GEM TN-93-269

Sub-Detector Simulation and Parametrization for GEMFAST Meeting - Boston University

January 8, 1993

Abstract:

Agenda, attendees and presentations of the GEM Sub-Detector Simulation and Parametrization for GEMFAST Meeting held at Boston University on January 8, 1993.

AGENDA

9:30am	GEMFAST status report	------ Tomasz Skwarnicki (SSCL)
10:30am	Central tracker simulation	------ Shawn McKee (Michigan)
11:30am	EM/HCAL simulation	------ Hong Ma (BNL)
12:15am	Scin. fiber calorimeter simu.	----- Rob Carey/Shmakov/Savin/Efremanko
12:45pm	Lunch	
1:45am	Scin. fiber calorimeter simu.	----- continue
2:00pm	Forward/backward cal. simu.	----- Mike Shupe (Arizona)
3:45pm	Trigger algorithm and simulation	-- Henk Uijterwaal (SSCL)
3:30pm	Break	
4:00pm	Discussions	
5:30pm	Summary	~~----- Bing Zhou (BU)~~
6:00pm	End of meeting	

μ-simulation Torre Wenaus (LLNL)

Sub-detector Simulation and parametrization for GEMFAST

Boston University

1/8/93

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Presentation by:

Tomasz Skwarnicki

gemfast

as of version vII 1ø1

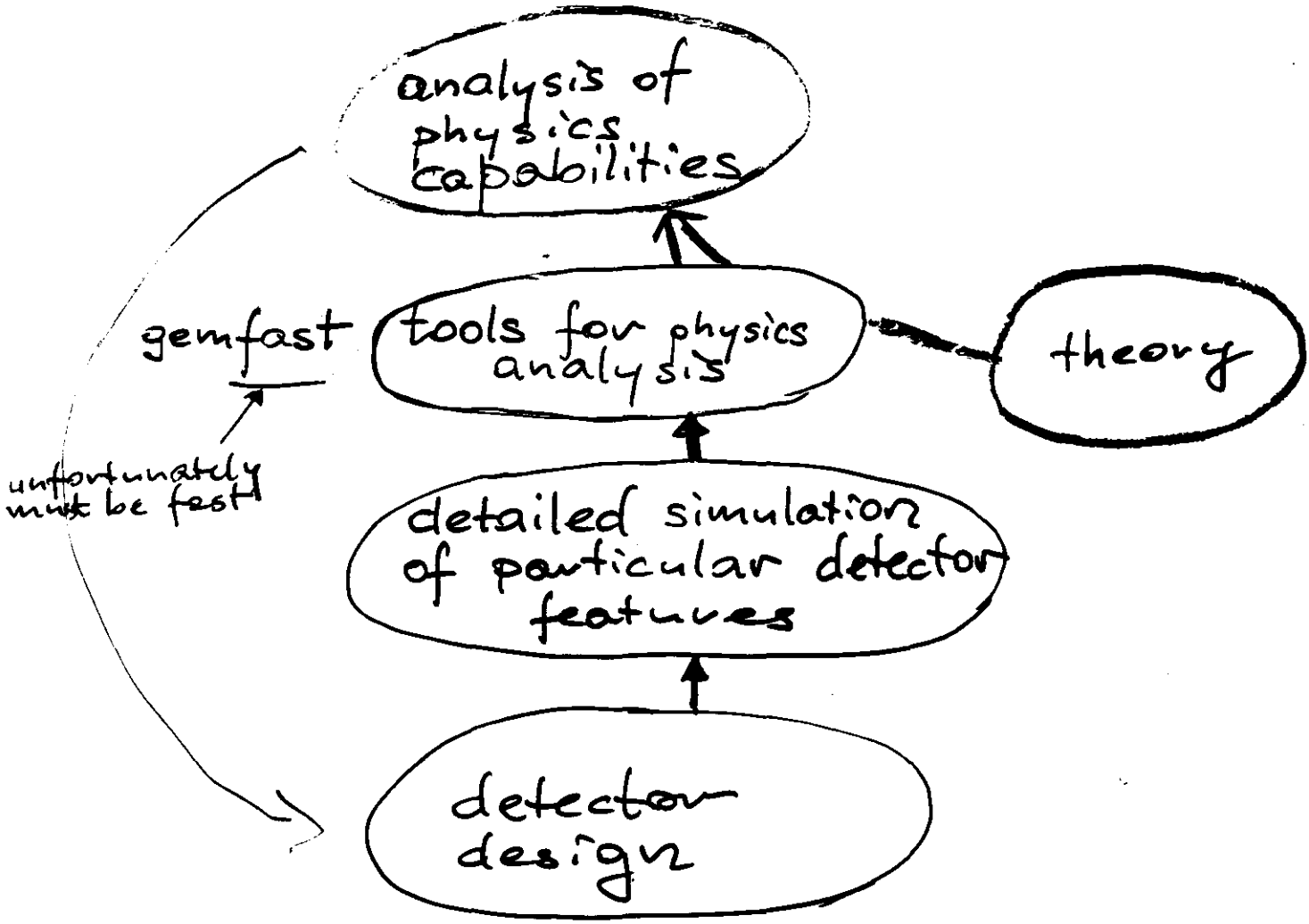
Outline:

what gemfast is

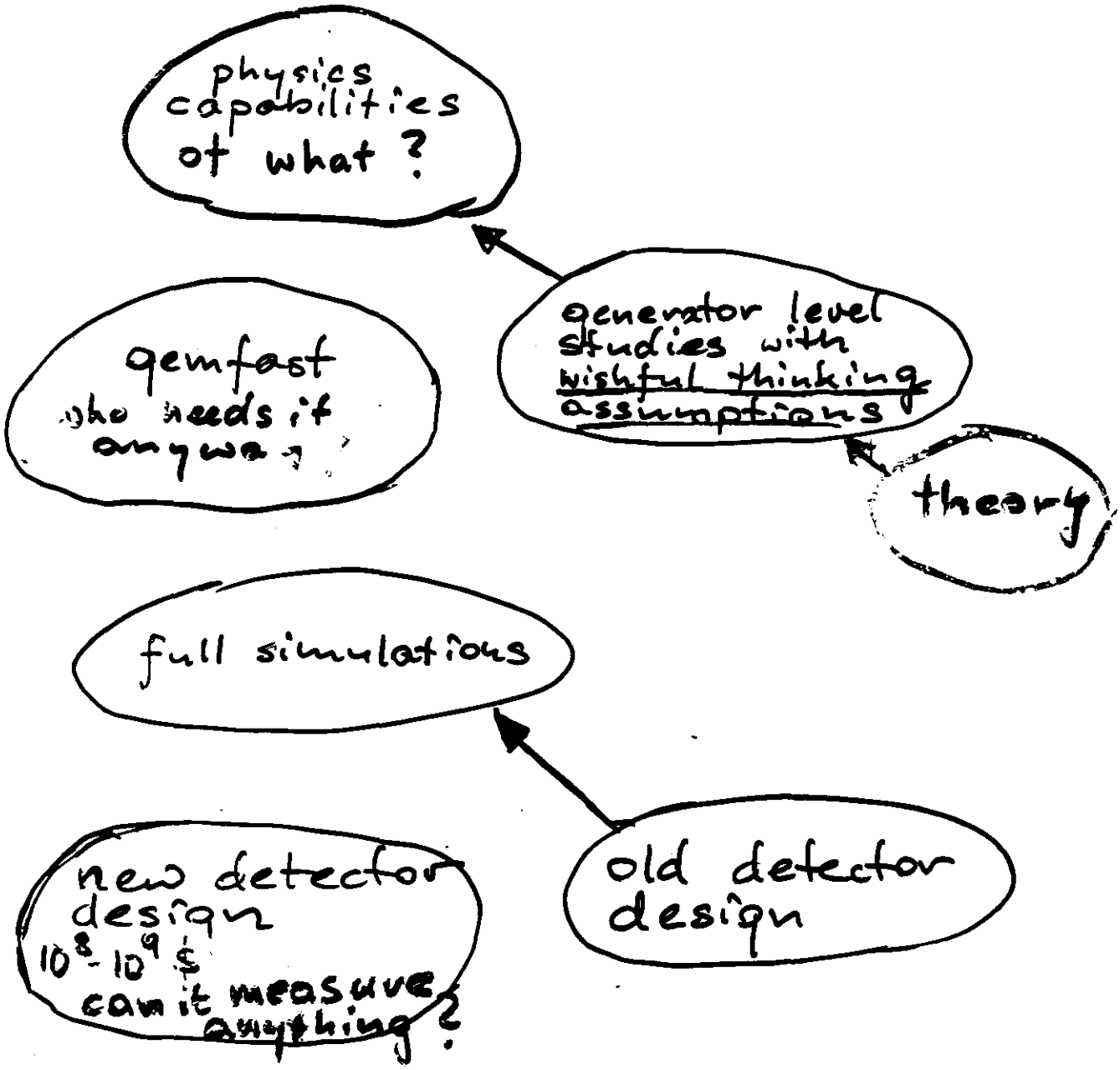
go through the simulation algorithms <u>without</u> going into detail but with indication of open questions

proposal how to proceed

GEM PROPOSAL
(in principle)



GEM PROPOSAL
(in ~~practice~~ past ?)



physics

link here still to be achieved

best test:
will $H \to \gamma\gamma$ ever go beyond generator level studies?

gemfast

a good progress recently

full simulations by:

S. McKee, M. Brooks
H. Ma, M. Shupe
P. Dinqus

soon (how soon?)

T. Wenaus
P. Dinqus
K. Shmakov, A. Savin
...?

full simulations

gemfast is a set of user callable subroutines

can be called from:

gemgen package

Irwin Sheer's interfaces to ISAJET, PHTHIA, LUND, single-particle-generator

GEANT

several people are using full simulation of CT + gemfast for calorimeters

user's main program

main user entries

CALL FSI_EVT

Loop through final state particles from /hepevt/ (stdhep-package conventions) one-by-one

transport through GEM geometry

decay if necessary

if hit active detector call subdetector parametrization

store results (smeared momenta, measured charges, energies in calorimeter cells ...) in common blocks accessed later by the user

add thermal noise to calorimeter cells

calculate global E_t

do naive primary vertex reconstruction

CALL FSI_ADDPILE

add pile-up to calorimeters from off-time minimum bias events

CALL FXB_XB

find single-particle showers

mostly useful for γ, e

CALL calorimeter trigger simulation

(code written but not yet brought to /gem standards)

CALL CAJETS

very naive jet finding algorithm

FSI_ECCONE ($\vec{P}$, $R = \sqrt{\Delta\varphi^2 + \Delta\eta^2}$, ...)

CA

HC

SC

CA = EC+HC

and few other simple utility routines

FSIEVT particle transport code

input

/hepevt/ IDHEP(i), VHEP(4,i), PHEP(5,i)

- IDHEP(i): particle ID in PDG convention
- VHEP(4,i): vertex i.e. initial particle position
- PHEP(5,i): four-moment

can be anything which GEANT would also accept e.g.

decayed by GEANT routines: γ, π^0, K_S, K_L, Λ

but not: τ, D, B, parton

people should be careful not to limit decays of these in generators only to certain modes !

on the other hand K_S, K_L, Λ .... should not be decayed by generators

can be anywhere in the GEM detector !

any value accepted

(parametrizations must accept multi-TeV particles)

trajectory

neutrals move along straight lines

charged particles move along perfect helix in constant $B = 0.8\,T$ anywhere in the detector

- → non-uniform B in MU is parametrized in momentum resolution !
- → curvature in calorimeters changes only after exiting subcomponent (e.g. EC, HC)
- → no multiple scattering

detector geometry

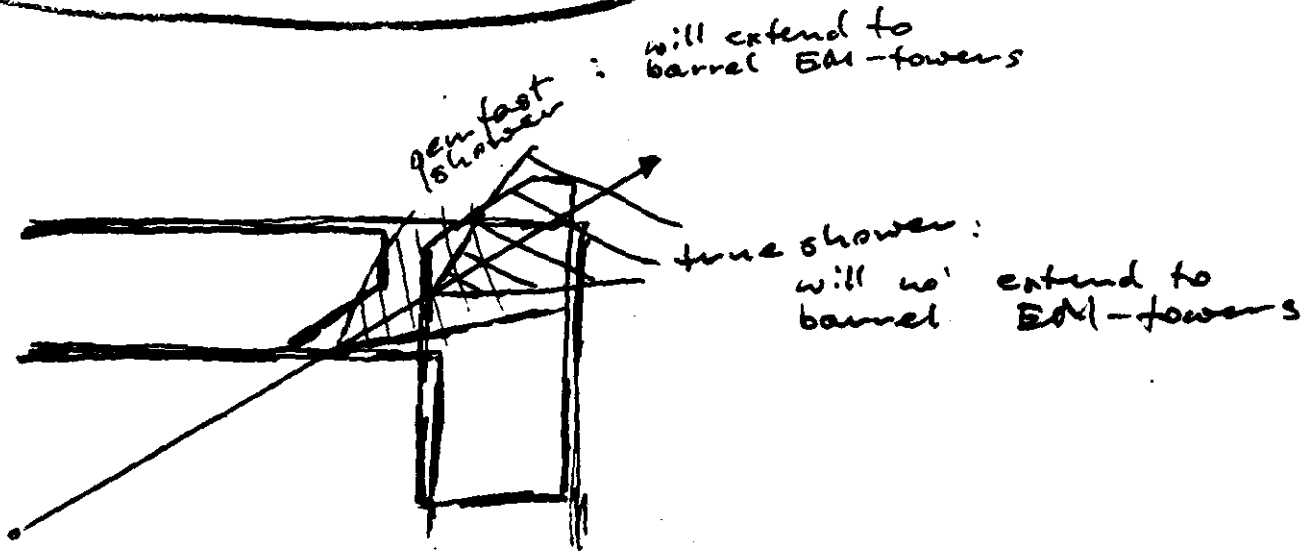
approximated by cylinders

+ limits in η → picture

true calorimeter thicknesses (from Martin Marieta model) are "mapped" into cylinders i.e. cylinders have nonuniform material density to produce non-cylindrical thicknesses

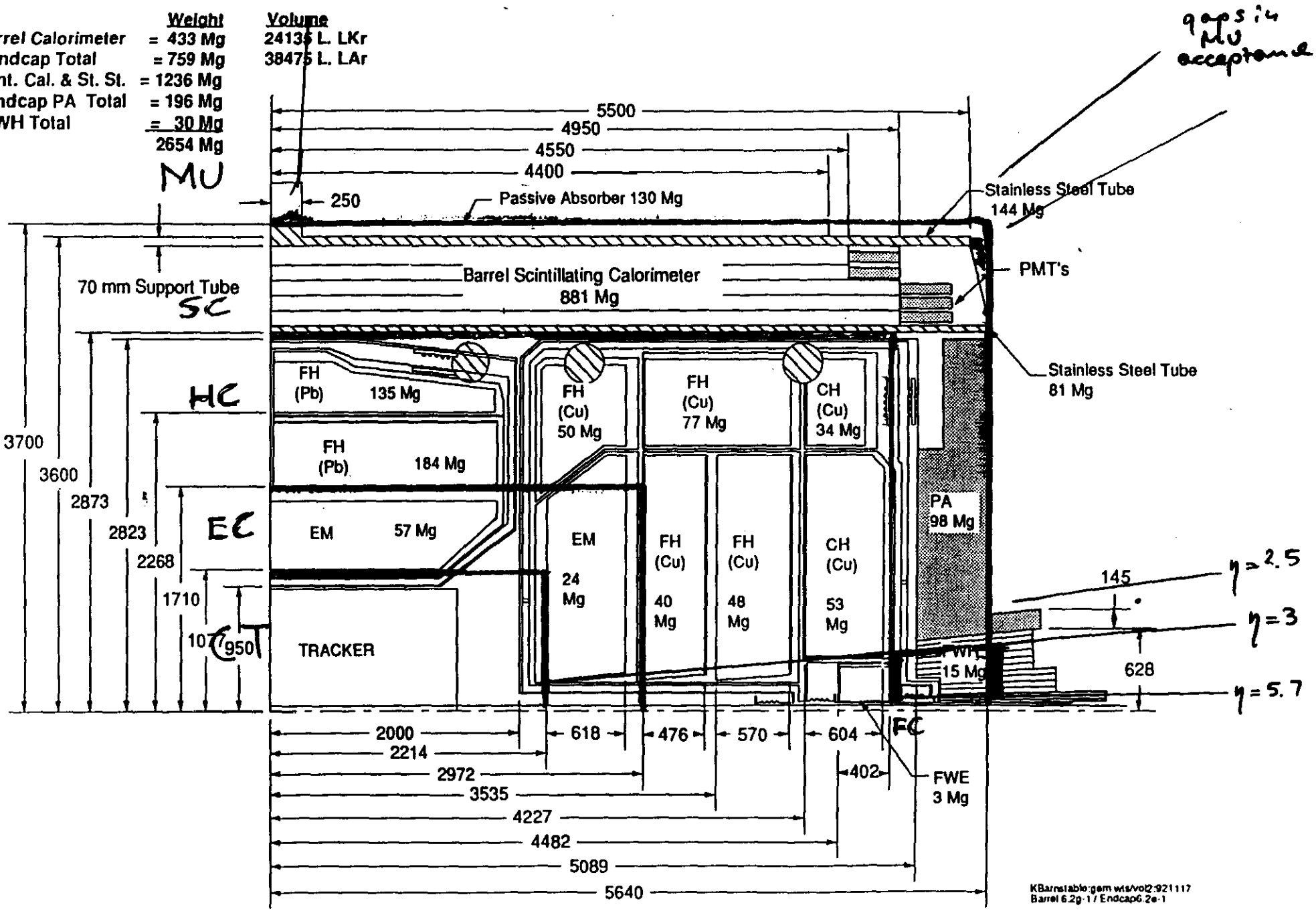
→ picture

does this cause any systematic problems in the simulation?

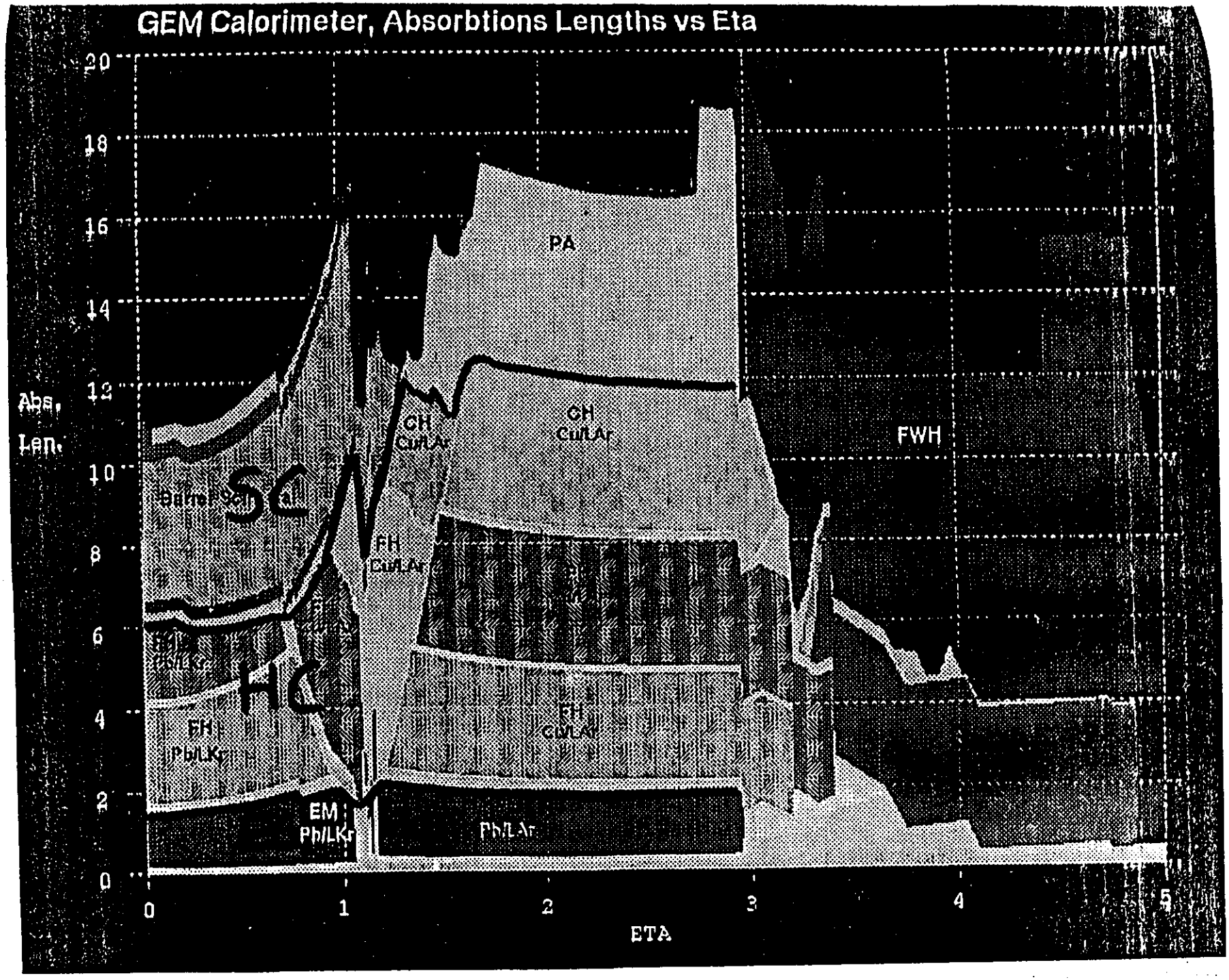


GEM Calorimeter

	Weight	Volume
Barrel Calorimeter	= 433 Mg	24135 L. LKr
2 Endcap Total	= 759 Mg	38475 L. LAr
Scint. Cal. & St. St.	= 1236 Mg	
2 Endcap PA Total	= 196 Mg	
2 FWH Total	= 30 Mg	
	2654 Mg	



gaps in μ acceptance


GEM Calorimeter, Absorbtions Lengths vs Eta
Abs. Len.
ETA
PA
CH CuLAr
FWH
FH CuLAr
FH PbLKr
EM PbLKr
PbLAr
SC
HC

CT

geometrical acceptance by "naive" intersection with Si and IPC layers
→ user should check # of layers intersected → picture

all charged tracks above $p_t > 0.1$ GeV kept
→ user must cut on p_t

all charged tracks not from the cone around the detector origin are flaged
→ user must check this flag to eliminate secondaries (e.g. $K_S \to \pi\pi$, $\gamma \to ee$)

cone size must be tuned

should secondaries be allowed to veto γ-clusters in calorimeter ?

→ optionally user may check reconstruction efficiency provided by Shawn McKee and Melanie Brooks

Shawn should talk about interpretation of this efficiency

by default particle overlapps ignored
→ user may use fsi_ctiso by Irwin Sheer to check isolation in CT on generated directions

momentum and measured charge are randomized, in correlated way, by code supplied by Shawn McKee and Melanie Brooks

electrons have non-gaussian smearing due to bremstrahlung, but γ's not explicitely generated

systematics

fsi-ctslay.f

written by Tomoe S.
geometry coded by
Shawn McKee

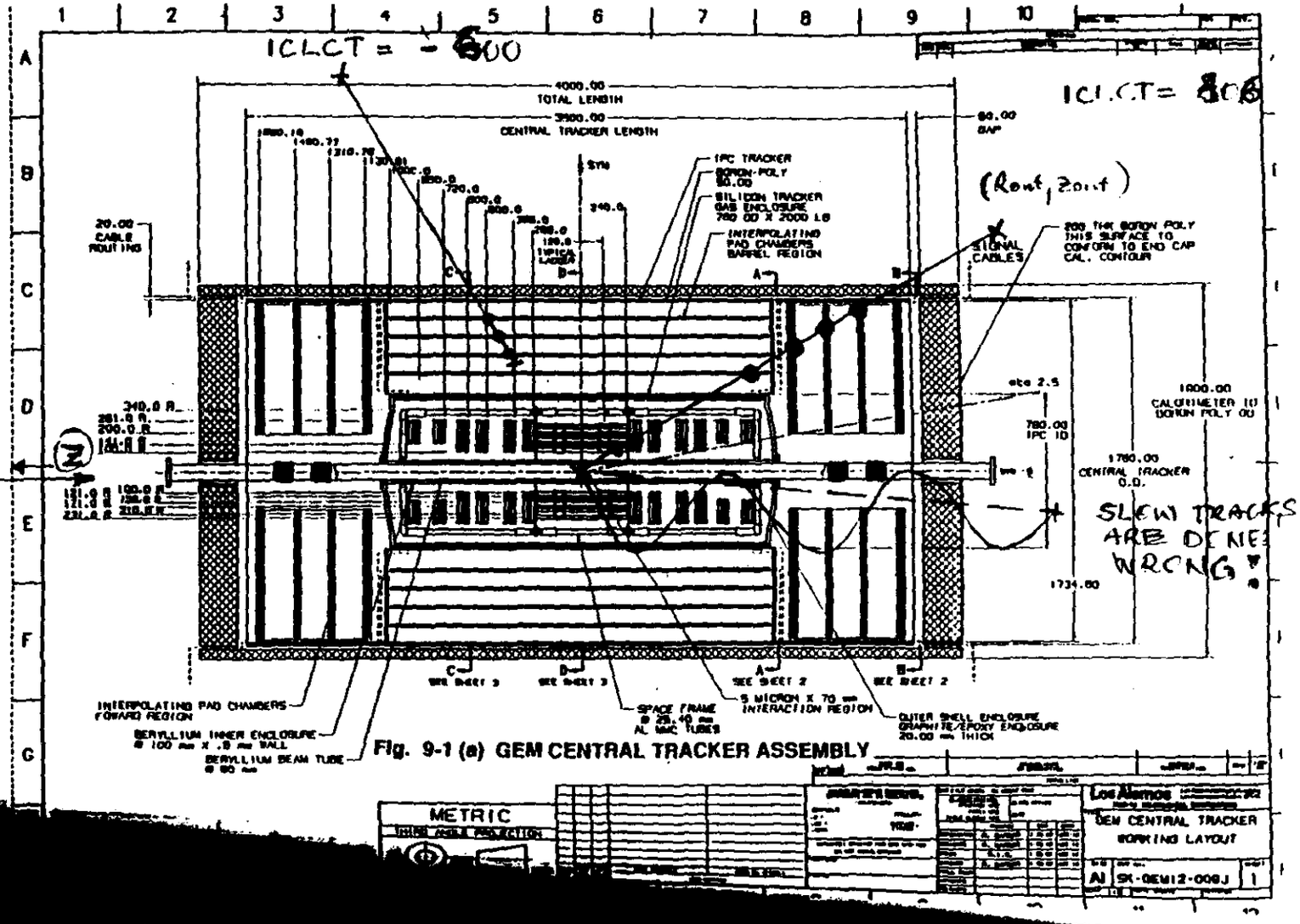


Fig. 9-1 (a) GEM CENTRAL TRACKER ASSEMBLY

- planned but not yet written : parameter resolution

explicit γ - conversions with generation of secondary electrons

physics motivation : early conversions may fake electrons (beam pipe must be included)

all conversions may lower γ efficien and help γ/jet isolation

VERTEXING (primary vertices)

FSI-EVT decomposes /hepevt/ into signal and minimum bias events and lists generated primary vertices

gemgen smears primary vertex

is this smearing correct ?

it also comes with naive vertex reconstruction all tracks within acceptance, above pt> ? coming from the generated vertex are counted

using track impact parameter resolution primary vertex is smeared and position error estimated

track overlaps ignored

confusion between two closed vertice ignored

this code is optimistic, real life may be worse

user may modified vertex code to different cuts (Pt cut, introdu track isolation etc.

CENTRAL REGION CALORIMETERS $|\eta| < 3.0$

Longitudinally divided into

EC — EM LKr/LAr – Pb

HC — hadronic LKr/LAr – Pb or Cu
fine and coarse together

SC — scintillation tail catcher

further subdivision possible but not implemented

e, γ shower immediately (no difference between e and γ showers)
no preshowering in CT except for effect on average energy resolution

hadronic interaction point fluctuates prop $\propto e^{-\frac{x}{\lambda}}$

MIP ionization before the interaction point
constant dE/dx, no fluctuations
(muons are exception → part of MU software)

EC, HC, SC are all subdivided into cells (towers) pointing to the origin
segmentation varies with η !
fake segmentation of SC in η-coordinate copied from (barell) HC

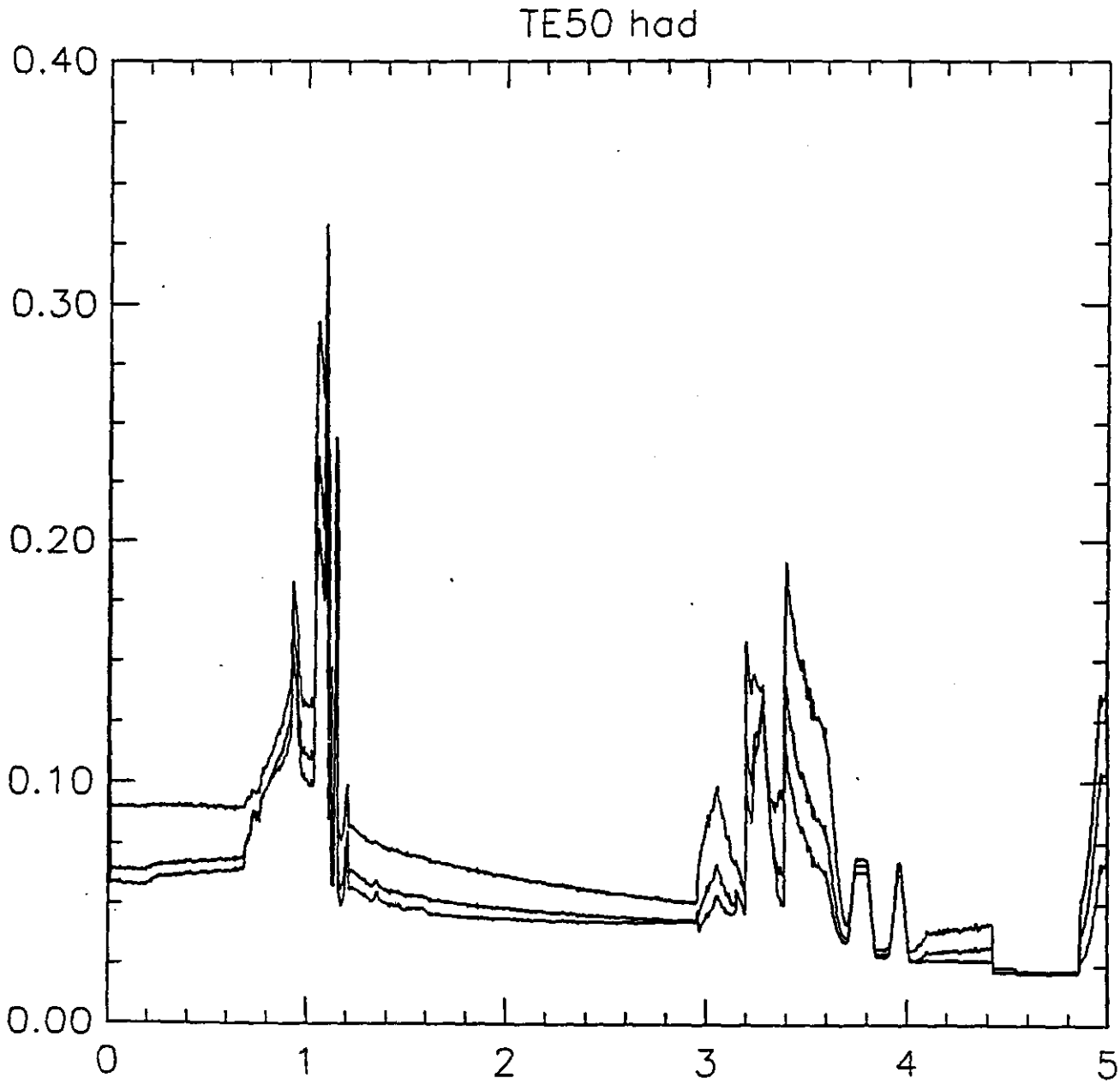
effects of timing measurement on η-position accuracy ?

shower energy is fluctuated as a whole before subdividing it longitudinally and transversely according to resolution parameters

right EM resolution parameters ?

File: /users/hep/tomasz/gemfast/H1050.DAT

ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
1050	0	−1	000000/0000	73.72	2.067	1.345
1200	0	1	000000/0000	60.16	2.155	1.401
1500	0	1	000000/0000	56.74	2.228	1.451



right hadronic resolution parameters ?

need <u>single hadron</u> resolutions

in principle could simulate non-compensation effects on hadron response

EM and <u>HAD</u> resolution in barrel – endcap transition region ?

disagreement between Mike Shupe's simulations and Martin-Marietta calculations should be understood

do we need extra smearing of energy seen in SC ?

- shower distribution to calorimeter transverse towers

at present 2 different options
(I) average shower profiles
(II) gflash ← NEW!

I) longitudinal profiles – Bock's formulae (Hong Ma)
transverse profiles – sum of two exponents
HAD: NA34 (Hong Ma)
EM: Bathow et al (Tomasz) ← NEW

no fluctuations
no change of transverse size with depth
shower develops always pointing to the detector origin even if parent particle does not

developed in experiments $\lesssim$ 50 GeV

(II) gflash – H1 package developed on LAr/Pb (EM) + LAr/Fe (HAD) calorimeter
version 1.3
(can be scaled to any material by absorption length and Molliere radius)
tested on data up to 170 GeV
used by H1 up to 500 GeV

original gflash worked in GEANT
I addopted it to simple gemfast geometry (substantial changes to the code organization)

correlated fluctuations of shower profile parameters

sampling fluctuations according to the user specified energy resolution formula

hadronic shower split into early π^0 + late π^0 + charged parts

possibility of $e/\pi \neq 1$ simulation used by H1 and checked against beam data

present pamfast $e/\pi = 1$

transverse profile changes with depth (in energy dependent fashion)

shower develops along true particle direction

accuracy of longitudinal distribution?

EM showers:

- limiting resolution factor for high energies (heavy $Z' \to ee$)
- e/π separation

HAD showers:

EC/tot fraction important for isolation cuts in EC

fraction seen in SC

back leakage for $\not{E}_T$

accuracy of transverse distribution?

effect on resolution in 5x5 sum?

angular resolution obtained in gemfast : for jets ?
for γ ?

thermal noise added to each EC and HC tower

are numbers we use up-to-date will effect EM resolution at lower energies in the barrel

do we need pedestal smearing ins

on-time pile-up events simulated explicitely

off-time pile-up added cell-by-cell from external file precalculated by weighting minimum bias events (after passed through gemfast) by time dependent weights

⇒ NOT DONE YET FOR BASELINE-11

FC FORWARD CALORIMETER

no longitudinal segmentation or transverse towers

Mike Shupe's smearing routine:

$\vec{p}_{generated} \rightarrow \vec{E}_{measured}$

used in geanfast for

$3 < \eta < 5.7$ is this right?

includes edges of HC

in baseline-II design decided?

CALORIMETER TRIGGER

Henk Vijterwaal has updated Charles Allen's Baseline-I code to new Baseline-II gemfast

not implemented yet under /gem

‖MU‖

what is ~~[illegible]~~ [illegible] :

energy loss in calorimeters constant below parametrization threshold (10 GeV for P. Dinguns code)

fluctuations effect efficiency ? low momentum μ's

is any physics effected ?

two parametrizations of energy losses for high momentum μ's

old : Roger McNeil's

new : Peter Dinguns'

energy loss = f(p_μ, calo. depth)

which one is better ?

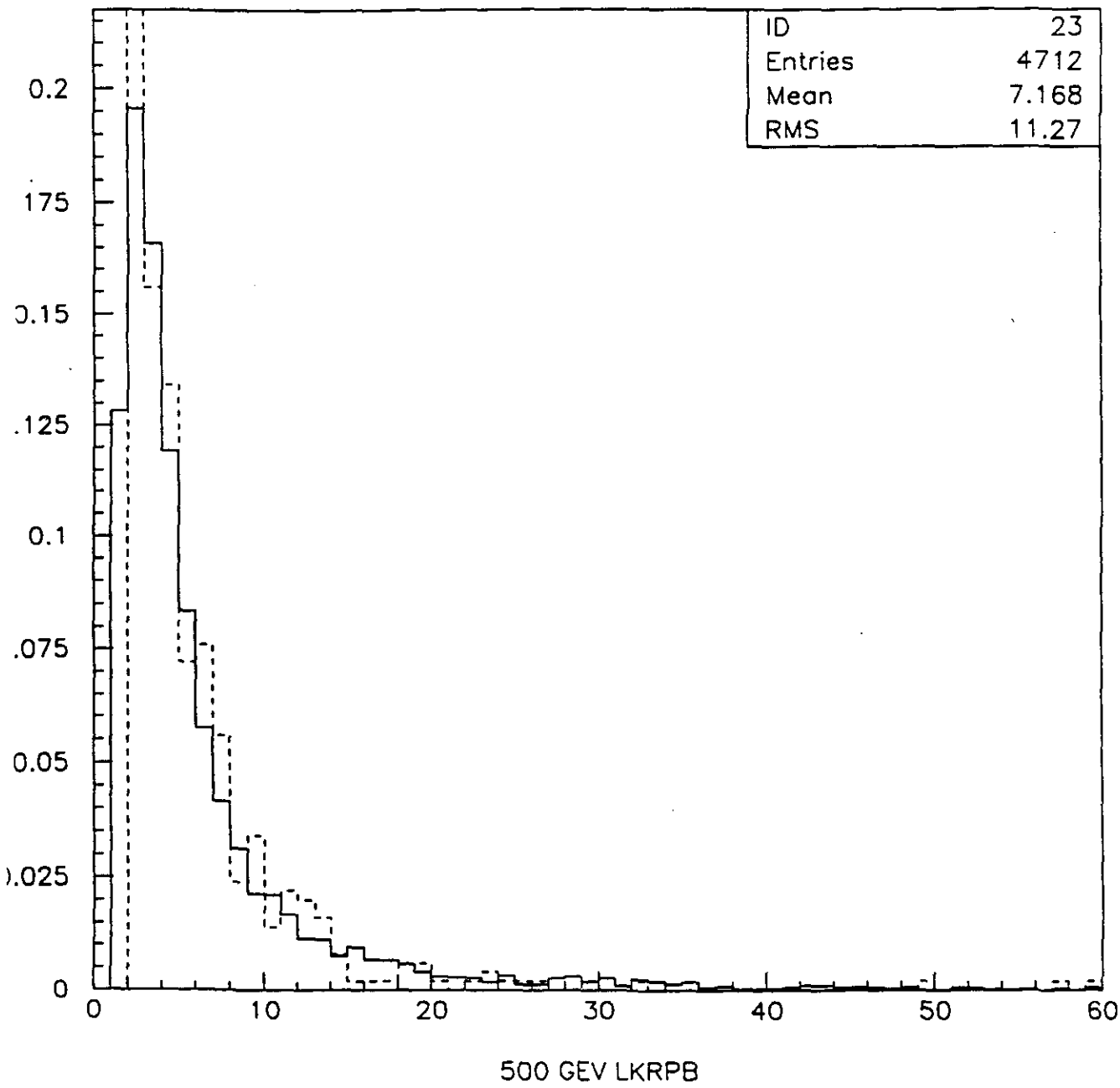
how accurate they are ? → pictures

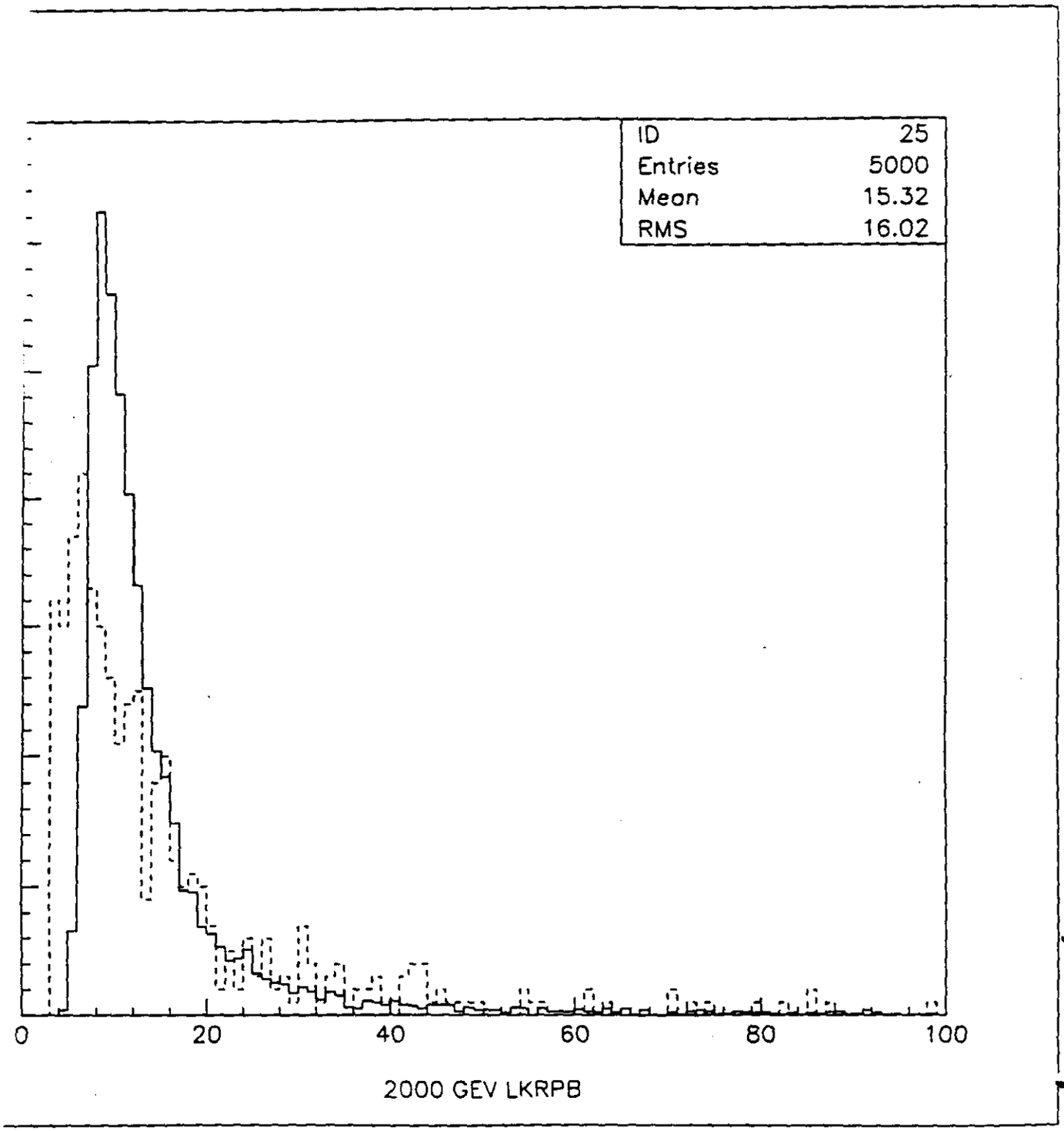
gemfast adds back average energy los

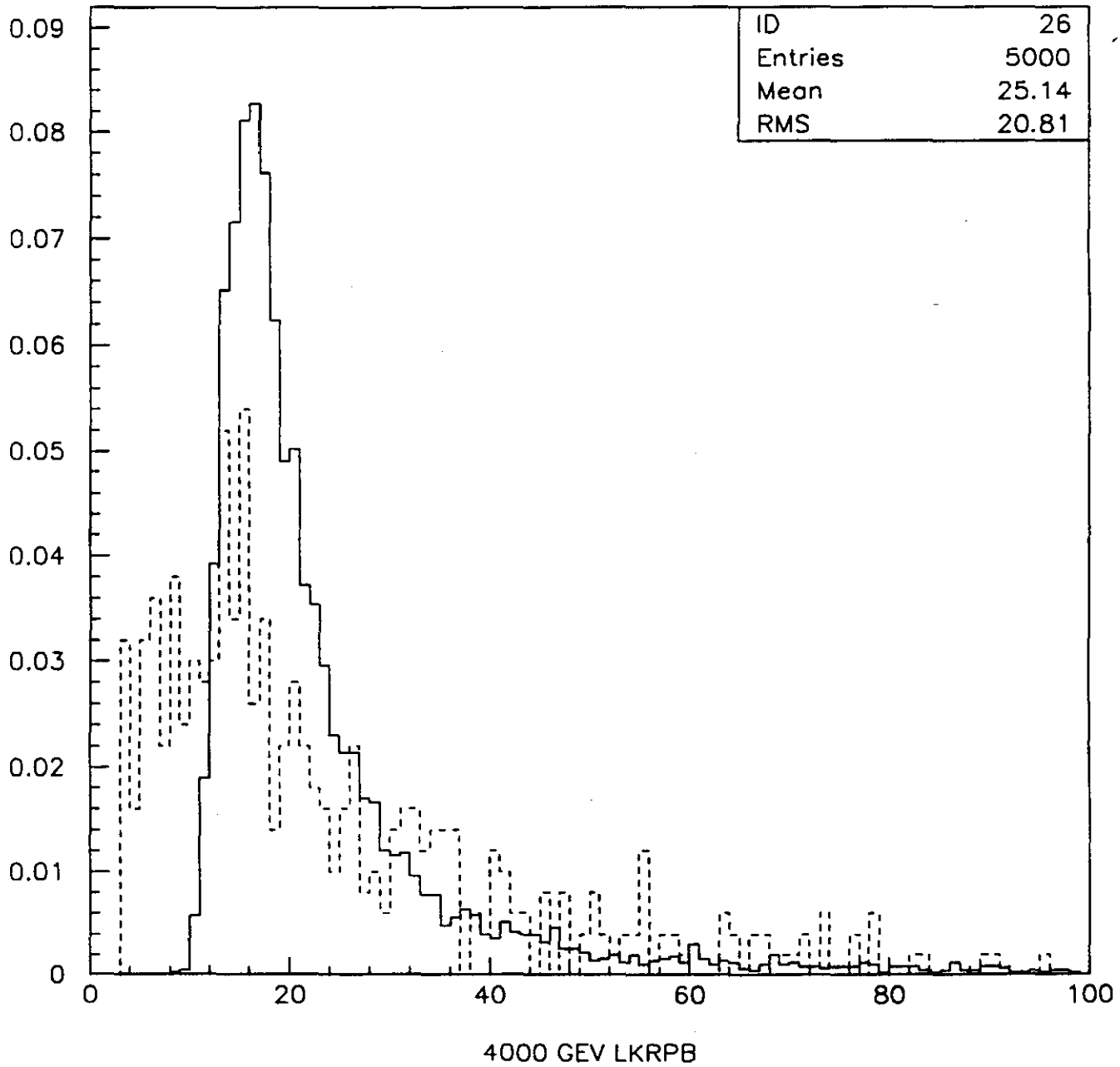
is average value used correct.

geometrical acceptance simulated by discarding μ's which enter MU at $\eta \approx 0$ or $\eta \sim 1$ (?) or $\eta > 2.5$

any φ gaps ?


ID 23
Entries 4712
Mean 7.168
RMS 11.27
0.2
175
0.15
.125
0.1
.075
0.05
).025
0
0
10
20
30
40
50
60
500 GEV LKRPB


ID 25
Entries 5000
Mean 15.32
RMS 16.02
0
20
40
60
80
100
2000 GEV LKRPB


ID 26
Entries 5000
Mean 25.14
RMS 20.81
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
4000 GEV LKRPB

momentum resolution

Torre Wenaus is working on it but has not provided anything yet

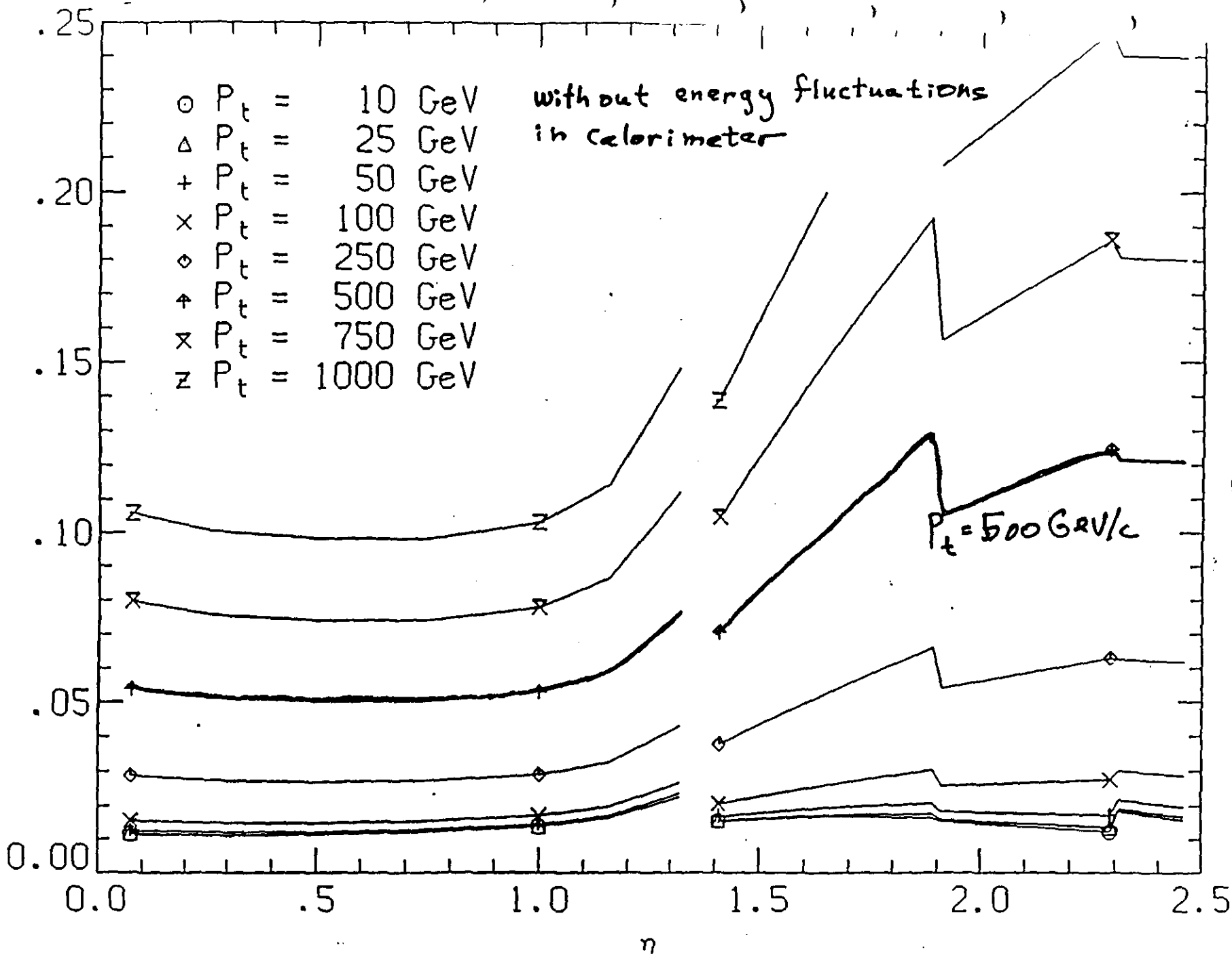
I fitted "analytical" calculations done by ?, which I copied from Peter Dinguis with Jim Sullivan's parametrization (he provided Baseline-I program)

→ picture

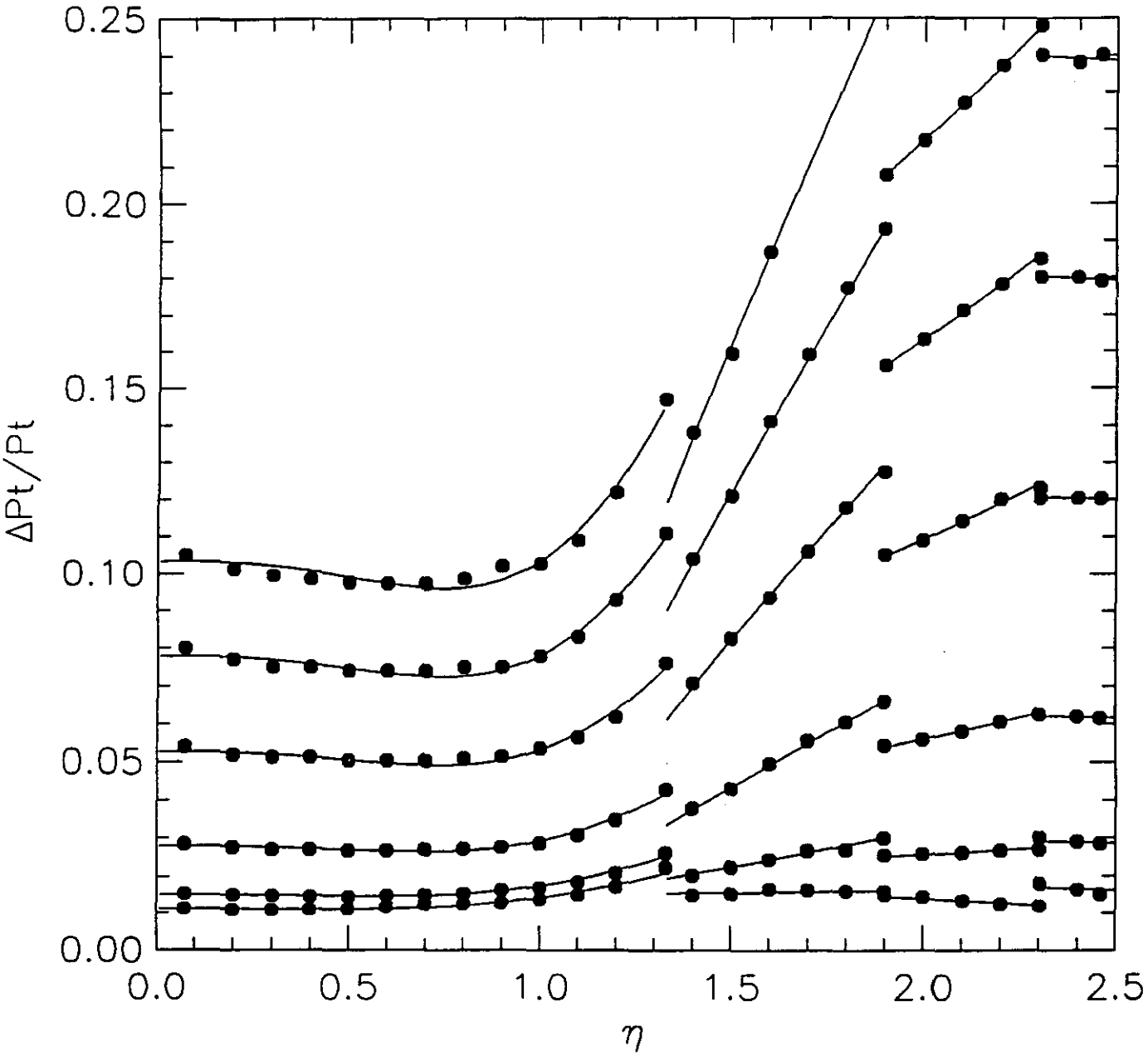
Change is smeared from momentum smearing

Peter Dinguis promised updated μ-trigger efficiency and new reconstruction efficiency but has not provided anything yet

old Peter's Baseline-I parametrization is called by gemfast



Muon CSC option but modified locations: 11/25/92


0.25
0.20
0.15
0.10
0.05
0.00
ΔPt/Pt
0.0
0.5
1.0
1.5
2.0
2.5
η

my own plans:

- implement any new codes from you (except for Henk's trigger code which should be a separate package)
- help in γ-conversion coding
- try to improve speed

p on pdsf

VI204	1.4 sek / bunch crossing	includes clustering and jet finding
VII101	1.9 sek / bunch crossing	

↑

1 $H \to \gamma\gamma$ + <1.6> min. bias

- debug any execution time errors
- write more examples and documentation
- help other people use gemfast

expect all people who provided parametrizations to:

- check how they work in gemfast
- produce some pictures useful for TDR section on detector simulation

main challange now is to make physics simulation people use gemfast and understand what they are doing

proposal how to proceed:

I. form working groups (or working people) who will:

1. write selection codes using gemfast tools
2. understand systematic limitations of 1.
3. pass them to physics simulat people

of

G γ
E e
M μ
jet
$\not{E}_t$

II. ask physics simulators to describe how they used gemfast to do the analysis
(send their codes for inspection?)

gem

γeμ

Presentation by:

Shawn McKee

Parameterization of the GEM Central Tracker

An description of the process and code

Shawn McKee

January 8th, 1993

The Subroutines

The central tracker paramaterization is accomplished by 5 subroutines:

- FSI_CTISO — Determines (at the generator level) if a track is isolated.
- FSI_CTRECON — Estimates the track reconstruction probability.
- FSI_CTSLAY — Returns the number of LAYERS of tracking crossed.
- FSI_CTSMEAR — Provides a measured momentum, measured charge and sigma for impact parameters.
- *FSI_CTCONV* — Converts gammas in the tracker based upon tracker material distributions. (Under construction)

FSI_CTISO

The FSI_CTISO routine has the following interface:

```
LOGICAL_FLAG = FSI_CTISO(ICT,DE,DP)
```

where **ICT** is the index of the charged track and **DE** and **DP** are the required separation in rapidity and phi. If the required separation arguments are less than or equal to zero a separation based on the size of the tracker IPCs is used as a default.

FSI_CTRECON

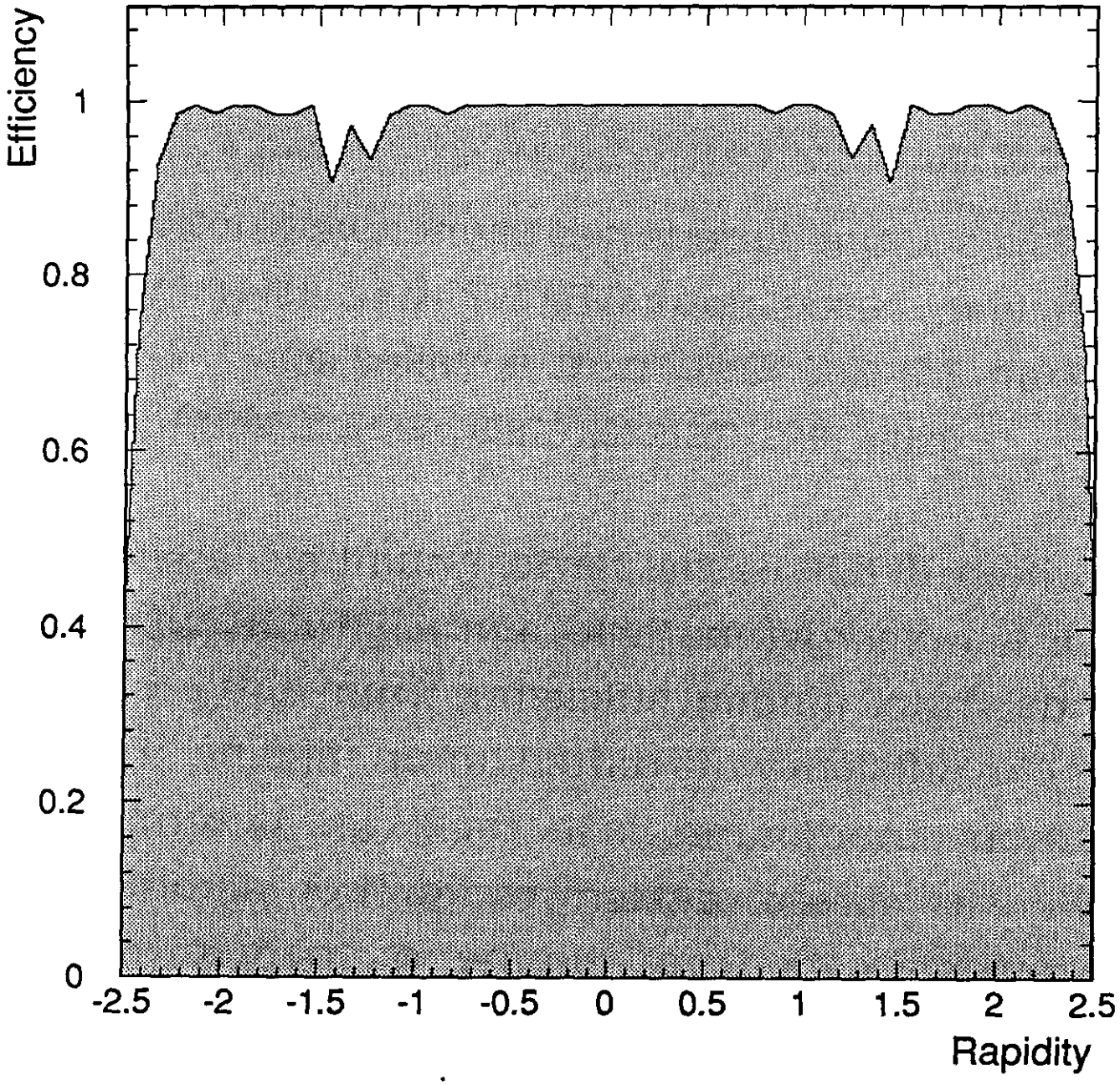
This routine determines the reconstruction efficiency based upon GEANT runs using muons from 10-100 GeV/c. It is called as:

```
CALL FSI_CTRECON(IHEP,EFFICIENCY)
```

where **IHEP** is the particle number (*assumes* it is a charged particle) and **EFFICIENCY** is the track finding efficiency from 0.0 — 1.0. The efficiency is based upon finding 10 or more coordinates in a track (as determined by the current pattern recognition algorithm) divided by the total number of charged tracks in this eta bin. Results are averaged over phi.

* Vertex : smeared 5 cm sigma

CT Tracking Efficiency



FSI_CTSLAY

This routine determines the number of layers crossed by a given charged track. It assumes the track is straight and that there are NO dead spaces inside the nominal detector extents. It is called as:

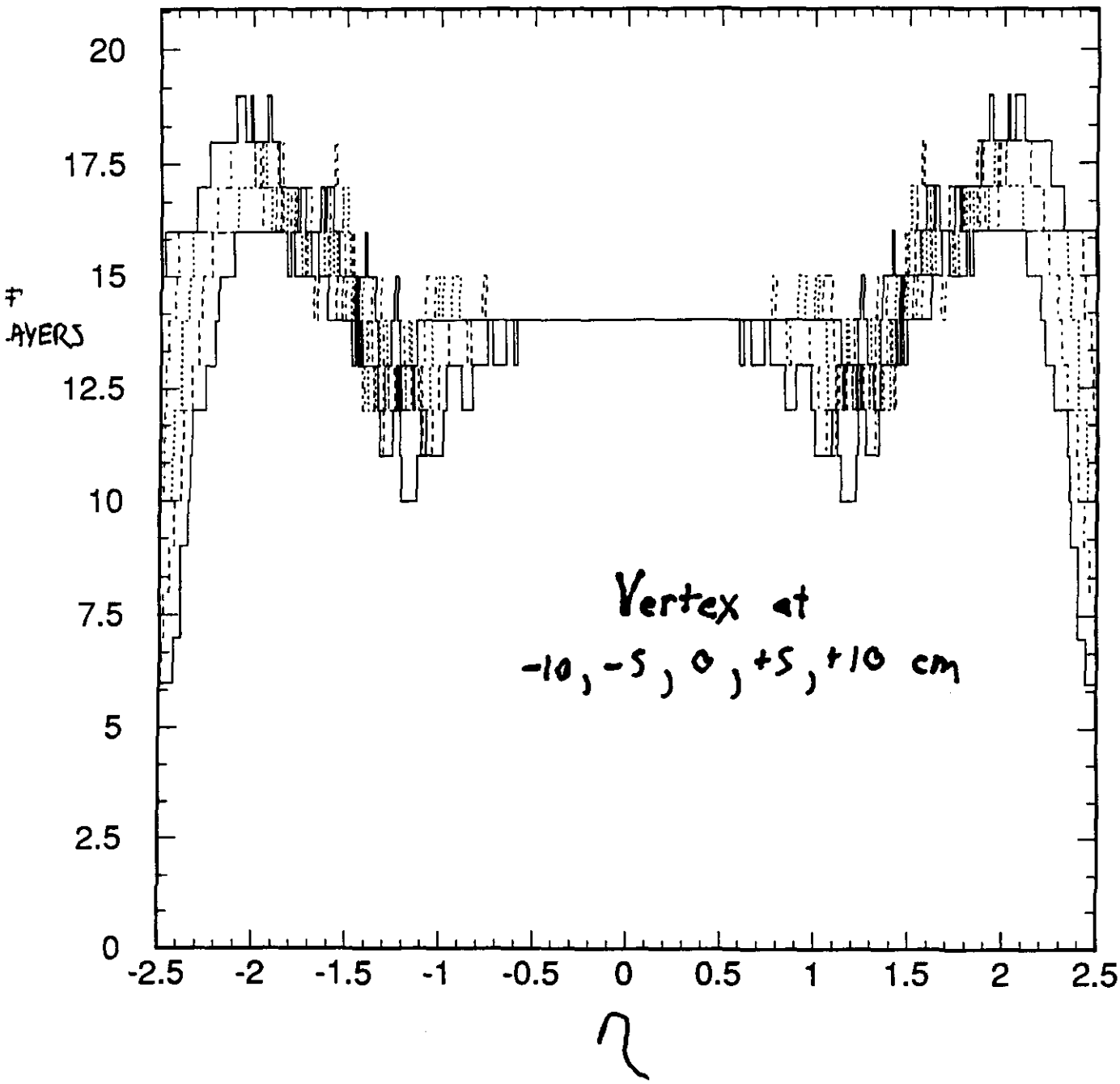
```
CALL FSI_CTSLAY(XIN,XOUT,ICODE)
```

where **XIN** is the input coordinate, **XOUT** is the output coordinate and **ICODE** is the return value specifying the number of layers crossed. The information is made available as:

$$\mathrm{ICODE} = N_{\mathrm{SI_layers}} + 100 \times N_{\mathrm{IPC_layers}}$$

FSI_CTSLAY

Tracking Layers



FSI_CTSMEAR

This routine is really the heart of the tracker response. It is called as:

```
CALL FSI_CTSMEAR(IHEP,PMCT,QMCT,DPMCT,DIMCT,DIZMCT,IFL
```

- **IHEP** is the particle ID.
- **PMCT** is the *measured* momentum vector.
- **QMCT** is the *measured* charge.
- **DPMCT** is the standard deviation of the $\frac{\delta(\frac{1}{P})}{(\frac{1}{P})}$ distribution.
- **DIMCT** is the impact parameter in mm ($R - \Phi$ plane).
- **DIZMCT** is the Z (along beam) impact parameter in mm.
- **IFL** is an error flag, 0 for normal return.

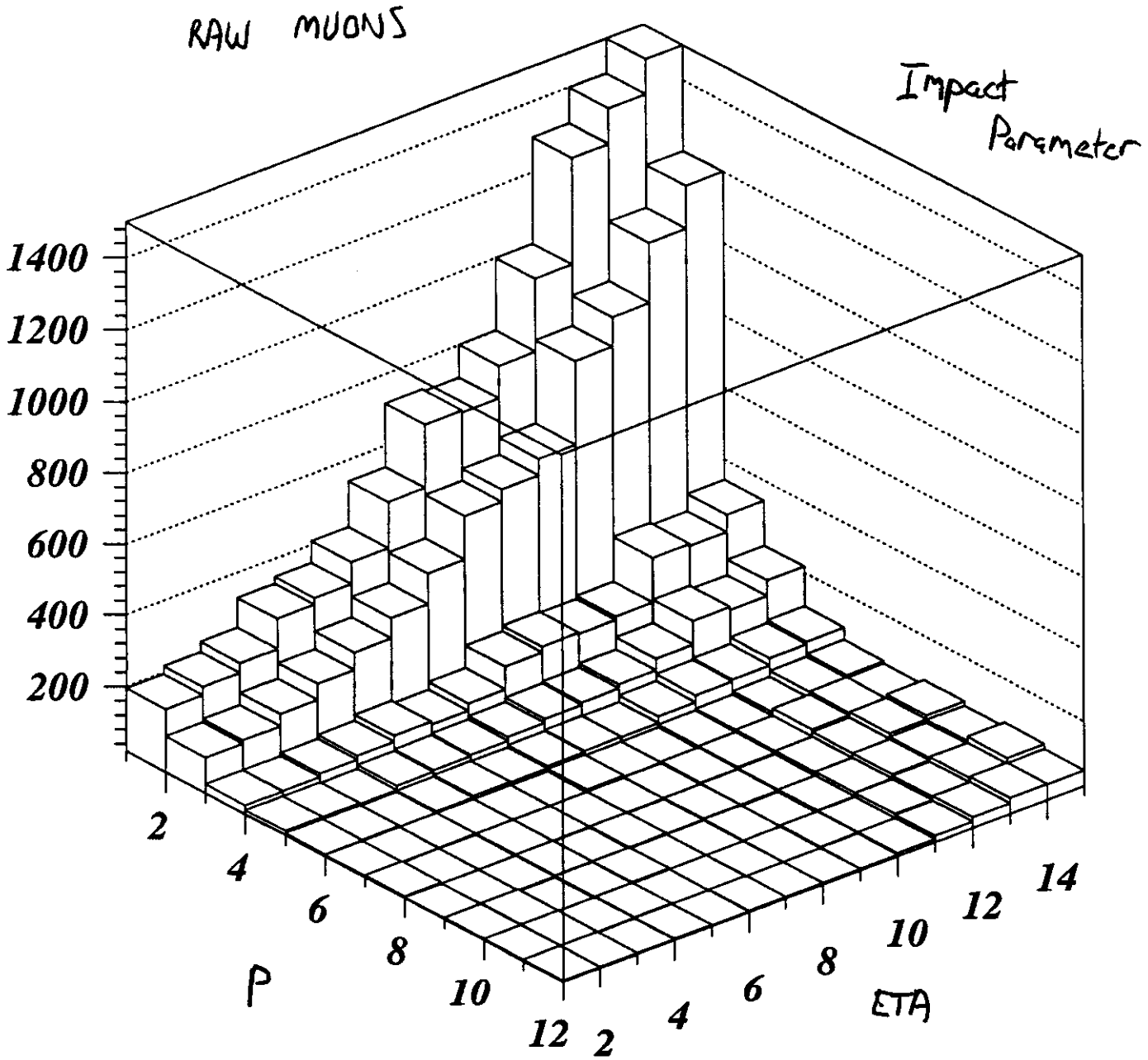
Details of FSI_CTSMEAR

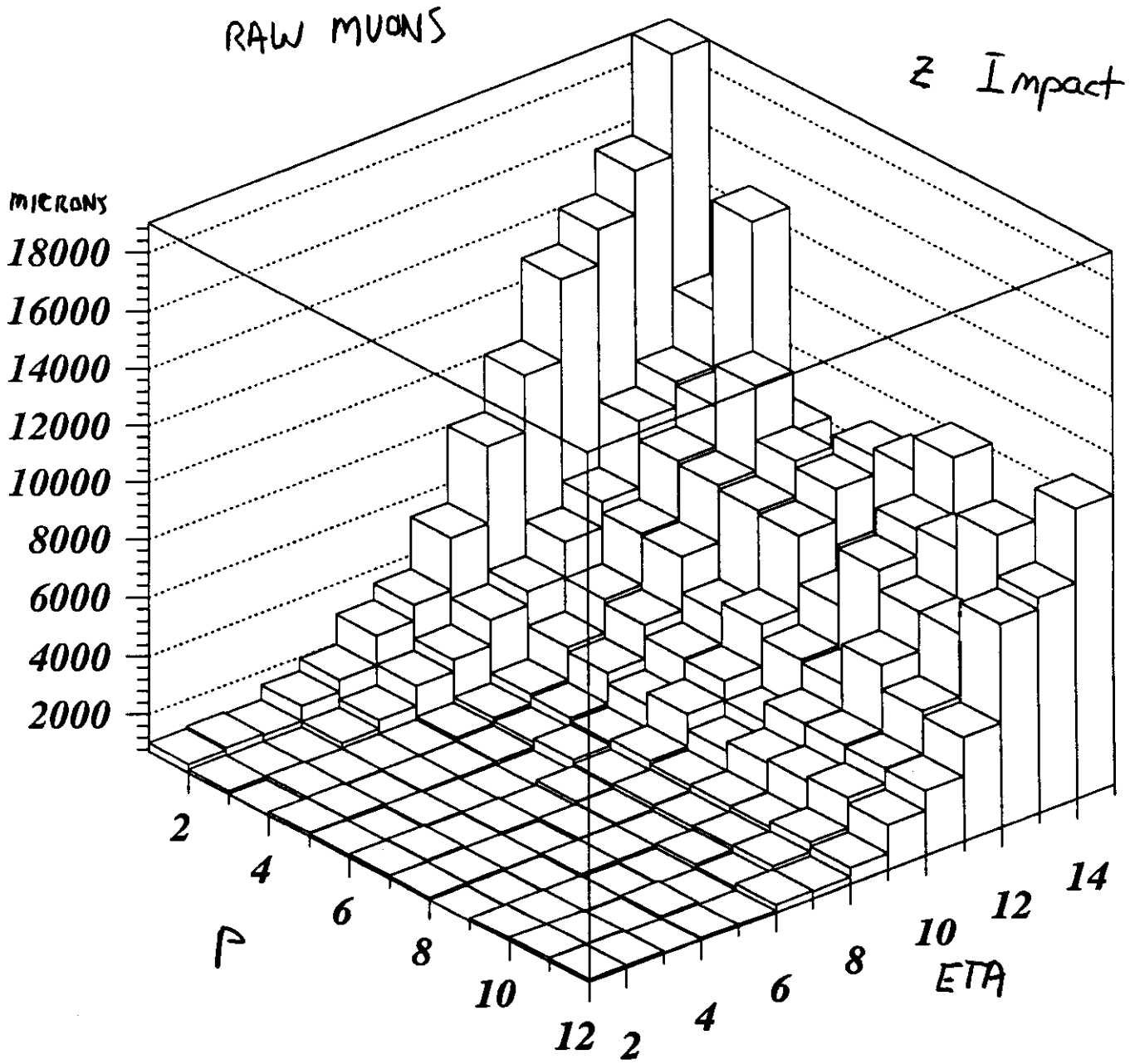
The smearing routine for the central tracker is based upon 154 runs of electrons and muons through the detailed GEANT model of the central tracker. All charged particles but electrons are parameterized using the muon results. Each run of muons had 300 events. The rapidity and momentum values for each run were as follows (14 eta$\times$11 mom = 154 runs):

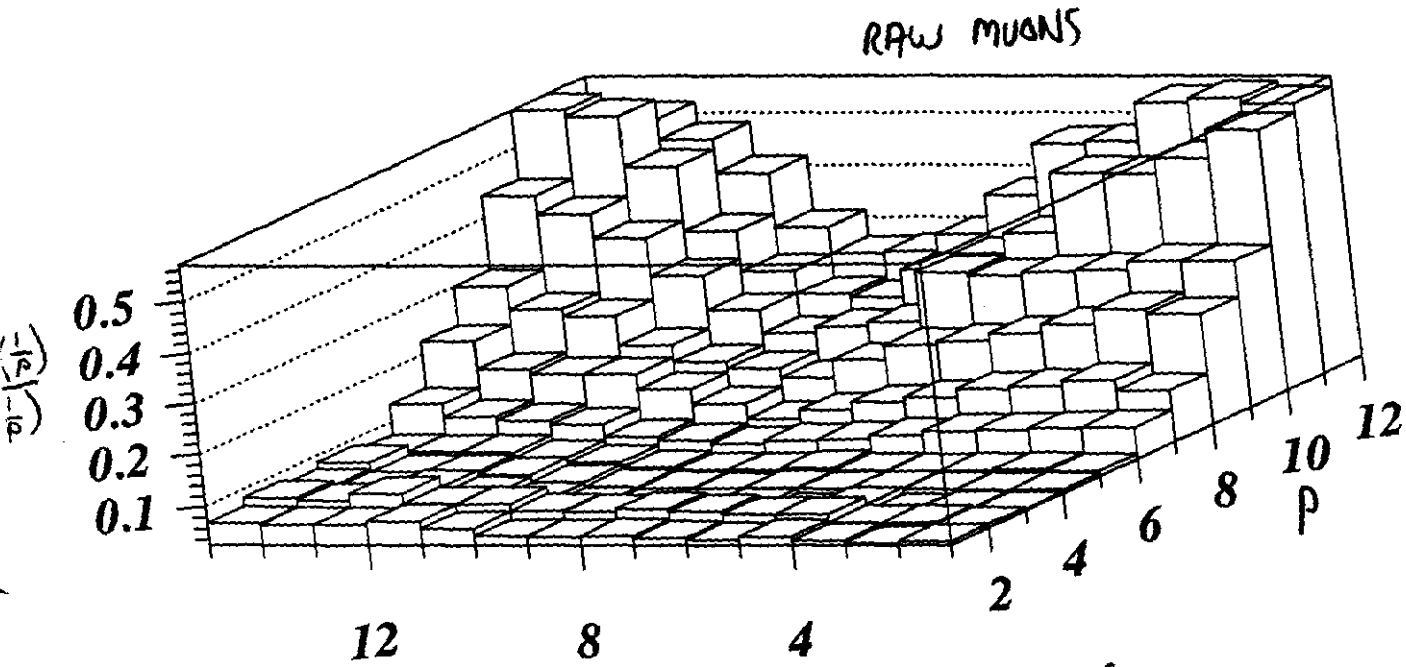
Rapidity: Starting with 0.0 and incrementing in steps of 0.2 to 2.4 (12 bins) plus events run at exactly 2.4 and 2.5 (14 bins).

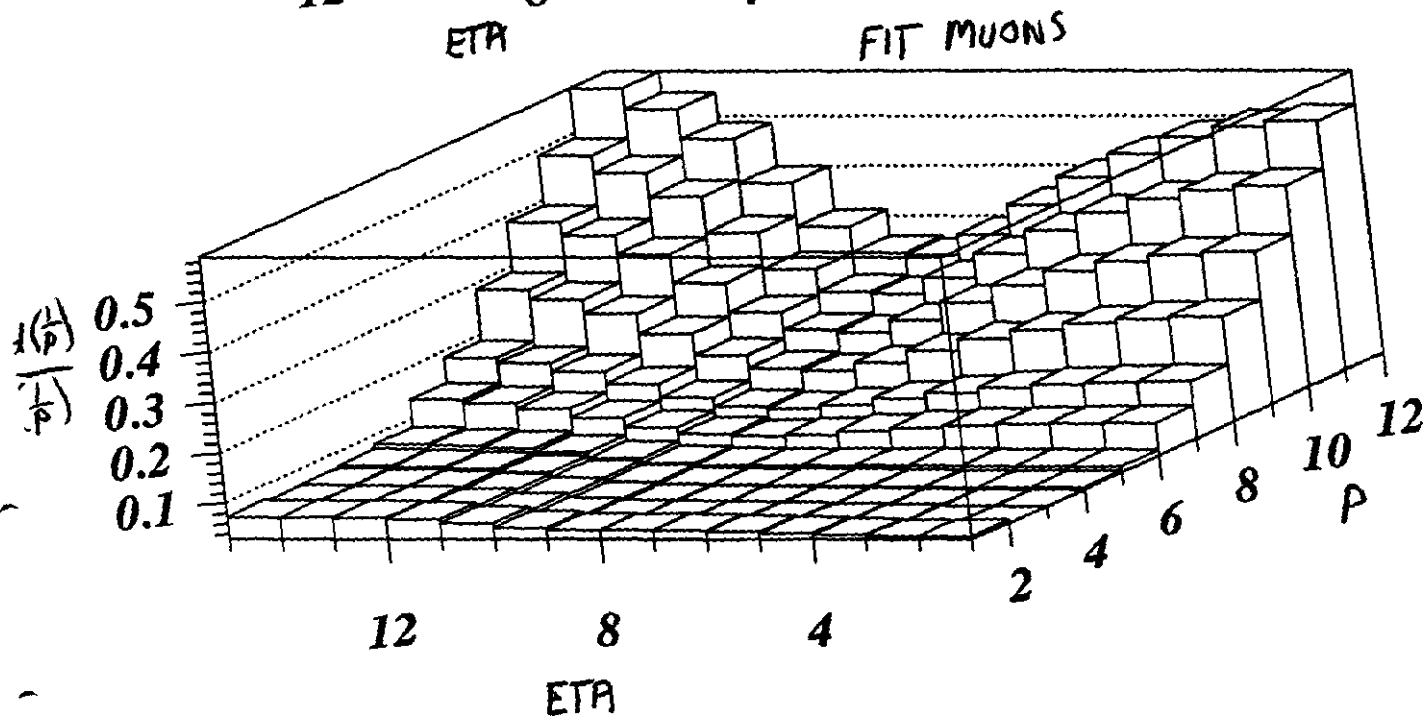
Momentum: 11 bins at 1, 2, 5, 10, 20, 75, 125, 225, 325, 425 and 525 GeV/c.

The electron results were in the same bins but used 500 events instead of 300.


RAW MUONS
Impact Parameter
1400
1200
1000
800
600
400
200
2
4
6
8
10
12
P
2
4
6
8
10
12
14
ETA


RAW MUONS
z Impact
MICRONS
18000
16000
14000
12000
10000
8000
6000
4000
2000
2
4
6
8
10
12
P
2
4
6
8
10
12
14
ETA


RAW MUONS
0.5
0.4
0.3
0.2
0.1
12
8
4
ETA
2
4
6
8
10
12
P


FIT MUONS
0.5
0.4
0.3
0.2
0.1
12
8
4
ETA
2
4
6
8
10
12
P

Muon Data

All muon histograms were fit to a gaussian. The important results were then parameterized versus η and ϕ. The functional form used varied. For the impact parameter the data was fit first as a function of momentum:

$$B_{impact} = \frac{P_1}{P} + P_2$$

while each parameter was fit to a special function versus η:

$$P_1 = (E_1^1 \times \eta + E_2^1) \times \eta + E_3^1$$

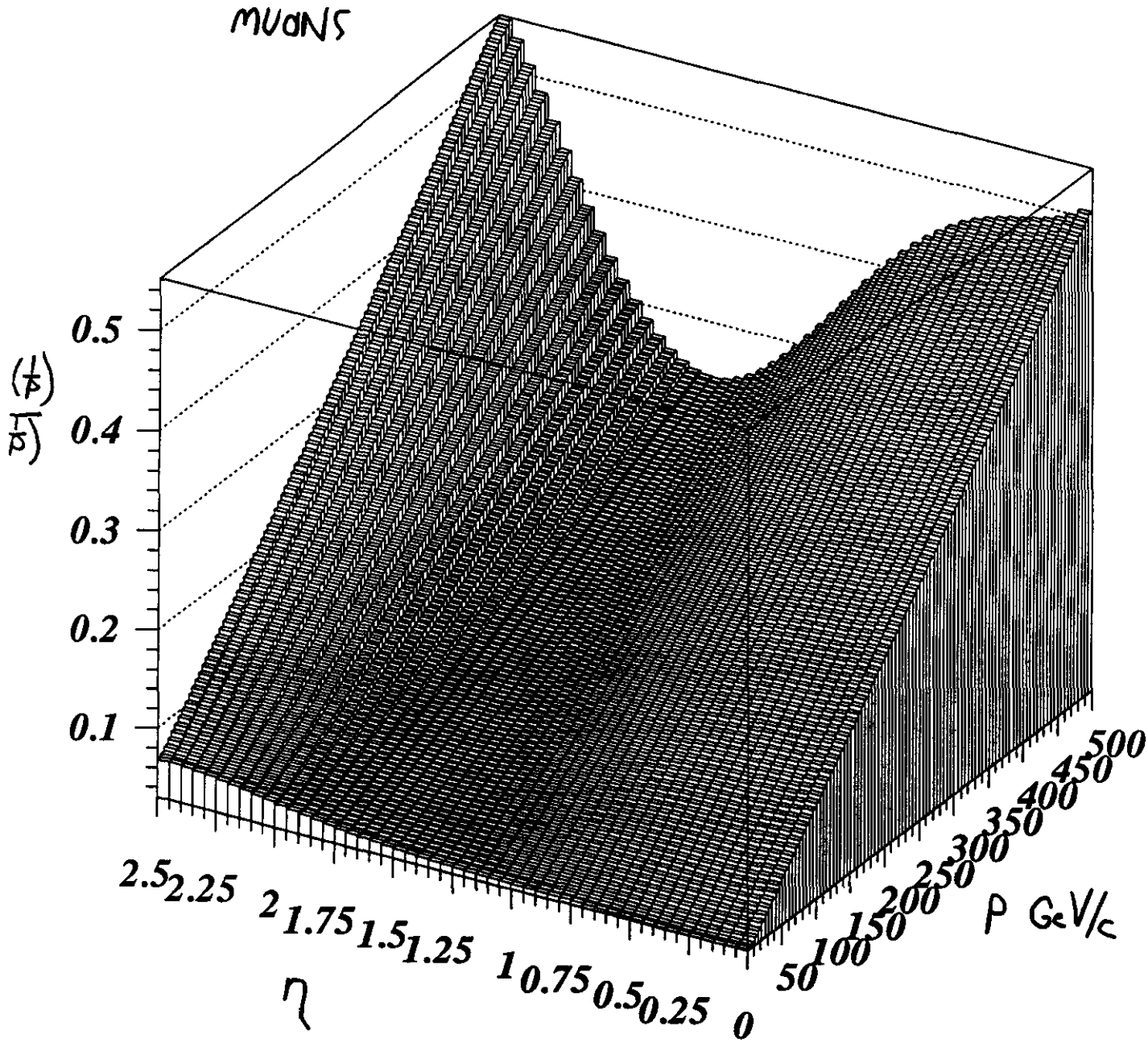
$$P_2 = \begin{cases} (E_1^2 \times (\eta - E_4^2) + E_2^2) \times (\eta - E_4^2) + E_3^2 & \text{if } \eta > E_4^2 \\ E_3^2 & \text{otherwise} \end{cases}$$

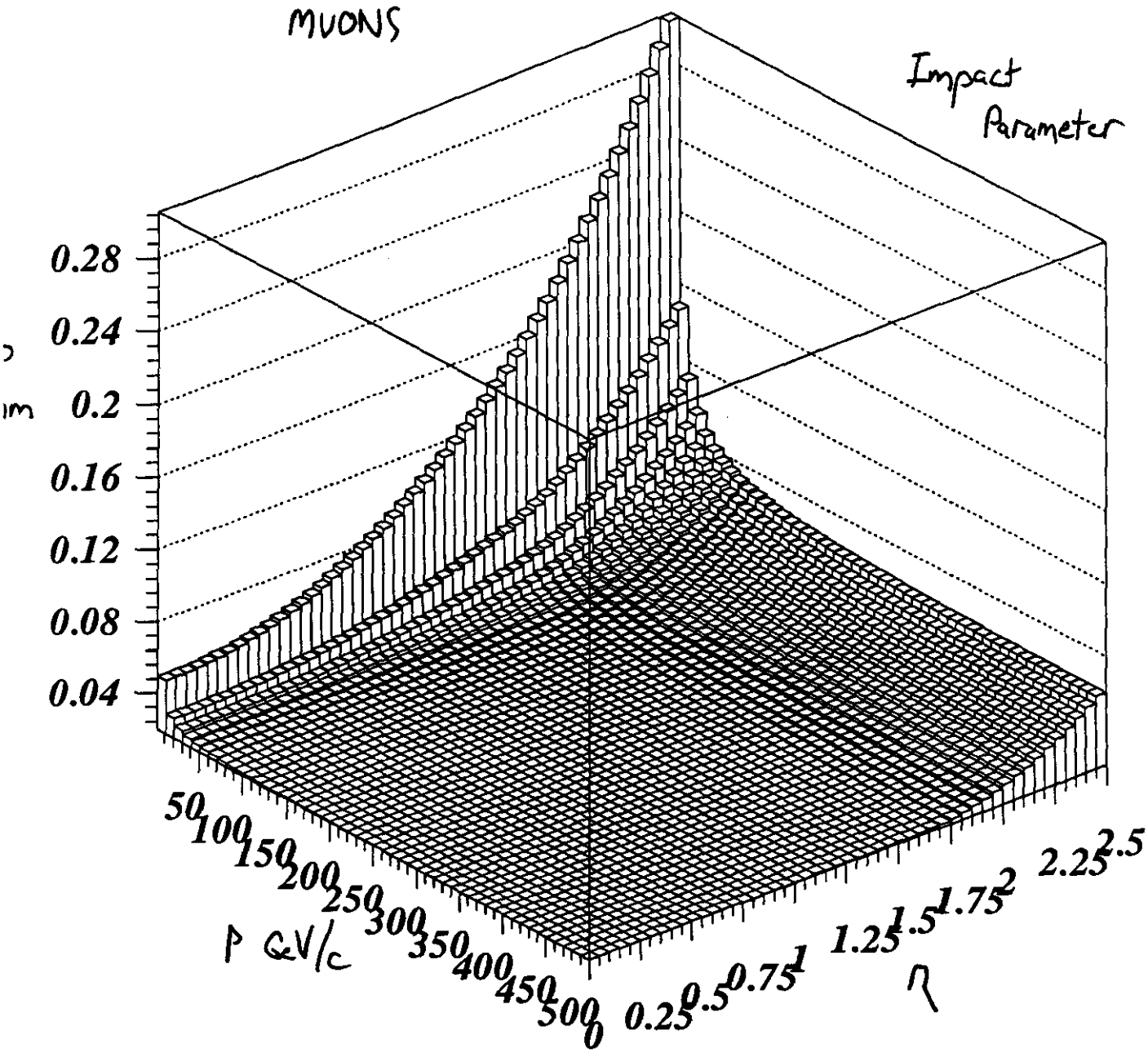
The same functional form with different parameters fit the Z impact parameter.

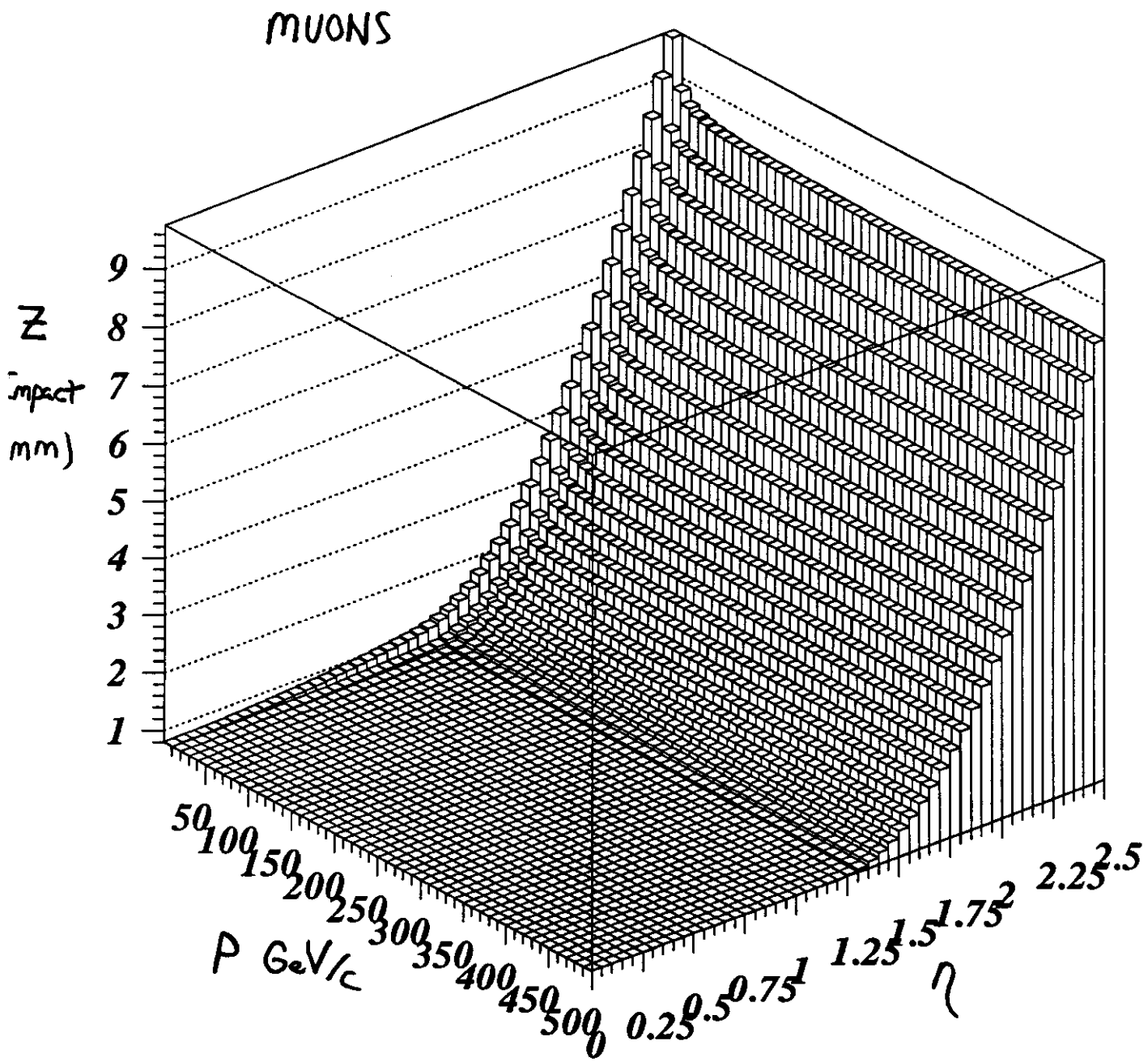
The muon resolution data was fit as follows:

$$\frac{\delta(\frac{1}{P})}{(\frac{1}{P})} = \frac{P_1}{P} + P_2 + P_3 \times P$$

with each parameter fit to a fifth order polynomial versus η.


MUONS
0.5
0.4
0.3
0.2
0.1
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
η
50
100
150
200
250
300
350
400
450
500
P GeV/c


MUONS
Impact Parameter
0.28
0.24
0.2
0.16
0.12
0.08
0.04
50
100
150
200
250
300
350
400
450
500
P GeV/c
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
η


MUONS
Z
impact
mm)
9
8
7
6
5
4
3
2
1
50
100
150
200
250
300
350
400
450
500
P GeV/c
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
η

Electron Data

All electron momentum resolutions histograms were fit to a special function of 4 parameters. The function form is:

$$P_1 \times \left(\frac{P_4}{\left(\frac{.38}{P_2 \times X^2}+1\right)} + G(X, P_2)\right) \qquad \text{if } X > 0$$

$$P_1 \times (1 + P_4) \times \left(G(X, P_2) + \frac{P_3}{\left(\frac{(X-1.5)^4}{P_2}+1\right)}\right) \qquad \text{otherwise}$$

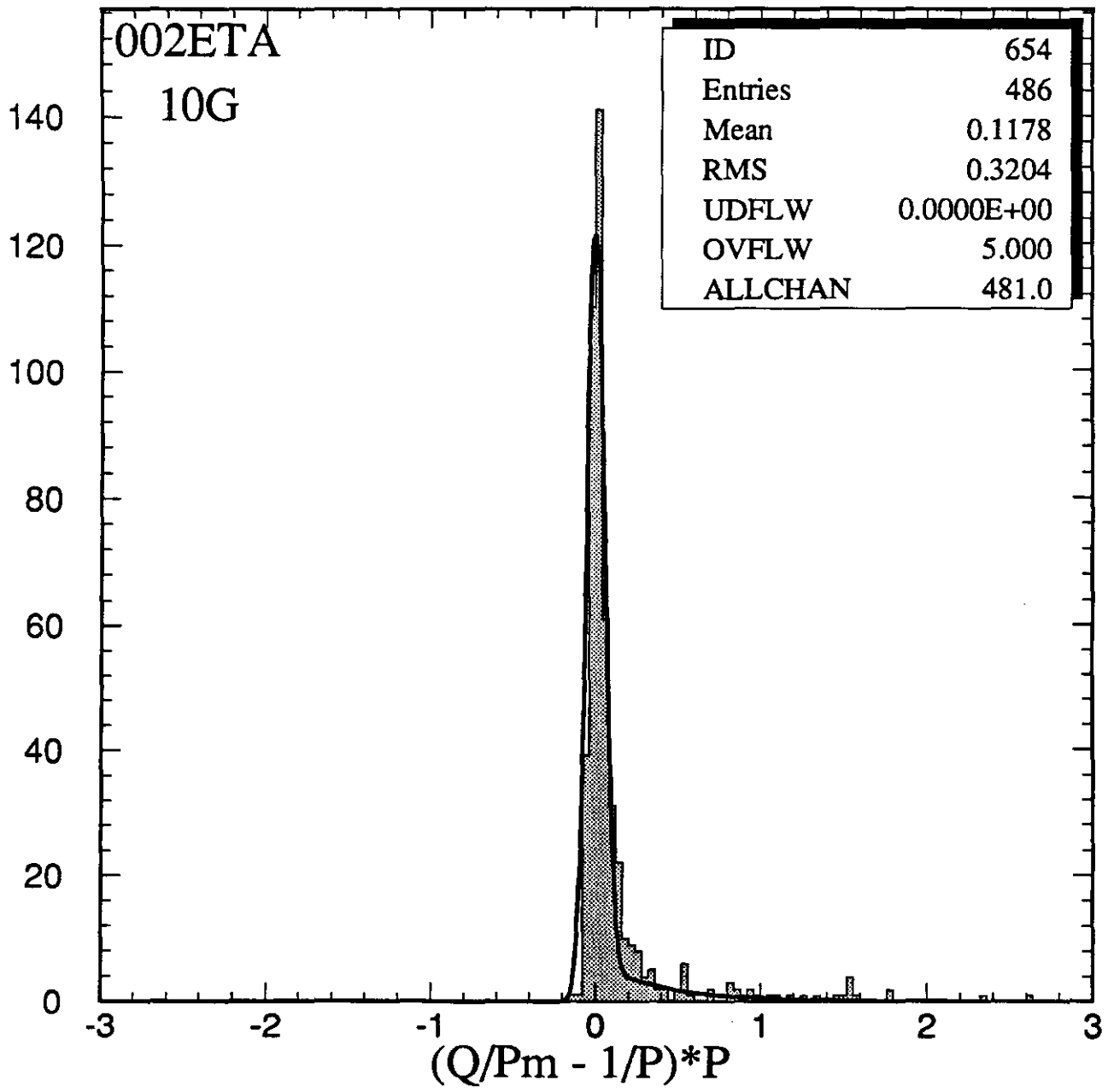
Gaussian, P_2 is sigma, centroid is 0.0

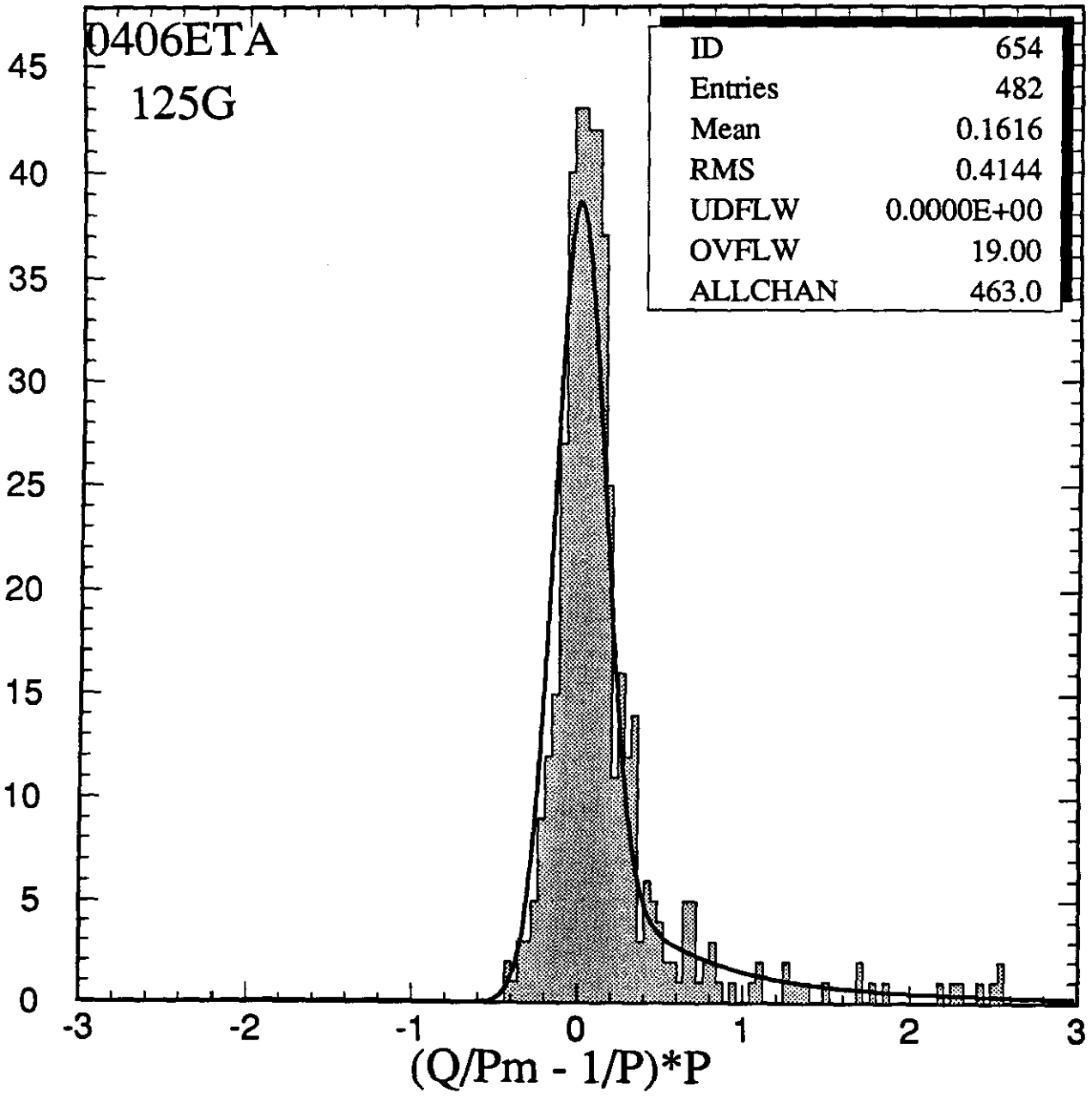
Each parameter in this equation is a function of η and P, i.e.,

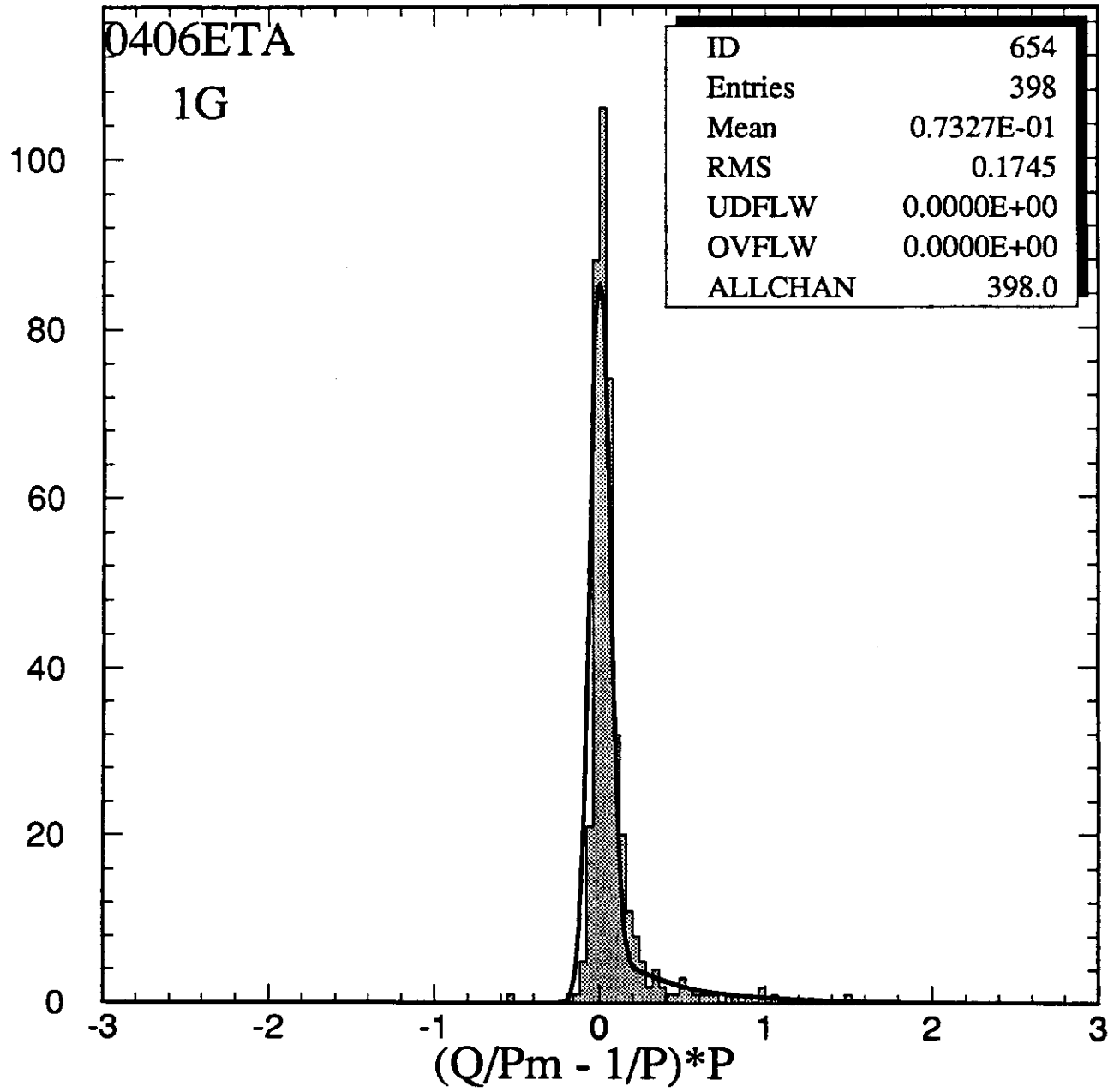
$$P_1 = P_1(P, \eta)$$

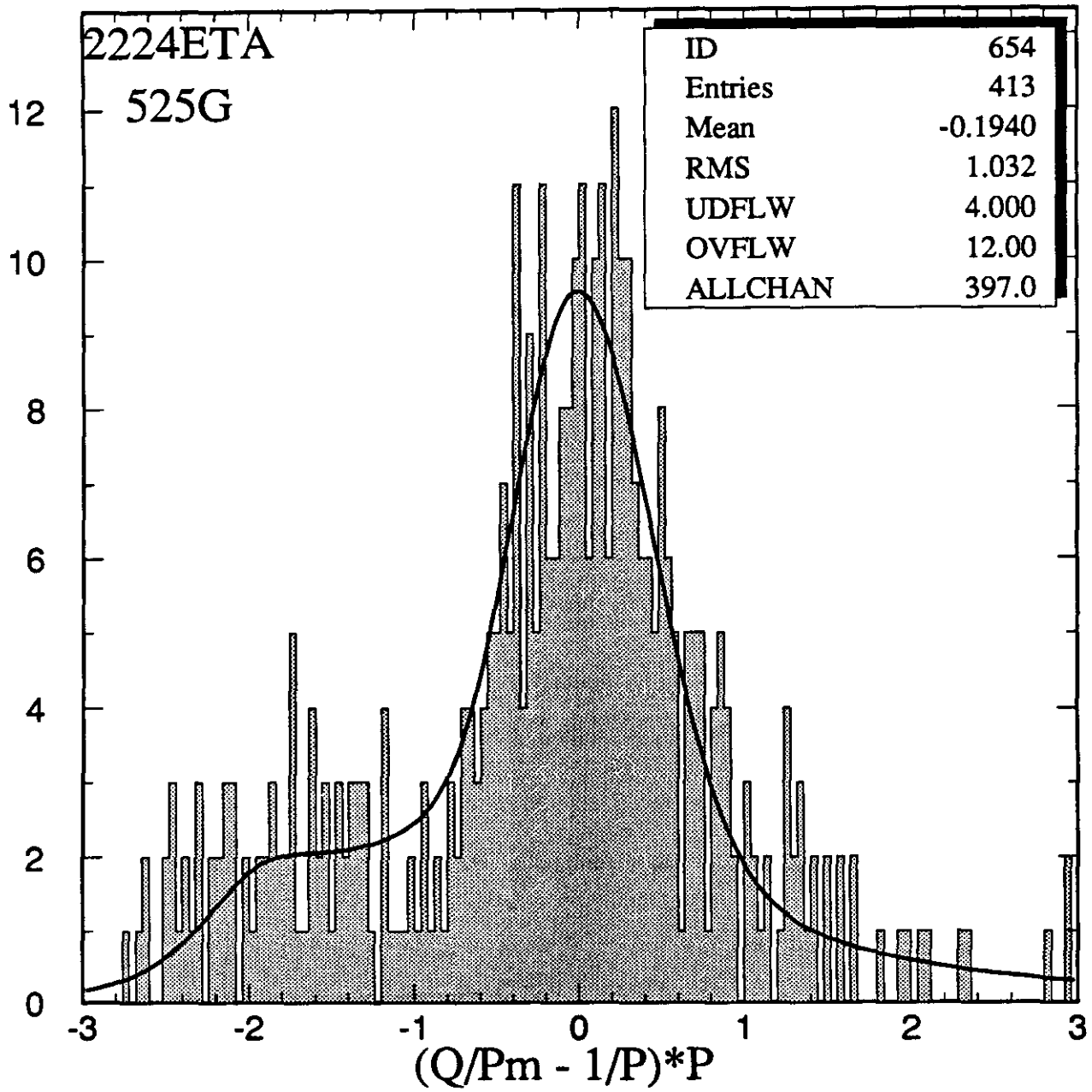
Function fits were found for each of the four parameters over the whole range of the electron data.

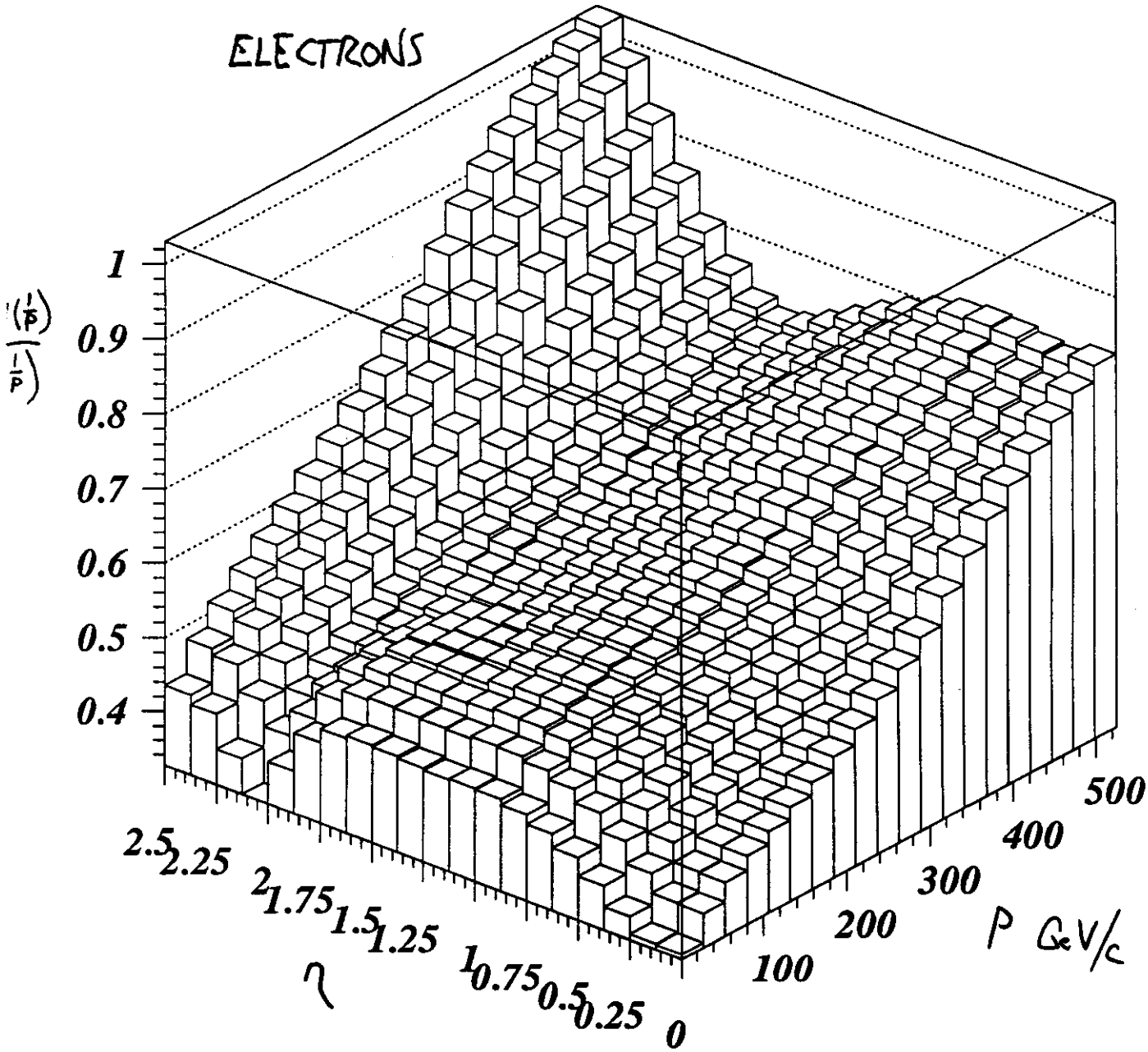
The electron impact parameters were fit to functional forms as well.

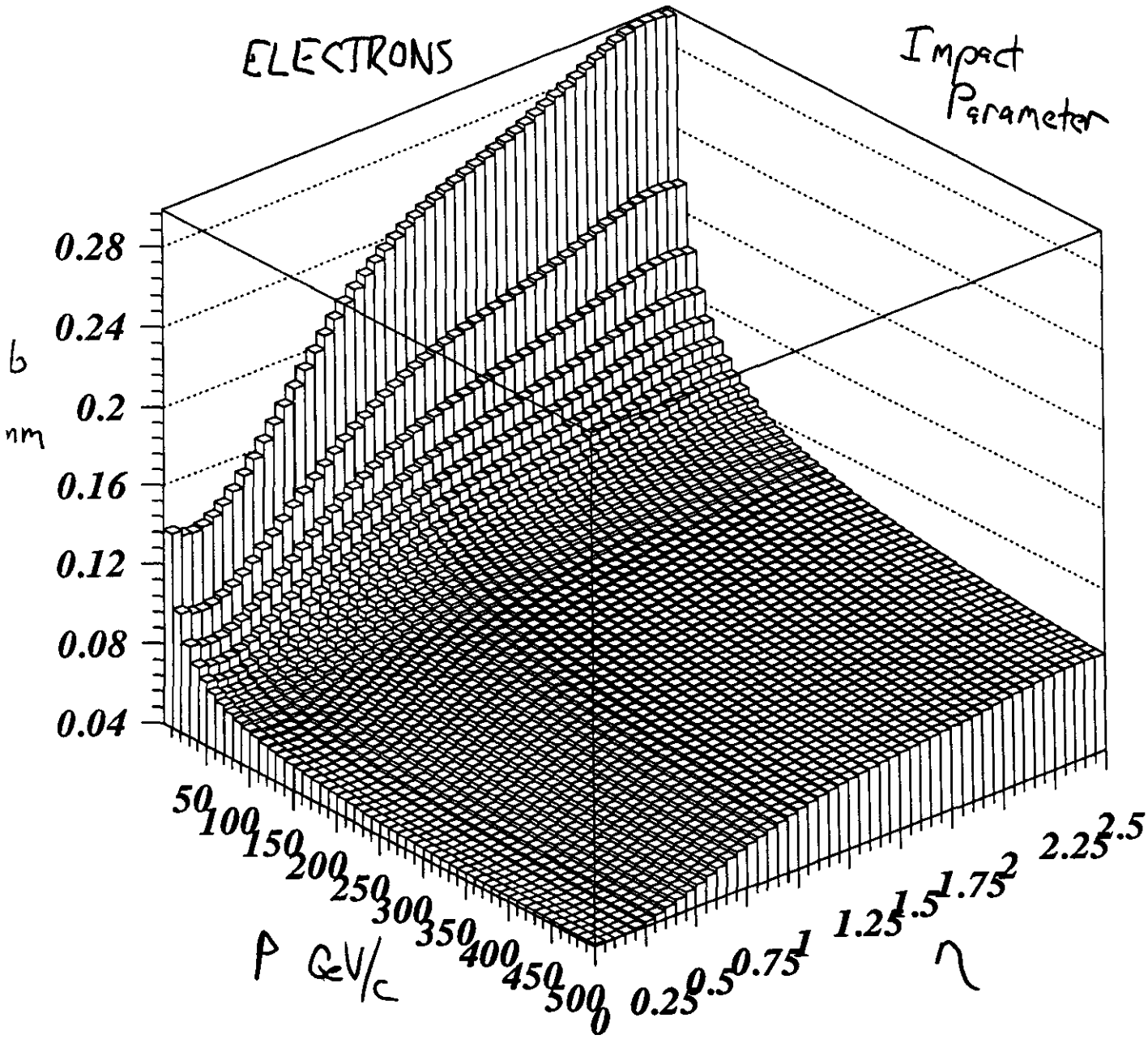

002ETA
10G
ID 654
Entries 486
Mean 0.1178
RMS 0.3204
UDFLW 0.0000E+00
OVFLW 5.000
ALLCHAN 481.0
140
120
100
80
60
40
20
0
-3
-2
-1
0
1
2
3
(Q/Pm - 1/P)*P

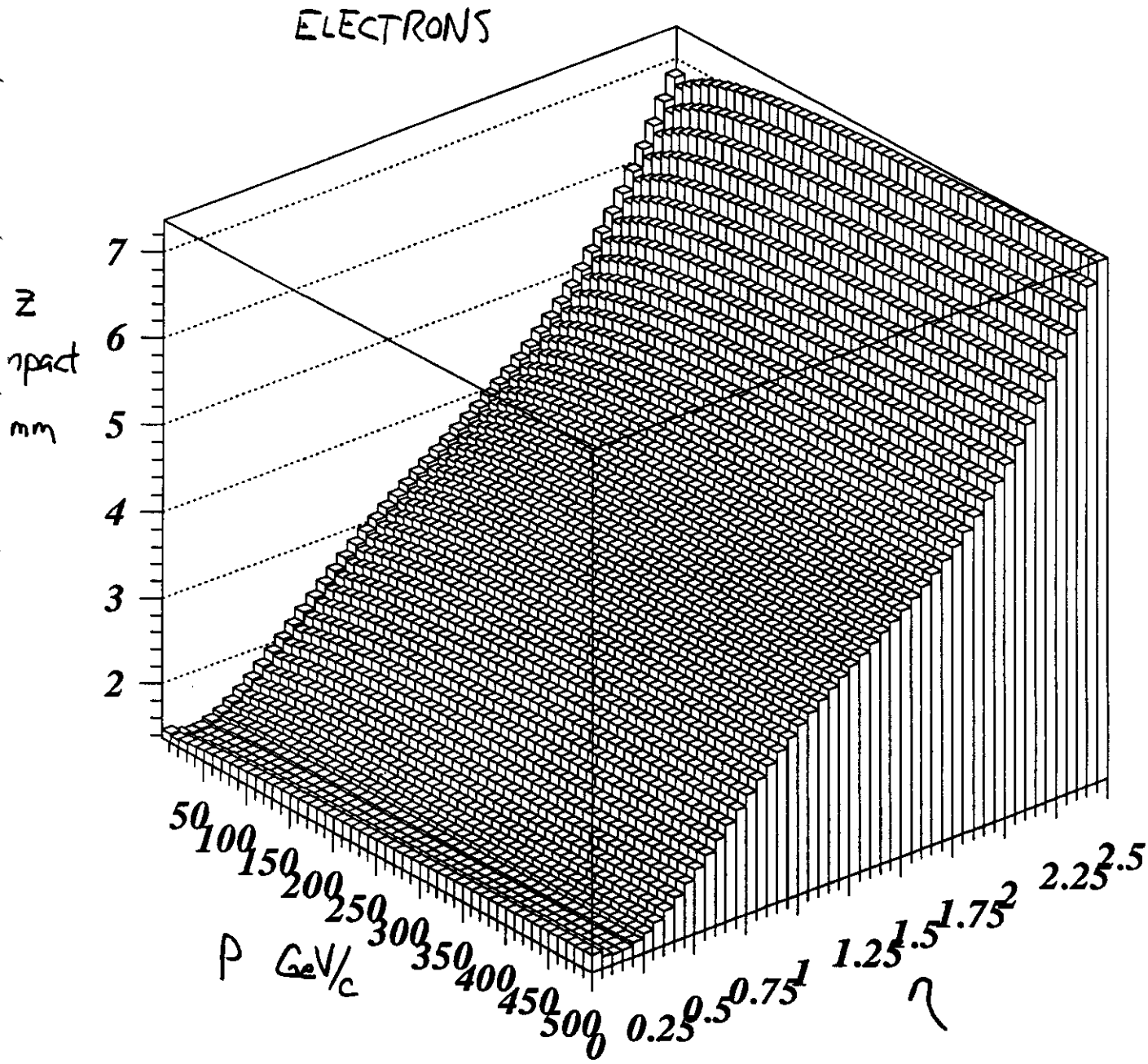

0406ETA
125G
ID 654
Entries 482
Mean 0.1616
RMS 0.4144
UDFLW 0.0000E+00
OVFLW 19.00
ALLCHAN 463.0
45
40
35
30
25
20
15
10
5
0
-3
-2
-1
0
1
2
3
(Q/Pm - 1/P)*P


0406ETA
1G
ID 654
Entries 398
Mean 0.7327E-01
RMS 0.1745
UDFLW 0.0000E+00
OVFLW 0.0000E+00
ALLCHAN 398.0
100
80
60
40
20
0
-3
-2
-1
0
1
2
3
(Q/Pm - 1/P)*P


2224ETA
525G
ID 654
Entries 413
Mean -0.1940
RMS 1.032
UDFLW 4.000
OVFLW 12.00
ALLCHAN 397.0
0
2
4
6
8
10
12
-3
-2
-1
0
1
2
3
(Q/Pm - 1/P)*P


ELECTRONS
1
0.9
0.8
0.7
0.6
0.5
0.4
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
η
100
200
300
400
500
P GeV/c


ELECTRONS
Impact Parameter
b
nm
0.28
0.24
0.2
0.16
0.12
0.08
0.04
50
100
150
200
250
300
350
400
450
500
P GeV/c
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
η


ELECTRONS
Z
mpact
mm
7
6
5
4
3
2
50
100
150
200
250
300
350
400
450
500
P GeV/c
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
η

Results from FSI_CTSMEAR

FSI_CTSMEAR returns measured momenta for charged tracks within the acceptance of the tracker ($0.0 \leq |\eta| \leq 2.5$). For charged tracks except electrons, the momentum is generated by selecting a number from a "normal" distribution. Since the original histograms were in terms of D:

$$D = (\frac{Q}{P_{meas}} - \frac{1}{P}) \times P \sim \frac{P}{P_{meas}} - 1$$

and our distribution was approximately gaussian, we take the normal random, add 1 and invert to give $\frac{P_{meas}}{P}$. PMCT is then found by multiplying the true momentum by this number.

Electrons are treated differently. The function described above is used to generate a distribution. HISRAN (CERNLIB) then draws a random number based on this distribution. This allows us to simulate the extensive tails which occur in the electron distributions.

Limitations of the Parameterizatior

- Efficiency currently is estimate for isolated particles ONLY.

- Response is incorrect for high luminosity (10^{34} after silicon fails).

- Routines assume no dead areas or detector inefficiencies (except for FSI_CTRECON).

- Effects of tracking in high occupancy areas are not simulated.

- Events below 1 GeV/c may "blow up" due to extrapolation effects.

Planned Work

There are a few more things to do that the CT group is aware of:

- Finish FSI_CTCONV using best estimate of CT materials.
- Create high luminosity data for FSI_CTSMEAR (no silicon).
- Update FSI_CTRECON as more accurate info becomes available.
- Suggestions from this meeting implemented...?

gem

γeμ

Presentation by:

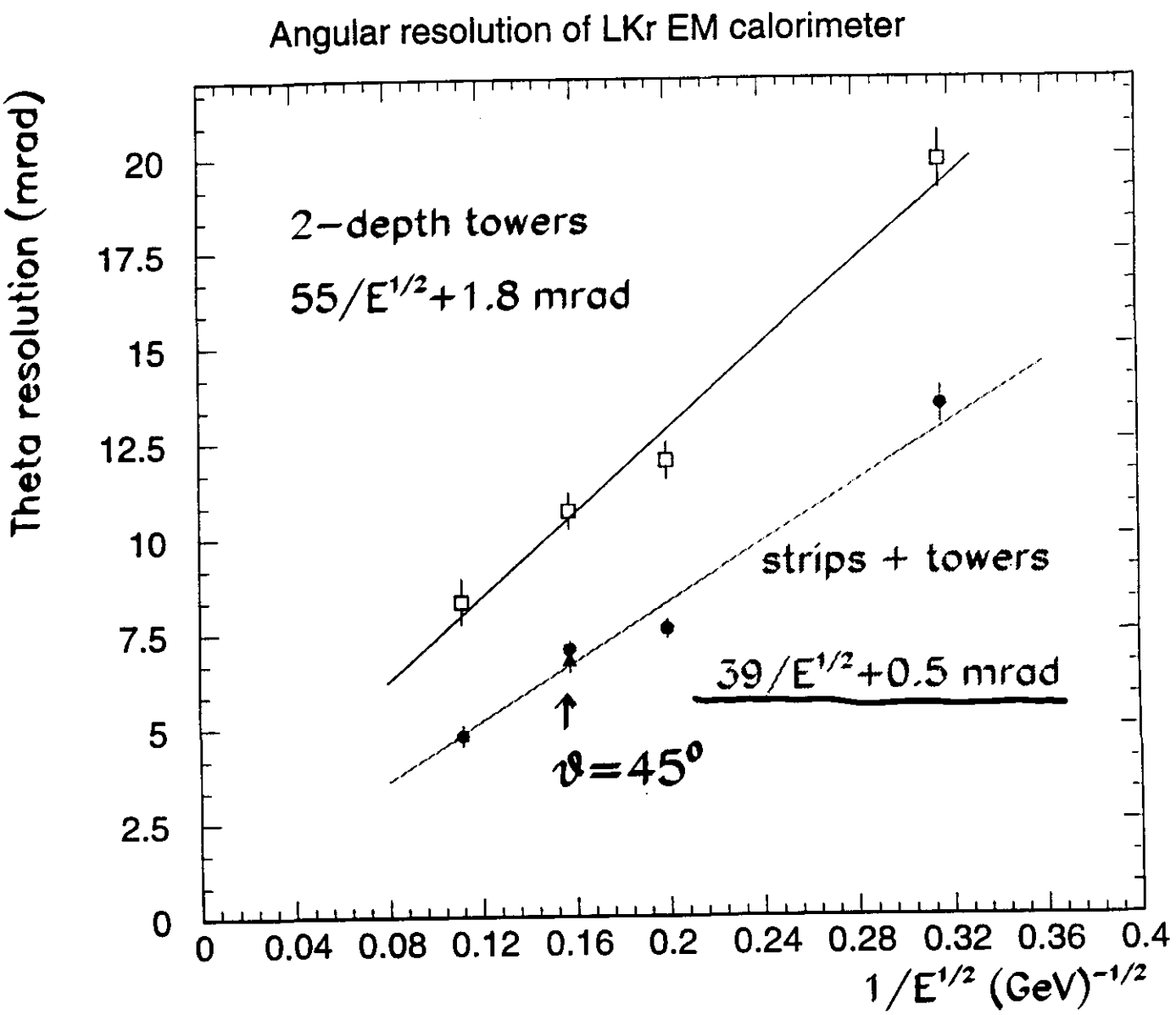
Hong Ma

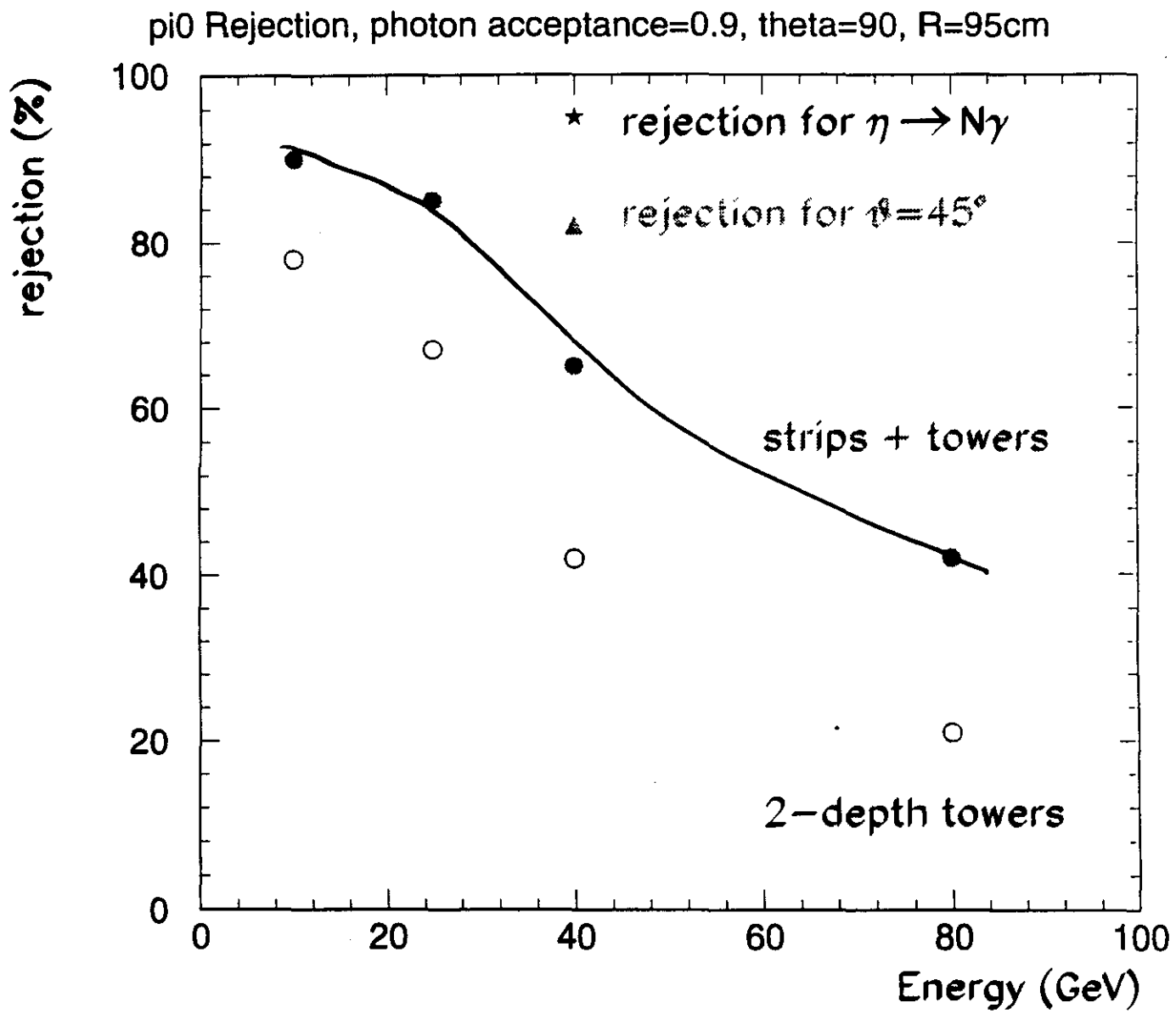
Calorimeter Simulation

Hong Ma Jan 8, 1993

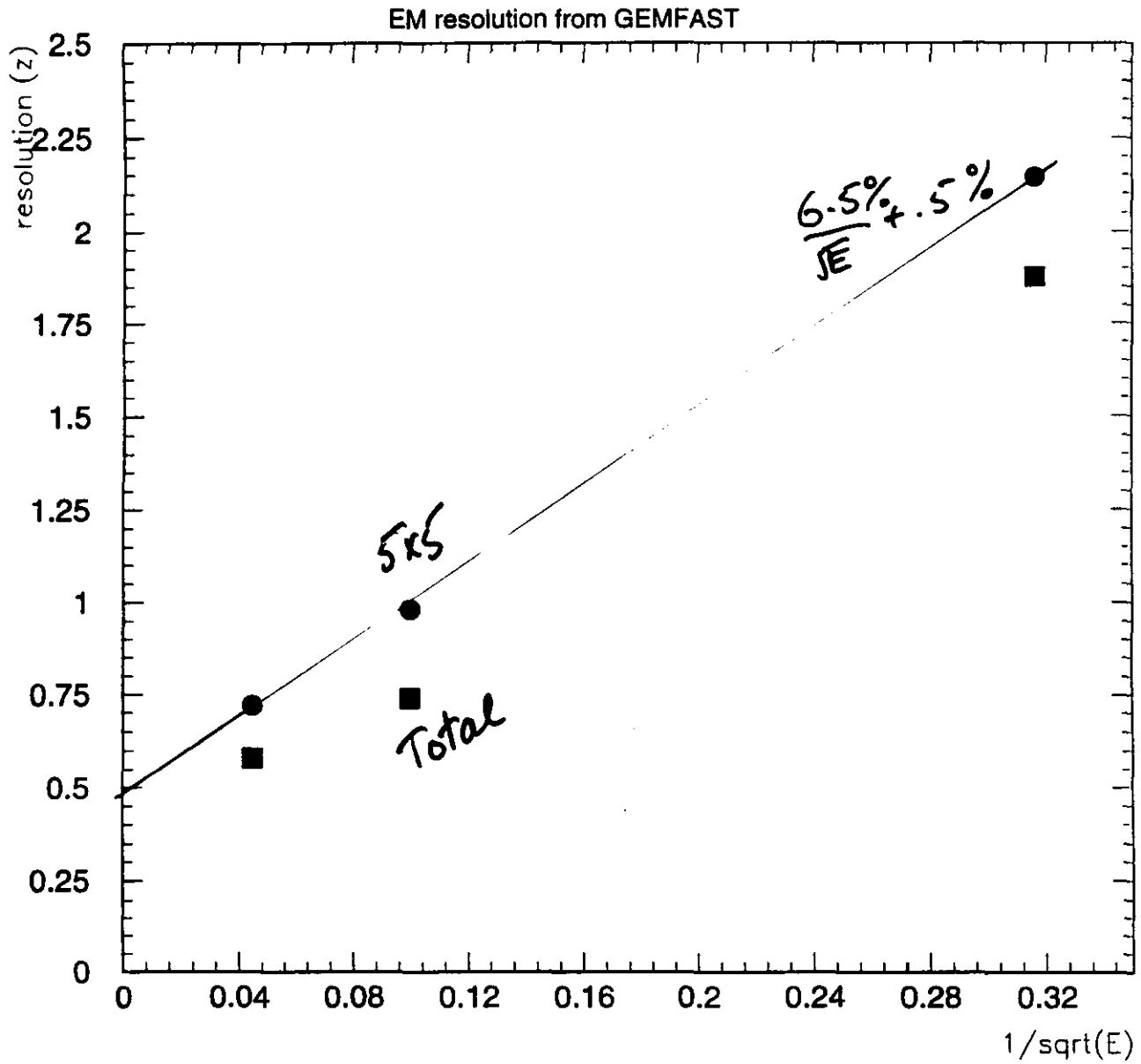
1. EM
   - Barrel
   - Endcap
   - Energy Resolution, Pointing Resolution
   - π^0 rejection
   - Comparison of GEMFAST with GEANT
2. Hadron
   - Single particle Response
   - Resolution vs η
   - longitudinal and Transverse shower Distribution,
   - Jet Resolution. RD3 study
     - GEMFAST
     - Savin

NOT COVERED: ScintCal, and forward.

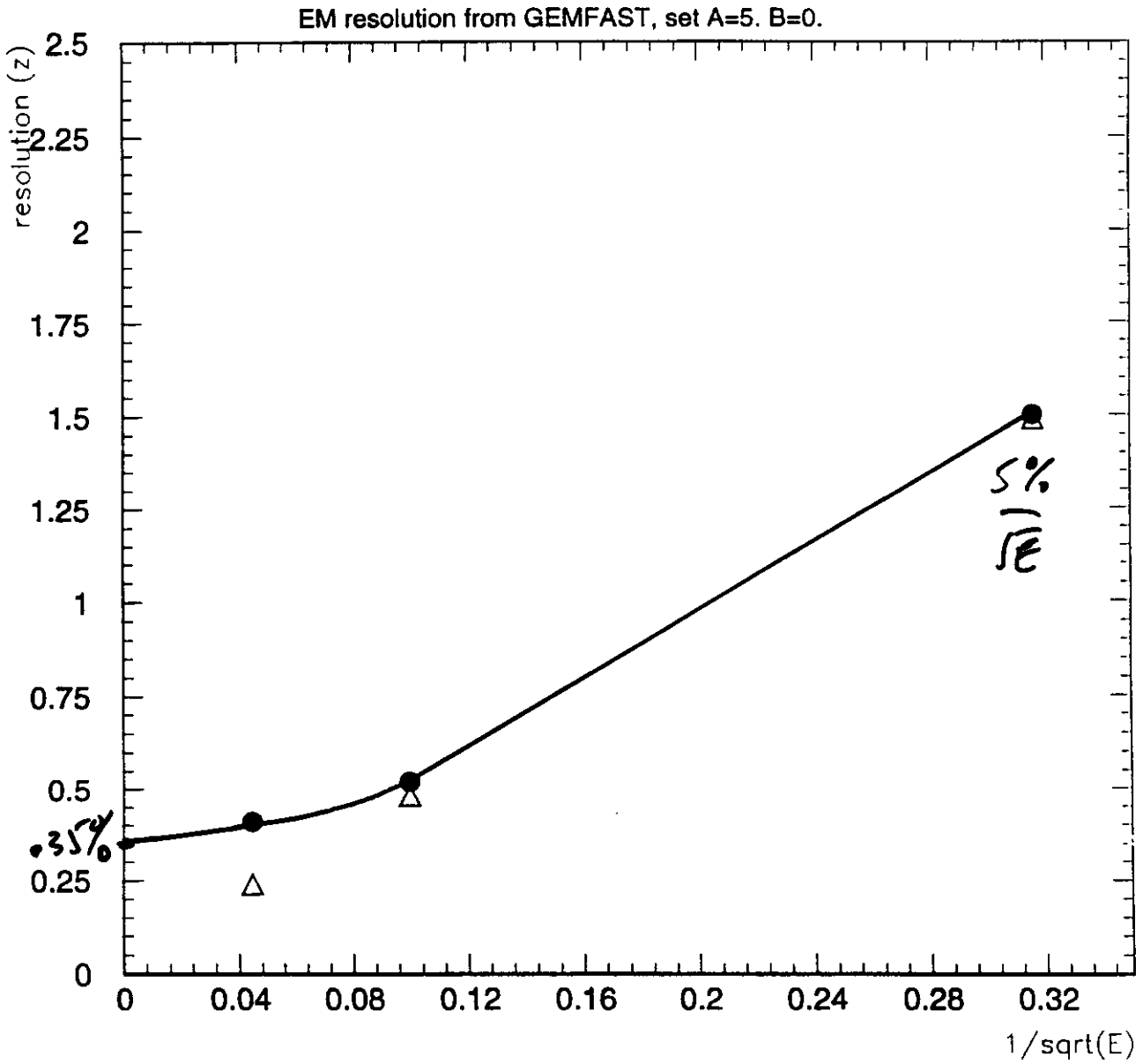

Angular resolution of LKr EM calorimeter
Theta resolution (mrad)
20
17.5
15
12.5
10
7.5
5
2.5
0
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.4
1/E^{1/2} (GeV)^{-1/2}
2-depth towers
55/E^{1/2}+1.8 mrad
strips + towers
39/E^{1/2}+0.5 mrad
ϑ=45°


pi0 Rejection, photon acceptance=0.9, theta=90, R=95cm
rejection (%)
100
80
60
40
20
0
0
20
40
60
80
100
Energy (GeV)
rejection for $\eta \rightarrow N\gamma$
rejection for $\vartheta=45°$
strips + towers
2−depth towers

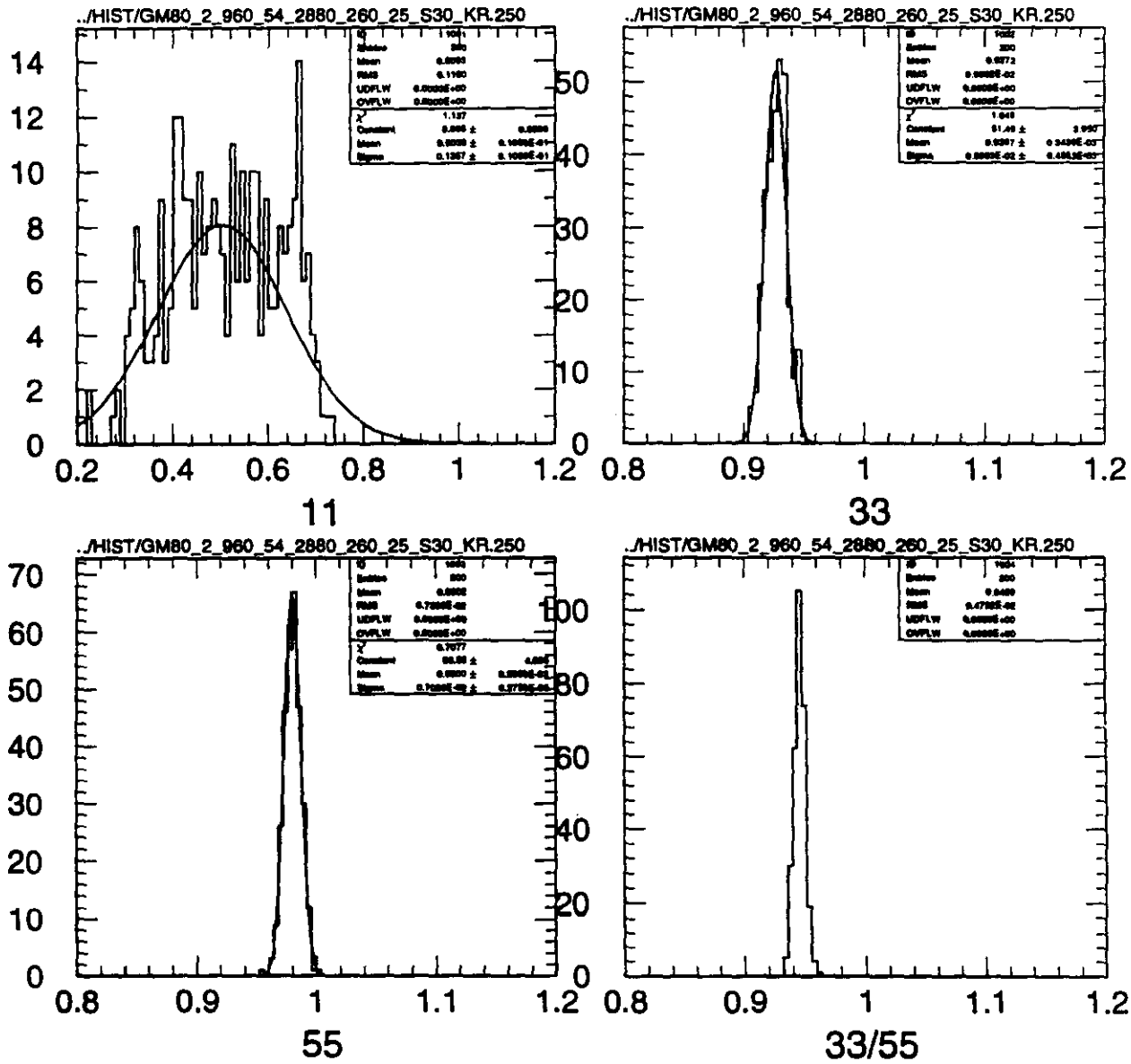
93/01/07 13.08


EM resolution from GEMFAST
resolution (z)
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
1/sqrt(E)
6.5%/√E + .5%
5x5
Total

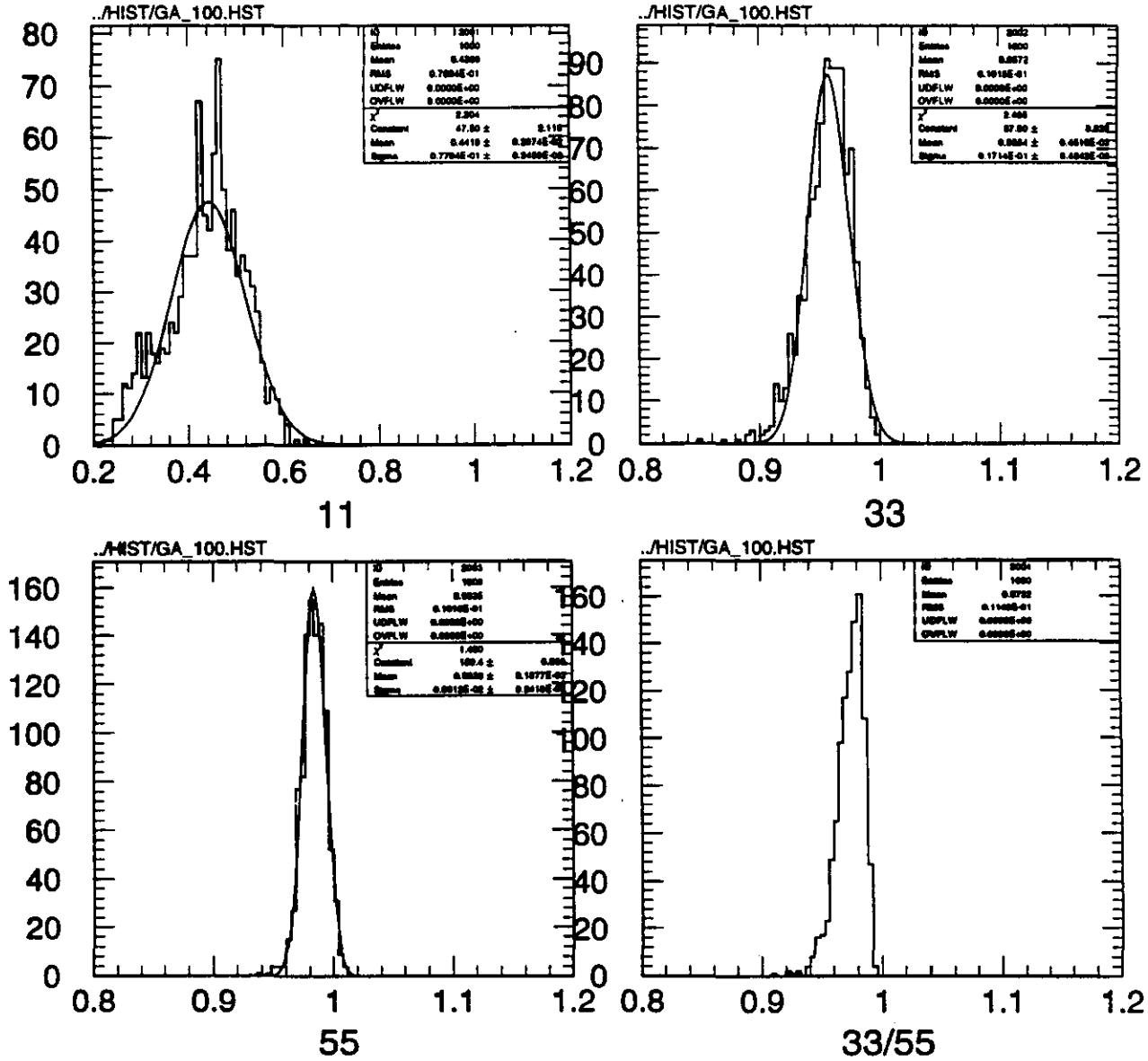
93/01/07 16.25


EM resolution from GEMFAST, set A=5. B=0.
resolution (z)
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
.35%
0.25
0
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
1/sqrt(E)
5%/√E

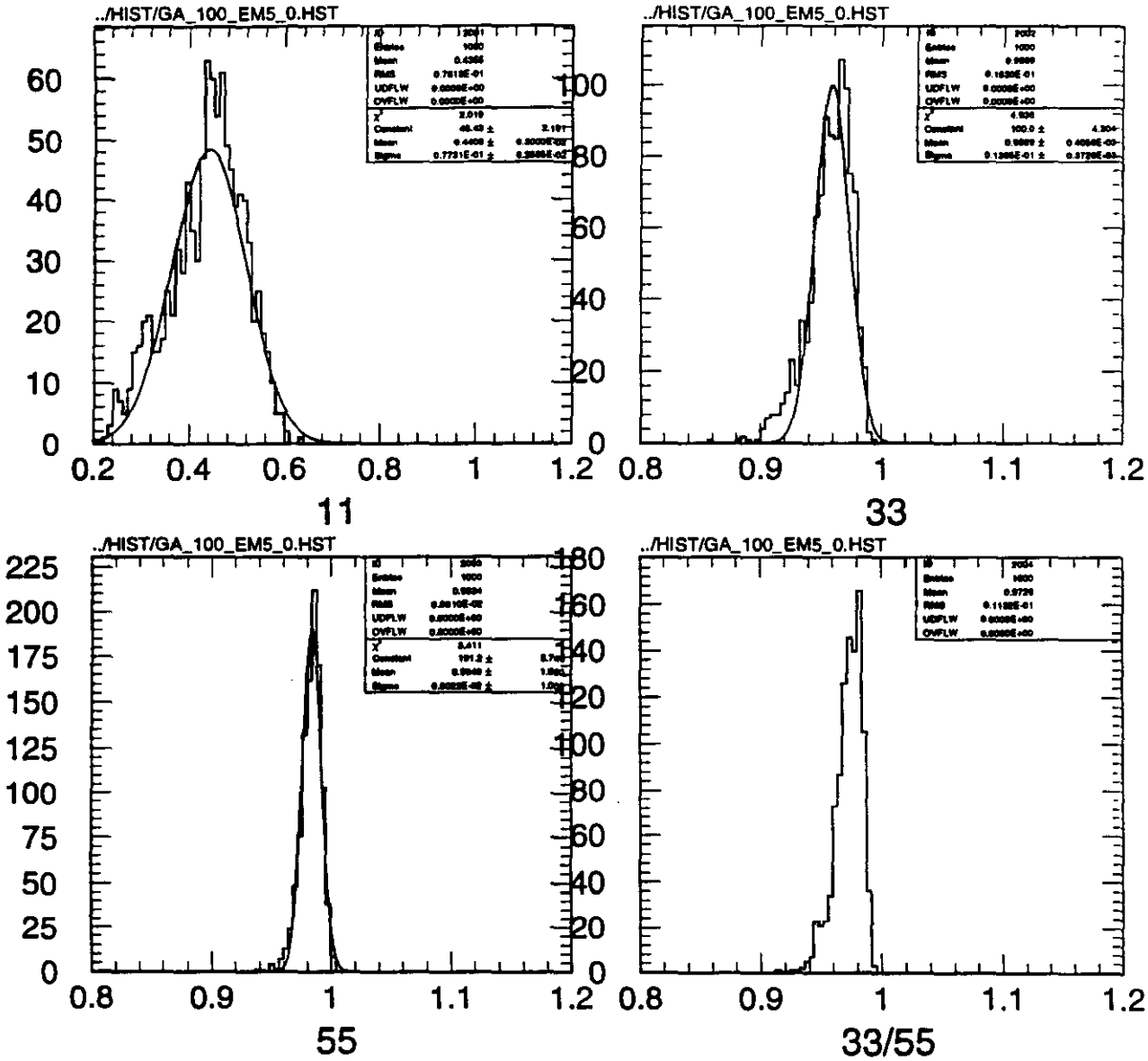
93/01/07 13.56


../HIST/GM80_2_960_54_2880_260_25_S30_KR.250
11
../HIST/GM80_2_960_54_2880_260_25_S30_KR.250
33
../HIST/GM80_2_960_54_2880_260_25_S30_KR.250
55
../HIST/GM80_2_960_54_2880_260_25_S30_KR.250
33/55

93/01/07 12.58


../HIST/GA_100.HST
11
../HIST/GA_100.HST
33
../HIST/GA_100.HST
55
../HIST/GA_100.HST
33/55

93/01/07 15.05


../HIST/GA_100_EM5_0.HST
11
../HIST/GA_100_EM5_0.HST
33
../HIST/GA_100_EM5_0.HST
55
../HIST/GA_100_EM5_0.HST
33/55

EM Endcap

$$\sigma_E/E = \frac{8.5\%}{\sqrt{E}} \oplus .4\%$$

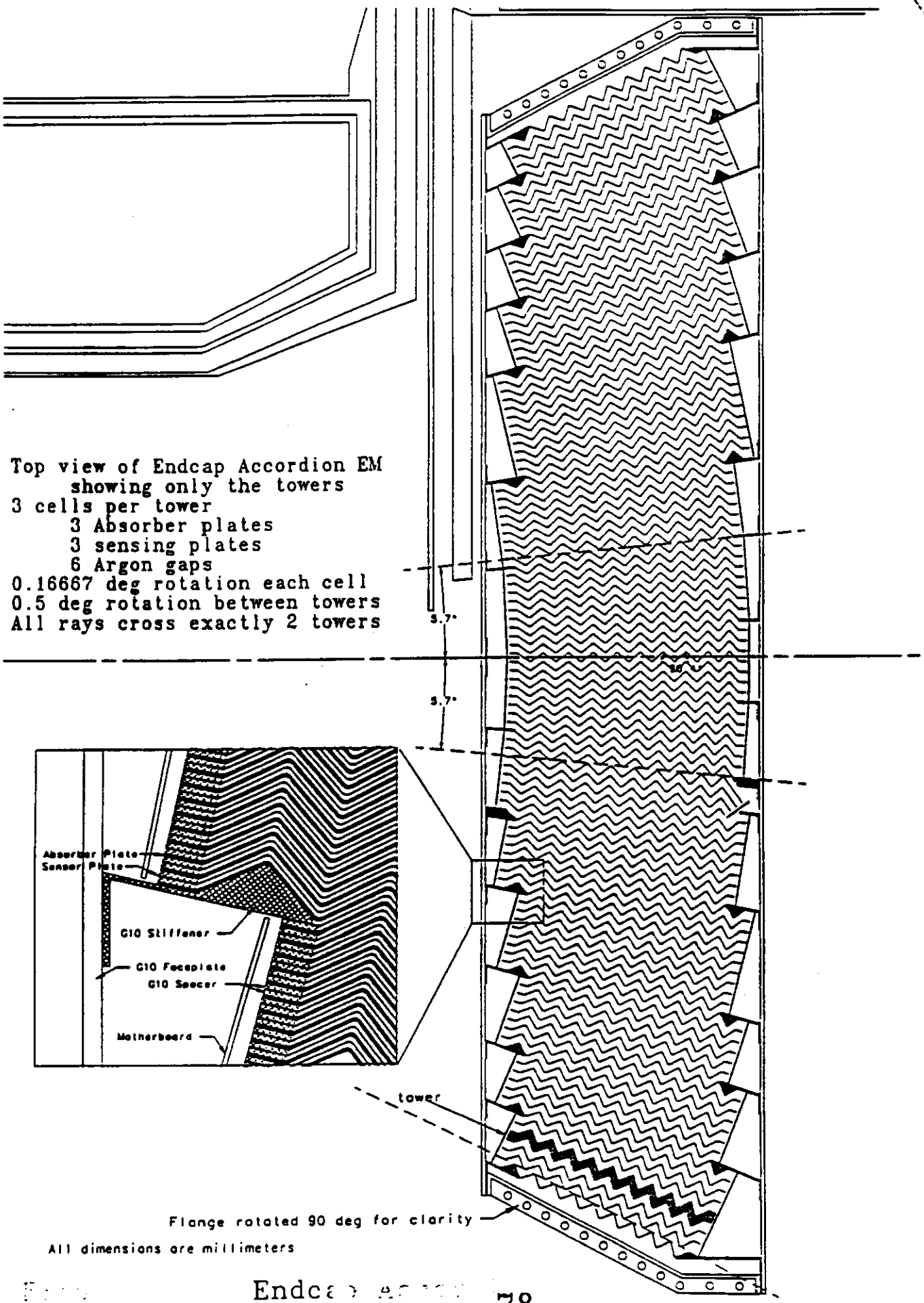
($\sim 2 X_0$ dead material in front)

Current design does not measure θ,
But angles in x-z, y-z plane

strips in ± 60 degrees.

Average $\sigma_\theta \sim 50$ mrad$/\sqrt{E}$
(φ dependent)

Physics requirement: better pointing!


Top view of Endcap Accordion EM
showing only the towers
3 cells per tower
3 Absorber plates
3 sensing plates
6 Argon gaps
0.16667 deg rotation each cell
0.5 deg rotation between towers
All rays cross exactly 2 towers
5.7°
5.7°
Absorber Plate
Sensor Plate
G10 Stiffener
G10 Faceplate
G10 Spacer
Motherboard
tower
Flange rotated 90 deg for clarity
All dimensions are millimeters

Endca

$$\sin\theta_1 = \sin\alpha / \cos\varphi$$

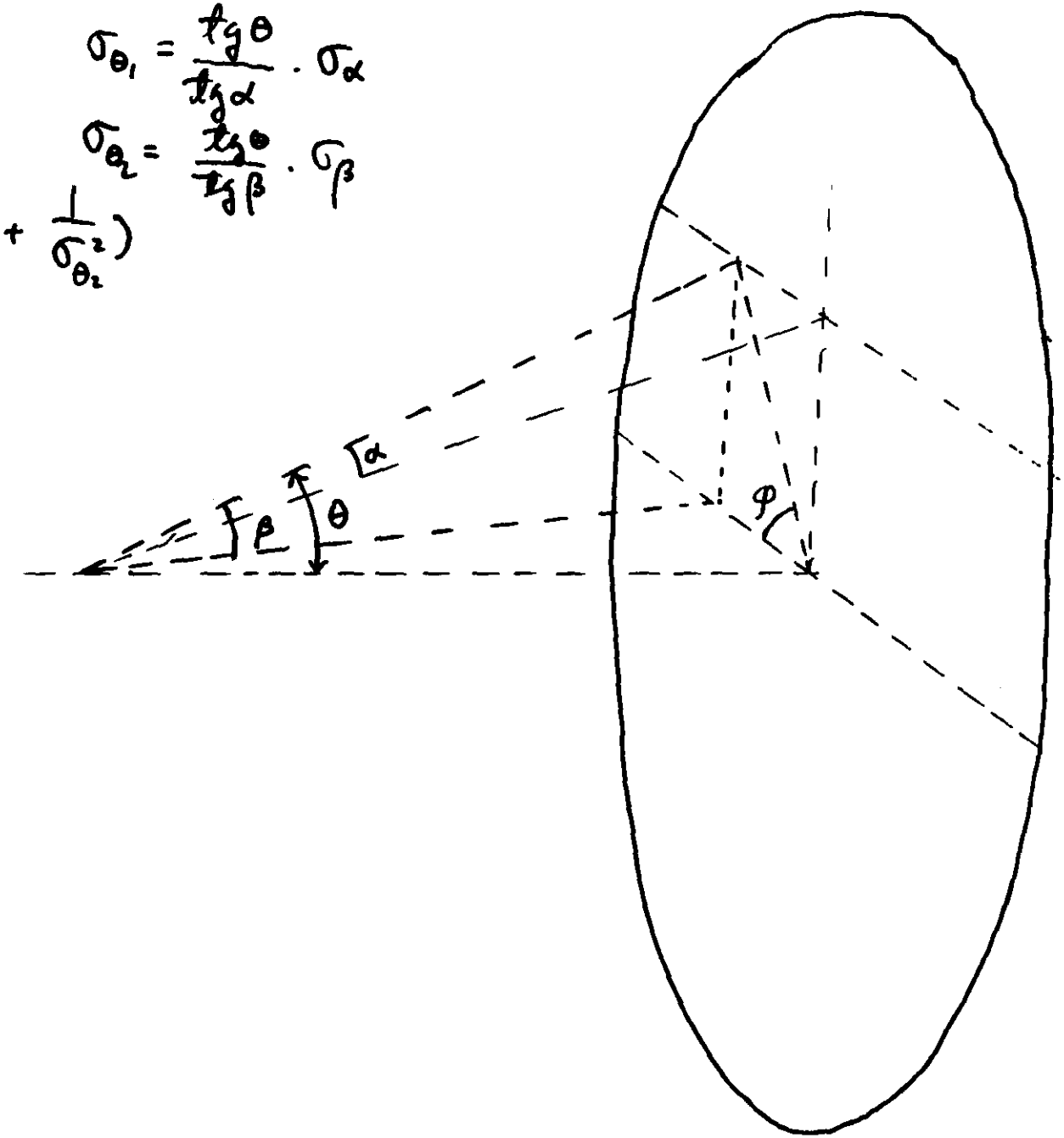
$$\sin\theta_2 = \sin\beta / \sin\varphi$$

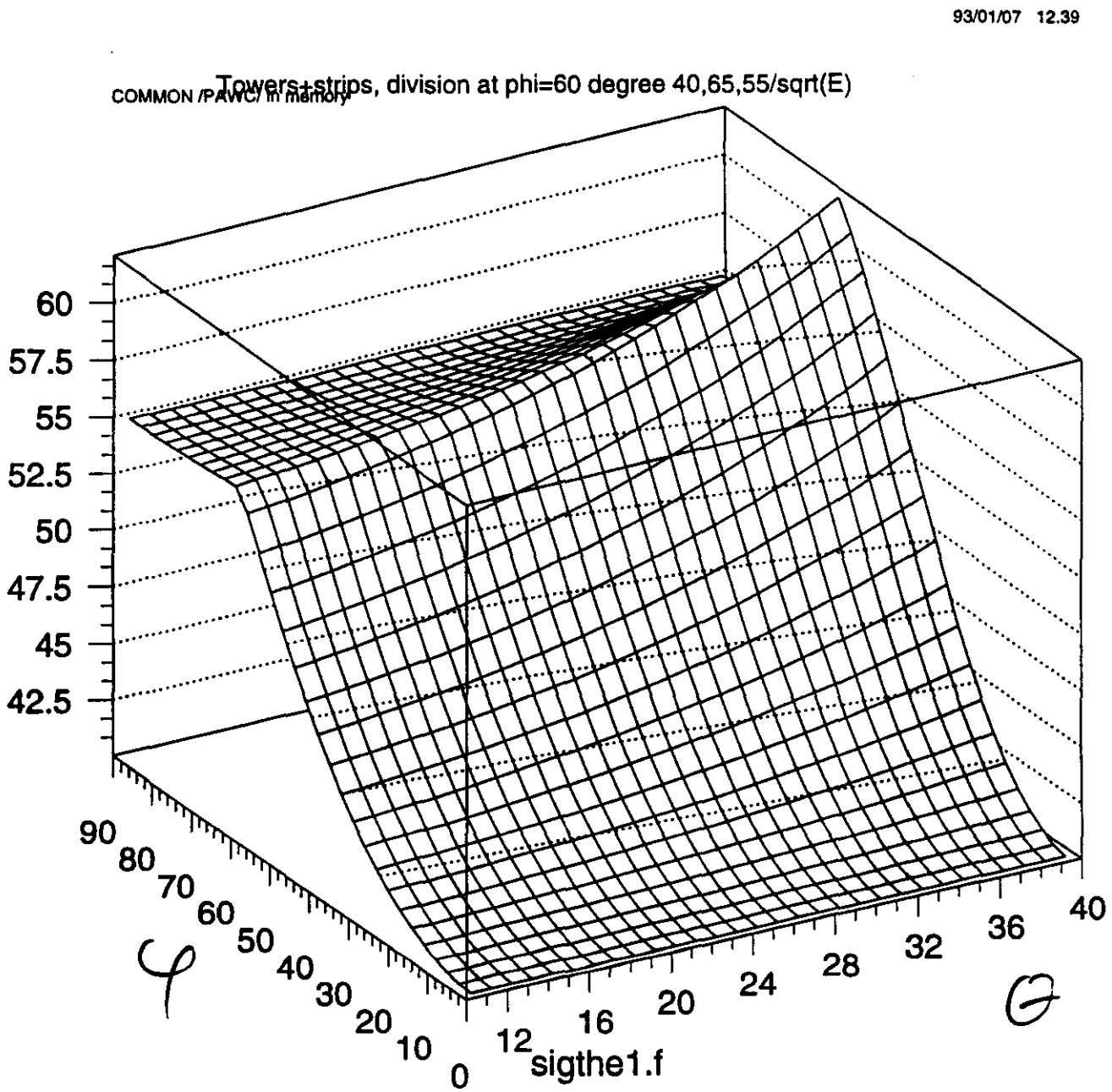
$$\sigma_{\theta_1} = \frac{tg\,\theta}{tg\,\alpha} \cdot \sigma_\alpha$$

$$\sigma_{\theta_2} = \frac{tg\,\theta}{tg\,\beta} \cdot \sigma_\beta$$

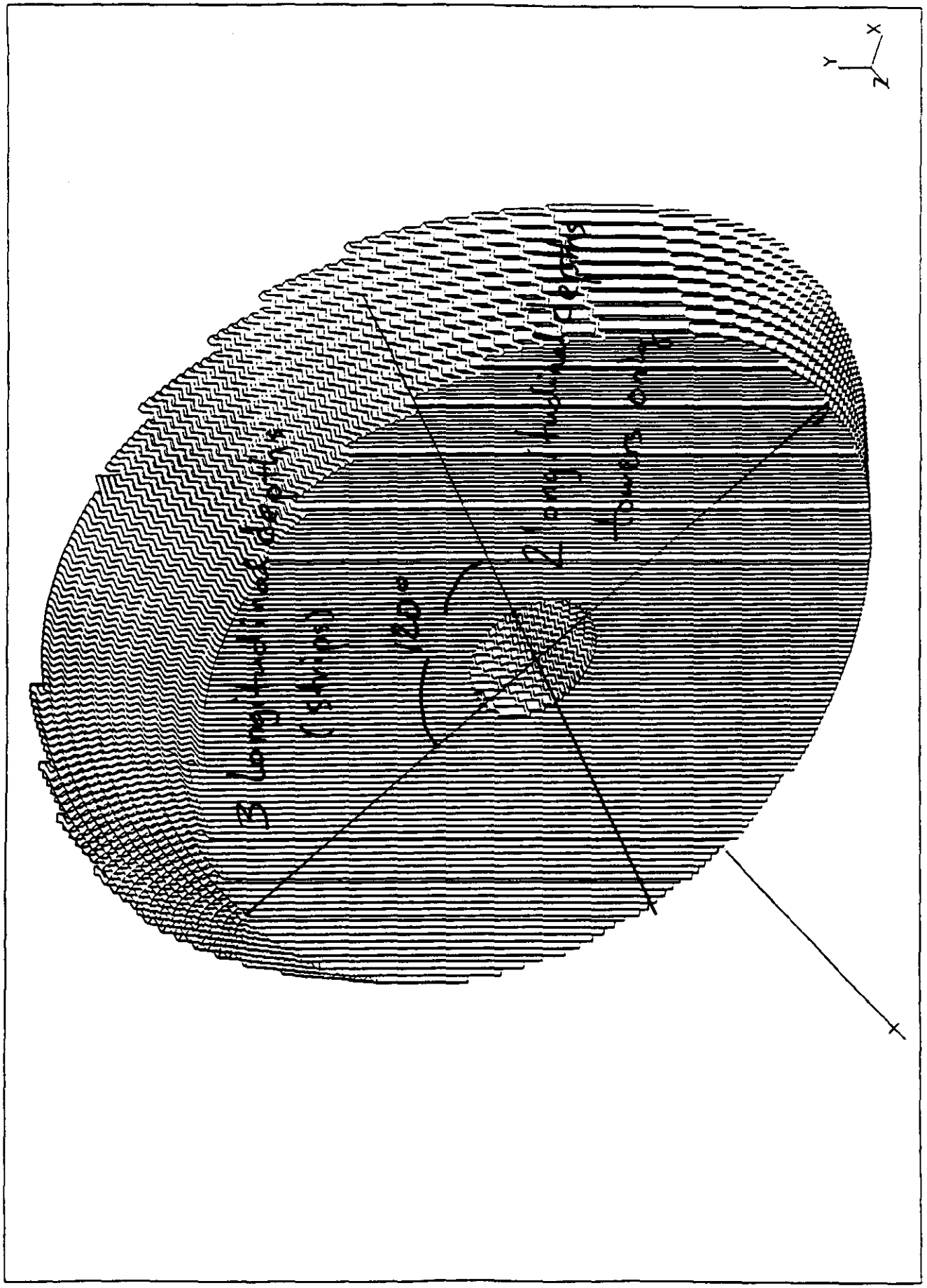
$$\bar{\theta} = \left(\frac{\theta_1}{\sigma_{\theta_1}^2} + \frac{\theta_2}{\sigma_{\theta_2}^2} \right) \Big/ \left(\frac{1}{\sigma_{\theta_1}^2} + \frac{1}{\sigma_{\theta_2}^2} \right)$$

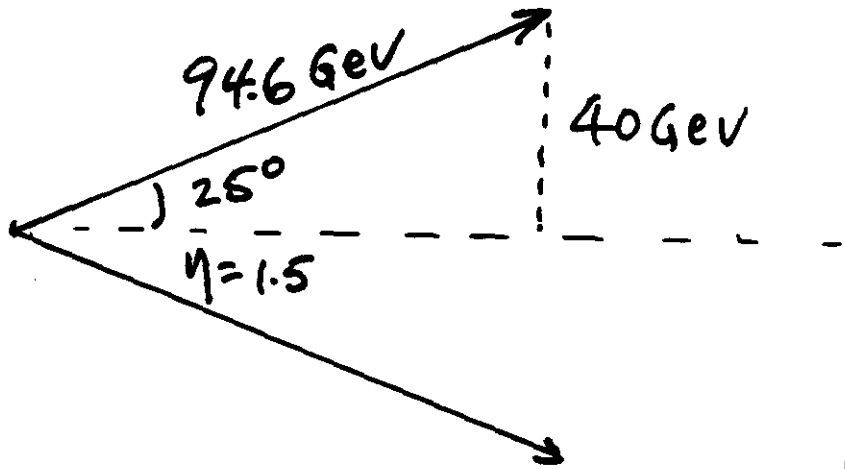
$$\sigma_\theta^2 = \frac{tg^2\theta}{\left(\frac{tg^2\alpha}{\sigma_\alpha^2} + \frac{tg^2\beta}{\sigma_\beta^2} \right)}$$




93/01/07 12.39
COMMON /PAWC/ in memory
Towers+strips, division at phi=60 degree 40,65,55/sqrt(E)
60
57.5
55
52.5
50
47.5
45
42.5
90
80
70
60
50
40
30
20
10
0
φ
12
16
20
24
28
32
36
40
θ
sigthe1.f

Endcap Accordion EM





(noise)

$$\sigma_E/E = \frac{7.5\%}{\sqrt{94}} \oplus 0.4\% \oplus \frac{0.180}{40}$$

$$= 0.77 \oplus 0.4 \oplus 0.45$$

$$= 0.977\ \%$$

$$\frac{\sigma_\theta}{tg\,\theta} = \frac{0.040}{\sqrt{94}} \cdot \frac{1}{tg\,25^\circ} = 0.88\%$$

$$\frac{\delta M}{M} = \frac{1}{\sqrt{2}} \cdot \sqrt{\left(\frac{\sigma_E}{E}\right)^2 + \left(\frac{\sigma_\theta}{tg\,\theta}\right)^2}$$

I. Low luminosity (10**33):
Higgs width because of the noise and energy resolution- 563 MeV.

Higgs width increasing because of pointing inaccuracy.

a.) With vertex information:

Barrel \ Endcap	55 mrad $\sqrt{\epsilon}_{TT}$	40 mrad $\sqrt{\epsilon}_{TS}$	32 mrad $\sqrt{\epsilon}_{SS}$
TT	1.09	1.05	1.04
TS	1.07	1.03	1.03
SS	1.03	1.04	1.02

b.) No vertex information:

Barrel \ Endcap	TT	TS	SS
TT	1.43	1.24	1.18
TS	1.34	1.20	1.20
SS	1.33	1.21	1.16

II. Hight luminosity (10**34):
Higgs width because of the noise and energy resolution- 687 MeV.

Higgs width increasing because of pointing inaccuracy.
a.) With vertex information:

Barrel \ Endcap	TT	TS	SS
TT	1.27	1.16	1.11
TS	1.22	1.12	1.13
SS	1.17	1.12	1.09

w/o vertex info.

Barrel \ dcap	TT	TS	SS
TT	1.32	1.19	1.13
TS	1.27	1.15	1.14
SS	1.22	1.14	1.11

Errors - 2% .

Best regards, Yuri E.

Hadron Calorimeter

M.M. ray tracing

X_0, λ vs η

GEMMIX

σ_E/E vs η

Longitudinal shower profile

Compare to GEANT EM 1.5λ

Had 4.6λ

Scint Cal 4.9λ

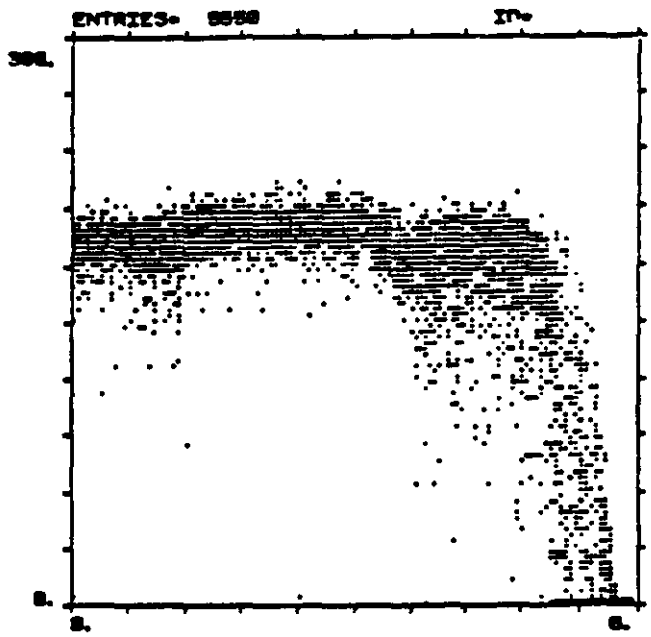
Transverse shower profile

$E1/E_{tot}$, $E9/E_{tot}$, $E25/E_{tot}$

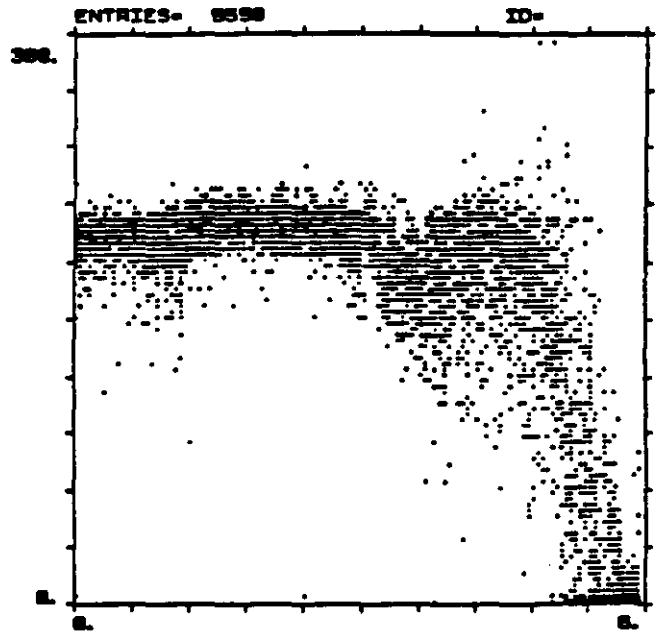
Jet Resolution:

$\sim \frac{50\%}{\sqrt{E}} \oplus 2.4\%$ RD3, Fe/LAr, Weighting.

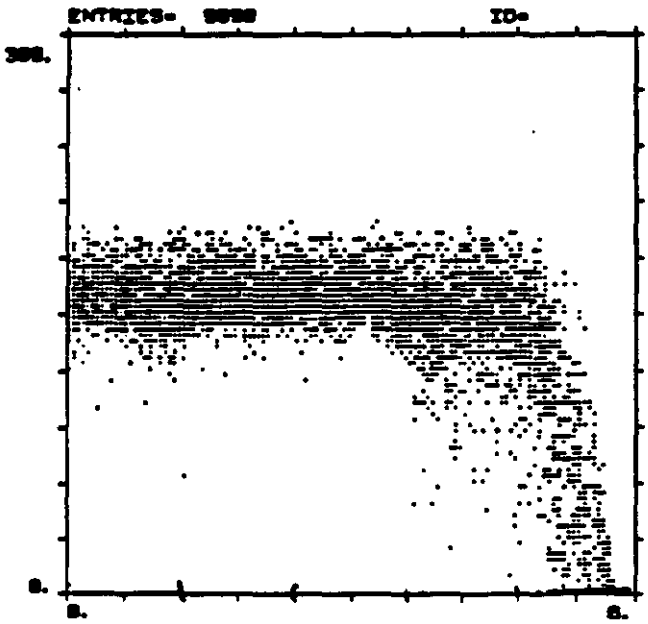
Current GEMfast: $\frac{50\%}{\sqrt{E}} \oplus 2\%$



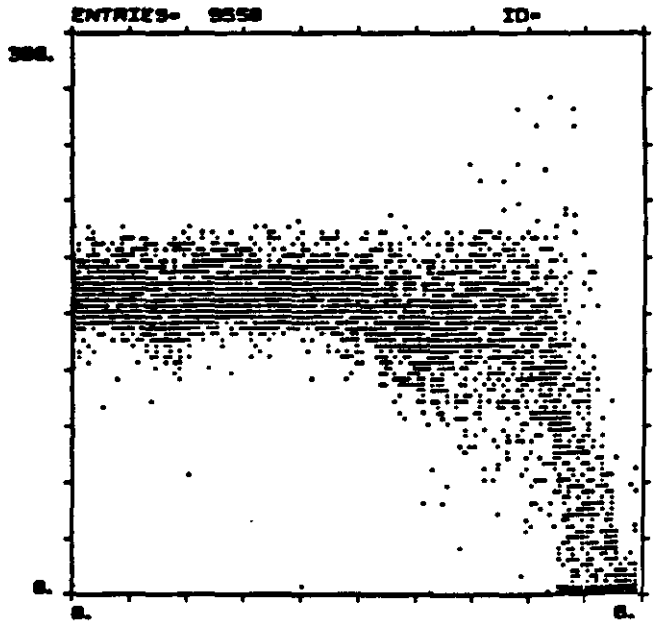
PTOT COMP V. ETA



PT/S COMP V. ETA

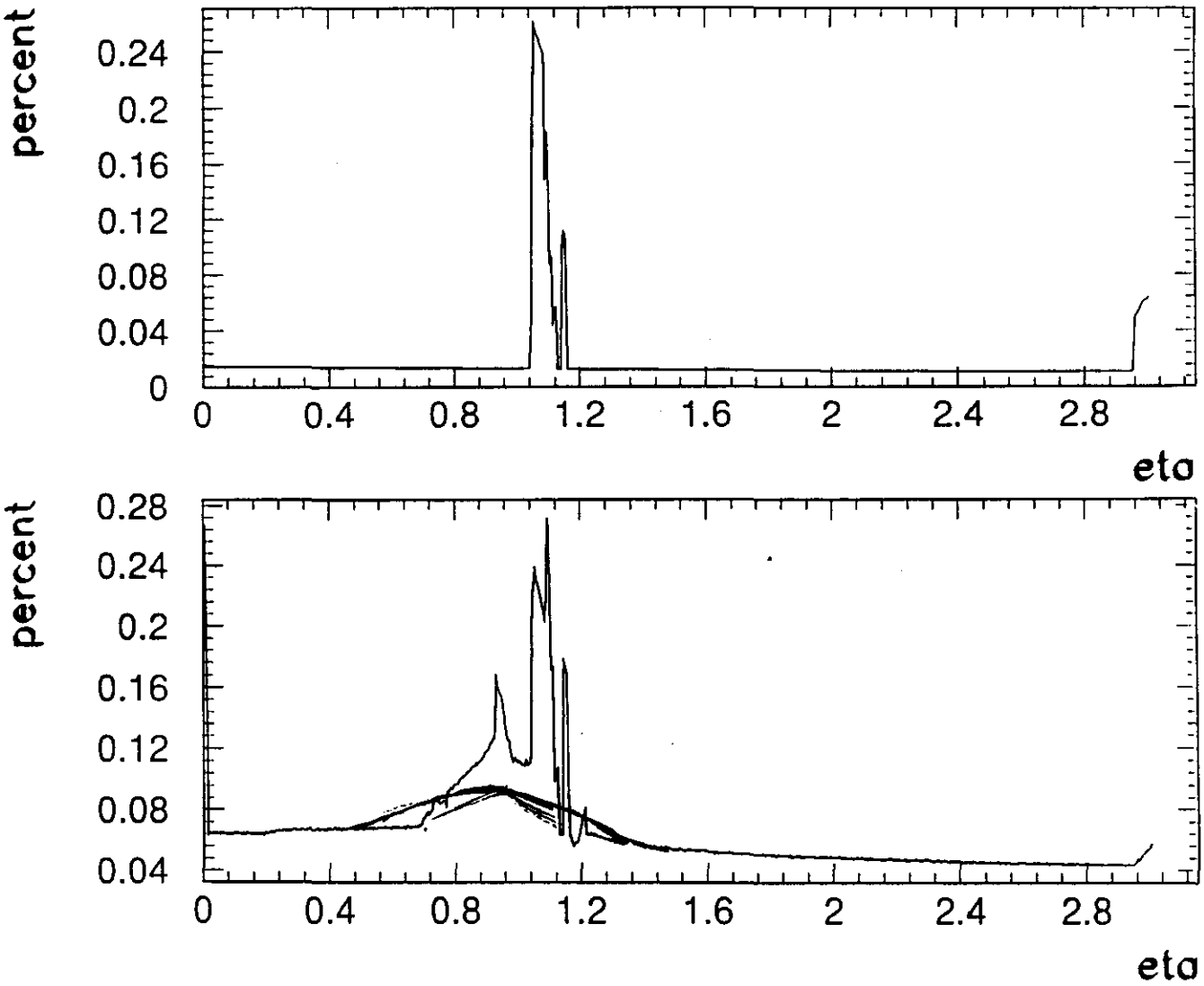


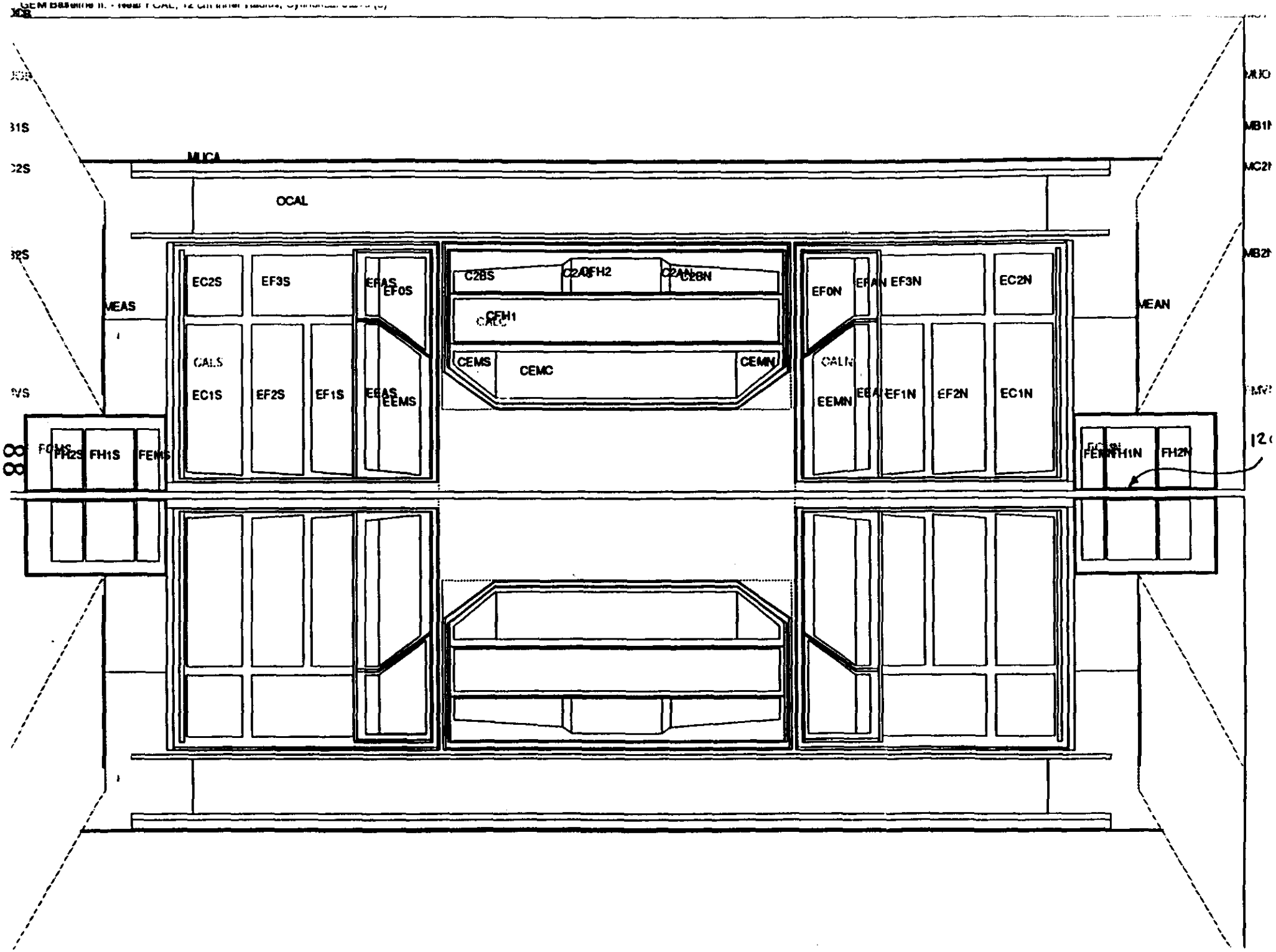
PTOT HYBR V. ETA



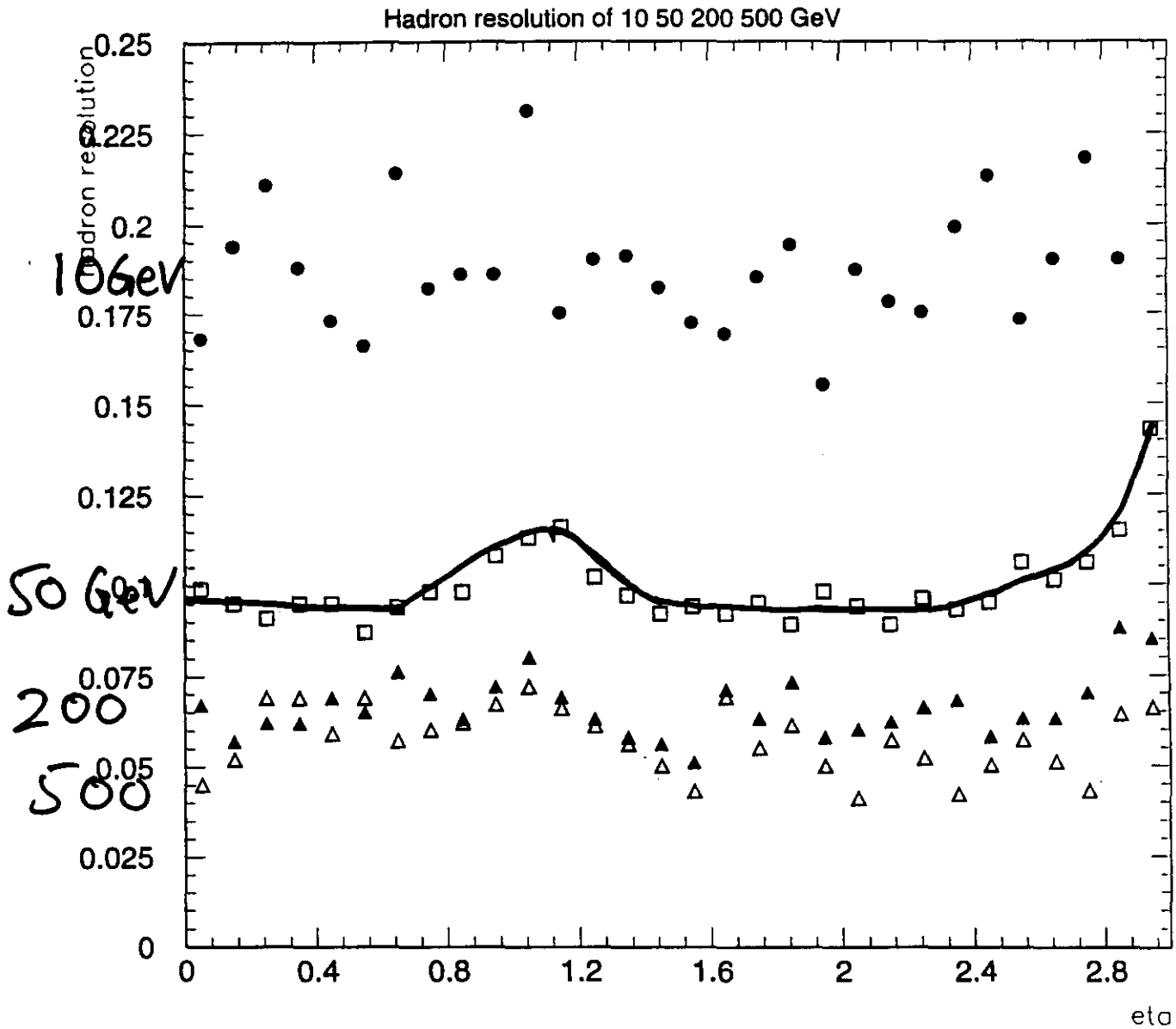
PT/S HYBR V. ETA

EM and HAD resolution at 200 GeV Et

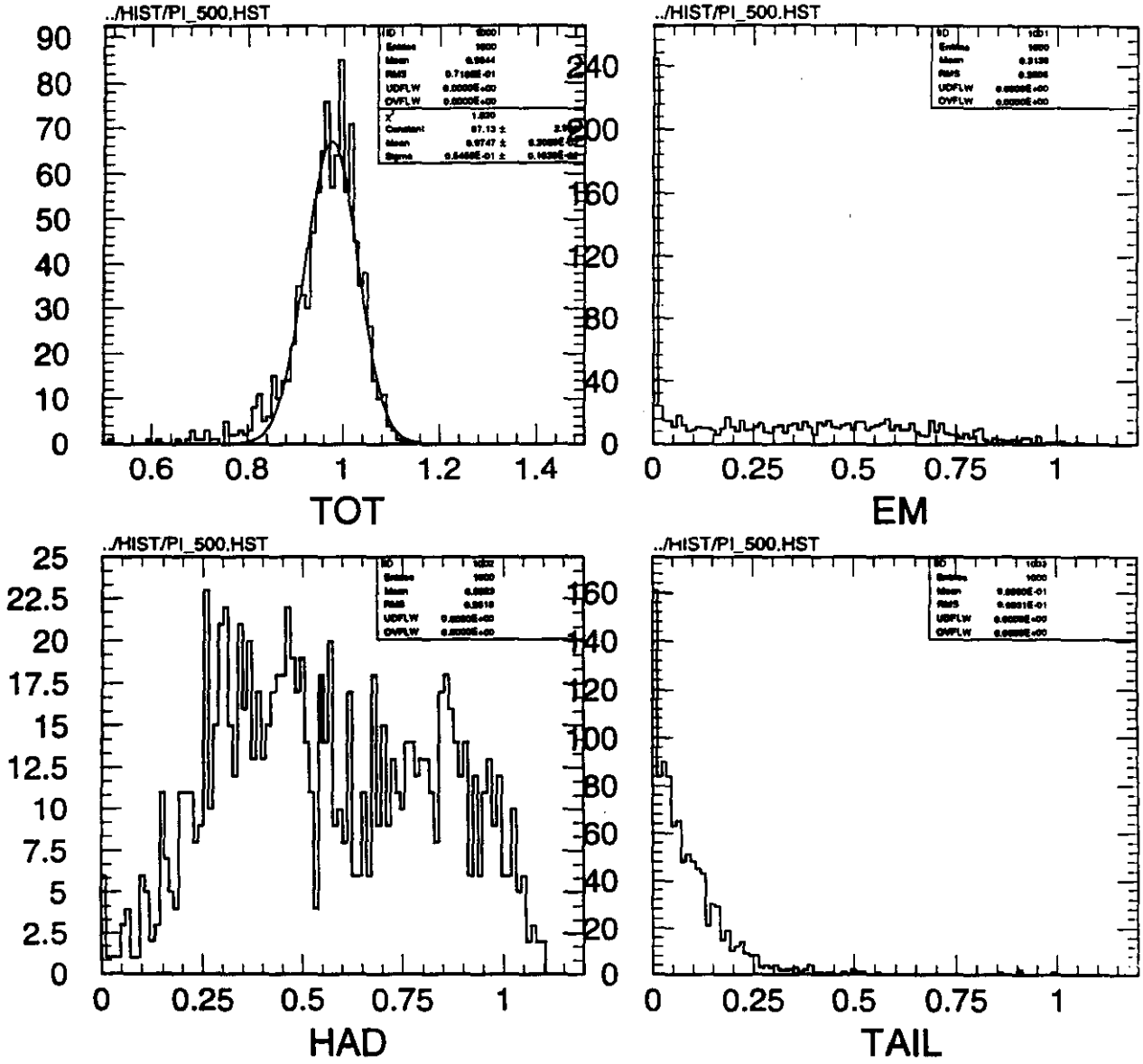



MUCA
OCAL
EC2S
EF3S
EF0S
C2BS
C2AS
FH2
C2AN
C2BN
EF0N
EF3N
EC2N
CFH1
CEMS
CEMC
CEMN
CALS
EC1S
EF2S
EF1S
EEMS
EEMN
EF1N
EF2N
EC1N
FH2S
FH1S
FEMS
FH1N
FH2N

93/01/06 14.05

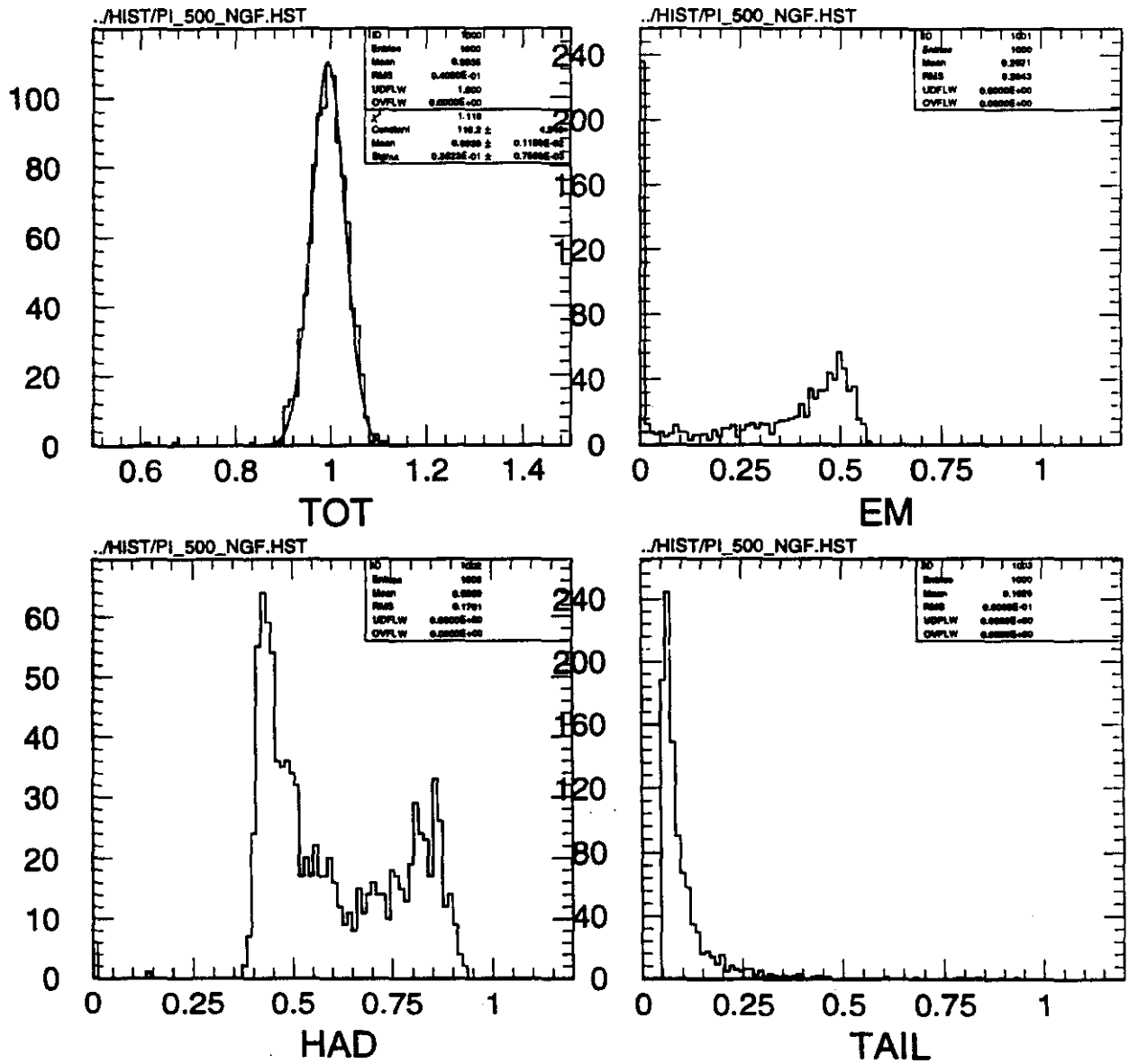

Hadron resolution of 10 50 200 500 GeV
hadron resolution
0.25
0.225
0.2
0.175
0.15
0.125
0.075
0.05
0.025
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
eta
10GeV
50 GeV
200
500

93/01/05 13.59

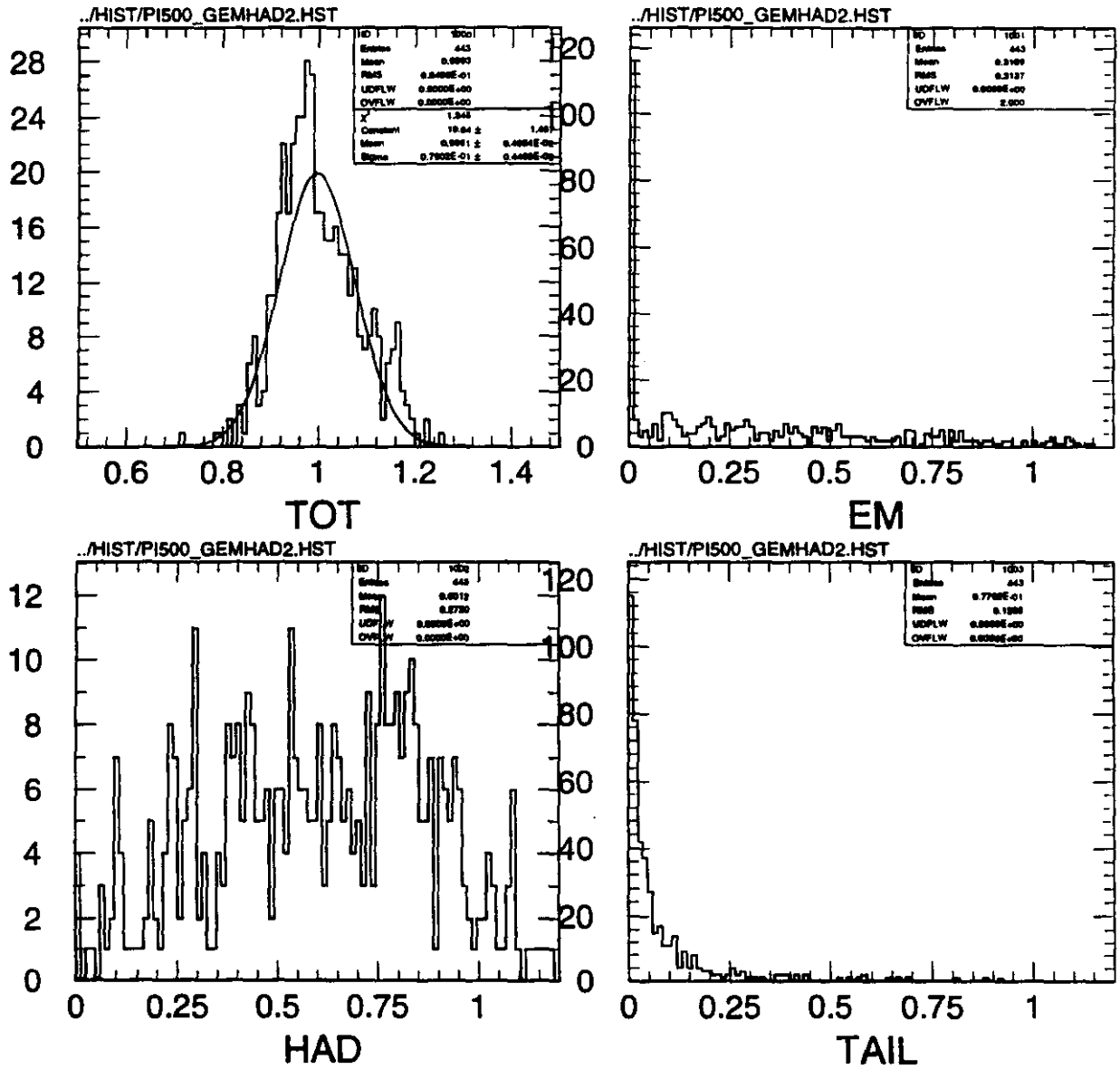


0.085

93/01/05 13.23

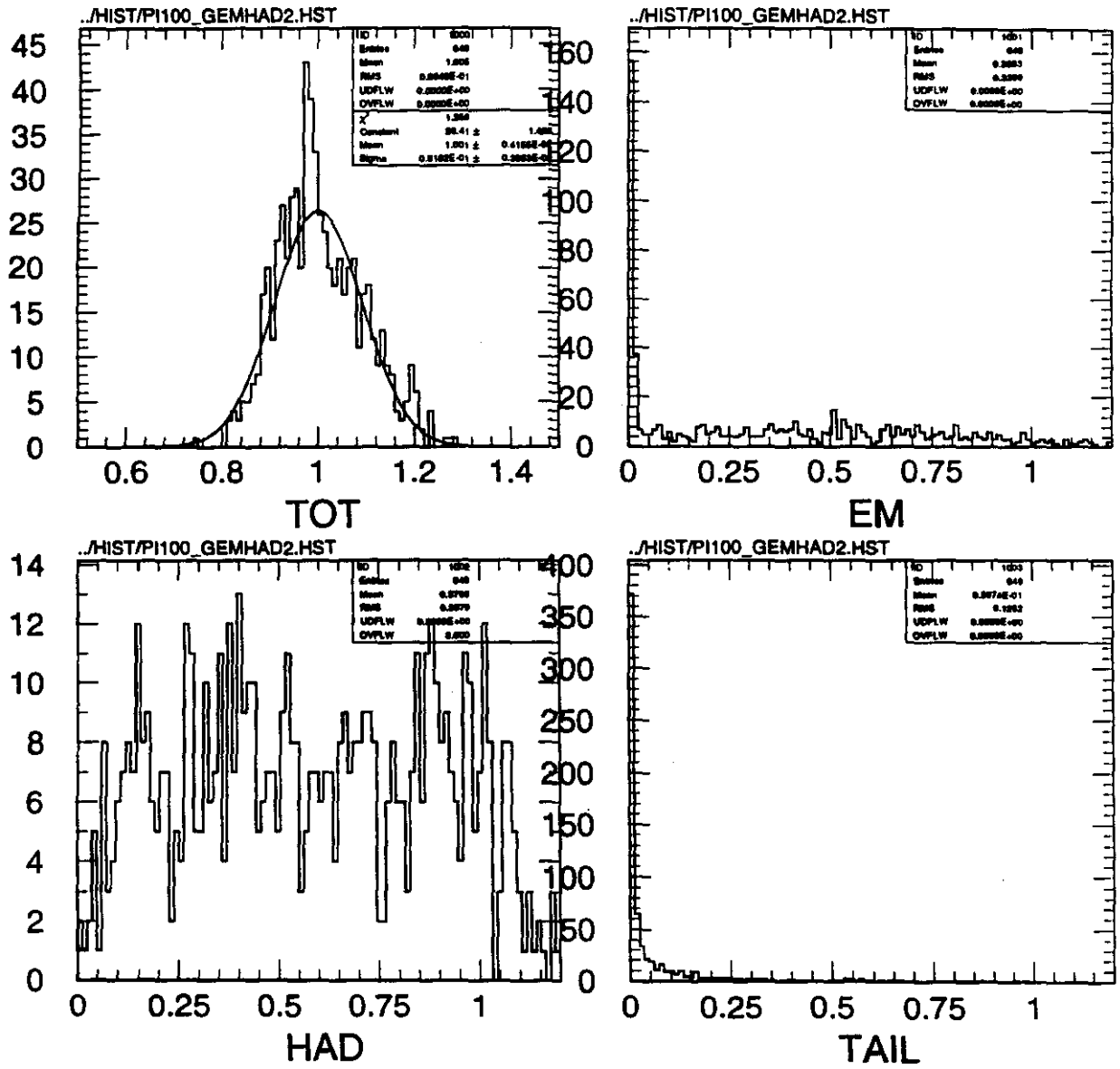

../HIST/PI_500_NGF.HST
TOT
../HIST/PI_500_NGF.HST
EM
../HIST/PI_500_NGF.HST
HAD
../HIST/PI_500_NGF.HST
TAIL

93/01/05 11.02



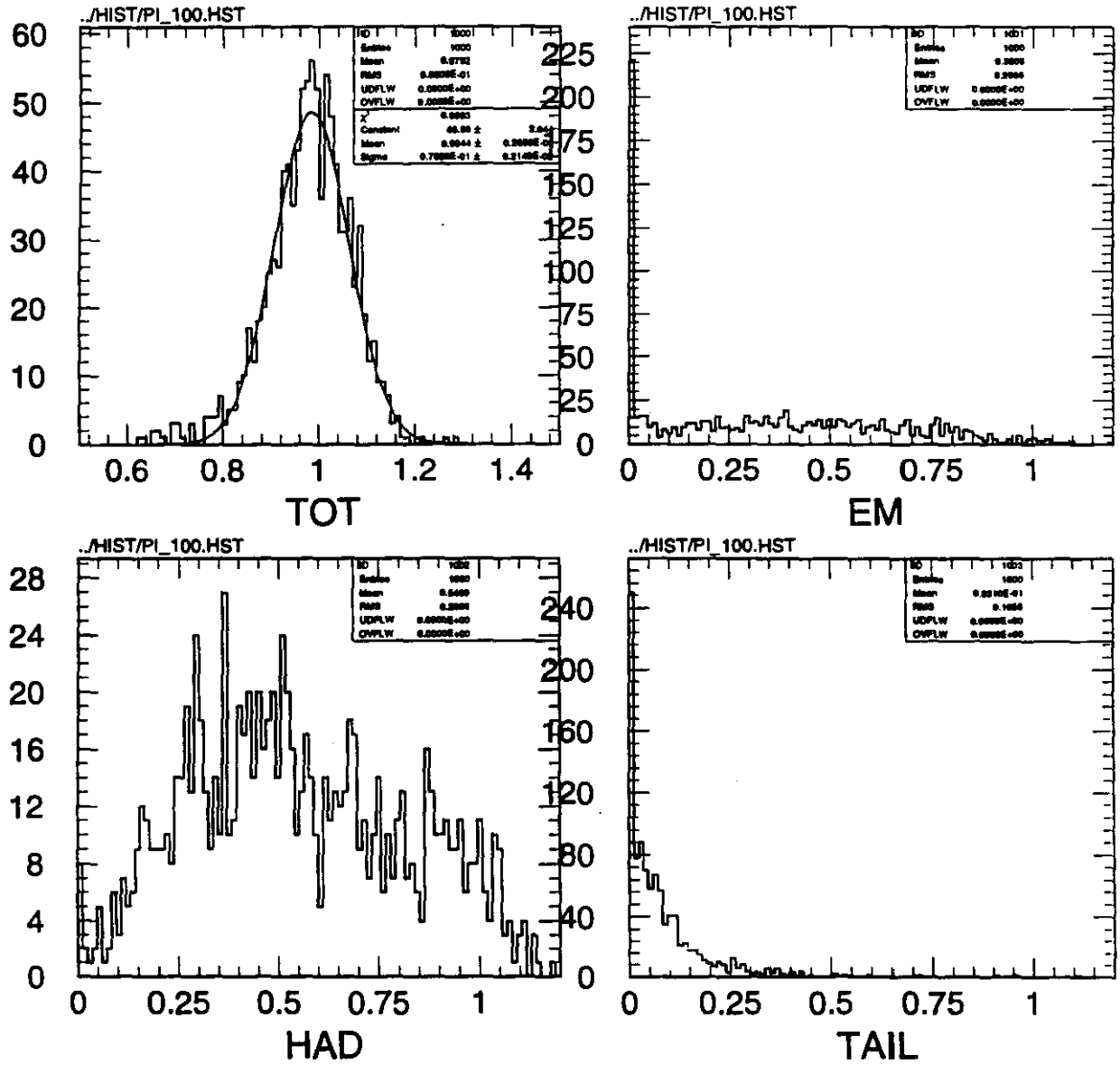
0.06

93/01/05 10.50



0.037

93/01/05 14.00



0.076

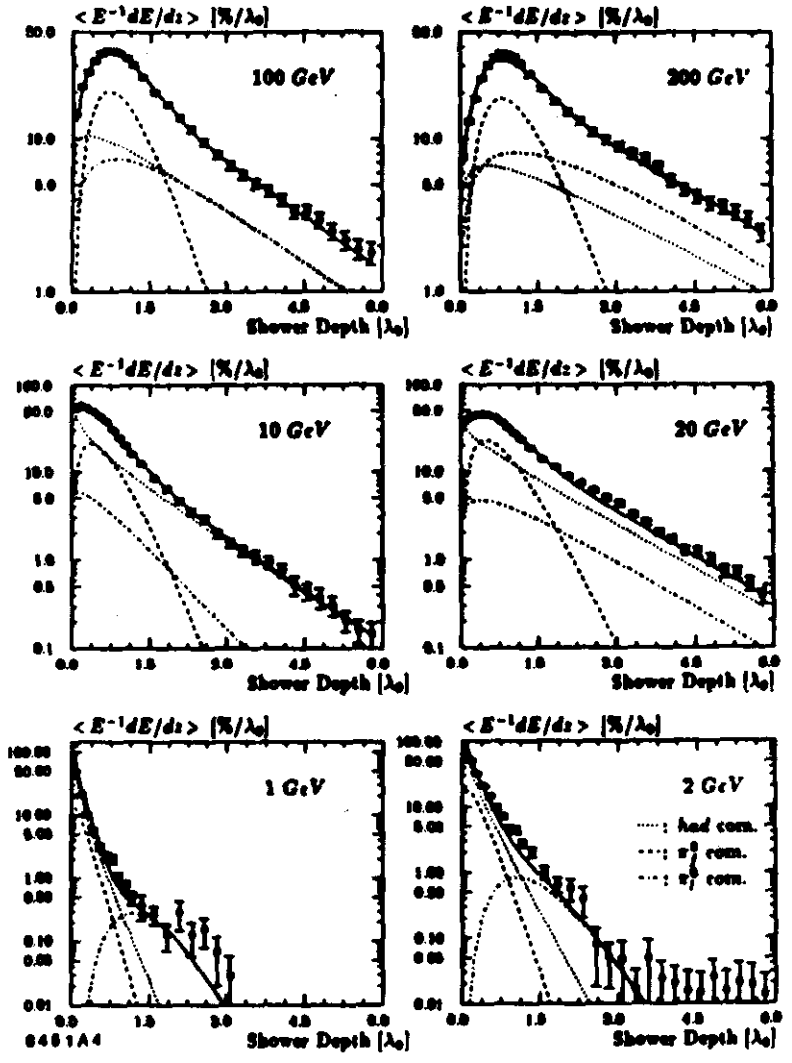


Figure 4: Mean longitudinal energy profile for π^+ showers: FIT (—) and GEANT (o).

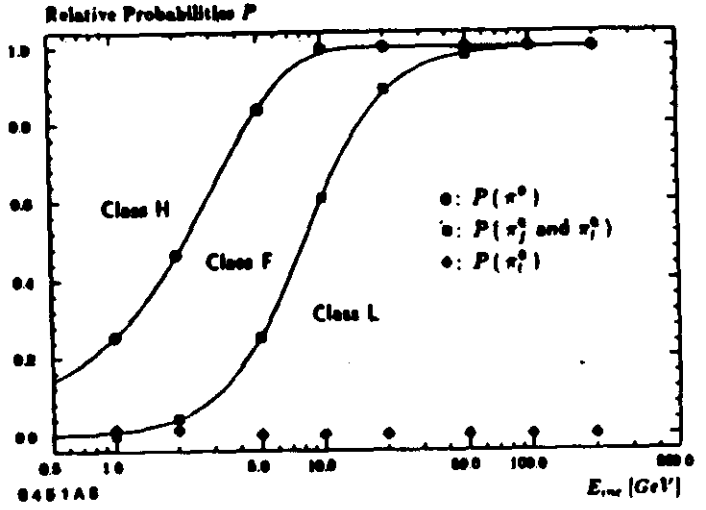


Figure 5: Relative probabilities for different hadronic shower-classes.

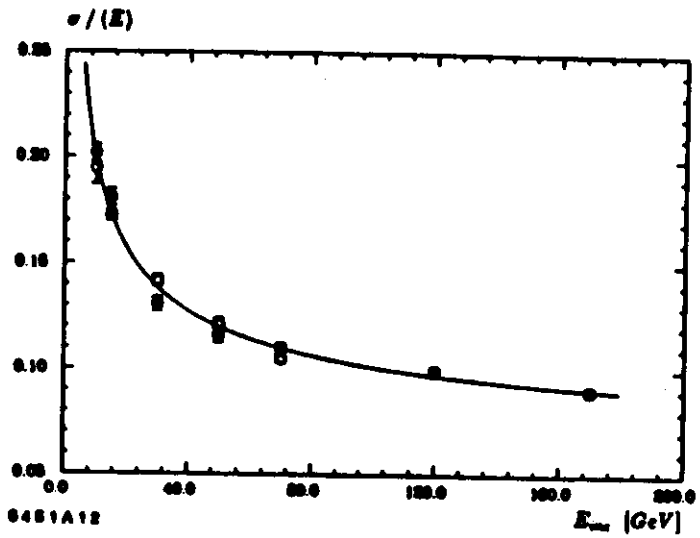


Figure 13: Energy resolution of the calorimeter (EC + HC + TC) for π^- showers: experiment (•) and GFLASH (•).

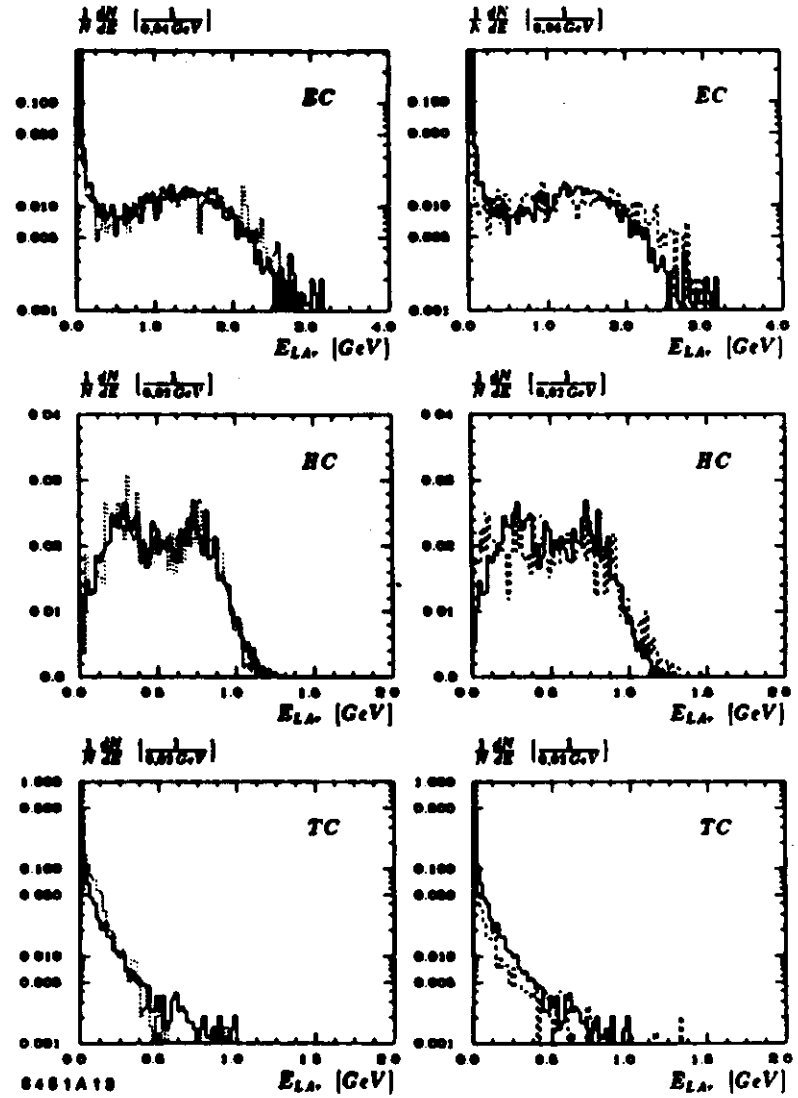


Figure 14: Energy distributions in the modules EC, HC, and TC for 30 GeV π^- showers: experiment (—), GFLASH (···), and GEANT (– – –).

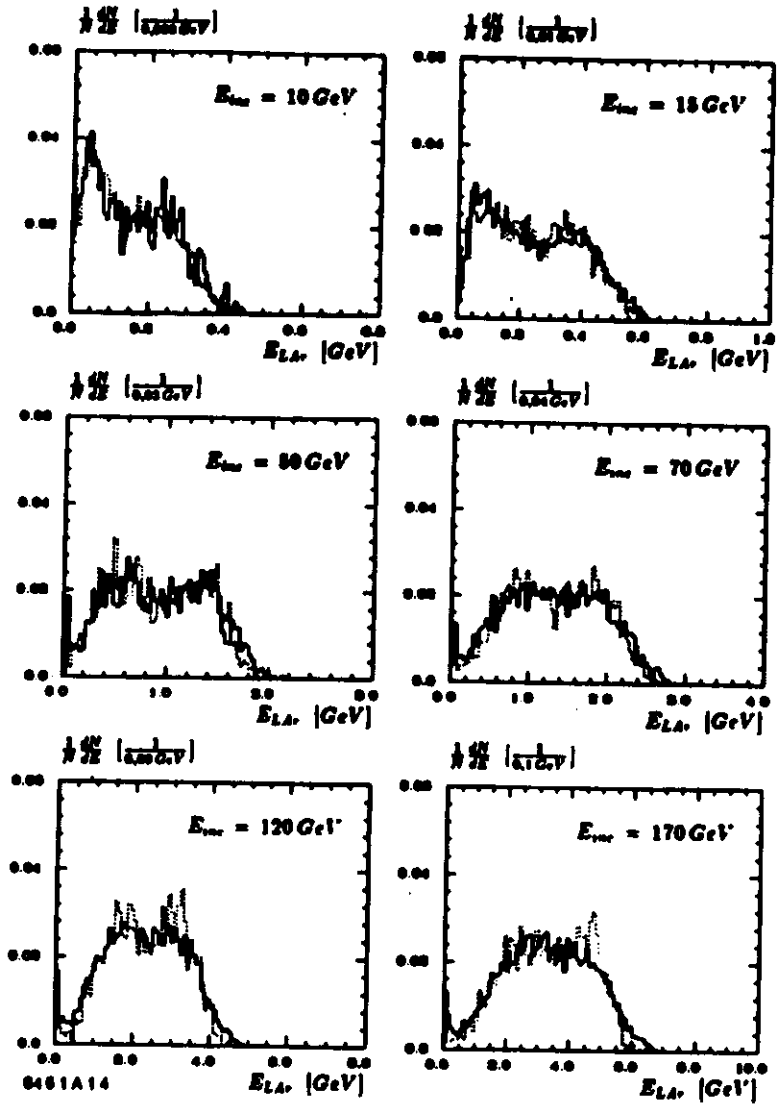


Figure 15: Energy distributions for π^- showers in HC for different energies: experiment (—) and GFLASH (···).

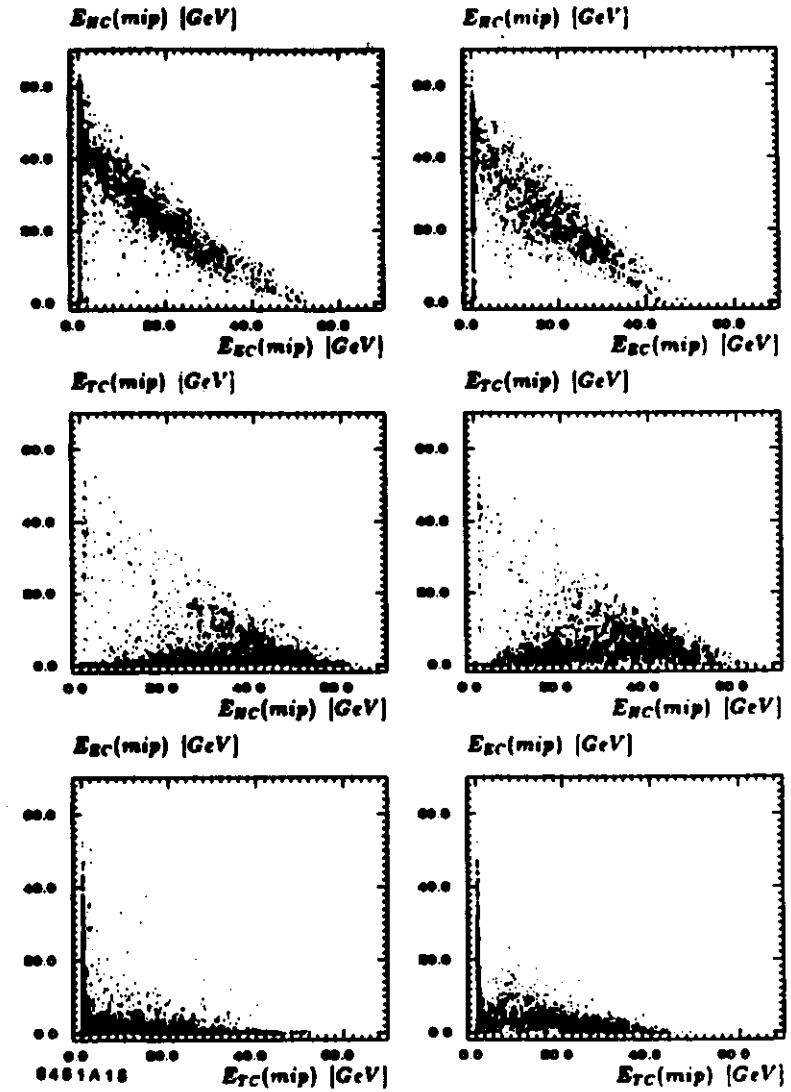
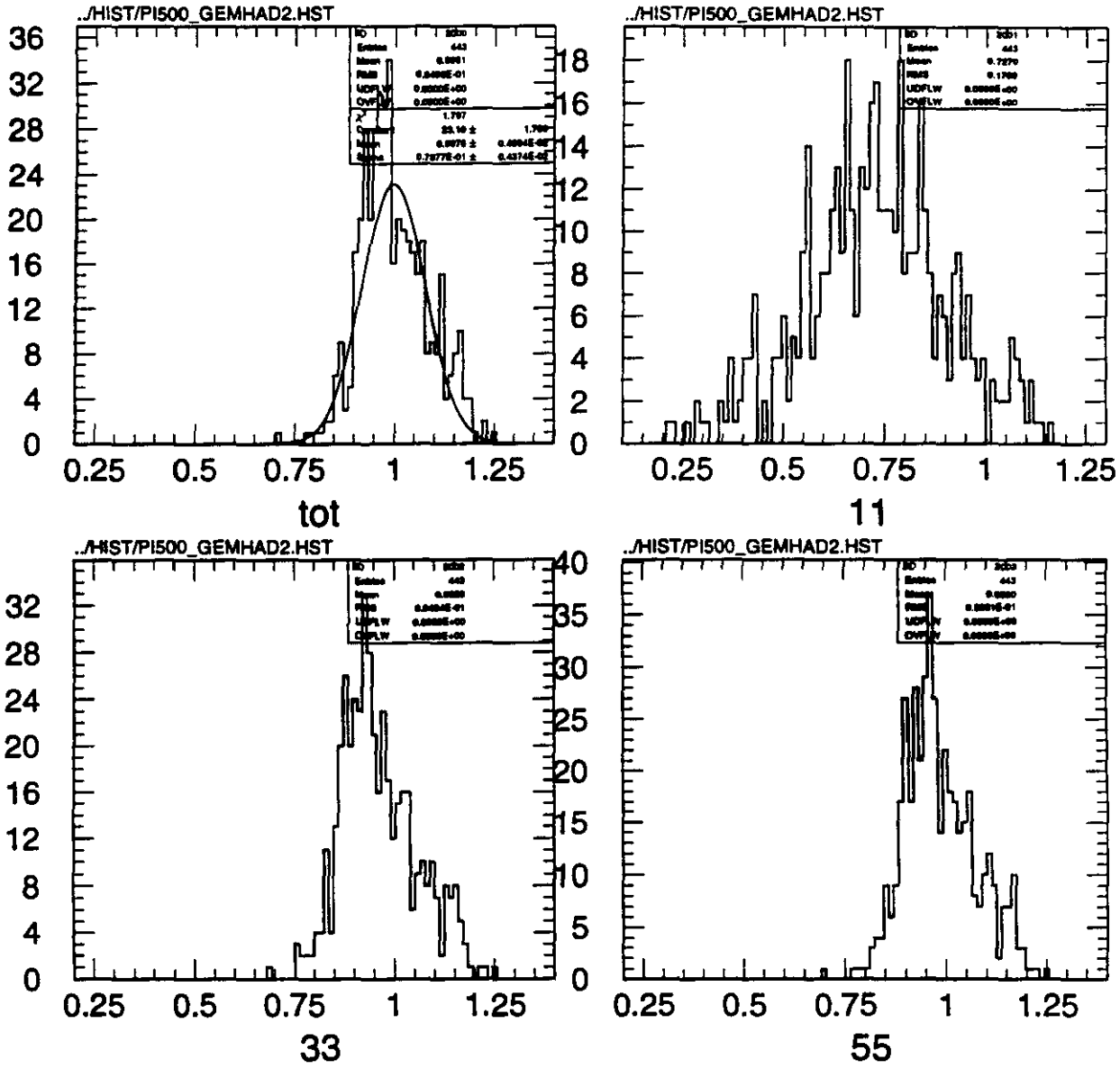
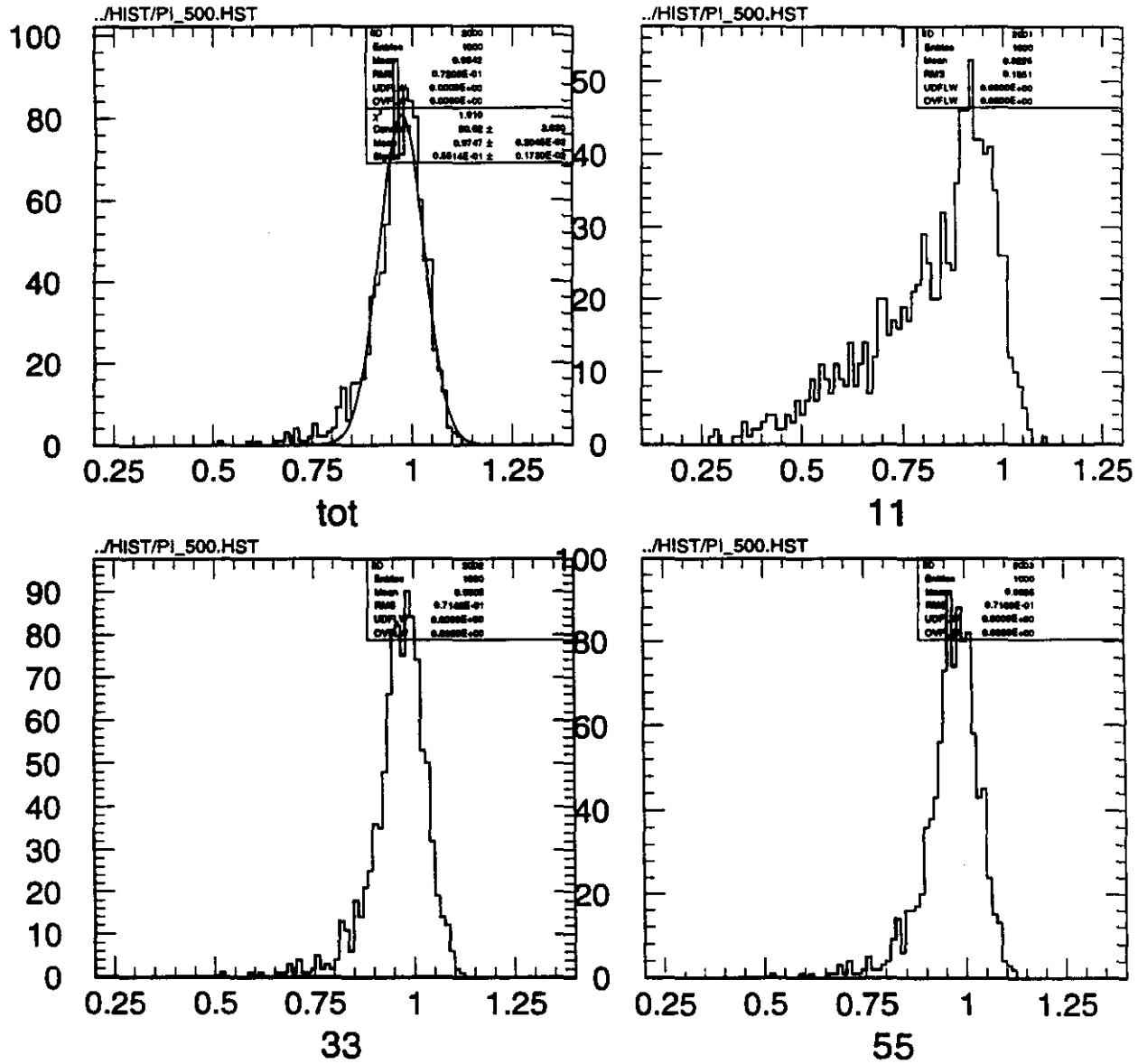


Figure 16: Energy correlations between different calorimeter modules for 70 GeV π^- showers: experiment (left) and GFLASH (right).

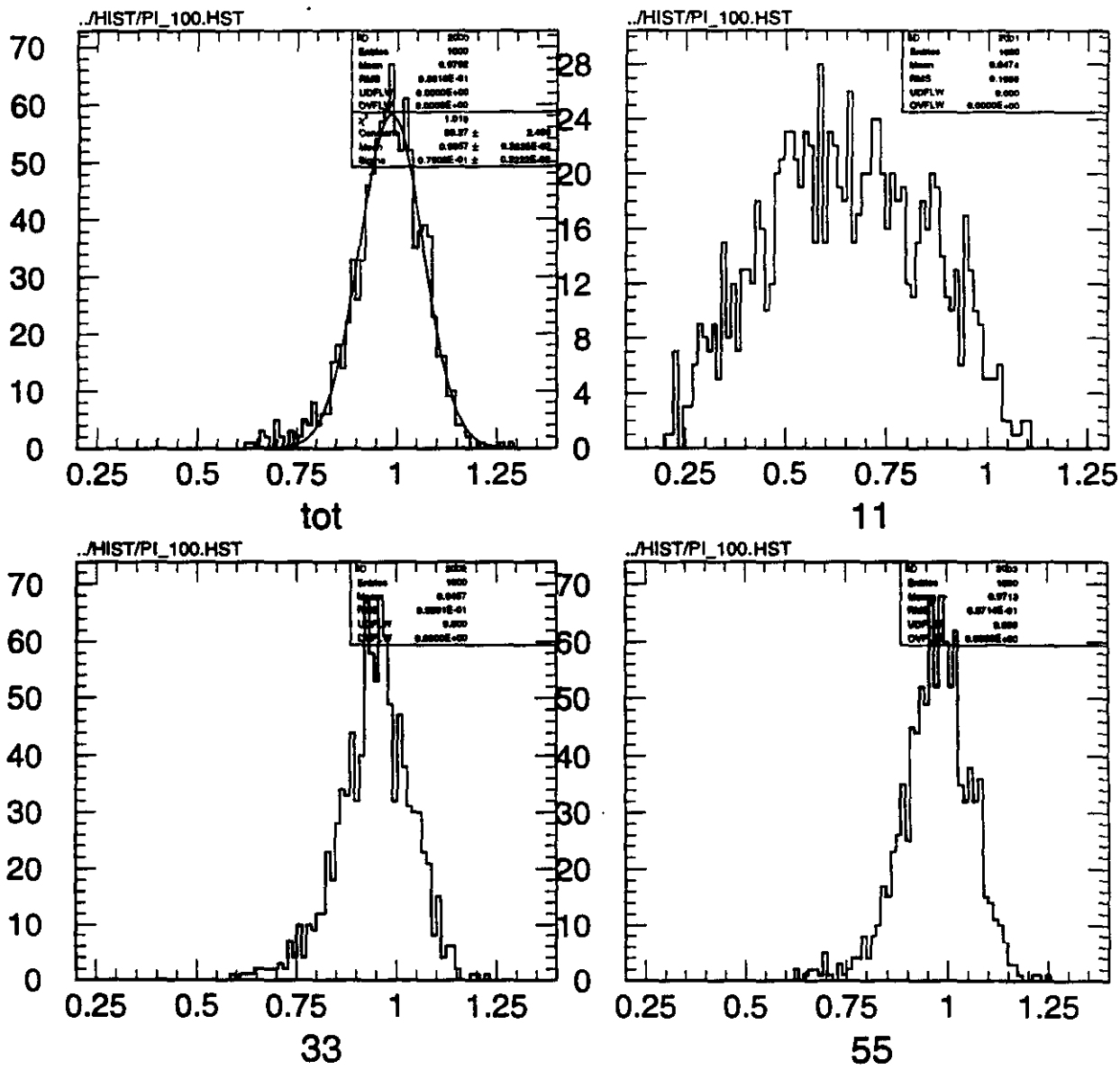
93/01/05 11.03


../HIST/PI500_GEMHAD2.HST
tot
../HIST/PI500_GEMHAD2.HST
11
../HIST/PI500_GEMHAD2.HST
33
../HIST/PI500_GEMHAD2.HST
55

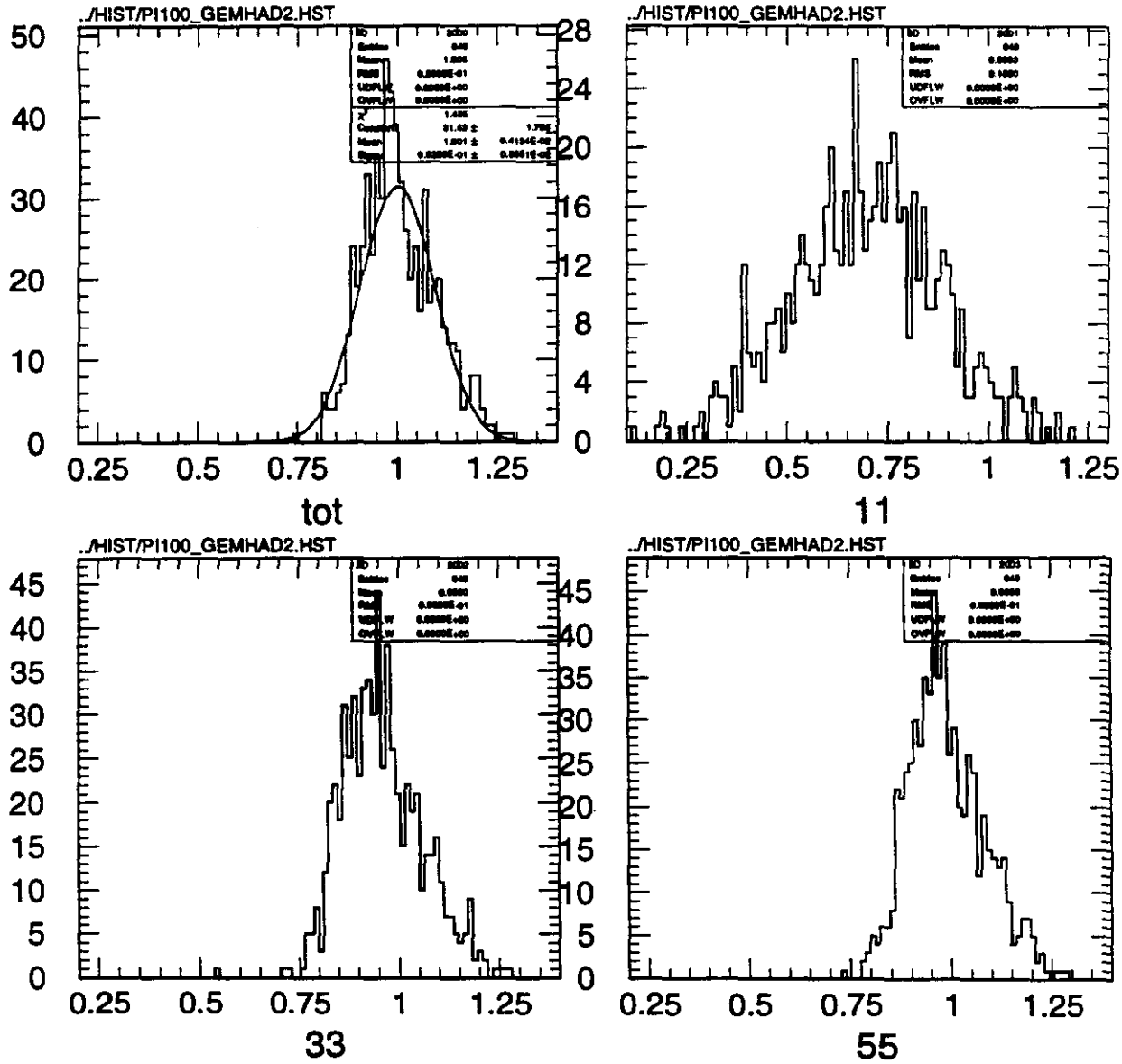
93/01/05 13.59


../HIST/PI_500.HST
tot
../HIST/PI_500.HST
11
../HIST/PI_500.HST
33
../HIST/PI_500.HST
55

93/01/05 14.00


../HIST/PI_100.HST
tot
../HIST/PI_100.HST
11
../HIST/PI_100.HST
33
../HIST/PI_100.HST
55

93/01/05 10.50


../HIST/PI100_GEMHAD2.HST
tot
../HIST/PI100_GEMHAD2.HST
11
../HIST/PI100_GEMHAD2.HST
33
../HIST/PI100_GEMHAD2.HST
55

Fit 8 parameters $\bar{R} = 0.7$

RD3 – P. Battaglia, L. Cossi, L. Perini

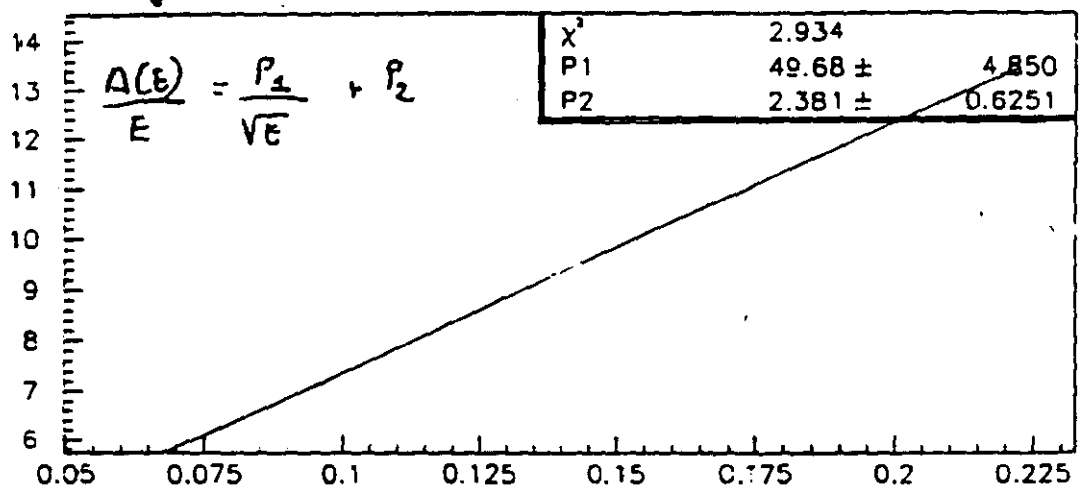
10/17/92

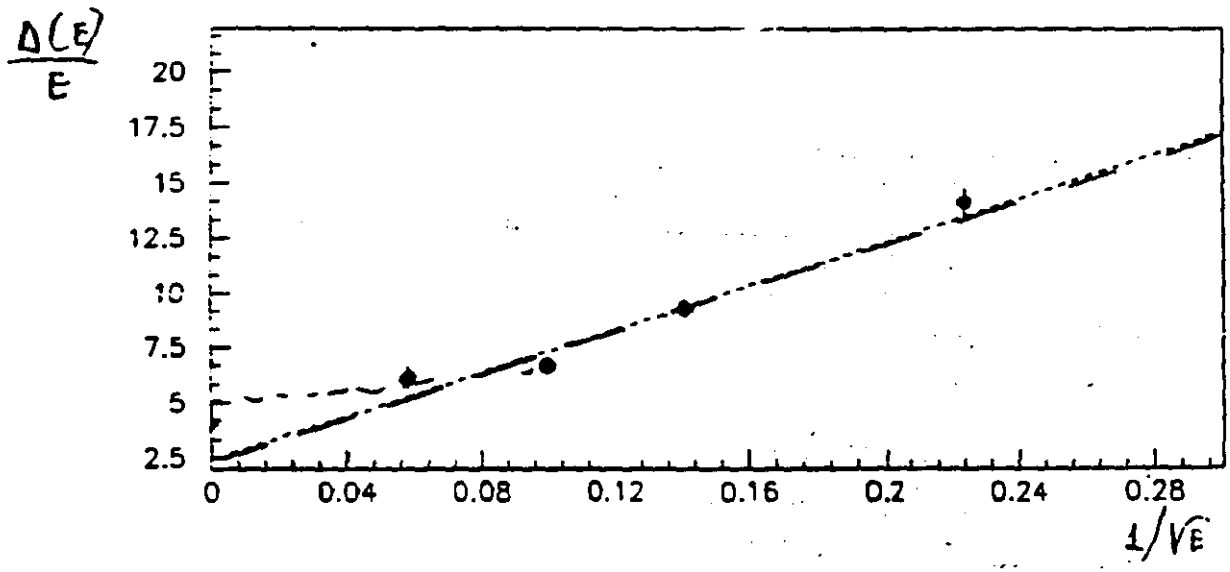
Accordion + Fe/LAr

Pythia Jets 20–300 GeV

GEANT 3.154

FLUKA

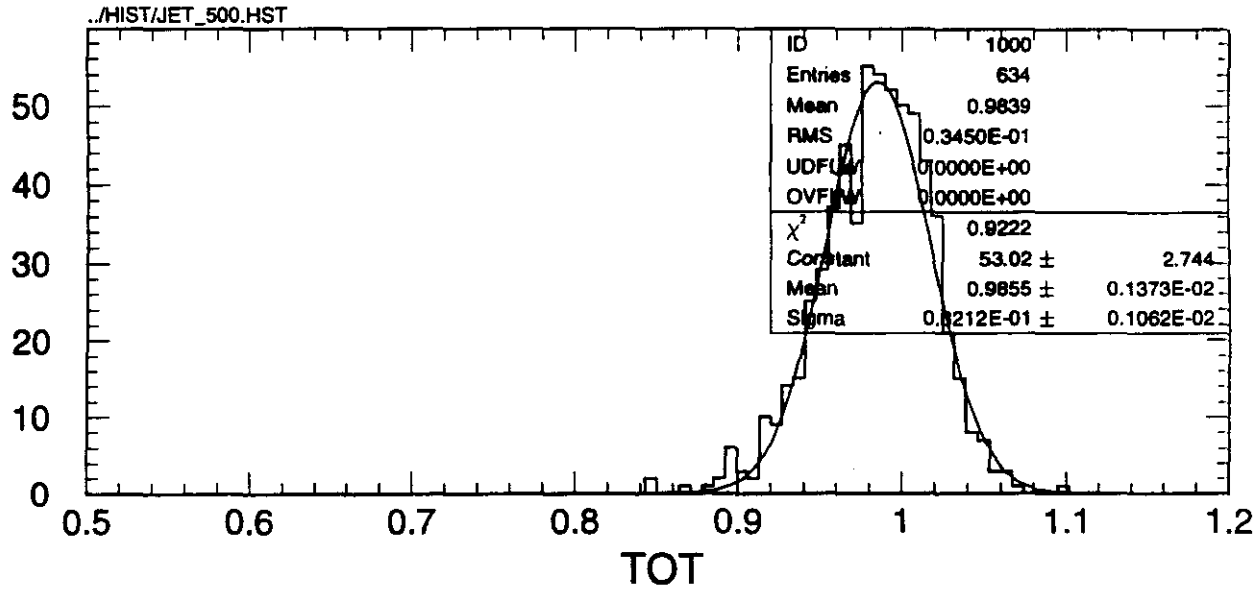


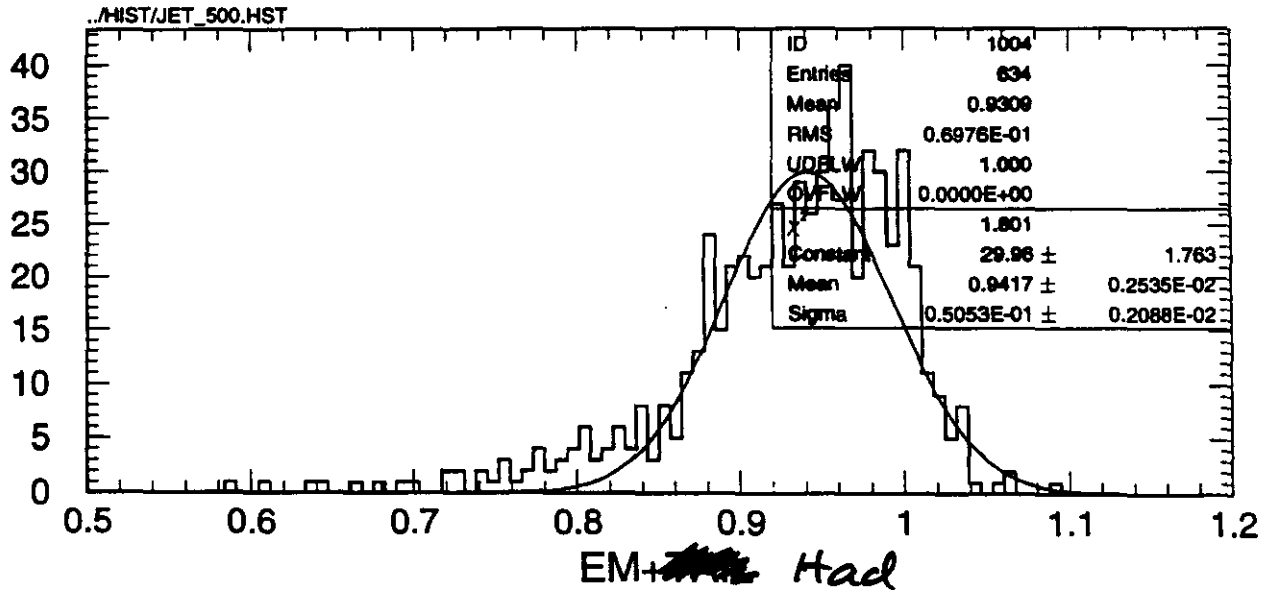


$$\frac{50 \pm 5\%}{\sqrt{E}} \oplus 2.4 \pm 0.6\%$$

8 parameters – 1 for each longitudinal division but NOT energy dependent

93/01/07 15.46


../HIST/JET_500.HST
ID 1000
Entries 634
Mean 0.9839
RMS 0.3450E-01
UDFLW 0.0000E+00
OVFLW 0.0000E+00
χ² 0.9222
Constant 53.02 ± 2.744
Mean 0.9855 ± 0.1373E-02
Sigma 0.3212E-01 ± 0.1062E-02
TOT


../HIST/JET_500.HST
ID 1004
Entries 634
Mean 0.9309
RMS 0.6976E-01
UDFLW 1.000
OVFLW 0.0000E+00
χ² 1.801
Constant 29.96 ± 1.763
Mean 0.9417 ± 0.2535E-02
Sigma 0.5053E-01 ± 0.2088E-02
EM+ Had

Tuning of GFLASH

1) EM

σ_E/E. Scale factor and constant term

transverse shower profile

E_{5x5} ok

E_{3x3}, mean too high
fluctuation too large.

2) Had. High Energy em shower leakage to hadron.

Transverse shower size at large energy.

Energy in Scint CAL

Understanding and justification of jet Resolut

$e/h \neq 1$?

weighting ?

---

others: e/π separation.

use EM position and pointing in GEANT

Summary

1) EM Barrel:

$$\sigma_E/E = \frac{5.6 - 6.6\%}{\sqrt{E}} \oplus .4\%$$

$$\sigma_\theta = 40 \text{ mrad}/\sqrt{E} + .5 \text{ mrad}$$

EM End Cap:

$$\sigma_E/E = \frac{8.5\%}{\sqrt{E}} \oplus .4\%$$

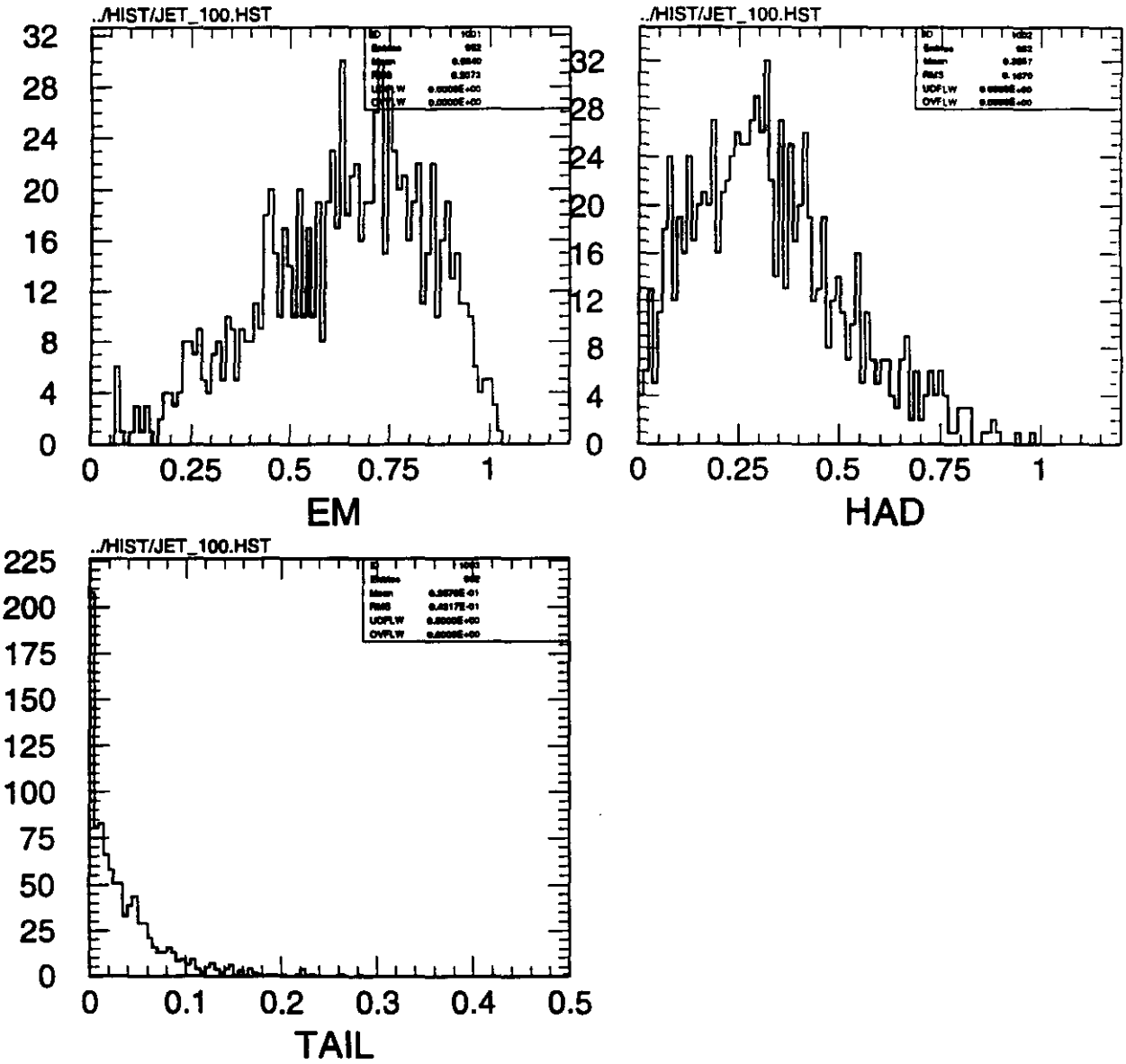
Average: $\sigma_\theta = 50 \text{ mrad}/\sqrt{E} + .5 \text{ mrad}$

2) Hadron

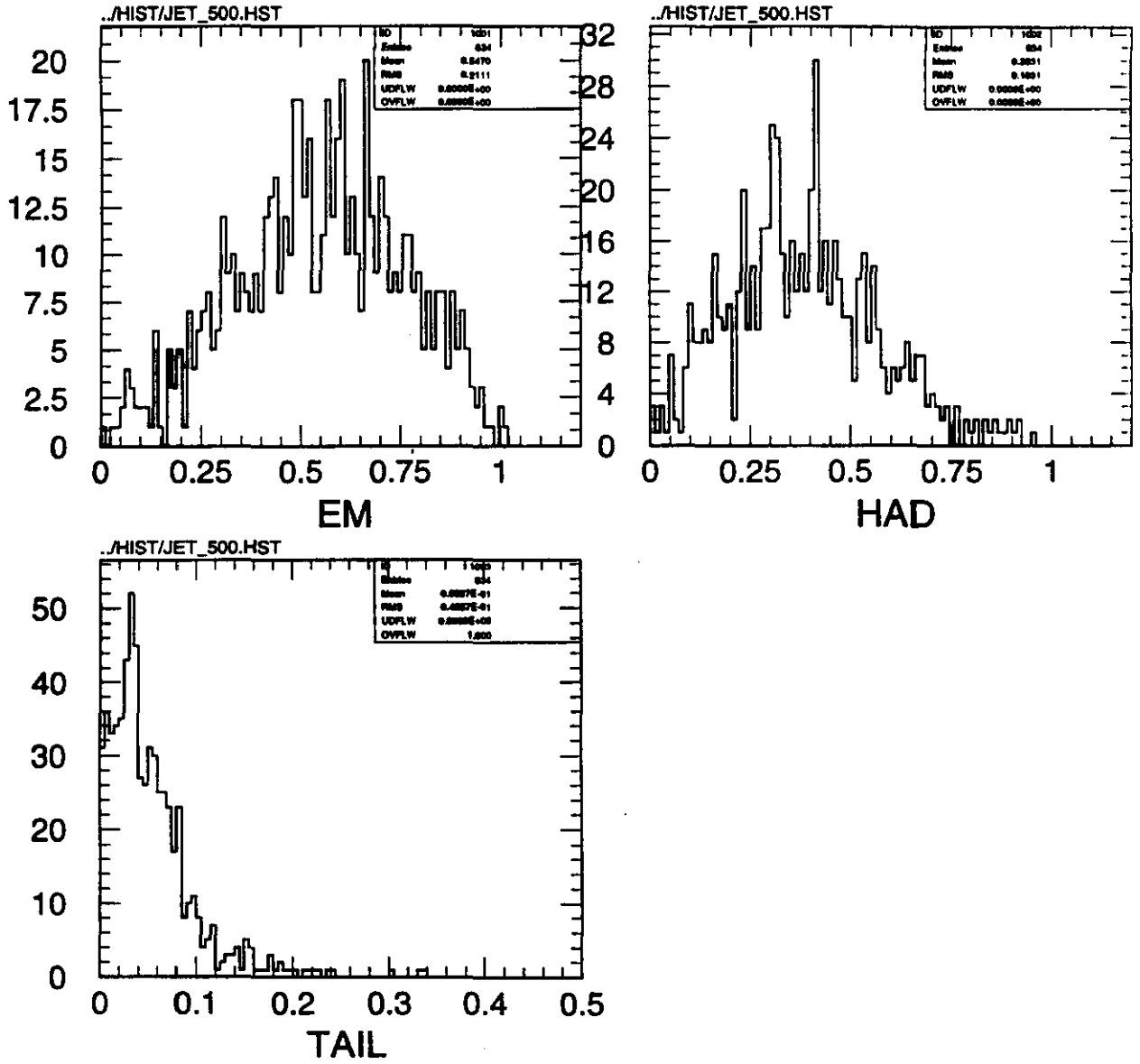
Single Particle Resolution: $\frac{\sigma_E}{E} = \frac{60-80\%}{\sqrt{E}} \oplus 2.5$

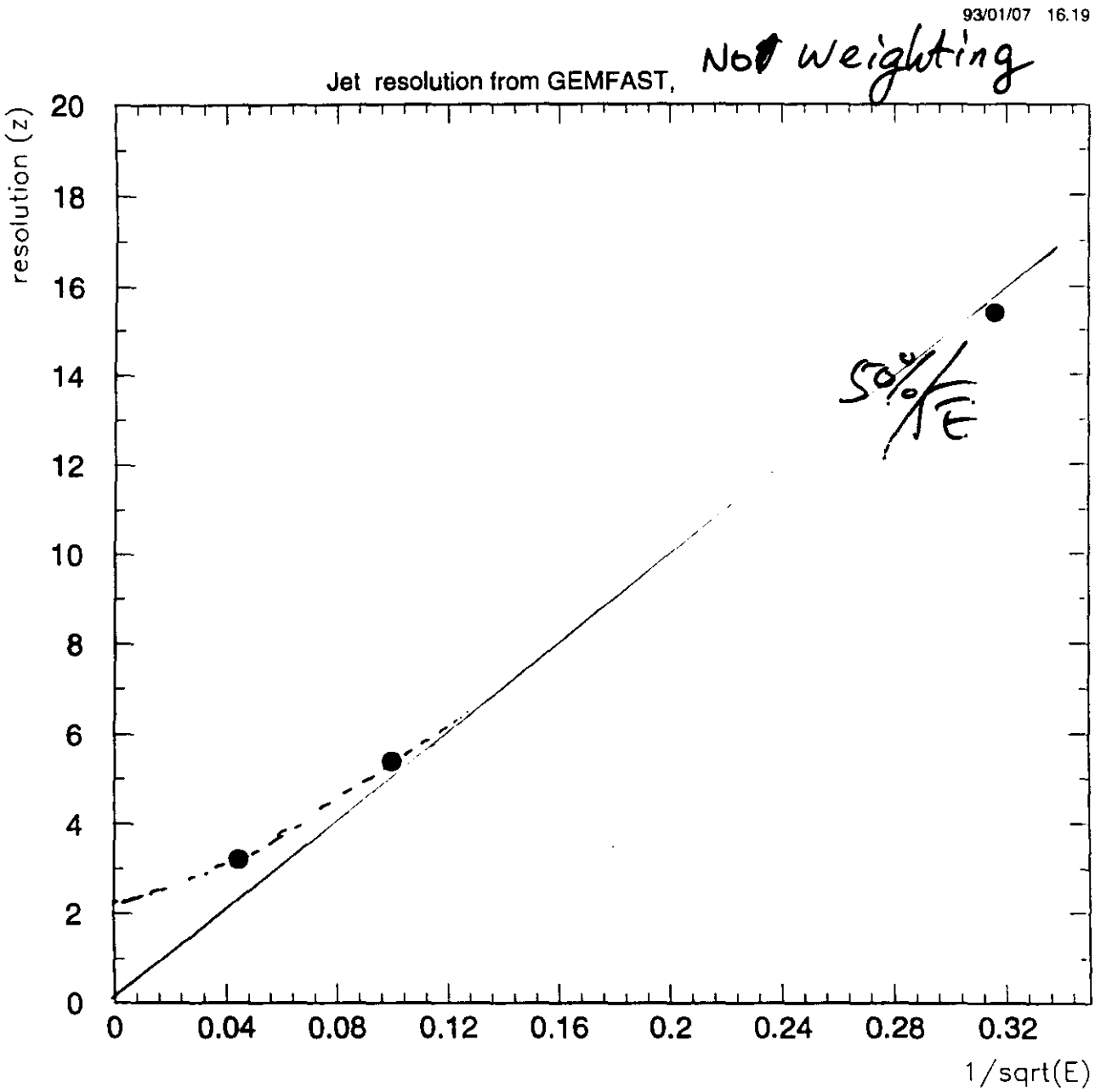
Jets: $\frac{\sigma_E}{E} = \frac{50\%}{\sqrt{E}} \oplus 2.5\%$

93/01/07 15.45

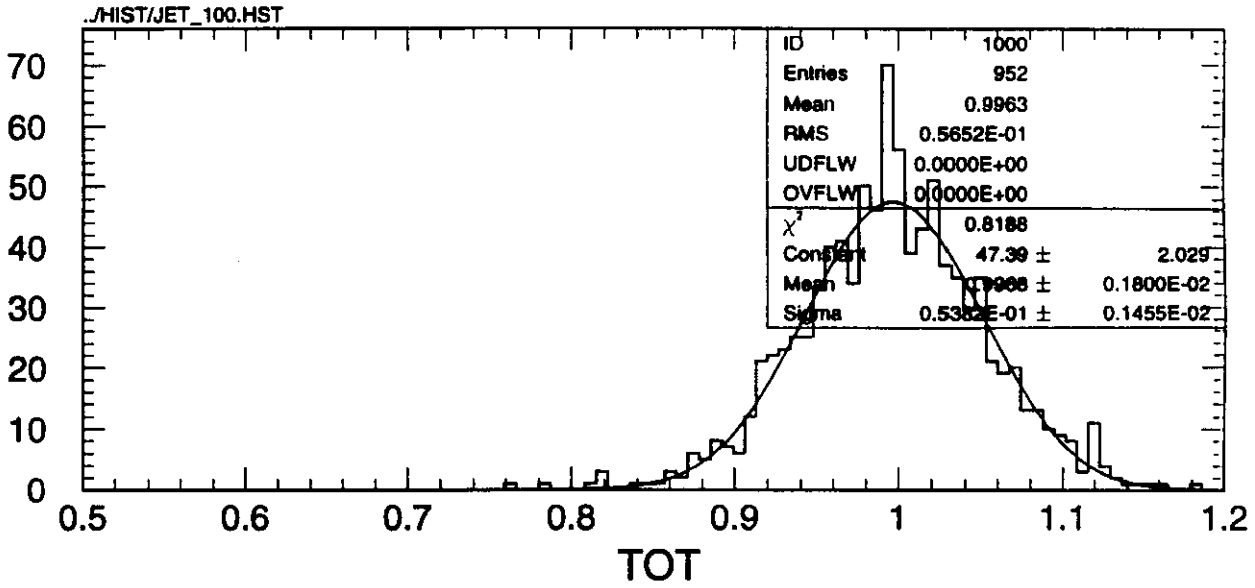

../HIST/JET_100.HST
32
28
24
20
16
12
8
4
0
0
0.25
0.5
0.75
1
EM
../HIST/JET_100.HST
32
28
24
20
16
12
8
4
0
0
0.25
0.5
0.75
1
HAD
../HIST/JET_100.HST
225
200
175
150
125
100
75
50
25
0
0
0.1
0.2
0.3
0.4
0.5
TAIL

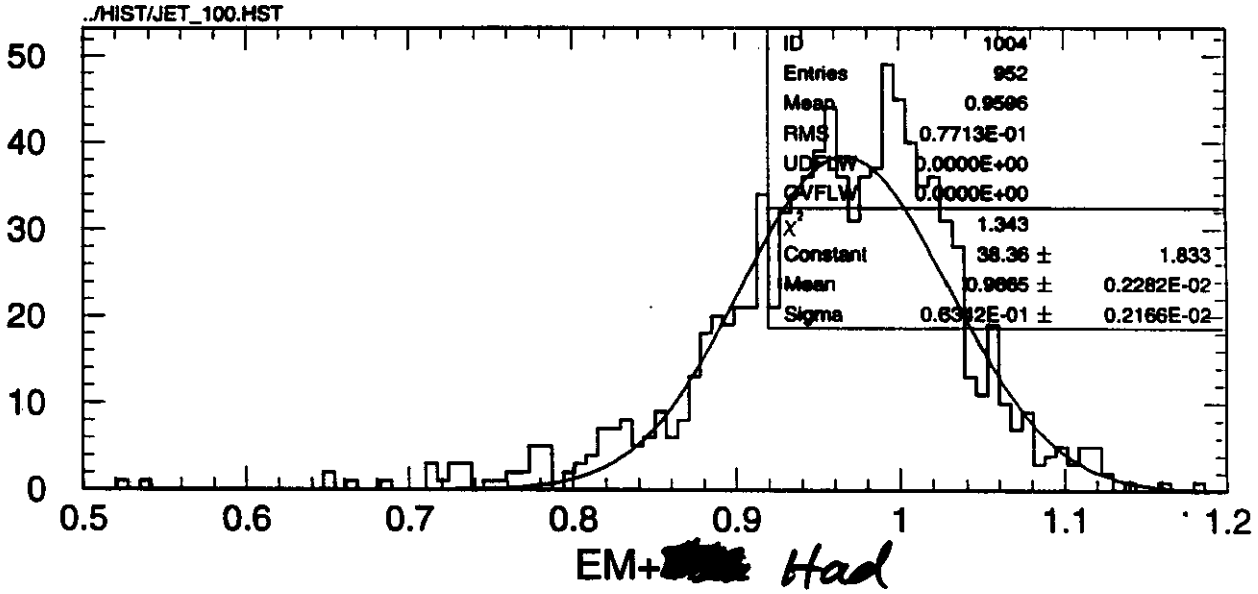
93/01/07 15.46



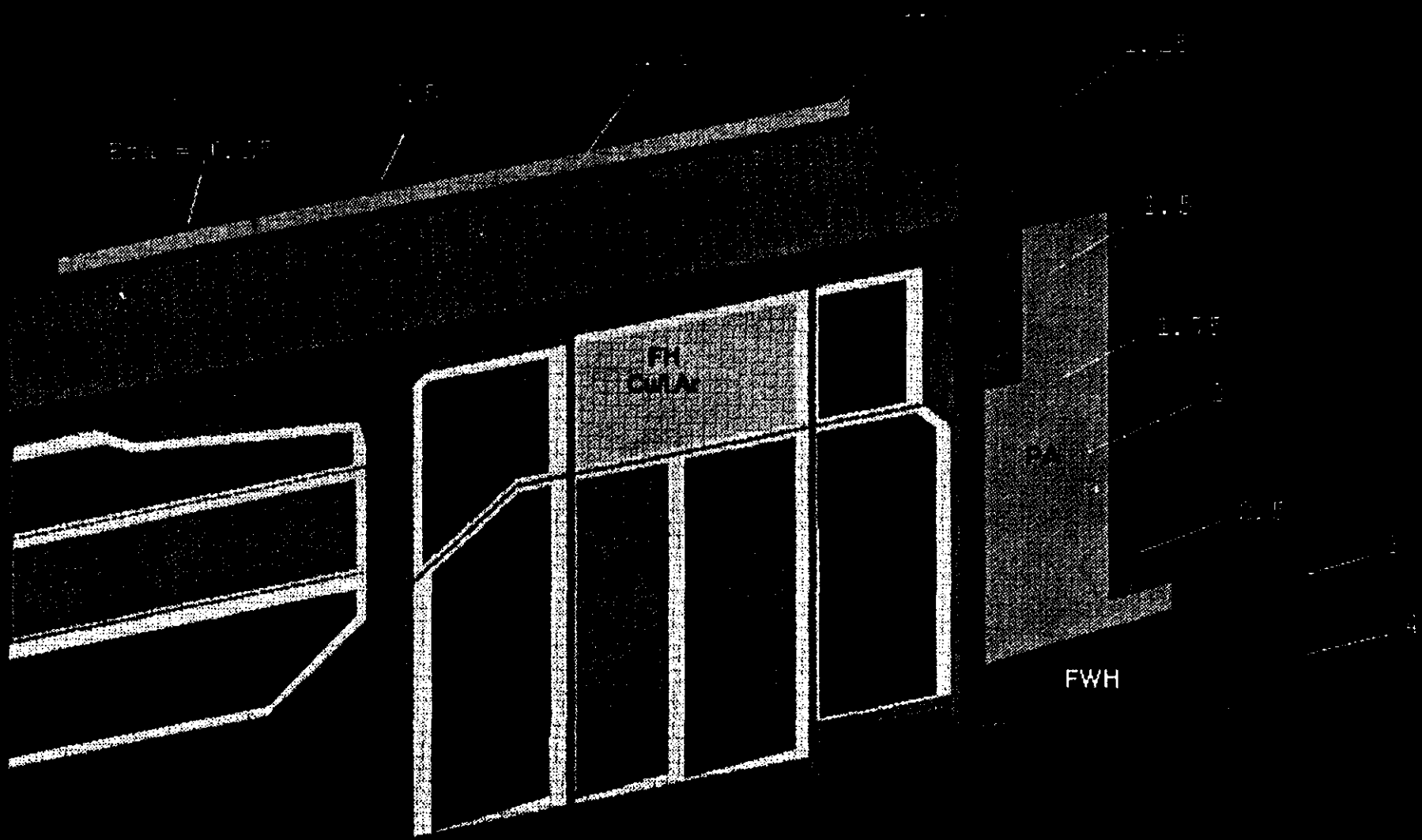

93/01/07 16.19
Jet resolution from GEMFAST, Not weighting
resolution (z)
20
18
16
14
12
10
8
6
4
2
0
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
1/sqrt(E)
50%/√E

93/01/07 15.45


../HIST/JET_100.HST
ID 1000
Entries 952
Mean 0.9963
RMS 0.5652E-01
UDFLW 0.0000E+00
OVFLW 0.0000E+00
χ^2 0.8188
Constant 47.39 ± 2.029
Mean 0.9968 ± 0.1800E-02
Sigma 0.5382E-01 ± 0.1455E-02
TOT


../HIST/JET_100.HST
ID 1004
Entries 952
Mean 0.9596
RMS 0.7713E-01
UDFLW 0.0000E+00
OVFLW 0.0000E+00
χ^2 1.343
Constant 38.36 ± 1.833
Mean 0.9865 ± 0.2282E-02
Sigma 0.6312E-01 ± 0.2166E-02
EM+[redacted] Had

GEM Calorimeter



gem

γeμ

Presentation by:

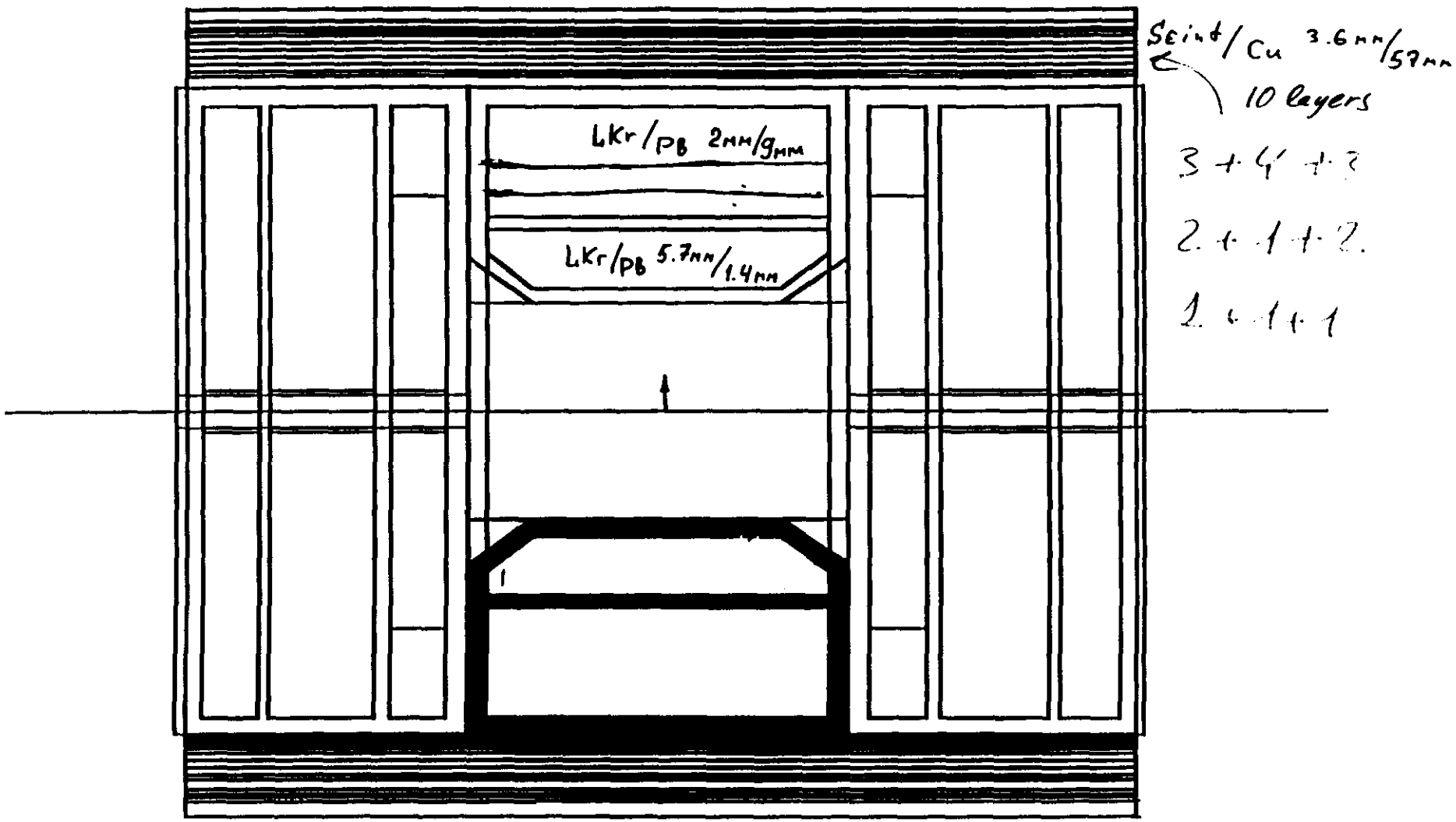
A. Savin

Tail catcher for Jet energy resolution

1. Can instrumented TC improve jet resolution?
2. How must it be instumented?

Jan 8/93, BU

by A. Savin


Scint/Cu 3.6mm/57mm
10 layers
3+4+3
2+1+2
1+1+1
LKr/Pb 2mm/9mm
LKr/Pb 5.7mm/1.4mm

Segmentation

① EM section: 1.4mm Pb/5.7 mm LKr plates

$4X_0 + 8X_0 + 13X_0$

3 separate "channels" or as one

② HC section 9mm Pb/2mm LKr plates

$\lesssim 1.25\lambda + \lesssim 1.25\lambda + \lesssim 2.5\lambda$ (active only)

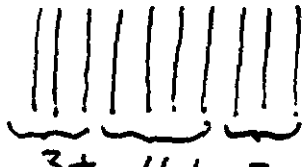
4.8λ ~~total~~

3 separate "channels" or as one

③ Tail Catcher (active section)

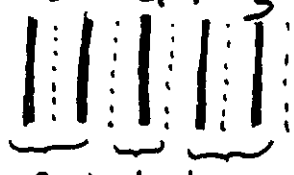
10 layers 57mm Cu/3.5mm Scintillator

Fine structure



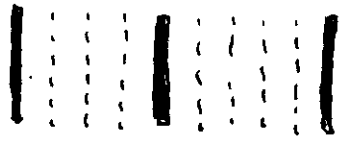
3 + 4 + 3

Half structure



2 + 1 + 2

Coarse structure



1 + 1 + 1

Tool for study –

PYTHIA JETS + GEANT 3.15 + GHEISHA

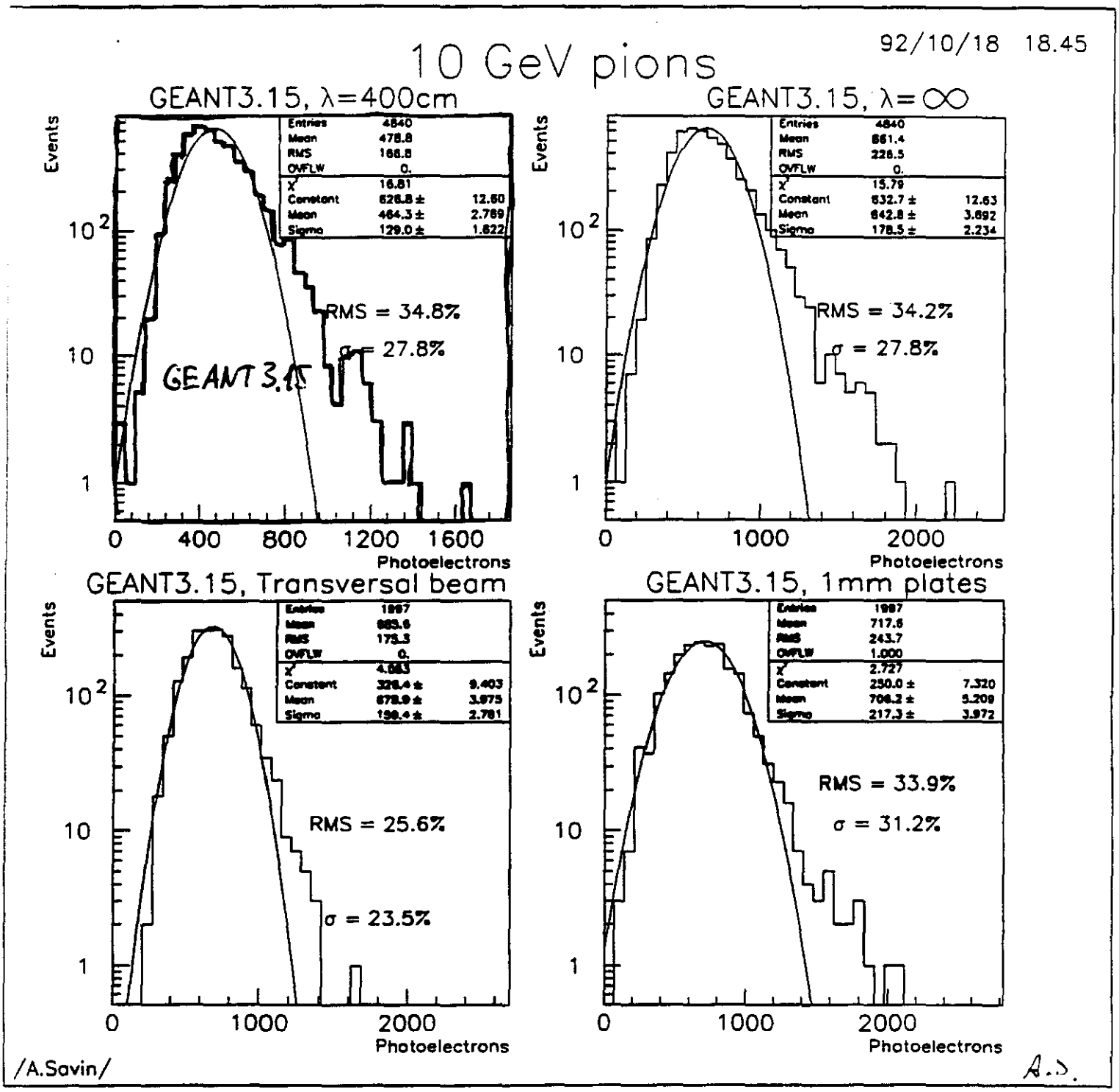
1. For Tail Catcher - Cu/Scint - looks Good.

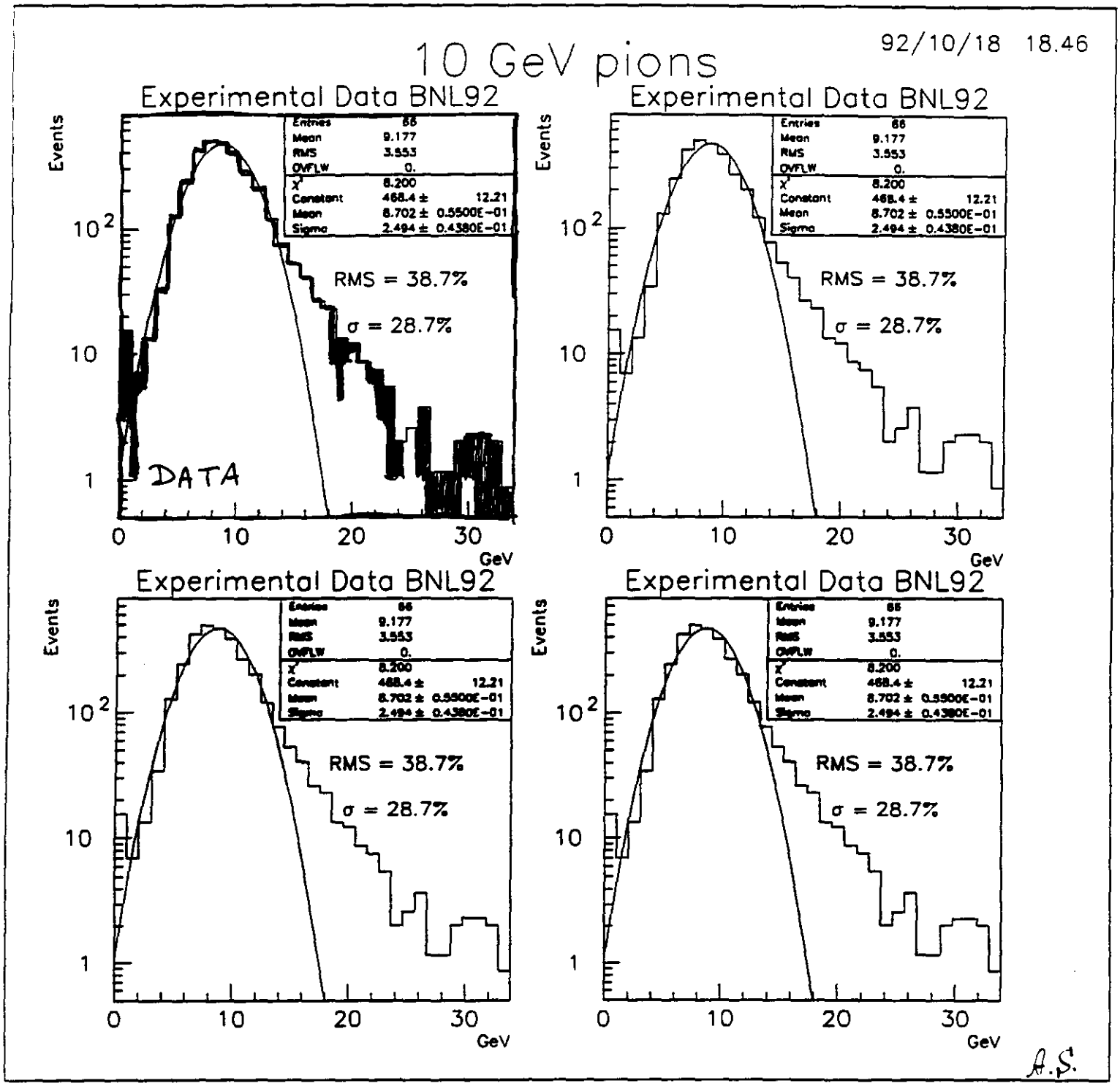
2. For PB/LKr - data?

↓

Only relative improvement may be predicted in this way.

(i.e. absolute is possible?).


10 GeV pions
92/10/18 18.45
GEANT3.15, λ=400cm
Entries 4840
Mean 478.8
RMS 166.8
OVFLW 0.
χ² 16.81
Constant 626.8 ± 12.60
Mean 464.3 ± 2.789
Sigma 129.0 ± 1.622
RMS = 34.8%
σ = 27.8%
GEANT 3.15
Events
Photoelectrons
GEANT3.15, λ=∞
Entries 4840
Mean 661.4
RMS 226.5
OVFLW 0.
χ² 15.79
Constant 632.7 ± 12.63
Mean 642.8 ± 3.692
Sigma 178.5 ± 2.234
RMS = 34.2%
σ = 27.8%
GEANT3.15, Transversal beam
Entries 1987
Mean 683.6
RMS 175.3
OVFLW 0.
χ² 4.663
Constant 326.4 ± 9.403
Mean 678.9 ± 3.975
Sigma 158.4 ± 2.781
RMS = 25.6%
σ = 23.5%
GEANT3.15, 1mm plates
Entries 1987
Mean 717.6
RMS 243.7
OVFLW 1.000
χ² 2.727
Constant 250.0 ± 7.320
Mean 706.2 ± 5.209
Sigma 217.3 ± 3.972
RMS = 33.9%
σ = 31.2%
/A.Savin/
A.S.


10 GeV pions
92/10/18 18.46
Experimental Data BNL92
Entries 66
Mean 9.177
RMS 3.553
OVFLW 0.
χ² 8.200
Constant 468.4 ± 12.21
Mean 8.702 ± 0.5500E-01
Sigma 2.494 ± 0.4380E-01
RMS = 38.7%
σ = 28.7%
DATA
Events
GeV
A.S.

Weighting procedure

1) Fixed weights, depending on jet energy

2)

a) $\mathrm{Min}\left(\sum_{evt's}\left(w_{EM}^{(1)}A_{EM}^{(1)}+w_{EM}^{(2)}A_{EM}^{(2)}+\ldots+w_{TC}^{(3)}\cdot A_{TC}^{(3)}-E_0\right)^2\right)$

b) $\frac{1}{N_{evt}}\sum_{evt's}\left(w_{EM}^{(1)}A_{EM}^{(1)}+\ldots+w_{TC}^{(3)}\cdot A_{TC}^{(3)}\right)=E_0$

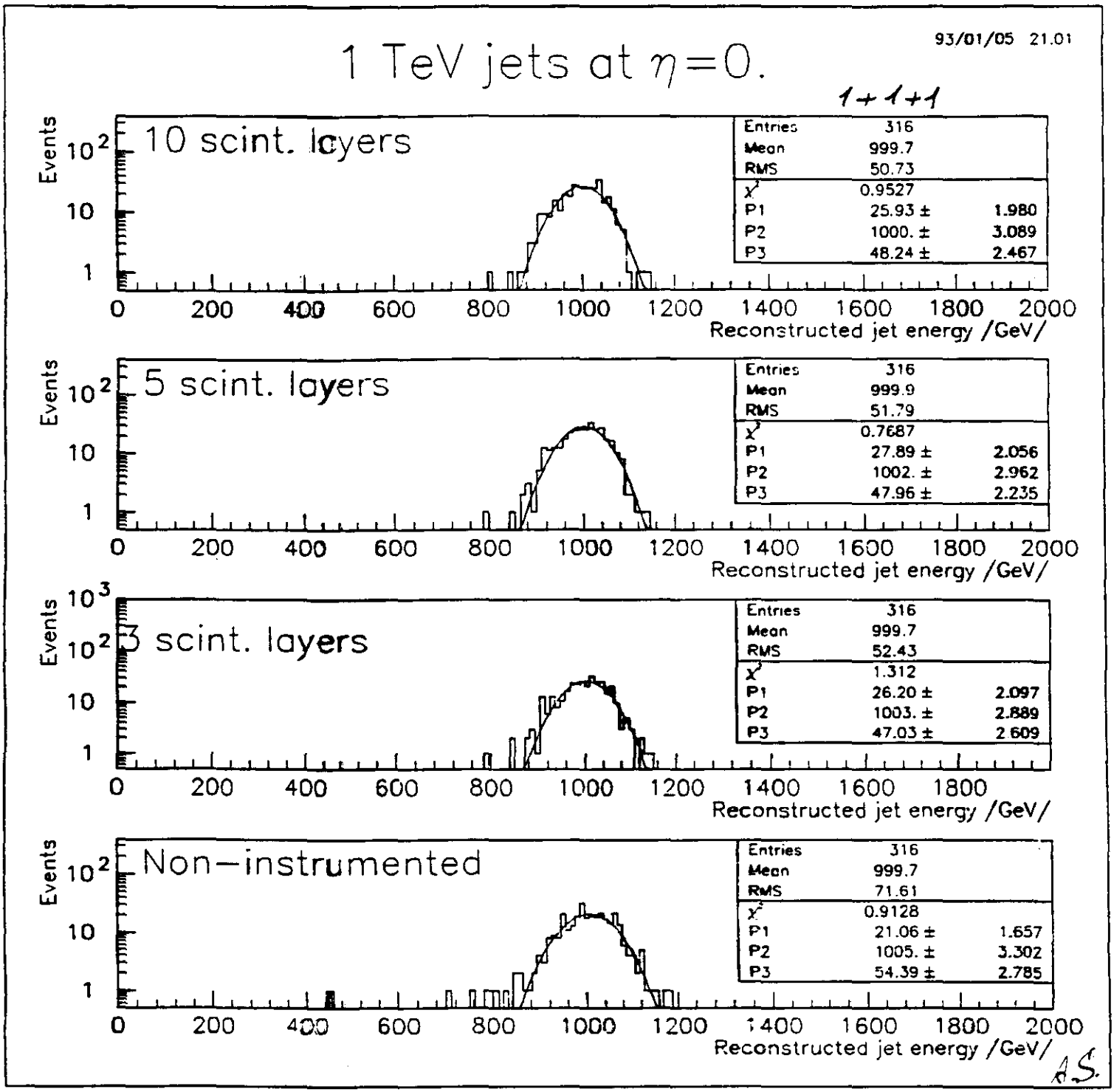
3) Procedure was tested by 50%/50% method – half of statistics

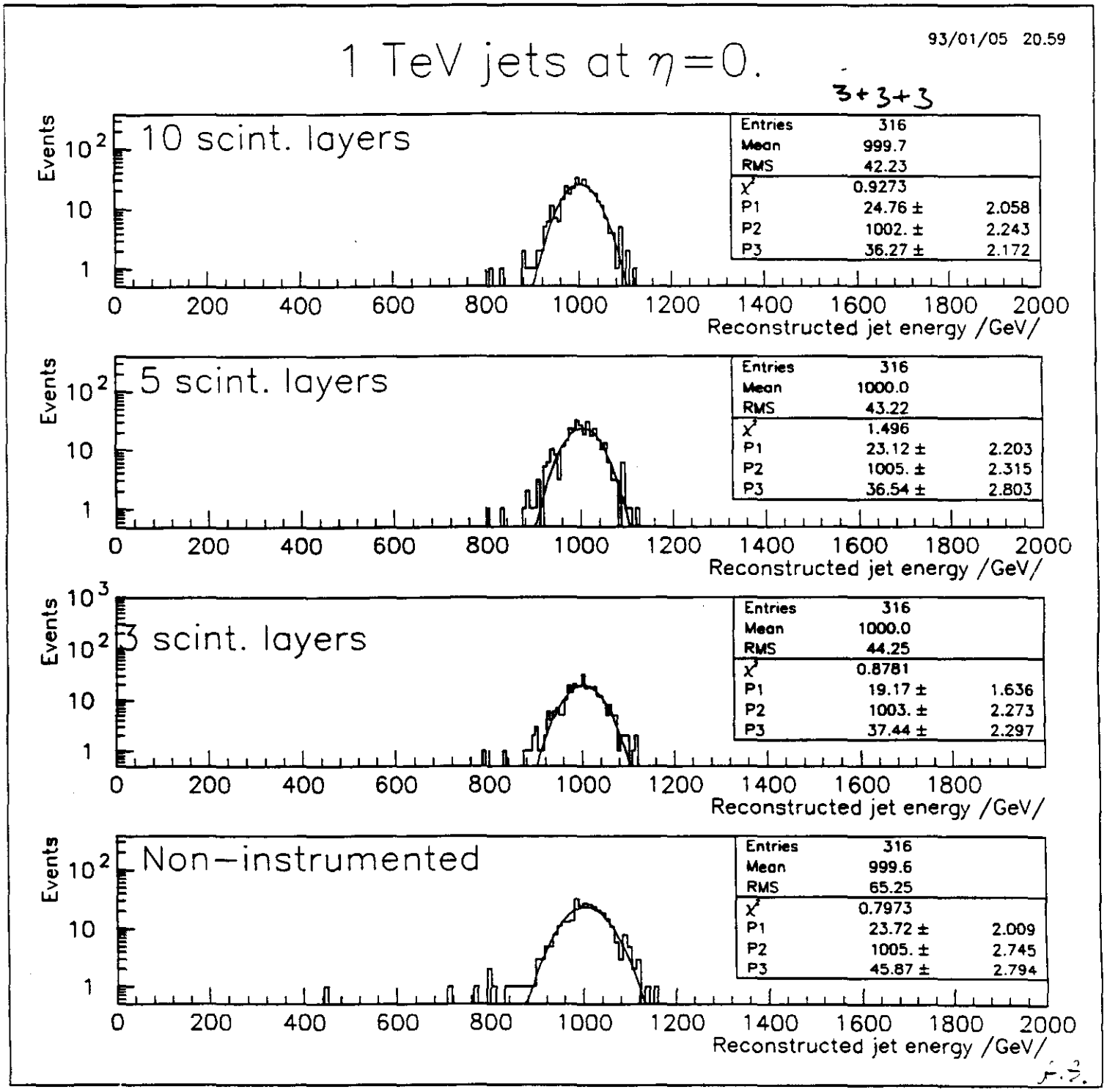
Weights

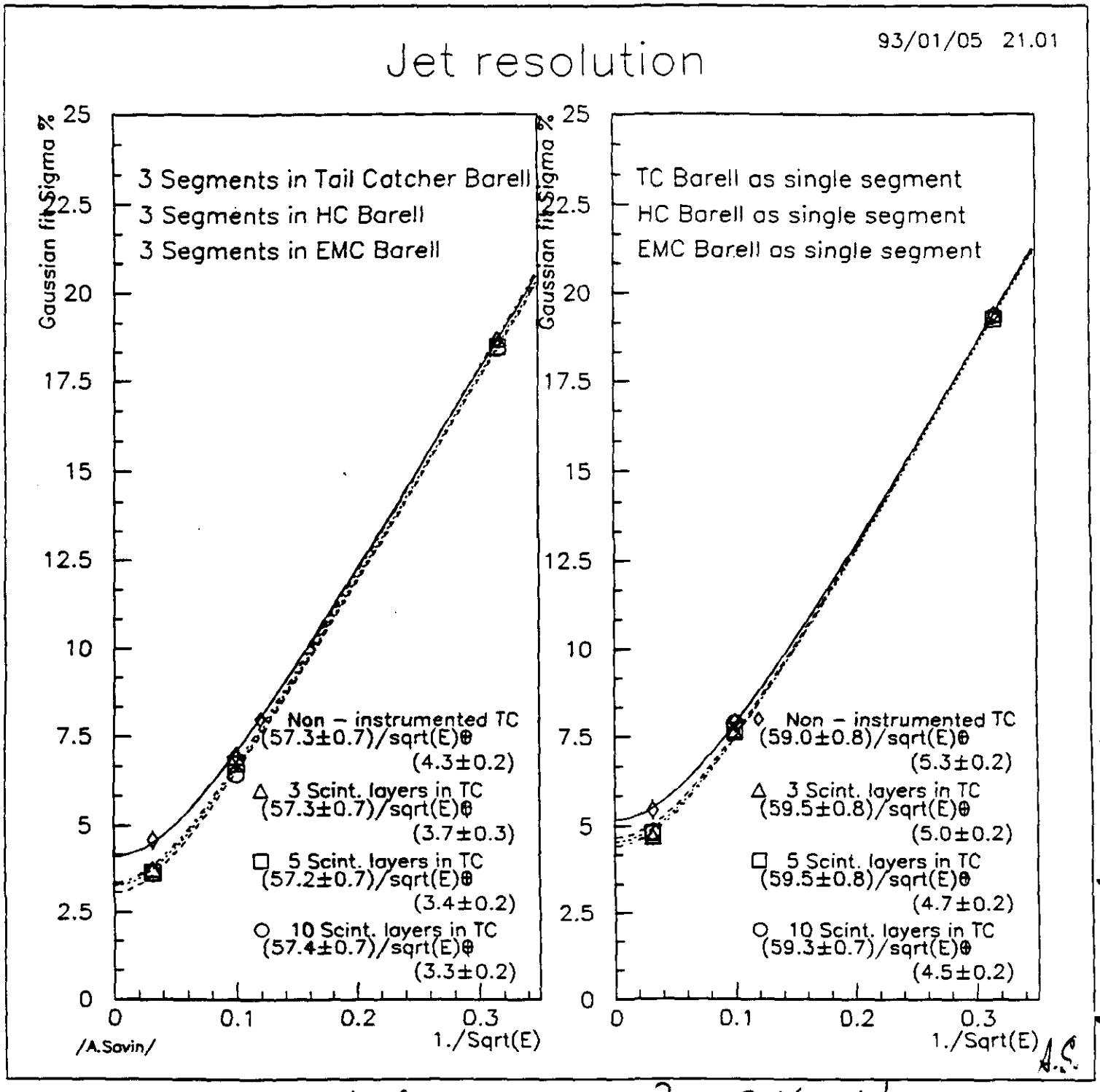
other half of statistics

Resolution

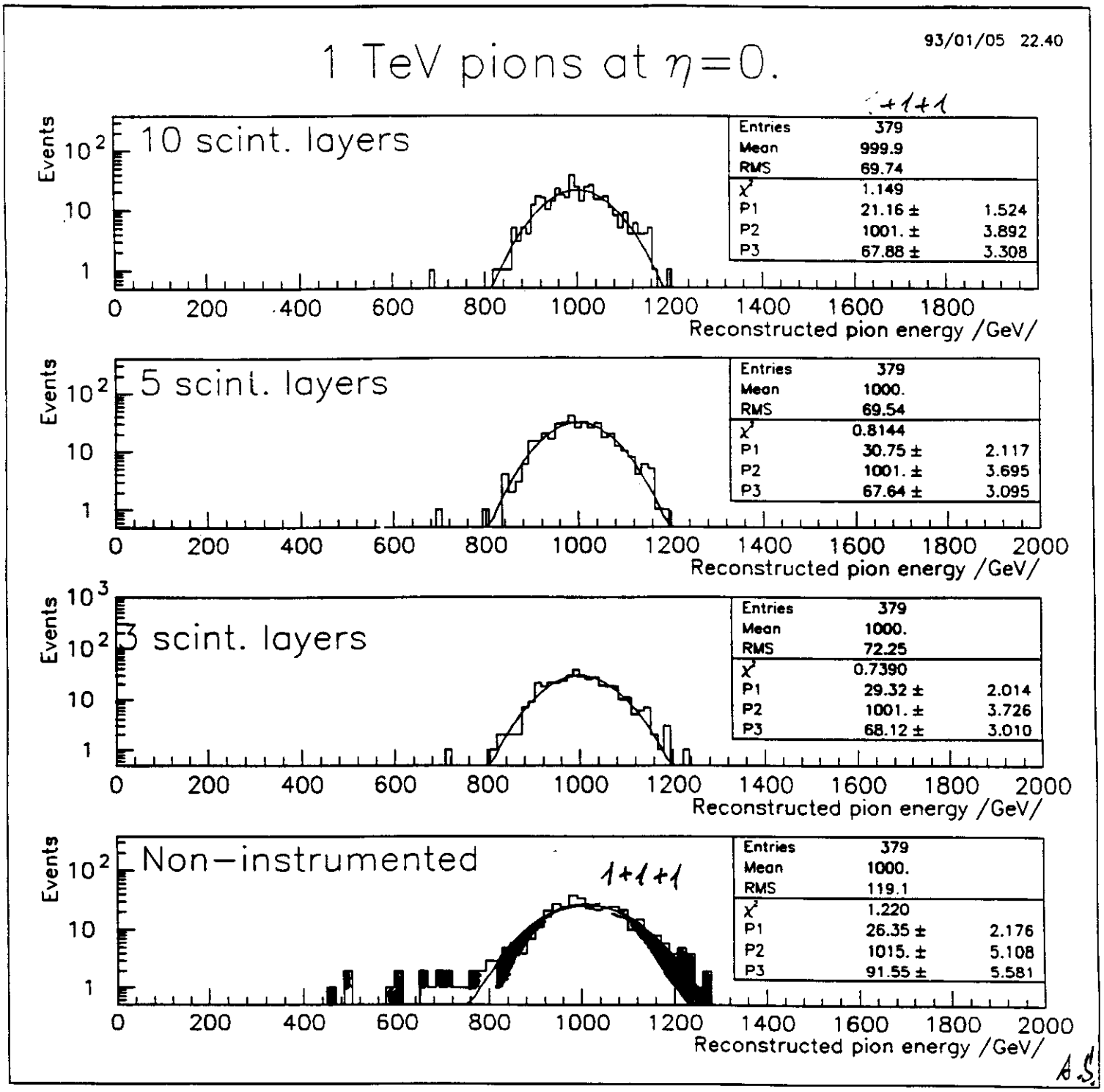
No difference with "self-weighting"

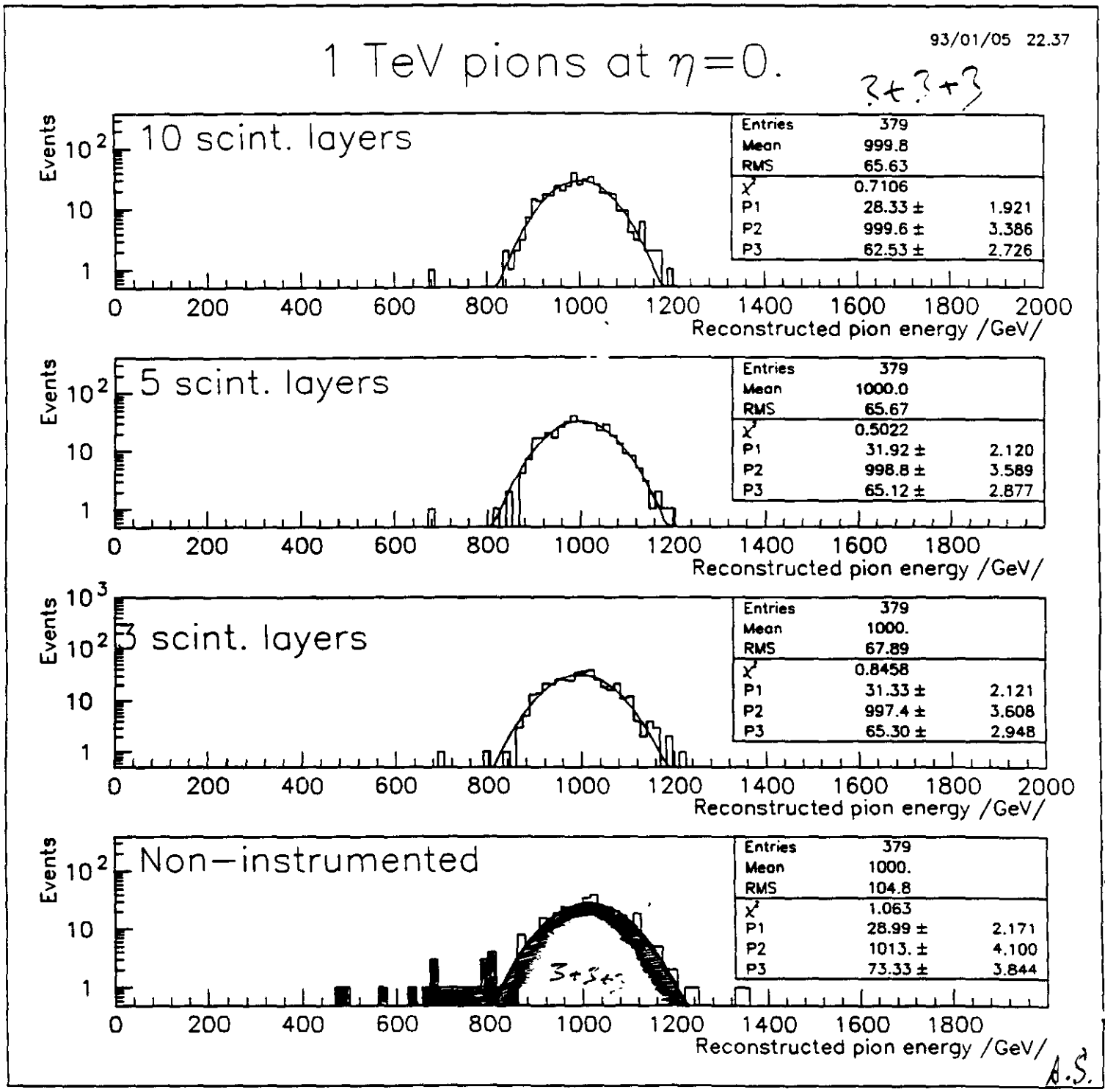

93/01/05 21.01
1 TeV jets at η=0.
1+1+1
10 scint. layers
Entries 316
Mean 999.7
RMS 50.73
χ² 0.9527
P1 25.93 ± 1.980
P2 1000. ± 3.089
P3 48.24 ± 2.467
5 scint. layers
Entries 316
Mean 999.9
RMS 51.79
χ² 0.7687
P1 27.89 ± 2.056
P2 1002. ± 2.962
P3 47.96 ± 2.235
3 scint. layers
Entries 316
Mean 999.7
RMS 52.43
χ² 1.312
P1 26.20 ± 2.097
P2 1003. ± 2.889
P3 47.03 ± 2.609
Non−instrumented
Entries 316
Mean 999.7
RMS 71.61
χ² 0.9128
P1 21.06 ± 1.657
P2 1005. ± 3.302
P3 54.39 ± 2.785
Events
Reconstructed jet energy /GeV/
A.S.

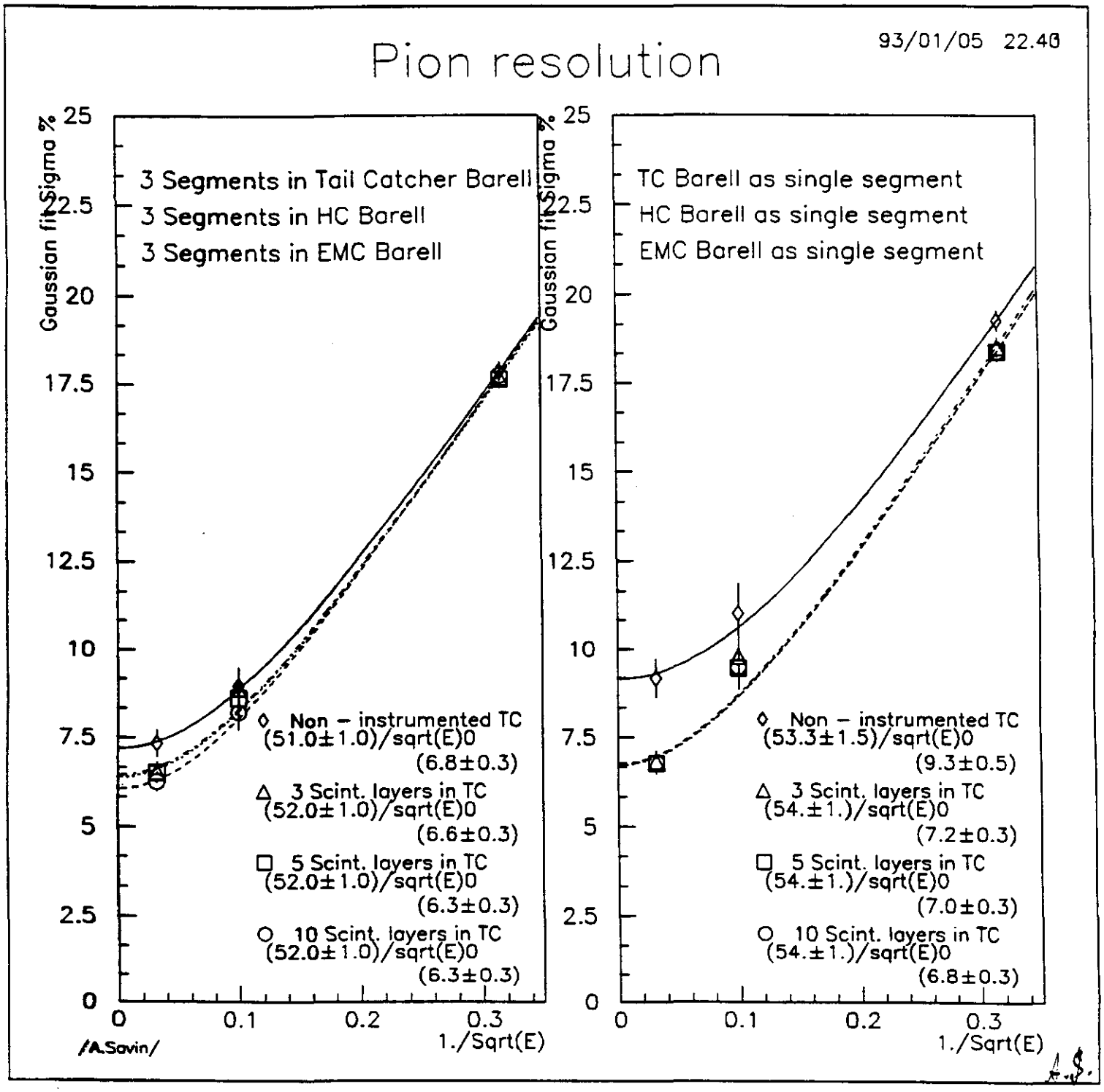

93/01/05 20.59
1 TeV jets at η=0.
3+3+3
10 scint. layers
Entries 316
Mean 999.7
RMS 42.23
χ² 0.9273
P1 24.76 ± 2.058
P2 1002. ± 2.243
P3 36.27 ± 2.172
5 scint. layers
Entries 316
Mean 1000.0
RMS 43.22
χ² 1.496
P1 23.12 ± 2.203
P2 1005. ± 2.315
P3 36.54 ± 2.803
3 scint. layers
Entries 316
Mean 1000.0
RMS 44.25
χ² 0.8781
P1 19.17 ± 1.636
P2 1003. ± 2.273
P3 37.44 ± 2.297
Non−instrumented
Entries 316
Mean 999.6
RMS 65.25
χ² 0.7973
P1 23.72 ± 2.009
P2 1005. ± 2.745
P3 45.87 ± 2.794
Events
Reconstructed jet energy /GeV/

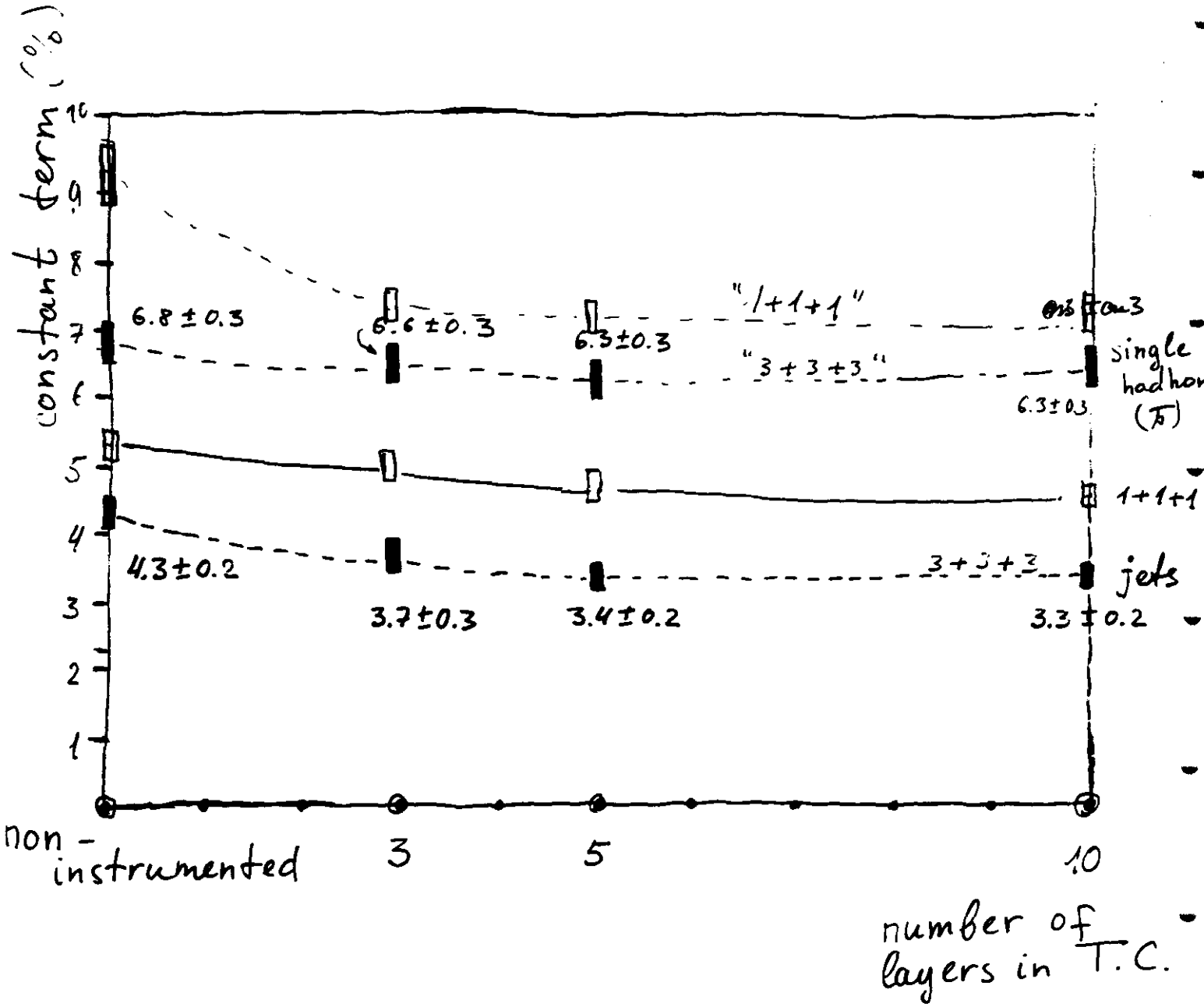


Points and lines are for 316 events;
Numbers – for 450 events.
One file with data (1TeV jets/π's)
was lost accidentally.


93/01/05 22.40
1 TeV pions at η=0.
10 scint. layers
Entries 379
Mean 999.9
RMS 69.74
χ² 1.149
P1 21.16 ± 1.524
P2 1001. ± 3.892
P3 67.88 ± 3.308
5 scint. layers
Entries 379
Mean 1000.
RMS 69.54
χ² 0.8144
P1 30.75 ± 2.117
P2 1001. ± 3.695
P3 67.64 ± 3.095
3 scint. layers
Entries 379
Mean 1000.
RMS 72.25
χ² 0.7390
P1 29.32 ± 2.014
P2 1001. ± 3.726
P3 68.12 ± 3.010
Non−instrumented
1+1+1
Entries 379
Mean 1000.
RMS 119.1
χ² 1.220
P1 26.35 ± 2.176
P2 1015. ± 5.108
P3 91.55 ± 5.581
Events
Reconstructed pion energy /GeV/


1 TeV pions at η=0.
93/01/05 22.37
3+3+3
10 scint. layers
Entries 379
Mean 999.8
RMS 65.63
χ² 0.7106
P1 28.33 ± 1.921
P2 999.6 ± 3.386
P3 62.53 ± 2.726
5 scint. layers
Entries 379
Mean 1000.0
RMS 65.67
χ² 0.5022
P1 31.92 ± 2.120
P2 998.8 ± 3.589
P3 65.12 ± 2.877
3 scint. layers
Entries 379
Mean 1000.
RMS 67.89
χ² 0.8458
P1 31.33 ± 2.121
P2 997.4 ± 3.608
P3 65.30 ± 2.948
Non−instrumented
Entries 379
Mean 1000.
RMS 104.8
χ² 1.063
P1 28.99 ± 2.171
P2 1013. ± 4.100
P3 73.33 ± 3.844
3+5+3
Events
Reconstructed pion energy /GeV/
A.S.


Pion resolution
93/01/05 22.40
Gaussian fit Sigma %
3 Segments in Tail Catcher Barell
3 Segments in HC Barell
3 Segments in EMC Barell
Non – instrumented TC
(51.0±1.0)/sqrt(E)0
(6.8±0.3)
3 Scint. layers in TC
(52.0±1.0)/sqrt(E)0
(6.6±0.3)
5 Scint. layers in TC
(52.0±1.0)/sqrt(E)0
(6.3±0.3)
10 Scint. layers in TC
(52.0±1.0)/sqrt(E)0
(6.3±0.3)
1./Sqrt(E)
/A.Savin/
TC Barell as single segment
HC Barell as single segment
EMC Barell as single segment
Non – instrumented TC
(53.3±1.5)/sqrt(E)0
(9.3±0.5)
3 Scint. layers in TC
(54.±1.)/sqrt(E)0
(7.2±0.3)
5 Scint. layers in TC
(54.±1.)/sqrt(E)0
(7.0±0.3)
10 Scint. layers in TC
(54.±1.)/sqrt(E)0
(6.8±0.3)
1./Sqrt(E)


constant term (%)
10
9
8
7
6
5
4
3
2
1
6.8 ± 0.3
6.6 ± 0.3
6.3 ± 0.3
"1+1+1"
"3+3+3"
6.3 ± 0.3
single had hor (π)
1+1+1
4.3 ± 0.2
3+3+3
jets
3.7 ± 0.3
3.4 ± 0.2
3.3 ± 0.2
non-instrumented
3
5
10
number of layers in T.C.

A.S.

Conclusion

1. Tail catcher is not a strong instrument for jet energy resolution

$(4.3 \pm 0.2)\%$ $\xrightarrow{①}$ $(3.3 \pm 0.2)\%$ for 9 weights procedure

$\downarrow$ ② $\qquad$ $\updownarrow$ ②

$(5.3 \pm 0.2)\%$ $\xrightarrow{①}$ $(4.5 \pm 0.2)\%$ for 3 weights.

2. Effect of internal segmentation of EM and HC is ~ the same w/out special device like TC

BU Jan 08/1993

gem

γeμ

Presentation by:

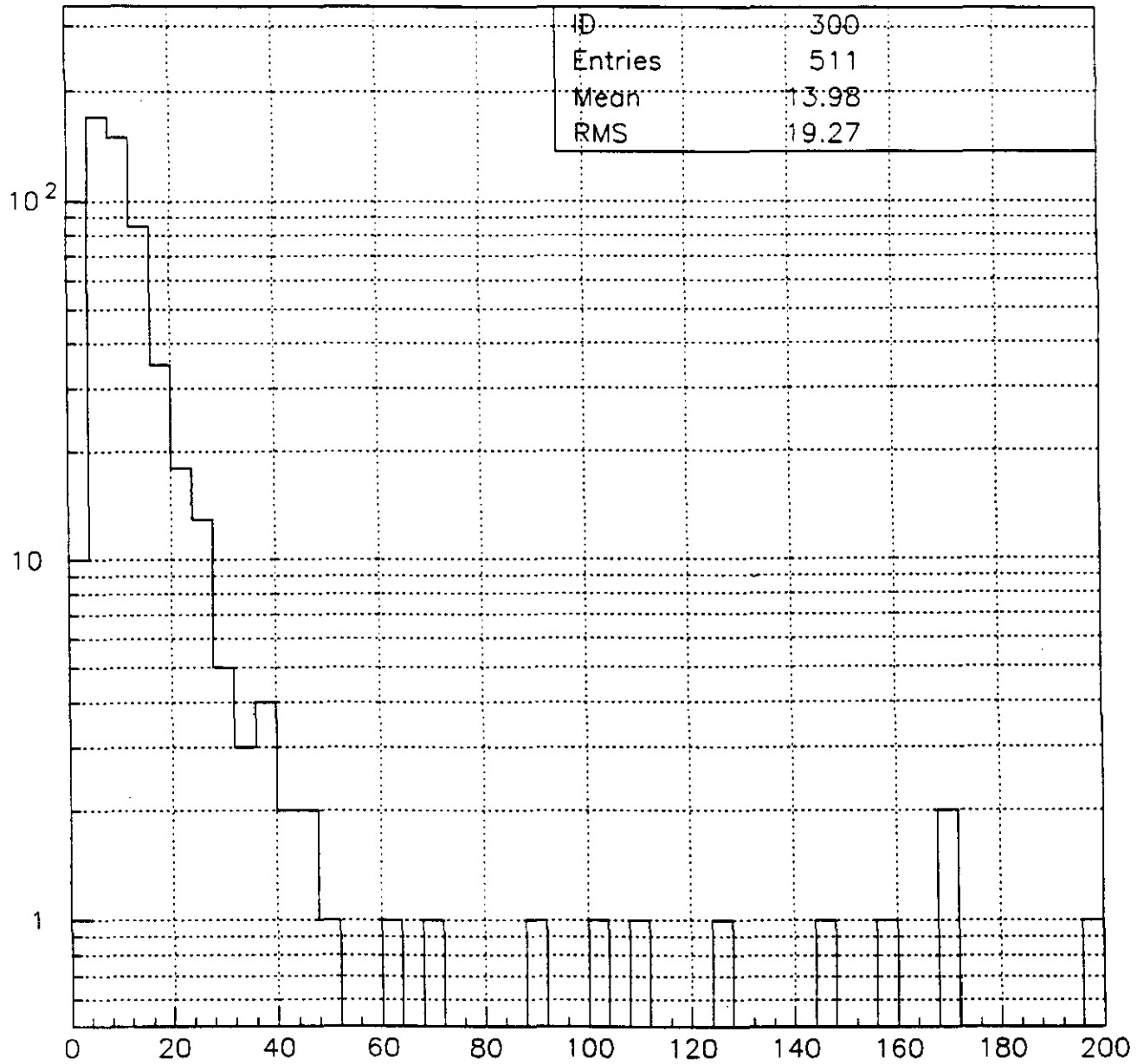
Yu. Efremekno

Yu. Efremenko

O R N L

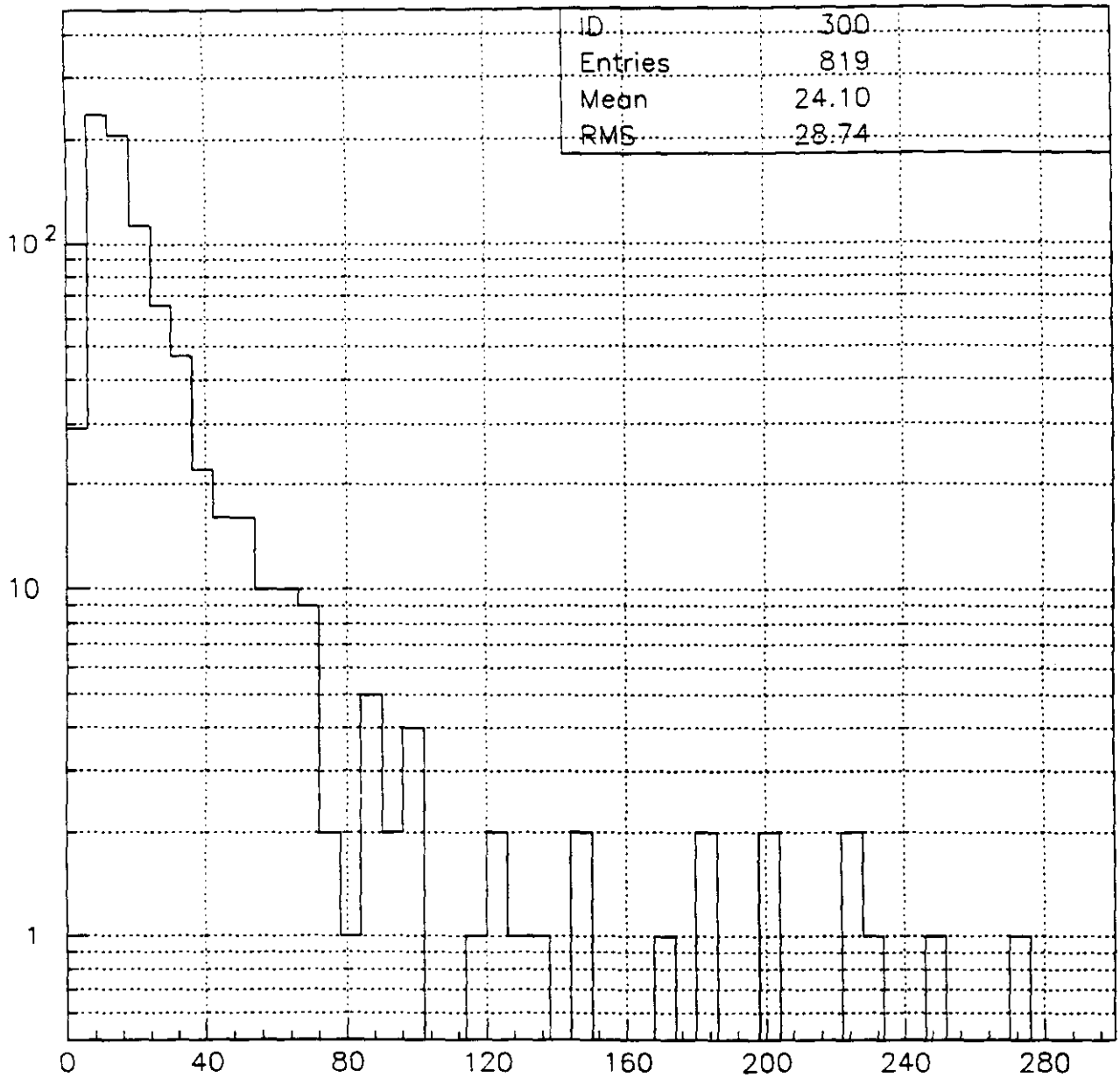
7-8 Jan. Boston

0.5 TeV Muon.



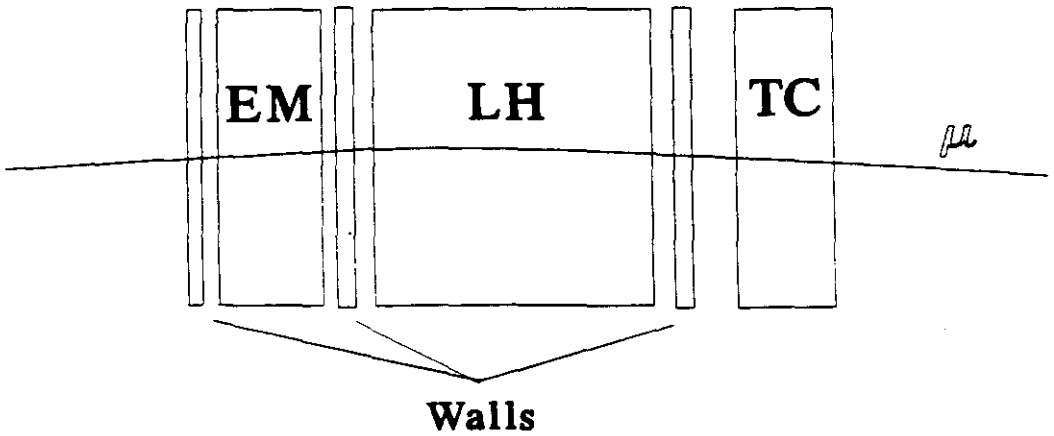
Energy losses in Calorimeter, GeV

1.0 TeV Muon.



Energy losses in Calorimeter, GeV

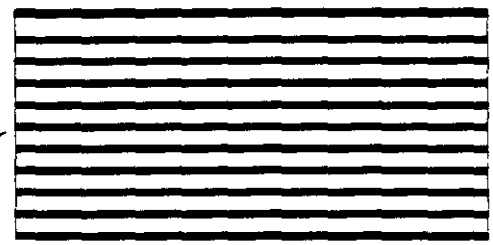
Geant simulation.



Muon Energy 0-200 GeV, 0.5 and 1.0 TeV

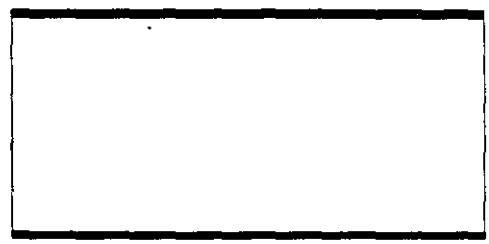
Four TC designs:

1. Fine instrumented.

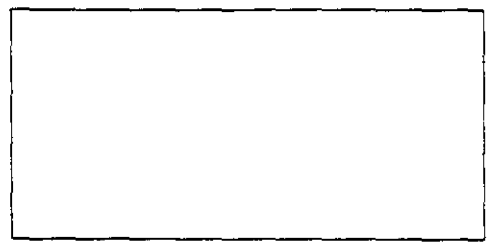


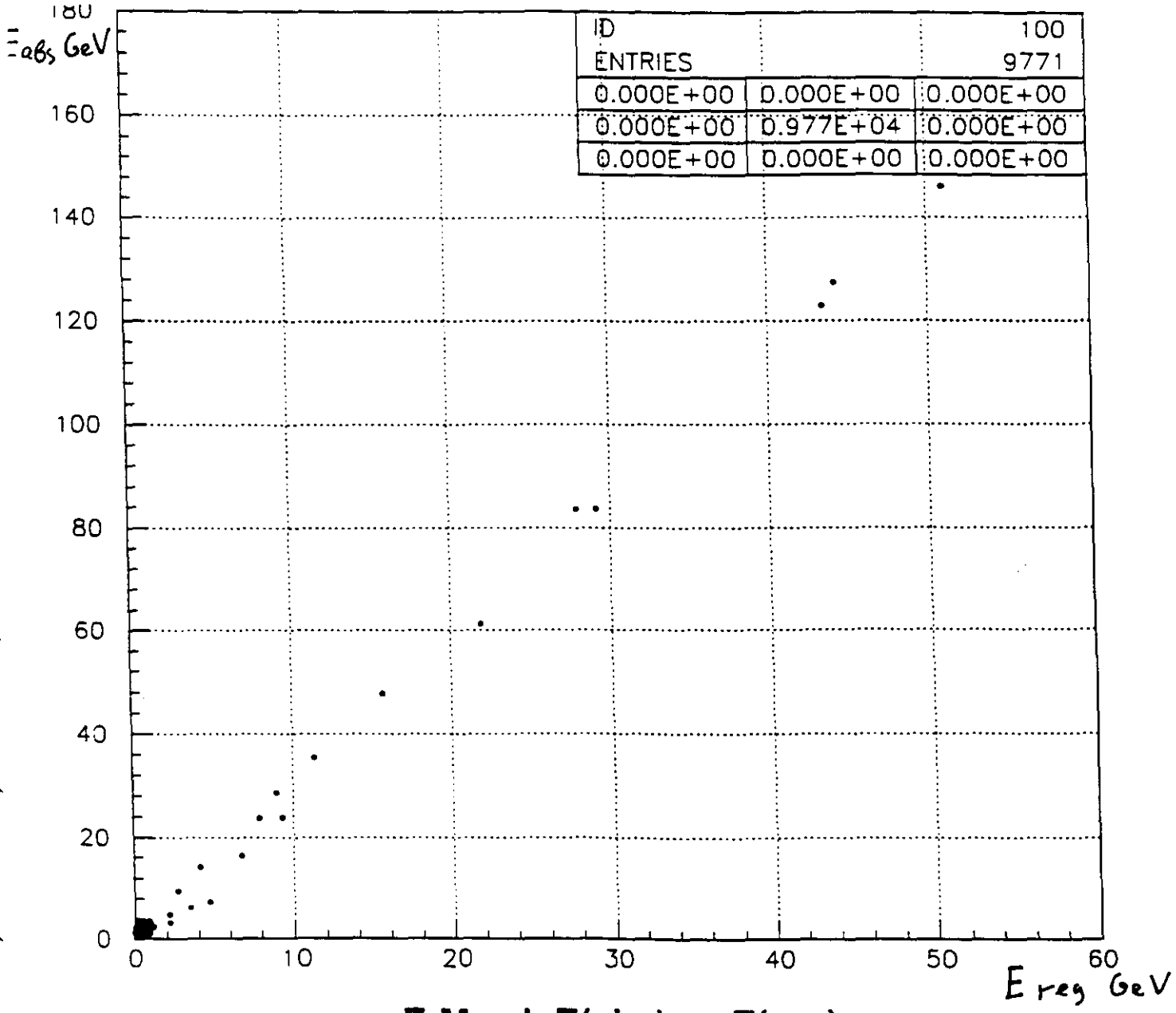
2. Coarse instrumented.

3. Only two scintillator layers.

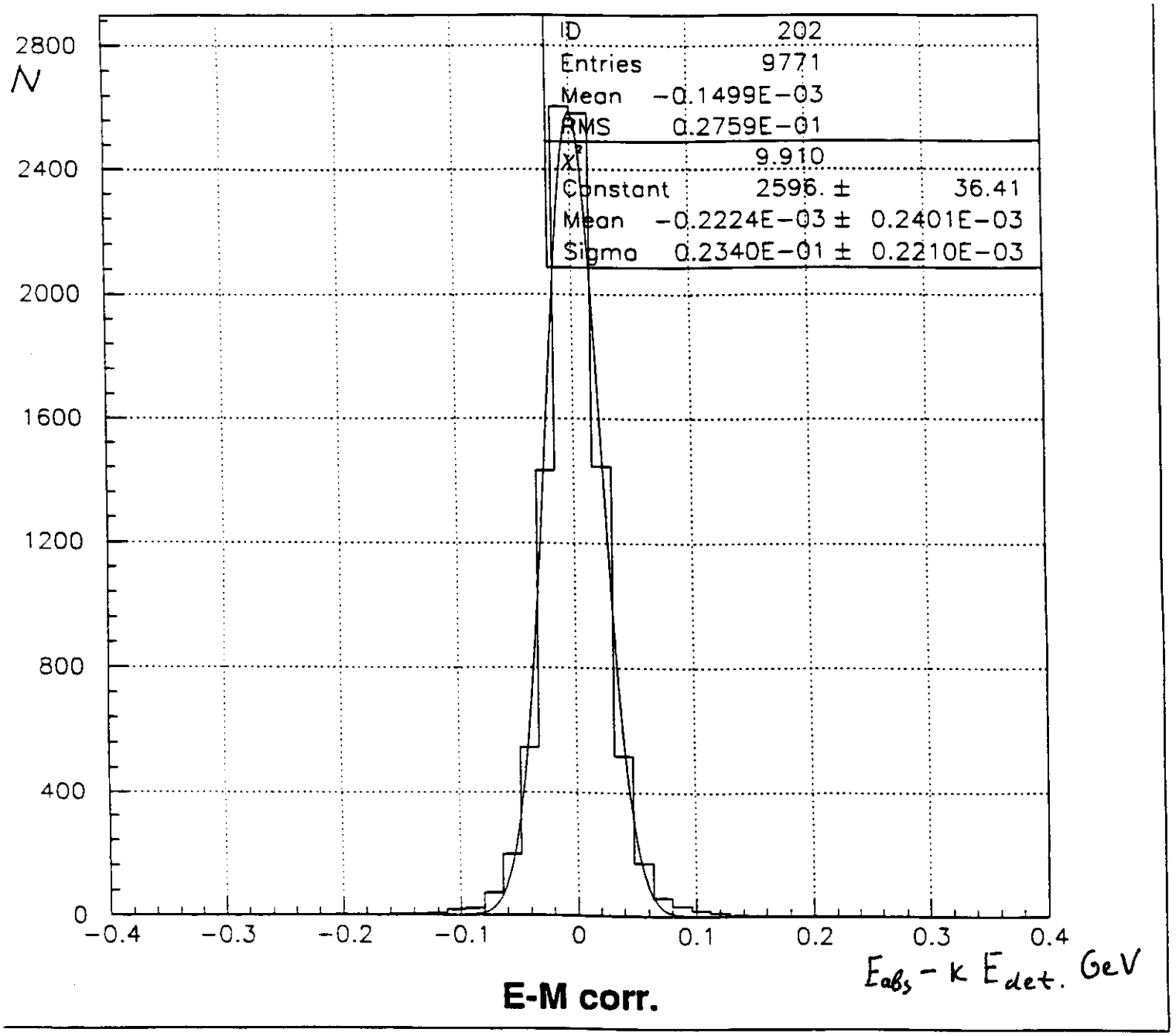


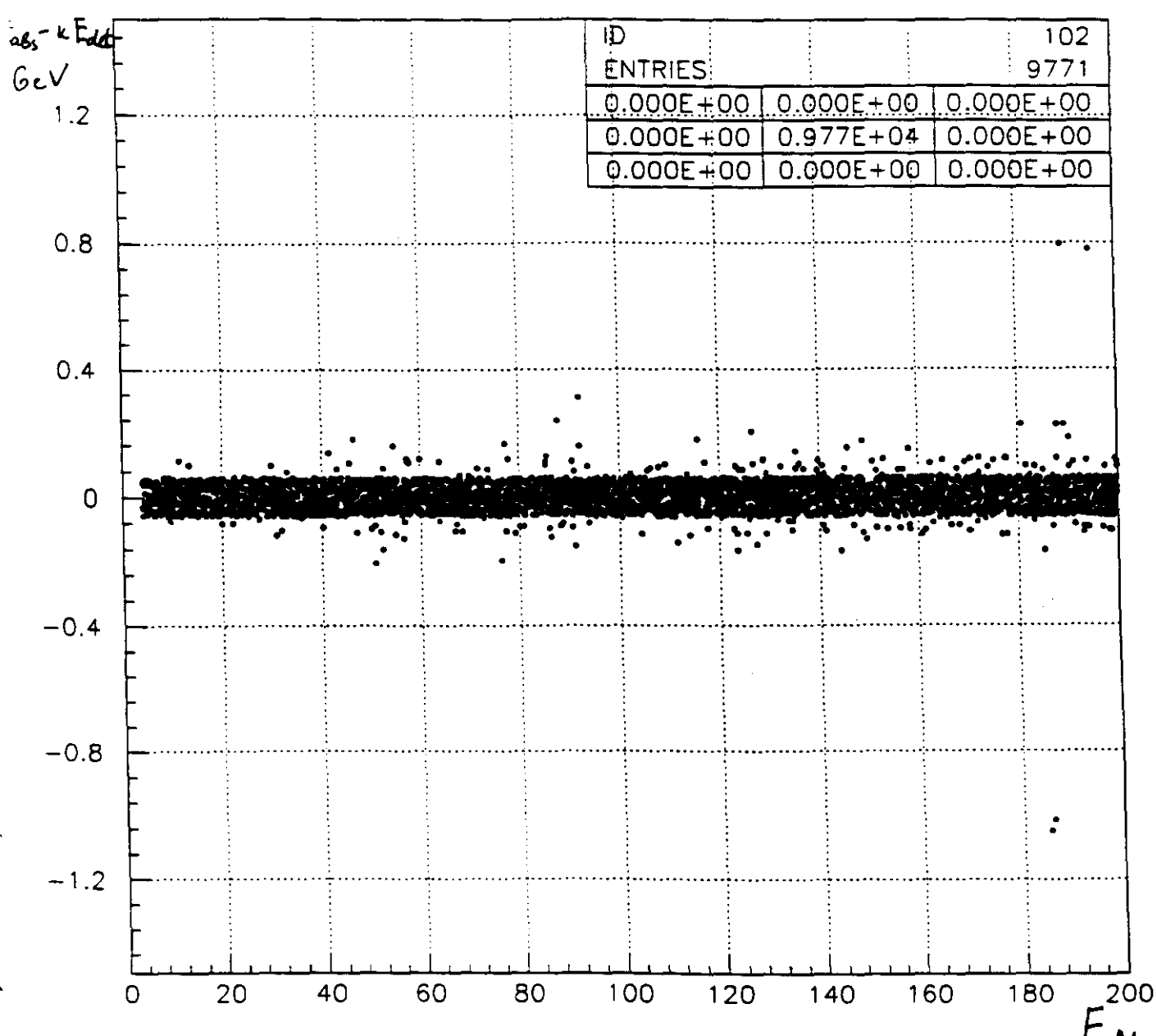
4. Noninstrumented.



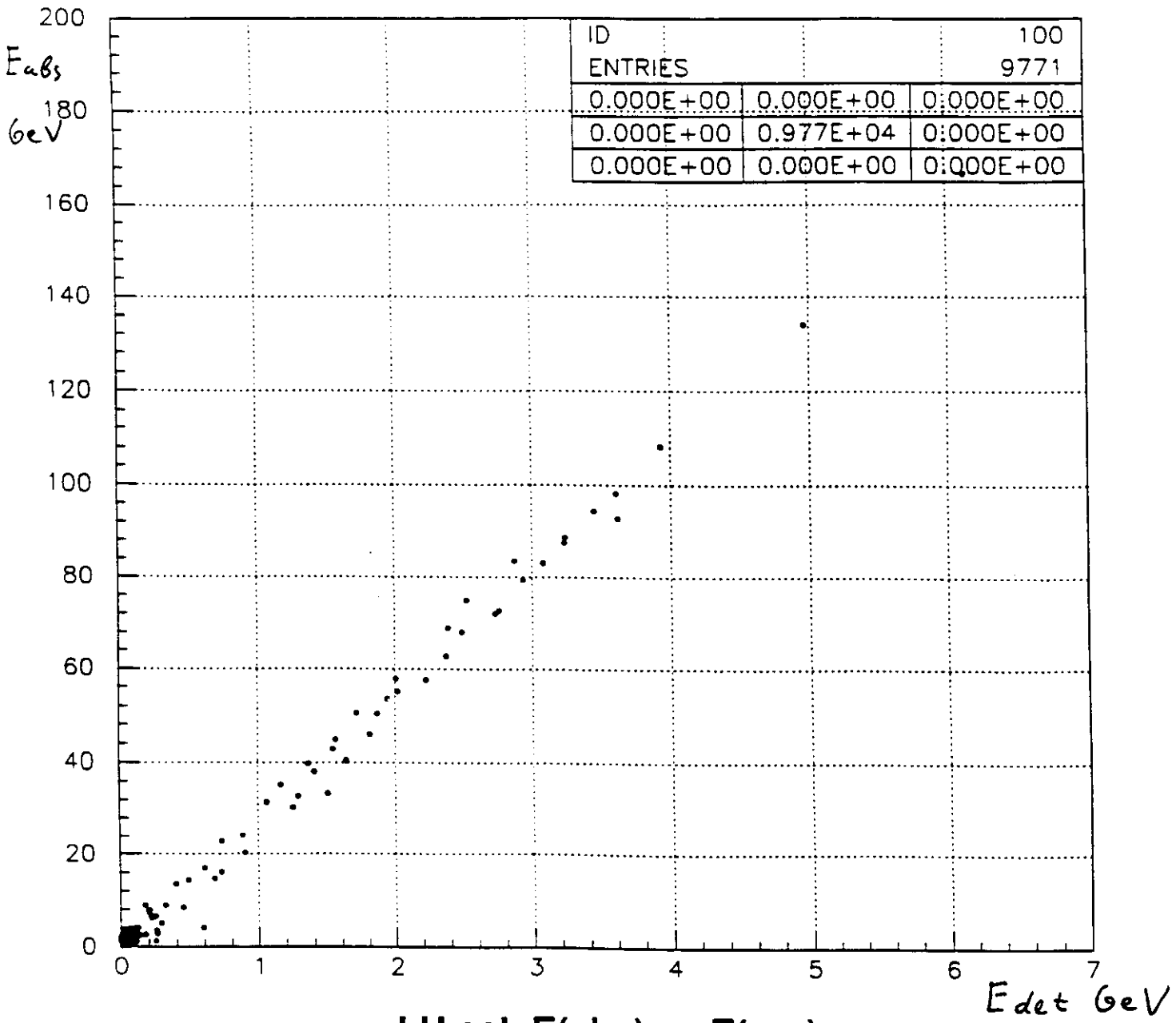


E-M cal, E(abs) vs E(reg)

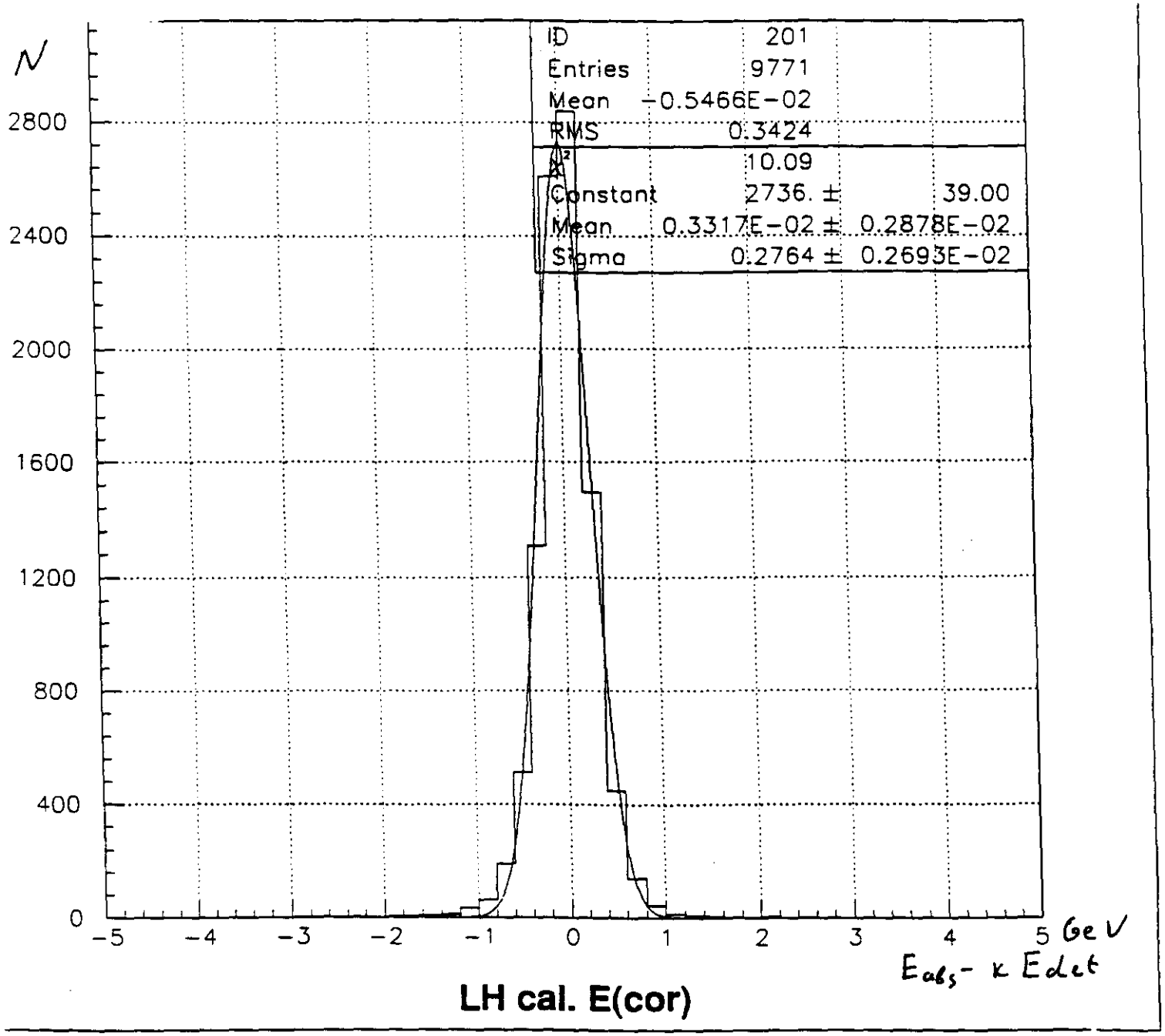

ID 202
Entries 9771
Mean −0.1499E−03
RMS 0.2759E−01
χ² 9.910
Constant 2596. ± 36.41
Mean −0.2224E−03 ± 0.2401E−03
Sigma 0.2340E−01 ± 0.2210E−03
N
2800
2400
2000
1600
1200
800
400
0
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
0.4
$E_{abs} - k\,E_{det.}$ GeV
E-M corr.

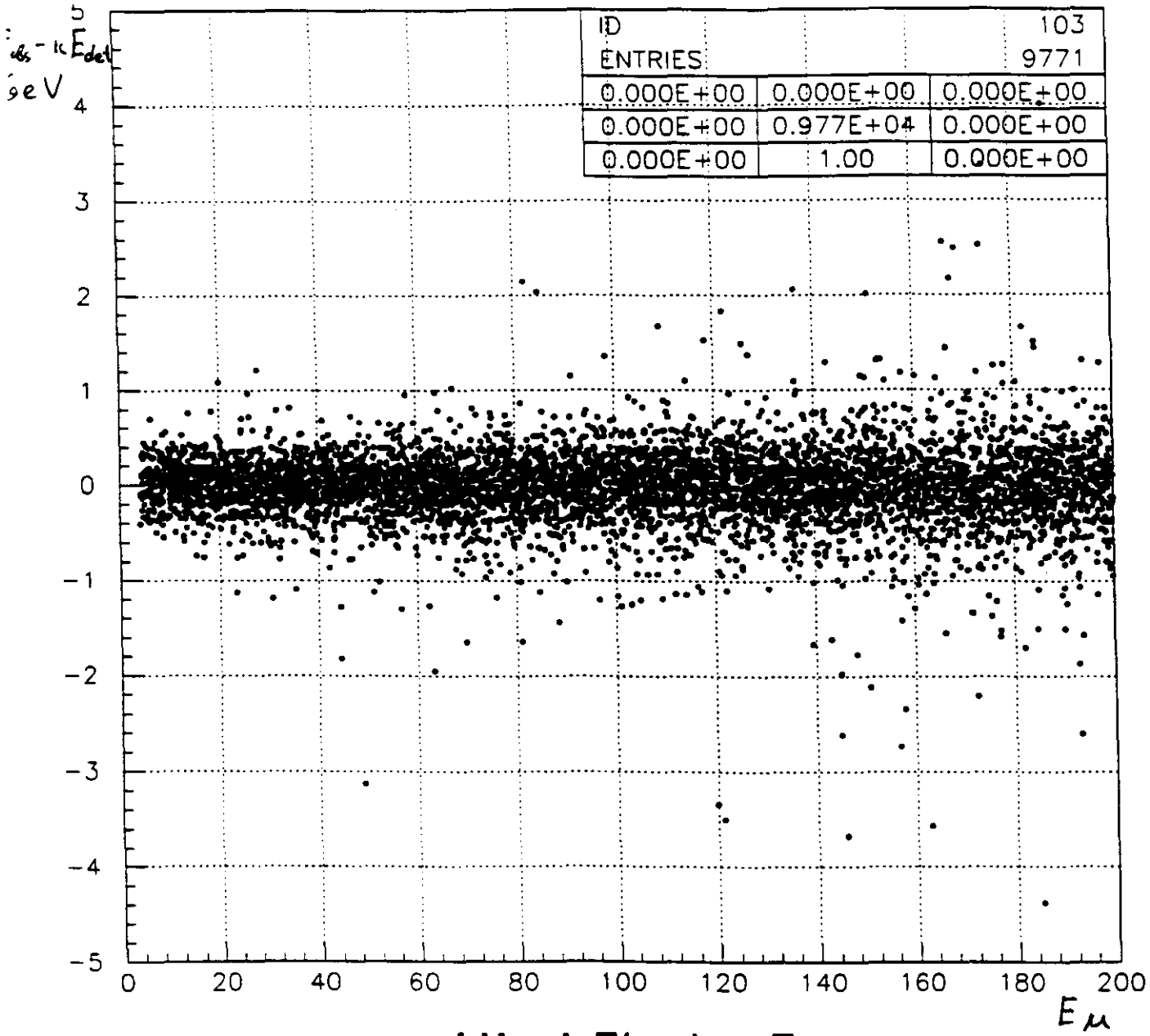


E-M cal, E(corr) vs Energy



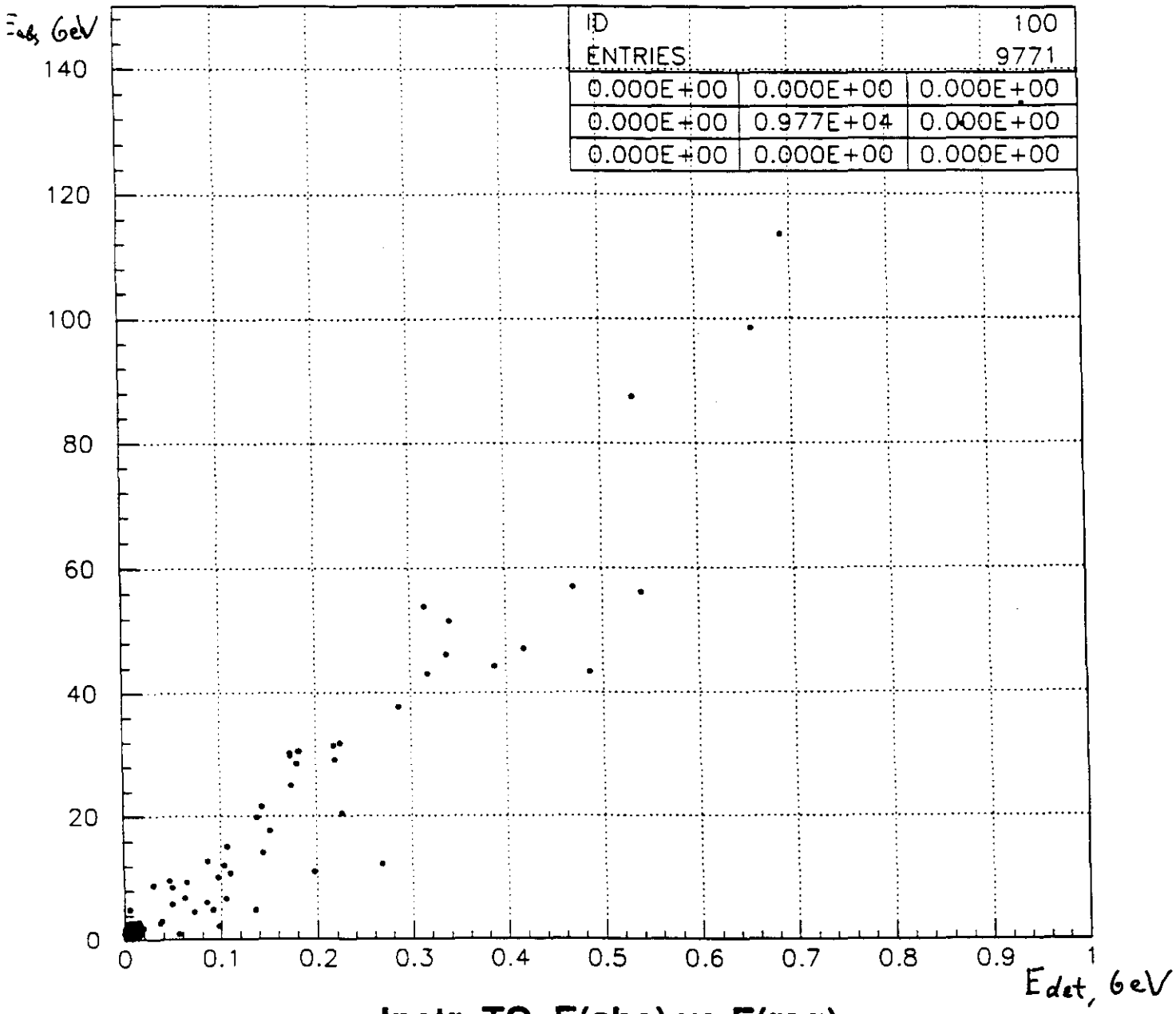
LH cal. E(abs) vs E(reg)


N
ID 201
Entries 9771
Mean −0.5466E−02
RMS 0.3424
χ² 10.09
Constant 2736. ± 39.00
Mean 0.3317E−02 ± 0.2878E−02
Sigma 0.2764 ± 0.2693E−02
2800
2400
2000
1600
1200
800
400
0
−5 −4 −3 −2 −1 0 1 2 3 4 5 GeV
E_abs − k E_det
LH cal. E(cor)



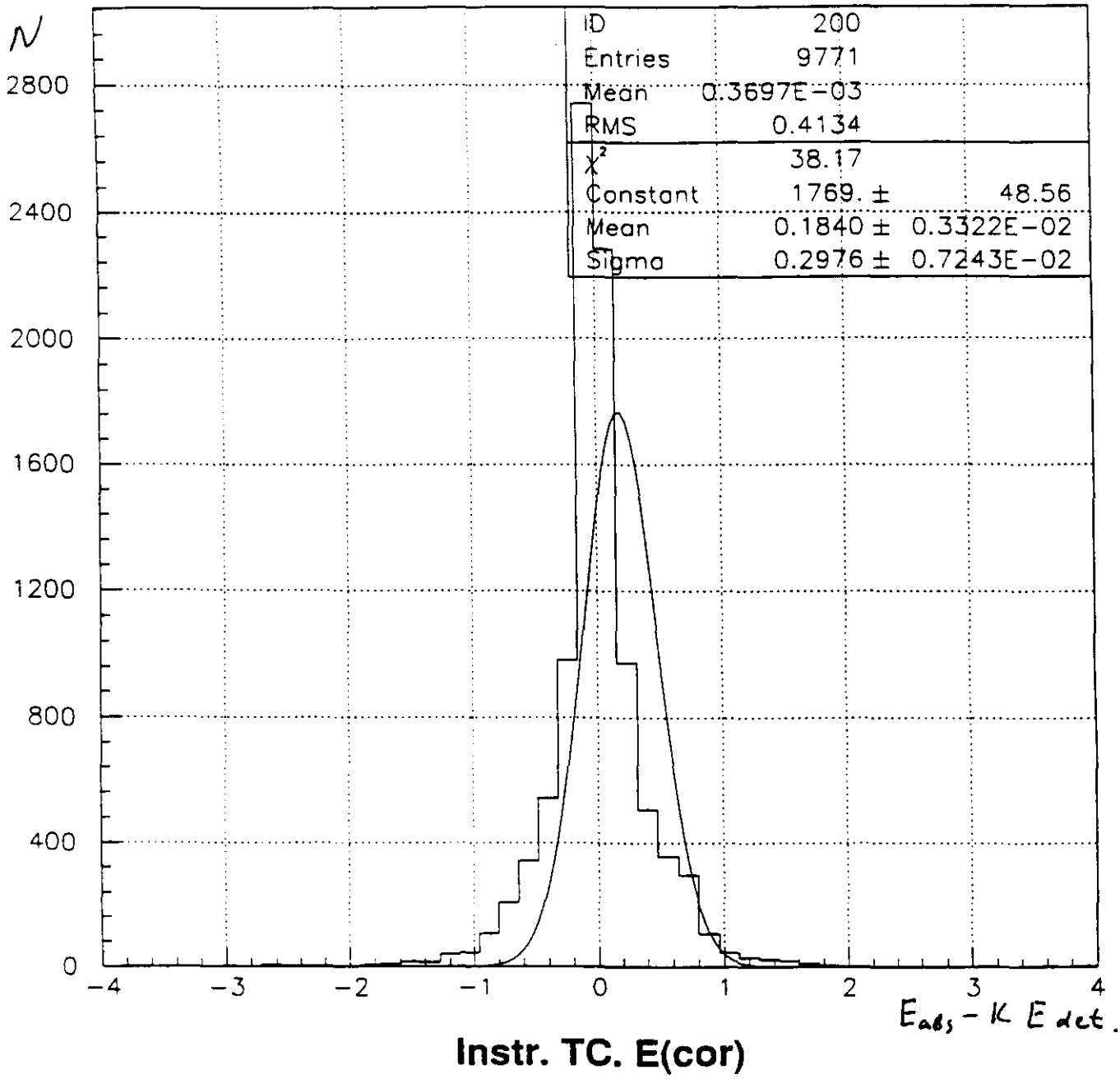
LH cal. E(cor) vs E

Muons in the Tail Catcher



Instr. TC. E(abs) vs E(reg)

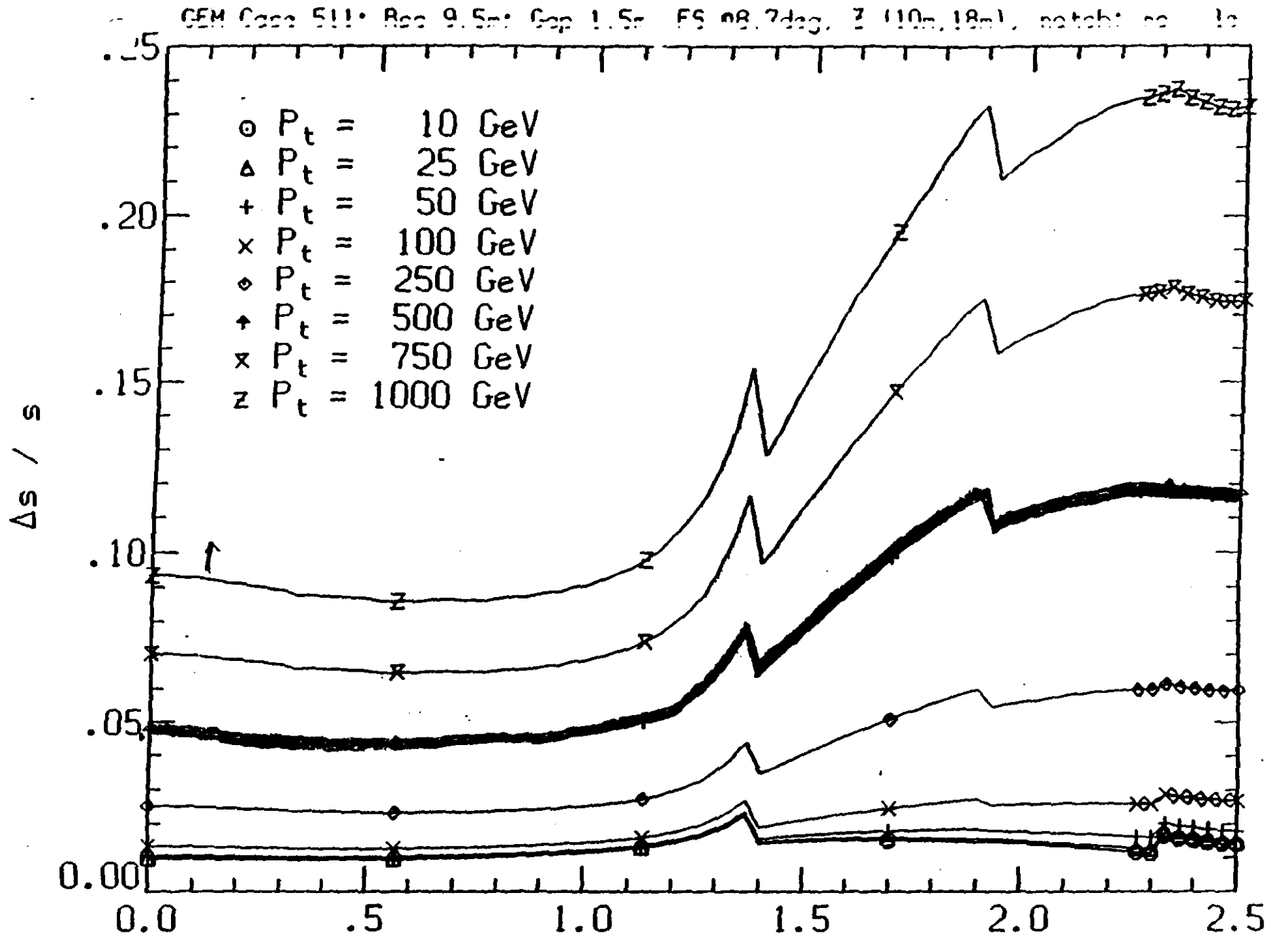
Muons in the Tail Catcher



$$\Delta E_{\mu} = E_{\mu}^{o} - (P_{\mu} + k_1 E_{EM} + k_2 E_H + k_3 E_{TC} + C)$$

1. $\delta P/P = 0.$

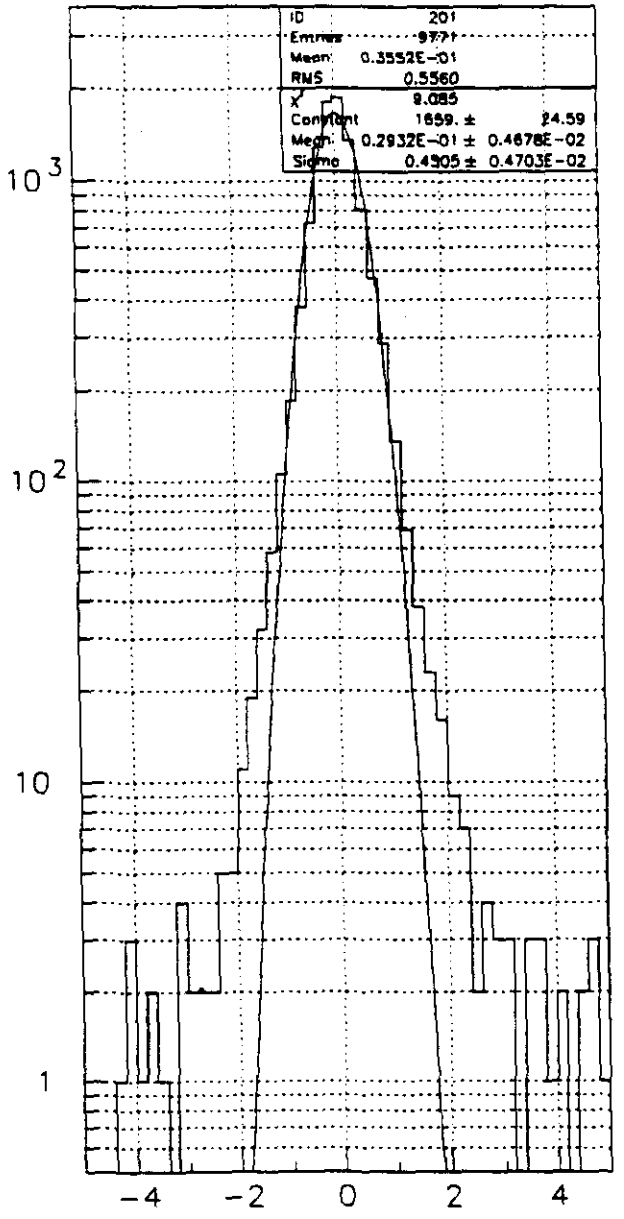
2. $\delta P/P = (0.0095 * P \oplus 1.0)\%$



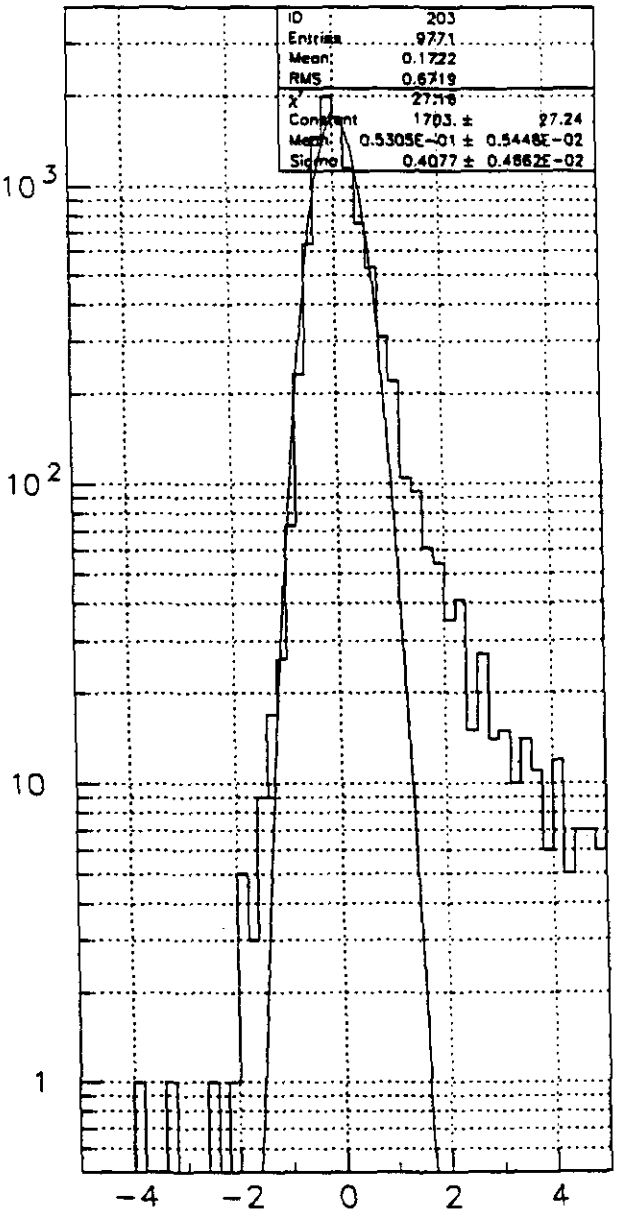
Muon system: 3/23/92 --- 8-8-4 100; Case (3)

$\delta P/P_m = 0.$

Muons in the Tail Catcher



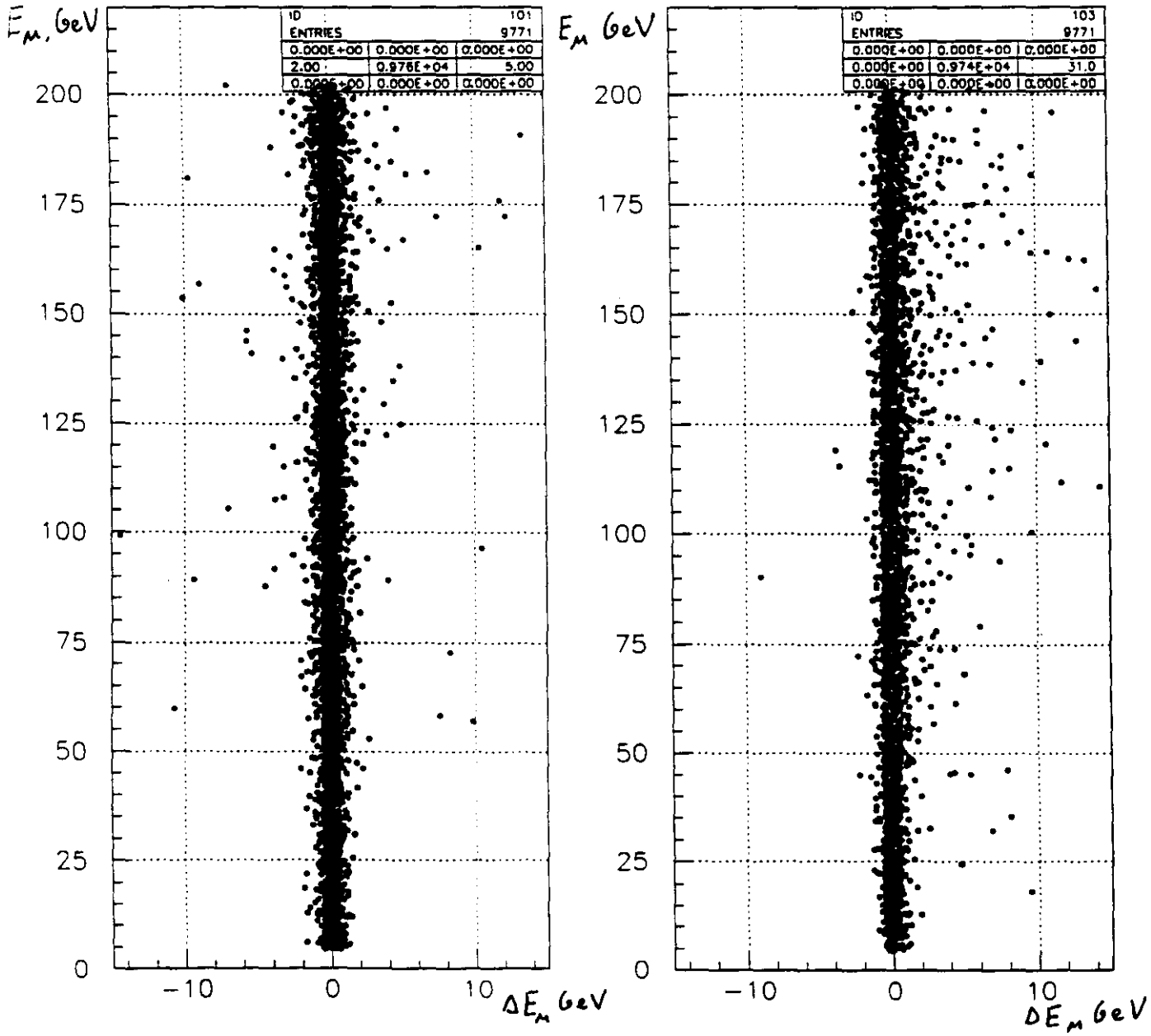
Act TC.



Pass TC.

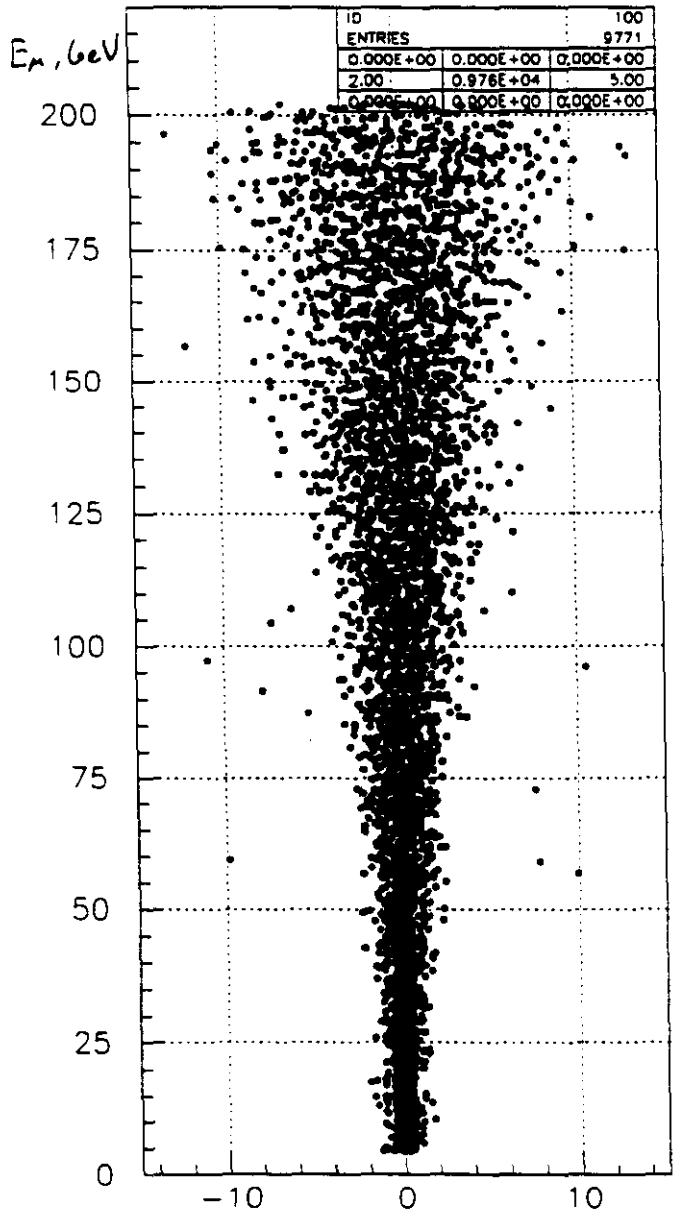
$\Delta P/P_\mu = 0.$

Muons in the Tail Catcher



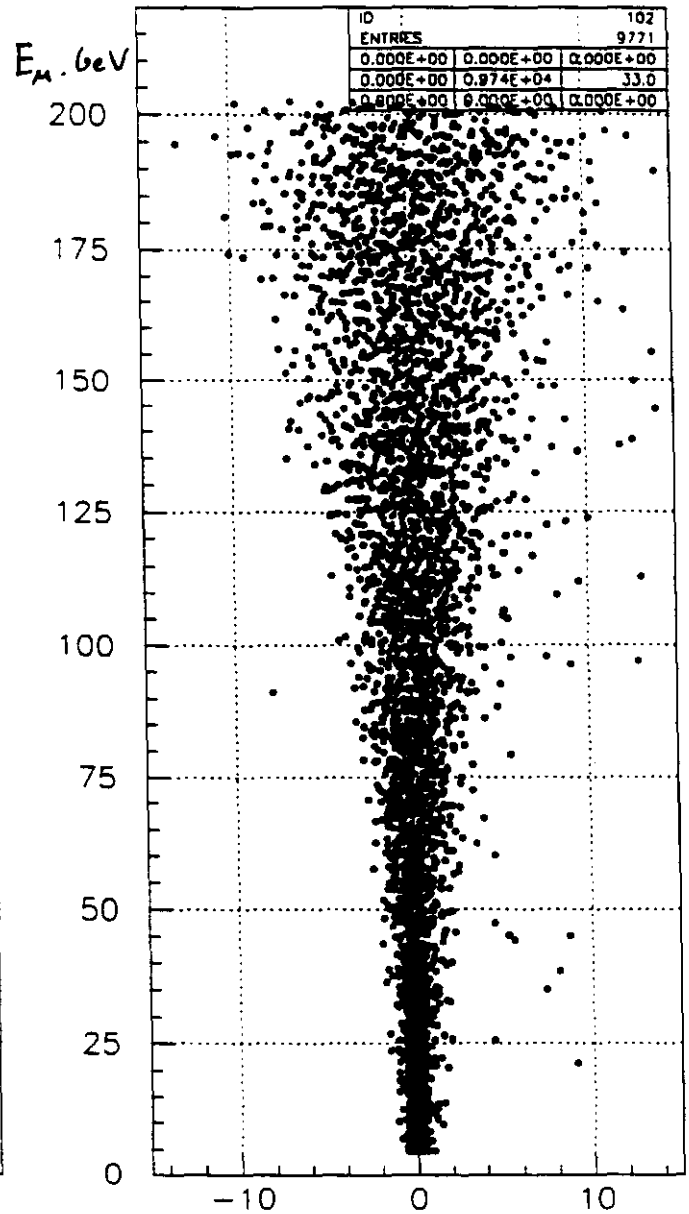
Act TC. **Pass TC.**

Muons in the Tail Catcher



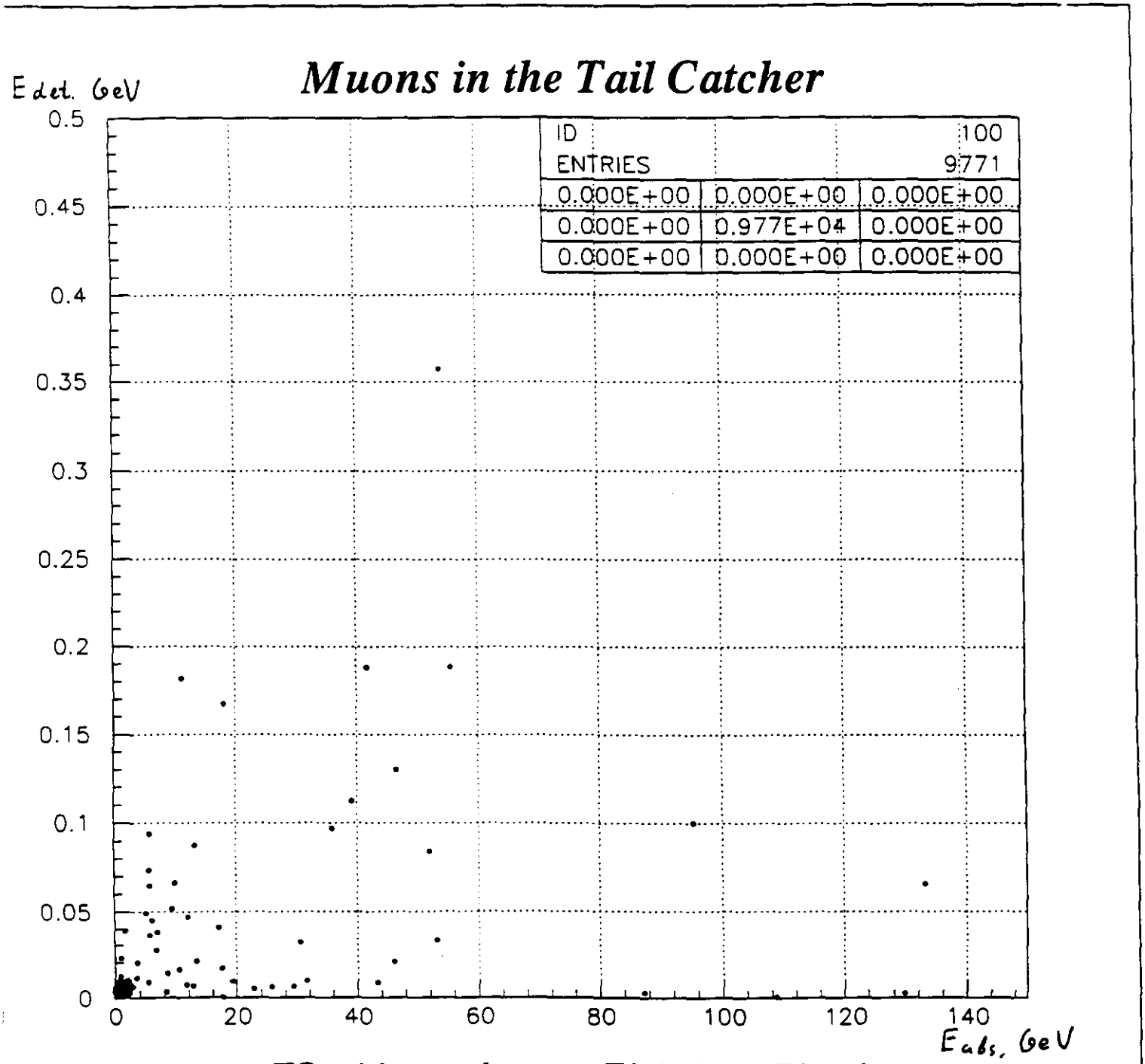
99.5% < 3σ$_\mu$ res

Act TC. 50 < E_μ < 200 GeV



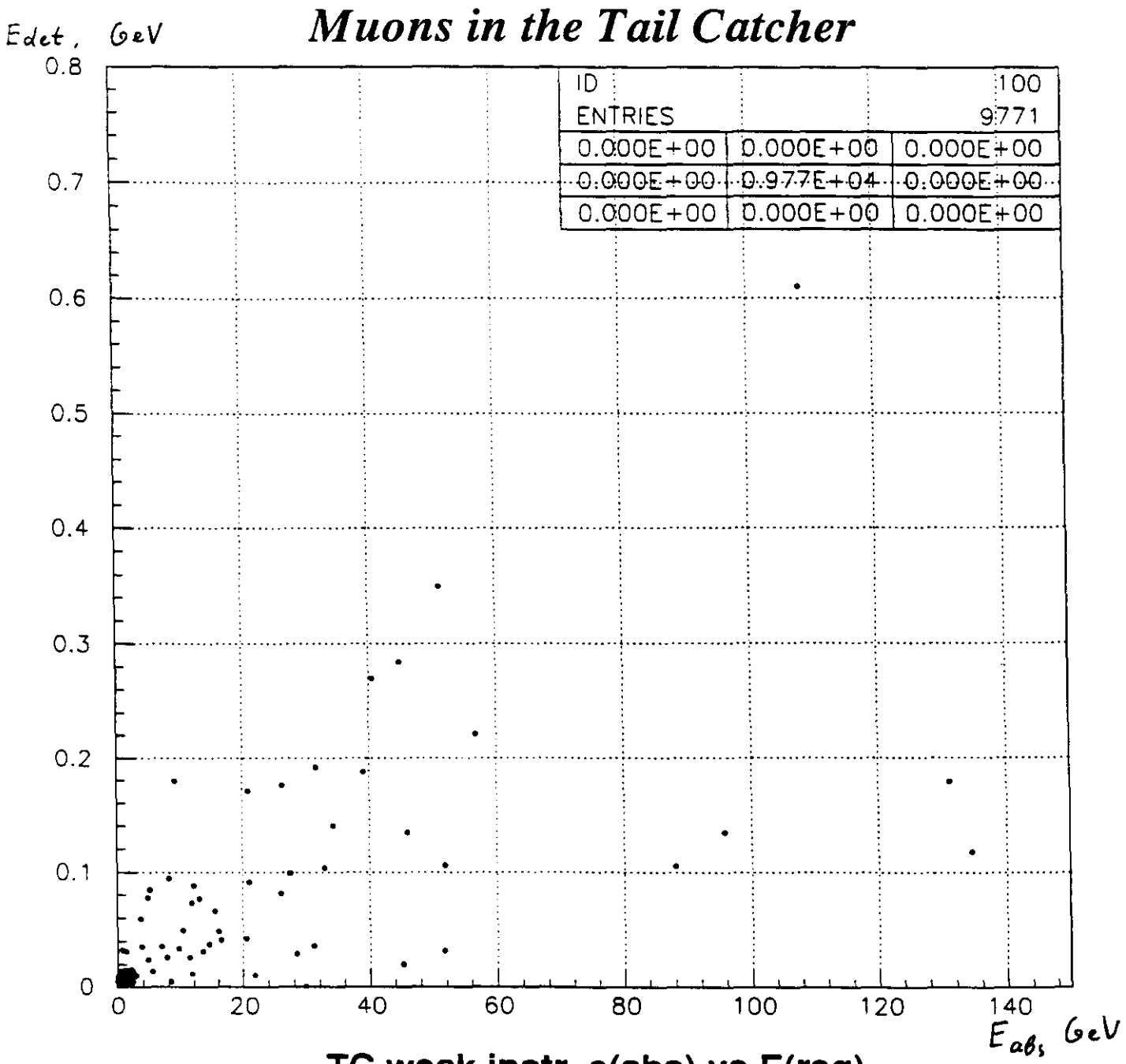
99.1% < 3σ$_\mu$ res.

Pass TC. 50 < E_μ < 200 GeV



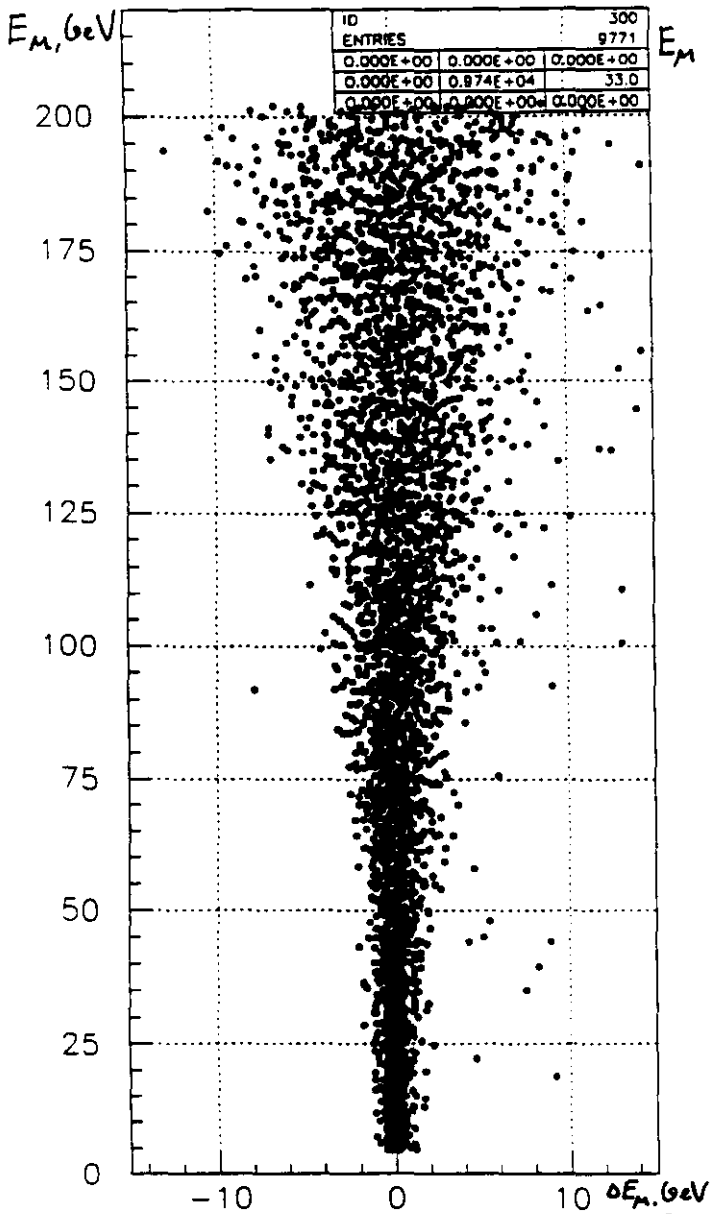
TC with two layers, E(abs) vs E(reg)

Muons in the Tail Catcher



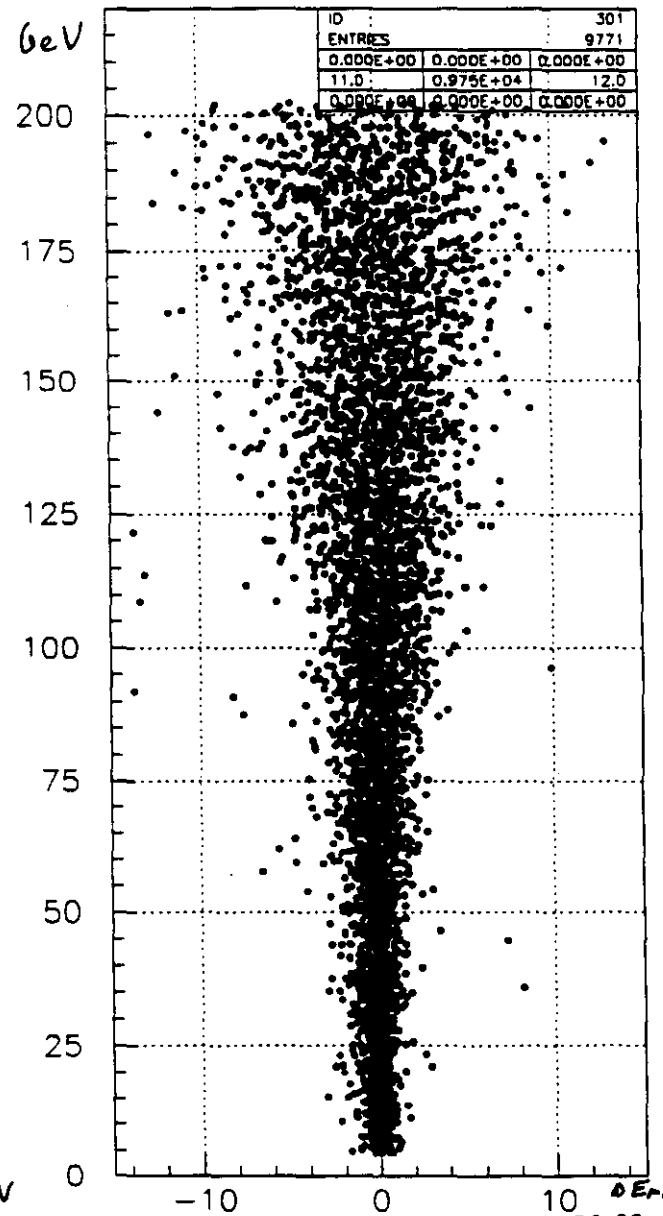
TC weak instr. e(abs) vs E(reg)

Muons in the Tail Catcher



99.1% < $3\sigma_\mu$ res

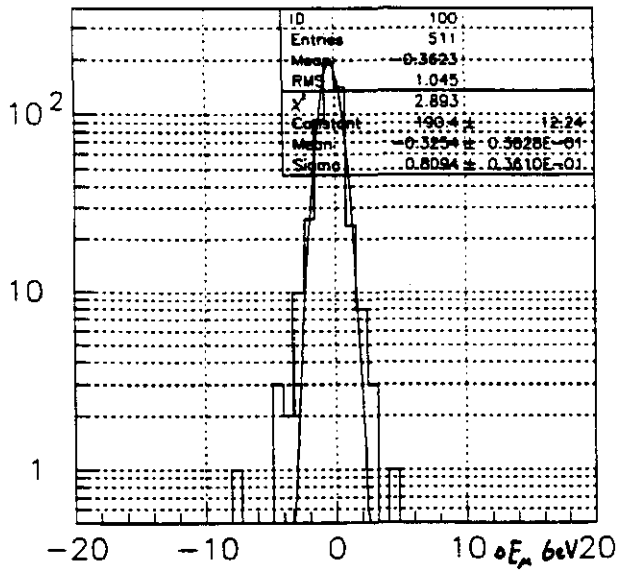
Pass TC $50 < E_\mu < 200$ GeV



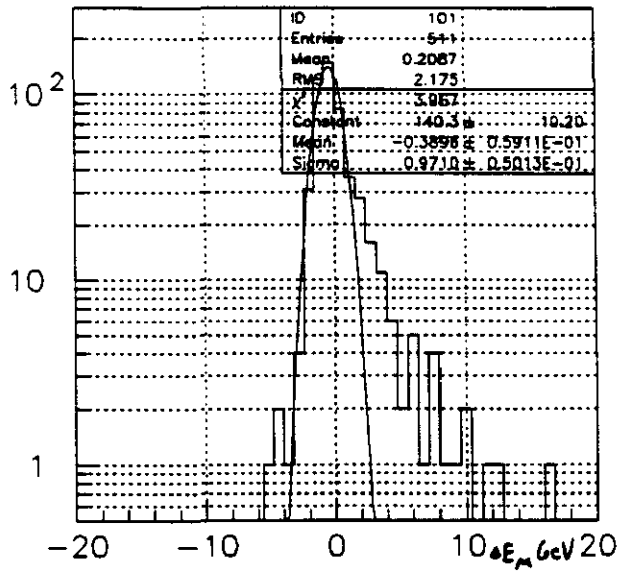
99.2% < $3\sigma_\mu$ res

Weak instr. TC $20 < E_\mu < 200$ GeV

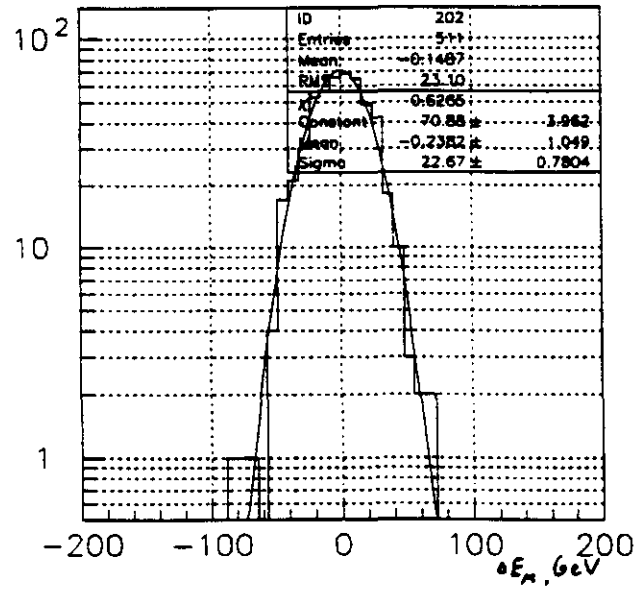
0.5 TeV Muon.



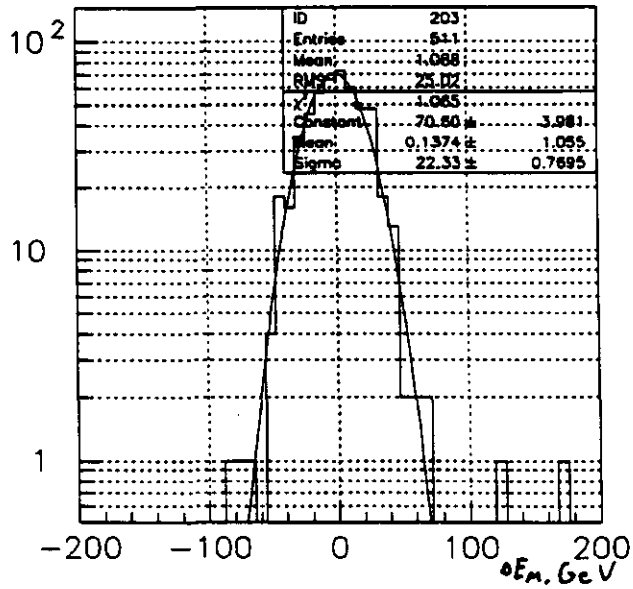
Delta E, GeV. Ideal muon resolution, ins TC



Delta E, GeV. Ideal muon resolution, non ins TC

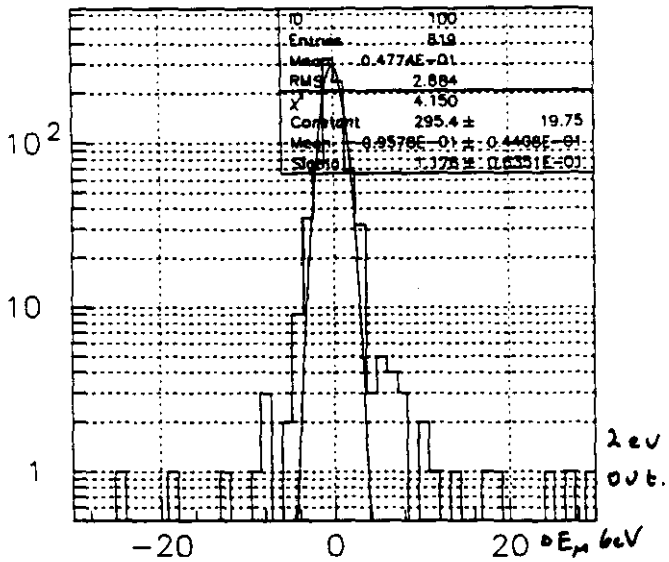


Delta E, GeV. Real muon resolution, ins TC

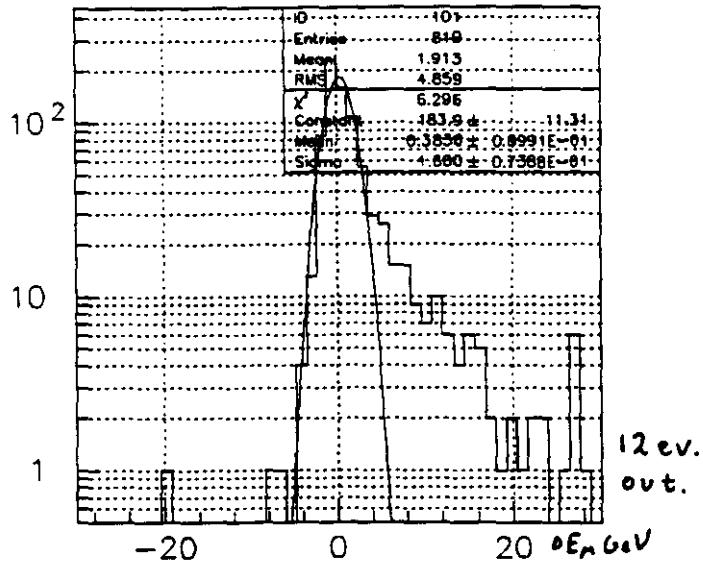


Delta E, GeV. Real muon resolution, non ins TC

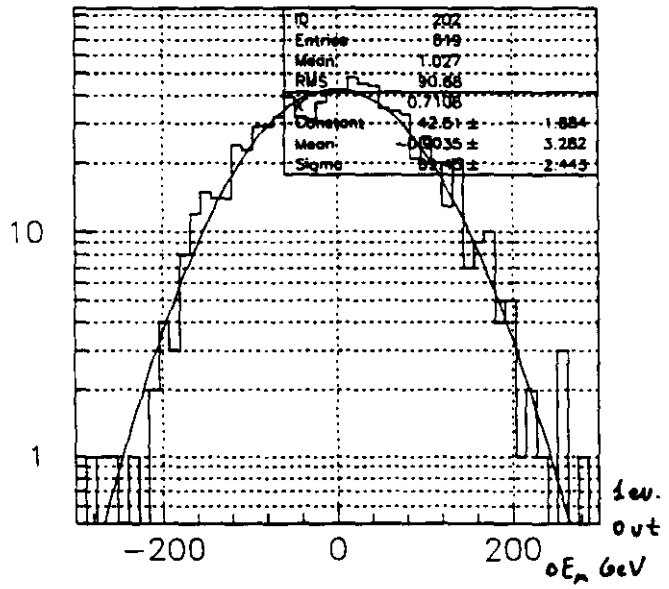
1.0 TeV Muon.



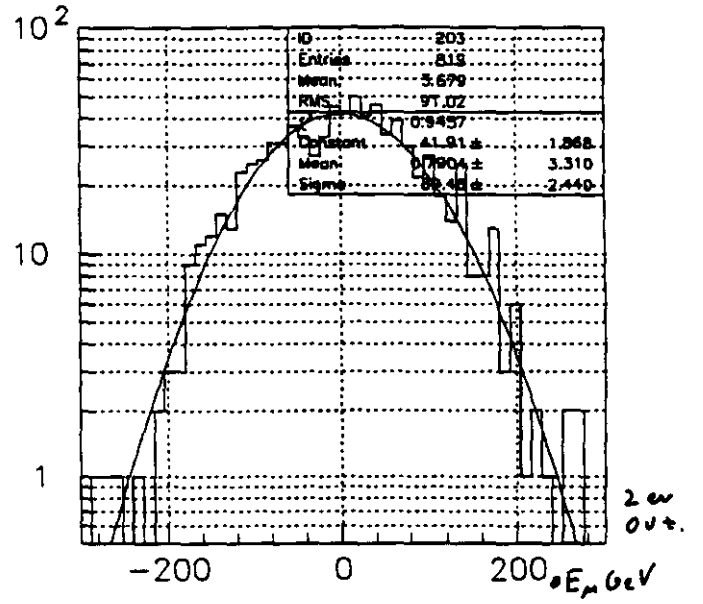
Delta E, GeV. Ideal muon resolution, ins TC



Delta E, GeV. Ideal muon resolution, non ins TC



Delta E, GeV. Real muon resolution, ins TC



Delta E, GeV. Real muon resolution, non ins TC

Fraction of muons losing their energy more than $3\sigma_{\mu}$ system.

Muon Energy	Ins. TC	Nonins. TC
50 - 200 GeV	0.5%	0.9%
500 GeV	0.6%	0.9%
1000 GeV	0.1%	0.2%

Muon Energy Loss in the Hadron Calorimeter and Muon Momentum Resolution

James G. Branson & Hans Peter Paar

September 28, 1992

what happens to the muon momentum resolution if the last three interaction lengths of the calorimeter are not instrumented.

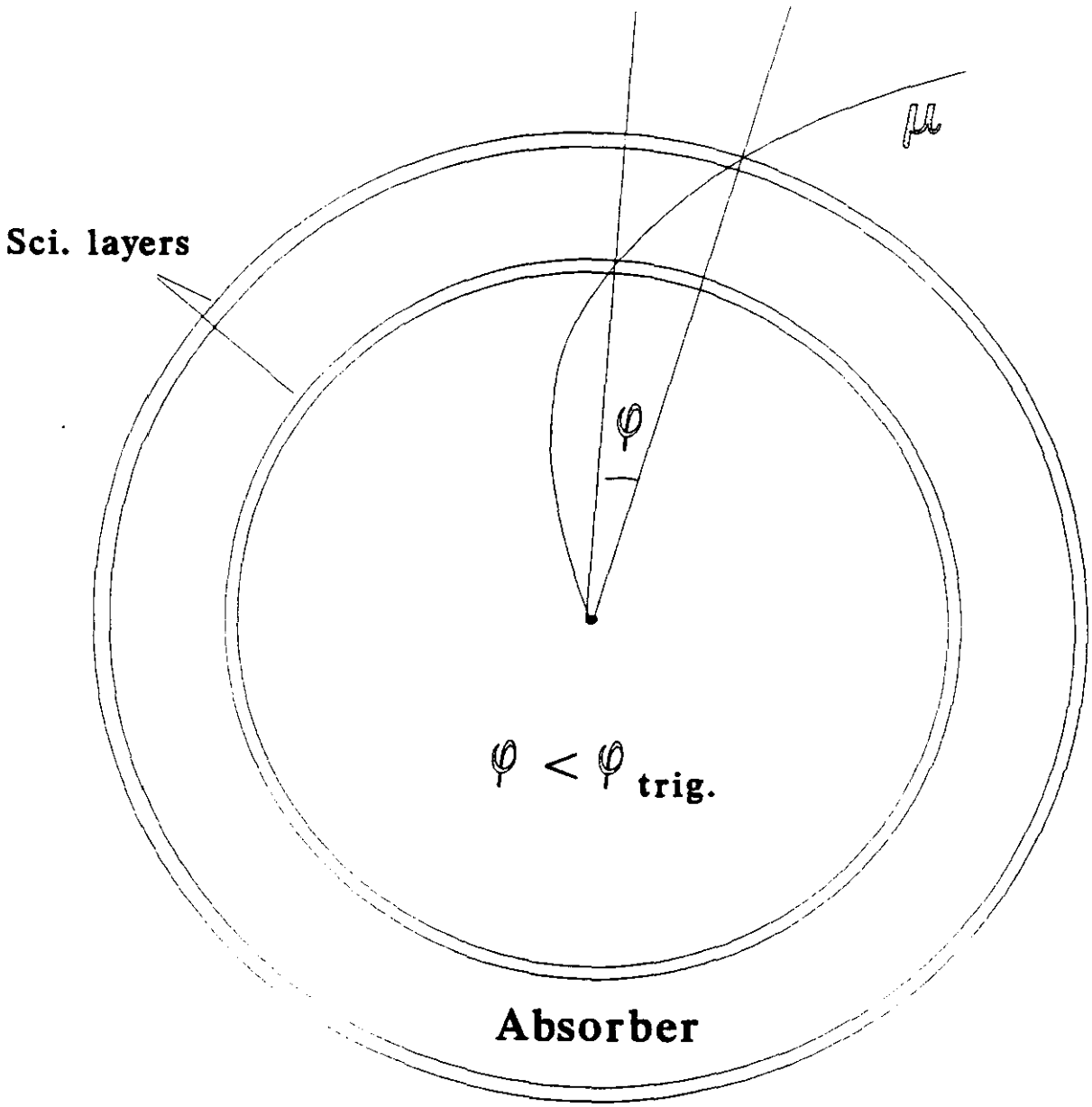
It is seen that the calorimeter resolution has a negligible effect at muon momenta of 500 GeV. In the 100 GeV region a 1.1% effect is seen. This must be added in quadrature to the 1% momentum resolution from the muon spectrometer. It does not seem to matter for the muon momentum resolution whether the last three interaction lengths are read out or not.

Yu. Efremenko

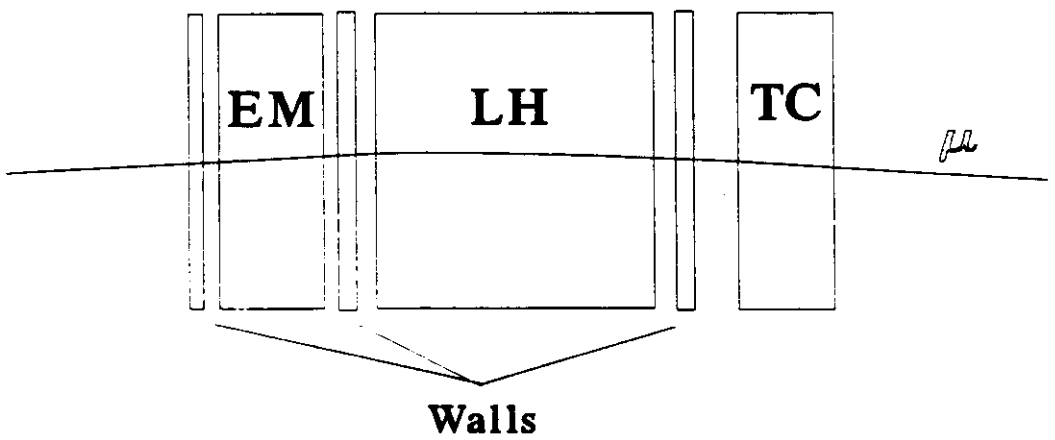
O R N L

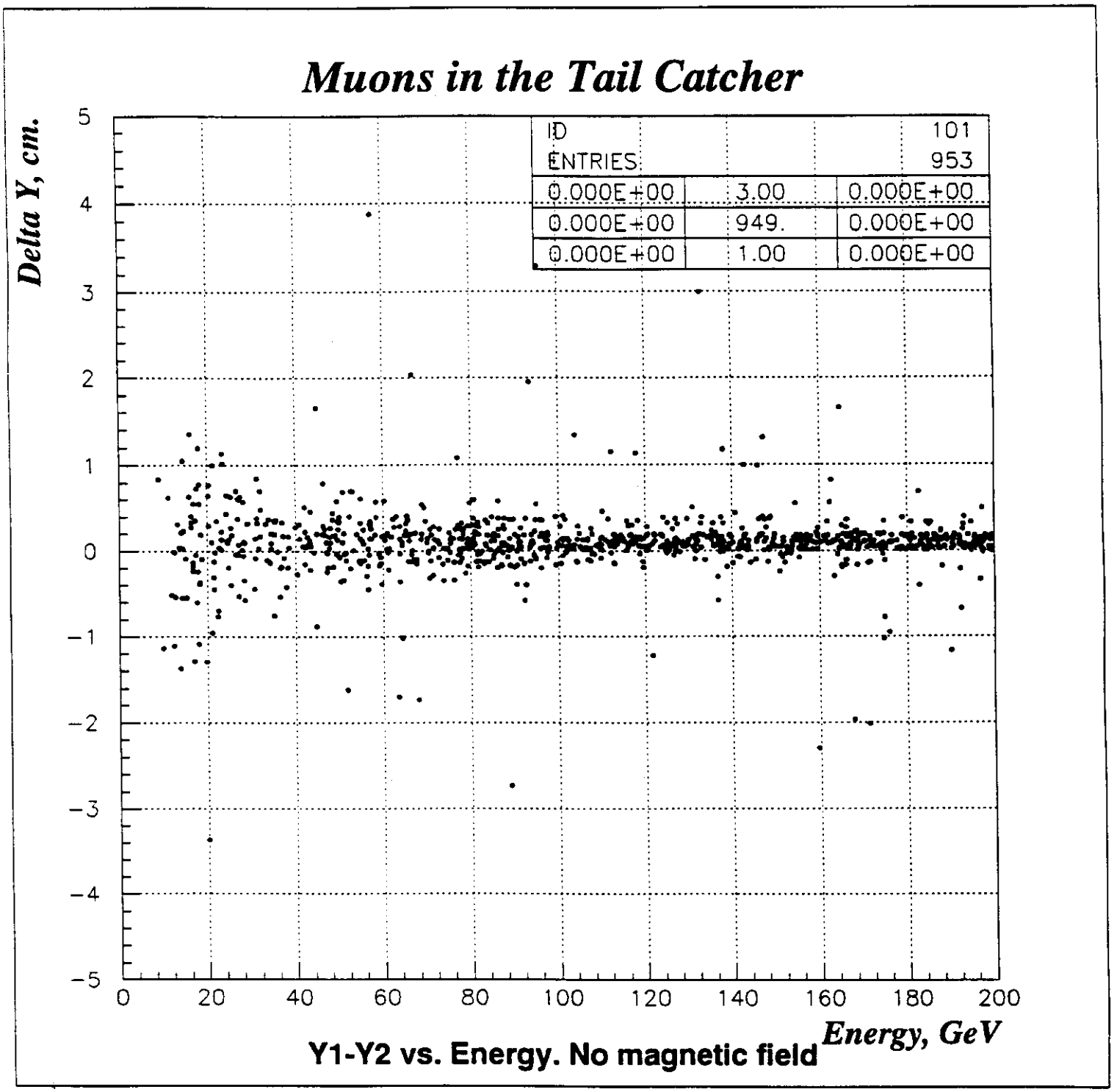
7-8 Jan. Boston

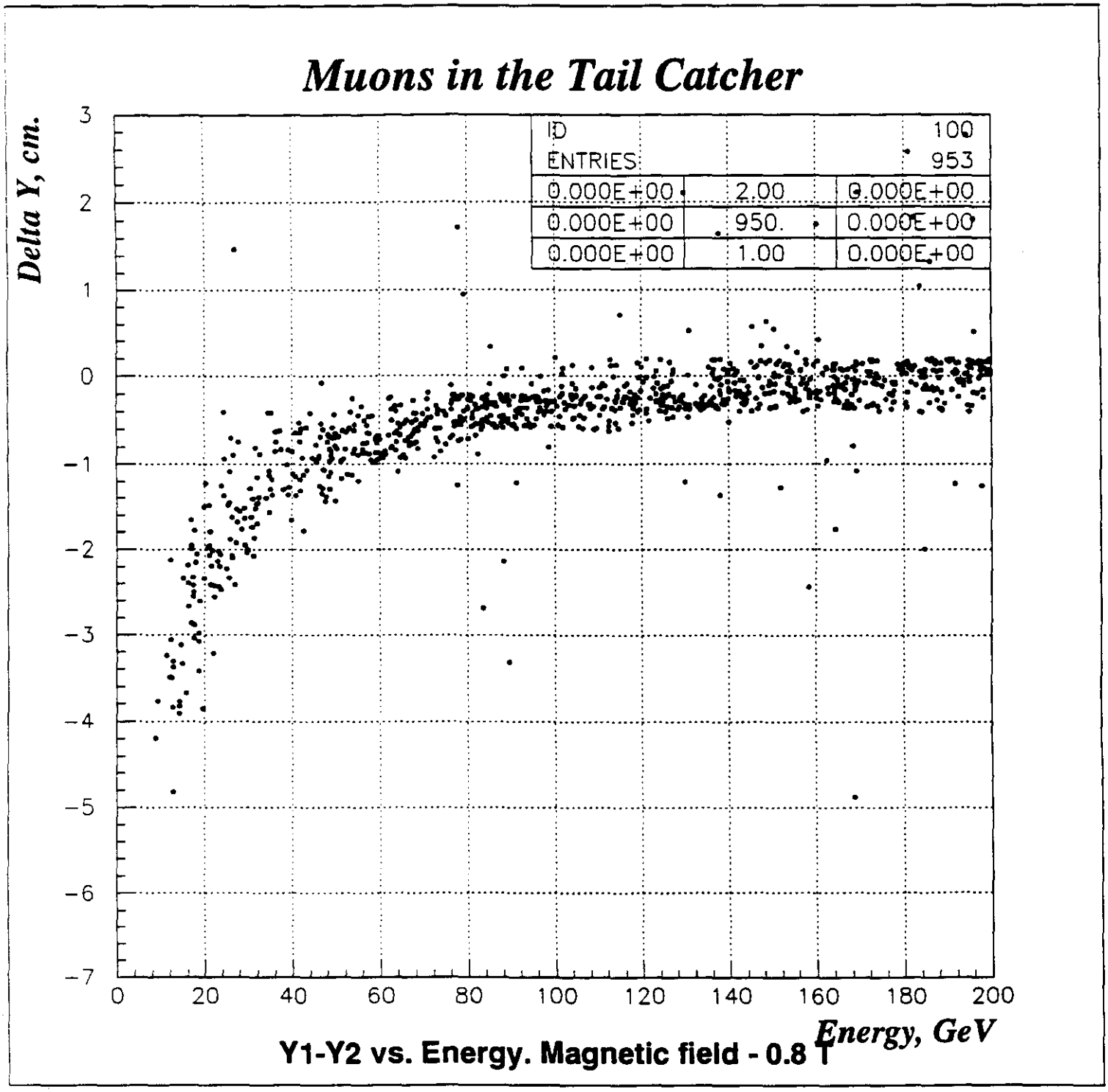
Is it possible to biuld muon trigger based on Tail Catcher information only?



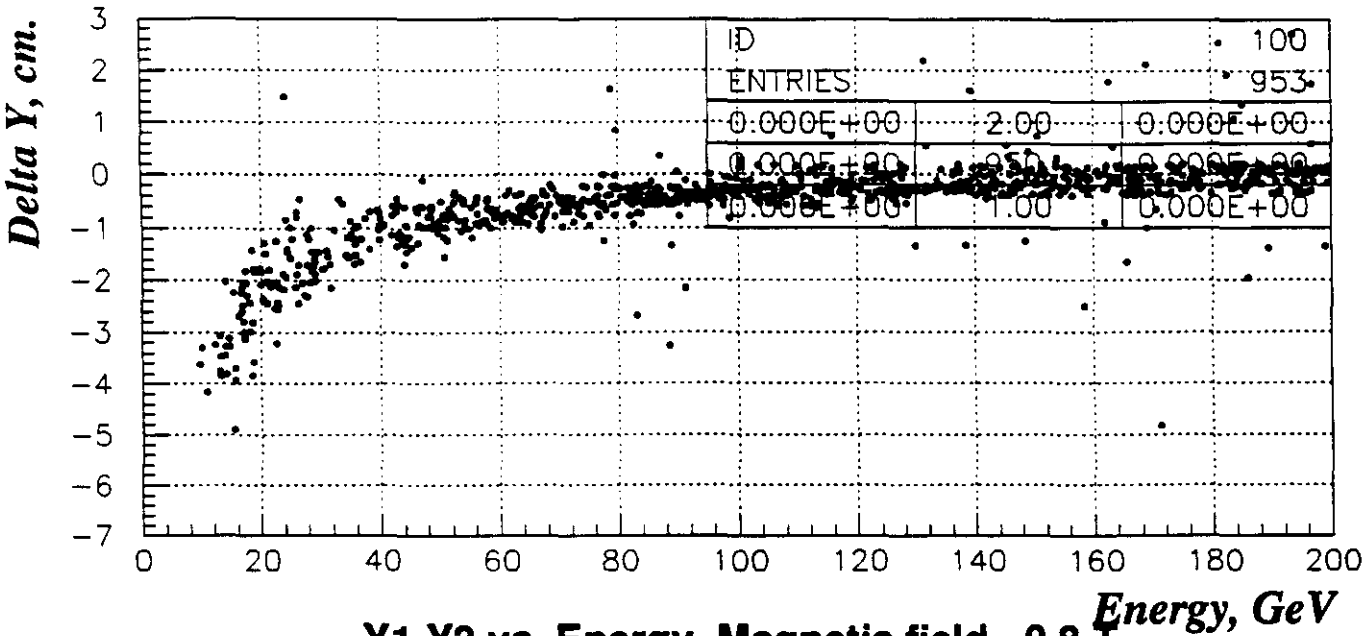
Geant simulation.



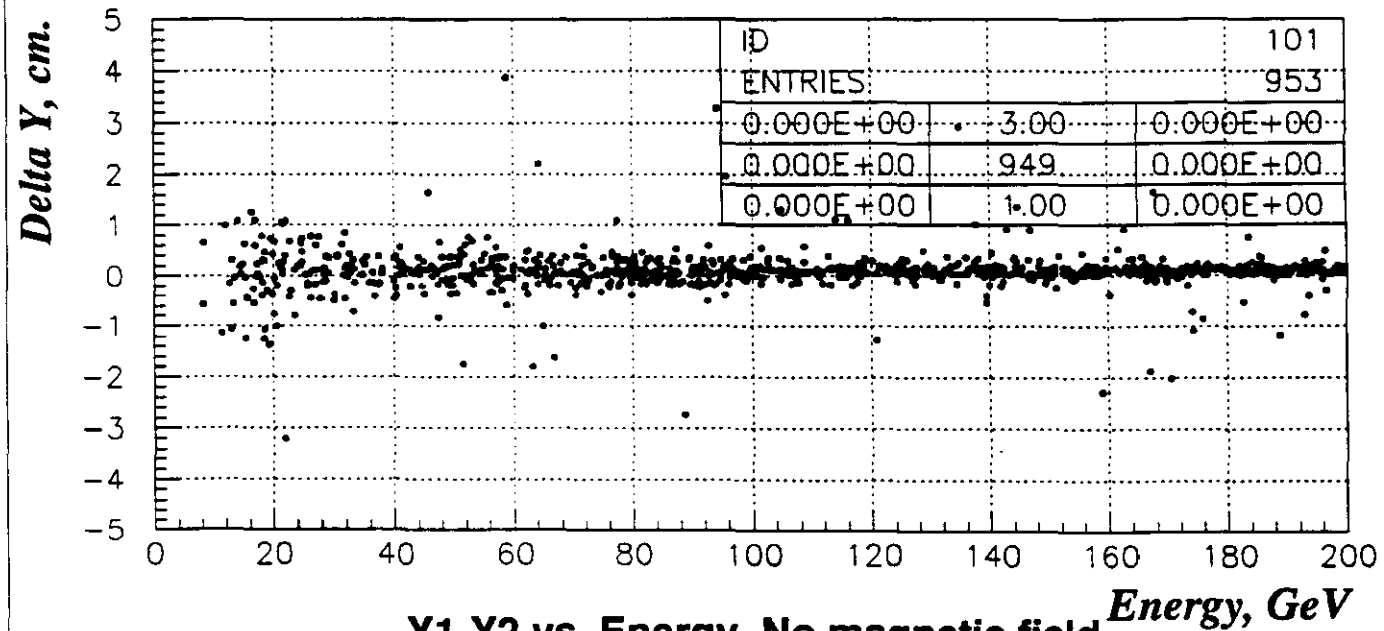

Muons in the Tail Catcher
ID 101
ENTRIES 953
0.000E+00 3.00 0.000E+00
0.000E+00 949. 0.000E+00
0.000E+00 1.00 0.000E+00
Delta Y, cm.
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
20
40
60
80
100
120
140
160
180
200
Energy, GeV
Y1-Y2 vs. Energy. No magnetic field


Muons in the Tail Catcher
Delta Y, cm.
Energy, GeV
ID 100
ENTRIES 953
0.000E+00 2.00 0.000E+00
0.000E+00 950. 0.000E+00
0.000E+00 1.00 0.000E+00
3
2
1
0
−1
−2
−3
−4
−5
−6
−7
0
20
40
60
80
100
120
140
160
180
200
Y1-Y2 vs. Energy. Magnetic field - 0.8 T

Muons in the Tail Catcher

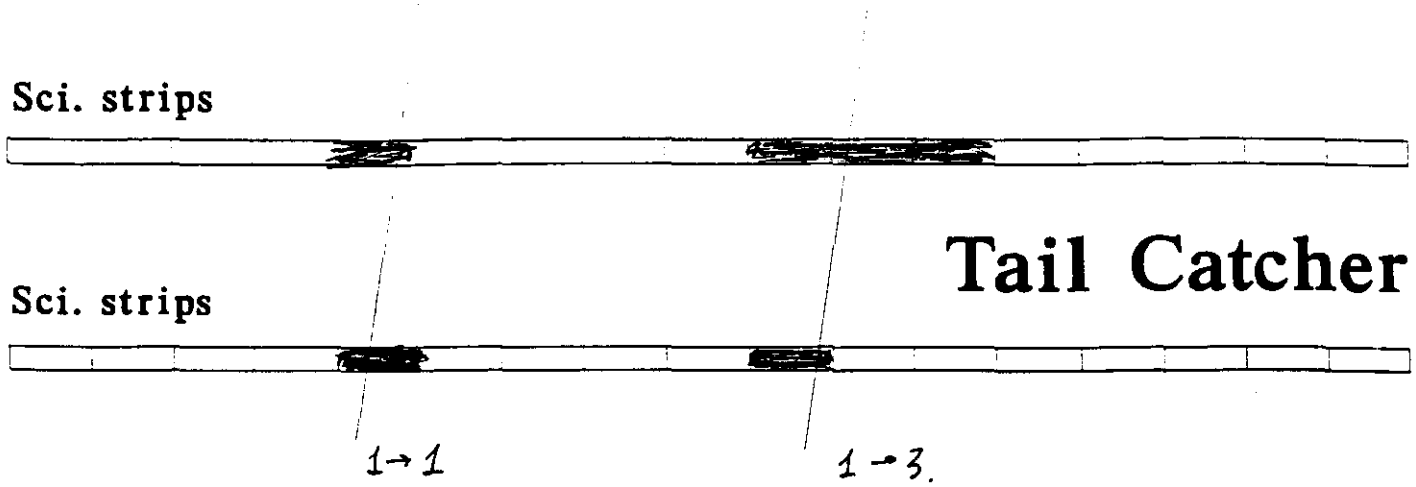


Y1-Y2 vs. Energy. Magnetic field - 0.8 T

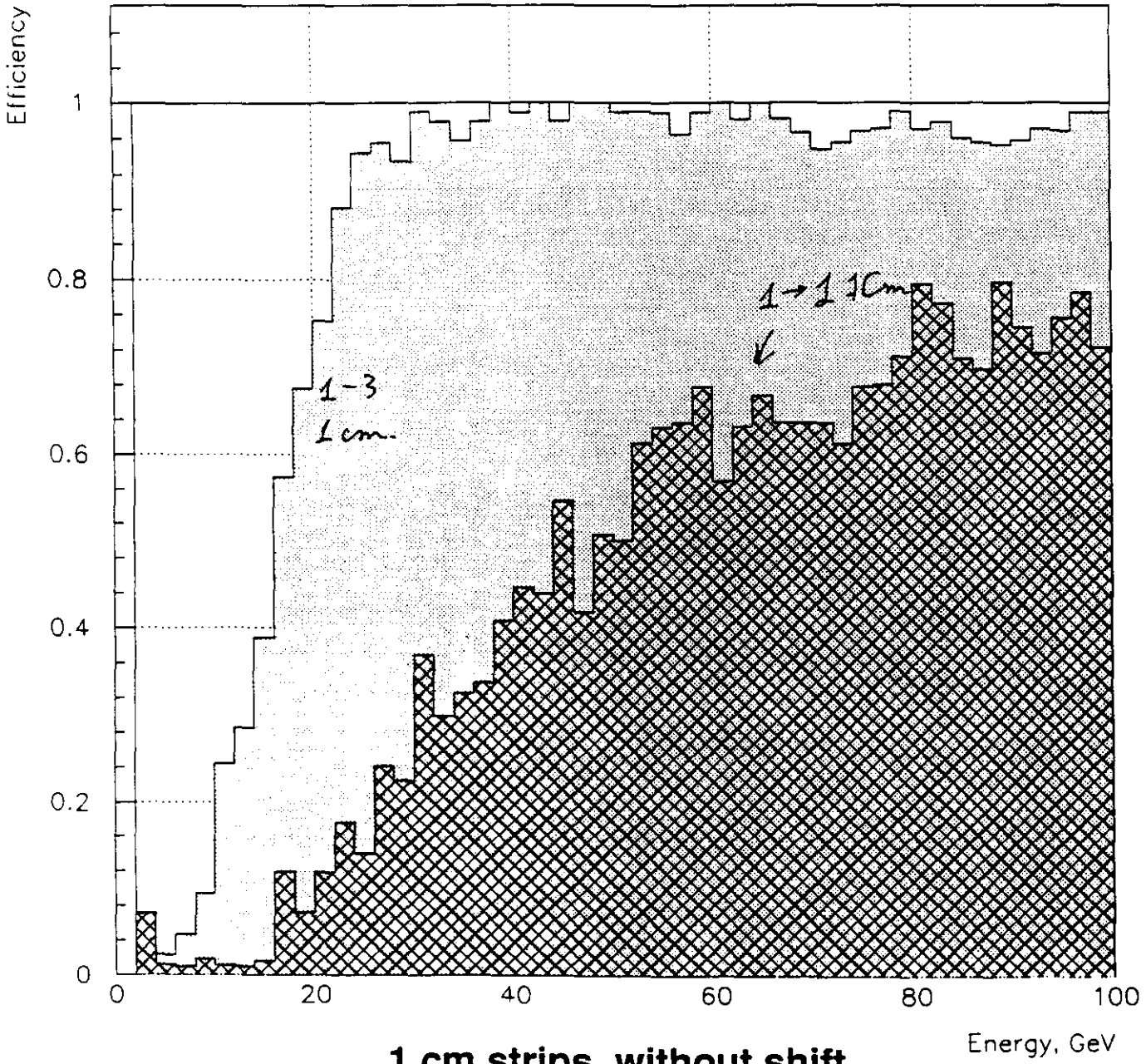


Y1-Y2 vs. Energy. No magnetic field

V1. Nonshifted strips.

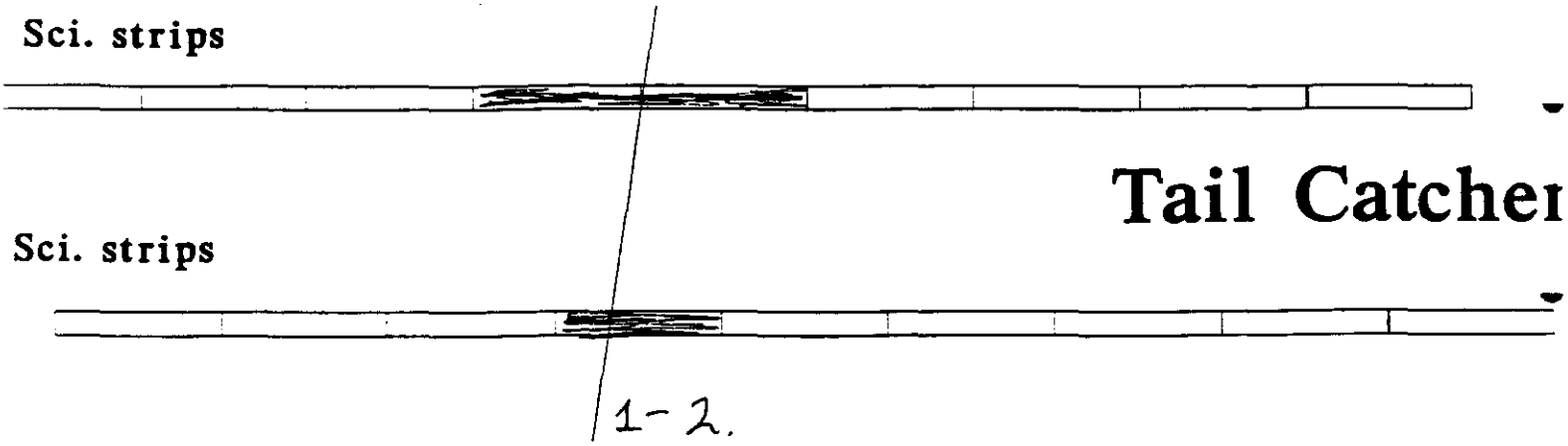


Muons in the Tail Catcher

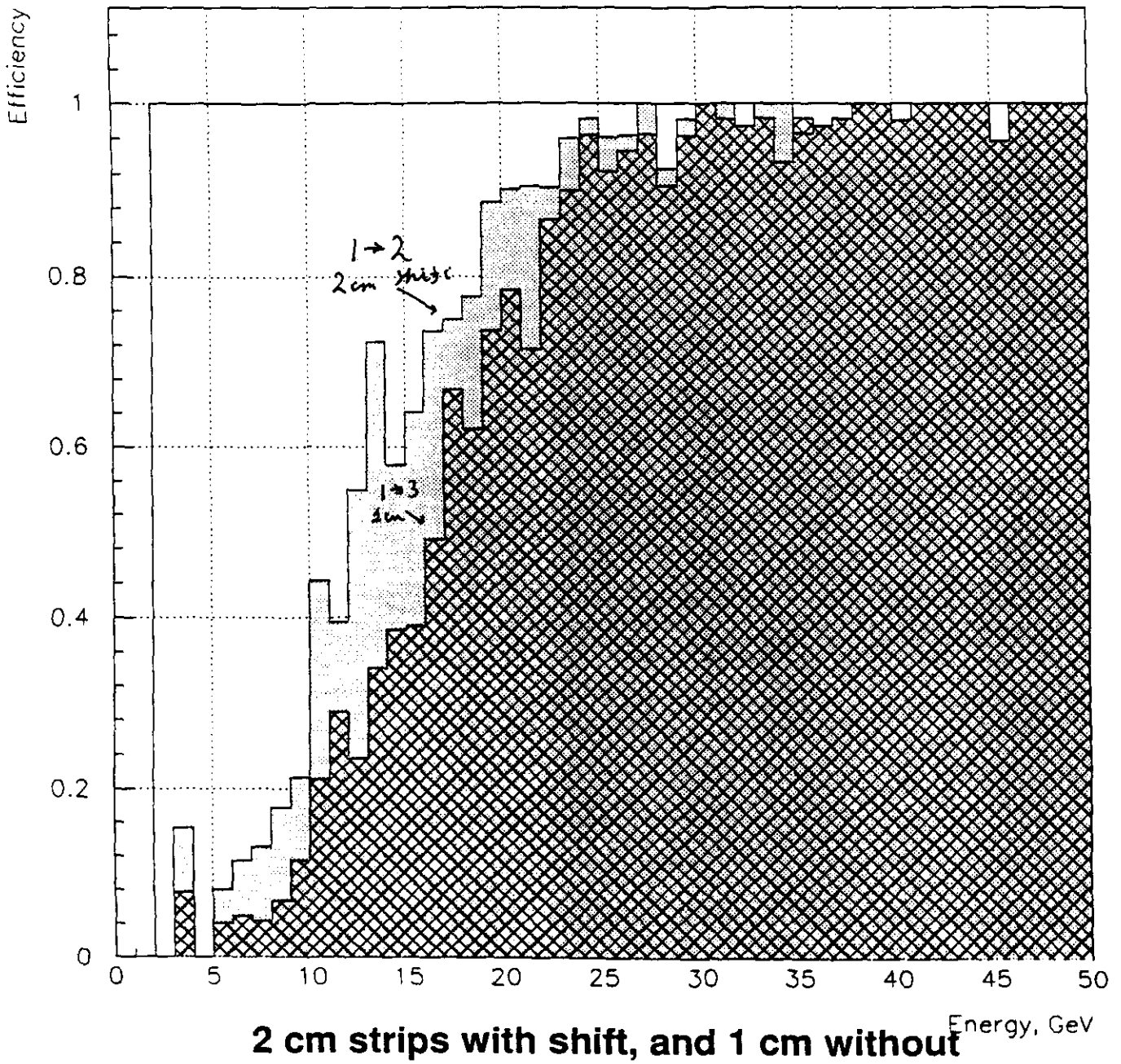


1 cm strips, without shift

V2. Shifted strips.

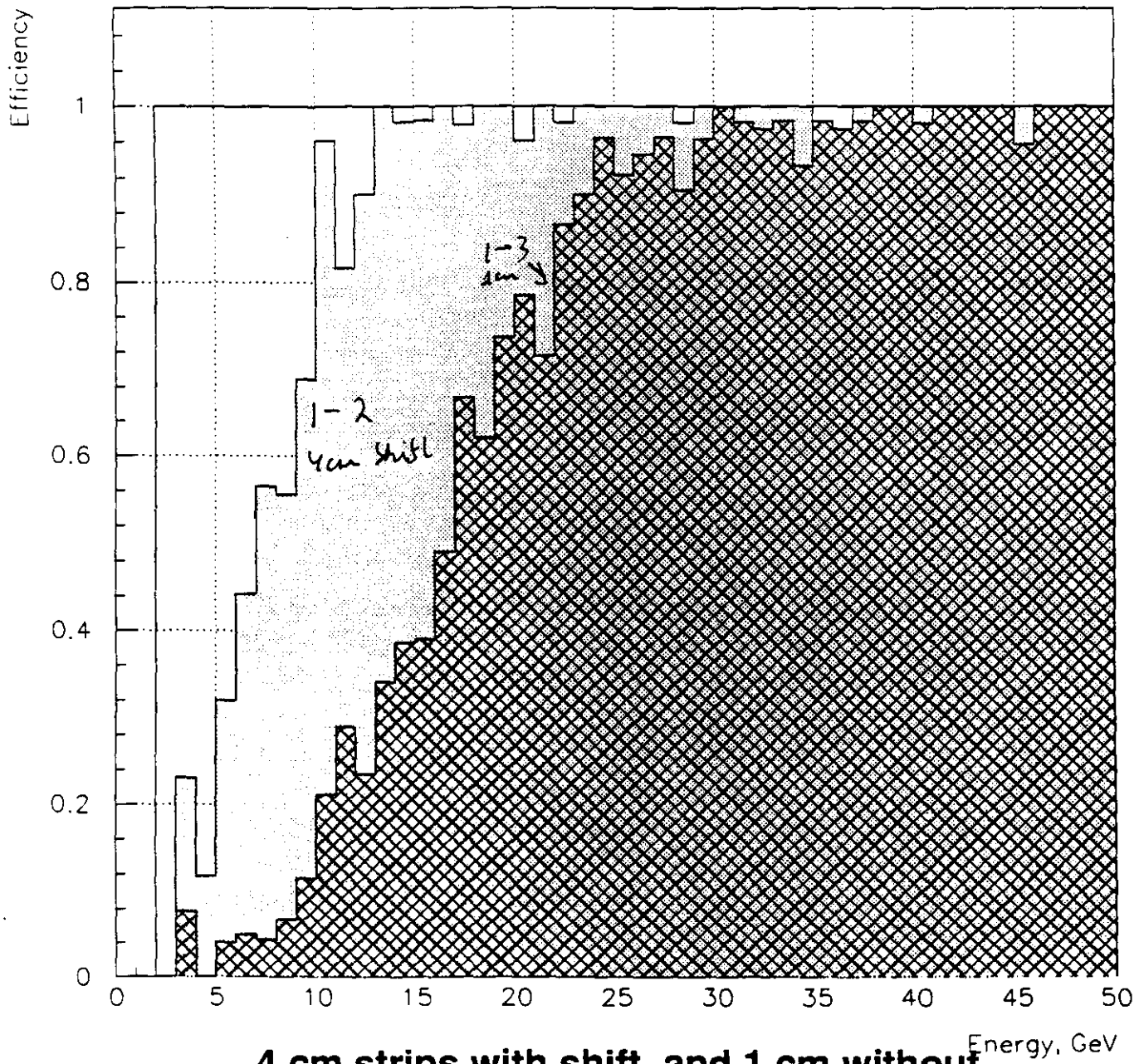


Muons in the Tail Catcher



2 cm strips with shift, and 1 cm without

Muons in the Tail Catcher



4 cm strips with shift, and 1 cm without

preserve a conservative safety margin regarding particle rates in the barrel even at the highest luminosities requires at least 12 λ for the barrel calorimeter.

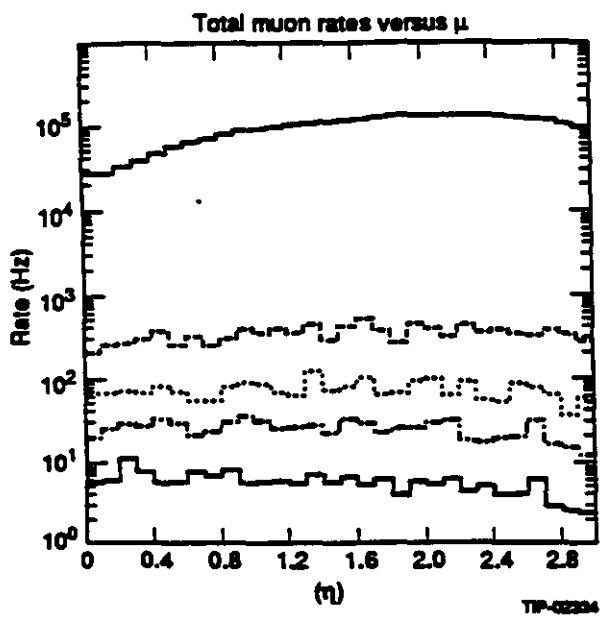


Figure 2.3-7 The total muon rate as a function of pseudorapidity for p_T cuts of 0, 5, 10, 15, 25 GeV/c

2.3.3 Description of Technologies

This section describes the technology options considered for the final design of the GEM muon system. For the barrel region, pressurized drift tubes (PDT) and limited streamer drift tubes (LSDT) are being investigated for the muon momentum reconstruction and Level 2 trigger. In

both the muon reconstruc
tagging and Levels 1 and

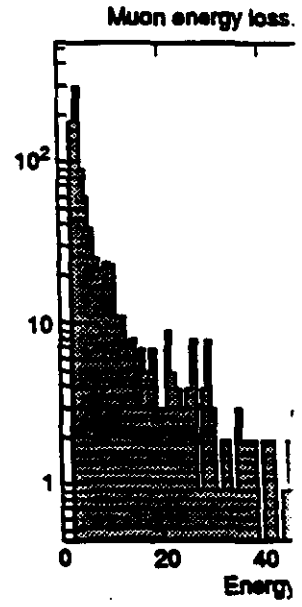
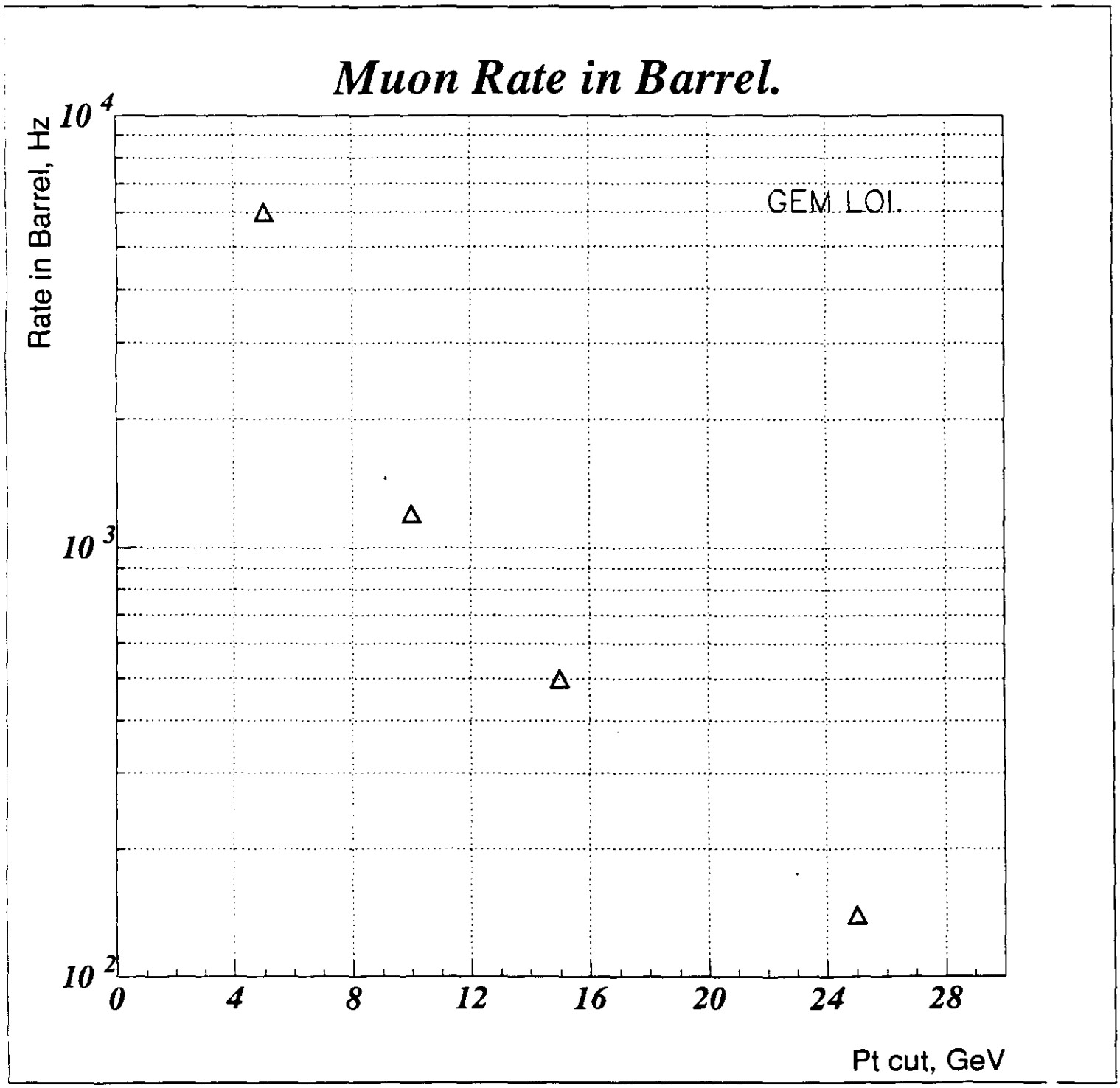
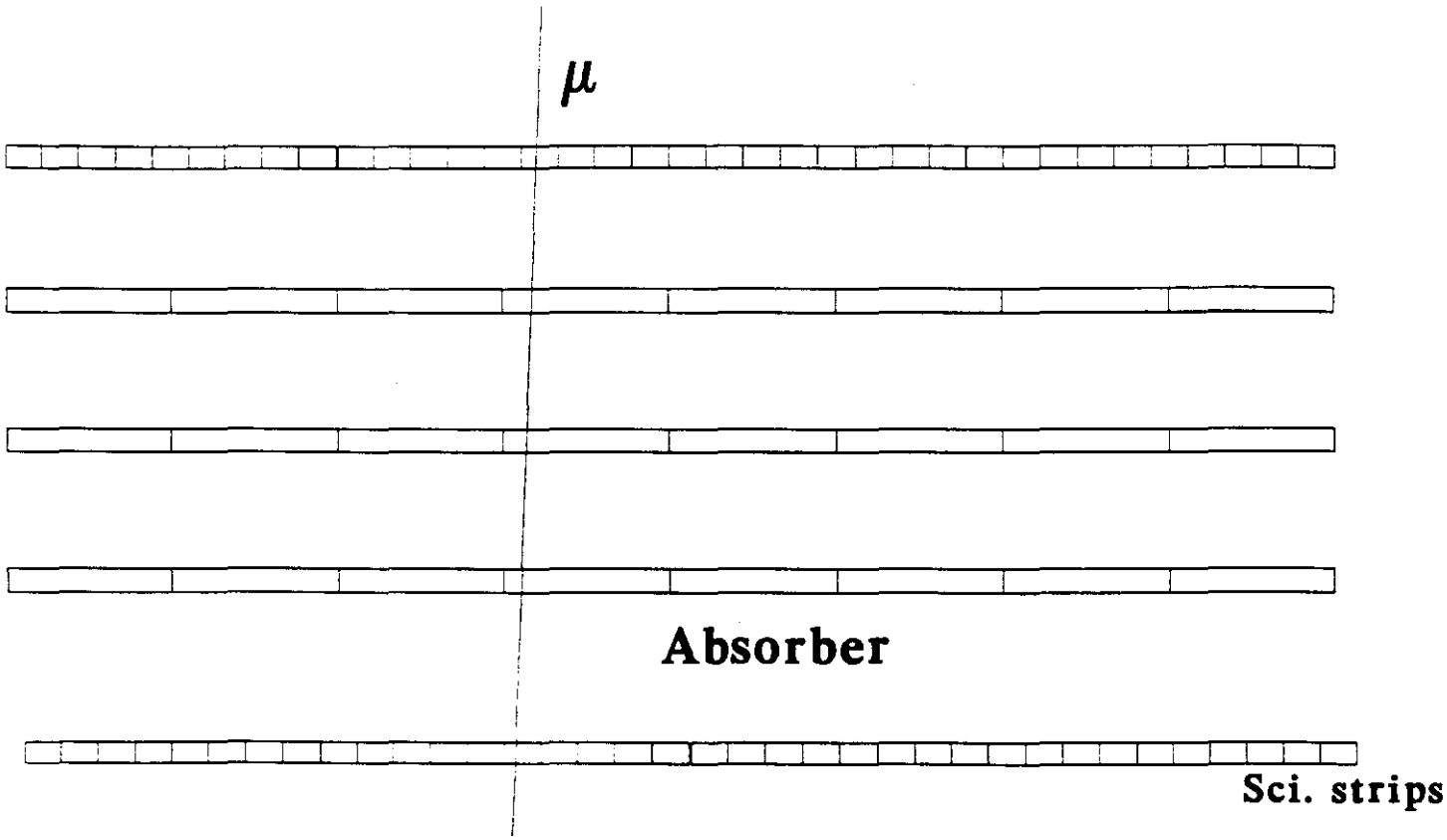


Figure 2.3-8 Energy loss c muon in the calorimete

(a) Pressurized Drift T
possible with cylindrica
parallel to the magneti
electric field configura
of the time-to-distance
incidence. The cylin
enables improvemen
pressurization as $1/\sqrt{P_T}$
the diffusion coefficien
cluster formation [1].


Muon Rate in Barrel.
Rate in Barrel, Hz
10^4
10^3
10^2
GEM LOI.
0
4
8
12
16
20
24
28
Pt cut, GeV

Tail Catcher



Rate in Barrel:

1 cm. strips - 820 Hz

2 cm. shifted strips - 1230 Hz

4 cm. shifted strips - 2800 Hz

Background:

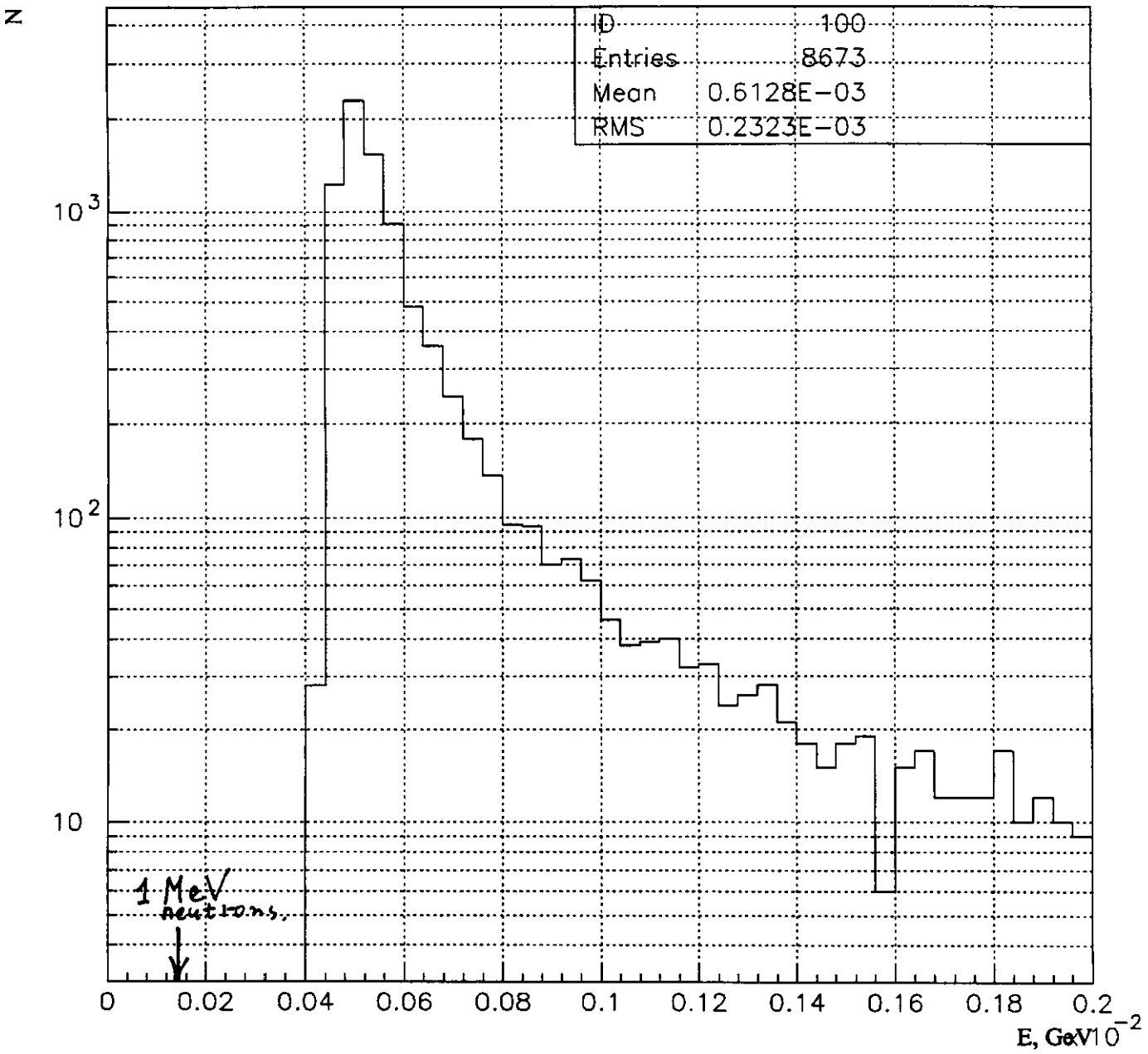
Signal from 1 Mev neutron is less than .15 MeV.
Muon signal in 1 cm scint. is in 8 times highte

Probability to imitate muon by hadrons is low because of the huge material thicness between trigger layers.

Number of channels:

1800, 2 cm strips are in both trigger layers, and
200 - 300, 10 cm strips in the middle of TC.

Muon signal in 3mm scintillator.



If muon trigger is based on the Tail Catcher:

1. It is fast,
   because it is based on the scintillator signals.

2. It is simple,
   because no complicated analysis is required.

3. It is cheap,
   because routine electronics and
   no information from other subsystem required.

gem

γeμ

Presentation by:

M. Shupe

FAST SIMULATION OF GEM W/LAr FORWARD CALORIMETER

M. SHUPE
UNIV. OF ARIZONA
JAN 8, 1993

I. OVERVIEW - FORWARD REGION

II. DESCRIPTION - THIN GAP TUBE DESIGN

III. MIXTURE LEVEL SIMULATION - UAZMIX (+ CONTEXT IN GEM)

IV. RESPONSE FUNCTIONS: $\frac{\delta p_T}{p_T}$ AND η COVERAGE. (TO $\eta = \phi$)

V. EXAMPLE: HEAVY $H \to \ell^+ \ell^- \nu \bar{\nu}$

VI. JET ALGORITHMS.

Physics Requiring a Forward Calorimeter

Missing E_T

Higgs

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

New heavy quarks

SUSY

Technicolor

$$\rho_{TC}^{\pm} \to W^{\pm}Z^o \to \ell^{\pm}\nu\ell^+\ell^-$$

Leptoquarks $gg \to P_3P_3 \to b\tau\bar{b}\bar{\tau}$

New Gauge Bosons

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

Other sources of boson pairs

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

Forward Jets

VV scattering with forward jet tagging

Low x physics via forward di-jets

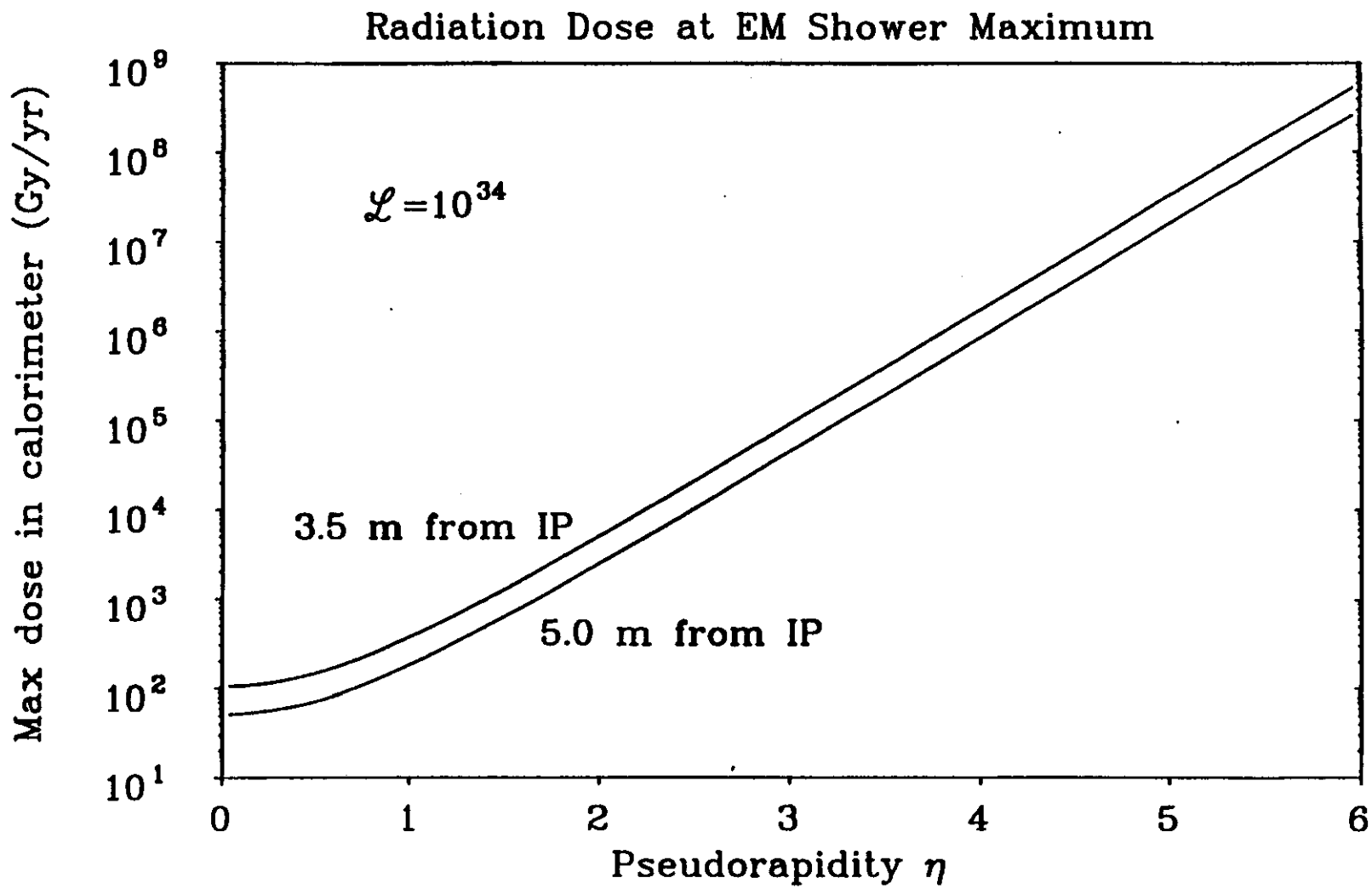

Radiation Dose at EM Shower Maximum
Max dose in calorimeter (Gy/yr)
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
$\mathcal{L}=10^{34}$
3.5 m from IP
5.0 m from IP
0
1
2
3
4
5
6
Pseudorapidity η

Figure 3

ENERGY AND ANGLE REGIMES FOR FORWARD CALORIMETRY.

η	θ DEG	θ RAD	p WHEN $p_T = 10$ GeV
3	5.7	.099	100 GeV
4	2.1	.037	270
5	.77	.014	740
5.5	.47	.0082	1220
6	.28	.0050	2020

AND HIGHER FOR "HIGH" p_T !

SOURCES OF ERROR IN p_T DETERMINATION:

$$\frac{\delta p_T}{p_T} = \left[\left(\frac{\delta p}{p}\right)^2 + \frac{1}{\sin^2\theta}\,\delta\theta^2\right]^{1/2}$$

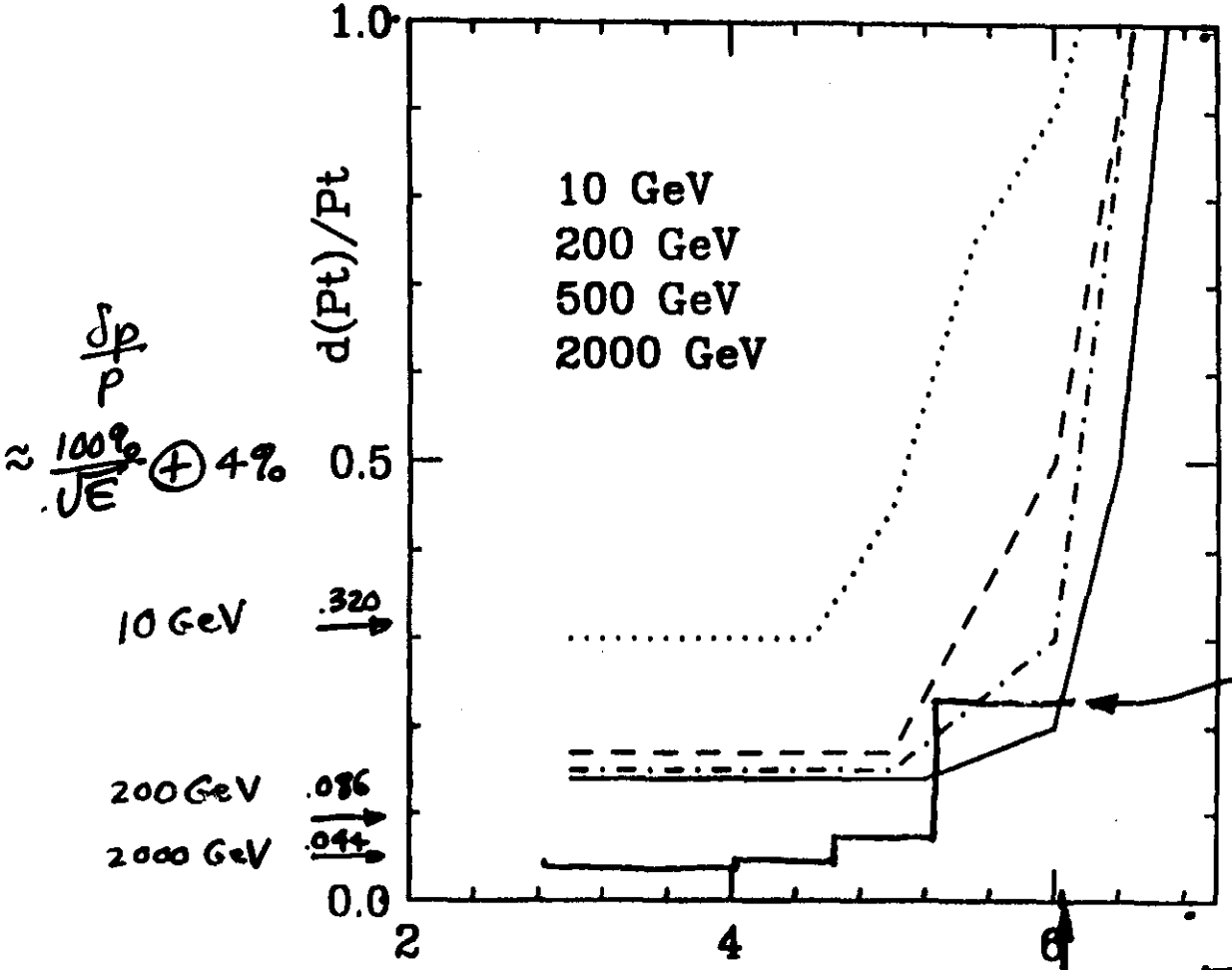
$$\approx \left[\left(\frac{\delta p}{p}\right)^2 + \left(\frac{\delta\theta}{\theta}\right)^2\right]^{1/2}$$

AND $\frac{\partial\eta}{\partial\theta} = \frac{1}{\sin\theta} \Rightarrow \delta\eta \approx \frac{\delta\theta}{\theta}$ IN FCAL.

WE SHALL SEE THAT $\frac{\delta\theta}{\theta}$ TERM IS COMPARABLE TO $\frac{\delta p}{p}$ CONTRIBUTION FOR TYPICAL FCAL DESIGNS.

CONTRIBUTIONS TO $\frac{\delta p_T}{p_T}$

GEM W/LAr Forward Cal. – Pion Showers



$\frac{\delta p}{p} \approx \frac{100\%}{\sqrt{E}} \oplus 4\%$

10 GeV .320

200 GeV .086

2000 GeV .044

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

$\frac{\delta \theta}{\theta} \approx \frac{\Delta \eta}{\sqrt{12}}$

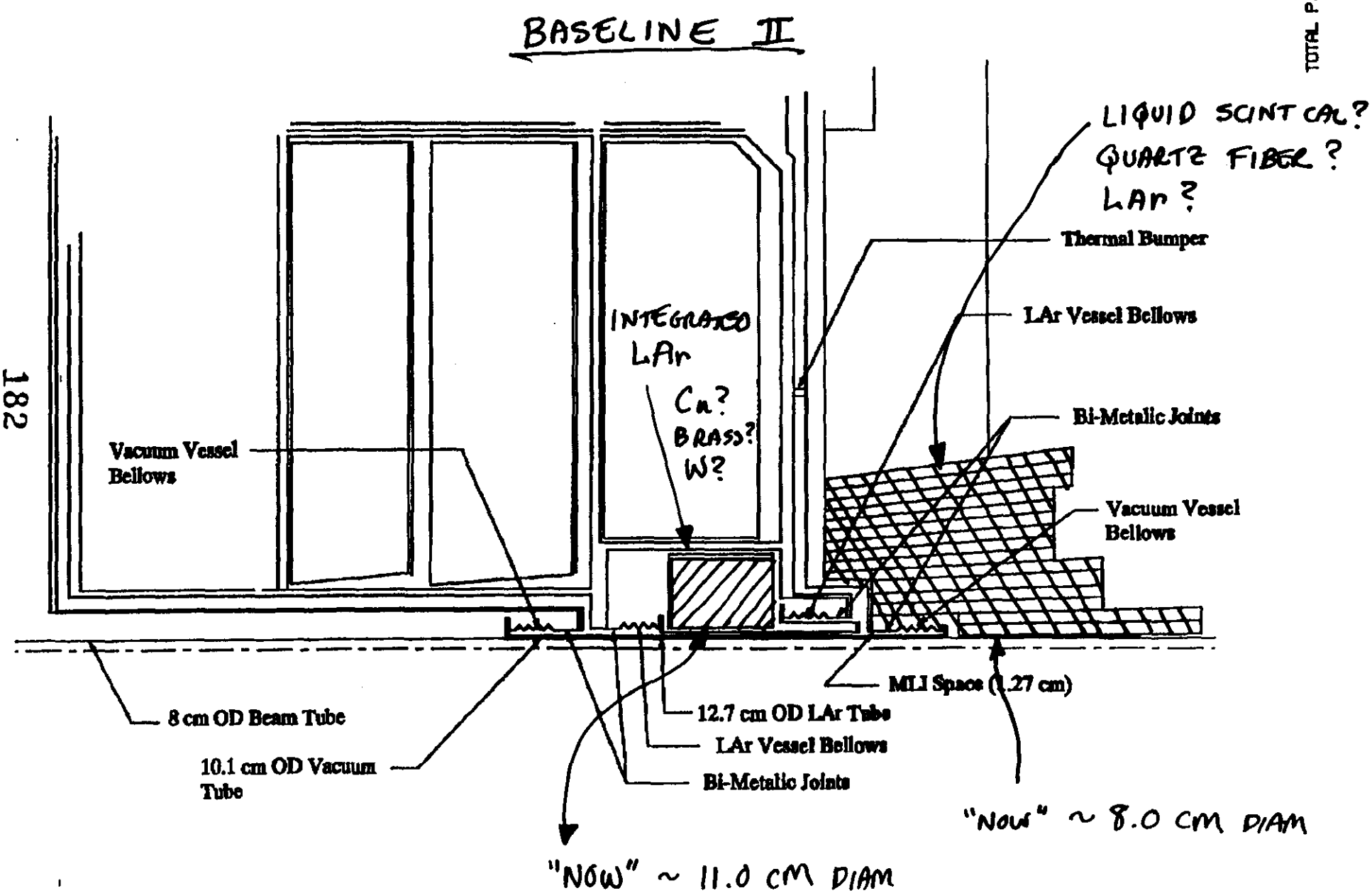
(POINT SHOWERS)

BUT SHOWER TRANSVERSE FLUCTUATIONS IMPORTANT

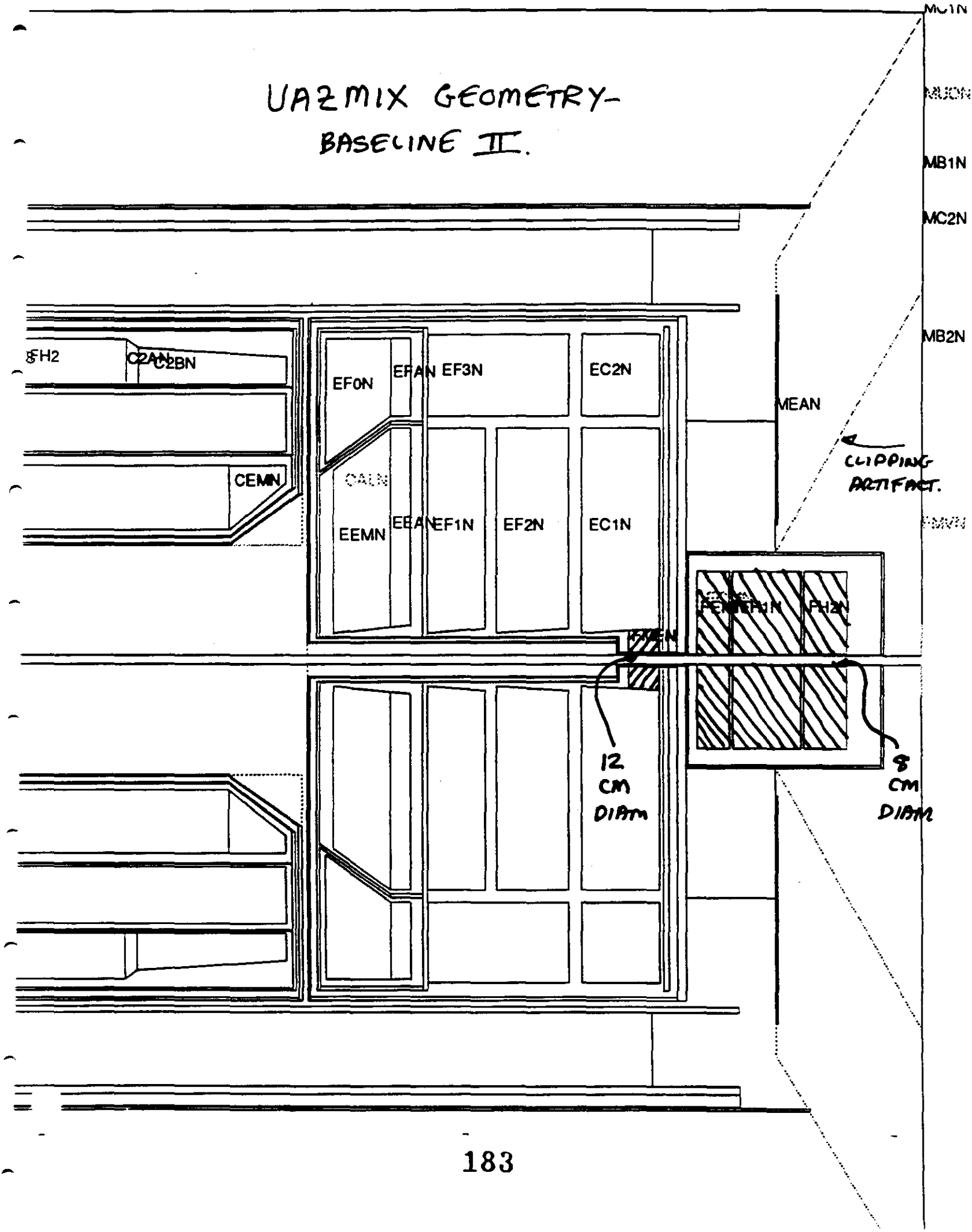
HIGH η EDGE.

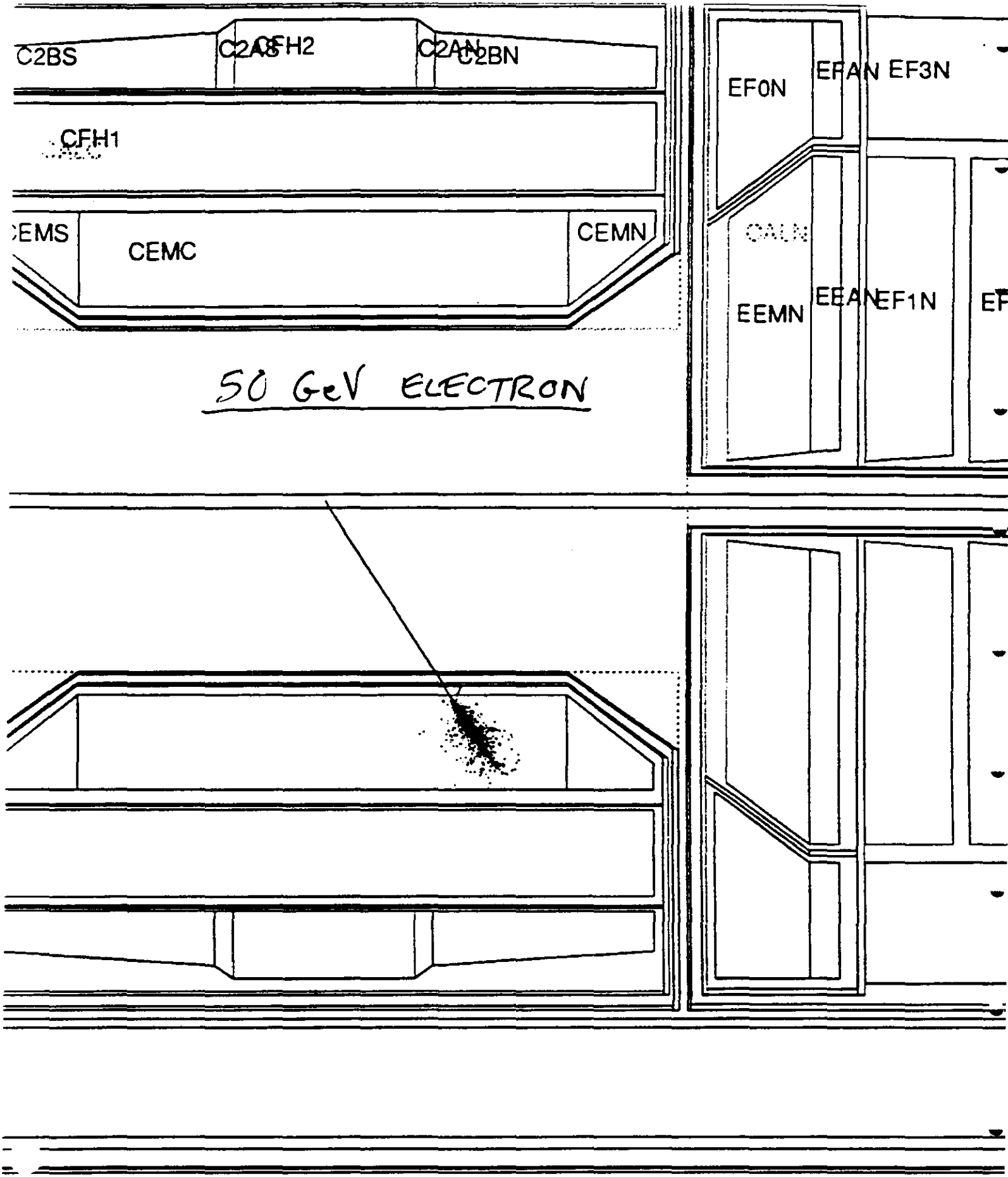
+ TRANSVERSE FLUCS.
+ LONG. FLUCS. + LEAKAGE.
+ E LOSS FLUCS.

GEM Forward Calorimeter - 11/16/92



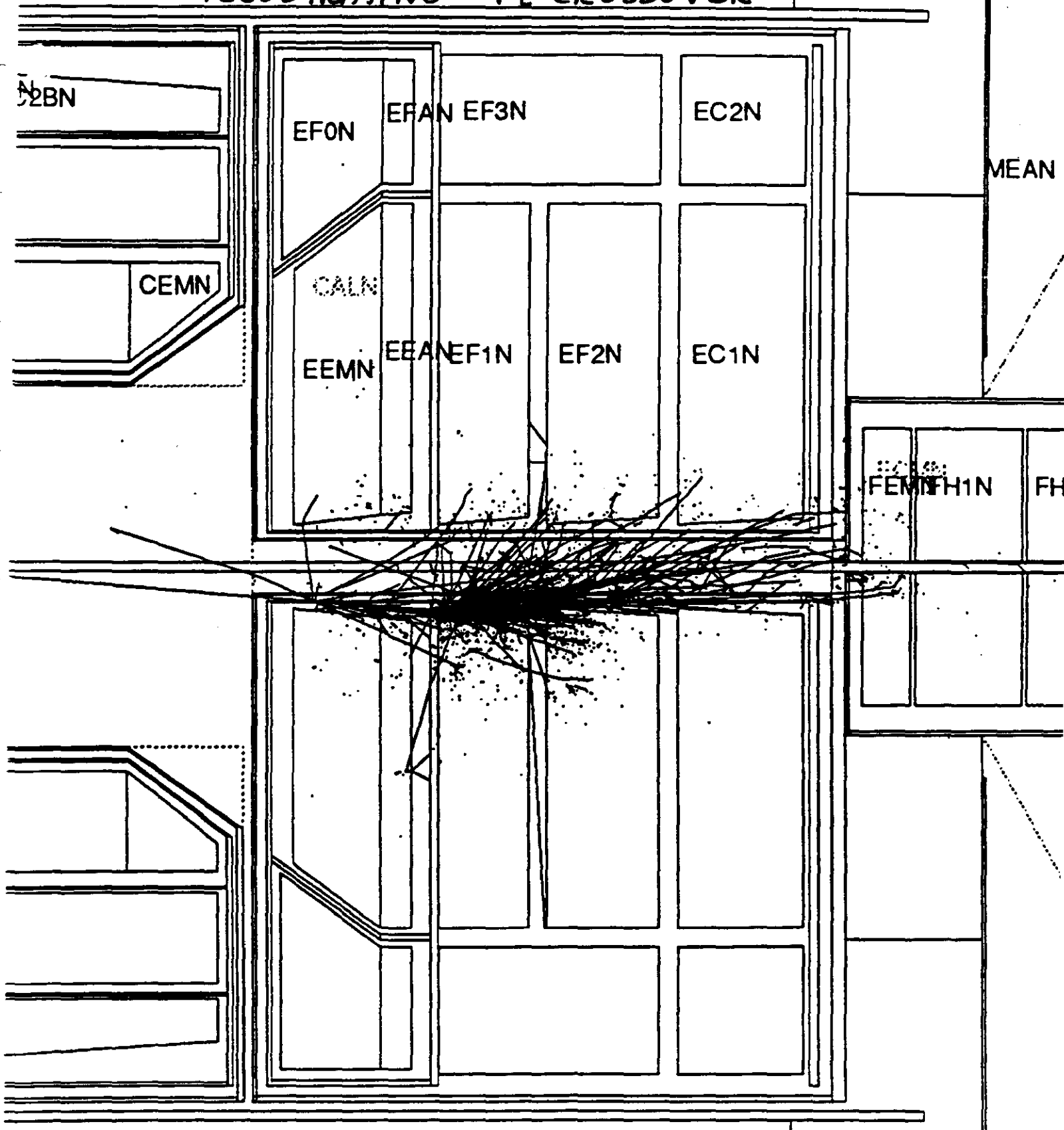
TOTAL P.82

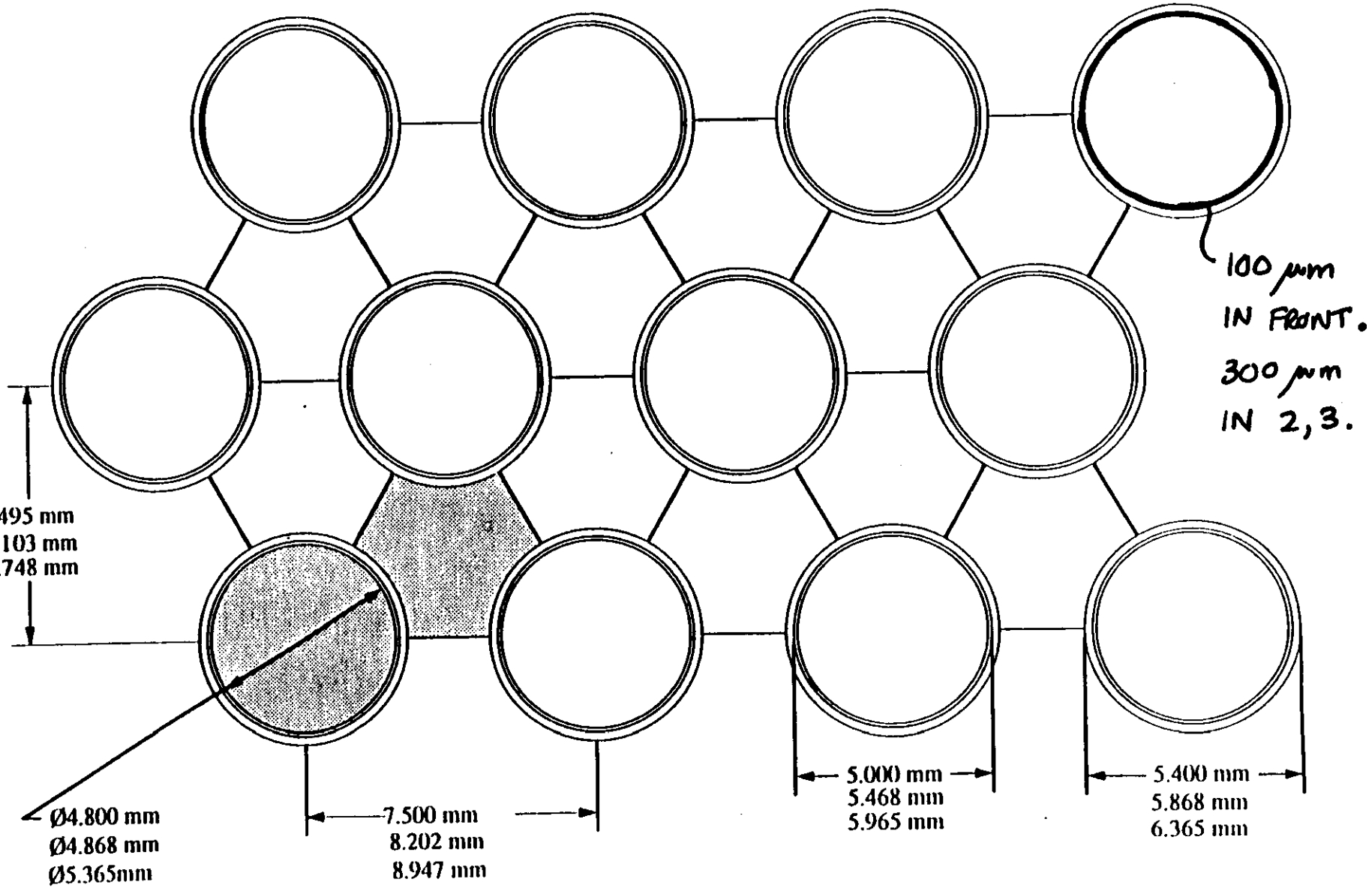

UA2MIX GEOMETRY-
BASELINE II.
MC1N
MUON
MB1N
MC2N
MB2N
FH2
C2AN
C2BN
EF0N
EFAN
EF3N
EC2N
MEAN
CLIPPING ARTIFACT.
CEMN
CALN
EEMN
EEAN
EF1N
EF2N
EC1N
FH1N
FH2N
12 CM DIAM
8 CM DIAM


C2BS
C2AS
CFH2
C2AN
C2BN
CFH1
CEMS
CEMC
CEMN
EF0N
EFAN
EF3N
EEMN
EEAN
EF1N
50 GeV ELECTRON

200 GeV PION

→ ILLUSTRATING "Pt CROSSOVER"



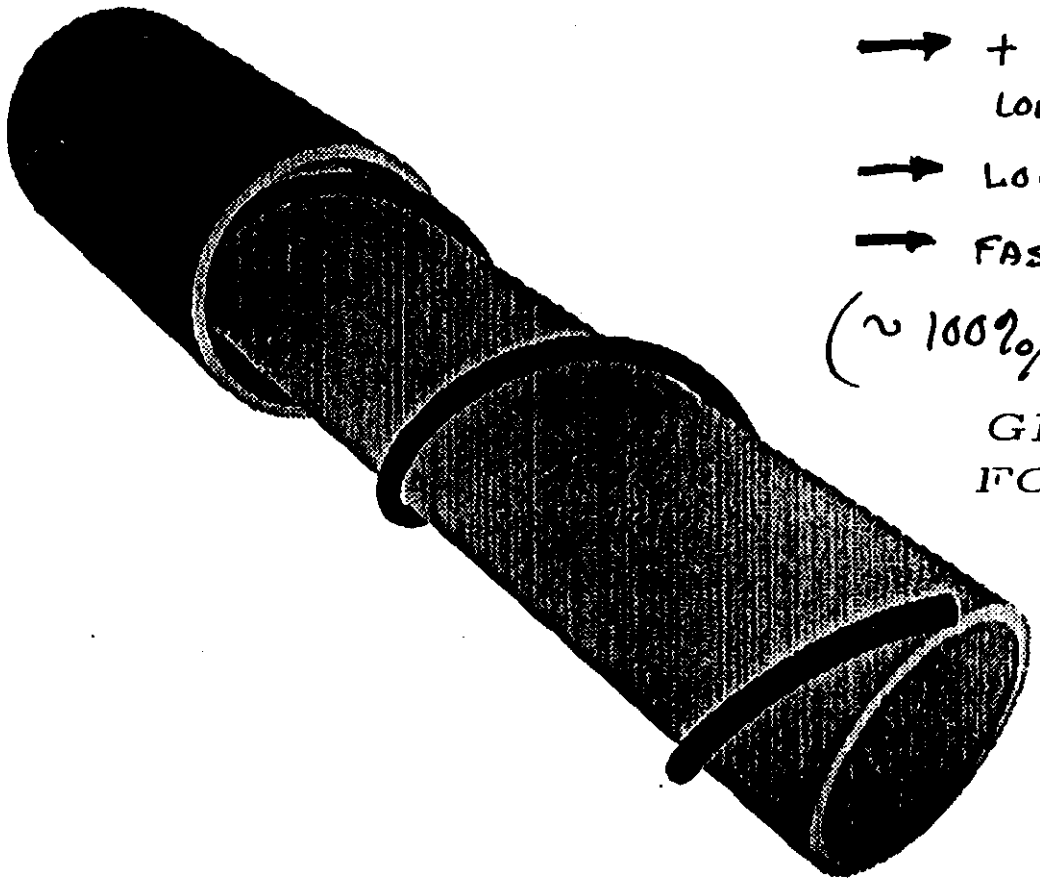


WORST CASE POINTING

FCAL MODULE - TUNGSTEN ARRAGEMENT
(SIC)

R MODULE DEFORM

SM CHAE



THIN GAP

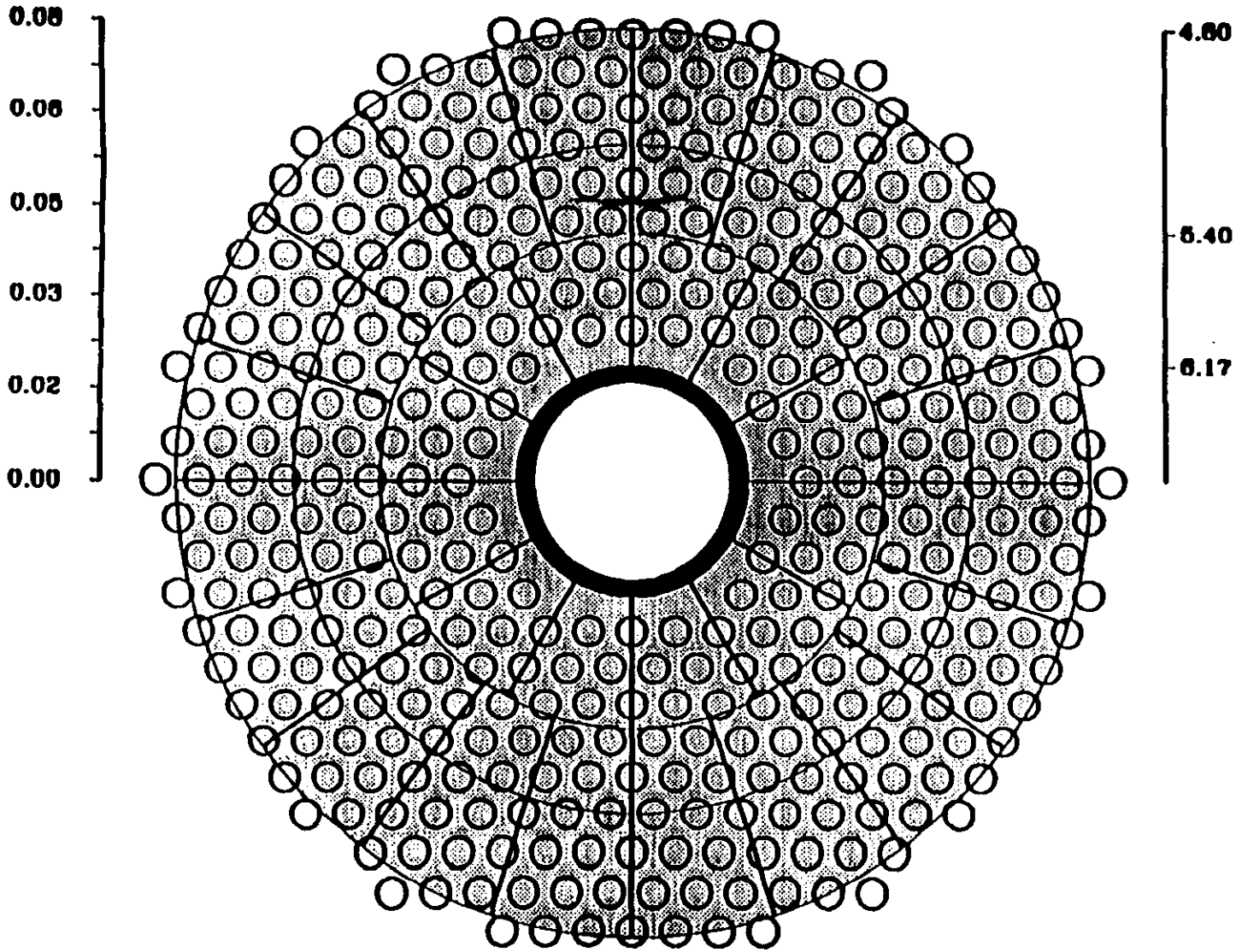
→ + ION BUILDUP NO LONGER A PROBLEM

→ LOW VOLTAGE (~100)

→ FASTER CHARGE COLLECTION

(~ 100%/√E NOT A PROBLEM.)

GEM LAC
FCal Tube


0.08
0.06
0.05
0.03
0.02
0.00
4.60
5.40
6.17

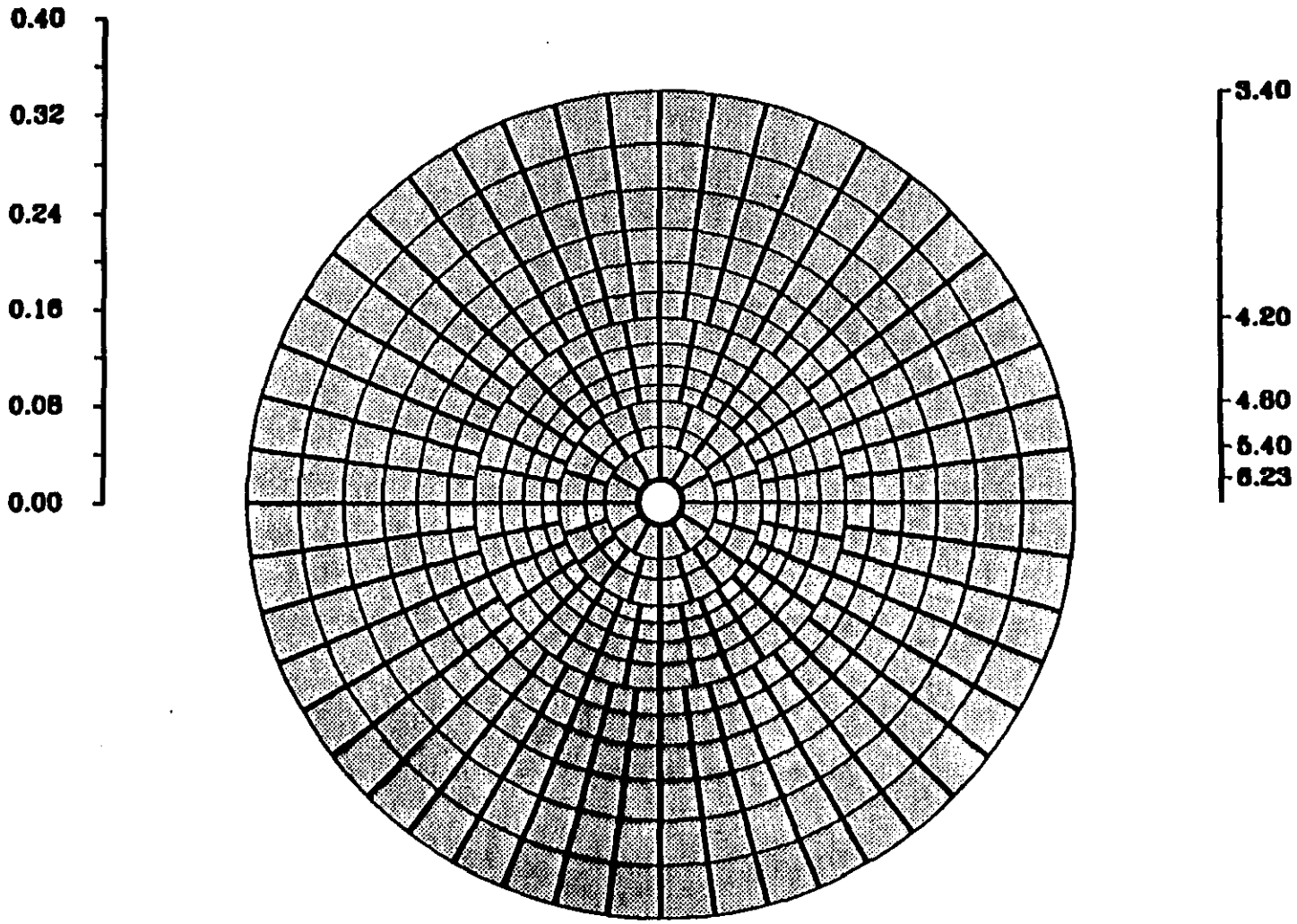
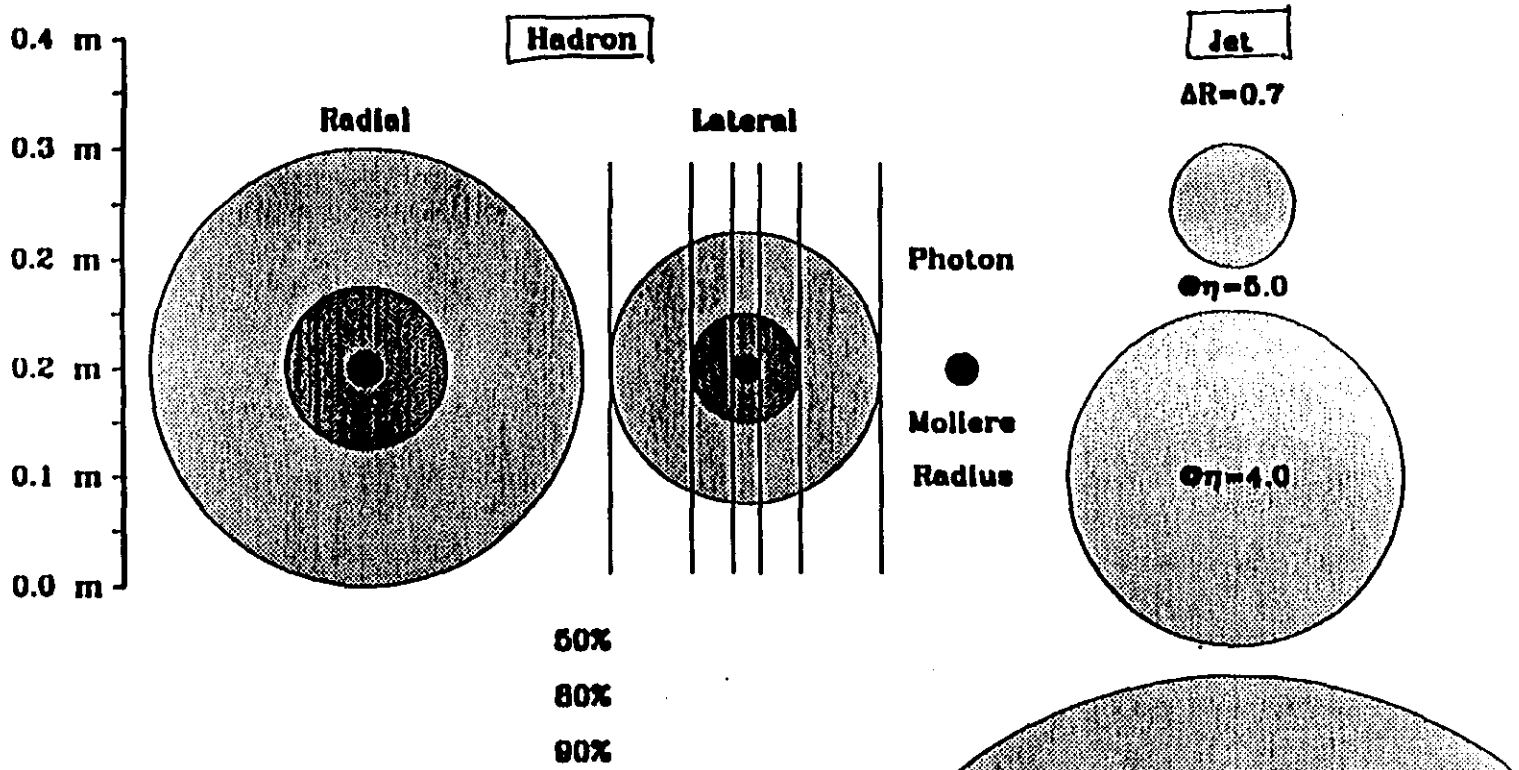


Figure 11

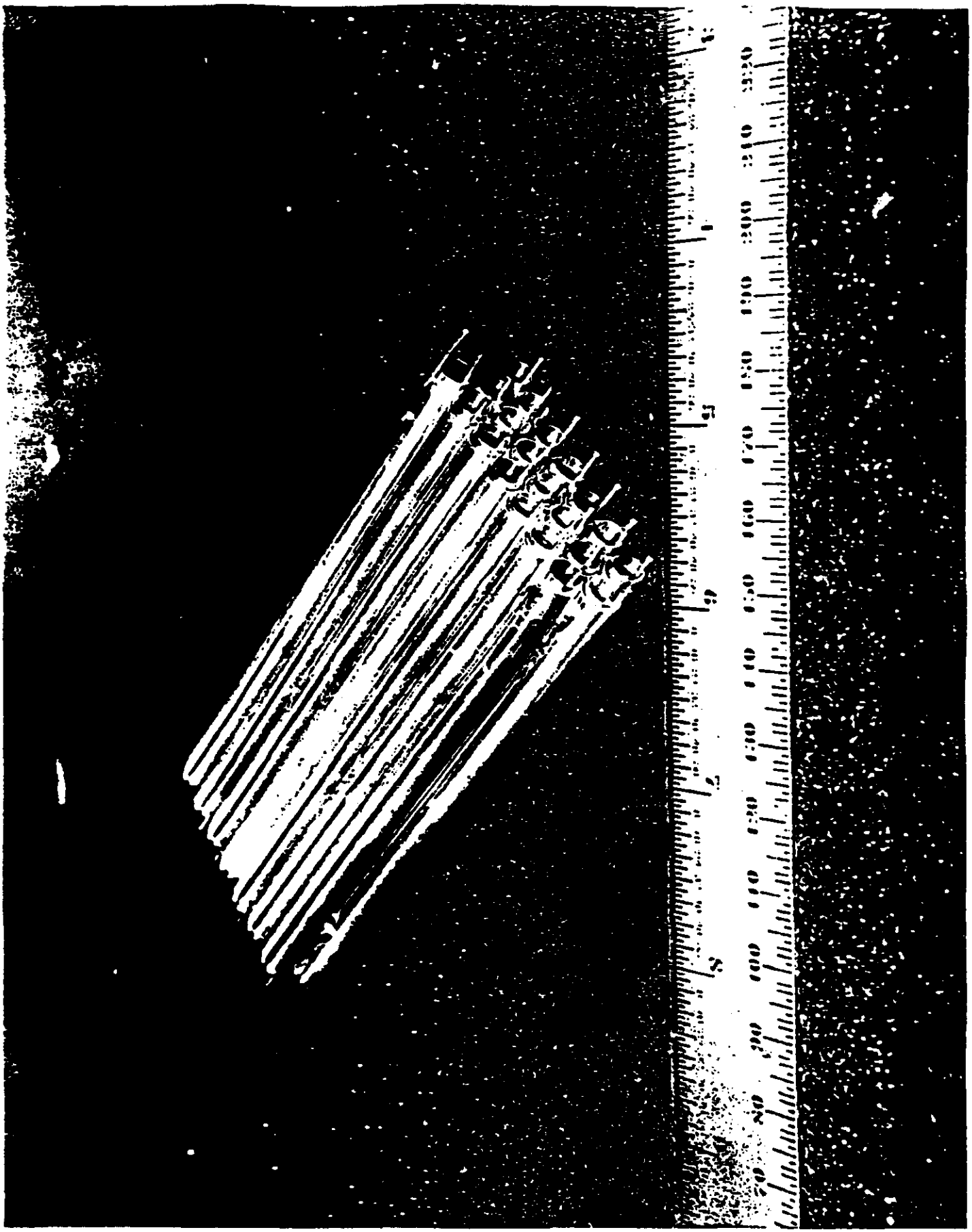


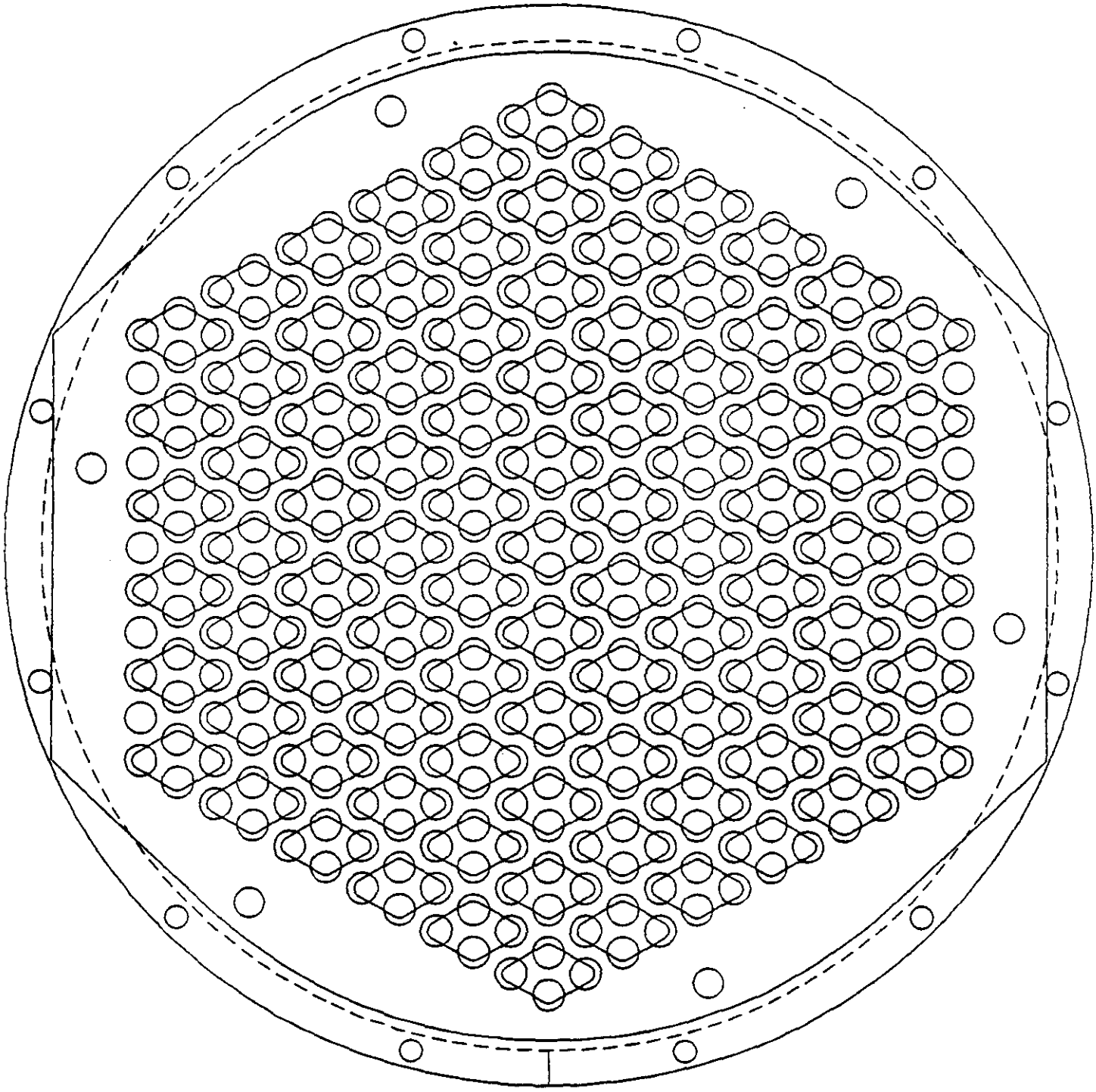
⇒ JET CORES ARE SMALL IN FCAL.

⇒ $\frac{\delta\theta}{\theta}$ RESPONSE SIMILAR TO SINGLE SHOWERS.

Figure 12

BENCH PROTOTYPE





BNL TEST RUN.

SUMMER, 1993.

(EM CONTAINING)

GEANT SETTINGS FOR FCAL SIMULATION:

- VERSION 3.1416
- GHEISHA
- STANDARD CUTS

  EM 1.0 MeV

  HADRONIC 10. MeV

- MIXTURE W/LAr (FOR EXAMPLE)

		f_{VOL}	f_{WT}	
$\rho = 18.24$	TUNGSTEN	.841	.937	$\rho = 17.31$, $\lambda = 11$ cm
	NICKEL	.067	.034	
	COPPER	.029	.015	
	STAINLESS	.021	.009	
	LIQ. ARGON	.042	.003	

- $\vec{B}$ FIELD .8 TESLA. (PURE SOLENOIDAL)

NOTE: $\lambda_{GEANT} = \lambda_{PDG} \pm 10\%$

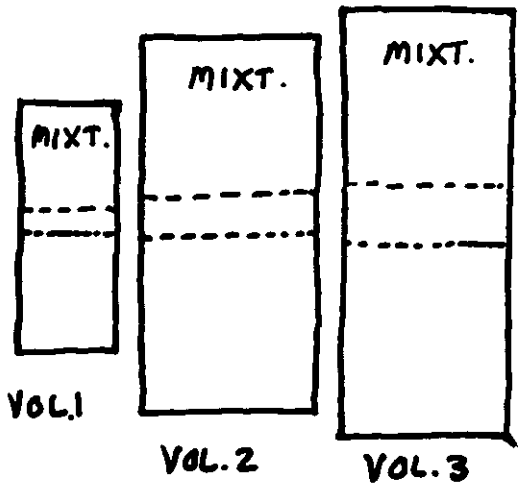
THIS NEEDS INVESTIGATION!

SOFTWARE CELLS "CAL TOWERS"

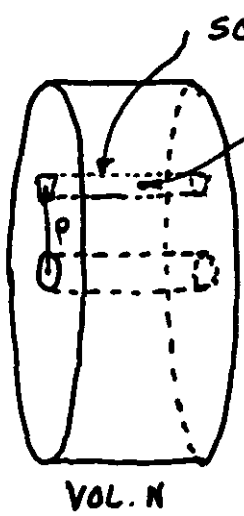
⇒ TO SPEED UP GEANT, REDUCE THE NUMBER OF VOLUMES.

⇒ USING MIXTURES ALLOWS VOLUMES TO FOLLOW ONLY "MAJOR" SEAMS AND CRACKS.

IN THE CURRENT FCAL SIMULATION:



+ BEAMPIPE
+ CRYOSTAT VOLUMES



FORM EM + HAD. SUMS IN THIS CELL WHEN

$\rho_{MIN} < \rho < \rho_{MAX}$

$\phi_{MIN} < \phi < \phi_{MAX}$

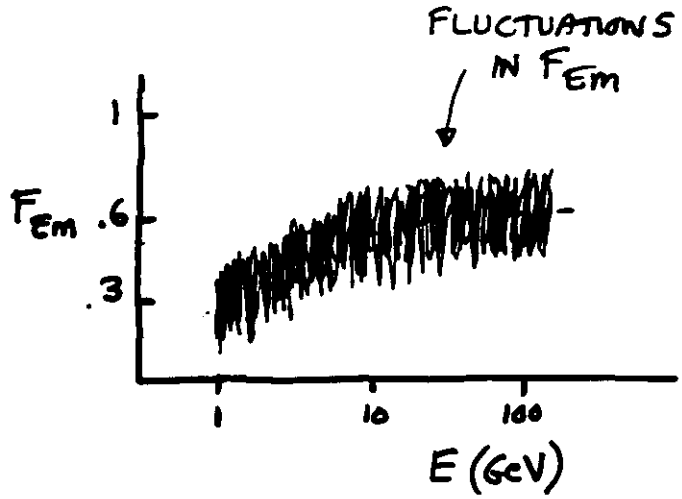
(QUICK!)

⇒ AVOIDS 100'S OF GEANT VOLUMES.

GEANT MIXTURES: ENERGETICS + FLUCTUATIONS

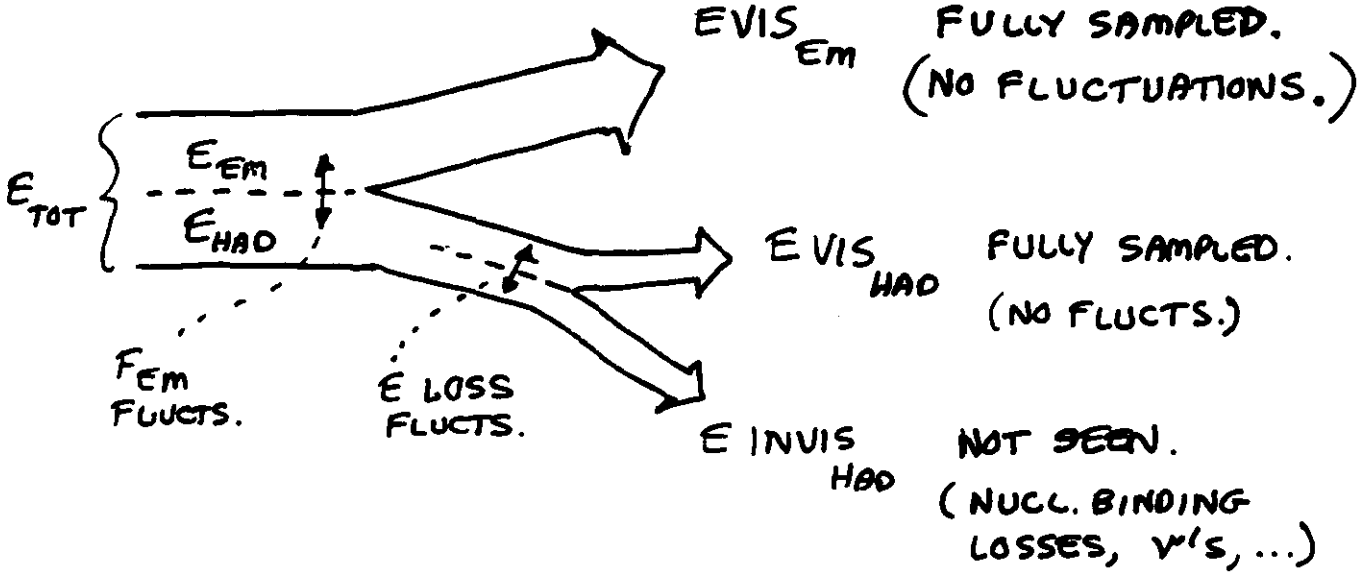
INTRINSIC BEHAVIOR OF HADRONIC SHOWERS:

$$F_{EM} = \frac{E_{e^\pm,\gamma}}{E_{TOTAL}}$$ "ELECTROMAGNETIC FRACTION"



(DO GEANT + HETC DISAGREE?)

RESPONSE OF MIXTURES:



IN MIXTURE CELLS, ONE IS SUMMING $EVIS_{EM}$ AND $EVIS_{HAD}$. WHAT DOES A <u>REAL</u> CALORIMETER DO TO THEM?

RESPONSE OF SAMPLING CALORIMETER:

$\Rightarrow$ $E_{VIS\,EM}$
- dE/dx WEIGHTED SAMPLING FRACTION S.
- e/MIP (TRANSITION EFFECT...).
- FLUCTUATIONS DUE TO S, SAMPLING FREQUENCY, etc.

$\Rightarrow$ $E_{VIS\,HAD}$
- dE/dx WEIGHTED SAMPLING FRACTION S.
- FLUCTUATIONS DUE TO S, SAMPLING FREQUENCY, etc.

NET RESULT: MIXTURES GET THE e/h RESPONSE WRONG, AND INCLUDE THE HADRONIC E LOSS FLUCTUATIONS, BUT NOT THE SAMPLING FLUCTUATIONS.

CORRECTING THE RESPONSE TO MATCH REAL DETECTOR

1. EM ENERGY OBSERVED: $E_{VIS\,EM} \times S \times e/MIP$
2. HAD ENERGY OBSERVED: $E_{VIS\,HAD} \times S$
3. THEN SUM + RECALIBRATE THE MONTE CARLO AT SOME REFERENCE E.

OR. "BOOST" $E_{VIS\,HAD}$ BY $\dfrac{S}{S \times e/MIP} = 1/(e/MIP)$, AND "DON'T RECALIBRATE." $\Rightarrow$ (EM STAYS CALIBRATED)

CORRECTING THE RESPONSE TO MATCH <u>ANY</u> DETECTOR OF A GIVEN e/h.

→ ONE MAY STUDY MANY DETECTOR OPTIONS AT ONCE!

WHAT PROPERTY DOES A PERFECTLY COMPENSATING DETECTOR HAVE?

$$\text{RESPONSE TO } E_{EM} = \text{RESPONSE TO } E_{HAD}$$

OR,

$$\cancel{S} \times e/_{MIP} = \cancel{S} \times f_{HAD\text{-}VIS}$$

$$\text{WHERE } f_{HAD\text{-}VIS} = E_{VIS_{HAD}} / E_{HAD}$$

$$\Rightarrow \boxed{e/_{MIP} \approx f_{HAD\cdot VIS}}$$

SO SINCE MIXTURES <u>DO</u> MODEL $f_{HAD\cdot VIS}$ CORRECTLY, BUT <u>DON'T</u> MODEL $e/_{MIP}$, ONE DOES THE FOLLOWING:

1. $f_{HAD\cdot VIS}$ IS ENERGY <u>INDEPENDENT</u>, BUT MATERIAL <u>DEPENDENT</u> (SLIGHTLY).
   SO DO DEDICATED RUNS WITH PION SHOWERS IN CONTAINING VOLUMES FOR EACH MATERIAL.
   (MUST FIND f_{EM}, AND THEN $f_{HAD\ VIS}$ FOR EACH SHOWER.)
2. SET $e/_{MIP} = f_{HAD\ VIS}$ AND CORRECT AS BEFORE TO MODEL PERFECT COMPENSATION.
3. FOR MATERIALS WITH $e/h \neq 1$,
   SET $e/_{MIP} = (f_{HAD\ VIS})(e/h)$ AND CORRECT
   or $(5Y_{1.R}) = 9$ AS BEFORE.

CORRECTING THE FLUCTUATIONS:

1. ASSUME σ_{EM} IS KNOWN EXPERIMENTALLY OR FROM DETAILED M.C..
   SMEAR E_{EM} BY σ_{EM} BEFORE SUMMING.

2. ASSUME σ_{HAD} IS KNOWN BY SAME ROUTE.
   SMEAR E_{HAD} BY $\sqrt{\sigma_{HAD}^2 - \sigma_{E\,LOSS}^2} = \sigma_{SAMPLING}$
   THAT IS, THE MIXTURE ALREADY HAS ENERGY LOSS FLUCTUATIONS, SO ONLY SMEAR BY THE ADDITIONAL HADRONIC SAMPLING FLUCTUATIONS.

$\boxed{\text{NOTE:}}$ EITHER A TEST BEAM RUN OR A DETAILED MONTE CARLO WITH LOW CUTS MUST BE USED TO FIND THESE FACTORS AND TUNE THE MIXTURE.

PROCEDURE USED HERE

I. GENERATE

1. ENERGY: 10, 50, 200, 500 (PROBLEM WITH GEANT 3.14 @ 2000)
2. PARTICLE: π $(e, \mu ..)$
3. η RANGE: $0.0 \rightarrow 7.0$ (GENERATE FLAT IN η, ϕ)
4. # TO GEN: $3000 \rightarrow 250$?
5. FOR EACH EVENT:
   - ACCUMULATE $E_{VIS\,EM}$ AND $E_{VIS\,HAD}$ IN EACH CELL. NO BOOST. NO SMEARING.
   - WRITE TO DISK: LIST OF HIT CELL INDICES WITH ABOVE ENERGIES. { "CELL" OR "VOL"

II. ANALYZE

1. READ EVENTS
2. CORRECT ENERGIES:
   - BOOST $E_{VIS\,HAD}$ BY $1/(f_{HAD \cdot VIS})(e/h)$
   - σ_{EM} SMEAR
   - σ_{HAD} SMEAR

     } SAMPLING FLUCTUATIONS
   - SUM TO GET ϵ_i CELL. { WOULD DO NOISE + CONST TERM HERE.?
3. RECONSTRUCT SHOWER ENERGY AND CENTROID:

$$\vec{p} = \sum_{\substack{i=1 \\ \text{CELLS}}}^{n} \epsilon_i \hat{n}_i \qquad \hat{n}_i = \text{CELL DIRECTION VECTOR.}$$

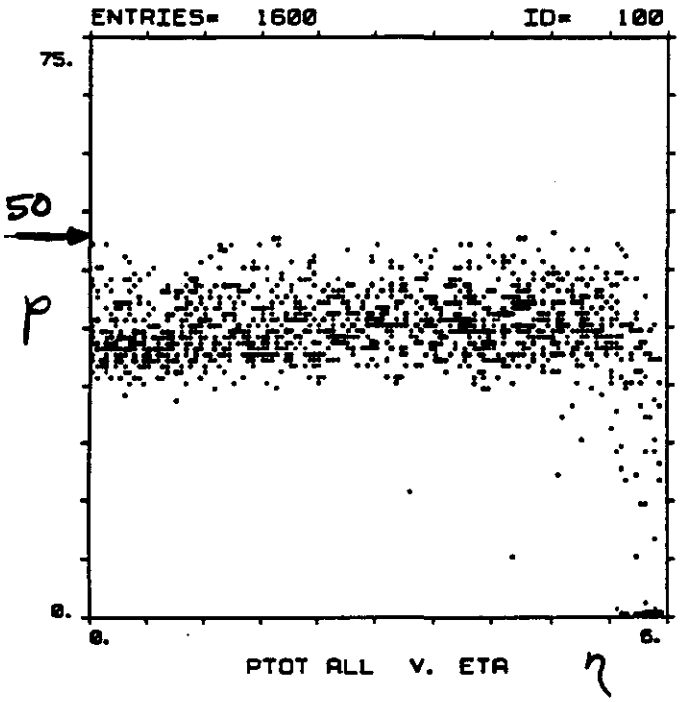
(OR DIRECTION VECTOR OF STEP IF SUMMING STEP BY STEP)

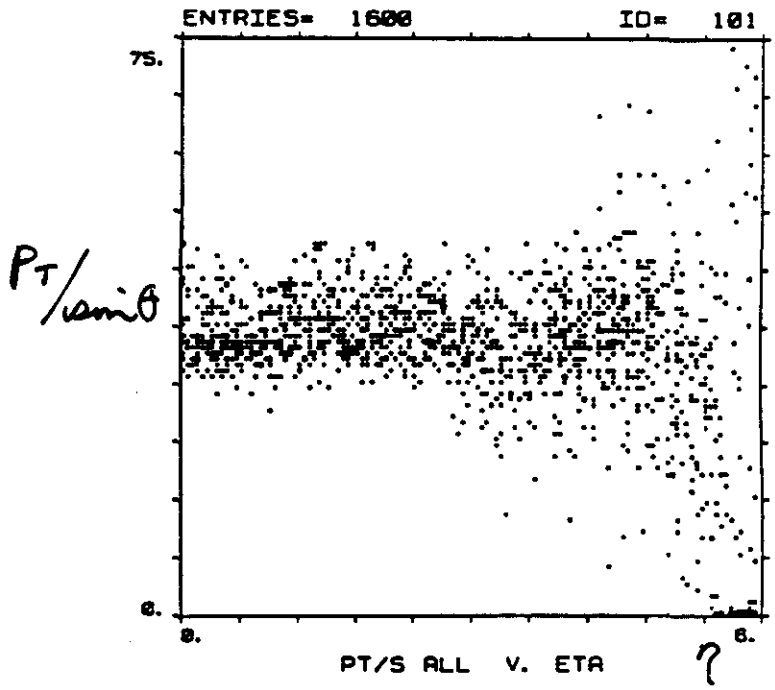
PARAMETER VALUES IN CURRENT STUDY

MIXTURE	$f_{HAD\ VIS}$	e/h	e/h (WIMER.)
EC			
ACC LKr Pb	.450	1.8	
FH LKr Pb	.498	1.6	(1.46)
EC			
ACC LAr Pb.	.500	1.8	
FH LAr Cu	.500	1.8	
FC			
FC LAr W	.515	1.4 (PETER LOCH SIMULATION)	

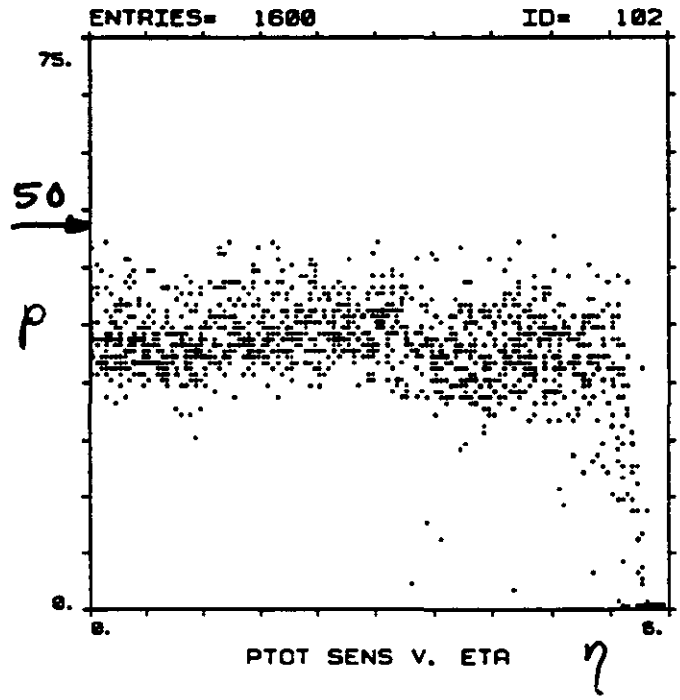
50 GeV PIONS

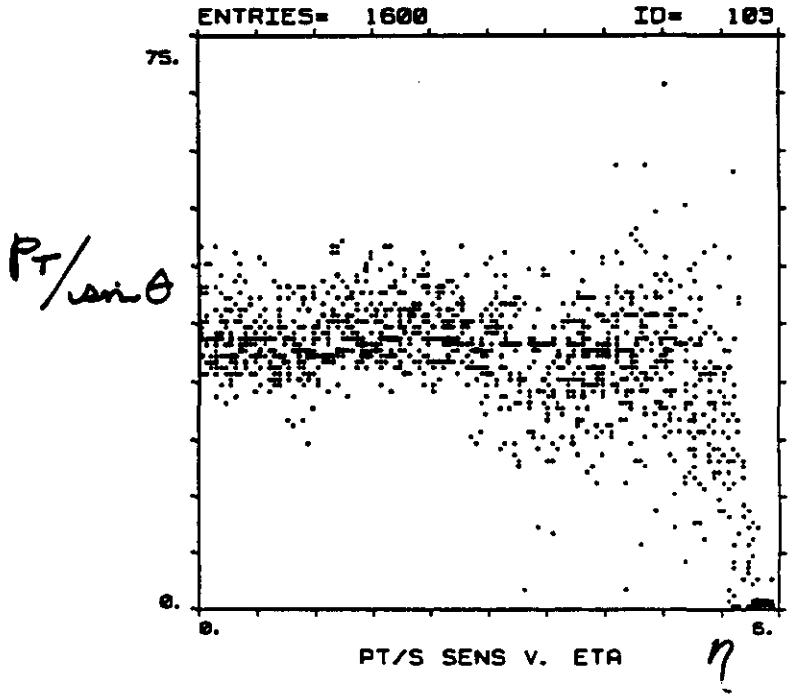
ALL VOLUMES





ACTIVE VOLUMES





(NO SMEARING)

NOTES ON P VS η AND P_t/mm A VS η

P VS η

$\langle P \rangle$ MEAN OF P WILL REFLECT:

1. LOSSES IN DEAD MATERIAL
2. LEAKAGE OUT BACK (PUNCHTHROUGH)
3. LEAKAGE OUT BEAM HOLE AT HIGH η
4. FOR NON-COMPENSATING CASES, LOSS OF HADRONIC COMPONENT. (BY OUR CONVENTION). } $f_{EM}(E)$ ⇓ ENERGY DEPENDENCE

⟹ CAN ALL WIGGLES BE REMOVED BY CALIBRATION ???

σ_P SPREAD OF P WILL REFLECT:

1. FLUCT. DUE TO DEAD MATERIAL
2. FLUCT. DUE TO LEAKAGE + LOSS.
3. HADRONIC ENERGY LOSS FLUCTUATIONS
4. FOR NON-COMPENSATING CASES, INTRINSIC FLUCT IN f_{EM} "+" e/h
5. FOR SMEARED CASES: σ_{EM}, σ_{HAD}

[NO NOISE OR CONSTANT TERM SMEARING ADDED IN CURRENT PLOTS.]

NOTES 2

$\boxed{P_T/\sin\theta \text{ VS } \eta}$

$\langle P_T \rangle$ MEAN

① WILL SEE SAME EFFECTS AS P VS η. CURVES WILL TEND TO COINCIDE.

② WILL FALL BELOW P VS η WHERE THERE IS P_t CROSSOVER.

NOTE: 2 IS A GEOMETRICAL EFFECT, AND CANNOT BE "CALIBRATED AWAY". CAN IT BE CORRECTED FOR ?? MAY DEPEND ON THE PHYSICAL PROCESS. (SMALL IN BASELINE II).

SPREAD

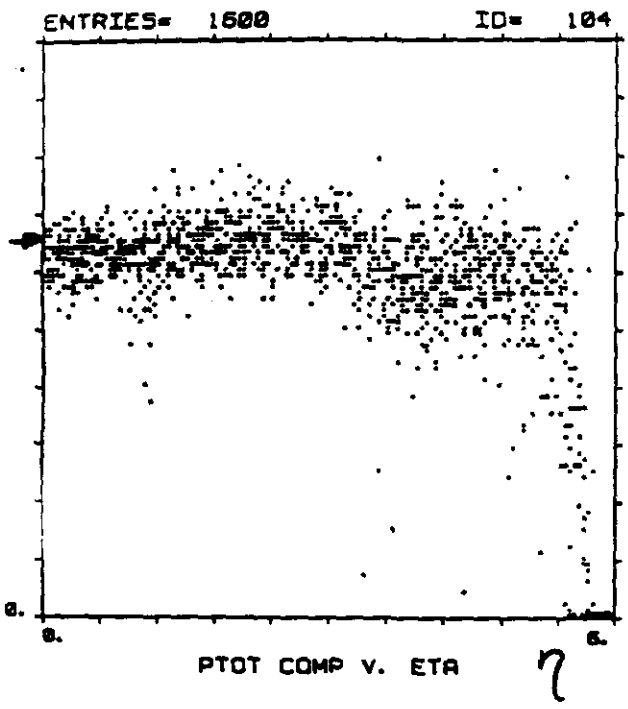
① COINCIDES WITH σ_p AT $\eta = 0$

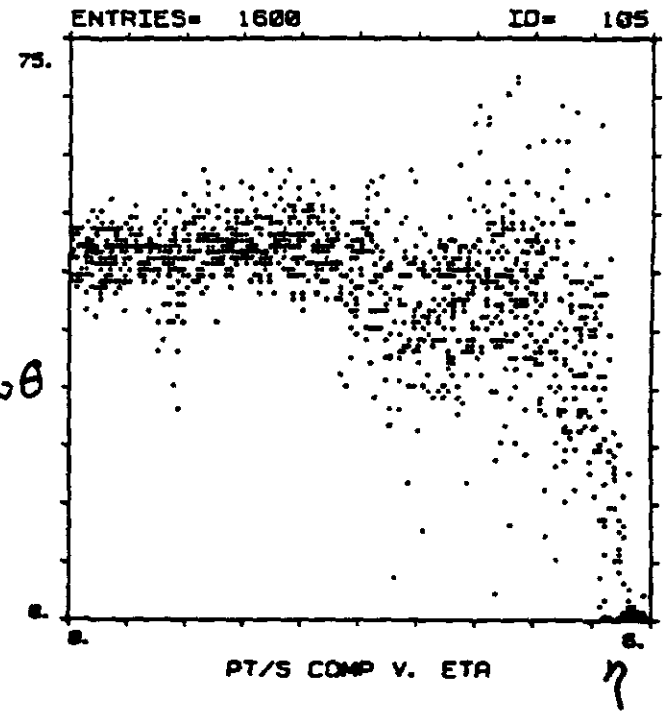
② GETS LARGER AT HIGH η AS $\delta\theta/\theta$ BEGINS TO DOMINATE.

→ INTRINSIC TRANSVERSE SHOWER DEVELOPMENT FLUCTUATIONS LEAD TO A CONSTANT TERM. (NOT PARTICULARLY MATERIAL SENSITIVE W, Cu)

50 GeV PIONS

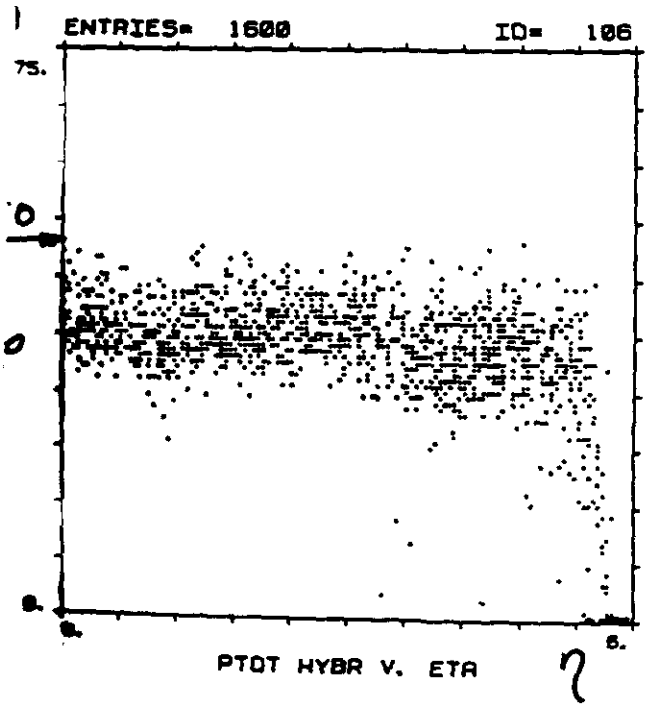
COMPENSATING CALORIMETER

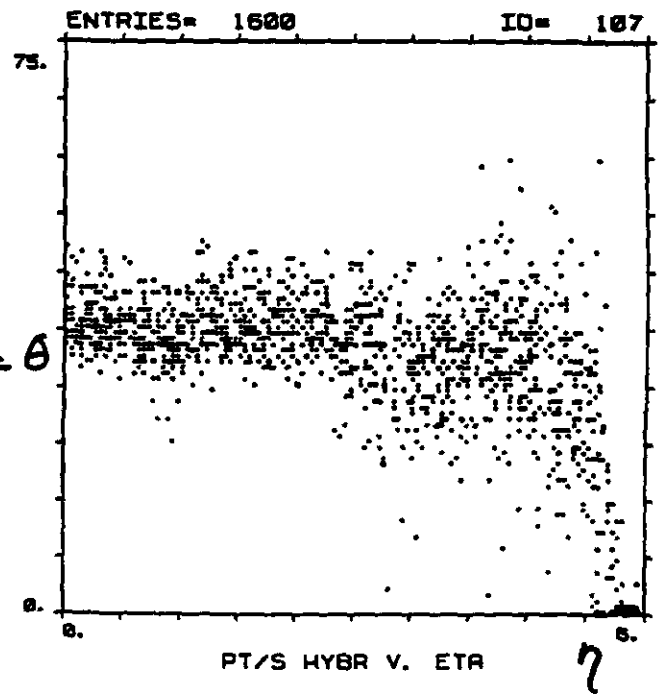




$P_T/\sin\theta$

BASELINE II



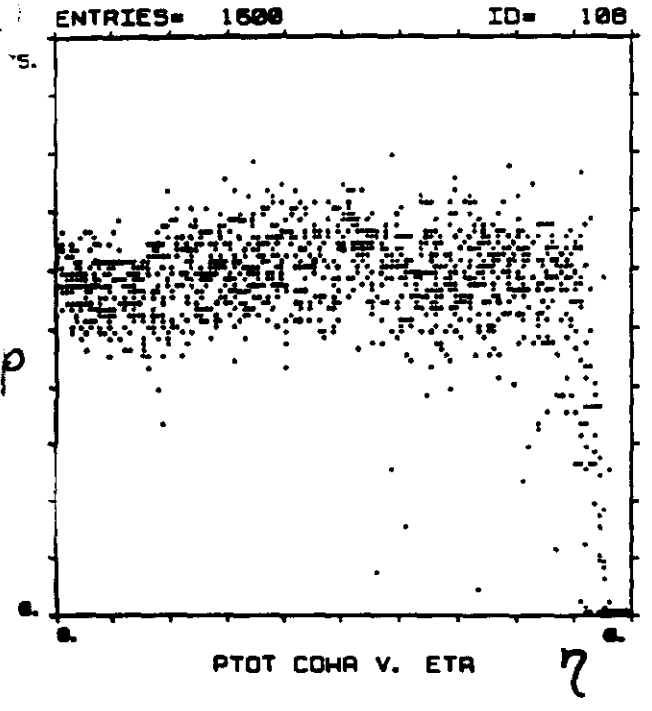


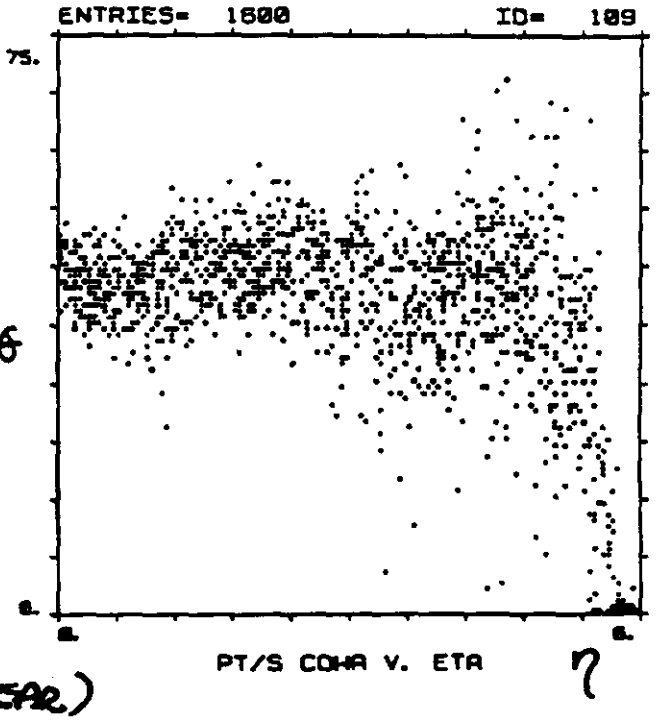
$P_T/\sin\theta$

(NO SMEARING)

50 GeV PIONS

EM ACCORDION + COMP HADRONIC

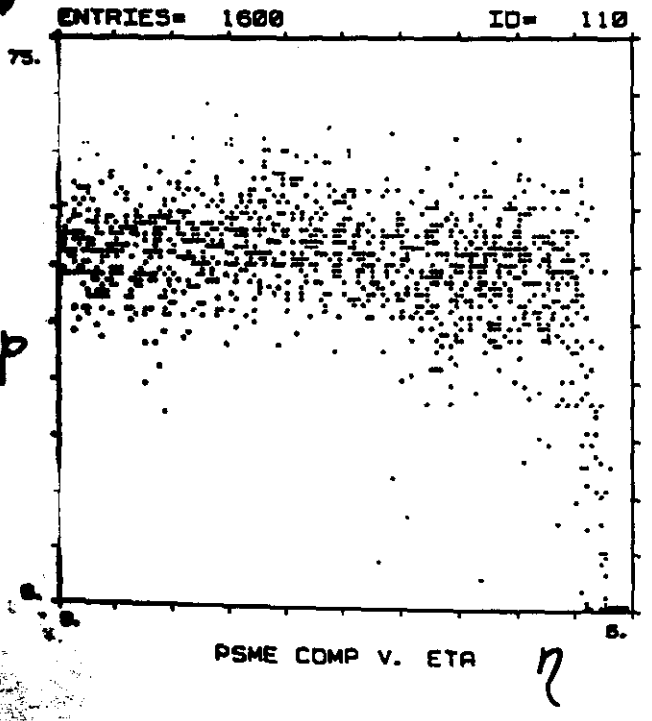


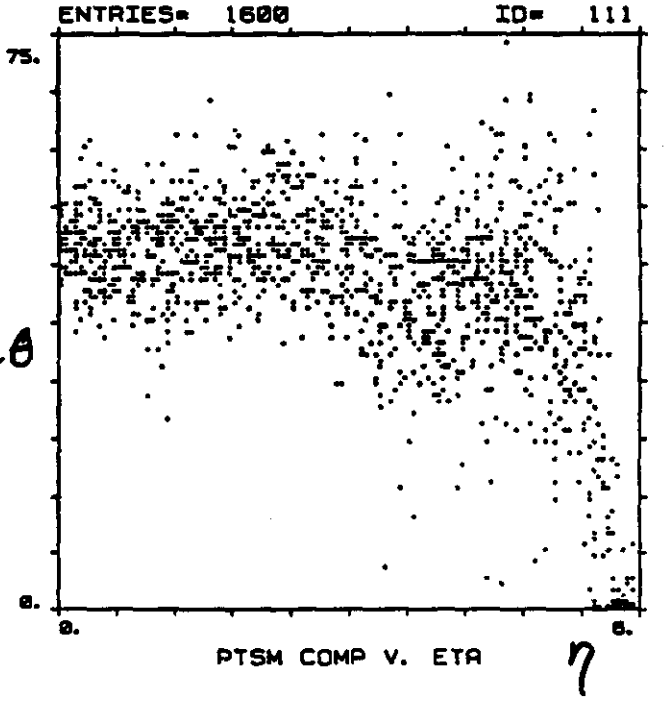


p $\quad$ $p_T/\sin\theta$

(NO SMEAR)

COMPENSATING





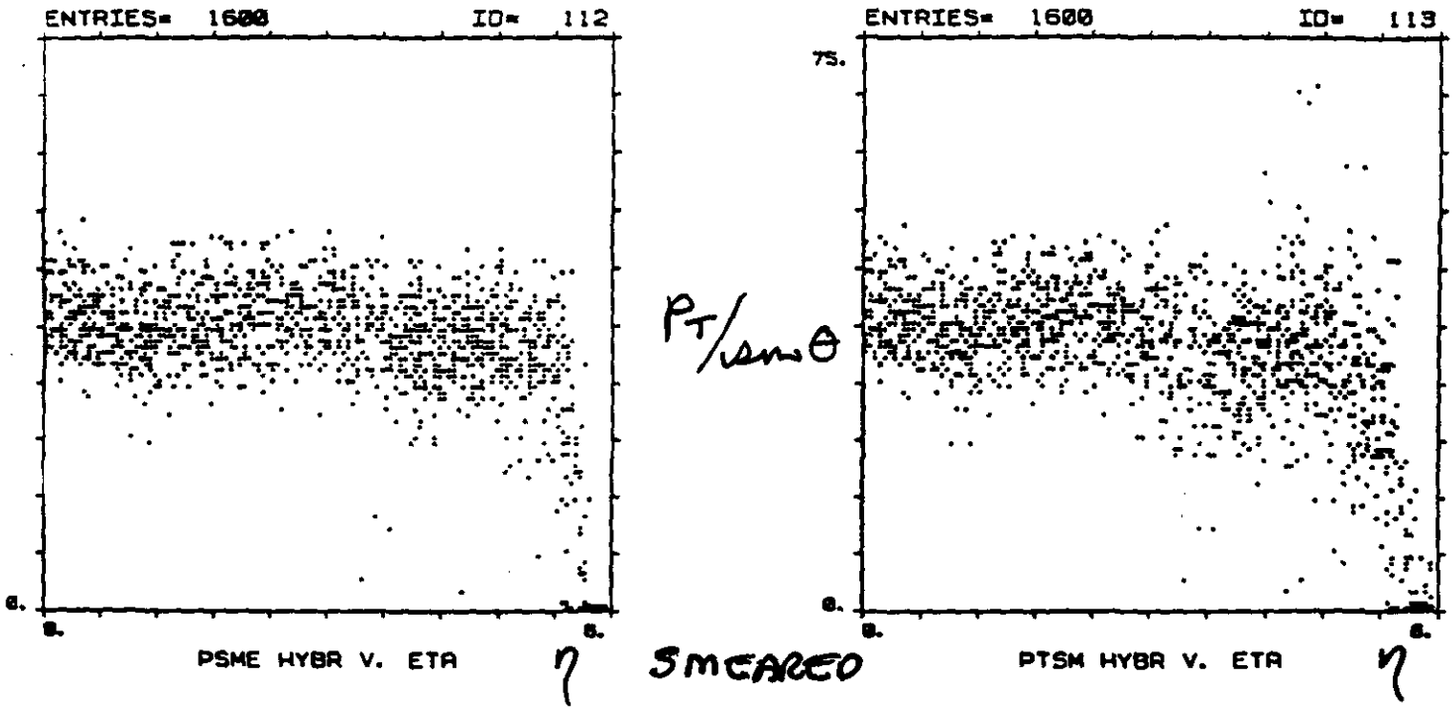
p $\quad$ $p_T/\sin\theta$

SMEARED

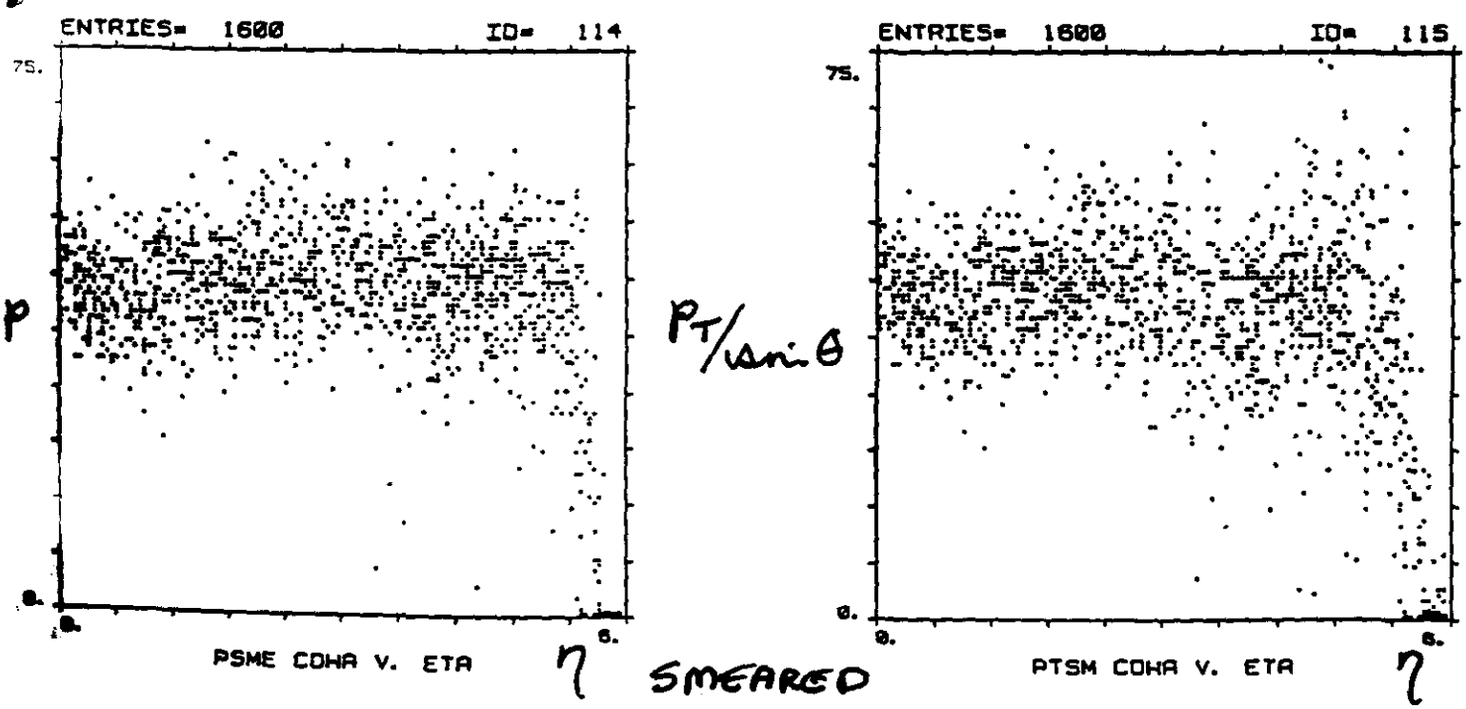
$(\sigma_{EM}, \sigma_{HAD})$

50 GeV PIONS

BASELINE II

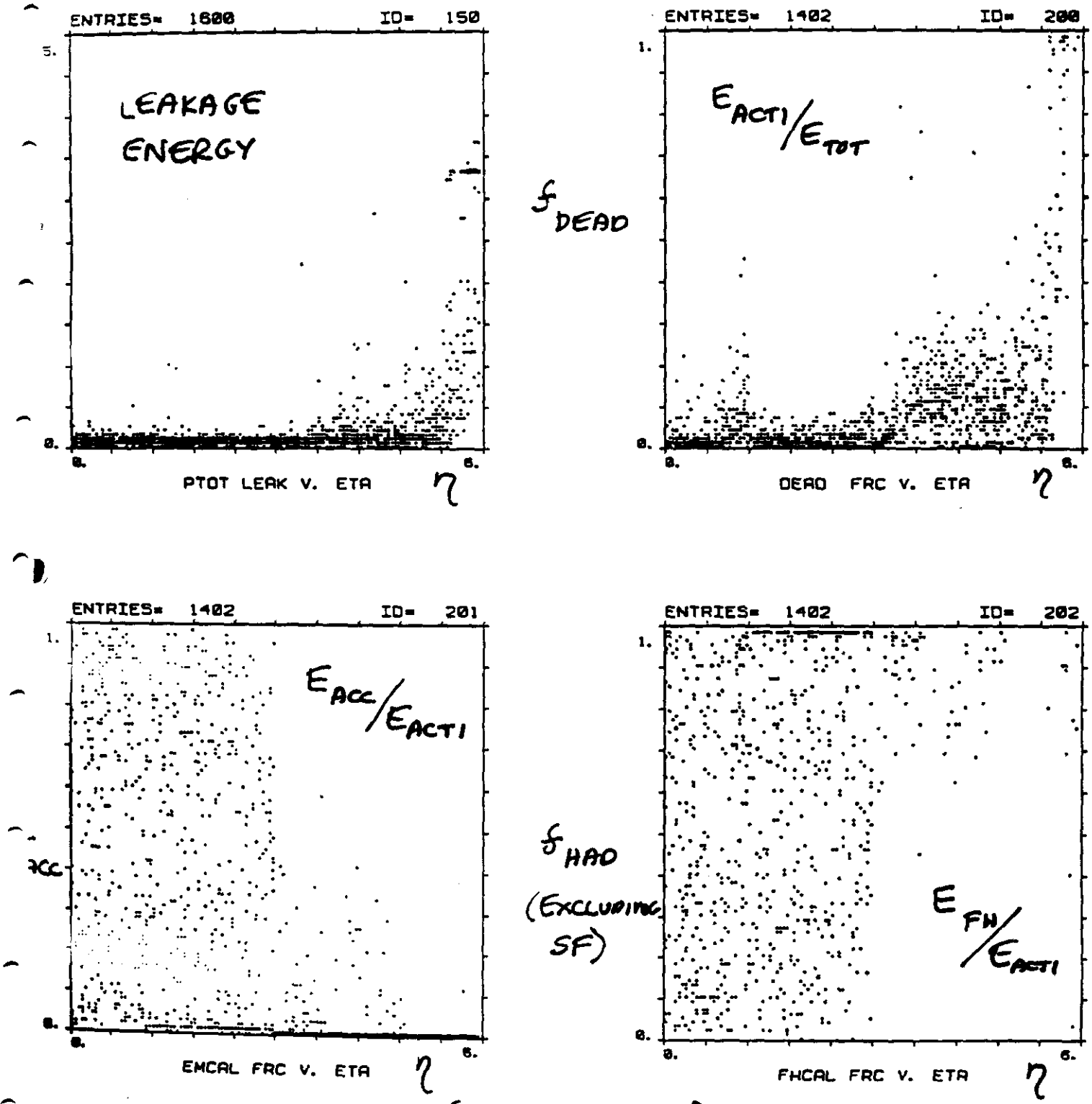


EM ACC. & COMP. HAD.



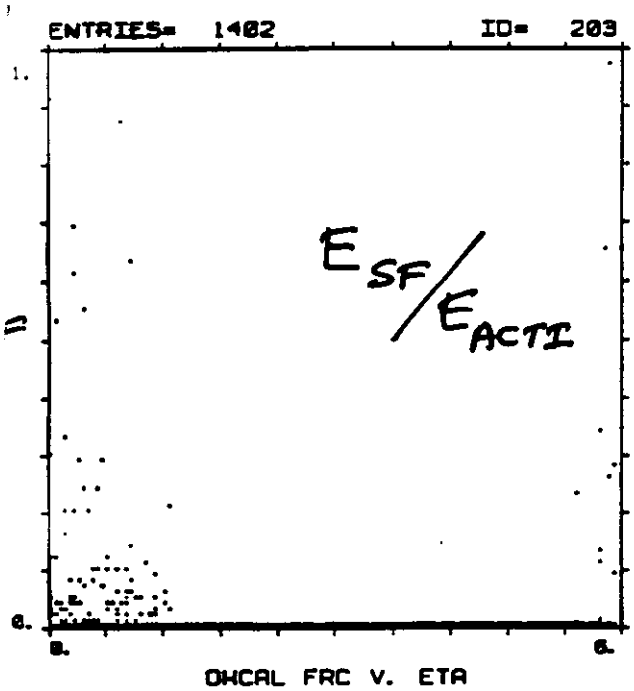
50 GeV PIONS

(FROM ALL + ACTIVE VOLUMES)



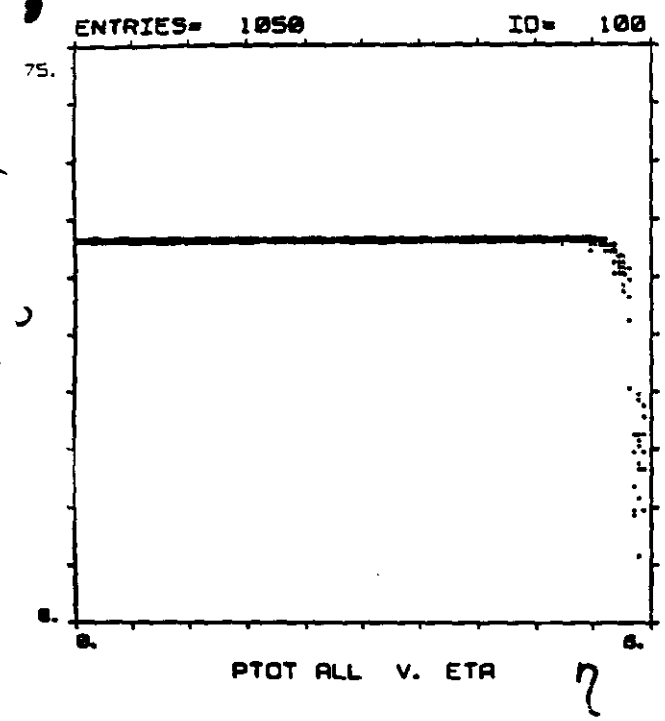
(NO SMEARING)

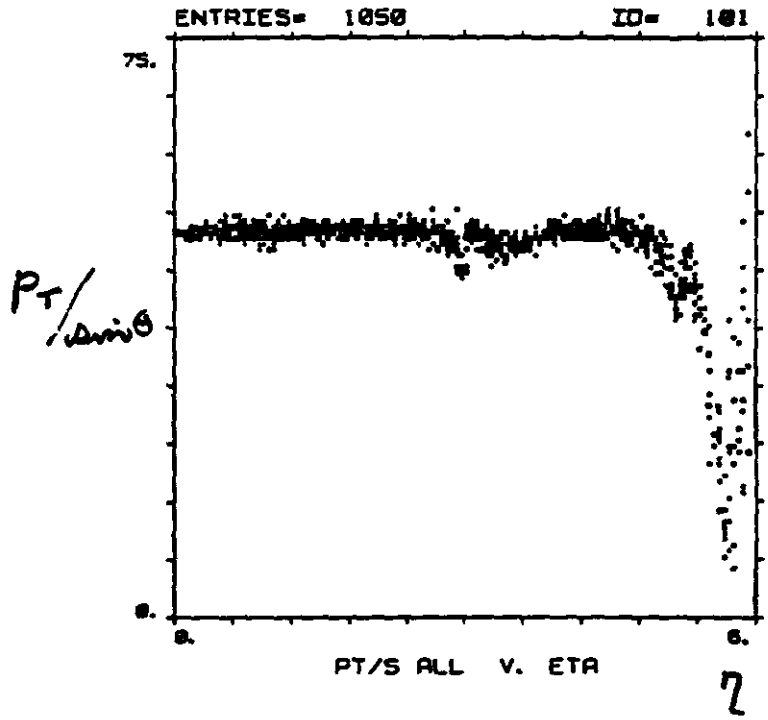
50 GeV PIONS



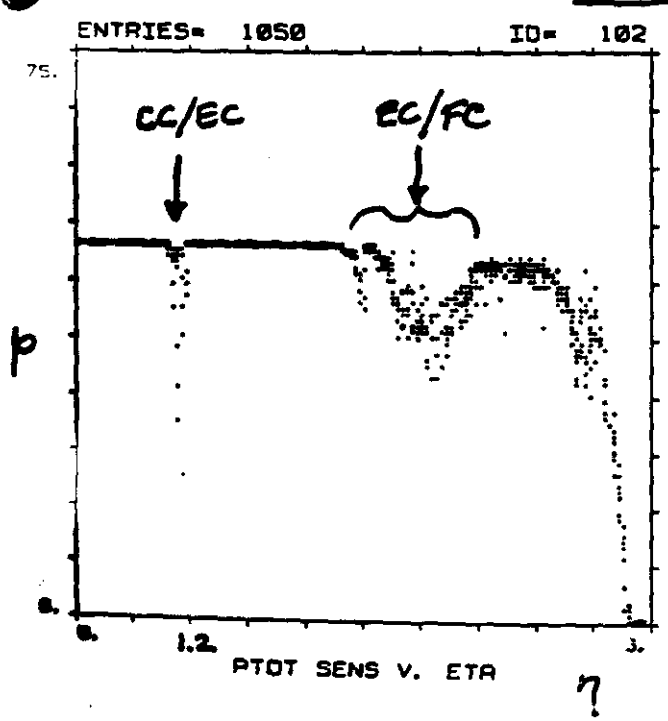
50 GeV ELECTRONS

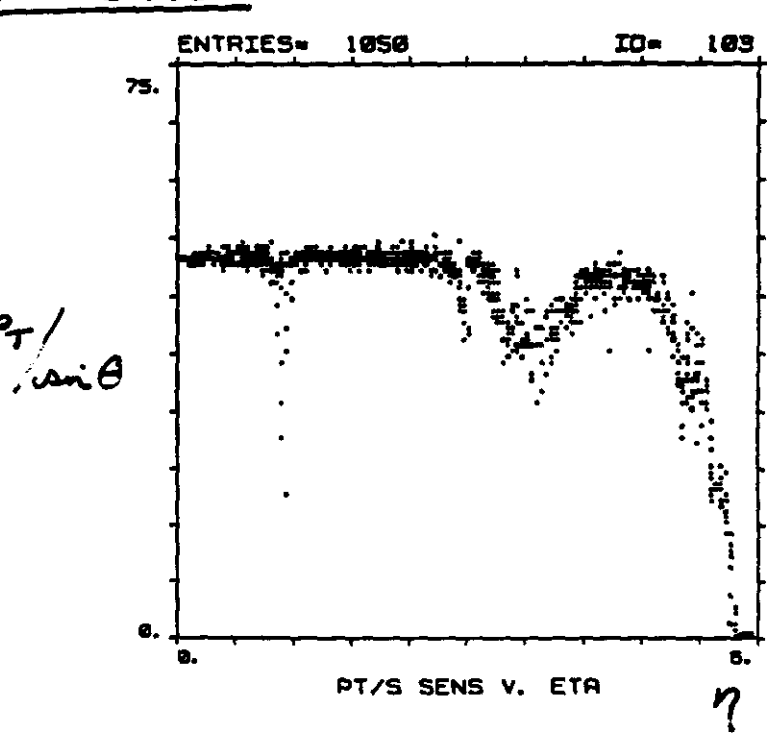
ALL VOLUMES





ACTIVE VOLUMES

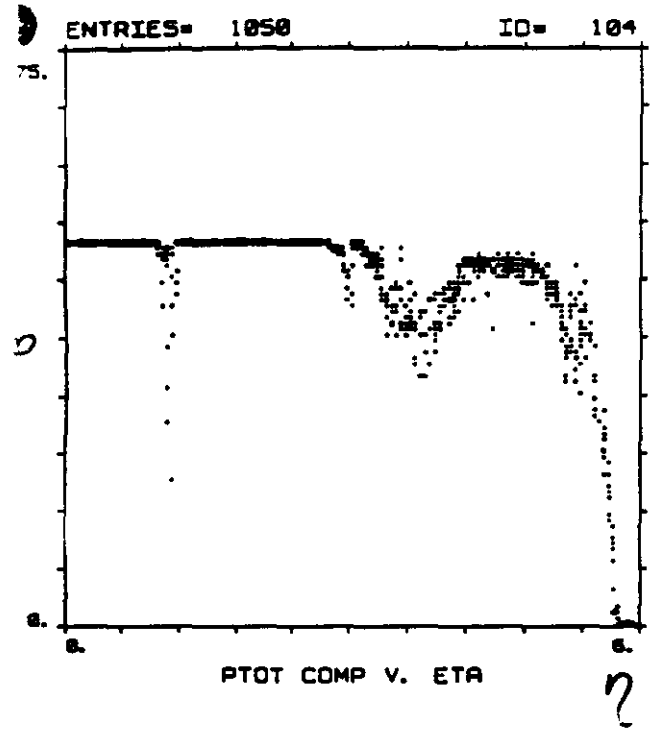




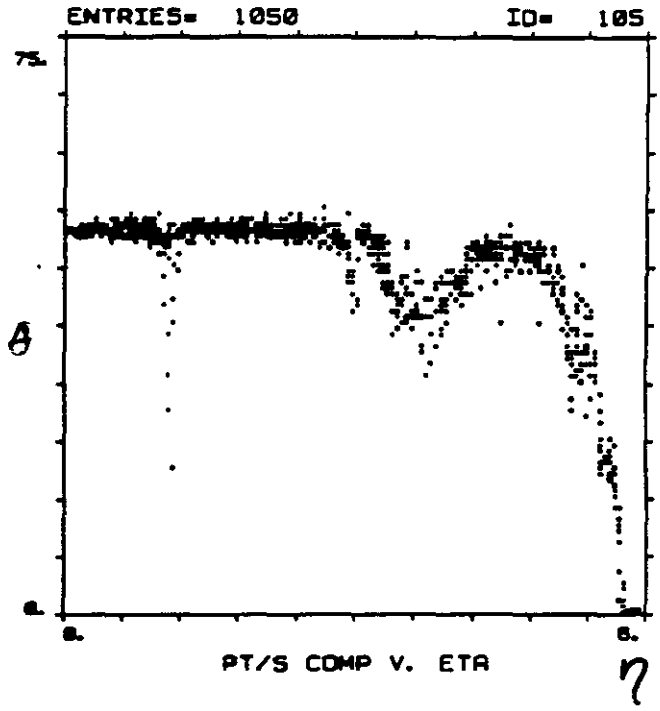
(NO SMEARING)

50 GeV ELECTRONS

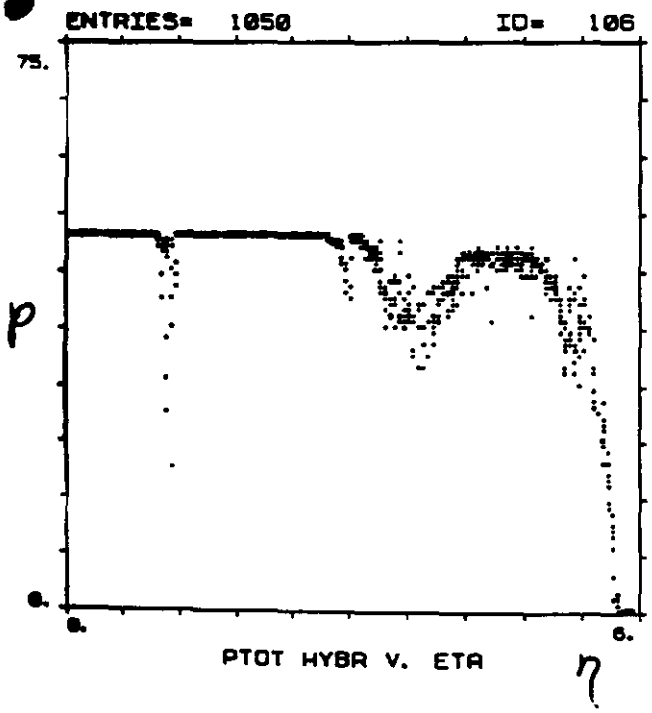
COMPENSATING DETECTOR



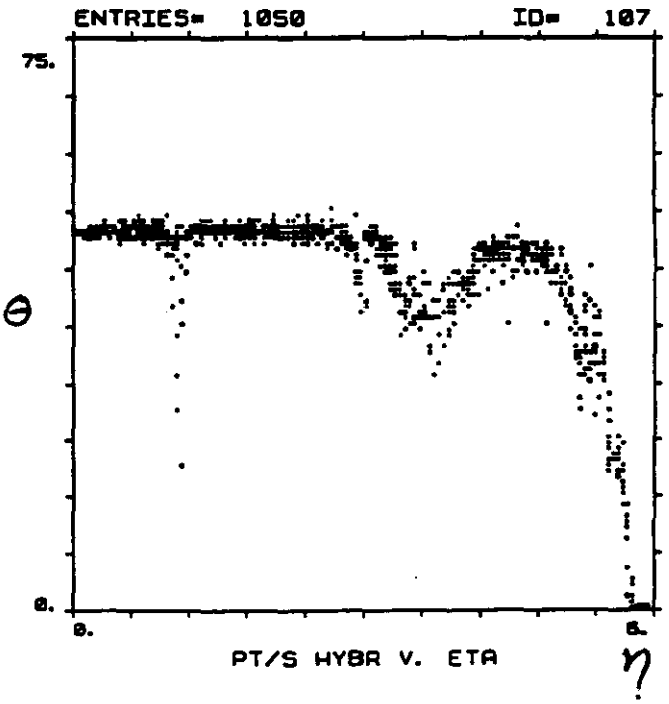
$P_T/\sin\theta$



BASELINE II



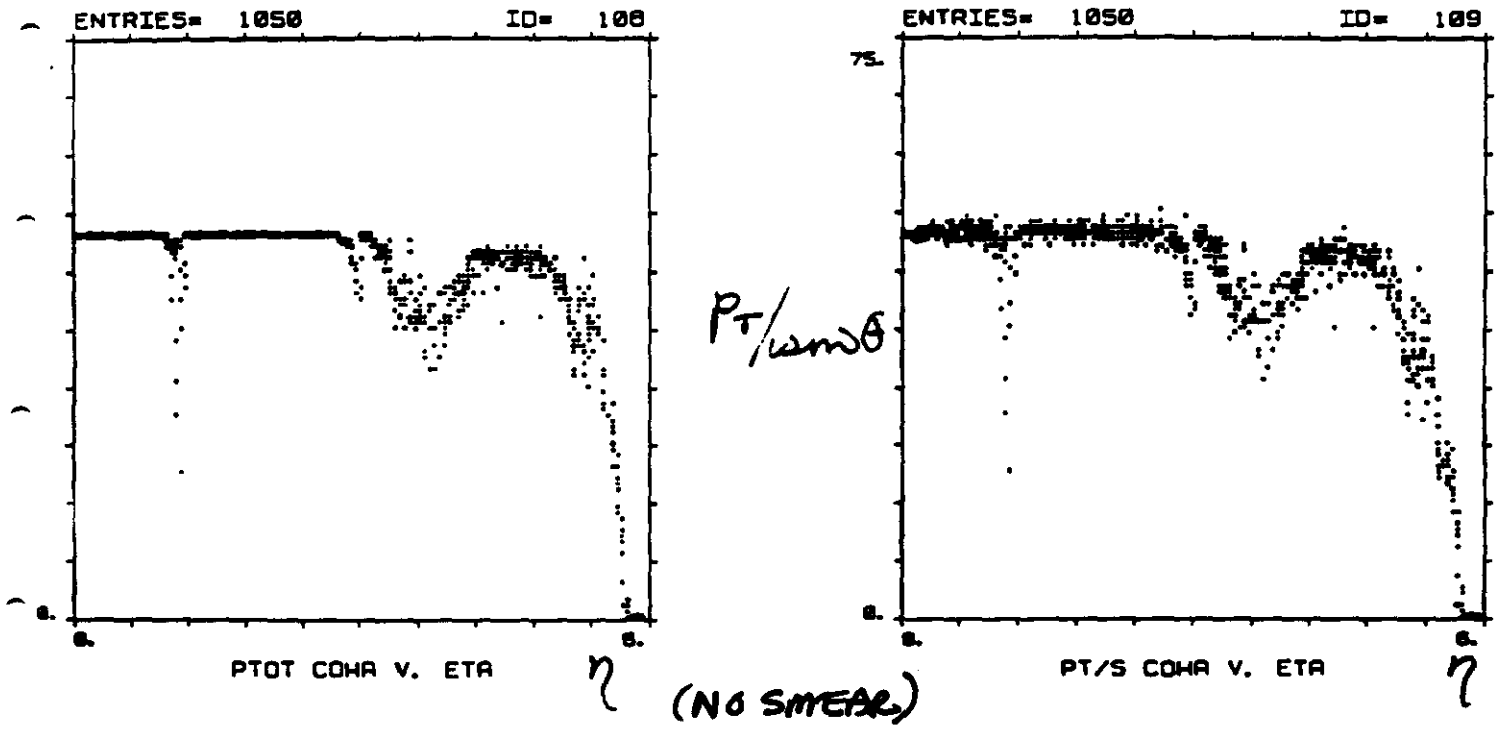
$P_T/\sin\theta$



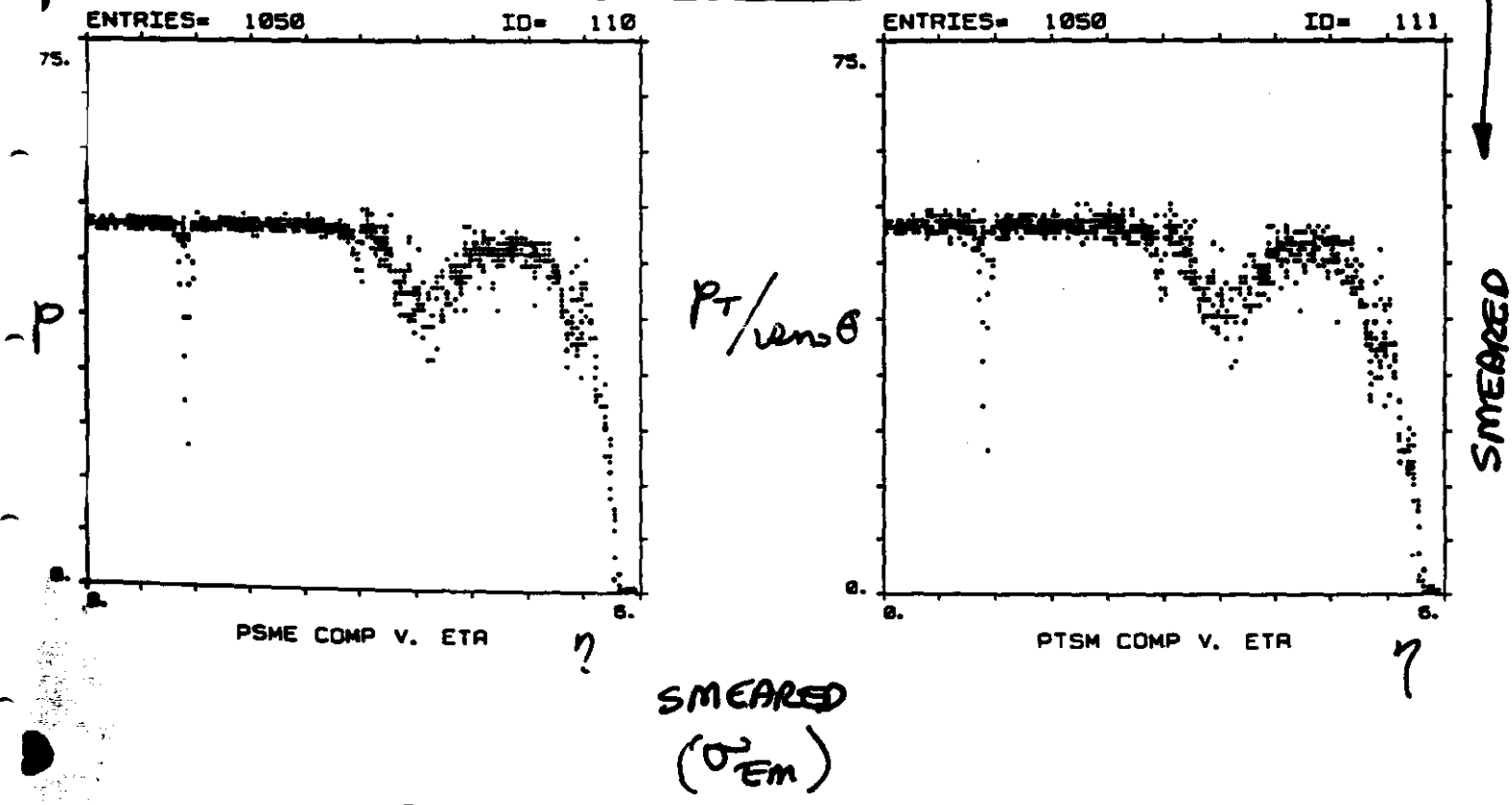
(NO SMEARING)

50 GeV ELECTRONS

EM ACCORDION + COMP. HADRONIC

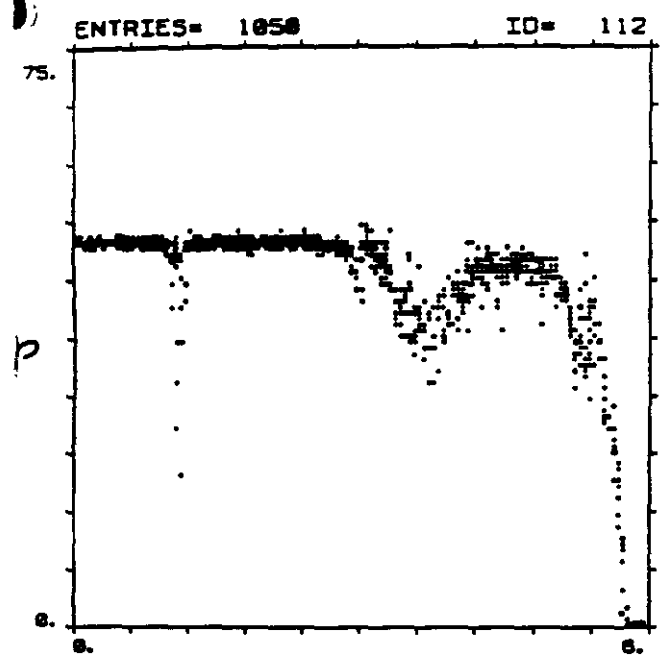


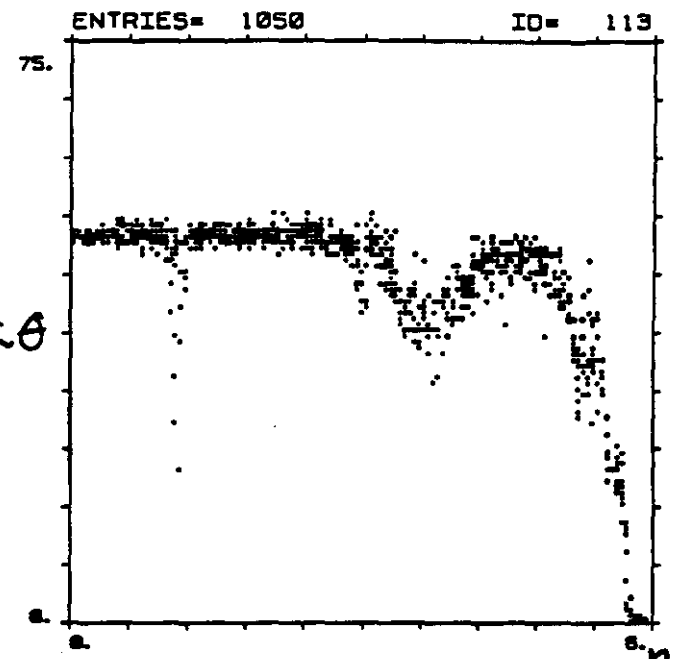
COMPENSATING



50 GeV ELECTRONS

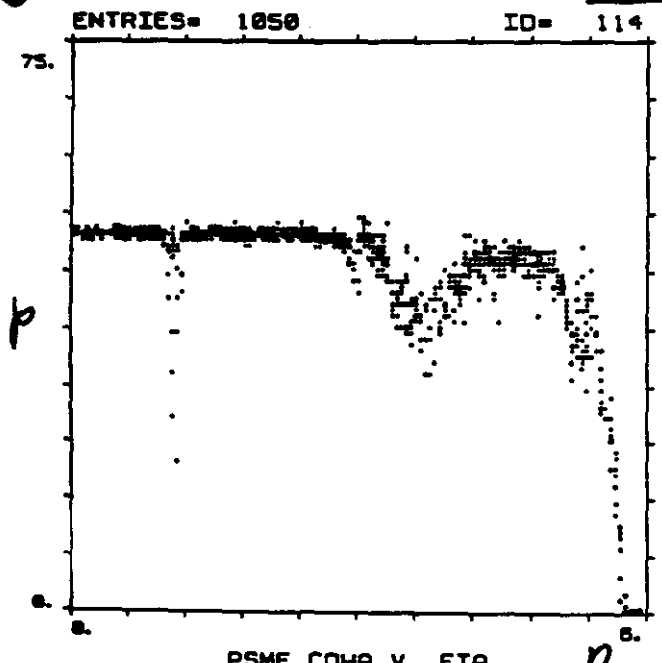
BASELINE II

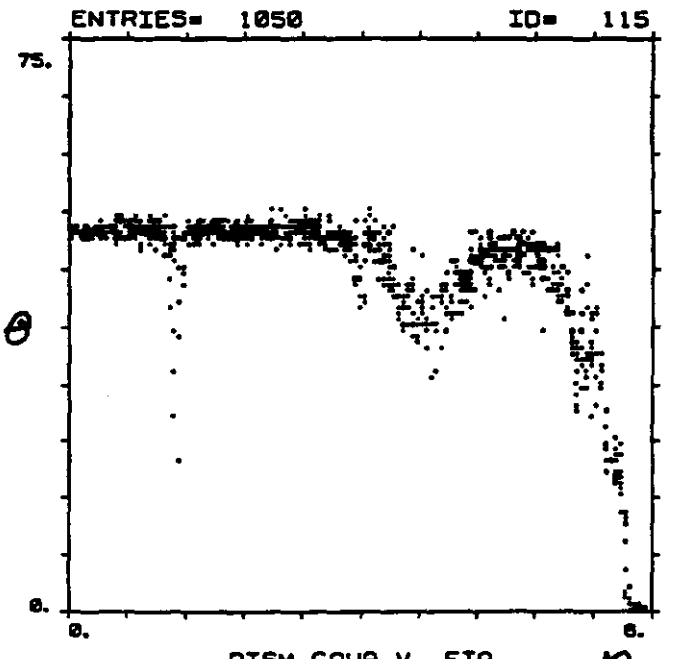




$P_T/\sin\theta$ SMEARED

EM. ACC + COMP. HAD.

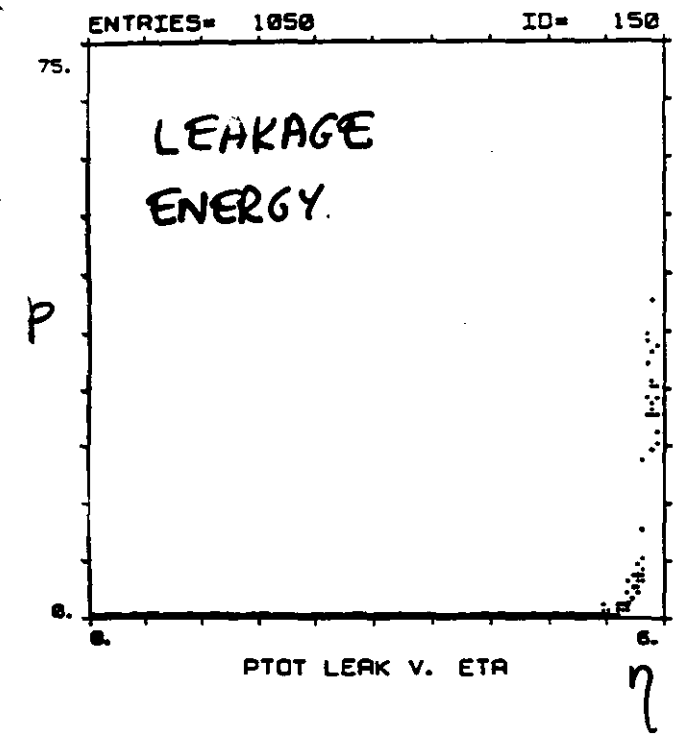


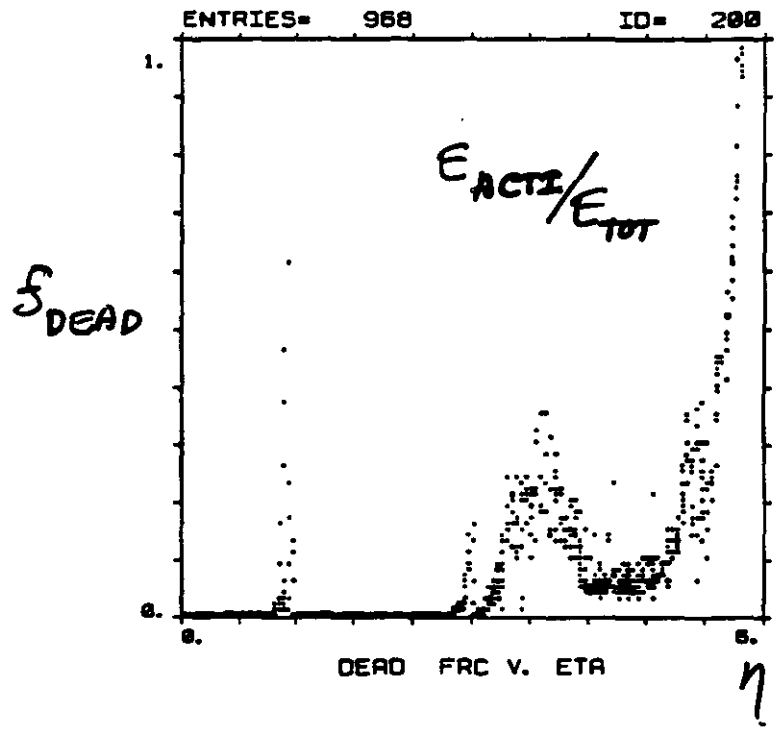


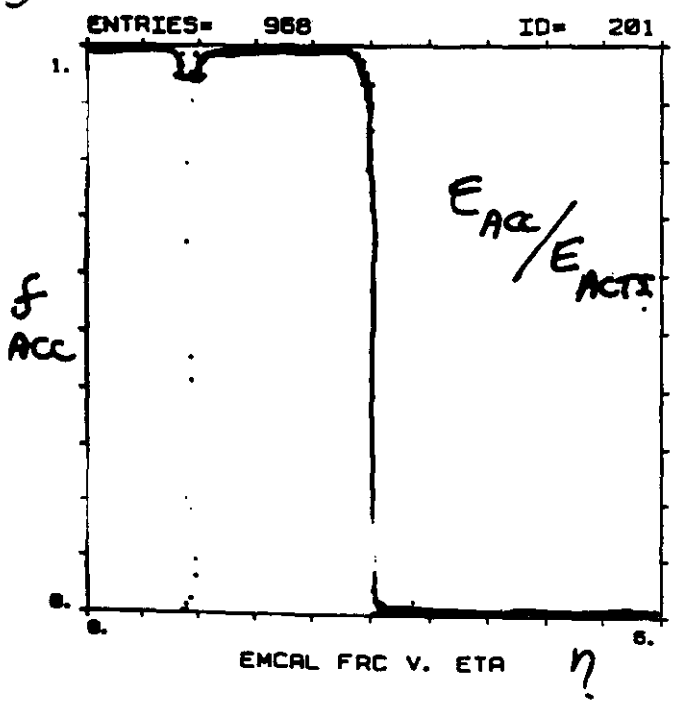
$P_T/\sin\theta$ SMEARED

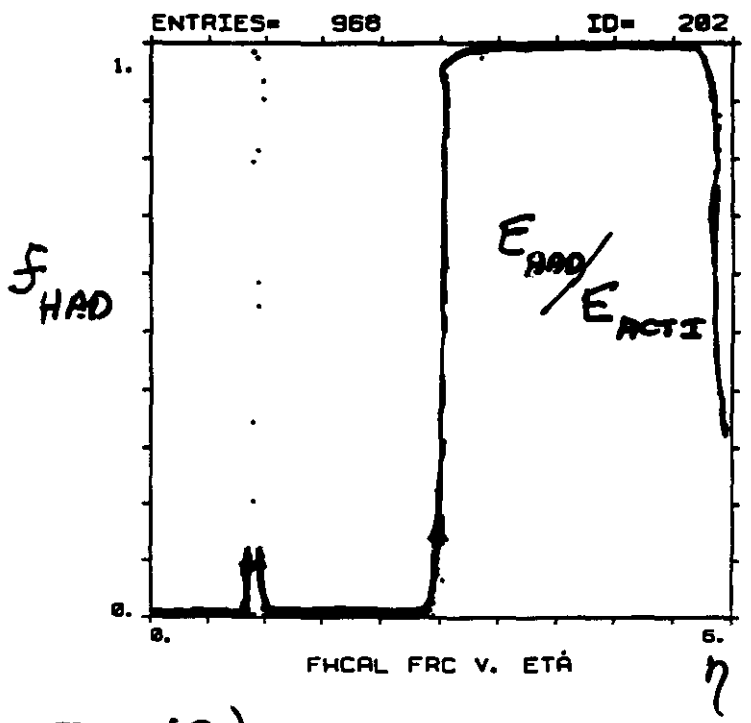
50 GeV ELECTRONS

(FROM ALL + ACTIVE VOLUMES)









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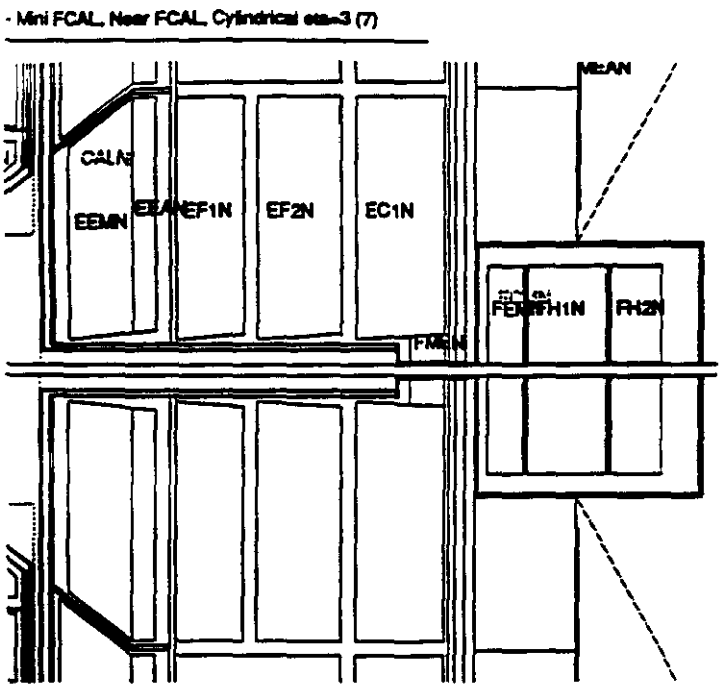
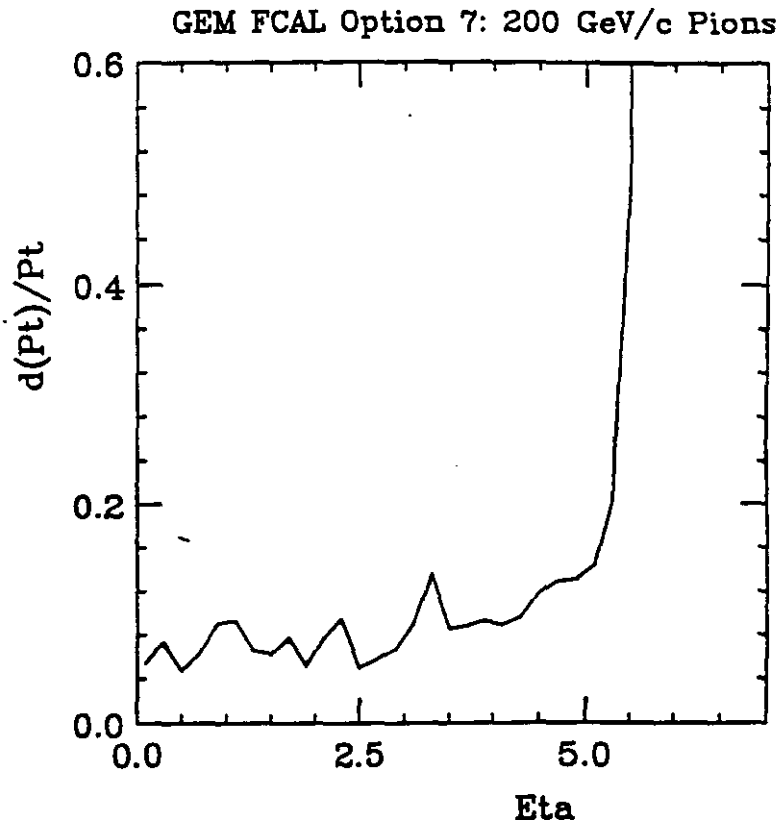
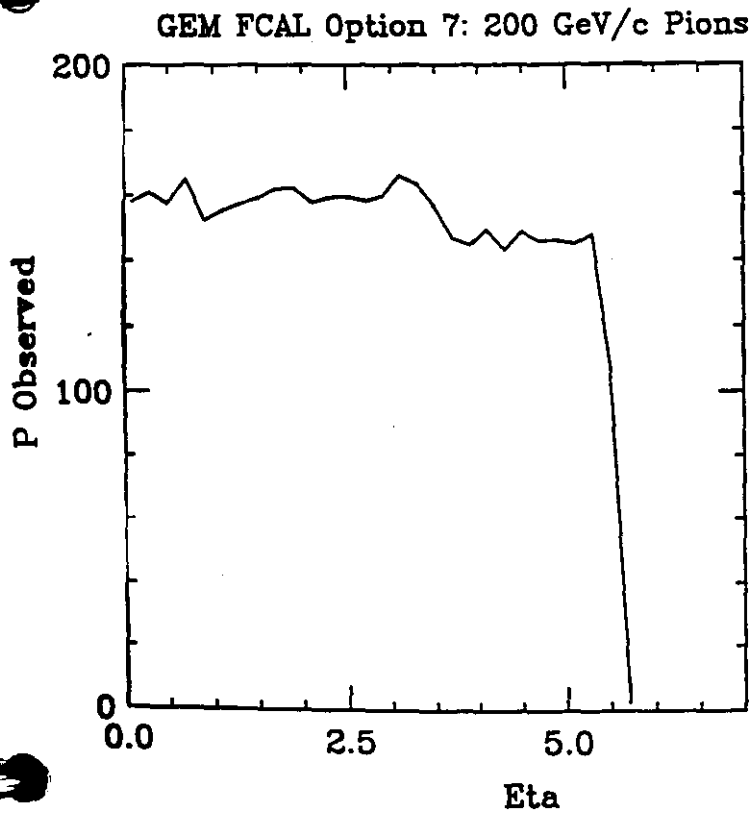
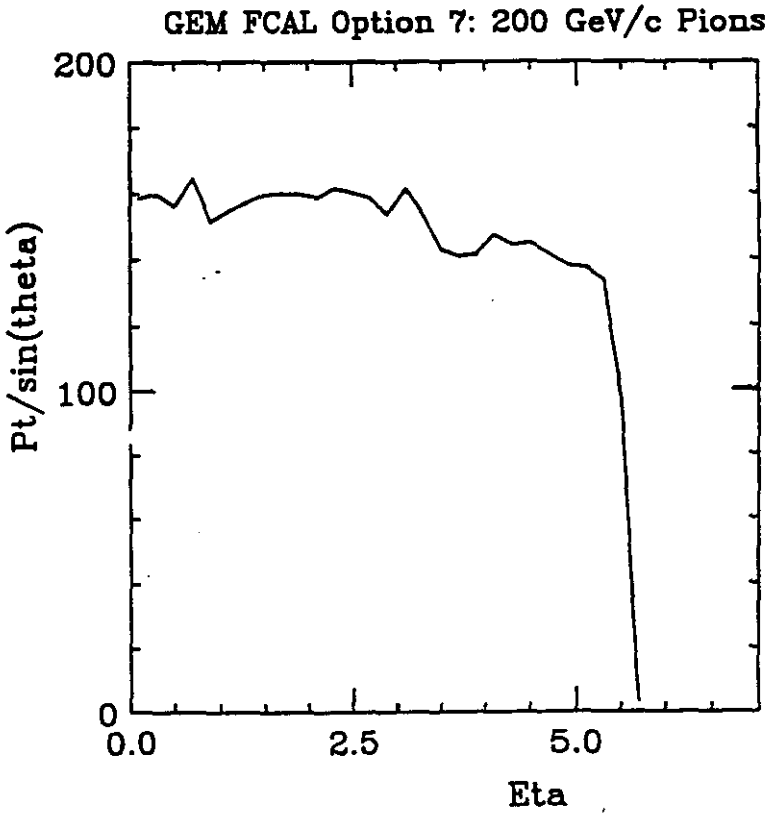
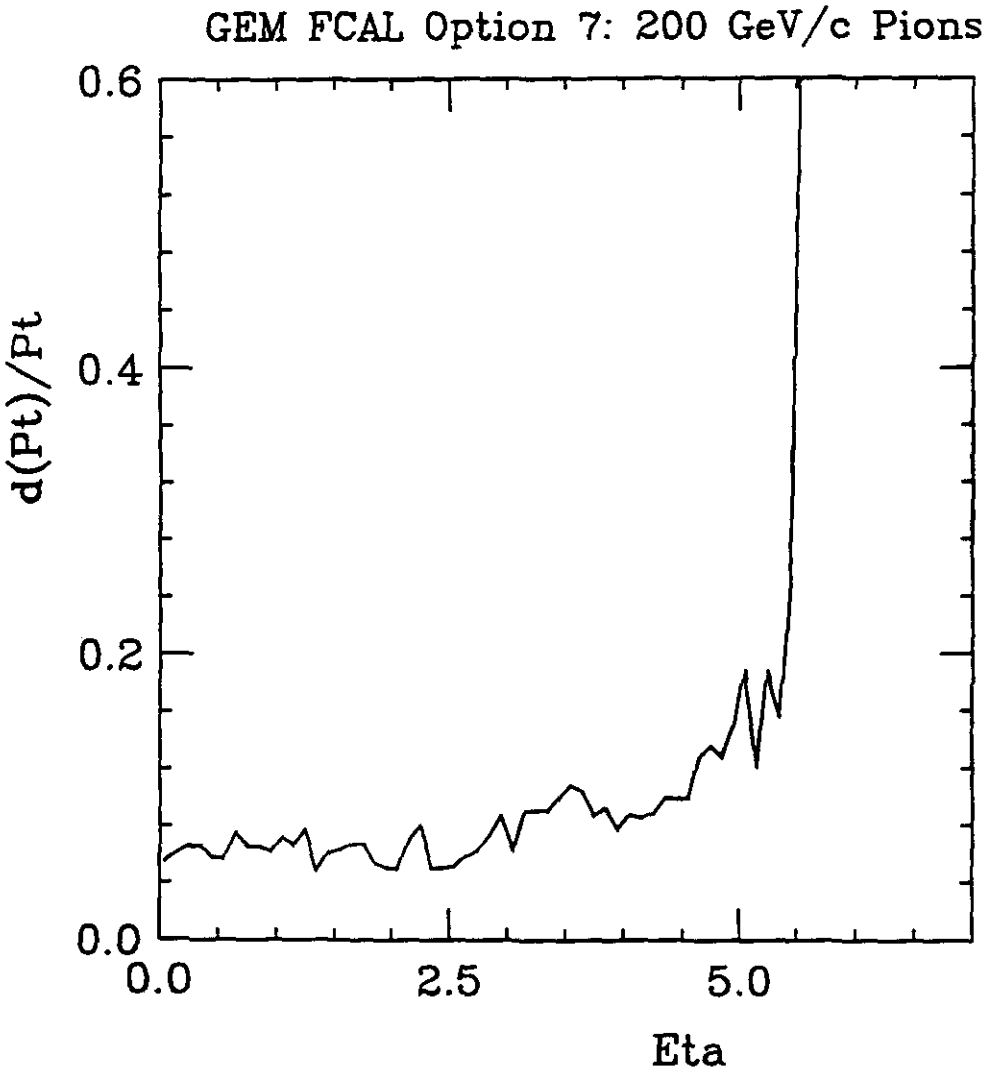
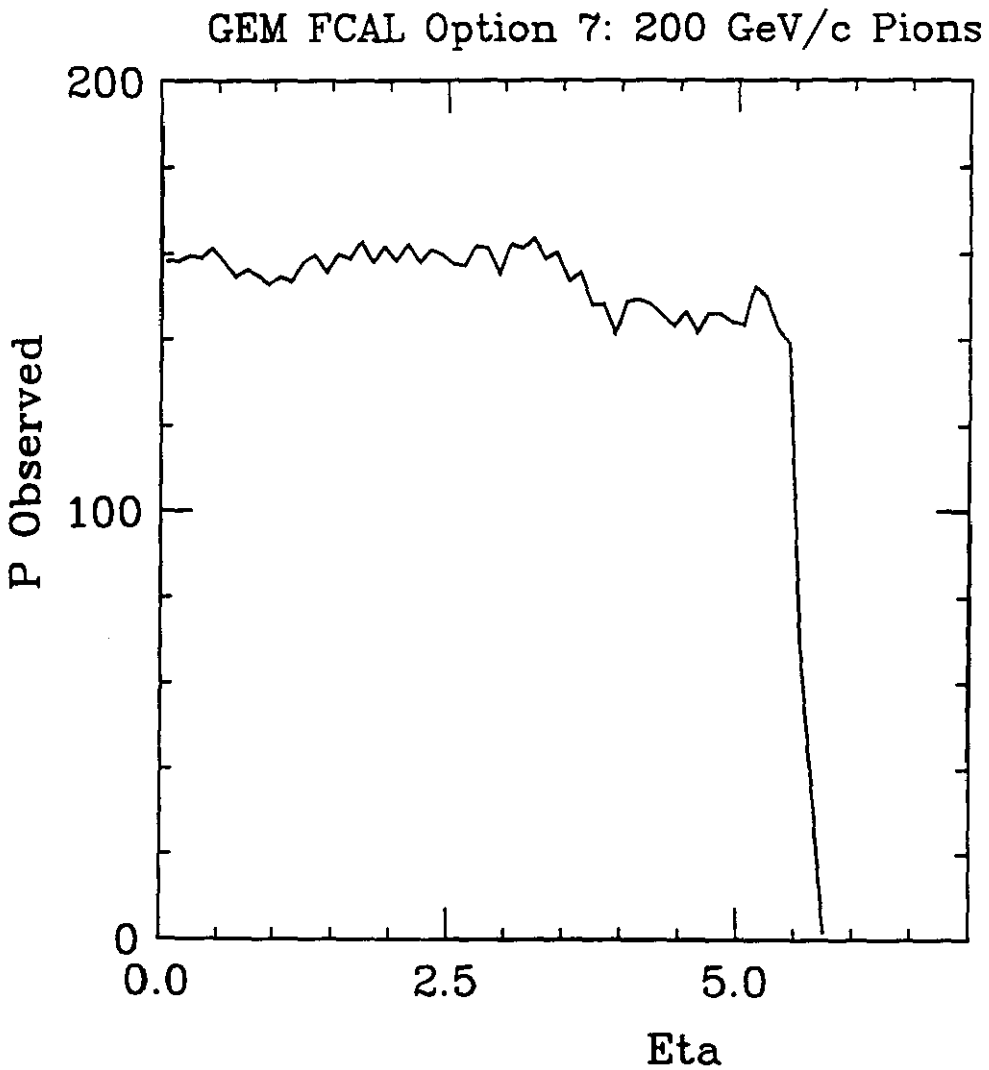

Mini FCAL, Near FCAL, Cylindrical eta=3 (7)
CALN
EEMN
EEAN
EF1N
EF2N
EC1N
FH1N
FH2N


GEM FCAL Option 7: 200 GeV/c Pions
d(Pt)/Pt
0.0
0.2
0.4
0.6
0.0
2.5
5.0
Eta

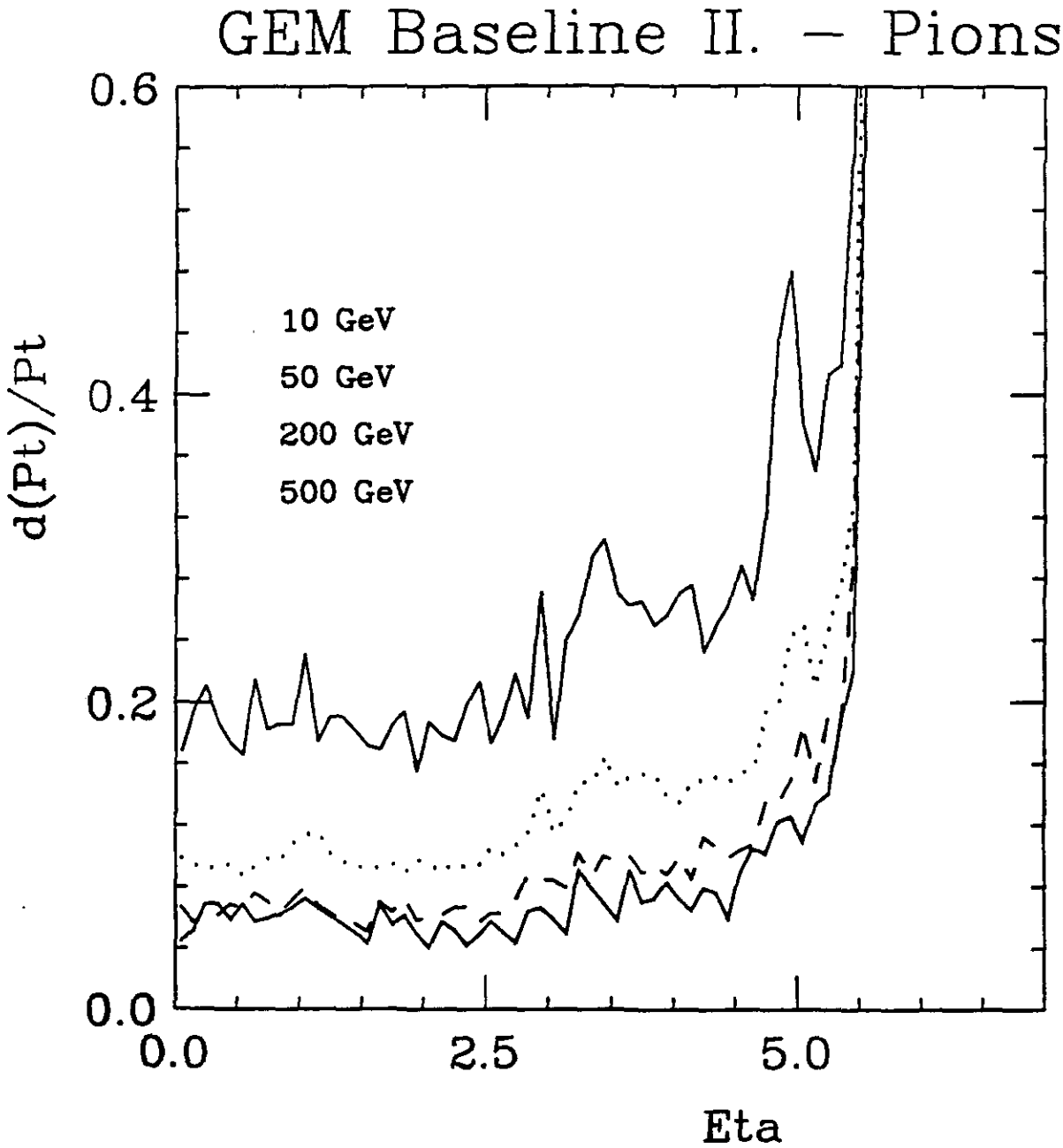

GEM FCAL Option 7: 200 GeV/c Pions
P Observed
0
100
200
0.0
2.5
5.0
Eta


GEM FCAL Option 7: 200 GeV/c Pions
Pt/sin(theta)
0
100
200
0.0
2.5
5.0
Eta

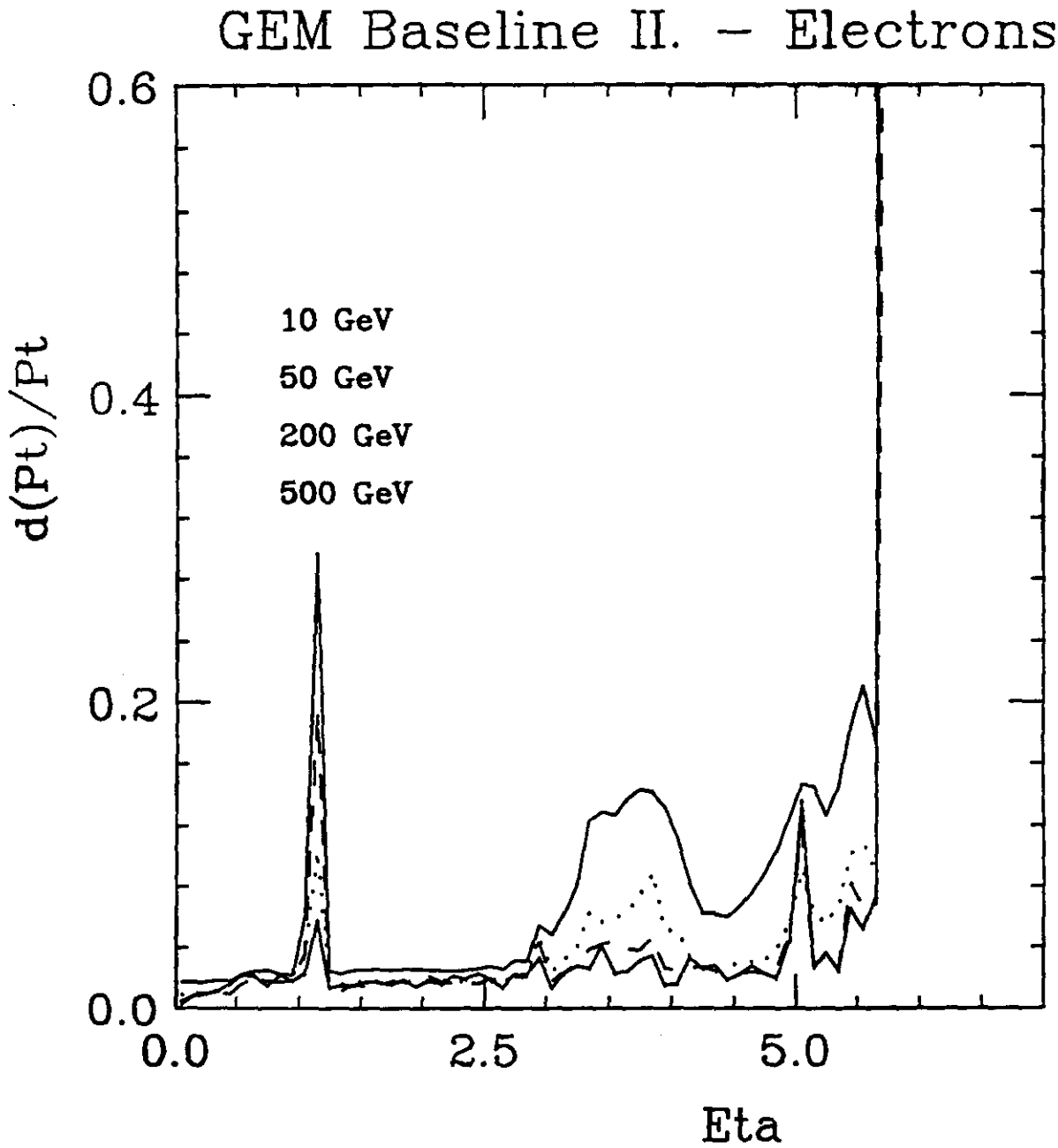

GEM FCAL Option 7: 200 GeV/c Pions
0.6
0.4
0.2
0.0
d(Pt)/Pt
0.0
2.5
5.0
Eta


GEM FCAL Option 7: 200 GeV/c Pions
200
100
0
P Observed
0.0
2.5
5.0
Eta

CURRENTLY IN FCSMEAR



CURRENTLY IN FCSMEAR



$\eta = \phi$
NOT FCAL

ENERGY DEPENDENCE STUDIES

WEIGHTING FOR GODOT?

TO LOOK AT THE EFFECTS OF NON-COMPENSATION, ENERGY SCANS AT $\eta = 0$ WERE MADE AT 10, 50, 200 AND 500 GeV WITH (1) PIONS AND (2) JETS.

THE RESULTS FOR PIONS:

	STOCHASTIC TERM	CONSTANT TERM
UNSMEARED		
FULLY COMPENSATING	.29 ± .01	* .021 ± .001
BASELINE II	.39 ± .01	.053 ± .002
COMP HADRONIC	.53 ± .02	.031 ± .002
SMEARED		
FULLY COMPENSATING	.71 ± .02	.011 ± .004
BASELINE II	.64 ± .02	** .058 ± .004
COMP HADRONIC	.74 ± .02	.023 ± .004

COMMENTS

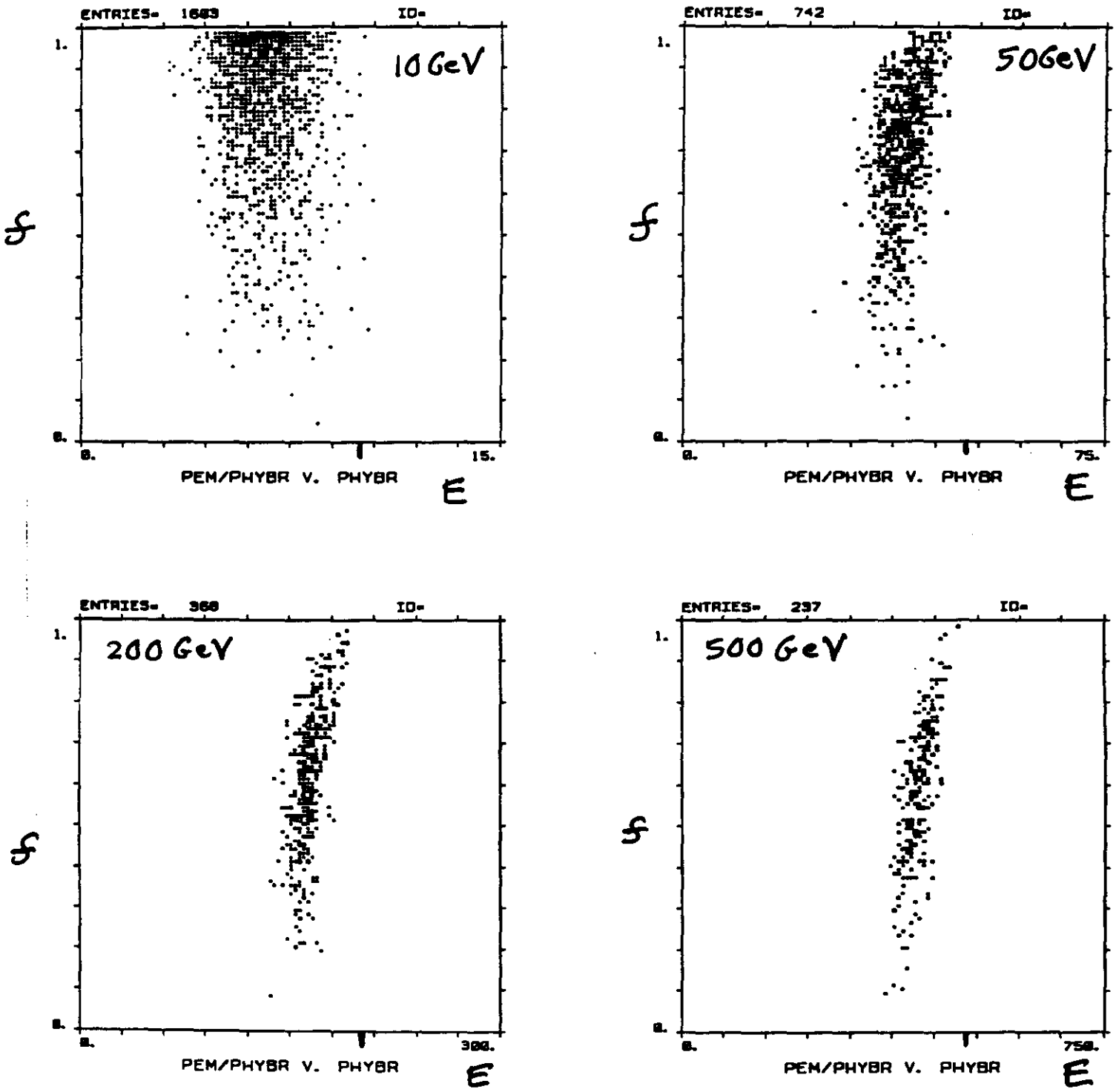
* EXHIBITS SOME FIT INSTABILITY (TRADEOFF IN STOCH/CONST)

** 6% IS BIG! JET STUDY IS NOT COMPLETE, BUT CORRESPONDING POINT IS 4.5% (BETTER)

⇒ MAYBE WE WILL NEED TO RELY ON A WEIGHTING SCHEME! UGH.

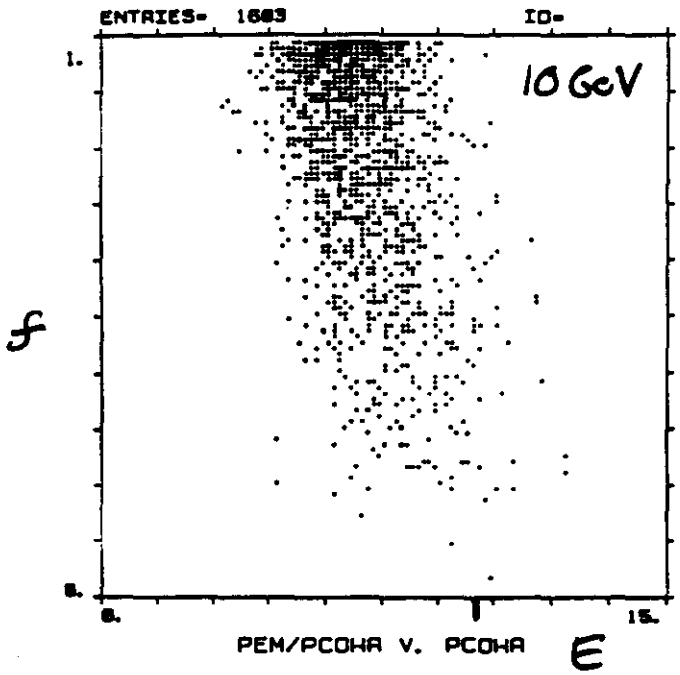
JET ENERGY SCAN AT $\eta = 0$ (JETSET)

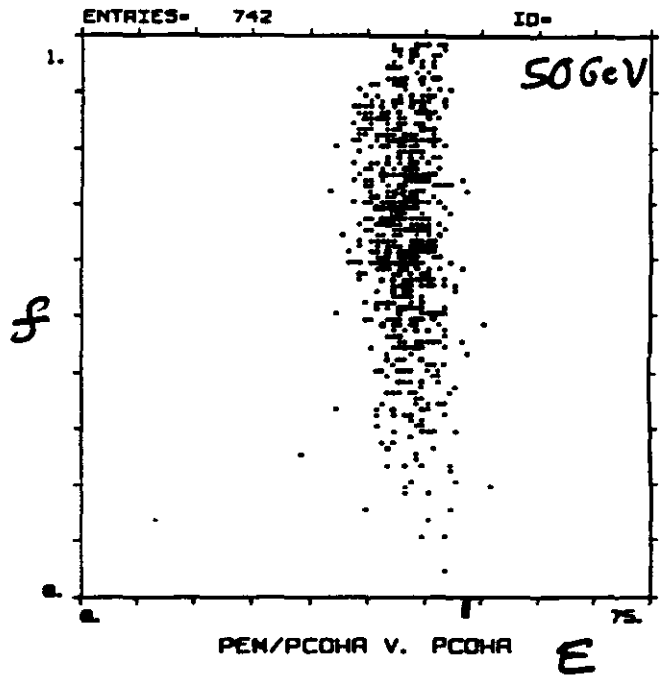
BASELINE II HYBRID

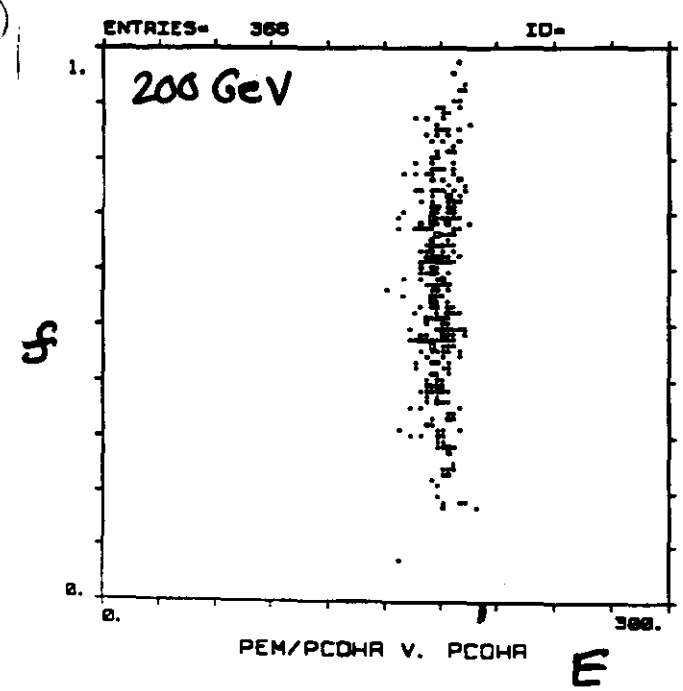


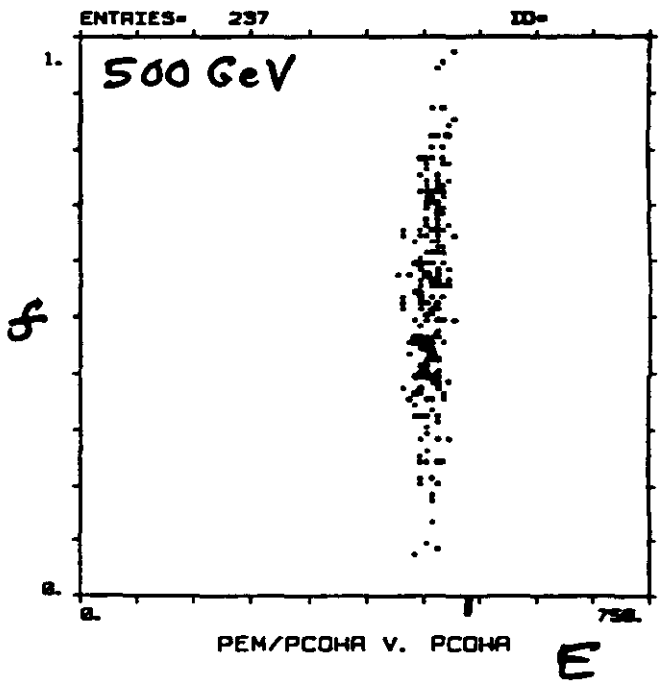
$$f = \frac{\text{ENERGY IN EM SECTION}}{\text{TOTAL ENERGY}}$$

JET ENERGY SCAN AT $\eta = 0$ (JETSET)
ACCORDION EM, FOLLOWED BY COMPENSATING HAD.









WEIGHTING SCHEME CONCLUSIONS:

- OUR CHOICE TO DO PRECISION EM CALORIMETRY HAS GIVEN US AN EM SECTION WITH POOR e/h, AS IT MUST.

- THIS CHOICE, AS WELL AS DEAD MATERIAL FLUCTUATIONS (ETC), LEADS TO A SIZEABLE CONSTANT TERM IN JET RESOLUTION IF NO WEIGHTING SCHEME IS USED.

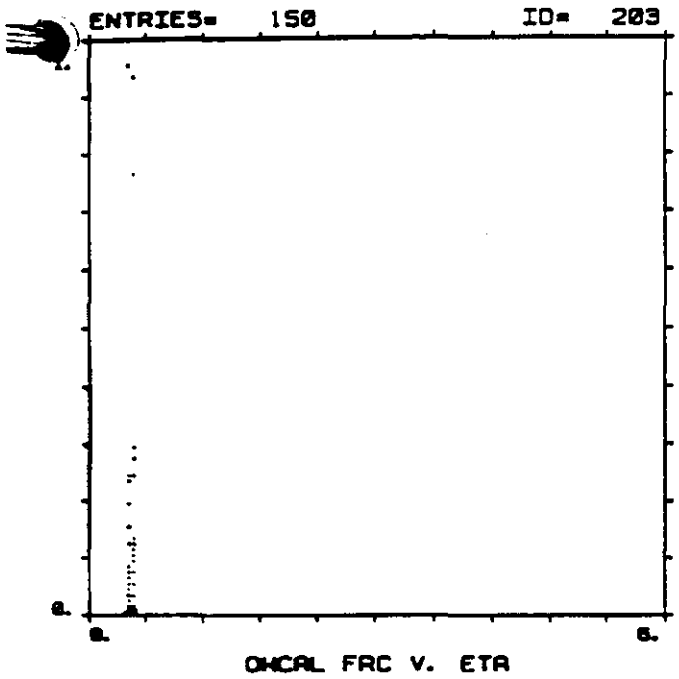
- TO REDUCE CONSTANT TERM (BY 1%, 2%?) WEIGHTING IS NEEDED WHETHER OR NOT HADRONIC SECTION IS COMPENSATING. (SEE GEM NOTE BY WIGMANS + PAAR)

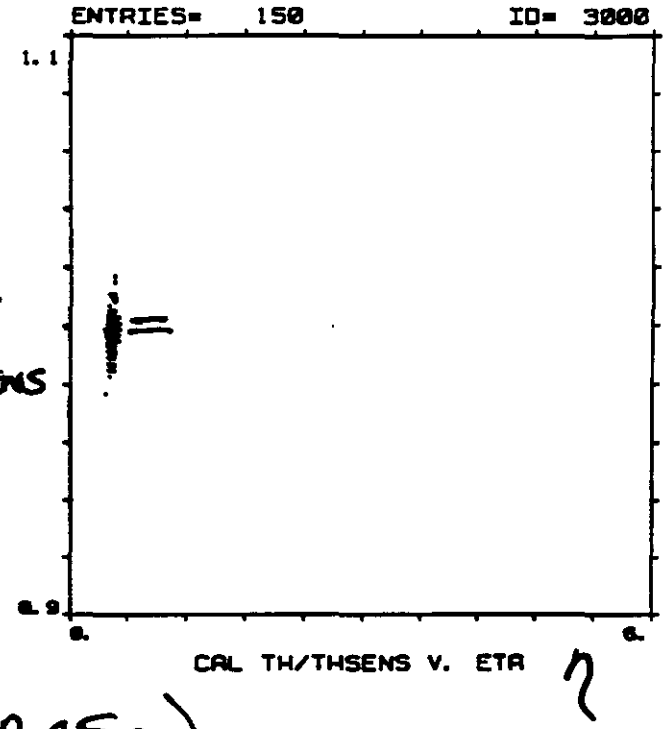
- RESULTS MAY OR MAY NOT BE LINEAR! (SAME GEM NOTE).

NOTE: WEIGHTING SCHEMES ARE APPLICABLE ONLY TO ISOLATED SHOWERS OR JETS, NOT TO GLOBAL QUANTITIES SUCH AS $\not{E}_T$.

FIRST ROTTEN PLOTS FROM SEGMENTATION STUDIES

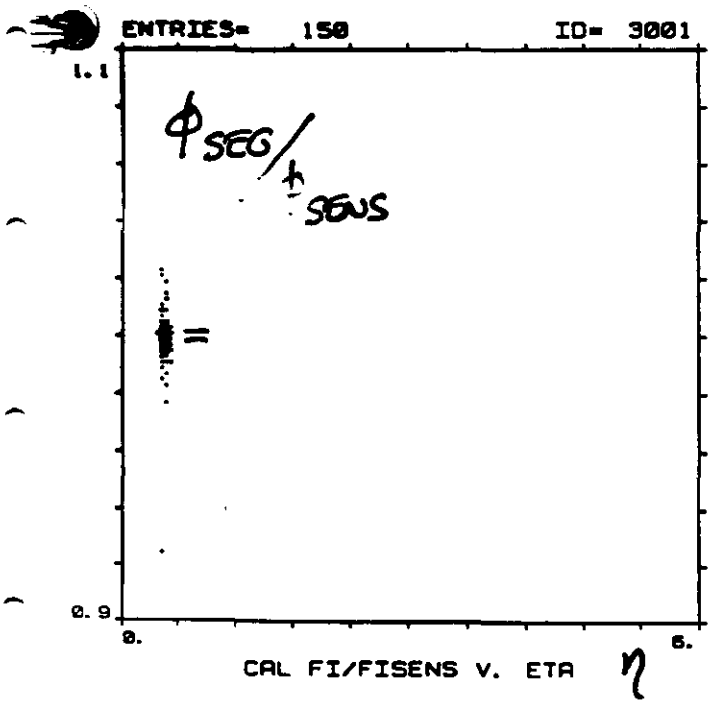
50 GeV PIONS



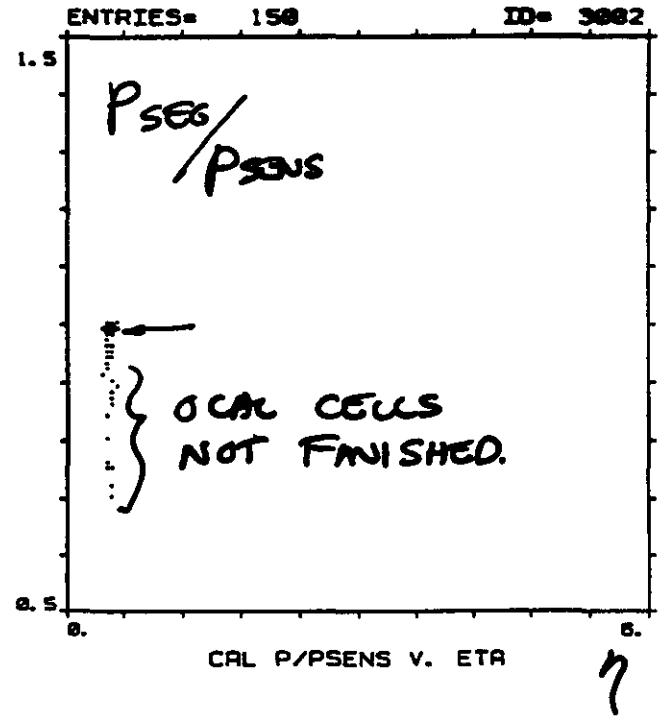


$\theta_{SEG}/\theta_{SENS}$

(GEN. NARROW BAND OF η)



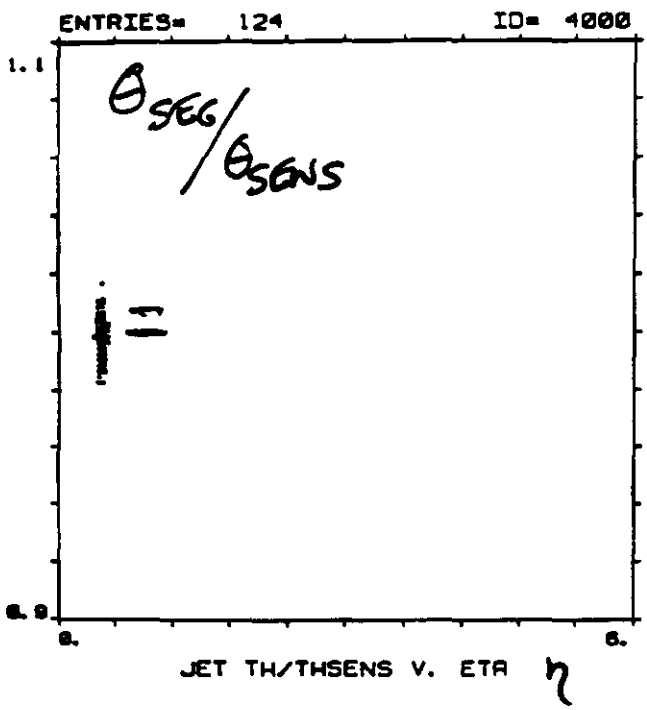
ϕ_{SEG}/ϕ_{SENS}

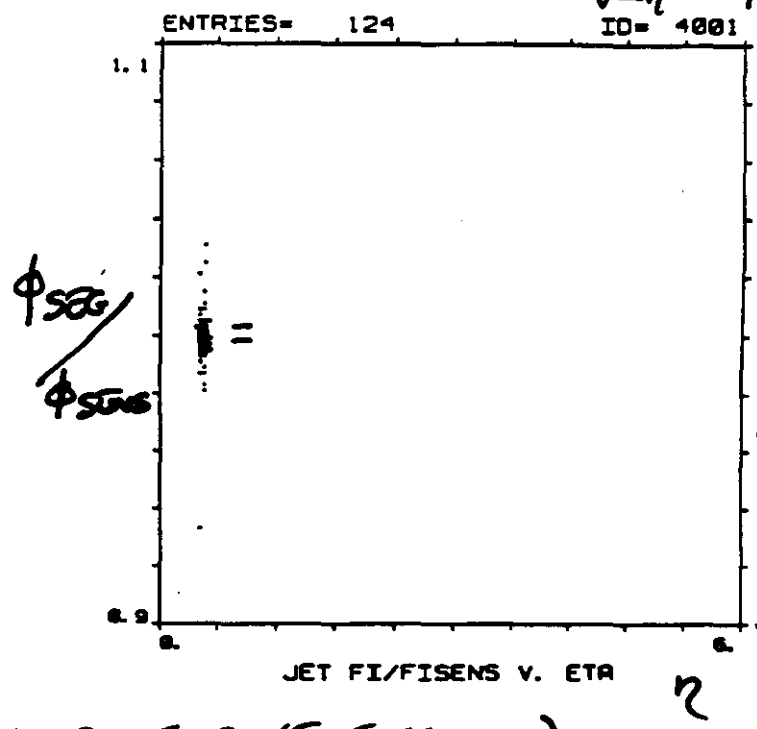


P_{SEG}/P_{SENS}

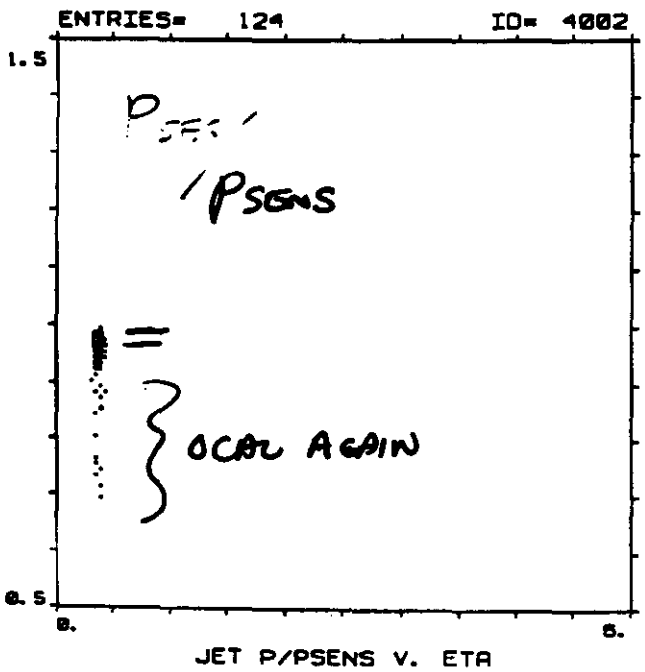
(USING JETFINDER) $R_{JET} = .7$

$\sqrt{\Delta\eta^2 + \Delta\phi^2}$





(WIDER → SOME CONE EFFECTS)



SEGMENTATION CONCLUSIONS

- AT LOW η, EFFECTS ON θ, ϕ, AND P APPEAR NEGLIGIBLE
- WILL FINISH SEGMENTATION IN UAEMIX + DO FULL SET OF PLOTS FOR ALL η.

META CONCLUSIONS

1. DESIGN LOOKS REASONABLE IN TERMS OF $\delta P/P$, $\delta P_t/P_t$, etc.

2. η COVERAGE MAY OR MAY NOT BE ADEQUATE. CONTINUE TO PRESS ON BEAM HOLE SIZE. GEMFAST SIMULATIONS WILL REVEAL THE ANSWER.

3. A WEIGHTING PROCEDURE WILL BE NEEDED IN ANY CASE TO RECOVER THE LAST 1-2% OF CONSTANT TERM, BUT MUST BE DONE CAREFULLY TO MAINTAIN LINEARITY.

4. BARREL SEGMENTATION LOOKS ØK. ONGOING STUDY.

IN PROGRESS. NEXT.

1. FINISH SEGMENTATION (OCAL, EC, FC)
2. ADD NOISE AND PILEUP
3. TUNE ALL DIMENSIONS + MATERIALS
   $\longrightarrow$ RESOLVE $\lambda_{GEANT} \neq \lambda_{PDG}$
4. CONTINUE WITH WEIGHTING SCHEME STUDIES
5. PRODUCTION. IMPROVEMENTS BACK INTO GEMFAST.

gem

γeμ

Presentation by:

A. Savin

Č fibers for forward calorimetry

Geant 3.15 + LTRANS

BU Jan. 08/95

D. Swain

1. Absorber – Tungstear.

2. Detector – Quartz fibers
Ø 1mm (n = 1.53/1.51 for 220 nm).

3. Packing fraction – 10%

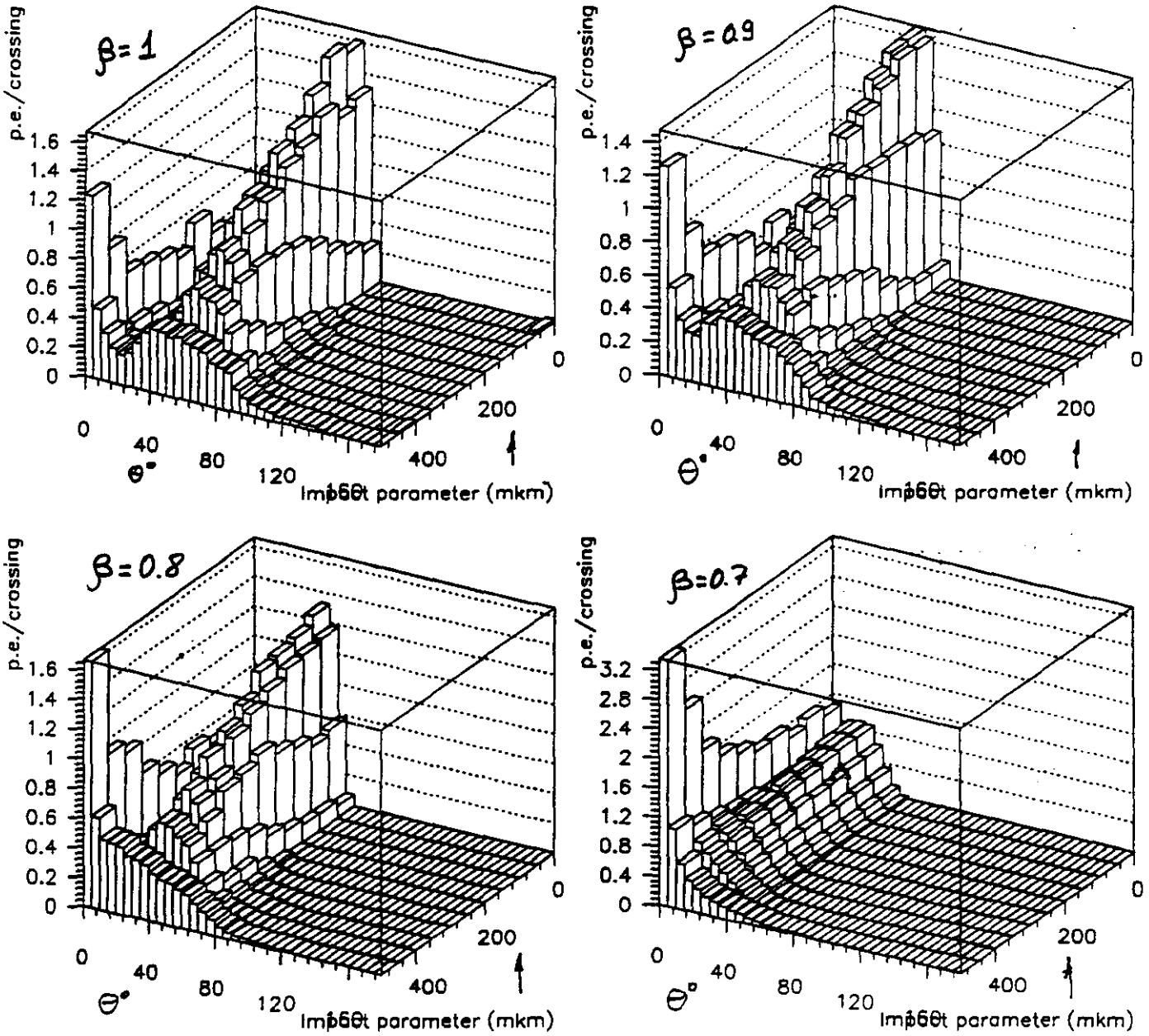
4. Slope – none (projective)

Reason – how to build device with
a) slope? b) position resolution?
c) packing fraction ≳ 3% ?
at the same time?

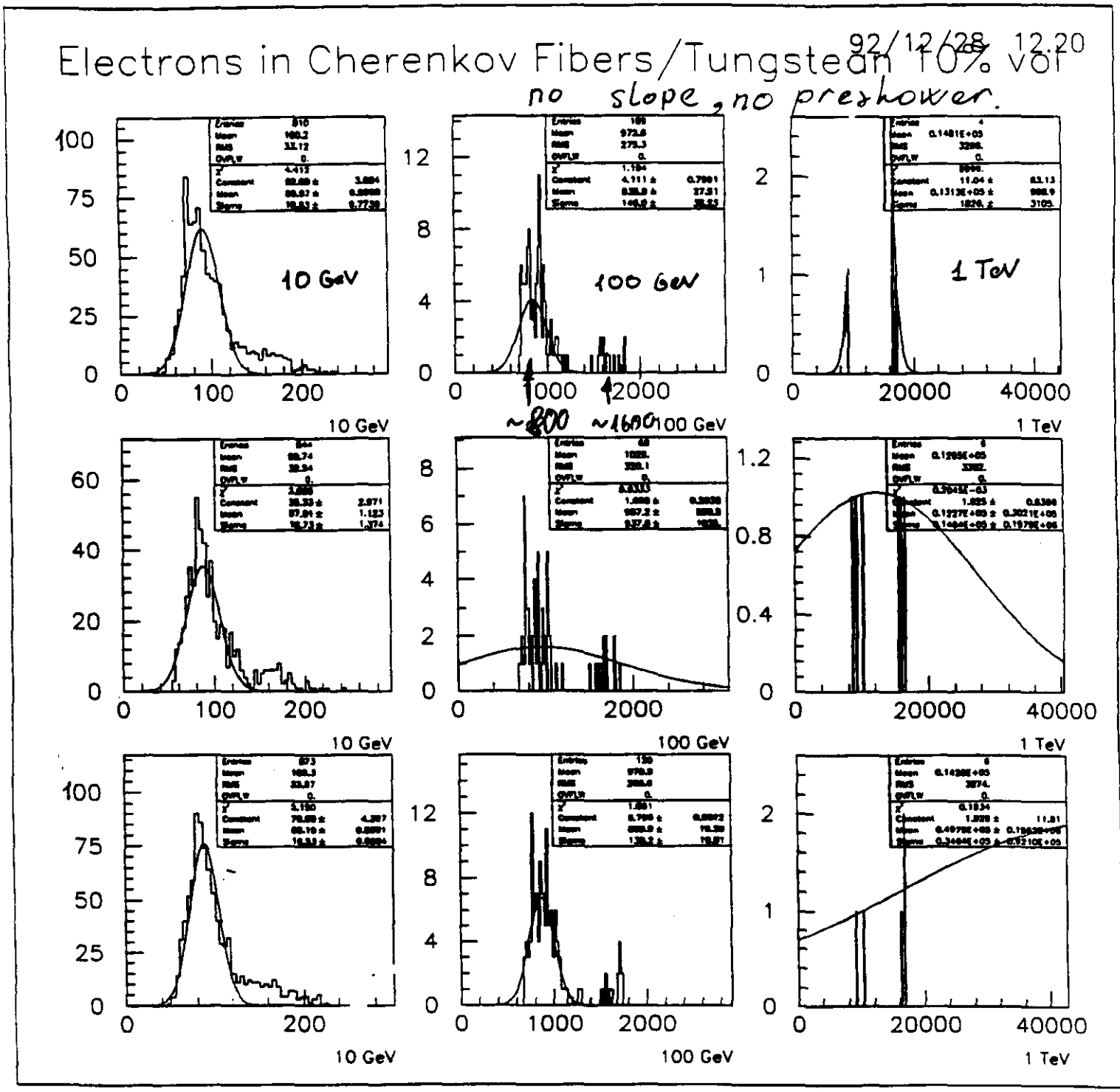
5. Correction of poor EM resolution – by "preradiator", spreading EM shower.
a) 3cm PB – done
b) more PB?
c) EM section with other(?) ~~[illegible]~~.
Technology – IF ANY other PROPOSED TECHNOLOGY is free ~~from~~ c̄ channeling.

05/12/92 21.51

Response of Cherenkov fibers (cladding 1.51/1.53)

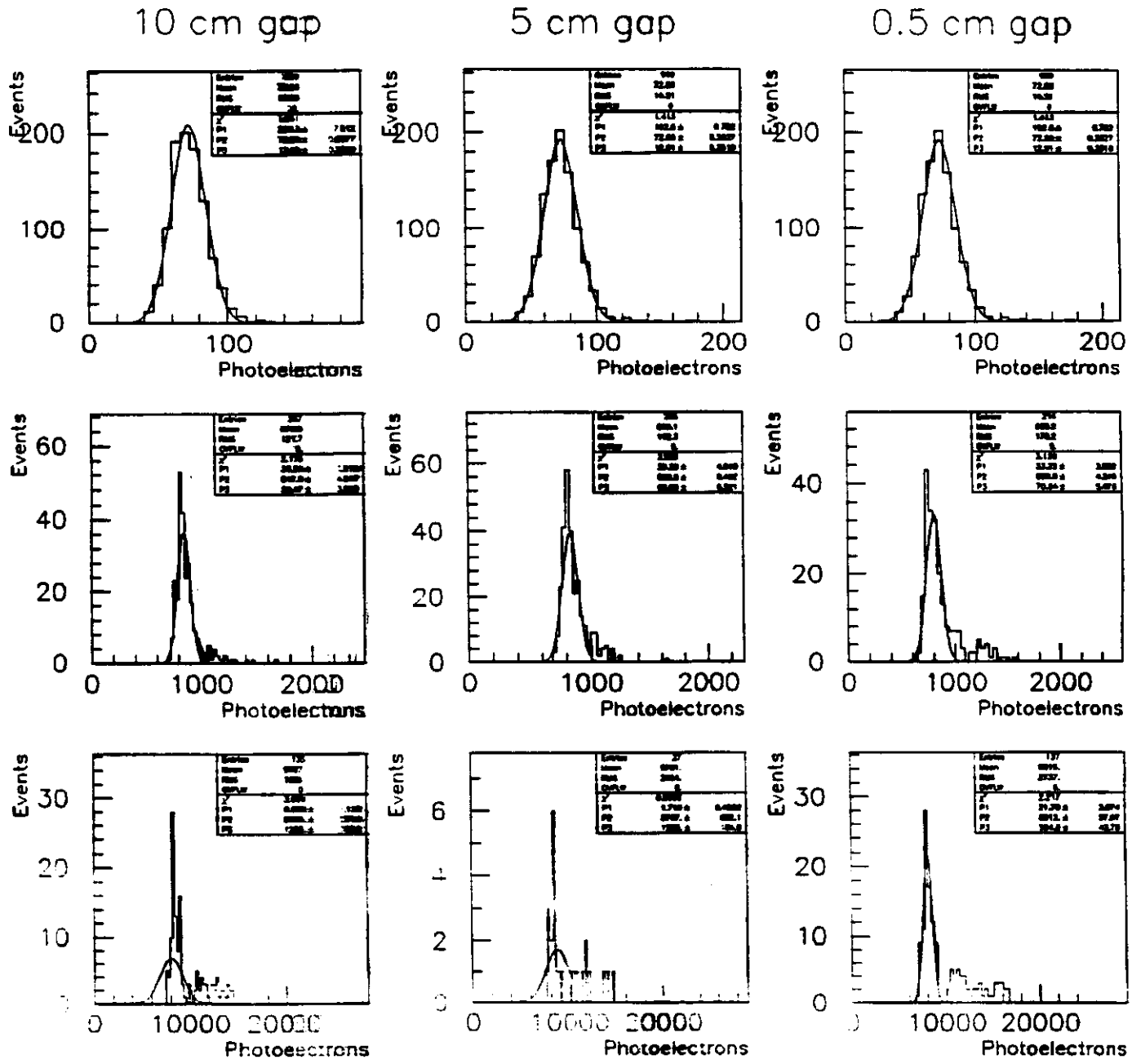


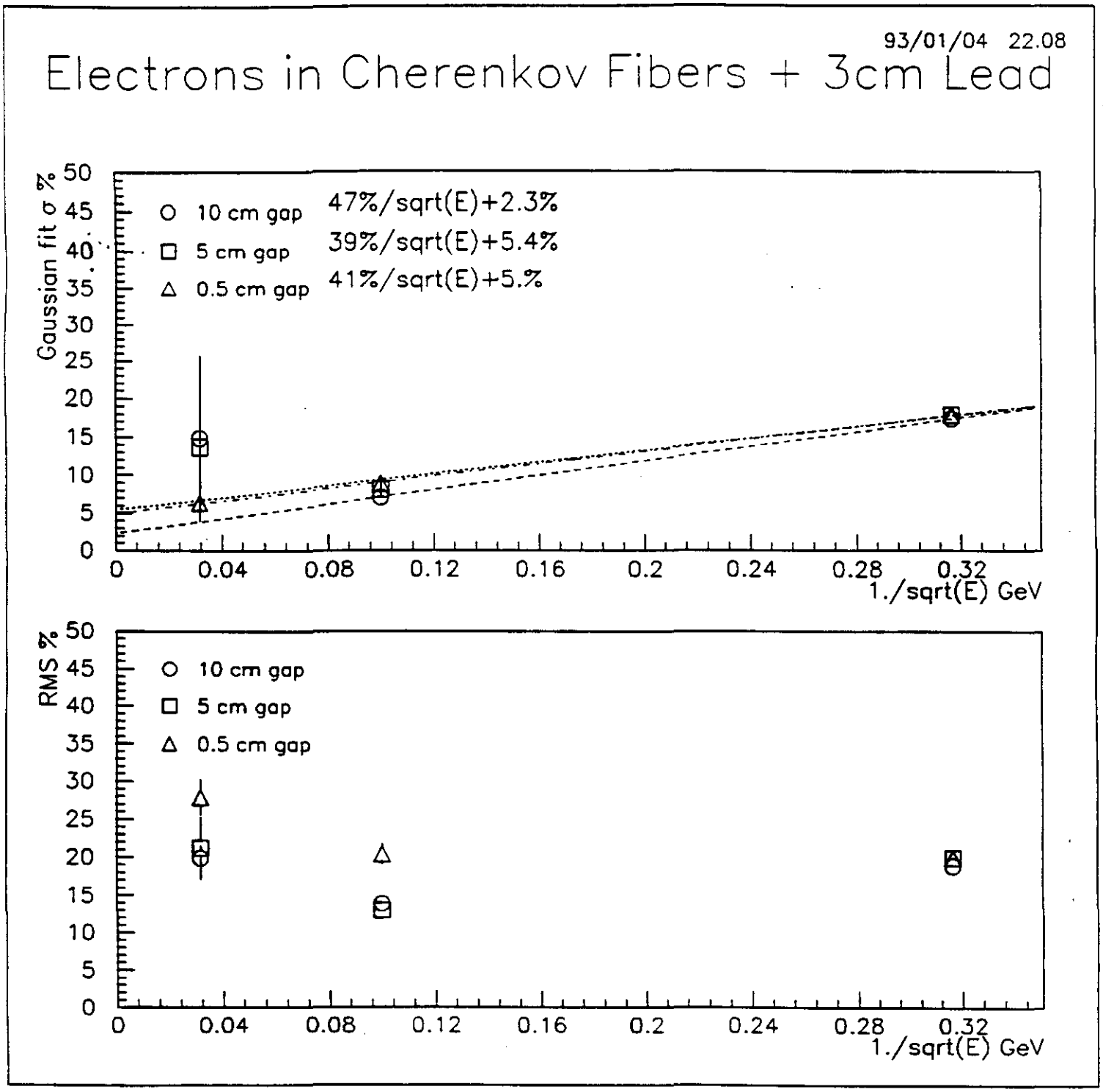
By E. Tarkovsky (ORNL)


Electrons in Cherenkov Fibers/Tungstean 10% vol
92/12/28 12.20
no slope, no preshower.
10 GeV
100 GeV
1 TeV
~800
~1600

93/01/04 22.07

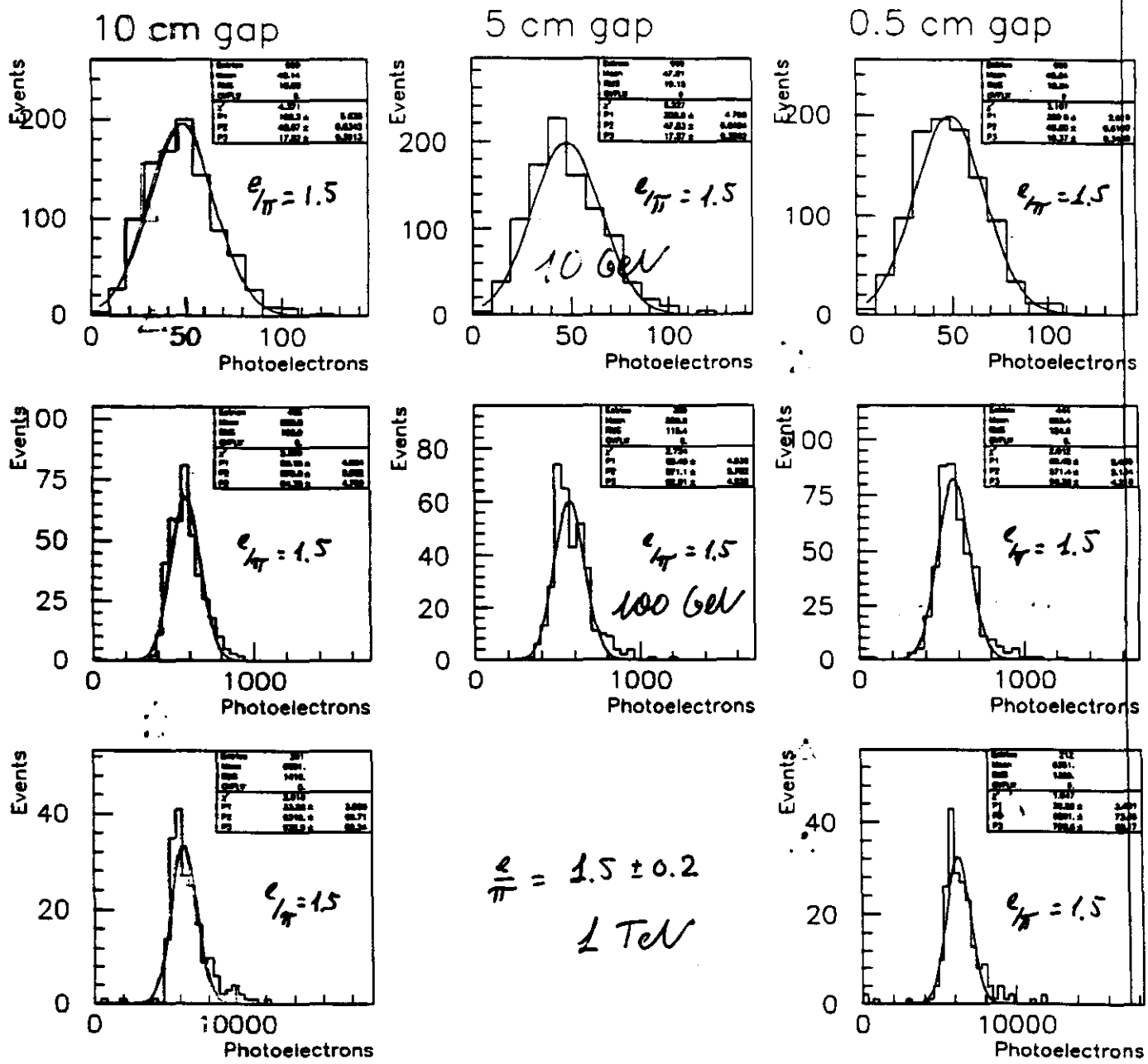
Electrons in Cherenkov Fibers + 3cm Lead



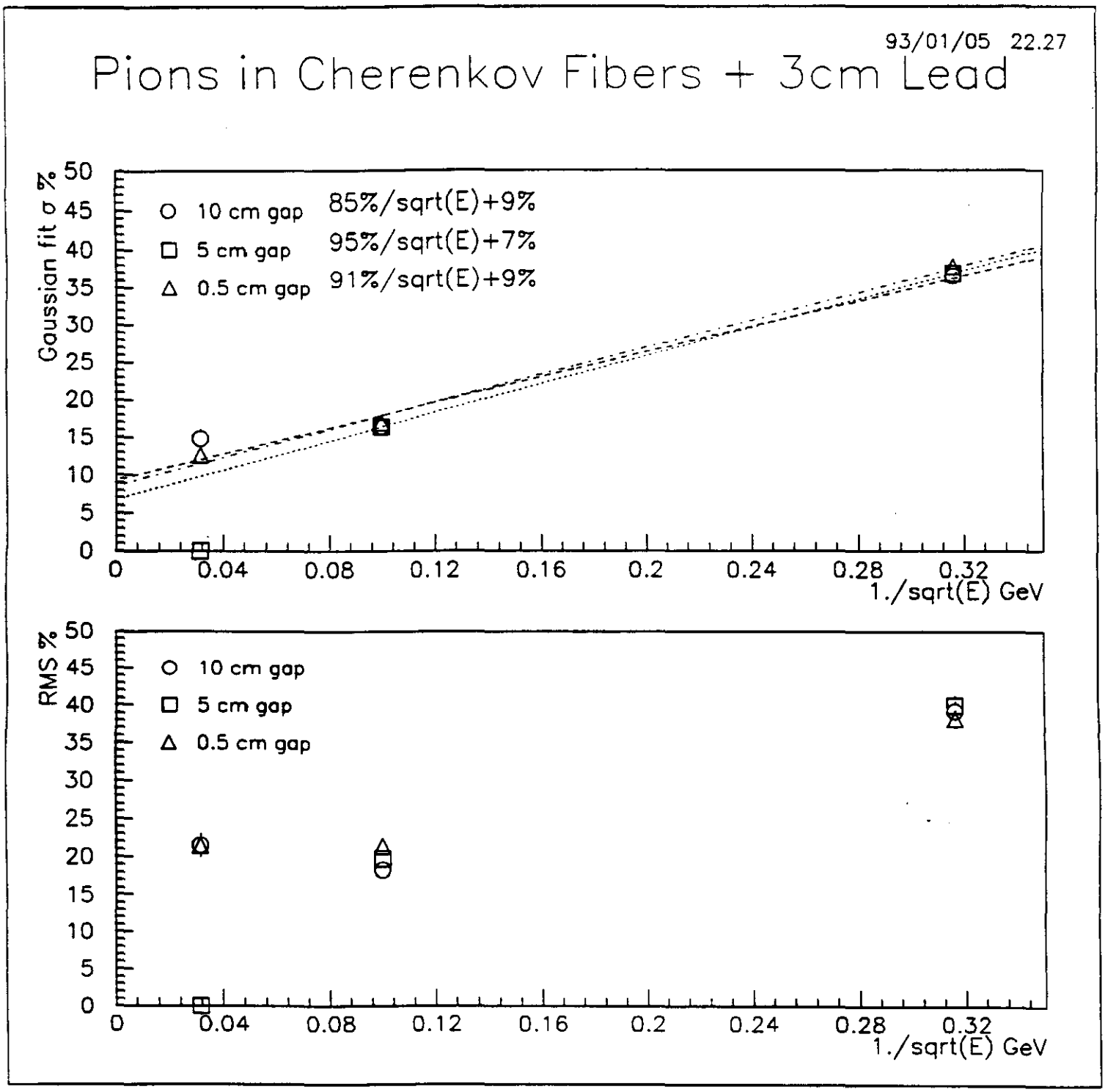

93/01/04 22.08
Electrons in Cherenkov Fibers + 3cm Lead
Gaussian fit σ %
10 cm gap
5 cm gap
0.5 cm gap
47%/sqrt(E)+2.3%
39%/sqrt(E)+5.4%
41%/sqrt(E)+5.%
1./sqrt(E) GeV
RMS %
10 cm gap
5 cm gap
0.5 cm gap
1./sqrt(E) GeV

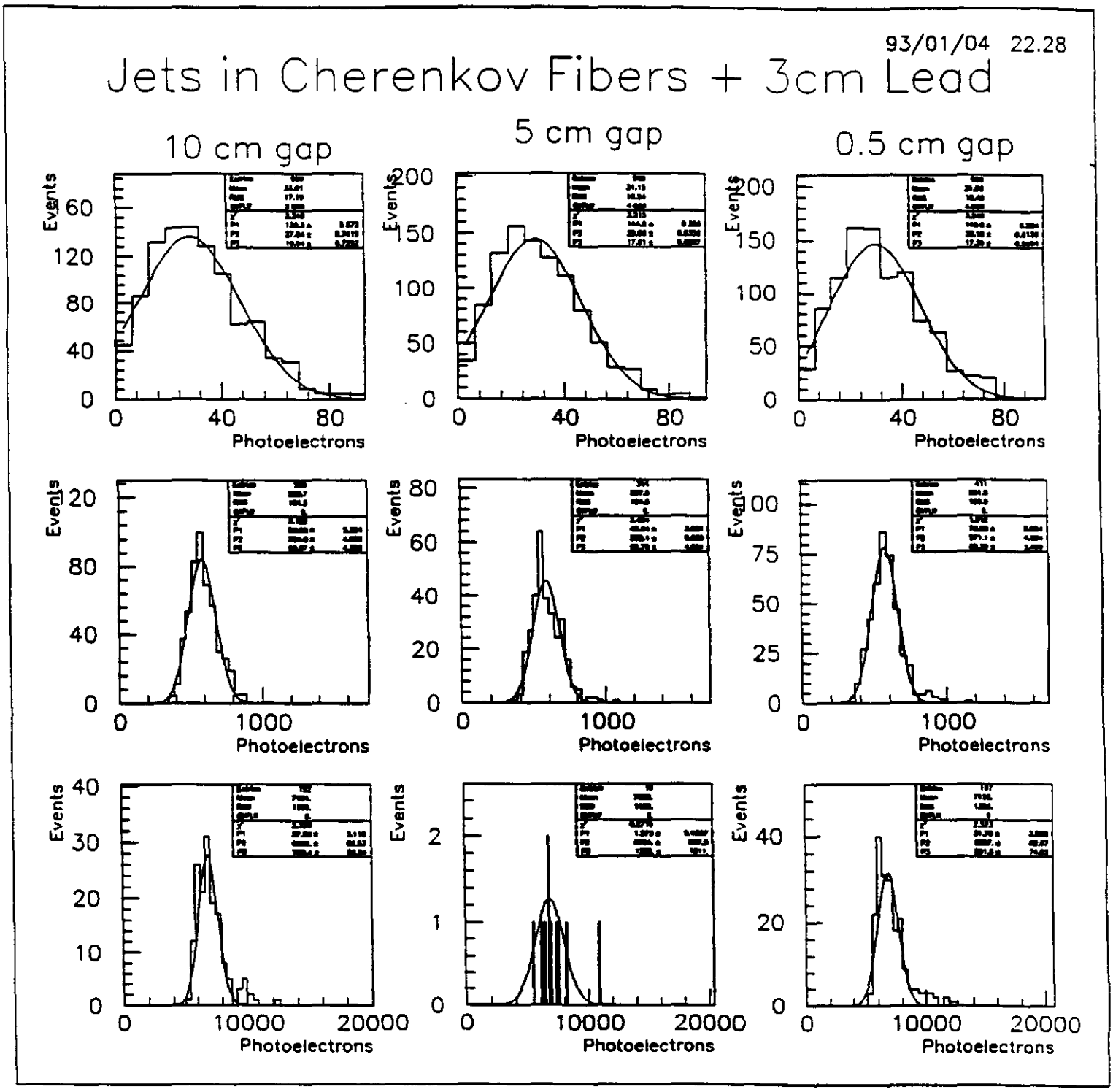
93/01/05 22.26

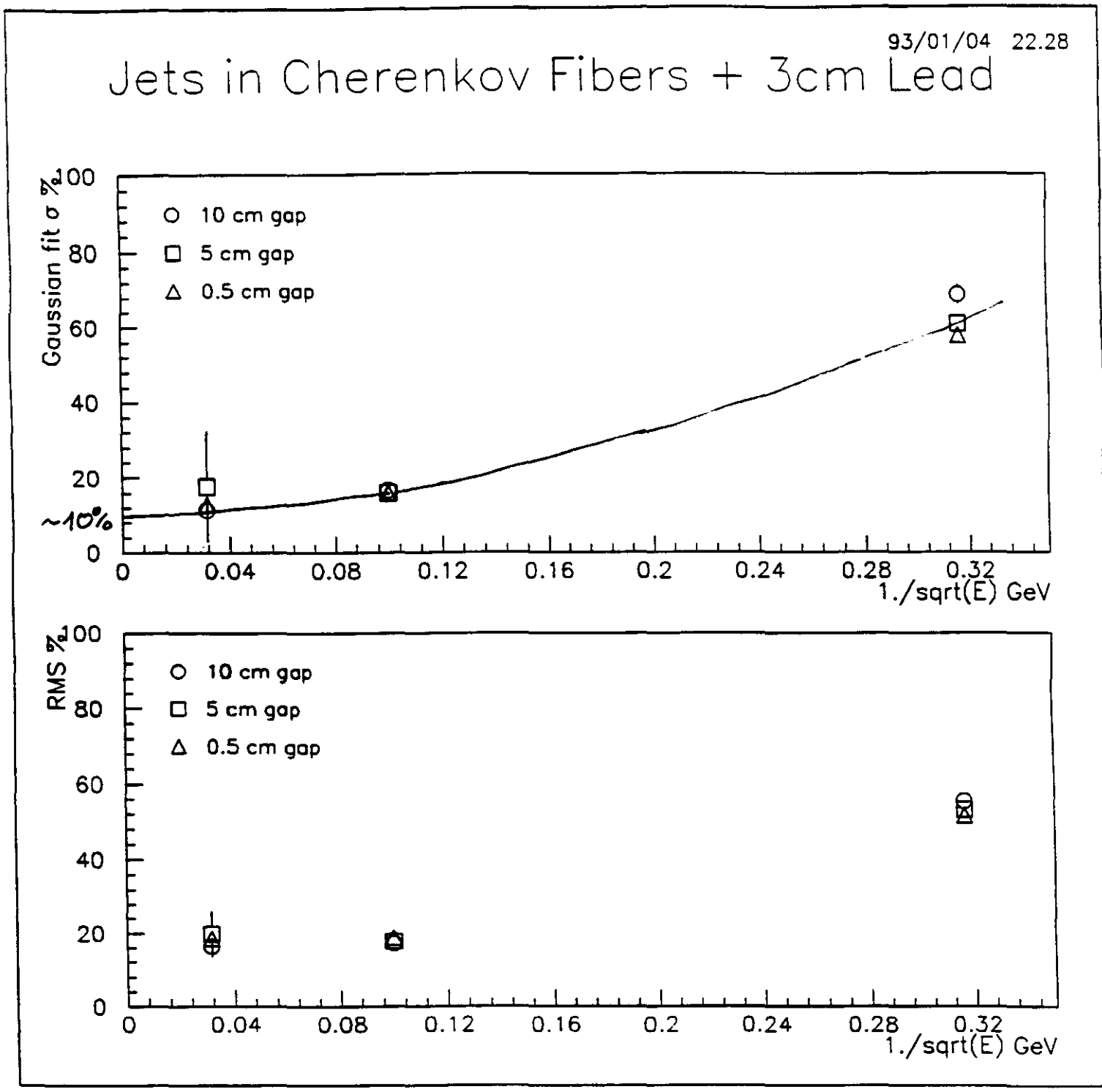
Pions in Cherenkov Fibers + 3cm Lead

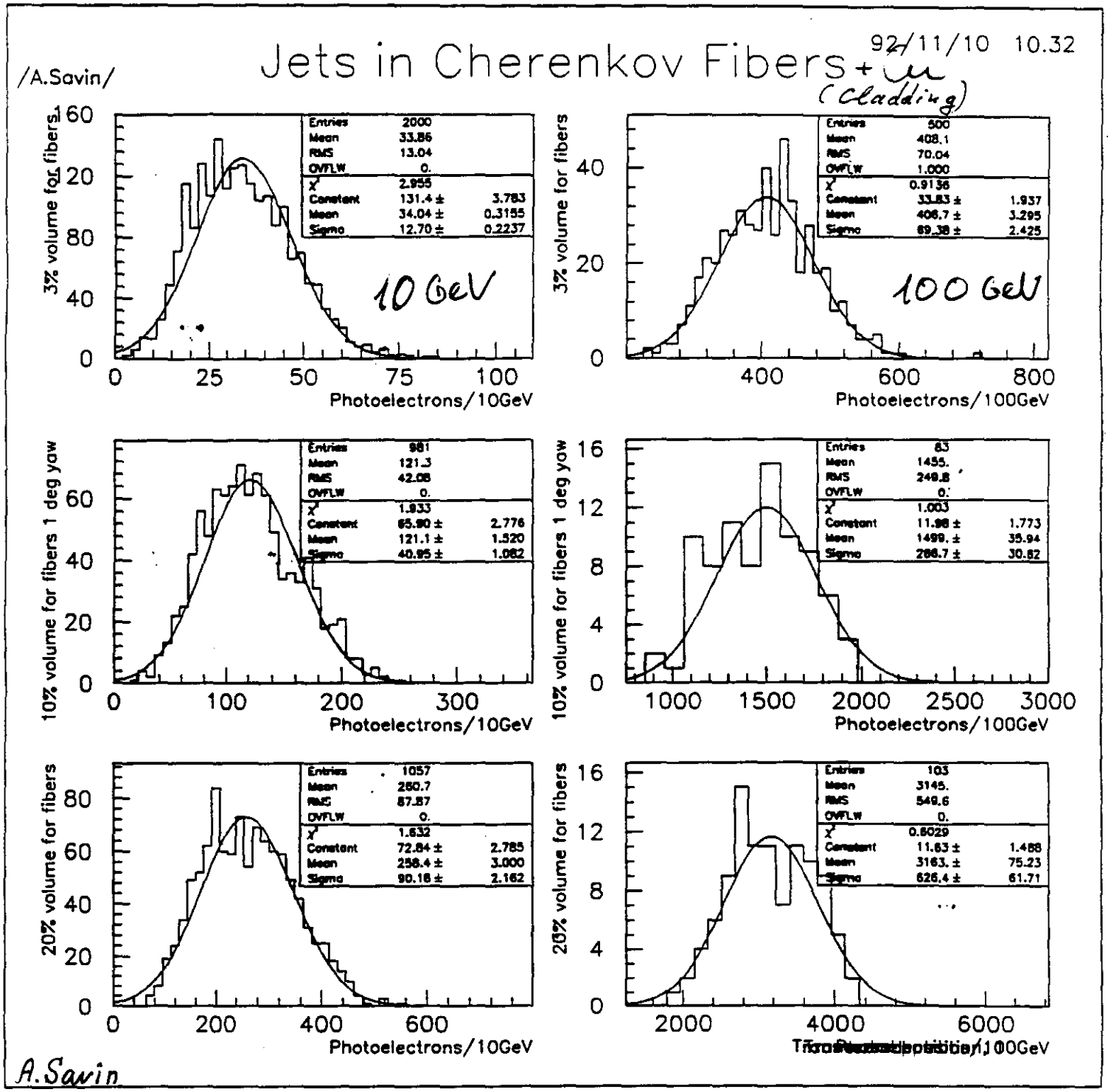


$\frac{e}{\pi} = 1.5 \pm 0.2$


93/01/05 22.27
Pions in Cherenkov Fibers + 3cm Lead
Gaussian fit σ %
10 cm gap
5 cm gap
0.5 cm gap
85%/sqrt(E)+9%
95%/sqrt(E)+7%
91%/sqrt(E)+9%
1./sqrt(E) GeV
RMS %
10 cm gap
5 cm gap
0.5 cm gap
1./sqrt(E) GeV


93/01/04 22.28
Jets in Cherenkov Fibers + 3cm Lead
10 cm gap
5 cm gap
0.5 cm gap
Events
Photoelectrons


93/01/04 22.28
Jets in Cherenkov Fibers + 3cm Lead
Gaussian fit σ %
10 cm gap
5 cm gap
0.5 cm gap
~10%
1./sqrt(E) GeV
RMS %
10 cm gap
5 cm gap
0.5 cm gap
1./sqrt(E) GeV



SSGL, Dec 1992

Jets in Čerenkov Cu

with cladding

3% vol: $\frac{93.6\%}{\sqrt{E}} + 7.7\%$ $4.1 \frac{p.e.}{GeV}$

10% vol: $\frac{76.8\%}{\sqrt{E}} + 9.5\%$ $14.6 \frac{p.e.}{GeV}$

20% vol: $\frac{60.6\%}{\sqrt{E}} + 9.5\%$ $31.5 \frac{p.e.}{GeV}$

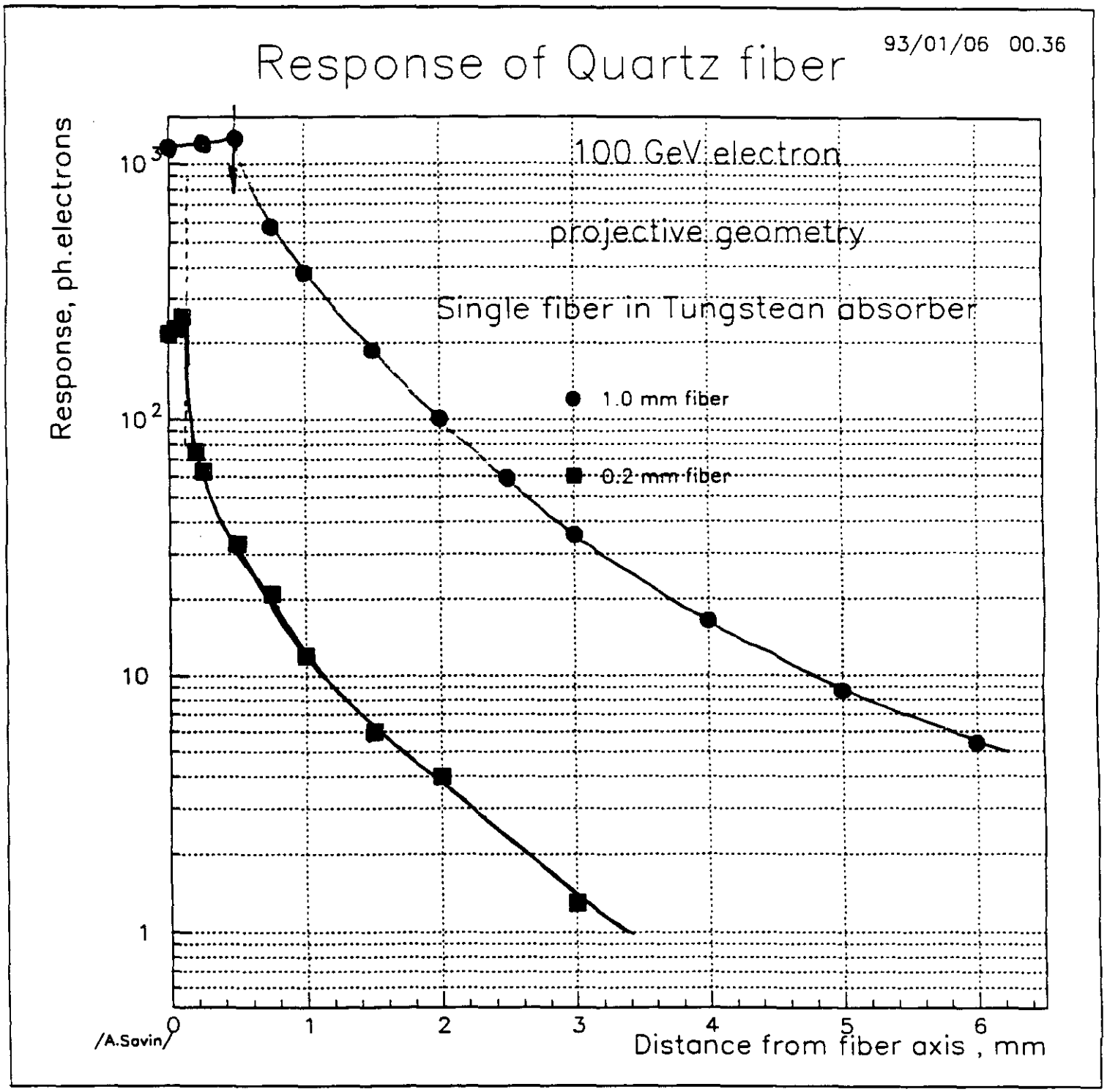
no cladding

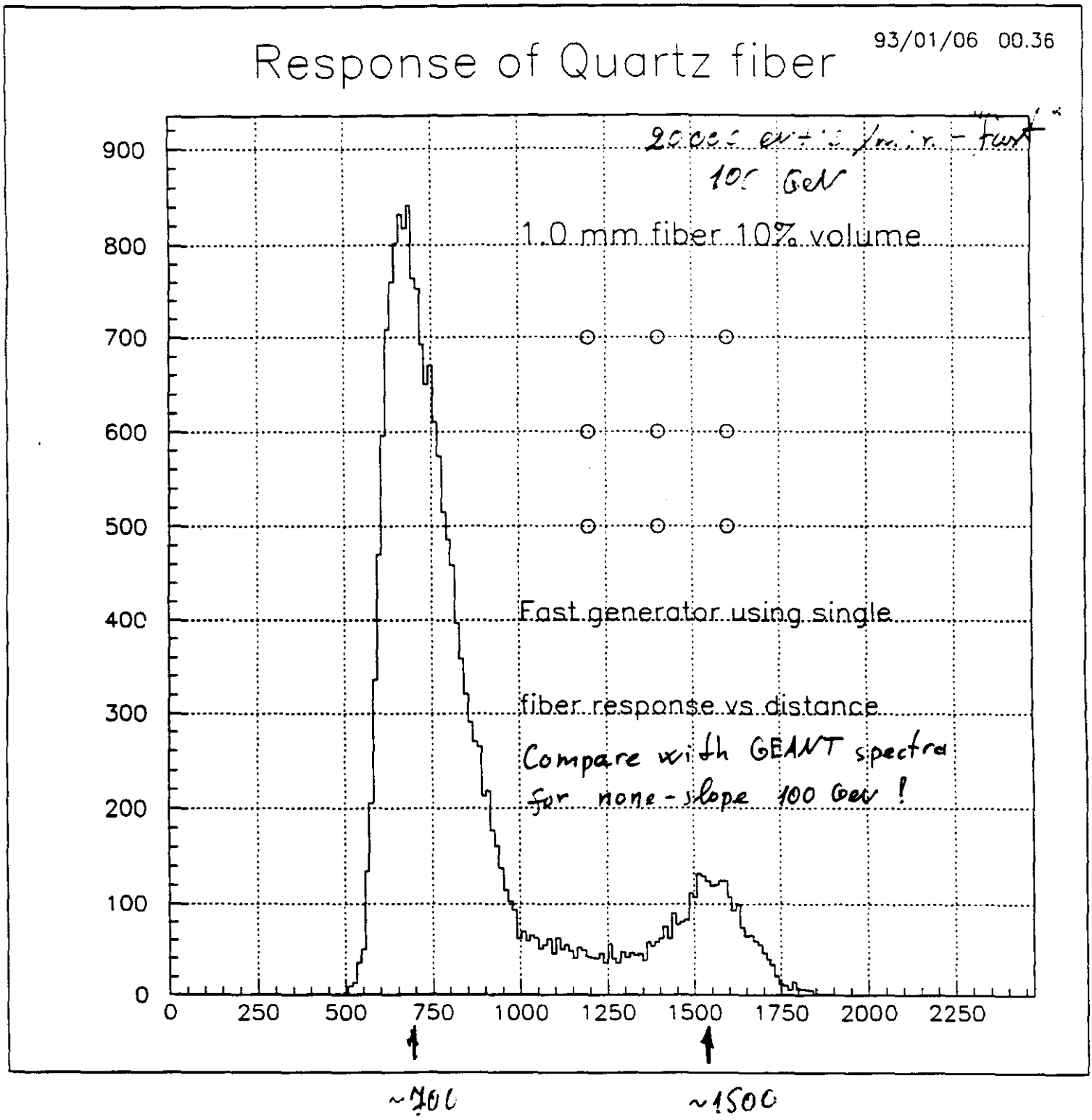
3% vol: $\frac{90.2\%}{\sqrt{E}} + 8.3\%$ $100 \frac{p.e.}{GeV}$

10% vol: $\frac{78.5\%}{\sqrt{E}} + 9.2\%$ $350 \frac{p.e.}{GeV}$

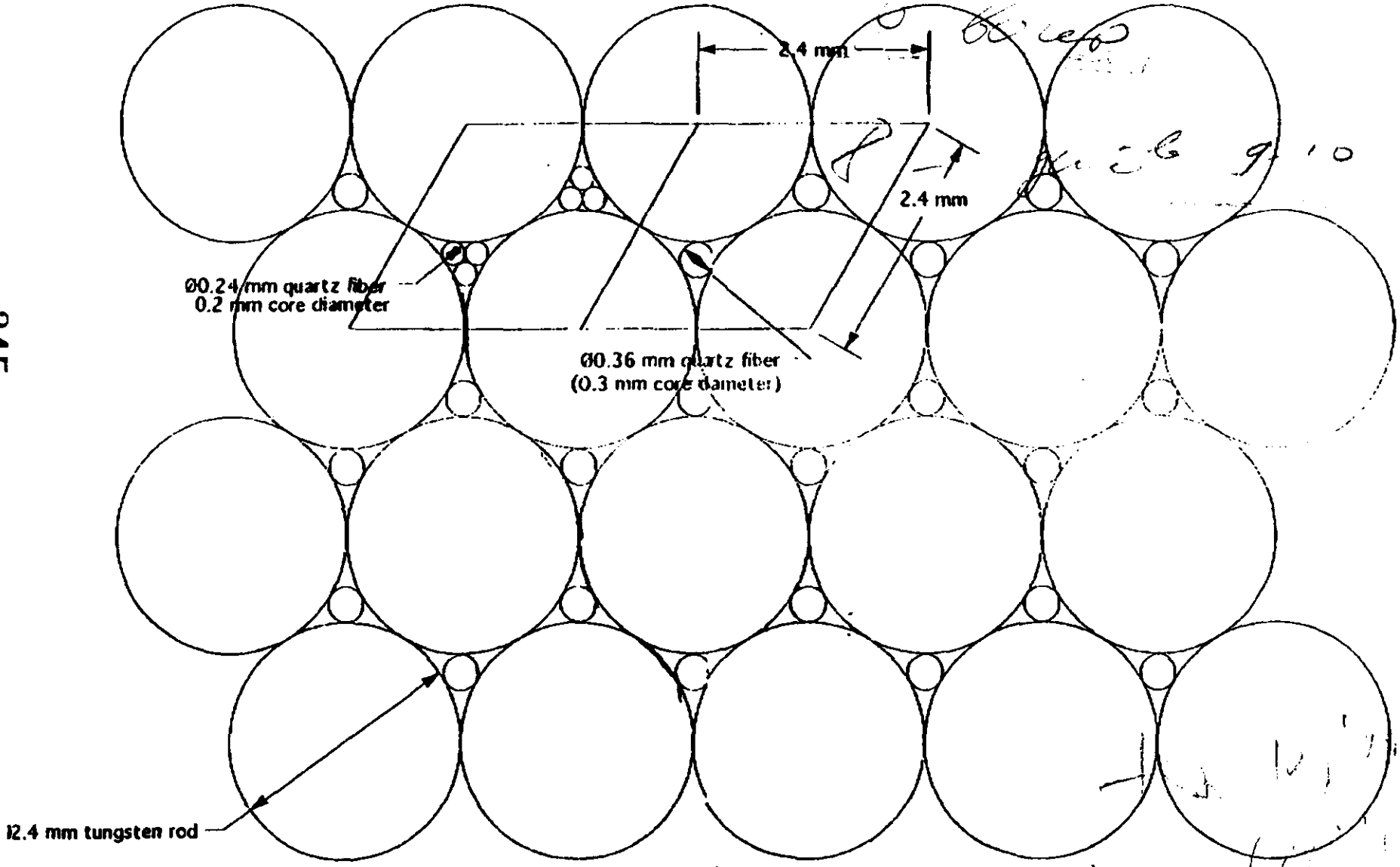
20% vol: $\frac{68.0\%}{\sqrt{E}} + 10.7\%$ $780 \frac{p.e.}{GeV}$

SSCL, Dec 1992


Response of Quartz fiber
93/01/06 00.36
100 GeV electron
projective geometry
Single fiber in Tungstean absorber
1.0 mm fiber
0.2 mm fiber
Response, ph.electrons
10^3
10^2
10
1
0
1
2
3
4
5
6
Distance from fiber axis , mm
/A.Savin/


Response of Quartz fiber
93/01/06 00.36
1.0 mm fiber 10% volume
Fast generator using single
fiber response vs distance
Compare with GEANT spectra
for none-slope 100 GeV !
900
800
700
600
500
400
300
200
100
0
0
250
500
750
1000
1250
1500
1750
2000
2250
~700
~1500

	200 micron core	300 micron core
Unit cell area:	4.9883 mm^2	4.9883 mm^2
W rod area:	4.5239 mm^2 (90.69 %)	4.5239 mm^2 (90.69 %)
Q-fiber core area:	0.1885 mm^2 (3.78 %)	0.1414 mm^2 (2.83 %)
Q-fiber cladding area:	0.0829 mm^2 (1.66 %)	0.0622 mm^2 (1.25 %)
Air area:	0.1930 mm^2 (3.87 %)	0.2608mm^2 (5.23 %)



QUARTZ FIBER OPTION HOLE ARRANGEMENT

ghetti-07wire

SM CHAE

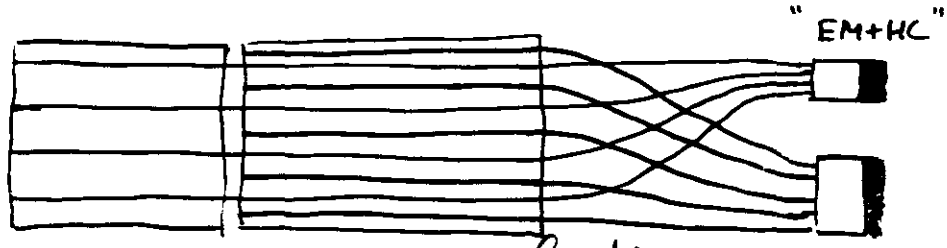
What to do?

1. Try thicker (4cm or more) passive "pre-shower"
2. Try mixture of 2.4mm Ø W rods & 0.2mm Ø Quartz fibers

   it has only 2.8% packing fraction, but

number of fibers/cm² ~2 times large → channeling effect expected be smaller.
And probability of channeling ~3.5 times smaller (packing fraction).

3. Possibility of 2 sections



4. What jet resolution is possible to achieve?

   10% constant term – no problem in ☺ fibers

5. Different absorbers?

gem

γeμ

Presentation by:

Henk Uijterwaal

TRIGGER SIMULATIONS.

HENK UIJTERWAAL
SSCL, 1/8/93.

This talk.

1) TRIGGER + DAQ system.

2) Implementation of the trigger simulation.
   - → Overview
   - → Description of the existing code

3) What has to be done next.

THE TRIGGER / DAQ SYSTEM.

- BASIC SCHEME:
  1) PIPELINED L1 trigger (HARDWARE)
  2) Event Builder
  3) PROCESSOR FARM FOR L2+L3 (SOFTWARE)
     $\geq$ 1000 CPU's, 500 MIPS each.
  4) 100 Hz to tape.

- 2 modes of operation.
  1) Ship full event data to L2 for each L1 trigger.
  2) Ship only a subset to L2, full data only after a L2 accept
     - Cheaper : less data $\Rightarrow$ cheaper links.
     - Questions : 1) How much data to L2?
       2) Effects on trigger Efficiency

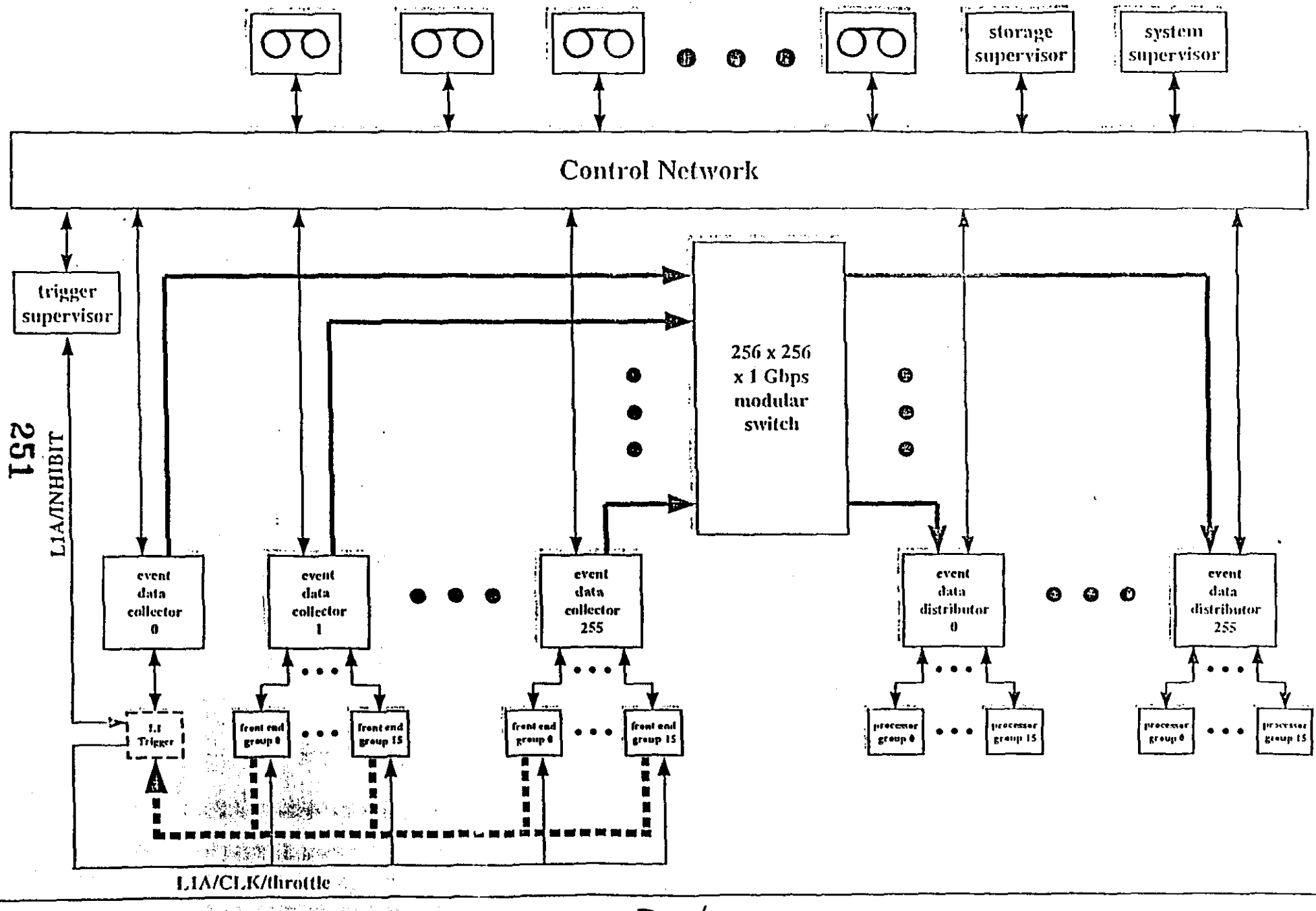
- RATES.

		RATE	REDUCTION	DATA VOLUME
L1	IN	60 MHz	600	19 GByte/s *
	OUT	100 kHz	10...100	
L2	IN			
	OUT	1...10 kHz	100...10	
L3	IN			
	OUT	100 Hz		19 MByte/s. *

* EVENT RATES Limited by the link speed.

* Assumes 190 Kbyte/Event $\Rightarrow$ ϕ suppression, no individual samples.

DAQ OVERVIEW



TRIGGER SIMULATION.

GOALS:

1) Understand the behaviour of the hardware.
   - DATA Volumes
   - Latency
   - Event Rates

   ⇒ NOT IN THIS TALK

2) Find Trigger criteria for L1, L2 and L3.
   - Physics Efficiency
   - Background Reduction
   - Processing time (L2, L3)
   - Hardware effects

3) Provide a data sample for the analysis groups
   - Physics without the events that will be rejected by the trigger.
   - Backgrounds that survive L3.

#2 can be accomplished by

1) Implementing possible algorithms in FORTRAN
2) Run them for various physics processes
3) Combine the algorithm outputs
4) Tune Thresholds and parameters

Input Samples for the trigger simulation.

1) the GEM physics programme :

- Higgs
- Heavy flavours
- Jets
- physics @ $\mathcal{L} = 10^{34} cm^{-2} s^{-1}$
- missing $\not{E}_T$
- .....

⇒ List of event signatures that should be recognised by the triggers: γ, e, μ, Jet, $\not{E}_T$ (ν)

2) Backgrounds

- Minimum Bias (ONLY).
- Proton Beam on Residual gas in the Beam pipe
  - ⇒ Rate 0,7 -- 2,5 MHz (1 to 5% of the interactions).
  - ⇒ Energy around the beam pipe; high η values
- Beam Scraping ⇒ high η values; Rate unknown.
- Cosmics
- Pile-up

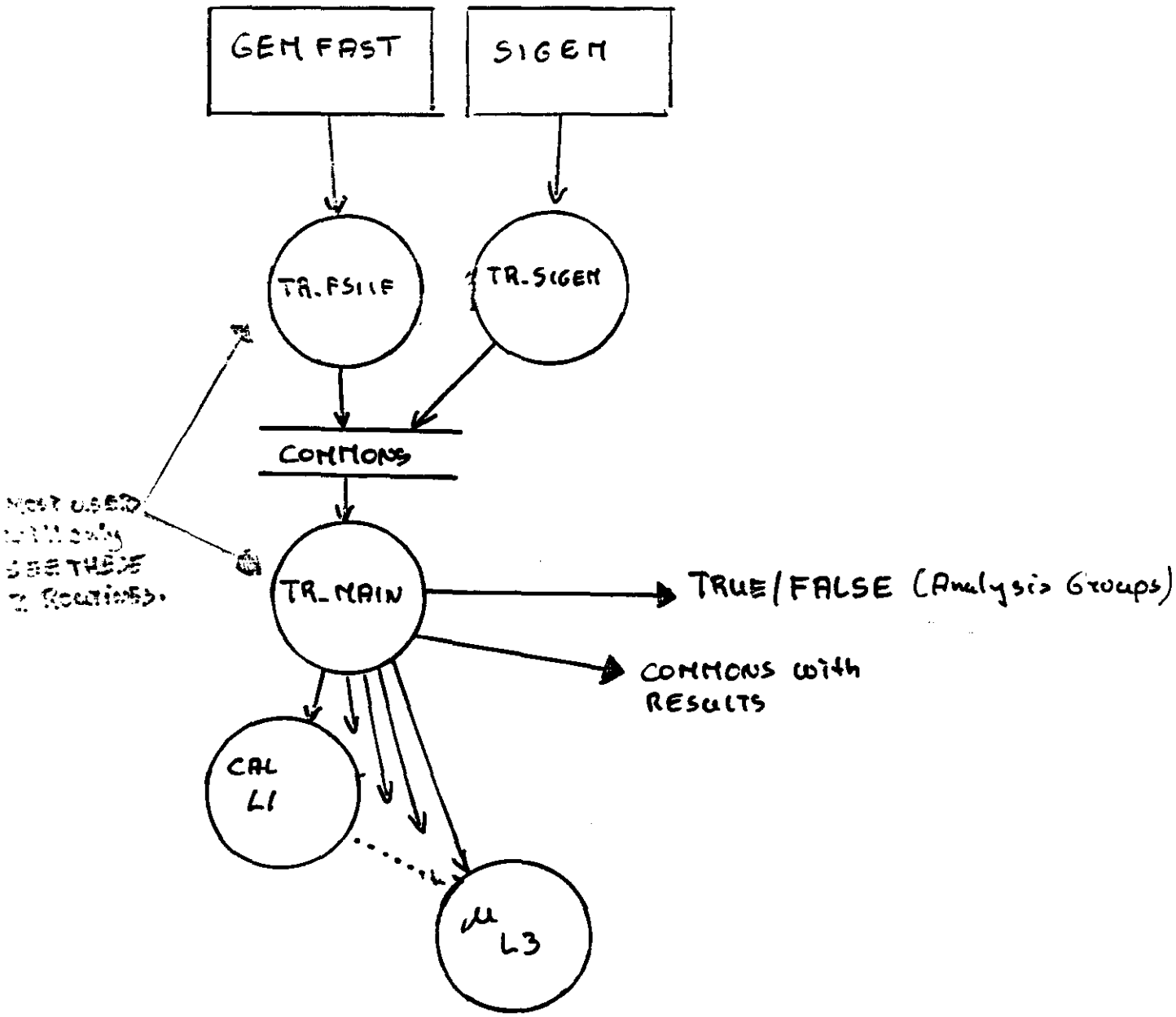
⇒ VETO Signals for the trigger: timing
Vertex position.

⇒ NOTE BY KEN McFarlane & HU in preparation.

IMPLEMENTATION OF THE TRIGGER SIMULATION.

⇒ The trigger simulation will be used with input from different MC (and eventually Real Data as well).

⇒ It should be data independent.



TRIGGER PRIMITIVES.

The Trigger SYSTEM DOES NOT PROVIDE THE TYPICAL EVENT SIGNATURES BUT ONLY SO-CALLED TRIGGER PRIMITIVES

THERE IS A MANY TO MANY RELATION BETWEEN THE EVENT SIGNATURES AND THE PRIMITIVES. (⇒ NOTE KMF & HU).

Example: "Isolated e":

- Energy in EC cells
- No Energy in HC cells behind EC
- Pointing track to EC cells
- Little energy in cells around the cluster.

Some of these trigger primitives have been implemented in the trigger simulation. ⇒ Next transparencies.

L1 CAL TRIGGER PRIMITIVES.

1) Global SUMS : E_T, $\not{E}_T$, P_x, P_y (includes FC)
(Baseline I & II).

2) e, γ trigger.

- Baseline I : 5 x 5 EC cells } ($\approx 0.16 \times 0.16$ in η, ϕ).
  2 x 2 HC " } Tower.

REQUIRE a) $E_{T,EC} > 10\ E_{T,HC}$ ("Electromagnetic")
b) $(E_{T,8\,neighbours} - MAX(E_T, 4\,nb)) \leq$ threshold.
("Isolated").

Count # of towers above E_T thresholds.

- BASELINE II

PROBLEM #1 : RATIO BETWEEN EC AND HC cells = 3 (was 2.5)

$\Rightarrow$ 6x6 EC cells with 2x2 HC cells.
($\approx 0.16 \times 0.16$)

PROBLEM #2 : Different # of cells at high (η) values.
How to map these onto towers.

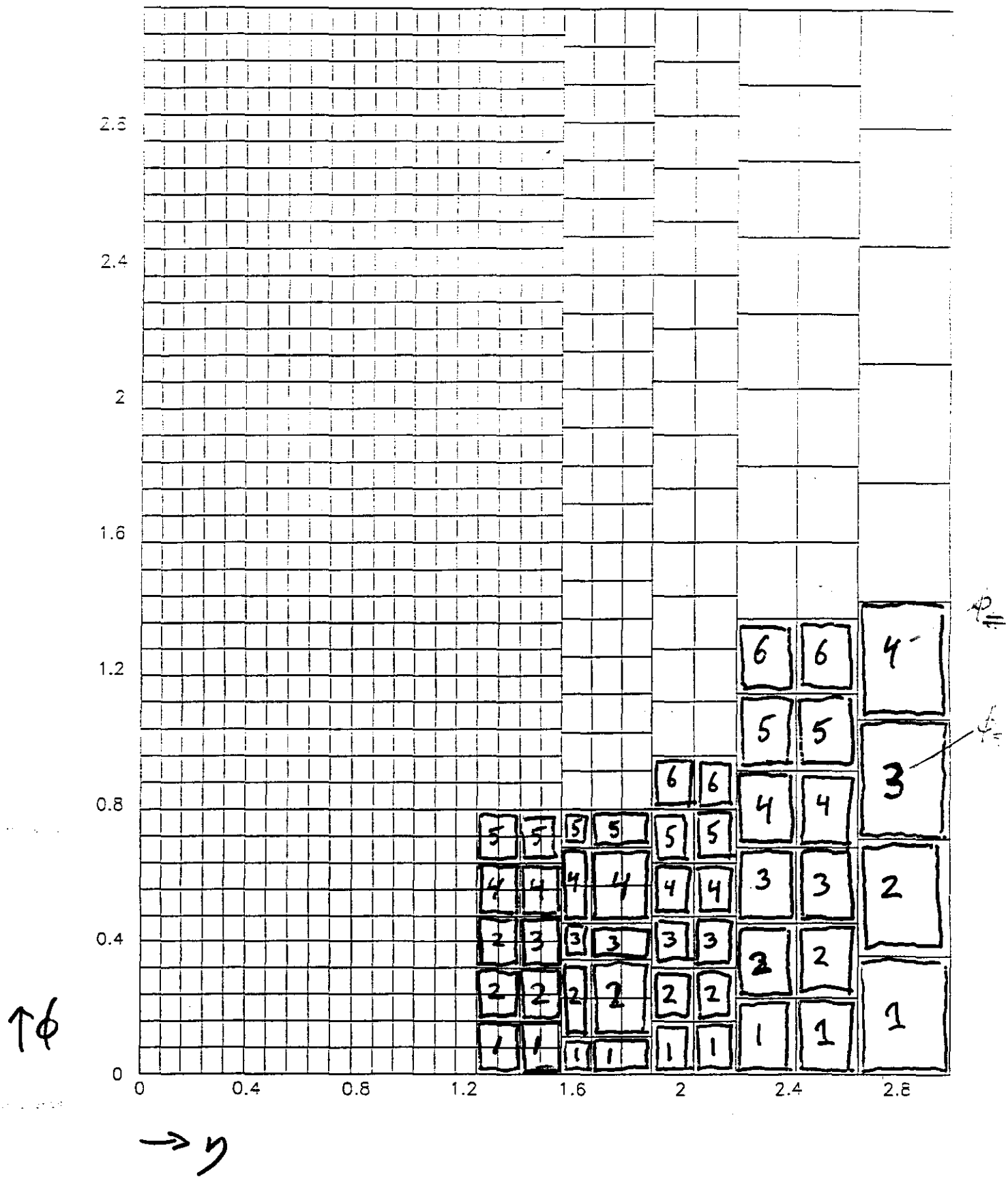
$\Rightarrow$ No clear answer from CAL groups.

$\Rightarrow$ Made some assumptions

REWROTE THE CODE with lookup tables.
for cells $\Rightarrow$ towers and neighboring towers.

$\Rightarrow$ this trigger is available for baseline II. and easy to reprogram for the final mapping of cells onto towers.

HC cells & towers.



3) Jet trigger.

<u>BASELINE I</u> 15 X 15 EC cells } $\approx 0{,}5 \times 0{,}5$ in η, ϕ
6 X 6 HC " }

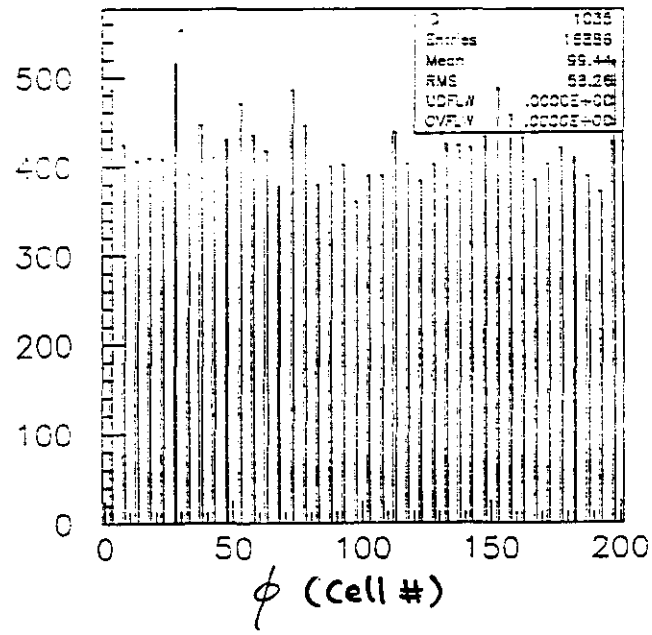
SELECT THOSE WITH THE HIGHEST ENERGY

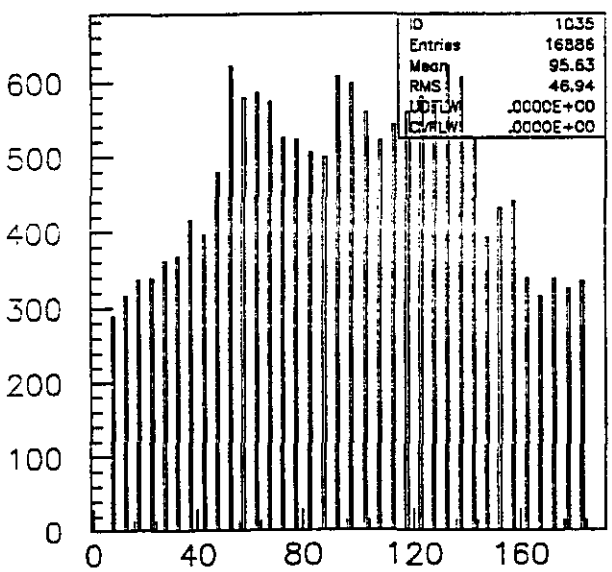
<u>BASELINE II</u> SAME PROBLEMS AS FOR e, γ trigger.
⇒ REWRITTEN WITH LOOKUP TABLES

The updated code is not completely tested (yet).
However, the first results look ok.

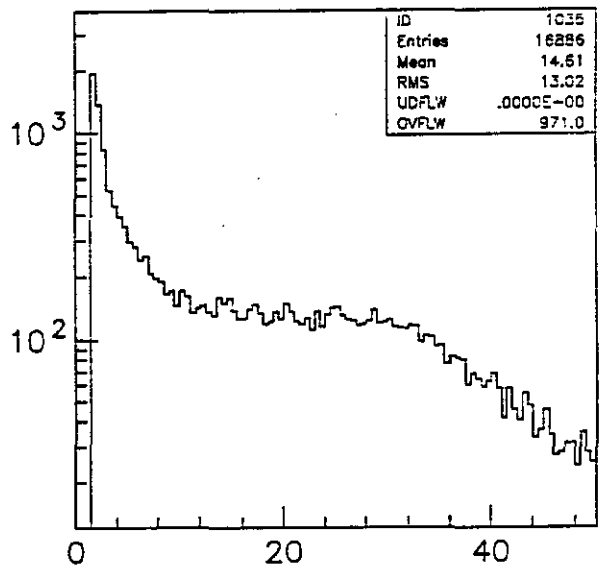
BASELINE I. $H \to \gamma\gamma$. Distribution of γ towers

92/10/18 12.52



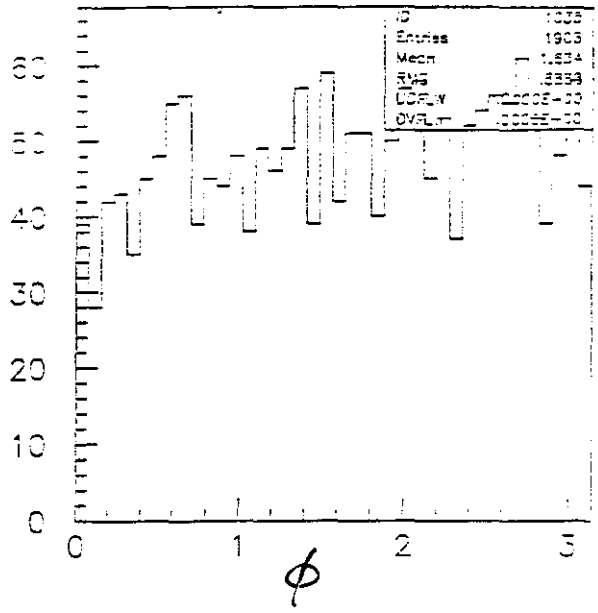


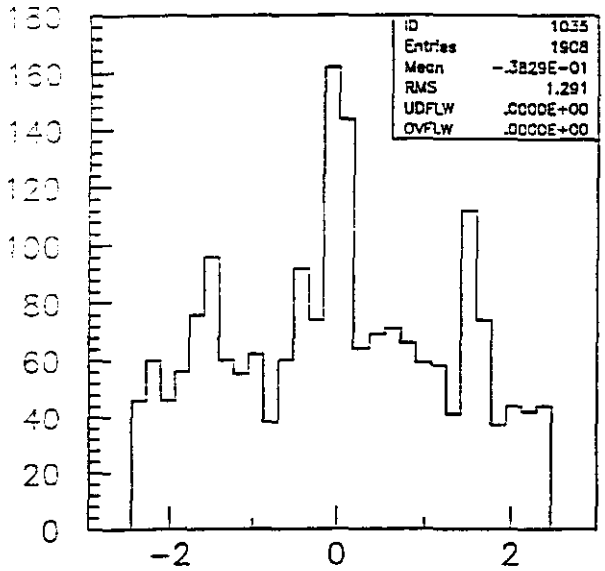
$|\eta| \leq 3.$

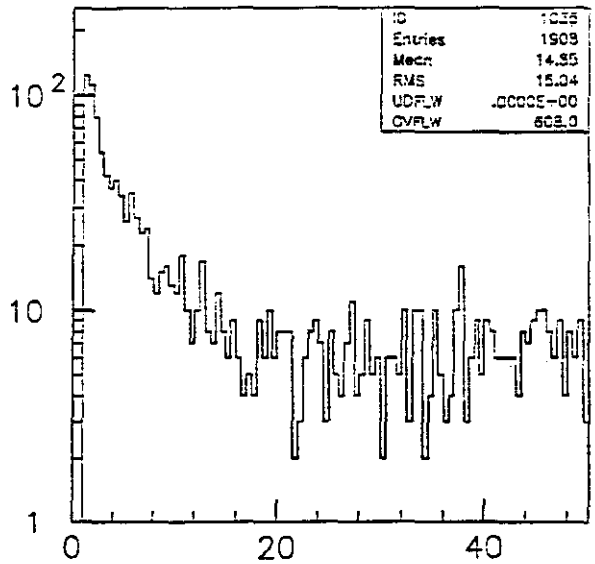


BASELINE II $H \to \gamma\gamma$.

93/01/06 16.55







CAL L2 TRIGGER PRIMITIVES.

1) Isolated e, γ finding algorithm.

BASELINE I 1) $\sum^{E_T}_{3\times3\,\text{cells}} / \sum^{E_T}_{5\times5\,\text{cells}} > 0.9$

2) $\sum^{E_T}_{3\times3\,\text{cells}} >$ threshold.

Baseline II ⇒ Lookup tables etc.

1st results seem ok.

⇒ NEW FEATURE: USE ONLY those CELLS WHERE L1 found something.

2) JET FINDING ALGORITHM. (Jheroen Dorenbosch, HU)

Baseline I Only. ⇒ UA1 Algorithm adapted for GEM (FDST).

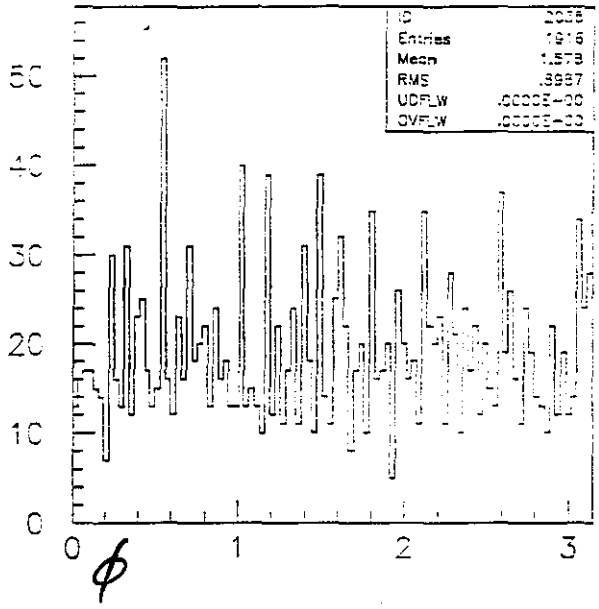
Important for a couple of reasons:

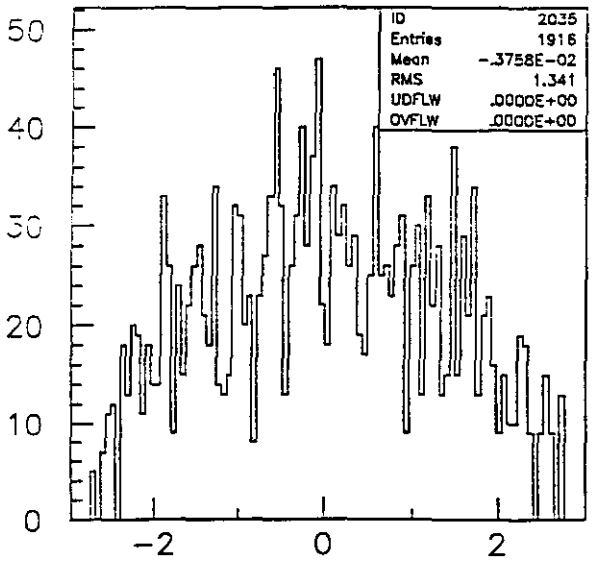
1) Get some idea about the processing time of a "Real" L2 algorithm
2) Starting point for L2 trigger studies
3) Jets are interesting, determine η, ϕ, E_T, R.

BASELINE II version soon.

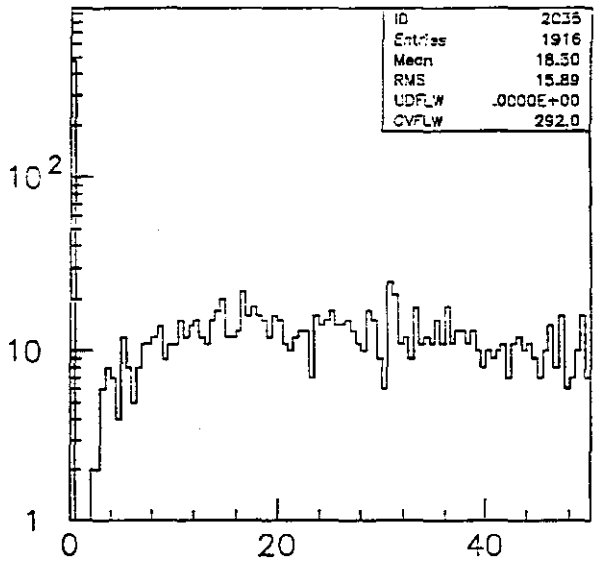
Base line II, $H \to \gamma\gamma$

93/01/06 11.03





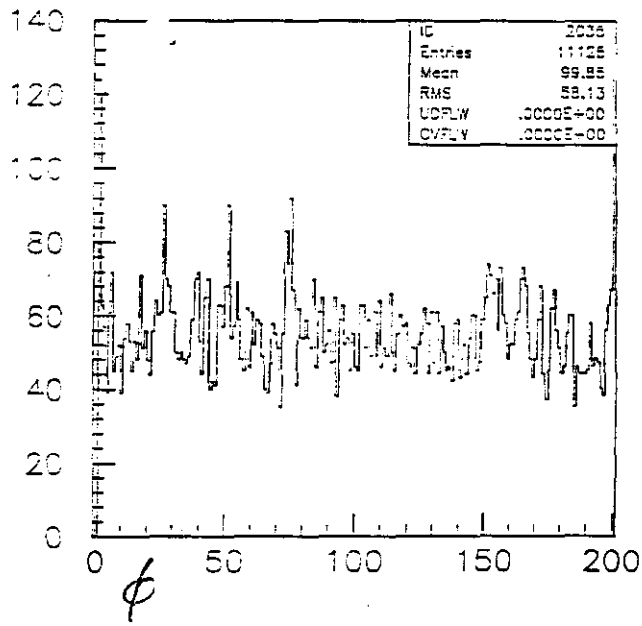
η $|\eta| \leq 2.5$

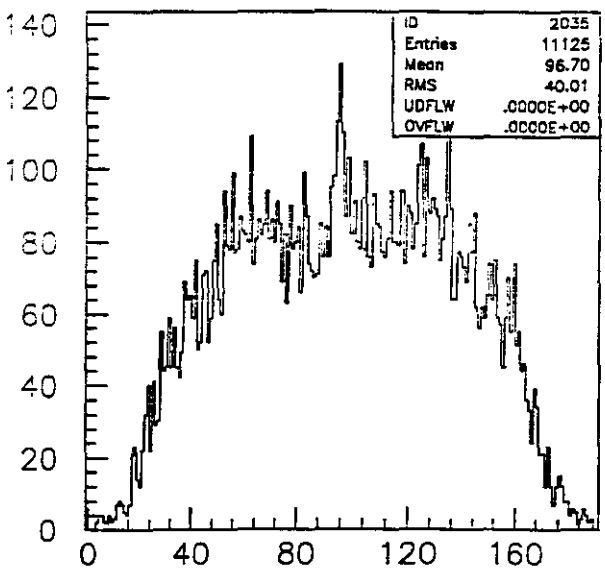


E_T

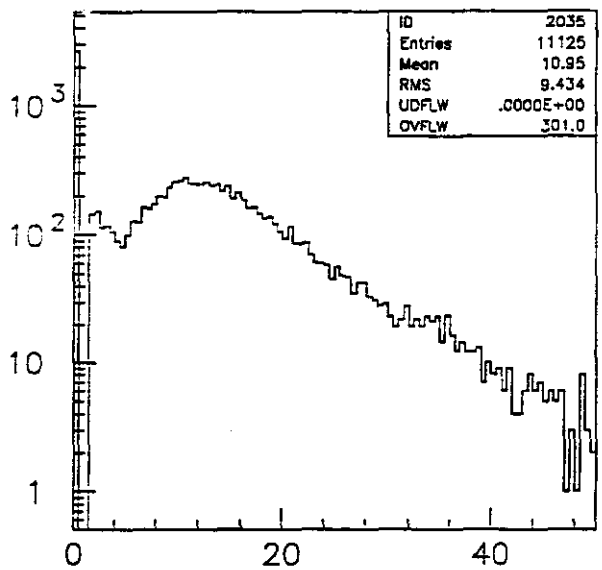
Baseline I, $H^{-2}\gamma\gamma$. ~~[illegible]~~ e, γ found by LZ.

92/10/18 12.58





η $|\eta| \leq 3.$



E_T

PRIMITIVES FROM OTHER COMPONENTS.

- μ system. (T. Dingus)
  - # tracks above P_T thresholds.
  - TRIGGER PROBABILITY IN GEMFAST.
  - L2 : μ momentum. (NOT in GEM fast.)
- CT
  - High P_T tracks @ L2 (NOT in GEM FAST).

⇒ More work necessary!

Combinations of the trigger primitives.

* Every physics process can be written in terms of trigger primitives.
  First attempt to do this in K McFarlane & HU's note for L2.

* OR-ing the equations gives the GEM L1 trigger.

* This list has to be coded in FORTRAN. (Relatively Easy).

* Study Rates, Efficiency, Background Reduction.

PEOPLE SHOULD START USING THIS ROUTINE IN THEIR ANALYSIS AND REPORT "STRANGE" BEHAVIOUR.

Reaction No.	Reaction	Trigger/Comment
0.1	single W	trigger on most W to lepton?
0.2	single Z	trigger on most Z to 2 leptons?
Higgs		
1.1	$H \to \gamma\gamma$	(2 of E_{16}) $\vee$ E_{50}
1.2	$t\bar{t} \to H \to \gamma\gamma$	(2 of E_{16}) $\wedge$ (3rd $E_{16} \vee M_{10}$)
1.3	$H \to \tau\tau$	(2 of E_{16}) $\wedge$ (2 of M_{10})
1.4	$H \to \ell\ell$ jet jet	(1.3)
1.5	$H \to \ell\ell\nu\bar{\nu}$	(1.3) $\vee$ P_{100}
1.6	$H \to \ell\ell\tau^-\tau^+$	(1.5)
Extended Higgs		
Heavy Flavor Physics		
3.1	$t\bar{t} \to W^+b$	($E_{50} \vee M_{30}$)
	$t\bar{t} \to H^+b$	($E_{50} \vee M_{30} \vee$ (multijet?) $\vee M_{10}$)
3.2	leptoquark	[H_{50} $\vee$ ((2 of E_{16}) $\vee$ (2 of M_{10}) $\wedge$ (2 of H_{50}) $\vee$ ($E_{16} \vee M_{10}$) $\wedge$ (3 of H_{50})] $\vee$[τ trigger? $\wedge$ (2 of H_{50})]
3.3	Technicolor	(3.2)?
Jet Physics		
4.1	quark substructure	H_{100} or H_{150} ?
4.2	$\rho_T^{\pm}$	(3.1) $\vee$((2 of H_{50}) $\wedge$ M_{10})
4.3	technicolour	(4.2)
Physics at high Luminosity		
5.1	quark substructure	(2 of E_{80}) $\vee$ (2 of M_{20})
5.2		$M_{highest\ possible} \vee E_{80}$
5.3	Z'^0	(5.1)
5.4	$W'^{\pm}$	Any trigger
5.5	$\rho_T^{\pm}$	Any trigger
Missing E_T Physics – Supersymmetry		
6.1	$\not{E}_T$	$P_?$
6.2	$\tilde{g}\tilde{g}$	$P_?$ $\vee$ (3 of H_{80})
6.3	$\tilde{q}$	(6.2)

Table 1: List of suggested Level 1 trigger criteria for the physics processes listed in section 2. The symbols E_X, H_Y, M_P, P_W and T_n are defined in section 5. The logic symbols used are: $\sim$ (not), $\wedge$ (and), $\vee$ (or) and $\underline{\vee}$ (exclusive or).

TO BE DONE:

1) Check Baseline II versions.
2) Baseline II version of the L2 jet finder ⇒ timing, Efficiency
3) Code L1 triggers in FORTRAN

} 1/92.

4) Less data to L2. Effects on trigger.
5) Backgrounds events in GEMfast (??)
   GEMfast still valid?
6) Efficiencies & Rates for physics & BG. (1st step)

} Before TDR Deadline.

7) Detailed study of BG events.
8) μ, CT trigger algo's.
9) HW in more detail in the trigger.
10) ....