SSC-SDE-2
SDC-89-00002

SSC-SDC
SOLENOIDAL DETECTOR NOTES

WORKING GROUP REPORTS
DALLAS SOLENOIDAL DETECTOR MEETING
JUNE 26-29, 1989

G. Hanson, G. Abrams, J. Bensinger, S. Errede, P. Sinervo, D. Theriot

TRACKING GROUP REPORT

G. Hanson

6-29-89

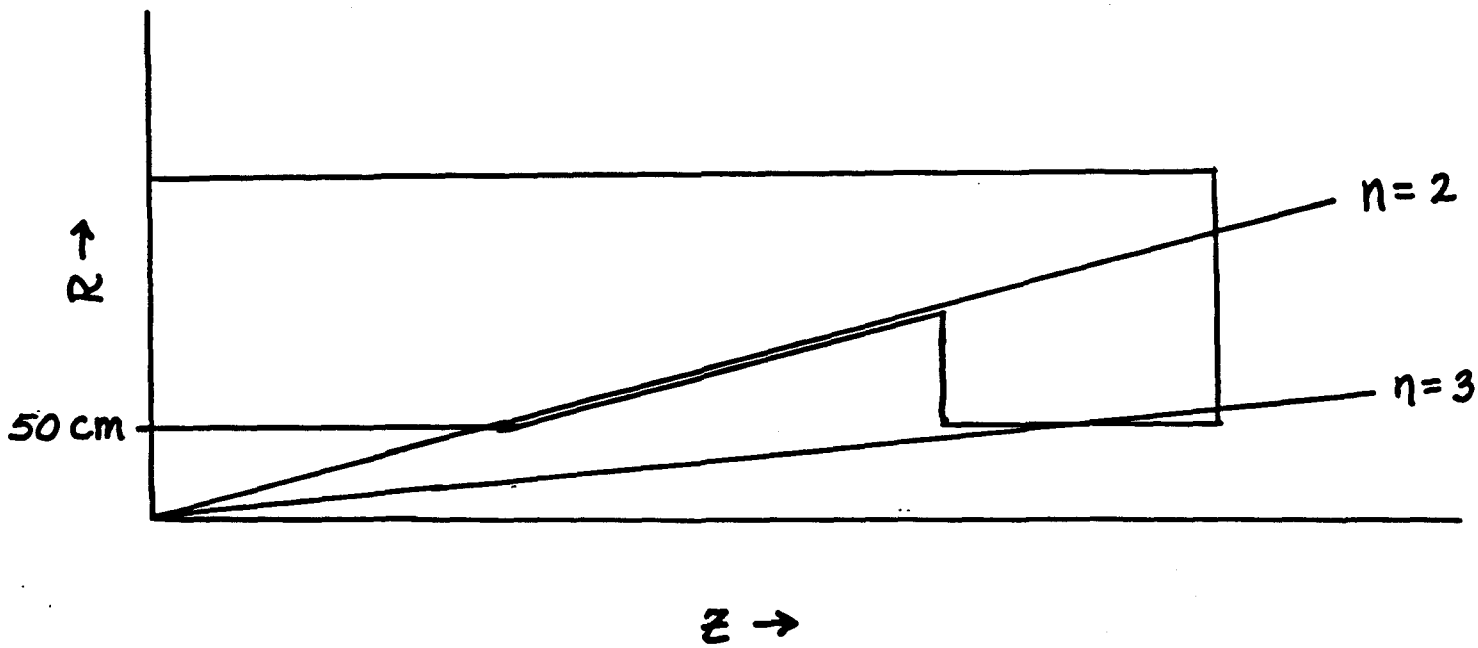
LIMITATIONS FOR SSC TRACKING

- Radiation Damage
- Current Draw
- Chamber Lifetime
- Gain Reduction from Particle Flux
- Hit Rate
- Occupancy
- Pattern Recognition

Philosophy for Wire Chamber Tracking

Momentum Measurement $|\eta| < 2$

Position Measurement $2 < |\eta| < 3$



MOMENTUM MEASUREMENT

1. Good Enough to See Bump In M_{ZZ}

$$\frac{\sigma_{p_T}}{p_T} = 0.54\, p_T \text{ (TeV/c) O.K.}$$

$$\frac{\sigma_p}{p} < 10\% \text{ O.K.}$$

2. Charge Sign for $p_T < X$ GeV/c

$$X = 250 - 1000$$

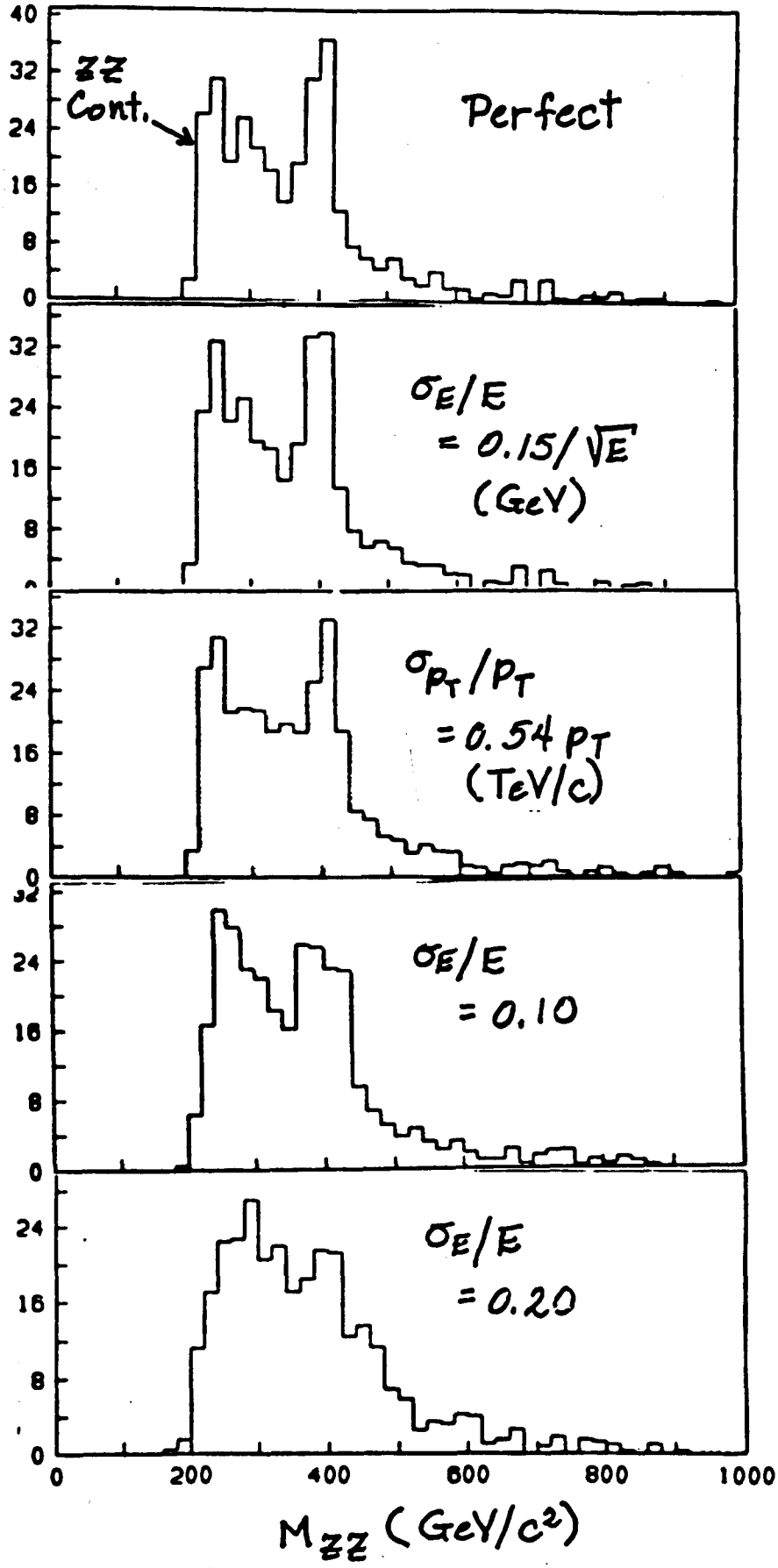
3. $$\frac{\sigma_{p_T}}{p_T} \sim \frac{\text{CDF}}{\ln(40/2)} = \frac{\text{CDF}}{3}$$

For A Large <u>Magnetic</u> Detector,

Want "Reasonable" Momentum Resolution

$H \to ZZ \to \ell^+\ell^-\ell^+\ell^-$

$M_H = 400\ GeV/c^2$



Berkeley '87 Large Solenoid Detector:

$$\left(\frac{\sigma_{p_T}}{p_T}\right)_{Theor} = \sqrt{\frac{720}{1+5/N}}\,\frac{\sigma_x}{0.3\,q\,BL^2\sqrt{N}}\,p_T$$

$$\left.\begin{array}{l} B = 2T \\ L = 1.1\,m \\ N = 104 \\ \underline{\sigma_x = 150\,\mu m} \end{array}\right\} \rightarrow 0.54\,p_T\ (TeV/c)$$

<u>Mark II</u> - Single Track (No Beam Constraint)

$$\left.\begin{array}{l} B = 0.45\,T \\ L = 1.25\,m \\ N = 72 \\ \text{"}\sigma_x = 175\,\mu m \end{array}\right\} \quad \begin{array}{l} \left(\frac{\sigma_{p_T}}{p_T}\right)_{Theor} = 0.25\,p_T\ (GeV/c) \\ \left(\frac{\sigma_{p_T}}{p_T}\right)_{Meas} = 0.46\,p_T\,(GeV/c)\,\% \end{array}$$

CDF - Single Track

$$\left.\begin{array}{l} B = 1.4\,T \\ L = 1\,m \\ N = 84 \end{array}\right\} \quad \left(\frac{\sigma_{p_T}}{p_T}\right)_{Meas} = 0.18\,p_T\,(GeV/c)\,\%$$

$(\sim \sigma_x = 260\,\mu m)$

Residual $= \sigma_x = 150\,\mu m$

$\sigma_x = 150\mu m$ <u>Not</u> <u>Realistic</u>, Including Systematic for a Large System!

CDF/3 $\rightarrow \sigma_{p_T}/p_T \sim 0.06\,p_T\,(GeV/c)\,\%$
$\rightarrow 0.60\,p_T\,(TeV/c)$

Scale LSD: $150\mu m \rightarrow 200\mu m$

$$\left(\frac{L}{1.1\,m}\right)^2 = \frac{200\mu m}{150\mu m} \Rightarrow \underline{L = 1.27\,m}$$

Conclude:

Want Tracking

$R_{MIN} = 50$ cm

$R_{MAX} = 1.8$ m

$\frac{\sigma_{p_T}}{p_T} = 0.67\, p_T$ (TeV/c), scaled to

<u>measured</u> CDF resolution

B: 1.4 T → <u>2 T</u>
L: 1 m → 1.3 m
N: 84 → 104

Charge Sign to 450 GeV/c

(Beam Constraint $\frac{\sigma_{p_T}}{p_T} = 0.35\, p_T$, but this

is not achieved in real systems,

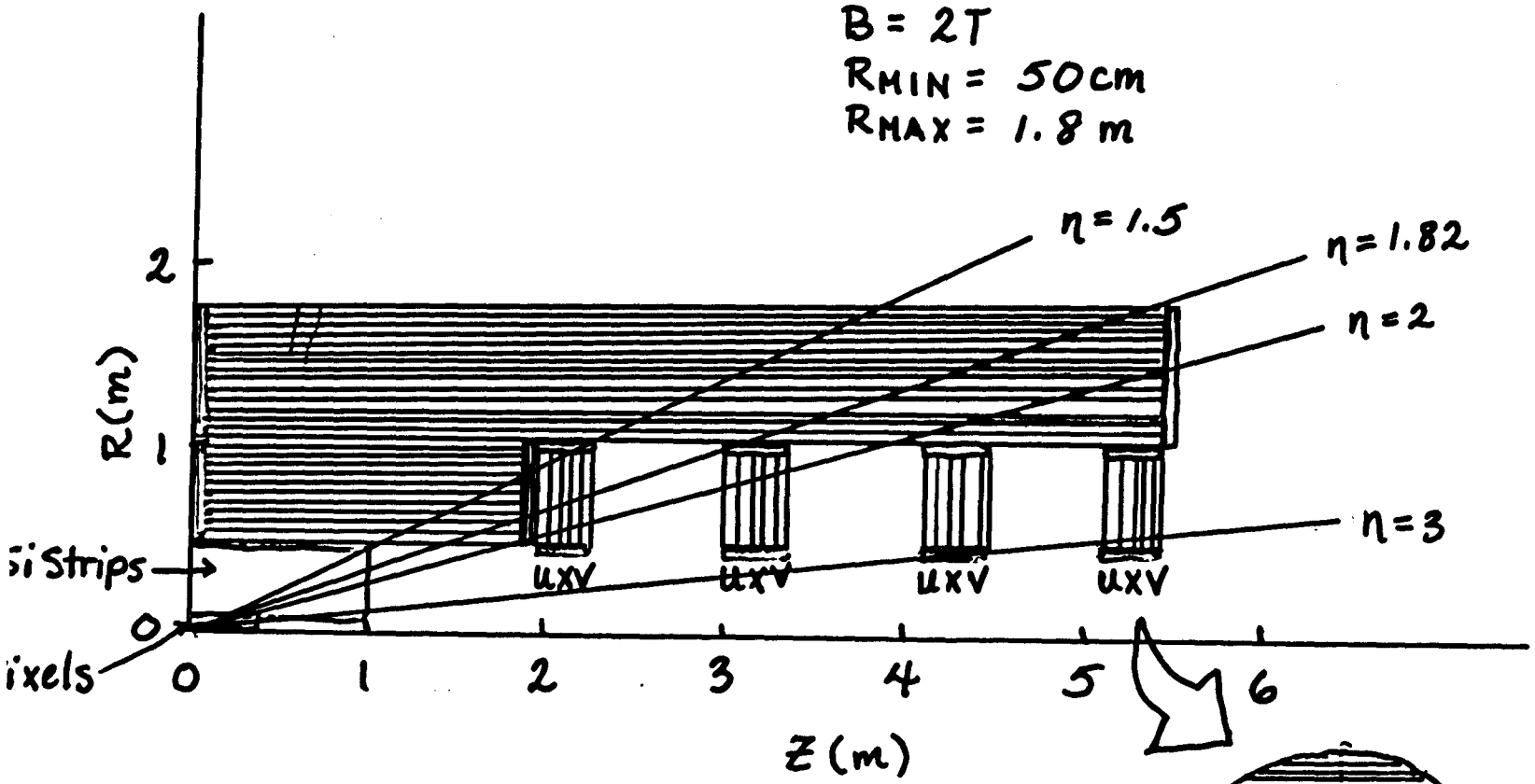
e.g., CDF would predict $0.09\, p_T$ (GeV/c)%,

but measures $0.13\, p_T$ (GeV/c) %)

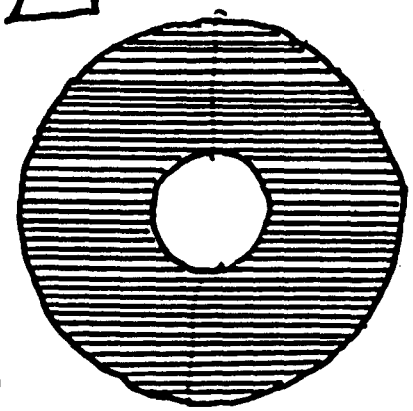
[If $R_{MAX} = 1.55$ m,

$$\frac{\sigma_{p_T}}{p_T} = 1.03\, p_T \text{ (TeV/c)}]$$

Large Magnetic Detector Tracking System



— Electronics
— HV



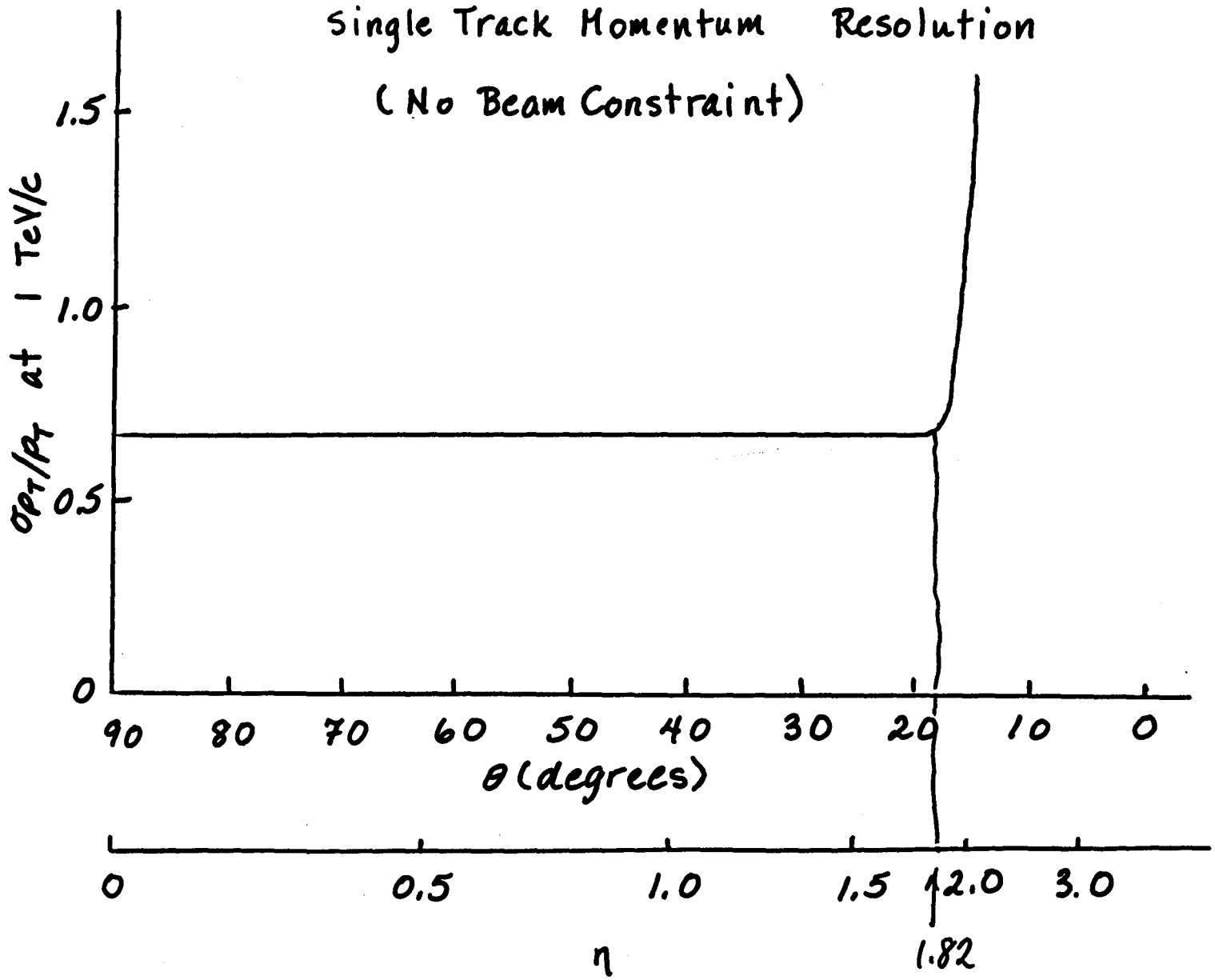
Central: 13 Superlayers
8 Layers / Superlayer
Alternating Axial / Stereo
Superlayers

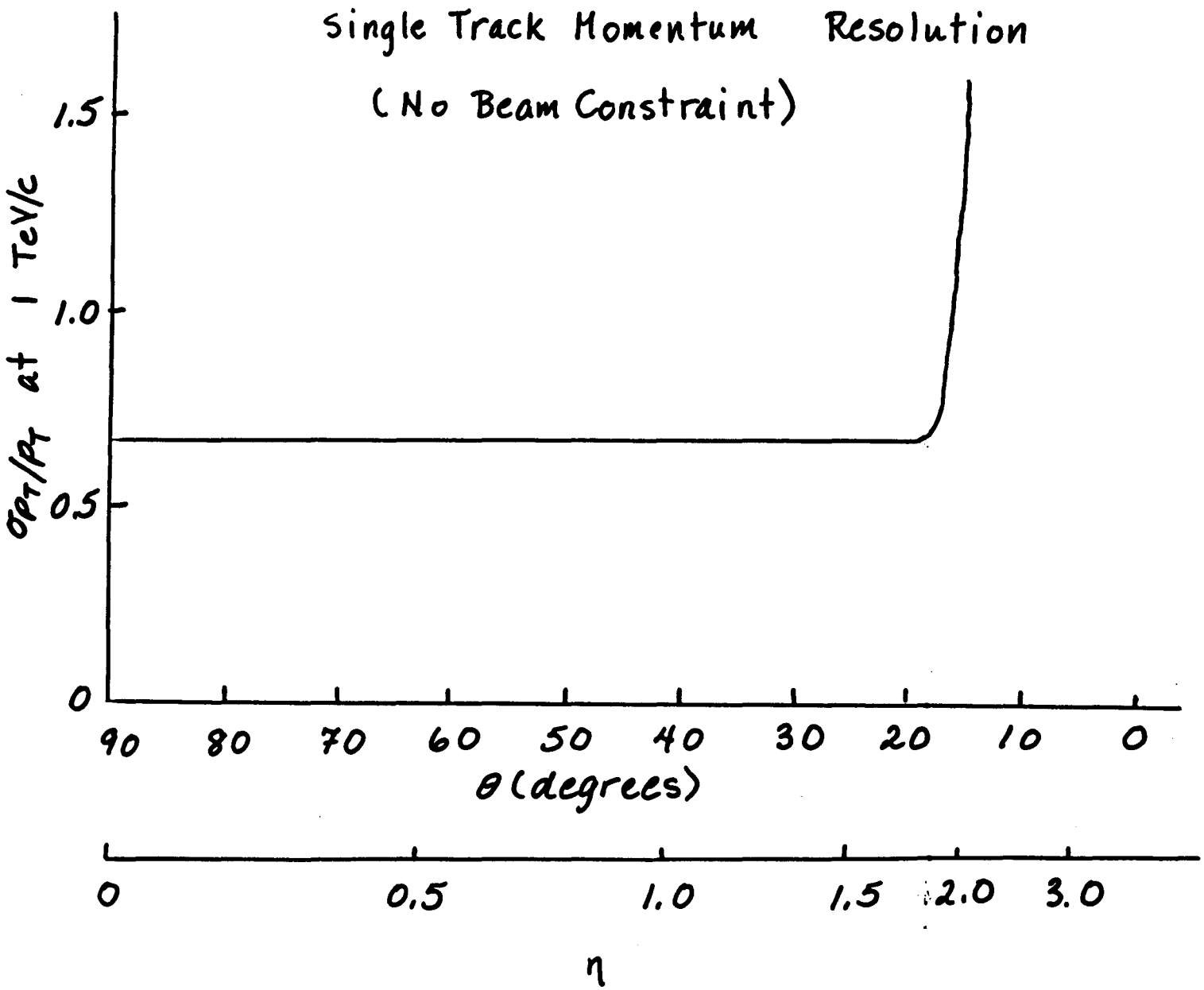
Central : 290 K Straws (4,6 mm), Split in Middle
Intermediate: 211 K Straws, Split in Middle

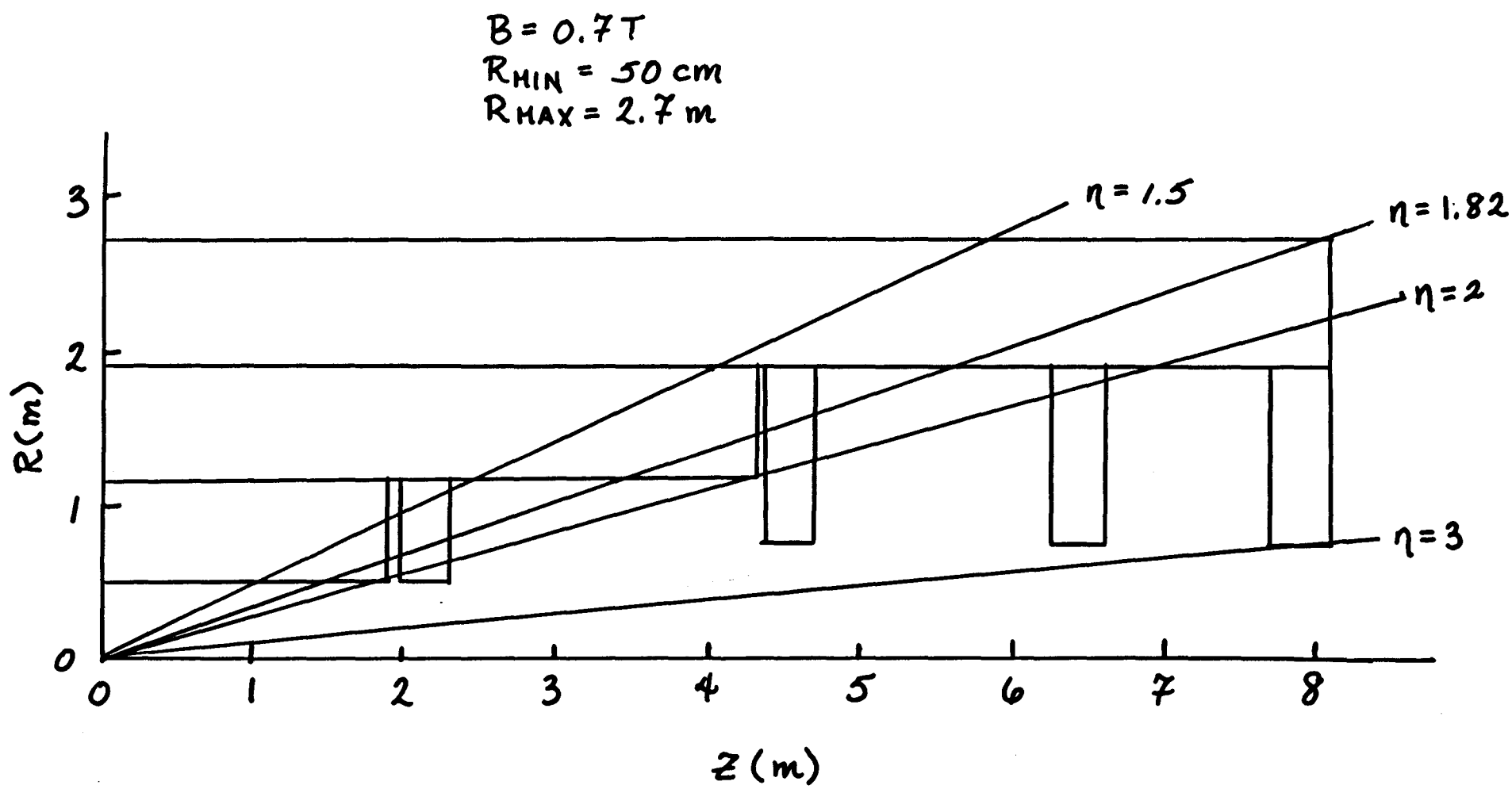
$R_{MIN} = 50\,cm$ $L = 5.4\,m$

$R_{MAX} = 1.8\,m$

$B = 2T$




Single Track Momentum Resolution
(No Beam Constraint)
σ_{p_T}/p_T at 1 TeV/c
1.5
1.0
0.5
0
90
80
70
60
50
40
30
20
10
0
θ (degrees)
0
0.5
1.0
1.5
2.0
3.0
η


B = 0.7 T
R_MIN = 50 cm
R_MAX = 2.7 m
η = 1.5
η = 1.82
η = 2
η = 3
R(m)
Z (m)
0
1
2
3
4
5
6
7
8

Tracking Simulation

$$H \to Z Z \begin{cases} \to e^+e^- \\ \to \mu^+\mu^- \end{cases}$$

No Minimum Bias

Field (T)	⟨Hits⟩	% All Tracks Kept	% High-p_T Leptons Kept
0	545	98.2	87.6
0.5	542	95.1	85.3
2.0	627	90.5	93.5

(Constant Geometry)

Straw Tube Tracking

Electronics

Preamp, Time Measurement

on Detector (Penn) & KEK

$\sigma_t = 500$ ps

~15 ns Recovery Time

Very Rough Cost Estimate: ~ \$20/channel

Power ~15 mw/channel

Trigger:

Track Segments in Outer Super layers
$|n| < 2$

$\Delta z \gtrsim 1.5$ mm (Needs Study)

Also Want Position to few mm

for $2 < |n| < 3$

2nd Level ?

Simulation Issues

1. Position Along Wire
   - Stereo Linking
   - Do We Need Cathode Pads?
   - Trigger
2. Forward (= Intermediate) Region
   - Pattern Recognition
   - Trigger
   - Optimal System (Cathode Pads?)
3. Track Fitting ($|\eta| < 2$)
   - What is <u>real</u> $\sigma p/p$ & track-finding efficiency?
4. Occupancy
5. Current Draw
6. Hits vs. B-field
7. Material, e^-'s from Conversions (Beam Pipe, Supports, Silicon)
8. Neutrons & Albedo
9. Dead Areas
10. Integration of Silicon

Straw Tube and Mechanical Issues

1. Alignment & Mechanical Stability
   - Need Real Engineering Help Here!
2. Getting Cabling, Power, Gas, Cooling In / Out
3. Study Power Dissipation

Straw Tubes

1. Understand Drift Time
2. Thinner Walls
3. Radiation Hardness of Materials
4. Cathode Coating? Gold?
5. Attenuation?
6. Maximum Length
7. Resistance, Impedance
8. Supports
9. Modular Structures
10. Lifetime, Current Draw Limitations

Straw Tube and Mechanical Issues

1. Alignment & Mechanical Stability
   - Need Real Engineering Help Here!
2. Getting Cabling, Power, Gas, Cooling In / Out
3. Study Power Dissipation

Straw Tubes

1. Understand Drift Time
2. Thinner Walls
3. Radiation Hardness of Materials
4. [illegible]
5. Attenuation?
6. Maximum Length
7. Resistance, Impedance
8. Supports
9. Modular Structures
10. Lifetime, Current Draw Limitations

Characteristics of Si tracking devices

Fast charge collection – separate different interaction

good position resolution – good momentum resolution at highest p

very small cells – low occupancy

Pixels or local stereo – unambiguous z determination

good 2 track resolution – ~100 μ

very good Signal/Noise possible – small number of spurious hits even in these devices with a large number of channels.

Interfacing and Integration in VLSI technique!

EXACT LOCATION OF PIXELS AND STRIPS WILL DEPEND ON M.C. STUDIES AND ON OCCUPANCY, RADIATION DAMAGE, NEEDED POSITION RESOLUTION.

PIXELS HAVE AN ARCHITECTURE TO READ OUT ONLY HIT CHANNELS WITHIN A FRACTION OF A μ SEC. ANALOG READ-OUT AT HIGH SIGNAL/NOISE WILL ALLOW TAGGING OF CONVERTED γ'S IN FRONT OF THE TRACKING VOLUME.

SEGMENTATION + HIGH S/N ⇒ RADIATION HARDNESS ALLOWING POSITIONING CLOSE TO THE BEAM ⇒ HIGH QUALITY VERTEXING OF SECONDARY VERTICES.

b.) Alignment:

The relative (and absolute?) position of the detectors has to be fixed over time to a few <u>microns</u>.

Very difficult!

The existing systems are encouraging but smaller!

i.) CDF proto-type experience

Short term stability of a full scale model (30 cm x 18 cm):

σ_x(3 param. fit) = 3 μ using precision touchprobe.

ii.) Mark II Silicon Vertex Detector

Laboratory survey:

σ(5 param. fit) = 1.8 μ

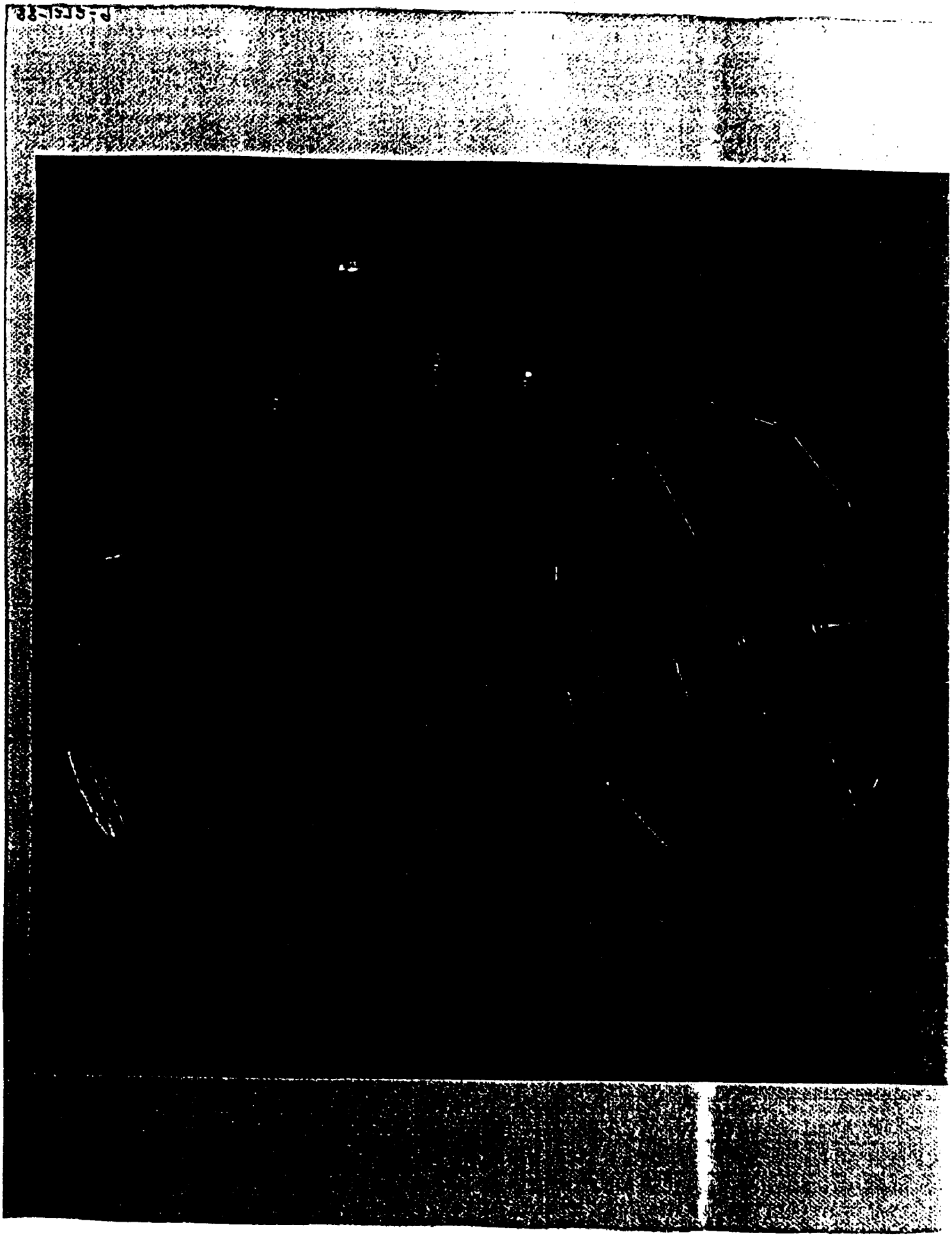
using collimated X-ray beam.

! REAL DATA !

Z^0 EVENTS in the MARK II at the SLC

Telescope of 3 detectors (~20 tracks)

$\sigma_x = 3.9\ \mu$

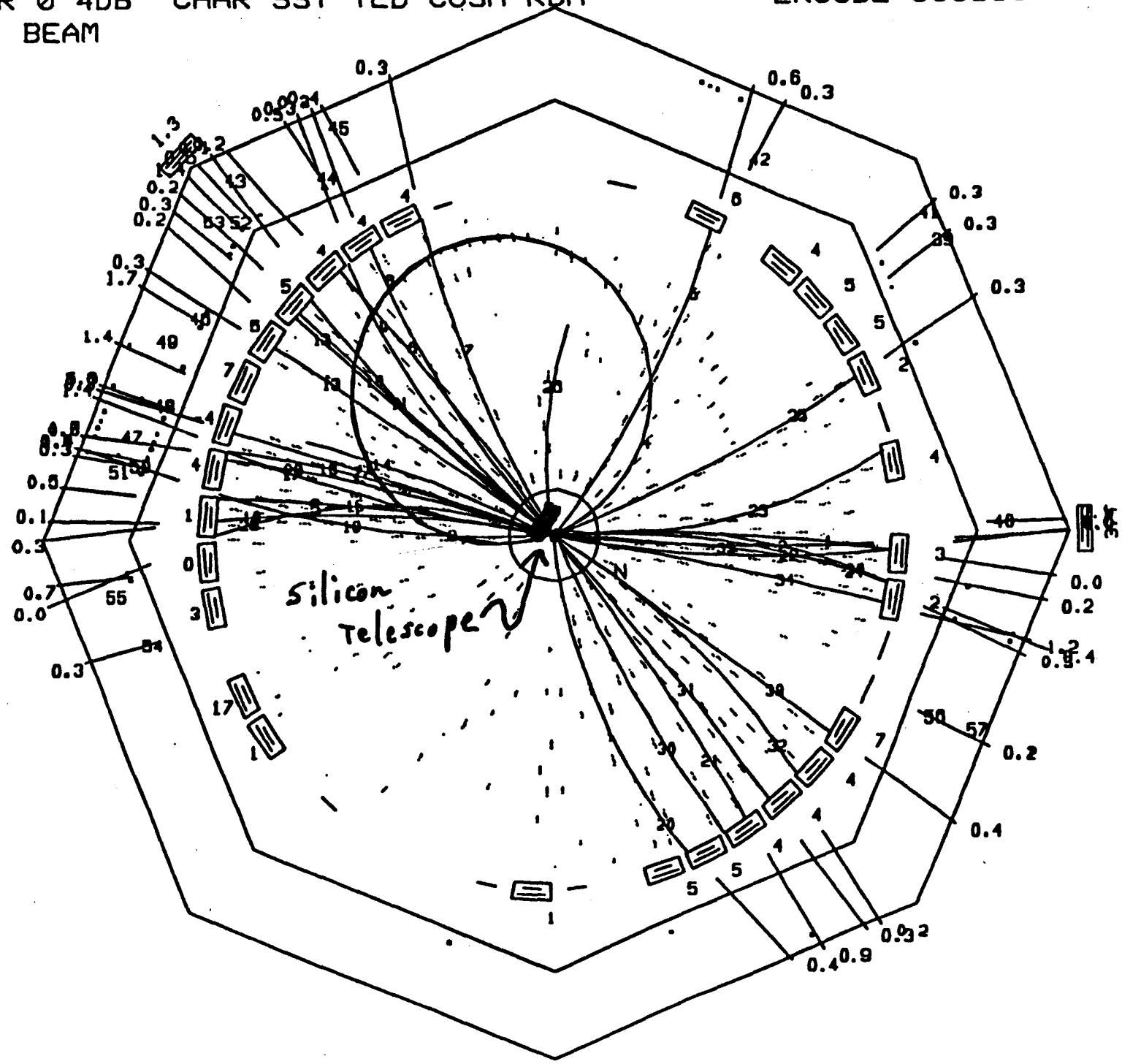


RUN 18394 REC 1471 E= 91.48 33 PRONG HADRON (5-0)

TRIGGER 0 4DB CHAR SST TED COSM RDM ERCODE=00080000

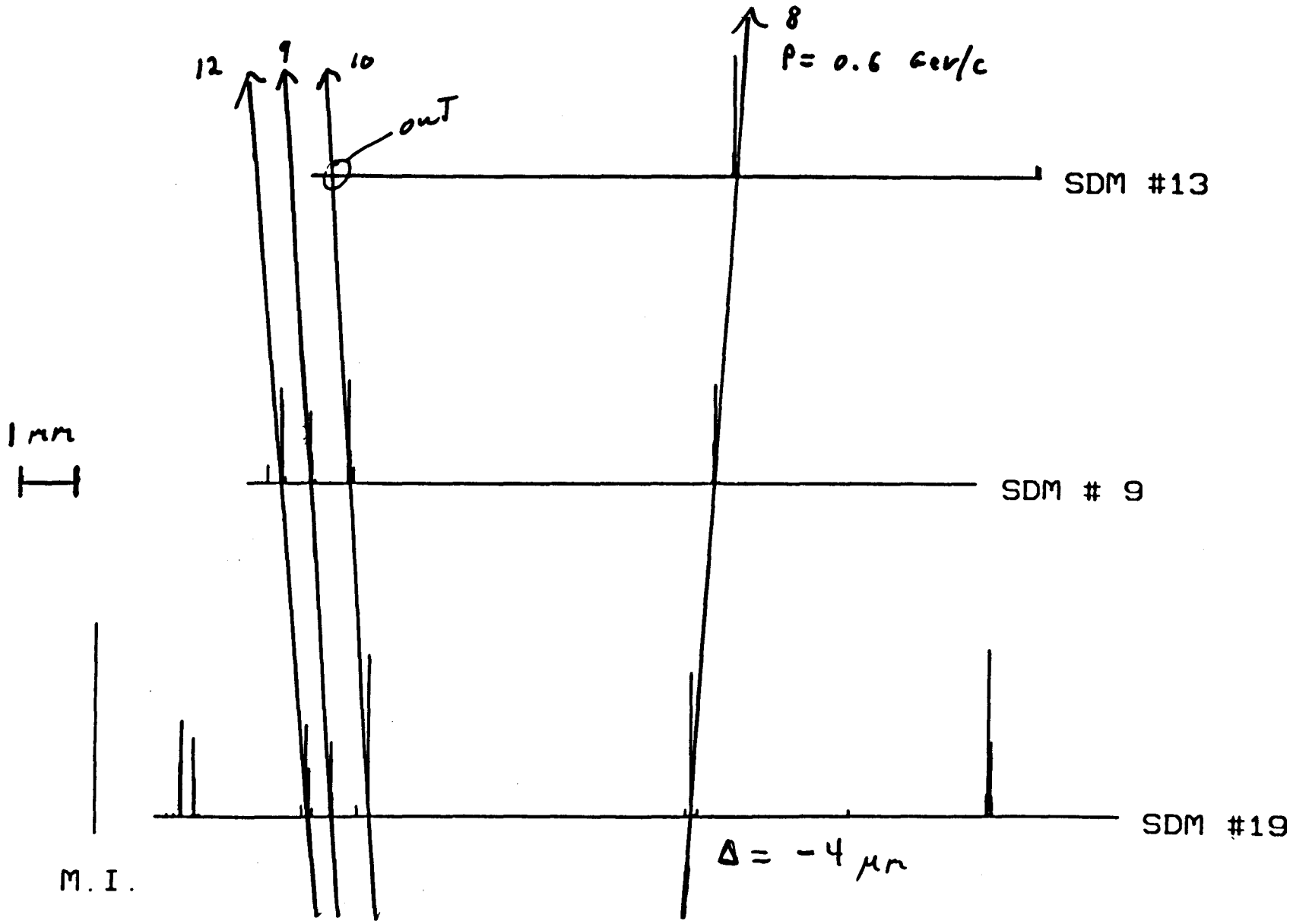
BEAM

TRK	P	ELATOT	ID
1	1.1	0.0	PI+
2	1.8	0.0	PI-
3	0.1		PI-
4	0.1		PI-
5	0.6	0.6	PI-
6	2.2	0.2	PI-
7	0.7	0.3	PI+
8	0.6	0.3	PI+
9	0.4	0.3	PI+
10	4.4	0.2	PI+
11	0.8	0.1	PI+
12	3.3	0.2	PI+
13	4.1	0.3	E-
14	1.5		PI-
15	1.2	0.1	PI-
16	1.0	0.3	PI-
17	1.3	1.4	PI+
18	1.2	1.7	PI-
19	0.7	0.0	PI+
20	0.4	0.4	PI-
21	1.9	0.9	PI+
22	0.8	0.0	K-
23	0.3		E-
24	0.5	0.4	PI+
25	0.9	0.3	PI-
26	0.5		PI+
27	5.3	0.3	PI-
28	0.4	0.0	PI-
29	1.4	0.8	PI-
30	0.9		PI-
31	2.7	0.3	PI+
32	0.6	0.2	PI+
33	15.6	0.4	MU+
34	3.6	1.2	PI+

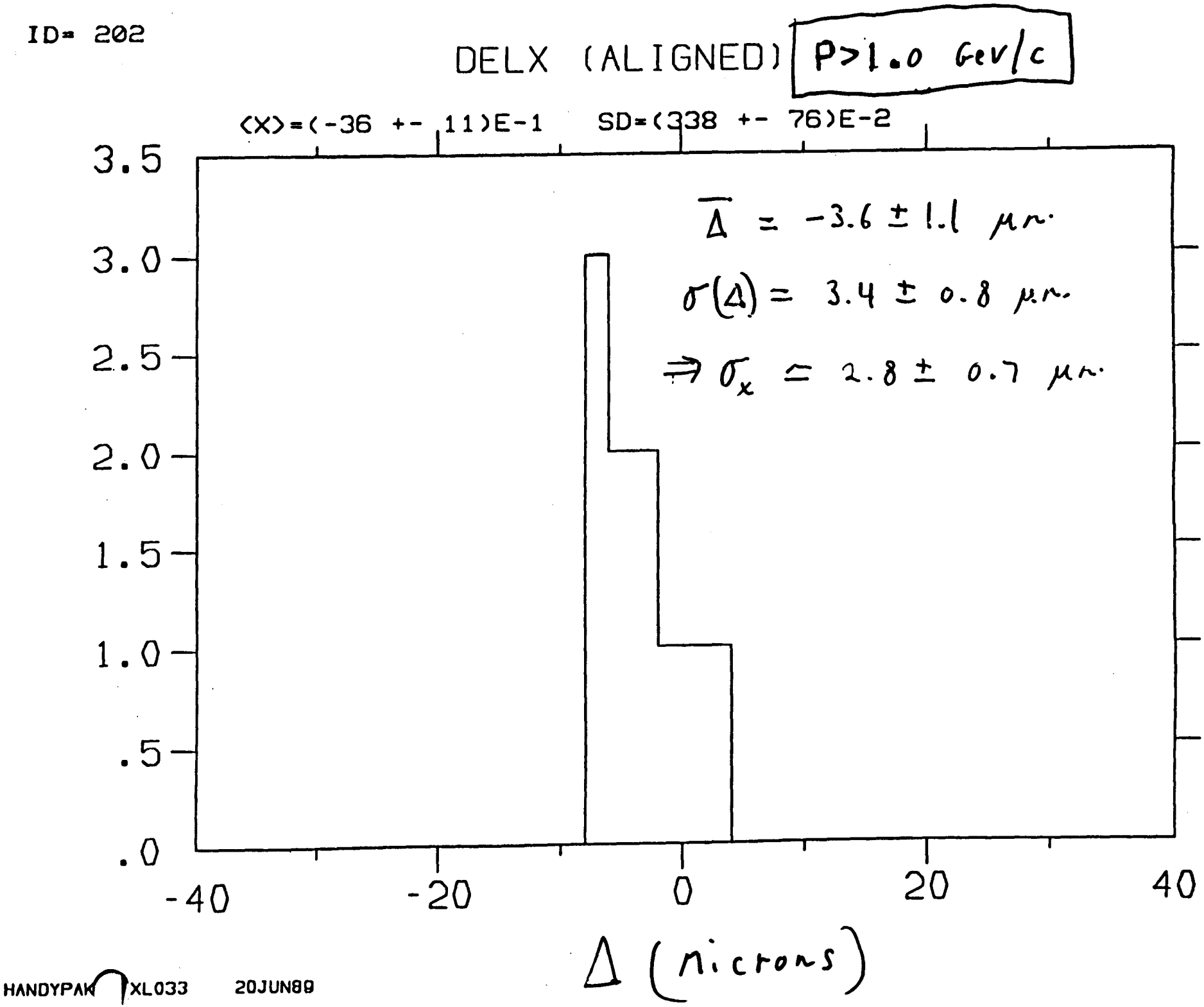


SILICON STRIP VERTEX DETECTOR

TELESCOPE DISPLAY



RUN 18394 EVENT 1471


ID= 202
DELX (ALIGNED)
P>1.0 GeV/c
<X>=(-36 +- 11)E-1
SD=(338 +- 76)E-2
$\bar{\Delta}$ = -3.6 ± 1.1 μm
σ(Δ) = 3.4 ± 0.8 μm
⇒ σ_x ≃ 2.8 ± 0.7 μm
3.5
3.0
2.5
2.0
1.5
1.0
.5
.0
-40
-20
0
20
40
Δ (microns)
HANDYPAK XL033
20JUN89

c.) Cooling

Very important for <u>all</u> systems!

Heat dissipation could compromise alignment.

(> 7 kW from before)

Alan Litke's solution....

d.) Electronics

Develop rad hard, fast, lowpower circuits.

Again common problem.

i.) Silicon system: digital system, fast clocking. Storage of digital time slice in buffer.

No interpolation between strips, only ZERO and ONE are kept.

ii.) Pixels:

Charge remains on pixel until read-out:

- ambiguity free 2D event
- big signal for read-out electronics
- Precision only limited by ADC because of S/N > 200.

Cooling System.

A. Litke
UC Santa Cruz

(1) Provide cooling for power density of at least 4 W/cm^2

(2) take up minimal space

(3) have minimal material for scattering

(4) have high reliability (e.g. no moving parts inside the detector)

(5) does not introduce mechanical vibrations that might interfere with the ~5 micron alignment requirements

(6) can be easily incorporated into a large system

(7) allow for temperature control

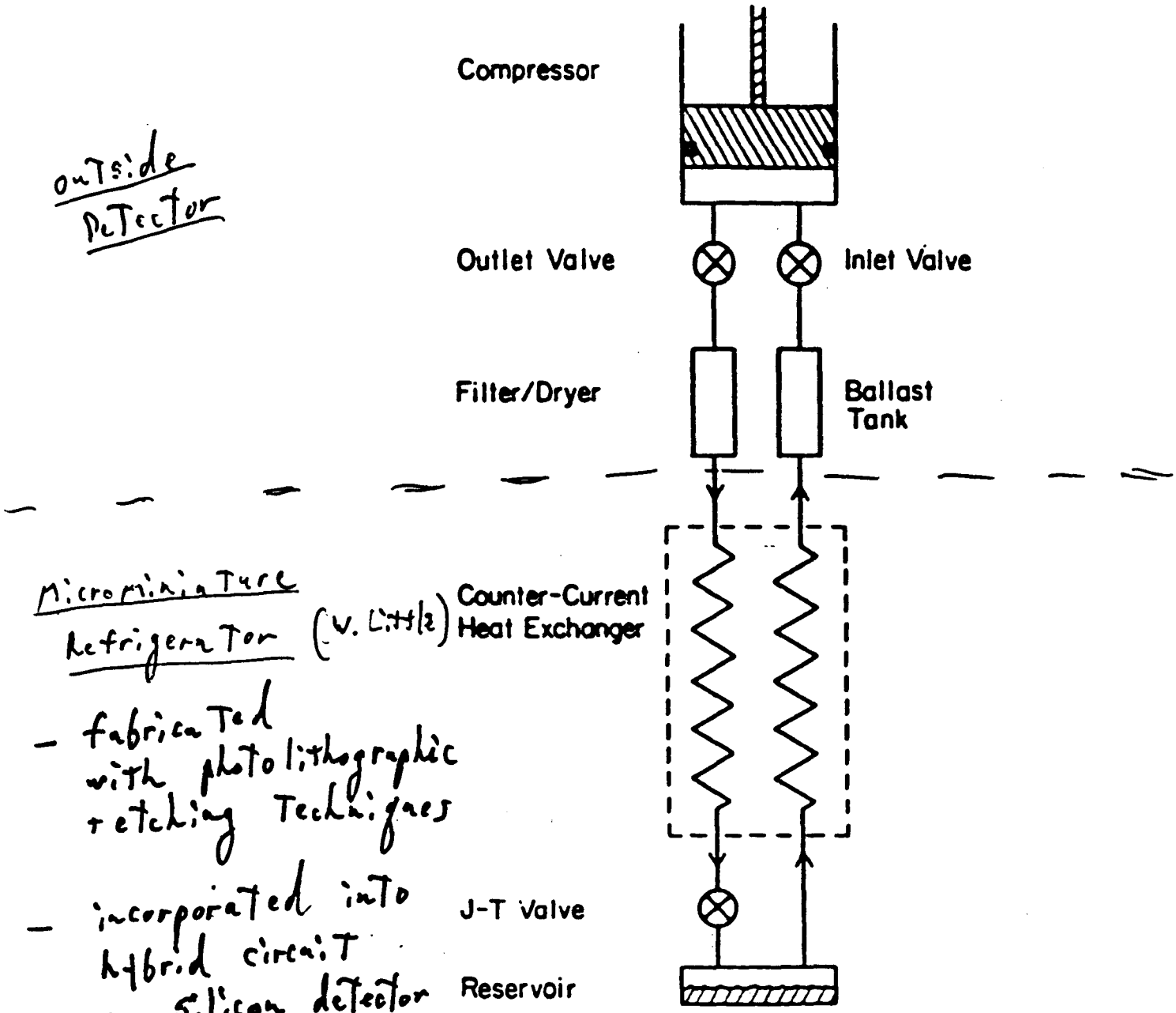
(8) radiation hard

(9) reasonable cost

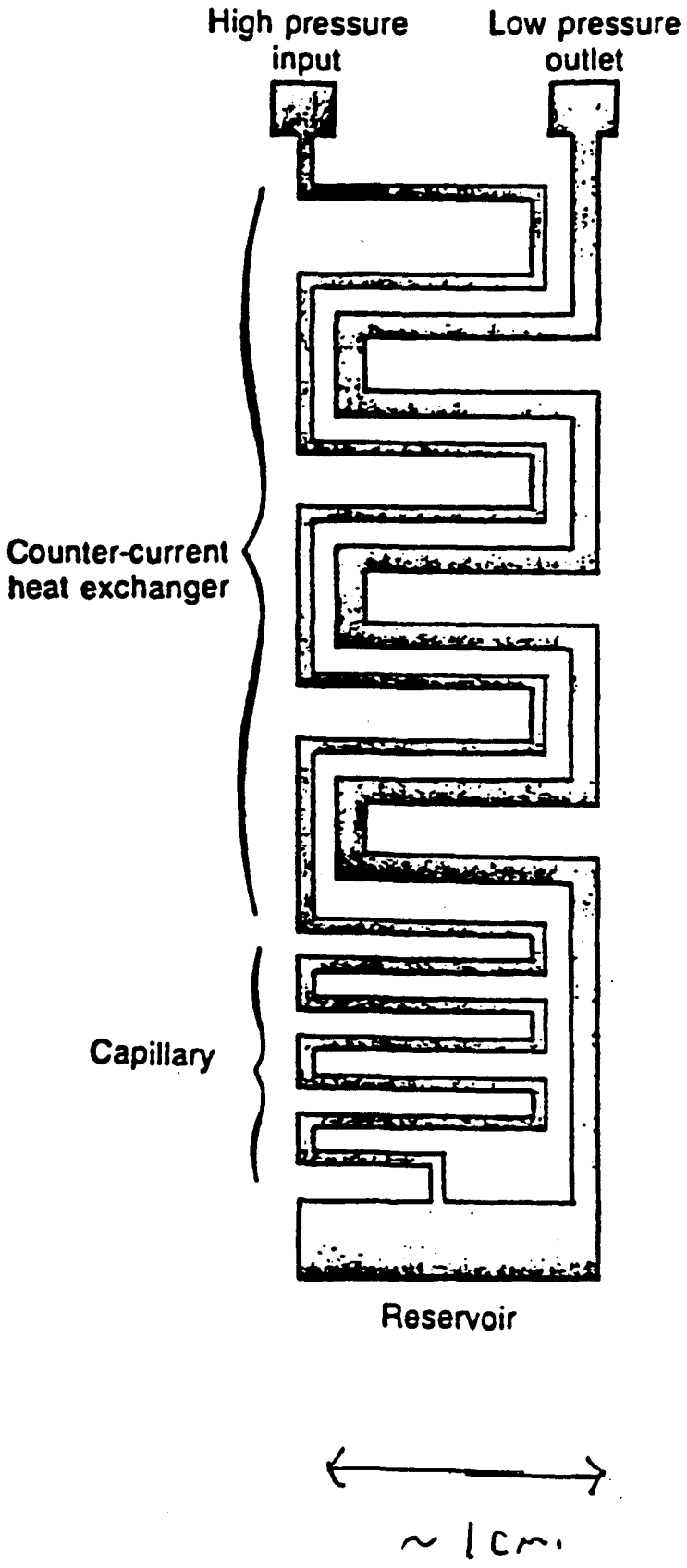
Possible Solution:

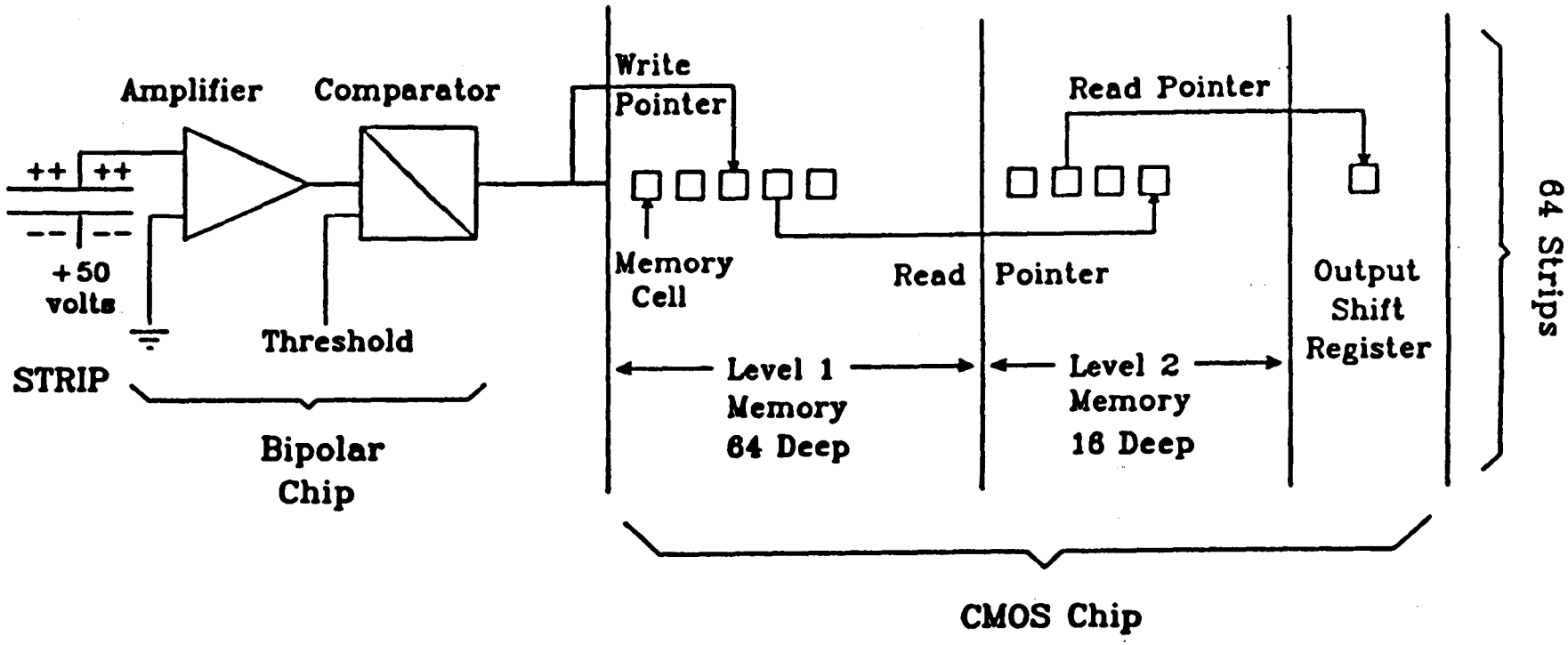
Micro miniature Refrigerators

Micro Miniature Refrigerator for Cooling.

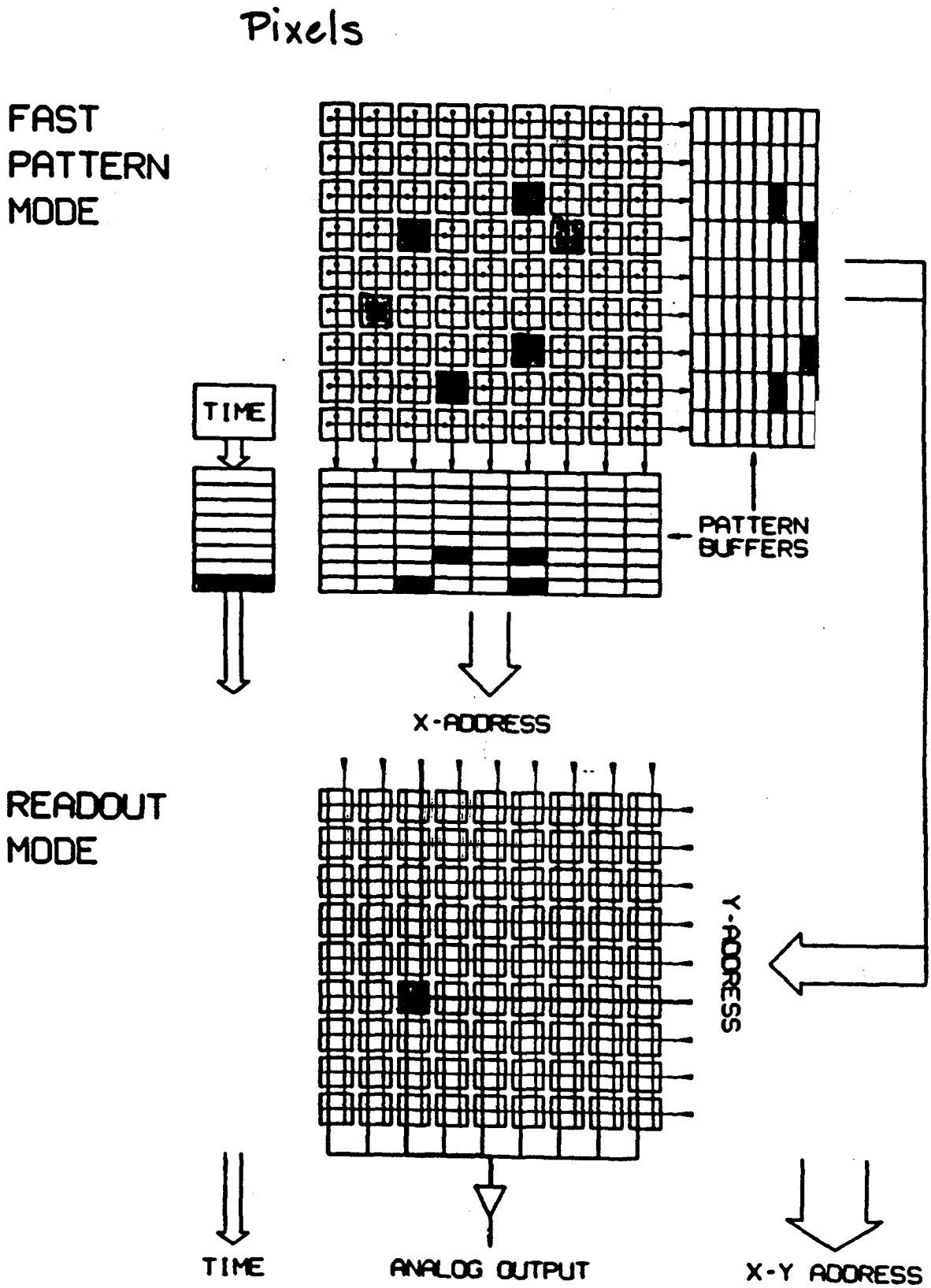


- fabricated with photolithographic + etching techniques
- incorporated into hybrid circuit on silicon detector module.


High pressure input
Low pressure outlet
Counter-current heat exchanger
Capillary
Reservoir
~ 1 cm.



Readout – VLSI chips.


Pixels
FAST PATTERN MODE
TIME
PATTERN BUFFERS
X-ADDRESS
READOUT MODE
Y-ADDRESS
TIME
ANALOG OUTPUT
X-Y ADDRESS

Radiation hardness of detectors
and electronics

Location and pitch of strips and pixels as function of radius is choosen such that the radiation damage in the detectors is tolerable.

Rad hard electronics is being developed in collaboration with United Technologies Microelectronics Center and Silicon Dynamics.

CONCLUSIONS

1. Wire Chamber System Should Be Capable of Minimal Performance for Physics

2. Need <u>Realistic</u> σ_p/p for Specification of <u>Real</u> System

3. Want $\sigma_{p_T}/p_T \sim 0.6\, p_T$ (TeV/c)

   $\rightarrow R_{MAX} = 1.8$ m

4. Silicon Tracking Helps But Needs Existence Proof As System (Mark II, CDF, SLD, ...)

Lots of Work to Do!

FUTURE COLLABORATIVE STRUCTURES

Subsystem Proposals (Due October)

1. Straw Tube Tracking System
2. Silicon
   - Strips
   - Pixels

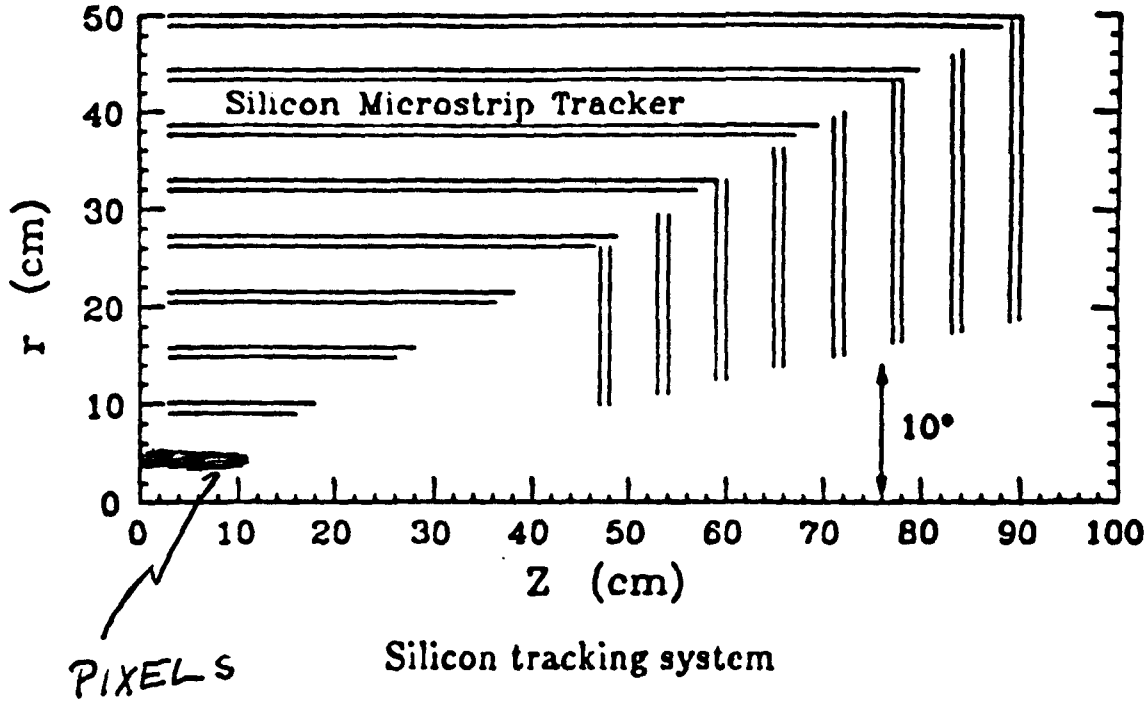
CONCEPTUAL DESIGN AND PARAMETERS OF THE Si TRACKER:

- PIXELS $r \approx 4$ cm
- Si STRIPS $r = 8$ cm to $r = 50$ cm:
  - Double sided detectors with axial and either u or v small angle stereo on the same detector.
  - Pairs of layers ("Superlayers") of detectors with the same pitch for ease of pattern recognition.
  - "Endcaps" of radial detectors measuring constant ϕ.
  - "Fixed occupancy" solution for the pitch of the detector $\sigma_x = \sigma' \cdot r$

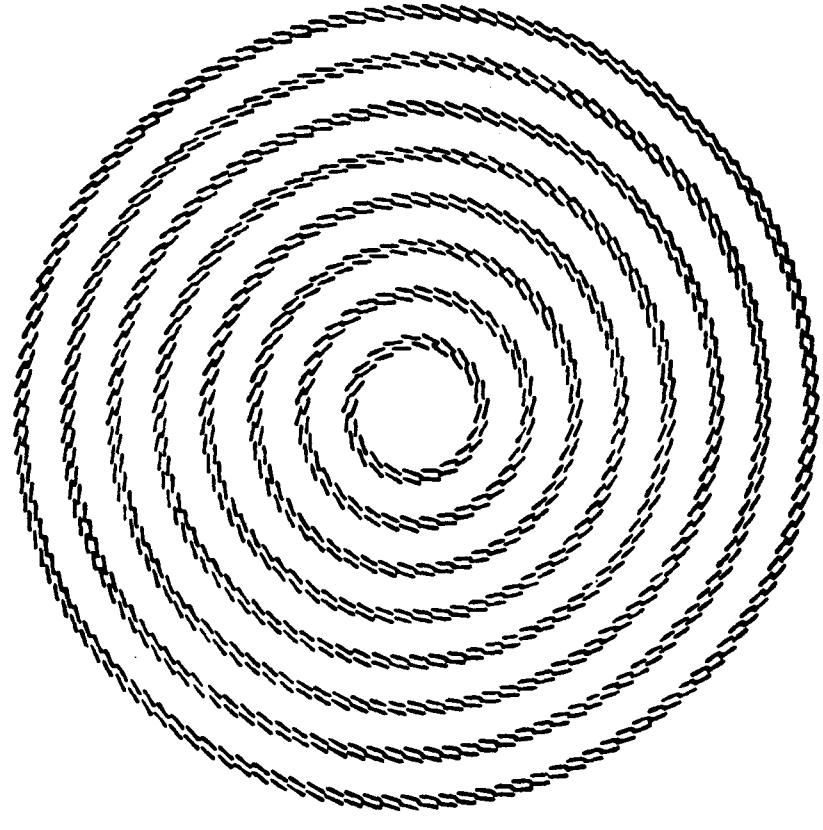
$$\sigma_x = \frac{25}{\sqrt{12}}\ \mu m \quad \text{at } r = 8\text{ cm}$$

$$\sigma_x = \frac{100}{\sqrt{12}}\ \mu m \quad \text{at } r = 50\text{ cm}$$

- Coverage Barrel $= -1.35 \leq \eta \leq 1.35$
  "Endcaps" $-2.4 \leq \eta \leq -1.35$ $1.35 \leq \eta \leq 2.4$
  Could be extended to larger η.
- Additional strips/pixels could cover very forward region ($|\eta| > 2.5$) for e/γ discrimination.



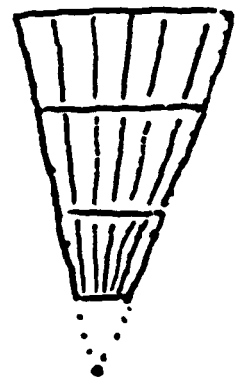
Silicon tracking system



Central silicon tracker

ALLOW THE "PITCH" TO CHANGE WITH RADIUS SO THAT STRIPS ARE RADIAL AND MEASURE ϕ.

RESOLUTION IN ϕ IS INDEPENDENT OF RADIUS because $\sigma = \frac{\text{pitch}}{\sqrt{12}}$ AND "PITCH" $\propto$ RADIUS.



EXAMPLE:

PITCH	RADIUS
10 μ	10 CM
50 μ	50 CM

OCCUPANCY $\approx 10^{-3}$

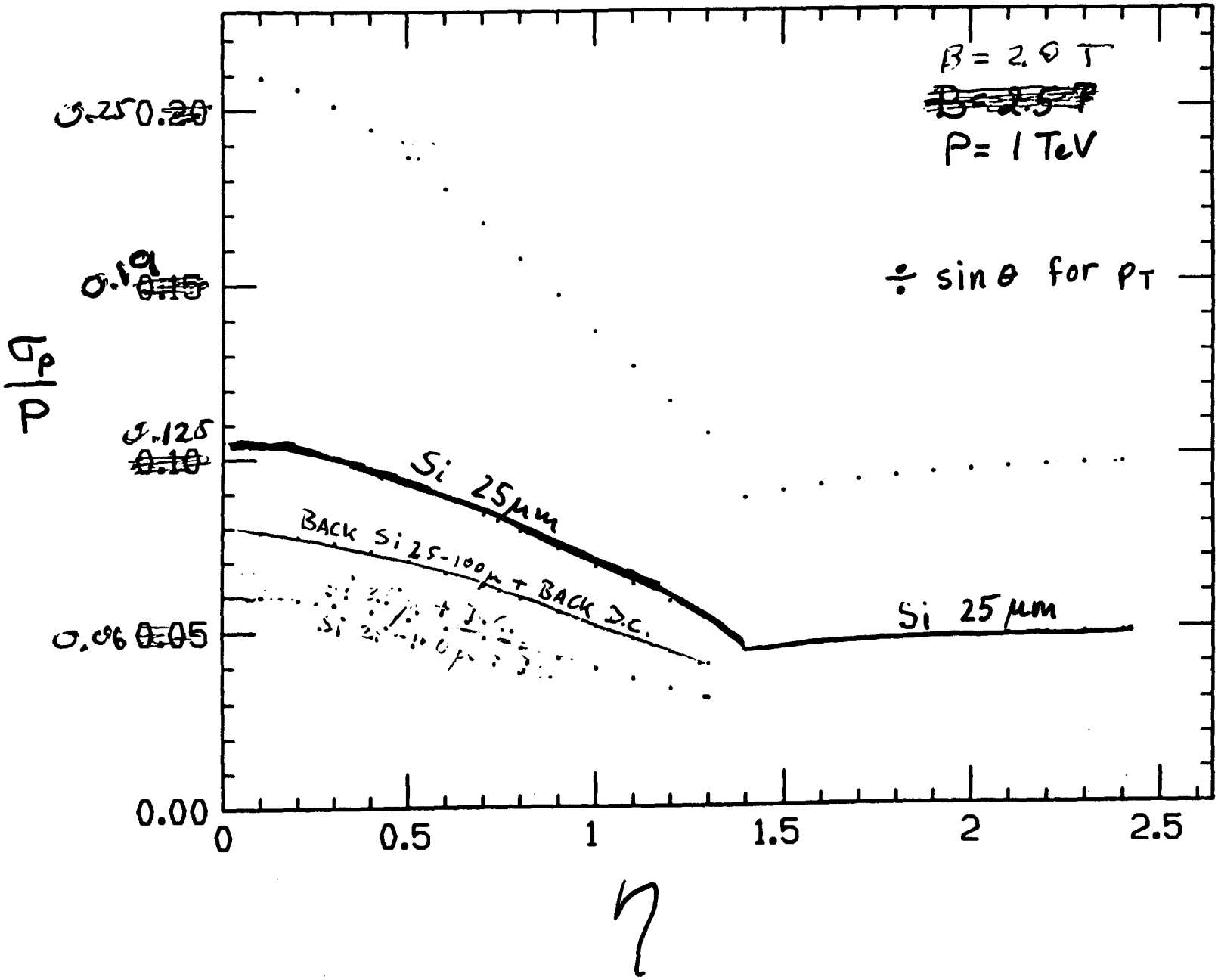
· Momentum resolution

Beam constraint fits "fixed occupancy":
(at 2 T).

$\frac{\Delta(p)}{p} = 26\%$ at 1 TeV

$\frac{\Delta(p)}{p} = 8.3\%$ at 1 TeV for Si tracker + D.C. (100 layers $\sigma_x \sim 200\mu$, $r = 50-150$ cm

$\frac{\Delta p}{p} = 9\%$ at 1 TeV for a "troubled" system where only the last 4 layers of the silicon tracker and the last 50 layers of the D.C. are used.



SIRES TOPDRAW B1 created on 24 Jun 1989 at 22:32.

AREAS OF RESEARCH (i.e. concern!)

a.) CHANNEL COUNT:

VERY LARGE INTEGRATION STILL LEAVES 3000 DETECTORS! (1000 Pixel chips) AND ABOUT 7M CHANNELS.

Our "fixed occupancy" scheme tried to adress this question. More work (M.C.) is needed to eliminate Si layers without compromising performance.

! Power! Even if we succeed to get 1mW/ch this leaves 7 kW for the Si Strips alone.

Solution: Cooling

Material: 5% X_0 for 8 Superlayers + Pixels.

CDF showed that supports add 1% to that. (at 90°)

Try to minimize this at the same time than channel count.

Report of the Calorimetry Working Group

Gerry Abrams (2)
June 28, 1989

Organizers

G. Abrams, H. Gordon, T. Kondo, M. Pripstein, D. Bintinger

Participants

P. Mockett, M. Barnett, R. Cahn, F. Paige, J. Hauptman, J. Brau, R. Rasack, V. Radeka, S. Rescia, E. Wang, I. Hinchcliff, L. Nodulman, A. Lankford, H. Williams, J. Siegrist, M. Levi, R. Kadel, V. Polychronakos, F. Lobkowicz, R. Wolgast, W. Edwards, H. Paar, L. Sahak, A. Para

Calorimeter Working Groups

Organization

1. Physics priorities (requirements) (technology independent)

2. Coil configuration (large diameter, long/short thin coils) consequences for the calorimeter; separately for LID's and scintillators

3. Issues requiring further study (again separate)

4. Cost and schedule

5. Interface issues

Tracking: R_{min}
Service requirements

$\mu^{\pm}$
$|\eta| > 3$

	Z' e^+e^-	Z' $\mu^+\mu^-$	Compositeness jet-jet	Higgs $4\ell^\pm$	Higgs $\ell^+\ell^-\nu\bar{\nu}$	Higgs Wjj	Higgs $\gamma\gamma$	4th Generation or Top >140GeV $\ell\ell'$	4th Generation or Top >140GeV ℓ jet p_T	SUSY (light) ~<350GeV	SUSY $\tilde{g}$ heavy ~750GeV	γ	J/ψ
Dynamic Range	4TeV		6TeV in jet cone										
Resolution (linearity, stability calibration)													
EM	$\sigma_{Z'}$ ~1%	–		$\frac{15\%}{\sqrt{E}}$	$\frac{15\%}{\sqrt{E}}$	$\frac{15\%}{\sqrt{E}}$	½% @ 100GeV	$\frac{15\%}{\sqrt{E}}$	$\frac{15\%}{\sqrt{E}}$	$\frac{15\%}{\sqrt{E}}$	$\frac{15\%}{\sqrt{E}}$	$\frac{15\%}{\sqrt{E}}$	$\frac{15\%}{\sqrt{E}}$
HAD	–	–		–									
JET	–	–	Constant term <5%	–		$\frac{50\%}{\sqrt{E}}$			$\frac{50\%}{\sqrt{E}}$	$\frac{50\%}{\sqrt{E}}$	$\frac{50\%}{\sqrt{E}}$		
Time Resolution	which bucket is the μ in?			$E_{jet} > 20$ GeV				$\Delta t \lesssim 16$ ns →					
SEGMENTATION								τ^*?					
$\Delta\eta = \Delta\phi$ EM						.02		.05		.05	.05		?
HAD						.04							
e/π separation longitudinal	brehm?			? brehms!	?	–	?	?	?	?	?		
Total Depth	?		~8λp							?	?		
Noise	μ's 2-3σ >ped			μ	μ			Electron isolation E_T <4GeV in $\Delta R \sim 0.4$?		$\not{E}_T \approx \nu$ <<100GeV?			
Hermeticity				<2% corner crack ? 30° 5°									
η range				$\lvert\eta\rvert < 2.5$	$\lvert\eta\rvert < 5.5$?					$\lvert\eta\rvert < 4.5$			

Survivability in 10 years 25 MR @ $\eta = 3$ $R = 4$ m

? Needs more study

Calorimeter Requirements

Dynamic Range

$Z' \to e^+e^-$ $\mu^+\mu^-$
4 TeV

Compositeness jet-jet 6 TeV in jet cone

Resolution (linearity, stability, calibration)

EM : $15\%/\sqrt{E}$ [$H \to \gamma\gamma$ (100 GeV H) 1/2 %]

Jet : $50\%/\sqrt{E}$
Compositeness jet-jet Constant term < 5 %

Time Resolution

$Z' \to e^+e^-$ $\mu^+\mu^-$
Need to tag μ bucket

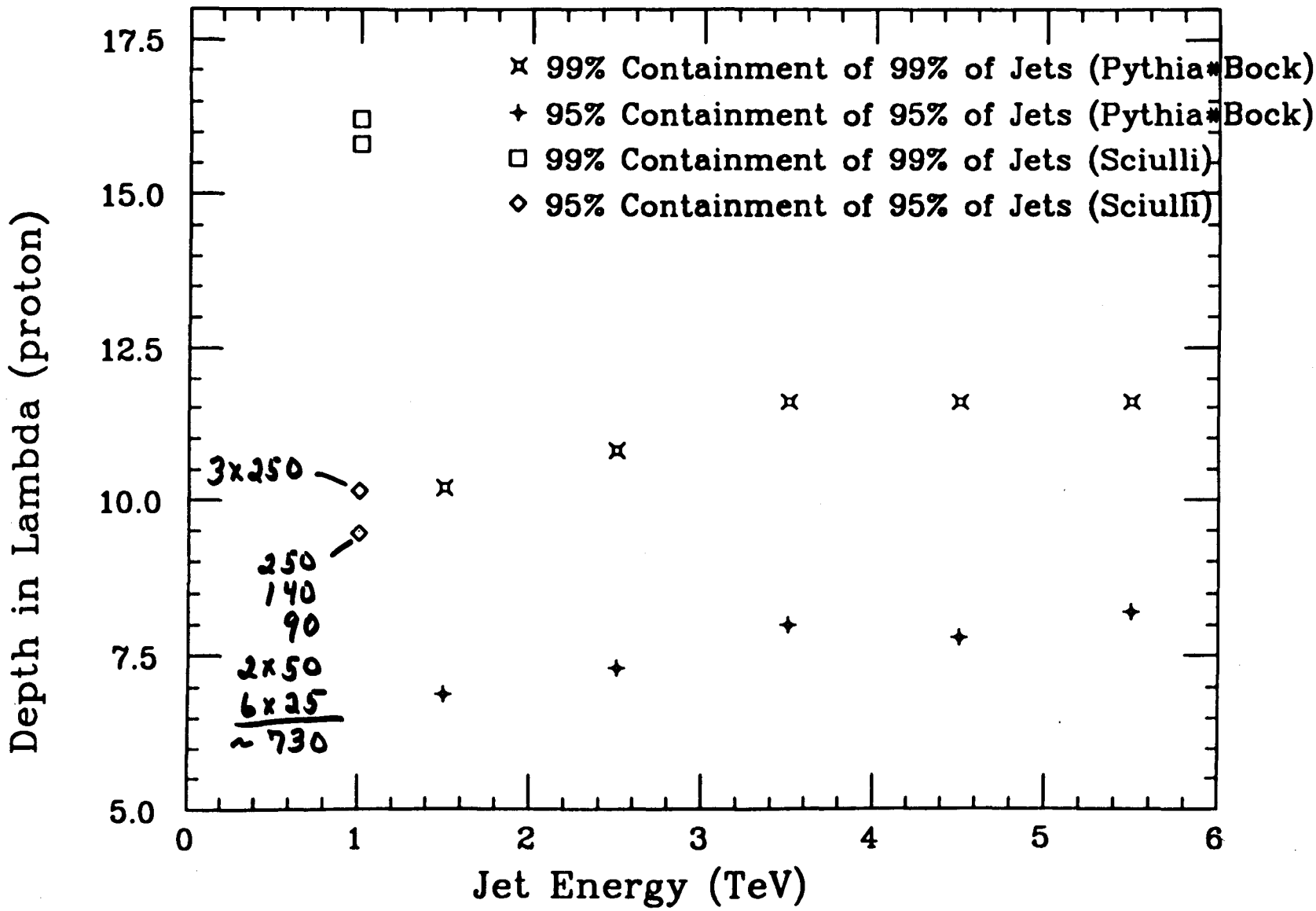
For $E_{Jet} > 20$ GeV, desire $\sigma_t \lesssim 16$ nsec

Lateral Segmentation

$H \to W^+ \; W^-$
$\hookrightarrow \ell^+\nu$ $\hookrightarrow$ jet-je

EM : $\Delta\eta = \Delta\varphi = 0.02$
Had : $\Delta\eta = \Delta\varphi = 0.04$

Energy vs Depth for Jet Containment



17% of 1 TeV Pythia jets have a hadron > 250 GeV

e/π Separation ?

Longitudinal Segmentation $\mu^\pm$ Bremss.

$Z' \to \mu^+\mu^-$

$H \to \mu^+\mu^- \nu\bar{\nu}$?

Total Depth EM $Z' \to e^+e^-$?

Had Compositeness jet-jet $\sim 8\lambda$

SUSY ?

Noise (inc. pileup) $\mu^\pm$ 2-3σ above ped

Heavy (>140 GeV) Quark $e^\pm$ isolation

$E_T < 4$ GeV in $\Delta R \sim 0.4$

SUSY (light) $\not{E}_T \lesssim 50$ GeV

Hermeticity $H \to \ell^+\ell^-\nu\bar{\nu}$ 2% dead channel

30° corner, 5° crack ?

η Range $H \to 4\ell^\pm$ $|\eta| < 2.5$

$H \to \ell\nu$ jet-jet $|\eta| < 5.5$?

SUSY (light) $|\eta| < 4.5$

Survivability 25 M Rad in 10 years at $\eta = 3$ 4m from IP

Coil Configuration

Subsystem Issues

Warm Liquids

Materials compatibility
Pb, Al, ...

Fast readout, S/N
Electrostatic transformer

Engineering studies
Hermeticity, safety

Swimming-pool prototype
Compensation } Beam test

Liquid Argon

S/N optimization for 50 nsec peaking times

- Local preamps and ferrite core transfer
  - Power dissipation in the LA
  - In a $|\vec{B}|$ field, shielding transformers

- Remote preamps, low Z cable and ferrite core (or electrostatic) transformers
  - Charge transfer time
  - Cross talk
  - Short cable runs

Materials issues

- Uranium availability

- Pb-LA : compensation ?

- Cladding, addition of CH_4, etc.

SCINTILLATING FIBERS

SUBSYSTEM ISSUES

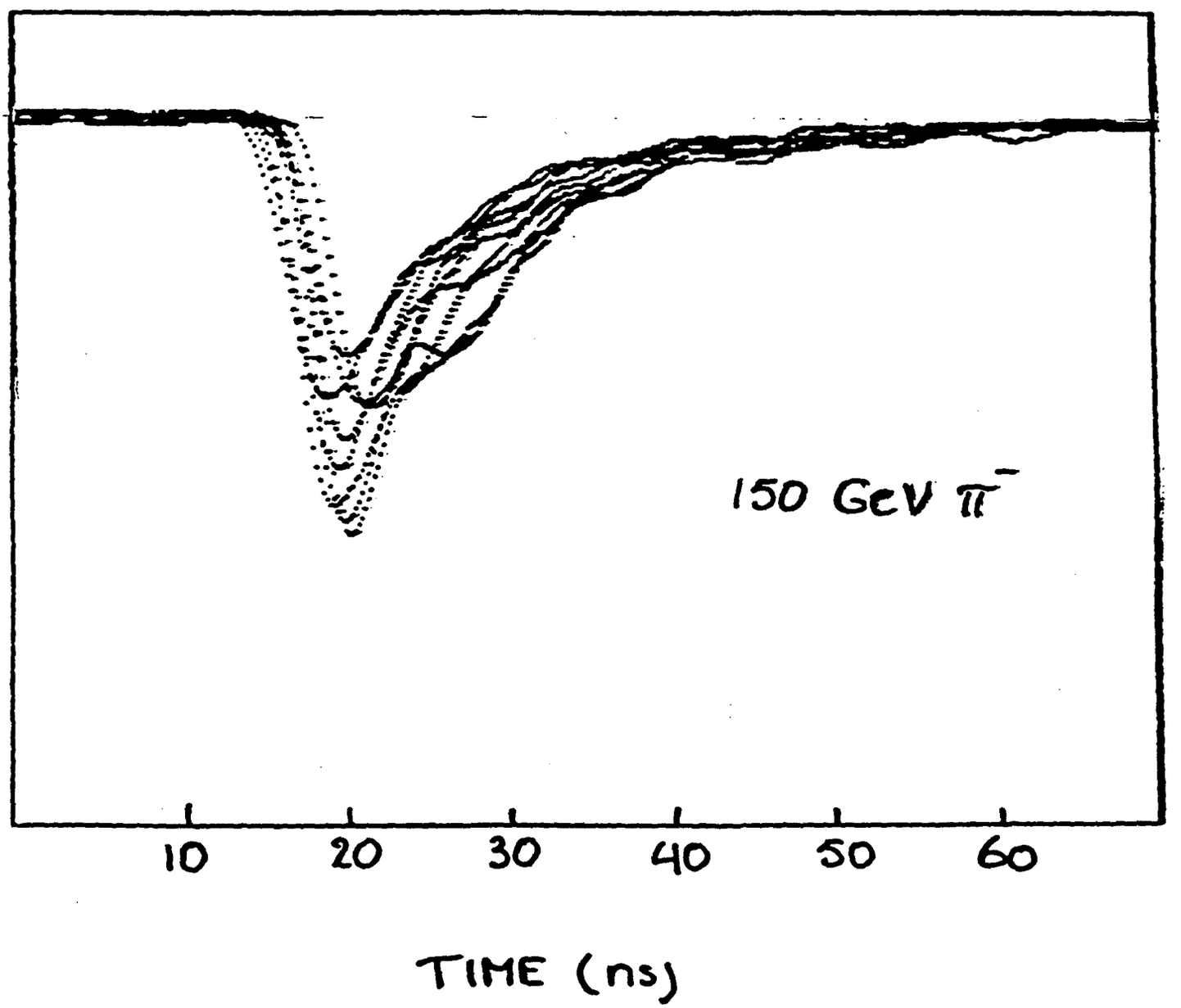
(R&D in progress or proposed)

- Radiation damage
  (role of O_2, new plastics, effect on calorimeter)
- Depth segmentation
  (how many depth segments? how?)
- Manufacturing techniques / engineering design
  (casting? lamination? fiber quality control? ..)
- Magnetic field:
  small solenoid: OK
  large solenoid, $B \lesssim .7T$: OK
  large solenoid, $B \gtrsim .7T$: R&D on read-out techniques
- Read-out: PM's OK, but expensive.
  Alternatives? Silicon? Other?
- Compensation:
  prove compensation for Pb-Sci, Pb/Fe-Sci calorimeter.
  Time dependence (gate)
- Stability / calibration:
  find a way to monitor response? as a function of depth? (radiation damage ?!)

Several generic R&D proposals submitted to investigate these issues. Subsystem proposal in preparation..

TIME STRUCTURE

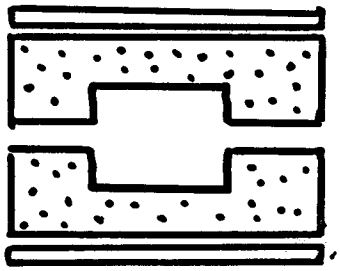
CALORIMETER SIGNALS



— COIL VS CALORIMETER —

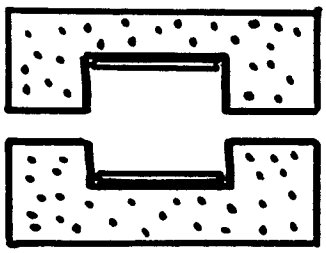
SOLUTIONS

non Fe calorimeter
Fe/Pb calorimeter
solenoid



LARGE SOLENOID

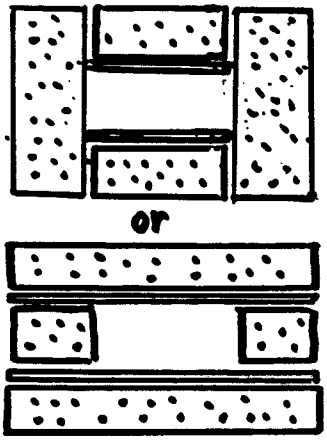
LID : electrostatic transformer
or
transformer/preamp. outside of large solenoid



AIR-CORE SOLENOID

LID : shielded transformer or electrostatic transformer

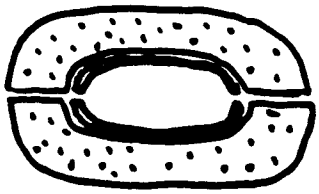
Scintillator : shielded PM



CDF-TYPE SOLENOID

Scintillator : instrumented endyoke

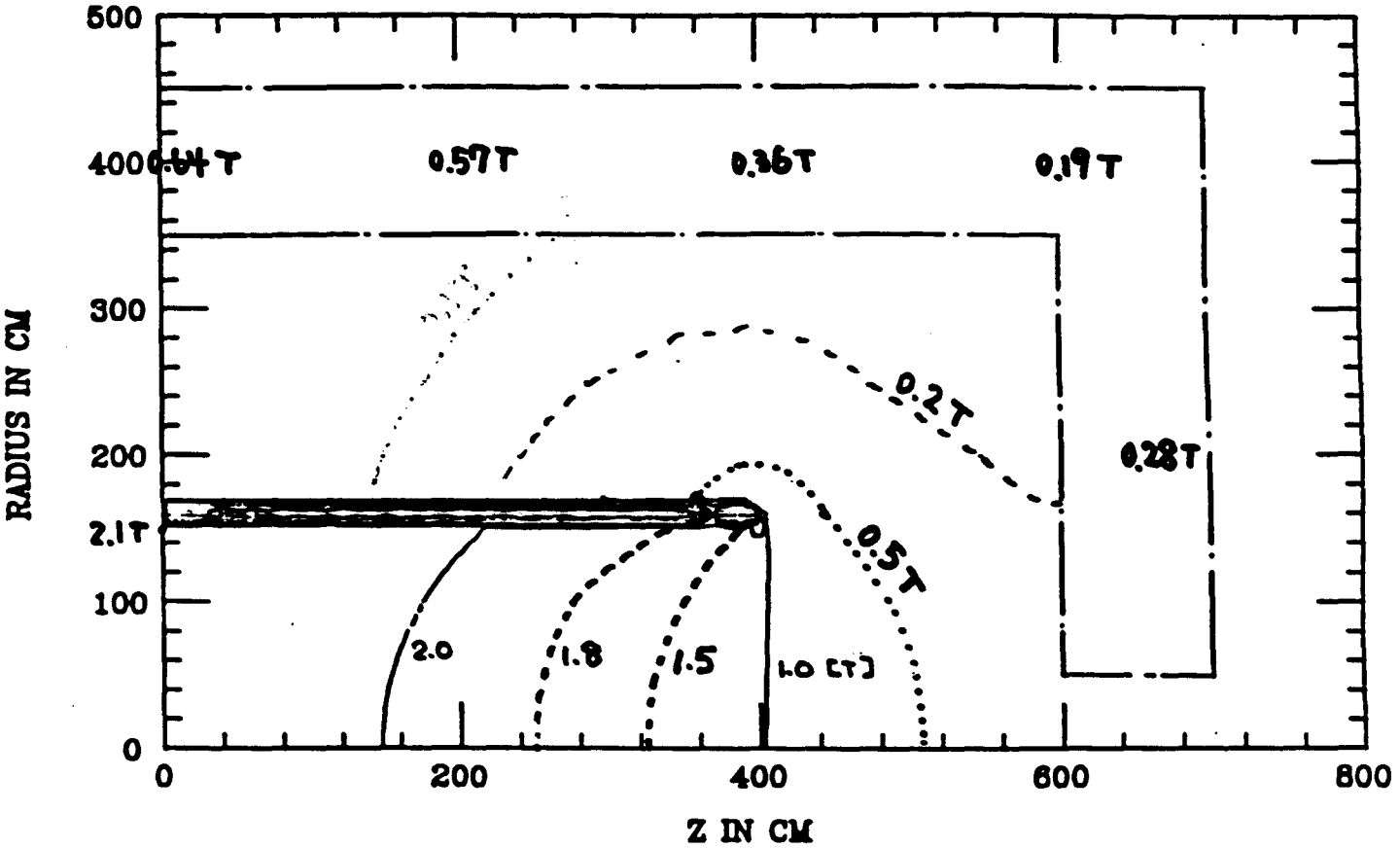
Hybrid : scintillator (barrel)
LID (endcap)



WATERMELON SOLENOID

Scintillator : scintillating fiber return yoke

FIELD CONTOUR PLOT



COIL CONFIGURATION CONSEQUENCES ON CALORIMETER

	ISSUES	SOLENOID OUTSIDE	SOLENOID INSIDE	
			AIR-CORE TYPE	CDF TYPE
LAr	support/installation	possible (M.M. design)	relatively easy	relatively easy
	magnetic transformer (if needed)	B = 2T not possible at detector low-R cables of ~4m (R&D) and modular solenoid	B = 0.5(endcap)~0.02T (barrel) magnetic shield might be possible → (R&D)	B ≒ 0(barrel) O.K. B = 2T(endcap) not possible
	hermeticity	OK	~OK (E. Wong)	to be studied
	electron - ID	OK	$0.8X_0(\eta=0) \sim 2X_0(\eta=1.5)$ to be studied, CDF	experience of CDF to be studied
Scintillator	PM shield	NOT FEASIBLE	existing experience of ZEUS	no problem (barrel)
	Endcap		"	instrumented return yokes (CDF upgrade?)
	light output		+ a few %	+5% (endcap)
			possibility of watermelon shaped coil cos θ winding, $1.5X_0$ (Bill Foster)	
	space	60cm at r ≈ 5m	25 cm at r ~ 1.7 m	

FORWARD CALORIMETER

CENTRAL (& e & μ) → 2.5-3 $|\eta|$

⇒ ENERGY FLOW FOR $\not{E}_T$

(e.w., i.H.)

QCD IMPLICIT ν ⇒ 1 Hz @ 175 GeV

(cosmics probably higher!)

UNSELECTED $|\eta| \sim 5$ Beam hole same

6.5 "overkill"

SIMILAR $e + \not{E}_T$ background from $W \to e$

CONSIDER $H \to ZZ$

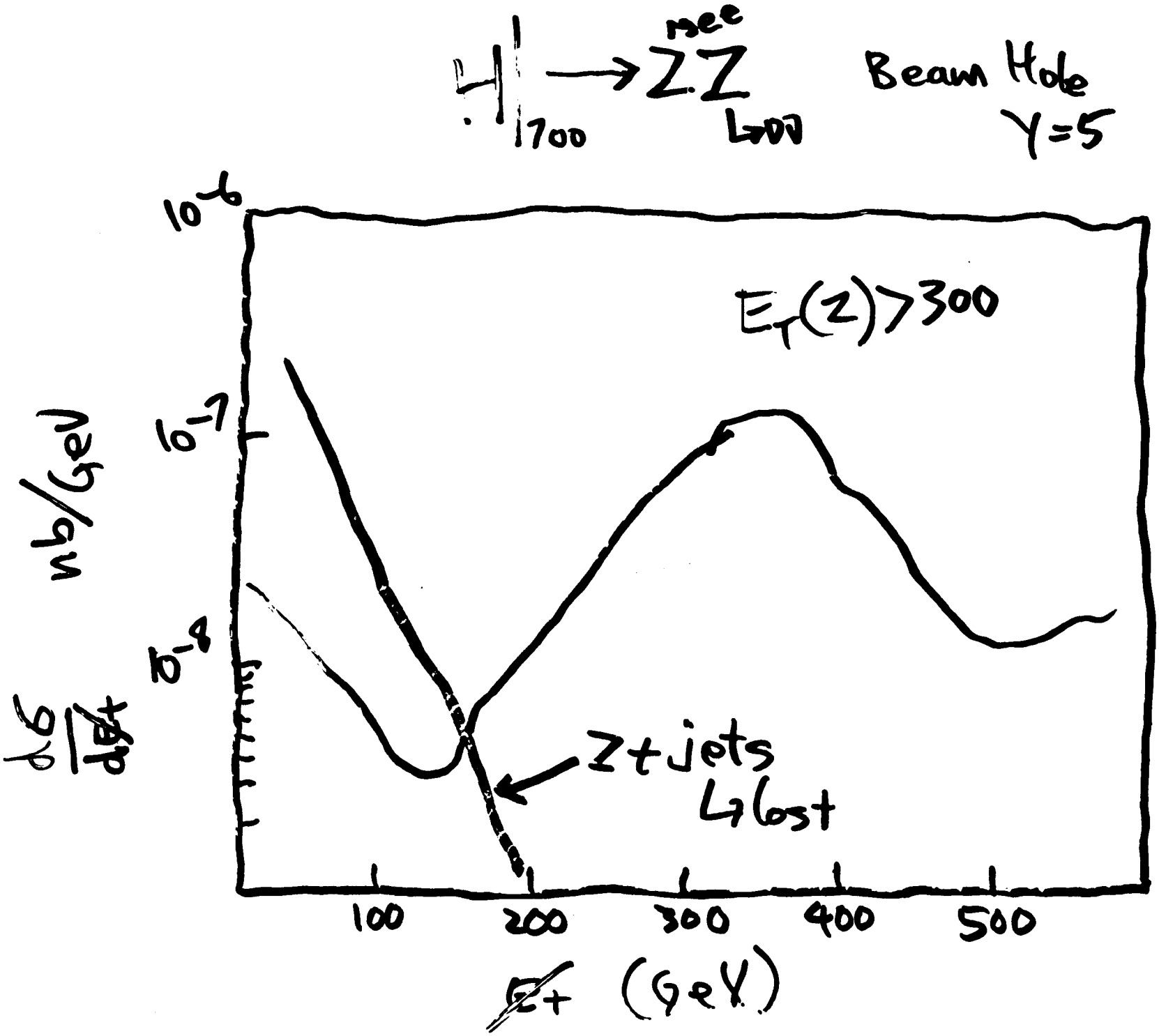
$ee \hookleftarrow \hookrightarrow 0\nu$ □

⇒ GOOD TO 4.5, GUARD BEYOND

SET BACK AT $|\eta| \sim 3$

⇒ TAG CLUSTERS AS BAD

SEGMENTATION? RESOLUTION?



H 700 → Z Z
nee
↳ DD
Beam Hole
Y=5
$E_T(Z) > 300$
Z+jets
↳ lost
10^{-6}
10^{-7}
10^{-8}
nb/GeV
$\frac{d\sigma}{d\not{E}_t}$
100
200
300
400
500
$\not{E}_t$ (GeV)

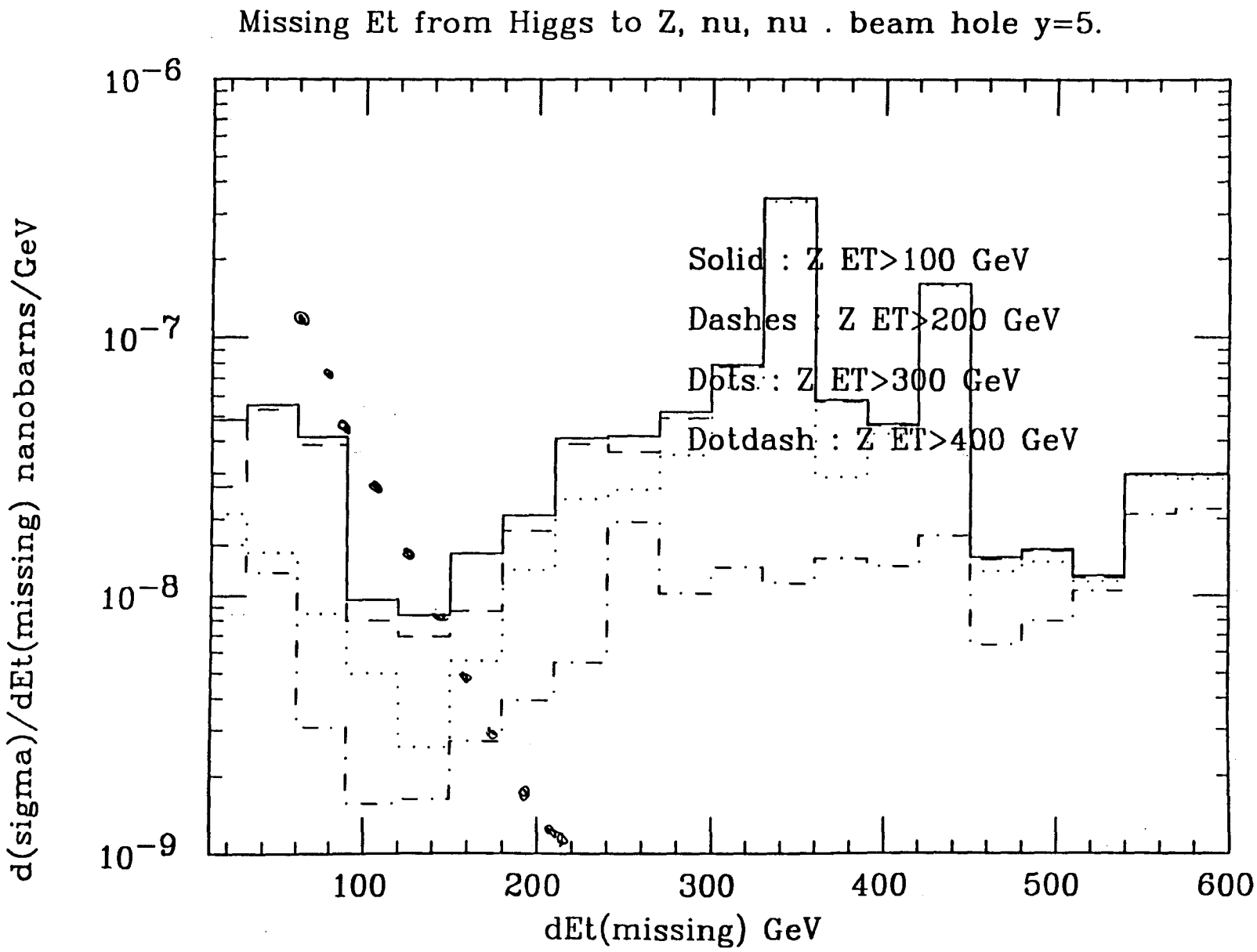
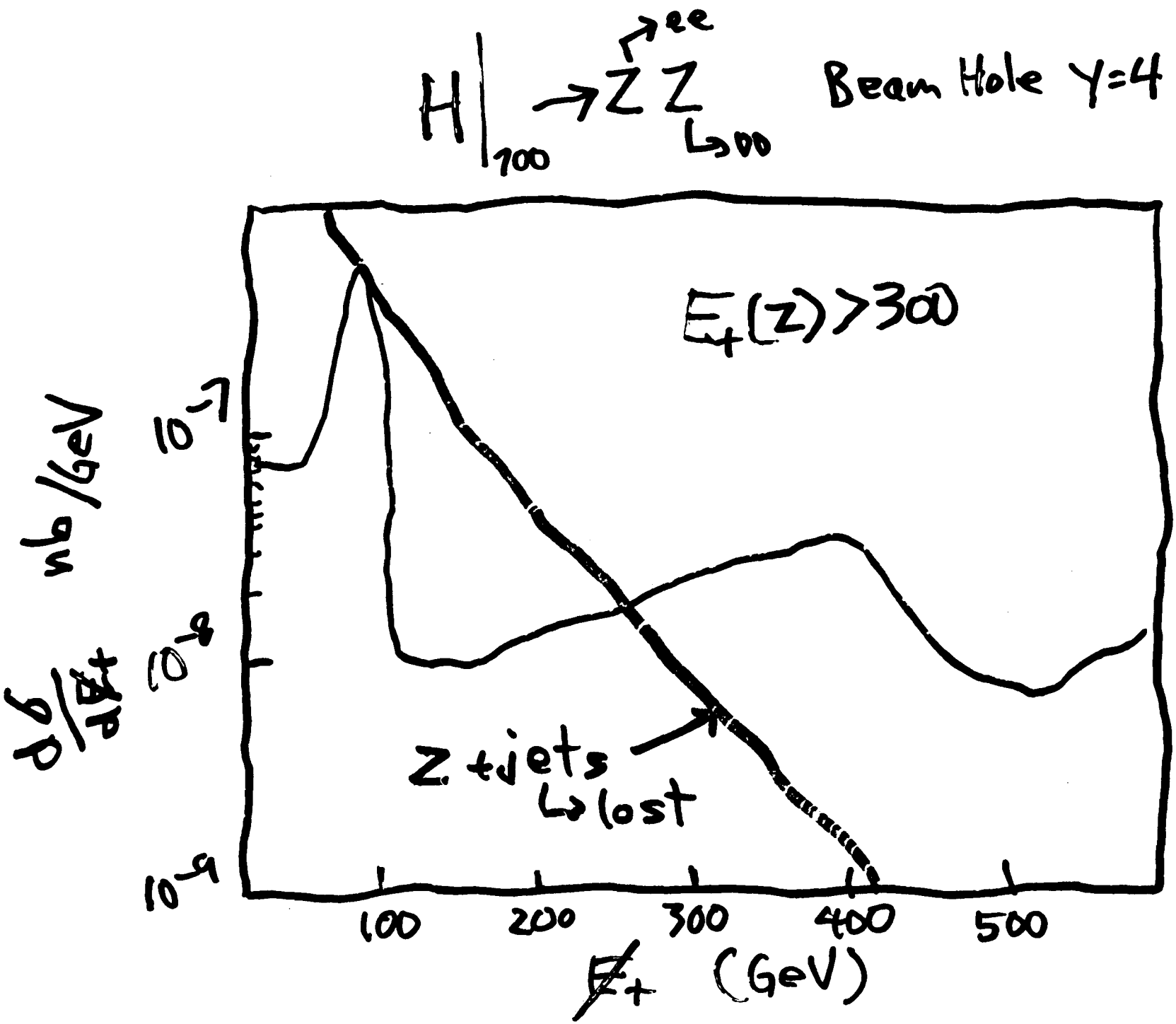


Figure 16

Ian Hinchliffe: 24 June 89



H|100 → Z Z
ee
↳ ∞
Beam Hole Y=4
E+(Z)>300
Z + jets
↳ lost
dσ/dE+ nb/GeV
10^-7
10^-8
10^-9
100
200
300
400
500
E+ (GeV)

Missing Et from Higgs to Z, nu, nu . beam hole y=4.

$m_H = ?$

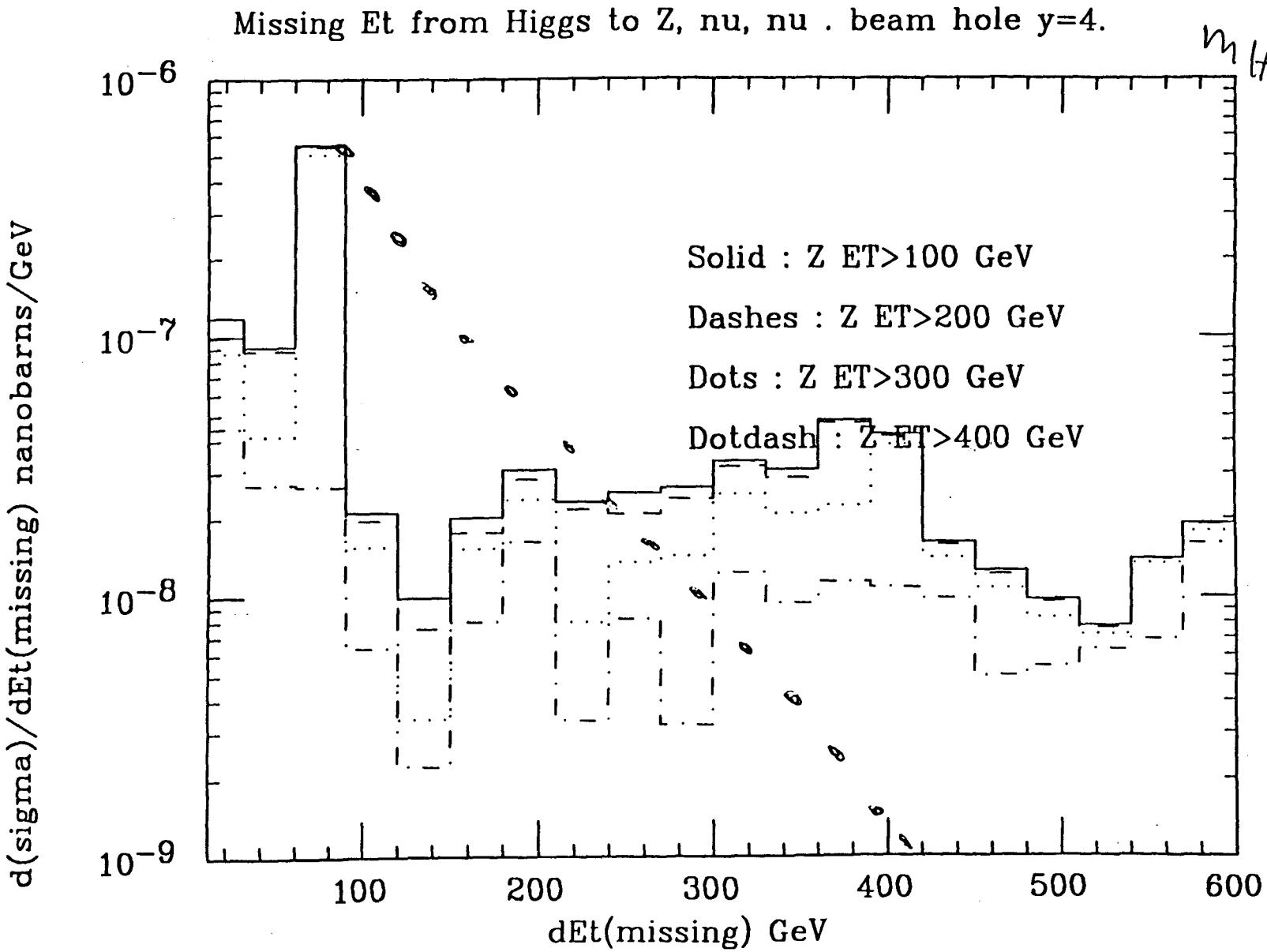


Figure 14

Ian Hinchliffe: 24 June 89

•• Background Z + jets

e^+e^- "ν st"

$M = 700$ GeV

Cost and Schedule

Boundaries and Interfaces

$|\eta| > 3$ region

$\mu^{\pm}$

Tracking volume

Penetrations for cables, gas, cooling, etc.

What is the minimal value of R_{inner}, the inside radius of the calorimeter:

for small λ (compact calorimeter small lateral shower spread allows R_{inner} to be small without overlap.

Need quantitative criterion.

Summary Report: J. Bensinger

Electron ID Group [Wicklund, Bensinger, Galtieri]

[Plans for next two days and beyond]

'3)
6/29/89

1. Collect Rates for different Physics Processes
   - electrons
   - jets (backgrounds)

2. Isolation of electron from physics consideration

   $H \to ZZ$ $H \to WW$ heavy top, etc.

3. Detector Issues (i.e. add showering)
   - segmentation { longitudinal / lateral
   - resolutions

4. Define Baseline Electron ID from
   - calorimetry
   - tracking (E/p)

5. Do we need special detectors to do physics we want?
   - TRD
   - Preradiator
   - Information at shower max
   - Synchrotron Radiation

6. Tracking requirements at small angle

[Meet in back of Large Conference Room]
at 10:45

People who spent ≥ 50% of their time with the Electron ID Group.

Hiroaki Yamamoto

Scott Whitaker

Barry Wicklund

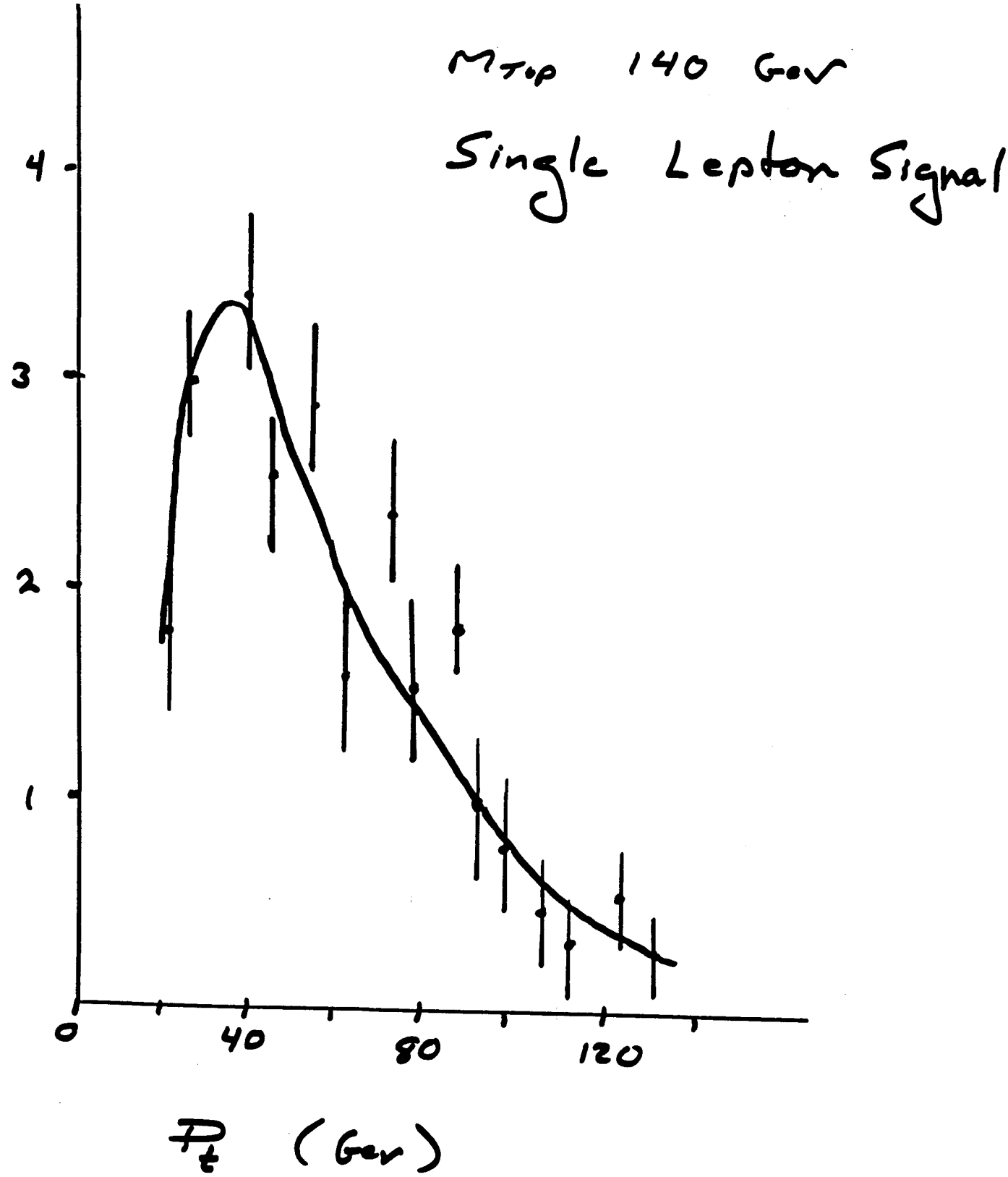
Roger Rusak

Lina Galtieri

Prisca Cushman

Jim Bensinger

Michael Barnett


M_{TOP} 140 GeV
Single Lepton Signal
4
3
2
1
0
40
80
120
P_t (GeV)

Cross Sections for Inclusive Electrons with $P_t(e) > 40$ GeV

$\sigma(W \to e\nu)$ 3 nb

$\sigma(t_{140}\bar{t}_{140} \to e \ldots)$ 2.2 nb

$\sigma(b,c \to e \ldots)$ $\sim 6 \pm 3$ nb

Background ... Jets that fake e's

$\sigma(1\ \text{Jet})$ $P_t > 40$ $2 * 10^5$ nb

we need a rejection of $> 10^5$

In CDF we achieve this

- Jet fragmenting into Isolated $\pi^{\pm}$ or $\pi^{\pm}\pi^0$ overlap $\sim 10^{-2}$

- In a 3 tower cell ($R \sim .15$)

$\pi/e \sim 1\text{-}2\ 10^{-3}$

$\frac{\gamma \to ee}{e} \sim 2\text{-}3\ 10^{-3}$

A Problem:

In CDF This is an offline analysis number. at trigger time we are a factor of 30-50 times worse.

This is the factor we have to beat.

Base-Line Detector

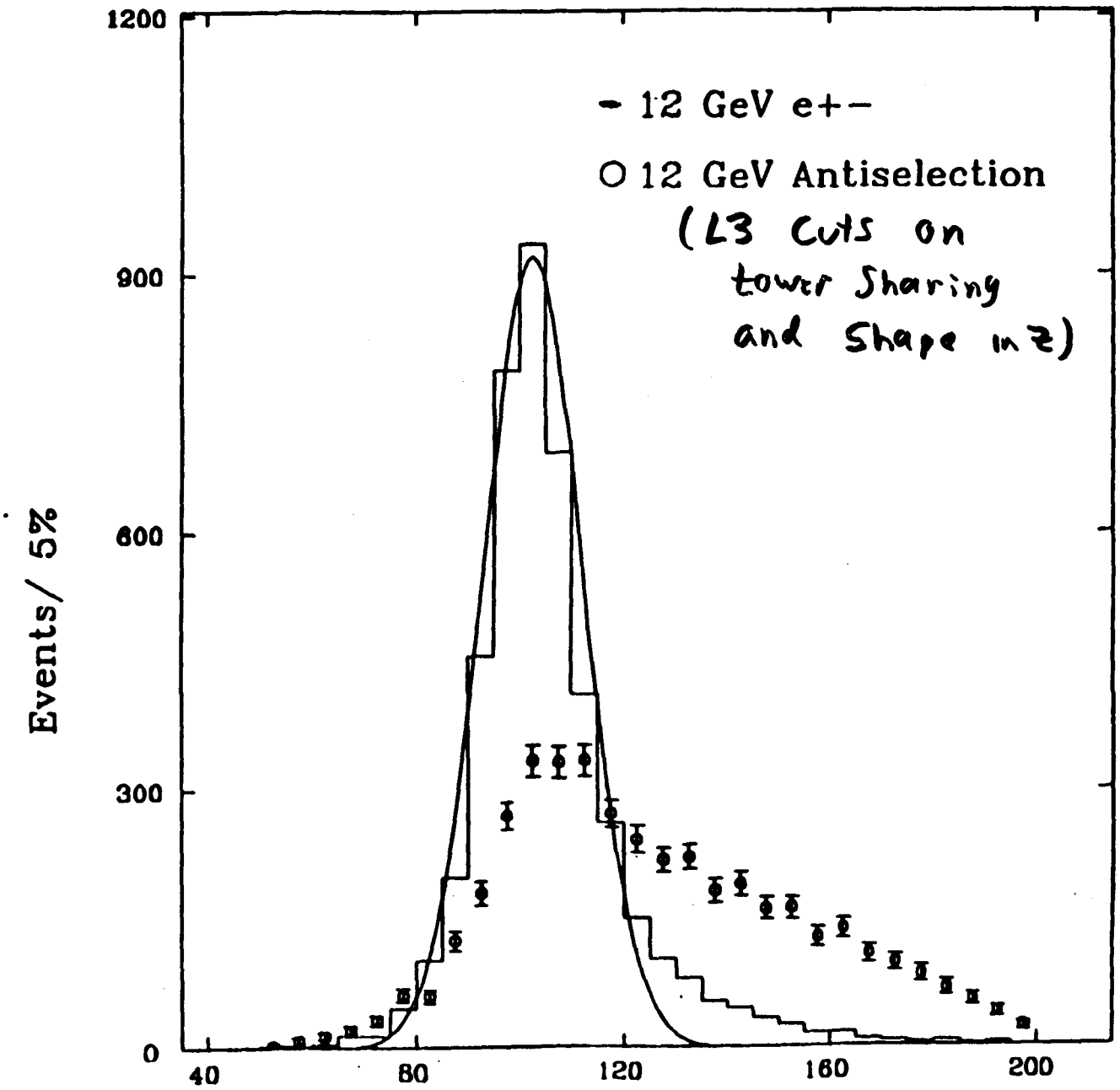
Handles on Electrons.

- Segmentation
  - Transverse $\gtrsim .03$
  - Longitudinal 2 EM +) Had
- Shower Position
  a few mm.
- Track pointing over entire calorimeter to ~ mm.
- $E/p < 1.2 - 2$. (due to brem)
- Isolation $R < .15 \sim .2$

Additional Tools:

- Preradiator
- Synchrotron Radiation
- Transition Radiation
- Chambers at Shower Max.

Doing everything is overkill. We should choose enough to get to 10^{-5}.
NB: They are not all independent.


1200
900
600
300
0
40
80
120
160
200
Events/ 5%
E/p (%)
- 12 GeV e+-
O 12 GeV Antiselection
(L3 Cuts on
tower Sharing
and Shape in z)

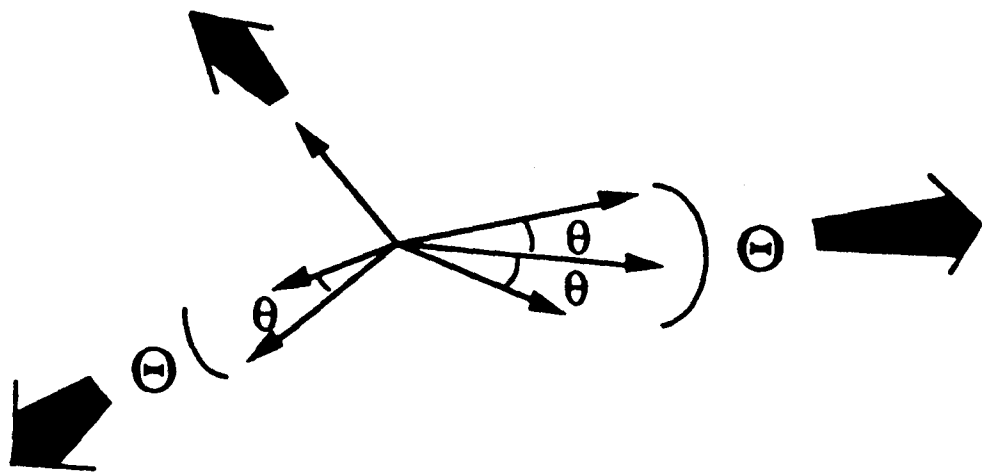
7

Track and event selections

Tracks used : Pt > 10 GeV, $|\eta| < 2.5$

Events used : # tracks >= 4

Clustering or simple segmentation



combine tracks with θ < resolution

Resolution for π^0/γ $\sigma\gamma = 30$ mr

charged $\sigma_{ch} = 50$ mr

Slim cluster : cone size Θ < resolution

== single isolated cell is fired

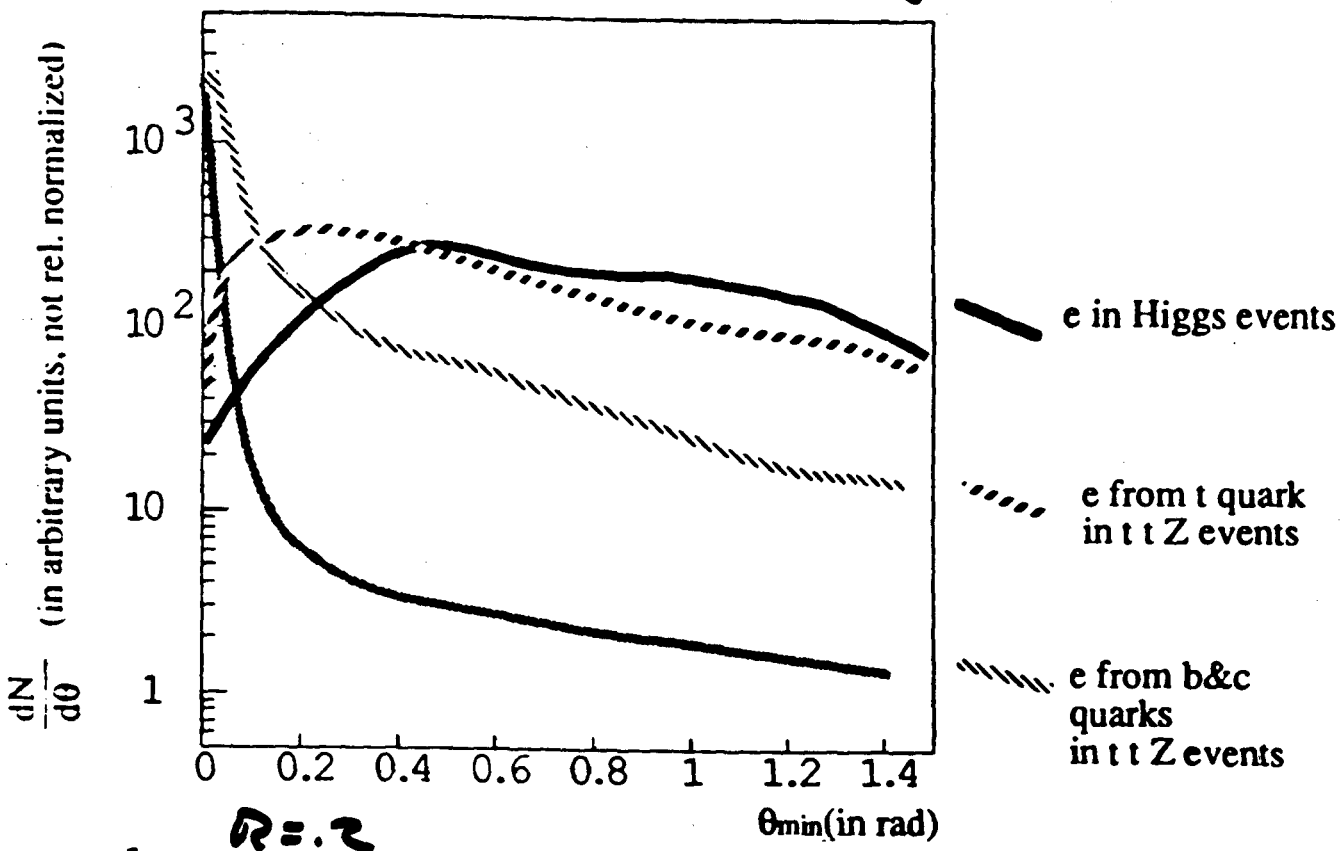
Fat cluster : cone size Θ > resolution

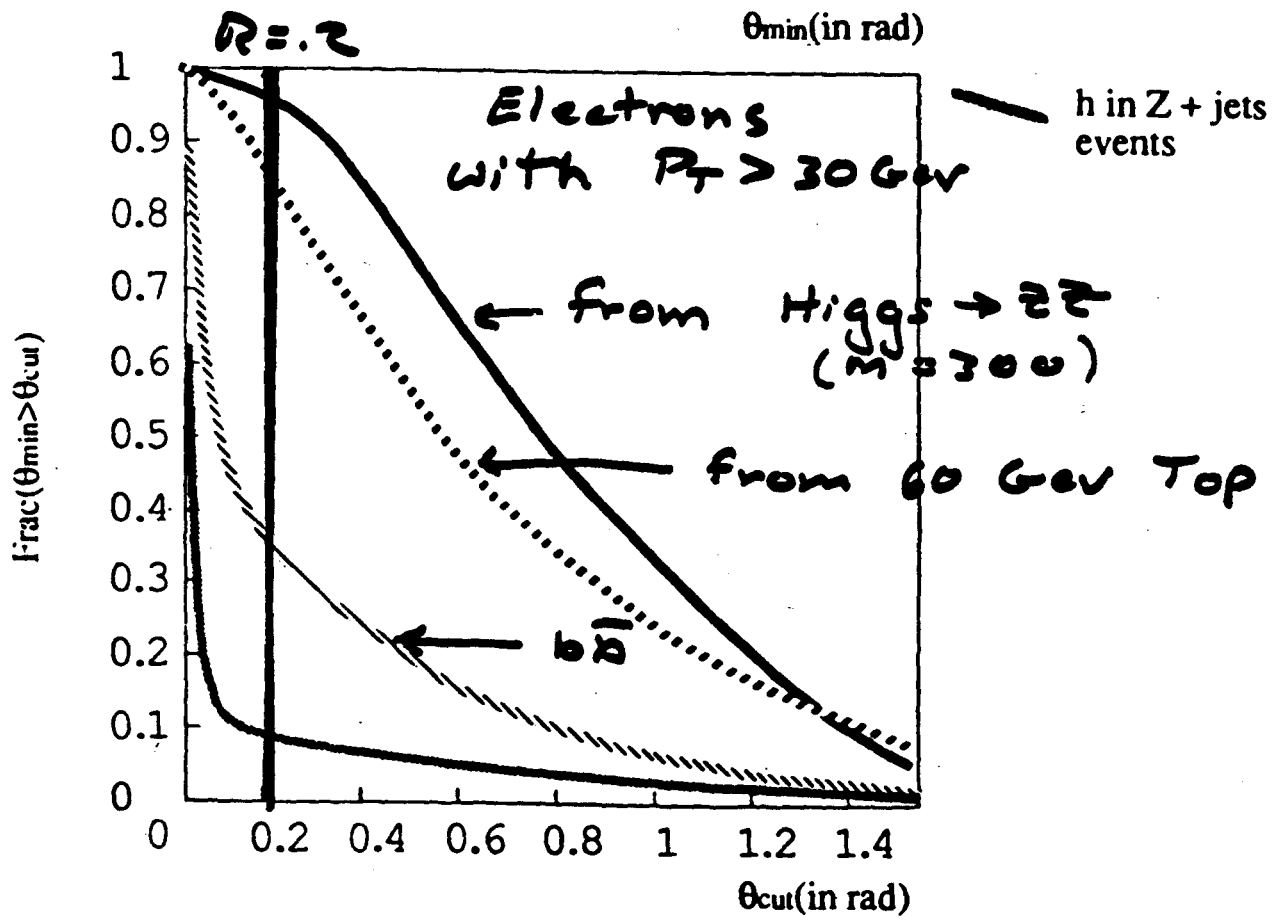
== several contiguous cells fired

Isolation of clusters to reduce tracks in jets

Minimum opening angle between the cluster and all other clusters. Isolated cluster : $\Theta_{min} > 0.2$

Yamamoto
Background Studies

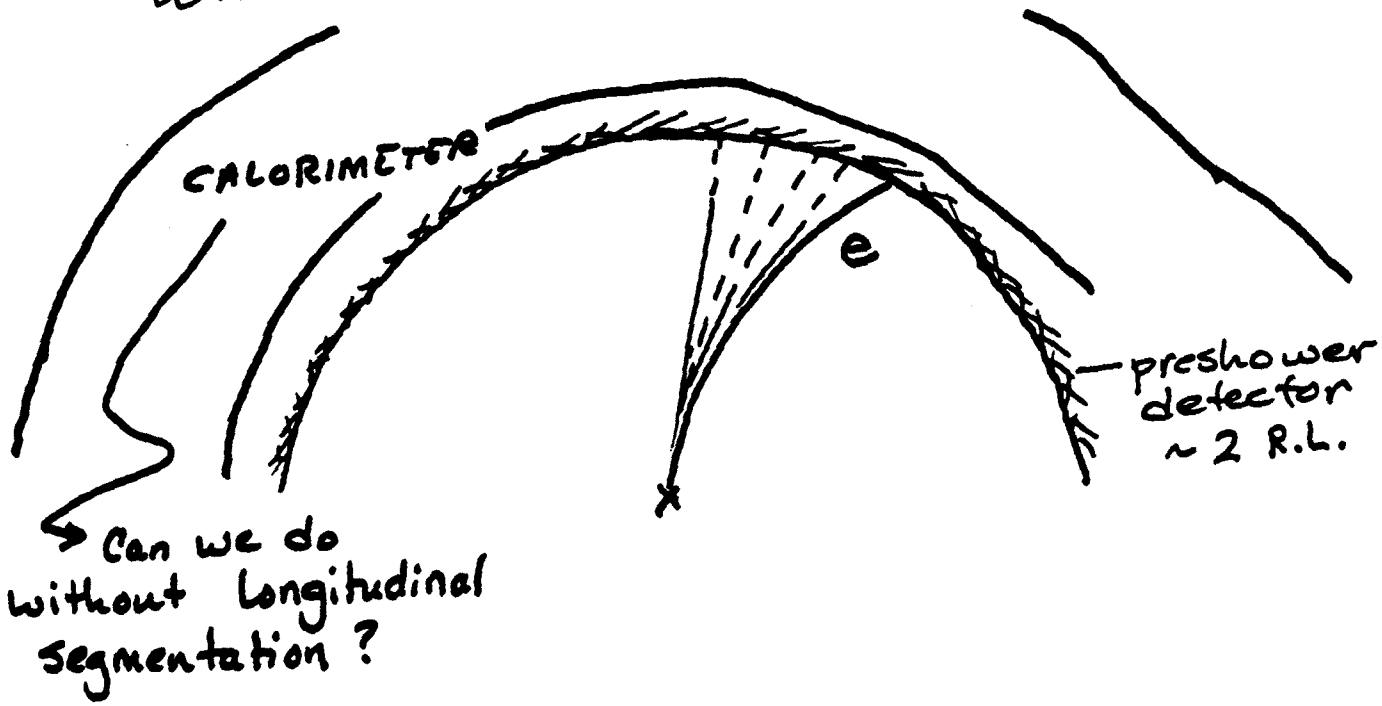




P. Cushman
R. Rusack

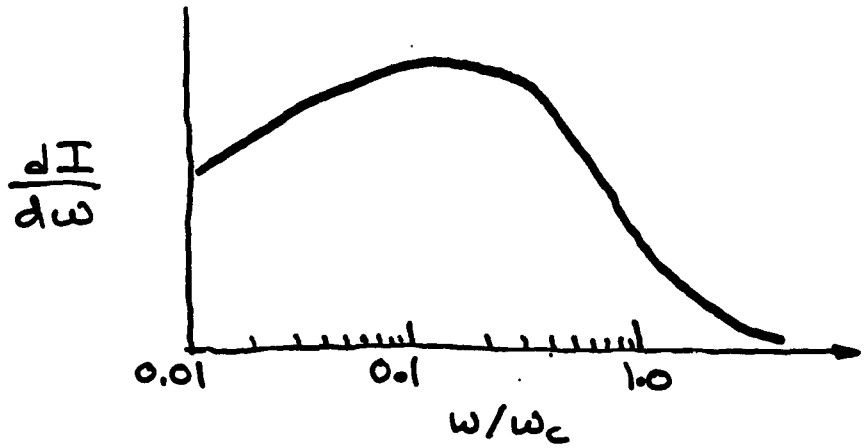
Electron ID using Synchrotron radiation.

What does it look like at SSC ?



<u>Principle</u> Use the synchrotron radiation emitted by an electron in a high B-field to distinguish between e-initiated e.m. showers and γ-initiated showers with a nearby π. Synchrotron radiation is energetic enough to pair produce in a sifi/lead sandwich when electron is 25 - 200 GeV

Physics of Synchrotron Radiation



$$\left\{\begin{aligned} I\,(\text{keV}) &= 1.27\ E^2 B^2 L \\ \hbar\omega_c\,(\text{keV}) &= 1.33\ E^2 B \\ &\left(\text{avg. } E_\gamma \sim \tfrac{1}{4}\hbar\omega_c\right) \\ N_\gamma &= 3.6\ B L \end{aligned}\right\}$$

E in GeV
B in Tesla
L in Meters

		Electron Energy			
		50 GeV	100 GeV	200 GeV	
For B=5T, L=1M	$\hbar\omega_c$	16.6	66.5	266	MeV
N = 18 γ's	Δx	24	12	6	mm
For B=2T, L=2M	$\hbar\omega_c$	6.7	27	106	MeV
N = 14 γ's	Δx	15	7.5	3.7	mm

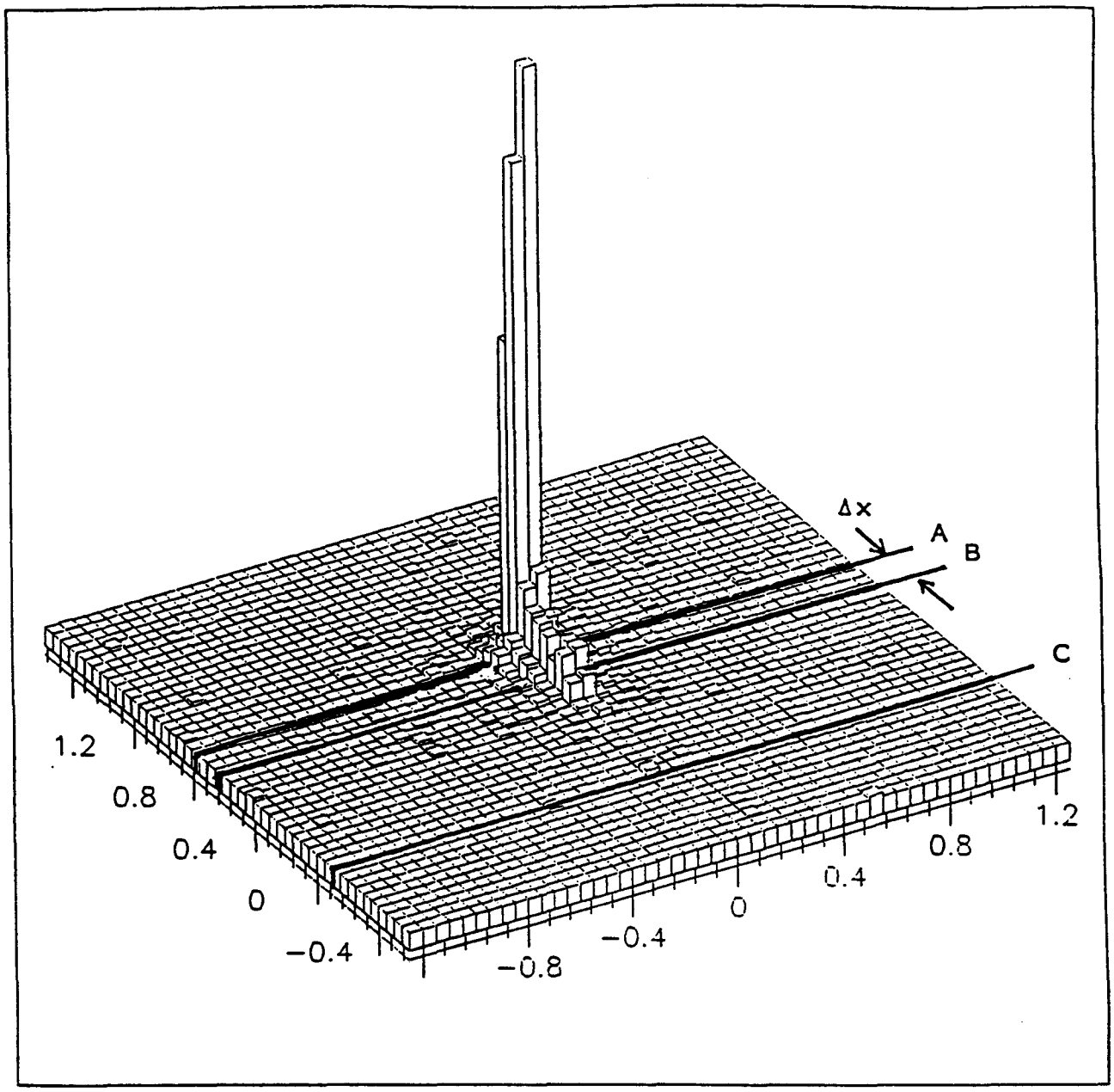
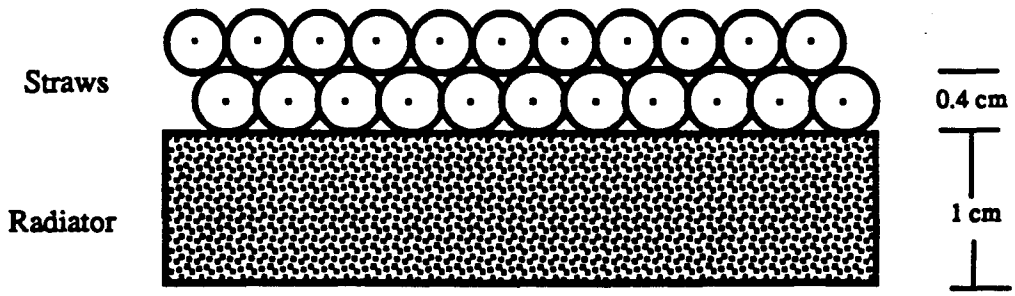


Figure (3)
Energy deposited by a 200 GeV electron and its associated synchrotron radiation in less than 1 radiation length of lead.

A "STRAW" DESIGN

TR MODULE:



RADIATOR: $50 \times [20\mu\ CH_2 + 180\mu\ He]$ .0021 X_0

2 × STRAWS: 4 mm dia 30μ "mylar" + 50μ Cu wire } .0008

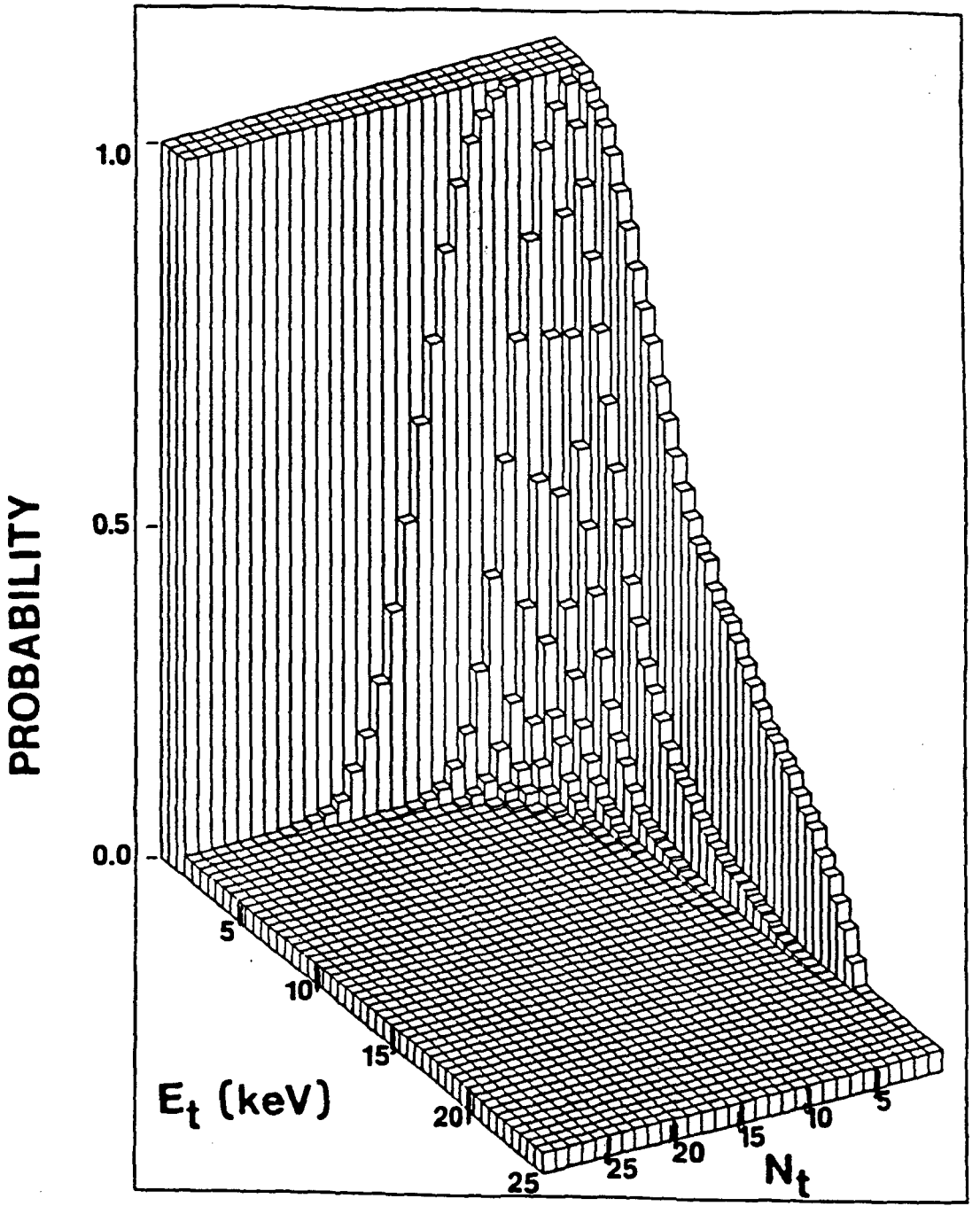
2 × gas: 60% Xe 40% CH_4 .0004

TOTAL THICKNESS ~ .33% X_0

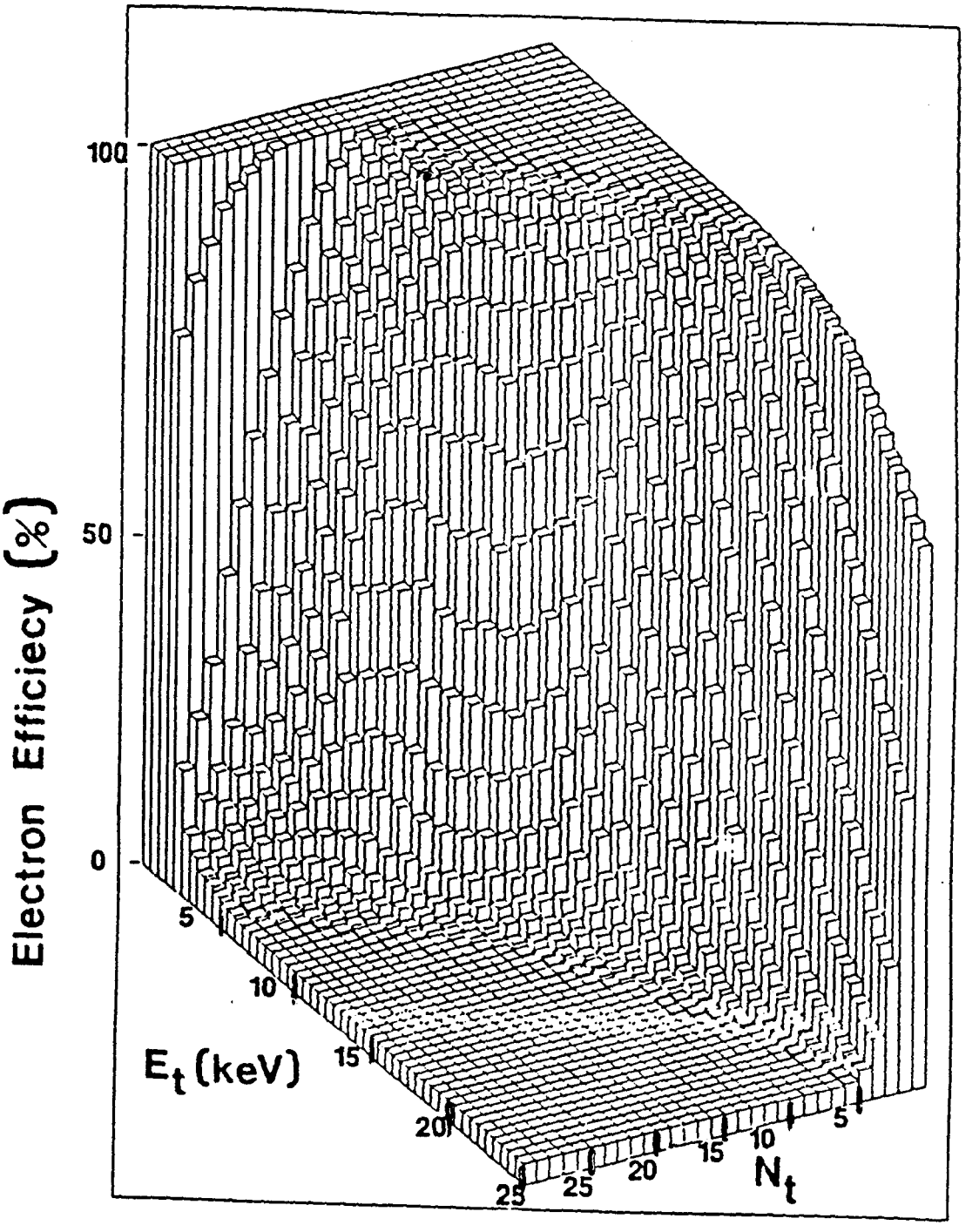
STRAWS IN r-φ plane? one option...

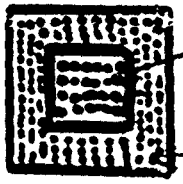
32 modules → 166K straws for $|\eta| < 1.5$

50 GeV $\pi^{\pm}$



50 GeV $e^{\pm}$



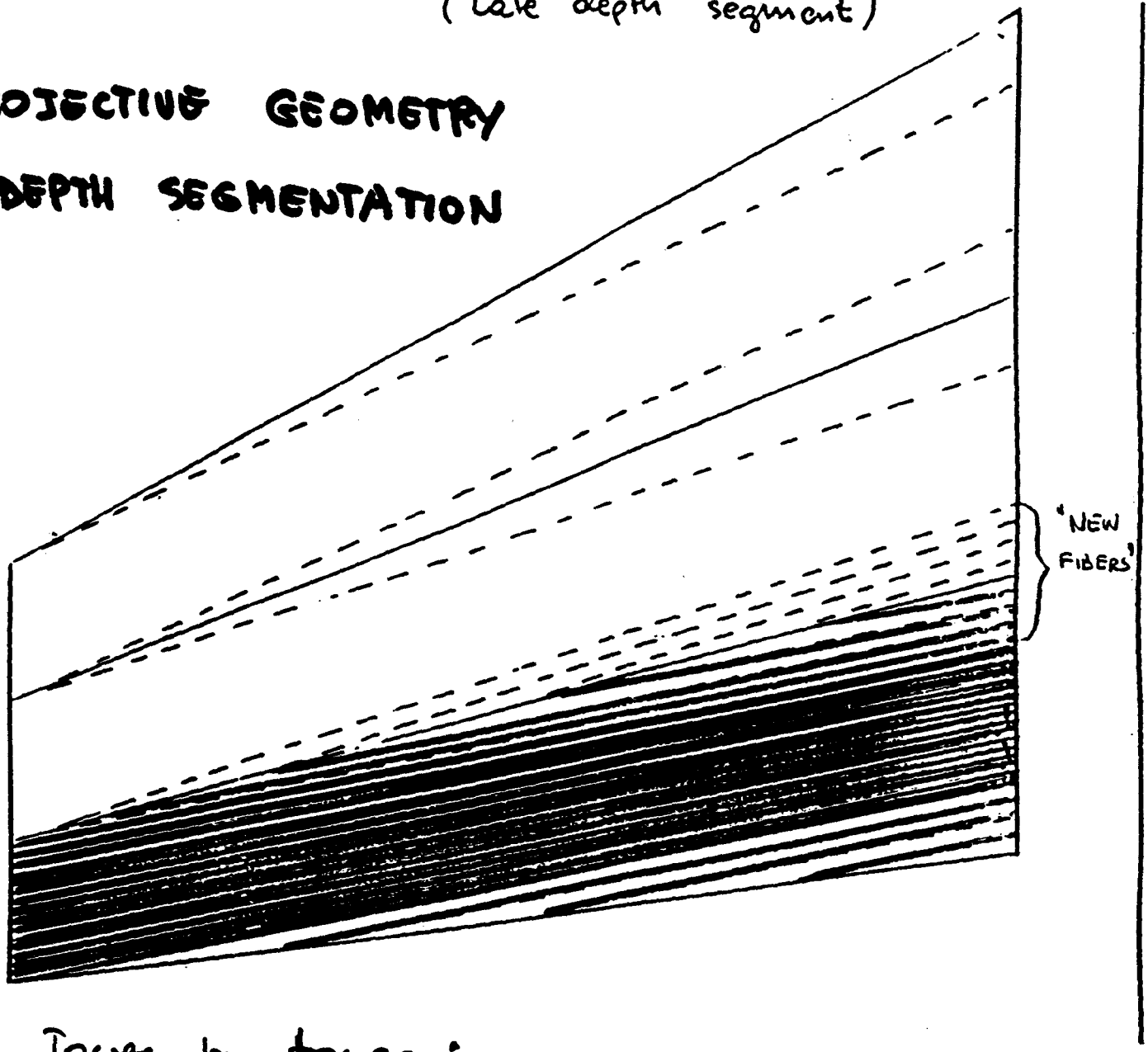


PM "central"

PM "side"
(late depth segment)

PROJECTIVE GEOMETRY

⇒ DEPTH SEGMENTATION



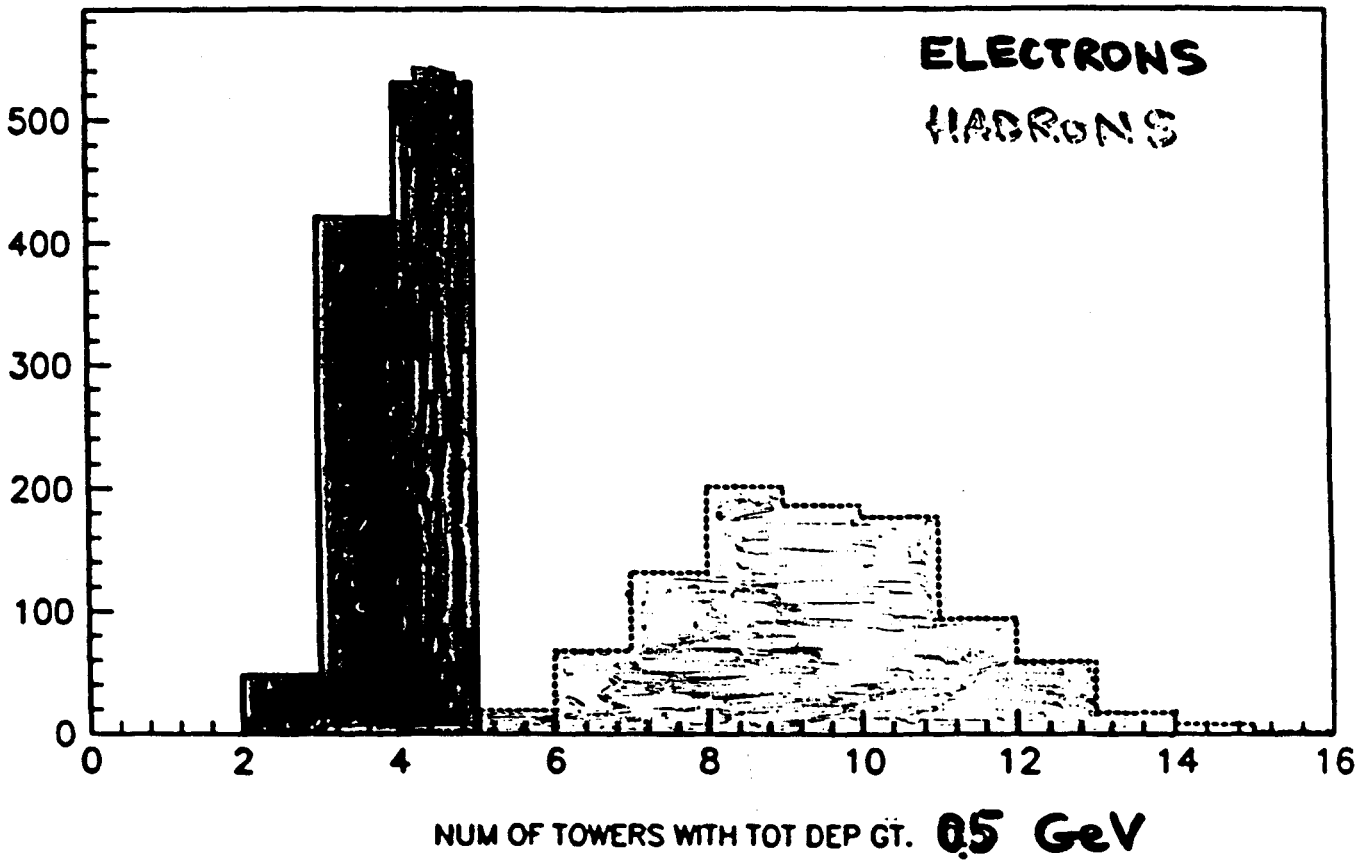
<u>Tower by tower</u> :

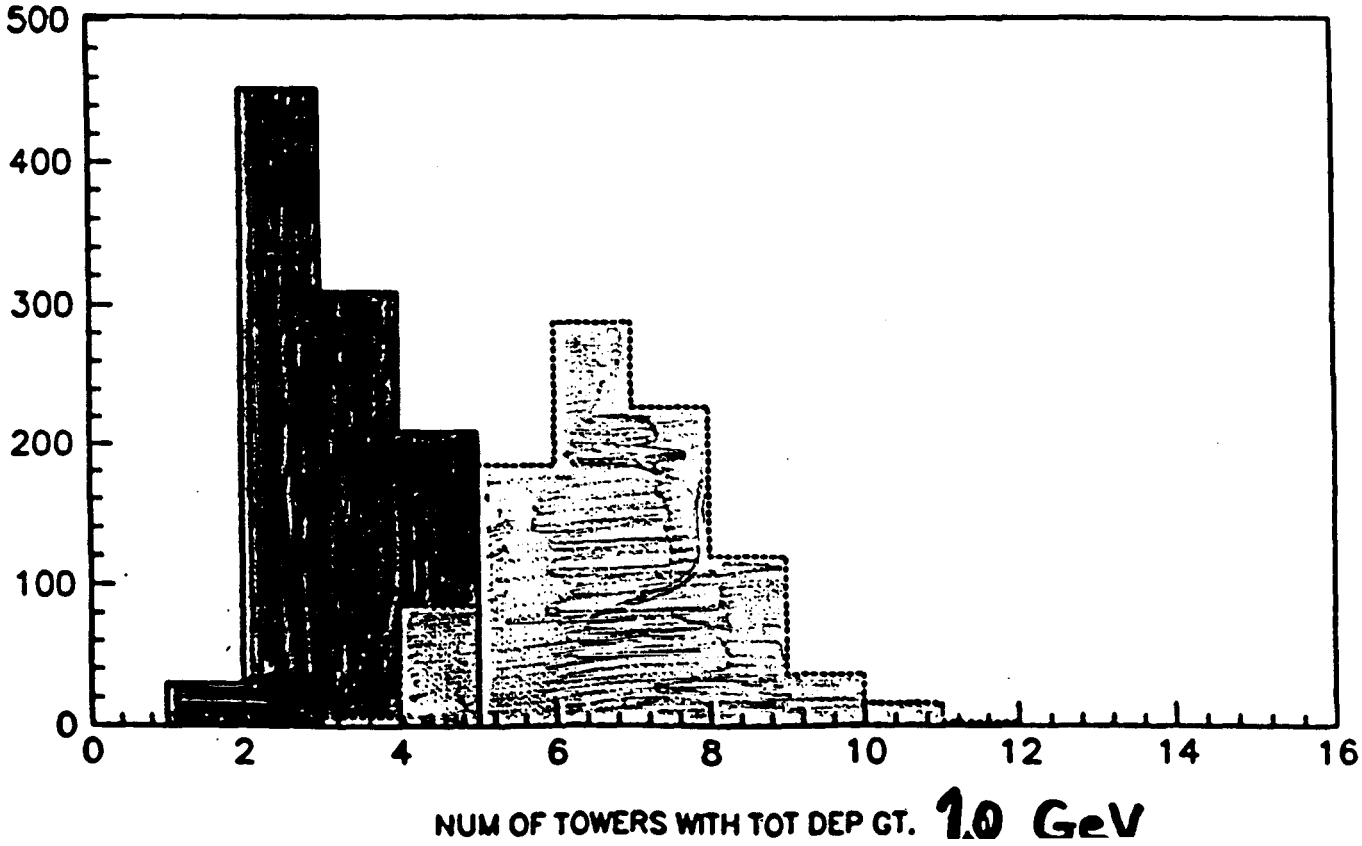
$$E_{side} \geq 0.1\, E_{cent} \Rightarrow E_{Had} = E_{cent} + E_{side}$$

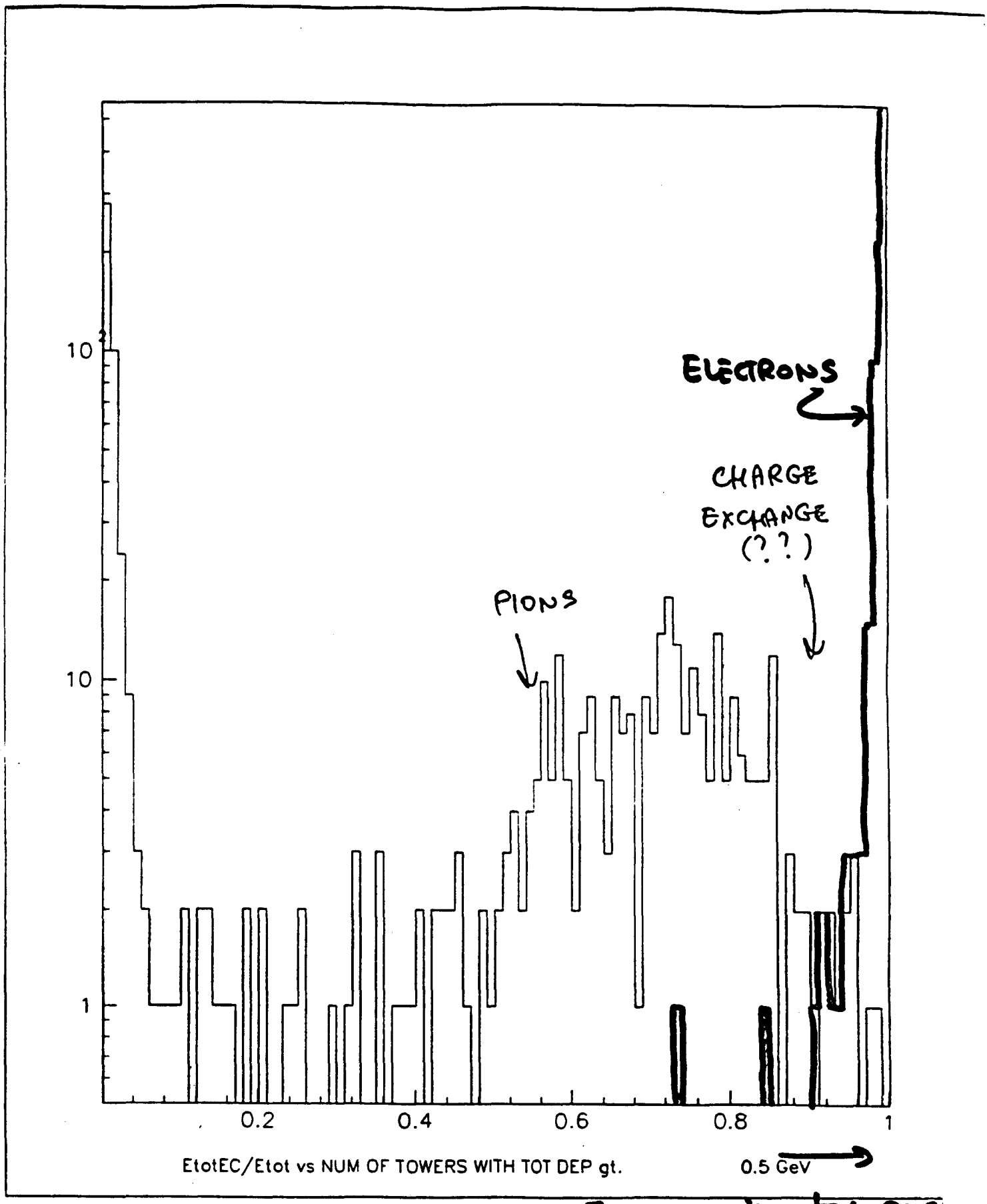
$$E_{side} \leq 0.1\, E_{cent} \Rightarrow E_{em} = E_{cent}$$

SEE S. TKACZYK

<u>TRIGGER</u>


ELECTRONS
HADRONS
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
NUM OF TOWERS WITH TOT DEP GT. 0.5 GeV


500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
NUM OF TOWERS WITH TOT DEP GT. 1.0 GeV



Energy in towers with no "side" energy

Job List $e^{\pm}$ ID

Tracking

(a) X, Z Projection to Cal (± 1mm)

(b) Count Σ High P_t Particles in Cell

(c) Flag e^+e^- Conversions
(Also, create ")

(d) Tag $b \to e$

(f) E/p
- Improve ID by ~20%? } OPTIONAL?
- Brehm loss limited ! }
- Calibration

(g) Particle Flow around $e^{\pm}$

Calorimeter

(a) EM/HAD $\Rightarrow$ ~1% SINGLE π/e

(b) X, Z Match to Track

(c) Shower Shape over Fiducial Volume

(d) Flag π^0, e^+e^- Conversions
4 $\gamma\gamma$

(e) Measure Isolation Energy ($W \to e$ vers $Q \to e$)

(f) Single γ ?

(g) Special Purpose
- TRD (INSIDE Coil !)
- Preradiator (Outside ? Coil)
- Synch. Rad (Inside Coil)

(h) 1 Long Segment.

June 29, 1989
Desoto, TX (4)

SUMMARY REPORT OF THE

LSD

M & M

(MUONS 'N MAGNETS)

WORKING GROUP

PARTICIPANTS:

Bob CAHN, LBL
KEN HELLER, MINN.
Tony Liss, U of I
Shigeki Mori, Tsukuba
Lou Osborne, MIT
Steve Errede, U of I
Bob Kephart, FNAL
Mike MARX, SUNY-SB
Uriel NAUENBERG, U. Colorado
Dick Wohlgast, LBL

w/ VISTATIONS FROM:

BILL FOSTER
IAN HINCHLIFFE
RICH KADEL
ANDY LANGFORD

LSD MUON PHYSICS PRIORITIES

	ISOLATED μ's	NON-ISOLATED μ's
SINGLE μ's:	OLD PHYS $\begin{cases} W \to \mu \bar{\nu}_\mu \\ t\bar{t} \to \mu + X,\ \mu + e \end{cases}$	$B\bar{B}$, $C\bar{C}$ (?) SEMI-MUONIC DECAYS
	Heavy $Q\bar{Q} \to \mu + X,\ \mu + e$	
	Muon LeptoQuarks	
	$W' \to \mu \bar{\nu}_\mu$	
	EXOTIC HEAVY STABLES: μ+TOF (SCINT??)	

DI + MULTI μ's:

$Z^0 \to \mu^+\mu^-$

$Z^{0\prime} \to \mu^+\mu^-$, LEPTON COMPOSITENESS (DRELL-YAN + MULTI LEPTONS)

$W^+W^+ \to \mu^+\mu^+,\ \mu^+e^+$

$t\bar{t} \to \mu^\pm\mu^\mp$

SUSY $\to$ LS μ's

$H^0 \to Z^0Z^0 \to 4\mu$'s, $\mu^+\mu^- + e^+e^-$, ...

Low Level μ-TRIGGER should save μ's w/ $P_t^\mu > 20$ GeV/ w/ High Effy.

$\Rightarrow$ Low Level MUON TRIG Thresh $P_t^{TRIG}(50\%) \simeq 10$ GeV/c

MUON PERFORMANCE REQUIREMENTS + PERFORMANCE CRITERIA

A.) MOMENTUM RESOLUTION:

Physics: ① WANT $H^0 \to 2Z^0 \to 4\mu \Rightarrow$ 10% MOMENTUM RESOLUTION IN RELEVANT P_t – DOMAIN.

$$\boxed{\frac{\delta P_\perp}{P_\perp} \lesssim 0.1\left(\frac{P_\perp\,(\mathrm{TeV}/c)}{0.3}\right)}$$

OR: $$\boxed{\frac{\delta P_\perp}{P_\perp} \lesssim 0.33\, P_\perp\,(\mathrm{TeV}/c)}$$

Fraction of leptons small for $M_H \approx 800\,\mathrm{GeV}/c^2$ w/ $P_t^\mu \gtrsim 300\,\mathrm{GeV}/c$

② WANT $\sigma_{m_{Z'}}/m_{Z'} \lesssim 30\%$ for $m_{Z'} \approx 2\,\mathrm{TeV}/c^2$

$$\Rightarrow \delta P_\perp/P_\perp \lesssim 0.15\, P_\perp\,(\mathrm{TeV}/c)$$

③ WANT CHARGE SIGN DETERMINATION for $W^+W^+ \to \mu^+e^+, \mu^+\mu^+$ GOOD TO $\lesssim 30\%$ @ 0.7 TeV/c

$$\Rightarrow \boxed{\frac{\delta P_\perp}{P_\perp} \lesssim 0.43\, P_\perp\,(\mathrm{TeV}/c)}$$

B.) ACCEPTANCE ISSUES

PSEUDO-RAPIDITY COVERAGE FOR MUONS (Mostly from H^0, Z'^0 ACCEPT.)

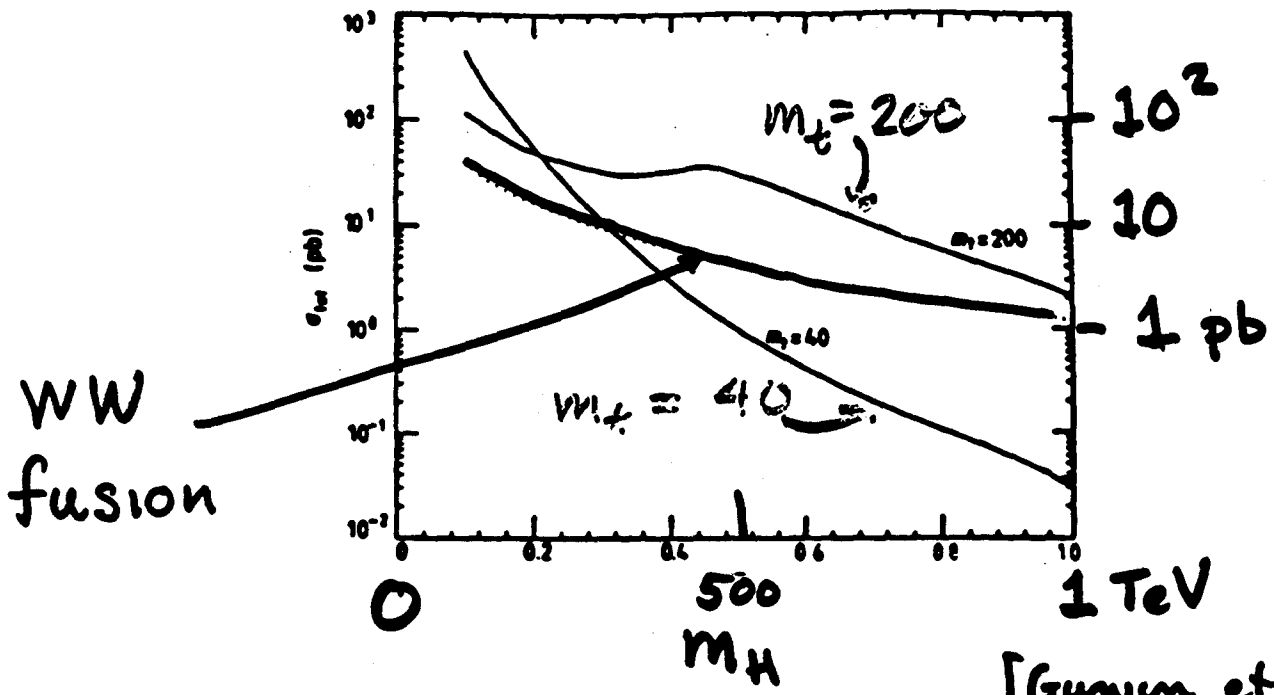
$|\eta|_\mu \lesssim 3.0$ $(5^\circ \lesssim \theta_\mu \lesssim 175^\circ)$ Looks ADEQUATE FOR AFOREMENTIONED PHYSICS GOALS

NEEDS FURTHER STUDIES...

$|\eta| > 3.0$ PASSIVE SHIELDING ONLY?

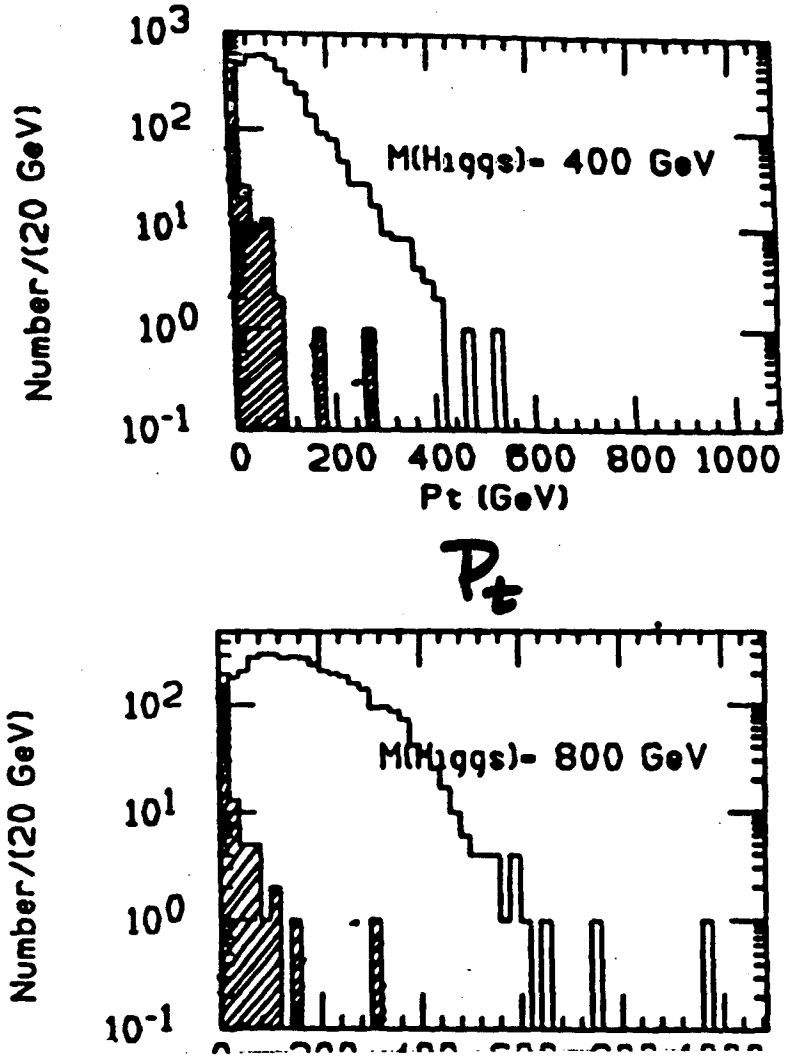
μ_{ID} — MINIMAL TRACKING + M.I. SIGNAL?

Bob Cahn
Nikos



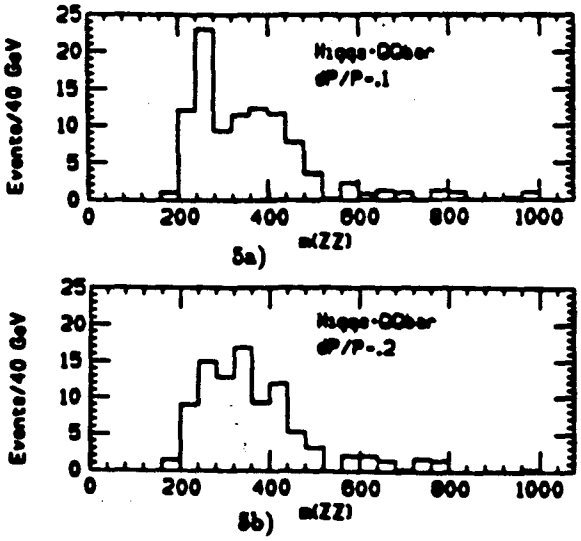
[Gunion et al NP B294, 621]

leptons from $H \to ZZ$, $Z \to \ell^+\ell^-$



Berkeley 1987

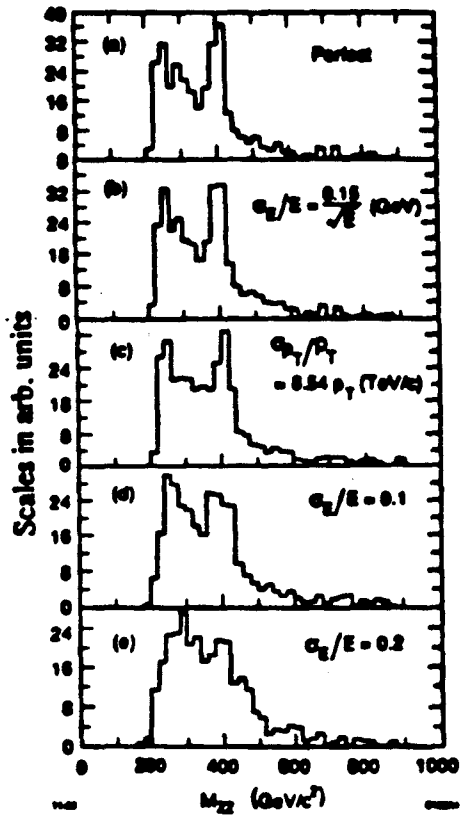
$m_H = 400$ GeV



$\Delta P/P = 10\%$

$\Delta P/P = 20\%$

HINCHLIFFE &
WANG
SNOWMASS 88



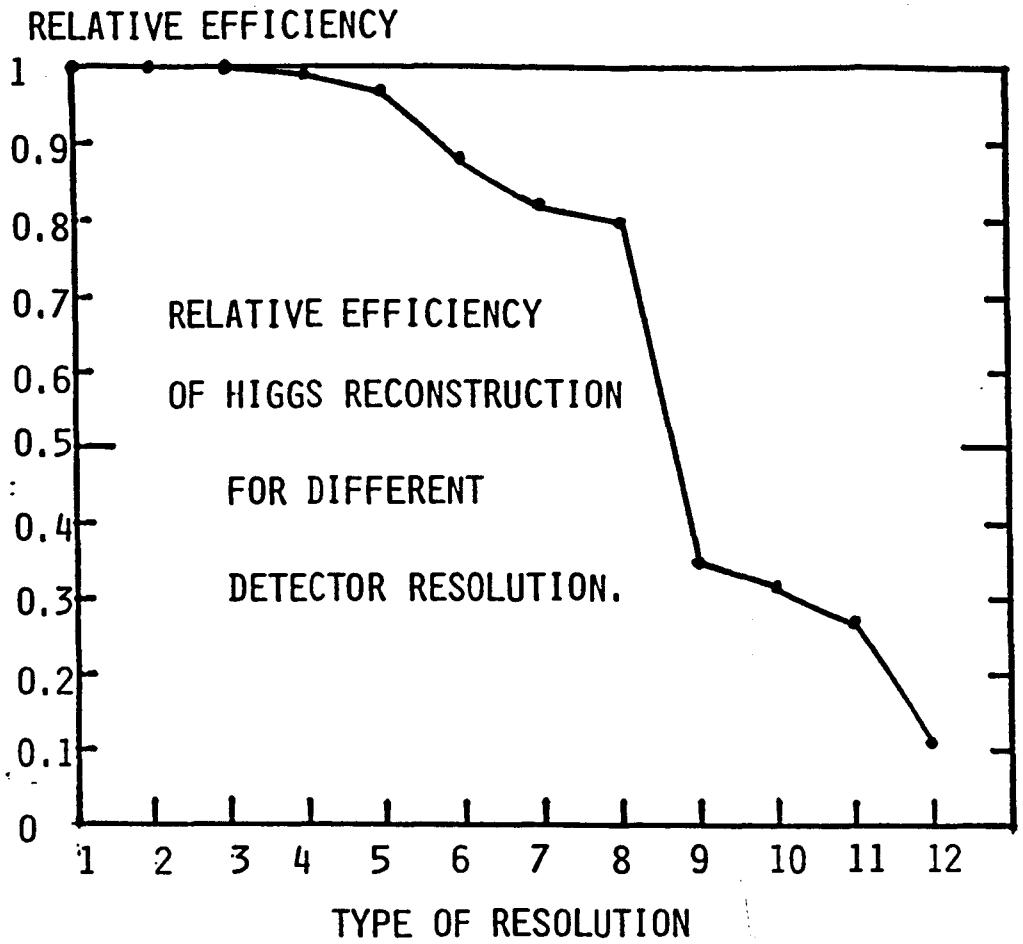
$\sigma_E/E = \frac{15\%}{\sqrt{E}}$

$\sigma_{P_T}/P_T = 0.54 P_T$ (TeV

$\sigma_E/E = 10\%$

$\sigma_E/E = 20\%$

WANG &
HANSON
SNOWMASS 88



Y. ASANO
TSUKUBA

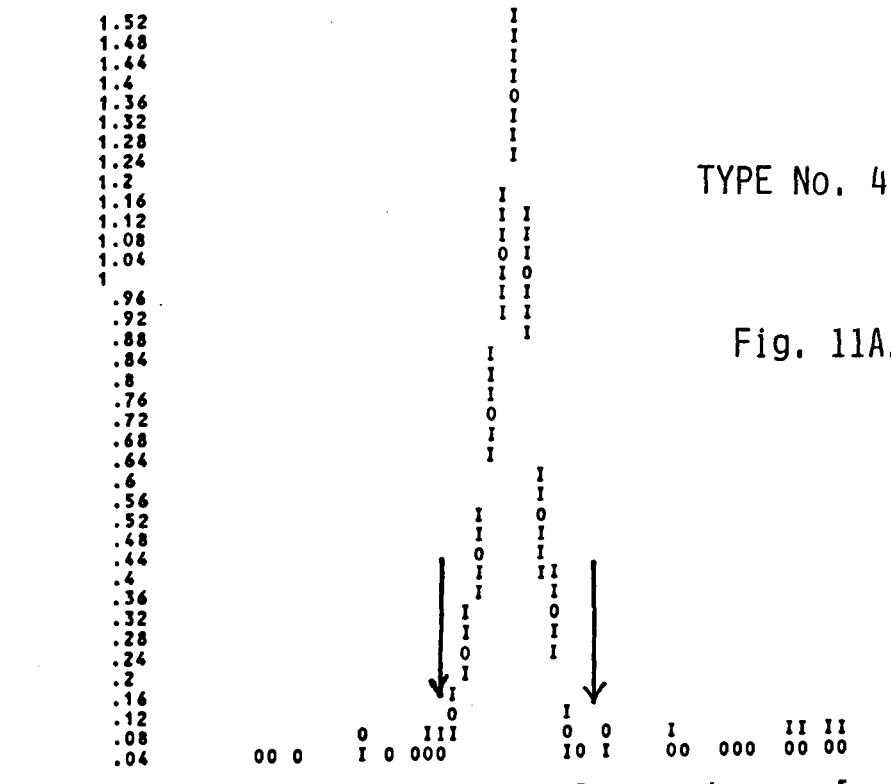
TYPE NO.	RESOLUTION ΔP/P
1	Perfect
2	2%
3	0.15/sqrt(E)
4	$0.3P_T$
5	4%
6	0.14P+0.01
7	$0.54P_T$
8	0.02 for ABS(y) .LT.1, 0.02+(ABS(y)-1)*0.06 for ly| .GT.1 and .LT.3
9	$0.1+0.1P_T$ (TeV/c)
10	Toroid case 3 (Amako program #3...muon vector is measured at the exit of the filter.)
11	Toroid case 2 (Amako program #2...only position of the is measured at the exit of the filter.)
12	20%

$|\eta_\mu| < 3$
$P_t^\mu > 20$
$P > 30$
$N_\mu \geq 4$
$0 \leq \cos\Theta_{\mu^+\mu^-} \leq 1$
$84 \leq 2\, m_{\mu^+\mu^-} \leq 100$
$M_Z = 94$ Assumed

Fig. 20

MU-PAIR MASS FOR SMEAR NO. 4

HBOOK ID = 117 DATE 07/06/89



TYPE No. 4

Fig. 11A.

MU-PAIR INVARIANT MASS

CHANNELS 0 0 1 2 3 4 5
0123456789012345678901234567890123456789012345678901

ZO-PAIR MASS FOR SMEAR NO. 4

HBOOK ID = 129

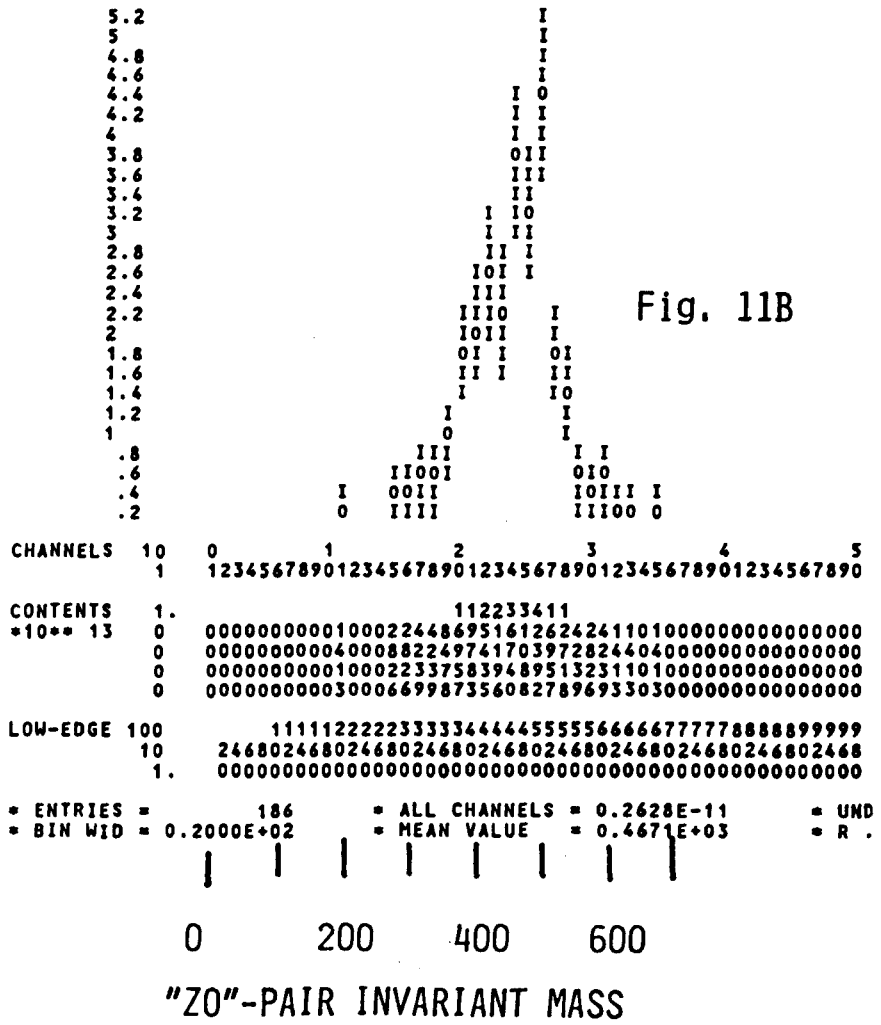


Fig. 11B

"ZO"-PAIR INVARIANT MASS

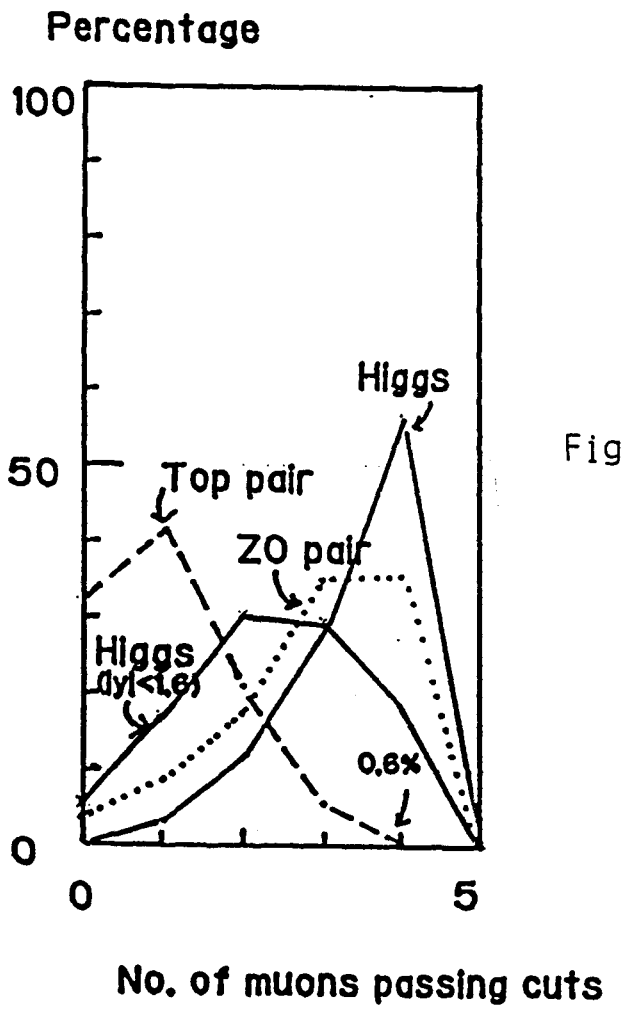

Percentage
100
50
0
0
5
Higgs
Top pair
ZO pair
Higgs
|y|<1.6
0.6%
No. of muons passing cuts

Fig. 10

HIGGS RECONSTRUCTION EFFICIENCY
IN CENTRAL TRACKER + TOROID

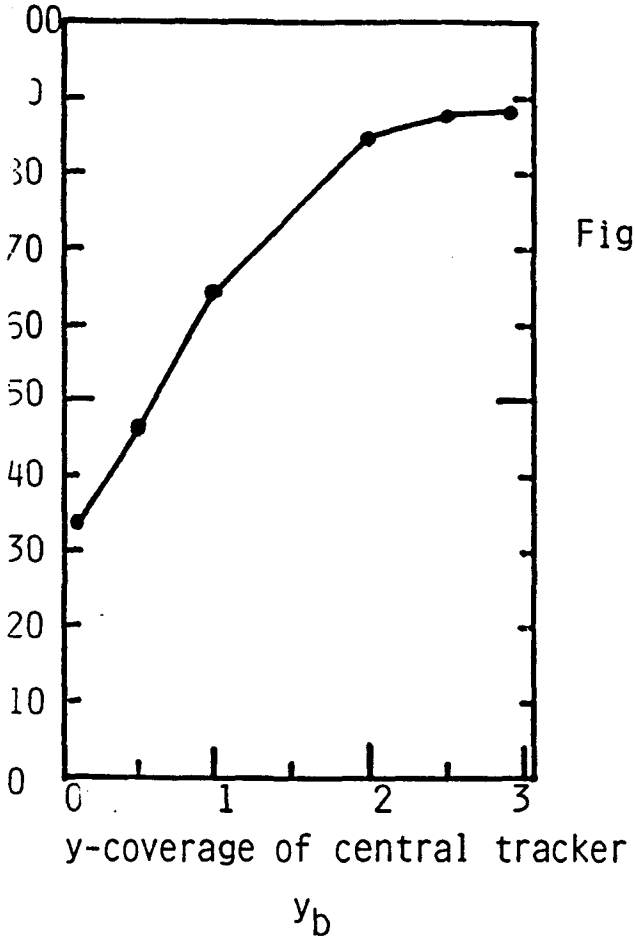


Fig. 1

FUTURE WORK

(GENERATED MORE ??? THAN ANSWERS...)

MEET EVERY OTHER FRIDAY IN URBANA???

1.) REDUX PARTICLE RATES (μ's PROMPT, DECAY IN FLIGHT, PUNCHTHROUGH) FROM $\sigma_{TOT}(pp)$ @ $\sqrt{s} = 40$ TeV
MIN-BIAS, 2 JET ($u\bar{u}, d\bar{d}, s\bar{s}, c\bar{c}, b\bar{b}, t\bar{t}, \ldots$)
DRELL-YAN, W, Z^0

ISAJET / ISALEP
PYTHIA

INCLUDE ALL PHYSICS PROCESSES
& REALISTIC DETECTOR SIMULATION (IN PROGRESS)

2.) FURTHER PHYSICS "BENCHMARK" STUDIES FOR IMPROVED DETECTOR PERFORMANCE CRITERIA, EVALUATION, INCLUDING BKGNDS.

3.) FURTHER μ-DETECTION STUDIES, TRIGGERING SCHEMES, BACKGROUND
CENTRAL + INTERMEDIATE (+ FWD) REGIONS

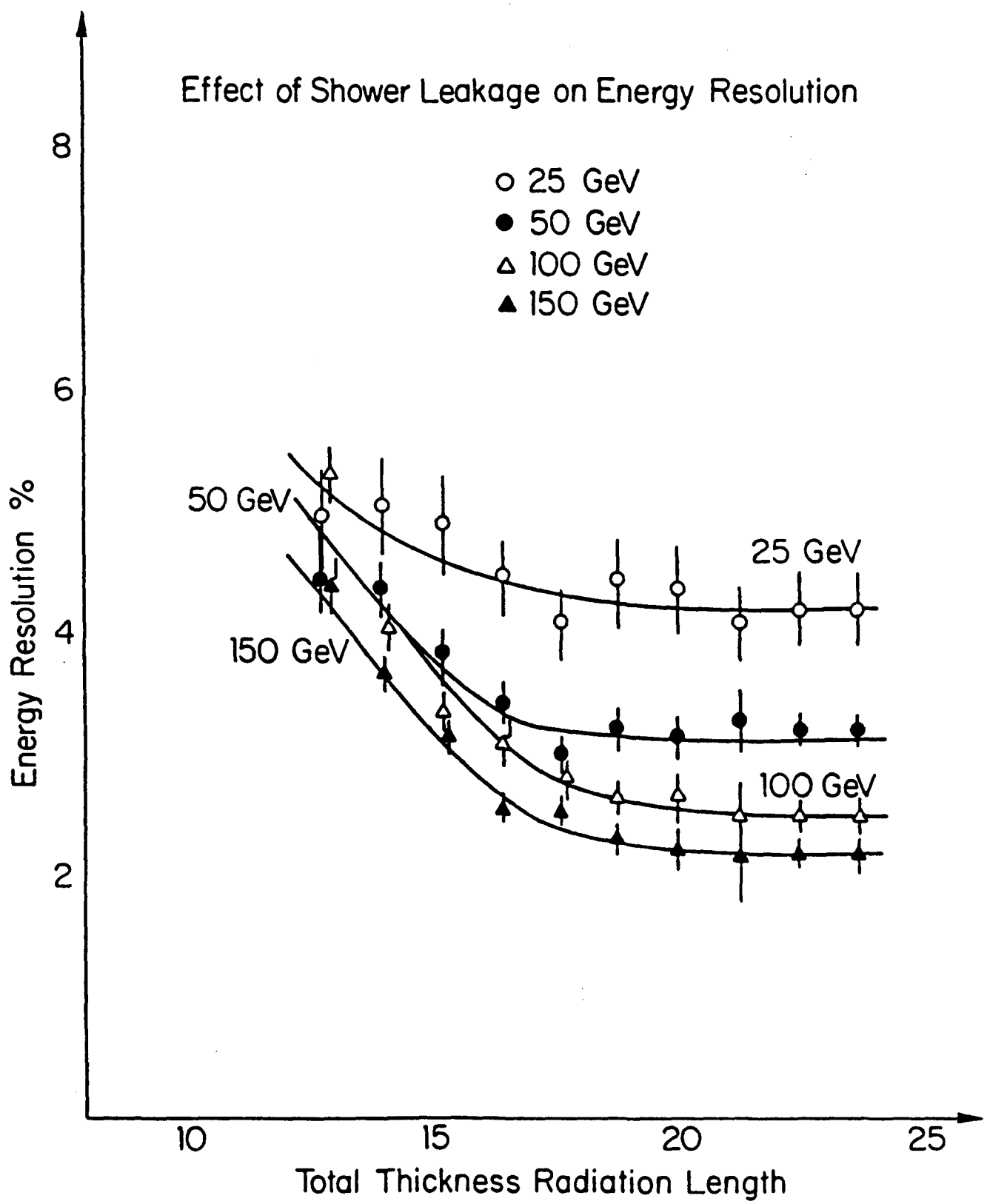
THRU TO FINAL RATE TO TAPE!

4.) DESPARATE! NEED FOR FAST TRACK PROCESSOR TO LINK w/ μ-STUBS $|\eta| < 3.0$

5.) HOW MUCH DOES $\sigma_{BEAM} \sim 10\mu$ BEAM CONSTRAINT REALLY IMPROVE $\delta p_\perp / p_\perp$ (IS SSC BEAM STABLE VS. TIME?)

6.) ACTUAL HARDWARE FOR μ-CHAMBS IN CENTRAL + INTERMEDIATE REGIONS = ? MWPC, PDT, SCINT. FIBER, LST's...

7.) WHAT IS TOTAL COST for LSD μ-SYSTEM & TIME TO BUILD


Effect of Shower Leakage on Energy Resolution
25 GeV
50 GeV
100 GeV
150 GeV
50 GeV
25 GeV
150 GeV
100 GeV
Energy Resolution %
8
6
4
2
10
15
20
25
Total Thickness Radiation Length

	LSD	ULS
WEIGHT OF FLUX RETURN	scaled $16800T\left(\frac{1.7}{2.0}\right)\left(\frac{9.6}{8.7}\right)^2 = 17{,}400T$	

WEIGHT =

$\left(\frac{\phi}{1.5T}\right) L \rho_{IRON} f$ — 14 - 18 KT — 8 - 10 KT

f: 1.5 ↔ 2.0 END multiplier

≲ 60% of flux RETURN

General Issues

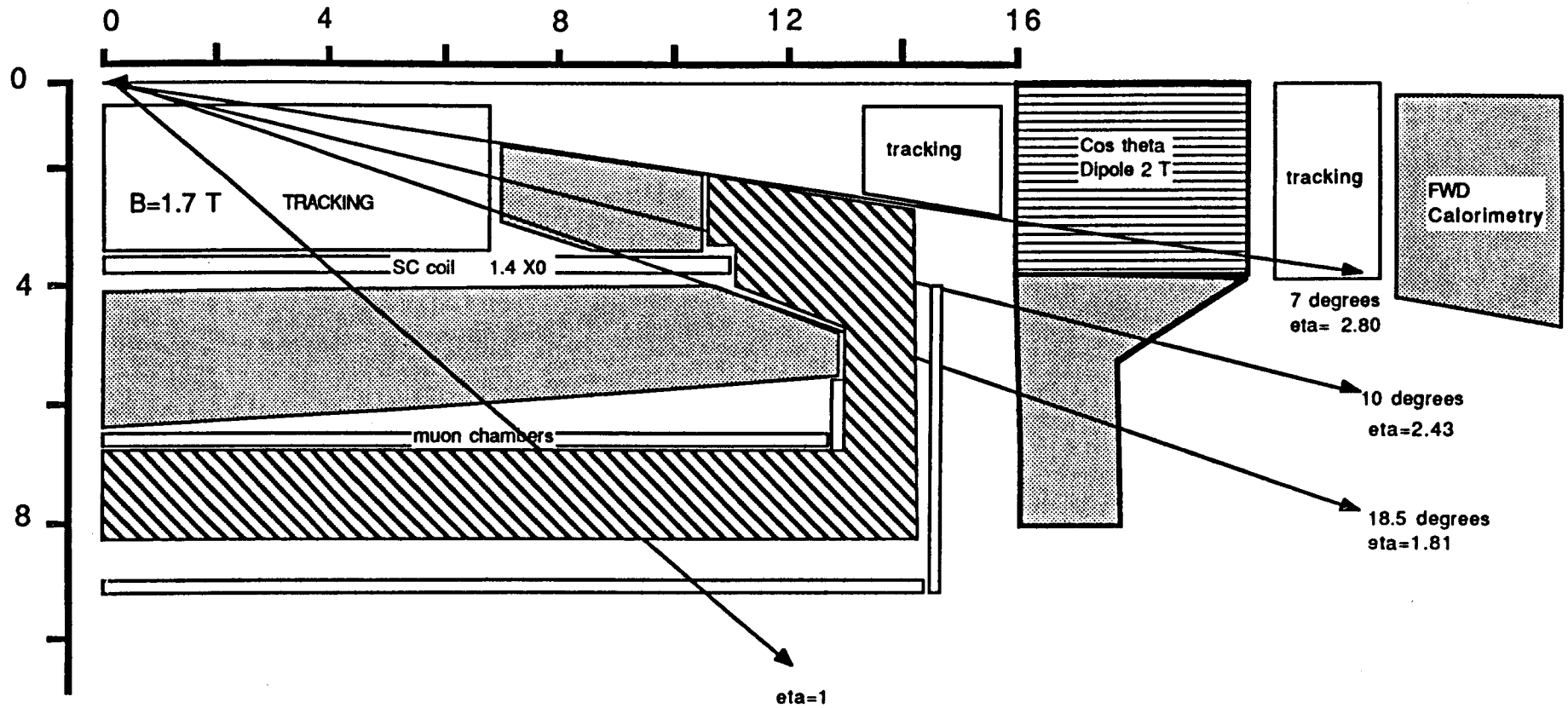
AS RADIAL SIZE GROWS ... TROUBLES INCREASE ⇒ ... schedule, cost, possibility of failure go up. ... HARD TO QUANTIFY but effect is SIGNIFICANT.

... # VENDOR is limited
... MACHINE Tools
... TRANSPORTATION
... ONSITE VS OFFSITE CONSTRUCTION

etc

↓

Bottom line The larger coil looks to be feasible .... we should be VERY SURE WE NEED it as opposed to WOULD LIKE IT.



Features:

1) two 6 m dia. 10.5 m long solenoids , B=1.7 T
2) momentum analysis to +/- eta = 2.5
3) use cosine theta dipole forward

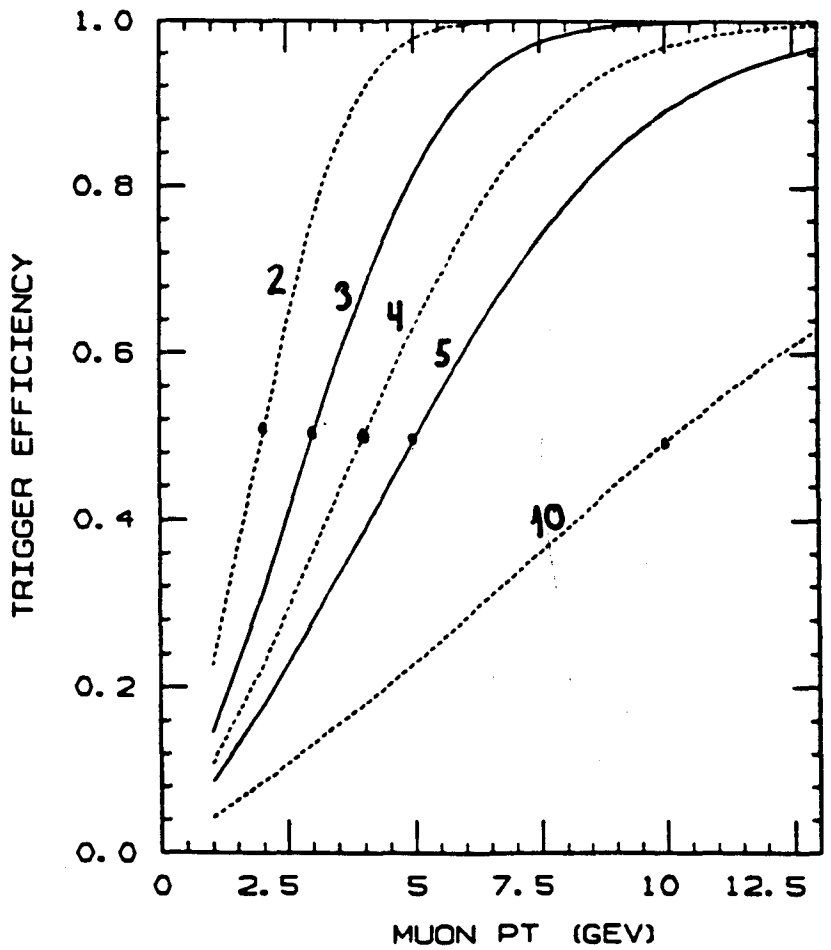


Figure 2: Trigger Efficiencies calculated by including the contribution of multiple scattering. From left to right, the curves are for a 2 *GeV*, 3 *GeV*, 4 *GeV*, 5 *GeV*, and 10 *GeV* threshold, respectively. At threshold, the efficiency is nominally 50%. The full lines show the two thresholds actually used in the 1988–1989 run.

CENTRAL MUON LEVEL-2 TRIGGER

USE PROMPT HIT INFO, ∝ FROM μ-CHAMBER PLANES AS SEGMENTS FOR μ-TRACK.

FAST TRACK SEGMENT PROCESSOR TO USE TO FIND TRACK

TAKES ~10-20μ FOR CTC

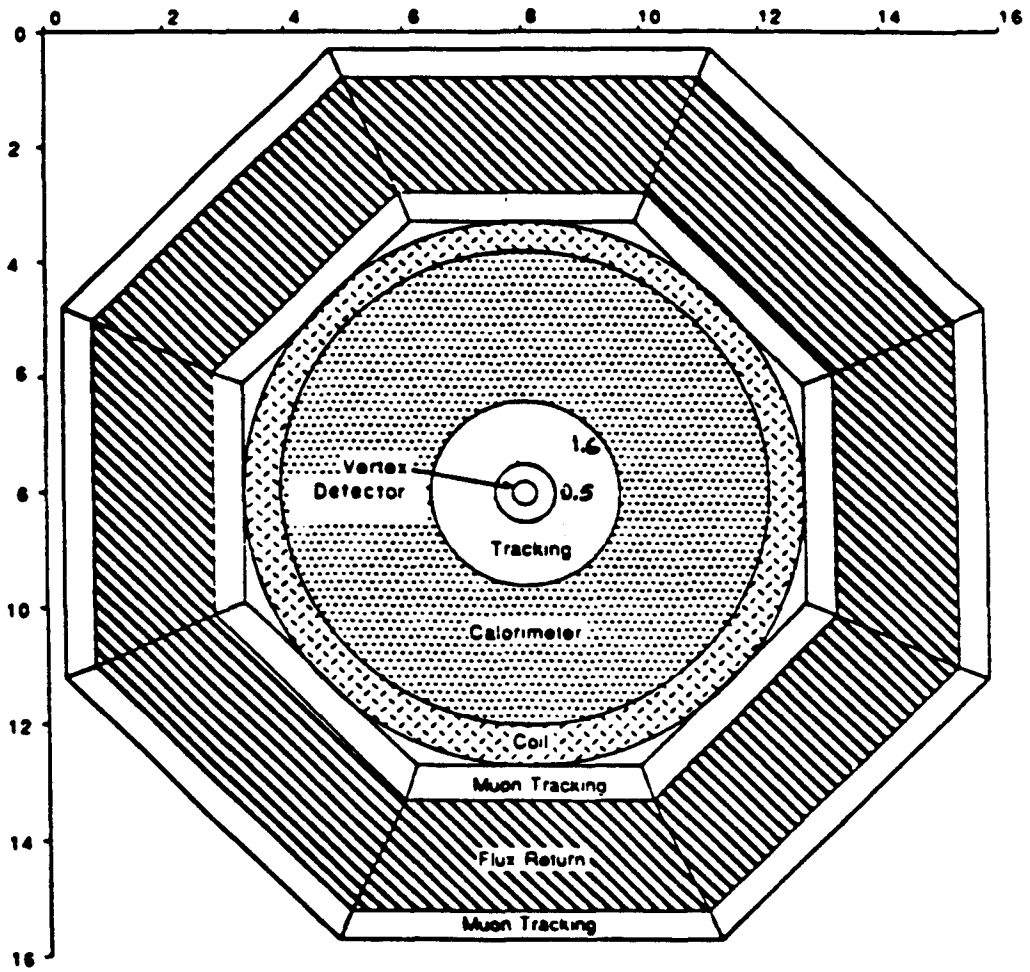
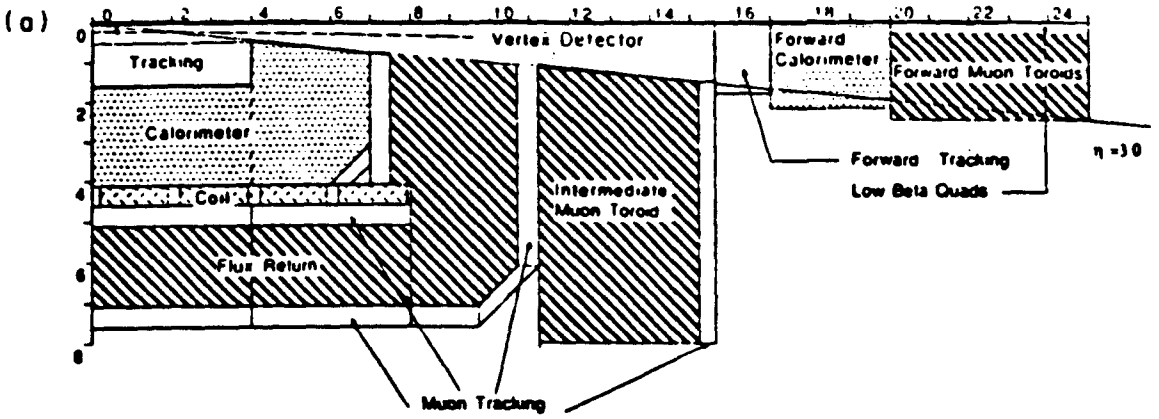
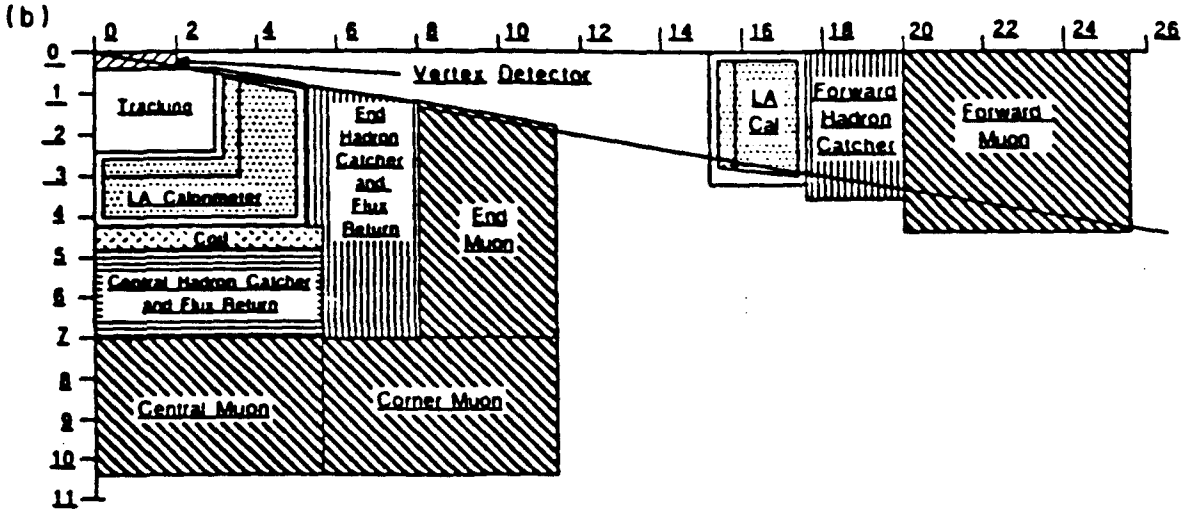


Fig. 2. End view of the Large Solenoid Detector.

Fig. 1. (a) Schematic view of the Large Solenoid Detector.

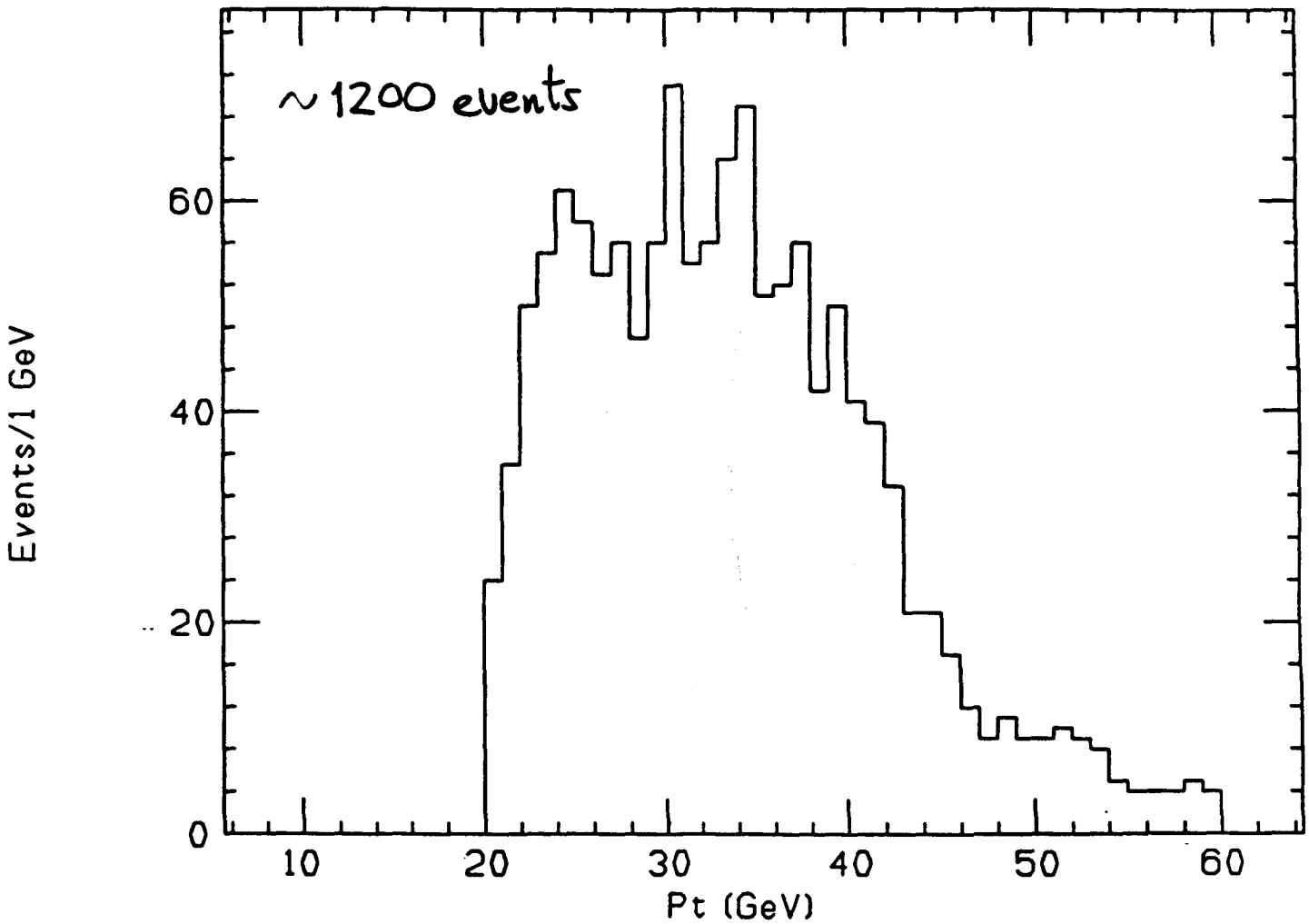




(b) Model A

CDF PRELIMINARY

Muon Pt Spectrum from W



Intermediate μs

Again, Rate & occupancy are ok after calorimeter + toroid steel.

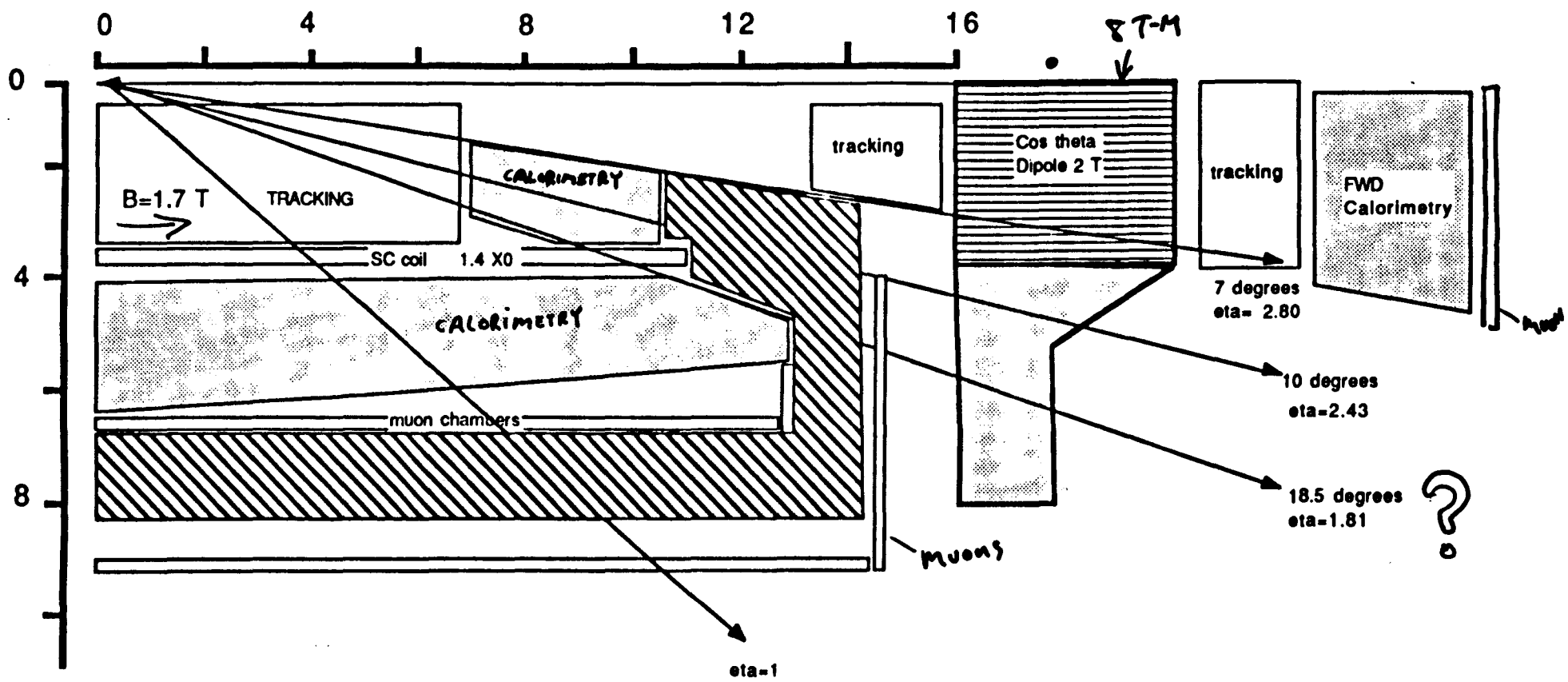
Level 1:
P_T cut from measuring entrance & exit $\not{X}$

Levels > 1

We have alot of work to do here.
In particular, we would like to be able to match to tracks coming from the vertex.
This gets very hard as the $\not{X}$ gets small.

The longer the solenoid the better!

VLS = VERY Long Solenoid ?



Features:

1) two 6 m dia. 10.5 m long solenoids , B=1.7 T
2) momentum analysis to +/- eta ≤ 2.5 (Solenoid)
3) use cosine theta dipole forward ≥ 2.8 ? (OR TOROIDS ETC)
4) Best available Calorimetry

$$\frac{\Delta P_\perp}{P_\perp^2} = \times 5.2 \left\{ \begin{matrix} \text{Better} \\ \text{That in CDF} \end{matrix} \right\} \text{ with same chamber resolution}$$

LSD' = FNAL VERSION of LSD

Comparison of Two Possible SC Solenoids for Large SSC DETECTOR

CALORIMETRY LOCATION	INSIDE COIL ≡ LSD	OUTSIDE COIL ≡ VL
TYPE of Coil	Thick / Pool Boiling cryostable	Thin / indirectly cooled Quasistable?
USEFUL Bore	8.2 M	6.0 M
CALORIMETER SUPPORT	{ SS TRUSS ΔR = .25M }	NONE
~Coil Diameter	9 m	6.5 m
length	16 m	21 m (?)
B_0 (T)	1.7 T	1.7 T
STORED ENERGY	1400 MJ	740 MJ
($\propto B^2R^2L$ .... COST $\propto E^{.75}$)		
$\frac{\Delta P_\perp}{P_\perp}$ (Tracker ONLY)	$.27\left(\frac{2.0}{1.7}\right) = .32\, P_\perp$ (TeV/c)	$(.27)\left(\frac{2.0}{1.7}\right)\left(\frac{1.6}{2.0}\right)^2 = .09\, P_\perp$

Assumes $\sqrt{\frac{720}{1+5/N}}\left(\frac{\sigma}{.3 I B L^2 \sqrt{N}}\right)$

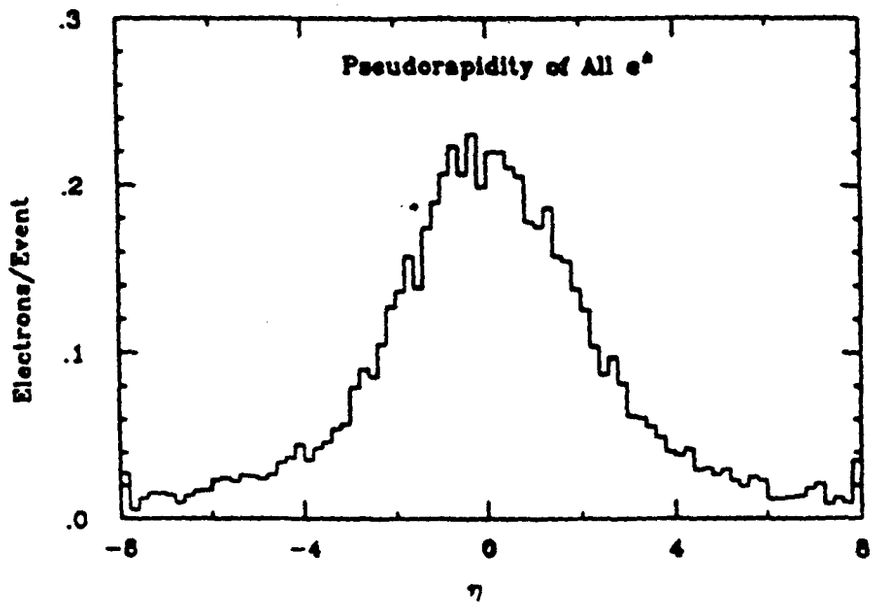
$\sigma \sim 150\mu$ $N \sim$ FIXED

E-W Symmetry Breaking

- σ=1 - 100 pb
- 1 pb = 10,000 events
- $m_H > 2m_Z$, $H \rightarrow ZZ, WW$
- Gold-plated $Z \rightarrow l^+l^-, Z \rightarrow l^+l^-$
  - BR $1/3 \times (0.066)^2 = 14 \times 10^{-4}$
  - Need $|\eta| < 2$ for leptons
  - Need better than 20% resolution
  - 10% resolution marginal

PSEUDORAPIDITY DIST.

400 GeV D quark



Dawson et al, Berkeley 1987

Does LSD Meet Our Needs?

Central Region:

Scale $\frac{\sigma_{P_T}}{P_T}$ from CDF

CDF: No Beam Constraint $\frac{\sigma_{P_T}}{P_T} = 0.0018 P_T \ \text{GeV}/c = 1.8 P_T \ \text{TeV}/c$

$(B = 1.4T \quad L = 1m)$

LSD: $B = 2T \quad L = 1.2m \Rightarrow$

$$\left.\frac{\sigma_{P_T}}{P_T}\right|_{LSD} = 1.8 P_T (\text{TeV}/c) \left[\frac{1.4T\,(1m)^2}{2T\,(1.2)^2}\right]$$

$$= 0.875 P_T (\text{TeV}/c) \approx \frac{1}{2} \left.\frac{\sigma_{P_t}}{P_t}\right|_{CDF}$$

$\overset{??}{\Rightarrow}$ With beam constraint $\frac{\sigma_{P_T}}{P_T} = 0.44 P_T (\text{TeV}/c)$

(N.B. CDF experience is only 40% improvement for beam constraint, but beam size is bigger at Tevatron than SSC, etc etc.)

Conclusion:

LSD BL^2 of 2.88 is marginal for our needs (at best).

A Larger Tracking Radius is Needed.

C

PHILOSOPHY

CDF SOLENOID & CTC MEET OUR NEEDS VERY NICELY AT THE TEVATRON. THEY DO A VERY NICE JOB, BUT ARE BY NO MEANS OVERKILL.

Typical P_T of interest < 100 GeV & $BL^2 = 1.4$ T-M

e.g. $Z^0 \to \mu^+\mu^-$ $\quad \tau = \frac{M^2}{S} = x_1 x_2$, $x_i = \frac{P_i}{P_{BEAM}}$ $\quad$ 10x !!

$= (0.05)^2$ for Z^0

AT SSC typical P_T of interest < 1000 GeV

BUT LSD BL^2 ONLY $\underline{2}\times$ CDF

IN ADDITION, EVENTS ARE MUCH MORE COMPLEX. A LARGER L HELPS PATTERN RECOGNITION IMMENSLY.

BUT LSD $L = 1.2 L_{CDF}$

THIS DOES NOT SEEM TO MAKE SENSE.

INTERMEDIATE REGION:

4m steel toroids magnetized to 2T

Chambers w/ $\sigma \sim 1\,\mu m$

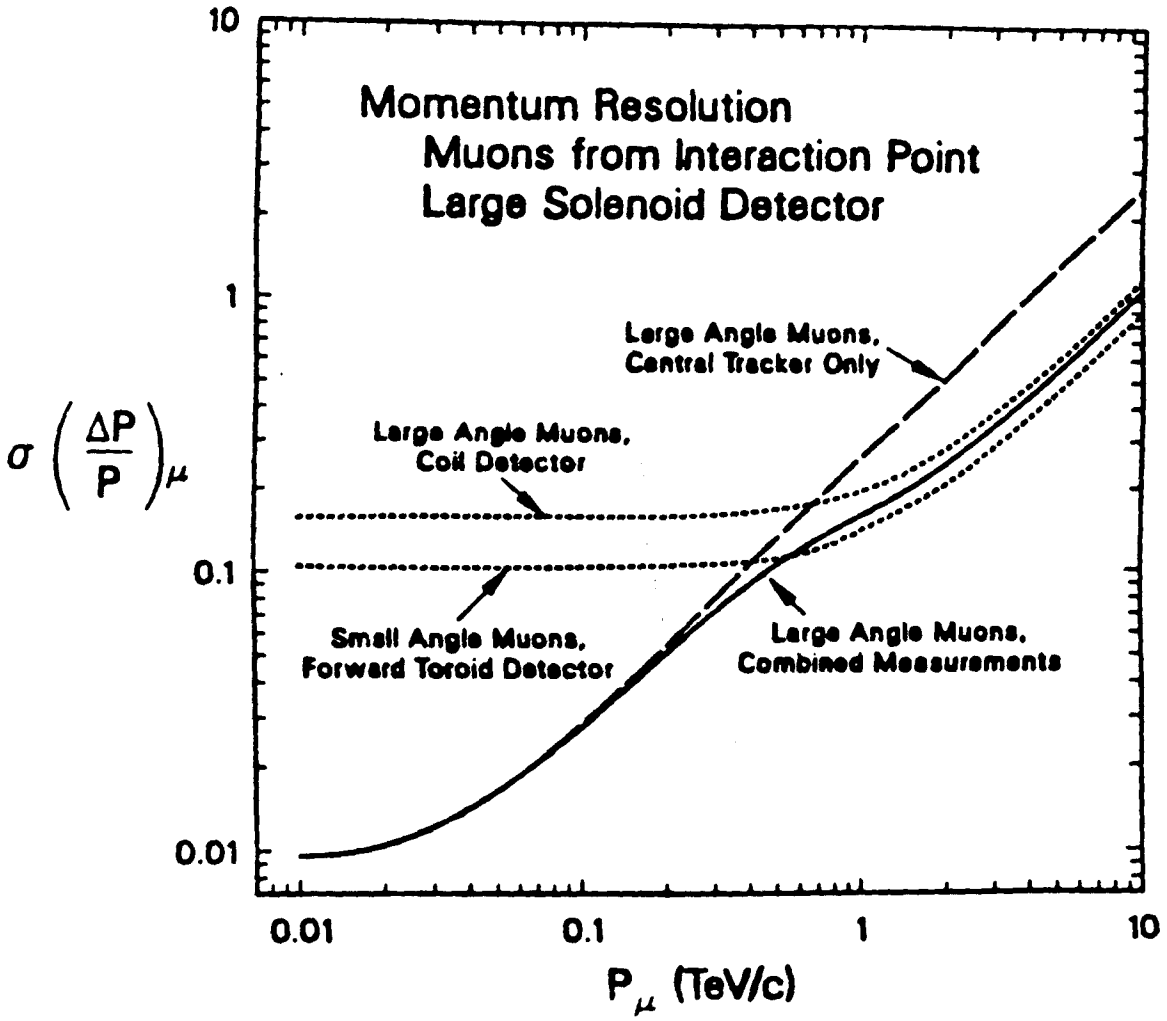
$$\frac{\sigma_{P_T}}{P_T} = 0.10 + 0.10\,P_T \ (\mathrm{TeV}/c)$$

This is well matched to capabilities of central region for standard LSD.

$\frac{\sigma_{P_T}}{P_T}$ better in toroids for $P_T \gtrsim 250$ GeV

AIR CORE TOROIDS ARE A NICE POSSIBILITY, but MAY BE TOO EXPENSIVE.

μ Resolution



C.) MUON DETECTION + TRIGGERING EFFICIENCY

FROM CDF EXPERIENCE, EFF'Y FOR μ-DETECTION + TRIGGERING EFF'Y (ISOLATED) HIGH ($\approx 100\%$)

BUT, FOR LSD, NEEDS DETAILED STUDY:

- DETECTOR TECHNOLOGIES CHOICE
- STUDY OF BREMM μ's
- PATTERN RECOGNITION (ON-LINE + OFF-LINE)
- TRIGGERING STUDIES - VERY DETAILED

D.) MUON BACKGROUND(S)

MAJOR BACKGROUND π/K DECAY, BUT MOSTLY @ LOW P_t (RANGED OUT IN CALORIMETER + RETURN YOKE) CONT RETURN λ_{CAL} !!

- NOT SERIOUS PROBLEM FOR LOW-LEVEL TRIGGER
- USE REDUNDANCY OF 2nd MOMENTUM MEAS. IN RETURN YOKE / TOROID $\delta P_t/P_t \sim 20\%\ P_t$ Ret. Y
  $\sim 10\% + 10\%\ P_t$ TO

- COSMIC RAY RATE $\sim 10^5$ Hz TOTAL
  BUT $\sim$ NEGLIGIBLE IF REQUIRE μ FROM I.P. REG
  NEED FAST TIMING (SCINTILLATOR INFO) ??
  - COSMIC RAY μ - BREMM IN CALORIMETER PROB
    - WANT CAPABILITY TO SEE $E_{MIN\ ION}$ IN CALORIM

$\Longrightarrow$ NEEDS FURTHER DETAILED STUDIES!!

e) TRIGGERING ISSUES

RATES at central μ chambers

Using both sets of μ chambers (before & after yoke) there is a natural cutoff @ $P \sim 10$ GeV/c from dE/dx. From Carlsmith et al. (SNOWMASS '86)

$R(P_T > 10 \text{ GeV}) \lesssim 10$ kHz. $\Rightarrow$

Level 1 trigger using associated hits in inner & outer chambers is ok. No P_T cut @ L1 other than dE/dx cutoff.

Occupancy is low $\Rightarrow$ ~ 500 ns drift time ok.
Maybe scintillator for crossing ID (or Σ Drift times)

Levels > 1 (Maybe this is all one level)

Measure stub χ in μ chambers? (a la CDF)
Turn on will be very slow due to MCS
$\Rightarrow$ NOT much rejection for full efficiency @ 20 GeV.

$\Rightarrow$ Use outer superlayer of central tracker for crude P_T measure. No MCS $\Rightarrow$ sharp turn on.

Further rejection from full track reconstruction & association with μ stubs.

Since most (but not all) physics processes of interest produce isolated μ's, it will be helpful to make an isolation cut at the trigger level.

$\Rightarrow$ I_{min} (or close to it) visible in calorimeter.

MUON TRIGGERING + RAW RATES

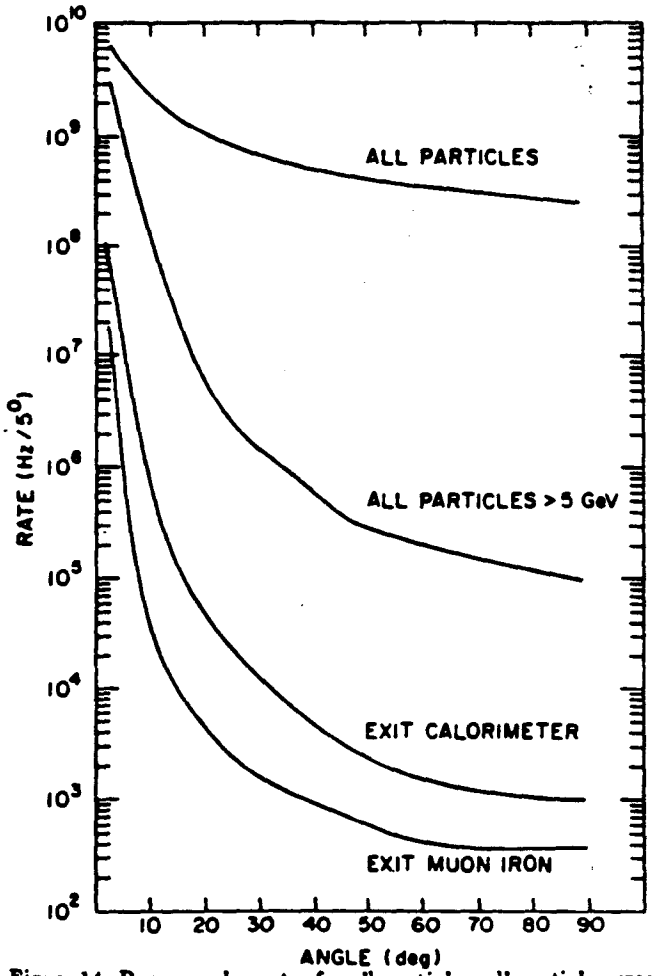


Figure 14: Raw angular rates for all particles, all particles greater than 5 GeV, all particles exiting the coarse calorimeter, and all particles exiting the muon iron.

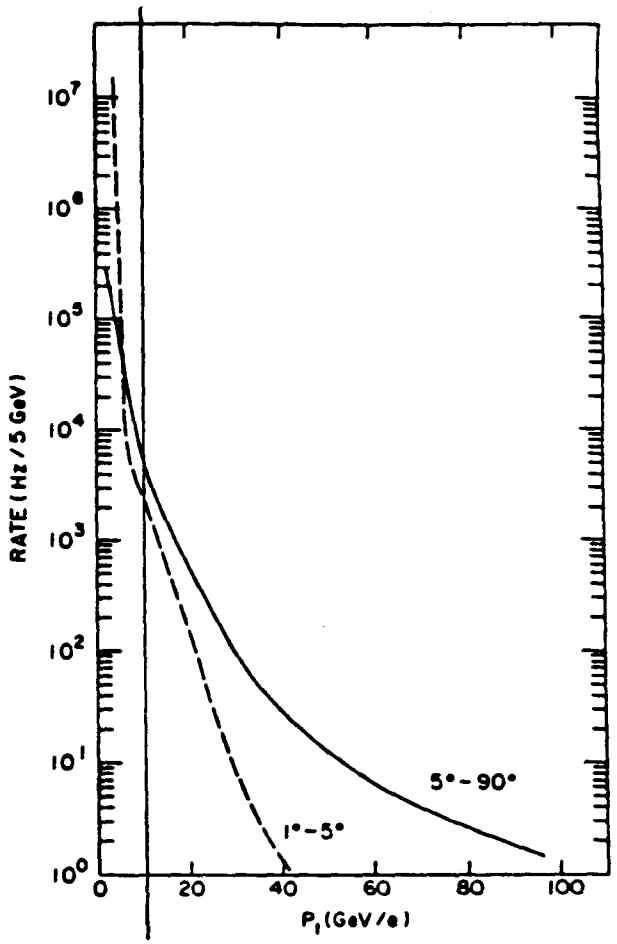
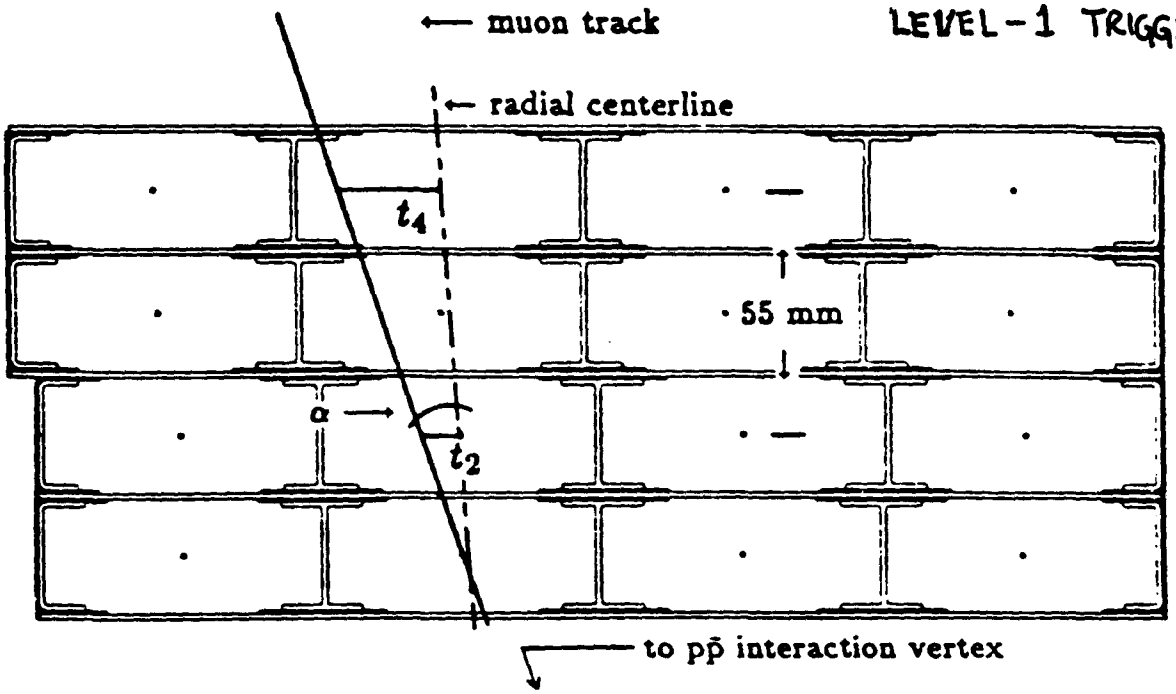
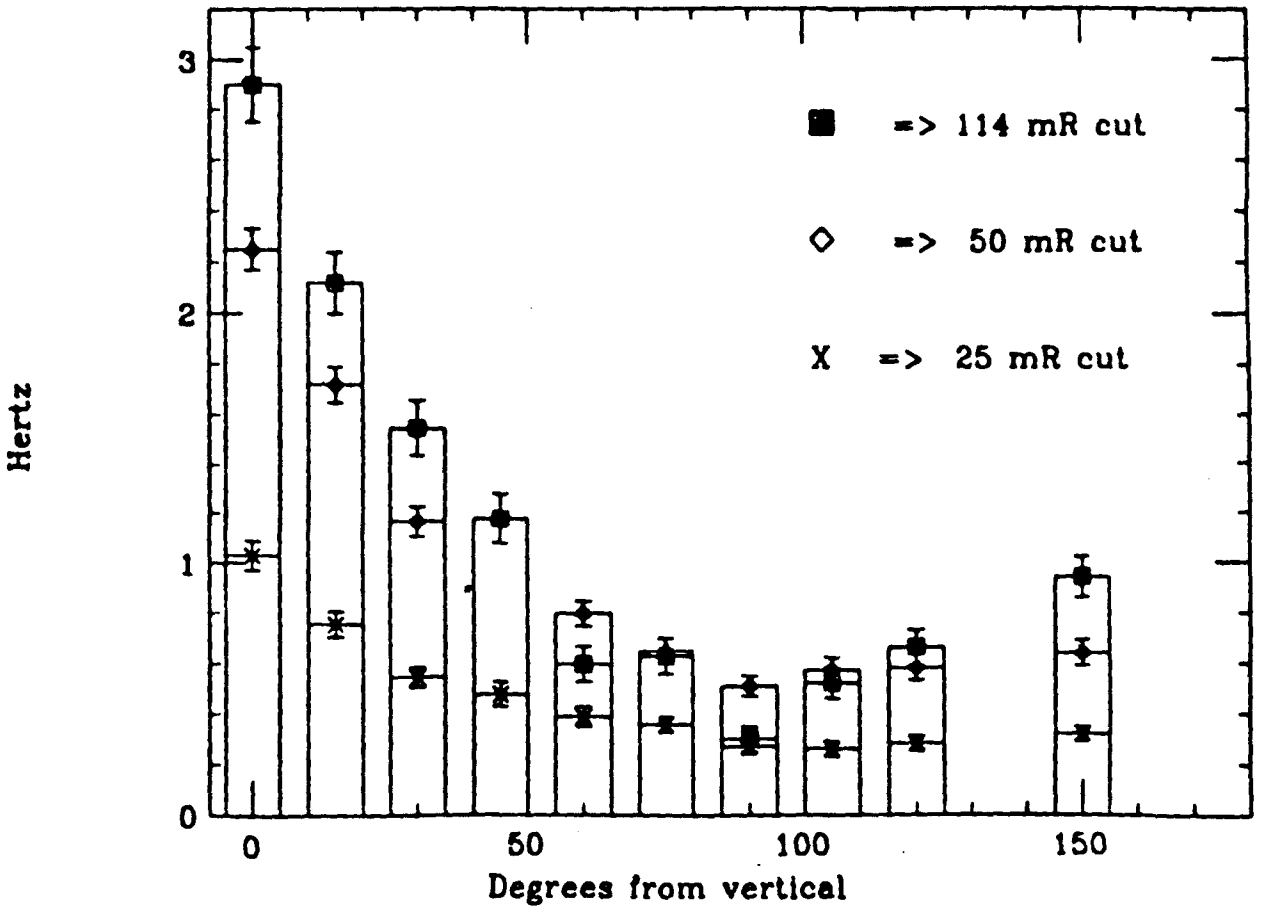


Figure 15: Rates versus p_t for particles exiting the muon iron in the end (1° – 5°) and central (5° – 90°) regions.

CDF CENTRAL MUON CHAMBERS
LEVEL-1 TRIGGERING





TRIGGERING, ELECTRONICS, AND DATA ACQUISITION

6/29/99
(6)

BILL FOSTER

LARRY GLADNEY

FRED KIRSTEN

ANDY LANKFORD

FRANK PAIGE

VELJKO RADEKA

SERGIO RESCIA

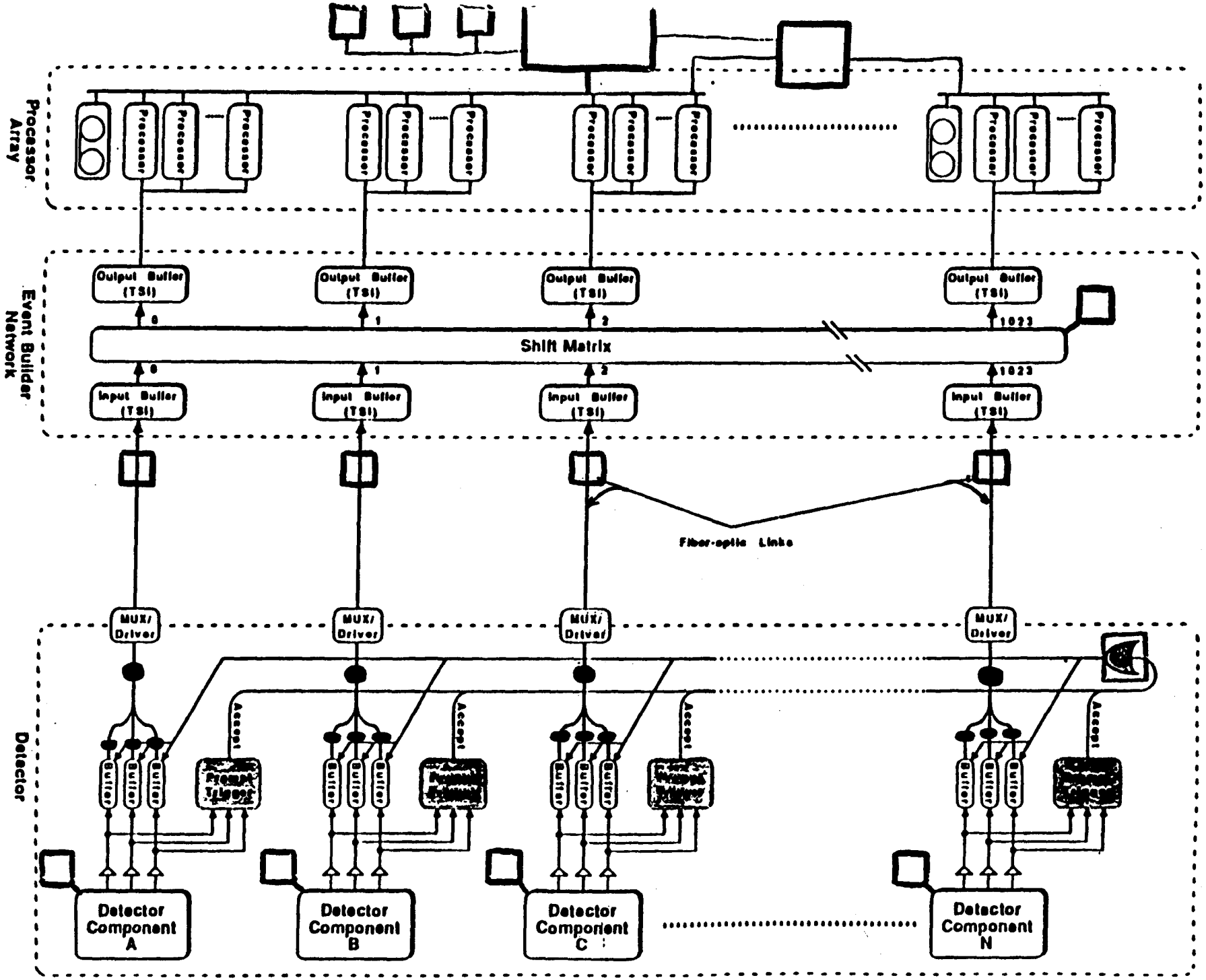
DAVE RUST

MARJORIE SHAPIRO

PEKKA SINERVO

ED WANG

BRIG WILLIAMS



Generalized System Architecture

SOME TOPICS DISCUSSED WITH OTHER SUBSYSTEMS:

SIGNAL PROCESSING AND RESPONSE TIME FOR READOUT OF SCINTILLATION CALORIMETRY.

EFFECTS OF SIGNAL CONNECTIONS ON NOISE AND RESPONSE TIME OF LIQUID IONIZATION CALORIMETERS.

PROMPT TRIGGERING SCHEME FOR SCINTILLATION CALORIMETER WITH MULTI-ANODE PMT'S.

SELECTION OF COMPONENTS TO MINIMIZE GAIN AND RISE TIME VARIATIONS IN VENUS LA ENDCAPS.

LENGTHS/CAPACITANCE OF STRAWS FOR PROTOTYPE DRIFT CHAMBER ELECTRONICS.

PAD CHAMBERS FOR INTERPOLATIVE READOUT FOR INTERMEDIATE ANGLE TRACKING.

R&D for Front End Electronics, Triggering, & Data Acquisition

Systems currently under development

hit only readout for silicon strips
analog readout for silicon strips
pixel detectors
wire chamber readout (drift time)
liquid argon readout
generic radiation hard electronics
some work on data acquisition

Areas where more R&D especially needed.

Triggering: electrons, clusters, muons
muons have received least attention, may be hardest problem.

Data Acquisition:
especially looking at overall flow, control signa
understand conceptual design (more import than har
ware

System Level Considerations for front ends
optimal storage for Level 1 - Level 2
interaction with trigger system
interaction with readout
Local distribution of control signals, calibration, power

DETECTOR SIGNALS REQUIRED BY PROMPT TRIGGERS

INCLUSIVE ELECTRONS

EM TOWERS (.2 × .2?) $\eta \lesssim 2.5$
HAD TOWERS " "

SEGMENTS FROM OUTER TRACKER SUPERLAYER(S)
(LEVEL 2 ONLY ?)

INCLUSIVE MUONS

SEGMENTS FROM MUON CHAMBERS w/ CROSSING ID ($\eta \lesssim 3.0$
MUON SCINTILLATORS (IF THEY EXIST)
SEGMENTS FROM OUTER TRACKER SUPERLAYER(S) (LEVEL 2?)
PERHAPS HAD TOWERS

INCLUSIVE JETS (ALSO $\not{E}_T$, E_T^{TOT})

EM + HAD TOWERS

COMBINATIONS OF ABOVE

e.g.: $\ell^{\pm} + \not{E}_T$
jets + $\not{E}_T$

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Abstract

Some aspects of triggering requirements for high P_T physics processes at the Superconducting Super Collider (SSC) are described. A very wide range of trigger types will be required to enable detection of the large number of potential physics signatures possible at the SSC. Although in many cases trigger rates are not now well understood, it is possible to conclude that the ability to trigger on transverse energy, number and energy of jets, number and energy of leptons (electrons and muons), missing energy and combinations of these will be required. An SSC trigger system must be both highly flexible and redundant to ensure reliable detection of many new physics processes at the SSC.

Introduction

The intent of this note is to give a few examples of potential high P_T physics signatures at the SSC and their related triggering requirements. The reader should be warned that not enough work has been done to quantify trigger rates (from background processes) so that precise energy thresholds or multiplicities for triggering may be given. Since it is readily apparent that any trigger system must have the ability to vary thresholds, multiplicity and other criteria, this lack of precise information about rates is of little consequence at the present stage of design of triggering systems for the SSC. I will not discuss triggering for B physics experiments. This issue has been covered in some detail in previous workshops.[1]

General Comments

It is important to remember that there is a very high probability that there will be a gradual approach to the design luminosity (10^{33} cm^{-2}sec^{-1}) of the SSC, just as has been the case in most previous colliders. This implies, for example, that energy or other thresholds of interest will change with time. In addition it will be important to be able to trigger on known physics processes, particularly during the initial operation of the SSC. Production cross sections for known processes (e.g., W production or jet production) will be of intrinsic interest in the new energy domain explored by the SSC. Furthermore, such processes will often be backgrounds to new physics and hence must be understood in detail. Known processes (e.g., $Z \rightarrow ee$ or $\mu\mu$)

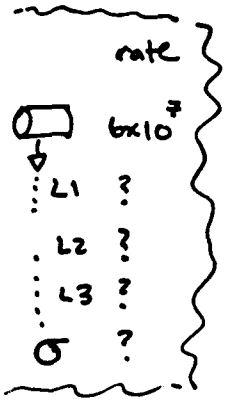
---

*Talk given at the Workshop on Triggering and Data Acquisition for SSC Experiments, Toronto, January 16–19, 1989, to appear in the Proceedings.

†Operated by the Universities Research Association, Inc., for the Department of Energy.

Larry Gladney
Frank Paige
Marjorie Shapiro
Pekka Sinervo
Ed Wang
{ Mike Barnett }

Trigger Rates for High-P_T Physics



- Why do we care at this stage?
  - Trigger has to totally flexible anyway
  - we'll be reading data @ 10-100 KHz - just take it all!
  - Don't know what the detector looks like

"BUT"

  - How flexible? Do we need jet clustering @ Level 1? Do we need multi-parton triggers?
  - Do we want to take all the physics? [Inclusive w/t?]
  - High P_T physics doesn't depend on the detector... our ability to measure it does

Physics choices ⇒ Detector Criteria

- Idea is to 1st estimate rate for "do-able" physics signatures - then ask do we need more than that.

- Estimated rates for
  - Inclusive e's
  - Inclusive μ's
  - Di-leptons ee, eμ, μμ
  - Jets
  - $\not{E}_t$

- Techiques we used were
  - direct calculations
  - extrapolations from UA1/2 & CDF
  - running more ISAJET...

Uncertainties in x-sections are $\gtrsim \times 2$

Electrons

		$P_T > 20$	$P_T > 40$	$P_T > 60$
• $W^{\pm} \to e\nu$	$\sigma_{tot} = 15$ nb, $\lvert\eta\rvert < 2.5$	~6 nb	2 nb	1
• $t\bar{t} \to eX$	$\sigma_{tot} = 17$ nb for $M_t = 140$	3.6 nb	2.2 nb	1.2 nb
• $Z^0 \to ee$	= 10% of $W \to e\nu$		.2 nb	.1 nb
• $b\bar{b} \to eX$	$\sigma(P_T > 40) = 6$ nb [ISALEP] From CDF studies, $\sigma(b\bar{b} \to eX) \sim \underset{\text{jet}\to b}{(.01)}\,\underset{\text{BR}}{(.10)}\,\underset{\text{isol}}{(.01)}\,\sigma(P_T^{jet} > 40)$ ~ 2 nb			≤1 nb
• $\gamma \to e$	Scaled CDF rate of 2 nb ($P_T > 12$); CDF σ(jet $P_T > 40$) = 2 μb; SSC σ(jet $P_T > 40$) = 200 μb; $\sigma_{jet}\ \frac{P_T > 40}{P_T > 12} \sim .005$			~1 nb

Bottom line is

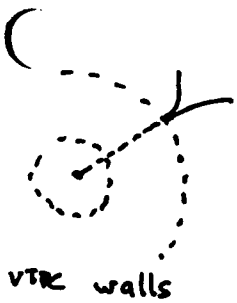
~1 nb	real electrons $P_T > 40$

Comments:

- Throwing away (or prescaling) most of the inclusive W, Z's
- Still reasonably efficient for $t\bar{t}$ @ $M_t \gtrsim 120$-140
- Conversion rate is not small (CDF has ~3% X_0) – can we take > 8 % X_0?
- Can we select electrons cleanly at SSC?
  - Can do it at CDF – jet rejection $< 10^{-5}$
  - Same rejection @ SSC gives < 1 nb of "electrons" from jets [$\sigma_{jet}(P_T > 40) \sim 200$ μb]

$\Rightarrow$ YES!

Conversion Route

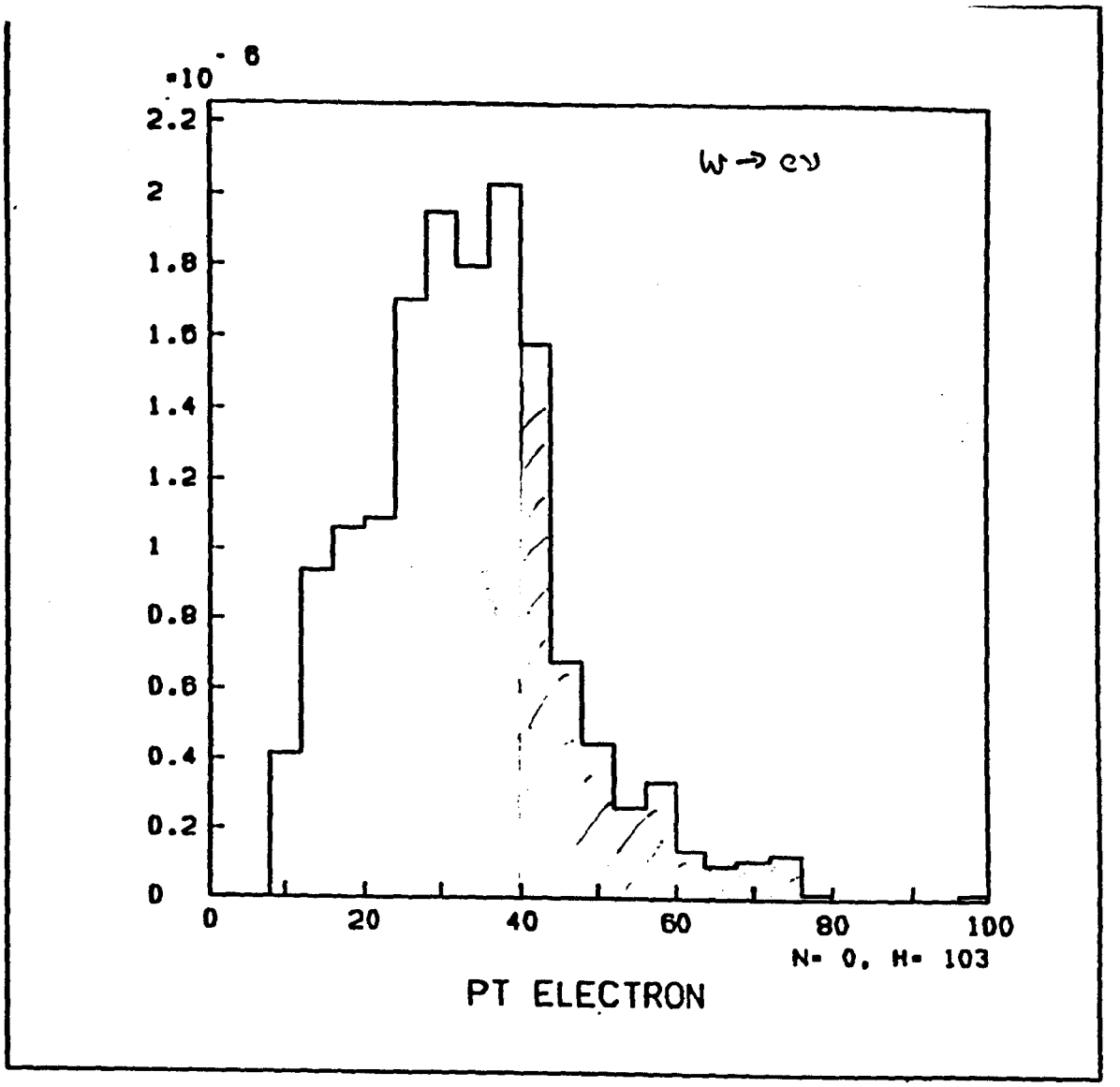


- At CDF $\sigma(P_T > 12) \sim 2$ nb for $|\eta| < 1.1$
  - dominated by VTPC material $3\% X_0$
- Scale to $P_T > 40$, $\sigma \sim 7$ pb
- Ratio of jet cross sections @ SSC / CDF ~ 100

  $\Rightarrow .7$ nb
- Scaling out to $|\eta| < 2.5$

  $\boxed{\Rightarrow \geq 2 \text{ nb}}$

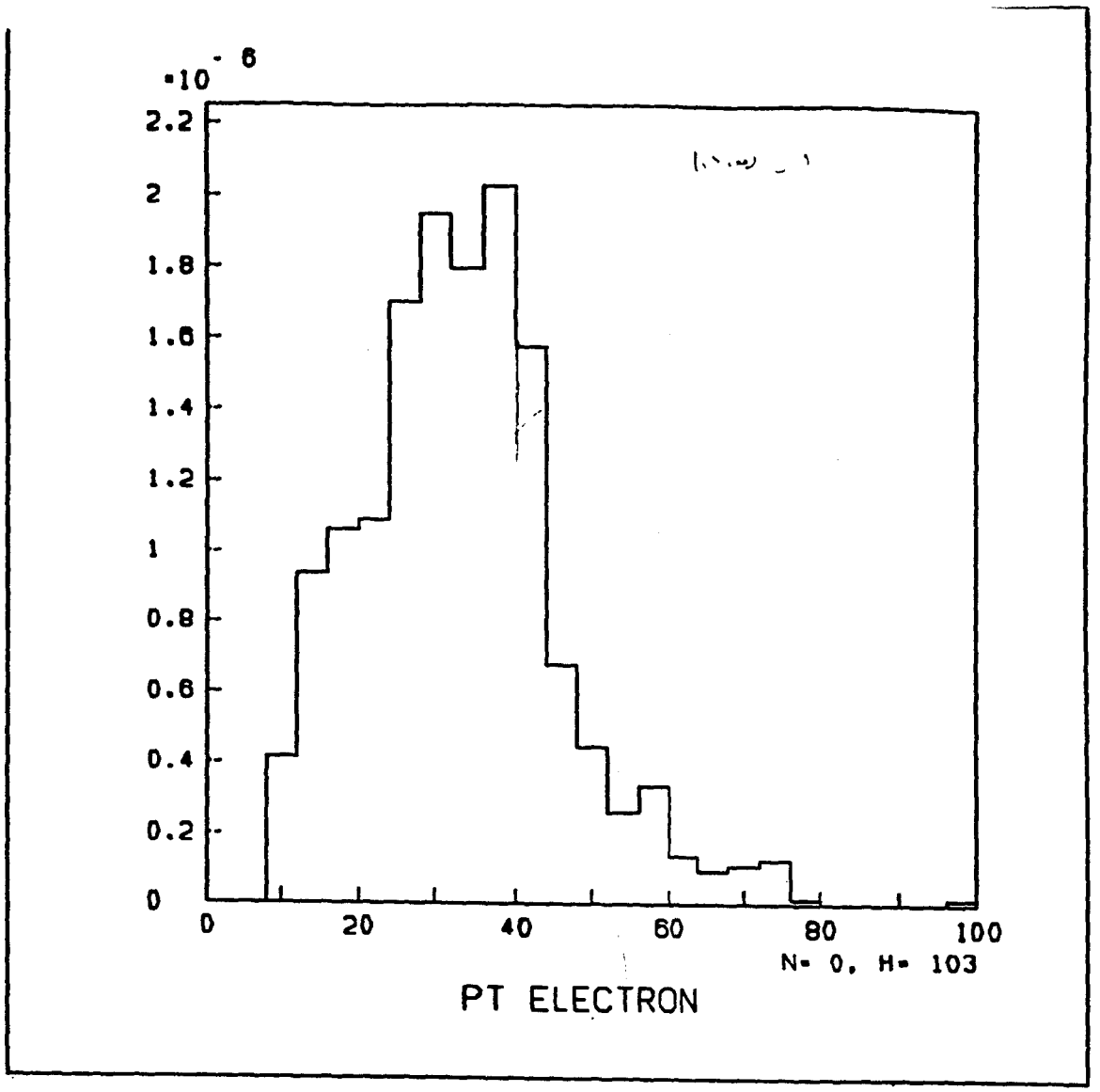
N.B. $3\% X_0$



cut...

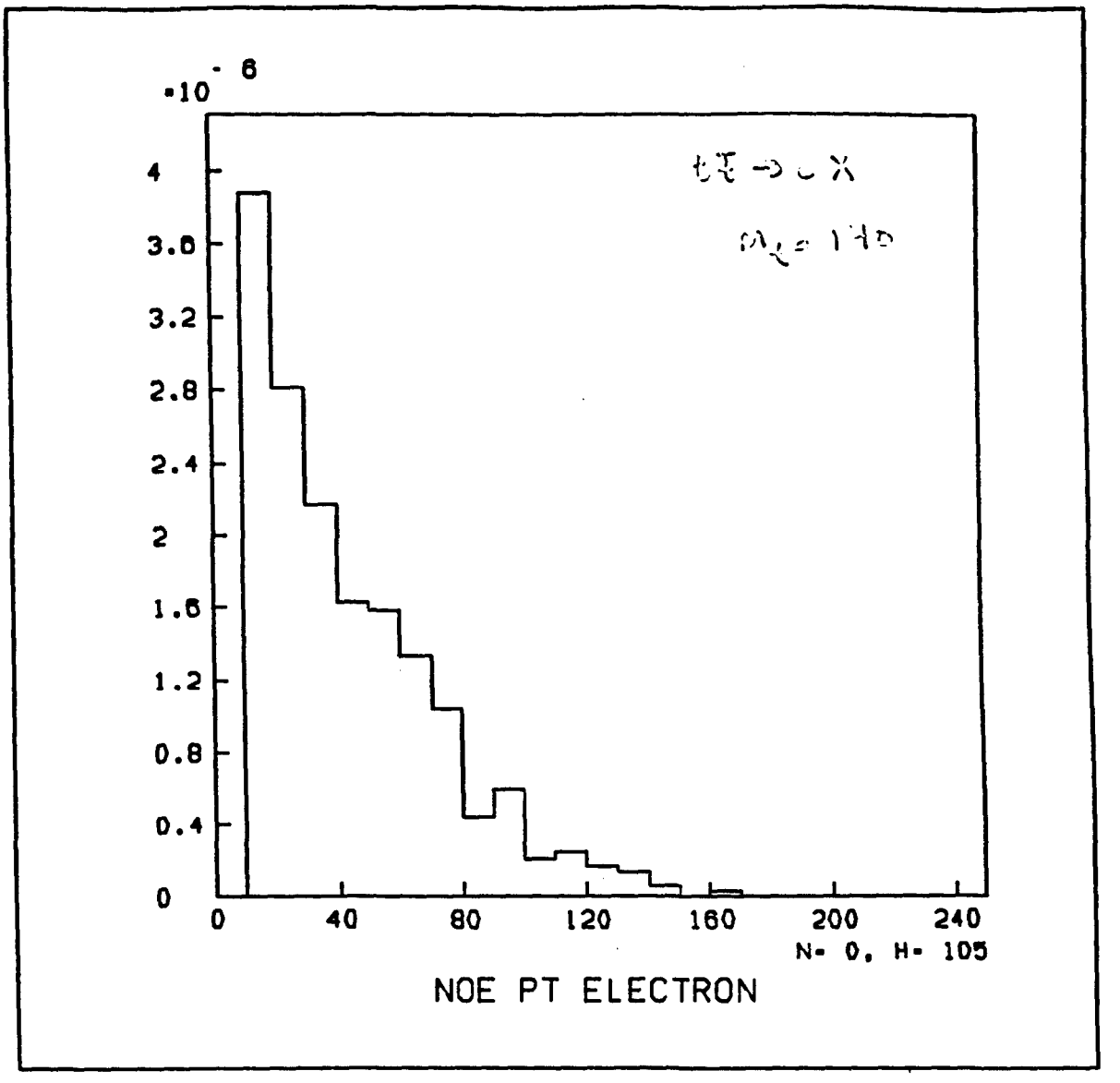
W → eν

27-Jun-89



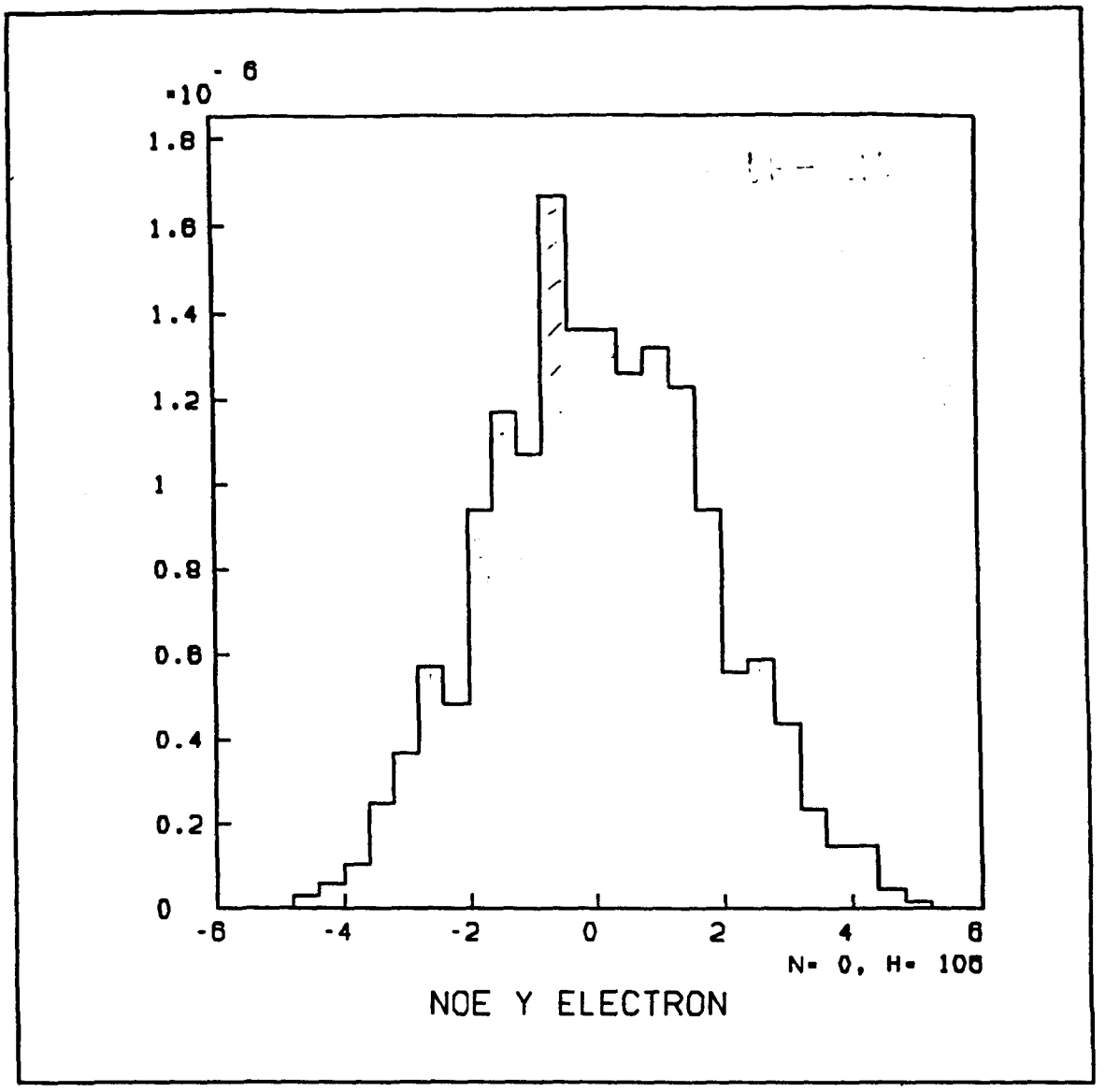
$W \to e\nu$

27-Jun-89

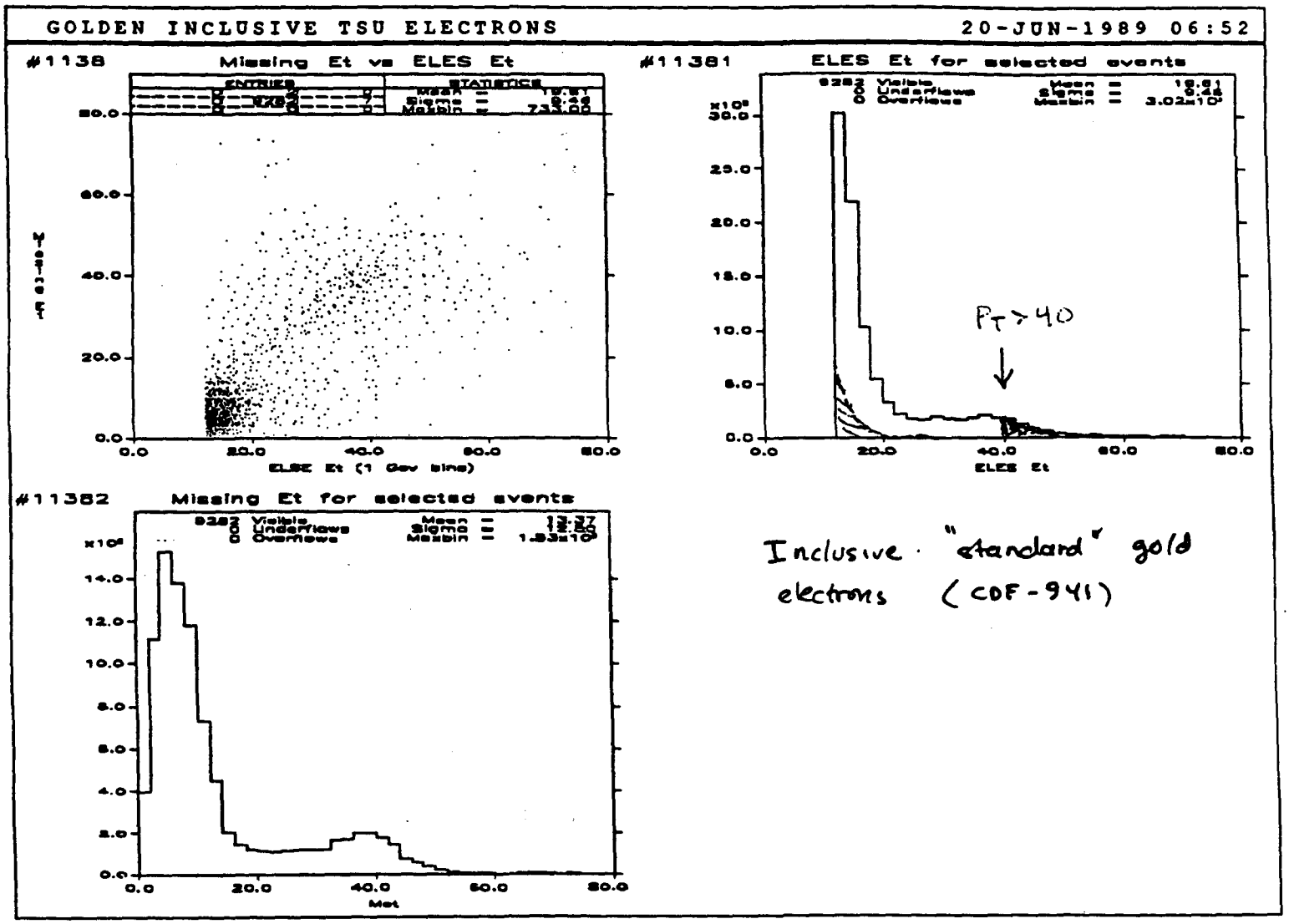


$t\bar{t} \to e X$ $m_t = 140$

27-Jun-89


*10^-6
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-6
-4
-2
0
2
4
6
N= 0, H= 106
NOE Y ELECTRON

CDF Inclusive Electrons



Inclusive "standard" gold electrons (CDF-941)

$E/p < 1.5$

$h/em < 0.05$

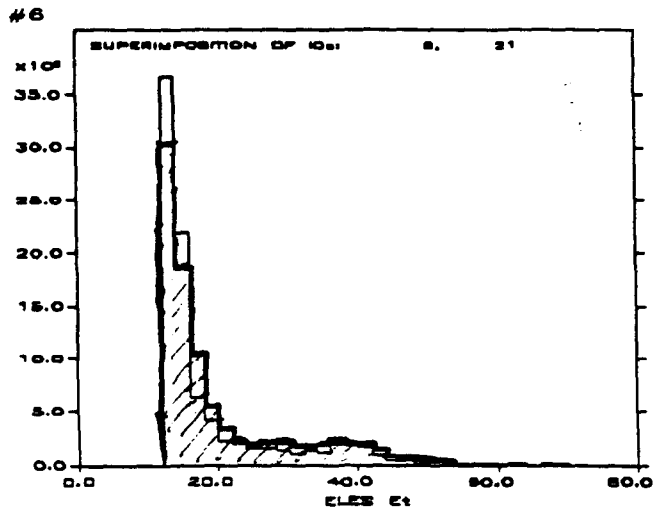
$\Delta x < 1.5$ cm

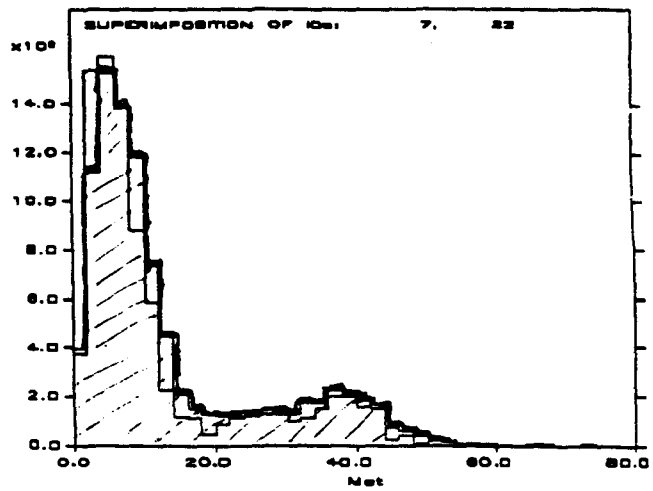
$\Delta z < 3.0$ cm

$\chi^2 < 10$ (both strip views)

$\Delta share < 0.2$

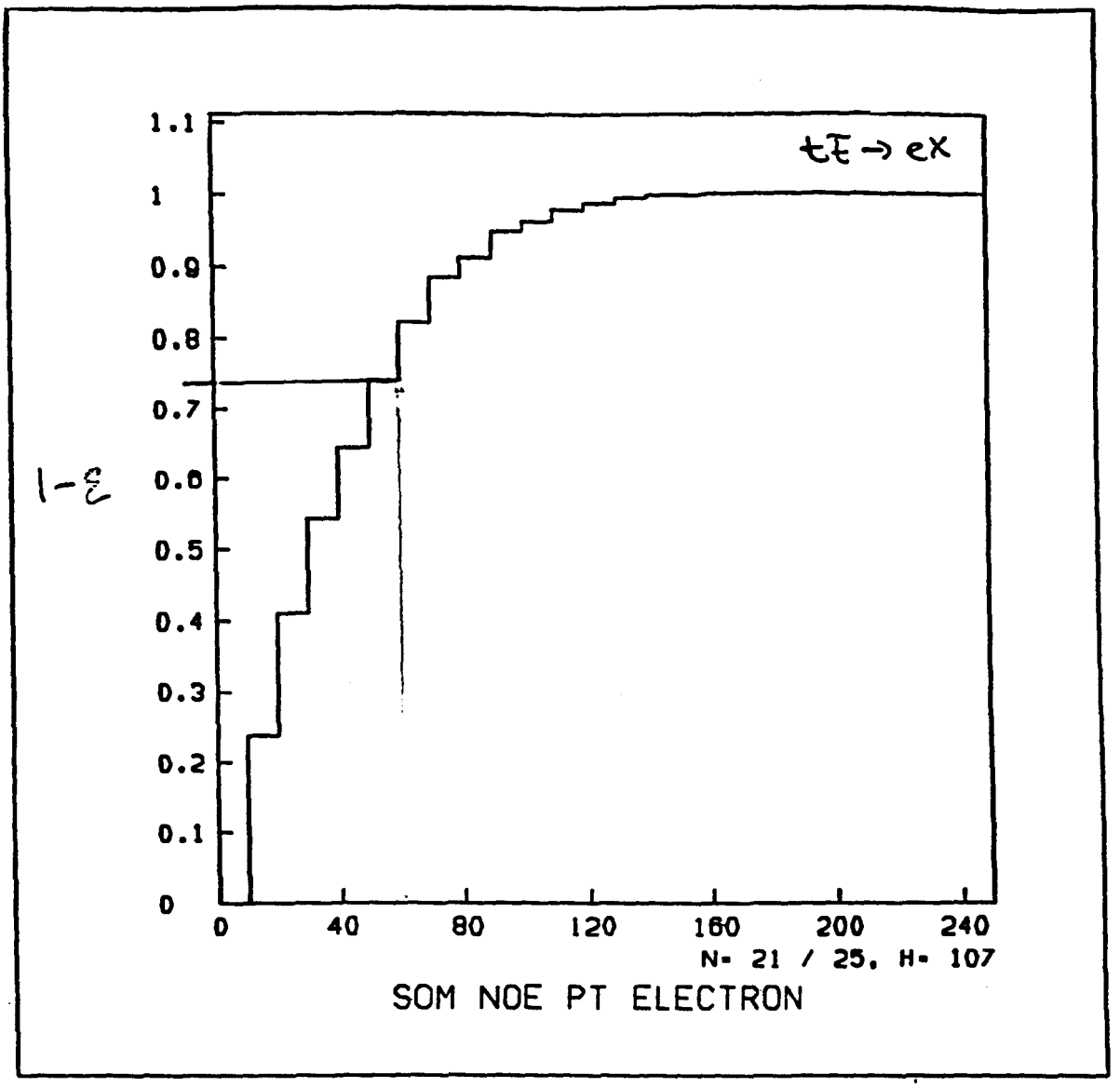
INCLUSIVE B + W 21-JUN-1989 12:13





Comparison with ISALEP b's + ISAJET Inclusive W's

- W's normalized to data $M_t > 80$
- b's is straight MC prediction


$t\bar{t} \to eX$
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$1-\varepsilon$
0
40
80
120
160
200
240
N= 21 / 25, H= 107
SOM NOE PT ELECTRON

Muons

		$P_T > 20$	> 40	> 60
• $W \to \mu\nu$	same as electron	6	2	1
• $t\bar{t} \to \mu X$	"	3.6	2.2	1.2
• $b\bar{b} \to \mu X$	No isolation necessary so rate is "selectable"		20	2
• $Z^0 \to \mu\mu$	same as electron		.2	.
• Decays	Assume: • 2-meter decay volume • prob ~1% for $z > 0.9$ for jet fragmentation		~	

$\Rightarrow$ rate ~ $4 \times 10^{-5}\, \sigma(\text{jet})$

Bottom Line is

~ [illegible]	"real" μ $P_T > 40$

Di-leptons

		$P_T > 20$
• $Z \to ee, \mu\mu$		1 nb
• $t\bar{t} \to ee, \mu\mu, e\mu$		2
• $b\bar{b} \to ee, \mu\mu$	(require isolated lepton)	2

~ [illegible]	real $ee, \mu\mu, e\mu$ $P_T > 20$

Jets

- Easy to trigger on - all physics
- Many interesting processes will give leptons + ≥ 2 jets
  $\Rightarrow$ want jet clustering in trigger
- Inclusive jet threshold of 1 TEV $\Rightarrow$ 1 nb

Missing E_T

- Inclusive rate of neutrinos with $P_T > \sim 175$ GeV => 1
- Didn't have time to estimate rate from detector screw-ups... Could be large depending on the calorimeter design
- Almost certainly want a $\not{E}_t$ trigger with several jets

Summary

- Inclusive lepton rates for "physics" are large

  ~ 10's of Hz $P_T > 40$ GeV
- Di-leptons are also comparable

  ~ [illegible] Hz $P_T > 20$ GeV
- Jets, $\not{E}_t$ have to be adjusted based on detector

  [illegible] Jet $P_T > 1$ TeV

  [illegible] $\not{E}_t > 175$ GeV

- Questions:
  - How much background do we write to media?
  - At which trigger levels does this rejection come?
  - Are these "reasonable" physics choices.
  - How do we pre-scale low P_T processes

INTEGRATION GROUP

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A. Tollestrup

Dallas, June 22, 1980
D. Theriot Talk (7)

Defined Detector:

a) Tracking, $B = 2.0T$

$R_{max} = 1.6m$

$L = 8m, 12m$

b) Calorimeters

$90^\circ - 7\lambda_\pi = 10.5\lambda_p$

$0^\circ - 9\lambda_\pi = 13.5\lambda_p$

Very Thick! This will cost a lot!

4 Technologies

U - Liq Ar

Pb - Wm Liq

U - Sc

Pb - Sc Fib

c) Magnets

1) LSD - 8m ϕ, $\ell = 16m$

2) Long LSD - 8m ϕ, $\ell = 20m$

3) Small Radius, Short Coil - 3m ϕ, 8m

4) Small Radius, Long Coil - 3m ϕ, 14m

d) Muon Systems

1) LSD

Instrument flux return

2) Small Coils

External Toroids

d) Muon Systems

1) LSD

Instrument flux return

2) Small Coils

External Toroids

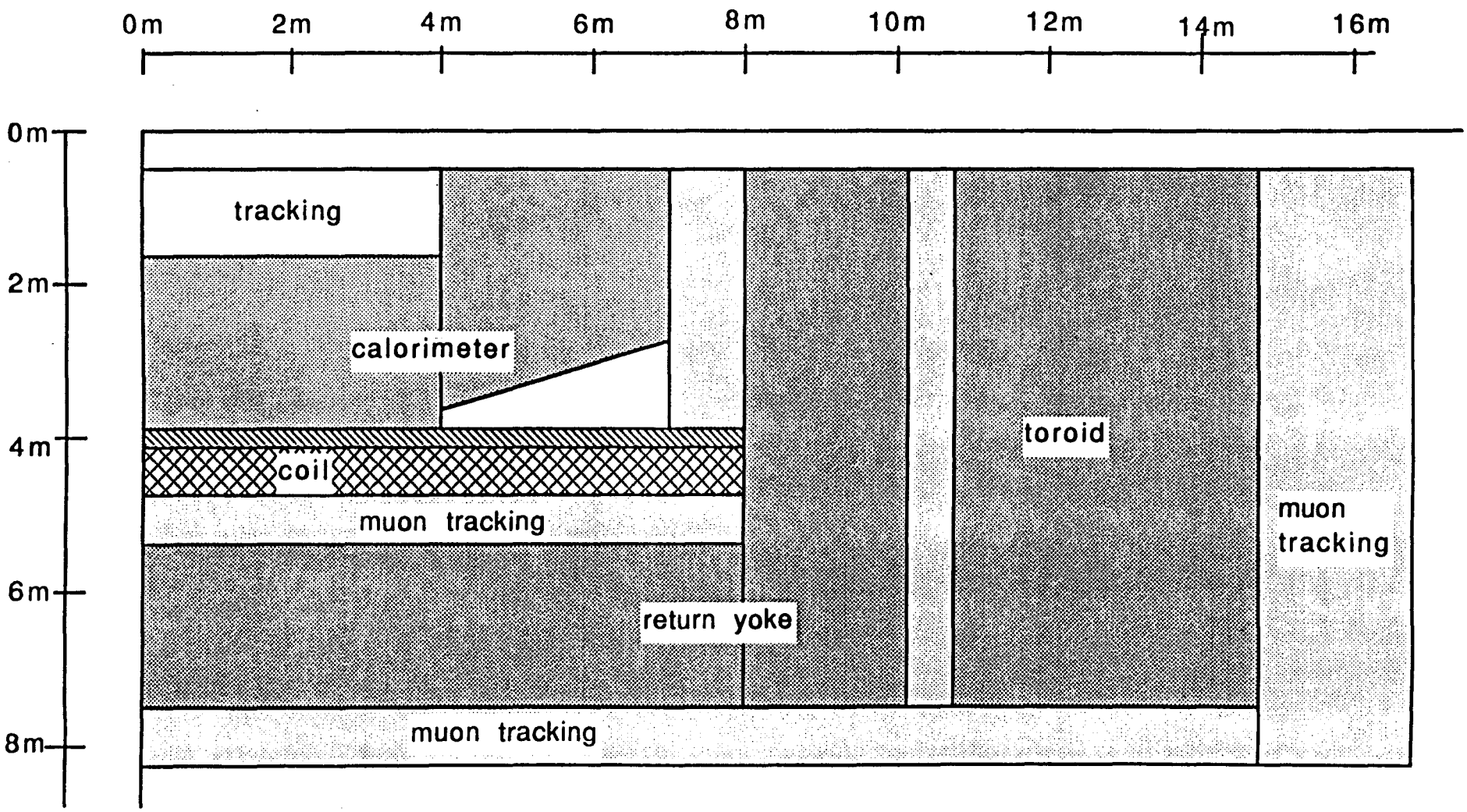
	A	B	C	D	E
1	Version:		Solenoid Radial Parameters		
2	6/28/89				
3					
4	Element	Param.	NoFe Cap Sol.	Fe Cap Sol.	Large Sol.
5					
6	Tracker	Rmax(m)	1.55	1.55	1.55
7					
8	Coil	Rmin(m)	1.60	1.60	-
9		Rmax(m)	1.95	1.95	-
10					
11	Calorim.	Rmin(m)	2.00	2.00	1.60
12		Rmax(m)	4.50	4.50	4.10
13					
14	Coil	Rmin(m)	-	-	4.15
15		Rmax(m)	-	-	4.75
16					
17	Mu Meas.	Rmin(m)	4.50	4.50	4.75
18		Rmax(m)	4.70	4.70	5.35
19					
20	Yoke	Rmin(m)	4.70	4.70	5.35
21		Rmax(m)	5.05	5.05	7.57
22					
23	Mu Meas.	Rmin(m)	5.05	5.05	7.60
24		Rmax(m)	5.65	5.65	8.20
25					
26	Toroid	Rmin(m)	5.65	5.65	-
27		Rmax(m)	7.55	7.55	-
28					
29	Mu Meas.	Rmin(m)	7.60	7.60	-
30		Rmax(m)	9.60	9.60	-
31					
32					
33		Bo(T) =	2.00	(all versions)	
34		Byoke(T) =	1.80	(all flux returns)	
35		Btoroid(T) =	1.80	(all magnetized Fe)	
36		pion lambda(m) =	0.32	(assumes 1.5xPDG with e/h=	
37					
38					
39					
40					
41					
42					
43					
44					
45					

Version:
6/28/89

Solenoid End Cap Parameters

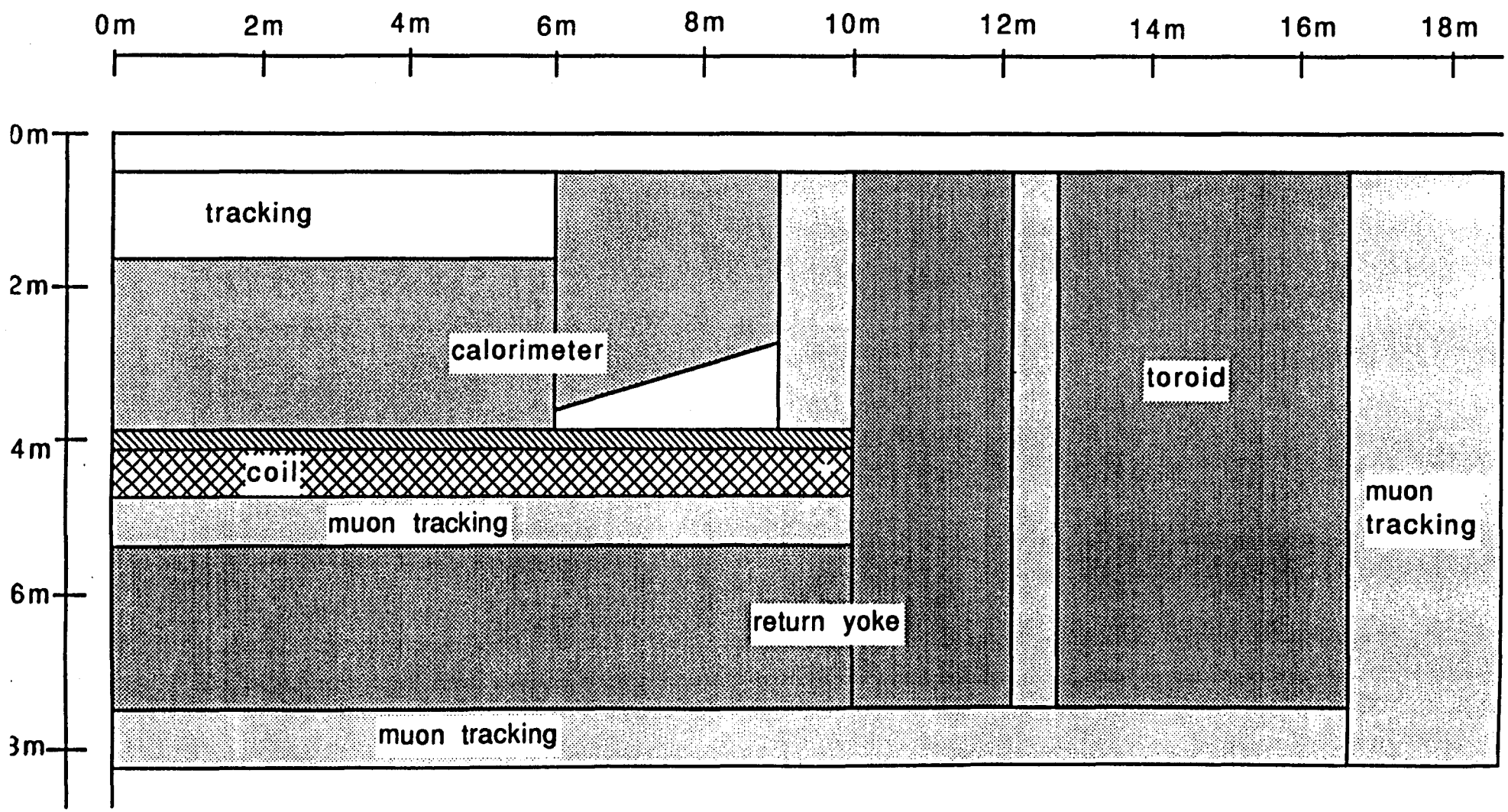
Element	Param.	NoFe Cap Solenoid	Fe Cap Sol. Solenoid	Large Sol.	Large Sol. Long Trkr.	Comment
Tracker	Zmax(m)	4.00	4.00	4.00	6.00	
Coil	Zmax(m)	4.00	7.00	8.00	10.00	
Barrel Calorim	Zmax(m)	4.00	7.00	4.00	6.00	
ECap Calorim	Zmin(m)	4.00	4.00	4.00	6.00	
	Zmax(m)	6.88	6.88	6.88	8.88	
Return Yoke	Zmin(m)	7.00	7.00	7.60	9.60	
	Zmax(m)	7.50	8.00	10.10	12.10	
Mu Meas.	Zmin(m)	7.50	8.00	10.10	12.10	
	Zmax(m)	8.10	8.60	10.70	12.70	
Toroid	Zmin(m)	8.10	8.60	10.70	12.70	
	Zmax(m)	12.10	12.60	14.70	16.70	
Mu Meas.	Zmin(m)	12.10	12.60	14.70	16.70	
	Zmax(m)	14.10	14.60	16.70	18.70	

Bo(T) =	2.00	(all versions)
Byoke(T) =	1.80	(all flux returns)
Btoroid(T) =	1.80	(all magnetized Fe)
pion lambda(m) =	0.32	(assumes 1.5xPDG with e/h=1 ratio of active/passive



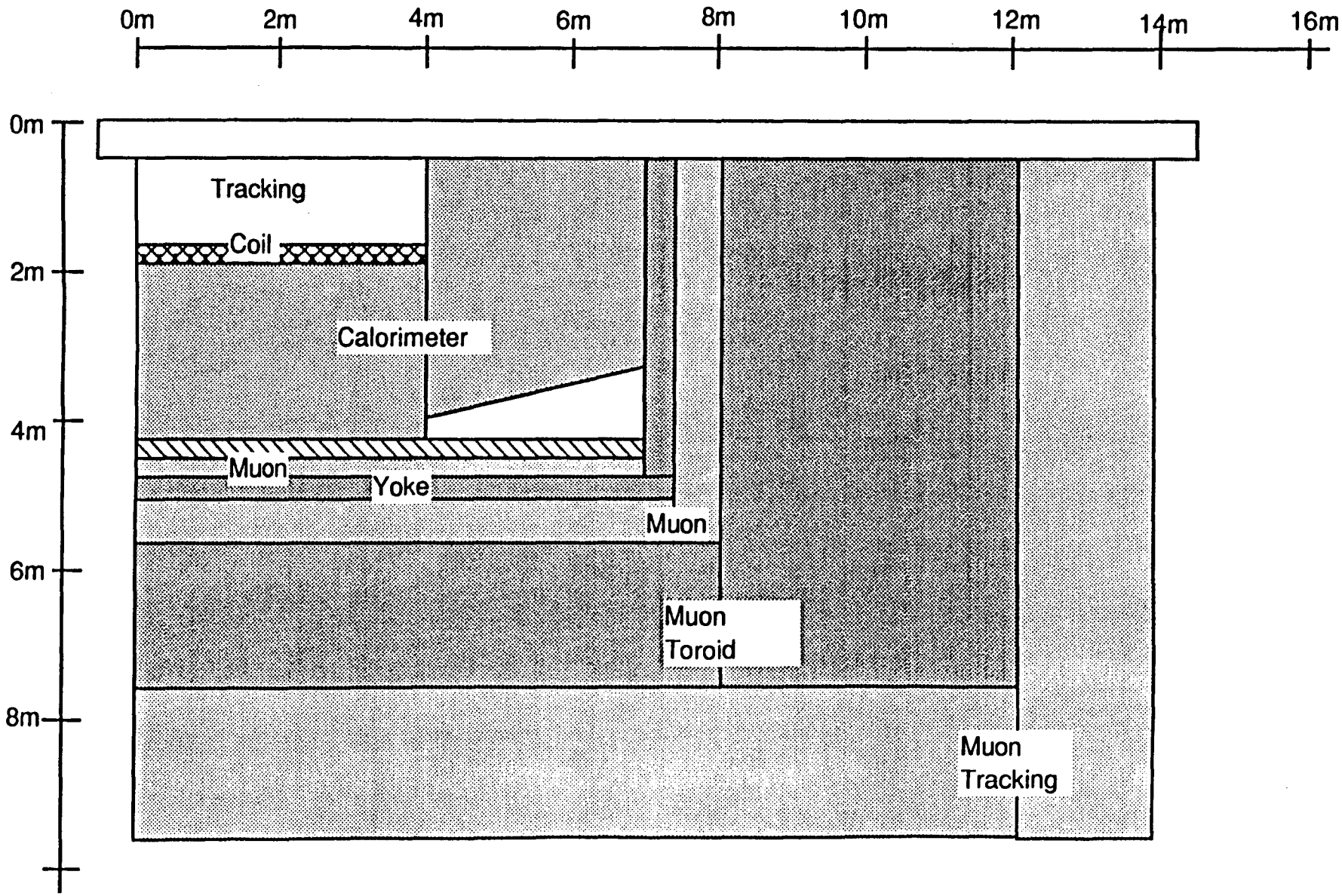
LSD SHORT TRACKING

$\eta = 1.65$

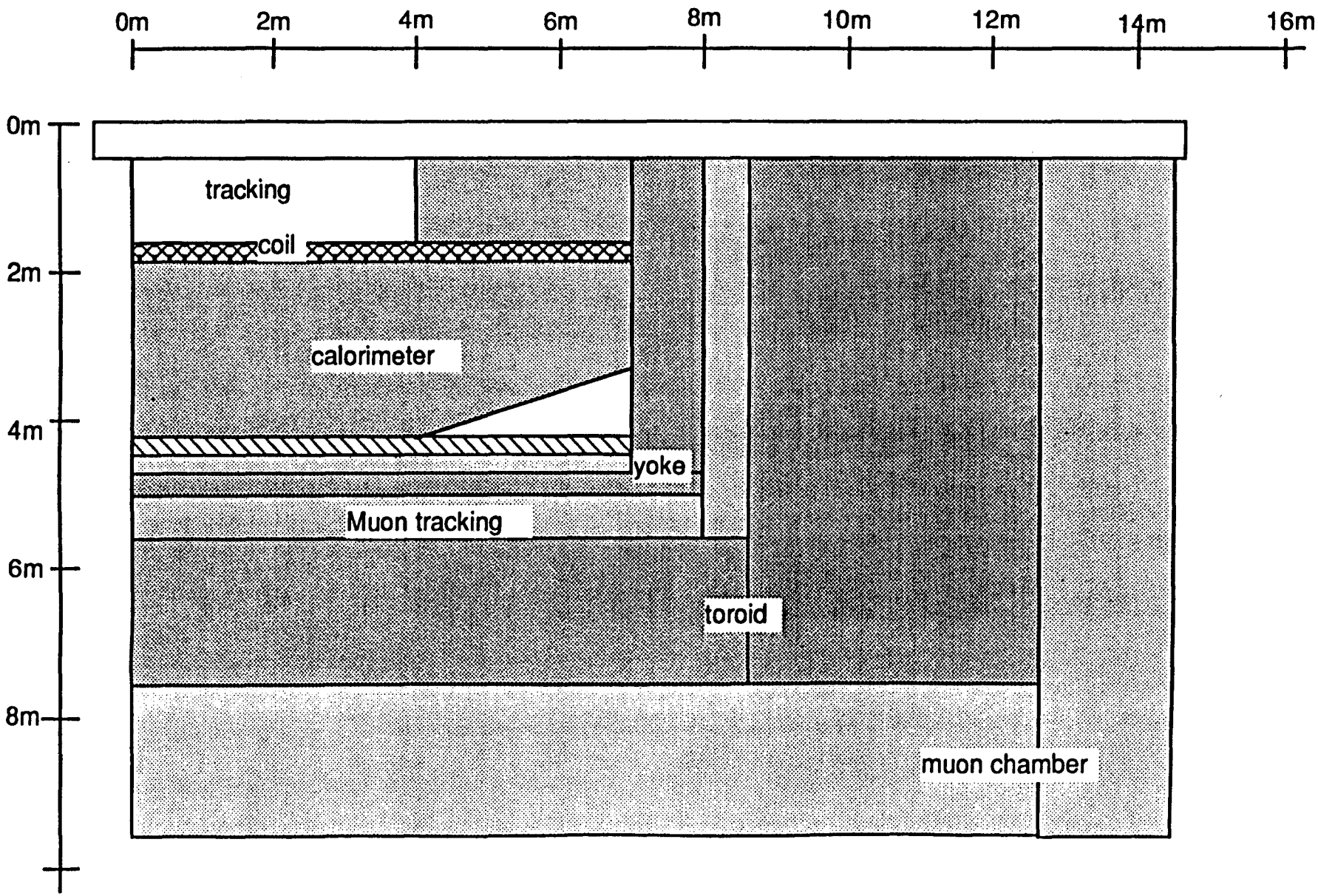


LSD LONG TRACKING

|η| = 2



SMALL DIAMETER SHORT COIL.



SMALL DIAMETER LONG COIL

Calorimeters:

Pb: 0.8 Pb + 0.2 Gap

U: 0.5 U + 0.5 Gap

$\lambda_\pi = 32$ cm

$\rho_{av} = 9.475$ gm/cm^3

M. Marx warning:

Current Martin-Marietta

Pb-LA design

$\rho_{av} = 7.5$ gm/cm^3

COSTS:

Pb-Liq Ar:

LAC Vessels	$18 m	
Modules	60 m	- 5000T
Storage Dewar	1 m	
Cryogenics	2 m	
	$81 m	
	$16 K/ton	

U-Liq Ar:

LAC Vessels	$18 m	
Module Fab	56 m	
Uranium	120 m	- 5000T
Storage Dewar	1 m	
Cryo	2 m	
	$197 m	
	$39 K/ton	

Pb-Warm Liq:

Pb-Liq Ar + $10 m

= $90 m -5000T

$18K/ton

U-Scin:

Uranium	$120 m -5000T
Fab	5 m
Phototubes, etc	70 m
	$195 m

$39K/ton

Pb-Scin Fiber

Pb structure	$55 m -5000T
Scin Fiber	78 m
Assembly	47 m
Phototubes, etc	40 m
	$220 m

$44K/ton

Summary:

	LSD	Long LSD	Small R, Short	Small Long
Coil:	$50m	$60m	$10m	$23m
Calorimeter:				
Weight	5128T	6587T	6113T	6113T
U-LAr	$200m	$257m	$236m	$236m
Pb-Wsl	92m	119m	110m	110m
U-Sc	—	—	238m	238m
Pb-Sc Fib	—	—	269m	269m
Yoke / Muon:				
Weight	27,600T	29,900T	29,200T	22,700
Cost	$49m	$54m	$44m	$46m

Bottom Line!

	LSD	Long LSD	Sm Rad, Short	Sm, Long
U-LA	$299m	$371m	$292m	$307m
Pb-WnL	191 m	233m	164m	179m
U-Sc	—	—	292m	307
Pb-ScFib	—	—	323 m	338

Plus:

Electronics, DAQ	$~100m
Tracking	25m
EDIA	15%
Contingency	25%

$400m - $650m

- no ~~forward~~ $|\eta|>3$ get

Version:
6/28/89

Large Solenoid Detector Parameters

lambda:	Fe	25
pion	Pb	26
(cm)	U	16

Magnet Coil

Parameter (unit)	Value
B(T)	2.00
1/2 L(m)	8.00
R min(m)	4.13
R max(m)	4.73
Xo (90 deg.)	1.00
lambda (90 deg.)	
Tot Wt(T)	
Max Stress (ksi)	
Cons Time(yrs)	
Cost($)	
Comment a	

Flux Return

Parameter (unit)	Value
B(T)	1.80
1/2 L(m) inner	7.60
1/2 L(m) outer	10.10
R min(m)	5.33
R max(m)	7.54
AvDensity (gm/cm3)	6.27
No. Meas. of Muons	3.00
No. Meas. Postions	5.00
Bar Wt(T)	11298
Ends Wt(T)	7028
Tot Wt(T)	18326
Comment b	

Muon System

Parameter (unit)	Value
Barrel:	
B(T)	-
R min(m)	-
R max(m)	-
Tot Wt(T)	-
No. Meas. Postions	-
eta Range	-
Ends:	
B(T)	1.80
R min(m)	
R max(m)	
Tot Wt(T)	
No. Meas. Postions	
Eta Range	

Calorimetry

Parameter (unit)	Liq A + Pb Value	Liq A + U Value	WLiq + Pb Value	Scin + U Value	Scifi (Pb) Value
Barrel:					
delta eta EM					
Had					
delta phi EM					
Had					
depth vs eta:					
eta = 0	7.00	7.00	7.00	7.00	7.00
= 1					
= 2					
= 3					
lambda	7.00	7.00	7.00	7.00	7.00
R min(m)	1.60	1.60	1.60	1.60	1.60
Rmax(m)	4.08	4.08	4.08	4.08	4.08
1/2 L(m)	4.00	4.00	4.00	4.00	4.00
Barrel Wt(T)	2811	3082	2811	3082	2811
End Caps:					
delta eta EM					
Had					
delta phi EM					
Had					
lambda	9.00	9.00	9.00	9.00	9.00
R min(m)	0.20	0.20	0.20	0.20	0.20
R max(m)	4.08	4.08	4.08	4.08	4.08
Z min(m)	4.00	4.00	4.00	4.00	4.00
Z max(m)	6.88	6.88	6.88	6.88	6.88
ECap Wt(T)	2447	2683	2447	2683	2447
AvDensity (T/m3)	9.28	10.18	9.28	10.18	9.28
deltaE/E EM					
Had					
e/h intrinsic					
eta Range					
Noise (GeV/gm)					
Total Wt(T)	5258	5765	5258	5765	5258
Cost/T($K)	16	39	18	39	44
Cal Cost($M)	84	225	95	225	231

Tracking:

Parameter (unit)	Value
Tracking Radius(m)	1.55
Tracker Length(m)	4.00
Total Xo	
delP/P vs eta:	
eta = 0	
=1	
=2	

Comments

a) The solenoid field can be uniform with Fe end plate outside of or incorporated in the end cap calorim.

Version: 6/28/89 — **Large Solenoid Detector Parameters (Long Tracker)**

lambda: pion (cm)	
Fe	25
Pb	26
U	16

Magnet Coil

Parameter (unit)	Value
B(T)	2.00
1/2 L(m)	10.00
R min(m)	4.13
R max(m)	4.73
Xo (90 deg.)	1.00
lambda (90 deg.)	
Tot Wt(T)	
Max Stress (ksi)	
Cons Time(yrs)	
Cost($)	
Comment a	

Flux Return

Parameter (unit)	Value
B(T)	1.80
1/2 L(m) inner	9.60
1/2 L(m) outer	12.10
R min(m)	5.33
R max(m)	7.54
AvDensity (gm/cm3)	6.27
No. Meas. of Muons	3.00
No. Meas. Postions	5.00
Bar Wt(T)	13536
Ends Wt(T)	7028
Tot Wt(T)	20564
Comment b	

Muon System

Parameter (unit)	Value
Barrel:	
B(T)	-
R min(m)	-
R max(m)	-
Tot Wt(T)	-
No. Meas. Postions	-
eta Range	-
Ends:	
B(T)	1.80
R min(m)	
R max(m)	
Tot Wt(T)	
No. Meas. Postions	
Eta Range	

Calorimetry

Parameter (unit)	Liq A + Pb Value	Liq A + U Value	WLiq + PB Value	Scin + U Value	Scifi + Pb Value
Barrel:					
delta eta EM					
Had					
delta phi EM					
Had					
depth vs eta:					
eta = 0	7.00	7.00	7.00	7.00	7.00
= 1					
= 2					
= 3					
lambda	7.00	7.00	7.00	7.00	7.00
R min(m)	1.60	1.60	1.60	1.60	1.60
Rmax(m)	4.08	4.08	4.08	4.08	4.08
1/2 L(m)	6.00	6.00	6.00	6.00	6.00
Barrel Wt(T)	4217	4623	4217	4623	4217
End Caps:					
delta eta EM					
Had					
delta phi EM					
Had					
lambda	9.00	9.00	9.00	9.00	9.00
R min(m)	0.20	0.20	0.20	0.20	0.20
R max(m)	4.08	4.08	4.08	4.08	4.08
Z min(m)	6.00	6.00	6.00	6.00	6.00
Z max(m)	8.88	8.88	8.88	8.88	8.88
ECap Wt(T)	2447	2683	2447	2683	2447
AvDensity (T/m3)	9.28	10.18	9.28	10.18	9.28
deltaE/E EM					
Had					
e/h intrinsic					
eta Range					
Noise (GeV/gm)					
Total Wt(T)	6664	7306	6664	7306	6664
Cost/T($K)	16	39	18	39	44
Cal Cost($M)	107	285	120	285	293

Tracking:

Parameter (unit)	Value
Tracking Radius(m)	1.55
Tracker Length(m)	6.00
Total Xo	
delP/P vs eta:	
eta = 0	
=1	
=2	

Comments

a) The solenoid field can be uniform with Fe end plate outside of or incorporated in the end cap calorim.

Version: 6/28/89

Fe Cap Solenoid Detector Parameters

lambda:	Fe	25.1
plion	Pb	25.6
(cm)	U	15.8

Magnet Coil

Parameter (unit)	Value
B(T)	2.00
1/2 L(m)	7.00
R min(m)	1.60
R max(m)	1.95
Xo (90 deg.)	1.00
lambda (90 deg.)	
Tot Wt(T)	
Max Stress (ksi)	
Cons Time(yrs)	
Cost($)	
Comment a	

Flux Return

Parameter (unit)	Value
B(T)	1.80
1/2 L(m) inner	7.00
1/2 L(m) outer	8.00
R min(m)	4.68
R max(m)	5.03
AvDensity (gm/cm3)	7.87
No. Meas. of Muons	0.00
No. Meas. Postions	2.00
Bar Wt(T)	1346
Ends Wt(T	1253
Tot Wt(T)	2599
Comment b	

Muon System

Parameter (unit)	Value
Barrel:	
B(T)	1.80
R min(m)	5.63
R max(m)	7.53
Tot Wt(T)	
No. Meas. Postions	5.00
eta Range	
Ends:	
B(T)	1.80
R min(m)	
R max(m)	
Tot Wt(T)	
No. Meas. Postions	
Eta Range	

Calorimetry

Parameter (unit)	Liq A Value	Liq A Value	WLiq Value	Scin Value	Scifi Value
Barrel:					
delta eta EM					
Had					
delta phi EM					
Had					
depth vs eta:					
eta = 0	7.00	7.00	7.00	7.00	7.00
= 1					
= 2					
= 3					
lambda	7.00	7.00	7.00	7.00	7.00
R min(m)	2.00	2.00	2.00	2.00	2.00
Rmax(m)	4.48	4.48	4.48	4.48	4.48
1/2 L(m)	7.00	7.00	7.00	7.00	7.00
Barrel Wt(T	5645	6190	5645	6190	5645
End Caps:					
delta eta EM					
Had					
delta phi EM					
Had					
lambda	9.00	9.00	9.00	9.00	9.00
R min(m)	0.20	0.20	0.20	0.20	0.20
R max(m)	4.48	4.48	4.48	4.48	4.48
Z min(m)	4.00	4.00	4.00	4.00	4.00
Z max(m)	6.88	6.88	6.88	6.88	6.88
ECap Wt(T)	2988	3276	2988	3276	2988
AvDensity (T/m3)	9.28	10.18	9.28	10.18	9.28
deltaE/E EM					
Had					
e/h intrinsic					
eta Range					
Noise (GeV/gm)					
Total Wt(T)	8633	9465	8633	9465	8633
Cost/T($K)	16	39	18	39	44
Cal Cost($M	138	369	155	369	380

Tracking:

Parameter (unit)	Value
Tracking Radius(m)	1.55
Tracker Length(m)	4.00
Total Xo	
delP/P vs eta:	
eta = 0	
=1	
=2	

Comments

Version: 6/28/89

No-Fe Thin Solenoid Detector Parameters

lambda:	
Fe	25.1
pion Pb	25.6
(cm) U	15.8

Magnet Coil

Parameter (unit)	Value
B(T)	2.00
1/2 L(m)	4.00
R min(m)	1.60
R max(m)	1.95
Xo (90 deg.)	1
lambda (90 deg.)	
Tot Wt(T)	
Max Stress (ksi)	
Cons Time(yrs)	
Cost($)	
Comment	
a	

Flux Return

Parameter (unit)	Value
B(T)	1.80
1/2 L(m) inner	7.00
1/2 L(m) outer	7.50
R min(m)	4.68
R max(m)	5.03
AvDensity (gm/cm3)	7.87
No. Meas. of Muons	0.00
No. Meas. Postions	2.00
Comment	
b	

Muon System

Parameter (unit)	Value
Barrel:	
B(T)	1.80
R min(m)	5.63
R max(m)	7.53
Tot Wt(T)	
No. Meas. Postions	5.00
eta Range	
Ends:	
B(T)	1.80
R min(m)	0.25
R max(m)	
Tot Wt(T)	
No. Meas. Postions	
Eta Range	

Calorimetry

Parameter (unit)	Liq A + Pb Value	Liq A + U Value	WLiq + Pb Value	Scin + U Value	Scifi + Pb Value
Barrel:					
delta eta EM					
Had					
delta phi EM					
Had					
depth vs eta:					
eta = 0	7.00	7.00	7.00	7.00	7.00
= 1					
= 2					
= 3					
lambda	7.00	7.00	7.00	7.00	7.00
R min(m)	2.00	2.00	2.00	2.00	2.00
Rmax(m)	4.48	4.48	4.48	4.48	4.48
1/2 L(m)	4.00	4.00	4.00	4.00	4.00
Barrel Wt(T	3226	3537	3226	3537	3226
End Caps:					
delta eta EM					
Had					
delta phi EM					
Had					
lambda	9.00	9.00	9.00	9.00	9.00
R min(m)	0.20	0.20	0.20	0.20	0.20
R max(m)	4.48	4.48	4.48	4.48	4.48
Z min(m)	4.00	4.00	4.00	4.00	4.00
Z max(m)	6.88	6.88	6.88	6.88	6.88
ECap Wt(T)	2988	3276	2988	3276	2988
AvDensity (T/m3)	9.28	10.18	9.28	10.18	9.28
deltaE/E EM					
Had					
e/h intrinsic					
eta Range					
Noise (GeV/gm)					
Total Wt(T)	6213	6813	6213	6813	6213
Cost/T($K)	16	39	18	39	44
Cal Cost($M	99	266	112	266	273

Tracking:

Parameter (unit)	Value
Tracking Radius(m)	1.55
Tracker Length(m)	4.00
Total Xo	
delP/P vs eta:	
eta = 0	
=1	
=2	

Comments