GEM TN-91-46

GEM FORWARD CALORIMETER DESIGN MEETING

November 18, 1991

G. Forden, J. Rutherfoord, L. Shaver and M. Shupe
University of Arizona

D. Makowiecki and E. Kistenev
Brookhaven National Laboratory

S. Chae and C. Eberle
Oak Ridge National Laboratory

Abstract:

Agenda, list of participants and transparencies contributed to the Forward Calorimeter Design Meeting held at the SSC Lab on November 18, 1991.

Memo to: Steve Chae, Geoff Forden, Edward Kistenev, Don Makowiecki, Leif Shaver, Mike Shupe, and Bob Webb

From: John Rutherfoord, 11/13/91

Re: GEM Forward Calorimeter Meeting

As you already know we have scheduled a meeting on GEM forward calorimetry in Tucson on Monday, November 18th. The meeting will be in the physics department room 486 starting at 9:00 AM. I am Fed Ex'ing a campus map with the Physics/Atmospheric Sciences building on it. Room 486 is in the north east cornor of the building on the 4th floor.

Some of you don't know Steve Chae. He is the engineer from Oak Ridge who will work on forward calorimetry. Much of the information imparted at this meeting should be directed towards him so he can get up to speed as quickly as possible on our physics and technology requirements, constraints, etc.

A suggested agenda might include

Physics requirements (J.Rutherfoord, ...)
General simulation (M.Shupe)
Integration issues and constraints (J.Rutherfoord)
Technology choices (Please include problem areas)
  High pressure gas option (E.Kistenev, D.Makowiecki)
  Spaghetti liquid scintillator option (R.Webb)
  Liquid Argon option (G. Forden, L.Shaver)
R&D plan, budget, time schedule, coordination (Much of this is done but we still must write up a proposal. Some of you already have some verbiage that should do the job.)
Decision process and timing
What happens after the technology choice is made

11/20/91
gemfcal.maillist

GEM FCAL CALORIMETRY GROUP

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GEM FCal Physics Requirements

1) Coverage $3 \leq |\eta| \leq ?$

Max $|\eta|$ as large as possible.

Need

1) High density, small sampling fraction cal.
2) Sensitive volume close to beam line

2) Resolution (in p_T)

Need to measure $\not{p}_T \gtrsim 200$ GeV/c with 10% accuracy.

10λ sufficient if longitudinal segmentation

For photons $\frac{\Delta E}{E} = 2\% + \frac{40\%}{\sqrt{E}}$

For hadrons $\frac{\Delta E}{E} = 2\% + \frac{100\%}{\sqrt{E}}$

With segmentation of $\Delta\eta \lesssim 0.17$

$$\frac{\Delta p_T}{p_T} \lesssim 10\% \quad \text{for } E \gtrsim 200 \text{ GeV}$$

3) Tagging jets

Coverage $|\eta| \lesssim 5.0$ seems sufficient

Physics Requiring a Forward Calorimeter

Missing E_T

Higgs

$$H \rightarrow ZZ \rightarrow \ell^+\ell^-\nu\bar{\nu}$$
$$H \rightarrow ZZ \rightarrow \ell^+\ell^-\tau\bar{\tau}$$

New heavy quarks

SUSY

Technicolor

$$\rho_{TC}^{\pm} \rightarrow W^{\pm}Z^{o} \rightarrow \ell^{\pm}\nu\ell^+\ell^-$$
Leptoquarks $gg \rightarrow P_3P_3 \rightarrow b\tau\bar{b}\bar{\tau}$

New Gauge Bosons

$$W'^{\pm} \rightarrow \ell^{\pm}\nu$$

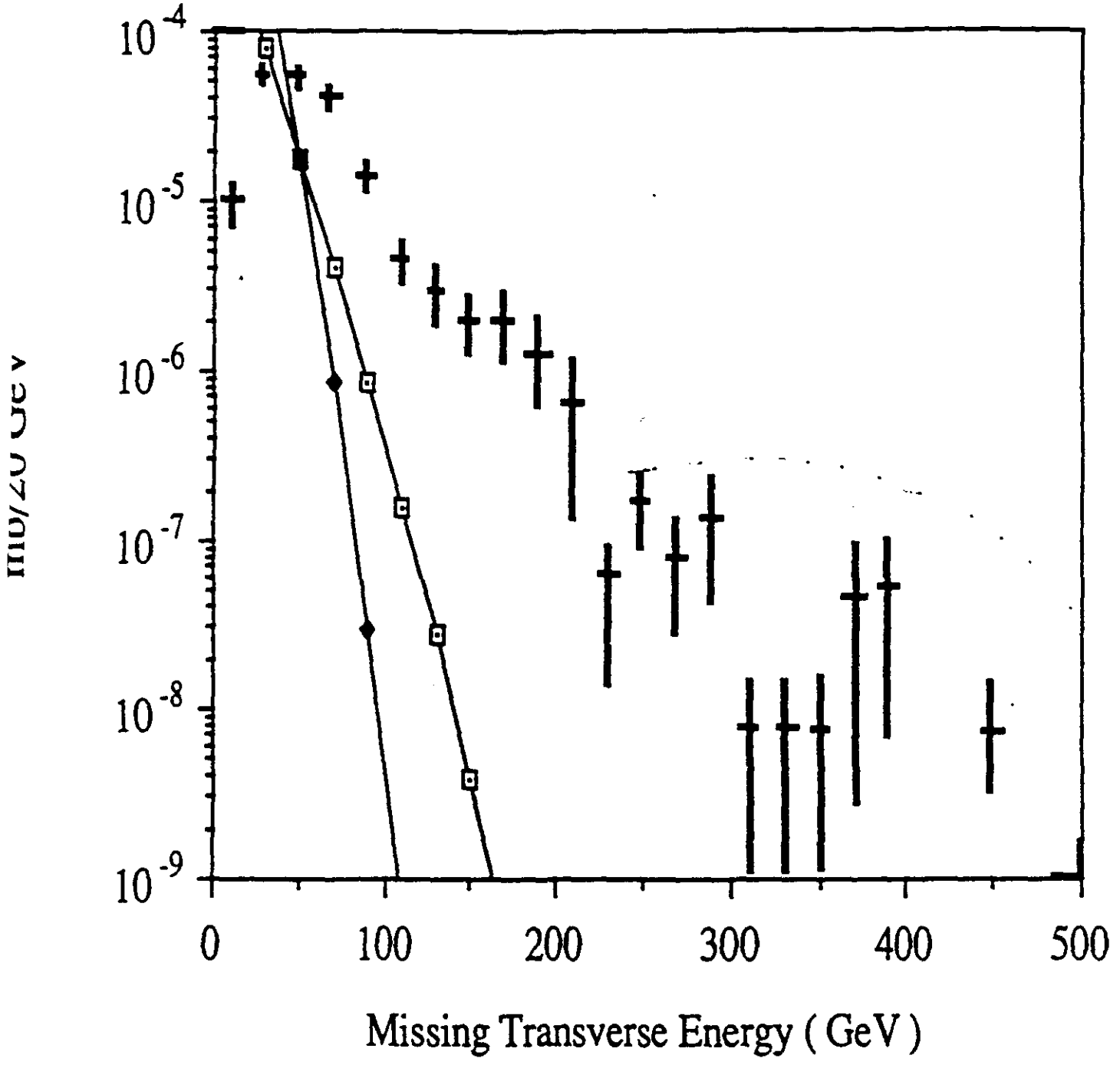
Other sources of boson pairs

$$W^{\pm}Z^{o} \rightarrow \ell^{\pm}\nu\ell^+\ell^-$$
$$W^{\pm}W^{\pm} \rightarrow \ell^{\pm}\nu\ell^{\pm}\nu$$
$W^+W^- \rightarrow \ell^+\nu\ell^-\nu$ if separable from $t\bar{t}$

Forward Jets

VV scattering with forward jet tagging

Low x physics via forward di-jets


10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0
100
200
300
400
500
Missing Transverse Energy (GeV)

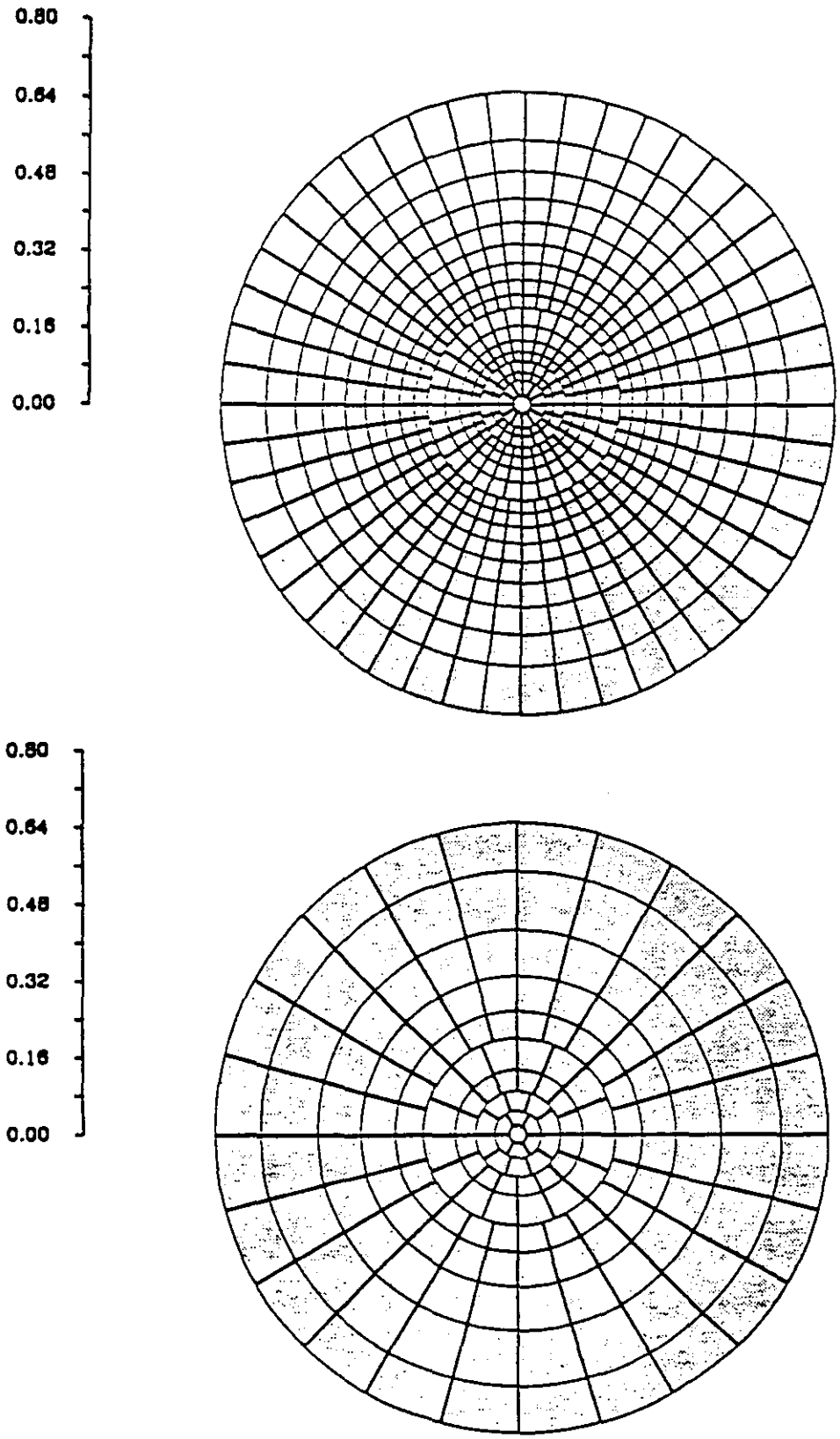
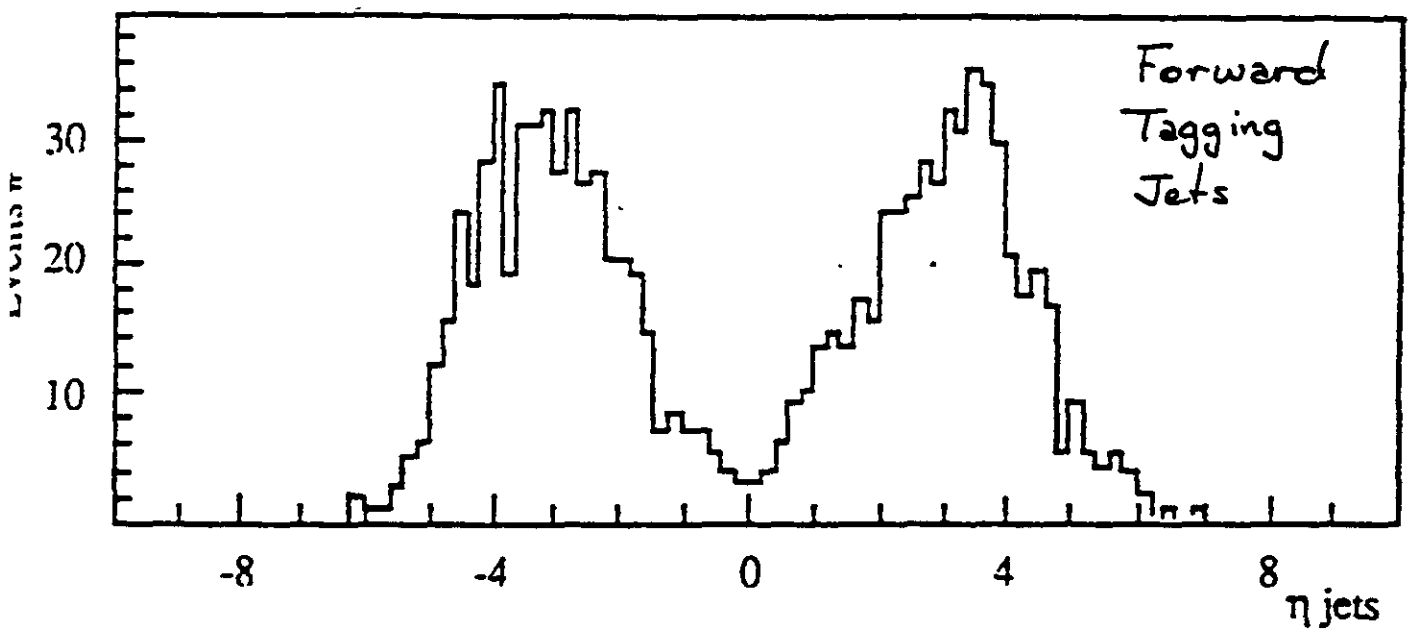
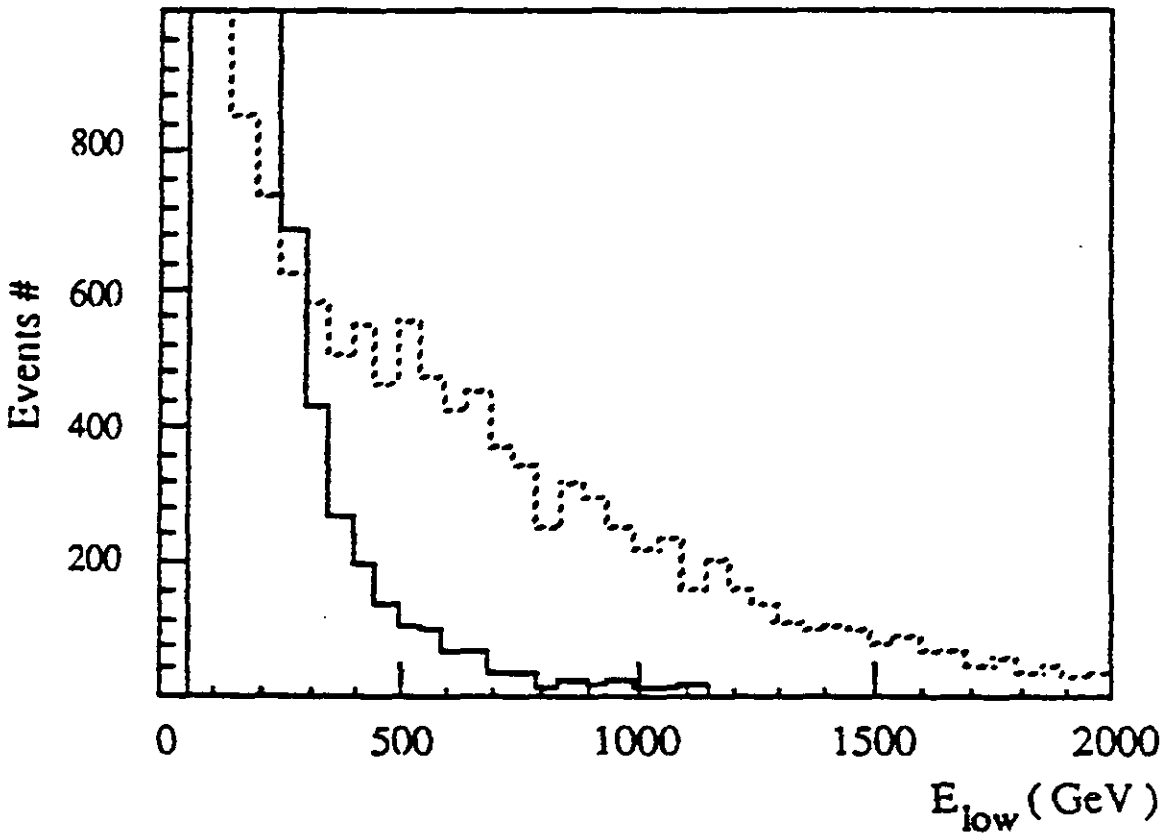


Figure 4

WW fusion





Rapidity distribution of the "tagging" jets and energy distribution of the lower energy jet for the WW fusion process pp -> qqH. Dashed line is the signal and the full line is the QCD background.

M. SHUPE
UNIV. OF ARIZONA
[redacted], 1991
NOV

DESIGN CRITERIA FOR FORWARD CALORIMETER.

- PHYSICS:
  1. $\not{E}_T$ COVERAGE TO $\sim |\eta| = 5.0$, WITH RESOLUTION UP TO ν IMPOSED LIMIT.
  2. JET RESOLUTION $\Rightarrow$ p_T RESOLUTION
- RADIATION HARDNESS:
  TO IONIZING RADIATION NEAR e SHOWER MAX. AND NEUTRON FLUX.
- INTEGRATE INTO FORWARD REGION DESIGN.
- HIGH RATE CAPABILITY:
  (FOR LIQUID ARGON)
  1. USE SHORT SHAPING TIMES, AND SMALL GAPS.
  2. CALCULATE AND MEASURE + ION PILEUP.
- COST
  (FOR PROPOSED DESIGN)
  1. COST OF TUNGSTEN
  2. CHANNEL COUNT

etc..

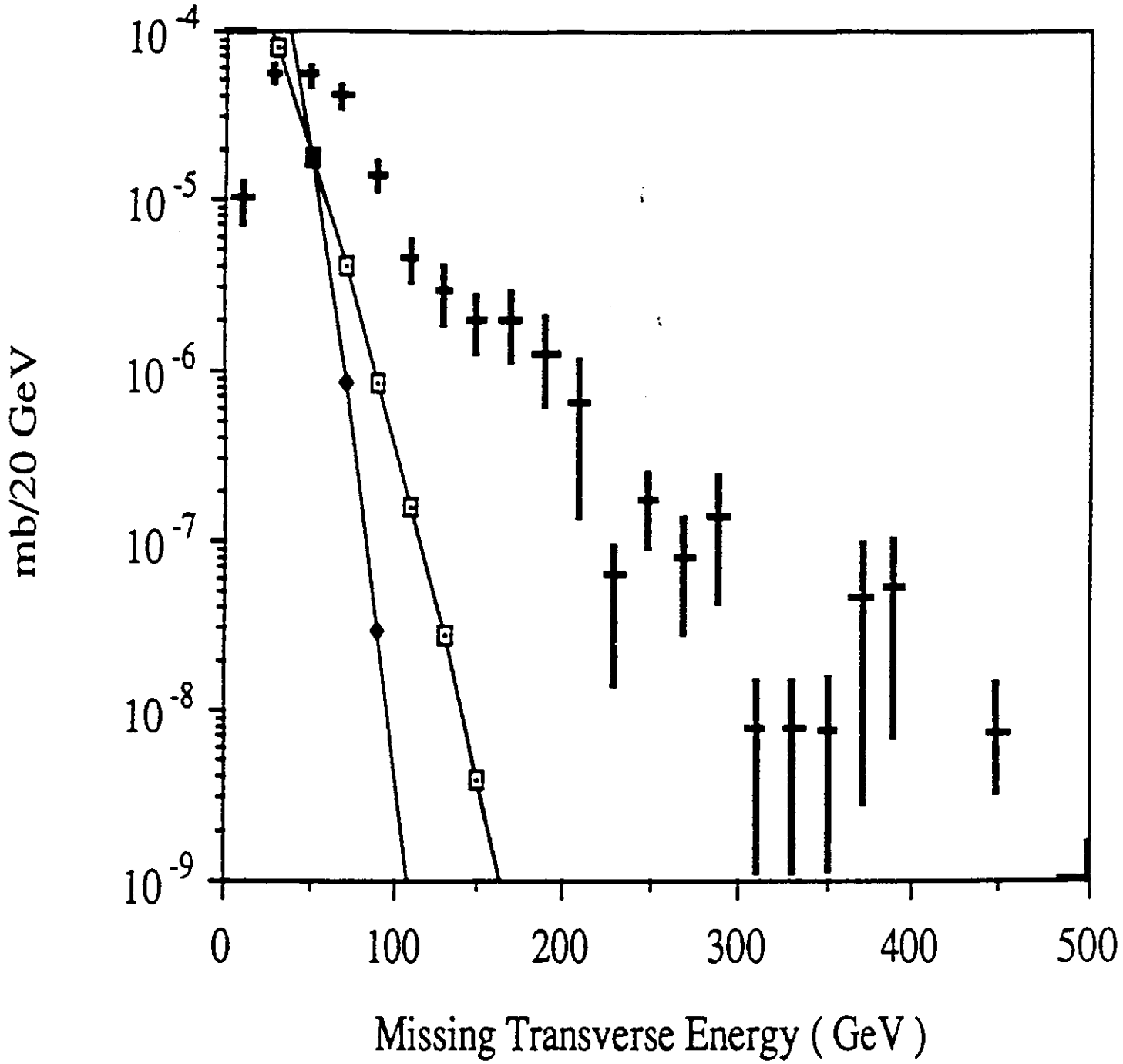


Figure 2 . The missing transverse energy cross scetion due to neutrino production (data points), whole jet fluctuations into the cryostat edge (solid diamonds) and "electromagnetic" jet fluctuations (open squares) is show. The neutrino cross section has ignored processes with energies less than 50 GeV while the other two mechanisims have included these energies.

MINBIAS

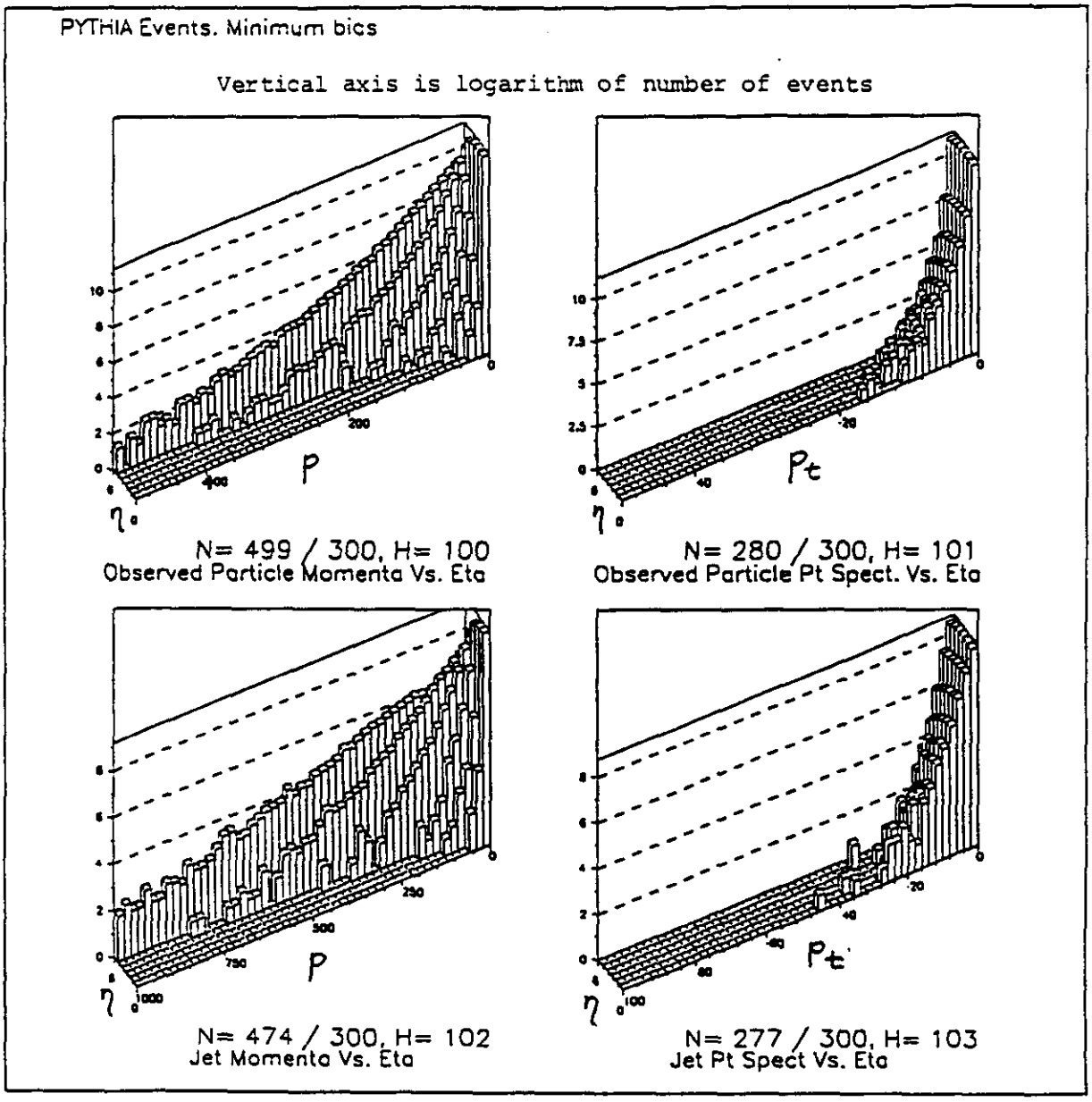


Figure 1

$P_t > 30$ GeV

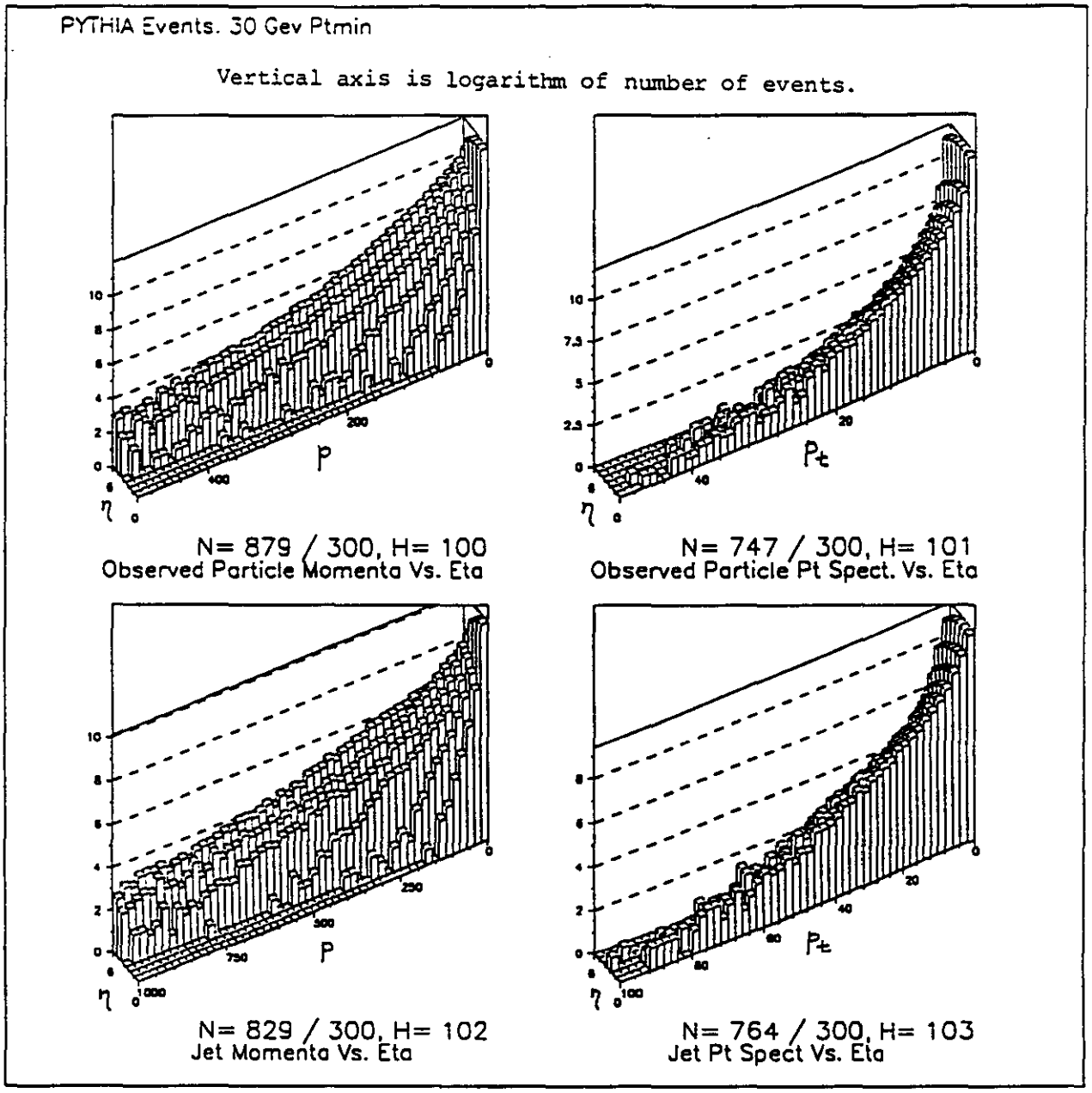
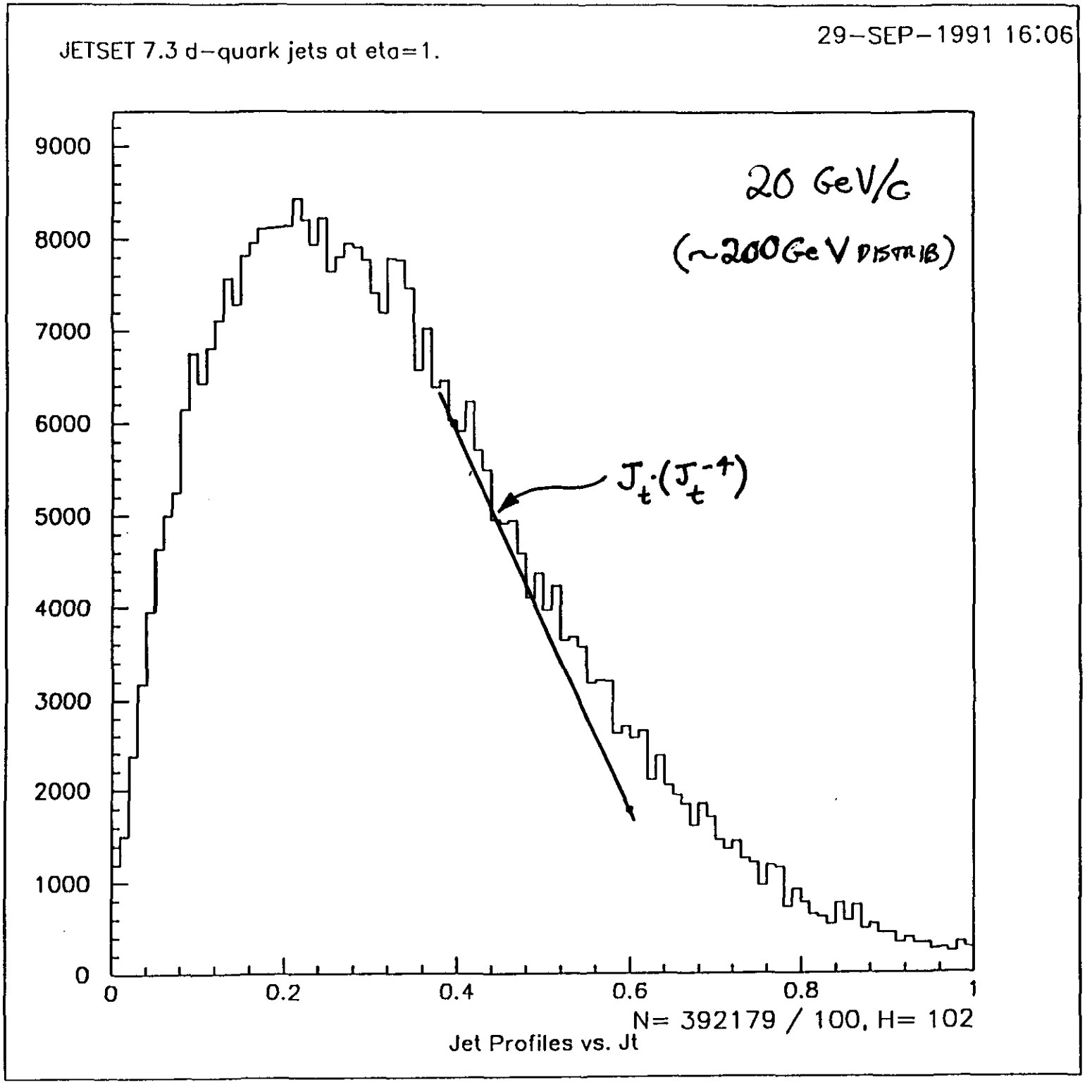
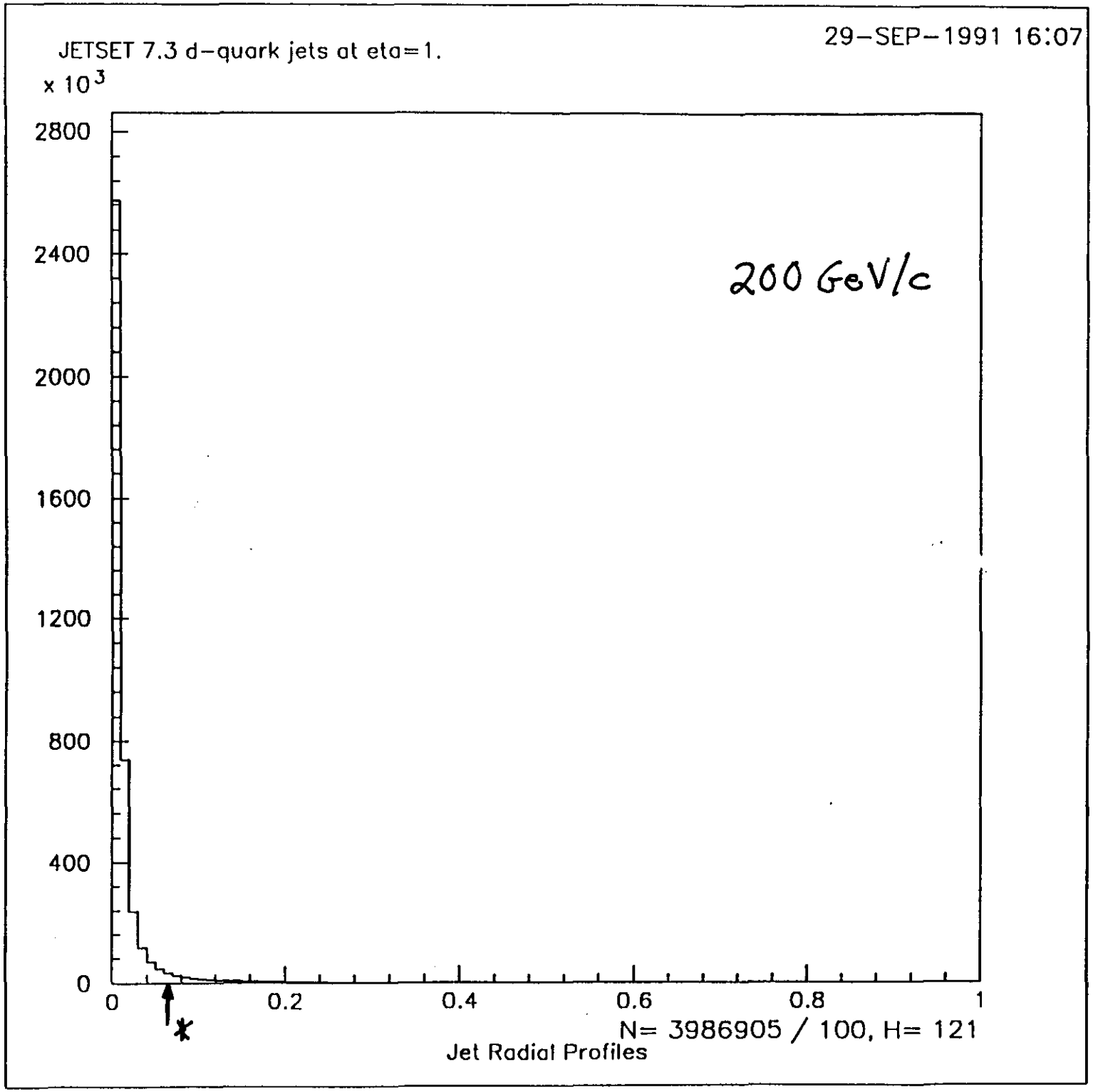


Figure 2


JETSET 7.3 d-quark jets at eta=1.
29-SEP-1991 16:06
20 GeV/c
(~200GeV DISTRIB)
$J_t \cdot (J_t^{-1})$
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
0.2
0.4
0.6
0.8
1
N= 392179 / 100, H= 102
Jet Profiles vs. Jt


JETSET 7.3 d-quark jets at eta=1.
29-SEP-1991 16:07
x 10^3
2800
2400
2000
1600
1200
800
400
0
0
0.2
0.4
0.6
0.8
1
200 GeV/c
N= 3986905 / 100, H= 121
Jet Radial Profiles

P_t RESOLUTION

STARTING FROM $p_T = p \sin\theta$

$$\frac{\delta p_T}{p_T} = \sqrt{\left(\frac{\delta p}{p}\right)^2 + \cot^2\theta\,\delta^2\theta}$$

$$\approx \sqrt{\left(\frac{\delta p}{p}\right)^2 + \left(\frac{\delta\theta}{\theta}\right)^2}$$

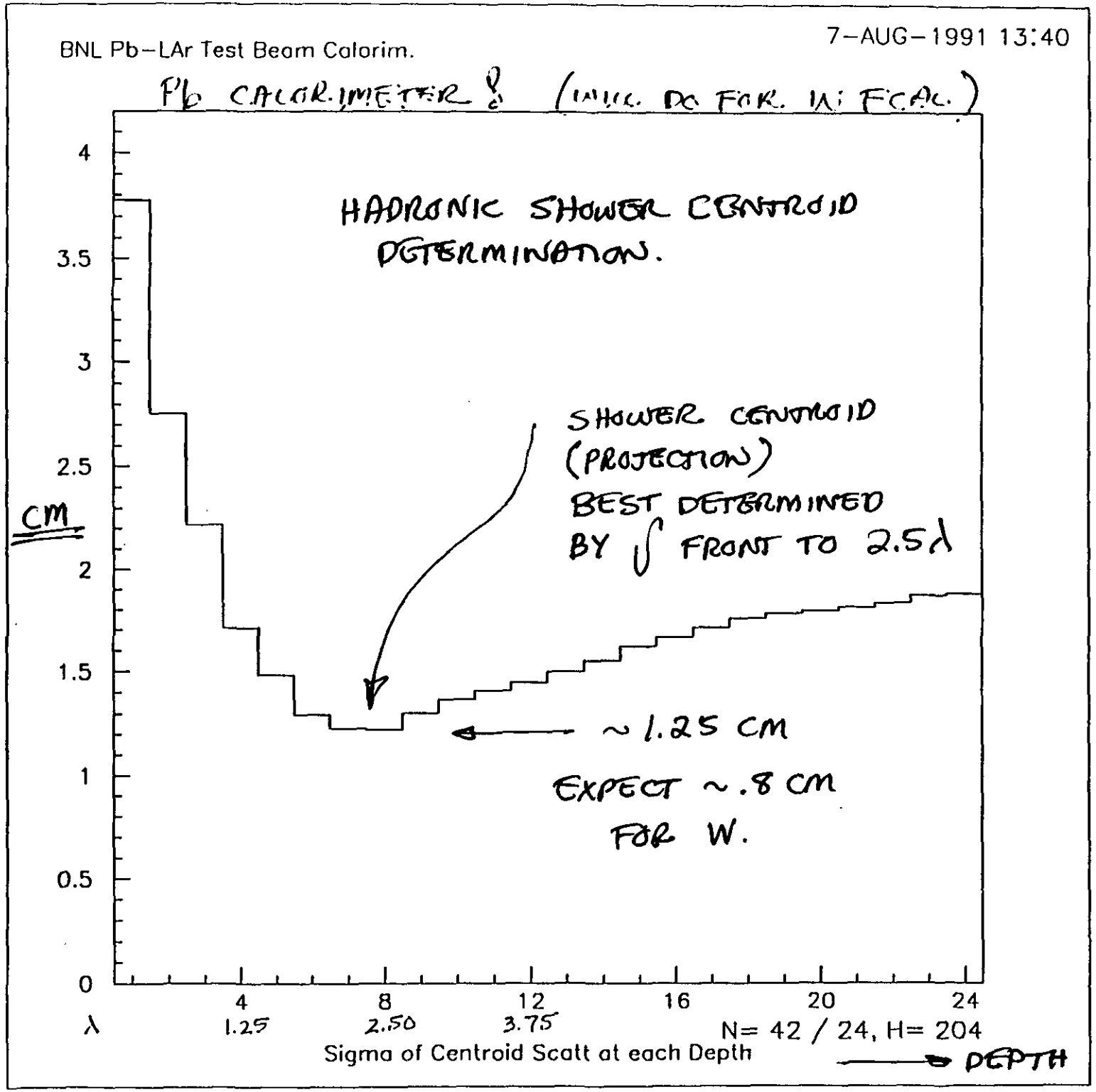
[ALSO HANDY: $\frac{d\eta}{d\theta} \doteq \frac{1}{\sin\theta}$]

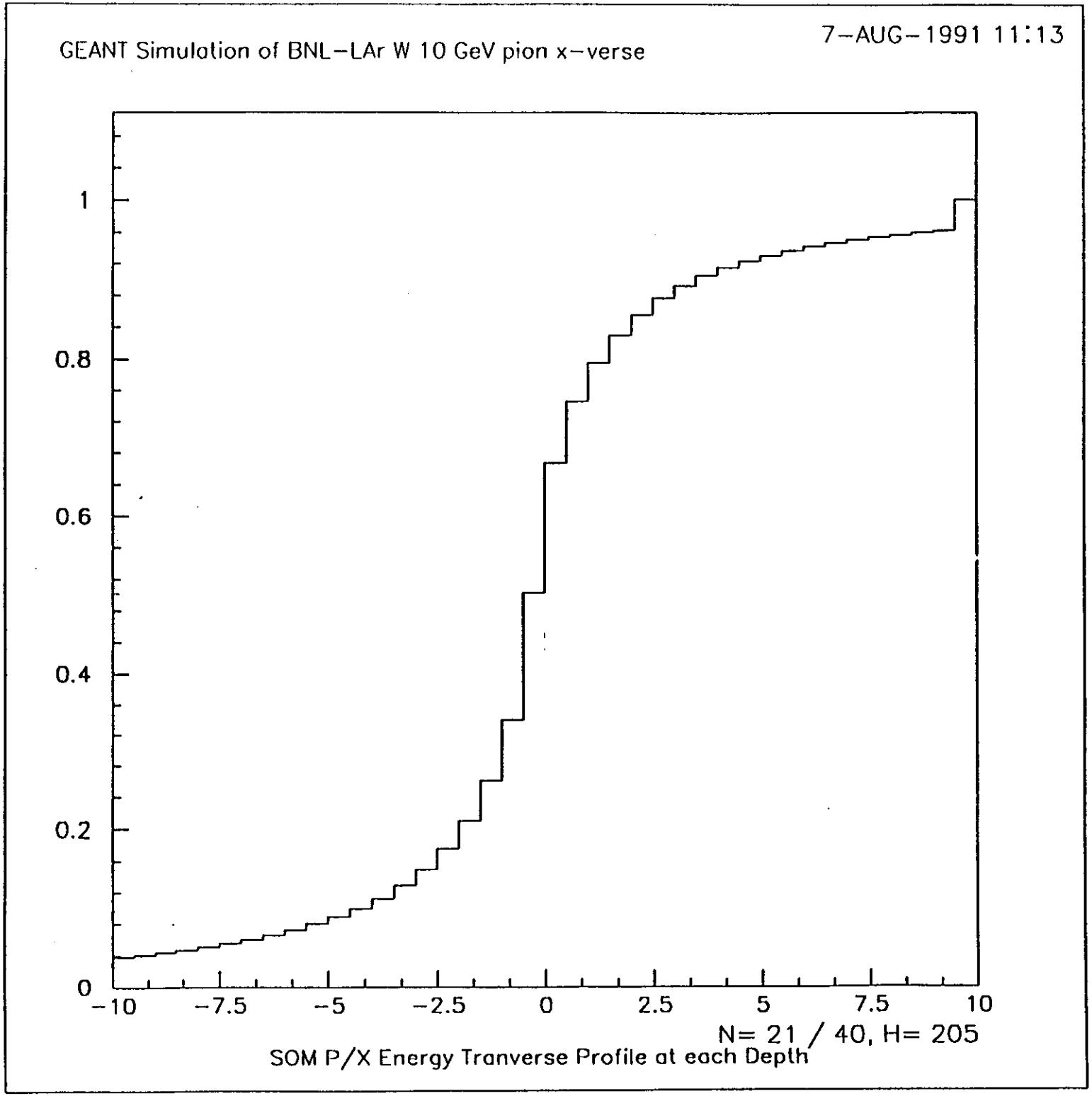
DOMINATES IN FORWARD CAL

IN FORWARD CAL, $p \gtrsim 100$ GeV, SO "POOR" RESOLUTIONS ARE ACCEPTABLE:

$$\text{EG. } \frac{\delta p}{p} = (2-4)\% \oplus \frac{100\%}{\sqrt{p}} \oplus \frac{100\%}{p}$$

$$\sim 3\% \oplus \leq 10\% \oplus \leq 1\%$$

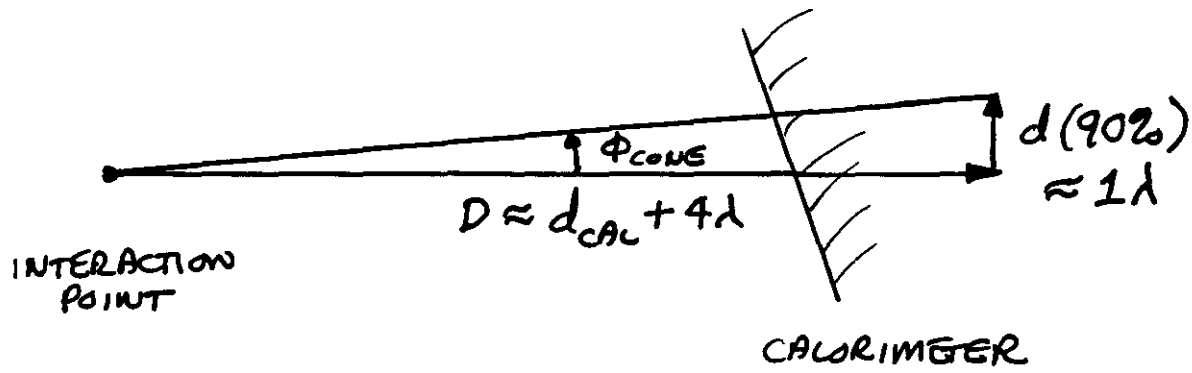

BNL Pb–LAr Test Beam Calorim.
7–AUG–1991 13:40
Pb CALORIMETER ? (WILL DO FOR W FCAL)
HADRONIC SHOWER CENTROID DETERMINATION.
SHOWER CENTROID (PROJECTION) BEST DETERMINED BY ∫ FRONT TO 2.5λ
~1.25 CM
EXPECT ~.8 CM FOR W.
CM
4
3.5
3
2.5
2
1.5
1
0.5
0
4
8
12
16
20
24
λ
1.25
2.50
3.75
N= 42 / 24, H= 204
Sigma of Centroid Scatt at each Depth
DEPTH


GEANT Simulation of BNL-LAr W 10 GeV pion x-verse
7-AUG-1991 11:13
1
0.8
0.6
0.4
0.2
0
-10
-7.5
-5
-2.5
0
2.5
5
7.5
10
N= 21 / 40, H= 205
SOM P/X Energy Tranverse Profile at each Depth

90% 9cm
≈λ

HADRONIC SHOWER AND JET CONTAINMENT

HADRONS

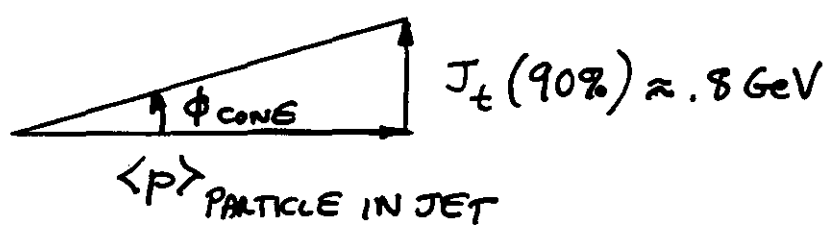


$d(90\%)$ IS THE LATERAL CONTAINMENT RADIUS TO CONTAIN 90% OF SHOWER ENERGY.

$$\Rightarrow \phi_{CONE} \approx \frac{d(90)}{D} \approx \frac{\lambda}{d_{CAL} + 4\lambda}$$

JETS

(MUCH MORE QUALITATIVE AT MOMENT)



ORDER OF MAGNITUDE $\Rightarrow \langle p \rangle_{PIJ} \approx P_{JET}/\langle n \rangle$

$$\Rightarrow \phi_{CONE} \approx \frac{J_t(90)}{P_{JET}/\langle n \rangle}$$

EG. 20 GeV/c, $\langle n \rangle \approx 10 \Rightarrow \phi_{CONE} \approx \frac{.8}{2} = .4$

NOTE $1/P_{JET}/\langle n \rangle$ DEPENDENCE ! 200 GeV $\Rightarrow$ .064

	20 GeV	200 GeV
$\eta = 0$ $D = 100$ CM $\lambda = 20$ CM $(d\eta/d\theta = 1)$	$\phi_{HAD} = .2$ $\phi_{JET} = .4$	$\phi_{HAD} = .2$ $\phi_{JET} = .064$
$\eta = 4.0$ $D = 500$ CM $\lambda = 10$ CM $(d\eta/d\theta) = \frac{1}{.036}$	$\phi_{HAD} = .02$ $\Delta\eta = .55$ $\phi_{JET} = .4$ $\Delta\eta = 11.1$ (BELOW THRESH)	$\phi_{HAD} = .02$ $\Delta\eta = .55$ $\phi_{JET} = .064$ $\Delta\eta = 1.78$ (GETTING THERE)

$(p_T = 20 \Rightarrow p = 550$ AT $\eta = 4.0)$

2. CONCLUSIONS:

(1) MAY CONSIDER p DEPENDENT CONES TO REJECT SPLASH IN.

(2) JET THRESHOLDS ARE STRONG FUNCTION OF η FOR FIXED CONE SIZE AT HIGH η.

(ROUGHLY CONST IN p_T, AS ONE EXPECTS)

JET MAPPING AT HIGH η

→ THE "MERCATOR PROBLEM"

PROCEDURE: ① FIND HIGHEST TOWER

② SCAN OVER ALL ϕ BINS NEEDED TO INCLUDE "CONE" OF SIZE $\Delta\eta \approx .7$ FOR EXAMPLE

③ DISTANCE $\Delta\rho$ TO CELL CENTER IS UNAMBIGUOUS.

SIMULATIONS WITH GEANT 3.14 (EGS4)

```
*  IPFIS =        1.  IDRAY =        1.  IANNI =        1. *
*  IBREM =        1.  IHADR =        3.  IMUNU =        0. *
*  IDCAY =        1.  ILOSS =        3.  IMULS =        2. *
*  IRAYL =        0.                                        *
*                                                           *
*     Special TPAR for TMED   1   W     TUNGSTEN            *
*     -------------------------                             *
*  CUTGAM= 10.00 KEV  CUTELE= 10.00 KEV  CUTNEU=100.00 KEV *
*  CUTHAD=100.00 KEV  CUTMUO=  1.00 MEV                     *
*  BCUTE = 10.00 KEV  BCUTM =100.00 KEV                     *
*  DCUTE = 10.00 KEV  DCUTM = 10.00 KEV  PPCUTM= 10.00 MEV *
*  IPAIR =        1.  ICOMP =        1.  IPHOT =        1. *
*  IPFIS =        1.  IDRAY =        1.  IANNI =        1. *
*  IBREM =        1.  IHADR =        3.  IMUNU =        0. *
*  IDCAY =        1.  ILOSS =        3.  IMULS =        2. *
*  IRAYL =        0.                                        *
*                                                           *
*                                                           *
*     Special TPAR for TMED   2   KAPT    KAPTON            *
*     -------------------------                             *
*  CUTGAM= 10.00 KEV  CUTELE= 10.00 KEV  CUTNEU=100.00 KEV *
*  CUTHAD=100.00 KEV  CUTMUO=  1.00 MEV                     *
*  BCUTE = 10.00 KEV  BCUTM =100.00 KEV                     *
*  DCUTE = 10.00 KEV  DCUTM = 10.00 KEV  PPCUTM= 10.00 MEV *
*  IPAIR =        1.  ICOMP =        1.  IPHOT =        1. *
*  IPFIS =        1.  IDRAY =        1.  IANNI =        1. *
*  IBREM =        1.  IHADR =        3.  IMUNU =        0. *
*  IDCAY =        1.  ILOSS =        3.  IMULS =        2. *
*  IRAYL =        0.                                        *
*                                                           *
```

→ CUTOFFS ARE 10 KeV EM, 100 KeV HADRONIC.

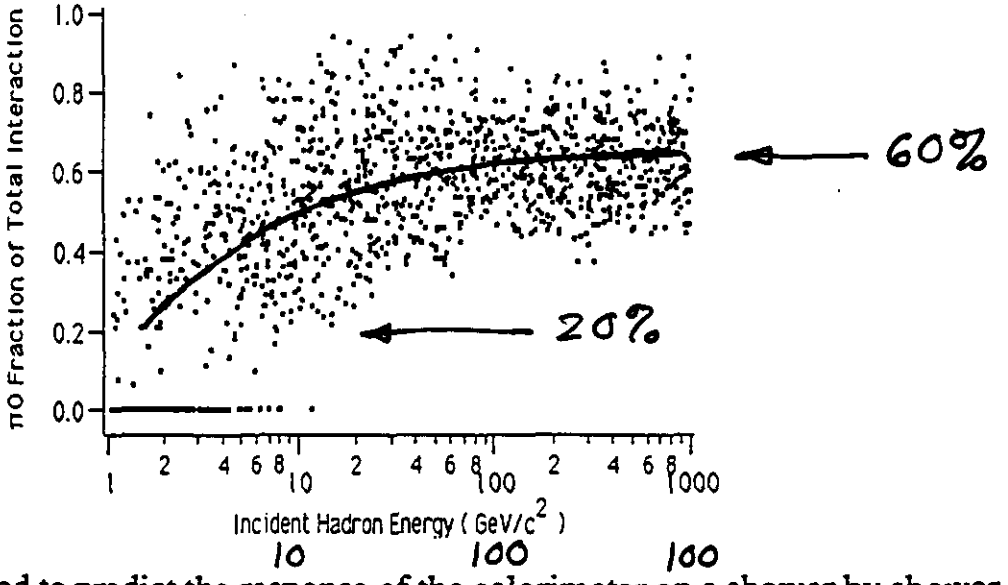
```
***** GPHYSI error for material nr   18
      Tracking medium NR   2 and  13 have different parameters

*                                                           *
*     Special TPAR for TMED   3   LAR   LIQUID ARGON        *
*     -------------------------                             *
*  CUTGAM= 10.00 KEV  CUTELE= 10.00 KEV  CUTNEU=100.00 KEV *
*  CUTHAD=100.00 KEV  CUTMUO=  1.00 MEV                     *
*  BCUTE = 10.00 KEV  BCUTM =100.00 KEV                     *
*  DCUTE = 10.00 KEV  DCUTM = 10.00 KEV  PPCUTM= 10.00 MEV *
*  IPAIR =        1.  ICOMP =        1.  IPHOT =        1. *
*  IPFIS =        1.  IDRAY =        1.  IANNI =        1. *
*  IBREM =        1.  IHADR =        3.  IMUNU =        0. *
*  IDCAY =        1.  ILOSS =        3.  IMULS =        2. *
*  IRAYL =        0.                                        *
*                                                           *

***** GPHYSI error for material nr   17
      Tracking medium NR   3 and  14 have different parameters

*                                                           *
*     Special TPAR for TMED   4   CU                        *
*     -------------------------                             *
*  CUTGAM= 10.00 KEV  CUTELE= 10.00 KEV  CUTNEU=100.00 KEV *
*  CUTHAD=100.00 KEV  CUTMUO=  1.00 MEV                     *
*  BCUTE = 10.00 KEV  BCUTM =100.00 KEV                     *
*  DCUTE = 10.00 KEV  DCUTM = 10.00 KEV  PPCUTM= 10.00 MEV *
*  IPAIR =        1.  ICOMP =        1.  IPHOT =        1. *
```

Calorimeter e/h Effects on Reconstructing High Pt W/Z → Hadrons

G. E. Forden
University of Arizona

The fractional energy deposited by secondary π^0's (as given by GFLASH) :

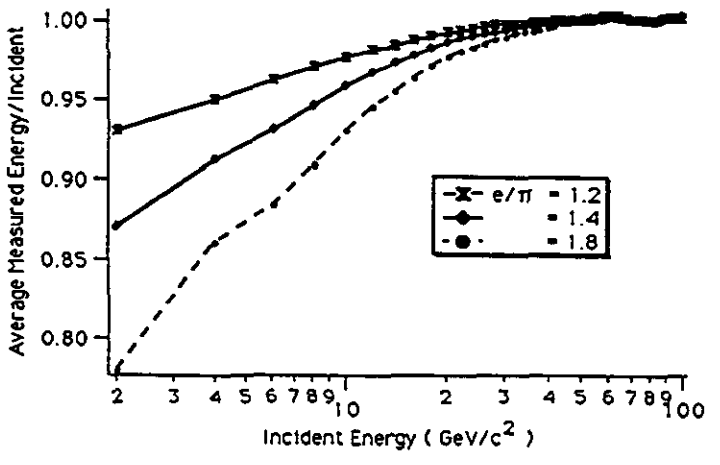
EM FRACTION IN HADRONIC SHOWERS



This fraction is used to predict the response of the calorimeter on a shower by shower basis using the relation:

$$E_{obs} = K\left\{f_\pi + \left(1 - f_\pi\right)\left(\frac{e}{h}\right)^{-1}\right\} E_{inc}$$

The average response to hadrons given by this model:



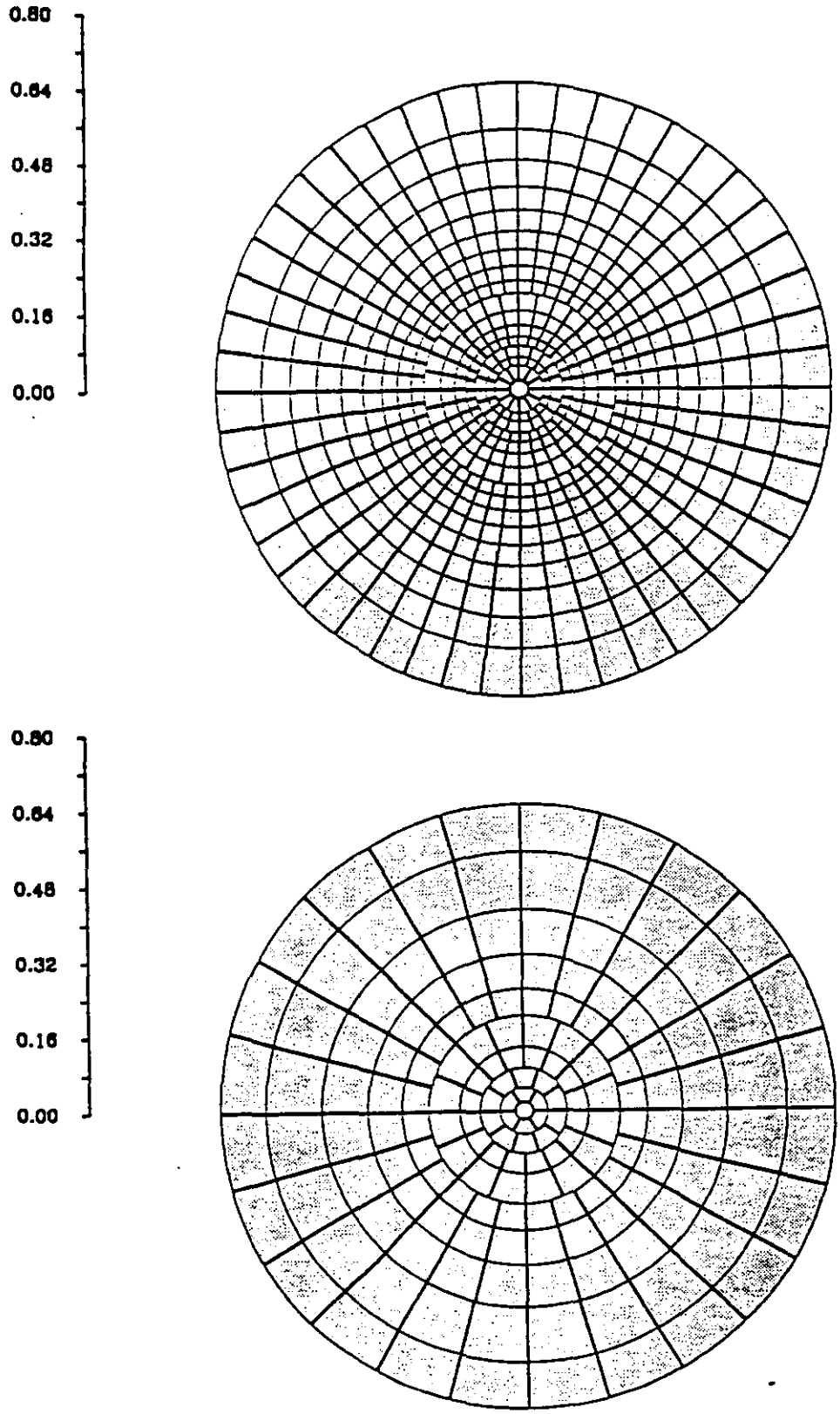


Figure 4

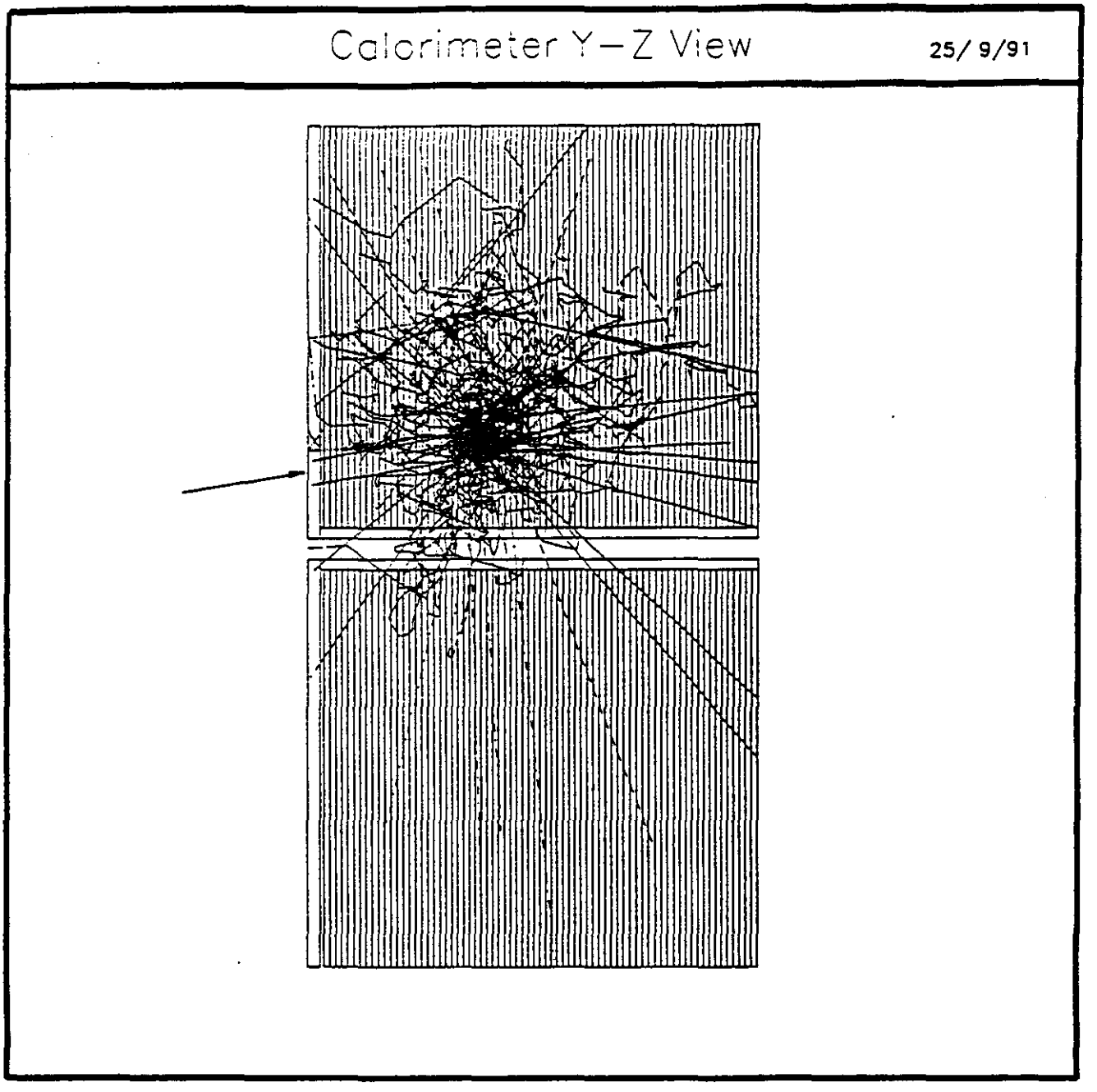


Figure 5

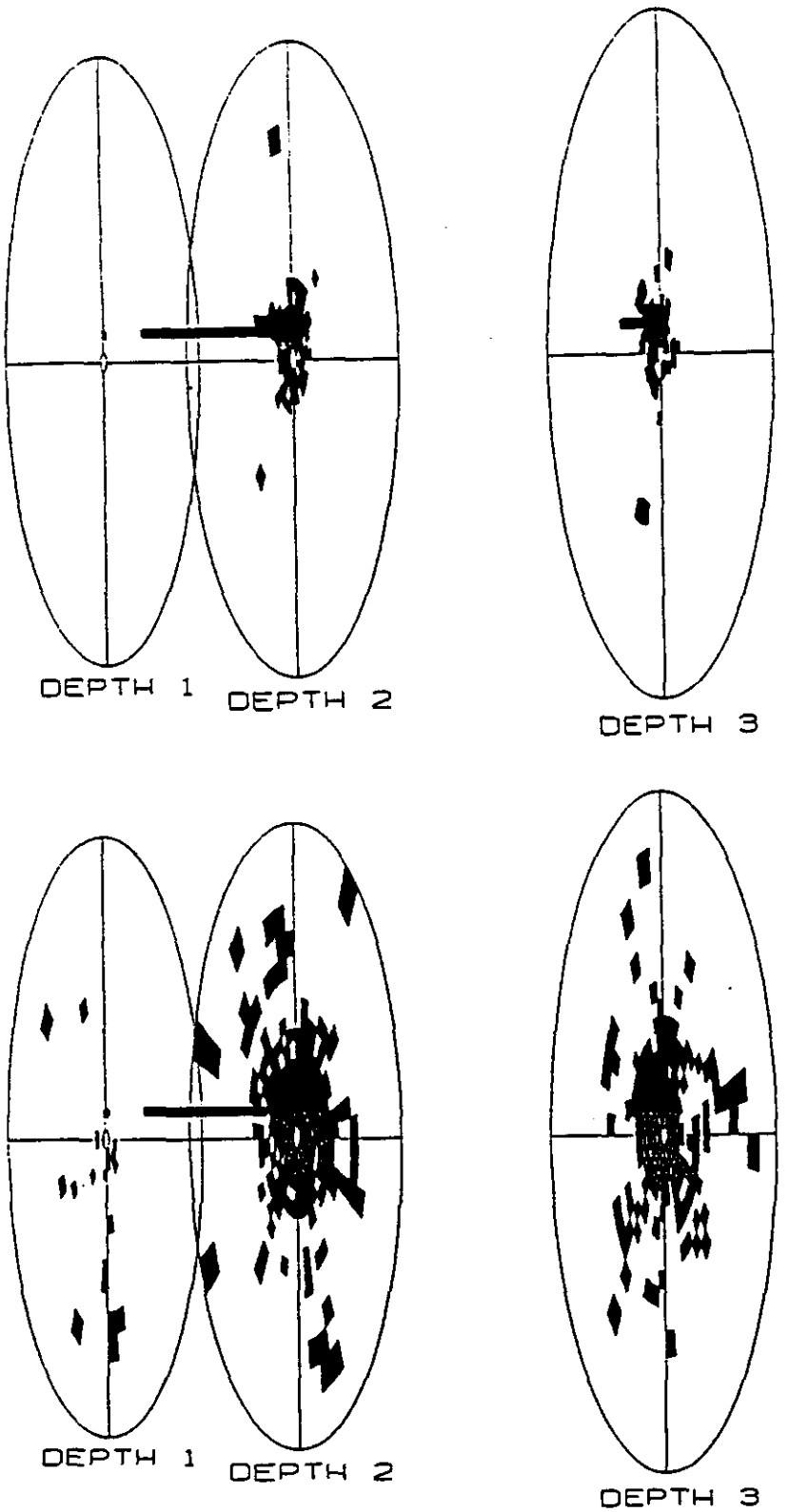


Figure 6

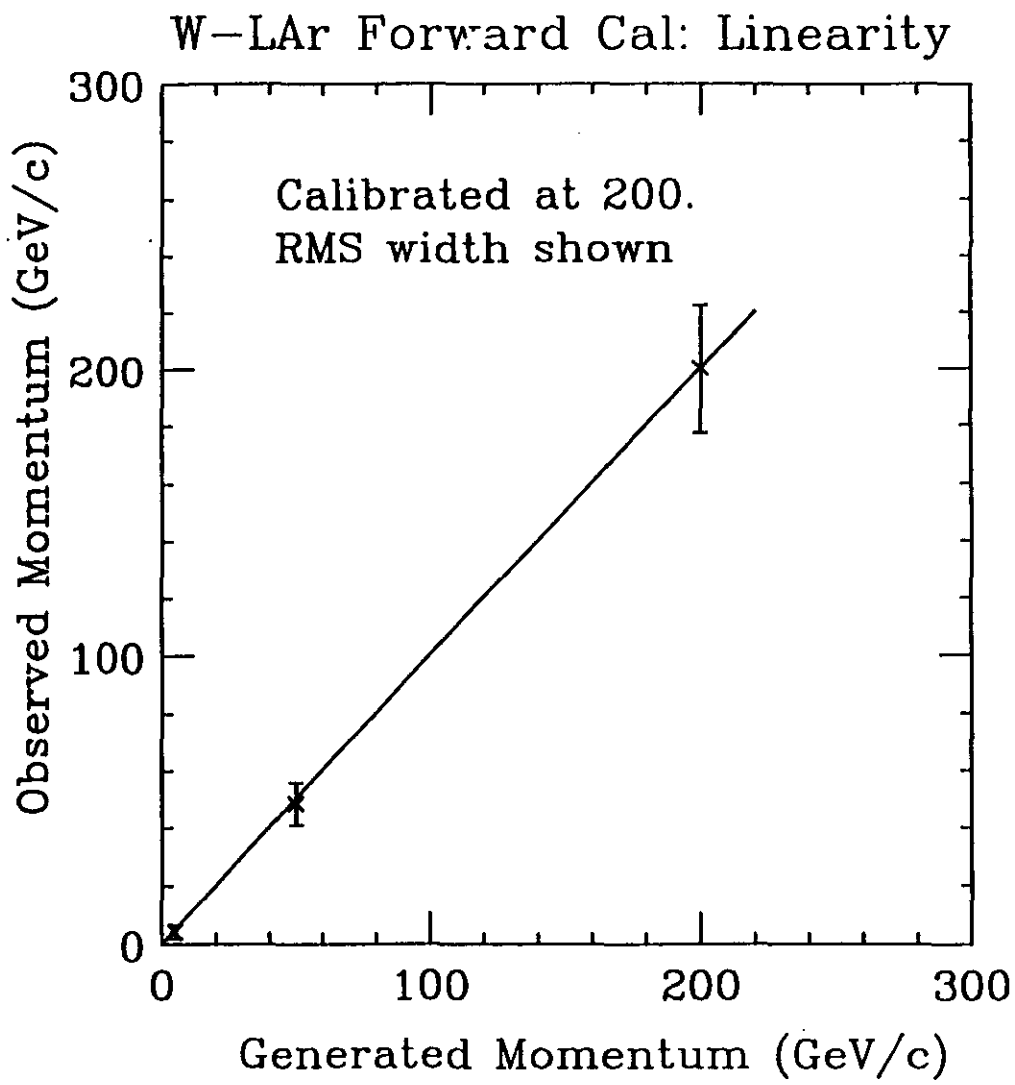

W−LAr Forward Cal: Linearity
Calibrated at 200.
RMS width shown
Observed Momentum (GeV/c)
Generated Momentum (GeV/c)
0
100
200
300
0
100
200
300

Figure 7

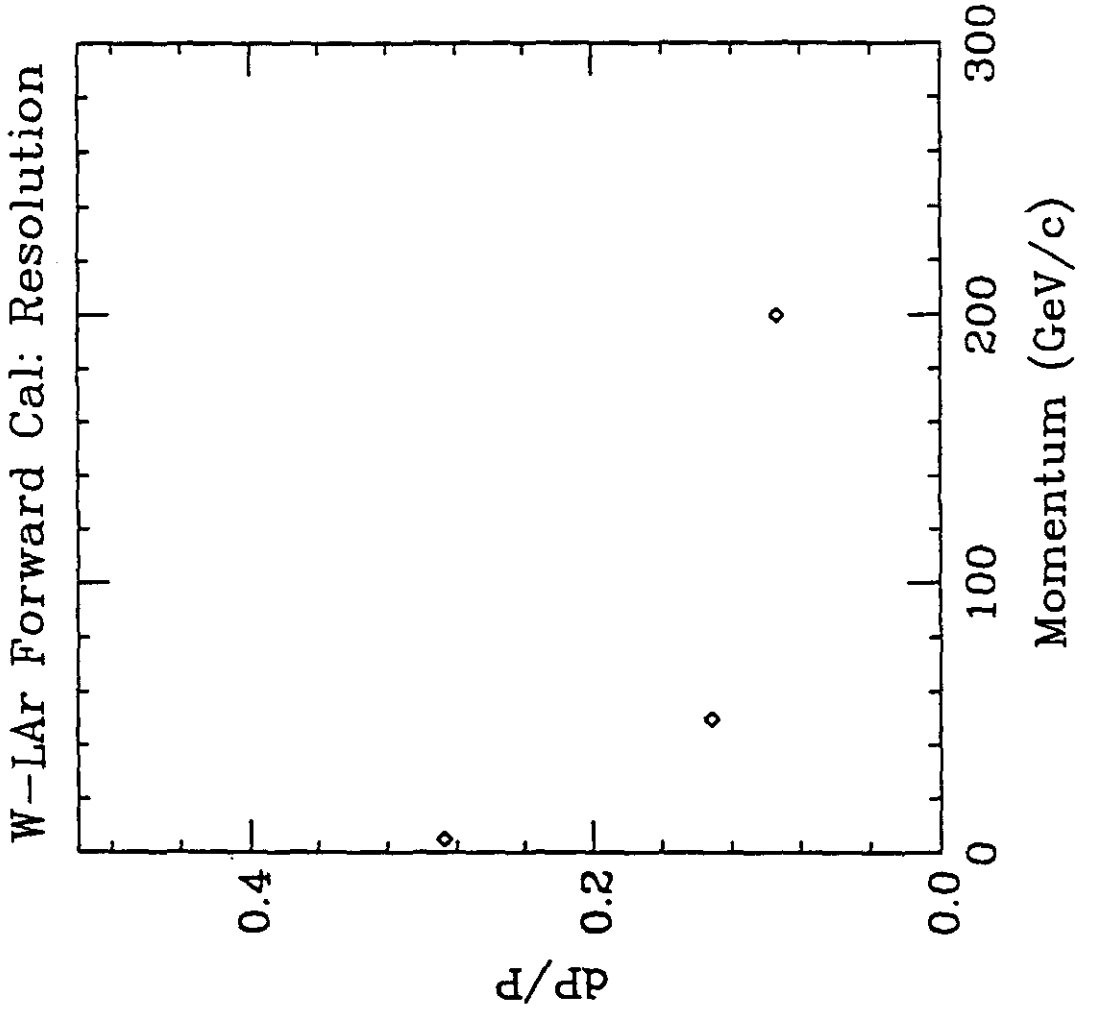

W-LAr Forward Cal: Resolution
dP/P
0.0
0.2
0.4
0
100
200
300
Momentum (GeV/c)

Figure 8

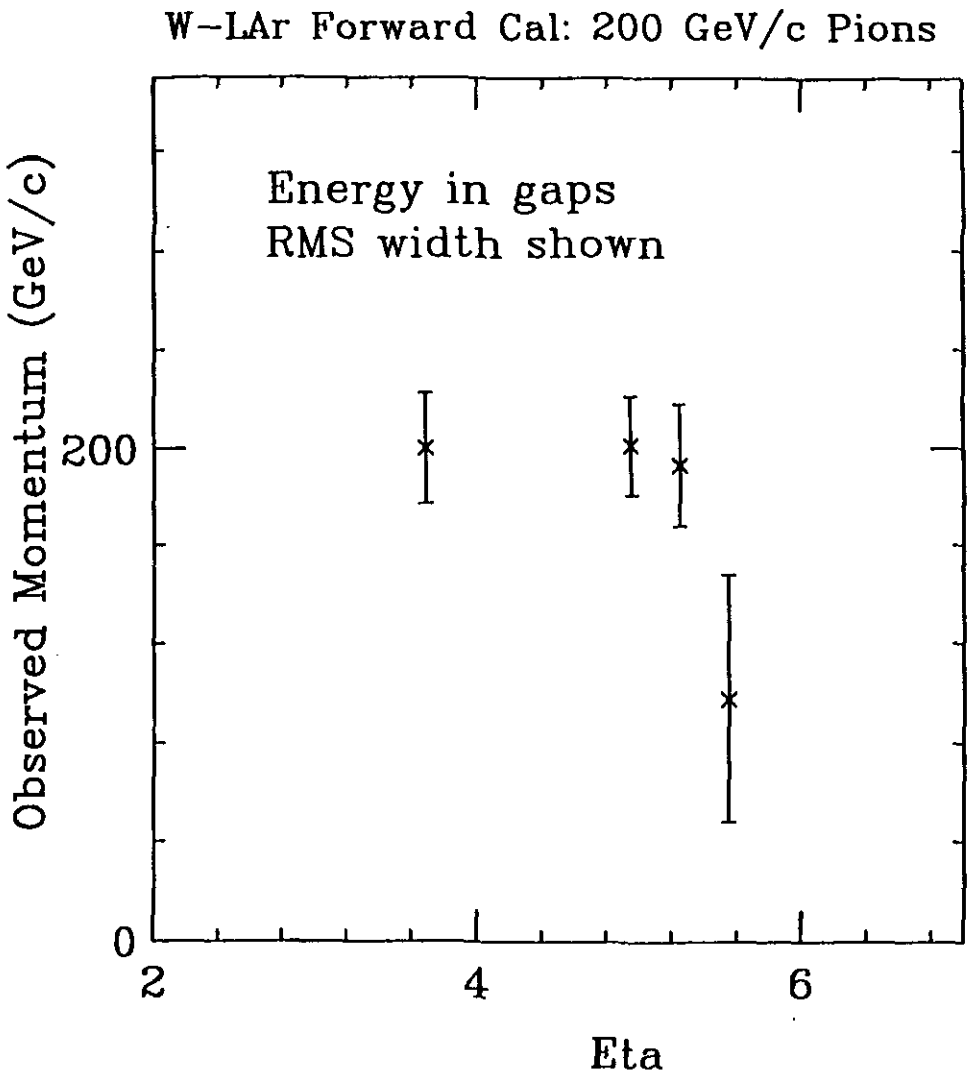

W-LAr Forward Cal: 200 GeV/c Pions
Energy in gaps
RMS width shown
Observed Momentum (GeV/c)
200
0
2
4
6
Eta

Figure 9

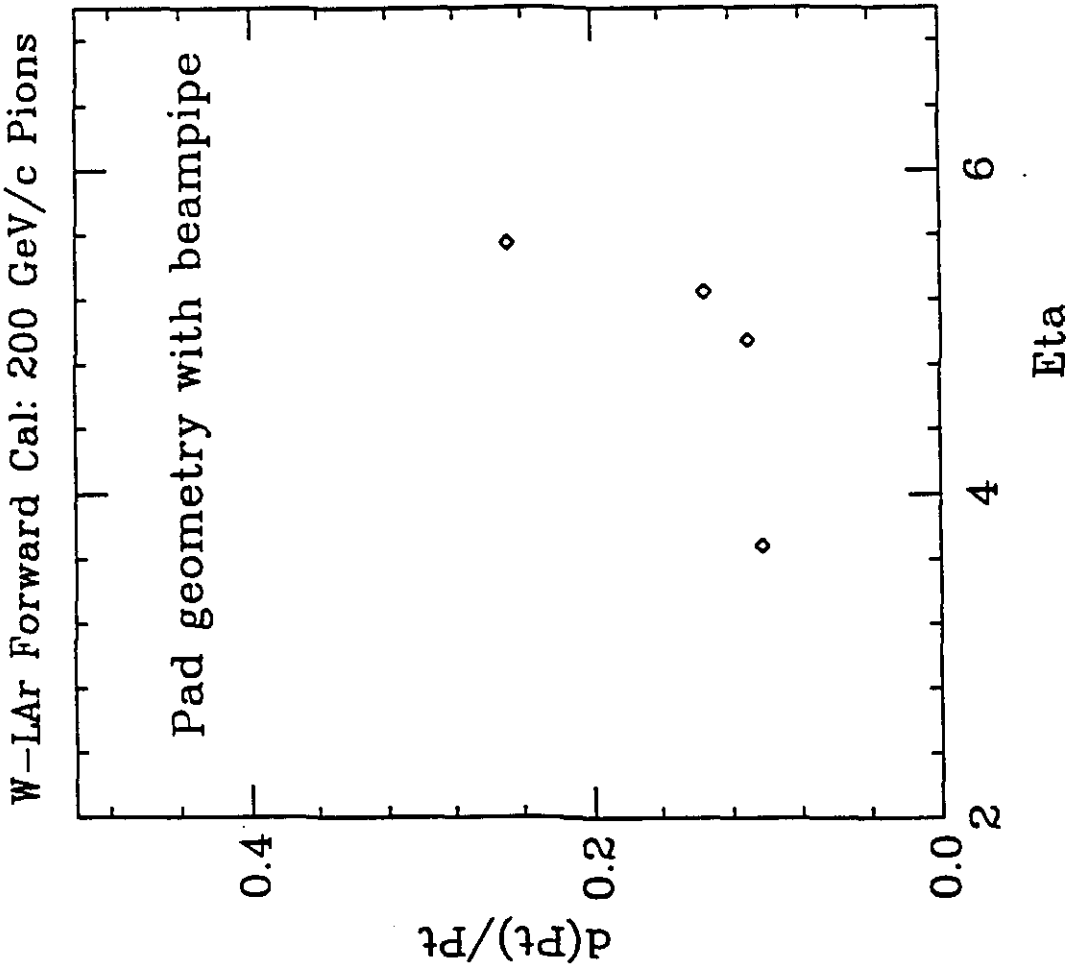

W-LAr Forward Cal: 200 GeV/c Pions
Pad geometry with beampipe
d(Pt)/Pt
0.0
0.2
0.4
2
4
6
Eta

Figure 10

SIGNAL AND RESOLUTIONS IN W-LAR FCAL

(MOSTLY 10 λ) (500 EVTS)

		SIGNAL (e/π)	RMS WIDTH	1/√E TERM	E ESC (RMS WID)	1/√E COMPARIB
2 GeV/c	π	.0064 ± .0001 (1.47)	.0039	.857 ± .073	.039 ± (.072)	.052
	e	.0094 ± .0001	.0027	.401 ± .013	NEGL.	
10 GeV/c	π	.0334 ± .0004 (1.46)	.0113	1.07 ± .03	.233 (.346)	.109
	e	.0487 ± .0002	.0054	.354 ± .011	NEGL.	
50 GeV/c (SMALL STATS)	π	.182 ± .003 (1.35)	.026	1.01 ± .11	1.56 (2.37)	.336
	e	.246 ± .001	.016	.450 ± .041	NEGL	
100 GeV/c	π	.378 ± .002	.043	1.12 ± .04	4.51 (7.43)	.743 *
	e	.493 ± .001	.021	.424 ± .019	NEGL	
100 GeV/c π (14 λ)		.379 ± .002	.043	1.14 ± .06	1.60 (1.94)	.194

LAr-TUNGSTEN FCAL OPTION FOR GEM

SUMMARY

- MANY BASIC DESIGN PARAMETERS TO BE DETERMINED BY INTEGRATION INTO GEM (FCAL SOMEWHAT FLEXIBLE)

- SMALL DETECTOR ⇒ SMALL RAW MATERIAL COSTS AND CHANNEL COUNTS

- EXPECT RAD. HARDNESS OF LAr. CARE TAKEN WITH ANY OTHER MATERIALS NEAR BEAMPIPE.

- (+) ION MOBILITY MEASUREMENT CRITICAL FOR HIGHEST η

- R+D EFFORT COMBINABLE WITH OTHER FCAL AND LAr WORK.

TO COMPLETE SOON

1. $\not{E}_T$ AND JET RESOLUTIONS FROM FULL-GEANT GANGED-CELL SIMULATIONS. (PYTHIA + ISAJET)

2. ADD JETFINDER

3. ADD ELECTRONIC NOISE

4. ADD PILEUP EVENTS.

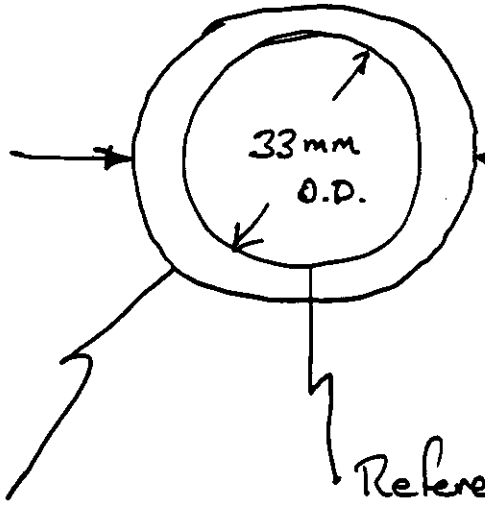
(SIMULATE TO 500 GeV → 5 TeV RANGE)

11/18/91 J. Rutherfoord GEM ForCal Mtg.

cdr.txt
11/18/91

FCAL CONCEPTUAL DESIGN REPORT
(Outline)

1. Physics with a forward calorimeter
   - Missing pT (lots of examples, e.g. SUSY)
   - Tagging jets (speculative but important, WW fusion)
   - Irreducible limits (Heavy quark neutrinos)
   - Properties of jets at large eta
2. Physics requirements
   - Need to measure Jets to measure global pT of an event
   - Properties of EM and hadronic showers
   - Depth in lambda
3. Geometry which satisfies physics requirements
   - D=6.0 meters, segmentation, shower containment
   - How close to beam pipe
   - Other options
4. Radiation levels, etc.
   - Materials handling
   - Activation and decay times
   - Radiation damage to components and electronics
   - Neutron albedo in central tracker
   - Spray into muon chambers
   - Heating and heat removal
5. Technologies (Include strengths and weaknesses)
   - Liquid Argon
     - Plates
     - Tubes
   - Liquid scintillating spaghetti
   - High pressure gas
6. Integration
   - Support
   - Beam pipe
   - Readout electronics, cables, timing, etc.
   - Interference with other systems ← spray into muon system, neutron albedo into tracking volume
7. Costs
   - Depends on technology choices for the central and endcap cals.



Sensitive Volume

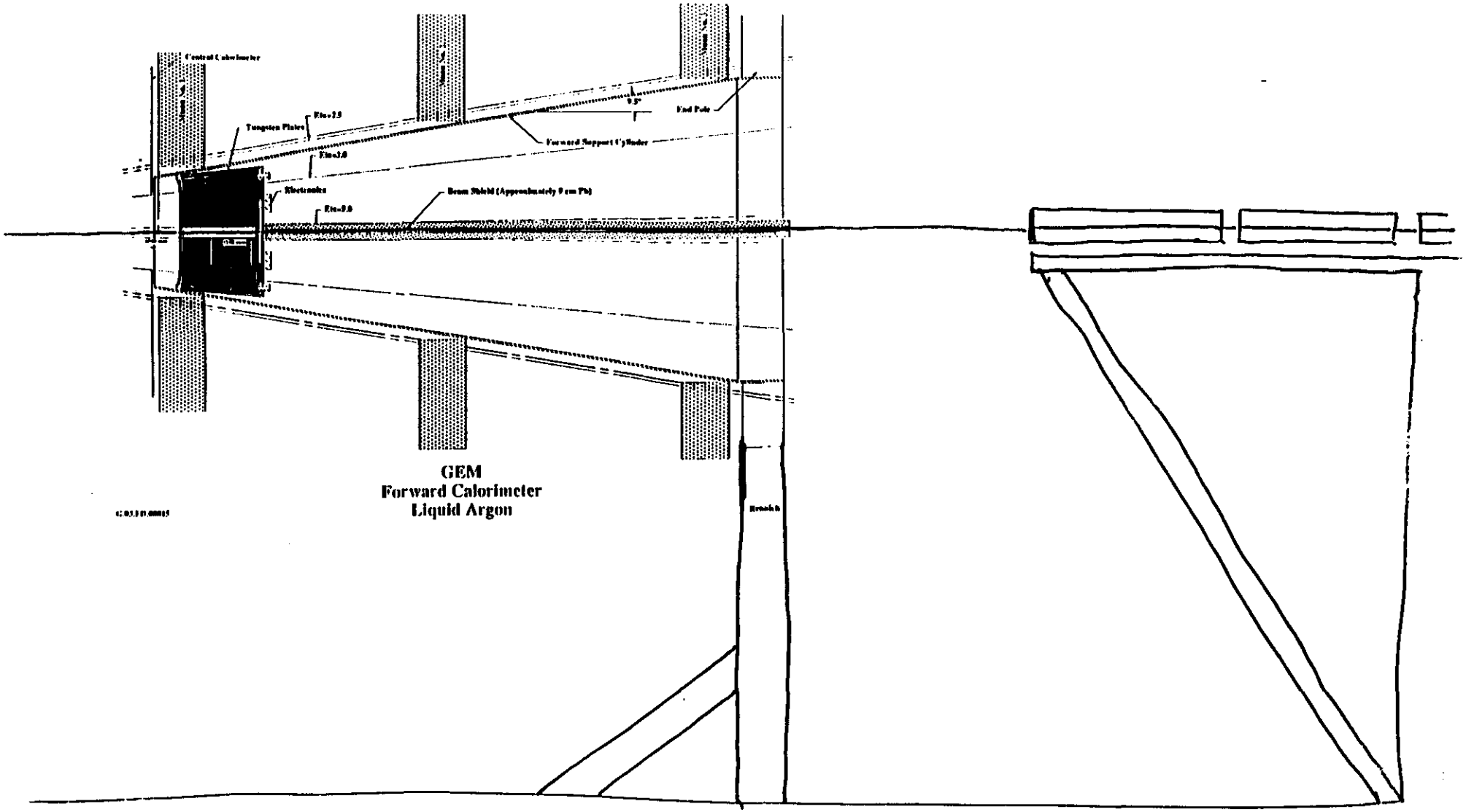
40 mm I.D.

Referenced to accelerator

@ ± 0.25 mm

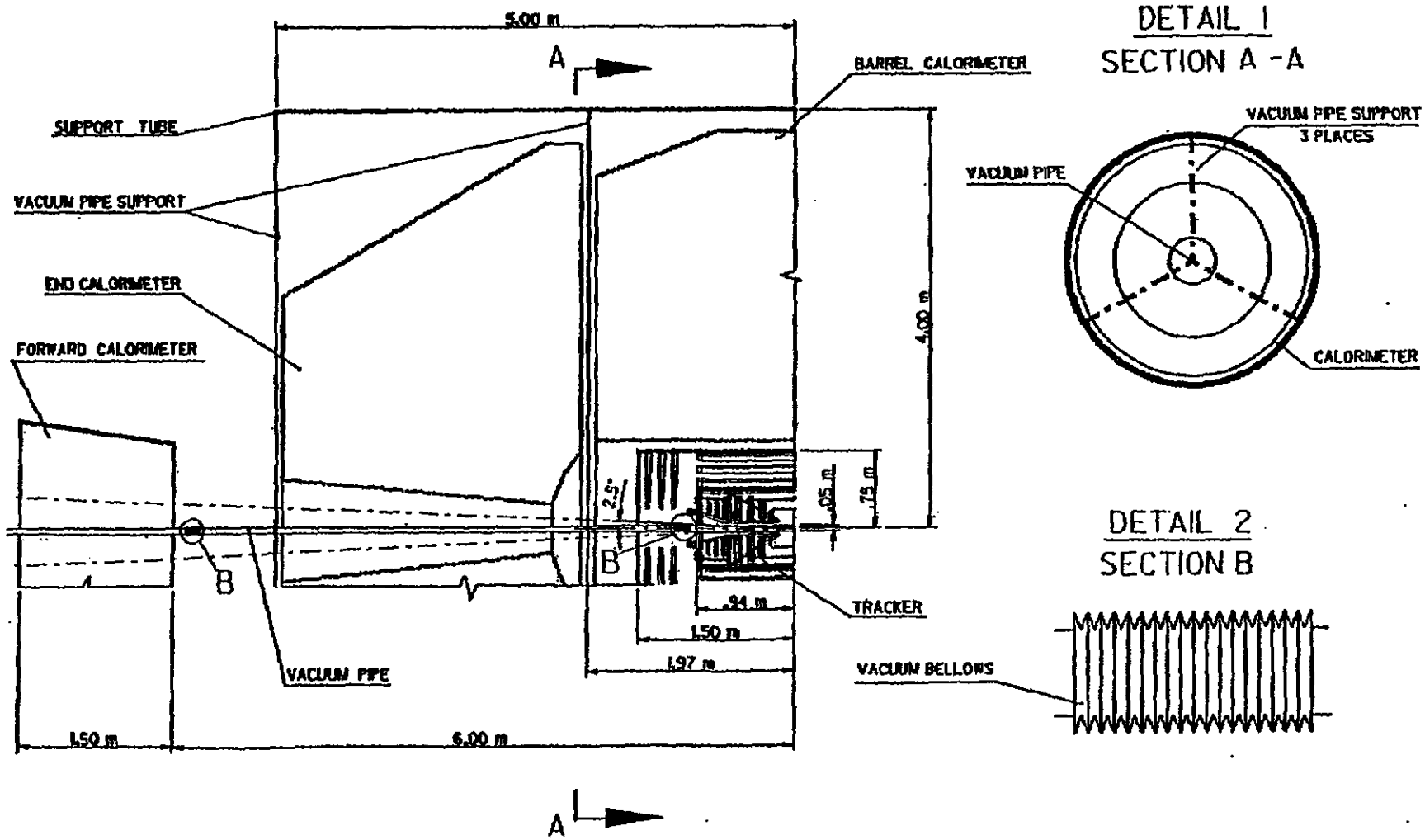
Referenced to detector

@ ± 1 mm ?


Central Calorimeter
Tungsten Plates
Electronics
Beam Shield (Approximately 9 cm Pb)
End Pole
Forward Support Cylinder
GEM
Forward Calorimeter
Liquid Argon

DENT BY:Xerox Telecopier 7021 ;11-13-91 ; 13:43 ;

DRAFT

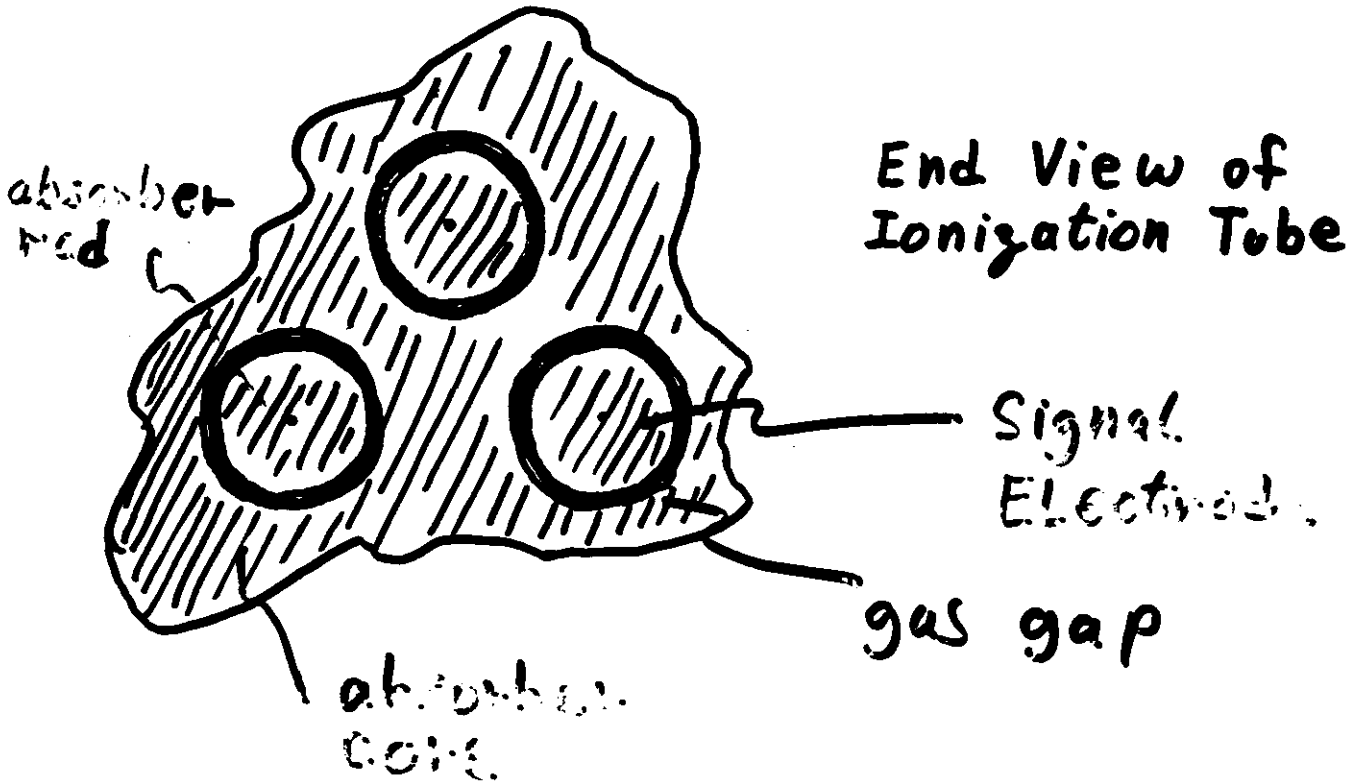


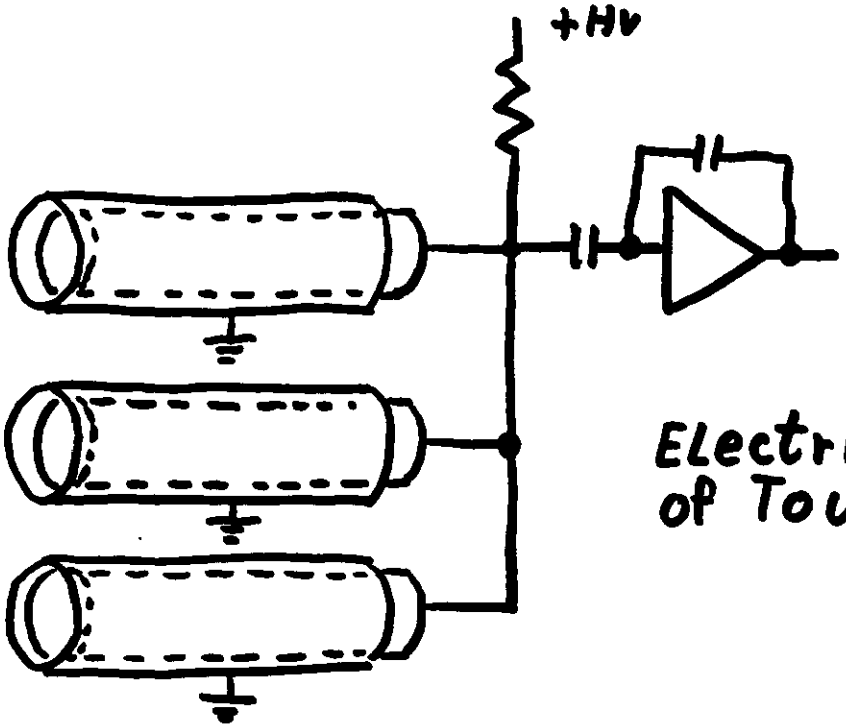
E. Kistenev
S. Rescia
D. Makowiecki

HIGH PRESSURE GASEOUS IONIZATION TUBES

ADVANTAGES:

- ABILITY TO HANDLE HIGH RATES
- DRIFT TIME FASTER THAN IN LIQUIDS
- SPACE CHARGE EFFECT REDUCED
- UNIFORMITY
- EASE OF CALIBRATION
- RADIATION HARD





Electrical Schematic of Towers

absorber core: Pb, W

absorber rod: Pb, W, DU

The sampling fraction for a tube calorimeter computed along the random path perpendicular to the tube axis is equal to ..

• ext t. diam [mm]	10	10	20	20	10	10
• gap [mm]	1	2	1	2	1	2
• p [atm]	50					
• absorber	Pb	Pb	Pb	Pb	W	W
• sensitive Volume [%]	24	44	13	24	24	44
• sampl. frac. [%]	.39	.92	.18	.39	.25	.60

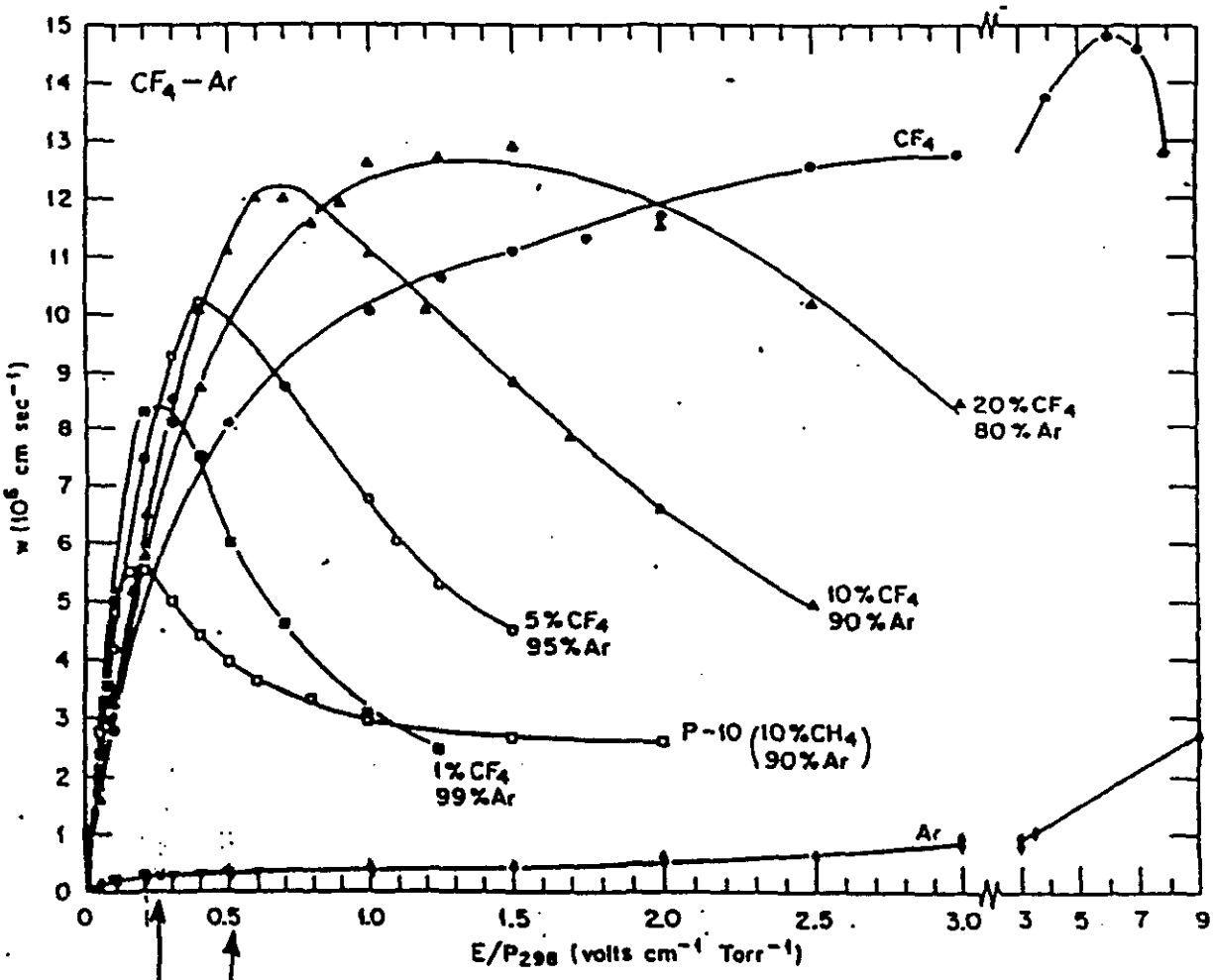


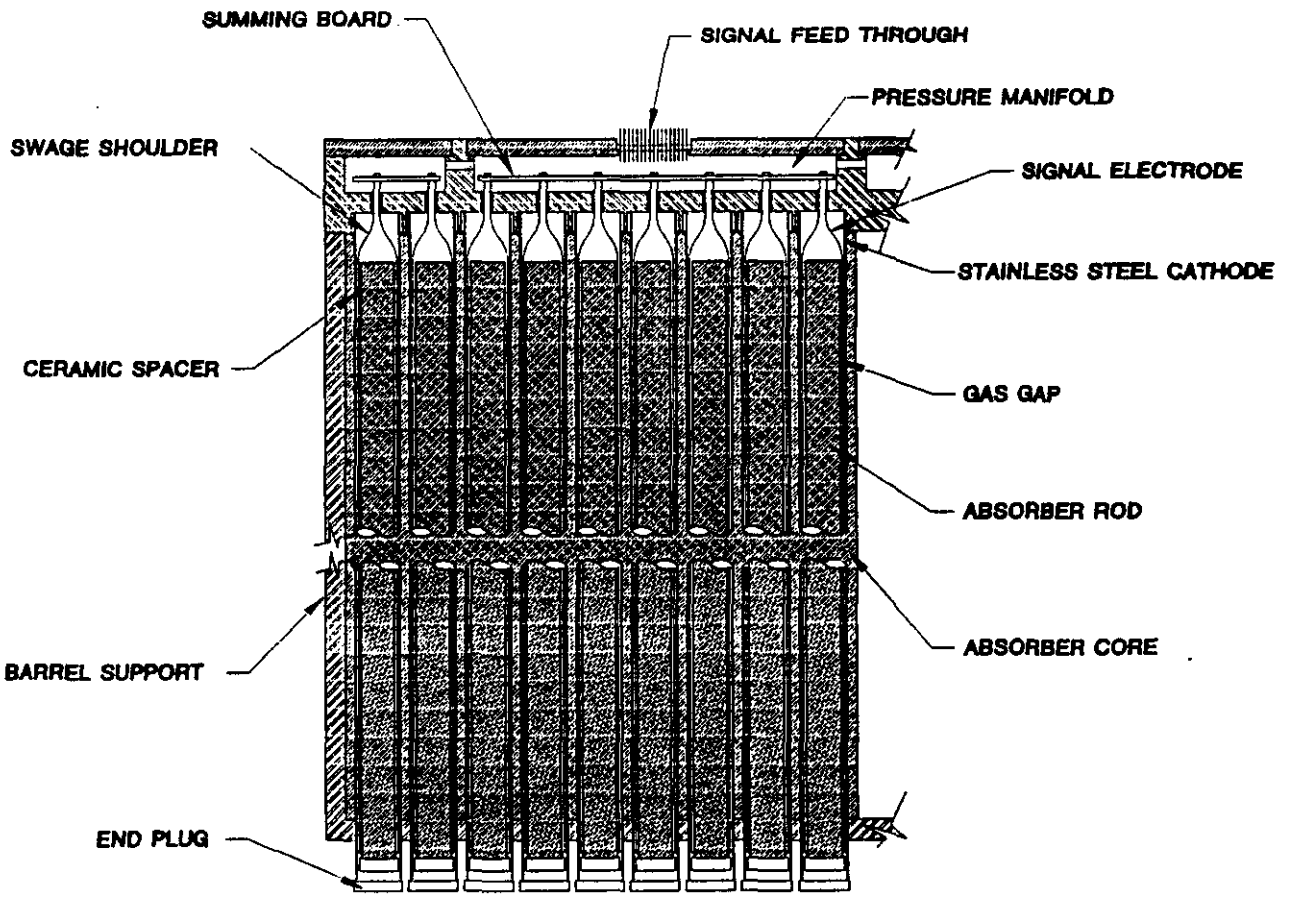
Fig. 125 Christophorou et al. (1979)

19 Kv/cm @ 50atm

9.5 kv/cm @ 50atm

Figure 3: Plotted is drift velocity as a function of electric field and pressure for different percentages of dopants. By varying the pressure and amount of dopant we are able to operate at comfortable voltages without substantially increasing the drift time.

D. Makowiecki



HIGH PRESSURE IONIZATION CHAMBER

(CROSS SECTION)

bnl

Figure 5: An enlarged view of the ionization chamber. Notice that there are no active elements on the summing boards which are located inside the pressure manifold.

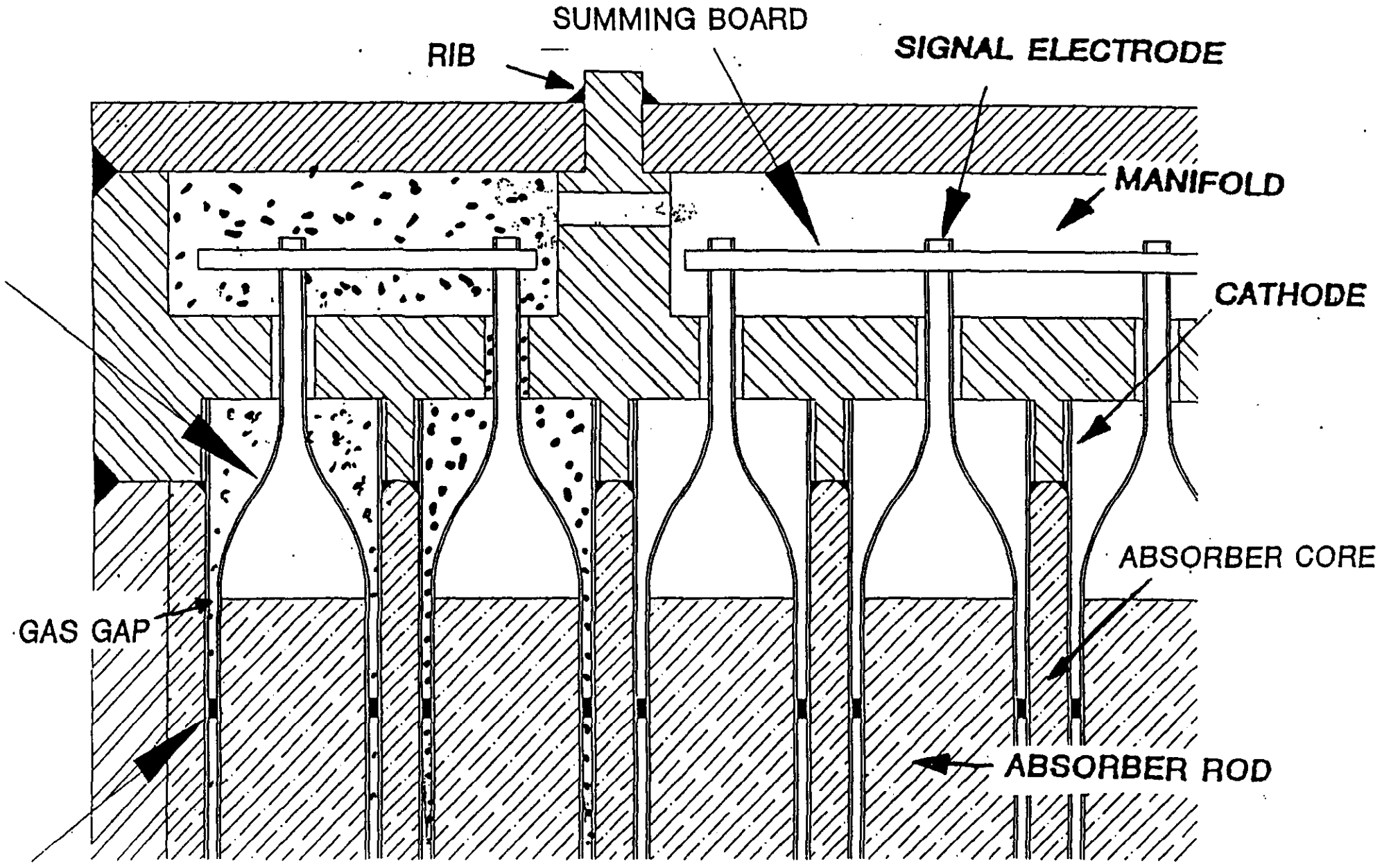
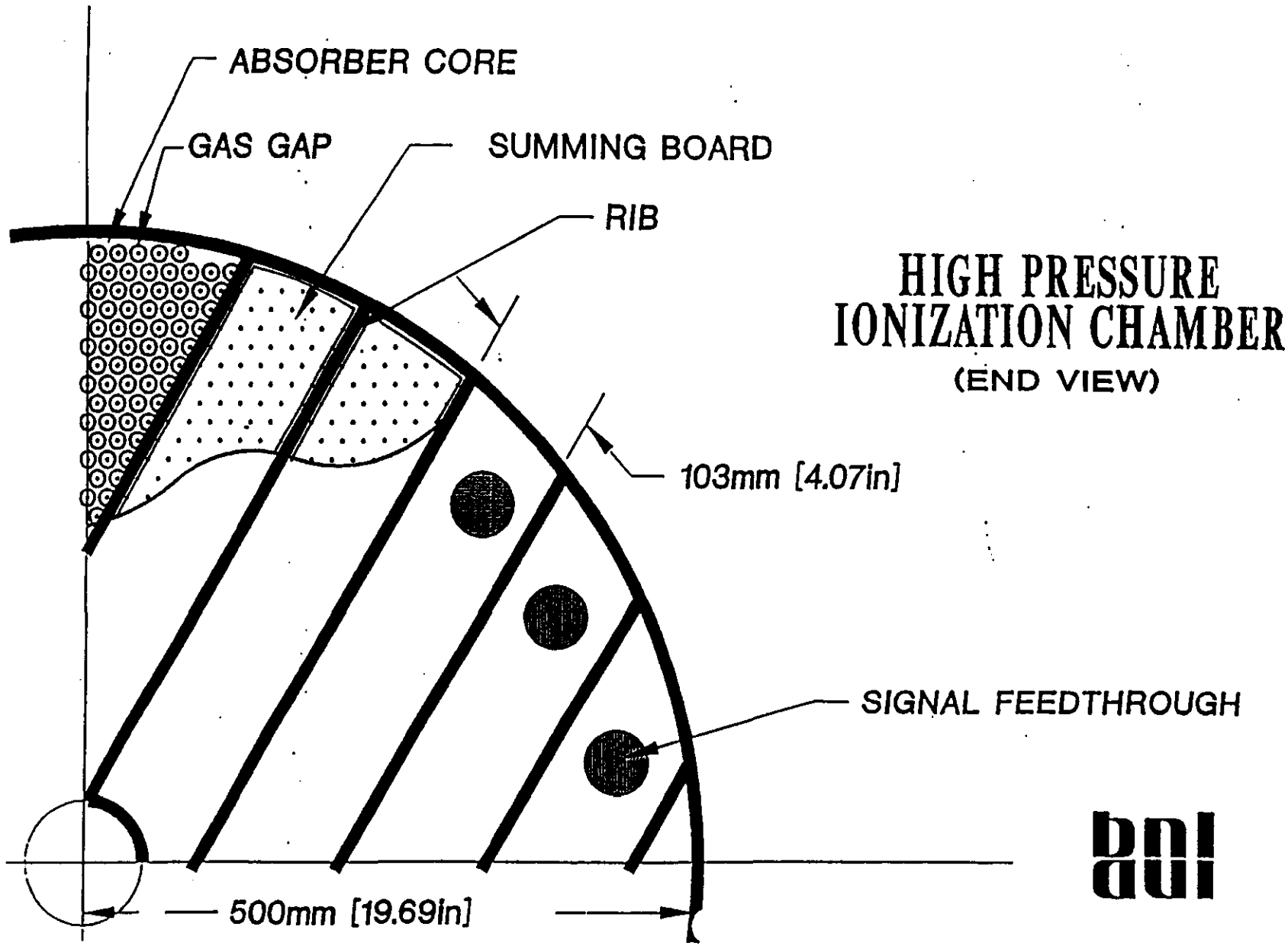


Figure 6: An end view of the high pressure ionization chamber.



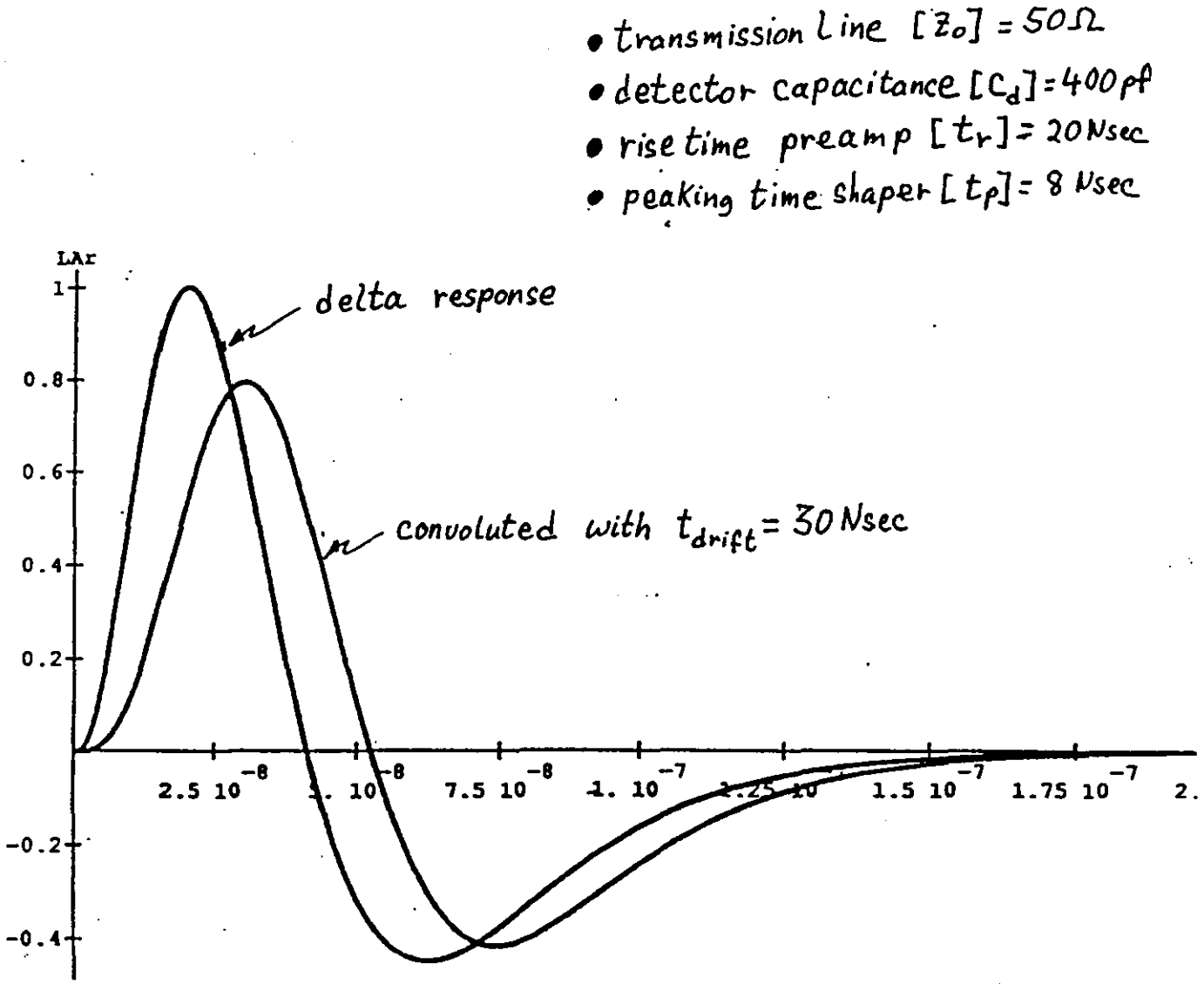


Figure 7: Simulations of the response of the proposed electronic chain to a delta pulse and convoluted with the detector signal.

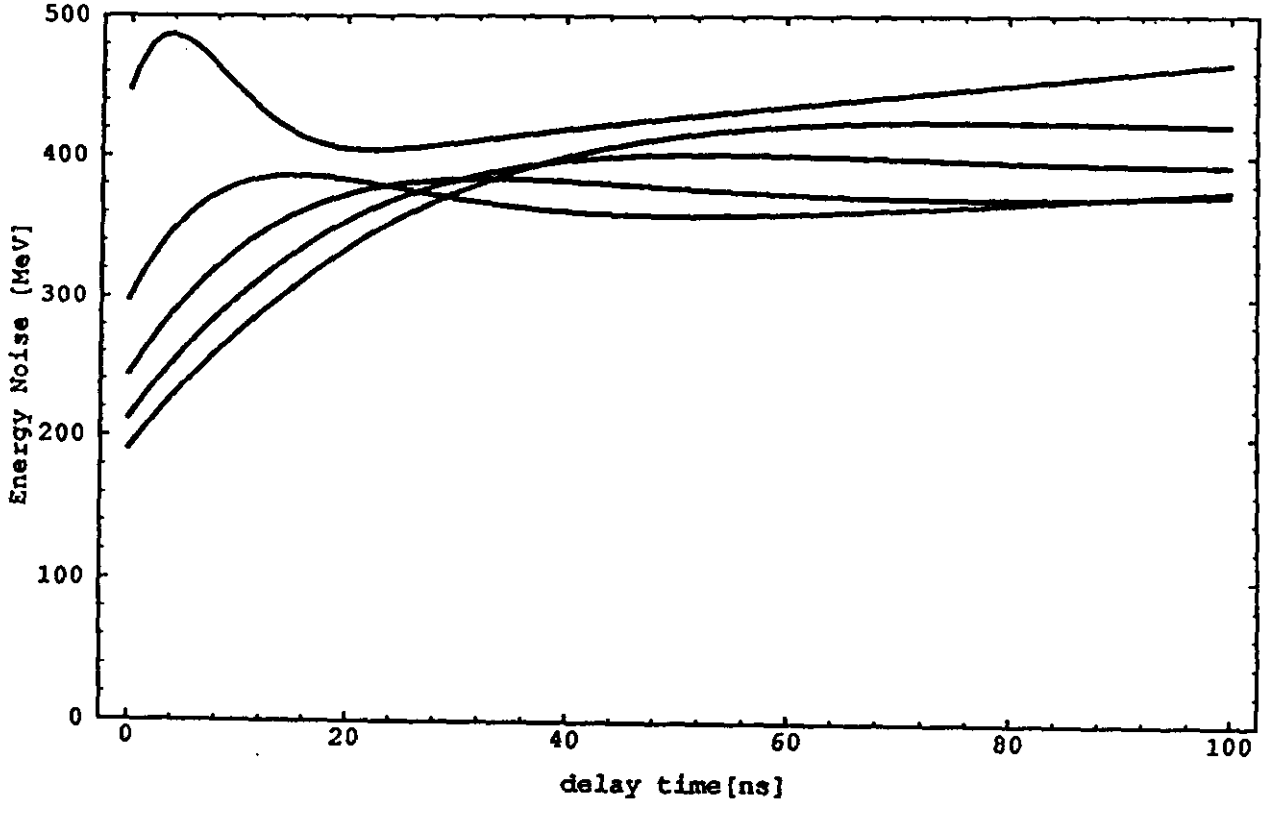


Figure 8: A simulation of the energy noise [MeV] as a function of delay time in the transmission line which connects the calorimeter to the external electronics. We have assumed for these calculations a gas mixture of $10\% CF_4$ and $80\% Ar$ with an operating pressure of $50atm$ and $t_{drift} = 30Nsec$. The absorber material was $25\chi_0$ of tungsten with a tube diameter of $10mm$ and a $1mm$ gas gap. Nine tubes were summed together for a tower size of $3cm \times 3cm$ and a detector capacitance of $400pf$.

E. Kistenev

High presure ionization tube calorimeter (HPITC)

(problems and perspectives)

Basic ideas:

- ionization
  - no internal amplificatio
  - no space charge build up,
  - easy calibration,
- gas
  - radiation hardness,
  - fast responce,
- high presure
  - compensation for a low sumpling fraction
- tubes
  - simplicity of the design

Similar ideas were expressed earlier by a number of people, some were even tested, but the only real data available are for a small Pb/Ar par. plate prototype made by Dolgosheins

Problems

- large pressure vessel,
- low sampling fraction,
- pure energy resolution.

Reasons for reconsideration

- radiation load and ability of HPC to cope with it,
- new design ideas.
  - charge collection scheme
  - manufacturing
  - cost.

Spagetti induced design, where it is today, what is understood, and what should be done to reach reliable conclusions.

Present work was started under influence of a Don - B. Willis discussi
setting some extreme goals

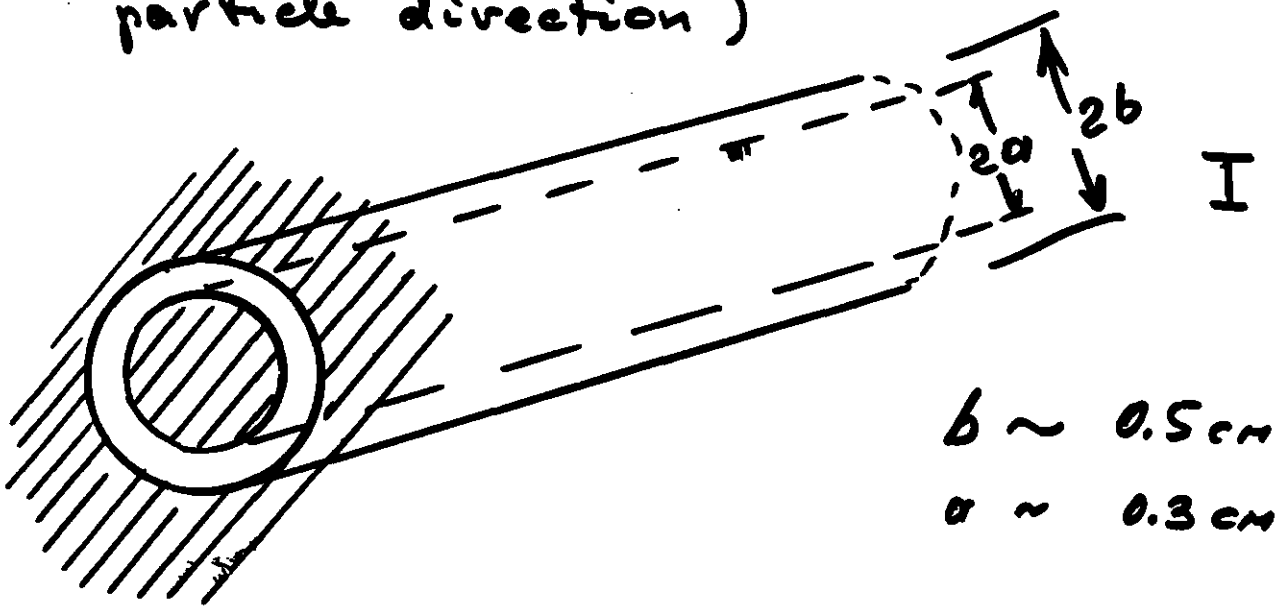
density - if possible equal or denser than W !

resolution - can be bad but should b
perfectly gaussian

e/m compartment - must !!!

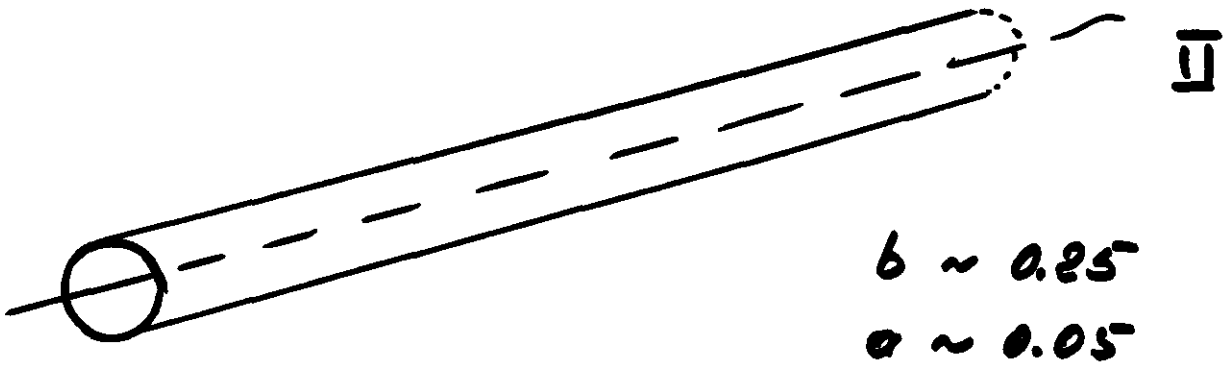
Sensitive element

- gas cilinder oriented along (or better slightly inclined relative to the particle direction)



$b \sim 0.5$ cm

$a \sim 0.3$ cm

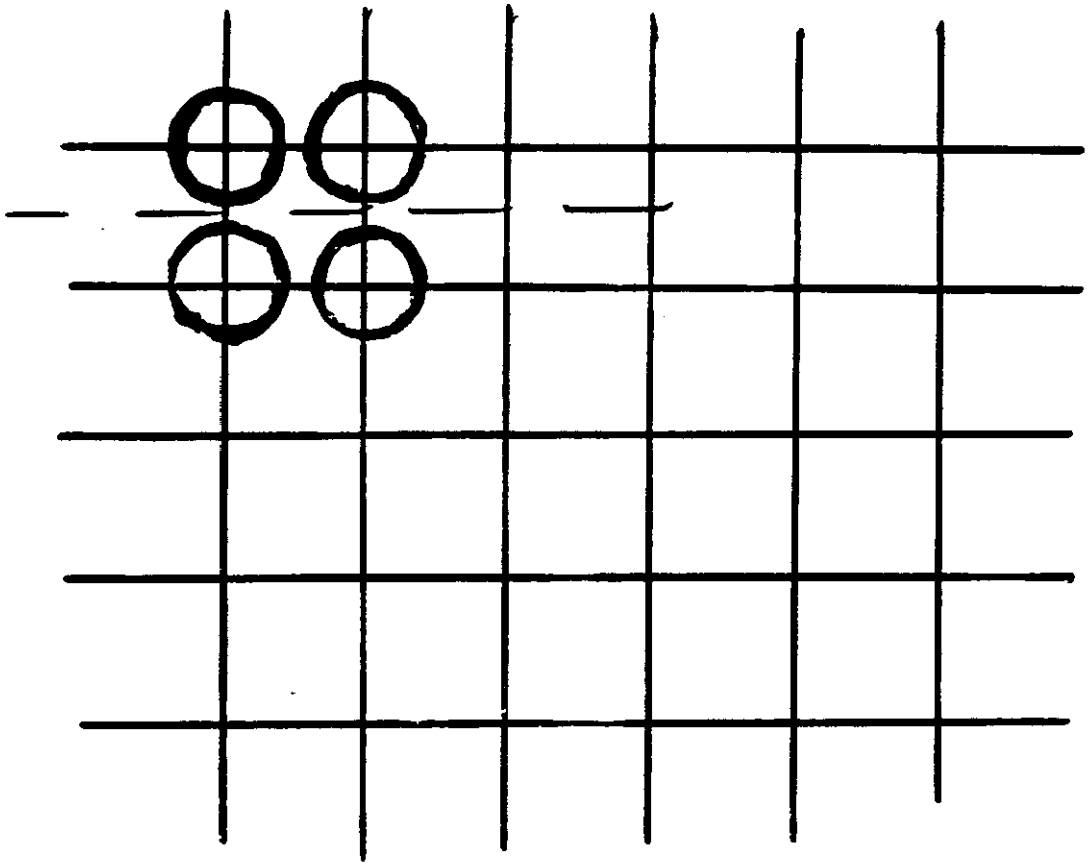


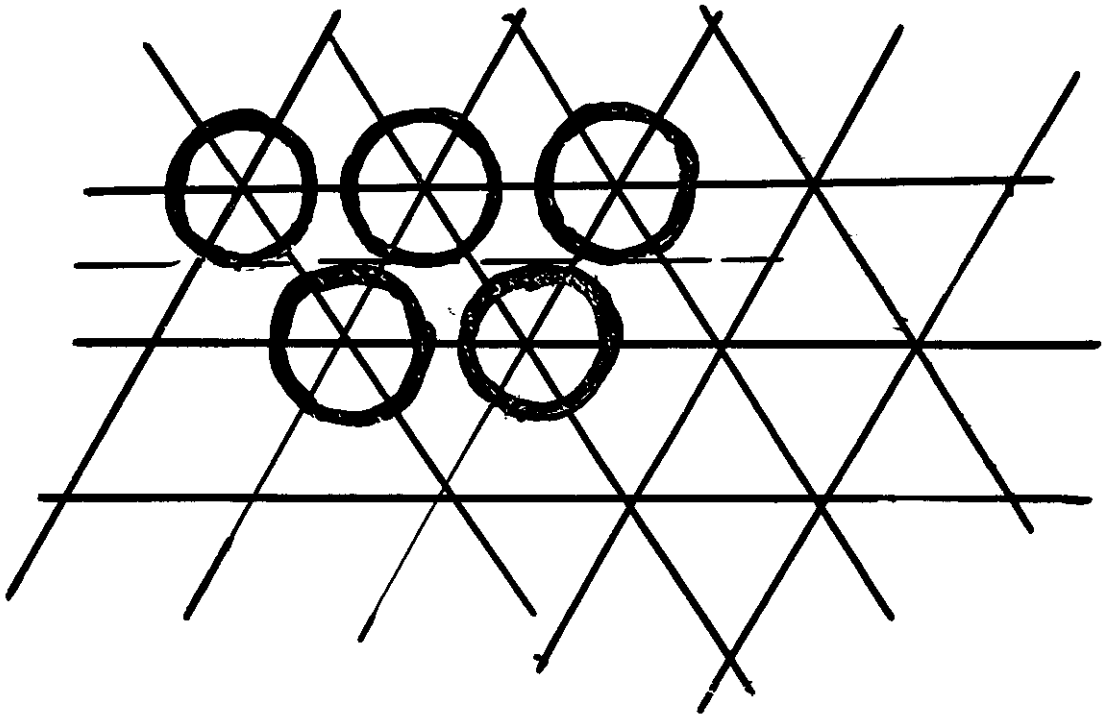
$b \sim 0.25$

$a \sim 0.05$

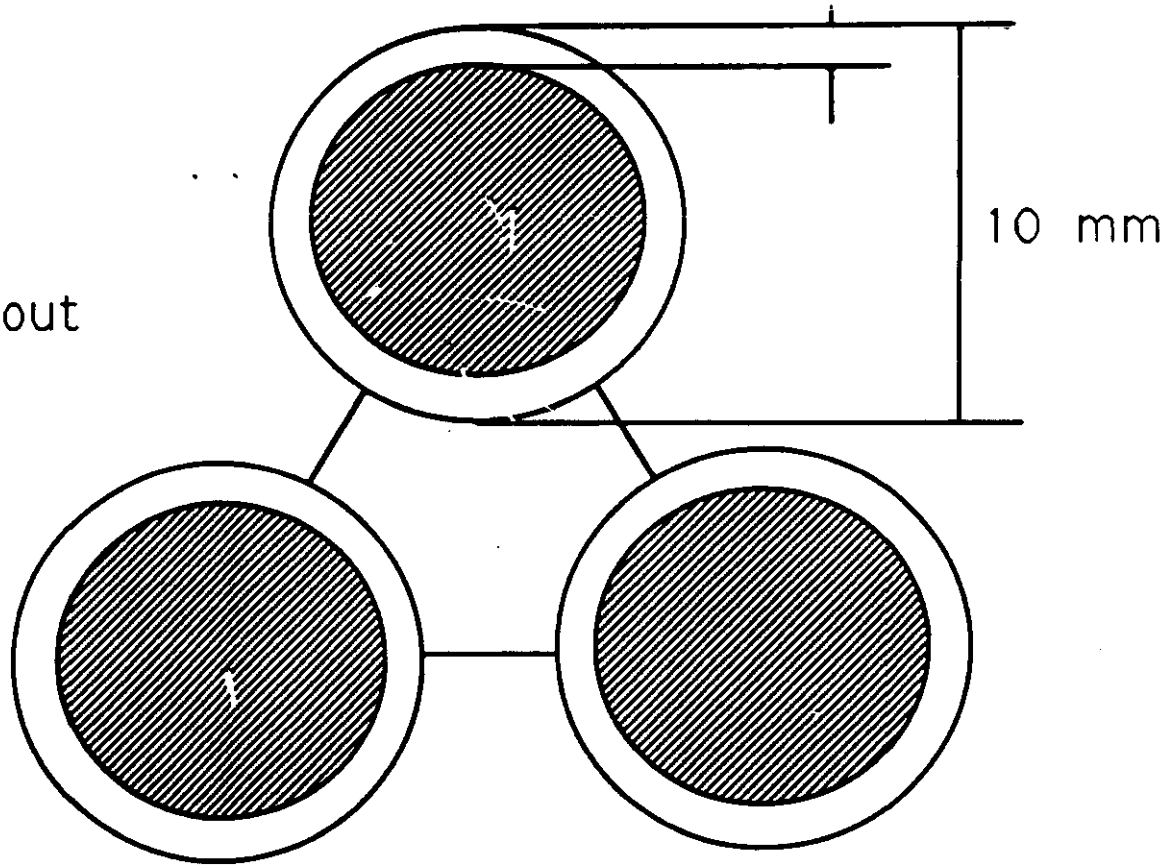
	I		II	
# of tubes	low		high	(x 3÷4)
capacitance	~12/cm	$\frac{2\pi\varepsilon}{\ln b/a}$	3.9 /cm [pf]	
C / unit surf		similar		
HV		20÷40v/mm/atm	(4kv at 100atm)	
collected charge	Q/2		0.6 Q	

Layout

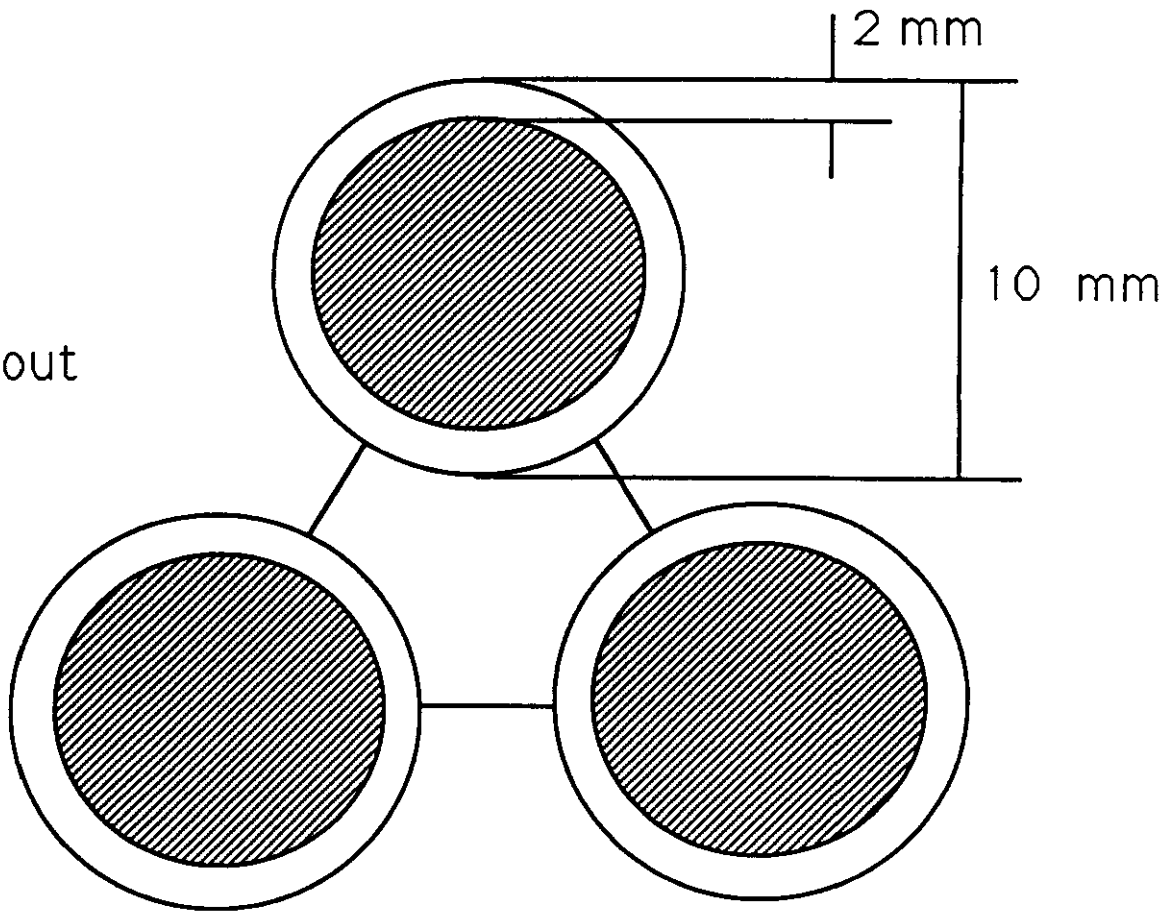


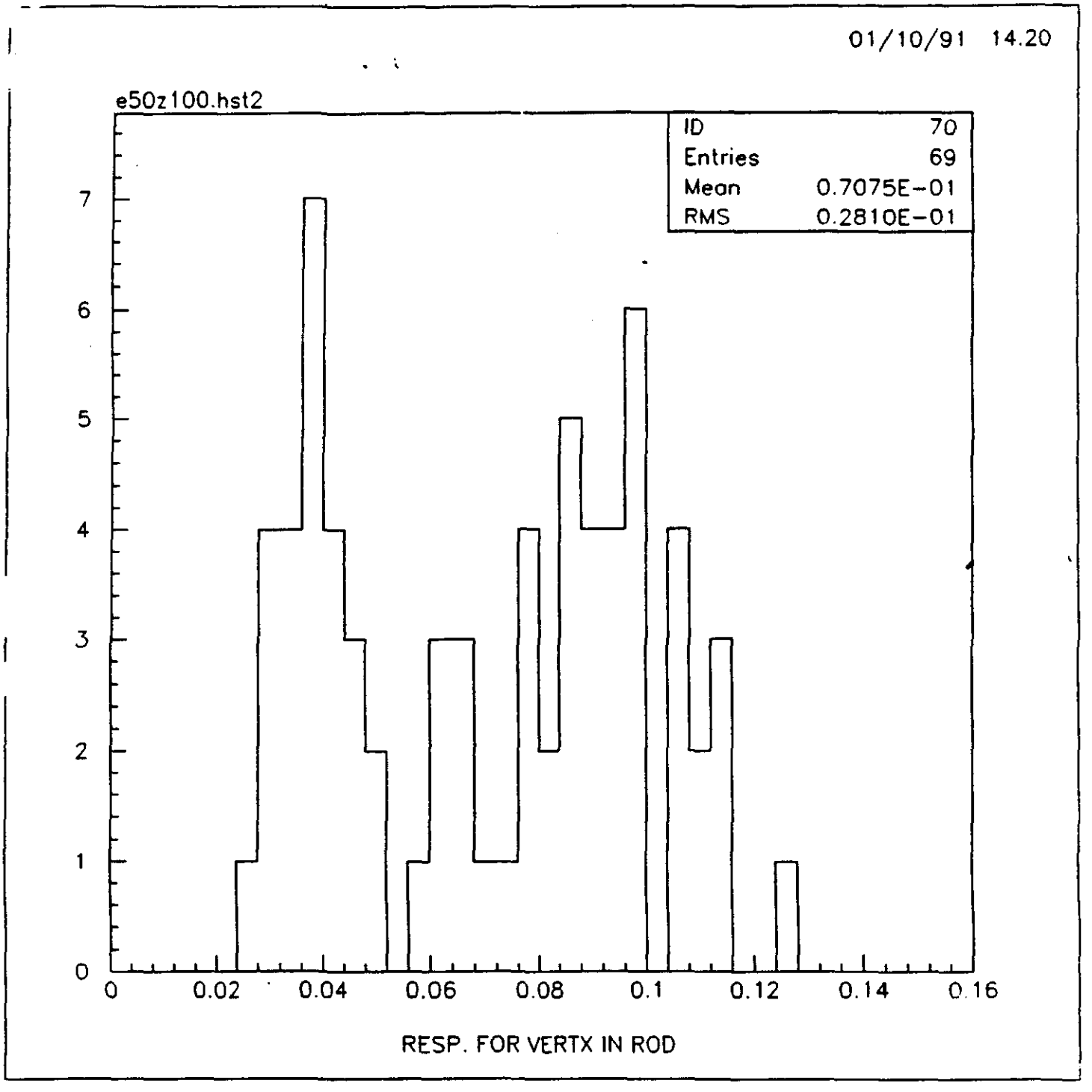


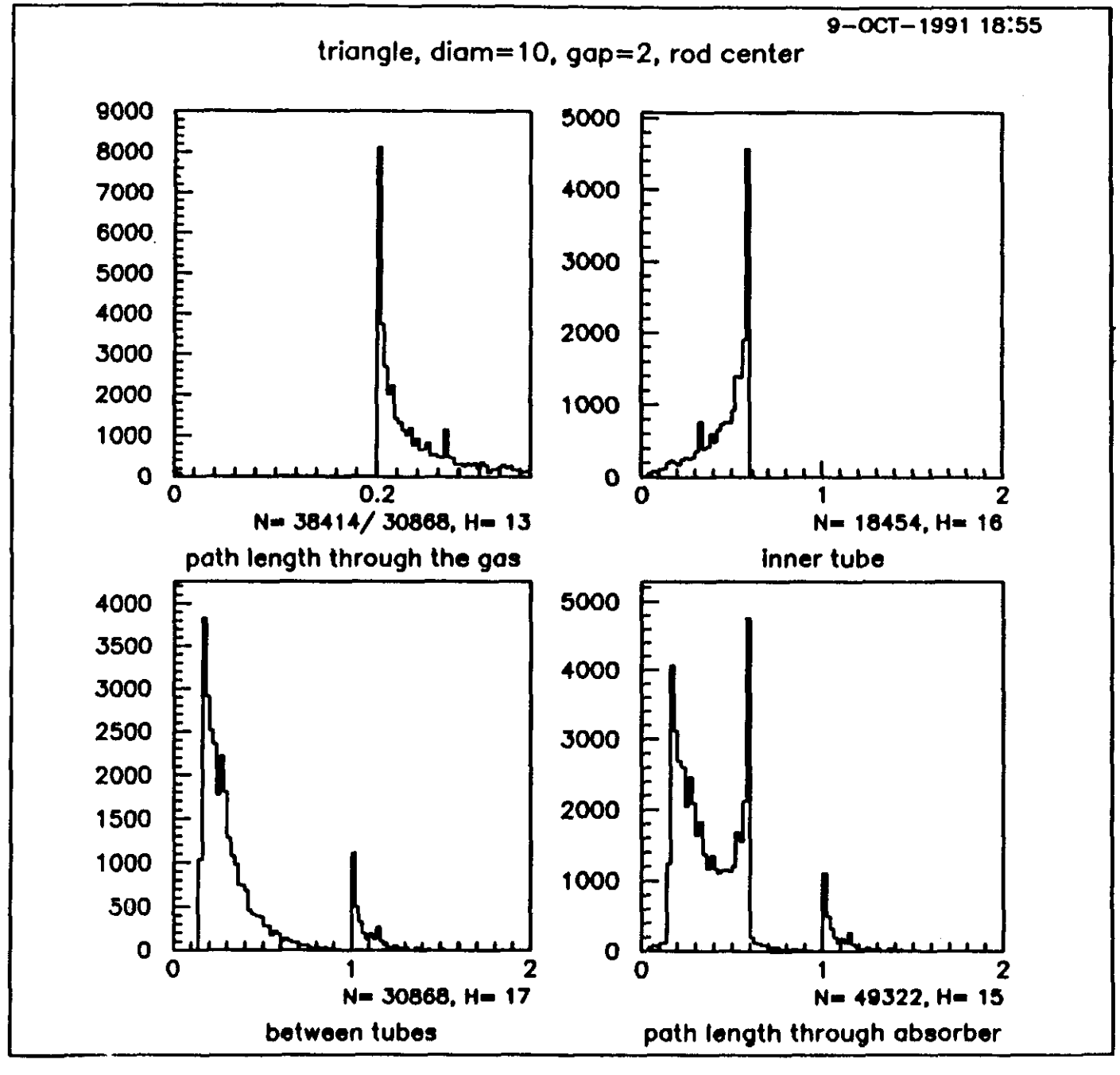
Tube layout

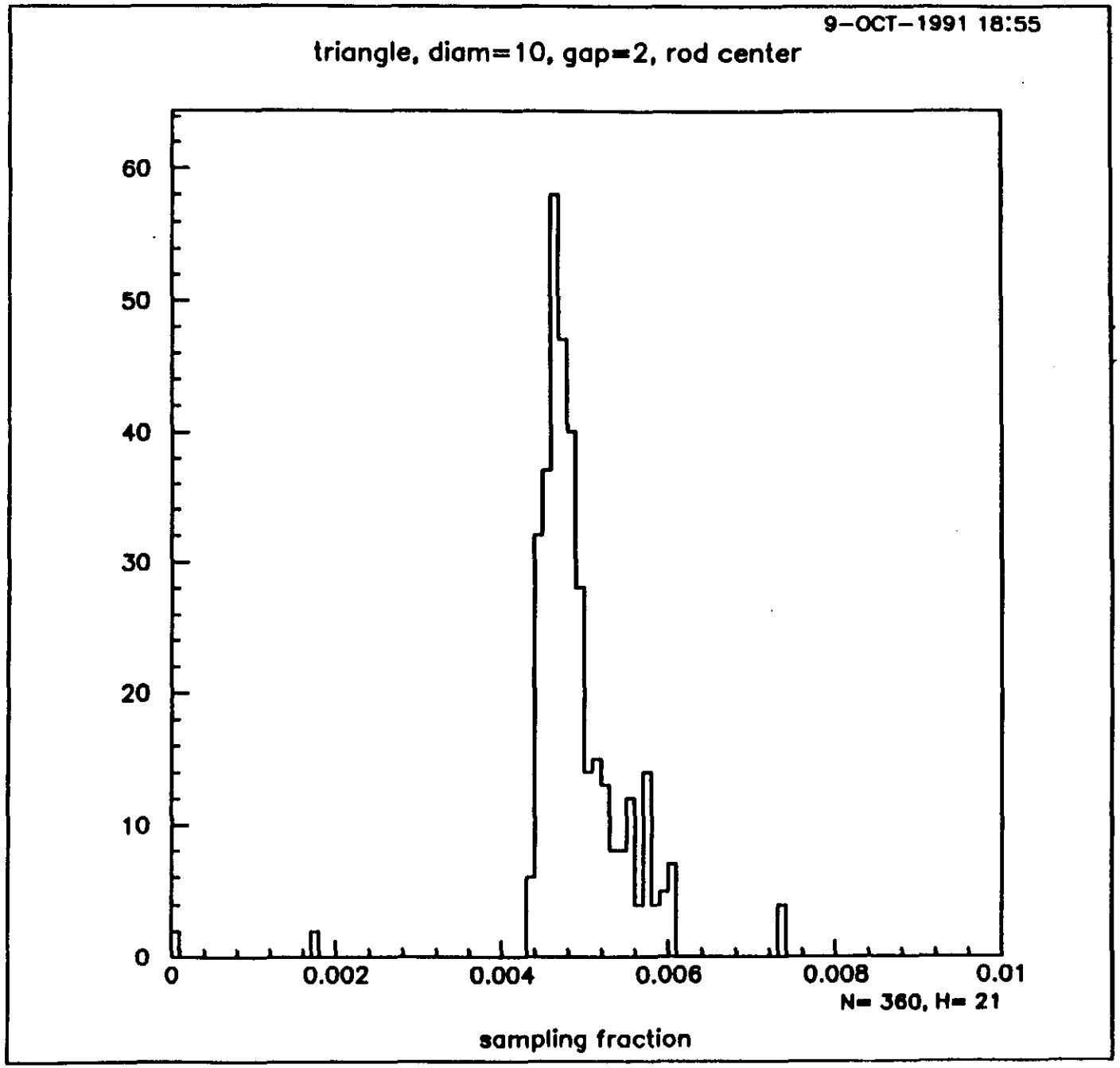


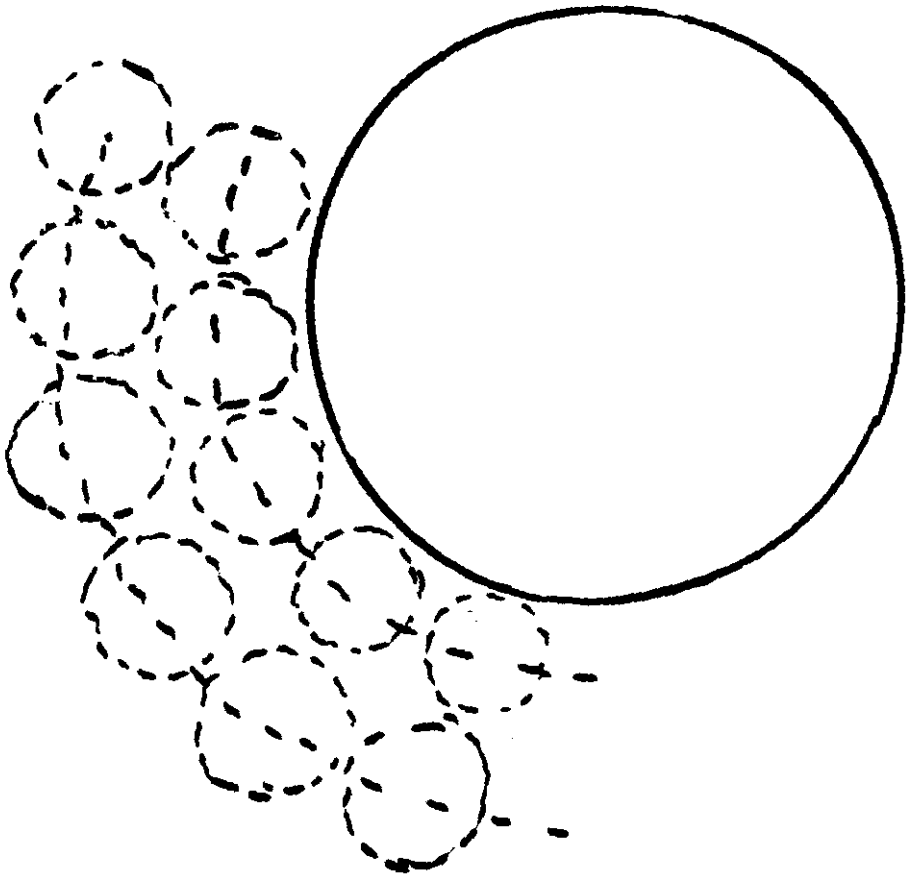
Tube layout




01/10/91 14.20
e50z100.hst2
ID 70
Entries 69
Mean 0.7075E-01
RMS 0.2810E-01
0
1
2
3
4
5
6
7
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
RESP. FOR VERTX IN ROD


9-OCT-1991 18:55
triangle, diam=10, gap=2, rod center
N= 38414/ 30868, H= 13
path length through the gas
N= 18454, H= 16
inner tube
N= 30868, H= 17
between tubes
N= 49322, H= 15
path length through absorber

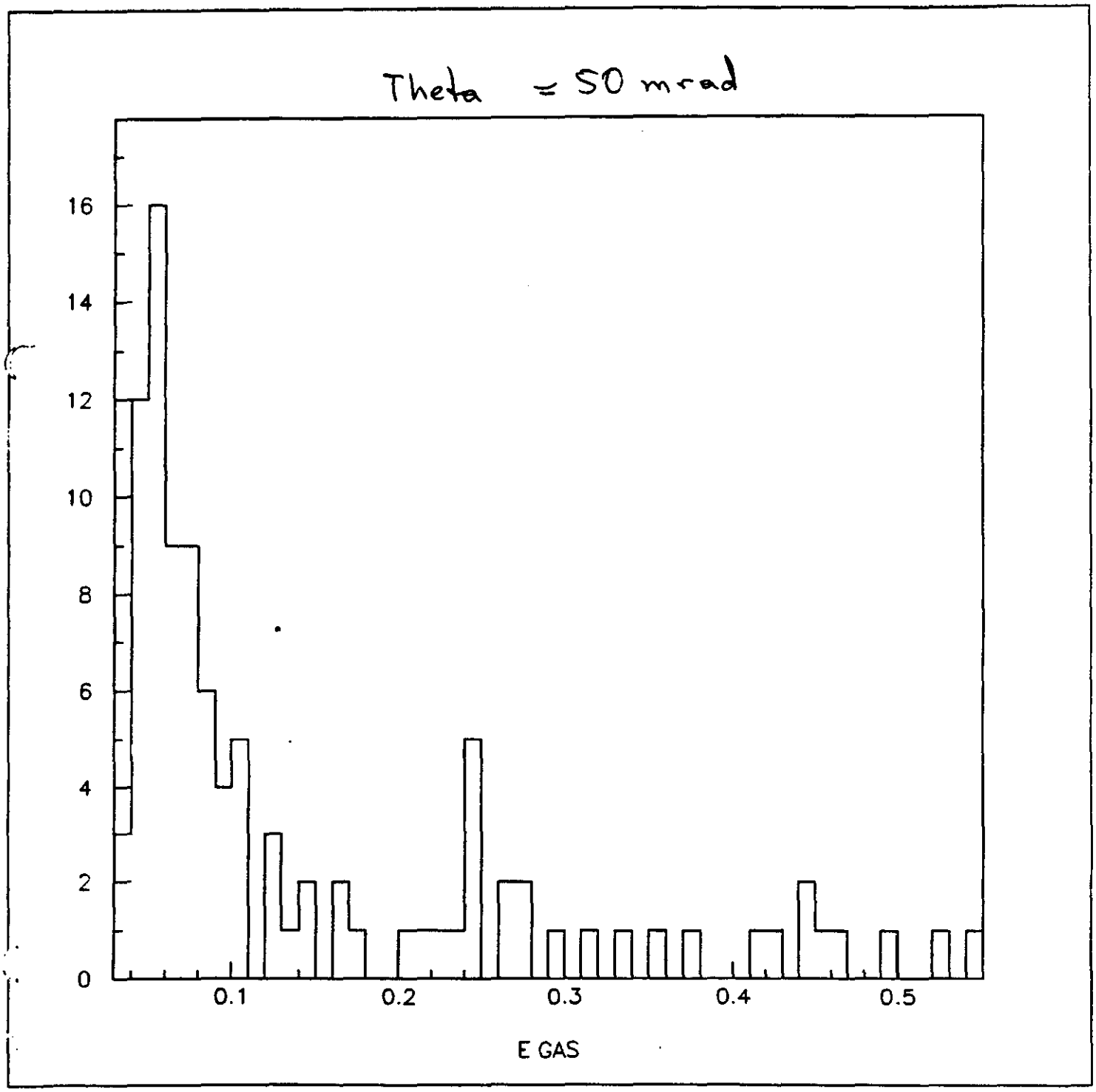

9-OCT-1991 18:55
triangle, diam=10, gap=2, rod center
60
50
40
30
20
10
0
0
0.002
0.004
0.006
0.008
0.01
N= 360, H= 21
sampling fraction

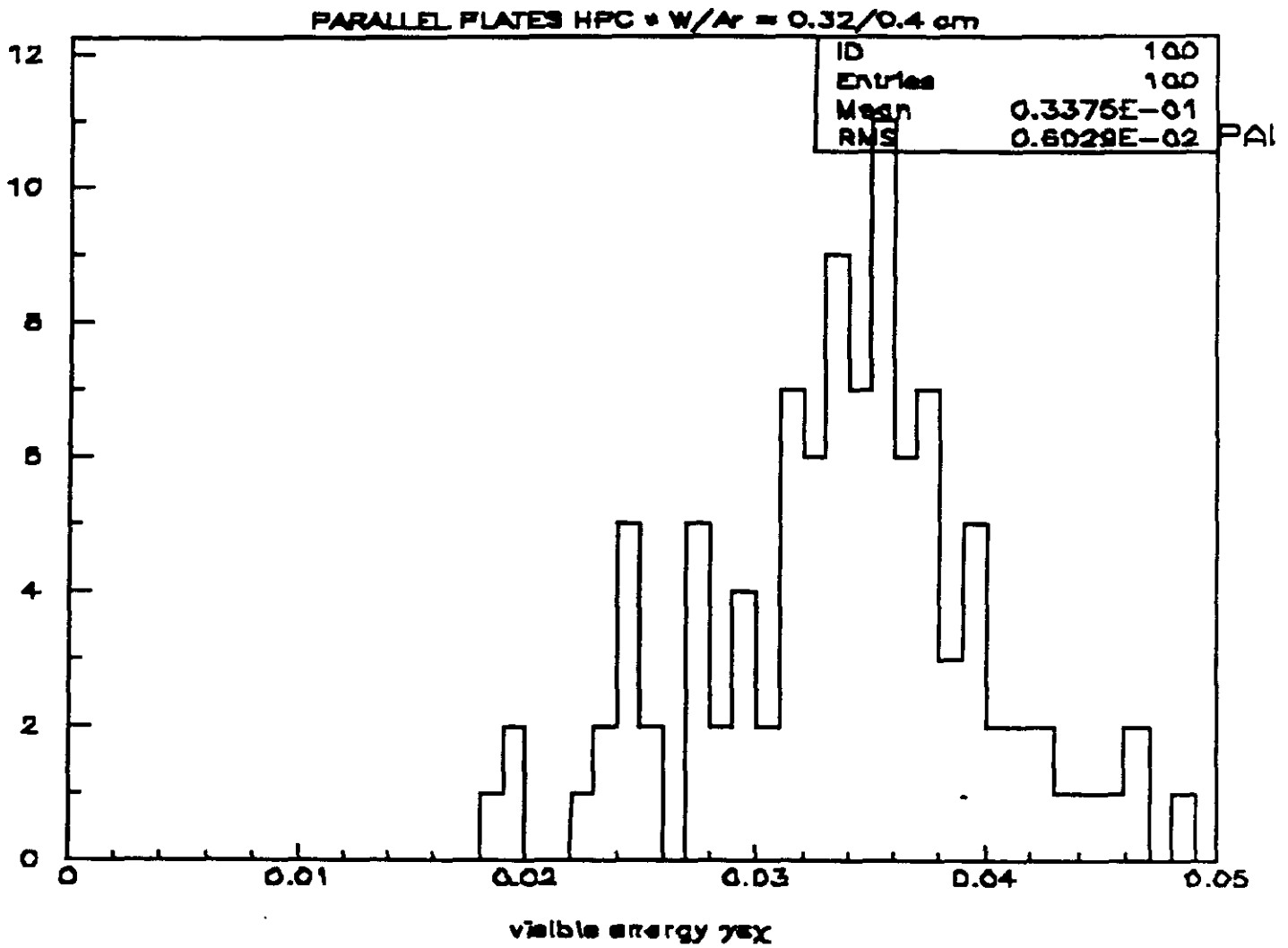


Ø 10 mm, gap = 2 mm.

file E50_25_100

Tubes + rods Ø 10/6





$$\frac{V_w}{V_{tot}} = \frac{0.32}{0.72} = 0.44$$

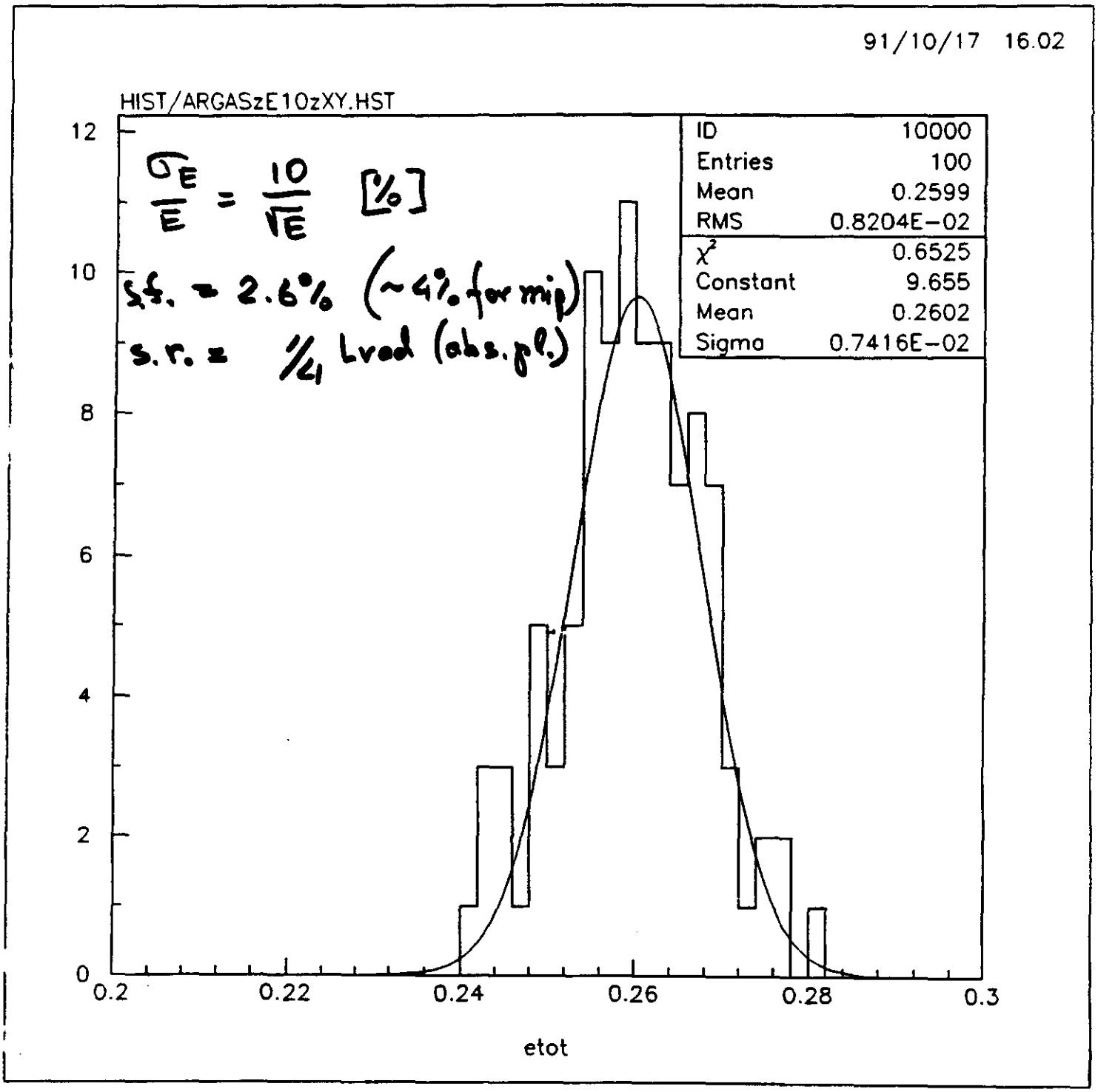
$$s.f = 0.0033 \quad (0.3\,\%)$$

$$\frac{\sigma}{E} = \frac{60}{\sqrt{E}}\,\% \quad \text{— ultimate goal } (e/m)$$

$$s.r = 1/L_{rad}$$

High pressure Accordion

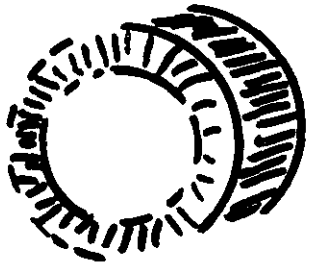
10gw $\rho = 0.2\ g/cm^3$, cate = 0.0000
γ = 0.0000



to cut high energy tail we need to move towards the parallel plate geometry

$\Downarrow$

let us introduce spacers into the tube (to cut the path)

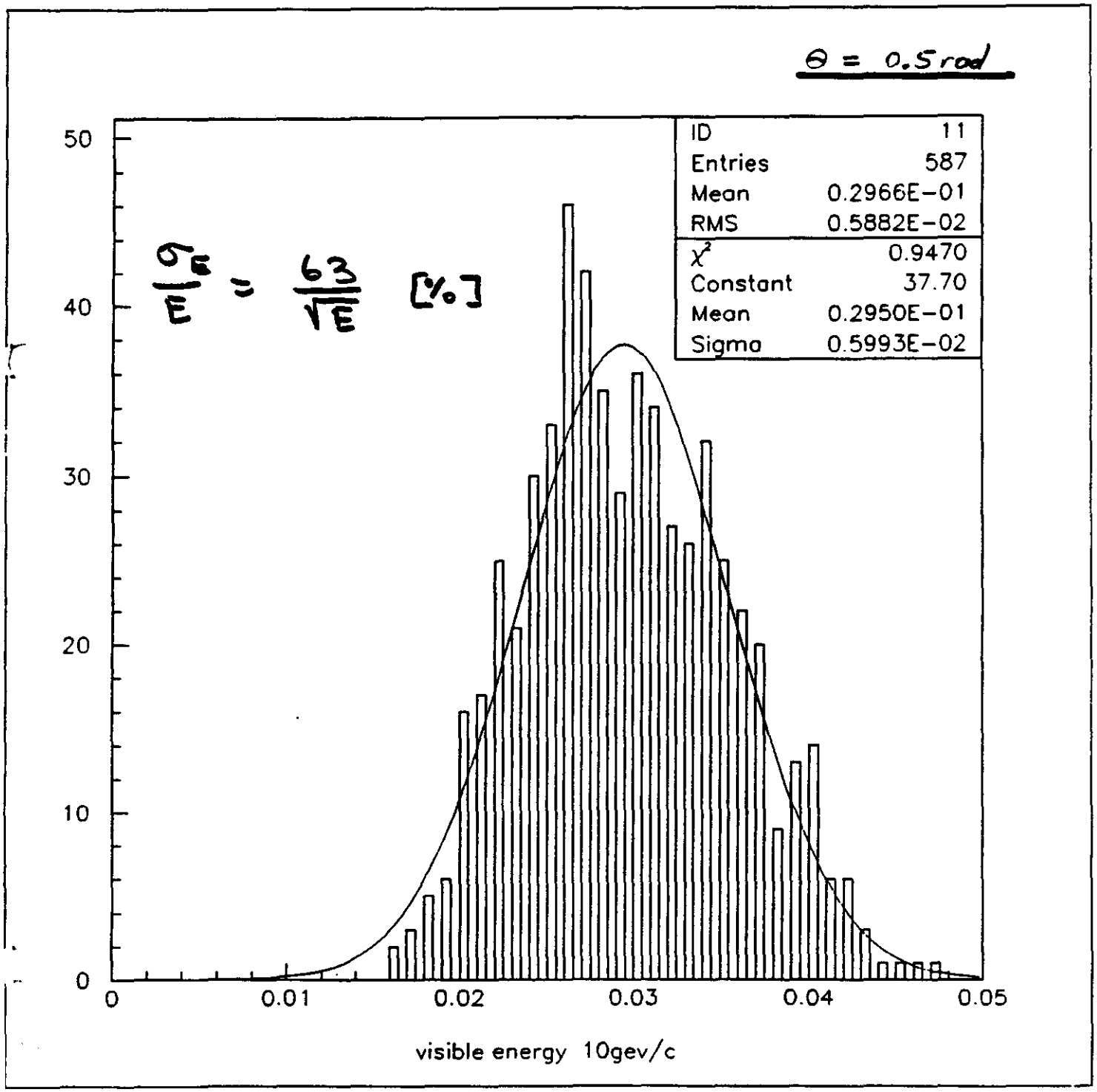


circular arrangement gap = 2 mm
sec.d. = 1.6 cm
spacer = 0.32 cm
θ = 0.5 rad

E = 10 gev

electron =

Tubes + rods + spacers

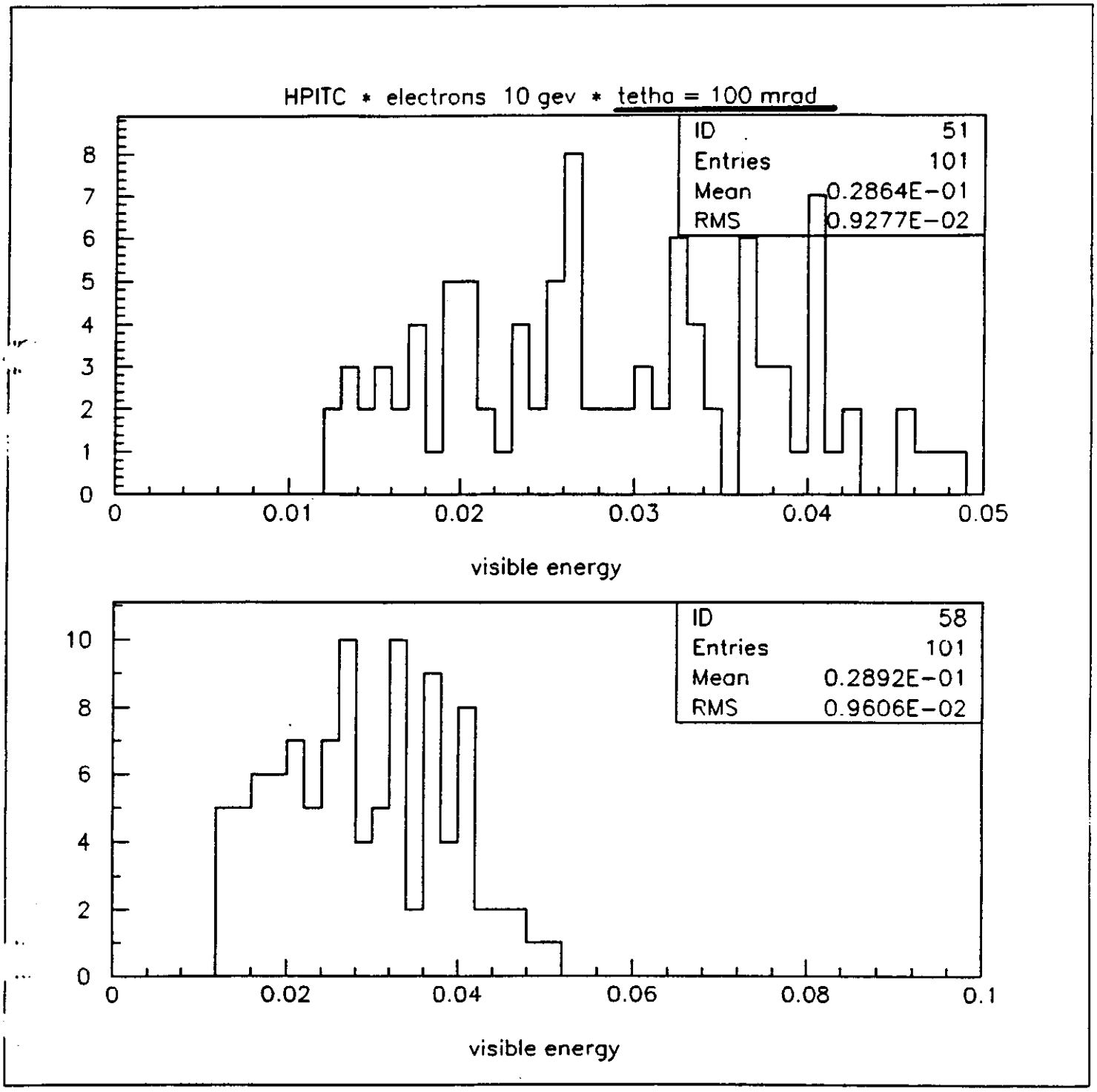


circular arrangement

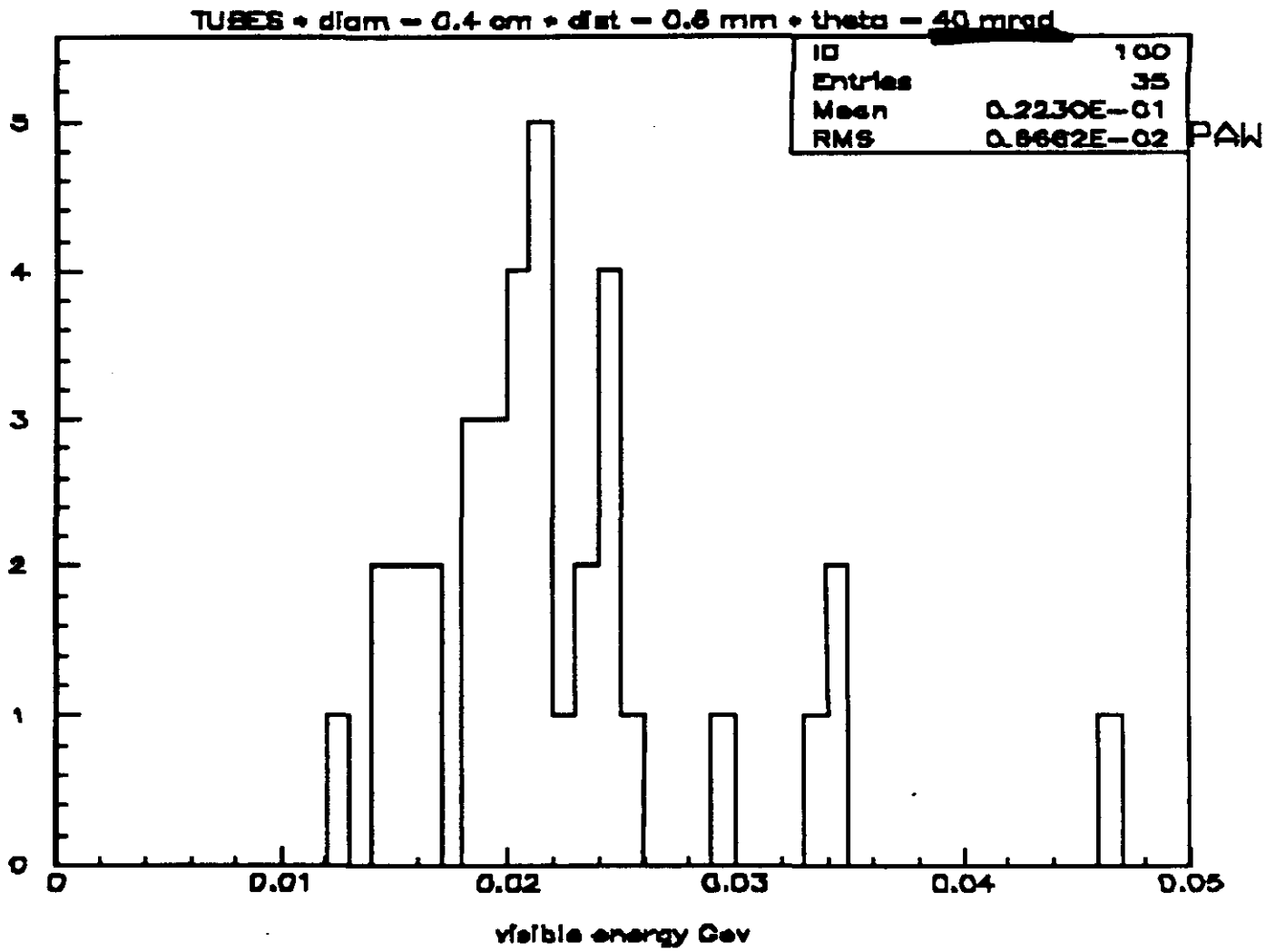
gap = 2 m
sec. depth = 1.6c
spacer = 0.32c

electrons
10 gev/c

Tubes + rods + spacers



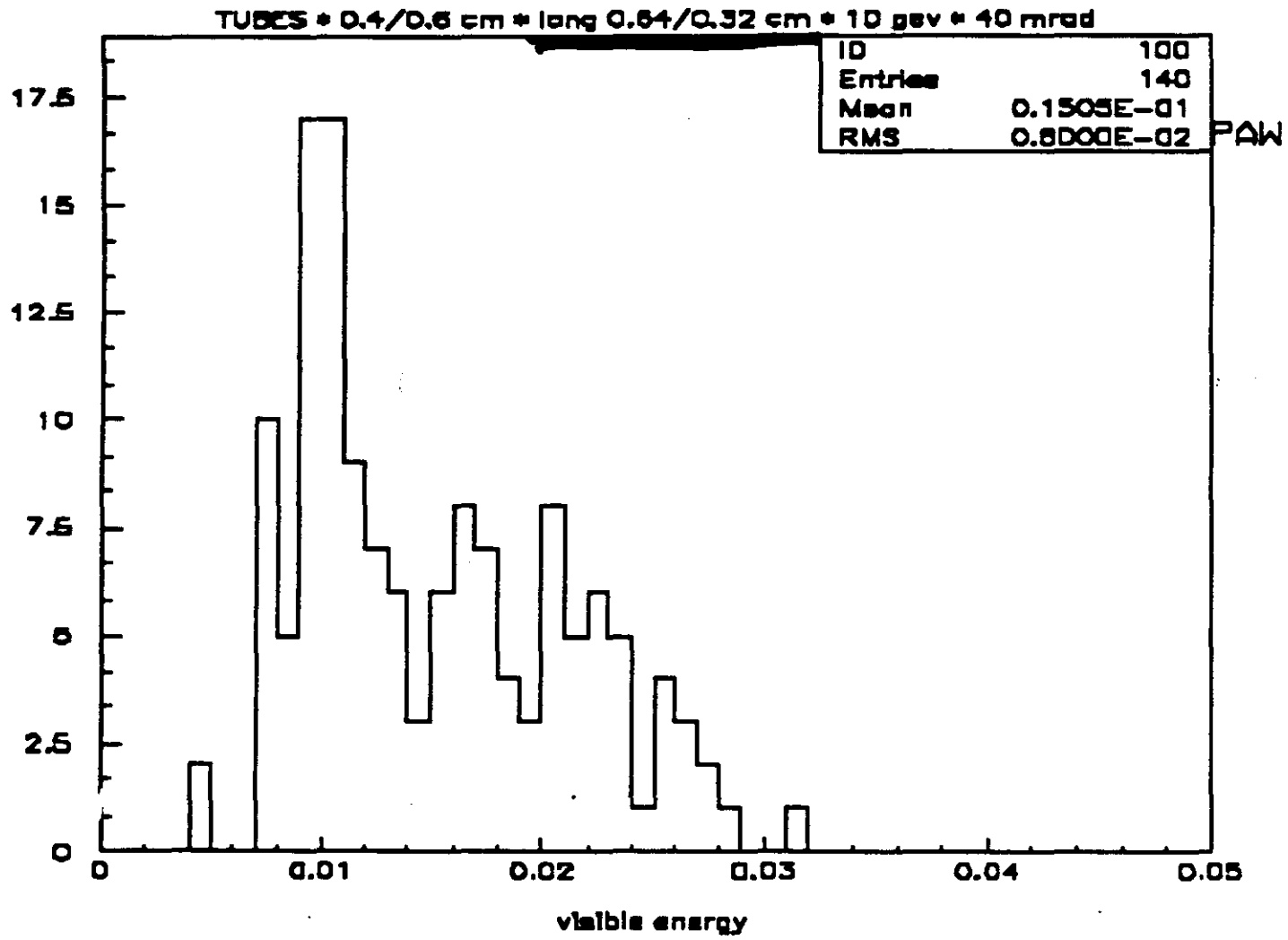
Tubes 0.4cm (nospacers)



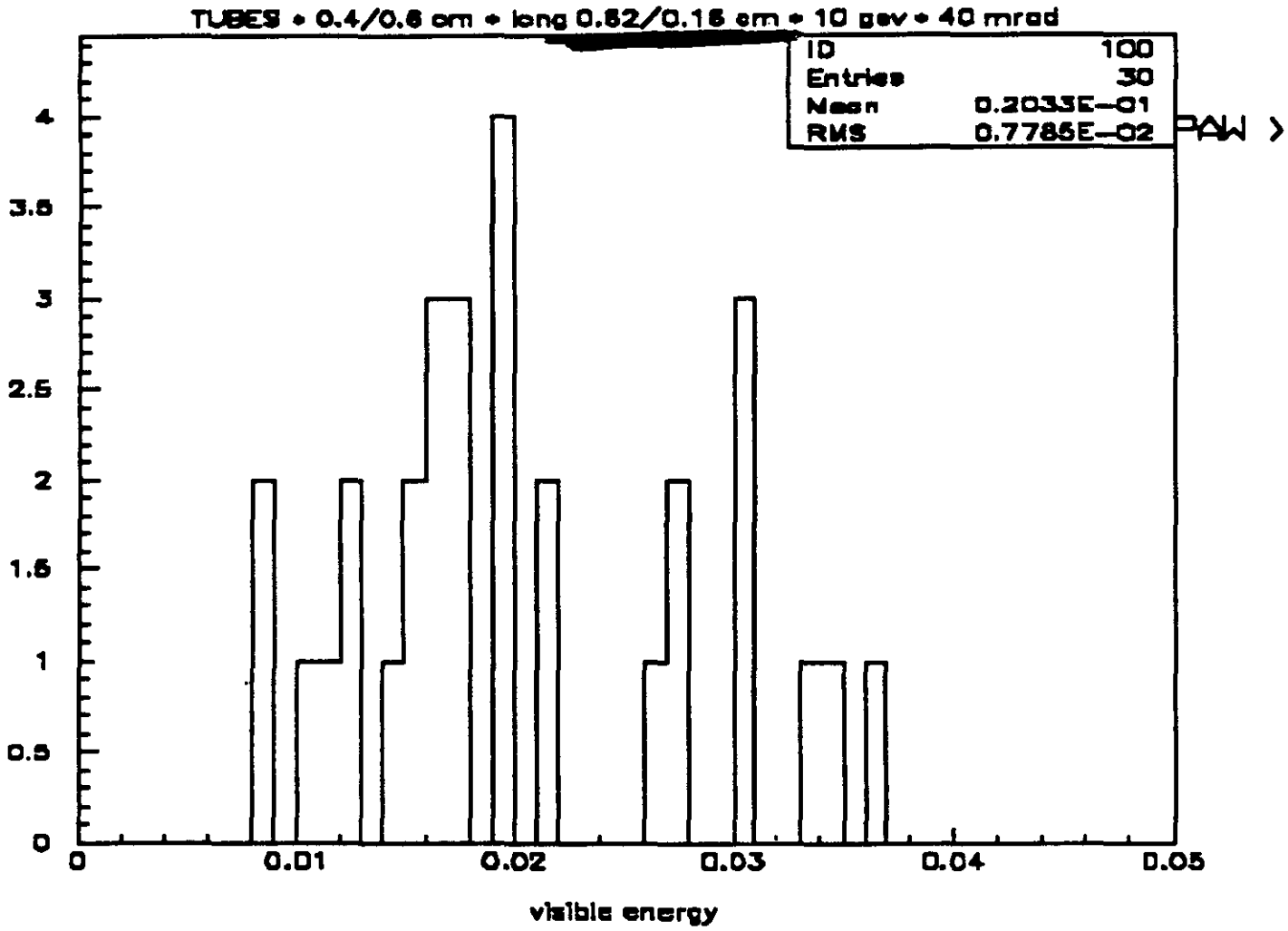
$$\frac{\sigma_E}{E} \sim \frac{90}{\sqrt{E}}\,[\%]$$

s.f = 0.22% (e) → (~0.3% for mip)

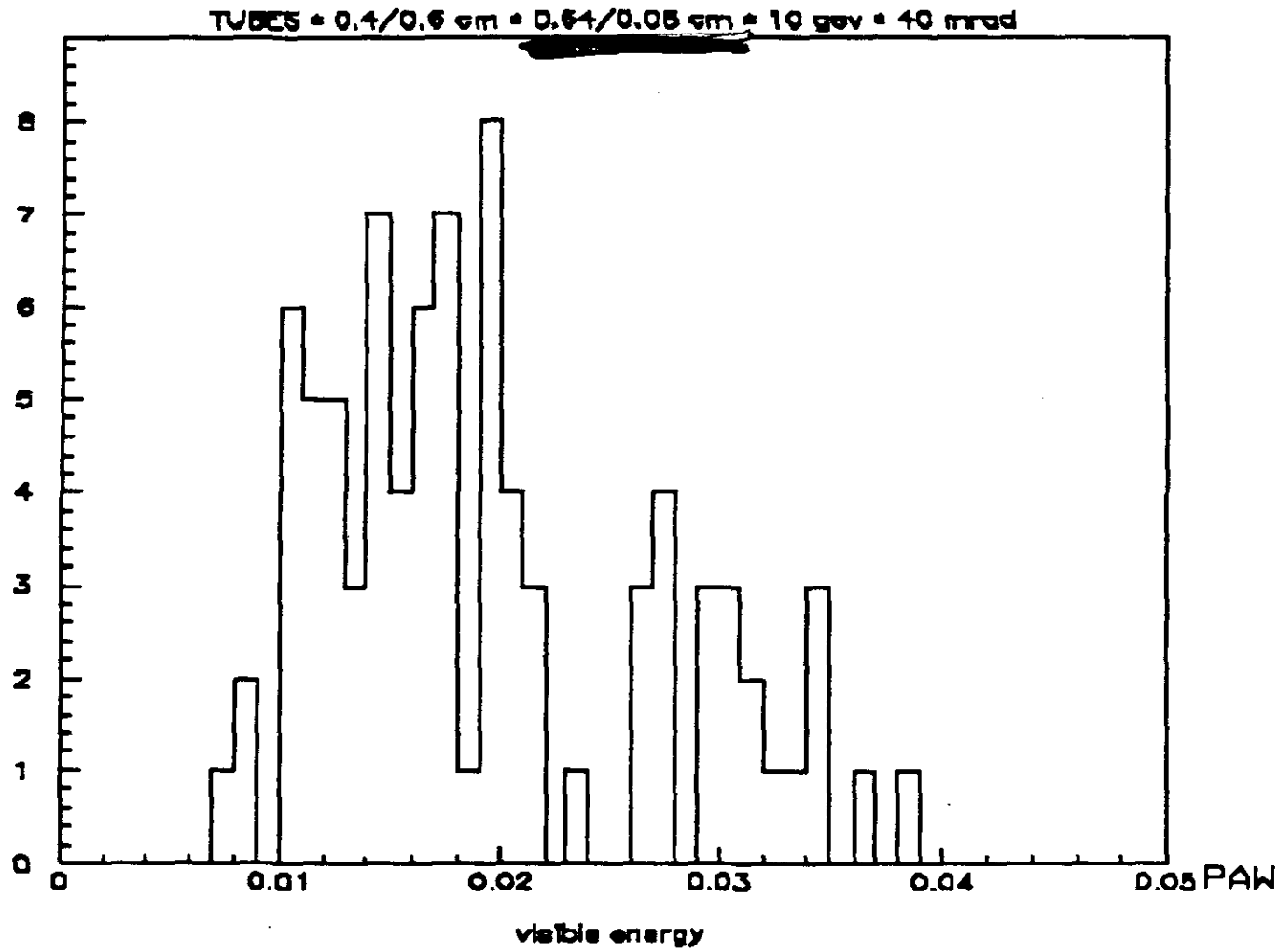
Tubes + spacers



Tubes + spacers



preliminary - 1rad/2 spacers
are probably O.K.


TUBES = 0.4/0.6 cm = 0.64/0.05 cm = 10 gev = 40 mrad
[redacted]
0
1
2
3
4
5
6
7
8
0
0.01
0.02
0.03
0.04
0.05
PAW
visible energy

Conclusions

- HPITC is doable;
- it can provide a gaussian response to electrons
- e/m - HAC1 should probably be made out of a relatively thin tubes (~ 5mm),
- need a couple of more months of a simulation work,
- engeeneering of prototypes can proceed - optimization is mainly aiming to the layout and spacer geometry and positioning

Finally

Needs a lot of prototyping work to be really proven.

Liquid Scintillator based Forward Capillary Calorimeter for GEM

R. Webb, N. Diaczenko, A. David, S. Zaman
A. Sanzgiri
Texas A&M University

C. Cane
Drexel University

Provide reasonably high performance FCAL for SSC physics program.

<u>Calorimeter Needs</u>

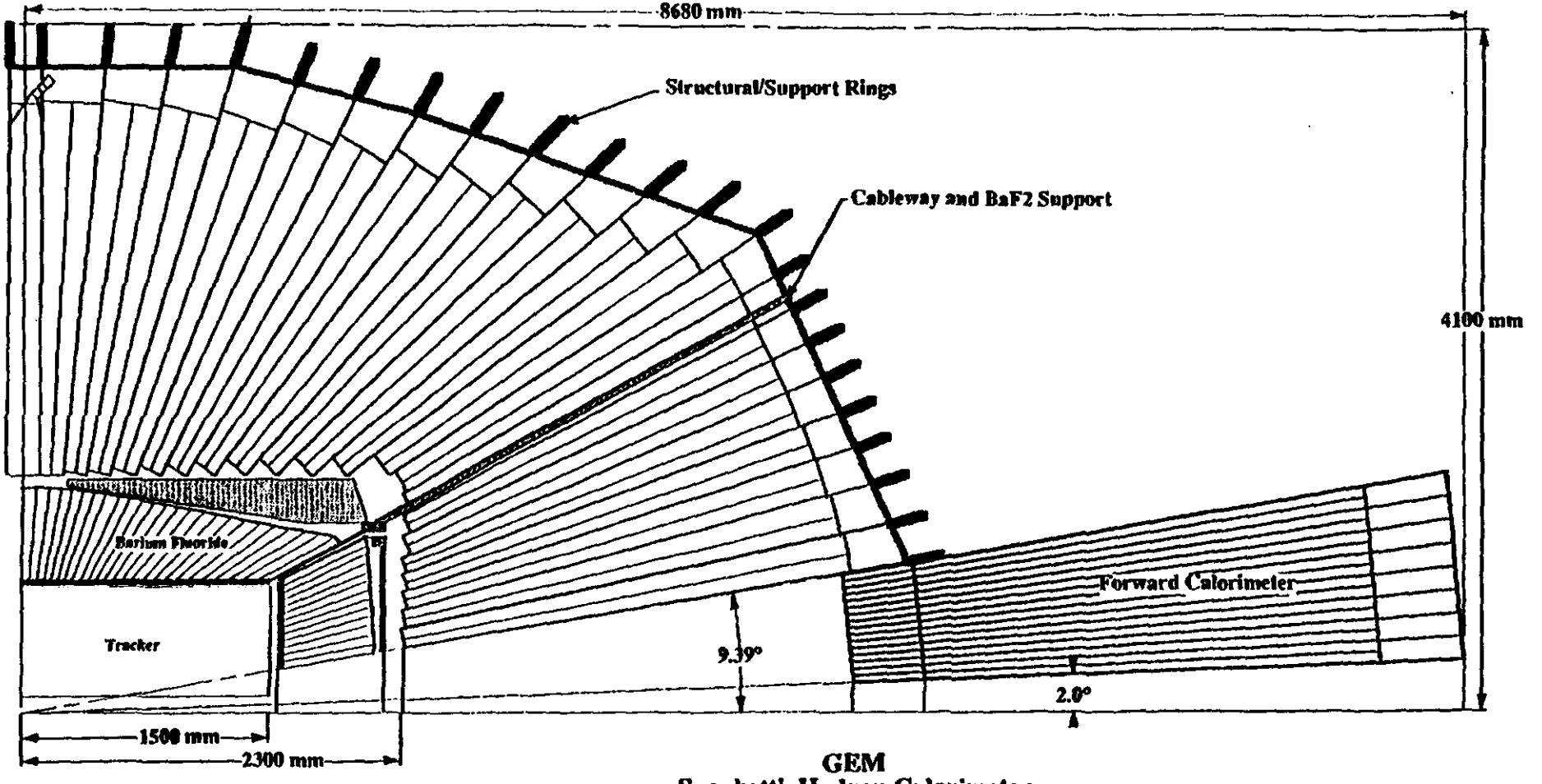
Modest Energy Resolution ; $\sigma/E \sim 50\text{-}100\%/\sqrt{E}$

Coverage to largest η possible. ; $\eta_{max} \sim 5$

Fast response ; able to work at bunch crossing rate

Affordable ; cost $\lesssim \$20M$

Radiation Resistant ; must survive MRad



G.03.SC.00044

GEM
Spaghetti Hadron Calorimeter
Barium Fluoride EM Calorimeter

Rennich

Early proposal to GEM
for a forward Capillary PCAL

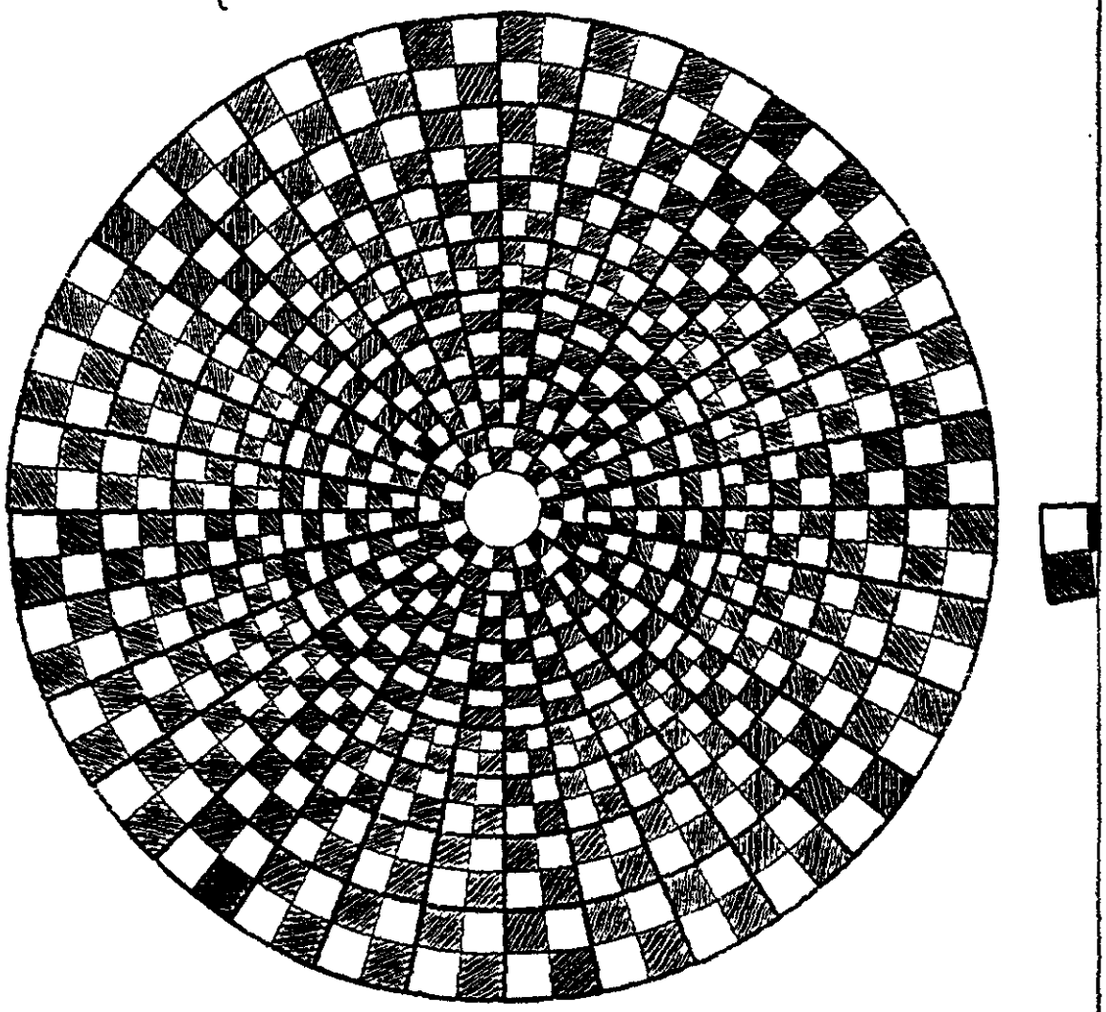
Table of Radii for GEM Forward Calorimeter
(calorimeter positioned at z=5.00 m from IR)
dimensions given in cm

		eta	theta(rad)	500	679	819	azimuthal
-	1	2.50000	.16380E+00	.82642E+02	.11223E+03	.13537E+03	64
	2	2.55000	.15585E+00	.78561E+02	.10669E+03	.12868E+03	
-	3	2.60000	.14827E+00	.74686E+02	.10142E+03	.12234E+03	"
	4	2.65000	.14107E+00	.71006E+02	.96426E+02	.11631E+03	
-	5	2.70000	.13421E+00	.67510E+02	.91679E+02	.11058E+03	"
	6	2.75000	.12768E+00	.64190E+02	.87170E+02	.10514E+03	
-	7	2.80000	.12147E+00	.61036E+02	.82887E+02	.99977E+02	"
	8	2.85000	.11556E+00	.58039E+02	.78816E+02	.95067E+02	
-	9	2.90000	.10994E+00	.55190E+02	.74948E+02	.90402E+02	"
	10	2.95000	.10458E+00	.52483E+02	.71273E+02	.85968E+02	
-	11	3.00000	.99492E-01	.49911E+02	.67779E+02	.81754E+02	"
	12	3.05000	.94647E-01	.47465E+02	.64458E+02	.77748E+02	
-	13	3.10000	.90038E-01	.45141E+02	.61301E+02	.73941E+02	"
	14	3.15000	.85652E-01	.42931E+02	.58300E+02	.70321E+02	
-	15	3.20000	.81479E-01	.40830E+02	.55447E+02	.66880E+02	"
	16	3.25000	.77510E-01	.38833E+02	.52735E+02	.63608E+02	
-	17	3.30000	.73733E-01	.36933E+02	.50156E+02	.60497E+02	32
	18	3.35000	.70140E-01	.35128E+02	.47703E+02	.57539E+02	
-	19	3.40000	.66722E-01	.33410E+02	.45371E+02	.54726E+02	"
	20	3.45000	.63470E-01	.31778E+02	.43154E+02	.52052E+02	
-	21	3.50000	.60376E-01	.30225E+02	.41045E+02	.49508E+02	"
	22	3.55000	.57433E-01	.28748E+02	.39040E+02	.47090E+02	
	23	3.60000	.54634E-01	.27344E+02	.37133E+02	.44790E+02	
-	24	3.65000	.51971E-01	.26009E+02	.35320E+02	.42602E+02	"
	25	3.70000	.49437E-01	.24739E+02	.33595E+02	.40522E+02	
	26	3.75000	.47027E-01	.23531E+02	.31955E+02	.38543E+02	
-	27	3.80000	.44734E-01	.22382E+02	.30395E+02	.36662E+02	"
	28	3.85000	.42553E-01	.21289E+02	.28911E+02	.34872E+02	
	29	3.90000	.40478E-01	.20250E+02	.27500E+02	.33170E+02	
	30	3.95000	.38505E-01	.19262E+02	.26158E+02	.31551E+02	
-	31	4.00000	.36627E-01	.18322E+02	.24881E+02	.30011E+02	"
	32	4.05000	.34841E-01	.17428E+02	.23667E+02	.28547E+02	
	33	4.10000	.33142E-01	.16577E+02	.22512E+02	.27154E+02	
	34	4.15000	.31526E-01	.15768E+02	.21413E+02	.25829E+02	
	35	4.20000	.29989E-01	.14999E+02	.20369E+02	.24568E+02	
-	36	4.25000	.28527E-01	.14267E+02	.19375E+02	.23370E+02	16
	37	4.30000	.27135E-01	.13571E+02	.18429E+02	.22229E+02	
	38	4.35000	.25812E-01	.12909E+02	.17530E+02	.21145E+02	
	39	4.40000	.24553E-01	.12279E+02	.16675E+02	.20113E+02	
	40	4.45000	.23356E-01	.11680E+02	.15862E+02	.19132E+02	
	41	4.50000	.22217E-01	.11110E+02	.15088E+02	.18199E+02	
-	42	4.55000	.21134E-01	.10568E+02	.14352E+02	.17311E+02	"
	43	4.60000	.20103E-01	.10053E+02	.13652E+02	.16467E+02	
	44	4.65000	.19123E-01	.95625E+01	.12986E+02	.15663E+02	
	45	4.70000	.18190E-01	.90960E+01	.12352E+02	.14899E+02	
	46	4.75000	.17303E-01	.86523E+01	.11750E+02	.14173E+02	
	47	4.80000	.16459E-01	.82303E+01	.11177E+02	.13481E+02	
	48	4.85000	.15656E-01	.78289E+01	.10632E+02	.12824E+02	
	49	4.90000	.14893E-01	.74470E+01	.10113E+02	.12198E+02	
	50	4.95000	.14167E-01	.70838E+01	.96197E+01	.11603E+02	
-	51	5.00000	.13476E-01	.67383E+01	.91505E+01	.11037E+02	"

This calorimeter has a total of 704 Towers/end with each one being readout via a photodevice of the same type being developed for the central SPACAL calorimeter. Four of these towers are then grouped together to form a Super-Tower for construction and assembly purposes(176 super-towers/end). The eta-phi segmentation chosen has been strongly influenced by the fact that the smallest sensible unit of segmentation for the forward hadron calorimeter should be comparable to the size of a typical shower in this device.

$\Delta\eta \times \Delta\phi$
Segmentation

All Towers in Forward Calorimeter
at exit face @ $Z \simeq 8.19$ m from IR
$2.5 < \eta < 5.0$



From E/T EOI

Each EM section is followed by a HAD section consisting of 3 mm diameter fibers and lead alloy in the volume ratio 1:5. These fibers will be exactly projective and have no mirroring on the front ends because of the larger attenuation lengths expected for 3 mm fibers. Fibers will end flush with the lead at the readout side and will be coupled through an optical fiber bundle to photomultipliers. Each fiber bundle is embedded in lead to increase the shielding of the muon chambers. The assembly of integrated towers and their installation into a complete calorimeter is illustrated in Fig. 2-4. Properties of the design are listed in Table 2-2 and Fig. 2-5.

A preliminary manufacturing design for all components of the scintillating fiber calorimeter has been developed [7]. For EM and HAD sections, fibers are fed in parallel from large numbers of spools through die-cast precision positioning plates.

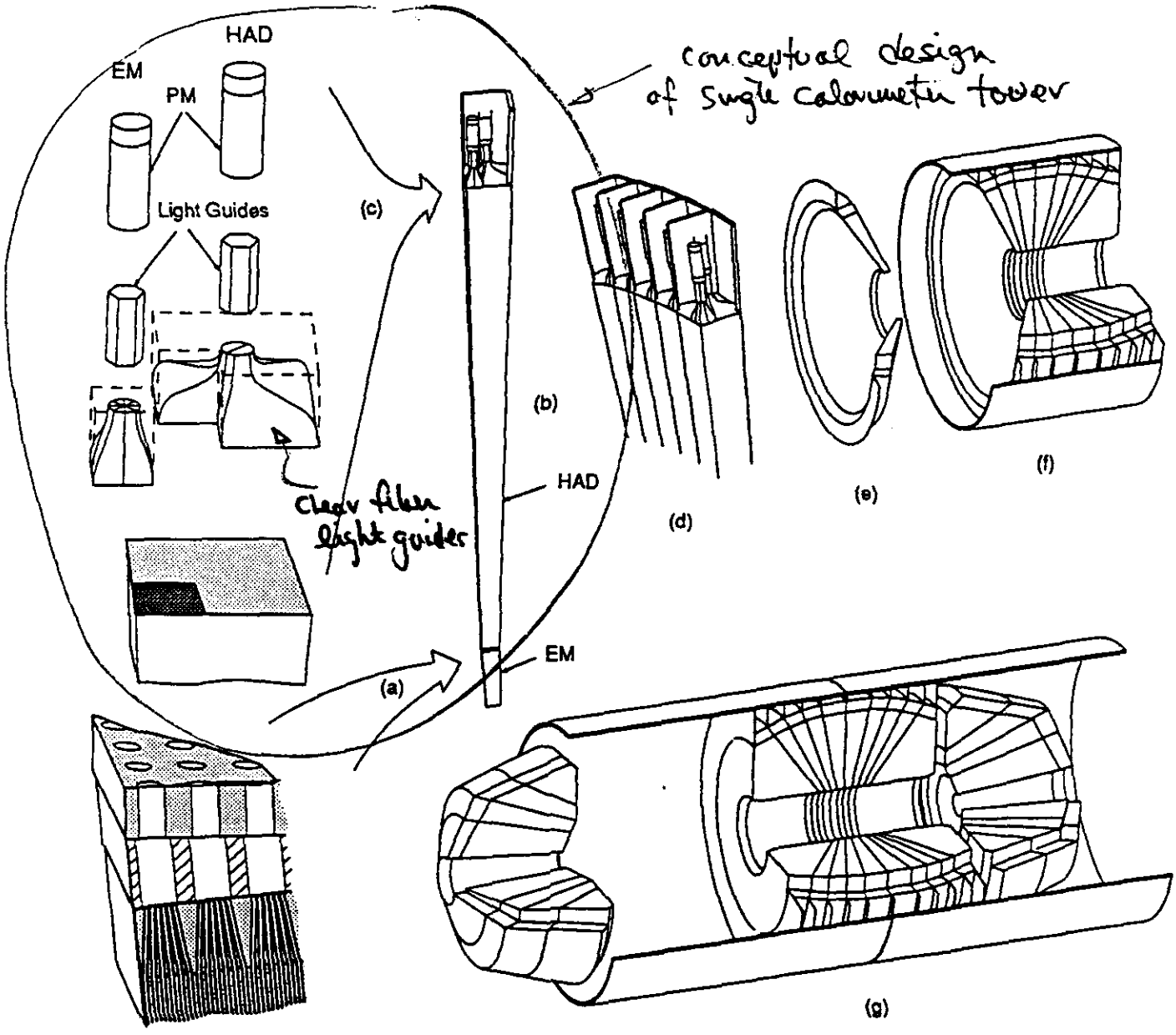
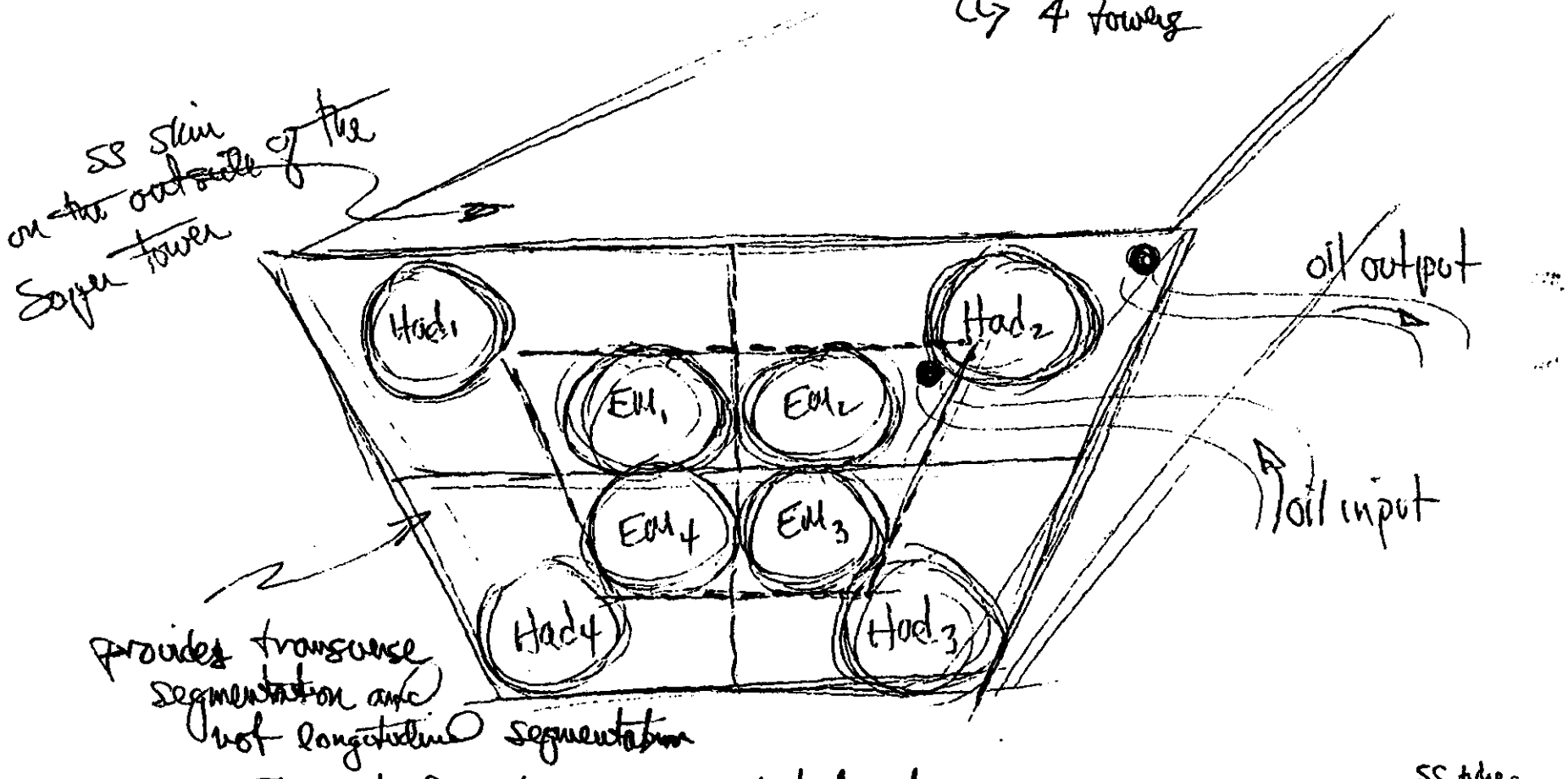


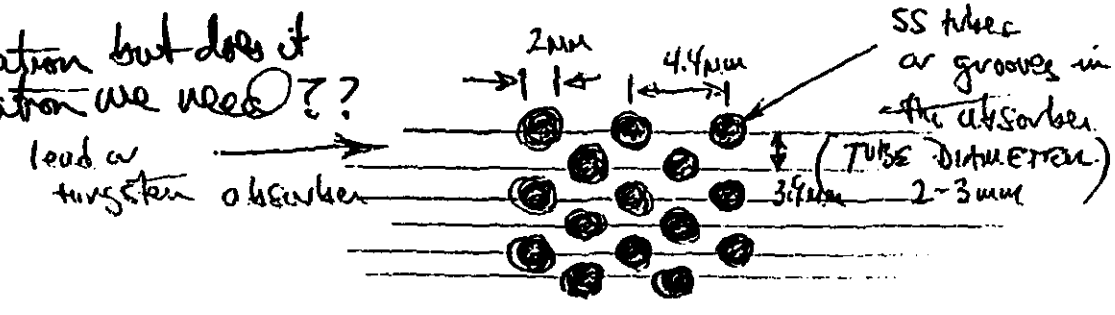
Figure 2-4 Construction details of the SPACAL design. (a) Coupling of 0.5 mm EM fibers to 3 mm HAD fibers; (b) single tower; (c) coupling of fibers to PMTs, dashed area will be filled with lead alloy; (d) ring detail; (e) super-ring; (f) central barrel; (g) full calorimeter.

PMT END OF "SUPERTOWER"

↳ 4 towers



This works for e/γ separation but does it give us the spatial information we need??



TUBE : ABSORBER

1 : 4

POSSIBLE MATERIALS

1) Grooved Lead w/ MgF_2 coated SS fibers or Eutectic

B) Grooved Lead w/ MgF_2 coated sheets.

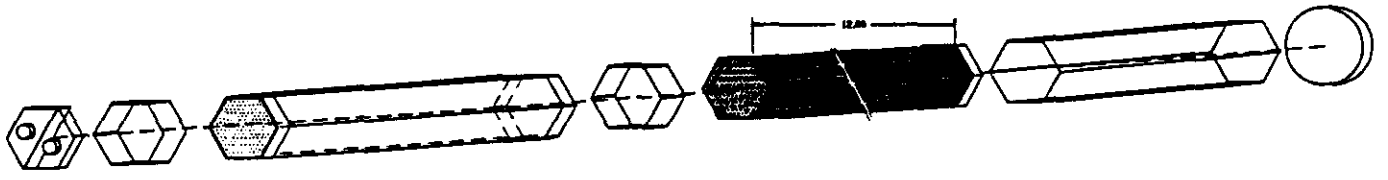
C) Grooved Tungsten w/ MgF_2 coated SS tubes

Early Costing of Capillary FCAL

Scintillating Liquid/Tube Forward Calorimeter-Cost Analysis

	Catagory	Tot Uts	$K/UNIT	Units	Costs W/Spa. Had.	Costs W/Spa. Had.
1.00	Material					
1.10	Lead	201.6	5.58	Mton	$1,124	$1,124
1.20	SS tubing	7.63E+05	0.0010	Meters	$763	$763
1.30	MgF2 coating	7.63E+05	0.0010	Meters	$763	$763
1.40	PMT's	2816	0.30	Each	$845	$845
1.50	Sheaths	352	1.50	Each	$528	$528
1.60	Light Guides	2816	0.10	Each	$282	$282
1.60	Spacers	352	0.20	Each	$70	$70
1.70	Calib. Loops	30	2.00	Each	$60	$60
1.80	Liquid Scint.	4494	0.01	Liters	$45	$45
2.00	Readout					
2.10	PMT's	2816	0.30	Each	$845	$845
2.20	Electronics	2816	0.25	Channels	$704	$704
3.00	Structure				$500	$500
4.00	Thermal Cont				$150	$150
5.00	Liquid Handling	2	100.00	Systems	$200	$200
6.00	Fab & Ass.					
6.10	Fab,Ass & Test	30	0.045	M-H/tower	$3,802	$3,802
6.20	Tooling				$1,500	$2,500
7.00	Testing				$750	$750
8.00	Transport.				$100	$100
9.00	Installation					
9.10	Install. Labor	5550	0.045	Man-Hour	$250	$250
9.20	Install. Equip				$500	$500
	Direct cost				$13,780	$14,781
	EDIA	25%			$3,445	$3,695
	Base Cost				$17,226	$18,476
	Contingency	40%			$6,890	$7,390
	Subtotal				$24,116	$25,866
	R&D	11%			$2,653	$2,845
	Total				$26,768	$28,711

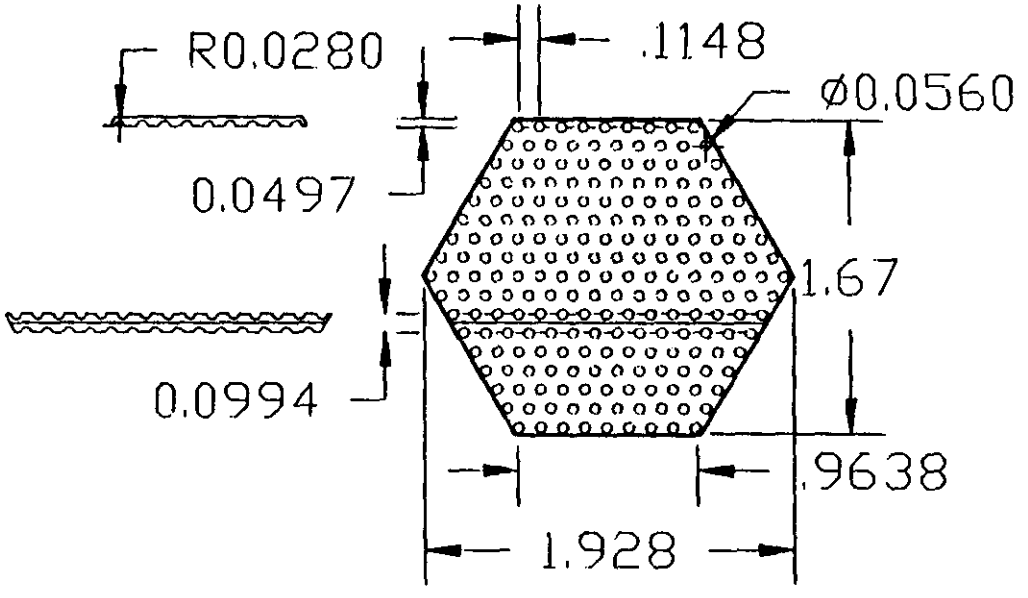
Current EM prototype under test at TAMU



TEXAS A&M HIGH ENERGY RESEARCH		
DATE: 8/13/90		DRAWN BY:
SCALE: .25:1		CONP DEA BY: A.D.D.
ASSEMBLY DRAWING OF CALORIMETER		
LIQ. SCIN. CALORIMETER		DRAWING NUMBER: TAMU-0020-6.0

Current EM prototype
under study at TAMU

END VIEW



TEXAS A&M HIGH ENERGY RESEARCH		
DATE: 8/03/90		DRAWN BY:
SCALE: 1:1		COMP. GEN. BY: A.D.D.
DETAIL OF LEAD PLATES		
LIQ. SCIN. CALORIMETER		DRAWING NUMBER: TAMU-0020-4.2

September 11, 1991

Mark,

Cost changes following GEM Costing Meeting in September.

I have gone through the costing exercise for the forward calorimeter with an eye toward reducing its cost in light of discussions held last week at the SSC Lab. Two major items come up which should change cost substantially

(a) eta range .... $3.0 < \eta < 5.0$ instead of starting at $\eta = 2.5$.

(b) calorimeter thickness .... $10 \lambda_a$ instead of the $15 \lambda_a$ calculated earlier.

I have done the new costing for a calorimeter located either at 5m from the IR or 10m from IR.

I would appreciate it if you could review these new numbers and see if you find any problems with what I have done.

Regards.

Bob Webb

Notes

for 5m location : thickness = 229cm ; front face radii 50 cm OR ; 6.76 cm IR ; Rear face radii 82cm OR ; 11.1cm IR total number of towers 896 with 2 pmt's/tower.

for 10m location : thickness = 229 cm ; front face radii 100cm OR; 13 cm IR ; Rear face radii 146 cm OR; 20 cm IR again total tower count 896 with 2 pmt's/tower.

Note that I continue to assume that for construction purposes we will deal with "Super towers" consisting of 4 towers. As a result we need only fabricate sheaths, spacers etc for the 224 super towers.

In calculating the cost of labor for fabrication in both of our earlier calculations, we were off by a factor of 2. This factor comes from the difference between channels of electronics and numbers of towers.

$$N_{\text{electronics channels}} = 2\, N_{\text{towers}}.$$

The previous figure for assembly labor used the channel number instead of tower number to calculate labor costs.

This system cost is starting to look a bit more manageable within the total GEM budget constraints.

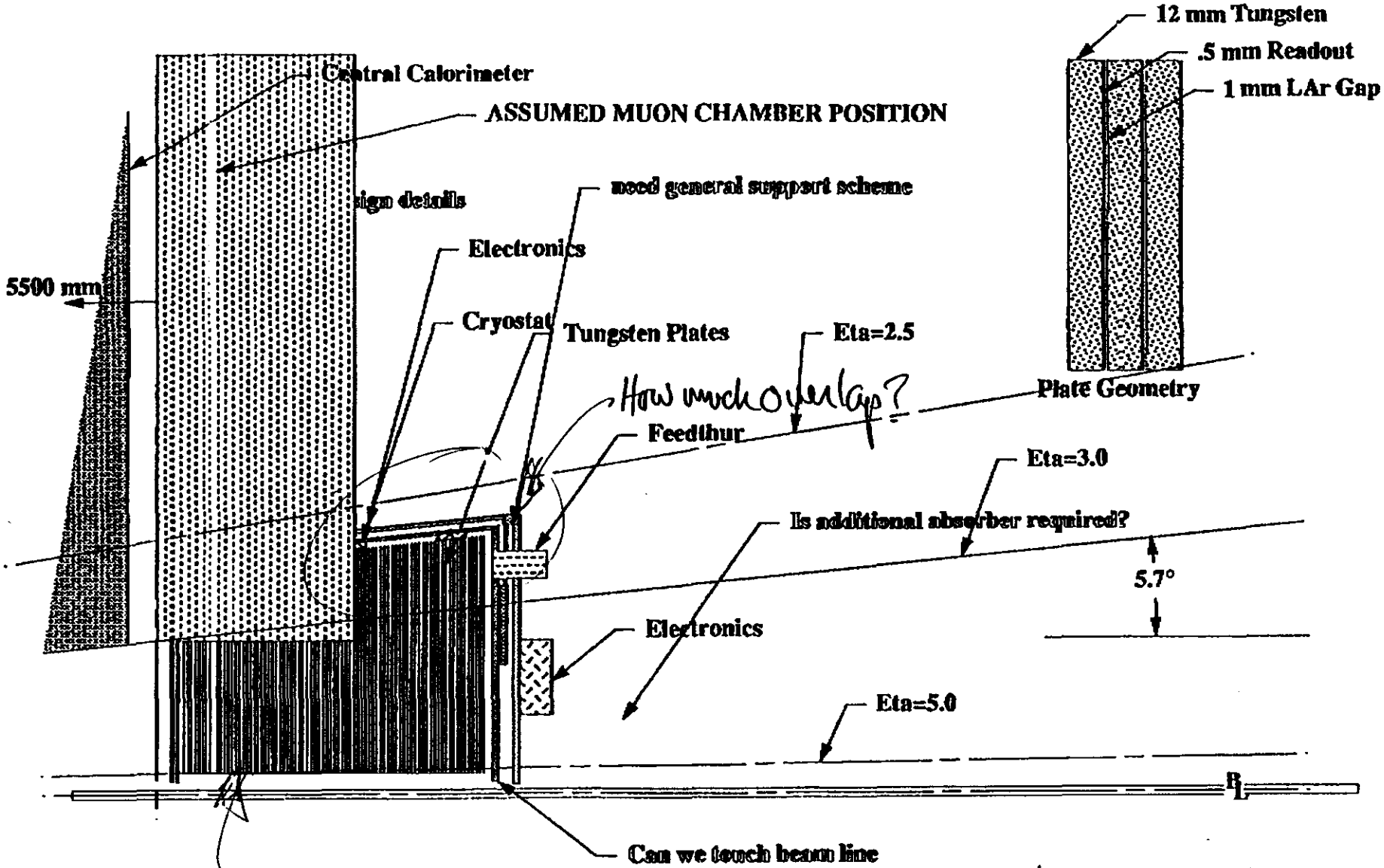
Let me know what you think.

Scintillating Fiber Forward Hadron Calorimeter Costs
(front face at 5 meters from IR)

ITEM	CATEGORY	Total Units	$K/ Unit	Units	Cost	Cont
1.00	**Material**					
1.10	Lead	41.2	5.58	Mton	230	
1.20	SS Tubing(3mm)	$1.67X10^5$	0.001	Meters	167	
1.30	MgF_2 coating	$1.67X10^5$	0.001	Meters	167	
1.40	Sheaths	224	1.50	Each	336	
1.50	Light Guides/Mixers	1792	0.1	Each	179	
1.60	Spacers	224	0.2	Each	45	
1.70	Calib. Loops	30	2.00	Each	60	
1.80	Liquid Scintillator	1060	0.010	Liter	11	
2.00	**Electronics**					
2.10	PMT'S	1792	0.3	Each	538	
2.20	Electronics	1792	0.25	Channels	448	
3.00	**Structure**				500	
4.00	**Thermal Control**				90	
5.00	**Liquid Handling**	2	100	System	200	
6.00	**Fab. & Assembly**					
6.10	Fab. Ass. & Test	30	0.045	MH/tower	1210	
6.20	Tooling				1500	
7.00	**Testing**				750	
7.10	Test Beam					
7.20	Test Beam Equipment					
8.00	**Transport**				100	
9.00	**Installation**					
9.10	Install. Labor	5556	.045	Man Hour	250	
9.20	Install. Equip.				500	
	DIRECT COST				7281	
	EDIA	25%			1820	
	Base Cost				9101	
	Contingency	40%			3640	
	Subtotal				12741	
	R&D	11%			1402	
	TOTAL				14143	

Scintillating Fiber Forward Hadron Calorimeter Costs
(front face at 10 meters from IR)

ITEM	CATEGORY	Total Units	$K/ Unit	Units	Cost	Cont
1.00	Material					
1.10	Lead	112.8	5.58	Mton	629	
1.20	SS Tubing(3mm)	$4.57X10^5$	0.001	Meters	457	
1.30	MgF_2 coating	$4.57X10^5$	0.001	Meters	457	
1.40	Sheaths	224	1.50	Each	336	
1.50	Light Guides/Mixers	1792	0.1	Each	179	
1.60	Spacers	224	0.2	Each	45	
1.70	Calib. Loops	30	2.00	Each	60	
1.80	Liquid Scintillator	2940	0.010	Liter	30	
2.00	**Electronics**					
2.10	PMT'S	1792	0.3	Each	538	
2.20	Electronics	1792	0.25	Channels	448	
3.00	**Structure**				500	
4.00	**Thermal Control**				90	
5.00	**Liquid Handling**	2	100	System	200	
6.00	**Fab. & Assembly**					
6.10	Fab. Ass. & Test	30	0.045	MH/tower	1210	
6.20	Tooling				1500	
7.00	**Testing**				750	
7.10	Test Beam					
7.20	Test Beam Equipment					
8.00	**Transport**				100	
9.00	**Installation**					
9.10	Install. Labor	5556	.045	Man Hour	250	
9.20	Install. Equip.				500	
	DIRECT COST				8279	
	EDIA	25%			2070	
	Base Cost				10349	
	Contingency	40%			4140	
	Subtotal				14489	
	R&D	11%			1594	
	TOTAL				16083	



GEM
Forward Calorimeter
Liquid Argon

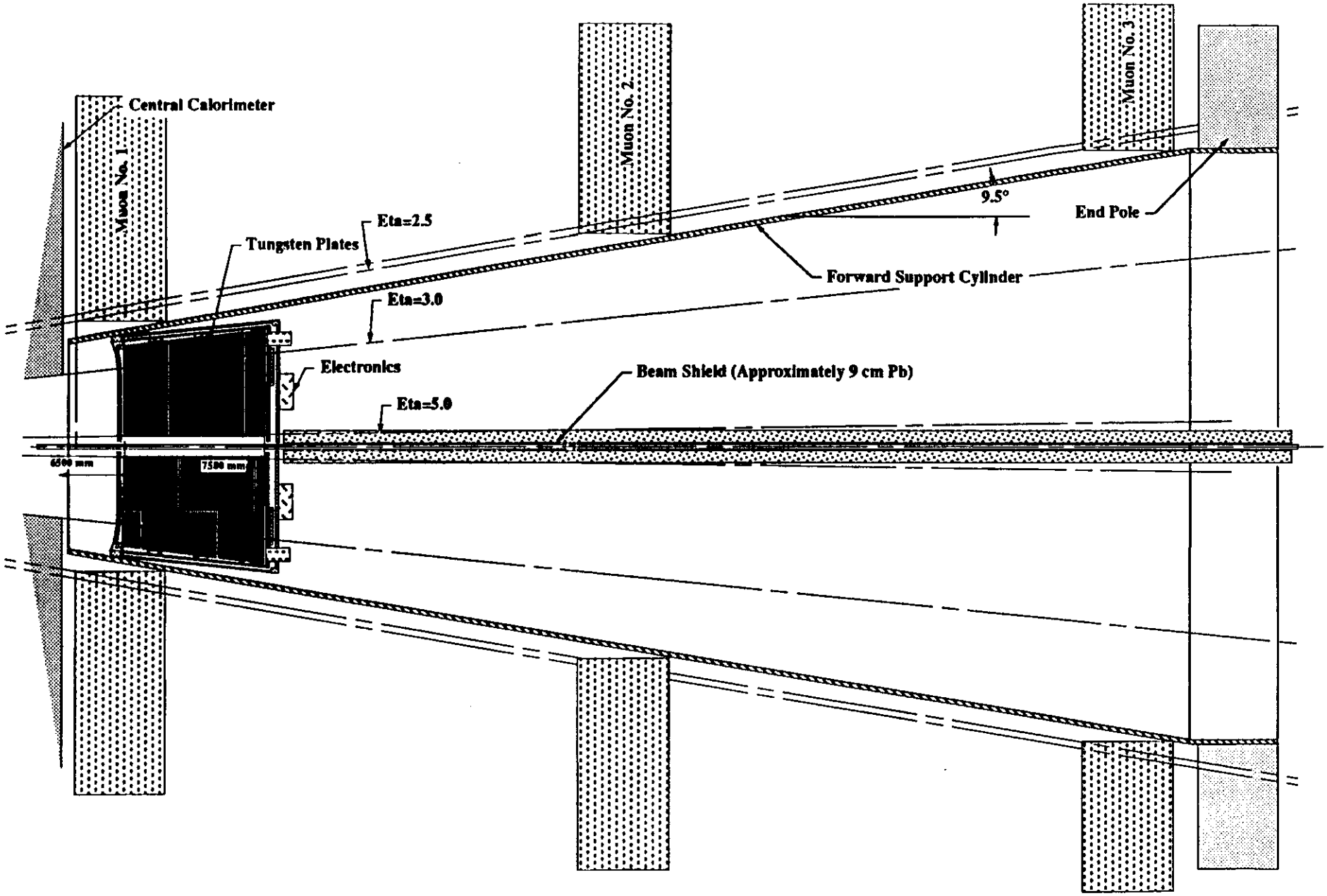
(Forward Scenario)

Where do we locate the PCAL?

How do we coexist with the muon systems?

G.03.FD.00012

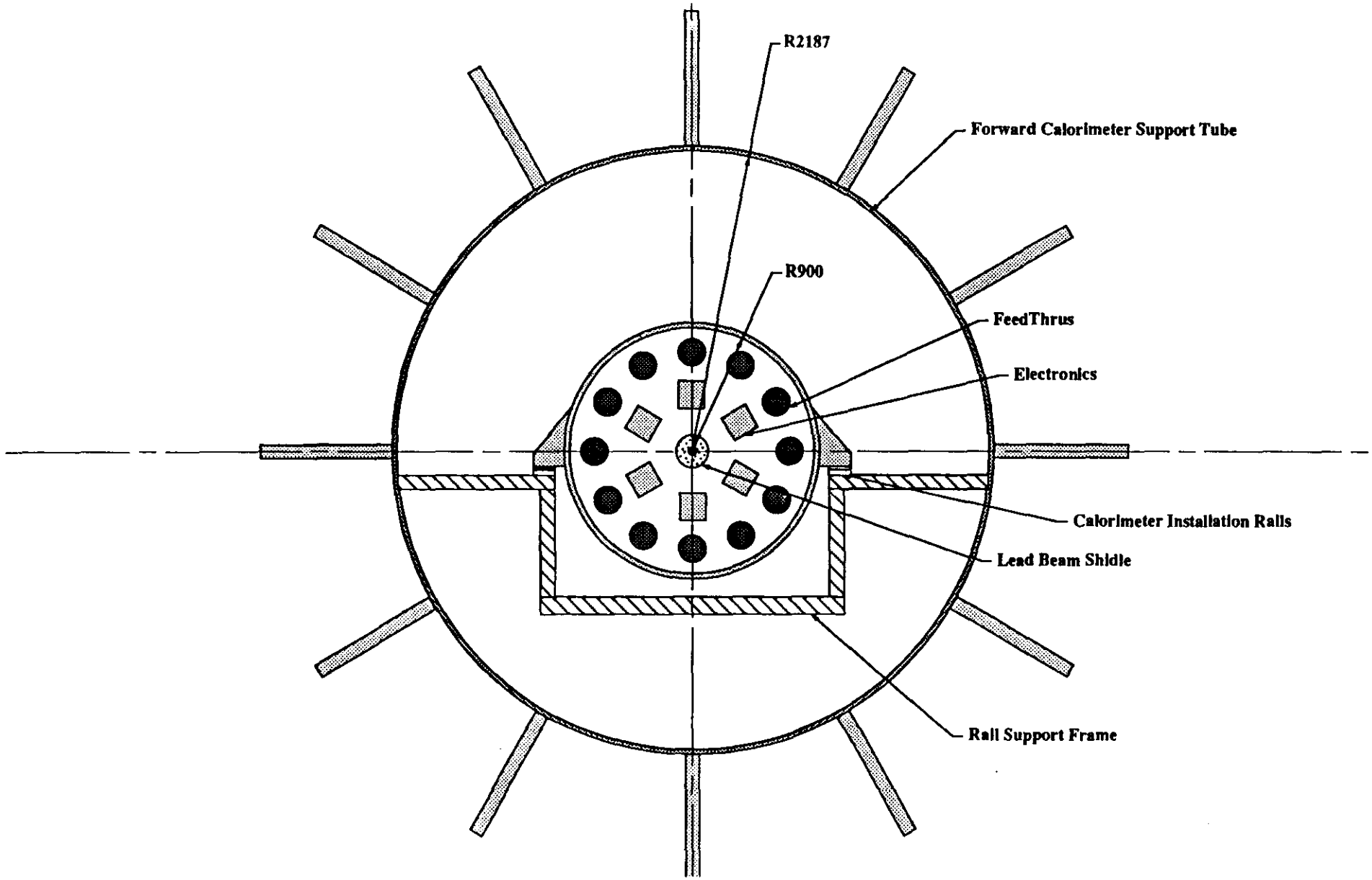
Rennich



GEM
Forward Calorimeter
Liquid Argon

G.03.FD.00015

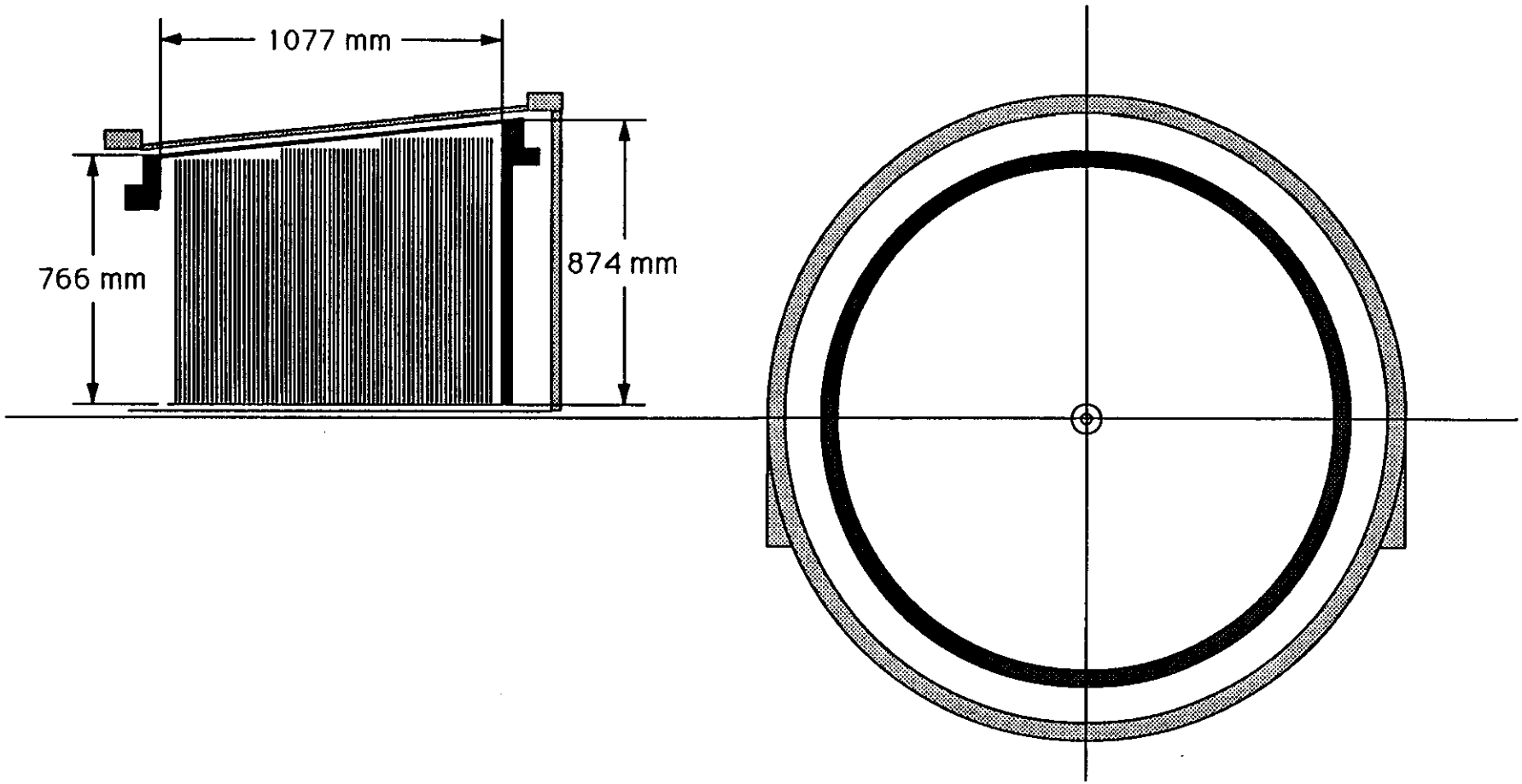
Rennich



GEM
Forward Calorimeter
End View
Liquid Argon

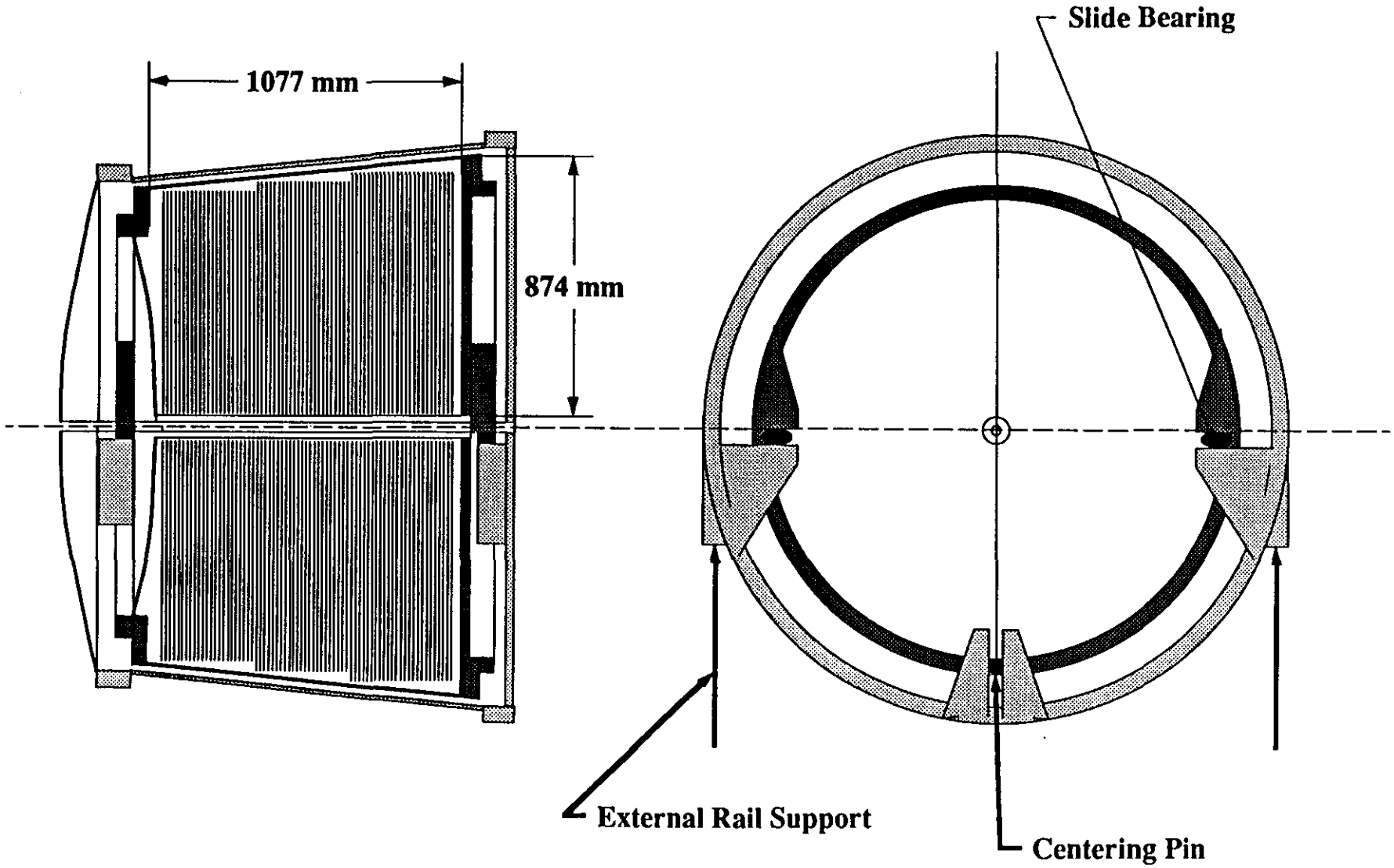
G.03.FD.00015

Rennich



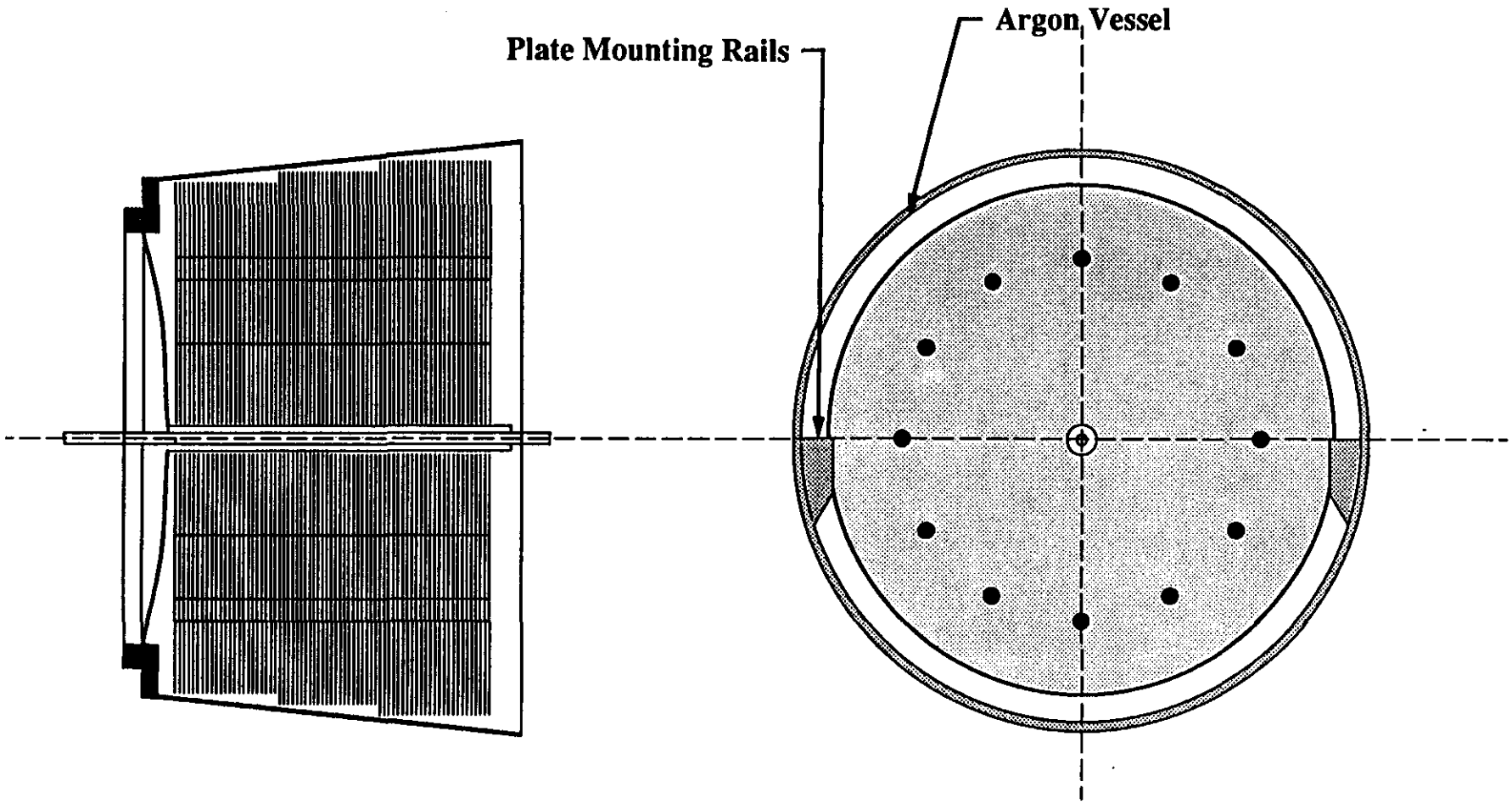
Liquid Argon Forward Calorimeter

Rennich/Chae



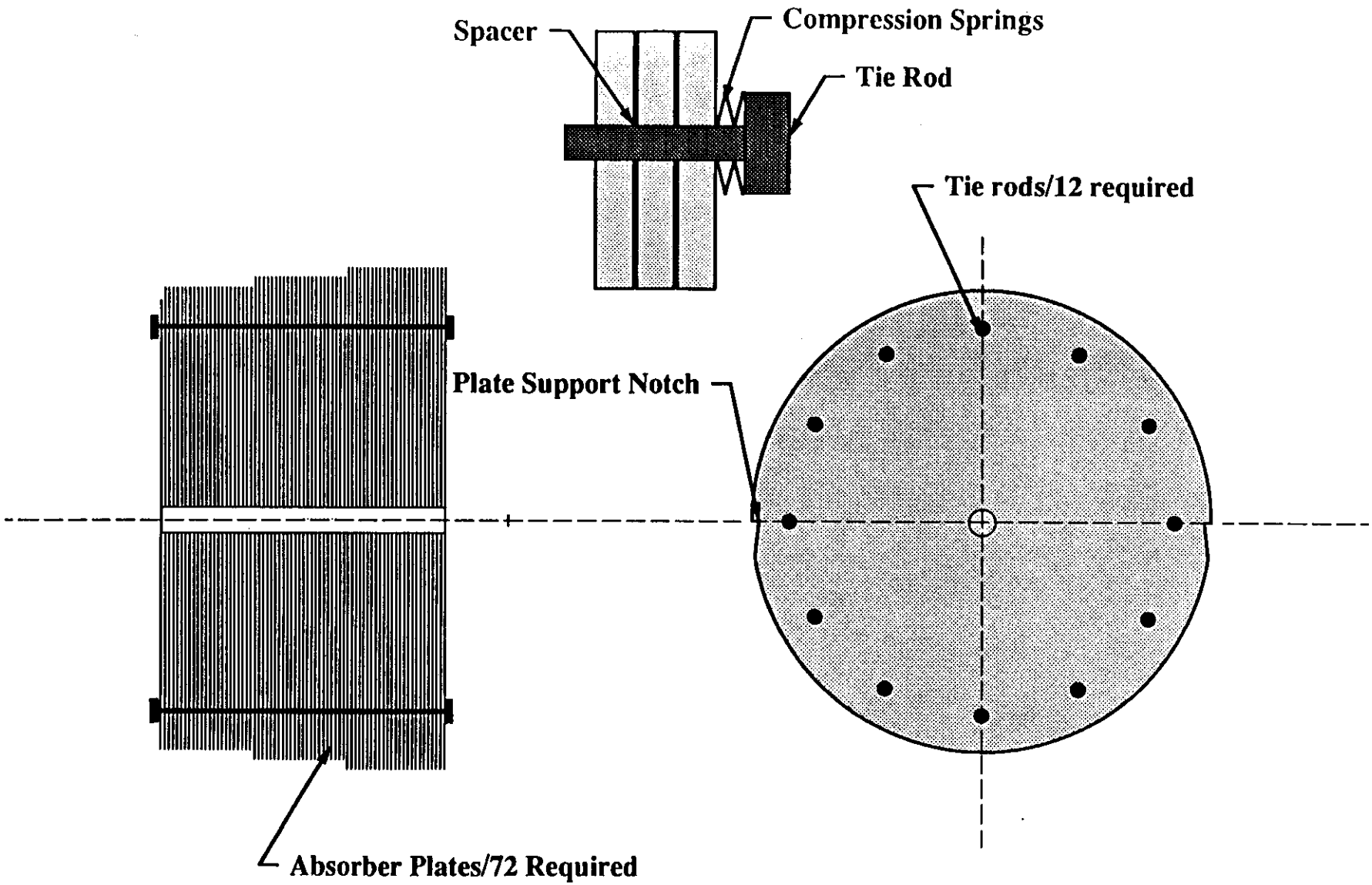
Liquid Argon Forward Calorimeter
Argon Vessel Support System

Rennich/Chae



Liquid Argon Forward Calorimeter
Tungsten Plate Support System

Rennich/Chae



Liquid Argon Forward Calorimeter
Absorber Stack Assembly

Rennich/Chae