GEM TN-93-415

GEM SSCL/Muon Meeting - San Diego, Ca

May 11, 1993

Abstract:

Agenda, attendees, and presentations of the GEM SSCL/Muon Meeting held in San Diego, CA May 11, 1993.

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TO: Muon Group
FROM: Mike Marx and Frank Taylor
SUBJECT:6Agendas for San Diego Meeting and PAC Defense
DATE: 5/6/93

Draft Agenda for San Diego GEM Muon Meeting

(I) Plenary Session: May 10, 1993

Overview of the Muon System, Status, and Motivation of Design Choices

o Overview of system and design choices	Frank Taylor (20 min.)
o Chamber and alignment details	Gena Mitselmakher (20 min.)
o Layout of chambers and support structure	Frank Nimblett (20 min.)

(II) Parallel Session - I : 8:00 - 14:00 May 11, 1993

The Muon Group Meeting will emphasize the preparation for the defense of the TDR before the PAC. Each speaker is asked to bring a first-draft of his talk. We will attempt to have a short version dry-run of the parallel session we have to conduct for the PAC meeting. The focus of the discussion will be on addressing the engineering and performance action items. The convenor (the first name shown in brackets below the subtopics list) of each topic is responsible for about 20 min. of formal presentation and 10 min. discussion. "Experts" for subtopics are indicated by brackets beside the subtopic. They are requested to cover the specific subtopic. All speakers please prepare a rough draft of your talk, a list of outstanding issues, and plan of attack of how to answer them. The convenor should coordinate with the experts.

Run-through of TDR defense - Parallel Session*:

(1) Overview of muon system
- design considerations and justification of choices

[Marx (Taylor to standin at San Diego) 8:00 - 8:30]

(2) Chamber technology
- summary of R&D program leading to CSCs [Mitselmakher]
- performance characteristics of CSCs [Polychronakos]
- realization of technology: mechanical and electrical design
- parameters outstanding to be determined by R&D
- summary of layout of chamber system (strip size, no. of chambers, etc.)

[Whitaker 8:30 - 9:00]

(3) Alignment system and technology choices
- description of "false sagitta method" [Mitselmakher]
- layout of alignment system
- straightness monitor technology choices
- tracks
- R&D program to answer remaining questions [Wuest]
- vertex constraint

[Paradiso 9:00 - 9:30]

(4) Support structure
- truss structure driven by chamber parameters and alignment scheme
- solid angle coverage and enhancements
- stress analysis
- vibration stability
- interface to magnet and chambers
- fabrication of parts, assembly, and installation in magnet

- assembly and installation in GEM
- access

[Nimblett/Belser 9:30 - 10:00]

(5) Trigger scheme and performance
- delta phi vs sagitta: definition of primatives and their resolutions
- nonbend plane
- beam tagging
- block diagram of electronics
- summary of trigger rates

[Atiya 10:00 - 10:30]

(6) Simulation of backgrounds
- neutrons and photons
- muon-associated electromagnetic

[Gavrilov 10:30 - 11:00]

(7) Simulation of muon system performance
- justification of shape and size of magnetic field [Rosenson]
- resolution performance (energy loss fluctuations, MS, chamber resol'ns) [Rosenson]
- pattern recognition [Dingus]
- results of hit level MC (reconstruction, resolution) [Wenaus]
- rate capability
- coverage (2 layers vs 3, and use of the CT and calorimeter)
- performance on physics benchmark processes (Ho and Z')

[McNeil 11:00 - 11:30]

(8) Construction of chambers and their commissioning
- plans for chamber factories [Johnson]
- discussion of chamber factories
- commissioning of detector [Wuest]

[Wuest/Johnson 11:30 - 12:00]

(9) Organization and plans
- responsibilities chart ("boxology")
- major milestones (R&D, SS, chambers, alignment)

[Taylor/Baker 13:00 - 13:30]

Postmortem of Cost Review
[Gustavson 10 min]

Summary discussion and action items

[Group 13:30 - 14:00]

* PAC Plenary Session to be given by Taylor

(3) Parallel Session - II 14:00 - 17:30 May 11, 1993

Joint meeting with elements of CT and Calorimeter groups to discuss ways to optimize the coverage and performance of the muon system using all systems of GEM. Details to be announced later by Ken Lane and co.

Agenda of PAC Muon Parallel Session May 24 - 28, 1993

Note: We will have a full dress rehersal of the PAC talks during the May 19 - 20 meeting at SSCL. All speakers should come prepared to give a complete run through.

(1) Overview of muon system
- design considerations and justification of choices
[Marx 1/2 hr]

(2) Chamber technology

part (a)
- summary of R&D program leading to CSCs
[Mitselmakher 1/2 hr]
- performance characteristics of CSCs: resolution, L-angle, tolerance requirements
[Polychronakos 1/2 hr]

part (b)
- realization of technology: mechanical and electrical design
- summary of layout of chamber system (strip size, no. of chambers, etc.)
- parameters outstanding to be determined by R&D
[Whitaker 1/2]

(3) Alignment system

part (a)
- general description of "false sagitta method"
[Mitselmakher 1/2 hr]

part (b)
- layout of local alignment system
- straightness monitor technology choices
- tracks
- global alignment
- vertex constraint
[Paradiso 1/2 hr]

part (c)
- R&D program to answer remaining questions
[Wuest 1/4 hr]

(4) Support structure and installation
- truss structure driven by chamber parameters and alignment scheme
- stress analysis
- vibration stability
- interface to magnet and chambers
- fabrication of parts, assembly, and installation in magnet
- access
- solid angle coverage and enhancements
[Nimblett/Belser 2 hr]

(5) Trigger scheme and performance
- delta phi vs sagitta: definition of primatives and their resolutions
- nonbend plane
- beam tagging
- block diagram of electronics
- summary of trigger rates
[Atiya 1hr]

(6) Simulation of backgrounds
- neutrons and photons
- muon-associated electromagnetic
[Gavrilov 1/2 hr]

(7) Simulation of muon system performance

part (a)
- justification of shape and size of magnetic field

- resolution performance (energy loss fluctuations, MS, chamber resol'ns)
- results of hit level MC (reconstruction, resolution)
  [Rosenson 1/2 hr]

part (b)

- pattern recognition
- chamber occupancy considerations
- coverage (2 layers vs 3, and use of the CT and calorimeter)
- performance on physics benchmark processes (Ho and Z')
  [McNeil 1 hr]

(8) Construction of chambers and their commissioning

- plans for chamber factories and industrialization of chamber design
  [Johnson 1/2 hr]
- commissioning of detector
  [Wuest 1/2 hr]

(9) Organization and plans

- responsibilities chart
- major milestones (R&D, SS, chambers, alignment, installation)
  [Taylor 1/2 hr]

SSC/Muon Meeting
May 11, 1993

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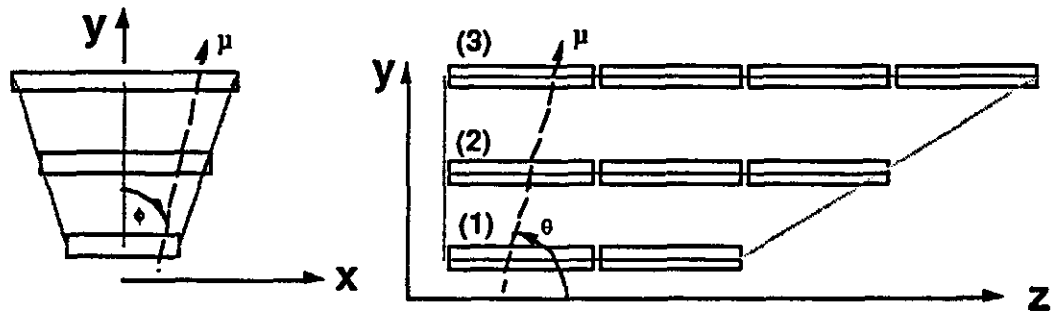
Alignment Analysis



Objectives and Action Items Covered:

- Check non-projective alignment corrections
- Check alignment monitors pulled in from chamber edges in phi
- Investigate Endcap Configuration
- Investigate hybrid strategies (i.e. axial/projective)
- Thermal effects
- PAC outline

J. Paradiso
San Diego/SSC, 5/93

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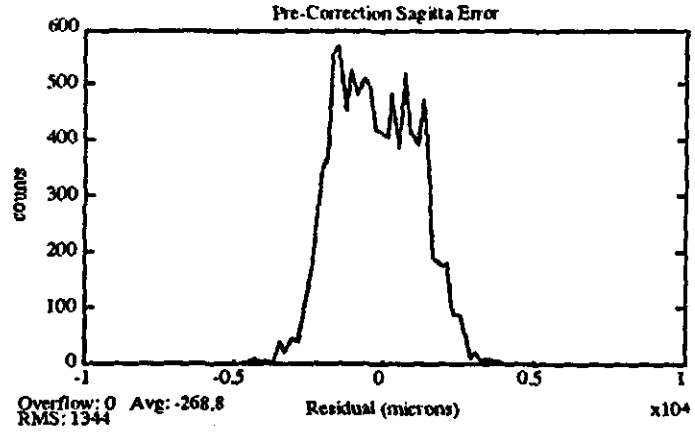
Analysis Package

- Old (10/92) MATLAB projective/axial analysis hacked up again to get a glimpse into new configurations
- Modified to do some statistical analysis a' la Ostapchuk, i.e.
  - Inject errors into monitors (axial and projective)
  - Injects alignment xfer errors, axial/projective handoff error
  - Inject errors into chamber z-coordinate
  - Smear LOS projectivity (always focused, however..)
  - Incorporate bunch width along z
  - Randomly displaces/rotates chambers according to Andre's TDR table
- No sag assumed in chambers as of now; rigid-body model
- No Lorentz chamber tilt

Sagitta error pre-correction:

$\sigma = 1.3$ mm



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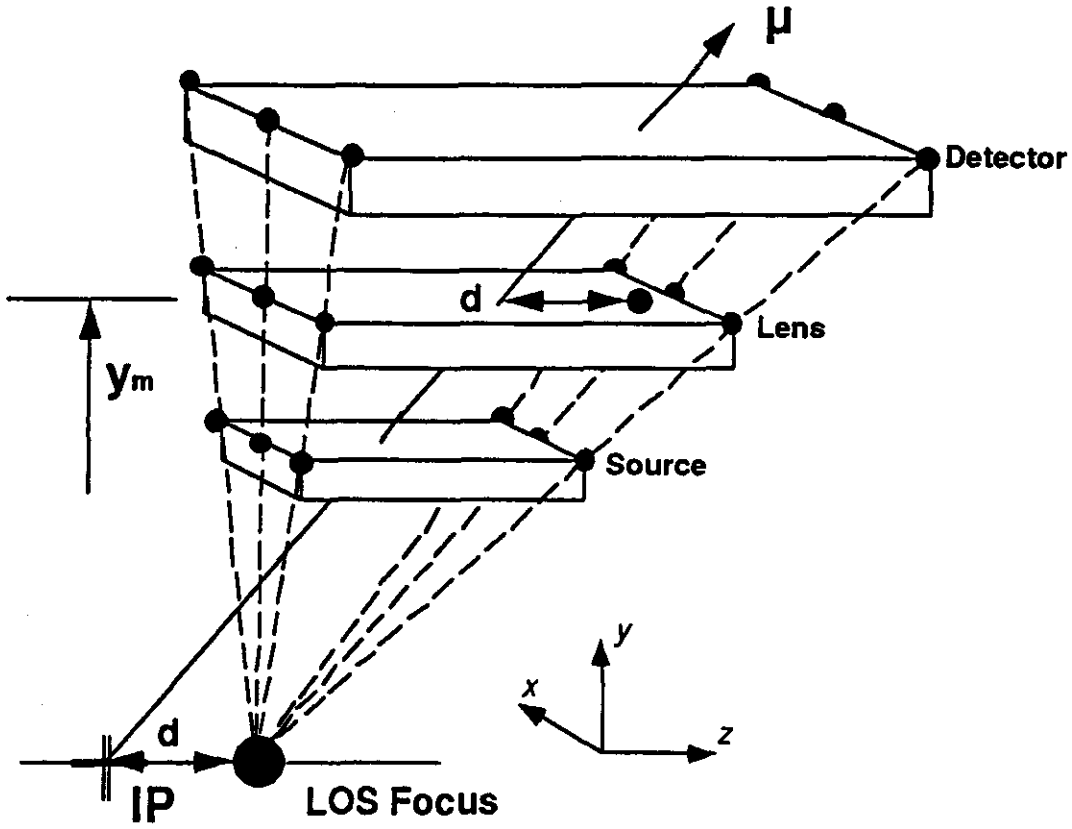
Projective Offset Correction



Simple Example:

Middle Chamber rotated by α along y:

$$S = y_m \cot\theta \tan\alpha - d$$

- Do linear interpolation over z-coordinate of middle chamber (from LSQ fit).
- Subtract the known value of d from the middle-chamber z-interpolation coordinate (i.e. lump all errors here).
- Correction helps for small non-projectivity; relevant measurement becomes singular for larger projectivity errors.

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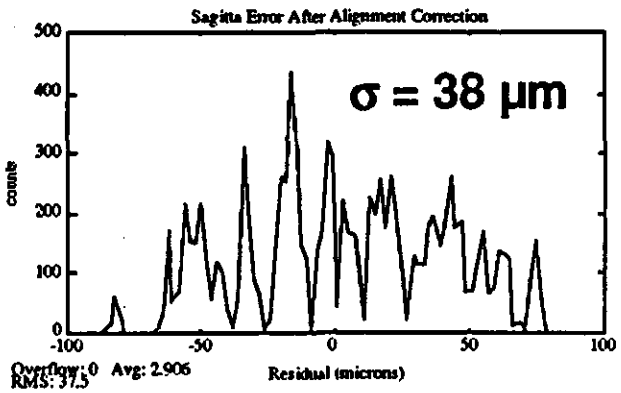
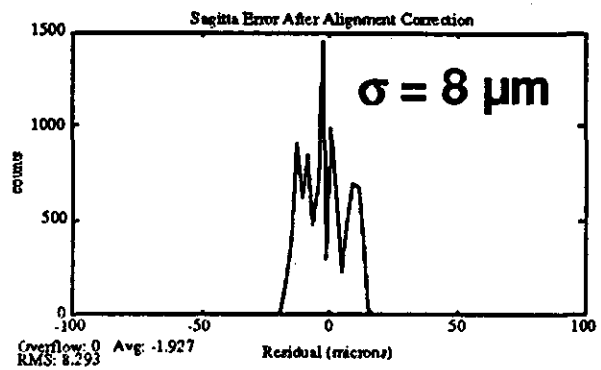
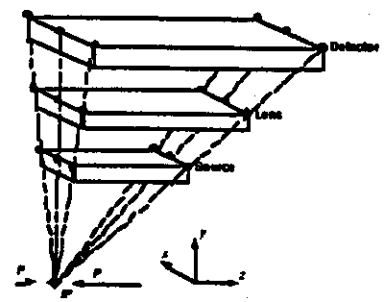
Non-Projective LOS; Statistical



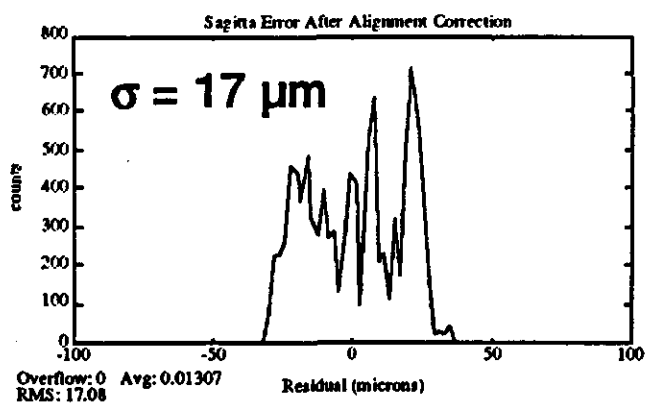
5 cm z-shift; uncorrected



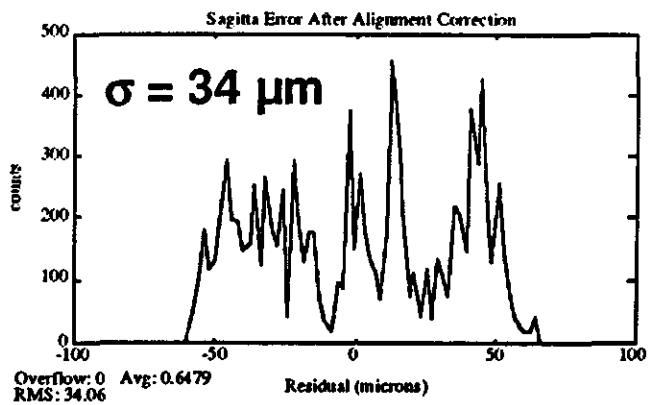
5 cm z-shift; corrected



Subtract z offset from middle-layer interpolation coordinate



10 cm z-shift; corrected



20 cm z-shift; corrected

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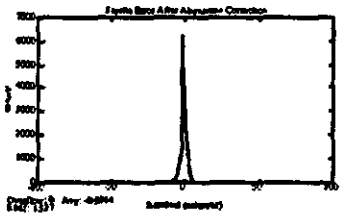
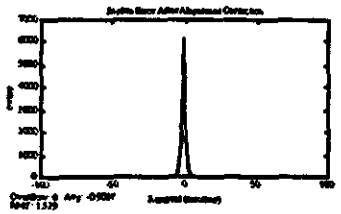
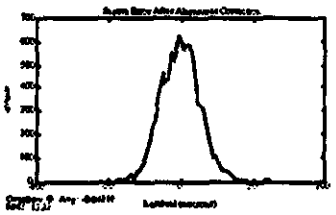
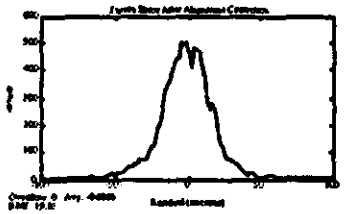
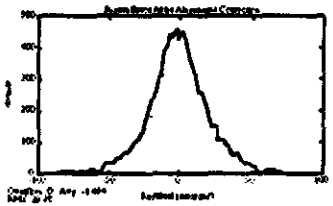
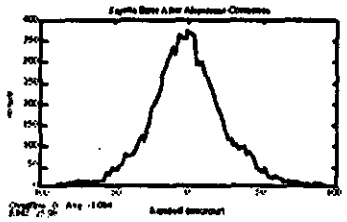
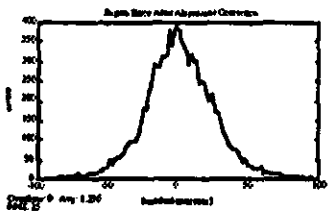
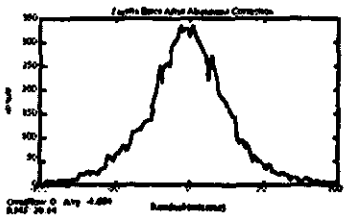
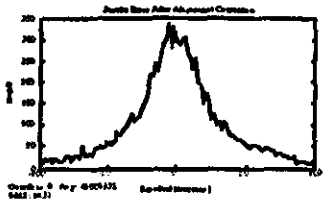
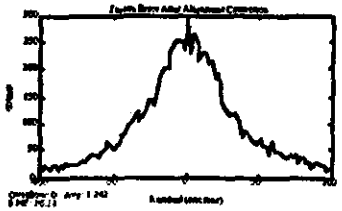
Monitor Location

Chamber Edge			60% of Chamber Edge
RMS			RMS
σ = 1.5 μm		1.0 ⟷ Ideal; no SLM, projectivity errors	 σ = 1.5 μm
σ = 13 μm		1.5 ⟷ 25 μm SLM error 13 μm Xfer error	 σ = 20 μm
σ = 22 μm		1.2 ⟷ 15 mm (outer) z-coord. error	 σ = 26 μm
σ = 25 μm		1.1 ⟷ ±3 cm SLM projection error	 σ = 28 μm
(AO = 22 μm) σ = 34 μm		1.05 ⟷ 4.25 cm bunch smear	 σ = 36 μm

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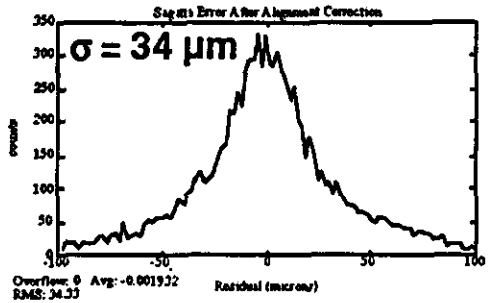
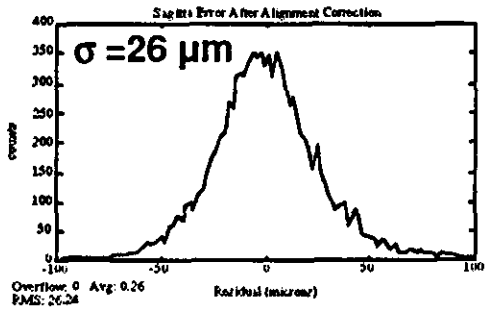
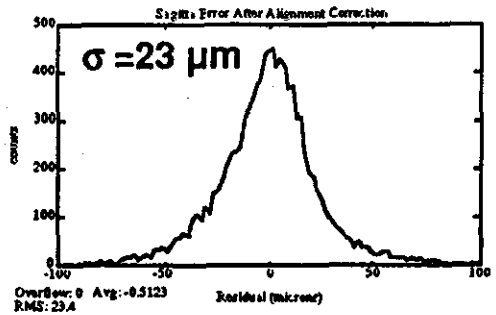
Z-Projectivity Compensation

Chamber Edge





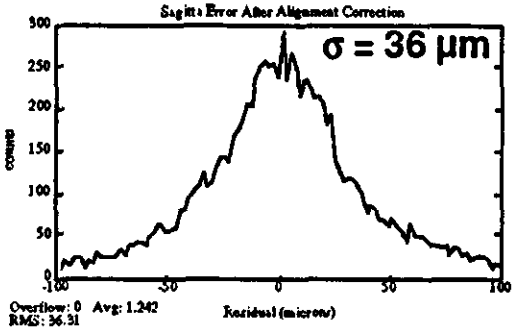


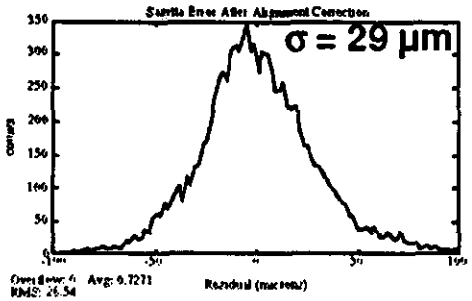
4.25 cm bunch smear

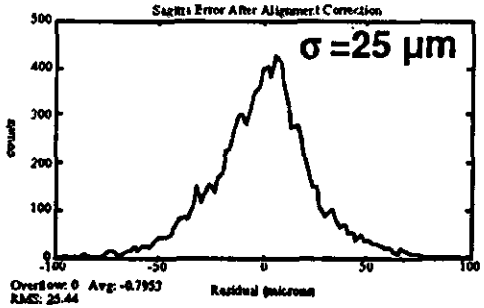
With Z-shift correction implemented

More precise 10 μm SLM's (as with tested systems)

60% of Chamber Edge







Also reach s = 25 μm with 25 μm SLM's and 20% less chamber positioning errors

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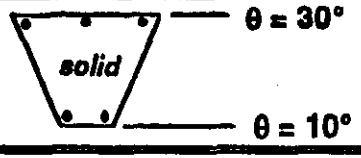
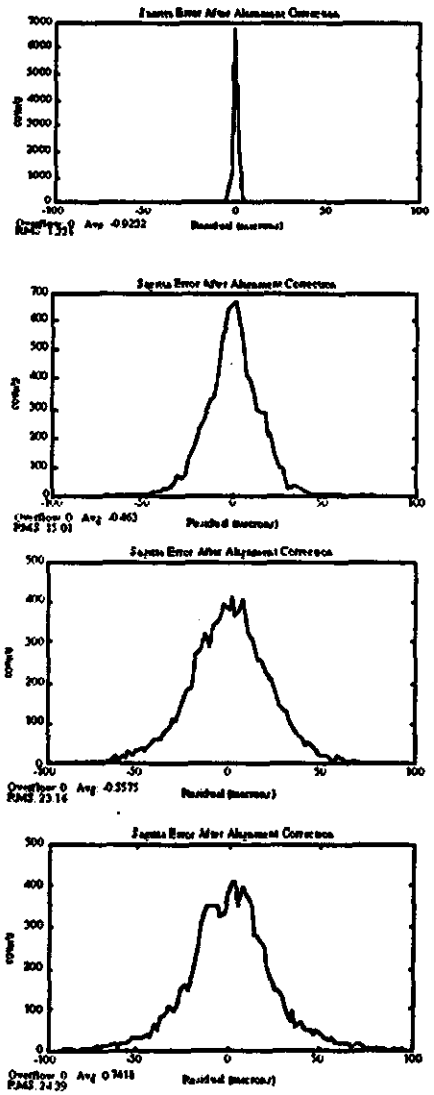
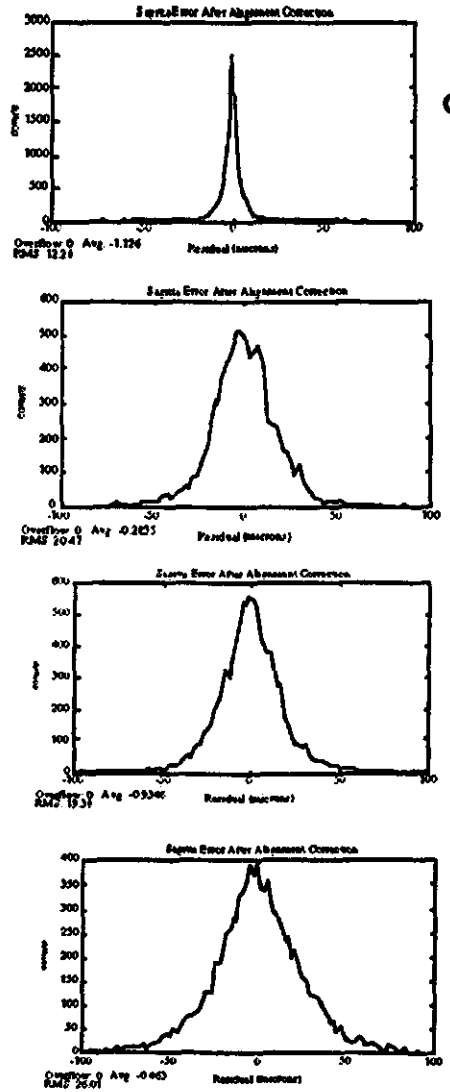


Initial Endcap Look...

Propagate quadratic down from 30° monitors		Assume zero quadratic component at 10°
σ = 1.3 μm	Ideal; no SLM, projectivity errors	σ = 12 μm
σ = 15 μm	25 μm SLM error 13 μm Xfer error	σ = 20 μm
σ = 23 μm	1.5 cm (outer) y-errors	σ = 25 μm
σ = 24 μm	Projectivity error, corrected beam-smear	σ = 26 μm





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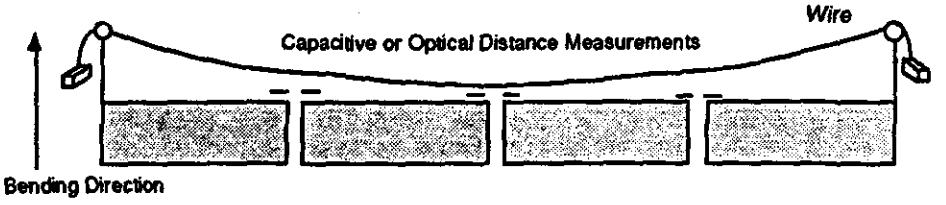
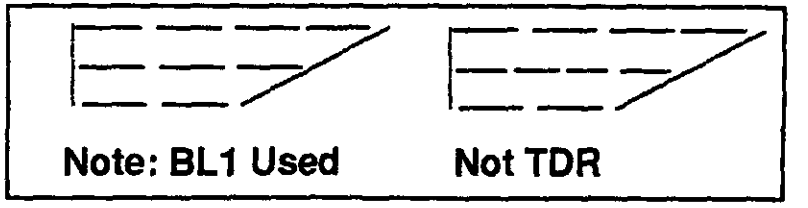
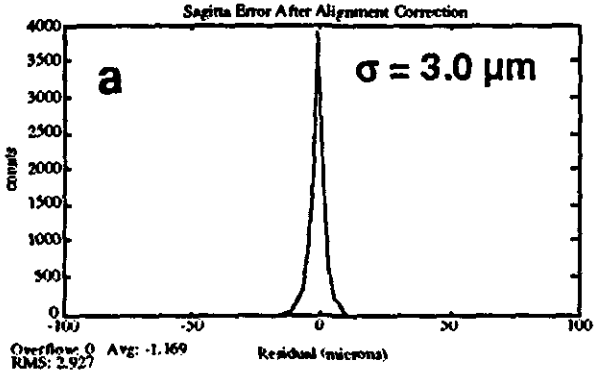
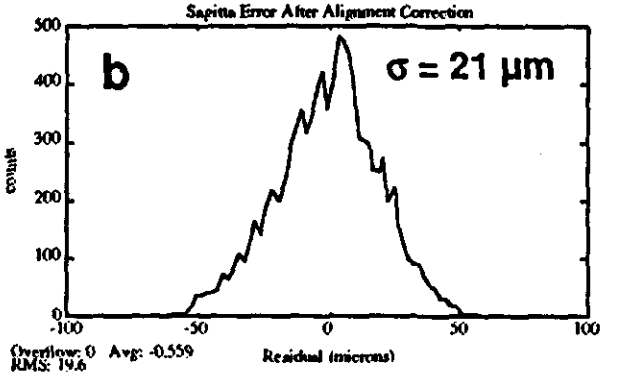
Hybrid Wire Monitors



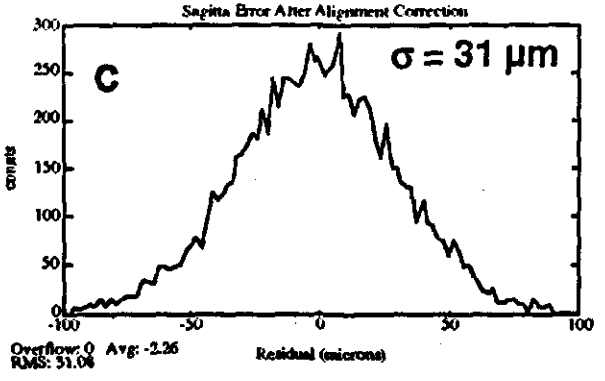




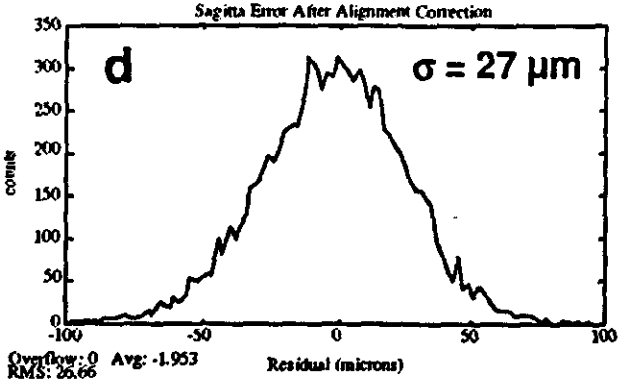
Ideal; no SLM, Projectivity errors



25/10 μm SLM, 15/10 μm wire, 10 μm handoff



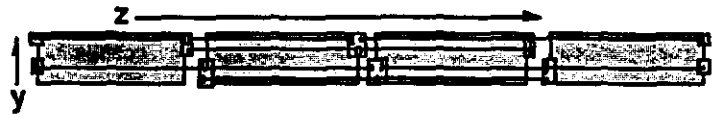
Projectivity, Bunch smear, 60% ϕ spacing



12/10 μm SLM, 10/5 μm wire

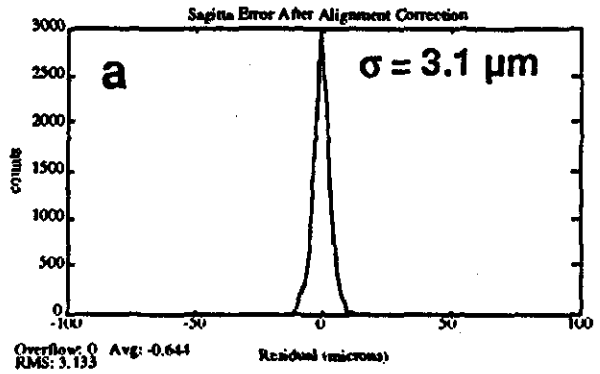
GEM

Hybrid Nested Optical Monitors

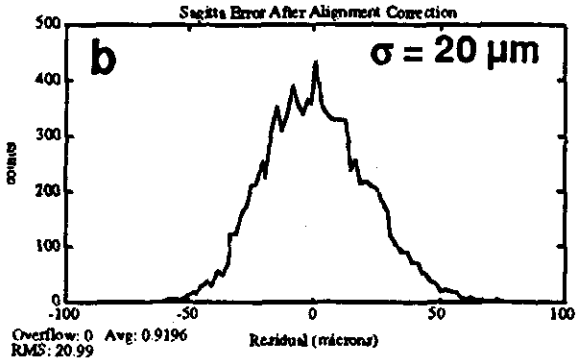


2 Sets of nested straight ness monitors for opposit e corners

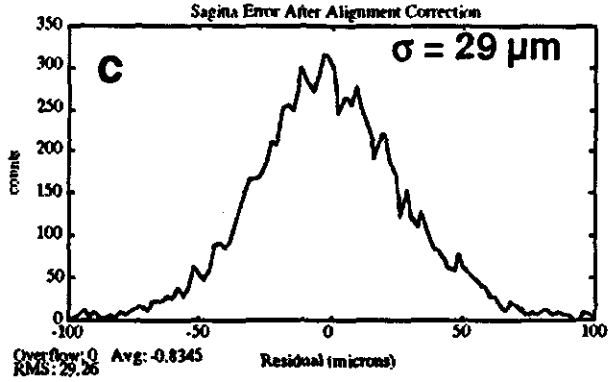
Again, BL1 not TDR!



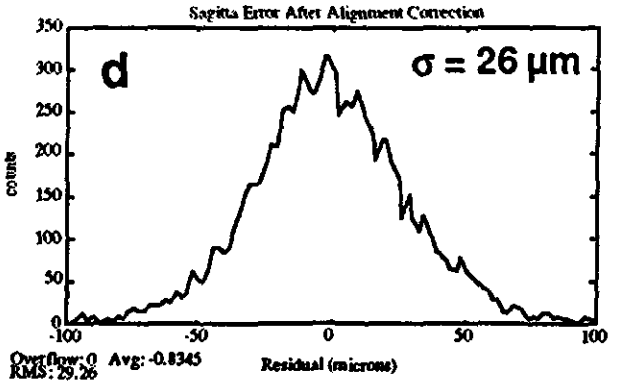
Ideal; no SLM, Projectivity errors



25/10 μm SLM 10 μm handoff



Projectivity, Bunch smear, 60% ϕ spacing



12/10 μm SLM

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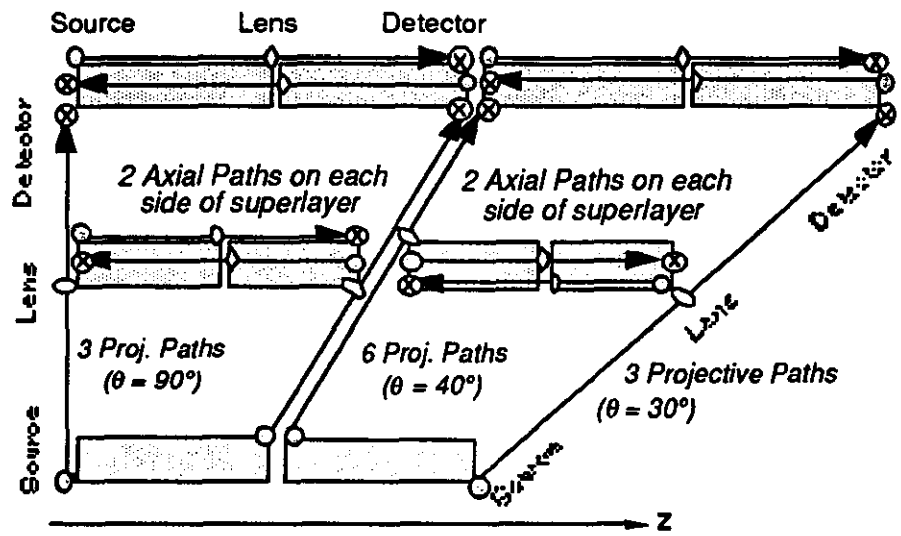
Relevant option...



b) All-Optical Axial/Projective Comprimise

- One SLM with added projective information through middle
- To be simulated (MATLAB code not set up appropriately)?
- Could adapt wire approach with added (single) middle projective path

Not compatible with theta overlap!!

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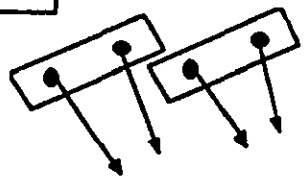
Coupled Chambers in Phi

A



Constraints on coupled cham

Normal

FROM: Joseph Paradiso Joseph Paradiso (4/30/93) Joseph Paradiso (4/30/93)
TO: Mike Marx
CC: John Horvarth, Frank Nimblett
BCC:

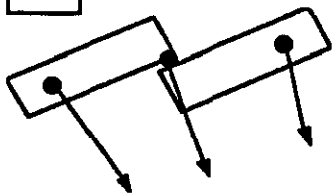
OFFICE MEMO

Subject: Constraints on coupled chambers

Time: 1:51 PM

Date: 4/30/93

B



Mike:

I looked quickly at the positioning constraints on the coupled chamber pair in phi. If we run 4 monitors here (i.e. two on each tower instead of three), a major constraint is introduced into the z-axis (beamline) rotation of each separate chamber (i.e. "hinging"), as we had discussed in the meeting (three monitors are needed to define the quadratic interpolant, as Gena and Andrey had demonstrated). Displacements and other rotations can still be described adequately by the two monitor systems and a linear interpolation, but the rotation about the z-axis must be additionally limited. If we assume that the major sagitta error introduced from the z-rotations is due to the mis-monitored delta-y displacement [Eq. 7 in TN-93-333 and Eq. 5 in TN-92-150], which should be limited to sigma = 180 μm [compare to the 60 μm that we had calculated for Baseline I in TN-92-125, where our towers were 3 times wider in phi], we must keep the z-rotations of the separate chambers to within **sigma = 0.3 mrad for the middle superlayer and sigma = 0.5 mrad for the inner and outer superlayer.** There may also be coupling to the other coordinates that can make things more restrictive, but this limit on the z-rotation is probably ball-park, and should get things started.

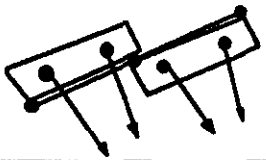
A

In the case where we would have only 3 monitors per chamber pair, the same z-rotation restriction again applies. There is now an additional restriction on x (the sagitta coordinate), however; the transfer from the shared alignment element (in the middle) to EACH of the chambers in the pair must be within our quoted 10 microns and the radial position $\Delta y \leq 150$ μm (and stay there).

B

As you would assume, these restrictions apply along the z-length of the chamber as well. The monitors will measure at the edges, and the chamber deflection will have to be properly described by a linear interpolation along z (assuming that chamber sag, etc. have been adequately parameterized or separately monitored, as we'd discussed).

A'



Add SLM to measure hinging; relax z-rotation limit? (like in endcap)

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Regs. -Joe-

SGH Alignment Discussions

Joe Paradiso, Jacques Govingnon, Mehdi Zargemi (SGH) 5/7/93

- Axial/projective alignment favored
- Concern about identifying chamber sag
  - Some interest in midpoint alignment monitor along chamber, depending on results from structural model
- Discussed ideas of making sectors self-contained alignment frames; i.e. aligning in r-phi and z with proximity sensors and/or wires (handoff error accumulation? useful in survey?)
- Discussed concept of using structural segments as "rulers"; i.e. measuring proximity and displacement along struts as lower-precision measurement (i.e. Δy to break ambiguity and widen range).
- Discussed the application of optimal estimator to blend all information (orthogonal SLM coordinate, structural model, thermal data, muon data, etc.), thus increase range/robustness of sagitta correction.
- Suggested that the 200 μm global alignment could be backed out by a good structural model and intelligently located thermal sensors
  - Such feats currently performed on radio telescopes

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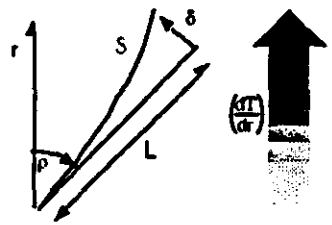
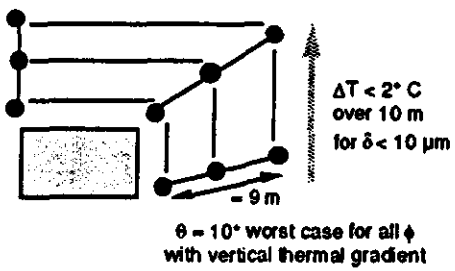
Thermal Effects

- Calculations from CERN AT report, 8/24/92, J.C. Gayde, C. Lasseur
- Displacement proportional to double integral (as with muon momentum).

$$\delta(\mu m) \approx \iint_s G(s) \sin\rho \, d^2s = \frac{1}{2} L^2 \left(\frac{\Delta T}{\Delta R}\right) \sin\rho$$

m — °C/m — For uniform thermal gradient

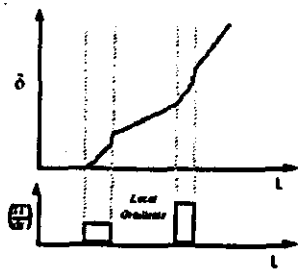




Assume ρ = 90°, L = 9 m (worst case). Then:
Δt = 2° C over detector half (10 m) ➡ δ = 8 μm

Measure temperature & compensate (structure and chambers will be monitored regardless)

- Local thermal gradients
  - First integral contributes quadratically only over regions with nonzero (dT/dr); second integral ramps linearly in between.
  - For 5 μm displacement and (dT/dr) extending 50 cm along & perpendicular to LOS, we can specify the local gradient:



(dT/dr) < 1° C/m near source (at 9 m); (dT/dr) < 2° C/m near lens (at 4.5 m)

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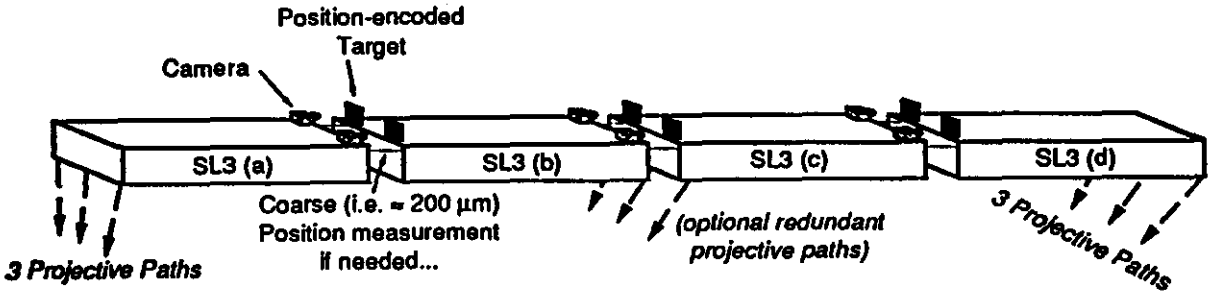
Hardware Tests

- Video Straightness monitor (and quad-cell version) tested with large box fan blowing full-tilt onto optics table to emulate air conditioning, turbulence.
  - Both systems seen to function perfectly under these conditions.
  - Measurements actually *better* (less noisy) than those taken without fan blowing (quantitative data coming).
  - Local, varying thermal gradients are randomized.
  - Don't need infamous cardboard tubes!
  - System goes to hell when heat gun blowing on optical path (as expected; a very extreme condition!!).

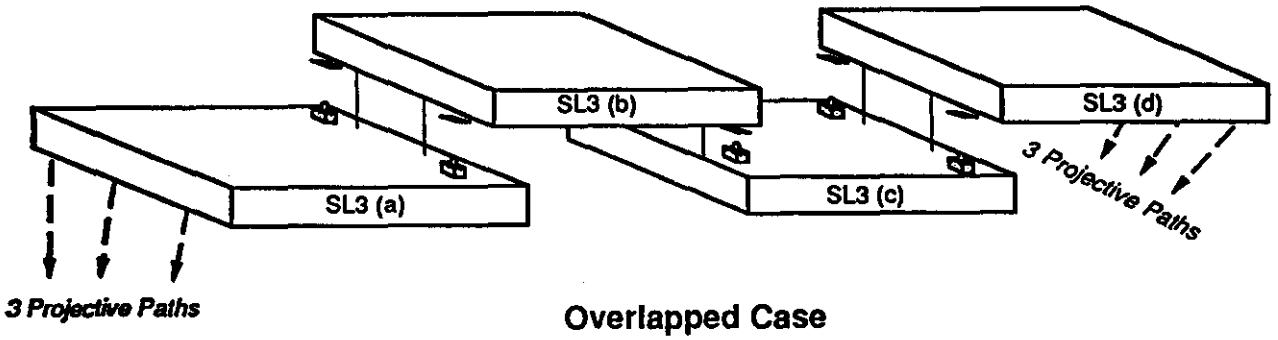
- The mini Chinon camera was tested at the Bldg. 44 magnet
  - Major shift in output image quality occurs at low field ($B \leq 1$ KG)
  - This was not unexpected, as there seem to be ferrite-core inductors on the card
  - This unit is fine for tests (i.e. the alignment test stand), but it should be robustified (or another device located; i.e. the single-chip camera) for operation in the GEM magnetic field.

GEM

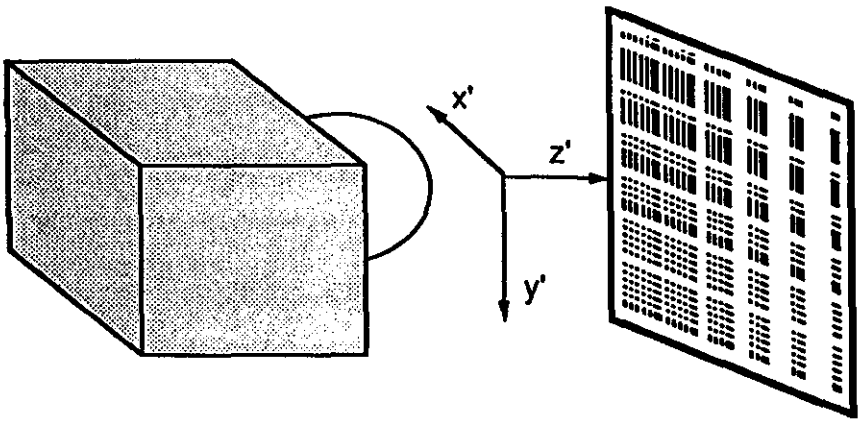
C.S. Draper Laboratory Sun May 16 1993 4:11 pm Page 14 of 14



Non-Overlapped Case



Overlapped Case



Video Proximity Monitor (VPM)

A mini SS camera (such as we now have) on one chamber images position-encoded tag on the adjacent chamber, determining x' and y' with very high accuracy. The z' distance may be determined to sufficient accuracy by measuring the scale between features on the encoded tag (or, if needed, a coarse position measurement may be able to be determined by using a simple proximity sensor). This system is sensitive to the angle of sight between the camera and tag (which is why I bypassed it for previous consideration), but the lever arm along z' can be made very short (i.e. a cm or so?), and a measurement of the Δz is made at each site, pulling out the effects of chamber rotation. The rotation angle may also be determined by measuring the perspective skew of the tag image. The code on the tag can be significantly finer that the code now used (since we are short range and won't suffer from diffraction limit problems that currently occur over 9 meters), and illumination will be trivial. One problem, however, is that rotations about the x' axis may not be sufficiently well determined...

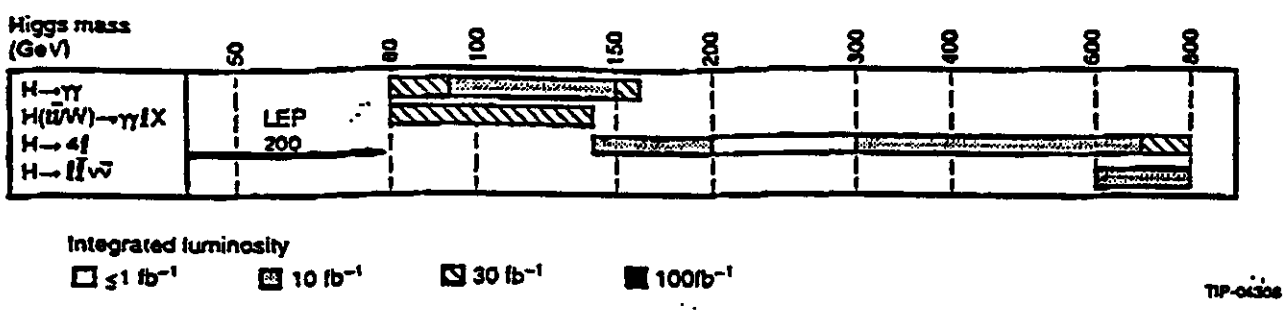
Muons in the calorimeter.

Y.Efremenko
ITEP/ORNL

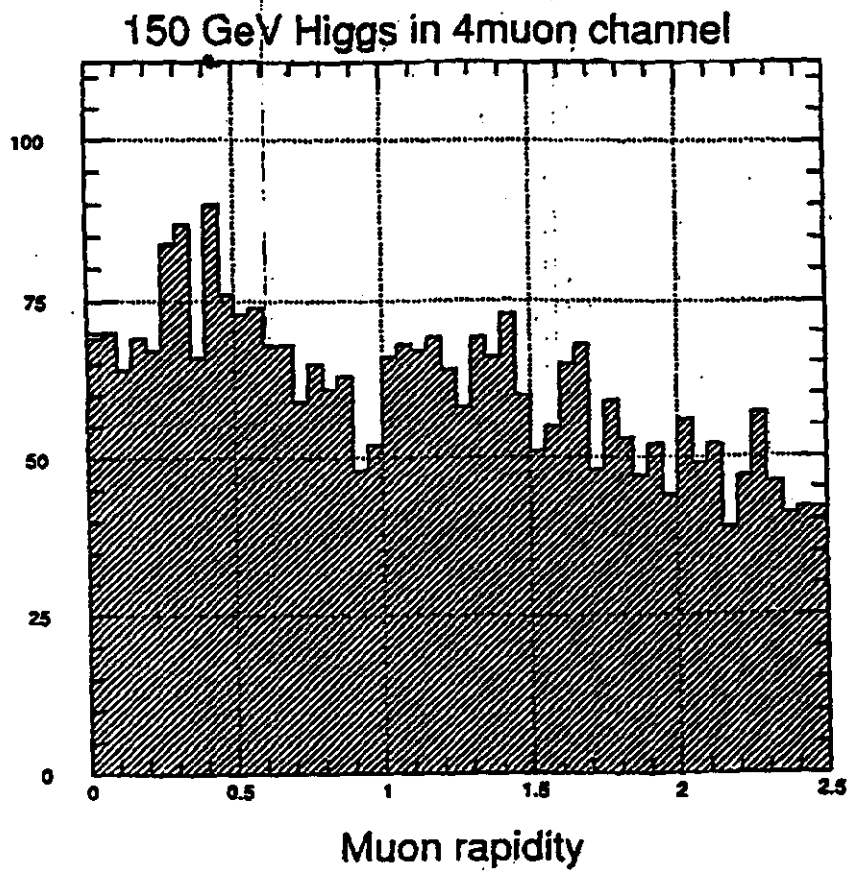
1. Muon Pt.
2. Muon energy loss correction in calorimeter
3. Noise in calorimeter.
4. Instrumentation of SBC
5. Endcap region.
6. Conclusion

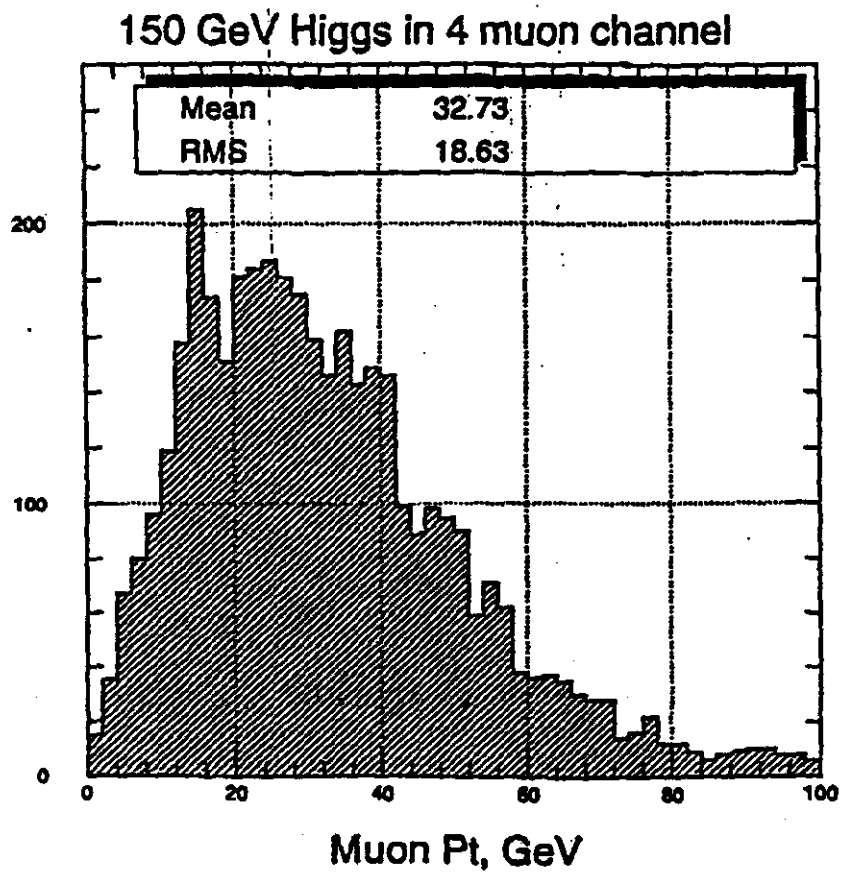
As was shown before (GEM-TN-269, 349) for muon with Pt higher,then 100 GeV the calorimeter influence on the muon resolution is negligible.

At the same time, muons with the low Pt (10-40 GeV) are very important for the Higgs detection.



The more difficult for detection Higgs in 4μ is the Higgs with the mass 140 - 185 GeV where the Z0 mass constrain doesn't work.

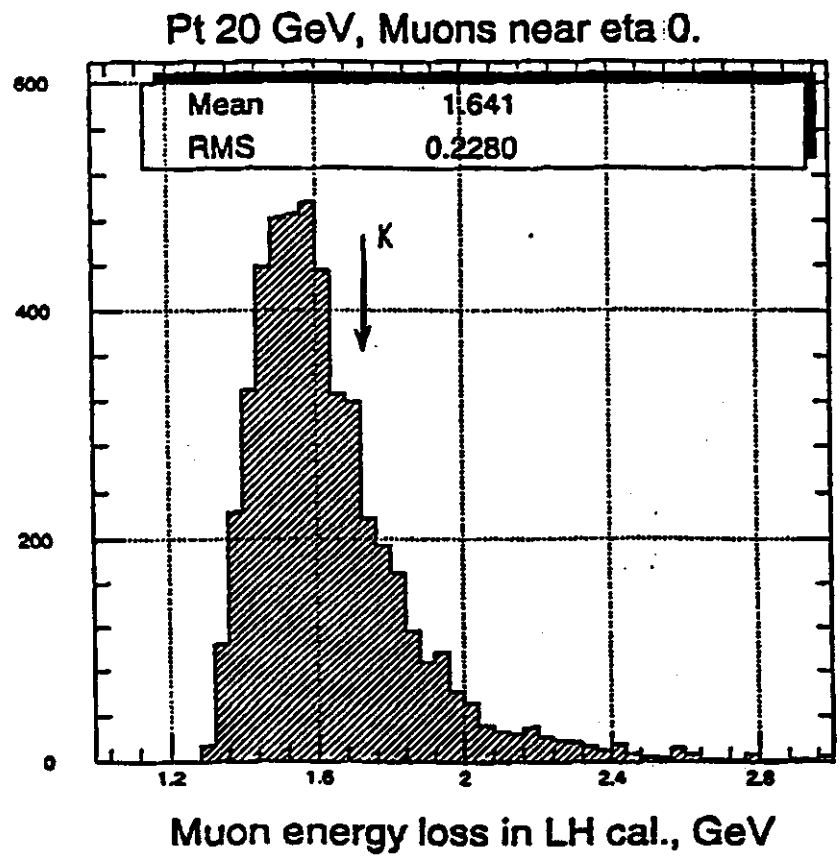

150 GeV Higgs in 4muon channel
100
75
50
25
0
0
0.5
1
1.5
2
2.5
Muon rapidity


150 GeV Higgs in 4 muon channel
Mean 32.73
RMS 18.63
200
100
0
0
20
40
60
80
100
Muon Pt, GeV

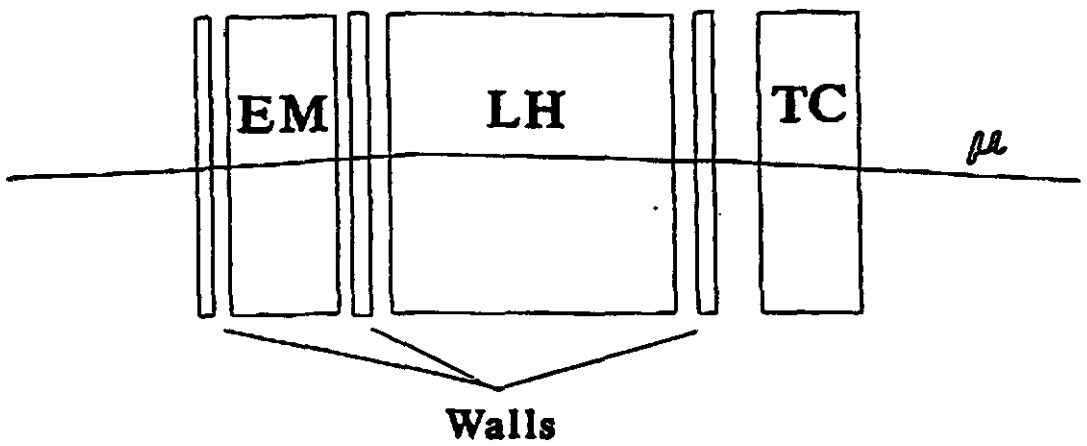
Muon energy loss correction in calorimeter.

1. Using calorimeter information
2. Using the most probable value

→ Combination.



Geant simulation.



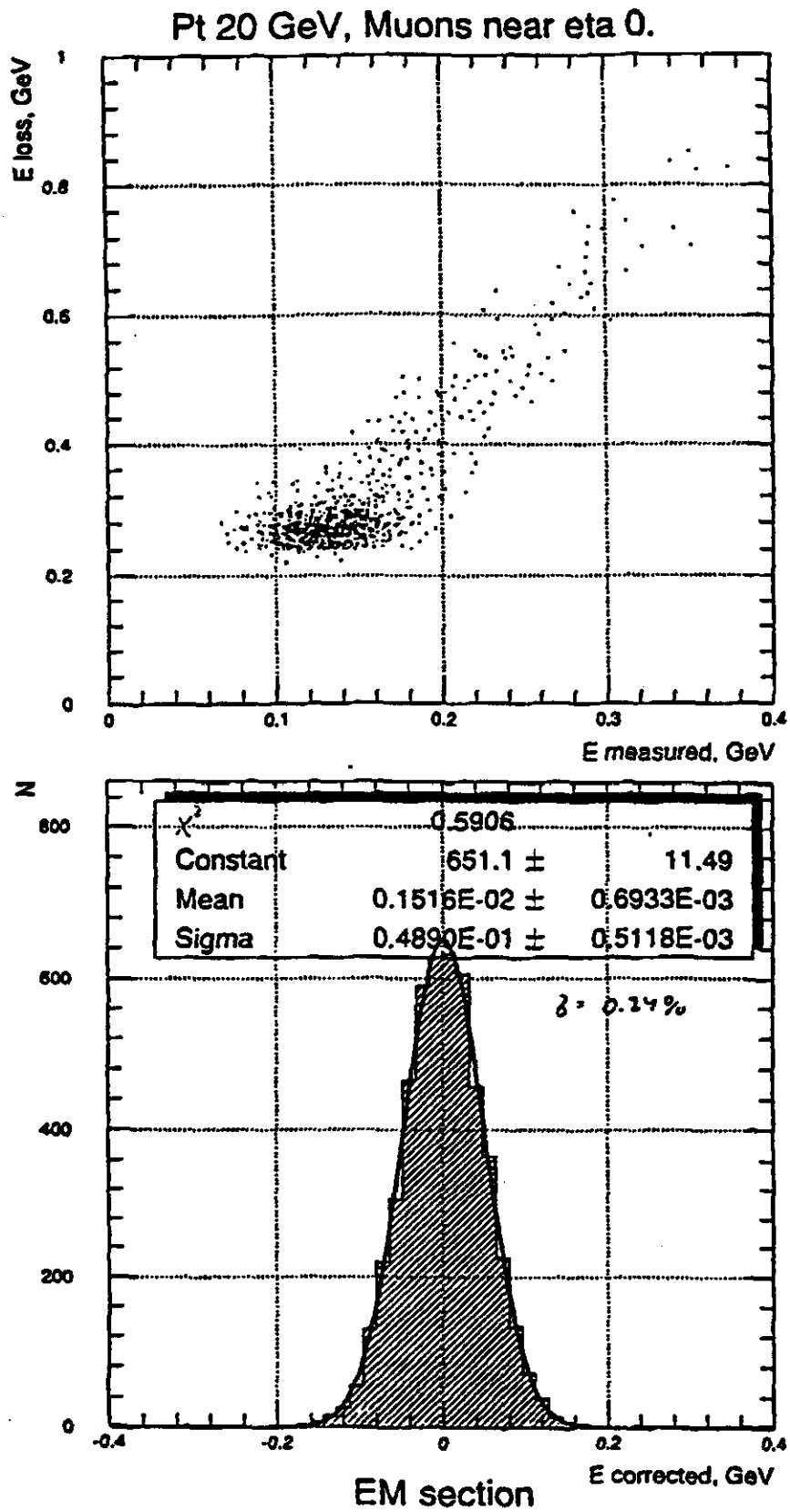
Muons Pt 10, 20, 50, 100, 500 GeV

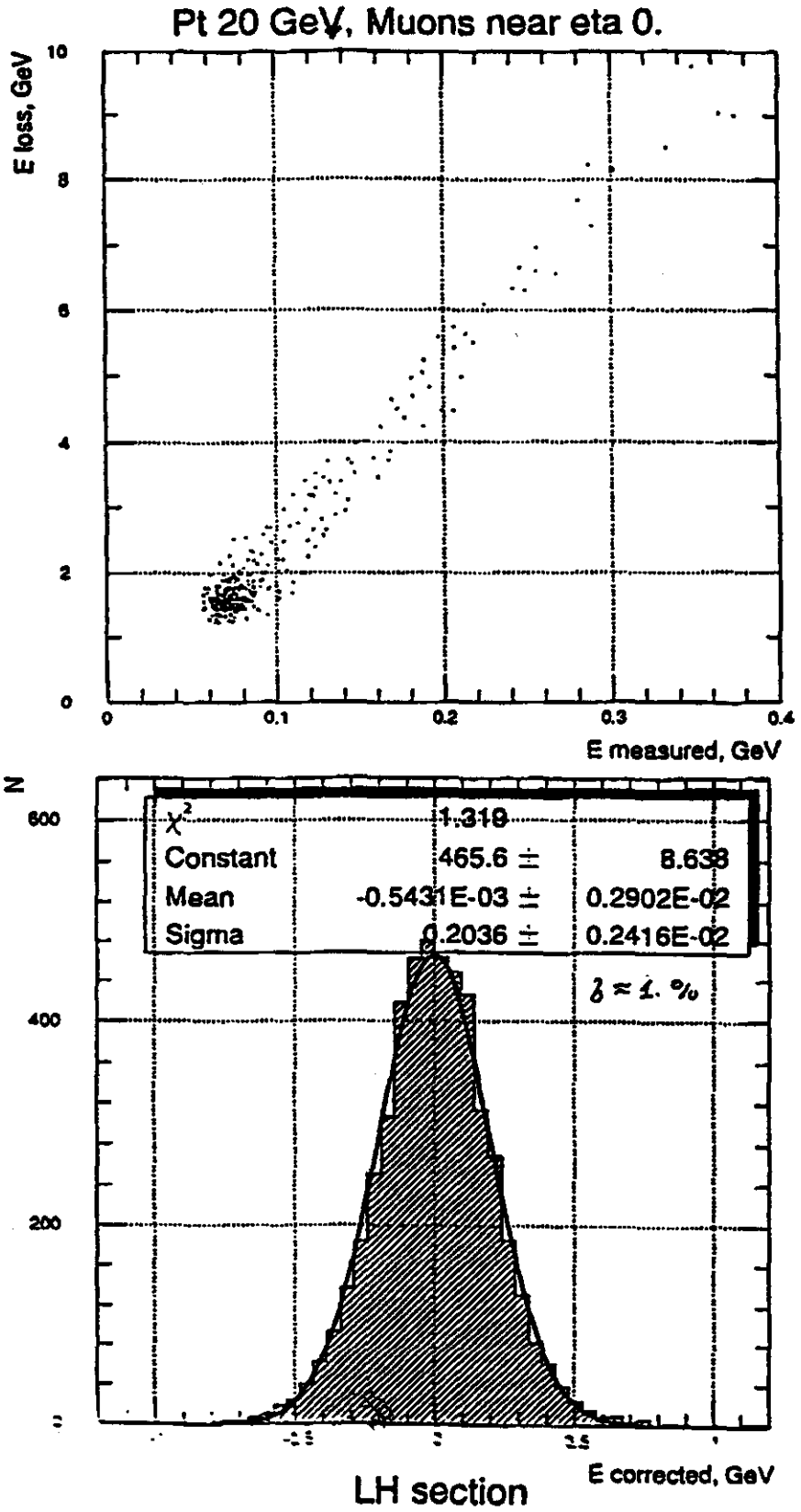
Rapidity region near 0.0 and 0.9

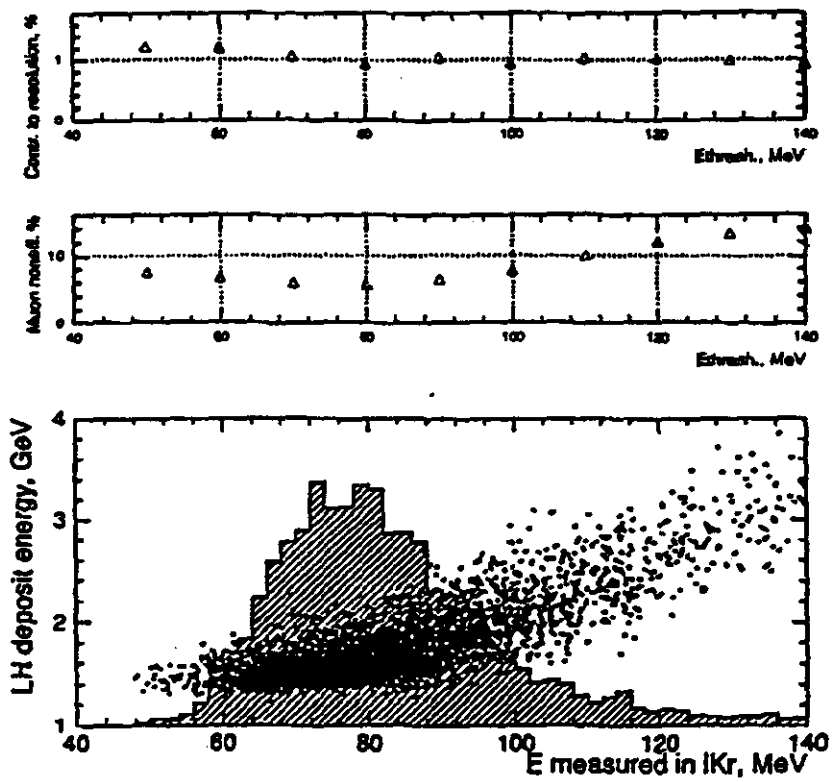
One point for endcap Pt 20 GeV η 2.0

$$\Delta E_\mu = E^0_\mu - (P_\mu + k_1 E_{EM} + K_2 E_H + K_3 E_{TC} + C)$$

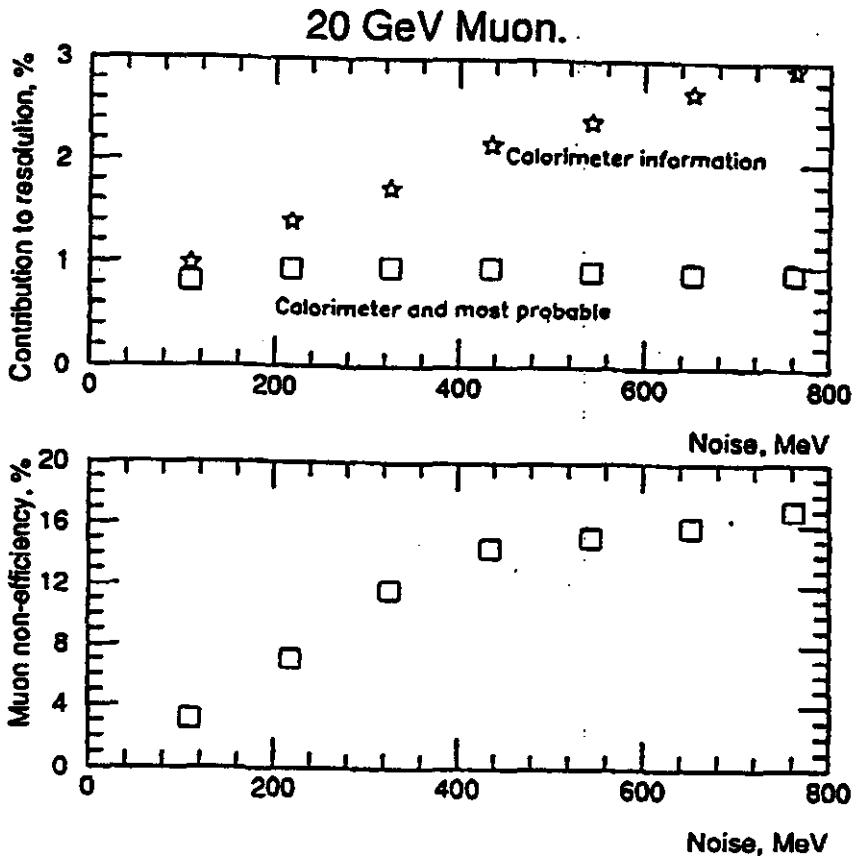
Contribution from calorimeter only if $\delta P_\mu / P_\mu = 0$

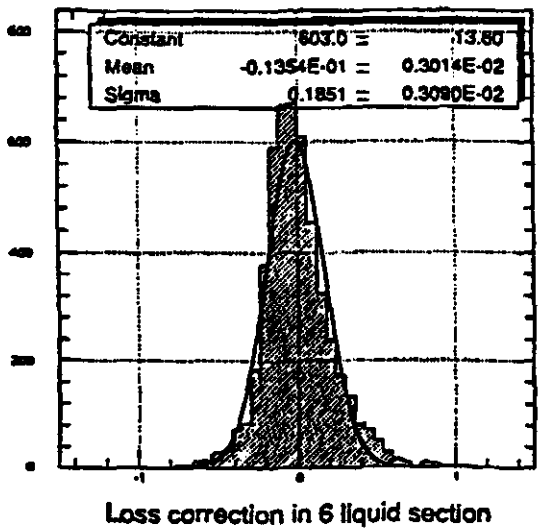

Pt 20 GeV, Muons near eta 0.
E loss, GeV
E measured, GeV
N
χ^2 0.5906
Constant 651.1 ± 11.49
Mean 0.1516E-02 ± 0.6933E-03
Sigma 0.4890E-01 ± 0.5118E-03
σ = 0.24%
E corrected, GeV
EM section

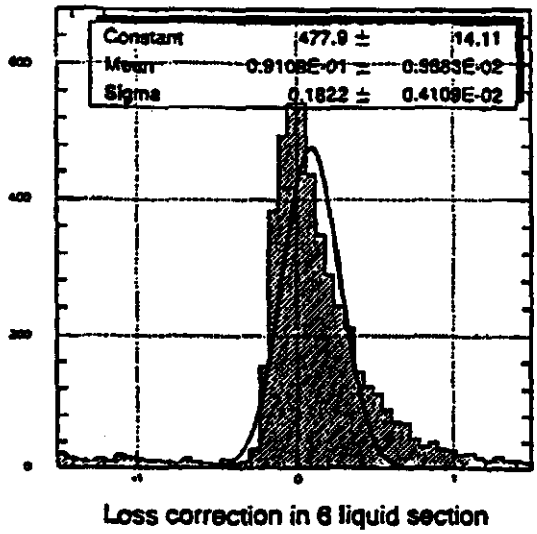

Pt 20 GeV, Muons near eta 0.
E loss, GeV
E measured, GeV
N
χ^2 1.319
Constant 465.6 ± 8.638
Mean -0.5431E-03 ± 0.2902E-02
Sigma 0.2036 ± 0.2416E-02
$\delta \approx 1.\%$
E corrected, GeV
LH section

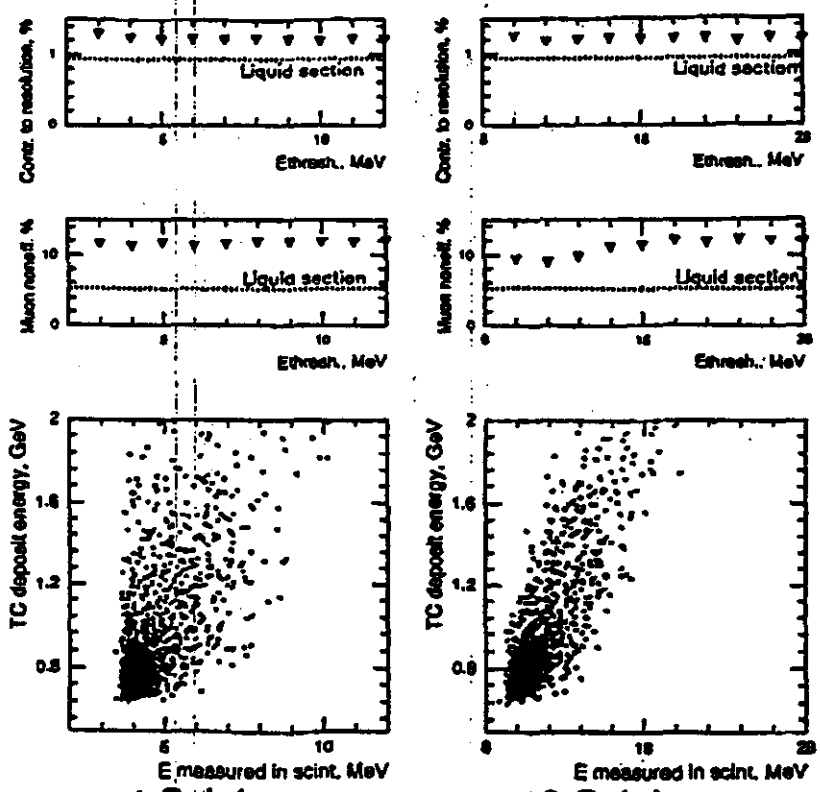


Liquid hadron section

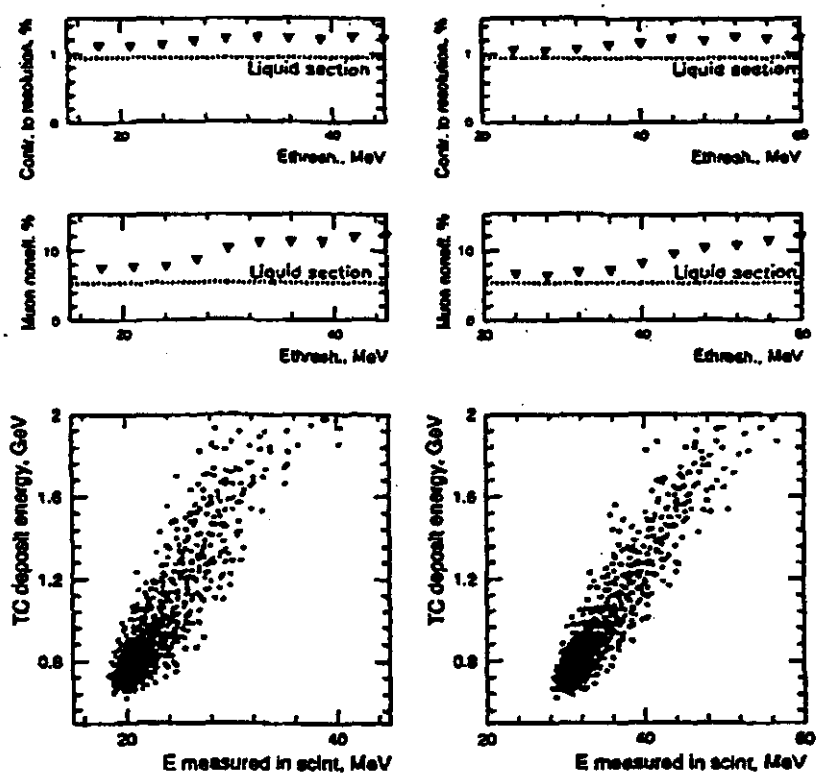

20 GeV Muon.
Contribution to resolution, %
Colorimeter information
Colorimeter and most probable
Noise, MeV
Muon non-efficiency, %
Noise, MeV


Constant 603.0 ± 13.60
Mean -0.1354E-01 ± 0.3014E-02
Sigma 0.1851 ± 0.3090E-02
Loss correction in 6 liquid section

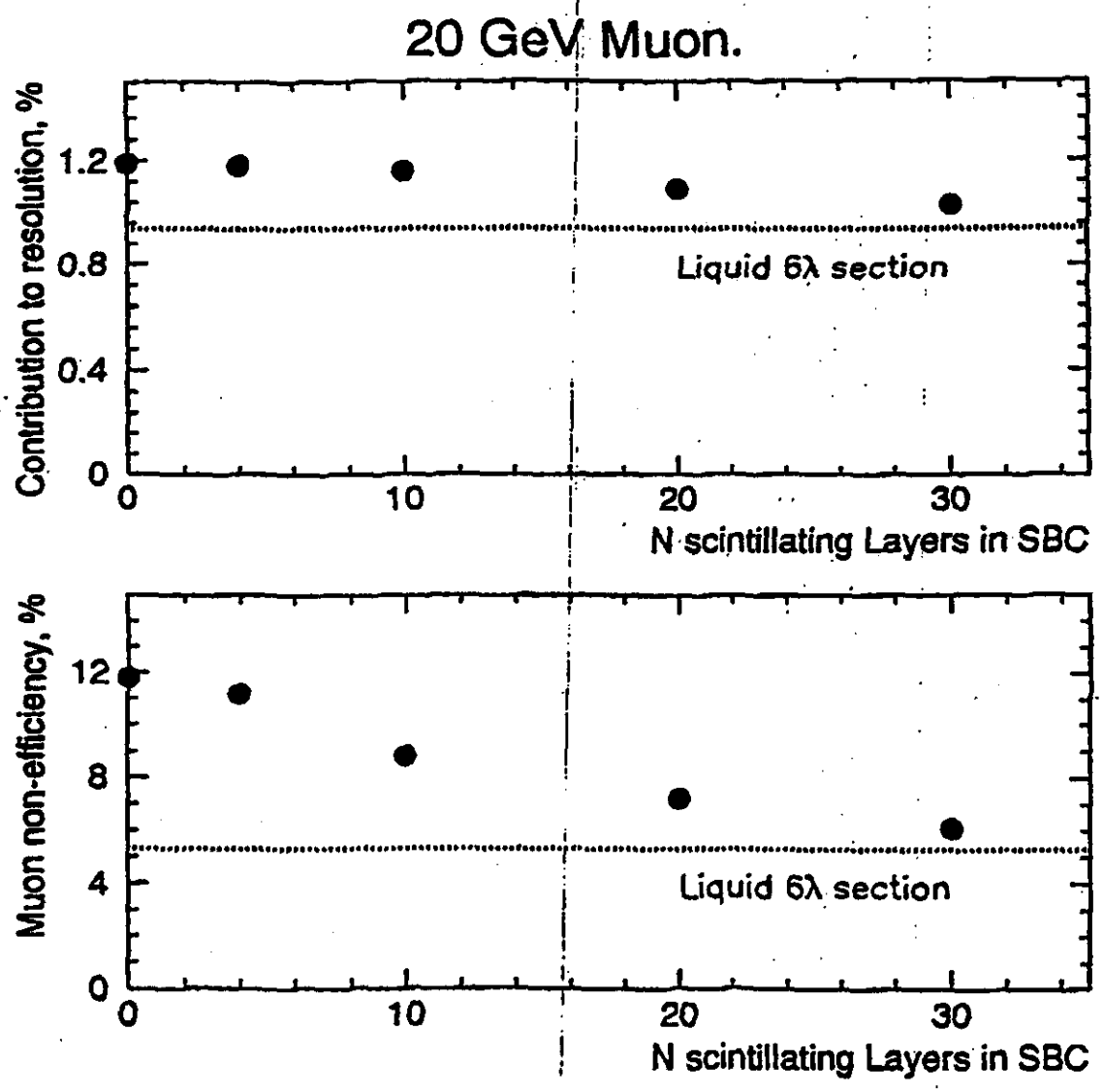

Constant 477.9 ± 14.11
Mean 0.9108E-01 ± 0.9883E-02
Sigma 0.1822 ± 0.4109E-02
Loss correction in 6 liquid section

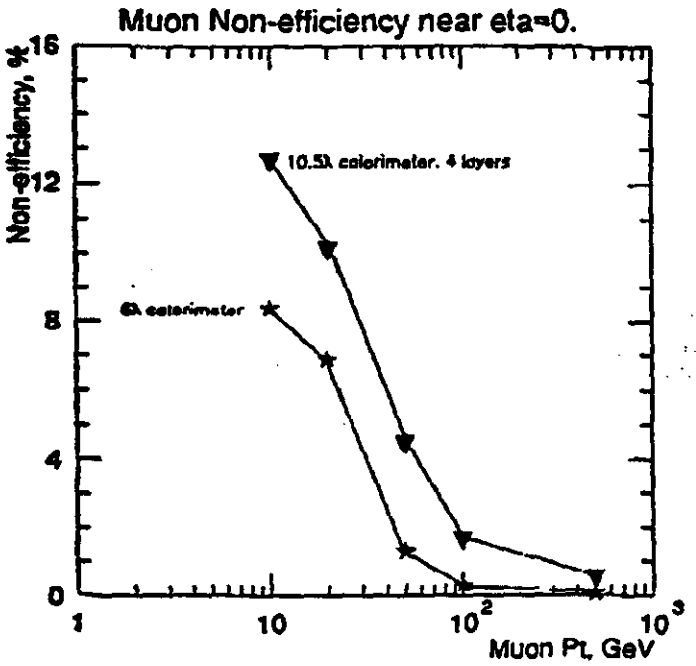


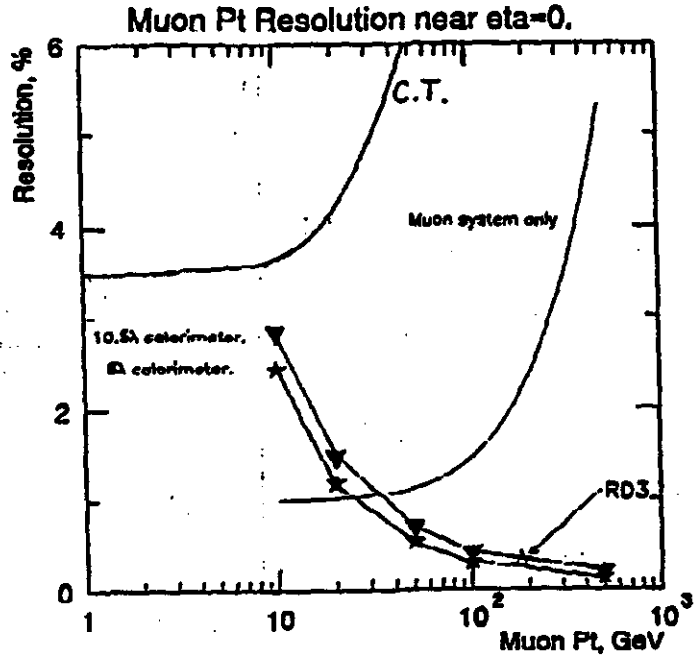
4 Sci. layers 10 Sci. Layers



20 Sci. Layers 30 Sci. Layers


20 GeV Muon.
Contribution to resolution, %
1.2
0.8
0.4
0
Liquid 6λ section
0
10
20
30
N scintillating Layers in SBC
Muon non-efficiency, %
12
8
4
0
Liquid 6λ section
0
10
20
30
N scintillating Layers in SBC


Muon Non-efficiency near eta=0.
Non-efficiency, %
10.5λ calorimeter, 4 layers
6λ calorimeter
Muon Pt, GeV


Muon Pt Resolution near eta=0.
Resolution, %
C.T.
Muon system only
10.5λ calorimeter,
6λ calorimeter,
RD3
Muon Pt, GeV

CONCLUSION

1. Barrel calorimeter is strongly affect on the resolution of muons with Pt less than 30 GeV.

2. Influence of the Endcap calorimeter on the muon is low.

3. Increasing of the pileup noise at the high luminosity will strongly affect on the efficiency or resolution of the low Pt muons.

4. For the low momenta muon there is almost no difference how many sensitive layers (from zero to ten) are in SBC.

   The real improvement will appear if SBC would have more than 25 sensitive layers.

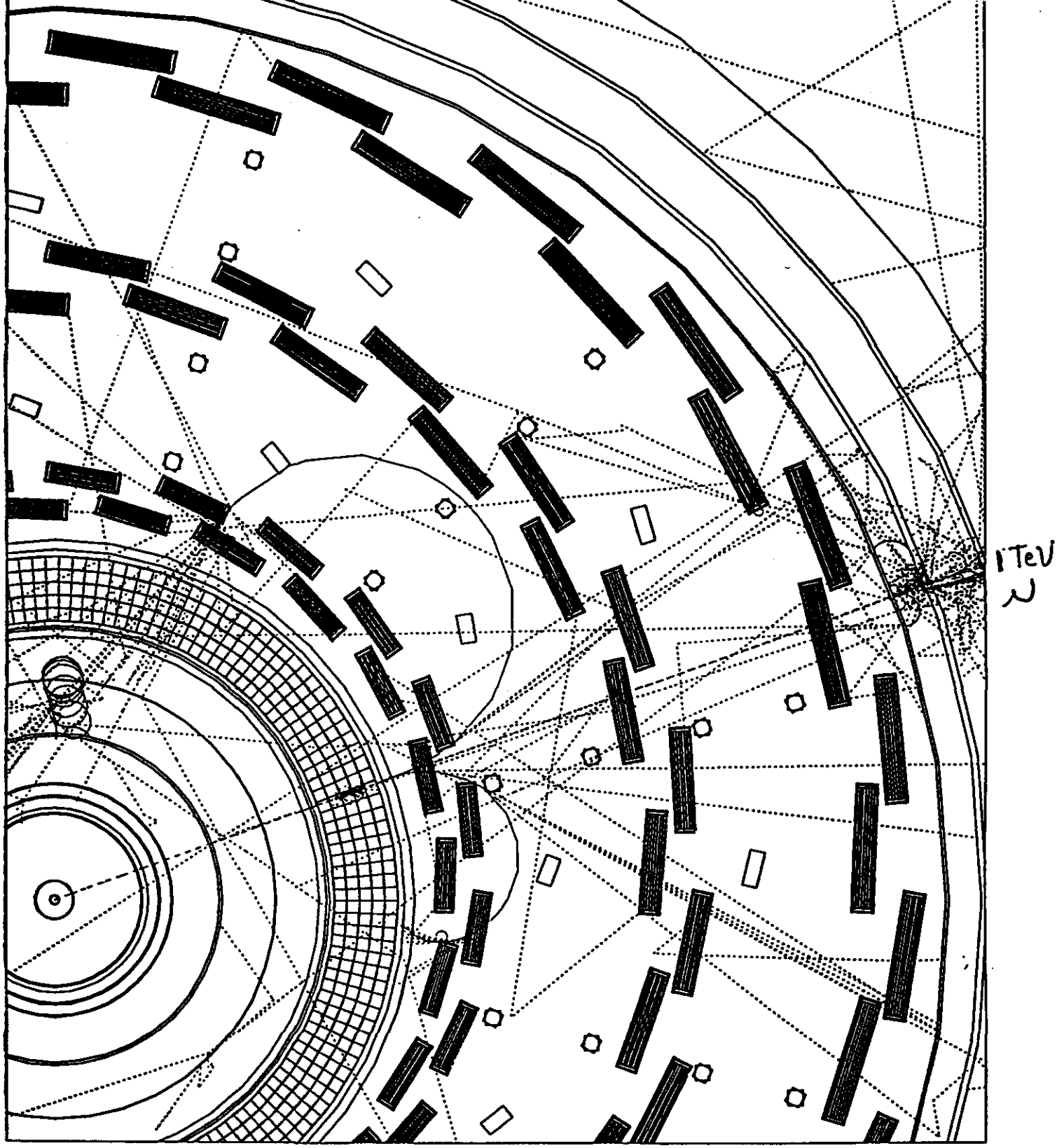
R. McNeil

GEM Muon System Performance - Pattern Recognition

The GEM Muon System with 6:6:6 (8:6:6 in endcap) CSC layers in SL1:SL2:SL3 provides high pattern recognition up to an exceeding $10^{34} cm^{-2} s^{-1}$ luminosity.

Full muon system simulation has been performed (SIGEM) considering the impact of backgrounds from:

- muon-induced electromagnetic background particles
- hadron punchthrough (uncorrelated and correlated)
- uncorrelated neutrons and associated gammas



1 TeV muon at $\theta = 60°$, $\phi = 20°$ in GEM
from SIGEM Simulation

Pattern Recognition in the GEM Muon System

Tasks

- Find road containing muon track with high efficiency, minimal wrong track assignment, moderate precision
- Find muon hits uncompromised by backgrounds to perform precise reconstruction of momentum

Strategy

1. Reconstruct ϕ projection

   a) Select good muon hits from charge distrubution on CSC

   resolution compromised $\quad 0.2\,mm < \Delta X_{we} < 2 \times W \quad$ W = strip-pitch

   Compromised hits still useful to find road, less useful for mom. rec.

   b) Fit muon hits into ϕ track segments with loose χ^2 constraint

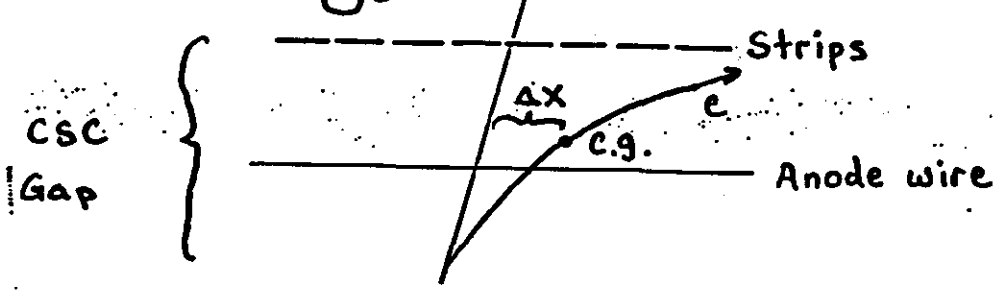
   Minimum $\underline{\underline{3}}$ good muon hits in superlayer $\equiv$ good track segment

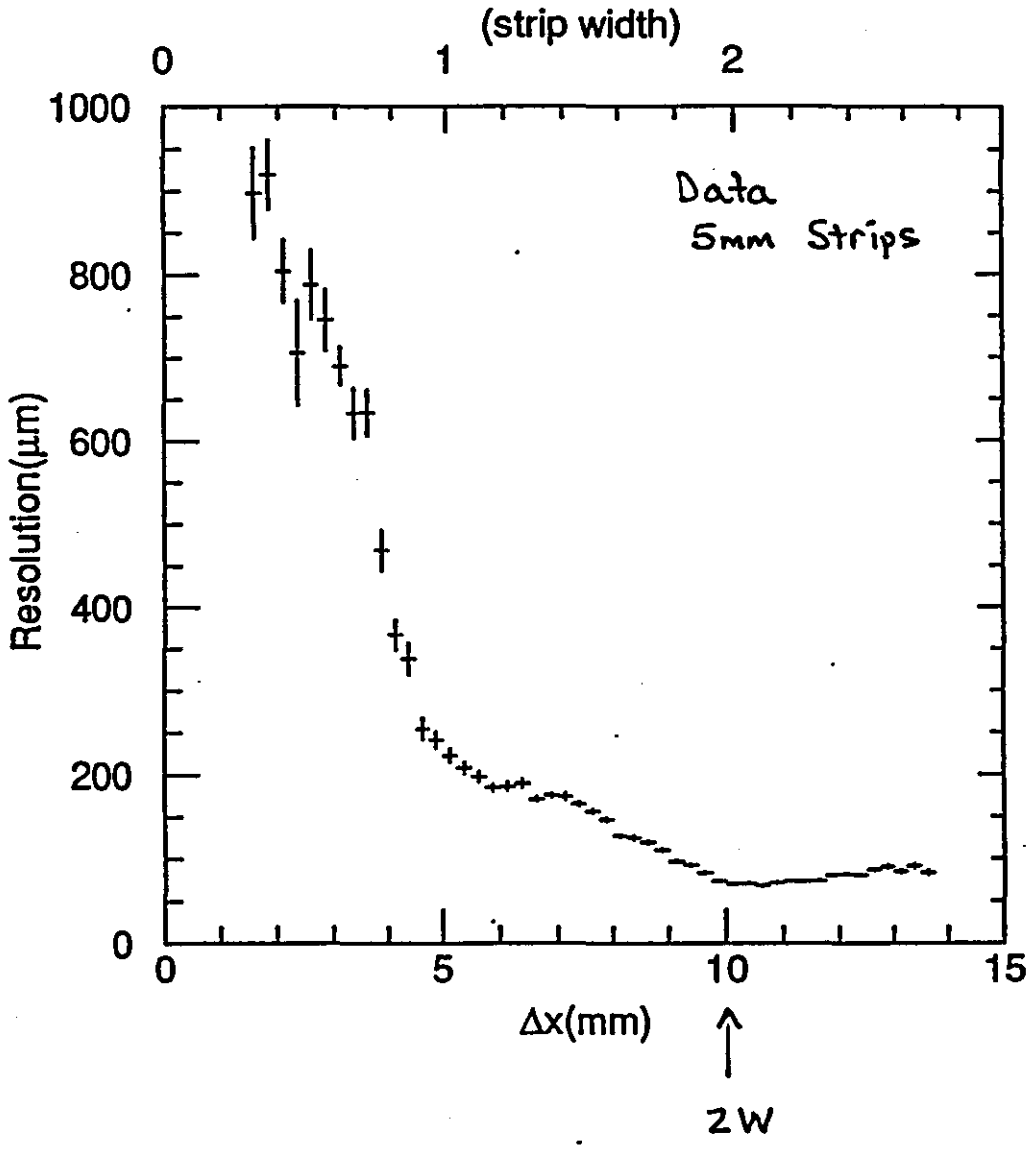
   $\therefore$ high efficiency ; minimal fake track segments

   c) Fit ϕ track segments from different superlayers

2. Reconstruct Z/R projection of tracks to loosely fit straight line through the I.P.

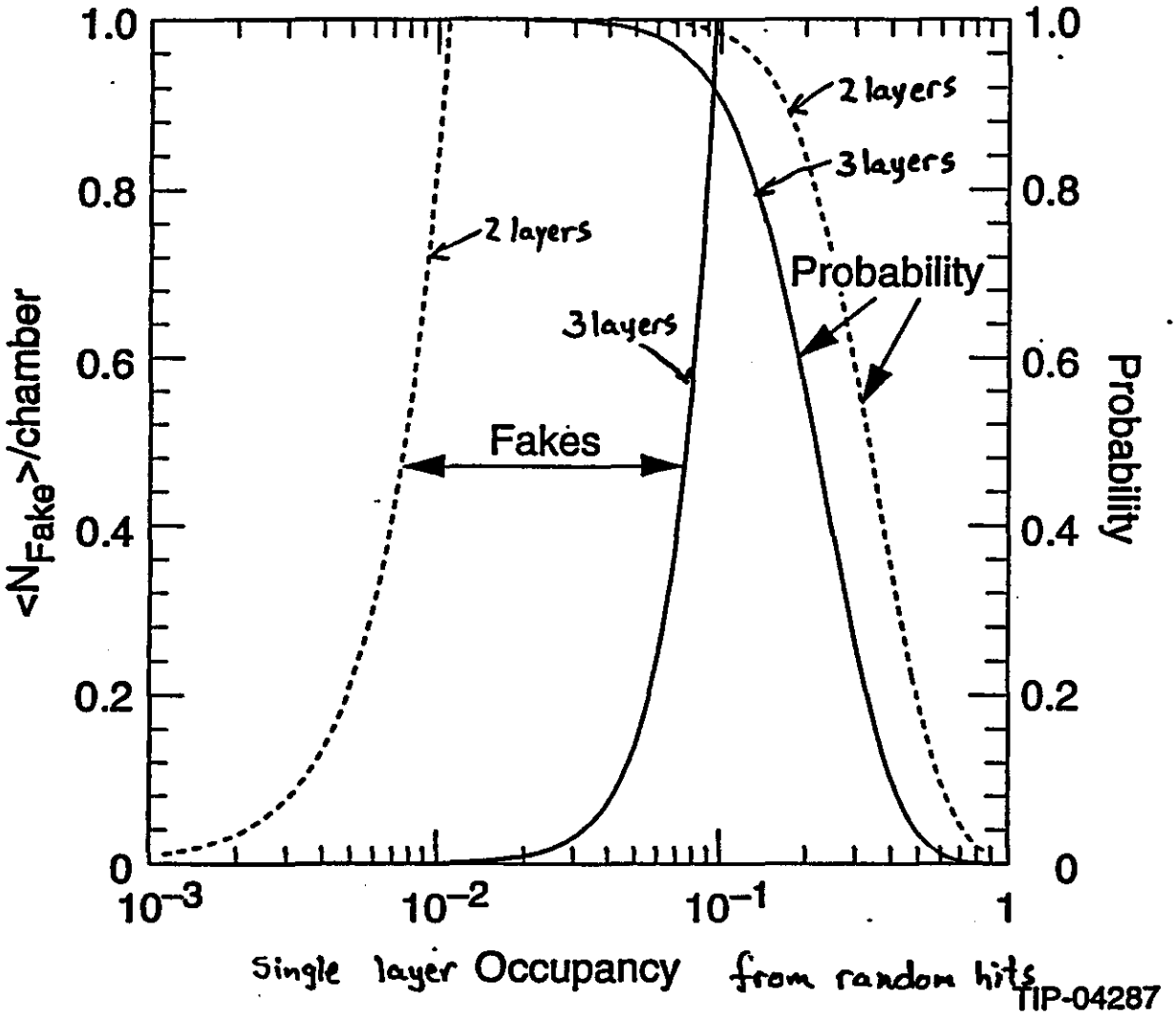
3. Assign ϕ and Z/R projection to same track


Strips
CSC
Gap
Δx
e
c.g.
Anode wire


(strip width)
0
1
2
1000
800
600
400
200
0
Resolution(μm)
Data
5mm Strips
0
5
10
15
Δx(mm)
2W

Track reconstruction efficiency and fake track segment rate is function of CSC occupancy:

Requiring minimum 3 good layers in a superlayer maintains high efficiency and minimal fake track segment rate for occupancy up to several percent (Not reached even at $10^{34}\ cm^{-2}s^{-1}$)



4-17

Pattern recognition performance for isolated muons. (no acceptance losses here)

Good track segment = minimum 3 uncompromised layers in a superlayer

Table 4-10. Probability for having good track segments for isolated muons in:

a) all three superlayers

Muon p_T (GeV)	Rapidity Range				
	0.1–0.50	0.50–0.92	0.92–1.34	1.38–1.86	1.86–2.46
20	0.99	0.99	0.96	0.97	0.98
100	0.99	0.98	0.96	0.95	0.96
500	0.97	0.98	0.94	0.89	0.89
1000	0.95	0.93	0.90	0.84	0.82

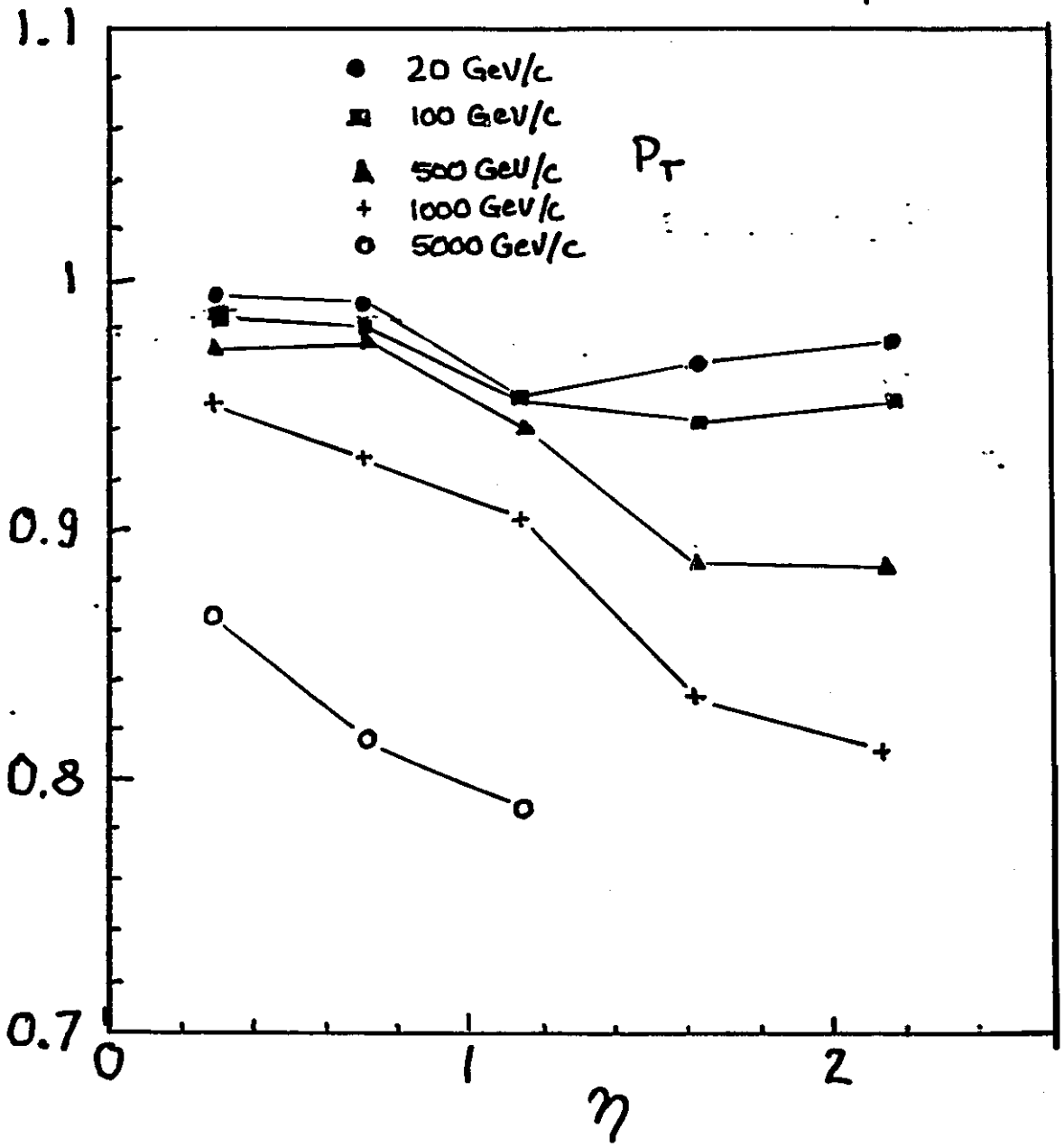
b) middle and outer superlayers only

Muon p_T (GeV)	Rapidity Range				
	0.1–0.50	0.50–0.92	0.92–1.34	1.38–1.86	1.86–2.46
20	0.99	0.99	0.96	0.98	0.99
100	0.99	0.99	0.96	0.97	0.98
500	0.99	0.99	0.96	0.95	0.97
1000	0.97	0.95	0.93	0.94	0.96

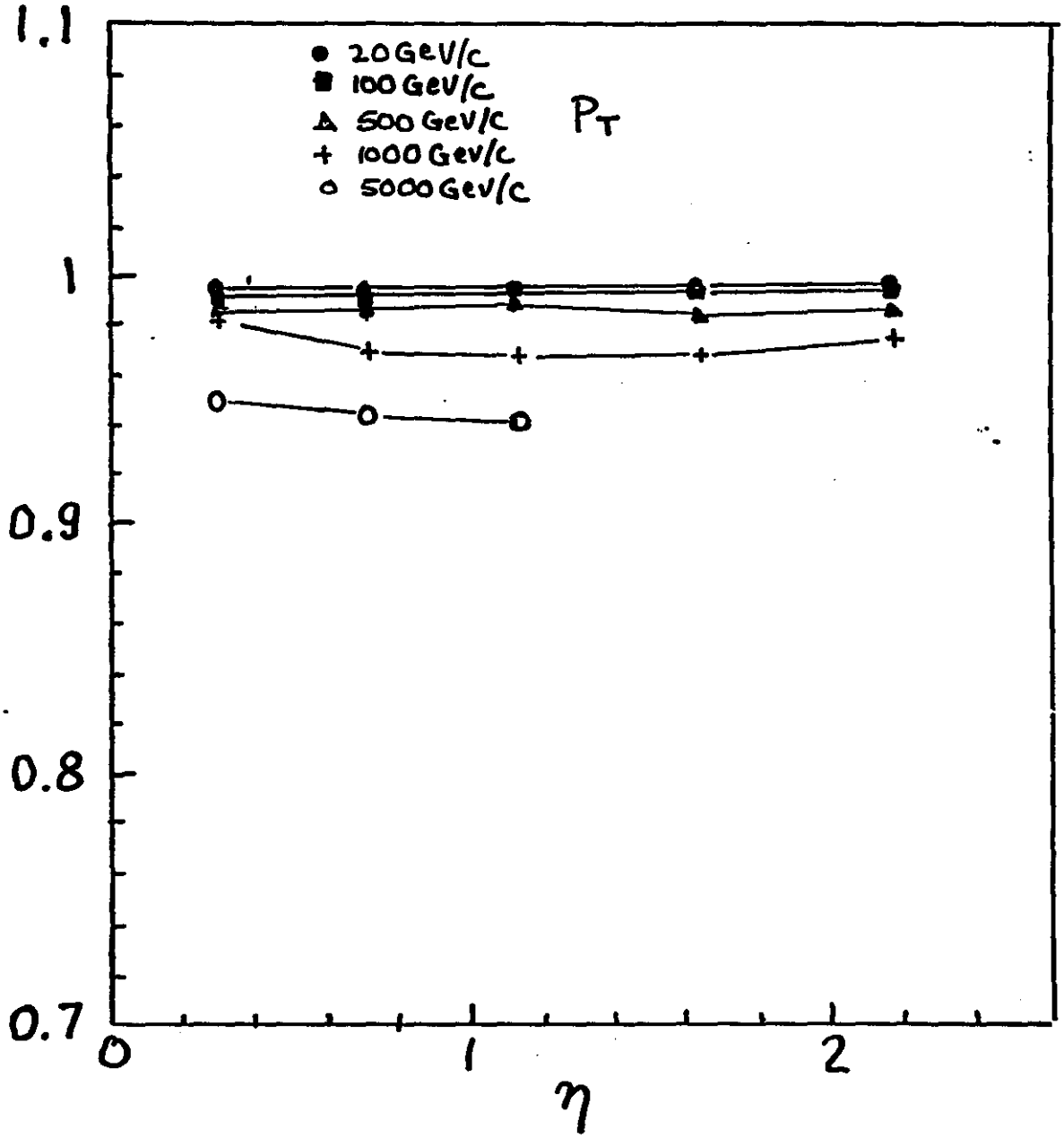
c) Any 2 superlayers

⋮

Isolated Muons - No acceptance losses



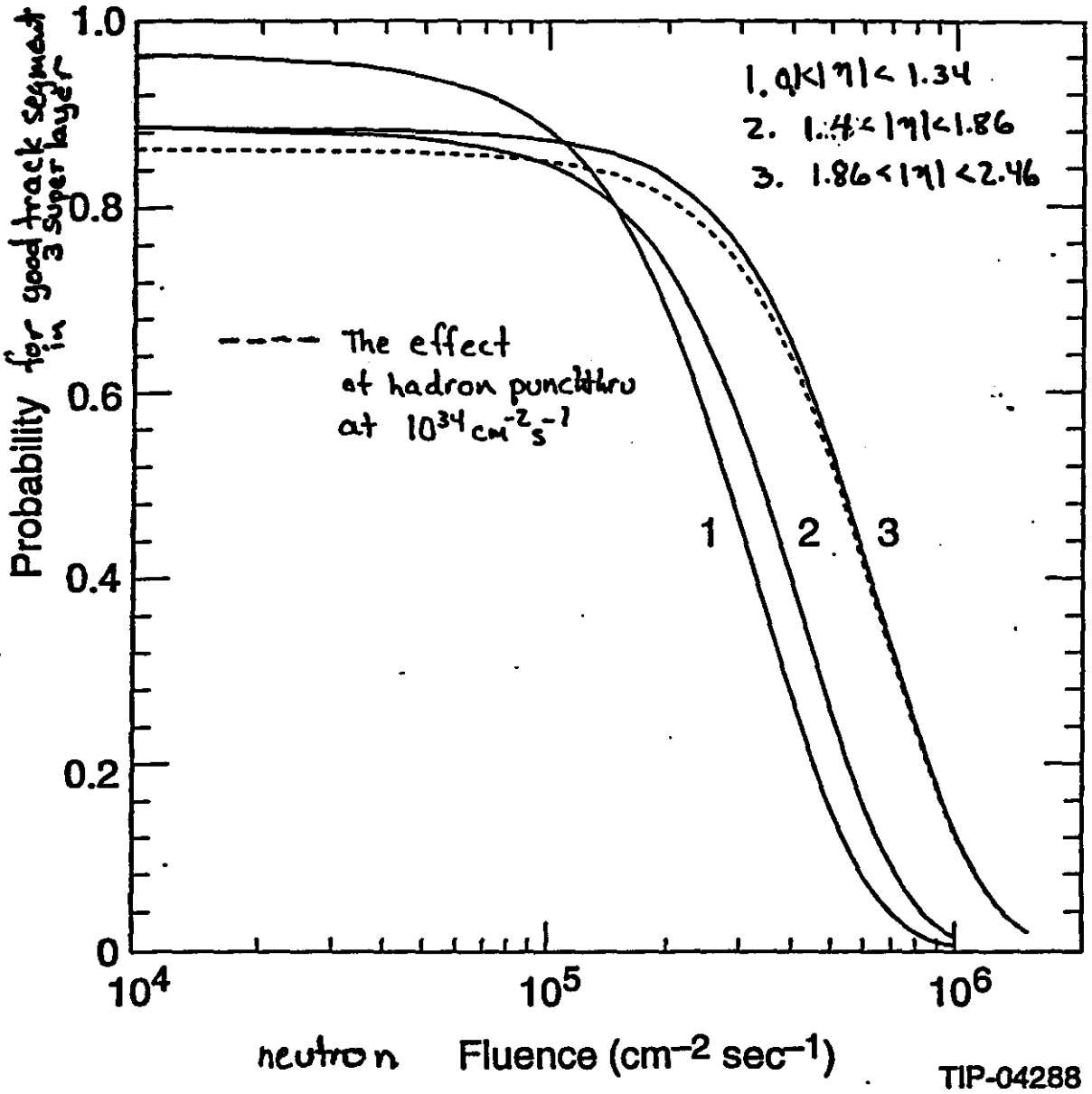
Isolated Muons - No acceptance losses



- em background included
- uncorrelated hadron punchthrough included

as a function of n, γ fluence:

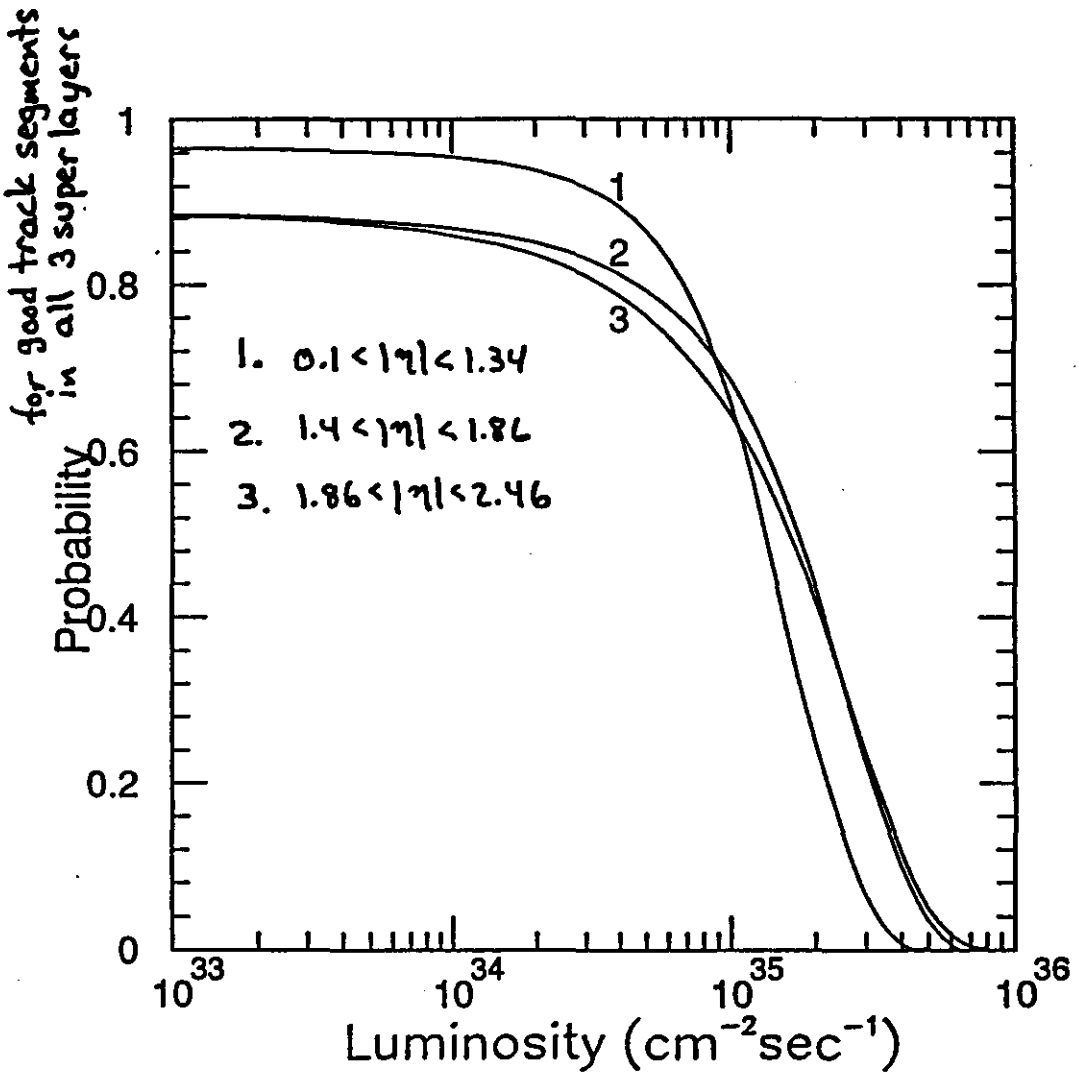
- γ fluence 30% of neutron fluence
- ±300ns time gate
- Thermal neutrons are 50% of neutrons



4-18

Track reconstruction efficiency for 0.5 TeV/c P_T muons

- em background included
- uncorrelated hadron punchthrough included
- uncorrelated n, γ hits included



Uncorrelated Punchthrough

CSC Occupancy $< 1\%$ @ $10^{34}\,cm^{-2}s^{-1}$ $\Rightarrow$ $< 3\%$ inefficiency for μ

Correlated Punchthrough - Muons in Jets

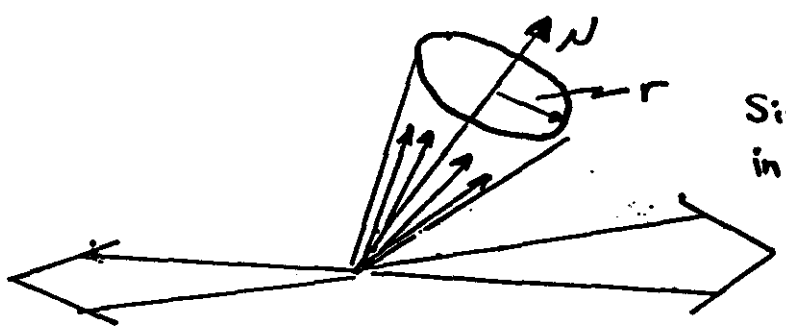
$$
\begin{array}{l}
t\bar{t} \longrightarrow X \text{ (including isolated lepton)} \\
\quad \hookrightarrow \bar{b} \longrightarrow \bar{c}, \bar{u} \\
\qquad\quad \hookrightarrow W^{+} \longrightarrow \mu^{+} \\
\qquad\qquad\quad \hookrightarrow \nu_{\ell} \\
\quad \hookrightarrow b \longrightarrow c, u \\
\qquad\quad \hookrightarrow W^{-} \longrightarrow \mu^{-} \\
\qquad\qquad\quad \hookrightarrow \bar{\nu}_{\mu}
\end{array}
$$

Muon in b-jet is not isolated - in the jet.

Generated $M_t = 250\,\frac{GeV}{c^2}$, $P_t|_{min} = 200\,GeV/c$ by PYTHIA

Forced decay through $b \rightarrow W + X$, $W \hookrightarrow \mu + \nu$

Make cone around hottest $b(\bar{b})$ - $r = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 1$



Simulate all particles in cone with SIGEM $\langle N_{cone} \rangle = 64$

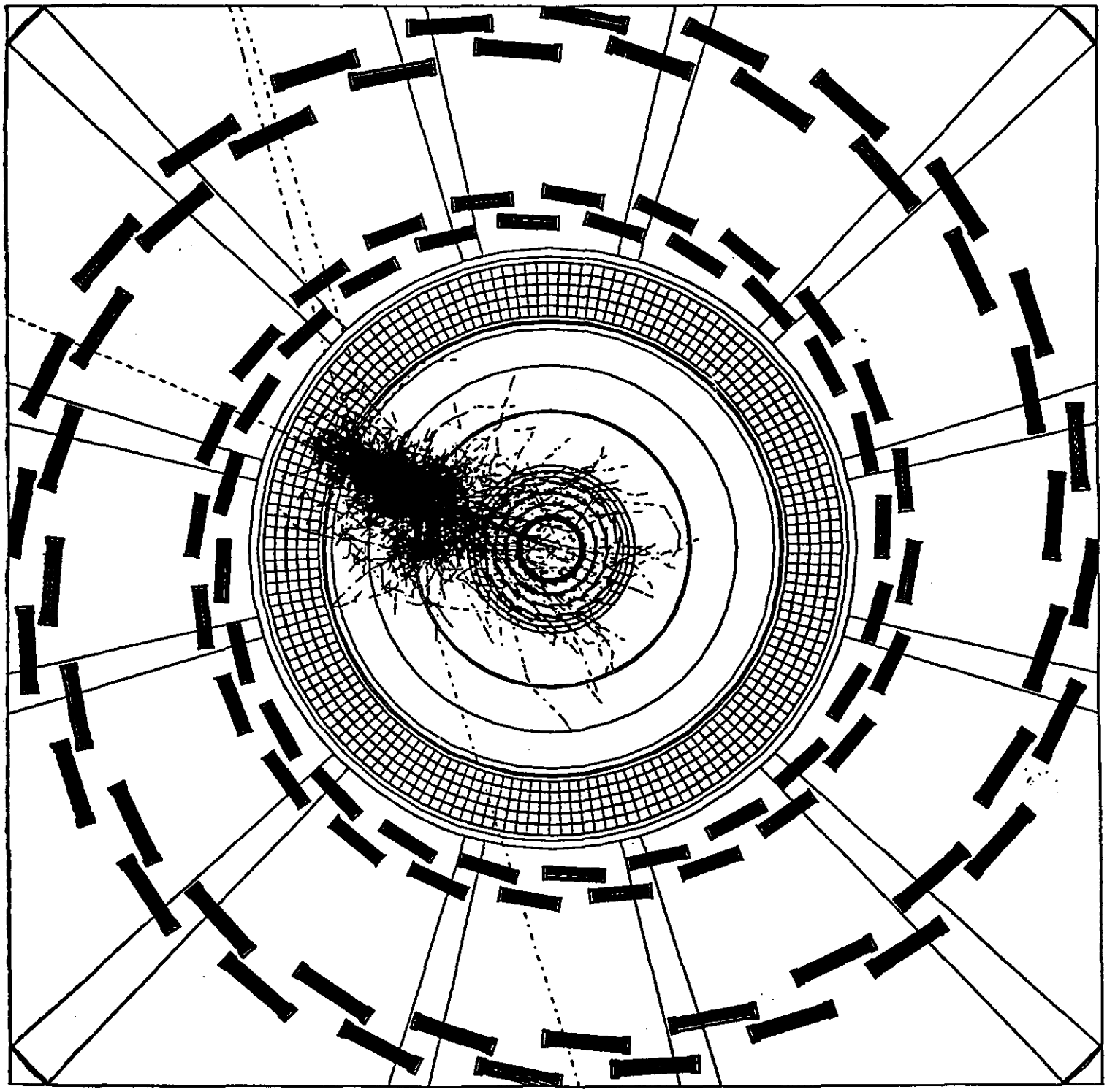
$\langle P_T \rangle_{\mu} = 39\,\frac{GeV}{c}$ $\langle E_{\mu} \rangle = 70\,GeV$ $\langle \Theta \rangle_{\mu\text{-jet}} = 1.1^{\circ}$

$t\bar{t} \rightarrow b\bar{b} \rightarrow \bar{u},\bar{c} + \mu^+\nu$

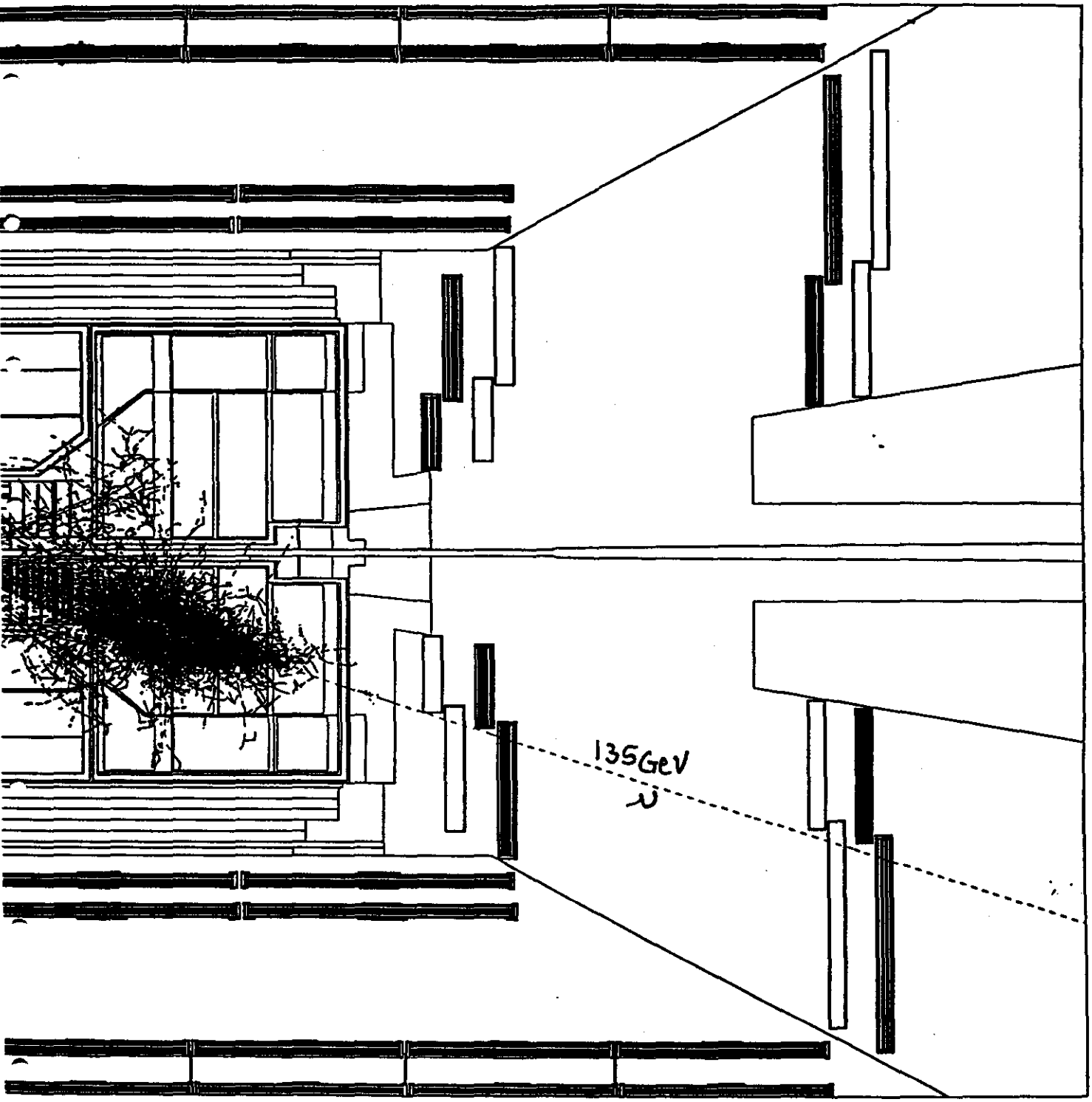
$\hookrightarrow W^+ \quad \hookrightarrow u,c + \mu^-\nu$

$\hookrightarrow W^-$

Particles in cone $r = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 1$ about most energetic μ simulated by SIGEM



Muon in b-jet



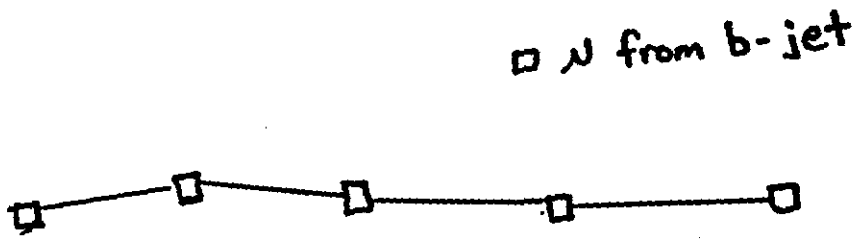
745 GeV π^+ in cone with the ν !

Pattern recognition performance for muons in b-jets from high P_T top decays.

(no acceptance losses here)

Table 4-11. Probability of having good track segments in a) all three superlayers and b) the middle and outer superlayers only, for muons in b-jets compared with isolated muons.

	Rapidity Range				
a) All Three Superlayers	0.1–0.5	0.5–0.92	0.92–1.34	1.38–1.86	1.86–2.46
$b \to \mu + X$: $\langle p^{\mu}_T \rangle = 39$ GeV	0.99	0.99	0.98	0.97	0.96
Isolated μ: $p^{\mu}_T = 20$ GeV	0.99	0.99	0.96	0.97	0.98
Isolated μ: $p^{\mu}_T = 100$ GeV	0.99	0.98	0.96	0.95	0.96
b) Middle and Outer Superlayers Only	0.1–0.5	0.5–0.92	0.92–1.34	1.38–1.86	1.86–2.46
$b \to \mu + X$: $\langle p^{\mu}_T \rangle = 39$ GeV	0.99	0.99	0.98	0.98	0.97
Isolated μ: $p^{\mu}_T = 20$ GeV	0.99	0.99	0.96	0.98	0.99
Isolated μ: $p^{\mu}_T = 100$ GeV	0.99	0.99	0.96	0.97	0.98


ν from b-jet

Pattern Recognition for Physics Benchmarks

USE SIGEM to simulate muons in GEM

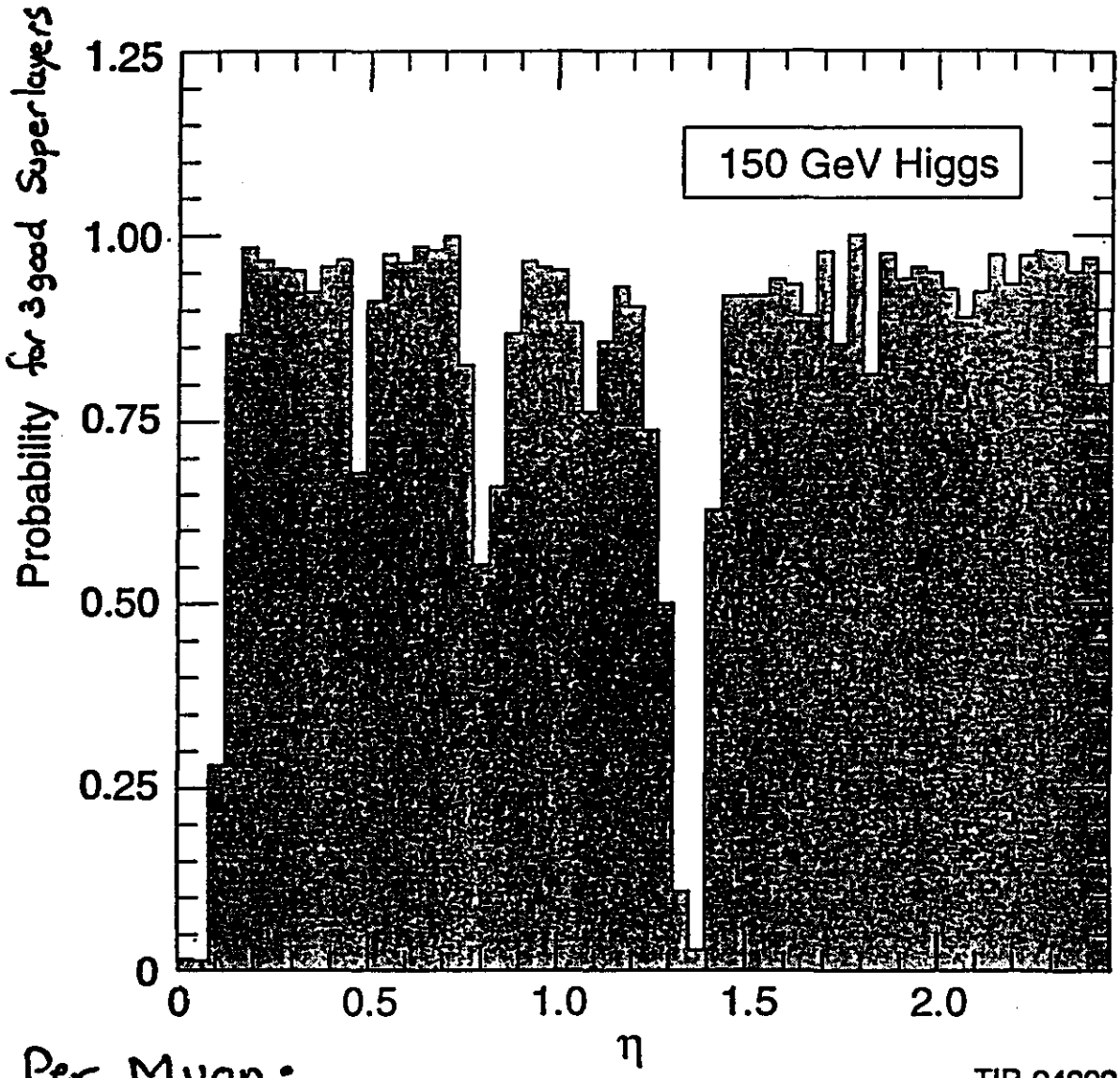
$H^0 \to ZZ \to \mu^+\mu^-\mu^+\mu^-$ $\quad |\eta_\mu| < 2.46$

M_H (GeV)	4μ with all 3 superlayers	3μ with all 3 superlayers + 1μ with at least 2 superlayers	4μ with at least 2 superlayers	Acceptan for $\lvert\eta\rvert<2.4$
150	42.6 %	52.7 %	54.0 %	54 %
400	45.0 %	56.9 %	57.9 %	64 %
800	47.4 %	58.0 %	59.1 %	78 %

$Z' \to \mu^+\mu^-$ $\quad |\eta_\mu| < 2.46$ - 87 % acceptance

$M_{Z'} = 4$ TeV

2μ with all 3 superlayers	1μ with all 3 superlayers + 1μ with at least 2 superlayers	2μ with at least 2 superlayers
59.6 %	71.5 %	72.6 %



Per Muon:

84% Acceptance for 3 superlayers $|\eta|<2.46$

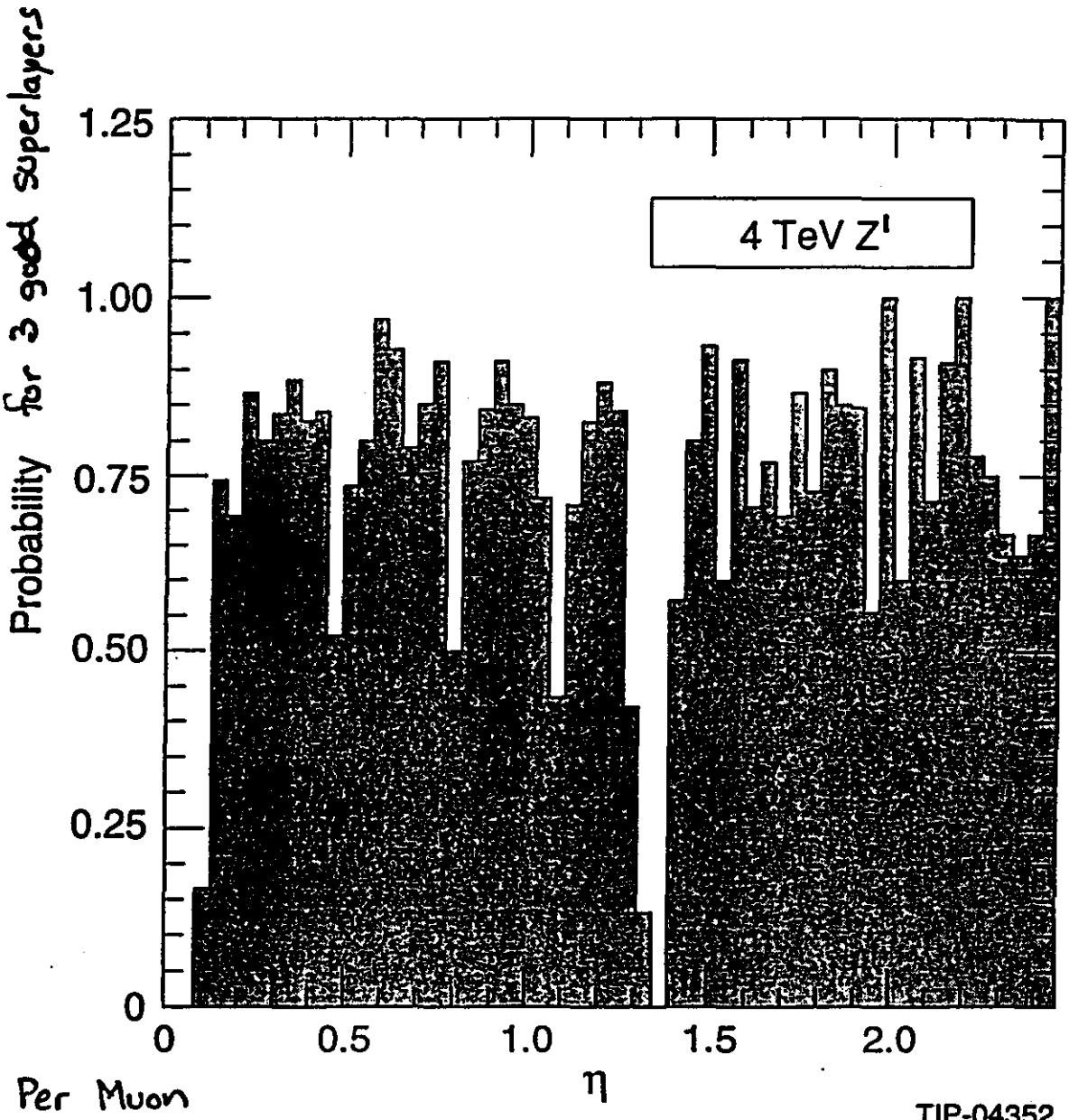
≈97% efficiency for good track segments in 3 superlayers

43% for Higgs $|\eta_\mu|<2.46$, 3SL

87% Acceptance for ≥2 superlayers $|\eta|<2.46$

~99% efficiency for good track segments in ≥2 superlayers

54% for Higgs $|\eta_\mu|<2.46$, 2SL.



Per Muon

84% Acceptance for 3 SL $|\eta|<2.46$
91% efficiency for good track segments in 3SL
60% for Z' $|\eta|<2.46$, 3SL.

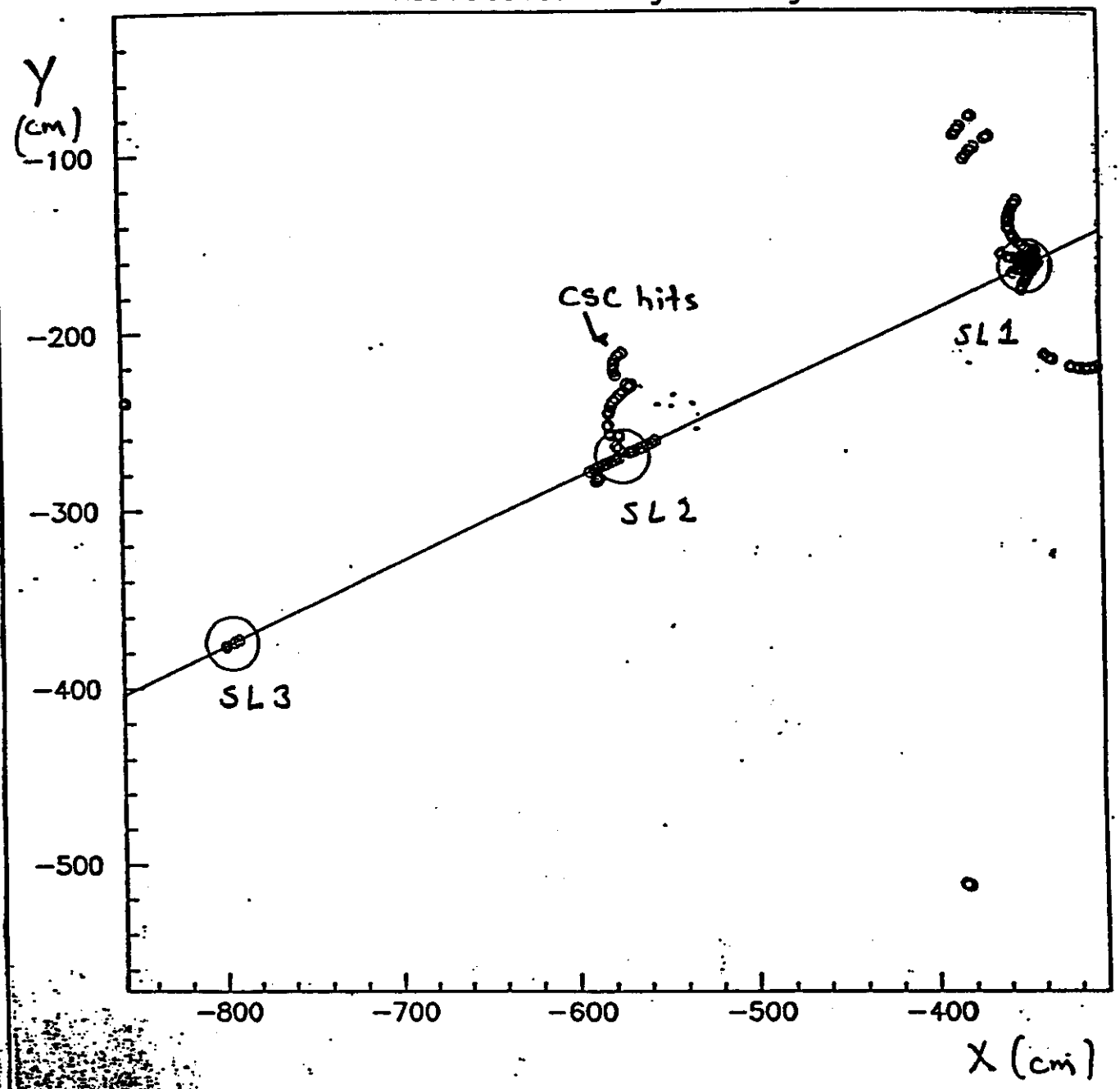
87% Acceptance for 2SL $|\eta|<2.46$
97% efficiency for good track segments in 2SL
73% for Z' $|\eta|<2.46$, 2SL

4-25

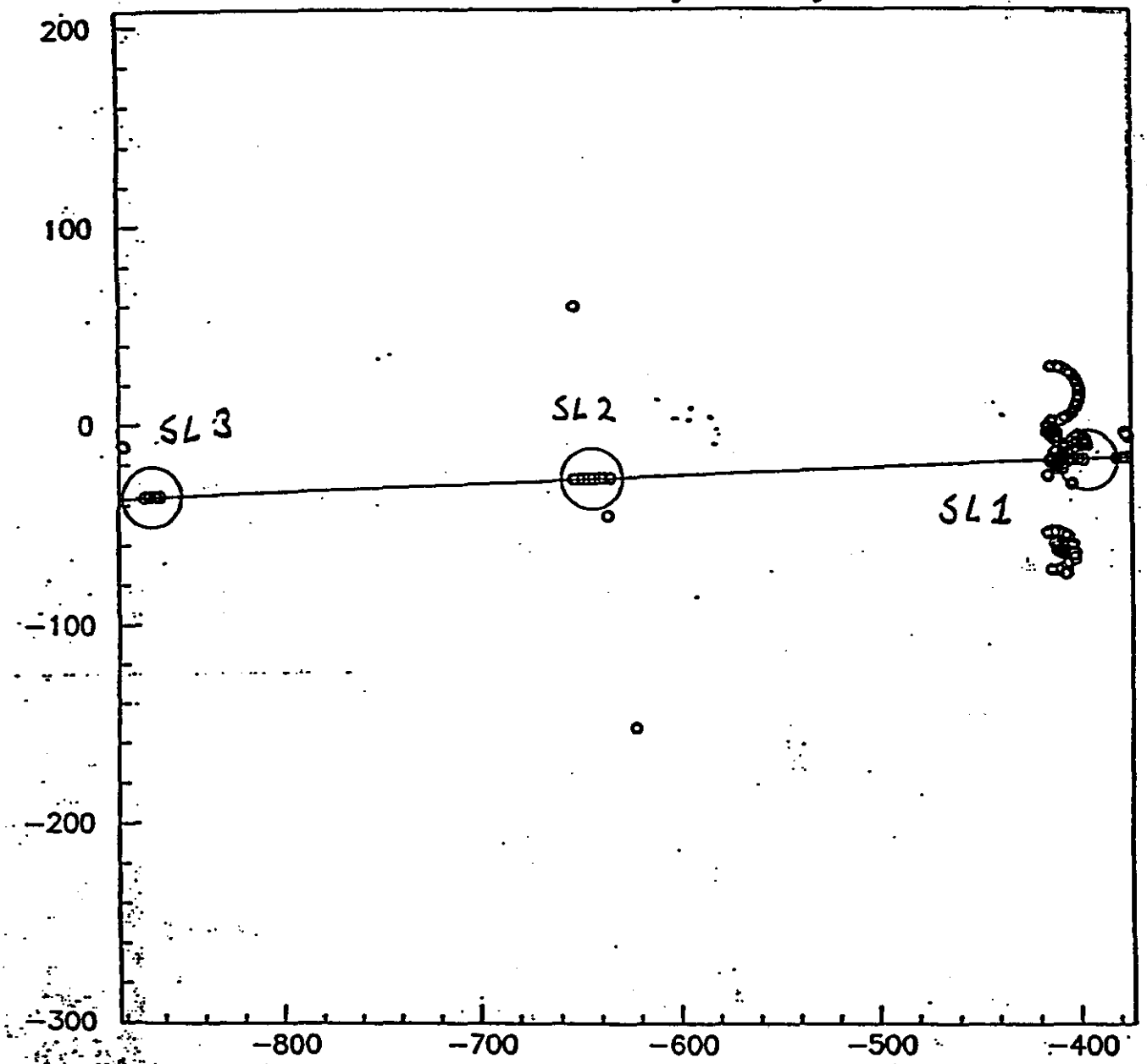
UP DATES...

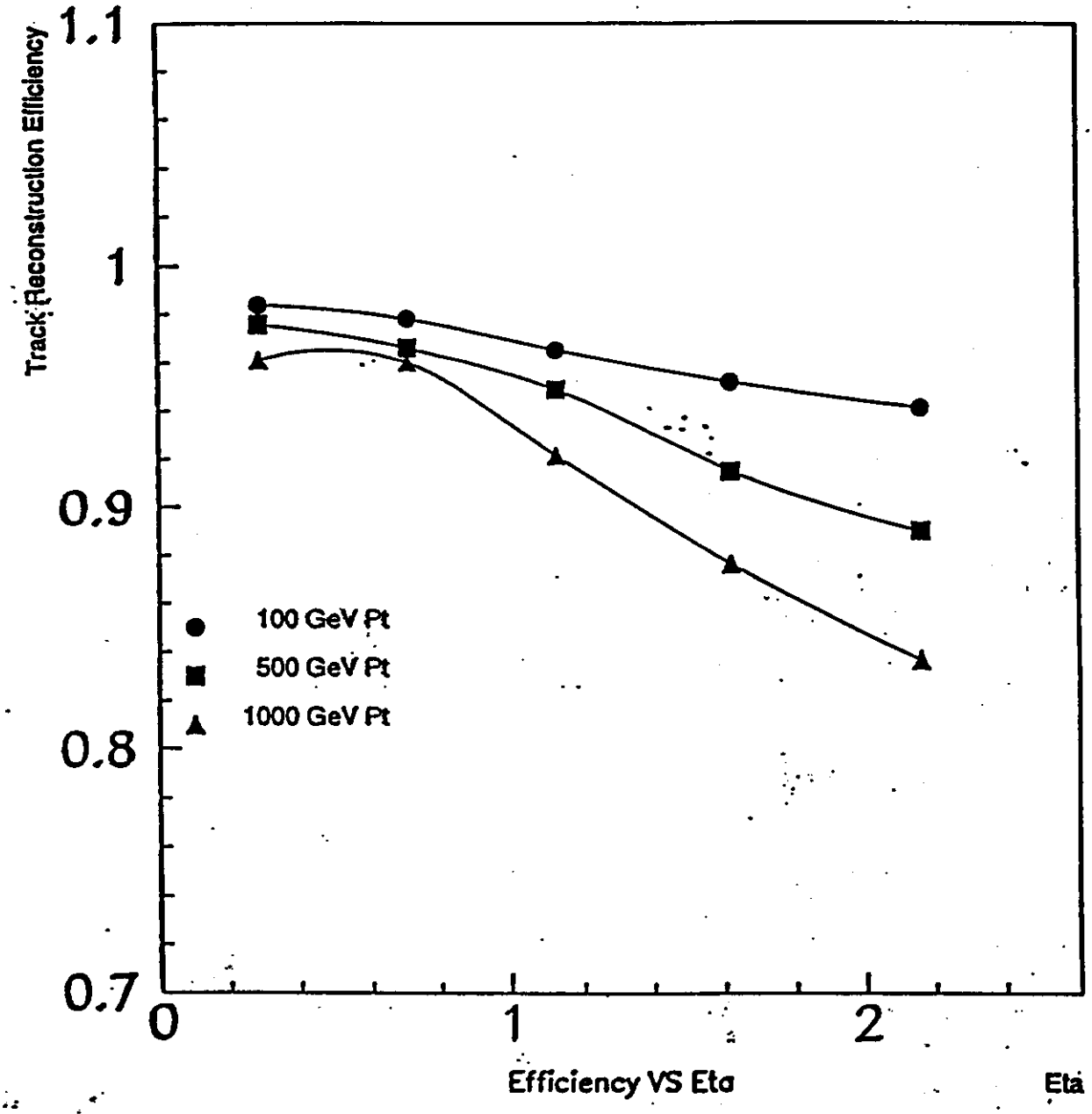
P. Dinqus

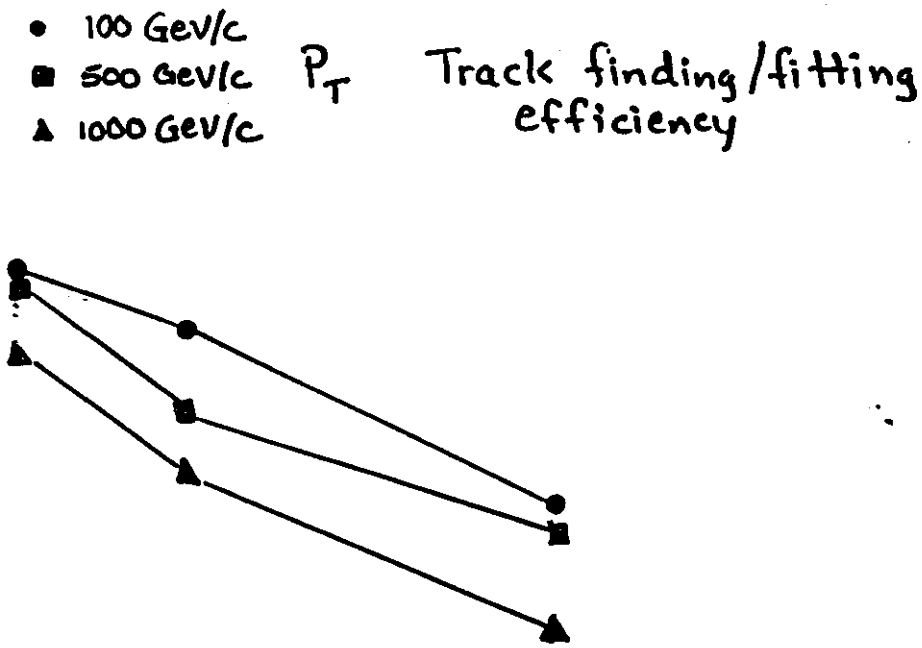
Muon track searching and fitting.

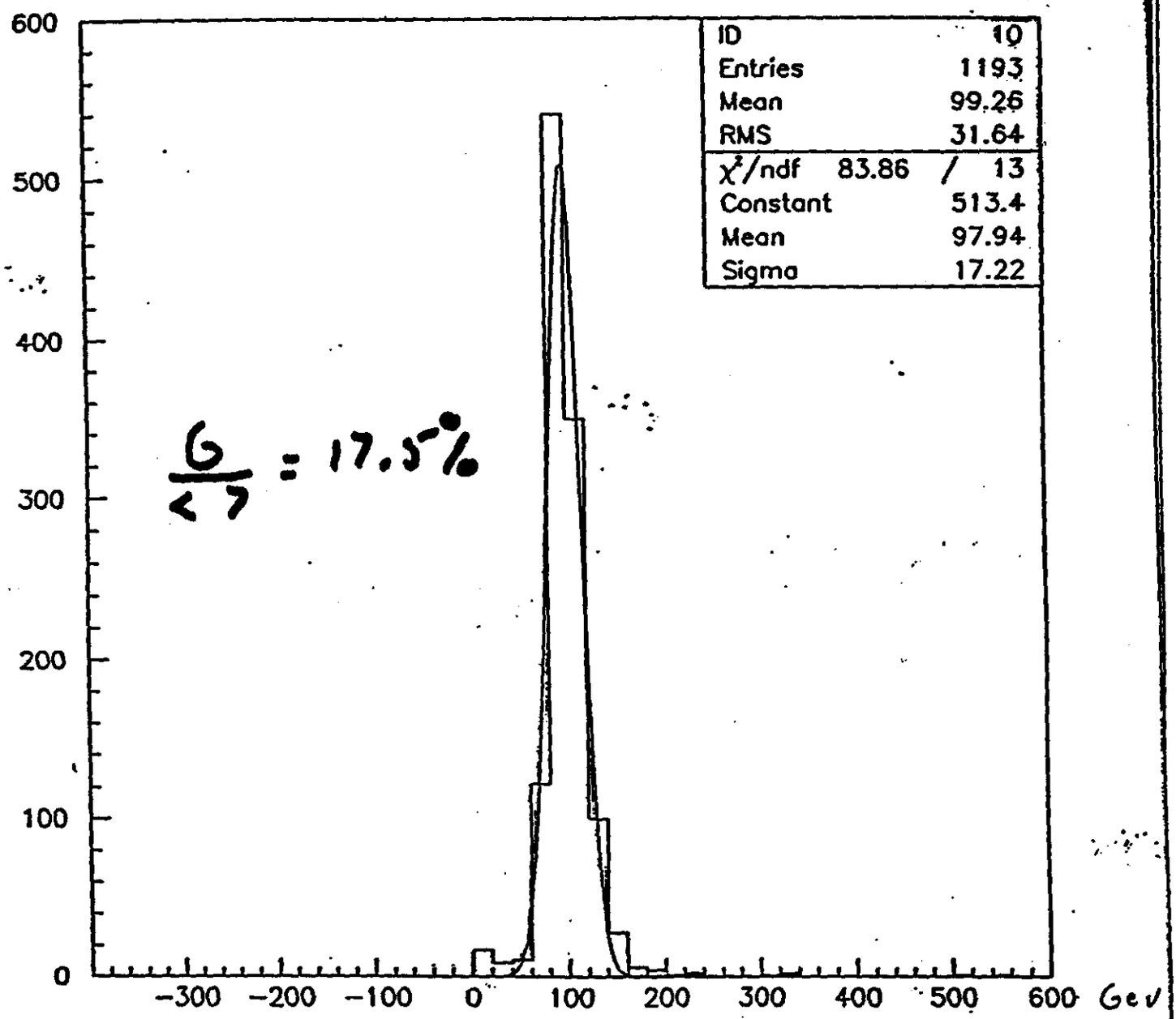


Muon track searching and fitting.




Track Reconstruction Efficiency
1.1
1
0.9
0.8
0.7
0
1
2
100 GeV Pt
500 GeV Pt
1000 GeV Pt
Efficiency VS Eta
Eta

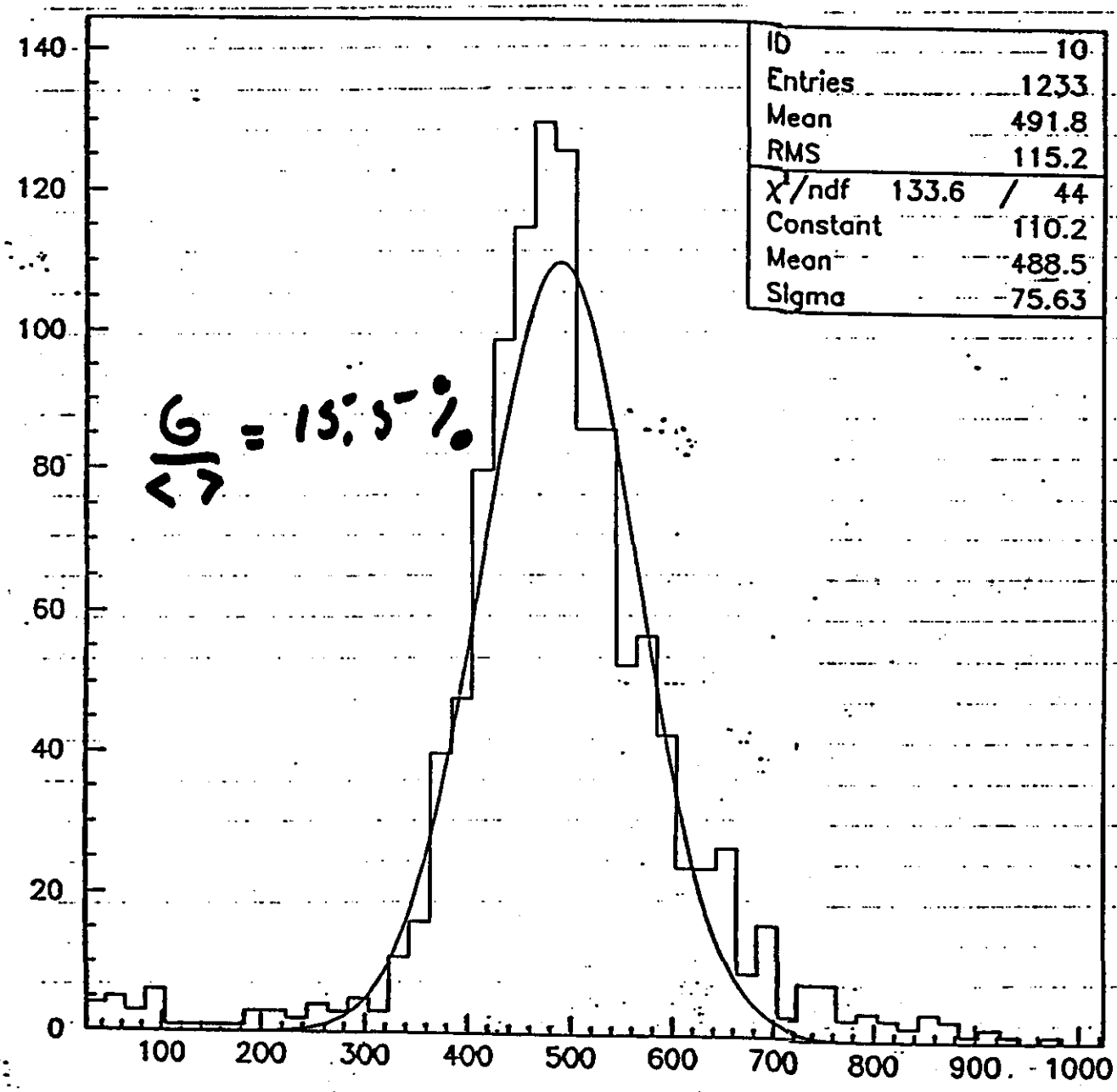

100 GeV/c
500 GeV/c
1000 GeV/c
P_T
Track finding/fitting efficiency



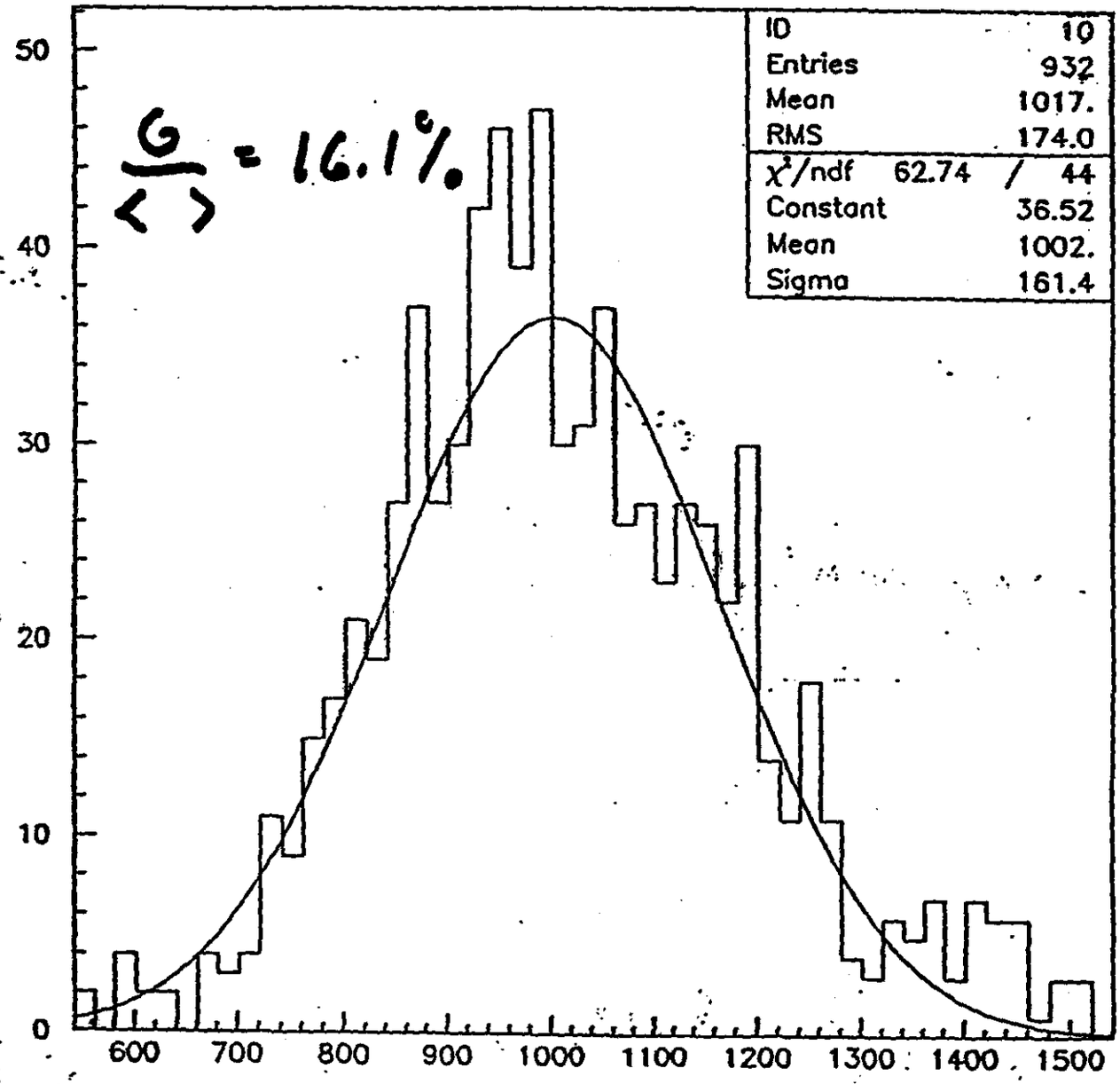
Distribution of Transversal Momenta of Muons

ESTIMATE OF P_T
FROM BEND
ANGLE

P



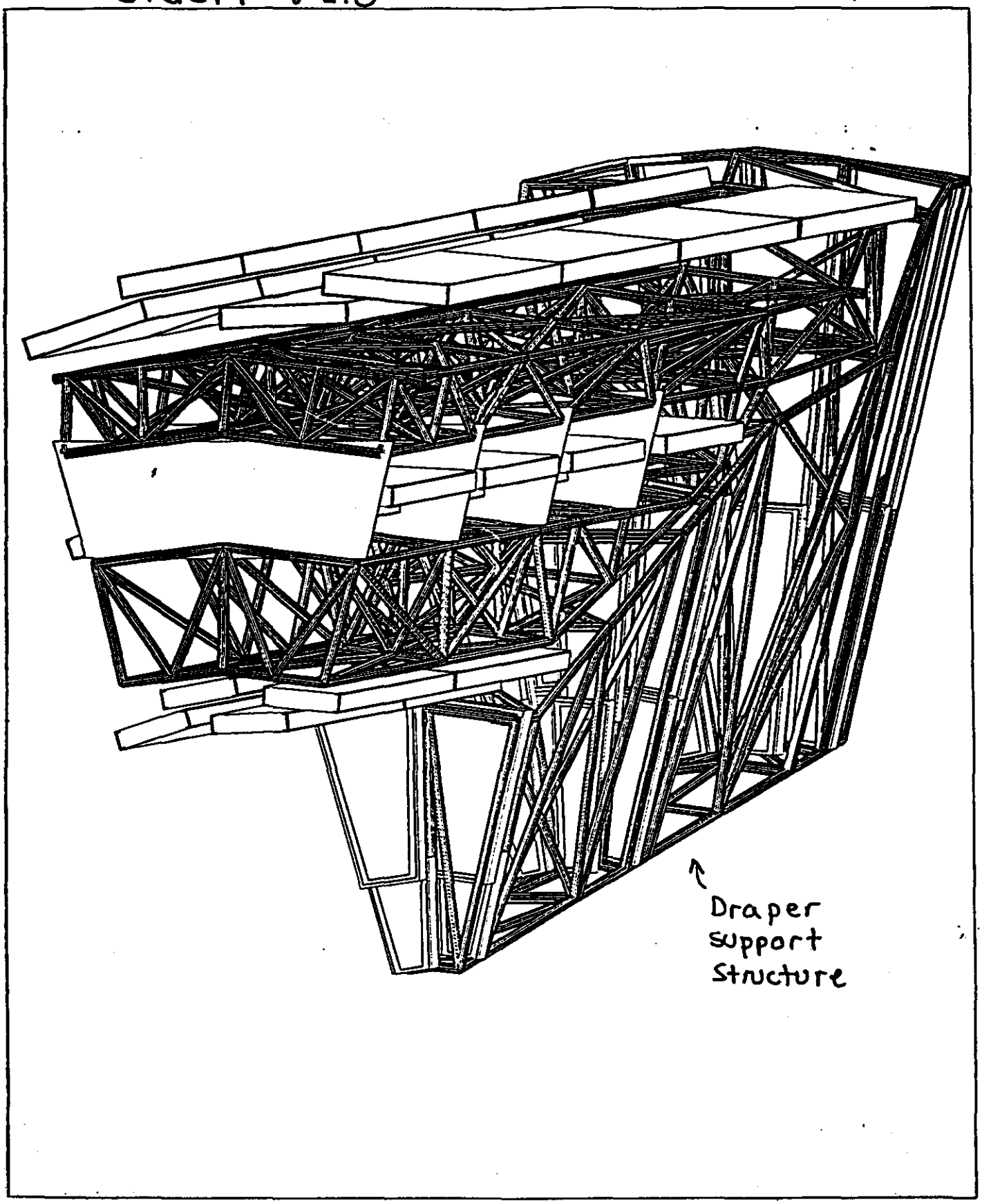
ESTIMATE OF P_T FROM BEND ANGLE



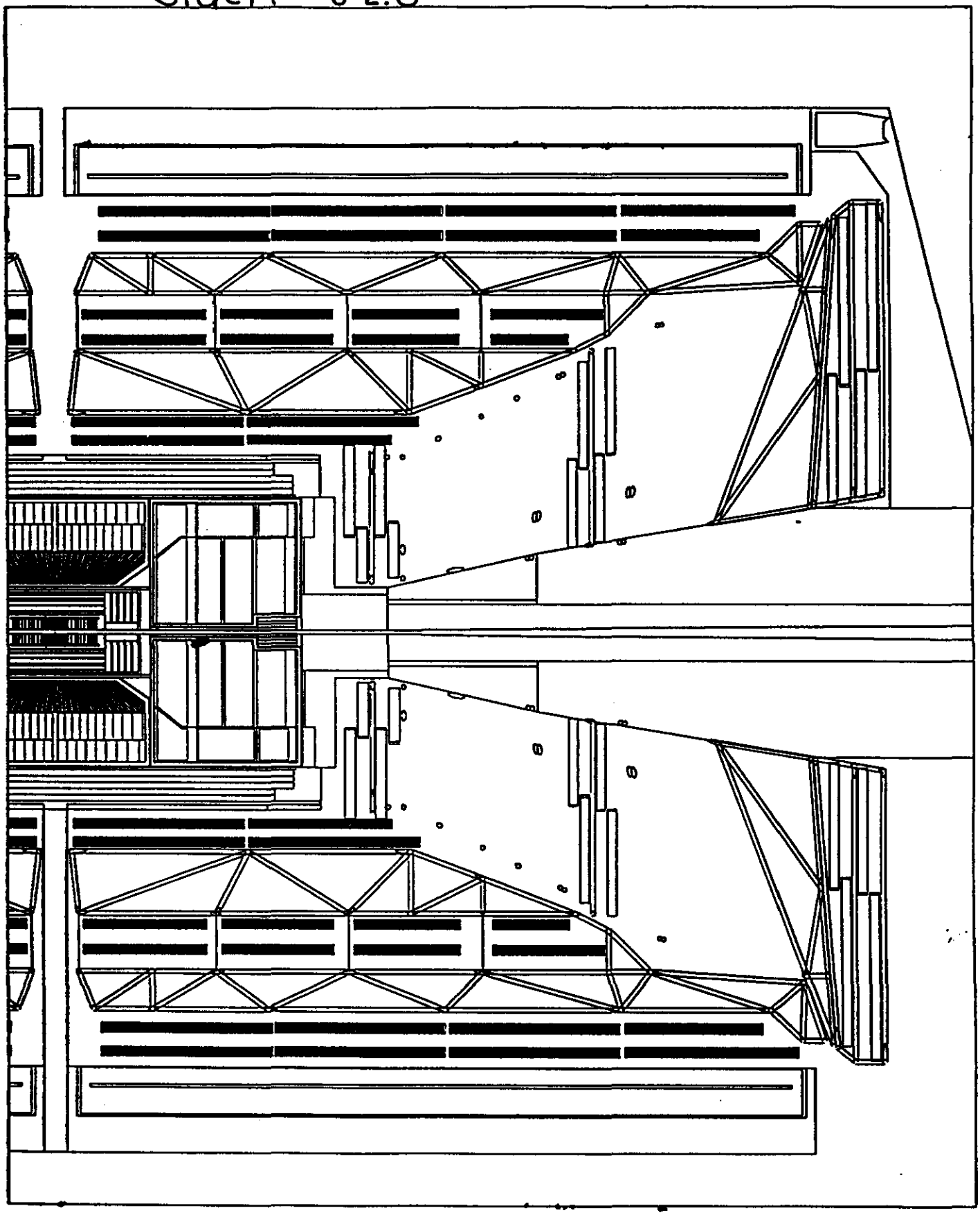
Distribution of Transversal Momenta of Muons

ESTIMATE OF
P_T FROM
BEND ANGLE

SIGEM V2.0 -



SIGEM V2.0



Summary of Muon Meeting

- Working Meeting to go through PAC presentation
  - fine-tuned agenda of muon parallel session
- Progress on muon simulation
  - Yuri Fisyak SIGEM 2.0
  - Torre Wenaus Hit Level MC results

V. Gavrilov 5/11/93

MUON BACKGROUNDS

- HADRON PUNCHTROUGH & DECAY MUONS
  ⇒ CALORIMETER DEPTH
- NEUTRONS/GAMMAS/ACTIVATION
  ⇒ SHIELDING DESIGN
- MUON INDUCED EM SHOWERS & δ-RAYS
  ⇒ MIN. CLEAR SPACE BETWEEN ABSORBER & CSC
- COSMIC RAYS
  ⇒ CALIBRATION & COMMISSIONING

HADRON PT & DECAY μ

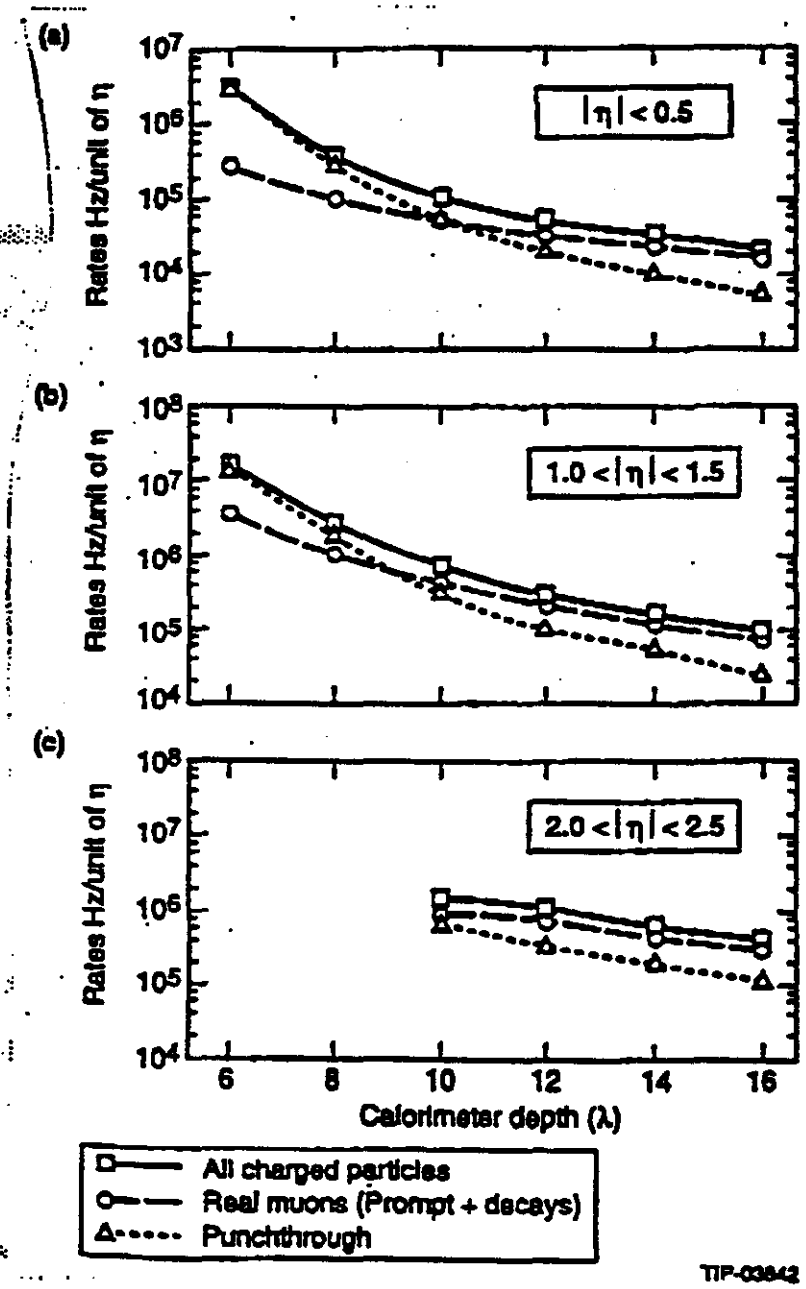
R. McNeil - GEM TN-92-68

Y.-H. Chang, B. Zhou - GEM TN-92-101

Mohammadi - Response to PAC

- μ track reconstruction efficiency
- μ trigger rate

$\lvert\eta\rvert$	Optimum depth
0.1 - 1.34	11λ
1.38 - 1.86	12λ
1.86 - 2.46	16λ


(a)
(b)
(c)
Rates Hz/unit of η
|η| < 0.5
1.0 < |η| < 1.5
2.0 < |η| < 2.5
Calorimeter depth (λ)
All charged particles
Real muons (Prompt + decays)
Punchthrough
TIP-03842

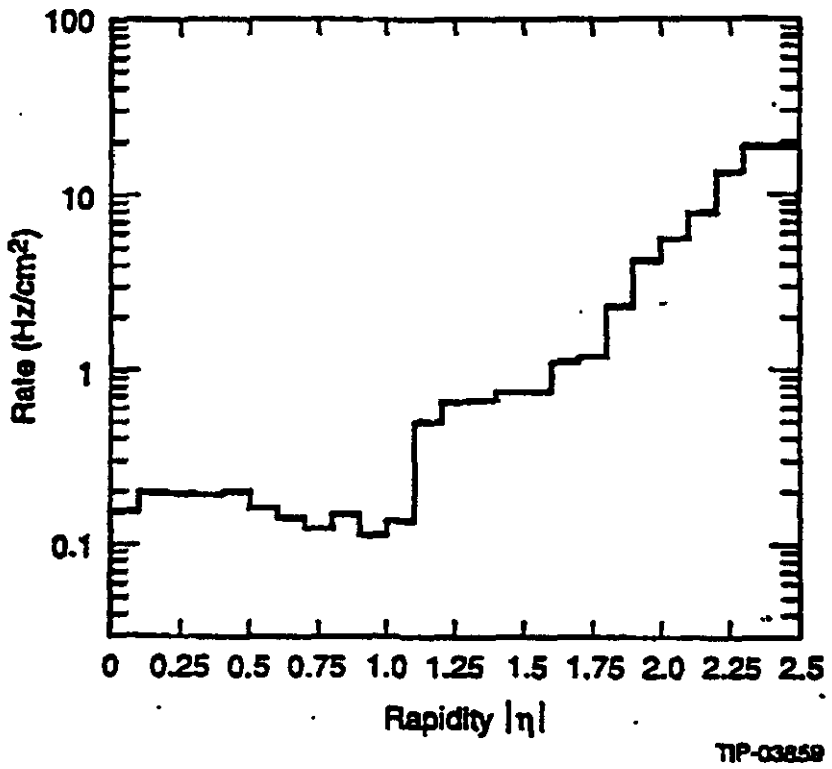


FIG. 4-11. Charged particle rate versus rapidity in the first muon system superlayer.

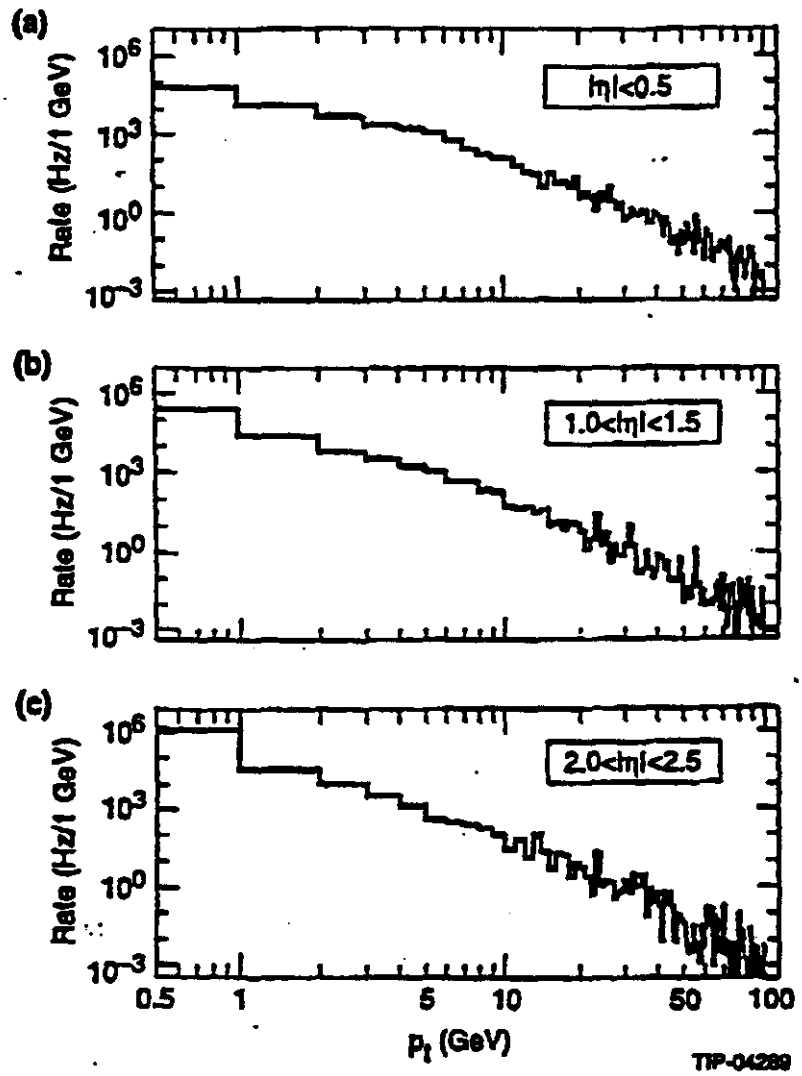


FIG. 4-12. Charge particle rate exiting the calorimeter versus transverse momentum a) $|\eta| < 0.5$, b) $1.0 < |\eta| < 1.5$, c) $2.0 < |\eta| < 2.5$.

Table 4-6. CSC single and 4 strip occupancy at 10^{34} cm^{-2} s^{-1} luminosity from particles exiting the calorimeter in two rapidity intervals as a function of calorimeter depth. 4-strip occupancy refers to any hit in a given 4 contiguous strips. The rates shown are for the highest rate strips in each rapidity region.

$0.1 < |\eta| < 1.34$

Calorimeter thickness (λ)	6	8	10	12	14
Rate per strip (Hz) Strip size 350 cm x 0.5 cm	33000	6600	2200	800	480
Single strip occupancy 300 nsec integration time	2.6%	0.40%	0.13%	0.05%	0.03%
4-strip occupancy	10.4%	1.6%	0.52%	0.20%	0.12%

$1.86 < |\eta| < 2.46$

Calorimeter thickness (λ)	10	12	14	16
Rate per strip (Hz) Strip size 93 cm x 0.5 cm	13100	10500	6640	4320
Single strip occupancy 300 nsec integration time	0.78%	0.64%	0.40%	0.26%
4-strip occupancy	3.1%	2.6%	1.6%	1.0%

NEUTRONS, PHOTONS, RADIOACTIVATION

NTF M. Diwan - shield optimization

SIGEM-CALOR - Yu. Fisyak

LAHET-MCNP - L. Waters

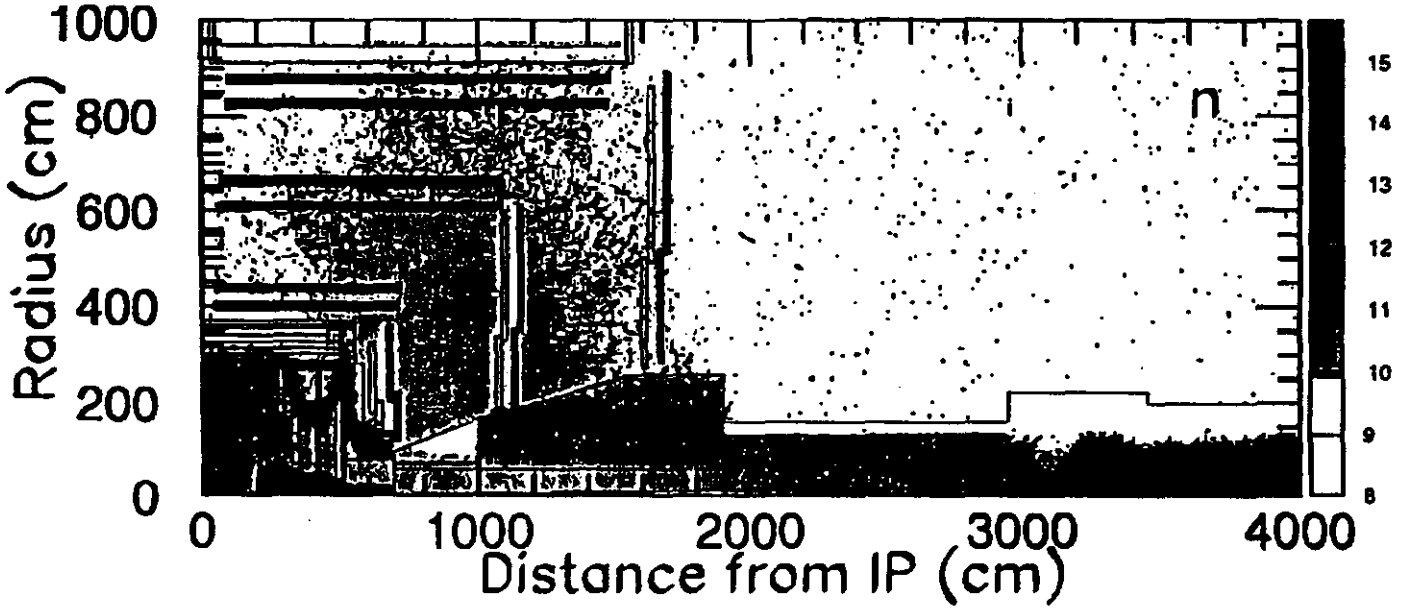
n/γ Fluxes, spectra

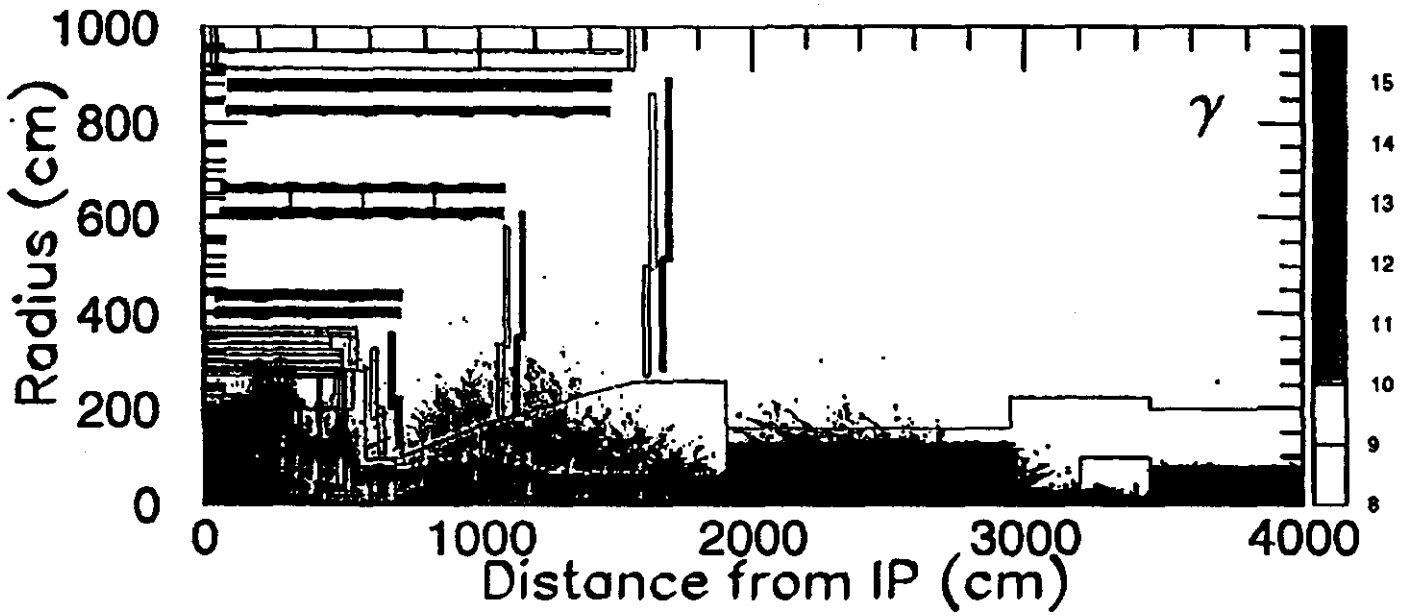
CSC sensitivity

^{252}Cf	GEM	TN-92-122,199	MIT
^{252}Cf, ^{60}Co	GEM	TN-93-345	ITEP
Neutron beam			PNPI

Radioactivation $^{63}Cu \rightarrow {}^{64}Cu$ 13h
↳ β-decay

M. Diwan


1000
800
600
400
200
0
Radius (cm)
0
1000
2000
3000
4000
Distance from IP (cm)
n
15
14
13
12
11
10
9
8


1000
800
600
400
200
0
Radius (cm)
0
1000
2000
3000
4000
Distance from IP (cm)
γ
15
14
13
12
11
10
9
8

Yu. Fisyak

TDR

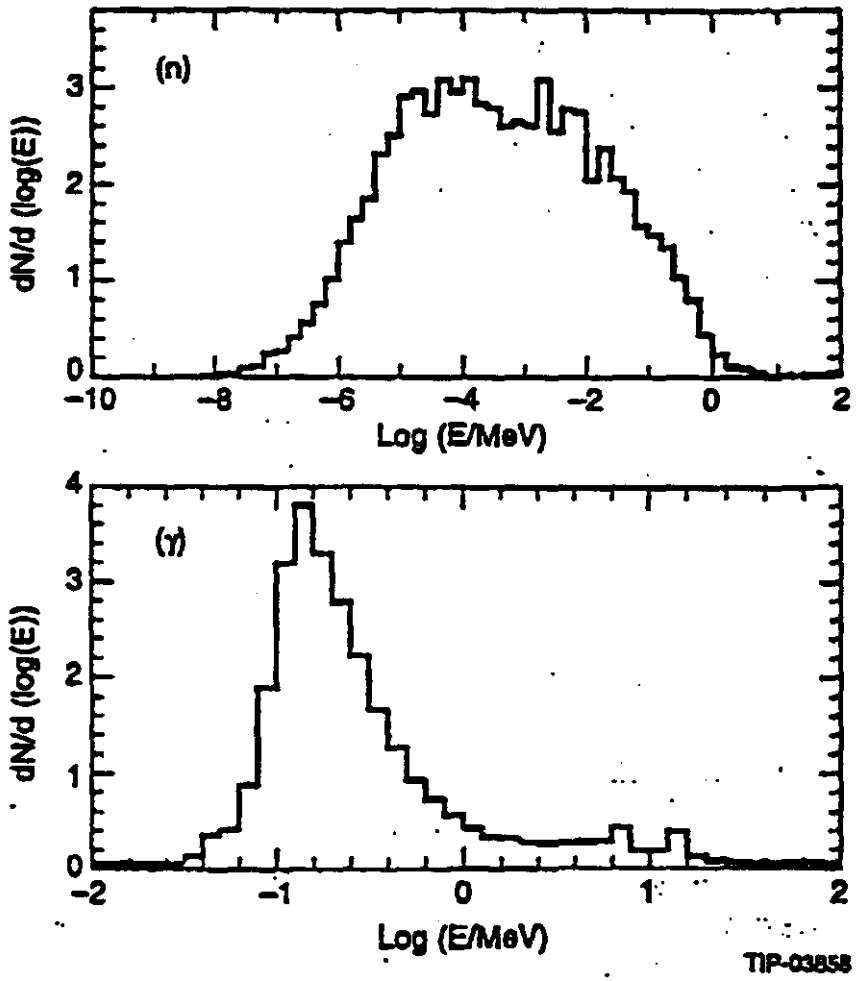
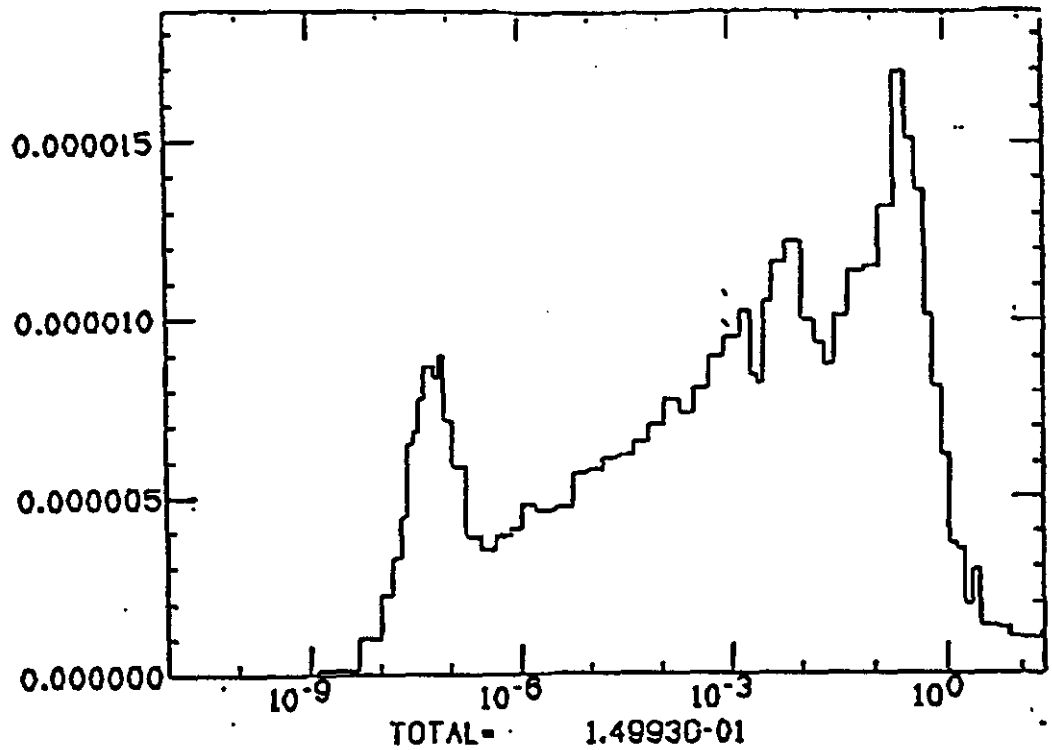


FIG. 12-11. The spectra of neutrons (n) and photons (γ) in the barrel muon system of the shielded detector calculated using the GEANT-CALOR package. The normalization is arbitrary in these plots.

L. Waters



FORWARD CHAMBER 12

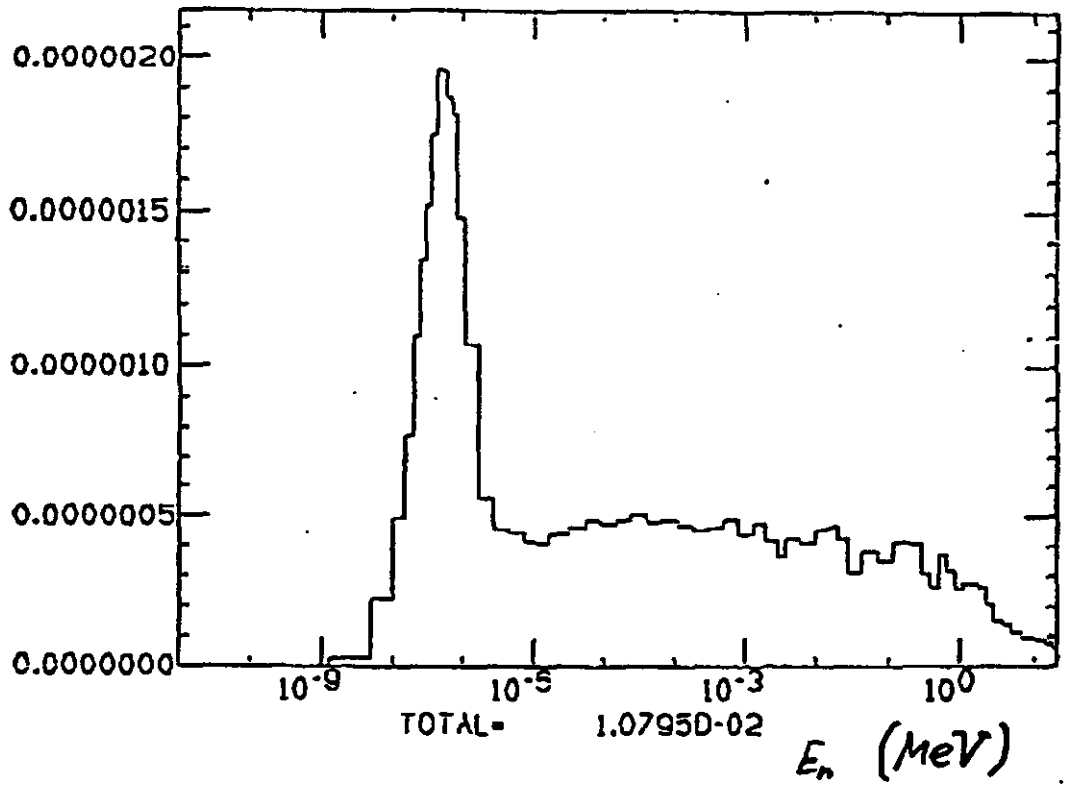


Table 4-8. Detection efficiency of CSCs for thermal and fast neutrons and photons.

Superlayer	gap thickness Barrel/Endcap (mm)	Detection efficiency (in units of 10^{-3}) Thermal neutrons	Fast neutrons	Gamma
Inner	5/5	0.65	0.20	4.3
Middle	8/7	0.82	0.32	5.5
Outer	10/10	0.98	0.40	6.5

Close to GEANT

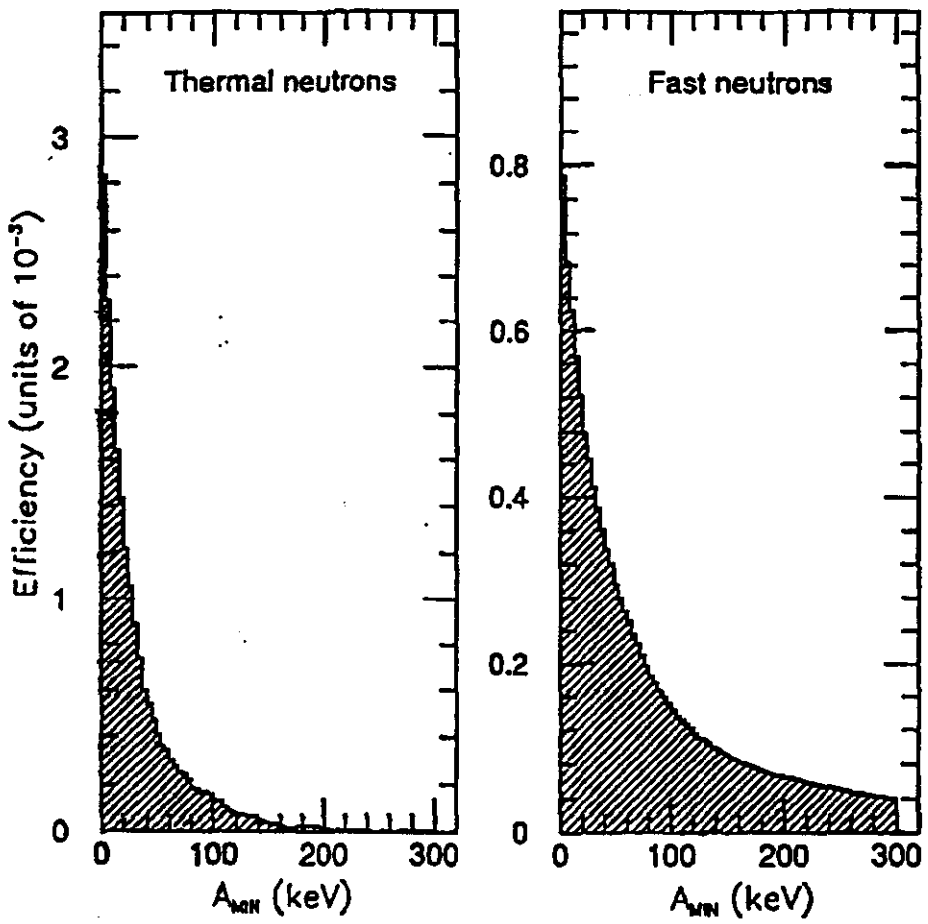
Table 4-9. Single strip occupancy (± 300 ns integration time) in the CSCs due to uncorrelated neutrons and gammas at 10^{34} $cm^{-2}s^{-1}$.

	Rapidity Range		
Superlayer	0.01–1.34	1.38–1.86	1.86–2.46
Inner	0.6%	0.3%	0.3%
Middle	0.6%	0.4%	0.4%
Outer	1.1%	0.6%	0.5%

8r ?

^{63}Cu radioactivation ⇒ rate

≈ 1/5 with respect to n/γ rate


Thermal neutrons
Fast neutrons
Efficiency (units of 10^{-3})
3
2
1
0
0.8
0.6
0.4
0.2
0
0
100
200
300
A_{MN} (keV)

4_2_64.ps

MUON INDUCED EM SHOWERS AND δ-RAYs

SIGEM - Yu. Fisyak

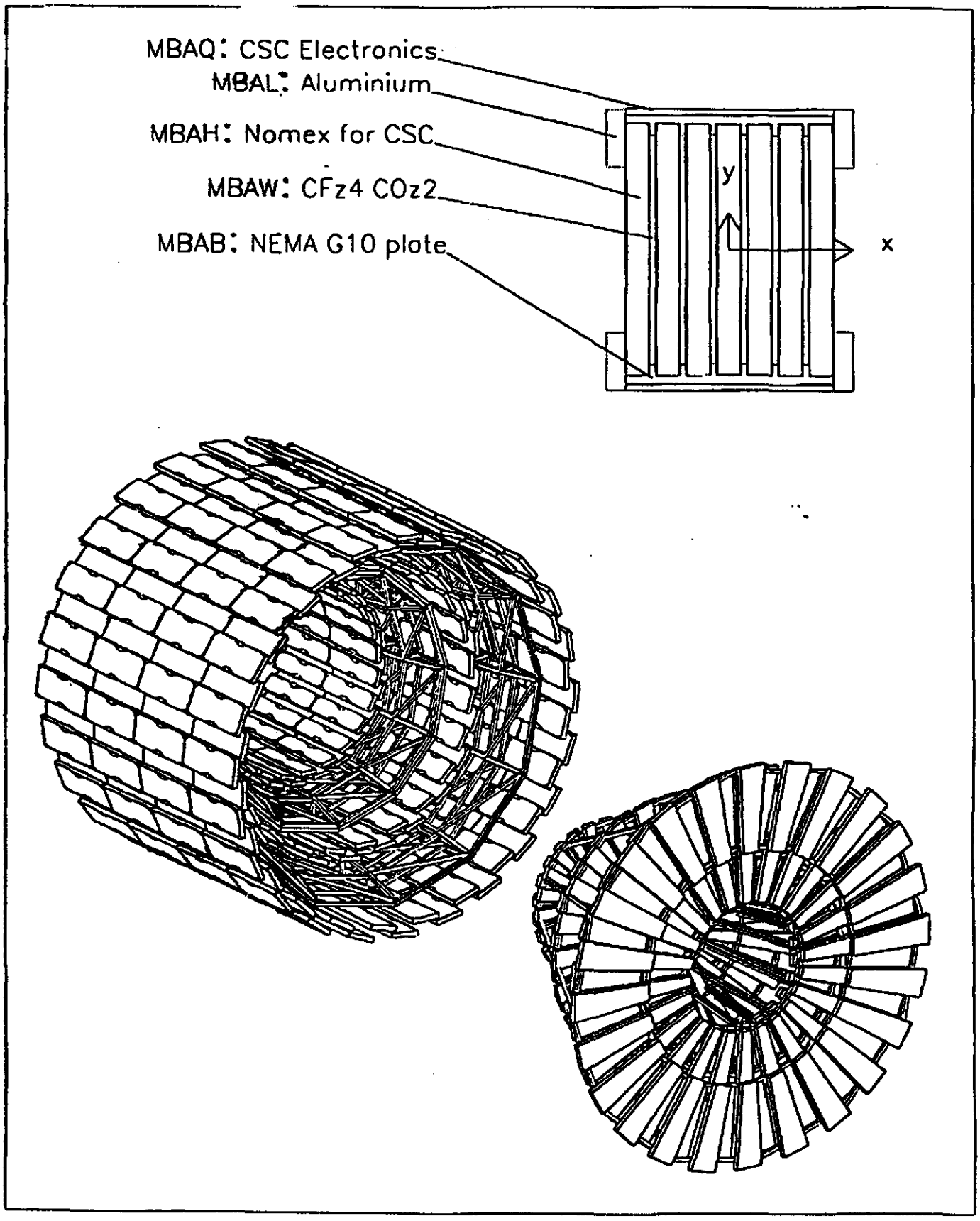
μ p_T 20GeV–5TeV

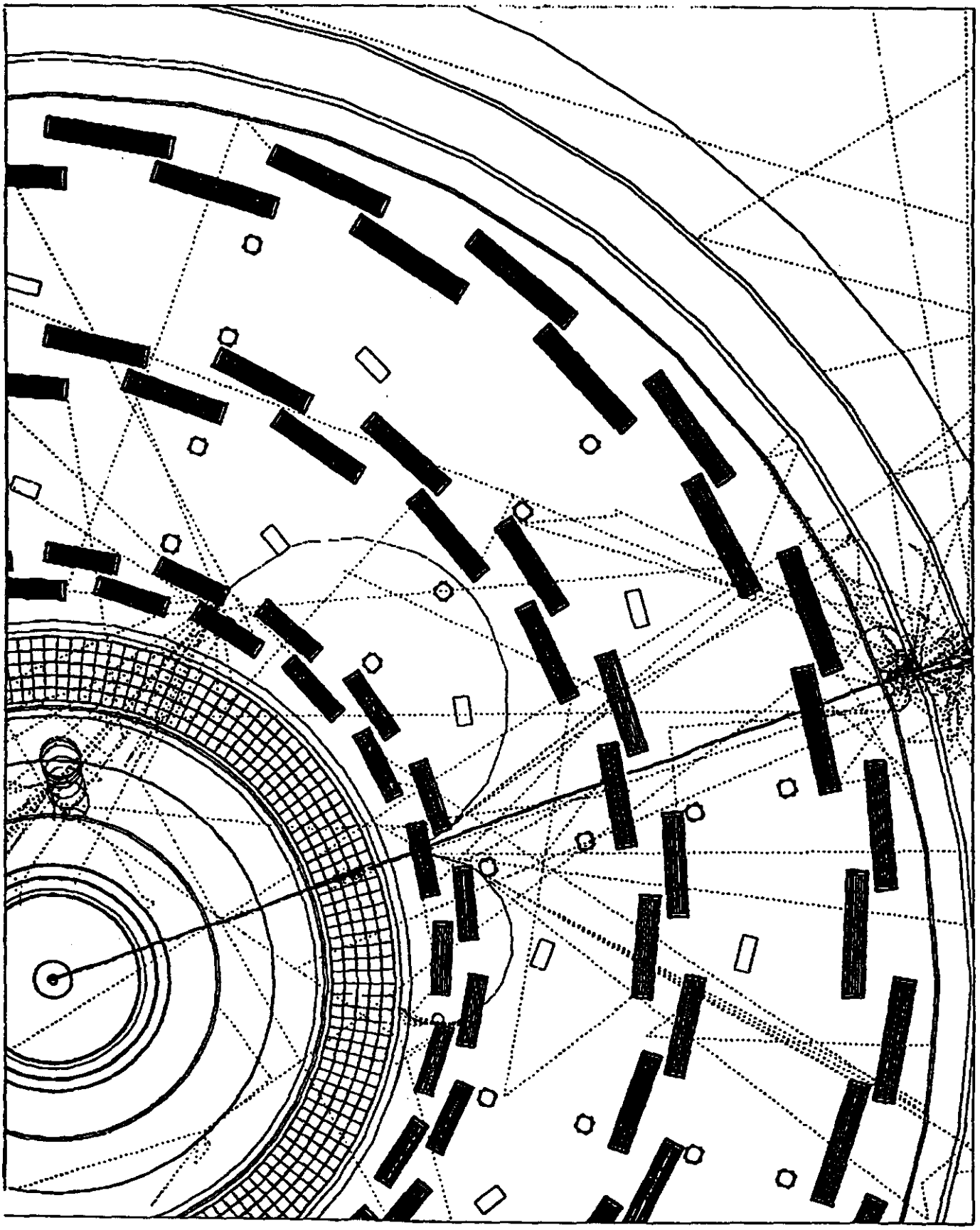
EM thr. – 10keV

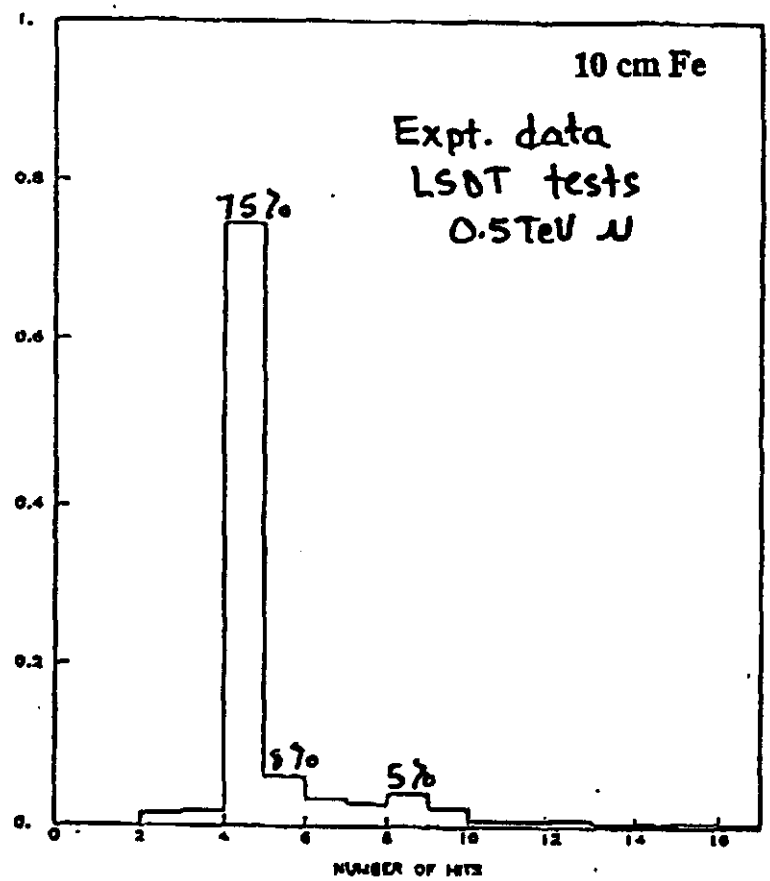
- μ track reconstruction eff.
- μ trigger threshold curves
- μ momentum resolution

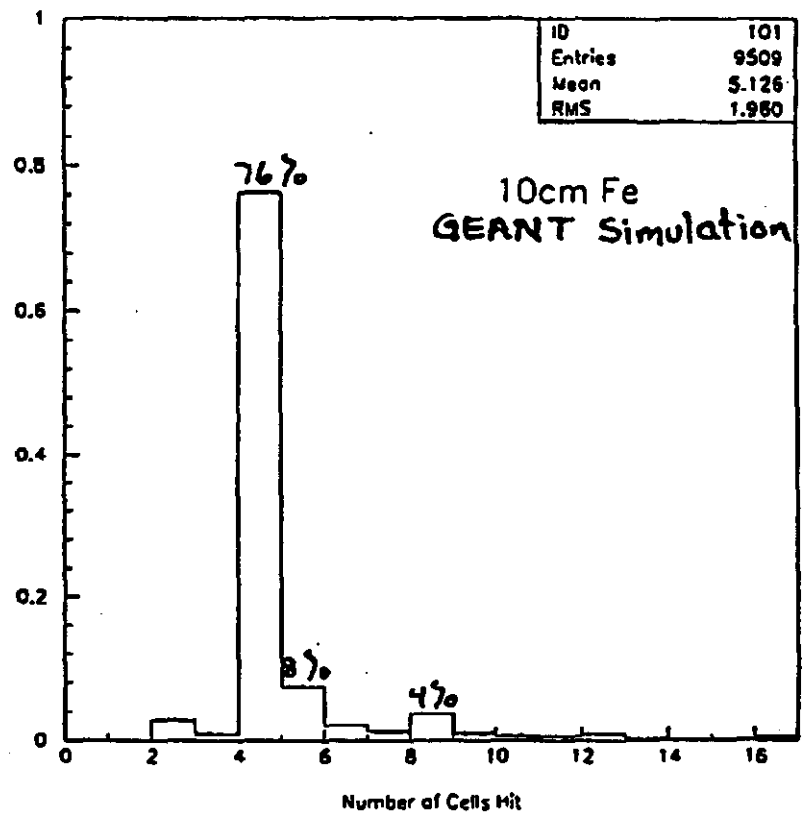
1 TeV μ, Inner Barrel SL

ΔR	Prob. ≥ 3 good hits
5 cm	85%
10 cm	89%
≥20 cm	94%

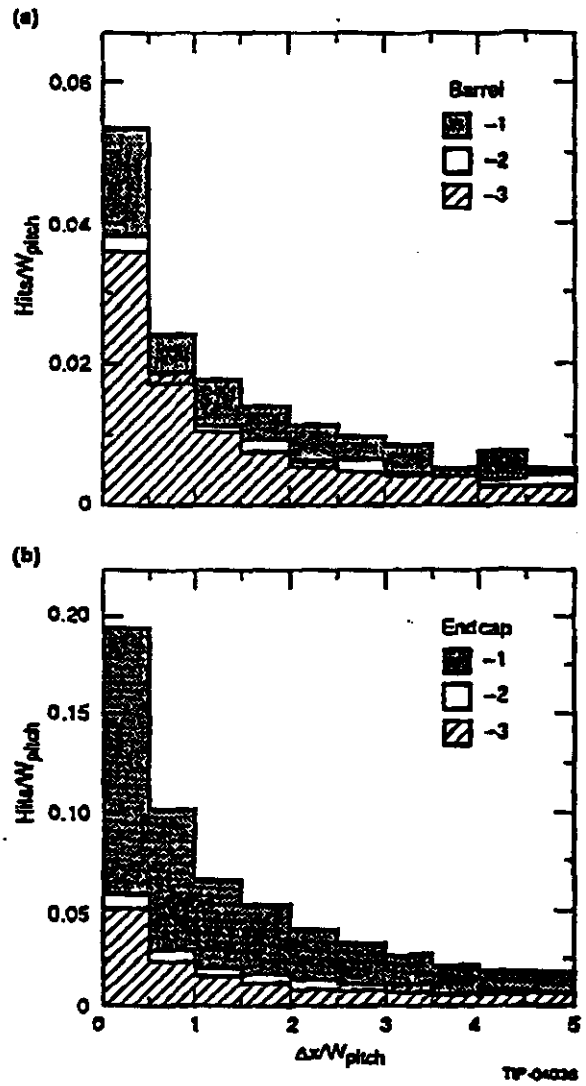

MBAQ: CSC Electronics
MBAL: Aluminium
MBAH: Nomex for CSC
MBAW: CFz4 COz2
MBAB: NEMA G10 plate
y
x

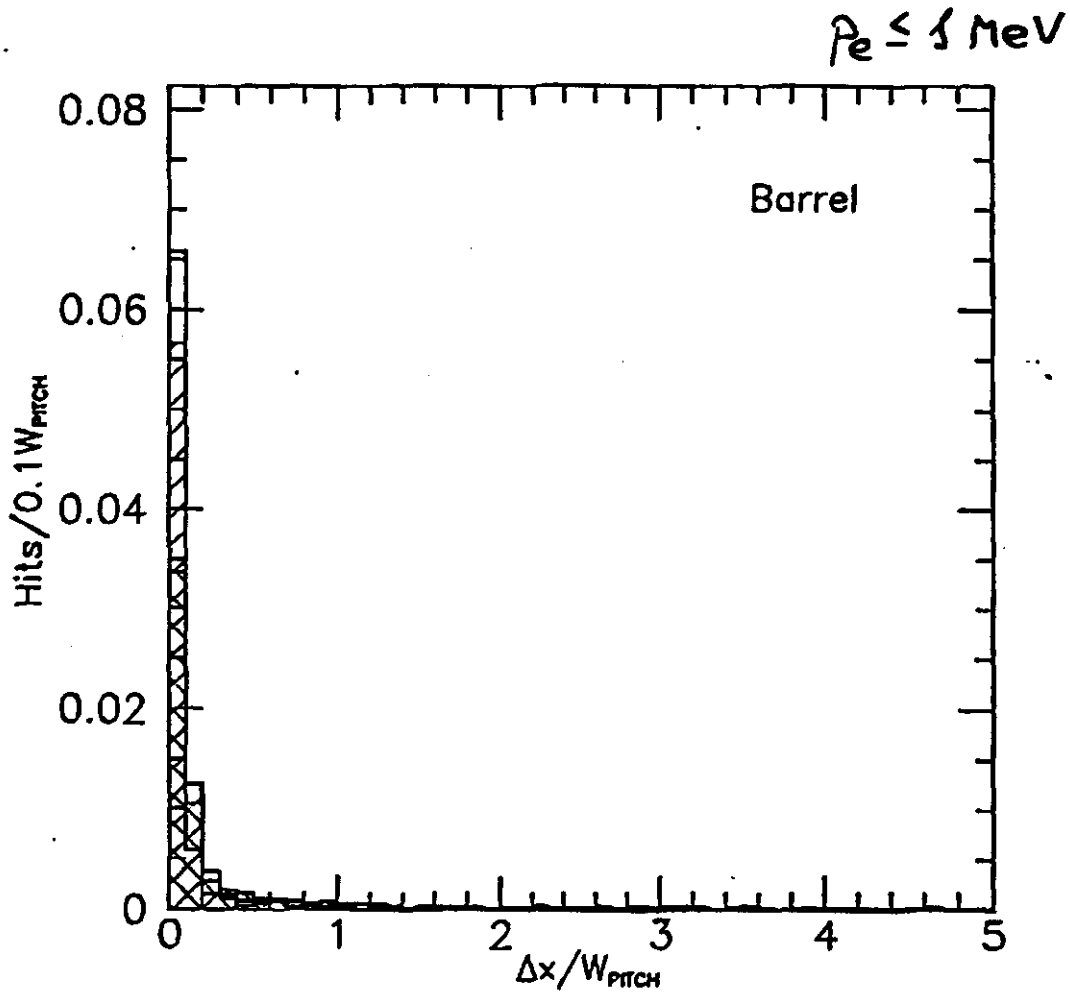


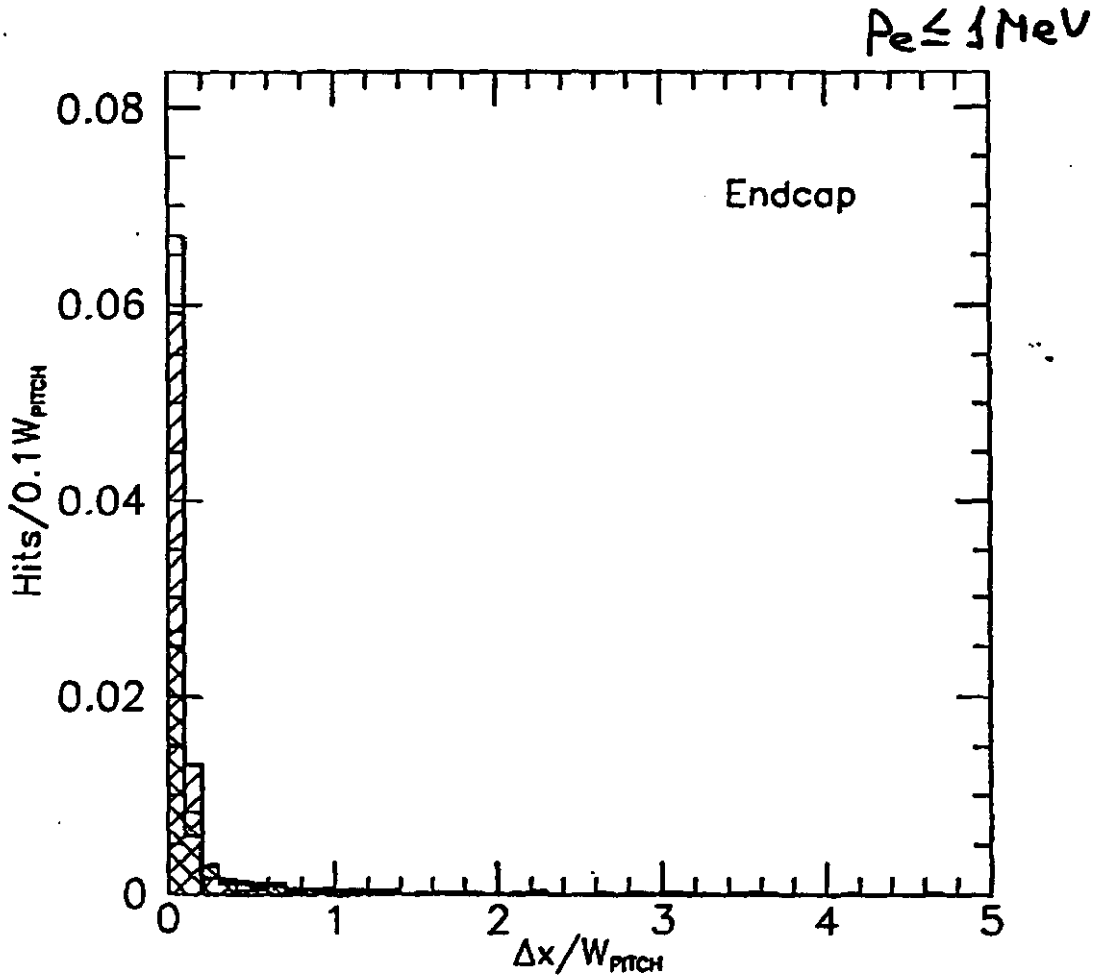

10 cm Fe
Expt. data
LSDT tests
0.5TeV ν
75%
8%
5%
NUMBER OF HITS


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

$p_e \geq 1$ MeV


(a)
Barrel
-1
-2
-3
Hits/W_pitch
0.06
0.04
0.02
0
(b)
Endcap
-1
-2
-3
Hits/W_pitch
0.20
0.15
0.10
0.05
0
0
1
2
3
4
5
Δx/W_pitch
TIP-04036


$P_e \leq 1$ MeV
Barrel
0.08
0.06
0.04
0.02
0
Hits/0.1W$_{PITCH}$
0
1
2
3
4
5
Δx/W$_{PITCH}$


$P_e \leq 1$ MeV
Endcap
Hits/0.1 W_{PITCH}
0.08
0.06
0.04
0.02
0
0
1
2
3
4
5
$\Delta x/W_{PITCH}$

COSMIC RAYS

$E_\mu \gtrsim 18$ GeV
under 43 m of rock

Flux $\sim 4 \cdot 10^{-4} cm^{-2} s^{-1}$

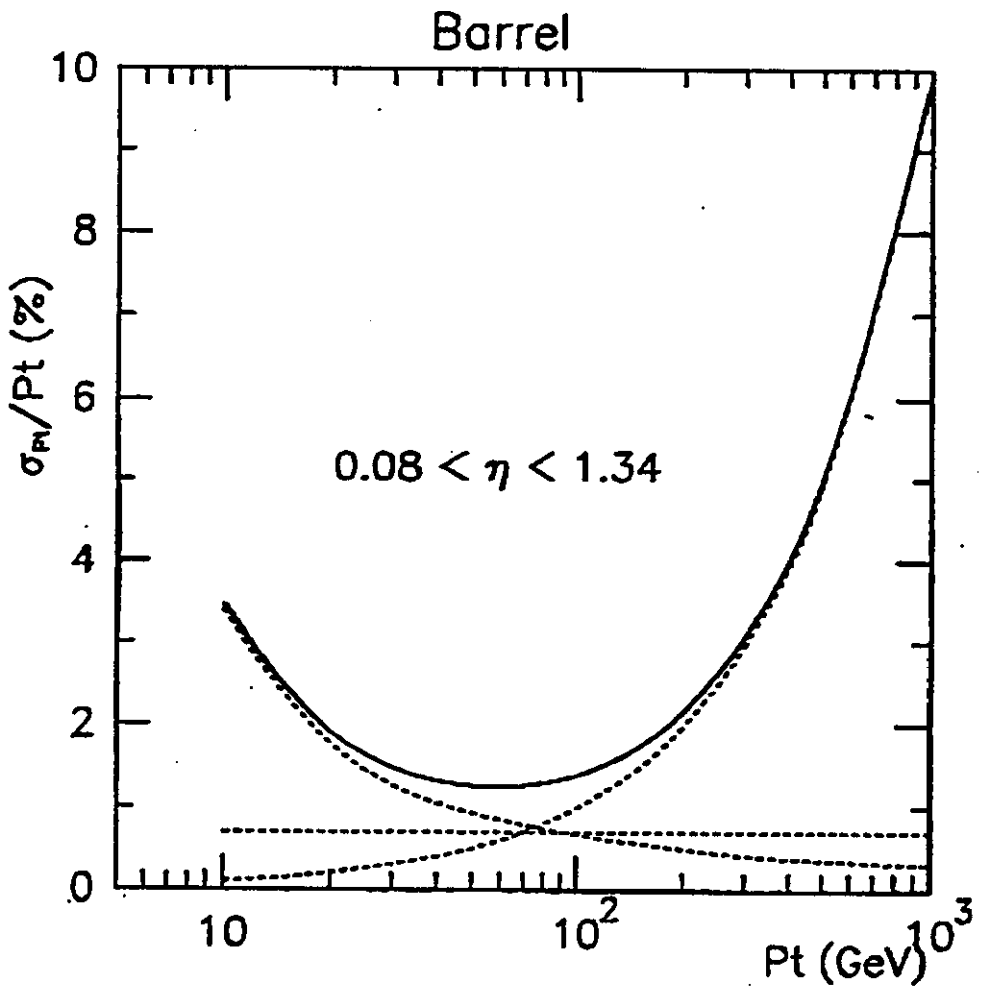
Trigger L1 rate $\lesssim 0.4$ Hz

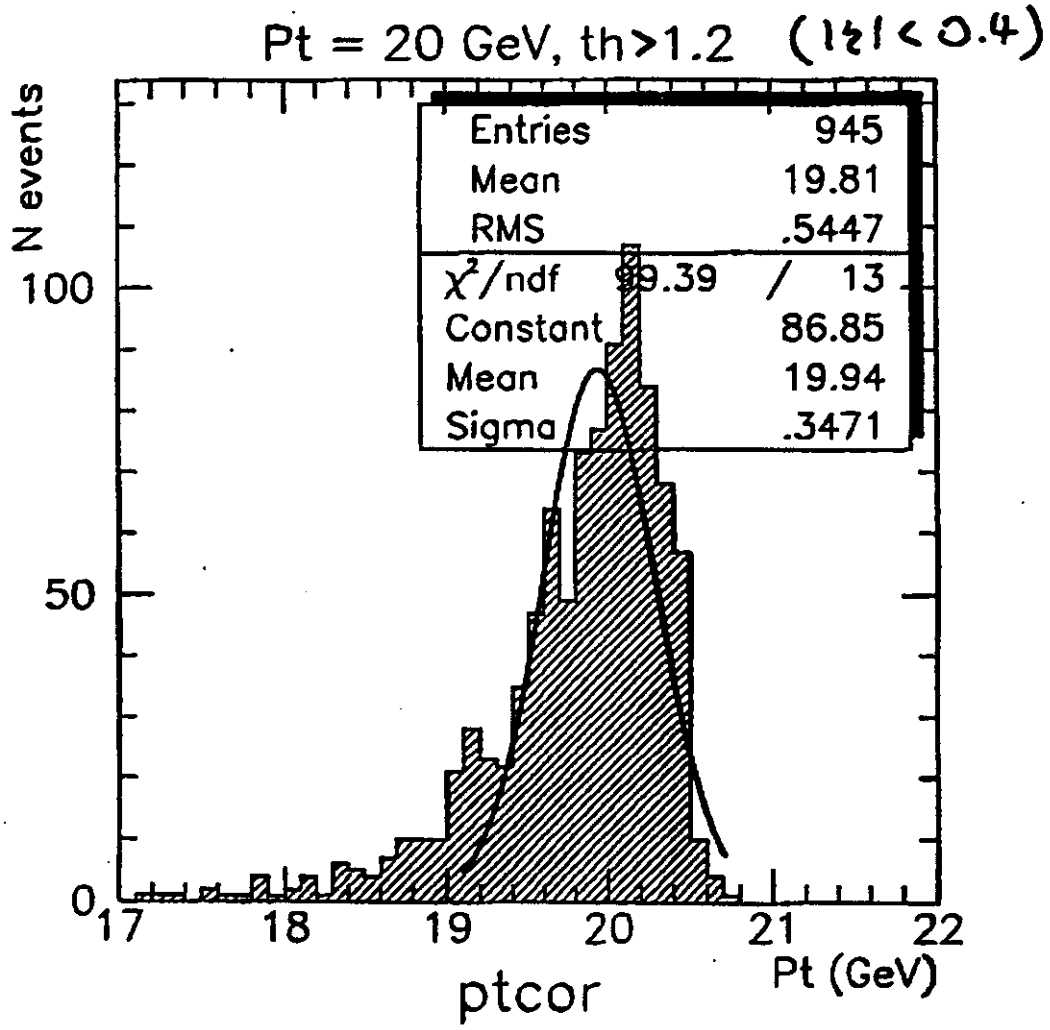
Good agreement with L3 results
($5 \cdot 10^{-4} cm^{-2} s^{-1}$)

05/11/93

V. Gavrilov

Muon energy loss correction


Barrel
10
8
6
4
2
0
σ_{Pt}/Pt (%)
$0.08 < \eta < 1.34$
10
10^2
10^3
Pt (GeV)

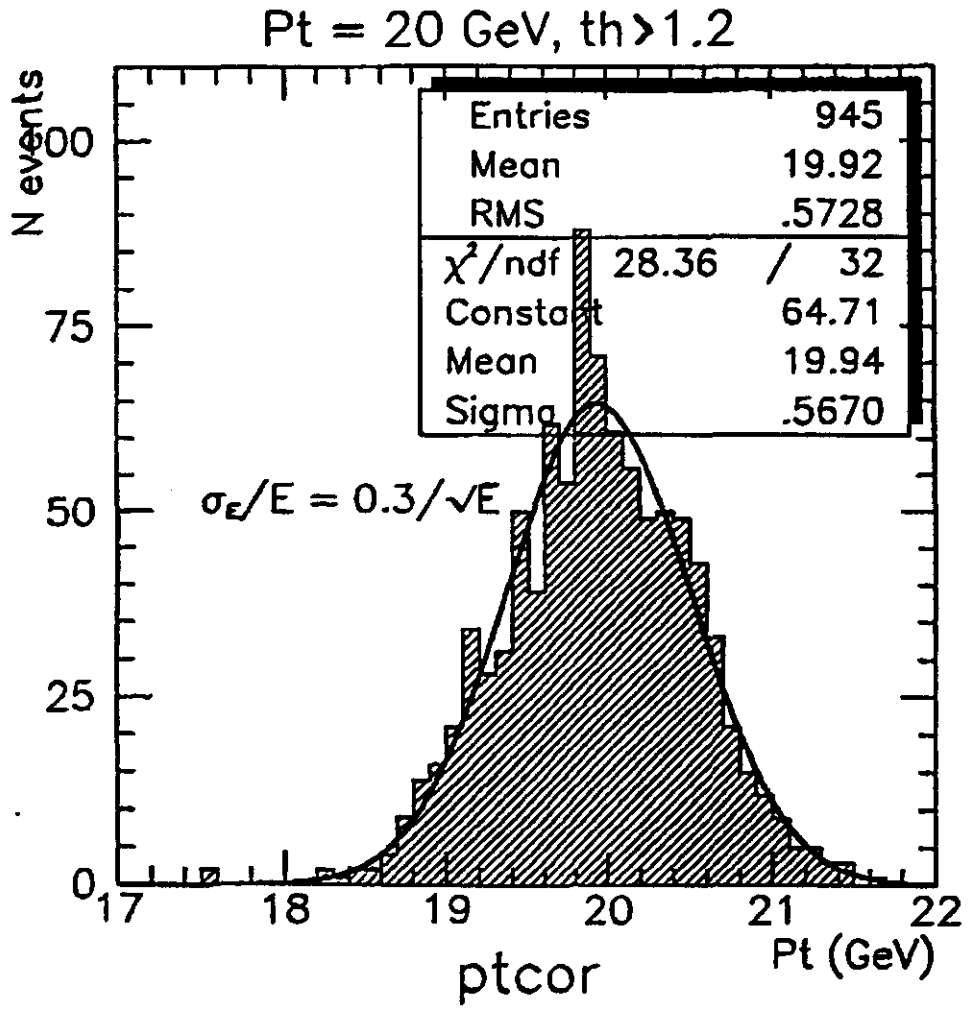

Pt = 20 GeV, th>1.2 (|z| < 0.4)
Entries 945
Mean 19.81
RMS .5447
χ²/ndf 99.39 / 13
Constant 86.85
Mean 19.94
Sigma .3471
N events
100
50
0
17
18
19
20
21
22
ptcor
Pt (GeV)

CALORIMETERS RESOLUTIONS FOR MUON ENERGY LOSS (TDR)

$$\frac{\sigma E}{E} \simeq \frac{a\%}{\sqrt{E}} + \frac{C}{E}$$ ← noise, pileup

$\mathcal{L} = 10^{33} cm^{-2} s^{-1}$

		Thick (λ)	a%	C (MeV)/# towers
Barrel	EM	1.3	6	50 / 4
	LH	4.5	~35	180 / 2
	SH	4.5	?	22 / 1
	Absor.	1-2	–	–
Endcap	EM	1.5	8	90 / 4
	LH	10	~35	215 / 2
	Absor.	≲ 5	–	–


Pt = 20 GeV, th>1.2
Entries 945
Mean 19.92
RMS .5728
χ²/ndf 28.36 / 32
Constant 64.71
Mean 19.94
Sigma .5670
σE/E = 0.3/√E
N events
100
75
50
25
0
17
18
19
20
21
22
Pt (GeV)
ptcor

L3
PL B271 (1991) 453

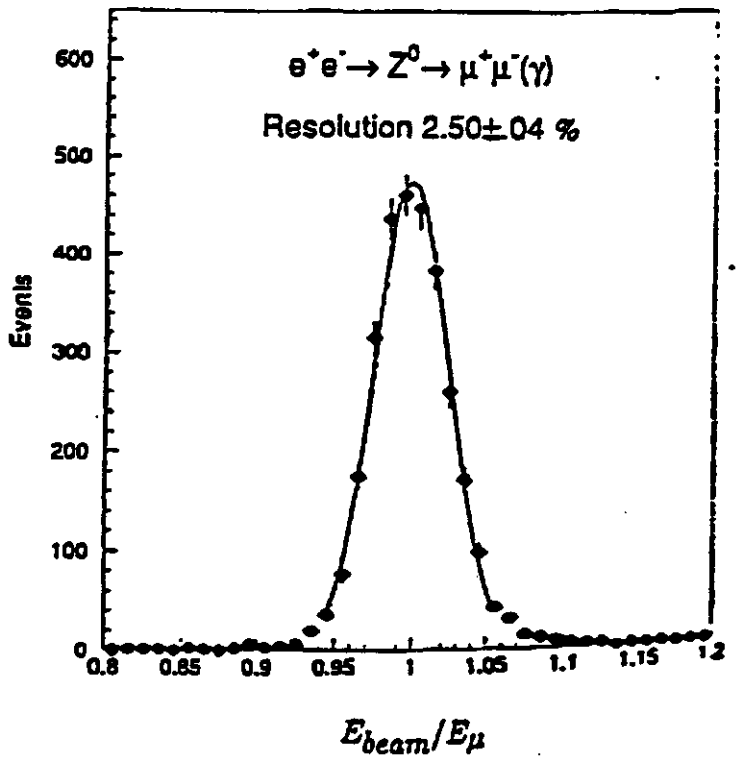
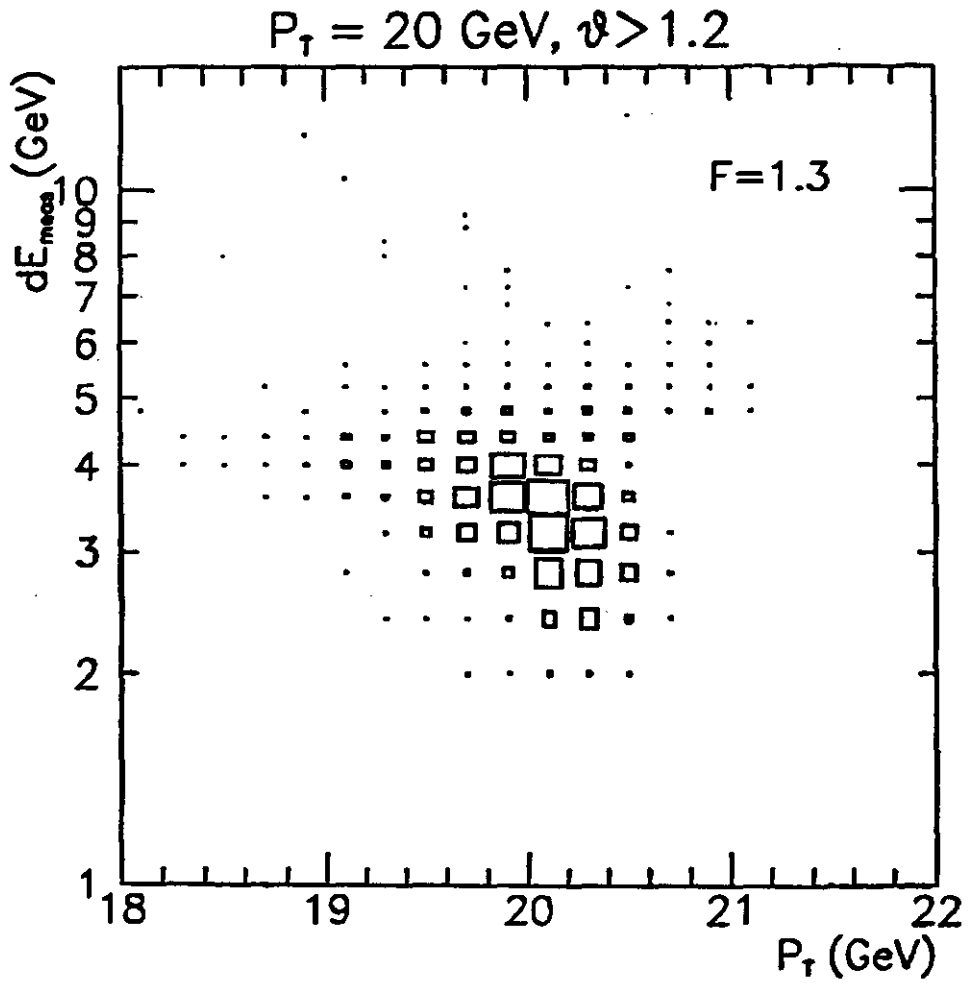
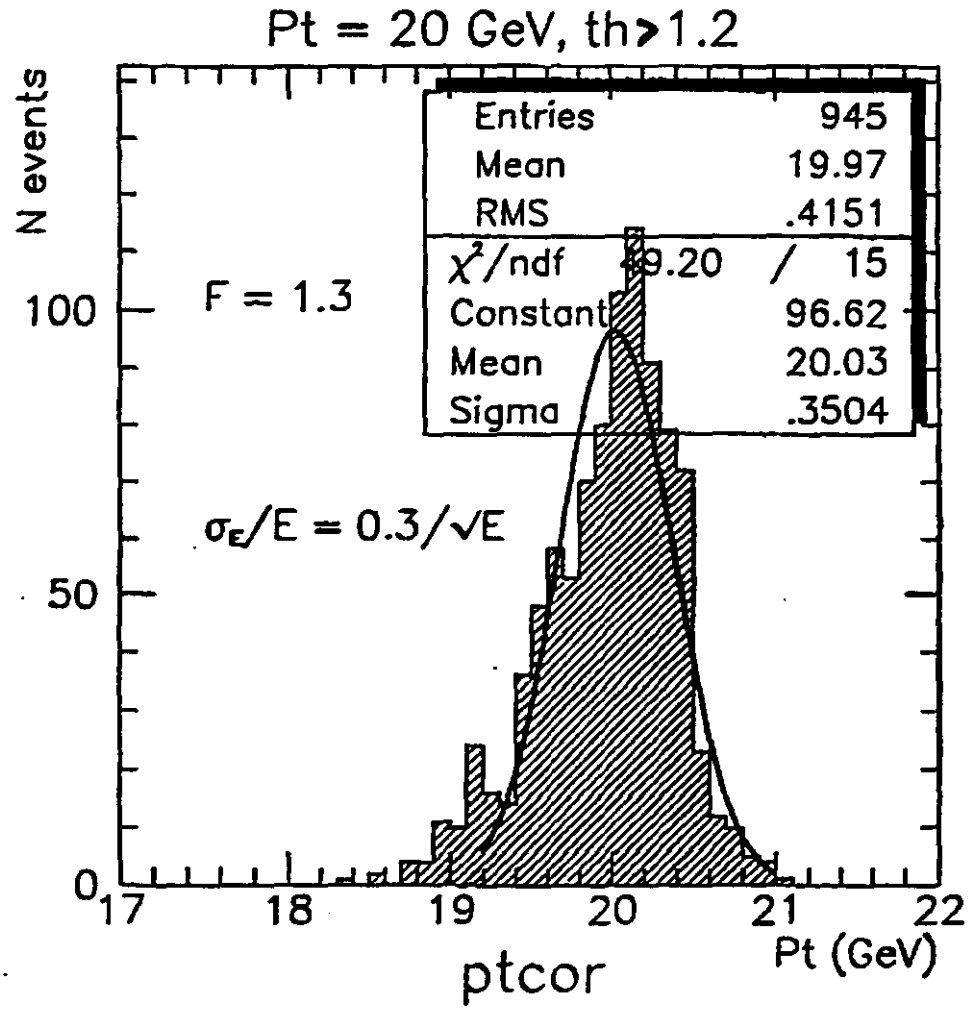


Fig. 1. Muon energy (E_μ) resolution from $Z^0 \rightarrow \mu\mu(\gamma)$ events.


P_T = 20 GeV, ϑ>1.2
F=1.3
dE_{meas} (GeV)
1
2
3
4
5
6
7
8
9
10
18
19
20
21
22
P_T (GeV)

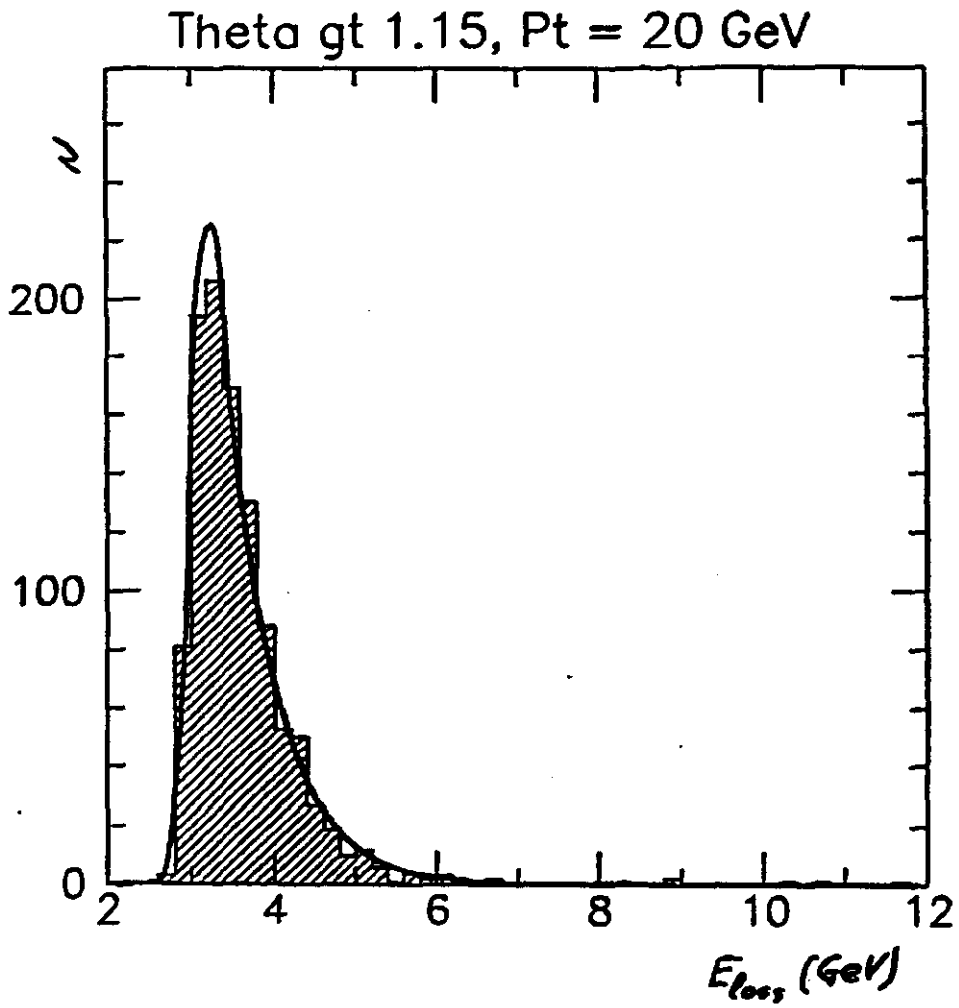

Pt = 20 GeV, th>1.2
N events
Entries 945
Mean 19.97
RMS .4151
χ²/ndf 49.20 / 15
Constant 96.62
Mean 20.03
Sigma .3504
F = 1.3
σE/E = 0.3/√E
100
50
0
17
18
19
20
21
22
Pt (GeV)
ptcor

V. Gavrilov

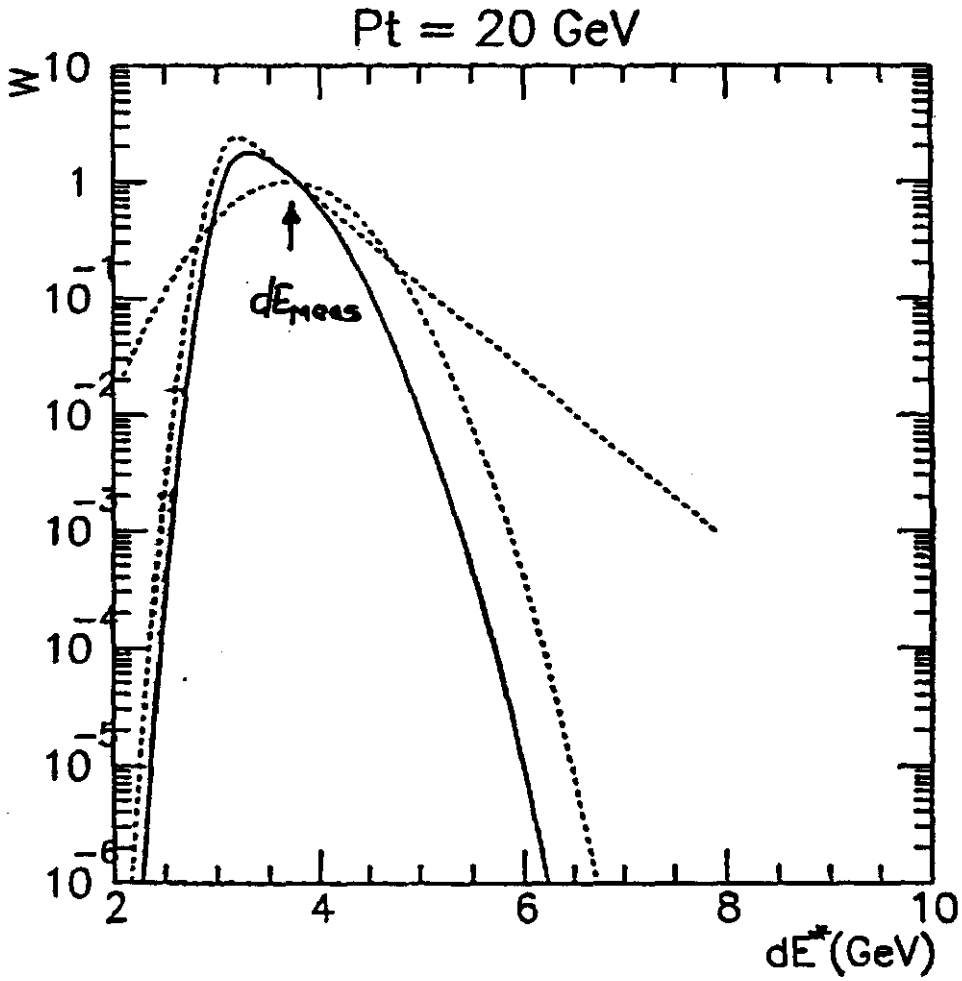
$$y = \frac{x - x_0}{\sigma}$$

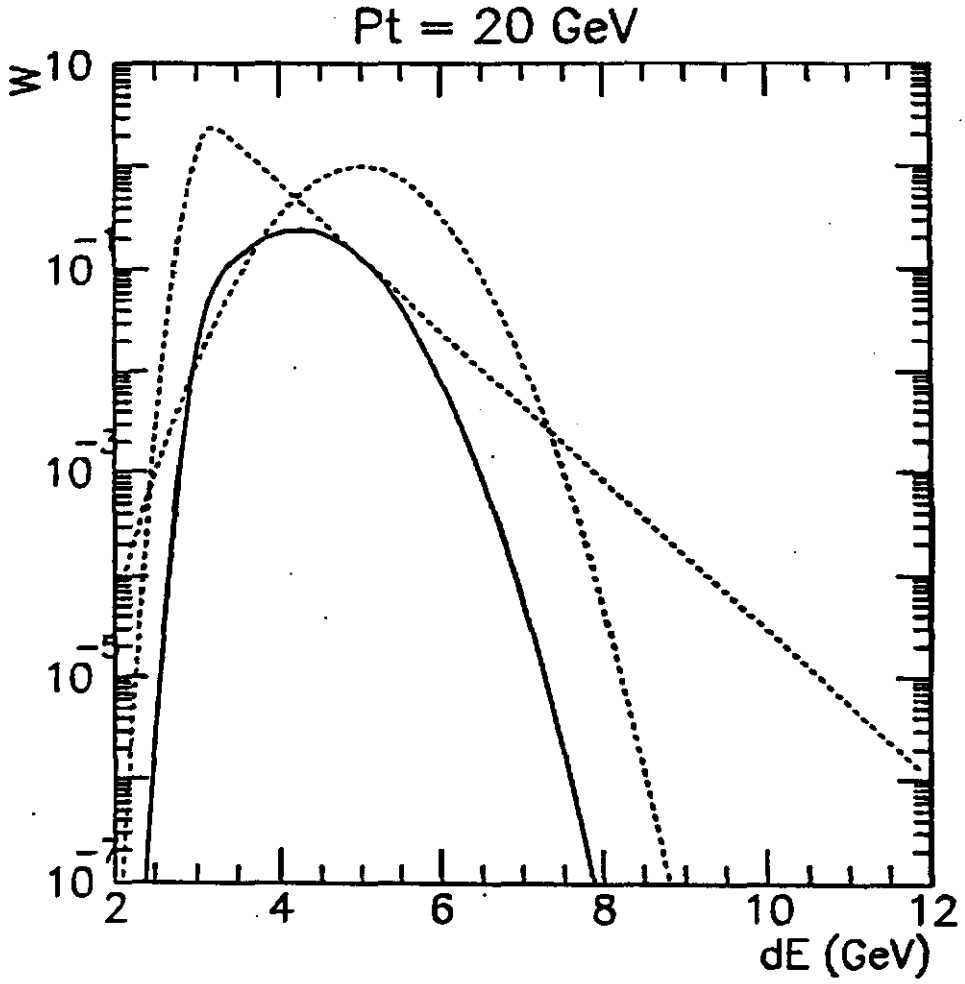
$y \le y_0$: $A \exp(-y^2)$

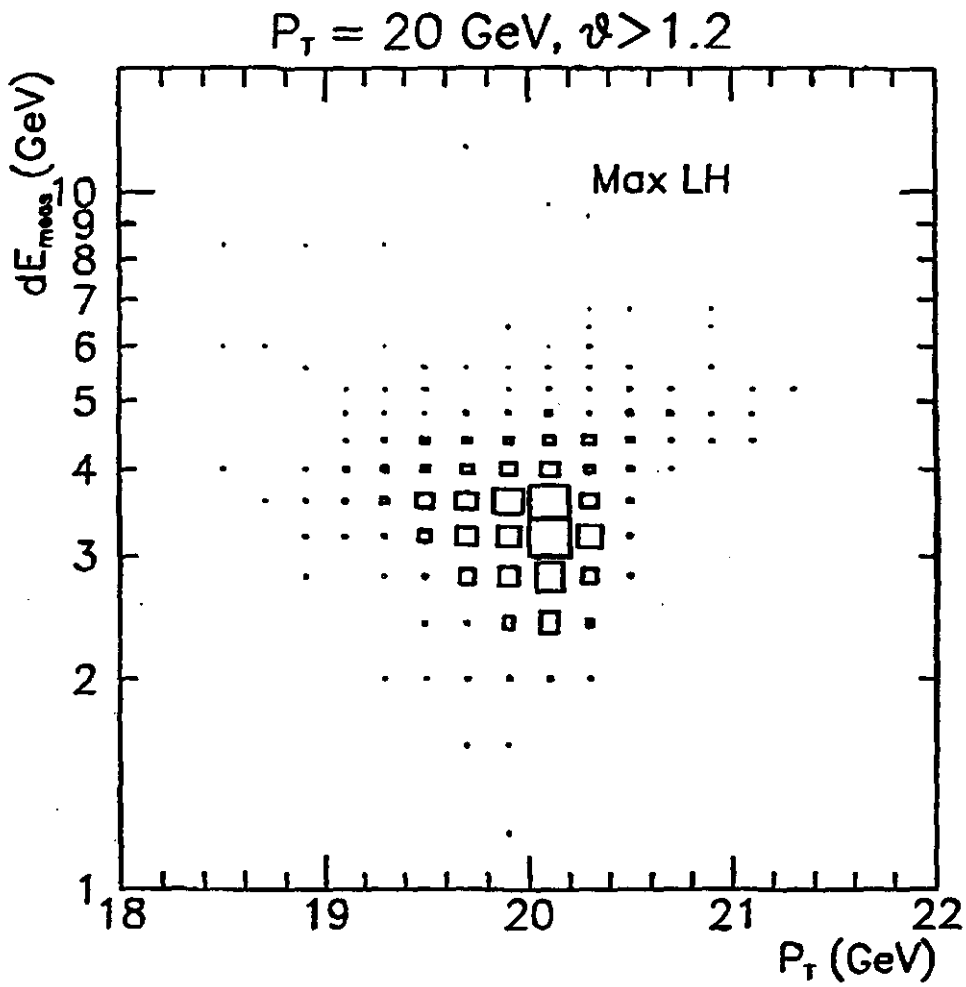
$y \ge y_0$: $A \exp[-2y_0 y + y_0^2]$



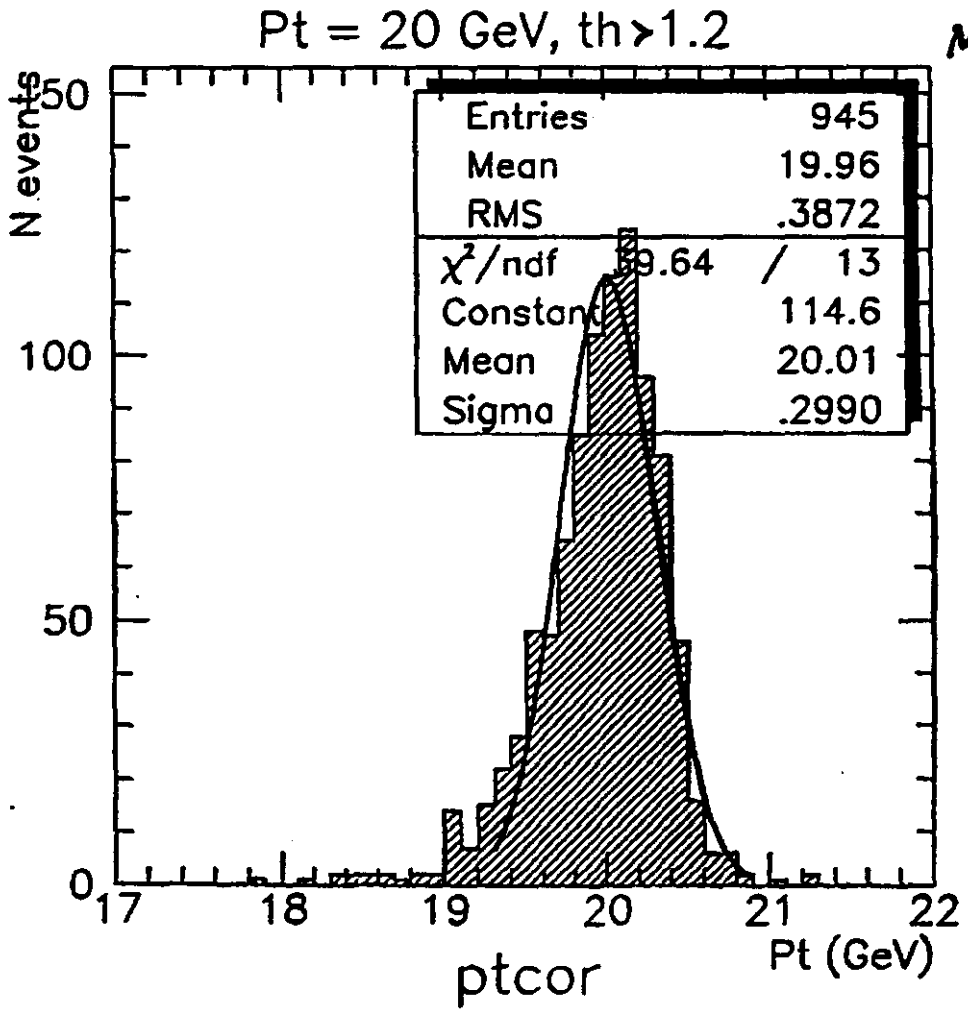
$$LH(dE^*) = R(dE_{meas} - dE^*) \cdot W(dE^*, p_m, \zeta_m)$$




Pt = 20 GeV
W
10
10^{-1}
10^{-3}
10^{-5}
10^{-7}
2
4
6
8
10
12
dE (GeV)


P_T = 20 GeV, ϑ>1.2
Max LH
dE_{meas} (GeV)
10
9
8
7
6
5
4
3
2
1
18
19
20
21
22
P_T (GeV)

V. Gavrilov.


Pt = 20 GeV, th>1.2
Max LH
Entries 945
Mean 19.96
RMS .3872
χ²/ndf 59.64 / 13
Constant 114.6
Mean 20.01
Sigma .2990
N events
0
50
100
150
17
18
19
20
21
22
Pt (GeV)
ptcor

$p_T = 20\ GeV \quad |\eta| < 0.4$

"Toy" calorimeter $\frac{\sigma_E}{E} = \frac{30\%}{\sqrt{E}}$

	"σ" (GeV)	RMS (GeV)
Cal only	0.57	0.57
F=1.3	0.35	0.42
Max LH	0.30	0.39

CONCLUSION

Adequate description of Calorimeters in SIGEM will allow:

- to take advantage of Max LH for muon E_{loss} corrections
- to joint optimally muon tracks in CT and muon chambers
- to provide accurate simulations of $H \to 4\mu$, $H \to 2\mu 2e$ mass distributions

μ RECONSTRUCTION

STATUS + RESULTS

- OVERVIEW OF RECO PROCEDURE
- IMPLEMENTATION STATUS
- RESULTS
  - MOMENTUM RESOLUTION
  - E LOSS FLUCTUATIONS
  - 150 GeV HIGGS $\rightarrow 4\mu$
    - ACCEPTANCE
    - ΔM_H
  - 4 TeV $Z' \rightarrow \mu\mu$
    - ACCEPTANCE
    - CHARGE DISCRIMINATION

– T. WENAUS APR 10

RECO PROCEDURE

INITIAL CONDITIONS

STARTING POINT:

MC HITS FROM SIGEM v1.3 / μ SIMV FOR GEMFAST } RESULTS AGREE

STANDARD SMEARING:

75μ CSC FIXED
50μ INT ALIGN
25μ EXT ALIGN

TWO-TRACK RESOLUTION:

HITS CLOSER THAN

3x	5 mm	SL1
	7 mm	SL2
	10 mm	SL3

RECO PROCEDURE

1) SEGMENT FINDING
   - CENTROID, SLOPE OF TRACK IN SL

2) SEGMENT MATCHING
   - TRIPLET (3-SL) AND DOUBLET (2-SL) FINDING WITH SLOPE χ^2 FOR COMBINATORICS SUPPRESSION

3) TRACK FITTING
   - MOMENTUM FIT USING CENTROIDS + SLOPES FOR GOOD CANDIDATES

4) BACK-TRACK TO VERTEX
   - E LOSS CORRECT
   - CT MATCH
   - VERTEX CONSTRAINT

IMPLEMENTATION STATUS

1) SEGMENT FIT
   - WORKS EFFICIENTLY IN PRESENCE OF ENVIRONMENTAL BACKGROUNDS (CALO SHOWERING, EM INTERACTIONS)

2) SEGMENT MATCH
   - BUILDS 3-SL (TRIPLET) AND 2-SL (DOUBLET) TRACKS
   - AMBIGUITY RESOLUTION DONE

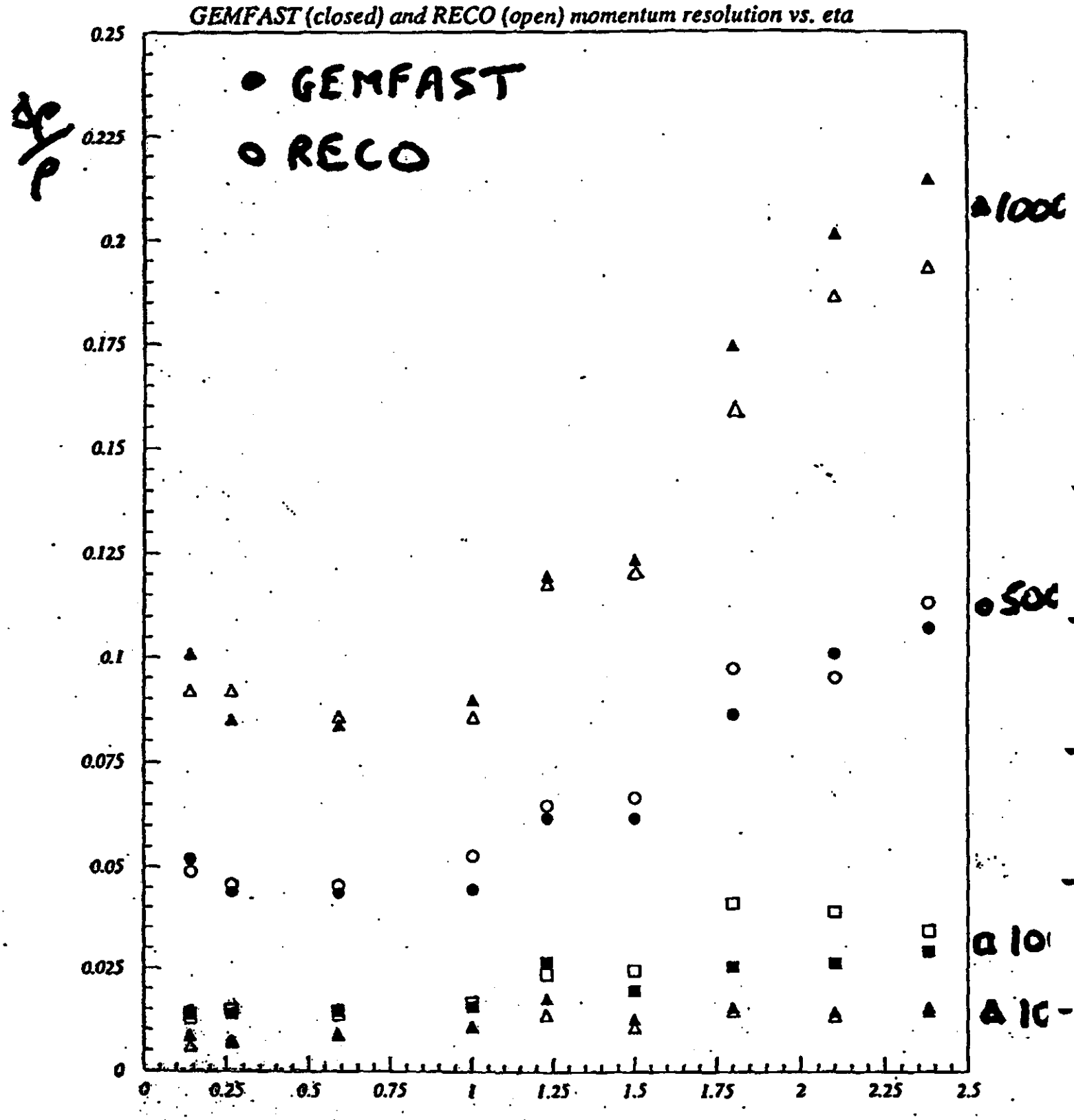
3) MOMENTUM FIT
   - FITS TRIPLET AND DOUBLET TRACKS

4) BACKTRACK
   - BACKTRACK TO VERTEX RETURNING
     - AVG E LOSS ALONG PATH
     - IMPACT PARAM
     - TRACK PARAMS, COV MATRIX AT VERTEX

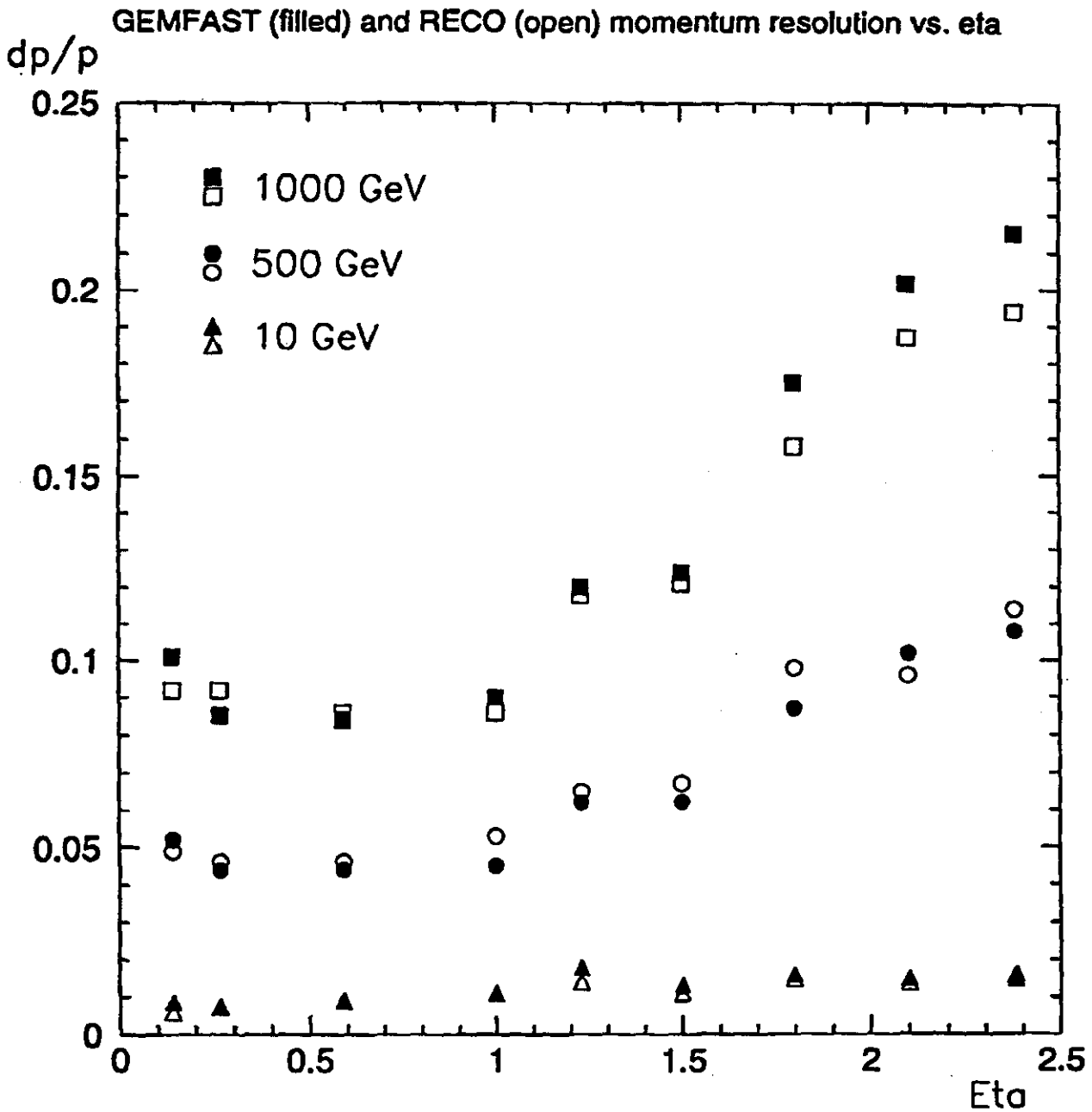
IMPLEMENTED

NEW RESULTS:

- DETAILED $\Delta p/p$ VS. η COMPARISON WITH GEMFAST
- DOUBLET RECONSTRUCTION USING SLOPES + CENTROIDS
- INCLUSION OF FULL ENVIRONMENTAL BACKGROUNDS
- 150 GeV HIGGS
- 4 TeV Z'



*E LOSS FLUCT NOT INCLUDED


GEMFAST (filled) and RECO (open) momentum resolution vs. eta
dp/p
0.25
0.2
0.15
0.1
0.05
0
1000 GeV
500 GeV
10 GeV
0
0.5
1
1.5
2
2.5
Eta

H(150 GeV) → ZZ* → 4μ

1000 EVS IN 4π, SIGEM v1.3, HONG JOO

EFFICIENCY:

	IN 4π	IN η<2.46
RECO, NO BACKGD	23%	44%
+ DOUBLETS	29%	54%
RECO, w/BACKGD	23%	42%
+ DOUBLETS	29%	56%
TDR* TRIPLETS	23%	43%
+ DOUBLETS	29%	54%

* CHAP 4, SIGEM w/3-HIT CRITERION

⇒ RECO EFF. IN GOOD AGREEMENT

ΔM_H :

TDR CHAP. 2 $\sigma_{M_H} = 1.62$ GeV @ 150 GeV

		σ_{M_H}
RECO, NO $\Delta E/E$,	BARREL:	$1.45^{\pm 1}$
"	ALL:	1.71
30 %/$\sqrt{E}$	" :	2.08
60 %/$\sqrt{E}$	" :	2.48
WITH BACKG, NO $\Delta E/E$,	ALL:	1.76
WITH DOUBLETS "	" :	1.80

⇒ • ΔM_H WORSE THAN TDR (GEMFAST)

WHY? • ENDCAP BUG IN RECO

• OPTIMISTIC $\Delta E/E$ IN GEMFAST

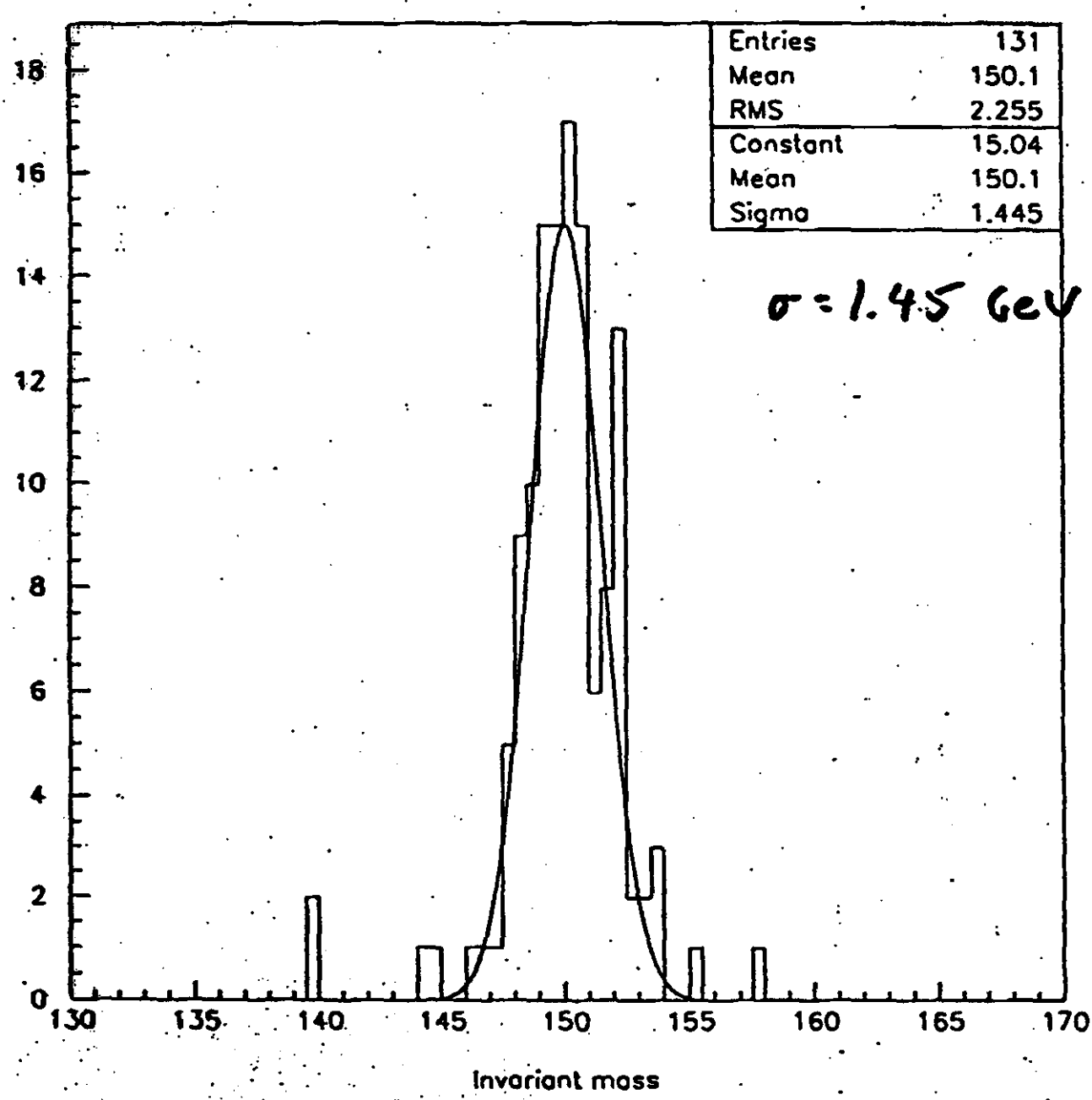
• OTHER RECO EFFECTS?

• EFFECT OF BACKGD IS SMALL:
1.71 → 1.76

• EFFECT OF DOUBLET INCLUSION:
1.71 → 1.80

M_H NO $\Delta E/E$ NO BACKGD

BARREL ONLY.



Z' (4 TeV $\to \mu\mu$

600 EVS IN 4π, SIGEM 1.3, HONG 100

EFFICIENCY:

86 % OF EVENTS IN $\eta < 2.46$
[TDR ch.4: 87%]

EVS WITH 2 RECONSTRUCTED ~~μ's~~ TRIPLETS:
BACKGD OFF: 62 % OF 4π ~~[TDR: 63%]~~
BACKGD ON: 57% OF 4π [TDR: 52 %]

INCLUDE TRIPLET + DOUBLET EVS:
BACKGD OFF: 66 % OF 4π [TDR: 63%]
BACKGD ON: 62 % OF 4π [TDR: 60 %]

RECO EFFICIENCY DUE TO BACKGD:

$$\frac{342 \text{ TRIPLET/TRIPLET, BACKGD } \overset{\text{ON}}{\cancel{\text{OFF}}}}{374 \quad " \quad " \quad \cancel{\text{ON}}} = 91\%$$

[TDR: RECO EFF FOR $Z'\mu$'s = 85%] ch.1
[TDR ch 4: 92 %]

$\Rightarrow$ RECO EFFICIENCY IN GOOD AGREEMENT

$Z' \to \mu^+\mu^-$ μ CHARGE MEASUREMENT

370 EVS WITH 2 RECONSTRUCTED μ's.

NO BACKGD:

0 SAME-SIGN TRIPLET-TRIPLET

$\Rightarrow$ 0% CHG CONFUSION

(9 SAME-SIGN DOUBLET-TRIPLET)

WITH BACKGD: {AFTER FURTHER WORK THIS IS DOWN TO 2}

5 SAME-SIGN TRIPLET-TRIPLET

$\Rightarrow$ 1.4% CHG CONFUSION

(14 SAME-SIGN DOUBLET-TRIPLET)

[TDR ch. 2 QUOTES 1% OR LESS CHG CONFUSION.]

LOOKING AT THE 5, 2 OR 3 MAY BE FIXABLE MATCHING ERRORS.

$\Rightarrow$ SOMEWHAT WORSE THAN TDR, BUT MAY IMPROVE [N.B TDR BASED ON GAUSSIAN $1\,dp/p$]

May 6, 1993

Yu. Fisyak

SIGEM
GEANT SImulation for GEM detector
Version 2.0

Base line 1 → vrs. 0
— " — 2 → vrs. 1
TDR → vrs. 2

SIGEM structure

I have borrowed L3 idea about using GEANT for simulation of systems and subsystem as combination of different level detailization description of these system:

- Level 0 — NO detector or subdetector at all.
- Level 1 — System as a "dead" material
- Level 2 — Simplified description (= mixture level Calorimeter with GFLASH) with HITS
- Level 3 — Full description (Barrel accordion) with HITS

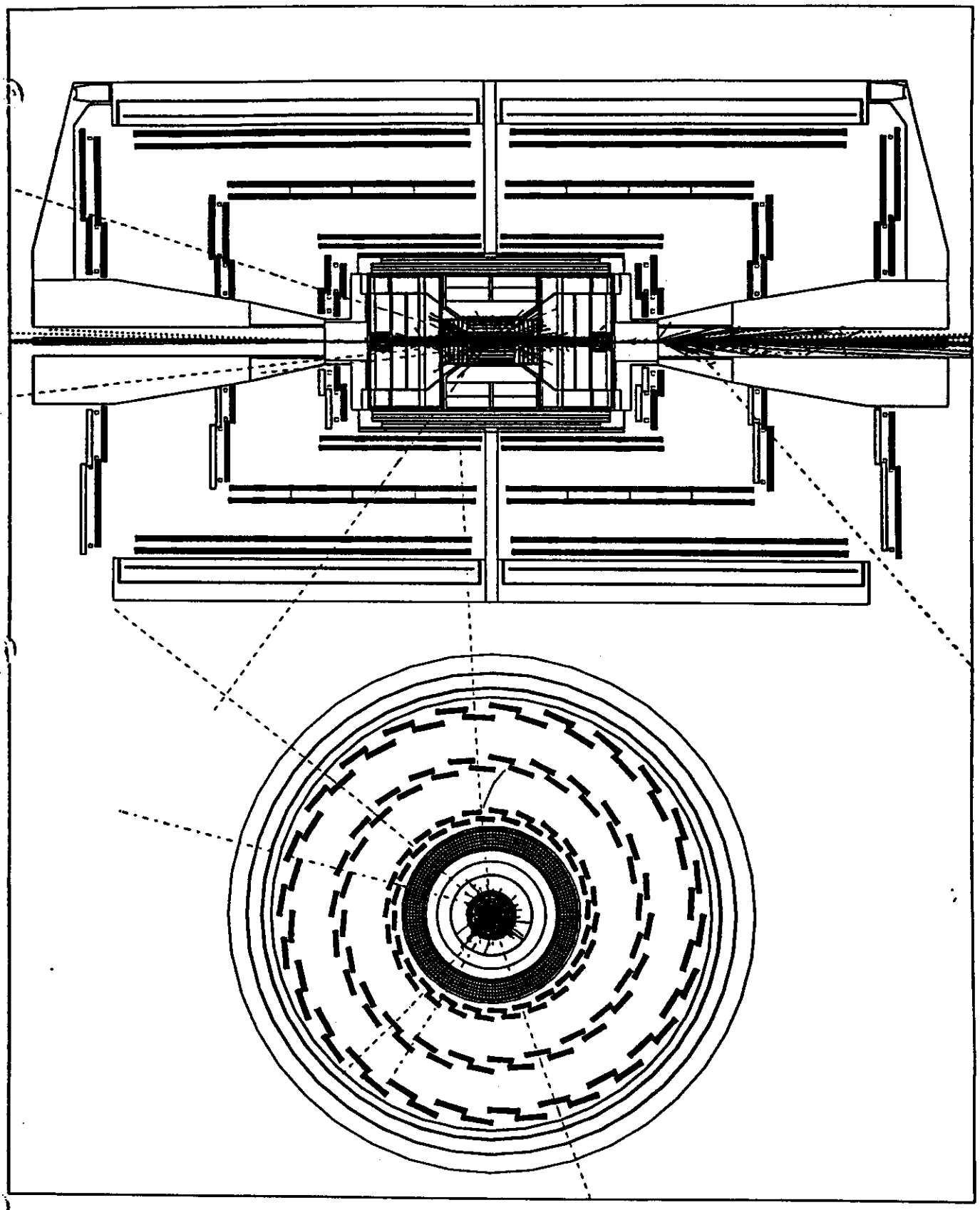
SIGEM consists of the following packages:

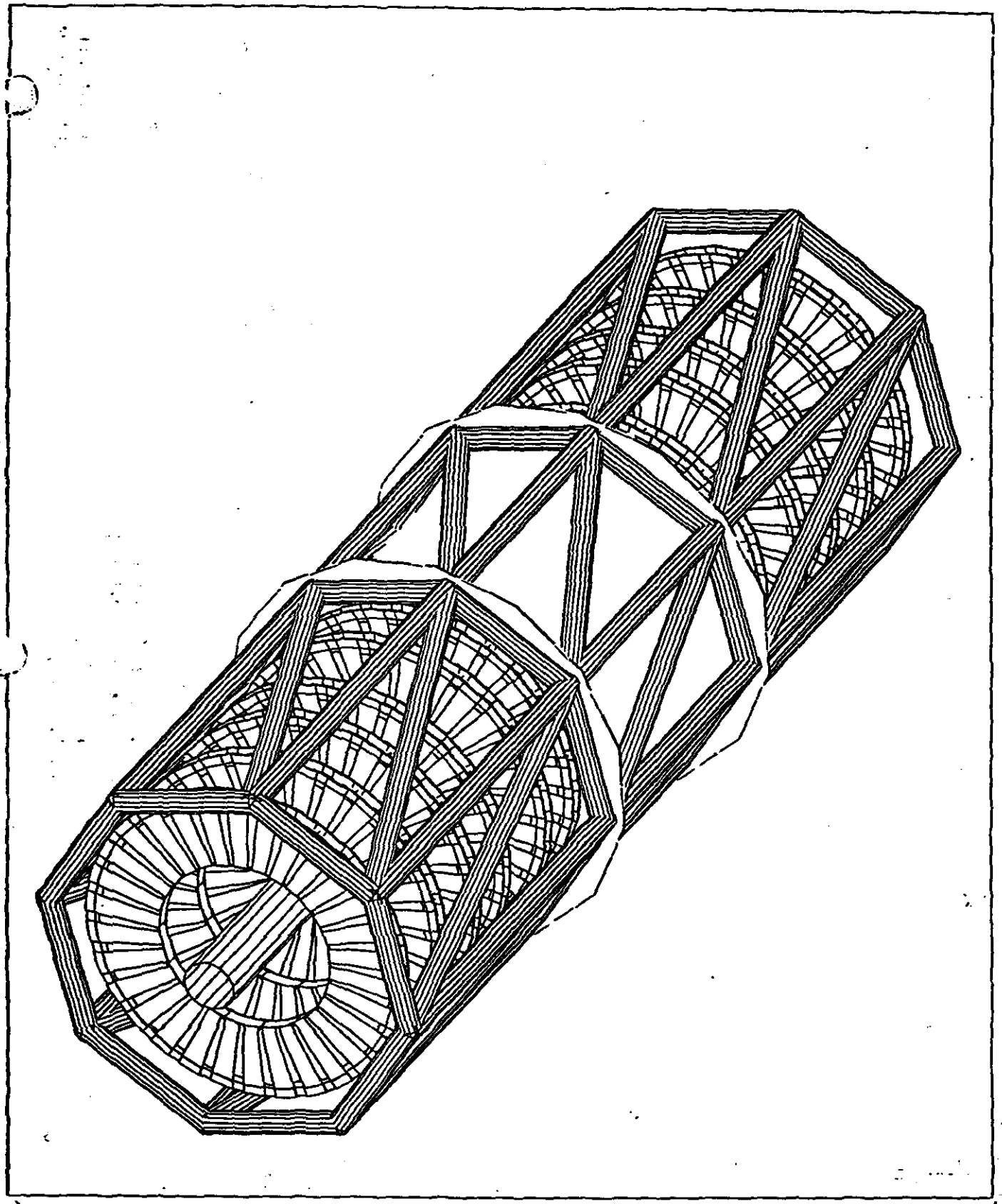
- si — SIGEM 2.00/00 930501 12.42 GEANT3/GEM SImulation program steering;
  - *SIGEM — Pilot for complete Simulation
  - SIGEM — High level steering routines for event Simulation
  - SIUSER — User routines for event Simulation
  - SIEVNT — routines control one event ← Kine
  - SISTEP — routine related to one step/hit
  - SIHSTA — histograms
  - SILUND — Pythia version for GEANT
  - SIDATA — FFREAD cards definition
  - SITRIG — trigger related topics
  - SIRUN — FFREAD Run cards for standard GEANT run
  - SICOM — Command (script) files for creation library and executable files
  - SIPYTH — Run cards for standard PYTHIA/JETSET

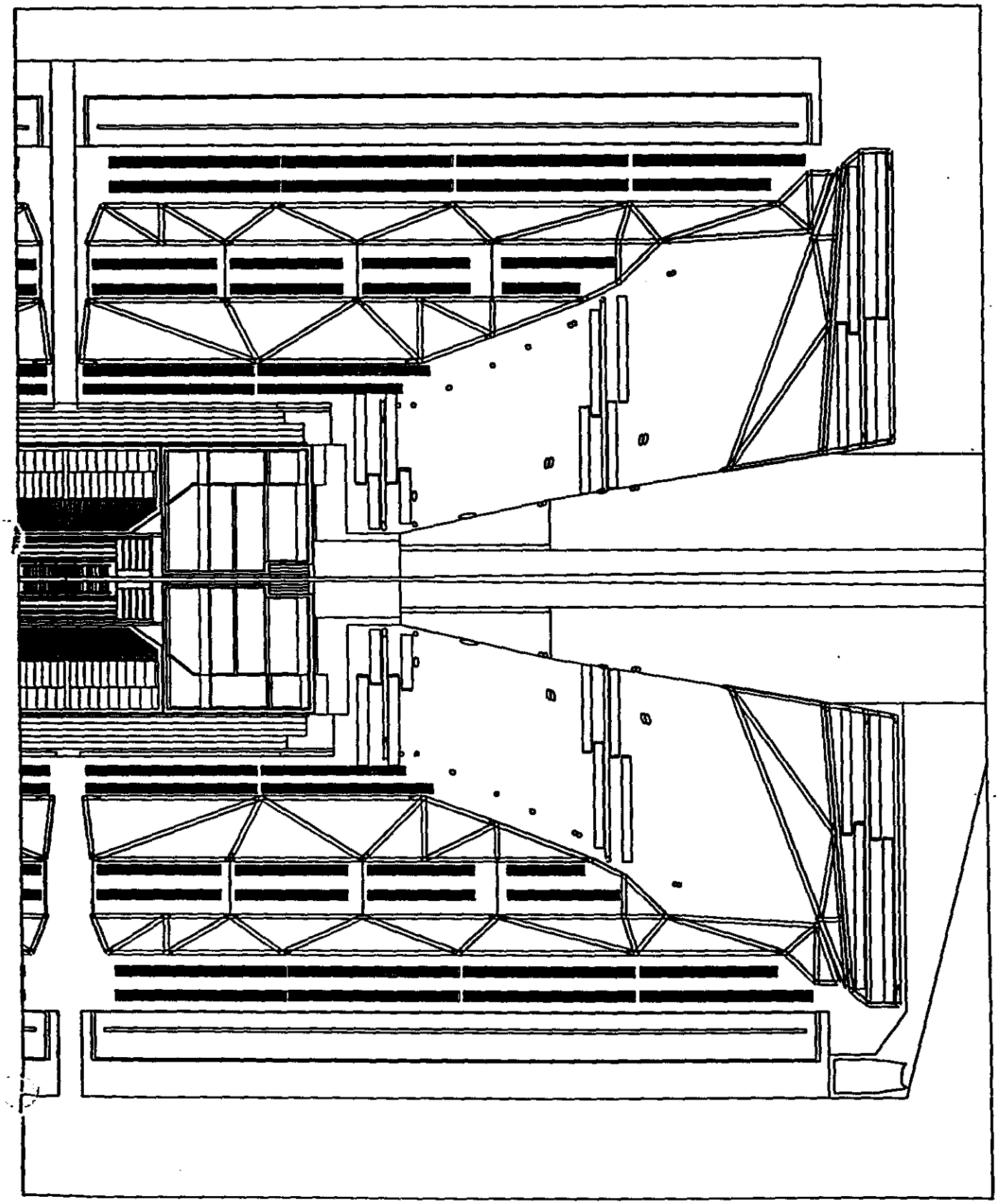
- xs — XSGEM 2.00/00 930501 12.31 eXperimental Setup of GEM detector, TDR version;
  - * XSGEM — General geometry routines for GEM experimental setup
  - * XSTRAK — Description of the central Track detector
  - * XSCALO — Description of the Central Calorimeter
  - * XSMUON — Description of the high precision Muon chambers
  - * XSMAGN — Description of the Solenoid
  - * XSFFSH — Description of the Flux CONcentrator
  - * XSPIPE — Description of the beam PIPE and beam QUADrupole regions
- ut — UTGEM 2.00/00 930501 12.34 GEM utility routines;
  - * UTBODY — General utility routines for simulation and reconstruction simulated data
  - * GEANT DEV — Specific GEM / GEANT3 / HBOOK4 interface
  - * DUTIL/DRPACK/DMPACK/DVPACK — double precision part of KERN lib
- tt — TTGEM 2.00/00 930501 12.56 GEM TiTle data base TDR version;

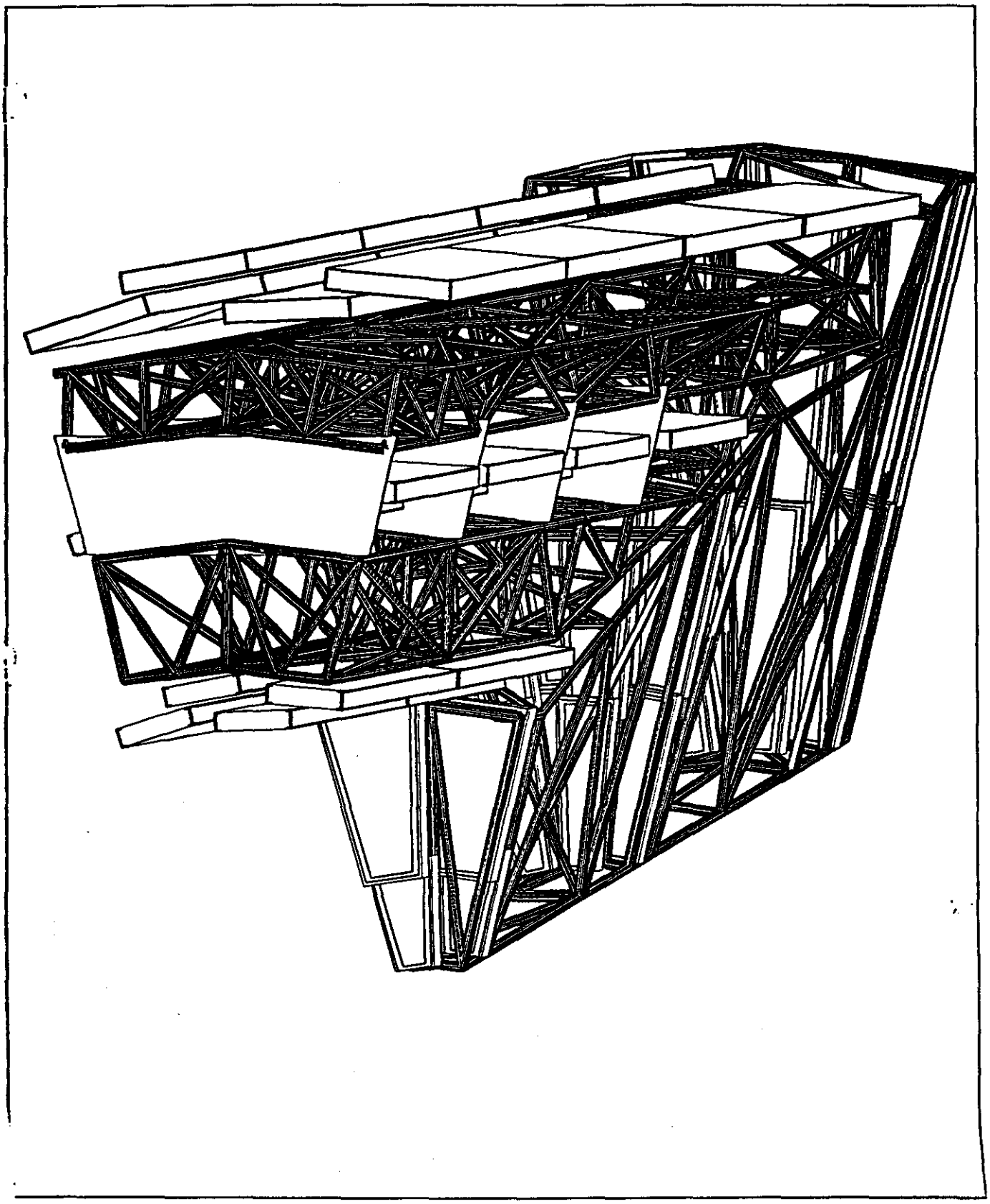
- * *TT GEM Pilot patch for GEM titles
- * TT GEM GEM materials, tracking media, standard rotation matrices and GEM as a whole
- * TT FIELD Field map
- * TT PIPE Beam pipe
- * TT TRAK Central tracker
- * TT CALO Calorimeter
- * TT MEMB Membrane
- * TT MUON Muon system
- * TT MSUPP Muon system support
- * TT FFSI Forward field shaper
- * TT MAGN Superconducting solenoid
- * TT QUAD Low beta quadrupole
- * TT SETS SETS and DETector definitions

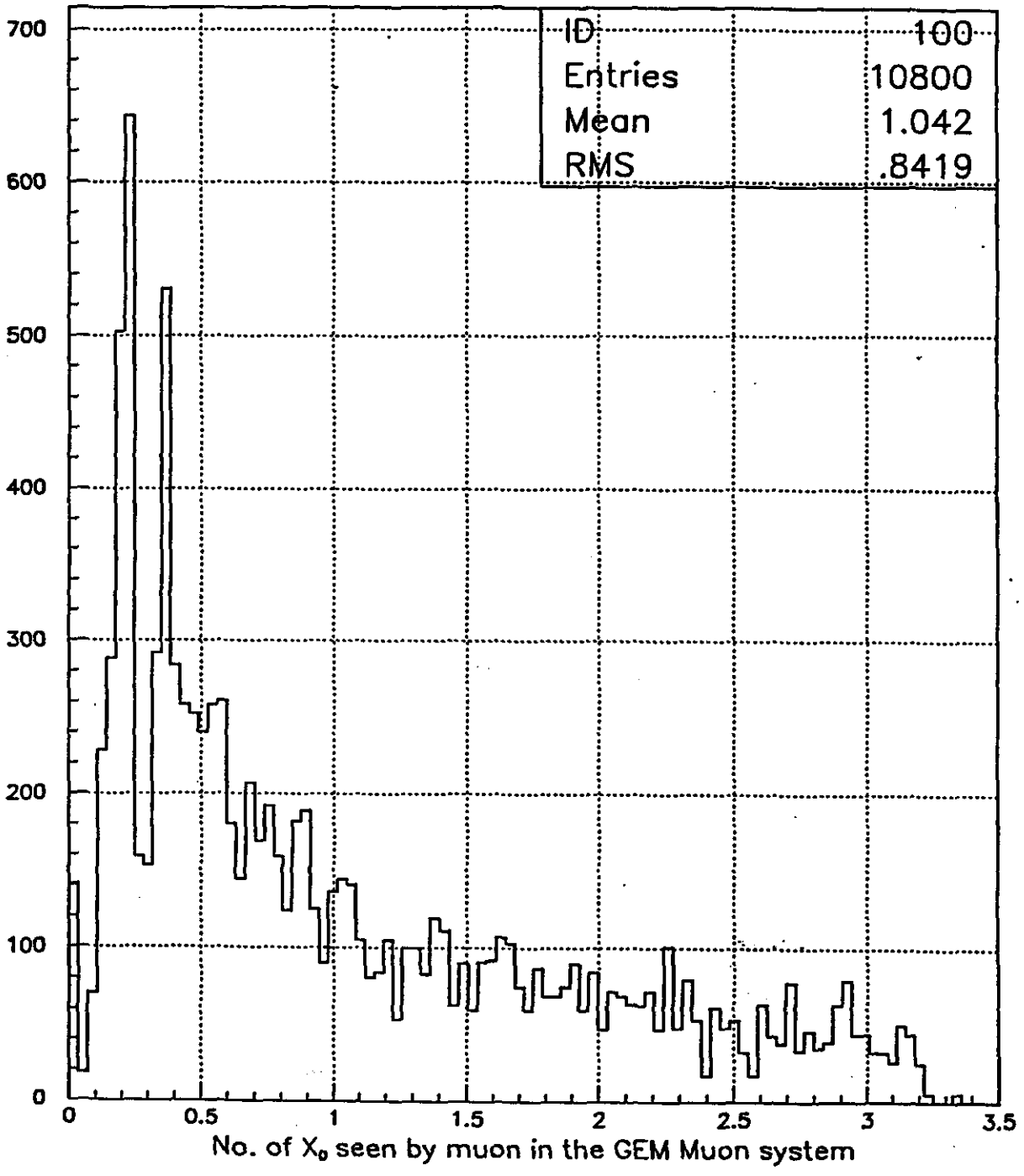
- gf — GFLASH 1.41/00 930125 17.54 by Stefan Peters;
- gc — CALOR 1.00/00 930427 14.36 by C.Zeitnitz;
- re — REGEM 2.00/00 930501 12.46 GEM REconstruction.
  - * REFUTY Kalman Fit UTiliY
  - * RETSEG finding and fitting of track segments
  - * RETRAK GEM implimentation of GEANE package.










ID 100
Entries 10800
Mean 1.042
RMS .8419
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
No. of X_0 seen by muon in the GEM Muon system

Digitization has not yet implemented. For the muon system this topics is in the agenda. Hopely it will be done by (V.Balagura + ITEP) in the nearest one - two months.

SIGEM is installed and supported now on VAX/VMS, HPUX and SUN as interactive, debug and batch version. The examples of different detector view are shown in Figures.

The SIGEM status can be expressed as the following:

- There is up to date (TDR) version for the GEM muon system including the Draper support structure and some elements of chamber construction .
- The calorimeter factually corresponds to the November Base line 2 design. GFLASH is installed, debugged but not yet tested in the sense of comparison full GEANT simulation with GFLASH results.
- The Central Tracker model is mainly corresponds to the November Base line 2 design.

V. Balagura
ITEP / SSCL
May 12, 1993

Muon trigger model

- Description of the model

real strips
↓
virtual strips
↓
virtual clusters

- resolution and efficiency curves
- Sagitta or $\Delta\varphi$?

Trigger based on the cutting of the road in 3-dimensional space $\varphi_1 \otimes \varphi_2 \otimes \varphi_3$ combines all available information for the trigger

$\Rightarrow$ includes naturally <u>both</u> sagitta and $\Delta\varphi$ methods.

Description of the model

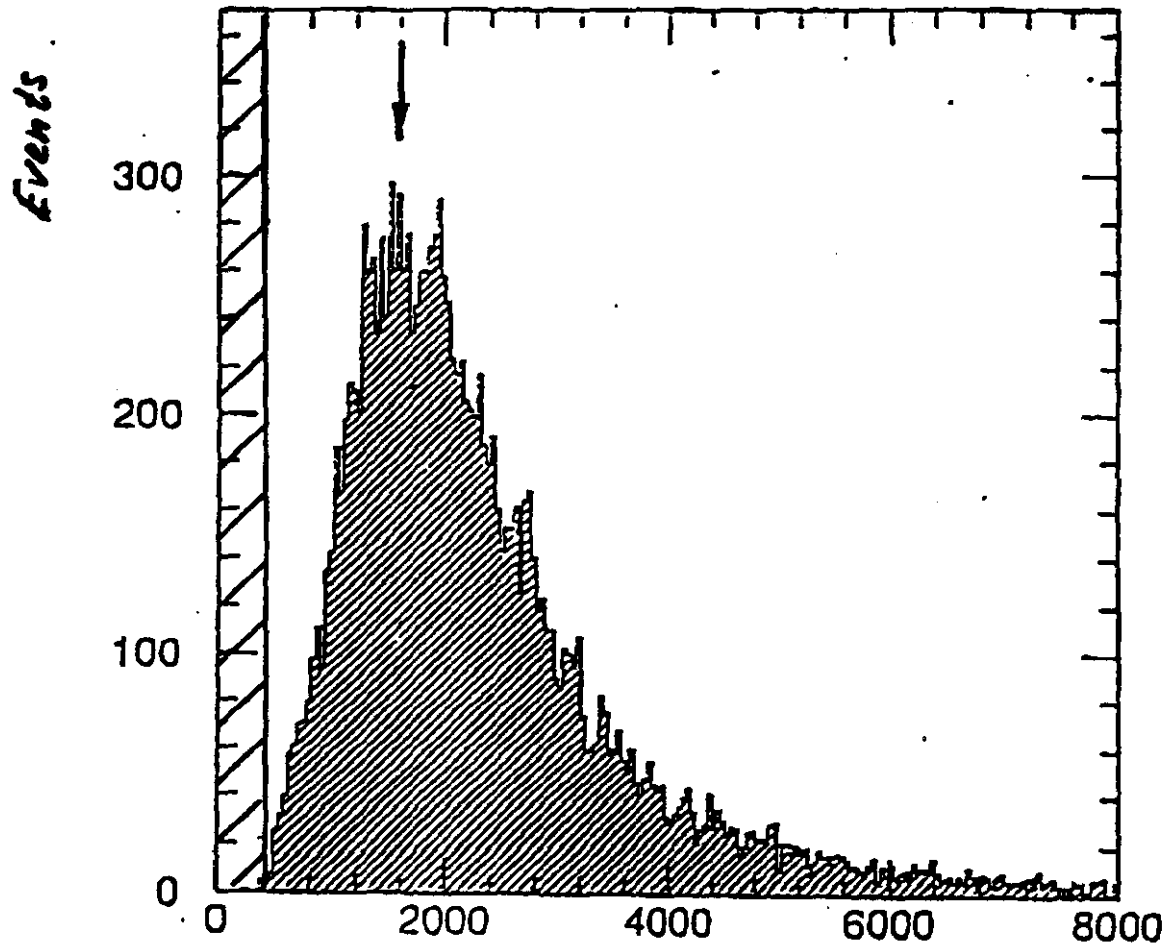
- based on <u>SIGEM</u>

  (<u>Yu. Fisyak</u>)

Takes into account:

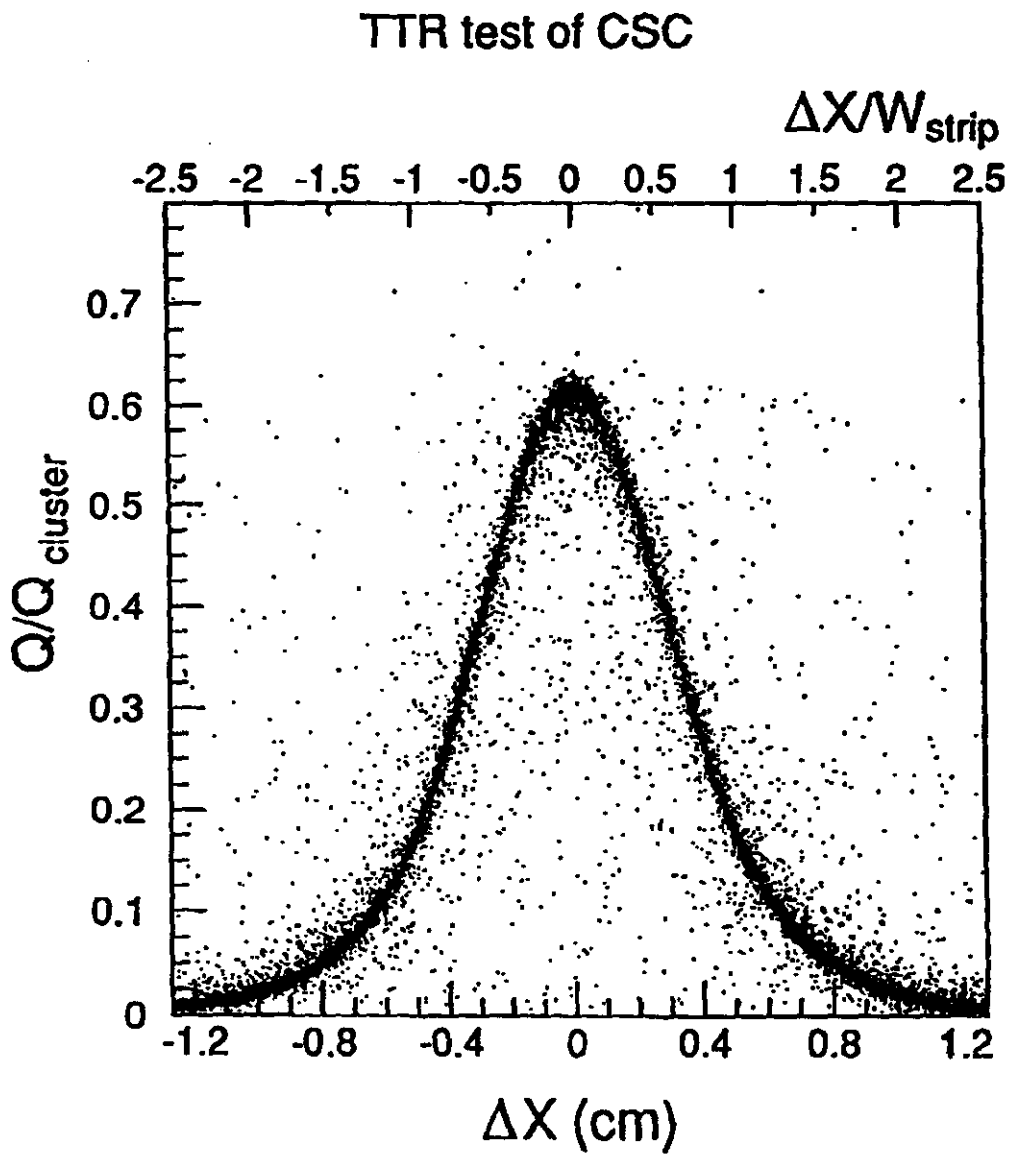
- Geometry
- Multiple scattering
- μ energy loss
- Electromagnetic backgrounds

- Discreteness due to strips
- Charge sharing between strips
- Clustering



dE/dX curve

$$Q^{(dE/dx)}_{threshold} = \frac{1}{4}(\text{The most probable } Q)$$

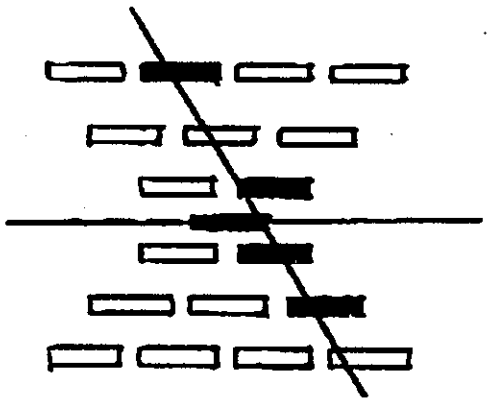


Distribution of charge induced on strips

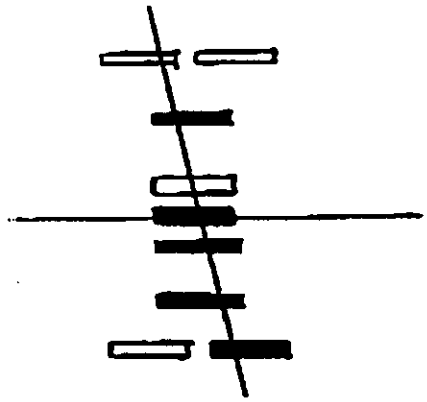
$$Q_{threshold} = 0.5 \cdot Q_{threshold}^{(dE/dx)}$$

Definition of the tower associated with virtual strip

Barrel

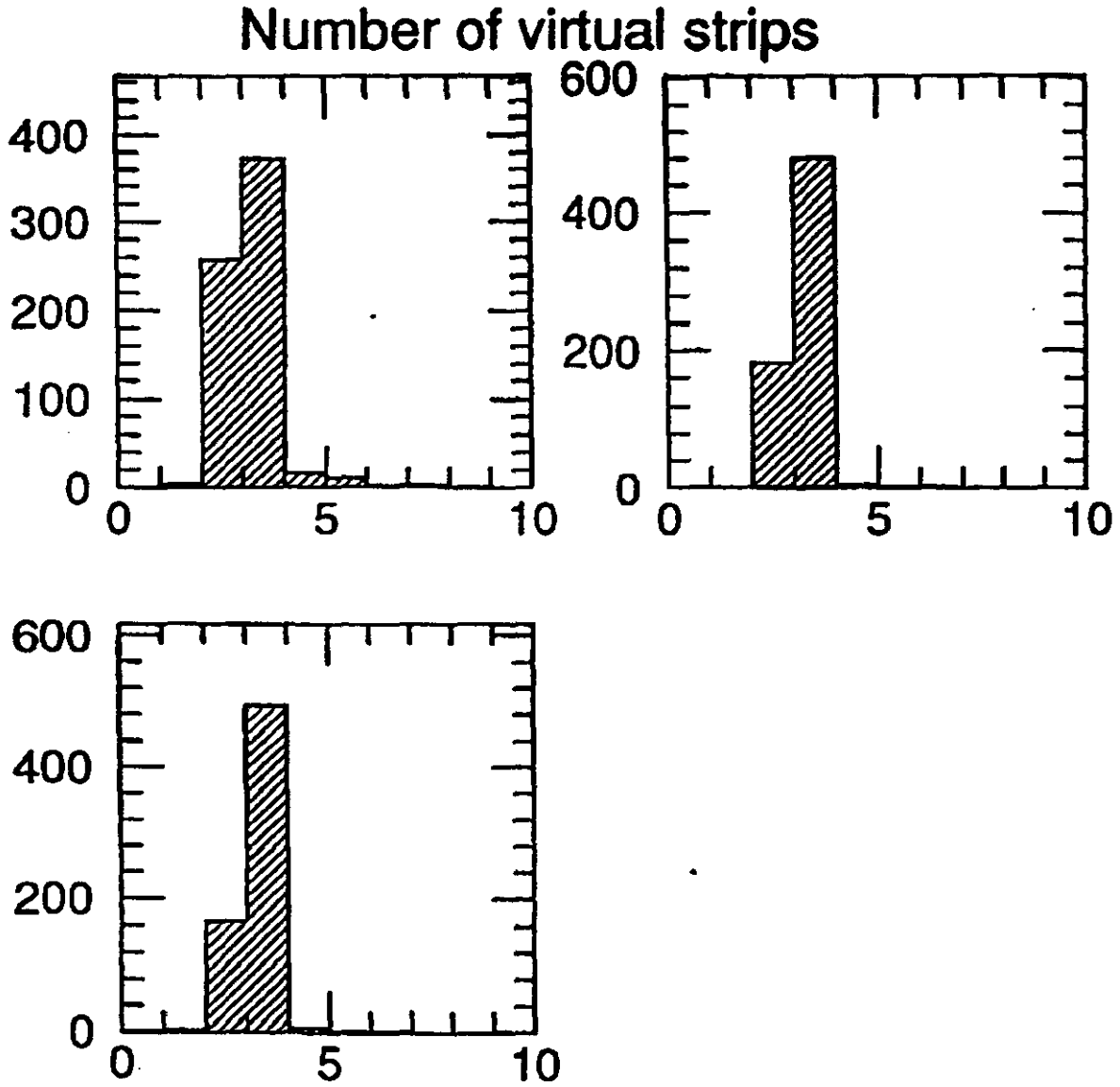


Endcap



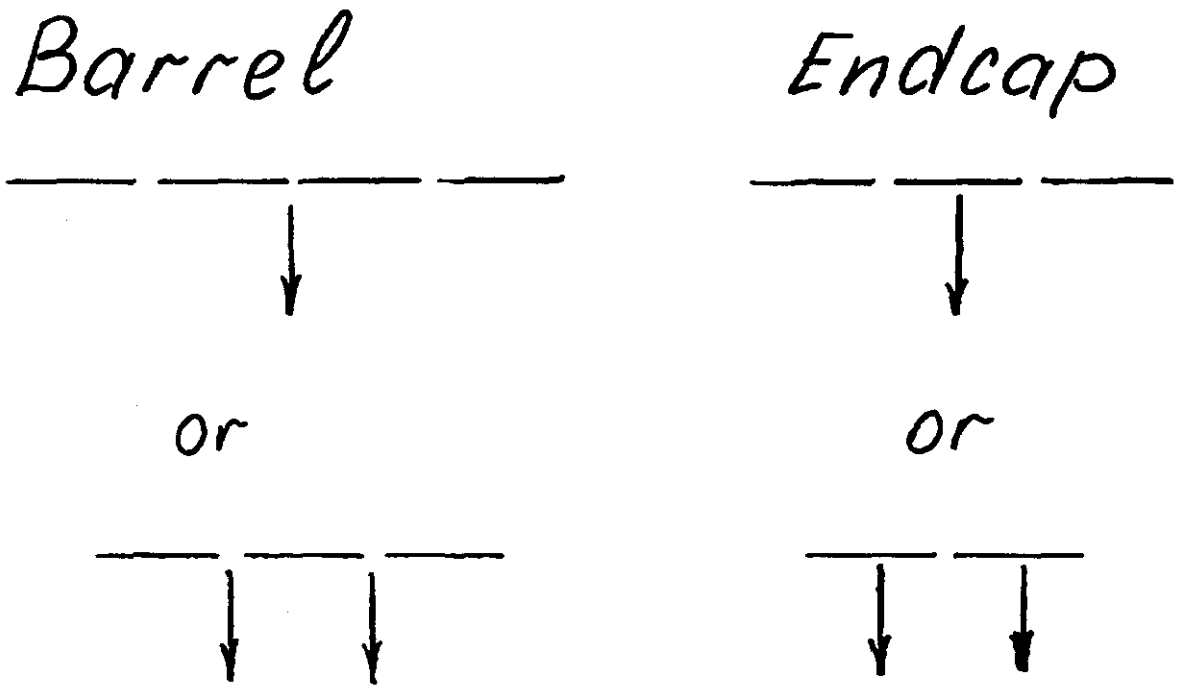
virtual strip ≡ tower with at least 4 strips in different layers with

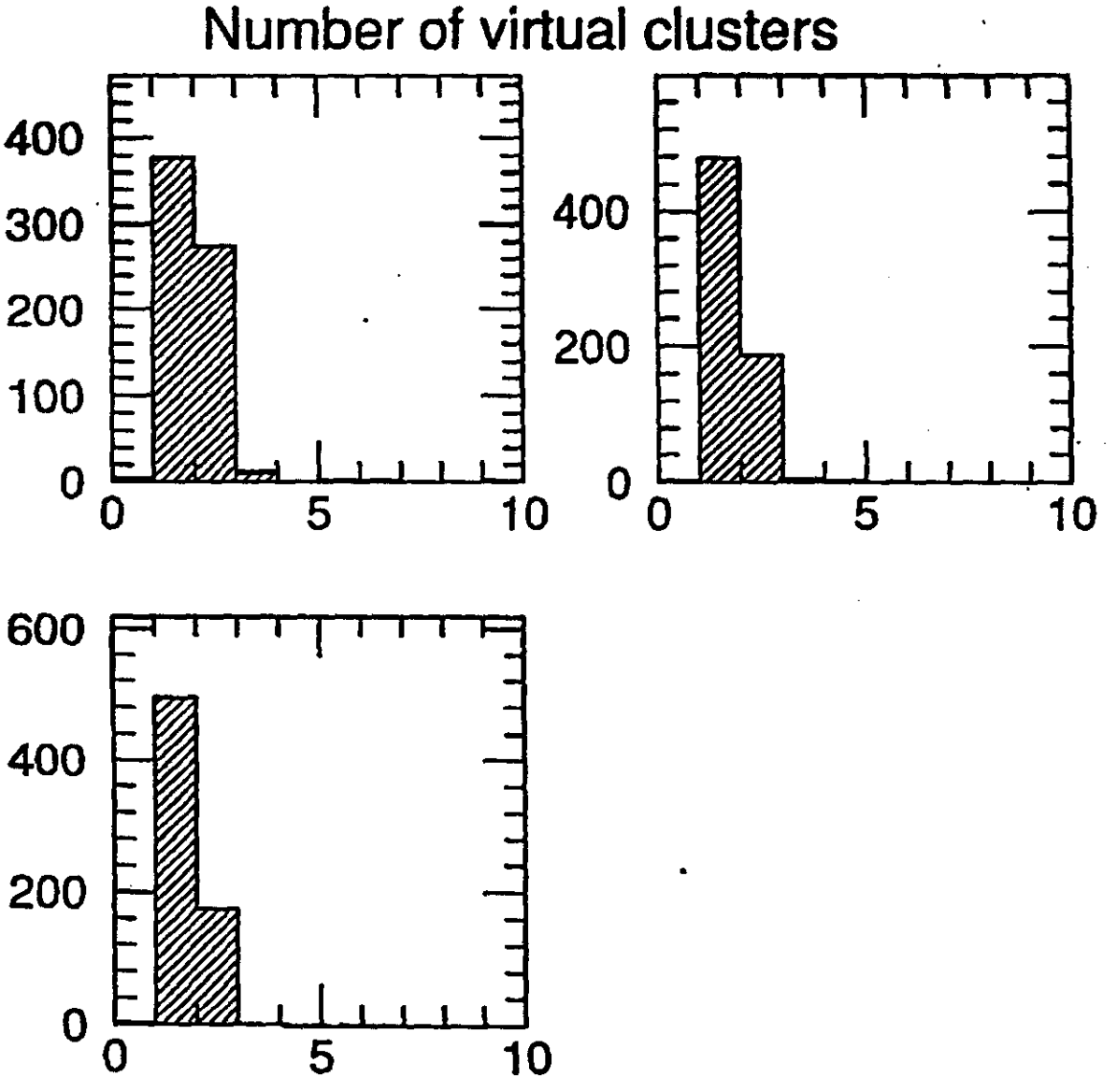
$Q > Q_{threshold}$


Number of virtual strips
400
300
200
100
0
0
5
10
600
400
200
0
0
5
10
600
400
200
0
0
5
10

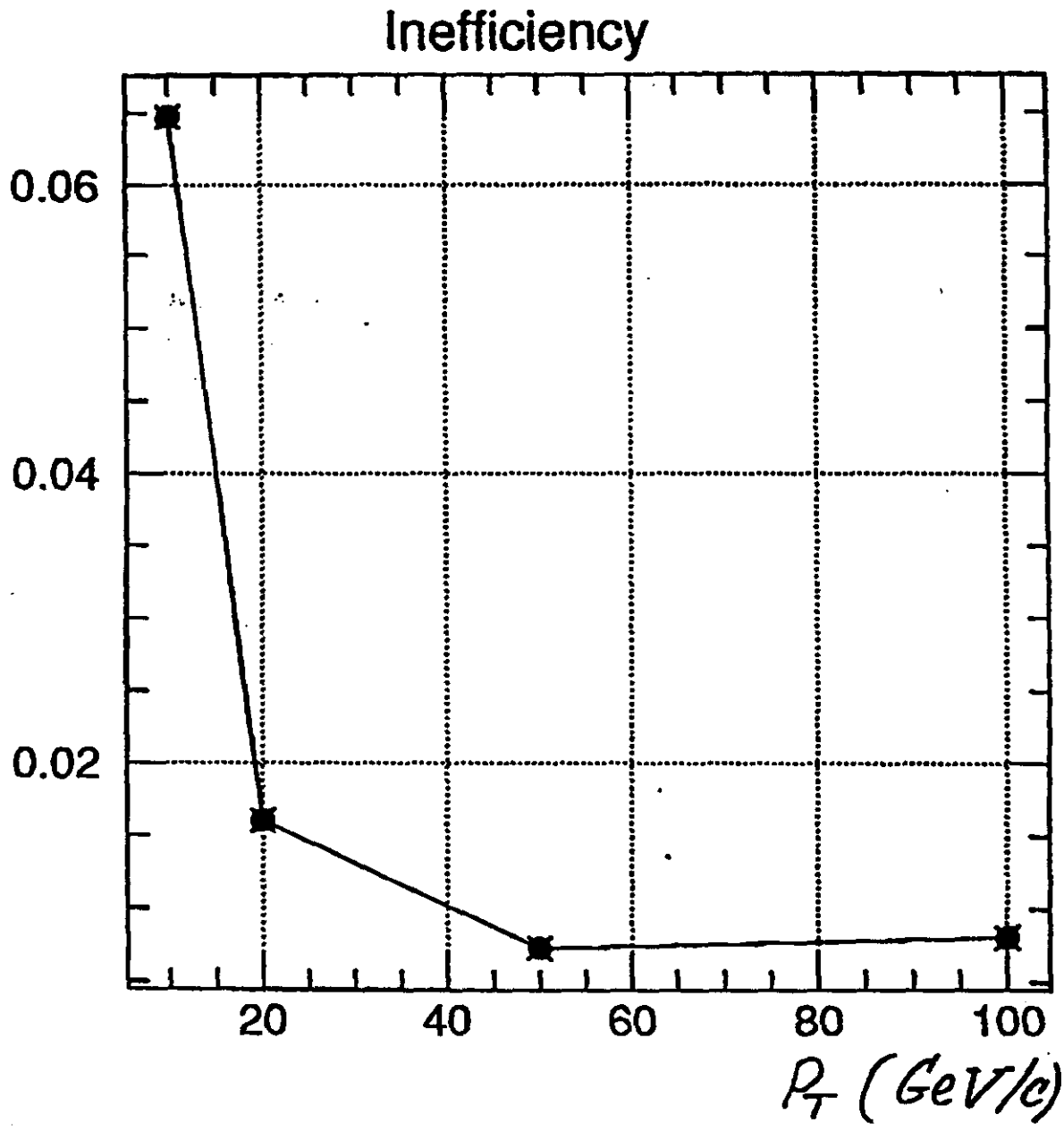
Endcap

Definition of the virtual cluster

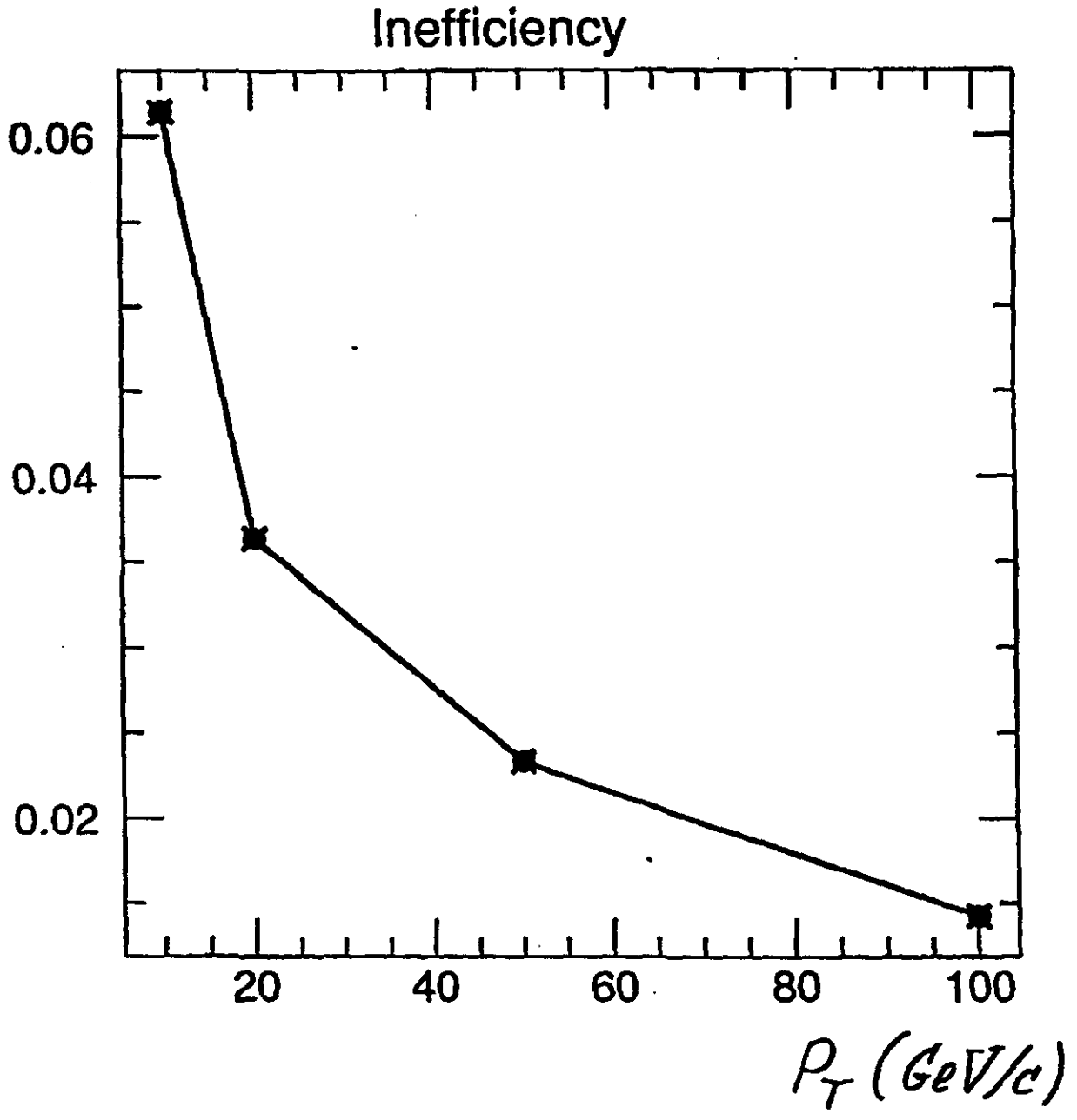



Number of virtual clusters
400
300
200
100
0
0
5
10
400
200
0
0
5
10
600
400
200
0
0
5
10

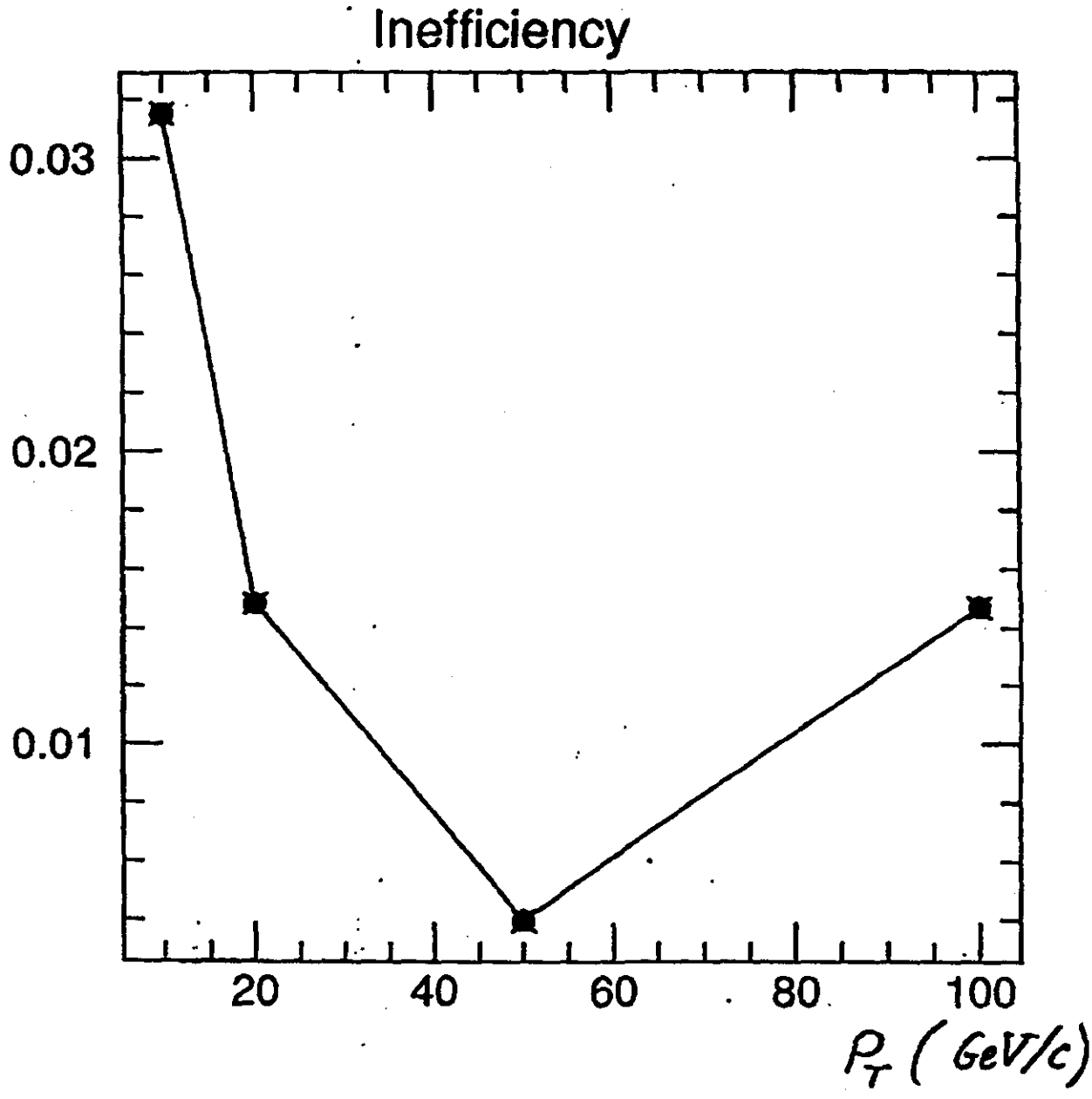
Endcap



Barrel

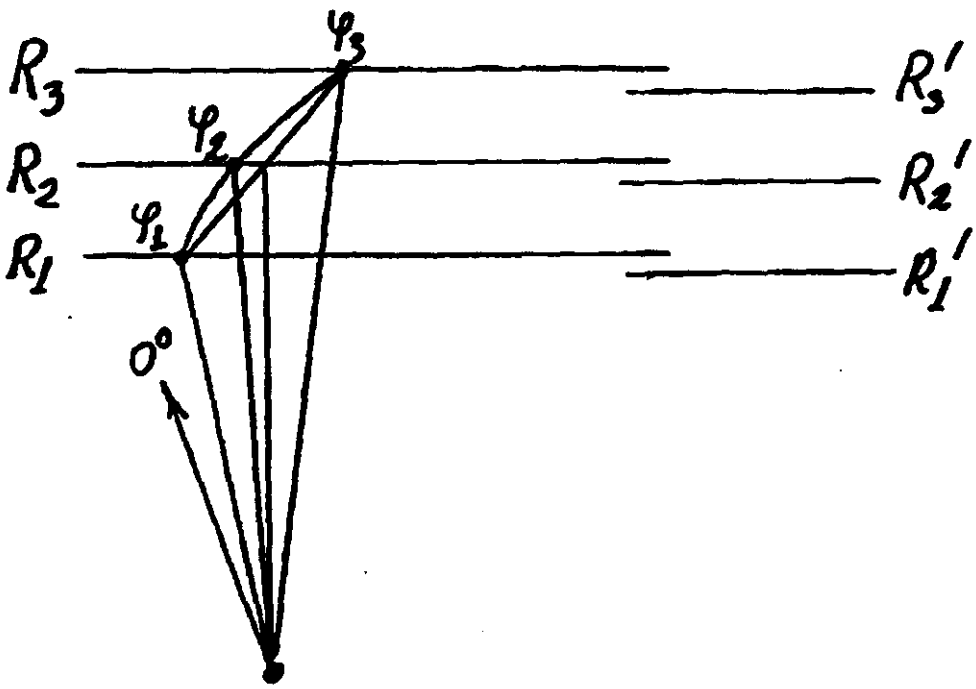


Endcap 2
(small η)



Endcap 1
(large η)

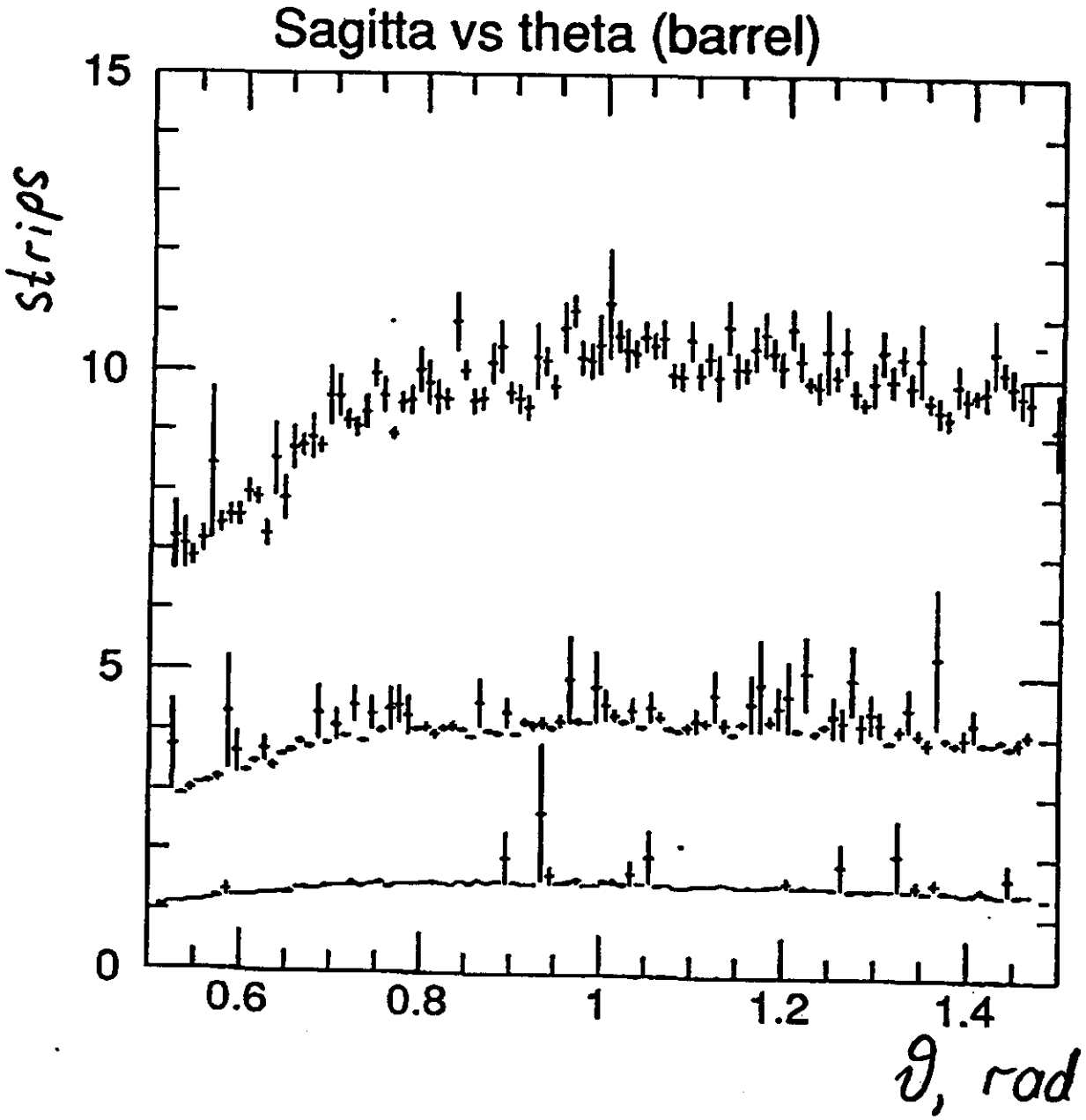
Barrel



$$\Delta\varphi_{23}^{(str)} = (\varphi_2 - \varphi_3)/(R_2 - R_3) * (\langle R_2\rangle - \langle R_3\rangle)/\Delta\varphi_{s}$$

$$Sagitta^{(str)} = \frac{\varphi_2 R_2 - \frac{(\varphi_1 R_1 + \varphi_3 R_3)}{2}}{(R_3 - R_1)^2 \, \Delta\varphi_{str}^{(2)}} (\langle R_3\rangle - \langle R_1\rangle)^2$$

Endcap : $$Sagitta^{(str)} = \frac{\varphi_2 - (0.3\varphi_1 + 0.7\varphi_3)}{\Delta\varphi_{str}^{(2)}}$$


Sagitta vs theta (barrel)
15
10
5
0
Strips
0.6
0.8
1
1.2
1.4
ϑ, rad

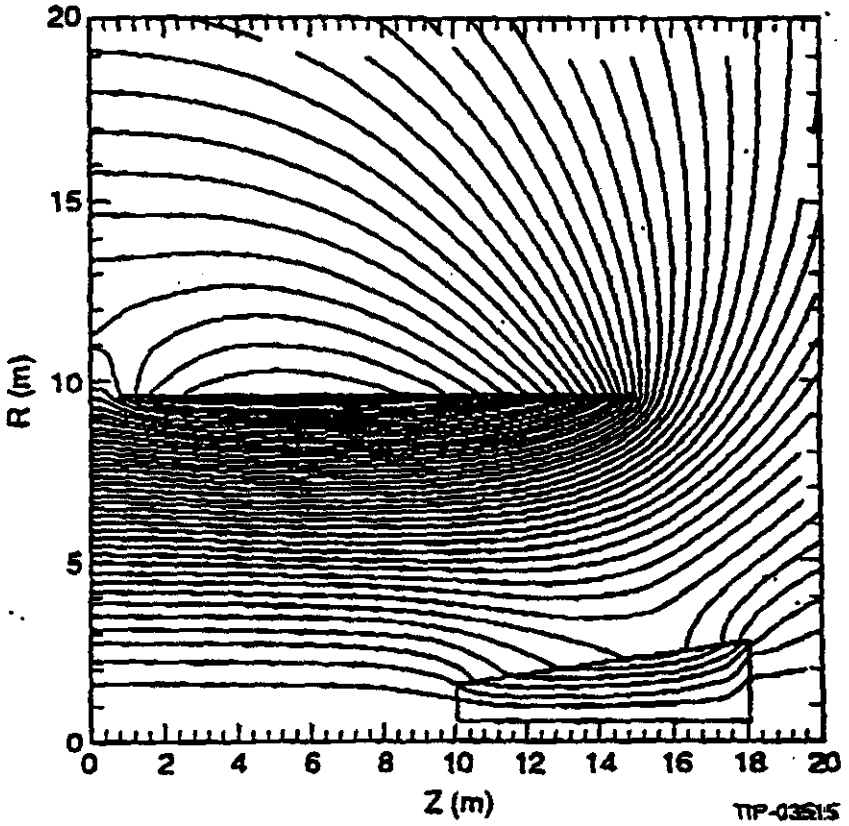


FIG. 3-4. Contours of constant flux.

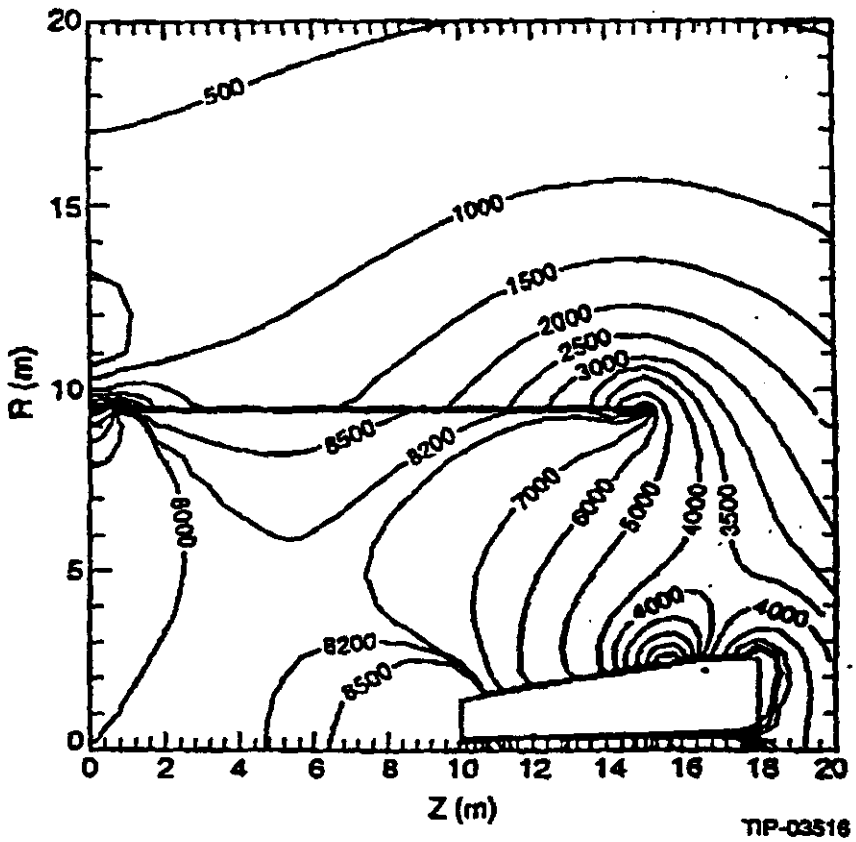
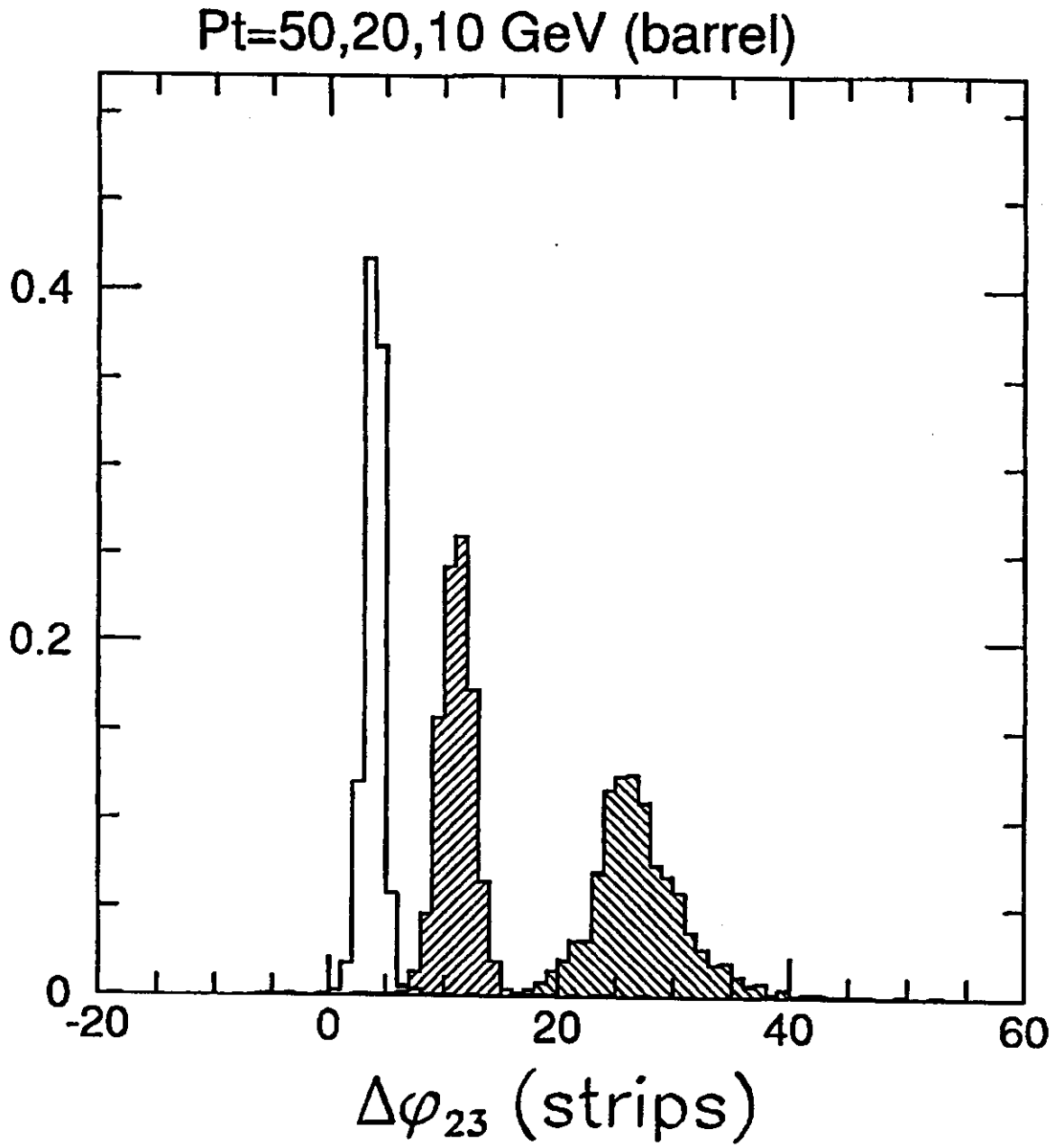
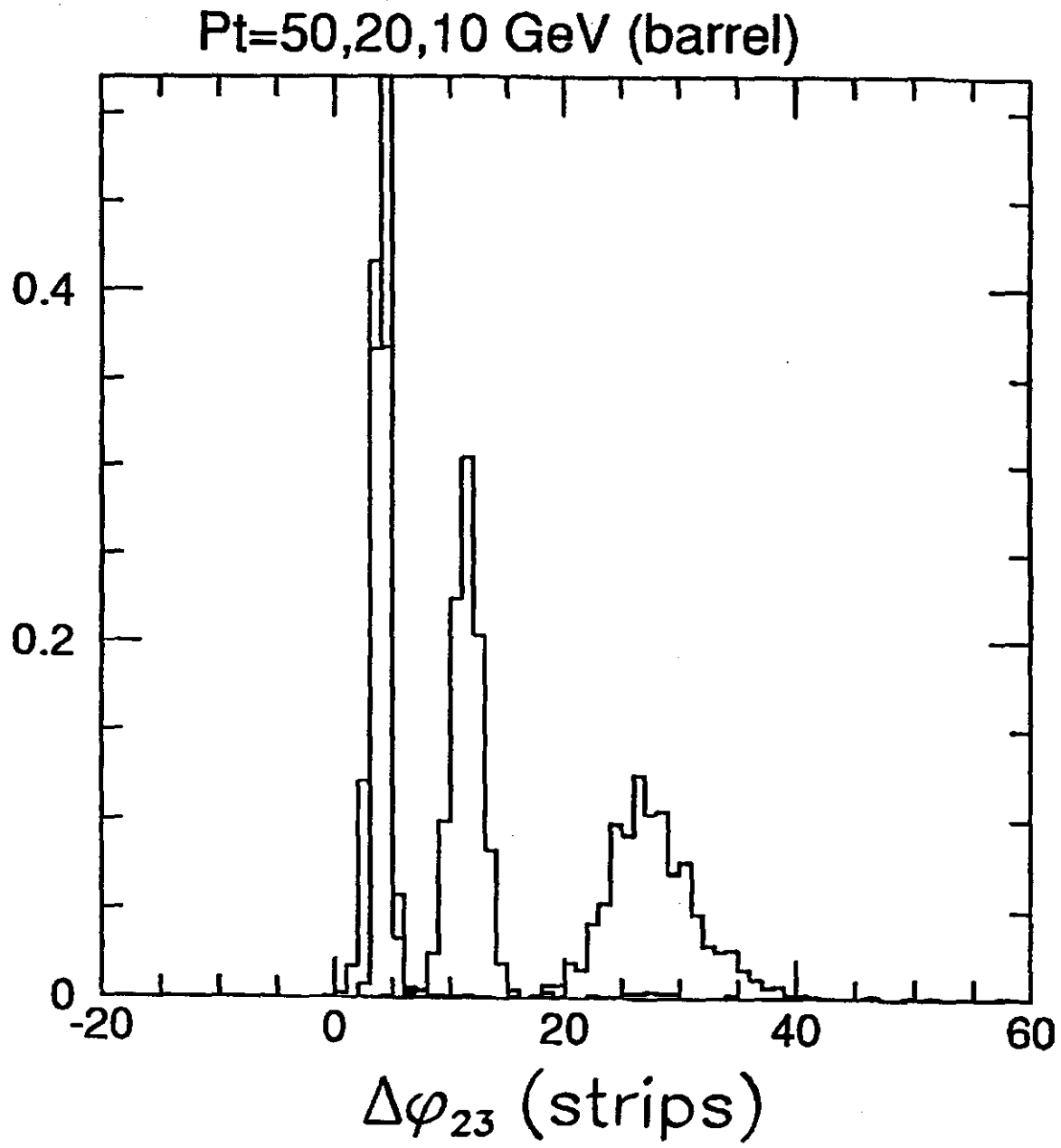
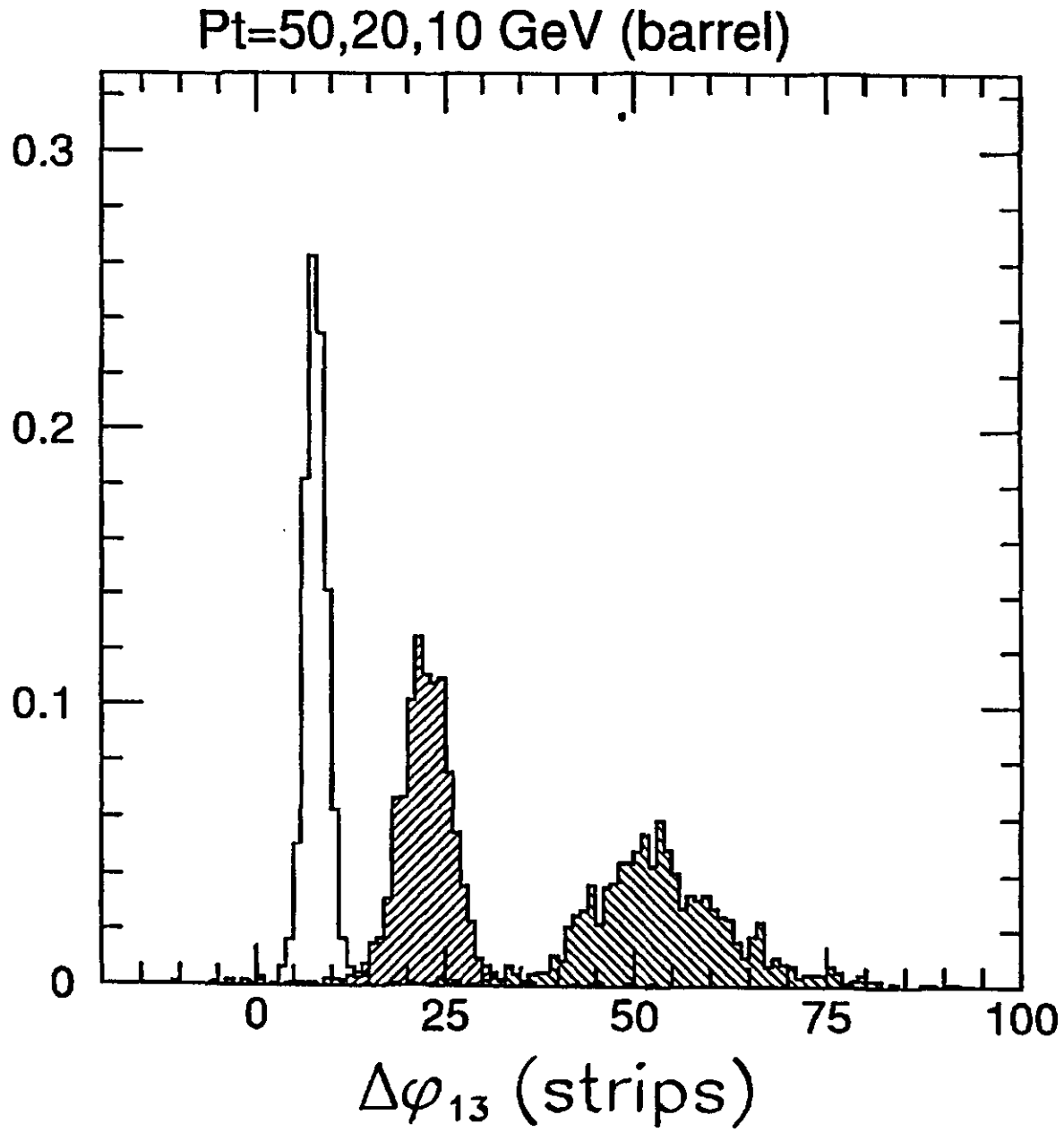
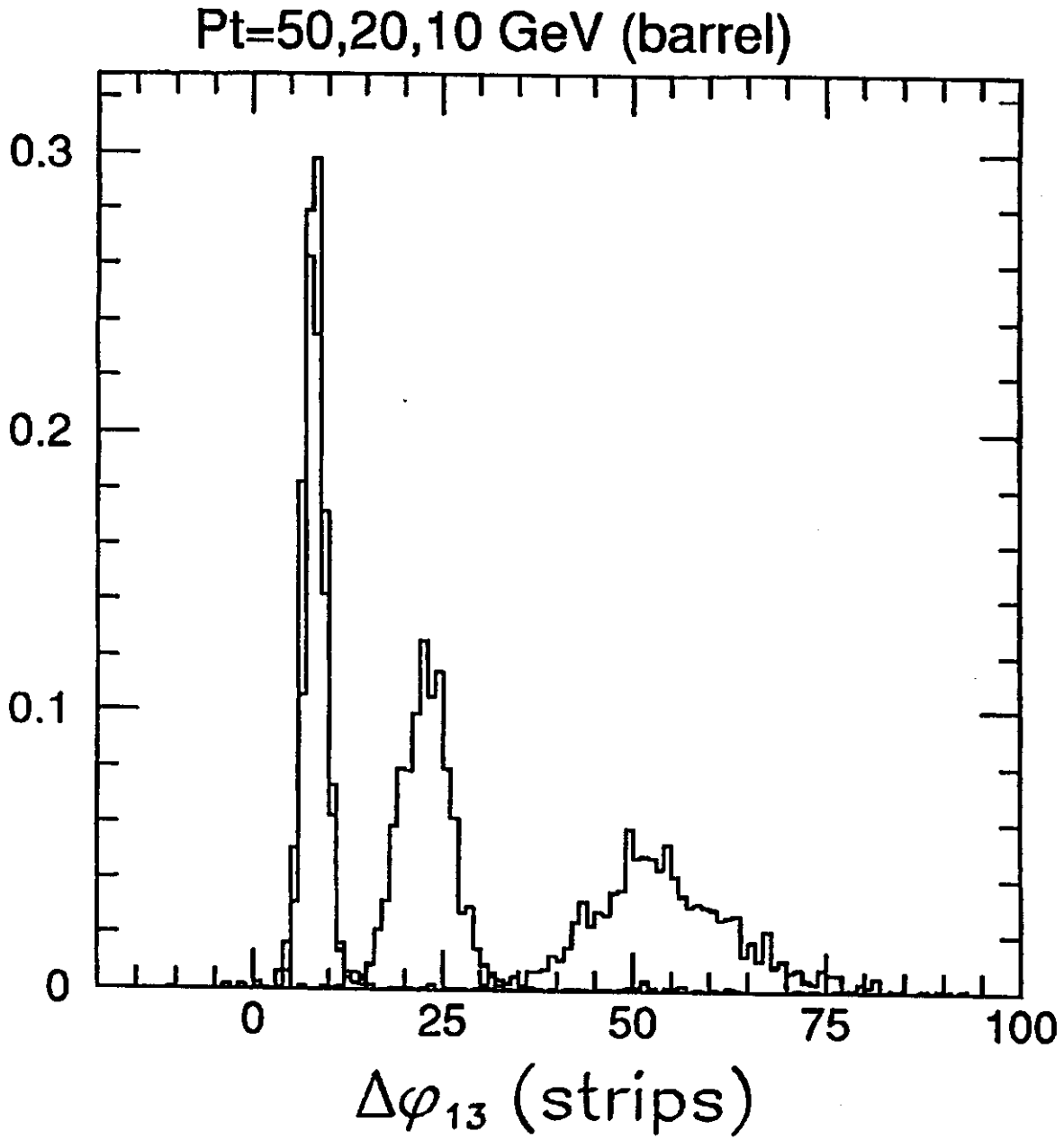


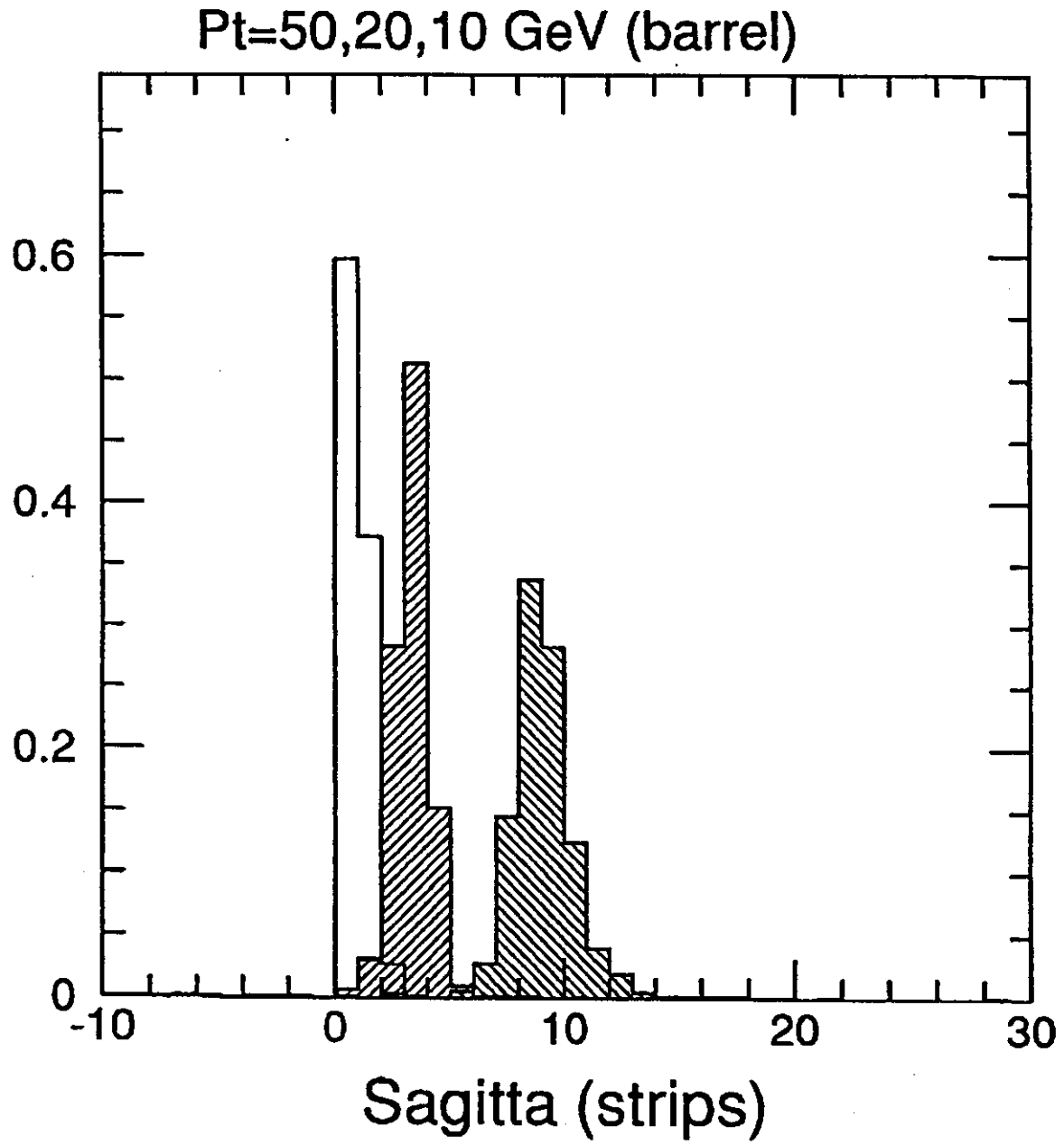
FIG. 3-5. Contours of constant B labeled in gauss.

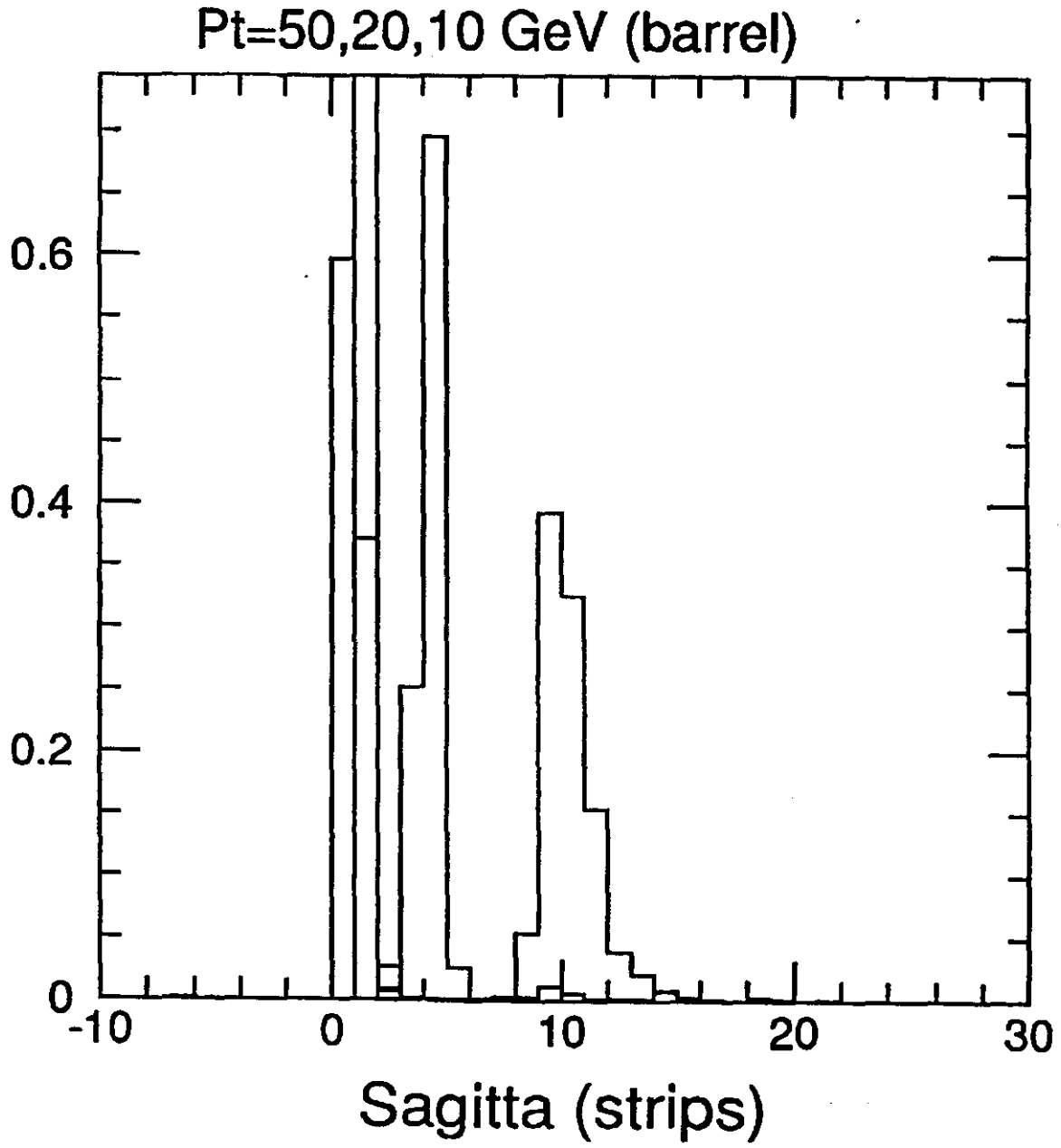

Pt=50,20,10 GeV (barrel)
0.4
0.2
0
-20
0
20
40
60
Δφ23 (strips)

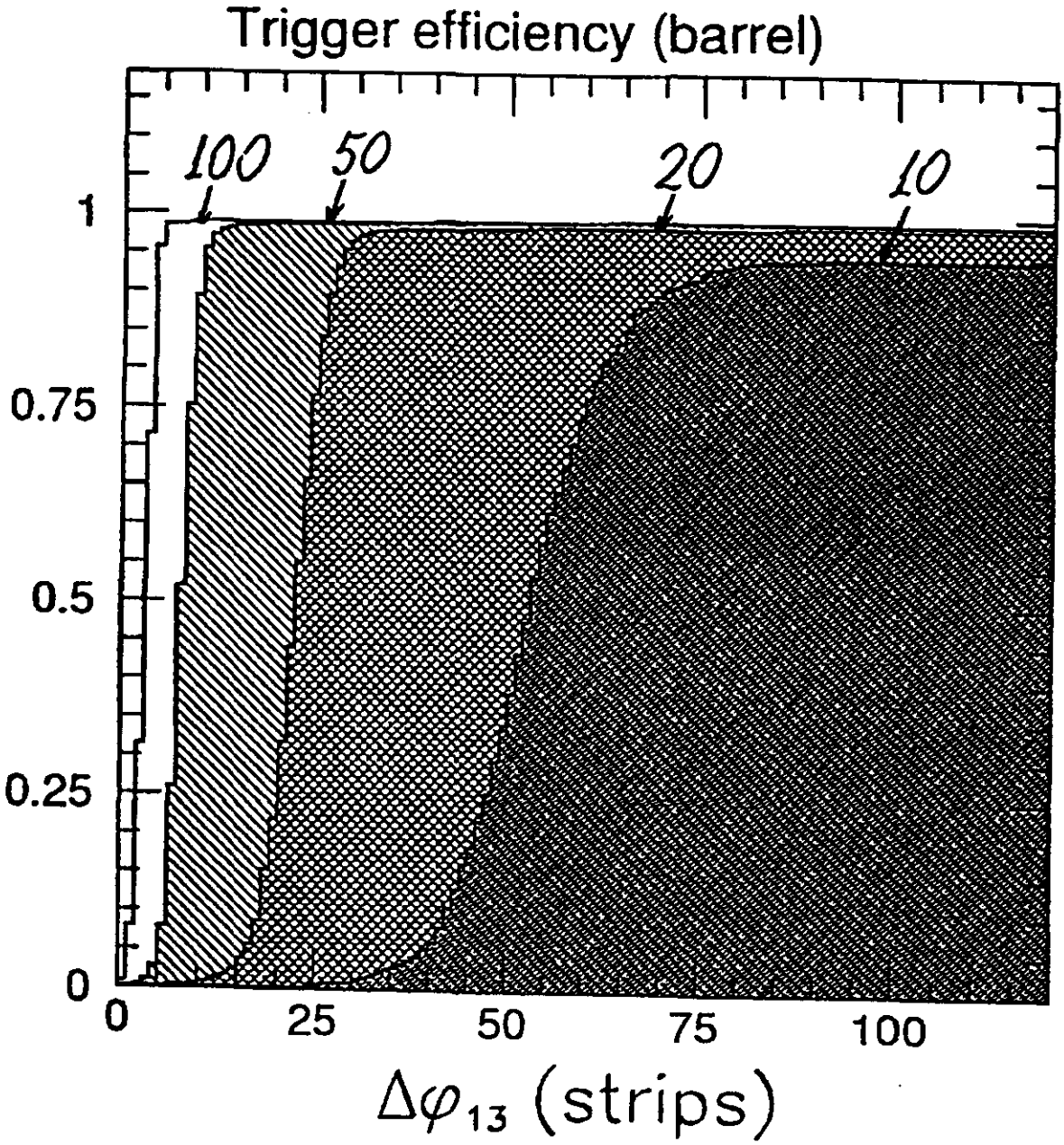

Pt=50,20,10 GeV (barrel)
0.4
0.2
0
-20
0
20
40
60
Δφ23 (strips)

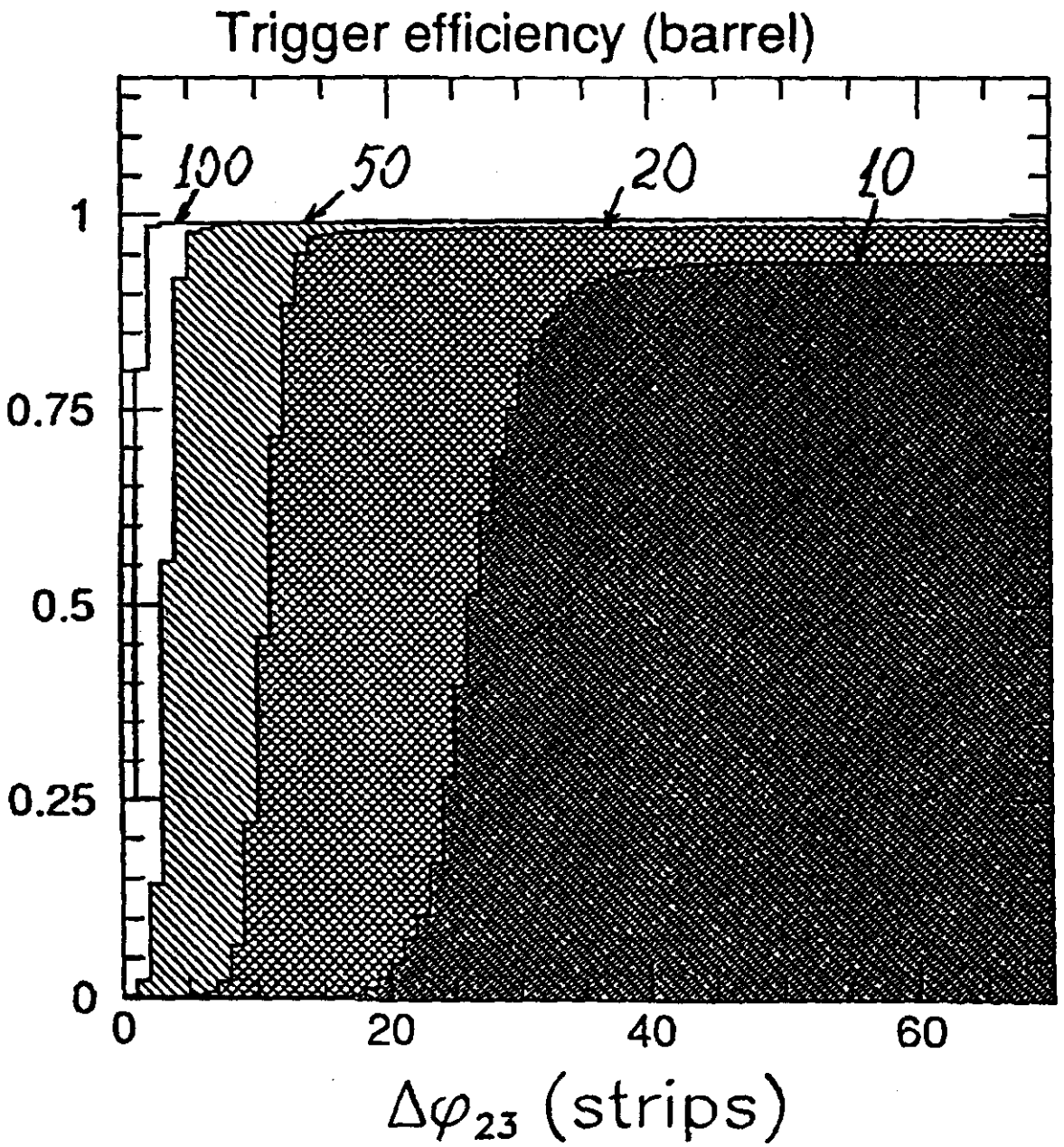

Pt=50,20,10 GeV (barrel)
0.3
0.2
0.1
0
0
25
50
75
100
Δφ13 (strips)

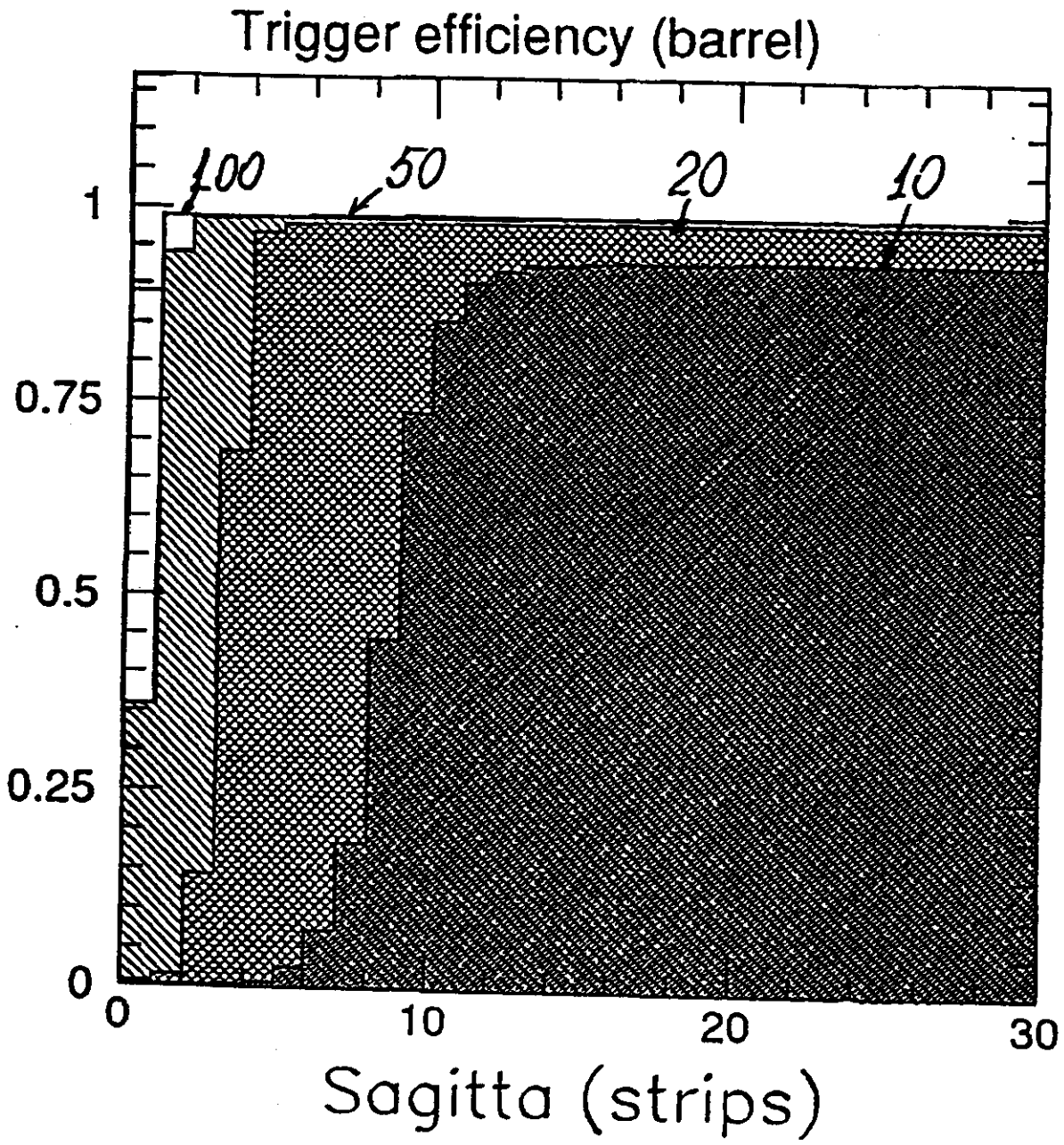

Pt=50,20,10 GeV (barrel)
0.3
0.2
0.1
0
0
25
50
75
100
Δφ13 (strips)

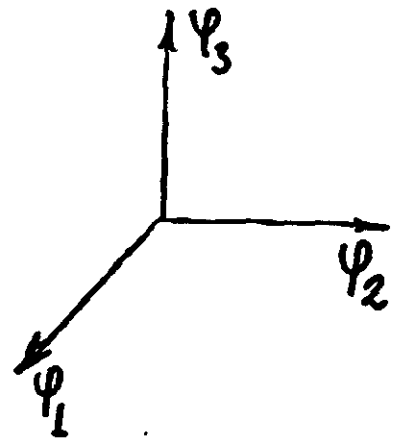

Pt=50,20,10 GeV (barrel)
0.6
0.4
0.2
0
-10
0
10
20
30
Sagitta (strips)


Pt=50,20,10 GeV (barrel)
0.6
0.4
0.2
0
-10
0
10
20
30
Sagitta (strips)

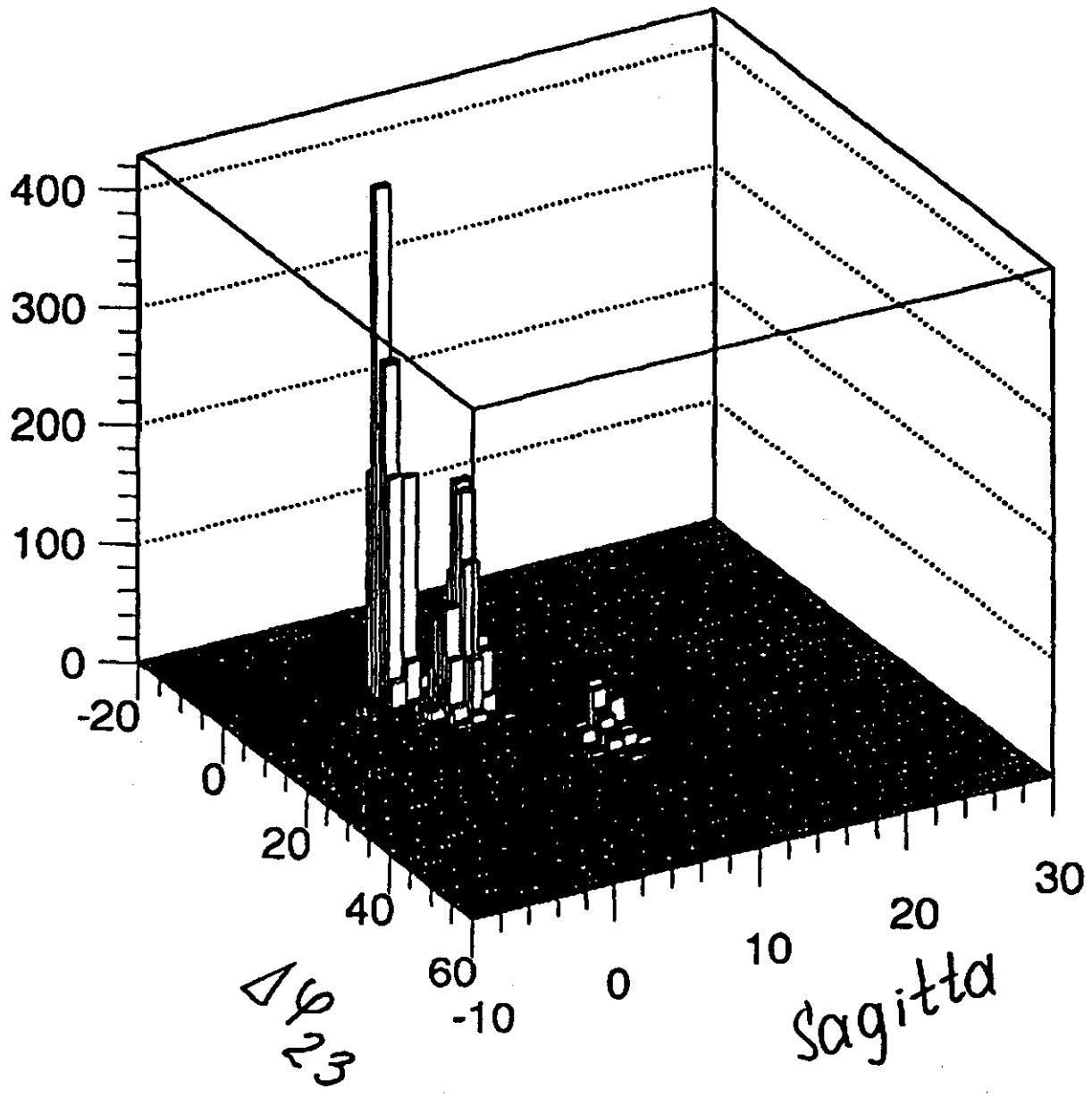

Trigger efficiency (barrel)
100
50
20
10
1
0.75
0.5
0.25
0
0
25
50
75
100
$\Delta\varphi_{13}$ (strips)

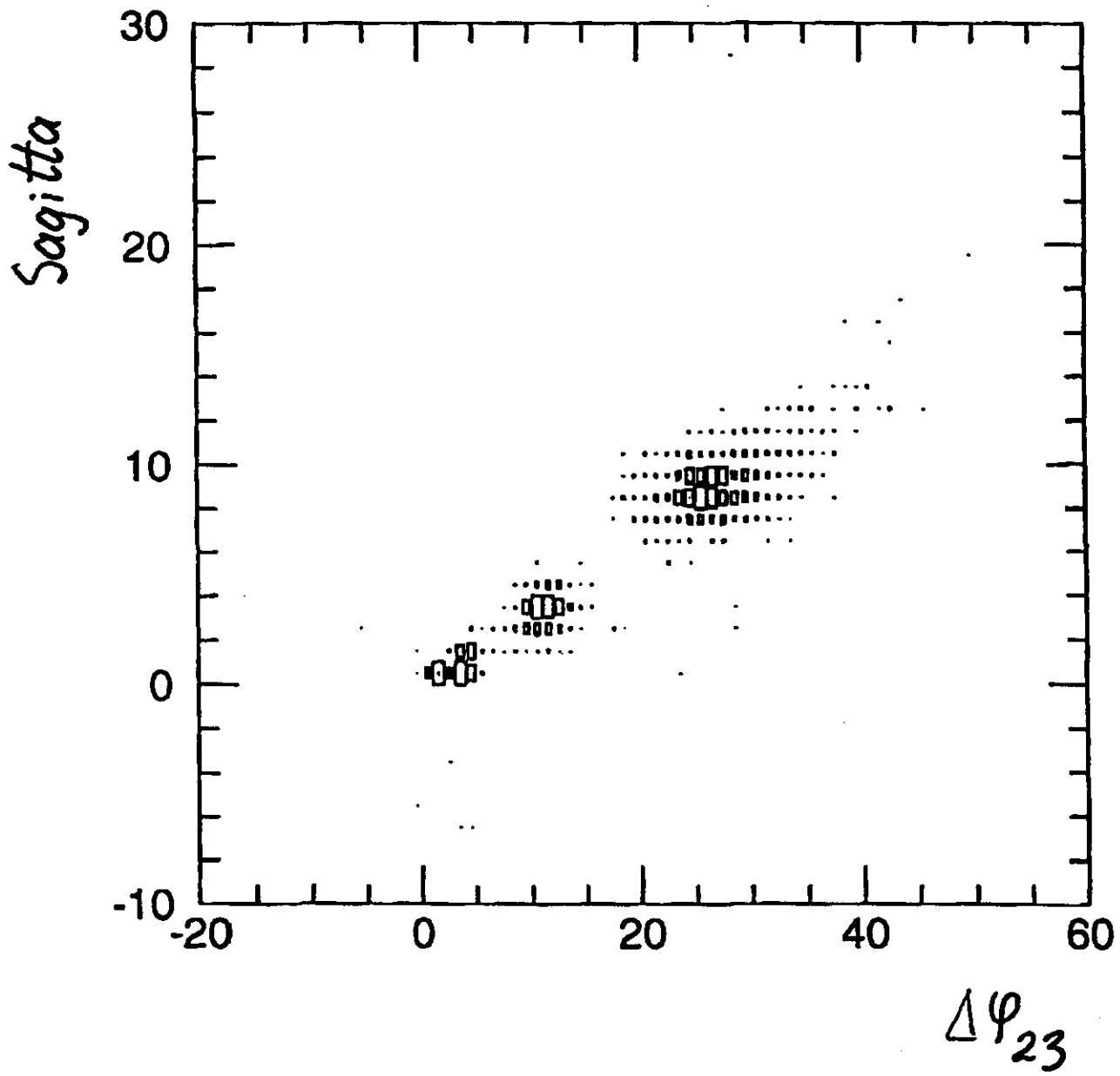

Trigger efficiency (barrel)
100
50
20
10
1
0.75
0.5
0.25
0
0
20
40
60
$\Delta\varphi_{23}$ (strips)

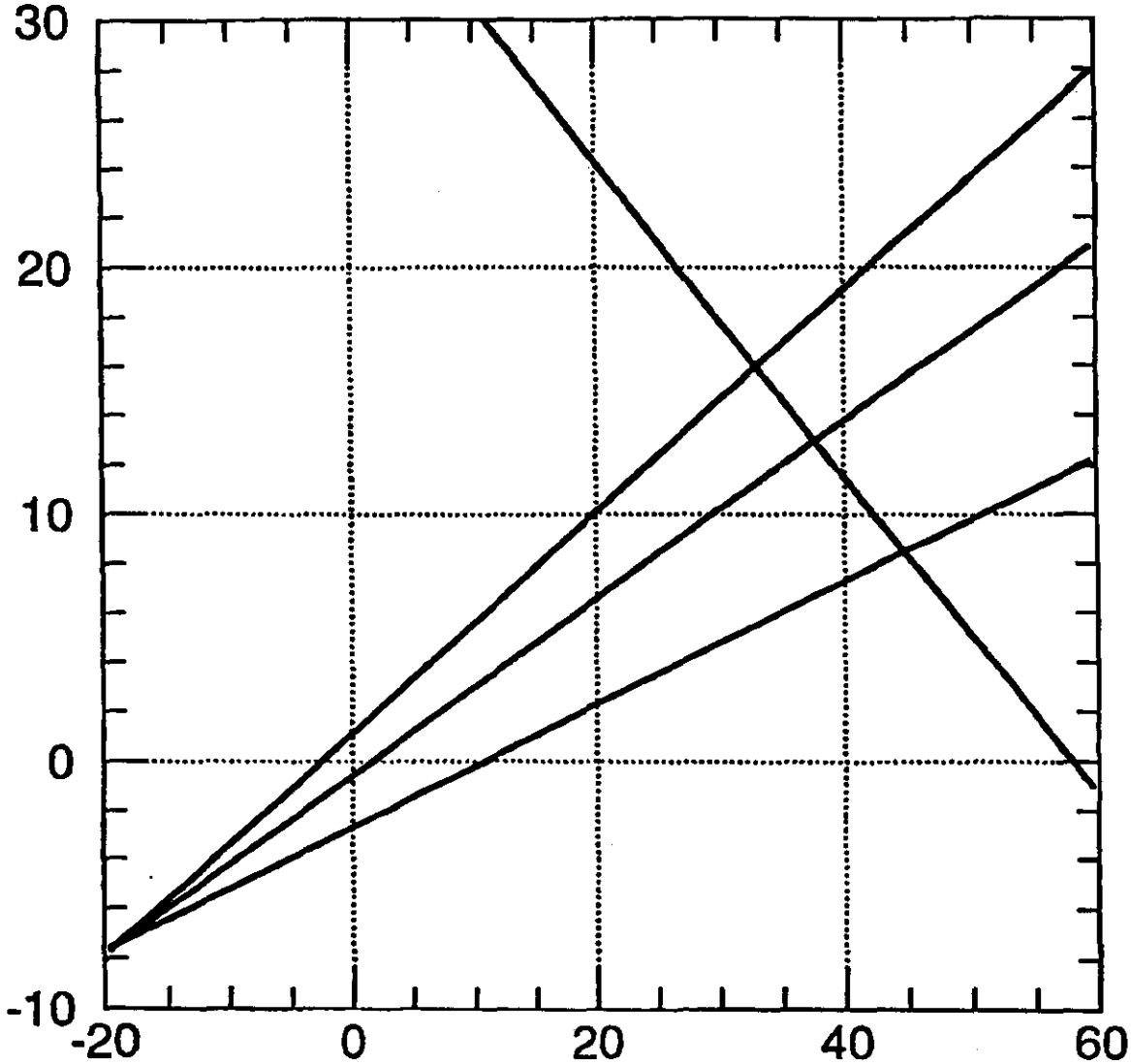

Trigger efficiency (barrel)
100
50
20
10
1
0.75
0.5
0.25
0
0
10
20
30
Sagitta (strips)

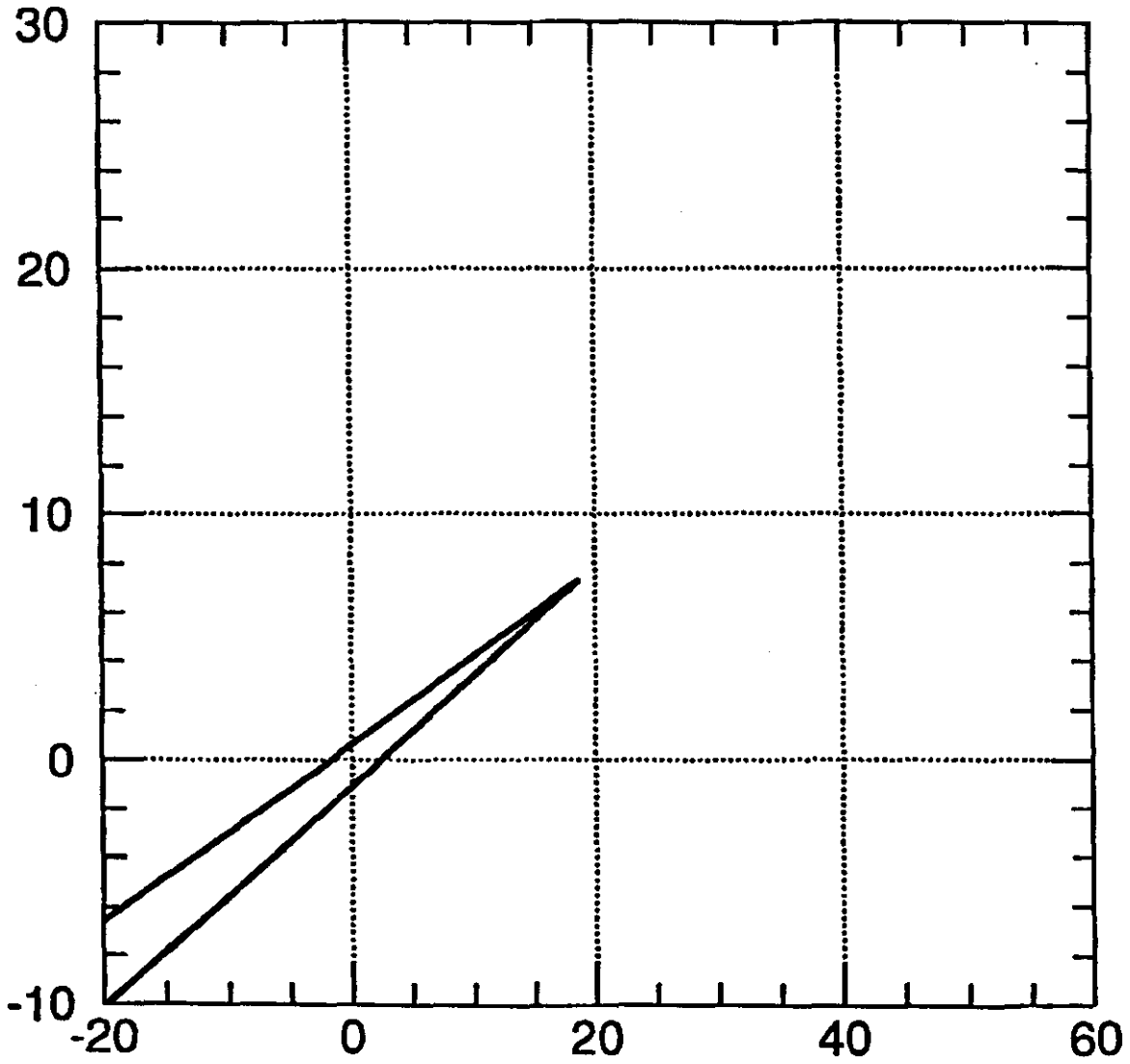


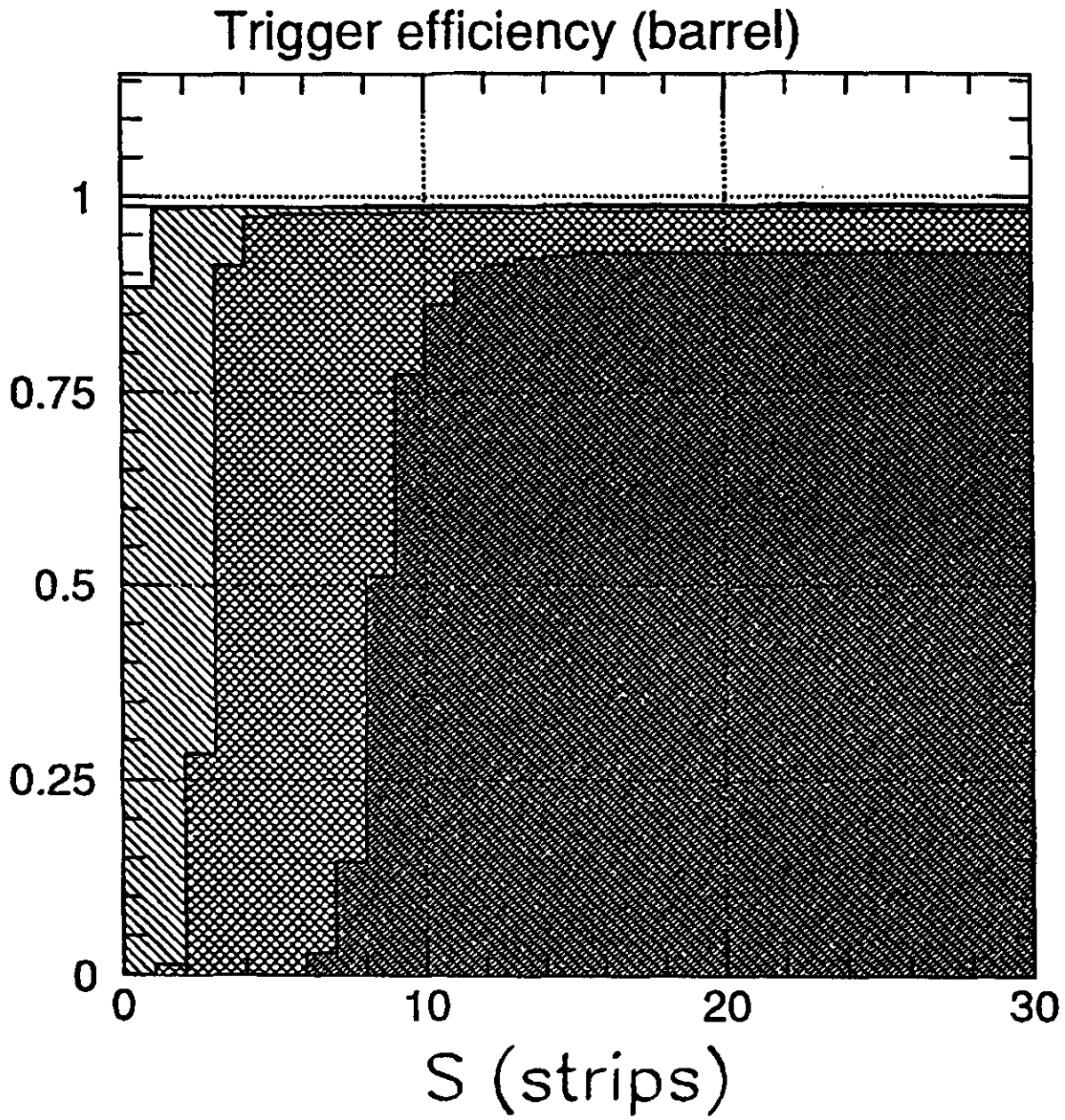
Rotation symmetry within each φ sector $\Rightarrow$ Number of parameters $= 2$ (e.g. $\varphi_2 - \varphi_1$, $\varphi_3 - \varphi_2$). Let's use liniar combinations of $\varphi_{1,2,3}$: Sagitta and $\Delta\varphi_{23}$.

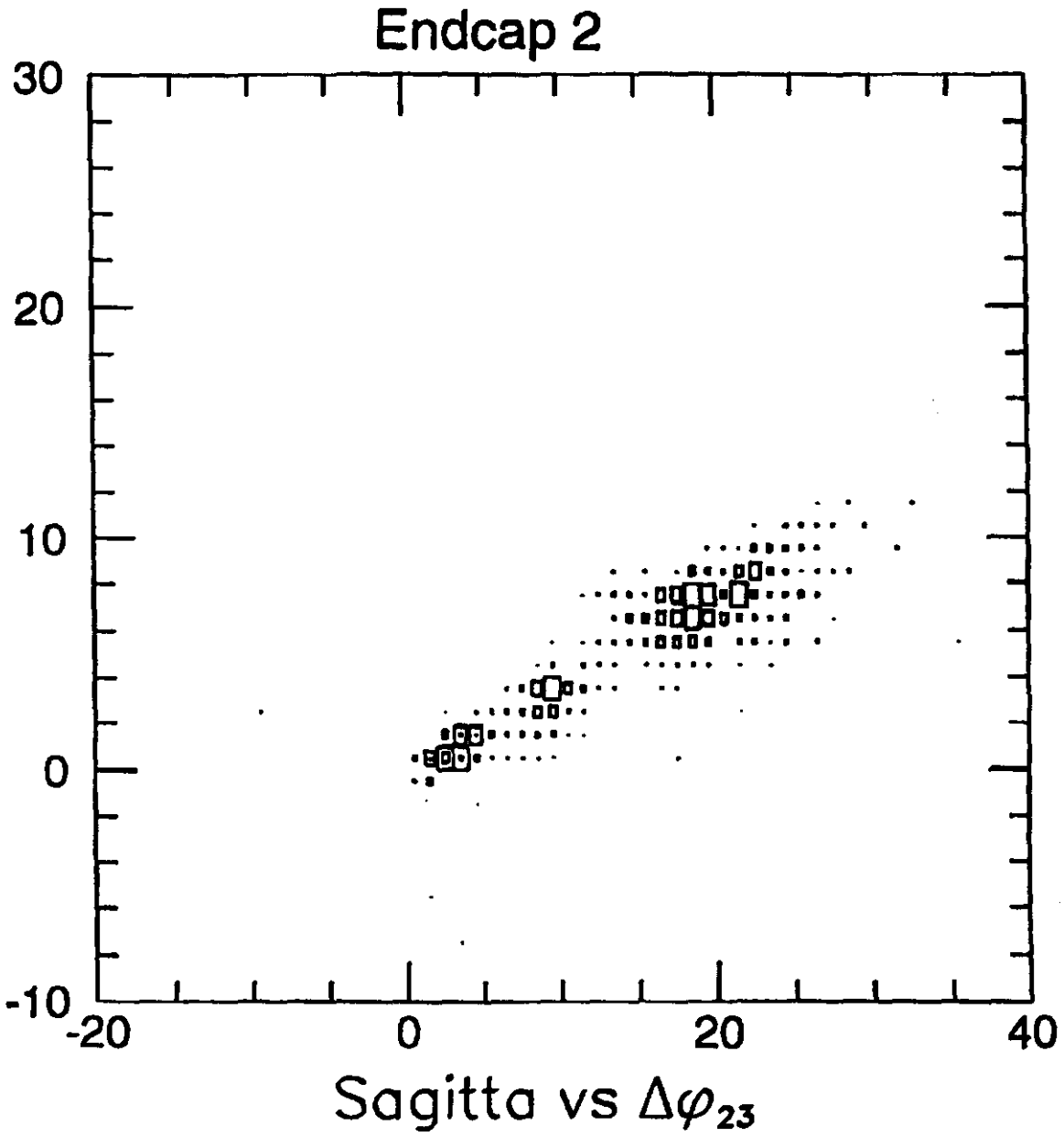

400
300
200
100
0
-20
0
20
40
60
-10
0
10
20
30
Δφ23
Sagitta

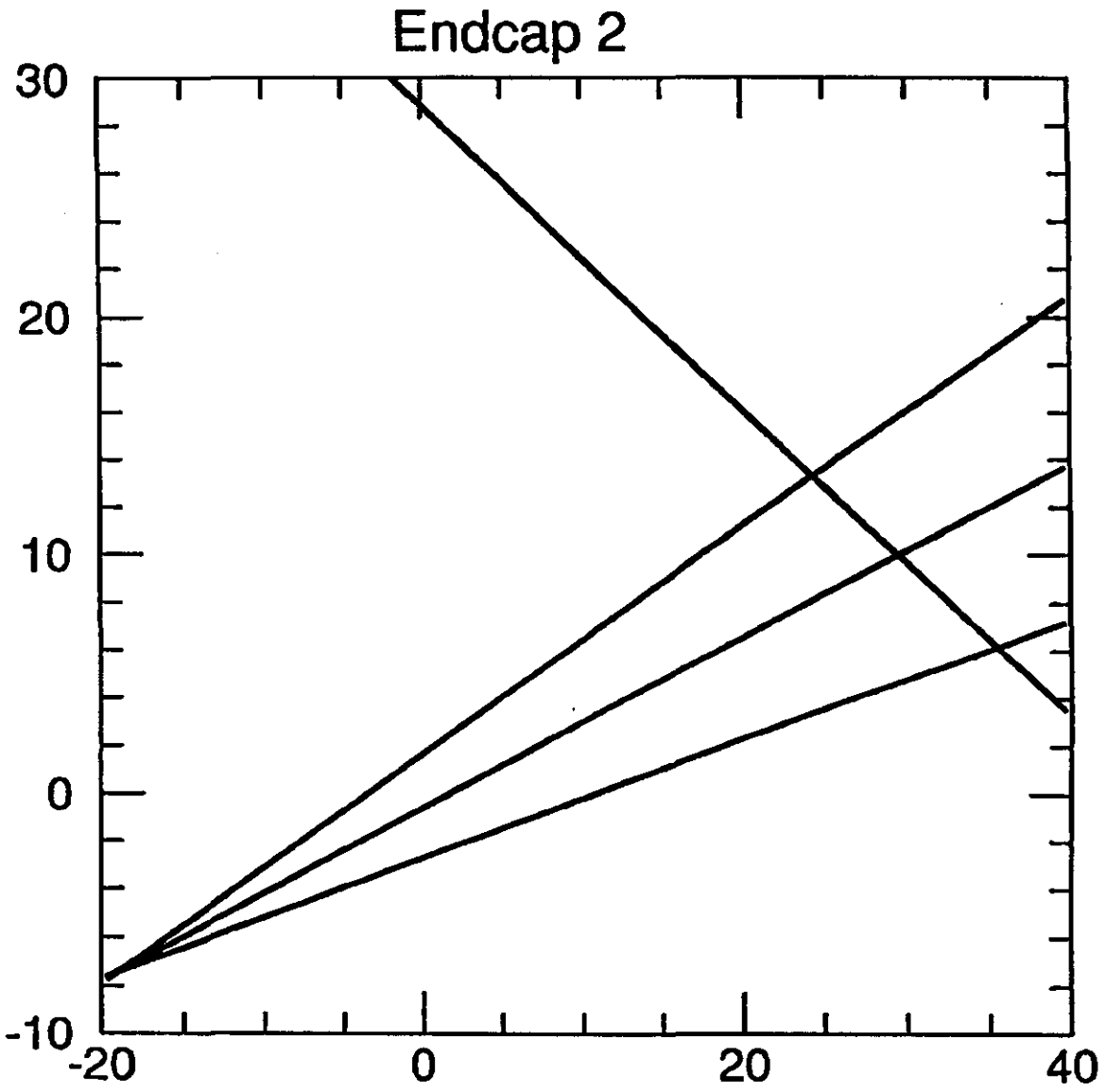

Sagitta
30
20
10
0
-10
-20
0
20
40
60
$\Delta\varphi_{23}$

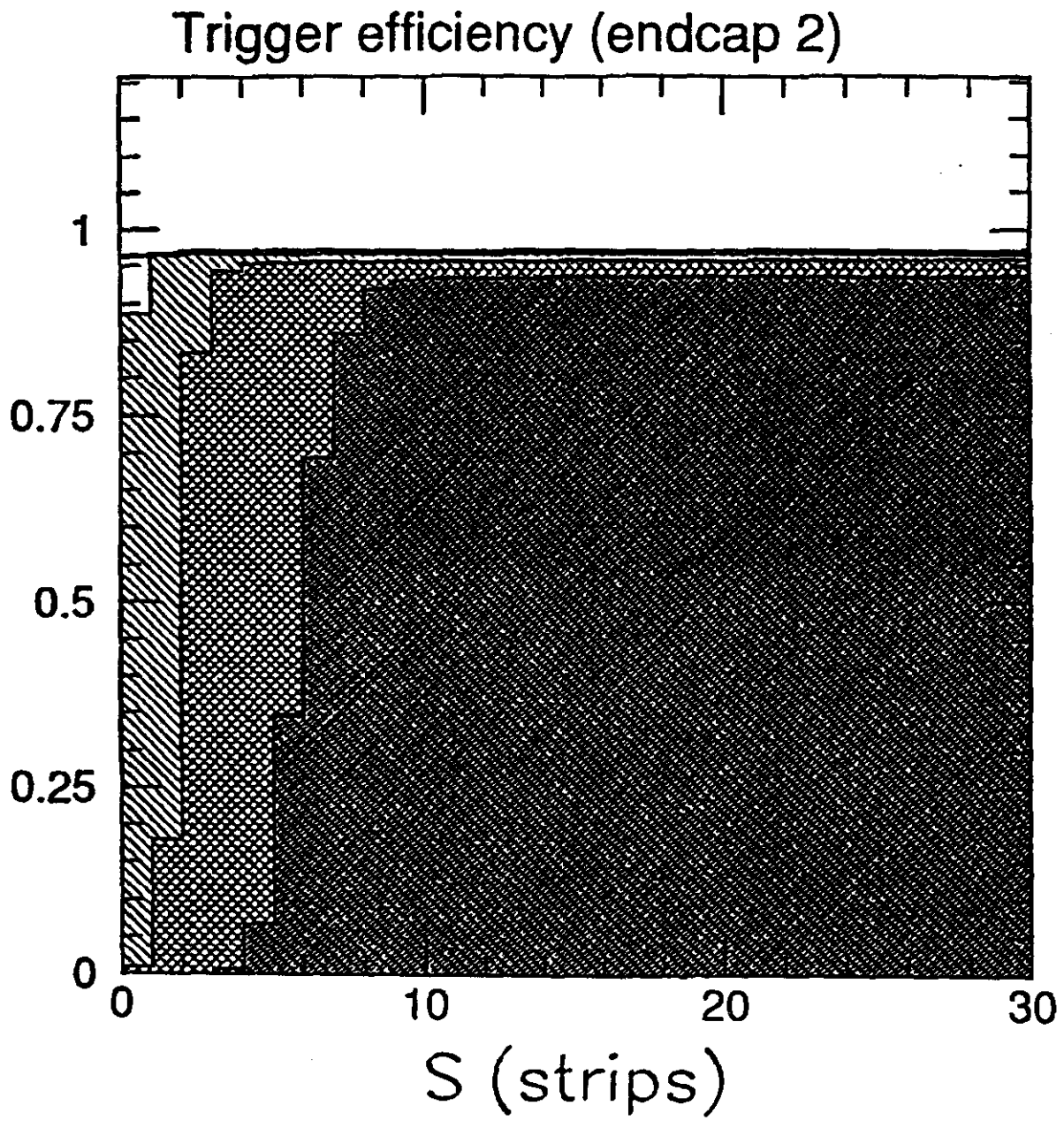

30
20
10
0
-10
-20
0
20
40
60


30
20
10
0
-10
-20
0
20
40
60

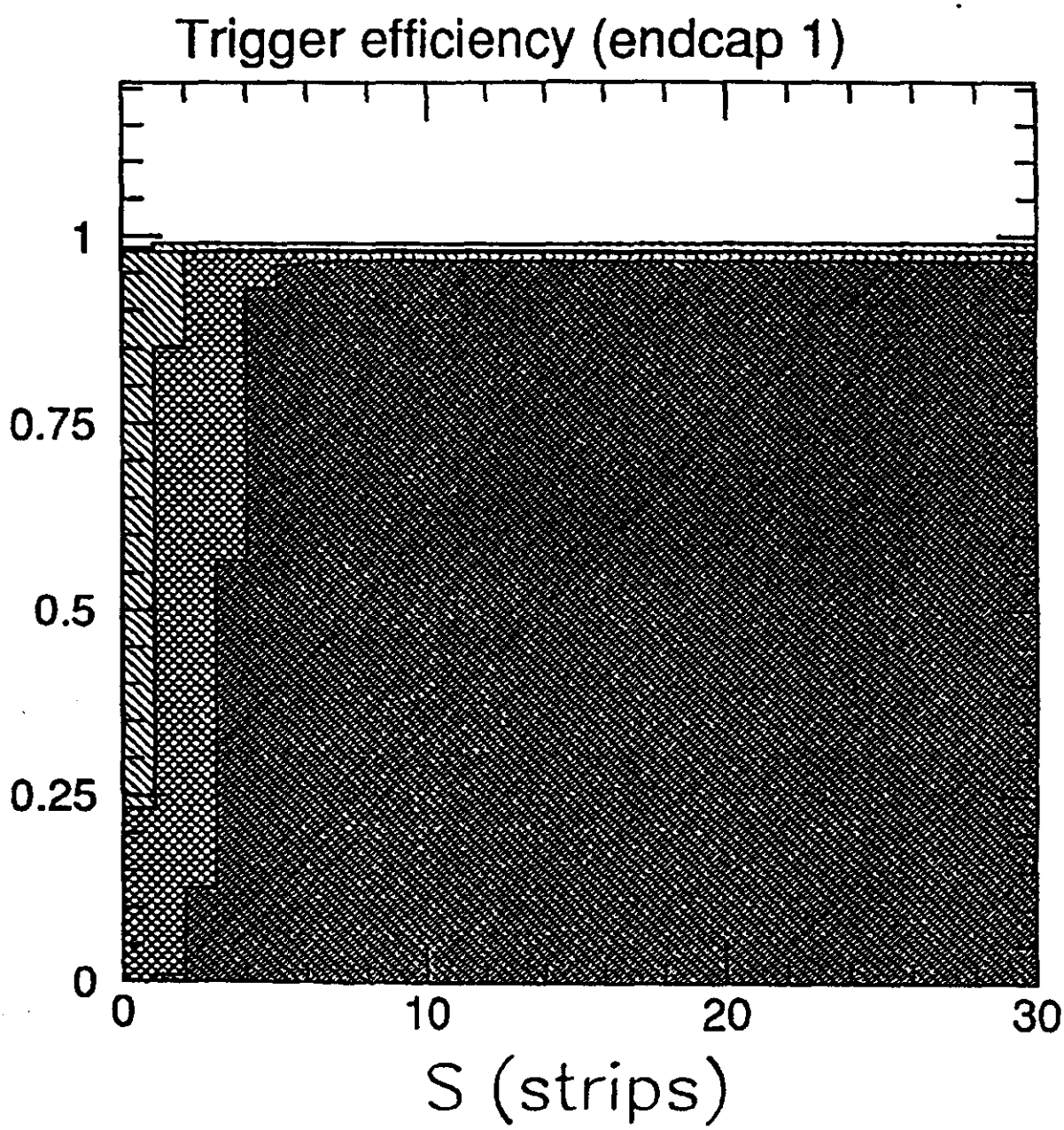

Trigger efficiency (barrel)
1
0.75
0.5
0.25
0
0
10
20
30
S (strips)


Endcap 2
30
20
10
0
-10
-20
0
20
40
Sagitta vs $\Delta\varphi_{23}$

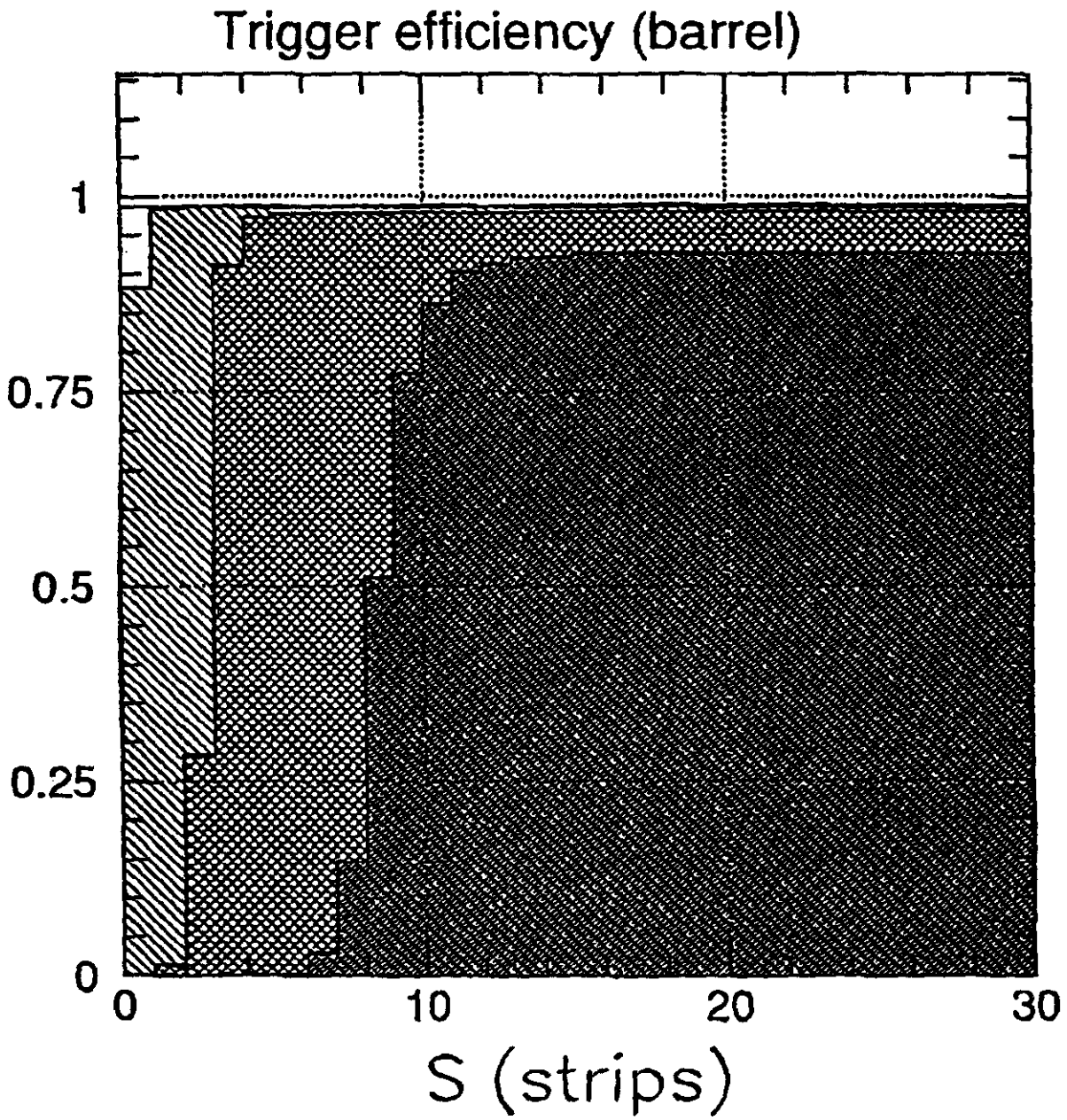

Endcap 2
30
20
10
0
-10
-20
0
20
40



Small η



Large η


Trigger efficiency (barrel)
1
0.75
0.5
0.25
0
0
10
20
30
S (strips)