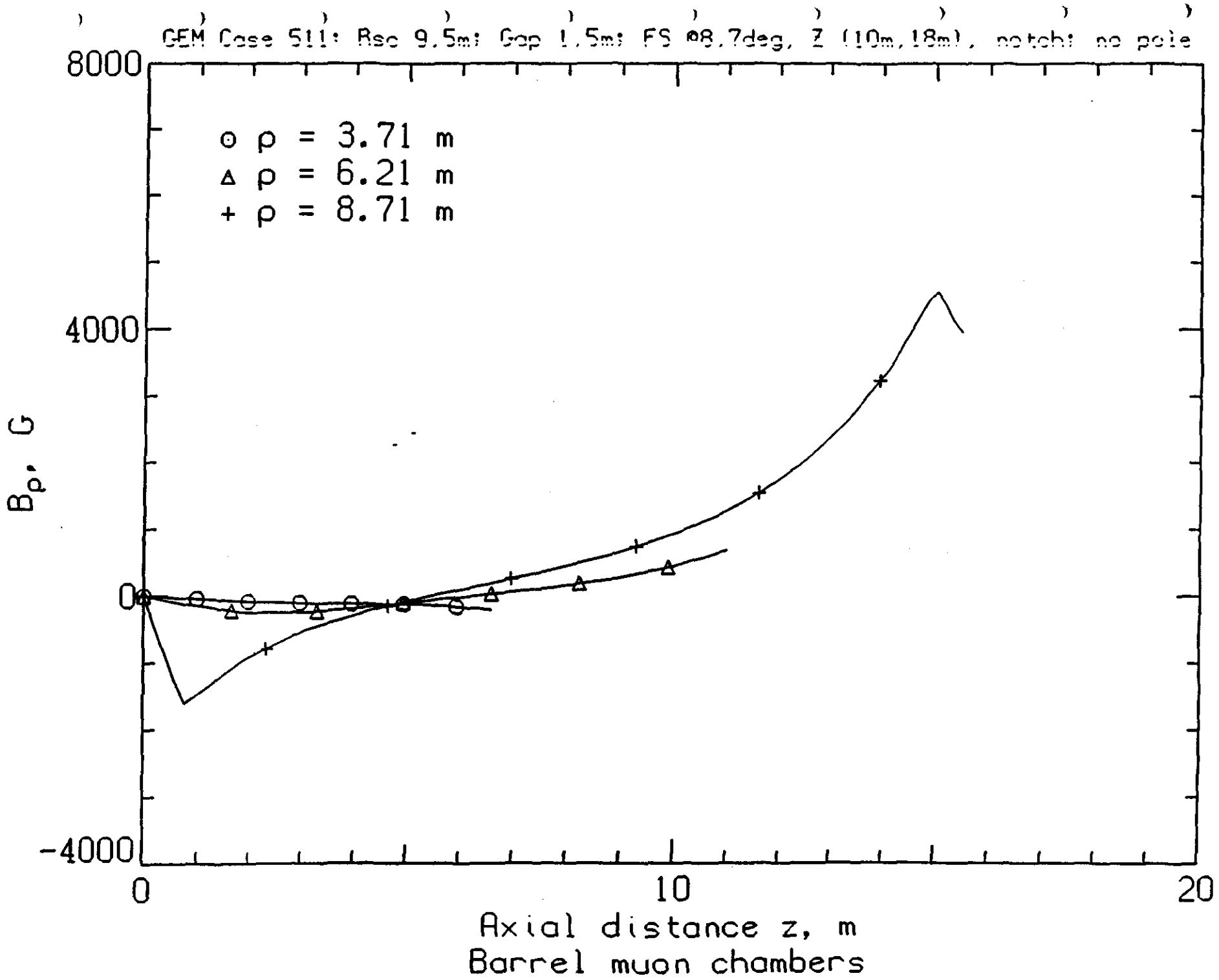
$$\text{impulse} = \int B dl$$

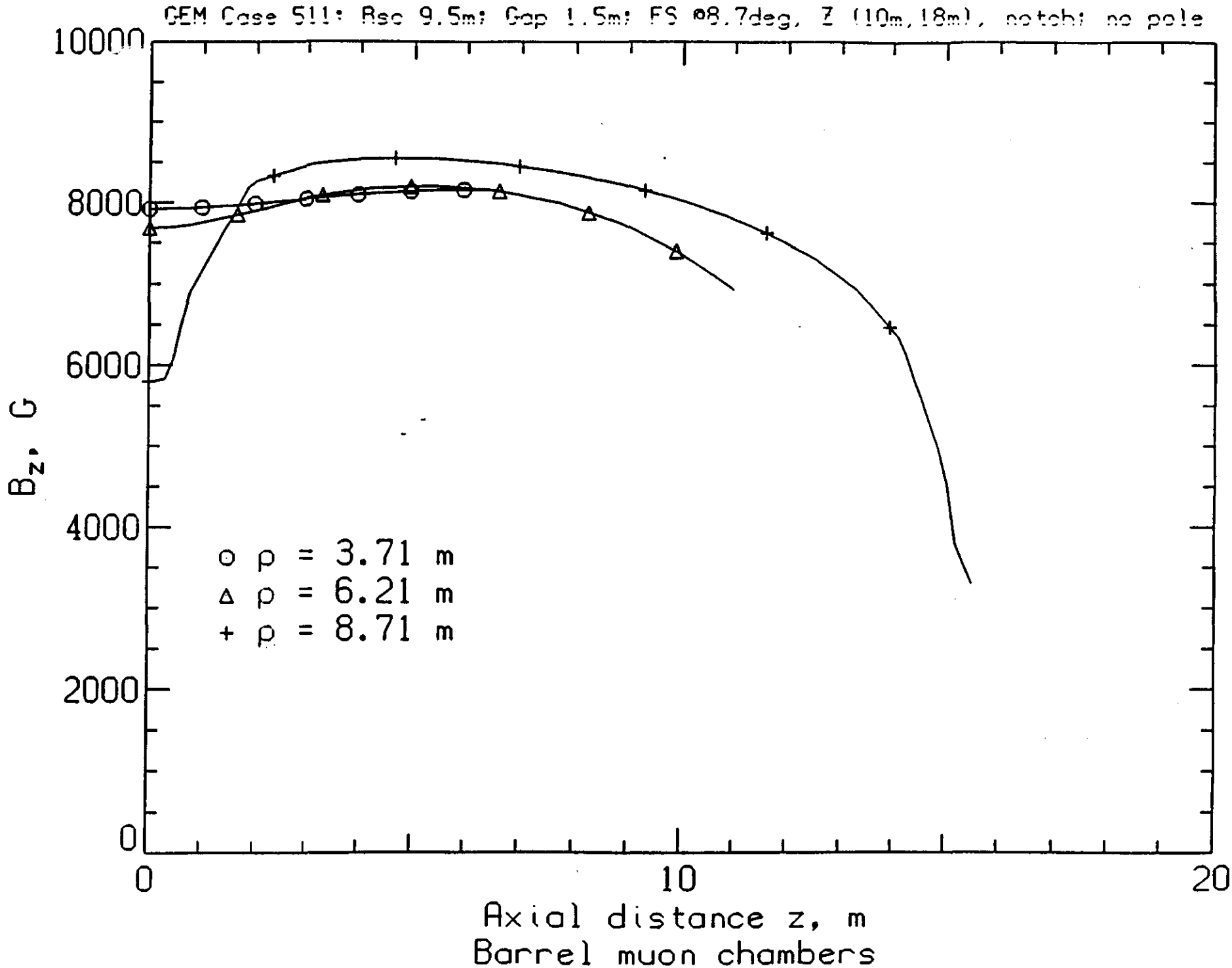
Although the 9.5 m flux concentrator (FC) has a slightly greater impulse, the 8 m long FC concentrates the radial field at the central plane resulting in a slightly greater sagitta.

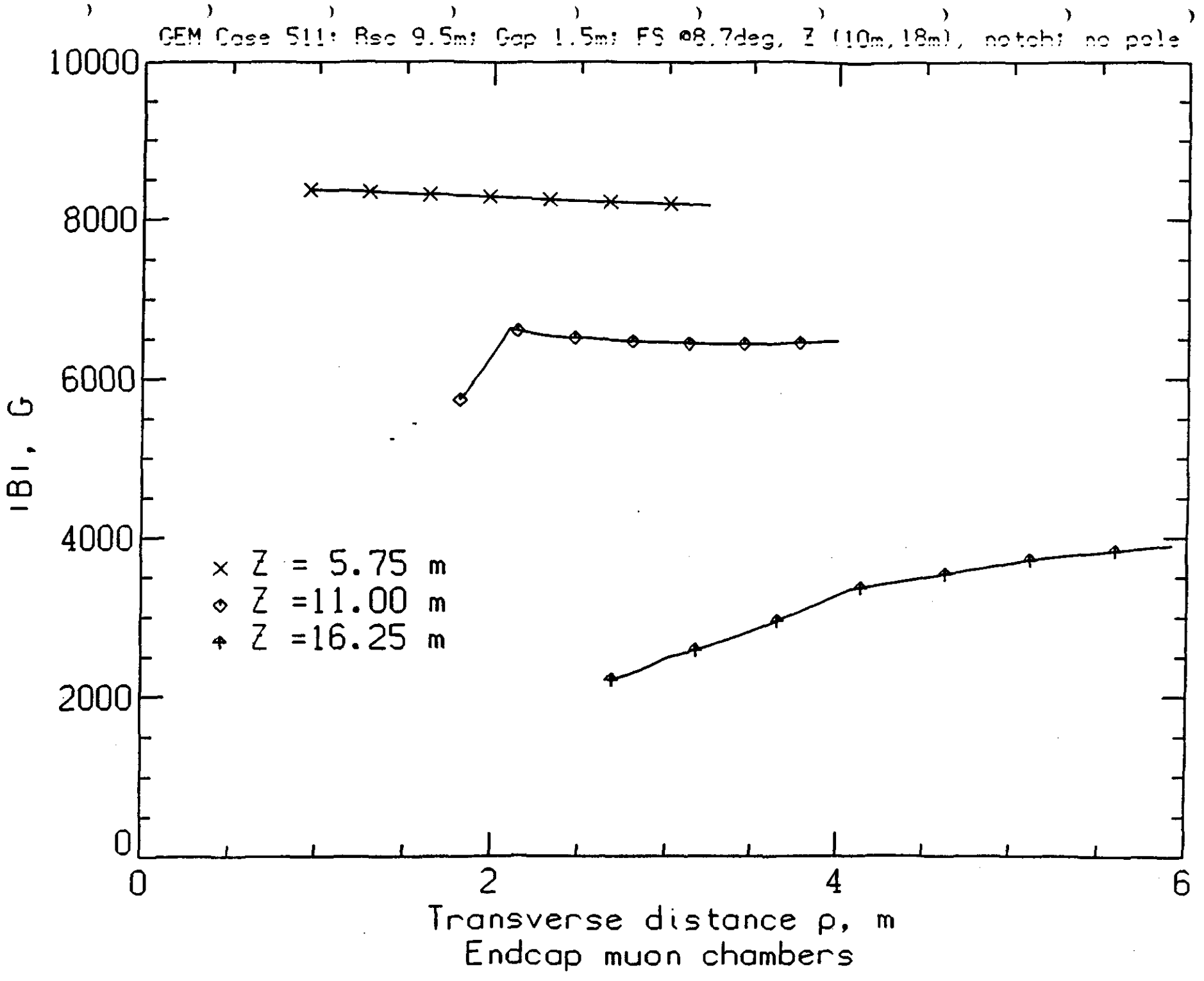
8 vs. 9.5 m Long Flux Concentrator

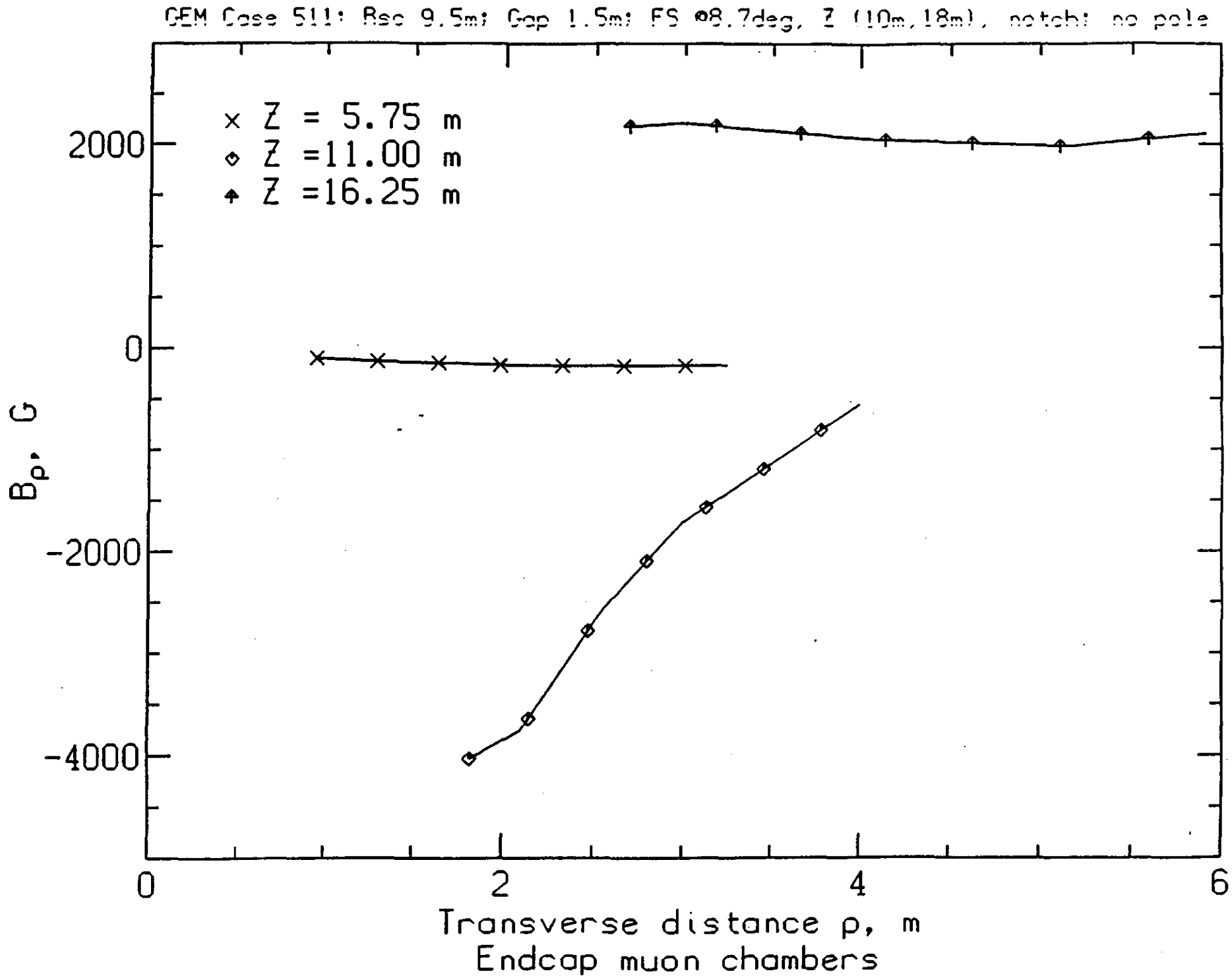

GEM Case 511: Rsc 9.5m; Gap 1.5m; FS @8.7deg, Z (10m,18m), notch: no pole
10000
8000
6000
4000
2000
0
|B|, G
0
10
20
Axial distance z, m
Barrel muon chambers
o ρ = 3.71 m
Δ ρ = 6.21 m
+ ρ = 8.71 m

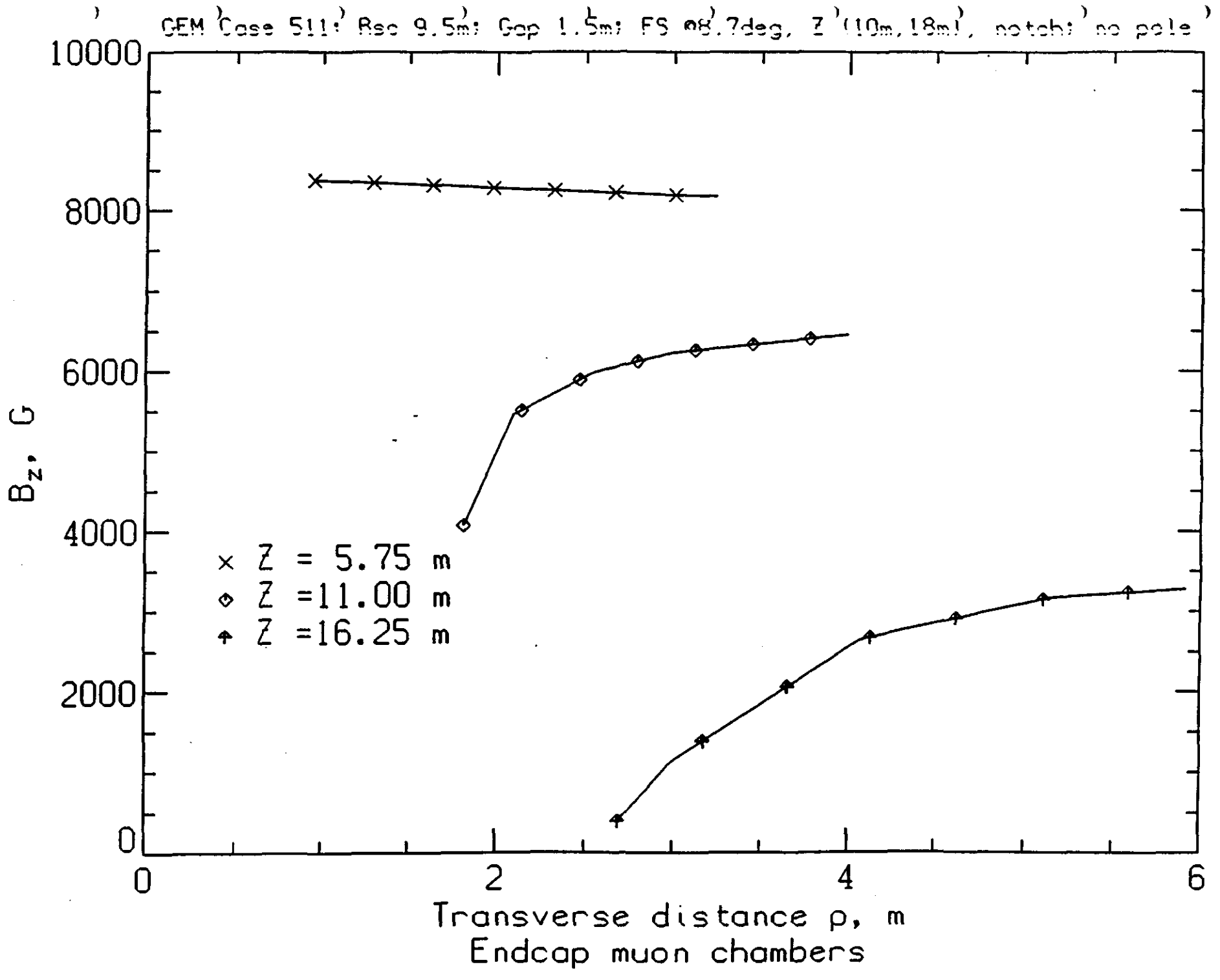

GEM Case 511: Rsc 9.5m; Gap 1.5m; FS @8.7deg, Z (10m,18m), notch: no pole
10000
8000
6000
4000
2000
0
|B|, G
0
2
4
6
8
10
Transverse distance ρ, m
Endcap muon chambers
× Z = 5.75 m
◇ Z =10.25 m
↑ Z =14.75 m

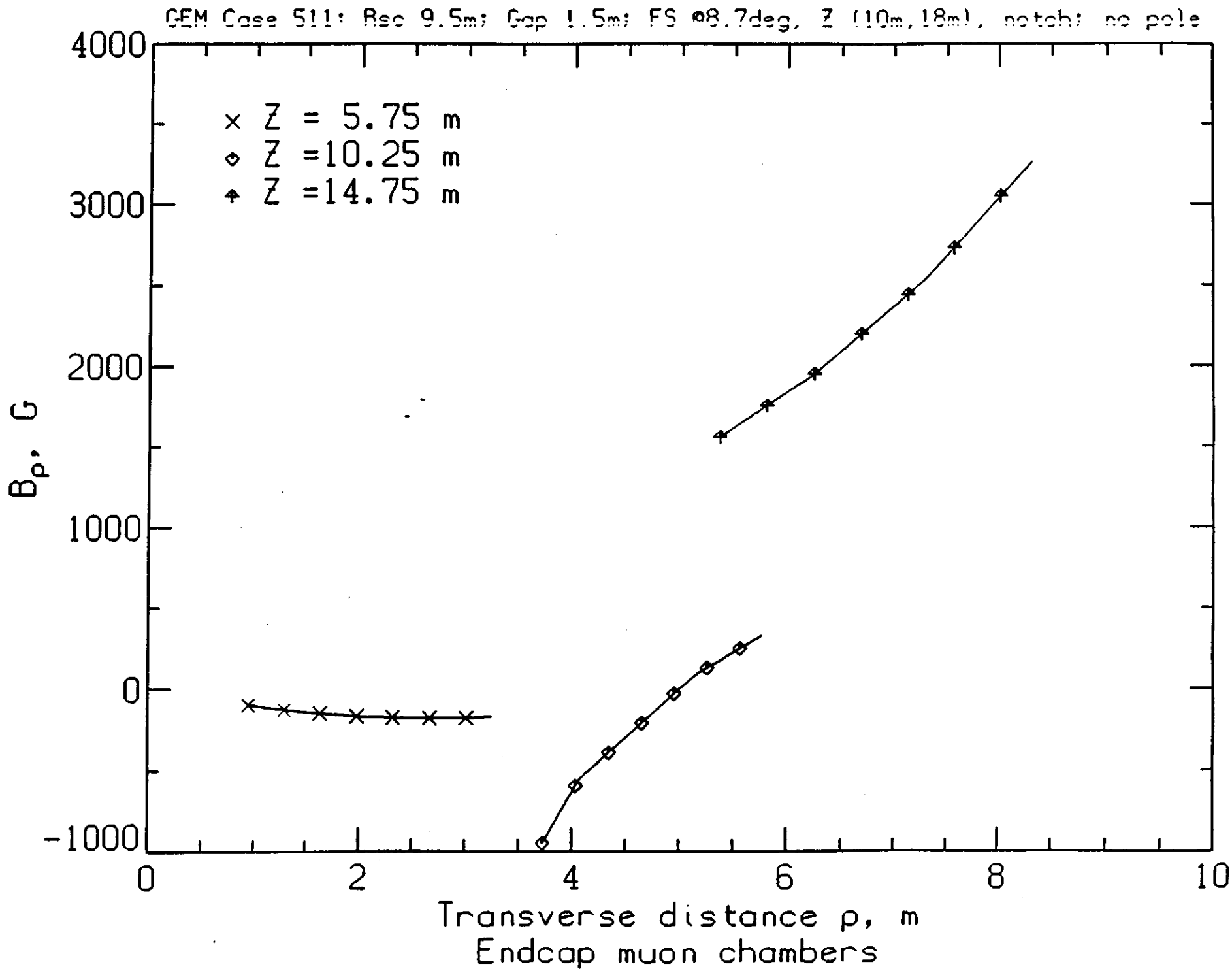

GEM Case 511: Rsc 9.5m; Gap 1.5m; FS @8.7deg, Z (10m,18m), notch: no pole
o ρ = 3.71 m
Δ ρ = 6.21 m
+ ρ = 8.71 m
8000
4000
0
-4000
B_ρ, G
0
10
20
Axial distance z, m
Barrel muon chambers

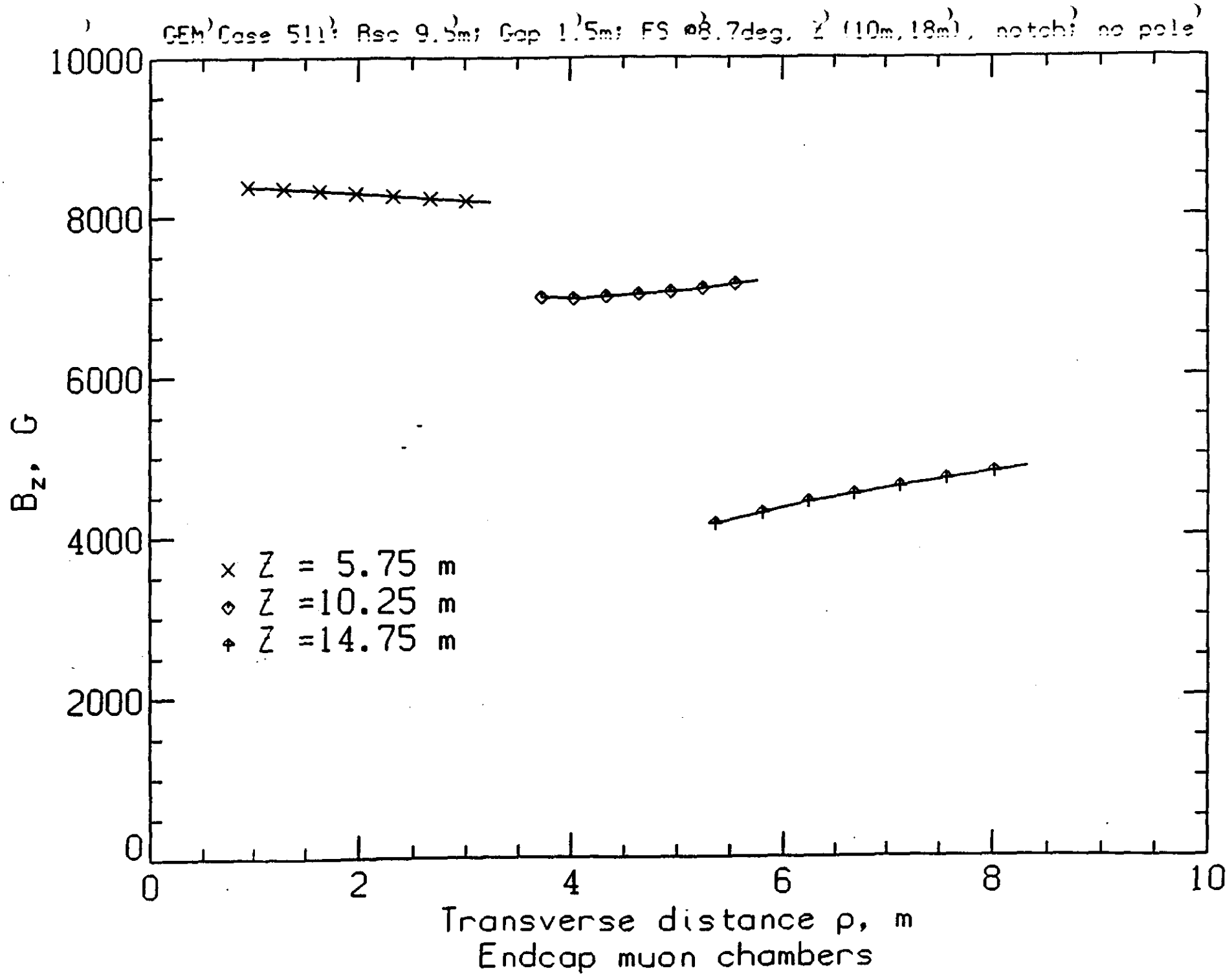

GEM Case 511: Rsc 9.5m; Gap 1.5m; FS @8.7deg, Z (10m,18m), notch; no pole
10000
8000
6000
4000
2000
0
B_z, G
o ρ = 3.71 m
Δ ρ = 6.21 m
+ ρ = 8.71 m
0
10
20
Axial distance z, m
Barrel muon chambers


GEM Case 511: Rsc 9.5m; Gap 1.5m; FS @8.7deg, Z (10m,18m), notch; no pole
10000
8000
6000
4000
2000
0
|B|, G
× Z = 5.75 m
◇ Z =11.00 m
+ Z =16.25 m
0
2
4
6
Transverse distance ρ, m
Endcap muon chambers


GEM Case 511: Rsc 9.5m; Gap 1.5m; FS @8.7deg, Z (10m,18m), notch: no pole
× Z = 5.75 m
◇ Z =11.00 m
♠ Z =16.25 m
2000
0
-2000
-4000
B_ρ, G
0
2
4
6
Transverse distance ρ, m
Endcap muon chambers


GEM Case 511: Rsc 9.5m: Gap 1.5m: FS ø8.7deg, Z (10m,18m), notch: no pole
10000
8000
6000
4000
2000
0
B_z, G
× Z = 5.75 m
◇ Z =11.00 m
↑ Z =16.25 m
0
2
4
6
Transverse distance ρ, m
Endcap muon chambers


GEM Case 511: Rsc 9.5m; Gap 1.5m; FS @8.7deg, Z (10m,18m), notch: no pole
× Z = 5.75 m
◇ Z =10.25 m
+ Z =14.75 m
4000
3000
2000
1000
0
-1000
B_ρ, G
0
2
4
6
8
10
Transverse distance ρ, m
Endcap muon chambers


GEM Case 511: Rsc 9.5m; Gap 1.5m; FS ø8.7deg, Z (10m,18m), notch; no pole
10000
8000
6000
4000
2000
0
B_z, G
× Z = 5.75 m
◇ Z =10.25 m
+ Z =14.75 m
0
2
4
6
8
10
Transverse distance ρ, m
Endcap muon chambers

Field Mapping Concept:

Use a finite number of measurements and an analytic fit to determine field in active detector volume.

Only need measure one component of the field as $B = \nabla \Psi_m$,

$$\Psi_m = c^i f_i$$

where Ψ_m is the magnetic scalar potential, c^i are the coefficients, and f_i are basis functions. So that,

$$B_\rho = \frac{1}{\rho}\frac{\partial \Psi_m}{\partial \rho} = \frac{c^i}{\rho}\frac{\partial f_i}{\partial \rho}$$

Field Mapping Next Step:

Initial study to determine what accuracy of measurement is needed, to compare accuracy, cost, and time of measurement with conventional techniques, and to define necessary field transducers (e.g., search coils, Hall probes, NMR probes, etc.) their number and spatial distribution.

In central detector volume, it can certainly be done; numerical simulation (experiment) will refine and scope technique.

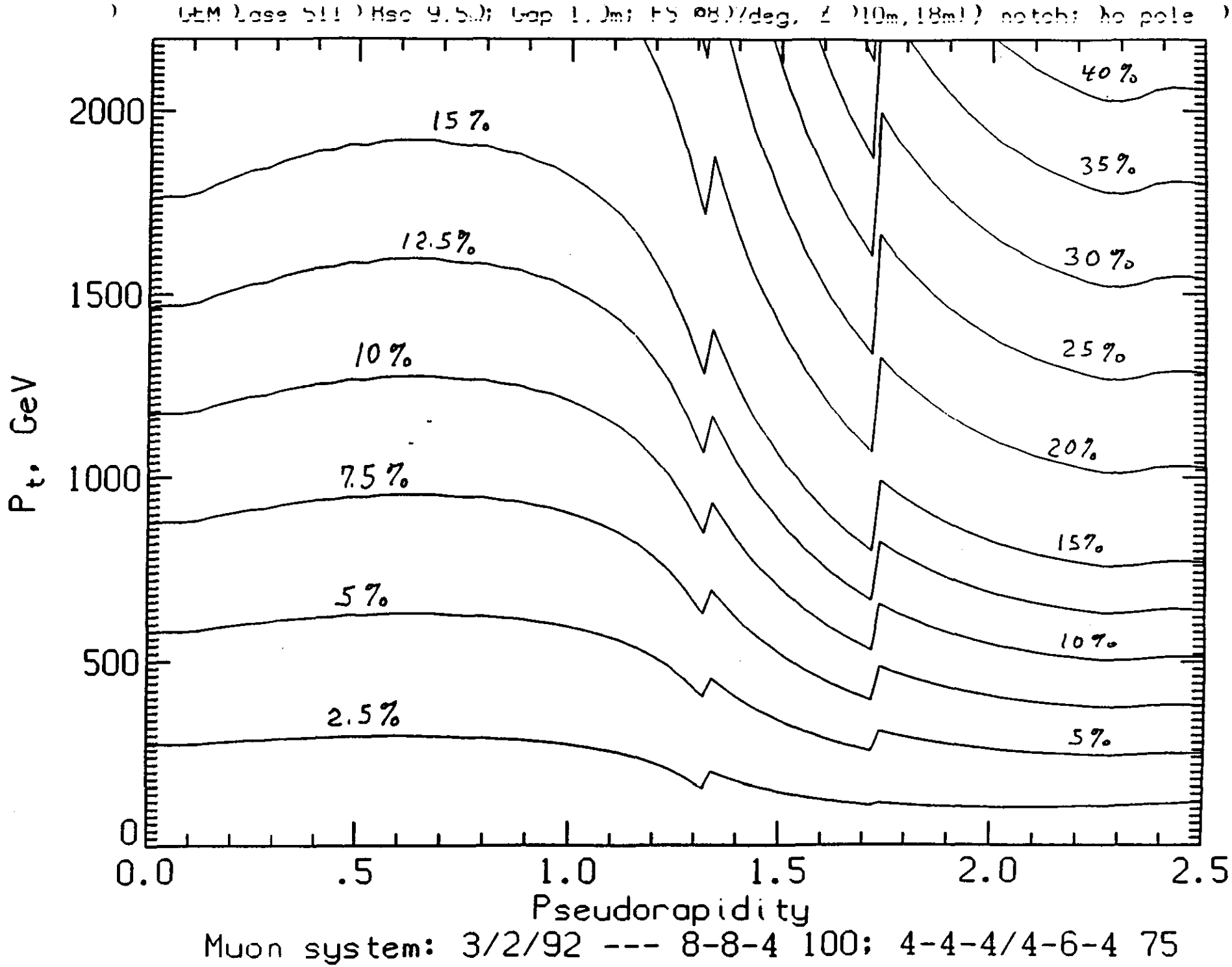
In muon detector volume, it is more complex and will require careful evaluation of choice of basis and number of measurements.

Need to know what accuracy, components, threshold values, etc before definitive results can be given.

Simulation Group:

Have supplied for case 511 (also LoI baseline, 332, and 478) and for a current muon detector configuration —

1. Field map and subprogram to read and to interpolate the field GUFLD.FOR,
2. Muon resolution function subprogram RESMAG.FOR, and
3. Magnet and flux concentrator geometry for case 511.



Muon system: 3/2/92 --- 8-8-4 100; 4-4-4/4-6-4 75

Properties of the Calorimeter:

(1) Hadron Punchthrough:
(R. McNeil)

Barrel Region: $0 < \eta < 1.3$

Criteria for determining calorimeter depth:

(1) For $L \approx 10^{34}$ /cm^2 sec rate of particles in first superlayer should be < 20 Hz/cm^2.

Find number of $\lambda > 10$

(2) The overall rate of particles exiting the calorimeter from hadron punchthrough should be much less than the sum of rates from prompt muons and π/K decay muons.

Find number of $\lambda > 12$

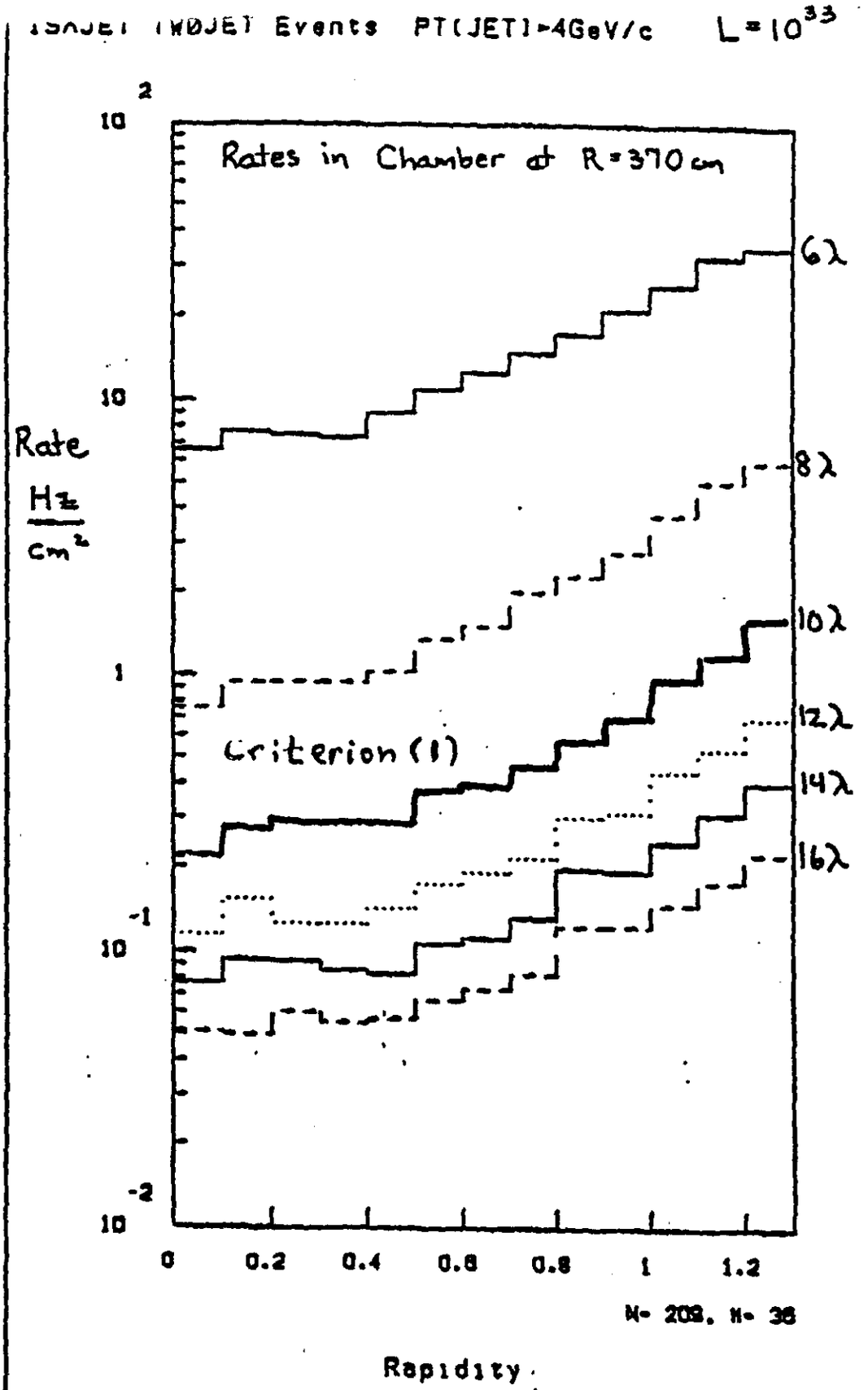
(3) The rate of particles with transverse momenta above a trigger threshold from hadron punchthrough should be less than that from prompt muons and π/K decay muons.

Find number of $\lambda > 10$

Conclusion:

Number of interaction lengths in barrel section of calorimeter should be thicker than 12 λ.

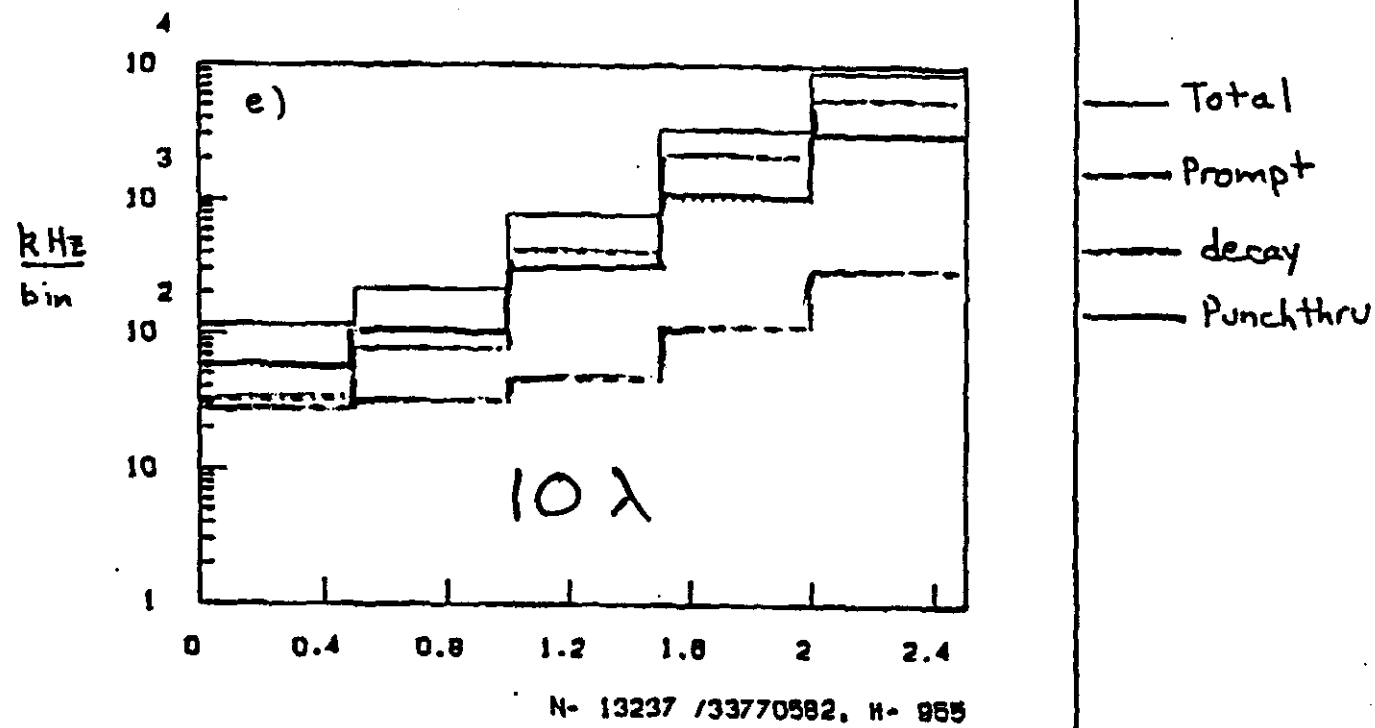
Endcaps will probably require 14 λ (being evaluated).



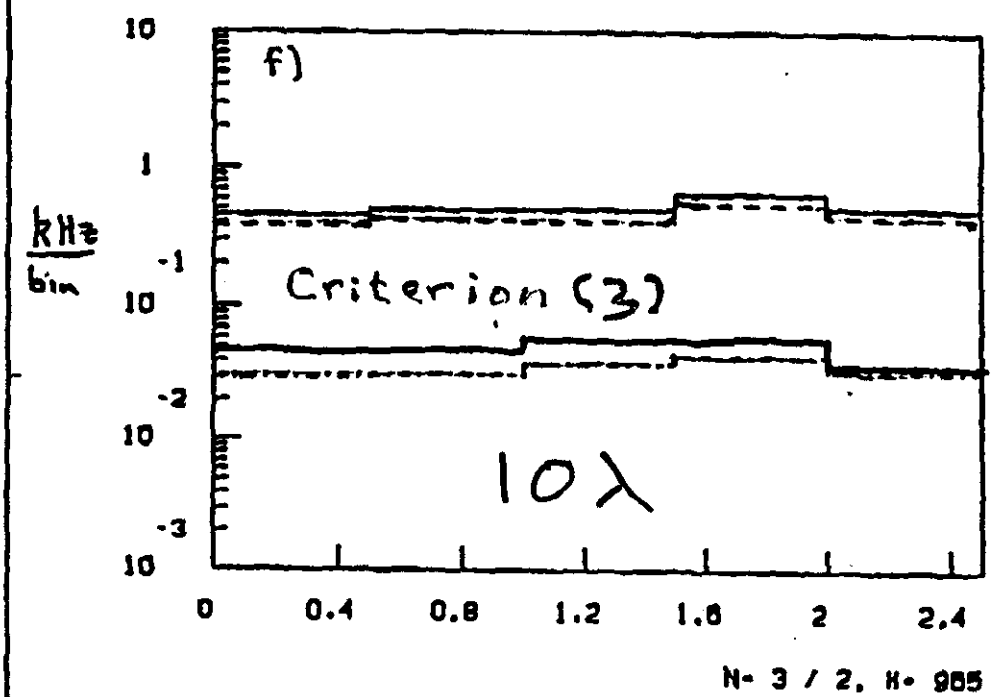
Rates after Constant Thickness Calorimeter

Figure 3

ISAJET TWOJET Events PT(JET)>4GeV/c L=10^{33}



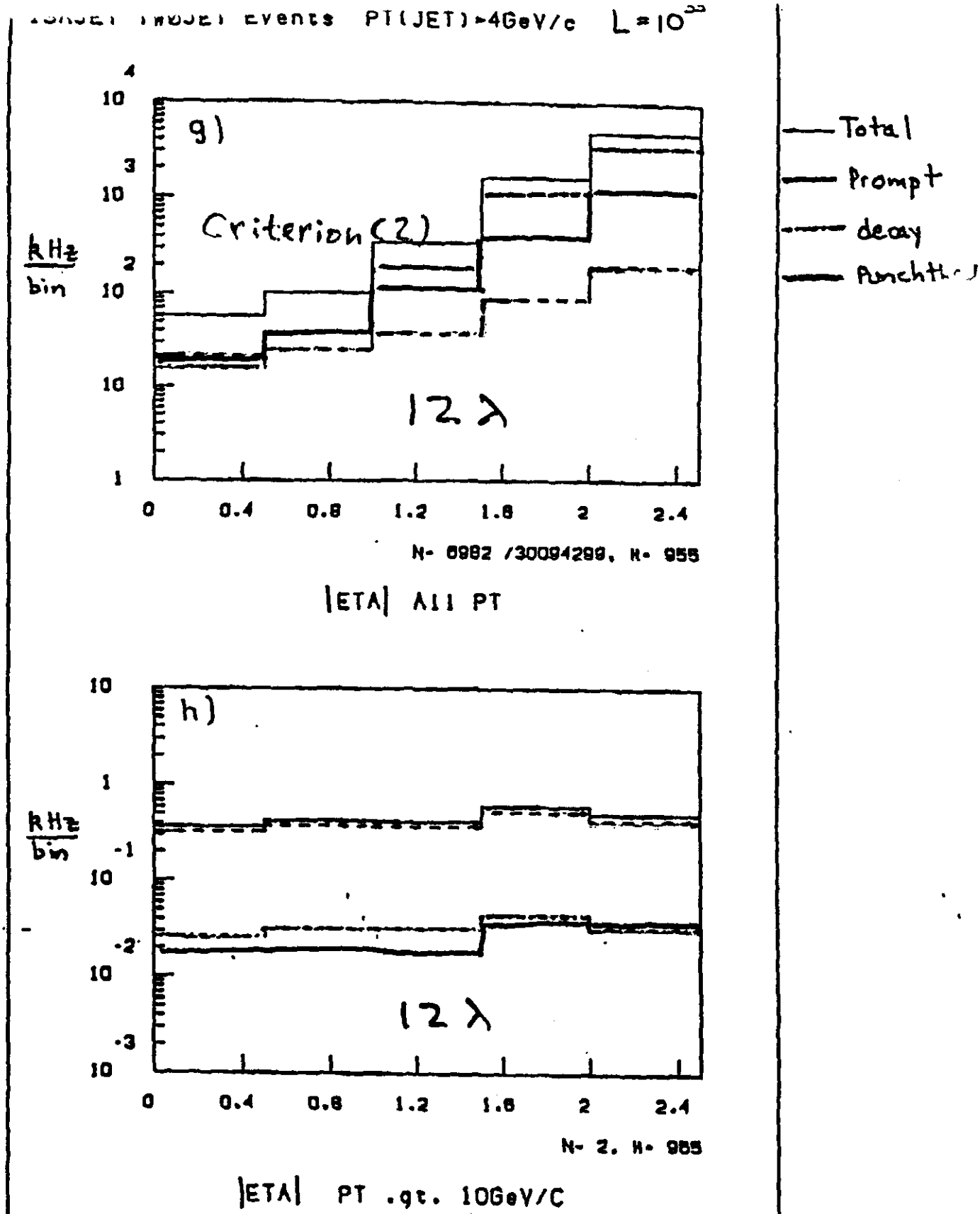
|ETA| All PT



|ETA| PT .gt. 10GeV/c

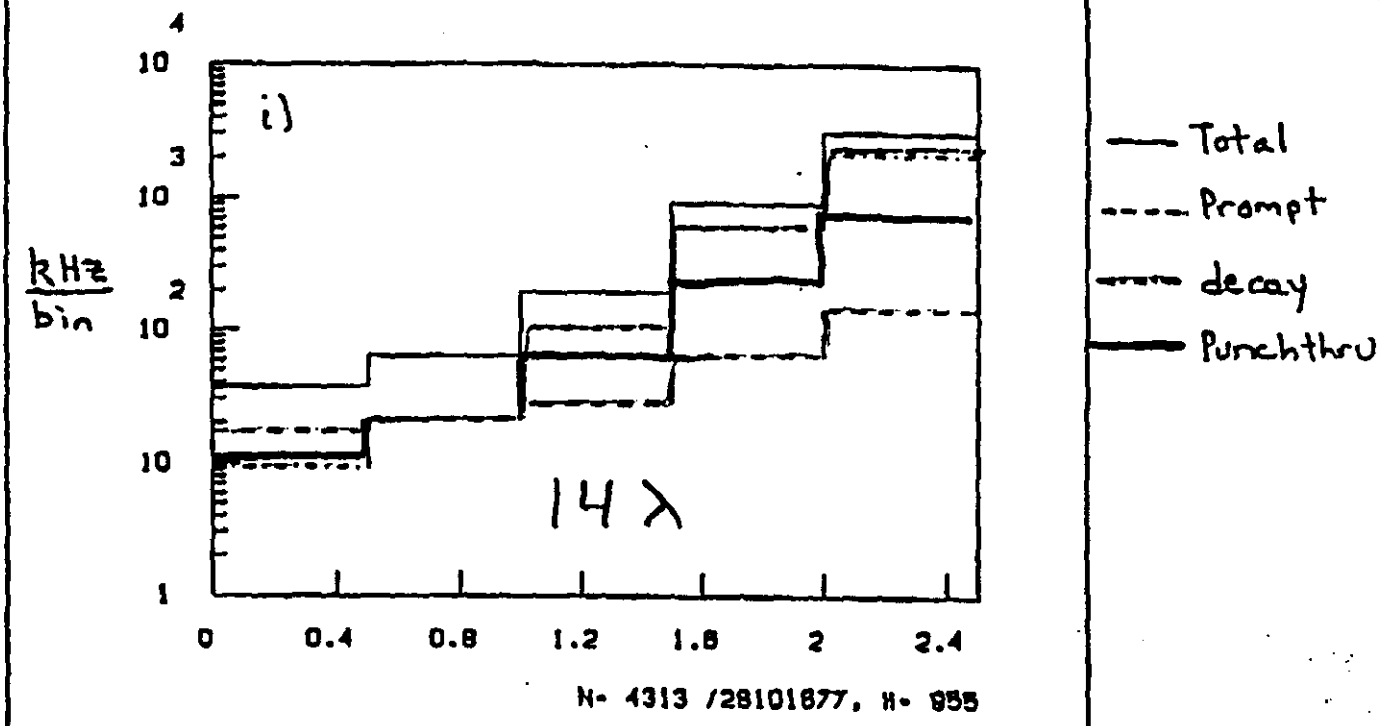
Rates after Constant Thickness Calorimeter - 10λ

Figure 4e-f

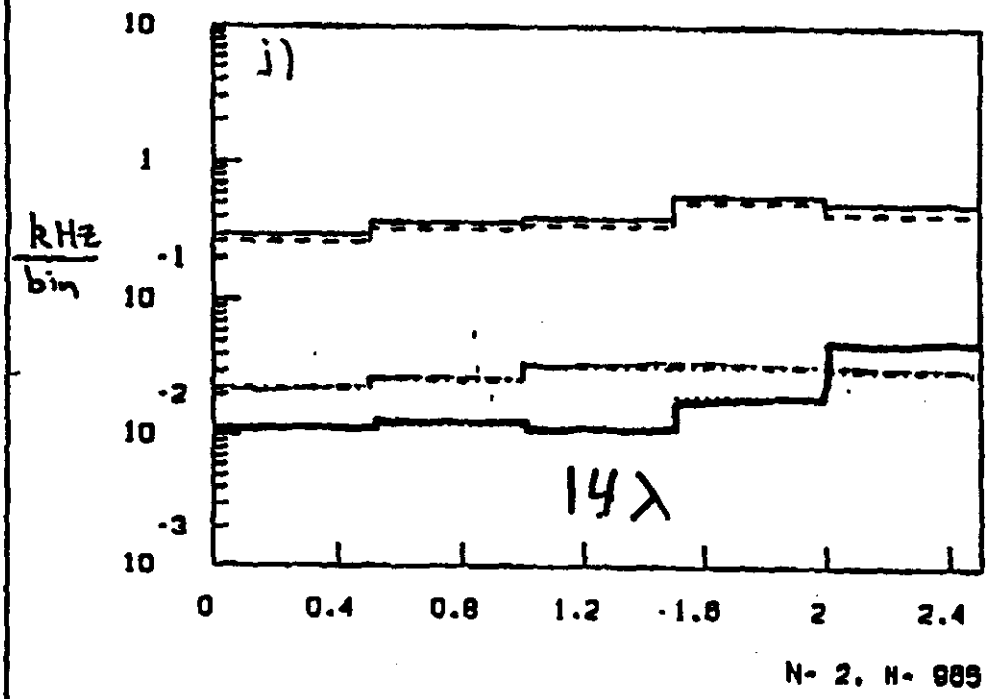


Rates after Constant Thickness Calorimeter - 121

Figure 4 g-h



|ETA| All PT



|ETA| PT .gt. 10GeV/c

Rates after Constant Thickness Calorimeter - 141

Figure 4 i-j

(2) Fluctuations of energy loss in calorimeter:

(R. McNeil and F. Taylor)

Problem:

Landau $\Delta E\mu$ in calorimeter can not be measured

How Bad?

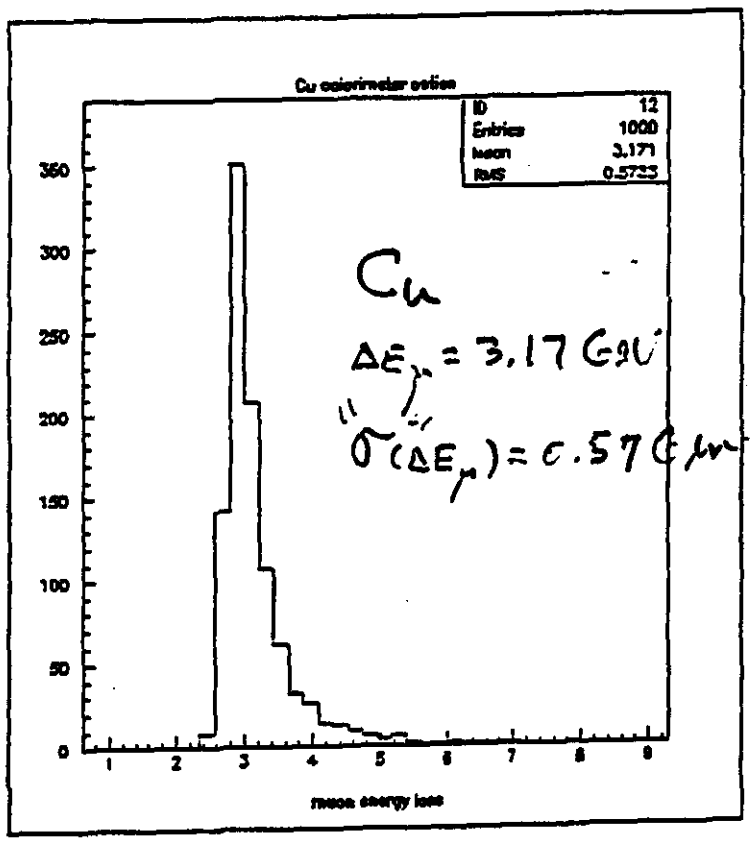
Use GEANT to simulate $\Delta E\mu$ distribution
Compute RMS($\Delta E\mu$)/$E\mu$ versus $E\mu$. Add to resolution smearing of magnet system.

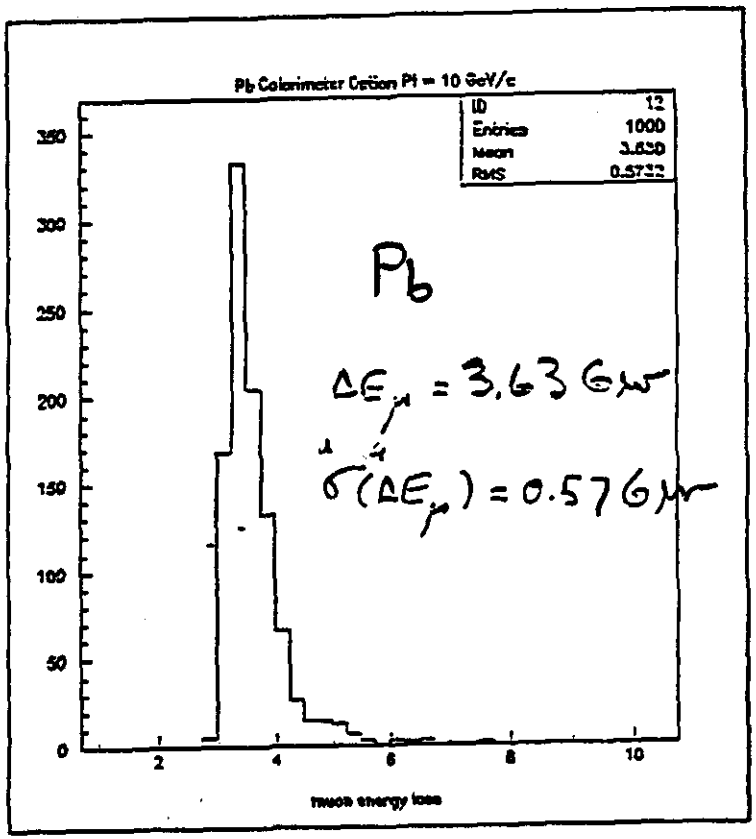
Conclusion:

Find significant contribution at low $E\mu$:
Effect dominates for $10 < E\mu < 100$ GeV
Cu calorimeter better than Pb

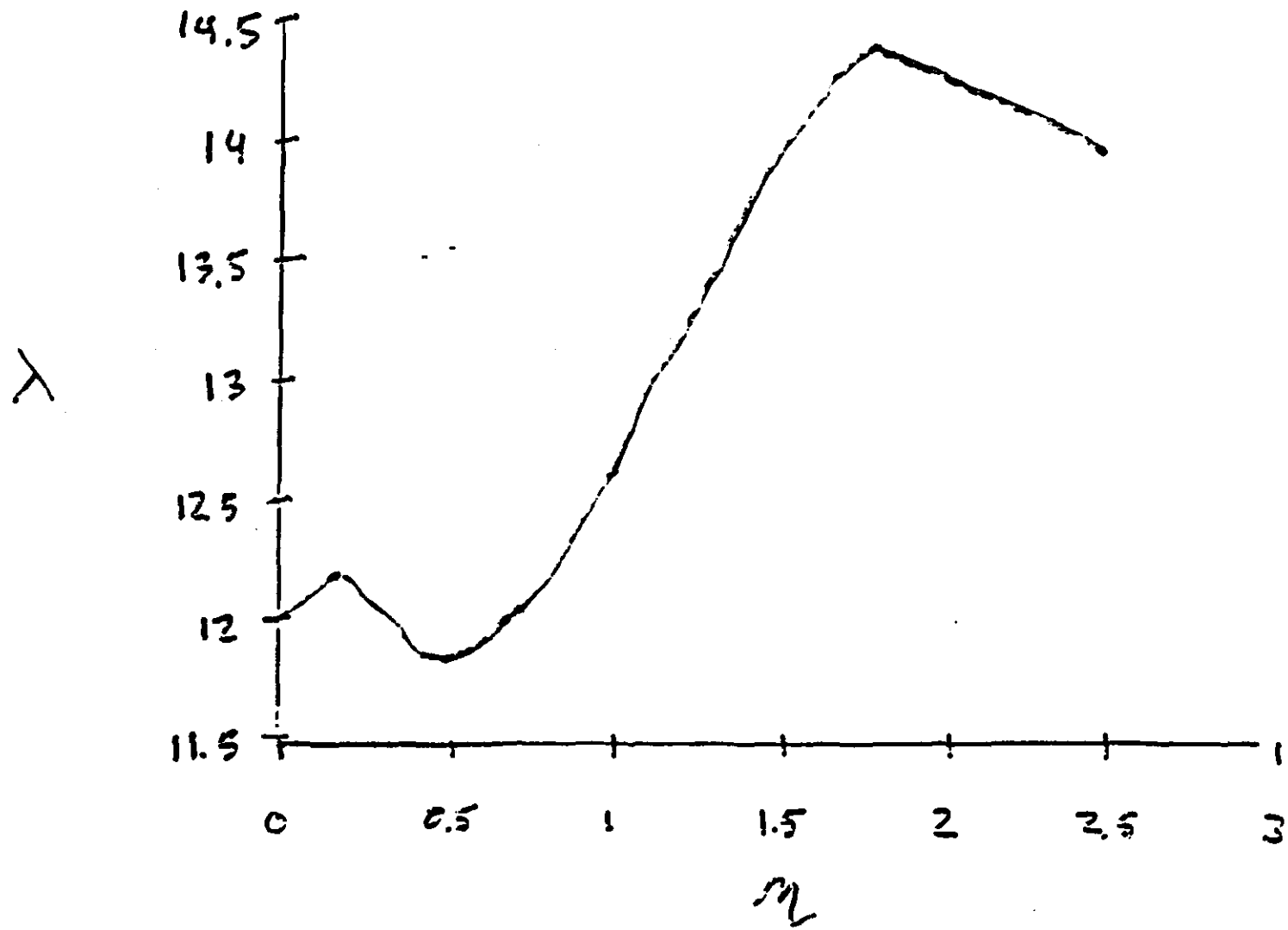
Fig. 5.2.2 a

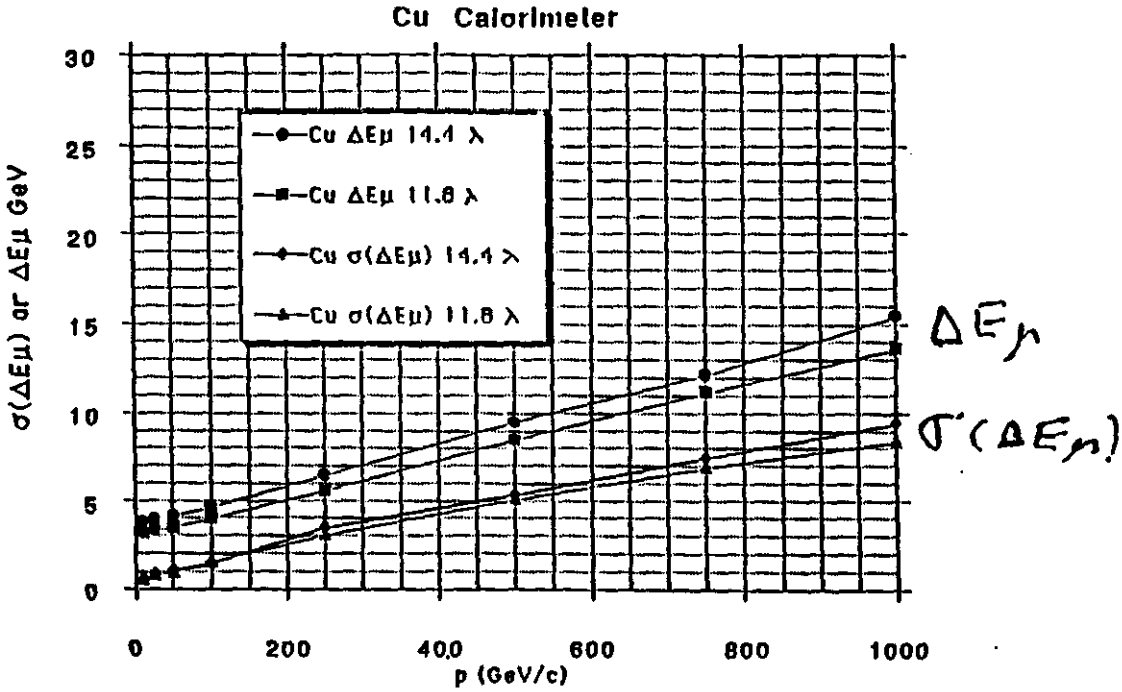
E_μ Loss through 12 λ.





"σ" = RMS (ΔE_μ)


14.5
14
13.5
13
12.5
12
11.5
λ
0
0.5
1
1.5
2
2.5
3
η


Cu Calorimeter
Cu ΔEμ 14.1 λ
Cu ΔEμ 11.8 λ
Cu σ(ΔEμ) 14.1 λ
Cu σ(ΔEμ) 11.8 λ
σ(ΔEμ) or ΔEμ GeV
p (GeV/c)
0
5
10
15
20
25
30
0
200
400
600
800
1000
ΔEμ
σ(ΔEμ)

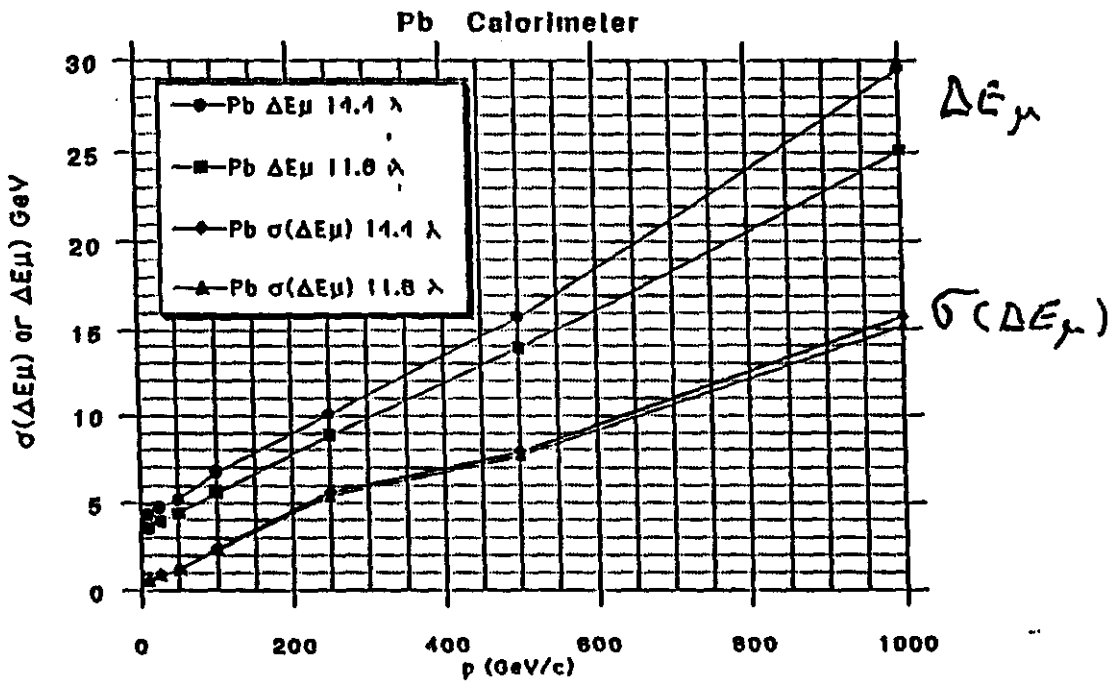

Pb Calorimeter
Pb ΔEμ 14.1 λ
Pb ΔEμ 11.8 λ
Pb σ(ΔEμ) 14.1 λ
Pb σ(ΔEμ) 11.8 λ
σ(ΔEμ) or ΔEμ) GeV
p (GeV/c)
0
5
10
15
20
25
30
0
200
400
600
800
1000
ΔEμ
σ(ΔEμ)

Fig. 5.2.2 b

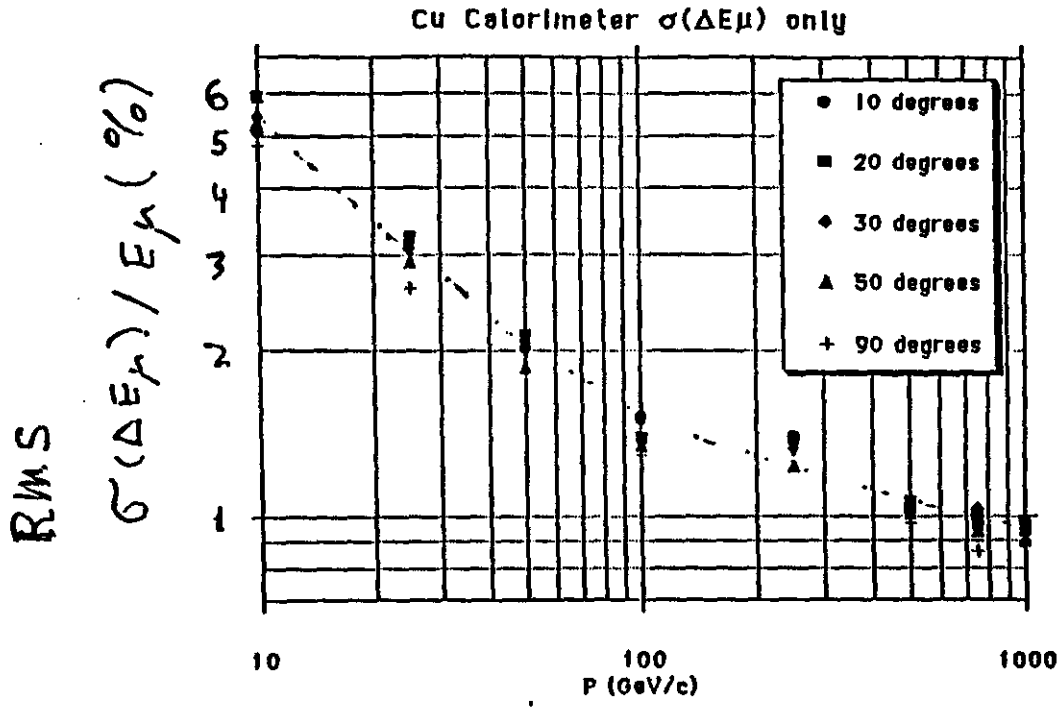


Fig. 5.2.3 a

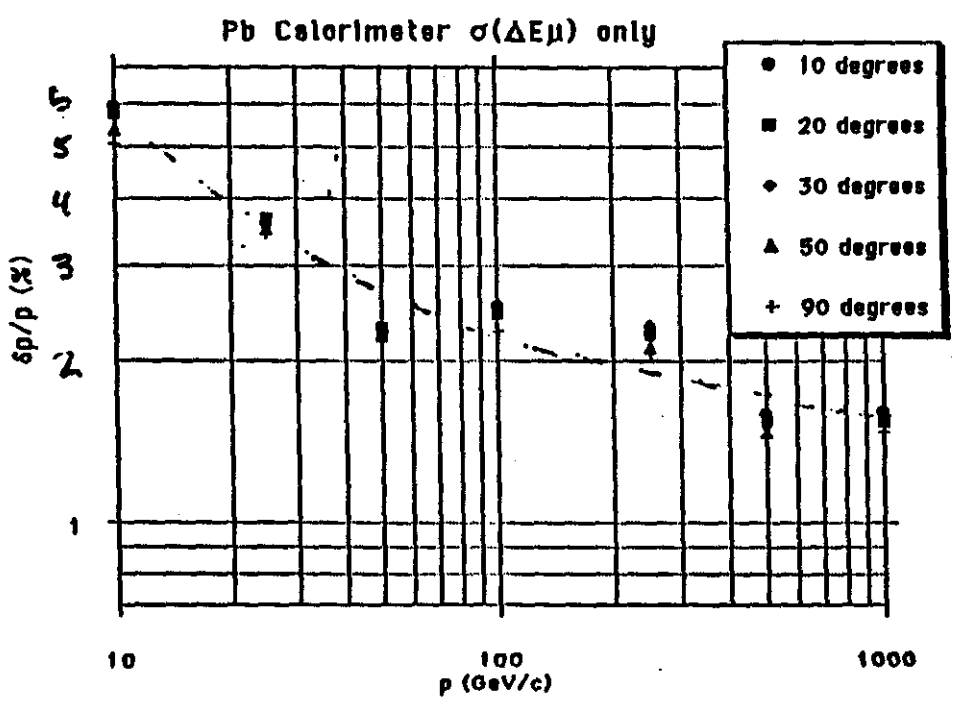
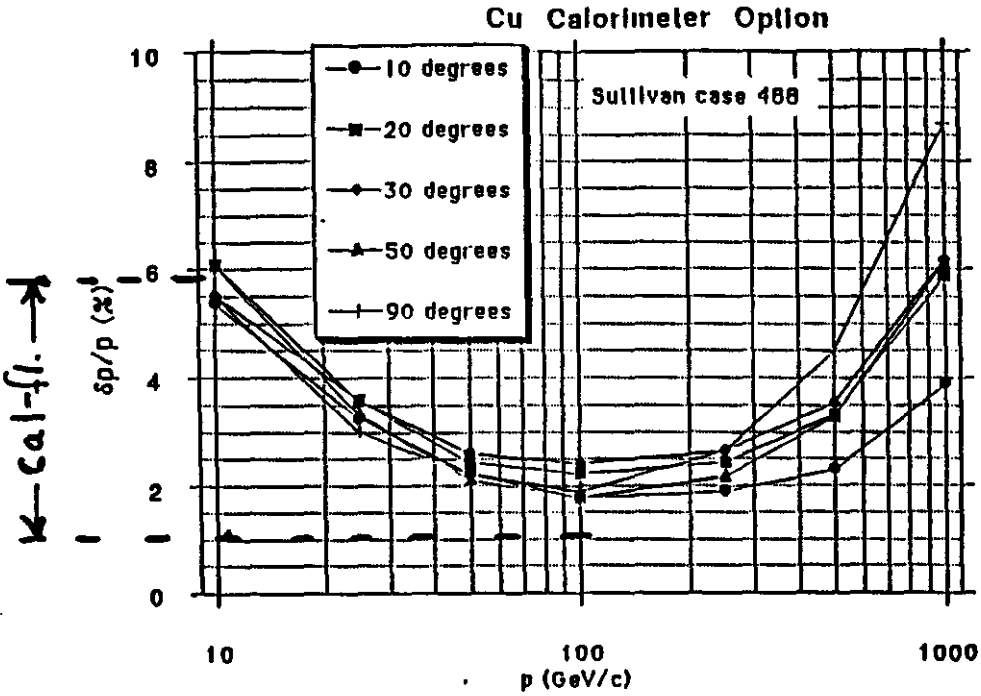


Fig. 5.2.3 b



Cu better choice than Pb

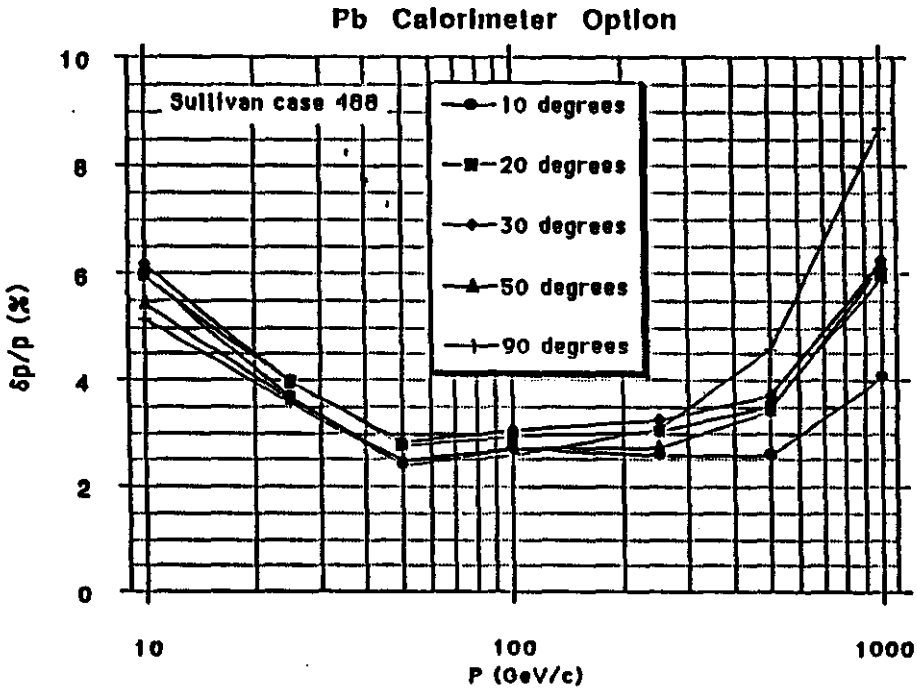
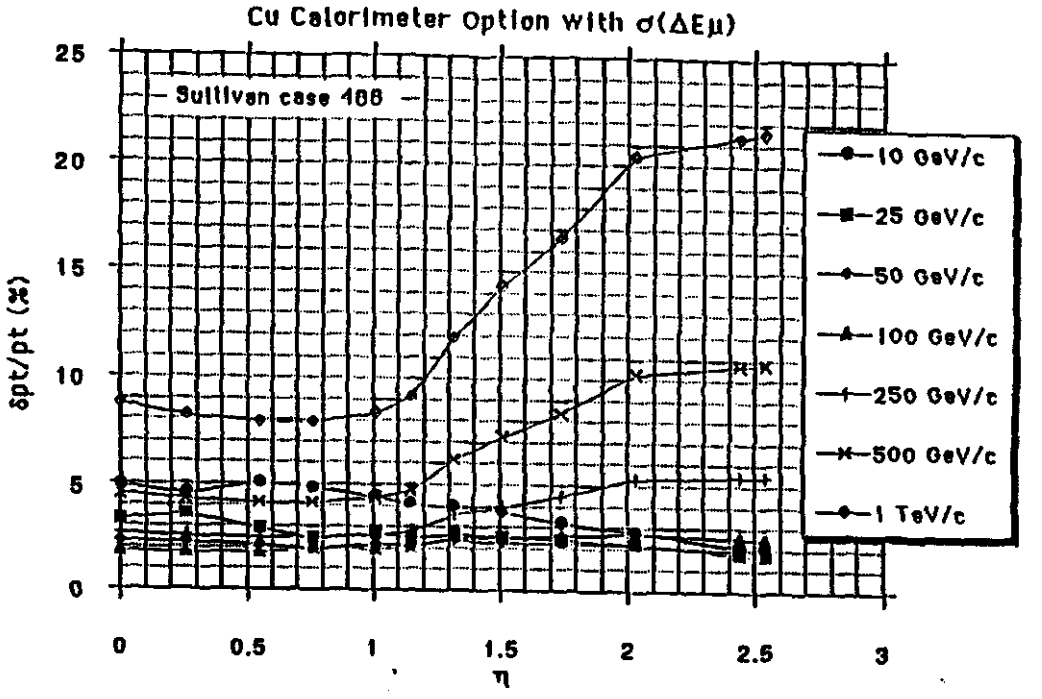


Fig. 5.3.1


Cu Calorimeter Option with σ(ΔEμ)
Sullivan case 466
δpt/pt (%)
η
10 GeV/c
25 GeV/c
50 GeV/c
100 GeV/c
250 GeV/c
500 GeV/c
1 TeV/c

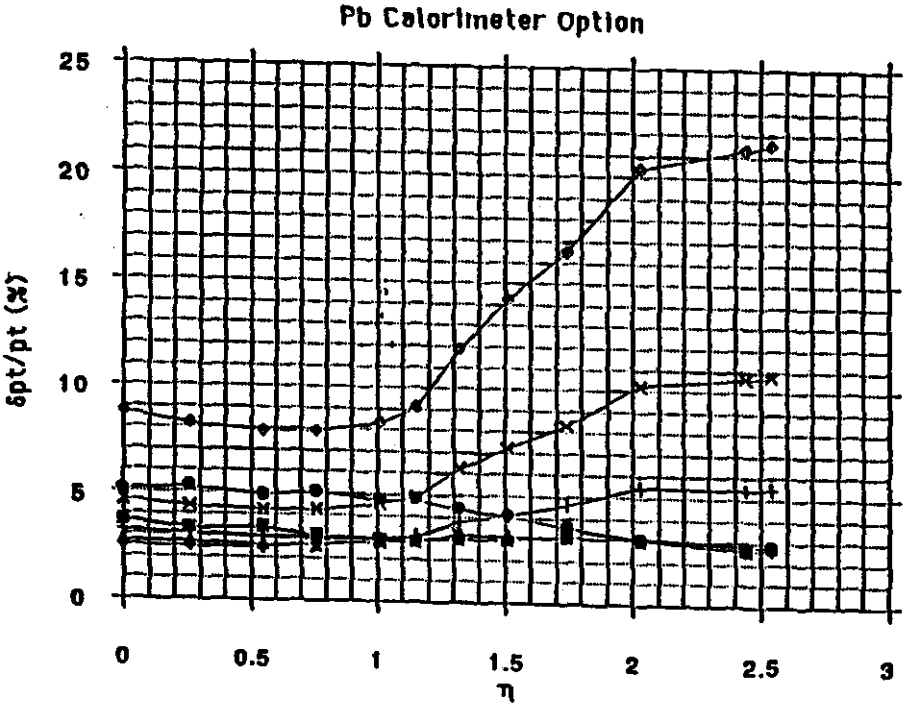

Pb Calorimeter Option
δpt/pt (%)
η

Fig. 5.3.3

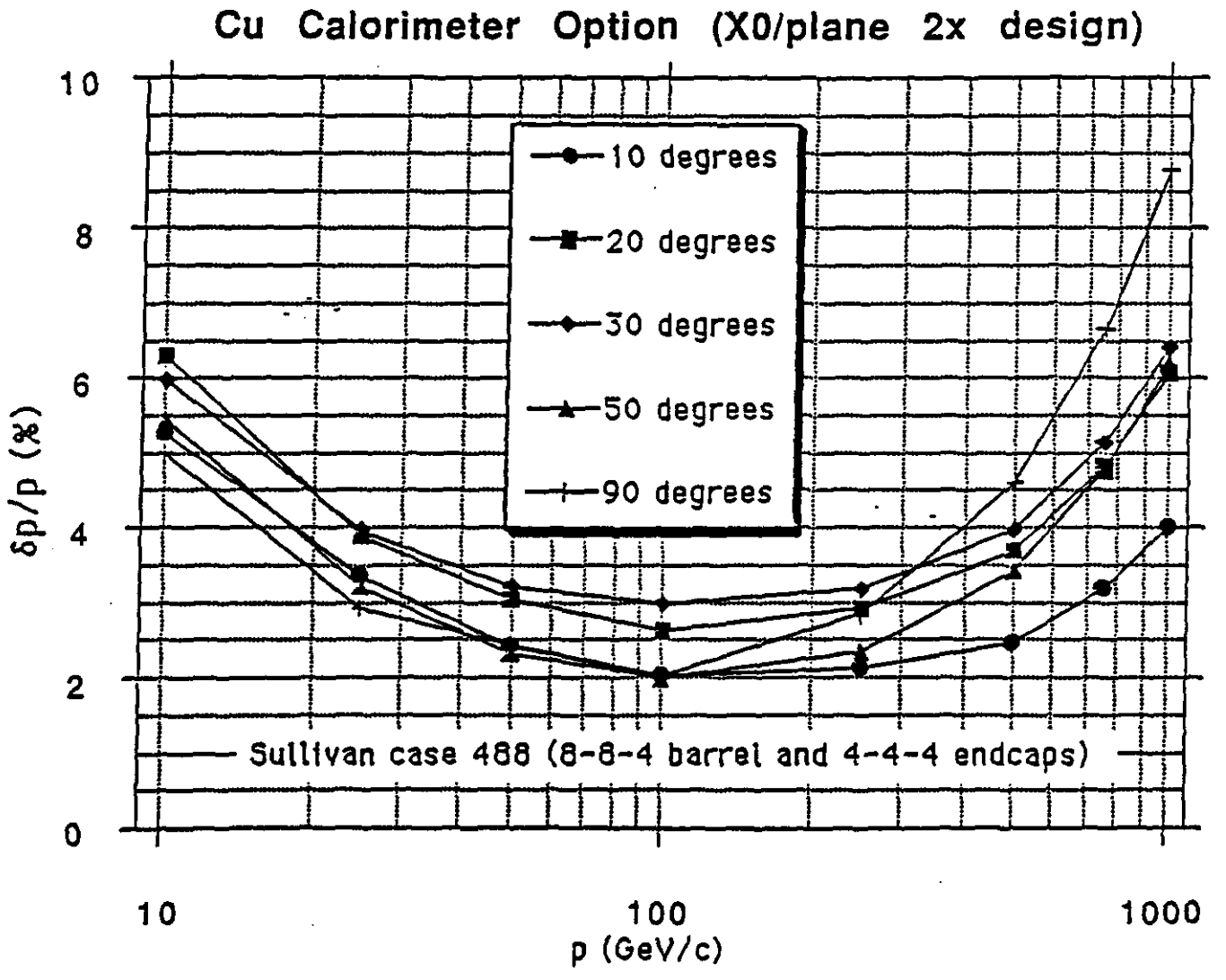

Cu Calorimeter Option (X0/plane 2x design)
10 degrees
20 degrees
30 degrees
50 degrees
90 degrees
Sullivan case 488 (8-8-4 barrel and 4-4-4 endcaps)
δp/p (%)
0
2
4
6
8
10
10
100
1000
p (GeV/c)

Fig. 5.3.2

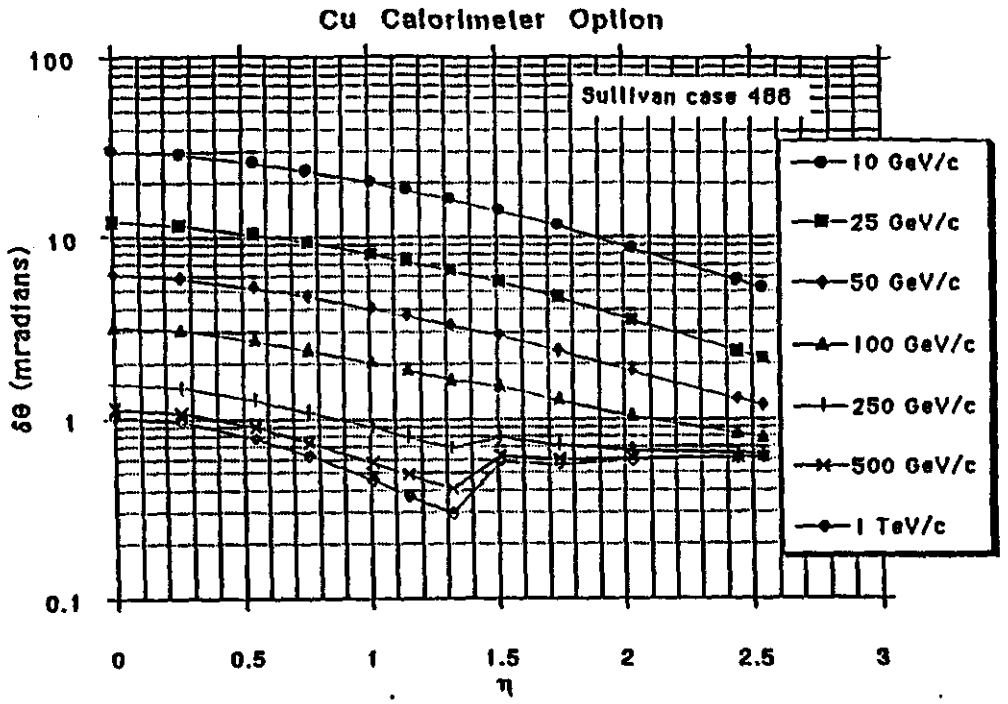


Fig. 5.2.4 a

Cu better choice than Pb

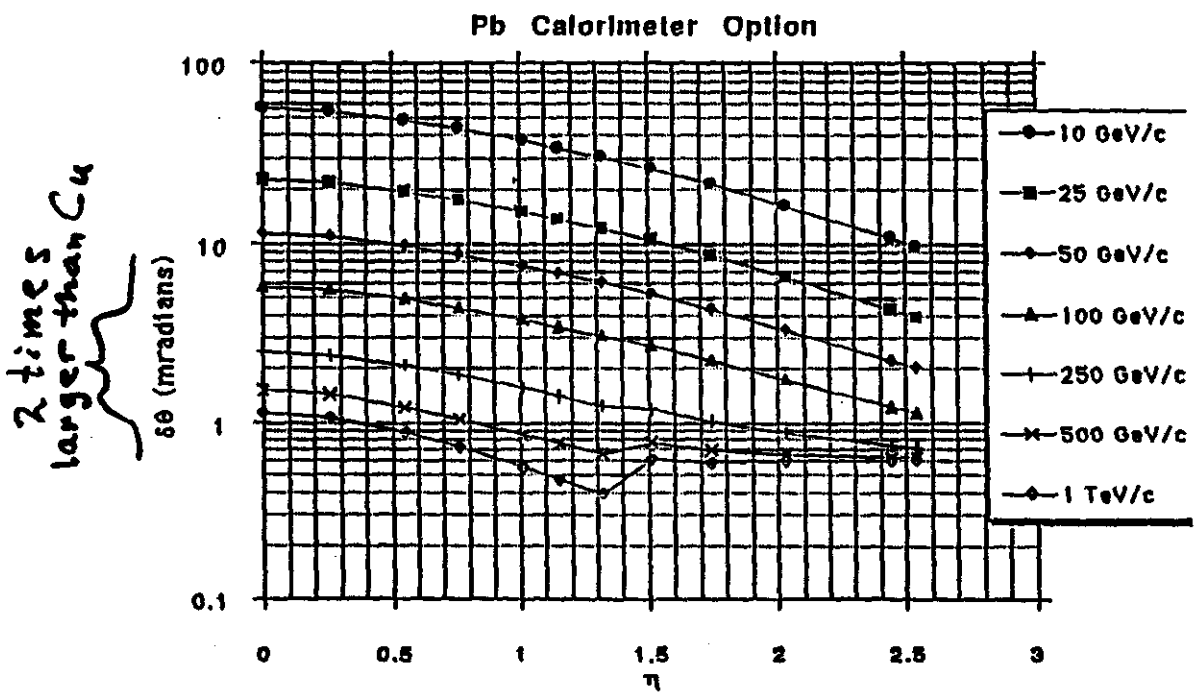


Fig. 5.2.4 b

STUDIES ON PERFORMANCE IMPROVEMENT OBTAINED VIA:

1 - ADDITION OF A FOURTH SUPERLAYER (2 LAYERS)

2 - INCLUSION OF A VERTEX CONSTRAINT (200 μm.)

RESULTS: FOURTH SUPERLAYER

- VERY LITTLE IMPROVEMENT IN RESOLUTION IN END CAP
  - DUE TO LARGE REVERSE BENDING IN FORWARD DIRECTION

- IMPROVEMENT OF RESOLUTION FOR ANGLES > 35°
  OF 20 - 40% FOR P_T BETWEEN 500 + 2500 GeV/c

- PROVIDE BACK UP MEASUREMENT WITH P_T RESOLUTION DEGRADED BY ~ FACTOR OF TWO IF 1ST SUPERLAYER AND VERTEX NOT AVAILABLE (e.g. at $\mathcal{L} \sim 10^{34}$).

VERTEX

- STEADY IMPROVEMENT OF RESOLUTION WITH INCREASING ENERGY - e.g. 10 → 20% FOR P_T 1000 → 2500 GeV/c

- PROVIDES BACK UP MEASUREMENTS WITH P_T RESOLUTION DEGRADED BY ~ FACTOR OF 600 IF 1ST SUPERLAYER NOT AVAILABLE.

STUDIES SUGGEST:

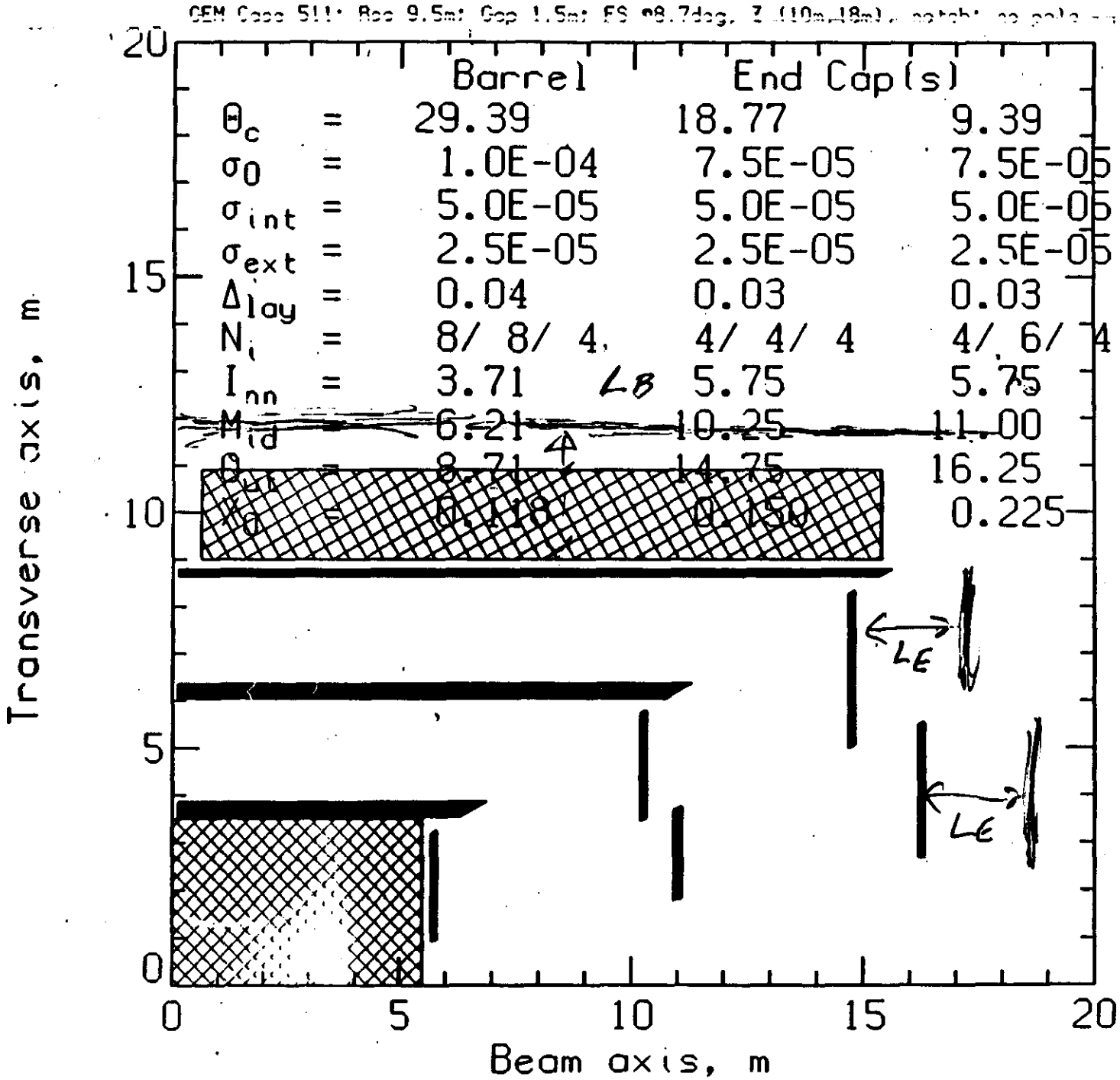
1 - LEAVE ROOM FOR EXTERNAL CHAMBERS ~ 3m.

* COSTS MUST BE ESTABLISHED FOR

1 - CHAMBERS & ELECTRONICS

2 - ALIGNMENT - MUST BE DEVELOPED

2 - INCLUDE PROVISION FOR ALIGNMENT OF VERTEX DETECTOR TO MUON SYSTEM NOW



Muon system: 3/5/92 --- 8-8-4 100; 4-4-4/4-6-4 75

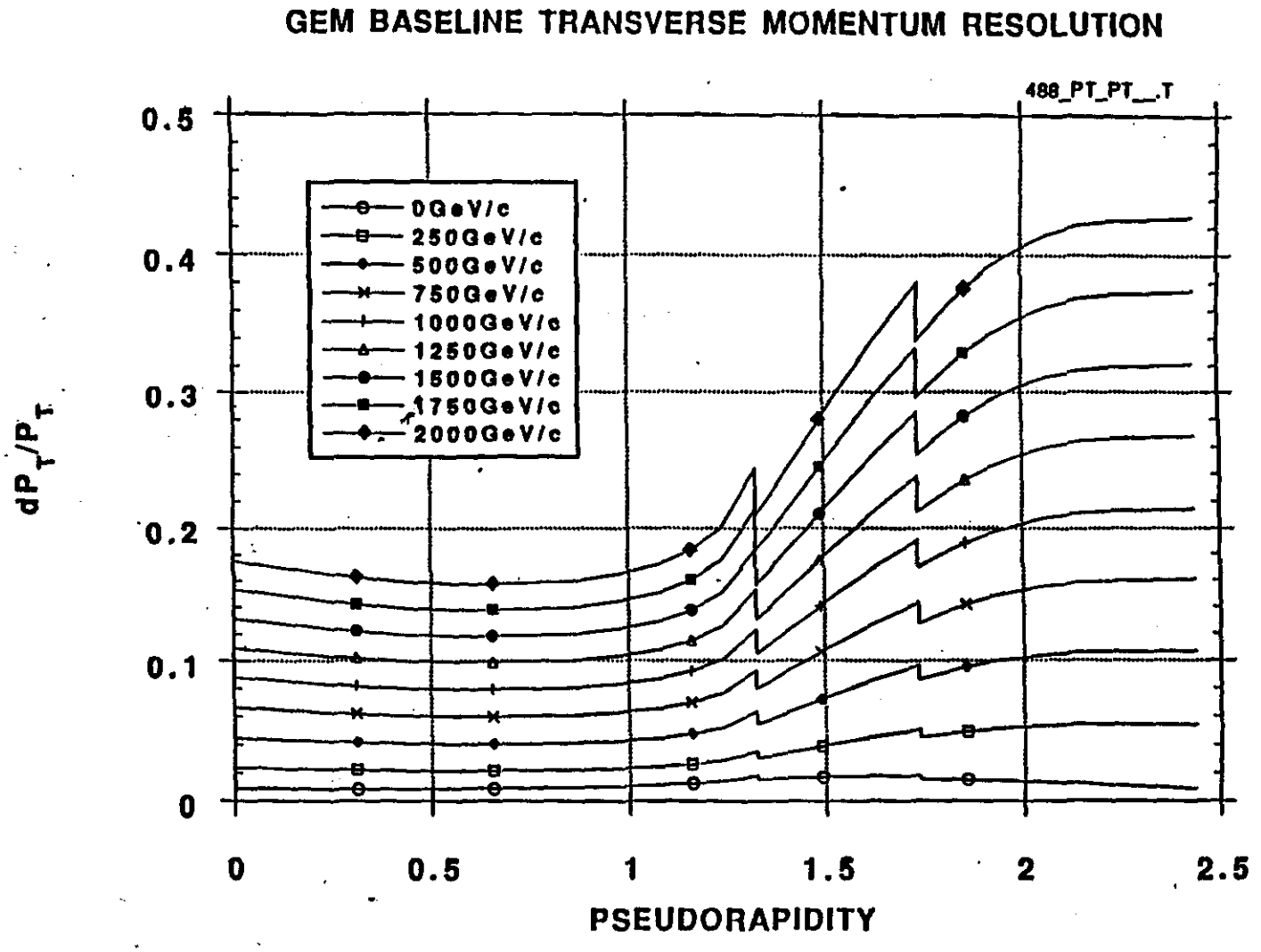

GEM BASELINE TRANSVERSE MOMENTUM RESOLUTION
488_PT_PT__.T
0.5
0.4
0.3
0.2
0.1
0
dP_T/P_T
0GeV/c
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
1250GeV/c
1500GeV/c
1750GeV/c
2000GeV/c
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY

Fig. 8.1

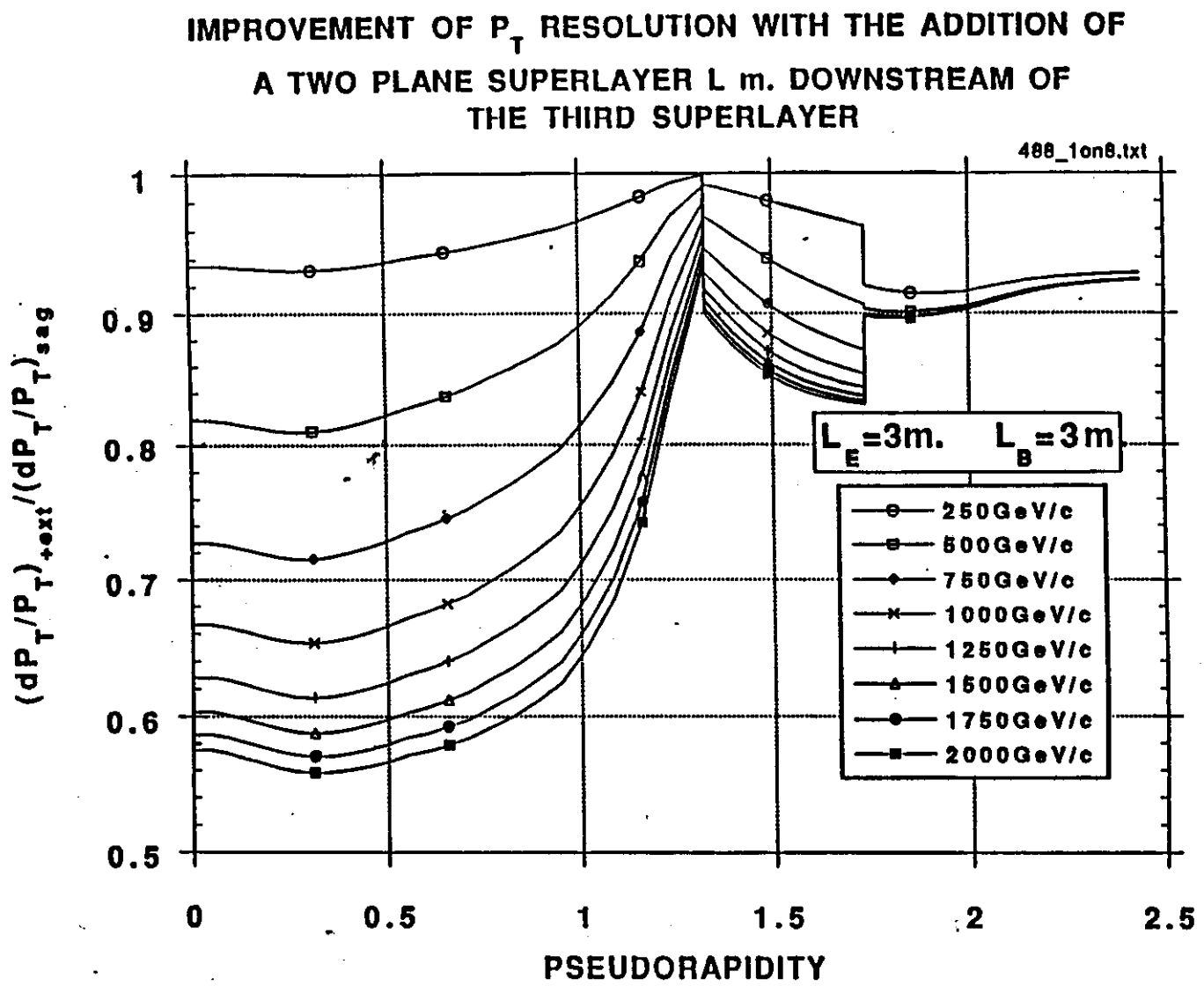

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
A TWO PLANE SUPERLAYER L m. DOWNSTREAM OF
THE THIRD SUPERLAYER
488_1on8.txt
$(dP_T/P_T)_{+ext}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
L_E=3m. L_B=3m
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
1250GeV/c
1500GeV/c
1750GeV/c
2000GeV/c

Fig. 8.2

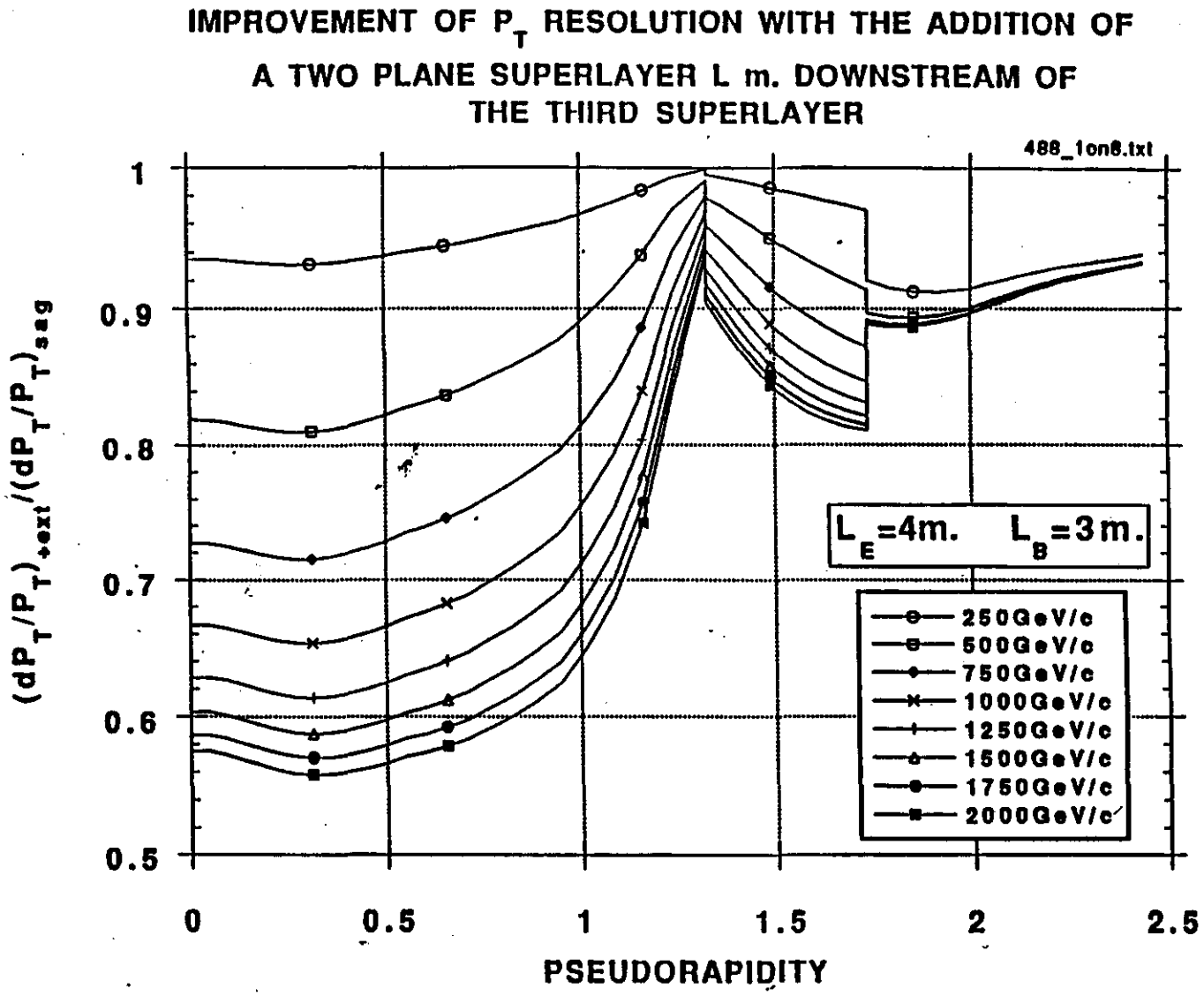

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
A TWO PLANE SUPERLAYER L m. DOWNSTREAM OF
THE THIRD SUPERLAYER
488_1on8.txt
$(dP_T/P_T)_{+ext}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
L_E=4m. L_B=3m.
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
1250GeV/c
1500GeV/c
1750GeV/c
2000GeV/c

Fig. 8.3

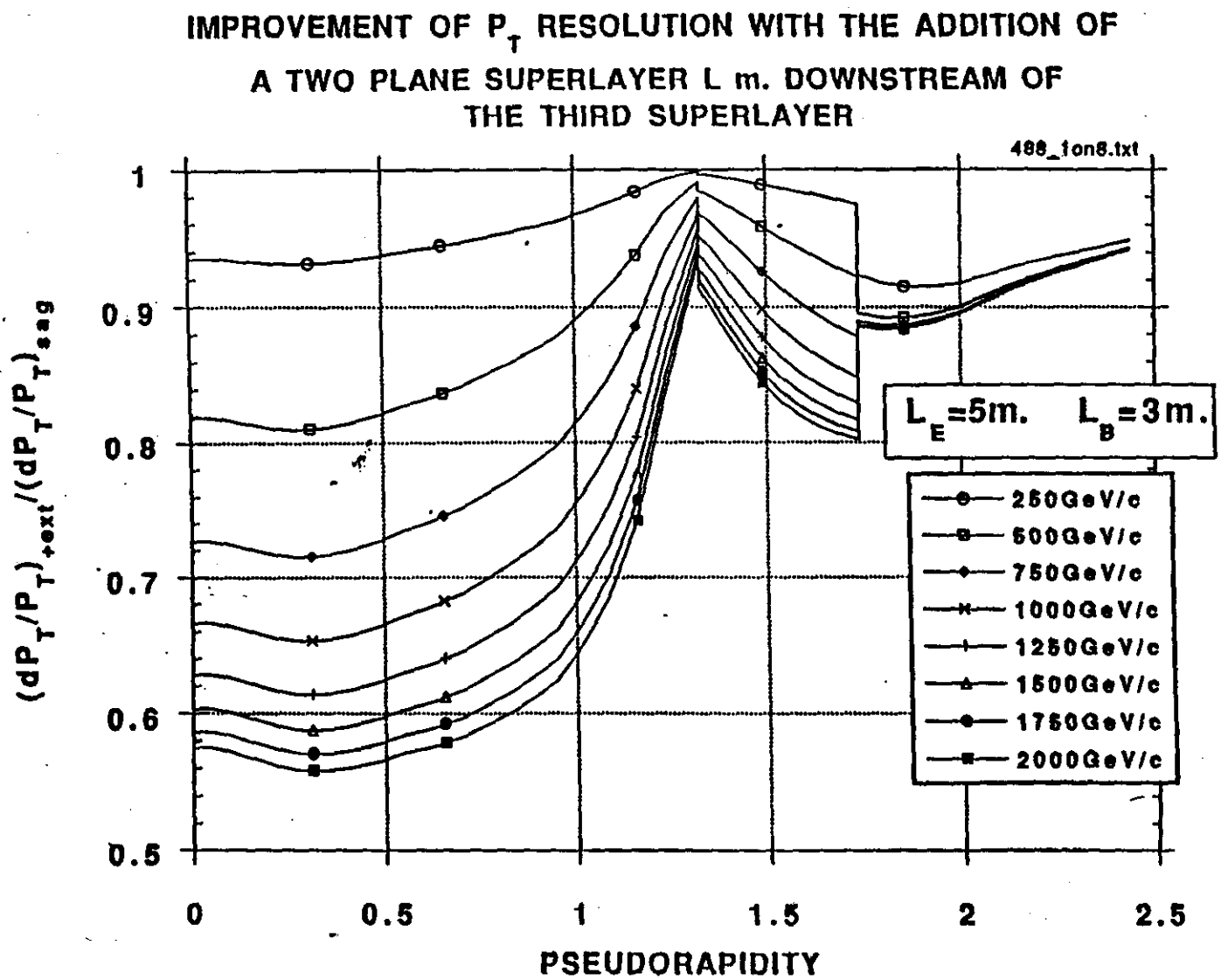

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
A TWO PLANE SUPERLAYER L m. DOWNSTREAM OF
THE THIRD SUPERLAYER
488_1on8.txt
$(dP_T/P_T)_{+ext}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
L_E=5m. L_B=3m.
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
1250GeV/c
1500GeV/c
1750GeV/c
2000GeV/c

Fig. 8.4

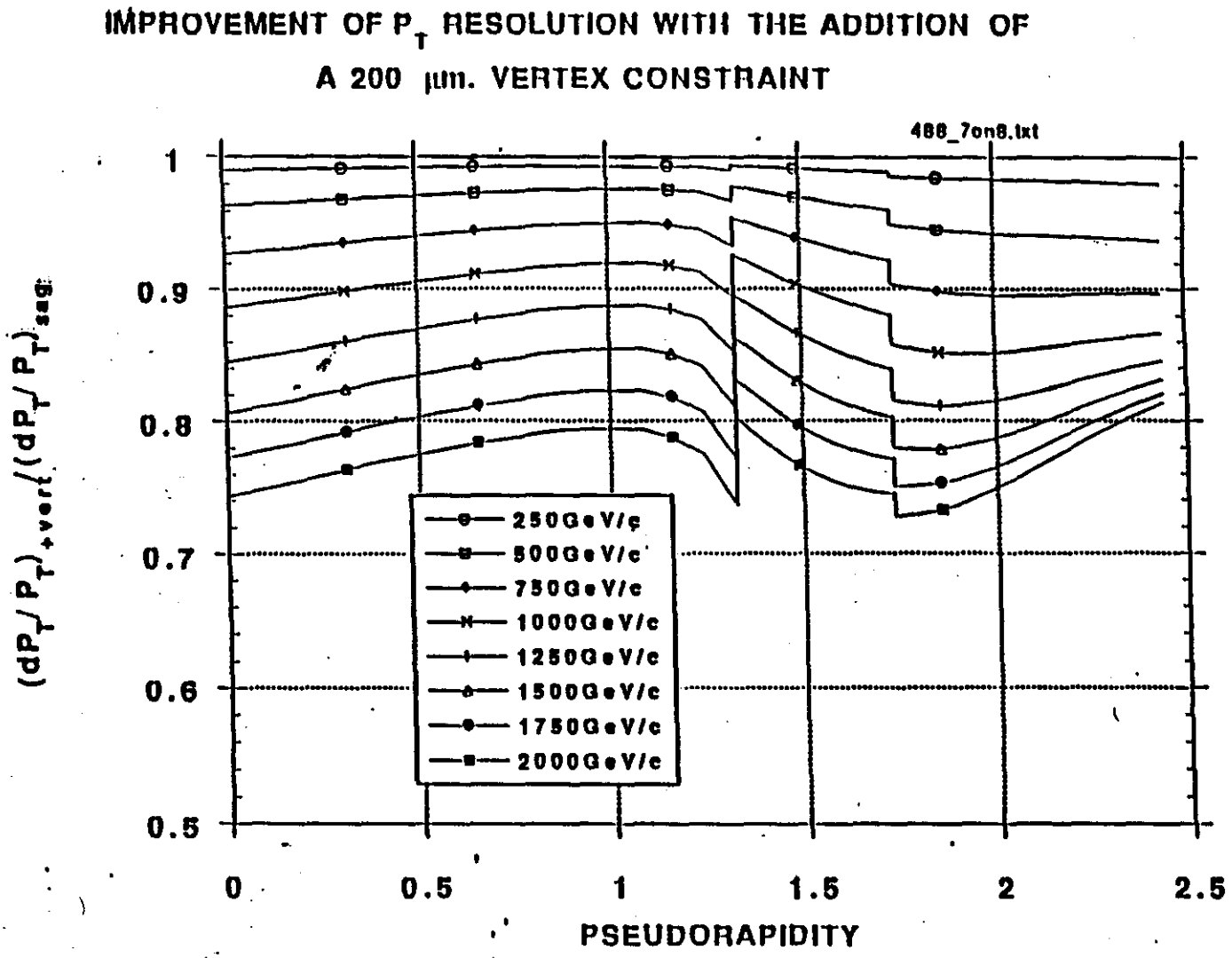
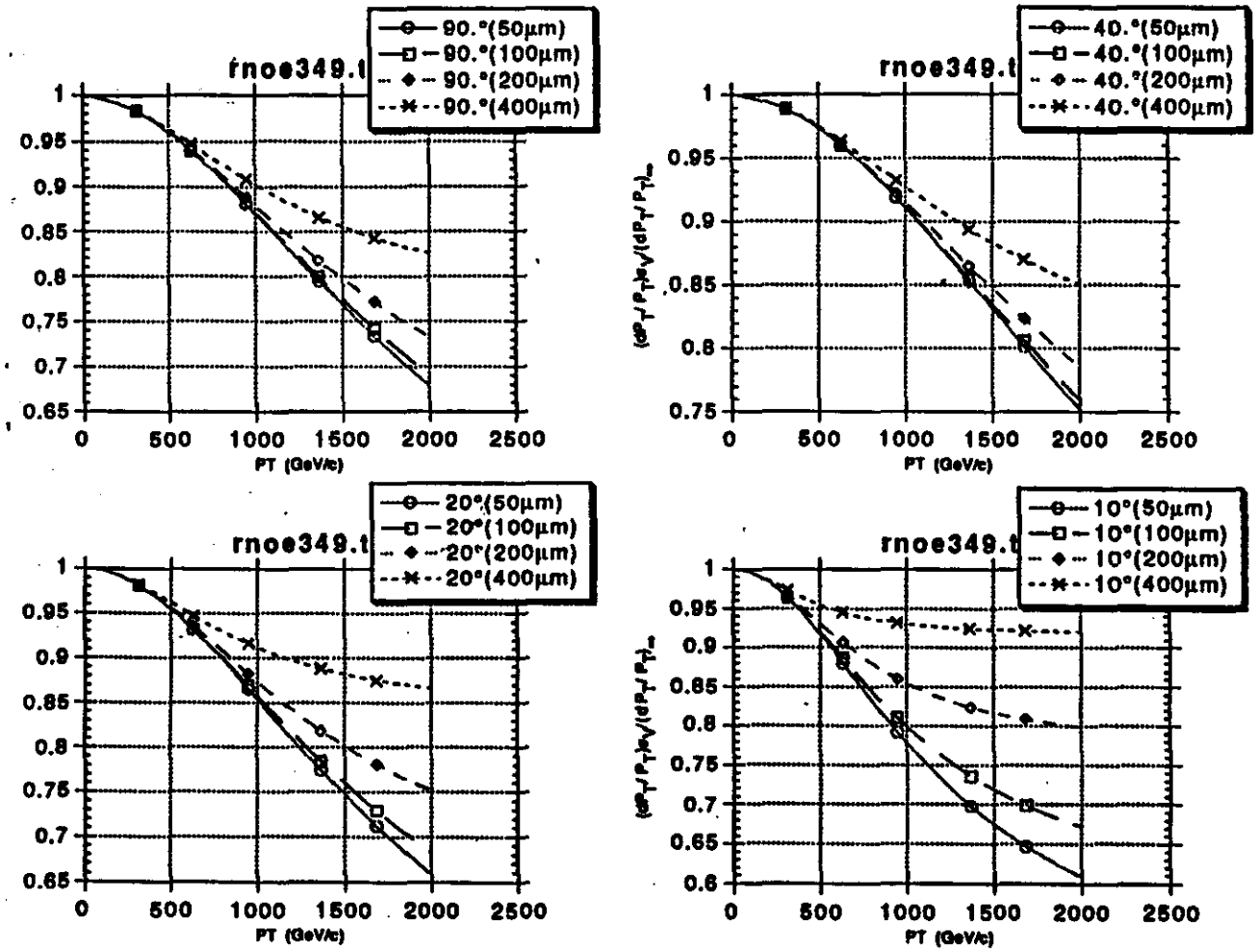

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
A 200 μm. VERTEX CONSTRAINT
488_7on8.txt
$(dP_T/P_T)_{+vert}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
1250GeV/c
1500GeV/c
1750GeV/c
2000GeV/c

Fig. 8.5



IMPROVEMENT OF MOMENTUM RESOLUTION AS A FUNCTION OF PRECISION OF VERTEX CONSTRAINT

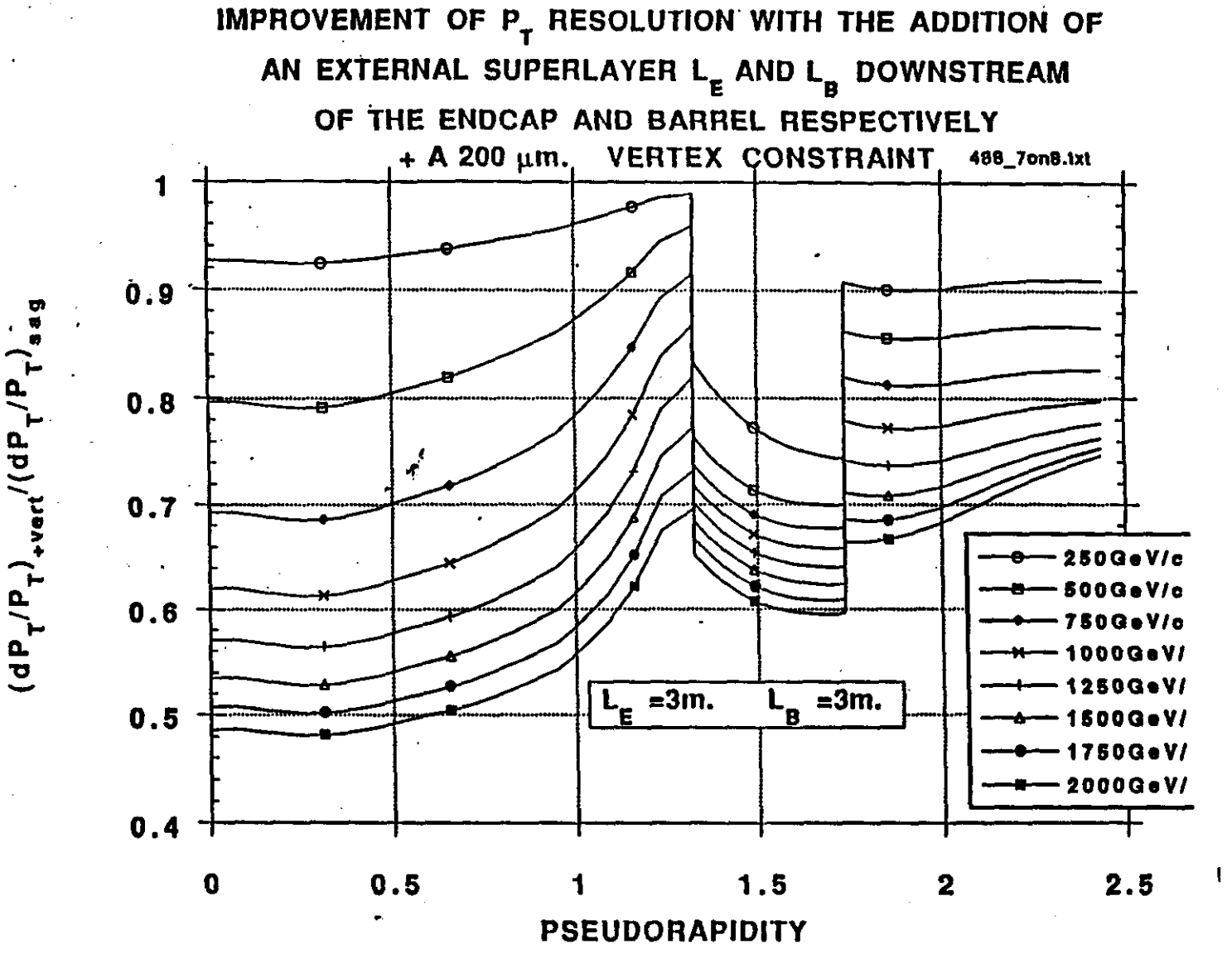

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
AN EXTERNAL SUPERLAYER L_E AND L_B DOWNSTREAM
OF THE ENDCAP AND BARREL RESPECTIVELY
+ A 200 μm. VERTEX CONSTRAINT
488_7on8.txt
$(dP_T/P_T)_{+vert}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0.4
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
L_E =3m. L_B =3m.
250GeV/c
500GeV/c
750GeV/c
1000GeV/
1250GeV/
1500GeV/
1750GeV/
2000GeV/

Fig. 8.6

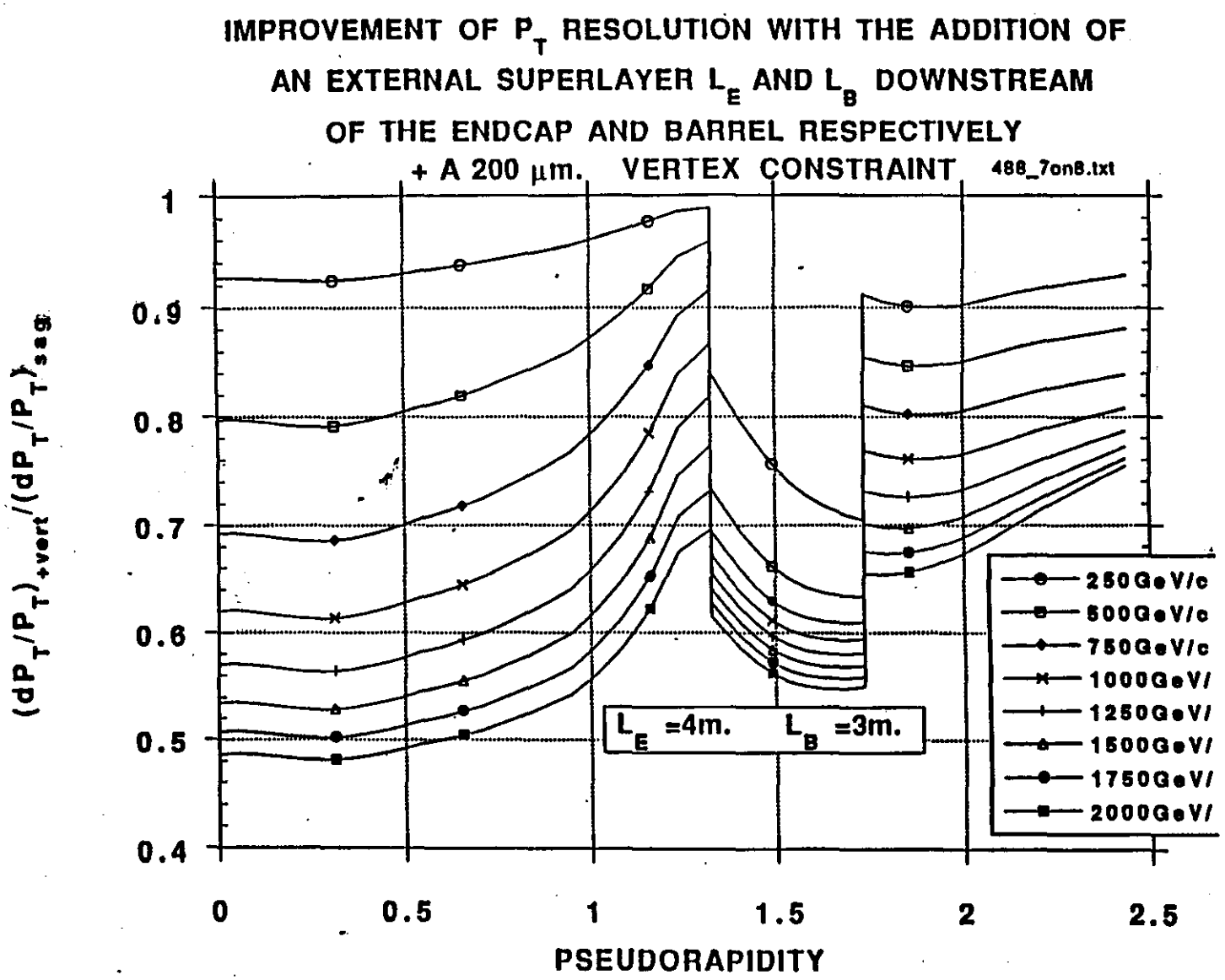

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
AN EXTERNAL SUPERLAYER L_E AND L_B DOWNSTREAM
OF THE ENDCAP AND BARREL RESPECTIVELY
+ A 200 μm. VERTEX CONSTRAINT
488_7on8.txt
$(dP_T/P_T)_{+vert}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0.4
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
L_E =4m. L_B =3m.
250GeV/c
500GeV/c
750GeV/c
1000GeV/
1250GeV/
1500GeV/
1750GeV/
2000GeV/

Fig. 8.7

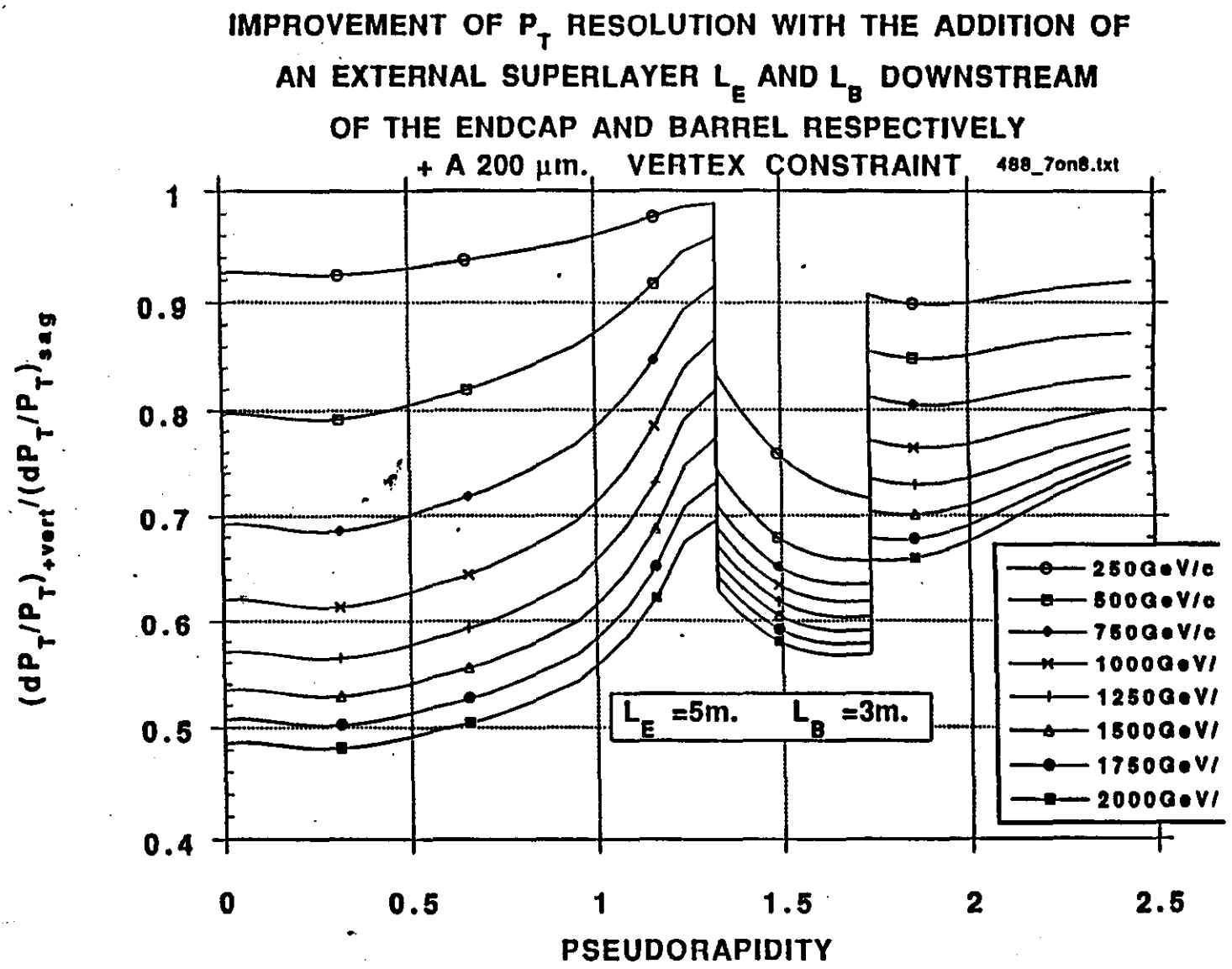

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
AN EXTERNAL SUPERLAYER L_E AND L_B DOWNSTREAM
OF THE ENDCAP AND BARREL RESPECTIVELY
+ A 200 μm. VERTEX CONSTRAINT
488_7on8.txt
$(dP_T/P_T)_{+vert}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0.4
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
L_E =5m. L_B =3m.
250GeV/c
500GeV/c
750GeV/c
1000GeV/
1250GeV/
1500GeV/
1750GeV/
2000GeV/

Fig. 8.8

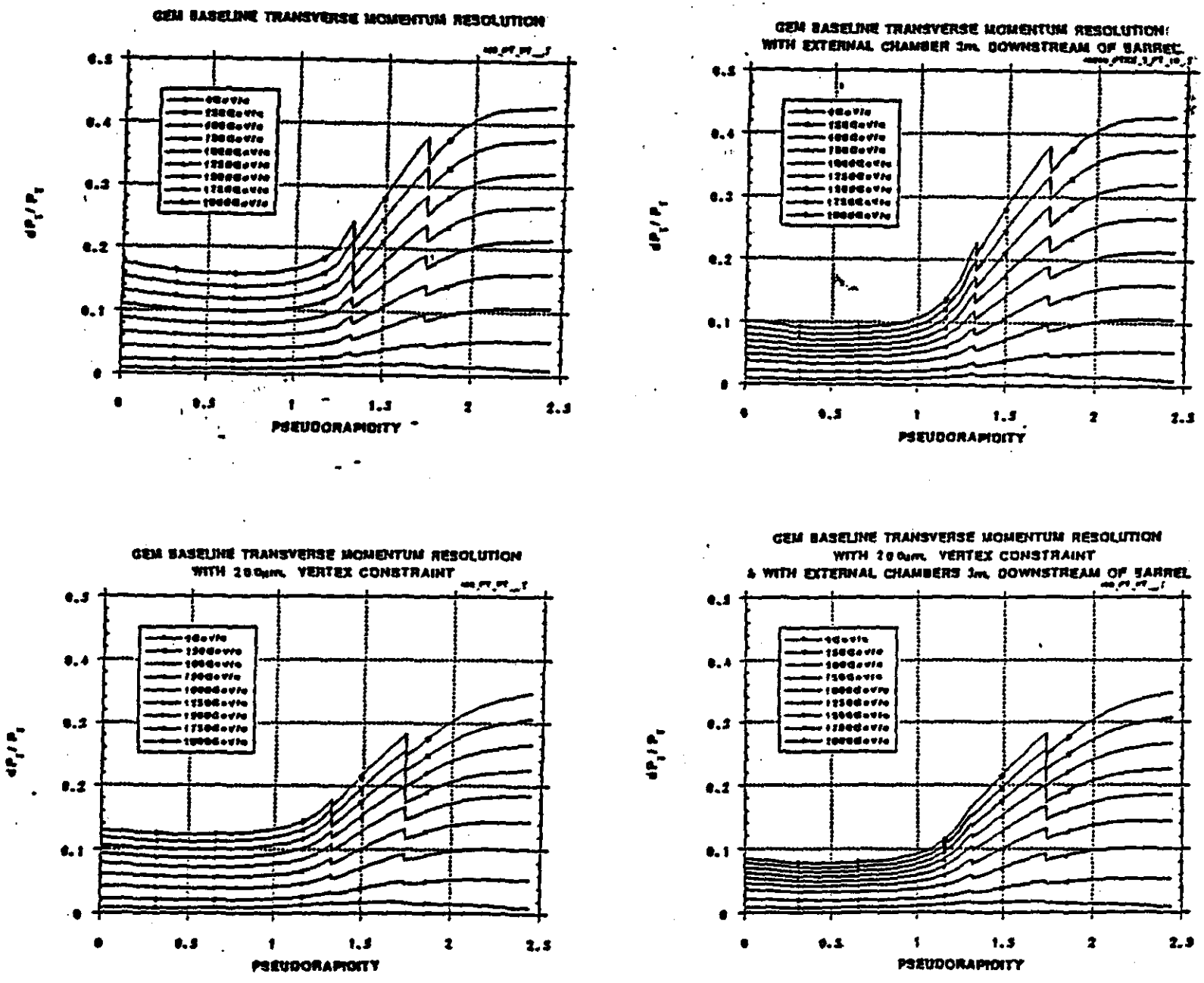

GEM BASELINE TRANSVERSE MOMENTUM RESOLUTION
PSEUDORAPIDITY
GEM BASELINE TRANSVERSE MOMENTUM RESOLUTION
WITH EXTERNAL CHAMBER 3m. DOWNSTREAM OF BARREL
PSEUDORAPIDITY
GEM BASELINE TRANSVERSE MOMENTUM RESOLUTION
WITH 20μm. VERTEX CONSTRAINT
PSEUDORAPIDITY
GEM BASELINE TRANSVERSE MOMENTUM RESOLUTION
WITH 20μm. VERTEX CONSTRAINT
& WITH EXTERNAL CHAMBERS 3m. DOWNSTREAM OF BARREL
PSEUDORAPIDITY

Fig. 8.9

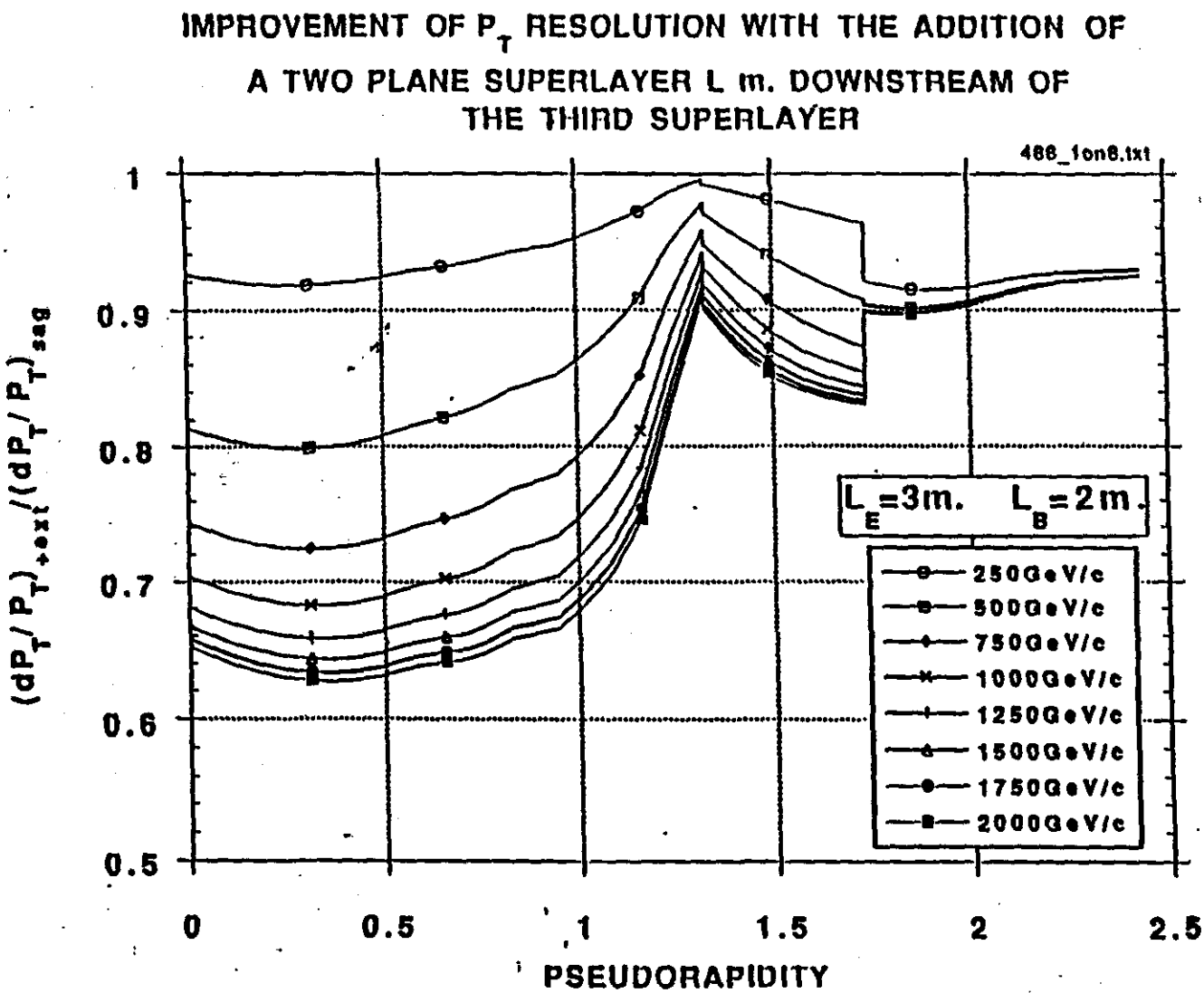
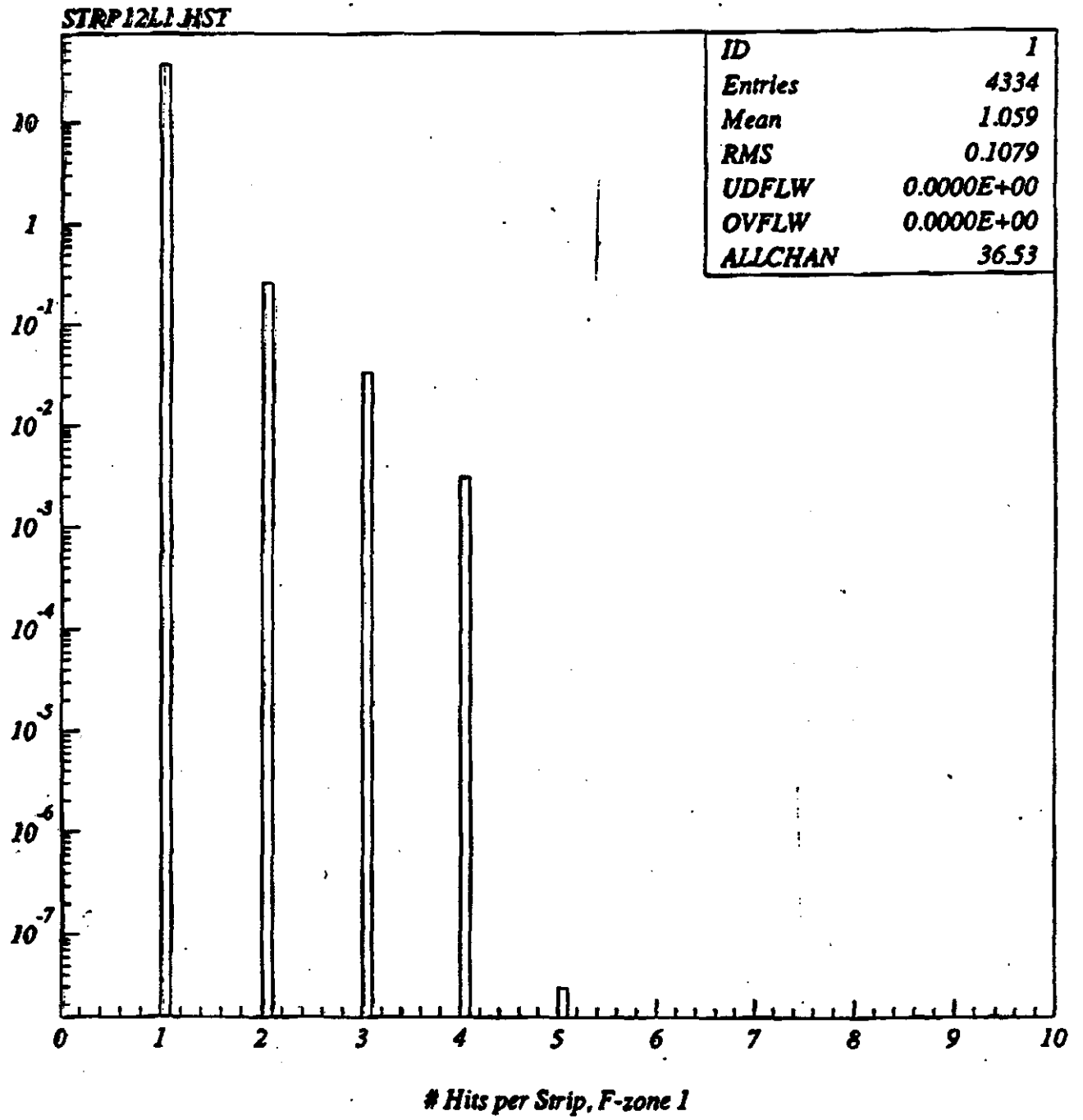
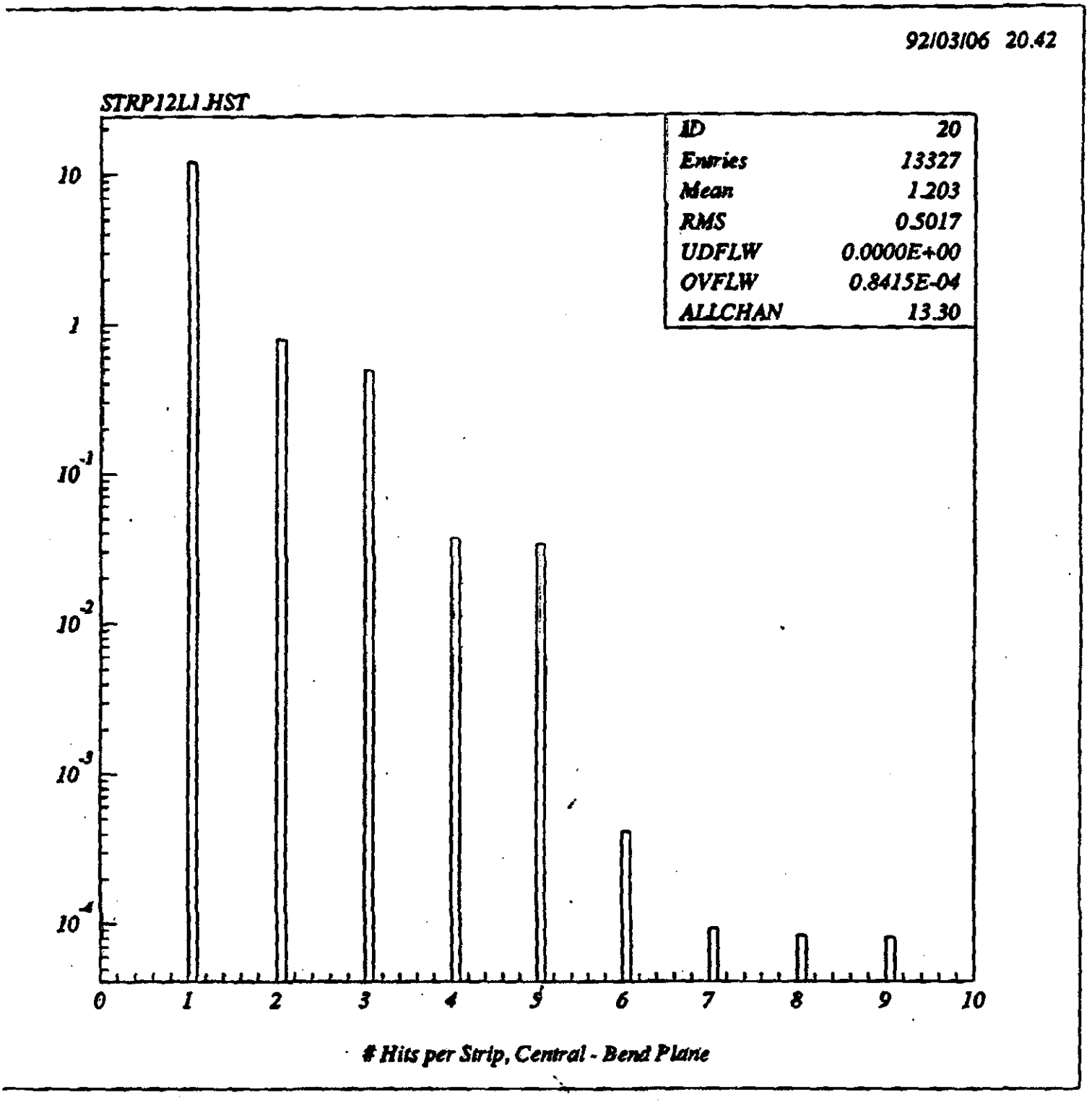

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
A TWO PLANE SUPERLAYER L m. DOWNSTREAM OF
THE THIRD SUPERLAYER
466_1on6.txt
$(dP_T/P_T)_{+ext}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
L_E=3m. L_B=2m.
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
1250GeV/c
1500GeV/c
1750GeV/c
2000GeV/c

Fig. 8.10

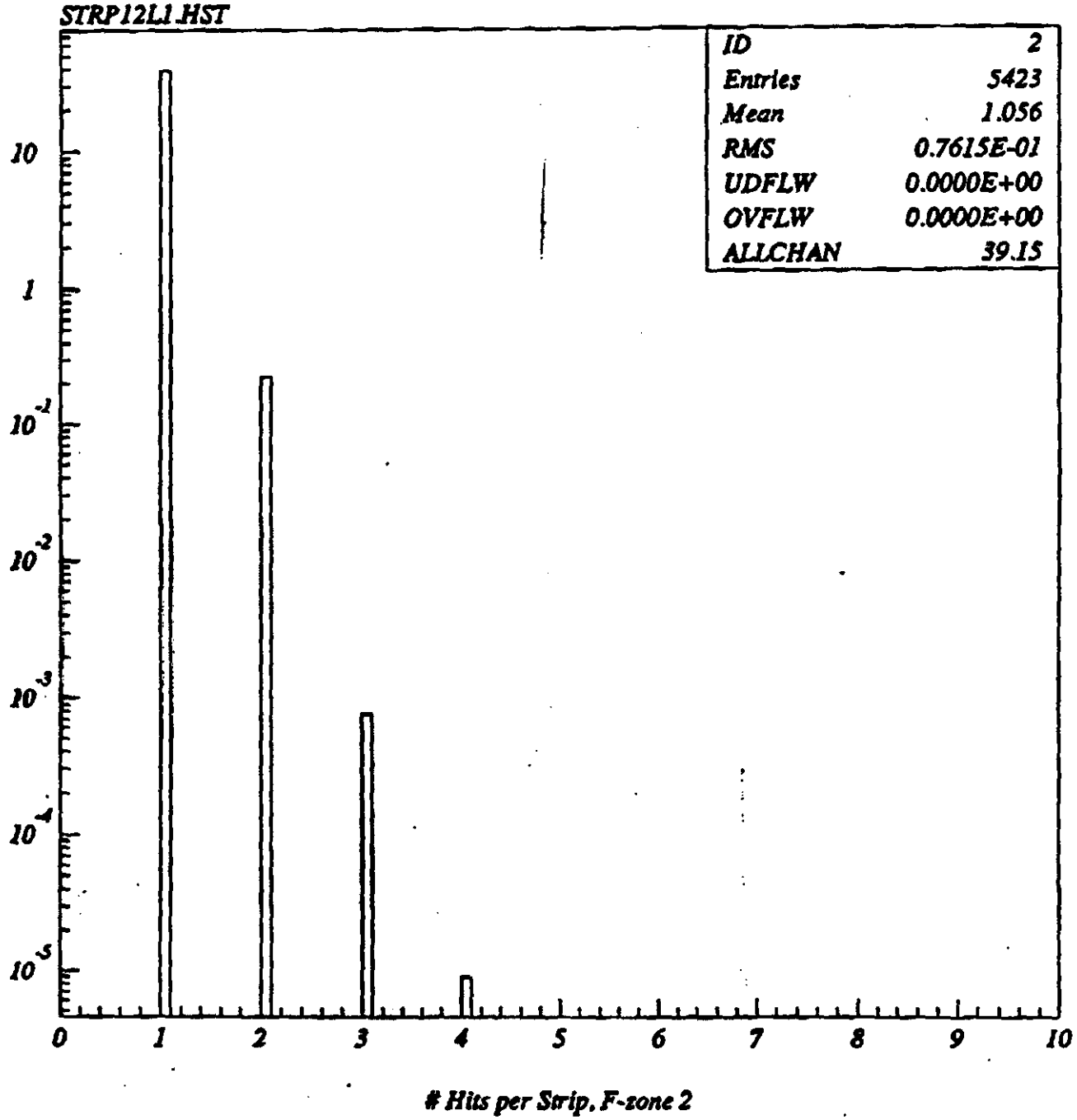
92/03/06 20.36

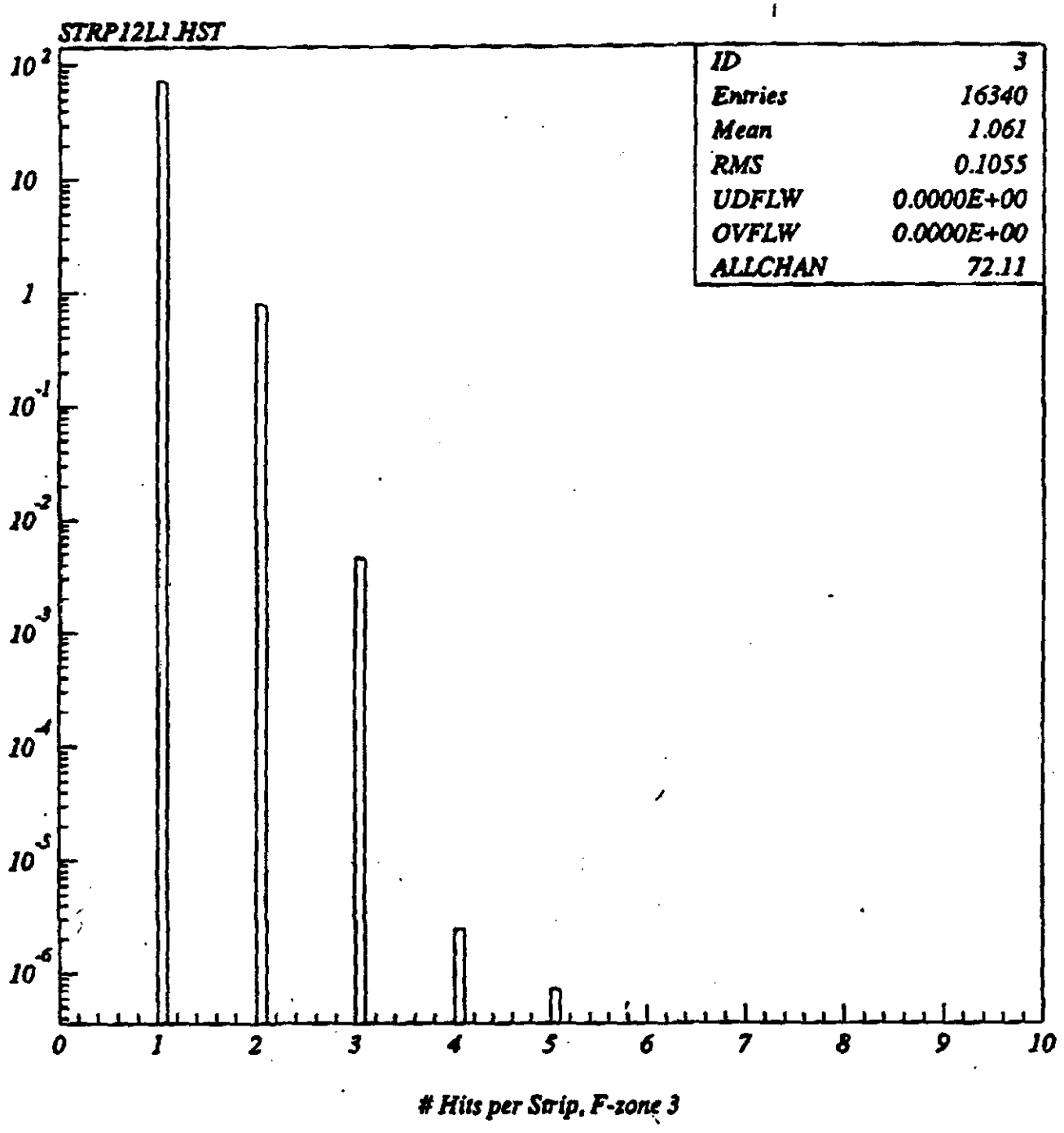

STRP12L1.HST
ID 1
Entries 4334
Mean 1.059
RMS 0.1079
UDFLW 0.0000E+00
OVFLW 0.0000E+00
ALLCHAN 36.53
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0 1 2 3 4 5 6 7 8 9 10
Hits per Strip, F-zone 1


92/03/06 20.42
STRP12L1 HST
ID 20
Entries 13327
Mean 1.203
RMS 0.5017
UDFLW 0.0000E+00
OVFLW 0.8415E-04
ALLCHAN 13.30
10
1
10^-1
10^-2
10^-3
10^-4
0 1 2 3 4 5 6 7 8 9 10
Hits per Strip, Central - Bend Plane

92/03/06 20.36

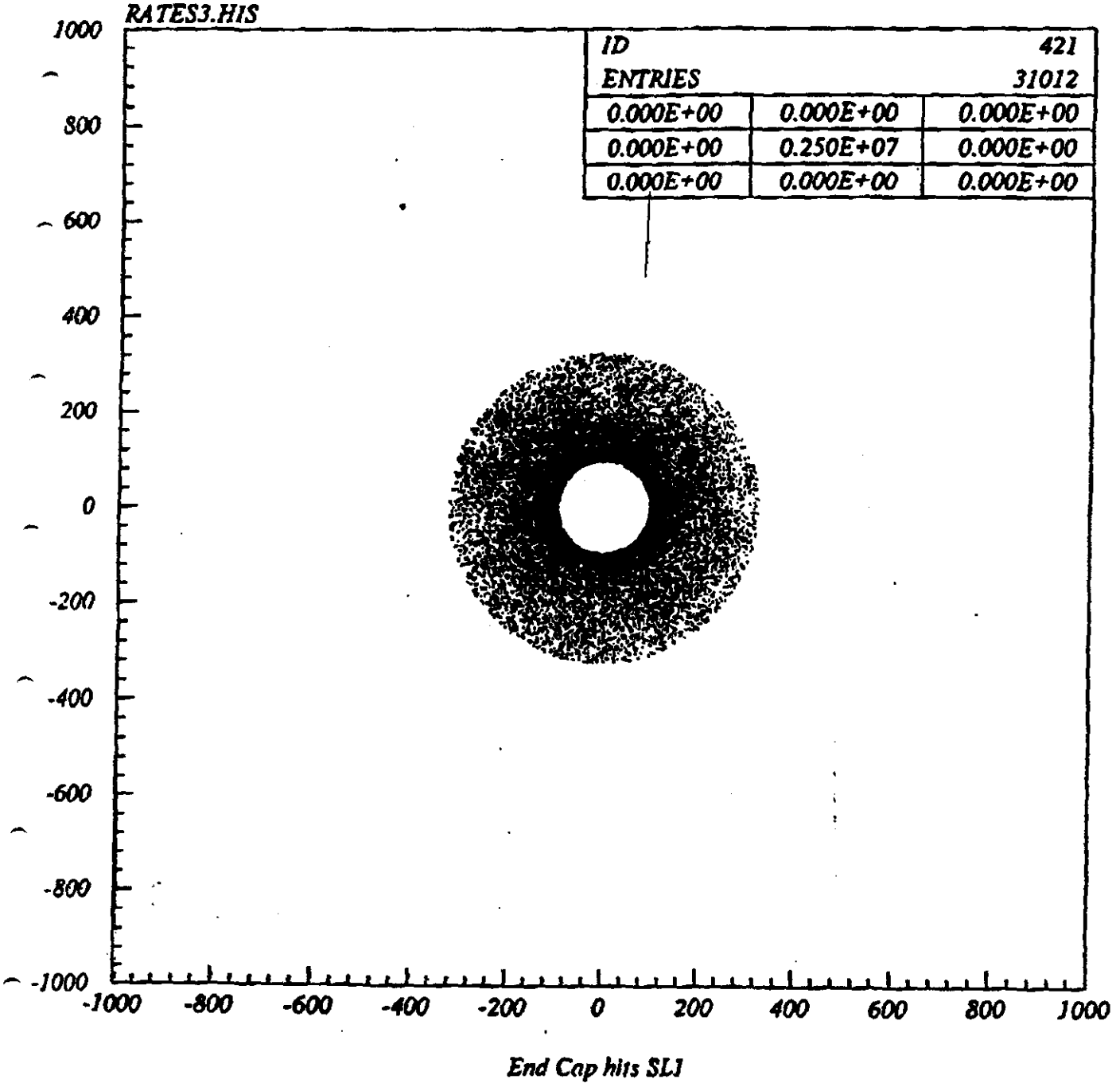
STRP12L1.HST

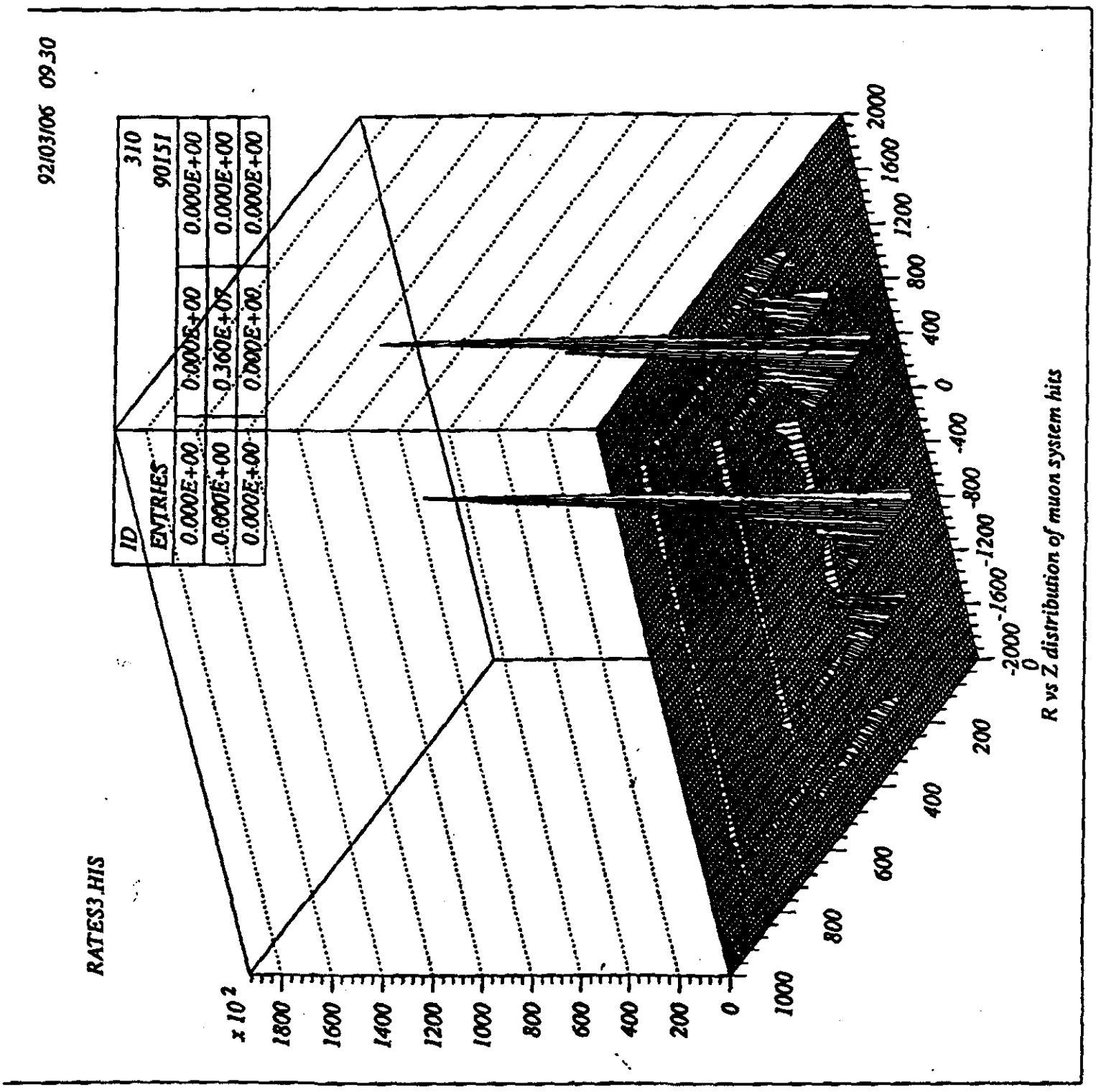


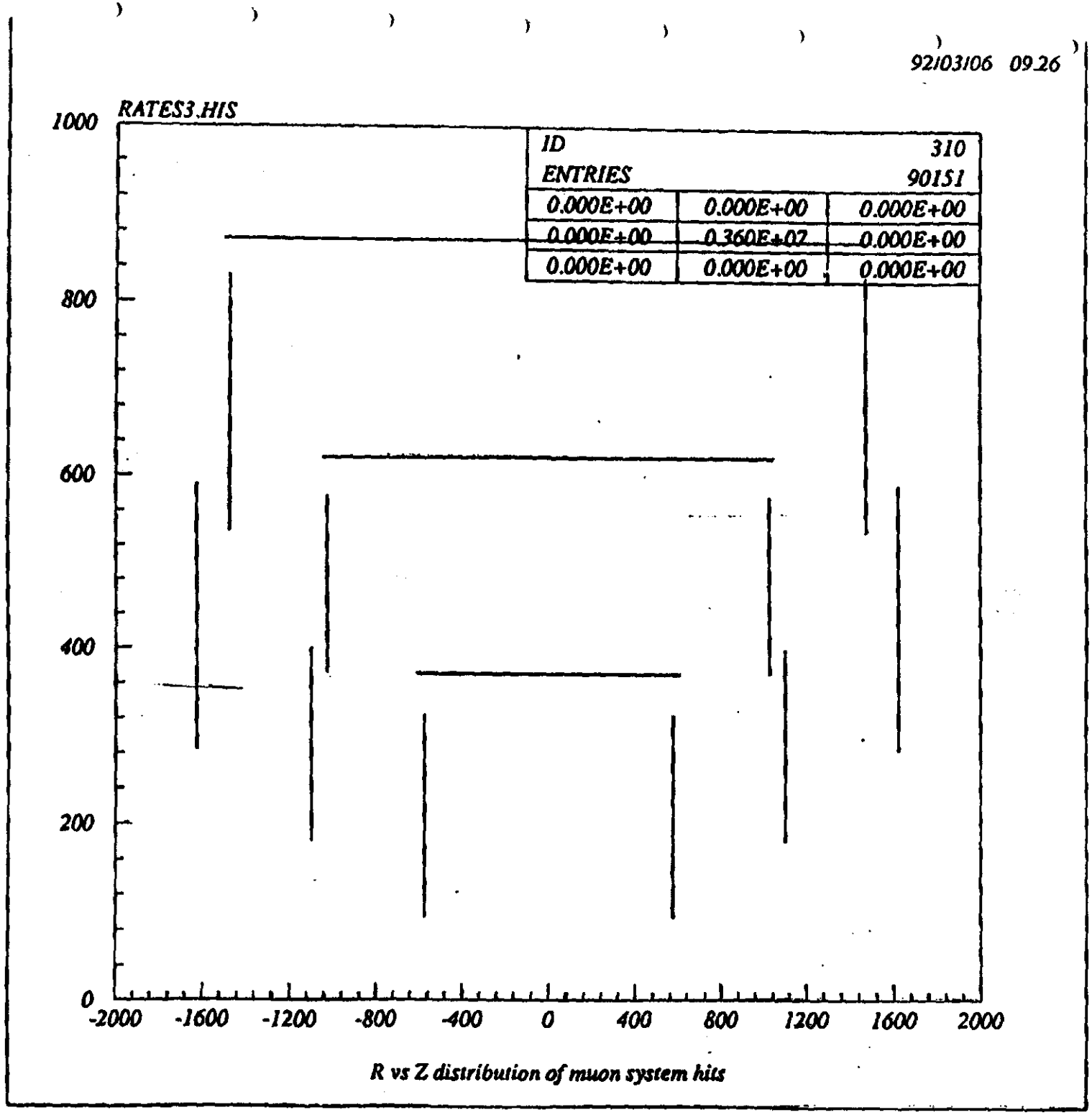

92/03/06 20.37
STRP12L1.HST
ID 3
Entries 16340
Mean 1.061
RMS 0.1055
UDFLW 0.0000E+00
OVFLW 0.0000E+00
ALLCHAN 72.11
10^2
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
0 1 2 3 4 5 6 7 8 9 10
Hits per Strip, F-zone 3

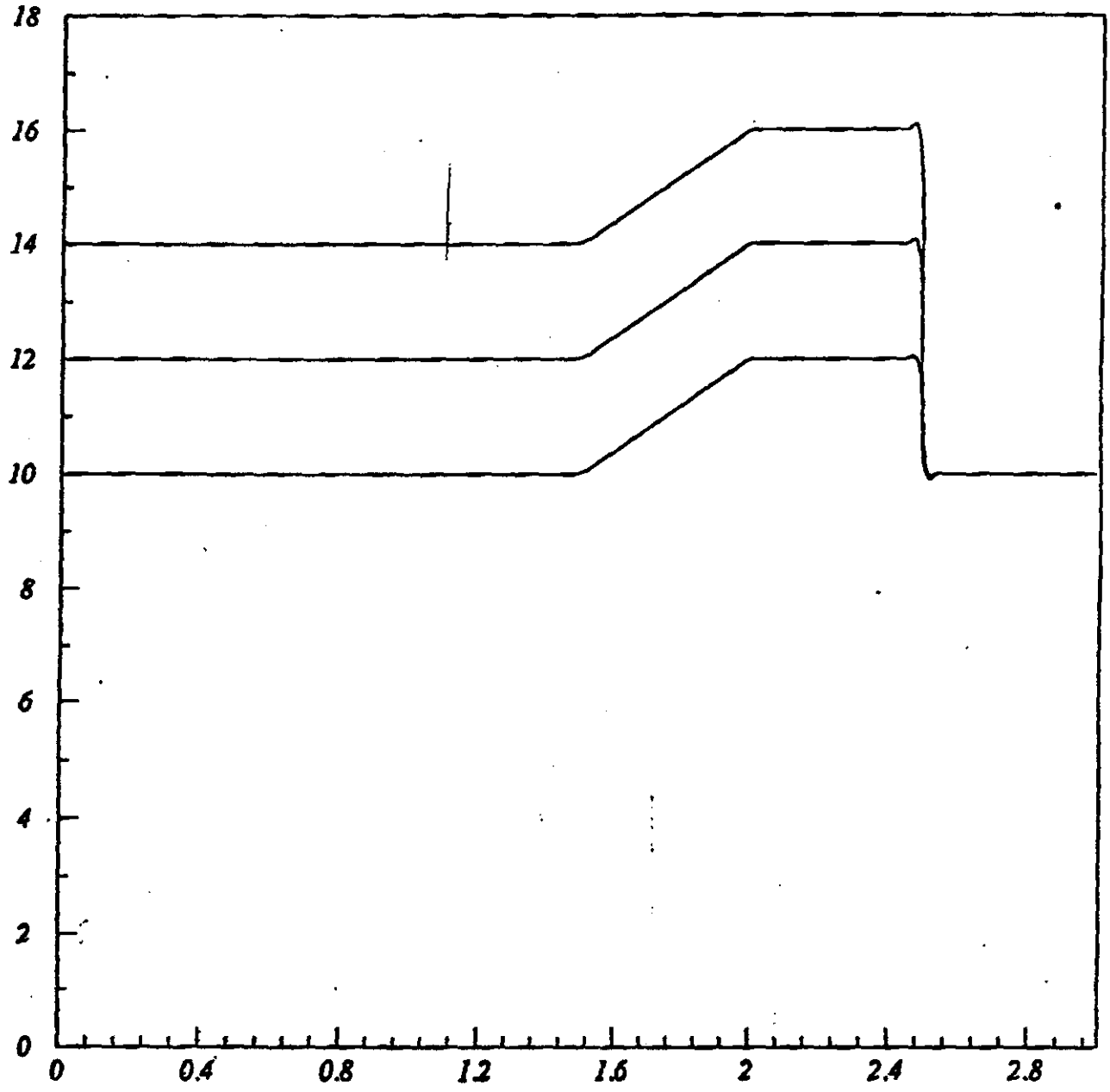
92/03/06 09.50

RATES3.HIS

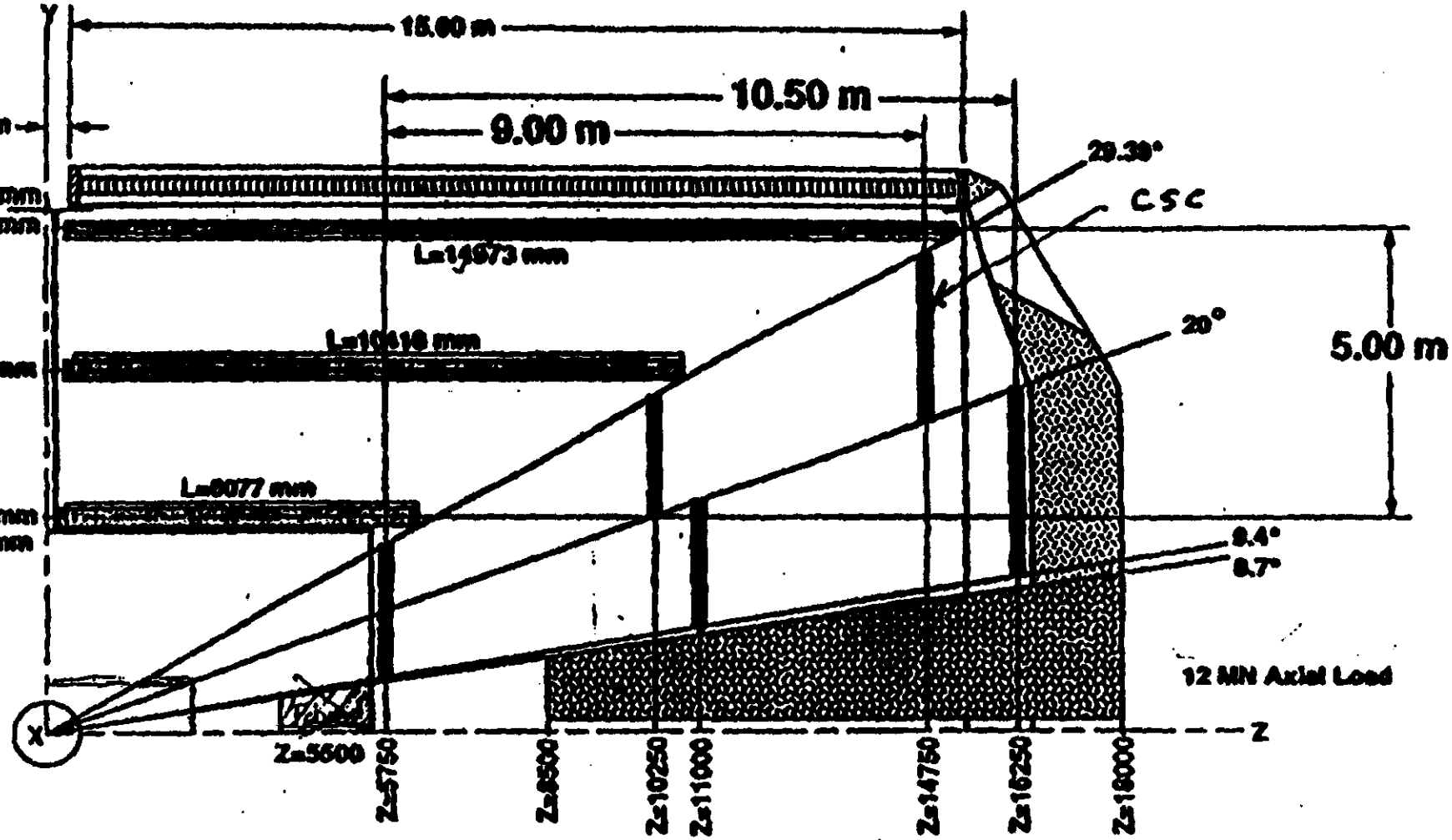



92/03/06 09.30
RATES3.HIS
ID 310
ENTRIES 90151
0.000E+00 0.000E+00
0.000E+00 0.360E+05
0.000E+00 0.000E+00
0.000E+00 0.000E+00
x 10 2
1800
1600
1400
1200
1000
800
600
400
200
0
1000
800
600
400
200
0
-2000
-1600
-1200
-800
-400
0
400
800
1200
1600
2000
R vs Z distribution of muon system hits


92/03/06 09.26
RATES3.HIS
ID 310
ENTRIES 90151
0.000E+00 0.000E+00 0.000E+00
0.000E+00 0.360E+07 0.000E+00
0.000E+00 0.000E+00 0.000E+00
1000
800
600
400
200
0
-2000 -1600 -1200 -800 -400 0 400 800 1200 1600 2000
R vs Z distribution of muon system hits



INTERACTION LENGTH VS ETA



GEM PDT 16/7 (8/8/4) Barrel
(4/4/4) Endcap
3 instrumented
ELEVATION

(Calorimeter 7m OD x11m Long)
(Extended Forward Field Shaper 18000mm Long)
(100 mm RPCs O/O/I)(Magnet half displaced along Z)

F. HAMBLETT
GEM920217

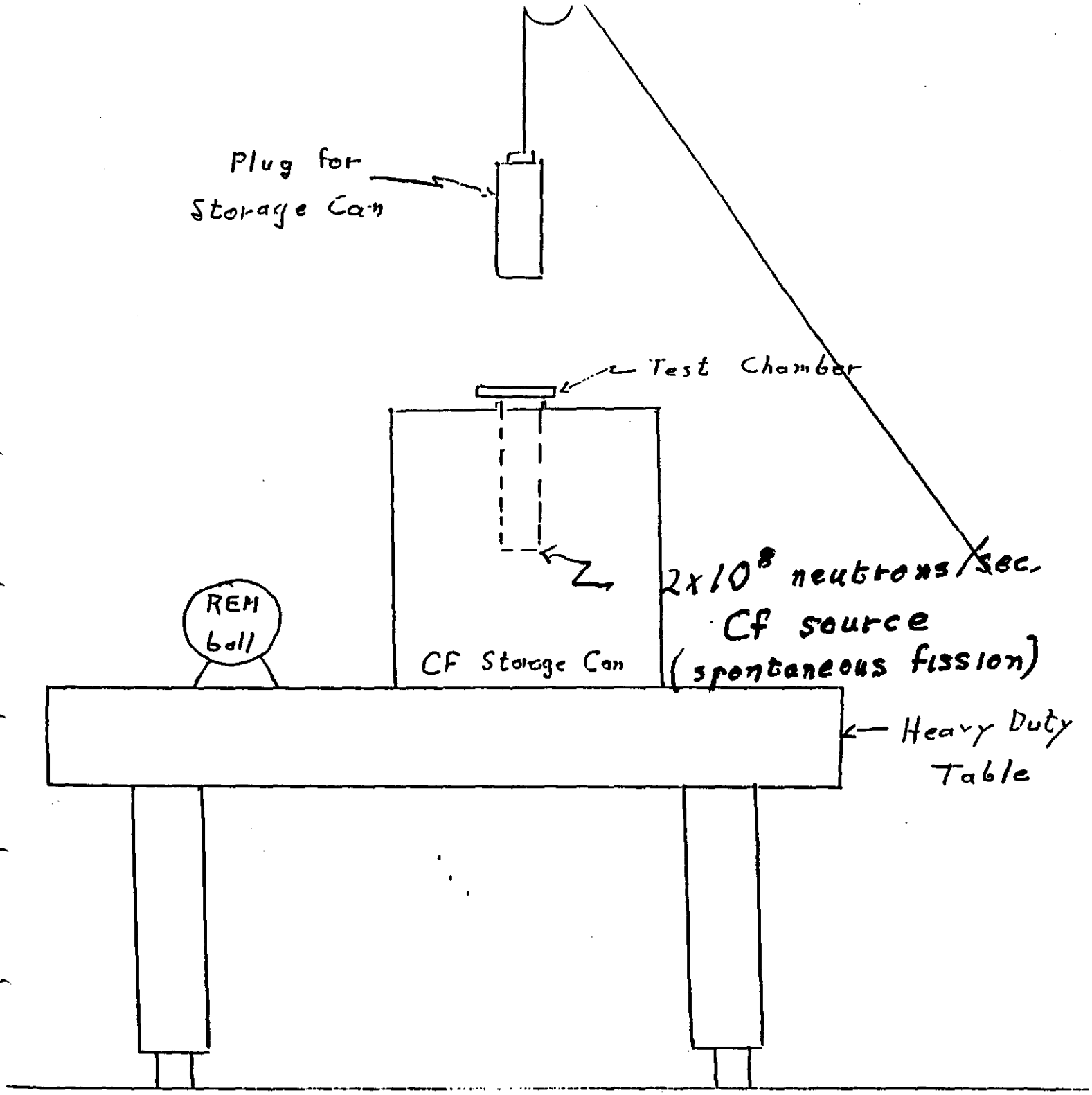


Fig. 2 Set-up for neutron flux detection in Room 24-040

GEM/TUCSON/ 8 MARCH 1992/ I. A. PLESS

TRIGGER ELECTRONICS MEETING

3 MARCH 1992 @ LECROY

1. TRIGGER CONCEPT
2. "HARDWARE" CONCEPT
3. CABLES
4. SUMMARY

PIPELINE MUON TRIGGER

FIELD PROGRAMMABLE GATE ARRAYS
APPLICATION SPECIFIC INTERGRATED CIRCUIT

RPC GEOMETRY AND CHANNEL COUNT
1 MARCH 1992

CHAMBER	THICKNESS	WIDTH	LENGTH	RADIUS (TO CENTER)
OUTER RPC	5 CM.	312.0 CM.	1471.4 CM.	858.5 CM.
CENTER RPC	5 CM.	234.1 CM.	1075.7 CM.	644.0 CM.
INNER RPC	5 CM.	143.5 CM.	642.6 CM.	394.9 CM.

TO CALCULATE THE WIDTHS AND LENGTHS, I USED THE INFORMATION OF THE 25 FEB 1992 BASE LINE FROM F. TAYLOR.

SECTOR ANGLE	20.60 DEGREES
THETA ANGLE OUTER SUPER LAYER	30.19 DEGREES
THETA ANGLE CENTER SUPER LAYER	30.81 DEGREES
THETA ANGLE INNER SUPER LAYER	31.41 DEGREES

CHANNEL WIDTH AND COUNT (PER SECTOR)
BEND PLANE

CHAMBER	OLD WIDTH	OLD COUNT	NEW WIDTH	NEW COUNT
OUTER RPC	1.3 CM.	254	1.3 CM.	240
CENTER RPC	1.3 CM.	185	1.3 CM.	187
INNER RPC	1.3 CM.	113	1.3 CM.	111
TOTALS		552		538

CHANNEL WIDTH AND COUNT (PER SECTOR)
NON BEND PLANE

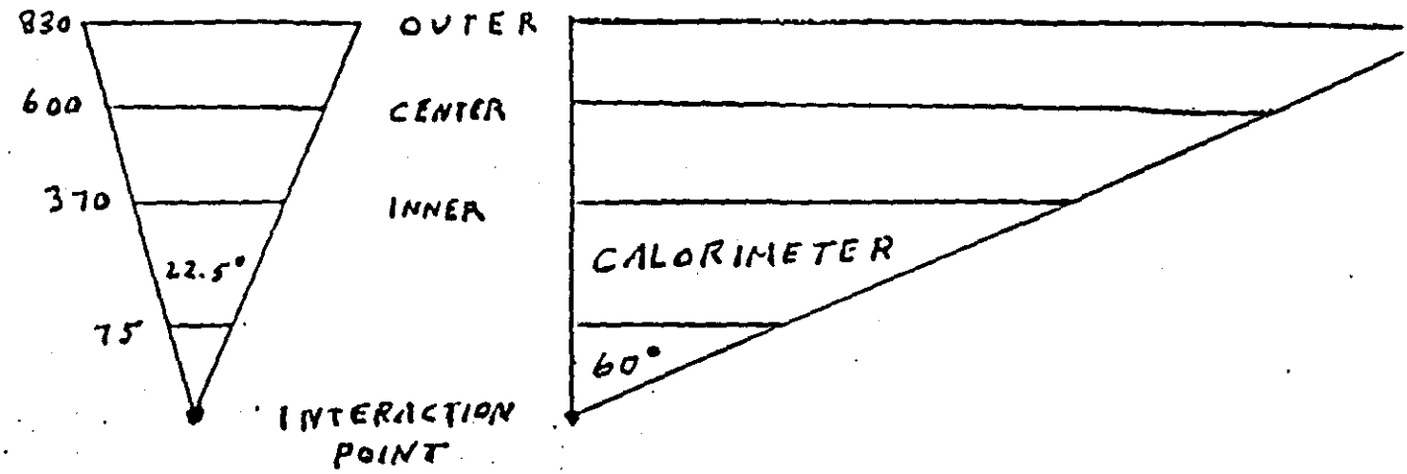
CHAMBER	OLD WIDTH	OLD COUNT	NEW WIDTH	NEW COUNT
OUTER RPC	9.0 CM.	161	8.9 CM.	166
CENTER RPC	1.3 CM.	805	6.5 CM.	166
INNER RPC	4.1 CM.	161	3.9 CM.	166
TOTALS		1127		498

OLD TOTAL COUNT 1679 (PER SECTOR)
NEW TOTAL COUNT 1036 (PER SECTOR)

1 MARCH 1992
I. A. PLESS

PRESENTATION TO THE GEM MUON TRIGGER SUBGROUP
MEETING OF 6 JANUARY 1992 AT BNL
IRWIN A. PLESS

BASE LINE GEOMETRY



	RADIUS	LENGTH	WIDTH
Outer plane	830	1450	330.2
Center plane	600	1048	239.7
Inner plane	370	664	147.2

CALORIMETER

Inner radius	= 75
Outer radius	= 370
Interaction thickness	= 12 λ
Total number of radiation lengths	= 12/.56 x 18.5 = 396

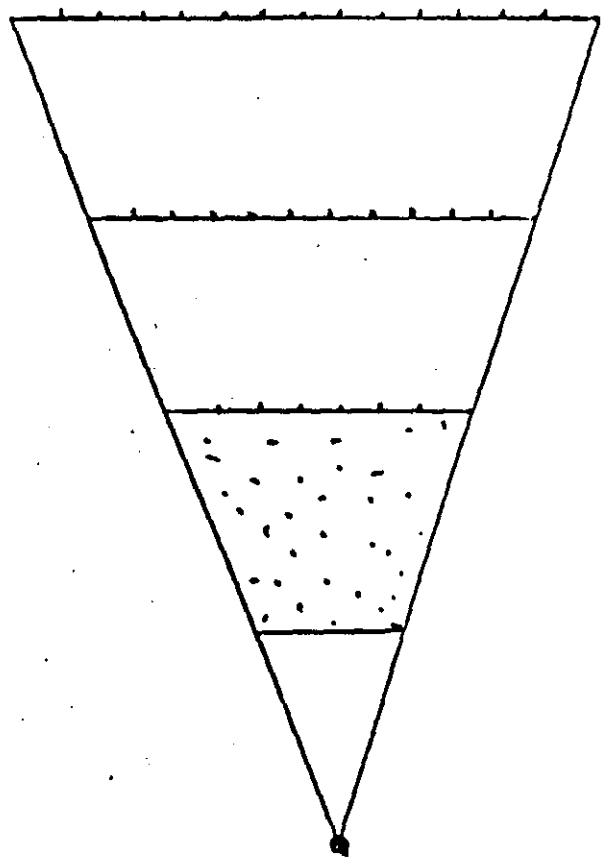
$$\theta_o = 21/E \sqrt{x/x_o} = 21/E \sqrt{396}$$

$$\theta^{RMS}_{plane} = 1/\sqrt{2}\, \theta_o$$

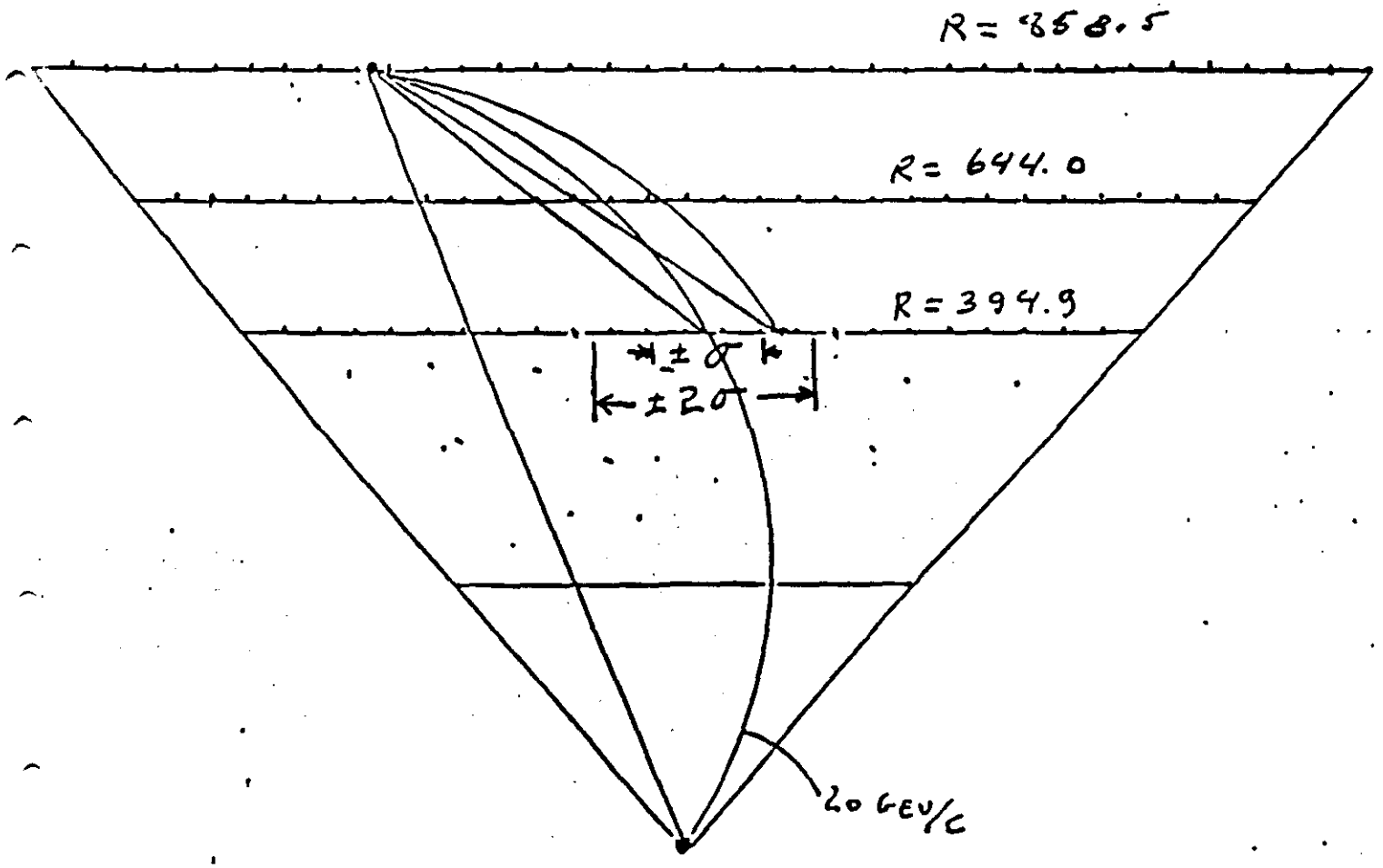
$$\sigma^{RMS}_{plane} = 1/\sqrt{3}\ L\ \theta^{RMS}_{plane}$$

BEND PLANE CALCULATIONS

All strip widths = 1.3 cm



Outside plane	= 254 strips
Center plane	= 185 strips
Inner plane	= 113 strips
Total number strips	= 552 (= number of discriminators)



A 20 GeV/c track has a sigma of 2 strips around the ideal intersection point at R = 395 due to multiple scattering. In order to have a 95% acceptance we have to be able to handle ± 4 strips around the ideal (no multiple scattering) intersection point.

At R=644.0 we have to accomodate just two strips for a given geometry at R=394.9. There is no additional effect from multiple scattering.

In a sense , we make two simultaneous measurements of the momentum. The first consists of the sagitta at R=394.9 formed between the interaction point and the strip at R=858.5. The second consists of the sagitta at R=644.0 formed between the strip struck at R=394.8 and the strip struck at R=858.5.

Multiple scattering plays a large role in the first measurement and a very small role in the second measurement.

P	S R = 370	S R = 600	σ R = 370	# σ	# STRIPS/2 R = 370	# STRIPS R = 370	# STRIPS S = 600	# STRIPS S = 370
	CM	CM	CM					
10	20.5	6.4	5.0	1	4	8	5	15.8
20	10.2	3.2	2.5	2	4	8	4	7.8
30	6.8	2.1	1.7	3	4	8	3	5.2
40	5.1	1.6	1.3	3	4	8	3	3.9
50	4.1	1.3	1.0	3	3	6	2	3.2

† 30 AND 40 CANNOT BE SEPERATED

To handle the multiple scattering problem we must have many circuits.

10 GeV positive charge. For example:

8 x 254 = 2032

10 GeV	= 2032
20 GeV	= 2032
(30 + 40) GeV	= 2032
50 GeV	= 1524

Total number of circuits for positive charge = 7620

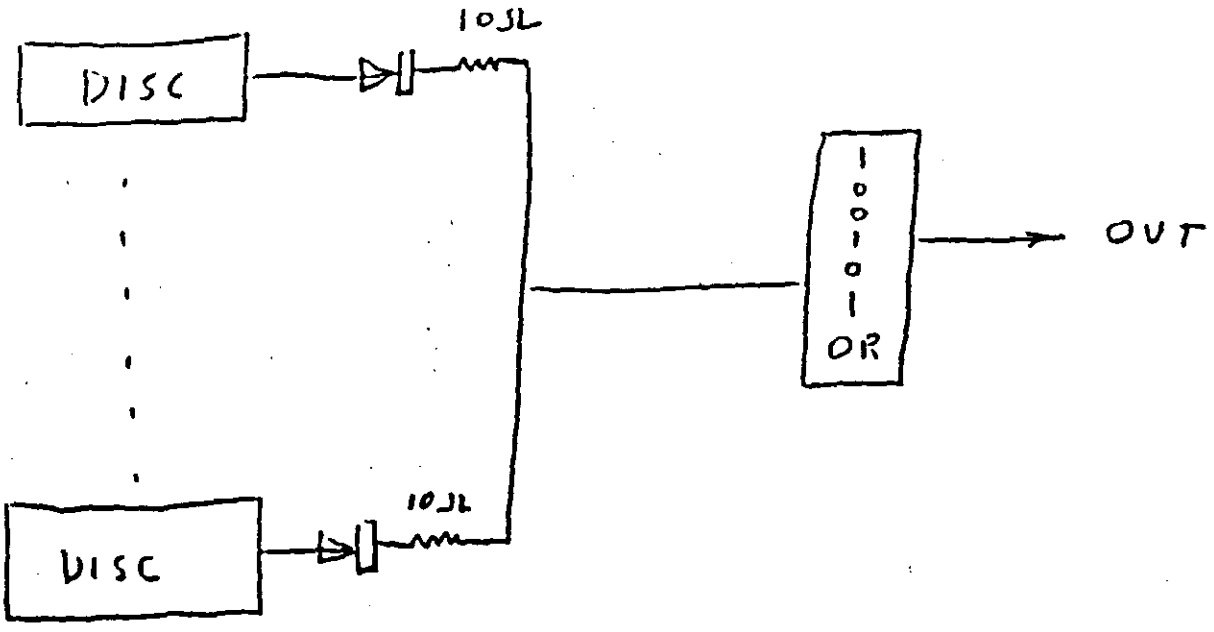
For both charges = 2 x 7620 = 15,240

The logic gives four momentum trigger ranges.

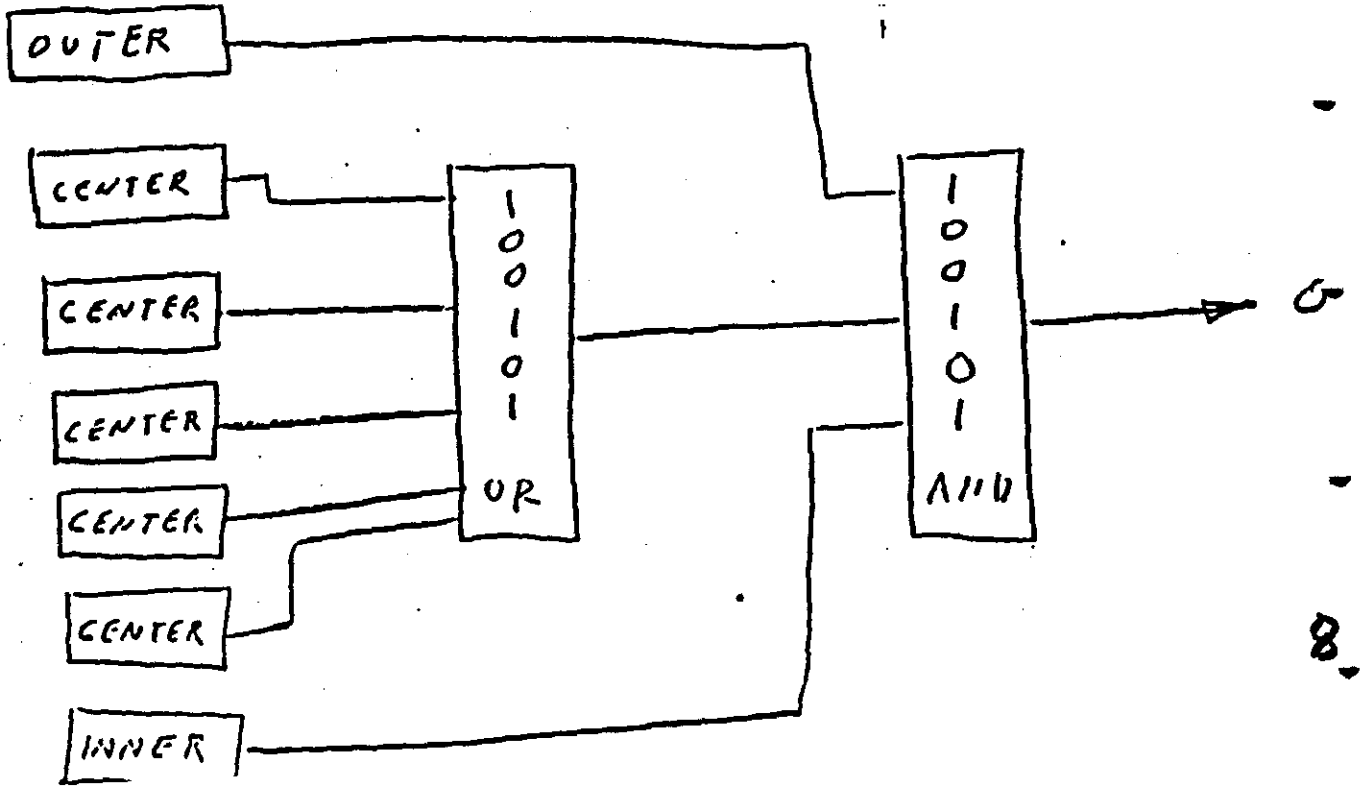
> 10 GeV/c
> 20 GeV/c
> 30 GeV/c
> 50 GeV/c

Circuit "Design" using signetics 100 K series ECL chip 100101. This is a 5 input and/or chip.

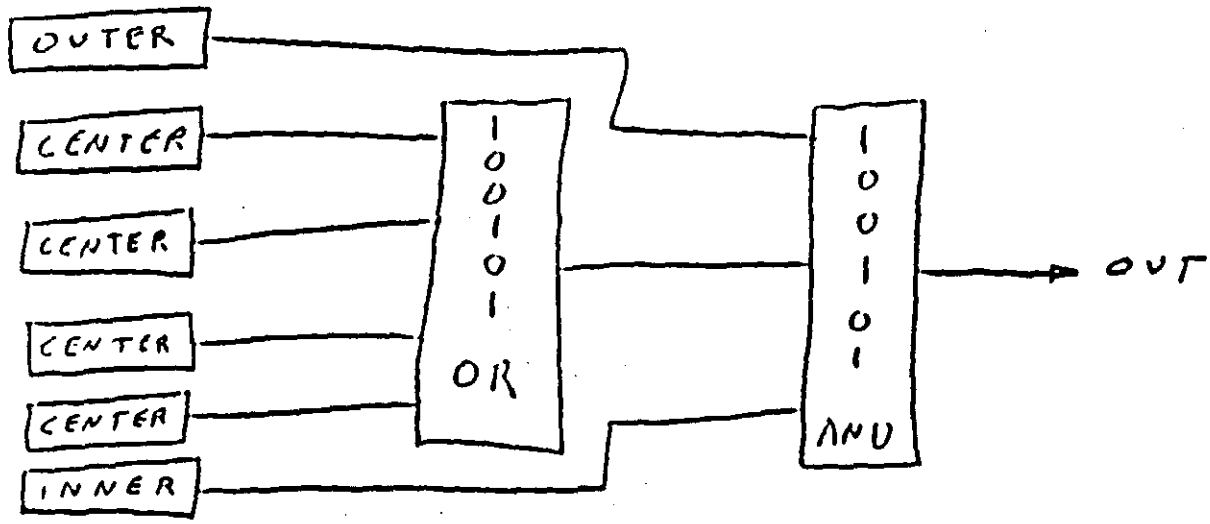
Need a fast infinite fan in circuit (infinity = 2032)



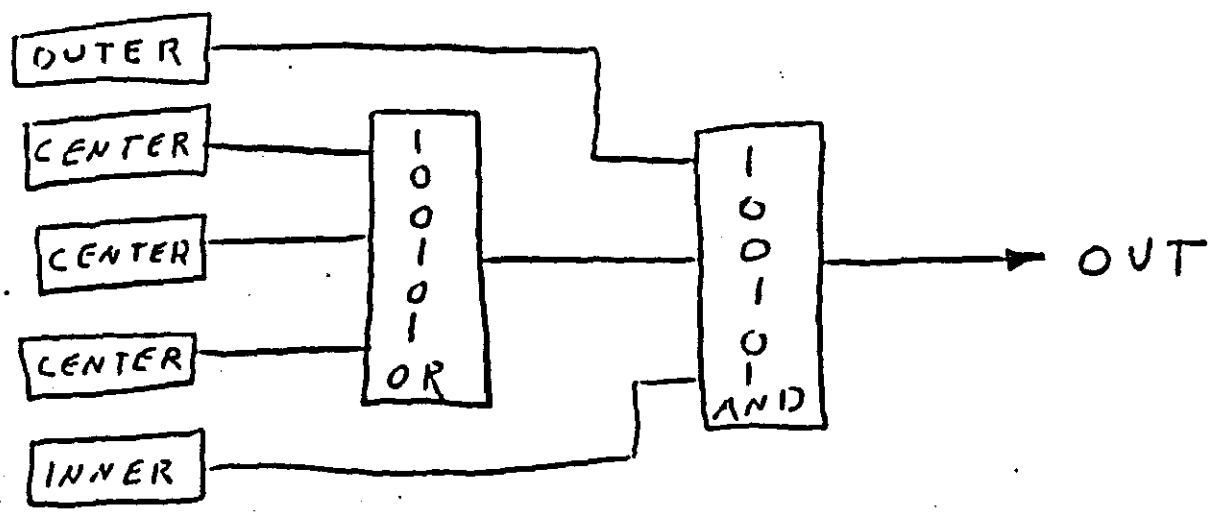
10 GeV Circuit = 8 x 2 x 254 = 4,064 circuits (2,032 positive; 2,032 negative).



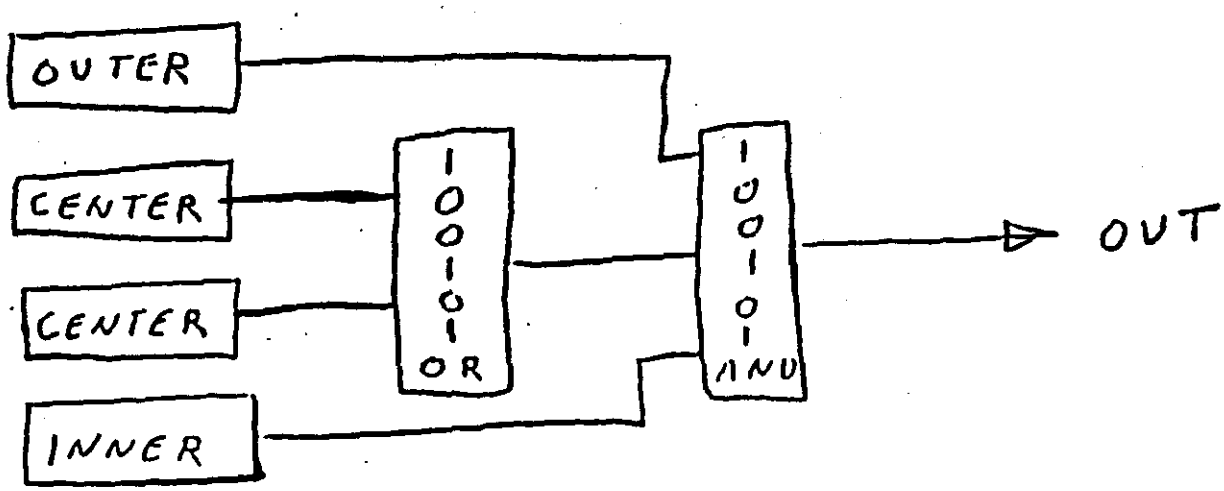
20 GeV circuit - need 4,064 circuits.



(30-40) GeV circuit - need 4,064 circuits

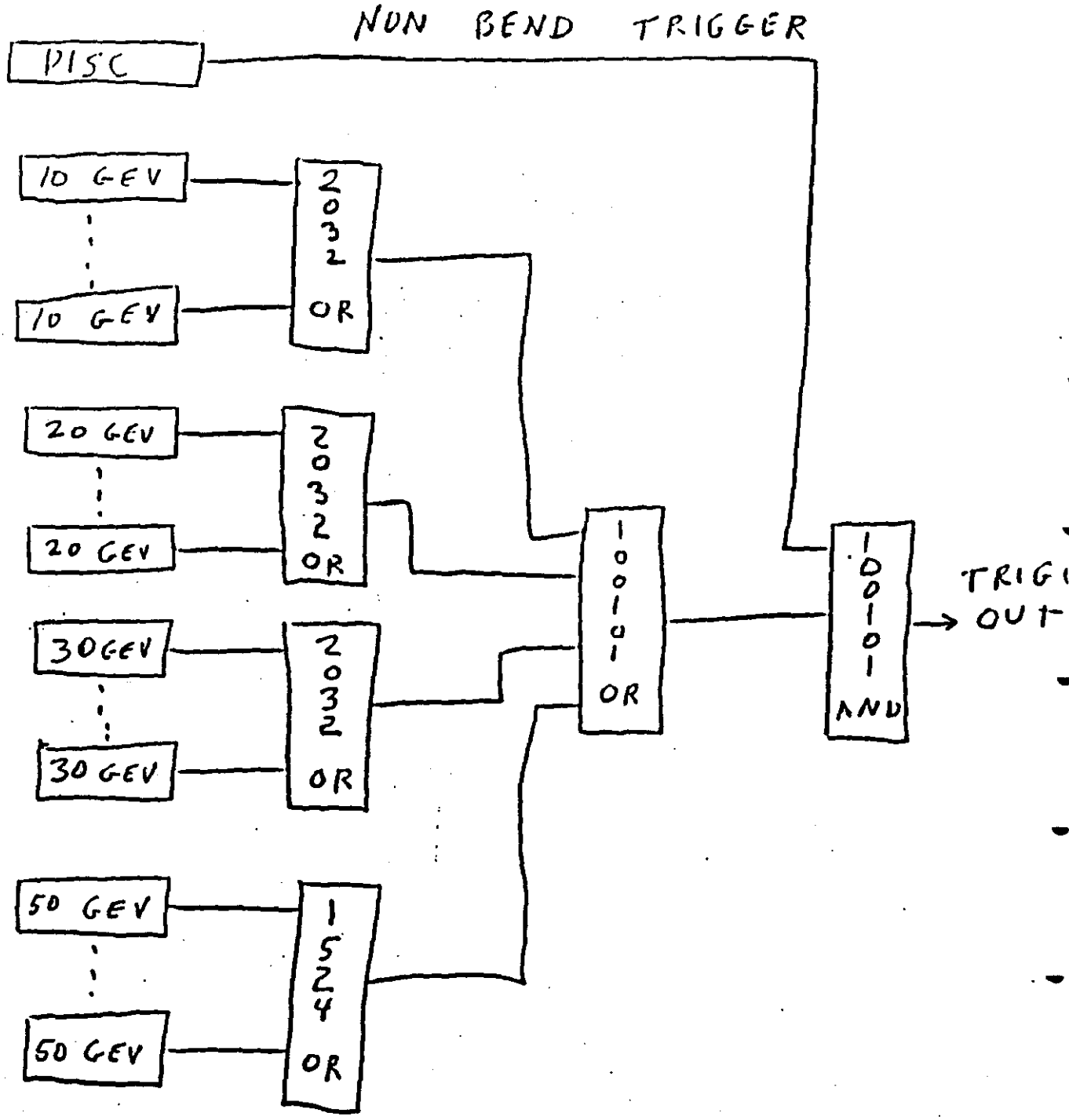


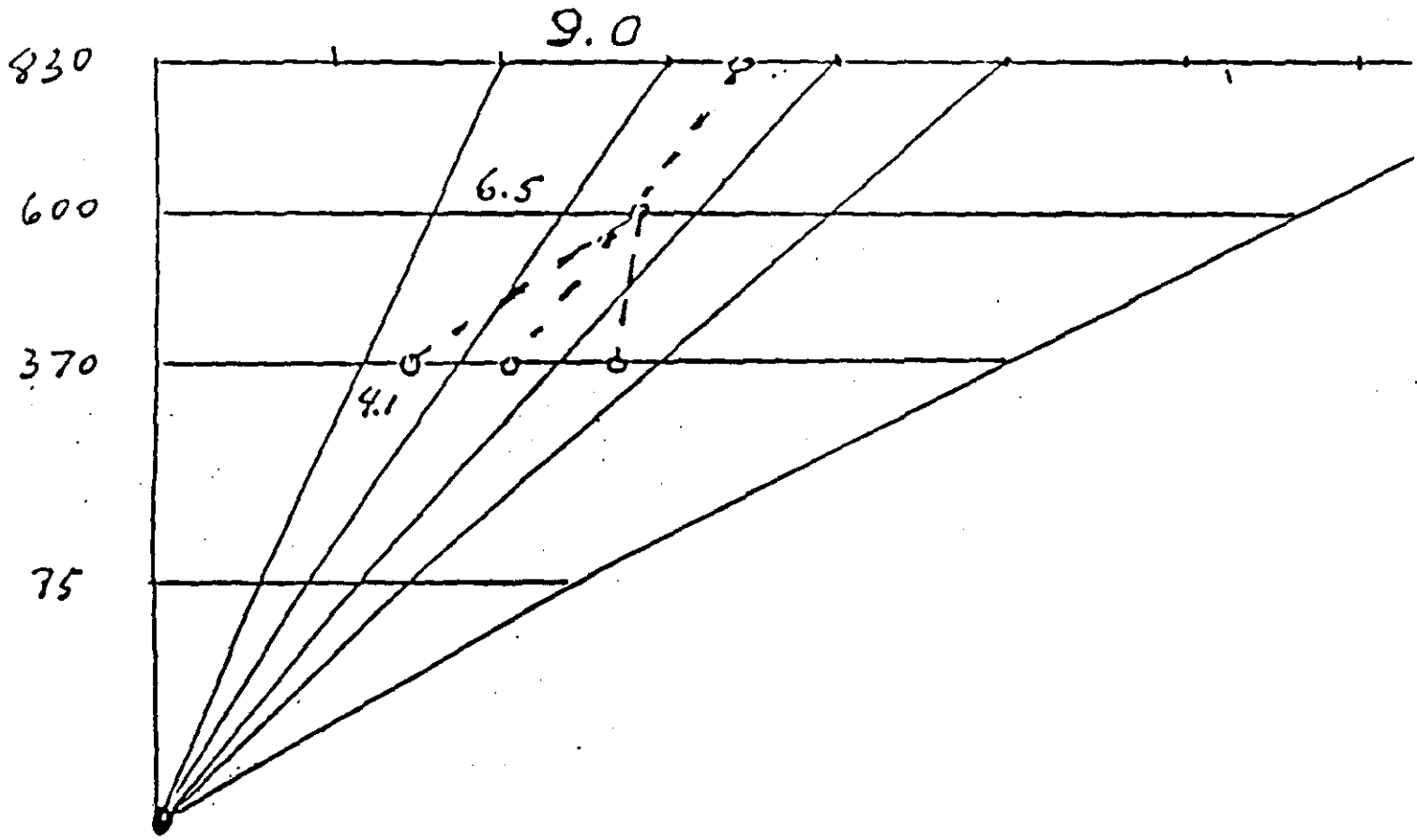
50 GeV/c circuit - need 6 x 2 x 254 = 3,048 circuits (1524 positive; 1524 negative)



POSITIVE MUON

Trigger > 10 GeV





For each outer strip there are three, three fold coincidence circuits. Any triple coincidence generates a non-bend trigger.

Tower geometry.

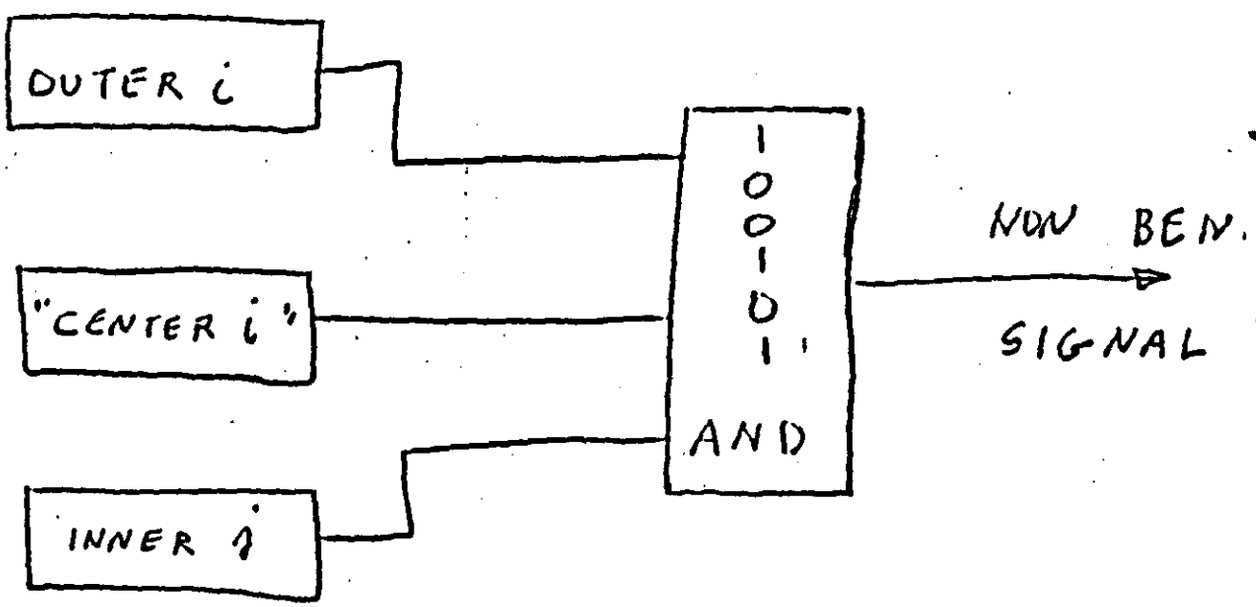
Each plane is divided into 161 strips.

Outer	= 9.0 cm
Center	= "6.5" cm
Inner	= 4.1 cm

Center is really 5 strips OR'd together, each strip is 1.3 cm wide to furnish the z coordinate of the track.

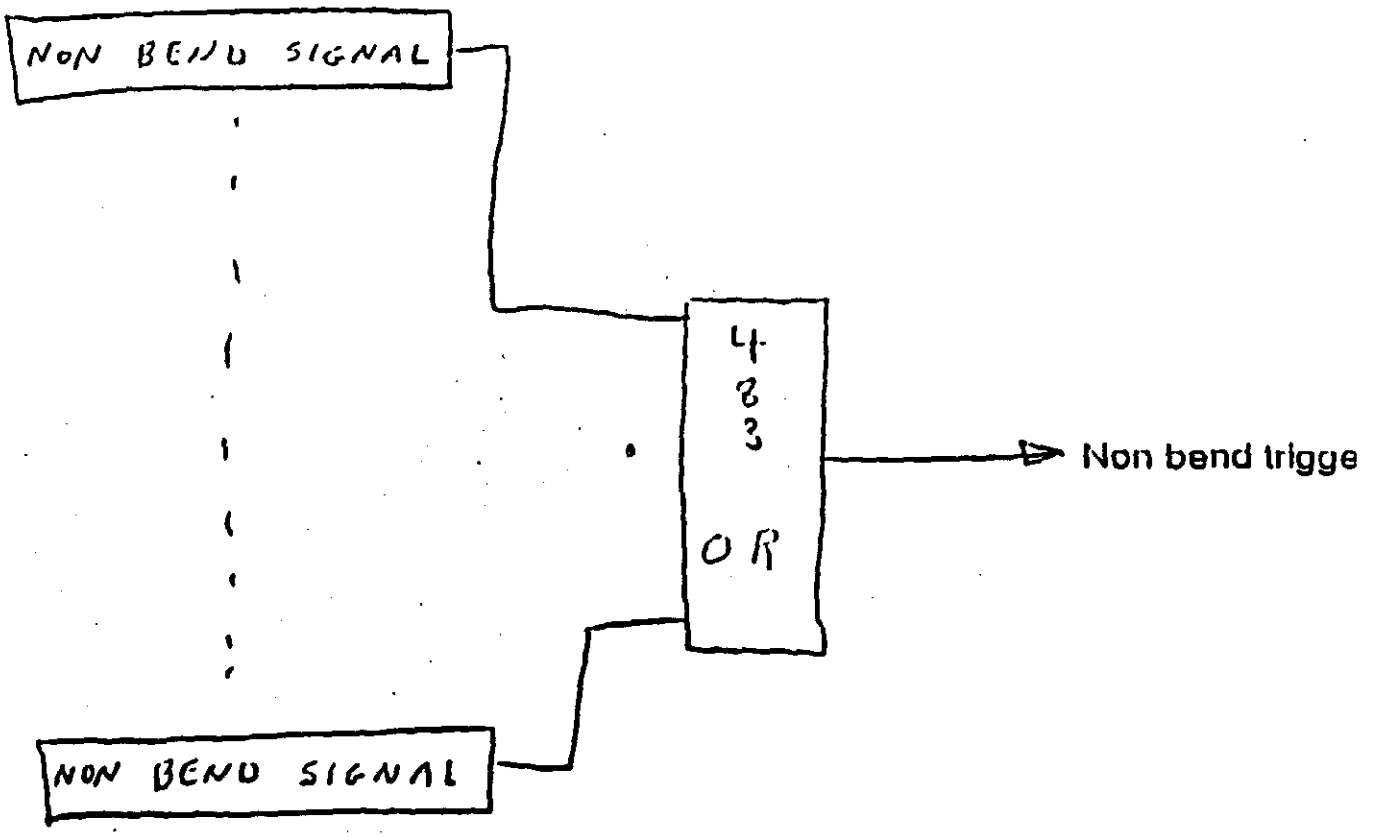
For each outer strip there are three coincidence circuits to account for multiple scattering.

This implies there are 3 x 161 = 483 circuits per sector. Each circuit is as follows:



$j = i-1,\ i,\ i+1$

NON BEND CIRCUIT



This has 100% acceptance for $P_t > 30$ GeV/c.

This has about 70% acceptance for $P_t = 10$ GeV/c

Acceptance falls rapidly for $P_t < 10$ GeV/c

We have	161 strips	4.1 cm (inner)
	161 strips	9.0 cm (outer)
	805 strips	1.2 cm (c[illegible]ter)

Hence a total of 1127 strips => 1127 discriminators per sector. Trigger box must accommodate 1127 connectors or about 2254 cm linear length.

SUMMARY

Strip count

Non	Bend	1,127
	Bend	552

Circuits

Non	Bend	483
	Bend	15,240

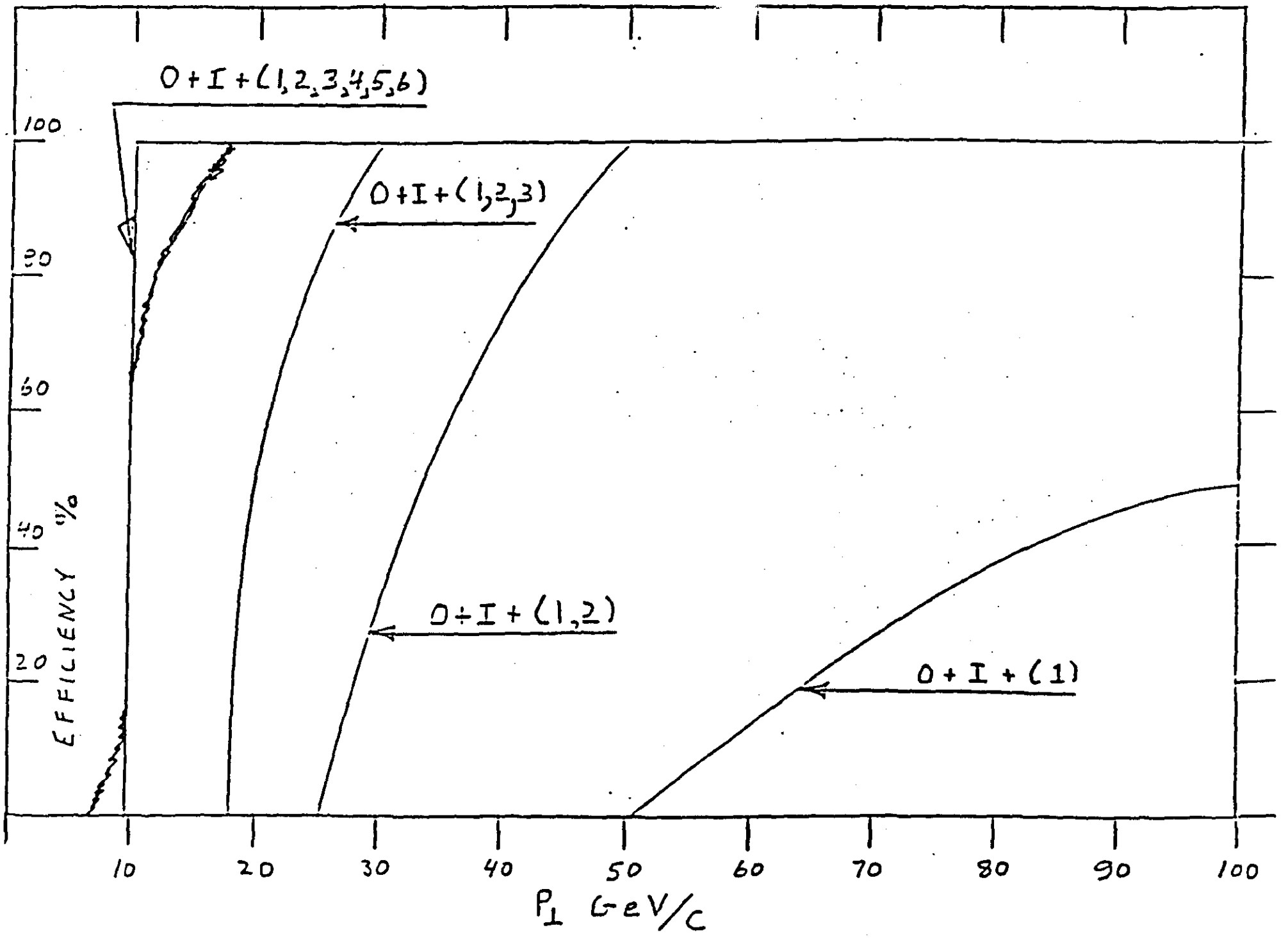
Chips

Non	Bend	644
	Bend	45,720

Each discriminator must connect to a maximum of 70 circuits. This puts either a constraint on the output impedance of the discriminator or a series input resistor to the 100101 ECL chip. As an alternative, to save power and money, all this can be redone in C-MOS with large scale integration techniques.

Question:

How do we write the simulation program?


O + I + (1,2,3,4,5,6)
O + I + (1,2,3)
O + I + (1,2)
O + I + (1)
100
80
60
40
20
EFFICIENCY %
10
20
30
40
50
60
70
80
90
100
P⊥ GeV/c

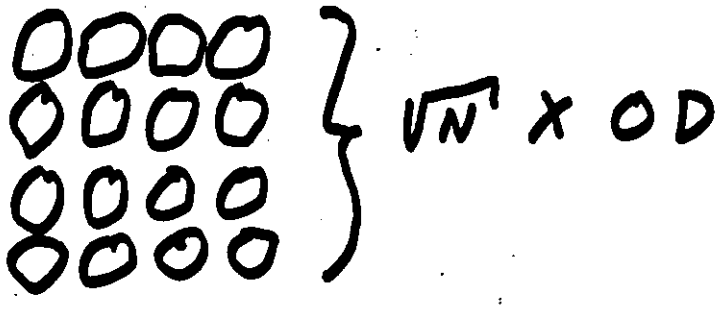
CABLES

RG 59 = .250" OD

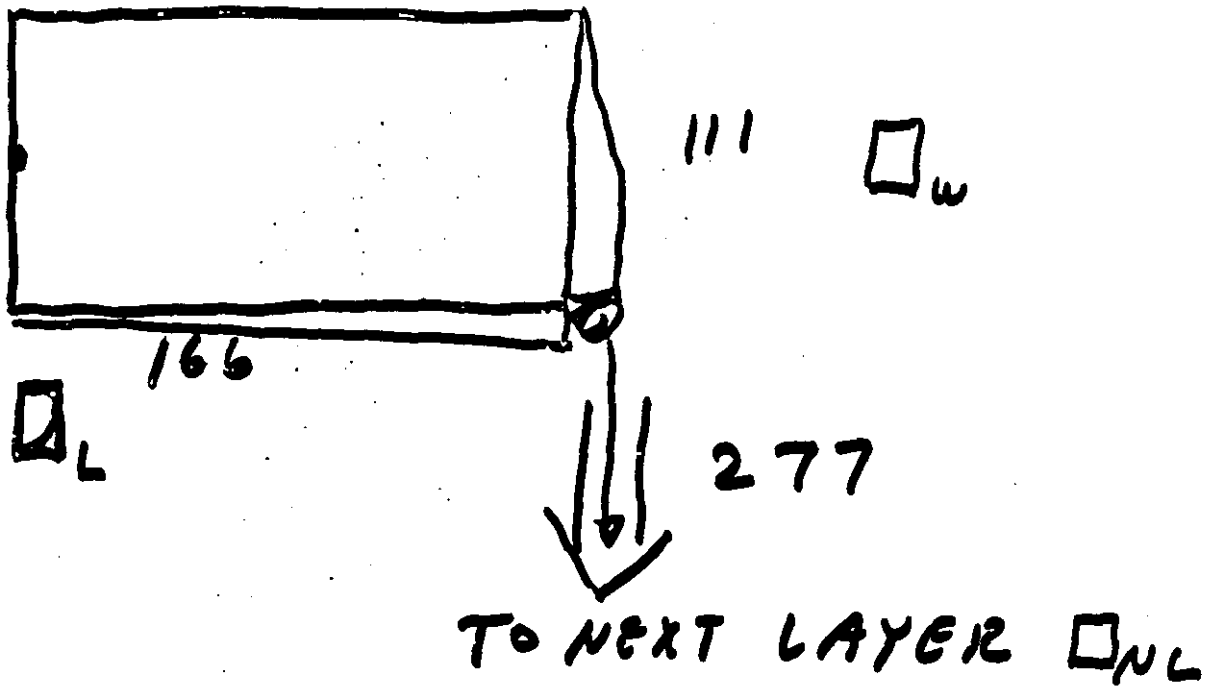
RG 58 = .200 OD

RG 174 = .105 OD

PACKING

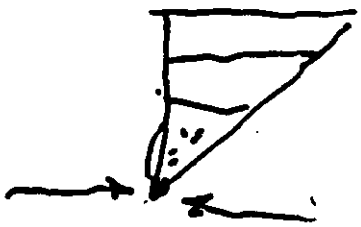


INNER PLANE



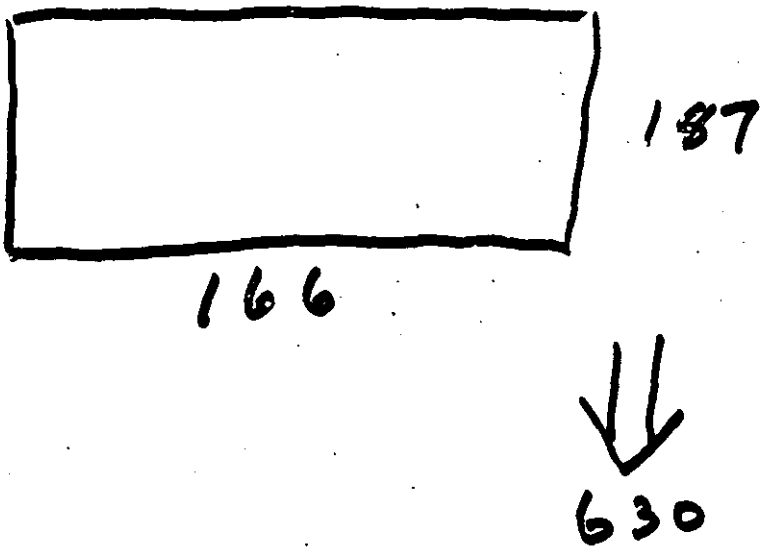
$$\square_L = \sqrt{166} \times .250 = 3.2$$
$$.200 = 2.5$$
$$.105 = 1.3$$

$$\square_W = \sqrt{111} \times .250 = 2.6$$
$$.200 = 2.1$$
$$.105 = 1.1$$



$$\square_{NL} = \sqrt{277} \times .250 = 4.2$$
$$\times .200 = 3.3$$
$$\times .105 = 1.7$$

CENTER PLANE

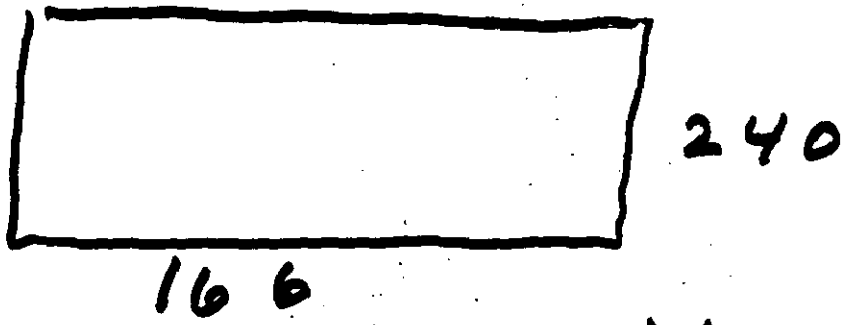


$\square_L$ = 3.2
2.5
1.3

$\square_W$ = 3.4
2.7
1.4

$\square_{NL}$ = 6.3
5.0
2.6

OUTER PLANE



1036 OUT OF MAGNET

$\square_L =$ 3.2
2.5
1.3

$\square_W =$ 3.9
3.1
1.6

$\square_{OM} = \sqrt{1036} \times .250 = 8.1$
$.200 = 6.4$
$.105 = 3.4$

MAXIMUM BUNDLE

8.1" X 8.1" FOR RG59

6.4" X 6.4" FOR RG58

3.4" X 3.4" FOR RG 174

CABLE VOLUME LOOKS

REASONABLE

SUMMARY

TRIGGER LOGIC:

1. SIMPLE
2. CAN BE PIPELINED (I THINK)

CABLES:

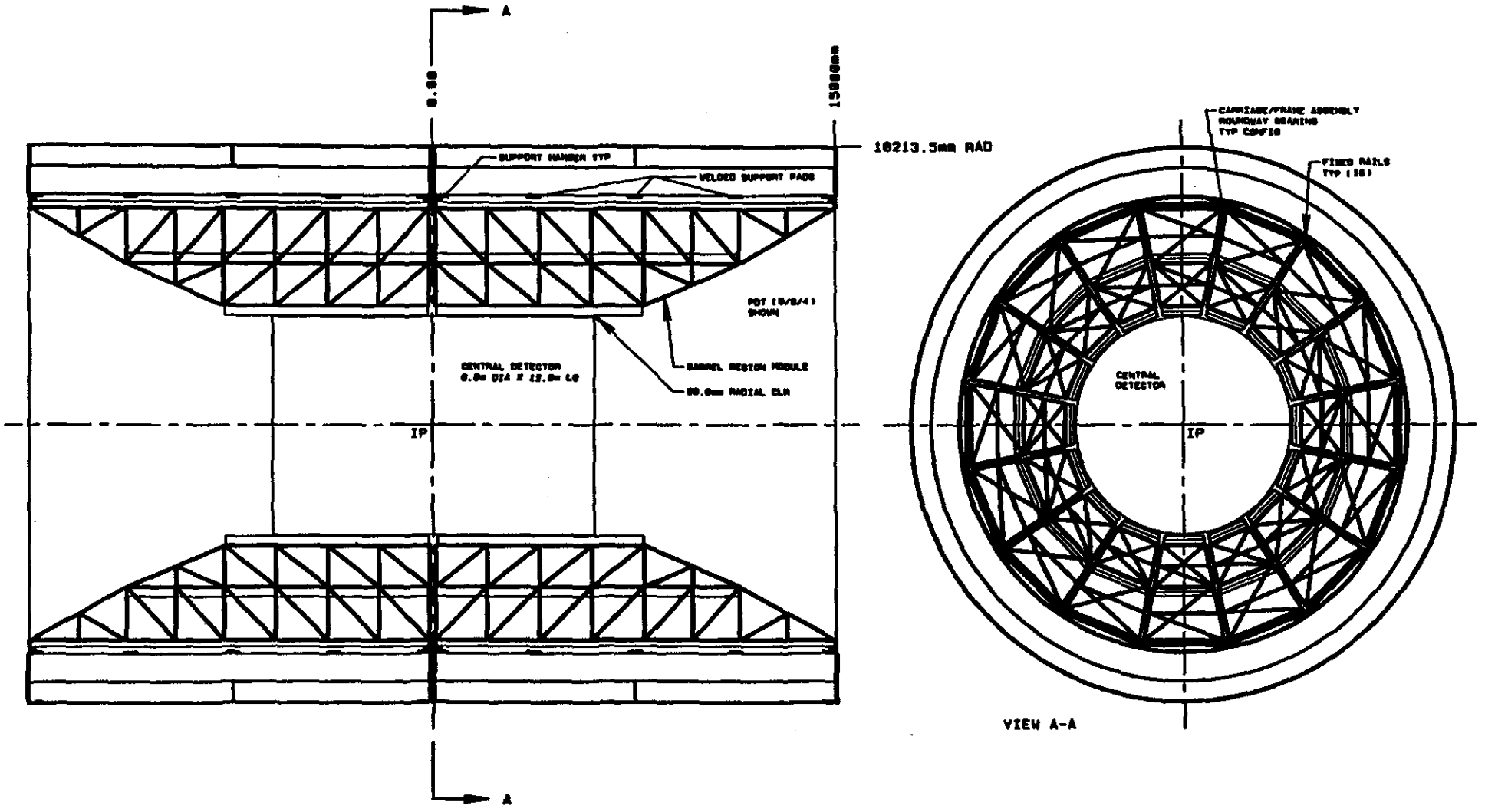
1. SMALL VOLUME

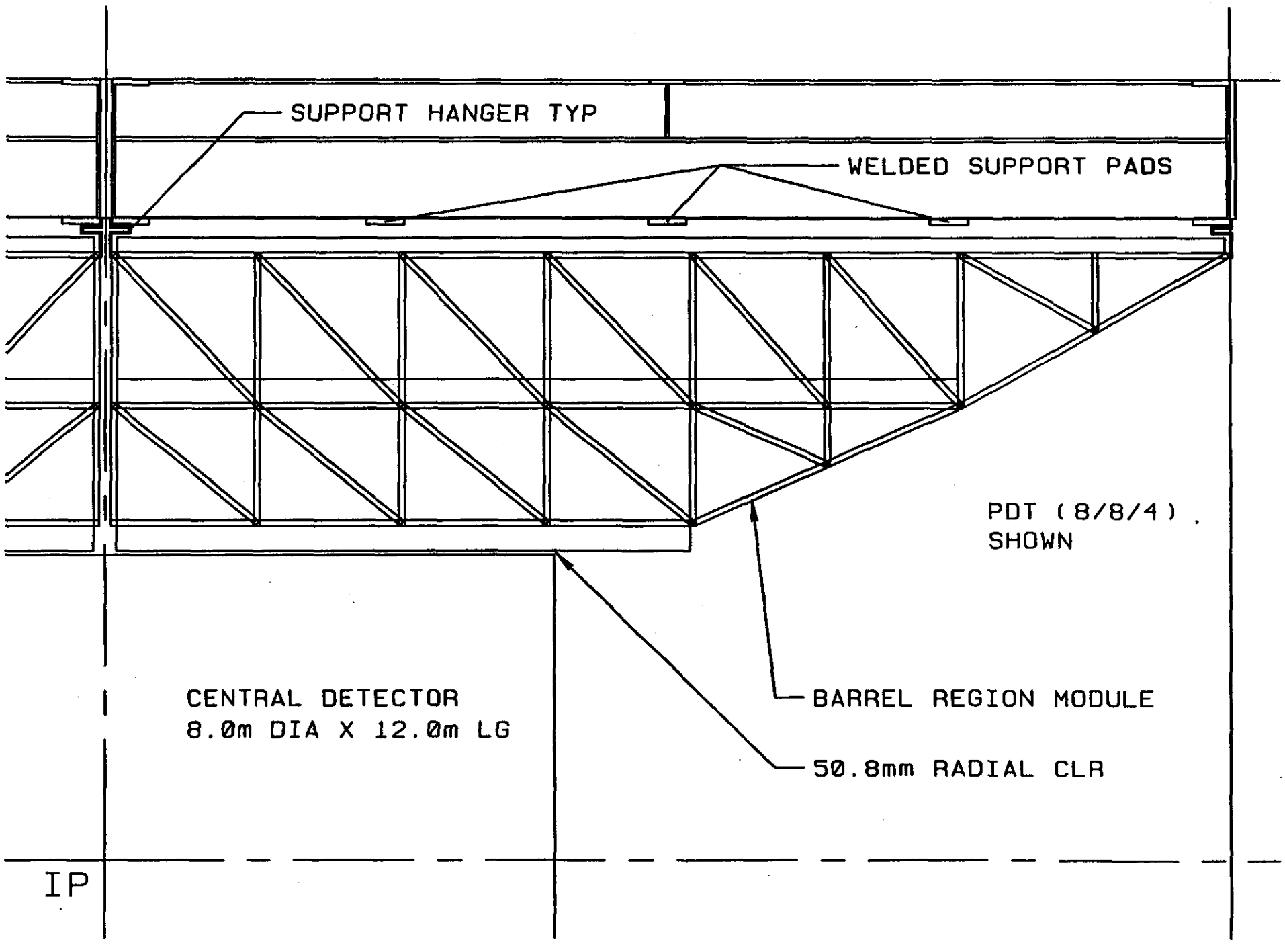
SUPPORT STRUCTURE

BARREL REGION:

- REVIEW "FEB 6" BASELINE (16.8m / 8m) 50mm webs
- ACCEPTANCE IN "Ø"
- ACCEPTANCE IN "Θ"
- STRUCTURAL PROBLEMS WITH HIGH ACCEPTANCE IN "Ø"
  - INSTALLATION HARWARE SPACE?
  - MODULE TO MODULE CLEARANCE?
  - ALIGNMENT LINES OF SIGHT?
  - STRUCTURAL ANALYSIS NOT DONE!
- SKEWED MODULE ?
- OPTIONAL INDEPENDENT MUON SUPPORT STRUCTURE
  - DUPLICATES STIFFNESS OF MAGNET END-RING STRUCTURE
  - COST $5M-$6M
  - ADVANTAGE - INDEPENDENT ADJUSTMENT OF MUON SYSTEM AS AN ASSEMBLY!

F. Nimblett
3/8/92

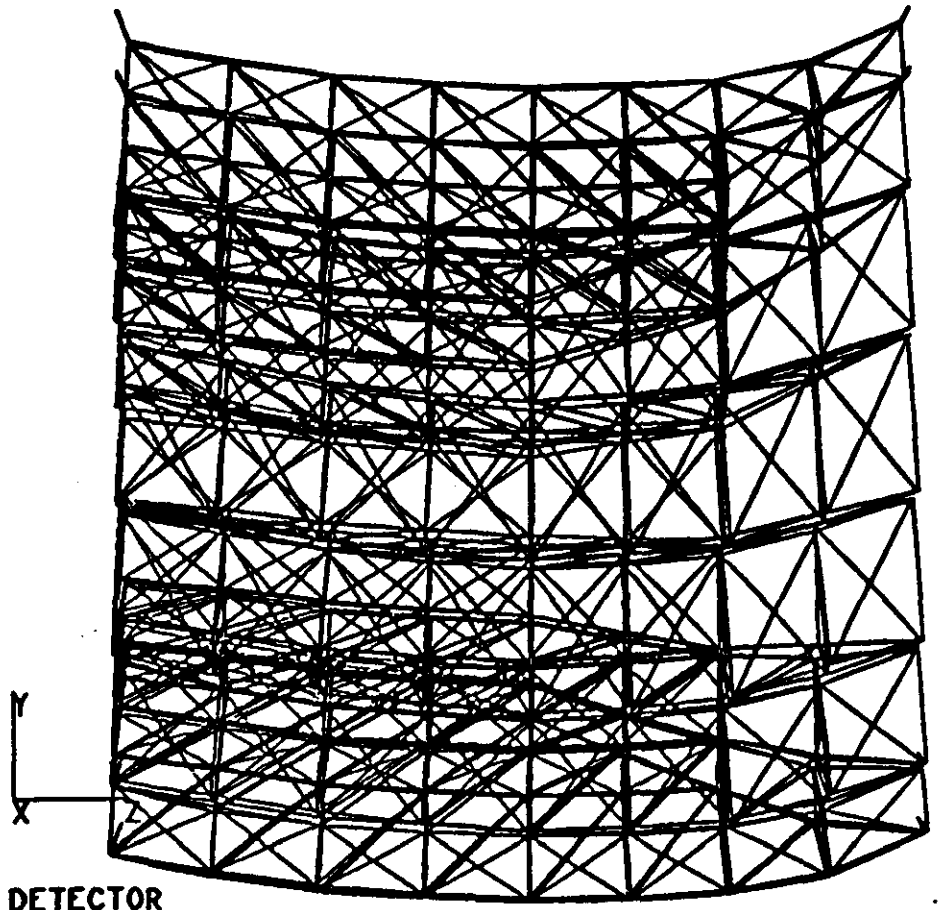

A
0.00
15000mm
10213.5mm RAD
SUPPORT HANGER TYP
WELDED SUPPORT PADS
PDT (5/8/4) SHOWN
BARREL REGION MODULE
CENTRAL DETECTOR
IP
A
CARRIAGE/FRAME ASSEMBLY ROUNDWAY BEARING TYP CONFIG
FIXED RAILS TYP (16)
CENTRAL DETECTOR
IP
VIEW A-A


SUPPORT HANGER TYP
WELDED SUPPORT PADS
PDT (8/8/4) .
SHOWN
BARREL REGION MODULE
CENTRAL DETECTOR
8.0m DIA X 12.0m LG
50.8mm RADIAL CLR
IP

FULL SYMMETRIC DEFORMED MODEL

G.E.M.

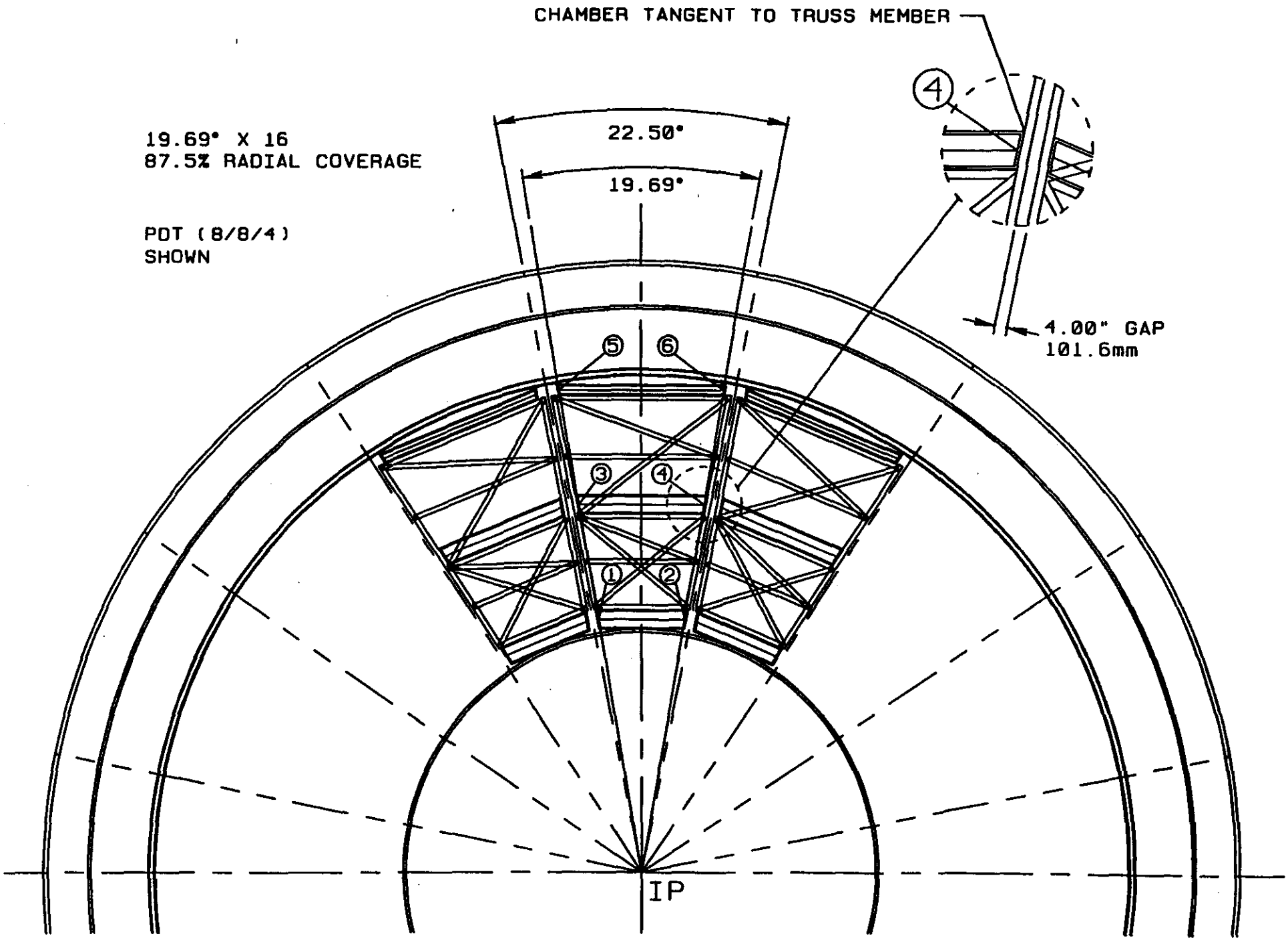
06 Feb. 1992

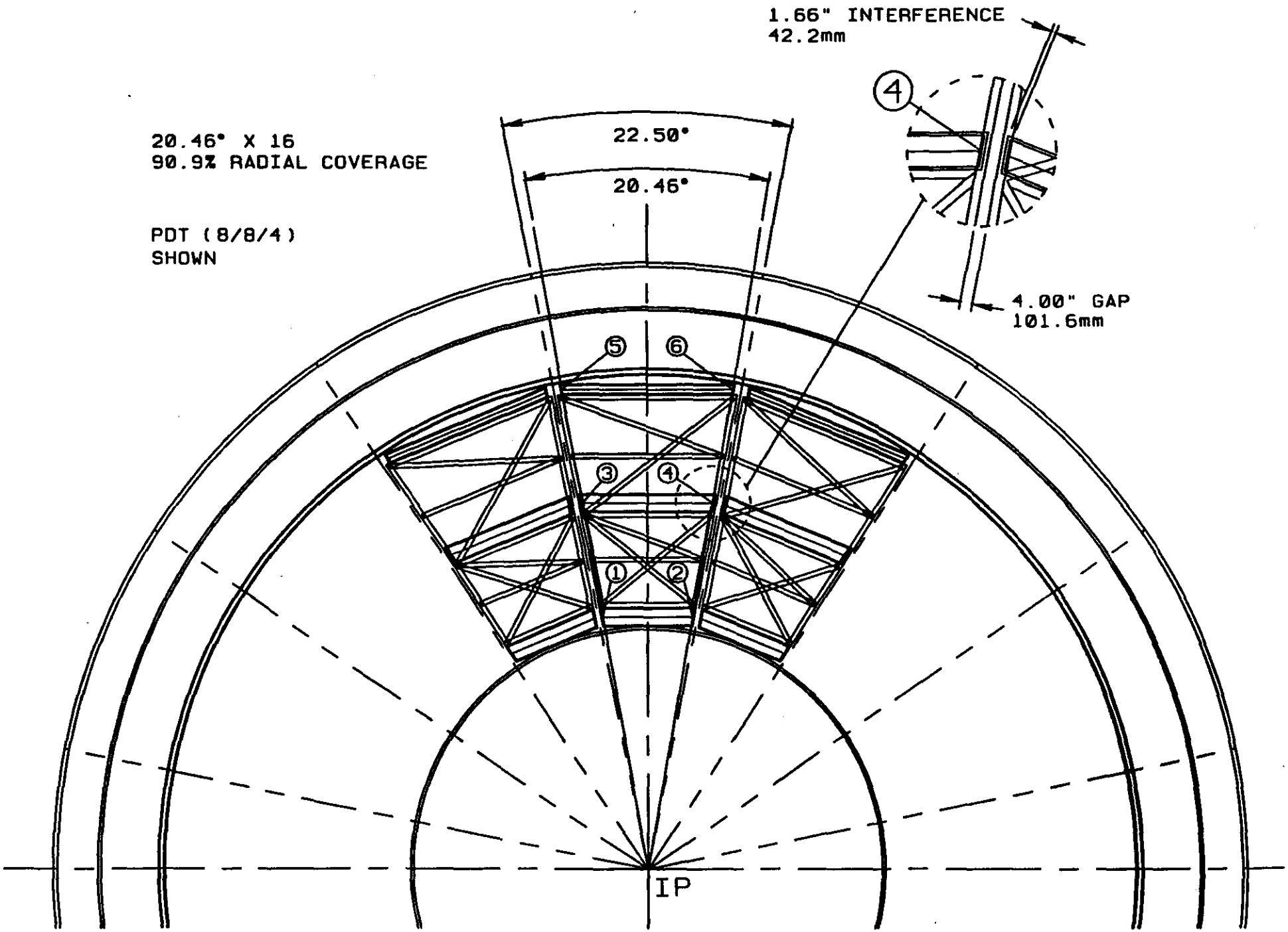


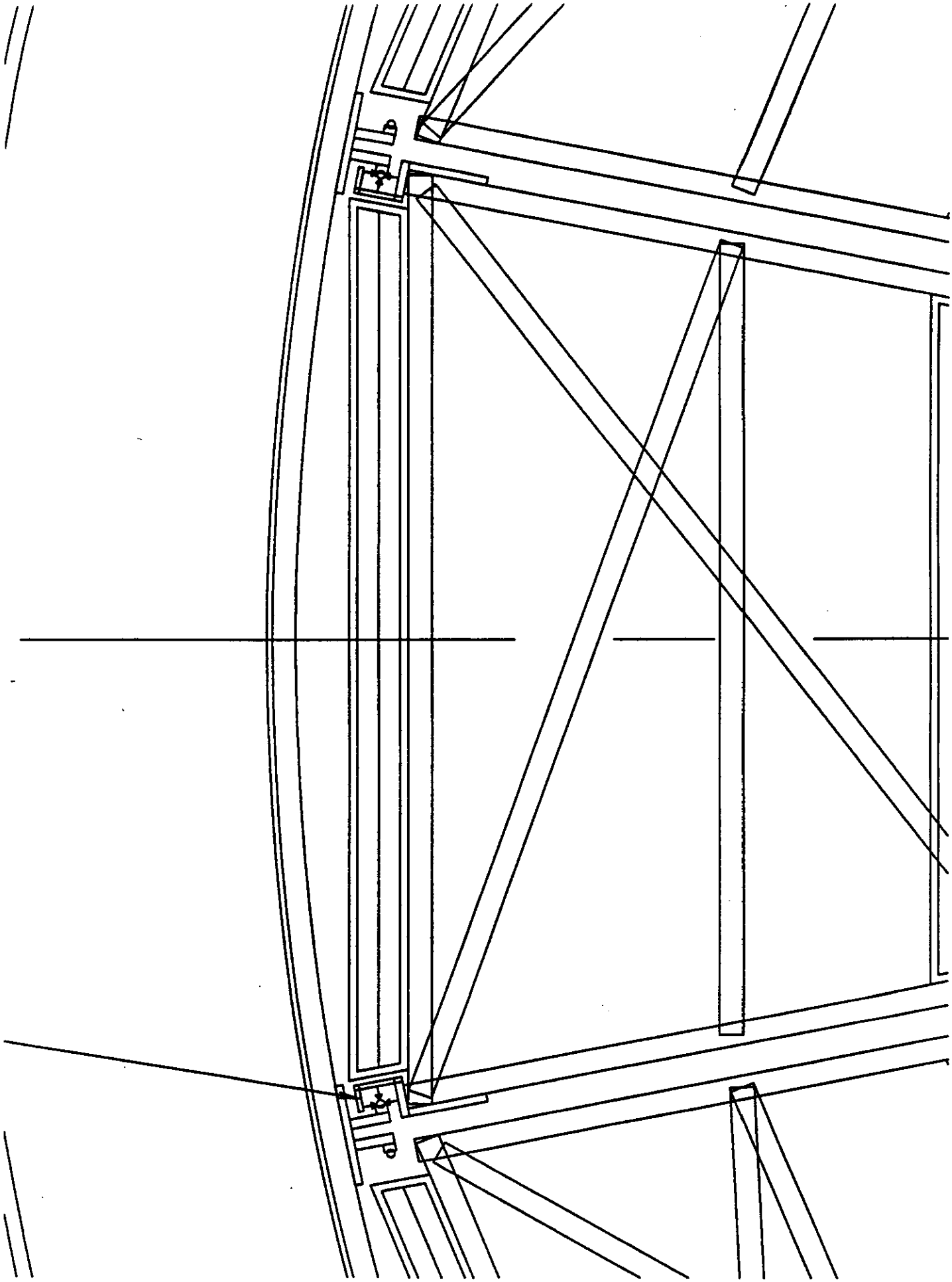
SSC MUON DETECTOR
GEM SUPPORT
1 G GRAVITY LOAD

R. Sapienza

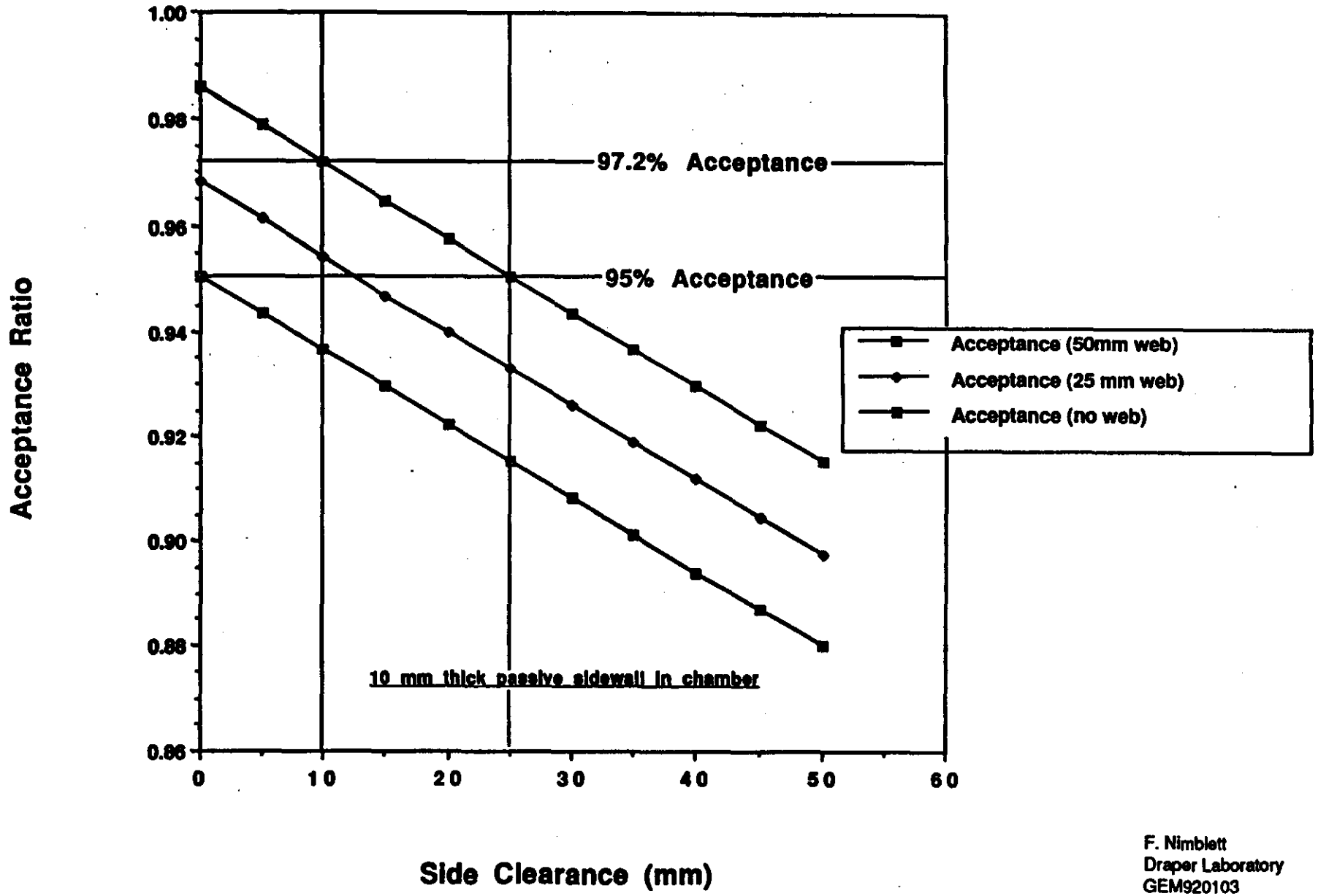
DRAPER LABORATORY


CHAMBER TANGENT TO TRUSS MEMBER
19.69° X 16
87.5% RADIAL COVERAGE
PDT (8/8/4)
SHOWN
22.50°
19.69°
4.00" GAP
101.6mm
IP


1.66" INTERFERENCE
42.2mm
4
20.46° X 16
90.9% RADIAL COVERAGE
22.50°
20.46°
PDT (8/8/4)
SHOWN
4.00" GAP
101.6mm
5
6
3
4
1
2
IP

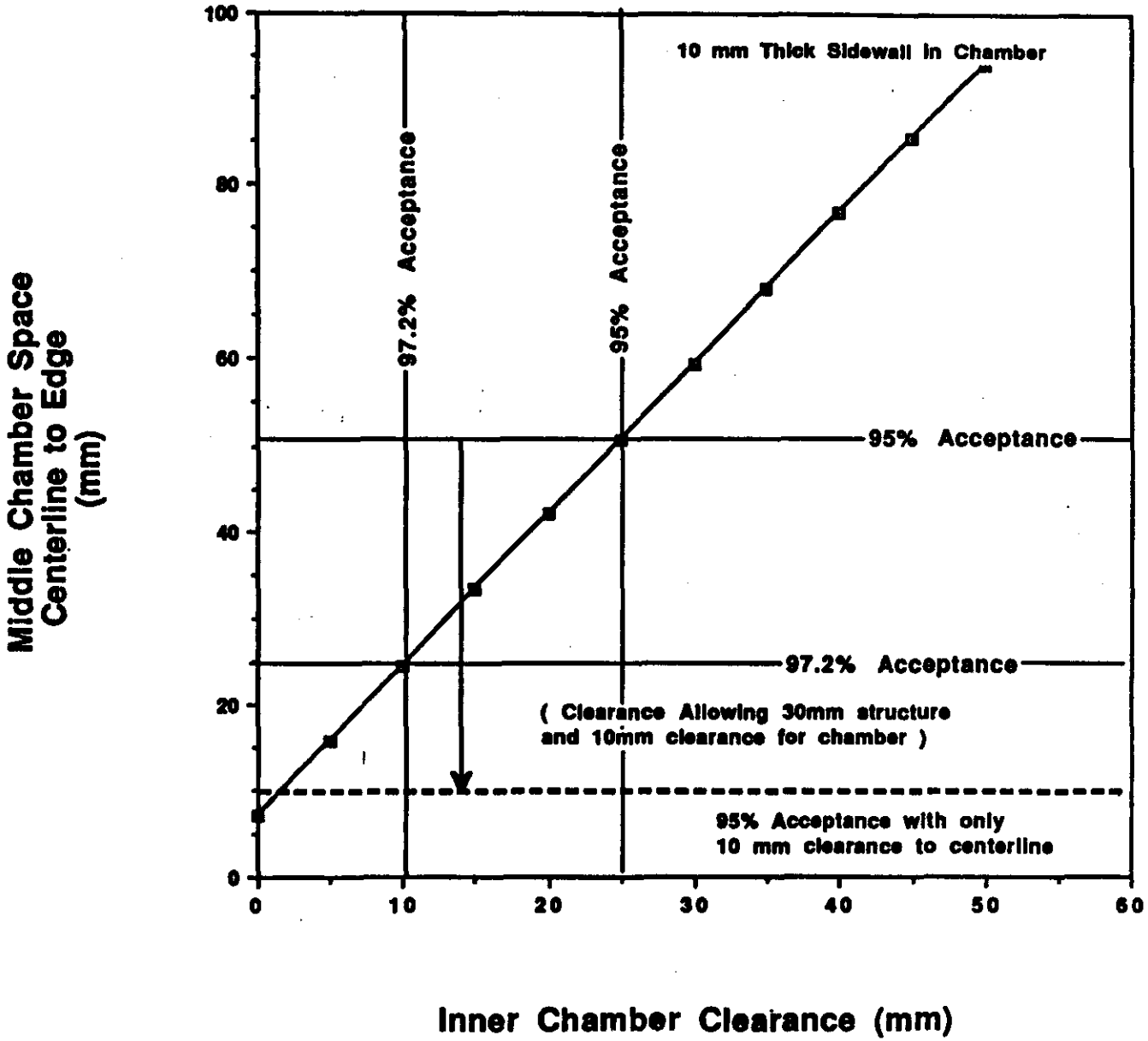


ANGULAR ACCEPTANCE VS INNER MUON CHAMBER CLEARANCE



F. Nimblett
Draper Laboratory
GEM920103

MIDDLE CHAMBER CLEARANCE
(NO WEBS)



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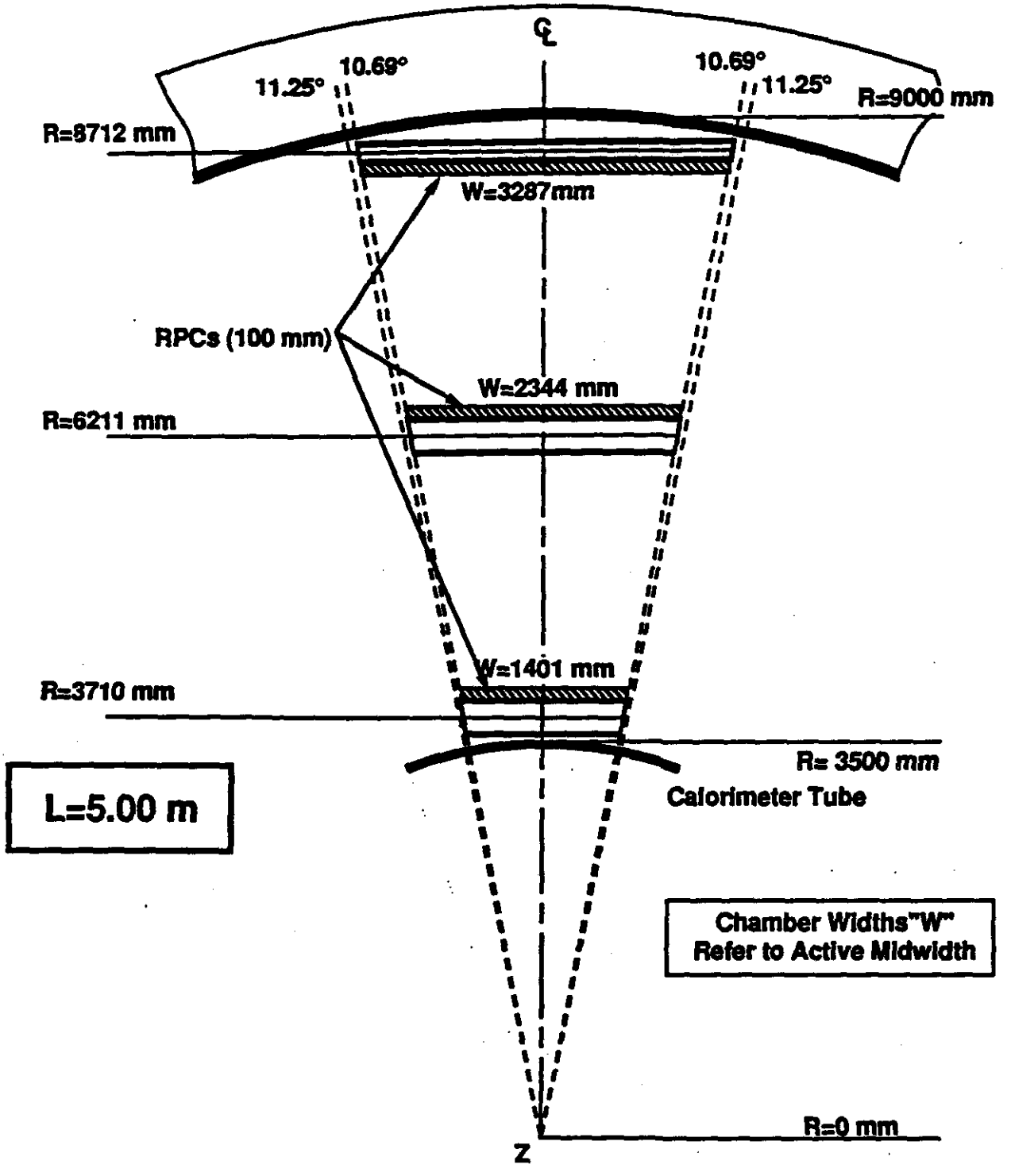
GEM920103

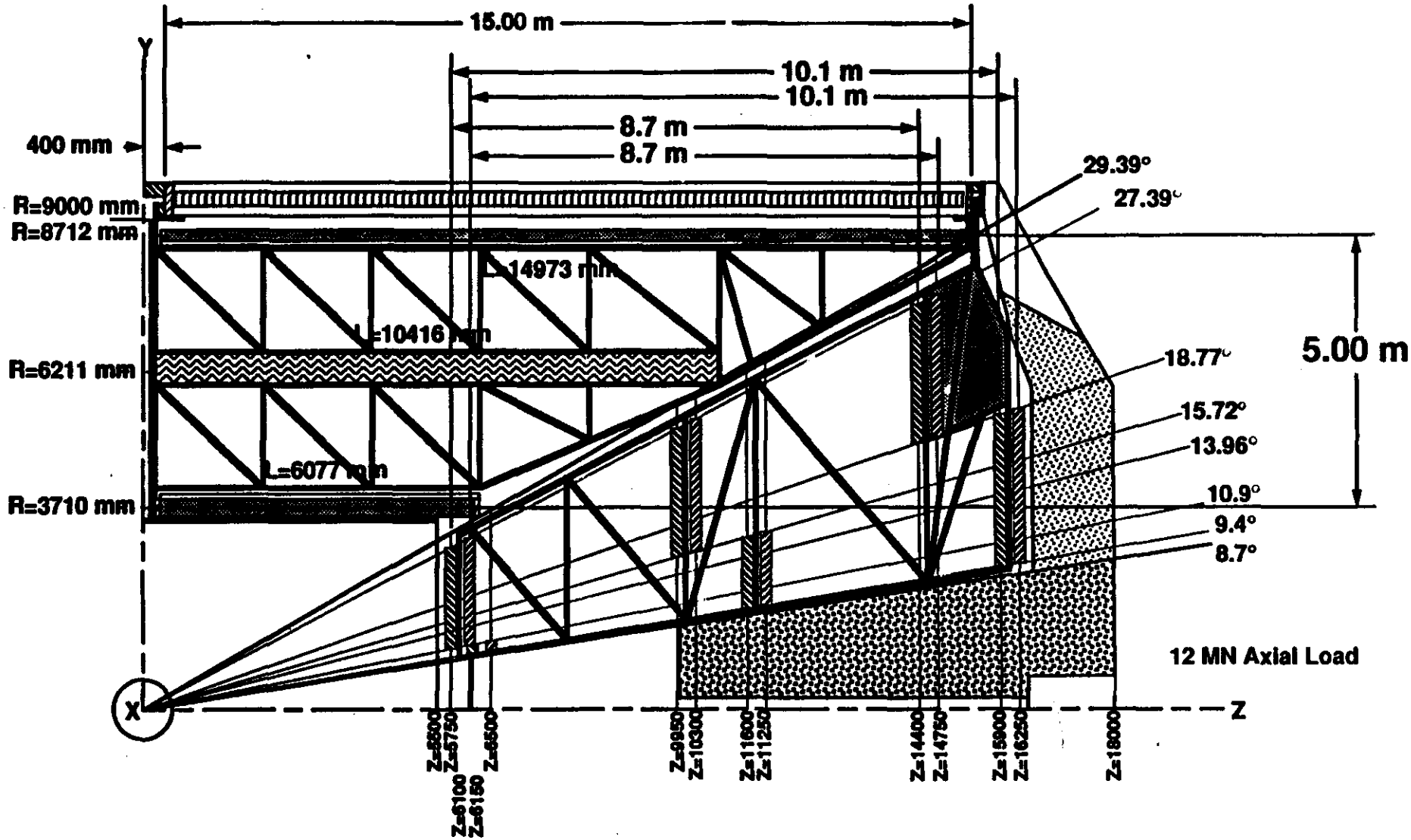


PDT 18/7 (8/8/4)

95% Acceptance

(Barrel Region Endview)

F. Nimblett
GEM 920306



GEM PDT 18/7 (8/8/4) Barrel

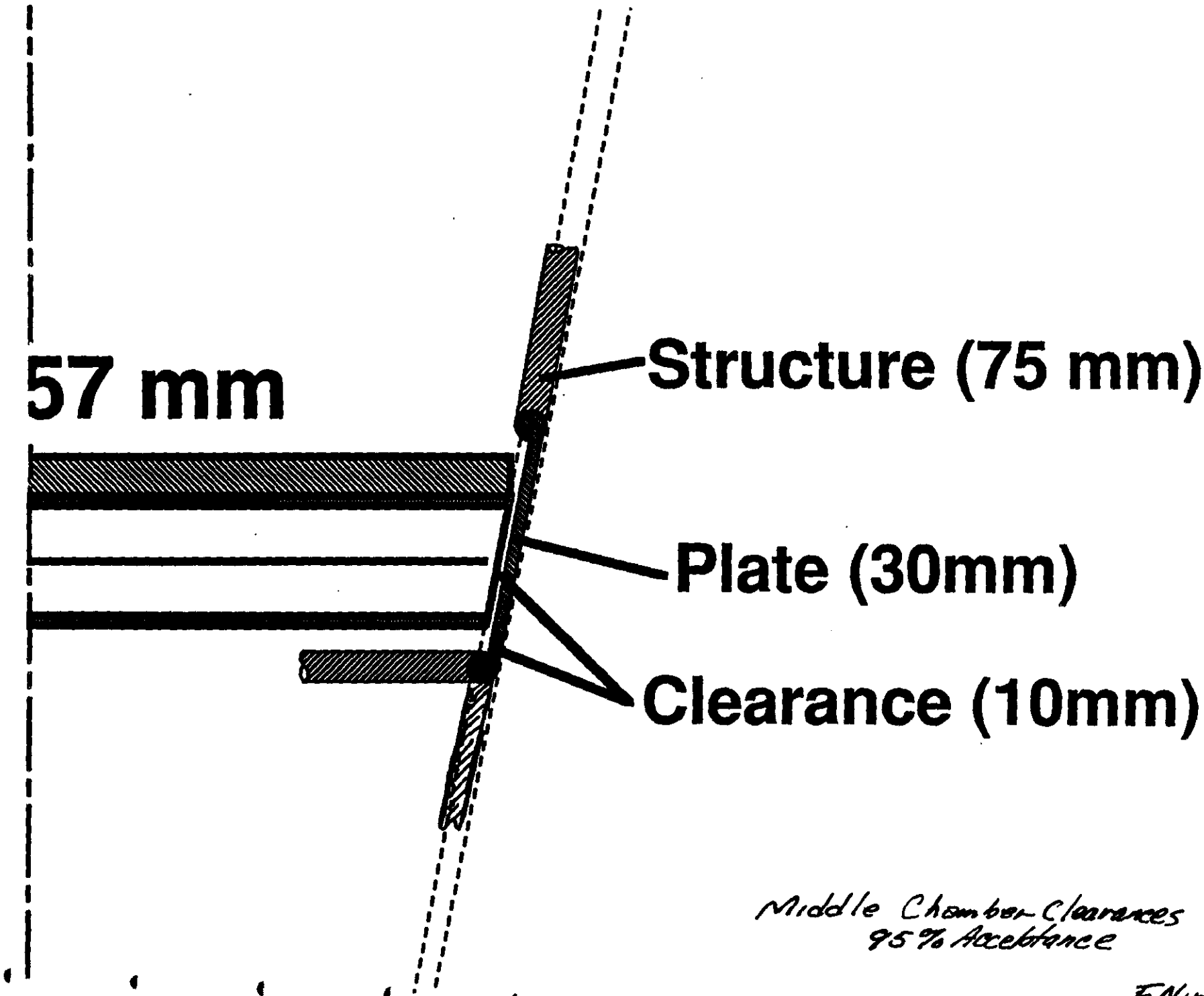
CSC Endcap (Modules A& B)

(Calorimeter 7m OD x11m Long)

(Extended Forward Field Shaper 18000mm Long)

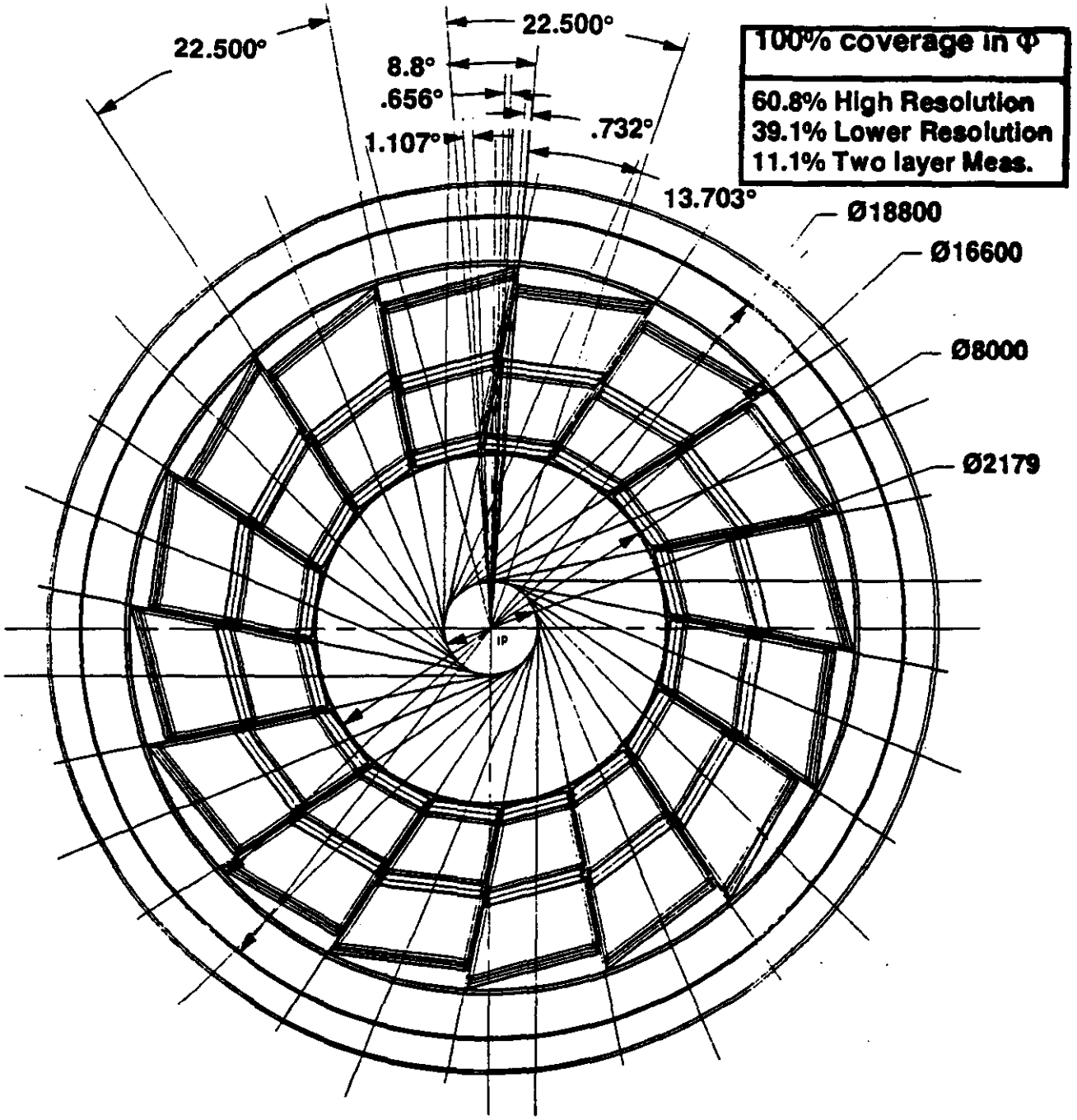
(100 mm RPCs O/O/I)(Magnet half displaced along Z)

F. Nimblett
Draper Lab.
GEM920306



Middle Chamber Clearances
95% Acceptance

F. Nimblett
3/8/92

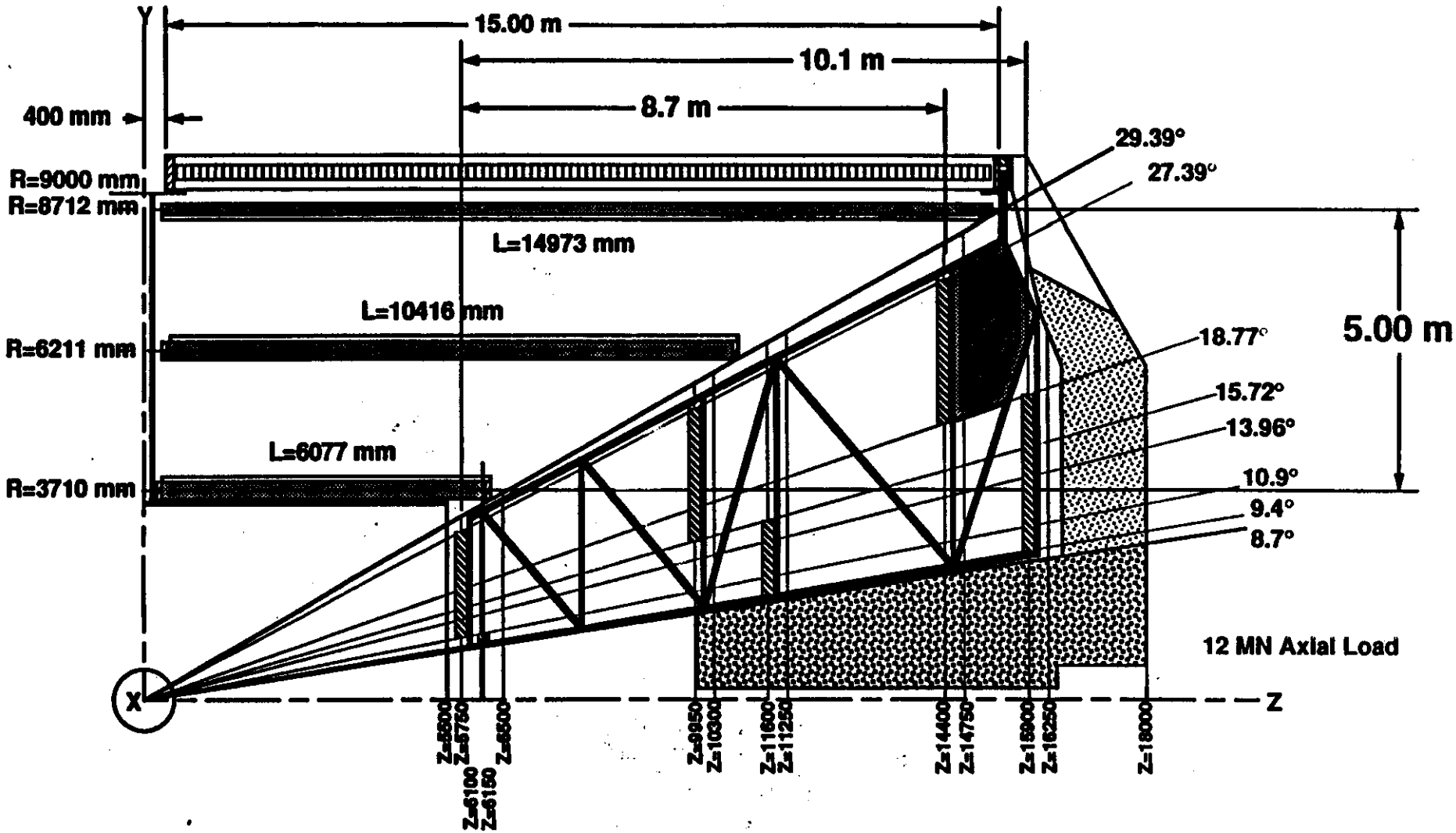


GEM BARREL REGION MUON SYSTEM (SKEWED OPTION)

Nimblett/DePiero
Draper Lab
14 February 1992

END CAP REGION STRUCTURE:

- TRAPEZOIDAL CHAMBERS OVERLAPPED IN "ϕ" & "θ"
- SPACE AVAILABLE FOR STRUCTURE
  - OUTER & INNER BOUDARIES IN "θ"
  - TRIANGULAR STRUCTURE IN ACTIVE CHAMBER AREA
  - CROSS-BRACING ALSO IN ACTIVE AREA
- TWO MODULE TYPES REQUIRED
  - MODULE A – STRUCT. BEHIND CHAMBERS
  - MODULE B – STRUCT. IN FRONT OF CHAMBERS
  - CHAMBER SUPPORT STRUCTURE AT SAME "Z" DIM FOR BOTH MODULE TYPES.
- DESIGN REQUIRES THE "RADIAL" INSTALLATION OF MODULES TO MAKE AN ENDCAP ASSY.!
  - INSTALLATION PROCESS NEEDS TO BE REEXAMINED
  - END CAP ASSEMBLY ALSO NEEDS DEFINITION!



GEM PDT 18/7 (8/8/4) Barrel

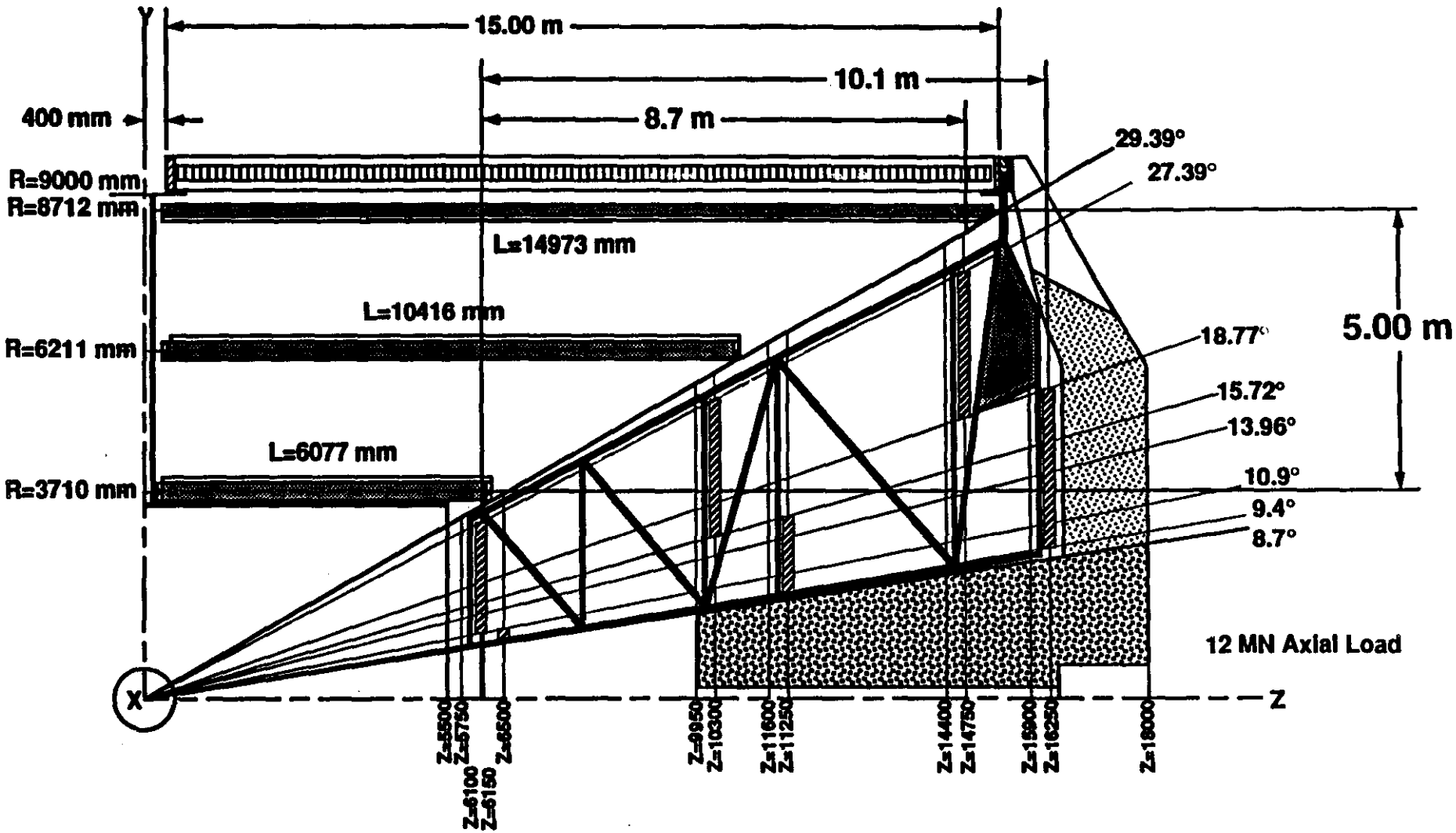
CSC Endcap (Module A)

(Calorimeter 7m OD x11m Long)

(Extended Forward Field Shaper 18000mm Long)

(100 mm RPCs O/O/I)(Magnet half displaced along Z)

F. Nimblett
Draper Lab.
GEM920306



GEM PDT 18/7 (8/8/4) Barrel

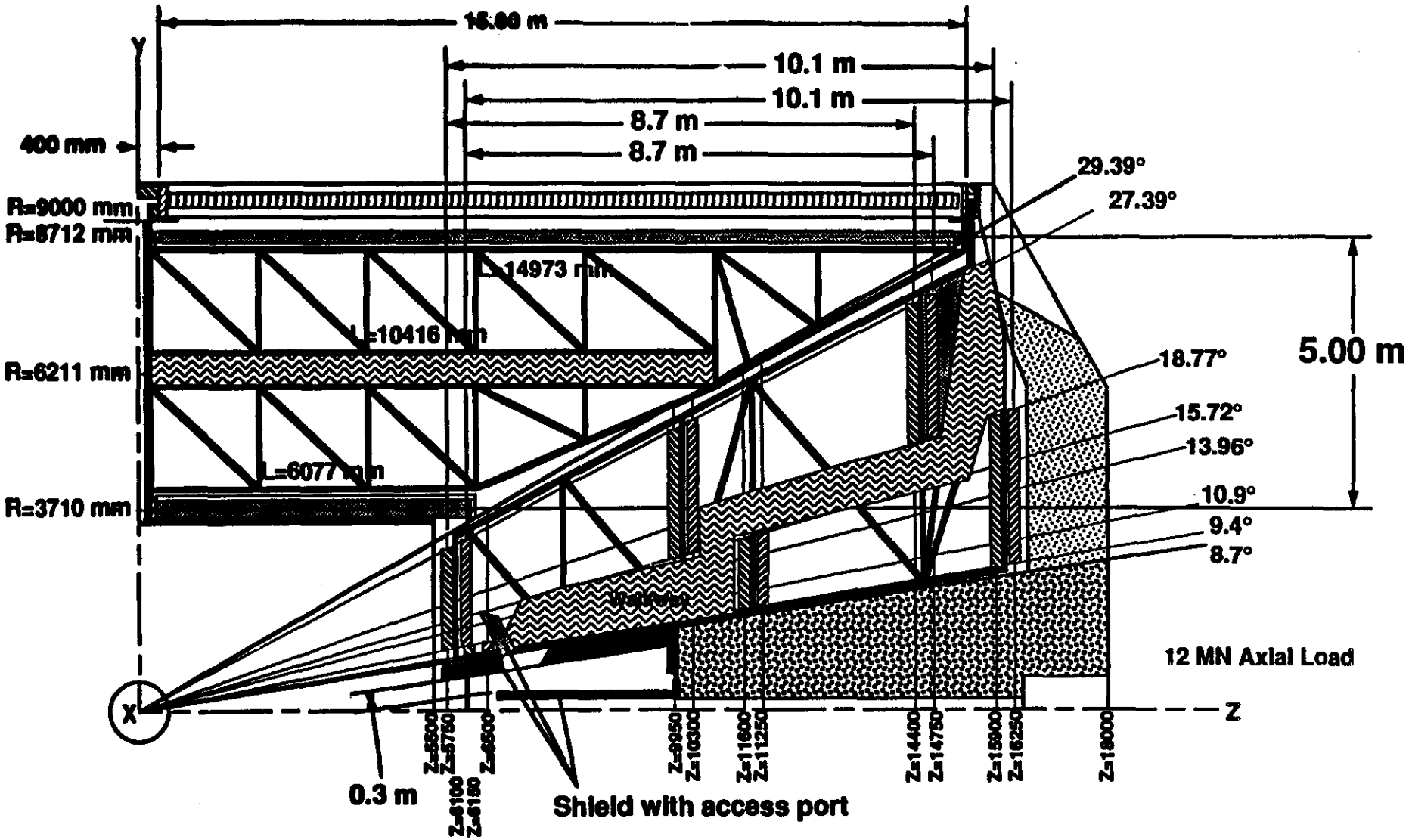
CSC Endcap (Module B)

(Calorimeter 7m OD x11m Long)

(Extended Forward Field Shaper 18000mm Long)

(100 mm RPCs O/O/I)(Magnet half displaced along Z)

F. Nimblett
Draper Lab.
GEM920306



GEM PDT 18/7 (8/8/4) Barrel with Support Structure

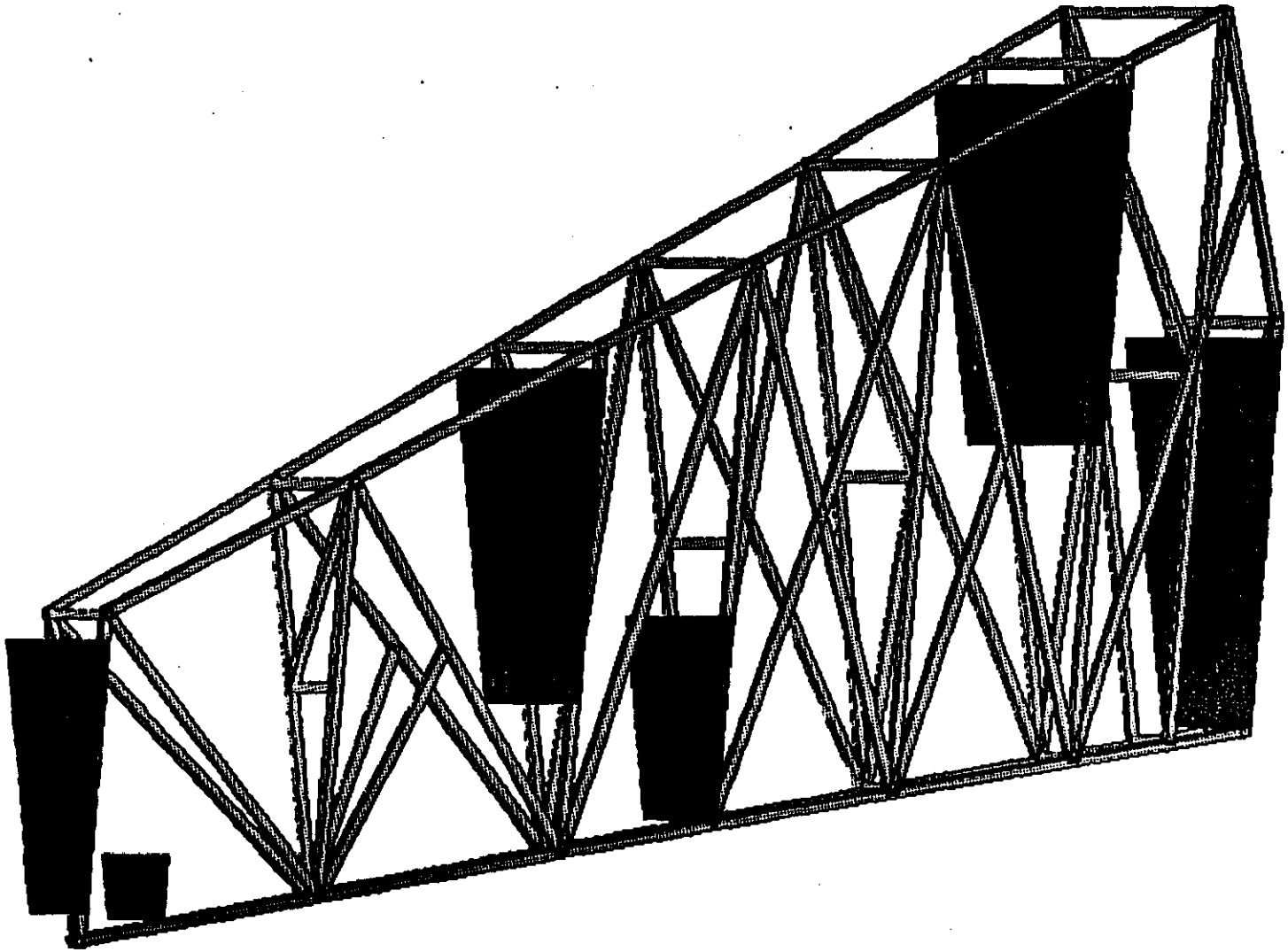
CSC Endcap (Modules A&B)

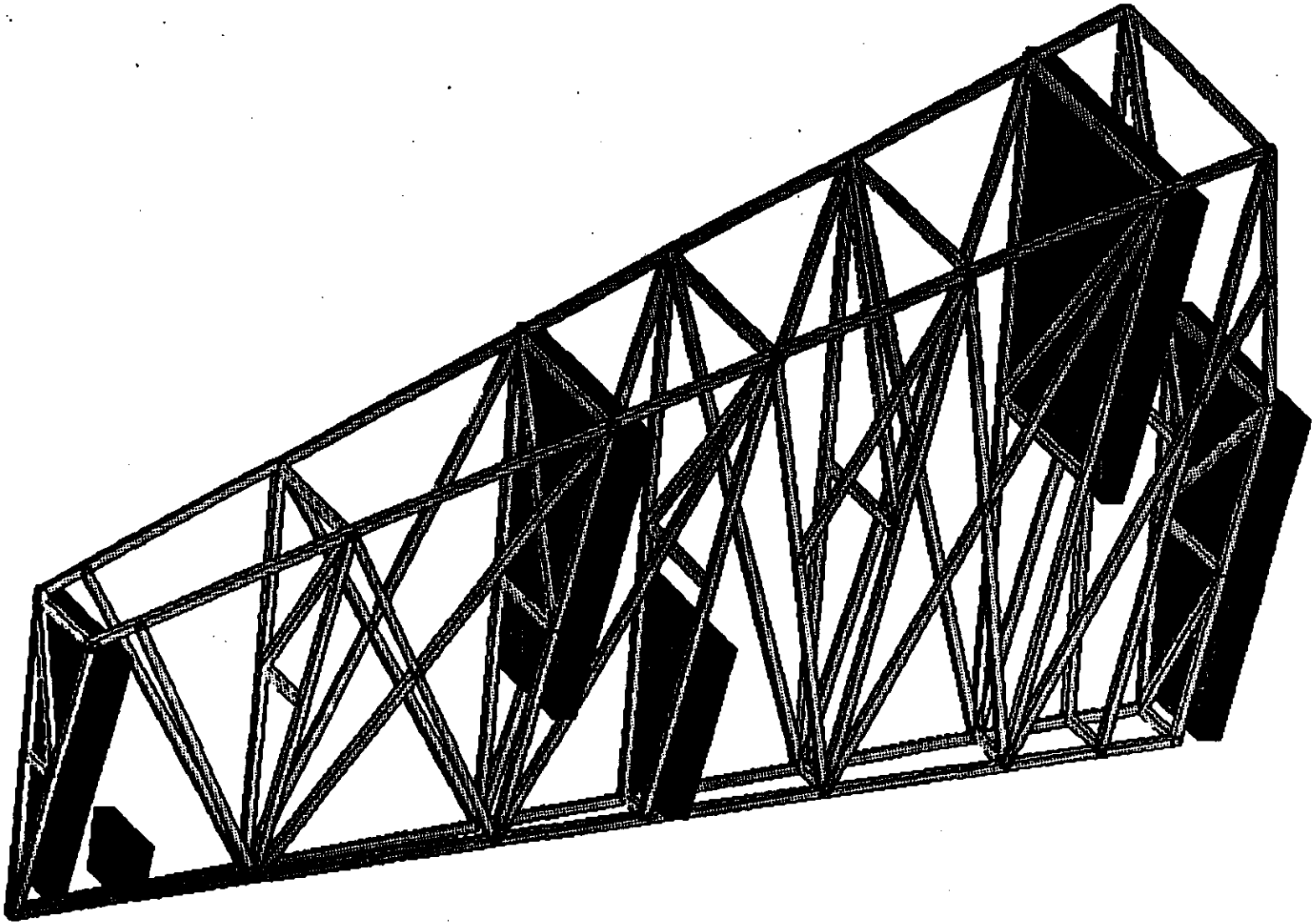
(Calorimeter 7m OD x11m Long)

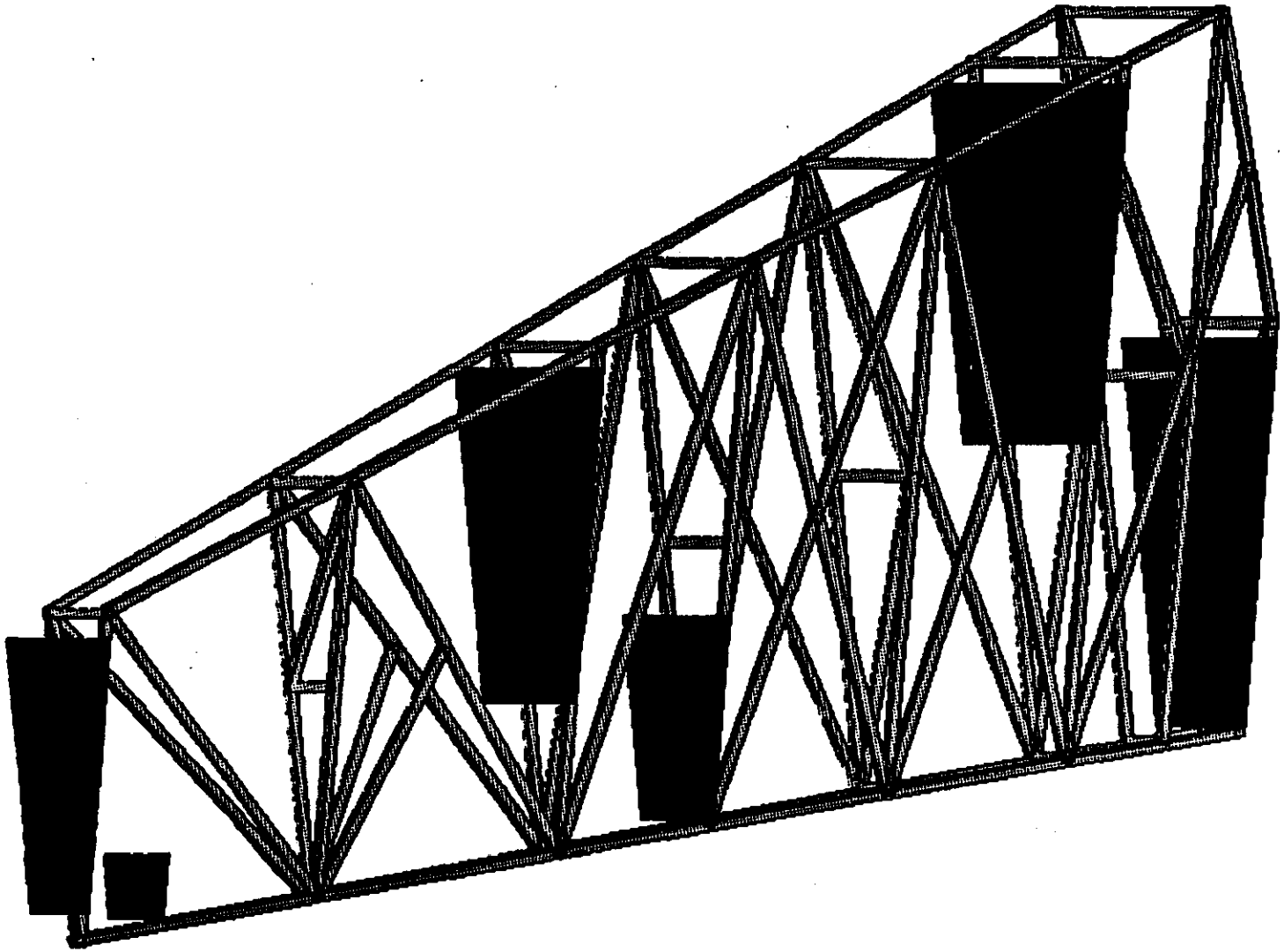
(Extended Forward Field Shaper 18000mm Long)

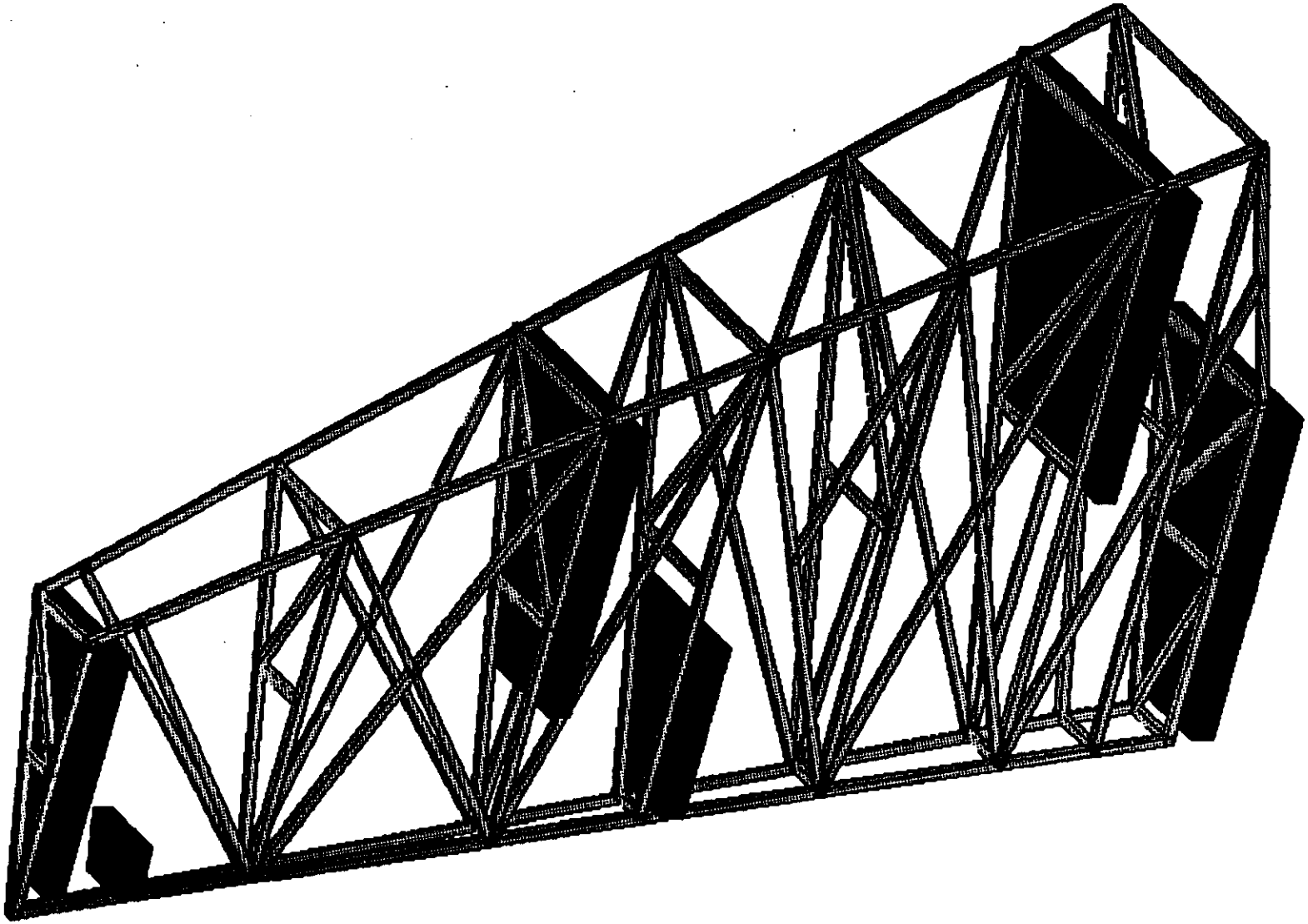
(100 mm RPCs O/O/I)(Magnet half displaced along Z)

F. Nimblett
Draper Lab.
GEM920306

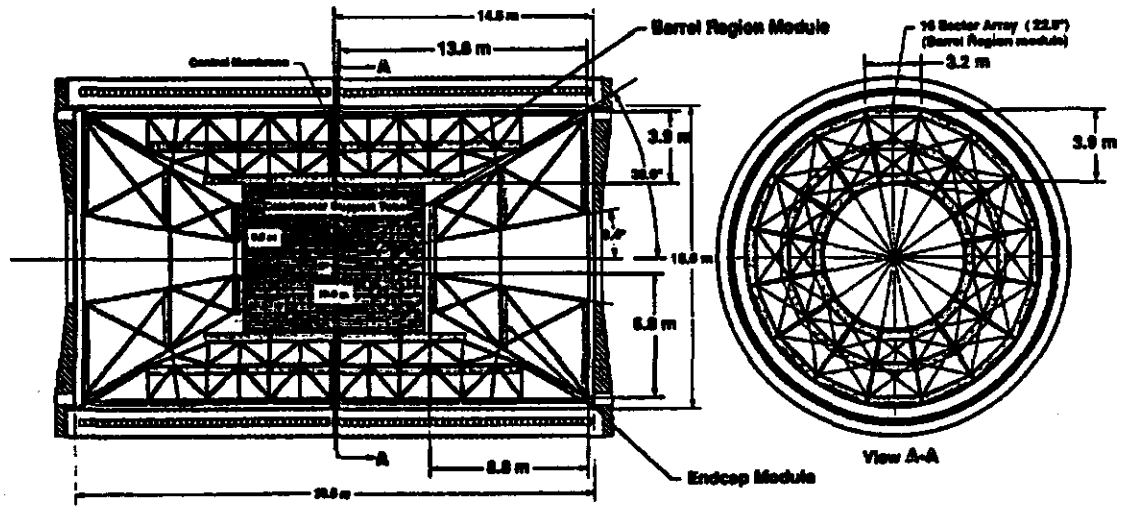








Optical Alignment of Muon Detector Components



GEM MUON SYSTEM

- Straightness Monitors
- Barrel Deployment & Issues
- Endcap Possibilities
- Approaches to Global Alignment

3/8/92 J. Paradiso

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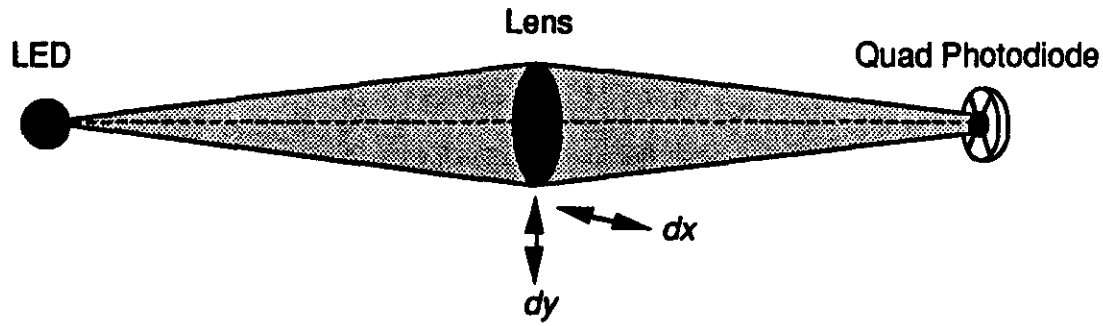
Straightness Monitors



- Measure 2-axis deviation (⊥ Optical axis) from straight line.
- Displacement of lens produces 2x (lens @ center) more image offset than movement of LED or quad diode.
- Rotation of lens, lens defects produce limited effect.
- LED defocused at diode (illumination sharing between quadrants).
- Sensitive (under few microns over 9m).
- Few components, inexpensive (i.e. $500).
- Modulation of source reduces background

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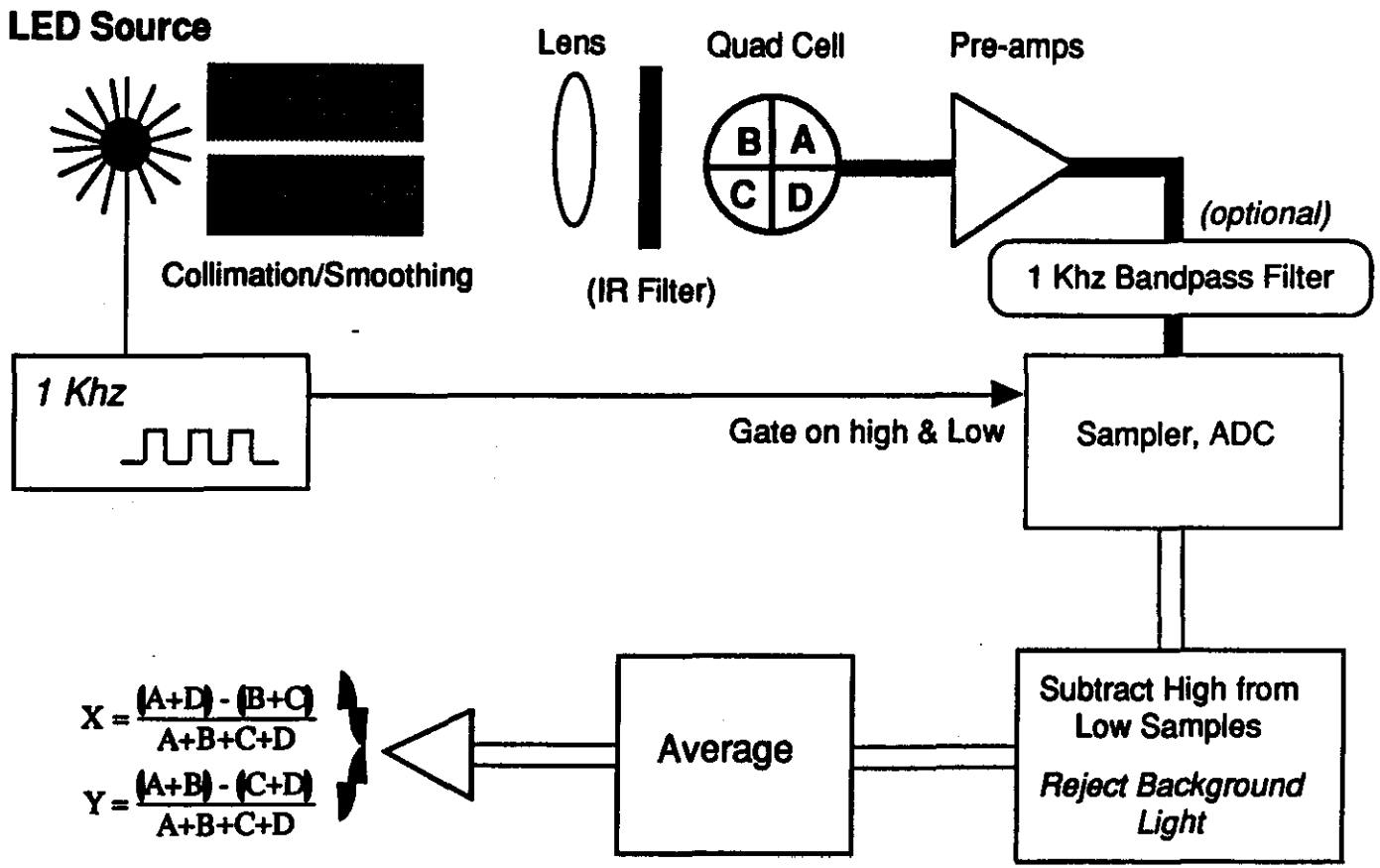
Straightness Monitor Electronics



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Straightness Monitor Issues

The Source

- The standard = LED (L3 application)
- LED's can exhibit spatial inhomogeneity in light output.
  - → Collimate or calibrate out?
- ➡ New Motorola LED applied w. smooth aperture function.
  - Glass ball embedded atop chip produces near-Gaussian profile.
- S/N looks good (i.e. ≤ 1 mV noise with 400 mV signal over 9 meters)
- Stronger sources for better S/N over longer paths?
- → Laser diodes have spatial jitter; need collimation, smoothing...
- ➡ Could launch into single mode fiber.
  - Plenty of light; more expensive (i.e. $500./laser-fiber assembly)
  - Not economical to split fibers; couplers expensive
  - Not needed anyway; LED OK?

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Straightness Issues (cont.)

- Potentially large diameter lens needed to focus to small spot over long path lengths.
  - i.e. 1 cm diameter lens will focus to 1 mm spot diameter (IR) over 9 meter path.
  - Current tests use 3" lens over similar length.
  - Large spot requires particular photodetectors.

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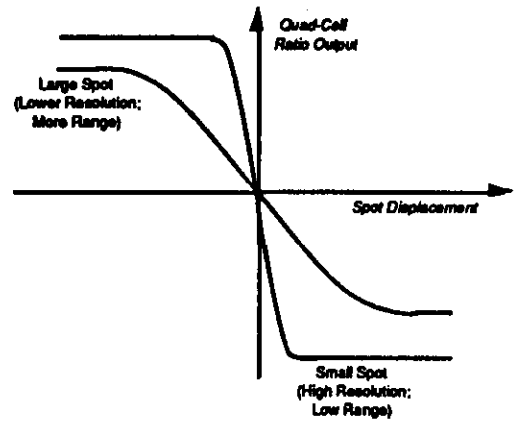
More Straightness Issues

The Receiver

- Quad Cell exhibits resolution vs. dynamic range tradeoff.
  - Measured position can depend on defocus



- Consider CCD?
  - Cell quantization removes this problem, electrical calibration.
  - More expensive, complicated readout (new "retinal" devices?)
- "Photopot" is most promising!
  - Each quadrant of quadcell subdivided and weighted in sum.
  - Yields wide range while maintaining few micron resolution
  - Amenable to centroiding wide spot sizes (i.e. 1 mm)

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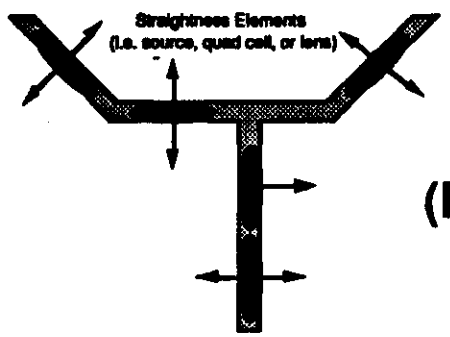
Straightness Caveats (cont.)

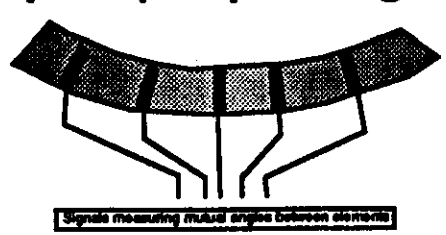
Mechanics, etc.

- Development/testing of precision mechanics needed to mount source, lens, receiver (alignment of optical axes).



(Fixed to chamber reference)

- Multi-purpose mount to simultaneously reference several optical paths?
- Multipoint alignment techniques (i.e. passing alignment between consecutive points?).



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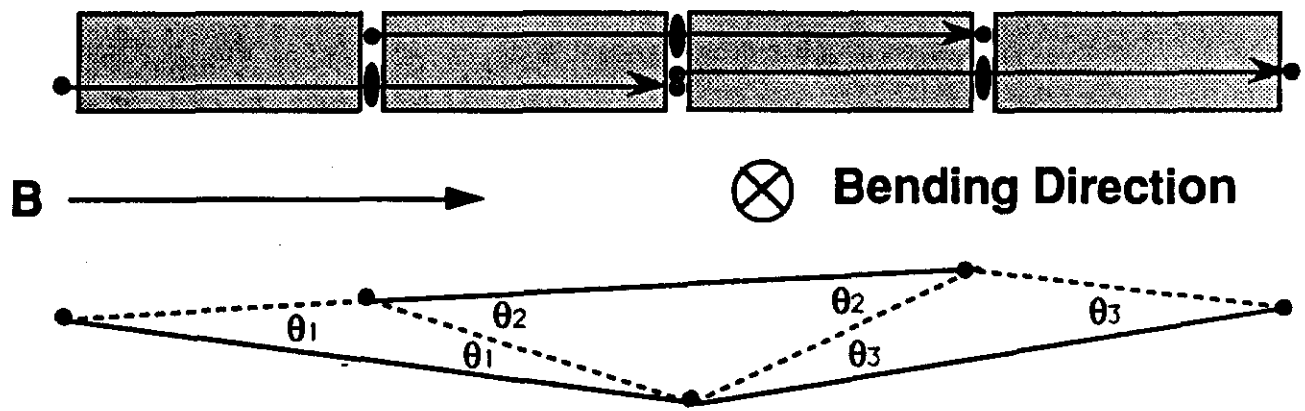
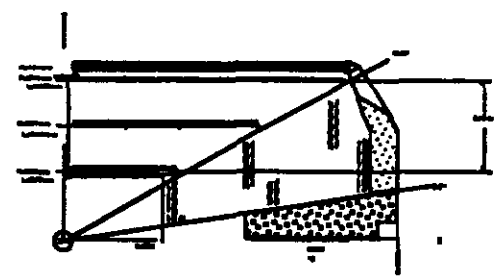
Multi-Package Straightness



- Nested monitors to determine straightness in bending direction between different packages and/or wire supports.
  - → Similar to L3 bridge monitors
- Could replace with multipoint monitor?



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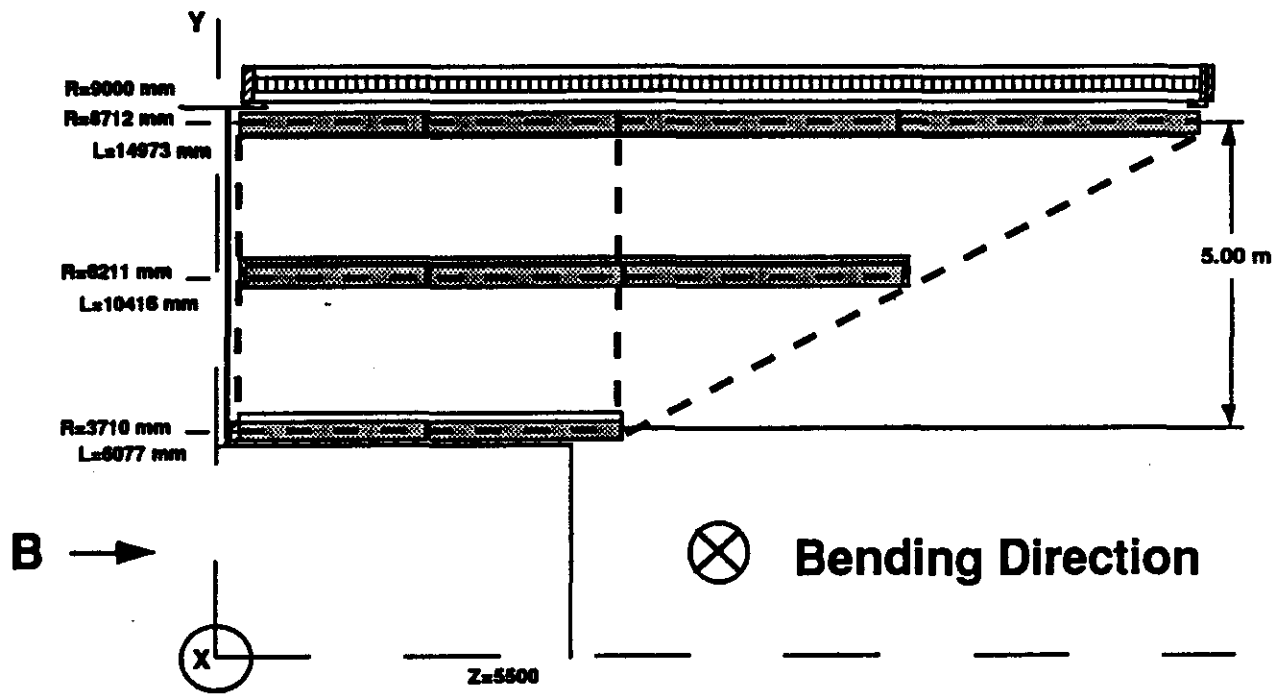
Straightness Between Barrel Layers



- Determine straightness along muon path
  - Particularly in bending direction!
- Role of L3 "planarity" measurements (i.e. laser beacon)?
- Minimal set; add other paths...?

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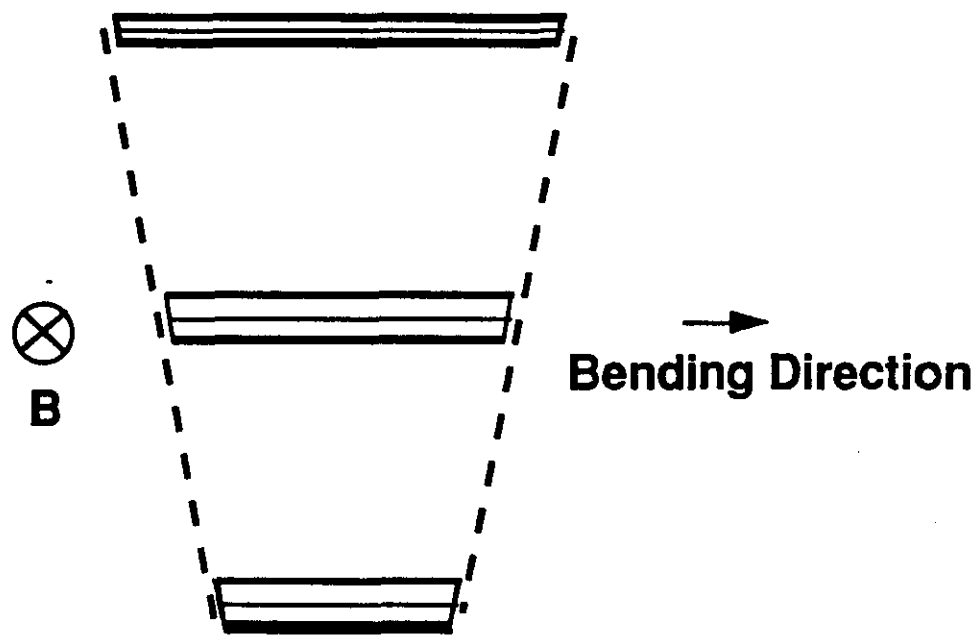
Edge View of Barrel Hexant



- Run alignment up each side of hexant.
- Align up centerline if chambers are split, as in L3?

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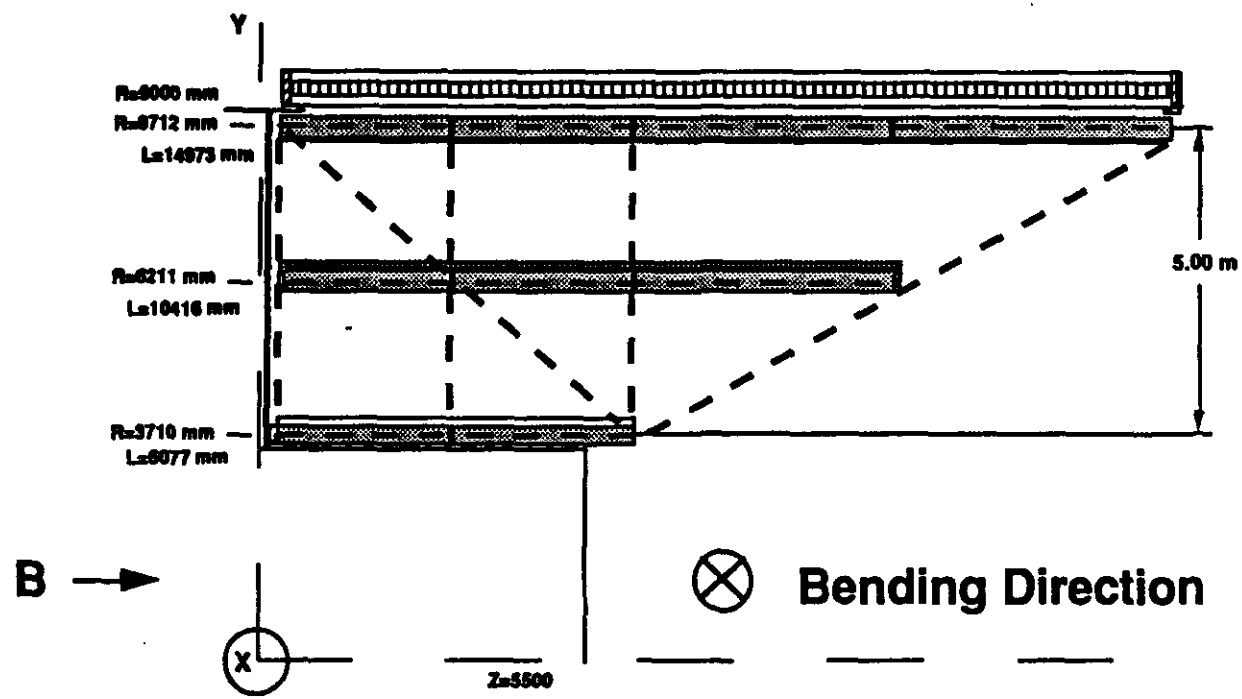
Additional Alignment Paths



- Additional vertical paths (better alignment in bending direction)?
- Add angled alignment paths to monitor vertical displacements?
  - Can't isolate particular chamber that is displaced.
    → Other implementations, systems if needed?
- Multiple direction alignment fixtures?

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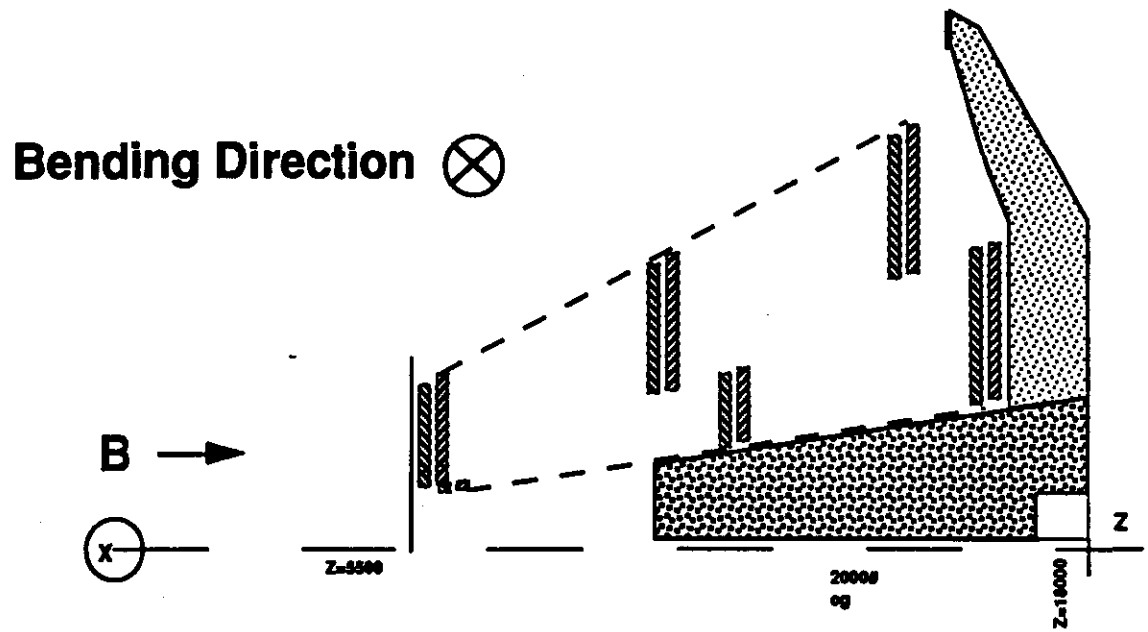
The Forward Region



- Can establish 2 lines of sight for straightness paths
  - Measure ϕ (bending) misalignments
  - Long path lengths
  - How to interrelate inner edges of middle/outer pairs?
    → No optical path without holes through chambers

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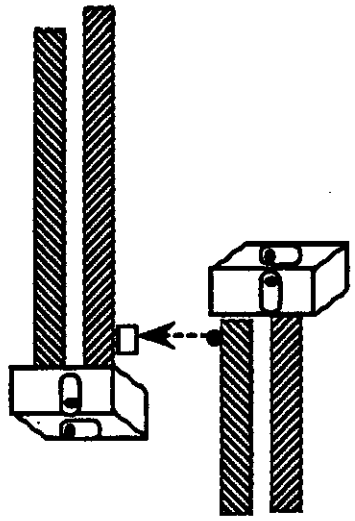
Forward Chamber Interrelation

Some ideas...



- Sight directly from source on one chamber to array on opposite
  - Original L3 idea (Becker & Paradiso, NIM, 1982)
  - Couples rotation into displacements
- Pull out rotations with Bubble Levels
  - Accuracies within 1 arcsec (used in L3 prototypes)
  - Can estimate phi (bending direction) rotation
- Measure interchamber distances with proximity detectors?
  - Accuracy within 10 μm, phi coordinate difficult?

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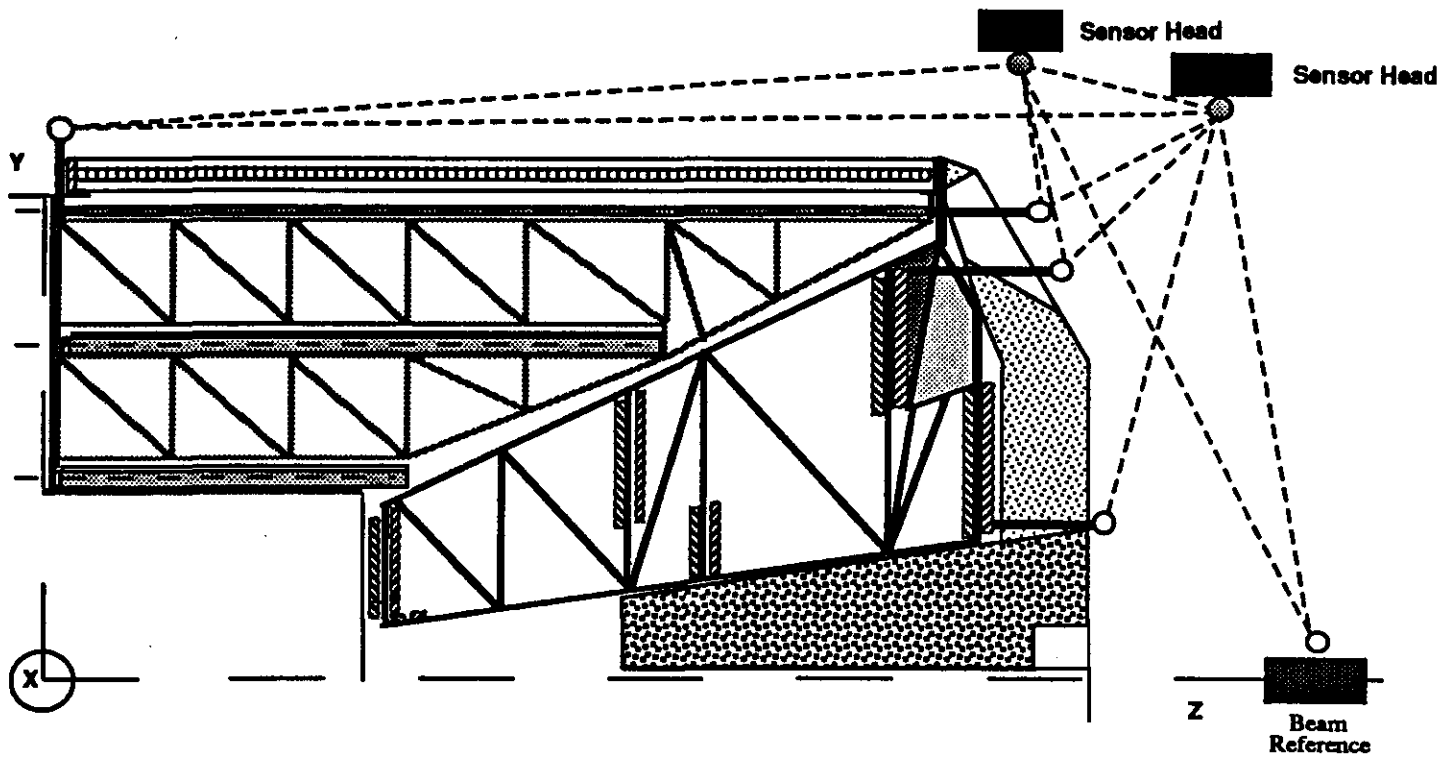
Global Alignment



- Must be able to sight out to sensors in hall.
  - Holes to muon array through forward support, hemisphere gap
  - "Reflectors" distributed in ϕ
  - Location of sensors precisely known wrt. beam (sight on quads?)

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Global Alignment Sensors

- Can measure angle and/or range (range more accurate).
- Range measurement can be taken in several scales.
  - Start with survey measurements and/or coarse TOF.
  - Progress from monochromatic light to white light interferometry.
    - → White light gives no fringe ambiguity, but null difficult to find.
    - ➡ Use information at other wavelengths to simplify fringe search.
- Temperature gradients?
- Quadrature AM phase detection on optical carrier (i.e. LADAR).
- Possible to attain resolutions of order hundreds of microns....
- Improve accuracy by adding more sensors, sighting same reflectors at multiple angles?

These devices could be useful throughout the SSC...

Workshop & Beyond...

- Straightness monitor technology (well underway...)
- Applications of straightness monitors in GEM
  - How many needed, coordinates to measure, ambiguities
  - Measure inside barrel hexants or at edges only?
  - Need for coplanarity; inject L3 experience
- Special problems in the forward region
  - Clear optical paths where needed?
  - Big lenses along long paths?
  - Interrelating the upper-lower chamber pairs.
- Global alignment
  - Accuracies involved
  - Where to sight on detector?
  - How to propagate measurements into barrel (i.e. muon angle)
  - Tying muon array into central tracker...
  - Technologies

DRAPER LABORATORY

Cathode Strip Chambers
Solid Angle Coverage

Scott Whitaker

Tucson 8 March 92

* Chambers overlap in r, ϕ
  ⇒ FULL COVERAGE

* Coverage is accomplished with staggering
  → Access

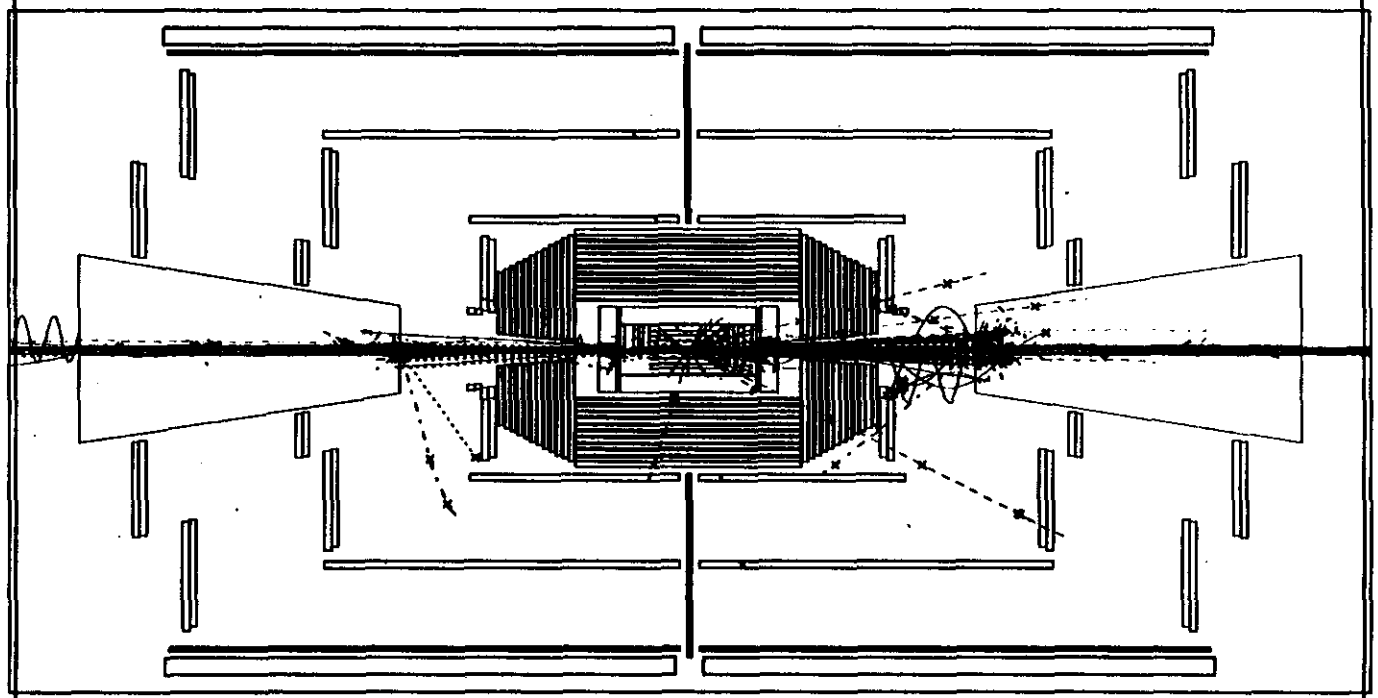
* Chamber material <u>averages</u> ~15% X_0

  overlap → more material - but ok if ΔE fluctuations in the calorimeter rules.

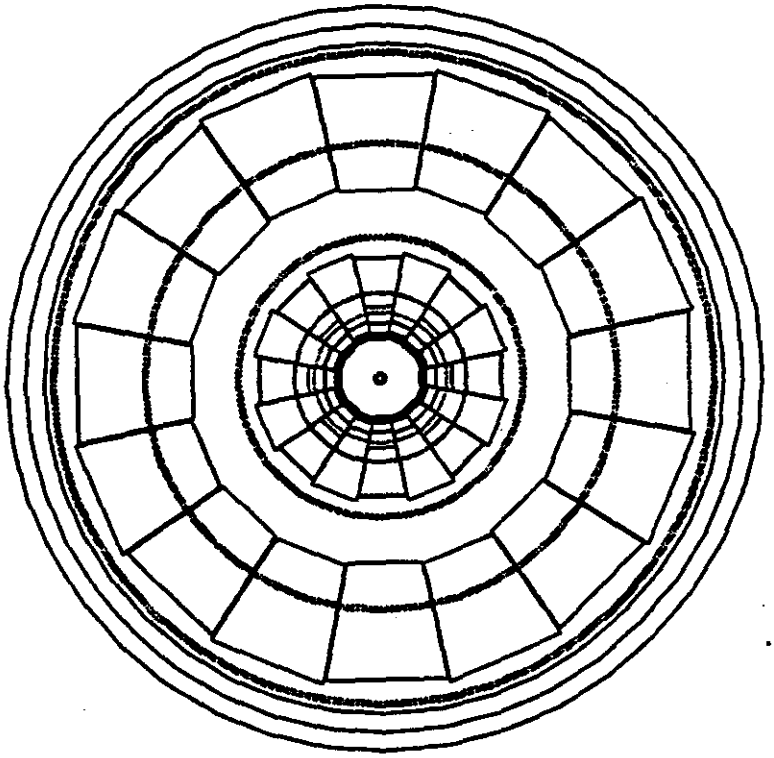
GEM

GEM Endcap Muon System

3/ 3/92



R

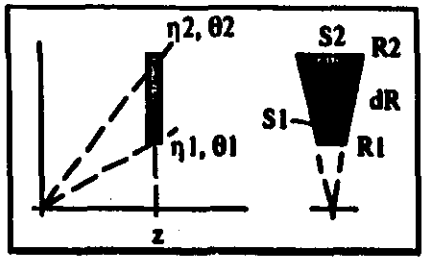


CSC Layout Specification

Open Magnet Geometry
Short calorimeter: z<5.5m; Coverage to 29.16°

JSW 27 Feb 92

Nsectors= 16
wires ganged by 20 = 5.00 cm
Strip width at middle = 5.00 mm



Nomenclature
Note: modules (a) occupy even-numbered sectors
modules (b) occupy odd-numbered sectors

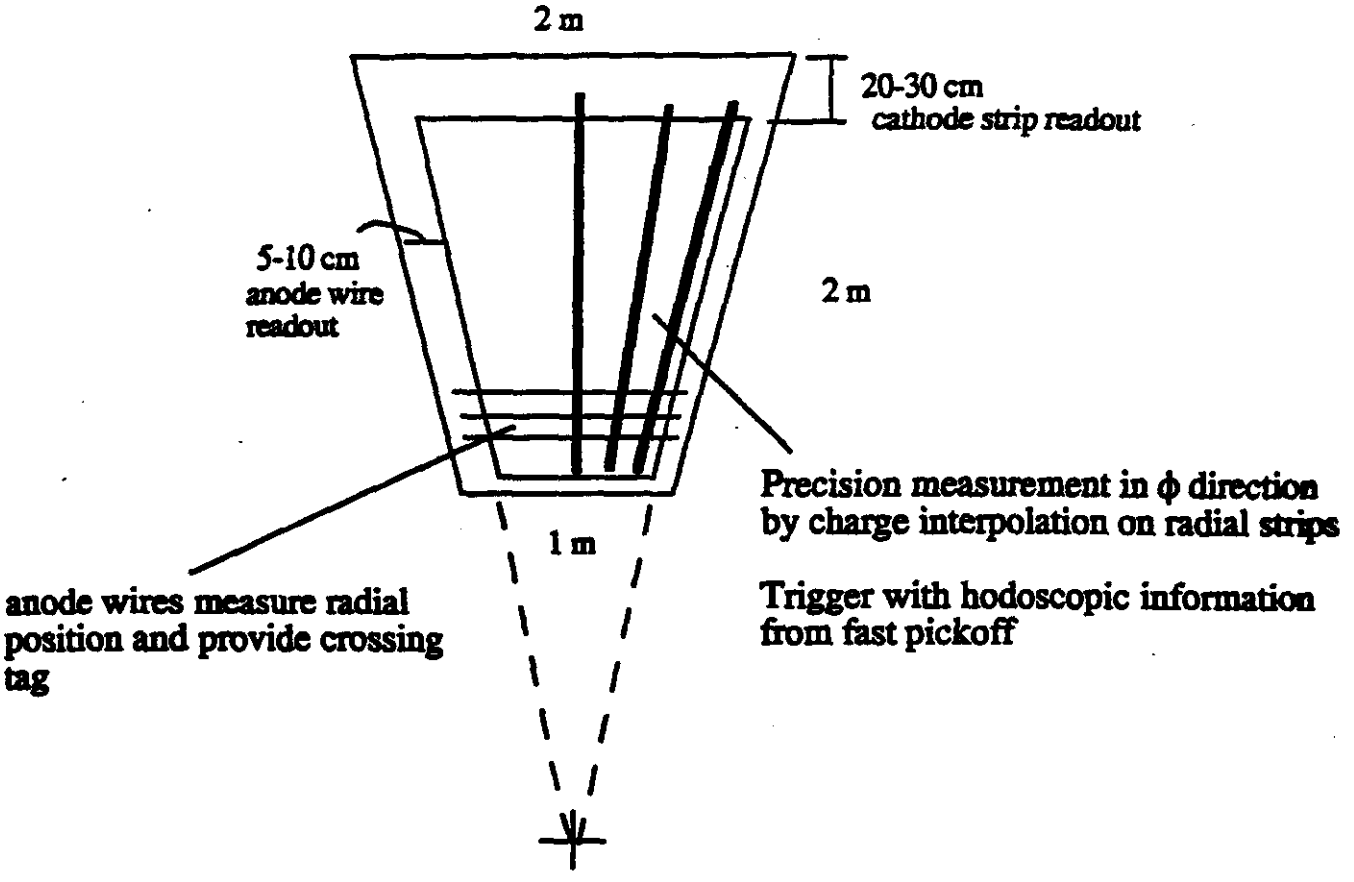
Total channel counts:
4/4/3 planes/module *
Nsectors/2 * 2 ends

	z	η1	θ1	η2	θ2	R1	R2	dR	S1	S2	area	# strips	strip occ	# r-chans	# strip chan	# r-chan
	m		deg		deg	m	m	m	m	m	m^2	/pl/sctr	/sec	/pl/sctr		
Inner modules																
1a)	6.15	2.50	9.39	2.35	10.90	1.02	1.18	0.17	0.40	0.46	0.07	86	101	3	5,494	214
1b)	6.35	2.50	9.39	2.35	10.90	1.05	1.22	0.17	0.41	0.48	0.08	89	104	3	5,673	221
2a)	5.75	2.35	10.90	2.10	13.96	1.11	1.43	0.32	0.43	0.56	0.16	99	88	6	6,334	413
2b)	5.95	2.35	10.90	2.10	13.96	1.15	1.48	0.33	0.45	0.58	0.17	102	91	7	6,554	428
3a)	5.75	2.10	13.96	1.35	29.16	1.43	3.21	1.78	0.56	1.25	1.58	181	65	36	11,582	2,277
3b)	5.95	2.10	13.96	1.35	29.16	1.48	3.32	1.84	0.58	1.30	1.69	187	67	37	11,985	2,356
Middle modules																
4a)	11.25	2.50	9.39	1.98	15.72	1.86	3.17	1.31	0.73	1.24	1.26	196	85	26	12,552	1,674
4b)	11.45	2.50	9.39	1.98	15.72	1.89	3.22	1.33	0.74	1.26	1.30	200	86	27	12,775	1,703
5a)	10.40	1.98	15.72	1.35	29.16	2.93	5.80	2.88	1.14	2.26	4.80	341	19	58	21,801	3,680
5b)	10.60	1.98	15.72	1.35	29.16	2.98	5.91	2.93	1.16	2.31	4.99	347	19	59	22,221	3,751
Outer modules																
6a)	16.05	2.50	9.39	1.80	18.77	2.65	5.46	2.80	1.04	2.13	4.35	316	42	56	15,185	2,690
6b)	16.25	2.50	9.39	1.80	18.77	2.69	5.52	2.84	1.05	2.16	4.46	320	43	57	15,374	2,724
7a)	14.55	1.80	18.77	1.35	29.16	4.95	8.12	3.17	1.93	3.17	7.93	510	5	63	24,467	3,046
7b)	14.75	1.80	18.77	1.35	29.16	5.01	8.23	3.22	1.96	3.21	8.15	517	5	64	24,803	3,088

total area of chambers (m^2)= 656
total volume of chambers (m^3)= 3.3
Total number of modules= 192

Total channels=> 196,800 | 28,265
Total for 4/4/4=> 223,409 | 30,177

Plan View of a typical CSC module



Chamber size limited by
- strip capacitance
- capacity of circuit board houses

Need to overlap chambers to limit acceptance losses

SC Power, Weight, X0 SW 5 Feb 92

typical module 2m (r) x 1m (theta)

ower

component	watts	ch/mod	power/mod	
strip ch	0.1	800	80	incl fast out for trigger
theta ch	0.05	160	8	
trigger	10	1	10	

total power per module 98 watts

Weight – middle module (extra spacer)

component	Kg/m^2	m^2/mod	Kg/mod	ave X0	
hexcel	1.80	12	21.60	0.0308	Hexcel HRH-10-1/4-2.0
circuit bds	2.03	24	48.72	0.0610	.047 in, rho = 1.7
copper	0.16	24	3.84	0.0123	1/2 oz/ft^2
wires			0.03	0.0002	4 * 800 * 25 mu W
Al sides			6.50	0.0112	50 cm * 6 m * 1/32 in
frames, closeouts			18.40	0.0230	G10 2.5cm *1.5cm * 6m * 5
electronics			5.00	0.0063	wild guess

average X0/module 0.1448

total weight per module 104.06 Kg

RPC PROTOTYPES AT MIT

ONE - .35M X 1.40M — 3.3mm MIRROR

ONE - .30M X 1.20M — 2.5mm MIRROR

4 - 8CM X 10CM - 2.0mm GLASS

DATA AQUISITION

LE CROY 9450 DIGITAL SCOPE

1 HERTZ CAPABILITY

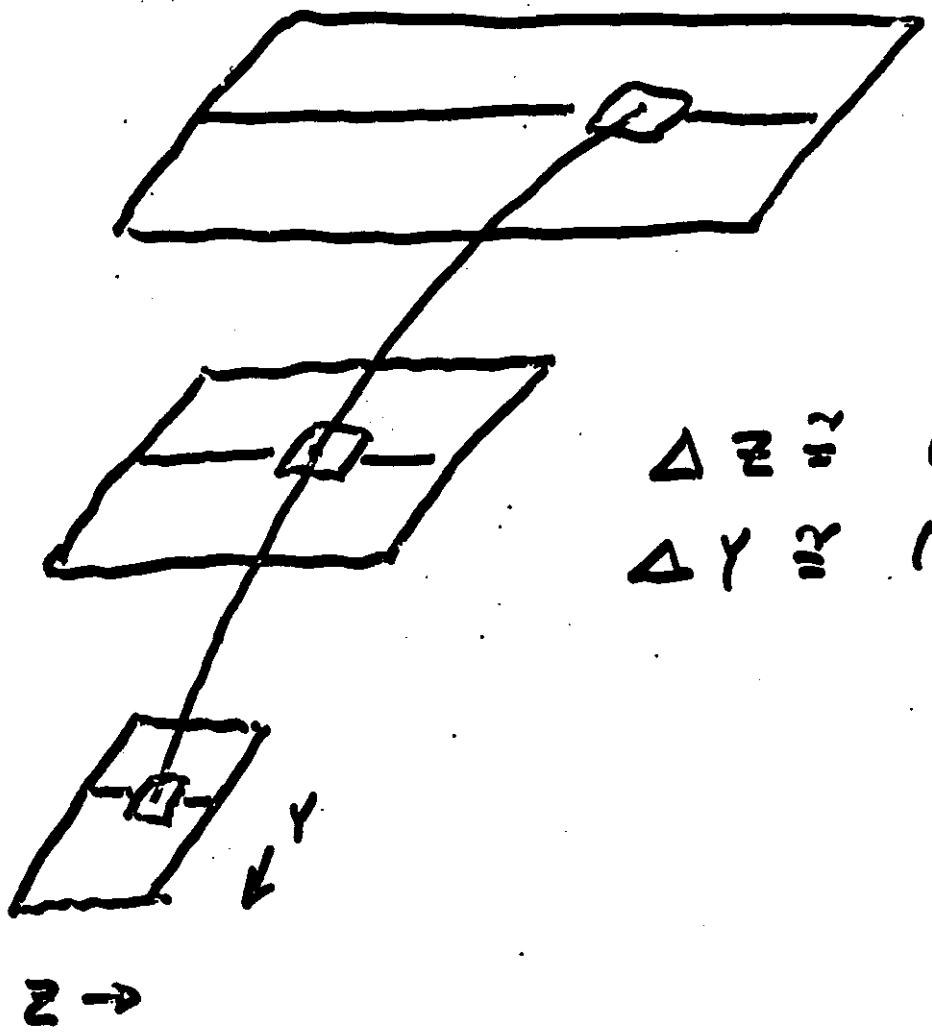
NEED - STABLE, REPRODUCABLE

GAS SYSTEM
AT LLNL

SEVERAL SMALL RPC

RESISITIVE PLATE COUNTERS AND PATTERN RECOGNITION

GENERAL CONCEPT OF RPC "ROAD"



$\Delta Z \cong 6\,CM$

$\Delta Y \cong 1.3\,CM$

WHAT ABOUT MULTIPLE TRACKS

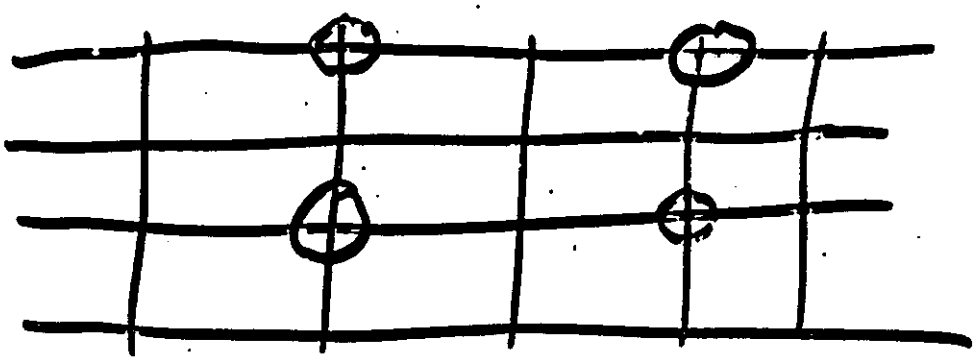
$H \rightarrow 4\mu$

s = NUMBER SECTORS
t = NUMBER OF TRACKS

$$P(2) = 1 - \frac{s!}{(s-t)!\, s^t}$$

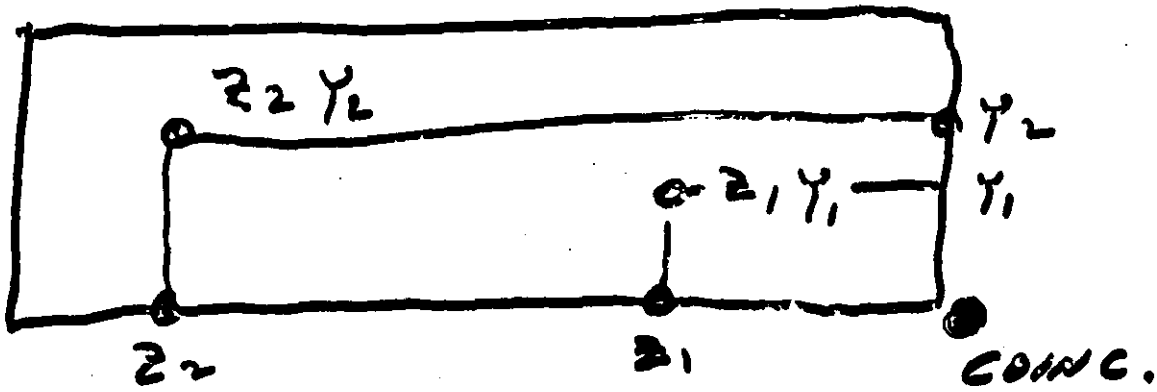
$s = 32 \quad t = 4$

$P(2) = 17.7\ \%$



IN PRINCIPLE 6 COMBINATIONS

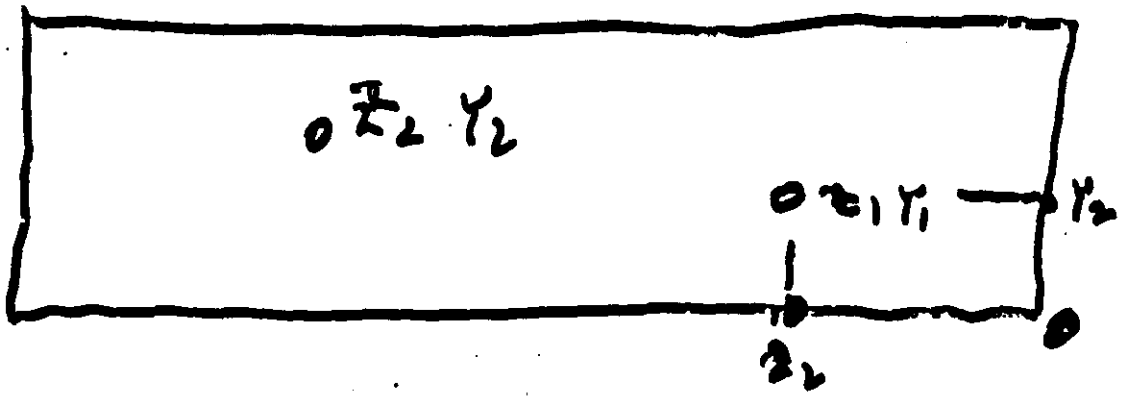
USUALLY ONLY 2 COMBINATION

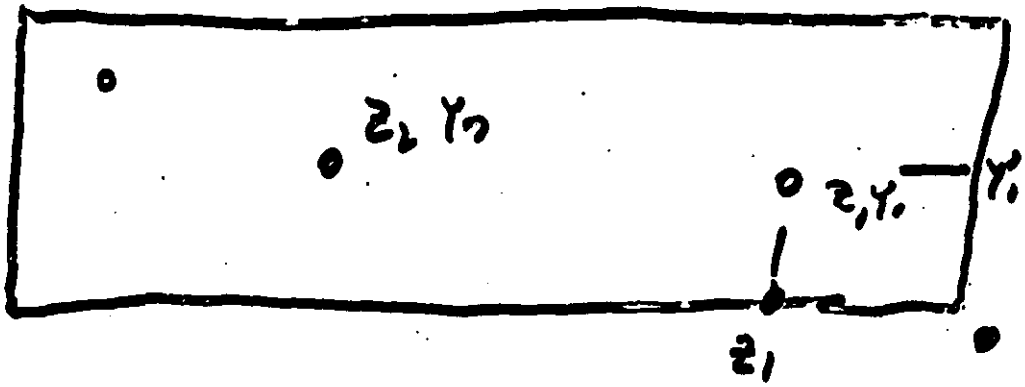


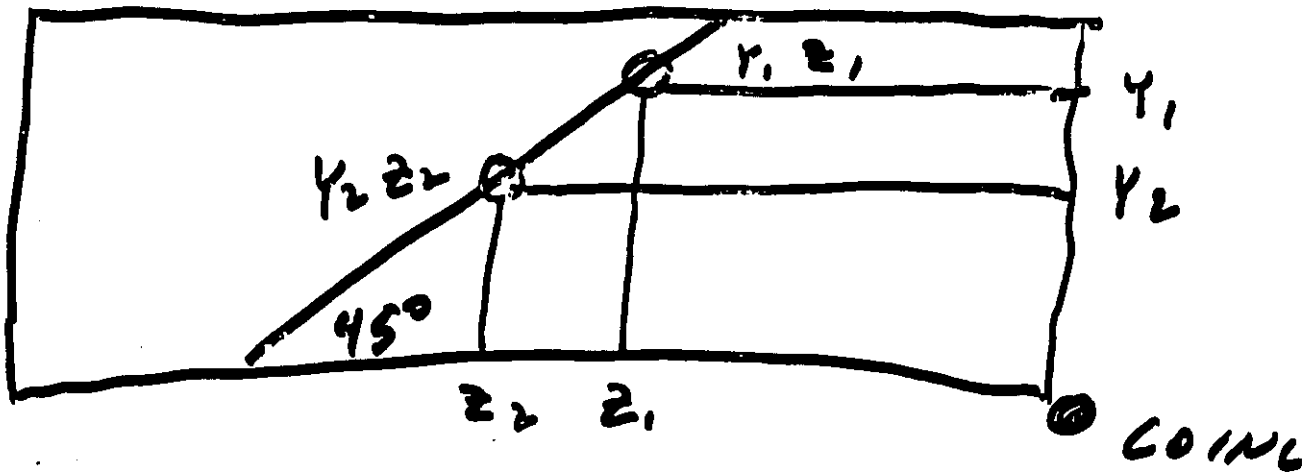
BEAM CLOCK

BEAM CLOCK $-(Z_1 + Y_1)$ = BEAM CROSSING

BEAM CLOCK $-(Z_2 + Y_2)$ = BEAM CROSSING





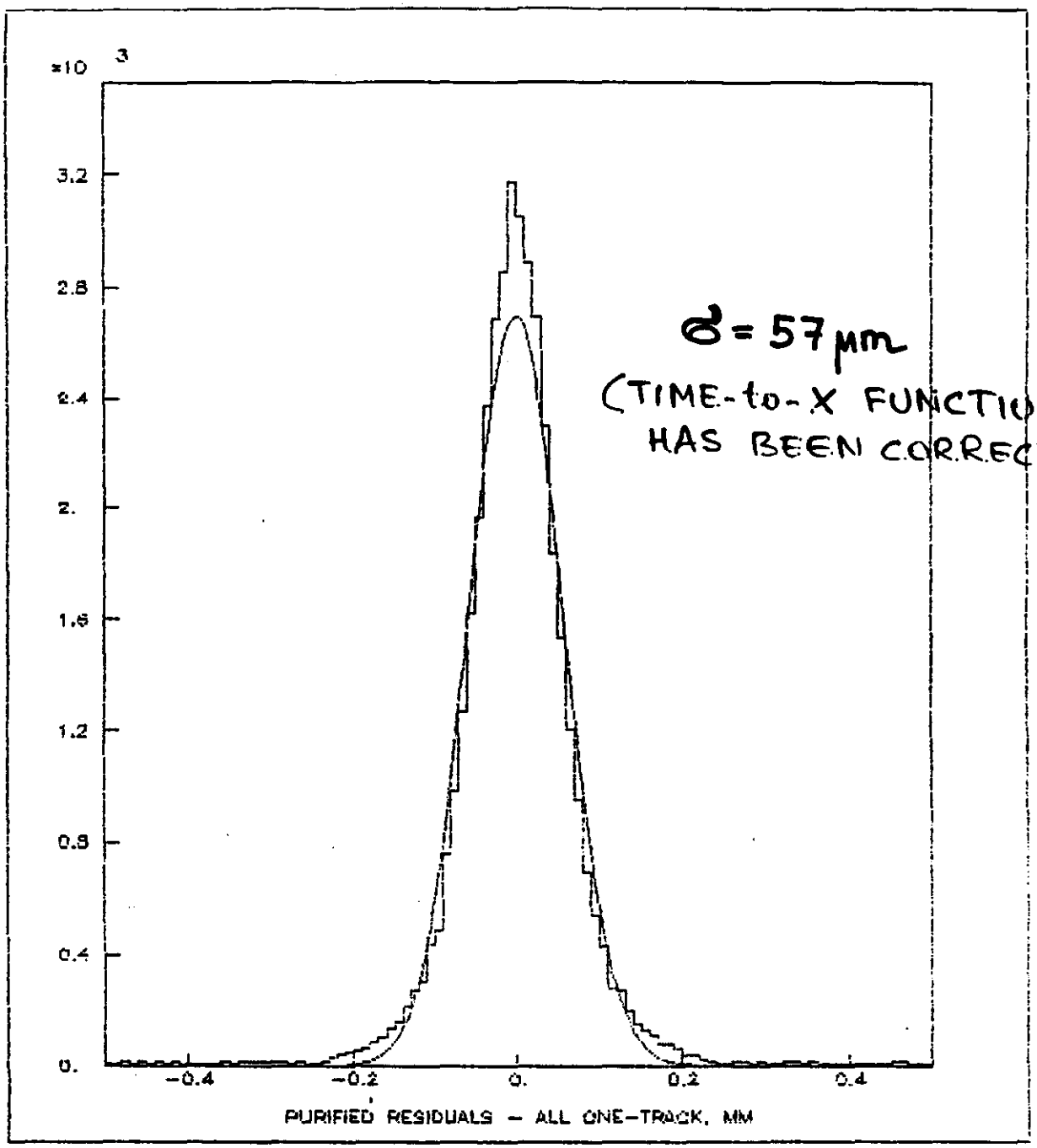


FIRST Y ASSOCIATED WITH SECOND Z

SECOND Y ASSOCIATED WITH FIRST Z

LSTD R&D

INTRINSIC RESOLUTION	(*) intrinsic resolution (*) magnetic field: – drift time vs distance – intrinsic resolution – $\delta B/B \Rightarrow \delta r$ (*) inclined tracks in square cells (*) search for the best gas (T_{drift}; σ_x; SQS; reliability; flammability; aging; B-sensitivity...
LARGE SCALE PROTOTYPE	(*) overall mechanical design (alignment...) (*) electronics (*) soft-ware (*) TESTS
BACKGROUND	(*) PUNCHTHROUGH (*) E/M DEBRIS (*) NEUTRON BACKGROUND

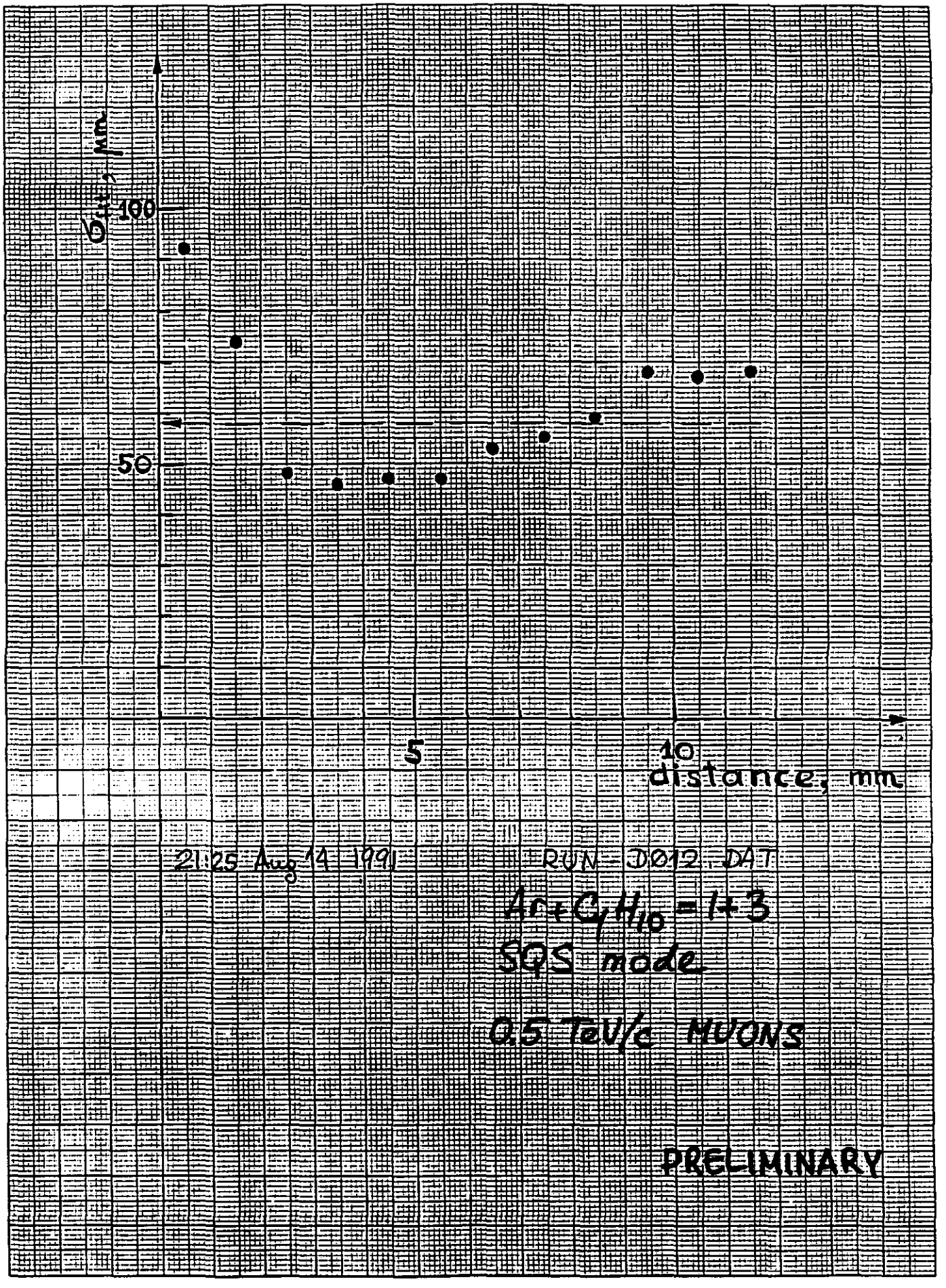


RUN-D012.DAT

$Ar + C_4H_{10} = 1+3$ (SQS) Threshold = 15 mV

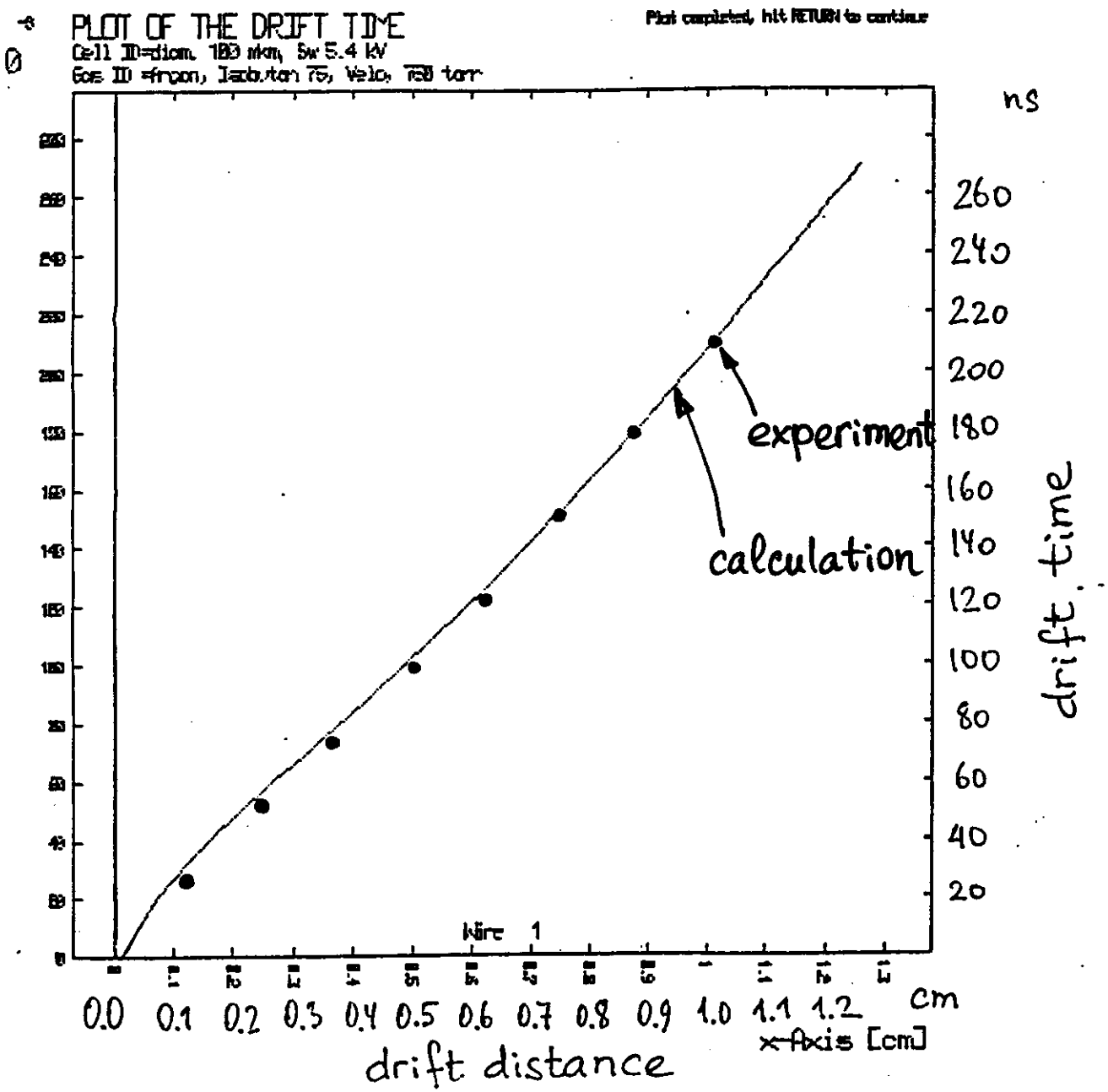
~0.5 TeV muons

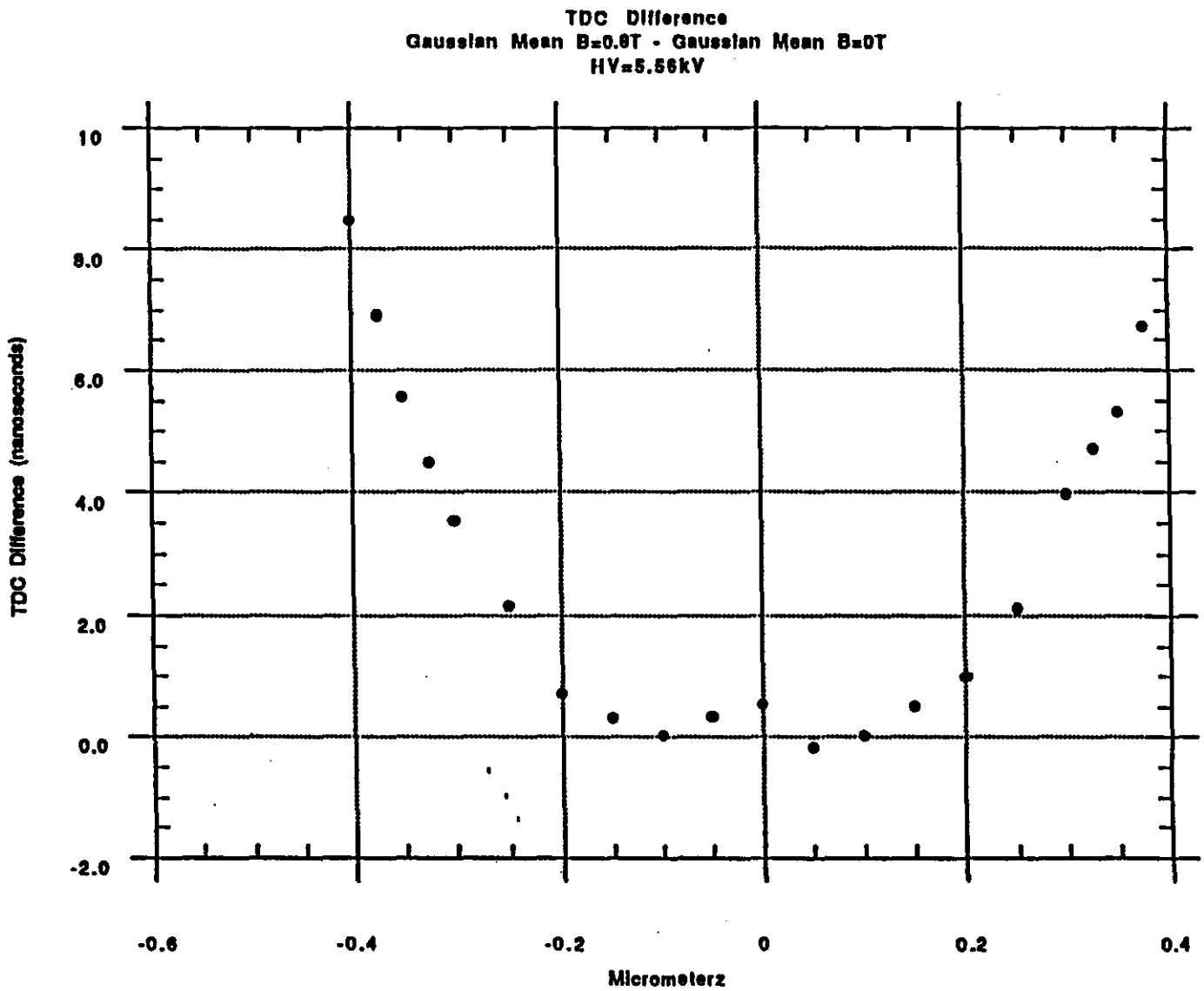
PRELIMINARY



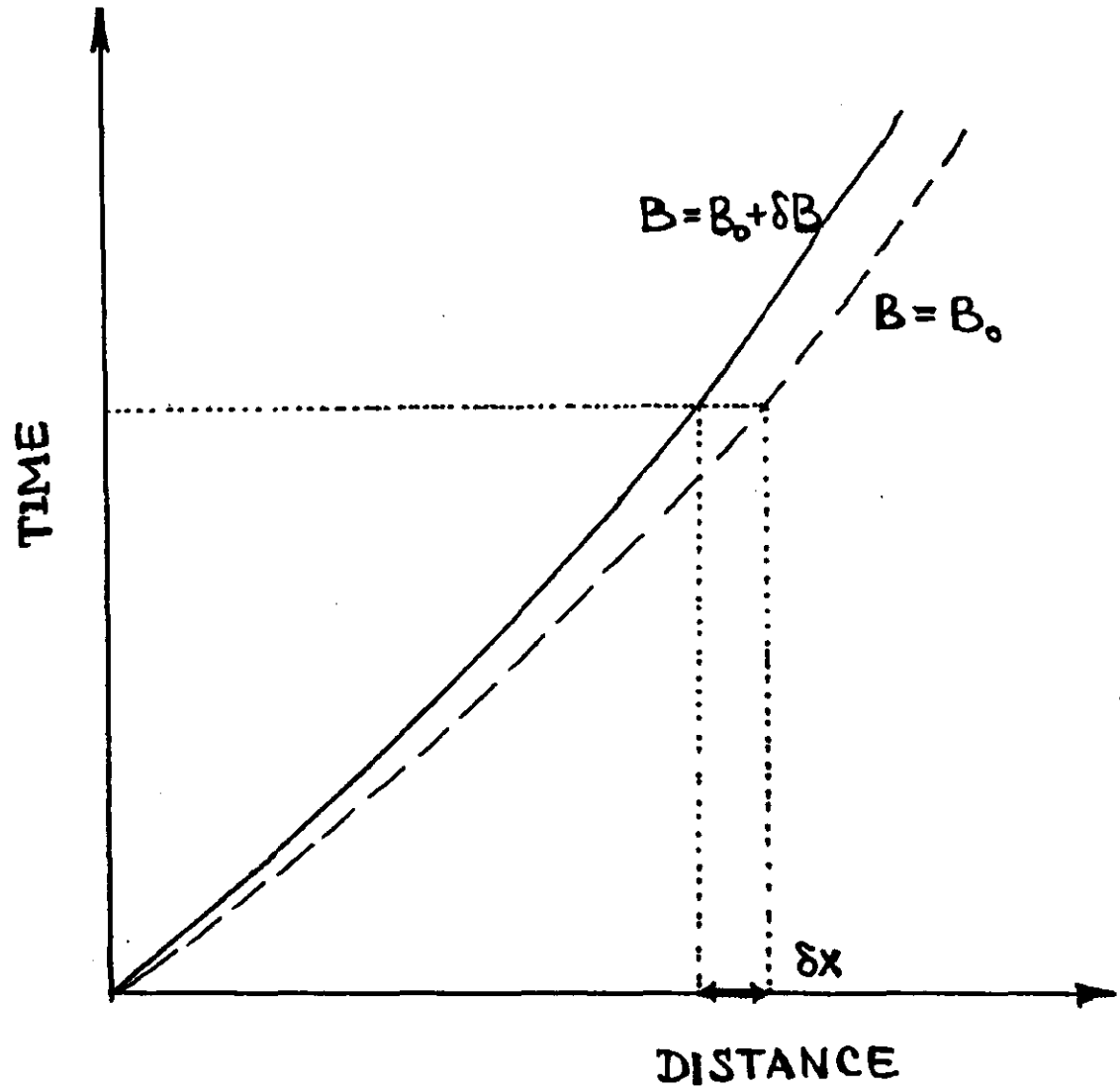
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1510

GAS	RESOLUTION		T_{max}	Flam / LS
	LASER	MUONS		
$Ar + C_4H_{10} = 25 + 75$	~35μm	~60μm	270ns	Yes / +
$Ar + CO_2 + C_4H_{10} = 2 + 88 + 10$	~50μm	—	820ns	No / +
$CF_4 + CO_2 + C_4H_{10} = 69 + 20 + 11$	~80μm	~120μm	270ns	No / +


PLOT OF THE DRIFT TIME
Cell ID=diam. 100 mm, Sw 5.4 kV
Gas ID =Argon, Isobutan 75, Velo, 760 torr
Plot completed, hit RETURN to continue
ns
260
240
220
200
180
160
140
120
100
80
60
40
20
drift time
experiment
calculation
Wire 1
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2
cm
x-axis [cm]
drift distance



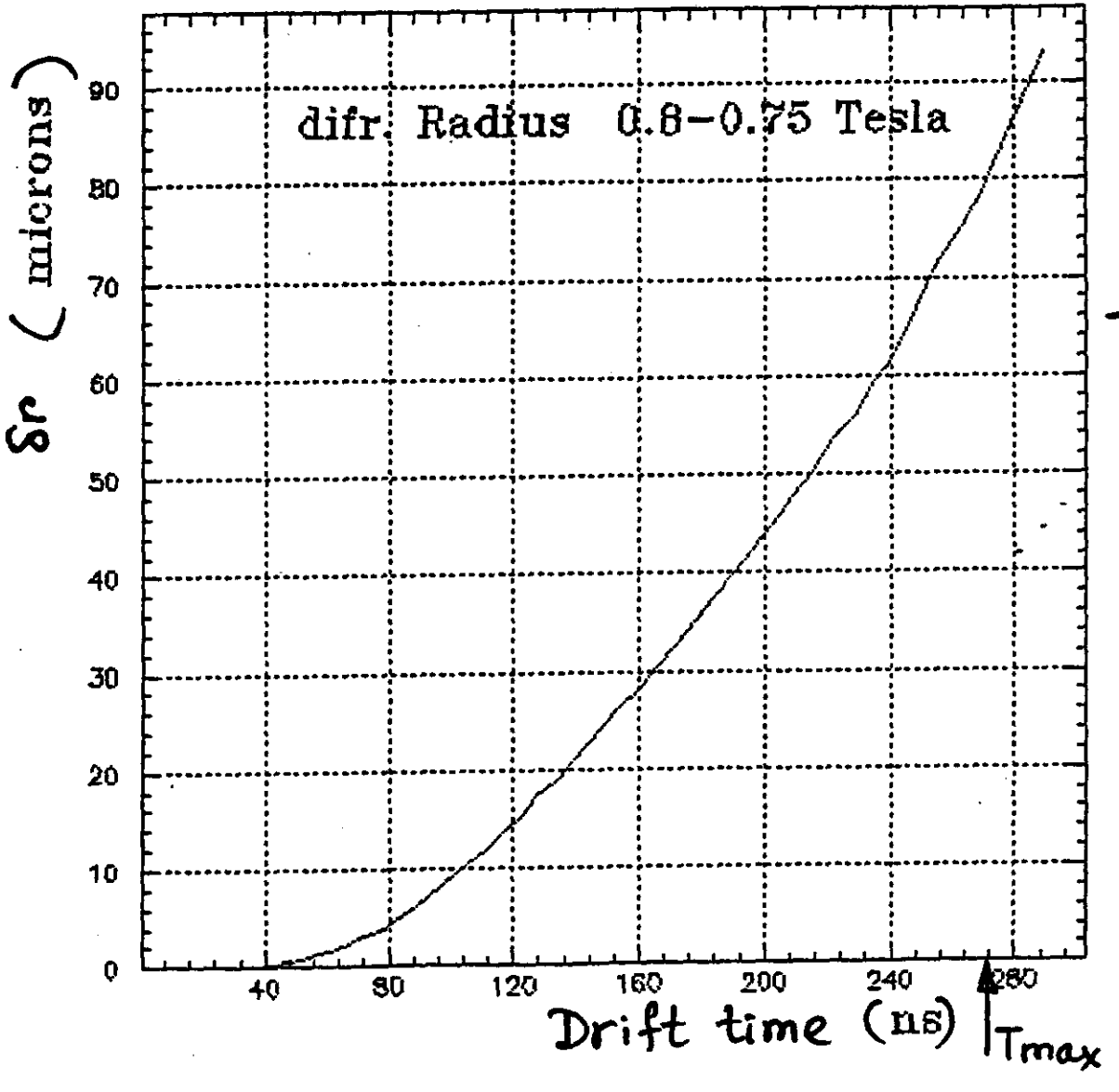
1) Magnetic Field does increase Drift Time
2) The increase is small ($\Delta T_{max} \sim 10$ns, while $T_{max} \sim 260$ ns)



Uncertainty in knowledge of magnetic field
gives
systimatic errors in determination
of coordinate

1A

Argon, Isobutan 75 21/02/92 16.11



$B_0 = .8\,T$ $\Delta B = .05\,T$

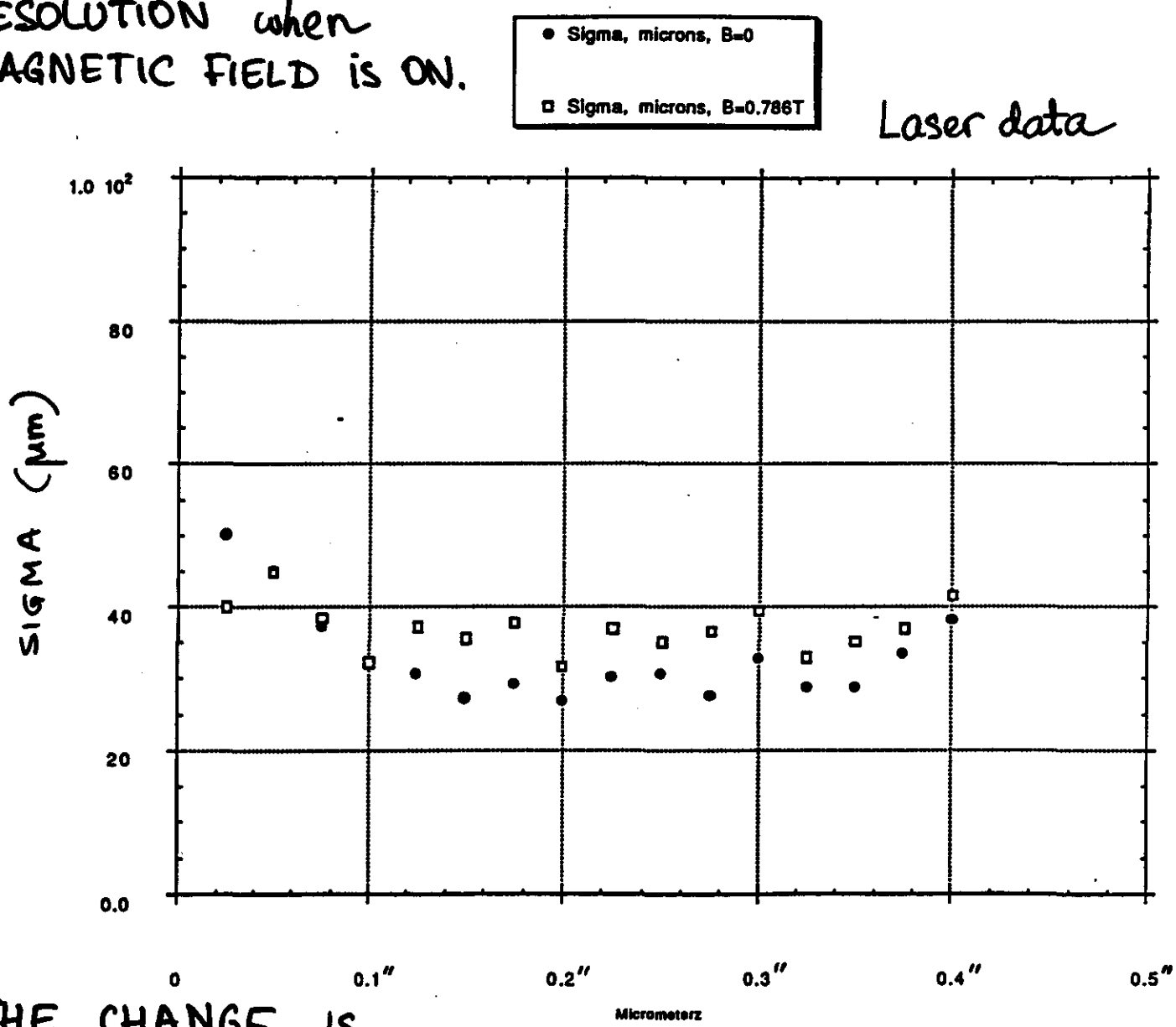
$\frac{\Delta B}{B} \sim 6\%$

$\delta r_{max} \sim 100\ \mu m$

$\delta r_{max} \lesssim 20\,\mu m$ for $\delta B/B \sim 1\%$

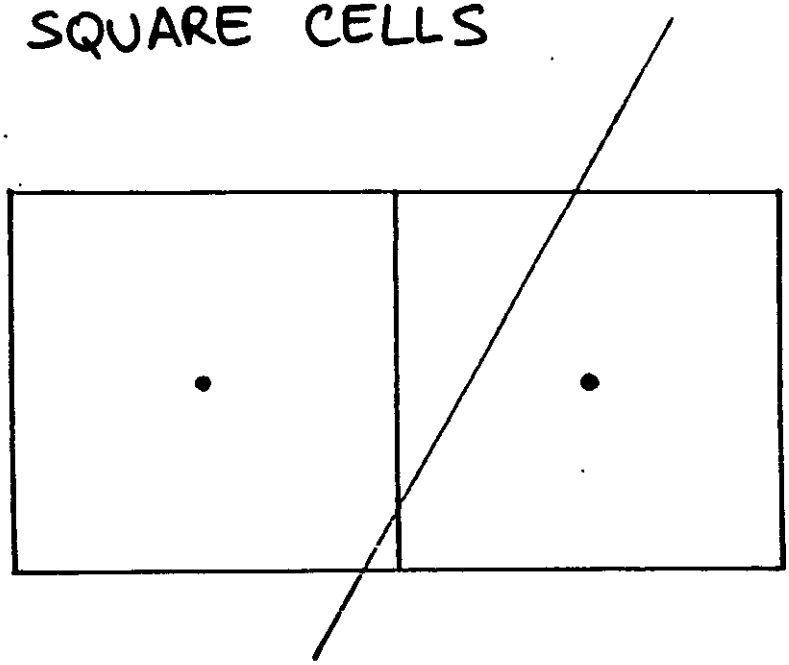
Requirements are NOT very strong

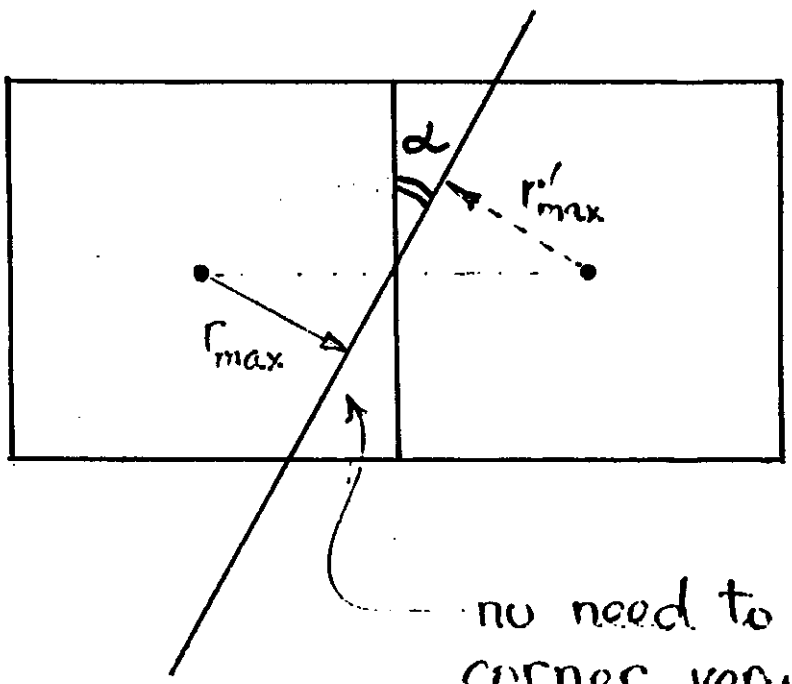
CHANGE of INTRINSIC RESOLUTION when MAGNETIC FIELD is ON.



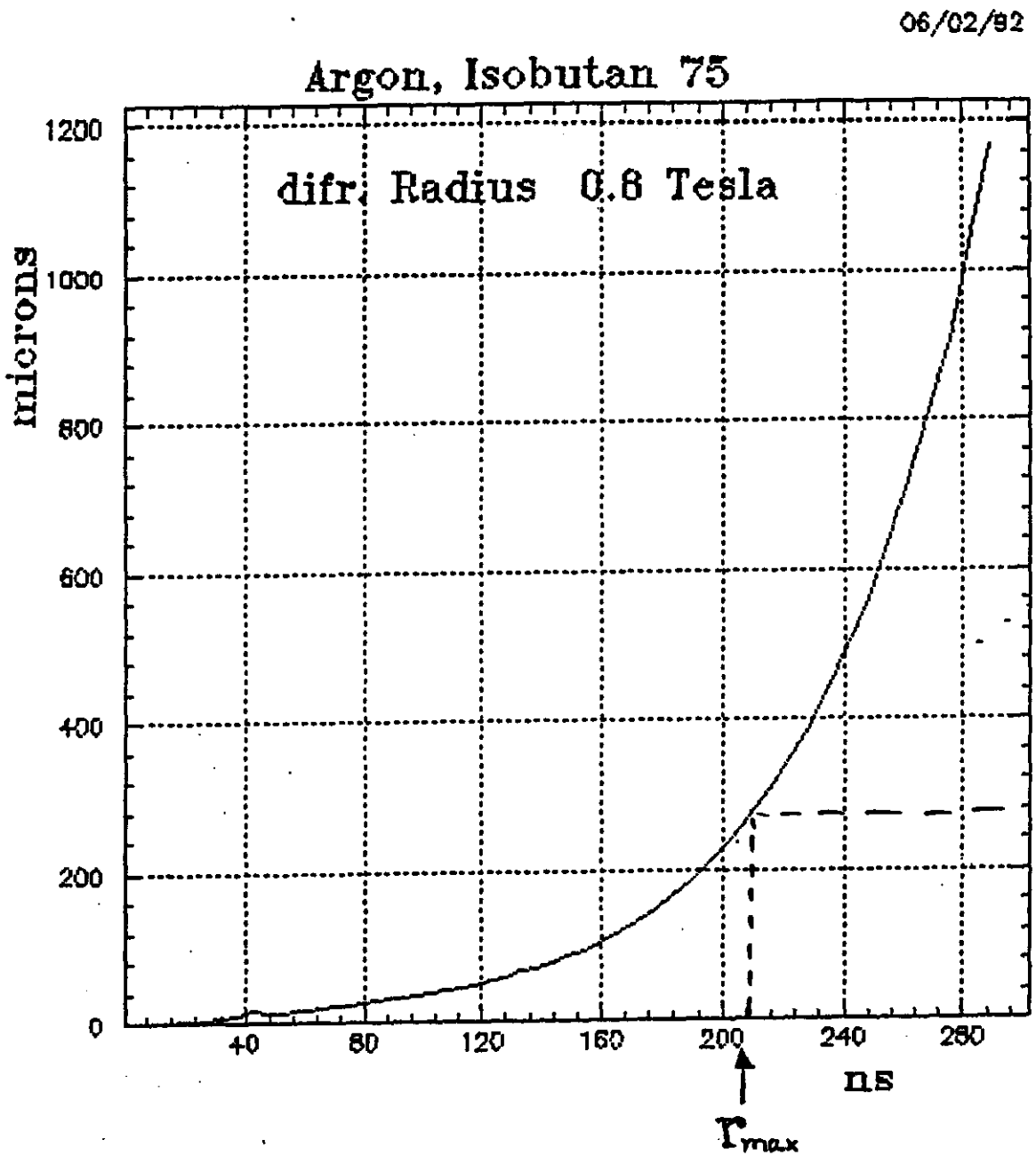
THE CHANGE IS VERY SMALL!

INCLINED TRACKS IN SQUARE CELLS





no need to go in the corner very deeply $\Rightarrow$ JUST use r'_{max} instead of r_{ma}



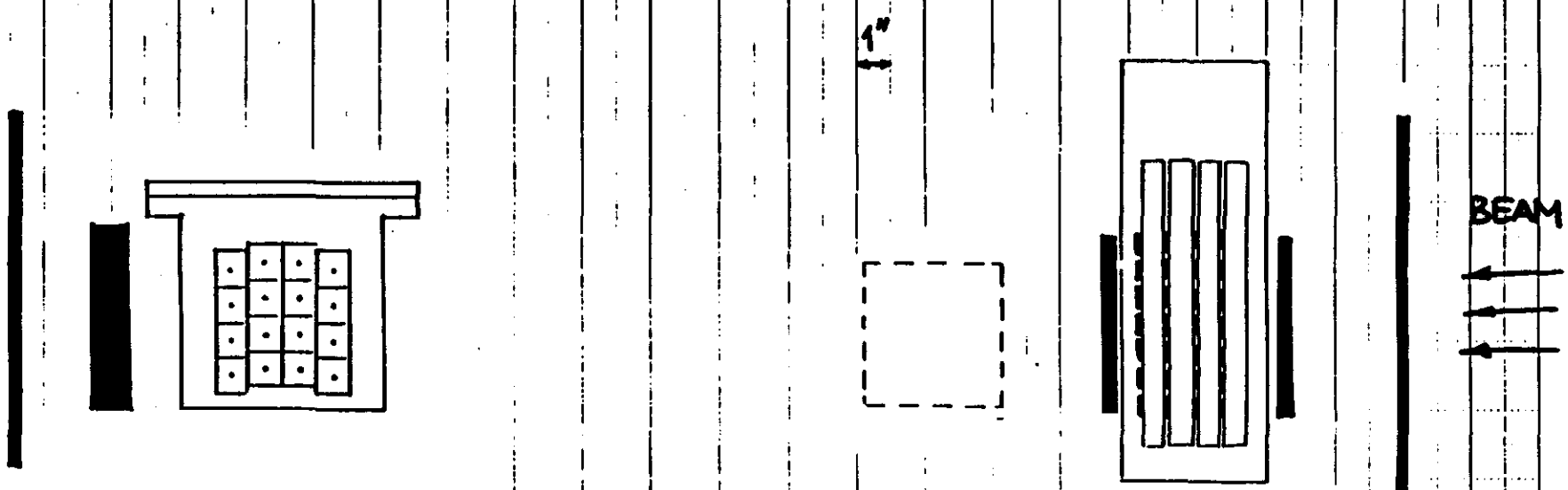
0° and 45°

if one does not go into the corner, the systematic error is not big even for unreasonably big angles (e.g., 45°):

$\delta r_{max} \sim 300\,\mu m$

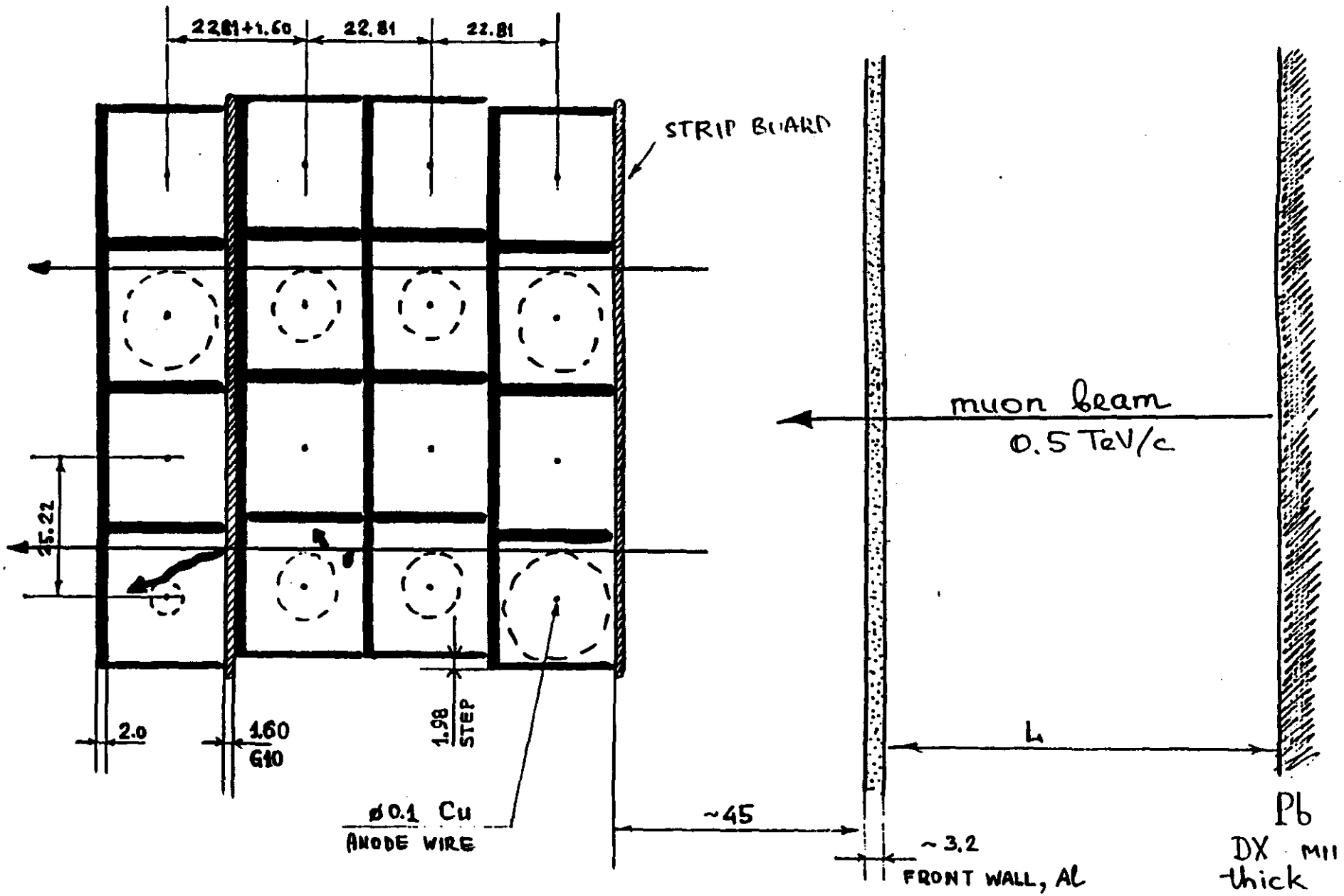
T819 Test Experiment at Fermilab

0.5 TeV/c muons

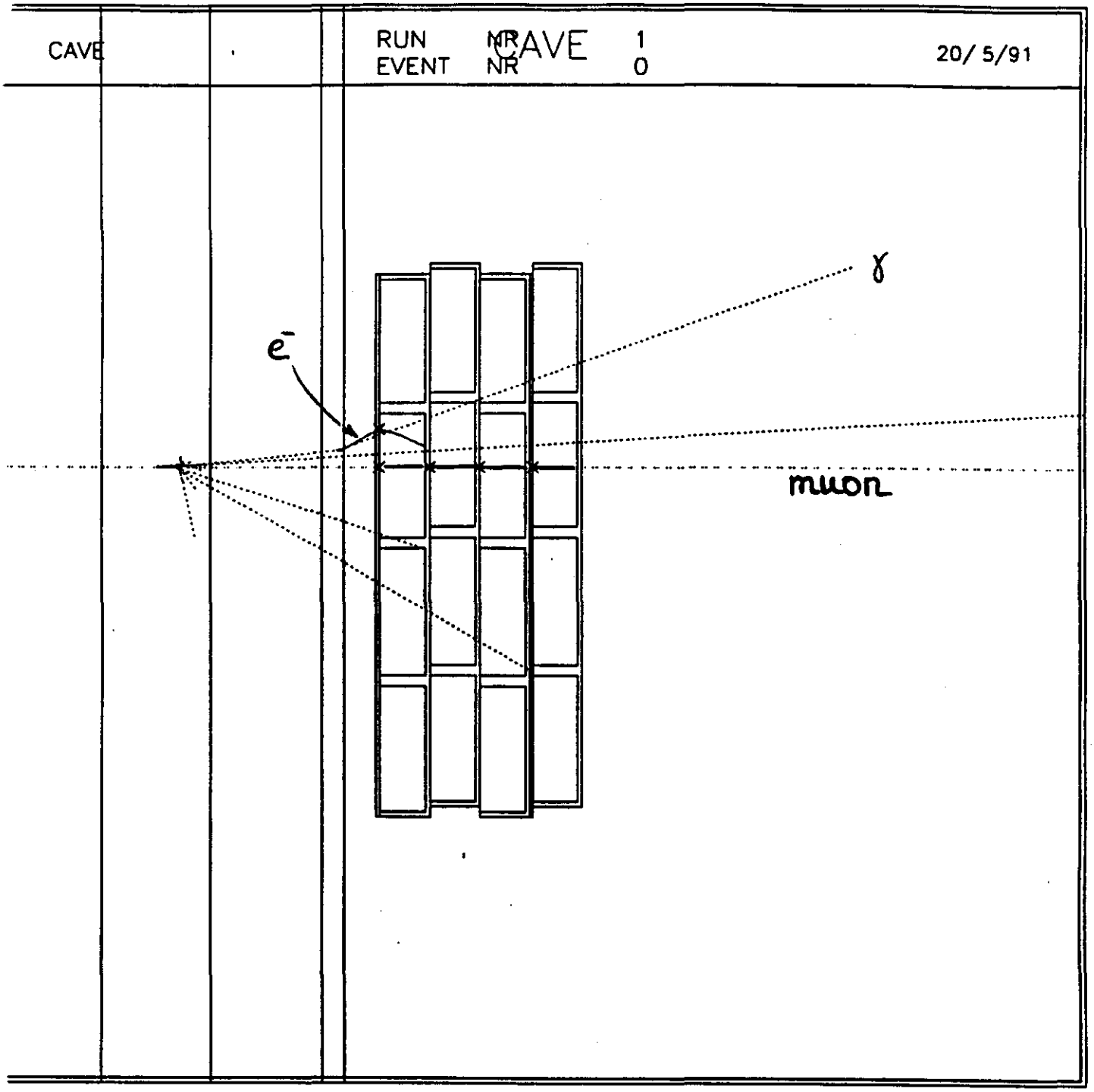


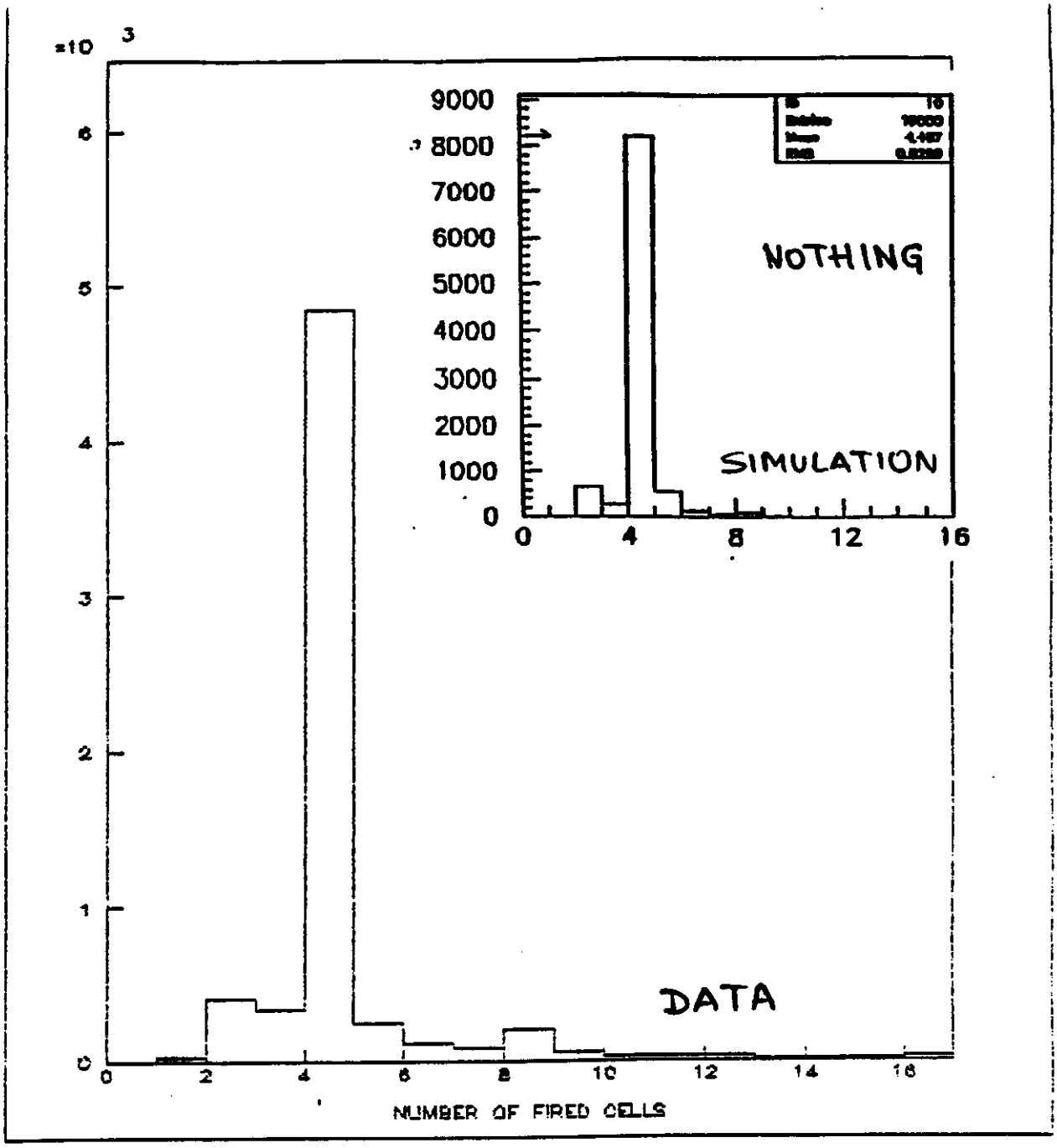
MATERIAL

(*) – nothing
(*) 5 + 5cm Al
(*) 5 + 5cm Fe
(*) 5 + 5cm Pl
(*) 10 cm Pl + 5cm Al


22.81+1.60
22.81
22.81
STRIP BOARD
15.22
2.0
1.60
G10
1.98
STEP
ø0.1 Cu
ANODE WIRE
~45
~3.2
FRONT WALL, Al
muon beam
0.5 TeV/c
L
Pb
DX MII
thick

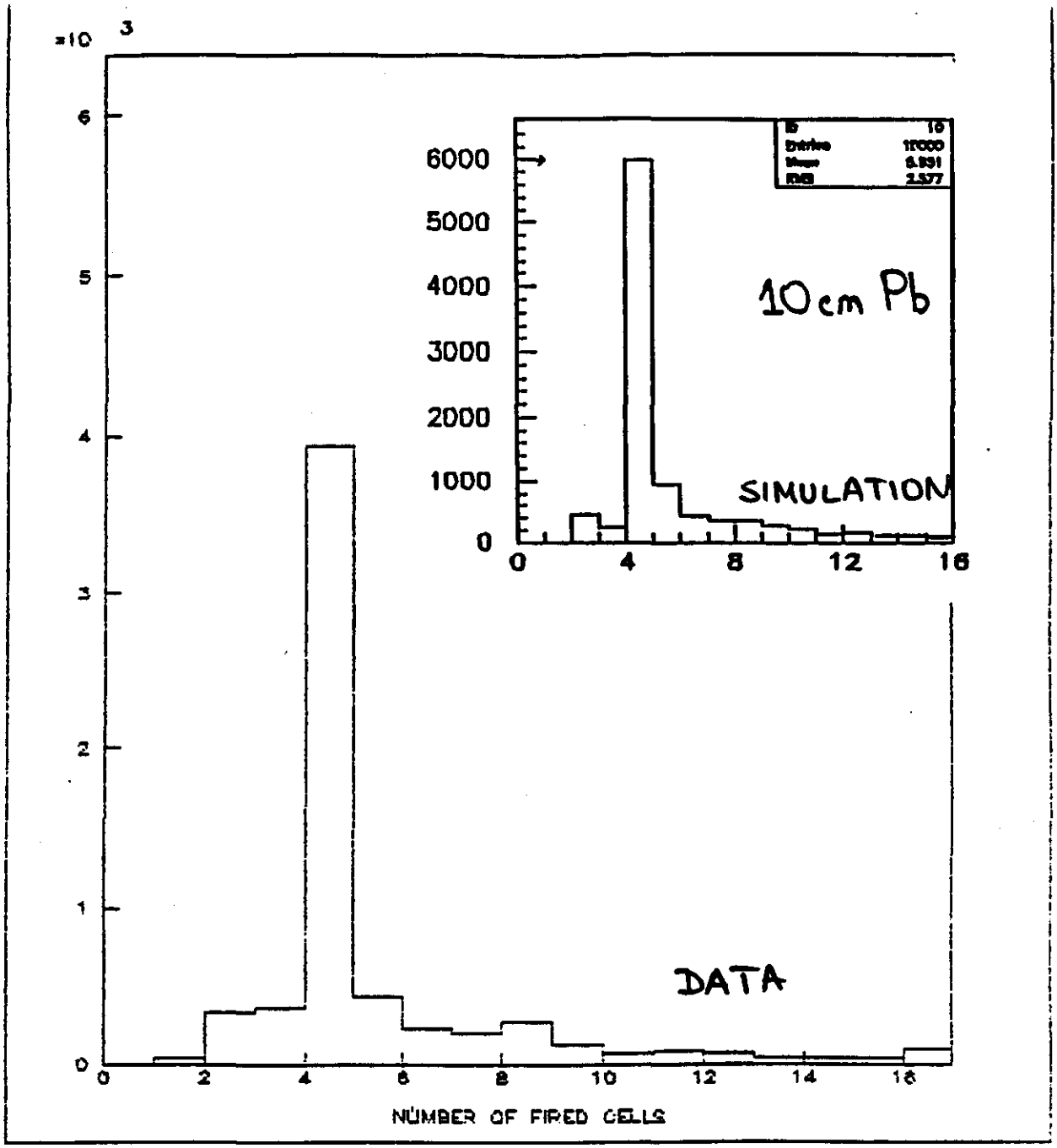
Example of a simulated event





VERY PRELIMINARY

RUN-3507



VERY PRELIMINARY

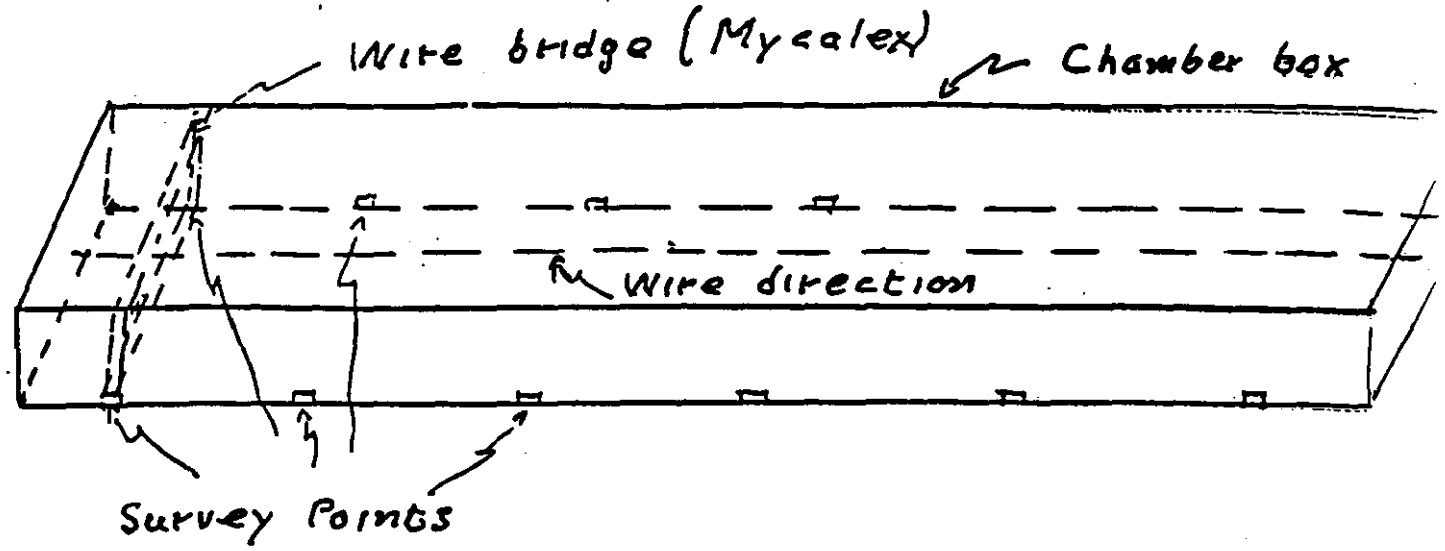
02

L. Osborne

Merits of Streamer-Drift System

1. Preservation of the fast rise time in pulse transmission. ~ 10 nsec. @ 100 mV
2. Open structure for laying down wires-allows multiple wire placement and placement checking for ease of construction.
3. Precision wire positioning.
4. Minimum scattering material.
5. No restriction on chamber length.
6. Parts and assembly amenable to mass production.
7. Stiffness in the final chamber to minimize support points.

8. Single wire resolution of $\sim 100 \mu m$.



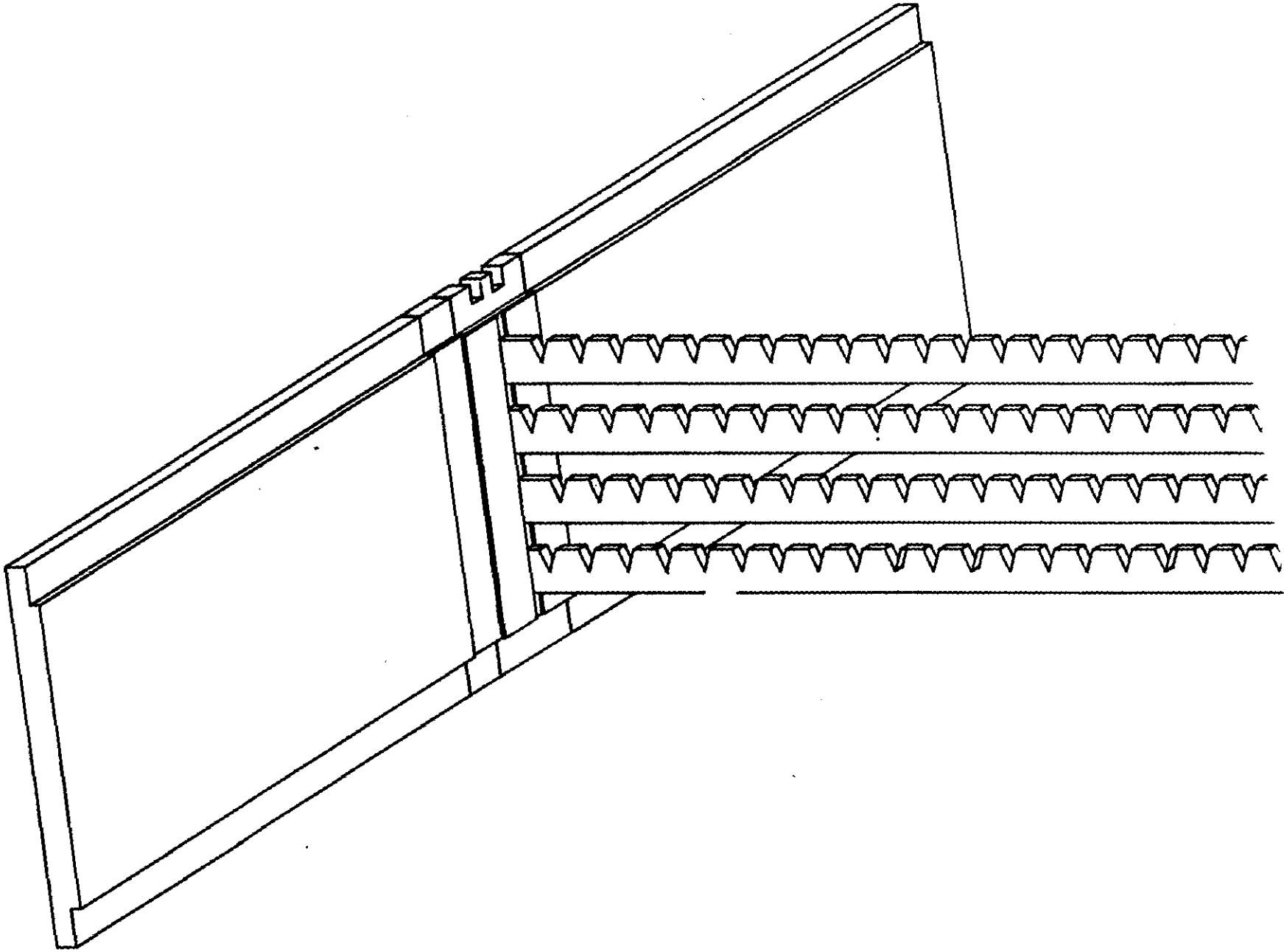
Philosophy

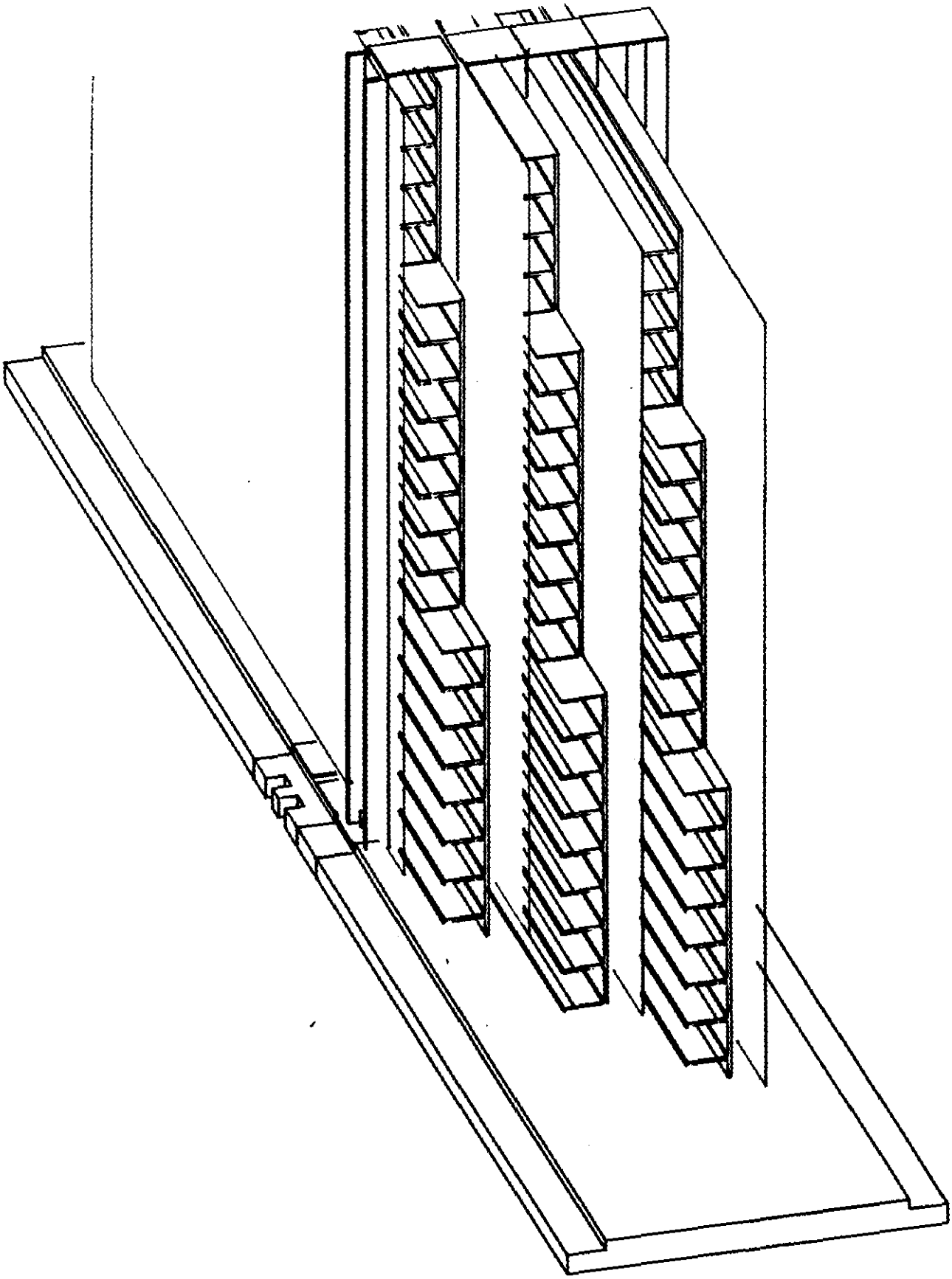
Wires placed to $\pm 12.5 \mu m.$ with respect to survey points,

1) indenpendent of gravity
2) " temperature
3) " warp and sag of the chamber.

Survey points known to $\pm 12.5 \mu m.$,

1)by surveying
2)by placement (unlikely)
3)by monitoring.





II. R & D Program.

A, The Tasks

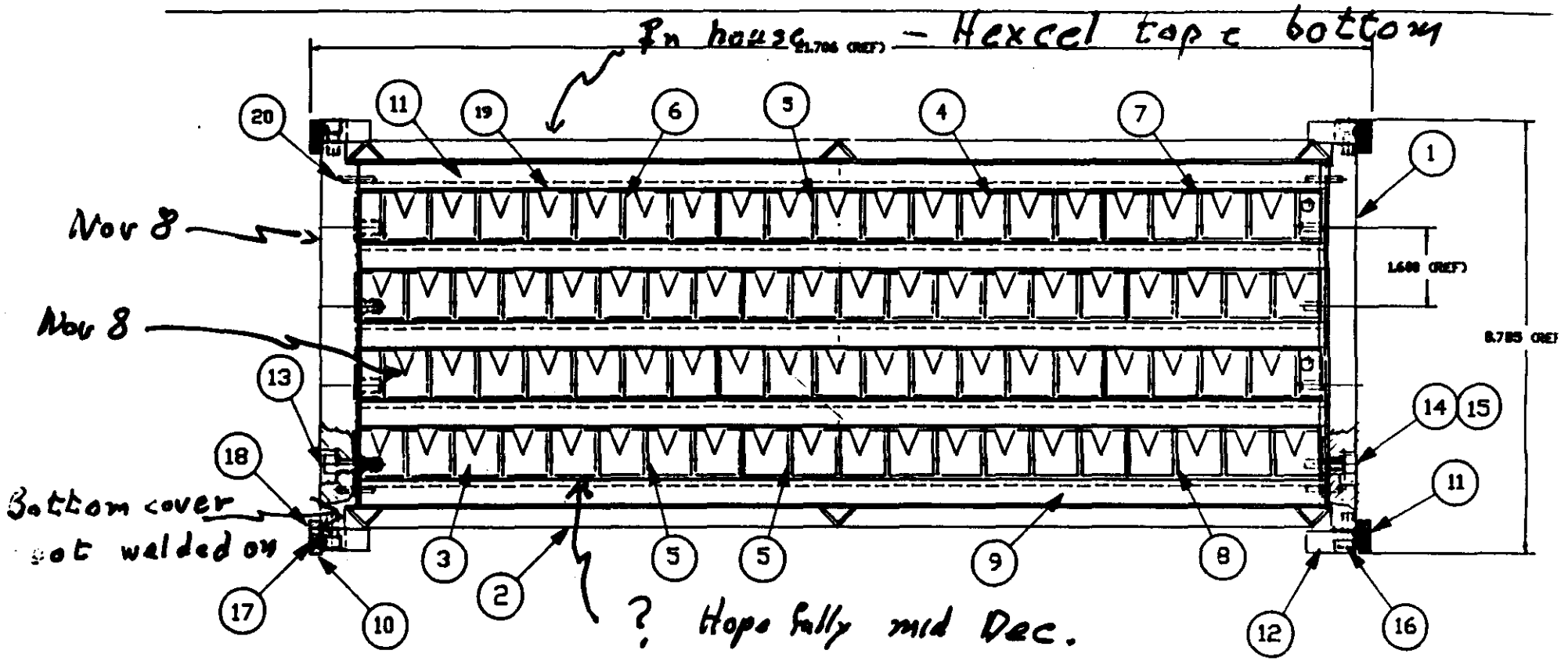
We list the tasks we expect to complete adding in parenthesis the institution(s) bearing the responsibility:

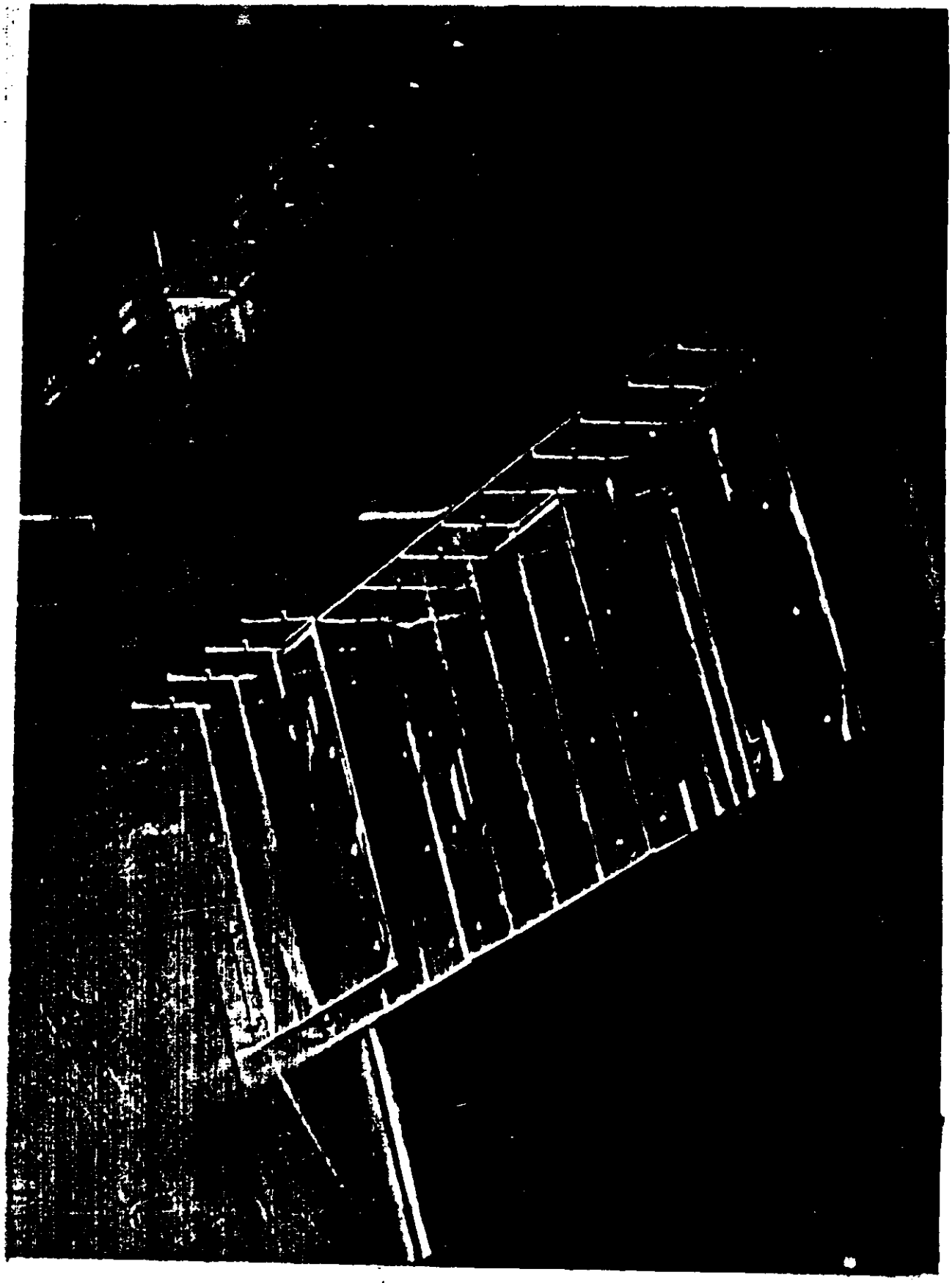
1) Finish assembly and test of 2, 0.5 m. wide chambers.(MIT)
2) Measure chamber tube performance in magnetic fields.(MIT)
3) Design and build (D & B) 2, 1 meter wide chambers.(MIT)
4) D & B pick-up strip plane.(MIT)
5) Investigate and make thinner cathodes.(MIT & UNY-SB)
6) D & B optical window system.(MIT)
7) D & B tiltable chamber stand as a cosmic ray muon telescope.(MIT)
8) Adjoin prototype optical alignment system to the chambers.(MIT, with the help of Draper Lab.)
9) Design of apparatus for mass production of chambers; estimate production costs.(U. of Houston)
10) Investigate various materials for use as cathodes.(MIT)
11) Analyse the data from both; 1) runs taken at Fermilab on a small prototype, and 2) data with cosmic rays on the 0.5 m. and 1.0 m. chambers.(MIT, UNY-SB, & LSU)
12) Simulation studies of the muon system directed toward optimization of the subsystem and integration with the rest of the detector.(MIT)
13) Provide chamber electronics, investigate state of the art electronics for TDC's, and examine scenarios for the use of chambers in a level 1 trigger system.(LeCroy,MIT)

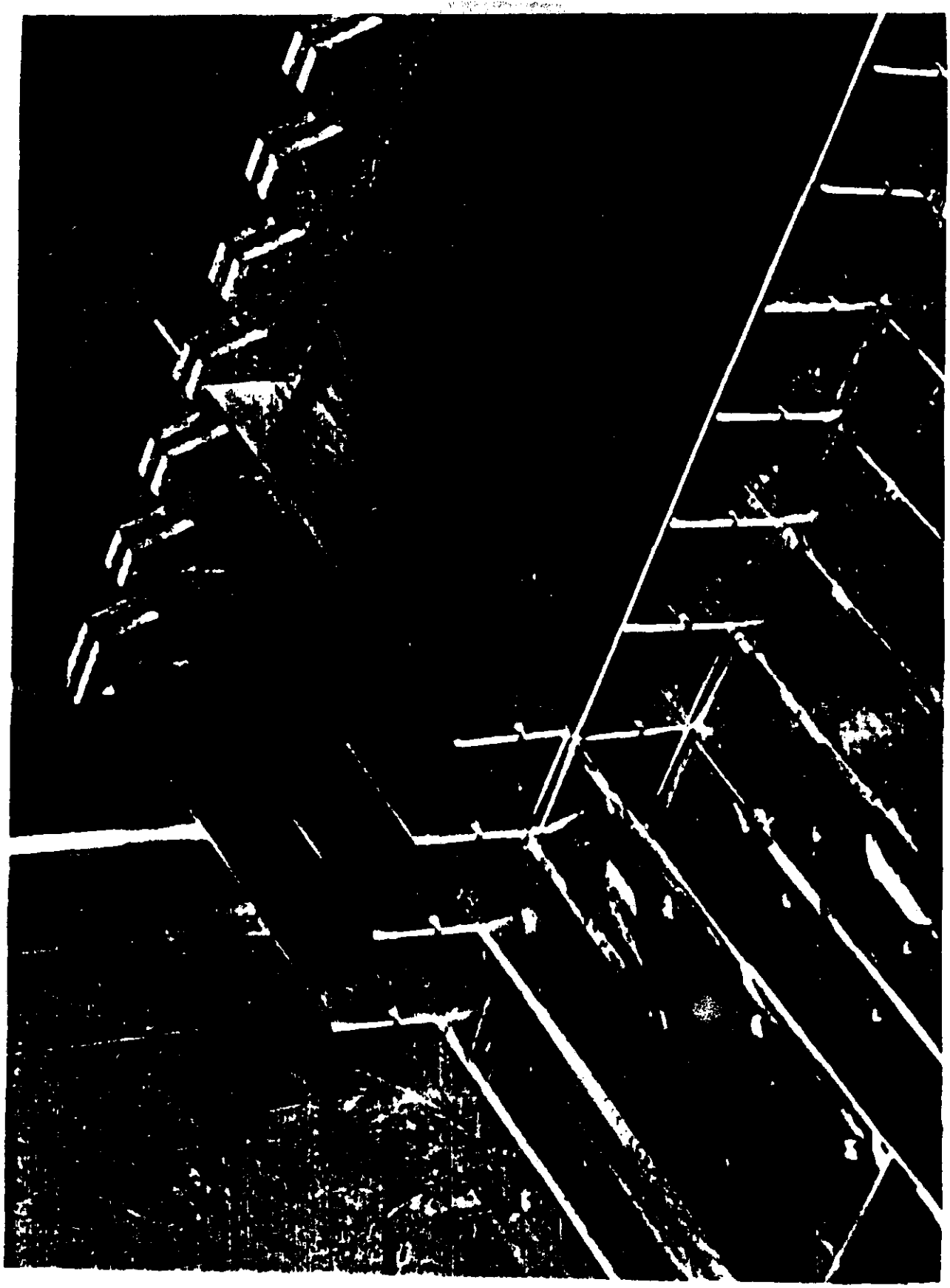
LSDT R&D Work

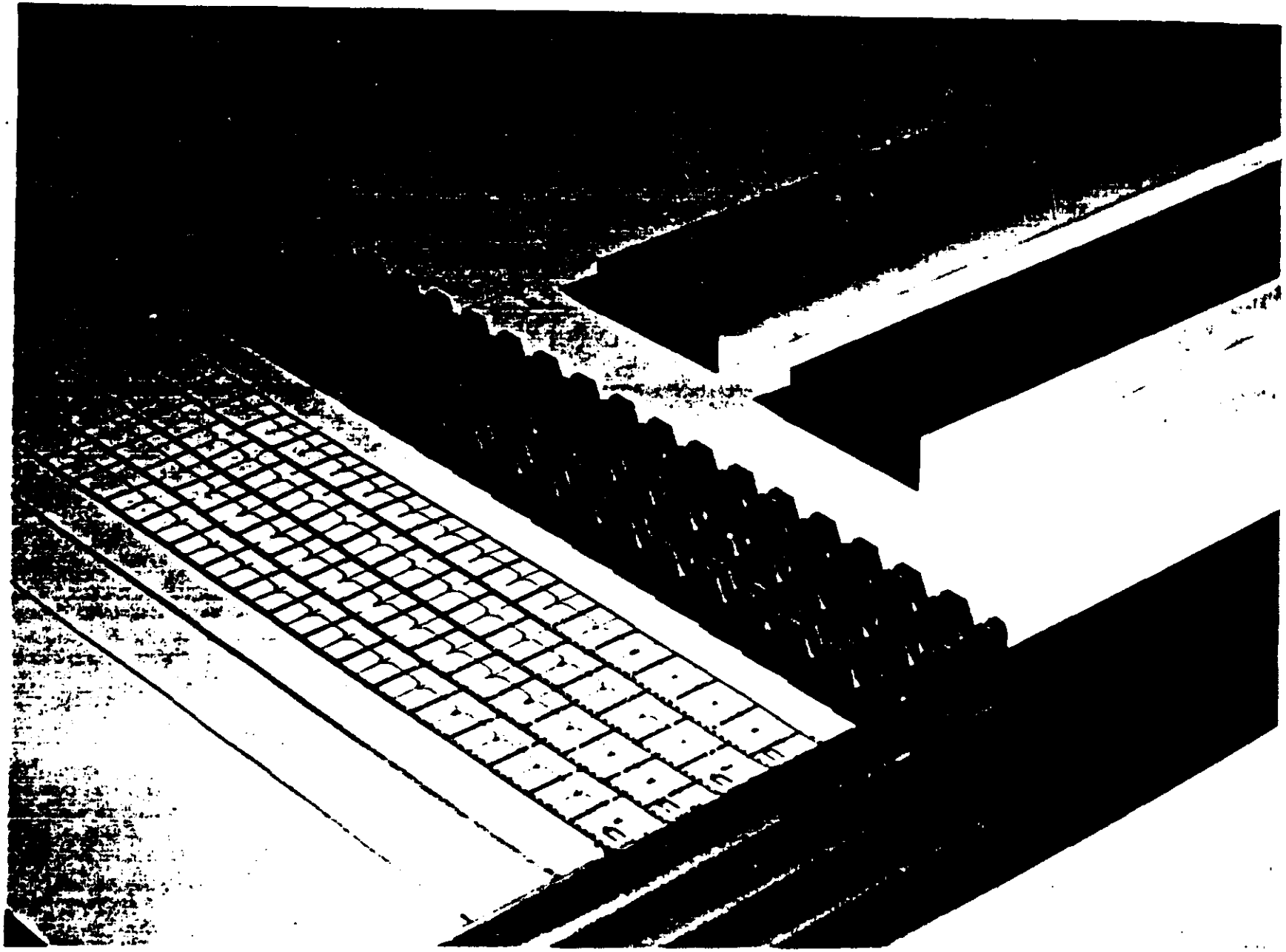
Milestones(all in '92): (from proposal to TNRLC)

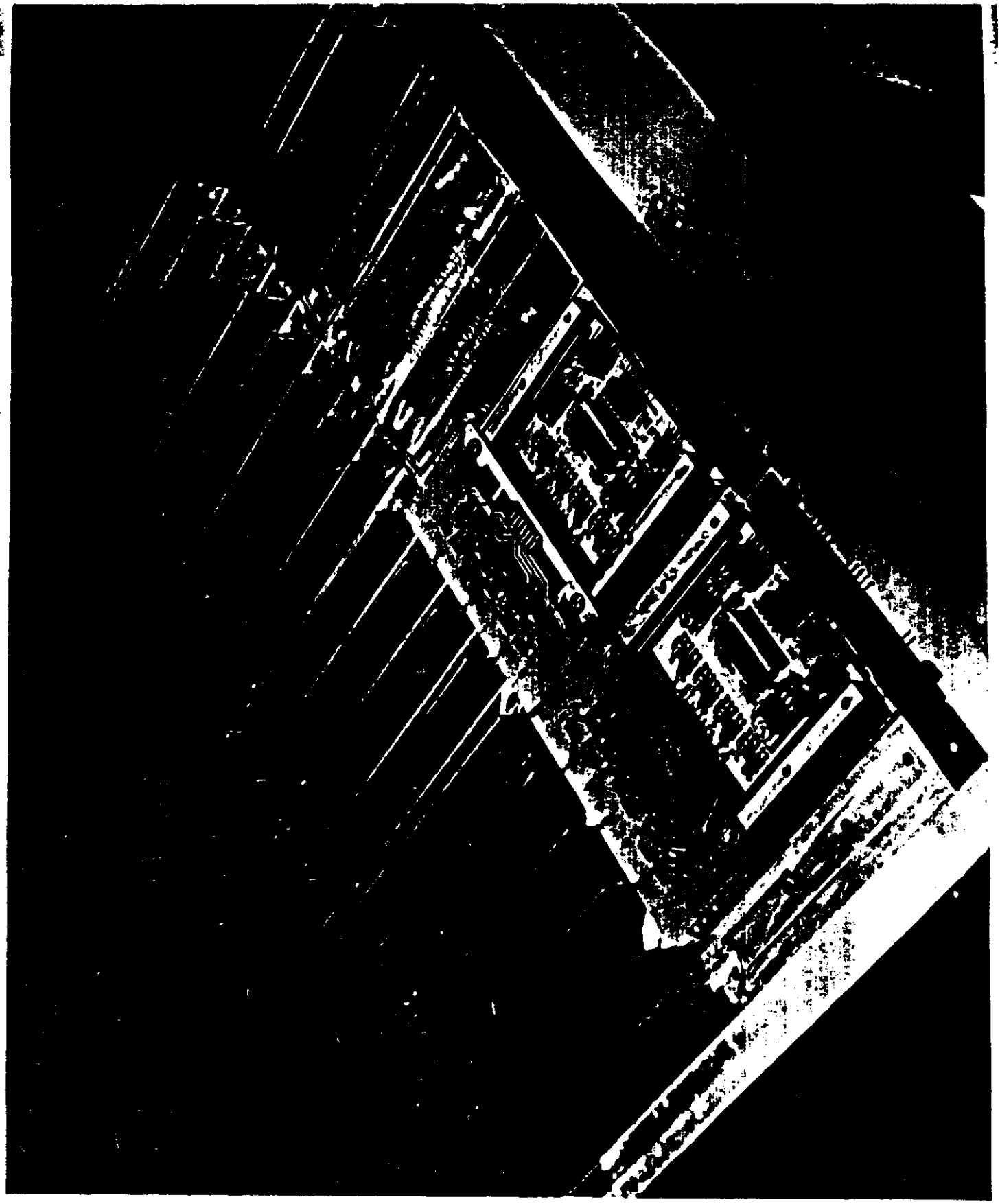
Delivery of LeCroy electronics for 0.5 m. chm	Jan. 1 ready
Design of thin cathodes	Jan. We are hoping "Solar Kinetics" succeeds
Design of 1.0 m. chamber	Jan. So far on schedule
Assembly of 0.5 m. chambers	Feb. Parts are in, Except!
Assembly of 1.0 m. chambers	March
Delivery of 1.0 m. chamber to SSCL	May
Set final specs. on chambers	Aug.
Assemble cost figures for EDR	Sept.

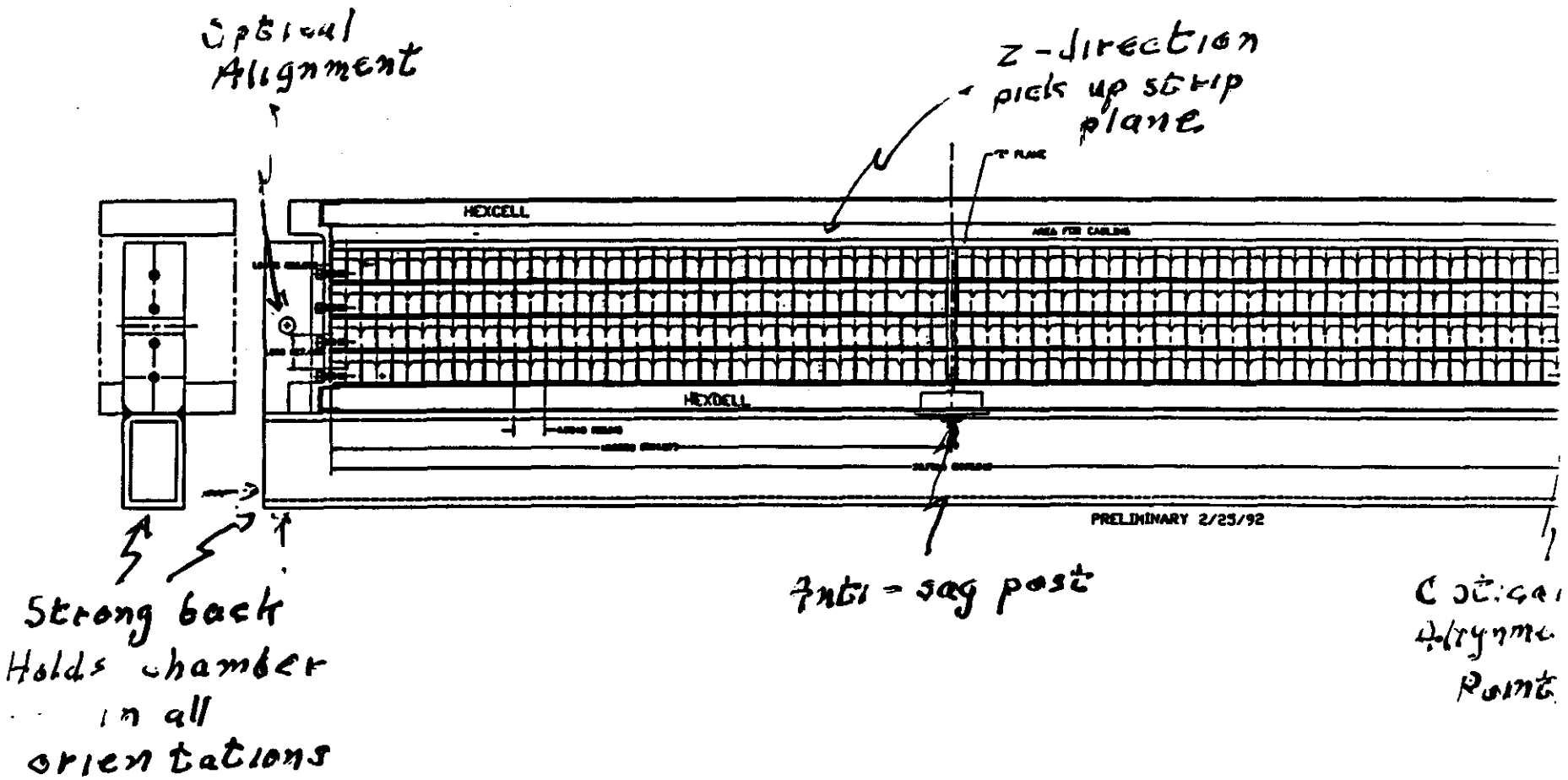

Fn house (21.706 (REF)) – Hexcel top & bottom
Nov 8
Nov 8
Bottom cover not welded on
1.600 (REF)
8.785 (REF)
? Hopefully mid Dec.
Electronics;
MIT Dec. 1
LeCroy Jan 1



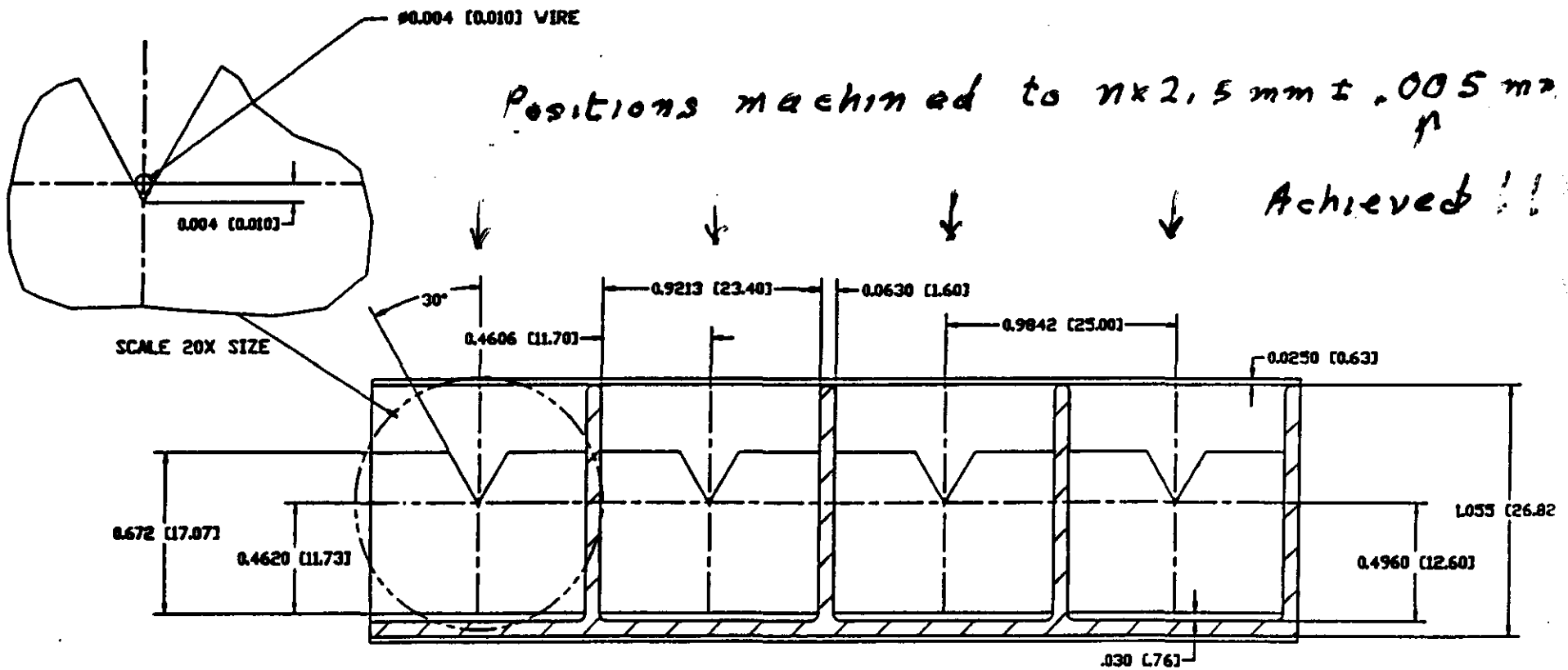








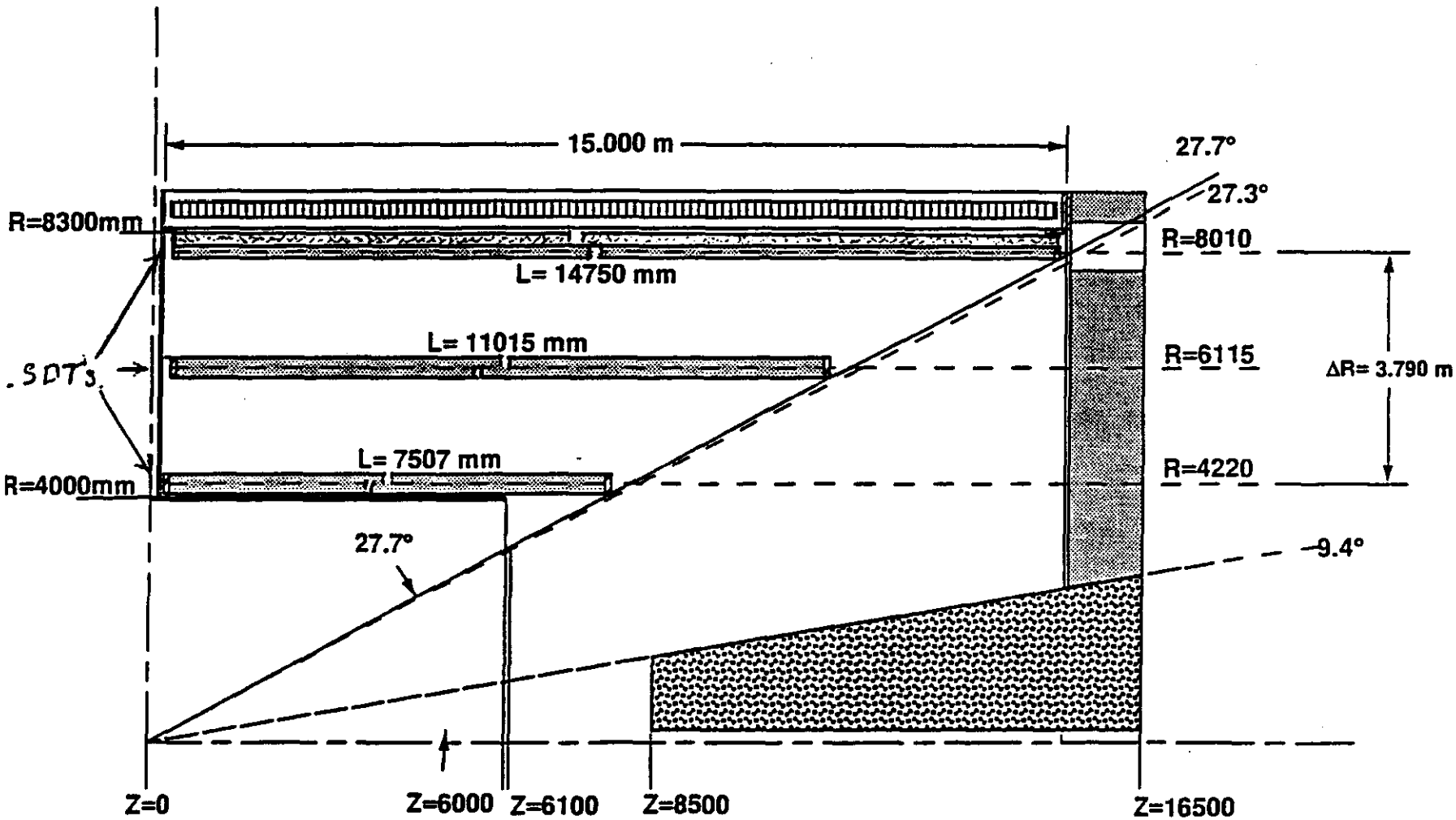
Support Points


Positions machined to n×2.5 mm ± .005 mm
Achieved !!
ø0.004 [0.010] WIRE
0.004 [0.010]
SCALE 20X SIZE
30°
0.4606 [11.70]
0.9213 [23.40]
0.0630 [1.60]
0.9842 [25.00]
0.0250 [0.63]
0.672 [17.07]
0.4620 [11.73]
1.055 [26.82
0.4960 [12.60]
.030 [.76]

Gases Considered

Argon(A), Isobutane(IB) Safety!!
A(few %),IB(10 %), CO_2
A(few %),IB(10%),CO_2,CF_4

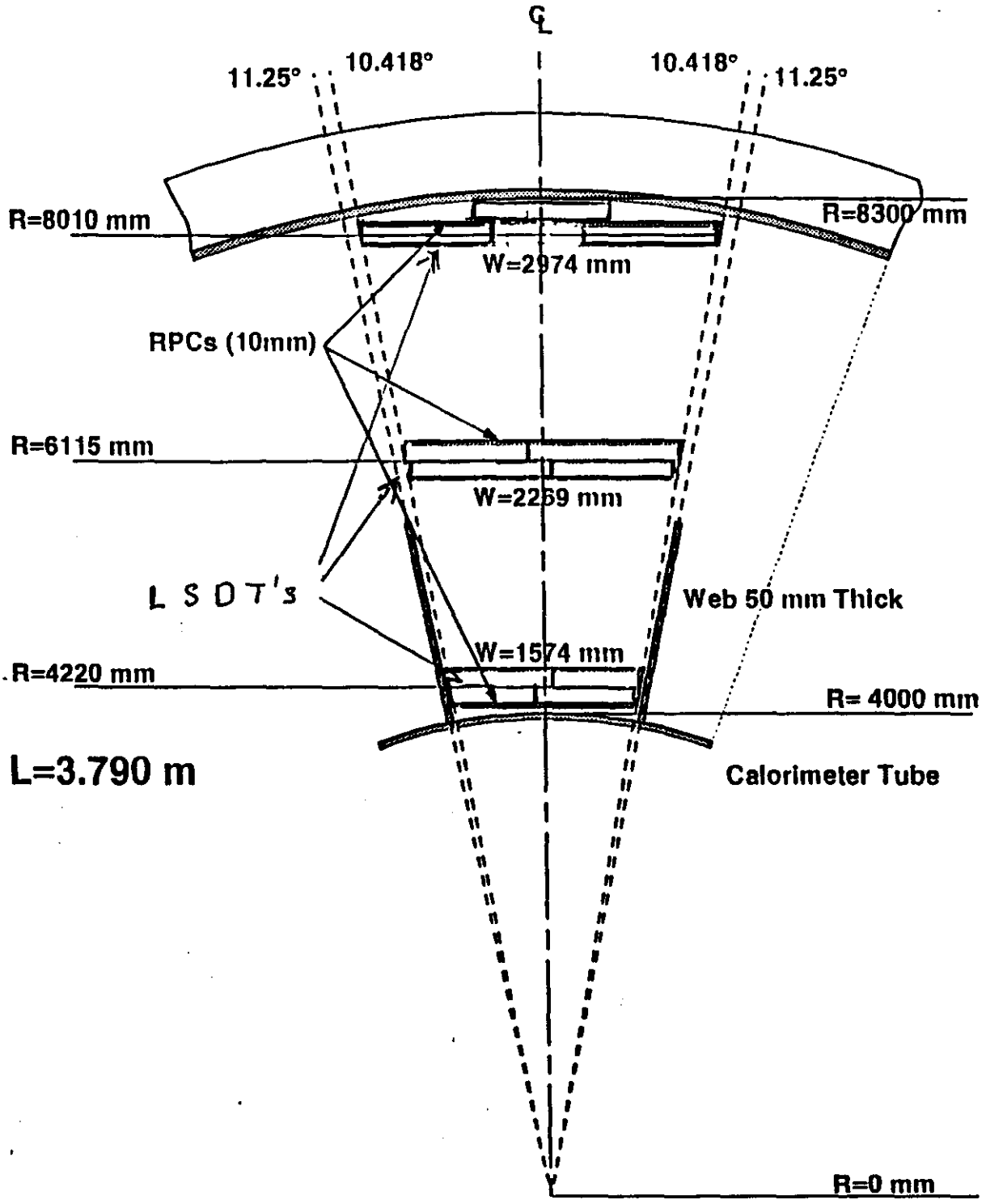
IB($\leq$10%)-non-flammable
CO_2-ohmic,slow,cool
CF_4-flat,fast



GEM PDT 1A (8/8/4)
ELEVATION

(Calorimeter 8m OD x12m Long)
(10mm RPCs I/O/O)

F. NIMBLETT
GEM920131



GEM PDT1A 8/8/4
(endview)

F. Nimblett
GEM 920102

Chamber Inventory: GEM LSTD System

for 8-8-4 system

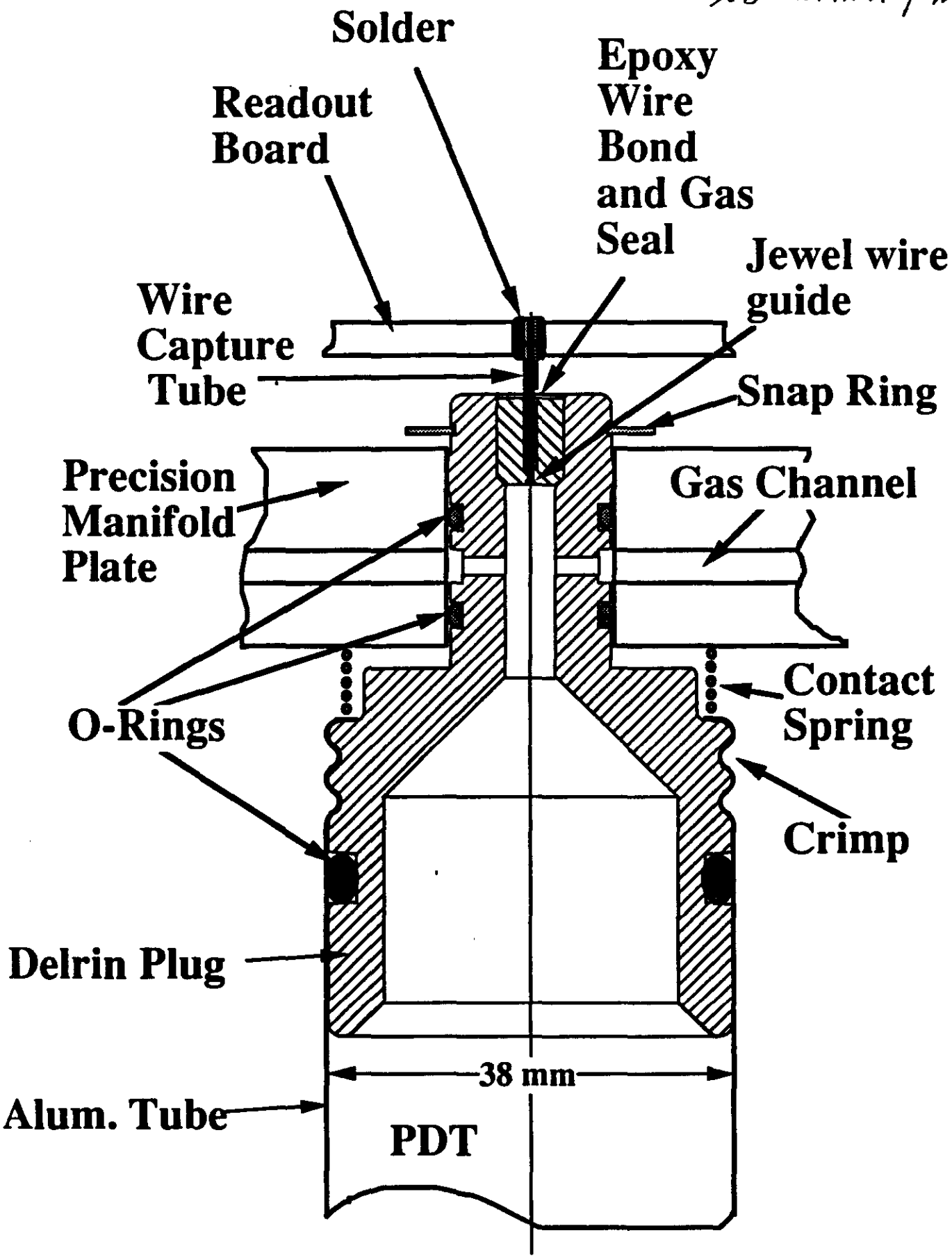
Barrel

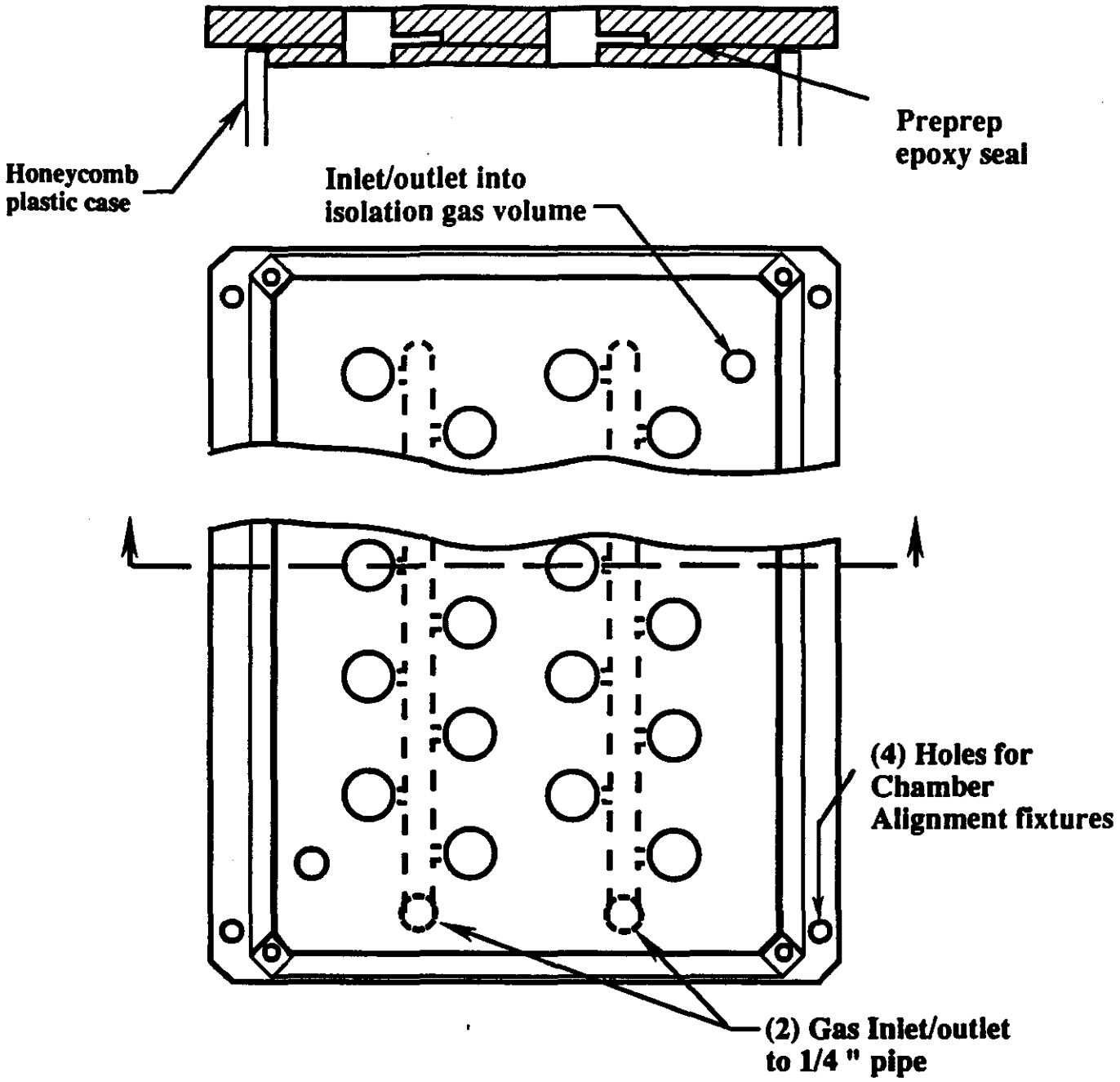
Layer	r(m)	ℓ(m)	chmbrs. /sect.	total chmbrs.	wgt/sect (lbs.)	vol/sect litres	wires	bridges
1A	4.23	3.3	8	128	1632	3960	20,480	1024
1B	4.23	2.5	8	128	1240	3000	20,480	1024
2A	6.57	5.0	11	176	3410	8250	28,160	2112
2B	6.57	4.0	11	176	2728	6600	28,160	2112
3A	8.76	6.8	7	112	2954	7100	17,920	1344
3B	8.76	6.4	7	112	2772	6720	17,920	1344
Total		$\bar{\ell}$ = 4.57		832		0.57×10^6	133,120	8960

Front and Back

Layer	z(m)	ℓ	chmbrs. /sect.	total	wgt/sect (lbs.)	vol/sect litres	wires	
1	6.5	3.3	4	64	812	1960	9,856	512
2	10.2	5.0	8	128	3717	8984	30,720	1536 (2304)
3	13.4	6.6	4	64 (128)	3296	7968	20,480	768 (1536)
Total		$\bar{\ell}$ = 4.98		256 (320)		0.30×10^6	61,056	2816 (4352)
Grand Total				1088		0.87×10^6	194,176	11,776 (13,312)

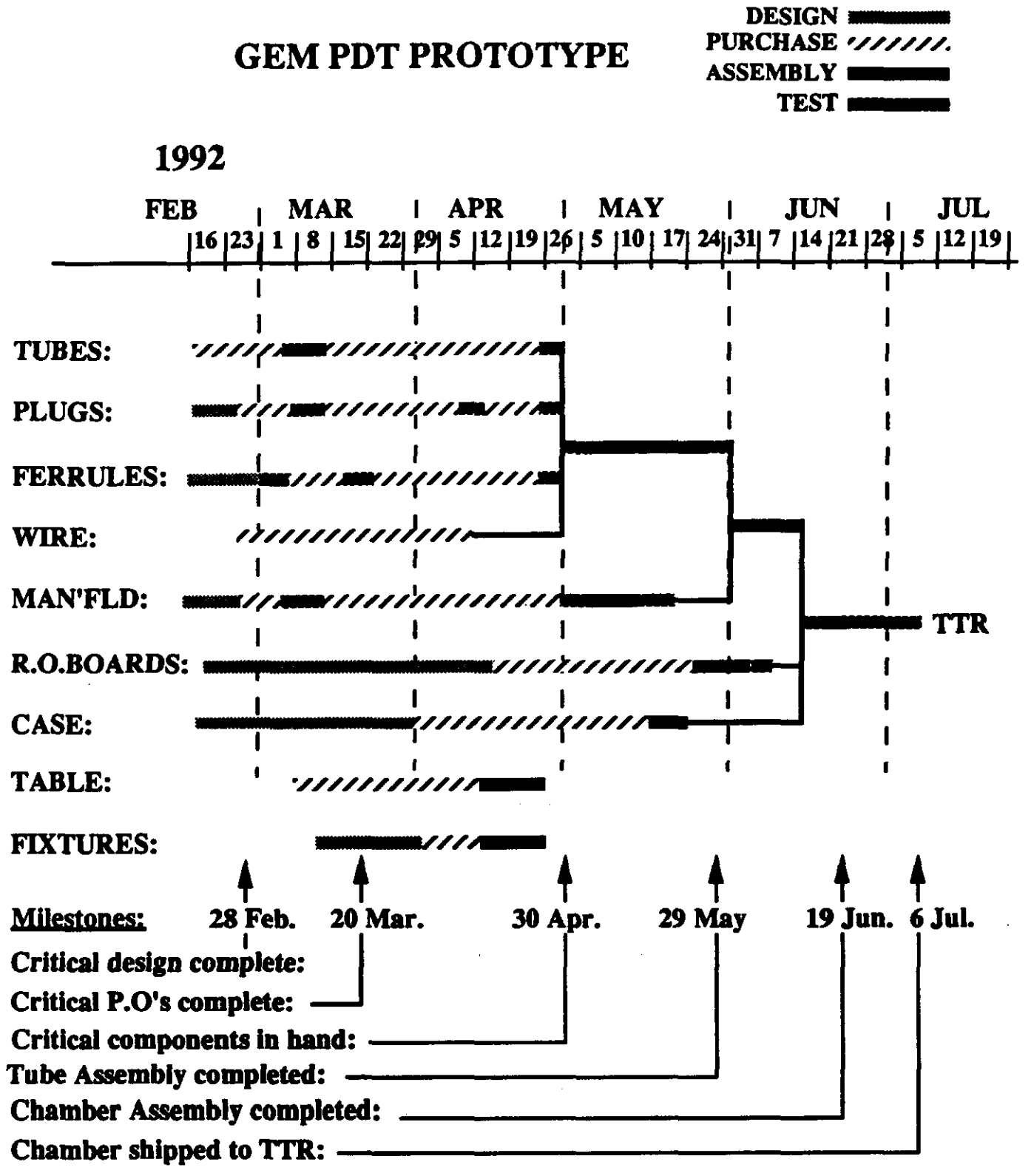
Deb Milm / MSU


Solder
Epoxy Wire Bond and Gas Seal
Readout Board
Jewel wire guide
Wire Capture Tube
Snap Ring
Precision Manifold Plate
Gas Channel
Contact Spring
O-Rings
Crimp
Delrin Plug
38 mm
Alum. Tube
PDT



ITEM	PART NO.	DESCRIPTION	QTY.
PARTS LIST			
UNLESS SPECIFIED: DECIMALS ±.005 FRACTNS ± ANGLES ± 1.0° BREAK ALL EDGES DO NOT SCALE DWG	ORIG. R. Miller		1-31-92
	DRAWN		
	PROJECT Gem Muon PDT - prototype		
	MATERIAL Alum. jig plate		
MICHIGAN STATE UNIVERSITY HIGH ENERGY PHYSICS			
TITLE Manifold Plate Assembly			
DWG. NO. HEP01-022-274		REV. A	SCALE 1:2

GEM PDT PROTOTYPE



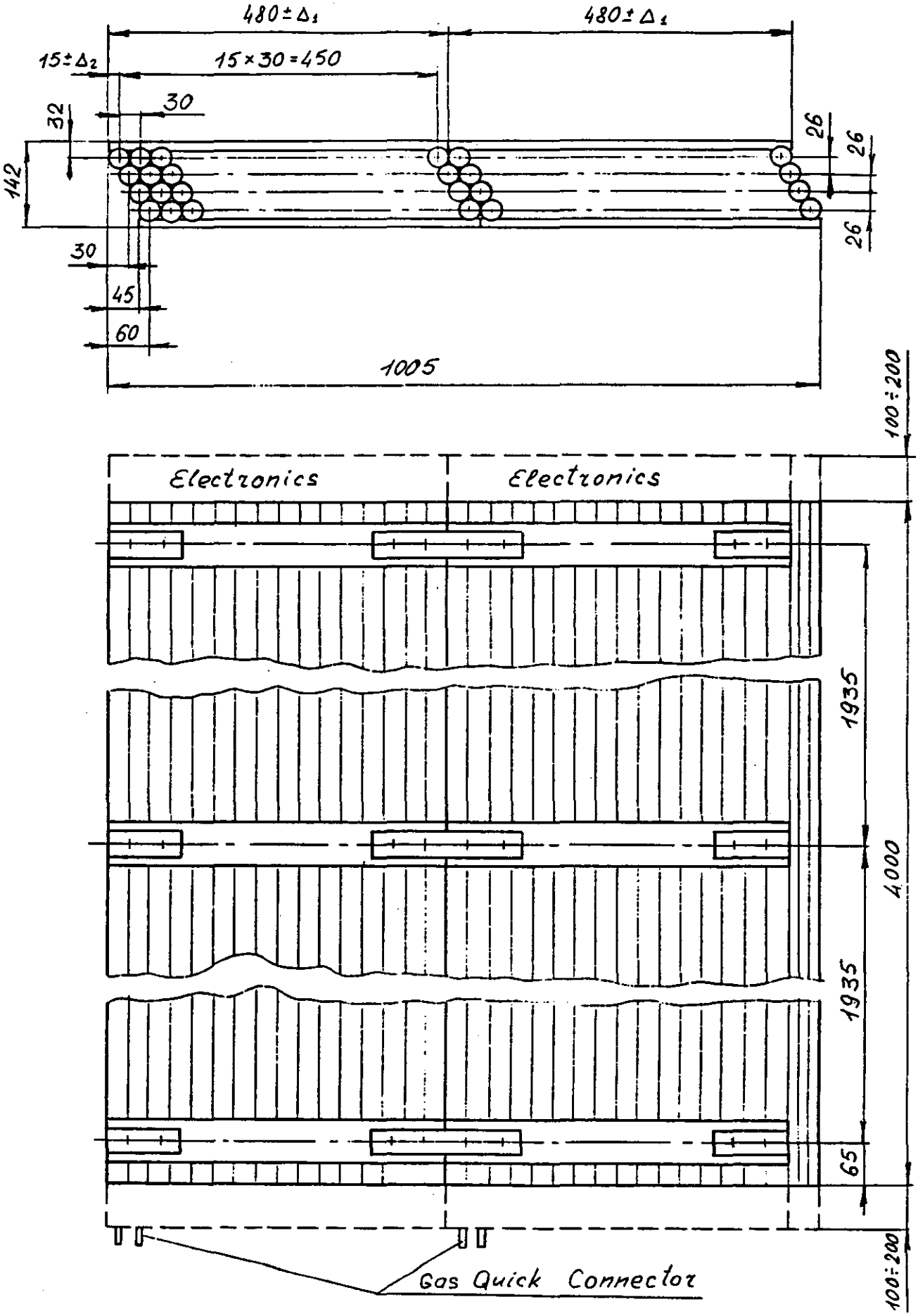
ITEP (Moscow) – LSHE-JINR (Dubna)
PDT subgroup

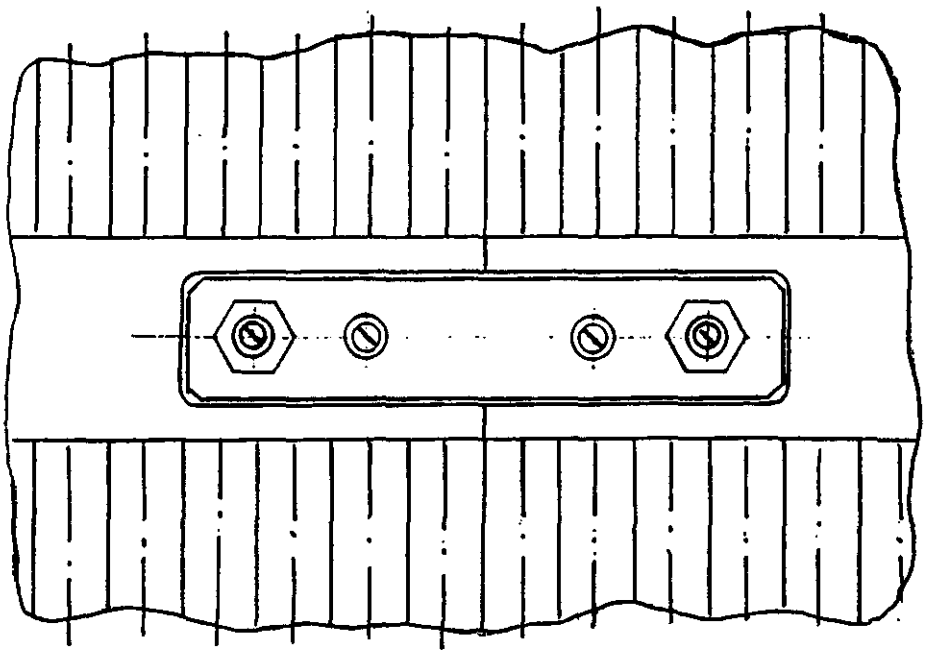
ITEP

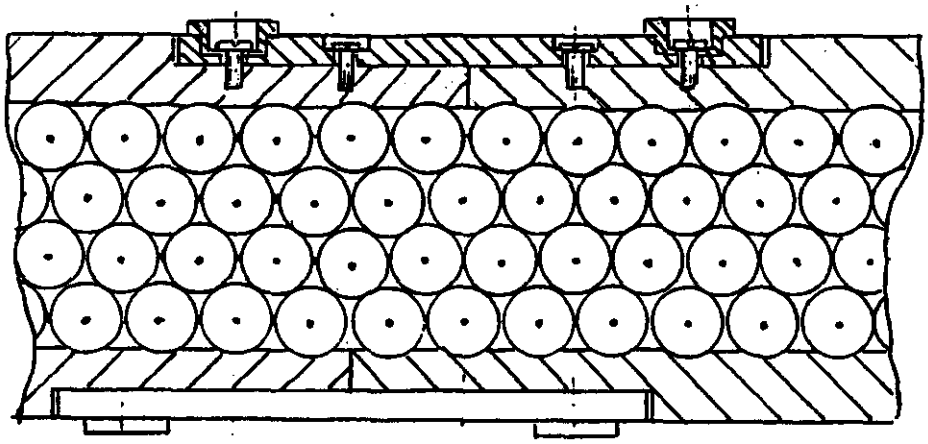
V. Balagura
A. Golutvin
I. Korolko
L. Laptin
P. Murat
V. Nagovitsin
A. Nepejpivo
A. Ostapchuk
P. Pakhlov
F. Ratnikov
I. Tikhomirov
V. Tchistilin

JINR

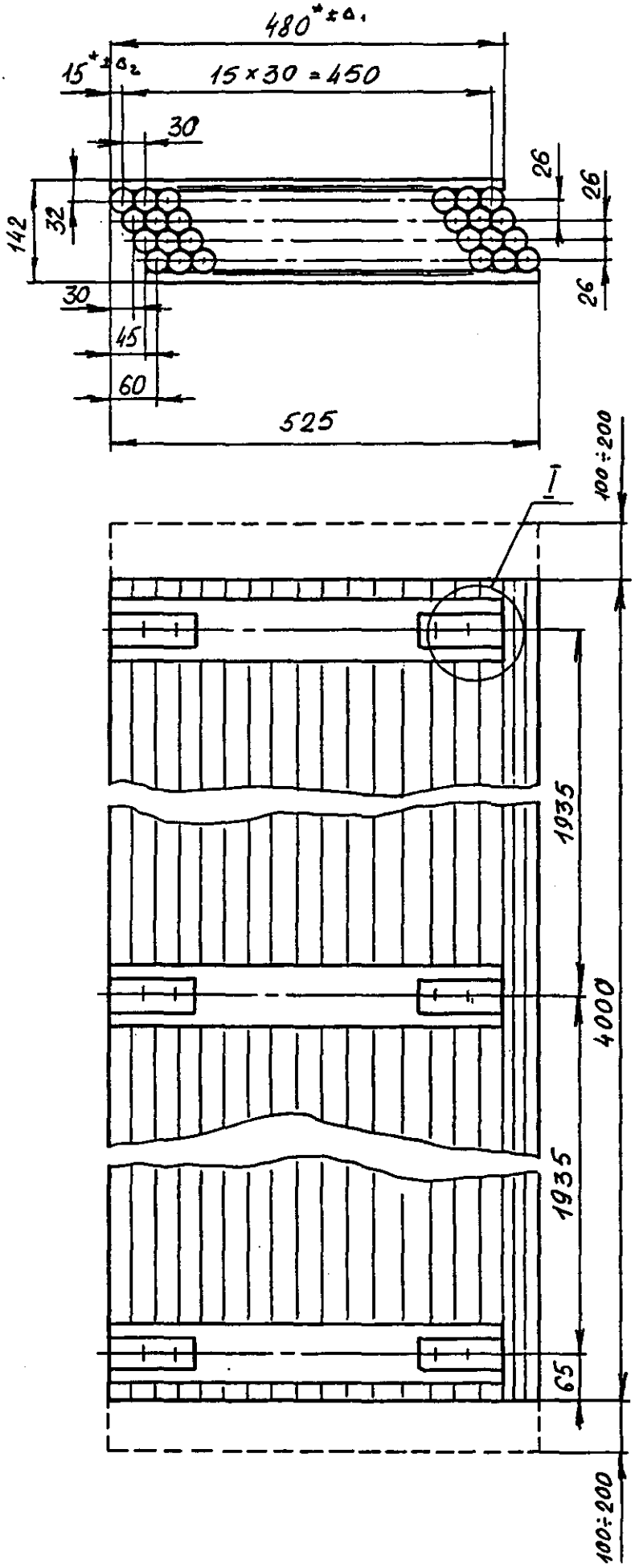
D.A. Belosludtsev
V.N. Bychkov
Yu.V. Ershov
I.A. Golutvin
N.V. Gorbunov
A.G. Karev
V. Yu. Karzhavin
S.V. Khabarov
V.S. Khabarov
Yu.T. Kiryushin
V.N. Lysiakov
A.L. Lyubin
A.V. Makhankov
S.A. Movchan
V.D. Peshekhonov
D. Pose
T. Predo
S. Yu. Selyunin
D.A. Smolin
A.V. Vishnevsky

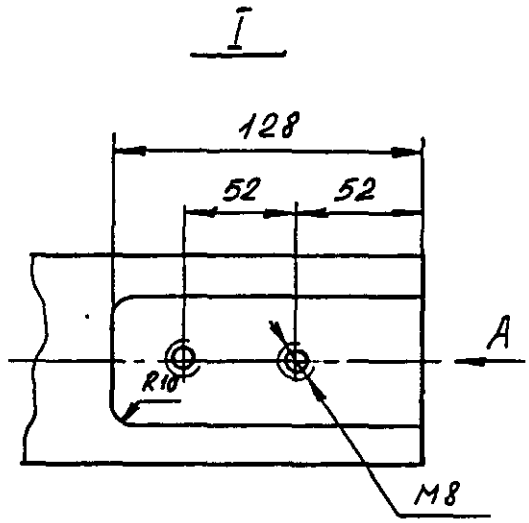

480±Δ1
480±Δ1
15±Δ2
15×30=450
30
32
142
26
26
26
30
45
60
1005
100÷200
Electronics
Electronics
1935
4000
1935
65
100÷200
Gas Quick Connector

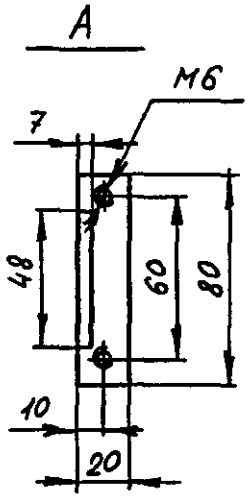


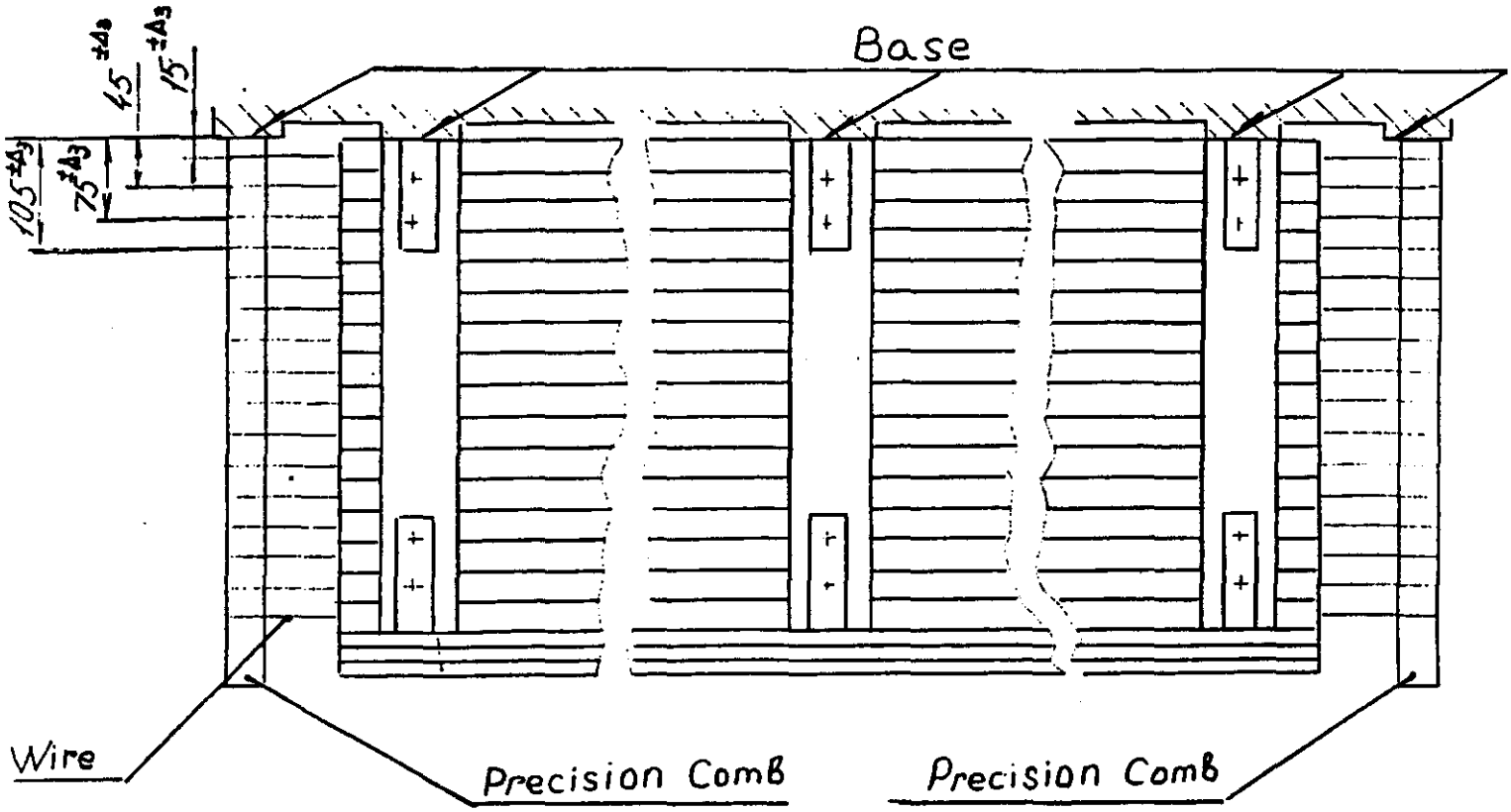


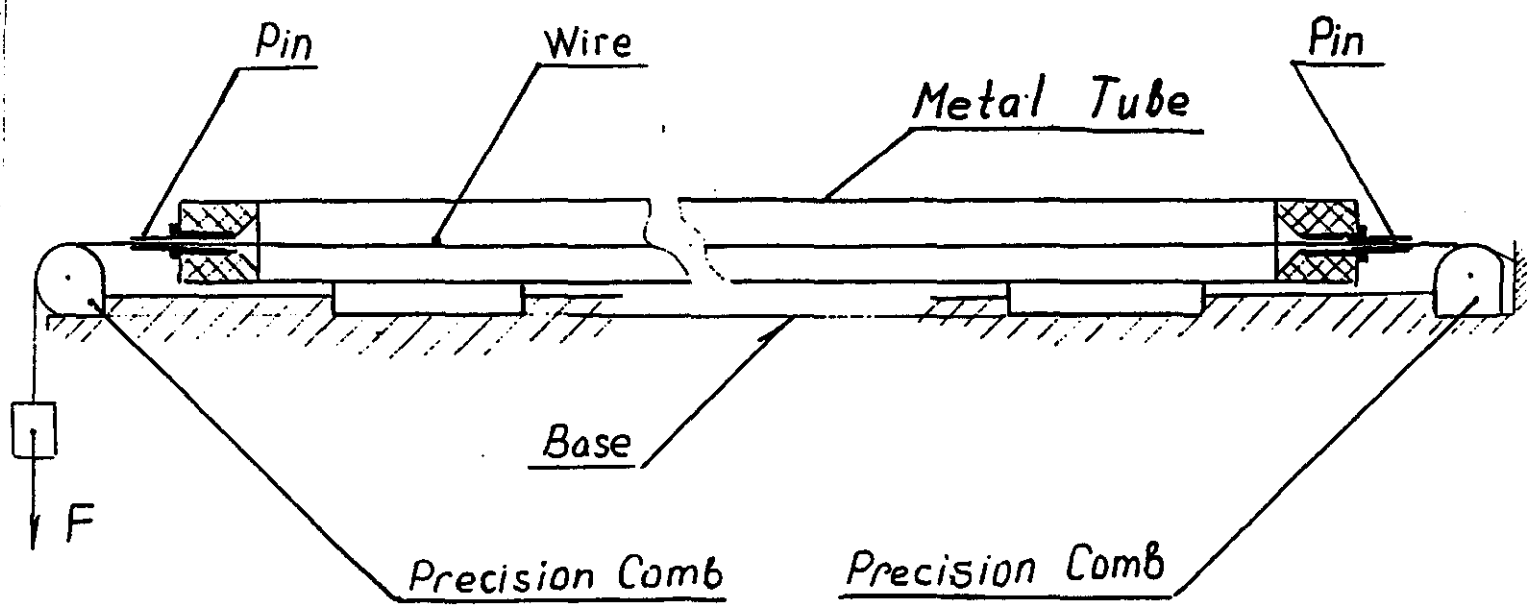
Module stack

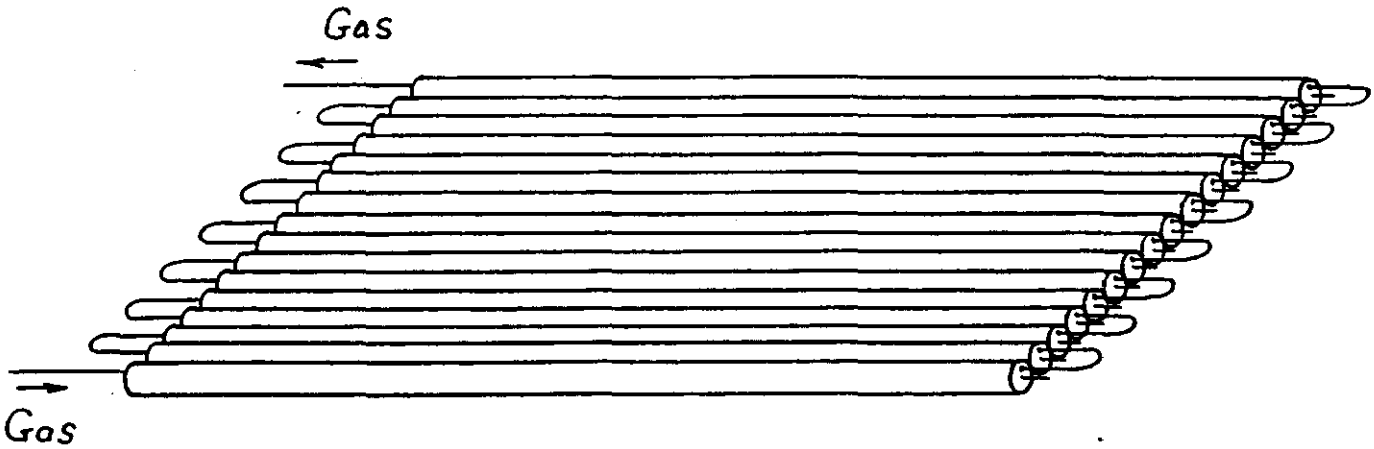

480*±Δ1
15+±Δ2
15×30=450
30
26
26
142
32
26
30
45
60
525
100÷200
I
1935
4000
1935
65
100÷200

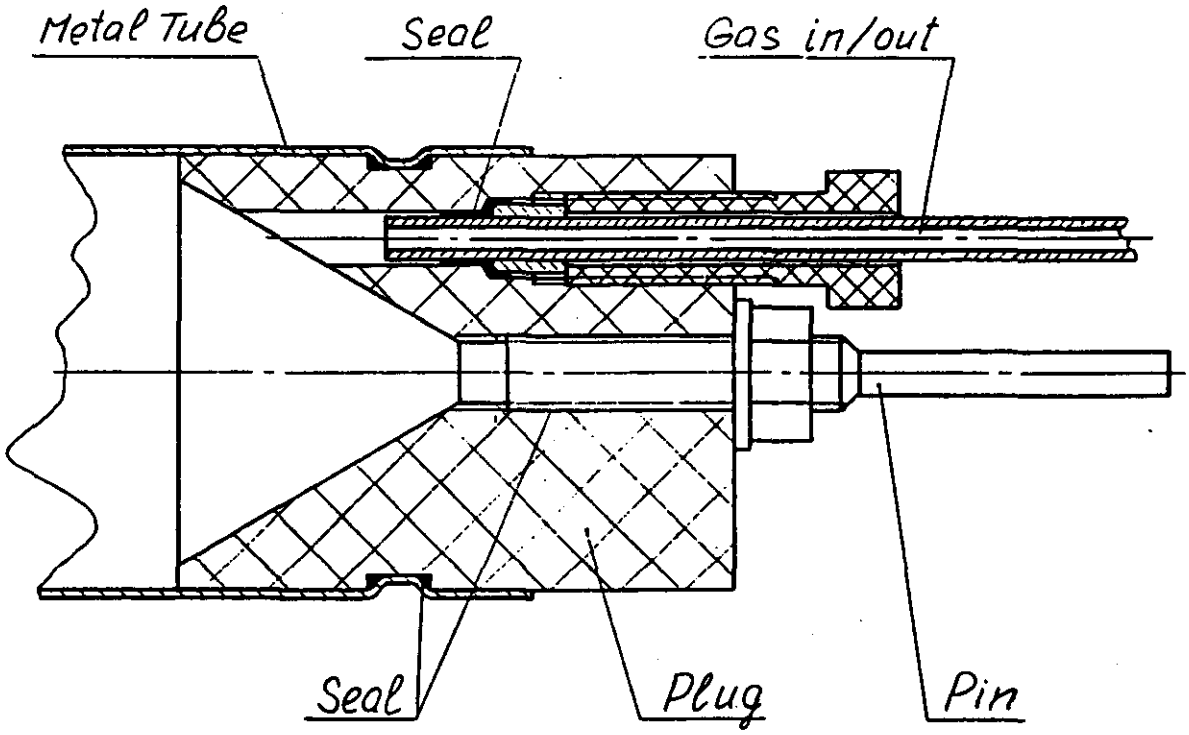

I
128
52
52
A
R10
M8


A
M6
7
48
60
80
10
20


Base
Wire
Precision Comb
Precision Comb


Pin
Wire
Metal Tube
Pin
Base
F
Precision Comb
Precision Comb


Gas
Gas


Metal Tube
Seal
Gas in/out
Seal
Plug
Pin

18 November 1991

PROPOSAL FOR CONSTRUCTION OF A MUON TEST FACILITY AT THE SSCL

M.Botlo, M. Hecht, K. McFarlane, M.Marx, C. Milner, G. Mitselmakher(*), T.Prosapio, F. Stocker, A. Vanyashin, L. Villasenor, G. Yost, E. Zimmer-Nixdorf (SSCL)

K. Lau, B. Mayes, J. Pyrlik, R. Weinstein (UH, Houston)

A.Gonzalez (IFUG,Leon)

A.Golutvin, V.Tchistilin, I.Tichomirov (ITEP,Moscow)

L. Barabash, Yu. Bonushkin, Z. Krumstein (JINR, Dubna)

Yu.Fisyak, V.Zhukov (MSU,Moscow)

V.Sarantsev (SNPI,Gatchina)

(*)-contact person

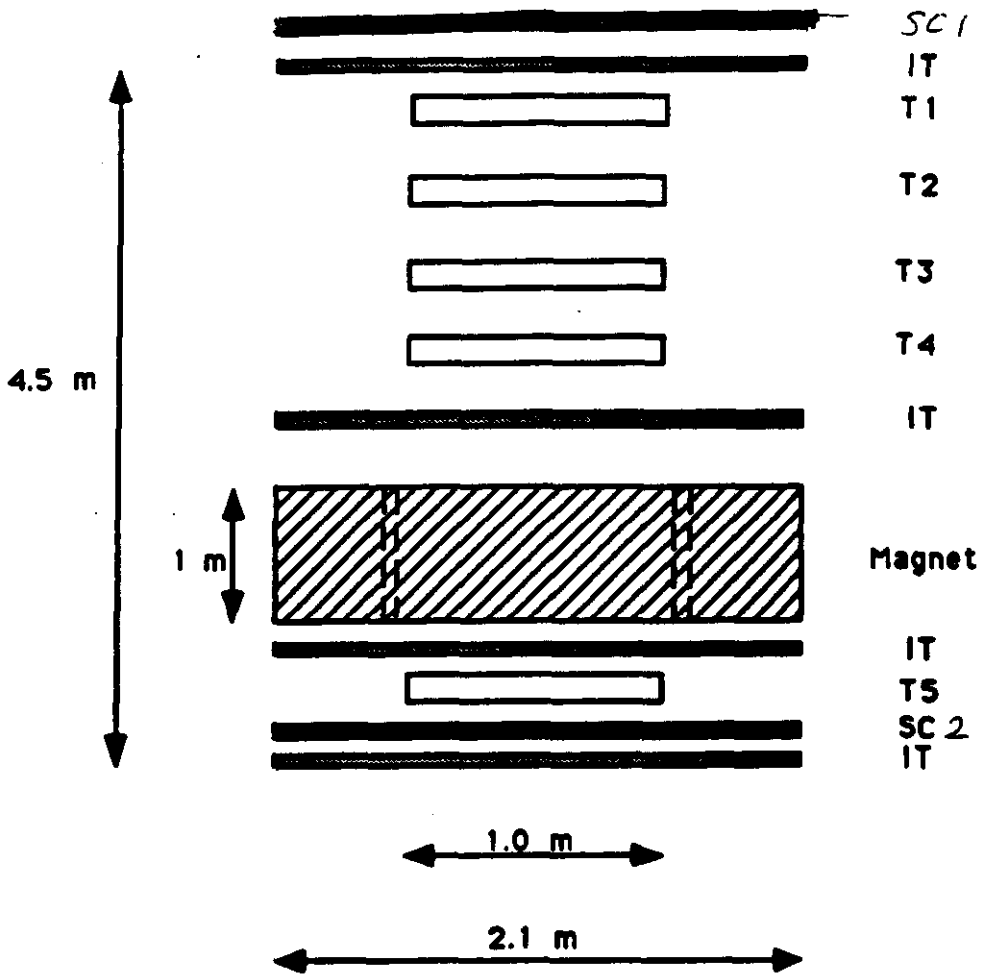
Participating Institutions:

Brookhaven National Laboratory
Boston University
Draper Laboratory
Joint Institute for Nuclear Research
Houston University
Institute of Theoretical and Experimental Physics
Los Alamos National Laboratory
Louisiana State University
Lawrence National Laboratory
Massachusetts Institute of Technology
Michigan State University
Moscow State University
Oak Ridge National Laboratory
St.Petersburg Nuclear Physics Institute
State University of New-York at Stony Brook
Superconducting Super Collider Laboratory
Texas A&M University
University of Guanajuato

REQUEST OF SSCL FOR FY 1992: $493,000
2.0 FTE engineers
3.5 FTE technicians

TTR TEXAS TEST RIG

GEM MUON CHAMBERS EVALUATION TEST STAND

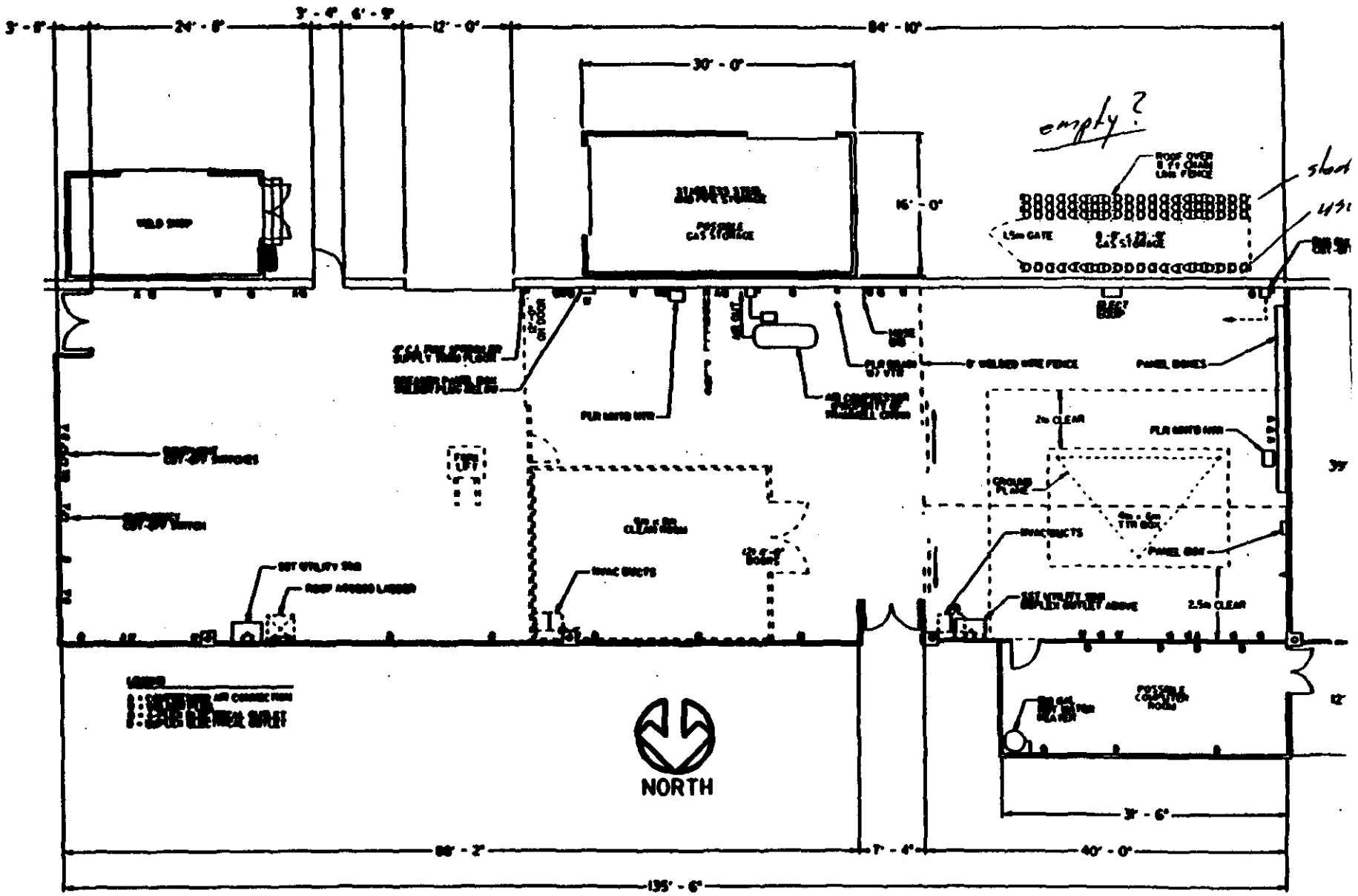


Legend:

T1-T5 Technologies to be Evaluated
- T1 Pressurized Drift Tubes
- T2 Limitied Streamer Drift Tubes
- T3 Cathode Strip Chambers, Multiwire Geometry
- T4 Cathode Strip Chambers, Open Profile
- T5 Resistive Plate Chambers

SC Scintillator Counters

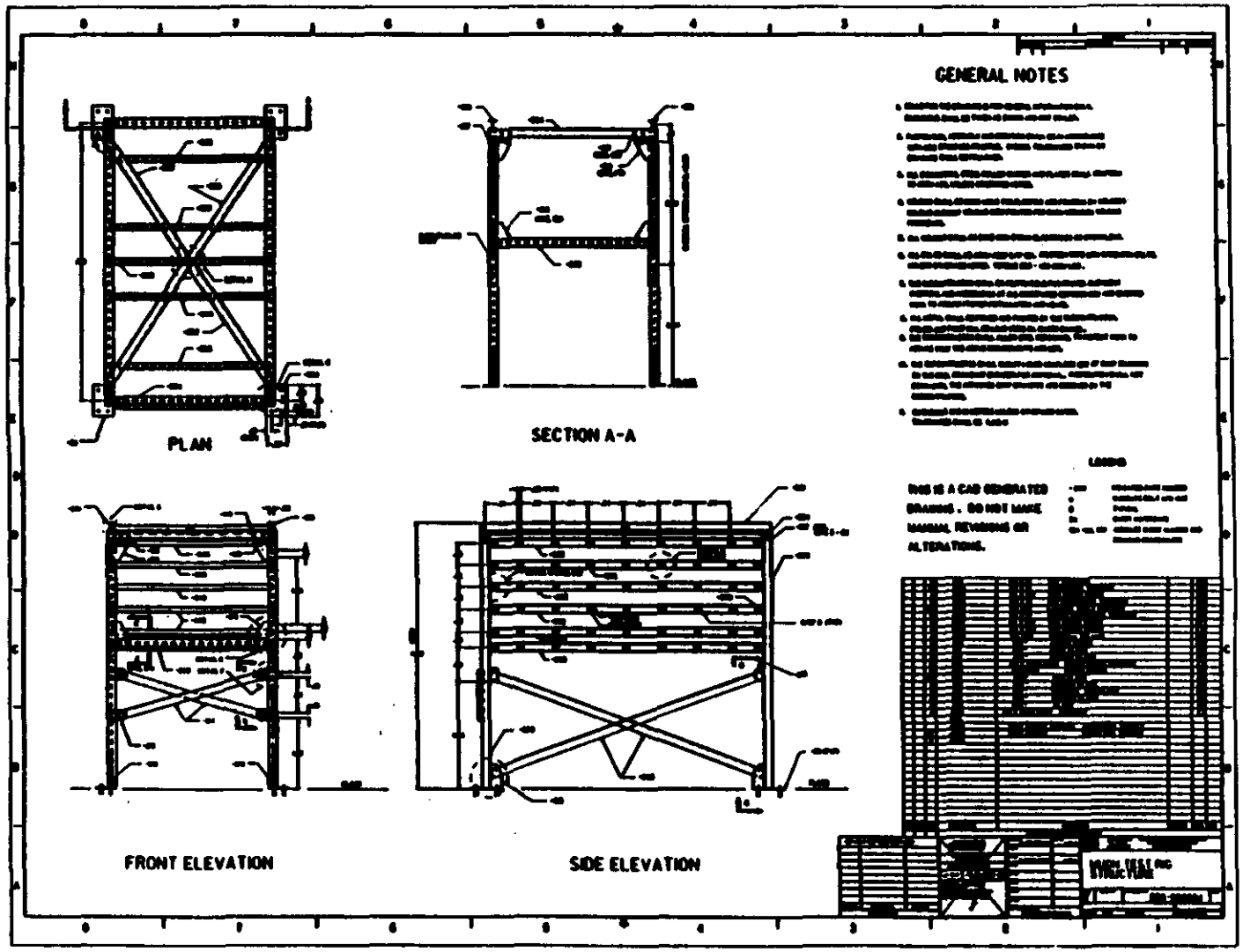
IT Iarocci-Tube Chambers for Trigger

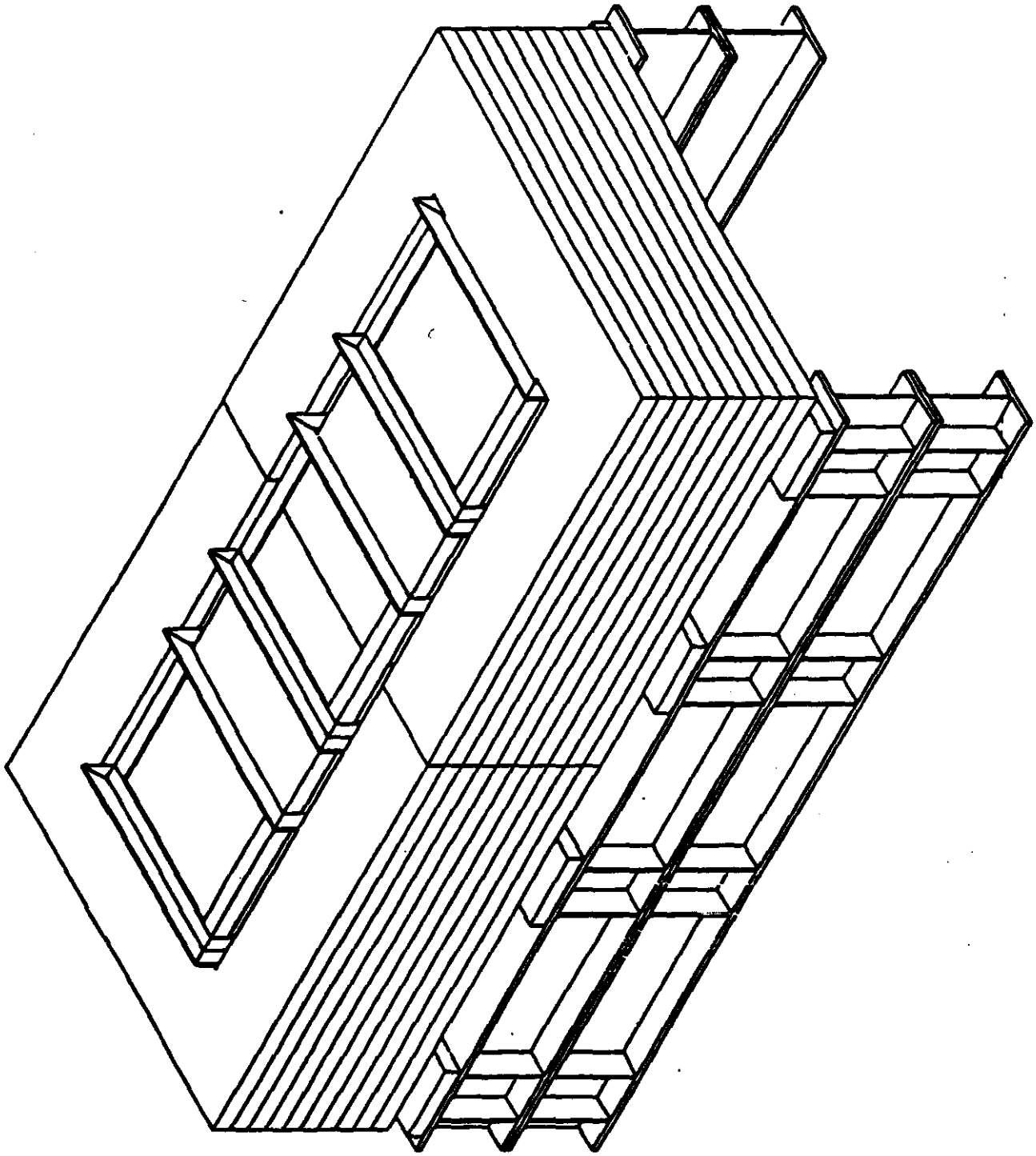


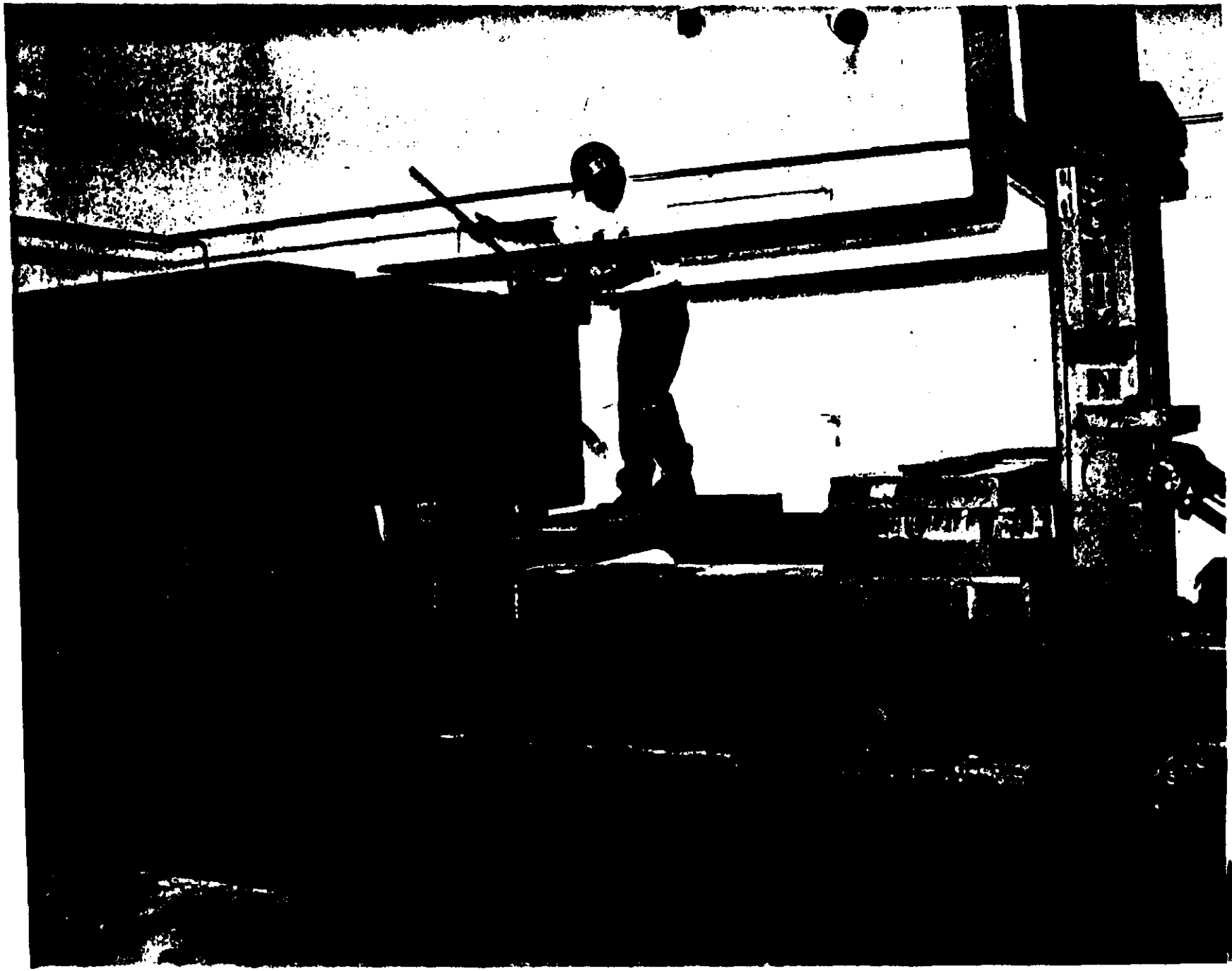
BUILDING 4 SHOP AREA

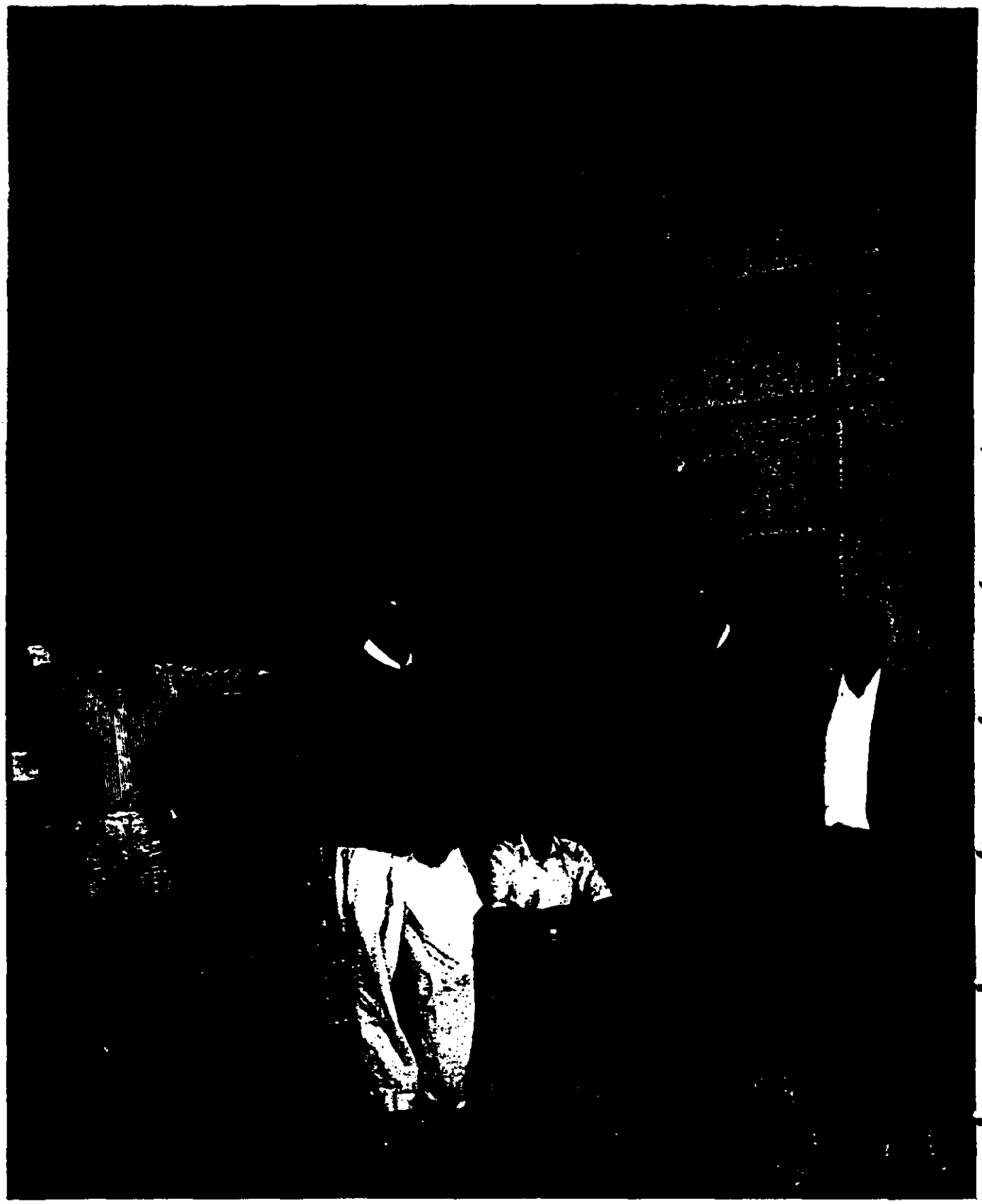
SCALE: 1" = 10'

EXISTING AND PROPOSED FLOOR PLA

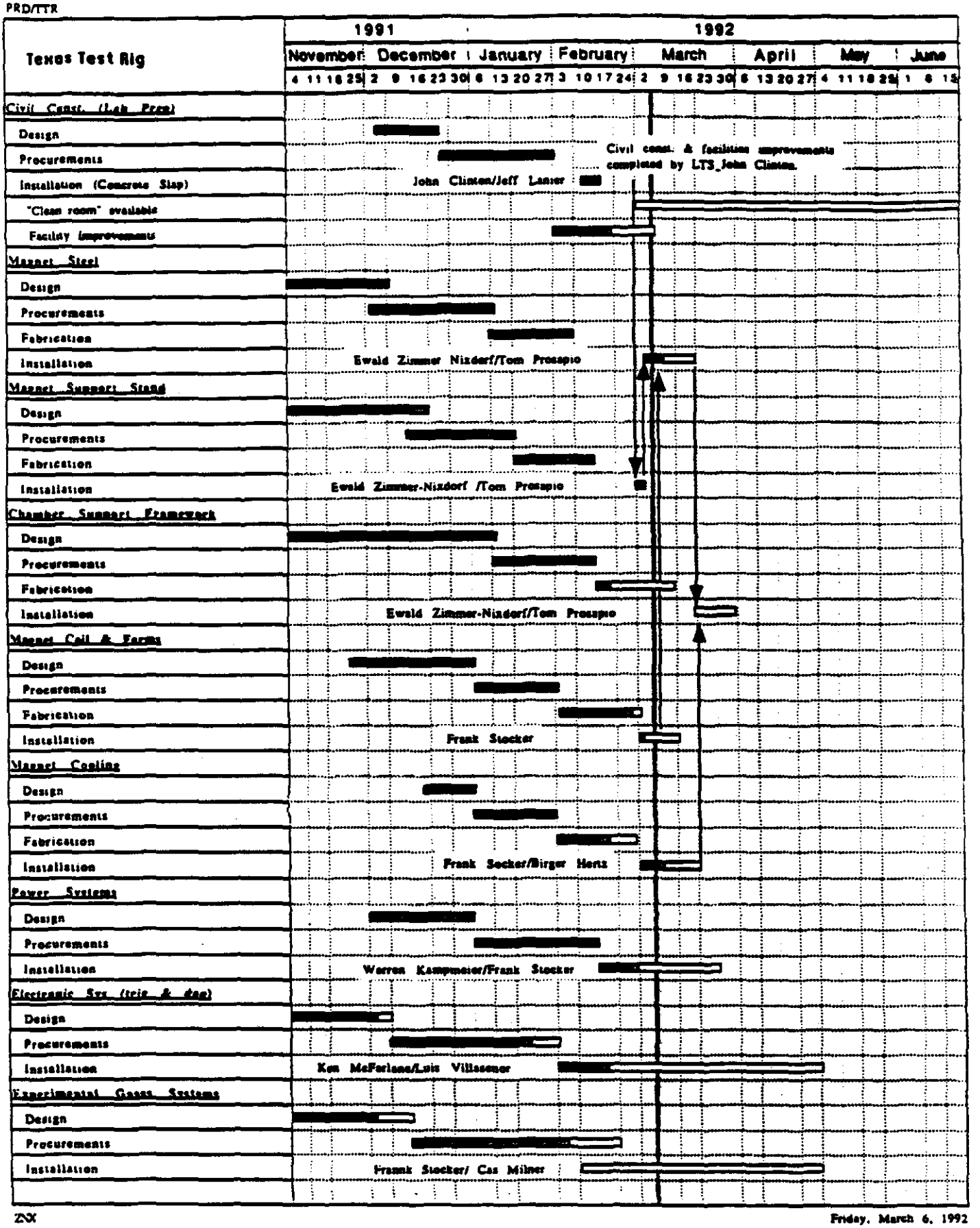

GENERAL NOTES
PLAN
SECTION A-A
FRONT ELEVATION
SIDE ELEVATION







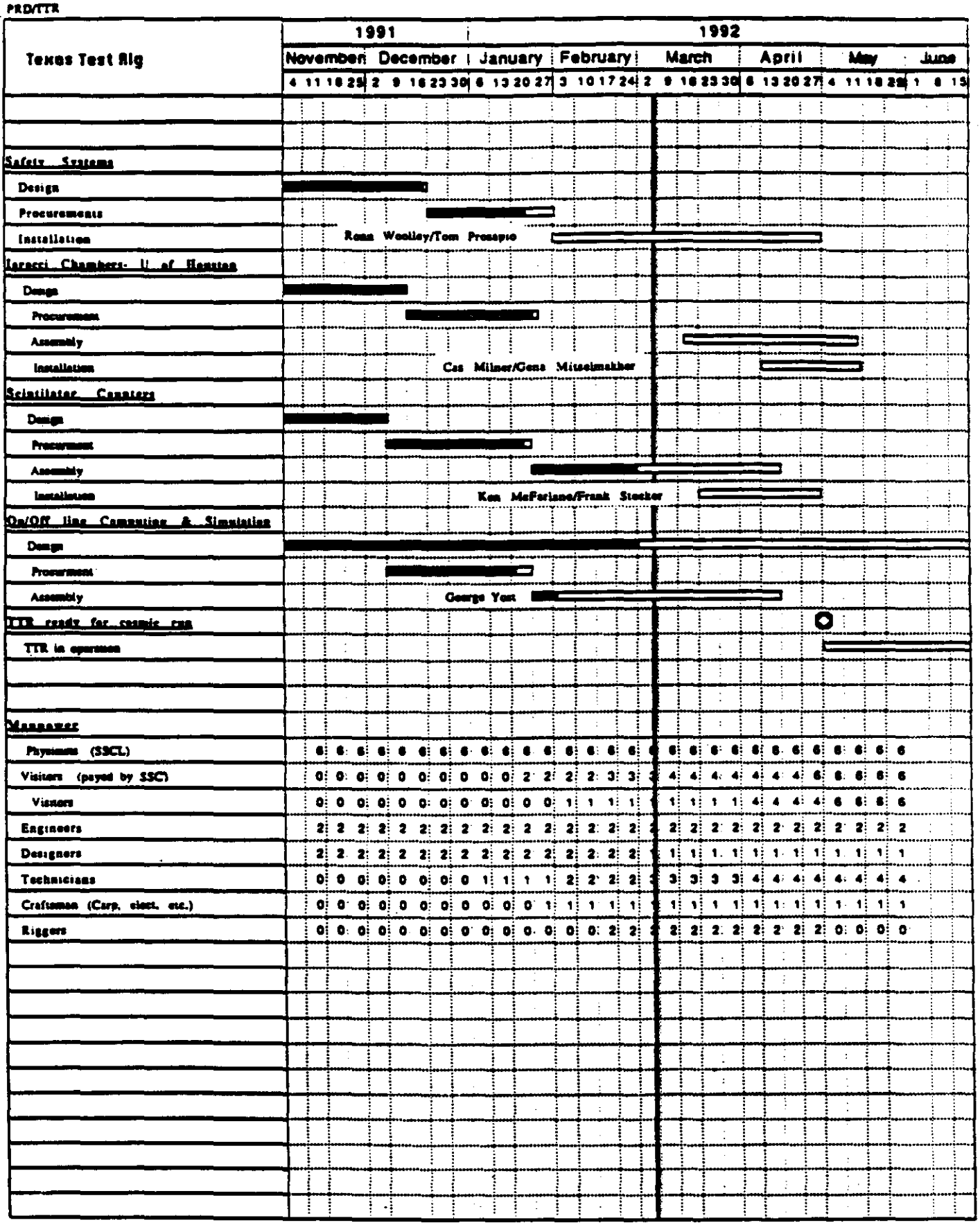
PRD/TTR



ZX

Friday, March 6, 1992

PRD/TTR

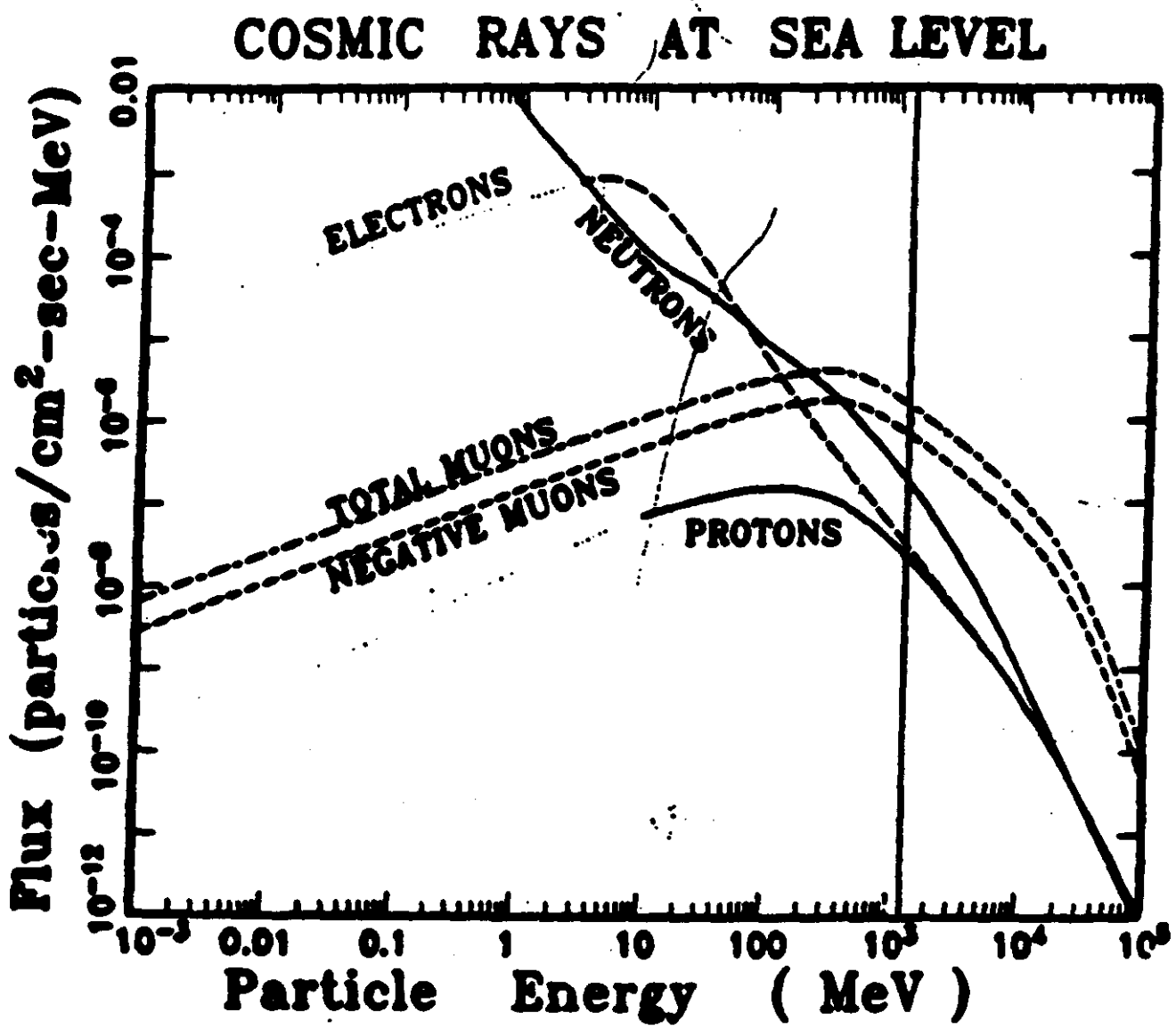


ZX

Friday, March 6, 1992

TTR L. Villasenor

Figure 4.11 Flux of cosmic ray particles at sea level at 40° N geomagnetic latitude. The low energy electron and proton spectra can differ significantly from the dotted lines depending on local conditions in the atmosphere. (J. Ziegler, Nuc. Instr. Meth. 191: 419, 1981.)



1 m of Fe ⇒ $P_{muon} \geq 1.4$ GeV

or ~ 60 μ's/m²s

for A = 4 m² ⇒ R ~ 240 Hz

Geometric Acceptance ⇒ Rates O(10-100)

From: SSCVXl::MITSELMAKHER 21-OCT-1991 19:11:16.47
To: JNET%"FET@MITLNS",BUPHYC::AHLEN
CC: STOCKER,VILLASENOR,YOST,MITSELMAKHER
Subj: LSP: assumptions and questions

Dear Frank and Steve,

We have updated our list of assumptions and questions.Please make your comments and advise us to whom we should send it(we need the mailing list of contactmen of technologies).

Gena,Frank,Luis,George

List of Assumptions for the Muon System Evaluation

1. Each technology proponent should provide us, as soon as possible, with a description of the equipment they are going to ship to SSCL, including a tentative schedule.

2. Each prototype should have enough layers to allow to estimate the resolution without the use of external (i. e., other modules) information.

3. We assume that only one acquisition electronics standard (either CAMAC, FASTBUS or VME) will be used in the DAQ system of the Large Scale Prototype (LSP). This standard will have to be selected by the GEM Muon Group as soon as possible. We propose to use CAMAC.

4. We assume the front-end electronics, the ADC's and/or TDC's, crate(s), power supplies and cables necessary for each prototype will be provided by the corresponding institution.The SSCL will provide the crate controllers if necessary.

5. We assume that each institution will make its own gas system (in

compliance with SSCL safety regulations) available to use at SSCL during the evaluation period.

6. We assume that each institution will be responsible for proper transportation of its prototype to SSCL and for making it operational at SSCL.

7. We assume all the involved institutions will take part in the data taking and analysis. The SSCL will participate by making computing resources available and helping with the design and construction of the software. However, each proponent will be responsible for providing any technology-specific software, including any necessary calibration software.

8. We will assume responsibility for the construction of the LSP.

9. We will assume full responsibility for the trigger system.

10. We will assume full responsibility for the DAQ system with equipme provided by SSCL.

11. All prototype modules should be at SSCL ready for installation into the LSP fixture by May 1, 1992.

12. Data taking will start June 1, 1992, and it will last for about one month.

List of Questions Concerning the Muon System Evaluation at SSCL

1. What are the dimensions, number of layers, number of wires/strips, etc., of your prototype?

2. What gas mixture do you need? With what tolerance? What flow? Please describe in detail the gas system you want to use. We will check compliance with SSCL safety regulations.

OFF-LINE (YOST)

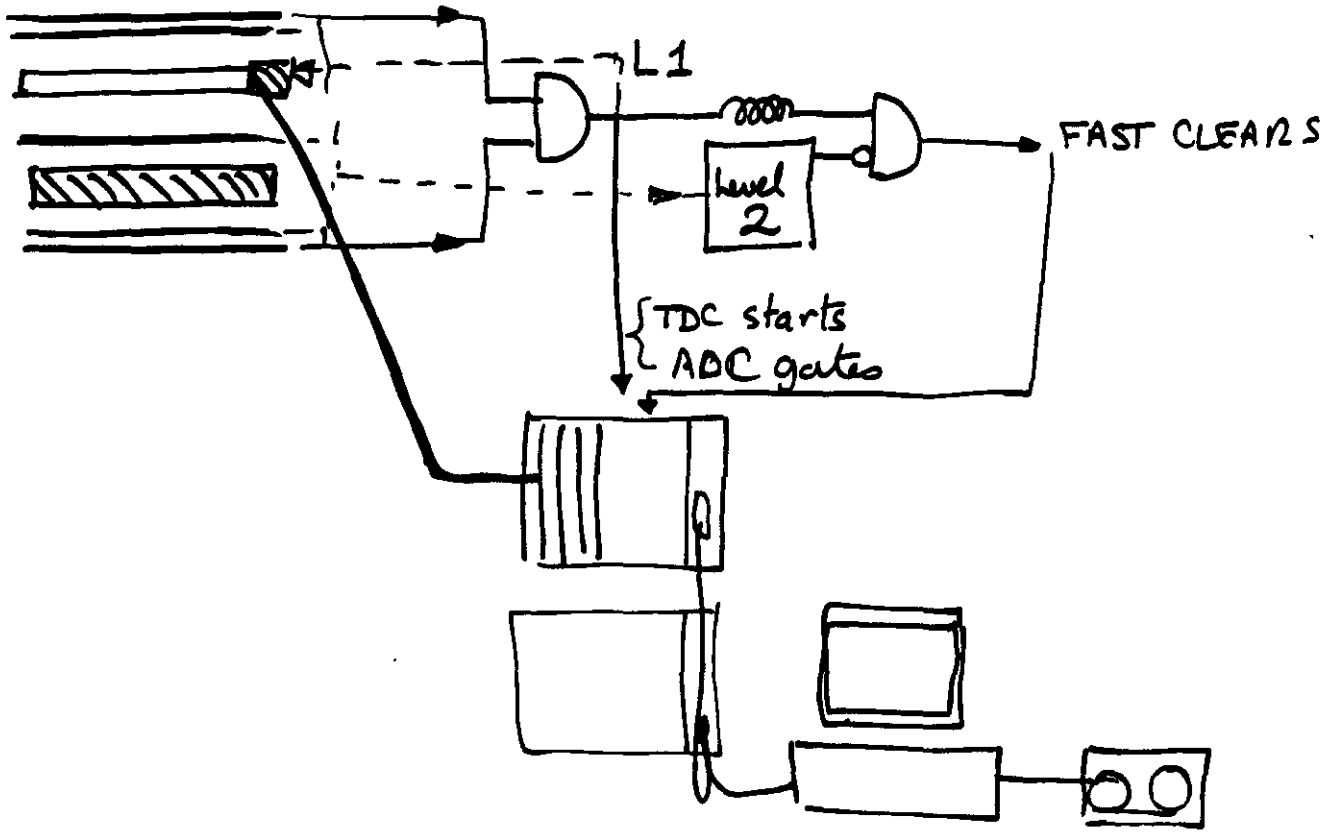
- CONTACT WITH PROPONENTS

- HOW TO GET FROM DAQ RECORD TO HITS
  - * ACTUAL ROUTINES, IF AVAILABLE. OTHERWISE, WE WILL CONSTRUCT ROUTINES FROM INFO YOU SEND US.
  - * ALL CORRECTIONS NEEDED

- DISTRIBUTION OF ERRORS
  e.g., if Gaussian, first guess at the σ.
  If not Gaussian, what?

SSCVX1::YOST

TTR Trigger/DAQ block diagram



SSCL Provides

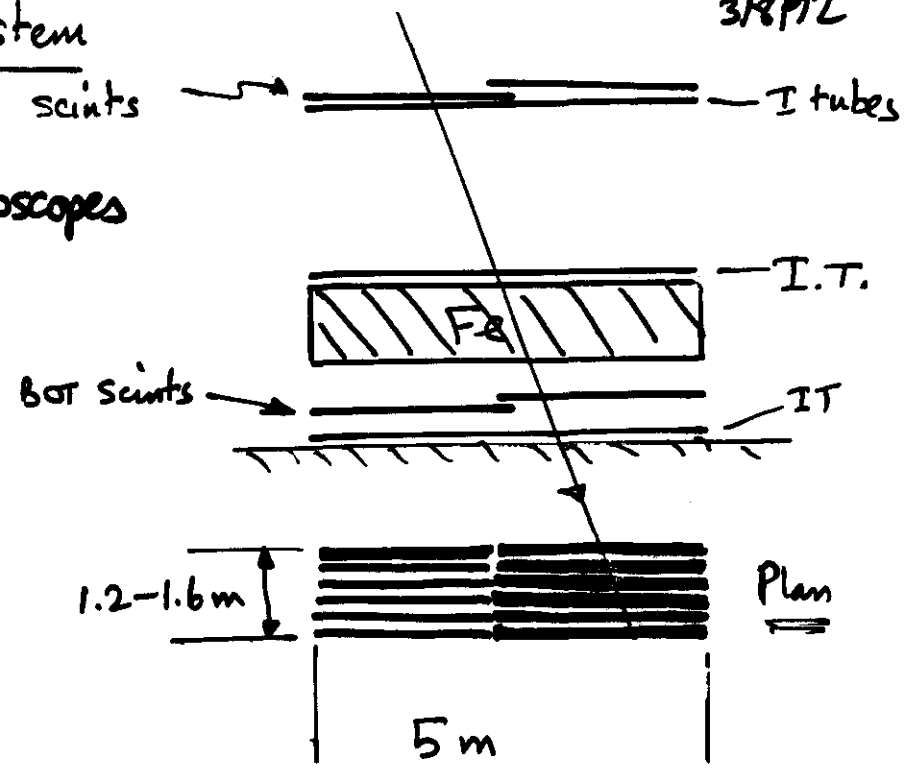
- CAMAC crates & controllers, DAQ computer, recording
- L1 signals (ECL, NIM) up to 16 starts + 16 gates
- Fast clear up to 32
- Level 2 capability given suitable signals

'User' provides

- Detector
- DAQ modules (ADC, TDC, special); manuals
- Cables to match L1 delay. (or other signal buffer)
- input sockets (BNC, lemo, or 0.1" space ECL)
- Any dead time signals if needed.

Muon Trigger System

- Top & bottom hodoscopes
- Iarocci tubes



Hodoscopes consist of 12 double-ended scintillation counters in two panels top & bottom. Total of 24 slats, 48 PMT's. Slats are 2.7 m × 0.2 m × 25 mm thick.

Trigger rate: ~100 Hz full solid angle

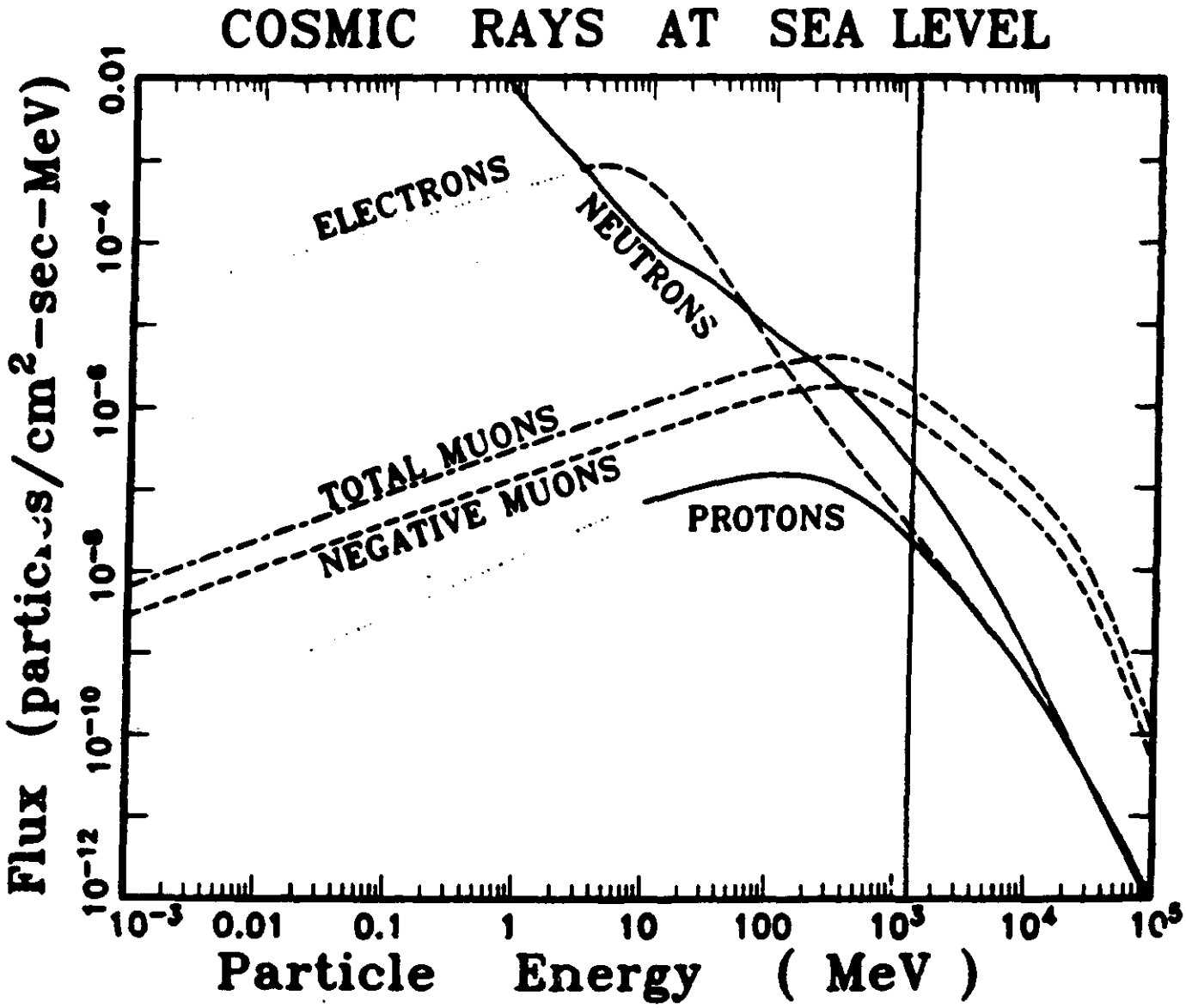
~1 Hz restricted angular range

Momentum ≳ 1.5 GeV/c

OFF-line, with Iarocci tubes, a higher threshold can be set — can greatly reduce event rate.

3/8/92 ③ ⑥

Figure 4.11 Flux of cosmic ray particles at sea level at 40° N geomagnetic latitude. The low energy electron and proton spectra can differ significantly from the dotted lines depending on local conditions in the atmosphere. (J. Ziegler, Nuc. Instr. Meth. 191: 419, 1981.)



1 m of Fe ⇒ $P_{muon} \geq 1.4$ GeV

or ~ 60 μ's/m² s

for A = 4 m² ⇒ R ~ 240 Hz

Geometric Acceptance ⇒ Rates O(

Performance and capabilities

Particle passage to Level 1 : 200 ns ± 20 ns

Accidentals $\ll$ 0.1 Hz

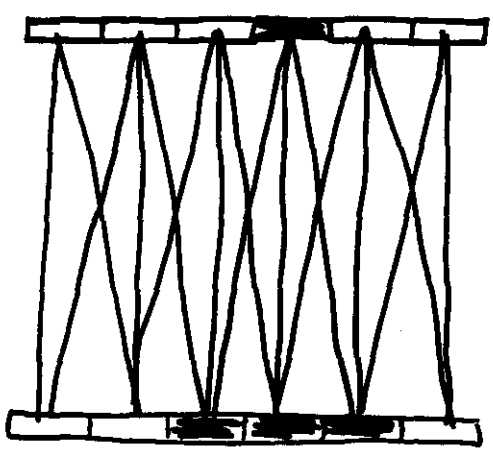
Timing accuracy (Level 1) : 10 ns jitter (± 5 ns)

off line : $\leq$ 250 ps

Programmability: at Level 2, any combination of slats.

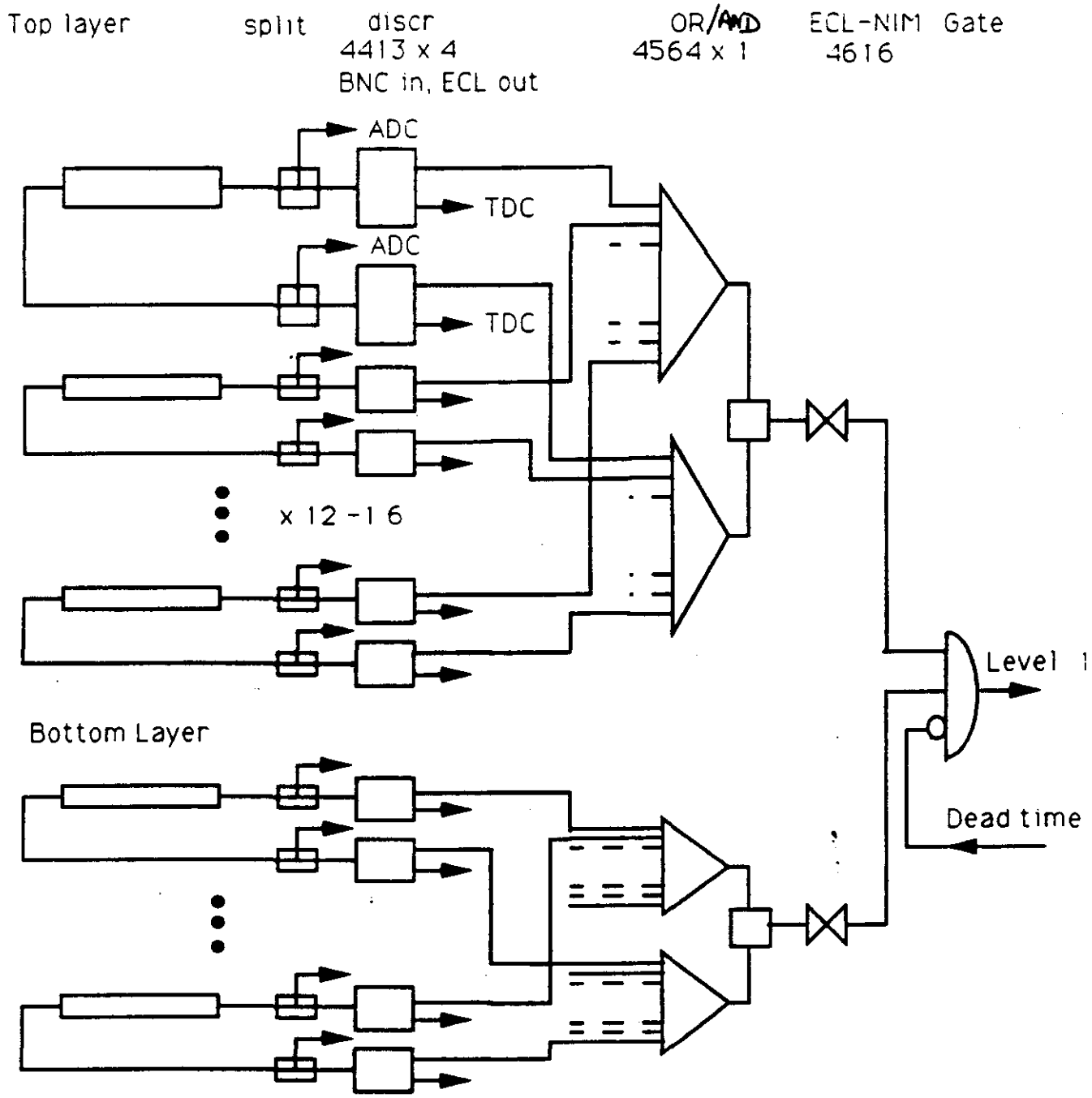
Iarocci tubes introduced at Level 2.

Sample Level 2



restrict angular range of triggers

Muon Trigger - Version 2

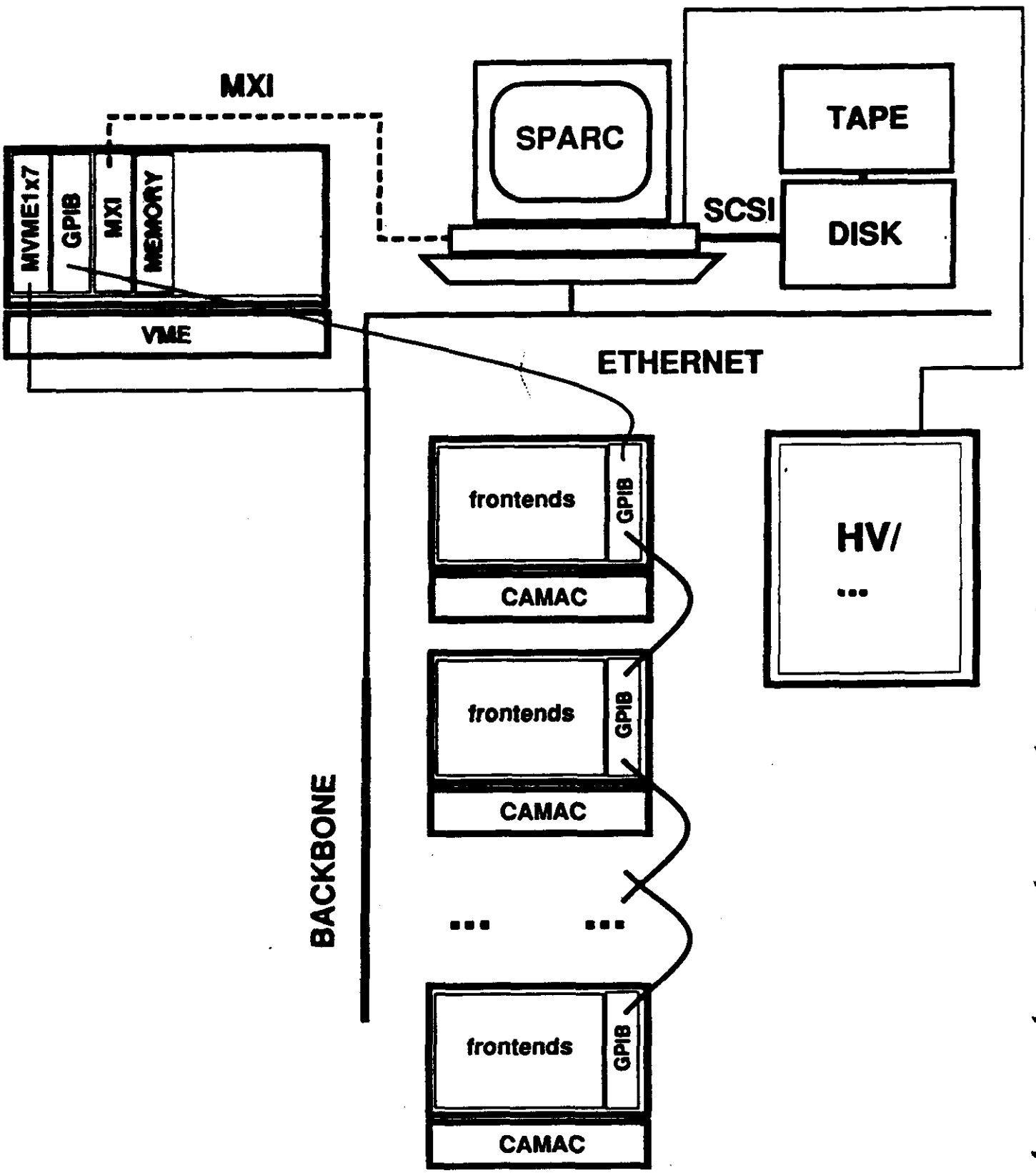


L1 Delay (sample calculation)

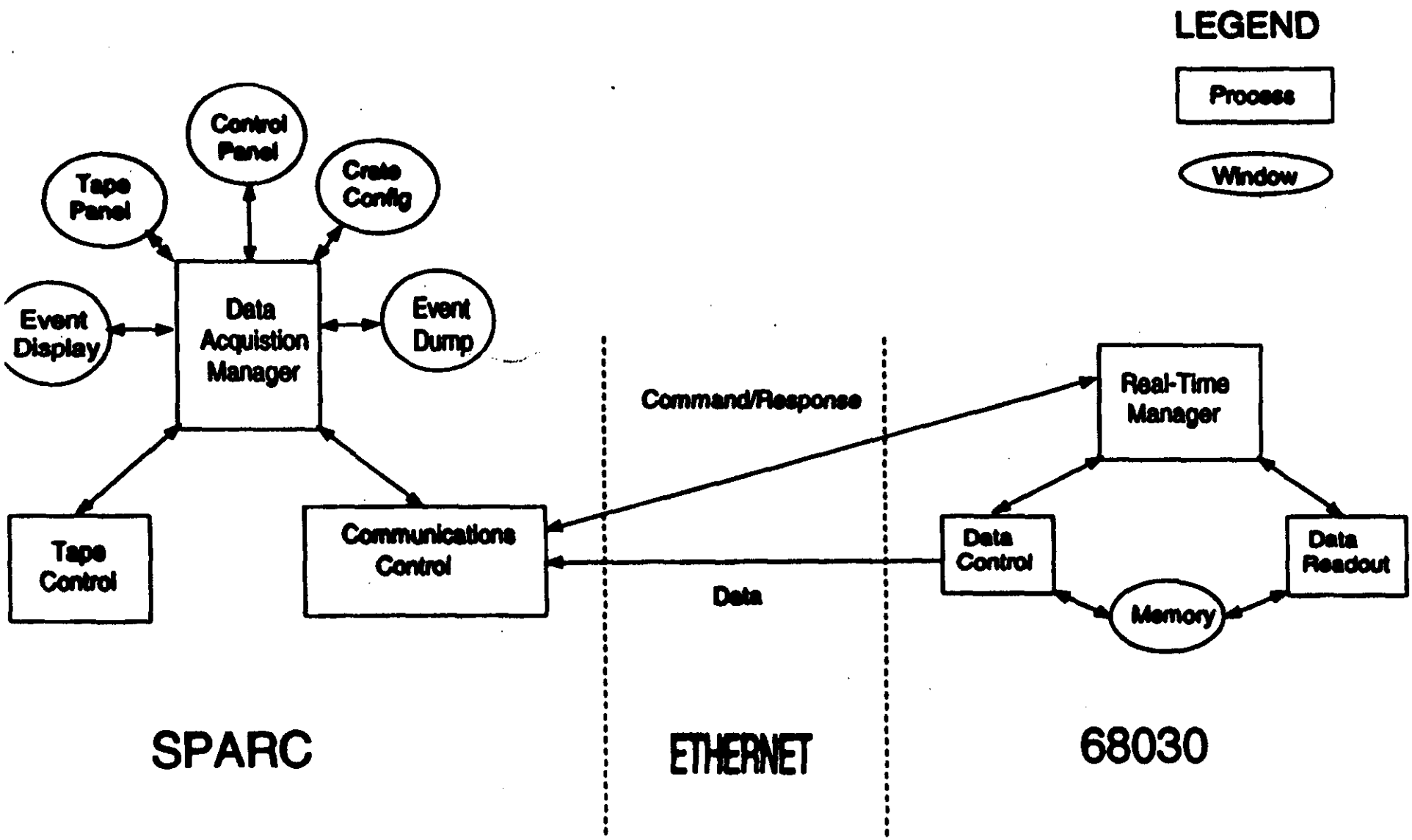
Scintillator	18 ns	$(^{+0}_{-2})$
PMT	43 ns	(±5)
Signal Cable	75 ns	~~(±5)~~ trimmed (min. 50ns)
Split	0 ns	
Cable	4 ns	
disc	18 ns	(±2ns)
cable	3 ns	
OR/AND	12 ns	(±2ns)
Cable	3 ns	
ECL-NIM	6 ns	(±1ns)
Cable	2 ns	
AND	10 ns	
	194	±10ns
Cable	2 ns	
disc (shaper)	10 ns	
cable	2 ns	
Fan out	7 ns	
	215 ns	

cable to detector DAQ ?

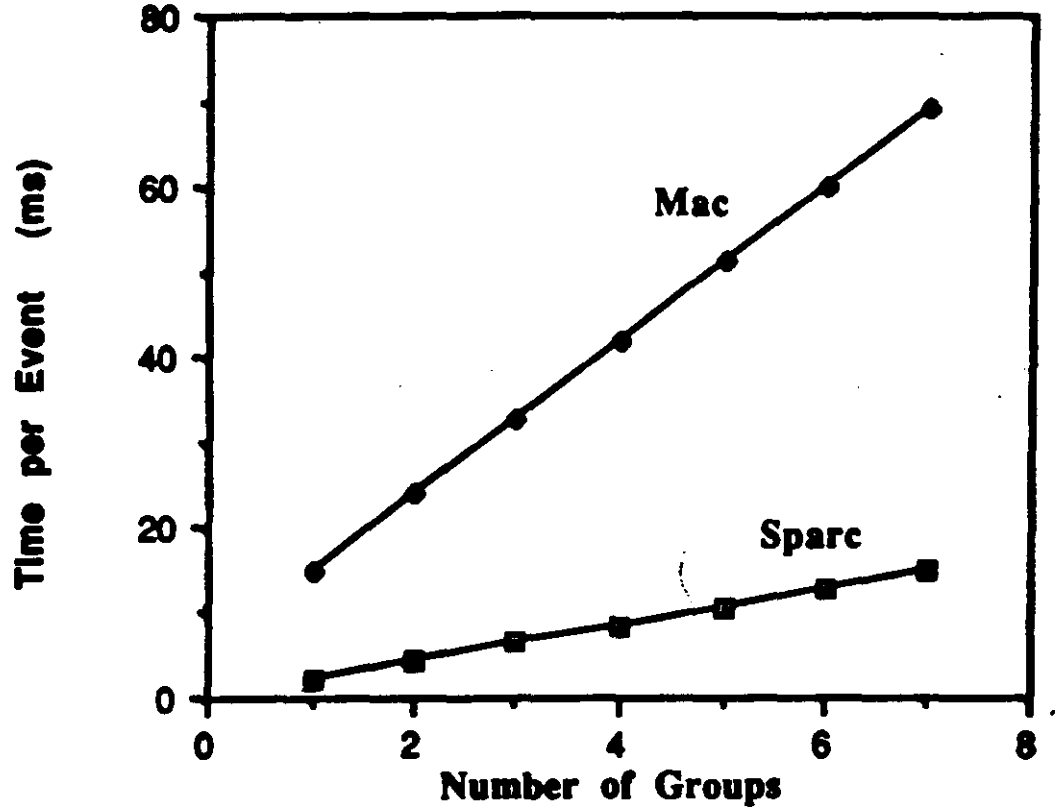
modular [VME]DAQ: present layout

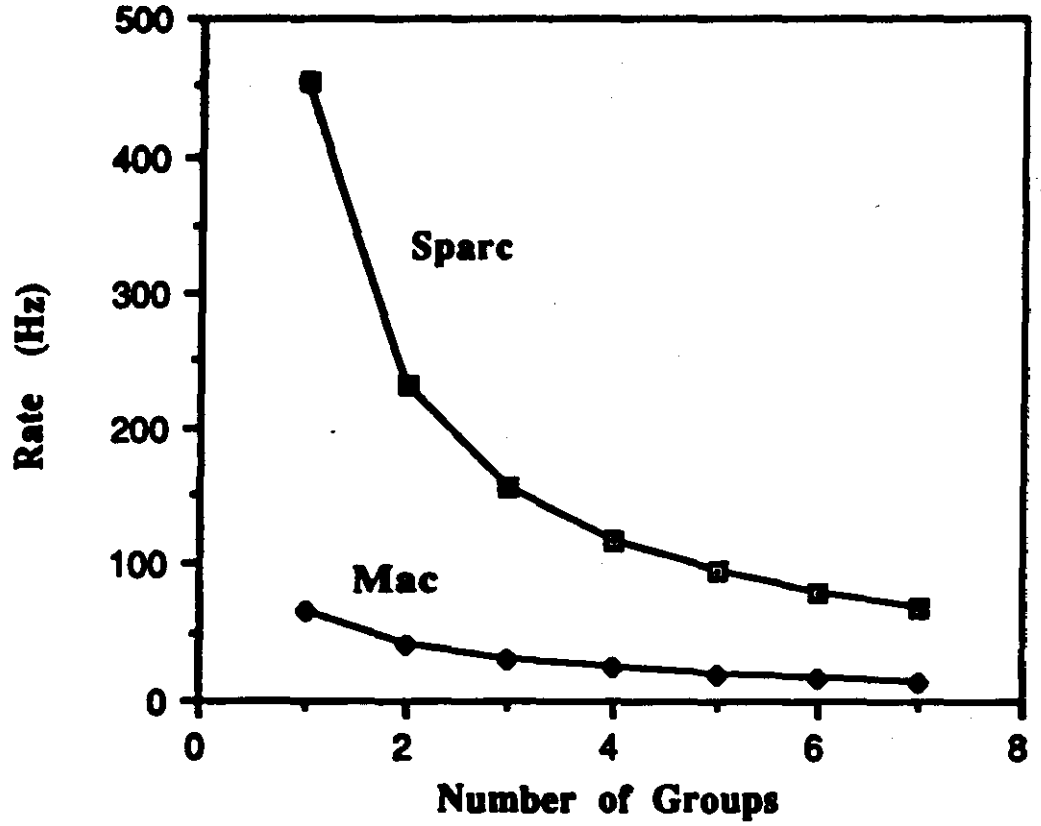


DAQ S/W MODULES (UNIX)



TTR DAQ System (Preliminary)





Main DAQ Window

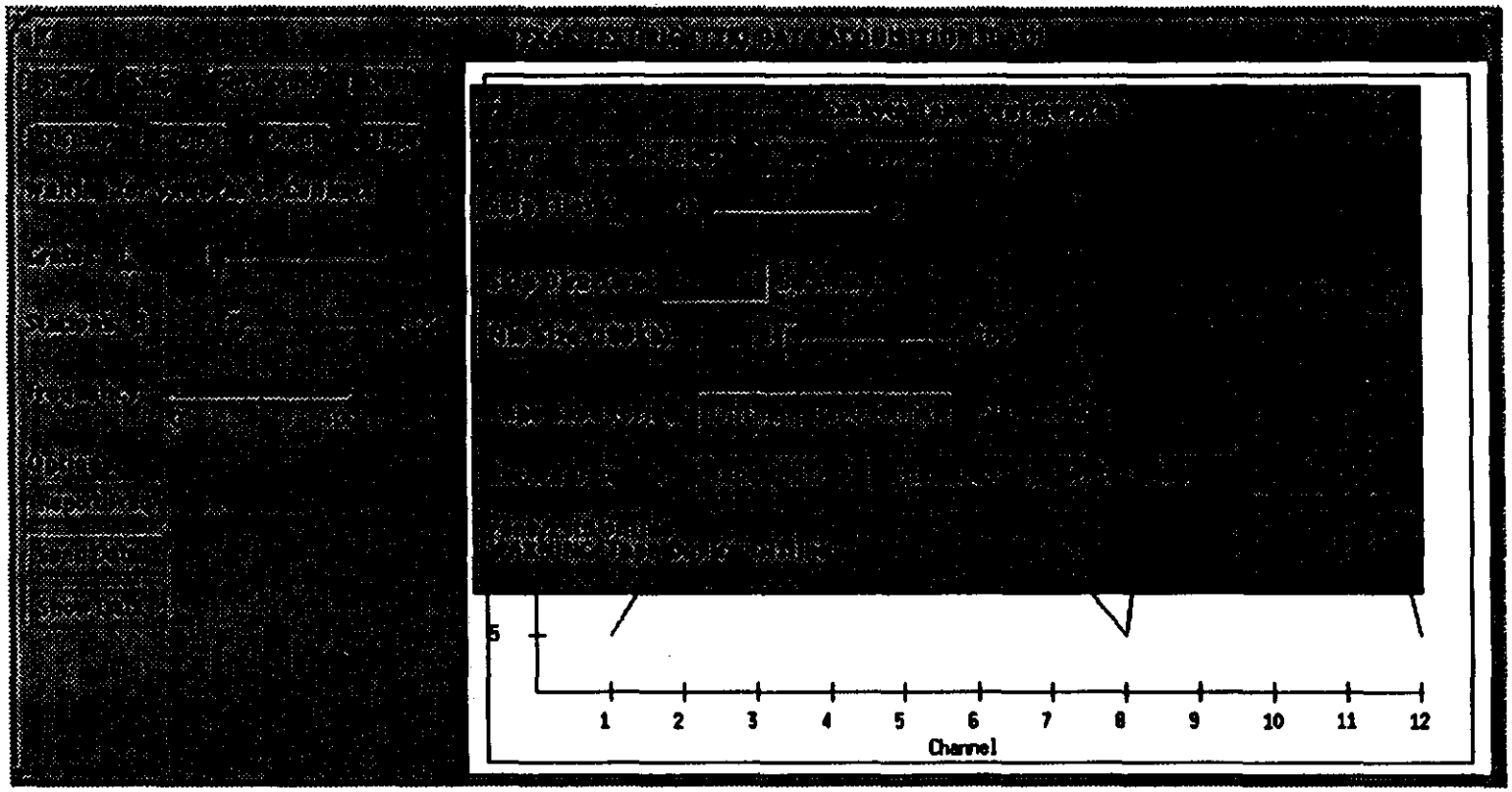
Histograms Window

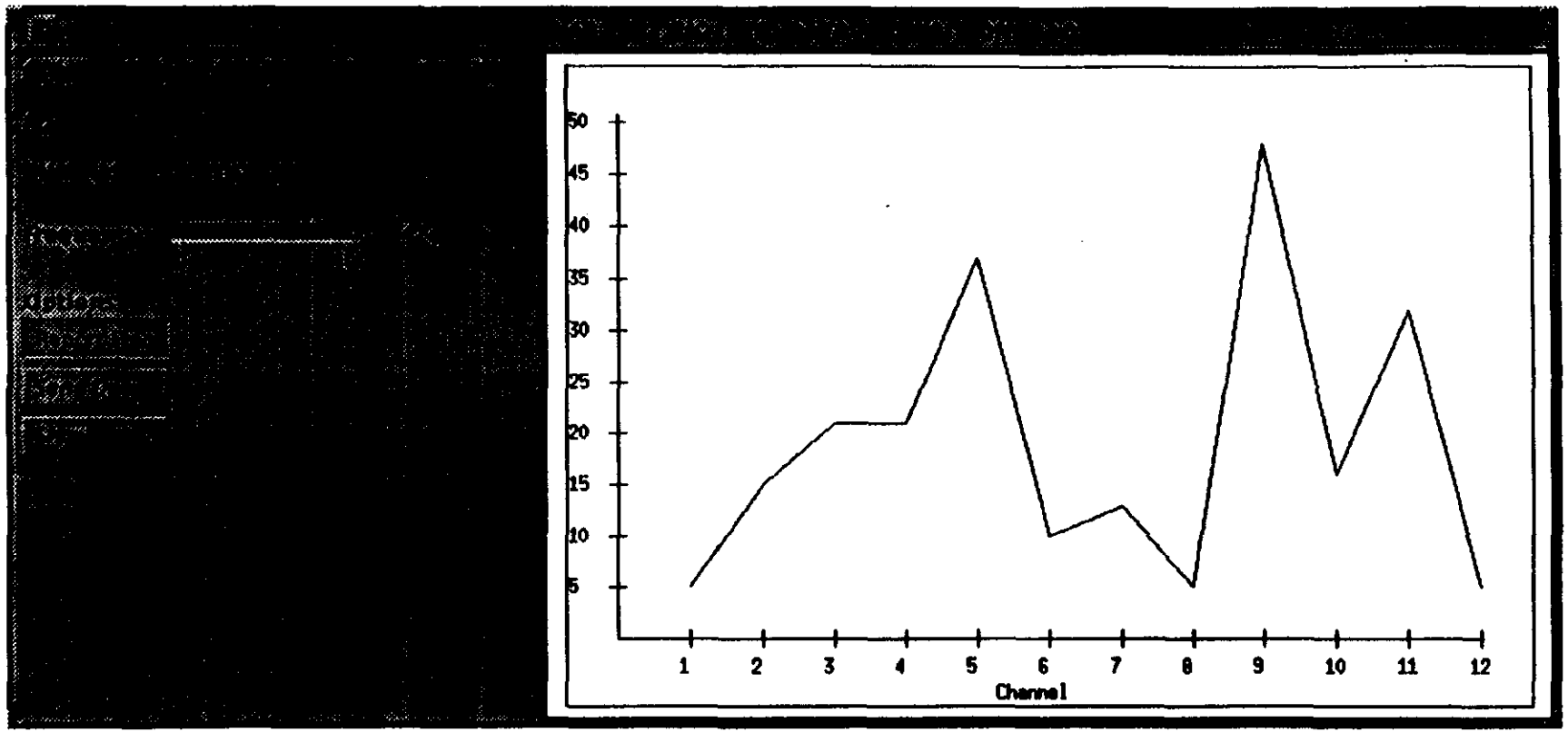
(PAW)

Control & Monitoring of

HV for SC's and Iarocci Tubes

Trigger C & M


5
1
2
3
4
5
6
7
8
9
10
11
12
Channel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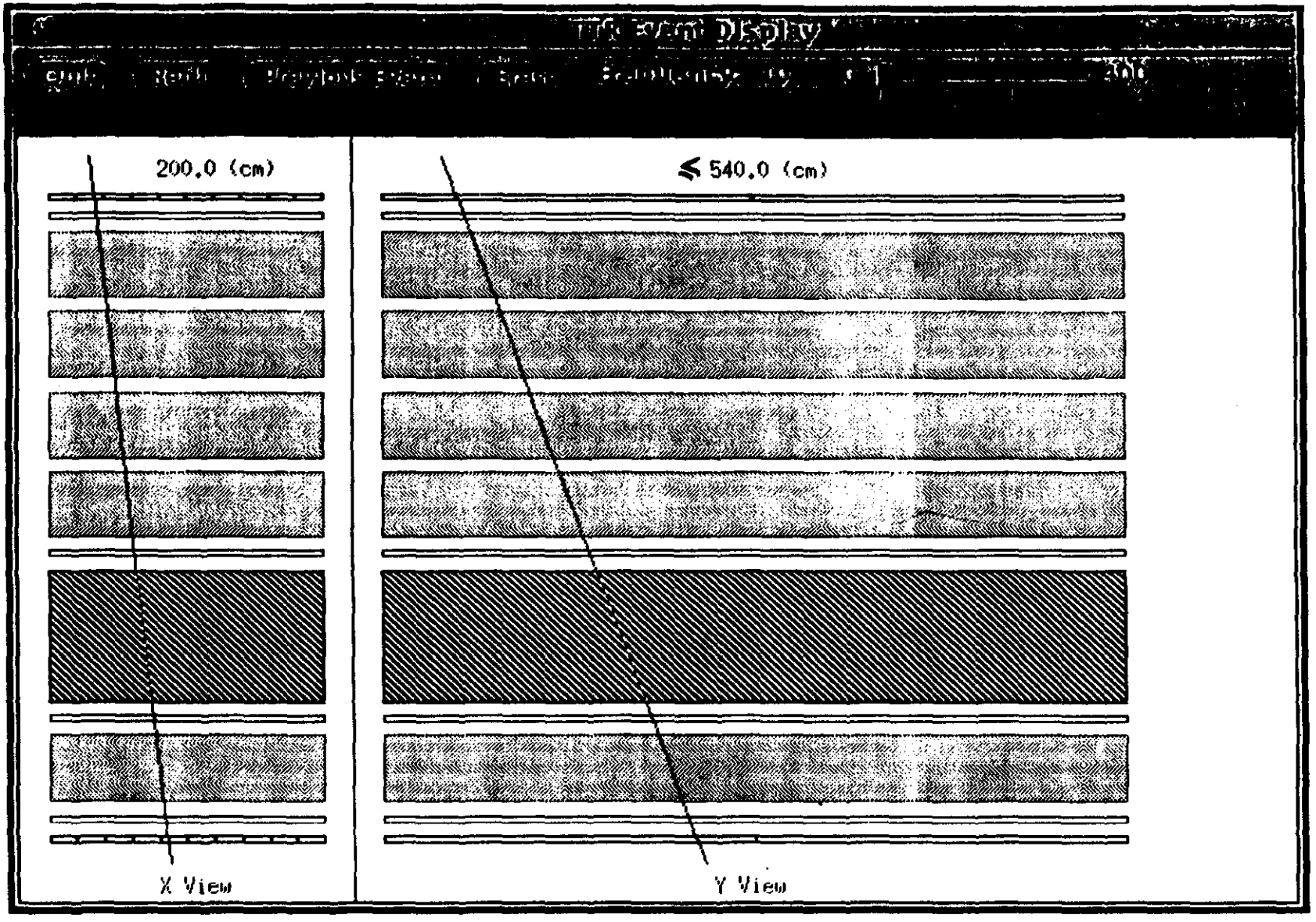
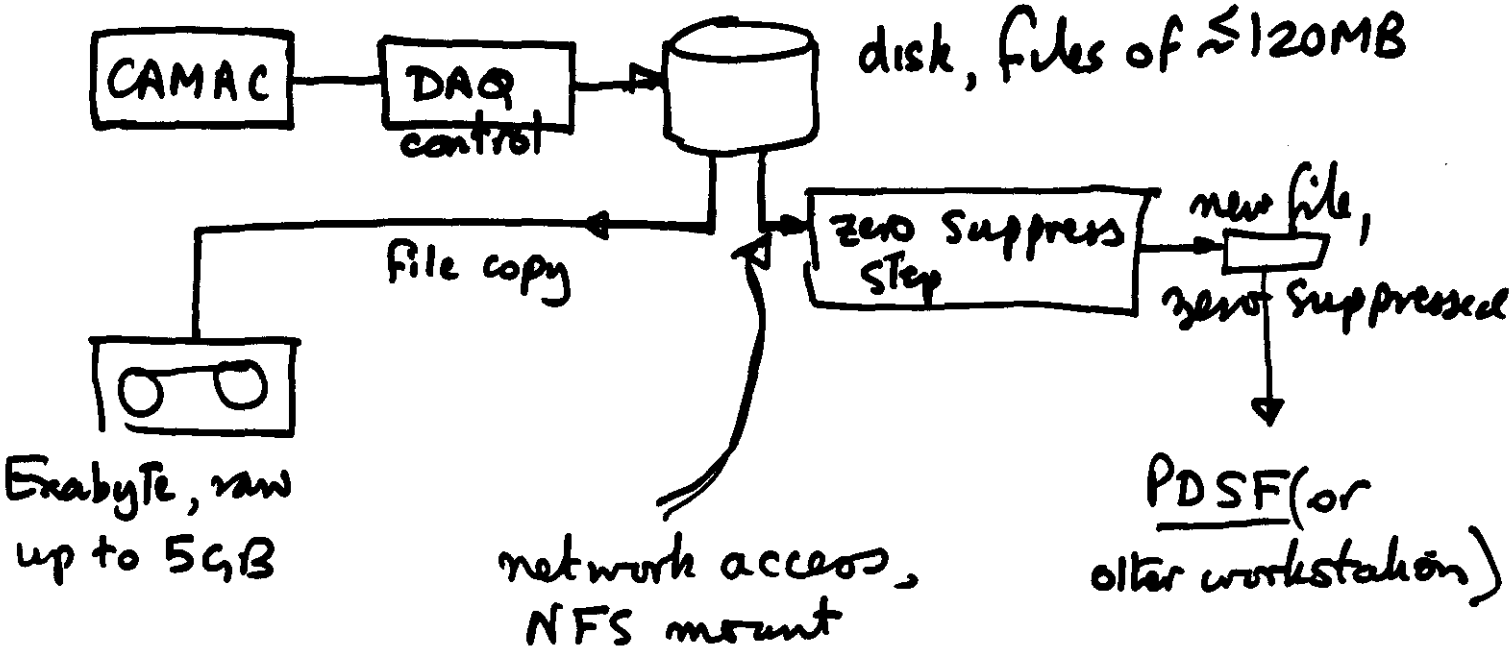

200.0 (cm)
540.0 (cm)
X View
Y View

Possible DAQ – Offline Sequence



Event size : ~1kB, non zero suppressed ≃ 120k per file
≲ 150 Bytes zero suppressed ≃ 1M per file

Off-line Analysis (see G. Yost)

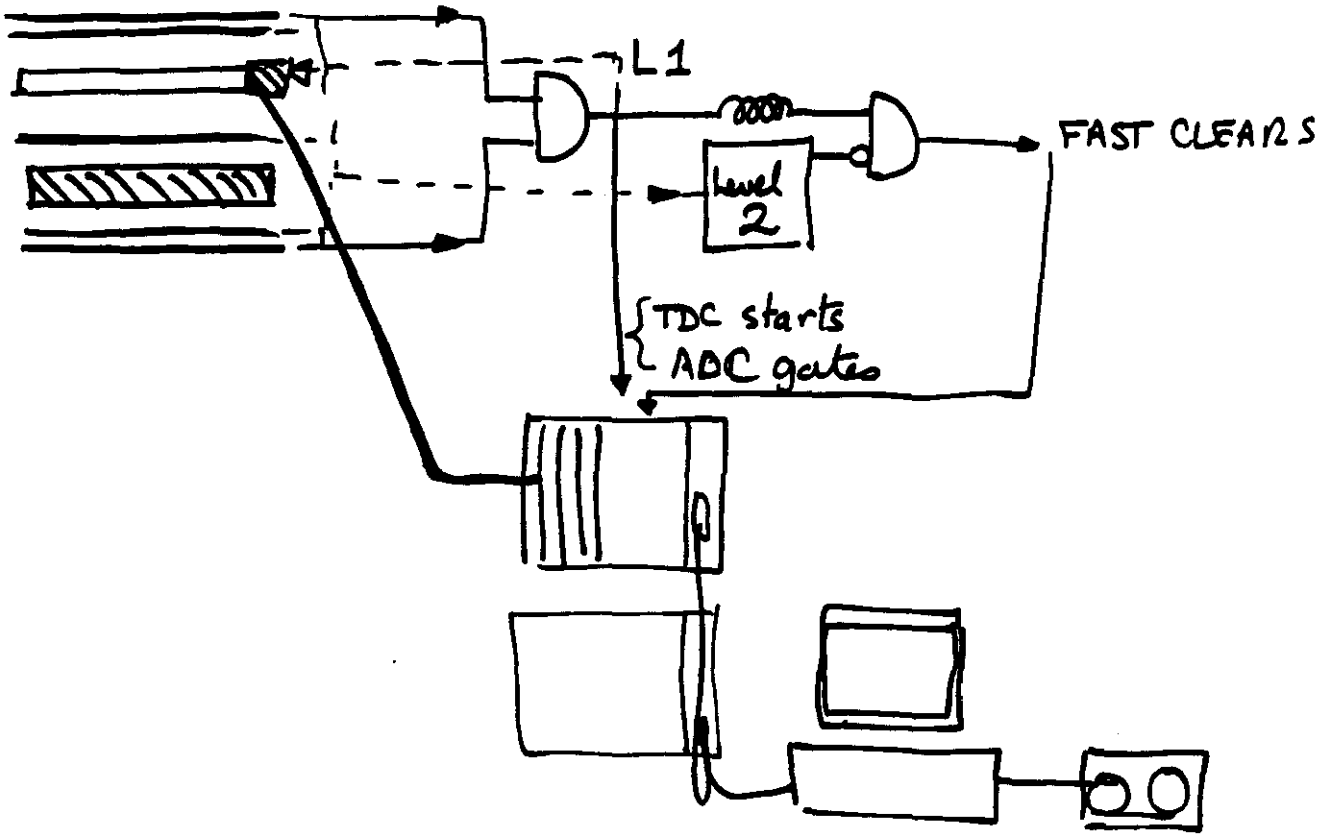
SSC provides framework; needs information from 'users'

'User' is to provide to SSCL:

- In Advance (NOW)
  - Tested detector with any HV supplies
  - Any front-end electronics with power supplies
  - Gas system ~~requirements~~
  - DAQ (CAMAC) modules with manuals
  - Description of DAQ modules, and data formats, CAMAC commands.
  - Cables to match L1 delay (or other signal buffer
  - Description of any signals to or from L1 with logic level (TTL, ECL, NIM) and timing. E.g. deadtime signals, enables to frontend? Give socket used (BNL, Lemo, ECL..)
  - Analysis requirements and other info:
    - Contact person
    - code
    - sample size needed
    - desired parameters
    - ⋮
  - Physical size, sensitive area, handling requirements
  - ETA, personnel

Red. Calibration sequences, signals ...

TTR Trigger/DAQ block diagram



SSCL Provides

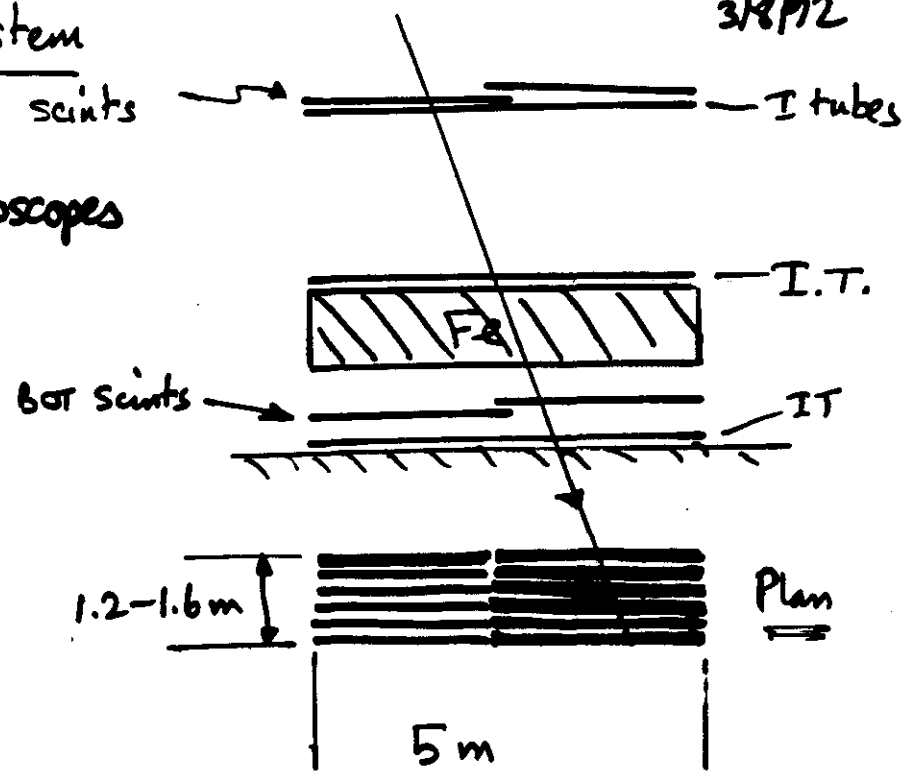
- CAMAC crates & controllers, DAQ computer, recording
- L1 signals (ECL, NIM) up to 16 starts + 16 gates
- Fast clear up to 32
- Level 2 capability given suitable signals

'User' provides

- Detector
- DAQ modules (ADC, TDC, special); manuals
- Cables to match L1 delay. (or other signal buffer)
- input sockets (BNC, lemo, or 0.1" space ECL)
- Any dead time signals if needed.

Muon Trigger System

- Top & bottom hodoscopes
- Tarocci tubes



Hodoscopes consist of 12 double-ended scintillation counters in two panels top & bottom. Total of 24 slats, 48 PMT's. Slats are 2.7 m × 0.2 m × 25 mm thick.

Trigger rate: ~100 Hz full solid angle

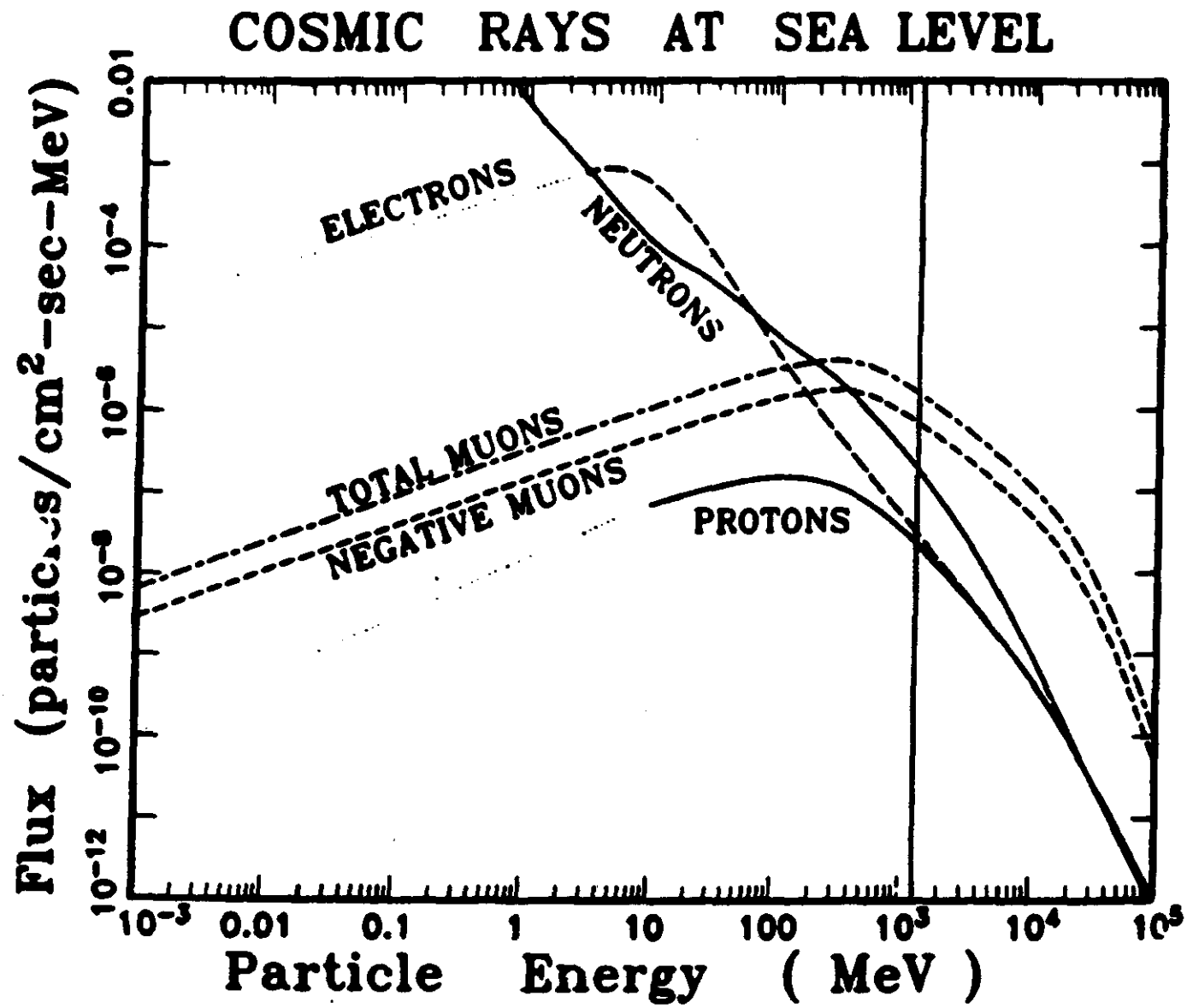
~1 Hz restricted angular range

Momentum $\gtrsim$ 1.5 GeV/c

OFF-line, with Tarocci tubes, a higher threshold can be set — can greatly reduce event rate.

3/8/92 ③ ⑥

Figure 4.11 Flux of cosmic ray particles at sea level at 40° N geomagnetic latitude. The low energy electron and proton spectra can differ significantly from the dotted lines depending on local conditions in the atmosphere. (J. Ziegler, Nuc. Instr. Meth. 191: 419, 1981.)



1 m of Fe ⇒ $P_{muon} \geq 1.4$ GeV

or ~ 60 μ's/m² s

for A = 4 m² ⇒ R ~ 240 Hz

Geometric Acceptance ⇒ Rates O(100)

Performance and capabilities

Particle passage to Level 1 : 200 ns ± 20 ns

Accidentals $\ll$ 0.1 Hz

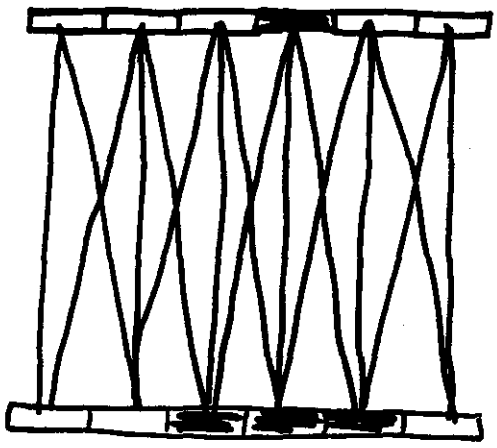
Timing accuracy (Level 1) : 10 ns jitter (± 5 ns)

off line : $\leq$ 250 ps

Programmability: at Level 2, any combination of slats.

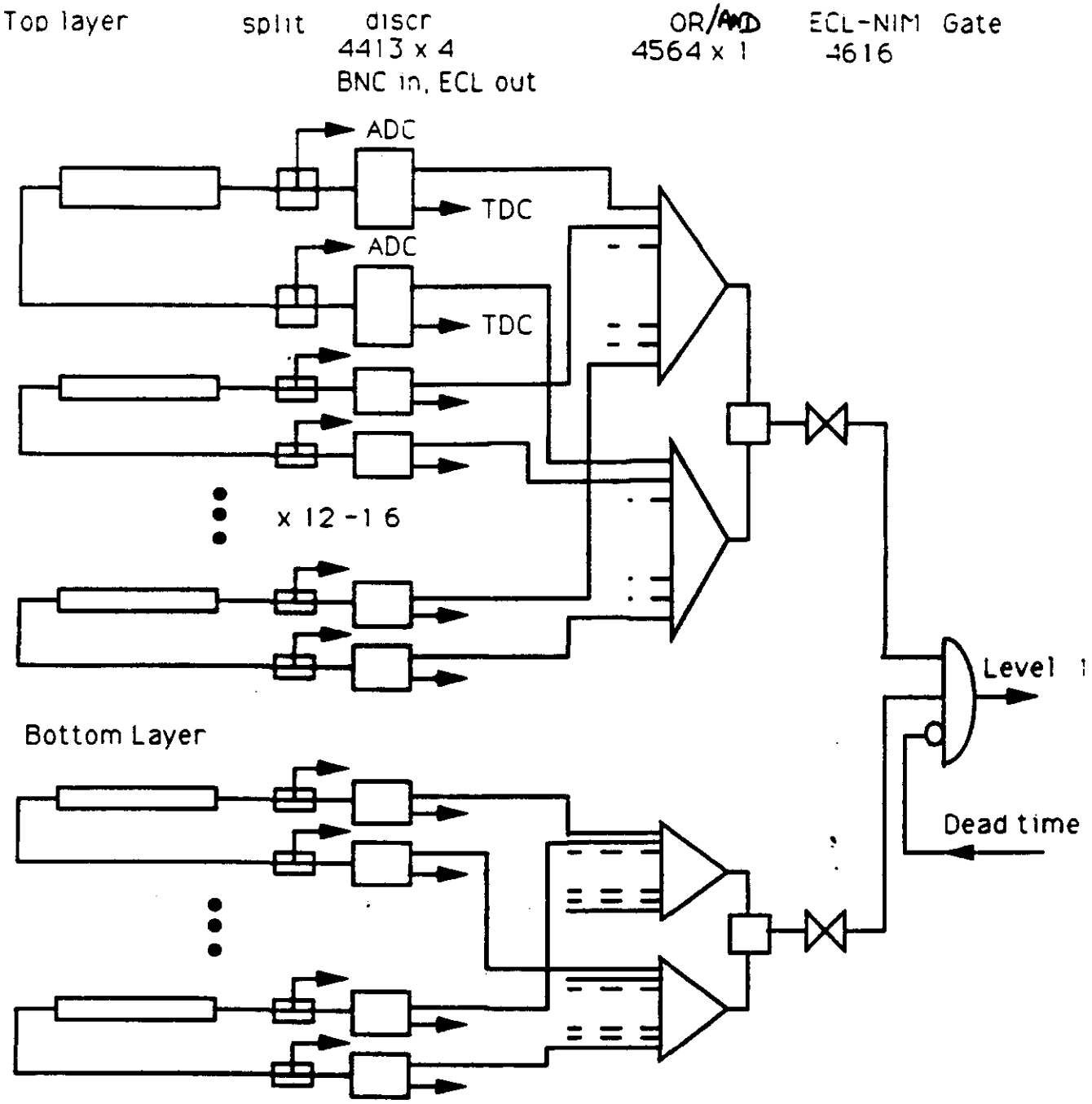
Iarocci tubes introduced at Level 2.

Sample Level 2



restrict angular range of triggers

Muon Trigger - Version 2

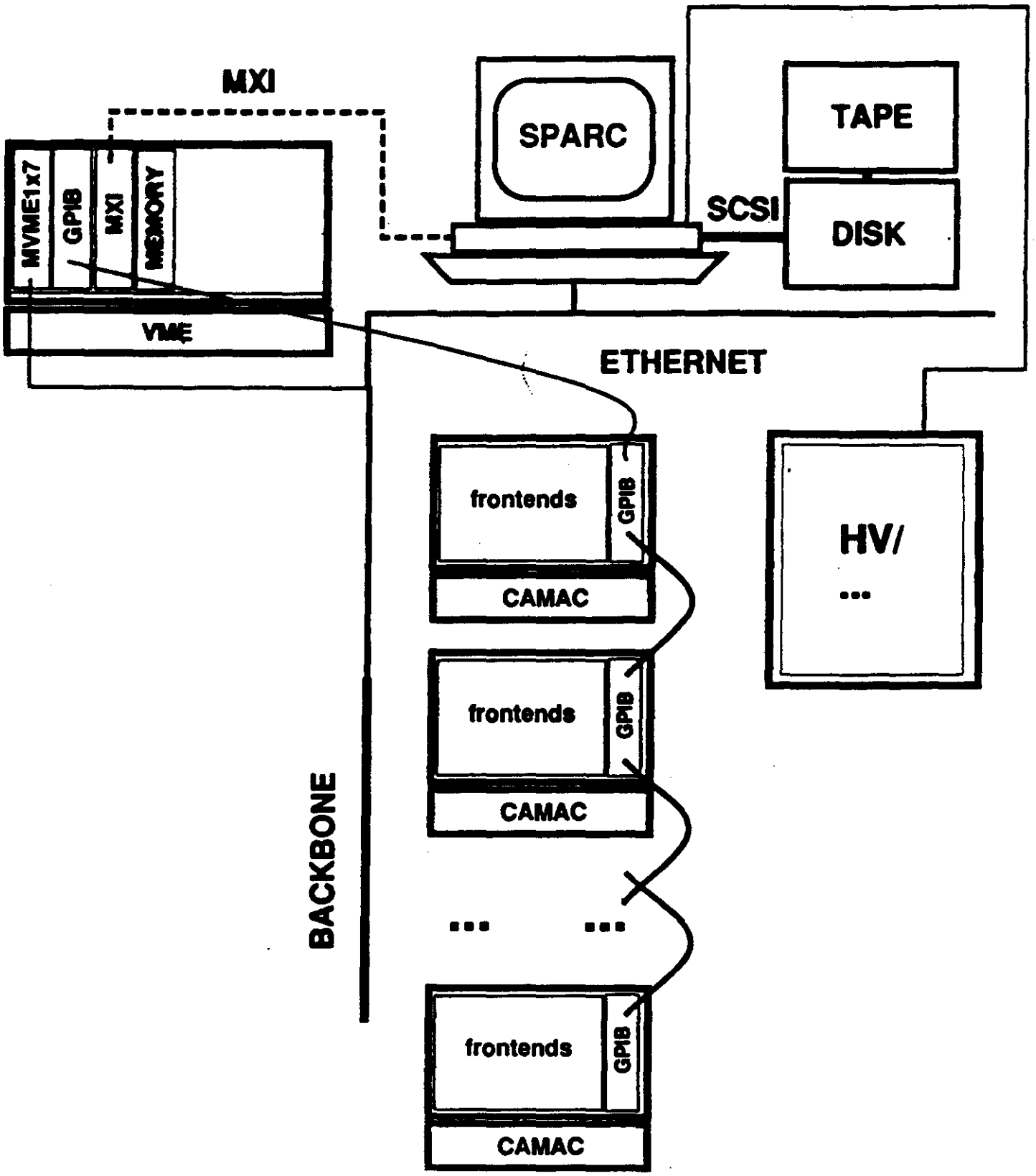


L1 Delay (sample calculation)

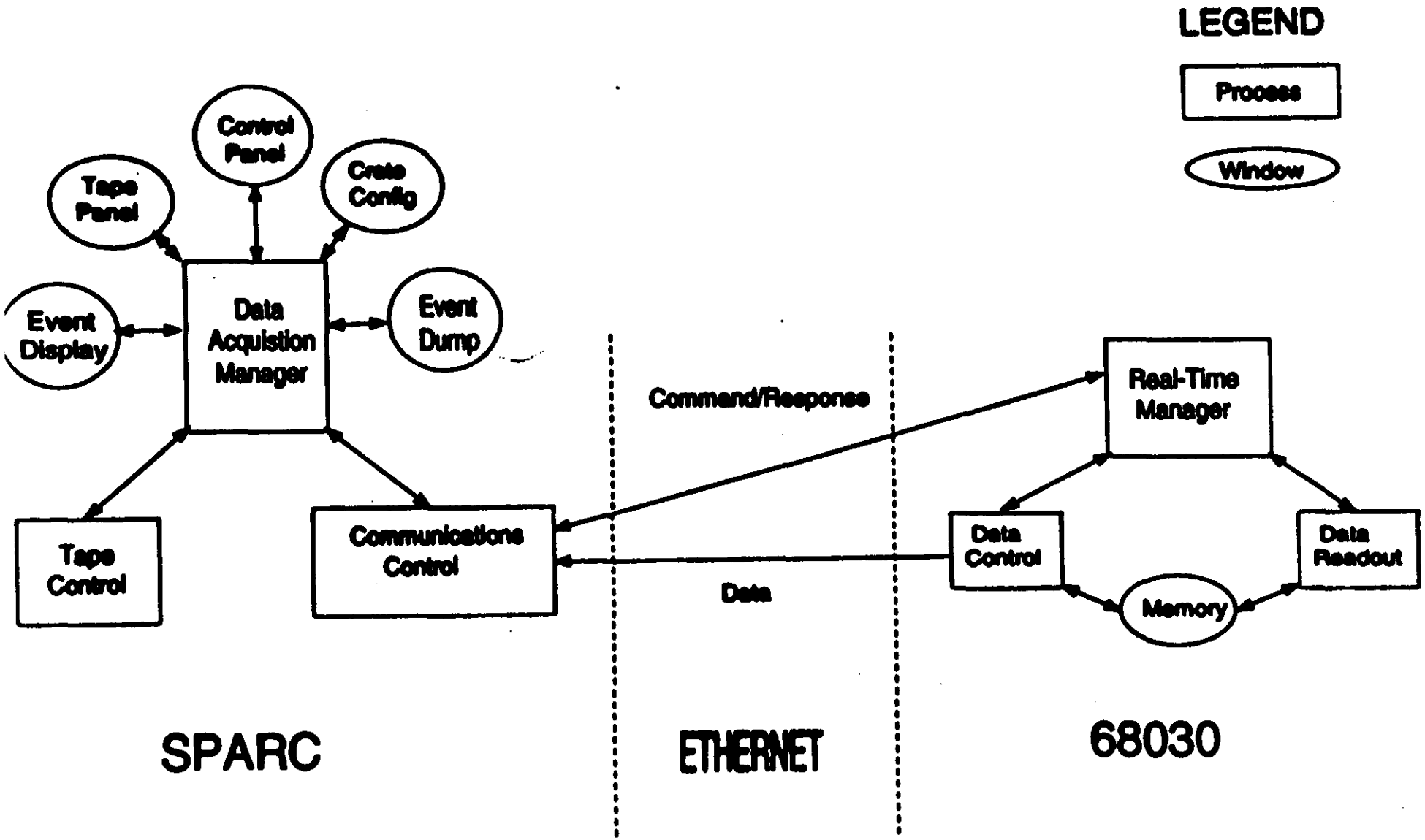
Scintillator	18 ns	$(^{+0}_{-2})$
PMT	43 ns	(±5)
Signal Cable	75 ns	trimmed (min. 50ns)
Split	0 ns	
Cable	4 ns	
disc	18 ns	(±2ns)
cable	3 ns	
OR/AND	12 ns	(±2ns)
Cable	3 ns	
ECL-NIM	6 ns	(±1ns)
Cable	2 ns	
AND	10 ns	
	194	±10ns
cable	2 ns	
disc (shaper)	10 ns	
cable	2 ns	
Fan out	7 ns	
	215 ns	

cable to detector DAQ ?

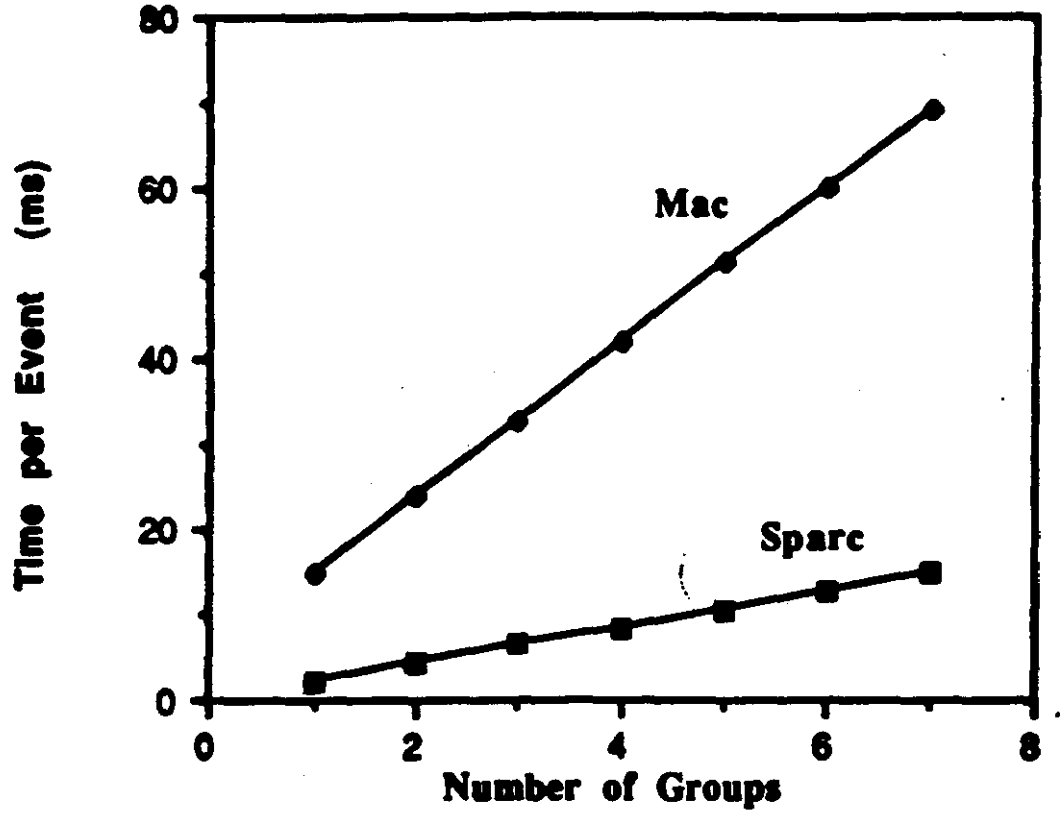
modular [VME]DAQ: present layout

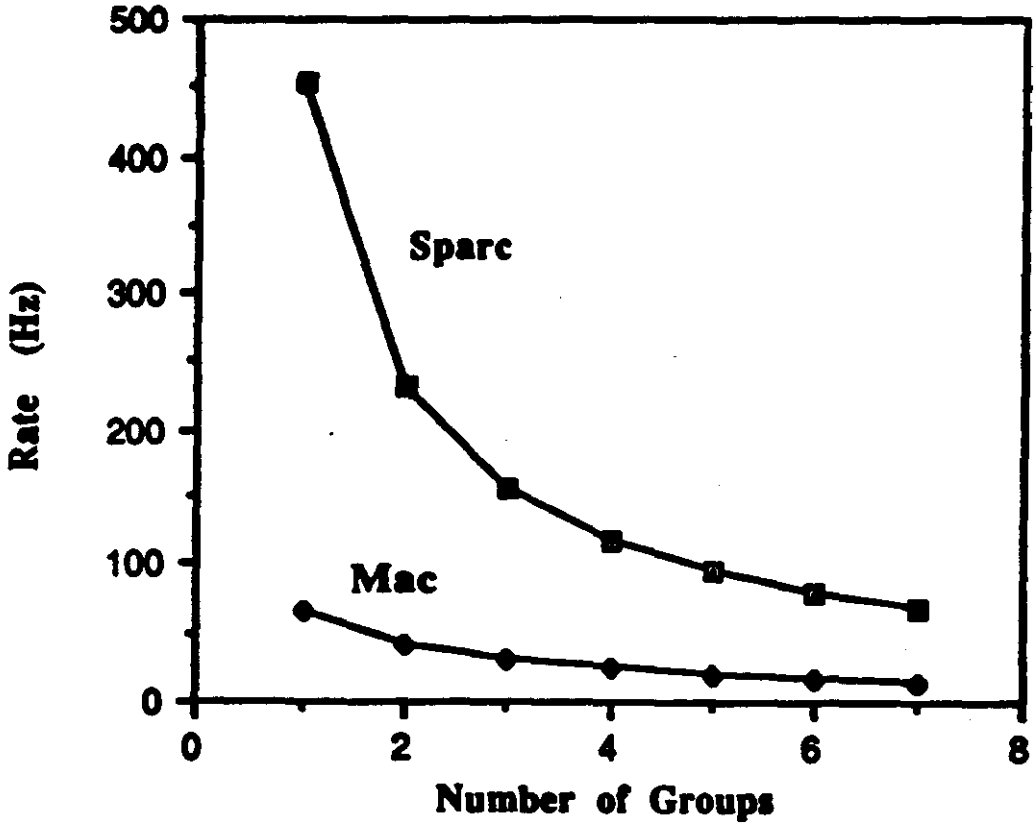


DAQ S/W MODULES (UNIX)



TTR DAQ System (Preliminary)





Main DAQ Window

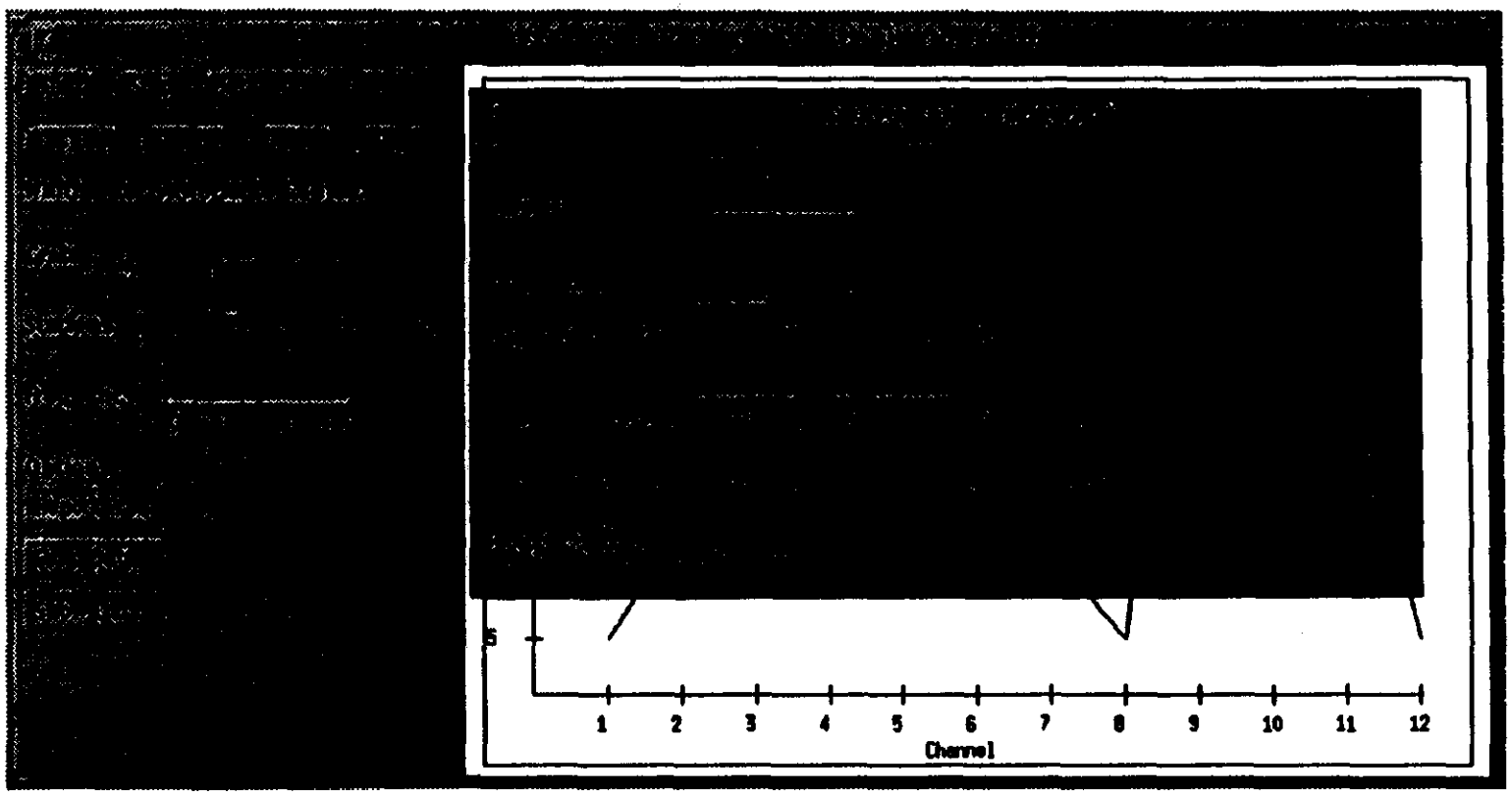
Histograms Window

(PAW)

Control & Monitoring of

HV for SC's and Iarocci Tubes

Trigger C & M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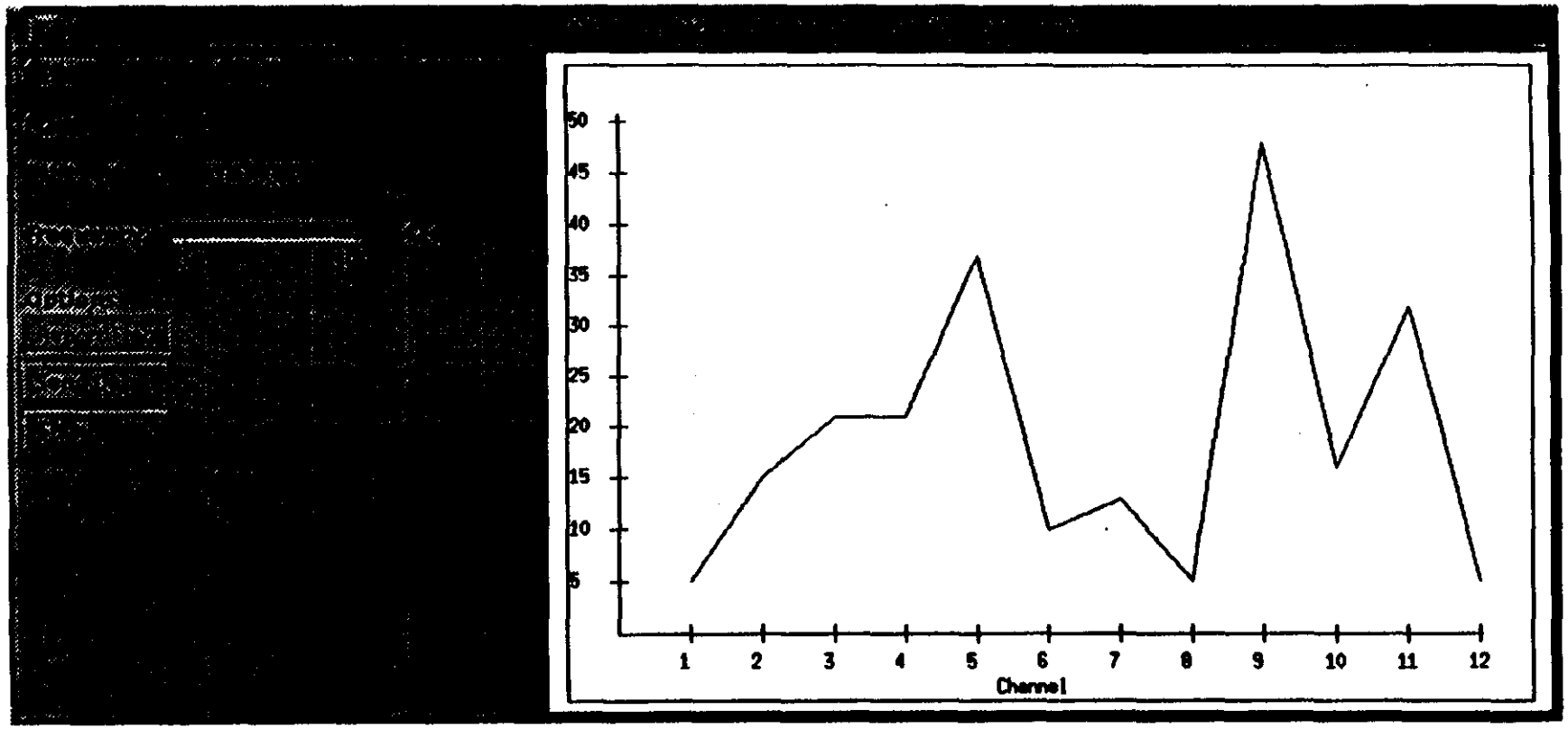
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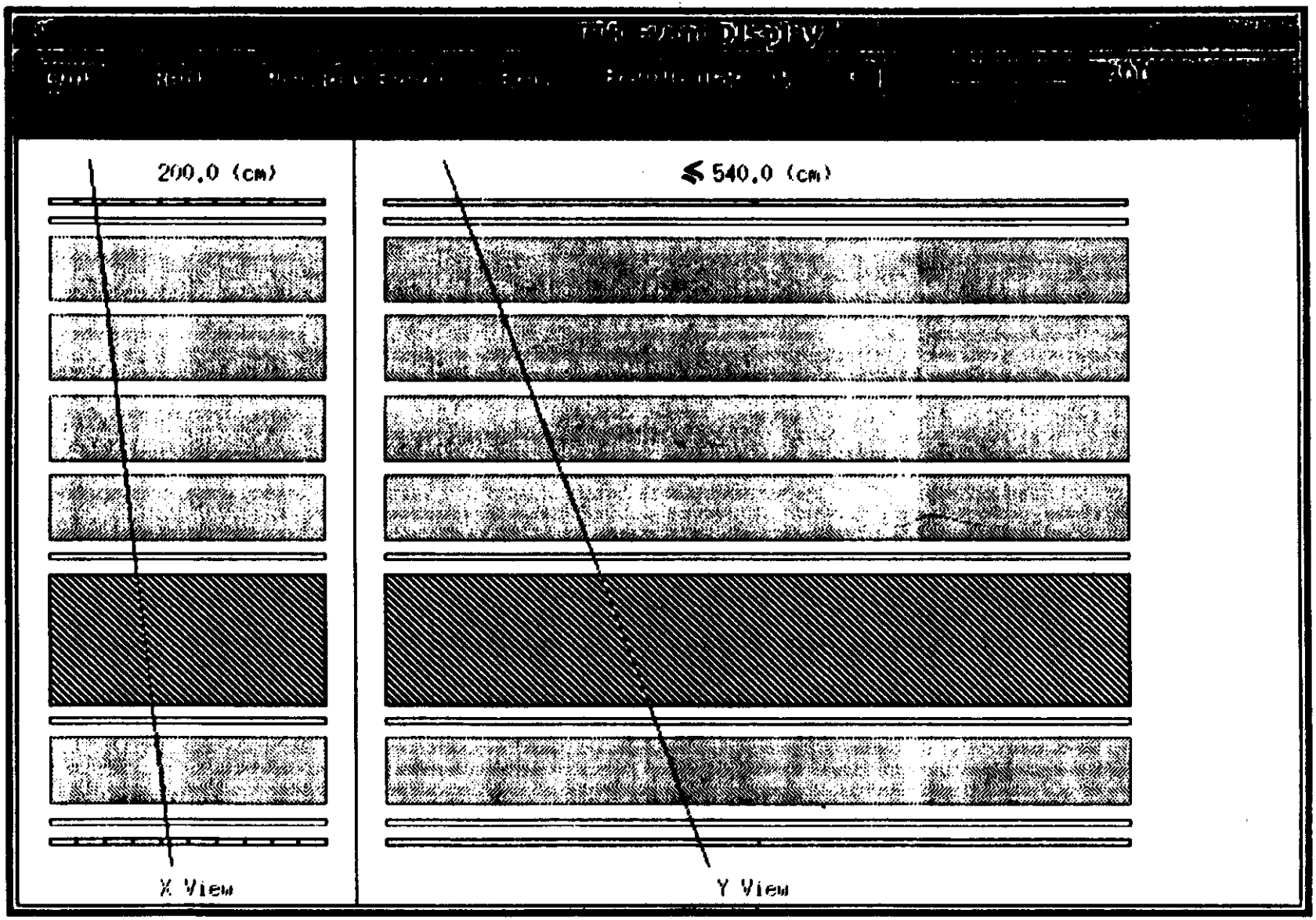
200.0 (cm)
540.0 (cm)
X View
Y View

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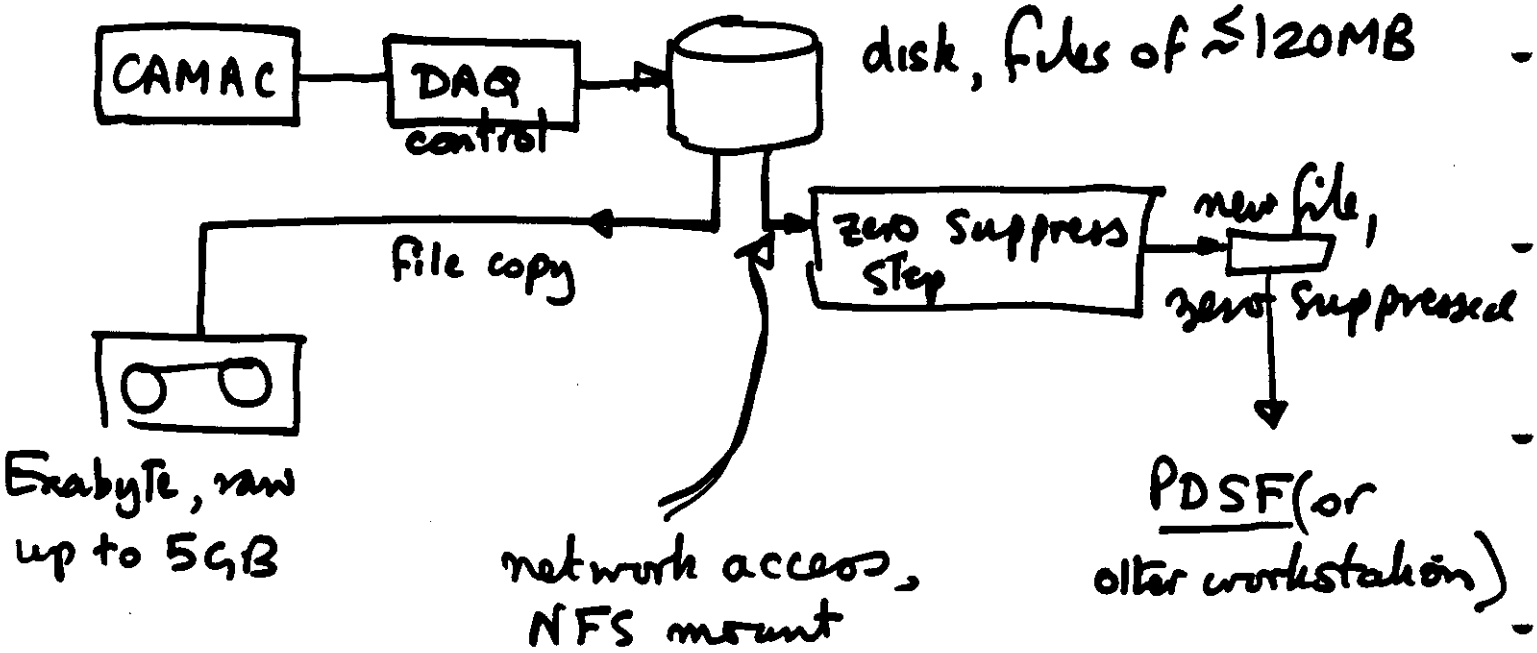

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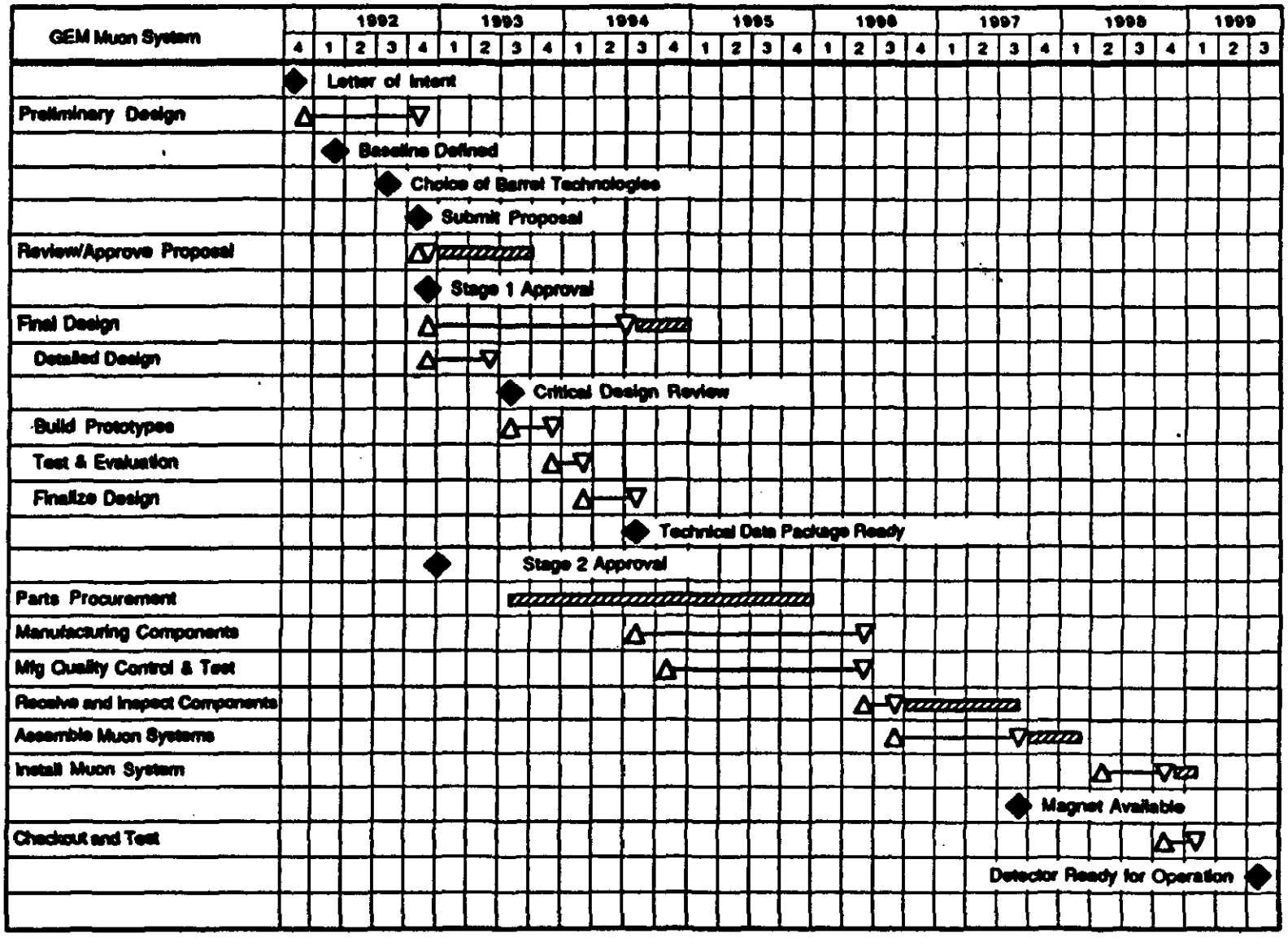
Red. Calibration sequences, signals ...


GEM Muon System
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Letter of Intent
Preliminary Design
Baseline Defined
Choice of Barrel Technologies
Submit Proposal
Review/Approve Proposal
Stage 1 Approval
Final Design
Detailed Design
Critical Design Review
Build Prototypes
Test & Evaluation
Finalize Design
Technical Data Package Ready
Stage 2 Approval
Parts Procurement
Manufacturing Components
Mfg Quality Control & Test
Receive and Inspect Components
Assemble Muon Systems
Install Muon System
Magnet Available
Checkout and Test
Detector Ready for Operation