GEM TN-92-58

GEM Muon Group Meeting
SSCL

January 22 , 1992

Abstract:

Transparencies and agenda of the GEM Muon Subgroup Meeting held at the SSCL on January 22, 1992.

1/21/92

5TH ORDER PROPOSAL FOR MUON BLACK BOX

WILL PROVIDE A SUBROUTINE THAT RETURNS FOR EVERY CHARGED TRACK IN AN EVENT:

a) SMEARED 4-VECTOR

B) TRIGGER PROB. (L1) IN μ SYSTEM

c) MOMENTUM RECONSTRUCTION PROB. IN THE μ SYSTEM

d) space-point

i.e. (* => RETURNS THESE OBJECTS)

CALL RMU(V4, IP, Q, VM4*, P^*_{TRIG}; P^*_{RECON})

THIS WILL BE DISCUSSED IN MUON MEETING 1/22

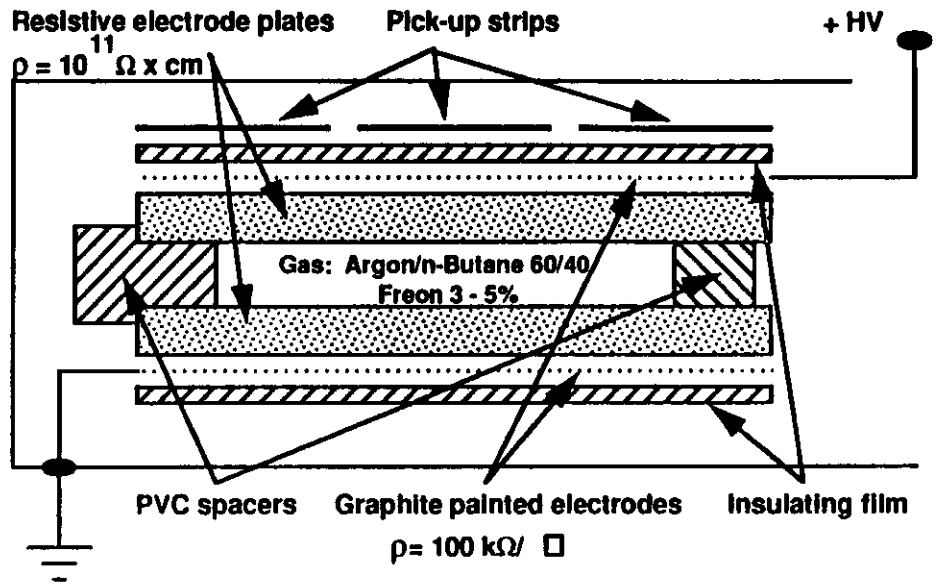
- ISolated μ
- non-isolated μ

M. MOHAMMADI, C. Yanagisawa, P. Dingus

Resistive Plate Counter (RPC) Program

Brown, Indiana, LLNL, MIT, Tennessee

Sketch of a Resistive Plate Chamber



Muon barrel RPC functions:

1. Beam crossing tag
2. Muon trigger
3. Z coordinate of muon
4. Pattern recognition road

Among the R&D goals are studies of:

1. Rise time jitter
2. Efficiency
3. Gas (non-flammable)
4. Noise and aging
5. Maximum counting rate
6. Materials
7. Manufacturing techniques

Resistive Plate Counter Basic R&D Program

1. Measure the properties of 1 m x 2 m Italian RPC.
2. Develop new materials and construction techniques.
3. Build a 1 m x 2 m RPC with new materials.
4. Measure the properties of the new RPC.

Brown, Indiana, MIT, and Tennessee will construct a muon telescope using drift chambers and scintillator hodoscopes, which will be used to measure the properties of the various RPCs.

LLNL will develop new materials and construction techniques. Using the new materials, LLNL will construct a 1 m x 2 m RPC.

R&D Work to Date:

1. Two glass RPCs (36 cm x 137 cm) have been constructed at MIT. Rise time < 5 ns; Width < 50 ns; Height ~ 600 mV into 50 ohms.

2. 30 cm x 30 cm RPC Test Stand constructed at LLNL. Chrome and Cermet electrodes deposited on resistive glass.

Global RPC Properties:

Each muon sector will have three RPC layers. One layer will be attached to each of the three muon tracking super-modules.

For each sector, the RPC strip count is:

Non-bend plane:	1,127
Bend plane:	552
TOTAL:	1,679

Total channel count for GEM RPC subsystem is:

$$32 \times 1{,}679 = 53{,}728$$

TO:GEM Muon Group 1/16/92
FROM: Steve Ahlen and Frank Taylor
SUBJECT: Muon Group News/Meetings

News Items:
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(1) The PAC has approved our LoI and recommends that the GEM Collaboration be supported to work on the development of a Technical Design Report. A review of the progress towards that goal will be in July, 1992.

(2) The Texas Commission funding did not go through. As a consequence our R&D budget will be about 70% to 75% of the requested FY'92 funds. There will be a discussion of this matter at the GEM Executive meeting Wednesday, Jan. 22, 1992, and will be an item of discussion at our Friday meeting.

(3) There will be a General Review of the Muon System on Feb. 5, 1992 to be held in Boston. Everyone is urged to attend. Please notify Steve or Frank if that date is not possible for you. Gary Sanders is calling the meeting as the start of a series of reviews of the major systems of GEM. (See Attachment)

(4) An effort is underway to update the baseline specifications of the GEM detector by the time of the Tuscon Meeting March 11, 1992. This will involve understanding of B-field shaping, hadronic punchthrough, chamber configurations, etc. Marx/Sanders/Harris are coordinating this.

Meetings:
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(1) Triggering/Simulations: Wednesday, Jan. 22, 1992 9:00 AM-12:00 Noon (from Maged Atiya)

(1)	Summary of Previous meetings Plan for more work	Atiya	15 min
(2)	RPC R&D at LLNL	Wuest	20 min
(3)	Update on Signal and background event generation	Chiaki Y.	20 min + MM
(4)	Update on PCHTHR code	R. McNeil	20 min
~~(5)~~	~~Update on muon GEANT model~~	~~BNL or UT~~	~~20 min~~
(6)	Associative Memory Trigger	Polychronakos	20 min
(7)	Further thoughts on muon triggers	Pless	30 min

PS: A BU person will talk about Pad chambers (probably Scott) on 1/24

(2) Muon Steering Committee: Thursday, Jan. 23, 1992 after Council Meeting
Approx. 4:00 PM-6:00 PM

(3) Hardware Meeting: Friday, Jan. 24, 1992 9:00 AM-3:00 PM

(1)	General remarks/R&D budget plan	Ahlen/Taylor	40 min
(2)	Engineering/Integration and Cost Review	Nimblett	40 min
(3)	Status of magnet/flux shaping	Taylor(for JDS)	30 min
(4)	TTR	Mitselmakher	30 min
(5)	PDT R&D	Ahlen	30 min
(6)	LSDT R&D	Osborne	30 min
(7)	RPC R&D	Wuest/Pless	30 min
(8)	CSC R&D	Polychronokas/	30 min

Summary of μ-trigger group meetings & efforts

2 General meetings

12/17/91 Software

1/6/91 Hardware

+ >5 working smaller meetings

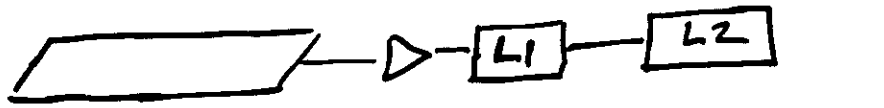
Groups

MIT, BNL, LLNL, UT, SUSB, LNPI, LSU

BU, ORNL, Tenn, Brown, Indiana, SSCL

Princeton ...

μ Trigger



chamber Readout Level 1 Level 2

1) RPC Issues

2) Pad Chamber Issues

1) RPC → none

2) Pad → AMPLEX II

We should aim for
Unified approach for RPC +
Pad chambers
"Associative" Processing ?

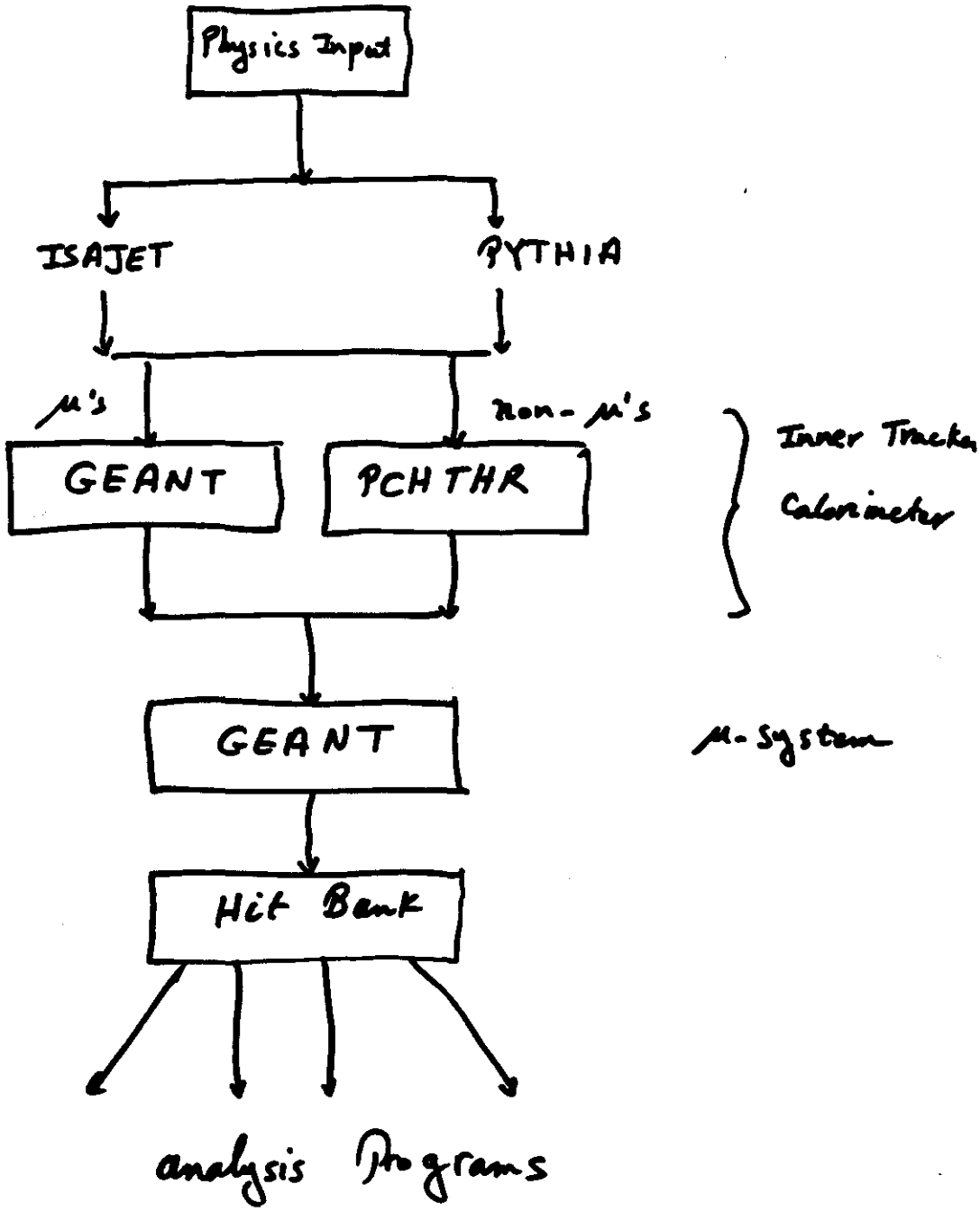
** Software Simulation

Unified approach

≥ 2 levels of details ⟶ overall system Perform.

⟶ Hardware detail

Software efforts



Pressing issues :

1) Calorimeter thickness & material $|\eta| < 1.5$. $|\eta| > 1.5$

2) Resolution

< 500 GeV/c P_t

$500 >$ < 1000 GeV/c P_t

> 1000 GeV/c P_t

3) Rates at 4, 6, 8 m as a function of η (< 1.5)

. $1.5 < |\eta| < 3.0$

Status of Muon trigger systems

1) RPC

a) Basic R&D underway

b) Dimensions / Sector 16 Sectors

R	L/2	W	cm
370	664	148	
600	1048	240	
830	1450	330	

To be built 1m x 2m "tiles" of 1.3 cm strips

12 - 15 % Dead area

Coverage to $\eta = 1.3$

$P_\perp$ Cut at 20 GeV

2) Pad Chambers

a) Prototype under Construction

b) Amplex IC under design

c) D-day ≈ June

RPC Issues:

1) Understanding of Basic Operational Principles

a) Rate Capability

b) Construction Yield

c) Capacitance of long Readout Sections (Timing)

d) Construction of $1 m^2$ section

MIT + LLNL + Brown + Indiana + Tenn 7/92

Pad chamber Issues:

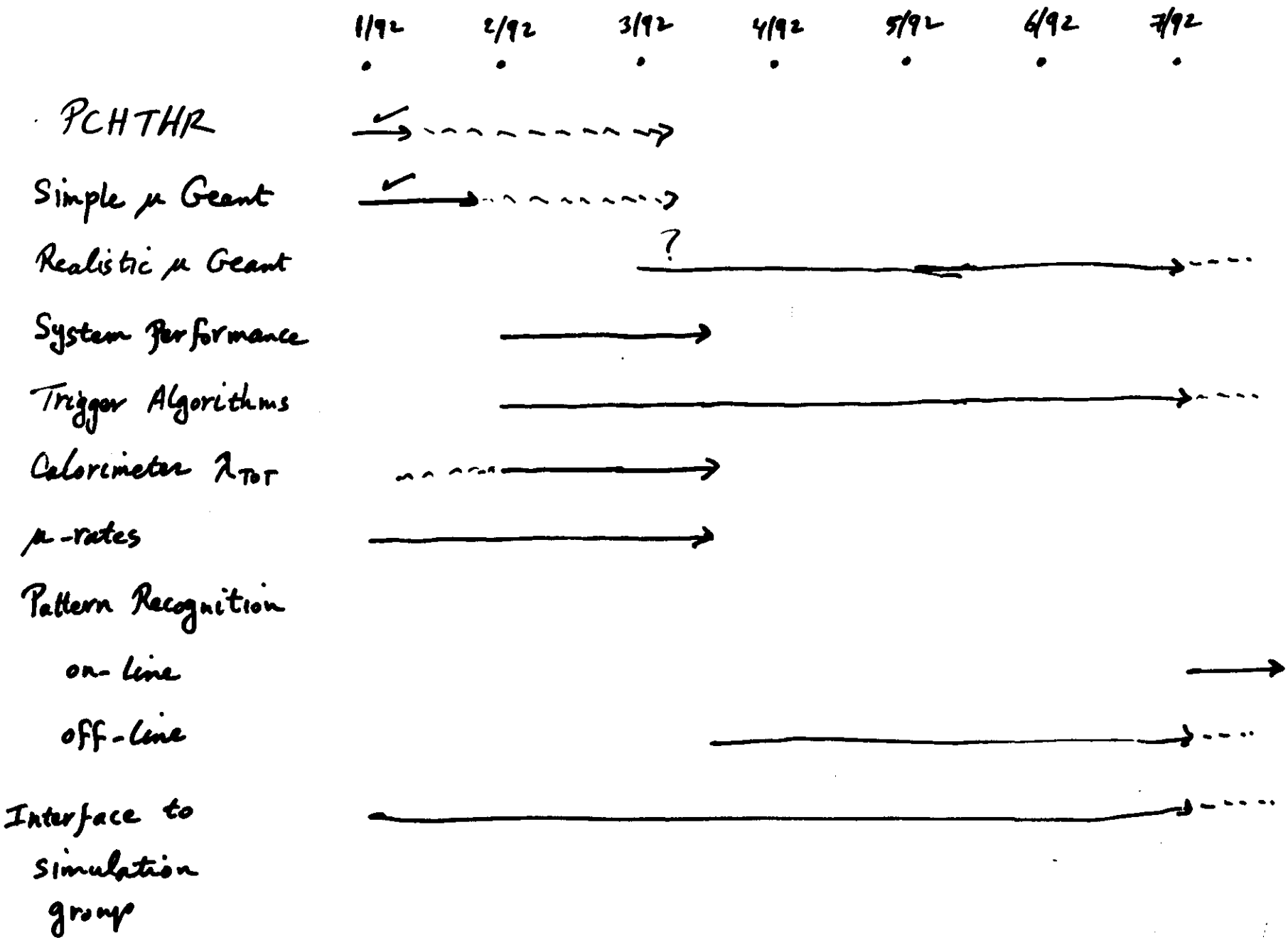
1) Construction of $1\,m^2$ Section

BNL + BU + ORNL + LNPI 7/92

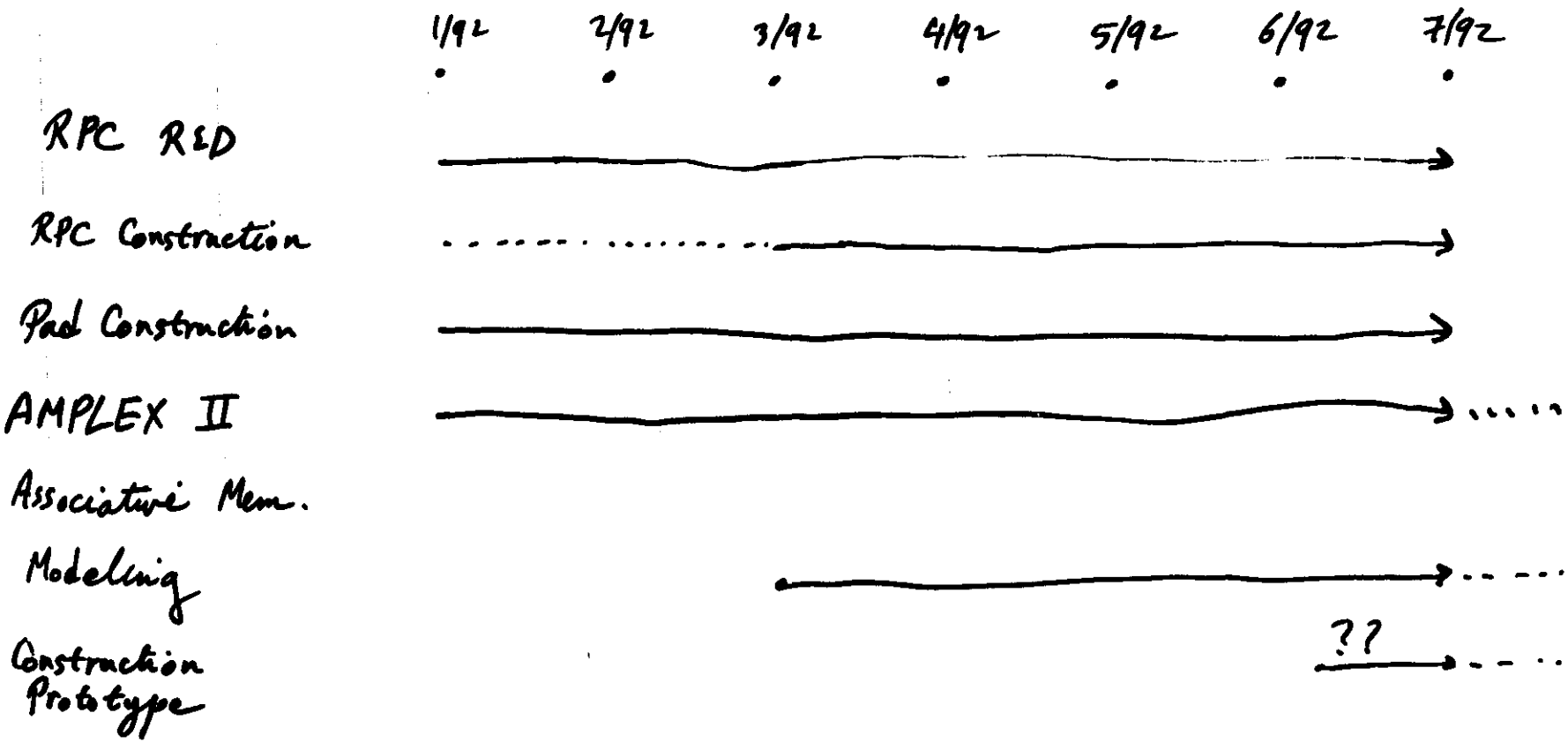
2) Understanding of Amplifier+ Costs

AMPLEX II IC ?

Software efforts



Hardware efforts



Jan 22, 1992

Status of PCHTHR (Punchthrough Subroutine)

Installing V.2.2 of PCHTHR on PDSF

Summary of updates for V2.1 & V2.2

1. K^+, K^- enhancement
   K^+ Punchthrough Prob $\approx$ 3-8 × π^- Prob $P_{INC} < 50$ GeV
   Use π^- distribution ~~[illegible]~~ and just increase probability

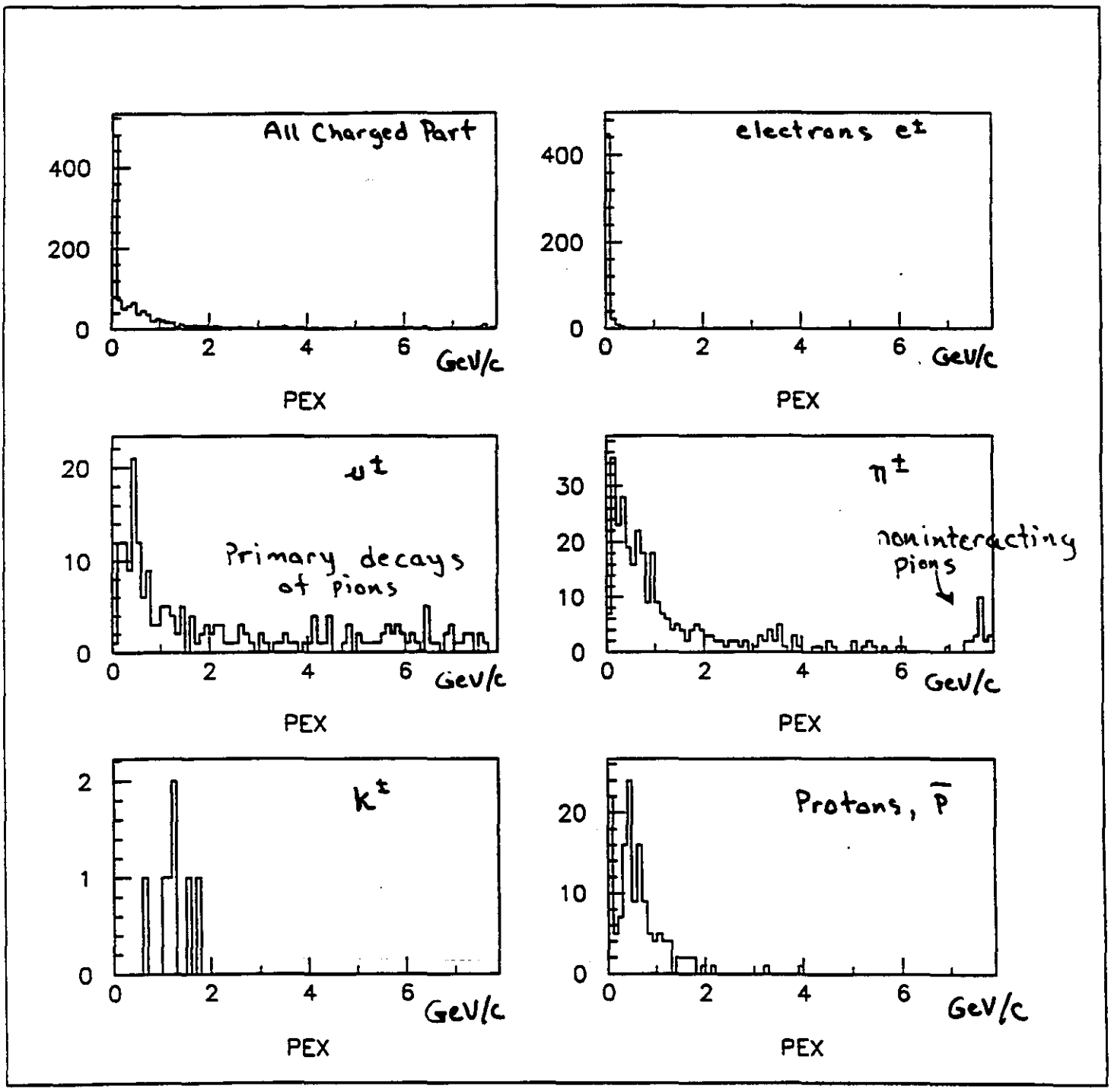
2. Charge Asymmetry $e^- : e^+$ $p : \bar{p}$

3. GEANT ID Codes for output tracks

4. User protection against out of range input
   Return flag to indicate fail/success

Still needs work on determination of Particle type for output; correlation Particle Type to Punchthrough Mult

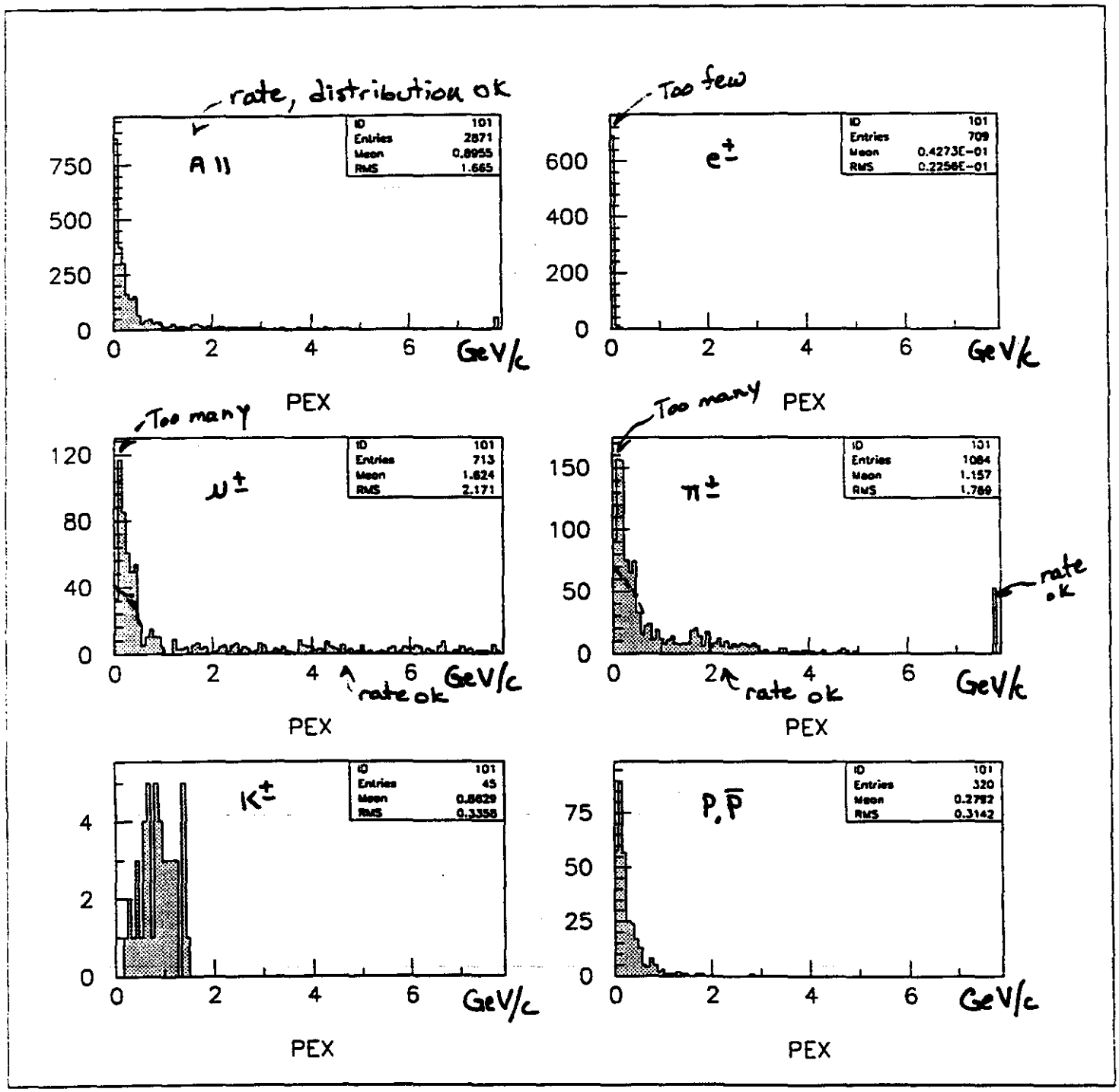
- Momentum Distribution of exiting particles by type
- 10 GeV/c Incident Pions
- After 10λ



PCHTHR output

10GeV π after $\underline{10\lambda}$

500,000 input tracks (takes $\lesssim$ 30 minutes)



K. McNEIL
Nov 8, 1991

Particle Rates in GEM Muon System
(How thick to make Calorimeter)

From a muon point of view - Calorimeter
ABSORBS Hadrons $\Longleftrightarrow$ Suppresses Punchthrough

To evaluate Calorimeter thickness, must consider different contributions to particles in Muon system

1. Prompt μs produced from c, b, t quark decays
2. Decay in-flight of π/K before Calorimeter
3. Hadron Punchthrough including decays in Calor.

The 1ST two components are muons incident on calorimeter and CAL serves only to range them

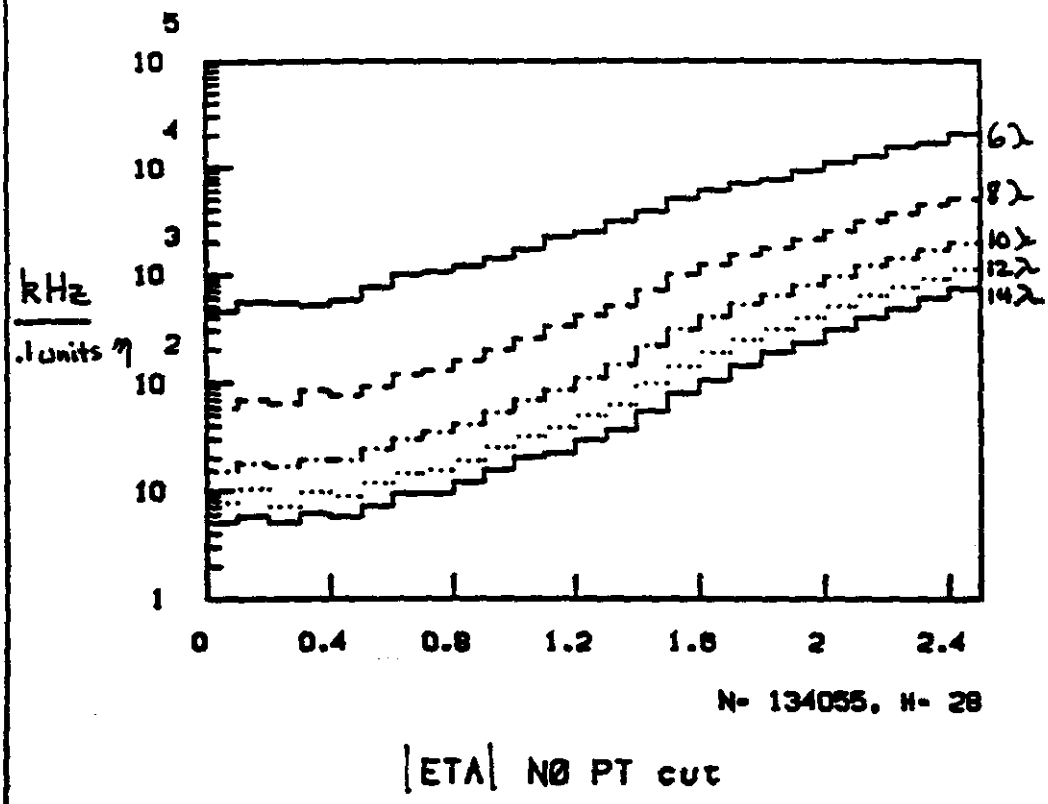
Possible Thickness Evaluation strategy

1) The overall rate from hadron punchthrough should be much less than that from prompt μ and π/K decay in tracking region

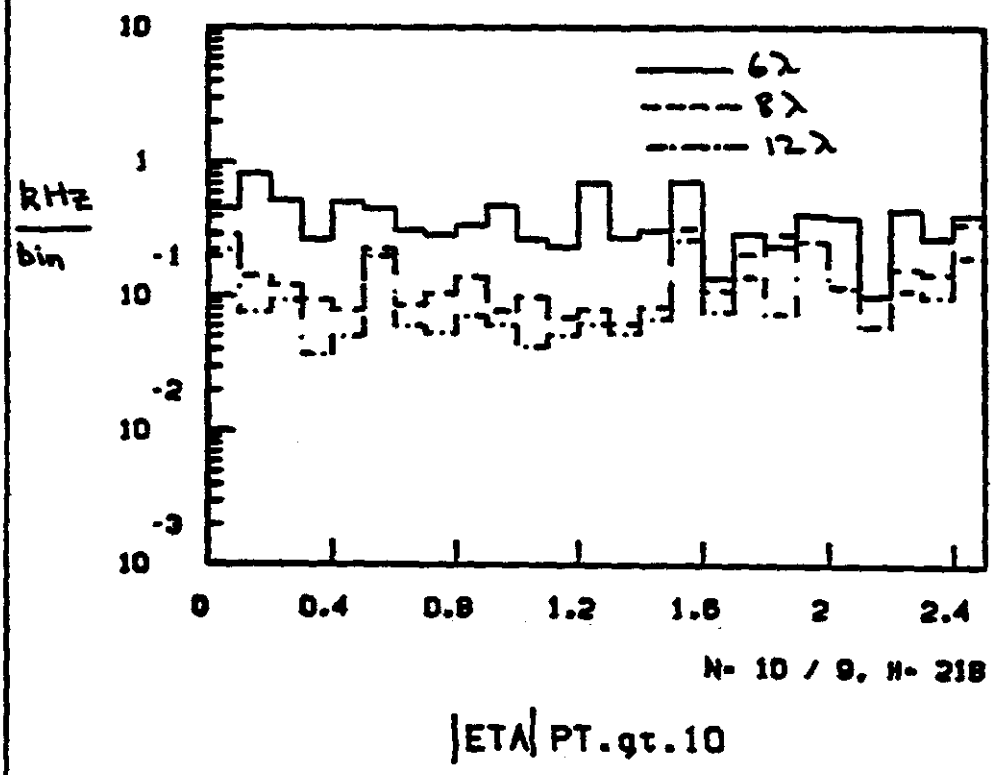
2) Rate of particles above P_T threshold (trigger) from Punchthrough should be much less than from Prompt μ + π/K decay in tracking region

3) Pattern Recognition? $\longrightarrow$ Need to Develop this criteria

TWØJET Events PTjet>4GeV/c $L = 10^{33}$



Large reduction of rate
$6\lambda \rightarrow 8\lambda \rightarrow 10\lambda$
Not so large reduction
$10\lambda \rightarrow 12\lambda \rightarrow 14\lambda$



with $P_T > 10$GeV cut and $> 8\lambda$
Rate change ∴ slow for increasing thickness

Simulation (This is NOT the PDSF ν Software package)

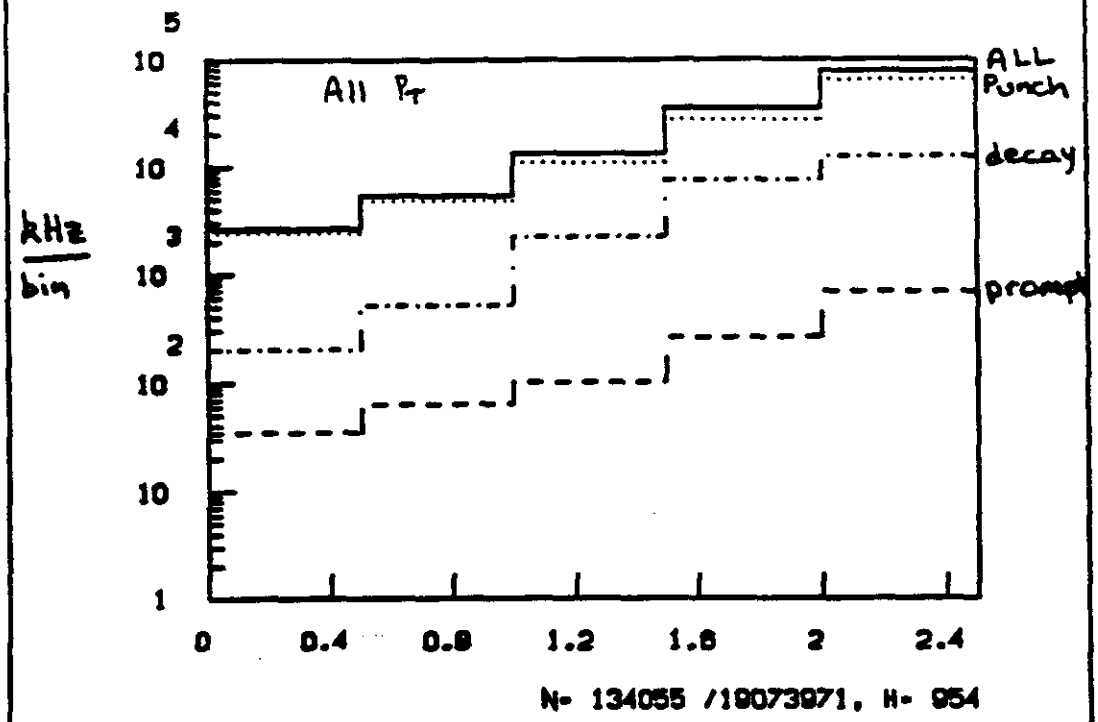
- Generator - ISAJET
  u, d, s, c, b m_t = default (140) $P_T^{JET} > 4 \frac{GeV}{c}$ $\sigma_{TOT} \sim 130 mb$

- "Tracking" Volume - 75 cm Radially out
  $\pm$ 220 cm in Z

- Calorimeter - Constant Thickness 6, 8, 10, 12, 14 λ
  Use PCHTHR-V22 for punchthrough
  Use Eloss = .22 GeV / λ for ν (Prompt & decays)

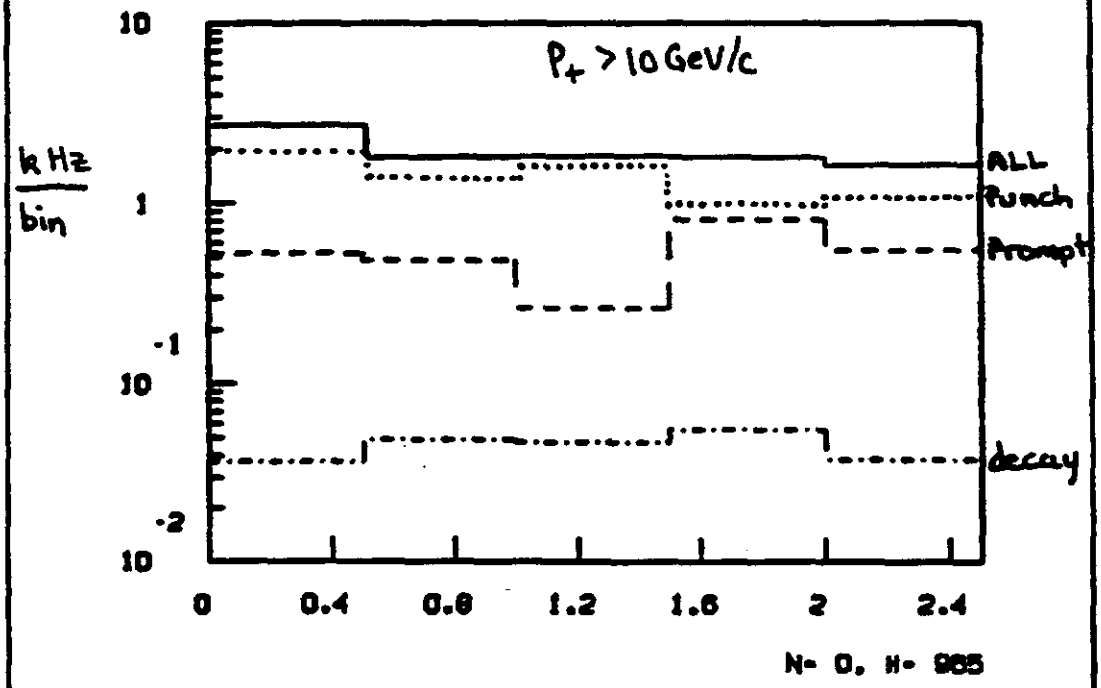
- No field in muon system.
  No cuts on Angle of tracks entering muon system (reject punchthrough)

TWØJET Events PTjet>4GeV/c $L = 10^{33}$



Punch through dominates

|ETA| of all mu PTB1

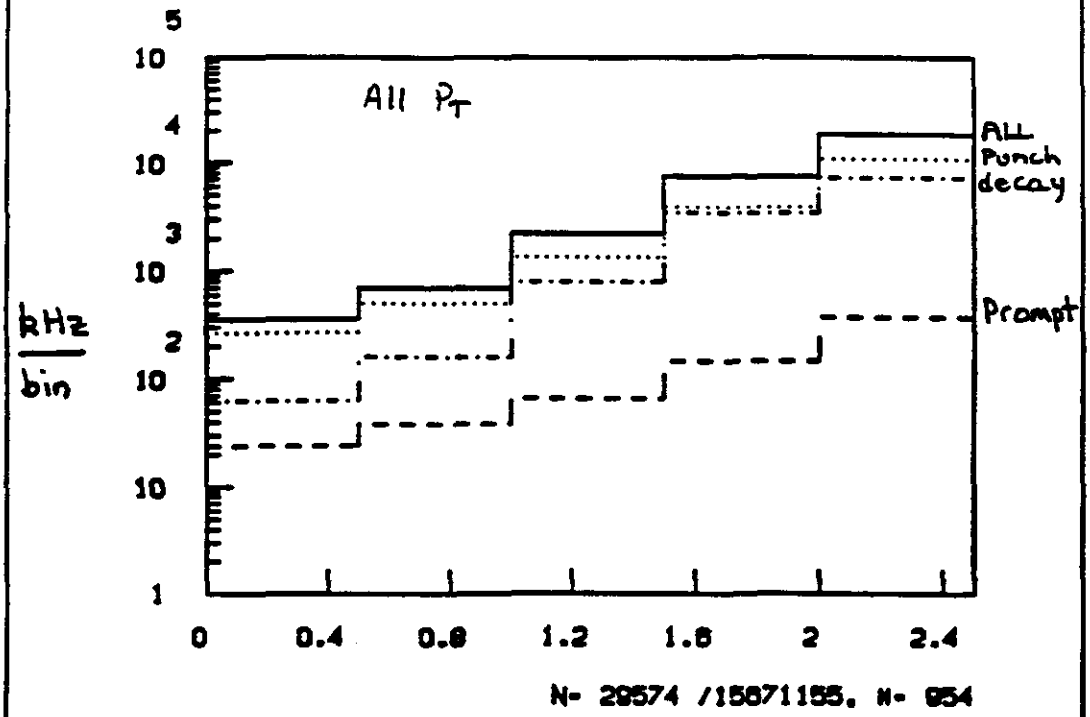


Punchthrough dominates

|ETA| Pt.gt.10

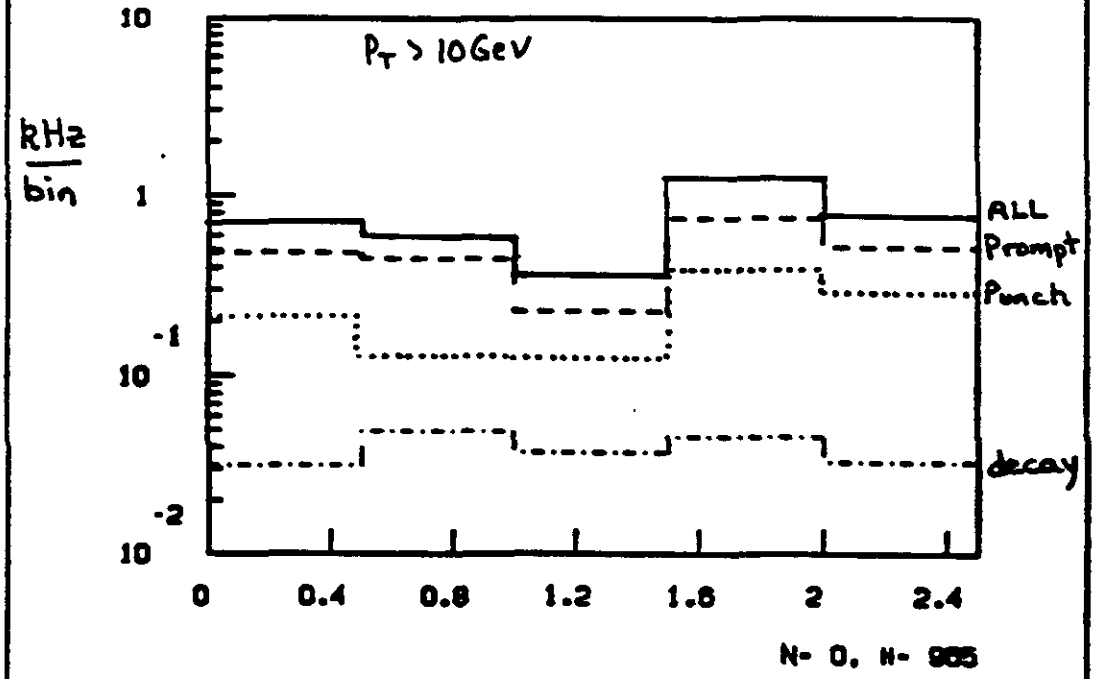
6 Lambda Calorimeter

TWØJET Events PTjet>4GeV/c $L = 10^{33}$



Punchthrough dominates

|ETA| of all mu PTB1

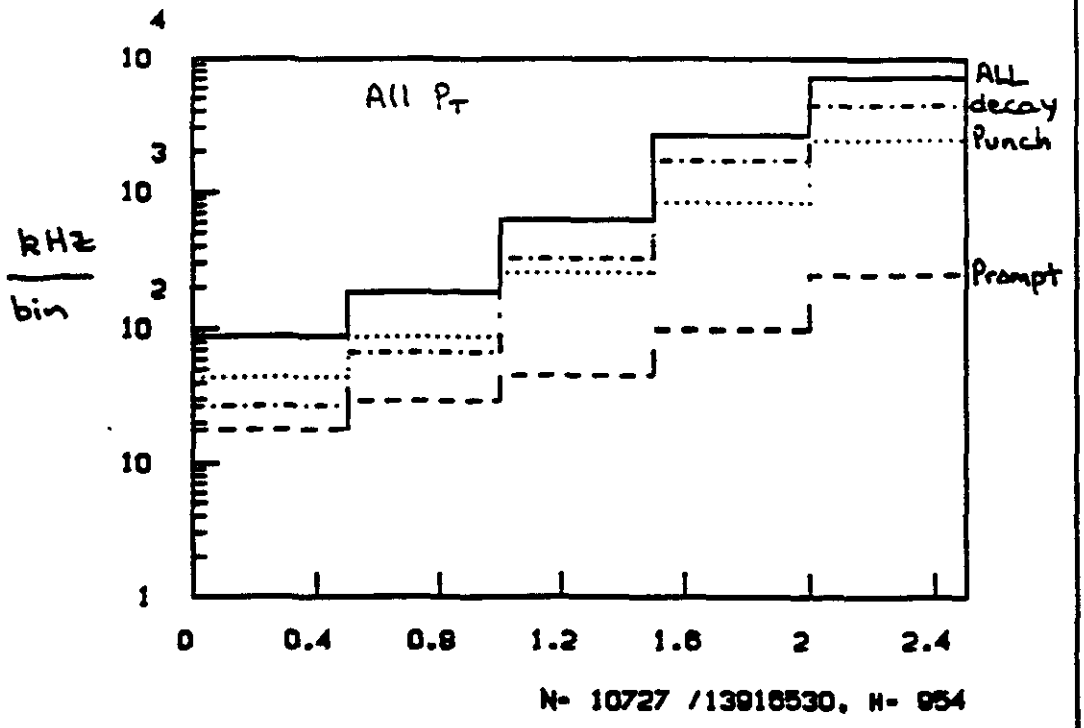


Prompt μ dominates

|ETA| PT.gt.10

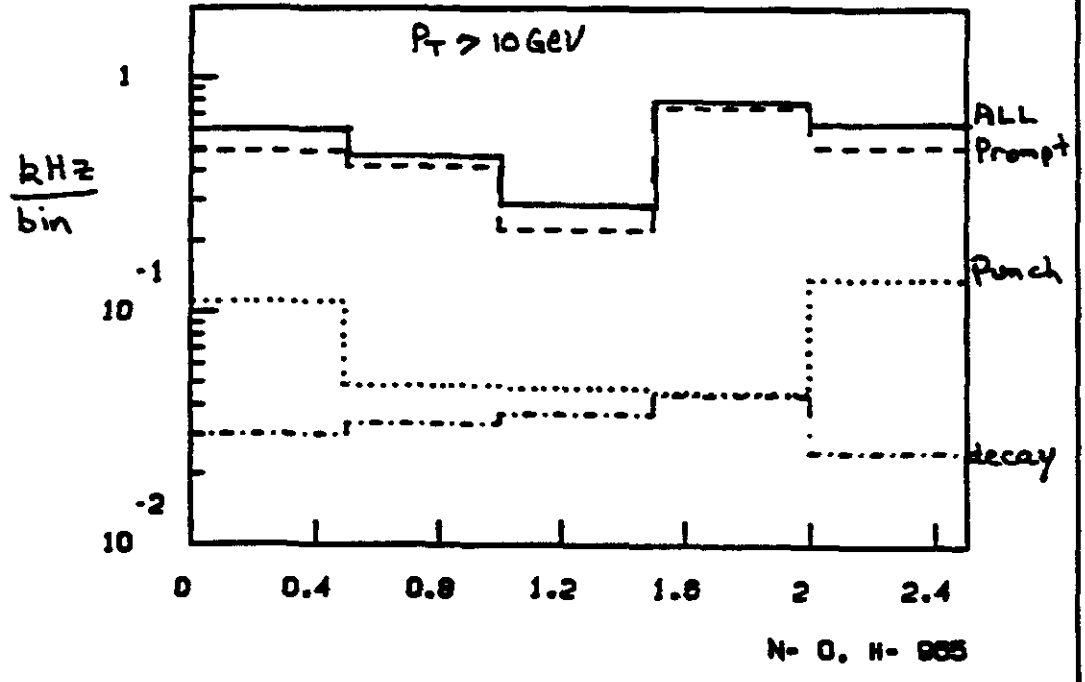
Lambda Calorimeter

TWØJET Events PTjet>4GeV/c $L=10^{33}$



Punchthrough dominates $\eta < 1$
decays dominate $\eta > 1.5$

|ETA| of all mu PTB1

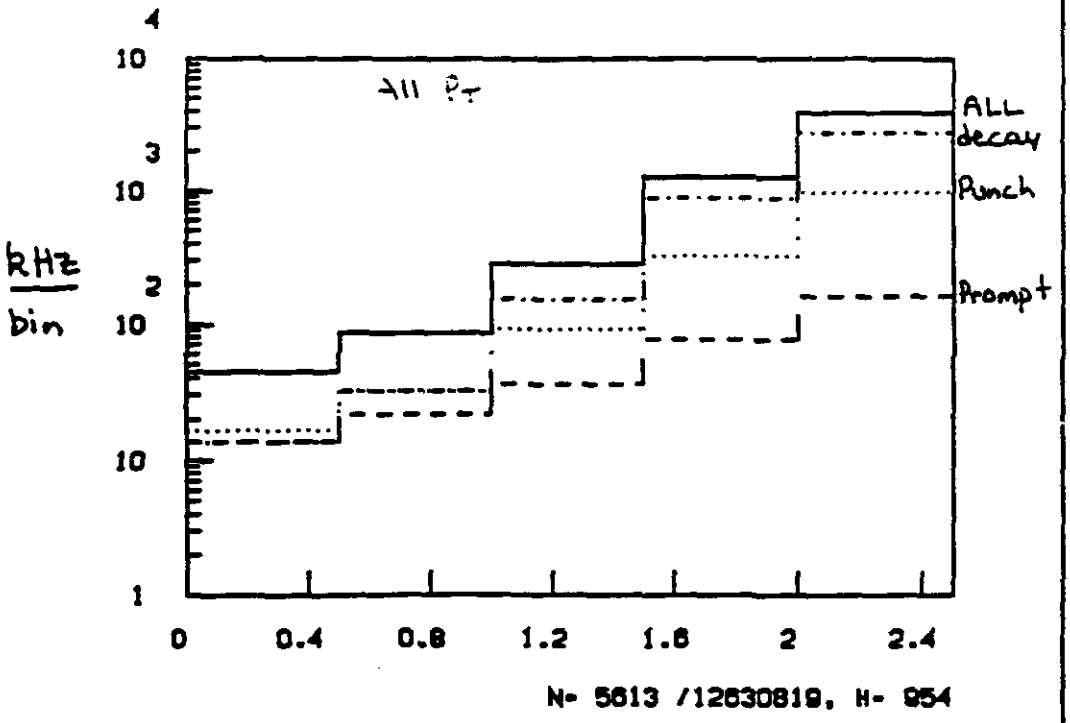


Prompt μ dominate

|ETA| PT.gt.10

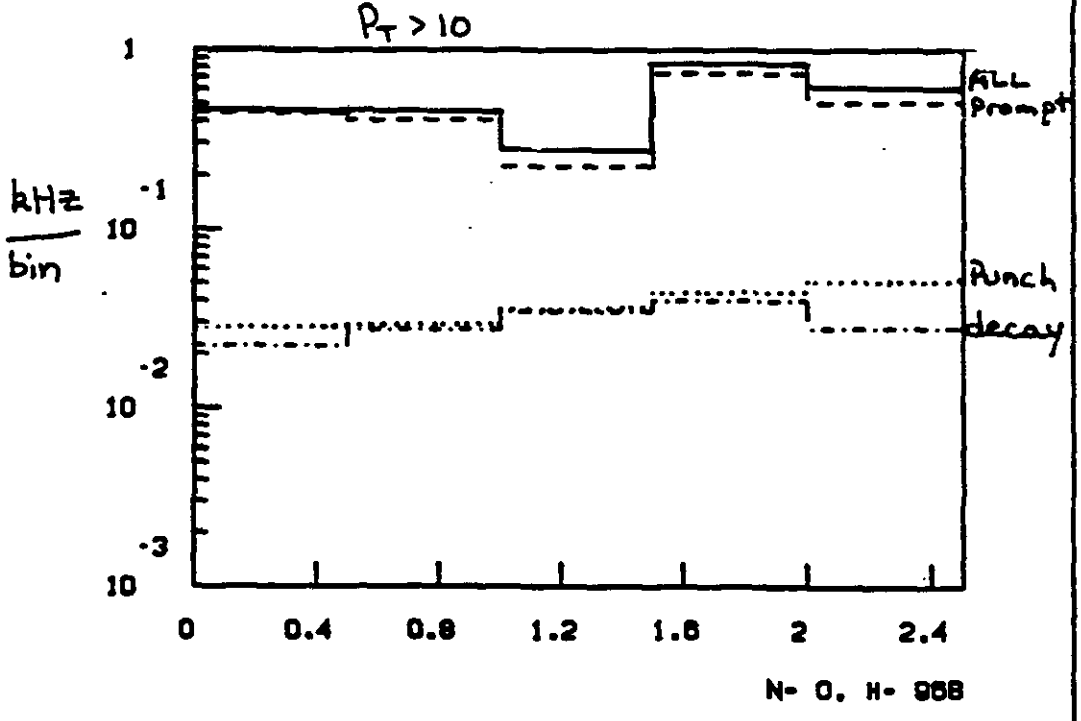
10 Lambda Calorimeter

TWØJET Events PTjet>4GeV/c $L = 10^{33}$



Prompt : decay : Punch comparable $\eta < 1$ decays dominate $\eta > 1.5$

ETA of all mu PTB1

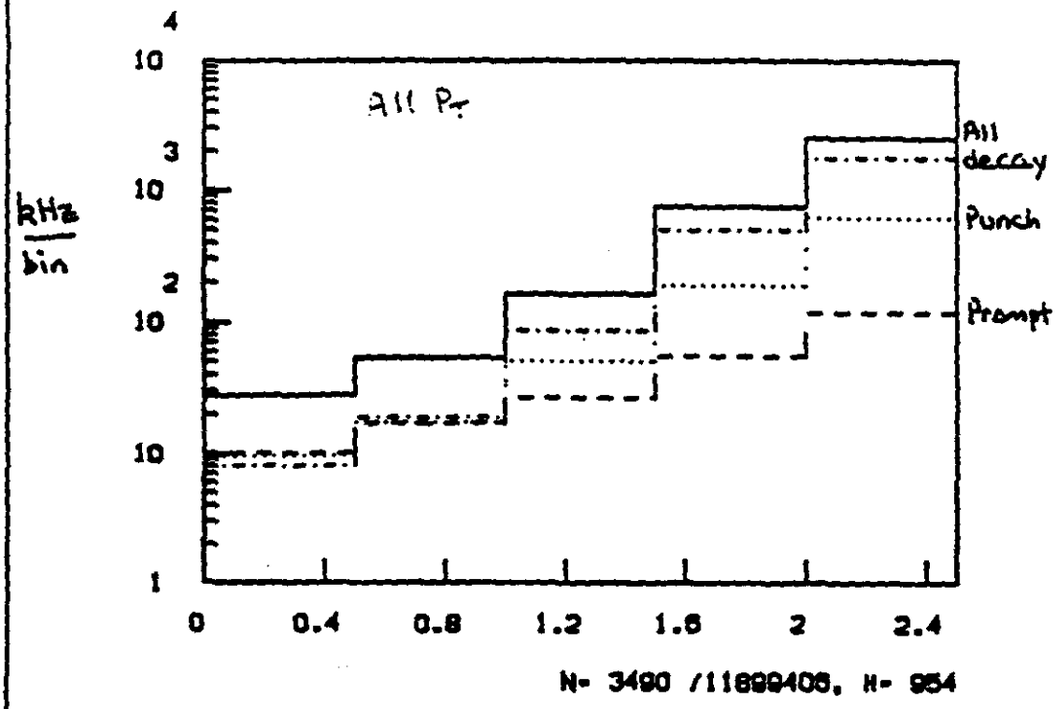


Prompt dominates

ETA Pt.gt.10

12 lambda Calorimeter

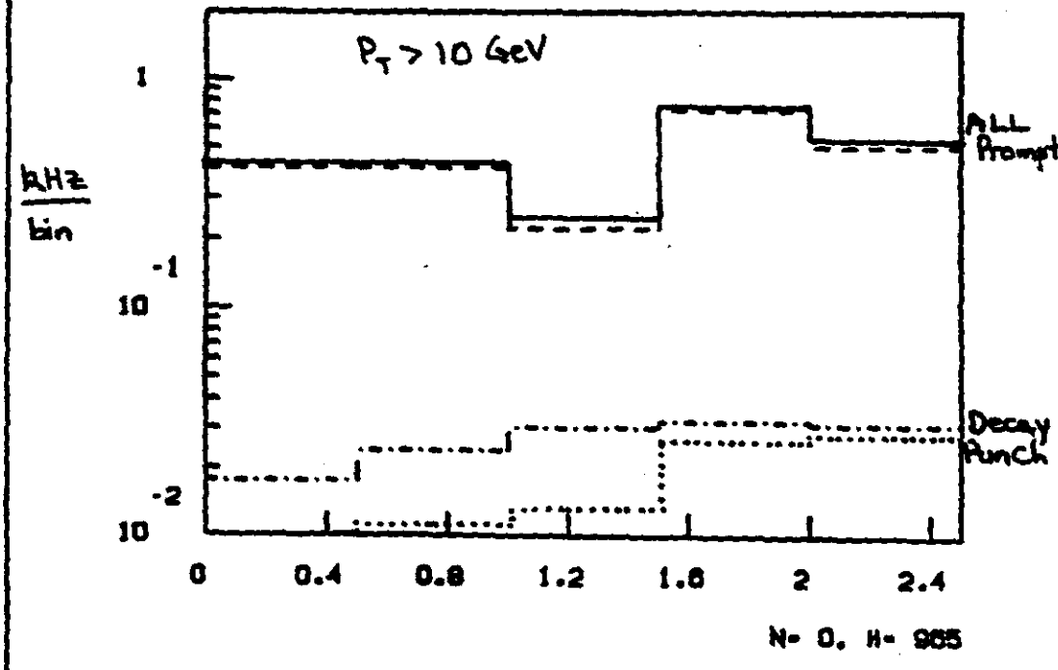
TWØJET Events PTjet>4GeV/c L=10



Prompt: decay: Punch same $\eta < 1$

decays dominate $\eta > 1.5$

|ETA| of all mu PTB1



Prompt ~ dominates

|ETA| PT.gt.10

14lambda Calorimeter

Conclusions

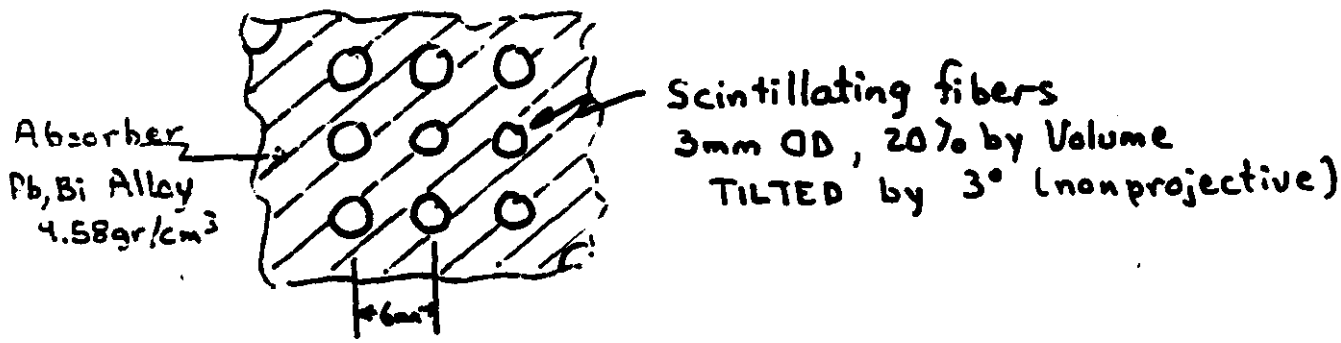
- For $|\eta| < 1.5$ $P_T > 0$ Punchthrough << decay + Prompt for $12\lambda, 14\lambda$ but not for $6, 8, 10\lambda$
- For $|\eta| < 1.5$ $P_T > 10$ GeV Punchthrough << Prompt $10\lambda, 12\lambda, 14\lambda$
- For $|\eta| > 1.5$ $P_T > 0$ decays dominate except 6λ
- For $|\eta| > 1.5$ $P_T > 10$ GeV Prompt ν dominate except 6λ

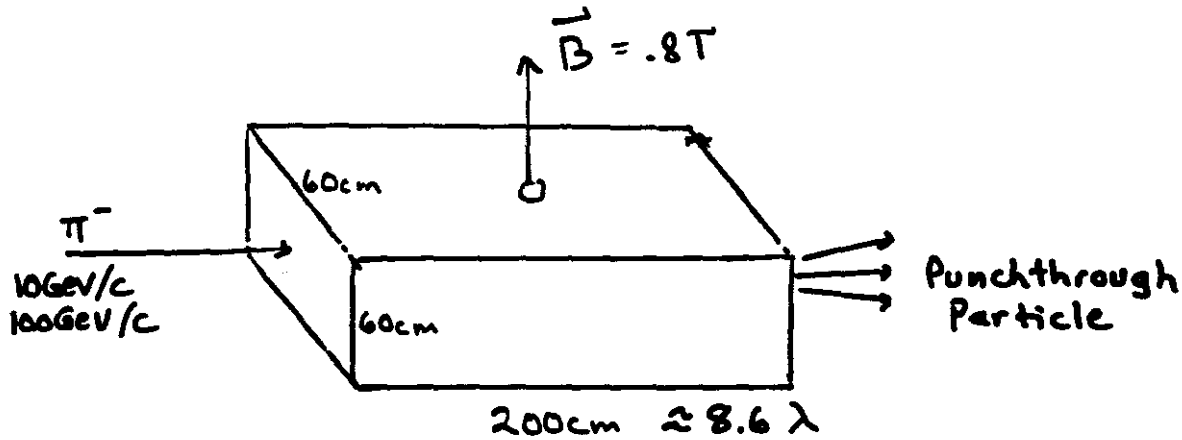
My Choice : $|\eta| < 1.5$: 12λ
$|\eta| > 1.5$: ? depends on

Issues to address:

- Need to Consider Pattern Recognition
  Can we form a trigger? New Muon Simulation Software Package on PDSF.
- Need to Consider Muons of interest (in Jets?)
  $t \to bW$
  $\hookrightarrow \mu\nu$ can we identify/measure this?
- Need to consider γ, n rate in Punchthrough (you'll see why later)

GEANT Simulation of SSCint CAL





All GEANT Process Flags set to 1 (ON)
Energy Cutoffs : 1MeV e,γ cutoffs 100keV in fibers

DO: Fibers provide free path for punchthrough?

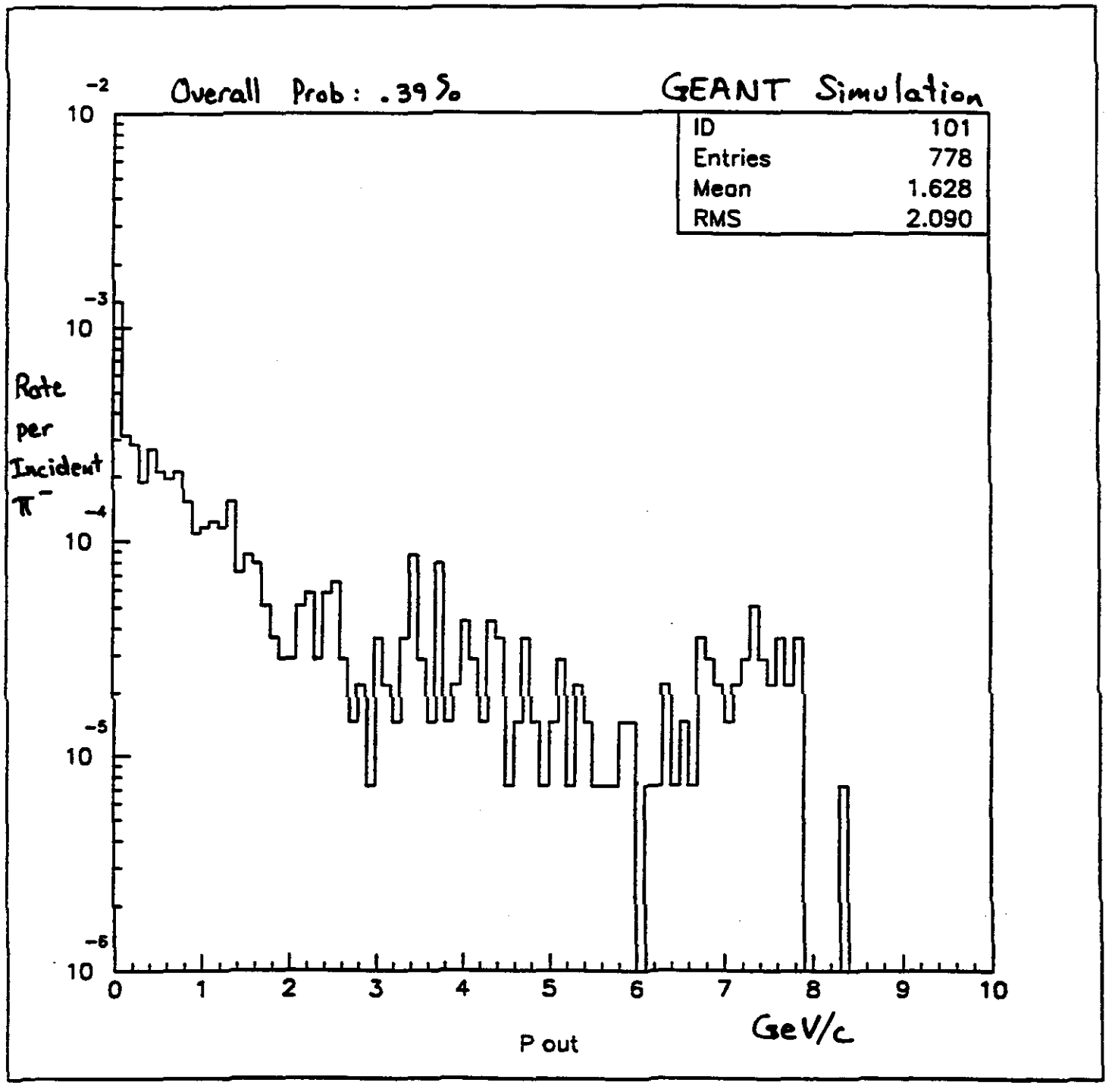
Simulation Test :

Compare

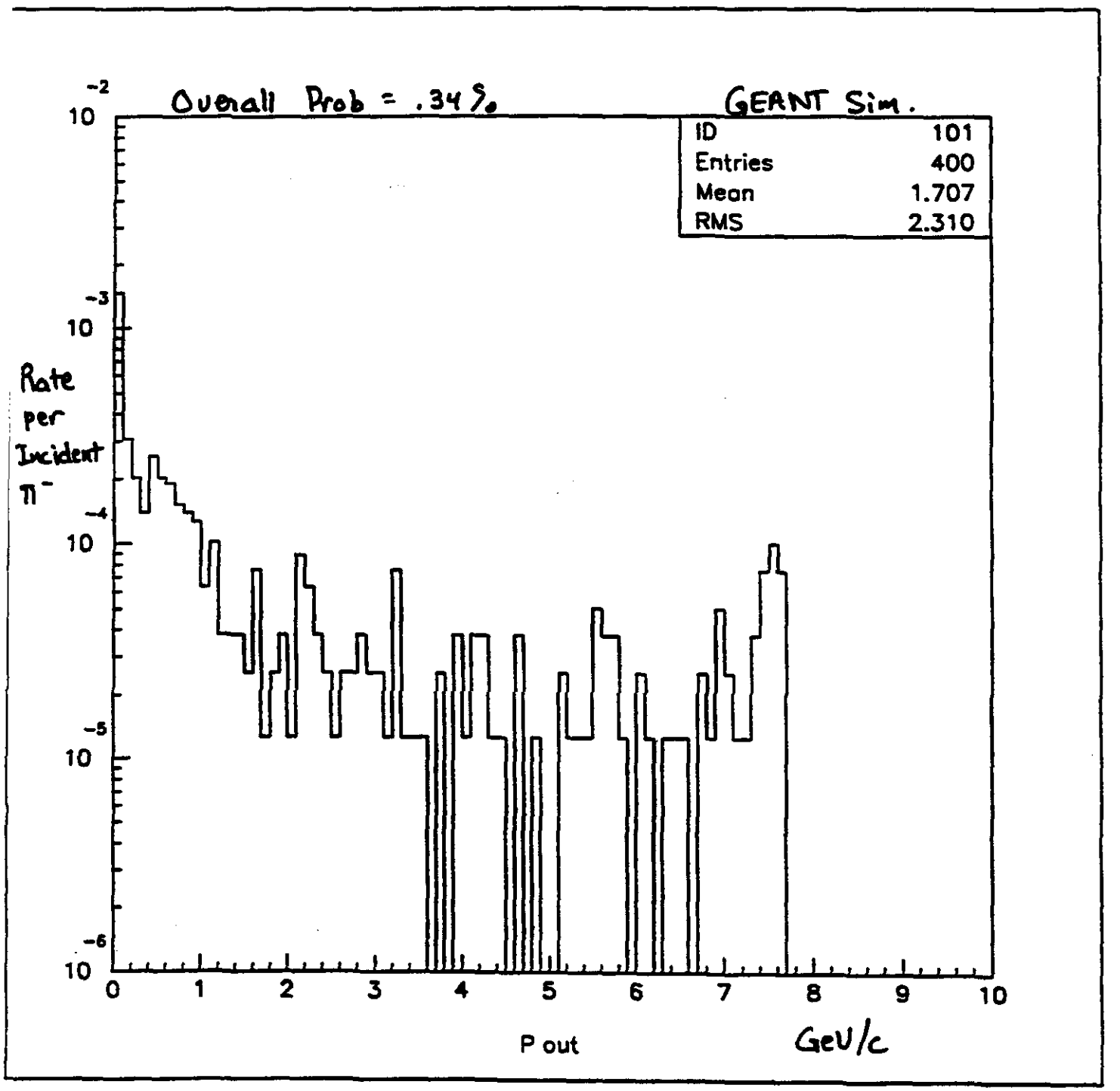
1. Calorimeter with Actual fibers in Pb Alloy absorber

2. Calorimeter with homogeneous mixture Alloy/Scintillator and same proportions & density

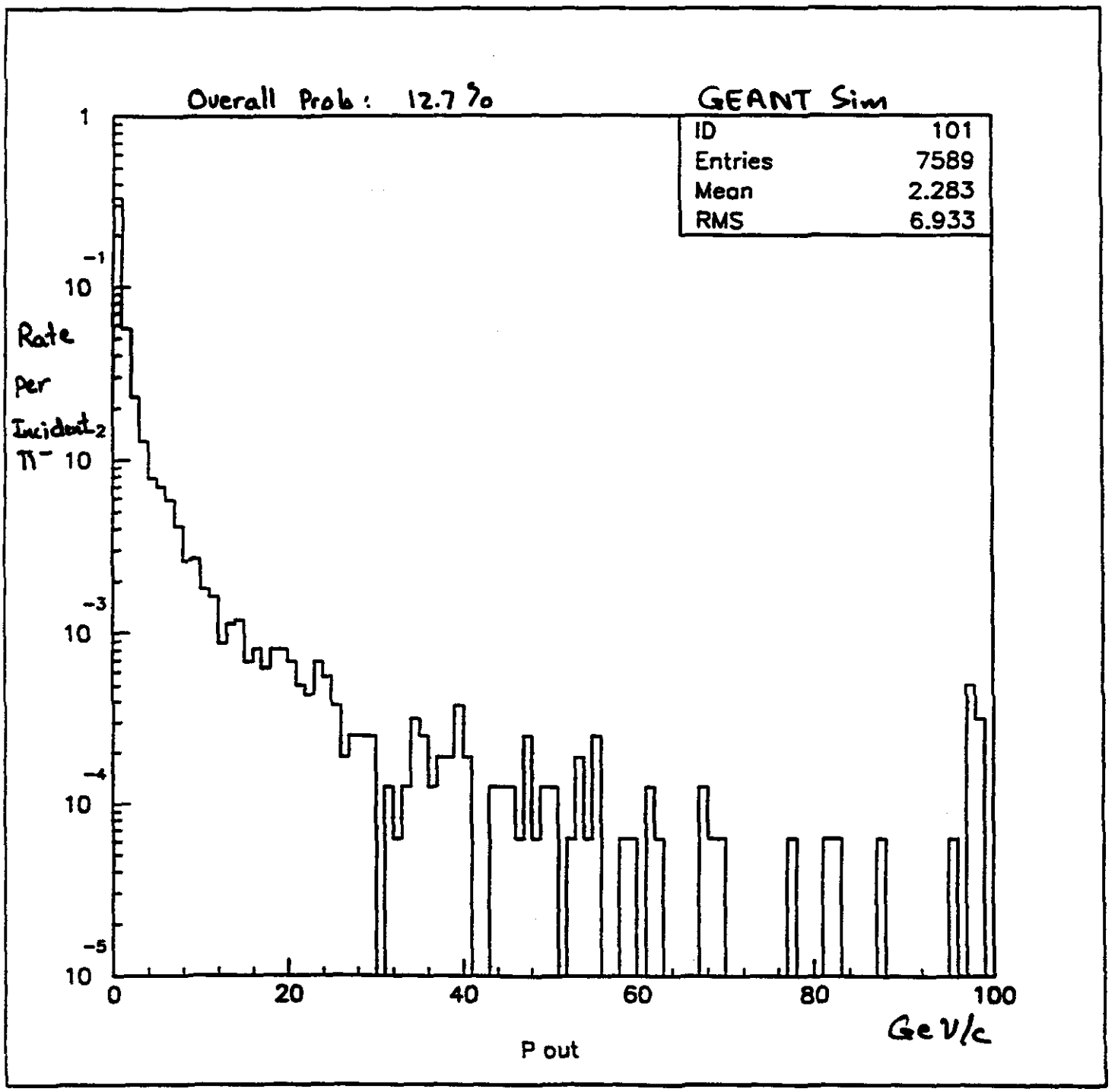
SSCIntcal: 10GeV π^- on 200cm



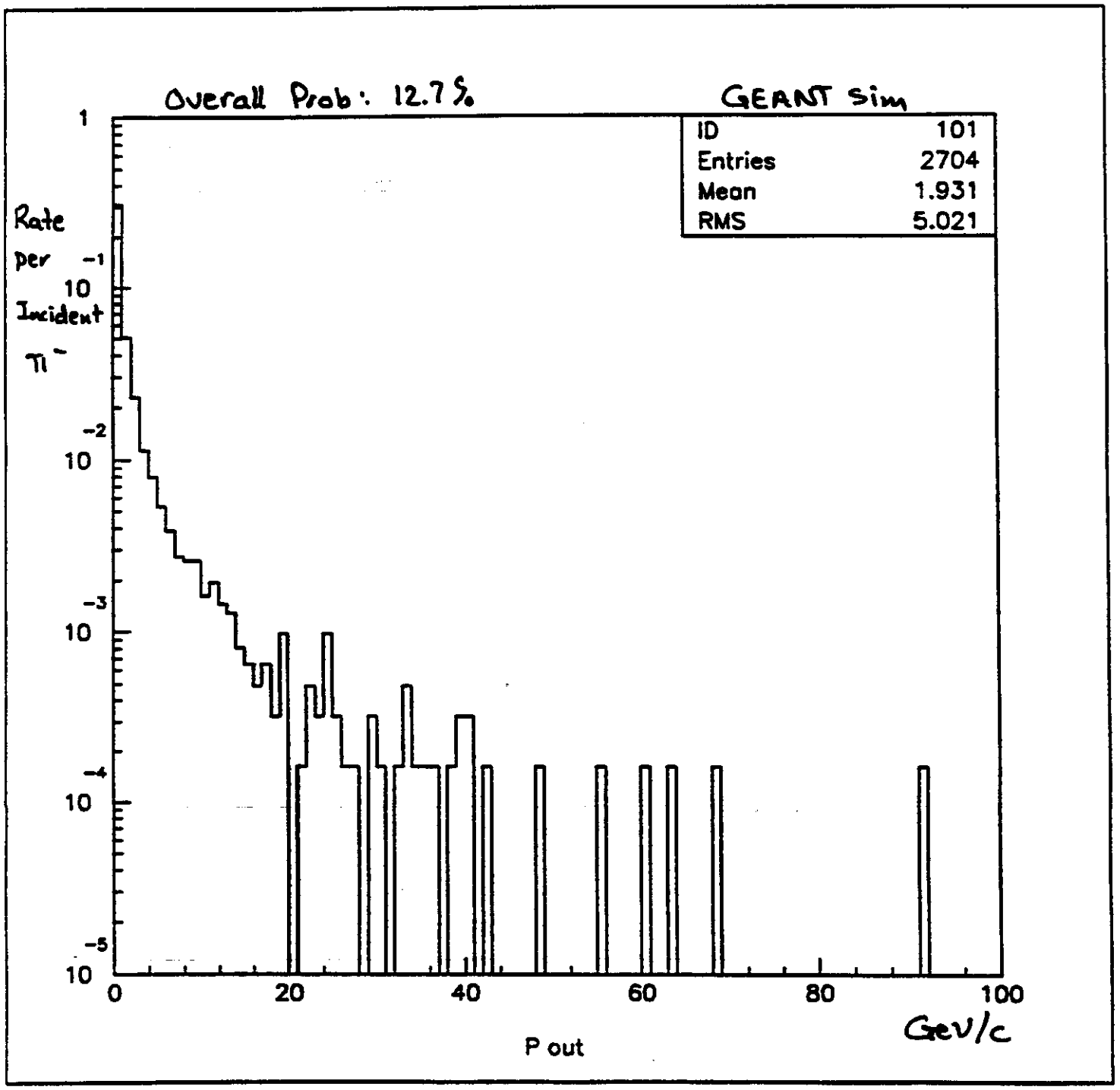
Homogeneous Cal : 10 GeV π^- on 200 cm



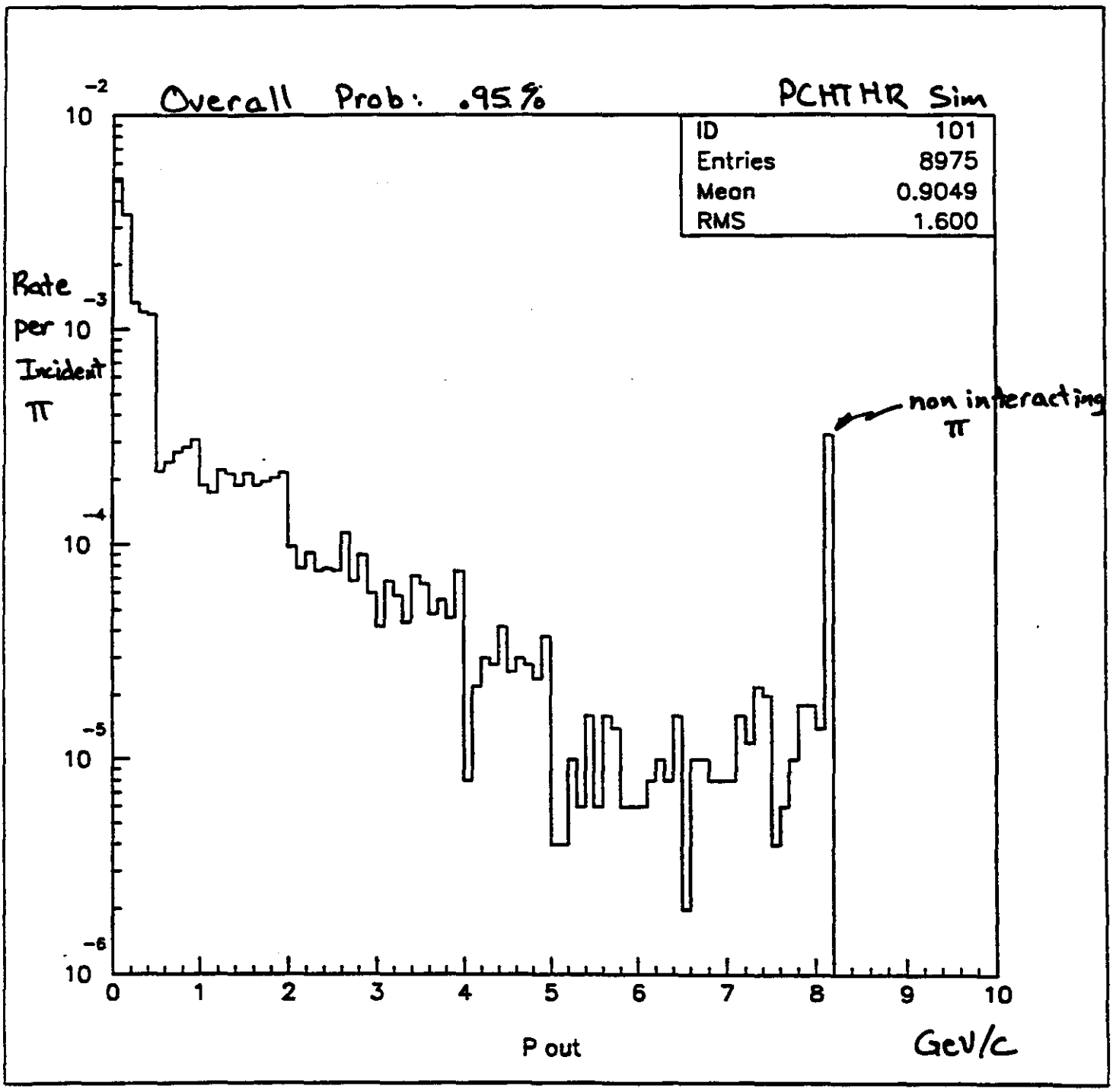
SSC intcal : 100 GeV/c π^- on 200 cm



Homogeneous Cal: 100 GeV π^- on 200 cm



PCHTHR Sim: 10GeV π on 8.6 λ



Conclusions

- No significant difference in
  - Punchthrough Probability
  - Punchthrough Multiplicity
  - Momentum Spectrum of Punchthrough Particles

  between SSCintcal with fibers (3mm OD) and a Homogeneous calorimeter of same composition/density

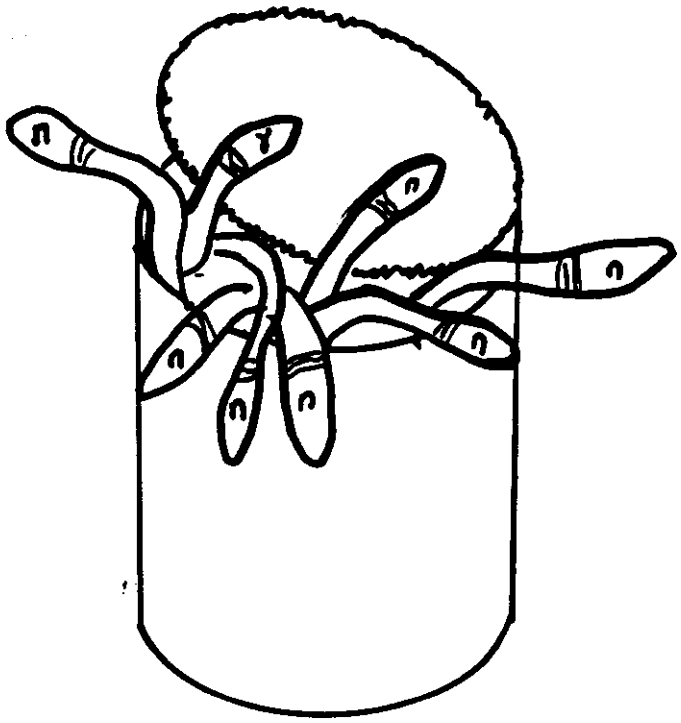
- Punch through Probability for SSCintcal factor $\gtrsim 2$ less than PCHTHR (Iron Absorber)
  The excess is predominantly at low momentum (output)

First Look at Punchthrough of γ, n
(very Preliminary)

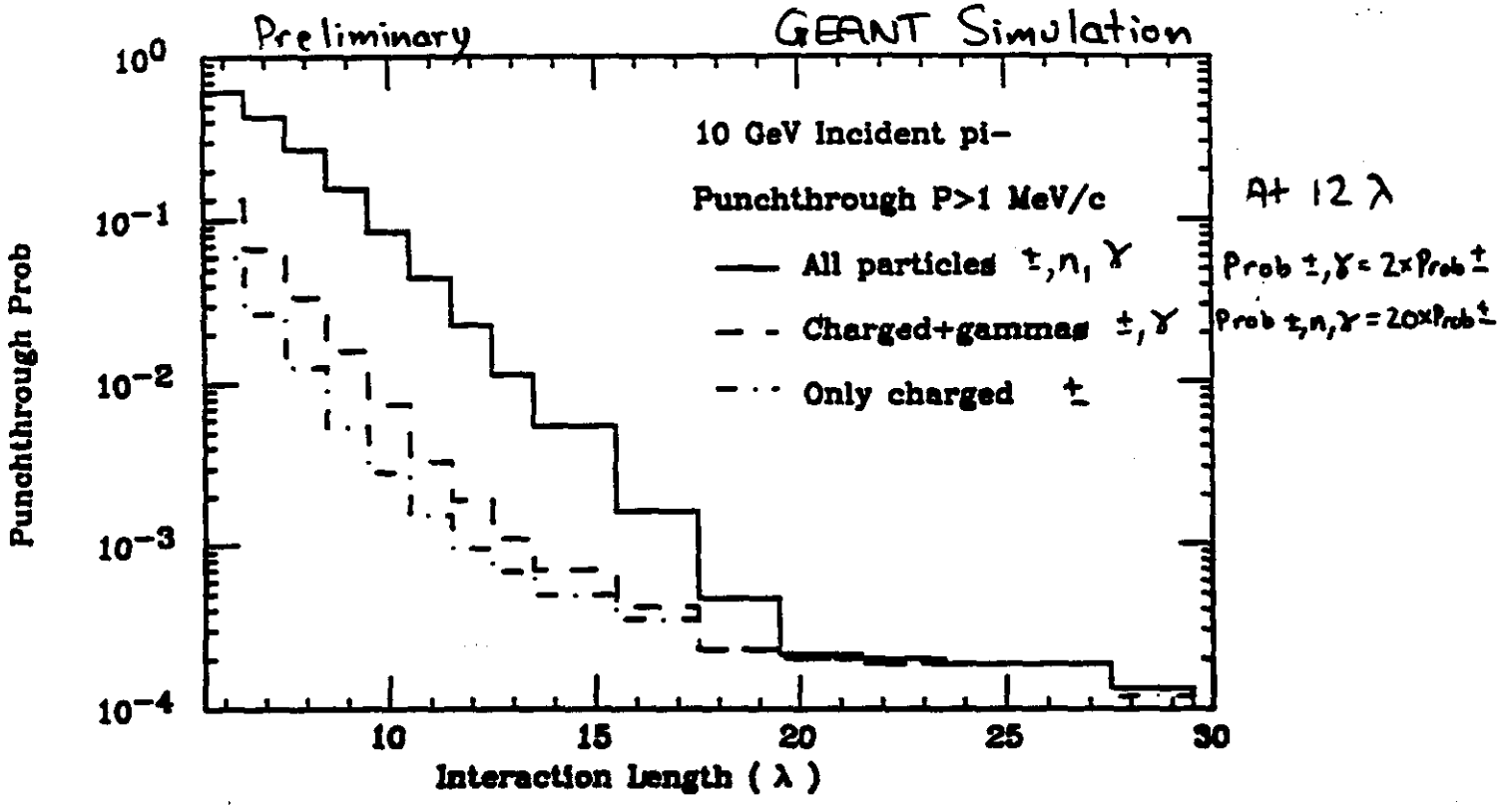
- Some γ exiting Calorimeter will interact in the mat'l of muon detectors

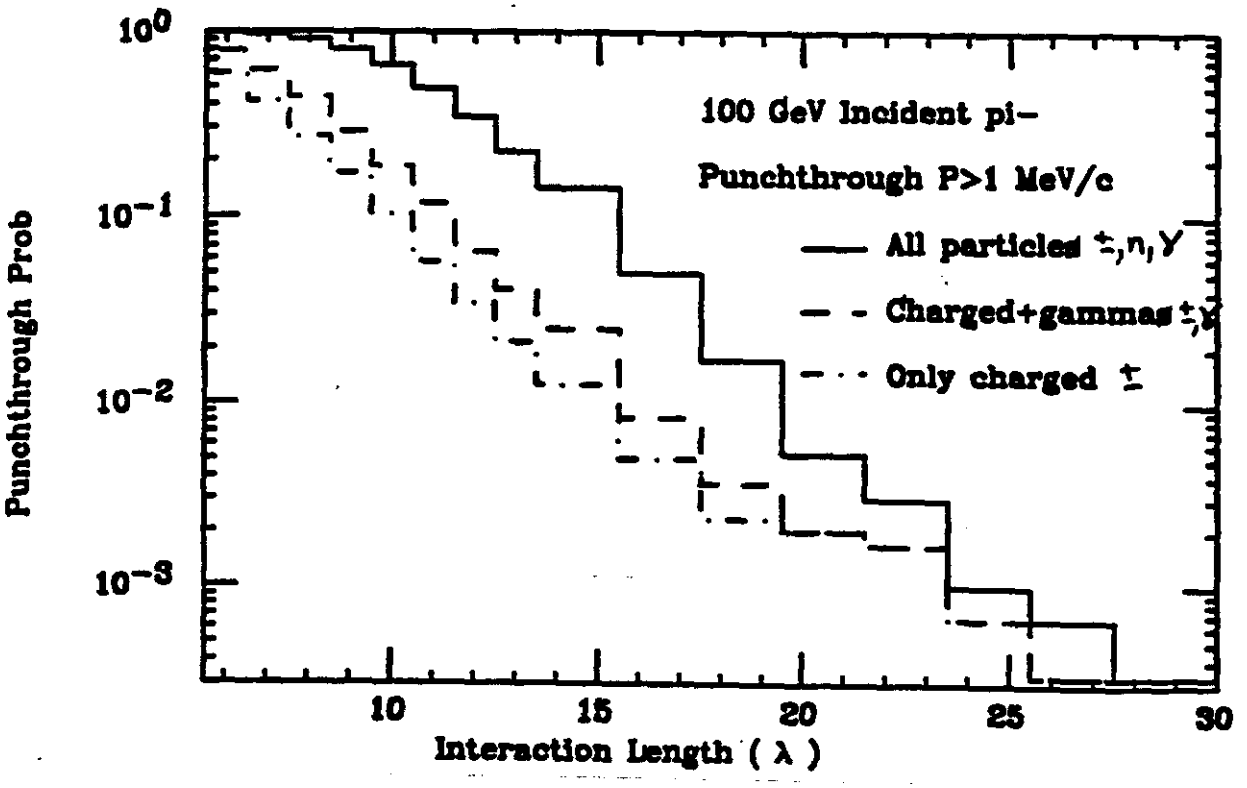
- Some Muon detectors are neutron sensitive

What is the Flux of neutrons/gammas exiting Calorimete



- Use same iron block geometry for <u>GEANT</u> Study
- Enable output of γ, n as well as charged particles
- Energy Cutoffs set to 1MeV





How Sensitive are Muon Detectors to Neutrons?

Conclusions (Preliminary)

- GEANT Simulations shows that for 1MeV Thresholds and Calorimeter thickness 8-16 λ, Punchthrough probability increased by factor 10-20 when neutrons/Gammas included.

What Now?

- Is GEANT (and I) correct? Verify result. Validate GEANT

- Determine Minimum Energy Cutoffs suitable for n, γ.

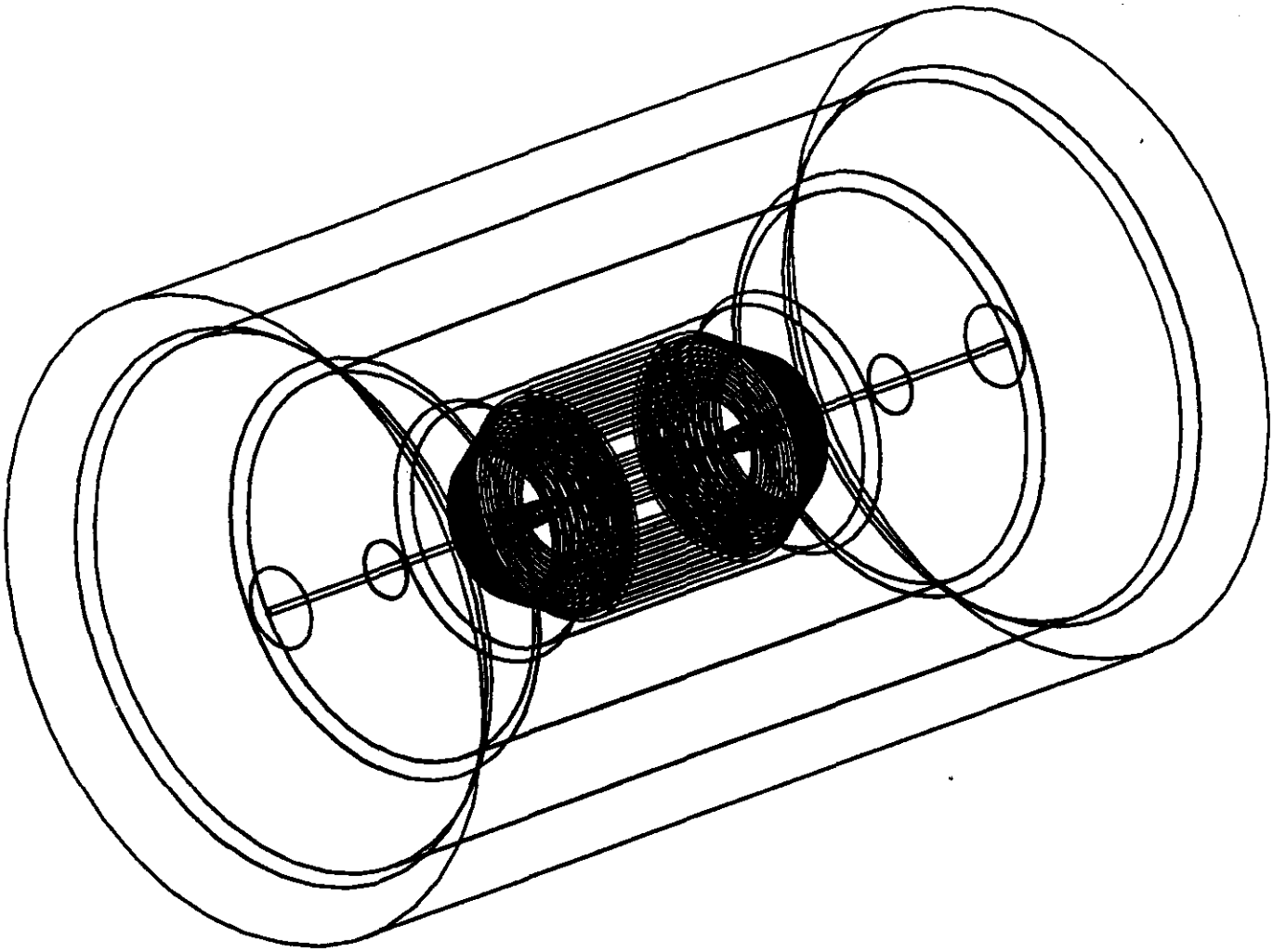
- Identify neutron sensitive detectors and simulate neutron-induced signals (use GEANT?)

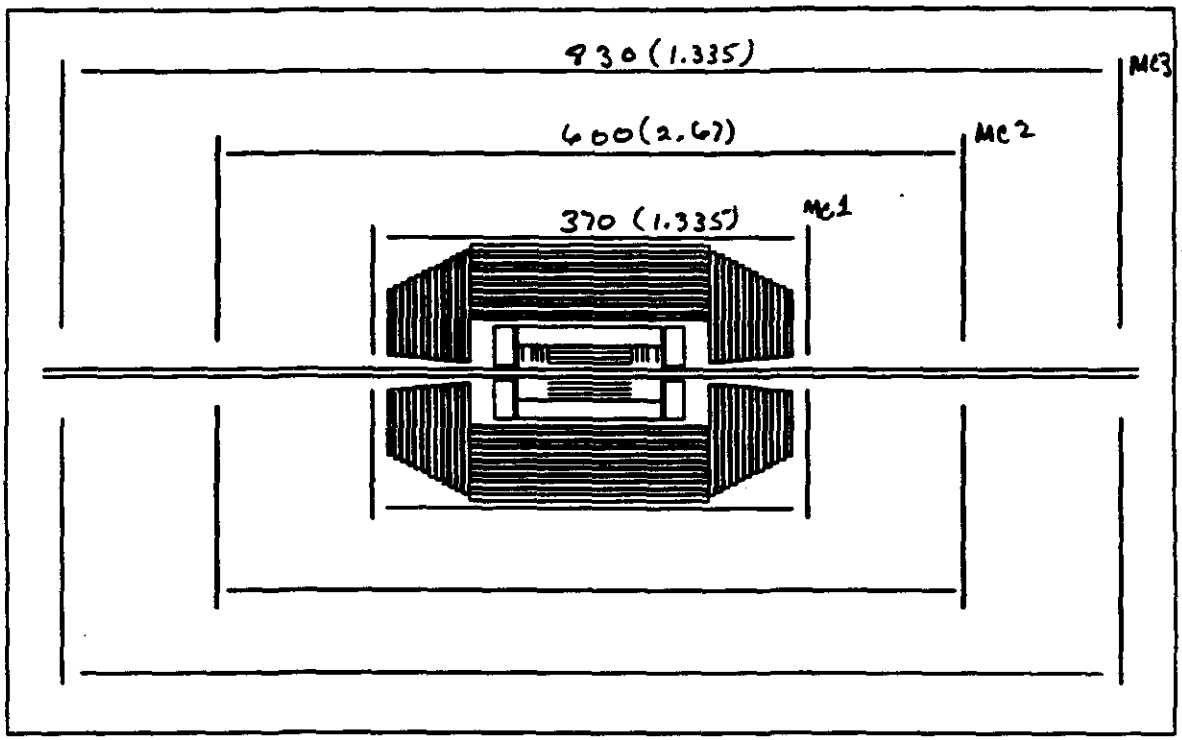
NEED HELP

- Prepare Probability Tables including n, γ Takes 1-2 months for 1MeV Cutoffs

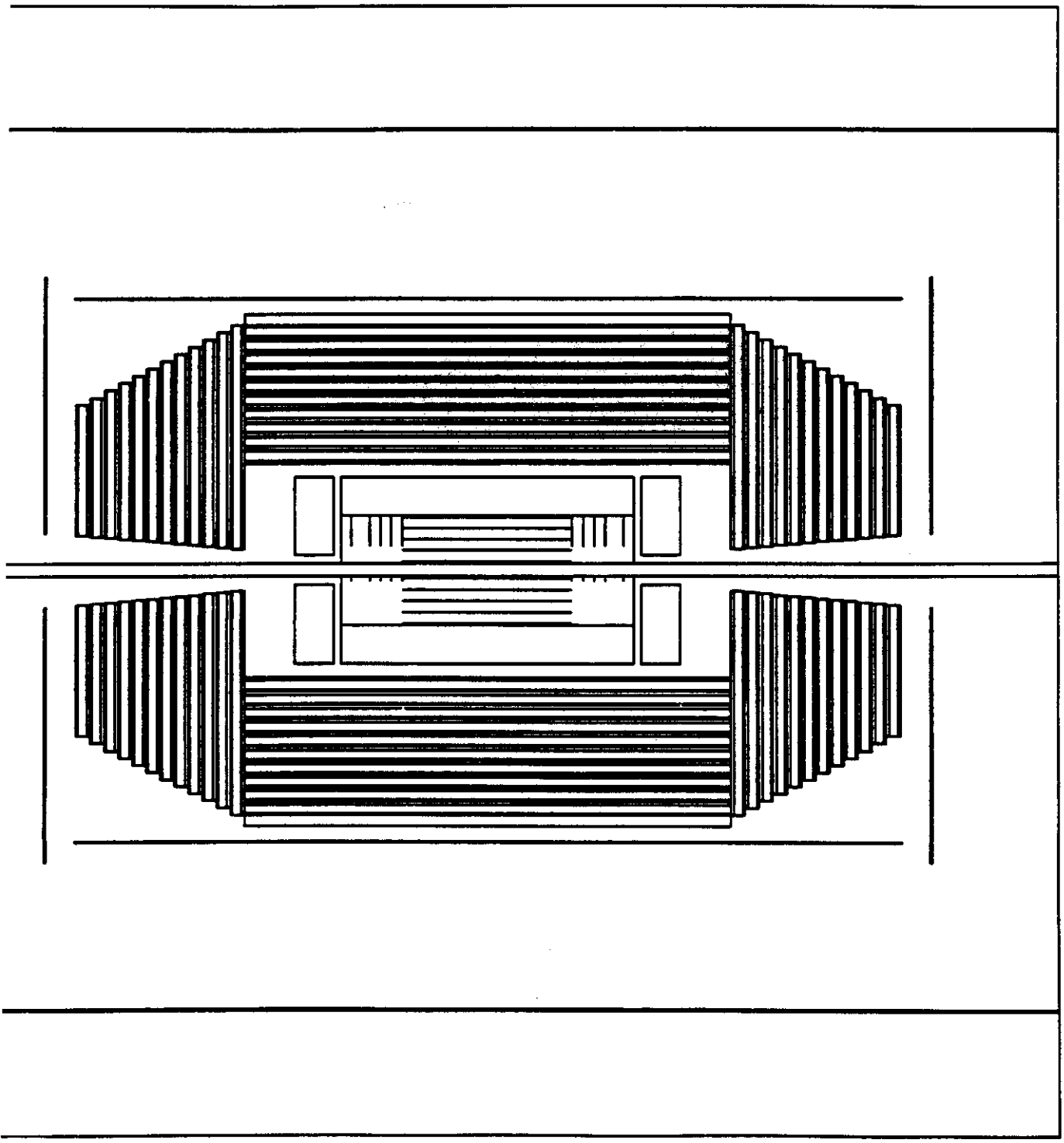
P. DINGUS 1/22/92

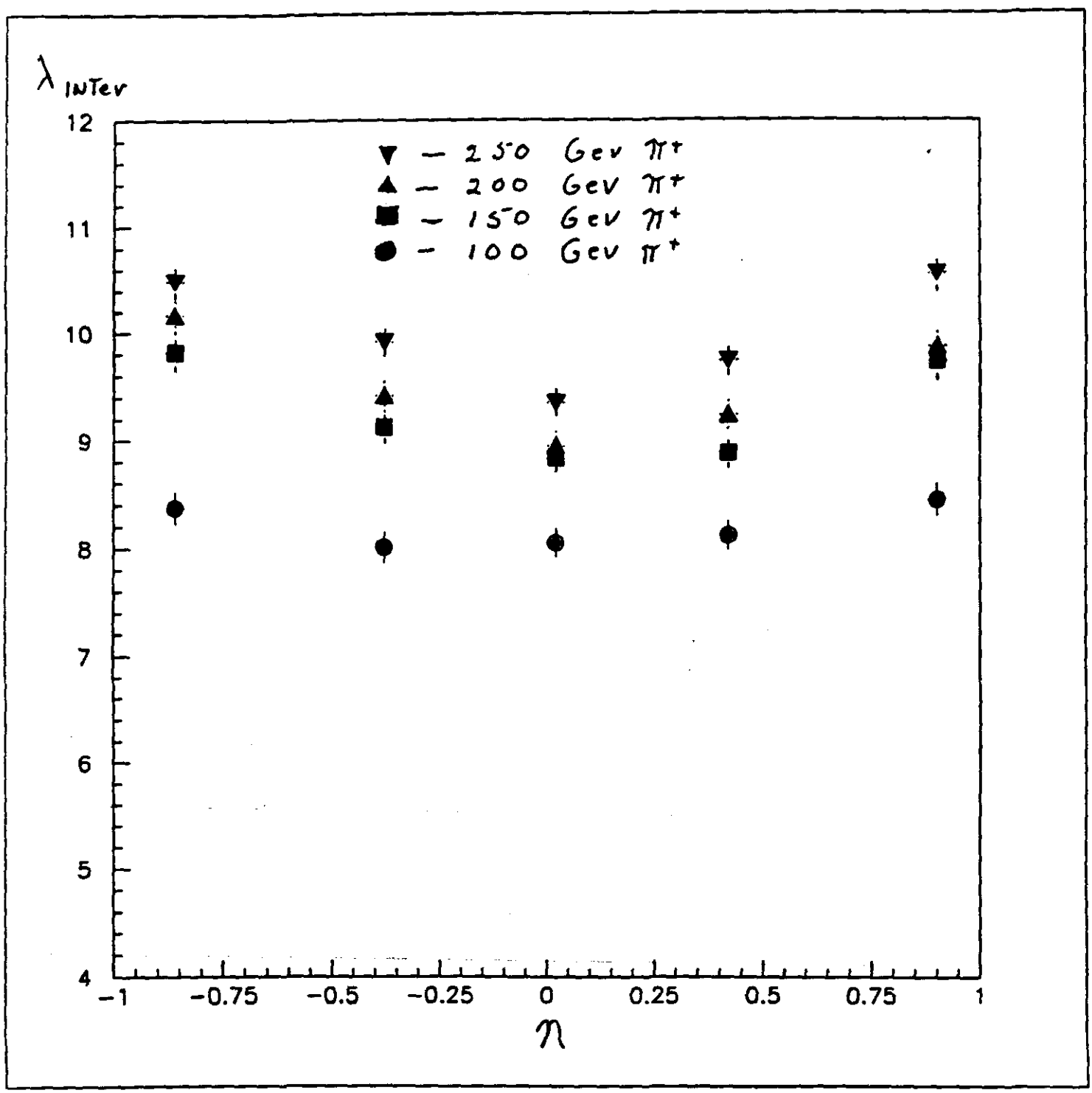
SSCL





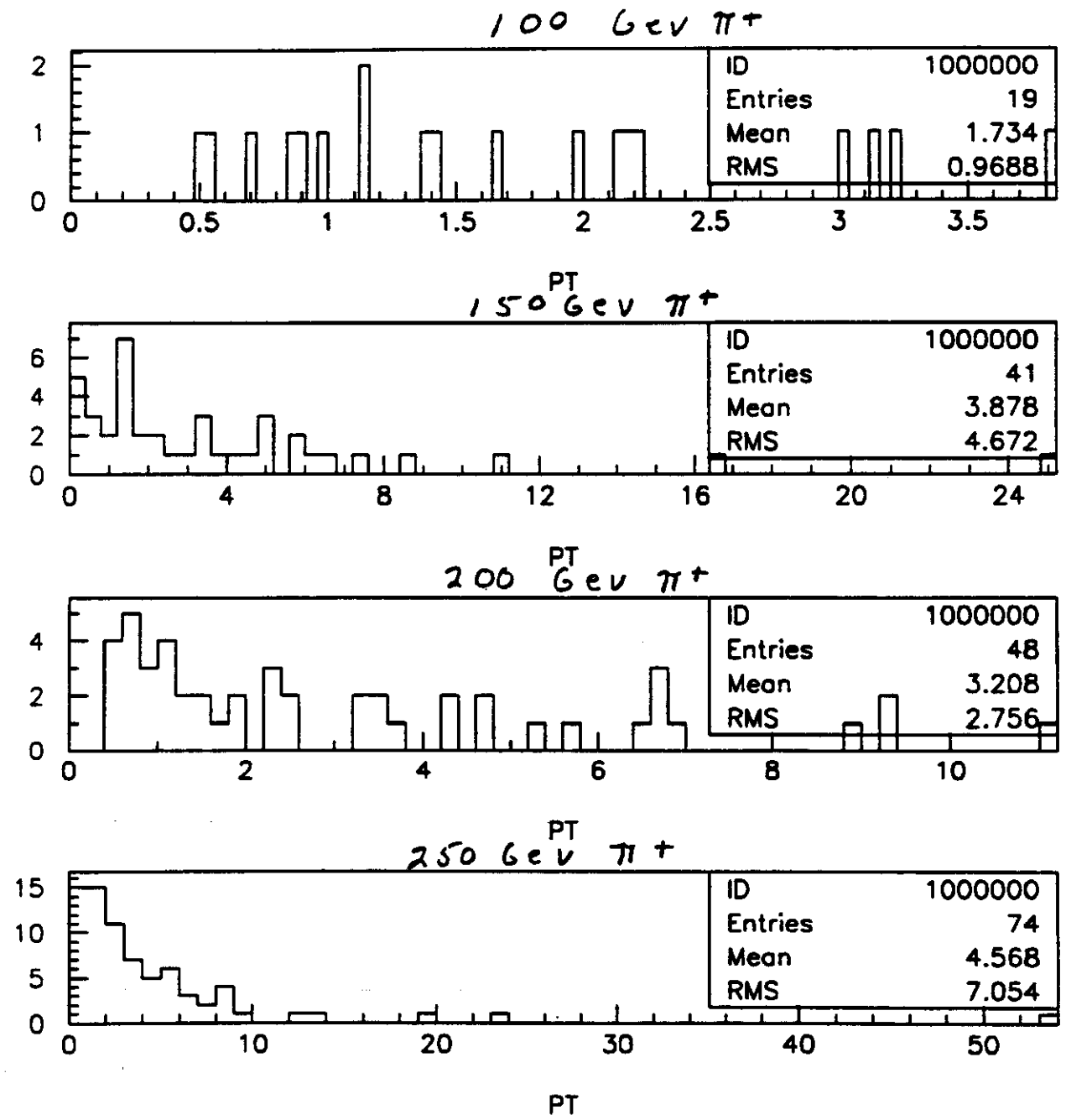
Insulizing sand




λ INTev
12
11
10
9
8
7
6
5
4
▼ — 250 Gev π+
▲ — 200 Gev π+
■ — 150 Gev π+
● — 100 Gev π+
−1
−0.75
−0.5
−0.25
0
0.25
0.5
0.75
1
η

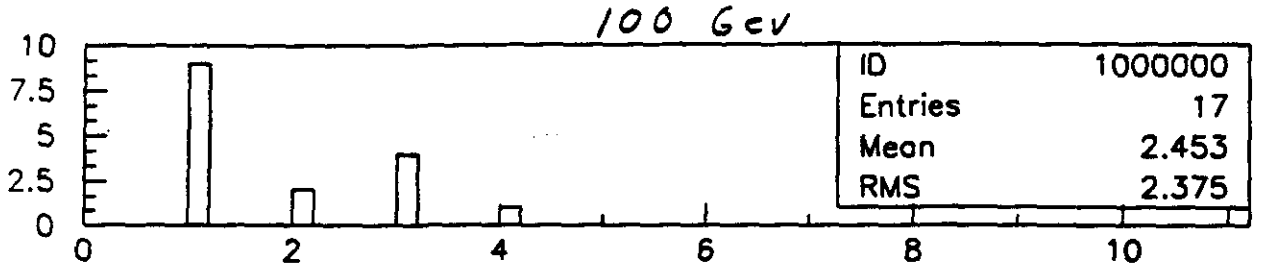
FOR π^+

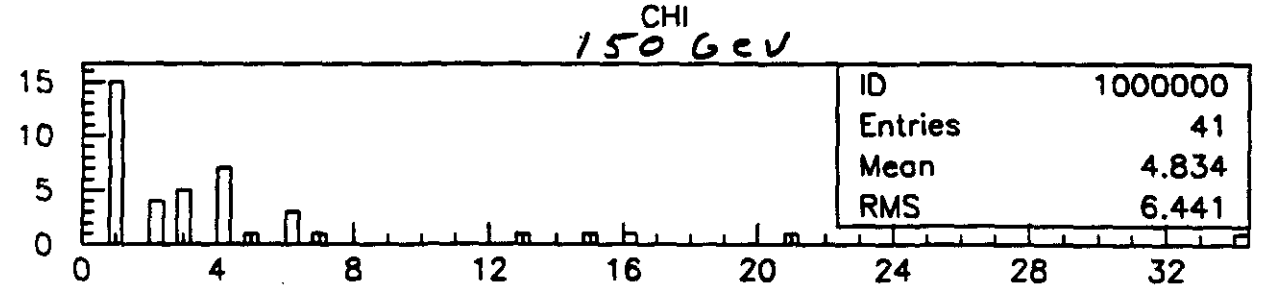
TOTAL # OF EVENTS WITH C.P. IN 3 S.L.

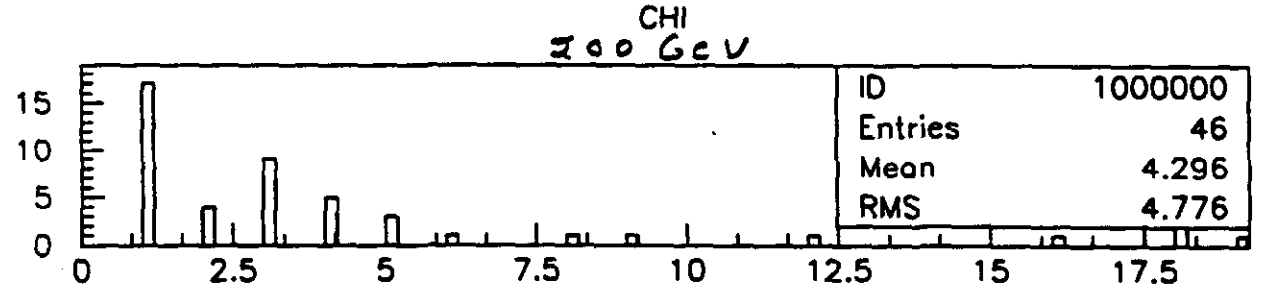


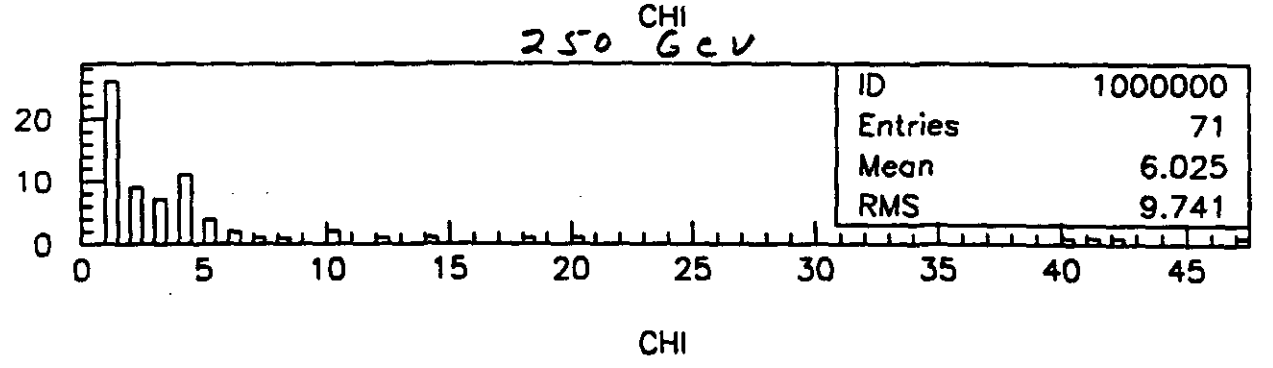
OF CHARGED PARTICLES

FOR π^+ EVENTS / SL

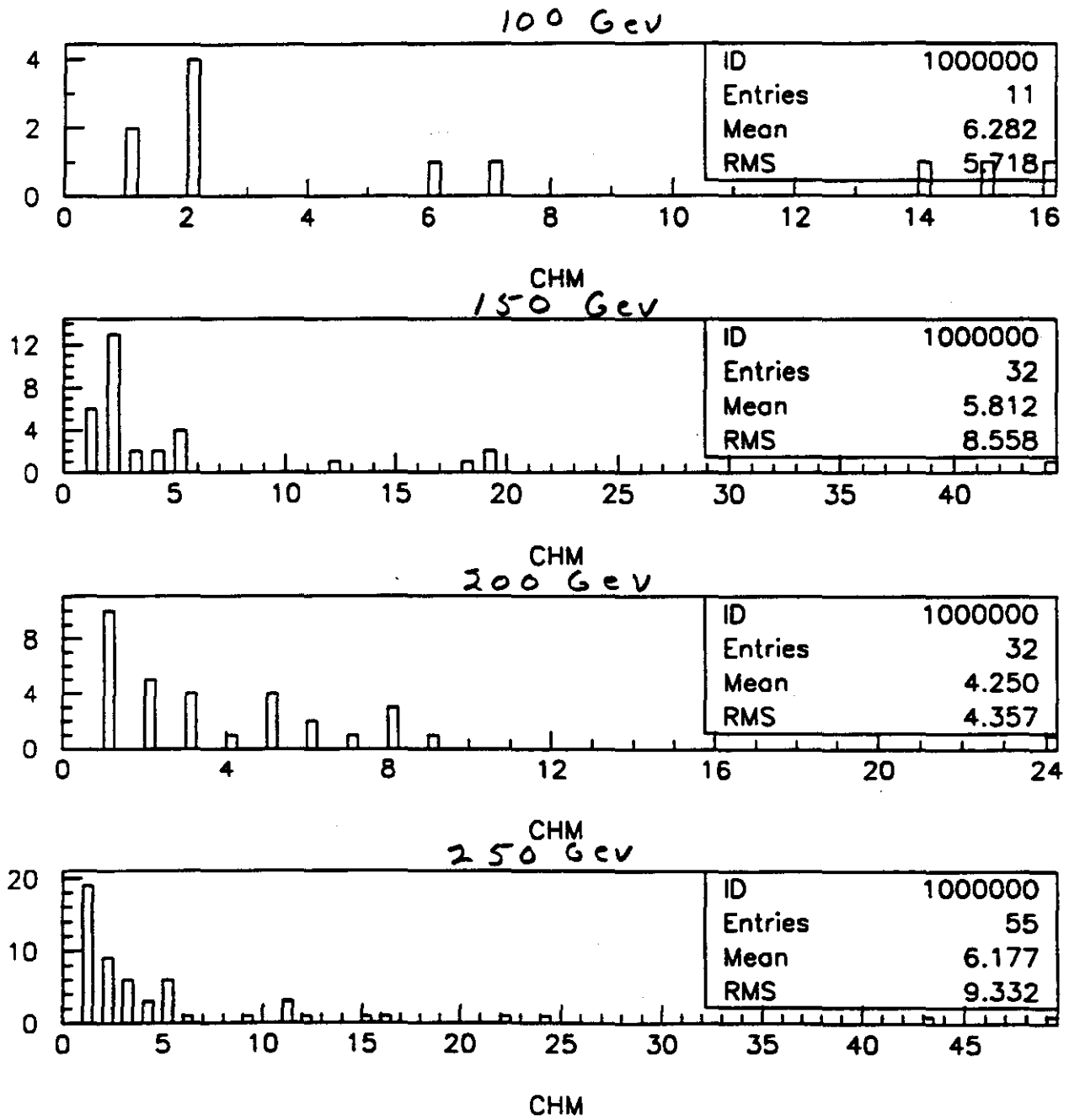




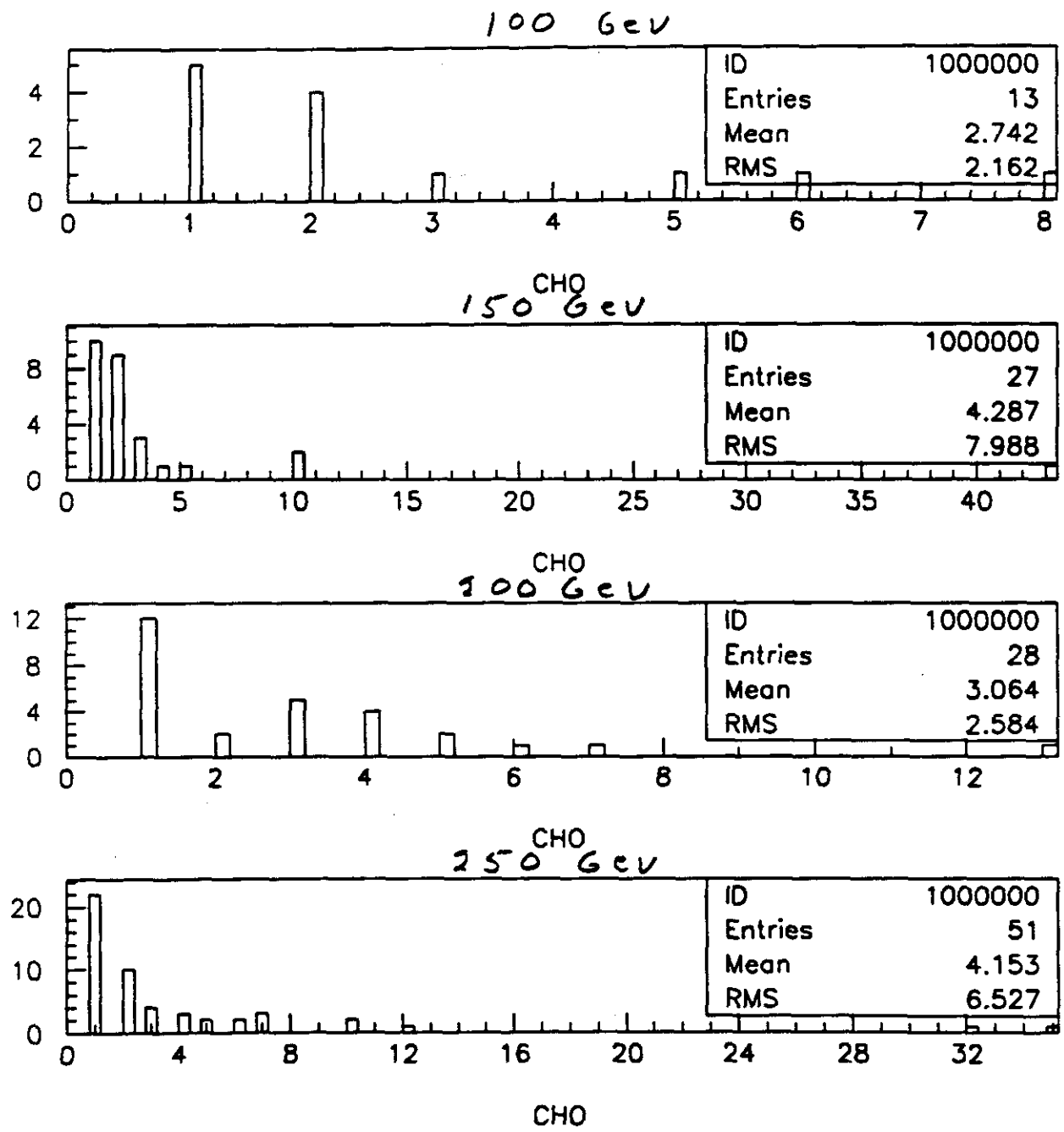




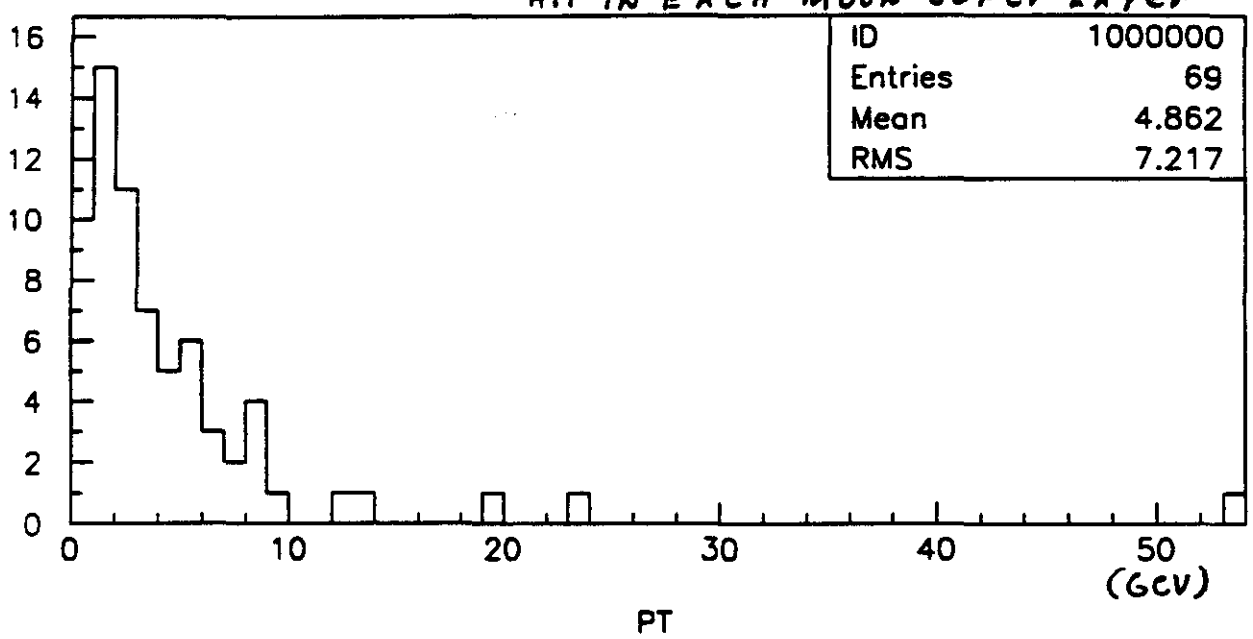
π^+ # CHARGED PARTICLES

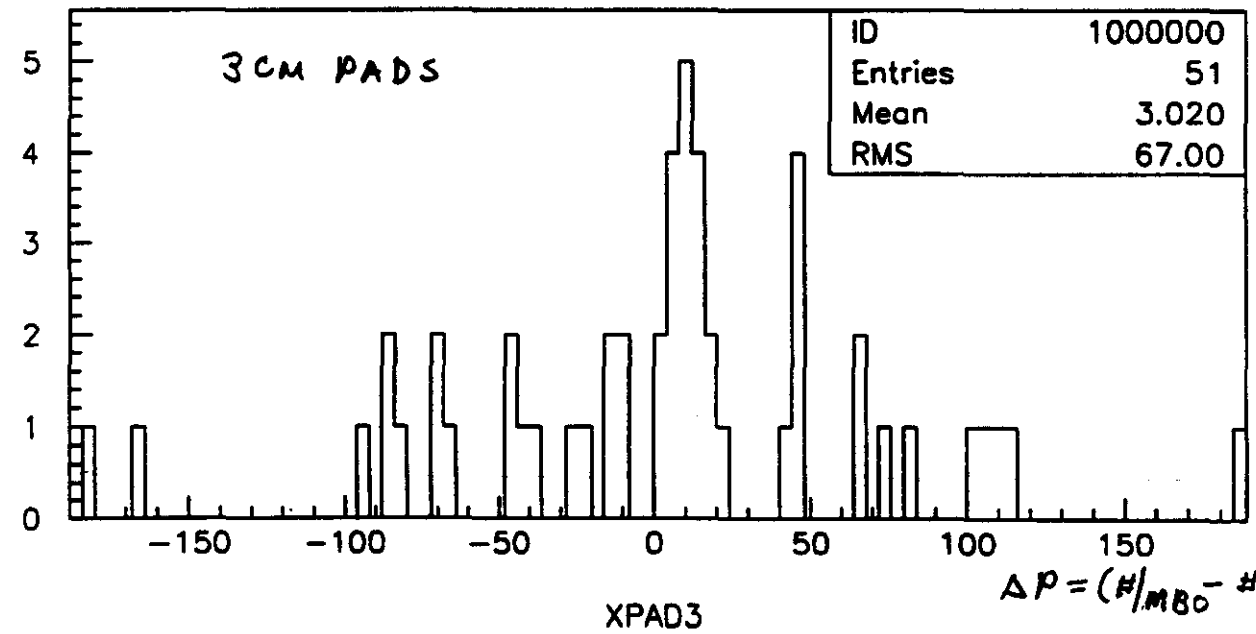


π^+ # CHARGED PART'S

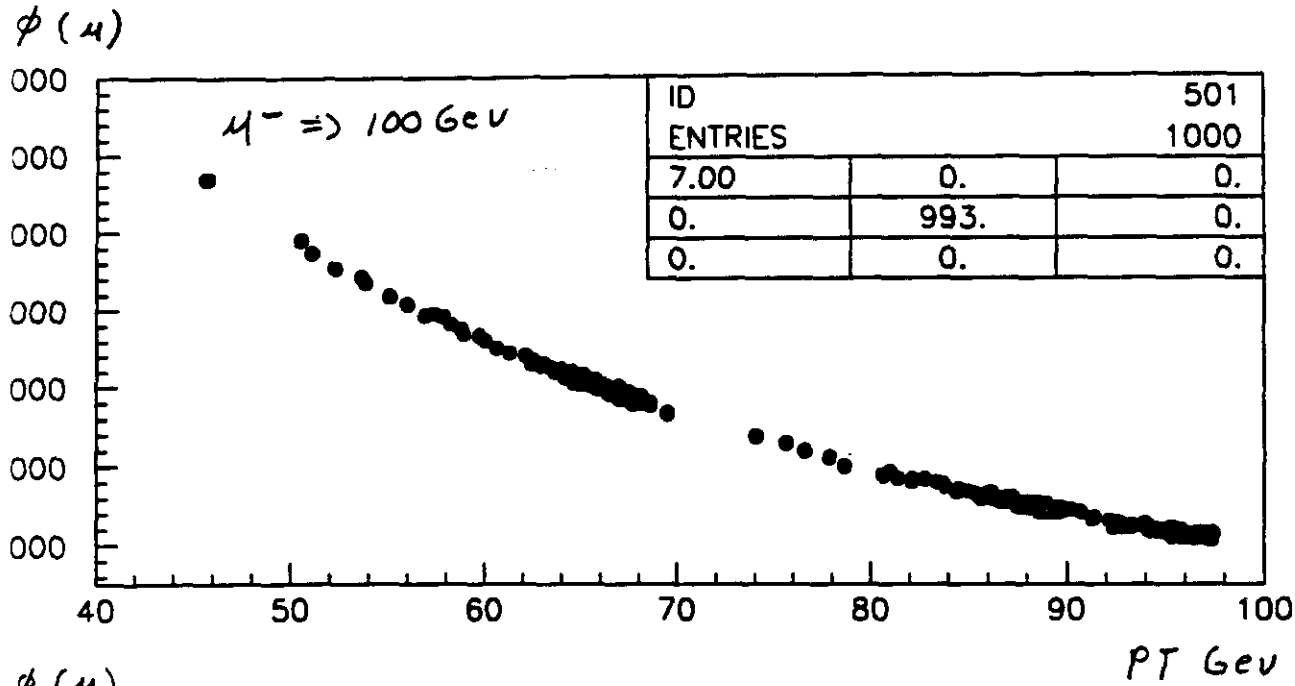


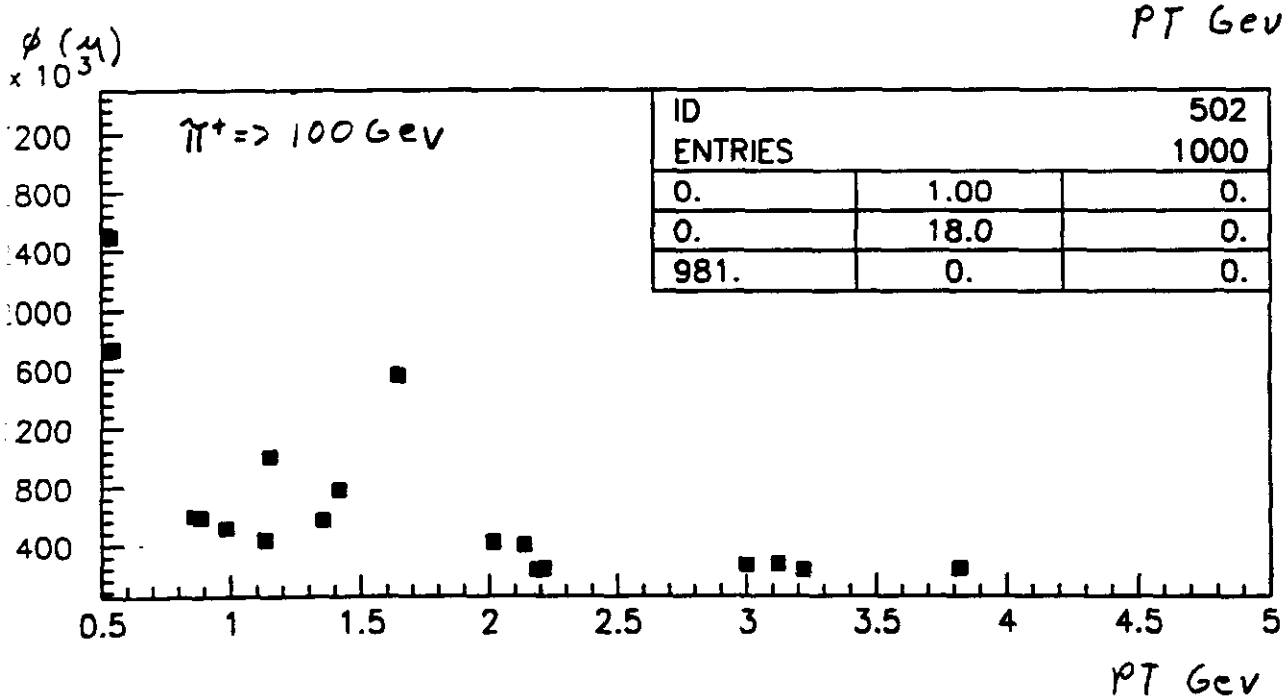
250 GeV π^+ (LEADING PARTICLE)
HIT IN EACH MUON SUPER LAYER

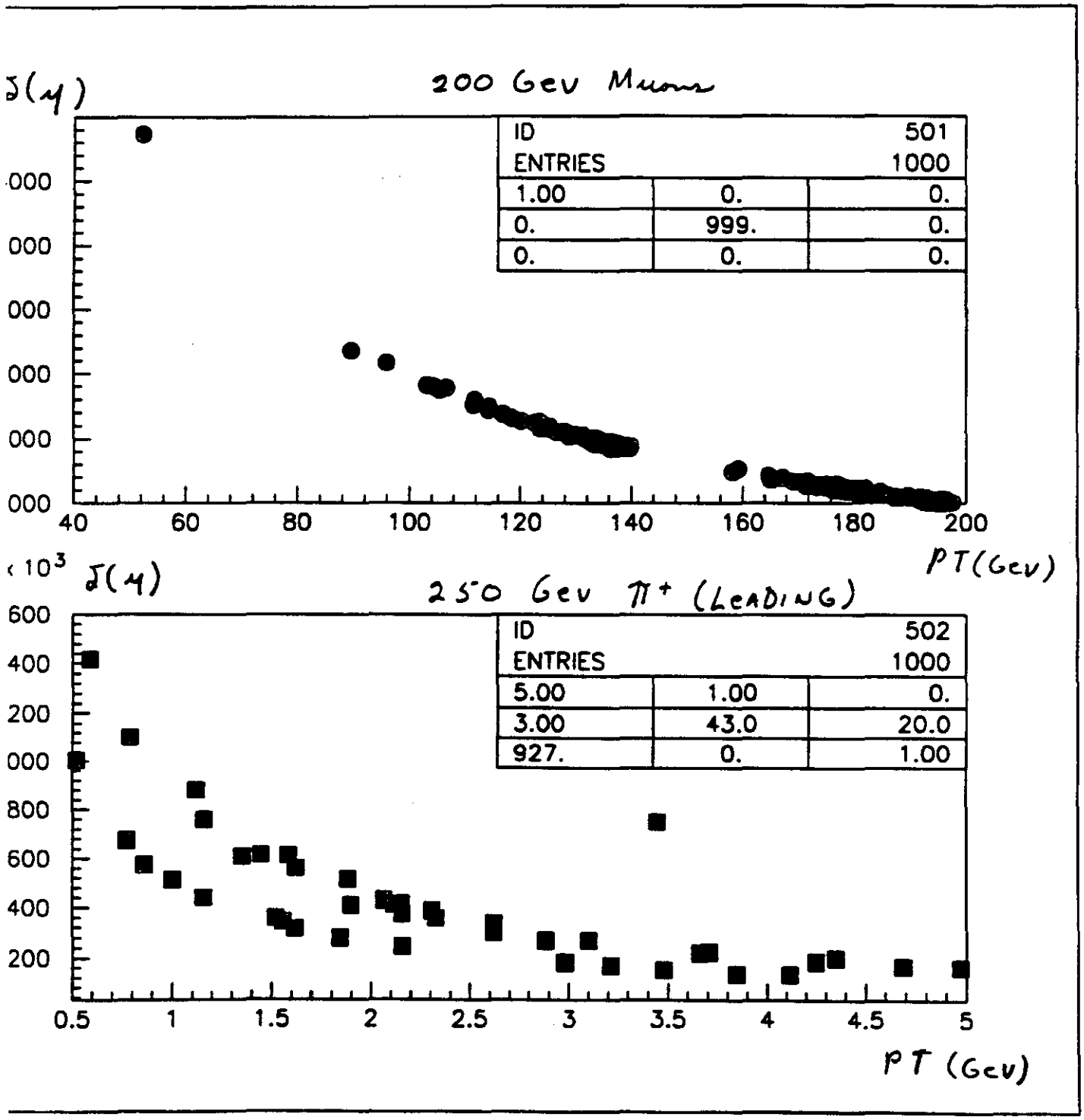


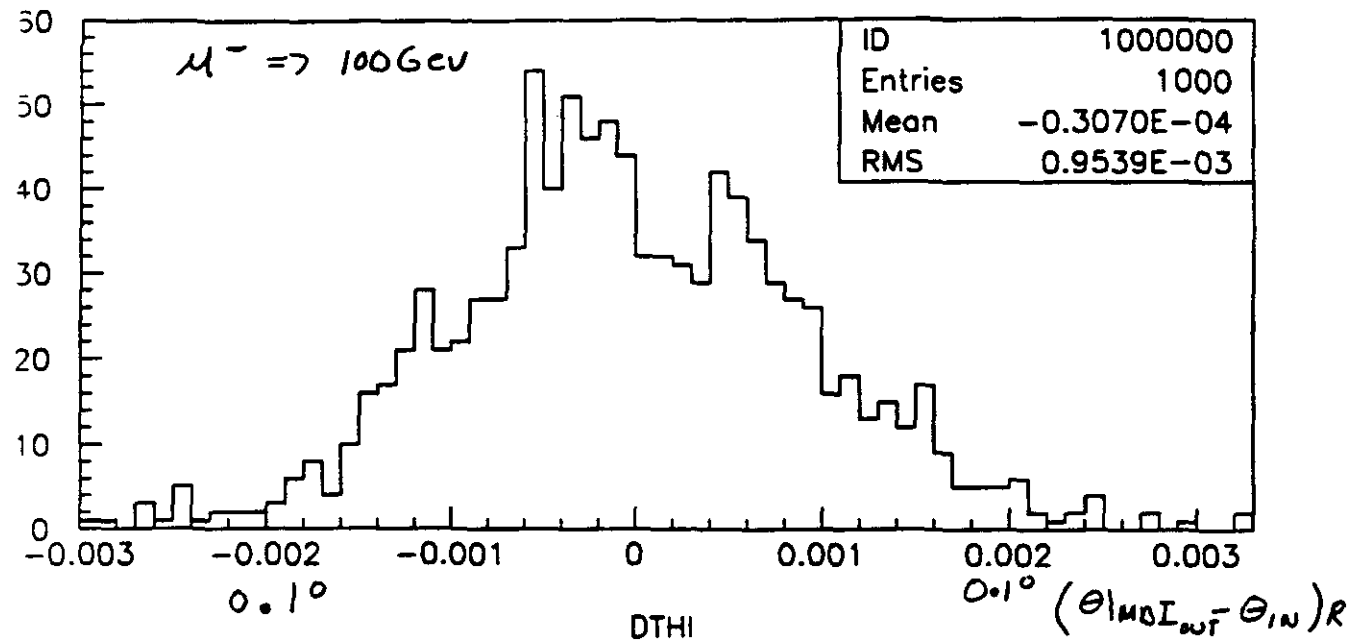


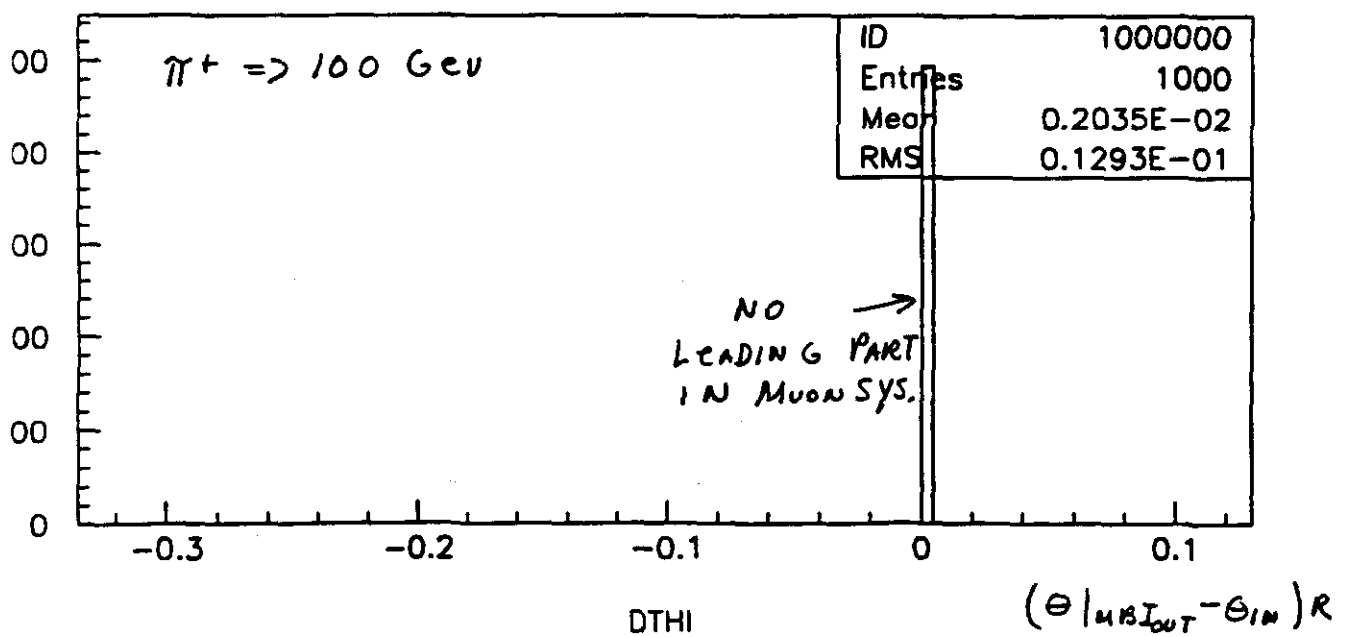
$\Delta P = (\#/_{MBO} - \#/_{MBI})$


φ (μ)
μ⁻ => 100 Gev
ID 501
ENTRIES 1000
7.00 0. 0.
0. 993. 0.
0. 0. 0.
000
000
000
000
000
000
40 50 60 70 80 90 100
PT Gev

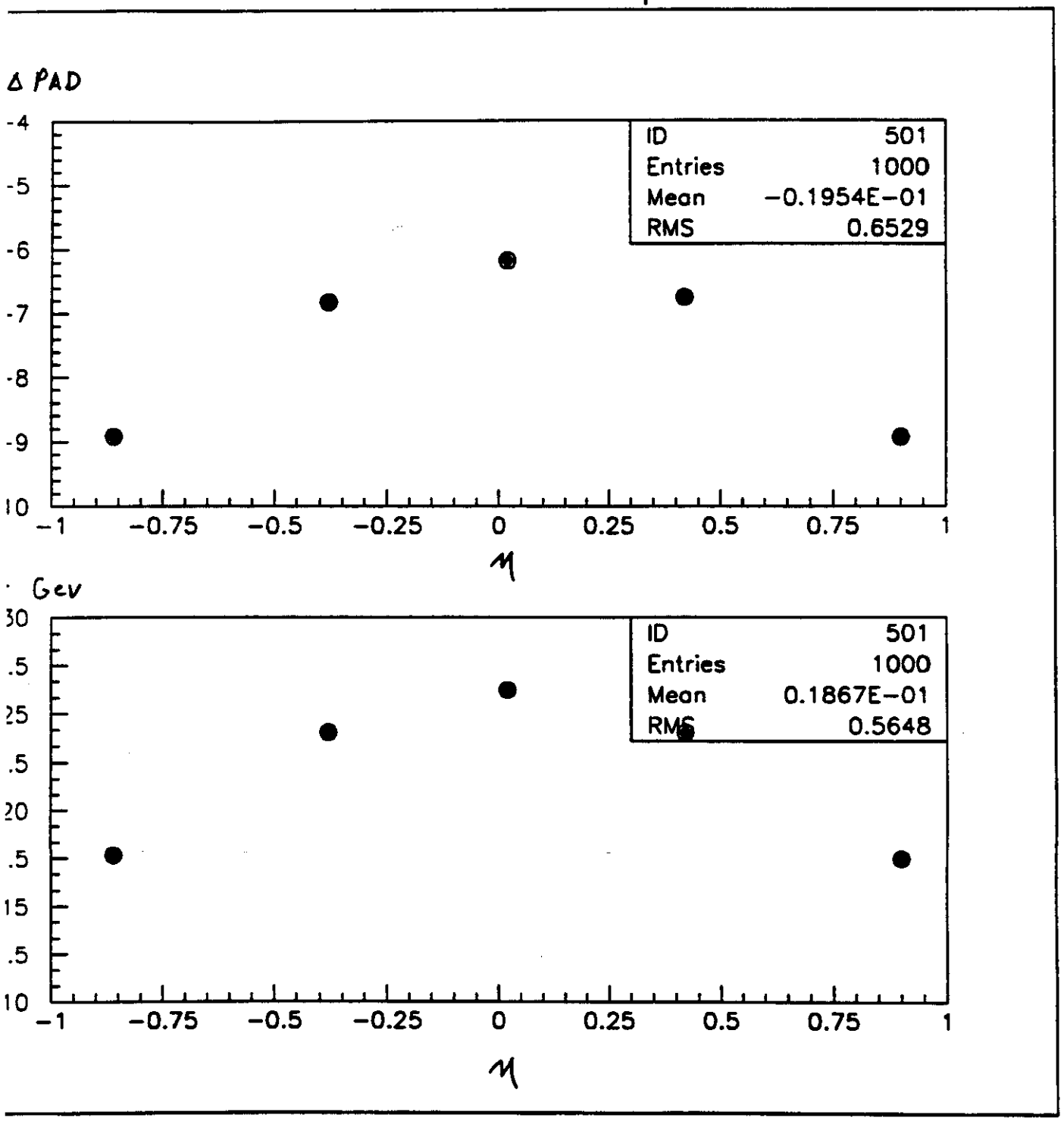

φ (μ)
x 10³
π⁺ => 100 Gev
ID 502
ENTRIES 1000
0. 1.00 0.
0. 18.0 0.
981. 0. 0.
200
800
400
000
600
200
800
400
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
PT Gev

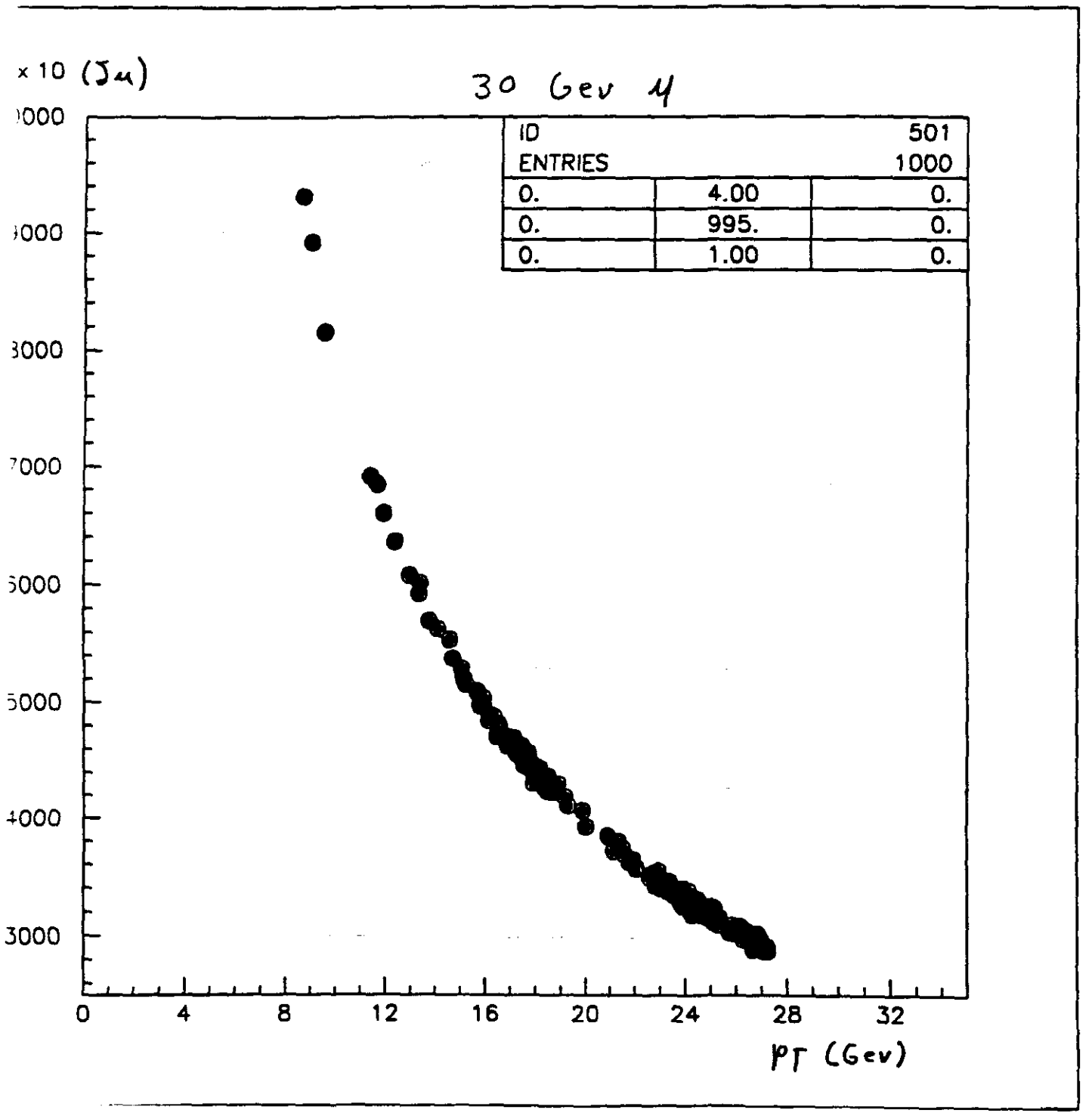

200 Gev Muons
ID 501
ENTRIES 1000
1.00 0. 0.
0. 999. 0.
0. 0. 0.
40 60 80 100 120 140 160 180 200
PT(Gev)
250 Gev π+ (LEADING)
ID 502
ENTRIES 1000
5.00 1.00 0.
3.00 43.0 20.0
927. 0. 1.00
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
PT (Gev)

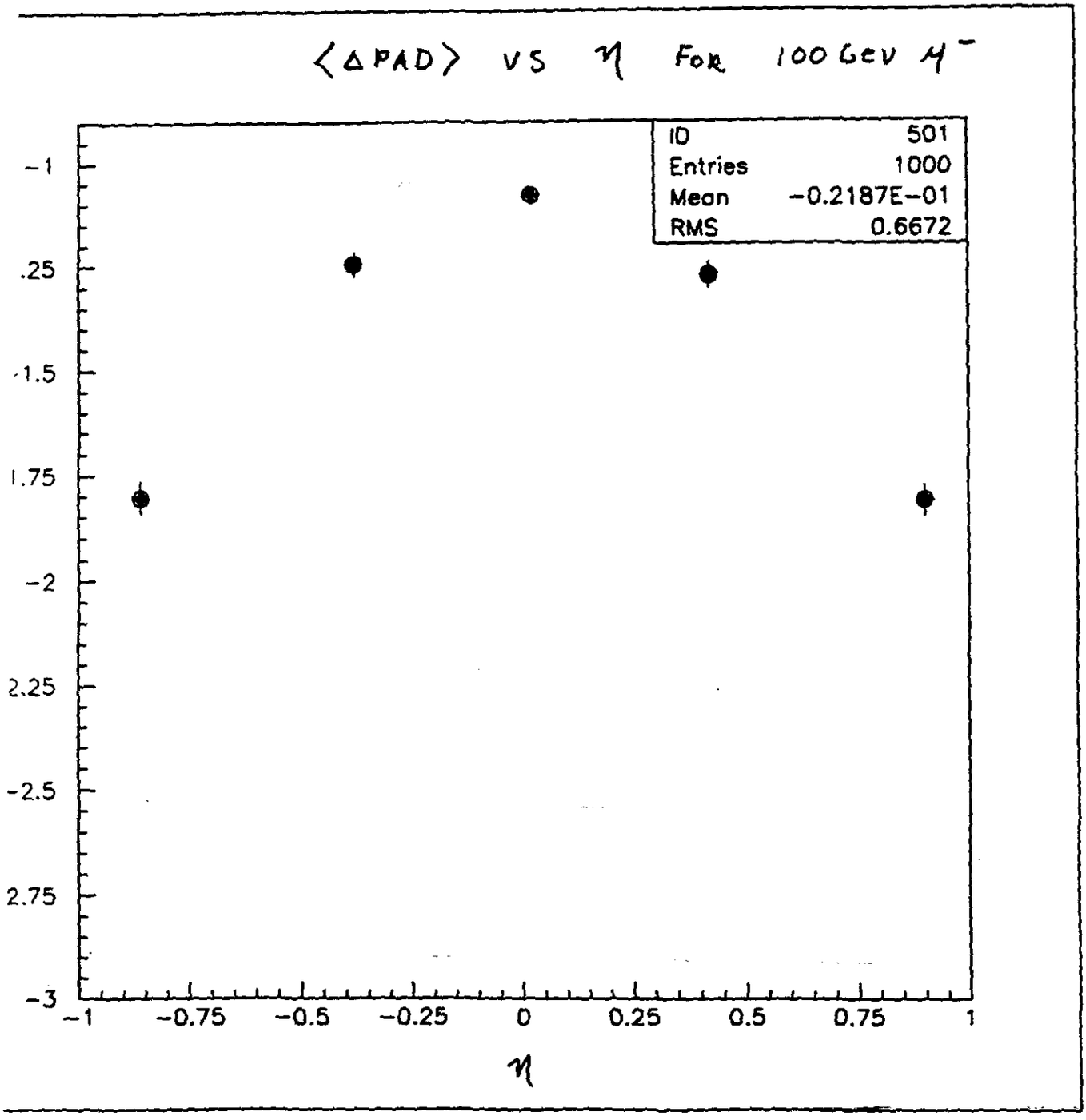

μ⁻ => 100Gev
ID 1000000
Entries 1000
Mean -0.3070E-04
RMS 0.9539E-03
0.1°
0.1°
(θ|MBI_OUT − θ_IN)R
DTHI


π+ => 100 Gev
ID 1000000
Entries 1000
Mean 0.2035E-02
RMS 0.1293E-01
NO
LEADING PART
IN MUON SYS.
(θ|MBI_OUT − θ_IN)R
DTHI

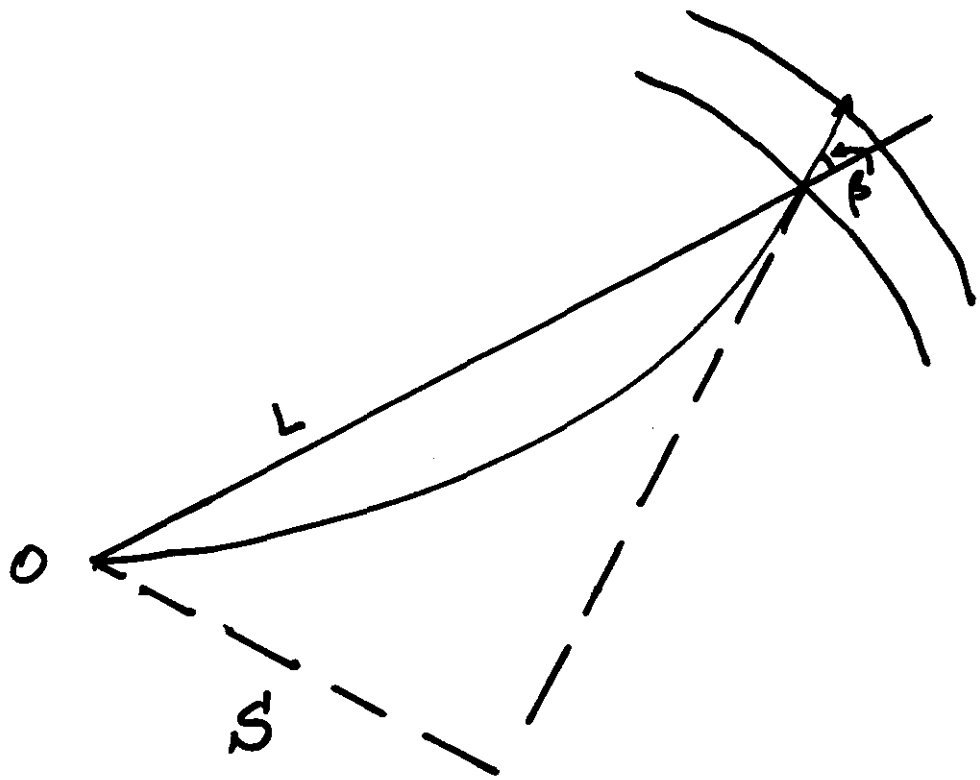
30 Gev η


Δ PAD
ID 501
Entries 1000
Mean −0.1954E−01
RMS 0.6529
-4
-5
-6
-7
-8
-9
10
−1
−0.75
−0.5
−0.25
0
0.25
0.5
0.75
1
η
Gev
ID 501
Entries 1000
Mean 0.1867E−01
RMS 0.5648
30
.5
25
.5
20
.5
15
.5
10
−1
−0.75
−0.5
−0.25
0
0.25
0.5
0.75
1
η


x 10 (Ju)
30 Gev μ
ID 501
ENTRIES 1000
0. 4.00 0.
0. 995. 0.
0. 1.00 0.
)000
)000
3000
7000
6000
5000
4000
3000
0
4
8
12
16
20
24
28
32
PT (Gev)

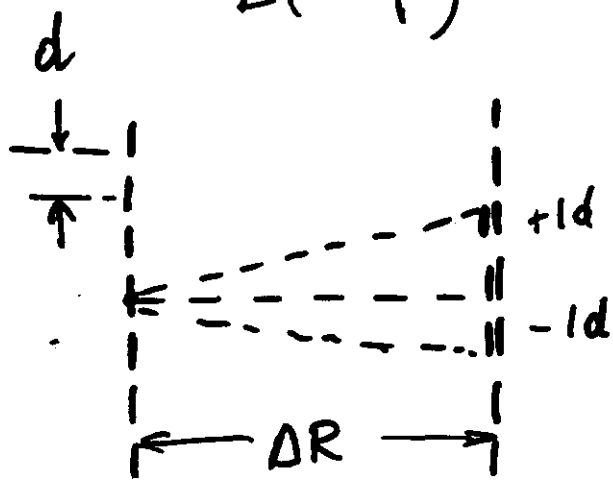

⟨ΔPAD⟩ VS η FOR 100 GEV μ⁻
ID 501
Entries 1000
Mean −0.2187E−01
RMS 0.6672
−1
.25
-1.5
1.75
−2
2.25
-2.5
2.75
−3
−1
−0.75
−0.5
−0.25
0
0.25
0.5
0.75
1
η

Trigger Algorithm for Endcap Muons



$$\sin\beta = \frac{0.3BL}{2P_T}$$

$$\Delta(\sin\beta) = \frac{0.015\sqrt{n}}{\sqrt{3}\,p} \quad \text{(Mutiple Scattering)}$$



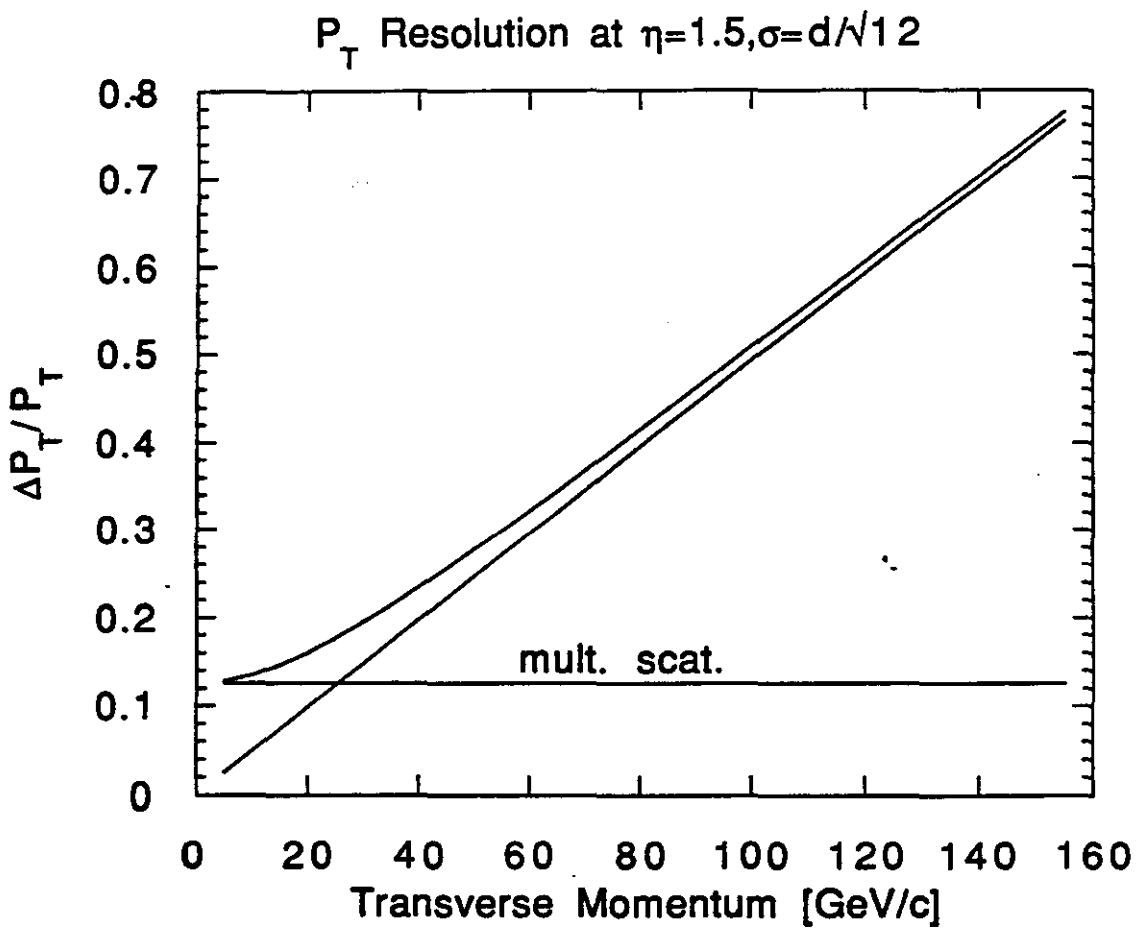
Assume

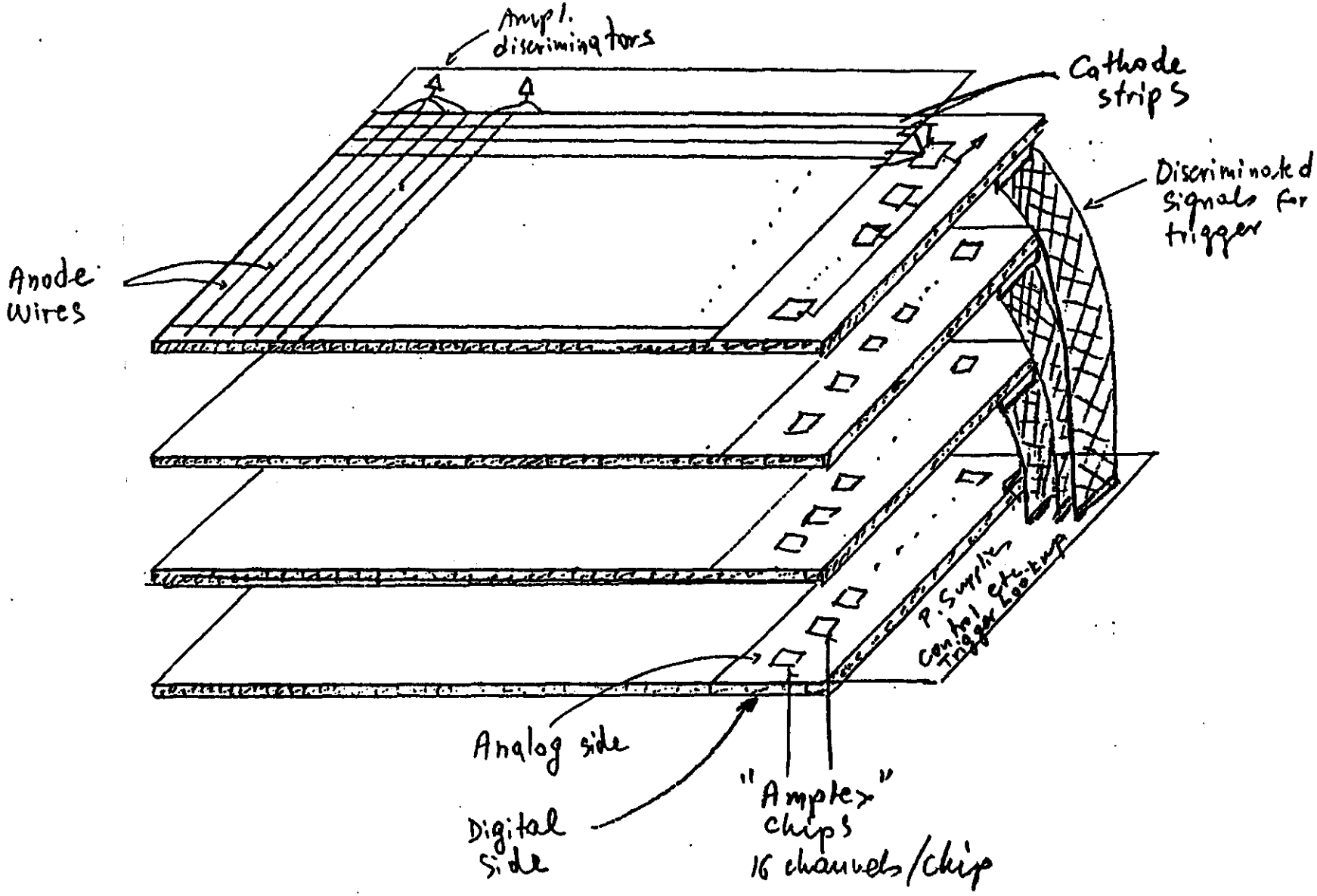
$\sqrt{n} = 20\ r_\ell$

$B = 0.83\ T$

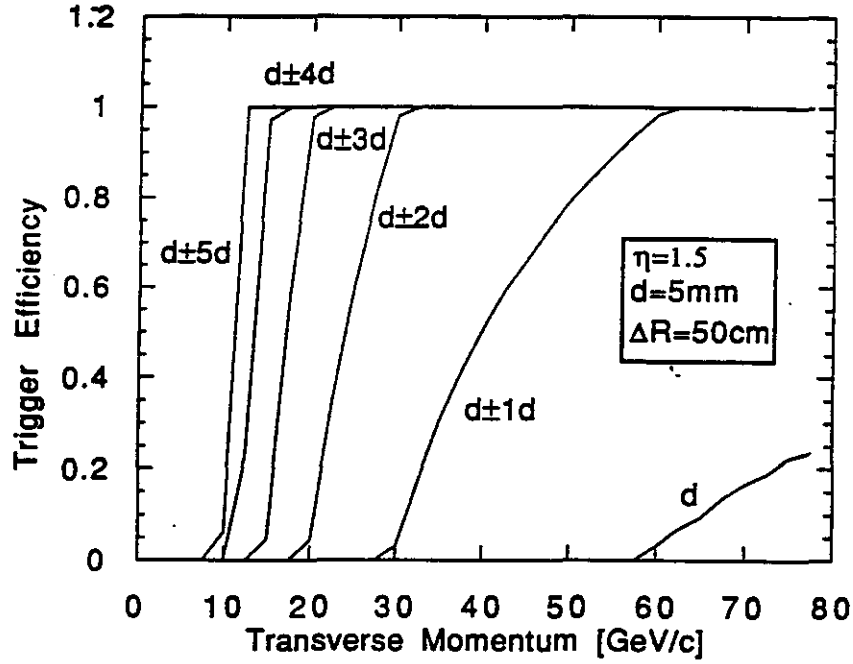
$L = f(n)$

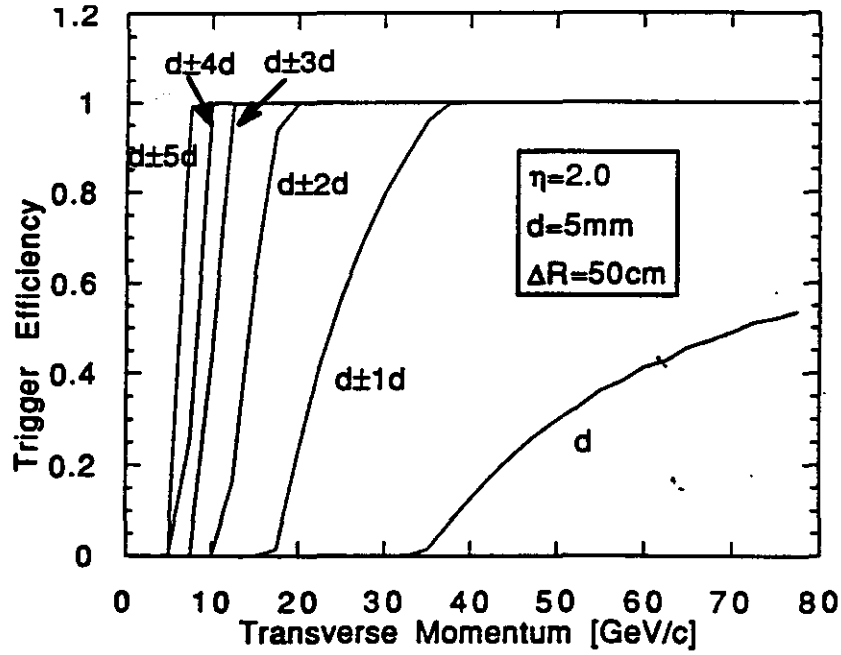
$R = 10\ m$

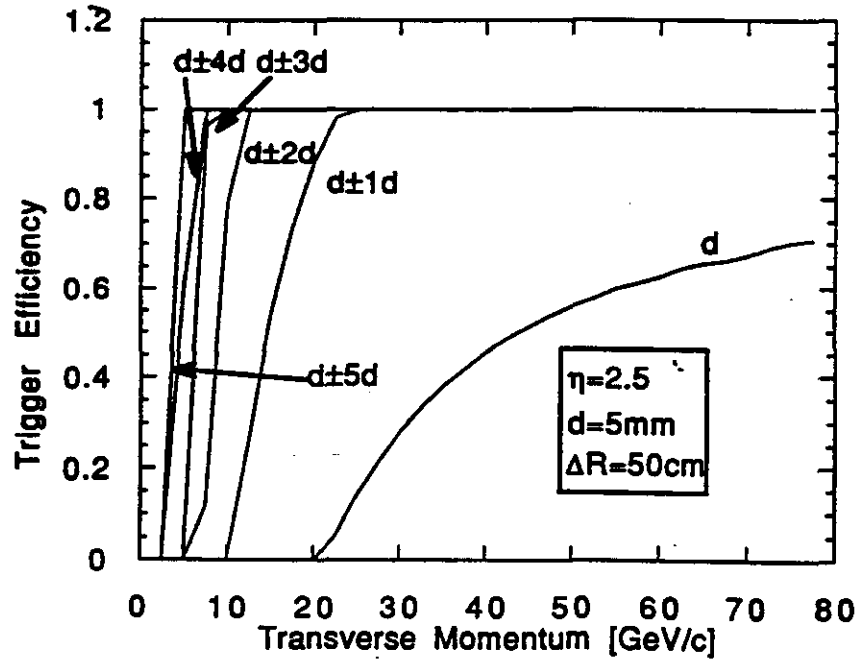

P_T Resolution at η=1.5,σ=d/$\sqrt{12}$
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$\Delta P_T / P_T$
mult. scat.
0
20
40
60
80
100
120
140
160
Transverse Momentum [GeV/c]

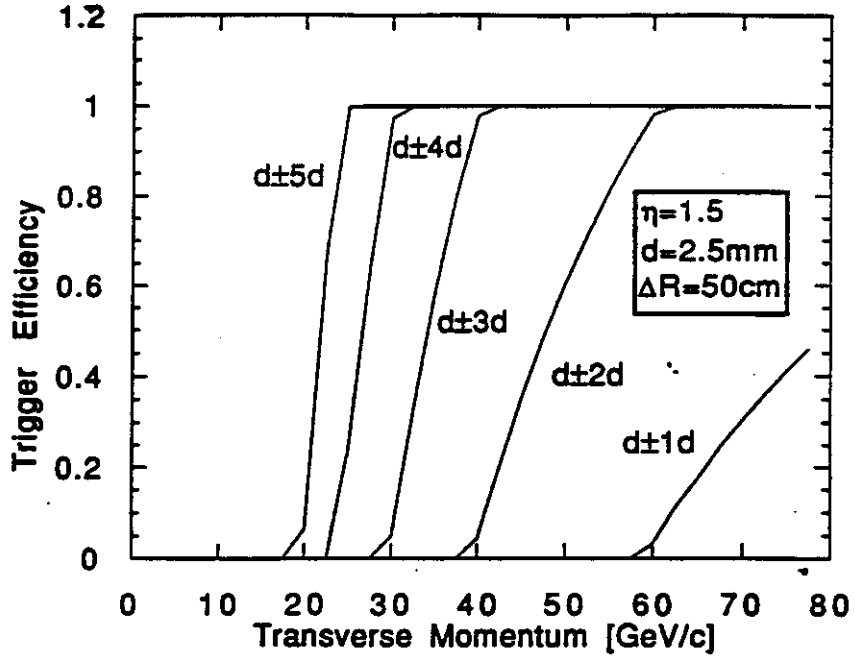


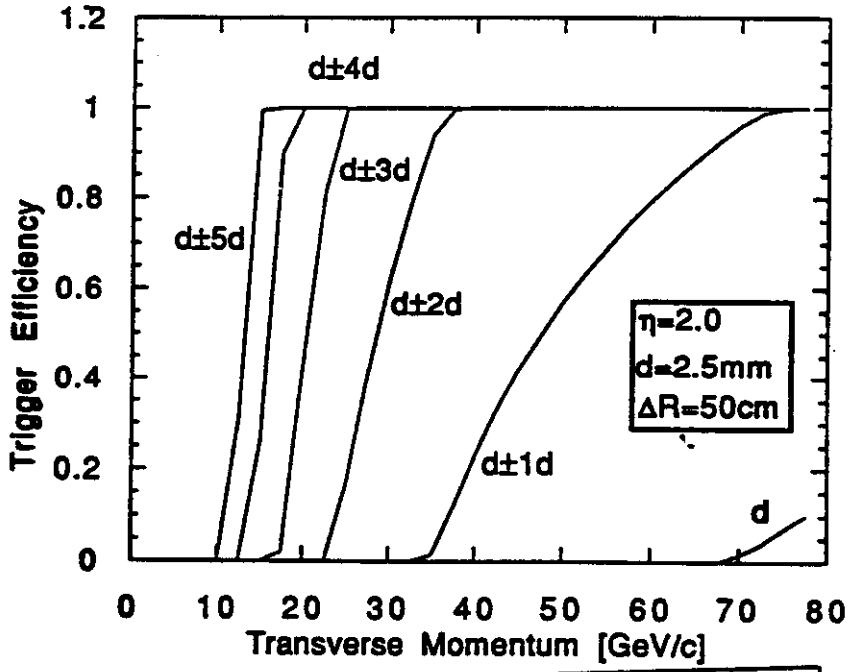
Schematic Layout of a Module

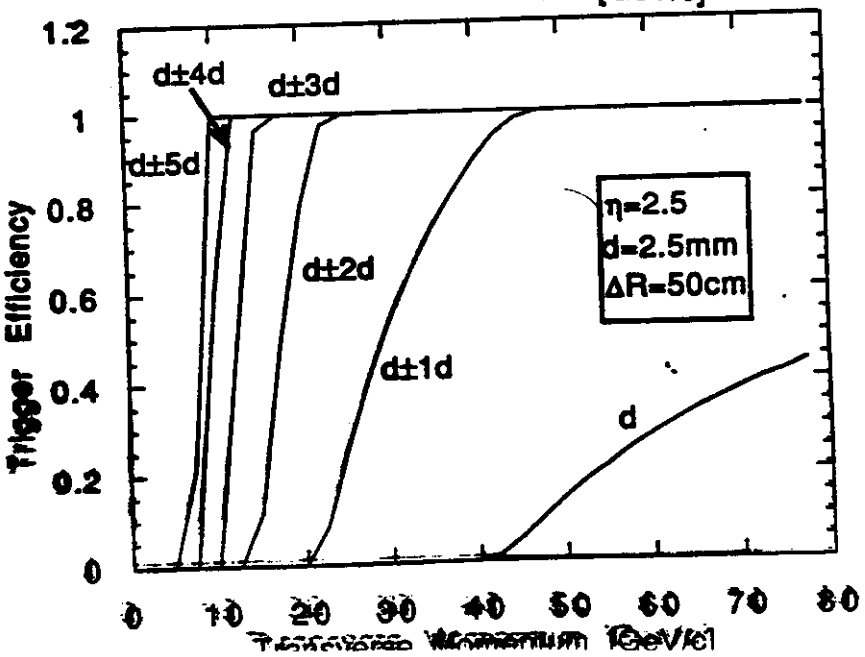

d±4d
d±3d
d±2d
d±5d
d±1d
d
η=1.5
d=5mm
ΔR=50cm
Trigger Efficiency
Transverse Momentum [GeV/c]

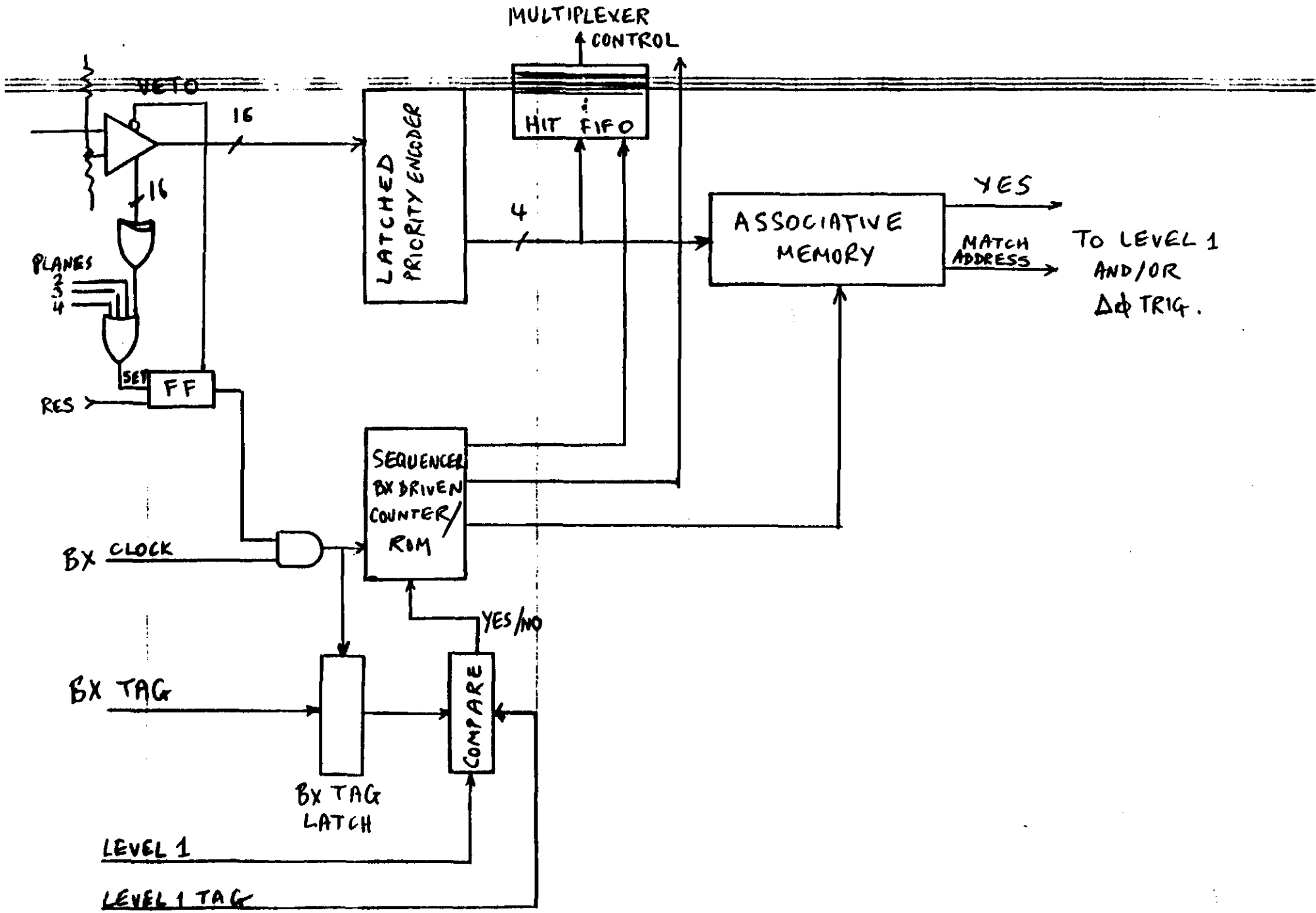

d±4d
d±3d
d±5d
d±2d
d±1d
d
η=2.0
d=5mm
ΔR=50cm
Trigger Efficiency
Transverse Momentum [GeV/c]


d±4d
d±3d
d±2d
d±1d
d
d±5d
η=2.5
d=5mm
ΔR=50cm
Trigger Efficiency
Transverse Momentum [GeV/c]

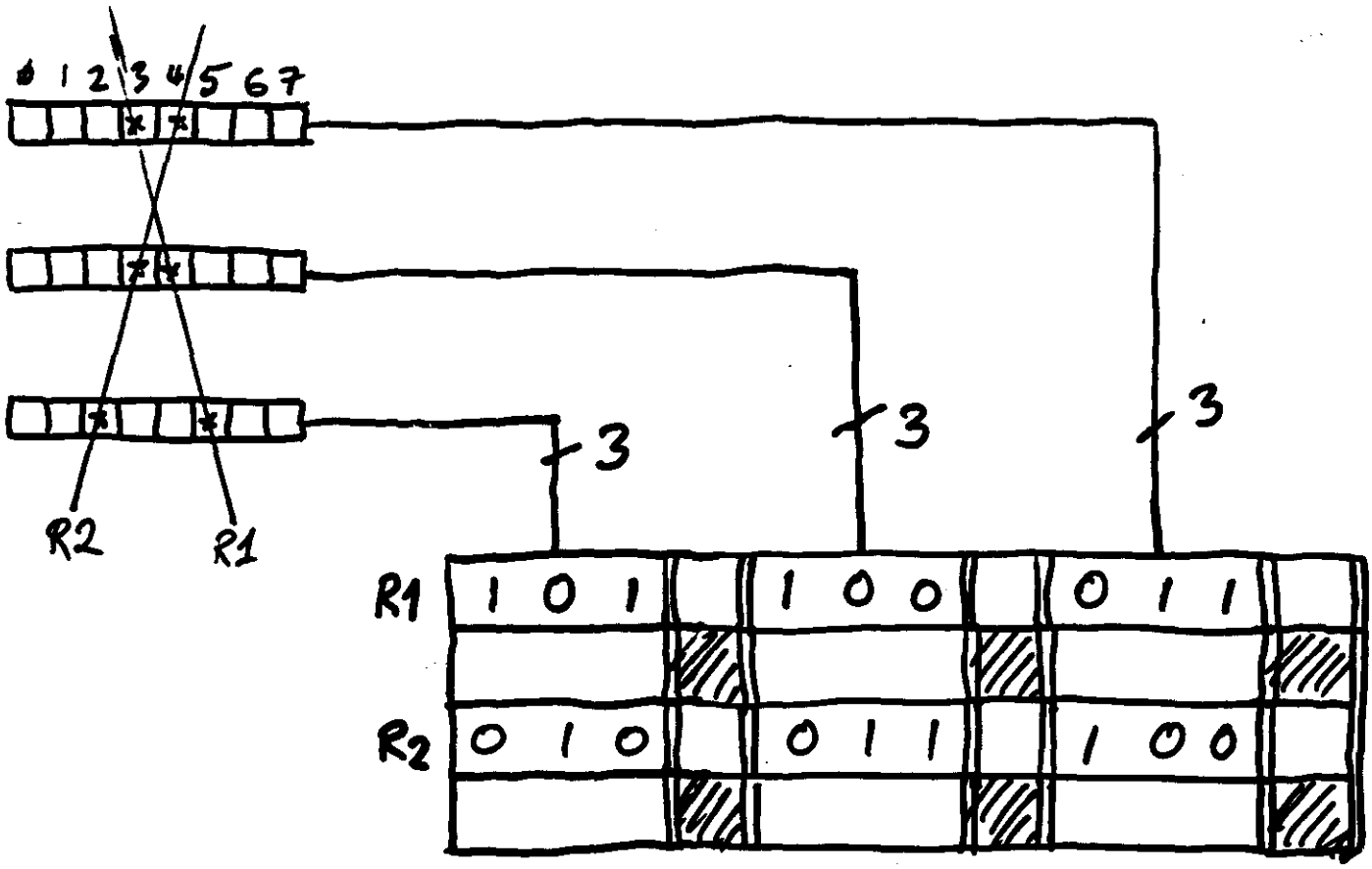

Trigger Efficiency
Transverse Momentum [GeV/c]
d±5d
d±4d
d±3d
d±2d
d±1d
η=1.5
d=2.5mm
ΔR=50cm


Trigger Efficiency
Transverse Momentum [GeV/c]
d±4d
d±3d
d±5d
d±2d
d±1d
d
η=2.0
d=2.5mm
ΔR=50cm

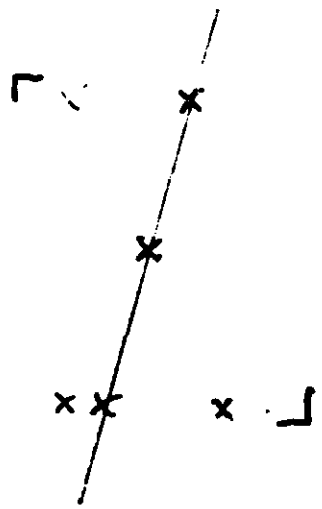

Trigger Efficiency
Transverse Momentum [GeV/c]
d±4d
d±3d
d±5d
d±2d
d±1d
d
η=2.5
d=2.5mm
ΔR=50cm


MULTIPLEXER CONTROL
VETO
16
16
LATCHED PRIORITY ENCODER
HIT FIFO
4
ASSOCIATIVE MEMORY
YES
MATCH ADDRESS
TO LEVEL 1 AND/OR Δφ TRIG.
PLANES 2 3 4
SET
FF
RES
SEQUENCER BX DRIVEN COUNTER/ ROM
BX CLOCK
YES/NO
BX TAG
COMPARE
BX TAG LATCH
LEVEL 1
LEVEL 1 TAG

1. Data Initialize



2. Event
3. Load hits and compare (N_{hits} cycles)



	Plane 1	Plane 2	Plane 3
1)	001	011	001
2)	100		010
3)			101

Activities of Muon Trigger Simulation Group.

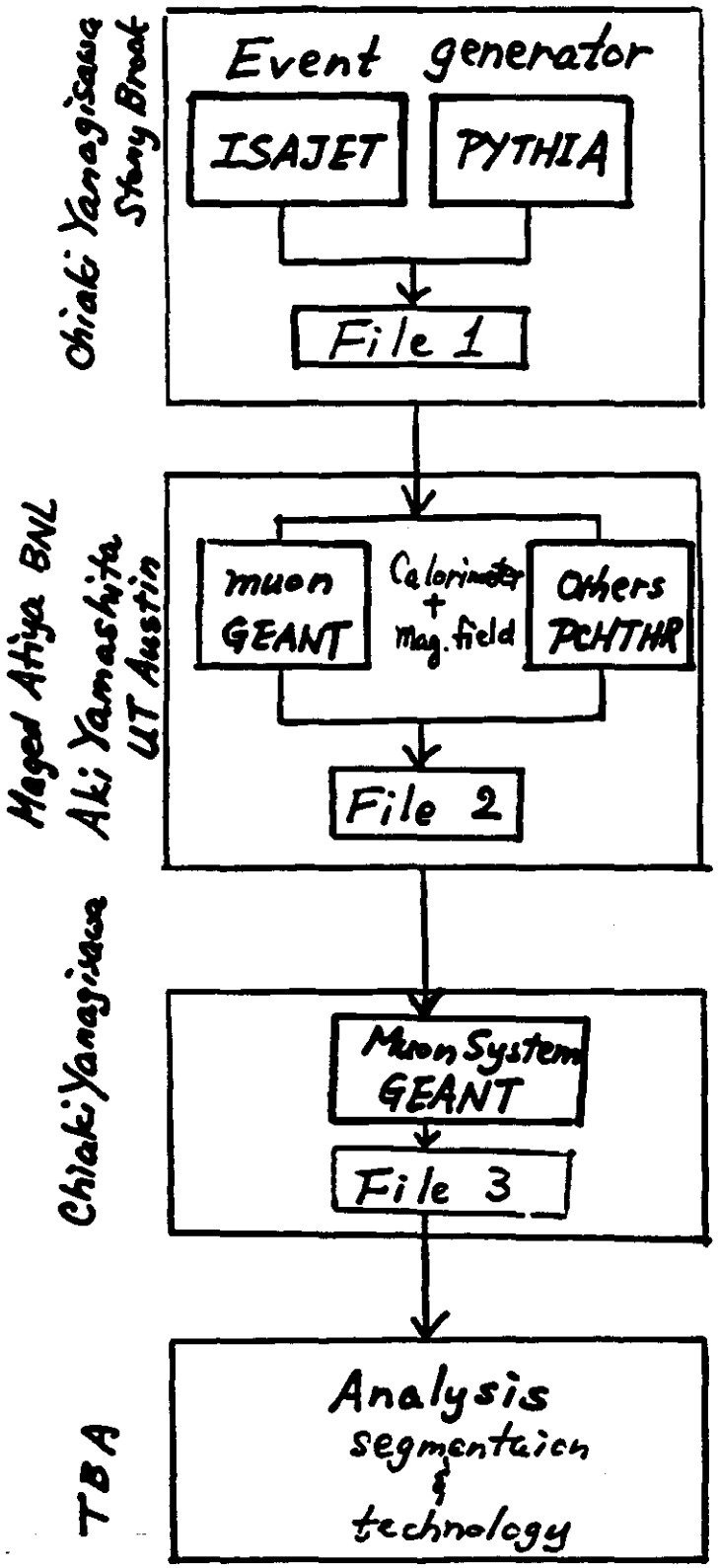
Chiaki Yanagisawa
Stony Brook

- Structure of trigger simulation
- Physics
- PCHTHR
- Standard configuration of the muon system
- Monte Carlo studies

Structure of trigger simulation

at SSCL PDSF

Maged Atiya
Aki Yamashi



- Physics
- File 1 format
  - Event#
  - # of particles
  - particle ID (P.D.G Standard
  - p_x
  - p_y
  - p_z
  - E
  - mass
- Binary or ASCII file?
  - Conversion of binary file?
  - UNIX ↔ VMS ?
- PCHTHR (by Roger McNeil L
- Simple geometry
  - No segmentation except planes.
- File 3 format
  - particle ID
  - p_x
  - p_y
  - p_z
  - # of hits
  - R
  - ϕ
  - z
  - ⋮
- MC studies

Physics

Signals

- $H \to ZZ^*$ ($m_H = 130, 150, 170, 190$ GeV/c^2)
- $H \to ZZ$ ($m_H = 200, 400, 800$ GeV/c^2)
- $Z' \to \mu\mu$ (4 TeV)
- Strongly interacting W, Z ($W_L^+ W_L^+$ etc.)
- $\tilde{g}\tilde{g} \to \mu^\pm\mu^\pm$
- Inclusive W/Z production including $Zq\bar{q}$
- $t\bar{t}$ ($m_t = 250$ GeV)

.... suggestions?

Backgrounds

- Prompt μ from c, b
- — " — t with $m_t = 140$ and 200 GeV
- Punch thru and decays QCD

PCHTHR (Roger McNeil)

Inputs:

- material thickness in λ
- particle ID
- p

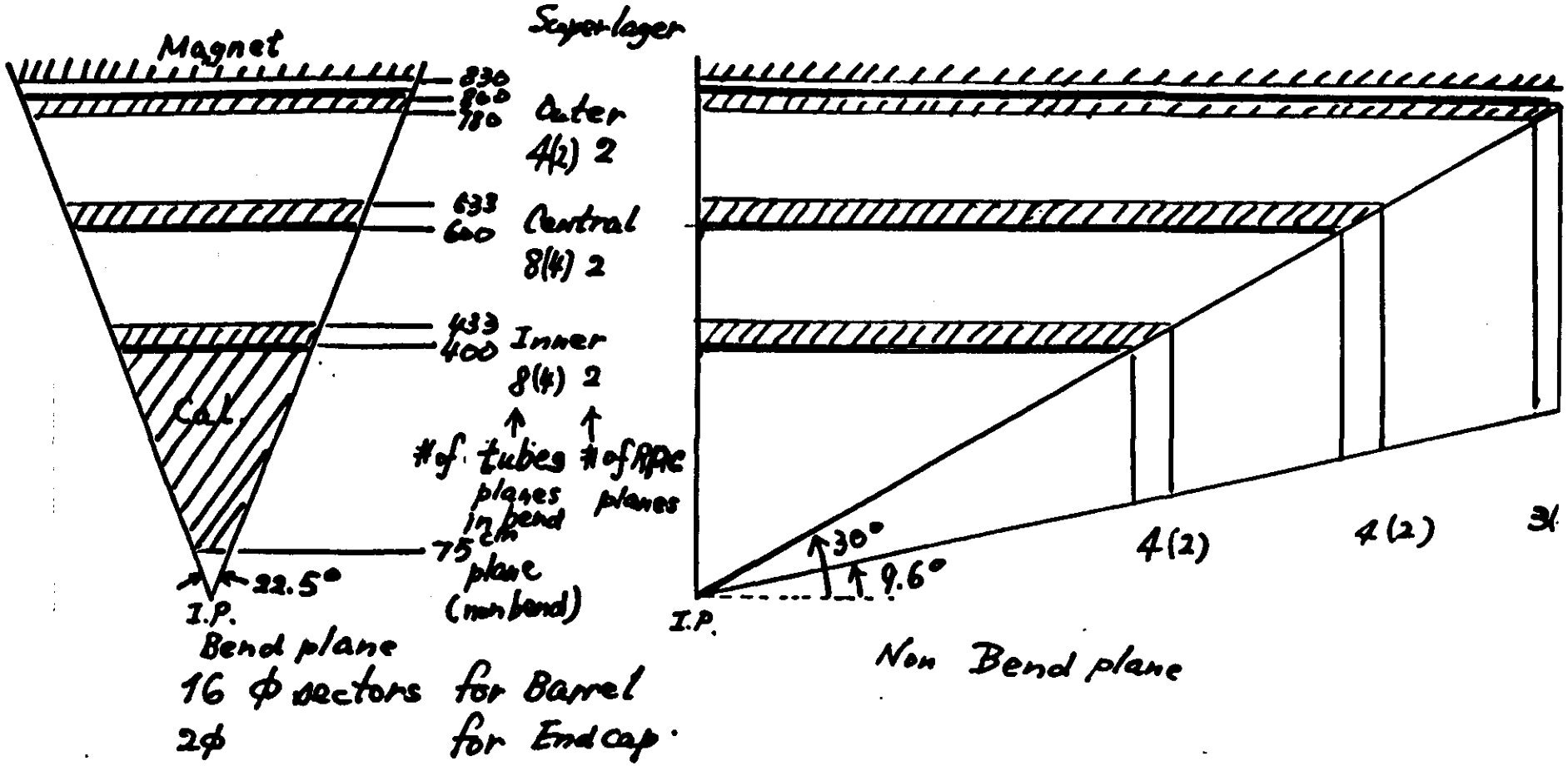
Outputs:

- # of punch thru particles
- p
- particle ID
- weight (prob. of punch thru)

! Validation of GEANT!

{ Mohammad Mohammadi
Roger McNeil

Standard configuration of the muon system



Monte Carlo studies

- Trigger efficiency – acceptance, dead area, ...
- Trigger rate at level 1 (decision $\lesssim 1\mu s$)
- — " — 2 ($2-100\mu s$)
- Fake rate
- Trigger hardware simulation
- ⋮

PRESENTATION TO THE MUON TRIGGER MEETING AT THE SSC LABORATORY 22 JANUARY 1992

IRWIN A. PLESS

BARREL RPC TRIGGER

I. INTRODUCTION

II. RATES

III. TIMING AND TRIGGER WIDTHS

IV. TRIGGER STRATEGY

V. HARDWIRE IMPLEMENTATION

VI. ASSOCIATIVE MEMORY IMPLEMENTATION

VII. SUMMARY

I. INTRODUCTION

THIS PRESENTATION IS DESIGNED TO DISCUSS ONLY THE TOPIC OF THE BARREL RPC TRIGGER. SOME ASPECTS OF THE TOPIC CONSIDERED MIGHT HAVE RELEVANCE TO THE FORWARD DIRECTION.

WE HAVE AS OUR STARTING DATA THE CURVES CALCULATED BY B. ZHOU AND R. McNEIL. THESE SEEM TO BE IN AGREEMENT WITH THE TABLE CALCULATED BY D. GREEN AND D. HEDIN.

WE WILL SHOW THAT TAKING ADVANTAGE OF THE ISOCHRONISITY OF THE BARREL GEOMETRY, OUR TRIGGER WIDTH NEED ONLY BE NINE NANO-SECONDS WIDE, PLUS THE RISE TIME JITTER OF THE RPC. WE SHOW THAT AT THE LEVEL 2 TRIGGER, THE BEAM CROSSING TIME IS KNOWN TO THE RISE TIME JITTER OF THE RPC. THE BEAM CROSSING TIME AT THE LEVEL 1 TRIGGER SHOULD BE KNOWN TO BETTER THAN 12 NANO-SECONDS. THIS MEANS THAT AT THE LEVEL 1 TRIGGER THE BEAM CROSSING IS UNAMBIGUOUSLY KNOWN. THE TRUTH OF THIS STATEMENT DEPENDS ON THE RPC RISE TIME JITTER BEING LESS THAN 4 NANO-SECONDS. THIS IS ONE OF MANY RPC PROPERTIES THAT WILL BE MEASURED BY THE RPC R AND D PROGRAM.

WE WILL PROPOSE A FOUR LEVEL TRIGGER. WE WILL ALSO DEMONSTRATE THAT THIS TRIGGER CAN

BE IMPLEMENTED IN A HARD WIRE FORM AND PROBABLY BE IMPLEMENTED USING ASSOCIATIVE MEMORIES.

IN OUR SUMMARY WE COLLECT ALL THE FEATURES OF THE TRIGGER SCHEME.

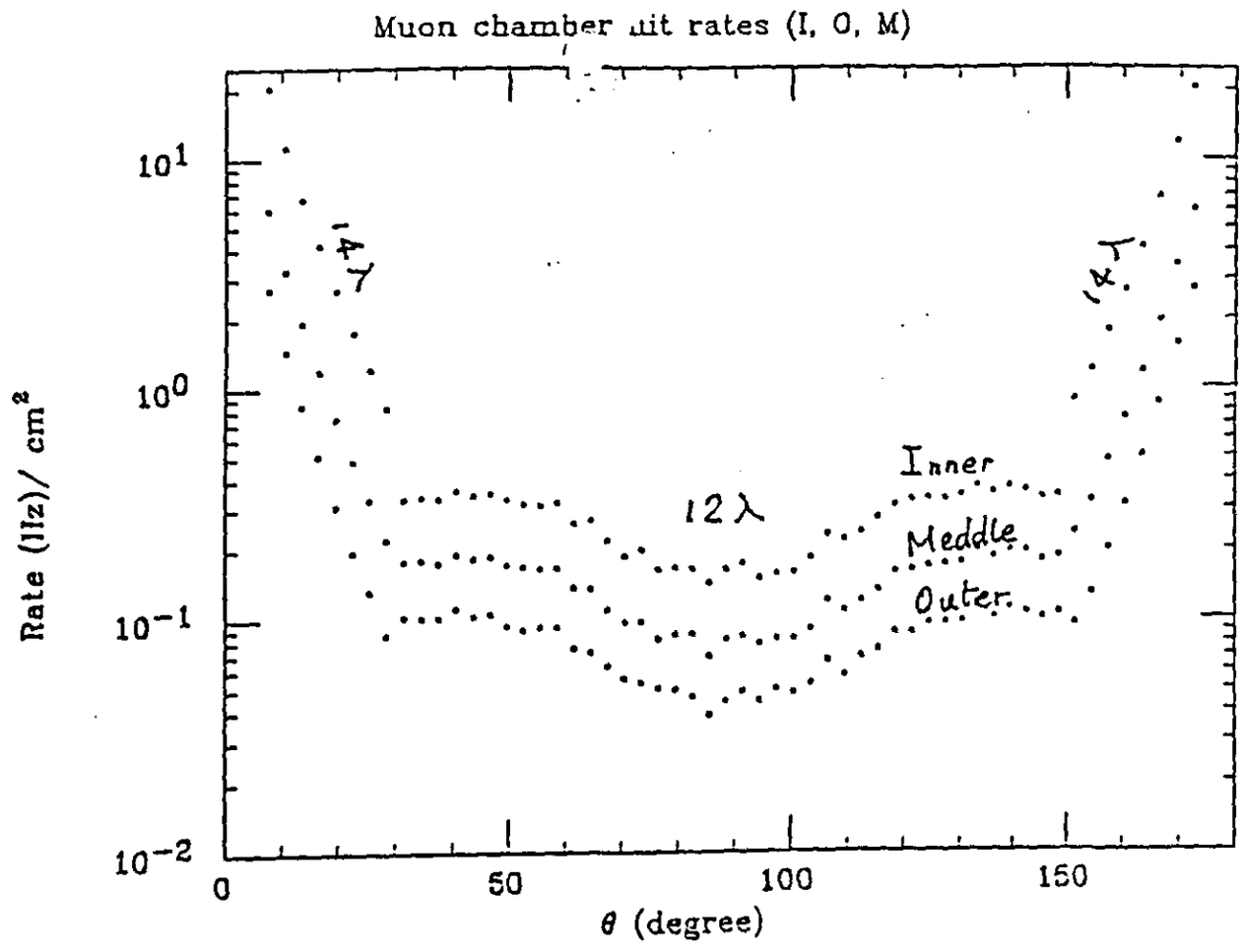


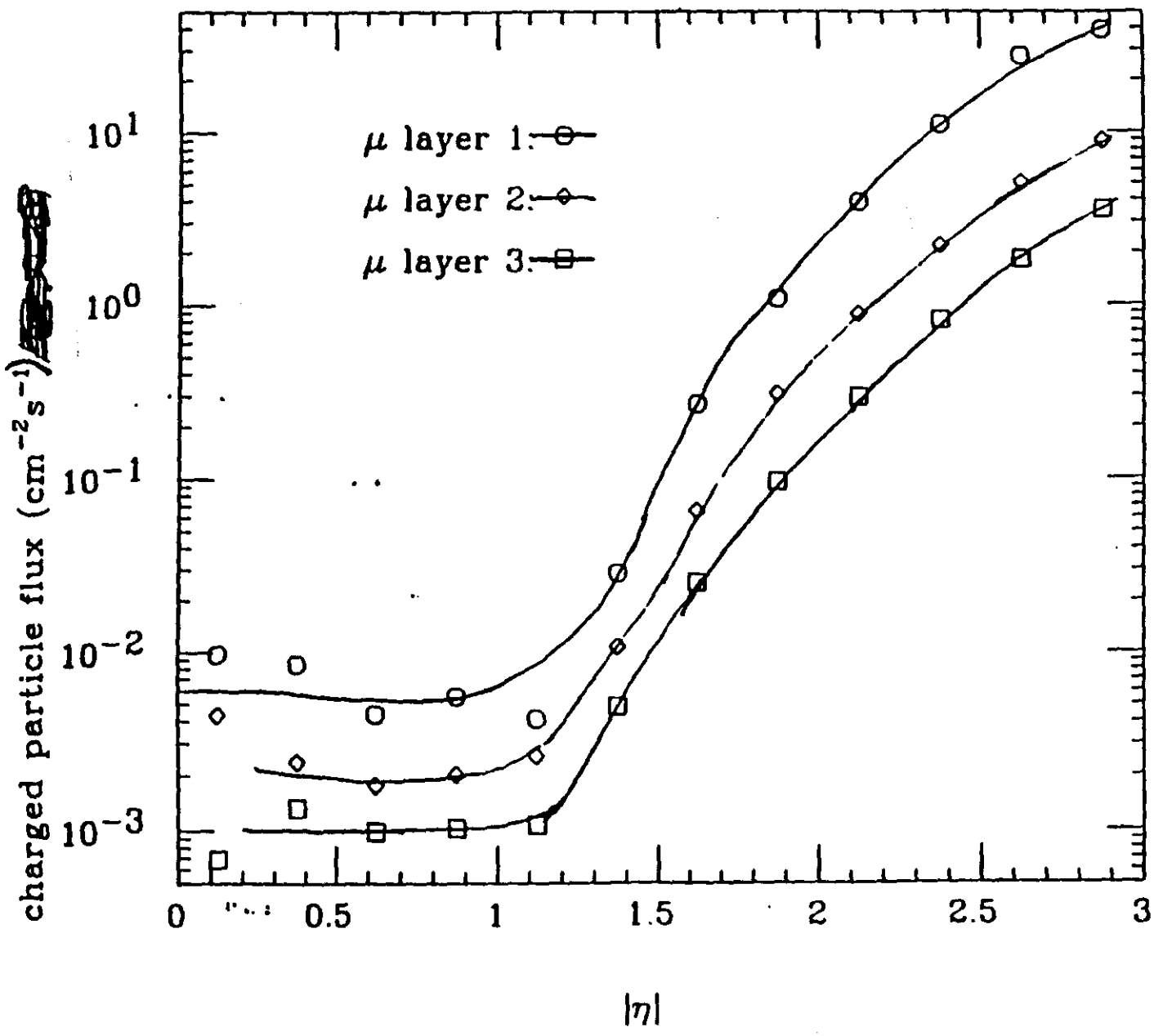
Figure 5

II RATES

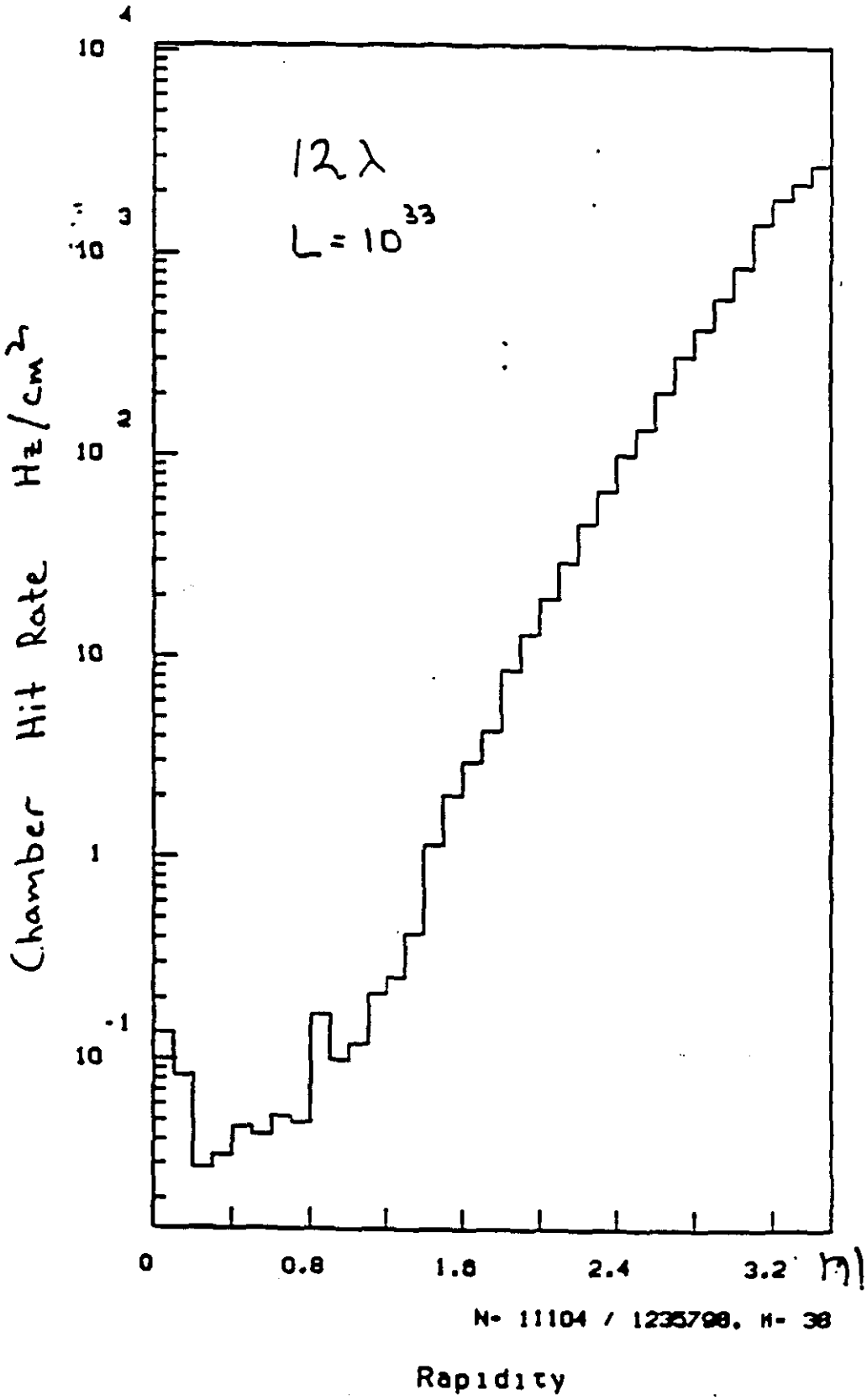
II-1

RATES

Hit Rate (#/cm²) in Muon Chambers

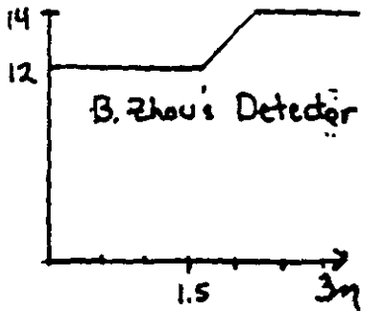


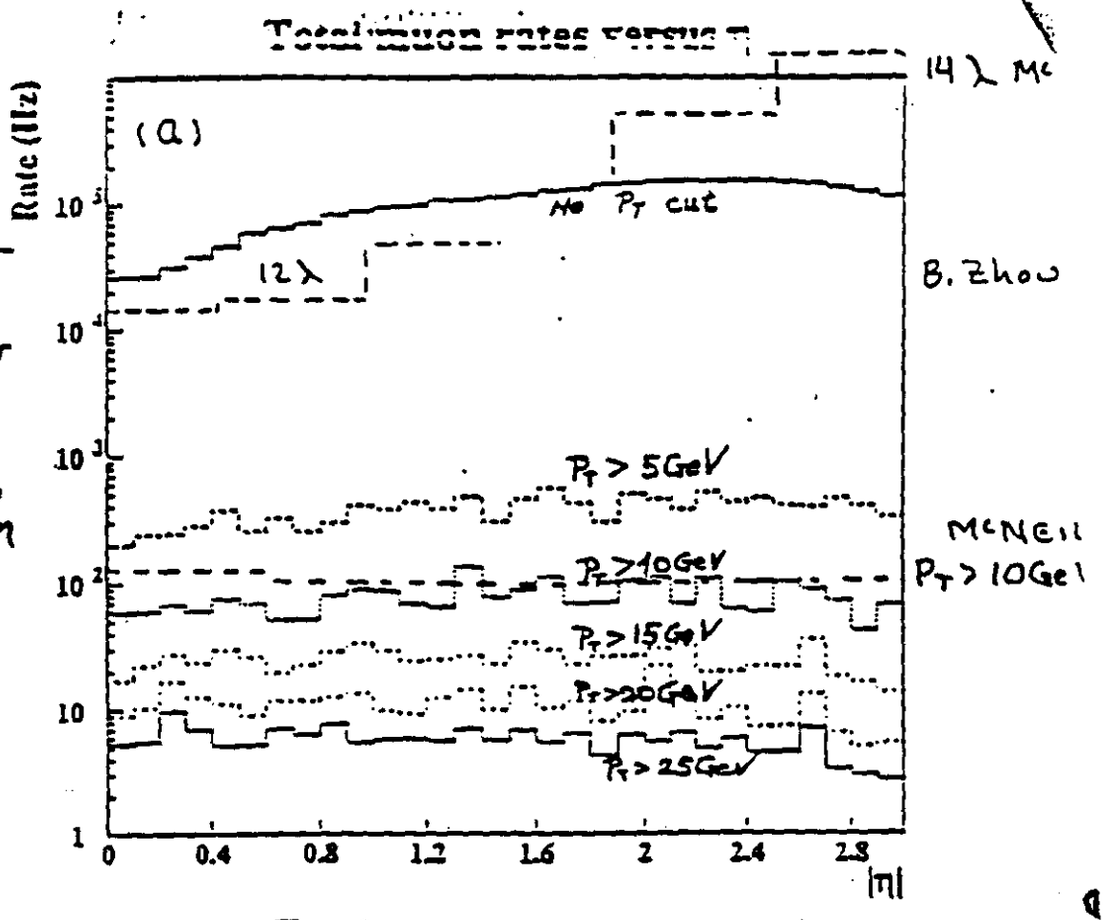
Twojet Events PtJET>4GeC/c STD LUM

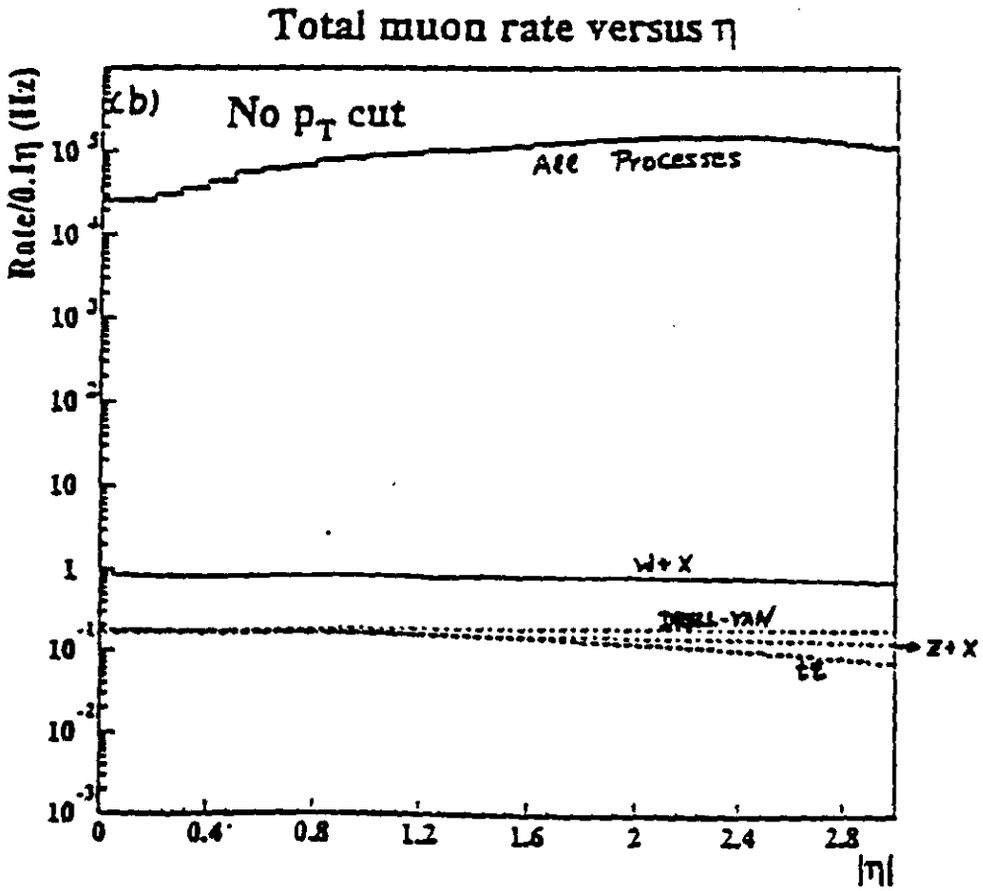


Hit Rate for First chamber after CAL

RATES


14
12
B. Zhou's Detector
1.5
3η


Total muon rates versus η
Rate (Hz)
(a)
14 λ Mc
No P_T cut
12λ
B. Zhou
P_T > 5GeV
McNeil
P_T > 10GeV
P_T > 10GeV
P_T > 15GeV
P_T > 20GeV
P_T > 25GeV
|η|


Total muon rate versus η
Rate/0.1η (Hz)
(b)
No p_T cut
All Processes
W+X
DRELL-YAN
Z+X
$t\bar{t}$
|η|

T. . 2
RATES

II-4

Dan Green & Dave Hedin

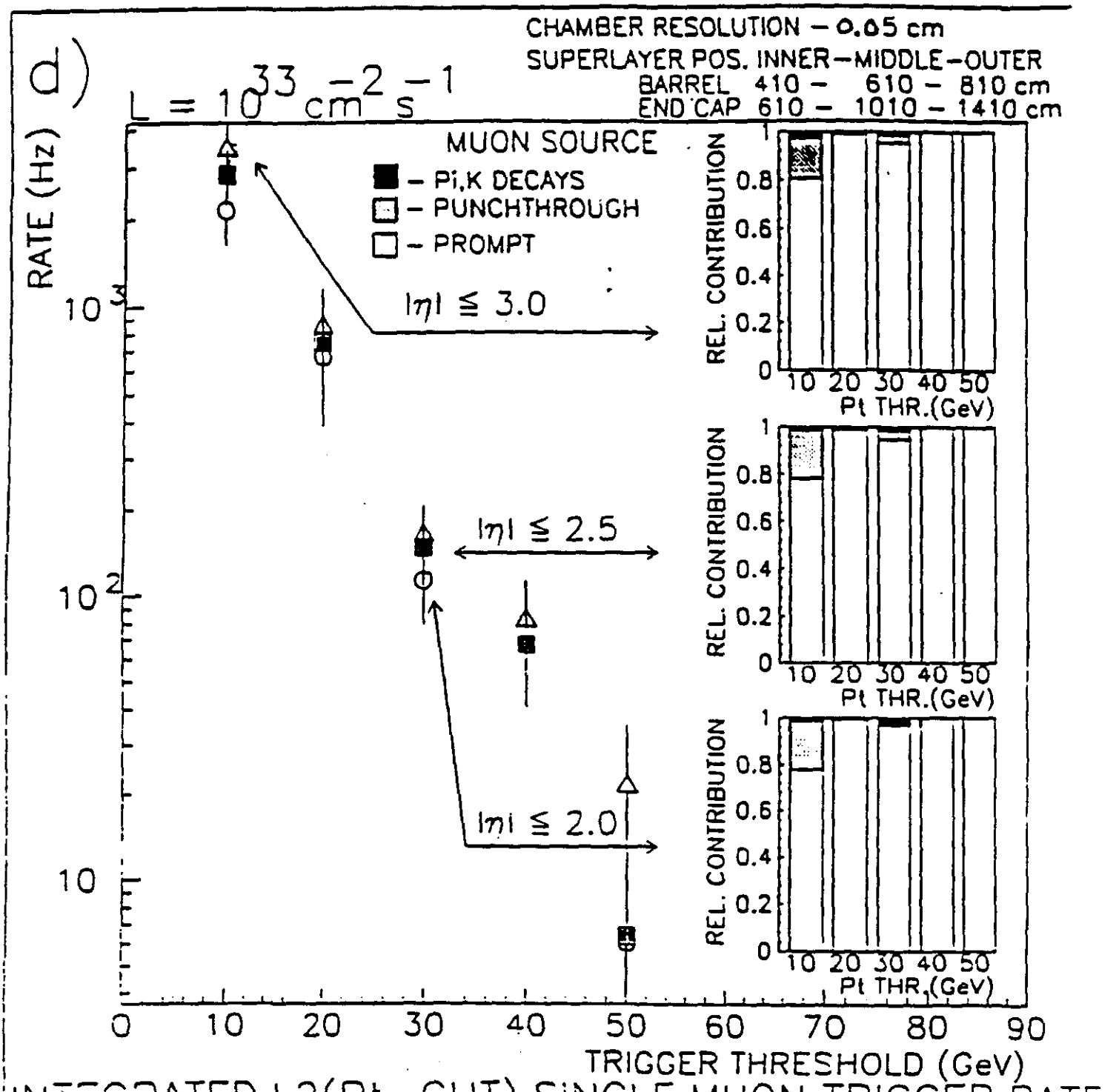
Table 2: Muon Rates versus Absorber Thickness

	$0 < \|\eta\| < 3$	$0 < \|\eta\| < 1$	$1 < \|\eta\| < 2$	$2 < \|\eta\| < 3$	
All	28,000	400	4100	23,000	
punch	4,900	70	420	4,400	9 λ
prompt	400	16	130	250	
All	18,000	250	2700	15,000	
punch	430	5	30	400	12 λ
prompt	400	16	130	250	
All	11,000	130	1500	9600	
punch	40	0.4	3	40	15 λ
prompt	380	13	120	250	
All	6800	80	700	6000	
punch	5	-	0.4	5	18 λ
prompt	270	13	70	190	
All	4400	50	460	3900	
punch	0.7	-	-	0.7	
prompt	270	10	70	190	
All	2700	30	270	2400	
punch	-	-	-	-	
prompt	270	10	70	190	
All	900	12	70	800	
punch	-	-	-	-	
prompt	150	7	10	135	
All	400	2	24	340	
punch	-	-	-	-	
prompt	140	0.6	7	130	

:b summed over p_t Rate (kHz)

RATES

Level 2 ($P_{T\,cut}$)



INTEGRATED L2(Pt–CUT) SINGLE MUON TRIGGER RATE

II. RATES

THE CALCULATIONS I HAVE JUST SHOWN ASSUMES A LUMINOSITY OF 10^{33}. FOR THIS SAME LUMINOSITY, I INTERPELLATE AND EXTRAPOLATE THE DATA FOR THE BARREL, AND ARRIVE AT THE FOLLOWING RATES FOR THE BARREL. WHERE THE DATA DID NOT AGREE, I ASSUMED THE HIGHER NUMBERS.

TOTAL RATE, NO P_t CUT	1.3×10^6 HERTZ
$P_t > 10$ GeV/c	2,000 HERTZ
$P_t > 20$ GeV/c	200 HERTZ
$P_t > 30$ GeV/c	75 HERTZ

THE TRIGGER LOI OVERVIEW CALCULATED THE FOLLOWING RATES:

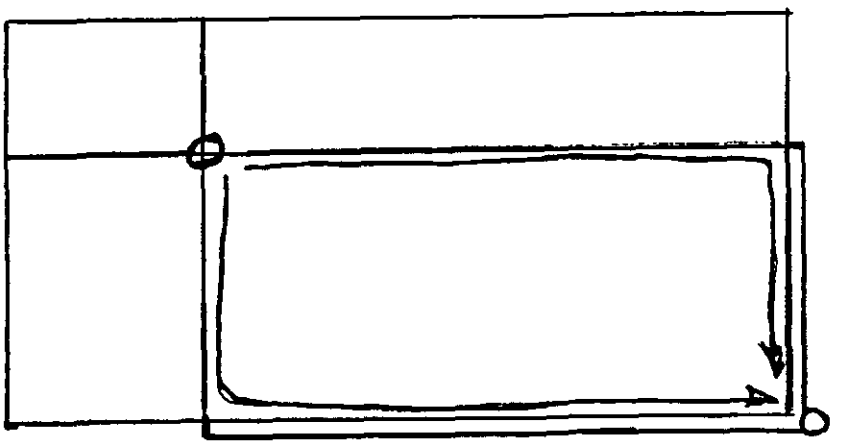
$P_t > 10$ GeV/c	1300 HERTZ
$P_t > 20$ GeV/c	390 HERTZ
$P_t > 30$ GeV/c	70 HERTZ

I CONSIDER THIS SURPRISING AGREEMENT.

THEREFORE WE WILL TAKE AS THE RATES THE HIGHER NUMBERS:

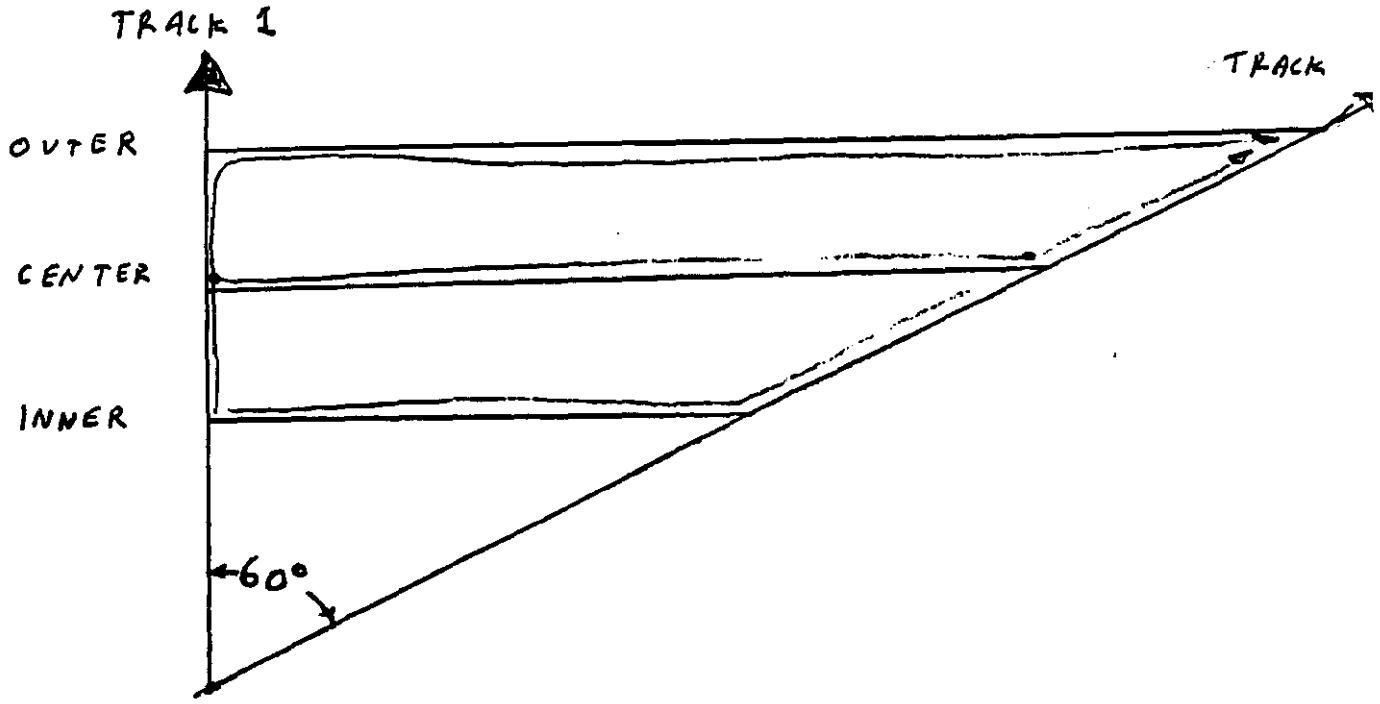
$P_t > 0$	1.3×10^6 HERTZ
$P_t > 10$	2,000 HERTZ
$P_t > 20$	400 HERTZ
$P_t > 30$	75 HERTZ

III. TIMING AND TRIGGER WIDTHS



IF WE COLLECT ALL SIGNALS FROM THE STRIPS IN ONE CORNER AND MATCH CABLE SPEEDS TO STRIP SPEEDS WE ARE MATCHED IN TIME AT THE CORNER. AT THE LEVEL 1 TRIGGER WE KNOW THE BEAM CROSSING TO BETTER THAN 12 NANO-SECONDS, 8 NANO-SECONDS DUE TO THE 1.59 M LENGTH OF THE STRIP AND 4 NANO-SECONDS DUE TO THE RISE TIME JITTER OF THE RPC PULSE. THIS LATTER NUMBER HAS TO BE VERIFIED BY THE RPC R AND D.

HOWEVER, AT THE TIME OF THE FIRST LEVEL TRIGGER, THE IDENTITY OF THE X AND Y STRIPS ARE KNOWN. AT THIS POINT, ONE CAN CALCULATE THE BEAM CROSSING TIME TO AN ACCURACY OF THE RISE TIME JITTER OF THE RPC.



FOR TRACK 1, THE SIGNAL FROM THE OUTER LAYER ARRIVES 9 NANO-SECONDS AFTER THE SIGNAL FROM THE INNER LAYER AND 4.5 NANO-SECONDS AFTER THE SIGNAL FROM THE CENTER LAYER.

FOR TRACK 2, THE SIGNAL FROM THE OUTER LAYER ARRIVES 13 NANO-SECONDS BEFORE THE SIGNAL FROM THE INNER LAYER AND 6.5 NANO-SECONDS BEFORE THE SIGNAL FROM THE CENTER LAYER.

HENCE THE TRIGGER WIDTHS ON THE OUTER LAYER MUST BE 13 NANO-SECONDS LONG, WHILE THE TRIGGER WIDTHS ON THE INNER LAYER MUST BE 9 NANO-SECONDS LONG AND THE TRIGGER WIDTHS OF THE CENTER LAYER MUST BE 6.5 NANO-SECONDS LONG.

IV. TRIGGER STRATEGY

IN THE LOI OVERVIEW, THE GOAL OF THE OUTPUT RATE OF THE LEVEL ONE TRIGGER WAS 10,000 HERTZ AT $L = 10^{33}$. A P_t CUT AT 10 GeV/c YIELDS A RATE OF 2,000 HERTZ. THIS IS ONLY 20% OF THE TOTAL TRIGGER RATE.

HOWEVER AT $L = 10^{34}$ A 10 GeV/c CUT YIELD A RATE OF 20,000 HERTZ, WHICH IS TOO HIGH.

A P_t CUT AT 20 GeV/c YIELDS A RATE OF 400 HERTZ AT 10^{33} AND A RATE OF 4,000 HERTZ AT A RATE OF 10^{34}, WHICH MAY NOT BE ACCEPTABLE.

HENCE A TRIGGER WITH P_t CUTS AT 10, 20, 30 AND 50 GeV/c SHOULD BE THE DESIRED GOAL.

THERE IS THE QUESTION OF PATTERN RECOGNITION IN THE PRESENCE OF ISOLATED SINGLE HITS AND TWO TRACKS IN THE SAME ACTIVE TIME.

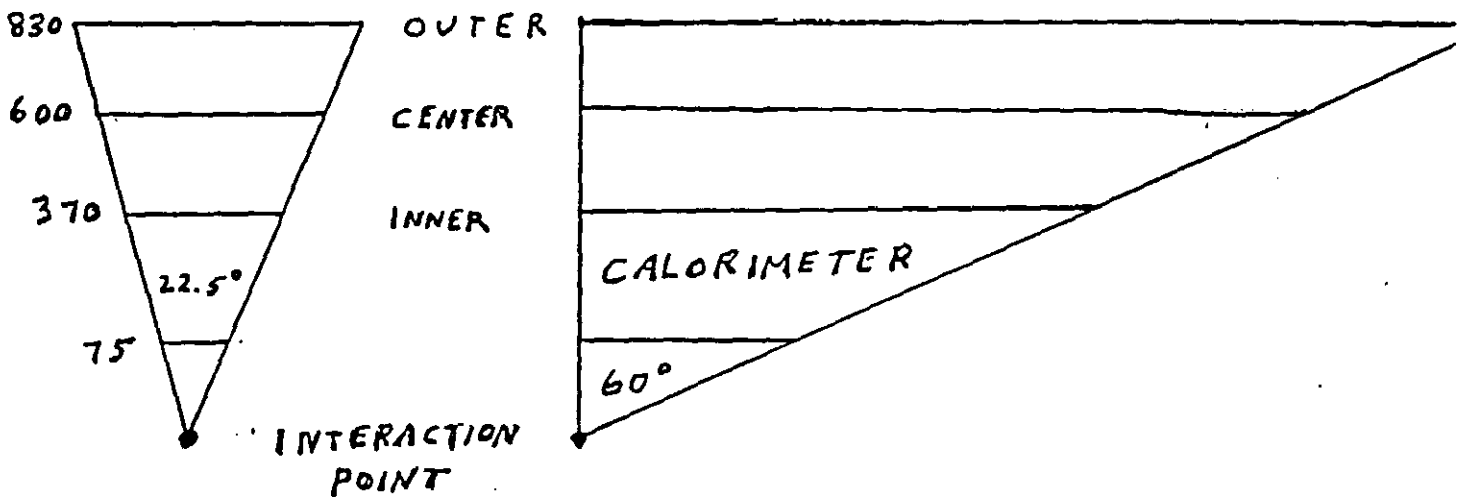
IF WE ASSUME THE VALUE OF 1.3×10^6 HERTZ RATE WITH NO P_t CUT, WE FIND THE RATE PER SECTOR TO BE 40,600 HERTZ. IF WE ASSUME A LIVE TIME OF 200 NANO-SECONDS WE FIND THE PROBABILITY OF GETTING TWO TRACKS IN THE SAME LIVE TIME TO BE ABOUT 8×10^{-3}. THIS

WOULD IMPLY ABOUT 1% OF THE EVENTS WOULD NEED SOME SPECIAL PATTERN RECOGNITION ANALYSIS. HENCE IT IS DESIRABLE TO KEEP THE LIVE TIME BELOW 200 NANO-SECONDS.

AS WE WILL SHOW, THIS IS EASILY DONE USING THE HARD WIRE APPROACH, AND PROBABLY CAN BE DONE USING THE ASSOCIATIVE MEMORY.

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

BASE LINE GEOMETRY



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

CALORIMETER

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

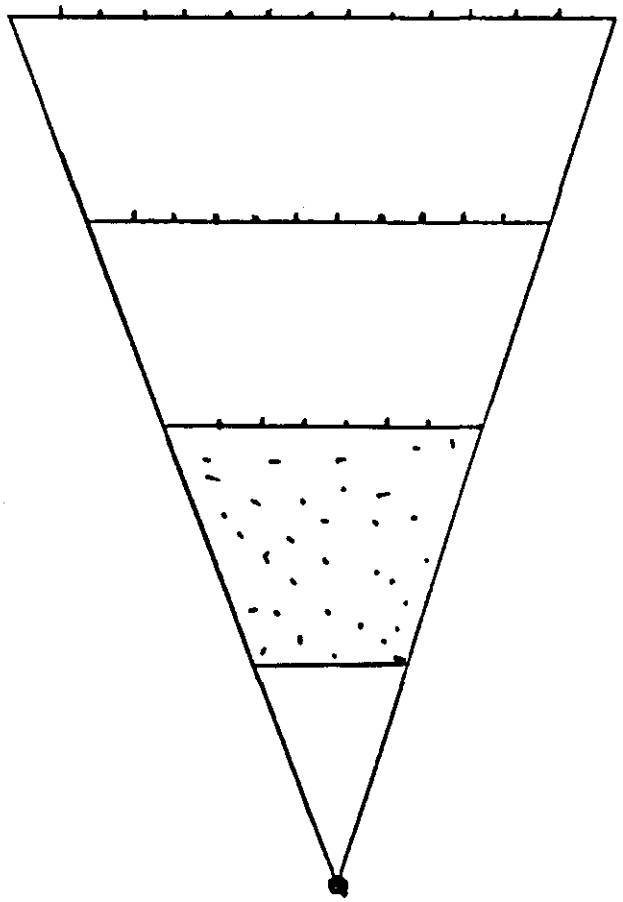
$$\theta_o = 21/E \sqrt{x/x_o} = 21/E \sqrt{396}$$

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

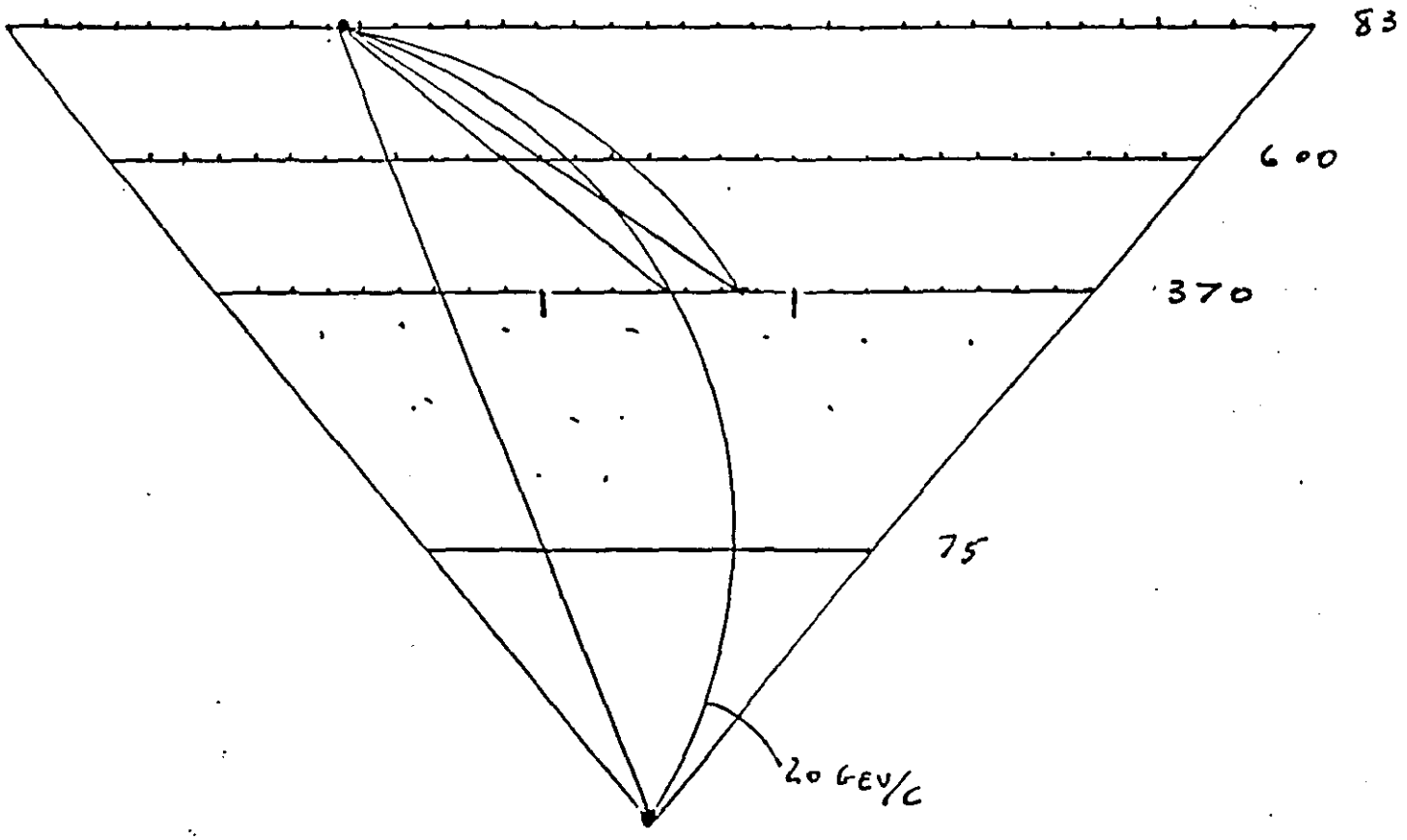
$$\sigma^{RMS}_{plane} = 1/\sqrt{3}\ L\ \theta^{RMS}_{plane}$$

BEND PLANE CALCULATIONS

All strip widths = 1.3 cm



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



A 20 GeV/c track has a sigma of 2 strips around the ideal intersection point at R = 370 due to multiple scattering. In order to have a 95% acceptance we have to be able to handle ± 4 strips around the ideal (no multiple scattering) intersection point.

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

† 30 AND 40 CANNOT BE SEPERATED

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

10 GeV positive charge. For example:

8 x 254 = 2032

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

Total number of circuits for positive charge = 7620

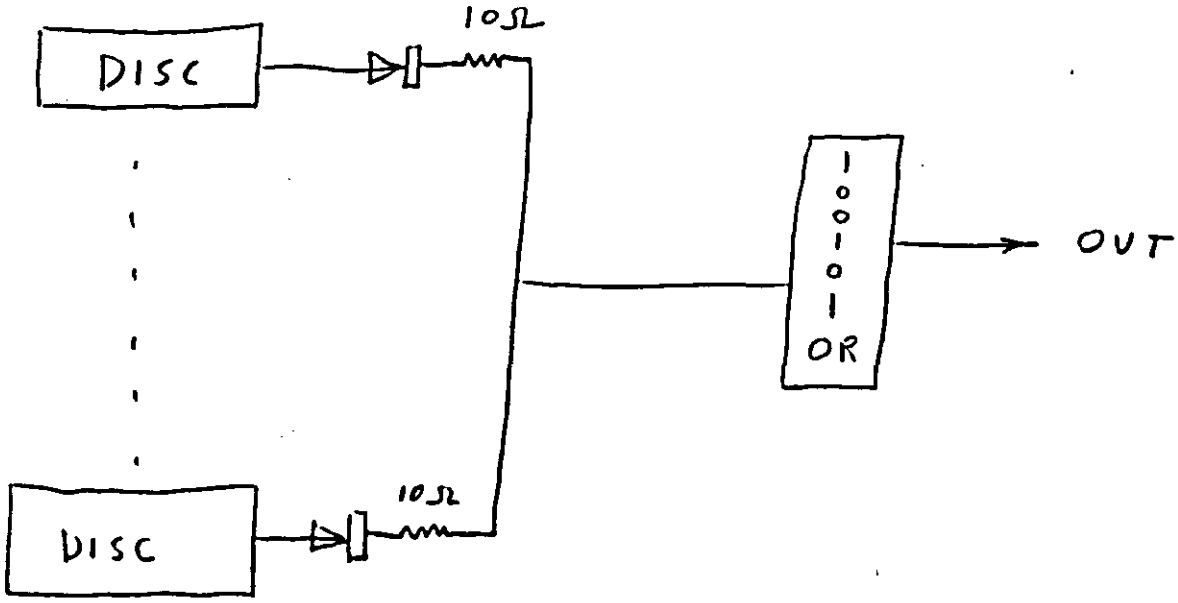
For both charges = 2 x 7620 = 15,240

The logic gives four momentum trigger ranges.

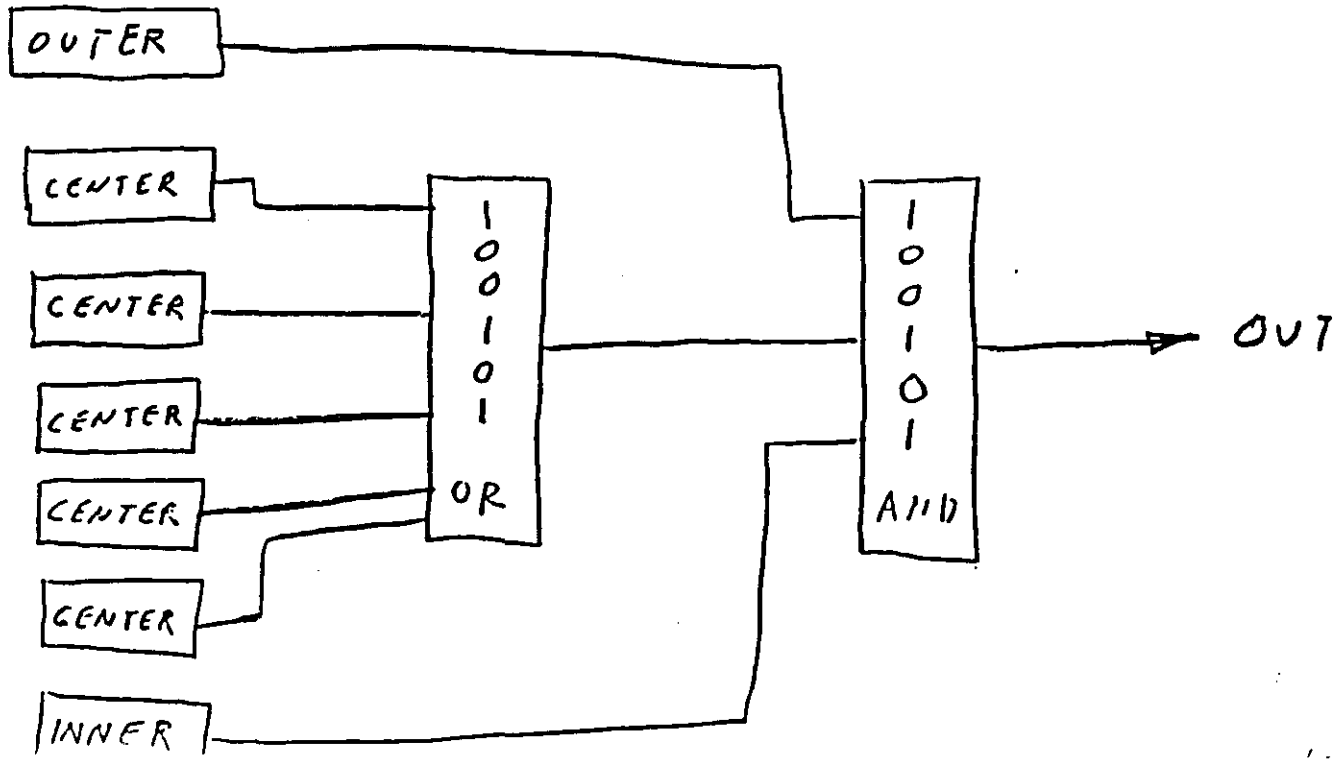
> 10 GeV/c
> 20 GeV/c
> 30 GeV/c
> 50 GeV/c

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

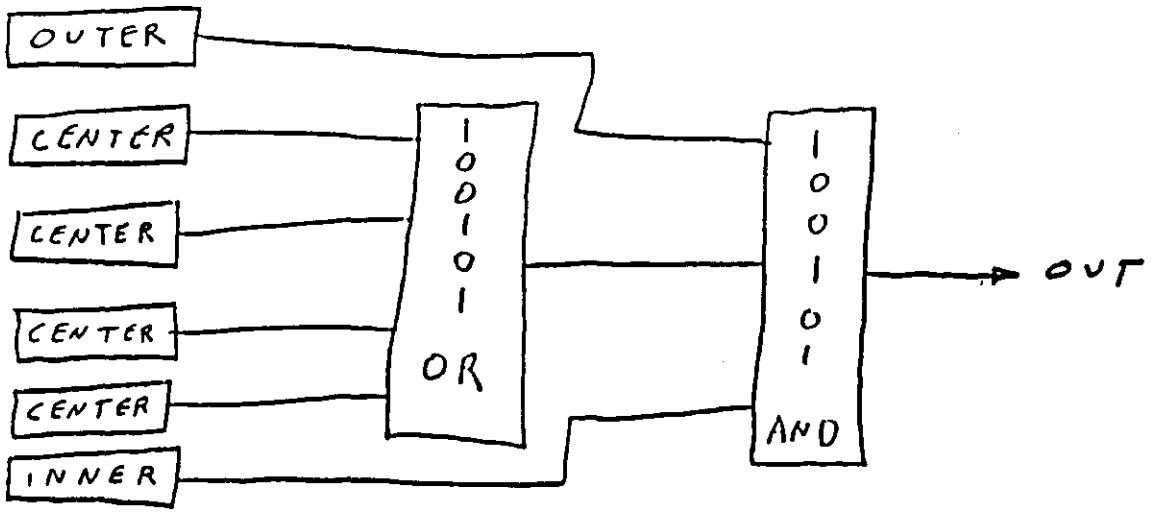
Need a fast infinite fan in circuit (infinity = 2032)



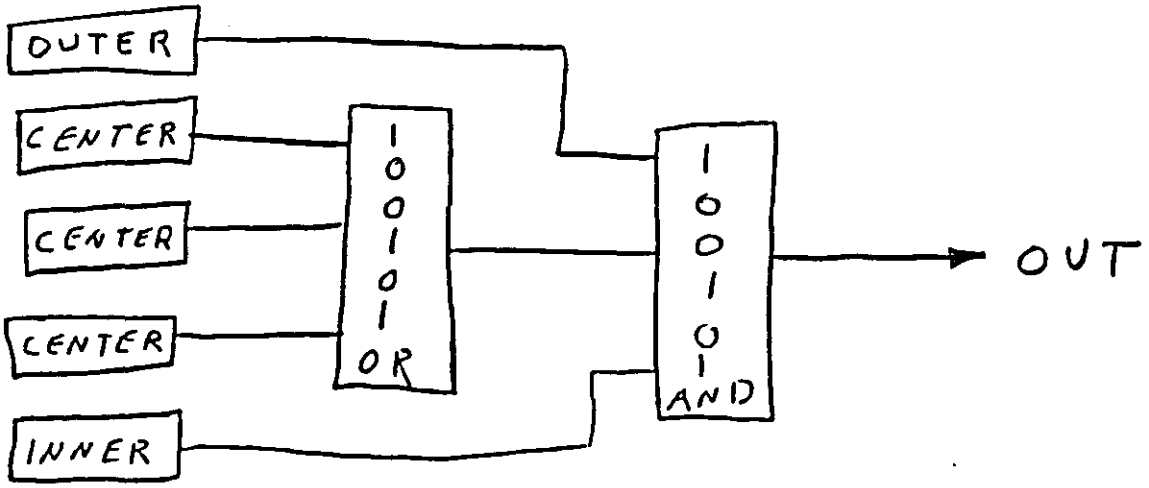
10 GeV Circuit = 8 x 2 x 254 = 4,064 circuits (2,032 positive; 2,032 negative).



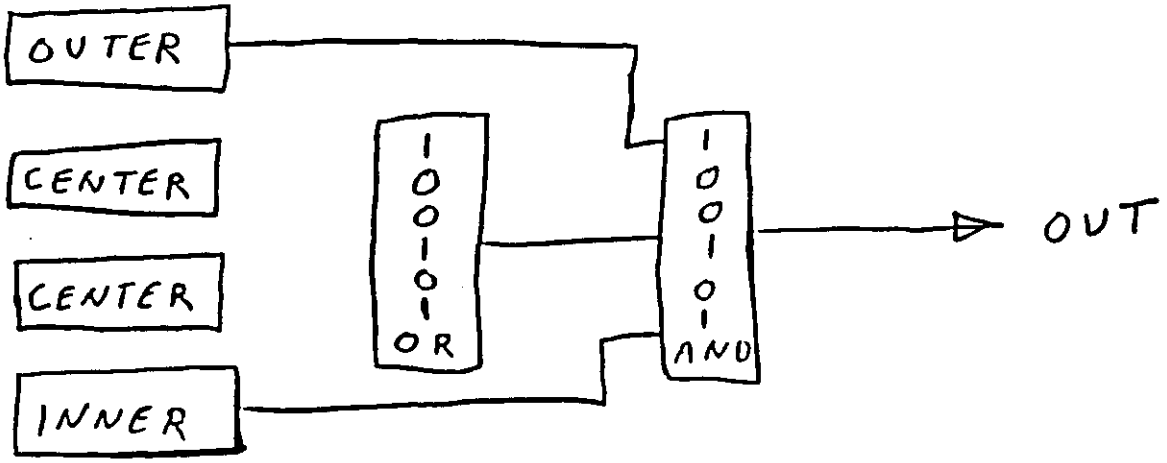
20 GeV circuit - need 4,064 circuits.



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

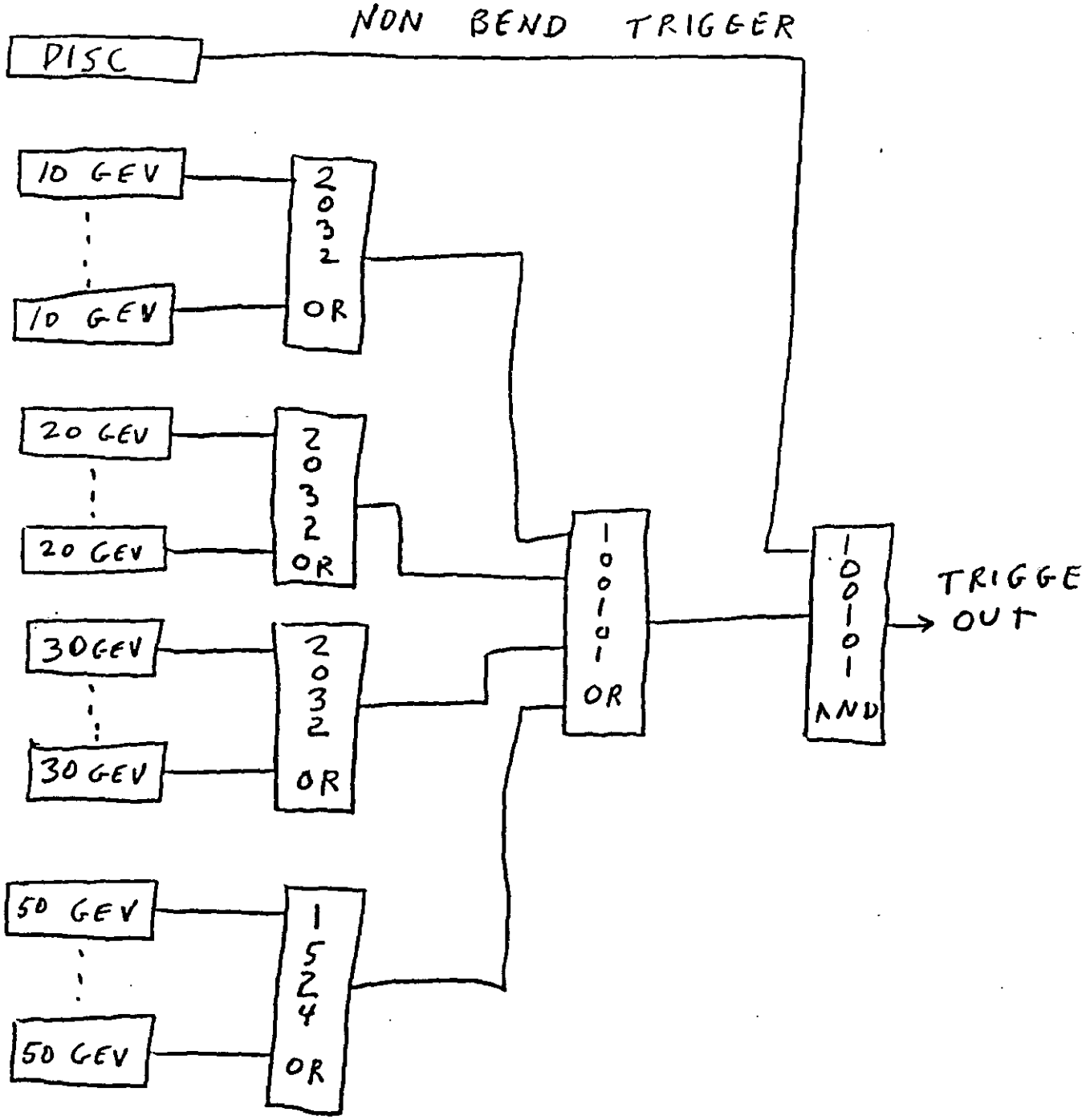


50 GeV/c circuit - need 6 x 2 x 254 = 3,048 circuits (1524 positive; 1524 negative)

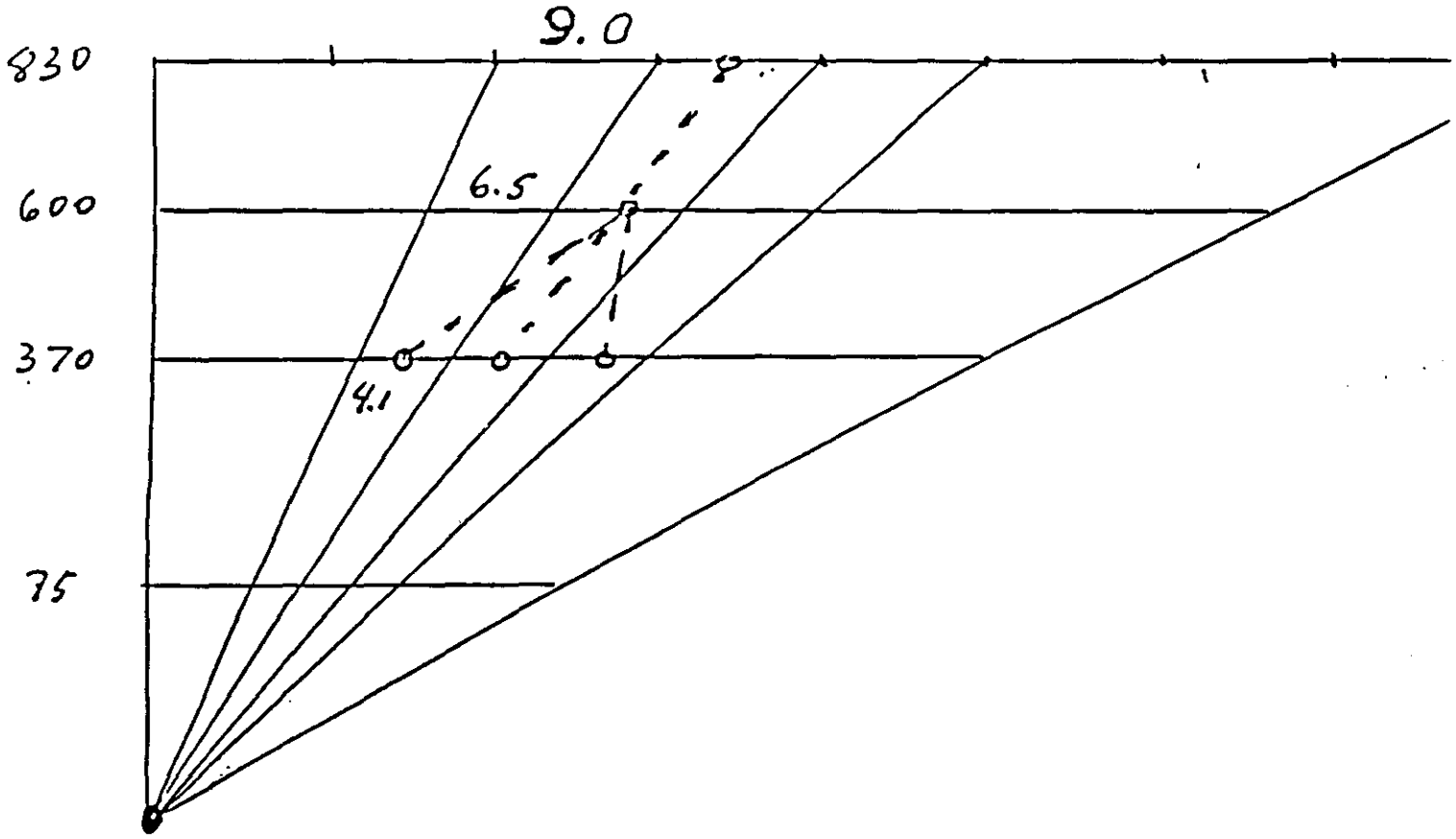


POSITIVE MUON

Trigger > 10 GeV



NON BEND TRIGGER



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

NON BEND TRIGGER

Tower geometry.

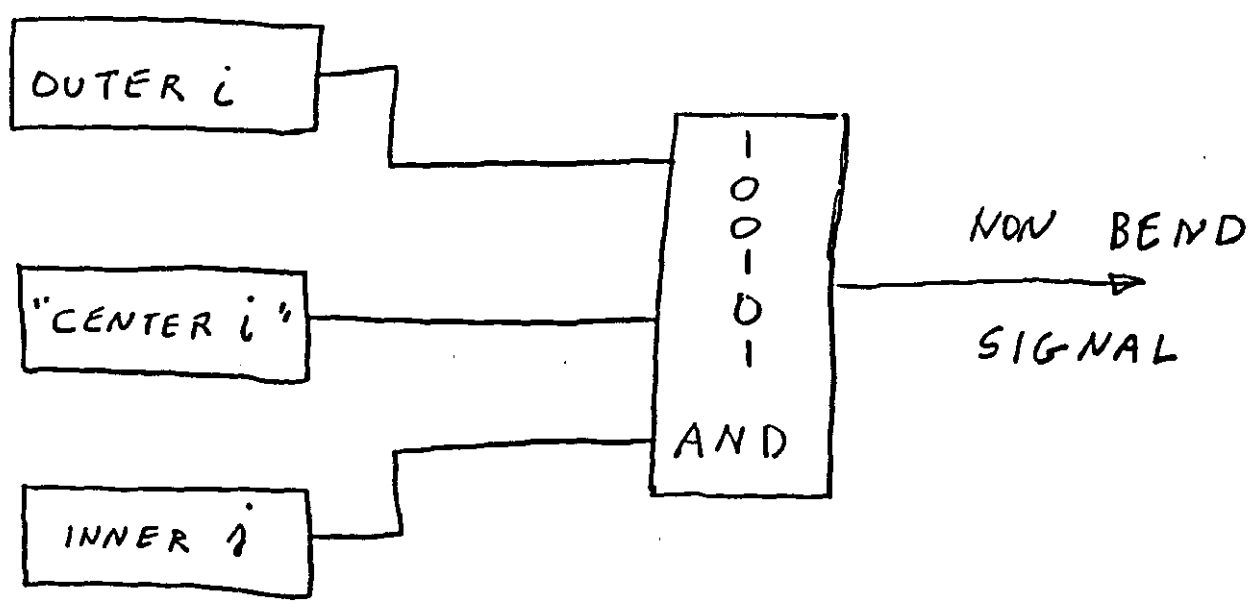
Each plane is divided into 161 strips.

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

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

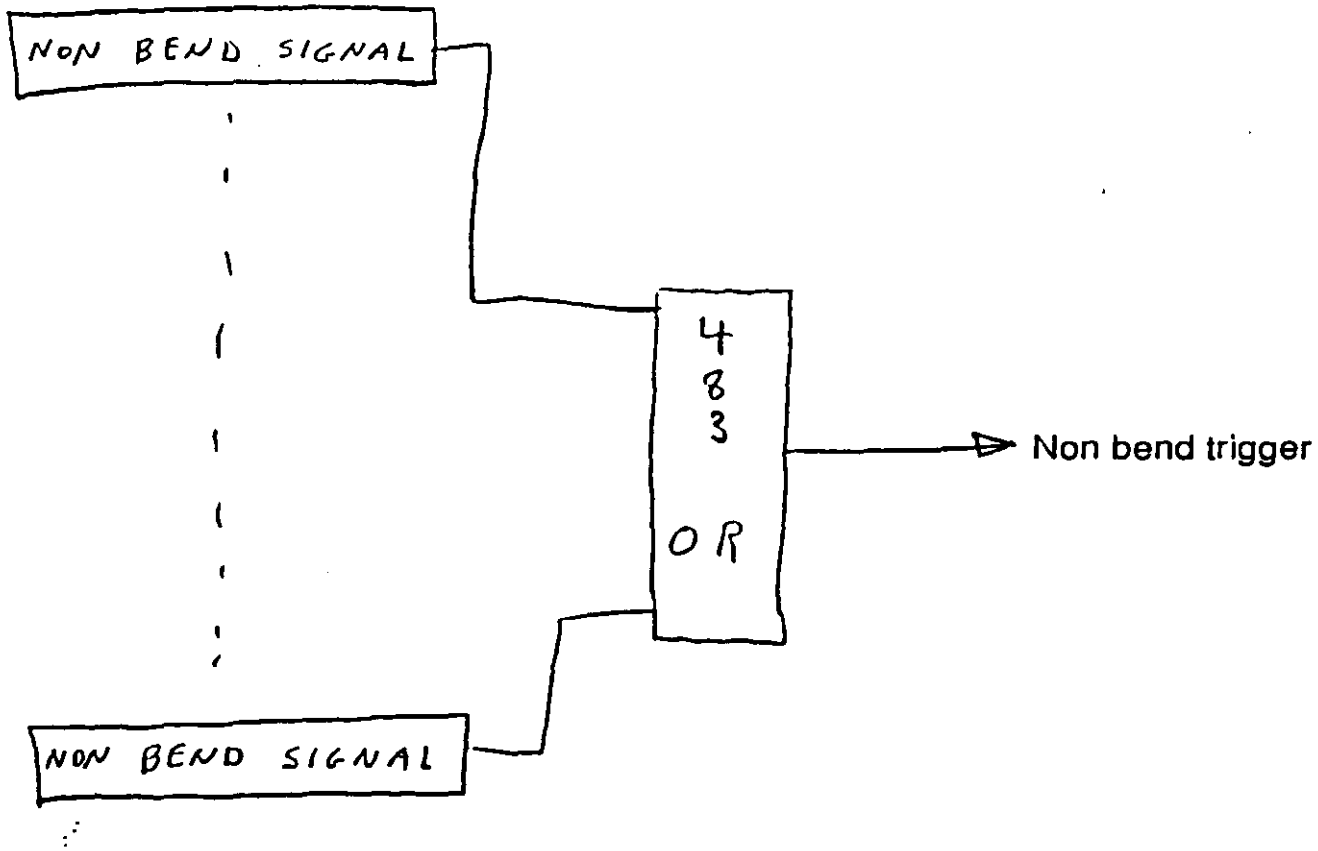
For each outer strip there are three coincidence circuits to account for multiple scattering.

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



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

NON BEND CIRCUIT



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

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

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

We have	161 strips	4.1 cm (inner)
	161 strips	9.0 cm (outer)
	805 strips	1.2 cm (center)

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

SUMMARY

Strip count

Non	Bend	1,127
	Bend	552

Circuits

Non	Bend	483
	Bend	15,240

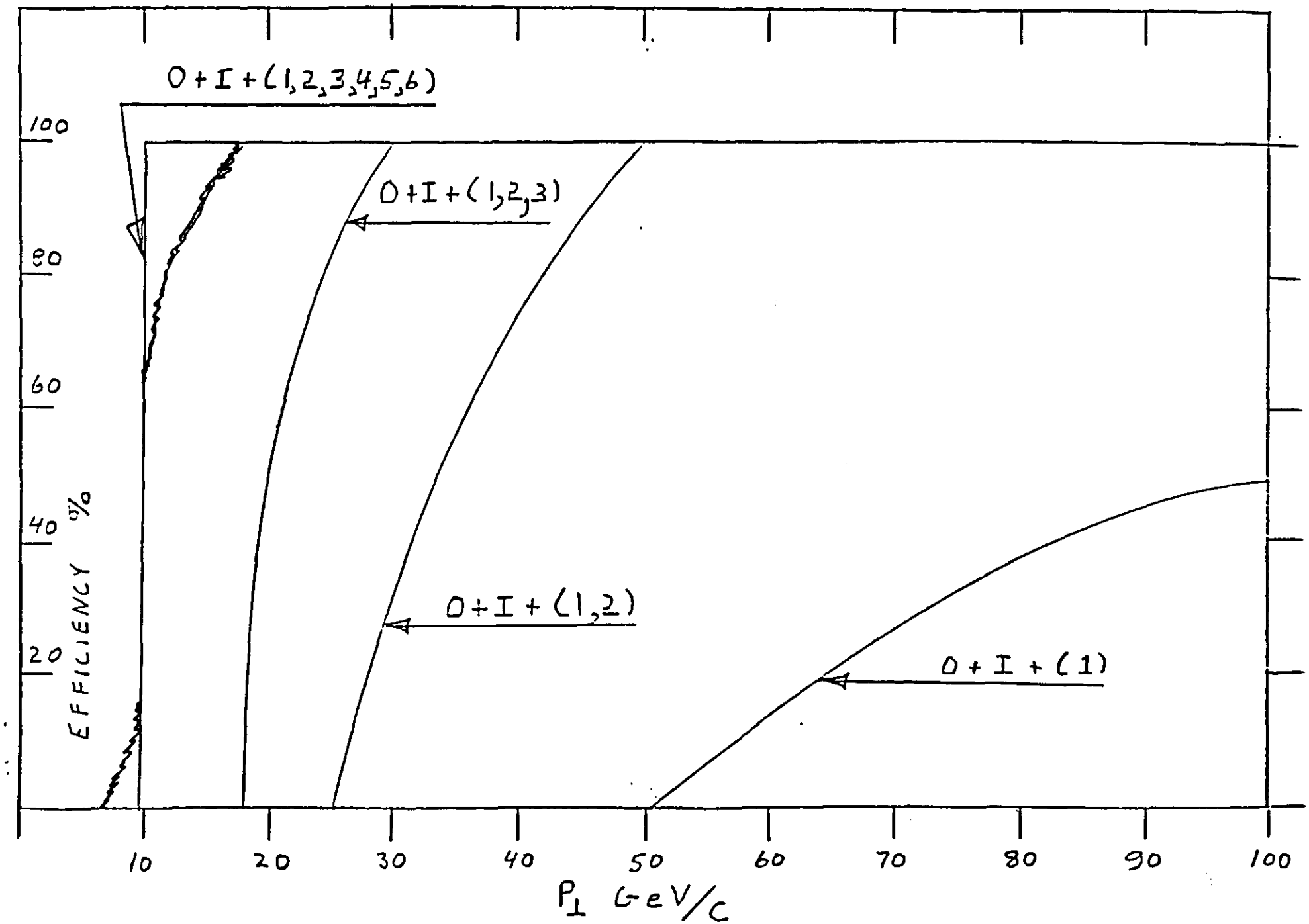
Chips

Non	Bend	644
	Bend	45,720

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

Question:

How do we write the simulation program?


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

V. HARDWARE IMPLEMENTATION

THE FIRST QUESTION WITH RESPECT TO HARDWARE, IS HOW DO YOU GET THE SIGNALS OUT TO THE COMMON ELECTRONICS POINT. IN OUR CASE WE PROPOSE TO BRING THE SIGNALS OUT ALONG THE EDGE OF THE RPC LAYERS AT THE LAYER LEVEL AND ALONG THE 60° LINE TO THE OUTER LAYER FOR THE INTER LAYER CONNECTIONS.

FOR EACH LAYER WE HAVE 161 CABLES RUNNING ALONG THE EDGE OF THE LAYER, USING RG 58 CABLE. THIS IS A CABLE BUNDLE 5.8 INCHES ON A SIDE.

FOR THE RUN FROM THE INNER LAYER TO THE CENTRAL LAYER WE USE 274 CABLES. THIS IS A CABLE BUNDLE OF 7.5 INCHES ON A SIDE.

FOR THE RUN FROM THE CENTER LAYER TO THE OUTER LAYER WE HAVE 1,264 CABLES. THIS IS A CABLE BUNDLE OF 16 INCHES ON A SIDE.

ALTERNATELY, WE CAN RUN ALL CABLES IN A FLAT PACKAGE TWO INCHES WIDE. THAT WOULD GIVE WIDTHS OF 17, 28.2, 128 INCHES WIDE, FOR ALONG THE LAYER, FROM THE INNER LAYER TO THE CENTER LAYER AND FROM THE CENTER LAYER TO THE OUTER LAYER RESPECTIVELY.

VI. ASSOCIATIVE MEMORY IMPLEMENTATION

AN ASSOCIATIVE MEMORY OPERATES BY HAVING STORED HIT PATTERNS AND THEN FOR EACH INPUT PATTERN, COMPARING EACH OF THE STORED PATTERNS WITH THE HIT PATTERN

THE NUMBER OF PATTERNS WE HAVE IS:

10 GeV	12,880
20 GeV	10,304
30 GeV	7,728
50 geV	3,864
TOTAL	34,776

SINCE EACH ASSOCIATIVE MEMORY CAN HANDLE 128 PATTERNS, WE NEED ONLY 272 SUCH MEMORIES. HOWEVER EACH MEMORY CONTAINS OVER 120,000 CIRCUITS. HENCE WE ARE TALKING ABOUT 9×10^6 CIRCUITS PER SECTOR.

HOWEVER, THESE SEEMS TO BE A FAIR AMOUNT OF EXTERNAL LOGIC THAT REQUIRES ADDITIONAL CIRCUITS, AND TIME, IN ORDER TO UTILIZE THIS APPROACH. IN PRINCIPLE, HOWEVER, IT SEEMS THAT ONE CAN USE THE ASSOCIATIVE MEMORY SCHEME FOR THE RPC TRIGGER.

MORE WORK MUST GO INTO THE ASSOCIATIVE MEMORY SCHEME TO SEE IF IT CAN BE MADE TO WORK.

VII. SUMMARY

WE FIND THE FOLLOWING TRIGGER RATES FOR THE BARREL:

$P_t > 0$ GeV/c	1.3×10^6 HERTZ
$P_t > 10$ GeV/c	2,000 HERTZ
$P_t > 20$ GeV/c	400 HERTZ
$P_t > 30$ GeV/c	75 HERTZ

WE CONCLUDE THAT IN ORDER TO OPERATE AT A LUMINOSITY OF 10^{34} WE SHOULD HAVE FOUR TRIGGER LEVELS:

$P_t > 10$ GeV/c

$P_t > 20$ GeV/c

$P_t > 30$ GeV/c

$P_t > 50$ GeV/c

USING OUR PROPOSED WIRING GEOMETRY, WE HAVE THE POSSIBILITY AT THE FIRST LEVEL TRIGGER OF CALCULATING THE EVENT TIME TO THE LEVEL OF THE RISE TIME JITTER OF THE RPC. IF THE RPC RISE TIME JITTER IS LESS THAN 4 NANO-SECONDS, THEN THE BEAM CROSSING IS UNIQUELY IDENTIFIED AT THE FIRST LEVEL TRIGGER.

WE FIND WE CAN DO COINCIDENCES OF THE VARIOUS STRIPS WITH GATE WIDTHS OF 13, 9, AND 6.5 NANO-SECONDS. THIS WILL REDUCE SINGLE RANDOM NOISE HITS BY A FACTOR 7.

WE HAVE SHOWN A TRIGGER STRATEGY THAT CAN BE IMPLEMENTED IN FIXED HARDWARE OR BY USING ASSOCIATIVE MEMORIES. IT WILL TAKE MORE STUDY TO DETERMINE WHICH IS THE OPTIMAL WAY TO GO FOR THE GEM DETECTOR.