GEM TN-93-270

# Muon Group Meeting - Duncanville, Tx.

December 9, 1992

Abstract:

Agenda, attendees and presentations of the GEM Muon Group Meeting held at the Holiday Inn in Duncanville, Tx. on December 9, 1992.

# Draft Agenda of 12/9/92 GEM Muon Group Meeting:

Location: Duncanville Holiday Inn
Time: Wednesday 12/9/92 9:00 AM until 4:30 PM

(I) Remarks about PAC presentations FET will distribute
- List of questions from PAC and discussion

[Marx/Taylor]

10:00 (II) Discussion of Baseline-2:

11:30 Am (1) Summary of muon concerns / calorimeter workshop [Dingus/McNeil]

with Cal. gr. (2) Resolutions of BL-2 [Sullivan]
- FFS design impact on resolution
- Lever arm, chamber locations, etc.

(3) Update of location and size of EC chambers/neutron bkg. [Whitaker]

(4) 16 vs 32 sectors for CSC ? [Johnson/Mitselmakher]
→ BNL meeting / CSC

(5) Alignment considerations of BL-2 [Wuest/Paradiso]

(6) Support structure design update [Nimblett/Sawicki]

(III) TTR progress report [Golutvin/Korytov] Lan

(IV) Status of RDT/RPC backup option [Bromberg/Wuest/Korytov]

(V) Progress reports from TDR coordinators
For each section:
- Outline
- List of figures
- Game plan (who's doing what, help needed, what needs to be defined)

(VI) TDR schedule and tasks [Group] Dec. 15

(VII) Plans for next Technology Review and Cost Review
Jan. 15 tech, Feb. 15 costs

(VIII) AoB

R&D Meeting: 4:45 PM to 6:30 PM

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Location: Duncanville HI

Meeting of the R&D task coordinators and institutional reps.to sign-off (we hope) on the Short-Term (pre-TDR) R&D FY93 plan.

Muon Meeting 12/9/92

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Mike Marx & Frank Taylor

# Discussion of PAC Questions

# PAC Questions from December 1992 Meeting:

The following is a list of some of the more "sticky" questions asked of the Muon System during the presentation on 12/6/92. The parenthetical questions are added and all should be addressed for the TDR.

(1) How well will the CSCs really tag the beam crossing ?

If the fast gas $CO_2$-$CF_4$ (50-50) is used then Vdrift = 100 $\mu$m/ns => 25 ns total drift time, so an OR of 4 will speak 99% of time < 12 ns. But what if that gas mix can not be used and Vdrift is smaller, say = 50 $\mu$m/ns, then the crossing tag becomes less reliable. ( What do the RD5 measurments say ? Maybe the jitter can be measured in the BNL 50-50 $cm^2$ chamber? Determine the sensitivity of the jitter to the gas mixture by measurements.)

(2) There was a questions from Dydak in which he worried about the 1 % beam tag inefficiency.

He was concerned that 1 % of the time the wrong calorimeter and tracker information would be read out and would lead to a dead time. (What is the dead time associated with this ? Do we have to worry about it and as a consequence the beam tag efficiency should be higher than 99 % ?)

(3) There were a lot a questions about the neutron background ? How many extra hits will there be ?

What does a hit-level MC simulation say about the number of fake tracks we will get with the neutron background at the trigger level and at the reconstruction level ? (Do we need to implement some local pattern recognition in the trigger and readout to reduce the number of spurious tracks ?)

(4) Why does the L-angle compensated resolution in the EC different from the corresponding resolution for the Barrel ?

( TPC effect or different simulation ? )

(5) What will the cost of the CSC system be ?

We did not discuss costs in any depth, but ~~it~~ the question was asked.

(6) How many channels are there in the backup technology option ?

(7) Will a stand-alone drift trigger work ?

(8) Will the spatial resolution of the RPC degrade when the lower resistivity plastic is used ?

(Maybe ? But will not be significant on the 0.5 cm scale ? Will have to measure this with new prototype ?)

Peter Dingus/Roger McNeil

# Summary of Muon Concerns/Calorimetry Workshop

This Section Empty

Yu. Kamyshkov

# Discussion of Sci. Barrel Calorimeter

Yu. Kamyshkov

# Possible functions of sci. barrel calorimeter.

① Muons:

- Detect $\mu$ in few longitudinal segments in the presence of n-background.
- Measure To at the trigger level (?)

  $\Rightarrow$ full $\mu$-barrel coverage needed
- Help in muon pattern recognition ? (mean timer timing $\sim 5$ ns). Cover gaps in $\mu$-system
- Muon trigger ?

  IP — sci. strips (3 cm) — last muon superlayer (L = 8.6 m)
- Measure muon bremstrahlung losses in $\sim 3.8\lambda$ Cu ?
- $\lambda$-coverage in the full range $|\eta| < 3$.
- scintillator shields against neutrons.

② Hadrons:

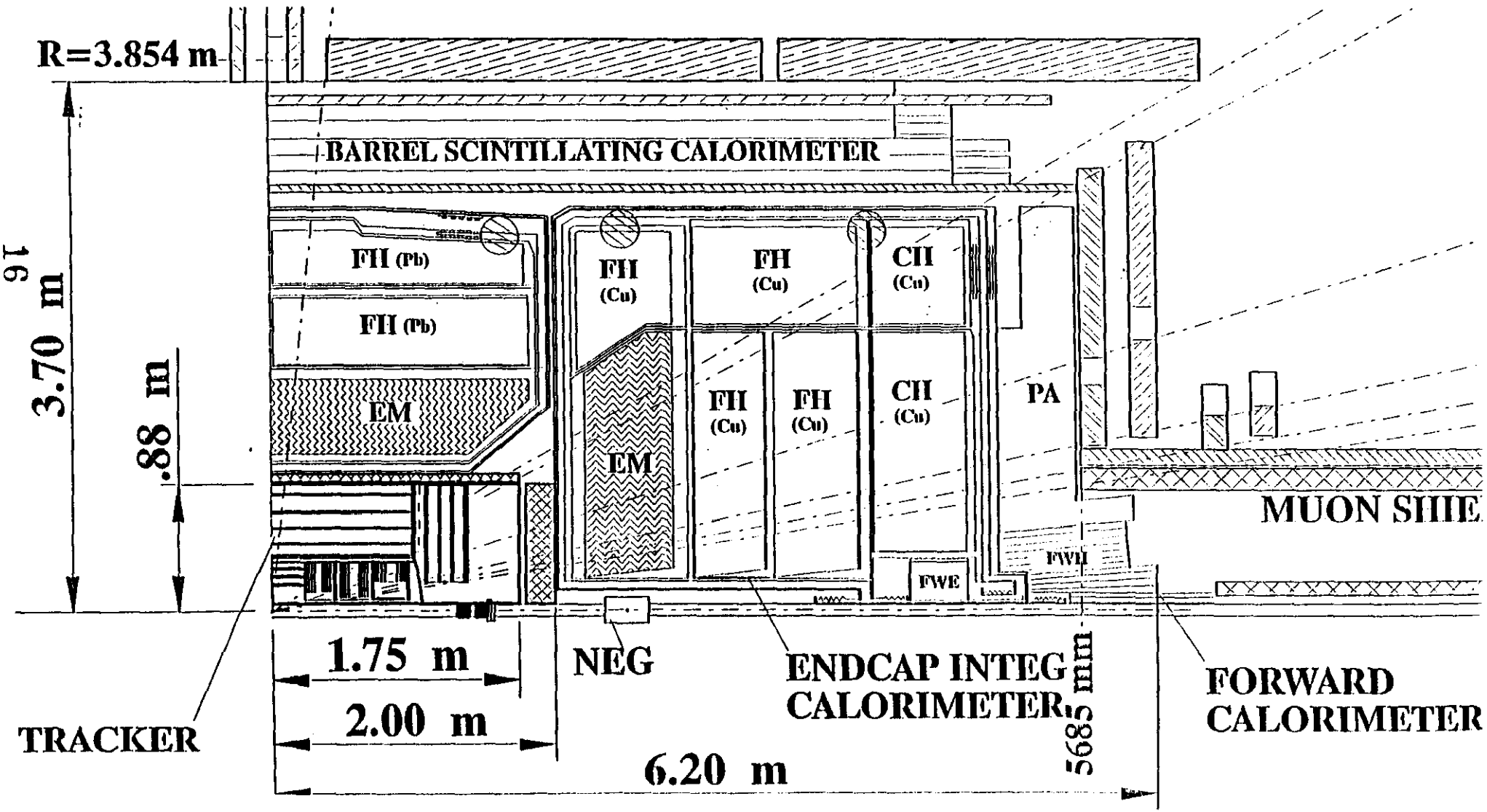
- Tail catcher

(?) Are there reasons for end-cap "tail catcher" part to be instrumented

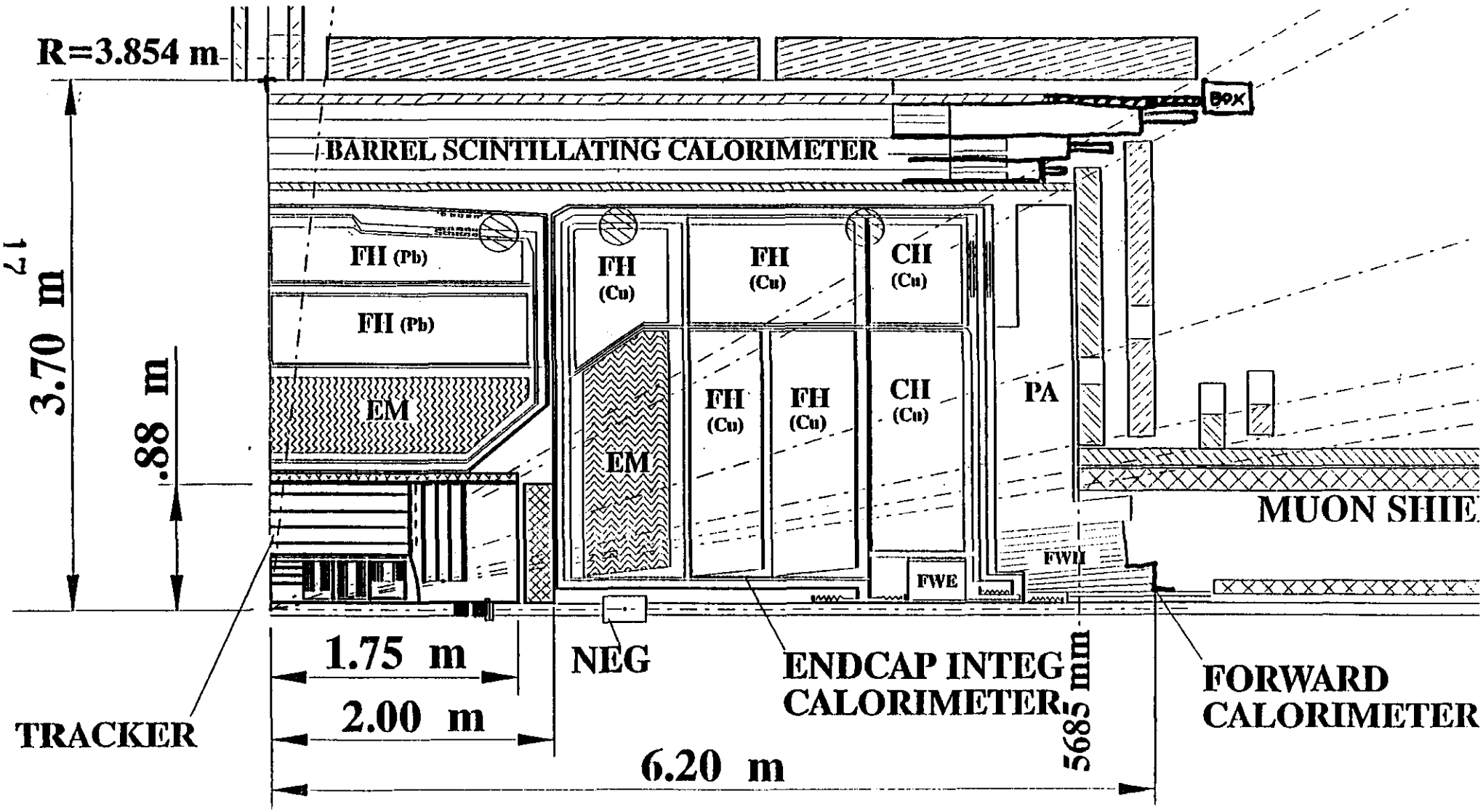
(12λ) Barrel scint. $4.5\lambda$ with structure

if not instrumented $+0.3\lambda$

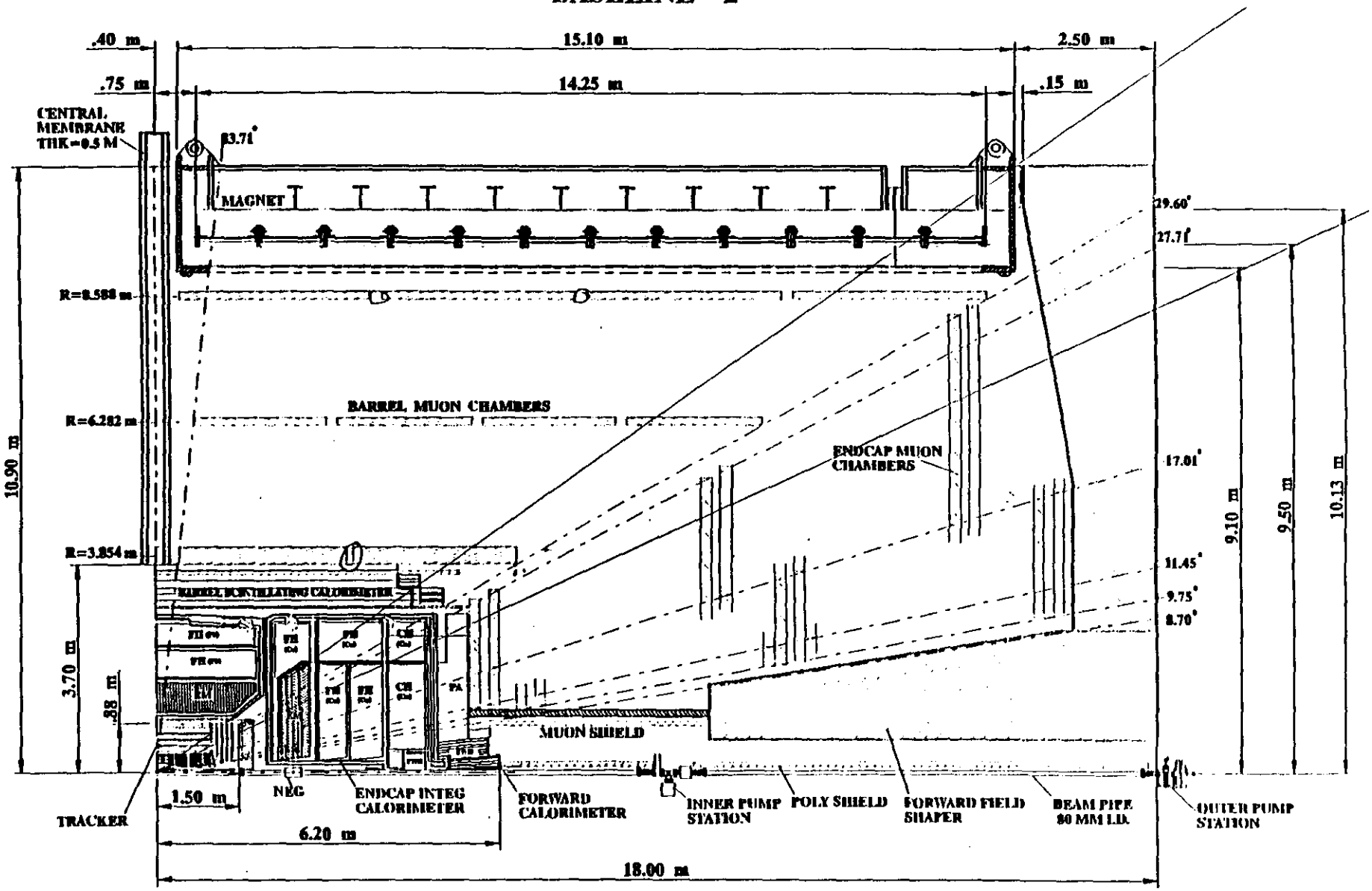
Baseline 2


R=3.854 m
BARREL SCINTILLATING CALORIMETER
FH (Pb)
FH (Pb)
EM
FH (Cu)
EM
FH (Cu)
FH (Cu)
CH (Cu)
CH (Cu)
PA
FWH
FWE
MUON SHIE
3.70 m
.88 m
1.75 m
2.00 m
6.20 m
5685 mm
NEG
ENDCAP INTEG CALORIMETER
FORWARD CALORIMETER
TRACKER

Baseline 2


R=3.854 m
BARREL SCINTILLATING CALORIMETER
BOX
FH (Pb)
FH (Pb)
EM
FH (Cu)
EM
FH (Cu)
FH (Cu)
FH (Cu)
CH (Cu)
CH (Cu)
PA
FWE
FWH
MUON SHIE
3.70 m
.88 m
1.75 m
2.00 m
6.20 m
5685 mm
NEG
ENDCAP INTEG CALORIMETER
FORWARD CALORIMETER
TRACKER

# GEM DETECTOR PARAMETERS
## BASELINE 2

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11/23/92
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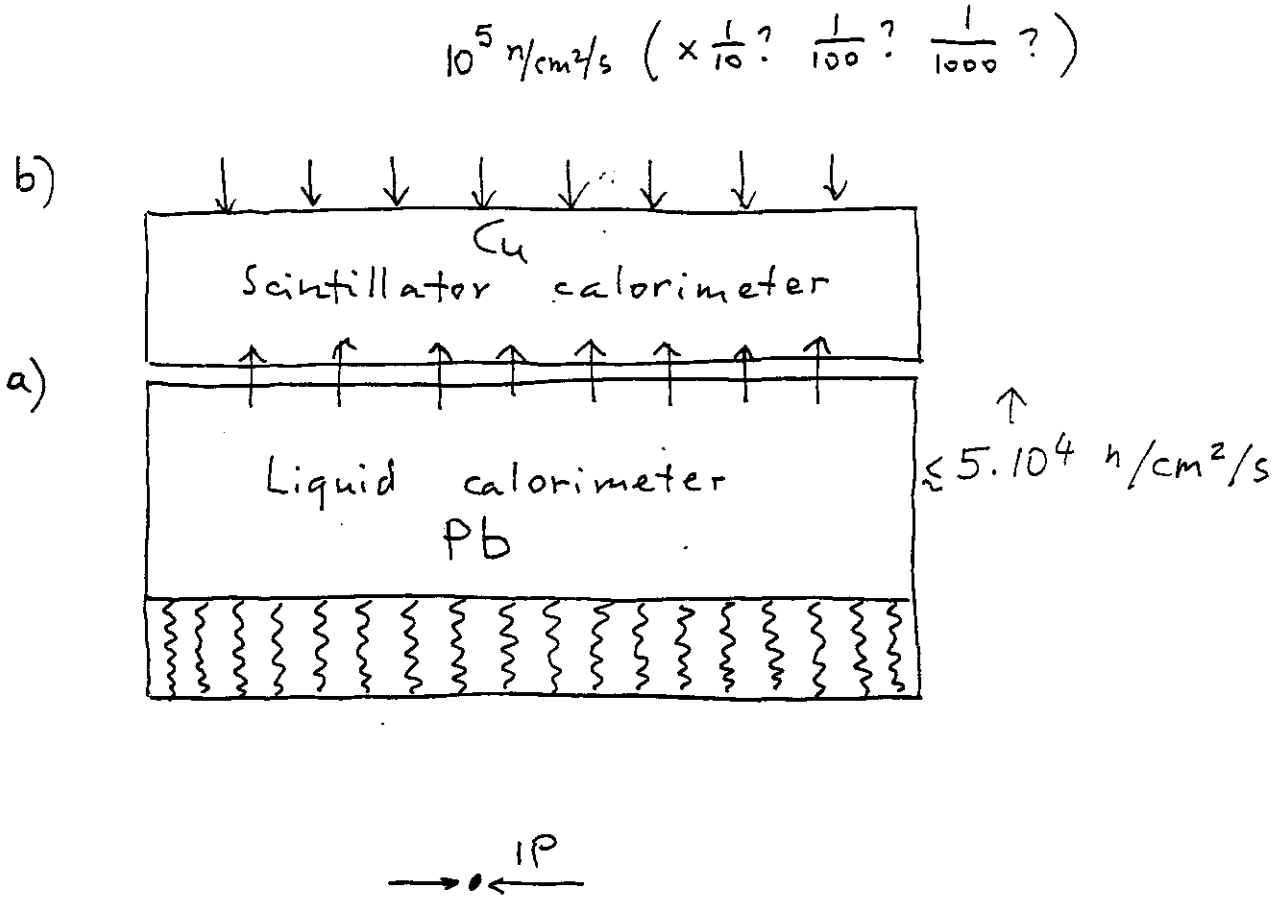
G.Leskens

# Neutrons in scintillator / Cu calorimeter barrel




Source a): $|\eta| < 2 \rightarrow \langle 30\ \text{GeV} \rangle$ per interaction

In lead: ~ 40 n/GeV are produced
( ~ 10 n/GeV if Cu )
No hydrogen in Liq. section to moderate neutrons.

Major part of these neutrons will be absorbed in sci. cal.
Average energy of these neutrons $\lesssim$ 1-2 MeV
2 MeV neutrons — 8% / cm det. effic. by sci
with 0.1 MeV (electron) threshold

$\Rightarrow 5 \cdot 10^3$ n-conversions / cm³ / s in sci.

5000 n-conversions / cm³ / s in sci

Let's assume scint. slab has a size

1000 x 10 x 2 cm³

Counting rate : $10 \cdot 10^7$ "n"/s/PMT

For the time interval of 100 ns :

10 "n" / PMT

1 MeV n ⇒ <0.5 MeV> p ⇒ 0.055 MeV signal (in μ-units)

m.i.p μ ⇒ 4 MeV / 2 cm sci. slab

| |
|---|
| "μ" signal is ~70 times larger than "n" signal |

2 cm slab can be subdivided into 6 x 3 mm layers with sample Cu absorber ~ each 3 cm (~ $2X_0$)

μ-signal from the far end of the 10 m slab

~ 12 p.e.

Neutron signals are from 0 to ~ 2 p.e.

<u>Source b</u>: is believed to be reduced by factor 10–1000

and will be less than source a)

B-110
1976

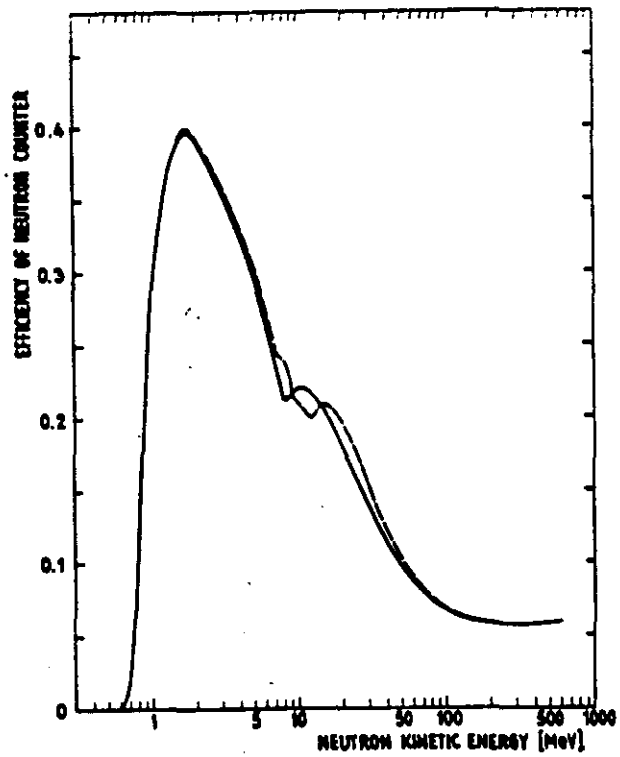


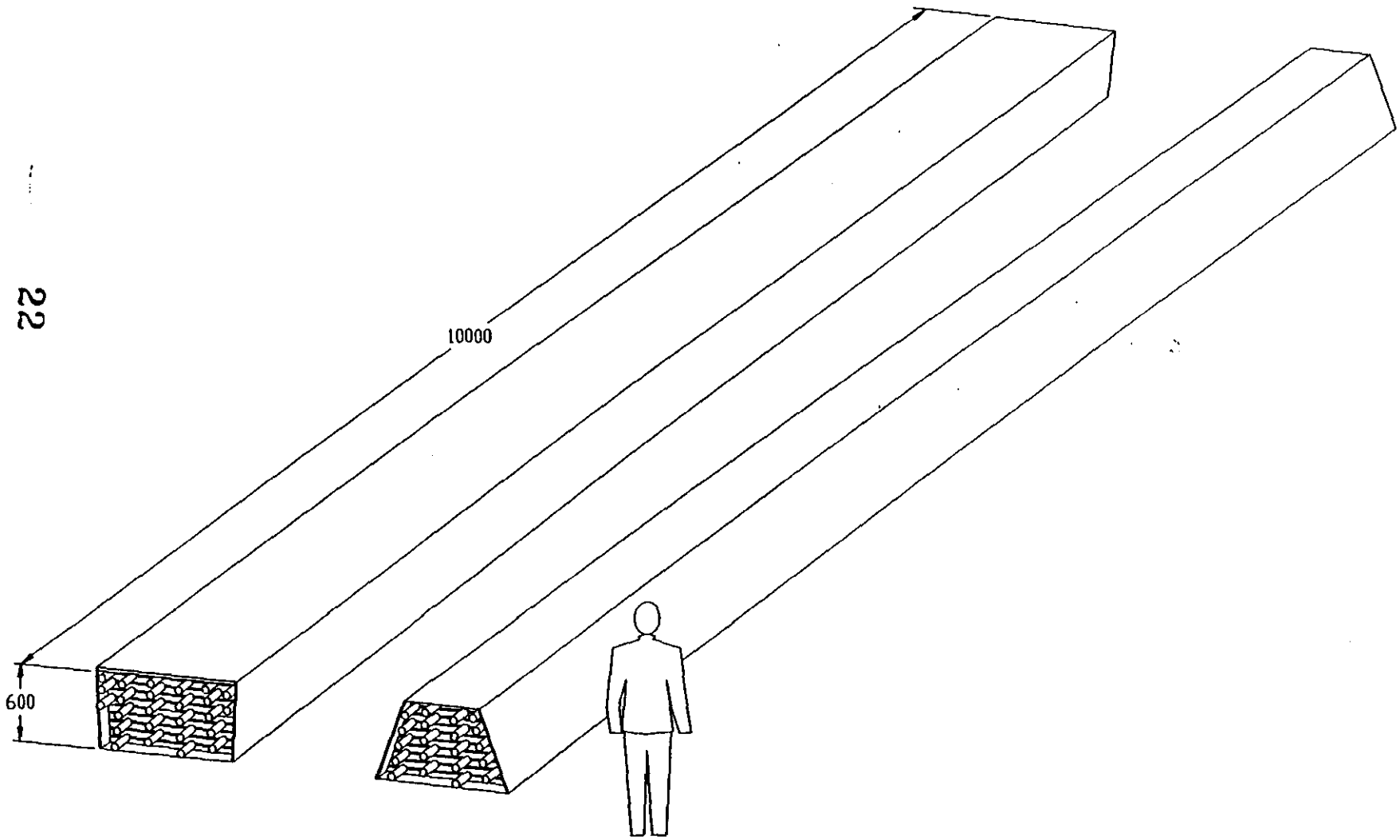

**Fig. 3. The neutron counter detection efficiency as calculated with a revised version of the Oak Ridge Code 05S (ref. [10]). The solid line curve was obtained with cross section data taken from ref. [11]; for the dashed line the Oak Ridge data were used. The evaluation of the cross sections was based on the solid curve.**

ranged in a circle with a radius of 62.5 cm from the target, the slabs being positioned horizontally parallel to the beam. Both ends of each scintillator were viewed by 56 AVP photomultipliers, allowing the localization of the neutron interaction point from the timing difference with an accuracy of ±3 cm. In order to achieve a good time resolution "constant fraction timing circuits" were used. Also the pulse heights from the photomultipliers were recorded in order to correct the timing for possible pulse-height effects. The time of flight of the neutron was measured by signals from the neutron interaction and from P2 as well as P3. The azimuthal angle of the recoil neutron was established by the number of the counter which had fired.

The threshold of the neutron counters were set at 0.1 MeV electron energy by means of $^{60}$Co and $^{137}$Cs sources. Their position was rechecked nearly every day.

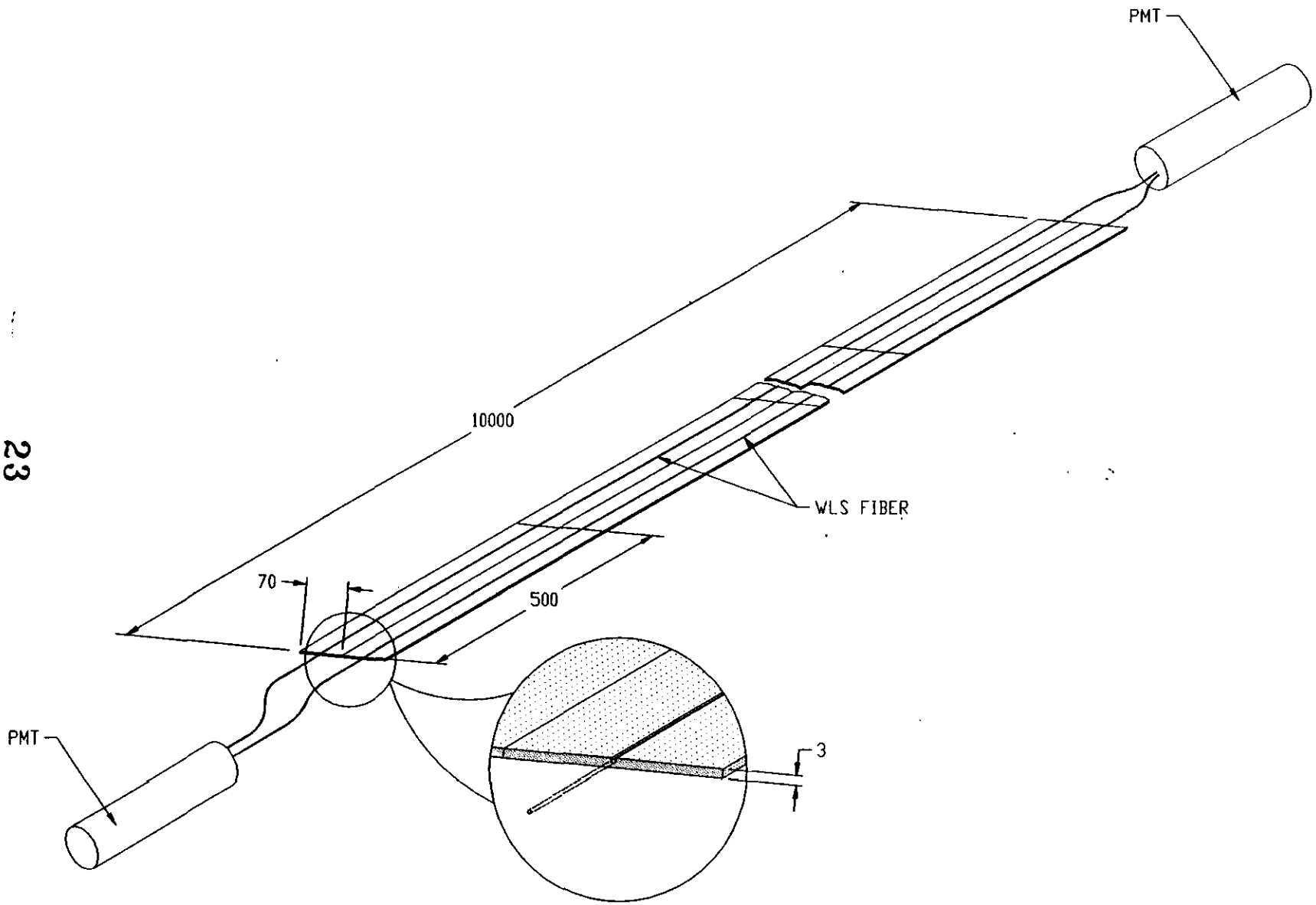
The efficiency of the counter was calculated using a Monte Carlo type program successfully applied previously [10] and adjusted for our geometry. The efficiency curve used for the final analysis is shown as a solid line in fig. 3. It has a maximum of about 40% at 2 MeV neutron energy and decreases to about 6% at 100 MeV.

Two possible sources of errors in this curve were investigated:



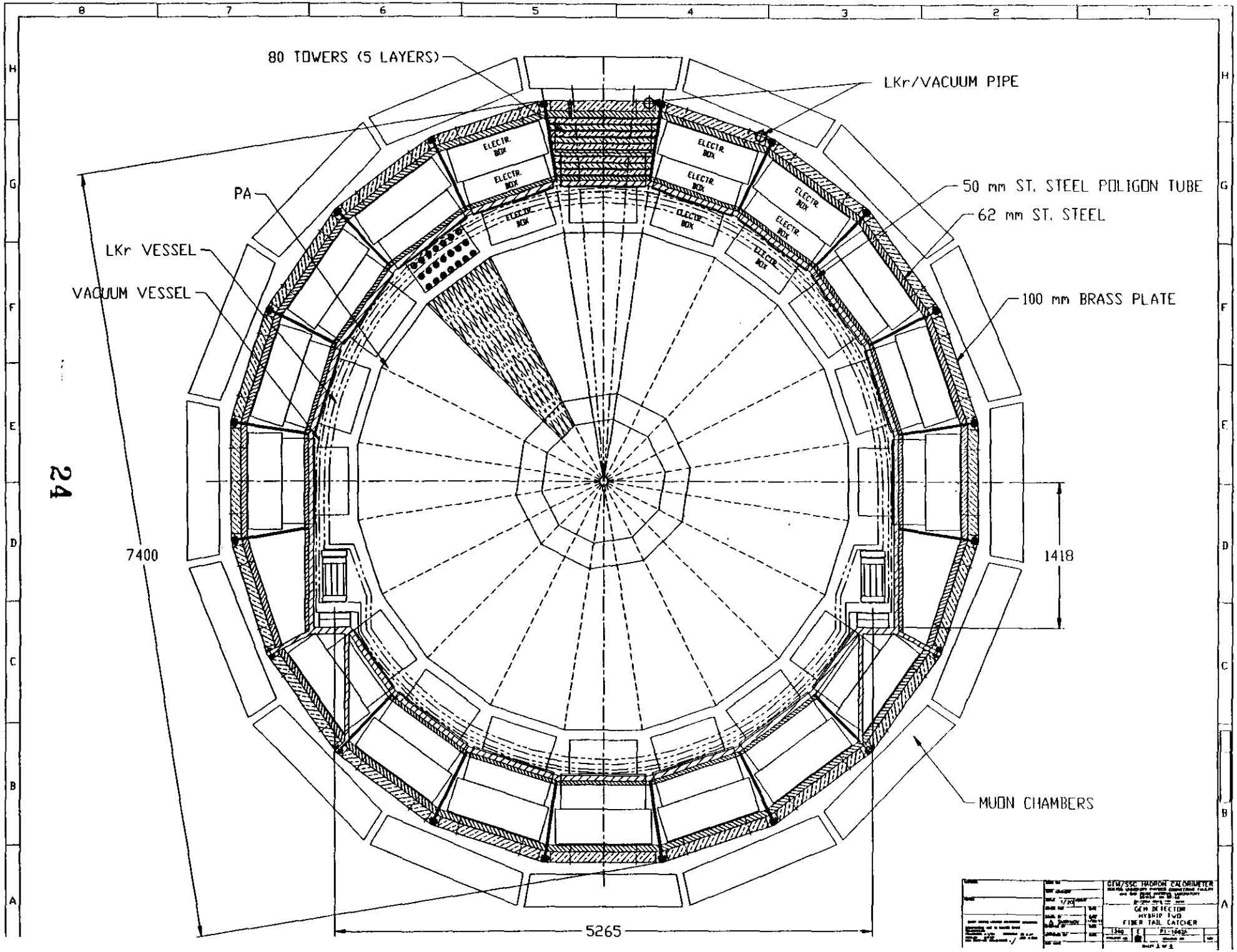

GEM/SSC HADRON CALORIMETER

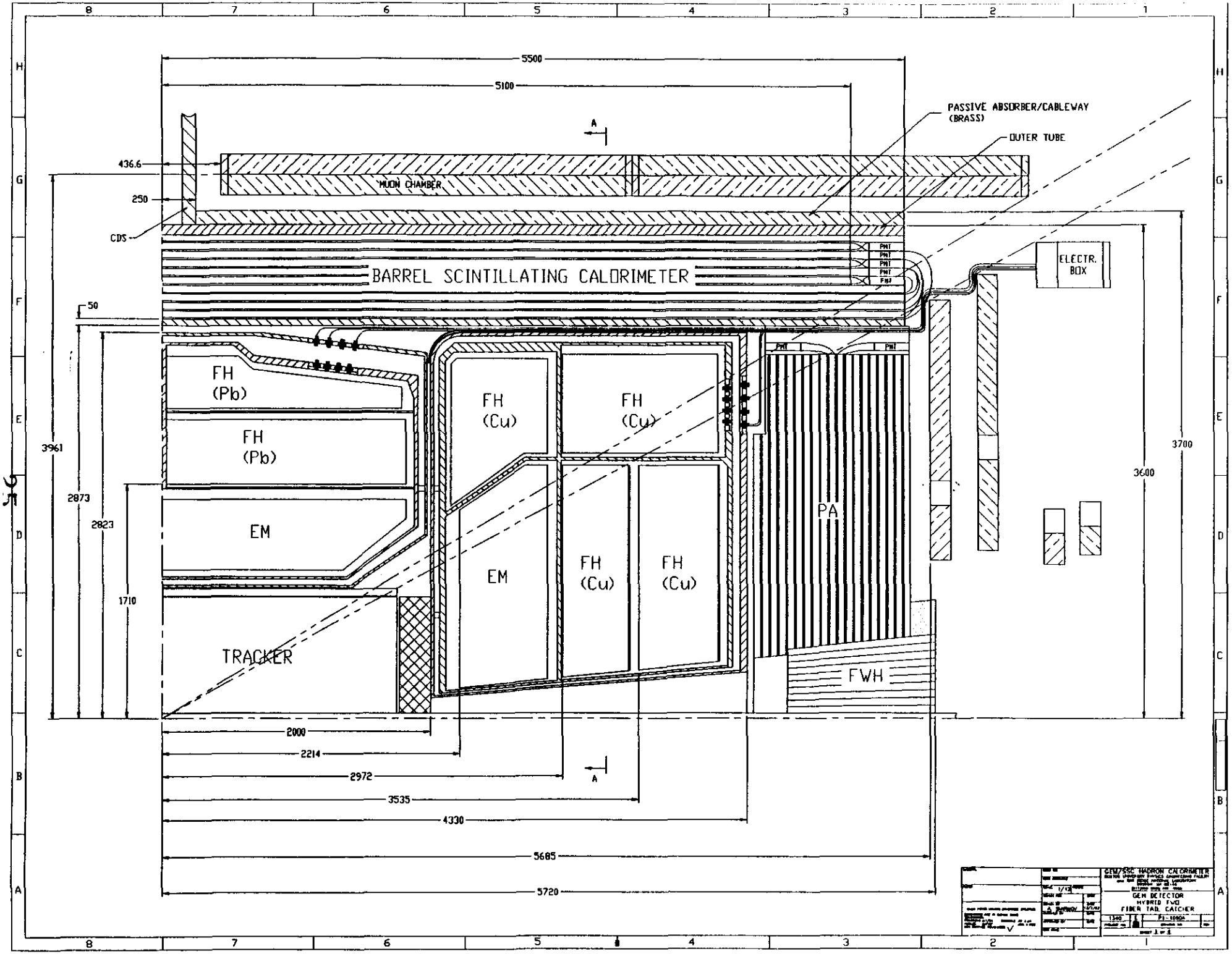
GEM DETECTOR
FIBER TAIL CATCHER
ISOMETRIC VIEW




GEM/SSC HADRON CALORIMETER

GEM DETECTOR
FIBER TAIL CATCHER
SCINTILLATING ASSEMBLY


80 TOWERS (5 LAYERS)
LKr/VACUUM PIPE
PA
LKr VESSEL
VACUUM VESSEL
50 mm ST. STEEL POLIGON TUBE
62 mm ST. STEEL
100 mm BRASS PLATE
MUON CHAMBERS
ELECTR. BOX
7400
1418
5265
GEM/SSC HADRON CALORIMETER
GEM DETECTOR
HYBRID TWD
FIBER TAIL CATCHER


5500
5100
PASSIVE ABSORBER/CABLEWAY (BRASS)
OUTER TUBE
A
436.6
250
CDS
MUON CHAMBER
BARREL SCINTILLATING CALORIMETER
PMT
ELECTR. BOX
50
FH (Pb)
FH (Pb)
EM
TRACKER
FH (Cu)
FH (Cu)
EM
FH (Cu)
FH (Cu)
PA
FWH
3961
2873
2823
1710
3700
3600
2000
2214
2972
3535
4330
5685
5720
GEM/SSC HADRON CALORIMETER
GEM DETECTOR
HYBRID FWD
FIBER TAIL CATCHER

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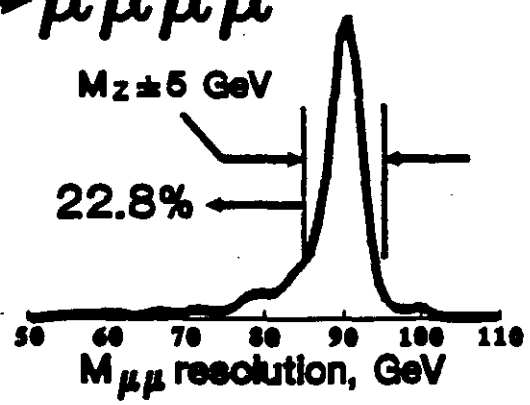
# COMMENT

**High precision in $\mu$-measurement implies:**

<u>Muon radiation losses are corrected for</u>

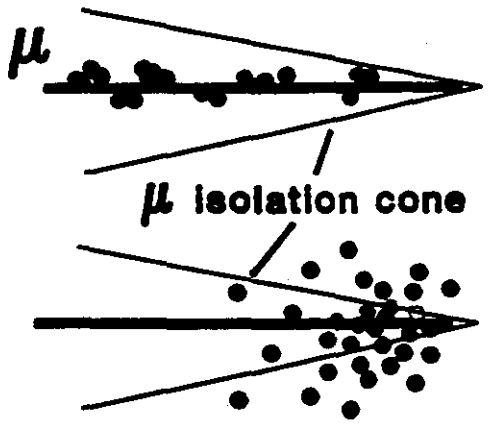
Example : $H \rightarrow Z^0 Z^0 \rightarrow \mu\mu\mu\mu$

**40% of**
**1 TeV $H^0$ events**
**will be lost**




**(a) $\mu$ radiation losses are UNIFORM along the track**

**(b) Hadron debris are quickly dying while spreading outwards**

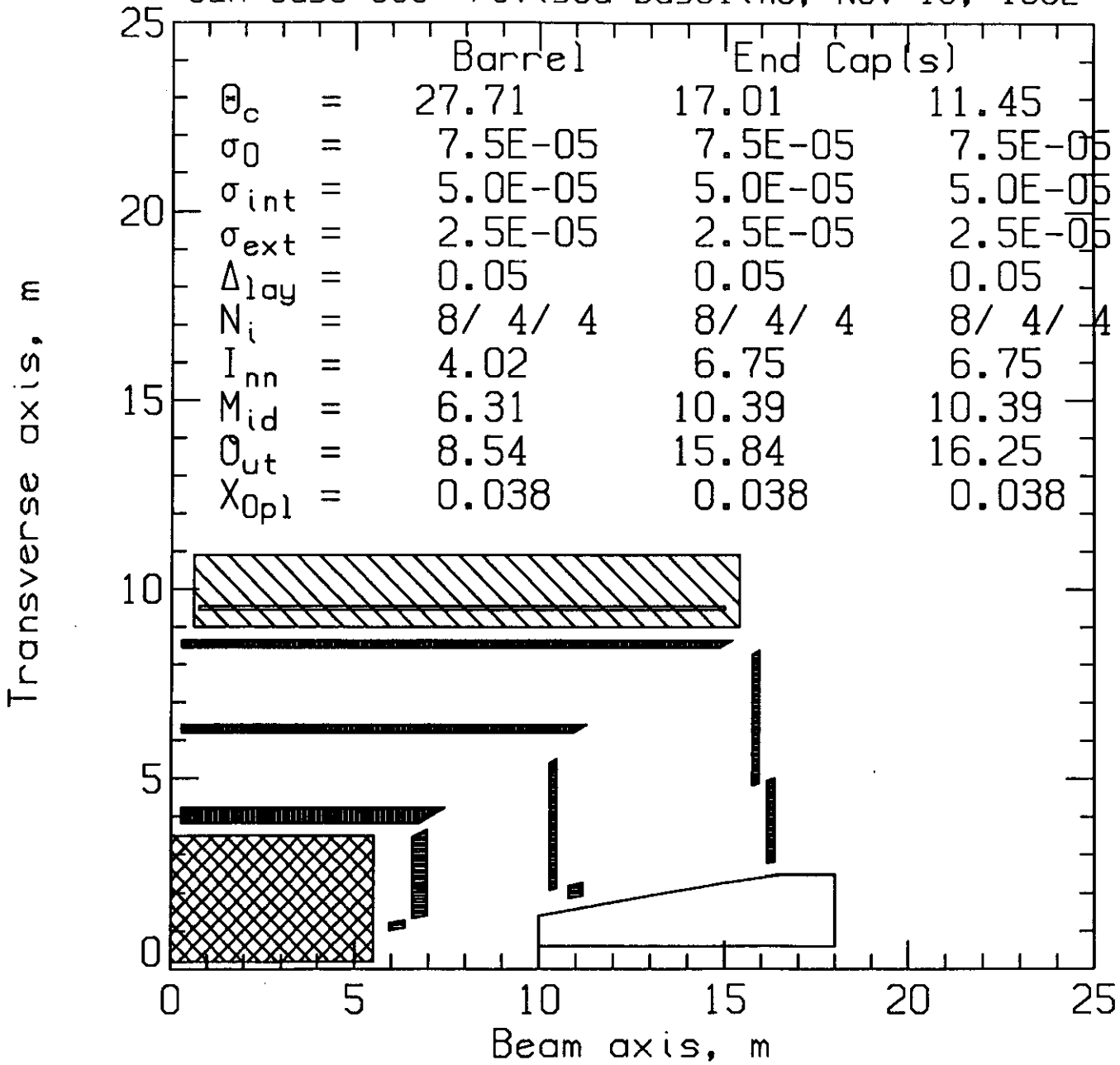



**To distinguish (a) from (b) longitudinal segmentation is necessary**

Jim Sullivan

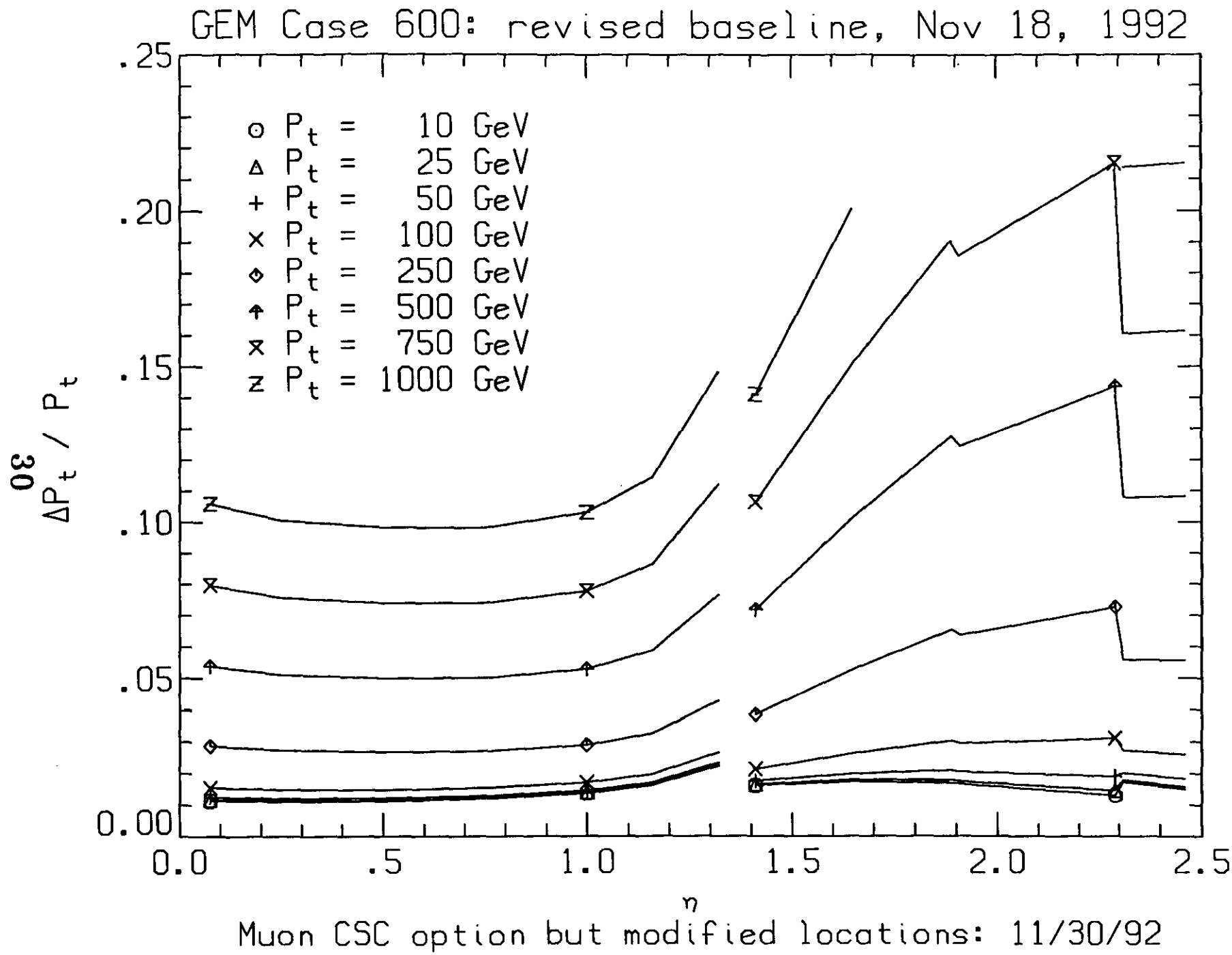
# Resolutions in BL-2

GEM Case 600: revised baseline, Nov 18, 1992

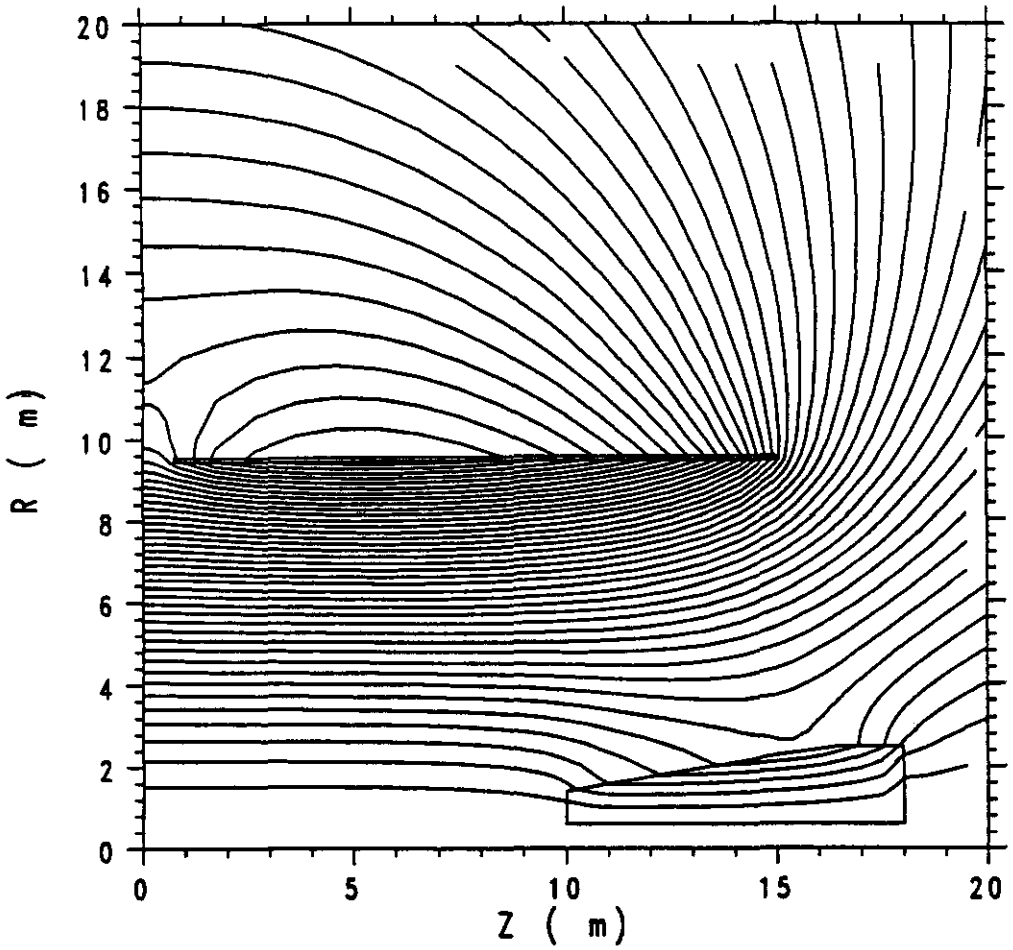



| | | | | | |
|---|---|---|---|---|---|
| $\Theta_c$ | = | 27.71 | 17.01 | 11.45 | 9.75 |
| $\sigma_0$ | = | 7.5E-05 | 7.5E-05 | 7.5E-05 | 7.5E-05 |
| $\sigma_{int}$ | = | 5.0E-05 | 5.0E-05 | 5.0E-05 | 5.0E-05 |
| $\sigma_{ext}$ | = | 2.5E-05 | 2.5E-05 | 2.5E-05 | 2.5E-05 |
| $\Delta_{lay}$ | = | 0.05 | 0.05 | 0.05 | 0.05 |
| $N_i$ | = | 8/ 4/ 4 | 8/ 4/ 4 | 8/ 4/ 4 | 8/ 8/ 4 |
| $I_{nn}$ | = | 4.02 | 6.75 | 6.75 | 6.14 |
| $M_{id}$ | = | 6.31 | 10.39 | 10.39 | 11.00 |
| $O_{ut}$ | = | 8.54 | 15.84 | 16.25 | 16.25 |
| $X_{0pl}$ | = | 0.038 | 0.038 | 0.038 | 0.038 |

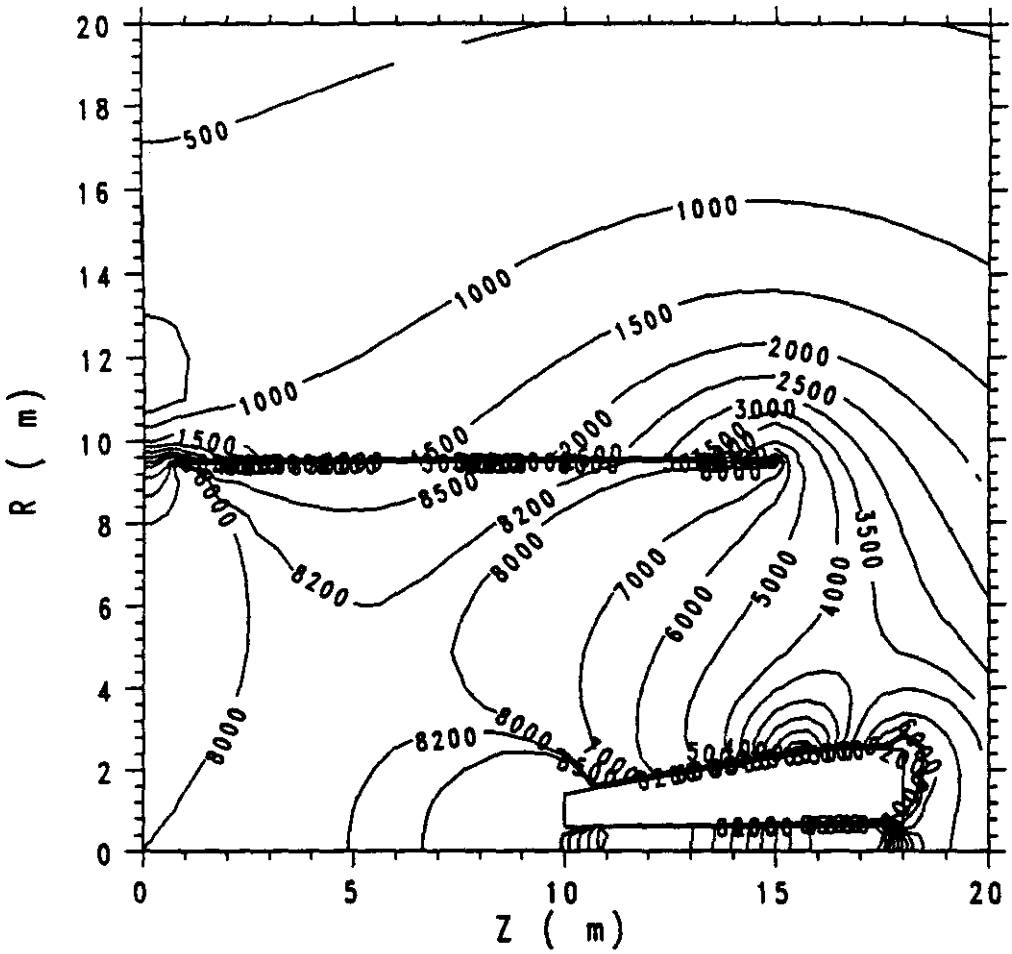
Muon CSC option but modified locations: 11/30/92


GEM Case 600: revised baseline, Nov 18, 1992
⊙ $P_t$ = 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
$\Delta P_t / P_t$
.25
.20
.15
.10
.05
0.00
0.0
.5
1.0
1.5
2.0
2.5
$\eta$
Muon CSC option but modified locations: 11/30/92

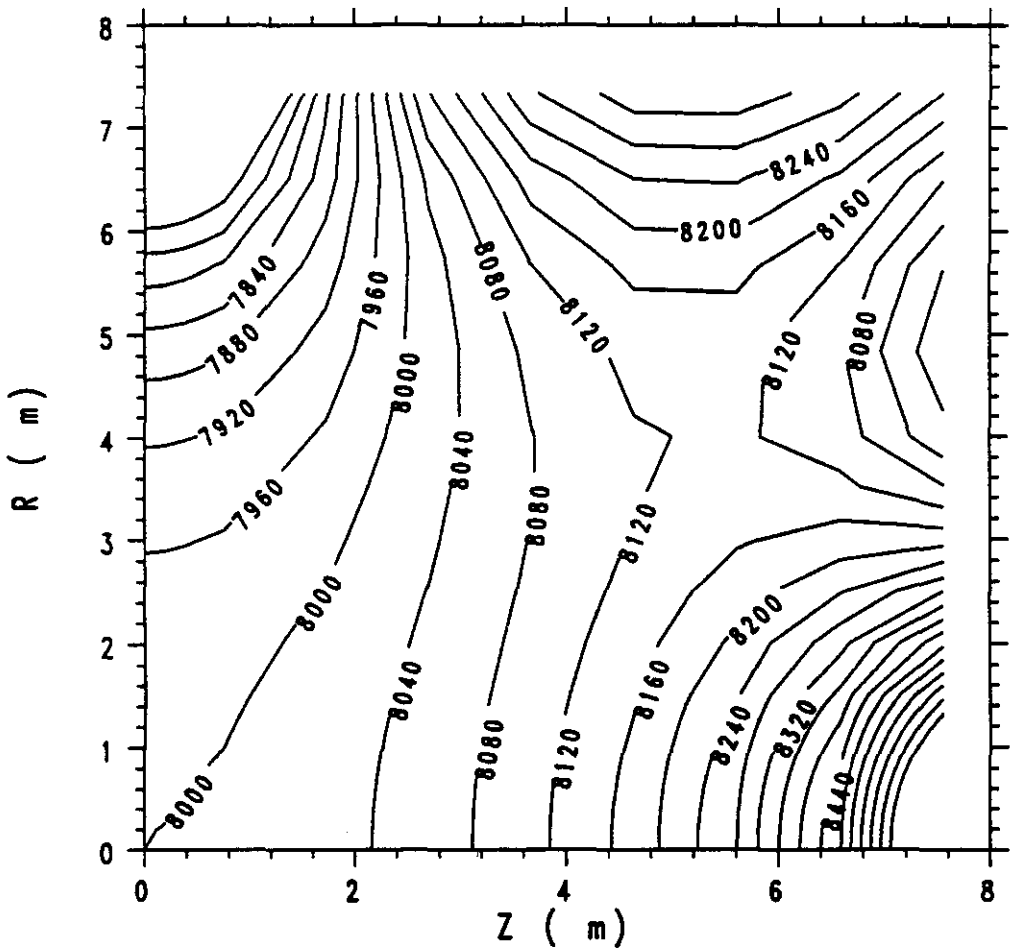
GEM Case 600: revised baseline, Nov 18, 1992



GEM Case 600: revised baseline, Nov 18, 1992



GEM Case 600: revised baseline, Nov 18, 1992



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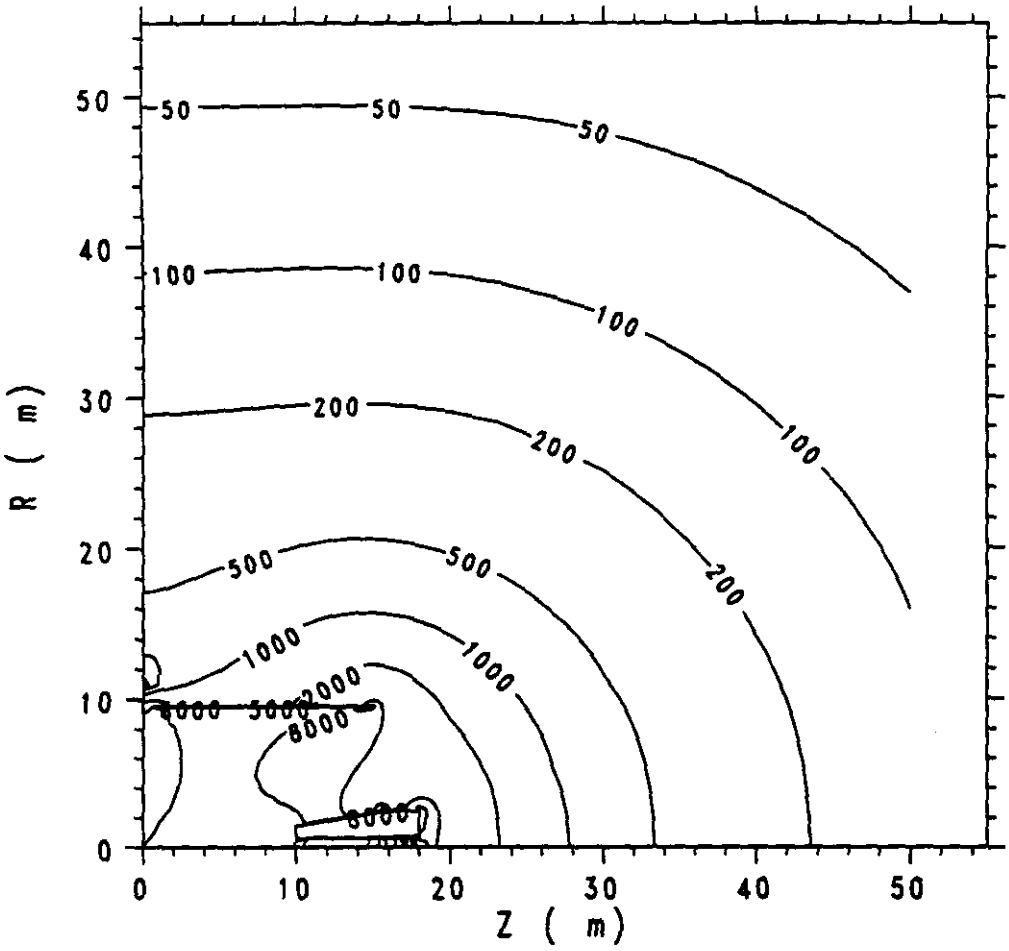
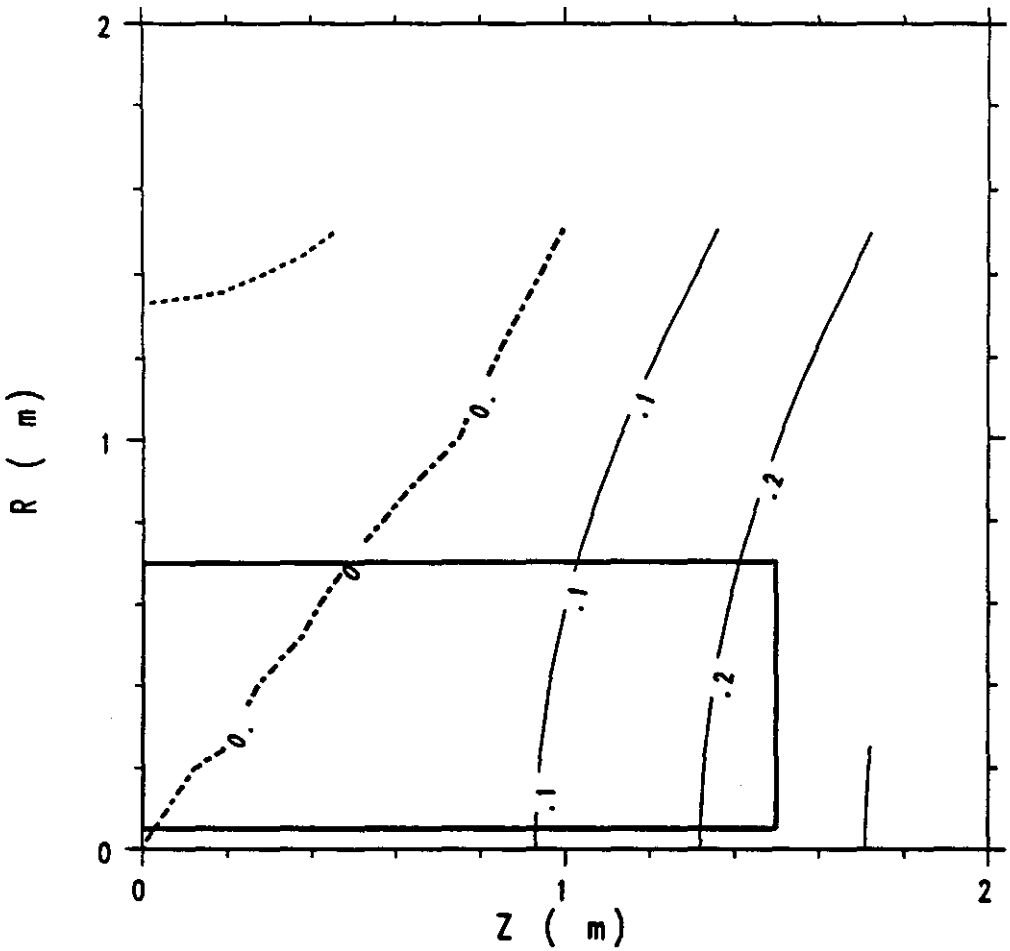
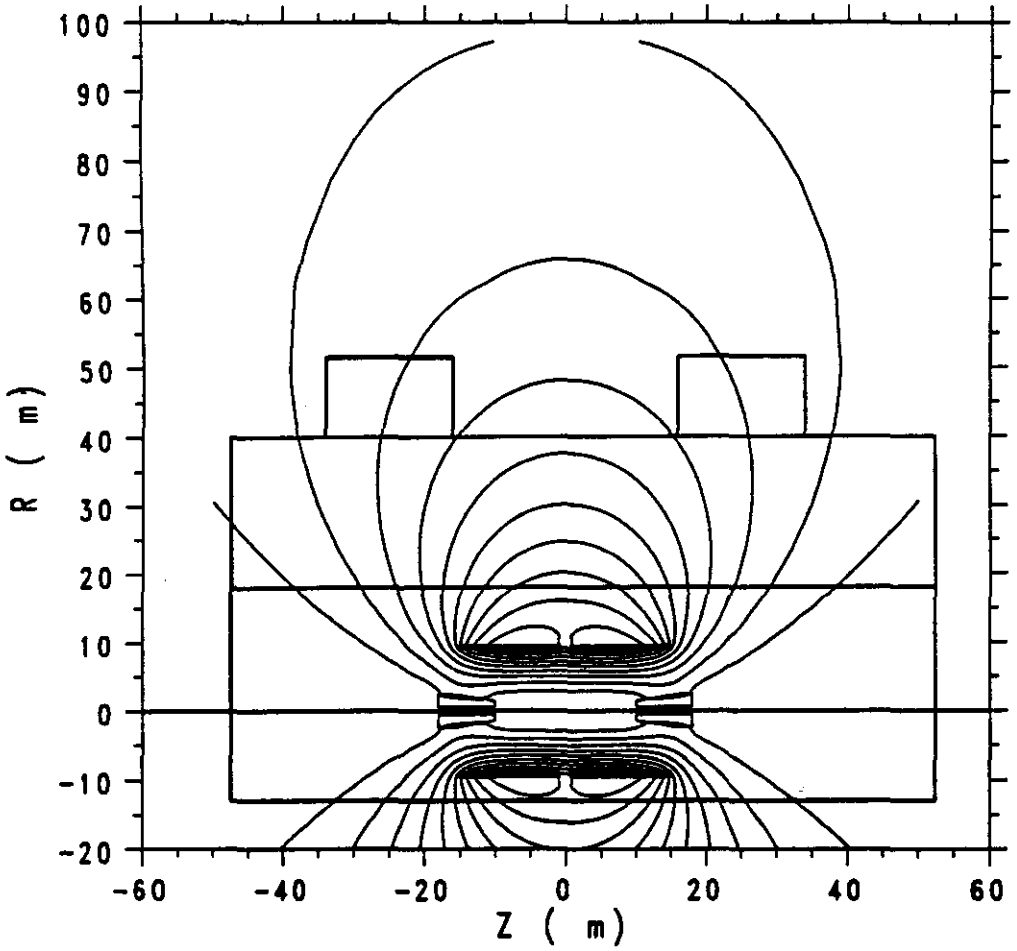
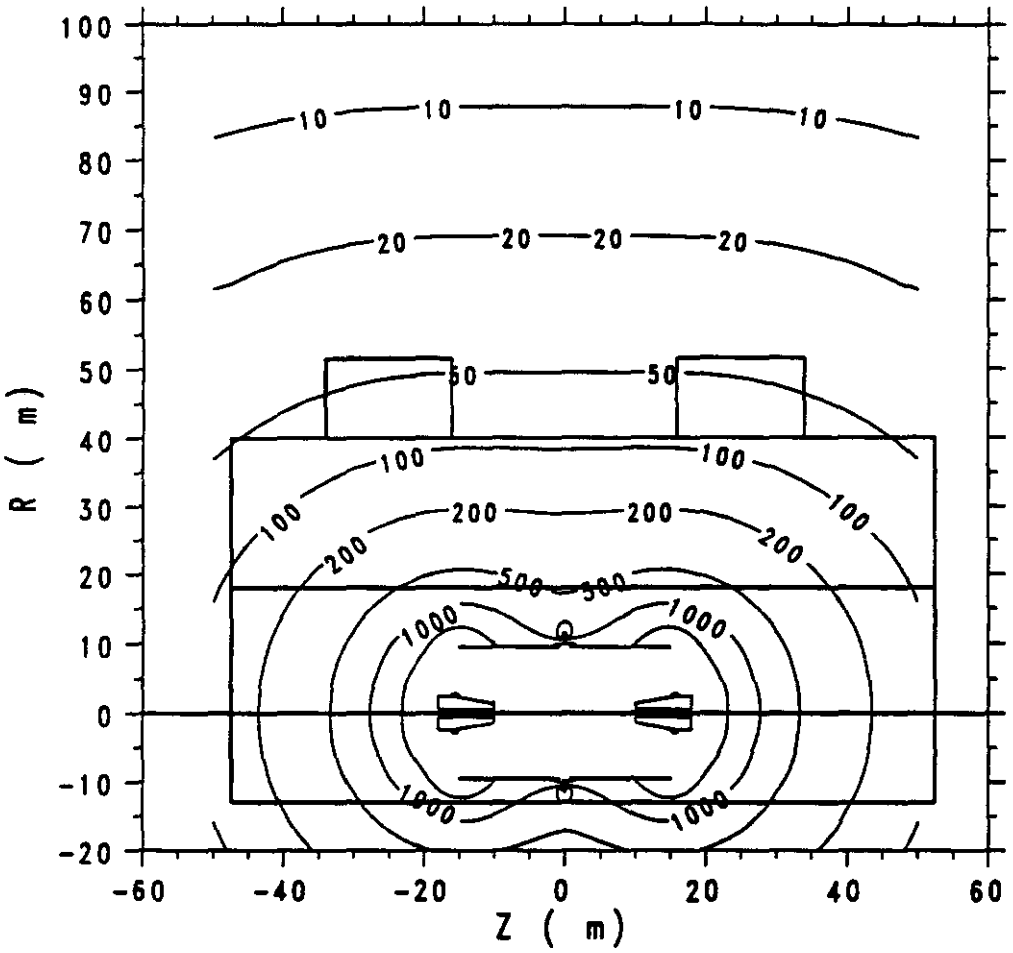
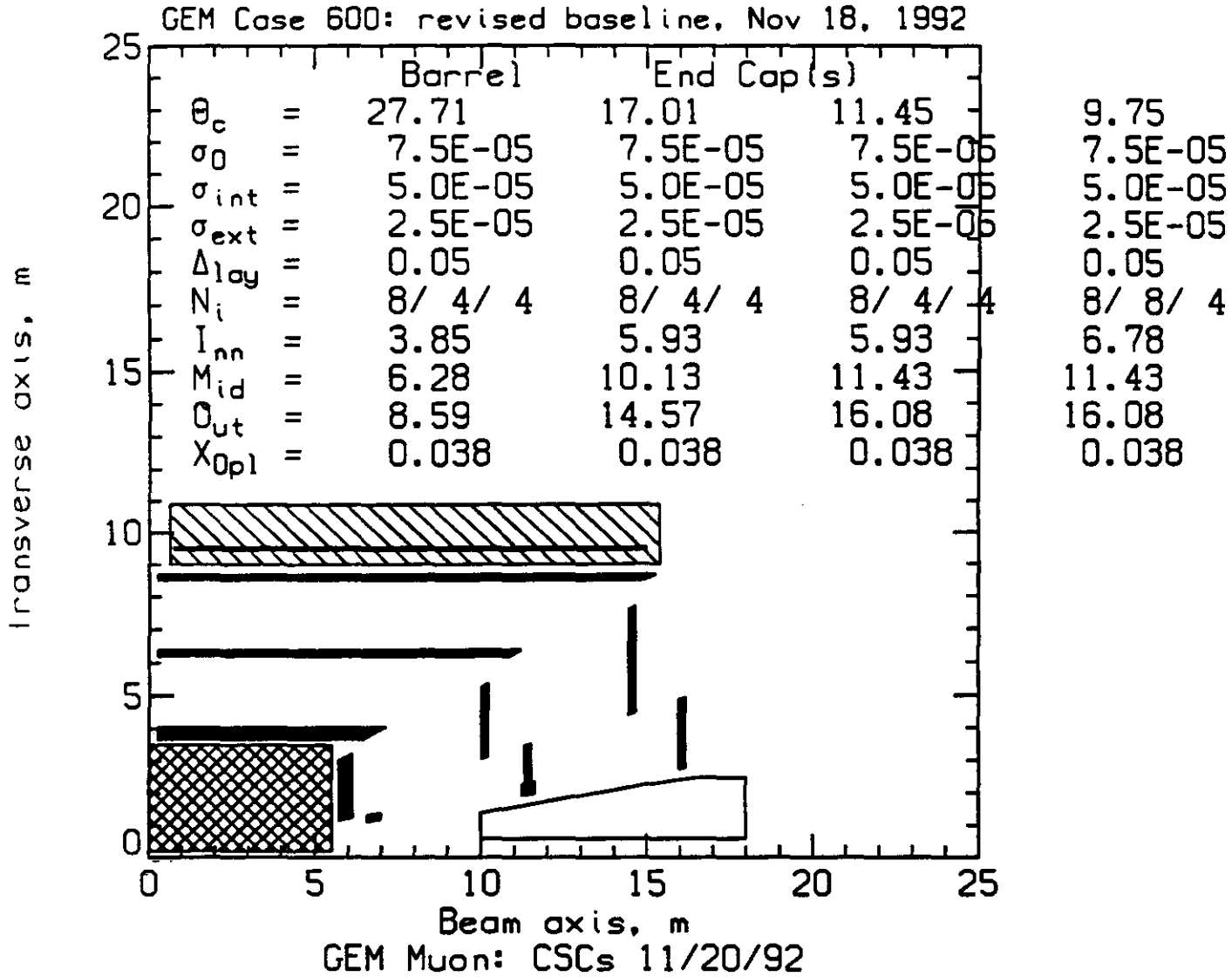


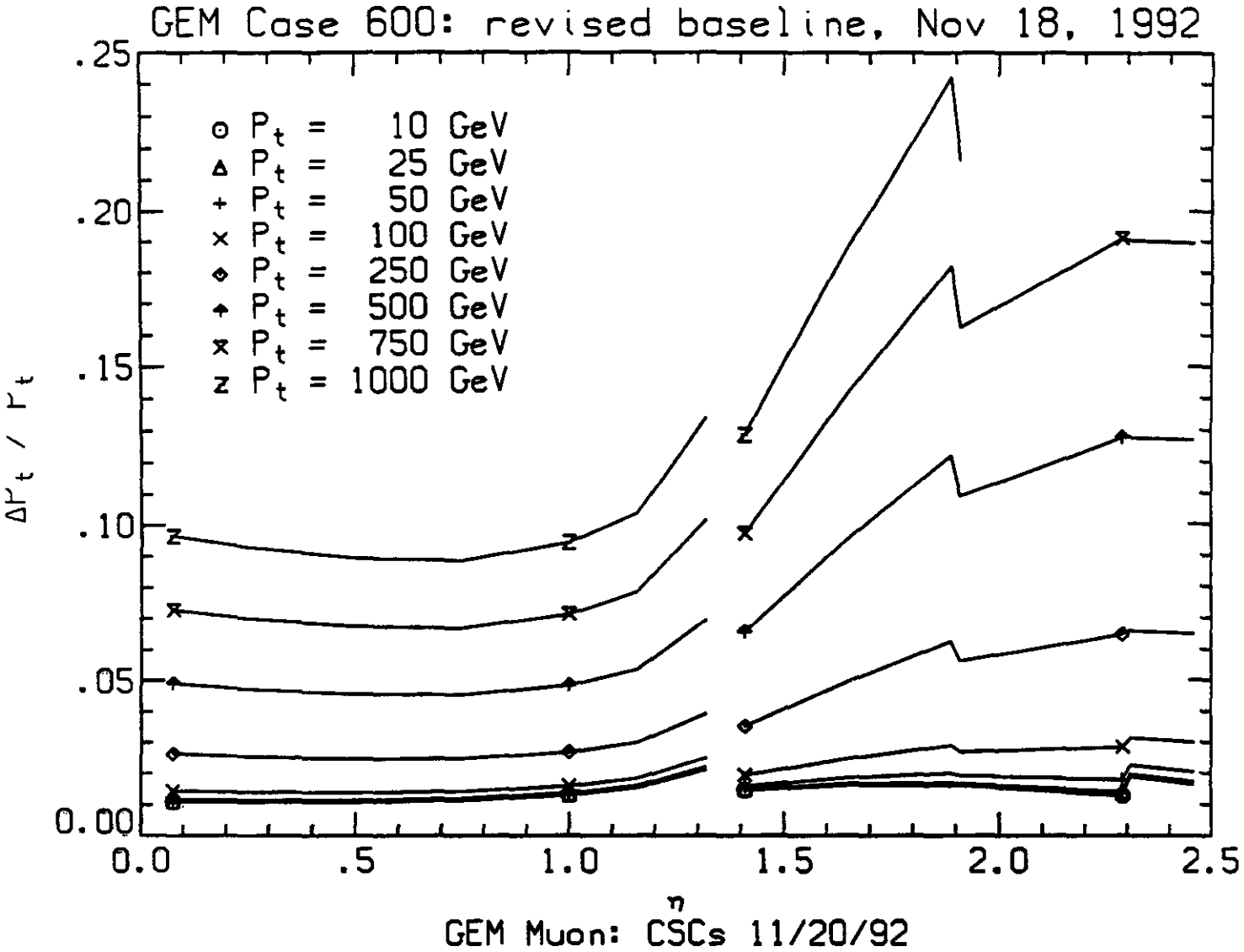
GEM Case 600: revised baseline, Nov 18, 1992




100
90
80
70
60
50
40
30
20
10
0
-10
-20
R ( m)
-60
-40
-20
0
20
40
60
Z ( m)


R ( m )
Z ( m )
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-60
-40
-20
0
20
40
60
10
20
50
100
200
500
1000


GEM Case 600: revised baseline, Nov 18, 1992
Barrel
End Cap(s)
θc = 27.71 17.01 11.45 9.75
σ0 = 7.5E-05 7.5E-05 7.5E-05 7.5E-05
σint = 5.0E-05 5.0E-05 5.0E-05 5.0E-05
σext = 2.5E-05 2.5E-05 2.5E-05 2.5E-05
Δlay = 0.05 0.05 0.05 0.05
Ni = 8/ 4/ 4 8/ 4/ 4 8/ 4/ 4 8/ 8/ 4
Inn = 3.85 5.93 5.93 6.78
Mid = 6.28 10.13 11.43 11.43
Out = 8.59 14.57 16.08 16.08
X0pl = 0.038 0.038 0.038 0.038
Transverse axis, m
Beam axis, m
0
5
10
15
20
25
GEM Muon: CSCs 11/20/92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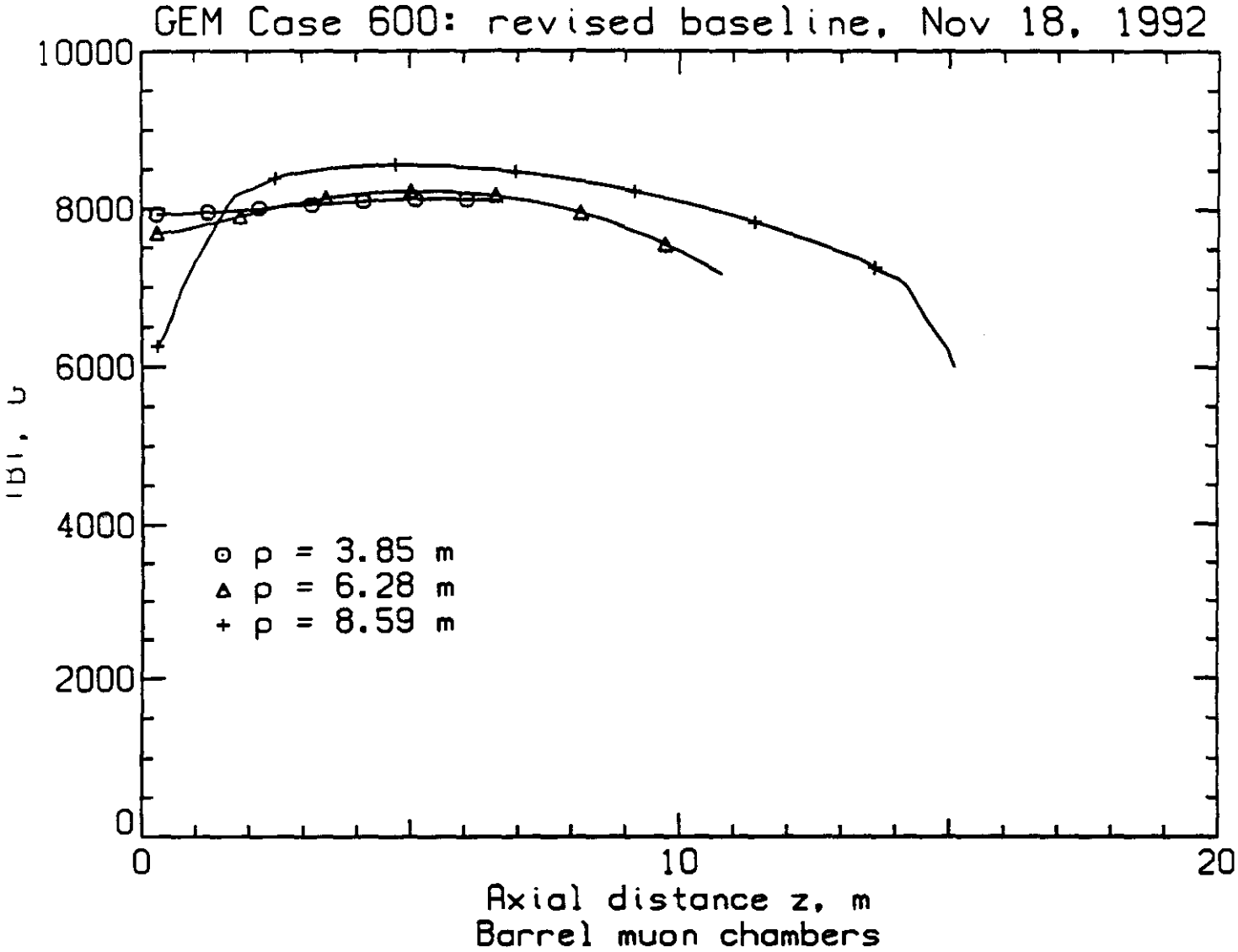
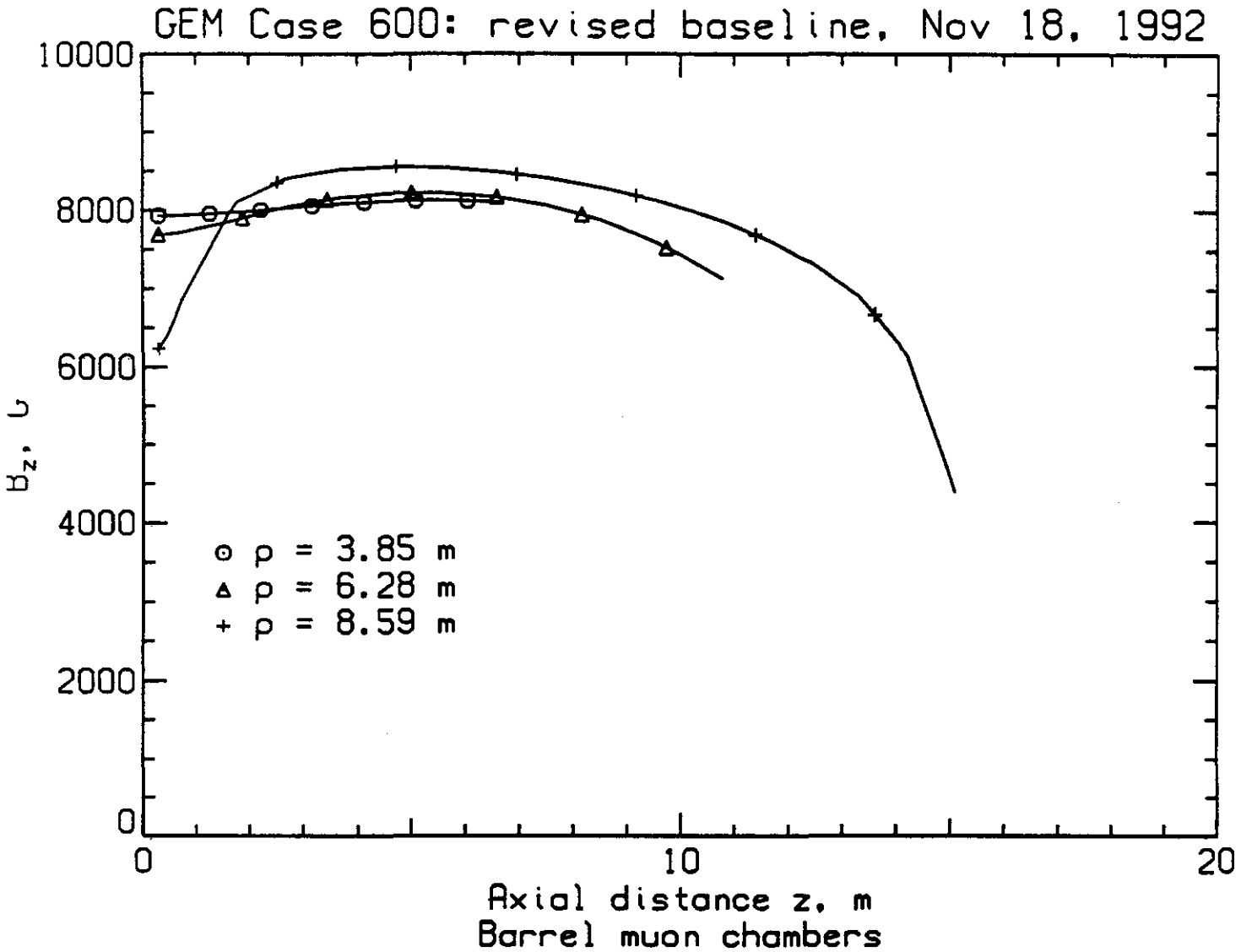
△ $P_t$ = 25 GeV
+ $P_t$ = 50 GeV
× $P_t$ = 100 GeV
◇ $P_t$ = 250 GeV
♠ $P_t$ = 500 GeV
⧖ $P_t$ = 750 GeV
z $P_t$ = 1000 GeV
$\Delta P_t / P_t$
.25
.20
.15
.10
.05
0.00
0.0
.5
1.0
1.5
2.0
2.5
$\eta$
GEM Muon: CSCs 11/20/92


GEM Case 600: revised baseline, Nov 18, 1992
10000
8000
6000
4000
2000
0
|B|, G
0
10
20
Axial distance z, m
Barrel muon chambers
p = 3.85 m
p = 6.28 m
p = 8.59 m

CSCs


GEM Case 600: revised baseline, Nov 18, 1992
10000
8000
6000
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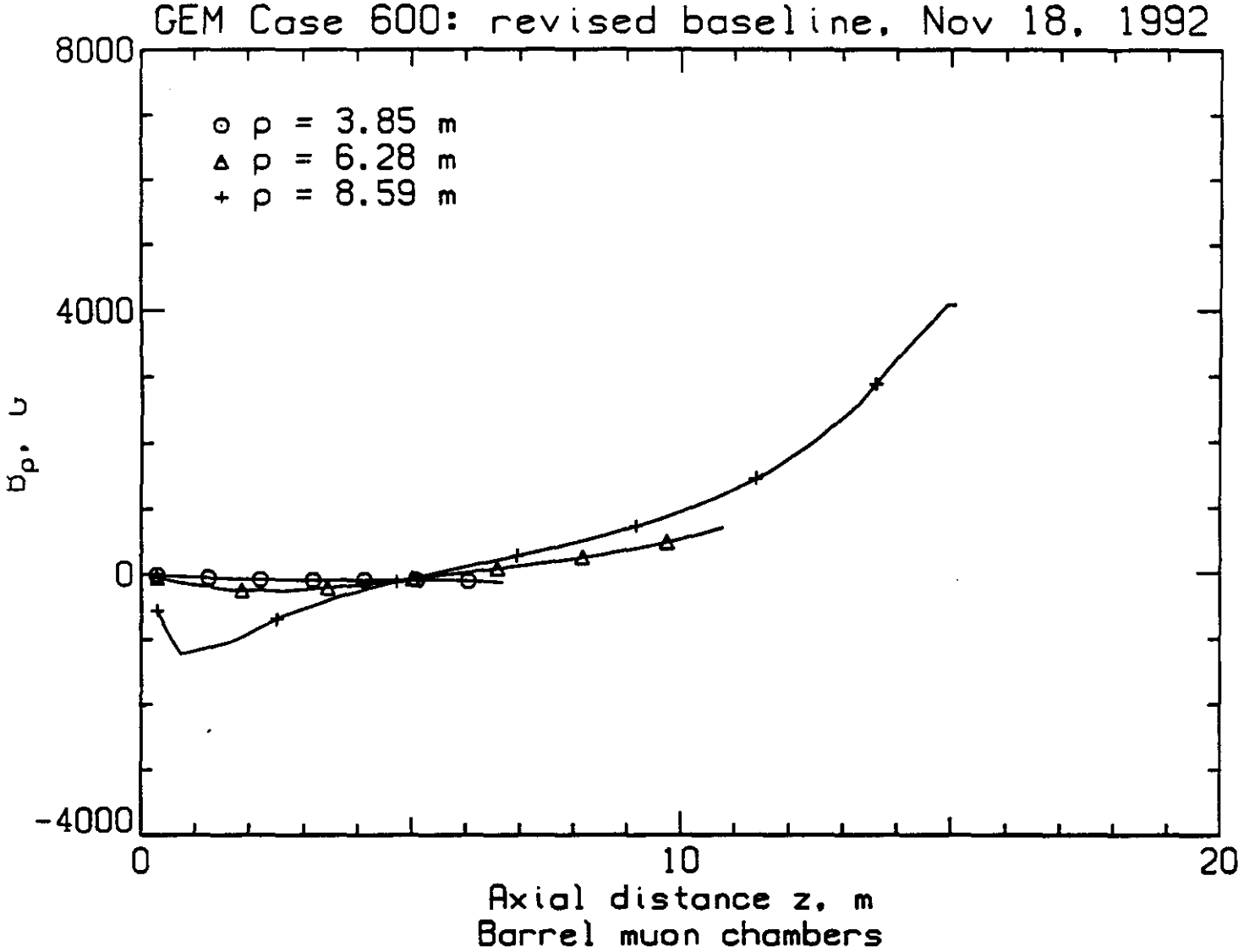
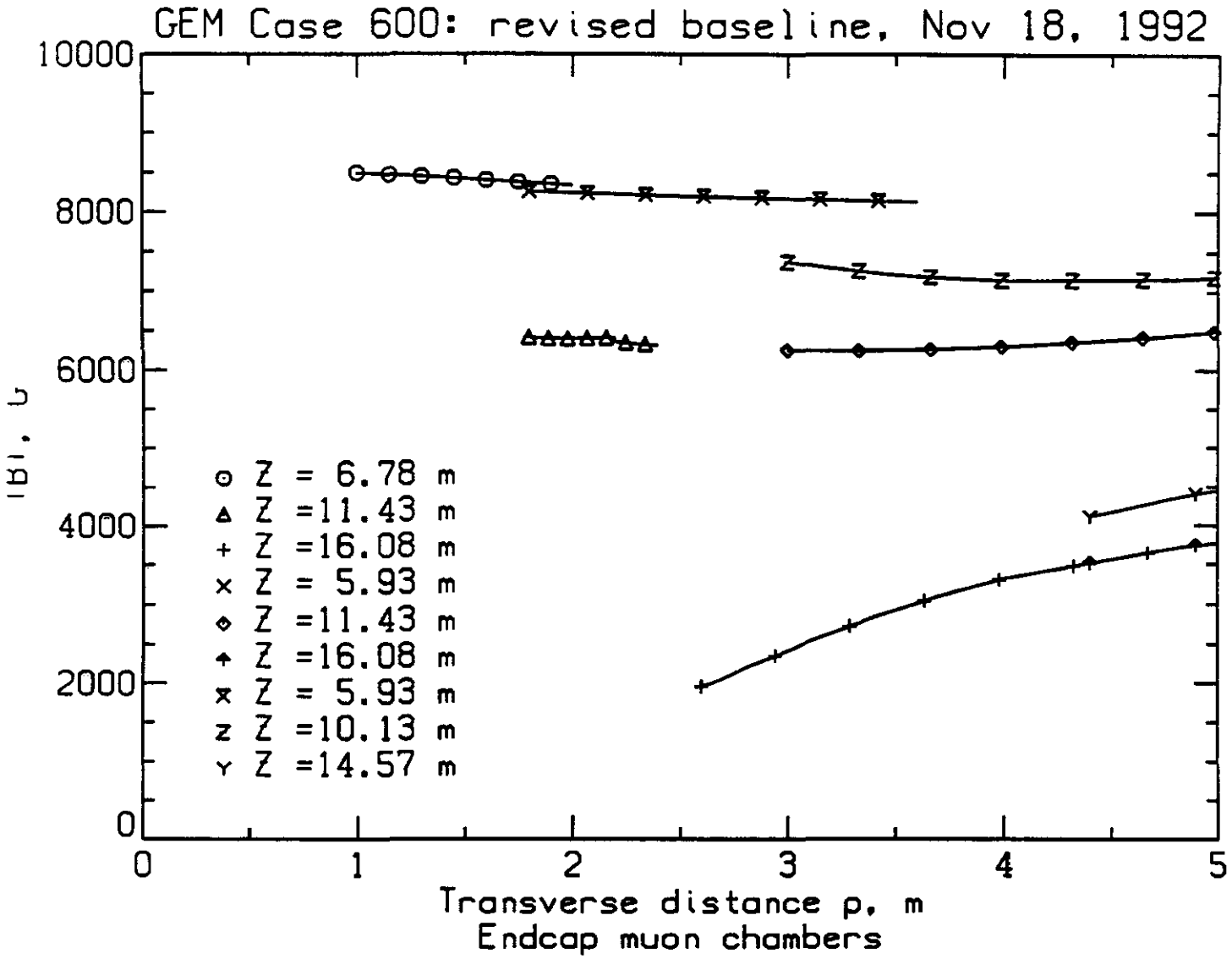
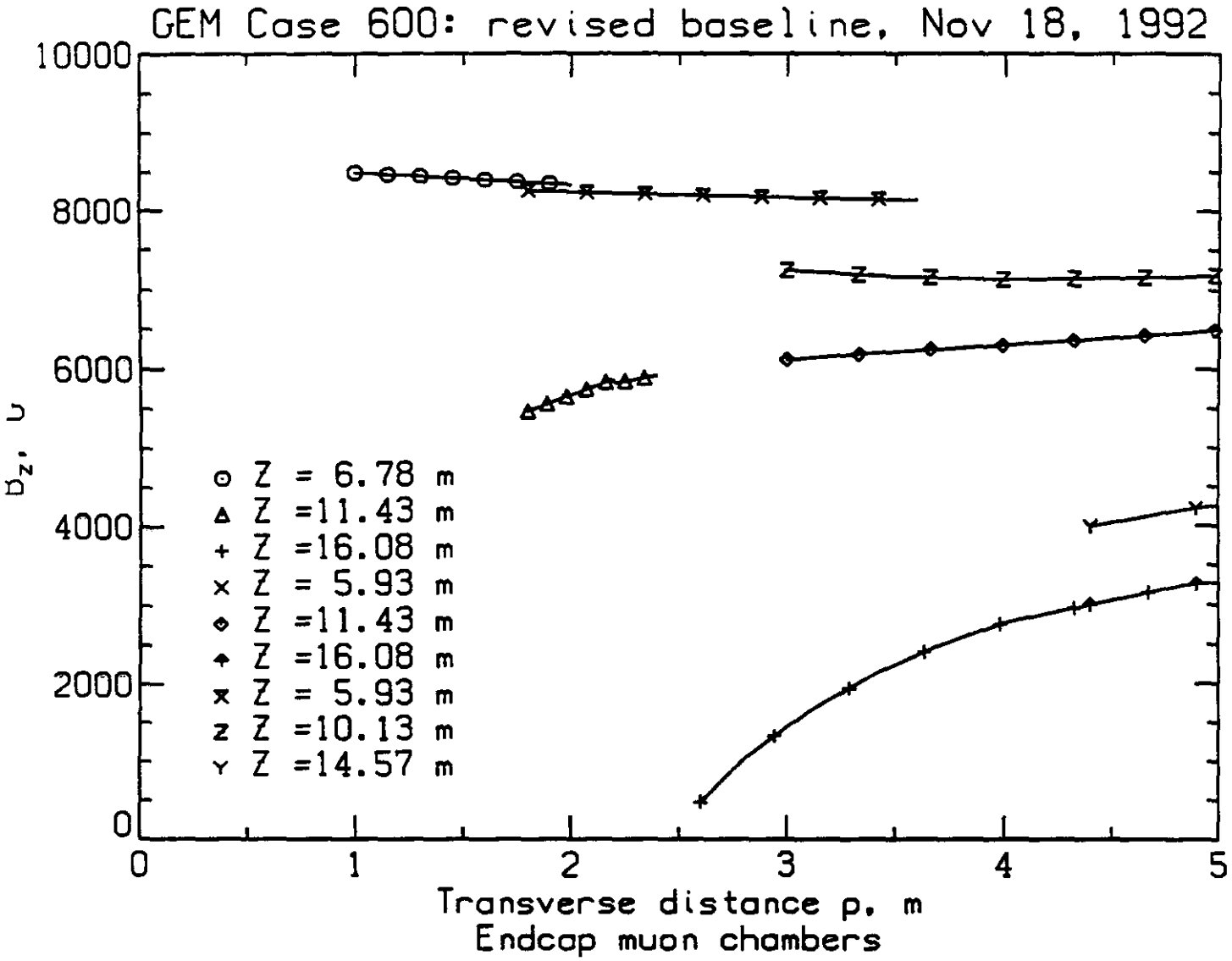
2000
0
$B_z$, G
⊙ ρ = 3.85 m
△ ρ = 6.28 m
+ ρ = 8.59 m
0
10
20
Axial distance z, m
Barrel muon chambers


GEM Case 600: revised baseline, Nov 18, 1992
8000
4000
0
-4000
0
10
20
o ρ = 3.85 m
Δ ρ = 6.28 m
+ ρ = 8.59 m
Axial distance z, m
Barrel muon chambers


GEM Case 600: revised baseline, Nov 18, 1992
10000
8000
6000
4000
2000
0
|B|, G
0
1
2
3
4
5
Transverse distance ρ, m
Endcap muon chambers
Z = 6.78 m
Z =11.43 m
Z =16.08 m
Z = 5.93 m
Z =11.43 m
Z =16.08 m
Z = 5.93 m
Z =10.13 m
Z =14.57 m


GEM Case 600: revised baseline, Nov 18, 1992
10000
8000
6000
4000
2000
0
$B_z$, G
0
1
2
3
4
5
Transverse distance ρ, m
Endcap muon chambers
Z = 6.78 m
Z =11.43 m
Z =16.08 m
Z = 5.93 m
Z =11.43 m
Z =16.08 m
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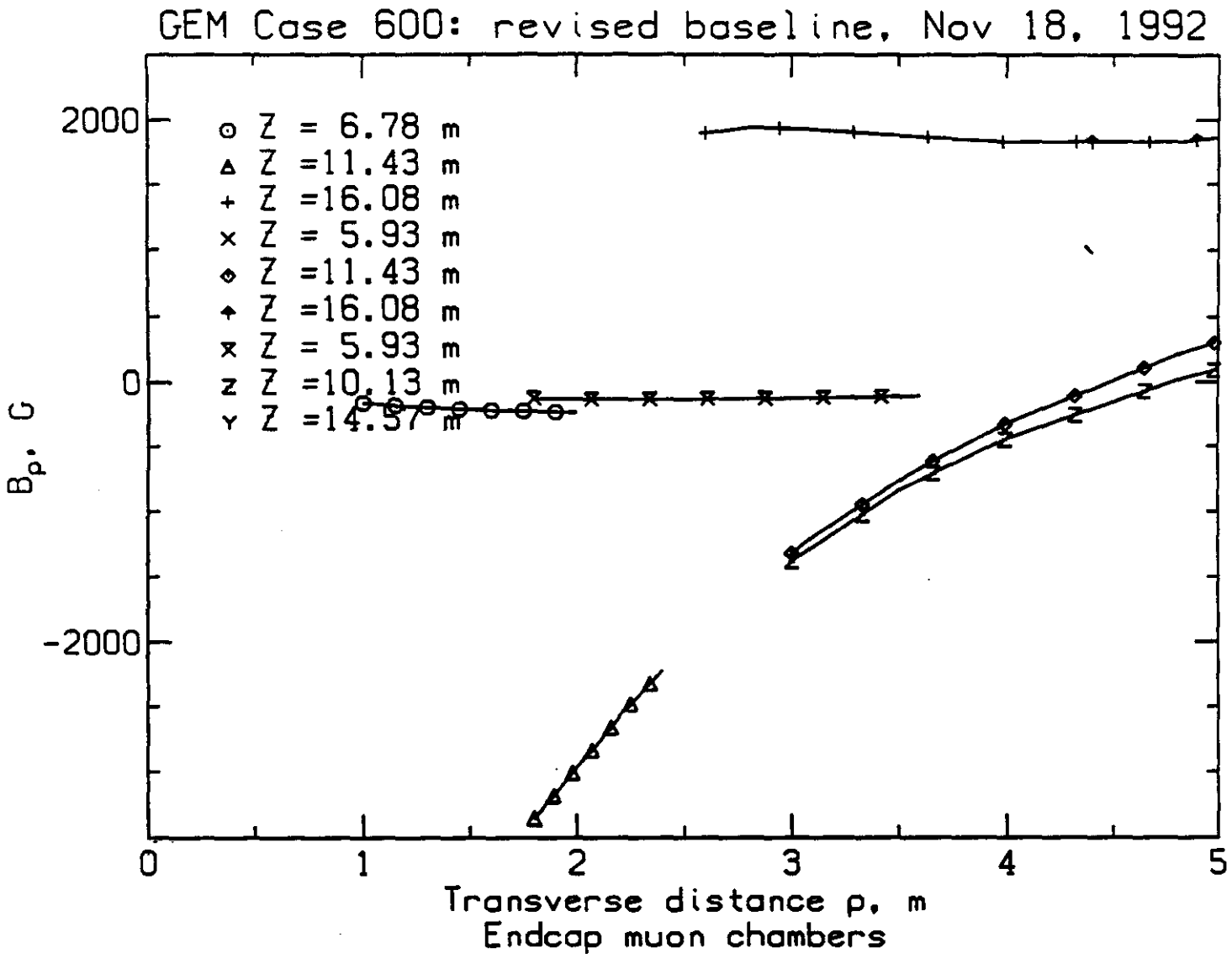
Z =10.13 m
Z =14.57 m


GEM Case 600: revised baseline, Nov 18, 1992
Z = 6.78 m
Z =11.43 m
Z =16.08 m
Z = 5.93 m
Z =11.43 m
Z =16.08 m
Z = 5.93 m
Z =10.13 m
Z =14.57 m
2000
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-2000
$B_\rho$, G
0
1
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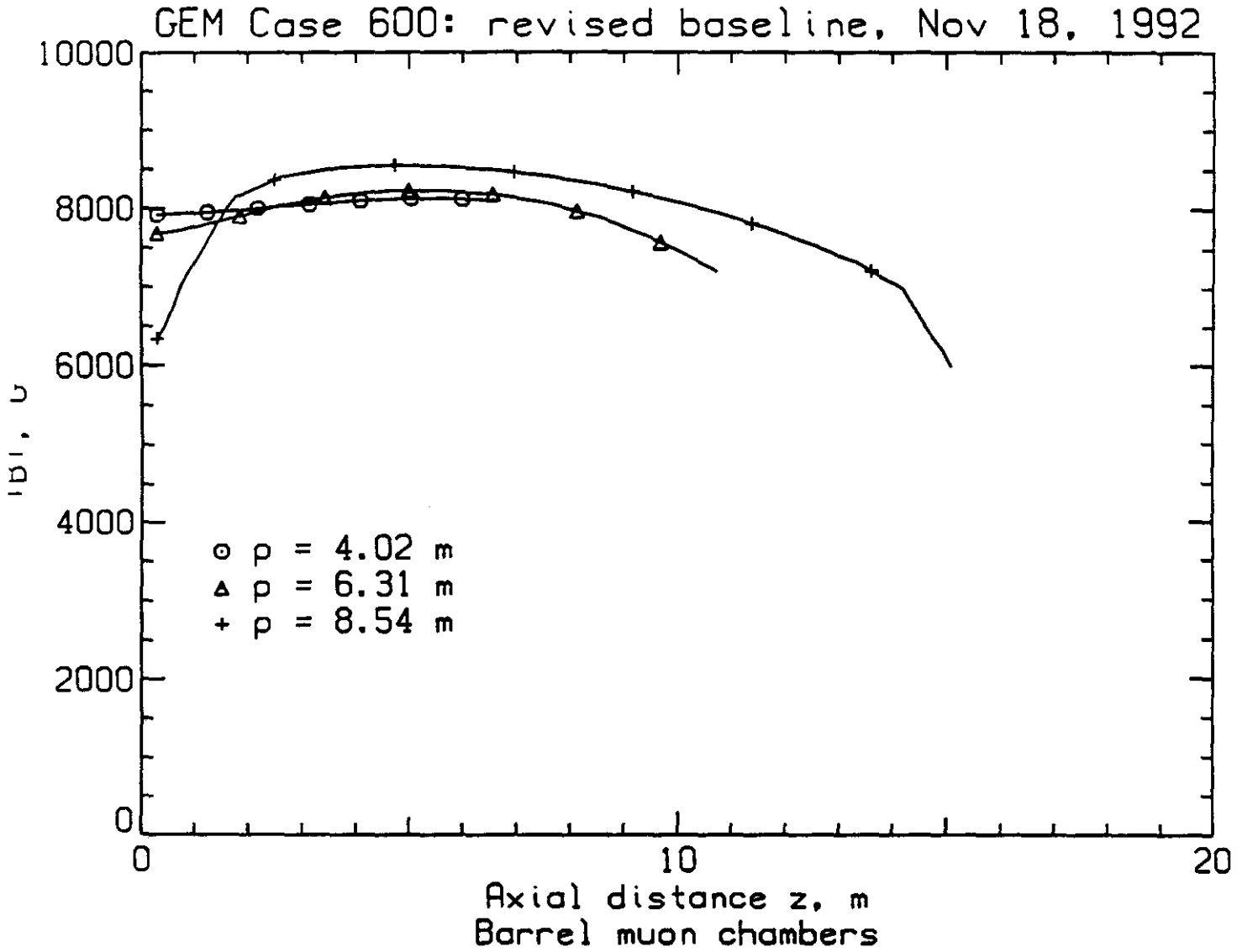
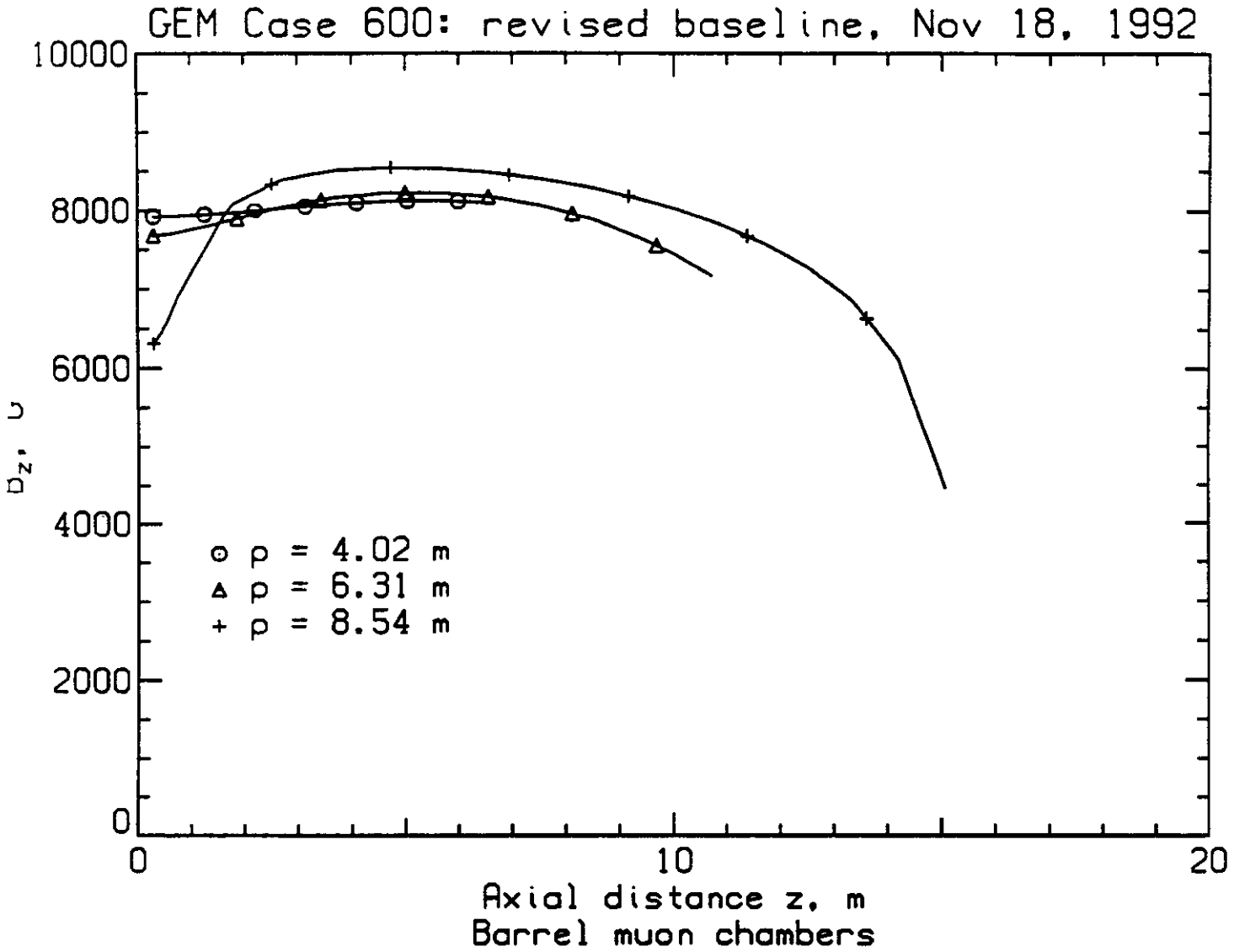
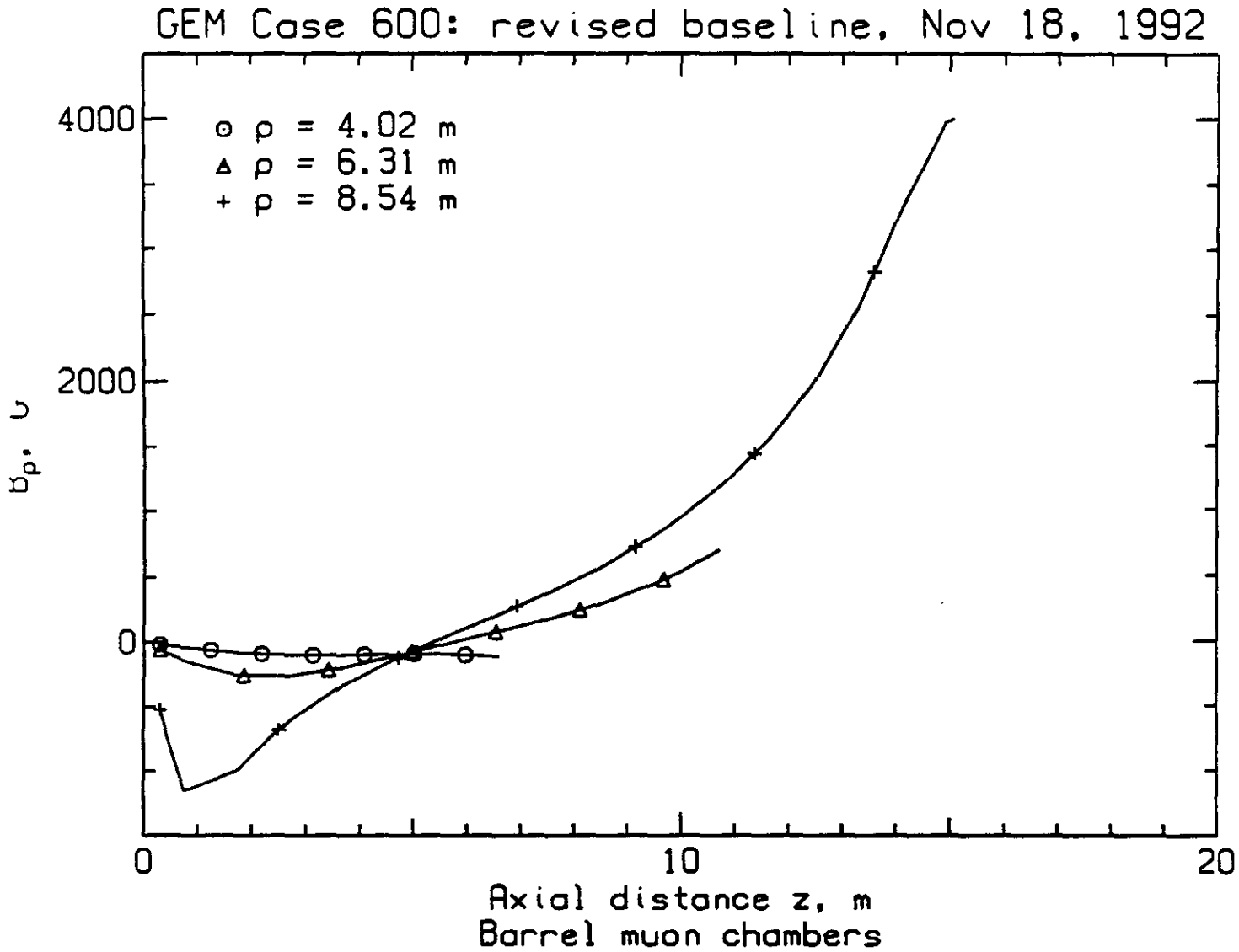
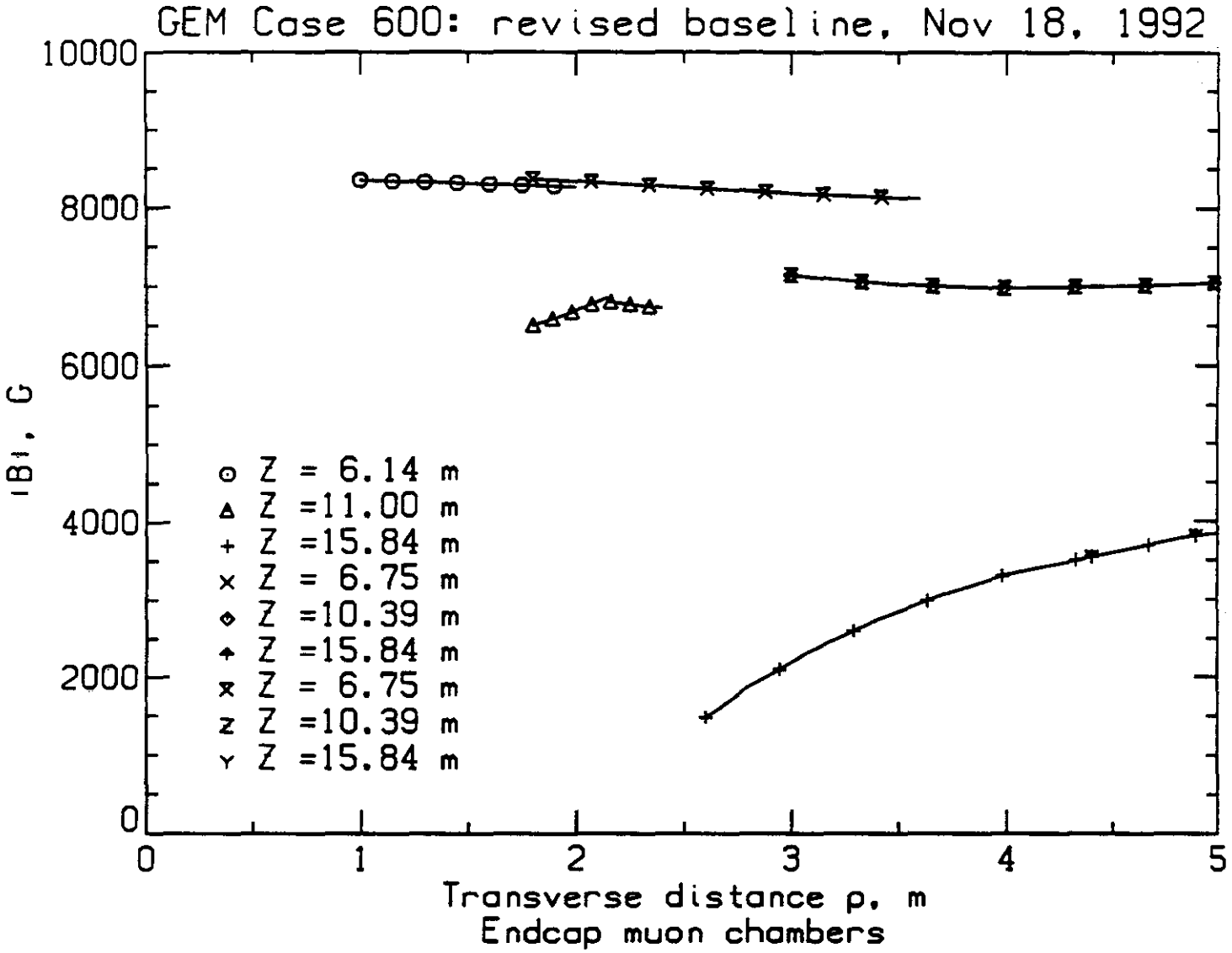
3
4
5
Transverse distance ρ, m
Endcap muon chambers

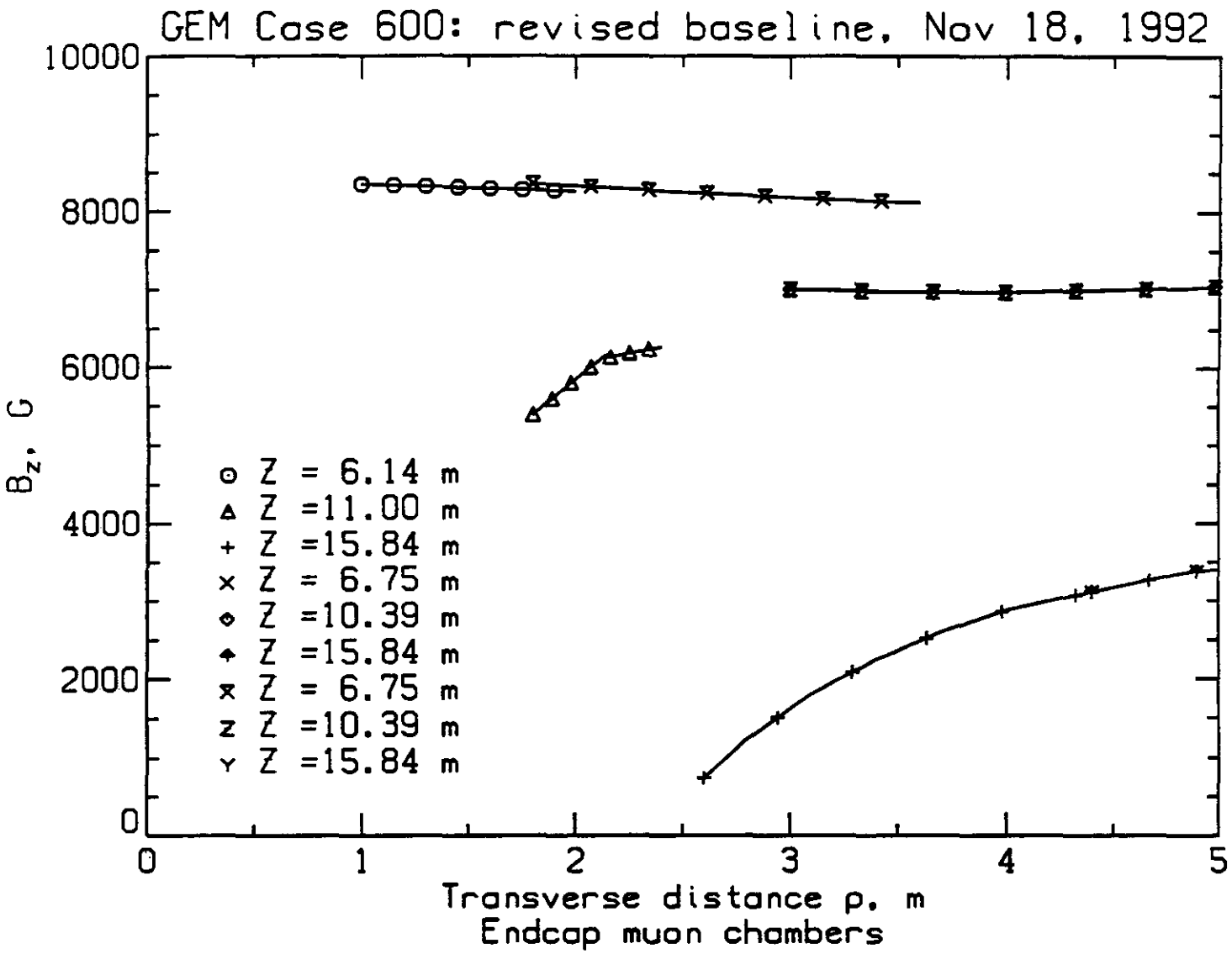

GEM Case 600: revised baseline, Nov 18, 1992
10000
8000
6000
4000
2000
0
0
10
20
Axial distance z, m
Barrel muon chambers
⊙ ρ = 4.02 m
△ ρ = 6.31 m
+ ρ = 8.54 m

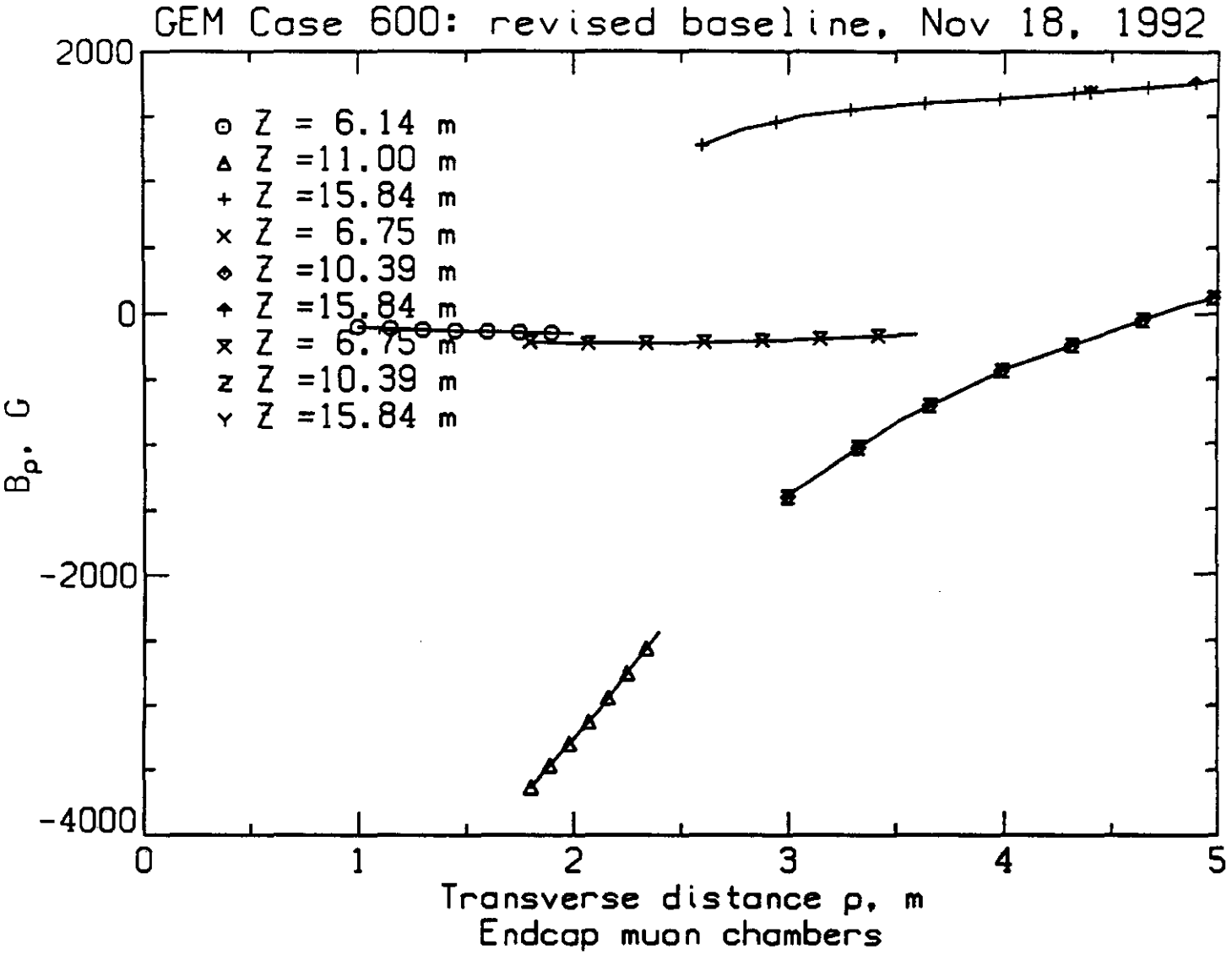
RDTs


GEM Case 600: revised baseline, Nov 18, 1992
10000
8000
6000
4000
2000
0
$B_z$, G
o ρ = 4.02 m
Δ ρ = 6.31 m
+ ρ = 8.54 m
0
10
20
Axial distance z, m
Barrel muon chambers


GEM Case 600: revised baseline, Nov 18, 1992
o ρ = 4.02 m
Δ ρ = 6.31 m
+ ρ = 8.54 m
4000
2000
0
$b_\rho$, G
0
10
20
Axial distance z, m
Barrel muon chambers


GEM Case 600: revised baseline, Nov 18, 1992
10000
8000
6000
4000
2000
0
|B|, G
0
1
2
3
4
5
Transverse distance ρ, m
Endcap muon chambers
Z = 6.14 m
Z =11.00 m
Z =15.84 m
Z = 6.75 m
Z =10.39 m
Z =15.84 m
Z = 6.75 m
Z =10.39 m
Z =15.84 m


GEM Case 600: revised baseline, Nov 18, 1992
10000
8000
6000
4000
2000
0
$B_z$, G
0
1
2
3
4
5
Transverse distance ρ, m
Endcap muon chambers
Z = 6.14 m
Z =11.00 m
Z =15.84 m
Z = 6.75 m
Z =10.39 m
Z =15.84 m
Z = 6.75 m
Z =10.39 m
Z =15.84 m

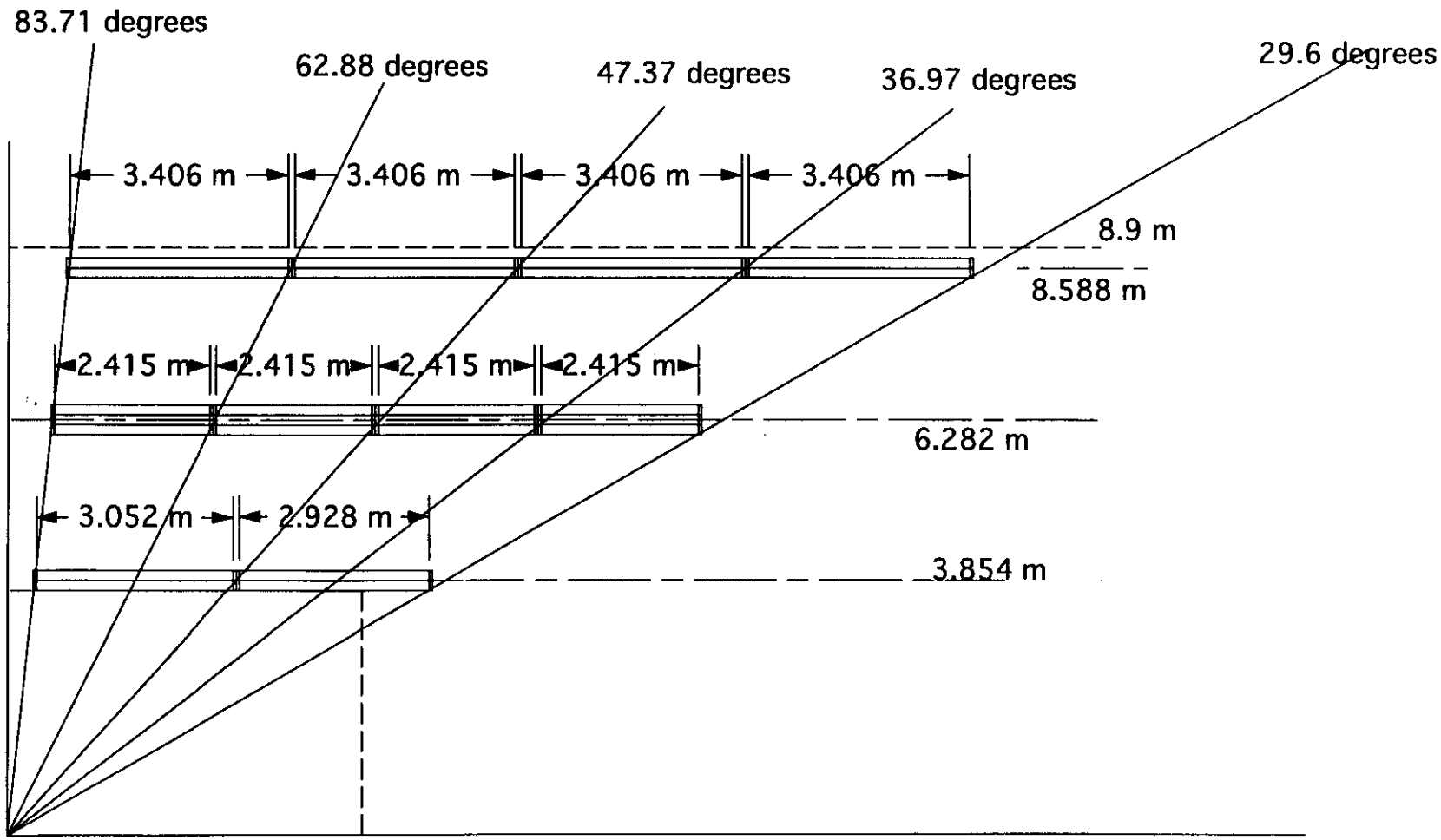

GEM Case 600: revised baseline, Nov 18, 1992
2000
0
-2000
-4000
$B_\rho$, G
Z = 6.14 m
Z =11.00 m
Z =15.84 m
Z = 6.75 m
Z =10.39 m
Z =15.84 m
Z = 6.75 m
Z =10.39 m
Z =15.84 m
0
1
2
3
4
5
Transverse distance ρ, m
Endcap muon chambers

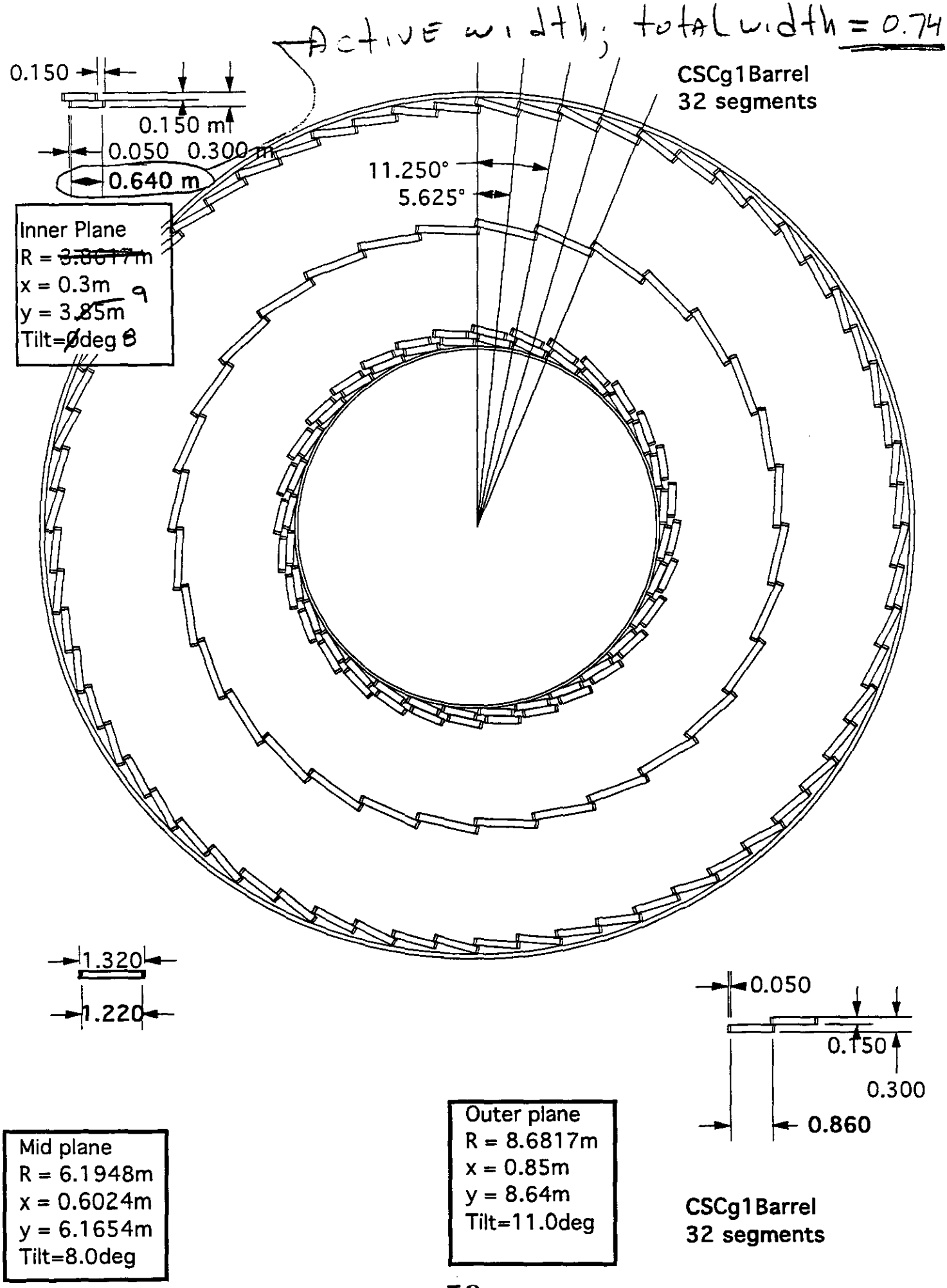
Coleman Johnson

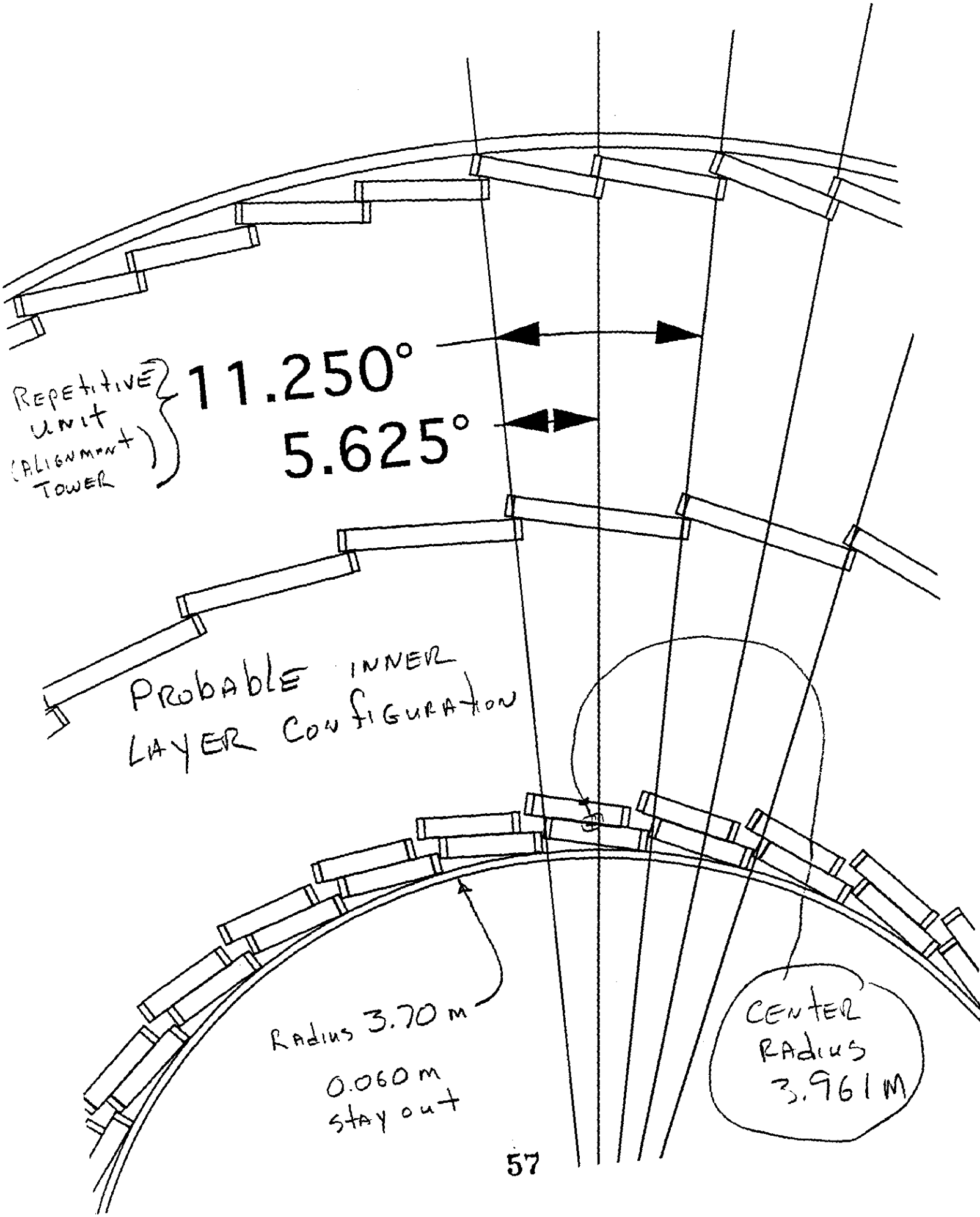
Layout of CSC in Barrel

**CSCf2crzBarrellayout**

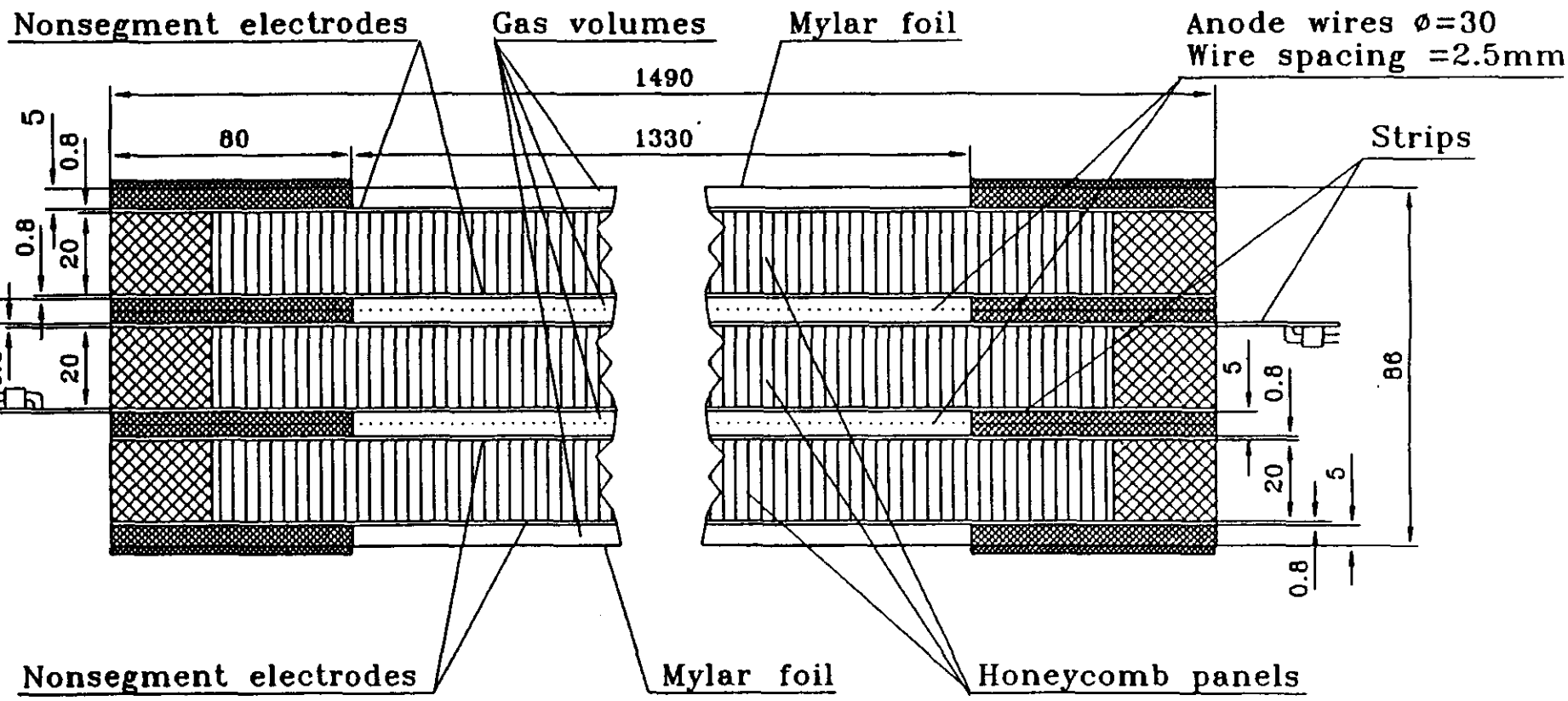
Lengths of active areas




Active width; total width = 0.74
0.150
0.150 m
0.050
0.300 m
0.640 m
CSCg1Barrel
32 segments
11.250°
5.625°
Inner Plane
R = ~~3.8617~~m
x = 0.3m
y = 3.85m 9
Tilt=0deg 8
1.320
1.220
0.050
0.150
0.300
0.860
Mid plane
R = 6.1948m
x = 0.6024m
y = 6.1654m
Tilt=8.0deg
Outer plane
R = 8.6817m
x = 0.85m
y = 8.64m
Tilt=11.0deg
CSCg1Barrel
32 segments


Repetitive unit (alignment tower)
11.250°
5.625°
Probable inner layer configuration
Radius 3.70 m
0.060 m stay out
Center radius 3.961 m

# DUBNA CSC PROTOTYPE




Cross-section of MWPC perpendicular to the wires

(All dimensions in mm)

Scott Whitaker

# Layout of CSC in End Caps

# Endcap CSC Layout

## Design considerations

- Full coverage in $\theta$ ( 9.75° to 27.71°) and in $\phi$ by overlapping and staggering chambers (with some corner cutting...)

- Chamber placement in z for "adequate" momentum resolution
  - ◊ November 30 design (J. Sullivan) (no overlap)

- Minimize module and channel count
  - ◊ cost
  - ◊ alignment paths, complexity

- Cathode dimensions within industrial capacity
  48" x 135"  1.2 m x 3.4 m

- Wire length < ~1.2 m for electrostatic stability

- Angle between wire and (radial) strips limited to mitigate resolution smearing and systematic shifts
  - ◊ $\Delta\phi < \sim \pi/16$ -- so $N_{sectors} \geq 32$
  - ◊ 12-fold symmetry desirable? (F. Nimblett)

- Strip width ~ 5 mm for required spatial resolution ( 7 mm ok for some chambers?)

- Strip capacitance? -- not a problem with floating strips

- Strip length limited by occupancy
  - ◊ occ/strip $\leq$ ~ 100 $cm^{-2}sec^{-1}$ for good $\varepsilon$ and $\sigma$
  - ◊ Charged particles ~ manageable (MC)
  - ◊ Neutrons ????? consider several scenarios...

- Theta strip segmentation
  - ◊ 5 cm (20 wires) adequate for $\theta$ measurement
  - ◊ Timing performance?
  - ◊ Occupancy ~30 ns shaping vs ~ 300 ns for strips
    → # of $\theta$-channels $\geq$ 1/10 # of strip channels
  - ◊ Pattern recognition
  - ◊ Mechanics of combined modules at small $\theta$

An accounting of the mass and radiation lengths in the principal components is given in Table 2.1 for a typical CSC module. Each chamber in the module has an active area surrounded by frames that are taken to be inactive for detecting muons. When the modules are overlapped to avoid acceptance losses, muons will sometimes traverse the frames of one chamber as well as the active area of another. For this (rough) design, muons traversing the active area only will pass through 8% of a radiation length. Approximately 10% of the time a muon would also pass through the frame of an overlapping module, for a total of 51% of a radiation length. The average thickness in radiation lengths, including the overlap, is about 12%.

**Table 2.1 Material in a typical CSC**

## Material Audit for Cathode Strip Chamber Module

Calculation of mass and radiation lengths for a four chamber module

Active area of chamber:
length (m) = 3.0
width (m) = 1.5
total area (m^2) = 5.0

frame material (and dead area):
width (m) = 0.050

(including inactive frames)
fraction of active area overlapped by frames = 0.098

| component | material | density | cm/X0 | thcknss (cm) | mass (Kg) | normal X0 |
|---|---|---|---|---|---|---|
| Hexcel core | Nomex | 0.14 | 485.7 | 2.5 | 86.80 | 0.0257 |
| circuit boards | .031" G10 | 1.7 | 19.4 | 0.079 | 66.39 | 0.0406 |
| copper | 1/2 oz.ft^2 | 8.96 | 1.43 | 0.0017 | 7.56 | 0.0119 |
| frames | ~ lucite | 1.2 | 34.4 | 3.0 | 82.80 | 0.4360 |

| | | |
|---|---|---|
| total mass (Kg) = | 243.5 | |
| mass/area (Kg/m^2) = | 49.1 | |
| average X0's = | 0.119 | |
| X0's through center = | 0.078 | |
| X0's, center + frames = | 0.514 | <- includes material of overlapping chamber |
| area-weighted ave X0's = | 0.121 | |

Wires are strung on printed circuit frames of precision thickness that are glued to the precision cathode. Wires are tensioned to ~170 grams, ~ 2/3 of the elastic limit; they are held by glue and solder and the wire pitch is set by the fixturing during construction. The panel takes the load of the anode wires; the symmetric loading offsets any tendency to distort the panel. The frames are circuit board material of precision thickness. They bus HV and route anode signals to an edge connector. On the non-precision cathode lamination is a frame fabricated with precise moldings produced with pultrusion technology; this frame controls the gas gap and provides access for electrical contact to the non-precision cathode. Gas distribution is achieved through a manifold built into this frame. This approach provides a precise, low-weight, low-cost structure that avoids extensive machining. It allows accurate control of the important parameters and provides access to the precision cathode all around the perimeter for alignment.

One alternative under study is to use Iarocci-type "profile" chambers where the wires are strung in individual channels in a conductive plastic extrusion. This approach has potential advantages in robustness of the chamber and disadvantages in efficiency and attainable wire pitch.

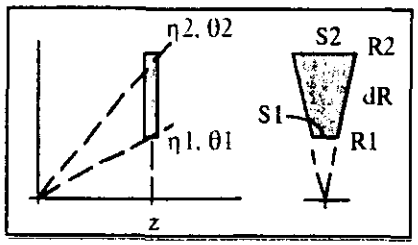
Endcap CSC Layout -- PRELIMINARY Baseline II

8-Dec-92
SW

active coverage 9.75° to 27.71°
module thickness 15 cm (4 gaps); intermodule space 10 cm

| | | |
|---|---|---|
| wires ganged by 20 = | 5.00 cm | everywhere |
| Strip width at middle = | 5.00 mm | everywhere |

Configuration: number of planes in 1st / 2nd / 3rd module
8 / 8 / 4 for eta > 2.3
8 / 4 / 4 elsewhere




WRONG

| | |
|---|---|
| neutron flux (Hz/cm^2) = | 500 |
| neutron efficiency = | 0.005 |

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

Total channel counts:

| | z | η1 | θ1 | η2 | θ2 | Nsctrs | R1 | R2 | dR | S1 | S2 | area | # strips | strip occ | strip occ | # r-chans | # strip chan | # r-chan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m | | deg | | deg | | m | m | m | m | m | m^2 | /pl/sctr | ch.p/sec | n det/sec | /pl/sctr | | |
| Inner modules | | | | | | | | | | | | | | | | | | |
| 1a) | 7.00 | 2.30 | 11.45 | 1.90 | 17.01 | 24 | 1.42 | 2.14 | 0.72 | 0.37 | 0.56 | 0.33 | 93 | 119 | 91 | 14 | 17,842 | 2,780 |
| 1b) | 6.75 | 2.30 | 11.45 | 1.90 | 17.01 | 24 | 1.37 | 2.07 | 0.70 | 0.36 | 0.54 | 0.31 | 90 | 115 | 87 | 14 | 17,205 | 2,681 |
| 2a) | 6.75 | 1.90 | 17.01 | 1.40 | 27.71 | 24 | 2.07 | 3.54 | 1.48 | 0.54 | 0.93 | 1.07 | 146 | 40 | 185 | 30 | 28,118 | 5,680 |
| 2b) | 7.00 | 1.90 | 17.01 | 1.40 | 27.71 | 24 | 2.14 | 3.68 | 1.53 | 0.56 | 0.96 | 1.15 | 152 | 42 | 192 | 31 | 29,160 | 5,891 |
| 3a) | 6.10 | 2.46 | 9.75 | 2.30 | 11.45 | 24 | 1.05 | 1.24 | 0.19 | 0.27 | 0.32 | 0.06 | 60 | 95 | 23 | 4 | 11,445 | 721 |
| 3b) | 6.50 | 2.46 | 9.75 | 2.30 | 11.45 | 24 | 1.12 | 1.32 | 0.20 | 0.29 | 0.34 | 0.06 | 64 | 101 | 25 | 4 | 12,195 | 768 |
| Middle modules | | | | | | | | | | | | | | | | | | |
| 4a) | 10.67 | 2.46 | 9.75 | 1.90 | 17.01 | 24 | 1.83 | 3.26 | 1.43 | 0.48 | 0.85 | 0.94 | 133 | 73 | 179 | 29 | 12,775 | 2,749 |
| 4b) | 11.07 | 2.46 | 9.75 | 1.90 | 17.01 | 24 | 1.90 | 3.39 | 1.49 | 0.50 | 0.88 | 1.02 | 138 | 76 | 186 | 30 | 13,254 | 2,852 |
| 5a) | 10.27 | 1.90 | 17.01 | 1.40 | 27.71 | 36 | 3.14 | 5.39 | 2.25 | 0.55 | 0.94 | 1.67 | 149 | 14 | 281 | 45 | 21,425 | 6,482 |
| 5b) | 10.51 | 1.90 | 17.01 | 1.40 | 27.71 | 36 | 3.22 | 5.52 | 2.30 | 0.56 | 0.96 | 1.75 | 152 | 14 | 288 | 46 | 21,925 | 6,633 |
| 8a) | 10.82 | 2.46 | 9.75 | 2.30 | 11.45 | 24 | 1.86 | 2.19 | 0.33 | 0.49 | 0.57 | 0.17 | 106 | 38 | 42 | 7 | 10,150 | 639 |
| 8b) | 11.22 | 2.46 | 9.75 | 2.30 | 11.45 | 24 | 1.93 | 2.27 | 0.35 | 0.50 | 0.59 | 0.19 | 110 | 39 | 43 | 7 | 10,526 | 663 |
| Outer modules | | | | | | | | | | | | | | | | | | |
| 6a) | 16.00 | 2.46 | 9.75 | 1.90 | 17.01 | 36 | 2.75 | 4.90 | 2.15 | 0.48 | 0.85 | 1.43 | 133 | 37 | 268 | 43 | 19,187 | 6,184 |
| 6b) | 16.25 | 2.46 | 9.75 | 1.90 | 17.01 | 36 | 2.79 | 4.97 | 2.18 | 0.49 | 0.87 | 1.47 | 135 | 37 | 273 | 44 | 19,487 | 6,281 |
| 7a) | 15.71 | 1.90 | 17.01 | 1.40 | 27.71 | 48 | 4.81 | 8.25 | 3.44 | 0.63 | 1.08 | 2.93 | 171 | 7 | 430 | 69 | 32,792 | 13,220 |
| 7b) | 15.96 | 1.90 | 17.01 | 1.40 | 27.71 | 48 | 4.88 | 8.38 | 3.50 | 0.64 | 1.10 | 3.03 | 174 | 7 | 437 | 70 | 33,314 | 13,431 |
| | | | | | | | | | | | | | | | | Total => | 310,802 | 77,656 |

| | |
|---|---|
| total area of strip cathodes (m^2) | 2851 |
| total volume of chambers (m^3) | 14.3 |
| Total number of modules | 480 |

(Number of modules and number of r-channels may be reduced by combining some of 1a/1b, 2a/2b, and 3a/3b)

Craig Wuest

# GEM Muon Alignment

# GEM Muon System Alignment

- A GEM Muon System Alignment meeting was held at SSCL on November 18, 1992 (~ 25 attendees).
- The meeting goal was to review accomplishments in FY 1992 relating to alignment for GEM and to focus on the upcoming year's program.
- Fifteen presentations were made:
  - Local and Global Alignment issues
  - Review of R&D of LED/Lens, SWAT, GaAs, Pad, CCD, Lat. Eff. P. D., x-ray
  - Review of interpolation methods for alignment
  - Background muons for global alignment
- Meeting has resulted in a detailed WBS for alignment R&D with short and long term R&D goals.

GEM Muon System Alignment Meeting - Updated Agenda - November 12, 1992

SSC Laboratory

November 18, 1992 1:00 pm - 6:00pm

There will a meeting of the GEM Muon System Alignment Group on the afternoon of Wednesday, November 18. The goal of the meeting is to review the past year's alignment R&D and to focus on the upcoming year's program now that the muon system is beginning to converge on a final design. The proposed agenda is as follows:

| | | |
|---|---|---|
| 1:00 | Introduction, Review of GEM Muon System Status - C. Wuest | 10 minutes |

Local Alignment

| | | |
|---|---|---|
| 1:15 | Introduction to GEM Muon System Local Alignment - R. Sawicki (LLNL) | 15 minutes |
| 1:30 | Review of Draper LED/Lens system, and other Draper R&D - J. Paradiso (Draper) | 30 minutes |
| 2:00 | Review of Alignment work at Tsinghua University - + Coleman Johnson | 15 minutes |
| 2:15 | Review of LLNL High-range Sensor R&D - E. Ables (LLNL) | 15 minutes |
| 2:30 | Review of LLNL Laser/Lens system - R. Sawicki (LLNL) | 15 minutes |
| 2:45 | Break | 15 minutes |
| 3:00 | U-AVLIS Alignment, Control Systems and Diagnostics L. Collins (LLNL) | 15 minutes |
| 3:15 | Interpolation schemes for alignment - A. Ostapchuk (SSCL) | 15 minutes |
| 3:30 | Interpolation schemes for alignment - J. Paradiso (Draper) | 15 minutes |
| 3:45 | X-ray alignment systems for CSCs - A. Vorobyov (BNL), A. Ostapchuk (SSCL) | 15 minutes |
| ~~4:00~~ | ~~Cosmic rays for alignment - G. Mitselmakher (SSCL)~~ | ~~15 minutes~~ |

Global alignment

| | | |
|---|---|---|
| 4:15 | Introduction to Global Alignment - R. Sawicki (LLNL) | 15 minutes |
| 4:30 | Background Muons for Alignment - Issues - G. Mitselmakher (SSCL), A. Ostapchuk (SSCL) | 15 minutes |
| 4:45 | Other options for vertex placement - Group | 15 minutes |
| 5:00 | Global muon tower pointing requirements - Group | 15 minutes |
| 5:15 | Wrap-up and plans for FY93 program - Group | 45 minutes |
| 6:00 | Adjourn | |

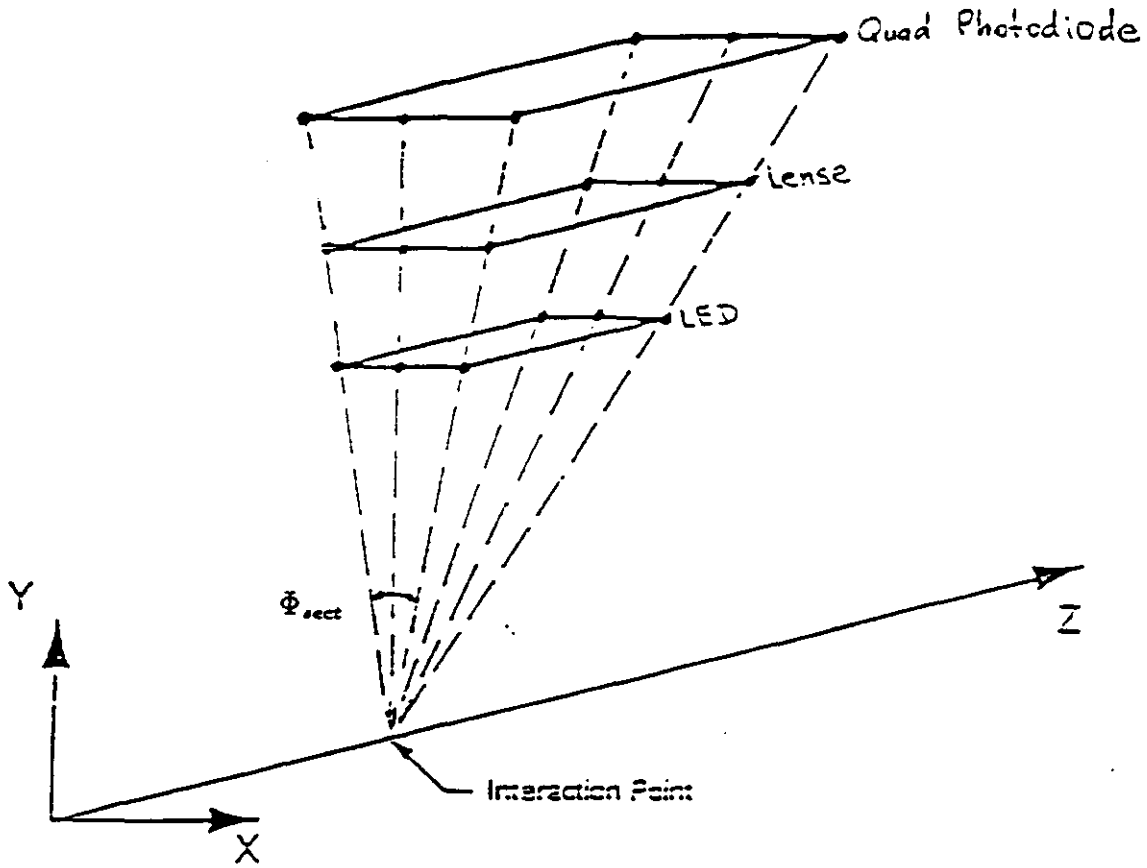
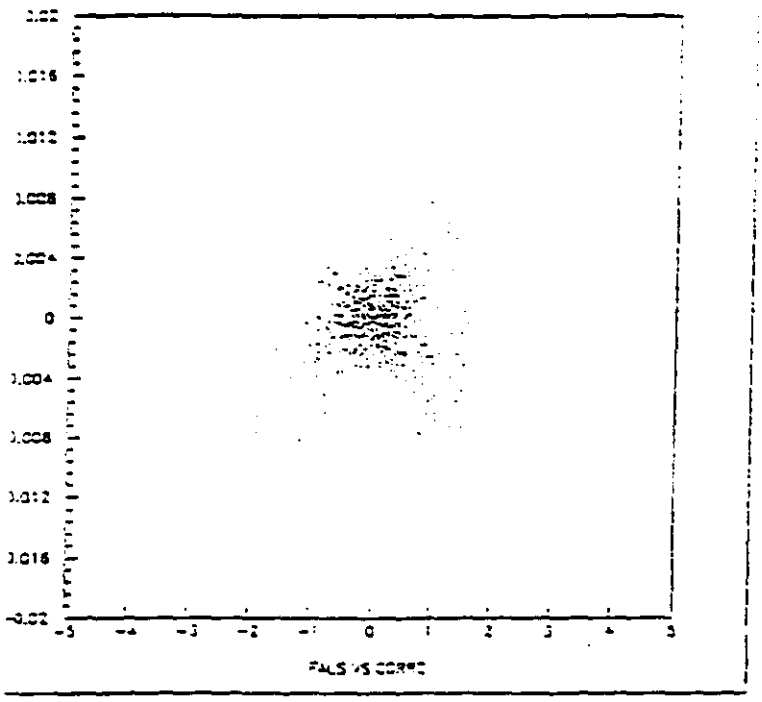
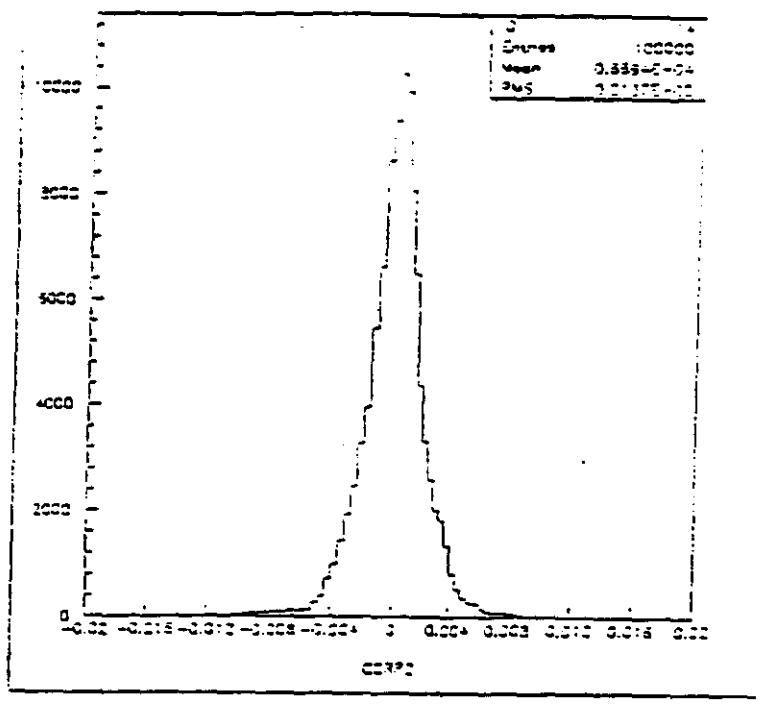



**Figure 1. Muon alignment tower**



Corrected Sagitta(cm) vs False Sagitta(cm)



Corrected Sagitta(cm)

Shifts and Rotations of Muon Chambers: $Dx, Dy, Dz \leq \pm 5mm$; $Sx, Sy, Sz \leq \pm 3mrad$

Deformations of Muon Chambers: $\Psi_{torqe} \leq \pm 3mrad$, $\Delta t^0 \leq \pm 5^0$

**Figure 2. Muon sagitta errors caused by chamber misalignment**

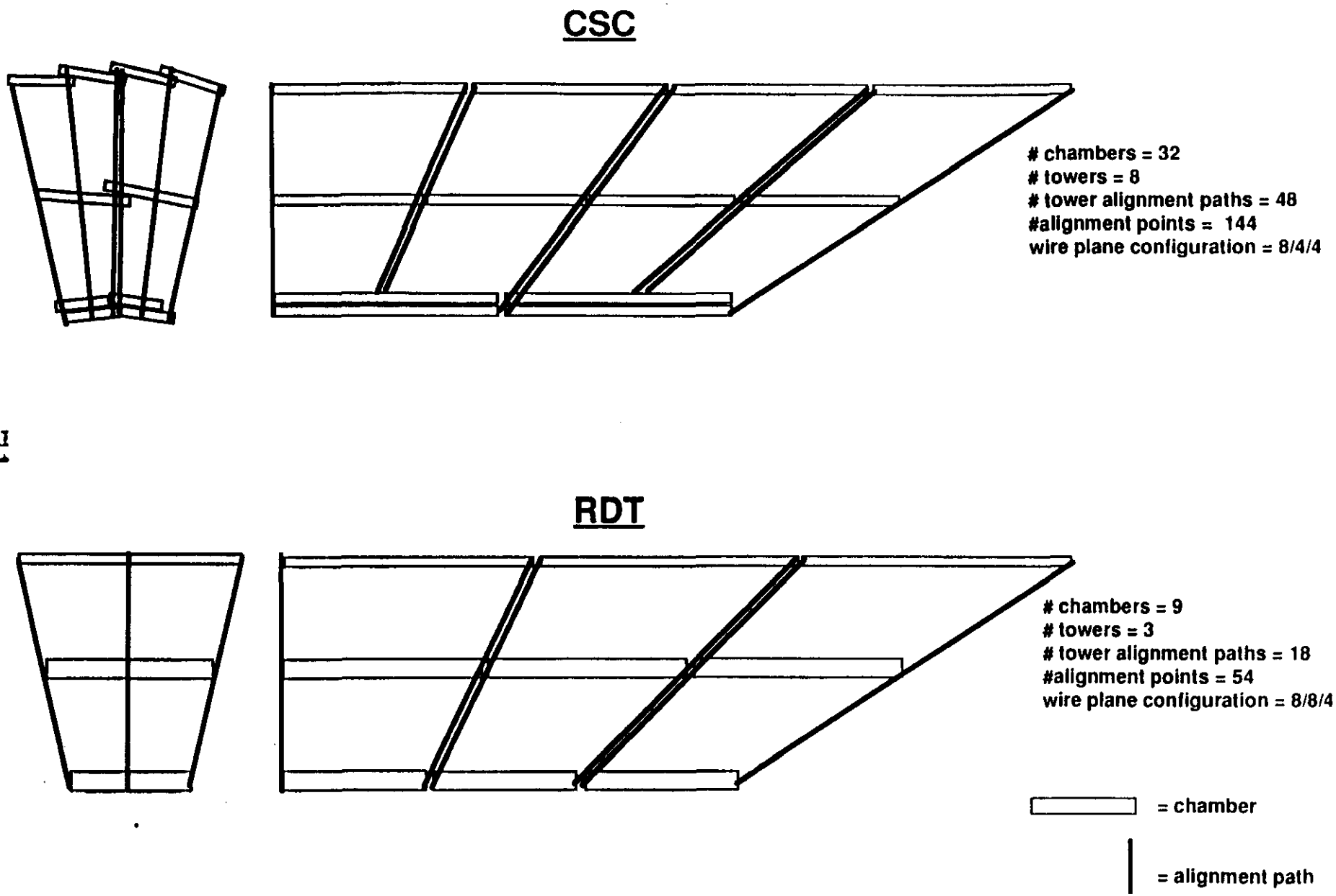



Figure 3. Local alignment schemes for muon barrel

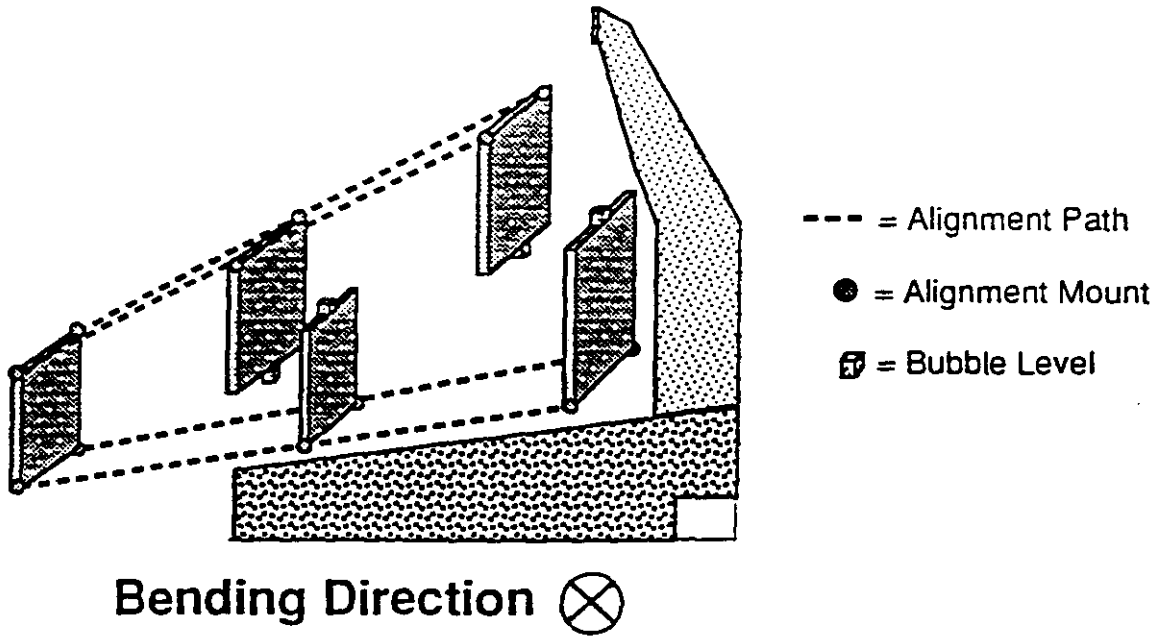
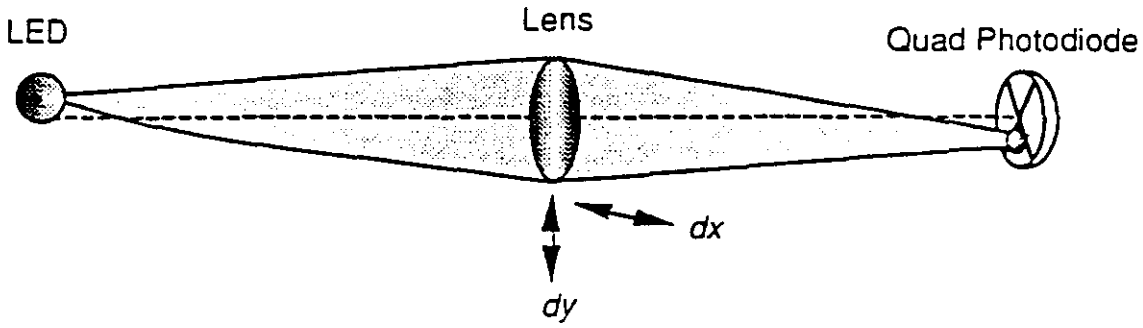
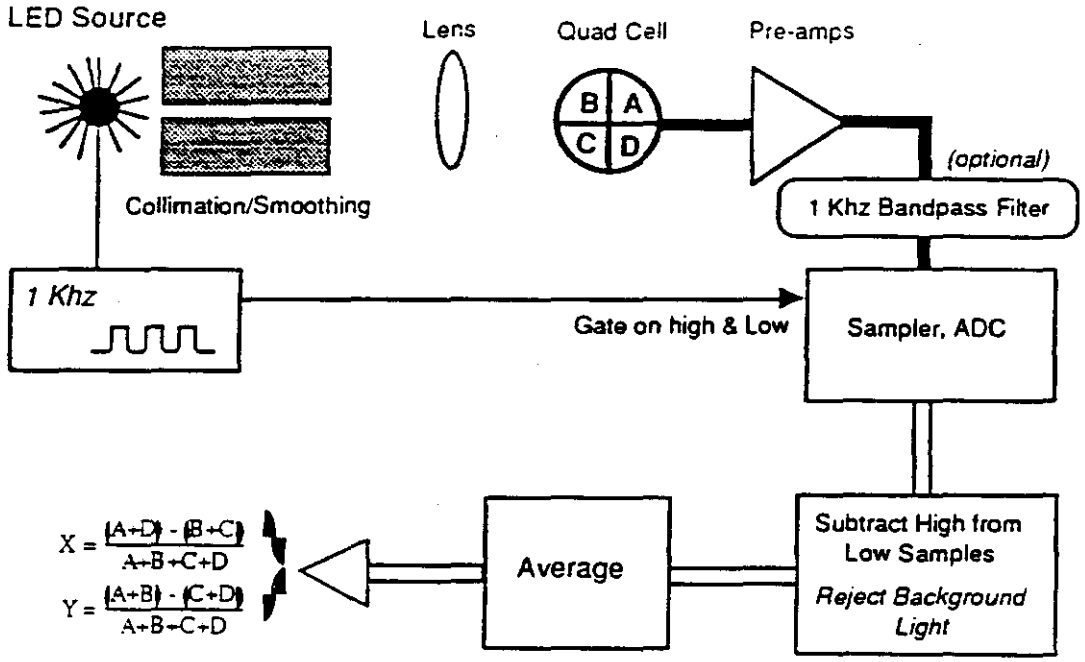



**Figure 4. Possible scheme for aligning muon endcap**




The Basic Straightness Monitor




Straightness Monitor Electronics

**Figure 5. LED/lens straightness monitor**

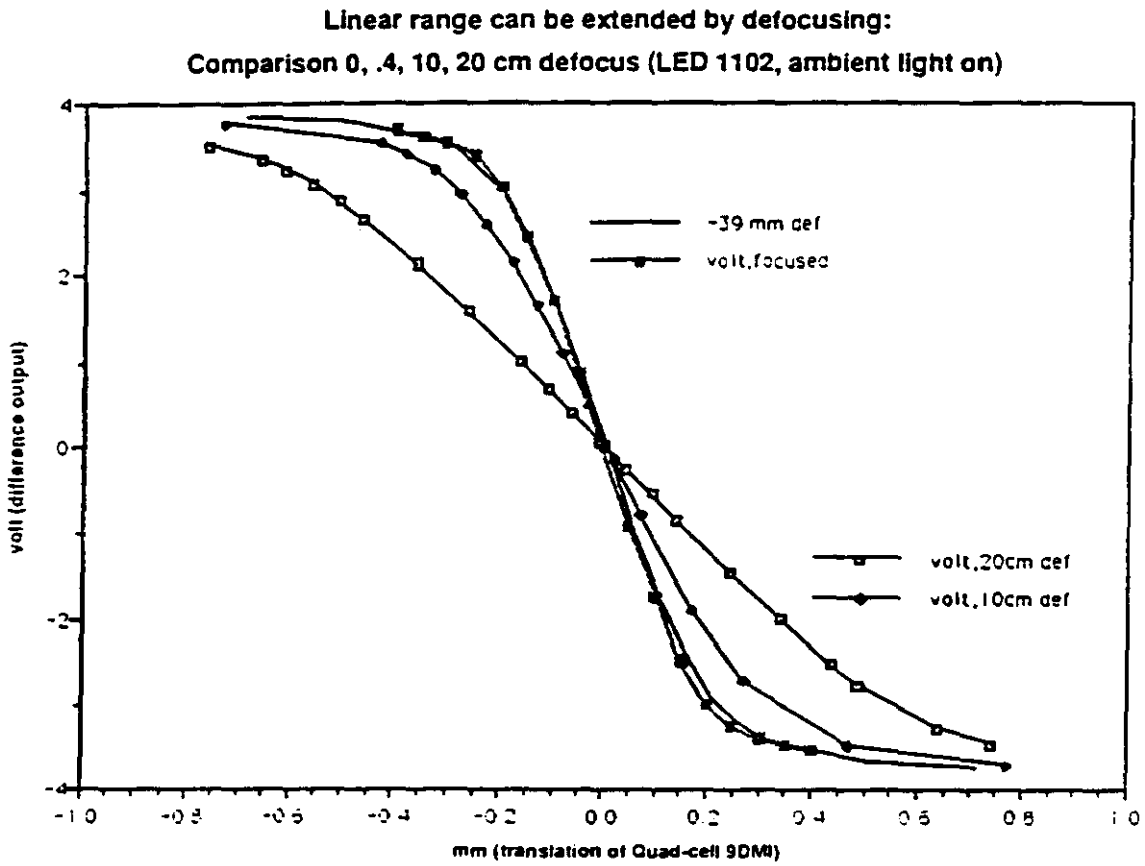



**Figure 6. Straightness monitor transfer function**

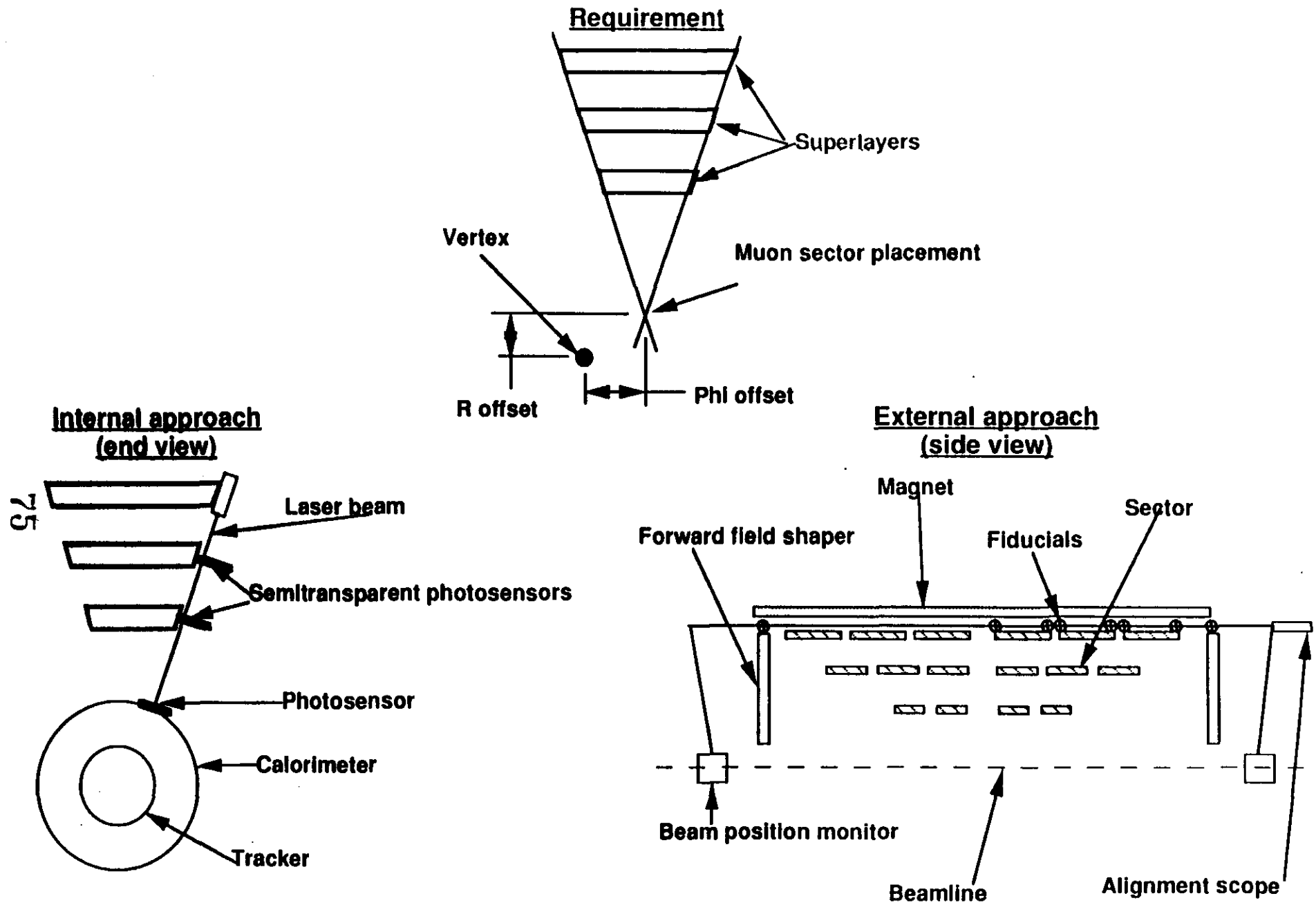



Figure 7. Global measurement concept

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.4.1 | Define and develop alignment technology (LLNL, SSCL, Draper) | | | | | | | | Oct-92 | Nov-92 | Dec-92 | Jan-93 | Feb-93 | Mar-93 | | | |
| | 2.4.1.1 | Review alignment systems on other HEP experiments | | | | | | | | | | | | | | | |
| | 2.4.1.2 | Review Draper R&D results | | | | | | | | | | | | | | | |
| | 2.4.1.3 | Review LLNL R&D results | | | | | | | | | | | | | | | |
| | 2.4.1.4 | Review Tsinghua University R&D results | | | | | | | | | | | | | | | |
| | 2.4.1.5 | Review PNPI/BNL x-ray alignment results | | | | | | | | | | | | | | | |
| | 2.4.1.6 | Review LLNL x-ray radiography results | | | | | | | | | | | | | | | |
| | 2.4.1.7 | Review six-point interpolation technique | | | | | | | | | | | | | | | |
| | 2.4.1.8 | Define alignment technology (chamber technology choice) | | | | | | | | | | | | | | | |
| 2.4.2 | Test benches (PNPI/BNL, MSU, Tsinghua U.) | | | | | | | | | | | | | | | | |
| | 2.4.2.1 | R&D of Draper LEDA.ons straight line monitoring system | | | | | | | | | | | | | | | |
| | | 2.4.2.1.1 | Continuation of Draper R&D - optimization, (electronics, visualization software | | | | | | | | | | | | | | |
| | | | 2.4.2.1.1.1 | LEDA.ons system procurement | | | | | | | | | | | | | |
| | | 2.4.2.1.2 | Cost analysis and design of Draper wide-grid concept | | | | | | | | | | | | | | |
| | | 2.4.2.1.3 | Electronics development | | | | | | | | | | | | | | |
| | | | 2.4.2.1.3.1 | Data acquisition systems definition | | | | | | | | | | | | | |
| | | | 2.4.2.1.3.2 | Data acquisition systems procurement | | | | | | | | | | | | | |
| | | | 2.4.2.1.3.3 | Data processing and visualization software procurement | and development | | | | | | | | | | | | |
| | 2.4.2.2 | Multi-point alignment monitor (in and out region if chambers cannot be out projectively) | | | | | | | | | | | | | | | |
| | | 2.4.2.2.1 | Develop capacitive pick-up sensor for stretched wire technique | | | | | | | | | | | | | | |
| | | | 2.4.2.2.1.1 | procurement for large scale (15 meter) prototype | | | | | | | | | | | | | |
| | | | 2.4.2.2.1.2 | fabricate large scale prototype | | | | | | | | | | | | | |
| | | | 2.4.2.2.1.3 | develop readout system for capacitive pick-up | | | | | | | | | | | | | |
| | | 2.4.2.2.2 | Develop GaAs transparent position-sensitive photodiodes | | | | | | | | | | | | | | |
| | | | 2.4.2.2.2.1 | procurement for large scale (15 meter) prototype, including IR laser | | | | | | | | | | | | | |
| | | | 2.4.2.2.2.2 | fabricate large scale prototype | | | | | | | | | | | | | |
| | | | 2.4.2.2.2.3 | develop readout system for GaAs photodiodes | | | | | | | | | | | | | |
| | | 2.4.2.2.3 | Laboratory tests at 15 meters | | | | | | | | | | | | | | |
| | | | 2.4.2.2.3.1 | Stretched wire | | | | | | | | | | | | | |
| | | | 2.4.2.2.3.2 | IR Laser/GaAs photodiodes | | | | | | | | | | | | | |
| | | 2.4.2.2.4 | Bench test of inductive strip pickup of stretched wire | | | | | | | | | | | | | | |
| | 2.4.2.3 | Development of 30 KeV x-ray technology for alignment of chambers | | | | | | | | | | | | | | | |
| | | 2.4.2.3.1 | Completion of prototype of x-ray station incl monochromator, moving table, control electronics | | | | | | | | | | | | | | |
| | | 2.4.2.3.2 | Pilot tests of chambers with x-ray station | | | | | | | | | | | | | | |
| | | 2.4.2.3.3 | Checks of the 6 point interpolation method with x-ray beams | | | | | | | | | | | | | | |
| 2.4.3 | Integration with chamber design and support structure (LLNL, SSCL, Draper) | | | | | | | | | | | | | | | | |
| | 2.4.3.1 | Mechanical | | | | | | | | | | | | | | | |
| | | 2.4.3.1.1 | Philosophization | | | | | | | | | | | | | | |
| | | 2.4.3.1.2 | Hardware design | | | | | | | | | | | | | | |
| | | | 2.4.3.1.2.1 | Procurement | | | | | | | | | | after TDR | | | |
| | | 2.4.3.1.3 | Structure fine-of-sight design and verification (technology dependent) | | | | | | | | | | | | | | |
| | 2.4.3.2 | Electronics | | | | | | | | | | | | after TDR | | | |
| | | 2.4.3.2.1 | Integration of sensor readout electronics into chamber design | | | | | | | | | | | after TDR | | | |
| | | 2.4.3.2.2 | Cabling for power, signals | | | | | | | | | | | after TDR | | | |
| 2.4.4 | Demonstration (possibly less than full-scale) (LLNL, SSCL, MSU, Tsinghua U.) | | | | | | | | | | | | | | | | |
| | 2.4.4.1 | Sub-scale verification testing of muon alignment system concept (six-point interpolation technique using three-point and multi point monitors, may have to be integrated into the prototype sector program) | | | | | | | | | | | | | | | |
| | | 2.4.4.1.1 | Design and assembly of structure and chamber test sector | | | | | | | | design only | design only | design only | design only | | | |

| | | | | | | Oct-92 | Nov-92 | Dec-92 | Jan-93 | Feb-93 | Mar-93 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2.4.4.1.1.1 | Procurement of materials for structure and chamber test segment | | | | | | | after TDR |
| | | | 2.4.4.1.1.2 | Fabrication of structure and chamber test segment | | | | | | | after TDR |
| | | | 2.4.4.1.1.3 | Software development for data acquisition and analysis | | | | | | | after TDR |
| | | 2.4.4.1.2 | Installation of structure and chamber test segment | | | | | | | | after TDR |
| | | | 2.4.4.1.2.1 | Development of alignment procedures - local | | | | | | | after TDR |
| | | | 2.4.4.1.2.2 | Procurement of auxiliary alignment equipment | | | | | | | after TDR |
| | | | 2.4.4.1.2.3 | Alignment survey of structure and chamber test segment | | | | | | | after TDR |
| | | 2.4.4.1.3 | Laboratory tests of interpolation techniques w/chamber test sector | | | | | | | | after TDR |
| | | | 2.4.4.1.3.1 | Alignment comparison and verification with "standard" | survey, | | | | | | after TDR |
| | | | 2.4.4.1.3.2 | Environmental sensitivity - temperature, vibration, air | currents, etc | | | | | | after TDR |
| 2.4.5 | Global alignment evaluation (LLNL, Draper, SSCL, ITEP) | | | | | | | | | | |
| | 2.4.5.1 | Evaluate feasibility of using background muons to define vertex location | | | | | | | | | |
| | 2.4.5.2 | Evaluate feasibility of survey/misalignments | | | | | | | | | |
| | 2.4.5.3 | If required, design global muon alignment monitoring system | | | | | | | | | |
| | 2.4.5.4 | Develop global alignment procedures | | | | | | | | | |
| 2.4.6 | Simulate operation of complete system (LLNL, Draper, SSCL, ITEP) | | | | | | | | | | |
| | 2.4.6.1 | Simulate and verify end-cap to improve alignment reconstruction | | | | | | | | | |
| | 2.4.6.2 | Coordinate design with system Paradise | | | | | | | | | |
| | 2.4.6.3 | Determine feasibility of using cosmic ray pre-alignment verification for all orientations of muon chambers | | | | | | | | | |
| | 2.4.6.4 | Coordinate structural analysis and truss structure | | | | | | | | | |
| | 2.4.6.5 | Comparison of six-point interpolation technique with analysis | | | | | | | | | |
| | 2.4.6.6 | Coordination of alignment sim/Simulations Group | | | | | | | | | |
| | | 2.4.6.6.1 | Studies of alignment results on muon tracking resolution | | | | | | | | |
| 2.4.7 | Industrialization (hardware, (LLNL, Draper) | | | | | | | | | | |
| | 2.4.7.1 | Transfer alignment designs to work must start in FY93 to develop a full-scale muon sector prototype) | | | | | | | | | after TDR |
| | | 2.4.7.1.1 | Generate detailed drawing packages for sensor/hardware | | | | | | | | after TDR |
| | | 2.4.7.1.2 | Identify potential industrial (or university) vendors | | | | | | | | after TDR |
| 2.4.8 | TDR Preparation | | | | | | | | | | |

## Descoped Budget for R&D of Alignment Technology

| Item | Lead Person | FTE | Budget (manpower/ procurement) |
|---|---|---|---|
| 2.4.1 | Joe Paradiso | 0.15 | $15K |
| 2.4.2 | Rick Sawicki | 0.34 | $54K (34/20) |
| 2.4.3 | Rick Sawicki | 0.08 | $12K (8/4) |
| 2.4.4 | Craig Wuest | 0.67 | $87 (67/20) |
| 2.4.5 | Andrei Ostapchuk | 0.17 | $17K |
| 2.4.6 | Joe Paradiso | 0.17 | $17K |
| 2.4.7 | Rick Sawicki | 0.05 | $5K |
| 2.4.8 | Craig Wuest | 0.05 | $5K |
| Subtotal | | 1.63 | $207K (163/44) |

# Integrated alignment system test objectives

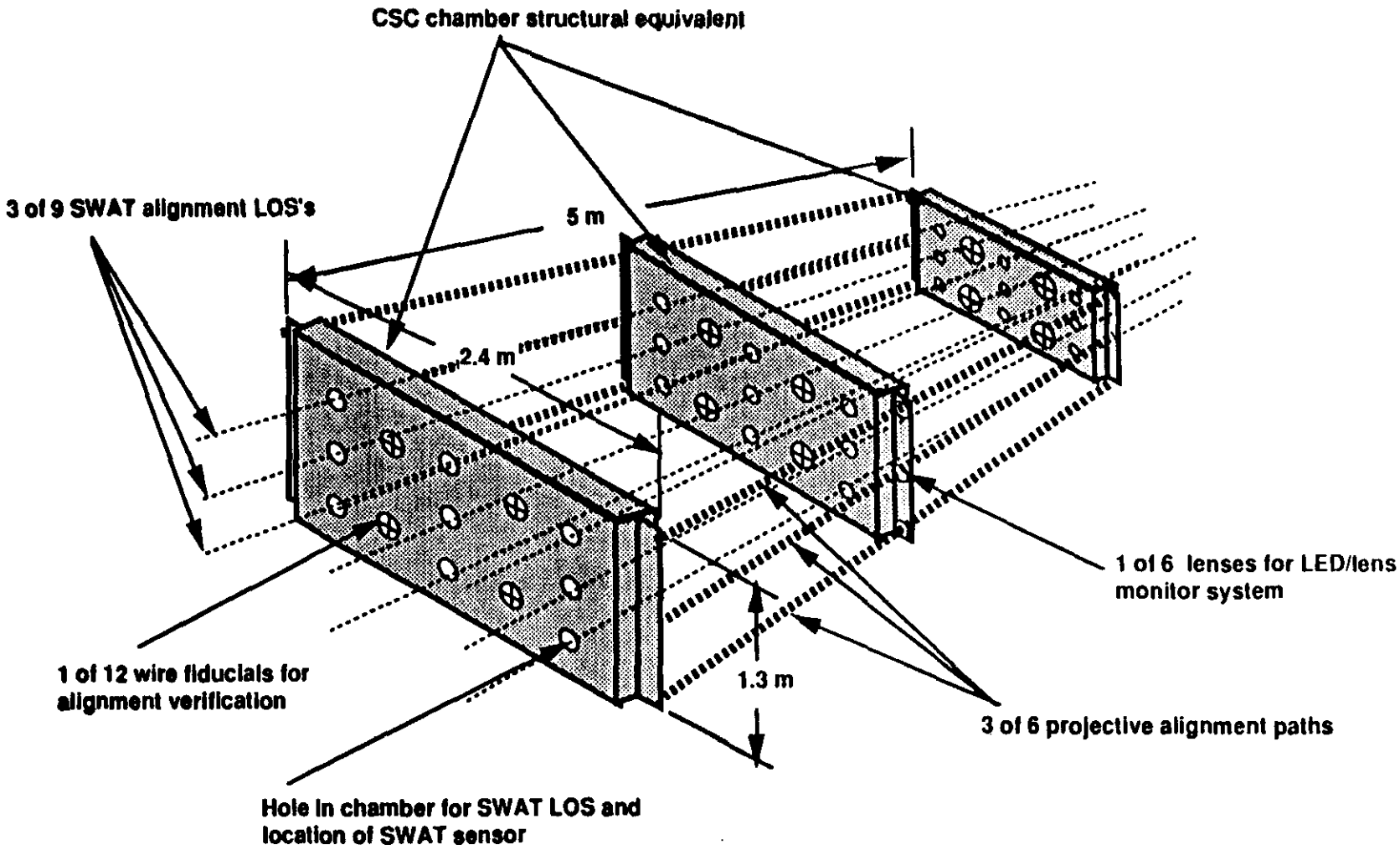
- The primary objective of the integrated alignment system test is to confirm the performance capability of a Projective Alignment System in a prototypical environment
  - measure superlayer-to-superlayer alignment with better than 25 micron accuracy

- Demonstrate integrated system performance
  - hardware
  - software
  - data acquisition and analysis

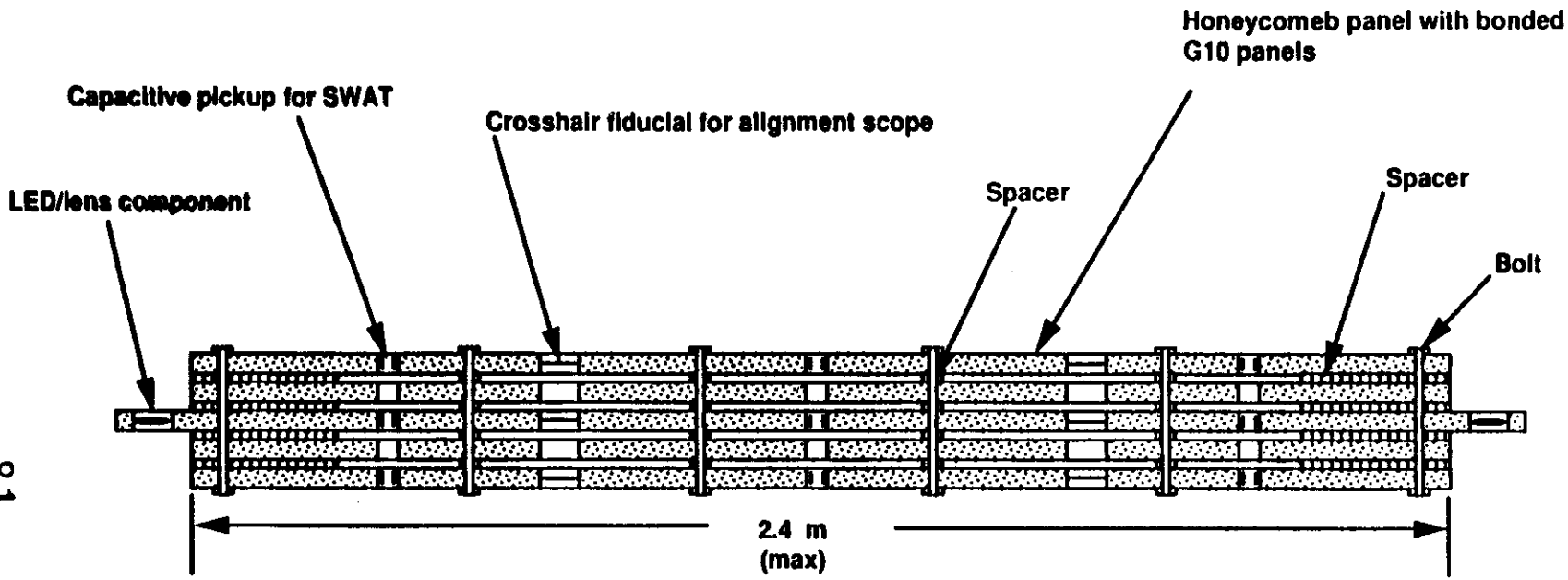
- Characterize system sensitivity to variable environmental conditions
  - varying temperatures
  - vibration
  - chamber rigid body motion
  - chamber flexible modes of deformation
  - tower structure deformation

- Optimize system design
  - software
  - alignment procedures
  - support and adjustment mechanisms

# Integrated alignment system test concept



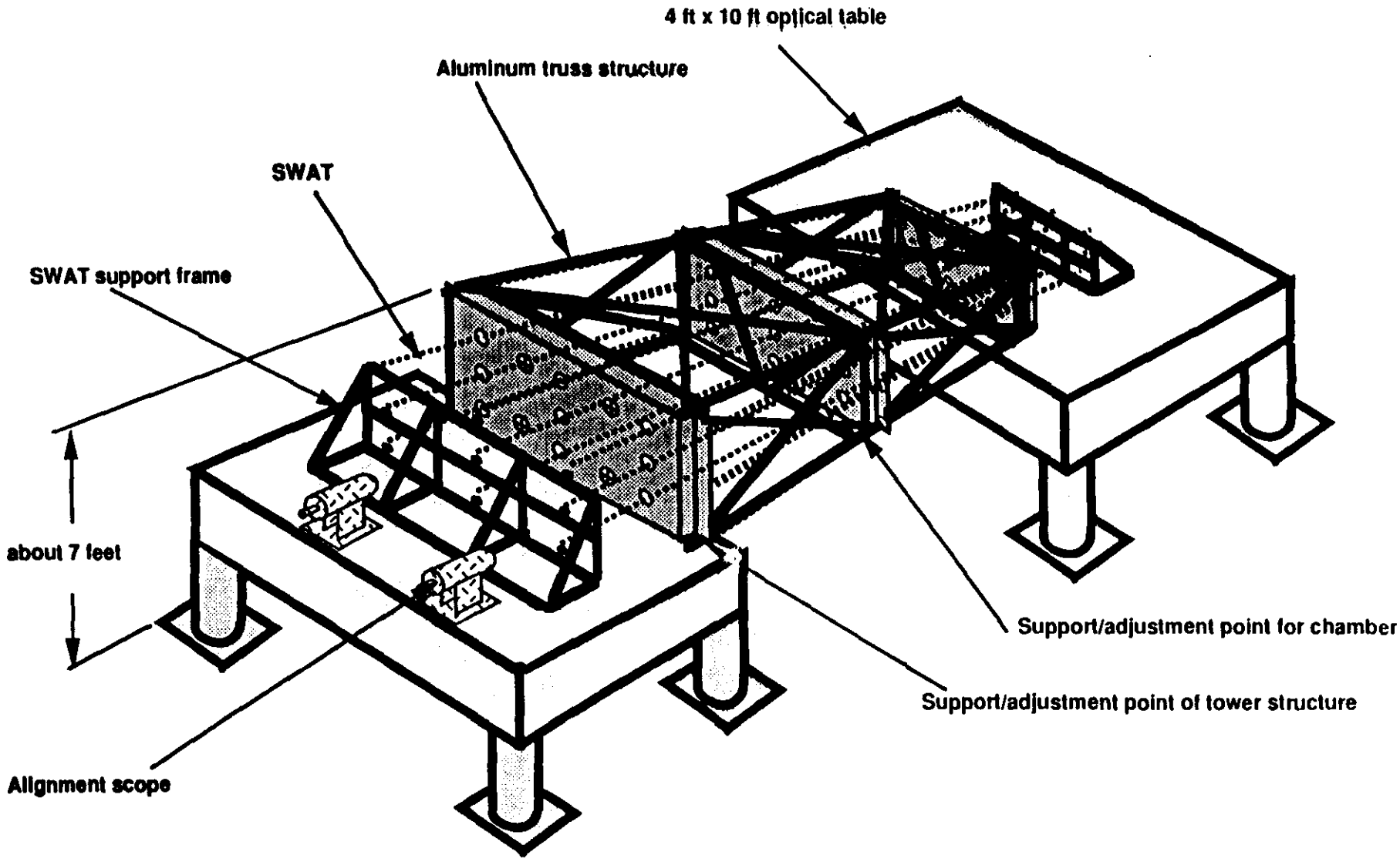
# Test chamber construction




Not drawn to scale
Panel construction requires no precision
- off the shelf G10 panel are glued to imprecise honeycomb sections
Spacers require no precision tolerances

**The concept is to mimic the structural behavior of a CSC chamber but at low cost without the precision required of the actual production unit**

# Integrated alignment system test setup



## IV. SUMMARY

The RPC trigger scheme has the following properties:

***Barrel***

1. Number of Channels

| | | | |
|---|---|---|---|
| Non-bend plane | 498 x 32 | = | 15,936 |
| Bend plane | 553 x 32 | = | 17,696 |
| TOTAL | | | 33,632 |

Strip Widths

| | | |
|---|---|---|
| *Non-bend plane* | | |
| SL1 | 3.9 | cm |
| SL2 | 6.5 | cm |
| SL3 | 8.9 | cm |
| *Bend plane* | | |
| SL1 | 1.3 | cm |
| SL2 | 1.3 | cm |
| SL3 | 1.3 | cm |

Strip Length

| | | |
|---|---|---|
| *Non-bend plane* | | |
| SL1 | 148.5 | cm |
| SL2 | 239.0 | cm |
| SL3 | 329.6 | cm |
| *Bend plane* | | |
| SL1 | 631.9 | cm |
| SL2 | 1,042.6 | cm |
| SL3 | 1,475.0 | cm |

| | | |
|---|---|---|
| Trigger acquisition time | 100 | nanoseconds |
| Beam crossing error | | |
| First level trigger | 11.7 | nanoseconds |
| Second level trigger | 5.0 | nanoseconds |
| Accidental rate at a neutron flux of $10^5$ neutrons per square centimeters per second (transverse momentum > 50 GeV/c | 22 | Hertz |
| Dead time at a neutron flux of $10^5$ neutrons per square centimeters per second (transverse momentum > 50 GeV/c | | |
| Signal dead time gate = 50 nanoseconds | 4% | |
| Signal dead time gate = 100 nanoseconds | 18% | |

### *End Cap*

Detailed strip information is in Table 1.

| | |
|---|---|
| Total number of end cap channels | 77,440 |
| Trigger acquisition time | 10 nanoseconds |
| Beam crossing error | |
| First level trigger | 11.7 nanoseconds |
| Second level trigger | 5 nanoseconds |

All accidental rates and dead times are less than the barrel by more than an order of magnitude.

## V. APPENDIX 1

Considerations of strip timing, accidental rates and system dead time.

### *A. Barrel Trigger*

#### I. *Timing*

The basic barrel trigger depends on the non-barrel plane timing. We will label each of the 166 non-bend strips with an index k (k = 0 - 155) where strip Δ is the strip closest to the interaction point. The non-bend plane strips form a projective tower with the interaction point. Every three corresponding strips (i.e. the three strips with the same index) can be brought into time coincidence at the input to the shift register logic. This is done by having a fixed cable length difference for each strip of SL2 and SL1 with respect to SL3. The fixed cable lengths [measured in nanoseconds] for SL2 and SL1 is listed in Table A.1. Following the cable delay which is common for all strips on a superlayer there is a timing gate delay, the width of which is determined by the bend strip index. Following the gate delays there is generated a signal gate whose length is determined by the superlayer. These timings are also listed in Table A.1.

The bend plane strips also have the same cable differences as the non-bend plane strips as indicated in Table A.1. The bend plane strips do not have any timing gate delays following the cable but rather generate just a signal gate whose width is superlayer dependent. This is also listed in Table A.1.

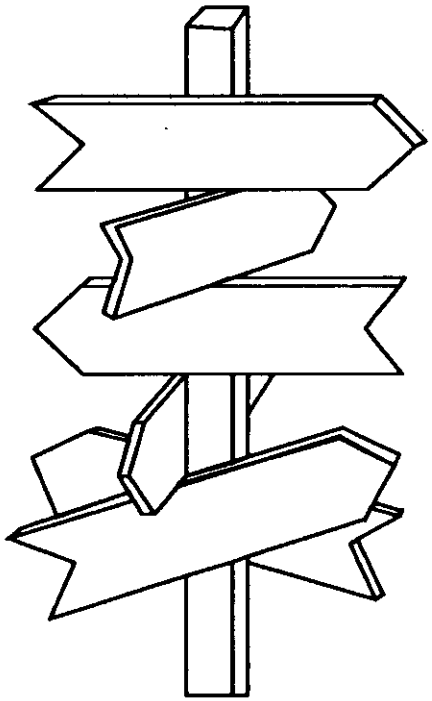
If the numbers listed in Table A.1 are used in a straight forward, but

Joe Paradiso

# Baseline 2 Alignment Issues

# Baseline 2 Alignment Issues

## Topics:

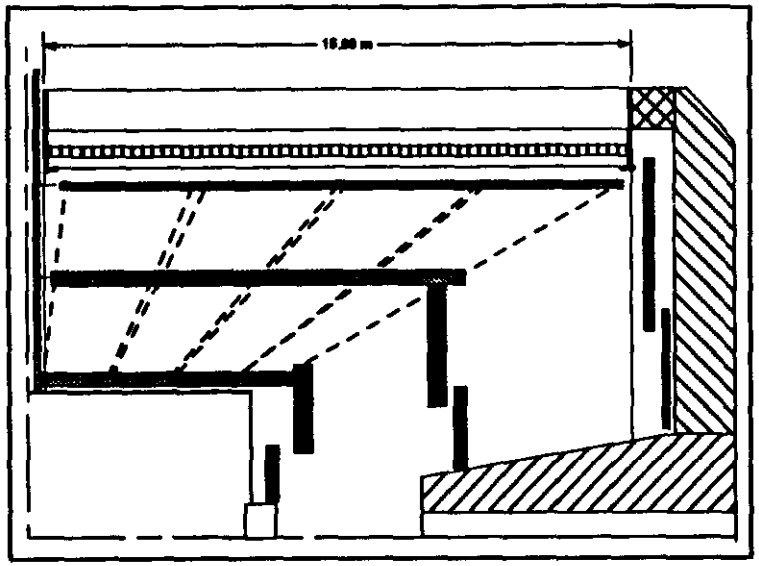


- Barrel CSC layout
- Endcaps
- Alignment hardware

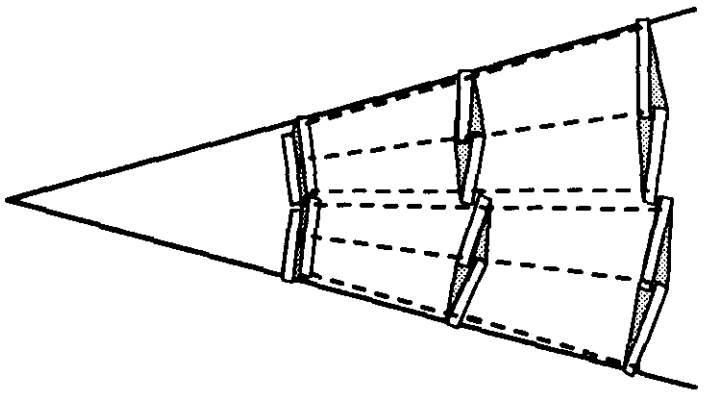
J. Paradiso
9-Dec.-92

GEM

# Barrel Layout



Side view (rθ)



End view (rϕ)

- Alignment elements on endplates (3 per endplate set?)
- Chambers overlap in phi
  - Common muon tracks can tie chambers together in phi-projection (not r)
- Projective breaks in theta
  - How to reference bottom chamber if unbroken (cover stable enough?)
    - * Use single LED source for neighboring chambers (enough range?)
  - Need clear optical paths!!
    - * Slice/stack chambers projectively?
    - * Endcap blockage at 30°?

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# Alignment Transfer

- Beauty of CSC's was that alignment reference could be directly to strips
  - Now, alignment is on endplate, adding another transfer!!
- Alignment reference to the chamber...
  - Ideal case: Make precisely

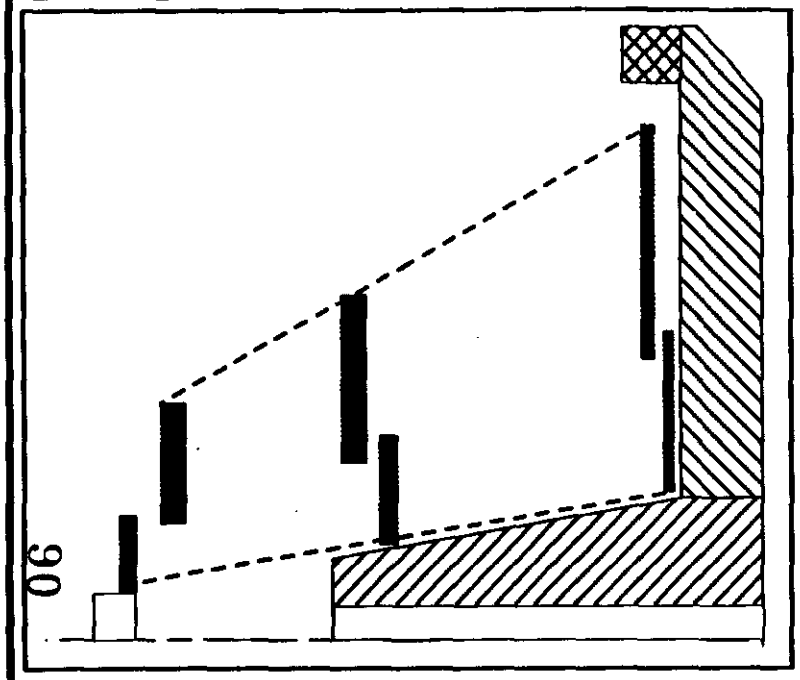
    => *Expensive*
  - Possibly less costly case: Make stable

    * Use muons and measured projective alignment errors to get offsets

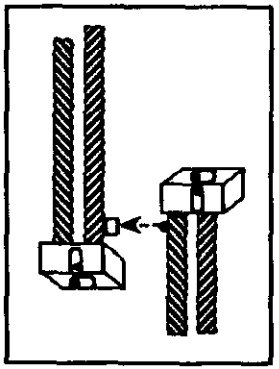
| |
|---|
| Structure works on timescale of hours/minutes<br>- *Measure w. monitors*<br>Muon data achieves precision in barrel with timescale of days<br>=> *Take out offsets* |

- May need absolute reference for initial global alignment, if straightness monitors used
  - Other techniques help (i.e. X-rays), coarser resolution (i.e. mm) needed

# Endcaps




- What is a believable layout??
  - Square chambers, daughters, etc...?
- Need lines of sight
  - 30° (problem w. barrel overlap?)
  - 10° (chamber layout, overlap?)
- Punch holes in chambers??
  - Would like circa 1" hole
  - Laminated construction (not honeycomb foil here...)
  - Continuity of strips
  - Different refraction in gas

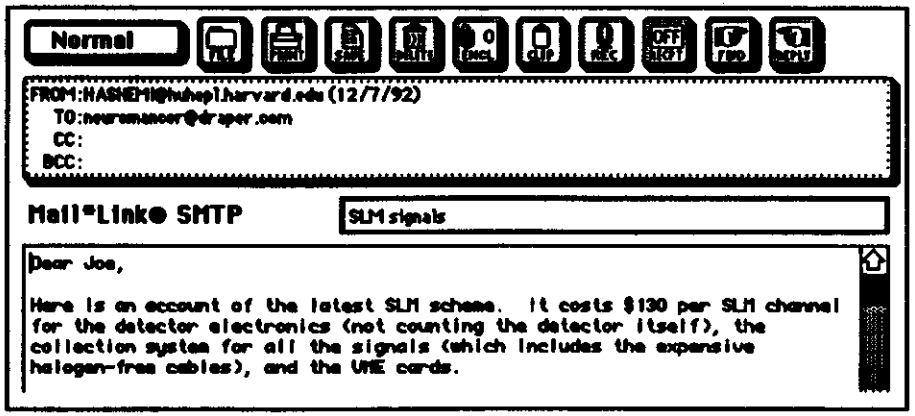


- Possibility:
  - LED/Lens align; 2 paths each at 10 & 30°
  - Mechanically tie inner chamber edges together (need only 200 μm or worse accuracy; 1 meter spacing)
  - Overlap chambers, and track muons through both to align offline.
  - Levels discussed, but can be singular in theta
- Global alignment (y,z) needed within 2 mm or so for fitting through field (Zhukov et. al.)?
  - Can also get with μ (rate huge in endcap; central tracker not needed...)

*- Would like to get such feasibility studies with muons ASAP (simulations should be nearly trivial, dep. on field model...)*

# The Harvard SLM Electronics

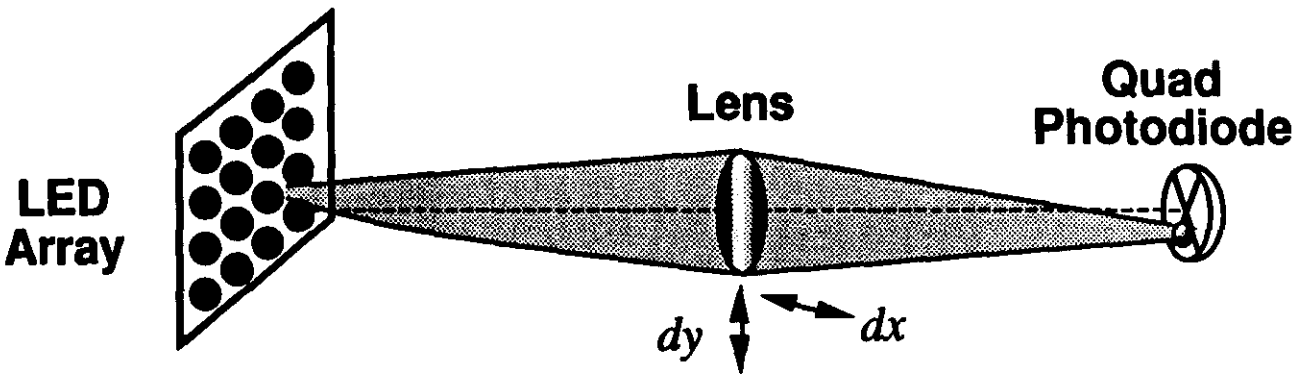
- Visited John Oliver and Kevan Hashimi @ HUHEP 12/4/92
- System composed of three cards
  - Detector card
    (Services Quad Cell; 3 analog Δ-outputs, 2 clock inputs)
  - Controller card
    (Serves 8 detector cards; fans out clocks, LEDs; multiplexes)
  - Scanning ADC (60 Δ-inputs; VME module, Harvard standard)
- Estimated @ $130. per channel




***Halogen-free cable expensive! (Design may be somewhat cable-intensive)***

GEM

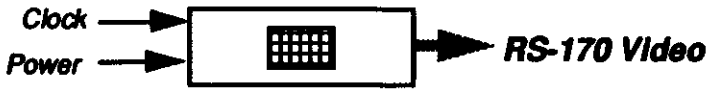
# The Extended Range Frontier




- Replace single LED with matrix of LED's.
  - Available as monolithic or moulded assemblies for displays
  - Wink LED's on/off sequentially, and interpolate between neighbors
  - Could still use quad cell if LED's are close enough
  - Issues are placement, precision, uniformity, light output.

    => Could use precision lensed LED's in machined mount...

# RS170 Imaging Chips




- Commercial CCD matrices for miniature cameras.
- Single chip needs power, clock (≈ 2 phases?)
- Outputs composite RS-170 signal for frame grabber.
  - => Simple and cheap!! (circa $40./chip; cost of quad cell!)
  - => Cabling is minimal (need power, 75Ω video out)

- Issues...
  - Light sensitivity, S/N
  - Neutron background/damage
  - Runs in magnetic field?
  - Clocked (≈3 Mhz) device near pickup strips?
    [No need for distributed clock; synch to composite RS170]

*Trivial to try...*

GEM

Frank Nimblett

# Support Structure Design Update

From: JOHNCOLE@SSCVX1.SSC.GOV (12/8/92)
To: Coleman Johnson
CC:
BCC:
Priority: Normal Date sent: 12/8/92 10:15 AM

**Mail*Link® SMTP** FFS

```
Received: by qmail.ssc.gov with SMTP;8 Dec 1992 10:11:56 -0600
Date:     Tue, 8 Dec 1992 10:09:38 -0600 (CST)
From:     JOHNCOLE@SSCVX1.SSC.GOV
Message-Id: <921208100938.20203d2c@SSCVX1.SSC.GOV>
Subject: FFS
To:       coleman_johnson.physics@qmail.ssc.gov
X-Vmsmail-To: SMTP%"Coleman_Johnson@QMail.ssc.gov"

From: SMTP%"@surname.draper.com,@ccfvx3.draper.com:nimblett@draper.com"  4-DEC-1992
12:05:07.50
To: "Coleman Johnson (SSCL)" <johncole@sscvx1.ssc.gov>,     "Rick Sawicki (qminternet)"
<rick_sawicki@engmail.llnl.gov>
CC:
Subj: FFS /Muon Structures confli

Date: 04 Dec 1992 12:51:00 -0500
From: Frank Nimblett <nimblett@draper.com>
Subject: FFS /Muon Structures confli
To: "Coleman Johnson (SSCL)" <johncole@sscvx1.ssc.gov>,
    "Rick Sawicki (qminternet)" <rick_sawicki@engmail.llnl.gov>
Cc: Howard_Baker@qmlink.draper.com,
    "Mike Harris(QMail)" <Mike_Harris@qmail.ssc.gov>,
    "Michael Marx(SSC)" <MARX@sscvx1.ssc.gov>,
    Frank Taylor <FET@mitlns.mit.edu>
Message-id: <01GRX2W7ZI769VVQU6@ccfvx3.draper.com>
Content-type: x-see-attachments
Content-transfer-encoding: 7BIT
Priority: Urgent
x-attachments: "GMUA020 (Deis/Nimblett replies)" (type: uuencode-apple-single),
 "GMUA020 Orig Sketch" (type: uuencode-apple-single),
 "GMUA022 Full Muon Struct" (type: uuencode-apple-single),
 "Muon/FFS Interface/rev1" (type: uuencode-apple-single)

                        Subject:                                Time:11:40 AM
  OFFICE MEMO           FFS /Muon Structures conflict           Date:12/4/92
Coleman and Rick,
     I sent this note off to Joel and Gary late yesterday and didn't have time
to handle the copies to everyone else.  For the time being, I'm going to limit
distribution of these notes to the five of us in the muon engineering group, or
whatever we are called.  We can then each decide upon appropriate distribution
beyond this group.  In this particular case, there are MacDraw II 1.1 sketches
enclosed so you can both read them.  Coleman if you would please print them out
(Claris Cad) and distrubute to Harris and Marx I would appreciate it. I'm not
sure who has what Mac CAD system, so this is this simplest format I can
produce.  I think only F.Taylor will have a problem receiving this and I will
FAX him a copy.
    Rick, hopefully this format is OK for you to read.  Please let me know if
there is any problem.  Are you planning to at SSCL next week?  If so give me a
call, I have to make a ten minute pitch on the muon structures next week at the
collaboration meeting and would like to see what's available for sketches .
Perhaps some of the ones sent to FET might be  appropriate, I'll check with him
today when he gets back.
     Coleman, on the the CSC front, our preliminary layouts at Draper are
                                        - more -
```

Memo to: Joel Bowers, Gary Deis

Subject: FFS / Muon System Interface Near Pressure Pads on Crysostat

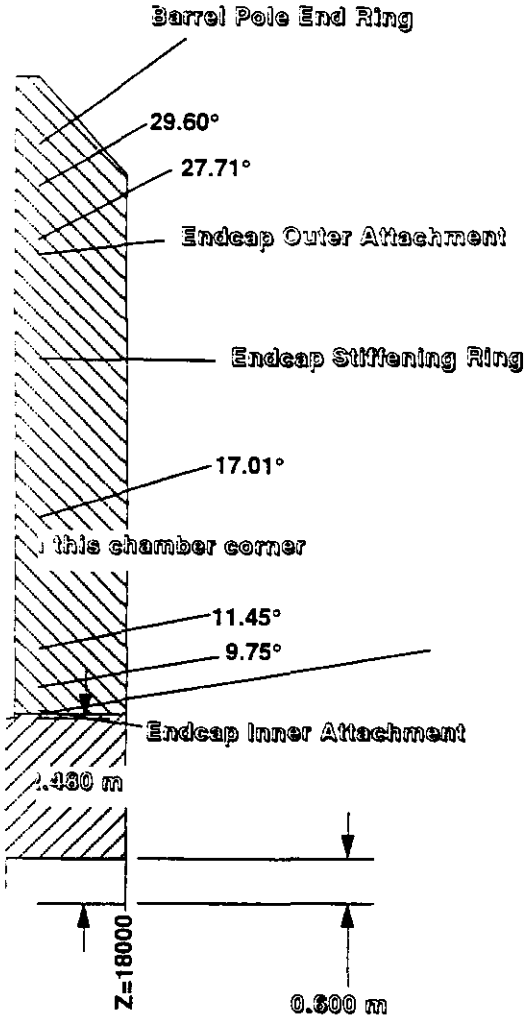
Copies to: M. Harris, M. Marx, C. Johnson, R. Sawicki, F. Taylor

Recently, the muon system engineers recommended that GEM proceed with a monolithic barrel and a monolithic endcap for the muon system, each of which will be built up from modules. The assembly of the two region monoliths will be done in the assembly buildings, and the two monoliths will be merged there as well, if the endcap is not staged. The entire muon system will then be brought down as an assembly and slid into the magnet on rails on a "beefed-up" portion of the cryostat wall (yet to be resolved). This memo is just a convenient way to send a lot of information quickly. I have included the succession of sketches which have been exchanged and couple which are new.

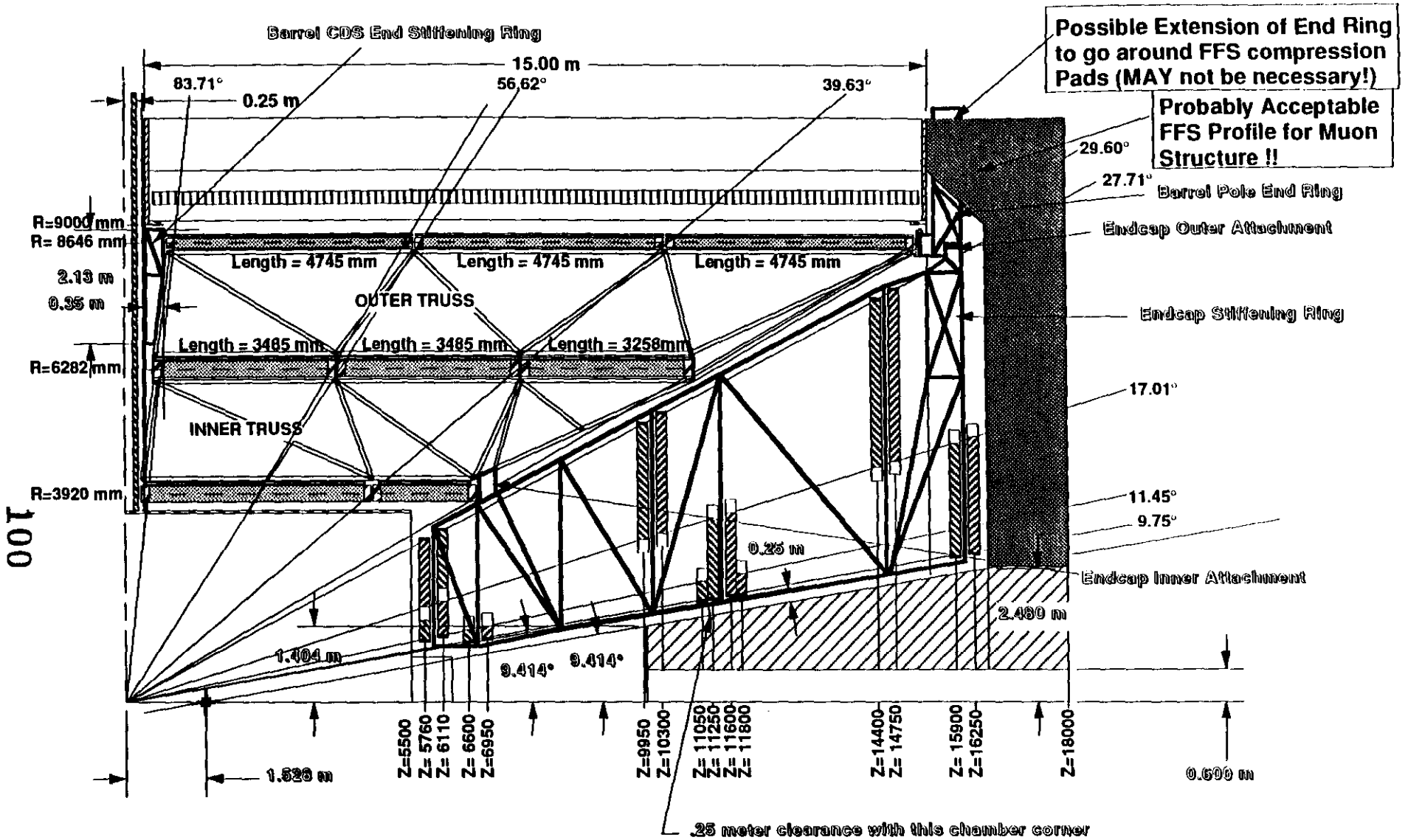
There has been no official word yet on the disposition of this reccommendation, but assuming it is approved, this option requires more space than previously planned. The largest potential problem is in the area of the contact points for the FFS and the magnet cryostat. We must provide additional structure for muon system support to replace that previously offered by the magnet cryostat. There is currently an obvious conflict between what is needed for the FFS structure and what is needed for these new "endring structures" to support the muon monoliths. I have enclosed 1) the sketch that I sent to Gary Deis, 2) the sketch Gary returned to me indicating the problem, 3) a sketch of a possible compromise, 4) side and end views of what this new muon structure concept looks like.

In an EMAIL note this morning I also requested some sketches from you better defining the FFS. Hopefully, this will be forthcoming today. Rather than enunciating all of the potential options, I will just send you this note, let you think about the plan and hopefully get back to me as soon as possible. I will do the same when I get the FFS details. I'm sure that there is some middle ground here unless the FFS structure design is so critical that it cannot tolerate moving radially outward to provide some space for the endring structure. It may well be appropriate to meet and discuss this issue in the very near future. I plan on being at SSCL on Dec 8-10th for GEM week. If you could be there during this time period I suspect we could find time over these three days to discuss these issues , hopefully resolve them or if not at least come up with a plan to come to resolution.

Something to keep in mind through all of this is that the FFS is a device whose goal is to improve muon resolution in th endcap region. The details of the structural design of the FFS should not force performance sacrifices for the muon system which quite frankly already has an extremly difficult task ahead of it. I believe I at least paraphrase Mike Harris in saying that it is precision muon measurement that differentiates GEM from SDC. The enclosed endview I think illustrates that the option exists to work muon stucture around the compression pads if the FFS structure in the immediate area is not too extensive.




| Draper Laboratory | | |
|---|---|---|
| GEM Muon System Chamber Layout | | |
| Drawn By: | F. Nimblett | Rev 1 |
| Dwg. No: | GMU0020 | 11/16/92 |
| Approved by: | | |

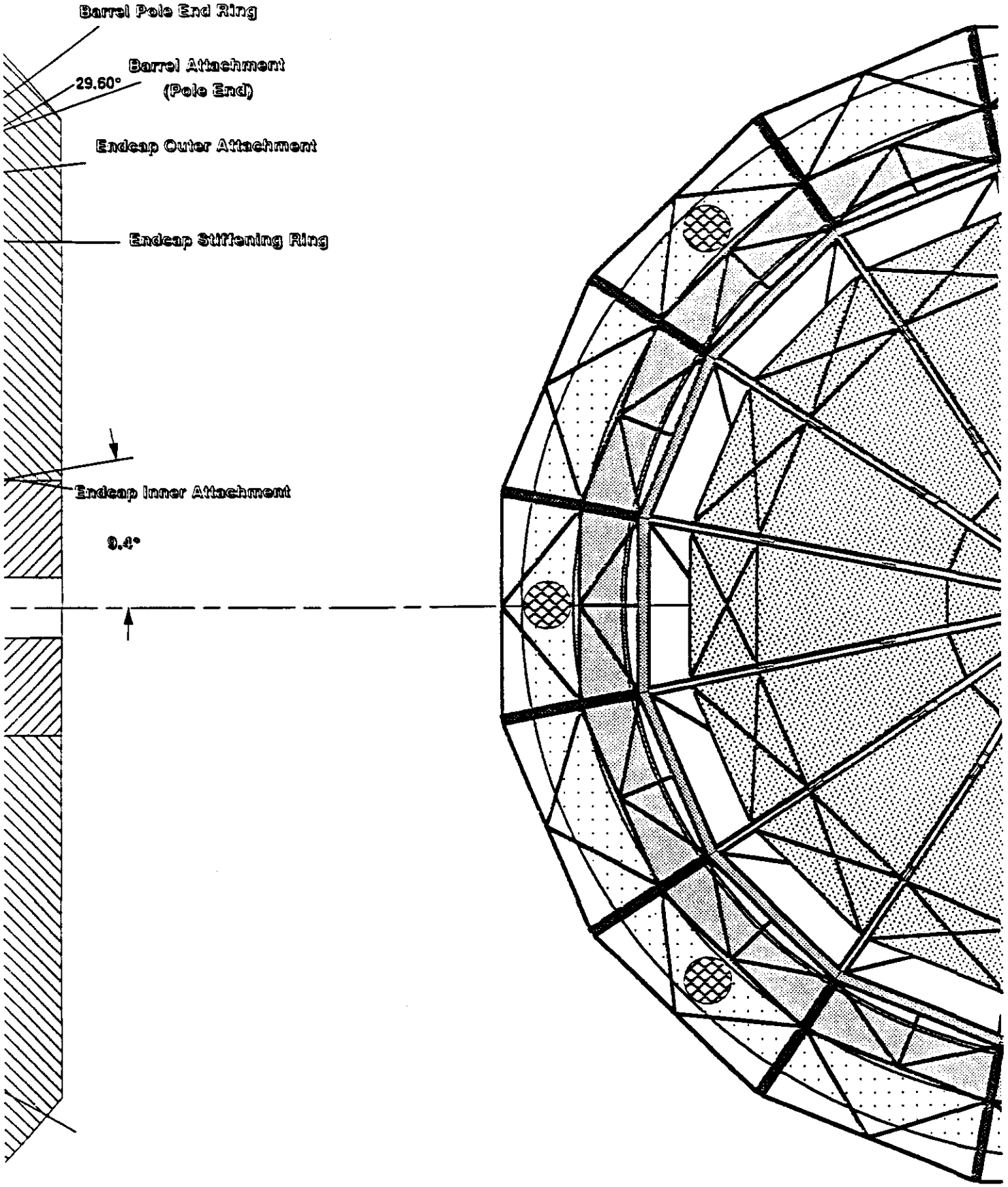



100

**Reply by Frank Nimblett to sketch from Gary Deis relative to incompatability of latest muon support structure end rings with the current FFS design**

**Nimblett's Reply**

| Draper Laboratory | |
|---|---|
| GEM Muon System Chamber Layout | |
| Drawn By: F. Nimblett | Rev 3 |
| Dwg. No: GMU0020 | 11/16/92 |
| Approved by: | |


Barrel Pole End Ring
Barrel Attachment
(Pole End)
29.60°
Endcap Outer Attachment
Endcap Stiffening Ring
Endcap Inner Attachment
9.4°

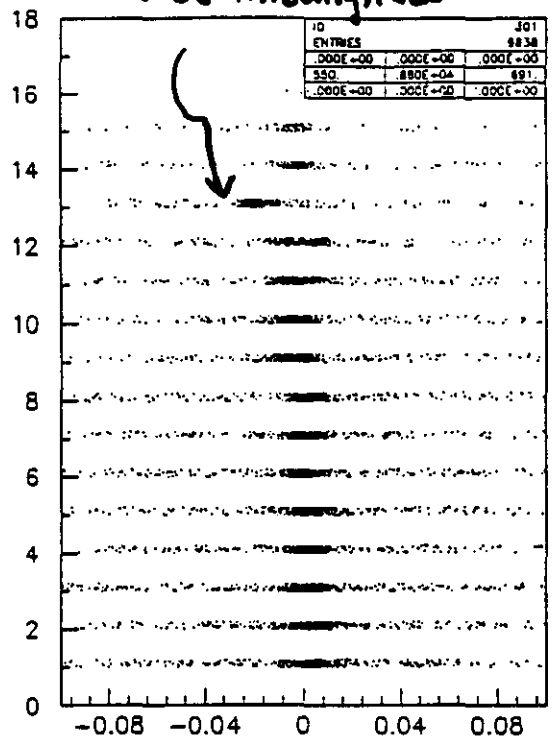
Andrey Golutvin

RDT Resolution Studies from TTR

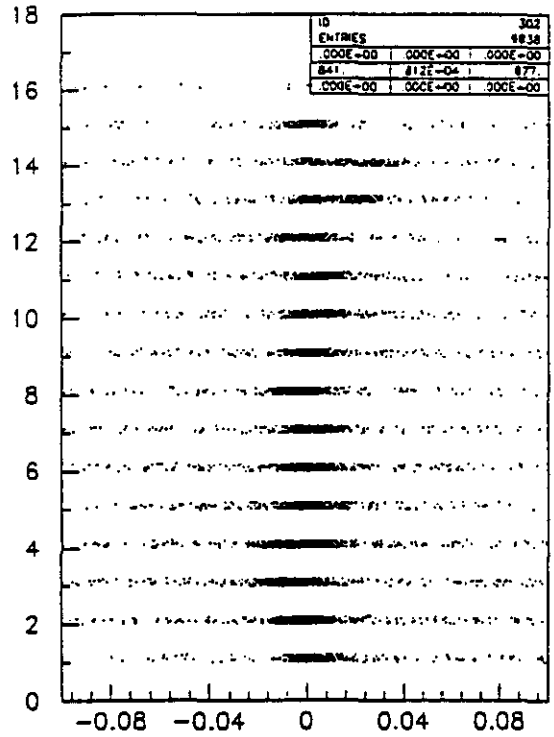
Analysis by ITEP Collaboration

92/12/01 17.20

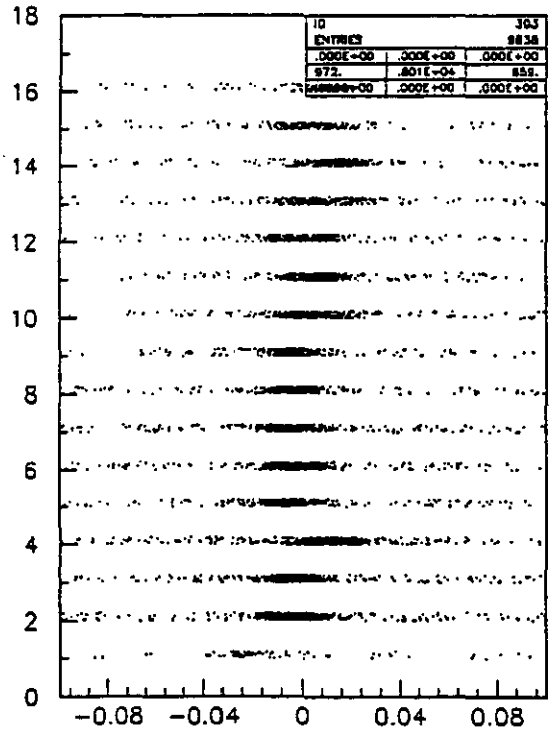
tube misaligned



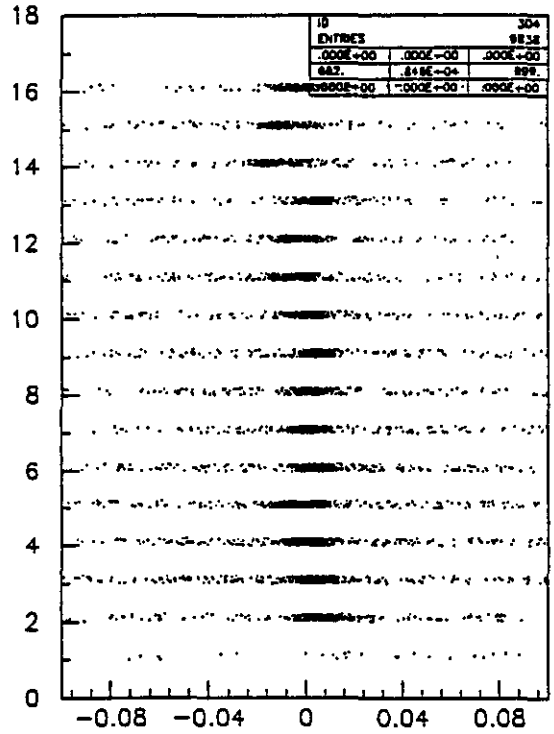

delta(Y) vs tube number for layer 1




delta(Y) vs tube number for layer 2



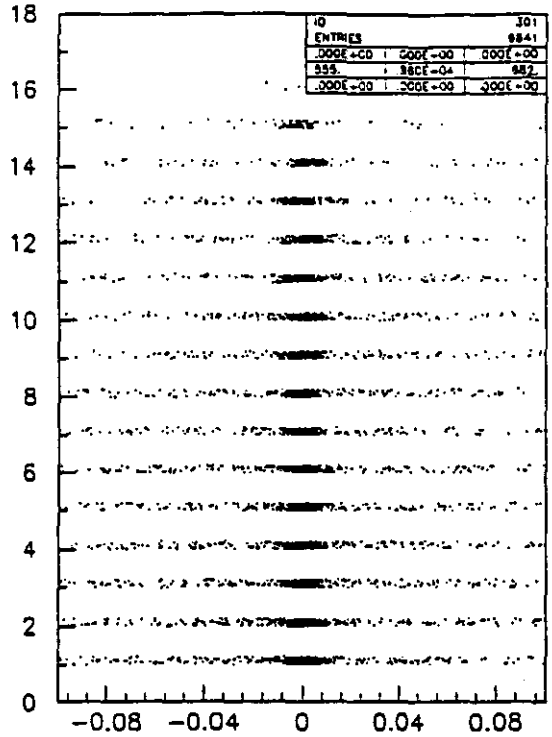

delta(Y) vs tube number for layer 3



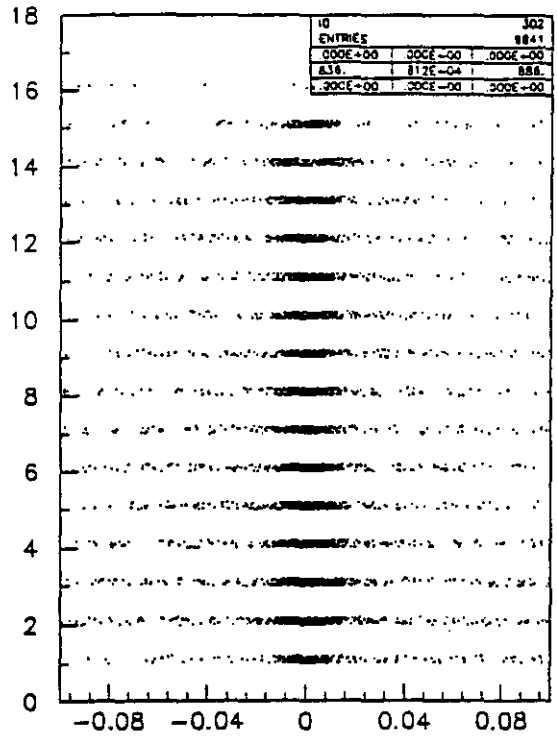

delta(Y) vs tube number for layer 4

Tubes now aligned (11 - shift)

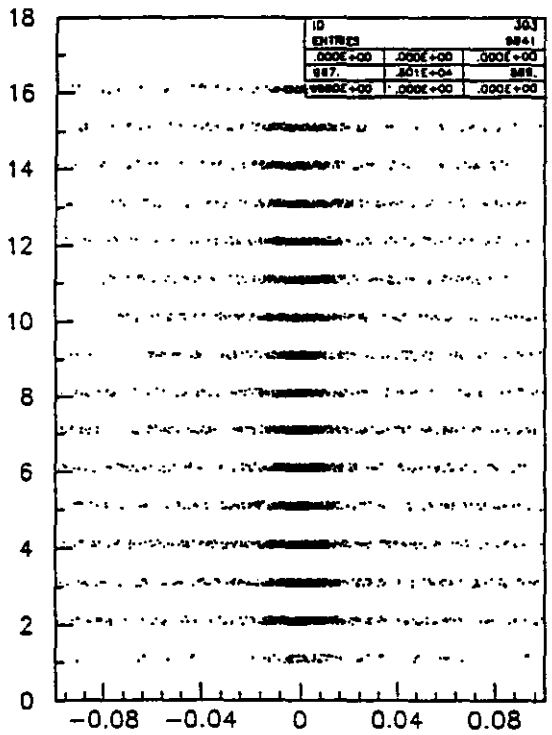
92/12/01 17.33



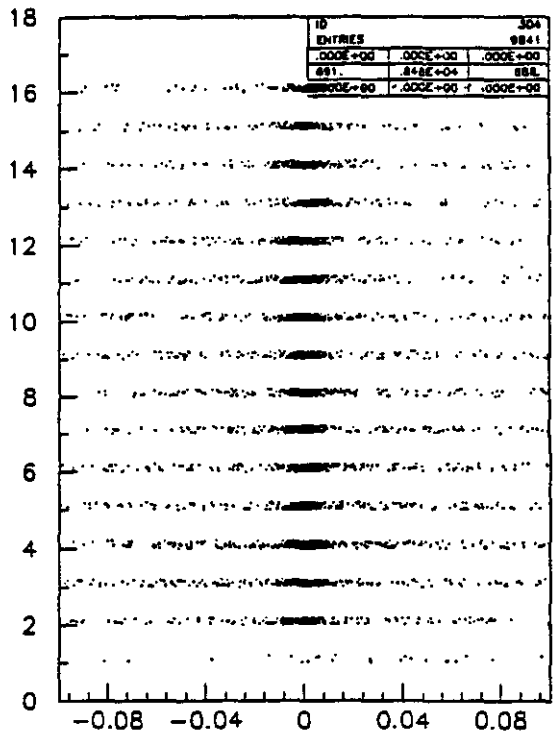

delta(Y) vs tube number for layer 1




delta(Y) vs tube number for layer 2

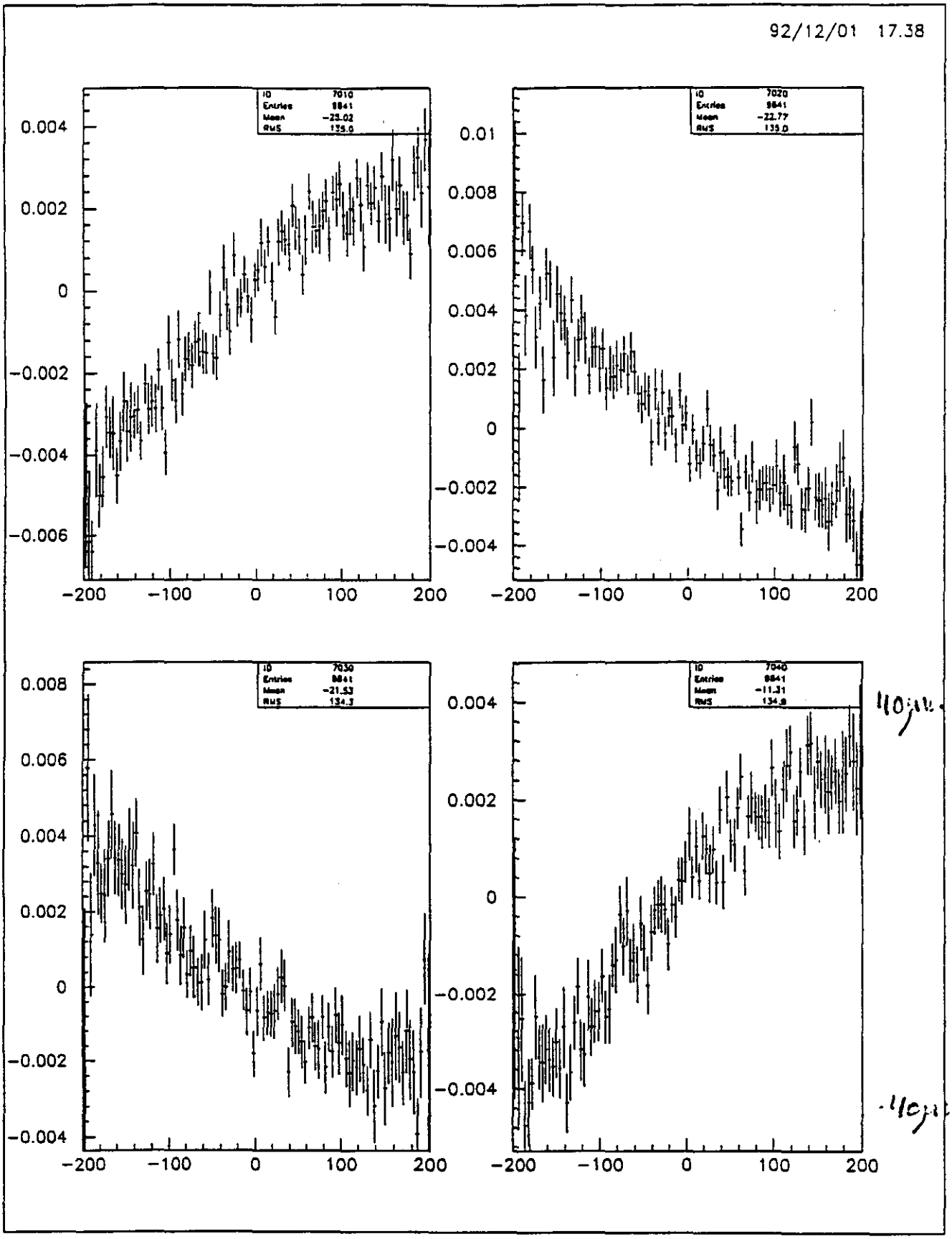



delta(Y) vs tube number for layer 3

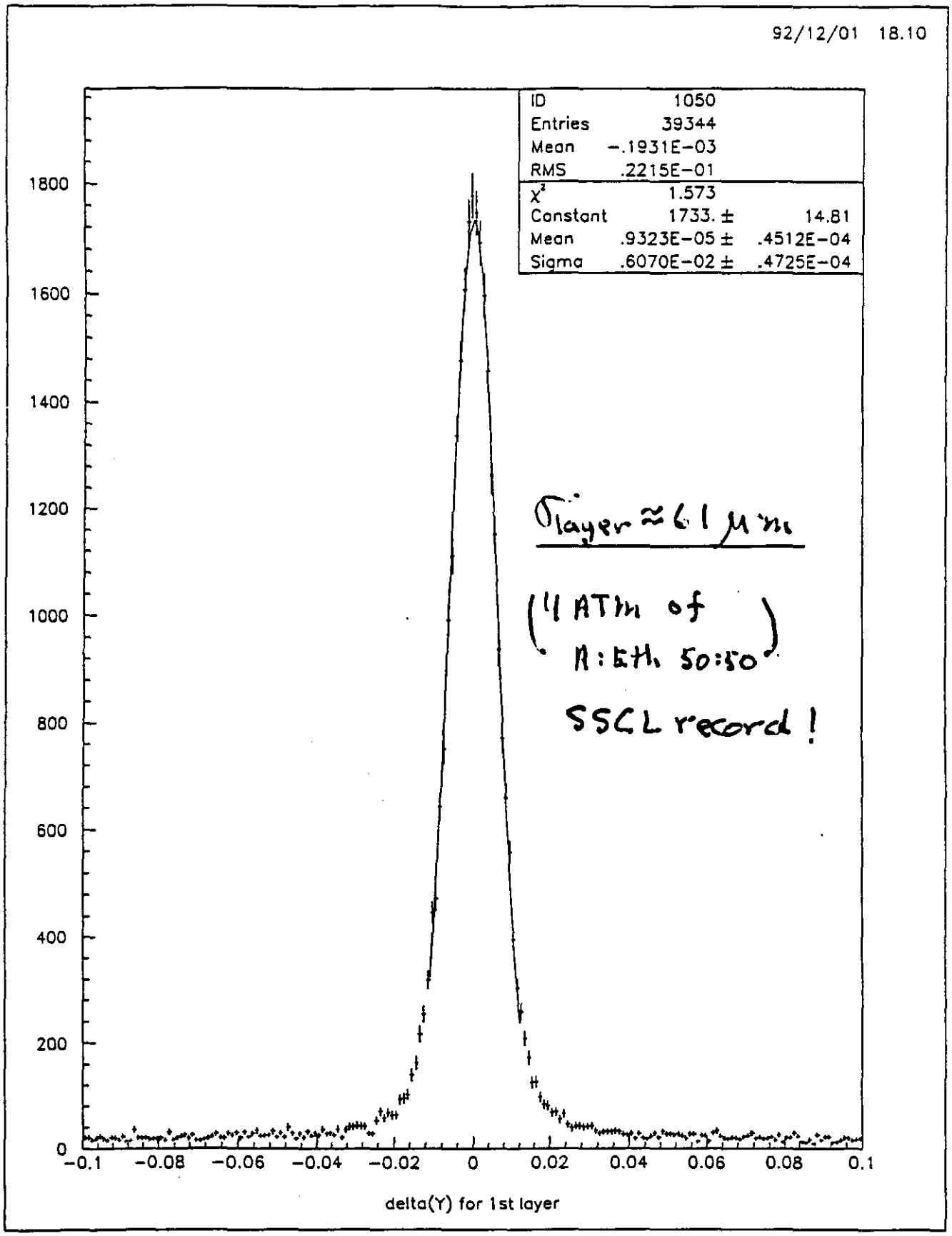



delta(Y) vs tube number for layer 4

Tilts have "crossed" misalignments



# RDT Resolution - all corrections




Data can be used to calibrate & align

Kwong Lau

# TTR Results - CSC/UH

UH CSC Prototype

- 3 layers of 1.0 m (long) x 0.5 m precision strips (pitch = 5.0 mm = 4 mm Cu + 1 mm gap)
- 3 layers ( 12 chambers per layer ) of 66-cm Iarocci-type carbon-coated (4 k$\Omega$ per square) profiles with 45 $\mu$m gold-plated tungsten wires
- standard ( 75/25 Isobutane-argon ) gas mixture in proportional mode ( 3.0 - 3.3 kV)
- 10 (top), 9 (middle), and 10 (bottom) strips at center from the three layers are instrumented with preamps (gain $\simeq$ 1000) and ADCs.
- preamp outputs are routed via 53-m RG174 coaxial cables to Lecroy 2249W ADCs with an integration time of 500 ns
- trigger on 2 top scintillators and all bottom scintillators

Key Milestones

- 9/15 Prototype delivered to SSCL
- 10/15 Prototype installed in TTR
- 11/10 First data run @ 3.1 kV (30 k triggers)
- 11/19 Preliminary results ( 96.3 $\mu$m @ 3.1 kV)
- 11/24 HV scan : chambers operated at 3.1, 3.2, and 3.3 kV (200 k triggers each)
- 12/09 Resolution as a function of HV (Preliminary)

## Analysis Procedure

- Fast Filter at TTR
  - select events with at least 1 strip with $\geq$ 100 ADC counts in each layer

- Pedestal and Gain Corrections
  - apply pedestal (20-40 ADC counts) subtraction and gain correction ( 1.00 $\pm$ 0.10 ) to all ADC counts.
  - ADC counts set to 0 if corrected counts are $\leq$ 0.

- Fiducial Cut
  - locate peak channel in each layer and require peak channel to be at least 1 or 2 channels from uninstrumented strips

- $\delta$-ray Cut
  - remove any event with 1 or more ADC overflows ($\geq$ 1900 raw ADC counts)

- Locate Cluster Centroid
  - determine c.o.g. of the hits for each layer ($z_{cog}$) by using a weighted mean of 3-strip ($z^{(3)}$) and 4-strip ($z^{(4)}$) c.o.g.'s

$$z_{cog} = \frac{z^{(3)}}{1 + \frac{2}{w}(z^{(3)} - z^{(4)})}$$

w = strip pitch = 5.0 mm

- Systematic Correction
  - apply a 3-term-Fourier-series systematic correction of the following form

$$\Delta z = A \times [sin(\frac{2\pi z_{cog}}{w}) - 0.077 \times sin(\frac{4\pi z_{cog}}{w}) + 0.041 \times sin(\frac{6\pi z_{cog}}{w})]$$

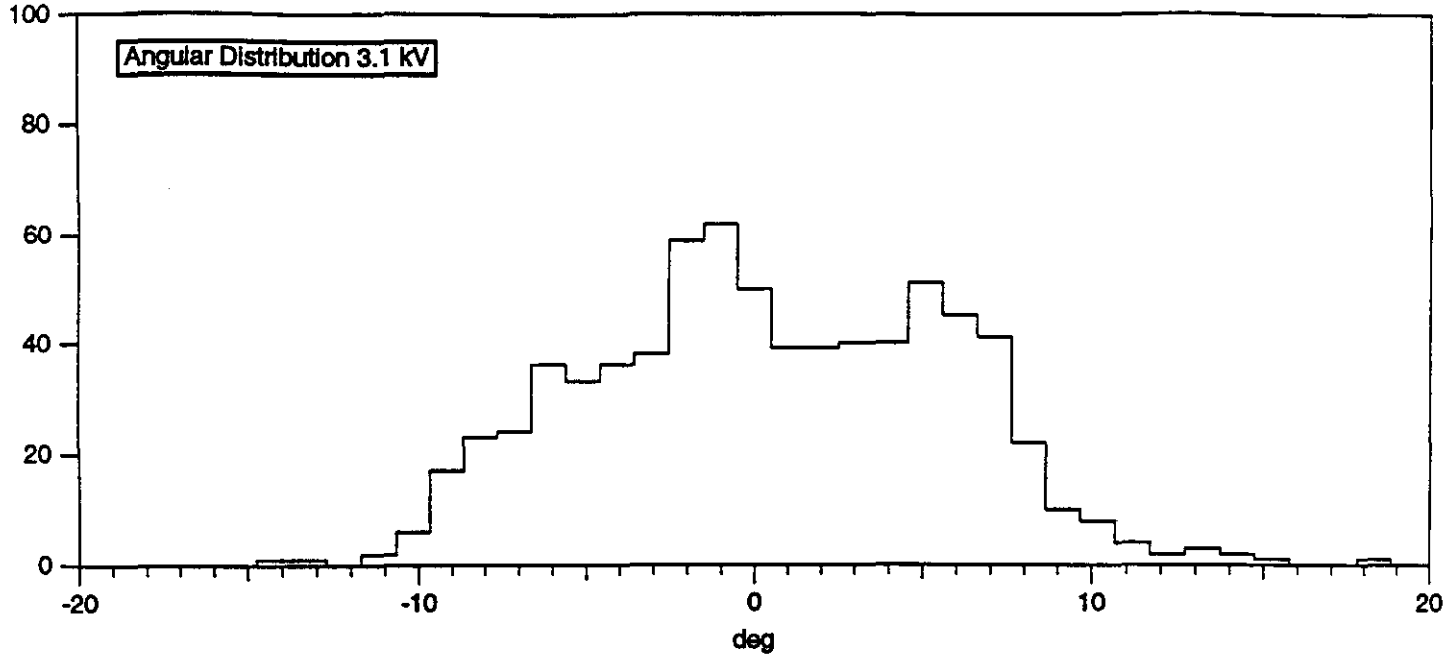
A is varied in the range : $60 \leq A \leq 100$ $\mu$m

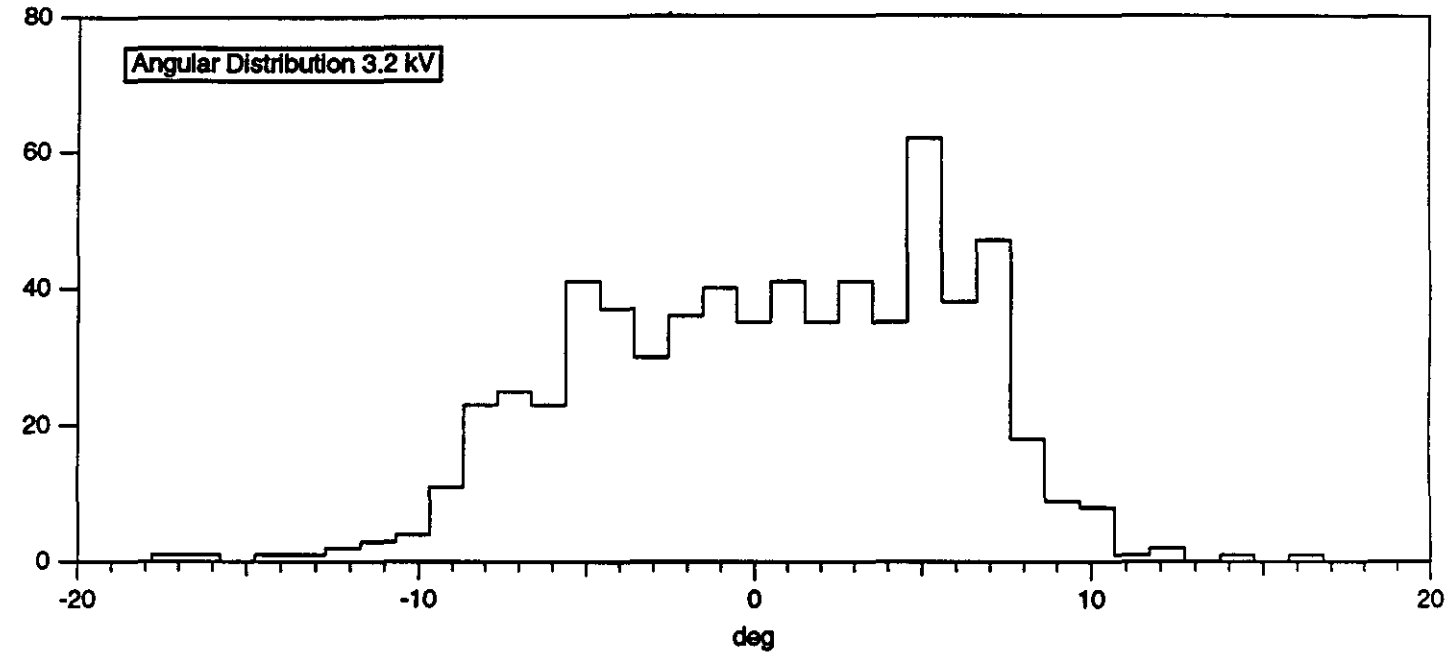
A = 117.1 $\mu$m according to monte carlo with a point inducing charge

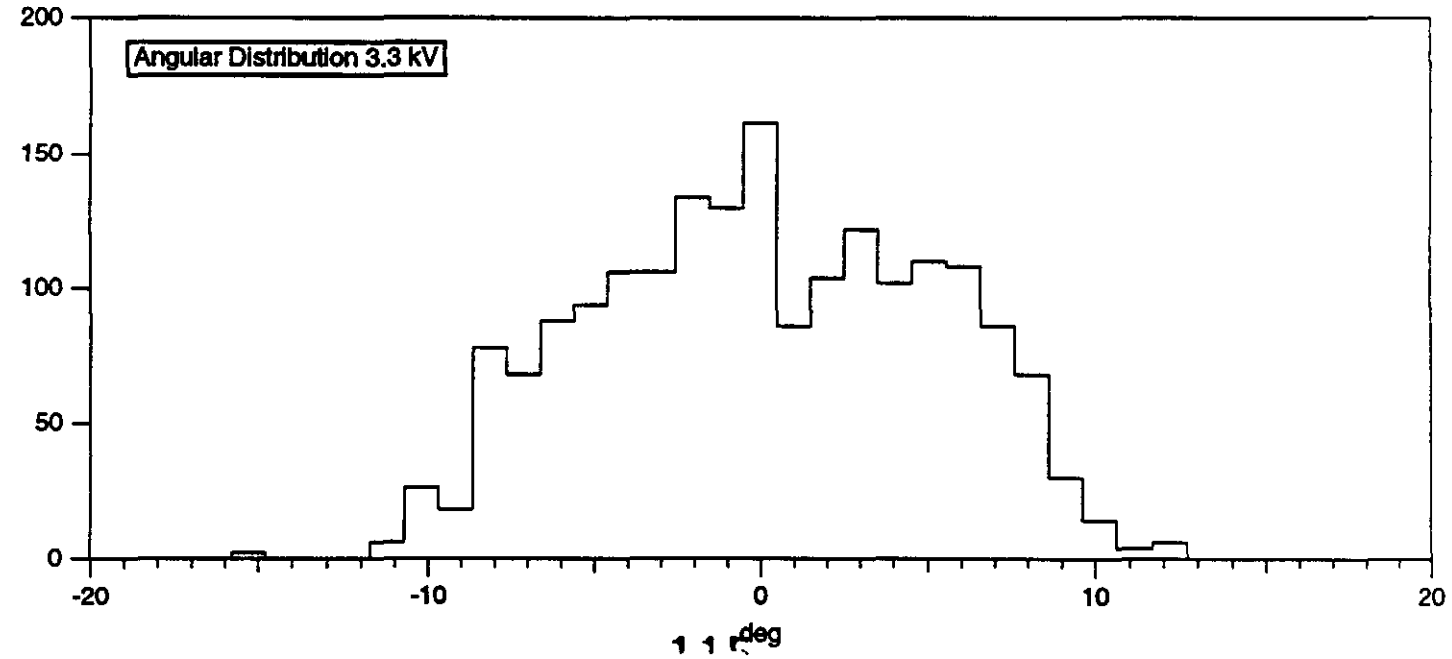
A $\simeq$ 80-90 $\mu$m gives best results

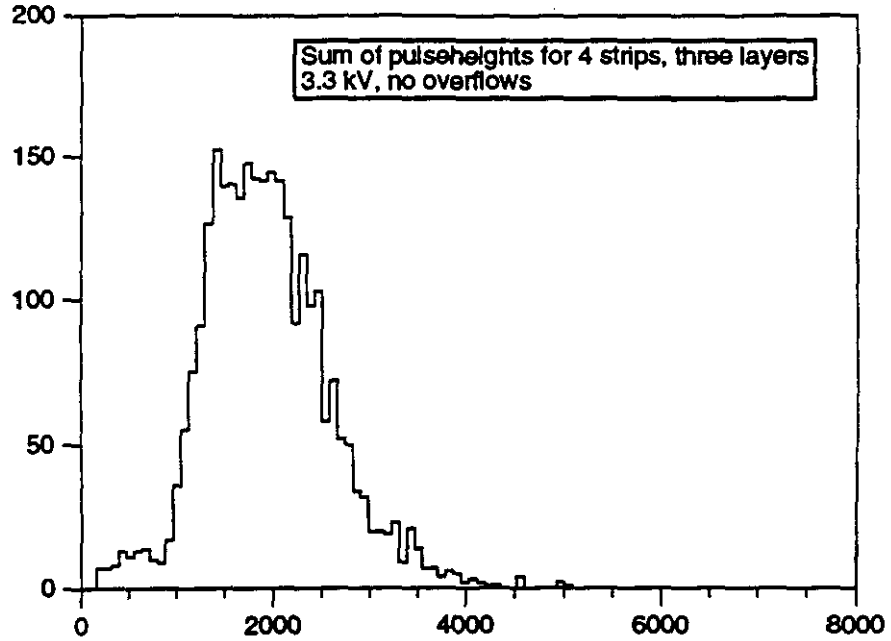
- Systematic Alignment Correction
  - middle plane is found to be off by $\simeq 33 \pm 5$ $\mu$m relative to top and bottom layers.
  - correct $z_{cog}$s in the middle plane by a systematic shift of 33 $\mu$m.

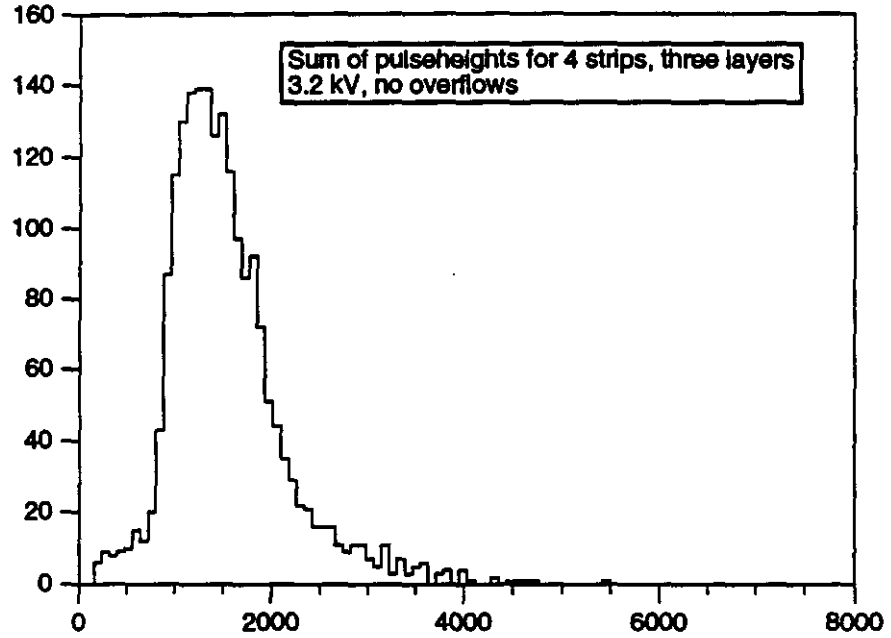
- Track Fitting
  - fit the corrected points (least square) to a straight line
- Resolution per Plane
  - residuals in the top layer ($R_1$) within $\pm$ 150 $\mu$m are fitted to a Gaussian + a constant.
  - resolution per plane $\sigma = \sqrt{6}\ \sigma_{R_1}$

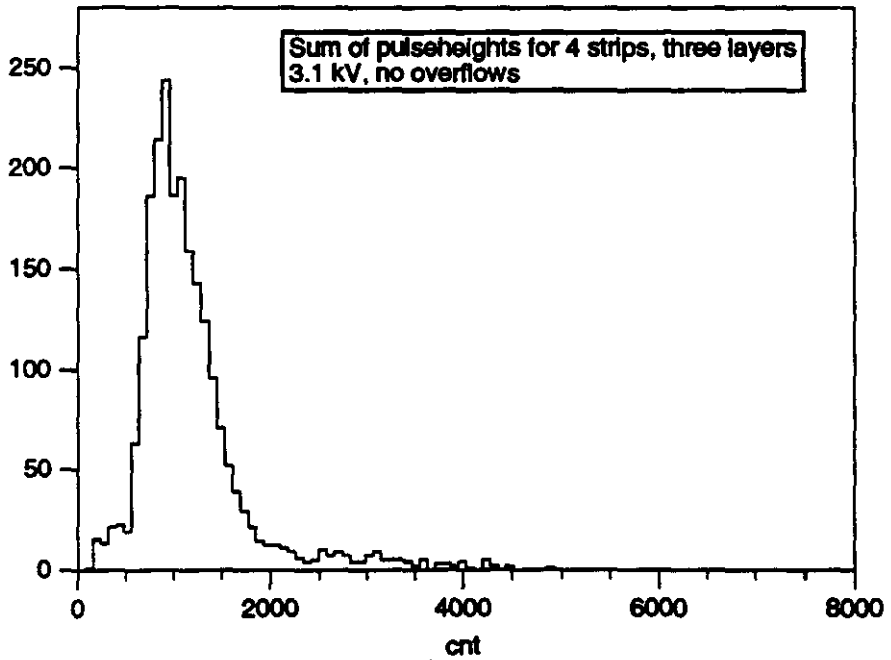

Angular Distribution 3.1 kV
100
80
60
40
20
0
-20
-10
0
10
20
deg

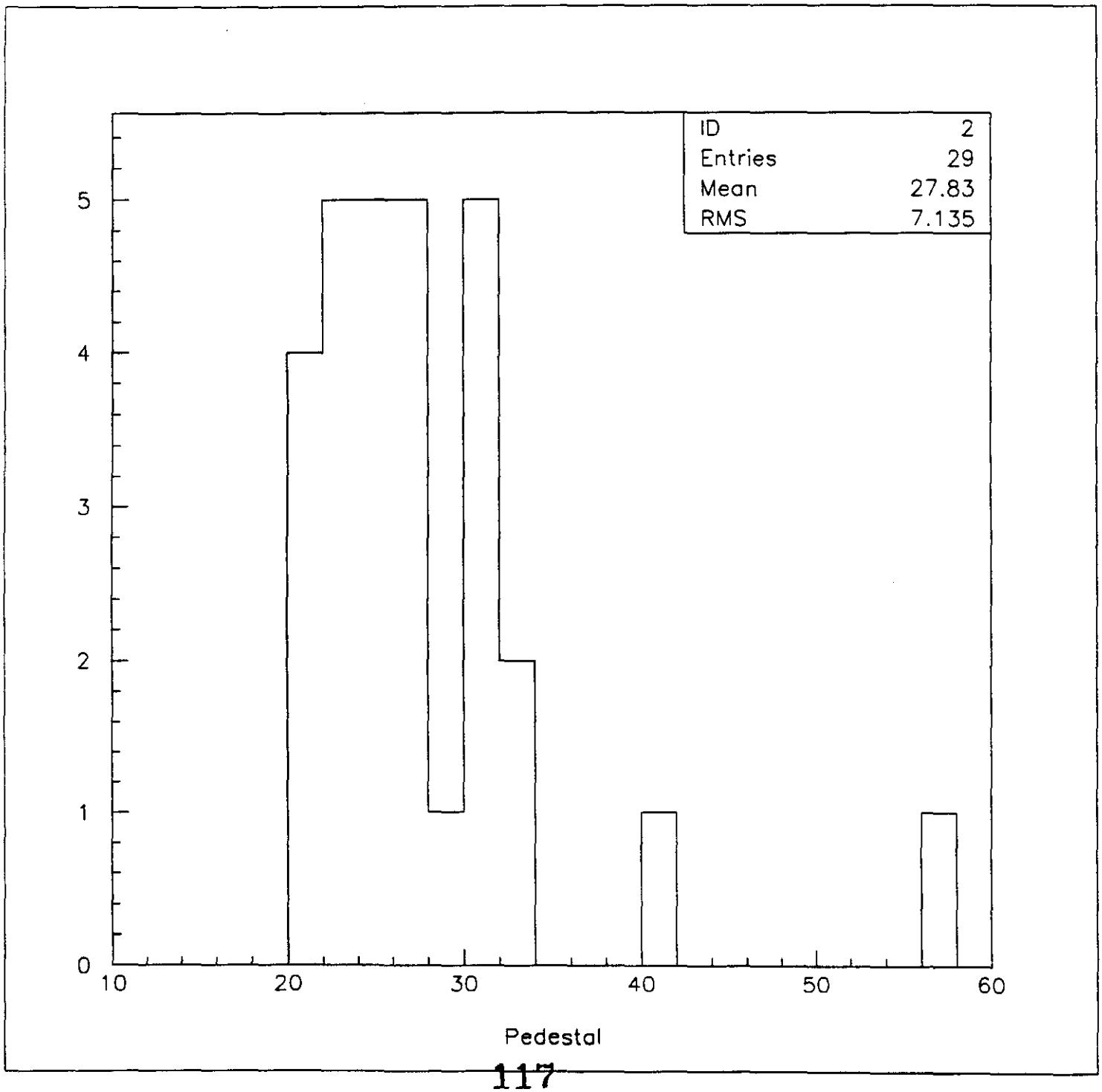

Angular Distribution 3.2 kV
80
60
40
20
0
-20
-10
0
10
20
deg

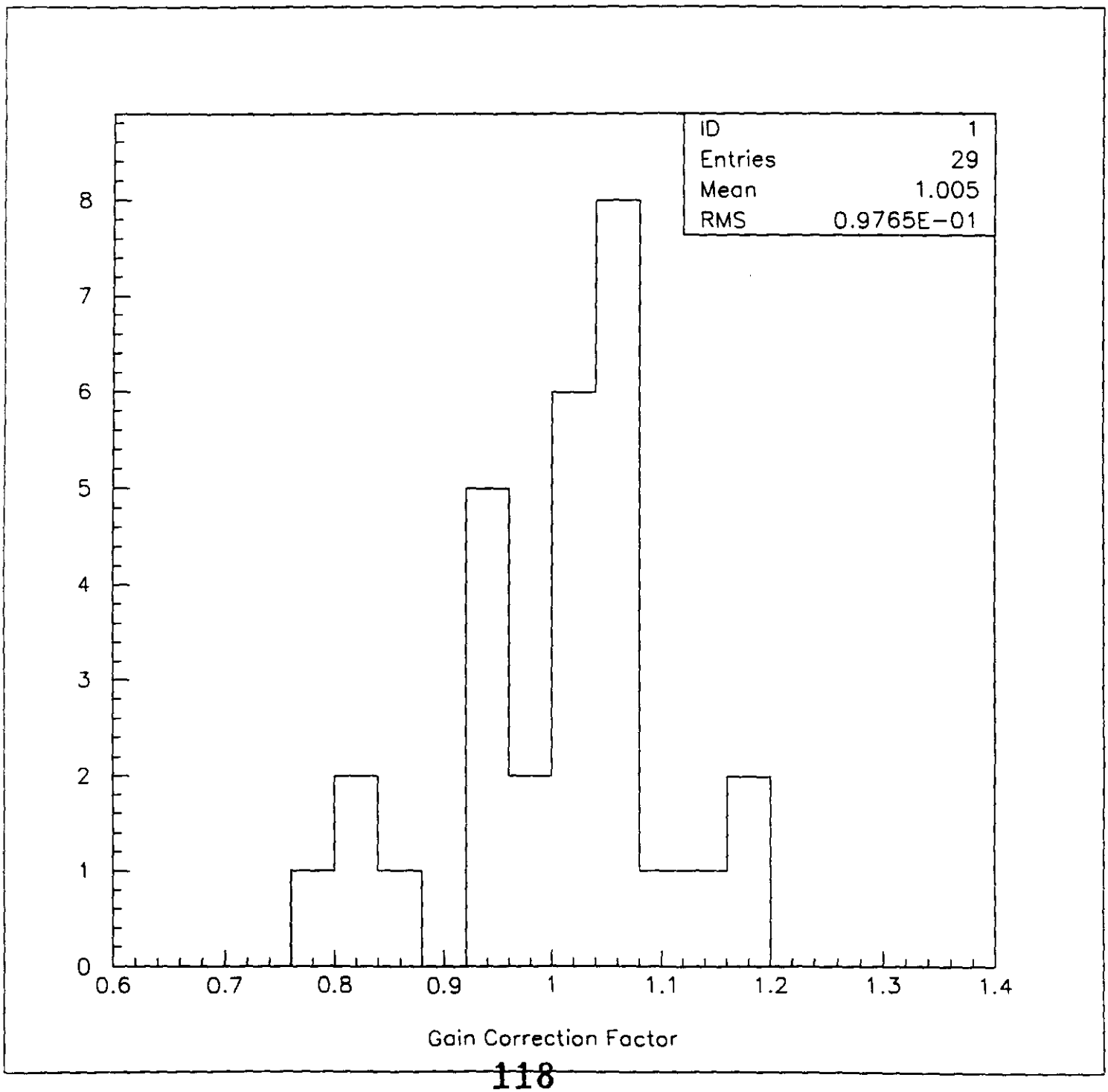

Angular Distribution 3.3 kV
200
150
100
50
0
-20
-10
0
10
20
deg


Sum of pulseheights for 4 strips, three layers
3.3 kV, no overflows
200
150
100
50
0
0
2000
4000
6000
8000

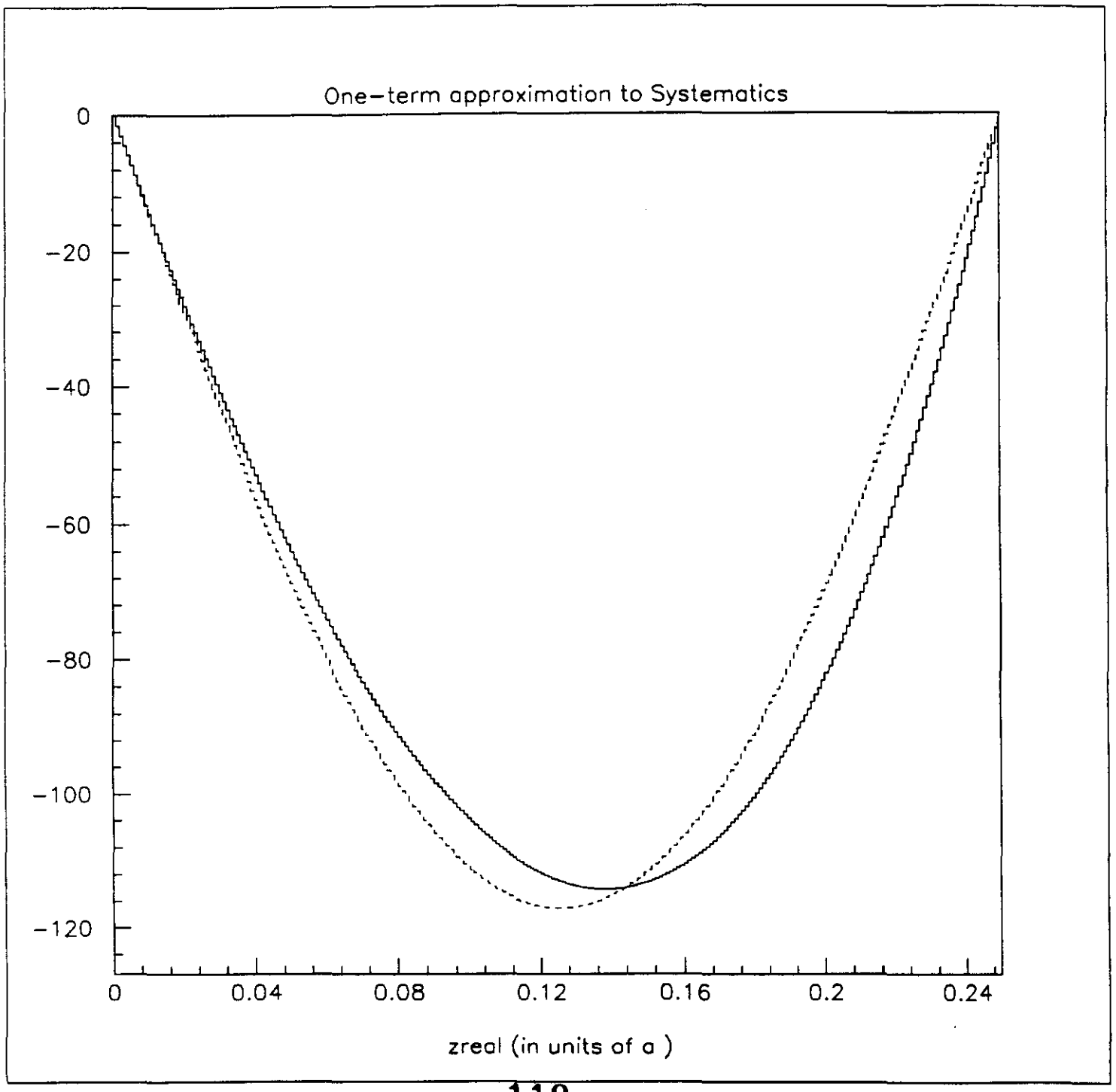

Sum of pulseheights for 4 strips, three layers
3.2 kV, no overflows
160
140
120
100
80
60
40
20
0
0
2000
4000
6000
8000


Sum of pulseheights for 4 strips, three layers
3.1 kV, no overflows
250
200
150
100
50
0
0
2000
4000
6000
8000
cnt


ID 2
Entries 29
Mean 27.83
RMS 7.135
0
1
2
3
4
5
10
20
30
40
50
60
Pedestal

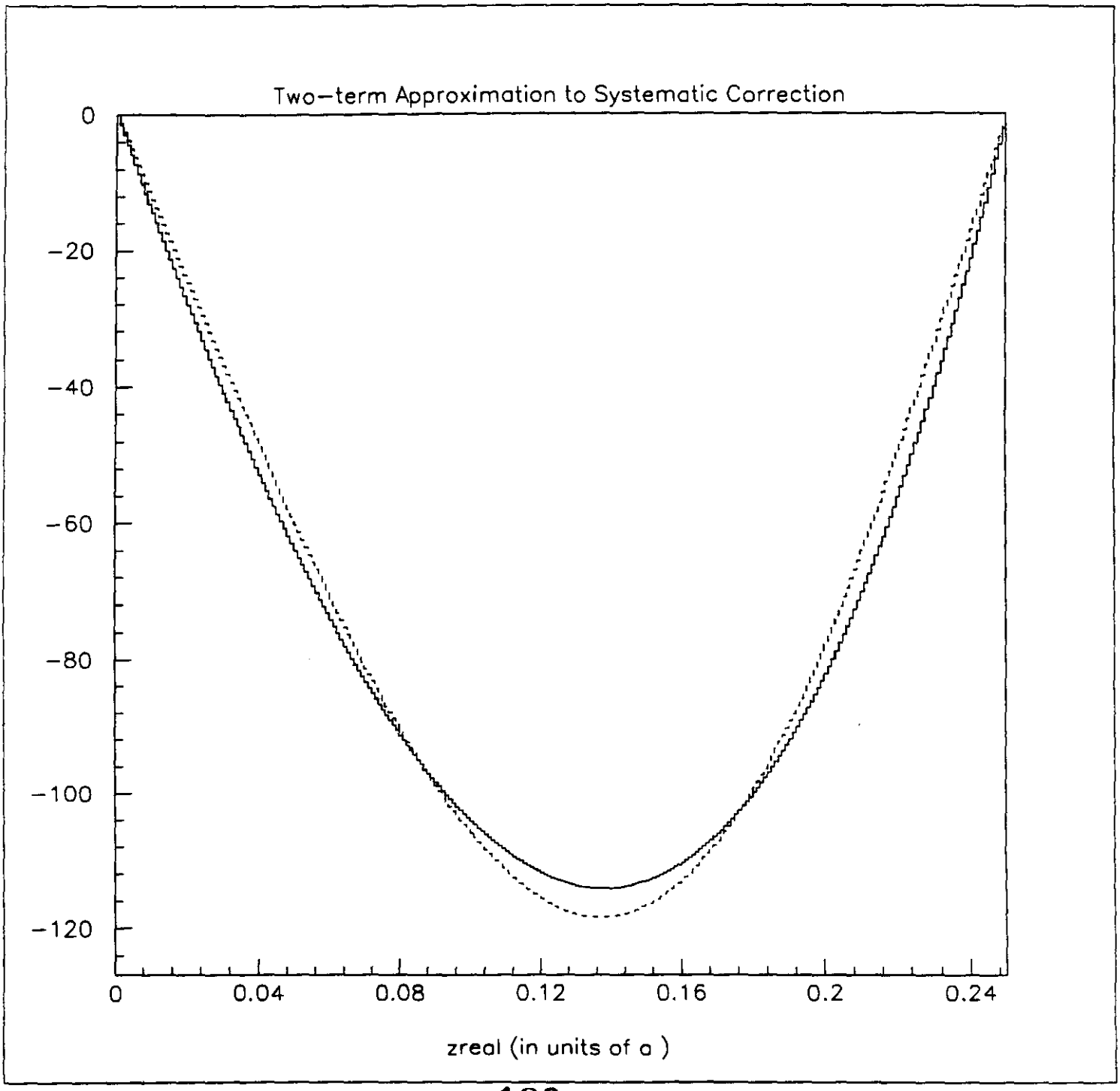

ID 1
Entries 29
Mean 1.005
RMS 0.9765E-01
0
1
2
3
4
5
6
7
8
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Gain Correction Factor

--- $\Delta z = -117.07 \sin\left(\frac{2\pi z}{0.5\,cm}\right) \quad 0 \le z \le 0.25\,cm$



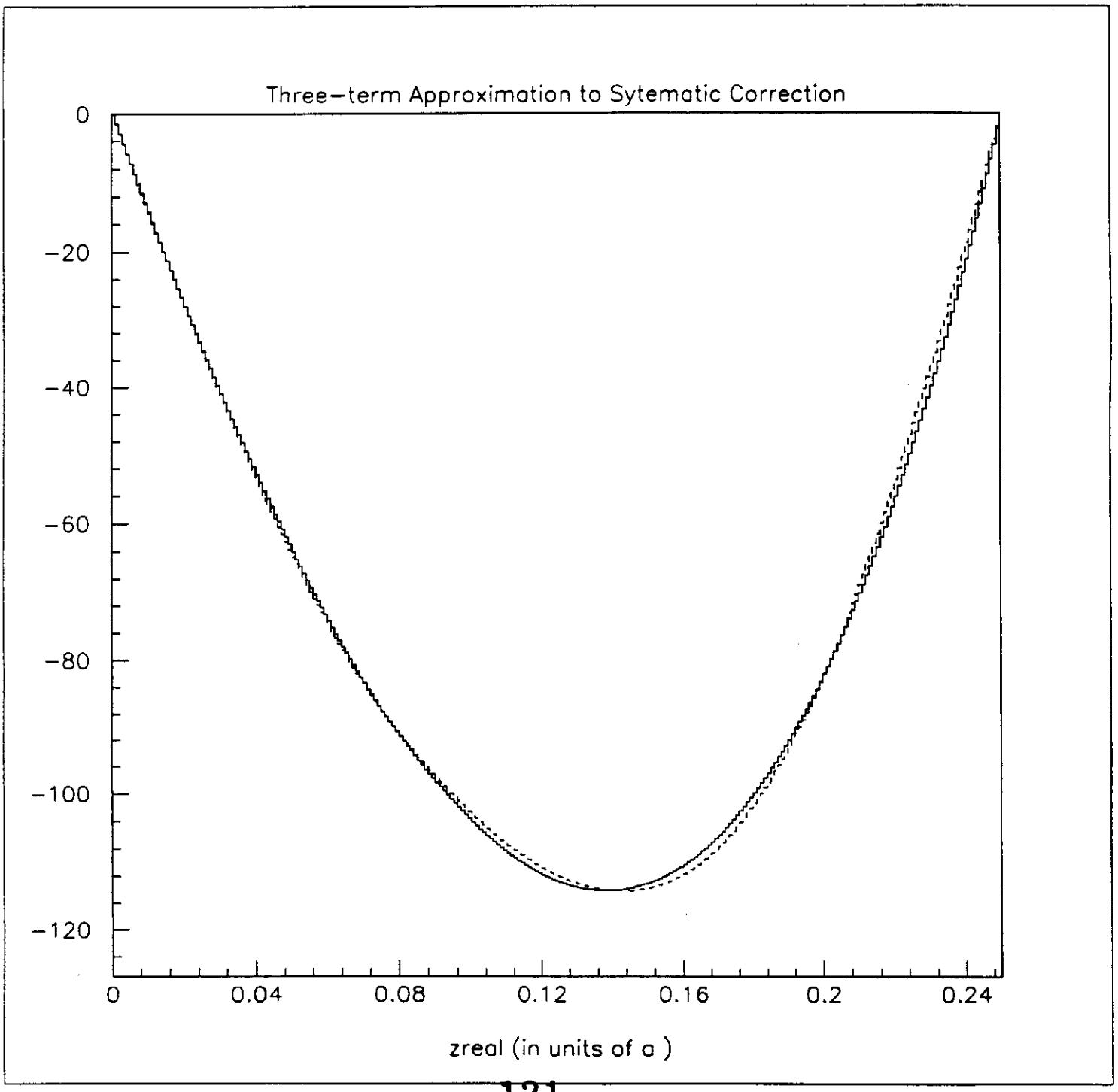
---- $\Delta z = -117.07 \sin\left(\frac{2\pi z}{0.5\,cm}\right) + 9.07 \sin\left(\frac{4\pi z}{0.5\,cm}\right)$

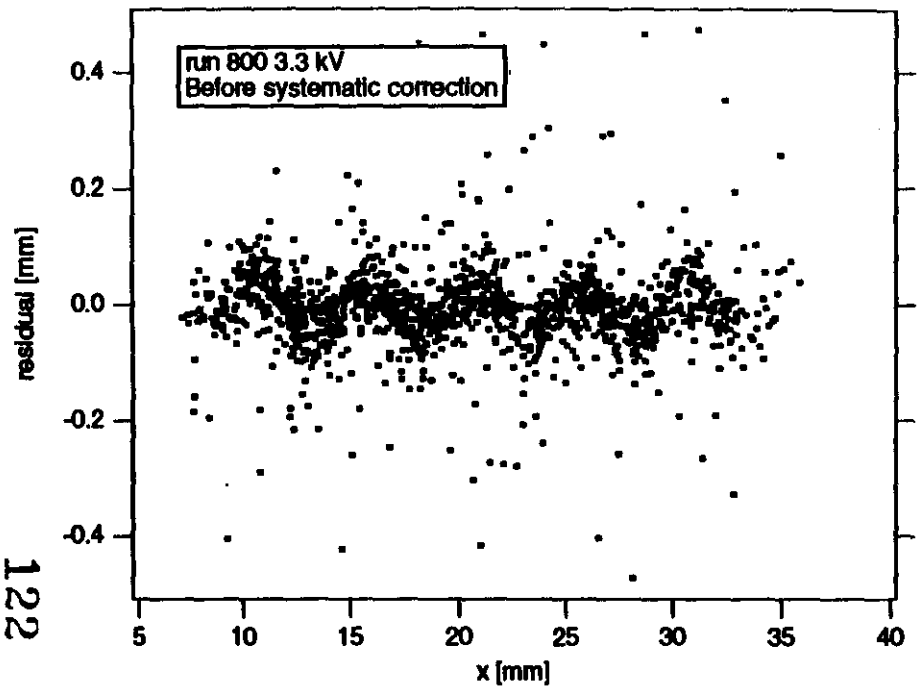
$0 < z < 0.25\,cm$

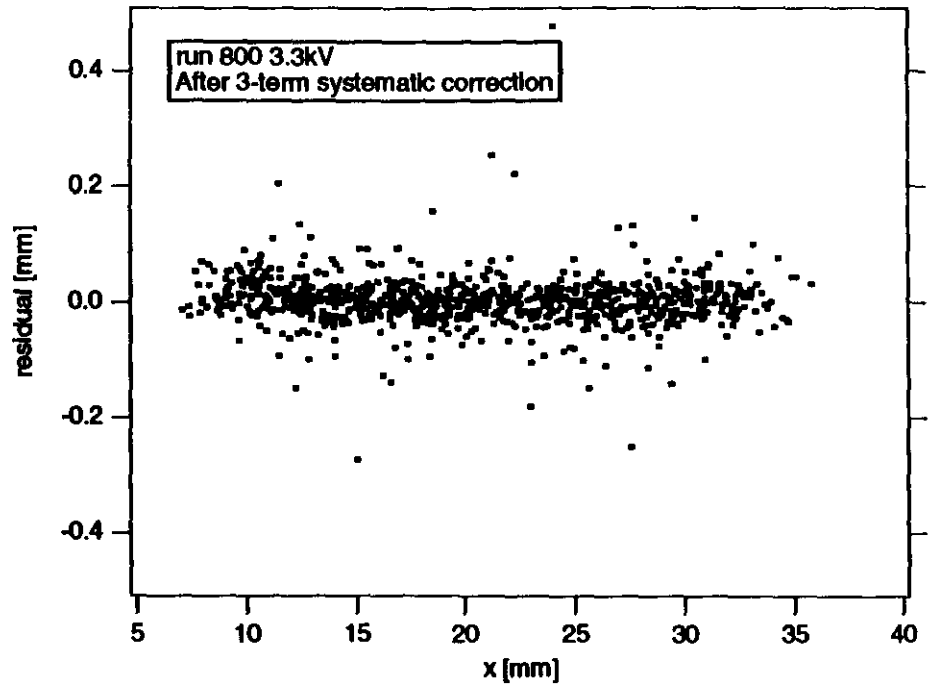


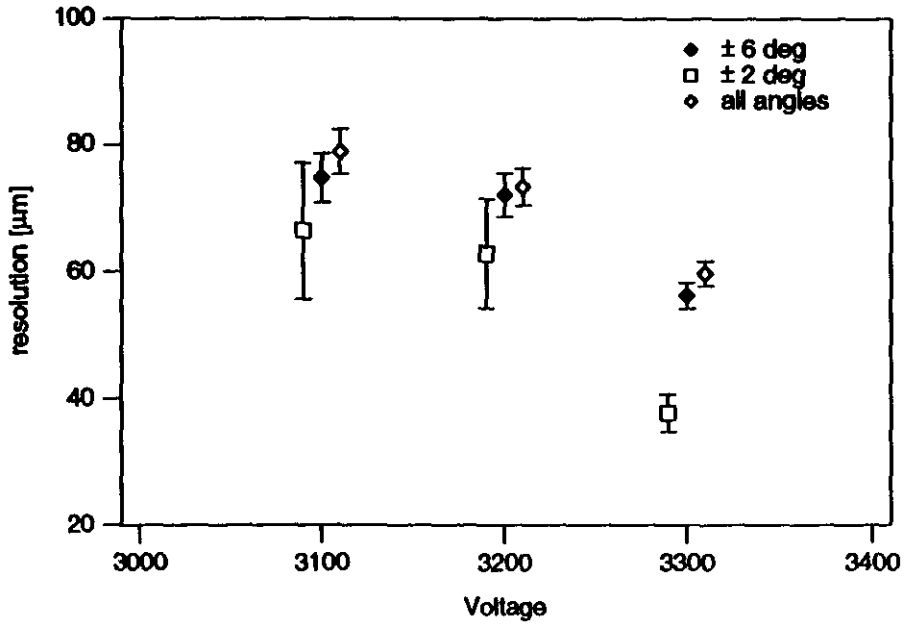
$$\Delta z = -117.07 \sin\left(\frac{2\pi z}{0.5\,km}\right) + 9.07 \sin\left(\frac{4\pi z}{0.5\,km}\right) - 4.85 \sin\left(\frac{6\pi z}{0.5\,km}\right)$$

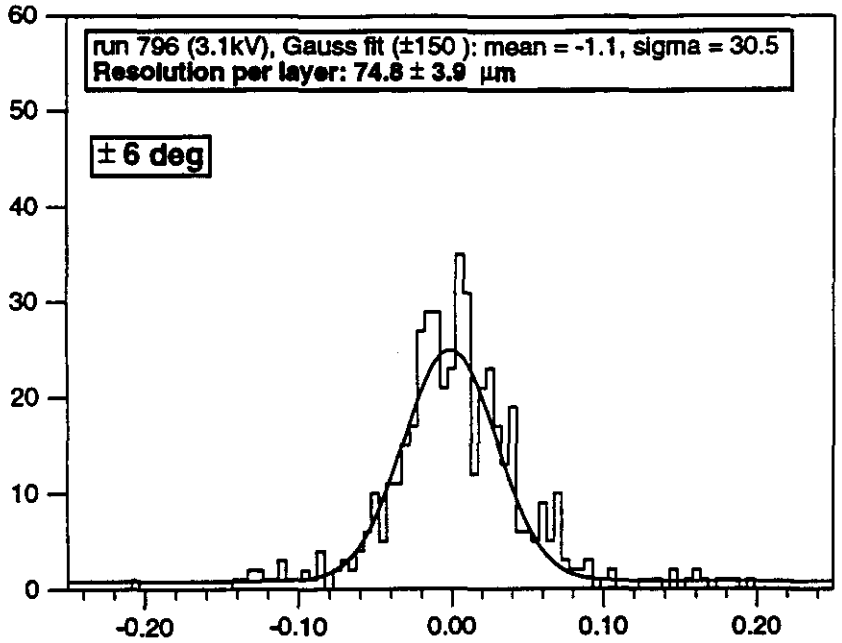
$$0 < z < 0.25\,km$$

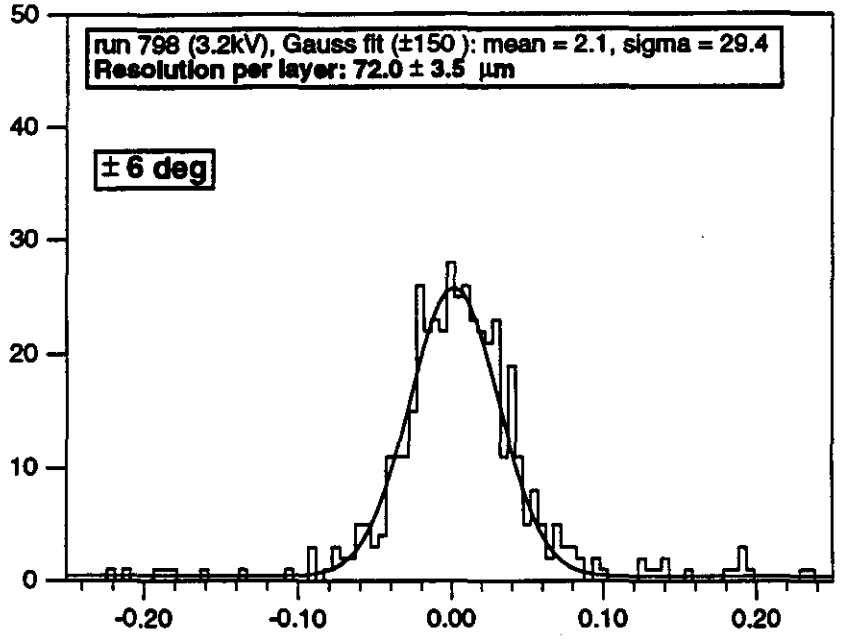


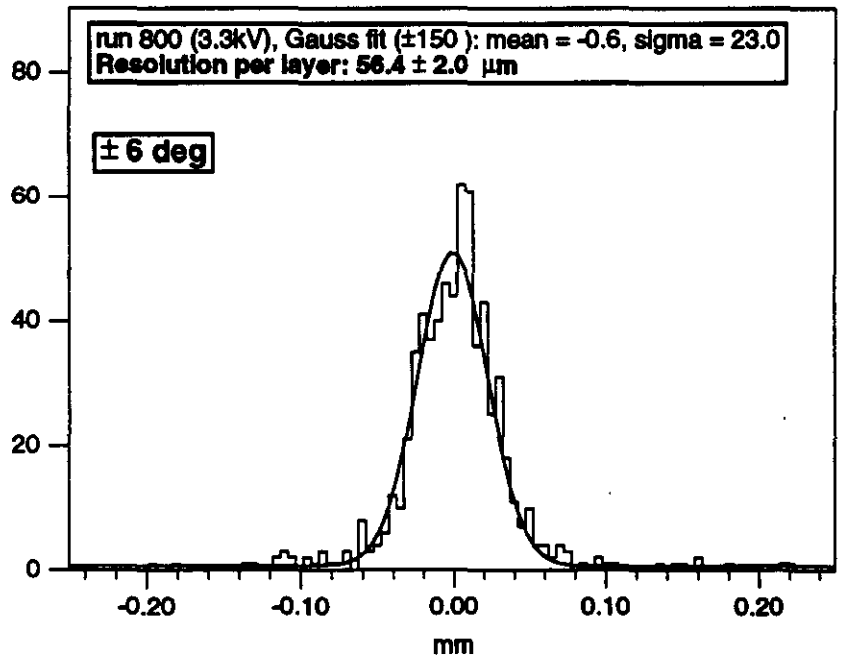

run 800 3.3 kV
Before systematic correction
residual [mm]
x [mm]

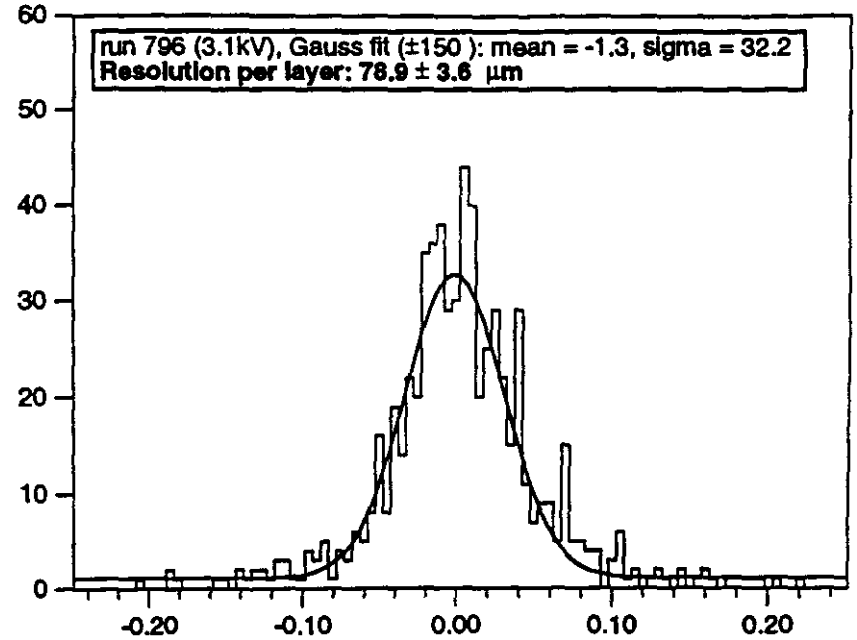

run 800 3.3kV
After 3-term systematic correction
residual [mm]
x [mm]

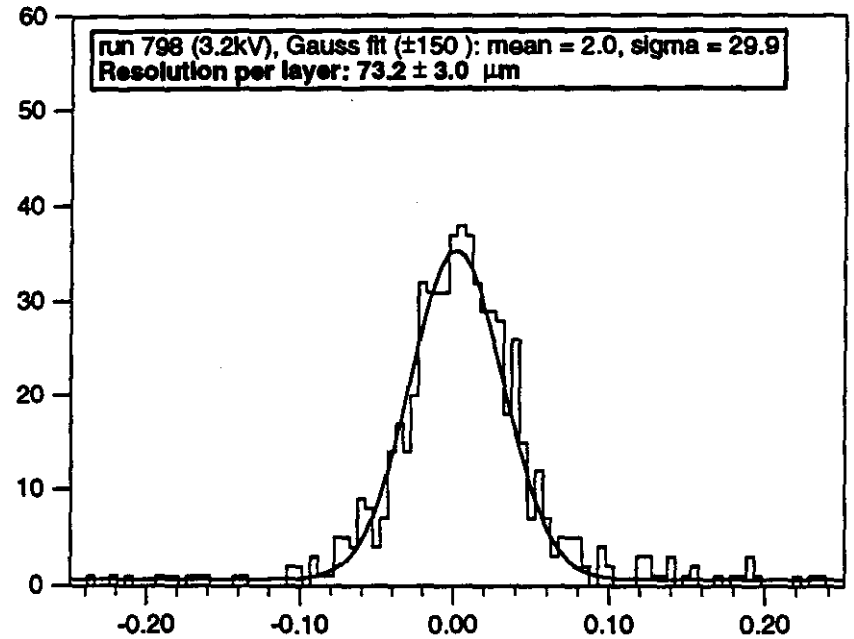

± 6 deg
± 2 deg
all angles
resolution [μm]
Voltage

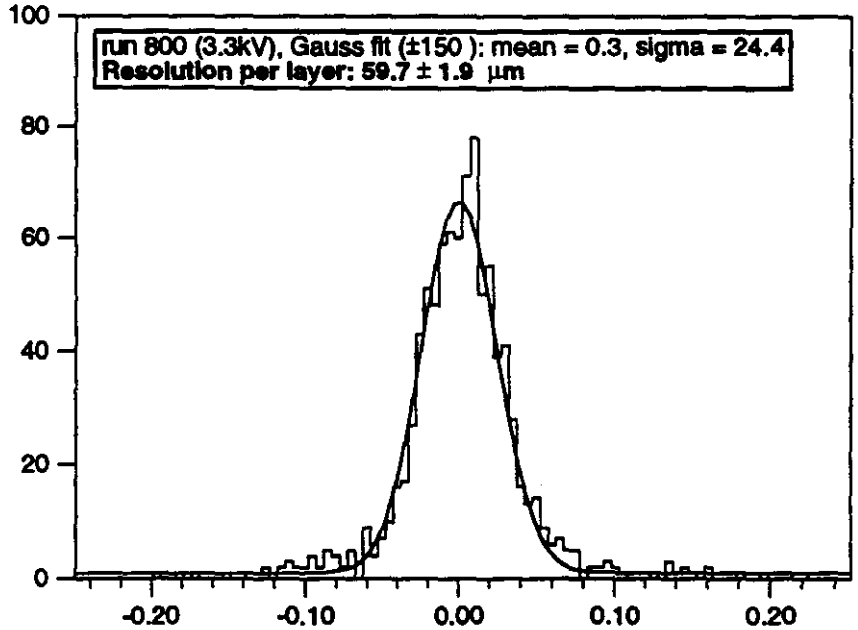

run 796 (3.1kV), Gauss fit (±150 ): mean = -1.1, sigma = 30.5
Resolution per layer: 74.8 ± 3.9 µm
± 6 deg
60
50
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20

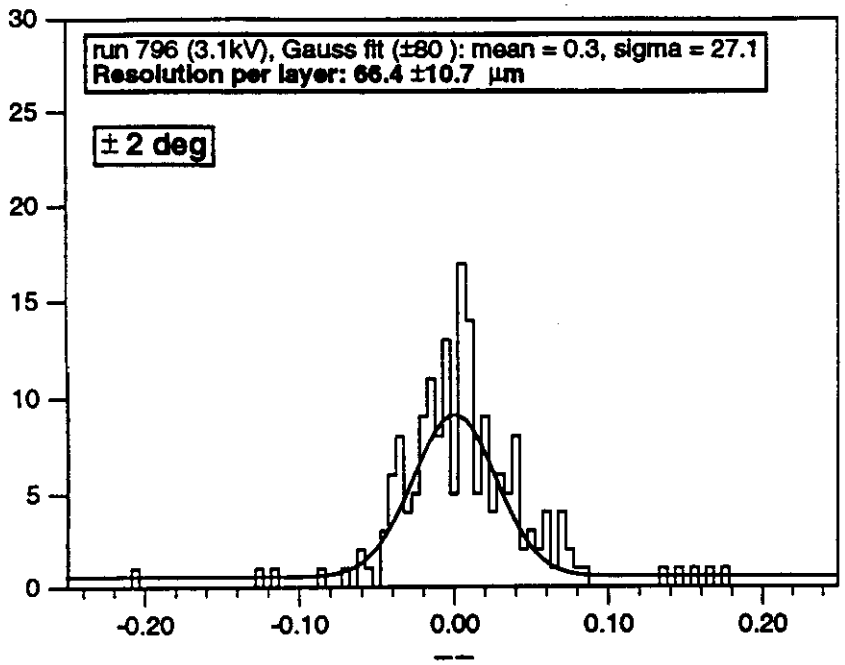

run 798 (3.2kV), Gauss fit (±150 ): mean = 2.1, sigma = 29.4
Resolution per layer: 72.0 ± 3.5 µm
± 6 deg
50
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20

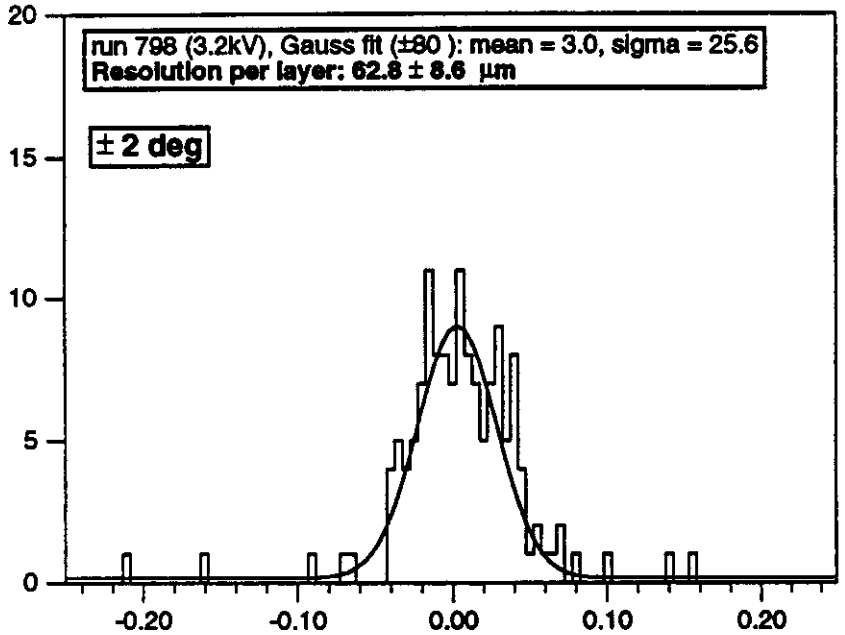

run 800 (3.3kV), Gauss fit (±150 ): mean = -0.6, sigma = 23.0
Resolution per layer: 56.4 ± 2.0 µm
± 6 deg
80
60
40
20
0
-0.20
-0.10
0.00
0.10
0.20
mm

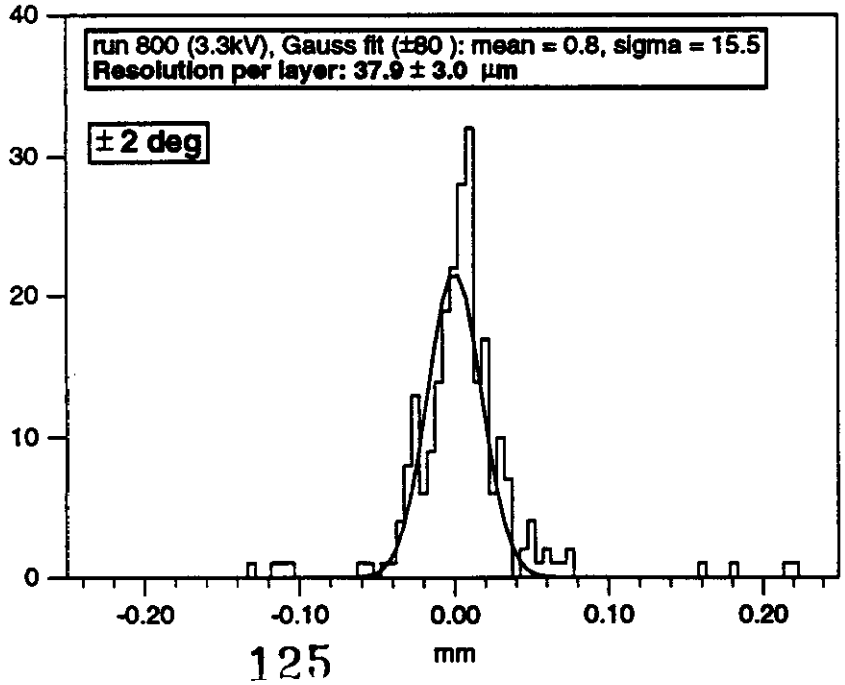

run 796 (3.1kV), Gauss fit (±150 ): mean = -1.3, sigma = 32.2
Resolution per layer: 78.9 ± 3.6 μm
60
50
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20


run 798 (3.2kV), Gauss fit (±150 ): mean = 2.0, sigma = 29.9
Resolution per layer: 73.2 ± 3.0 μm
60
50
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20


run 800 (3.3kV), Gauss fit (±150 ): mean = 0.3, sigma = 24.4
Resolution per layer: 59.7 ± 1.9 μm
100
80
60
40
20
0
-0.20
-0.10
0.00
0.10
0.20
mm


run 796 (3.1kV), Gauss fit (±80 ): mean = 0.3, sigma = 27.1
Resolution per layer: 66.4 ±10.7 µm
± 2 deg
30
25
20
15
10
5
0
-0.20
-0.10
0.00
0.10
0.20


run 798 (3.2kV), Gauss fit (±80 ): mean = 3.0, sigma = 25.6
Resolution per layer: 62.8 ± 8.6 µm
± 2 deg
20
15
10
5
0
-0.20
-0.10
0.00
0.10
0.20


run 800 (3.3kV), Gauss fit (±80 ): mean = 0.8, sigma = 15.5
Resolution per layer: 37.9 ± 3.0 µm
± 2 deg
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20
mm

Summary of Results ( Preliminary )

- Averaged over $\pm \simeq 6°$

| HV(kV) | $\sigma(\mu m)$ |
|---|---|
| 3.1 | $74.8 \pm 3.9$ |
| 3.2 | $72.0 \pm 3.5$ |
| 3.3 | $56.4 \pm 2.0$ |

- Averaged over all angles $\pm \simeq 8°$

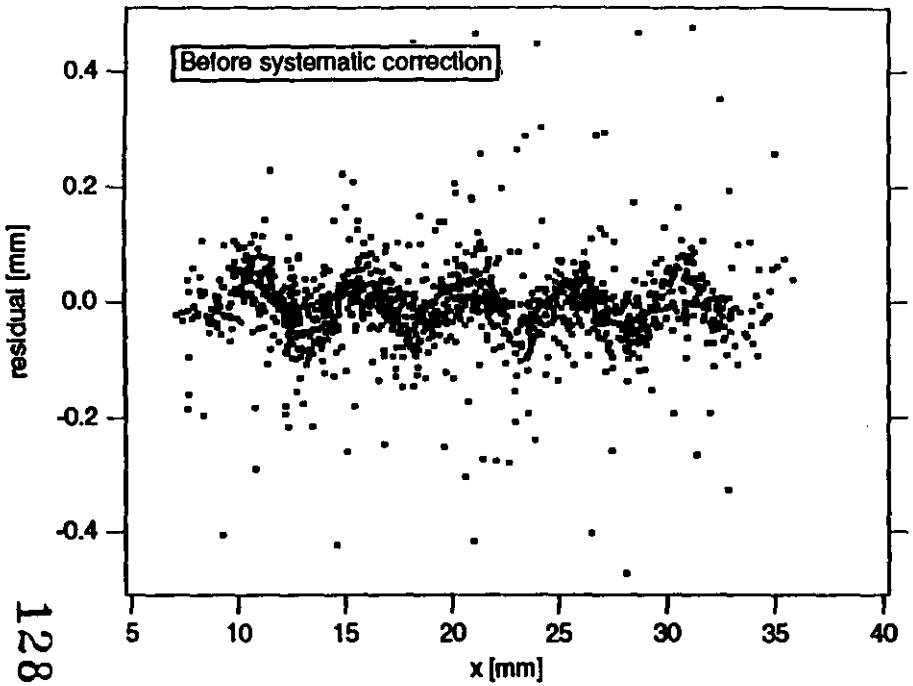
| HV(kV) | $\sigma(\mu m)$ |
|---|---|
| 3.1 | $78.9 \pm 3.6$ (96.3) |
| 3.2 | $73.2 \pm 3.0$ |
| 3.3 | $59.7 \pm 1.9$ |

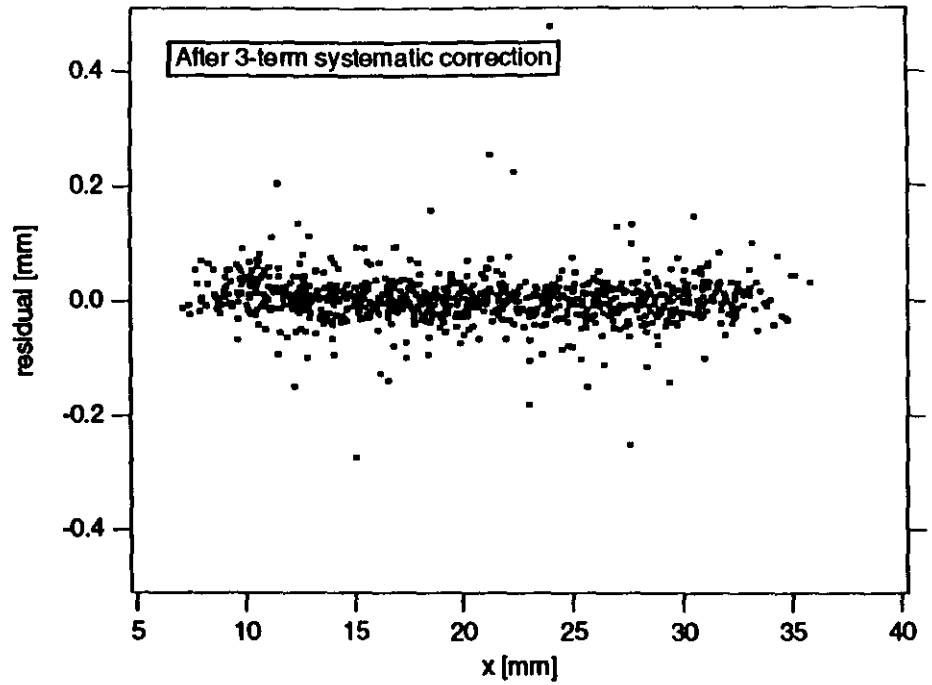
- Normal incidence $\pm$ 2.0°

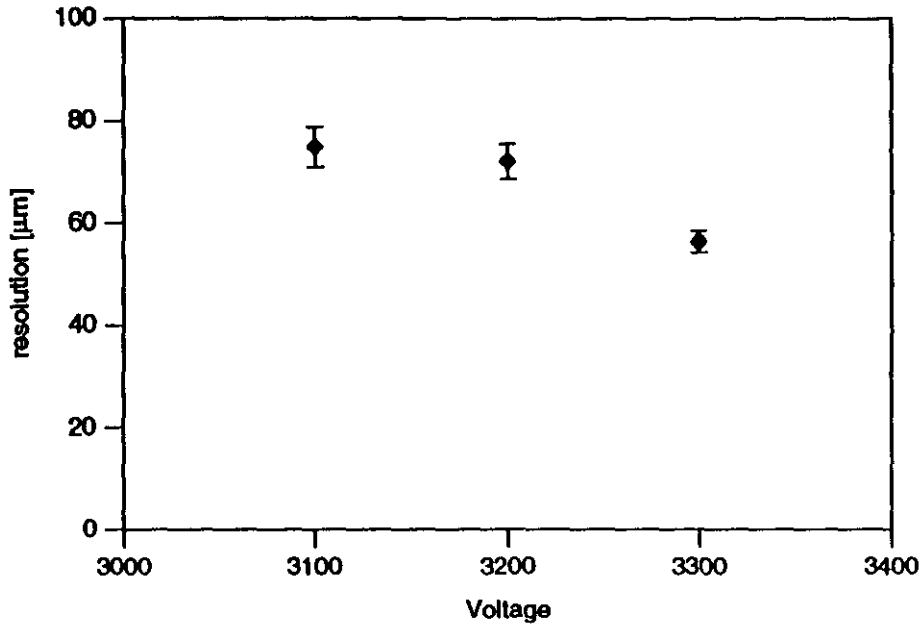
| HV(kV) | $\sigma(\mu m)$ |
|---|---|
| 3.1 | $66.4 \pm 10.7$ |
| 3.2 | $62.8 \pm 8.6$ |
| 3.3 | $37.9 \pm 3.0$ |

Short-term Program ( by March 15, 93 )

- study angle dependence of resolution
- study effect of noise from environ and RPCs
- study gas dependence ( fast vs standard )
- study dependence on resistivity of carbon coating ( 0.4 to 4.0 k$\Omega$ per square )
- study timing of wire signals
- resolution in streamer mode


Before systematic correction
residual [mm]
0.4
0.2
0.0
-0.2
-0.4
5
10
15
20
25
30
35
40
x [mm]


After 3-term systematic correction
residual [mm]
0.4
0.2
0.0
-0.2
-0.4
5
10
15
20
25
30
35
40
x [mm]


resolution [µm]
100
80
60
40
20
0
3000
3100
3200
3300
3400
Voltage

Bob Miller and Carl Bromberg

# Layout of RDT in Endcap

# GEM END CAP RDT CHAMBERS

## 16 SECTORS; 8-8-8; 3/4 in. TUBES

**INPUT PARAMETERS:**

| | | |
|---|---|---|
| Tube Material, density: | Alum. | 2.7 |
| Tube Wall: (mm) | 0.30 | |
| M. Plate Thickness (mm), density | 19.05 | 2.7 |
| Case Thickness (mm), density: | 6.40 | 0.25 |
| # of Sectors: | 16 | |

**VARIABLES:**

| Z Location (m): | 5.8 | 6.1 | 10.5 | 11.5 | 14.8 | 16.0 | Total |
|---|---|---|---|---|---|---|---|
| Inner Theta | 17.0 | 9.0 | 17.0 | 9.0 | 17.0 | 9.0 | |
| Outer Theta | 28.0 | 17.0 | 28.0 | 17.0 | 28.0 | 17.0 | |
| Chambers/Half: | 16 | 16 | 16 | 16 | 16 | 16 | 96 |
| # of Layers: | 8 | 8 | 8 | 8 | 8 | 8 | 24 |
| Tube Dia: (mm) | 19.1 | 19.1 | 19.1 | 19.1 | 19.1 | 19.1 | |

**RESULTS:**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Tube Length: (m) | 1.3 | 0.9 | 2.4 | 1.7 | 3.3 | 2.4 | |
| Tubes/Chamber: | 512 | 304 | 928 | 576 | 1296 | 800 | |
| Chamb. width: (m) | 1.23 | 0.74 | 2.22 | 1.40 | 3.13 | 1.95 | |
| Chamb. thick.: (m) | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | |
| Weights (lb) | | | | | | | |
| Tubes: | 72 | 29 | 235 | 104 | 463 | 202 | |
| Manifold plates: | 70 | 42 | 127 | 80 | 179 | 111 | |
| Plugs: | 49 | 29 | 88 | 55 | 123 | 76 | |
| Case: | 16 | 8 | 45 | 22 | 85 | 40 | |
| Electronics,cable: | 256 | 152 | 464 | 288 | 648 | 400 | |
| Total/Chamber: | 462 | 260 | 960 | 549 | 1499 | 829 | |
| Weight/Half: | 7399 | 4163 | 15360 | 8789 | 23984 | 13264 | 46743 |
| Tubes/Half: | 8192 | 4864 | 14848 | 9216 | 20736 | 12800 | 70656 |
| | | | | | TOTAL | | 141312 |

# GEM END CAP RDT CHAMBERS

## 16 SECTORS; 8-8-8; 1 in. TUBES

**INPUT PARAMETERS:**

| | | |
|---|---|---|
| Tube Material, density: | Alum. | 2.7 |
| Tube Wall: (mm) | 0.30 | |
| M. Plate Thickness (mm), density | 19.05 | 2.7 |
| Case Thickness (mm), density: | 6.40 | 0.25 |
| # of Sectors: | 16 | |

**VARIABLES:**

| Z Location (m): | 5.8 | 6.1 | 10.5 | 11.5 | 14.8 | 16.0 | Total |
|---|---|---|---|---|---|---|---|
| Inner Theta | 17.0 | 9.0 | 17.0 | 9.0 | 17.0 | 9.0 | |
| Outer Theta | 28.0 | 17.0 | 28.0 | 17.0 | 28.0 | 17.0 | |
| Chambers/Half: | 16 | 16 | 16 | 16 | 16 | 16 | 96 |
| # of Layers: | 8 | 8 | 8 | 8 | 8 | 8 | 24 |
| Tube Dia: (mm) | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | |

**RESULTS:**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Tube Length: (m) | 1.3 | 0.9 | 2.4 | 1.7 | 3.3 | 2.4 | |
| Tubes/Chamber: | 384 | 224 | 688 | 432 | 976 | 608 | |
| Chamb. width: (m) | 1.23 | 0.74 | 2.22 | 1.40 | 3.13 | 1.95 | |
| Chamb. thick.: (m) | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | |
| Weights (lb) | | | | | | | |
| Tubes: | 72 | 29 | 232 | 104 | 464 | 204 | |
| Manifold plates: | 84 | 51 | 152 | 96 | 215 | 134 | |
| Plugs: | 43 | 25 | 77 | 48 | 109 | 68 | |
| Case: | 17 | 8 | 47 | 23 | 88 | 41 | |
| Electronics,cable: | 192 | 112 | 344 | 216 | 488 | 304 | |
| Total/Chamber: | 407 | 225 | 852 | 488 | 1364 | 751 | |
| Weight/Half: | 6519 | 3596 | 13638 | 7802 | 21818 | 12013 | 41975 |
| Tubes/Half: | 6144 | 3584 | 11008 | 6912 | 15616 | 9728 | 52992 |
| | | | | | TOTAL | | 105984 |

# GEM BARREL RDT CHAMBER SPECS
# 16 SECTORS; 8+8+4; 1 in. Dia.

**INPUT PARAMETERS:**

| | | |
|---|---|---|
| Theta angular coverage ±: | 60.0 | |
| Tube Material, density: | Alum. | 2.7 |
| Tube Wall: (mm) | 0.30 | |
| Plate Thickness (mm), density: | 19.05 | 2.7 |
| Case Thickness (mm), density: | 6.40 | 0.25 |
| # of Segments: | 16 | |

**VARIABLES:**

| Radius (m): | 3.9 | 6.3 | 8.7 | Total |
|---|---|---|---|---|
| Chambers/Theta | 3 | 3 | 3 | |
| # of Layers: | 8 | 8 | 4 | 20 |
| Tube Dia: (mm) | 25.4 | 25.4 | 25.4 | |
| Chambers/Half: | 48 | 48 | 48 | 144 |

**RESULTS:**

| | | | | |
|---|---|---|---|---|
| Tube Length: (m) | 2.3 | 3.6 | 5.0 | |
| Tubes/Chamber: | 480 | 784 | 544 | |
| Chamb. width: (m) | 1.55 | 2.51 | 3.46 | |
| Chamb. thick.: (m) | 0.30 | 0.30 | 0.20 | |
| Weights (lb) | | | | |
| Tubes: | 154 | 405 | 389 | |
| Manifold plates: | 106 | 172 | 158 | |
| Plugs: | 54 | 88 | 61 | |
| Case: | 33 | 77 | 134 | |
| Electronics,cable: | 240 | 392 | 272 | |
| Total/Chamber: | 587 | 1134 | 1014 | |
| Weight/Segment: | 1760 | 3403 | 3041 | 8204 |
| Weight/Half: | 28153 | 54452 | 48658 | 131264 |
| Tubes/Half: | 23040 | 37632 | 26112 | 86784 |
| | | TOTAL | | 173568 |

12/15/92

# GEM BARREL RDT CHAMBER SPECS
# 16 SECTORS; 8+8+6; 1 in. Dia.

**INPUT PARAMETERS:**

| | | |
|---|---|---|
| Theta angular coverage ±: | 60.0 | |
| Tube Material, density: | Alum. | 2.7 |
| Tube Wall: (mm) | 0.30 | |
| Plate Thickness (mm), density: | 19.05 | 2.7 |
| Case Thickness (mm), density: | 6.40 | 0.25 |
| # of Segments: | 16 | |

**VARIABLES:**

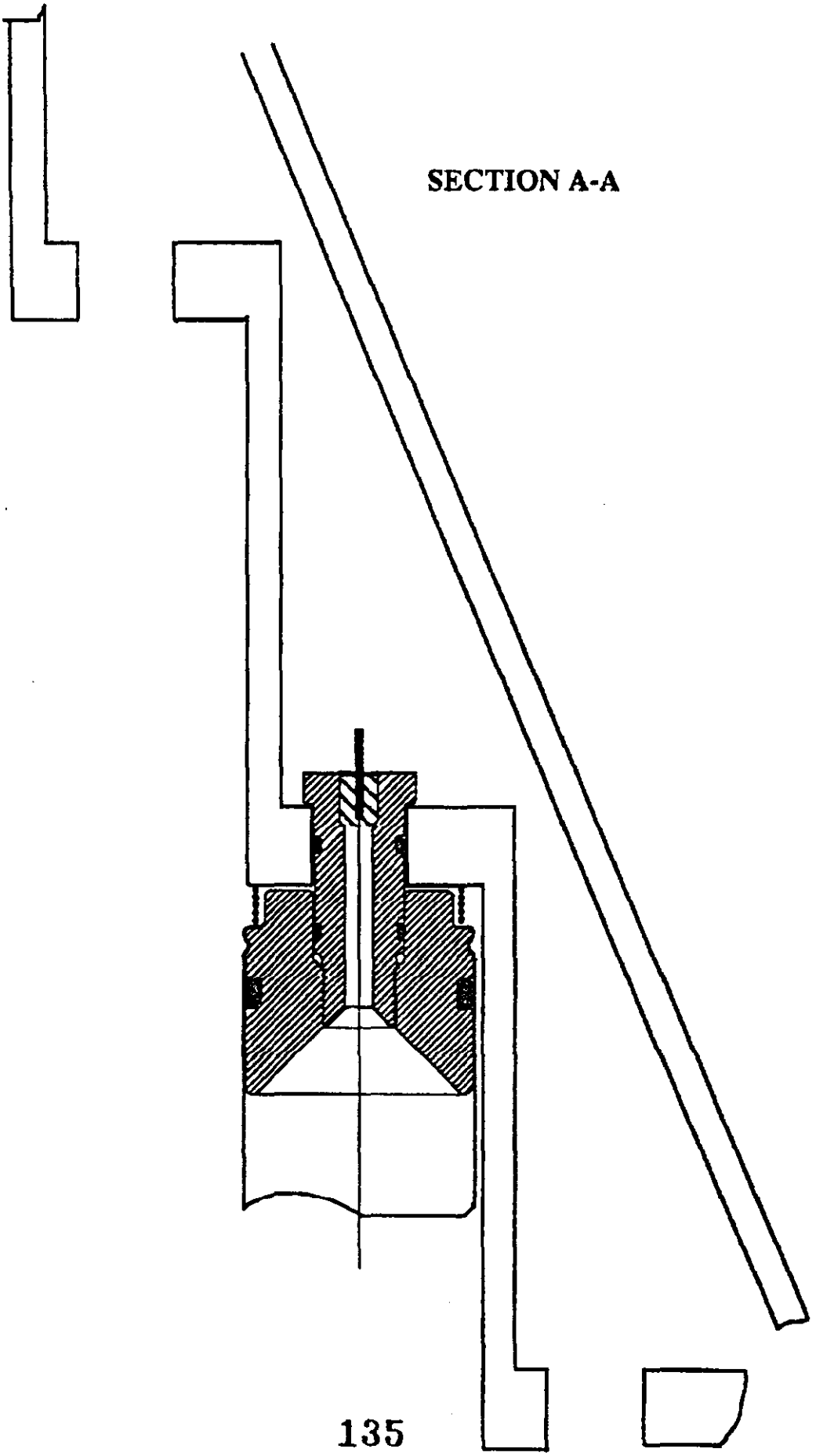
| Radius (m): | 3.9 | 6.3 | 8.7 | Total |
|---|---|---|---|---|
| Chambers/Theta | 3 | 3 | 3 | |
| # of Layers: | 8 | 8 | 6 | 22 |
| Tube Dia: (mm) | 25.4 | 25.4 | 25.4 | |
| Chambers/Half: | 48 | 48 | 48 | 144 |

**RESULTS:**

| | | | | |
|---|---|---|---|---|
| Tube Length: (m) | 2.3 | 3.6 | 5.0 | |
| Tubes/Chamber: | 480 | 784 | 816 | |
| Chamb. width: (m) | 1.55 | 2.51 | 3.46 | |
| Chamb. thick.: (m) | 0.30 | 0.30 | 0.25 | |
| Weights (lb) | | | | |
| Tubes: | 154 | 405 | 583 | |
| Manifold plates: | 106 | 172 | 198 | |
| Plugs: | 54 | 88 | 91 | |
| Case: | 33 | 77 | 137 | |
| Electronics,cable: | 240 | 392 | 408 | |
| Total/Chamber: | 587 | 1134 | 1417 | |
| Weight/Segment: | 1760 | 3403 | 4252 | 9415 |
| Weight/Half: | 28153 | 54452 | 68027 | 150632 |
| Tubes/Half: | 23040 | 37632 | 39168 | 99840 |
| | | TOTAL | | 199680 |

12/15/92

RDT TRAPEZOIDAL CHAMBER



# RDT

Summary: 1" tubes everywhere (drift-time + neutron optimized)

±(-2)mr stereo

| | | | |
|---|---|---|---|
| Barrel: | 8-8-4 | 173,000 tubes | $\sigma_z \leq 25\mu$ |
| EndCap: | 8-8-8 | 106,000 tubes | " |
| | | 279,000 tubes | |

$\boxed{\text{Stereo ?}}$

Build Chambers with a designed in (MIS)ALIGNMENT

$\pm 5\,mr$ ($\frac{1}{2}u$, $\frac{1}{2}v$) or less

Tubes are translated by $\frac{1}{2}$ - 1 tube (25mm) over the tubes length (2.5m — 5.0m)

$$\sigma_z/\text{tube} = (200)\times(\sigma_x) = (200)(0.1\,mm) = 2\,cm$$

~16 effective tubes/track

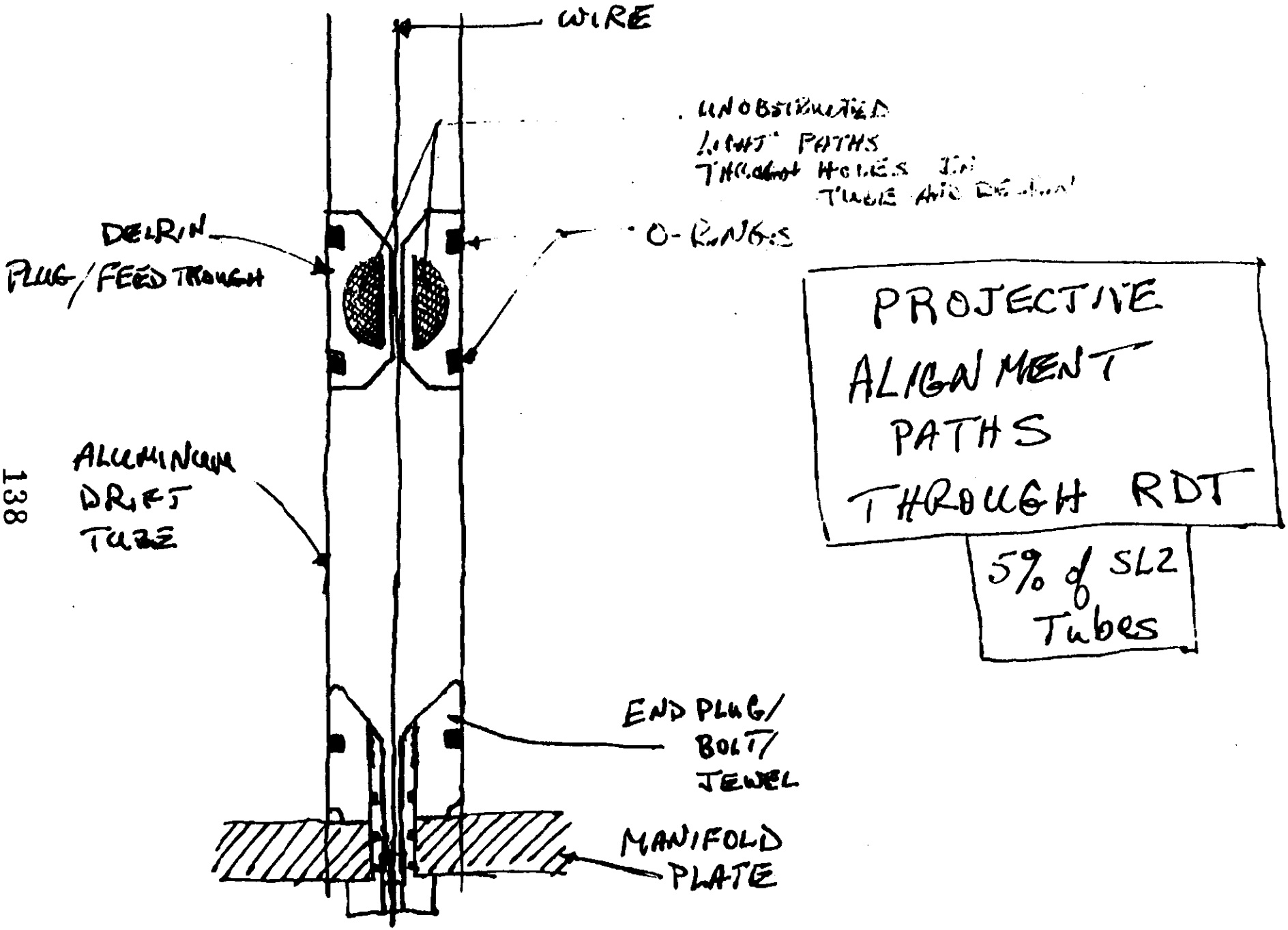
$$\boxed{\sigma_z = \frac{2\,cm}{\sqrt{16}} = \frac{2\,cm}{4} = 0.5\,cm}$$ ⟸ Too Good

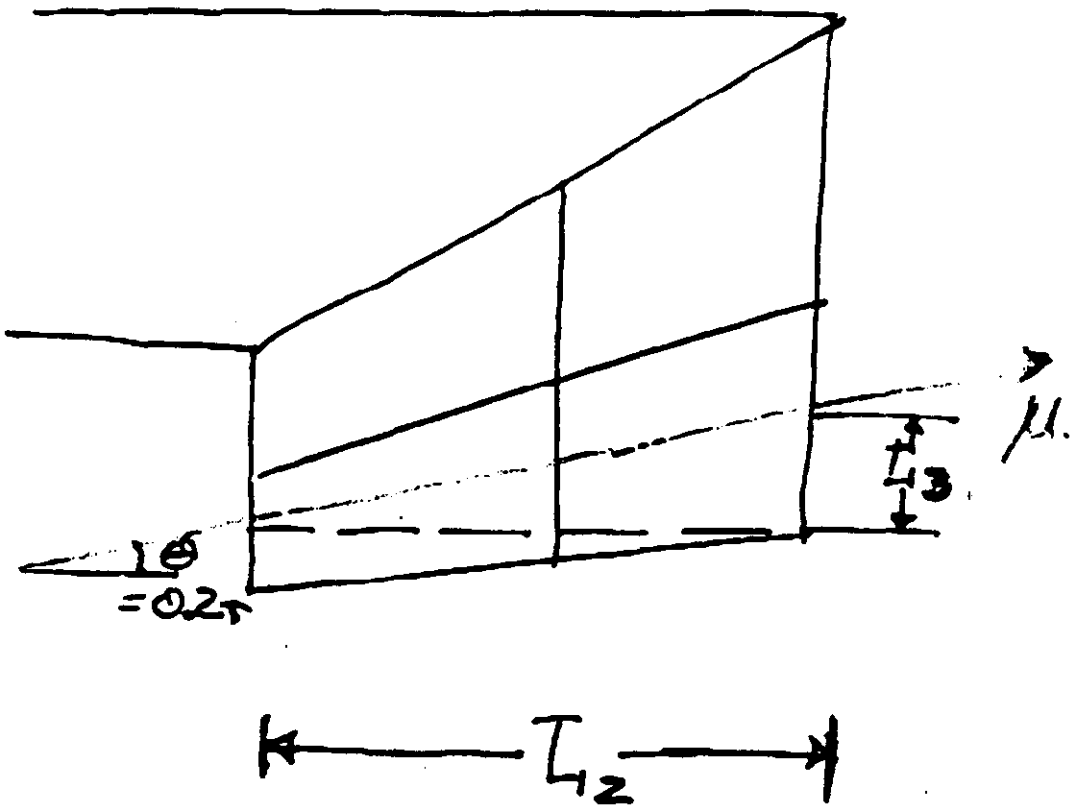
Make Stereo 4 $\pm 1\,mr$

Tubes Translated by 5 mm over length

This is Comparable to Alignment Shifts we hope to hold to.

$$\boxed{\sigma_z = 2.5\,cm}$$


WIRE
UNOBSTRUCTED
LIGHT PATHS
THROUGH HOLES IN
TUBE ARE DESIRED
DELRIN
PLUG/FEED TROUGH
O-RINGS
ALUMINUM
DRIFT
TUBE
END PLUG/
BOLT/
JEWEL
MANIFOLD
PLATE
PROJECTIVE
ALIGNMENT
PATHS
THROUGH RDT
5% of SL2
Tubes




In Barrel $\quad s \sim B_z L_1^2 \qquad p_T \propto \frac{1}{s}$

In EndCap $\quad s \sim B_z L_3^2 + B_r L_2^2$

$B_r \sim 0.2 B_z$ (Flux Concentrator)

$L_3 \sim 0.2 L_2$

$L_3^2 \sim 0.04 L_2^2$

$\boxed{\text{S - Dominated by } B_r L_2^2 \text{ term.}}$

Also $\quad p \sim \frac{1}{s} \qquad p_T \sim p\theta$

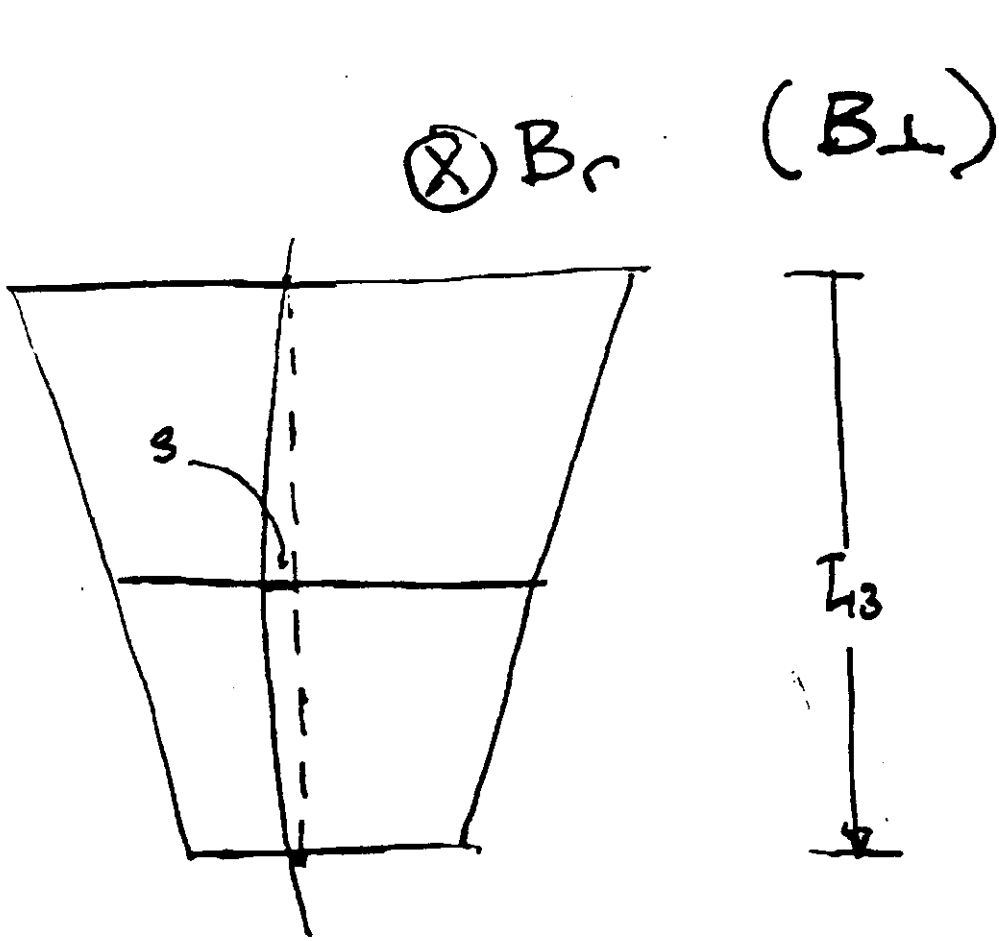
Both are Needed

Sagitta Measures $p$ not $p_T$

Trigger on $p_T = p\theta$

Need Both!

Top View



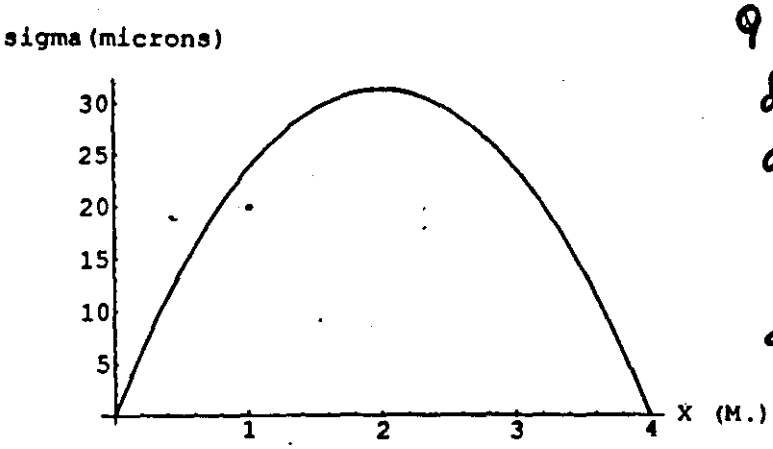

Typical Spectrometer Geometry.
$B_r$ and $B_\perp$ nearly the same.

Larry Rosenson

RDT Wire Sag

Rosenson'.

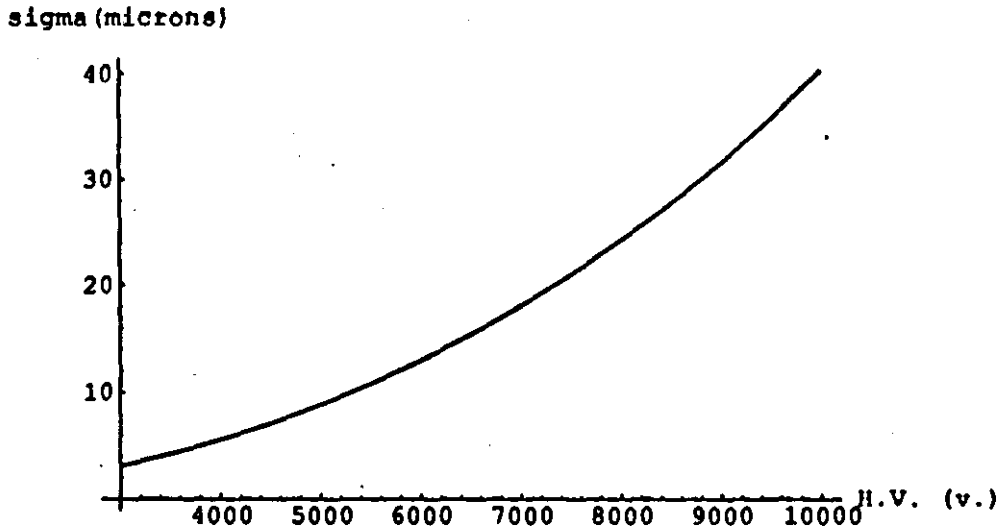
```
Plot[10^6 sigTube[x,9000,.0125,50 10^-6,1.25,4,21.3 10^3,250 10^-6,
AxesLabel->{"X (M.)","sigma(microns)"}]
```

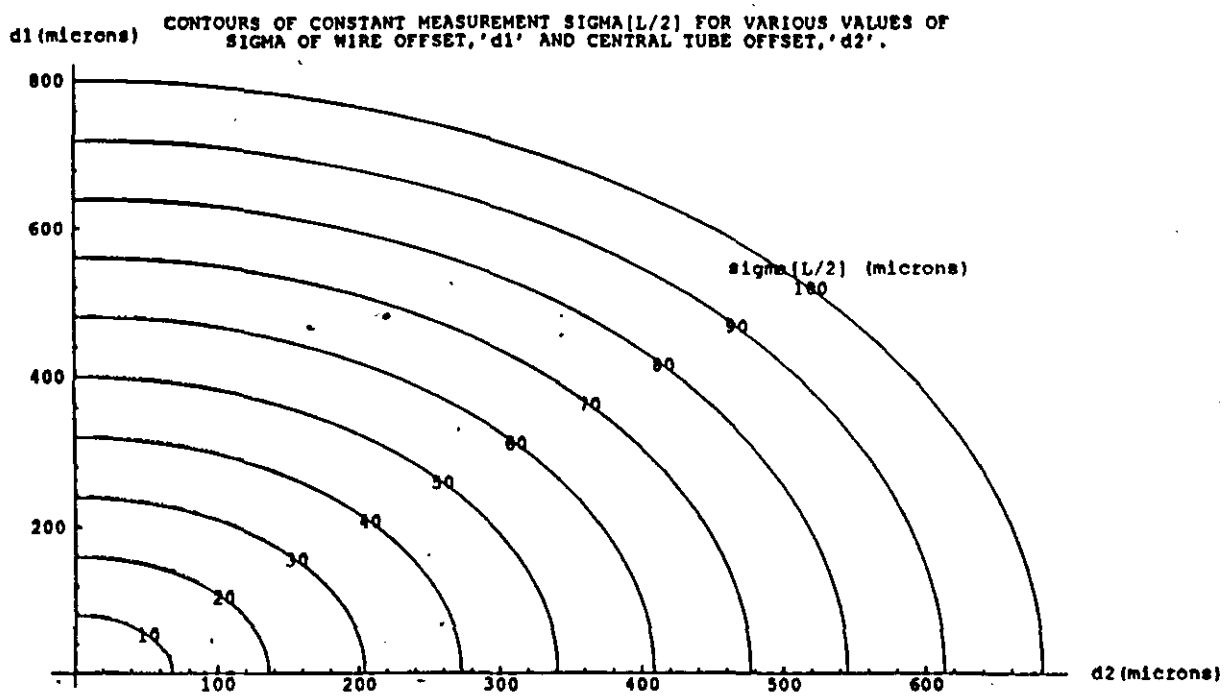



9 K.V., 50μm wire
d1 = "offset" = 250μm.
d2 = "bow" = 250μm.

-Graphics-

```
Plot[10^6 sigTube[2,V,.0125,50 10^-6,1.25,4,21.3 10^3,250 10^-6,250
AxesLabel->{"H.V. (v.)","sigma(microns)"}]
```




CONTOURS OF CONSTANT MEASUREMENT SIGMA[L/2] FOR VARIOUS VALUES OF SIGMA OF WIRE OFFSET,'d1' AND CENTRAL TUBE OFFSET,'d2'.
d1(microns)
800
600
400
200
sigma[L/2] (microns)
100
90
80
70
60
50
40
30
20
10
100
200
300
400
500
600
d2(microns)

Craig Wuest

RPC R & D Review

- Results since November 19, 1992:
  - We have built numerous RPCs from low resistivity ABS plastics:
    - Three 51 cm x 51 cm (0.25 square meters each).
    - One 76 cm x 127 cm (0.96 square meters).
    - One 15 cm x 46 cm with x-y strip readout.
    - Three 6 cm x 6 cm test RPCs with strips and pads.
  - Noise – 3-6 Hz/cm**2 for new 0.25 m**2 counter (-10 mV threshold)
  - Pulse Height - 200-500 mV
  - Plateau > 800 Vwide (measured with four-fold cosmic ray coincidence)
  - Rate capability - 10-20 KHz/cm**2 (measured with 36 cm**2 RPC)
  - Jitter - less than 5 ns (measured with 36 cm**2 RPC)
  - Single layer 1 m**2 RPC weighs 0.4 g/cm**2 (4.1 kg)
  - Ar/CO2/isobutane/freon, CO2/CF4, and Ar/iso/CF4 gas mixes tested in RPCs.
  - Successful operation of Italian and LLNL RPCs with MSU RDTs at TTR - 11/19/92

- Current RPC R&D:
  - LLNL
    - 1.2 m x 2.4 m RPC under construction.
      - frame, gas distribution, electrical designed.
      - strip plane laminates under construction.
      - New order for low resistivity ABS plastic placed 11/18/92.
      - Goal: deliver to TTR by January 15, 1993.
    - New lower resistivity plastics being tested - 10**9 - 10**10 ohm-cm.
  - MIT
    - Time jitter, slewing on 0.25 m**2 counters.
    - Gas studies.
    - Trigger layout for RPCs in barrel and endcap.
  - TTR
    - RPC operation with UH CSCs, Dubna RDTs (prop. mode) - 12/11/92.

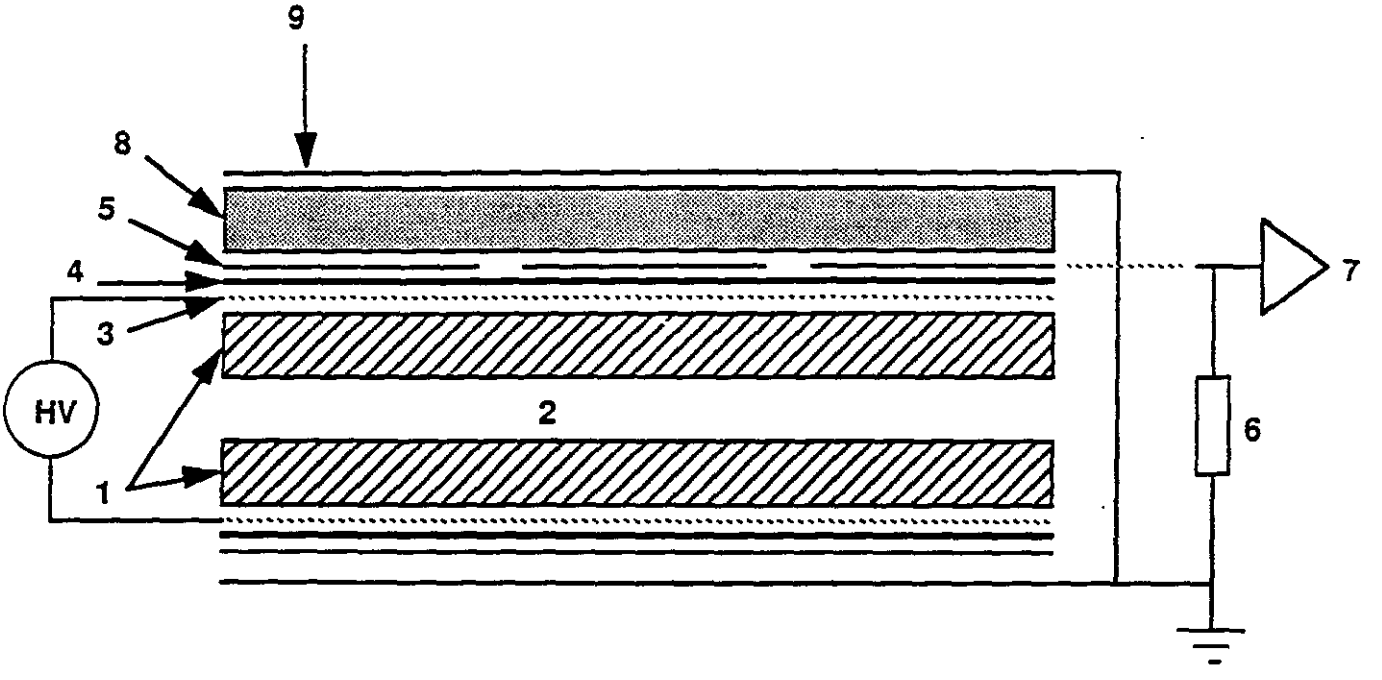
# Resistive Plate Counter Design

- Resistive Plate Chambers (RPCs) have been in operation in experiments throughout the world since 1981.
- The current standard (Italian) design is two meters long by one meter wide with a sensitive gas gap of 2 millimeters.
- There are no wires or conductors anywhere in the sensitive region.
- The walls of the chamber - in contact with the gas of the sensitive volume - consists of a semi-conductor (Bakelite, for example) with a bulk resistance of about 10**11 ohm-centimeters.
- An ioniz ing particle passing through the sensitive volume (2 m x 1 m x 2 mm) breaks down the gap and creates an electrical discharge.
- This discharge is very fast (a few nanoseconds).
- The discharge is capacitively coupled to pick-up strips which are located outside the semiconductor walls of the gas cell.

- Results since October 6, 1992:
  - We have built 3 RPCs from low resistivity ABS plastics:
    - Two 51 cm x 51 cm (0.25 square meters each).
    - One 76 cm x 127 cm (0.96 square meters).
  - Measurements have been made on efficiency, noise rate, rate capability, jitter.
  - Noise - 20 Hz/cm**2
  - Pulse Height - 200-500 mV
  - Plateau > 800 Vwide (measured with two-fold cosmic ray coincidence)
  - Rate capability - 10-20 KHz/cm**2 (measured with 36 cm**2 RPC)
  - Jitter - less than 5 ns (measured with 36 cm**2 RPC)
- Single layer 1 m**2 RPC weighs 0.4 g/cm**2 (4.1 kg)
- Ar/CO2/isobutane/freon and CO2/CF4 gas mixes tested in RPCs.

# Resistive Plate Counter Design

- Hundreds of these chambers have been produced and are operating in experiments all over the world.
- A set of these chambers have operated at Frascati for 7 years.
- Such chambers are currently being used in E-771 at Fermilab.
- Recently L3 at CERN has ordered 400 of these chambers from General Technica, Colli, Italy, a company that is a commercial supplier of RPCs.
- Not a new technology, but rather a mature technology which is well understood and for which the manufacturing technology has already been transferred to industry.

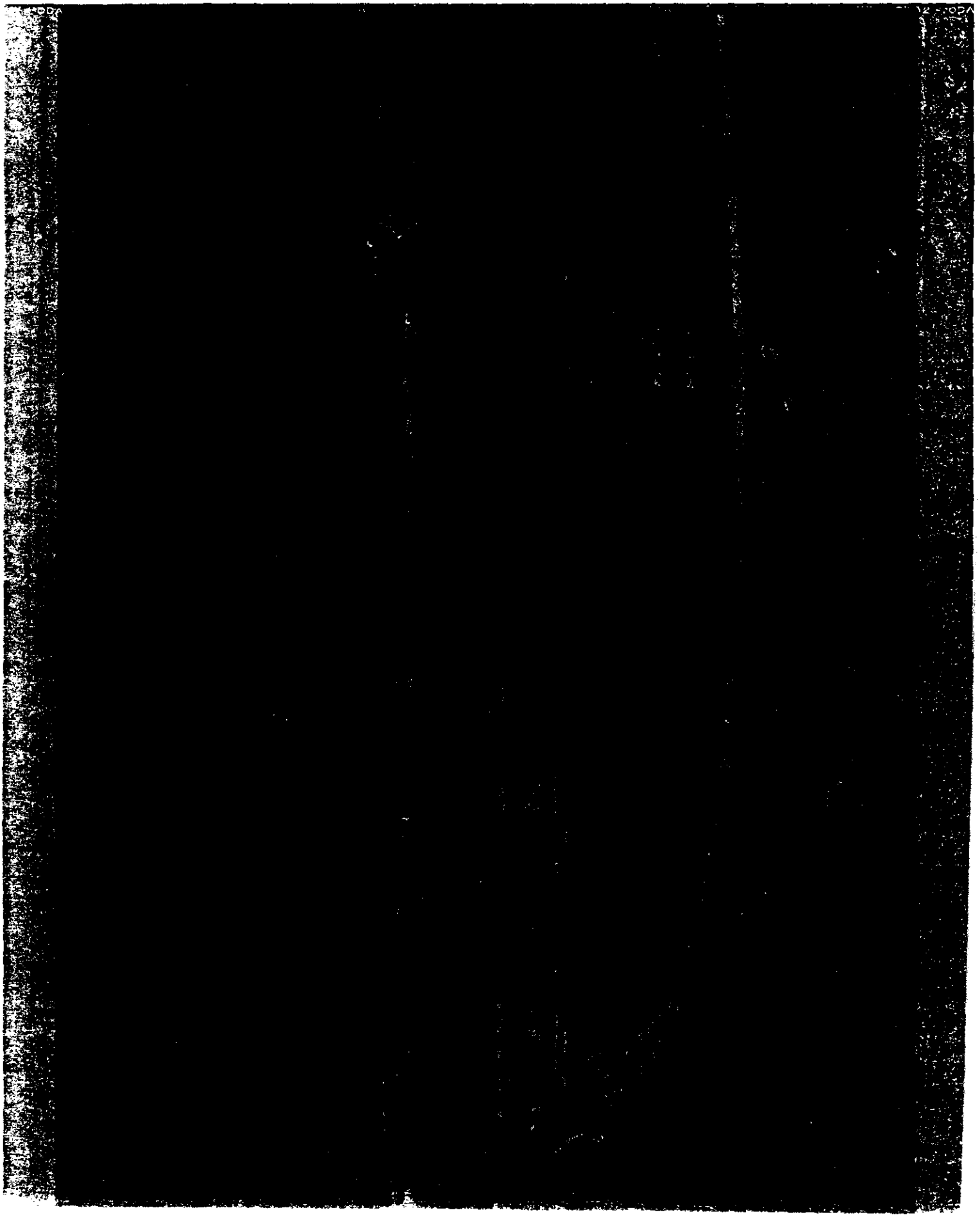



1 Bakelite plate
2 gas
3 graphite coating
4 insulating foil
5 aluminum strips
6 line termination
7 discriminator
8 foam
9 aluminum ground plane

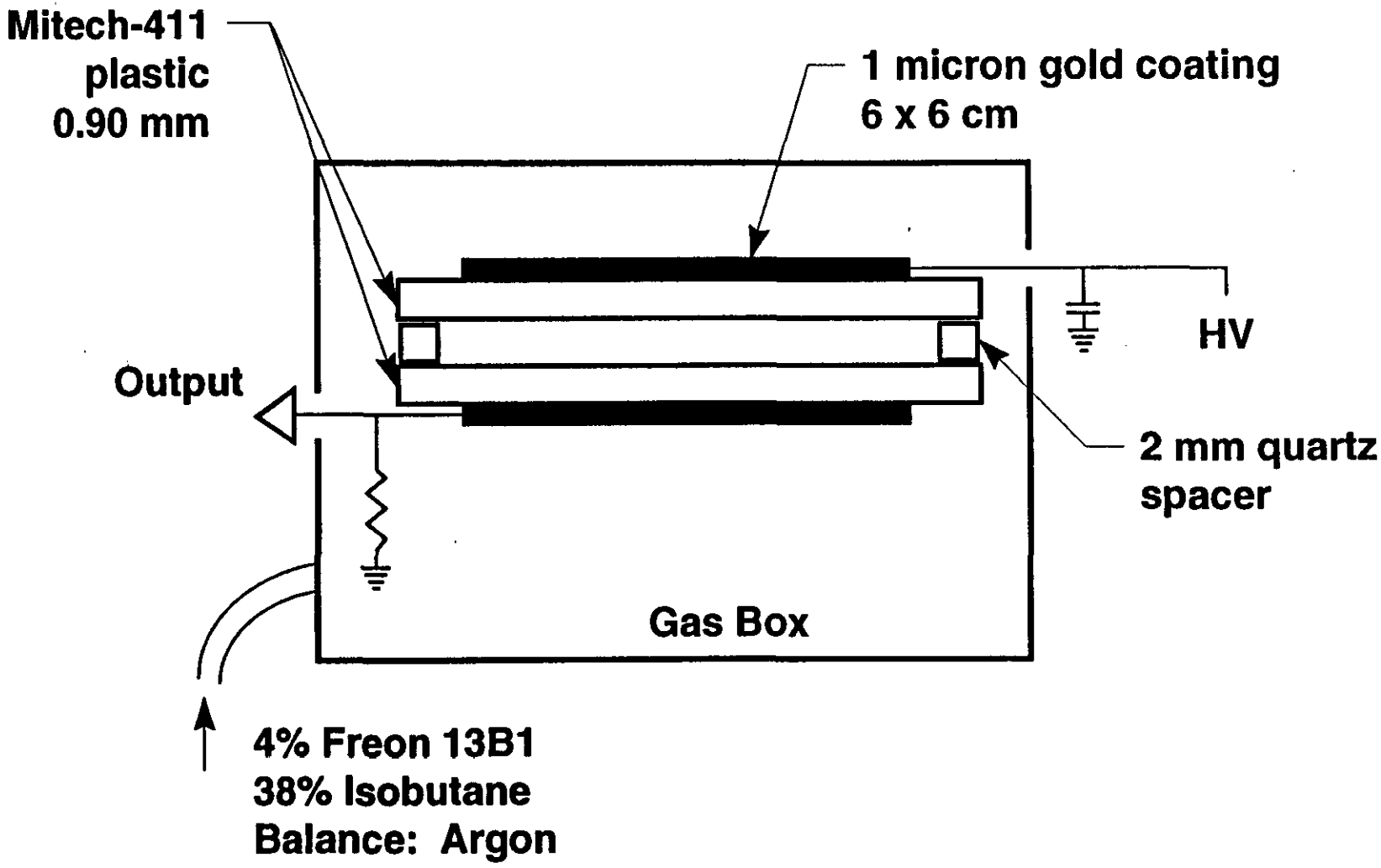
Figure 1

- Results from the RPC R&D program:
  - Pulse rise-time jitter measured on 1m x 2 m Italian RPC - 1.4 ns
  - Pulse rise-time -2.5 ns
  - Pulse width - 50 ns
  - Pulse height - 200-500 mV into 50 ohms without amplification.
  - Saturated counting rate -
    - Glasses - 50-75 Hz/cm^2
    - Bakelite - 560 Hz/cm^2
    - Static-dispersive plastics - 15 KHz/cm^2
  - Efficiency – 95% using cosmic ray scintillator telescope.
  - Lifetime – 1% decrease in efficiency measured for 8.2 SSC years exposure.
  - Noise – 10 x cosmic rays.
  - Neutron sensitivity (1-10 MeV) – 4.8 x 10^-3, same as other technologies.
  - Photon sensitivity (1-10 MeV) – 6.6 x 10^-3.

- Conclusions:
  - The R&D program has successfully addressed the major concerns of RPC counting rate, aging/lifetime, neutron sensitivity, and noise.

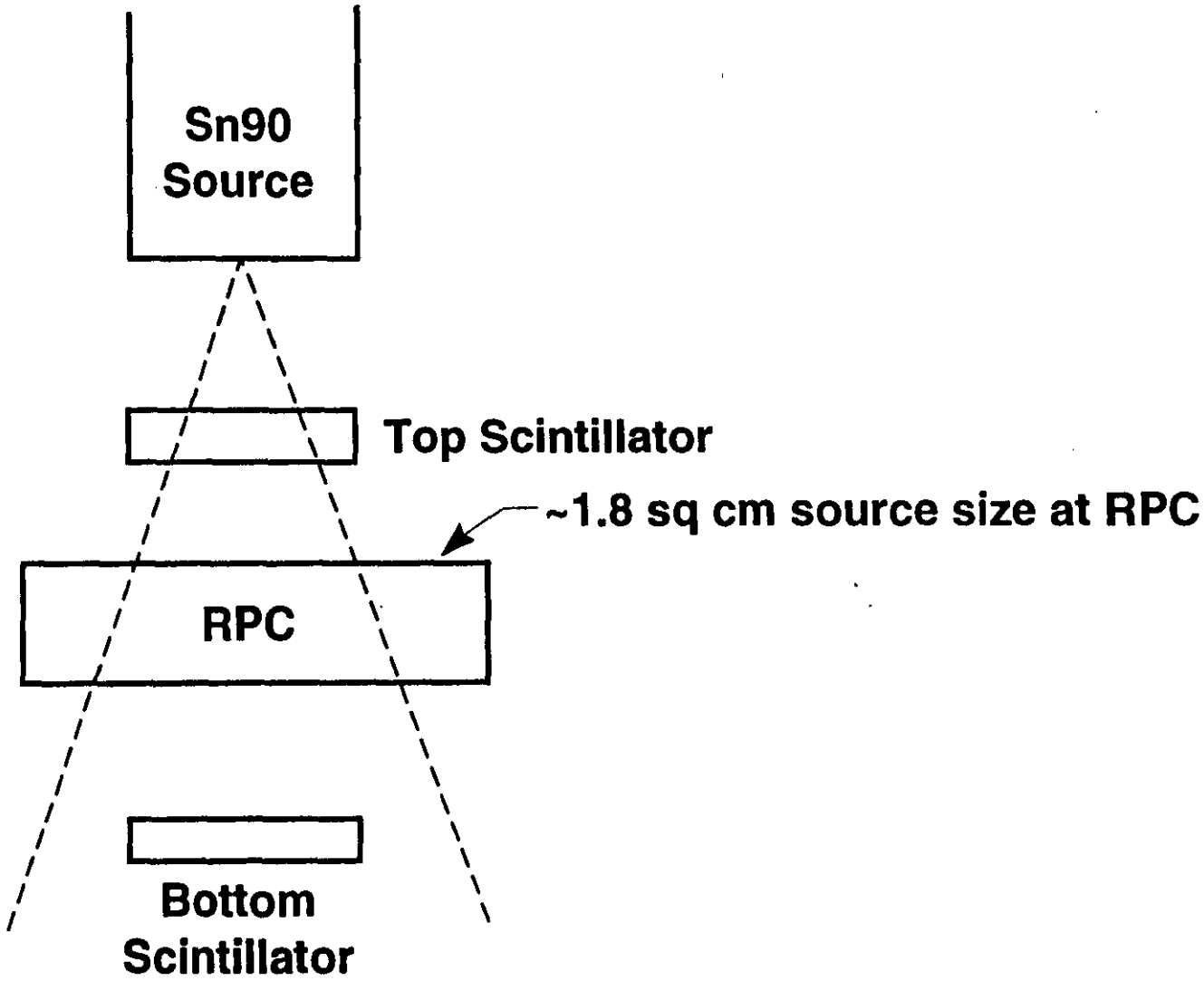


# Materials Test Detector



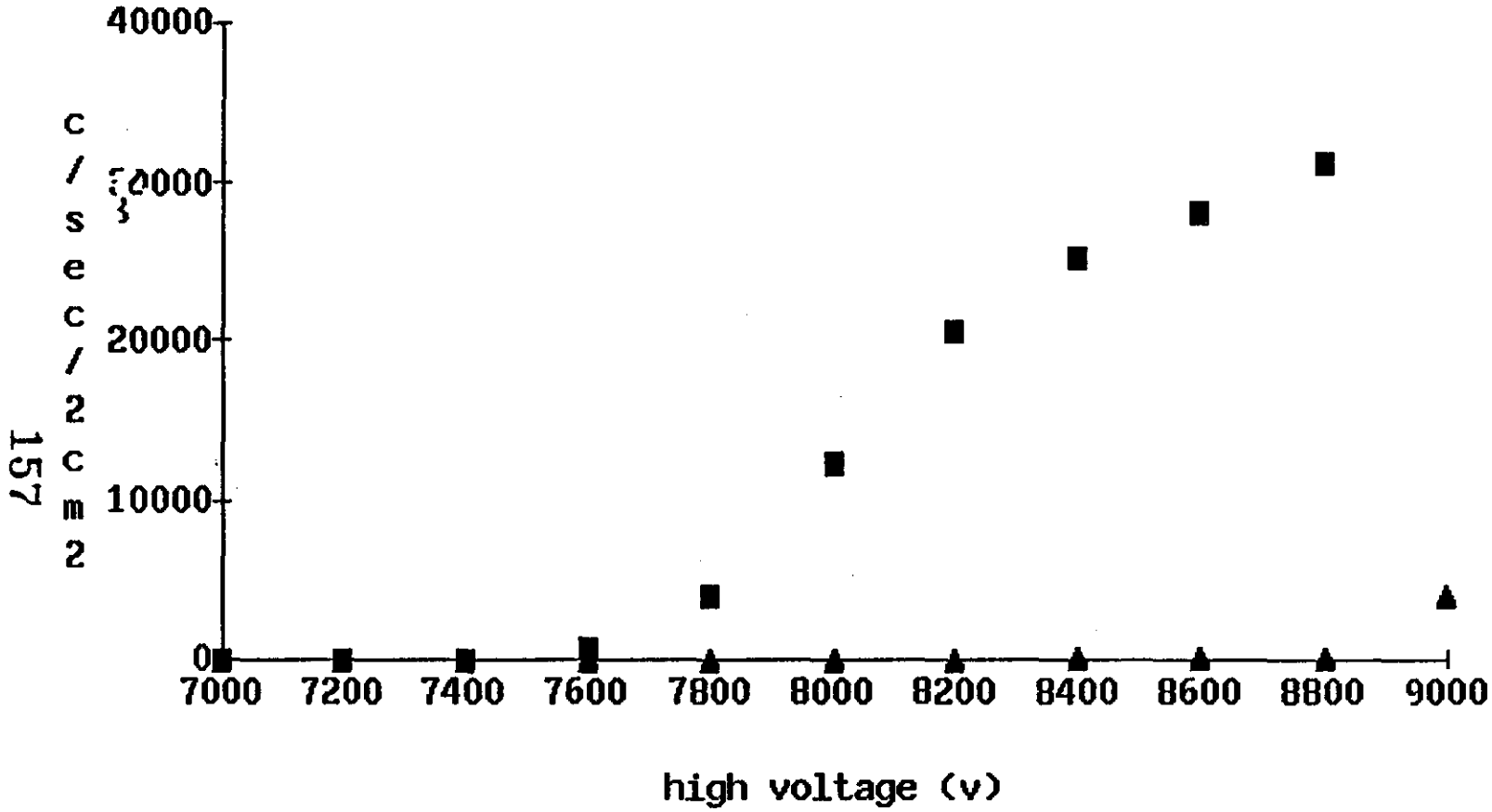

BAK.KA-03/RMB

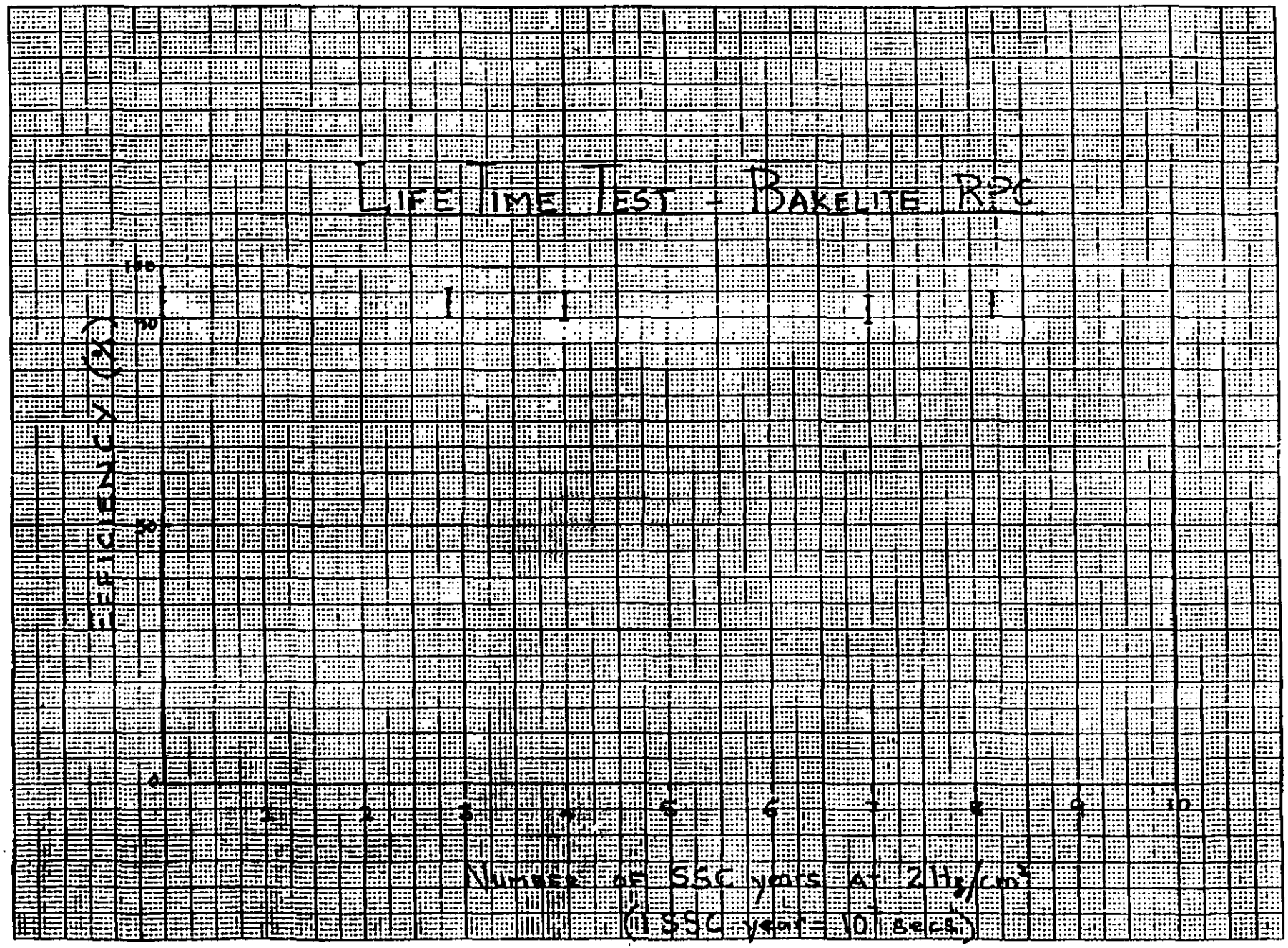
# RPC Source Test

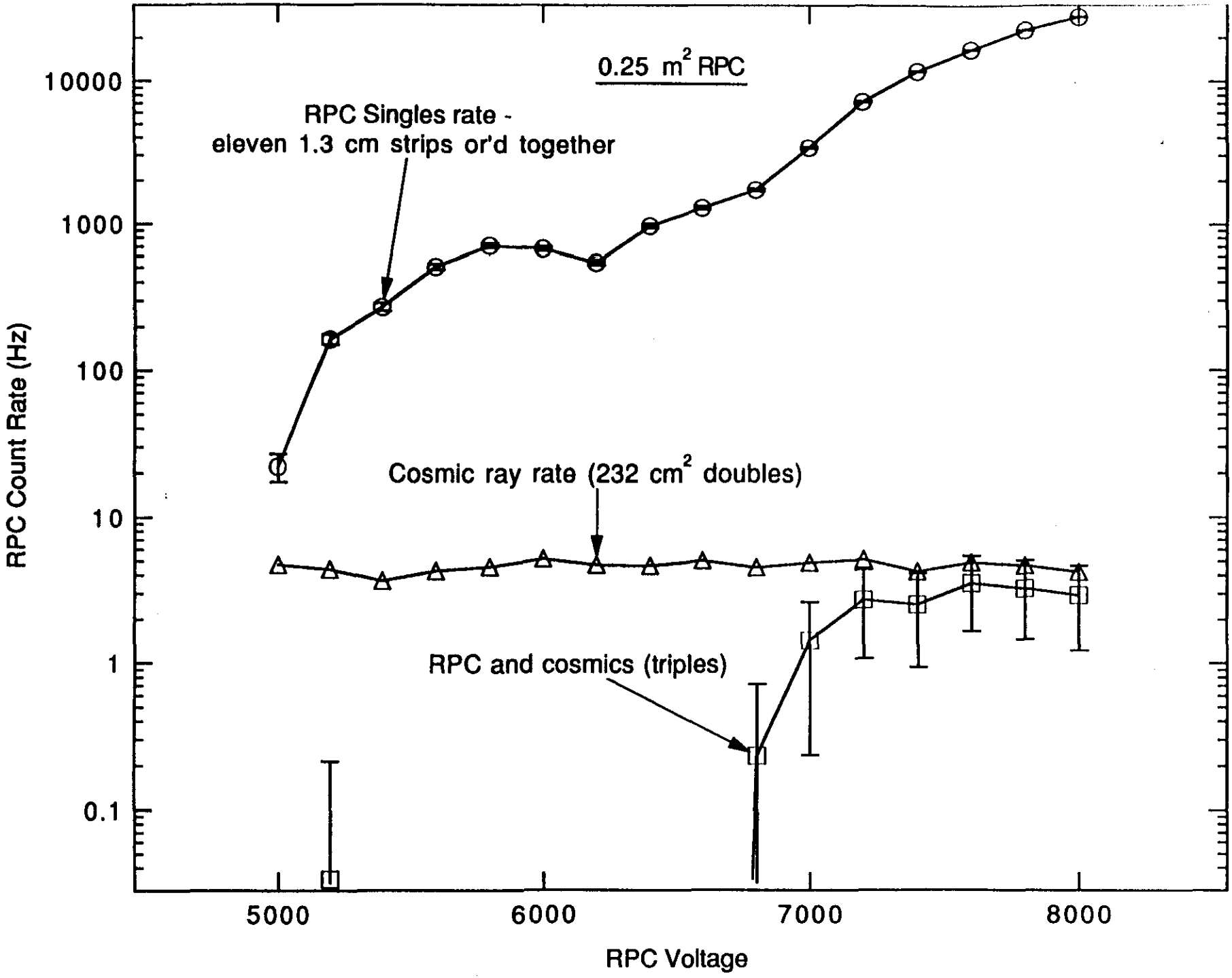


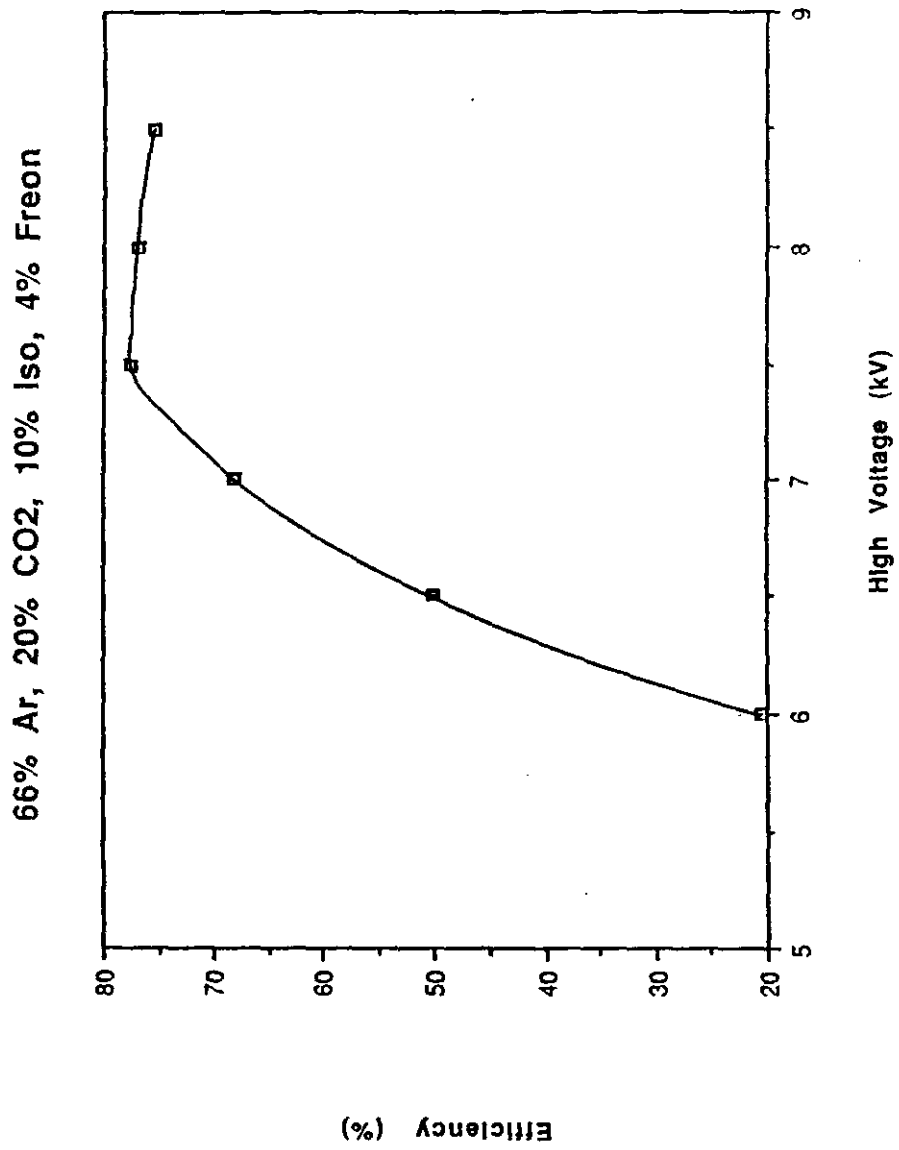

BAK.KA-02/RMB

Mitech-411 Singles

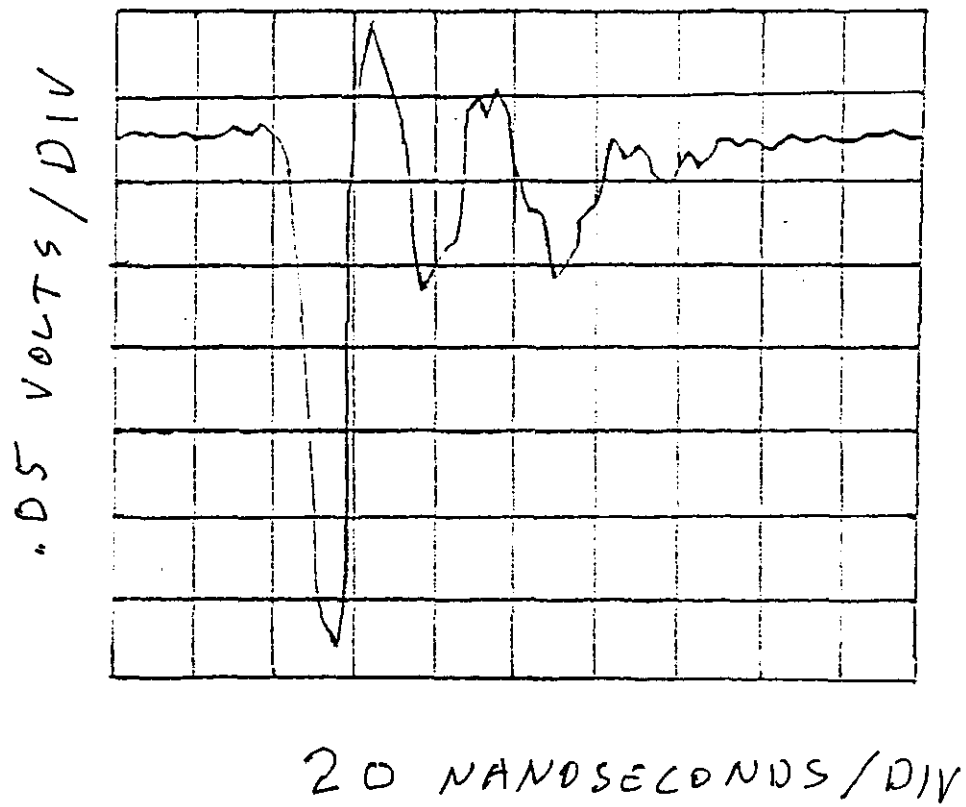


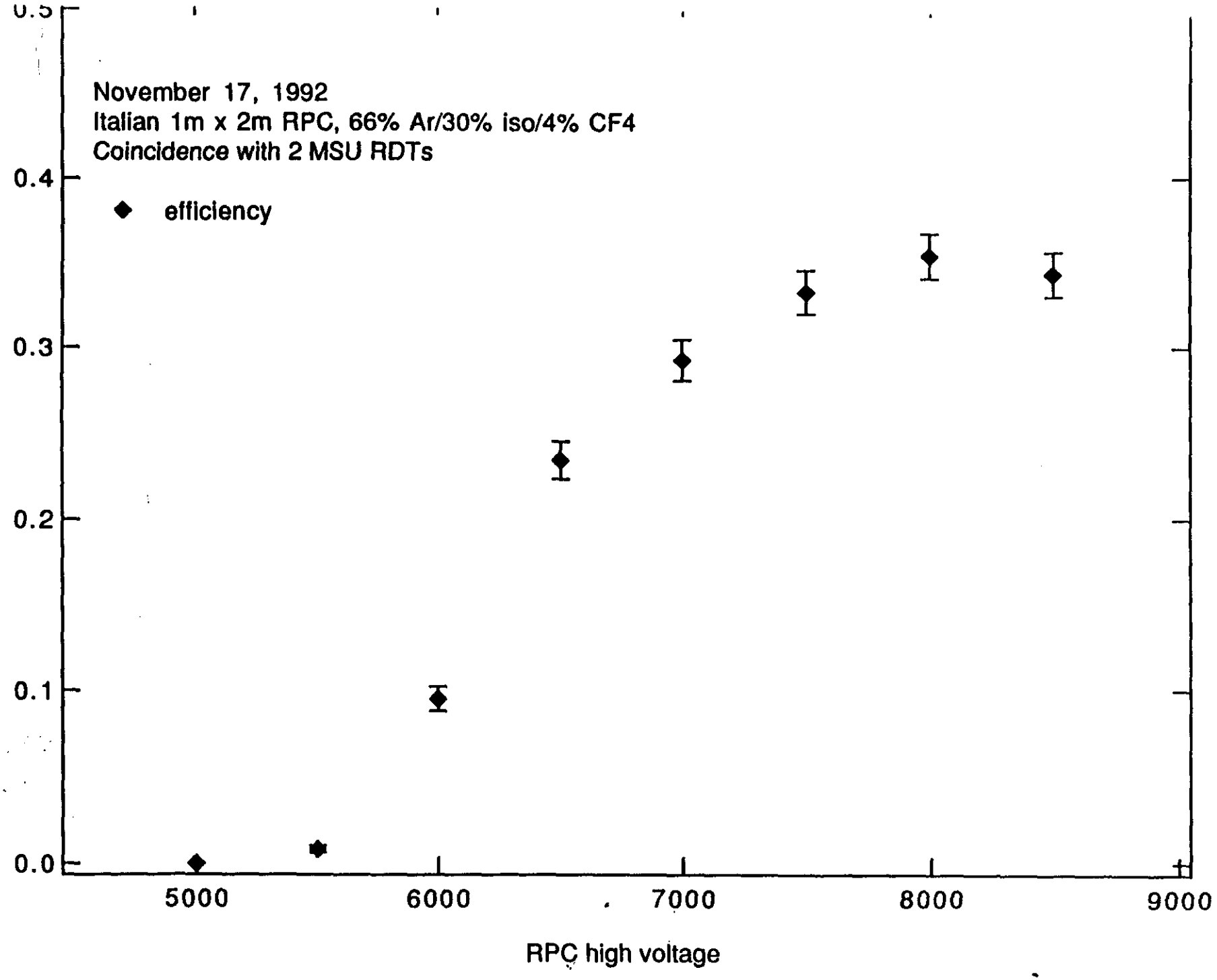

LIFE TIME TEST - BAKELITE RPC
EFFICIENCY (%)
100
90
80
1
2
3
4
5
6
7
8
9
10
Number of SSC years at 2 Hz/cm²
(1 SSC year = 10⁷ secs)

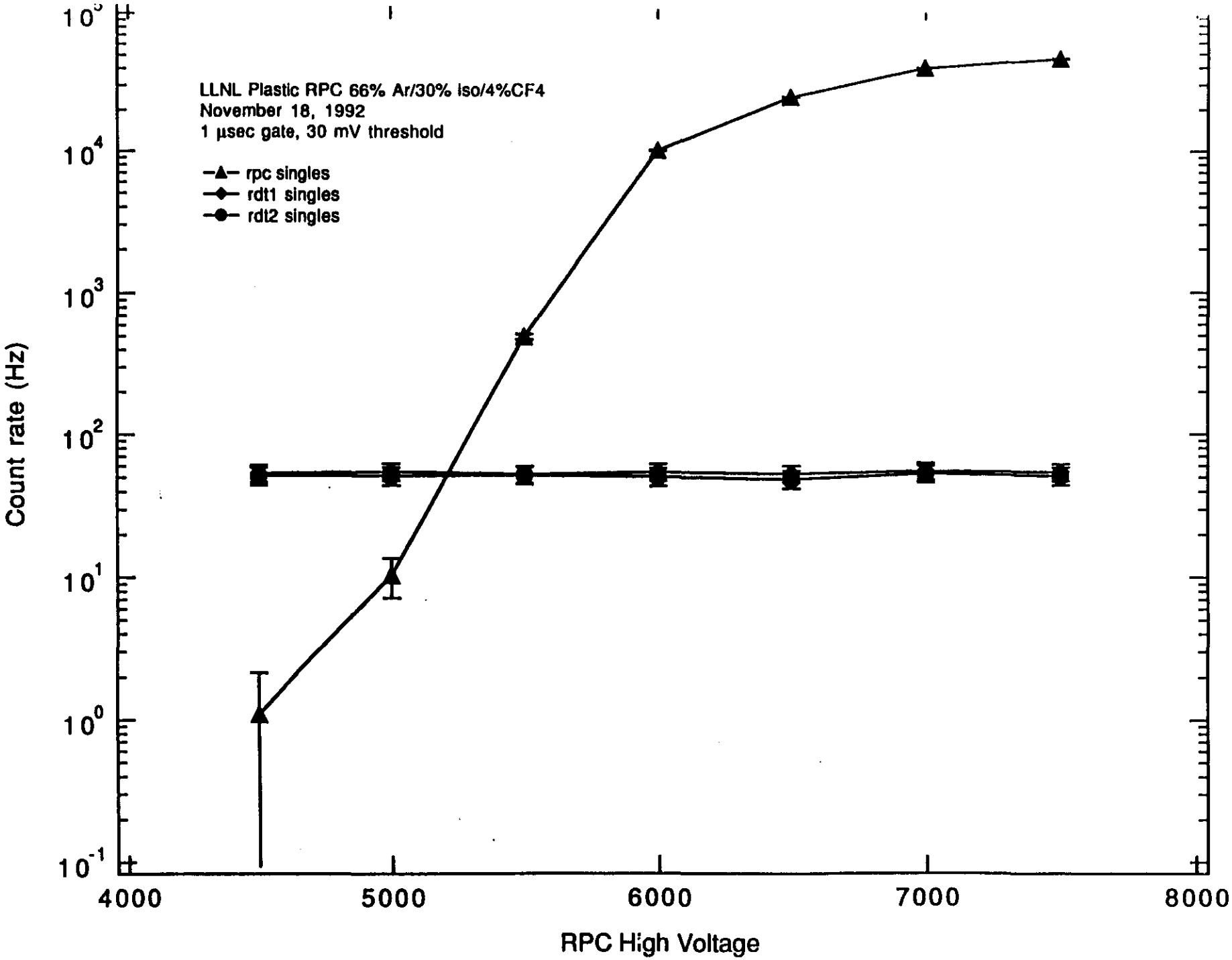

0.25 m² RPC
RPC Singles rate -
eleven 1.3 cm strips or'd together
Cosmic ray rate (232 cm² doubles)
RPC and cosmics (triples)
10000
1000
100
10
1
0.1
RPC Count Rate (Hz)
5000
6000
7000
8000
RPC Voltage

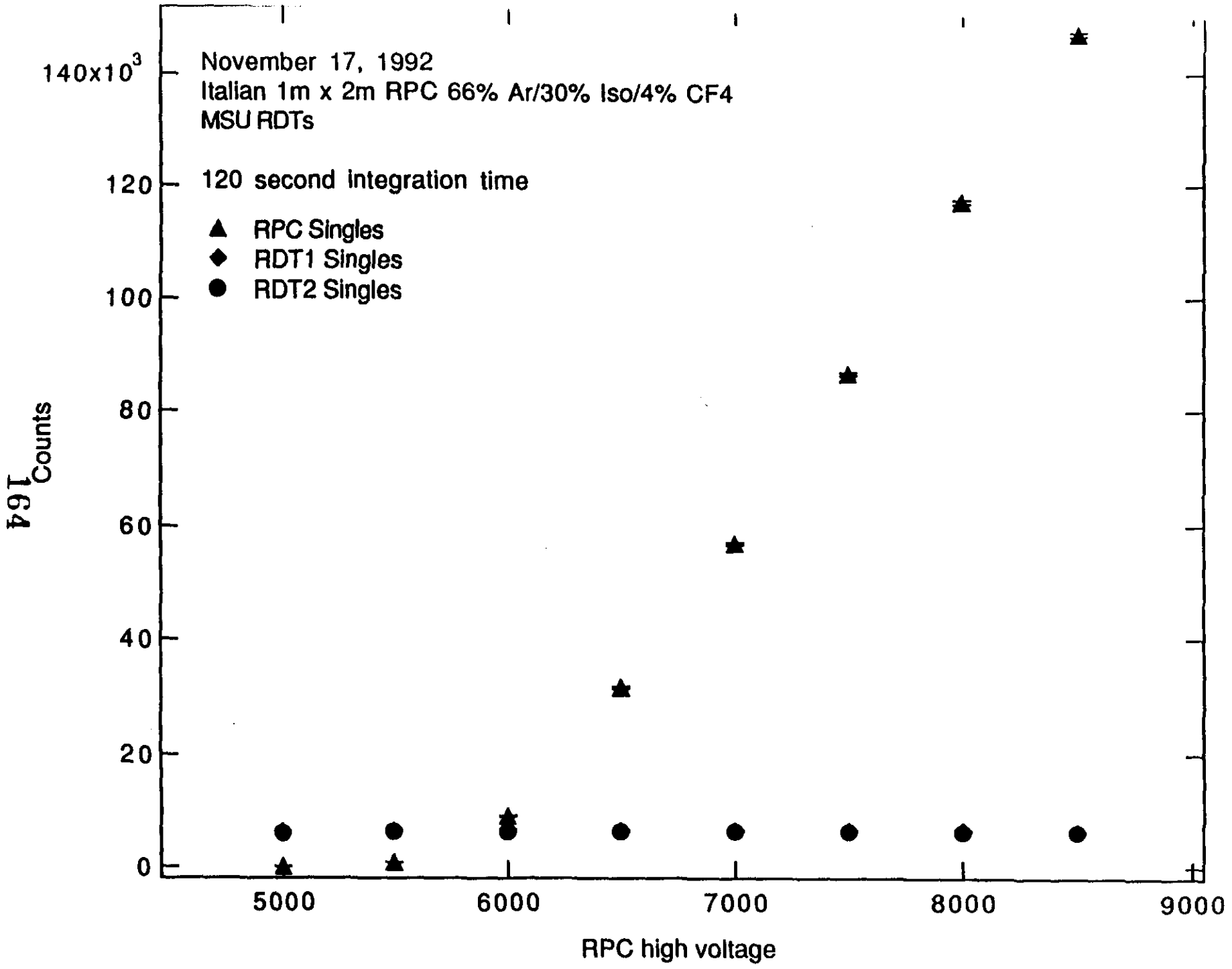

66% Ar, 20% CO2, 10% Iso, 4% Freon
Efficiency (%)
80
70
60
50
40
30
20
5
6
7
8
9
High Voltage (kV)

60% AR, 20% CO2, 10% ISO,
4% FREON




November 17, 1992
Italian 1m x 2m RPC, 66% Ar/30% iso/4% CF4
Coincidence with 2 MSU RDTs
efficiency
0.5
0.4
0.3
0.2
0.1
0.0
efficiency
5000
6000
7000
8000
9000
RPC high voltage


LLNL Plastic RPC 66% Ar/30% iso/4%CF4
November 18, 1992
1 µsec gate, 30 mV threshold
rpc singles
rdt1 singles
rdt2 singles
Count rate (Hz)
RPC High Voltage
4000
5000
6000
7000
8000


November 17, 1992
Italian 1m x 2m RPC 66% Ar/30% Iso/4% CF4
MSU RDTs
120 second integration time
RPC Singles
RDT1 Singles
RDT2 Singles
140x10^3
120
100
80
60
40
20
0
Counts
5000
6000
7000
8000
9000
RPC high voltage

Irwin Pless

# Pipe Line Muon Trigger

# A PIPE LINE MUON TRIGGER FOR BOTH BARREL AND ENDCAPS

# OF

# THE GEM DETECTOR BASED ON RESISTIVE PLATE COUNTERS (RPC)

November 1992

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*Massachusetts Institute of Technology*
*Cambridge, MA 02139*

12/08 12:37 7312025 #02

I. Features of an RPC plane

II. Simplified logic for the barrel trigger
- A. Introduction
- B. Geometry of an RPC sector
- C. Simplified trigger and beam crossing logic
- D. Non-bend plane trigger logic and beam crossing tag

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## I. FEATURES OF AN RPC PLANE

The basis for the proposed muon trigger is the resistive plate technology. The properties of this technology are:

1. Pulse rise time jitter ≤ 1.4 nanoseconds
2. Pulse full width, half height ≤ 20 nanoseconds
3. Pulse height ≅ 500 millivolts into 50 ohms

In principle, the RPC planes can be made as long and wide as is required. For the purpose of this note, we will assume the dimensions of GEM Base Line 1 dated April 23, 1992. Any change in dimensions from Base Line 1 can easily be incorporated in the trigger design. We will assume that the RPC trigger will be used with the round drift tube technology.

The geometry assumed for the barrel is indicated on pages 11 - 11 and 11 - 13 of Gem Base Line - 1, Figure 3, 2b and 3.4 respectively.

The geometry assumed for the endcap is based on the work of Frank E. Taylor.

## II. SIMPLIFIED LOGIC FOR THE BARREL TRIGGER

### *A. Introduction*

We discuss the barrel trigger first as it is more complicated then the endcap trigger.

The barrel trigger is based on 250 megahertz shift register logic. As we will show in the various appendixes, one can adjust cable lengths and gate widths so that all relevant signals from the non-bend strips and the bend strips can be loaded synchronously into shift registers. The outputs of these shift resistors can be put into simple logic to form the trigger and beam crossing tag. The trigger is formed in 100 nanoseconds. At a neutron flux of $10^5$ Hertz per square centimeter per second the accidental trigger rate in the barrel is about 22 Hertz. In the end cap the accidental rate is more than an order of magnitude less. The dead time is about 4%.

### *Geometry of an RPC Barrel Plane*

In Figure 1 is the typical X and Y strip lay out. The crucial thing to note is that a hit anywhere on the plane generates signals on an X strip and Y strip that arrive at the collection point in coincidence. Another point to note is that half the bend plane strips are in coincidence with the lower half of the non-bend plane strips while the other half of the bend plane strips are in coincidence with the upper half of the non-bend plane strips. This division has two virtues, the first it reduces the time resolution in tagging the beam crossing by about a factor two and it also reduces the ambiguity of double hits by a factor two. Note that this is achieved without increasing the electronic channel count. These points will be discussed in detail in later sections of this paper.

It should be noted that each RPC chamber consists of two identical RPC counters. This increases the efficiency of the RPC trigger system from about 90% to essentially 97% without increasing the electronic channel count. It does, however, increase the total number of signal cables and electronic inputs. This is discussed in detail in Appendix 1.

### *B. Geometry of an RPC Sector*

Figure 2 is a simplified sketch of the three RPC chambers that form an RPC sector.

Figure 2A is an end view of a sector and Figure 2B is a side view of a sector.

As can be seen from Figure 2, there is a outer RPC chamber which we will label SL3, a central RPC chamber which we will label SL2, and an inner RPC chamber which we will label SL1 in accordance with the GEM Base Line 1 notation.

The non-bend strips form projective towers with respect to the interaction point. The non-bend plane strip widths are:

| | |
|---|---|
| SL1 (A and B) | = 3.9 cm |
| SL2 (A and B) | = 6.5 cm |
| SL3 (A and B) | = 8.9 cm |

The number of non-bend plane strips per sector are given below:

*Non-bend plane strip count:*

SL1 = 166 strips
SL2 = 166 strips
SL3 = 166 strips

All bend plane strips are each 1.3 cm wide. The number of bend plane strips per sector are given below:

*Bend plane strip count:*

SL1 = 115 strips
SL2 = 184 strips
SL3 = 254 strips

The total number of electronic channels we have for each sector is:

Non-bend plane = 498 electronic channels
Bend plane = 553 electronic channels

As we stated above, note, that we have more cables and connectors than we have electronic channels.

The total number of electronic channels is 33,632.

### *C. Simplified Trigger and Beam Crossing Logic*

The bend plane logic for the barrel is the most difficult to work out. Hence we will discuss this case first. It can be shown that with proper choice of cable lengths between SL1 and SL3; and SL2 and SL3, corresponding strips in the three layers can be placed in coincidence using predetermined delays as inputs to the shift registers. This is discussed in Appendix 1.

The proposed trigger is a three layer trigger. Due to the multiple scattering in the calorimeter, a number of possibilities must be considered. Figure 3 illustrates this.

For each pair of strips in SL3 and SL1 there is a range of strips in SL2 that determine the momentum of the track.

For a given strip in SL3 and a given strip in SL1 there is a shift register logic for forming a trigger.

A trigger can be formed under computer control. The trigger momentum for each strip in SL3 that forms a trigger is chosen by which strips in SL1 are selected, and then for each selected strip in SL1 which strips in SL2 are selected. Figure 4 illustrates the situation for a 20 GeV/c track.

As a specific example we consider a trigger for momentum greater than 30 GeV/c. In this case, for each sign of charge, three strips in SL1 must be selected for each strip in SL3. In addition, for each strip selected in SL3, two strips must be selected for SL2. If we consider both possible charges, then we activate six similar sets of shift register logic. We define the following symbols:

| | |
|---|---|
| SL3i | The strip in super layer three that has been struck |
| SL1j (j = 1 to 6) | The strip in super layer one that has been struck. The eight possible strips are determined by the 30 GeV/c sagita at super layer 1 with respect to an infinite momentum track that passes through SL3i and the interaction point and the multiple scattering due to a 30 GeV/c muon passing through the calorimeter. |
| SL2k (k = 1 to 3) | The strip in super layer two that has been struck. The three strips are determined by the 30 GeV/c sagita at super layer 2 with respect to an infinite momentum track that passes through strips SL3i and SL1j. |

The shift register logic for this situation is shown in Figure 4.

Every four nanoseconds the first eight shift registers are loaded with the eight bit address of strip SL3i. The next shift register is the input of SL3i, which we have assumed has been hit. The next 3 shift registers contain the hit pattern in SL2. The following 8 shift registers contain the eight bit address of SL1j. The following shift register is the input of SL1j, which we have assumed has been hit. The last shift register is the local trigger flag for this logic circuit. Note that we have allowed five clock ticks to fan out all strips to their required logic. Clock ticks 6 and 7 form an or of the SL2 strips. Clock ticks 8 and 9 form a triple coincidence between SL3i, SL1j, and the or of the SL2 strips. This is the actual trigger. Clock ticks 10 and 11 form a fanout of the trigger. Clock tick 12 sets the local trigger flag and feeds the pipelined 256 or circuit, one for

each strip of SL3. Clock ticks 13 through 16 form this or. The output at clock tick 18 is the bend plane master trigger. Clock tick 18 and 19 form the coincidence between the bend plane master trigger and the non-bend plane master trigger. The formation of the non-bend plane master trigger is discussed later in this paper. Clock ticks 20 and 21 open a 64 line data bus. Clock ticks 22 and 23 activate the 64 line data bus. Clock ticks 24 and 25 load the data bus. Note that the local trigger addresses the bus in the usual memory fashion. Clock ticks 24 and 25 send the trigger and the complete information to the second level trigger. We use a 64 bit data bus so that we can transfer 22 bits of bend plane and 42 bits of non-bend plane information. Hence at the end of 25 clock ticks we have the decoded addresses of the SL3 and SL1 hit strips and the SL2 hit strips. The same is true for the non-bend plane. The non-bend plane also furnishes the clock time of the beam crossing. The complete trigger is accomplished in 100 nano seconds.

Triggers for 20 GeV/c and 10 GeV/c can be produced in similar fashions. By including appropriate gates, which are under computer control, one can select the desired trigger.

### *D. Non-Bend Plane Trigger Logic and Beam Crossing Tag*

Figure 5 shows the geometry of the non-bend plane. The projective strip design has been optimized to account for multiple scattering.

As indicated in Figure 5 for each strip in SL3 there is only one strip in SL2 and three possible hits in SL1. Hence only strips in SL1 are shared by other logic. Each strip in SL1 is fanned out to three logic circuits.

For the non-bend plane, the logic is the same for all momentum. Also for the non-bend plane we only need the 8 bit address of SL3i. SL2j has the same address. The SL1k strips have addresses one less than SL3i, the same as SL3i and one more than SL3i. As we have noted earlier each non-bend strip is effectively divided in half. The uncertainty in time is therefore given by:

SL1 = 1.485/2 x 5 = 3.7 nanoseconds

SL2 = 2.390/2 x 5 = 6.0 nanoseconds

SL3 = 3.296/2 x 5 = 8.3 nanoseconds

Since we have a four nanosecond clock and a 1.5 nanosecond pulse rise time jitter, all three super layers can uniquely determine the beam crossing time. However, since we will be using cable and electronic delays to place the relevant strips in coincidence, only one superlayer can be kept in absolute synch with the beam crossing time. We chose SL1 as the beam crossing timing superlayer. The gate widths of superlayer 1 channels will be four nanoseconds, while the gate widths of the other two superlayers will be larger. This is discussed in Appendix 1. Figure 6 is a sketch of the non-bend plane logic.

The first shift register indicates whether or not the hit in SL3 is on the lower half of SL3i. In this example we assume the lower half of SL3i was hit. The second shift register indicates whether or not the upper half of SL3i was hit. The next 8 shift registers contain the eight bit address of SL3i. The next shift register indicates whether or not SL3i was hit. In this example we assume SL3i was hit. The next three shift registers contain the hit pattern in SL1. In this example we assume only SL(i + 1) was hit. The following 10 shift registers contain the 10 least significant bits of the master beam crossing clock which is loaded every clock tick. The next 6 bits contain the fixed, known delay time from strip SL2i to the master clock. This includes all cable delays and flight time delays from the interaction point. Any delays to the master beam clock from the interaction point can be included in these ten bits. The next 10 shift registers contain the beam crossing time. The final shift register contains the non-bend plane trigger.

On clock tick 1 all data is loaded into the 42 shift registers. There is no fan out delay as there is in the bend plane trigger. On clock ticks 2 and 3 we perform the subtraction between the clock 10 bits and SL2i $\Delta t$ six bits. Also on clock ticks 2 and 3 we perform the or between SL1 (i - 1), SL1 (i), and SL1 (i + 1). On clock tick 4 we deposit the ten bit beam crossing time. Hence in four clock ticks we have the unique beam crossing time. On clock ticks 4 and 5 we form the and between SL3i, SL2i and the or of the three strips centered on SL1i. This forms the non-bend plane trigger. Hence in 5 clock ticks we have the non-bend plane trigger. On clock ticks 6 and 7 we fan out the non-bend trigger to the trigger bit and to the 166 fan in system. On clock ticks 8 and 14 we generate the non-bend plane trigger. Clock tick 16 - 18 places the master non-bend trigger in coincidence with the master bend plane trigger. Clock ticks 19 to 25 places the non-bend plane information on the 64 bit bus to the level 2 trigger. As indicated in the discussion of the bend plane trigger, the complete muon trigger is formed in 25 ticks or 100 nanoseconds.

It should be noted that the beam crossing tag is now at this level with a maximum error of 3.7 + 4.0 + 4 = 11.7 nanoseconds. The 3.7 comes from the effective strip length of SL1, the 4.0 is the clock period and the 4 is the three sigma error of the rise time jitter. This can be verified to within a maximum error of 5 nanoseconds at the second level.

## III. END CAP MUON TRIGGER

Figure 7 is a sketch of the end cap geometry. This is roughly the geometry of Frank E. Taylor. All dimensions are in millimeters. Figure 8 is the calculated sagitta by Frank E. Taylor for a similar geometry. A completely correct calculation will not change the trigger design in any significant way. We see from Figure 8 that the sagitta at 18° is about 6 mm for 50 GeV/c transverse momentum. If we choose our strip width for the region 18.3° to 30° to be 6 mm, then the trigger response will be similar to that shown in Figure 9. In fact, it will actually be a bit better than shown in Figure 9.

If we look at Figure 8 we see that at 9.5° the sagitta is roughly 4.4 millimeters for 50 GeV/c transverse momentum. Again, if we take our strip width to be 4.4 mm in the region between 9.5° and 18.3° our trigger resolution will be similar to that shown in Figure 9.

This above consideration has determined our strip width for the bend plane. For the non-bend plane, the strip width has to be consistent with multiple scattering and the precision we wish to know the non-bend coordinate. For the barrel, SL2 determines the non-bend coordinate and that was chosen as 6.5 cm which about matched the multiple scattering requirement. For the end cap it seems 6.5 cm will match the requirement for the non-bend plane. It also seems that the 6.5 cm will also about match the multiple scatter requirement. Hence we will choose a tower geometry with the width at SL2 = 6.5 centimeters. Table 1 lists the strip widths and the number of strips for the six chambers in the end cap.

TABLE 1

*Strip Information for the End Caps*

| SL3 Non-Bend Plane | | | | SL3 Bend Plane | | |
|---|---|---|---|---|---|---|
| CHAMBER | STRIP | WIDTH | NUMBER STRIPS | STRIP | WIDTH | NUMBER STRIPS |
| 30° | 93 | mm | 40 | 6 | mm | 583 |
| 18.3° | 93 | mm | 26 | 4.4 | mm | 486 |

| SL2 Non-Bend Plane | | | | SL2 Bend Plane | | |
|---|---|---|---|---|---|---|
| CHAMBER | STRIP | WIDTH | NUMBER STRIPS | STRIP | WIDTH | NUMBER STRIPS |
| 30° | 65 | mm | 40 | 6 | mm | 409 |
| 18.3° | 65 | mm | 26 | 4.4 | mm | 320 |

| SL1 Non-Bend Plane | | | | SL2 Bend Plane | | |
|---|---|---|---|---|---|---|
| CHAMBER | STRIP | WIDTH | NUMBER STRIPS | STRIP | WIDTH | NUMBER STRIPS |
| 30° | 38 | mm | 40 | 6 | mm | 238 |
| 18.3° | 38 | mm | 26 | 4.4 | mm | 186 |

Total number non-bend strips = 198 per sector.

Total number of bend strips = 2,222 per sector.

Total number of channels per sector = 2,420.

Total number of channels for GEM = 77,440.

This is about 2.4 times the number of channels in the barrel.

The trigger logic for each bend plane set of 3 chambers (three 30° chambers and three 18.3° chambers) is identical to the barrel bend plane trigger logic. The same is true for the non-bend plane. Since there are two separate sets of chambers in the end cap, there will be two 64 bit data buses to carry the information to the second level trigger. The accidental rate and dead time calculation, however, are different. These calculations are discussed in Appendix 1.

The layout and wiring of each end cap RPC chamber will be similar to the layout and wiring of the RPC chamber in the barrel.

## IV. SUMMARY

The RPC trigger scheme has the following properties:

***Barrel***

1. Number of Channels

| | | | |
|---|---|---|---|
| Non-bend plane | 498 x 32 | = | 15,936 |
| Bend plane | 553 x 32 | = | 17,696 |
| **TOTAL** | | | 33,632 |

Strip Widths

| | | |
|---|---|---|
| *Non-bend plane* | | |
| SL1 | 3.9 | cm |
| SL2 | 6.5 | cm |
| SL3 | 8.9 | cm |
| *Bend plane* | | |
| SL1 | 1.3 | cm |
| SL2 | 1.3 | cm |
| SL3 | 1.3 | cm |

Strip Length

| | | |
|---|---|---|
| *Non-bend plane* | | |
| SL1 | 148.5 | cm |
| SL2 | 239.0 | cm |
| SL3 | 329.6 | cm |
| *Bend plane* | | |
| SL1 | 631.9 | cm |
| SL2 | 1,042.6 | cm |
| SL3 | 1,475.0 | cm |

| | | |
|---|---|---|
| Trigger acquisition time | 100 | nanoseconds |
| Beam crossing error | | |
| First level trigger | 11.7 | nanoseconds |
| Second level trigger | 5.0 | nanoseconds |
| Accidental rate at a neutron flux of $10^5$ neutrons per square centimeters per second (transverse momentum > 50 GeV/c | 22 | Hertz |
| Dead time at a neutron flux of $10^5$ neutrons per square centimeters per second (transverse momentum > 50 GeV/c | | |
| Signal dead time gate = 50 nanoseconds | 4% | |
| Signal dead time gate = 100 nanoseconds | 18% | |

### *End Cap*

Detailed strip information is in Table 1.

| | |
|---|---|
| Total number of end cap channels | 77,440 |
| Trigger acquisition time | 10 nanoseconds |
| Beam crossing error | |
| First level trigger | 11.7 nanoseconds |
| Second level trigger | 5 nanoseconds |

All accidental rates and dead times are less than the barrel by more than an order of magnitude.

## V. APPENDIX 1

Considerations of strip timing, accidental rates and system dead time.

### *A. Barrel Trigger*

#### I. *Timing*

The basic barrel trigger depends on the non-barrel plane timing. We will label each of the 166 non-bend strips with an index k (k = 0 - 155) where strip Δ is the strip closest to the interaction point. The non-bend plane strips form a projective tower with the interaction point. Every three corresponding strips (i.e. the three strips with the same index) can be brought into time coincidence at the input to the shift register logic. This is done by having a fixed cable length difference for each strip of SL2 and SL1 with respect to SL3. The fixed cable lengths [measured in nanoseconds] for SL2 and SL1 is listed in Table A.1. Following the cable delay which is common for all strips on a superlayer there is a timing gate delay, the width of which is determined by the bend strip index. Following the gate delays there is generated a signal gate whose length is determined by the superlayer. These timings are also listed in Table A.1.

The bend plane strips also have the same cable differences as the non-bend plane strips as indicated in Table A.1. The bend plane strips do not have any timing gate delays following the cable but rather generate just a signal gate whose width is superlayer dependent. This is also listed in Table A.1.

If the numbers listed in Table A.1 are used in a straight forward, but

tedious, hand calculation one finds that all the signals from any track with a transverse momentum greater than 10 GeV which passes through SL1, SL2 and SL3 will arrive in coincidence at the shift register logic with an overlap in time greater than 2 nanoseconds.

It should be noted that this system requires ± 5% logic throughout. This has been included in the above calculations.

### *Accidental Rates*

We assume then the neutron flux is $10^5$ Hertz per square centimeter per second everywhere in GEM. Hence our RPC rate is 500 Hertz per square centimeter per second.

We calculate the accidental trigger rate for all tracks with transverse momentum greater than 50 GeV/c. In order to handle this high rate, we place the two RPC counters in SL1 in coincidence and the two in SL2 in coincidence. However we or the two RPC counters in SL3. This yields a 95% efficient RPC system which can handle the $10^5$ neutrons per square centimeter.

The non-bend plane accidental trigger rate = NBA is given by the following formula:

$$NBA = [12]\,[R_1\ R_2\ R_3\,(\tau_1 + \tau_2)\,(\tau_1 + \tau_3)]\,[166]\,[32]$$

$R_1$ = Rate in superlayer 1

$R_2$ = Rate in superlayer 2

$R_3$ = Rate in superlayer 3

$\tau_1$ = Signal gate width in superlayer 1

$\tau_2$ = Signal gate width in superlayer 2

$\tau_3$ = Signal gate width in superlayer 3

The factor [12] is because for each SL3 strip there are two possible SL2 strips and six possible SL1 strips involved. The factor [166] and [32] are the number of strips and number of sectors.

$$R_1 = (R \times W_1\ L_1)^2 \times 2\tau_1$$

$R = 500$

$W_1 = 3.9$

$L_1 = 148.5$

$\tau_1 = 4 \times 10^{-9}$

$R_1 = 2.8 \times 10^3$ Hertz

$R_2 = (R \times W_2 L_2)^2 \times 2\tau_2$

$R = 500$

$W_2 = 6.5$

$L_2 = 239$

$\tau_2 = 10 \times 10^{-9}$ $\tau_3 = 11.5 \times 10^{-9}$

$R_2 = 2.7 \times 10^4$

$R_3 = 2(R \times W_3 L_3) = 2 \times 500 \times 8.9 \times 329.6 = 2.9 \times 10^6$

NBA =
[12] [2.8] [$10^3$] [2.7] [$10^4$] [2.9] [$10^6$] [1.4] [$10^{-8}$] [1.55] [$10^{-8}$] [166] [32]
$= 3.0 \times 10^3$

The non-bend trigger must be placed in coincidence with the bend trigger. Since for every non-bend hit there is a <u>random</u> hit in coincidence in the bend plane, we have to multiply NBA by the combinatorial factor = C to calculate the GEM false trigger rate = F.

F = NBA x C
C = N3 x N2 x N3

The factor:

N3 = 1 as one strip in SL1 is hit in coincidence with NBA.

N2 = 3/184 as there are only 3 strips determined by the strip hit in SL3 which can form a bend plane trigger of either charge that has a transverse momentum of 50 GeV/c.

N1 = 6/115 as there are only six strips in super layer one that can form a trigger for the hit in SL3.

$C = 8.5 \times 10^{-4}$
$F = 3.0 \times 10^3 \times 8.5 \times 10^{-4} = 2.6$ Hertz

If it is required to match a neutron flux of $10^6$ neutrons per square centimeter per second we can and the two RPC counters in SL3. This will yield an RPC system with an efficiency of about 94%.

### *Accidentals caused by Muons with less than 50 GeV/c Transverse Momentum*

The trigger rate, in the barrel, for muons with momentum greater than 10 GeV/c is about 1,000 Hertz. Although there is no real calculation, I will assume the number of muons in the barrel less than 10 GeV/c is $6 \times 10^6$ Hertz, which is of course, essentially the same for muons less than 50 GeV/c. These muons do not make a trigger in the bend plane. The hit they make in SL1 and SL2 is wrong for the hit they make in SL3. Hence for this case we must calculate the accidental rate per sector for a 50 GeV/c bend plane trigger given a specific struck hit strip in SL3 = BPA due to the trigger rate in the bend plane = LBA/32 = $6 \times 10^6/32$.

$$BPA = R1\ R2\ R3\ (\tau_1 + \tau_2)\ (\tau_1 + \tau_3)$$

We note here that while the non-bend plane counter strips for SL1 and SL2 are in coincidence and the non-bend strips in SL3 are ored together, in the bend plane the strips in SL1, SL2 and SL3 are ored together.

| | | |
|---|---|---|
| R1 = | 2 (631.9) (1.3) (500) 6 = | $4.9 \times 10^6$ |
| R2 = | 2 (1,042.6) (1.3) (500) 3 = | $4.1 \times 10^6$ |
| R3 = | LBA = $6 \times 10^6/32$ = | $1.9 \times 10^5$ |
| $(\tau_1 + \tau_2)$ = | | $14 \times 10^{-9}$ |
| $(\tau_1 + \tau_3)$ = | | $15 \times 10^{-9}$ |
| BPA = | | $8 \times 10^2$ |

The accidental rate for triggers = LTA per sector is:

$$LTA = 1/32\ LBA \times BPA \times 2\tau$$
$$\tau = 4 \times 10^{-9}$$

$$LTA = 6/32 \times 10^{6} \times 8 \times 10^{2} \times 4 \times 10^{-9} = 6 \times 10^{-1}$$

Hence the accidental trigger rate for all GEM = $32 \times 6 \times 10^{-1} = 19.2$ Hertz. This dominates the accidental rate. The total accidental rate is about 22 Hertz.

### *Dead Time*

To calculate the dead time, we must consider the non-bend plane and the bend plane separately. For the non-bend plane, we have to calculate for each superlayer what the probability for that superlayer being "alive" when a real muon passes through each superlayer. A real muon passes through a particular strip in each of the superlayers, hence we must calculate the probability that each of the strips is "alive." We note that an RPC pulse is 50 nanoseconds full width at the base. Hence the dead time for each RPC pulse = DT = $5 \times 10^{-8}$ live time per strip for SL1 = LT1.

$$LT1 = 1 - DTR1$$
$$LT1 = 1 - (5)(10^{-8})(500)(3.9)(148.5) = 1 - 1.5 \times 10^{-2} = .985$$

The probability that both counters in SL1 are alive is $(LT1)^2 = .97$. We can use the same technique for calculating the live time for SL2 = LT2.

$$LT2 = 1 - (5)(10^{-8})(500)(6.5)(239) = 1 - 3.2 \times 10^{-2} = .968$$

$$(LT2)^2 = .94$$

The calculation for superlayer SL3 is different, as in this case the two counters are ored together.

$$\begin{aligned} LT3 &= 1 - (DTR3)^2 \\ &= 1 - [(5 \times 10^{-8})(500)(8.9)(329.6)]^2 \\ &= 1 - [7.2 \times 10^{-3}]^2 = .90\,[1 - 5 \times 10^{-5}] \\ &= .99995 = 1 \end{aligned}$$

The total live time is $[LT1]^2 \times [LT2]^2 \times LT3 = .96$

Hence we have a 4% dead time in the non-bend plane. This dead time must be modified by the dead time in the bend plane. All superlayers in the bend plane are the same as SL3 in the non-bend plane.

### *Bend Plane*

LT1 $= 1 - (DT \cdot R1)^2 = 1 - [(500)\ (1.3)\ (631.9)\ (5)\ (10^{-8})]^2$
$= 1 - [(2.1)\ (10^{-2})]^2 = .9996$

LT2 $= 1 - [(500)\ (1.3)\ (1{,}042.6)\ (5)\ (10^{-8})]^2 = 1 - [(3.5)\ (10^{-3})]^2$
$= .9987$

LT3 $= 1 - [(500)\ (1.3)\ (1{,}475)\ (5)\ (10^{-8})]^2 = 1 - [(4.8)\ (10^{-2})]^2$
$= .9976$

The total live time = LT1 x LT2 x LT3 = .996. Hence the total live time of the non-bend plane and bend plane is (.96) (.9976) = .958. Hence the total dead time 4.2%.

If we assume that we double the dead time from 50 nanoseconds to 100 nanoseconds our dead time goes from 4.2% to 18%. This is clearly acceptable.

### *End Cap*

The problems of the end cap are much simpler than the barrel due to the much greater segmentation. Without presenting the details, all accidentals and dead times are reduced by about two orders of magnitude. The timings are essentially as in the barrel, but all delays are reduced by about a factor two.

TABLE A.1

Cable length difference for all strips (both bend plane and non-bend plane):

| | |
|---|---|
| SL3 and SL2 | = 30.65 (nanoseconds) |
| SL3 and SL1 | = 59.82 (nanoseconds) |

(Note about half this (difference) is used just to get the signals to the input to the shift registers). This cable delay should be accurate to ± 0.5 nanoseconds or about ± 10 centimeters of cable.

The delay gate width $\Delta T_k$ for non-bend strip k superlayer SL3:

$\Delta T_k = k/165\ (31)$ nanoseconds (k = 0 to 165)

Superlayer SL2:

$\Delta T_k = k/165\ (13)$ nanoseconds (k = 0 to 165)

Superlayer SL1:

$\Delta T_k = 0$

The error on any delay gate width can be as large as ± 5%.

The signal gate width $\Delta T_s$ for non-bend strips:

Superlayer SL3:

$\Delta T_s = 11{,}5$ nanoseconds

Superlayer SL2:

$\Delta T_s = 10$ nanoseconds

Superlayer SL1:

$\Delta T_s = 4$ nanoseconds

The signal gate width $\Delta T_s$ for bend strips superlayer SL3:

$\Delta T_s = 42.5$ nanoseconds

Superlayer SL2:

$\Delta T_s = 23$ nanoseconds

Superlayer SL1:
$\Delta T_S$ = 4 nanoseconds

The error on any signal gate width can be as large as ± 5%.

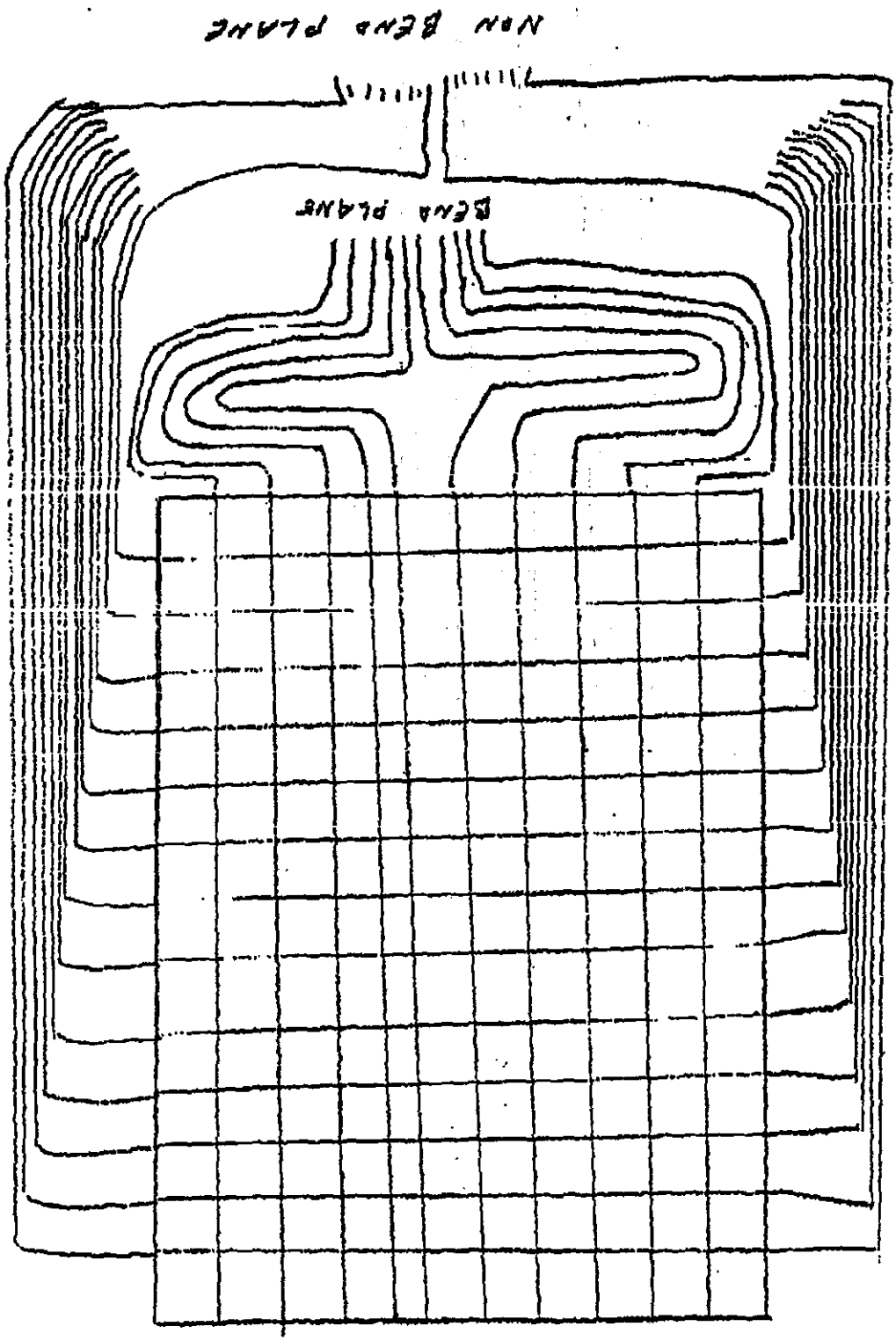
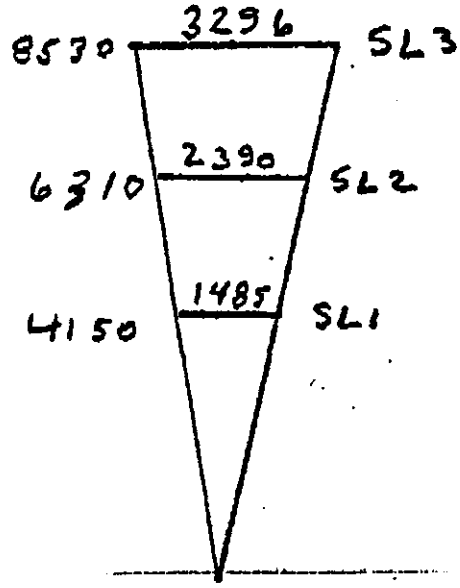
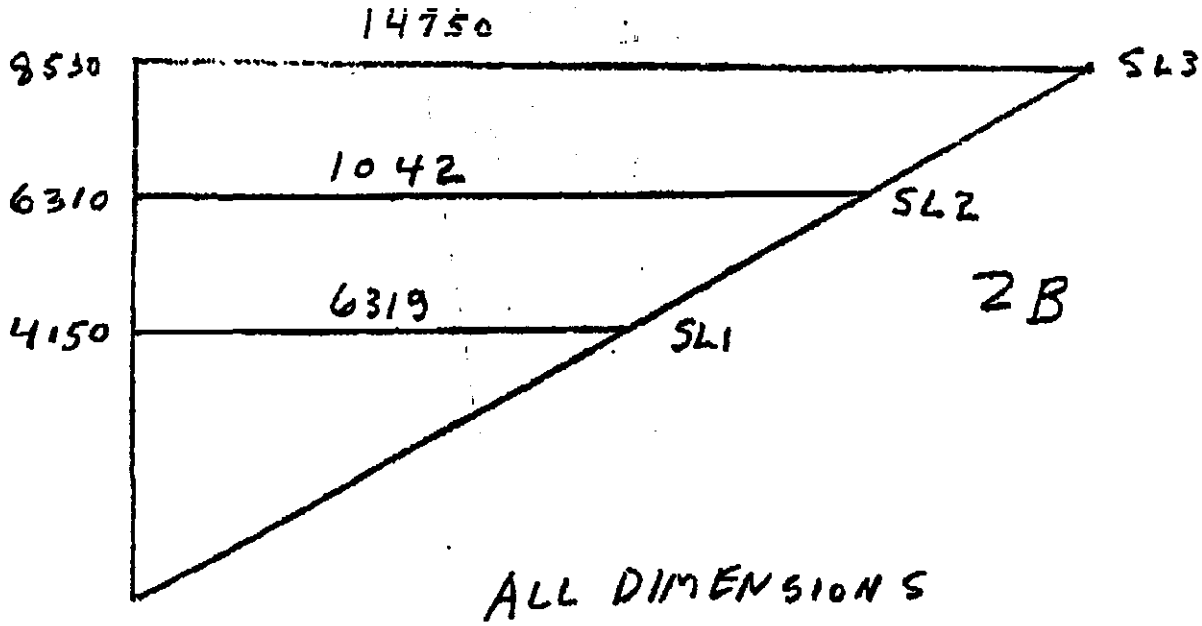



FIGURE 1

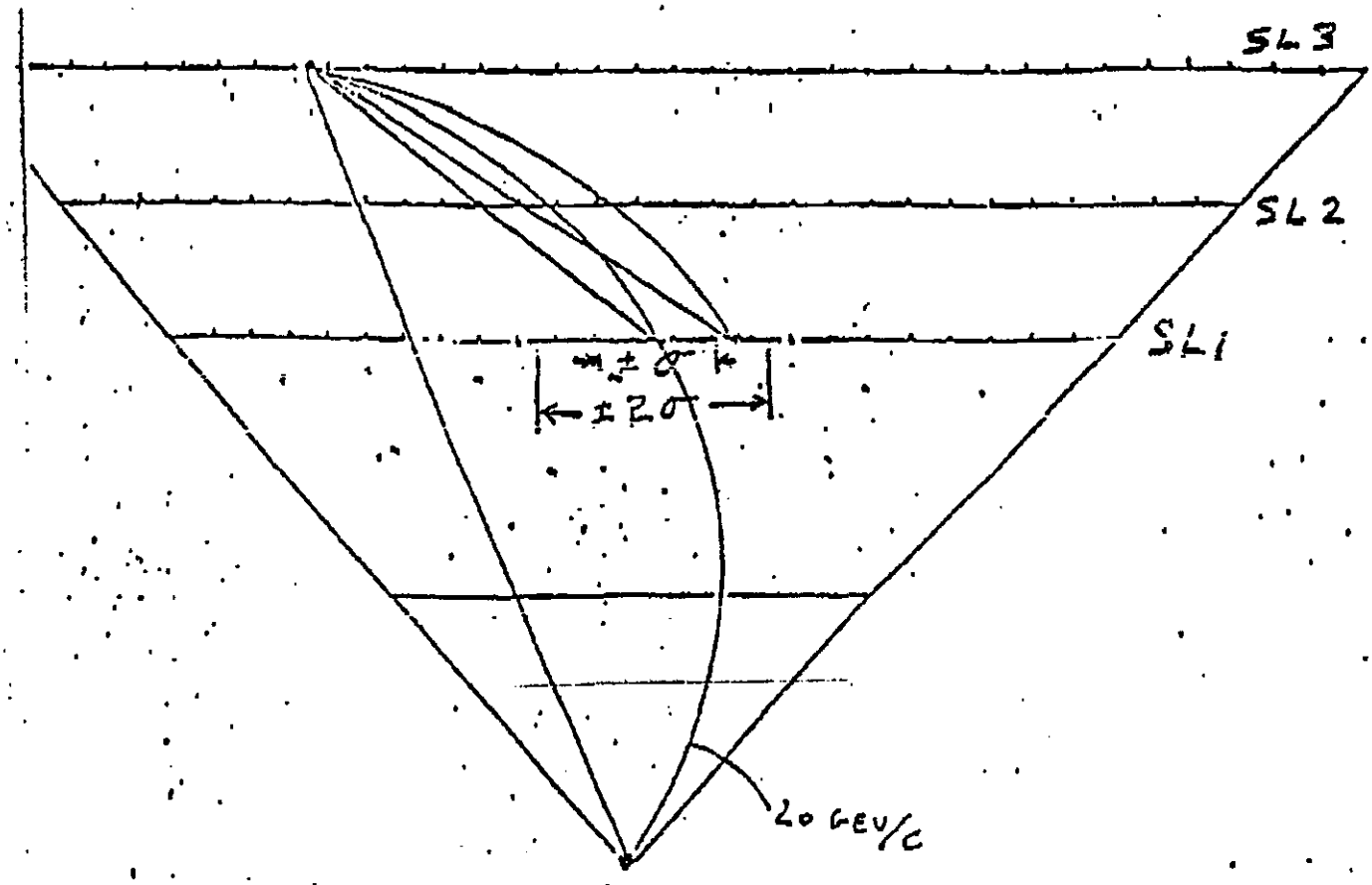



2A




2B

ALL DIMENSIONS
IN MILLIMETERS



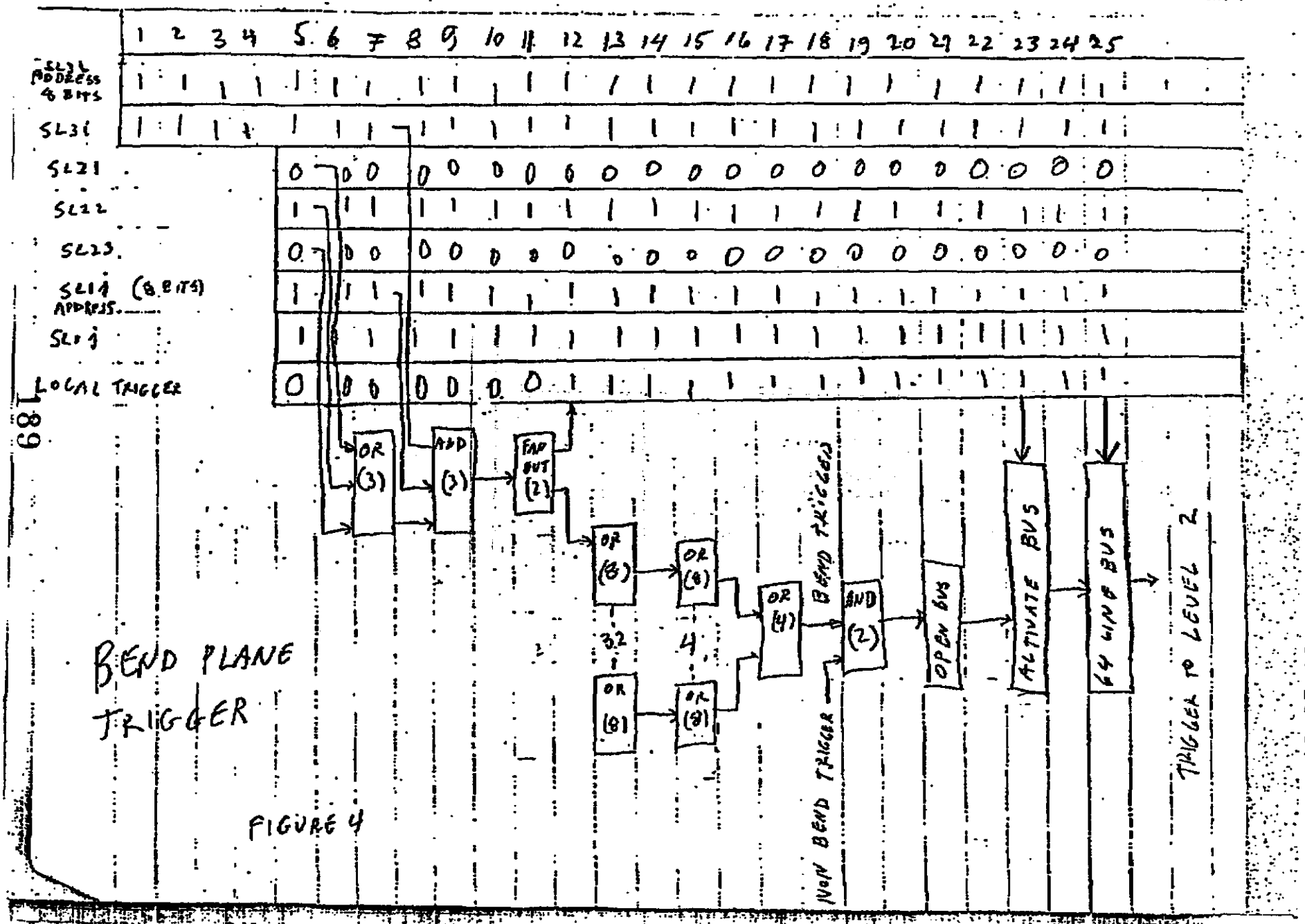

A 20 GeV/c track has a sigma of 2 strips around the ideal intersection point at SL1 due to multiple scattering. In order to have a 95% acceptance we have to be able to handle ± 4 strips around the ideal (no multiple scattering) intersection point.

At SL2 we have to accomodate just two strips for a given geometry at SL1. 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 SL1 formed between the interaction point and the strip at SL3. The second consists of the sagitta at SL2 formed between the strip struck at SL1 and the strip struck at SL3.

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

FIGURE 3




BEND PLANE TRIGGER

FIGURE 4

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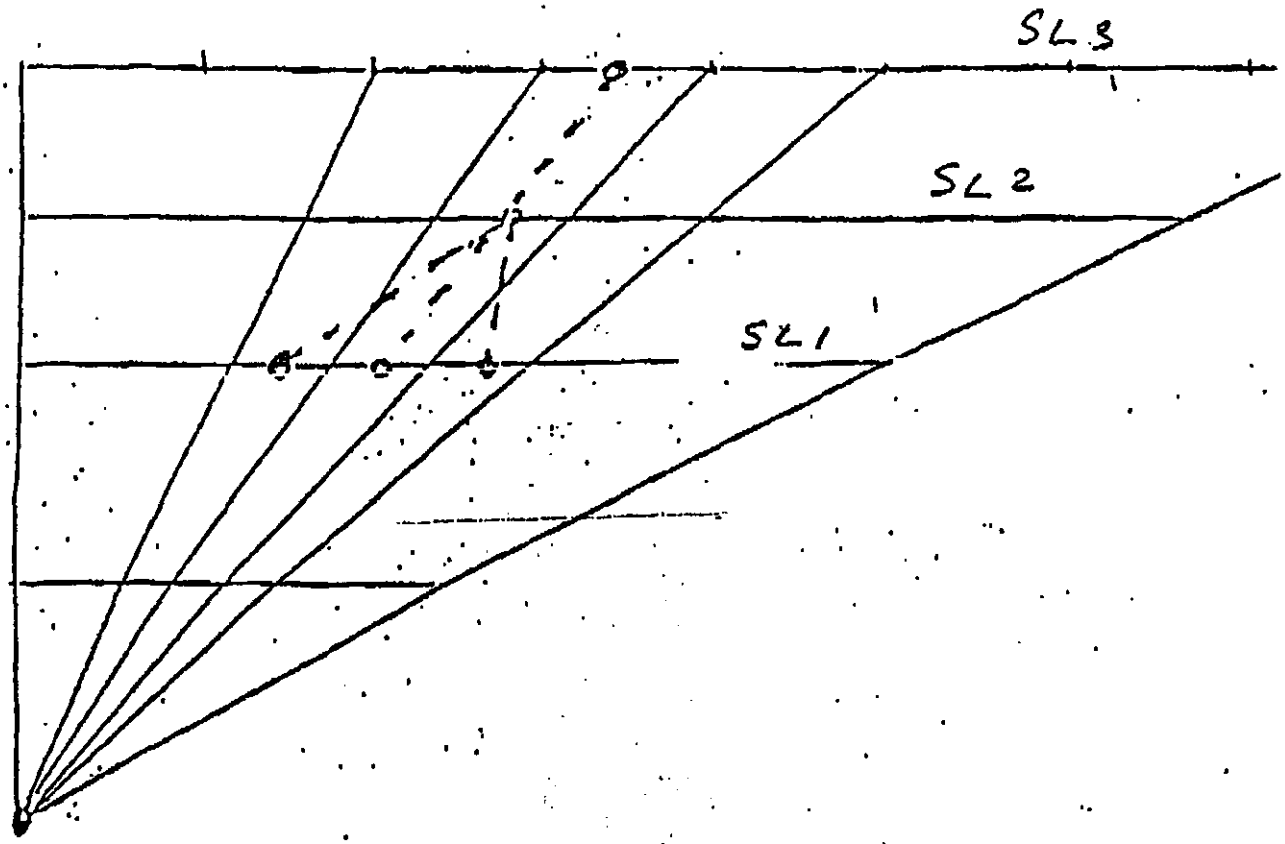
12/07 18:48




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

FIGURE 5

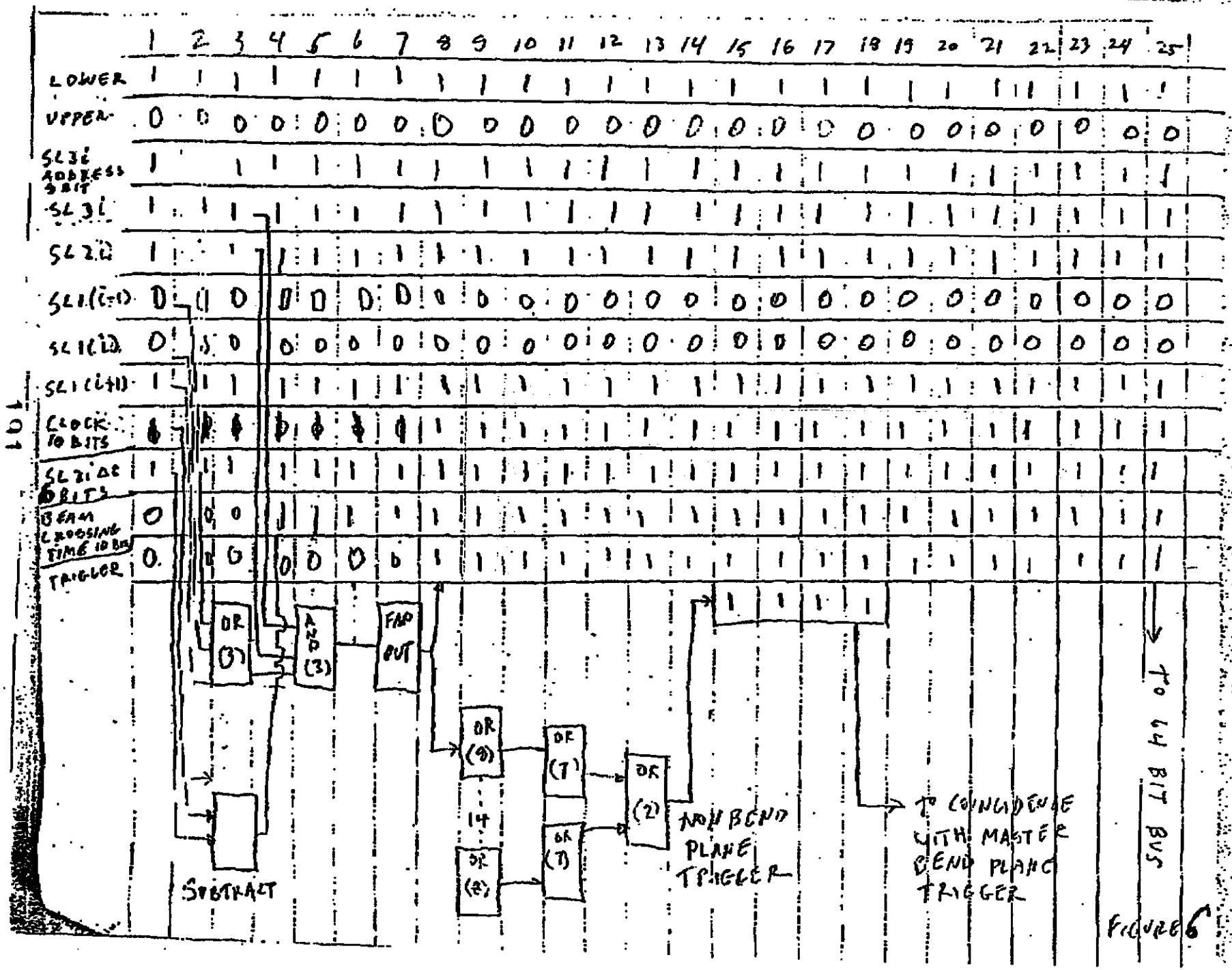
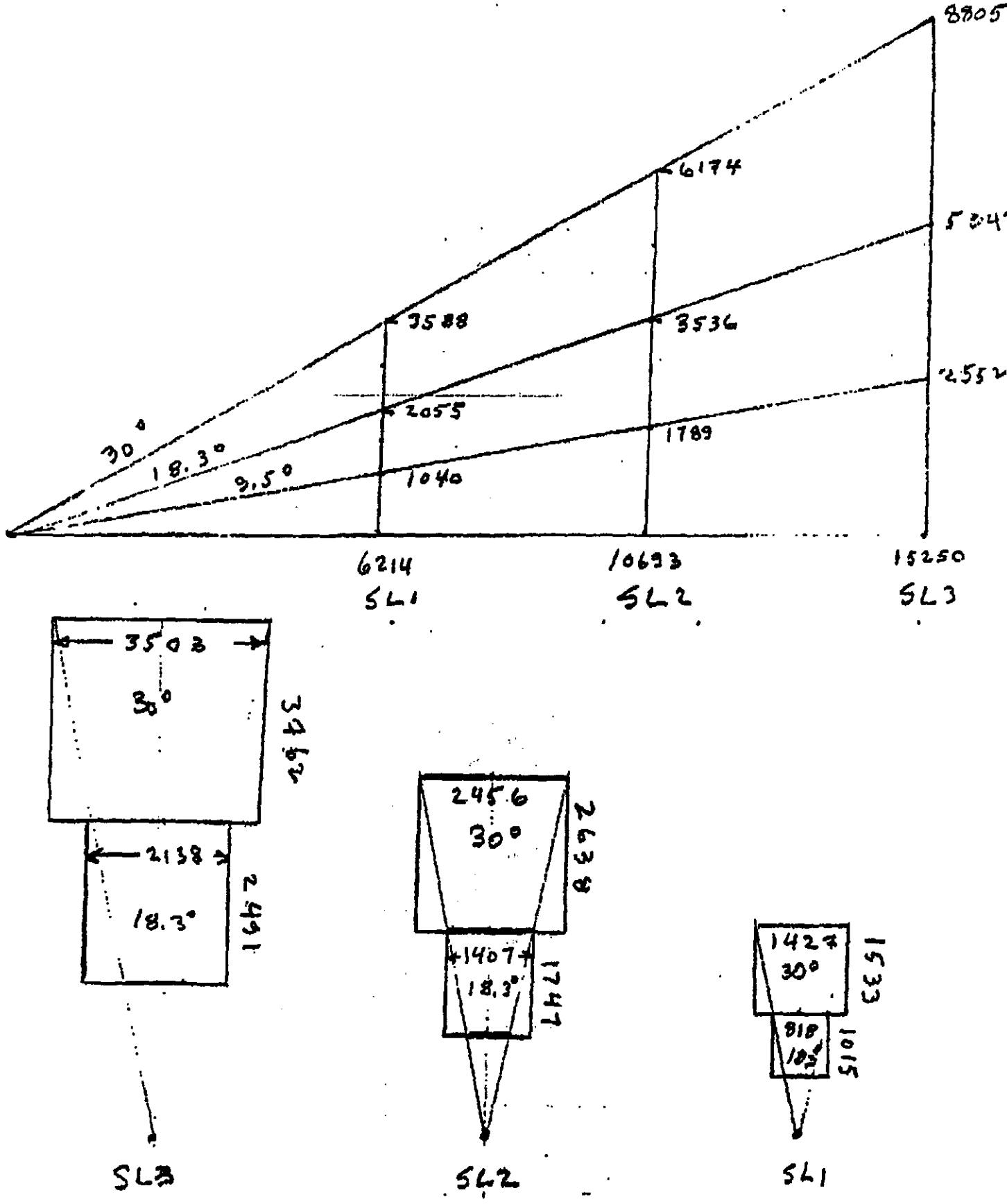

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
LOWER
UPPER
SL3i ADDRESS BIT
SL3i
SL2i
SL1(i-1)
SL1(i)
SL1(i+1)
CLOCK 10 BITS
SL2i ΔC BITS
BEAM CROSSING TIME 10 BITS
TRIGGER
OR (3)
AND (3)
FAN OUT
OR (9)
OR (8)
14
OR (7)
OR (7)
OR (2)
SUBTRACT
NOW BEND PLANE TRIGGER
TO COINCIDENCE WITH MASTER BEND PLANE TRIGGER
TO 64 BIT BUS

FIGURE 6




12/07 18:50 7312025 #29

cosu 488

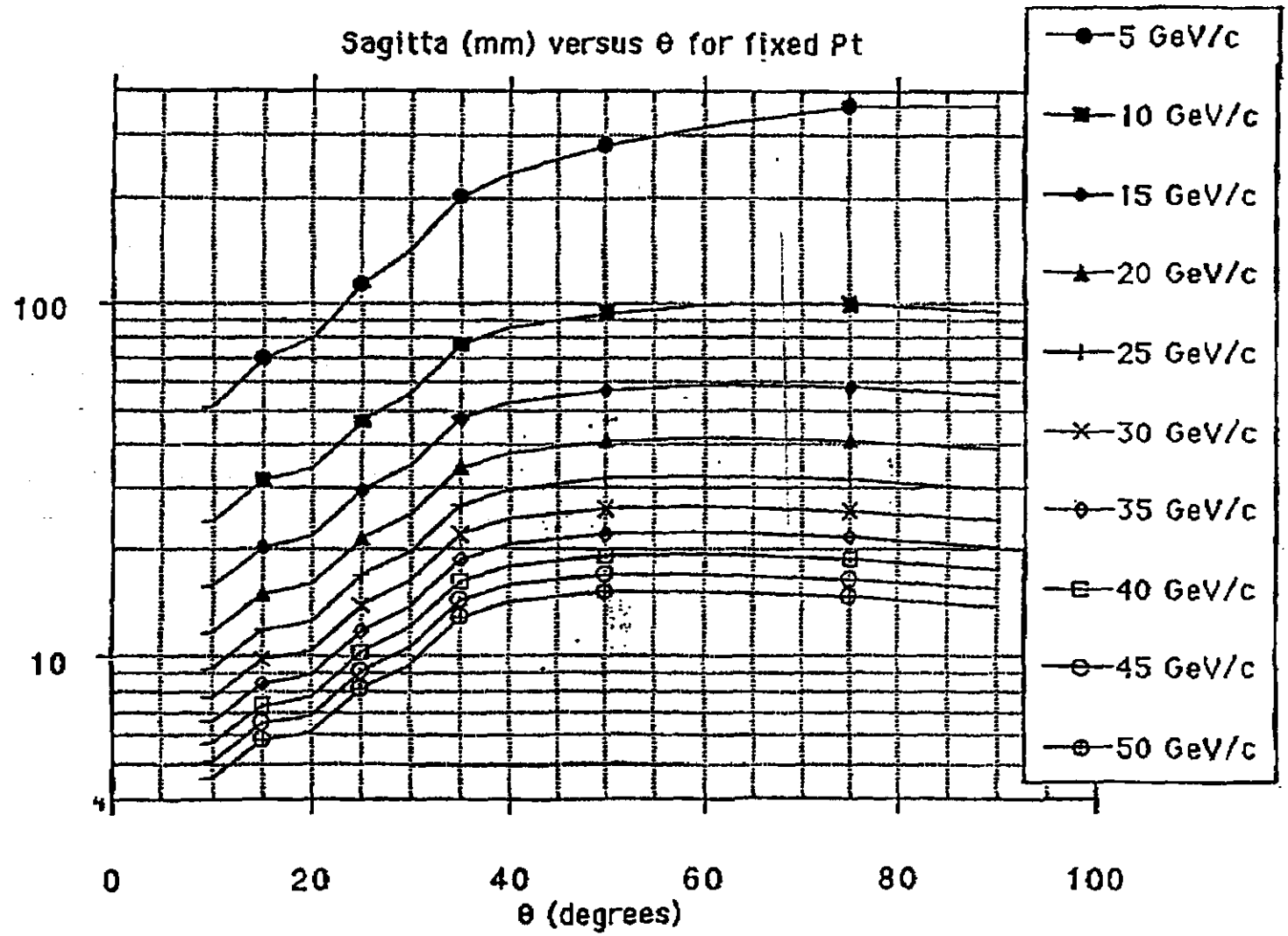



FIGURE 8

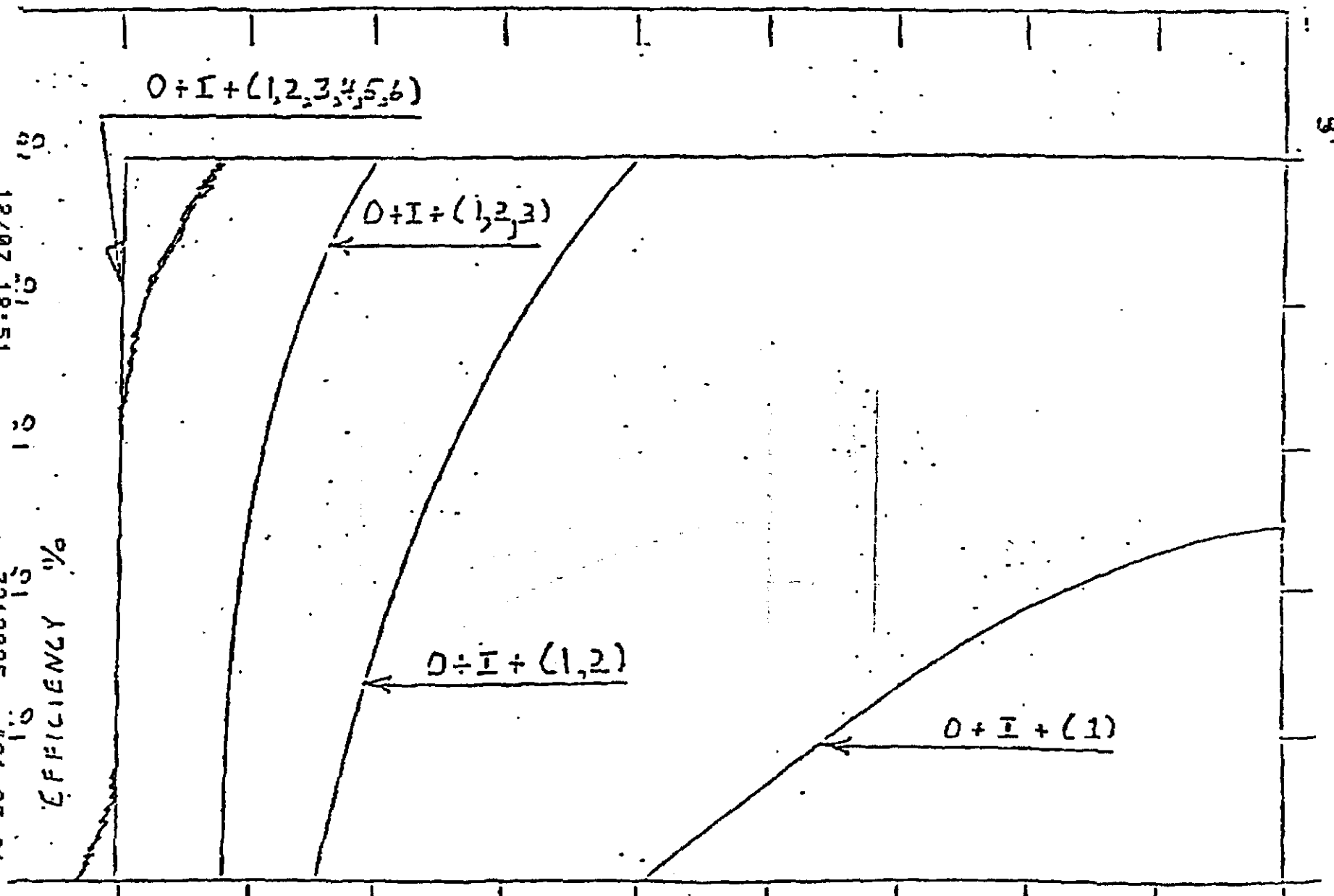

0+I+(1,2,3,4,5,6)
0+I+(1,2,3)
0+I+(1,2)
0+I+(1)
EFFICIENCY %
10
20
30
40
50
60
70
80
90
100
P⊥ GeV/C

FIGURE 9

# Muon Group

# TDR Outline

TO: GEM Muon Group 11/11/92
FROM: Mike Marx and Frank Taylor
SUBJECT: Outline of Muon part of TDR/Task Assignments-Revised

In light of the new direction set at the BNL meeting the following is a revised outline of the TDR. The names listed are suggestions of people to serve as editors for the various sections. They are responsible for soliciting and generating copy and are requested to form groups of people (most already exist) to help them perform the measurements and calculations needed for their section, as well as producing their text.

To get things moving again, each editor is asked to present a detailed outline of his section by the Dec. 10 GEM CC meeting. As a guide we have been allocated 100 pages for the entire muon chapter of the TDR. Indicated by "[###]" is the estimated number of pages for each section (without applying closure).For those sections where multiple editors are listed, a "chief-section-editor" needs to be designated from among the names listed. Please decide this and write your outline by Dec. 10.

Outline:
---

(1) General description of physics mission of and desired characteristics of muon system as driven by physics mission. [5]

(Note that the physics analysis will be presented separately, so that this section should indicate how the requirements of the muon system are driven by the various physics processes of interest. This should cover the low and high Pt resolution, trigger requirements, multiple scattering considerations, fluctuations of the energy loss in the calorimeter, etc.)

- Higgs detection
- Z* detection ...
  (Roger McNeil with help from the simulations group)

(2) Description of system and summary table according to BNL baseline. [6]

- overview
- sagitta method
- forward flux concentrator
- precision tracking
- muon system behind thick calorimeter to reduce backgrounds
- trigger rates
  (Frank Taylor/Mike Marx)

(3) Mechanical layout of system. [5]

- support structure
- deflection analysis
- chamber coverage
- interface fixturing
- integration of alignment system with ss and chambers
- installation procedure of chambers and ss in GEM
  (Frank Nimblett/Rick Sawicki/Coleman Johnson)

(4) Detailed specification of magnetic field. [5]

- Bz and Br
- integrals for bend power
- Lorentz angle considerations
- field mapping requirements and technique
  (Jim Sullivan/Larry Rosenson)

(5) Alignment system. [6]

- criteria of system (error analysis)
- design (Mitselmakher-Ostapchuk concept)
- engineering data to support design
  (Craig Wuest/Joe Paradiso/Rick Sawicki)

(6) Momentum resolution. [5]

- magnet system performance
- energy fluctuations in calorimeter
- potential contribution of CT and vertex constraint
- combined performance
  (Jim Sullivan/Larry Rosenson/Frank Taylor)

(7) Trigger concept. [5]

- basic requirements: T0 tag and Pt sensitivity
- barrel region concept
- endcaps " "
- electronics
- channel count
- resolution and trigger rates
  (Maged Atiya/Larry Rosenson/Irwin Pless)

(8) Backgrounds. [5]

- low bias muon background
- hadron punchthrough (how many lamda and what material)
- neutron background
- how detector responds to neutrons - estimate rates
  (Roger McNeil/Mike Marx)

(9) Pattern recognition performance and sample physics analysis with hit-level Monte Carlo. [5]

- trigger simulation
- extraction of physics signal
- all calculations done with backgrounds simulated
  (Roger McNeil/Andrei Golutvin)

(10) Possible system upgrades. [2]

- external muon planes
- vertex constraint (also mentioned above)
  (Larry Rosenson)

(11) Description of technologies. [10]

CSC - (Polychronakos, Whitaker, and Milselmakher)

RDT - (Taylor and Bromberg)
RPC - (Pless and Wuest)

- mechanics chamber construction (tolerances, etc.)
- electronics

(12) Layout of utilities. [3]

- gas system
- requirments for environmental control
- cable routing
  (Kwon Lau)

(13) R&D program. [5]

- TTR cosmic ray studies
- test beam program
- alignment studies
- sector tests
  (Gena Mitselmakher/Mike Marx)

(14) Fabrication and assembly [3]

- support structure
- chambers (foreign construction)
- electronics
- support buildings requirements
  (Coleman Johnson and Frank Nimblett)

(15) Foreign Participation. [2]

- Russia
- China
  (Gena Mitselmakher and Chinese vistor)

(16) Costs, manpower estimates, schedules. [5]

(Rick Sawicki/Frank Nimblett/Coleman Johnson/Howard Baker)

Computer addresses:
---
igw::edseq1::wuest,
phepds::mcneil,
sbhep::chiaki,
sbhep::mohammadi,
sscvx1::mitselmakher,
irene::osborne,
irene::korytov,
mitpfc::mit132::sullivan,
smtp%"nimblett@draper.com",
smtp%"neuromancer@draper.com",
irene::pless,
buphyc::scott,
jnet%"bromberg@msupa",
irene::fet,
irene::rosenson,
sscvx1::marx,

sscvxl::johncole,
smtp%"hbaker@draper.com",
SMTP%"RICK_SAWICKI@ENGMAIL.LLNL.GOV"

Organization:
---
For the moment Mike Marx will serve as chief editor (to be confirmed).
When multiple names are listed the first is considered the contact.

Format of drawings:
---
Kaleidagraph

Computers:
---
MAC and VAX

List of Figures and Tables TDR Section 2

Outline:

- overview

Brief description of system, its philosophy, requirements, physics mission, and advantages.

- sagitta method

Three point determination of muon trajectory, large lever arm, modest B-field gives good resolutions. Small momentum limited by MS and energy fluctuations in calorimeter, large momentum by spatial resolution.

- FFS

Increases bend power in the forward direction where good resolution is hard to acheive in a solenoid.

- precision tracking

Brief discussion of how large the sagitta is and what the overall error budget must be to obtain the baseline performance.

- muon system behind a thick calorimeter

Discuss the muon filtering through the thick calorimeter, energy fluctuations, hadronic punch-through in very general terms. Contrast the SDC philosophy with GEM's.

- environment

Describe the environment of the muon system, charged particle, neutrons.

Figures and Tables:

(1) Figure showing layout of muon system

features: - layout of chambers
- location of calorimeter and FFS

(2) Figure showing how sagitta is defined

features: - superlayer concept (N-chamber layers/SL)

(3) Table of parameters of system

features: - number of chambers, etc.