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SDC-92-204

# SDC
# SOLENOIDAL DETECTOR NOTES

## JOINT EXECUTIVE/TECHNICAL BOARD MEETING

### SSC LABORATORY

February 1-3, 1992

# JOINT EXECUTIVE/TECHNICAL BOARD MEETING

SSC LABORATORY

UPSTAIRS CONFERENCE ROOM, BLDG. 4
FEBRUARY 1 - 3, 1992

**FEBRUARY 1**

8:30 Introduction and goals for meeting - Trilling
8:45 Status of detector parameters and cost summary - Gilchriese/Etherton
9:30 Trigger strategy summary - W. Smith
10:15 Discussion
10:45 Break
11:15 Summary of physics section of Technical Proposal with emphasis on detector parameters required for the physics - Einsweiler
12:15 Discussion

12:30 Lunch Executive Board meeting

1:30 Report from the muon chamber selection committee - Maki/Thun
2:30 Discussion
3:30 Break
4:00 Report on US/Russia forward muon system workshop - Skuja/Bensinger
4:30 Report from Cerenkov counter review committee - Reeder
5:00 Report on US/Russia meeting on barrel toroid - Bensinger
5:30 Muon scintillator -- layout recommendation and report on US/Russia discussions - Thun
6:00 Summary of muon system cost - Bensinger
6:15 Discussion
6:30 Adjourn

7:00 Group dinner

AA07151

**FEBRUARY 2**

8:30 Discussion and formulation of EB/TB recommendations on muon system
- Barrel chamber selection
- Inclusion of Cerenkov counters in forward system
- Layout of scintillation counters
- Implementation of muon system

10:00 Break

10:30 Report from the forward calorimeter review committee - Strovink/Frisken

11:15 Discussion of FCAL recommendation and formulation of EB/TB recommendation on FCAL

11:45 Working Lunch

1:00 Front-end electronics (Proposal content, decision process and schedule) Lankford/Williams

Report from electronics cost meetings and electronics cost summary Williams/Gaines/Smith et al.

2:15 Discussion and formulation of EB/TB recommendations on electronics

Brief updates from tracking subsystems on scope, cost, or other new items since the last EB/TB meeting

2:45 Silicon tracker - Seiden

3:15 Straw tracker - Ogren

3:45 Fiber tracker - Ruchti/Elias

4:15 Intermediate angle gas microstrip tracker (including discussion of boundary between barrel and intermediate angle region) - Edwards

4:45 Break

5:00 Report from Tracking Evaluation Committee (including summary of simulation results) - T. Kondo

6:30 Adjourn

**FEBRUARY 3**

| | |
|---|---|
| 8:30 | Discussion of Tracking Evaluation Committee recommendations and formulation of EB/TB recommendations on tracking |
| 10:15 | Break |
| 10:45 | Summary of latest central calorimeter parameters and cost for Technical Proposal - Mantsch/Hubbard |
| 11:30 | Discussion of EM resolution, hadronic segmentation,... - Green et al |
| 12:30 | Working Lunch |
| 1:30 | Central calorimeter prototype - Green/Hubbard/Mantsch/Takikawa et al. |
| 2:15 | Test beam feasibility report - Amendolia/Gilchriese/Green/Siegrist/ Trilling |
| 3:00 | Discussion and formulation of EB/TB recommendations on calorimetry |
| 3:45 | Summary of other cost items - Etherton |
| 4:15 | Discussion and formulation of action items |
| 5:00 | Adjourn |

PRESENTATION BY:

GEORGE TRILLING

Trilling
Sat am

# Meeting Goals

Definition of SDC Detector for TDR (including options)
- Justifications for all subsystems
- Corresponding cost estimates

Where we retain options
- Critical R&D questions
- Time scale for decisions

Test beam needs for 1993 and beyond
- Understand what goal of beam test is
- Understand schedules for needed tests
- (NOTE: Fermilab wants a coherent plan based on our needs)

Assessment of progress of TDR preparation

# Some Specific Issues

Design of barrel/intermediate muon chambers
  Muon chamber evaluation committee (Maki/Thun)

Forward muon system
  Cerenkov ctr. committee (Reeder)
  Russian/U.S. workshop (Kubarovsky/Skuja)

Toroid fabrication
  Izhora/JINR/U.S. discussions

Muon scintillator layout

Tracking technologies in TDR
Tracker layout (layers, ITD ..)
  Tracking evaluation committee (Kondo)

Options and geometry for forward calorimetry
  FCAL committee (Strovink)

# Remarks
(GHT opinions)

Overall cost should be limited to ~$580M.

TDR must provide coherent justification for all cost correlated parameters. PAC has not seen convincing justification of parameters. This needs discussion at this meeting

Tech. Board should act here as overall technical group rather than just as leaders of particular subsystems. Be prepared to question everyone's design choices.

PRESENTATION BY:

GIL GILCHRIESE

Gilchriese

Sat am

## Executive/Technical Board Meeting

## February 1 - 3 , 1992

## Issues and Decisions

- Layout of baseline tracking system - straws and GMD?
- Fibers in Technical Proposal - yes or no?
- Barrel muon chamber selection
- Layout and performance of forward muon system
- Cerenkov counter in forward system in Tech. Prop.?
- Scintillator layout(pt trigger, uniform, rapidity bins.....two layers)?
- Forward calorimeter options
- Central calorimeter parameters
- Calorimeter prototype
- Test beams - Fermilab or CERN? What is the plan

# COST CONTAINMENT!

PRESENTATION BY:

WESLEY SMITH

# SDC TRIGGER SYSTEM

Sat am

**Level 1:**

Identify Physics Objects:

- Electrons
- Photons
- Muons
- Jets
- Neutrinos

**Level 2:**

Refine Identification of Physics Objects:

- Sharper $P_T$ Cuts
- Electrons From Conversions
- Muons from Decay/Punchthrough
- Refine Energy Sums/Clusters

**Level 3:**

Full Physics Analysis/Decisions

**Benchmarks for Trigger Performance:**

- e's, $\mu$'s from inclusive W's, Z's
- Jets at high $P_T$
- High $P_T$ $\gamma$'s
- Missing $E_T$
- Low $P_T$ multileptons

# LEVEL 1

**Electrons & Photons:**

Find (.1 x .1) Cal Towers with $E_{em}$ > Thr

Require $E_{hac}/E_{em}$ < .04 - .10

Require Pattern of surrounding quiet towers (isolation)

*γ's:* Match w/Shower Max in .2η x .2φ

*e's:* Find Outer Track Segments w/$P_T$ > 10 GeV/c

Match Track Segments w/Shower Max in φ in 1/1024 . Option: 1/64 - reduction in cost, complexity

Assign Δη = 0.2 from Shower Max to Track

Match Track w/Cal on Δη=0.2, Δφ=0.2

**Muons:**

Muon Tracks from Scint + θ-layers w/$P_T$ > 10 GeV/c

*Option:* Find Outer Track Segments w/$P_T$ > 10 GeV/c

Match w/Muon Segment from φ-layer in 1/1024

Use Momentum cut based on Tracker $P_T$ bits

(Use Scint to associate φ and θ tracks)

Match Track w/Quiet Cal on Δη=0.2, Δφ=0.2

**Jets:**

.8 x .8 grids of overlapping towers > $E_{thr}$

**Neutrinos:**

Sum Missing $E_T$ over .1 x .1 Towers > $E_{thr}$

# LEVEL 2

**Electrons:**

Use Si Track to Tag (Kill) Conversions

Use Si Track to impose $P_T$ vs. E cut

**Muons:**

Use Si Track to Kill/Tag Punchthrough/Decay

Compare Si Track $P_T$ vs. Muon $P_T$

Additional Muon $\theta$-layer reduces beam spot $\sigma(P_T)$

**Jets:**

Measure Energy in cone

Find Stiff Tracks in Jet

Search for Unisolated Electrons near/in Jet

(stiff track + Tower w/low H/E)

**Neutrinos**

Add Muon Energy into missing $E_T$ sum

Sum Jet (cone) Energies

Topology: location of $E_T$ vector (hole)

Search for lower energy leptons

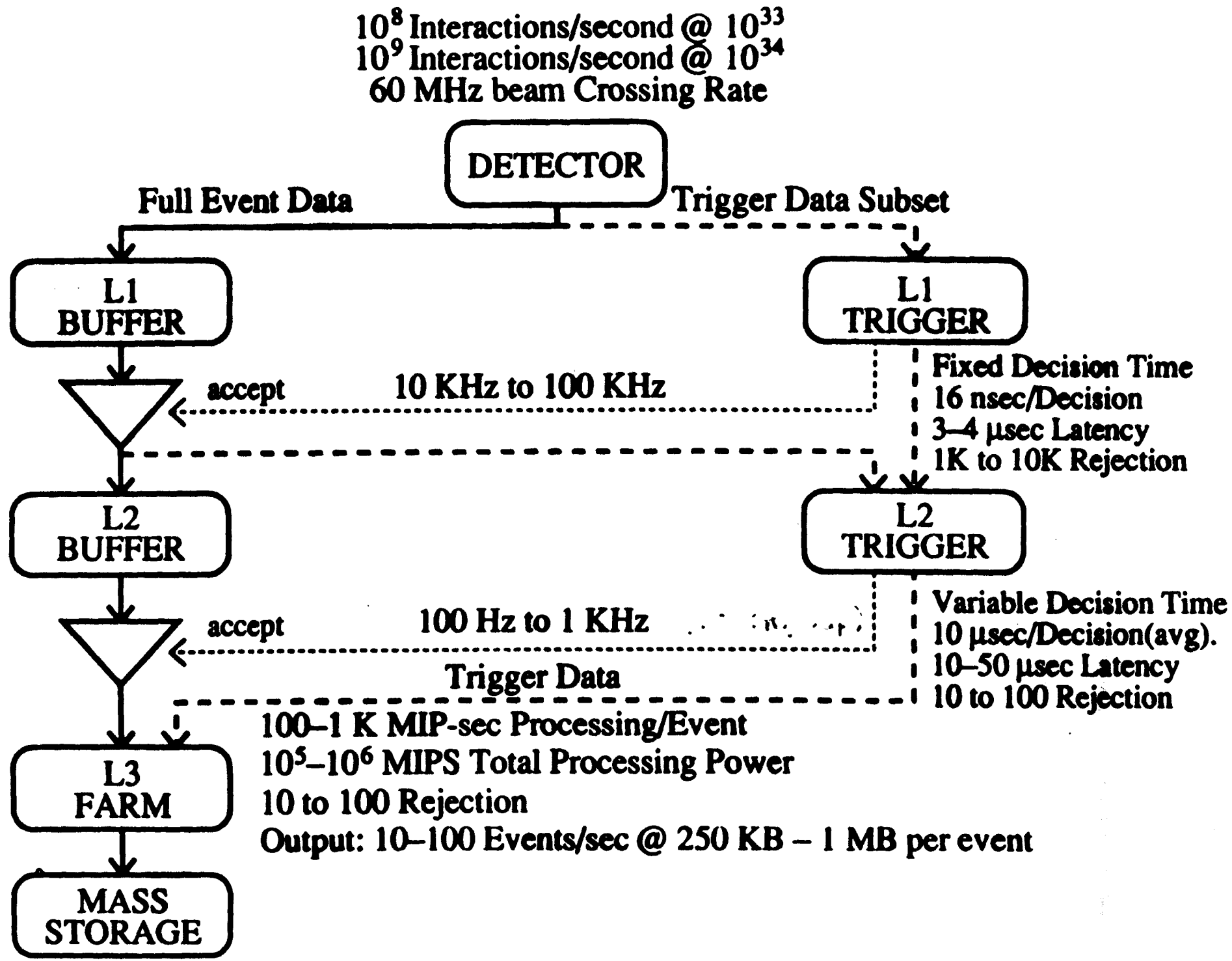
## TRIGGER

01/29/92

| | Level 1 Segmentation per half/end | Level 1 Data/bin | Level 2 Segmentation per half/end | Level 2 Data/bin |
|---|---|---|---|---|
| **Silicon** | -- | -- | 2048$\phi$ x 6$\eta$ | 5 $p_T$ bits |
| **Barrel Track** | 1024$\phi$ | 4 $p_T$ bits | 1024$\phi$ | 4 $p_T$ bits |
| **Int. Track** | 1024$\phi$ x 4$\eta$ | 4 $p_T$ bits | 1024$\phi$ x 4$\eta$ | 4 $p_T$ bits |
| **Cal $\lvert\eta\rvert < 1.8$** | | | | |
| Cal Towers | 64$\phi$ x 18$\eta$ | EM & HAC 8 bits Egy | 64$\phi$ x 18$\eta$ | EM & HAC 8 bits Egy |
| Sh. Max Layer X | 1024$\phi$ x 9$\eta$ | Hit Flags | 1024$\phi$ x 9$\eta$ | 8 bits Egy |
| Sh. Max Layer Y | -- | -- | 144$\eta$ x 32$\phi$ | 8 bits Egy |
| **Cal $1.8 < \lvert\eta\rvert < 2.6$** | | | | |
| Cal Towers | 64$\phi$ x 8$\eta$ | EM & HAC 8 bits Egy | 64$\phi$ x 8$\eta$ | EM & HAC 8 bits Egy |
| Sh. Max Layer X | 512$\phi$ x 4$\eta$ | Hit Flags | 512$\phi$ x 4$\eta$ | 8 bits Egy |
| Sh. Max Layer Y | -- | -- | 64$\eta$ x 32$\phi$ | 8 bits Egy |
| **Cal $2.6 < \lvert\eta\rvert < 3.0$** | | | | |
| Cal Towers | 32$\phi$ x 2$\eta$ | EM & HAC 8 bits Egy | 32$\phi$ x 2$\eta$ | EM & HAC 8 bits Egy |
| Sh. Max Layer X | 256$\phi$ x 2$\eta$ | Hit Flags | 256$\phi$ x 2$\eta$ | 8 bits Egy |
| Sh. Max Layer Y | -- | -- | 16$\eta$ x 32$\phi$ | 8 bits Egy |
| **Cal $\lvert\eta\rvert > 3.0$** | 8$\phi$ x 4$\eta$ | EM+HAC 8 bits Egy | 8$\phi$ x 4$\eta$ | EM+HAC 8 bits Egy |
| **Muon $\lvert\eta\rvert < 1.0$** | 1024$\phi$ | Hit Flags | 1024$\phi$ x 5$\eta$ | 5 $p_T$ bits |
| | 32$\phi$ x 5$\eta$ | 4 $p_T$ bits | -- | -- |
| **Muon $1.0 < \lvert\eta\rvert < 2.5$** | 1024$\phi$ | Hit Flags | 1024$\phi$ x 8$\eta$ | 5 $p_T$ bits |
| | 32$\phi$ x 8$\eta$ | 4 $p_T$ bits | -- | -- |

# MAJOR MILESTONES

| | |
|---|---|
| Completion of Trigger System Design Specs. *(incl. Technical Choices)* | 1993 |
| Test Trigger System for use in front end & DAQ system bench and test beam operations *(incl. simulation of clock & control)* | 1993 |
| Complete Design of Global & Subsys. Trigs. | 1994 |
| Prototypes of Global & Subsys. Triggers | 1995 |
| Initial Delivery of Trigger Interfaces to Front End and DAQ. | 1996 |
| Delivery of Trigger System Begins | 1997 |
| Integration and Test of Subsystem and Global Trigger Systems begins | 1997 |
| Integration and Test of Trigger with Final DAQ/FE Systems begins | 1998 |
| Commissioning of Trigger System Completed | 1999 |


$10^8$ Interactions/second @ $10^{33}$
$10^9$ Interactions/second @ $10^{34}$
60 MHz beam Crossing Rate
DETECTOR
Full Event Data
Trigger Data Subset
L1 BUFFER
L1 TRIGGER
accept
10 KHz to 100 KHz
Fixed Decision Time
16 nsec/Decision
3–4 μsec Latency
1K to 10K Rejection
L2 BUFFER
L2 TRIGGER
accept
100 Hz to 1 KHz
Variable Decision Time
10 μsec/Decision(avg).
10–50 μsec Latency
10 to 100 Rejection
Trigger Data
100–1 K MIP-sec Processing/Event
$10^5$–$10^6$ MIPS Total Processing Power
10 to 100 Rejection
Output: 10–100 Events/sec @ 250 KB – 1 MB per event
L3 FARM
MASS STORAGE

Overall Level 1 Rate

Target: 10 KHz – 100 KHz

Individual Level 1 Rate

Target: 3 KHz.

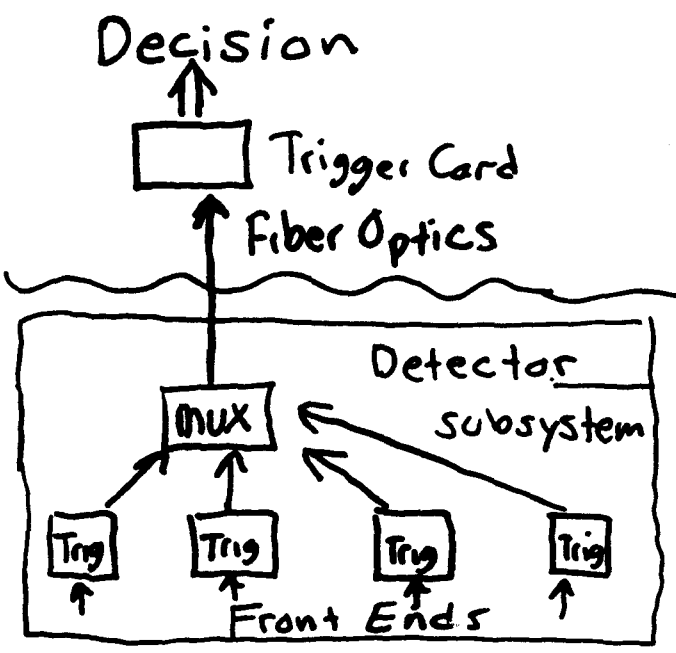
i.e. 3 KHz for Barrel e
Endcap e
Barrel $\mu$
Endcap $\mu$
2e
2$\mu$
Jet
Missing $\not{E}$
Barrel $\not{\gamma}$
Endcap $\not{\gamma}$
⋮ ~ 30 KHz

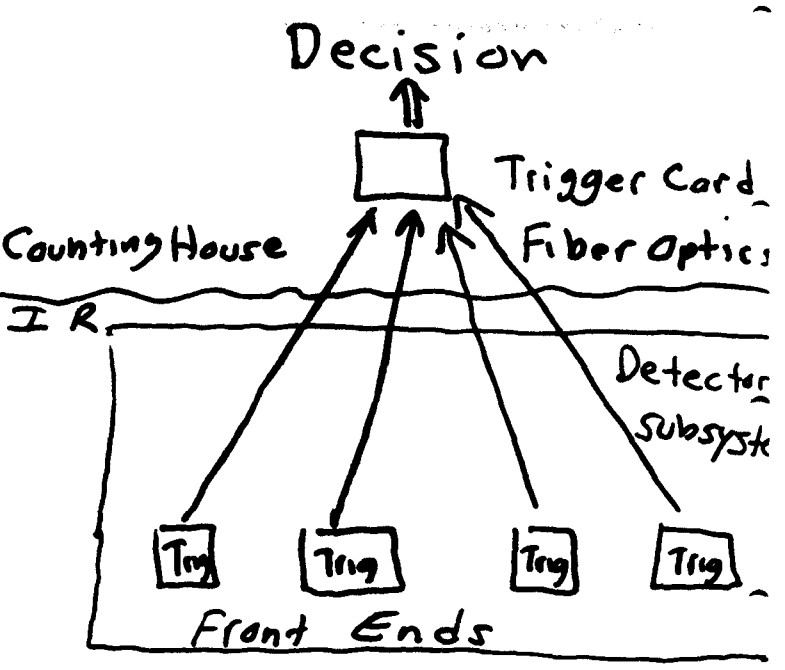
Remember 1nb = 1Hz @ $10^{33}$

$W \to e\nu$ 10nb
$W \to \mu\nu$ 10nb
$t\bar{t}$ 1–90nb

> Physics ≈ 50nb @ $10^{33}$
500nb @ $10^{34}$

# Trigger Hardware Strategy - I




Reduce Fiber Optics

Extra Card (MUX)

Single point failure worse

BUT

Increase Fiber Optics

Fewer Cards

More Reliable

# Trigger Hardware Strategy - II

## Minimize Interconnects

FE's ⇒ Trigger Logic ⇕ Interconnect Logic ⇒ Result ⇒ Decision Logic

Large volume of data / cables (synchronization + Latency)

FE's ⇒ Trigger Logic

VS.

## Feed-Forward Architecture

FE's ⇒ Trigger Logic ⇒ Summary

FE's ⇒ Trigger Logic ⇒ Summary

small volume data/cables

only bring together when required

Result ⇒ Decision Logic

Build in diagnostics, efficiency, understand

FE ⇒ [?] ⟶ Yes/No ⟶ [OR] ⟶ Trigger

VS.

FE ⇒ [Primitive Generation] ⟹ Primitives ⟹ [Logic] ⟶ Trigger

subtriggers prescaled.

# SDC Trigger Hardware Implementation

## Minimize on-detector hardware: (counting house trigger)

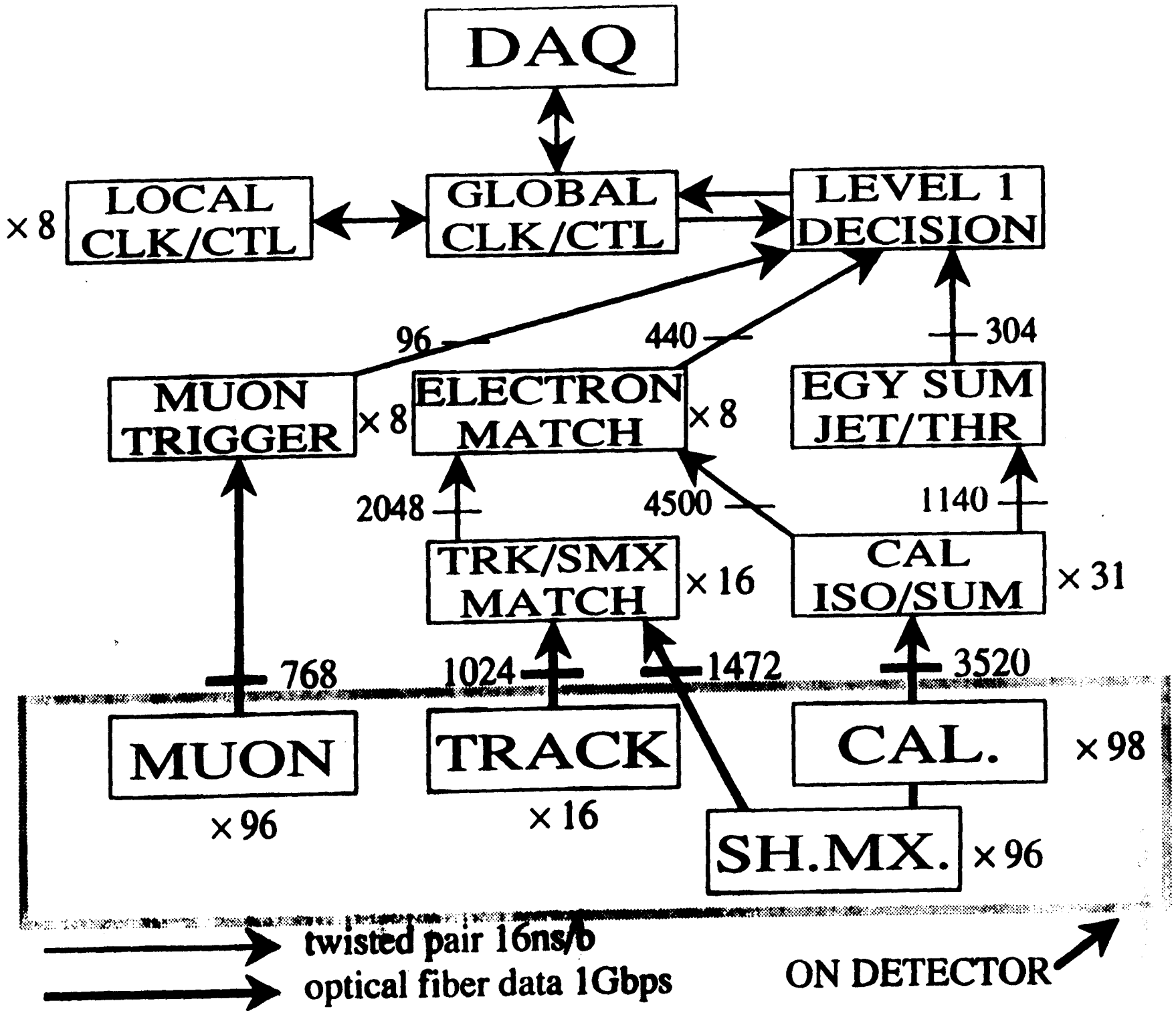
- Reduce detector cooling, power, crates, etc.
- Decouple detector + trigger geometry:
  - (Map geometry in counting house)
  - Adjacent $\eta$-$\phi$ towers may be physically distant (ITD-Barrel Track, Barrel-Endcap Cal)
- Allow Control of Trigger Hardware Environment
- Use of "standard" Crate
- Access ⇒ Reduces Reliability requirements
- Eases Ability to upgrade/change trigger
- Eases Ability to debug, monitor, commission
- Decouple Detector Mechanical/Trigger Design

## Minimize Interconnects

- Design based on feed-forward architecture
- Connectors are major source of unreliability
- Connectors must be carefully chosen (engineer time) for impedance matching, crosstalk, noise ⇒ $\phi$

## Board Testability

- Boards w/ 16nsec clocks need tight impedance cm
- Physical size of 90X400mm ⇒ up to 7nsec board prop
- Build in (design) testability (assembly test underpo
- (May need to run backplane signals differential if bussed, otherwise may need to custom tune backplane term.)


DAQ
LOCAL CLK/CTL
×8
GLOBAL CLK/CTL
LEVEL 1 DECISION
96
440
304
MUON TRIGGER
×8
ELECTRON MATCH
×8
EGY SUM JET/THR
2048
4500
1140
TRK/SMX MATCH
×16
CAL ISO/SUM
×31
768
1024
1472
3520
MUON
×96
TRACK
×16
CAL.
×98
SH.MX.
×96
twisted pair 16ns/b
optical fiber data 1Gbps
ON DETECTOR

# Total/Missing Energy Trigger

## Hardware Configuration for Pipeline Length Calculation

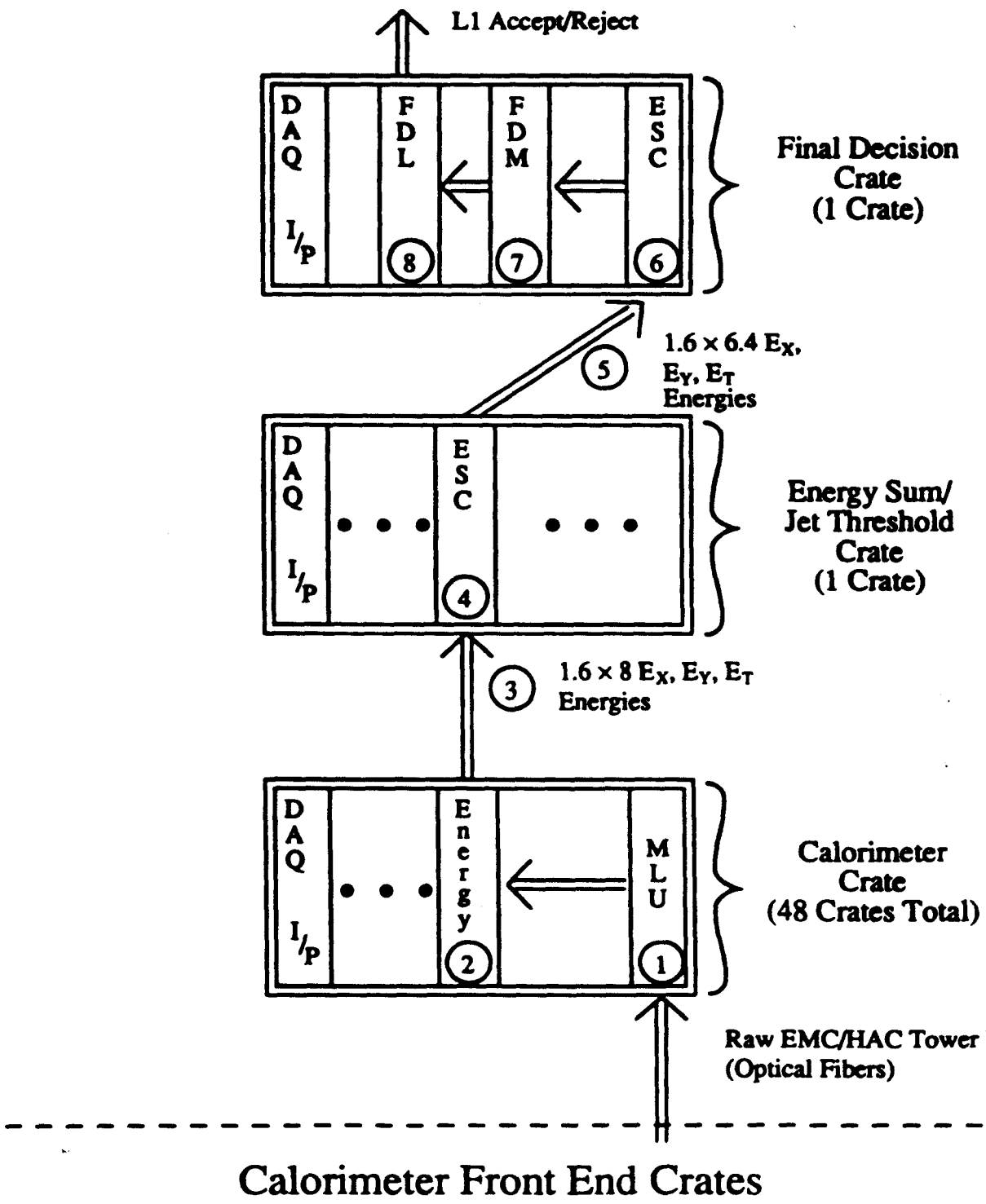



Figure 1

8 GW FOSTER

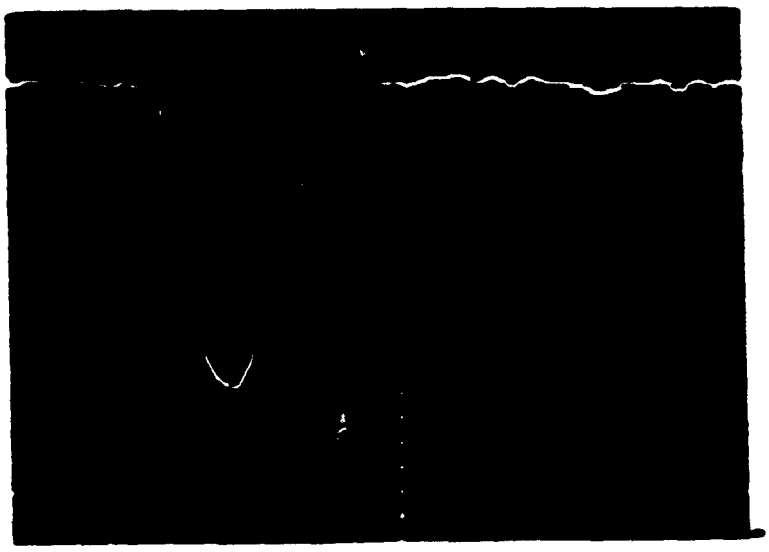
# TILE/FIBER SCINTILLATOR SPEED

OUTPUT PULSE FROM FNAL RAD-HARD MODULE

SCSN-81 + K-27

$t_f \sim 12$ ns

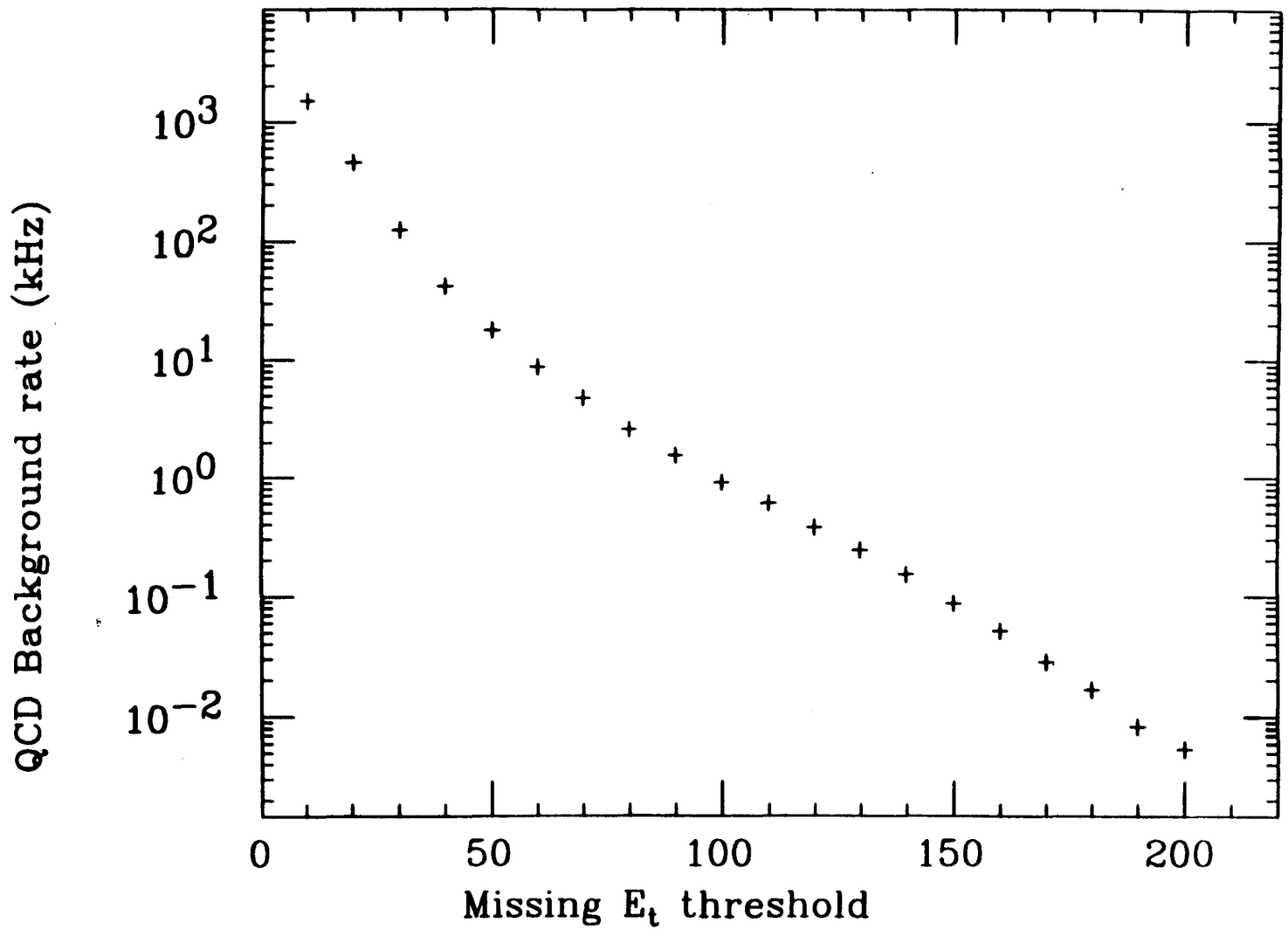
100 GeV $e^+$ beam



OUTPUT WITH 5 nsec $\frac{50\Omega}{3}$ CLIP LIN

100 GeV $e^+$

⇒ AT PRESENT, WE SHOULD USE TWO CROSSINGS' PICKUP


QCD Background rate (kHz)
$10^3$
$10^2$
$10^1$
$10^0$
$10^{-1}$
$10^{-2}$
0
50
100
150
200
Missing $E_t$ threshold

# Jet Threshold Trigger

## Hardware Configuration for Pipeline Length Calculation

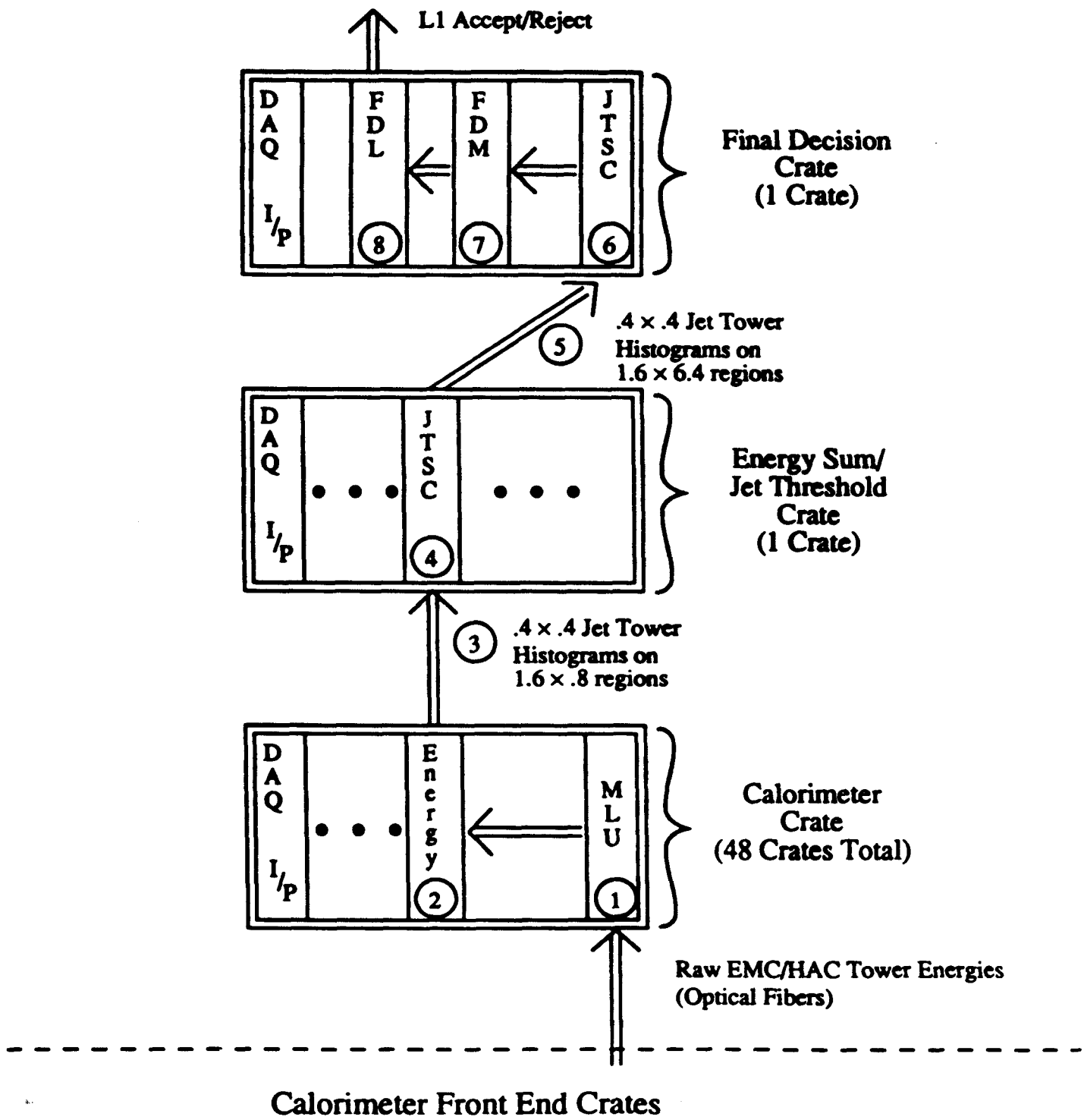



Figure 2

# JET TRIGGER RATES

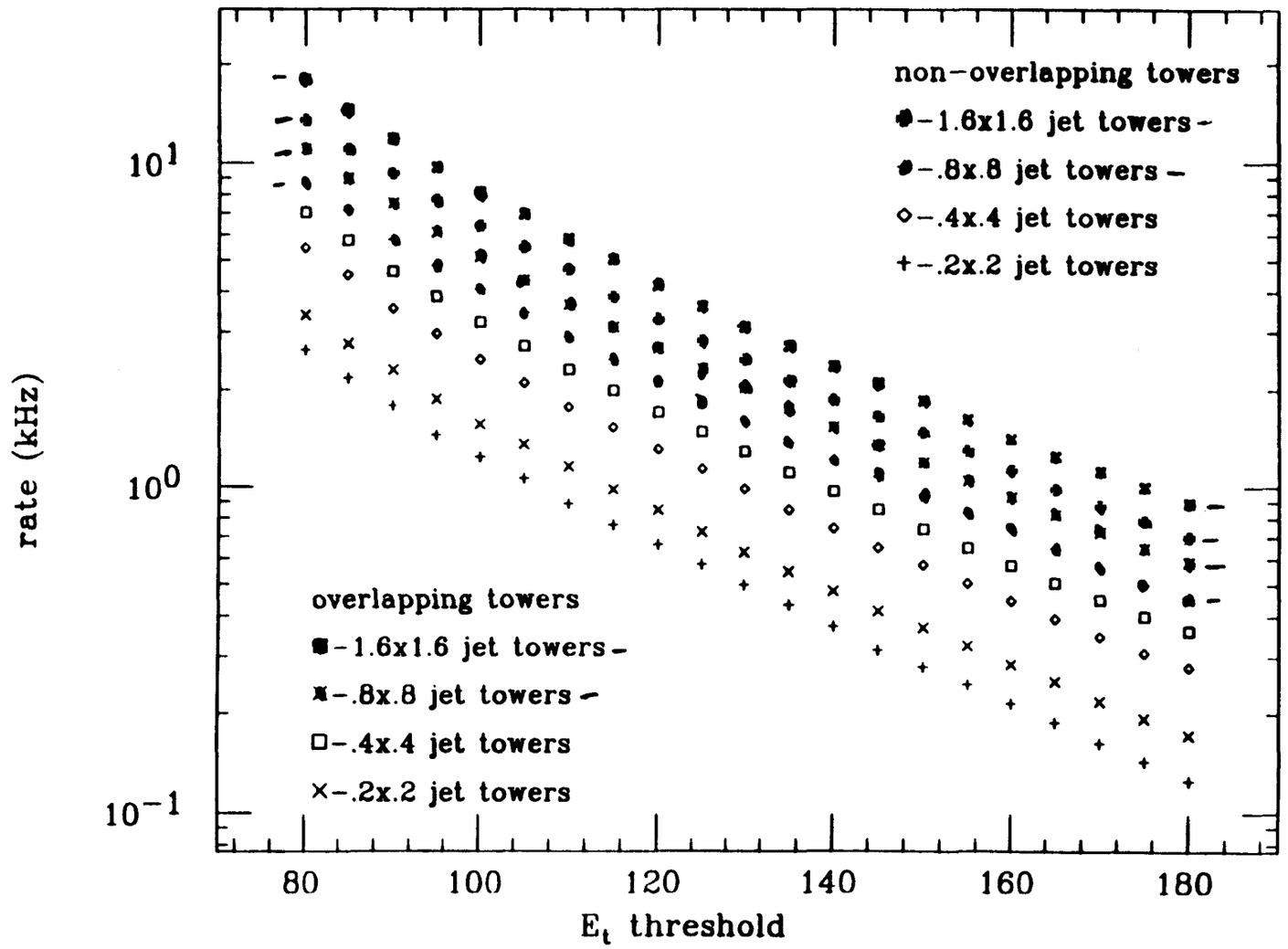



Figure 0

60K QCD 2-Jet Events , 120-400 GeV/c , ,

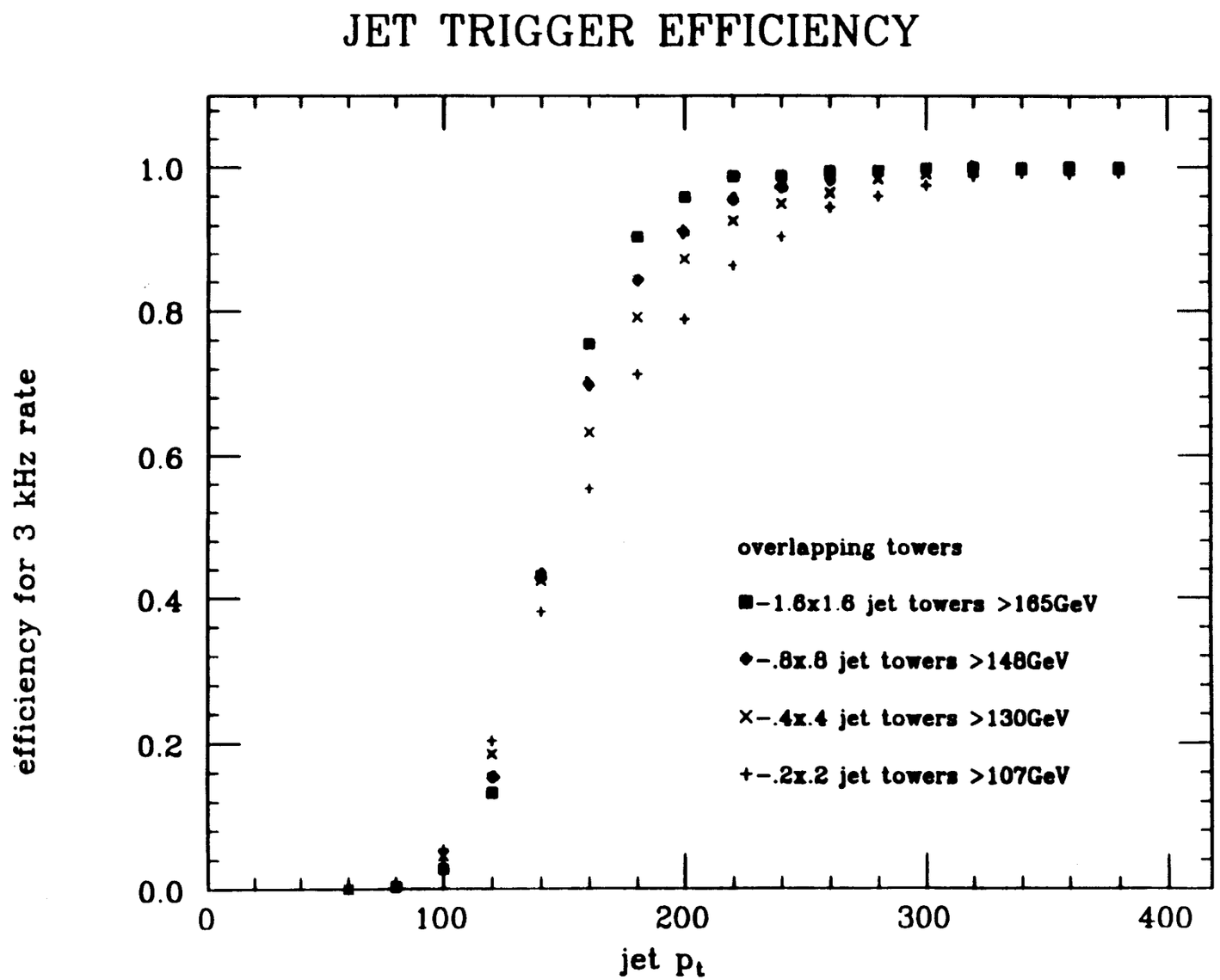

JET TRIGGER EFFICIENCY
efficiency for 3 kHz rate
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
jet $p_t$
overlapping towers
■–1.6x1.6 jet towers >165GeV
◆–.8x.8 jet towers >148GeV
×–.4x.4 jet towers >130GeV
+–.2x.2 jet towers >107GeV

Figure 18

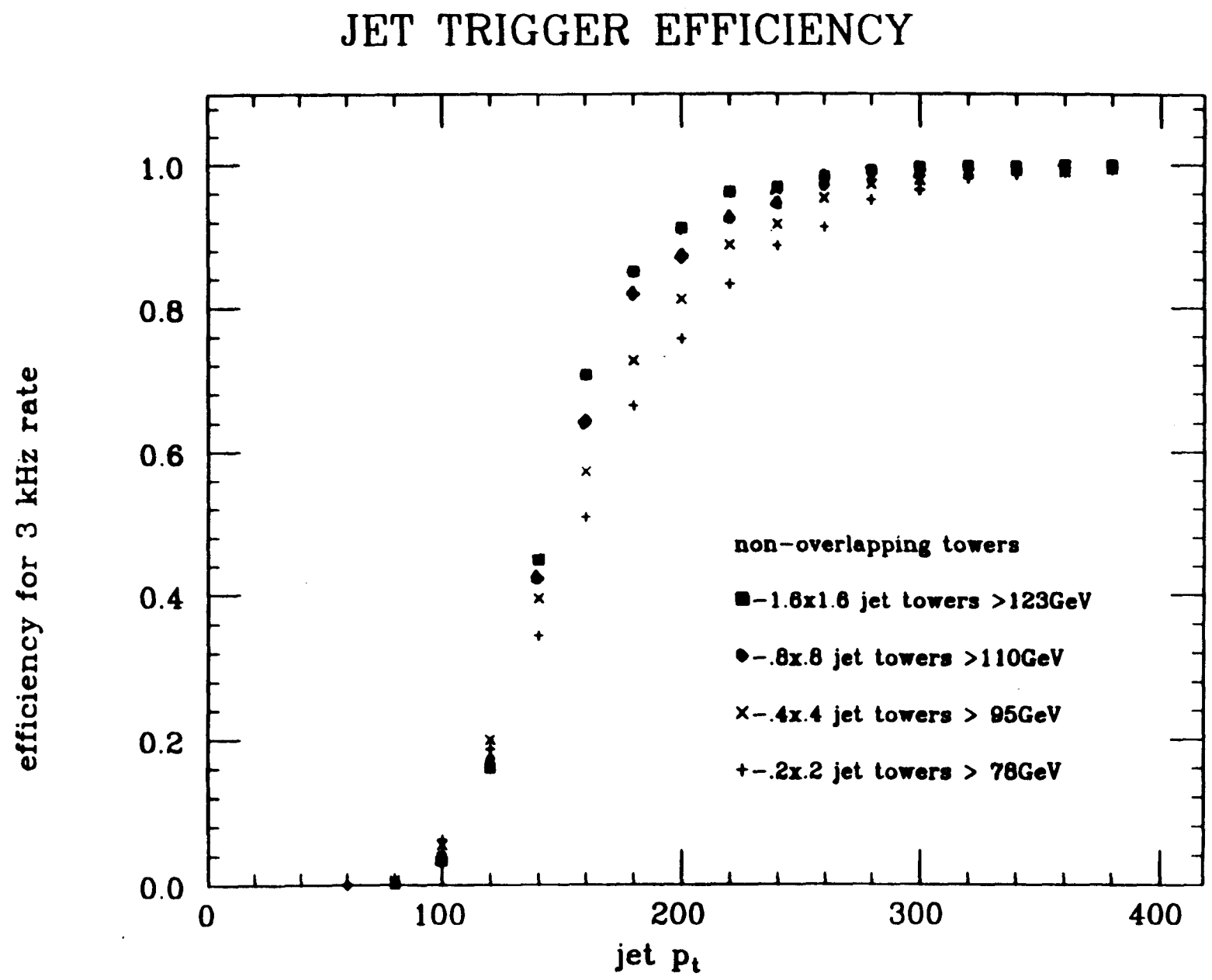

JET TRIGGER EFFICIENCY
efficiency for 3 kHz rate
jet $p_t$
0.0
0.2
0.4
0.6
0.8
1.0
0
100
200
300
400
non-overlapping towers
■-1.6x1.6 jet towers >123GeV
◆-.8x.8 jet towers >110GeV
×-.4x.4 jet towers > 95GeV
+-.2x.2 jet towers > 78GeV

Figure 16

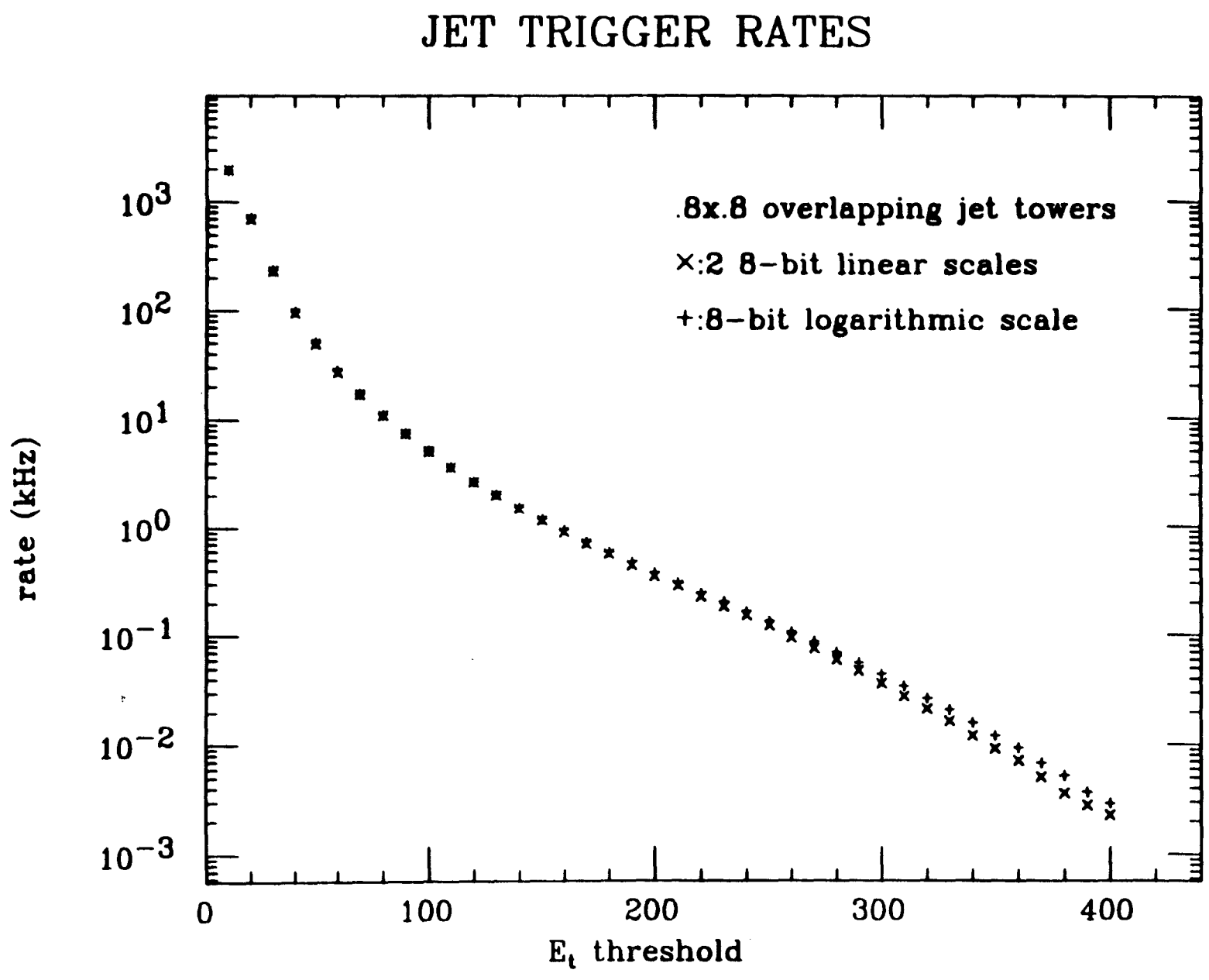

JET TRIGGER RATES
.8x.8 overlapping jet towers
×:2 8-bit linear scales
+:8-bit logarithmic scale
rate (kHz)
$10^3$
$10^2$
$10^1$
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
0
100
200
300
400
$E_t$ threshold

Figure 7

# Isolated Electron Trigger
# Calorimeter Data Path
## Hardware Configuration for Pipeline Length Calculation

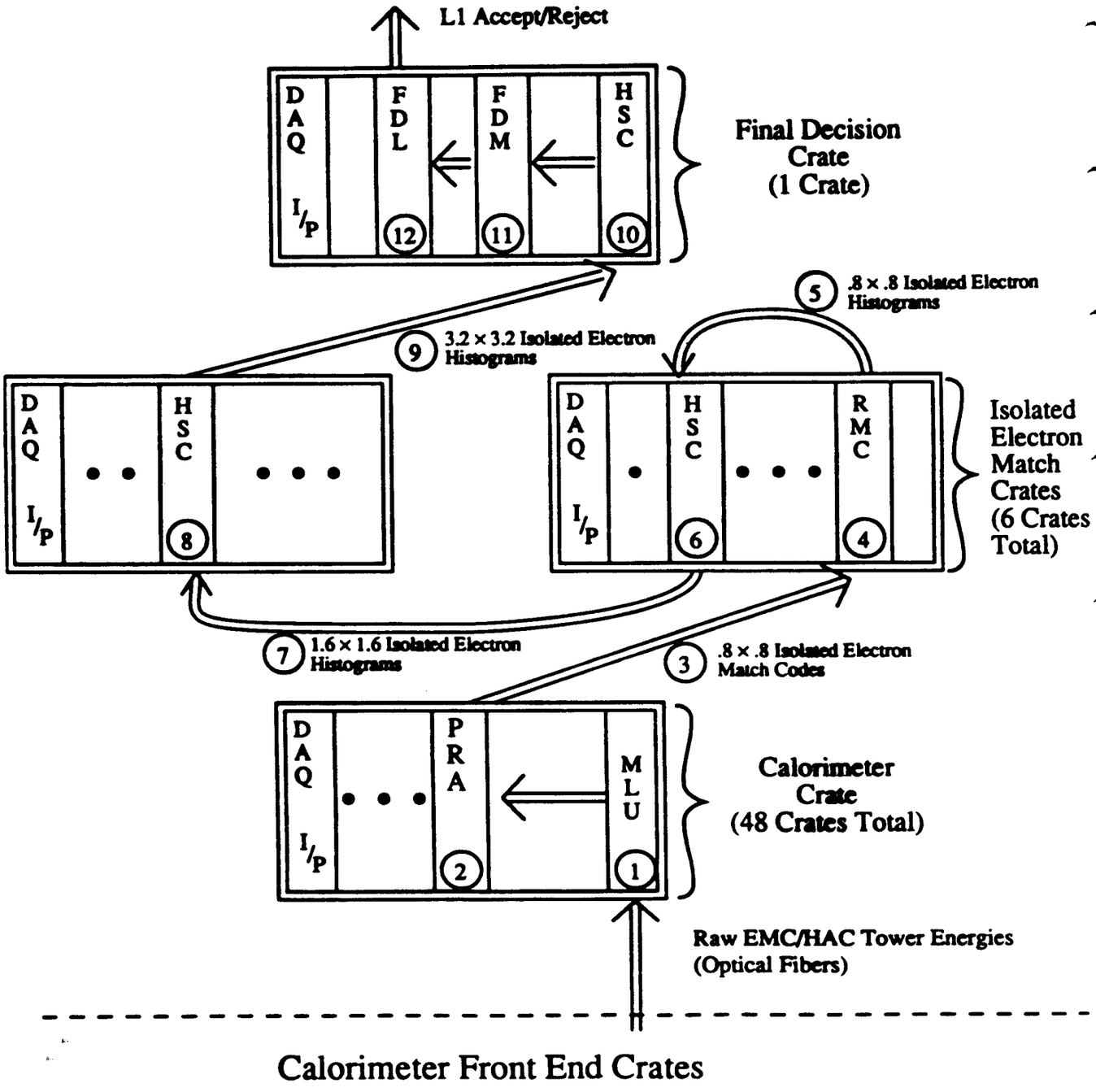



Figure 3

# Isolated Electron Trigger
## Tracker/ Shower Max Data Path
### Hardware Configuration for Pipeline Length Calculation

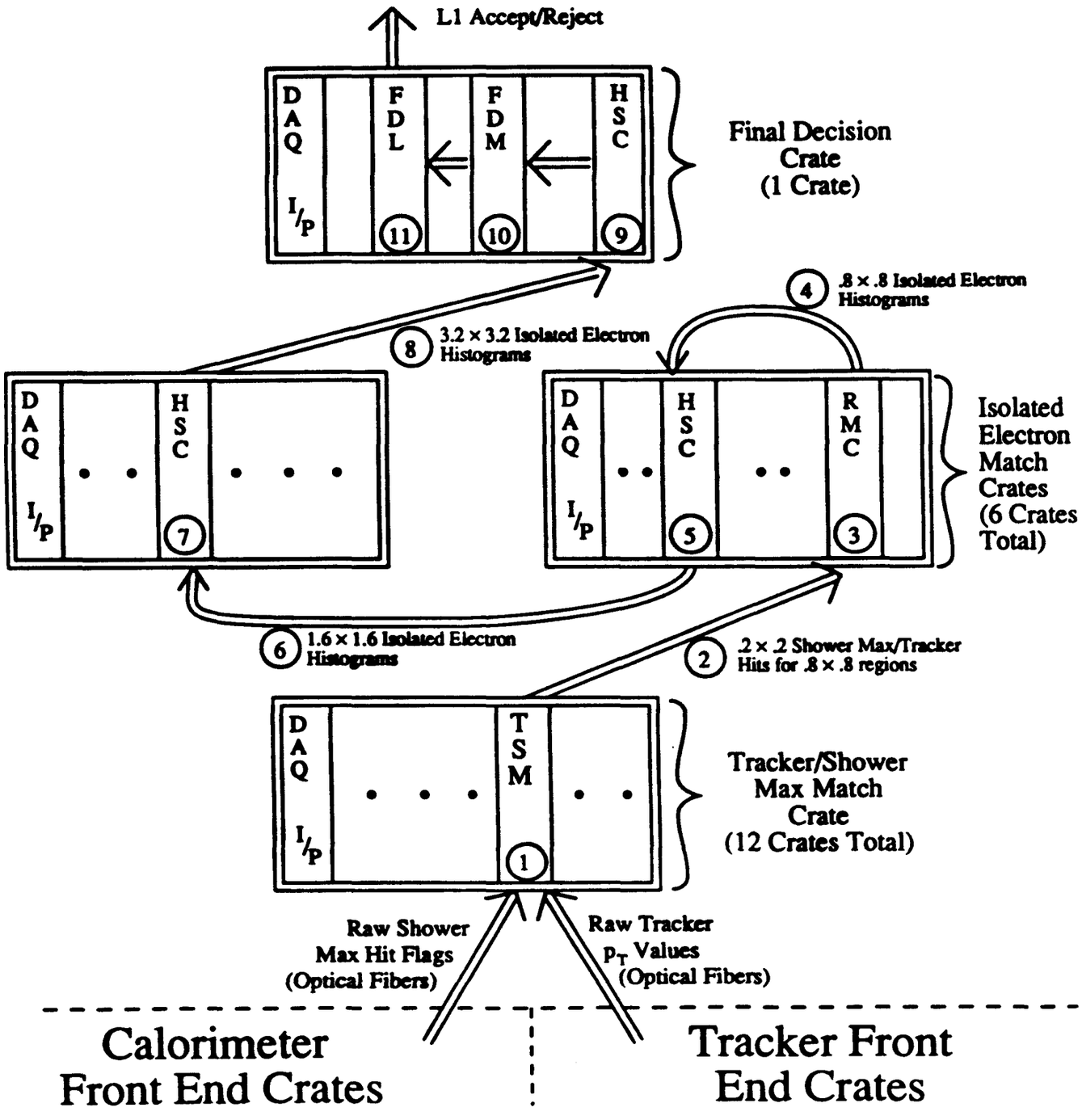
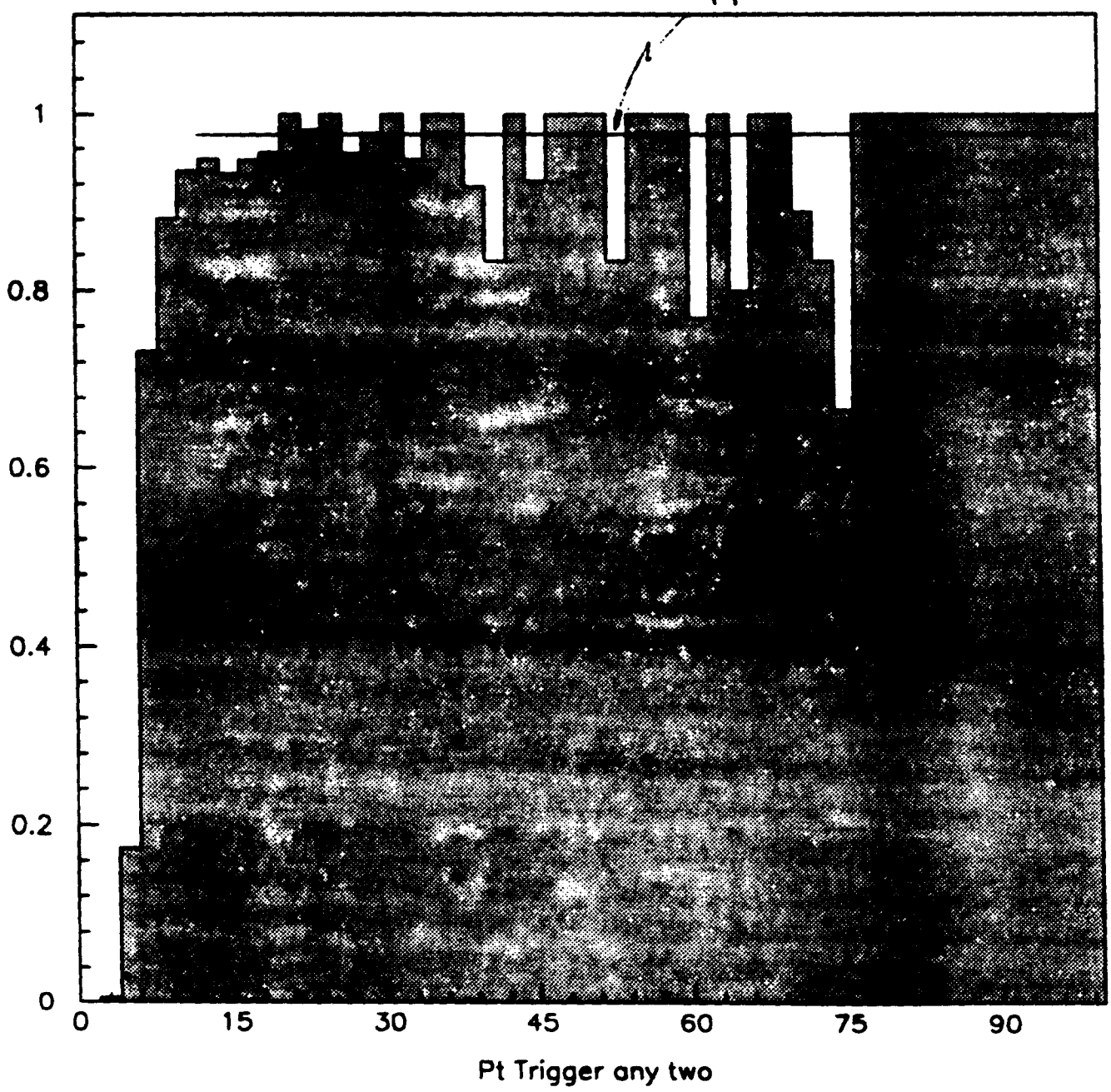
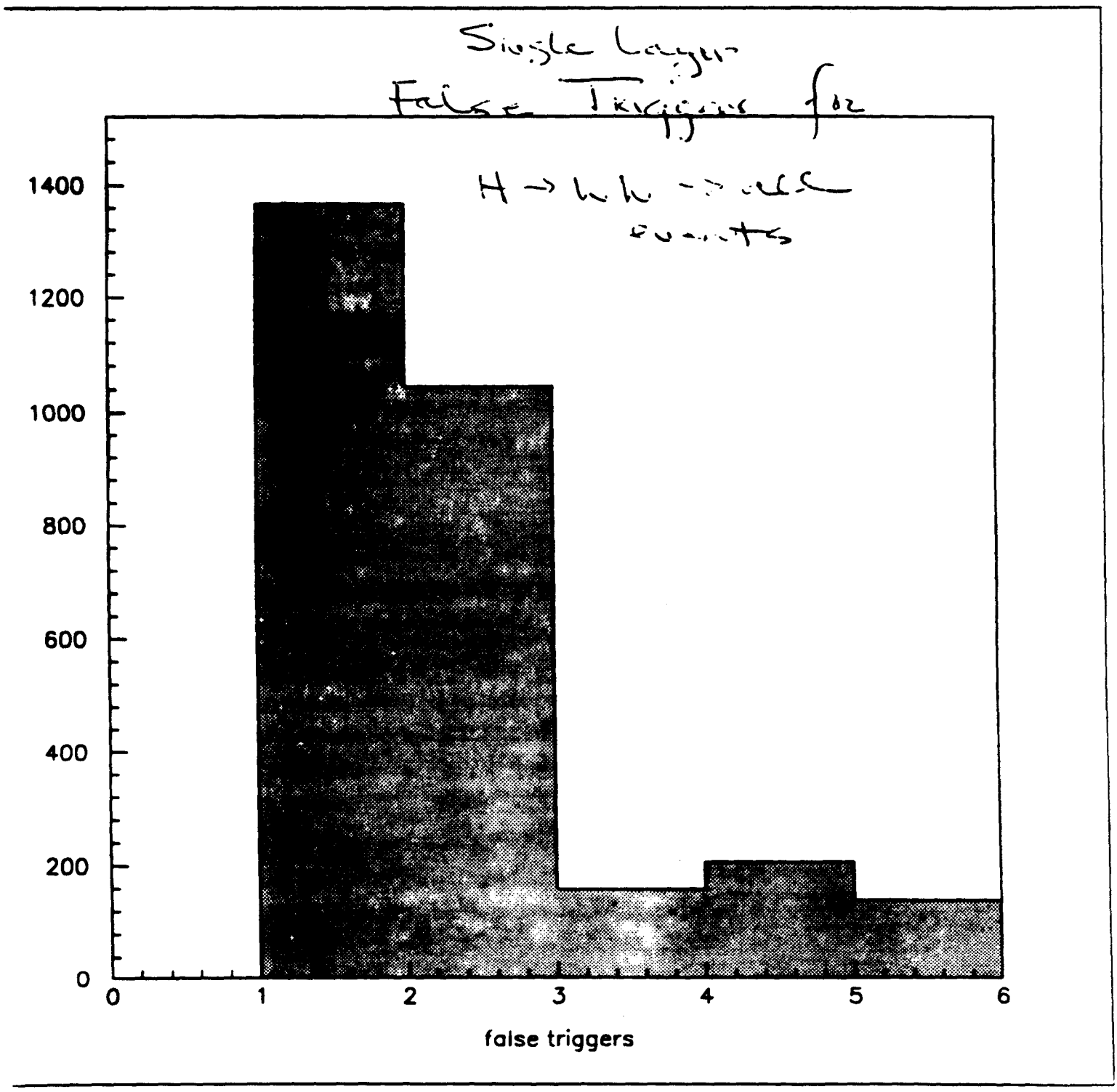
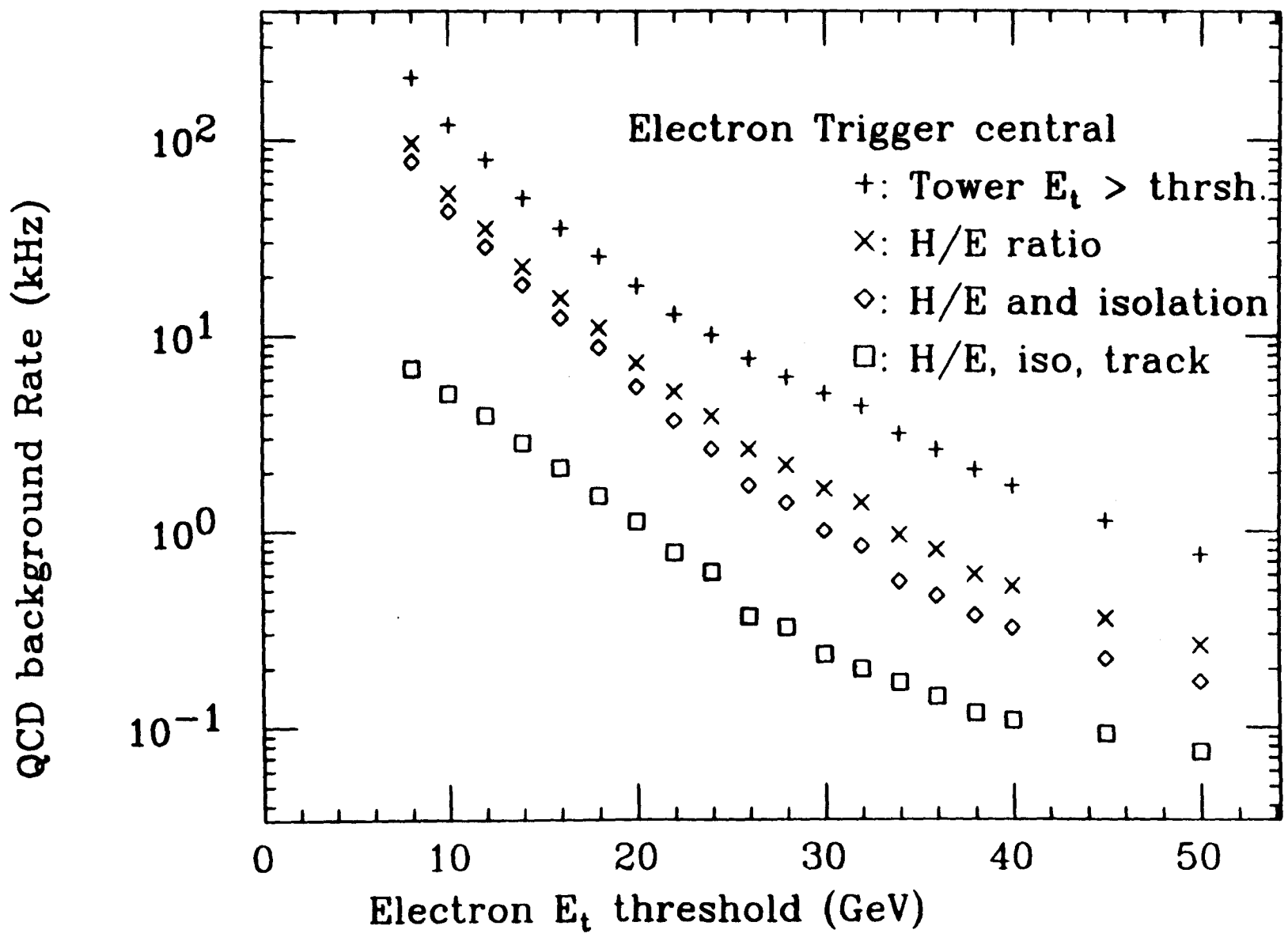



Figure 4

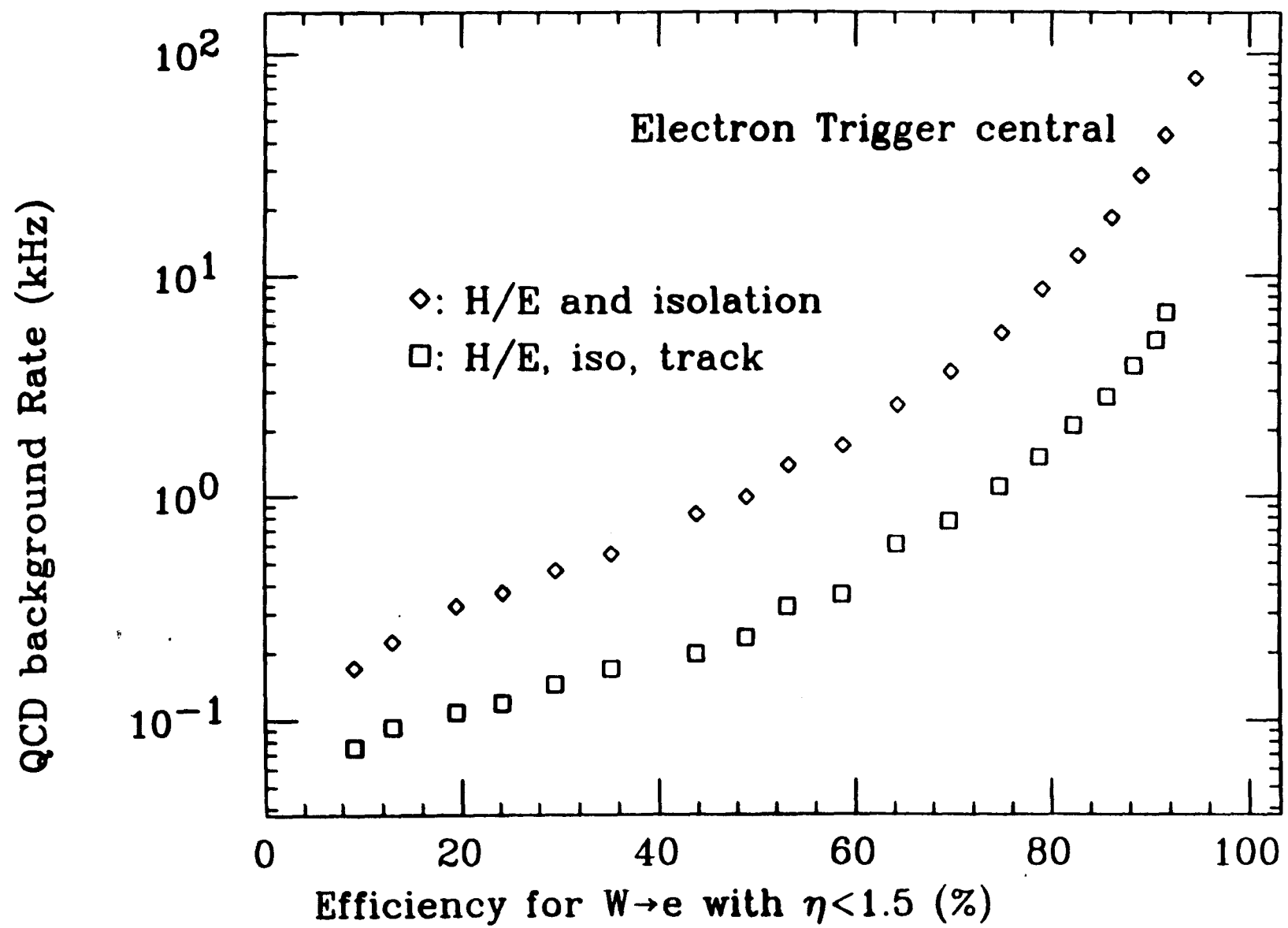
Tracking Triggers



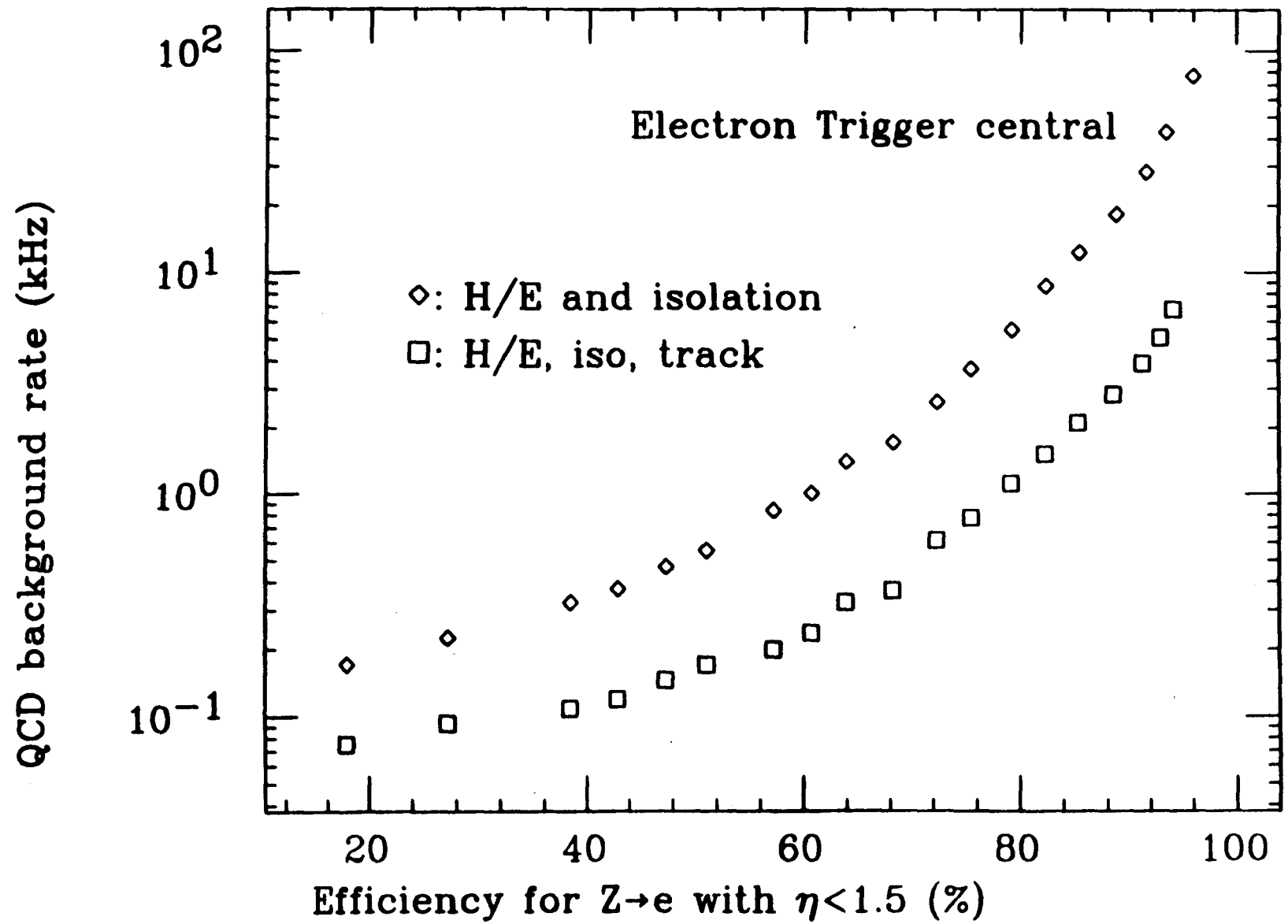

Single Layer
False Triggers for
H → hh → 4b
events
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
false triggers




120K QCD 2-Jet events 20-200 GeV $P_T$




20K W→e events



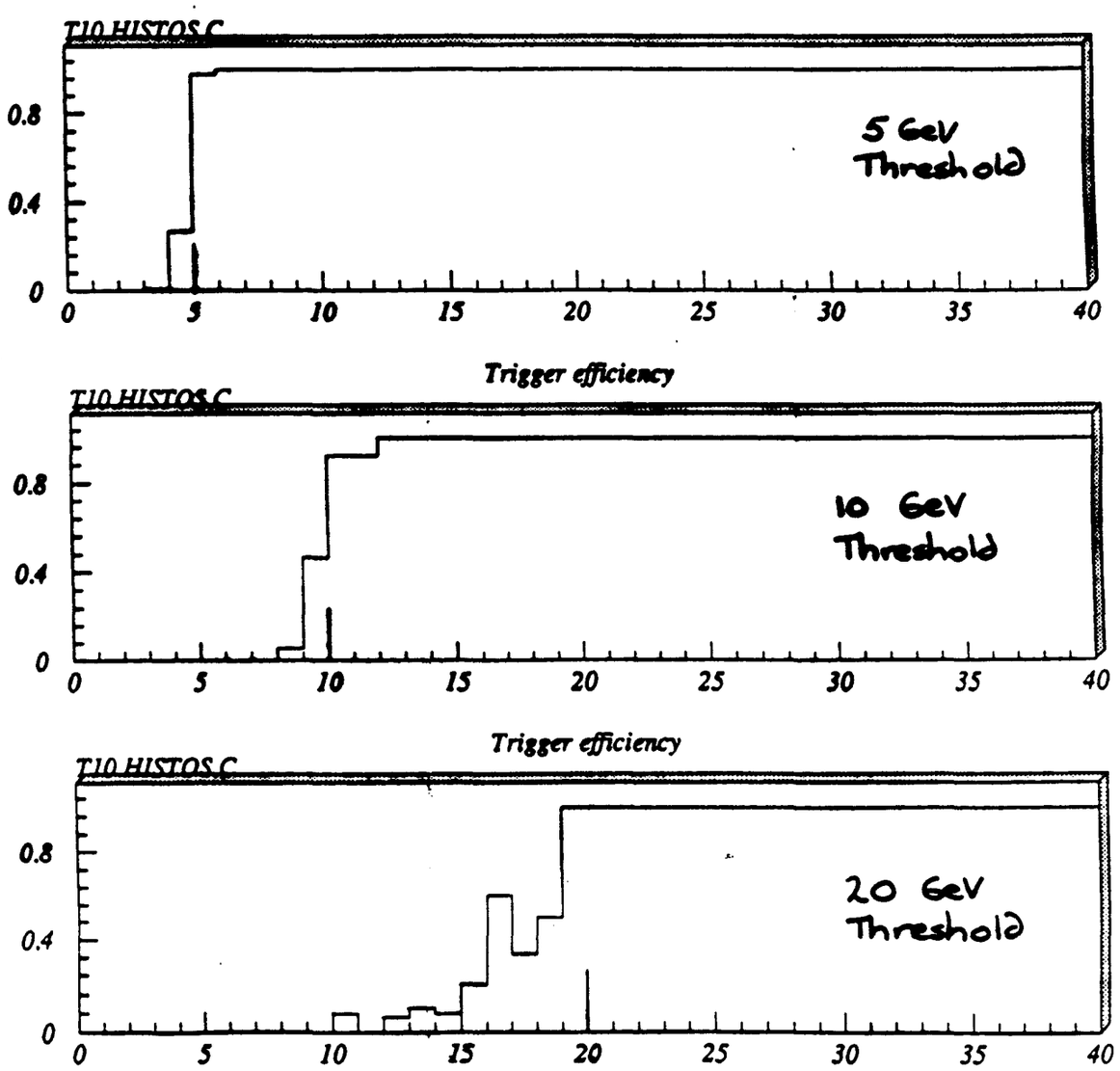

20k $Z \to e$, events

Steve Maxfield 9/

# ITD Tracker Trigger Resolution Studi
(Gas μstrip)

Broadening of trigger edge
– finite resolution in $\Delta\phi$
$\Delta p \sim \frac{1}{p_t}$

## Efficiency:



# CONCLUSIONS

- The projective geometry and fine granularity in $\phi$ of the ITD microstrips enable it to provide both tracking and contribute to a level 1 trigger.

- Low occupancy (~0.03%) ⇒ hits from particular bunch-crossing can be isolated for pattern recognition.

- The ITD contribution to the level 1 trigger can be:-

  - Close to 100% efficient at triggering on high Pt tracks.
  - Between 50% and 75% of Higgs events provide such a high Pt track.
  - The 'background' rate is typically between 1/3 and 1 MHz for L=10**33.
    - must be supplemented.

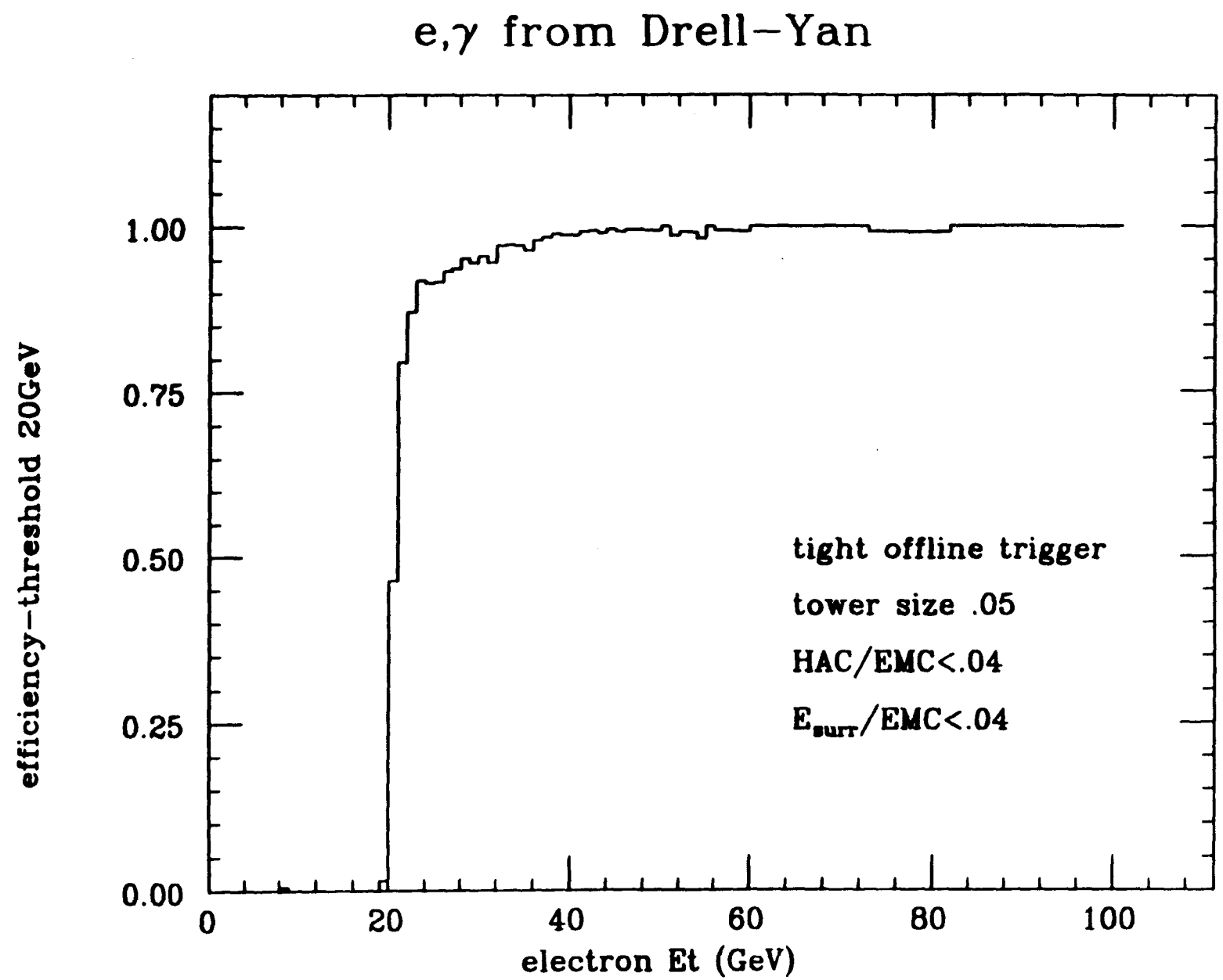

e,γ from Drell−Yan
efficiency−threshold 20GeV
1.00
0.75
0.50
0.25
0.00
0
20
40
60
80
100
electron Et (GeV)
tight offline trigger
tower size .05
HAC/EMC<.04
E_surr/EMC<.04

Figure 30

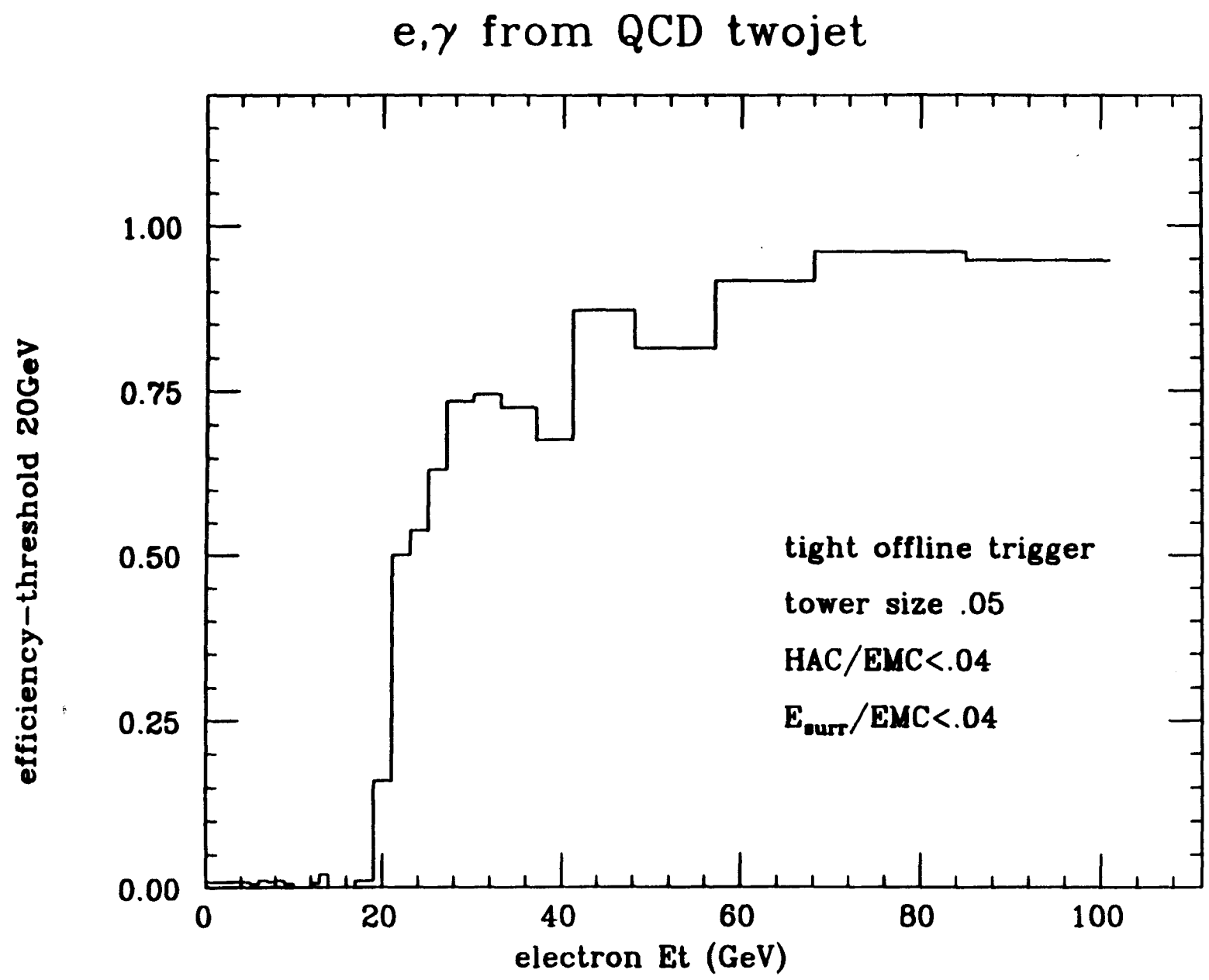

e,γ from QCD twojet
efficiency−threshold 20GeV
1.00
0.75
0.50
0.25
0.00
0
20
40
60
80
100
electron Et (GeV)
tight offline trigger
tower size .05
HAC/EMC<.04
E_surr/EMC<.04

Figure 36

# Initial Conclusions from Calorimeter Trigger studies

Jets: A .8x.8 or 1.6x1.6 overlapping grid of Tower sums over threshold, works best. Sums of .2x.2 non-overlapping have poorer performance (and by inference single towers/threshold)

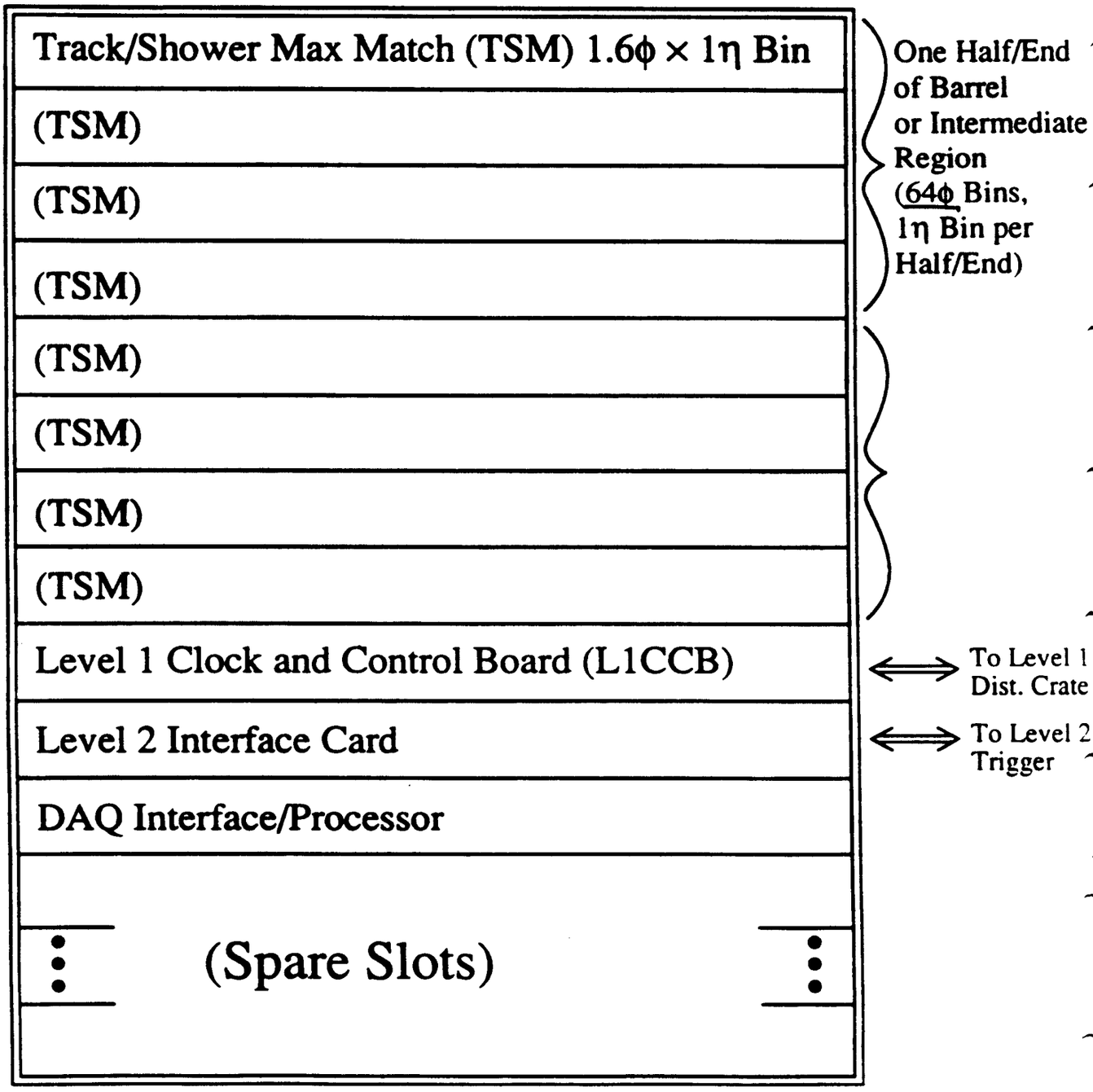
Electrons: Pattern Logic using .1x.1 Towers to do H/E + Isolation (and track match) has a high efficiency and understandable performance when compared with a full offline analysis using .05x.05 em towers.

An 8-bit nonlinear scale gives good performance ⇒ no support for high resolution linear scal.

Simplified Tracking / Shower Max trigger

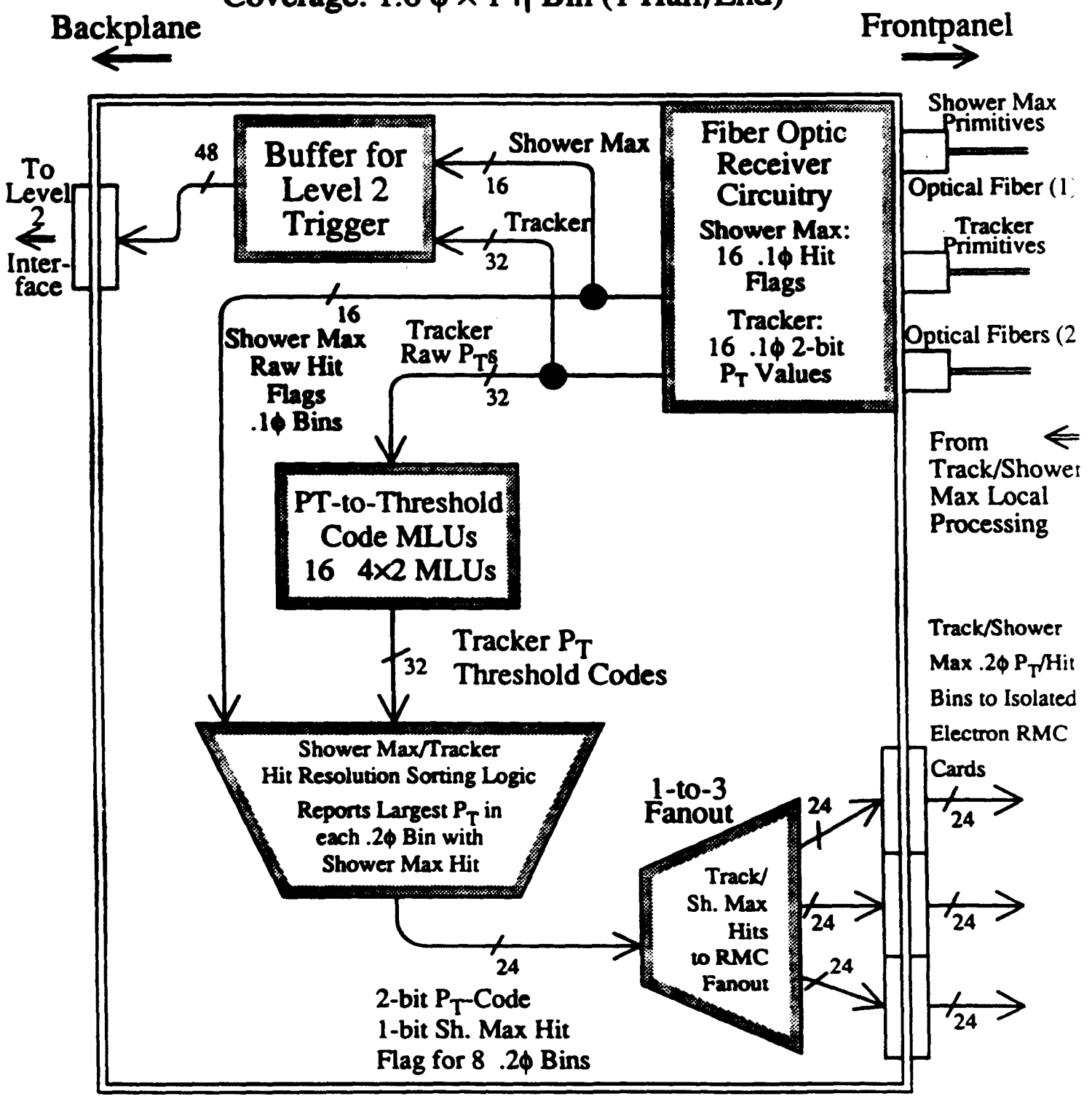
# Tracker/Shower Max Match Crate

**Number of Crates: 1 Barrel, 1 Intermediate**
**Coverage: 6.4$\phi$ × 2$\eta$ Bins (2 Halves/Ends)**



# Track/Shower Max Hit Card
# (TSM Card)

**Coverage: 1.6 $\phi \times 1\ \eta$ Bin (1 Half/End)**



$P_t$ TURN ON

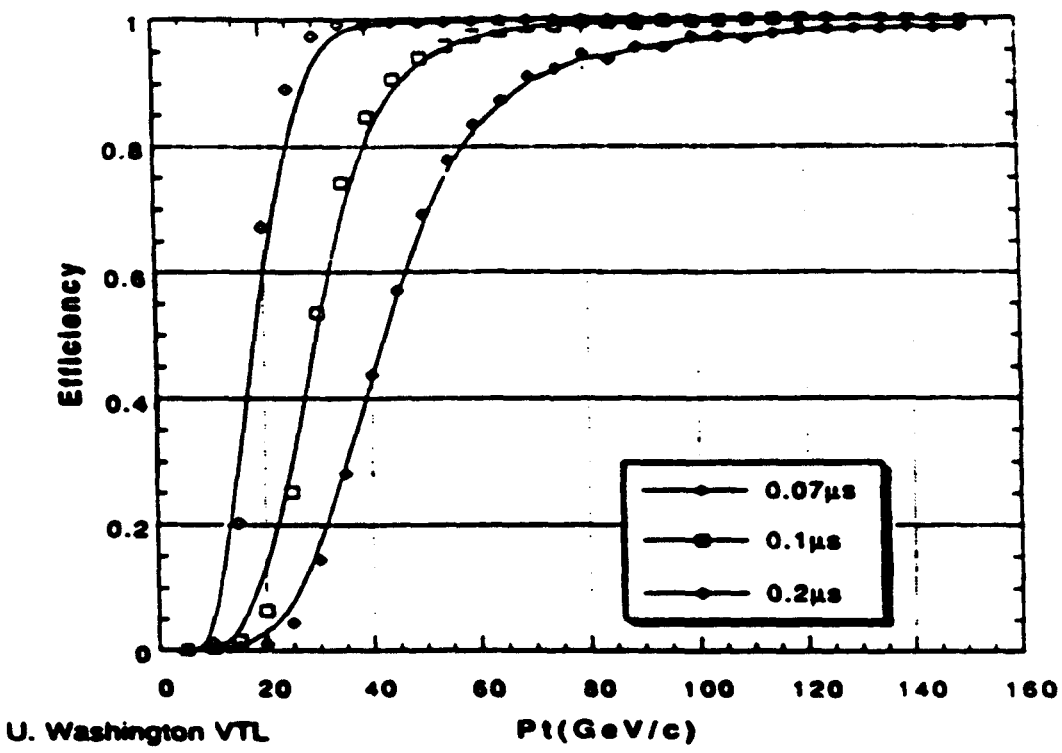



**Figure 5.7. Trigger efficiency vs $P_t$ assuming a non-linear x-t correlation.**

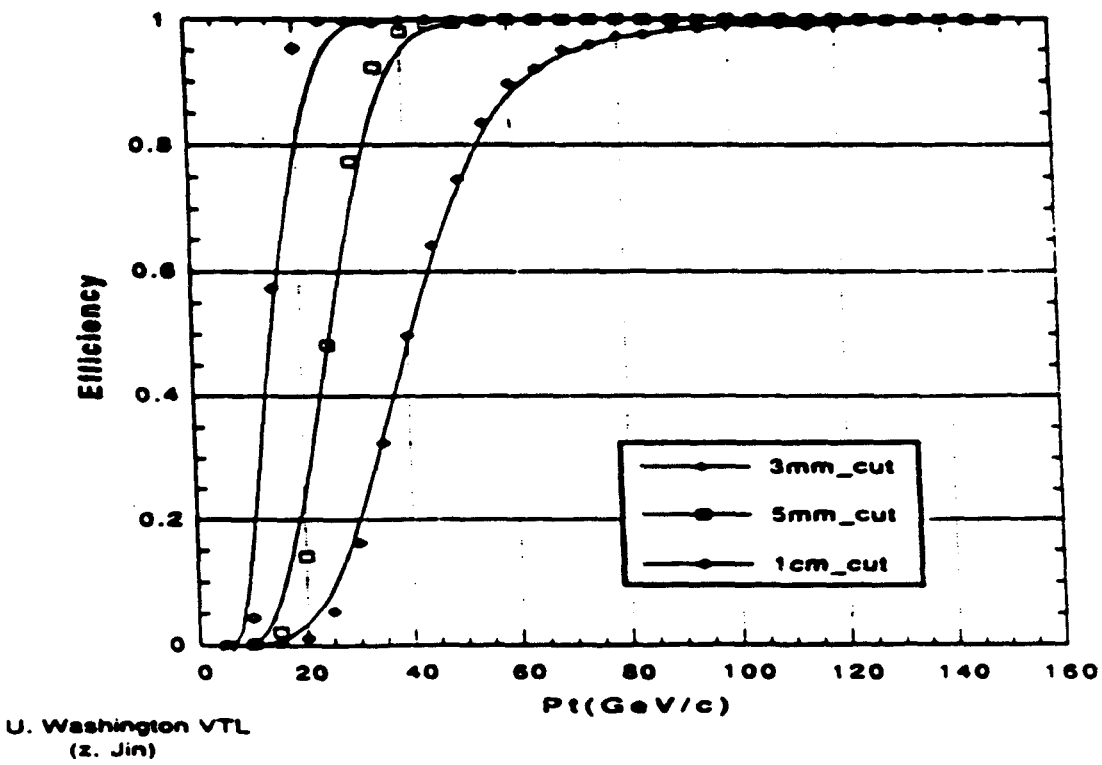
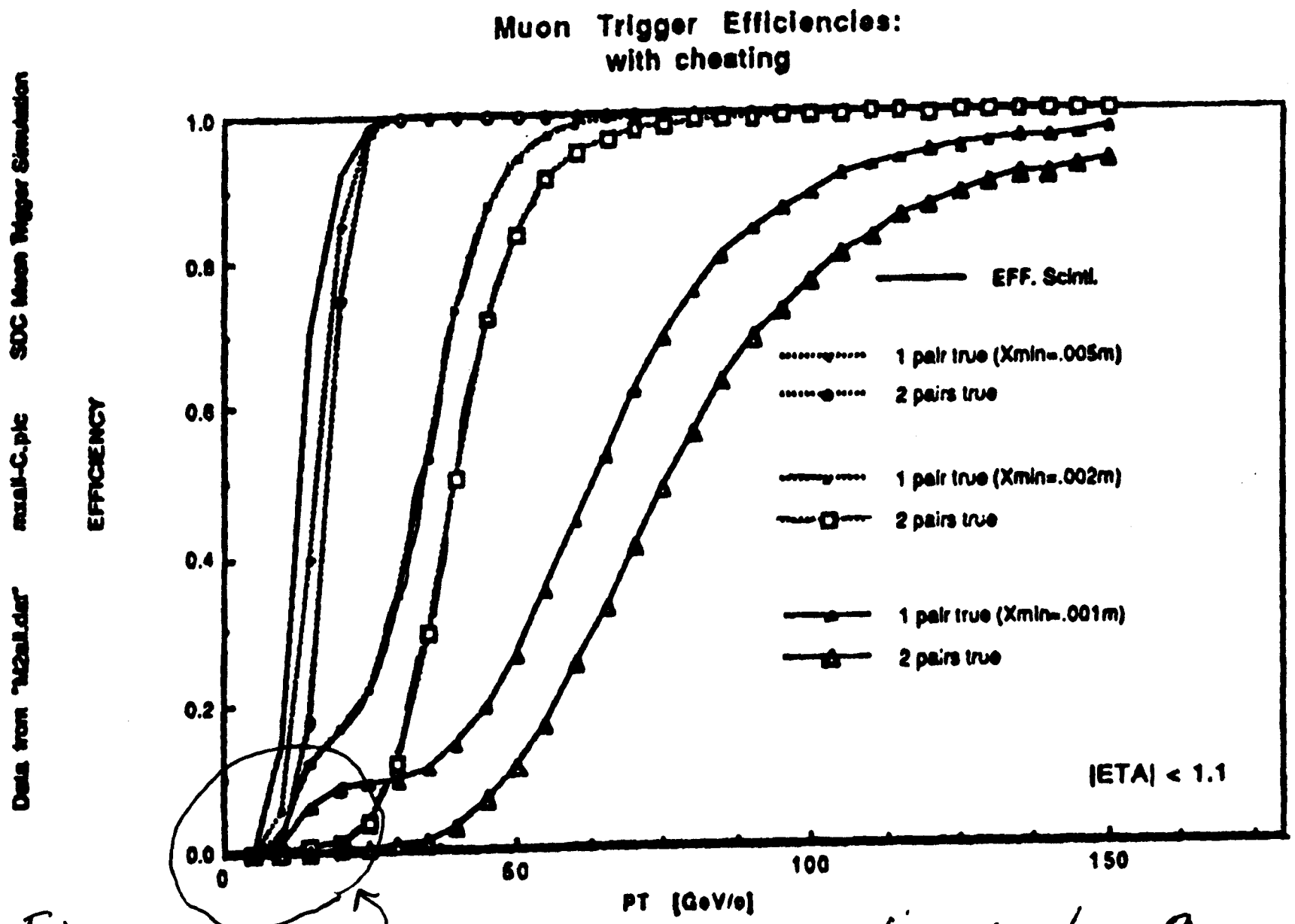



**Figure 5.8. Trigger efficiency vs $P_t$ assuming a linear x-t correlation.**

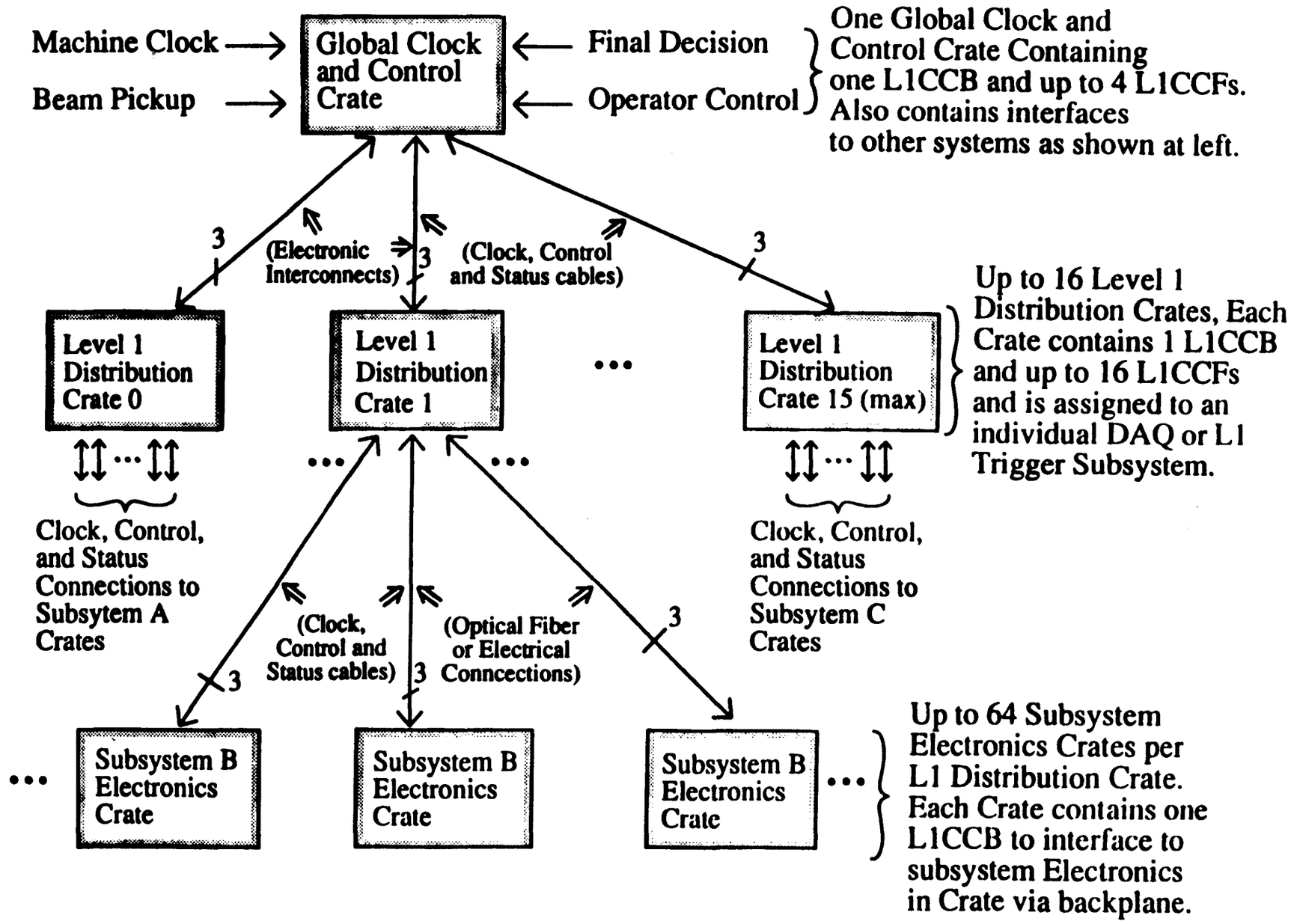



Fold against exponential tail!

Need for 2 OR MORE pairs.

Fig. 10

when demanding:


Machine Clock
Beam Pickup
Global Clock and Control Crate
Final Decision
Operator Control
One Global Clock and Control Crate Containing one L1CCB and up to 4 L1CCFs. Also contains interfaces to other systems as shown at left.
3
(Electronic Interconnects)
3
(Clock, Control and Status cables)
3
Level 1 Distribution Crate 0
Level 1 Distribution Crate 1
Level 1 Distribution Crate 15 (max)
Up to 16 Level 1 Distribution Crates, Each Crate contains 1 L1CCB and up to 16 L1CCFs and is assigned to an individual DAQ or L1 Trigger Subsystem.
Clock, Control, and Status Connections to Subsytem A Crates
Clock, Control, and Status Connections to Subsytem C Crates
(Clock, Control and Status cables)
3
(Optical Fiber or Electrical Conncections)
3
3
Subsystem B Electronics Crate
Subsystem B Electronics Crate
Subsystem B Electronics Crate
Up to 64 Subsystem Electronics Crates per L1 Distribution Crate. Each Crate contains one L1CCB to interface to subsystem Electronics in Crate via backplane.

# Level 1 Clock and Control Distribution
# Hardware Configuration for Pipeline Length Calculations

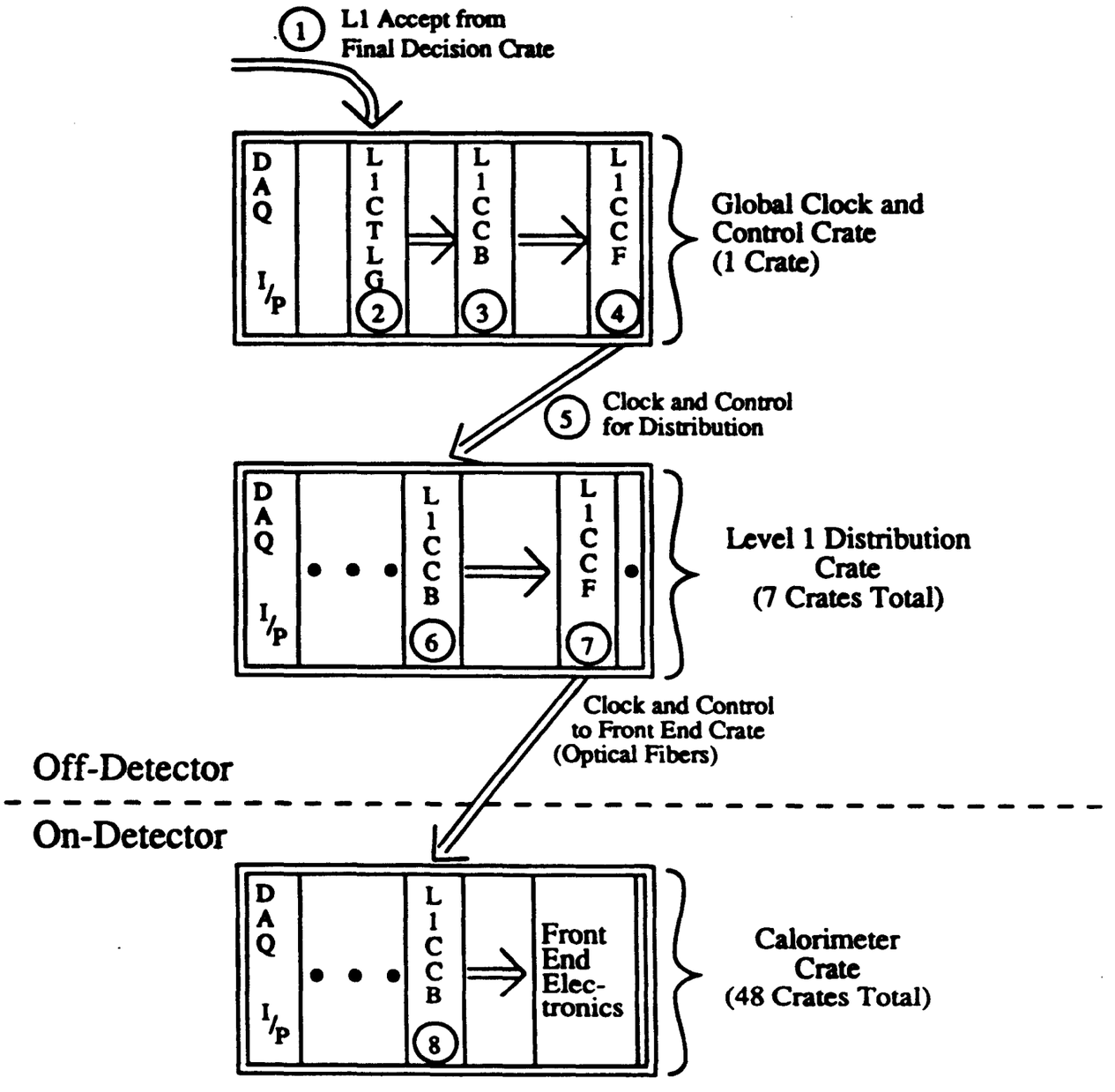



Figure 6

Initial Conclusions from Muon Trigger Studies:

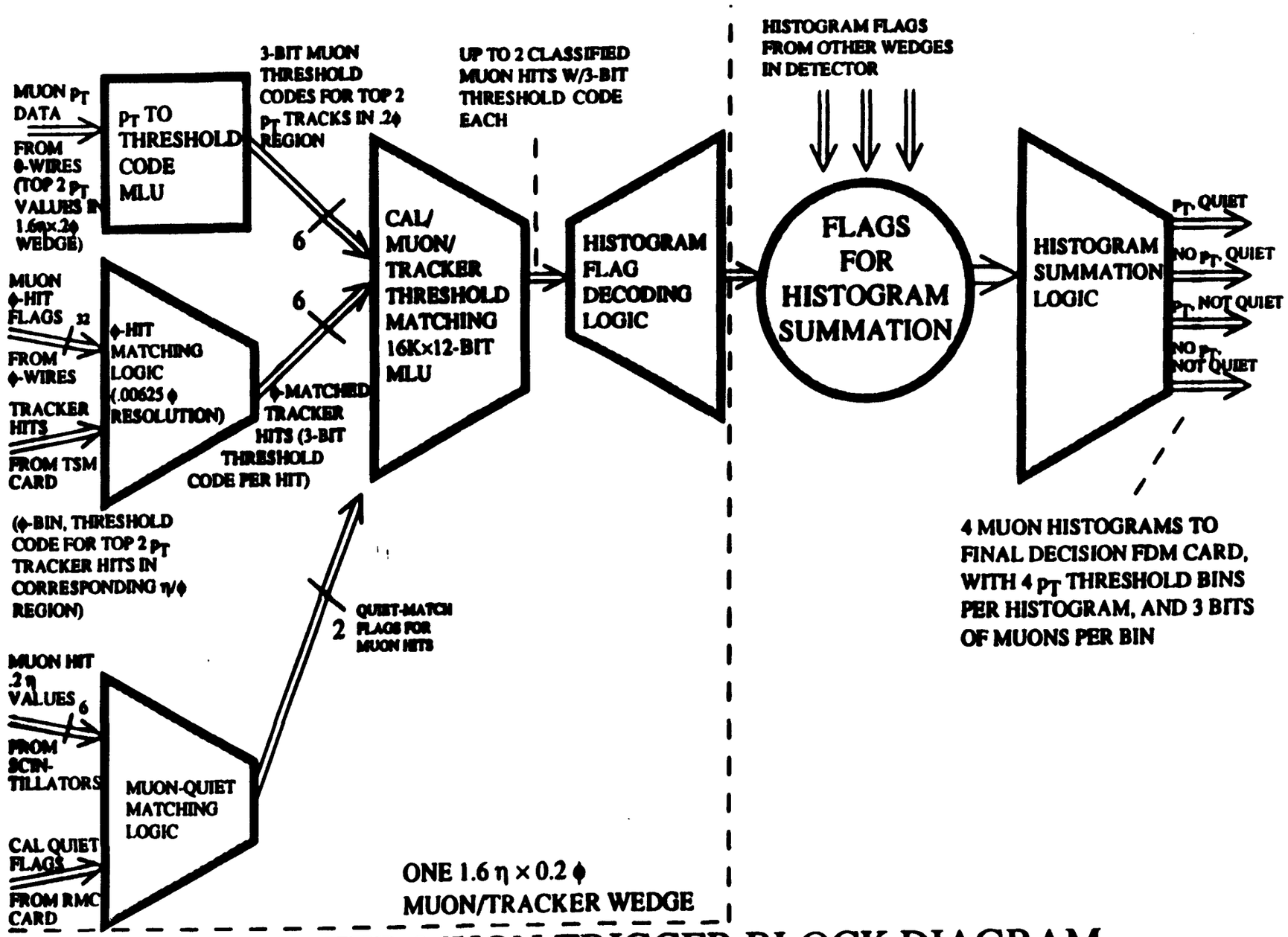
For a $P_T$ cut of $\sim$ 15 GeV @ $10^{33}$

Trigger Rate $\sim$ 4 - 8 kHz

using pairs + Linking (of BW2 + BW3)

However, this linking is simple ($\theta$ only)

Explore option to use tracker $P_T$ linked to muon $\phi$.




CORRELATED MUON TRIGGER BLOCK DIAGRAM

Figure 1

# Correlated Muon Trigger
# Muon and Tracker Data Paths
# Hardware Configuration for Pipeline Length Calculations

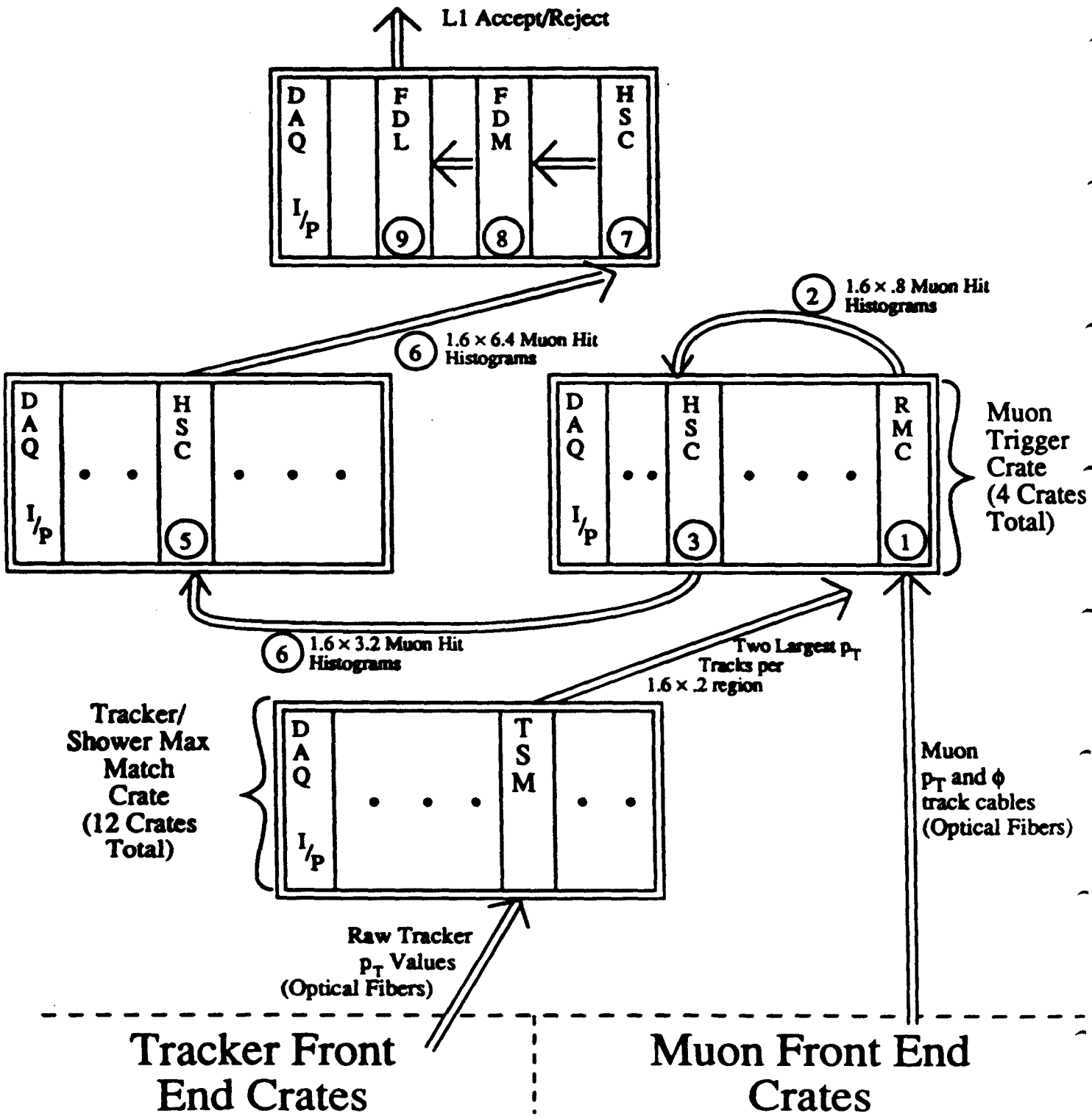



Figure 5

# Level 2 Logic

## Strategy

- Identify and isolate the different building blocks and their interfaces.
- Be sure that ALL necessary signals and primitives will be available
  ↳ $\boxed{\eta, \phi \text{ map}}$
  Coherent!

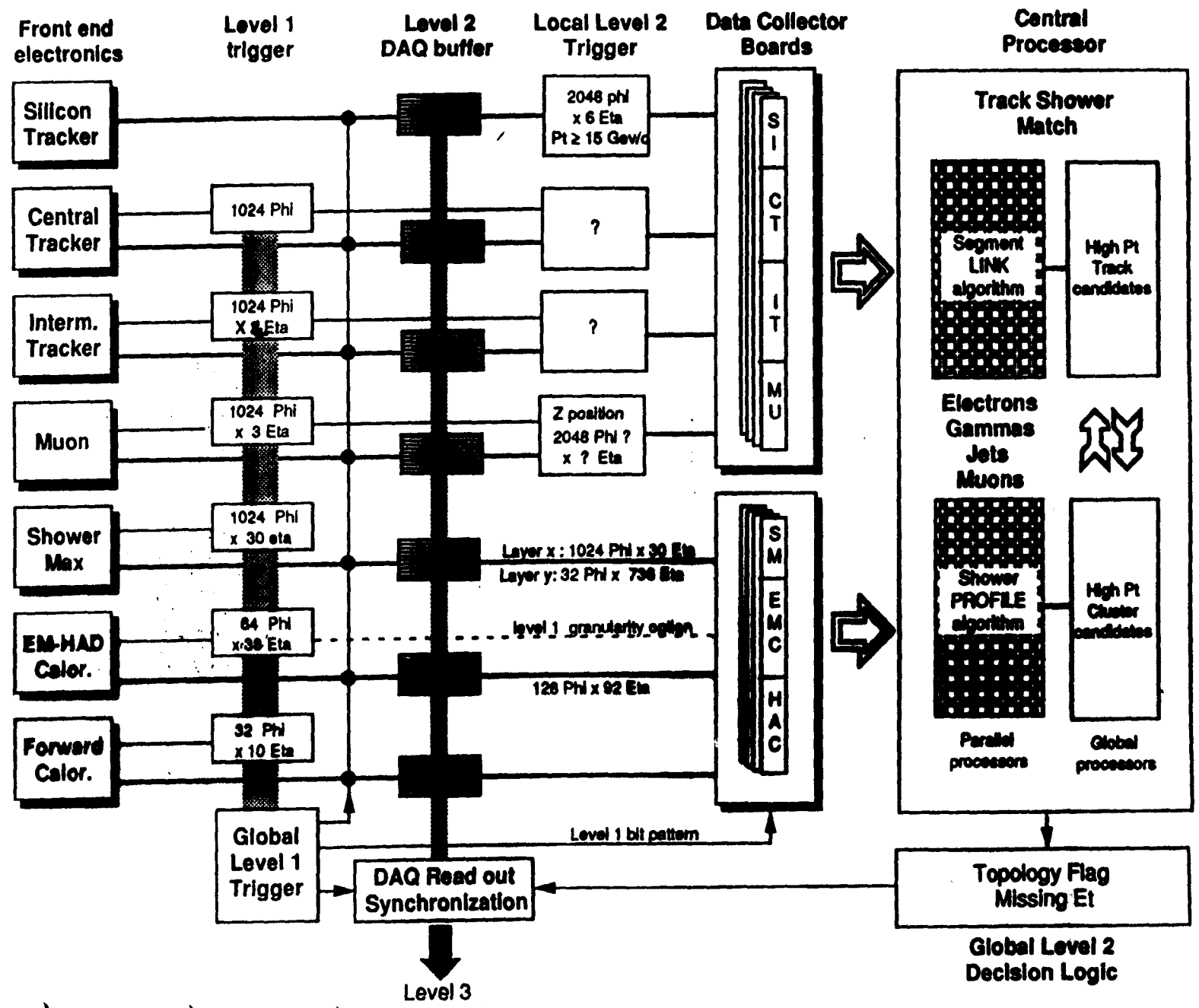
## Input Signals

- Level 1 primitives and results.
- Digitized data (after level 1)
  ↳ $\boxed{\text{common L2T-DAQ buffer}}$
  ↳ DAQ design!

## Algorithms and Logistic

- Extract primitives in "Local" processors.
  - track segments, $p_T$...
  - Track-segment linking
  - shower profile (SMD centroid)
- Global correlation in a common $\eta, \phi$ map.
  - Shower-Track match
  - Energy sum
  - Topology.

# SDC LEVEL 2 TRIGGER LOGIC



# Contributions to L1 Inclusive Electron Rate

| Type | (%) Loose Cuts | (%) Tight Cuts |
|---|---|---|
| Overlap (btw $\gamma$ + chd hadron) | 25 | 20 |
| Conversion | 42 | 57 |
| Early Shower (of hadron in em) | 21 | 13 |
| Overlap/Conv (together) | 11 | 10 |

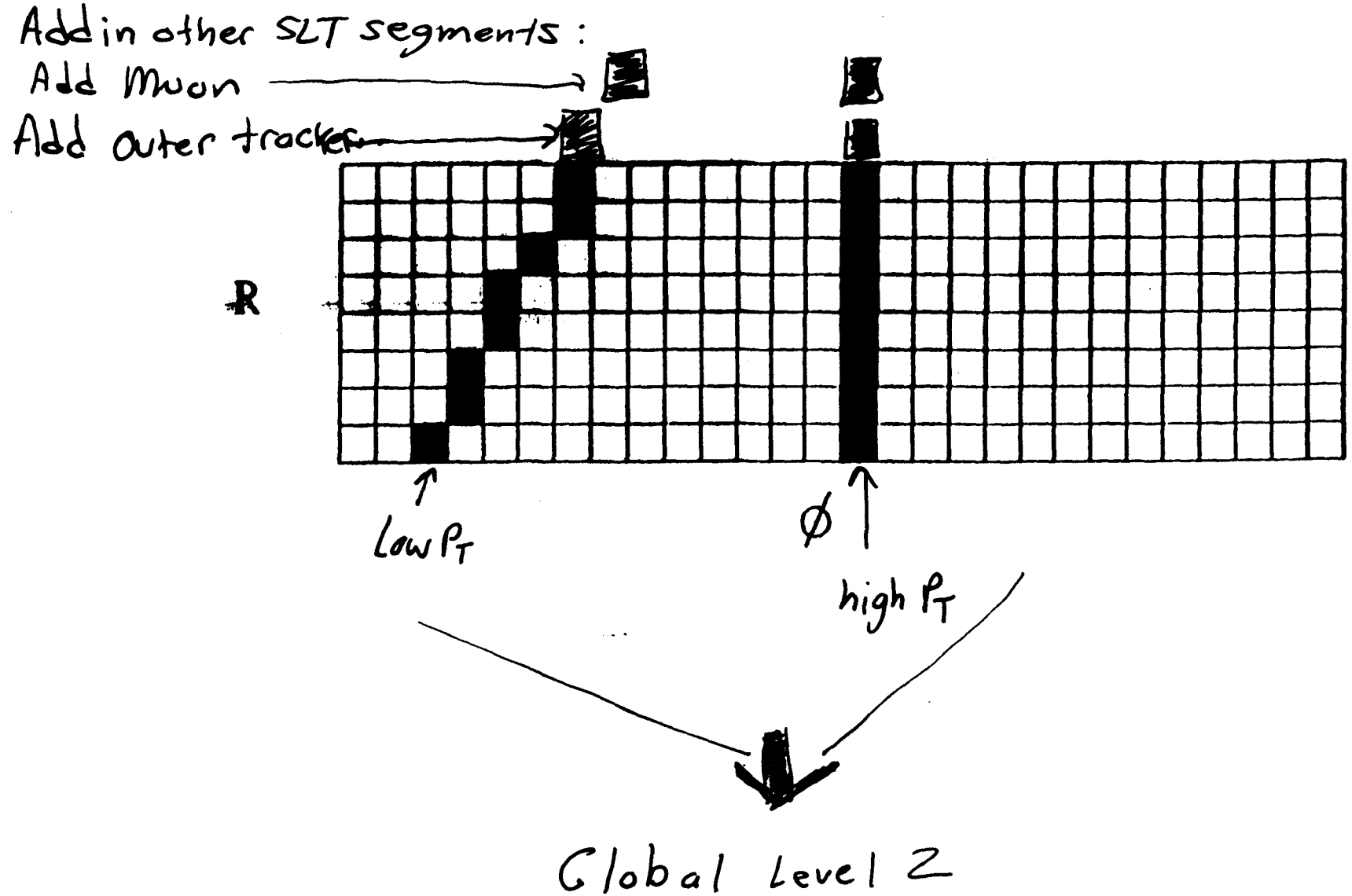
| Cut | Loose | Tight |
|---|---|---|
| HAC/EM | $<0.1$ | $<0.05$ |
| Track $P_T$ | 5 GeV/c | 5 GeV/c |
| Cluster $E_T$ | $>10$ GeV | $>10$ GeV |
| Isolation | $<0.1$ | $<0.07$ |

(G. Sullivan + M. Miller)

# Silicon Second Level Trigger

B. Foster, Bristol

Create Histogram in R-Ø space



| Item | Cost (K$) | Conting (K$) | Total (K$) |
|---|---|---|---|
| Level 1: | 17,772 | 6,082 | 23,854 |
| Track | 4,466 | 1,567 | 6,034 |
| Calorimeter | 4,871 | 1,583 | 6,455 |
| Muon | 3,892 | 1,407 | 5,299 |
| Silicon | 128 | 37 | 165 |
| Global | 2,148 | 721 | 2,869 |
| Level 2: | 6,429 | 1,864 | 8,294 |
| Track | 315 | 91 | 406 |
| Calorimeter | 435 | 126 | 561 |
| Muon | 255 | 74 | 329 |
| Silicon | 2,819 | 818 | 3,637 |
| Global | 2,605 | 756 | 3,360 |
| Proj. Manag. | 552 | 160 | 712 |
| Total | 24,753 | 8,107 | 32,861 |

OLD

# Reductions in Trigger Cost

## Tentative

Simplified Track / sh. Mx. Trigger $\Delta = -4.04M$

Simplified Muon Linking $\Delta = -2.66M$

(incl. Contingency)

$\Rightarrow$ New Trigger Cost = 25.6 M

(L1 + L2 + Conting.)

Note:

Correlated Muon Trigger Eliminates these savings + costs 0.5 M more

# Trigger Conclusions

We have developed a baseline design that

1. Shows we can trigger the SDC detector
2. Provides a preliminary list of what is needed from front ends
3. Has determined the overall cost and scope of the trigger
4. Will serve as the basis for further system optimization

What's Next:

Detailed $\eta$-$\phi$ maps of subsystem detectors and front end electronics (boards/cra

Simulation studies with parameterizations of subsystem detector performance

PRESENTATION BY:

KEVIN EINSWEILER

KFE 1/31/92

Einsweiler
Sat am

# Status of Physics Section

## Overview:

- survey relevant physics, isolate most demanding aspects ⇒ detector requirements

- understanding of "relevant physics" may change over next decade ⇒ address general capabilities

- make simple detector models to get at essentials
  ⇒ detailed simulations in detector section

- use parametrizations of baseline detector, vary to demonstrate performance implications

# Model of Detector :

Tracking : resolution parametrization
received 1/28 debugged 1/30

8 Si layers, 4 Straw layers
+ ITD (SciFi results ~ same

$\frac{\Delta p_T}{p_T}$ ~ 15% for 1 TeV in Barrel

Calorimeter :

- coverage $|\eta| < 6$, EM/HAD1/HAD2
- segmentation = multiples of 0.05
  ($\Delta\phi \Rightarrow 2\pi/128 \sim .049$ ...)
- Barrel / Endcap transition $\eta = 1.4$
- Endcap / Forward transition $\eta = 3.2$
- no cracks, non-uniformities,
- resolutions & non-linearities
  from CALOR89 ...
- shower parametrizations (~ from ZEUS

Muons : ???

From: CSA::EINSWEILER 15-JAN-1992 15:47:55.01
To: @CALO.DIS
CC: EINSWEILER
Subj: Calorimeter Performance for the Proposal

Gentlemen,

In the absence of any better results from the calorimeter group, I am planning to start a number of simulation runs with the following parametrization of the baseline calorimeter :

1) EM resolution

Barrel .14/sqrt(Et) + 0.01
Endcap .17/sqrt(El) + 0.01

These numbers ~~are based on a calculation by~~ Chris Hearty, and include the effect of a 400 photoelectons/GeV photo-statistics term (I believe this is Dan Green's official number). The radiator is assumed to be 4mm Pb in the Barrel and 6mm Pb in the Endcap. I have been 'conservative' and accepted a 1% constant term. I would prefer to use something better, but that is presumably unrealistic... (Of course the + means the two terms are added in quadrature).

2) HAD non-linearity : Chris Hearty's fits of the form a + b/E**c for the pi/e response ratio are being used. The values of ~~the parameters~~ were derived by Chris from Tom Handler's CALOR89 simulations of the Model B calorimeter that was considered as part of the absorber task force decision. The particular fits that I am using are for the case that one 'calibrates' at 300 GeV (i.e. pi/e is defined to be 1). The suggested parameters are :

Barrel : a = 1.132, b = -0.3073, c = 0.15
Endcap : a = 1.163, b = -0.3782, c = 0.15

3) HAD resolution : Again, these parameters were derived from Tom Handler's CALOR89 work. The functional form is

Barrel : .67/sqrt(Et) + 0.06
Endcap : .73/sqrt(El) + 0.08

I have asked Chris Hearty to get newer versions of these resolution functions for the current geometry (and different integration times, etc.) I suspect they will arrive too late to be useful... My bottom line is that in order to get through a large backlog of simulation jobs, I need to finalize these functions pretty soon (and I believe they will have to appear in the Overview sub-section of the Physics section), so it will look bad for us if the calorimeter section contains some different set of parameters...

So - please object violently now or forever (at least until April 1) rest in silence...

Kevin

## More Details:

### I) Electroweak Symmetry

a) Low Mass Higgs

i) Direct production : (Partridge)

- re-run Snowmass 88/90 plots using baseline resolutions (neglects jet backgrounds)
- discuss $z_{vtx}$ resolution effects

$\Rightarrow$ why SDC doesn't rely on this process ...

ii) Associated Production: (Einsweiler)

- combine $W+H$, $t\bar{t}+H$ ; $H \to \gamma\gamma$
  lepton tag $\Rightarrow$ provides trigger + $z_{vtx}$
  $\Rightarrow$ much better S/N ratio

- Kinematics + acceptance ($p_T$, $\eta$)
- lepton photon ID
- mass resolution
- backgrounds
- signal + significance

i) improved calorimeter simulation with real 'photon reconstruction'

⇒ use 2x2, 3x3 cell arrays in EM/HAD: to measure $\gamma$ energy

attempt to prove that in these complex events, can find $\gamma$'s and reconstruct mass to 1-2 $\sigma_0$

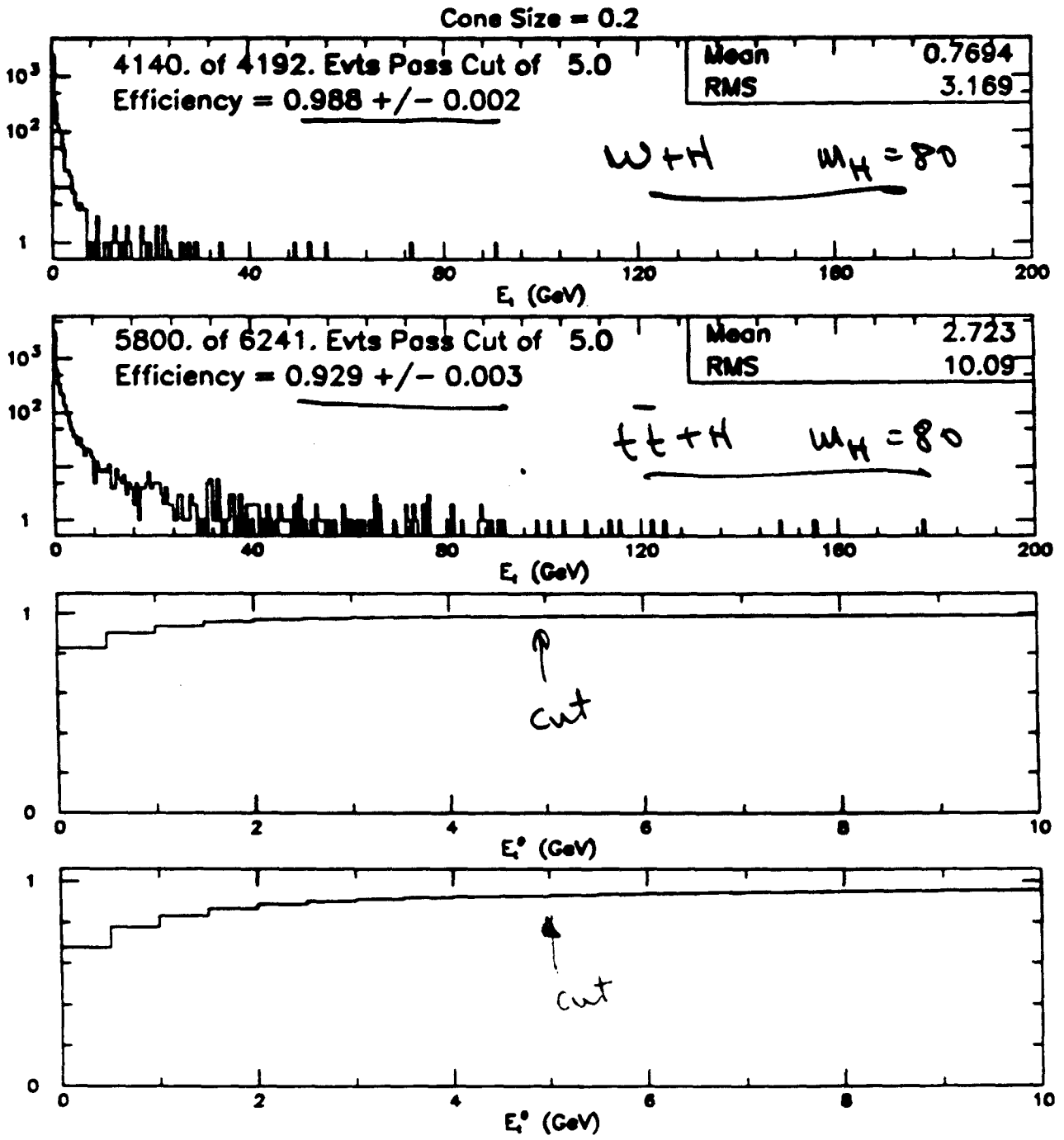
ii) extend background analysis to include: jet jet, $\gamma$ jet (in progress)

iii) significance analysis:

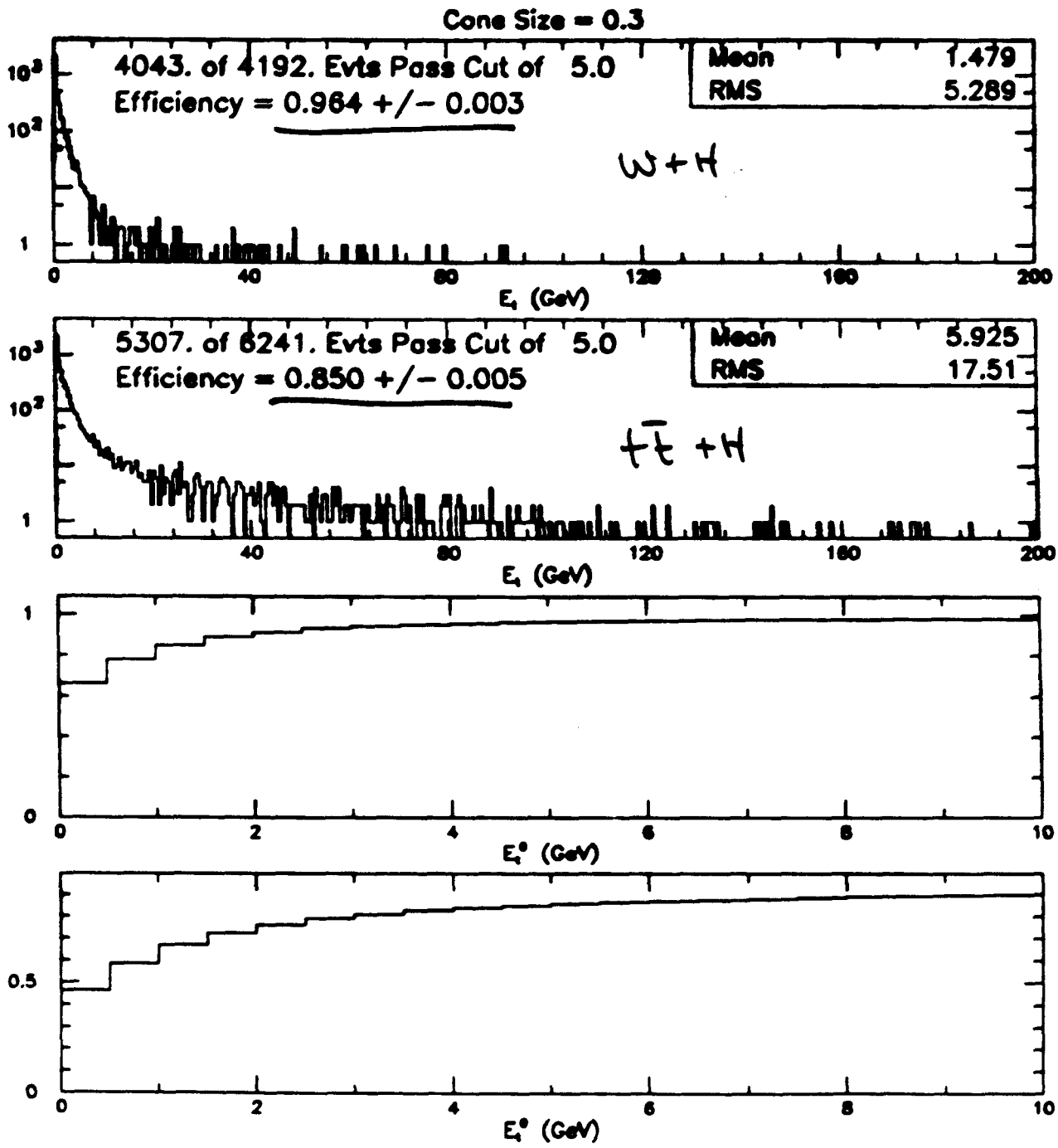
- include 7-5% stochastic case { 2 mm Pb + 6 mm Scint }
- fix bugs

Isolation Plots :

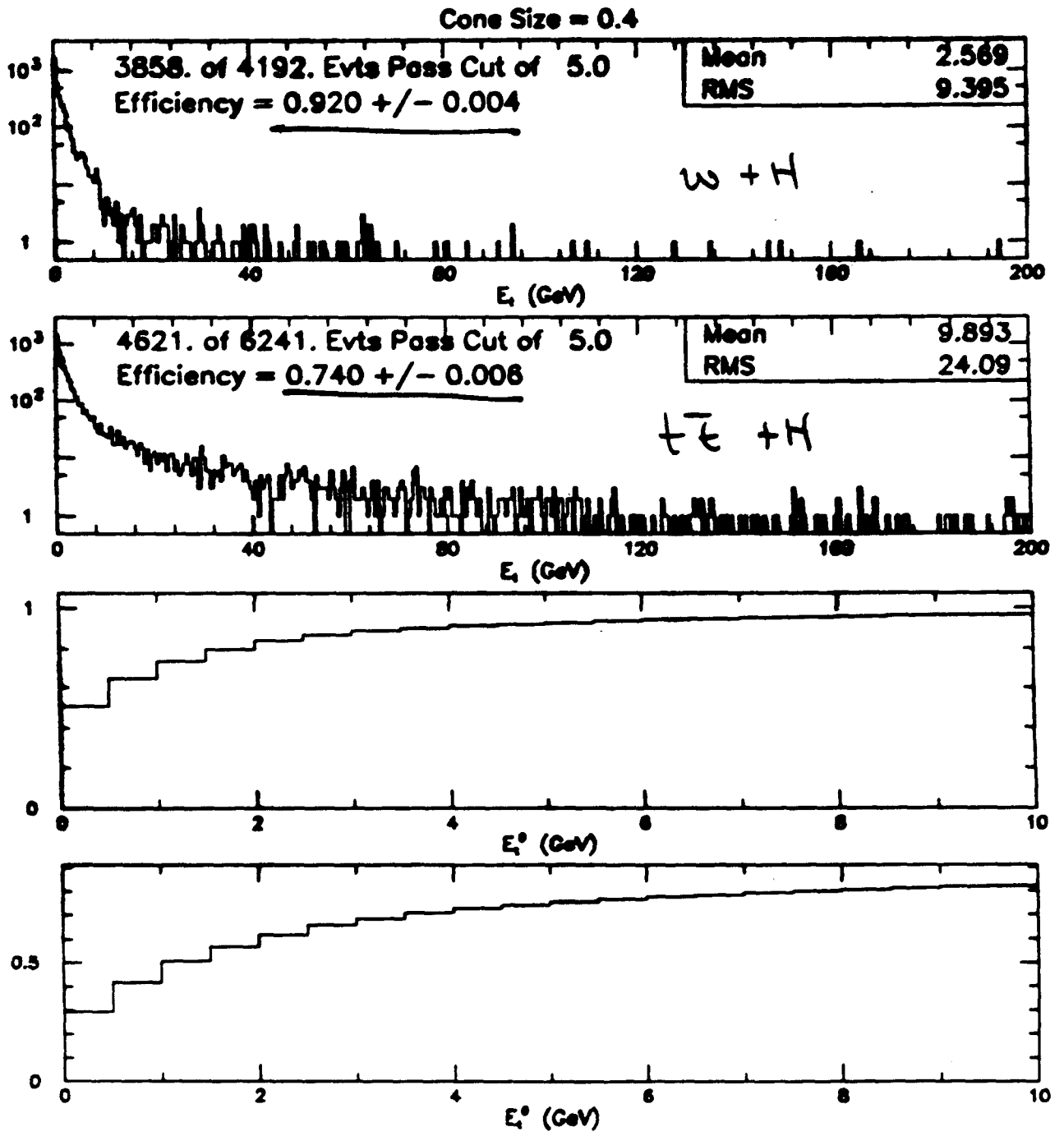
- $E_T$ in cone of $\Delta R = 0.2$ around $\gamma$
- $\gamma$ energy reconstructed from 2x2 area subtracted from cone



cone of $\Delta R = 0.3$



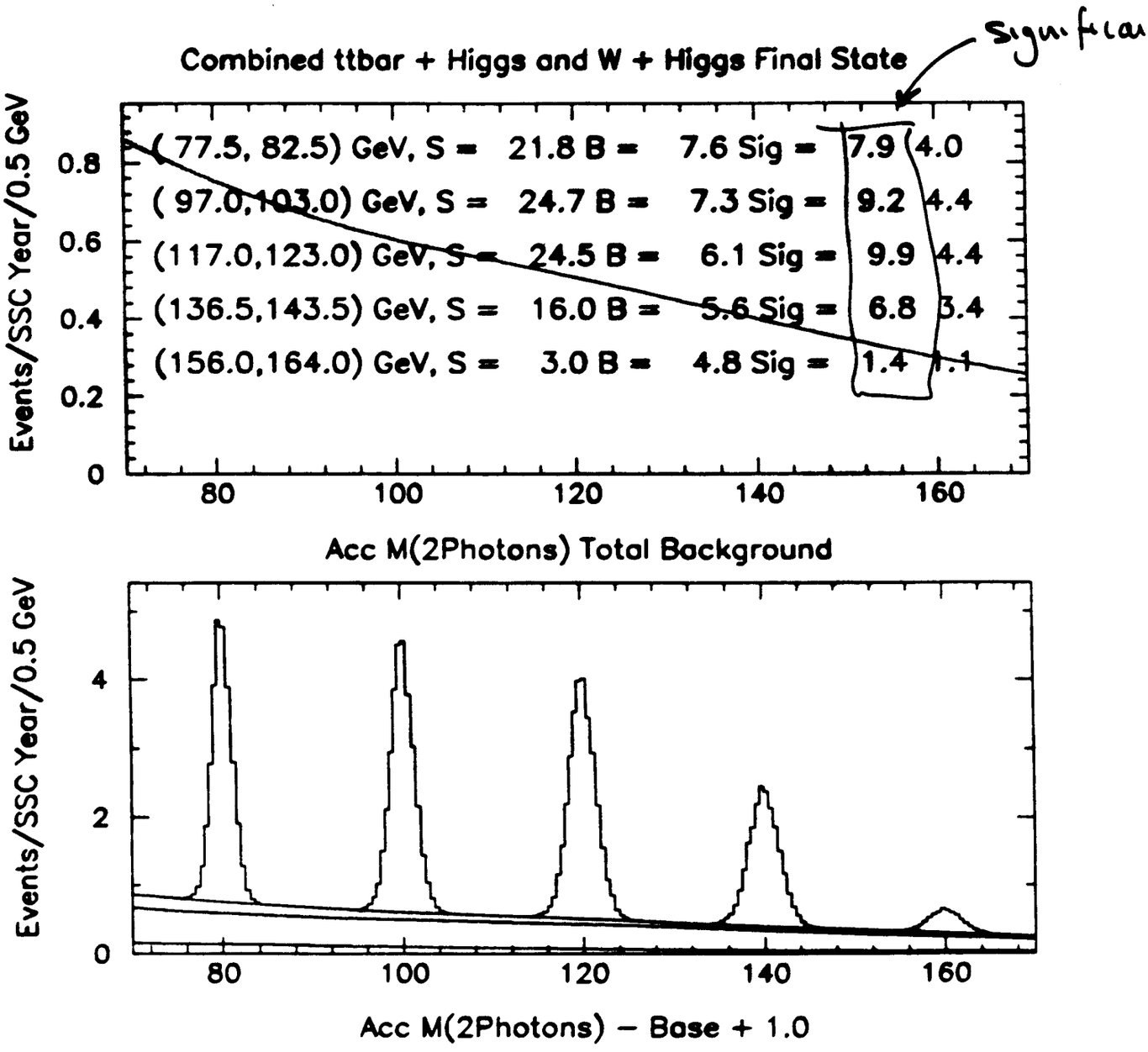
cone of $\Delta R = 0.4$



Typical Result

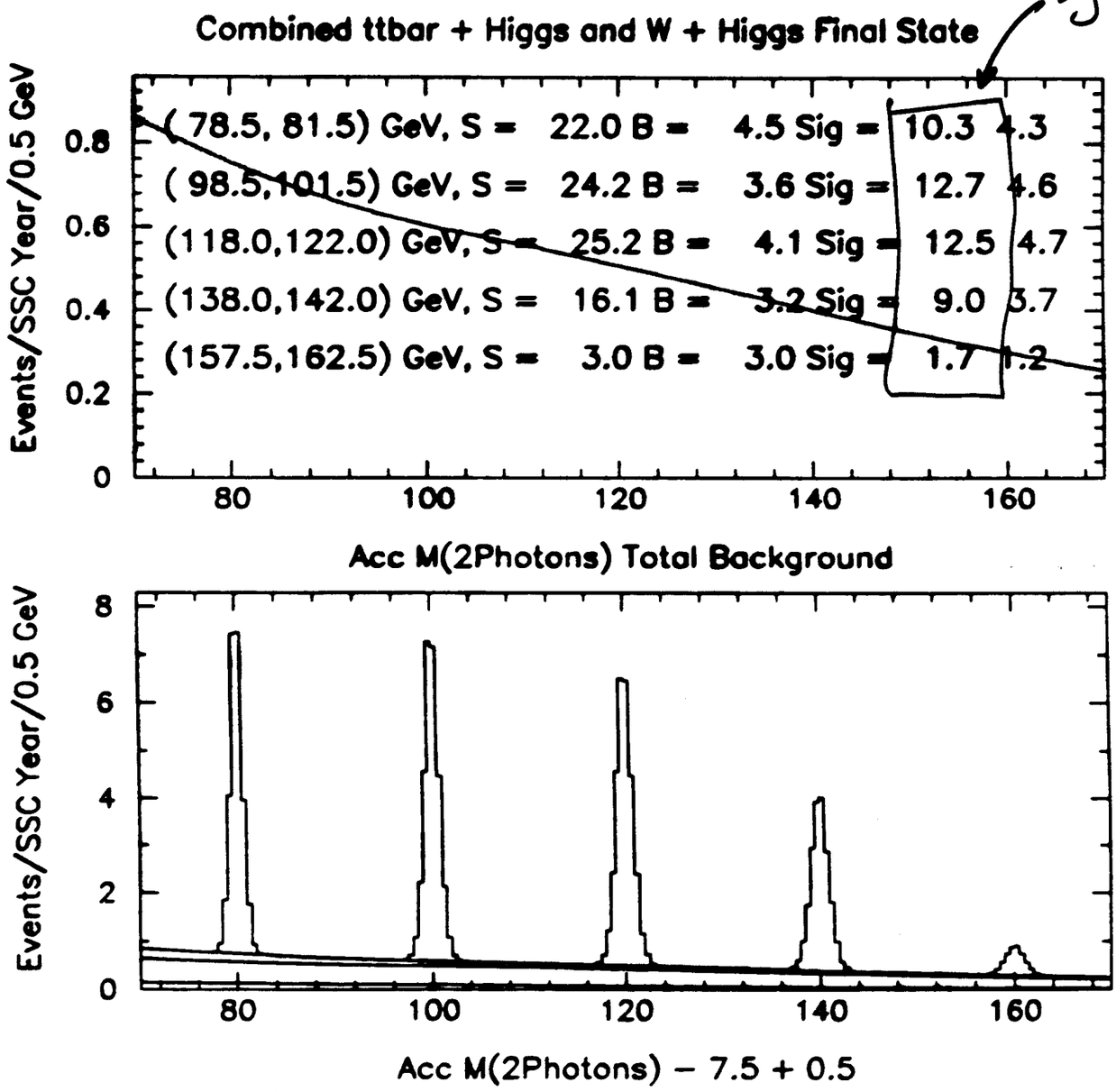
significance $\equiv \frac{S}{\sqrt{B}}$ in $\pm 2\sigma$ window

resolution = Baseline



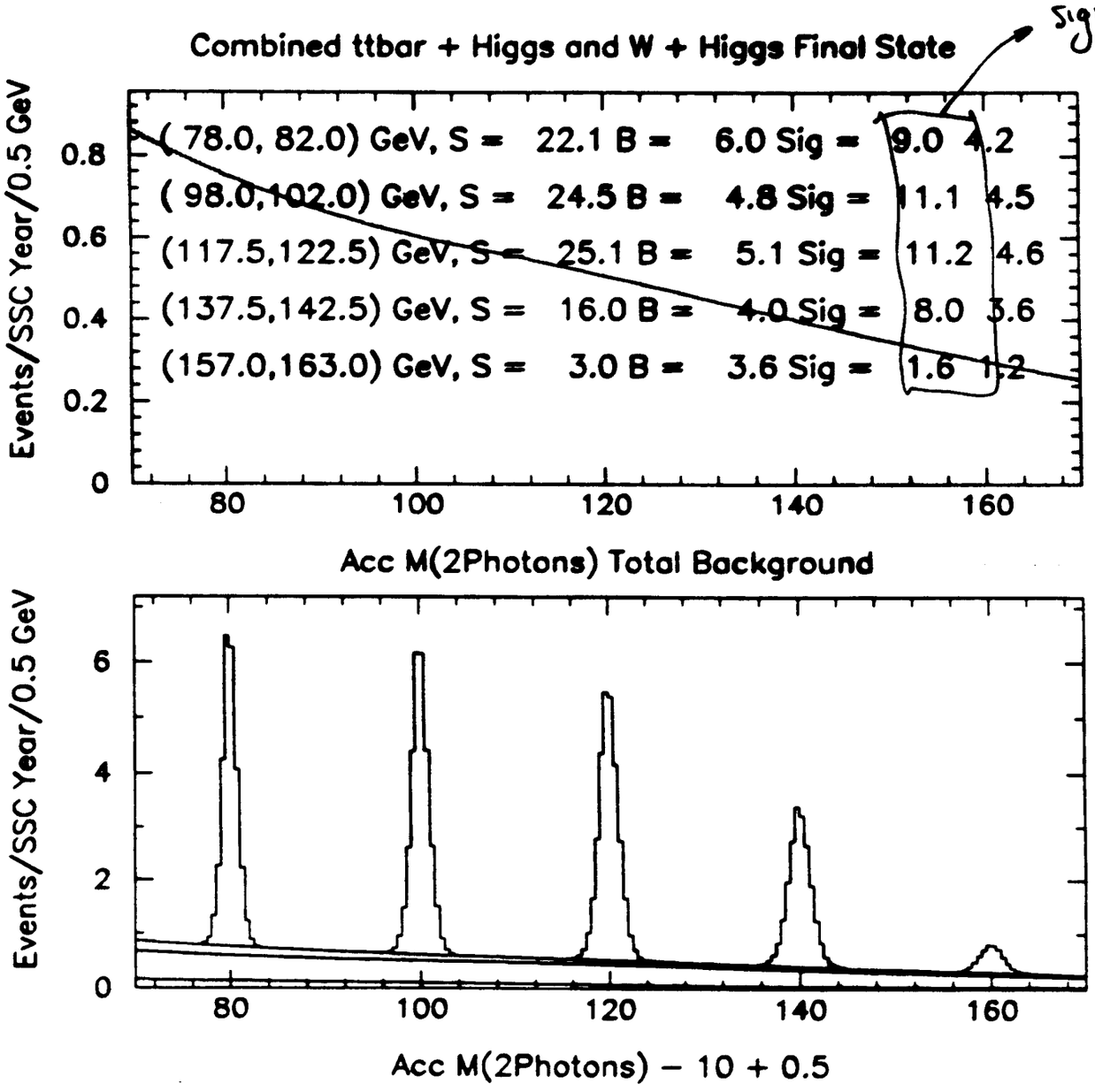
$$\text{resolution} = \frac{7.5\%}{\sqrt{E_T}} \oplus 0.5\%$$

significance



$$\text{resolution} = \frac{10\%}{\sqrt{E_T}} \oplus 0.5\%$$

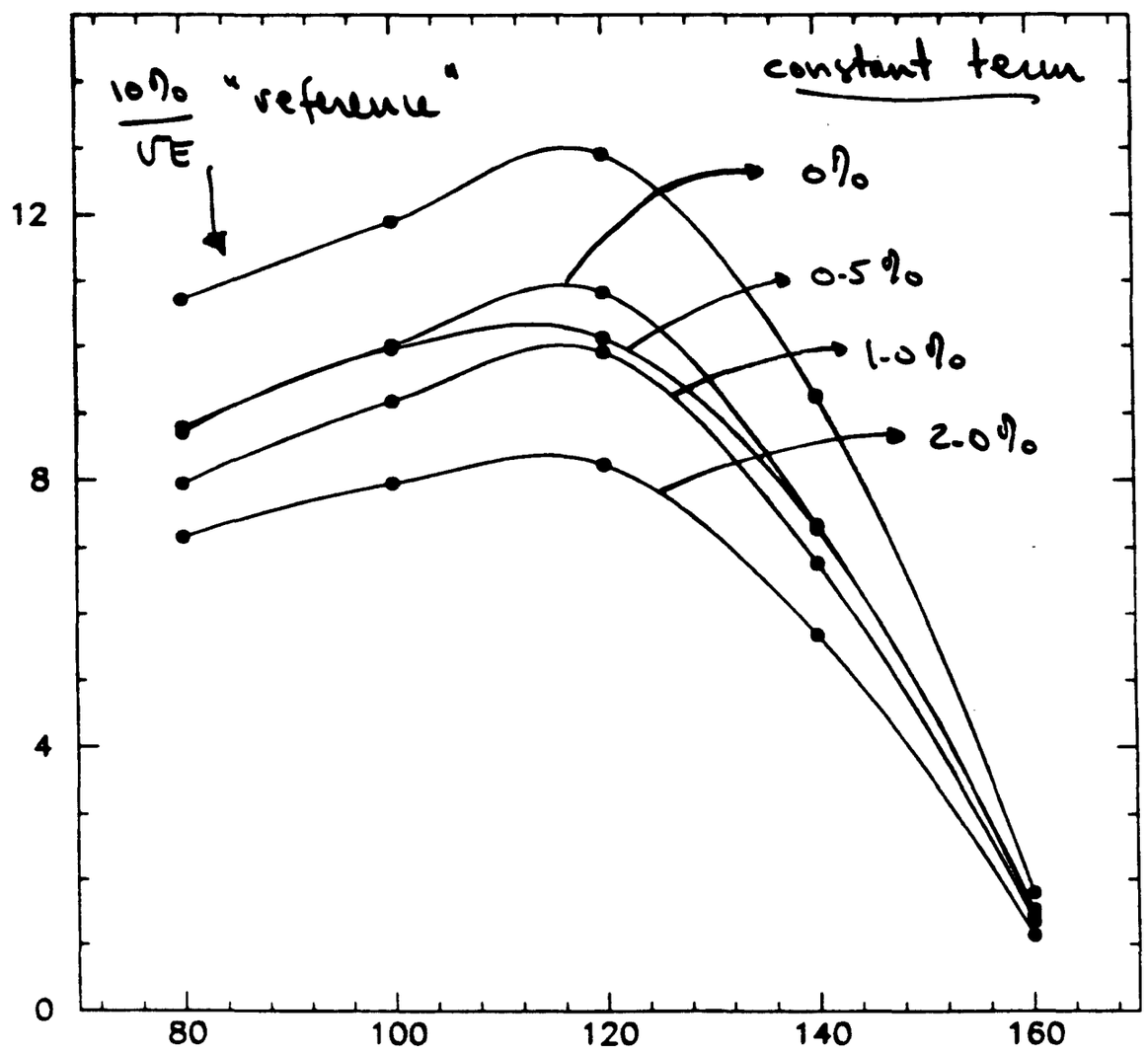
significance



significance vs $\begin{cases} \cdot\ m_H \\ \cdot\ \text{resolution} \end{cases}$

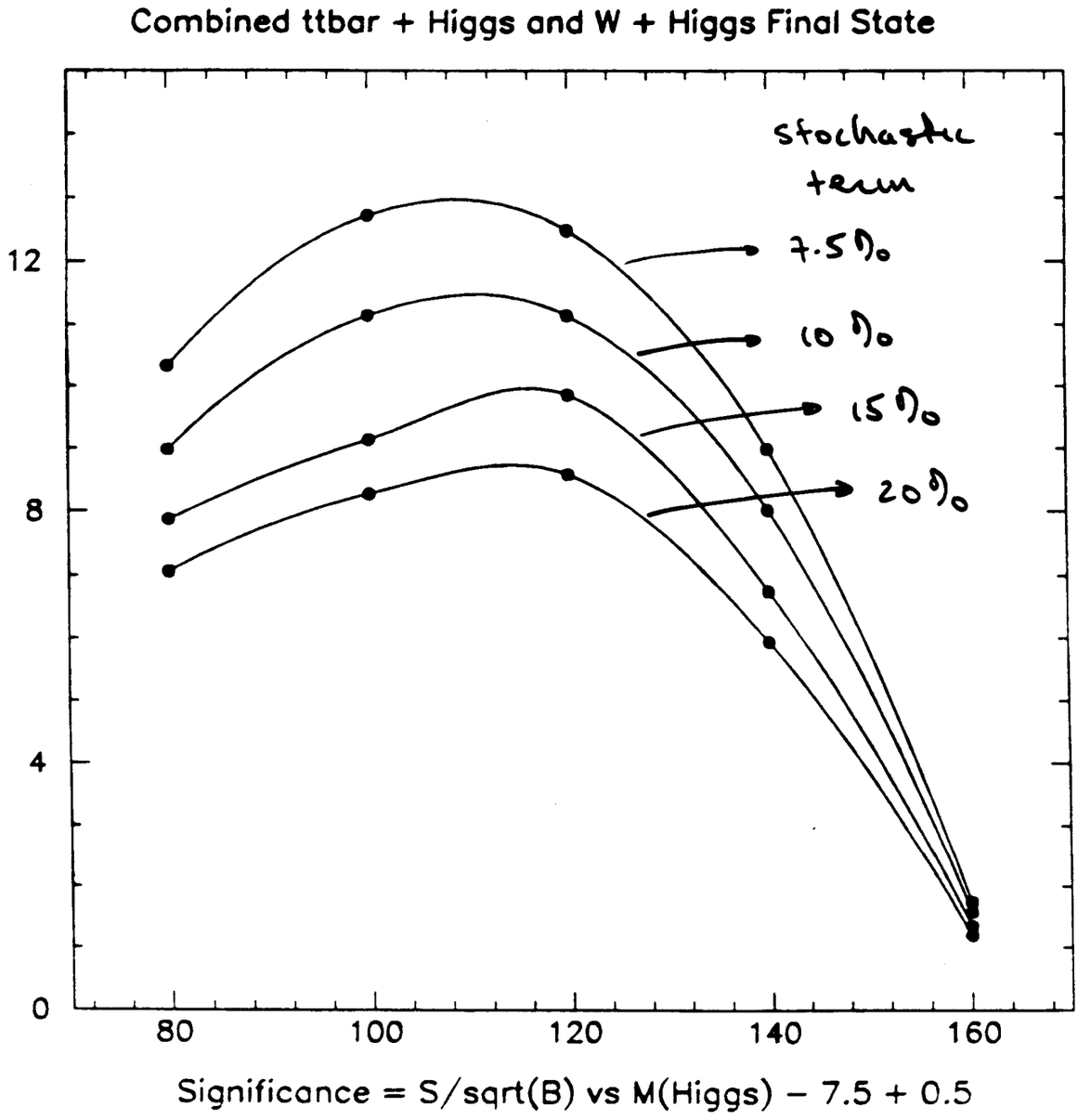
"Base" $\begin{cases} .14/\sqrt{E_T} & \text{Barrel} \\ .17/\sqrt{E_L} & \text{Endcap} \end{cases}$

**Combined ttbar + Higgs and W + Higgs Final State**

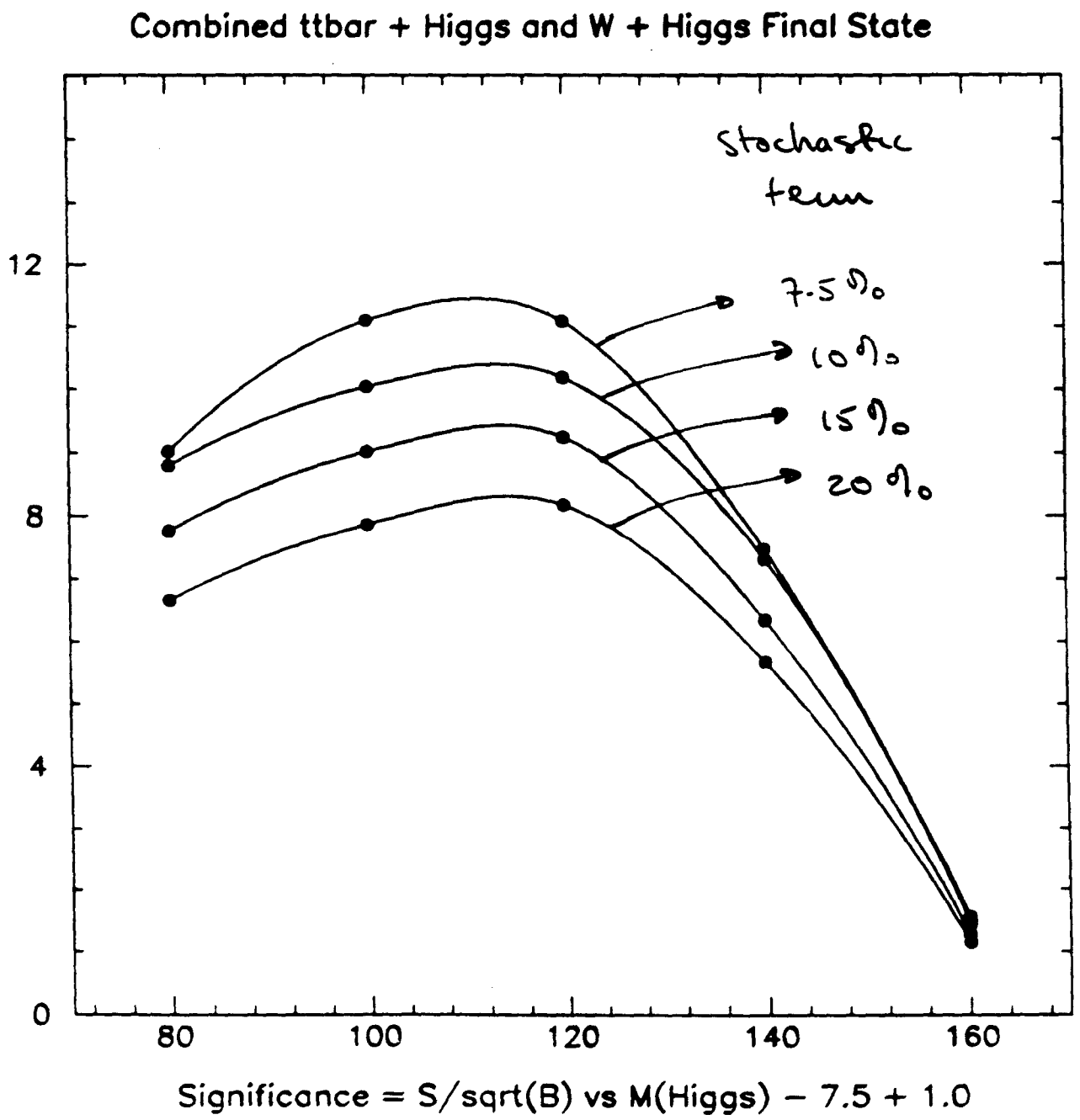



Significance = S/sqrt(B) vs M(Higgs) – Base + 0.0

resolution: constant term fixed = 0.5%



resolution : constant term
fixed = 1-0 %



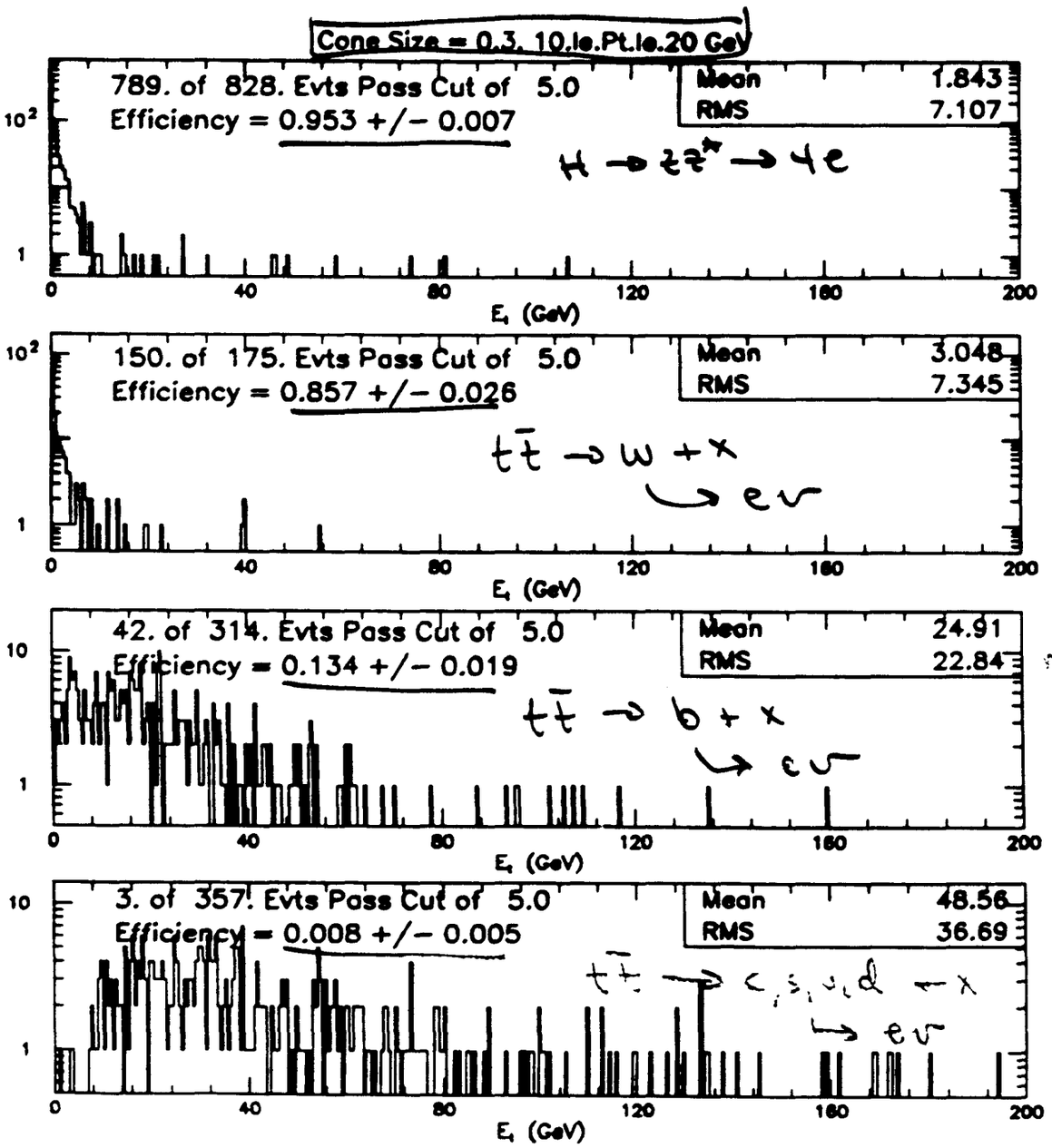
b) Intermediate Mass Higgs (Einsweiler)

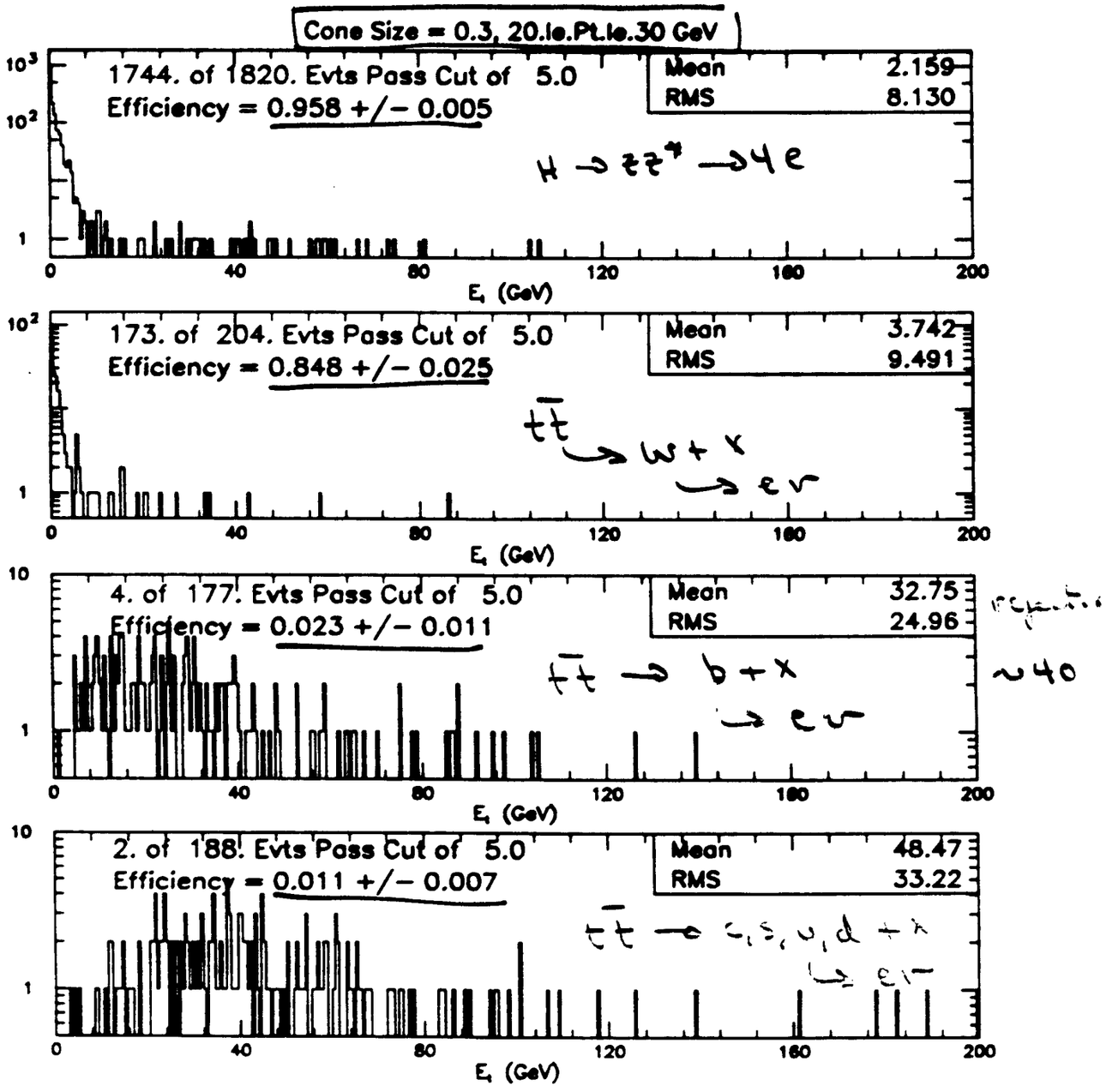
- kinematics + acceptance
- lepton ID + isolation
- mass resolution
- backgrounds
- signals & significance

i) isolation & mass resolution
uses better calorimeter simulation

ii) results on tracking resolution
for e, μ from K. O'Shaughnessy
(further work in progress)

Isolation effects for $\begin{cases} H \to ZZ^* \\ t\bar{t} \to \ell + x \end{cases}$




Cone Size = 0.3, 20.le.Pt.le.30 GeV
1744. of 1820. Evts Pass Cut of 5.0
Efficiency = 0.958 +/− 0.005
Mean 2.159
RMS 8.130
H → ZZ* → 4e
173. of 204. Evts Pass Cut of 5.0
Efficiency = 0.848 +/− 0.025
Mean 3.742
RMS 9.491
tt̄ → W + X
→ eν
4. of 177. Evts Pass Cut of 5.0
Efficiency = 0.023 +/− 0.011
Mean 32.75
RMS 24.96
tt̄ → b + X
→ eν
~40
2. of 188. Evts Pass Cut of 5.0
Efficiency = 0.011 +/− 0.007
Mean 48.47
RMS 33.22
tt̄ → c, s, u, d + X
→ eν
E_t (GeV)

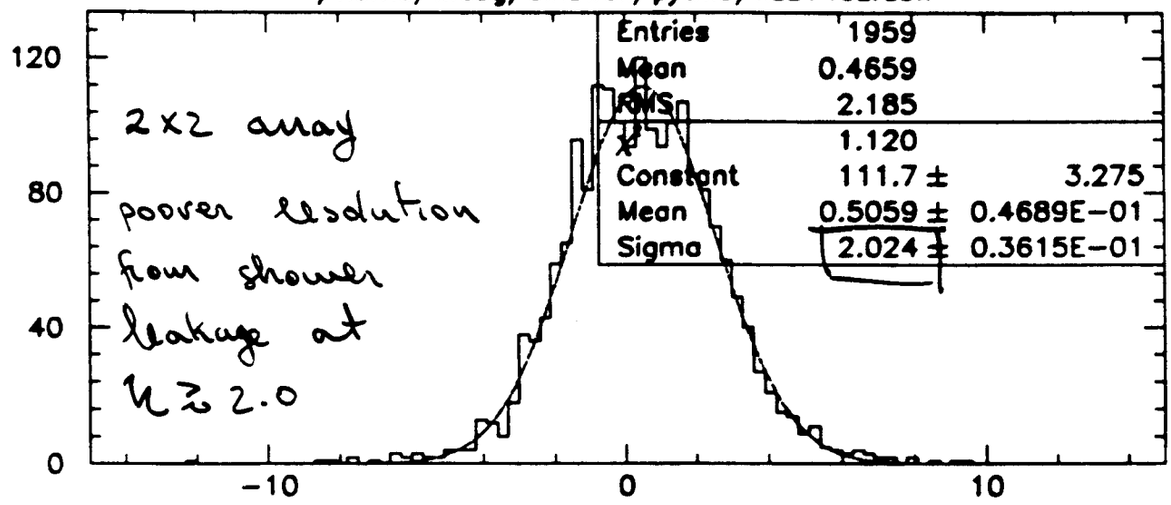
$H \to 4e$ mass resolution ($m_H = 140$)

.05 x .05 EM, HAD segmentation, $|\eta^\ell| < 2.5$

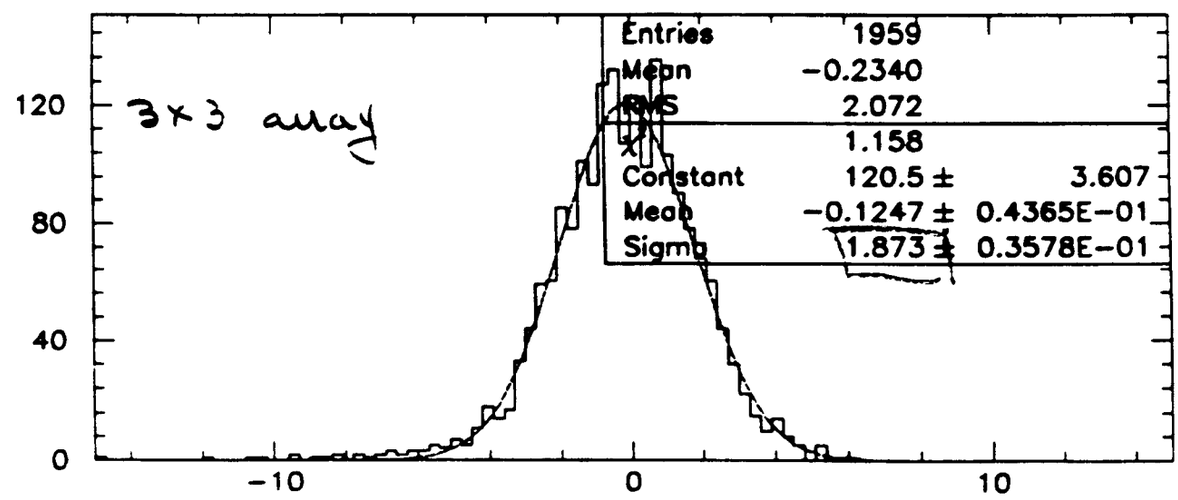
parametric resolution ~ 1.85 GeV

92/01/30 20.14

/home/kfesg/einsweil/pythia/hzz140zrsbx




M(4l) − M(4l) 2x2 Eta.le.2.5

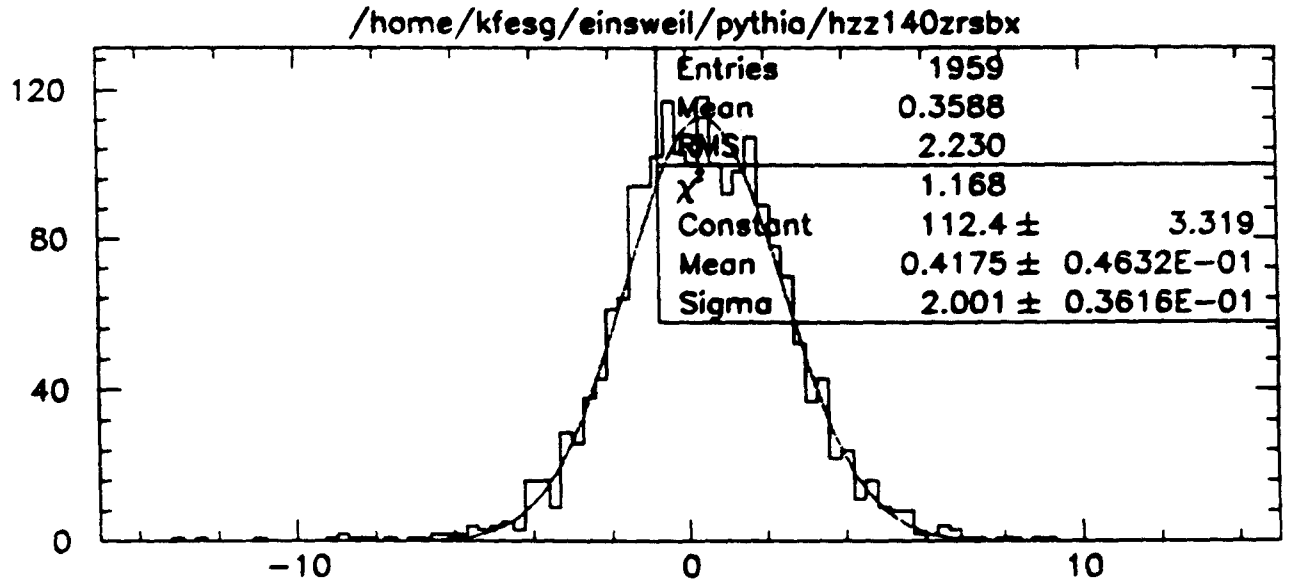



M(4l) − M(4l) 3x3 Eta.le.2.5

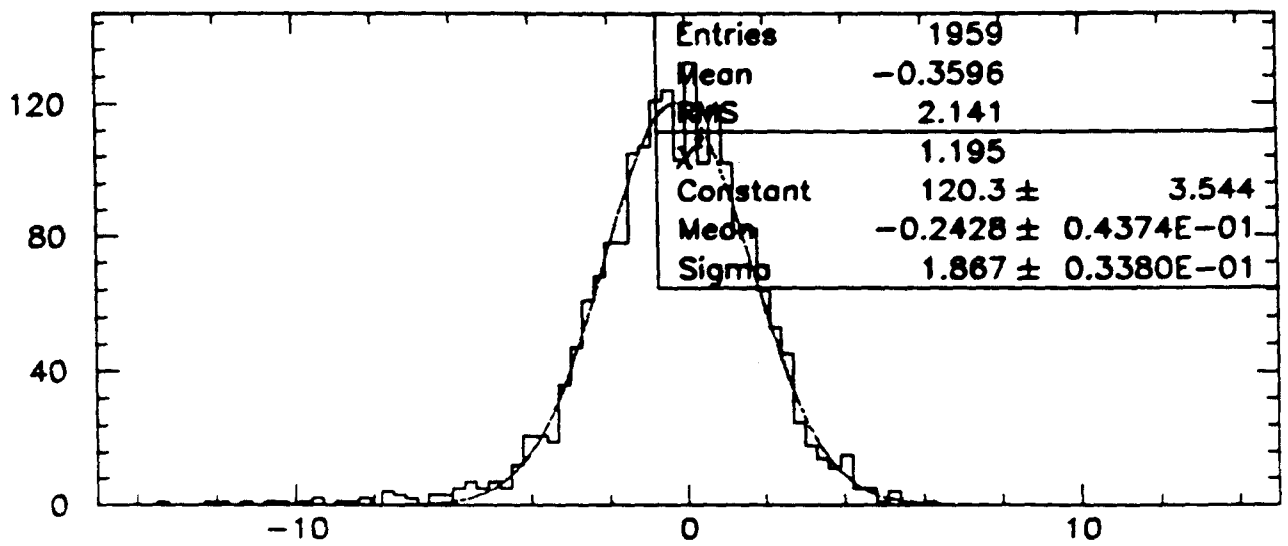
.05x.05 EM segmentation
.1x.1 HAD segmentation

$|\eta^{\ell}| < 2.5$

92/01/30 20.14




M(4l) − M1(4l) 2x2 Eta.le.2.5

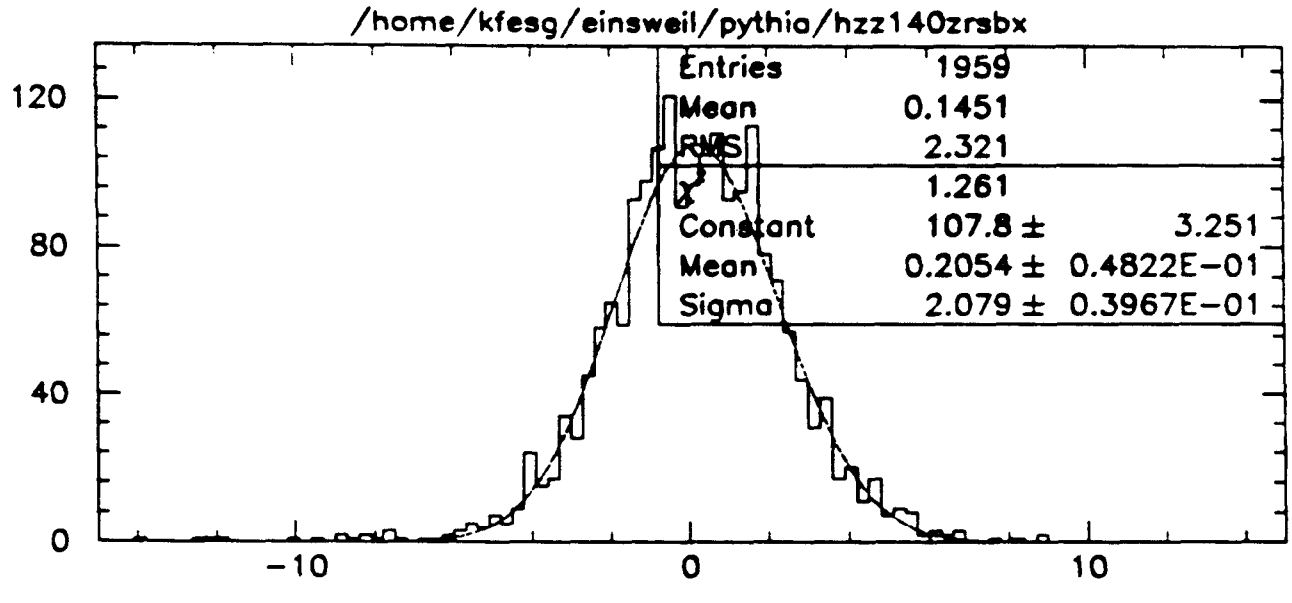



M(4l) − M1(4l) 3x3 Eta.le.2.5

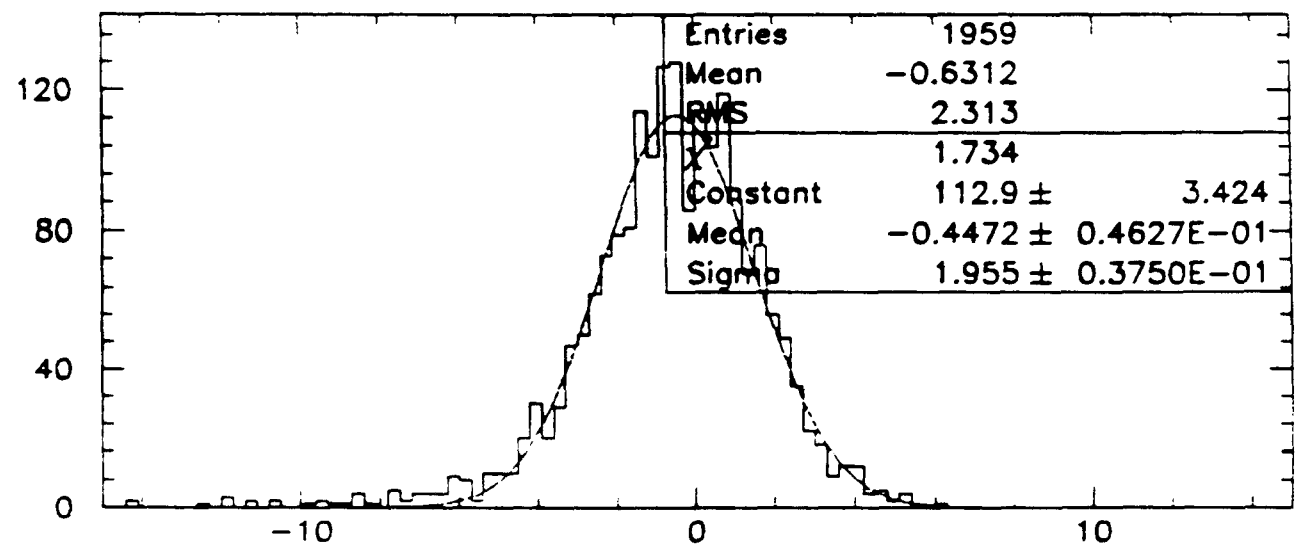
.05x.05 EM segmentation
.2 x.2 HAD segmentation

$|\eta^{\ell}| < 2.5$

92/01/30 20.14




M(4l) − M2(4l) 2x2 Eta.le.2.5



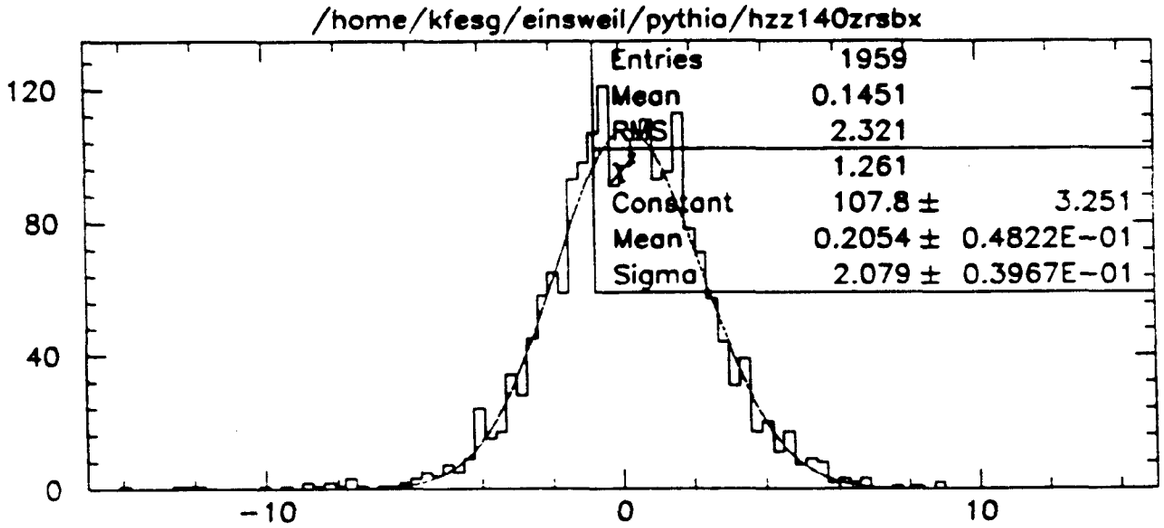

M(4l) − M2(4l) 3x3 Eta.le.2.5

.05x.05 EM segmentation
.2 x.2 HAD segmentation

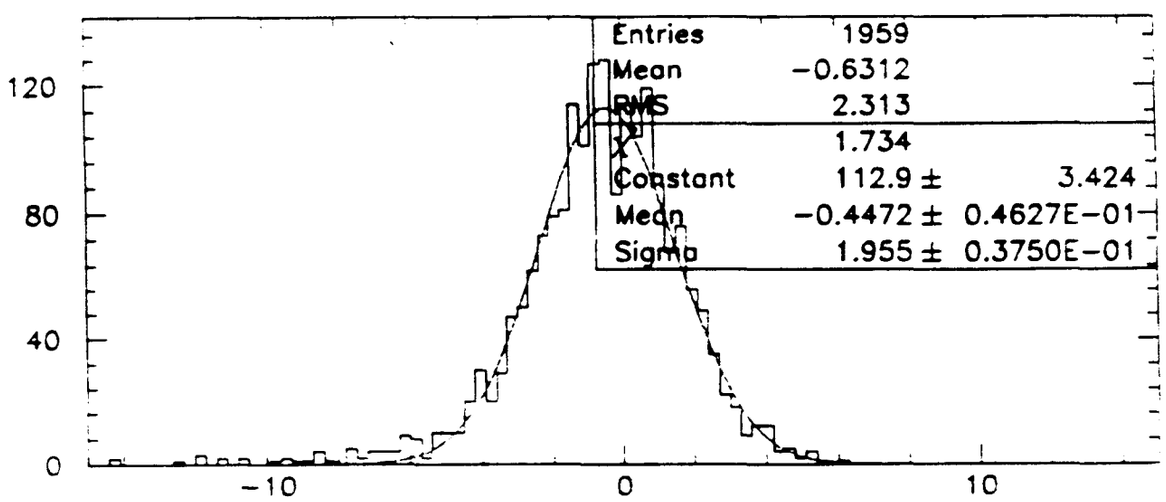
$|\eta^{\ell}| < 2.5$

92/01/30 20.14

/home/kfesg/einsweil/pythia/hzz140zrsbx




M(4l) – M2(4l) 2x2 Eta.le.2.5

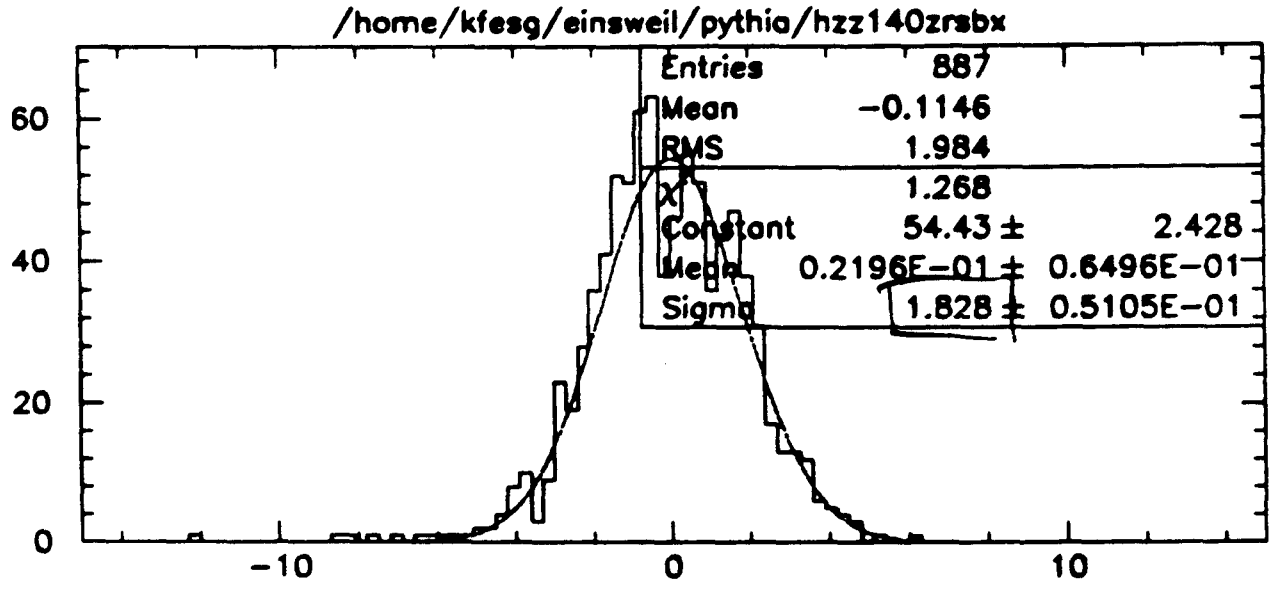



M(4l) – M2(4l) 3x3 Eta.le.2.5

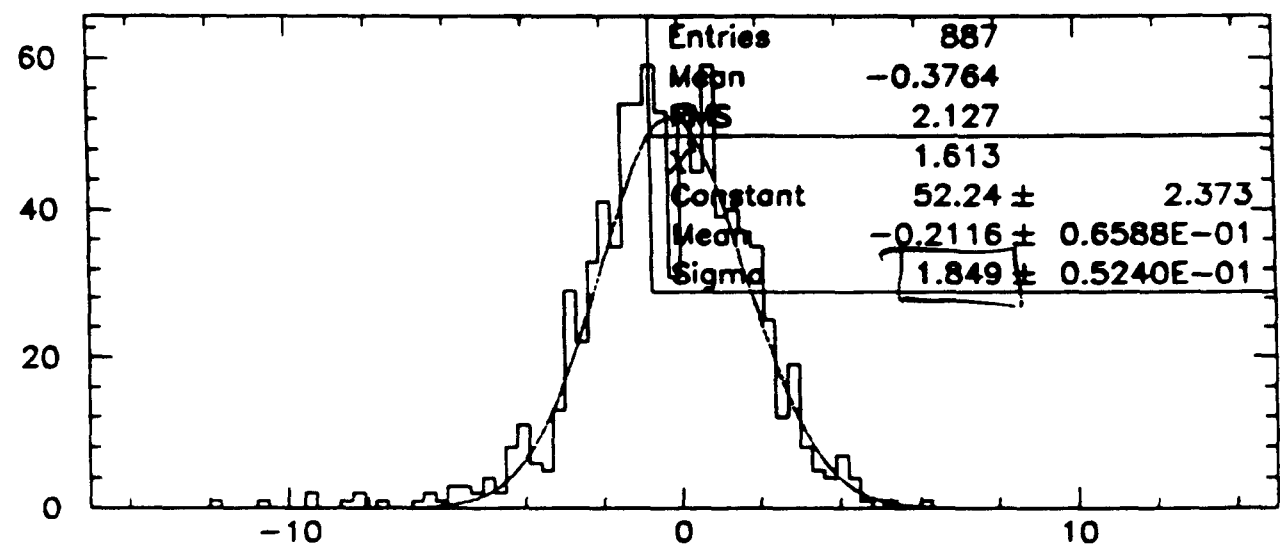
.05 x .05 EM, HAD

$|\eta^{\ell}| < 1.5$

92/01/30 20.14




M(4l) − M(4l) 2x2 Eta.le.1.5



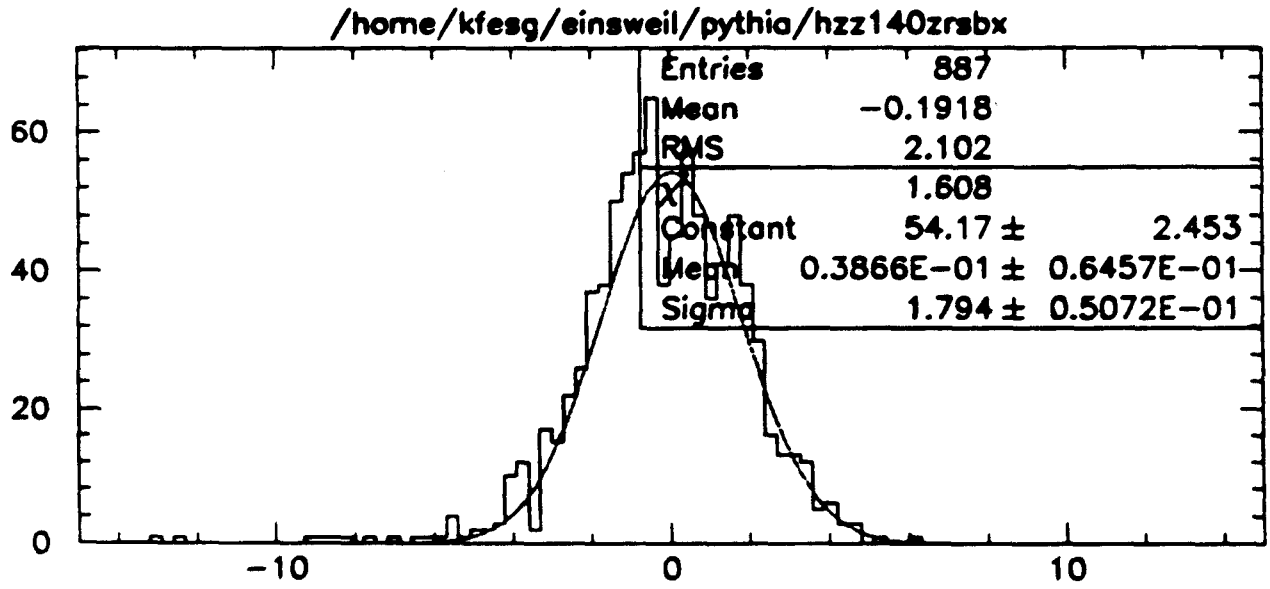

M(4l) − M(4l) 3x3 Eta.le.1.5

.05 x .05 EM

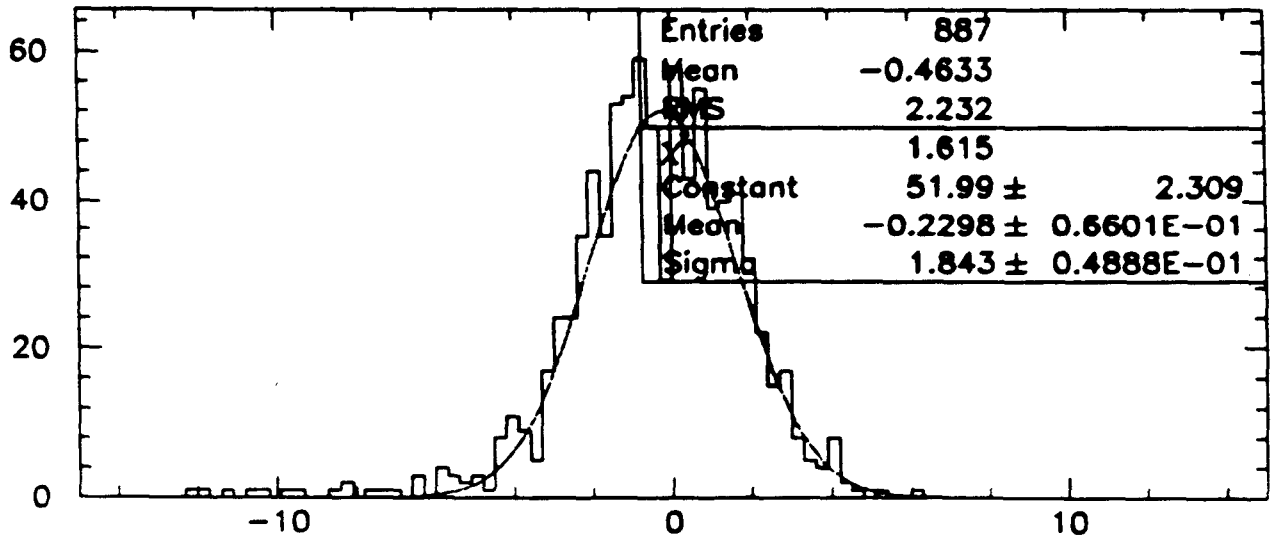
.1 x .1 HAD

$|\eta^{\ell}| < 1.5$

92/01/30 20.14




M(4l) − M1(4l) 2x2 Eta.le.1.5



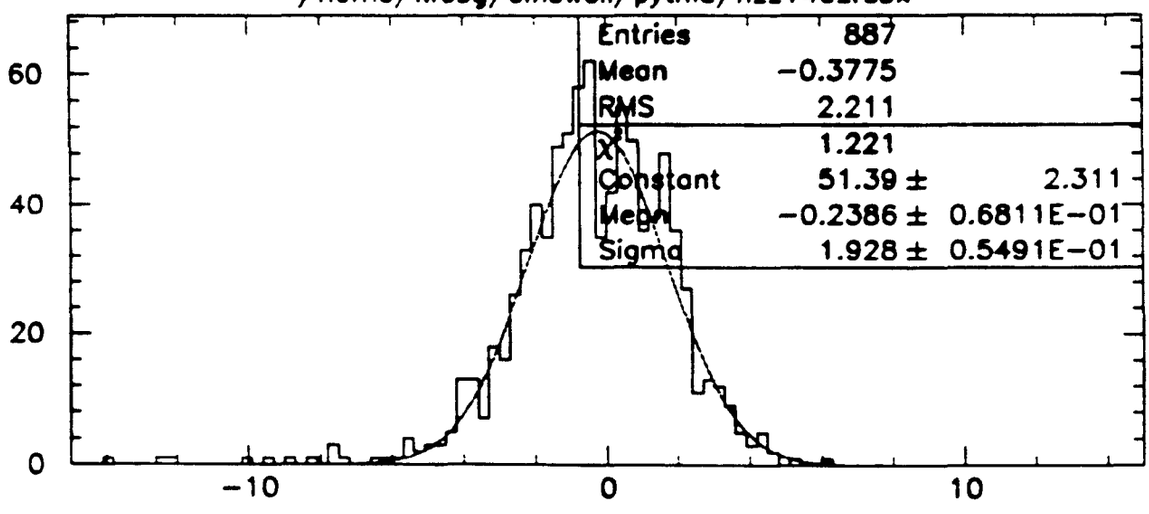

M(4l) − M1(4l) 3x3 Eta.le.1.5

.05 x .05 EM
.2 x .2 HAD

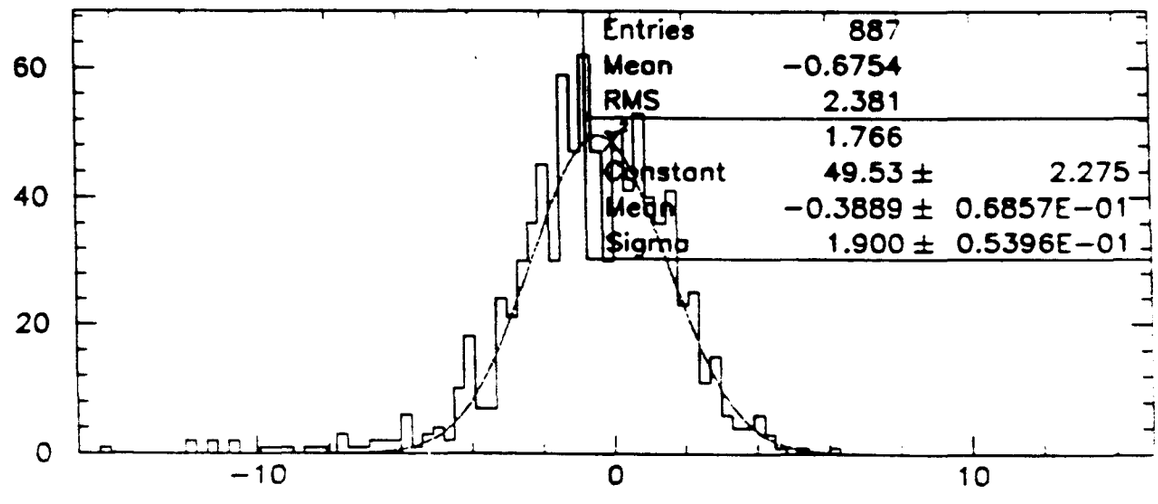
$|\eta^{\ell}| < 1.5$

92/01/30 20.15

/home/kfesg/einsweil/pythia/hzz140zrsbx




M(4l) − M2(4l) 2x2 Eta.le.1.5

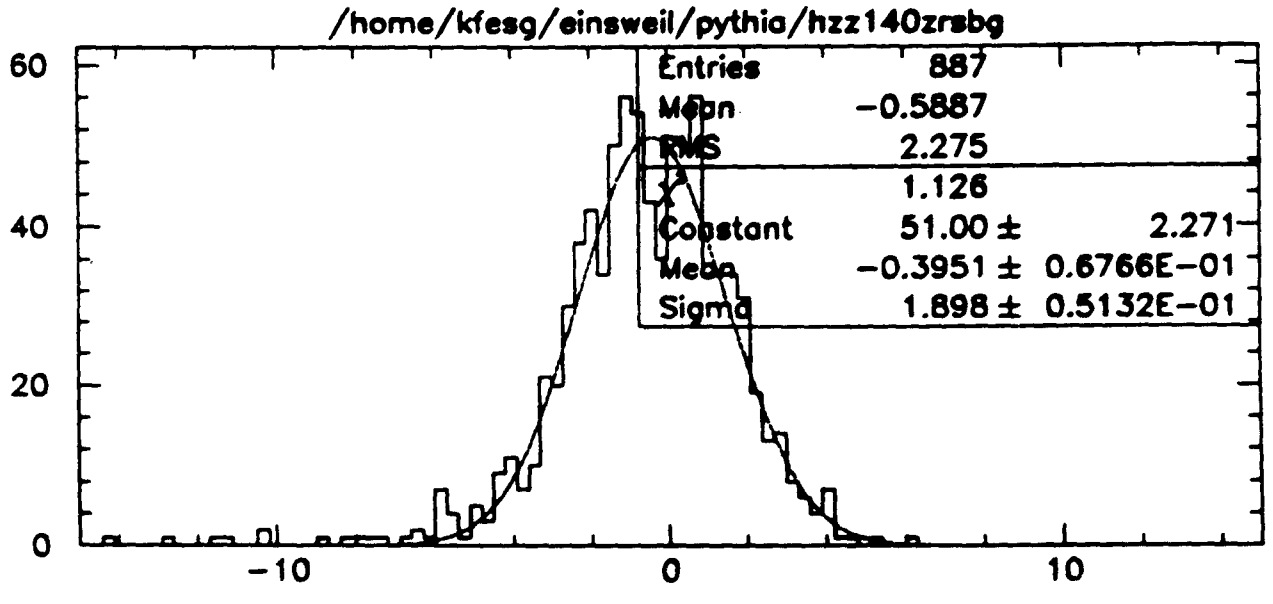



M(4l) − M2(4l) 3x3 Eta.le.1.5

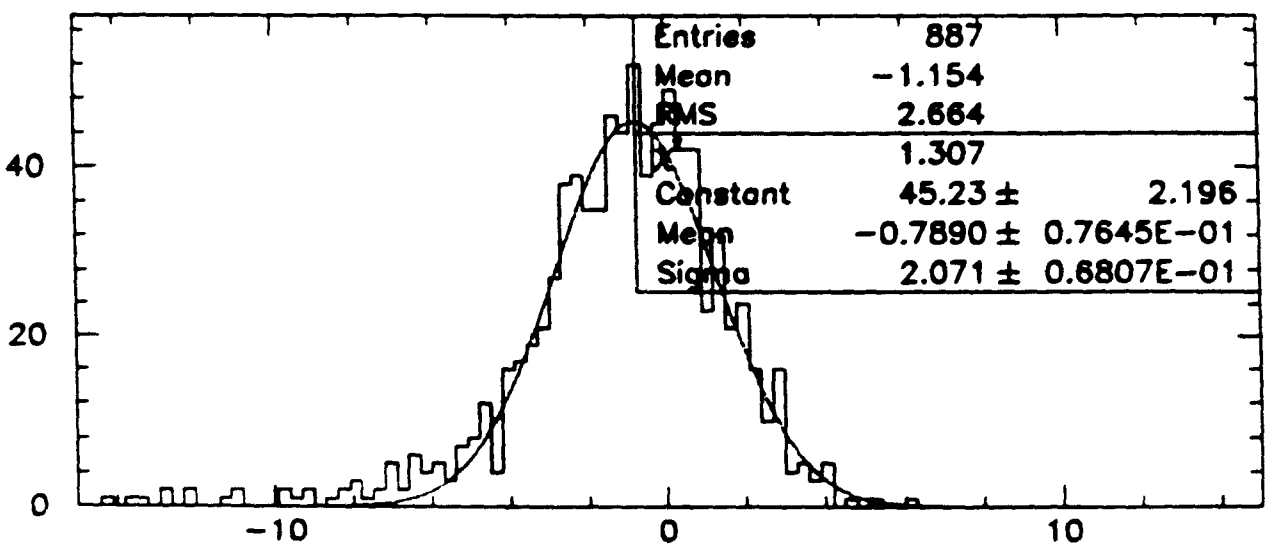
EM, HAD .1 x .1

$|\eta^{\ell}| < 1.5$

92/01/30 20.21




M(4l) − M1(4l) 2x2 Eta.le.1.5



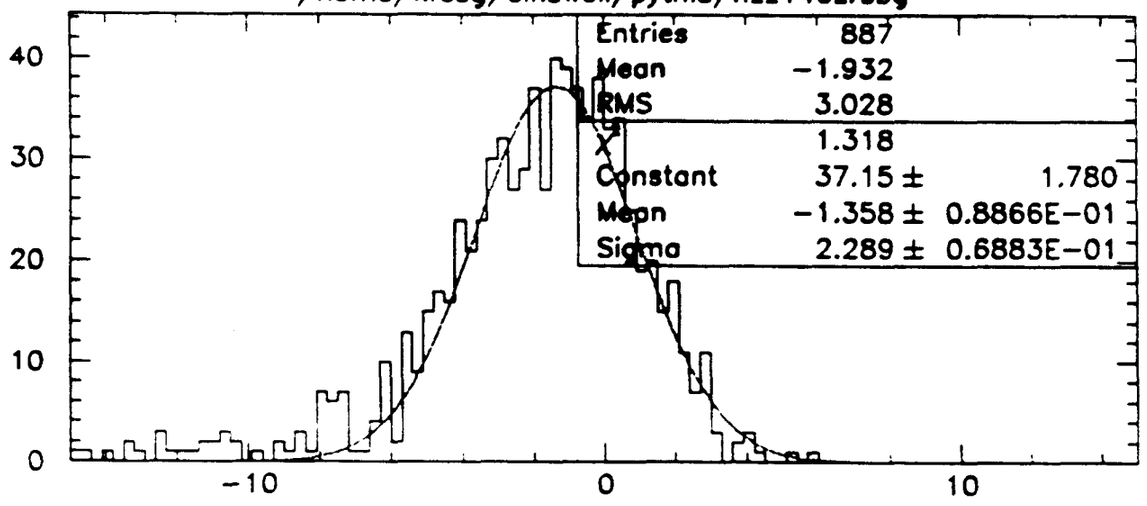

M(4l) − M1(4l) 3x3 Eta.le.1.5

EM, HAD .2x.2

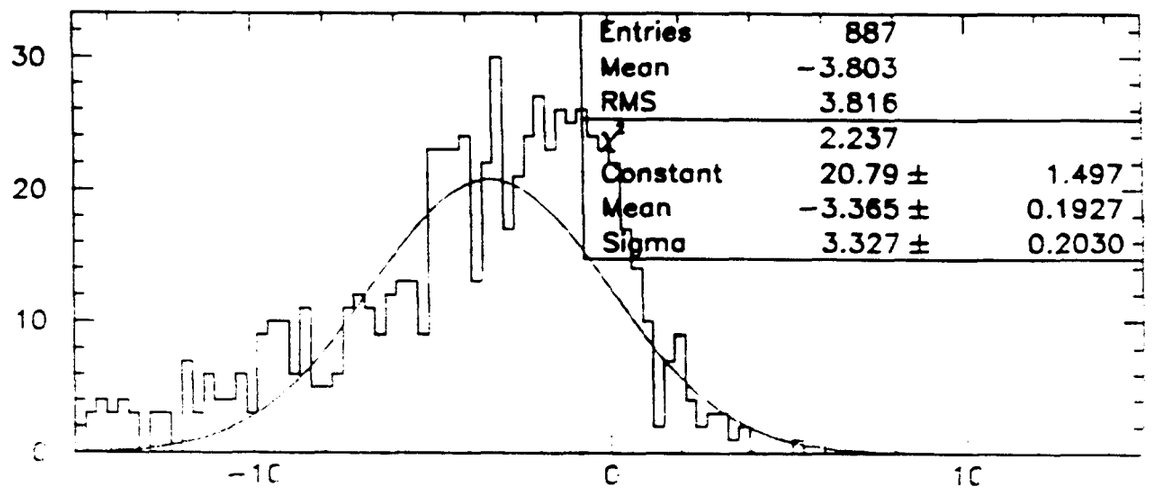
$|\eta^{\ell}| < 1.5$

92/01/30 20.21

/home/kfesg/einsweil/pythia/hzz140zrsbg




M(4l) − M2(4l) 2x2 Eta.le.1.5




M(4l) − M2(4l) 3x3 Eta.le.1.5

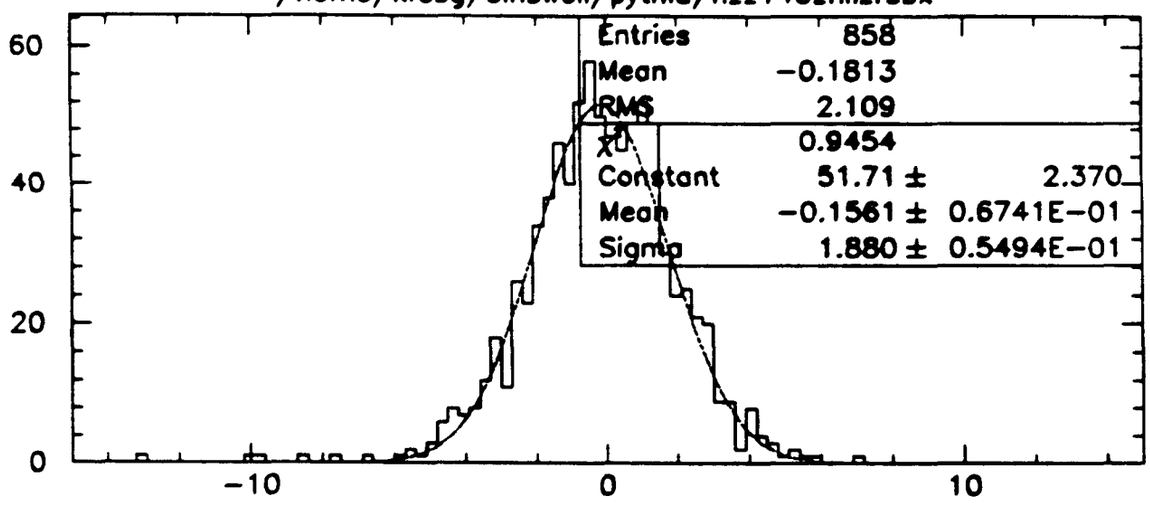
.05 x .05 EM, HAD

$\mathcal{L} = 5 \times 10^{33}$

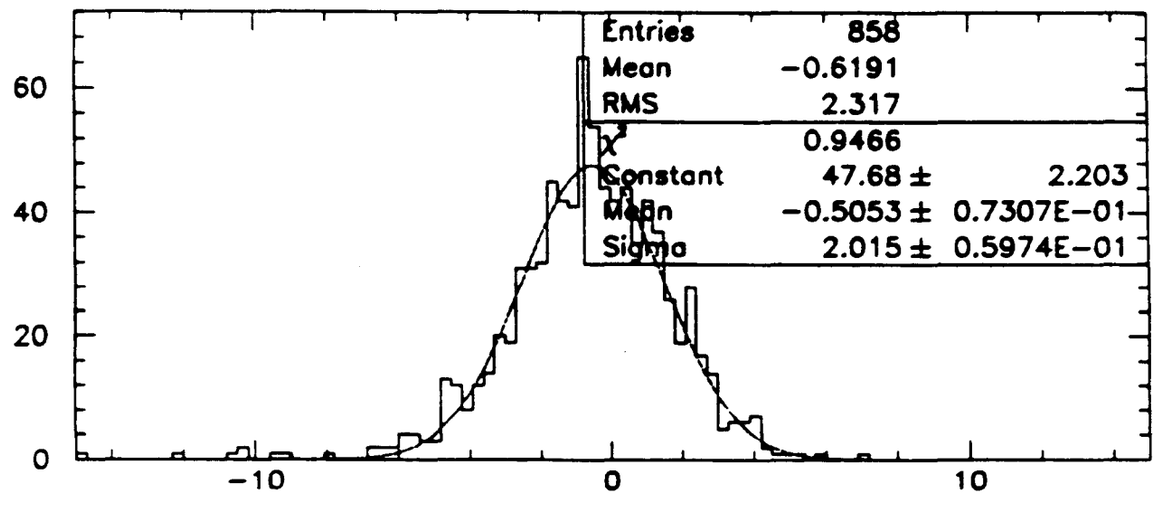
$|\eta^{\ell}| < 1.5$

92/01/31 11.15

/home/kfesg/einsweil/pythia/hzz140zhilzrsbx




M(4l) − M(4l) 2x2 Eta.le.1.5




M(4l) − M(4l) 3x3 Eta.le.1.5

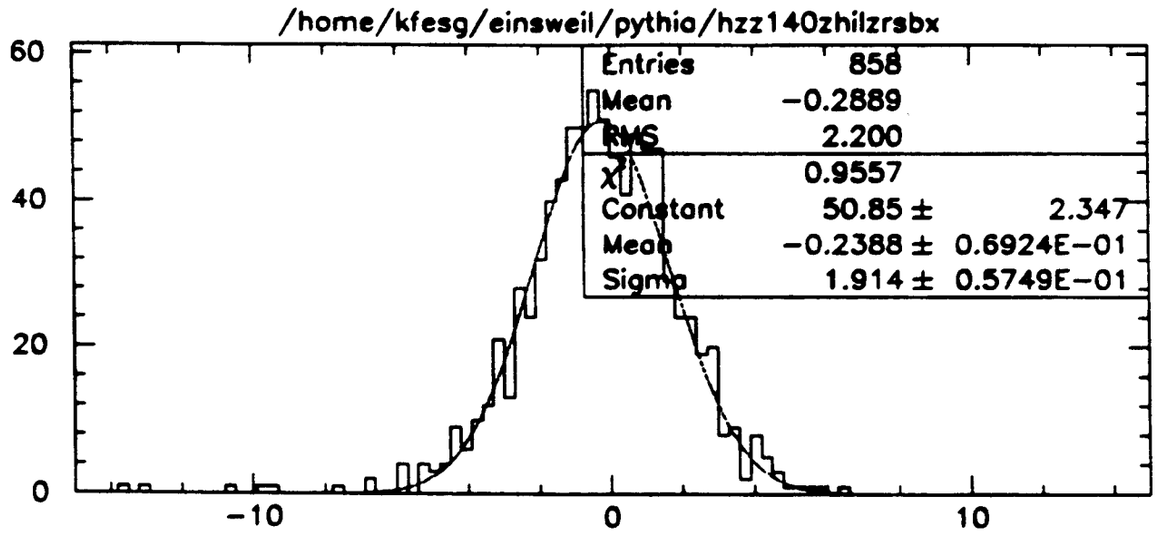
.05 x .05 EM

.1 x .1 HAD

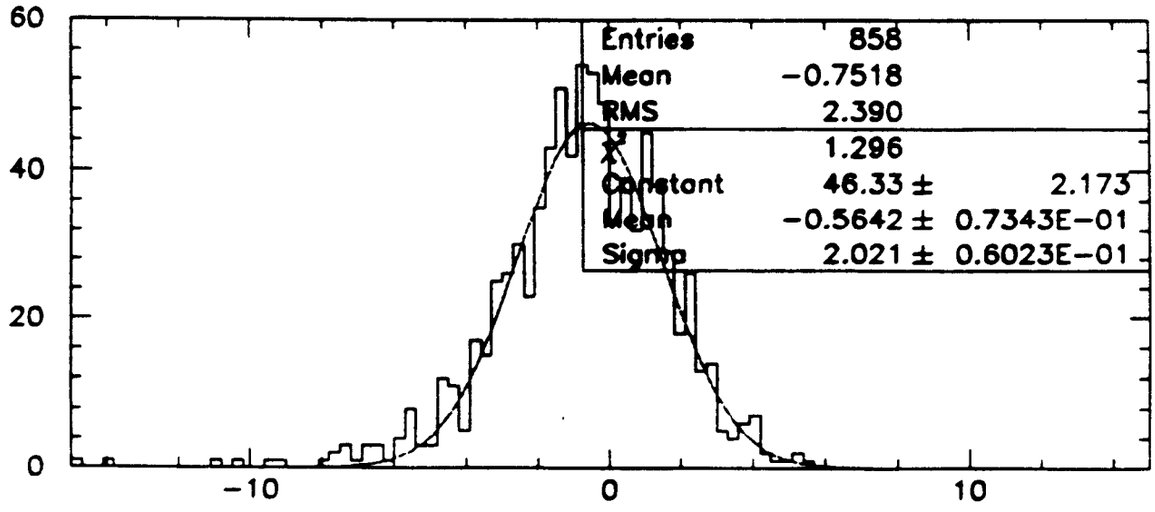
$\mathcal{L} = 5 \times 10^{33}$

$|\eta^{\ell}| < 1.5$

92/01/31 11.16




M(4l) − M1(4l) 2x2 Eta.le.1.5




M(4l) − M1(4l) 3x3 Eta.le.1.5

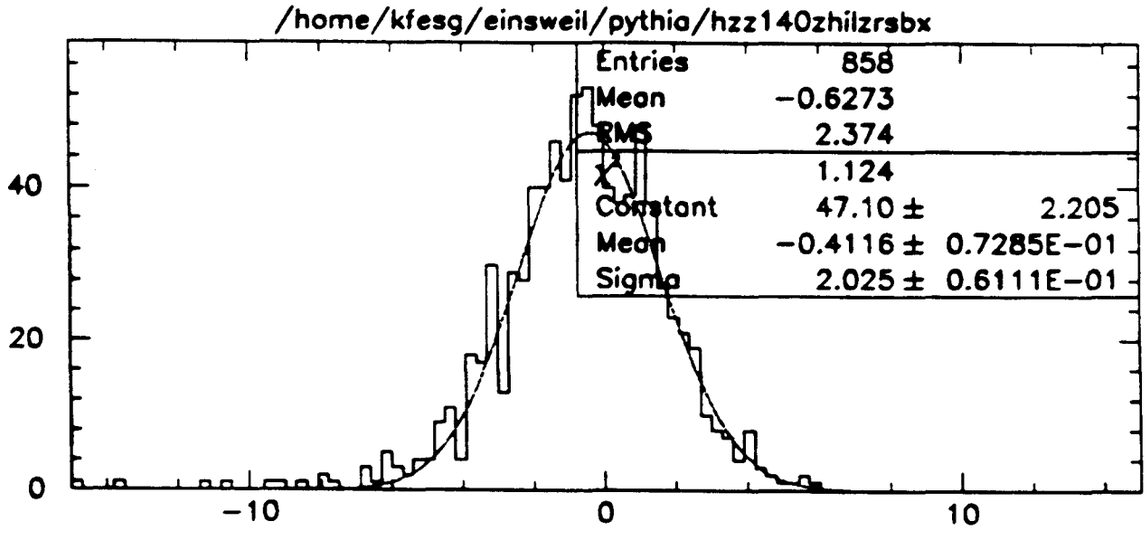
.05 x .05 EM

.2 x .2 HAD

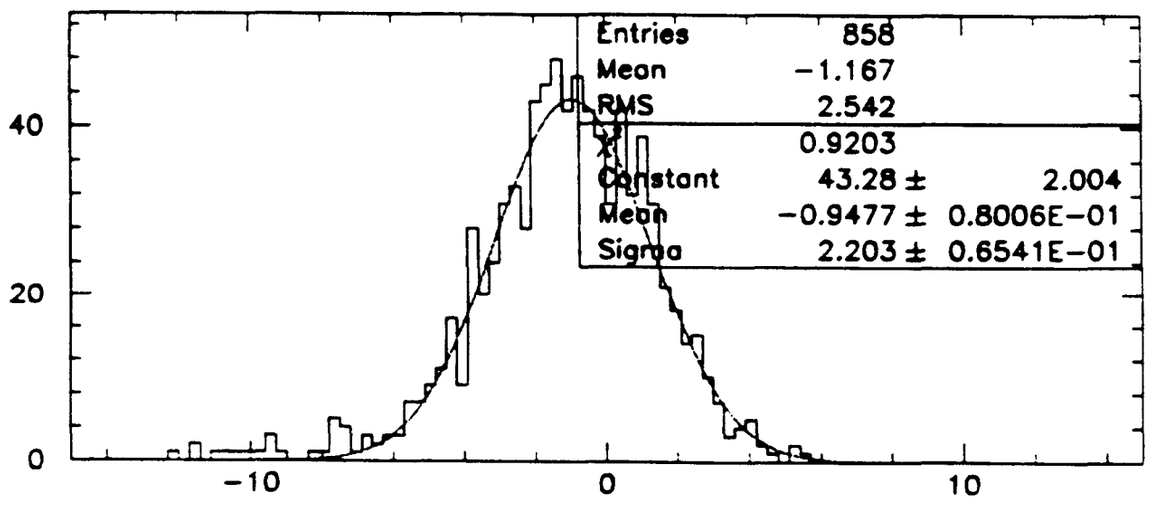
$\mathcal{L} = 5 \times 10^{33}$

$|\eta^{\ell}| < 1.5$

92/01/31 11.16




M(4l) − M2(4l) 2x2 Eta.le.1.5



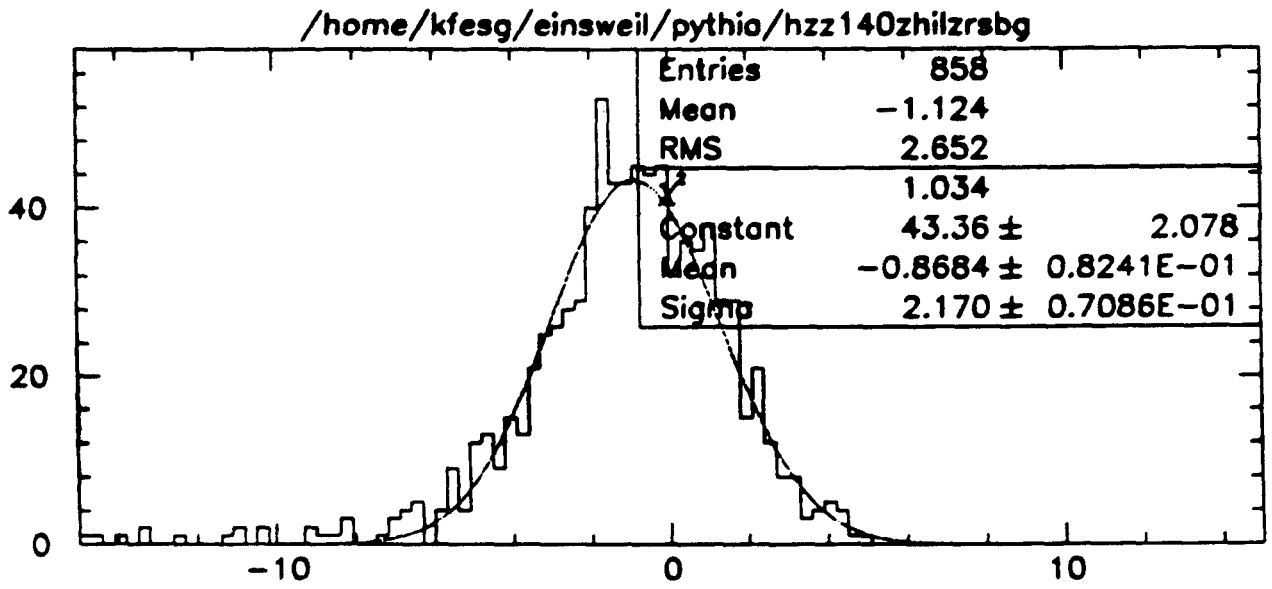

M(4l) − M2(4l) 3x3 Eta.le.1.5

.1 x .1 EM, HAD

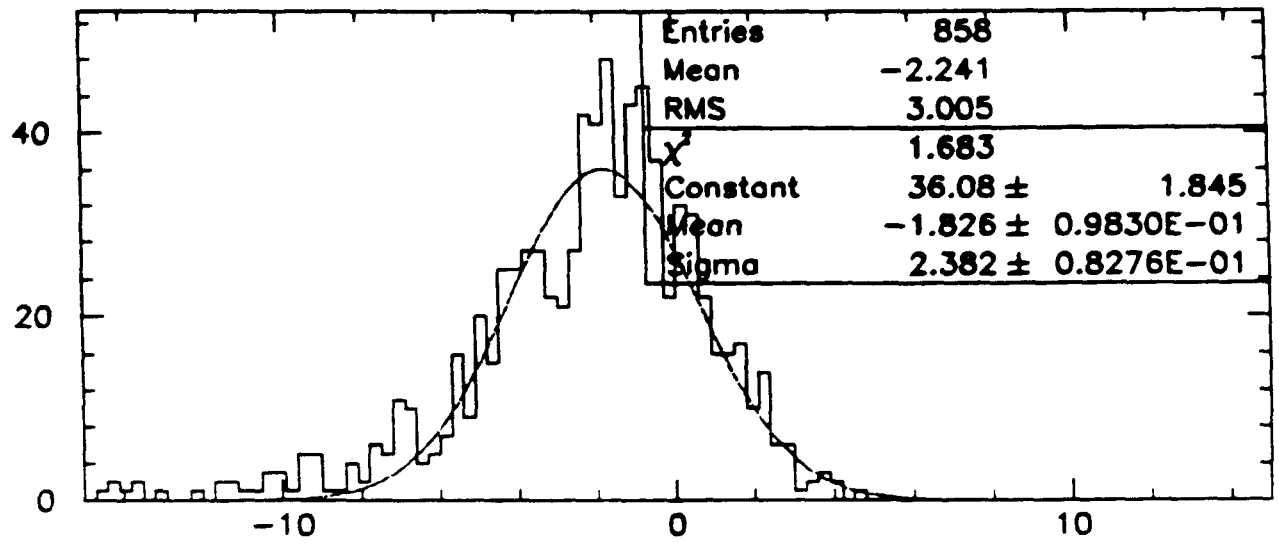
$\mathcal{L} = 5 \times 10^{33}$

$|\eta^{\ell}| < 1.5$

92/01/31 11.04




M(4l) − M1(4l) 2x2 Eta.le.1.5



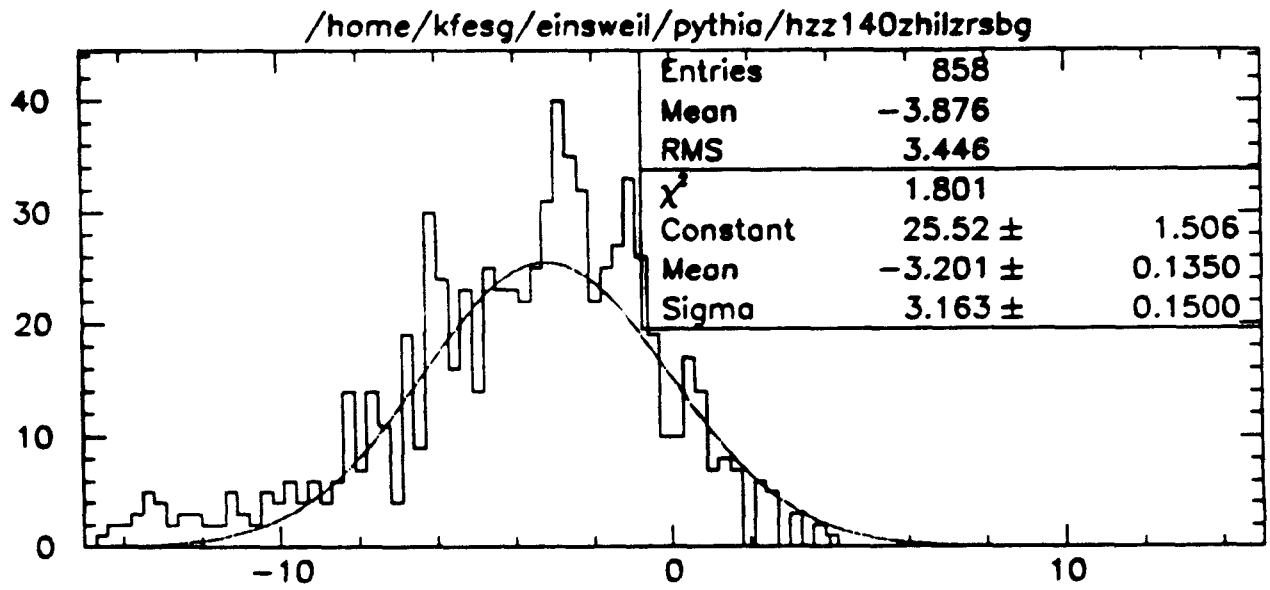

M(4l) − M1(4l) 3x3 Eta.le.1.5

.2x.2 EM, HAD

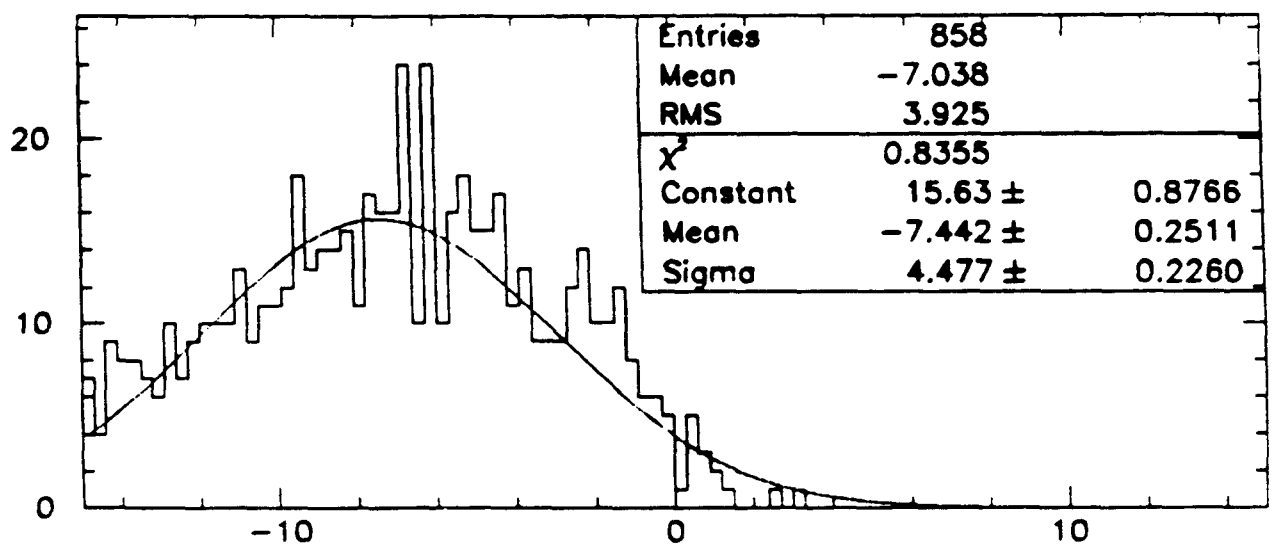
$\mathcal{L} = 5\times10^{33}$

$|\eta^{\ell}| < 1.5$

92/01/31 11.04




M(4l) − M2(4l) 2x2 Eta.le.1.5




M(4l) − M2(4l) 3x3 Eta.le.1.5

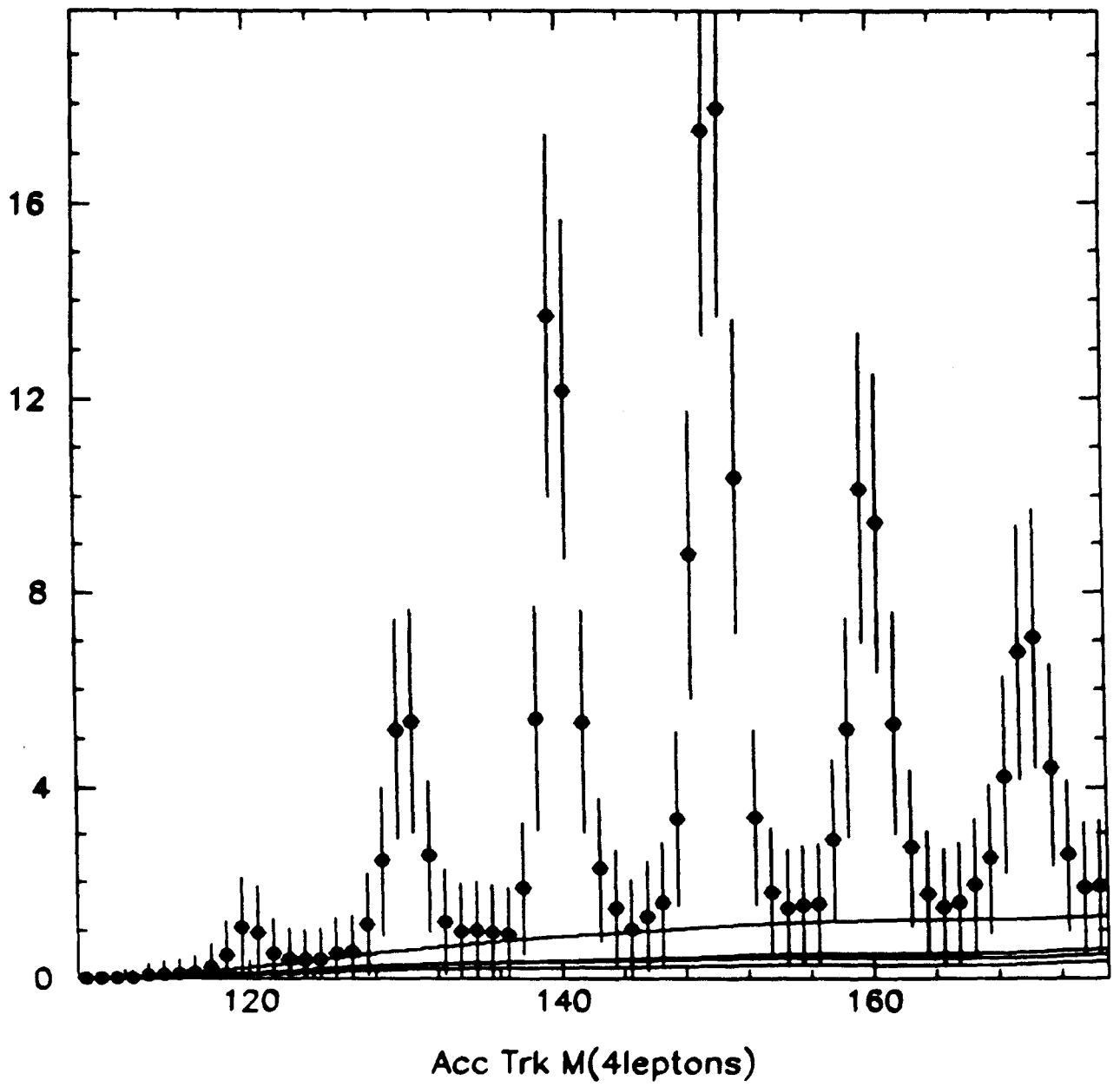
- Parametric Tracking resolutions (Lot)

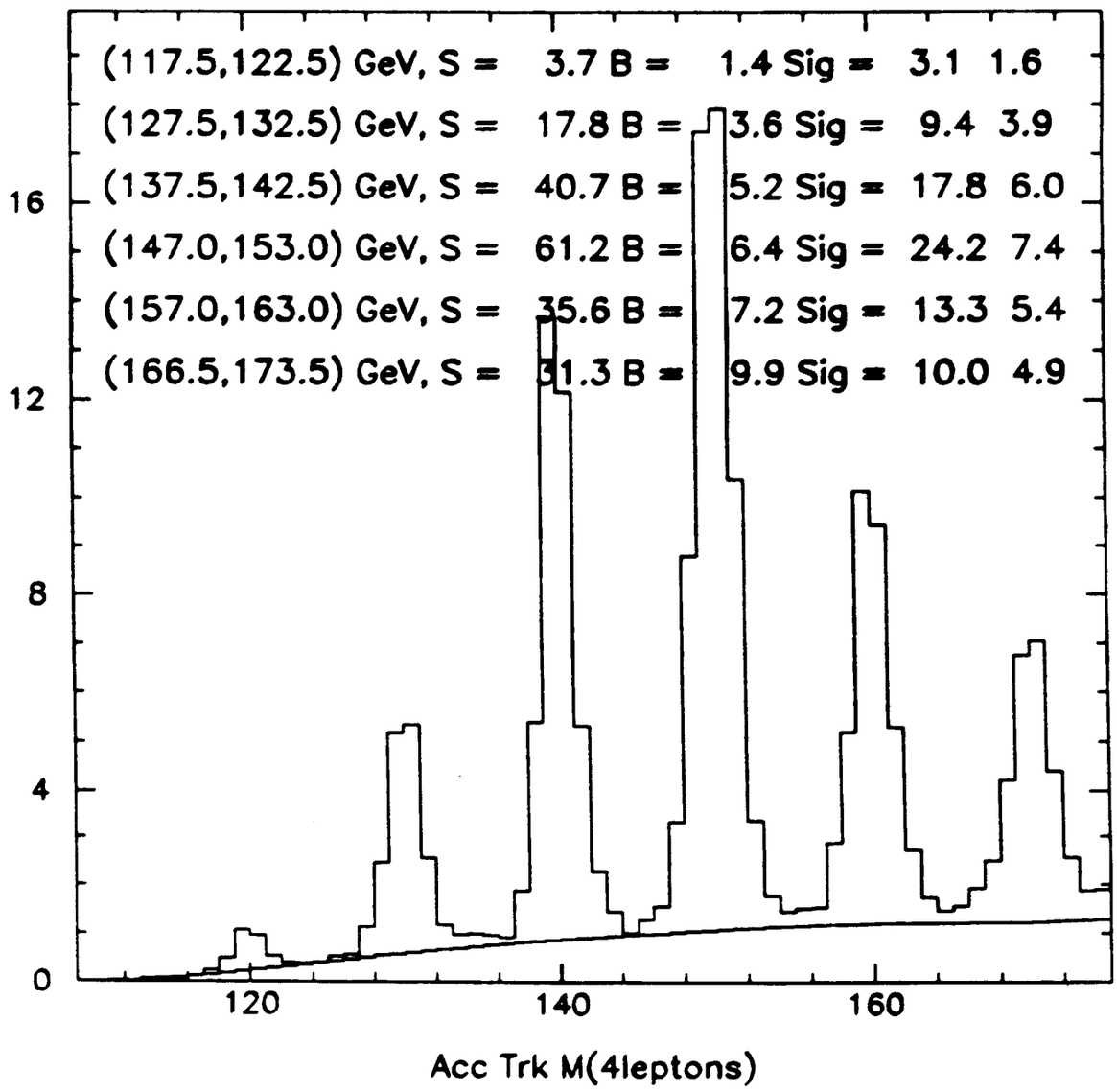
- $m_H$ = 120
  130
  140
  150
  160
  170

mass = from tracking system

$m_H = 140$ $\sigma \sim 1.1$ GeV (Trk

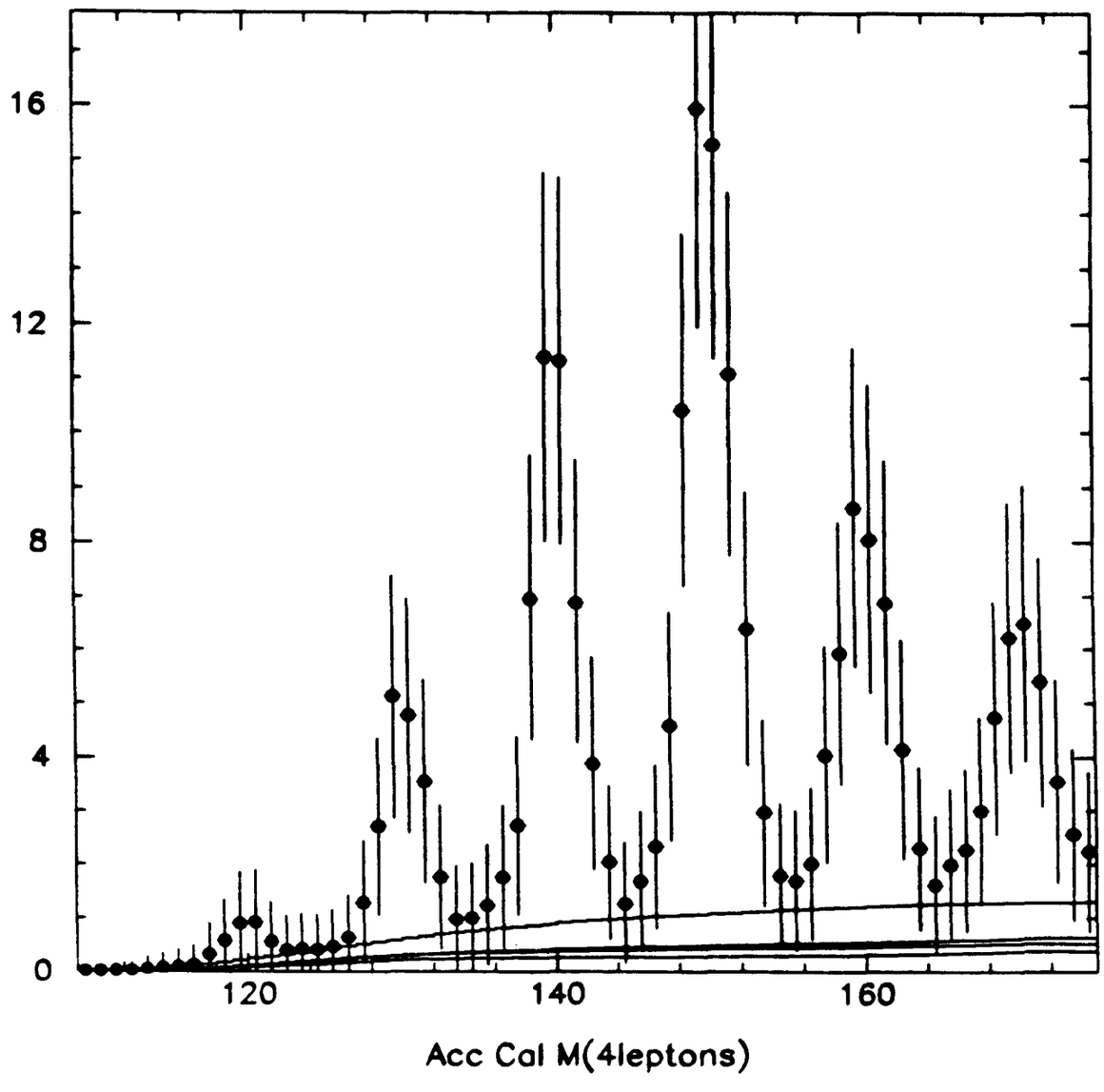
$\sigma \sim 1.85$ GeV (Calo

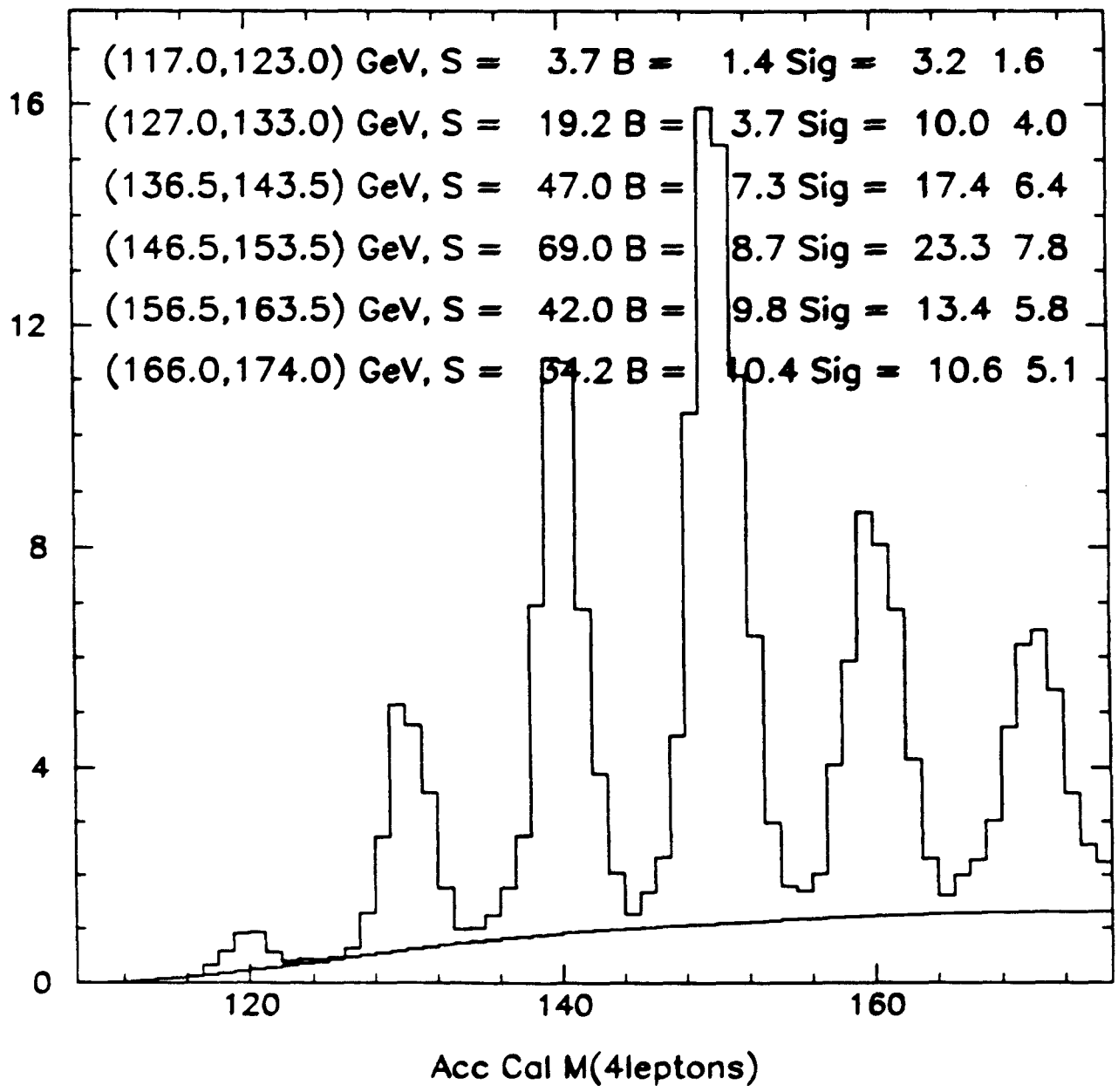



(117.5,122.5) GeV, S = 3.7 B = 1.4 Sig = 3.1 1.6
(127.5,132.5) GeV, S = 17.8 B = 3.6 Sig = 9.4 3.9
(137.5,142.5) GeV, S = 40.7 B = 5.2 Sig = 17.8 6.0
(147.0,153.0) GeV, S = 61.2 B = 6.4 Sig = 24.2 7.4
(157.0,163.0) GeV, S = 35.6 B = 7.2 Sig = 13.3 5.4
(166.5,173.5) GeV, S = 31.3 B = 9.9 Sig = 10.0 4.9
16
12
8
4
0
120
140
160
Acc Trk M(4leptons)

· use calorimeter for electrons

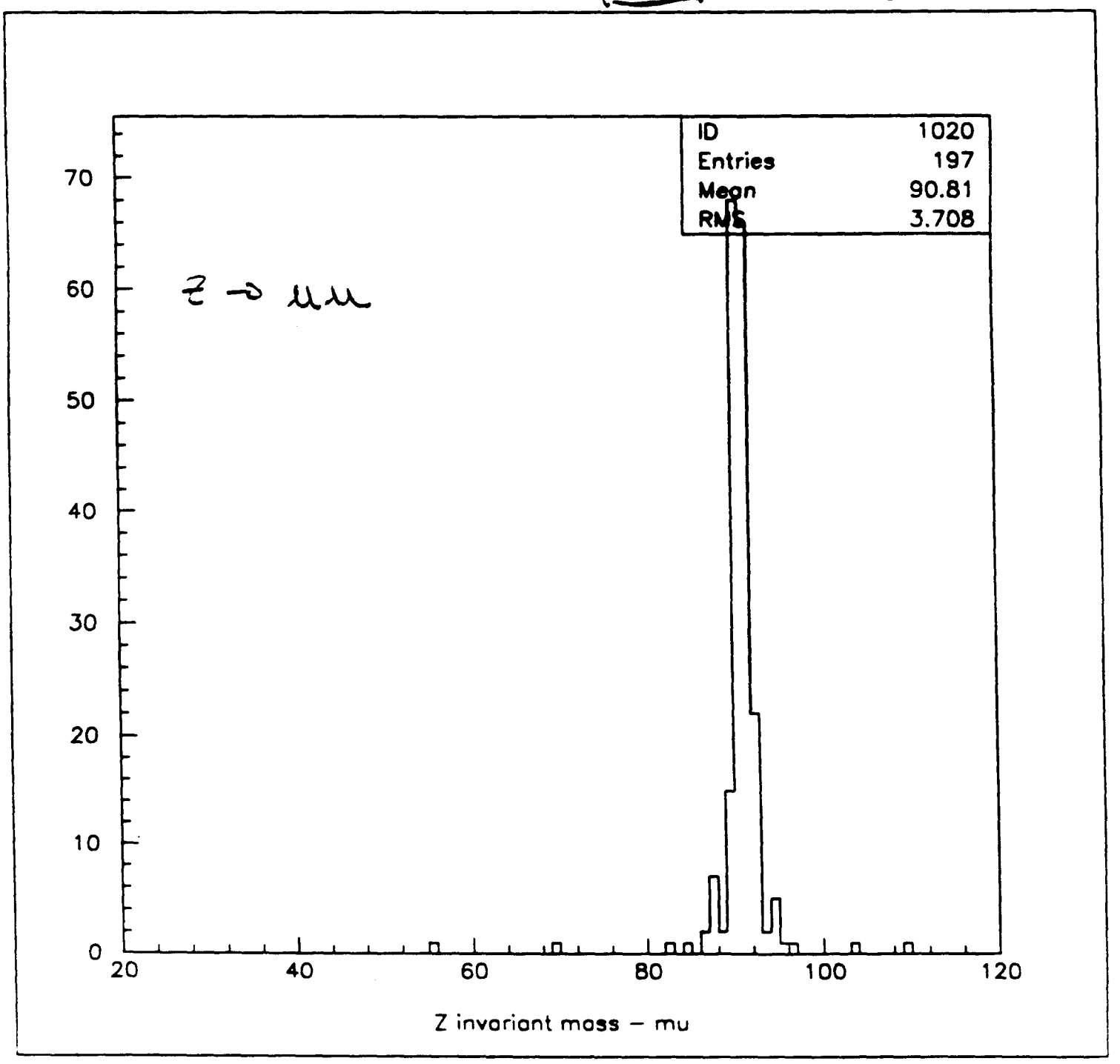
| brem is a serious problem for tracking

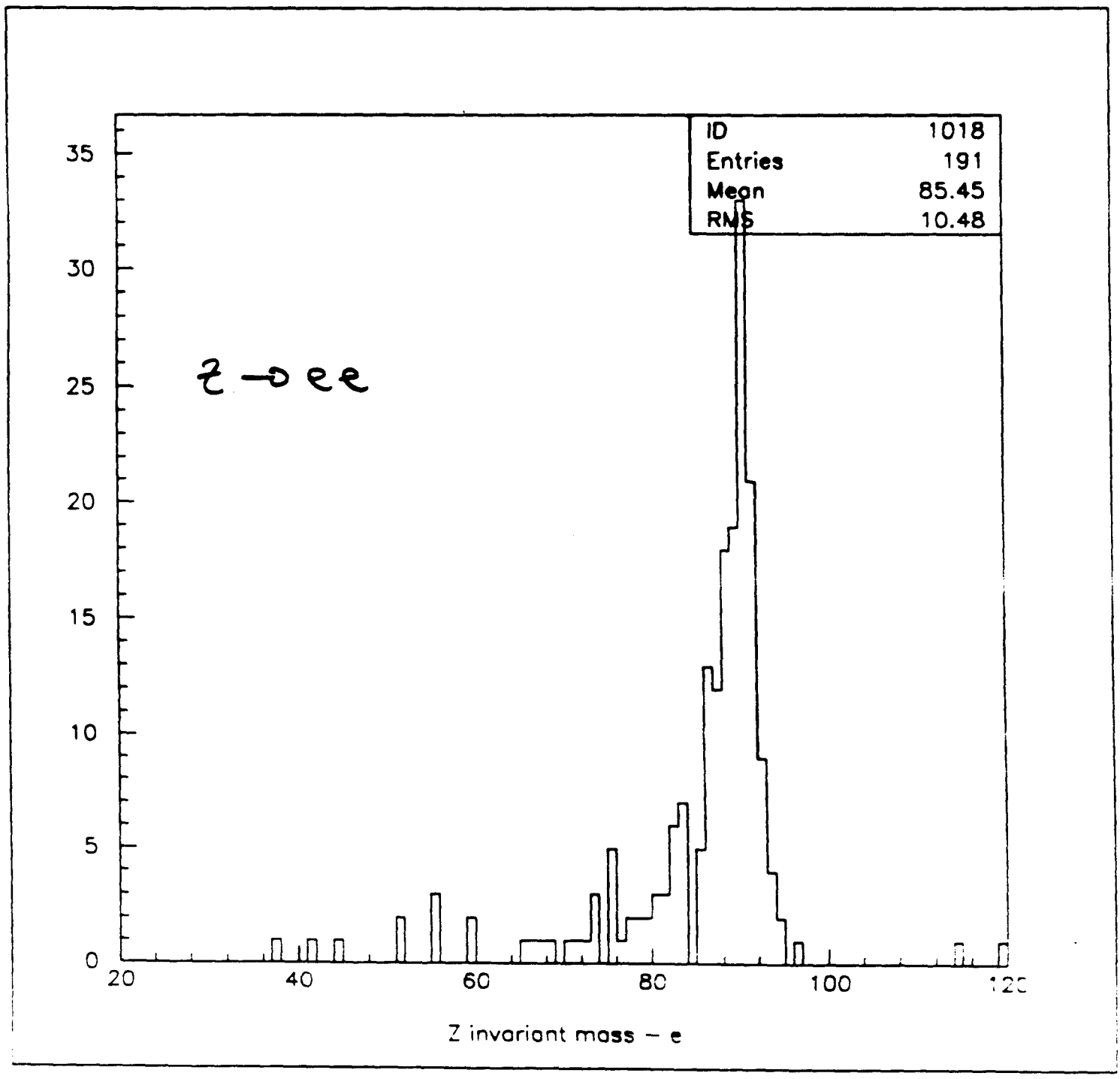


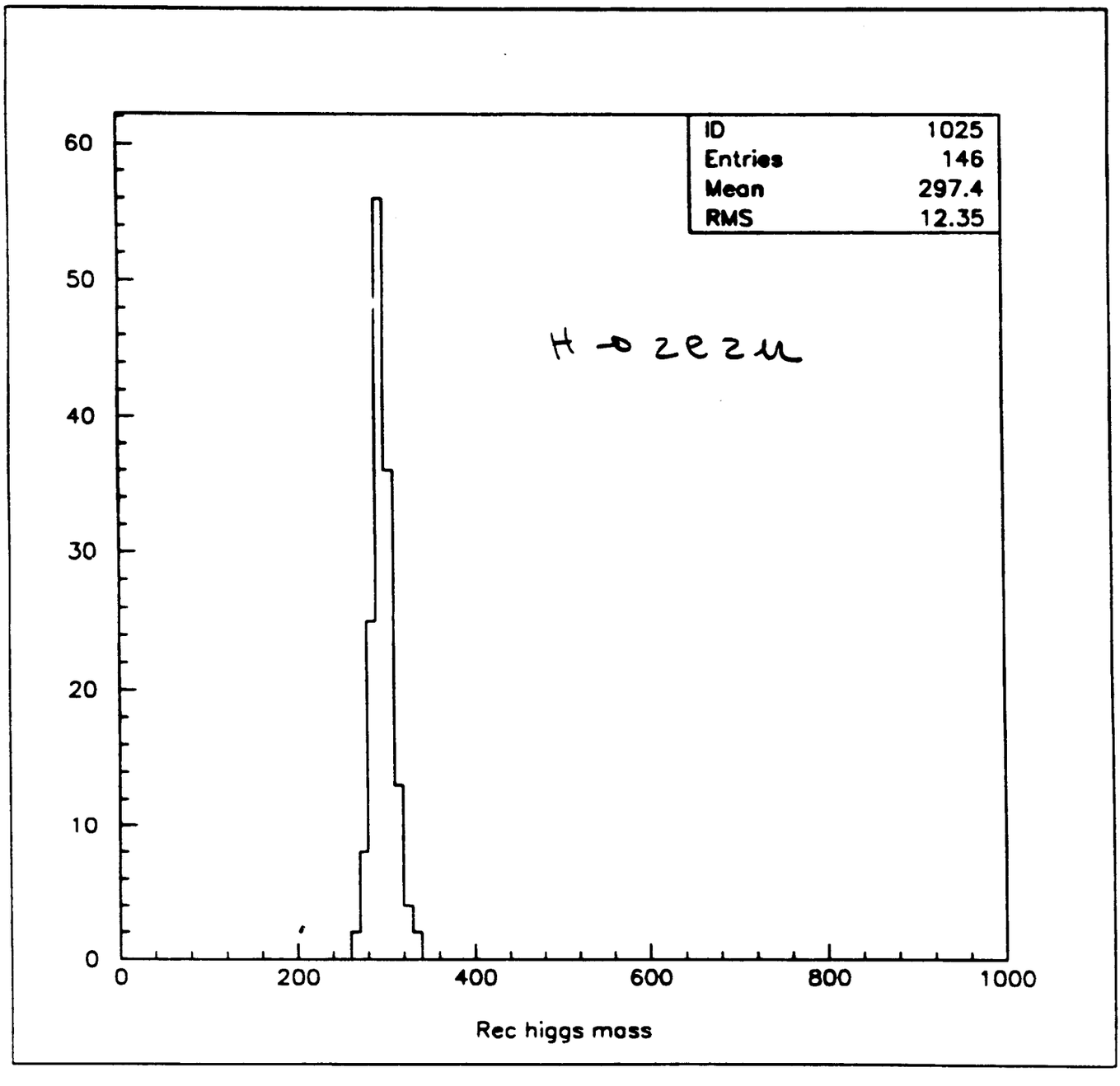

(117.0,123.0) GeV, S = 3.7 B = 1.4 Sig = 3.2 1.6
(127.0,133.0) GeV, S = 19.2 B = 3.7 Sig = 10.0 4.0
(136.5,143.5) GeV, S = 47.0 B = 7.3 Sig = 17.4 6.4
(146.5,153.5) GeV, S = 69.0 B = 8.7 Sig = 23.3 7.8
(156.5,163.5) GeV, S = 42.0 B = 9.8 Sig = 13.4 5.8
(166.0,174.0) GeV, S = 54.2 B = 10.4 Sig = 10.6 5.1
16
12
8
4
0
120
140
160
Acc Cal M(4leptons)

Preliminary SDCSIM results for baseline tracker, $m_H = 300$ GeV $H \to 2e\,2\mu$

- track efficiency 99%
- E/p .7 → 1.4 94%
- $m_Z \pm 10$ cut : $2\mu$ 98% $2e$ 81%




ID 1018
Entries 191
Mean 85.45
RMS 10.48
Z → ee
35
30
25
20
15
10
5
0
20
40
60
80
100
120
Z invariant mass – e


ID 1025
Entries 146
Mean 297.4
RMS 12.35
H → 2e2μ
60
50
40
30
20
10
0
0
200
400
600
800
1000
Rec higgs mass

c) Heavy Higgs (Einsweiler)

i) $H \to ZZ \to 4\ell$
ii) $H \to ZZ \to 2\ell 2\nu$ } ~ unchanged since LOI

iii) $H \to ZZ \to 2\ell\, 2jet$
$\to WW \to \ell\nu\, 2jet$

Address in terms of <u>capabilities</u>
(actual demonstration of feasibility difficult for ZZ, <u>very</u> difficult for WW)

Capabilities:

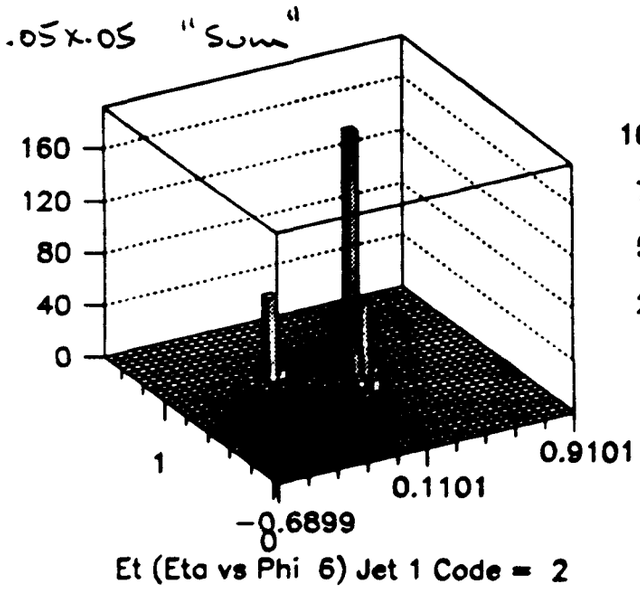
i) $W/Z \to jj$ reconstruction
- mass resolution
- $\cos\theta^*$ reconstruction

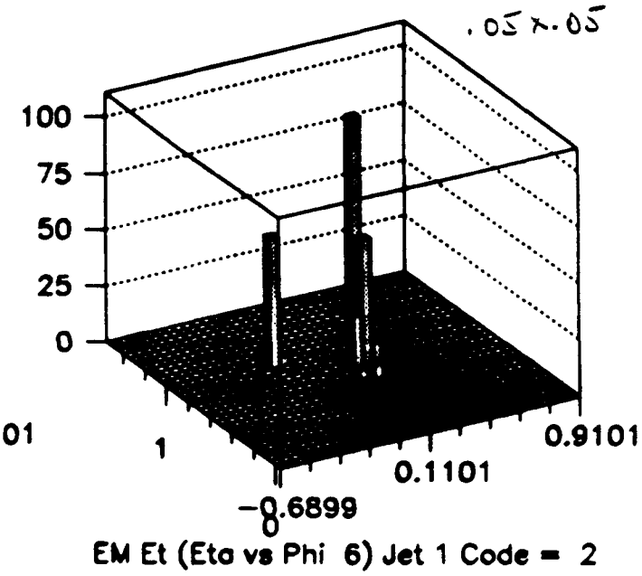
ii) jet tagging
- resolutions at particle / detectn level

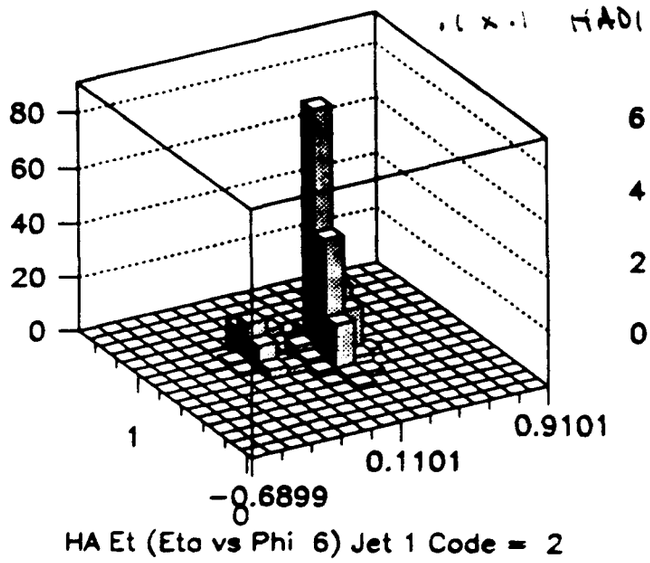
"Typical" Event

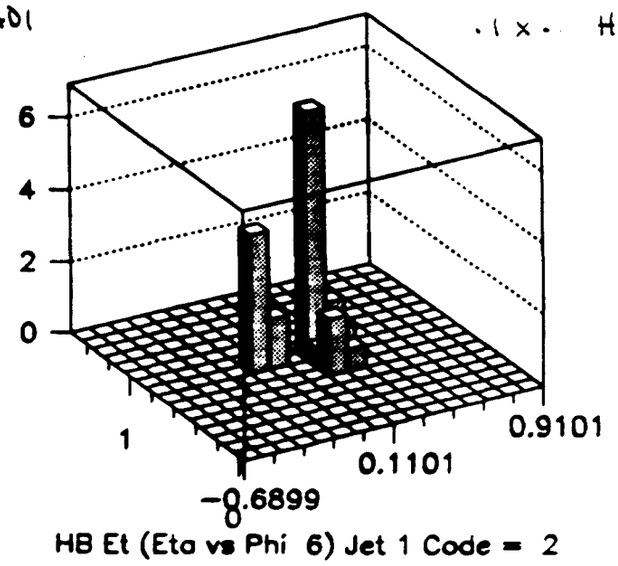
$P_T(W) \sim 500$ $\Delta R \sim 0.4$

92/01/30 18.53



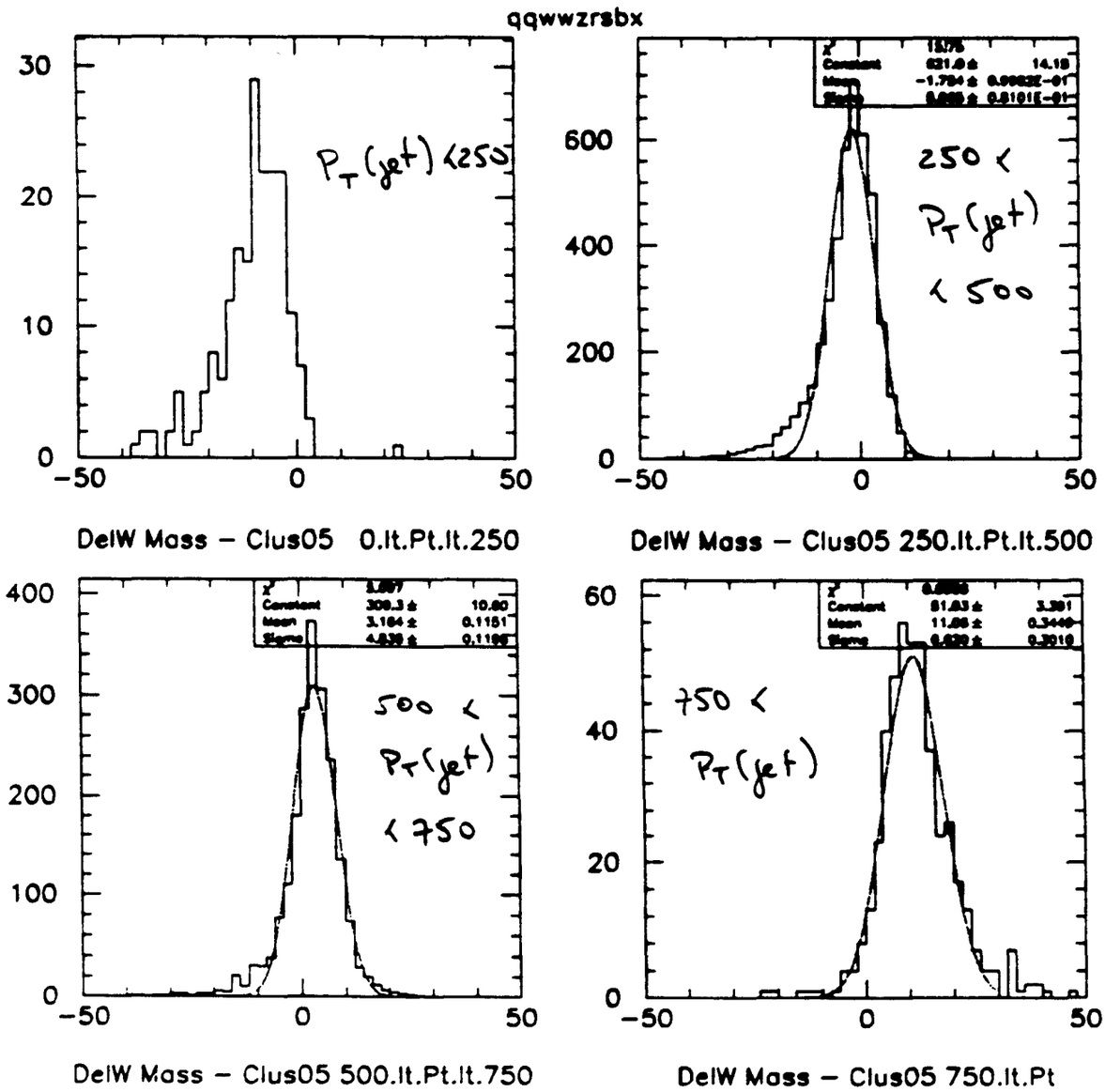
W mass resolution

for $H \to WW$, $m_H = 1$ TeV

jet cone $\Delta R = 0.6$

.05x.05 EM, HAD

92/01/09 15.55

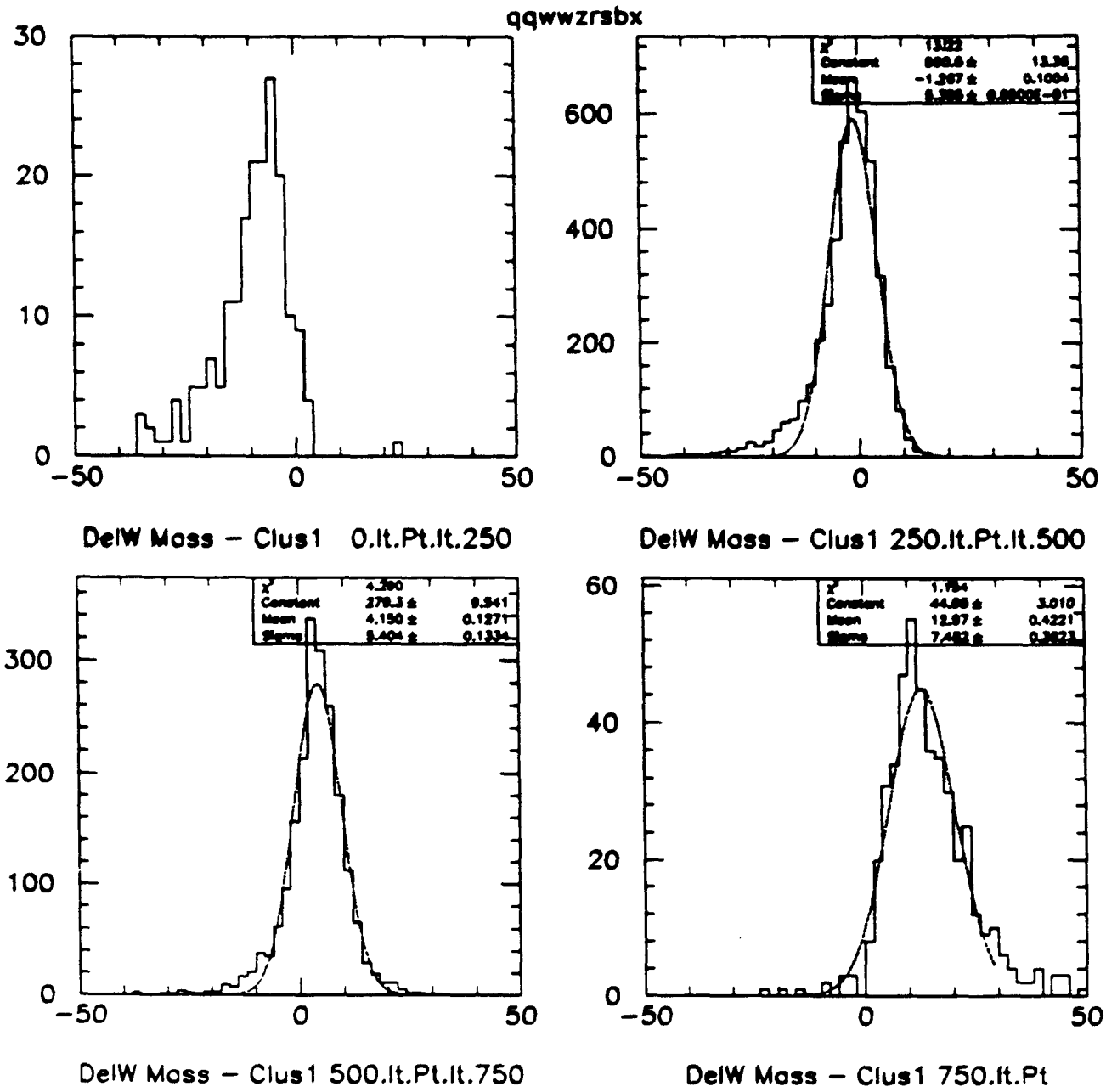


jet cone $\Delta R = 0.6$

.05x.05 EM
.1 x .1 HAD

92/01/09 15.55

qqwwzrsbx

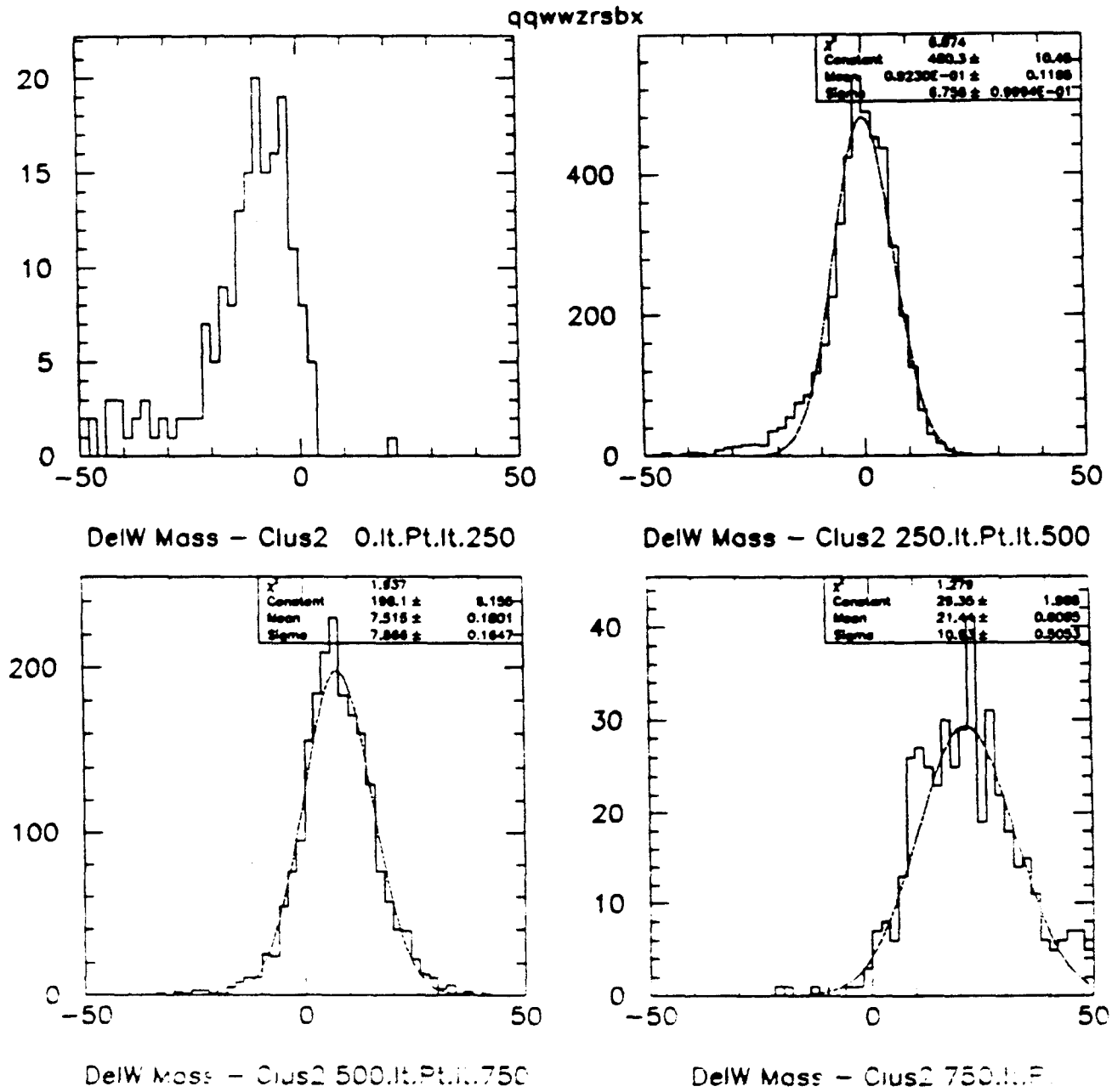


jet cone $\Delta R = 0.6$

.05 x .05 EM
.2 x .2 HAD

92/01/09 15.56

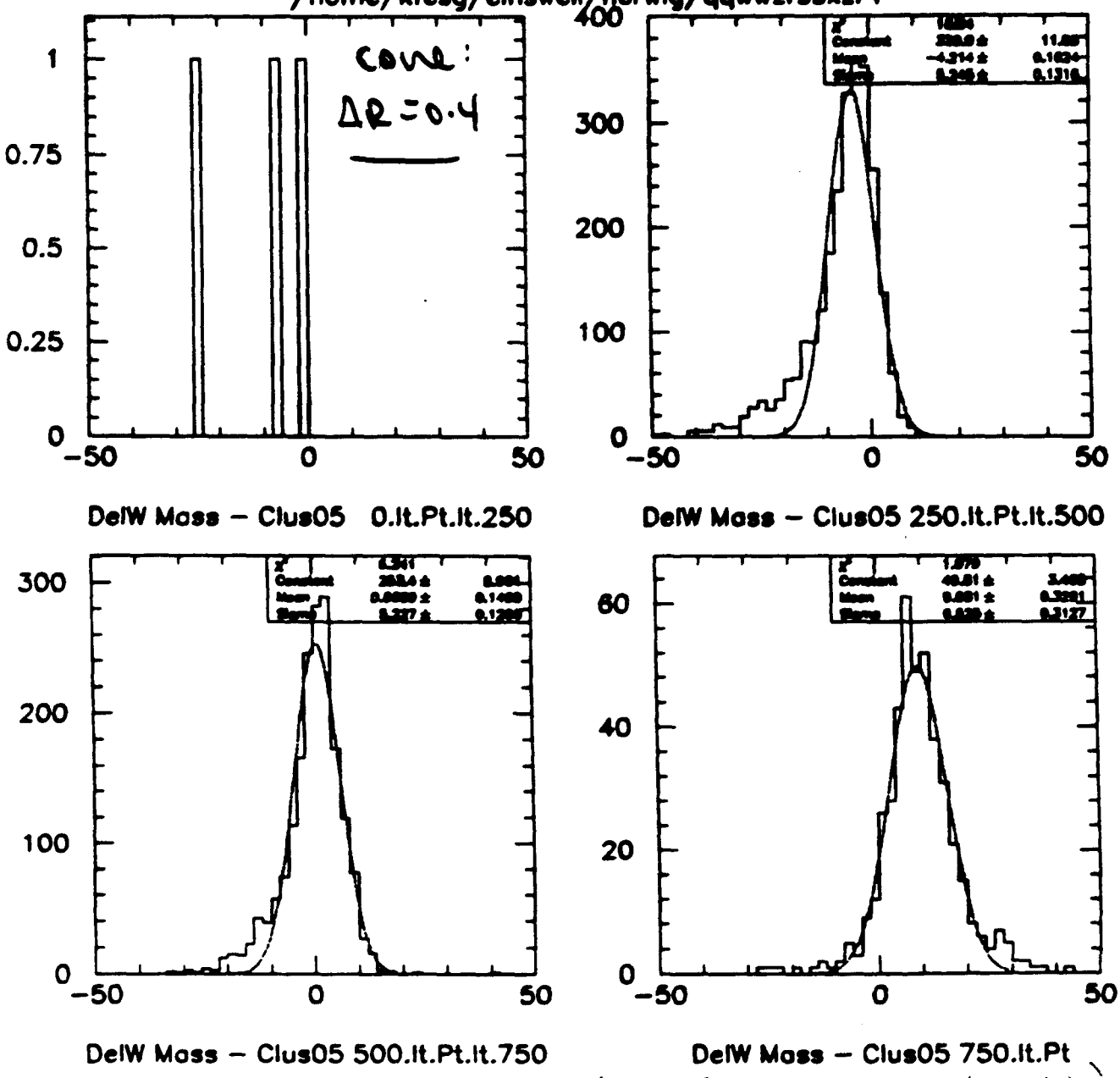
qqwwzrsbx



possibly improve signal/noise ratio using smaller cone
(higher $p_T$ threshold but smaller masses for QCD jet background ...)

92/01/30 20.03

/home/kfesg/einsweil/herwig/qqwwzrsbxzr4



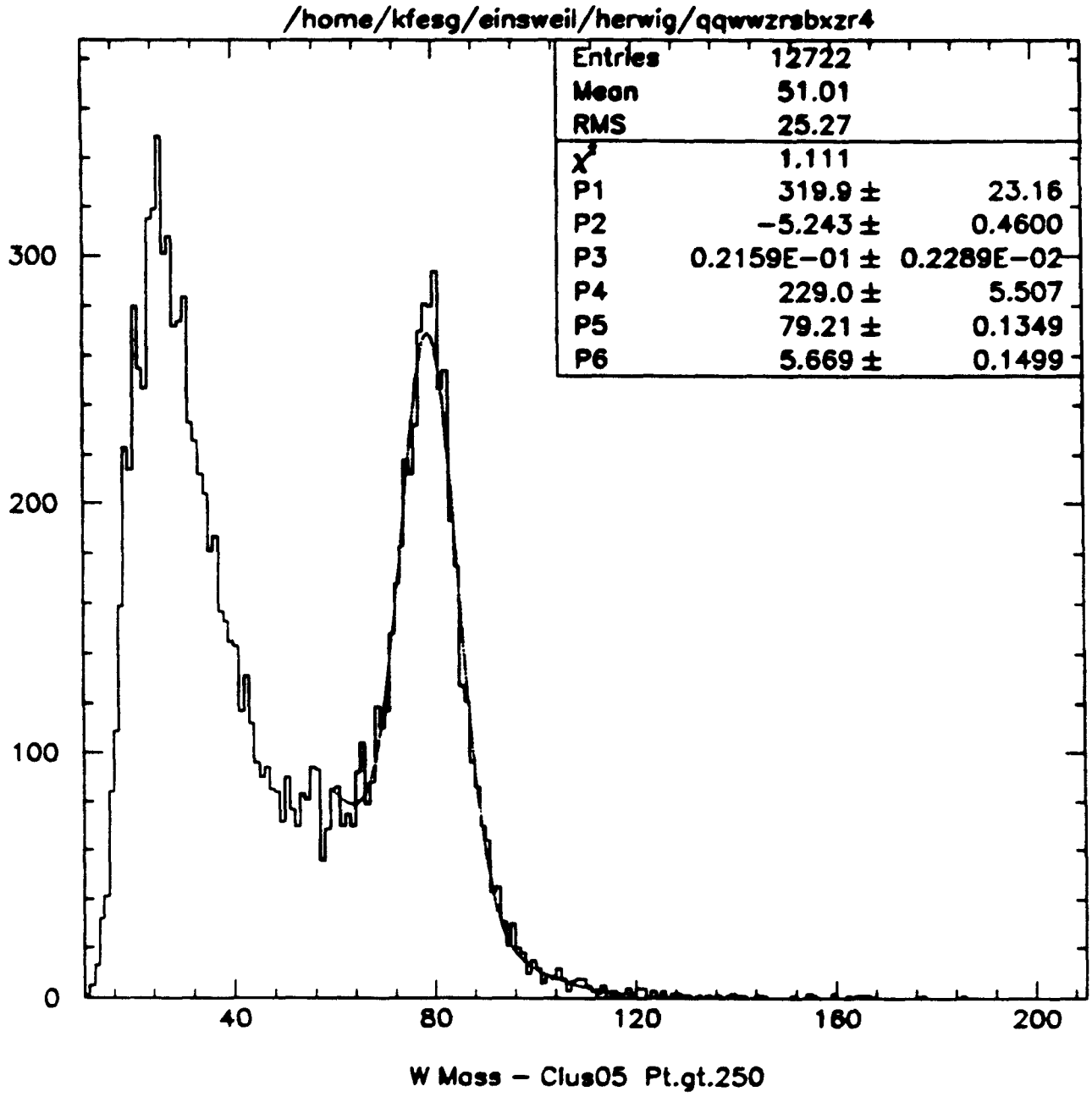

⇒ resolution ~ identical (.05 × .05 EM, HAD)
peak shifted several σ

Show mixture of { W + jets (background
H → WW (signal)

cone $\Delta R = 0.4$

.05 x .05 EM, HAD

92/01/29 10.43

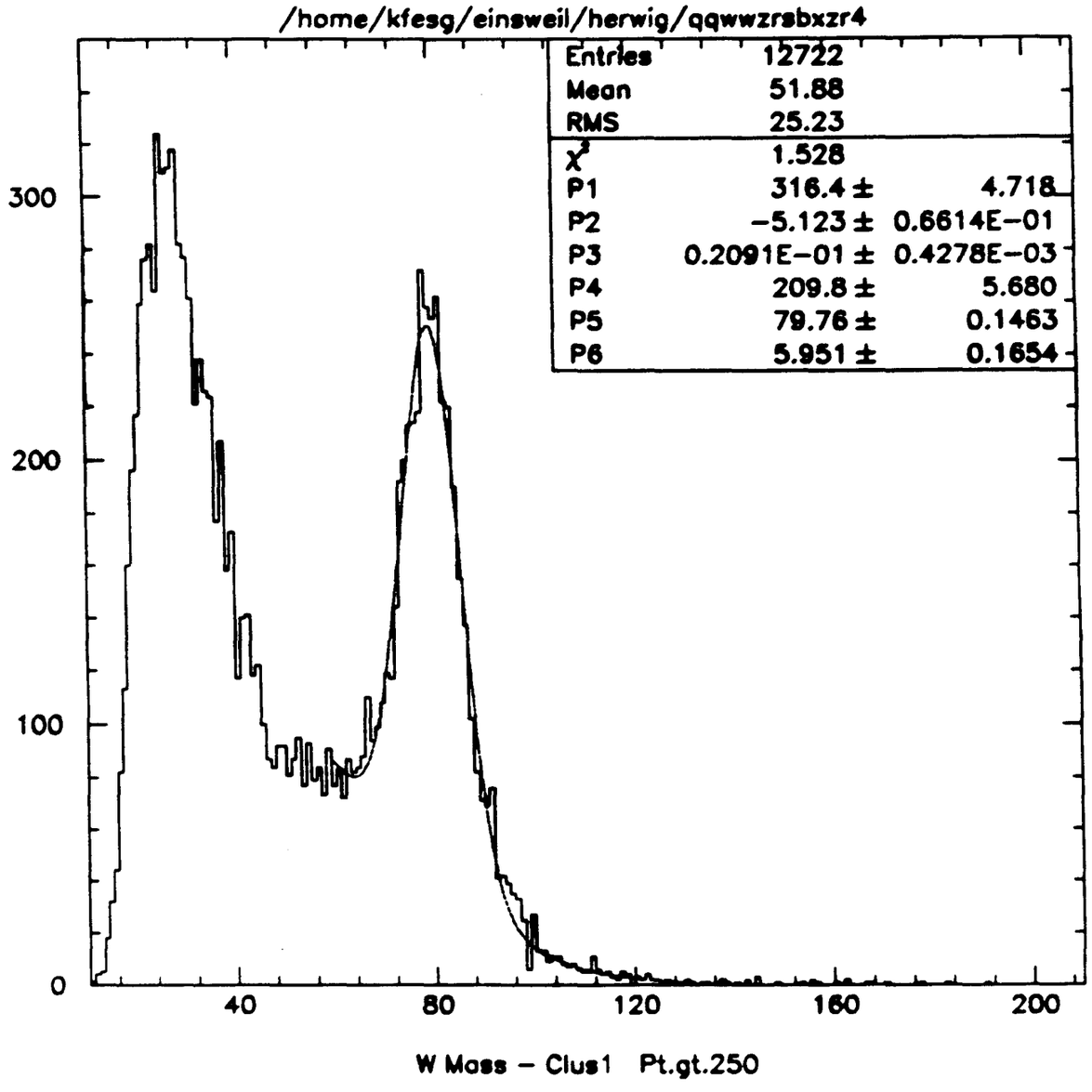


$\Delta R = 0.4$

.05 x .05 EM

.1 x .1 HAD

92/01/29 10.43



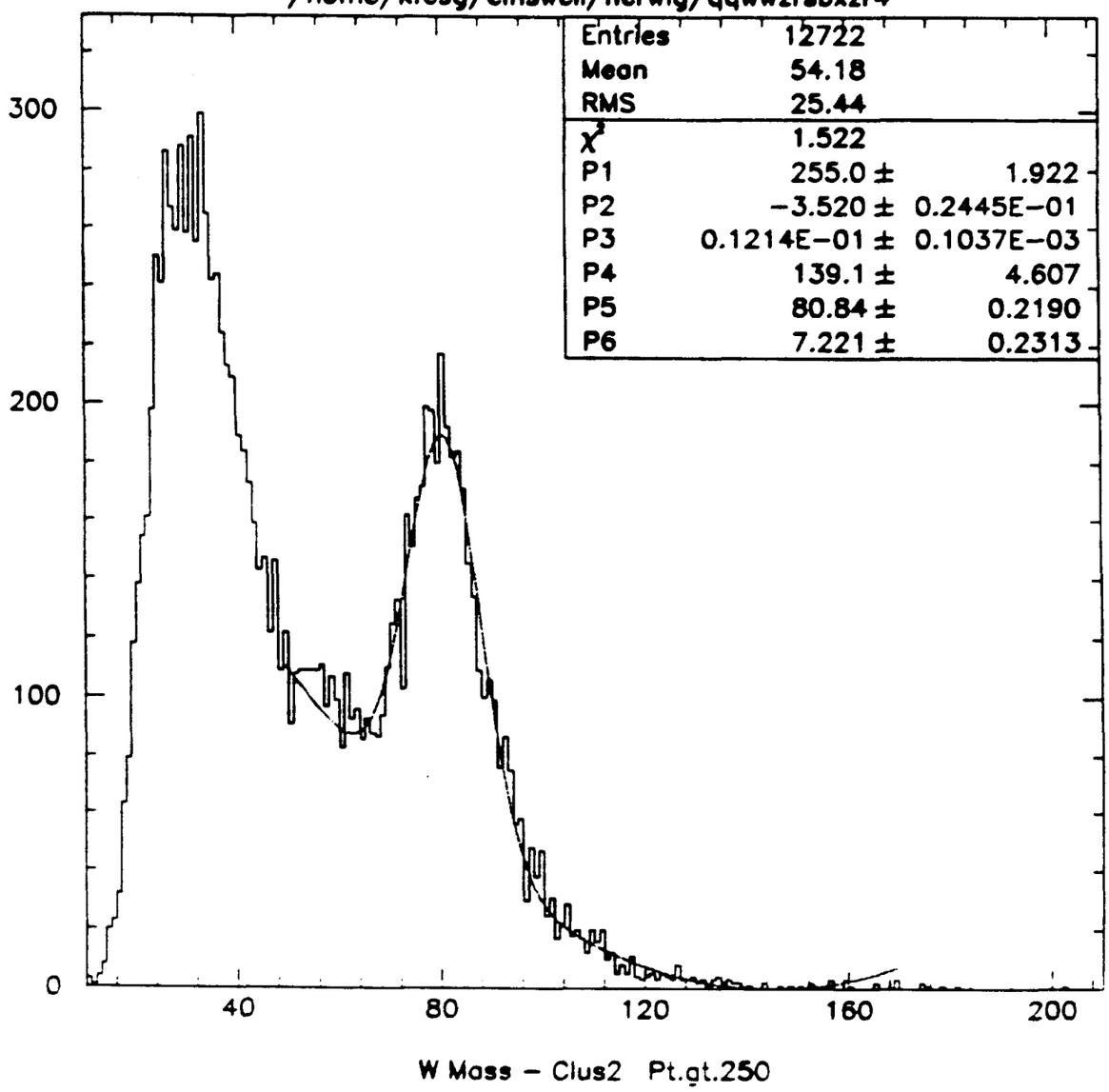
$\Delta R = 0.4$

.05x.05 EM

.2 x .2 HAD

92/01/29 10.43

/home/kfesg/einsweil/herwig/qqwwzrsbxzr4



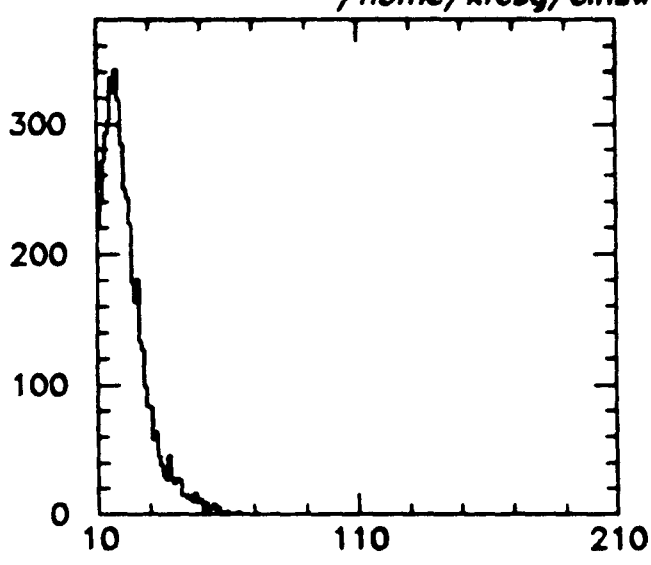

W Mass – Clus2 Pt.gt.250

$\Delta R = 0.4$

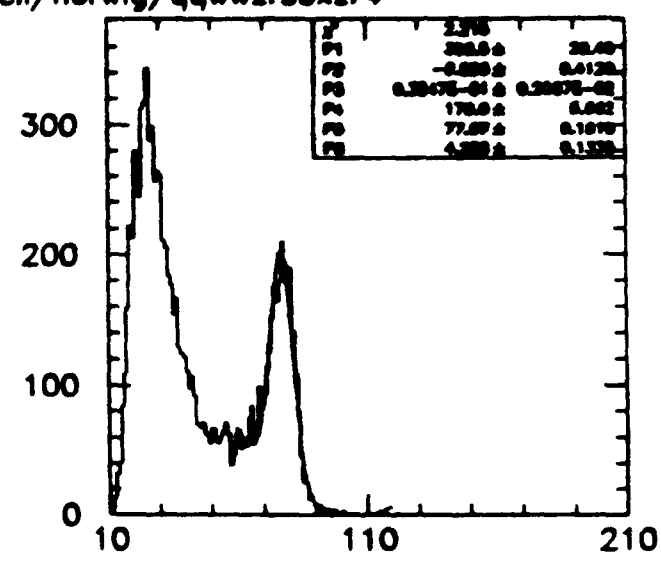
.05 x .05 EM, HAD

92/01/29 10.43

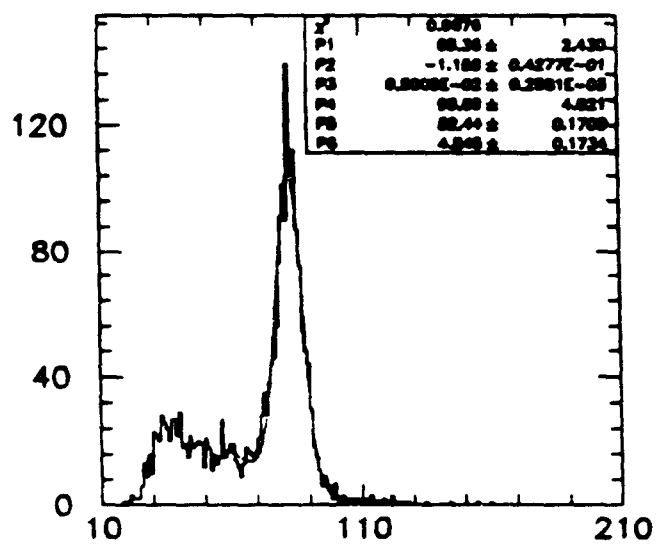
/home/kfesg/einsweil/herwig/qqwwzrsbxzr4



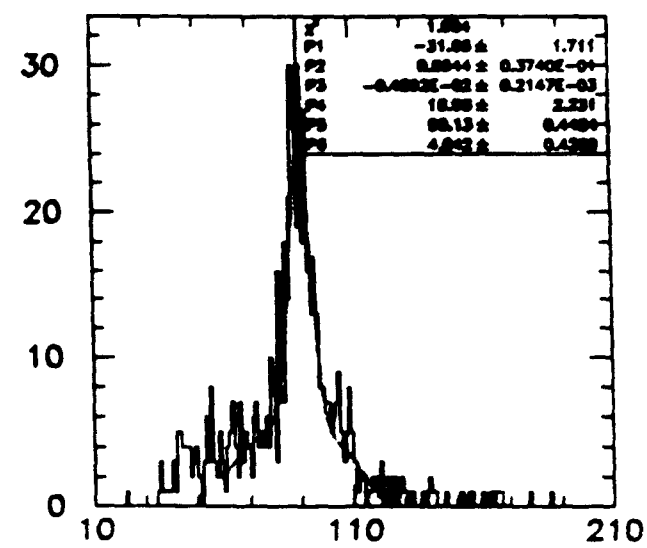

W Mass – Clus05 0.lt.Pt.lt.250




W Mass – Clus05 250.lt.Pt.lt.500




W Mass – Clus05 500.lt.Pt.lt.750




W Mass – Clus05 750.lt.Pt

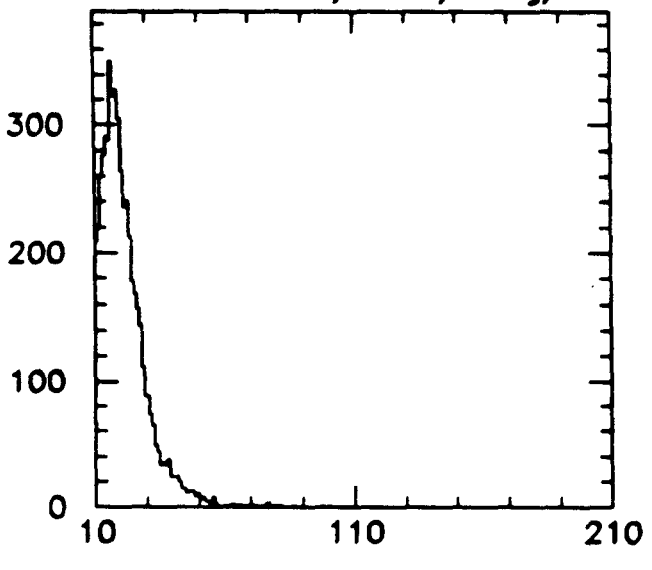
$\Delta R = 0.4$

.05 x .05 EM

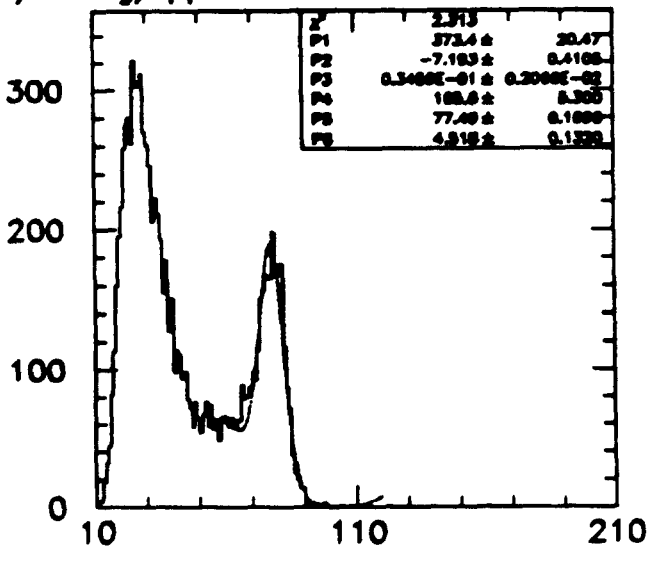
.1 x .1 HAD

92/01/29 10.44

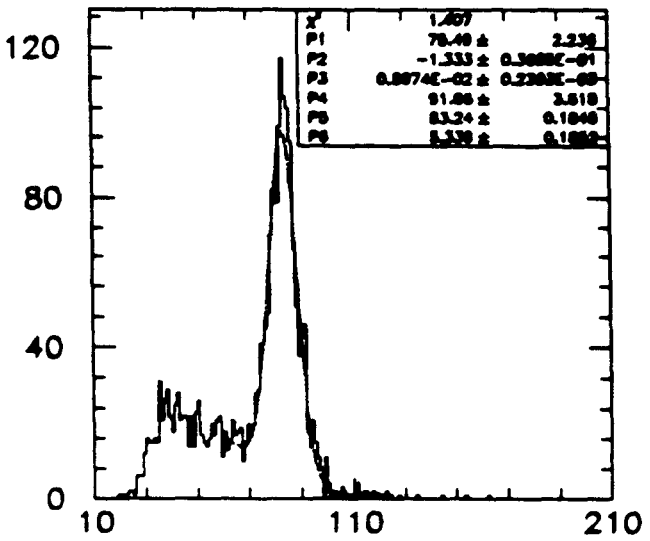
/home/kfesg/einsweil/herwig/qqwwzrsbxzr4



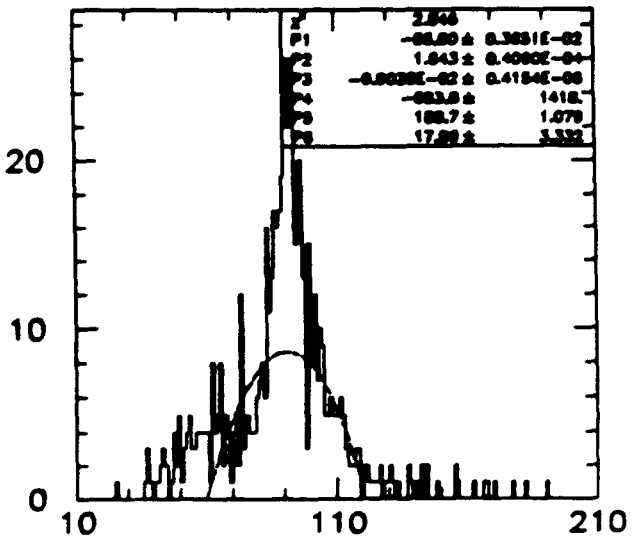

W Mass – Clus1 0.lt.Pt.lt.250




W Mass – Clus1 250.lt.Pt.lt.500




W Mass – Clus1 500.lt.Pt.lt.750




W Mass – Clus1 750.lt.Pt

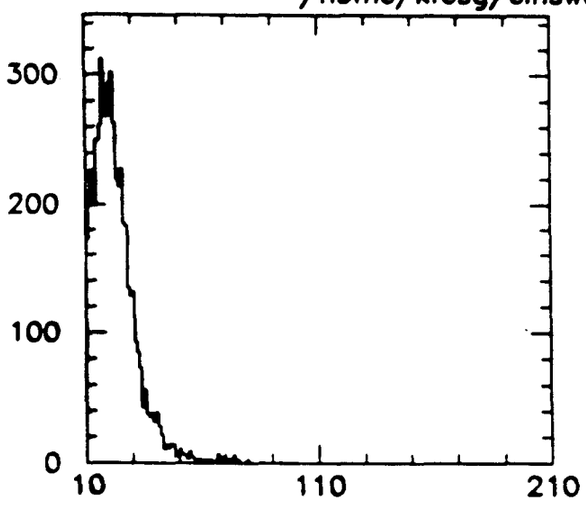
$\Delta R = 0.4$

.05x.05 EM

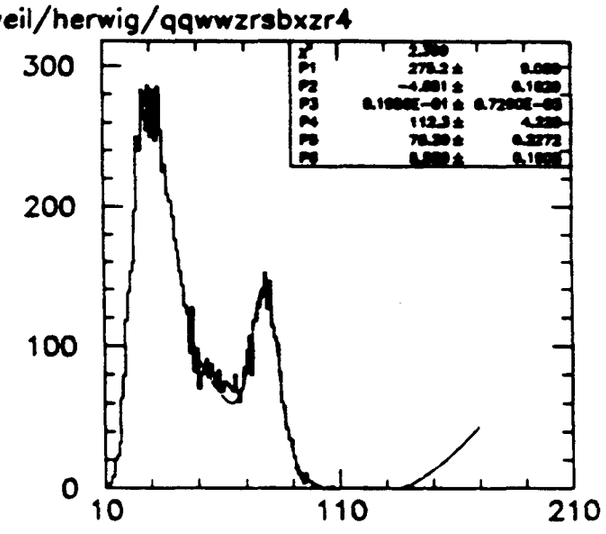
.2 x .2 HAD

92/01/29 10.44

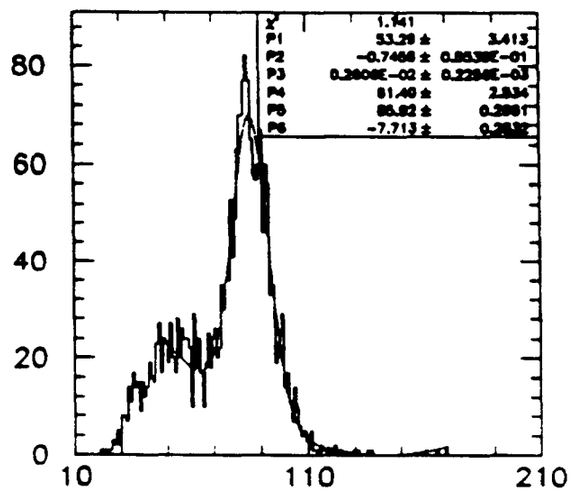
/home/kfesg/einsweil/herwig/qqwwzrsbxzr4



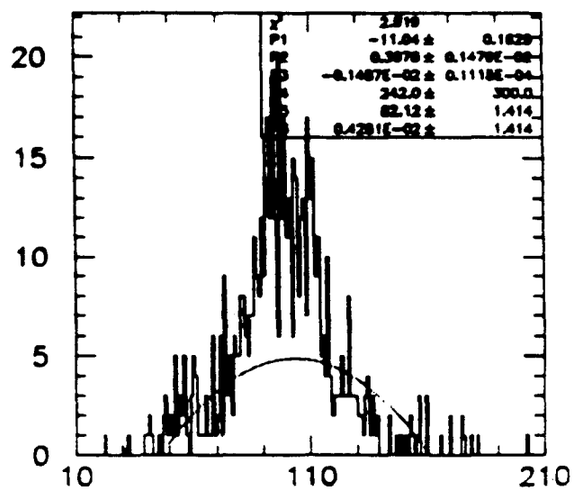

W Mass – Clus2 0.lt.Pt.lt.250




W Mass – Clus2 250.lt.Pt.lt.500




W Mass – Clus2 500.lt.Pt.lt.750



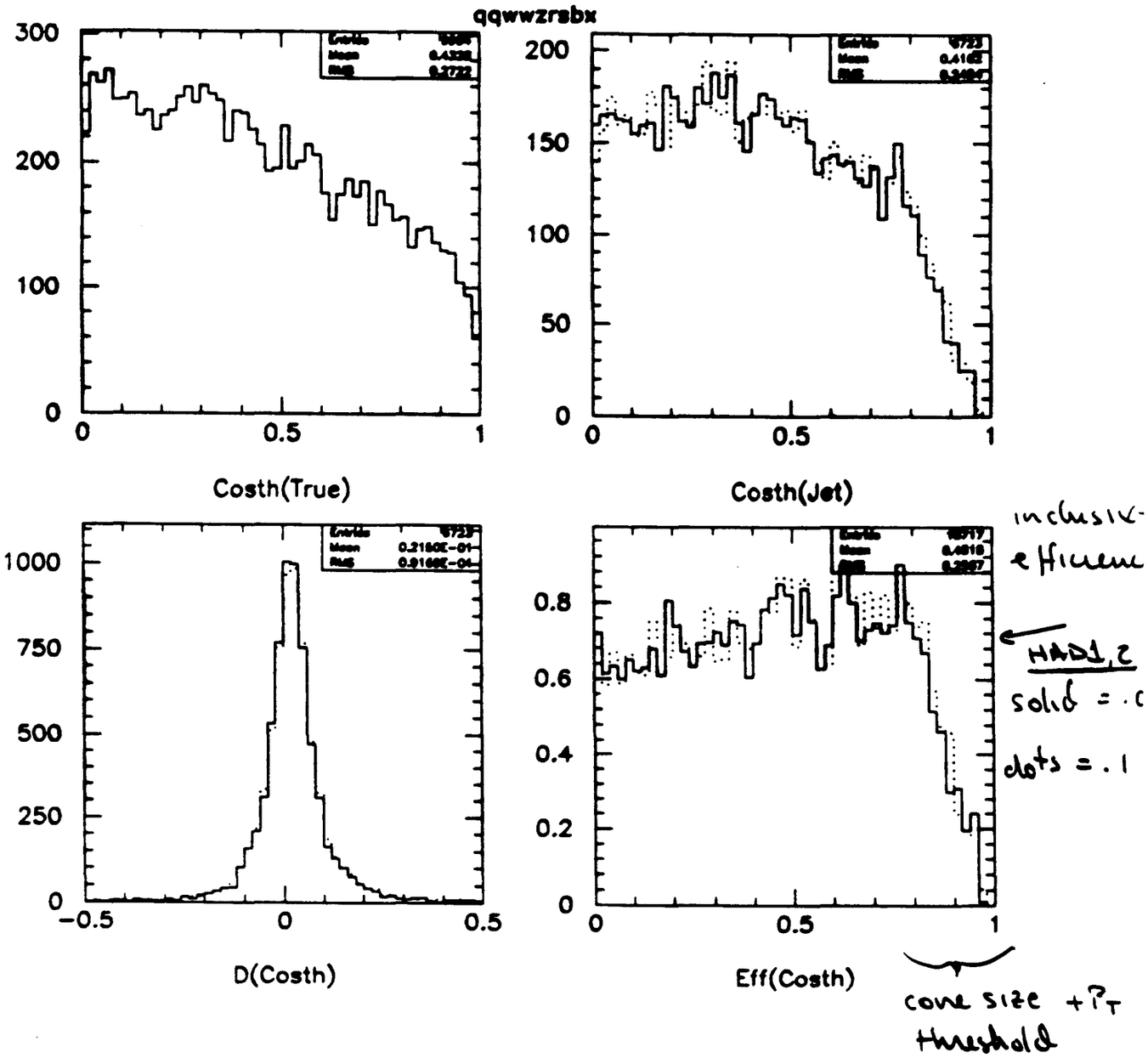

W Mass – Clus2 750.lt.Pt

Reconstruction of $\cos\theta^*$ from $W \to jj$

using $\Delta R = 0.15$ cones inside $\Delta R = 0.6$ con

$\cos\theta^* \sim \frac{E_1 - E_2}{E_1 + E_2}$ ⇒ need to measure $E_{\parallel}$

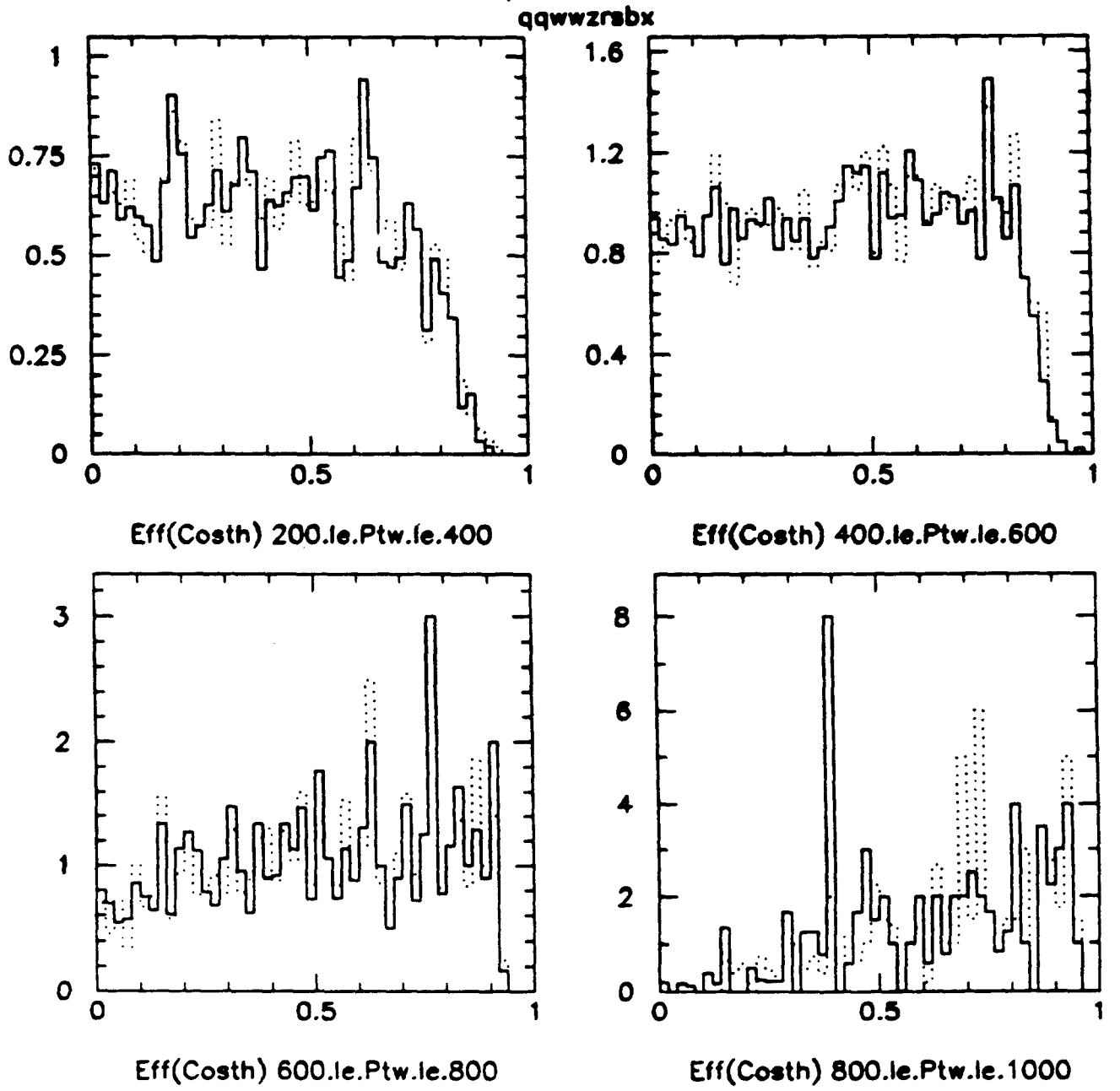
92/01/08 11.18



Same but as a function of $P_T$ (jet) :

large $P_T$ (jet) | small $\cos\theta^*$ $\epsilon$ decreases
large $\cos\theta^*$ $\epsilon$ increases

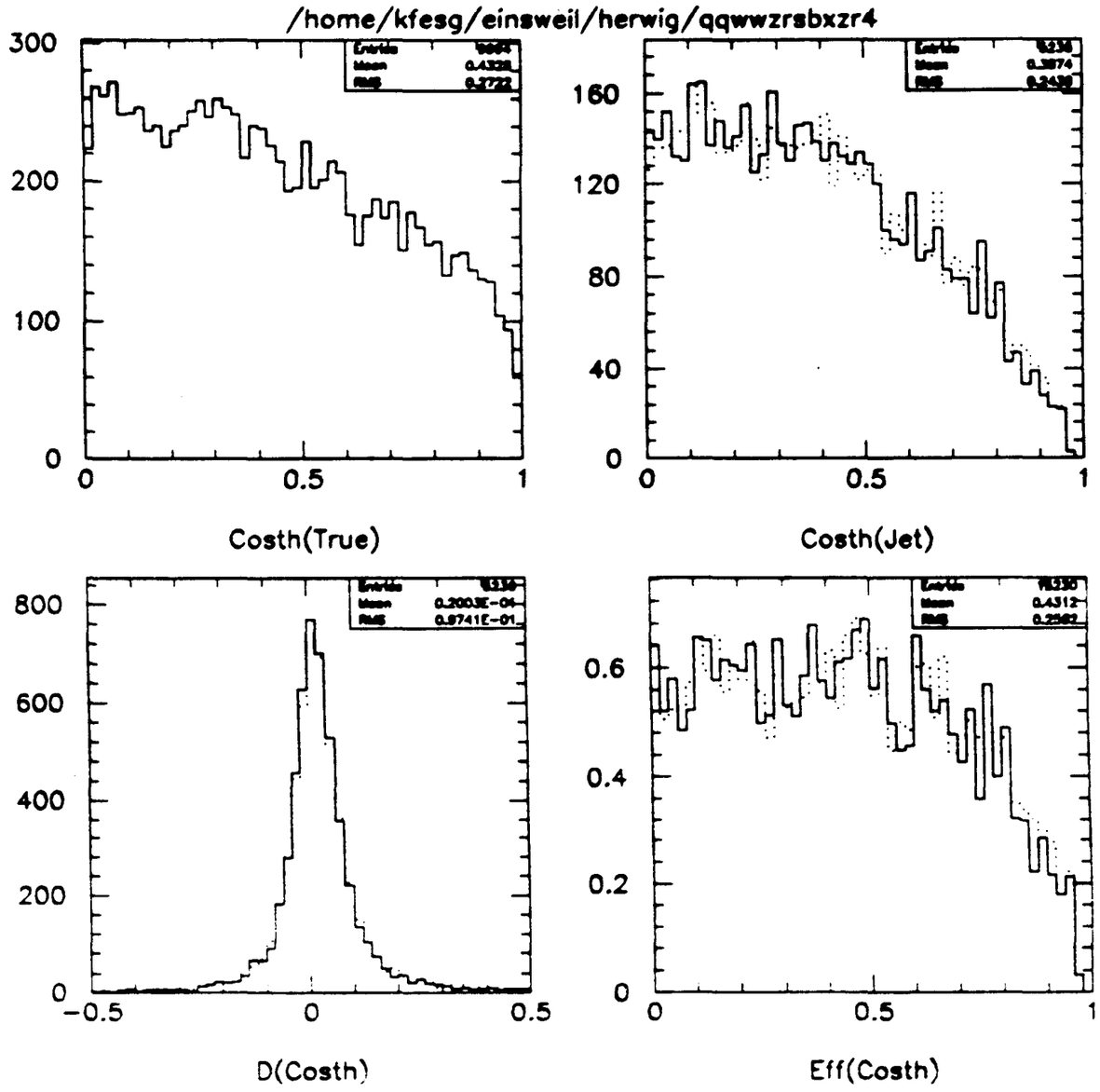
92/01/08 11.20



using cone of $\Delta R = 0.4$

$\Rightarrow$ cuts off large $\cos\theta^*$

92/01/30 19.46

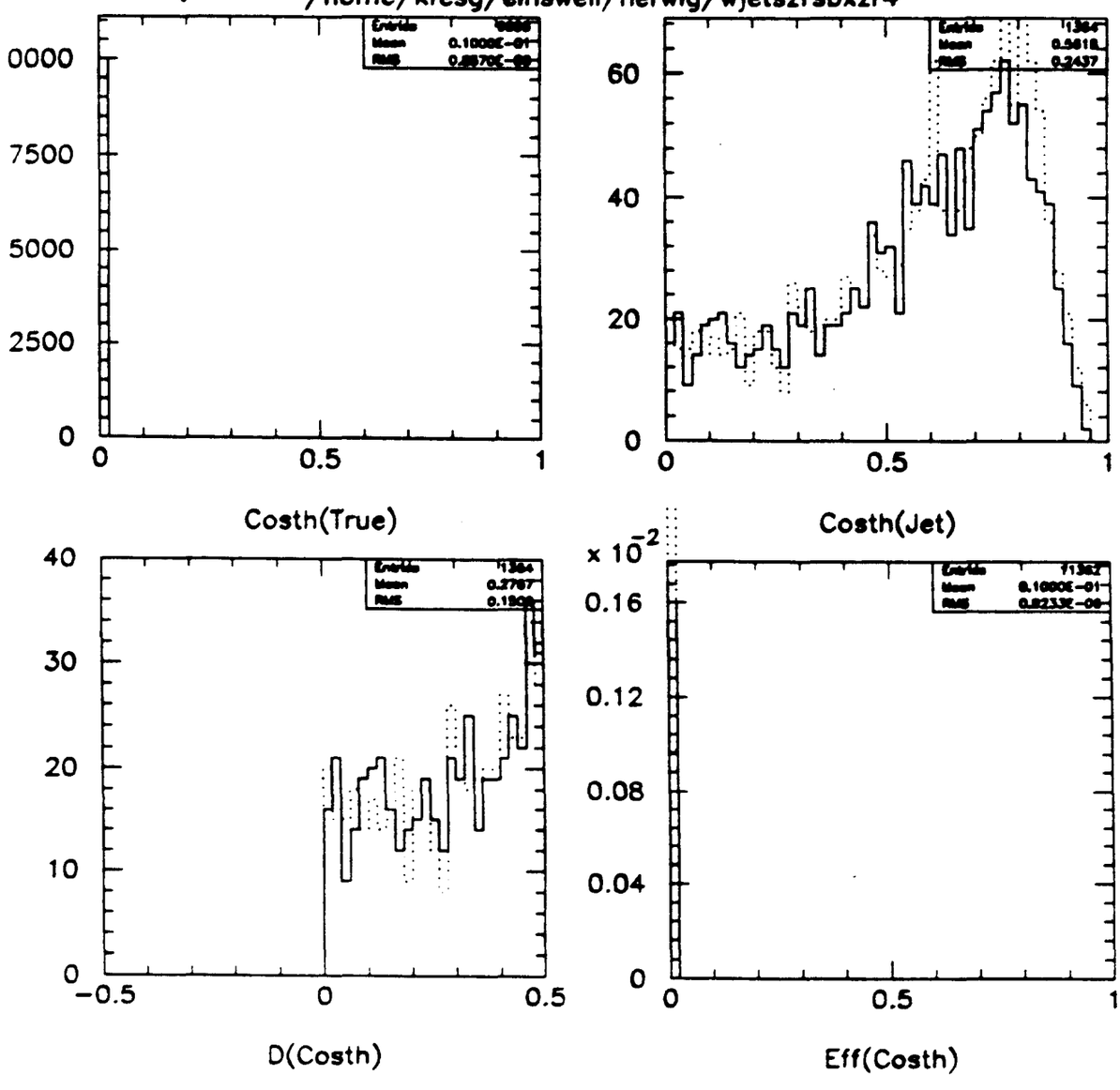


indication of large difference for background shape (W + jets)

{ 2nd jet fragment at large angle, low E }

92/01/30 19.26

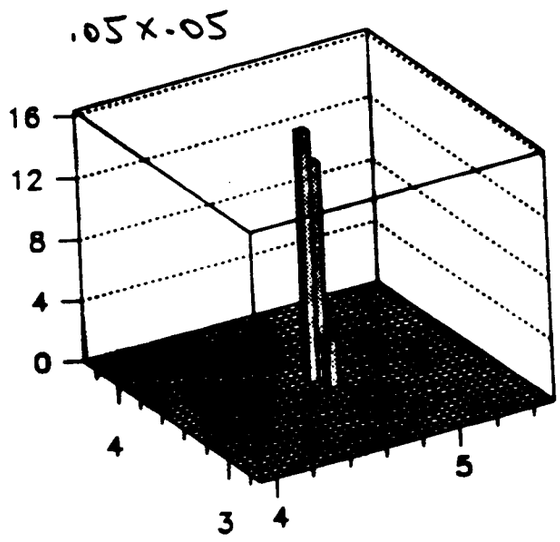
/home/kfesg/einsweil/herwig/wjetszrsbxzr4



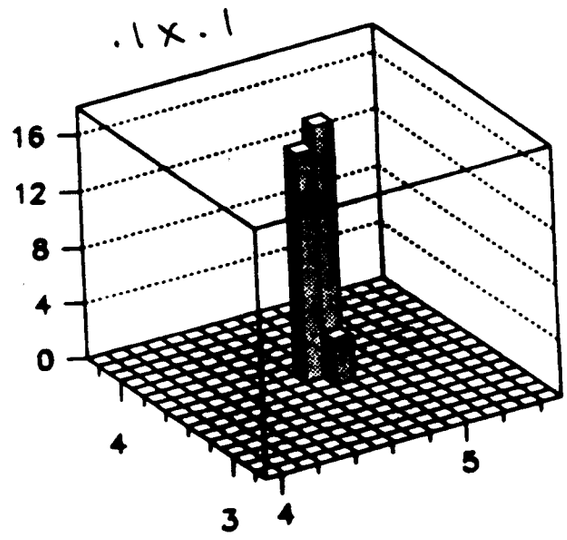
# Forward Jet Tagging

"Typical" Event (Particle level)

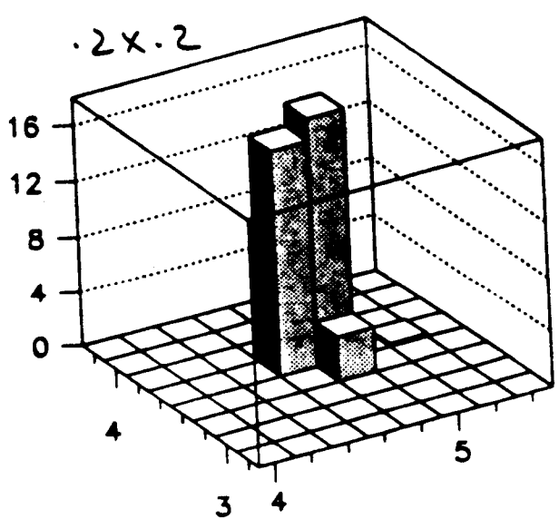
92/01/21 15.34



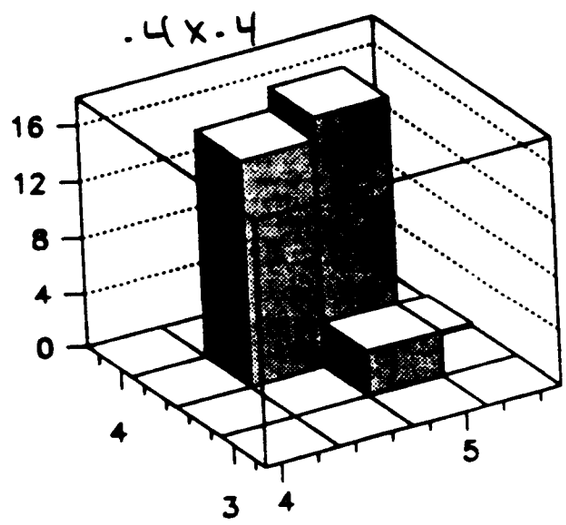

Et (Eta vs Phi 7) Jet 2 Code = 10




Et (Eta vs Phi 7) Jet 2 Code = 10



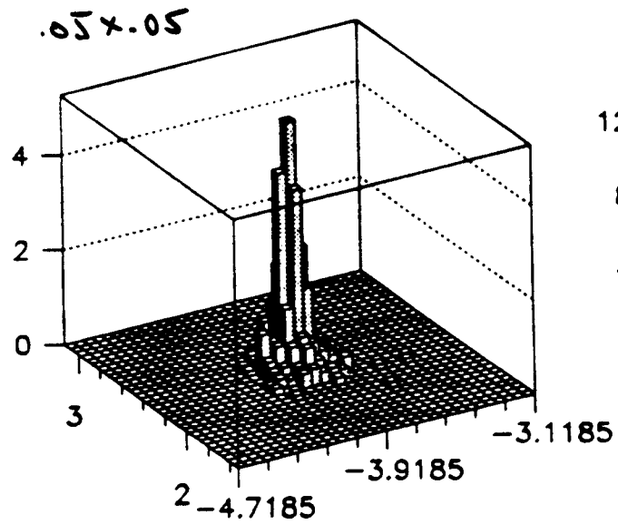

Et (Eta vs Phi 7) Jet 2 Code = 10



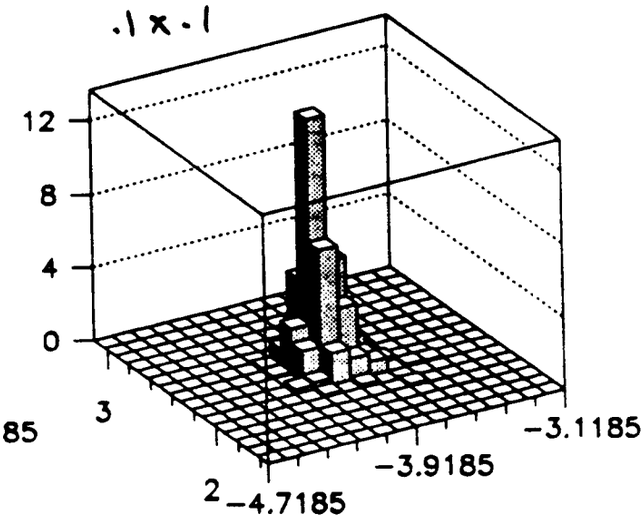

Et (Eta vs Phi 7) Jet 2 Code = 10

"Typical" Event ( Detector level )

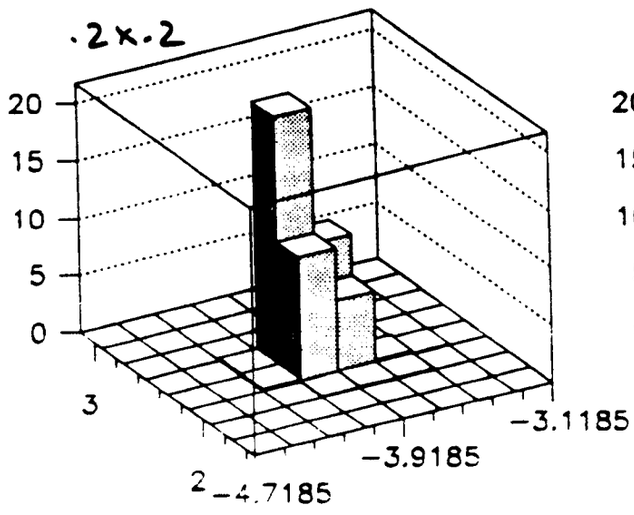
92/01/21 15.35



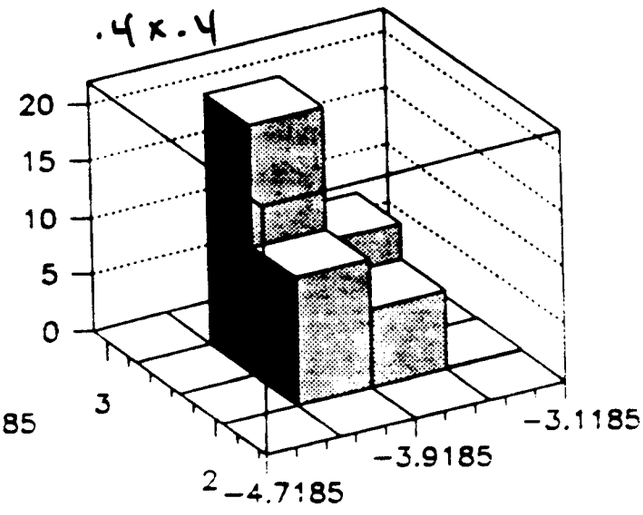

Et (Eta vs Phi 7) Jet 2 Code = 10




Et (Eta vs Phi 7) Jet 2 Code = 10




Et (Eta vs Phi 7) Jet 2 Code = 10




Et (Eta vs Phi 7) Jet 2 Code = 10

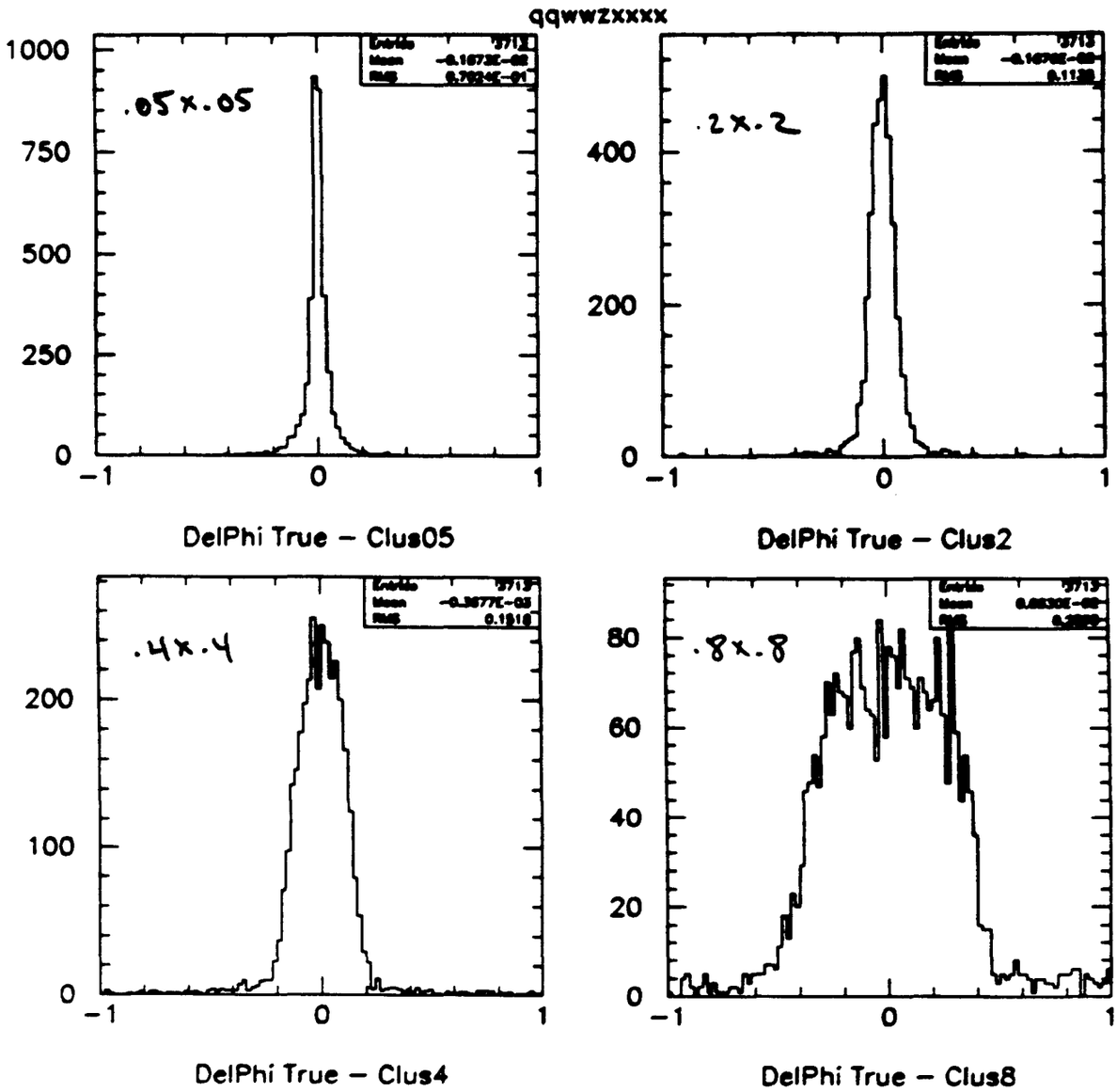
Compare True - observed quantities

at { · Particle level (Black)
· Detector level (Red)

$\Delta\phi$ vs segmentation

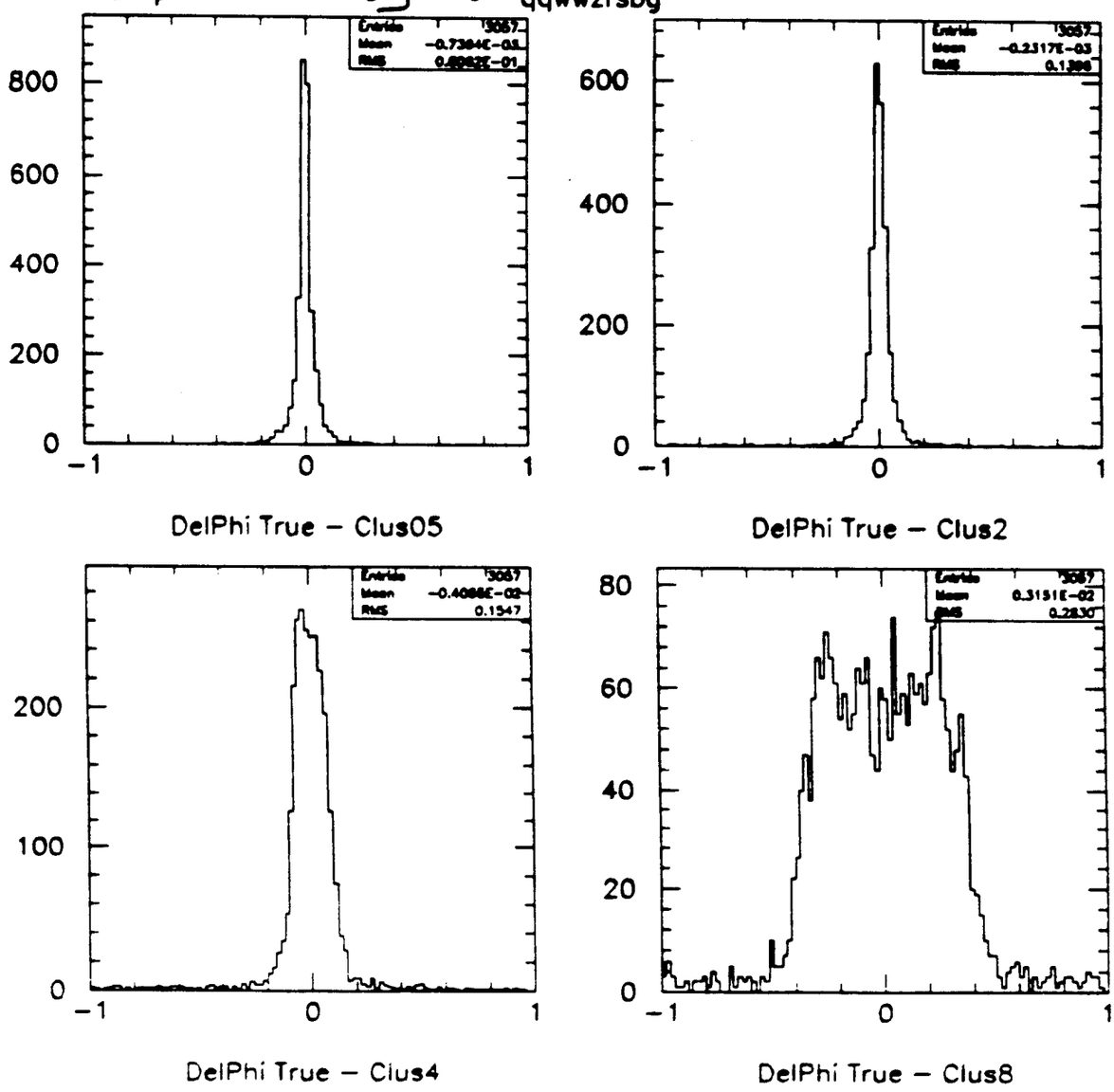
91/12/16 17.15

qqwwzxxxx



92/01/09 20.13

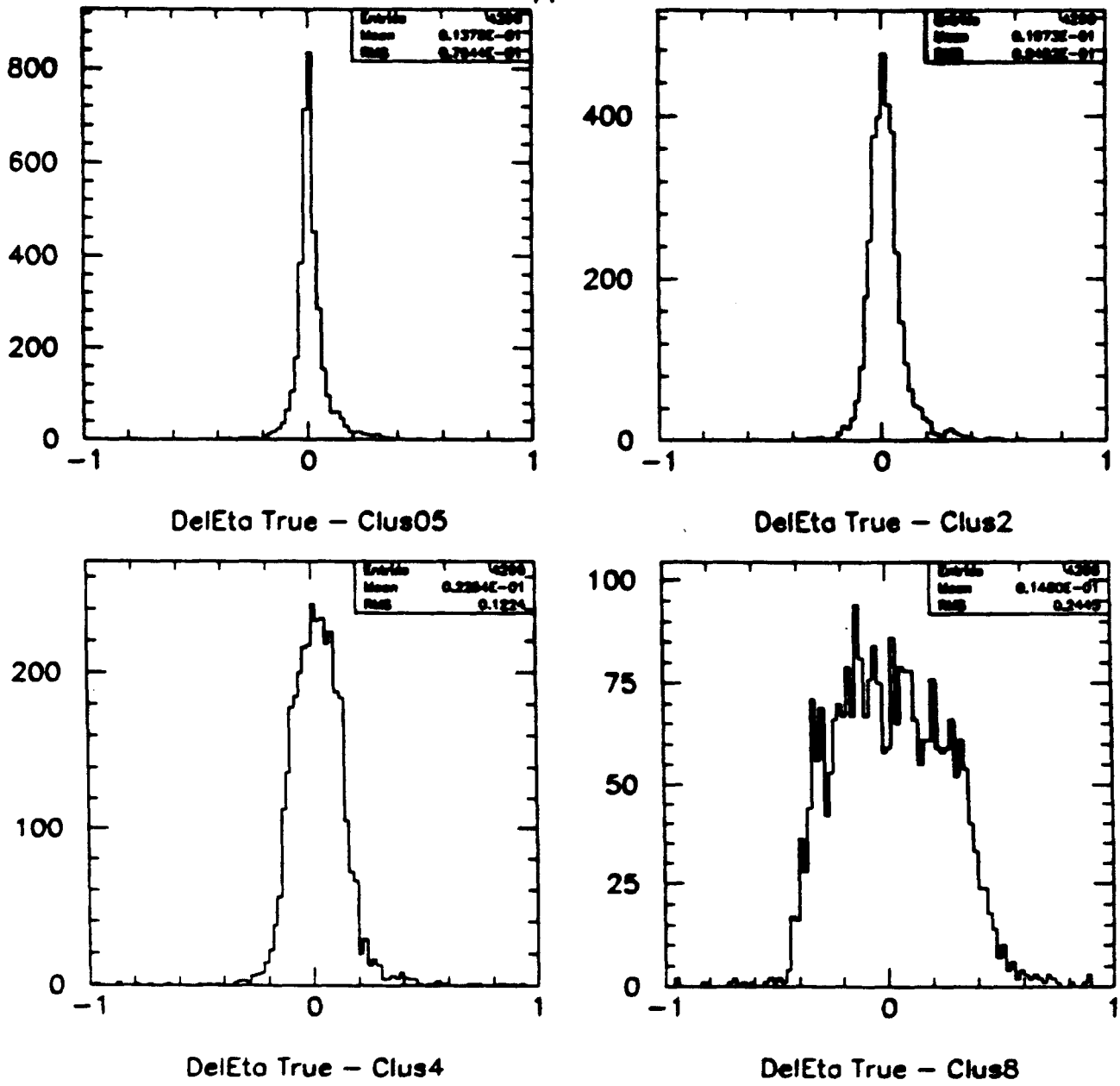
Δφ vs segmentation



$\Delta\eta$ vs segmentation

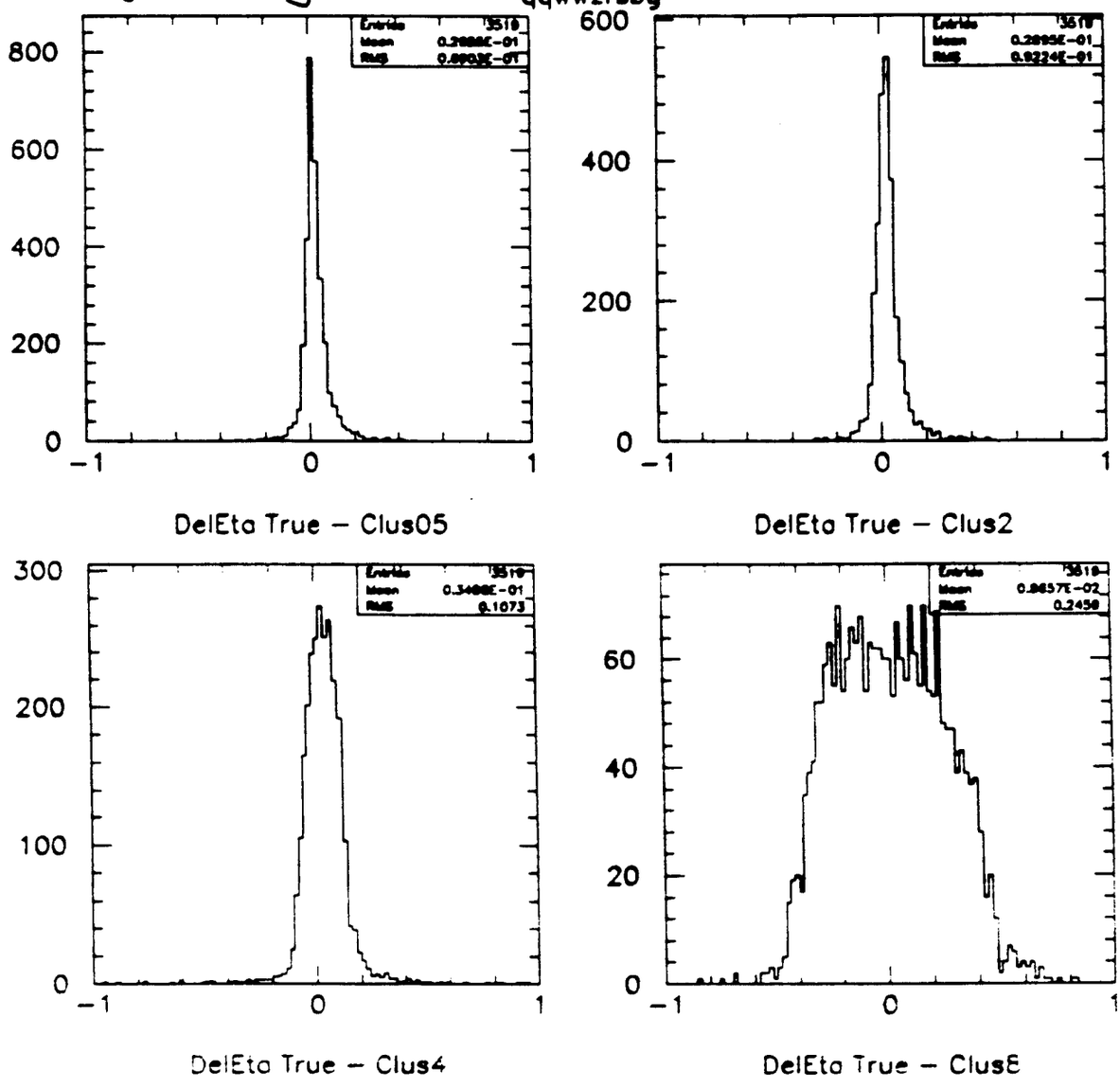
91/12/16 17.15

qqwwzxxxx



92/01/09 20.13

Δk vs segmentation qqwwzrsbg

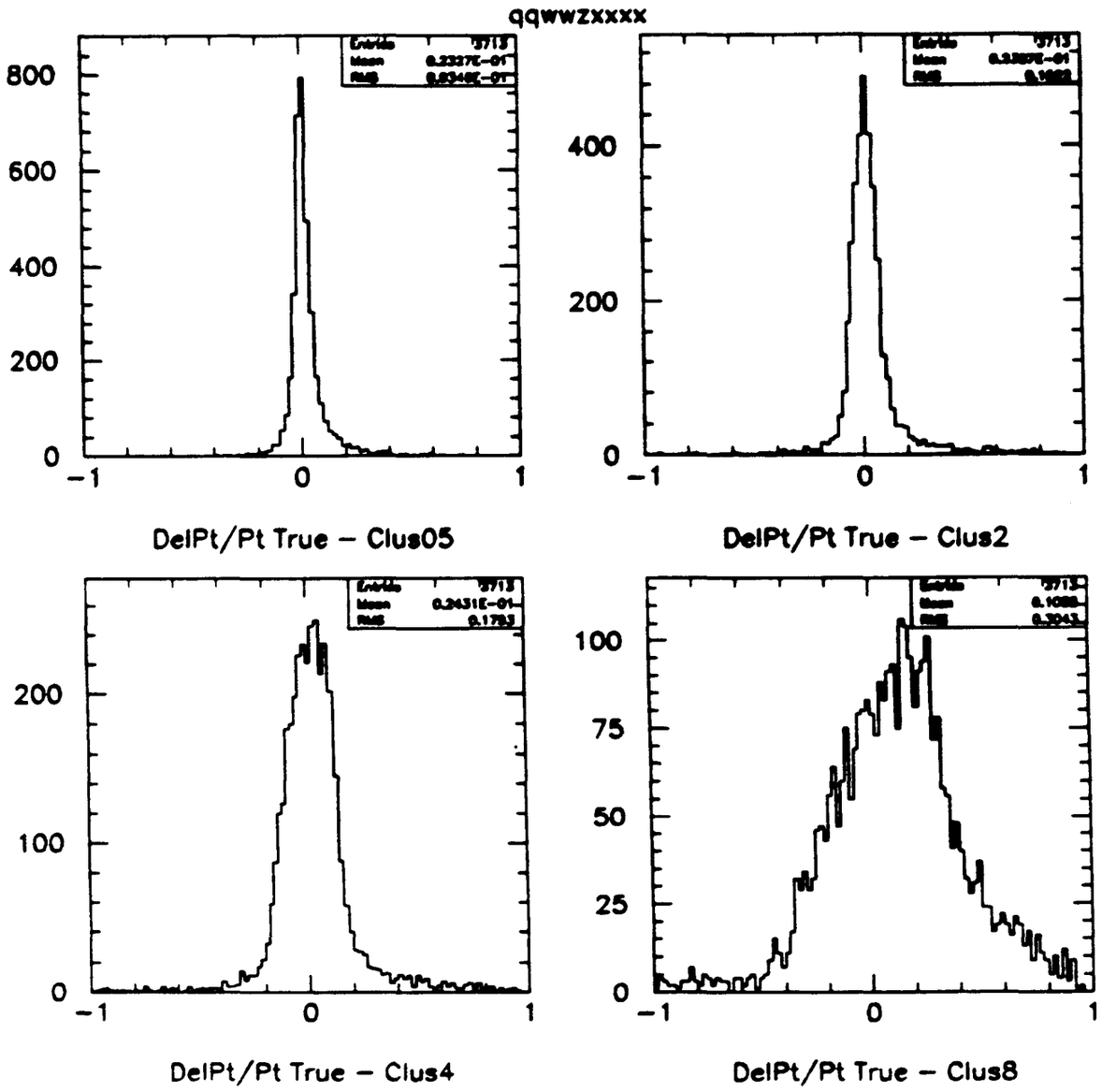


<u>note</u> : assumed Fcal performance

$$= \frac{100\%}{\sqrt{E_L}} \oplus 10\%$$

$\Delta P_T / P_T$ vs segmentation

91/12/16 17.15

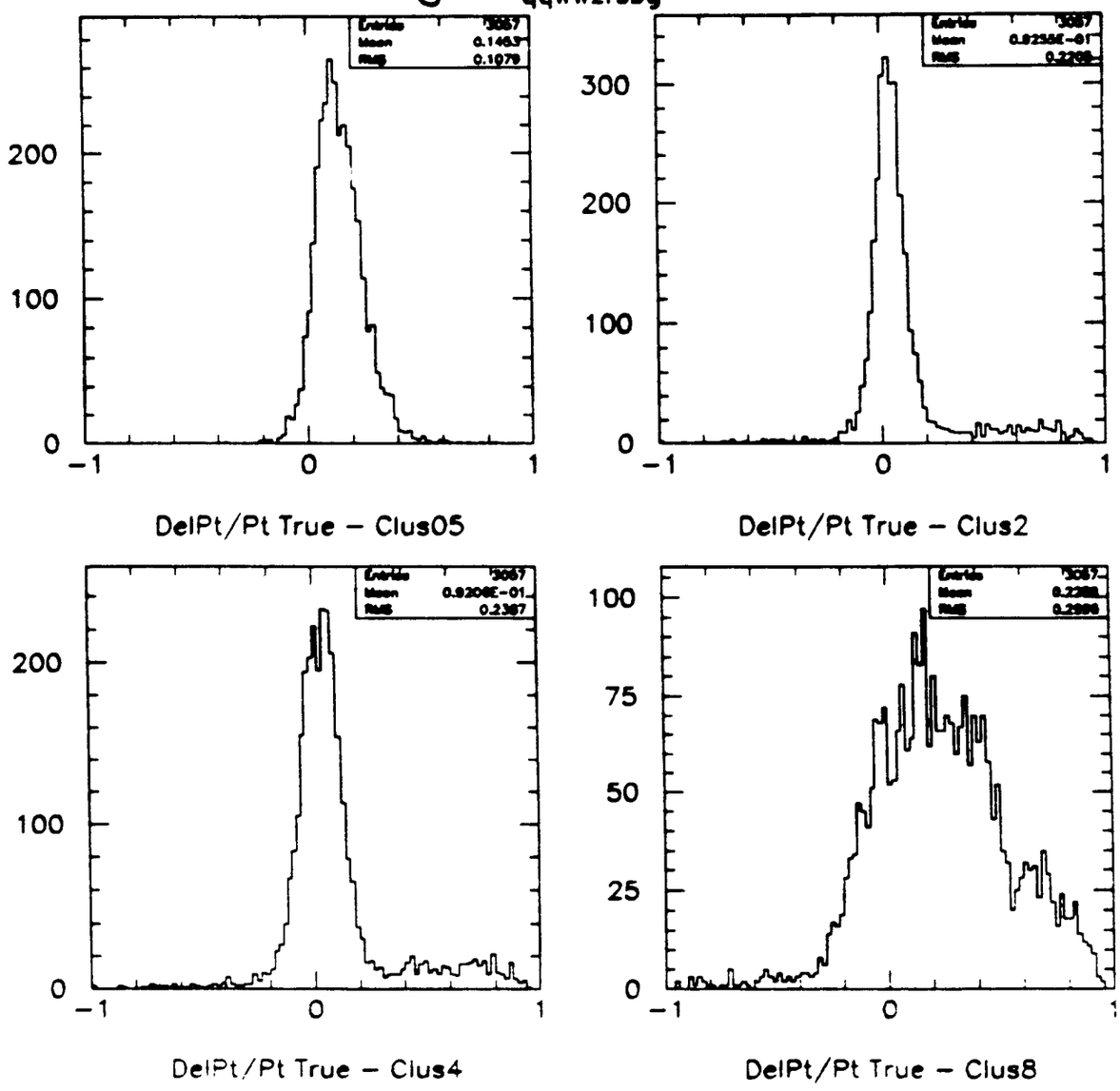


poor resolution for
0.05×0.05 due to
cell threshold cut...

92/01/09 20.13

$\Delta P_T / P_T$ vs segmentation

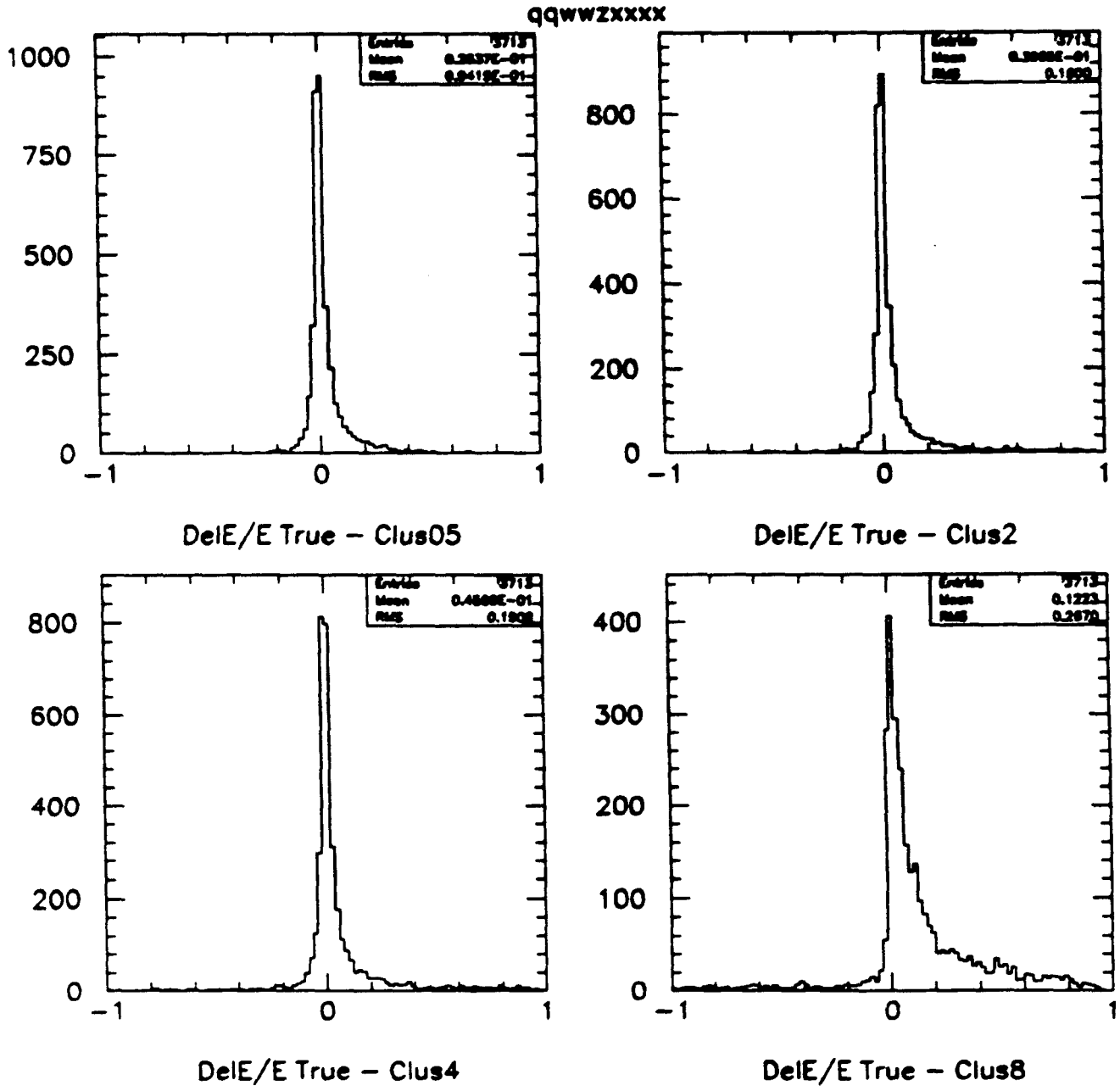
qqwwzrsbg



ΔE/E vs segmentation

91/12/16 17.15

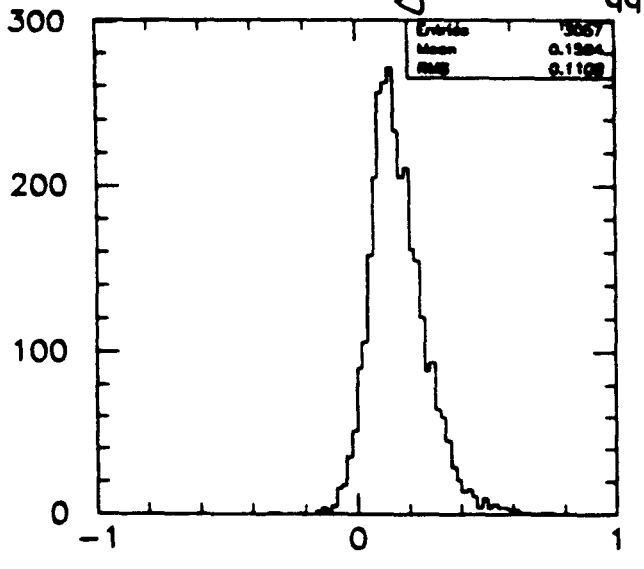
qqwwzxxxx



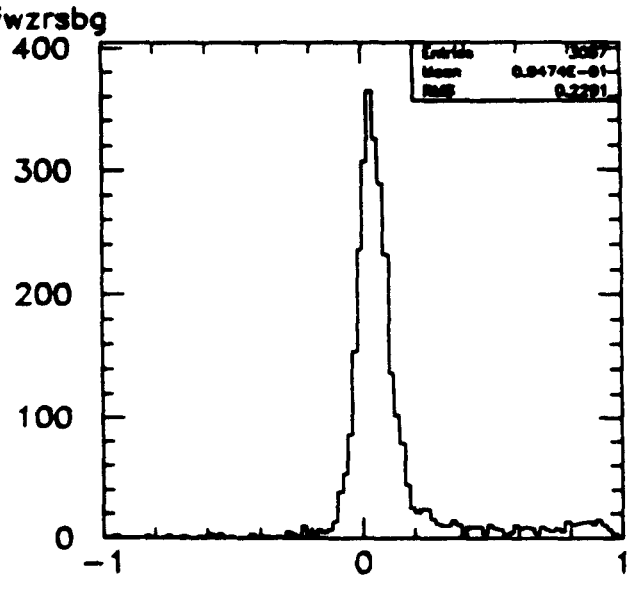
92/01/09 20.13

ΔE/E vs segmentation

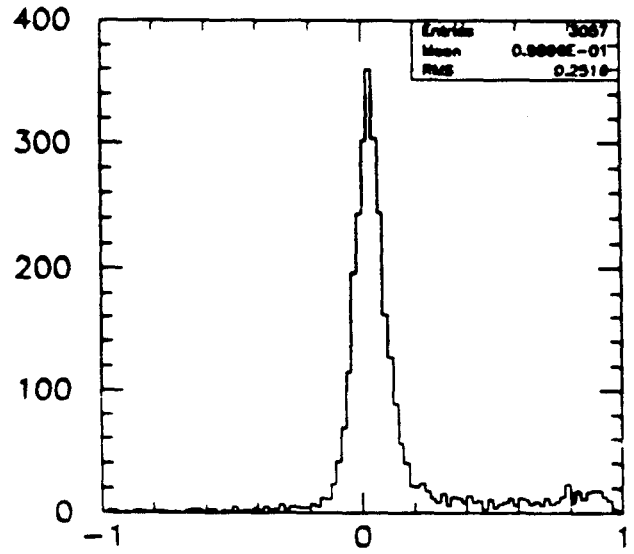
qqwwzrsbg



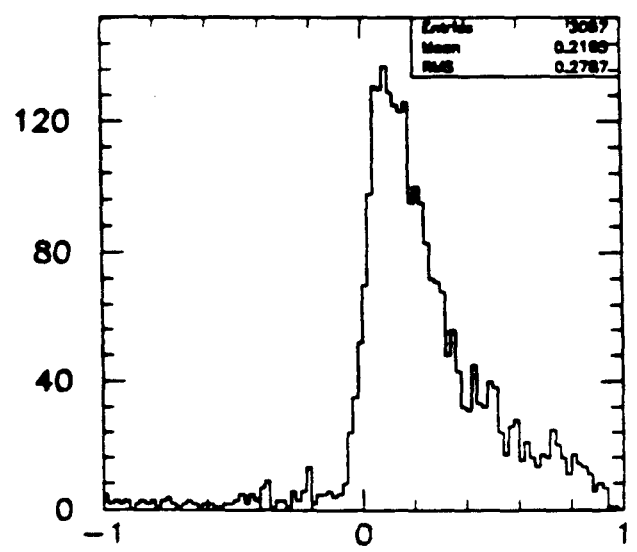

DelE/E True – Clus05




DelE/E True – Clus2




DelE/E True – Clus4




DelE/E True – Clus8

d) SUSY extensions (Einsweiler/Barnett/Gunion

consider Minimal SUSY model : 5 Higgs'

$h, H, A, H^{\pm}$

assuming sparticles all heavy with no large splittings, ... $\Rightarrow$ 2 params $\left\{ \begin{array}{l} \tan\beta \\ m_A \end{array} \right.$

<u>Comment</u>:

at <u>tree</u> level, theory is very restrictive (e.g. $m_h < m_Z \Rightarrow$ LEP II discovery). with 1-loop corrections and "large" $\tan\beta$ (expected for large $m_t$), things change substantially ...

1) modifications to standard Modes

$\left\{ \begin{array}{l} BR(H \to \gamma\gamma), \quad BR(H \to ZZ) \\ \sigma(t\bar{t}H), \quad \sigma(gg \to H), \quad \sigma(qq \to qq \end{array} \right.$

2) new discovery modes

e) <u>Gauge Boson Pairs</u> (Hinchliffe / Mangano

idea: $W\gamma$, $WW$, $ZZ$, $WZ$ are all probes of Electroweak Lagrangian

→ what can be done at SSC beyond LEP-II ?

→ use $WZ$ as example

f) <u>Strong Breaking</u> (Einsweiler / Hinchliffe

· plethora of ideas, models, ...

→ concentrate on $W^+W^+$ - "non-resonan

( $WZ$, $W^+W^-$ may show resonance structur

· signal is small ( $\lesssim 10$ evts / SSC year )

· large "opposite sign background" $W^+W^-$

· large $t\bar{t}$ background (isolation + kinemat
(10⁻ - 10⁵)

→ study charge separation at high $P_T$ using SDC SIM ( O'shaughnessy ) : want 4-5 σ //

I) Top (Sinervo / Hubbard / Galtieri)

idea: SSC will be a "top factory"

→ think about what SSC can do ...

a) Mass measurement ($m_t$ = 150, 250 GeV)

i) lepton + jets: (Sinervo / Hubbard)

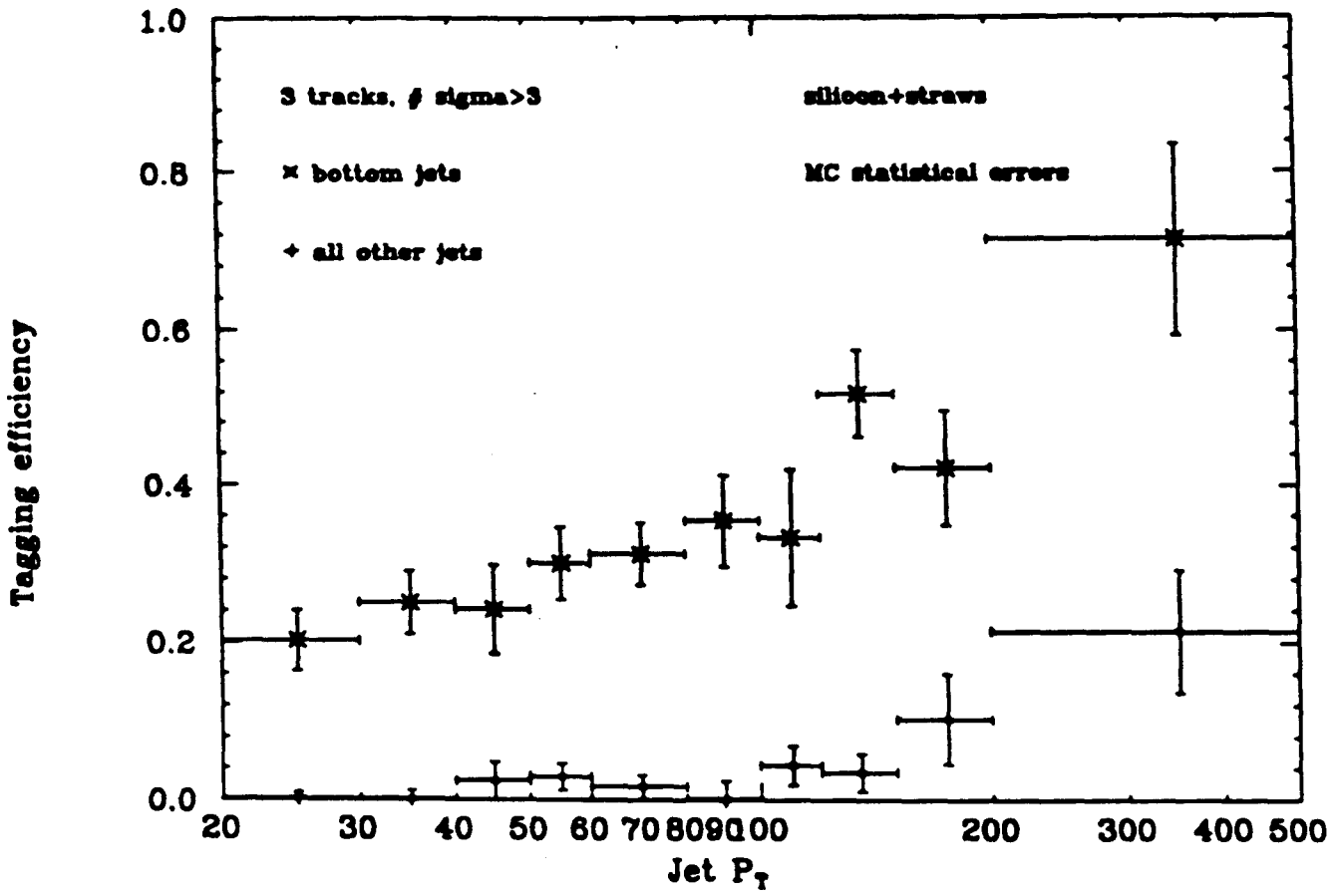
- both masses studied in part
- improve kinematics, algorithms, etc. for jet spectroscopy
- use new b-tagging studies

ii) dileptons: (Galtieri)

- $m_t$ = 250 already well-studied
  → generate results for $m_t$ = 150

b) BR measurement (Sinervo)

Latest b-tagging results (Hubbard)




when folded with top kinematics, appears to give double-tag efficiency in $t\bar{t}$ events similar to LoI value (~10%)

c) non-standard decays (Barnett / Hubbard

$t \to H^+ b$ previously studied

$\hookrightarrow \tau\nu$, $c\bar{s}$ for $m_t = 250$ $m_{H^+} = 150$

- improve detectn model
- study larger set of cases:

$m_t = 150$ $m_{H^+} = 120$ harder

( $m_{H^+}$ closer to $m_t$ and $m_W$ )

d) other tests (Mangano)

- V-A check
- Higgs induced polarization

( hard to observe )

e) fourth generation mass limit ?

III) SUSY (Barnett / Gunion)

a) Gluinos + Squarks (Barnett / Gunion)

signatures:
- $\not{E}_T$ + jets
- like sign dileptons

- for lighter of the two, discovery is straight forward
- for heavier it is very difficult (good case for NLC ...)

b) other sparticles (Mangano)

- direct chargino + neutralino production

c) broken R-parity

- LSP is unstable ⇒ $\not{E}_T$ signature los
- pair production, etc no longer requ

⇒ like-sign dileptons still OK

## IV) Heavy Bosons (Hinchliffe)

- consider $Z'$ only
- analyze discovery limit + properties

for given $m_{Z'}$,
measure: $\Gamma(Z')$, $\sigma(Z')$, $A_{FB}$
$\Rightarrow$ identify model ...

analyze several cases, including statistics (vary calorimeter constant term ...

## V) Compositeness (Shapiro / Hearty)

- redo previous analysis using more realistic calorimeter non-linearities

but: CALOR 89 + FNAL Fe data not in good agreement ?

VI) QCD, ... (Mangano)

W
Z
jet
b
t
⋮

cross sections & general kinematics of basic processes and what can be learned ...

PRESENTATION BY:

AKIHIRO MAKI AND RUDOLPH THUN

A. MAKI
R. THUN
31 JAN 92
Sat #1

# SDC MUON CHAMBER COMMITTEE

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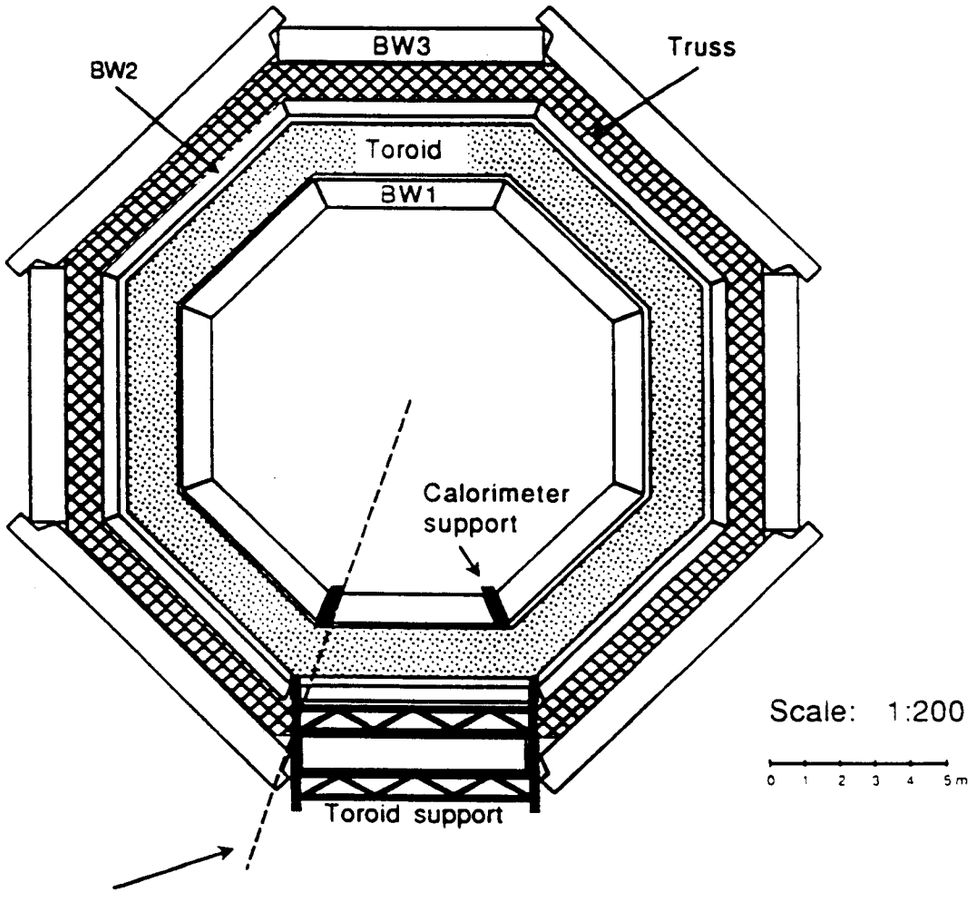
2.) VISIT BOSTON - MADISON - SEATTLE - KEK

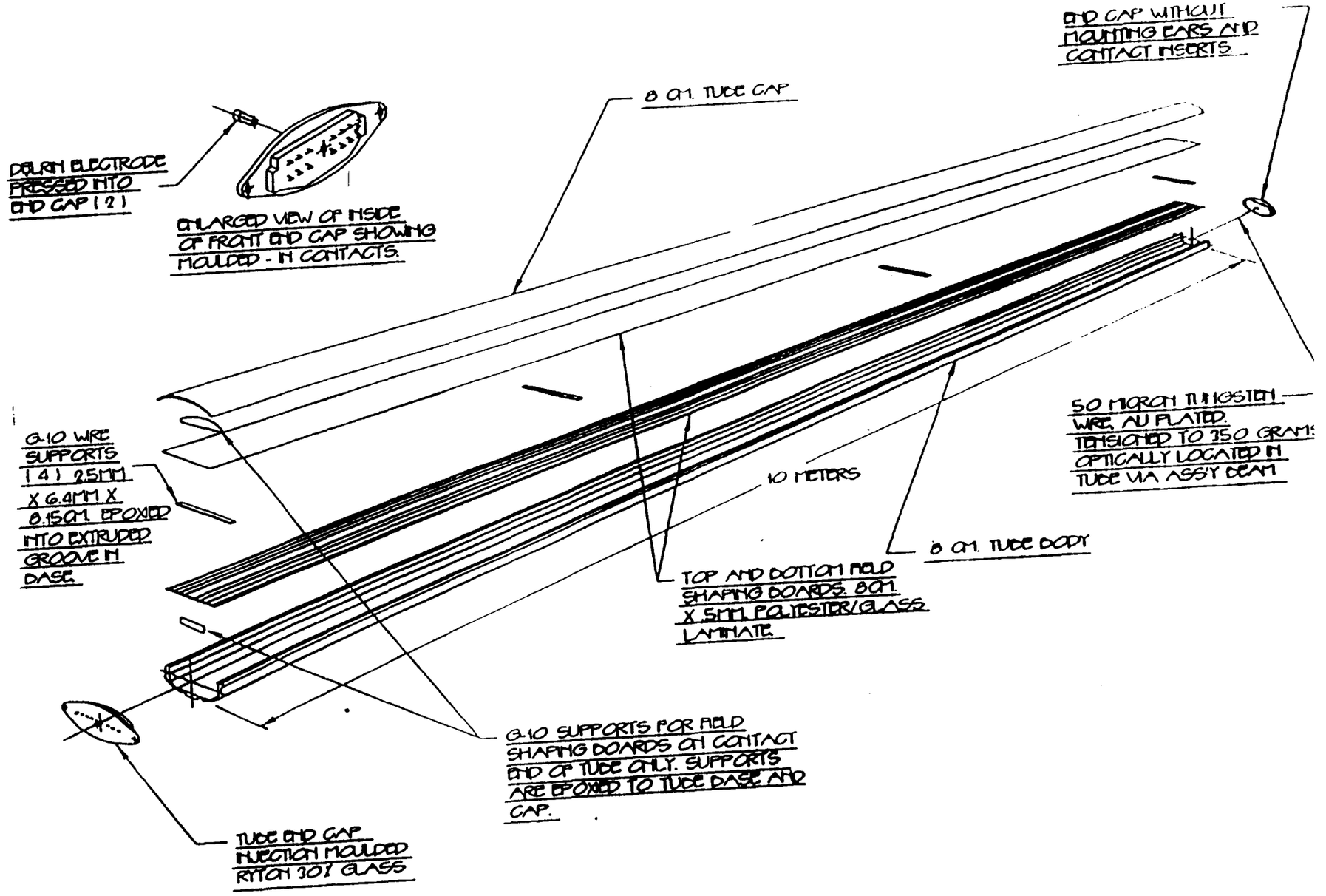
8 - 13 JAN 92

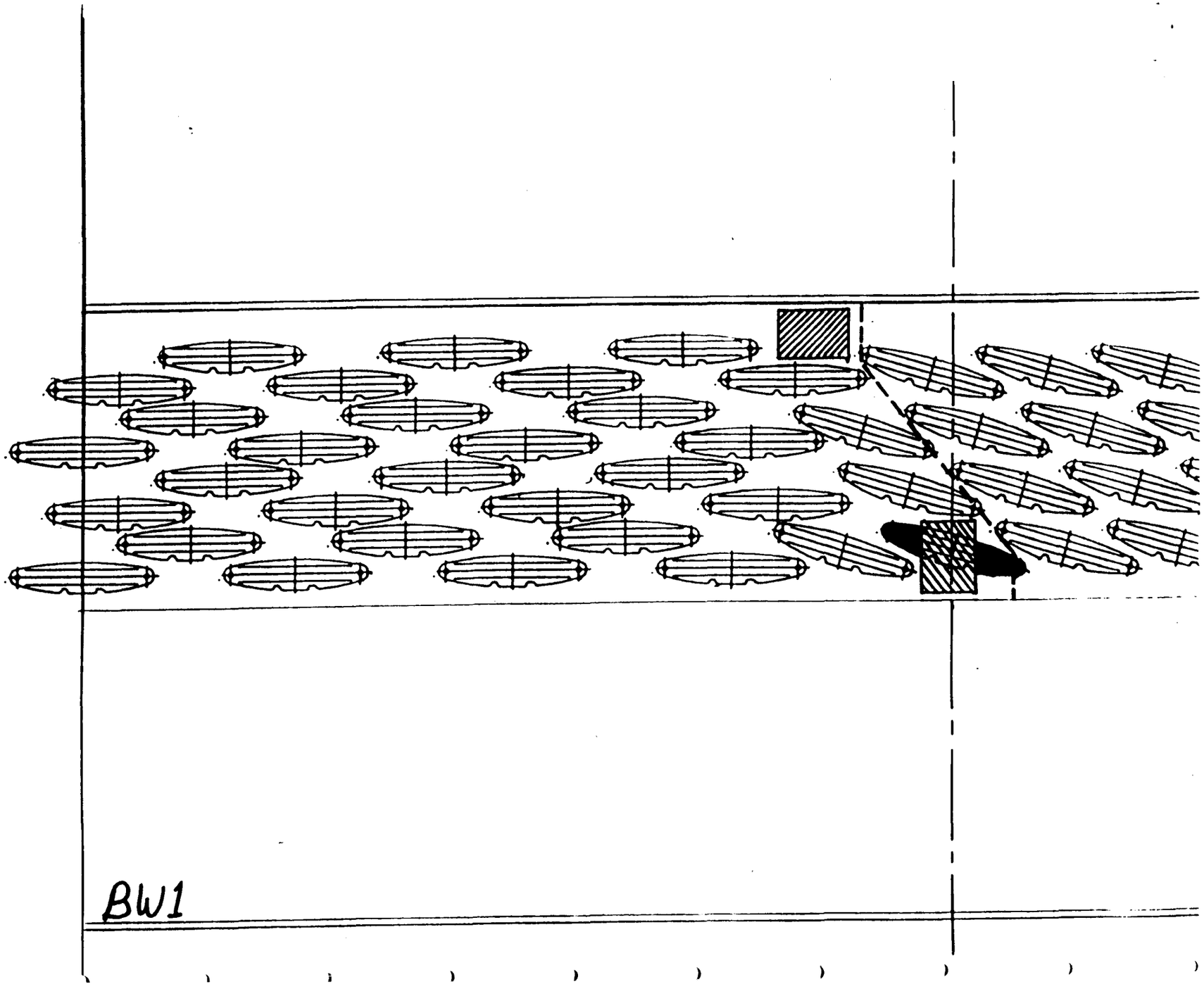
3.) MEET SSCL 30 - 31 JAN 92

# Long-Short BW3 Option




Radial line showing full coverage in $\phi$ for both $\theta$ and $\phi$ tubes.


END CAP WITHOUT MOUNTING EARS AND CONTACT INSERTS.
8 CM. TUBE CAP
DOWN ELECTRODE PRESSED INTO END CAP (2)
ENLARGED VIEW OF INSIDE OF FRONT END CAP SHOWING MOULDED - IN CONTACTS.
G-10 WIRE SUPPORTS (4) 2.5MM X 6.4MM X 0.15CM EPOXIED INTO EXTRUDED GROOVE IN BASE.
50 MICRON TUNGSTEN WIRE, AU PLATED. TENSIONED TO 350 GRAMS OPTICALLY LOCATED IN TUBE VIA ASS'Y BEAM
10 METERS
8 CM. TUBE BODY
TOP AND BOTTOM MOLD SHAPING BOARDS. 8CM X 5MM POLYESTER/GLASS LAMINATE.
G-10 SUPPORTS FOR MOLD SHAPING BOARDS ON CONTACT END OF TUBE ONLY. SUPPORTS ARE EPOXIED TO TUBE BASE AND CAP.
TUBE END CAP INJECTION MOULDED RYTON 30% GLASS


BW1

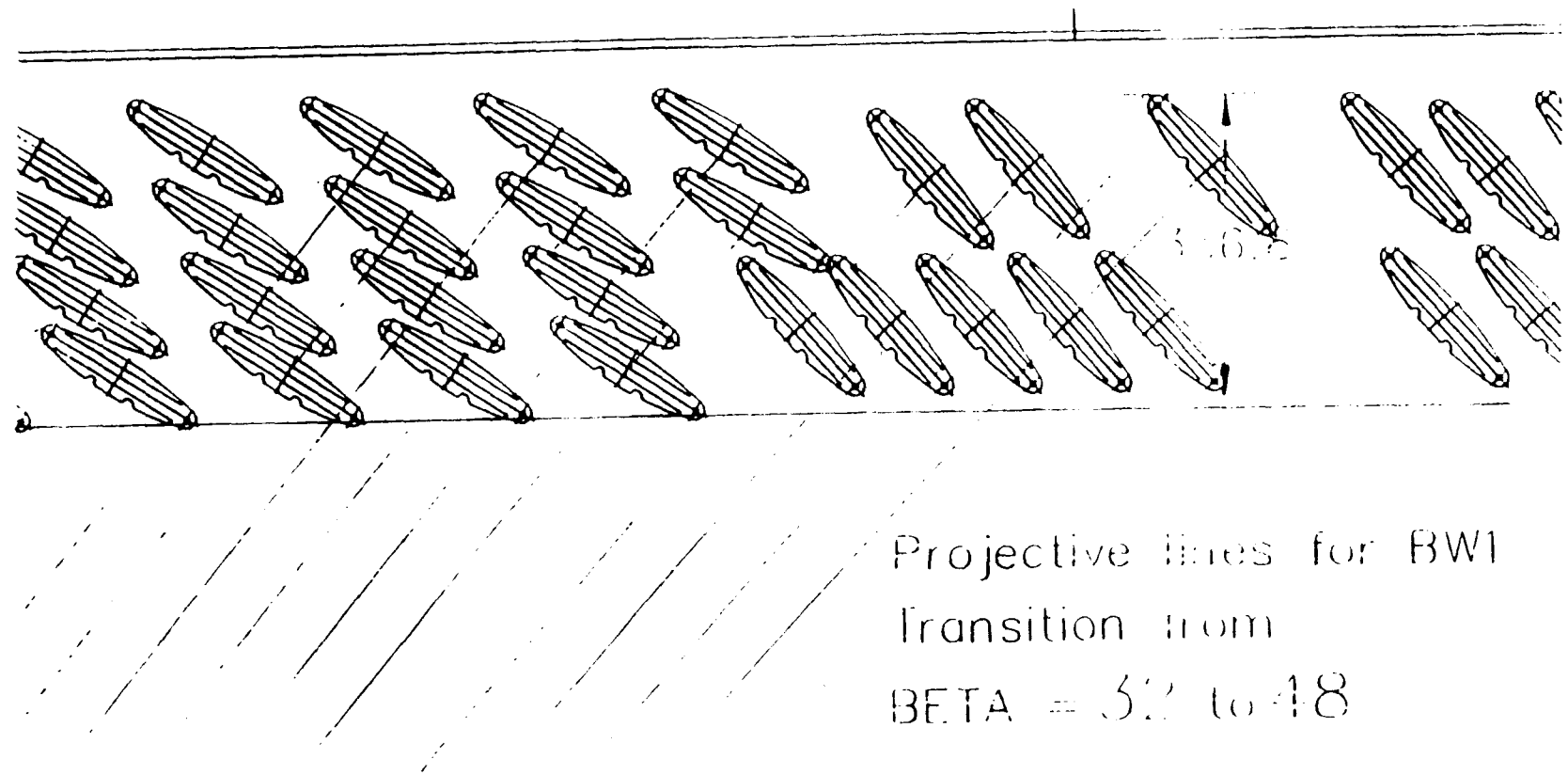
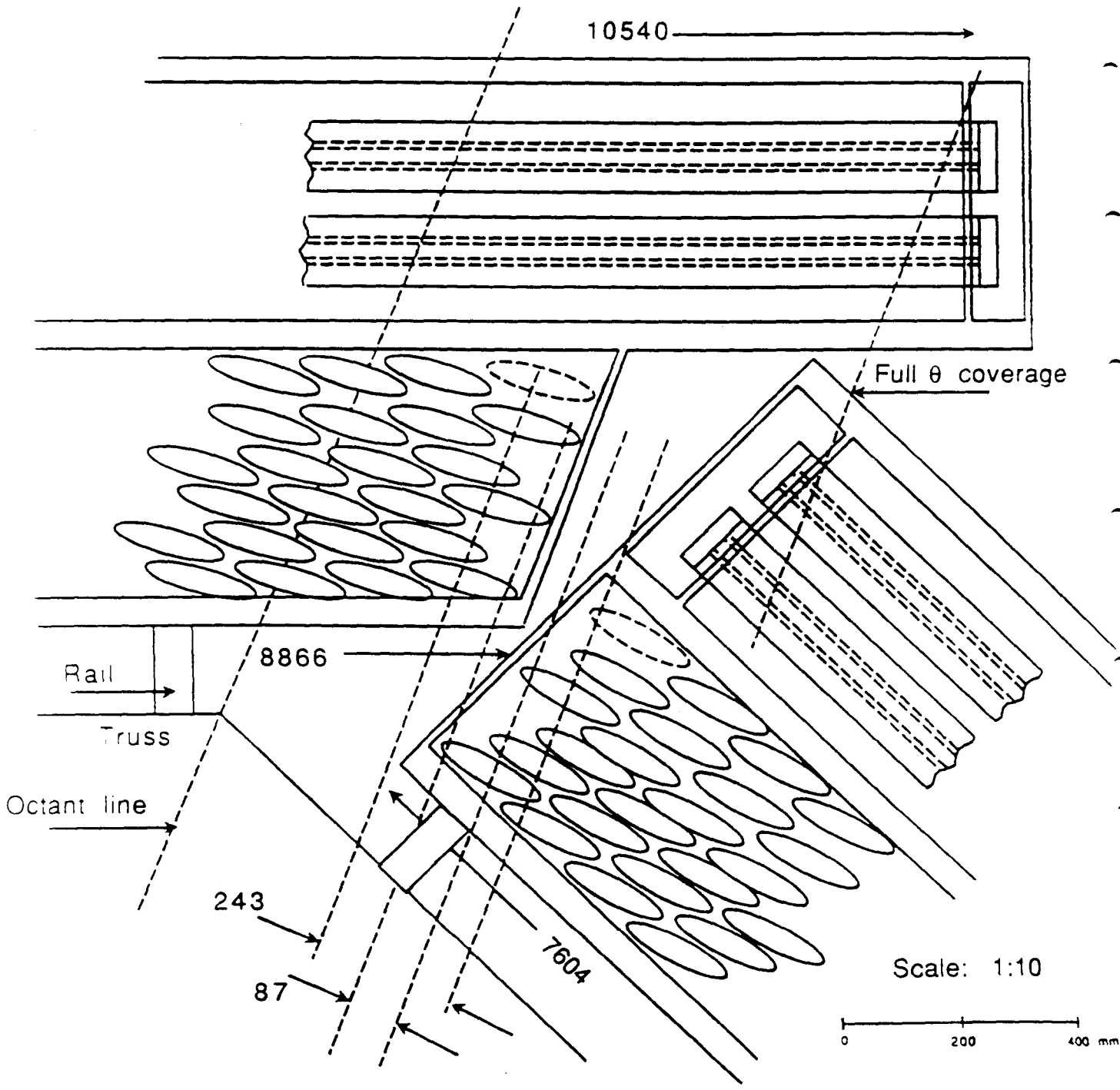



**Figure V.A-4. Detail of θ drift tubes in BW1 showing the transition between the 32° step and the 48° step.**
A few tubes have been omitted from the drawing to show the dimensions more clearly.

# Long-Short BW3 Option

BW2 + BW3: ≥2 layers θ : 1.000
4 layers θ : 0.965 (6/8 octant boundaries)




BW1 + BW3: ≥2 layers φ : 1.000
≥3 layers φ : 0.966
4 layers φ : 0.916

BW3: ≥1 layer φ : 0.989 coverage
2 layers φ : 0.971 coverage

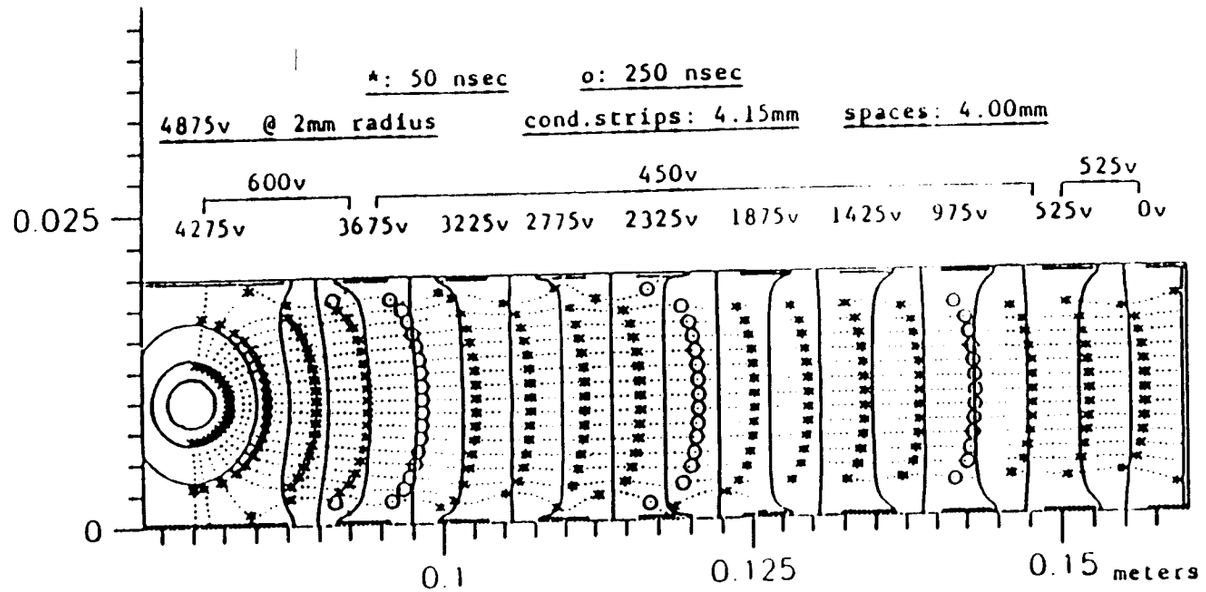
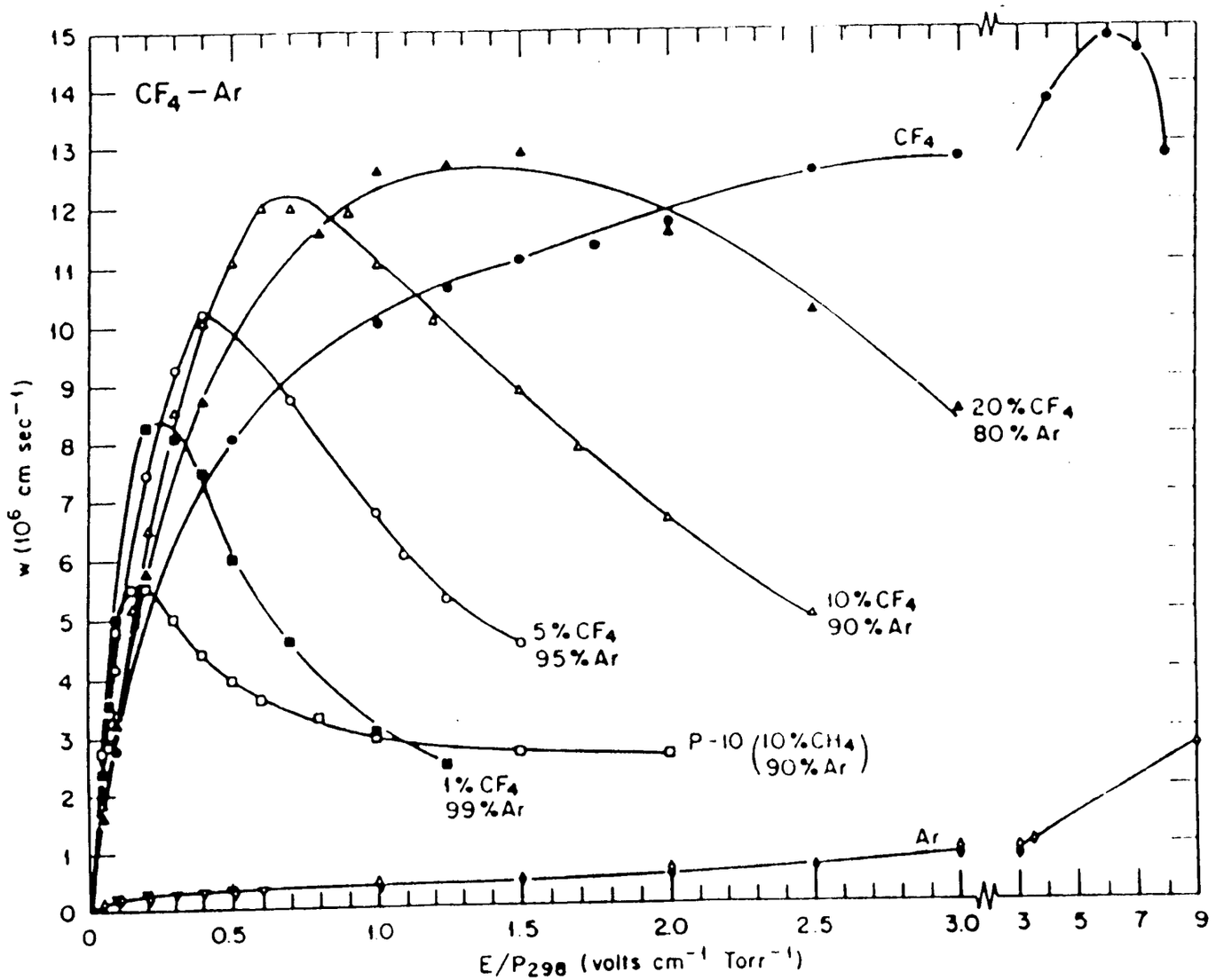
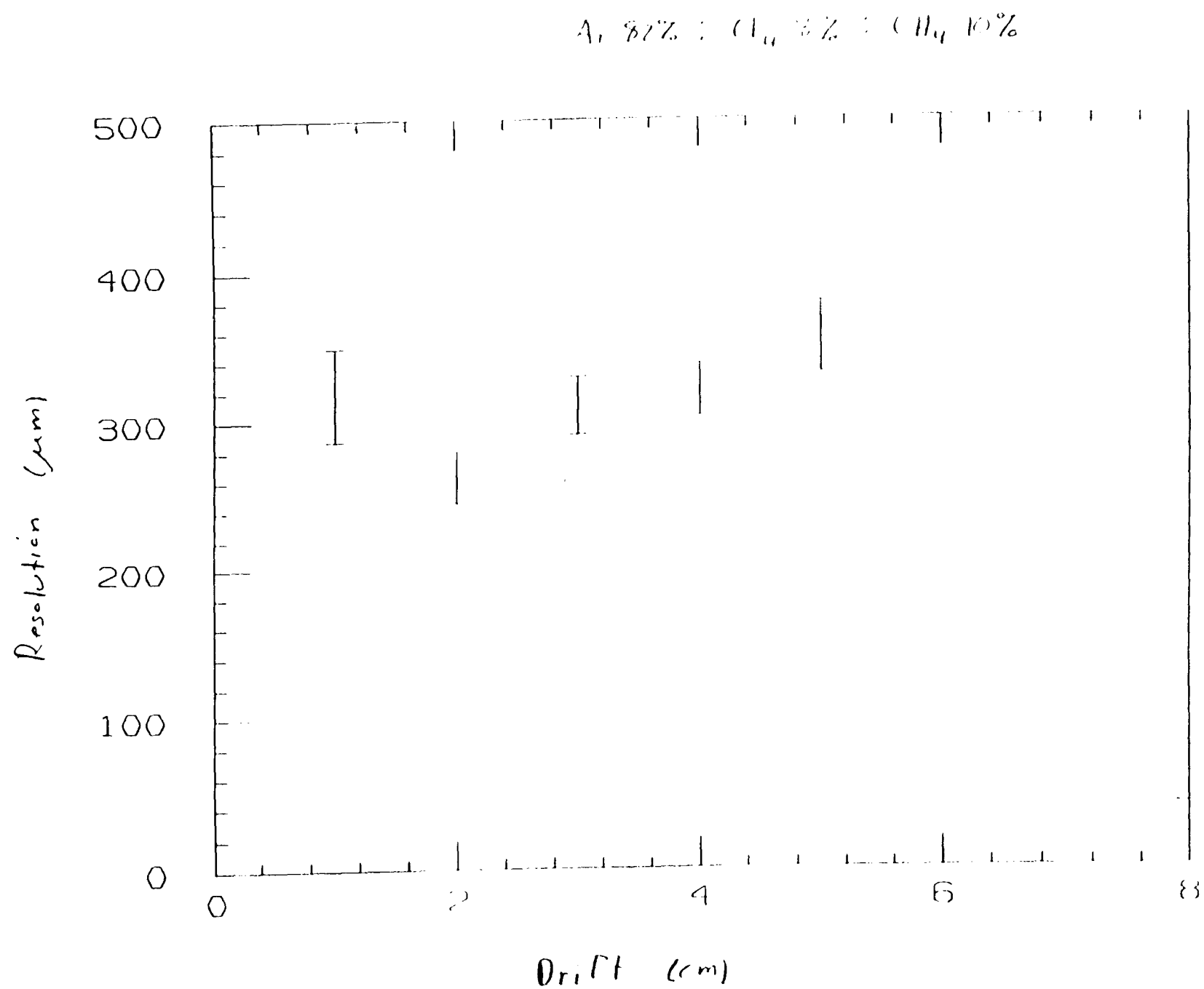
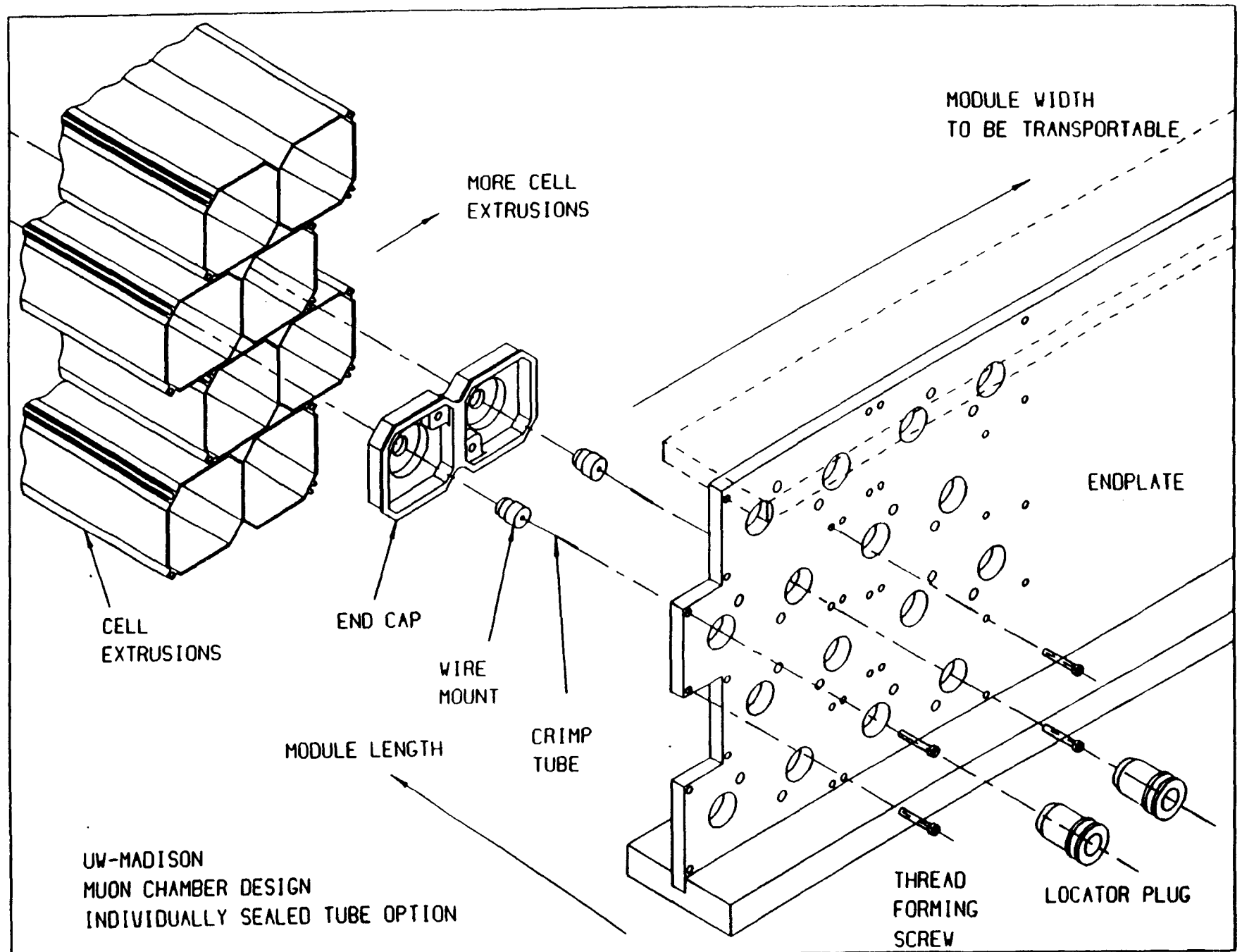


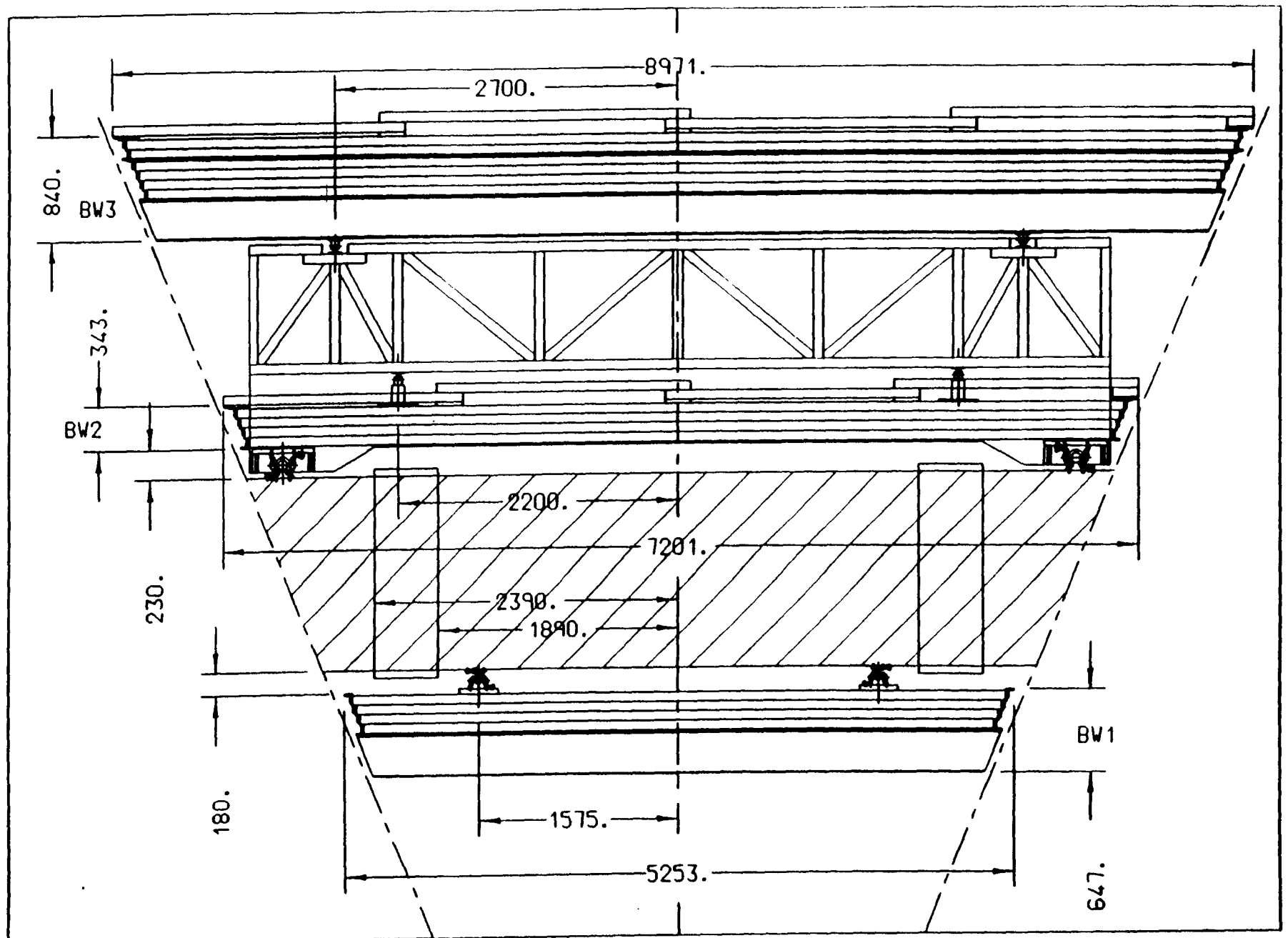

Figure I-5. Drift cell for the 8-cm drift version using an Ar-$CF_4$-$CH_4$ mixture in a 90:5:5 ratio with the voltages listed. Equipotentials are shown in solid lines, electric field lines in dotted lines, and isochrones in asterisks every 50 ns and open circles every 250 ns.


CF4 – Ar
CF4
20% CF4
80% Ar
10% CF4
90% Ar
5% CF4
95% Ar
P-10 (10% CH4 90% Ar)
1% CF4
99% Ar
Ar
w (10^6 cm sec^-1)
E/P298 (volts cm^-1 Torr^-1)
0
0.5
1.0
1.5
2.0
2.5
3.0
3
5
7
9
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


Ar 82% : $CH_4$ 8% : $CH_4$ 10%
500
400
300
200
100
0
Resolution (μm)
0
2
4
6
8
Drift (cm)

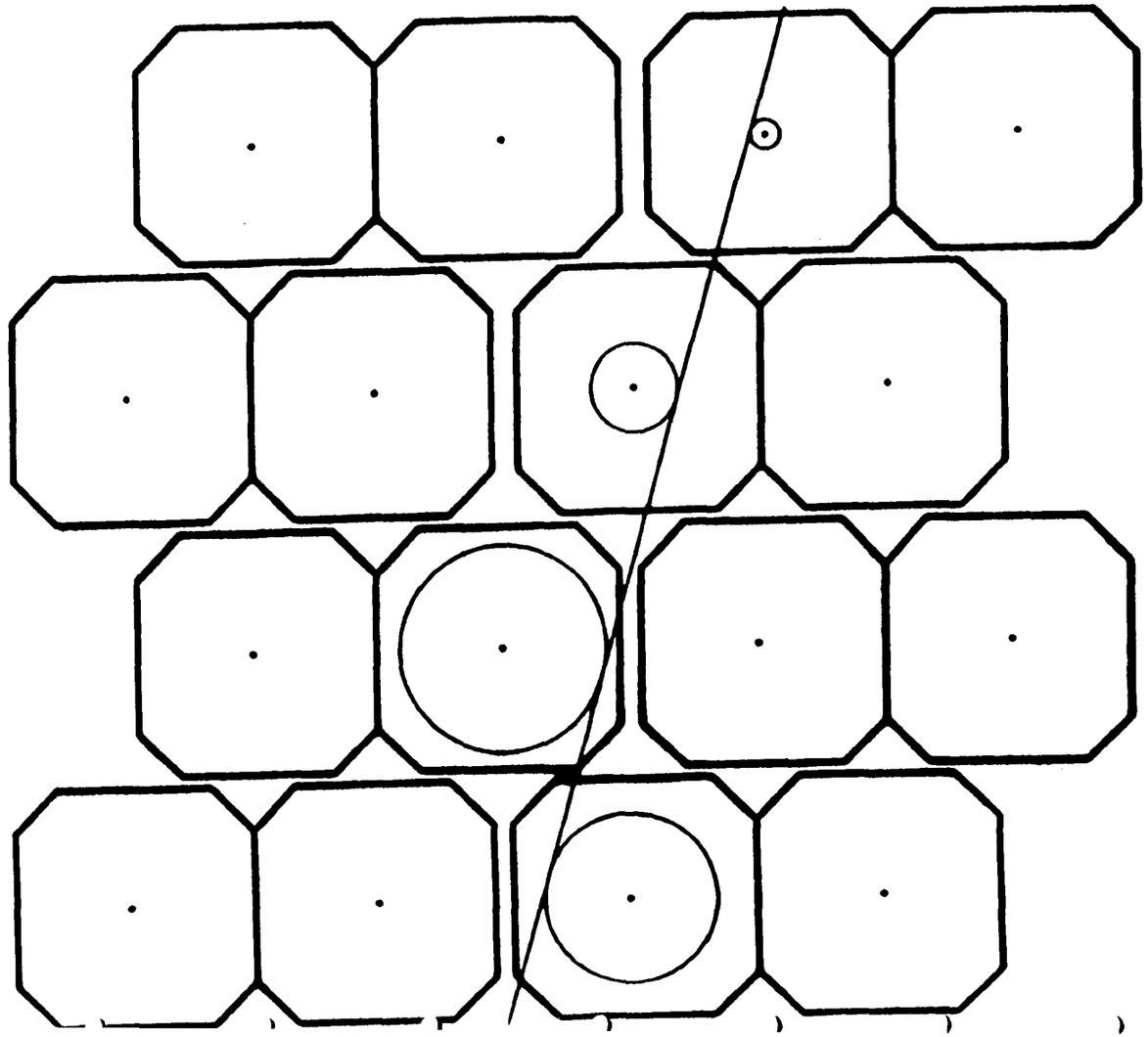



PRODUCED BY FF DRAWING FILENAME SAT002B

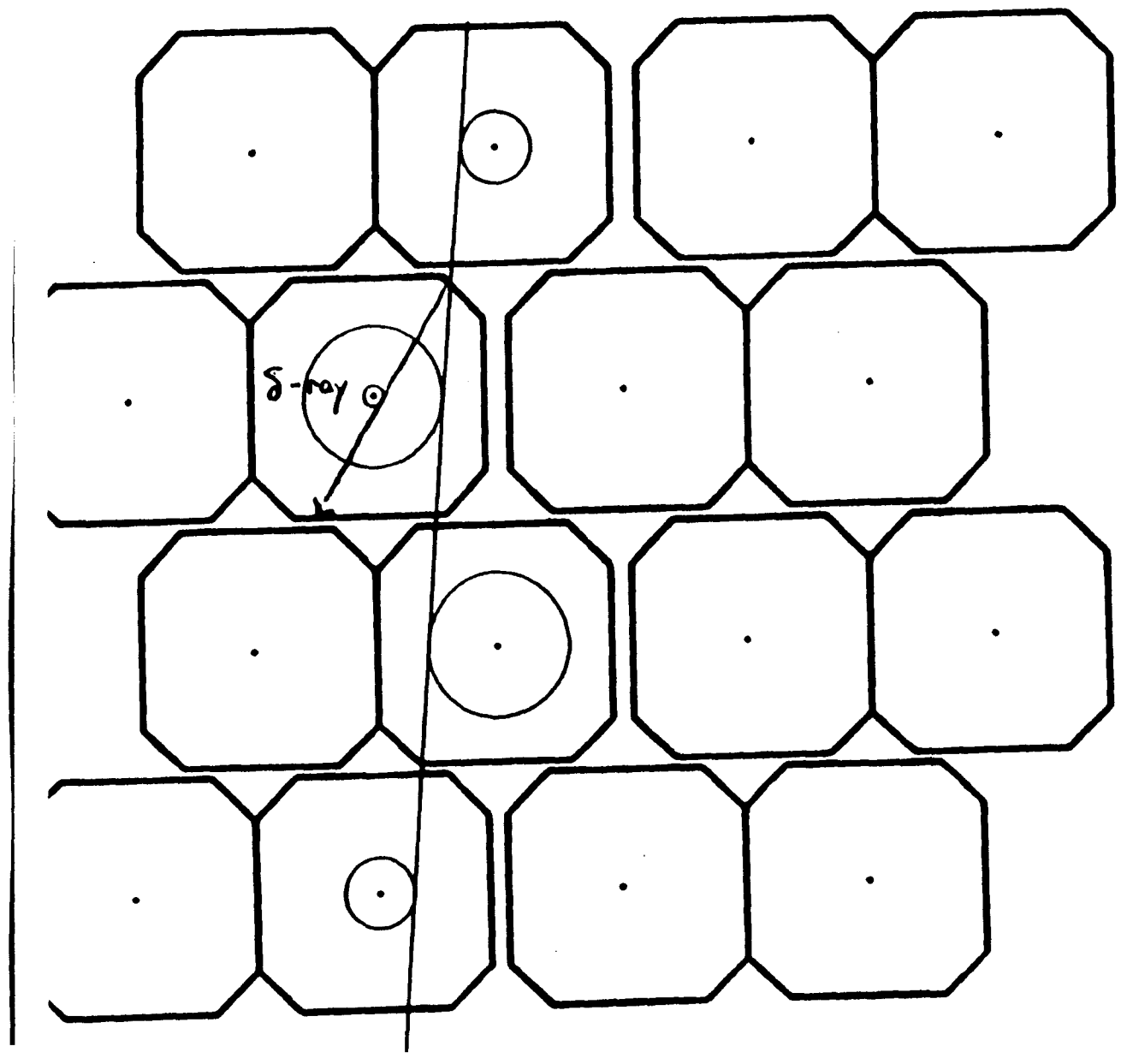


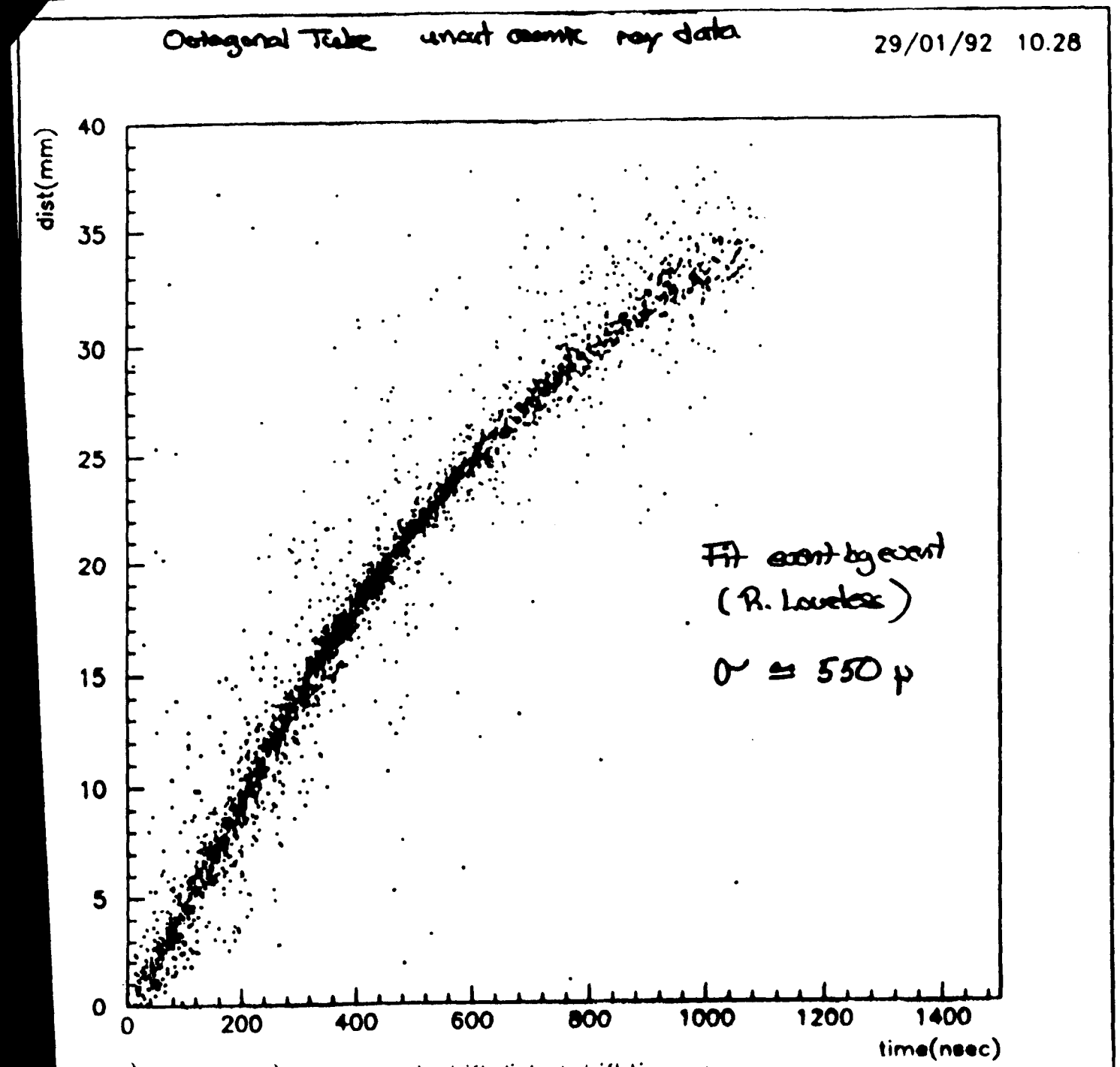

PRODUCED BY FF
ON 01/29/92 AT 13:37
DRAWING FILENAME R4626067E
PLOTTED AT SCALE 0.1

University of Wisconsin



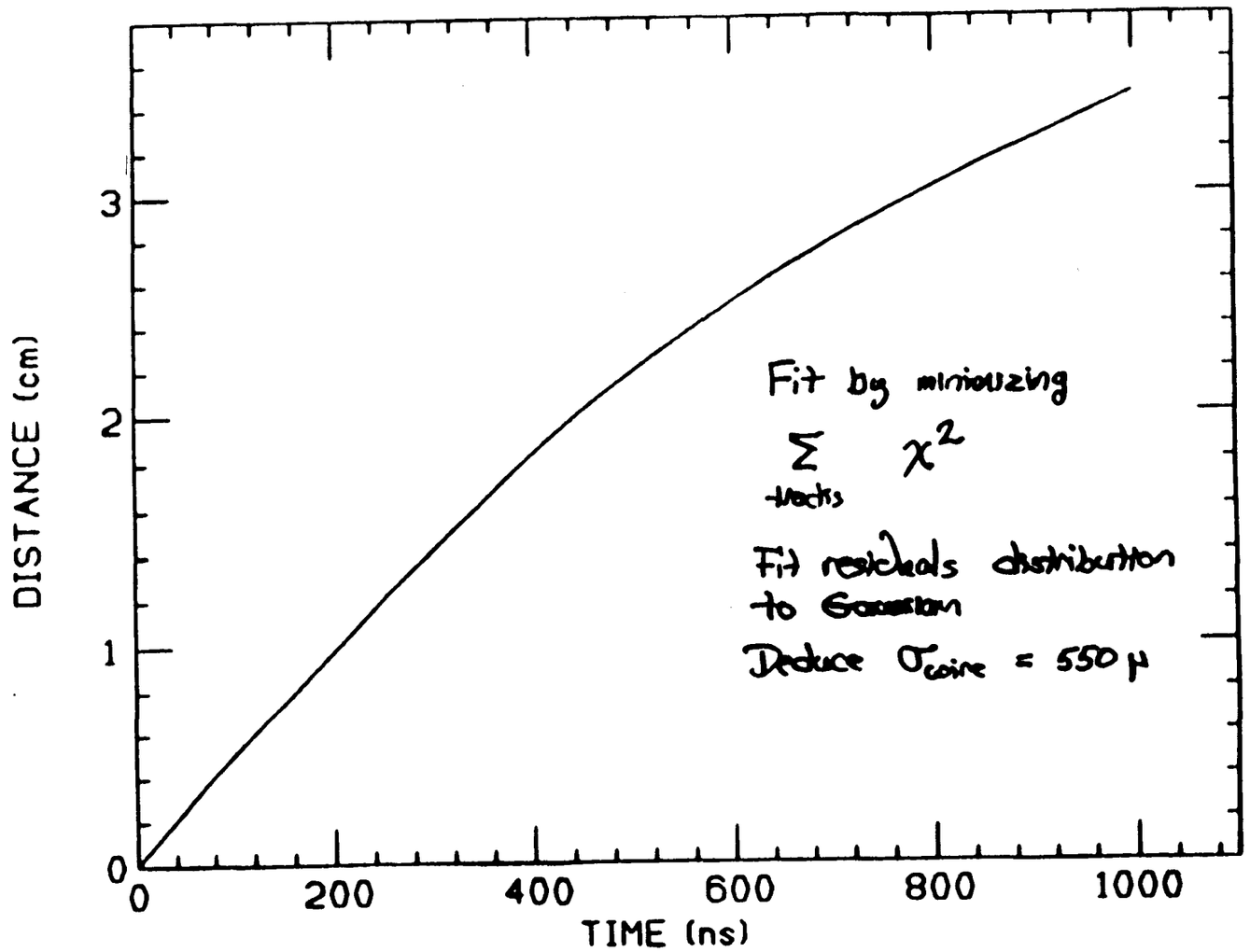
University of Wisconsin




Octagonal Tube unact cosmic ray data
29/01/92 10.28
dist(mm)
40
35
30
25
20
15
10
5
0
0
200
400
600
800
1000
1200
1400
time(nsec)
Fit event by event
(R. Loveless)
σ ≃ 550 μ

Octagonal Tube : Time to distance fit to cosmic ray data in 16 cell prototype

3900 V, 1.3 V threshold



# Resolution of a Simple Drift Tube

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*University of Tsukuba*
*Tsukuba City, Ibaraki 305 Japan*

*5 Jan. 1992*
*Revised 23 Jan. 1992*

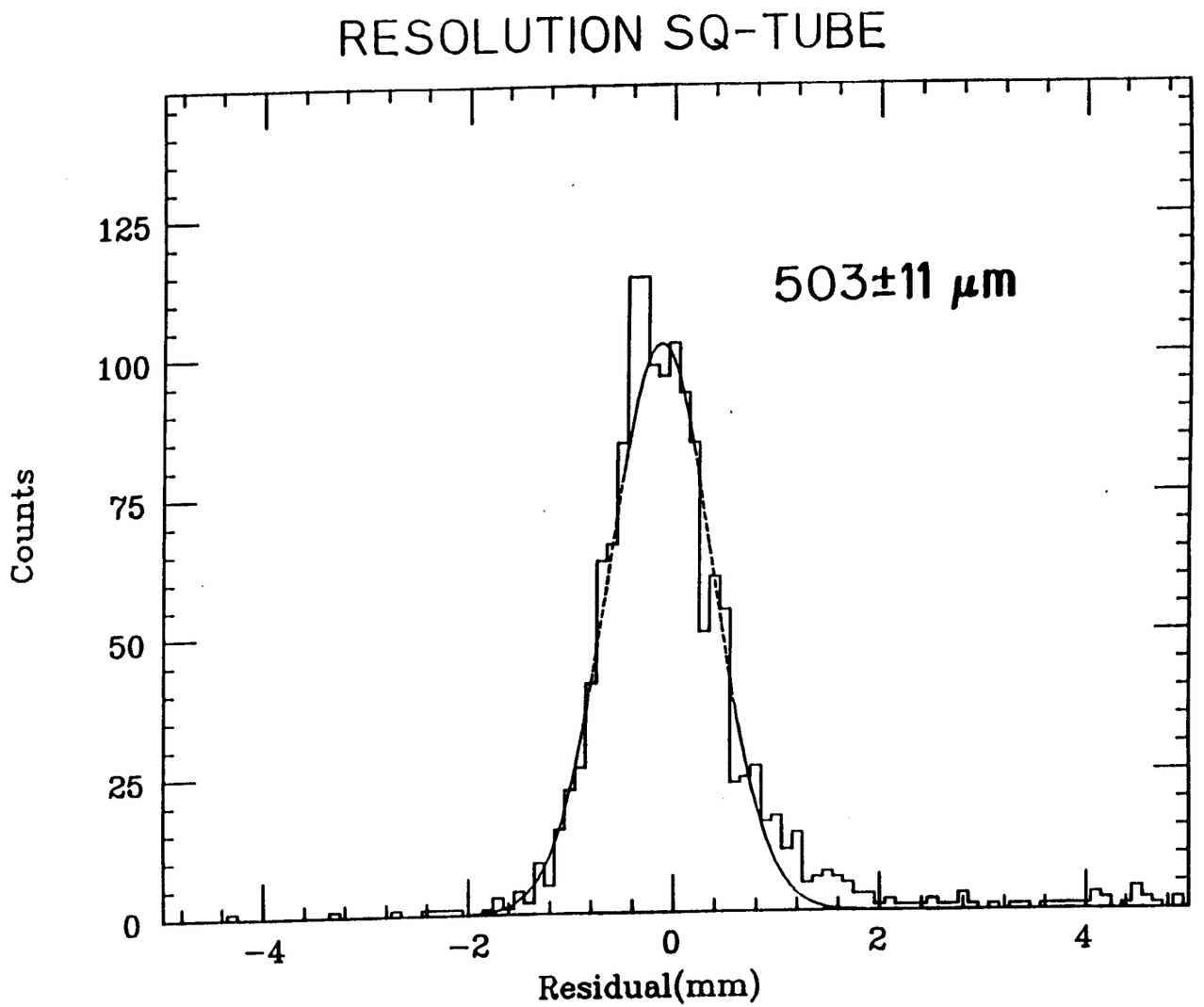
## Abstract

In a cosmic-ray test, a spatial resolution for a simple drift tube with a square cross section of dimension 8cm x 8cm was studied[1]. The resolution was found to be about 460 μm (standard deviation) when data were fitted with a gaussian shape excluding the very proximity of the anode wire (2mm from the wire) where the resolution becomes significantly worse, and a constant fraction timing discriminator was employed. With a careful optimization of the signal shaping and fraction value, the resolution is expected to become about 420 μm.

A direct evidence has been obtained that there is almost no angular dependence of the R-T relation for the drift tube. With 4 layers in a station, the aimed resolution of 250 μm/station can be achieved with this simple large-cell drift tube and there is no need to tilt each tube in order to face the interaction point.

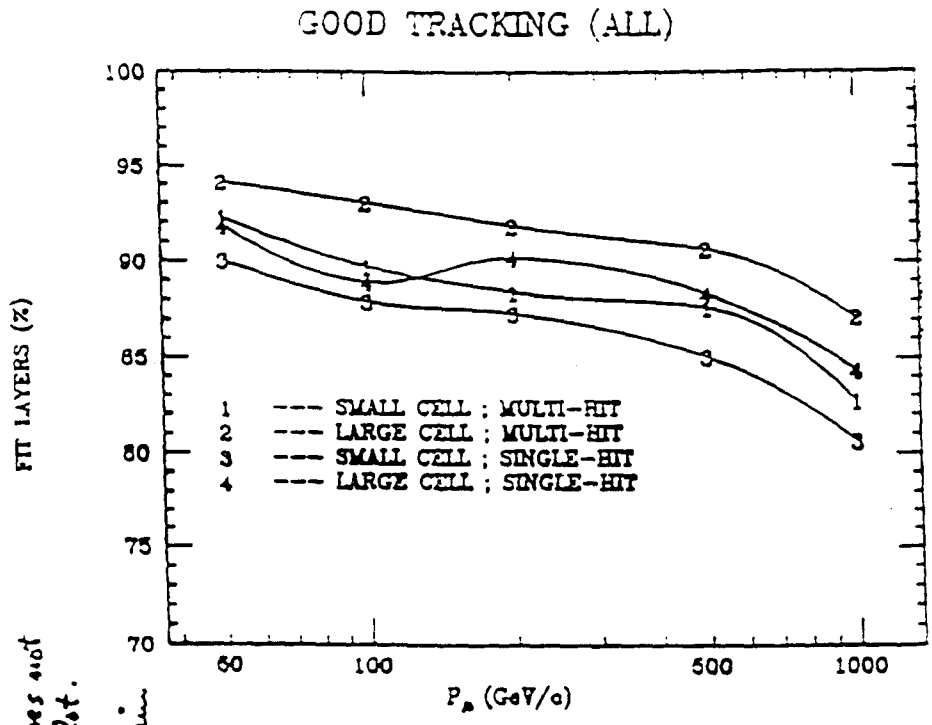
## Drift Tube

The drift tube employed in the test has a square cross section of inner dimension 8cm x 8cm. Its length is 50 cm. An anode wire of 100 μm in diameter was strung at the center. A high voltage of 3.3 kV was applied to the anode, whereas the tube wall made of aluminum was grounded. Original design was to apply 3.5 kV to the anode, but with P10 gas, it produced partial-streamer mode signals; the high voltage was lowered.




CFTD USED, 3.3kV

Fig. 6



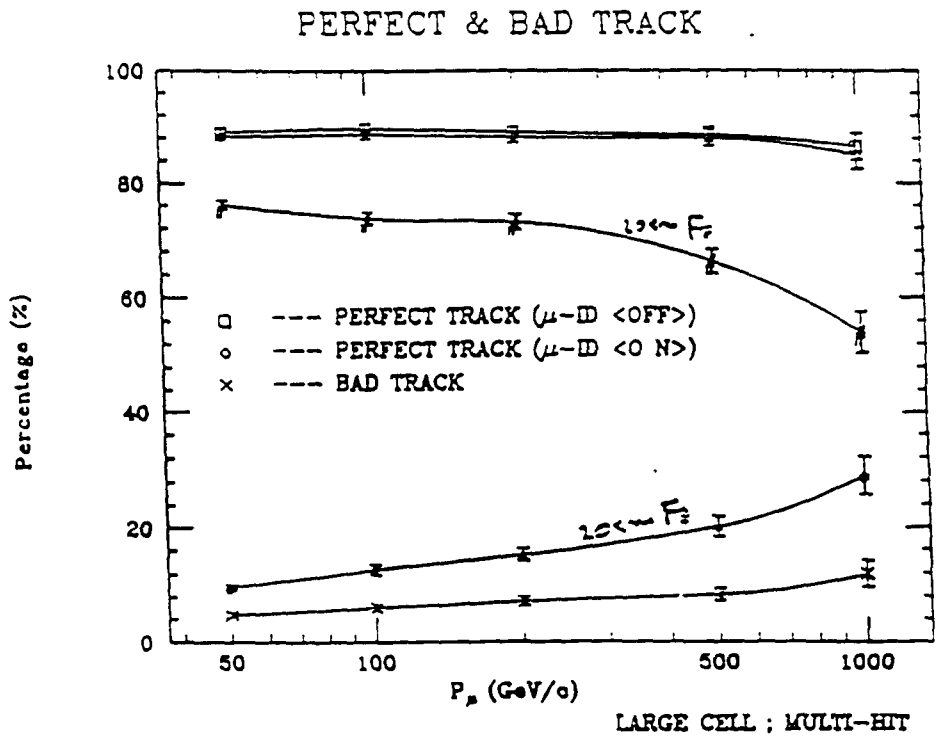

H. Hara

multi hit does not improve a lot.

Only ~5% gain in tracking efficiency.

Fig. 5-1

Fig. 16A




H. Hara

Perfect track is a muon track

Fig. 7-2

Fig. 16B

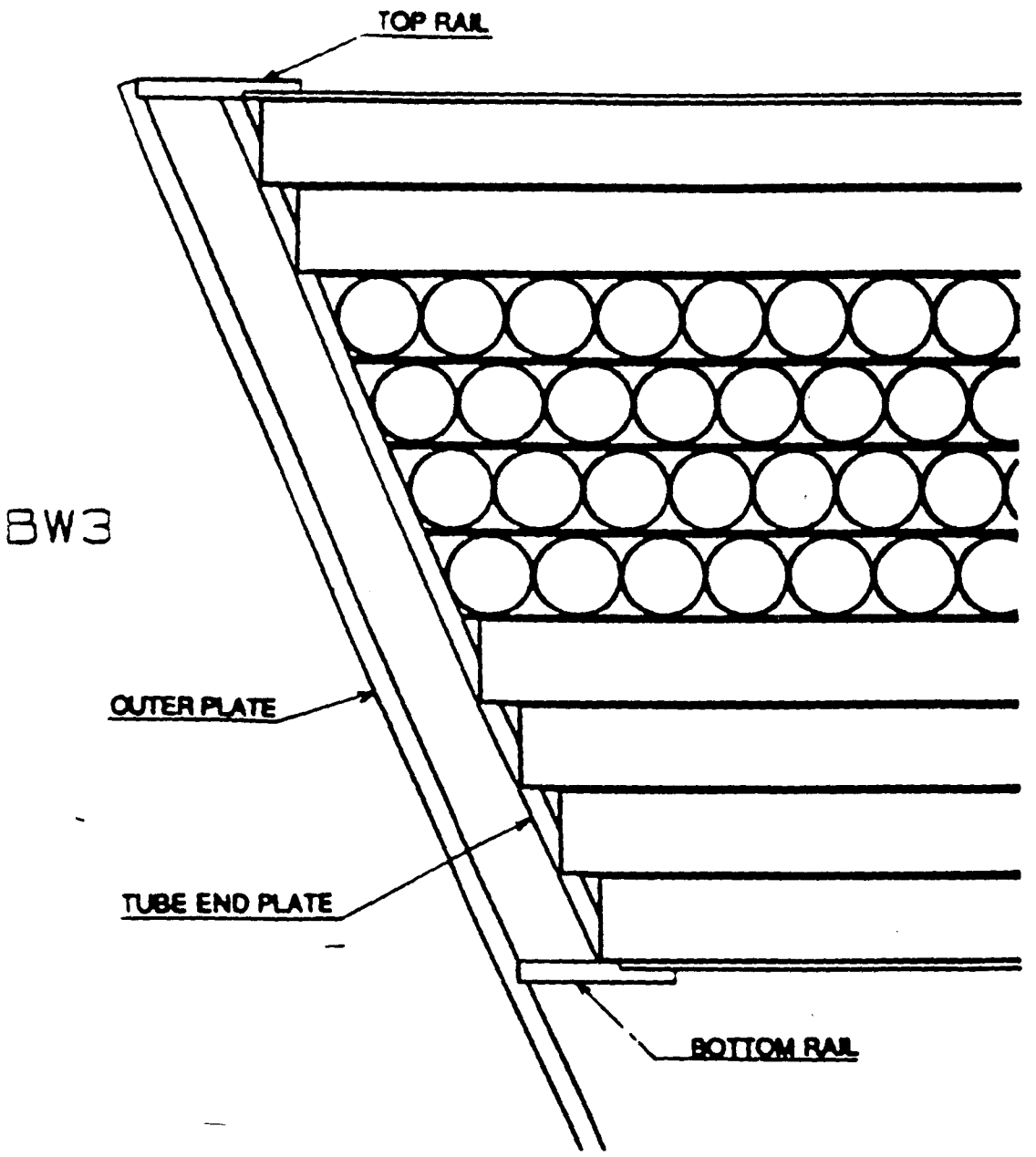
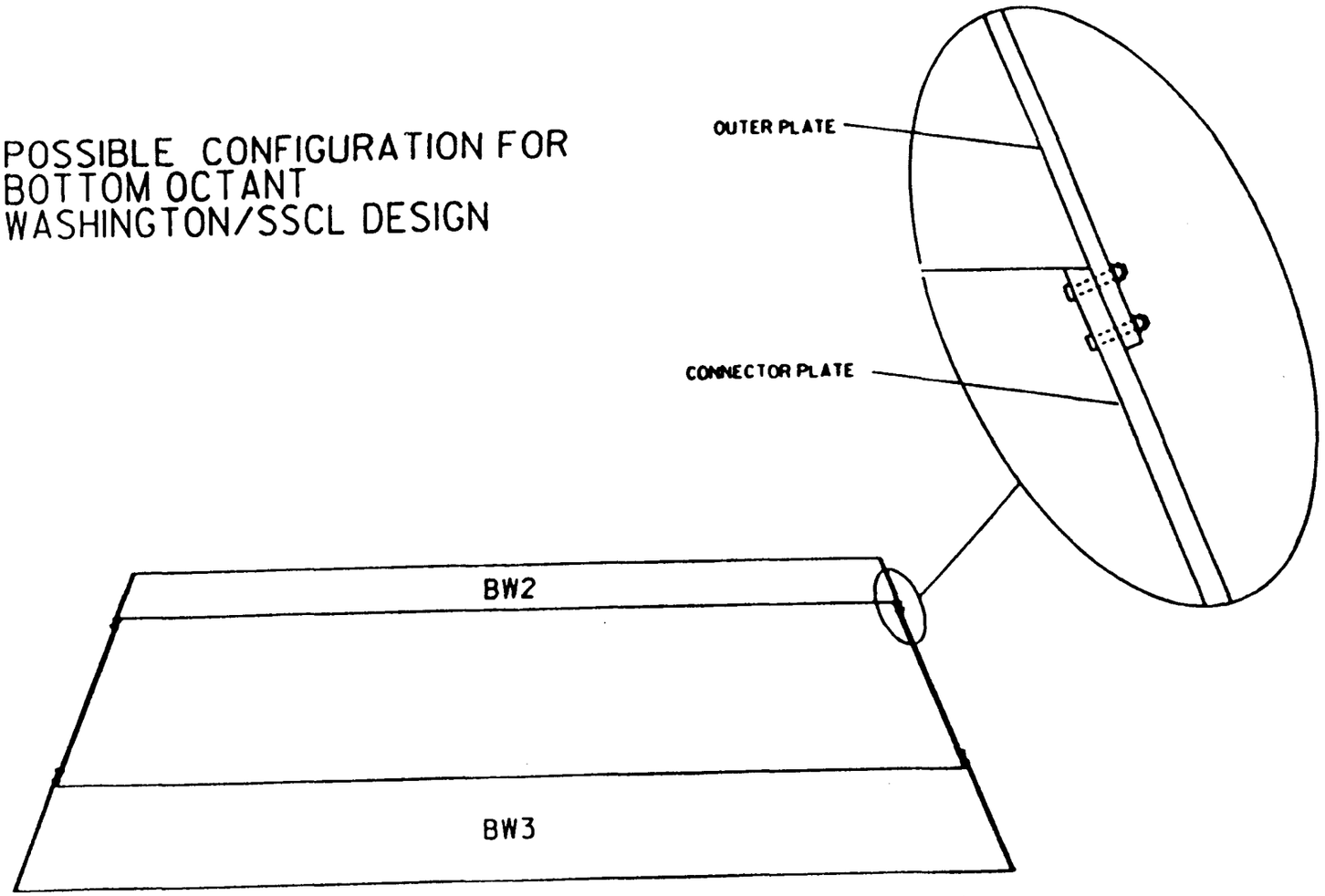



Figure 2.12. Cross section of module edge showing the tube end plate, top and bottom rails and outer plate. For this BW3 module, the outer plate continues down to the BW2 module to form a BW2/BW3 tower.

POSSIBLE CONFIGURATION FOR
BOTTOM OCTANT
WASHINGTON/SSCL DESIGN



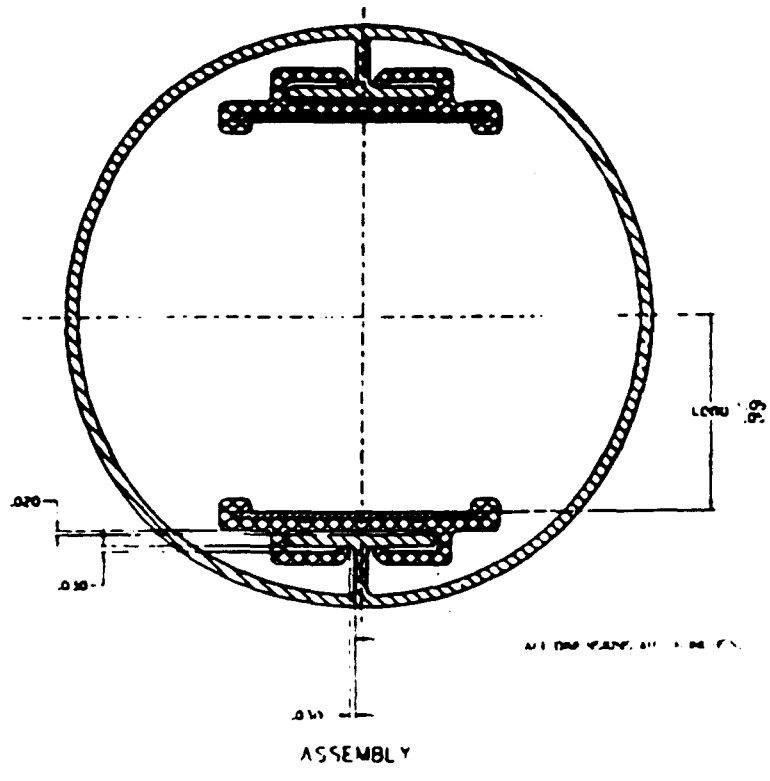



Figure 4.10. Cross section of a drift tube.

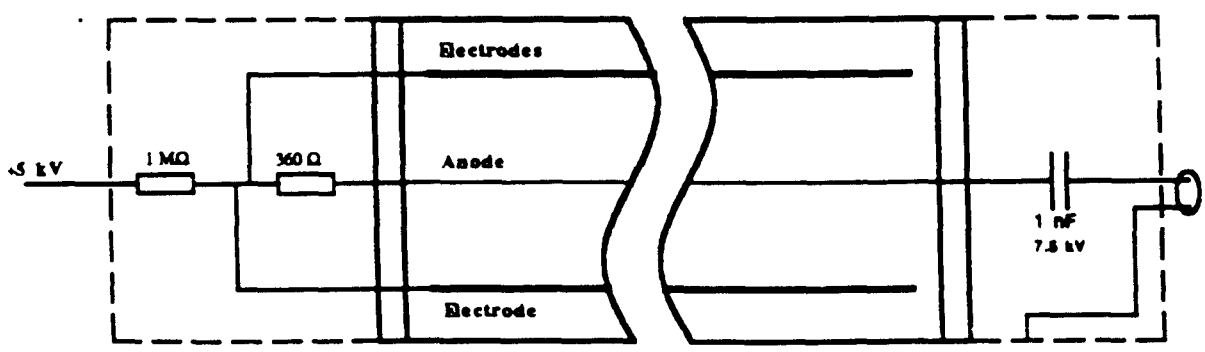



Figure 4.11. High voltage and signal connections. Field shaping electrodes and anode are both at +5 kV.

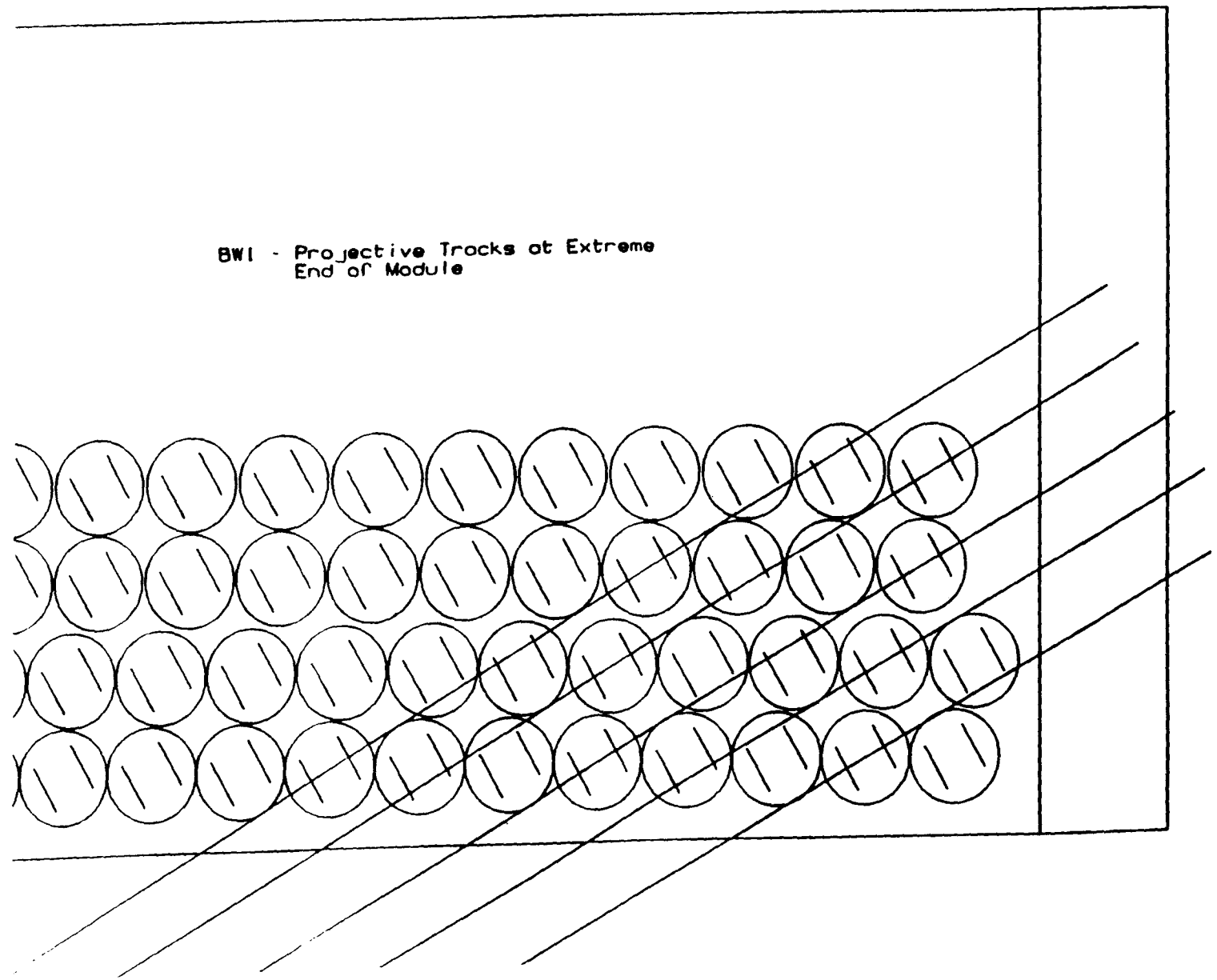
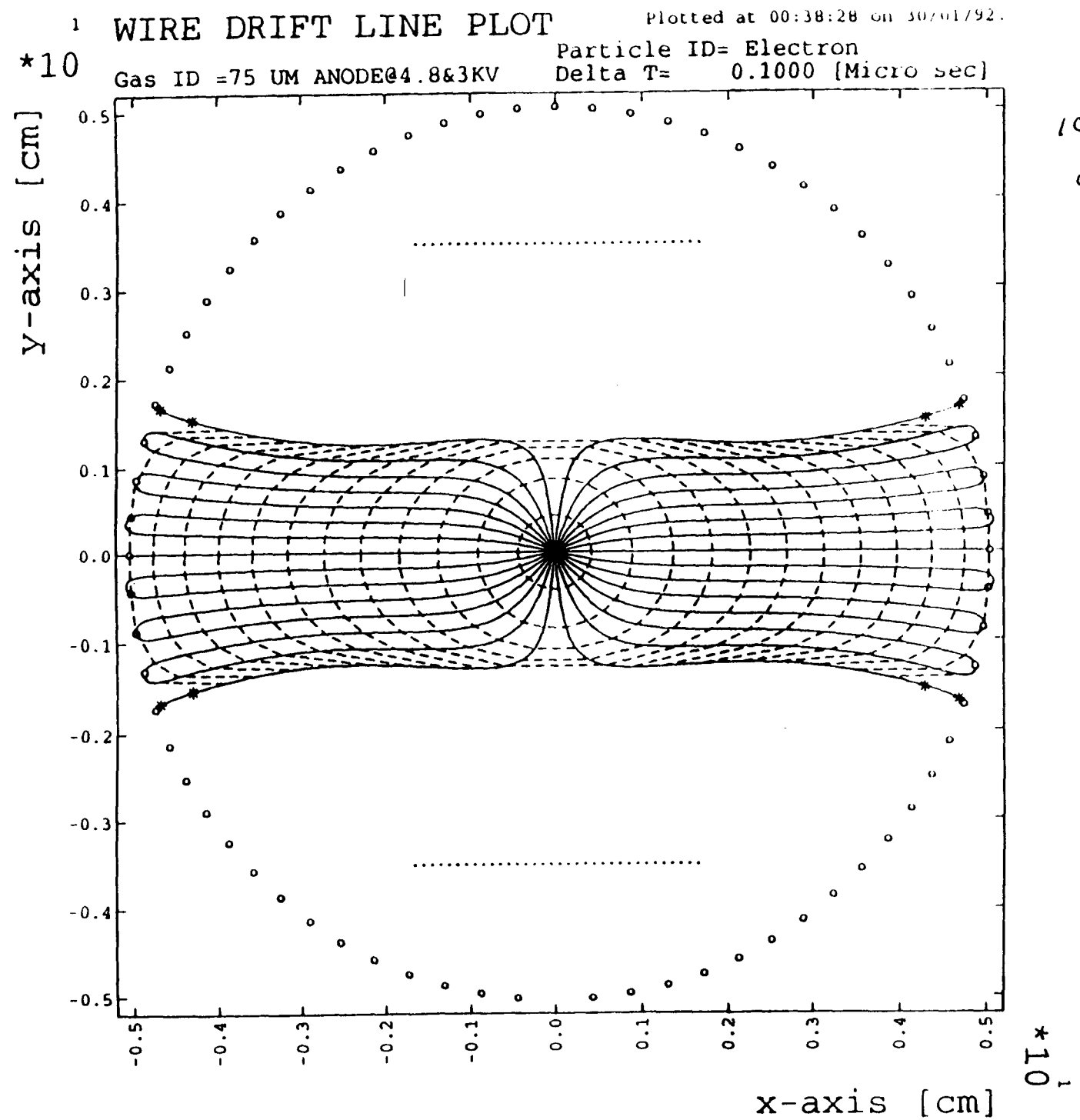



**Figure 2.5. BW1—Projective tracks at extreme end of module.**




100 mm TUBE

0.075 mm wire

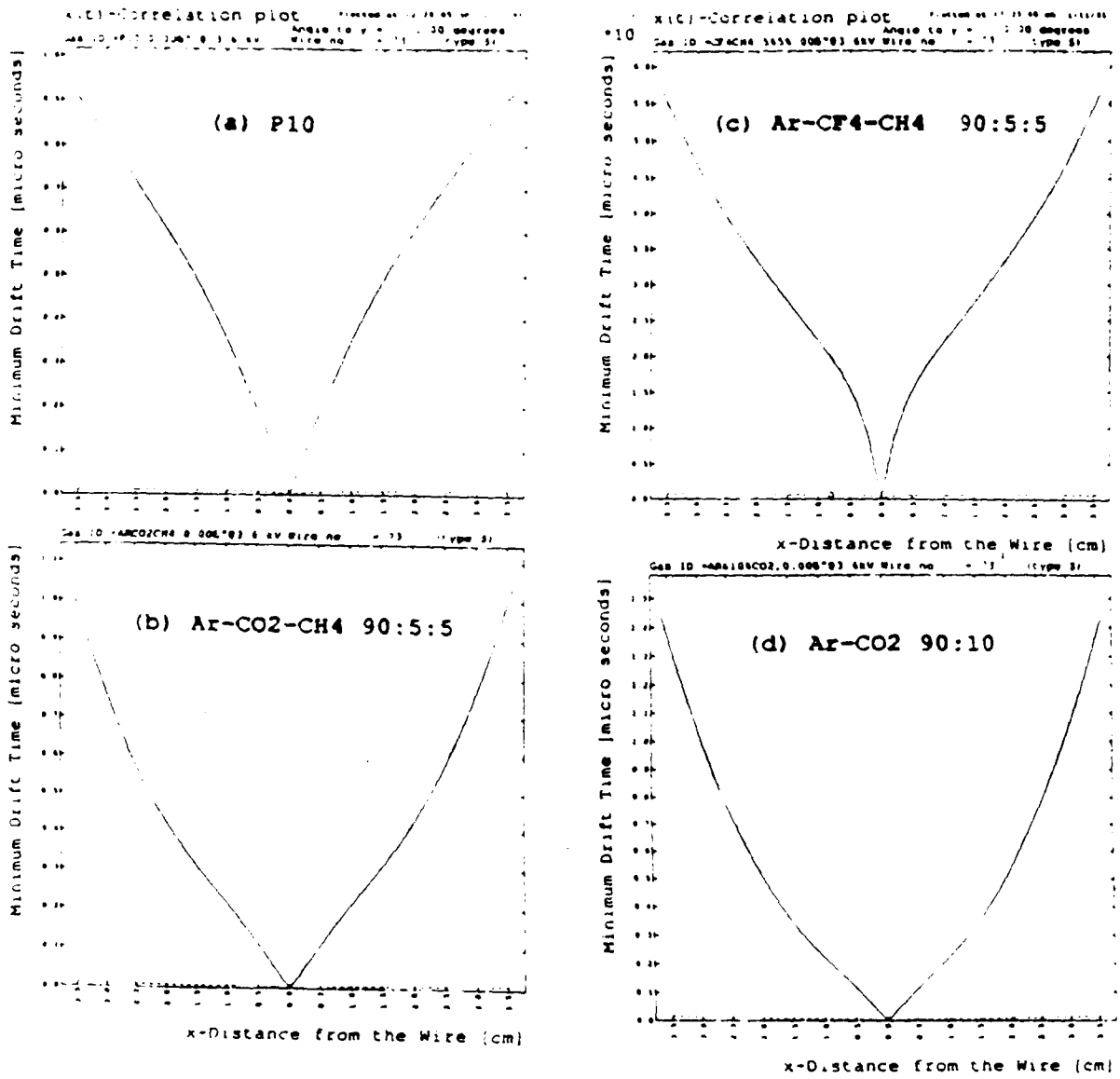



**Figure 4.6. x-t correlation plots.**

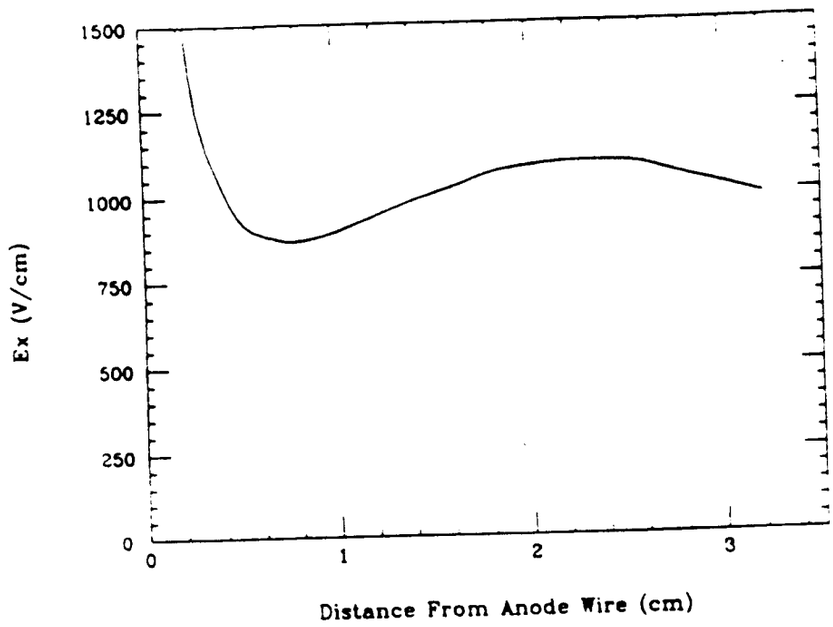



Figure 4.13. Drift field uniformity in the drift cell. Anode and electrodes are both at +5 kV.

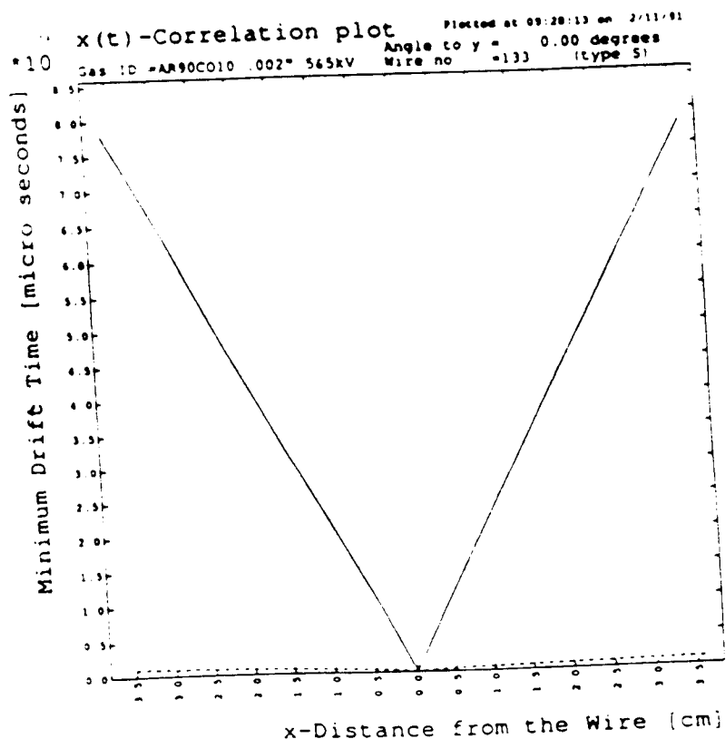
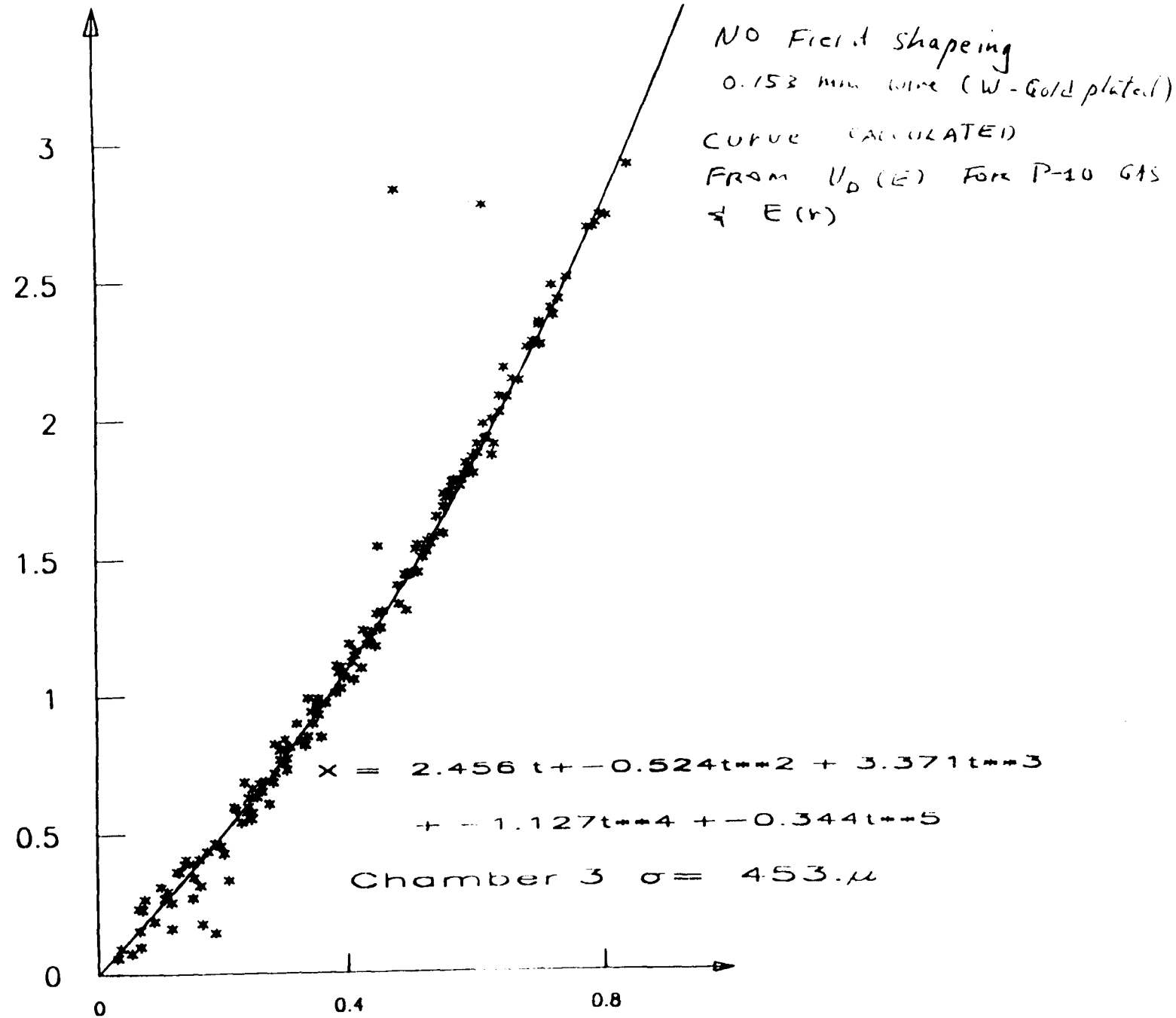
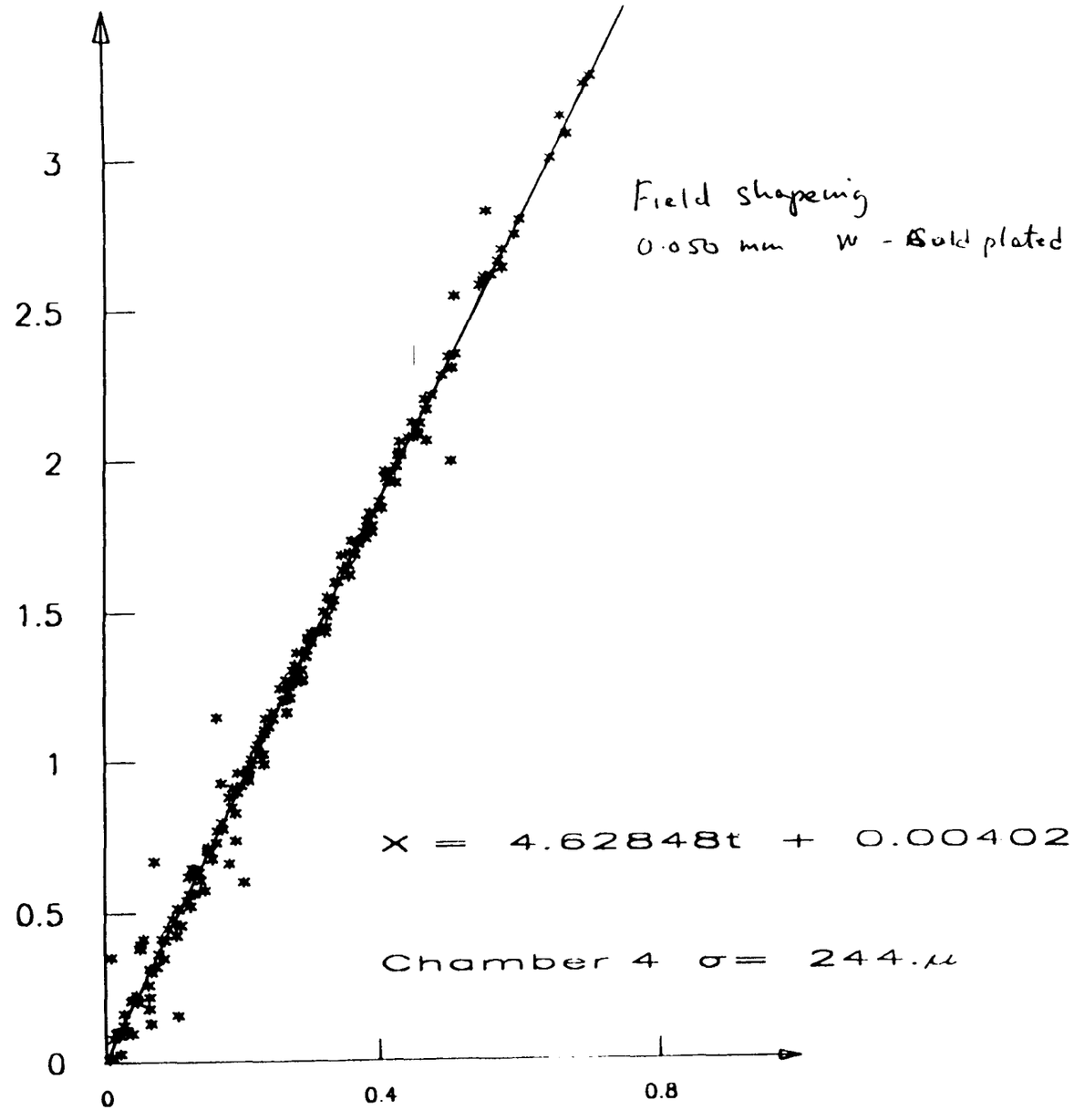



Figure 4.14. x-t correlation curve for Ar-$CO_2$ (90:10%). The maximum drift time is 780 ns.


NO Field Shapeing
0.153 mm wire (W-Gold plated)
CURVE CALCULATED
FROM $U_D(E)$ FOR P-10 GAS
& E(r)
3
2.5
2
1.5
1
0.5
0
0
0.4
0.8
x = 2.456 t+-0.524t**2 + 3.371t**3
+ -1.127t**4 +-0.344t**5
Chamber 3 σ= 453.μ


Field shapeing
0.050 mm W - Gold plated
X = 4.62848t + 0.00402
Chamber 4 σ= 244.μ
3
2.5
2
1.5
1
0.5
0
0
0.4
0.8

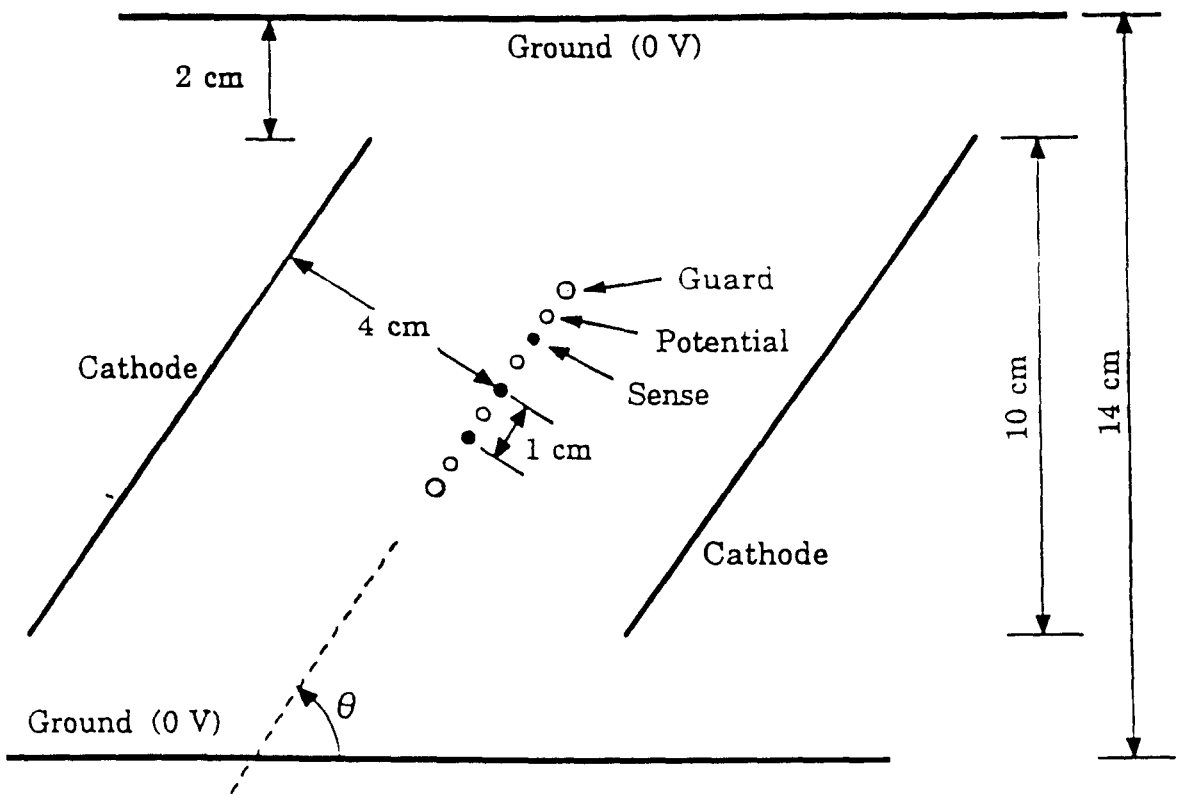



Fig. 2.1. A schematic illustration of the drift cell structure.

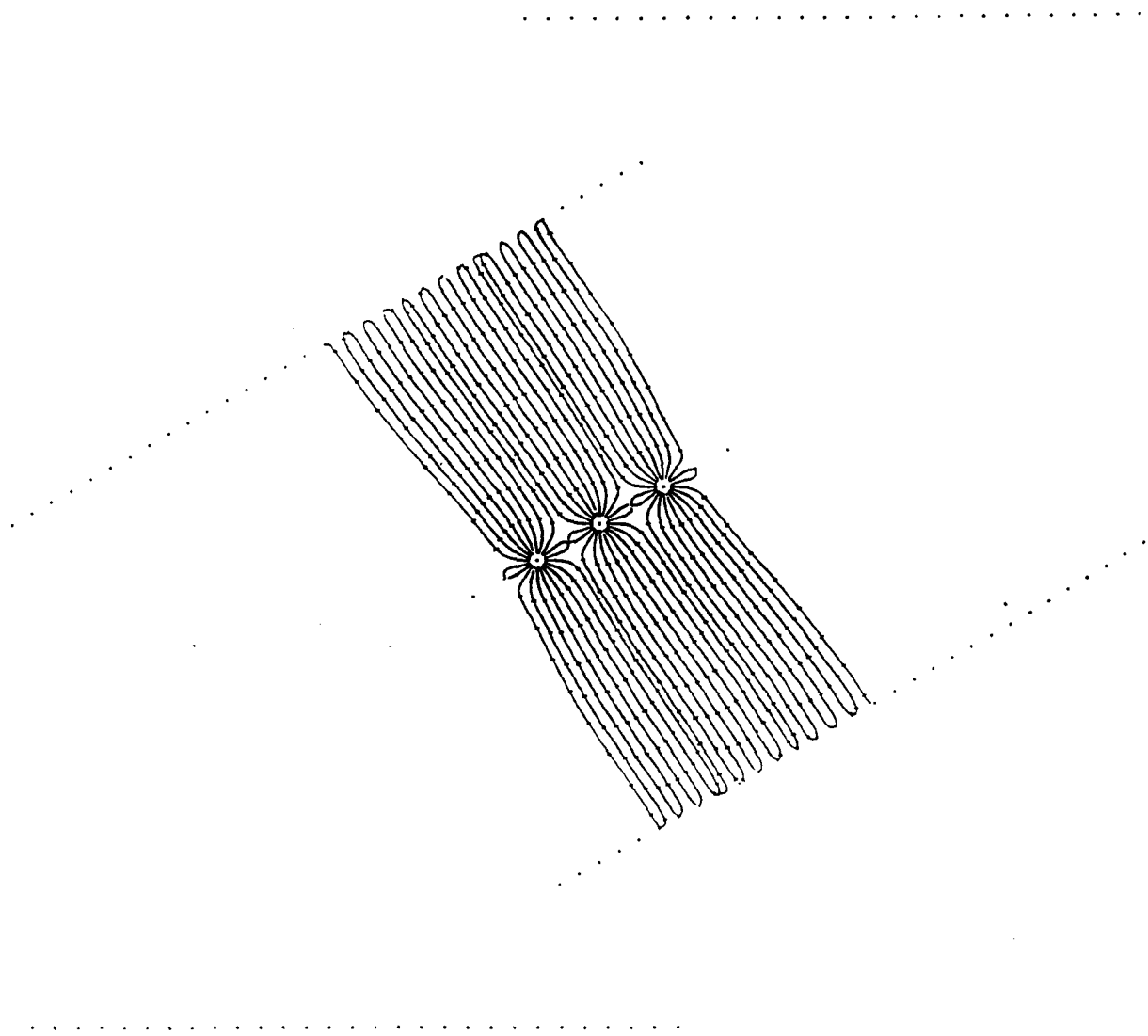


Fig. 4.1.4b. The same figure for the 30° cell.

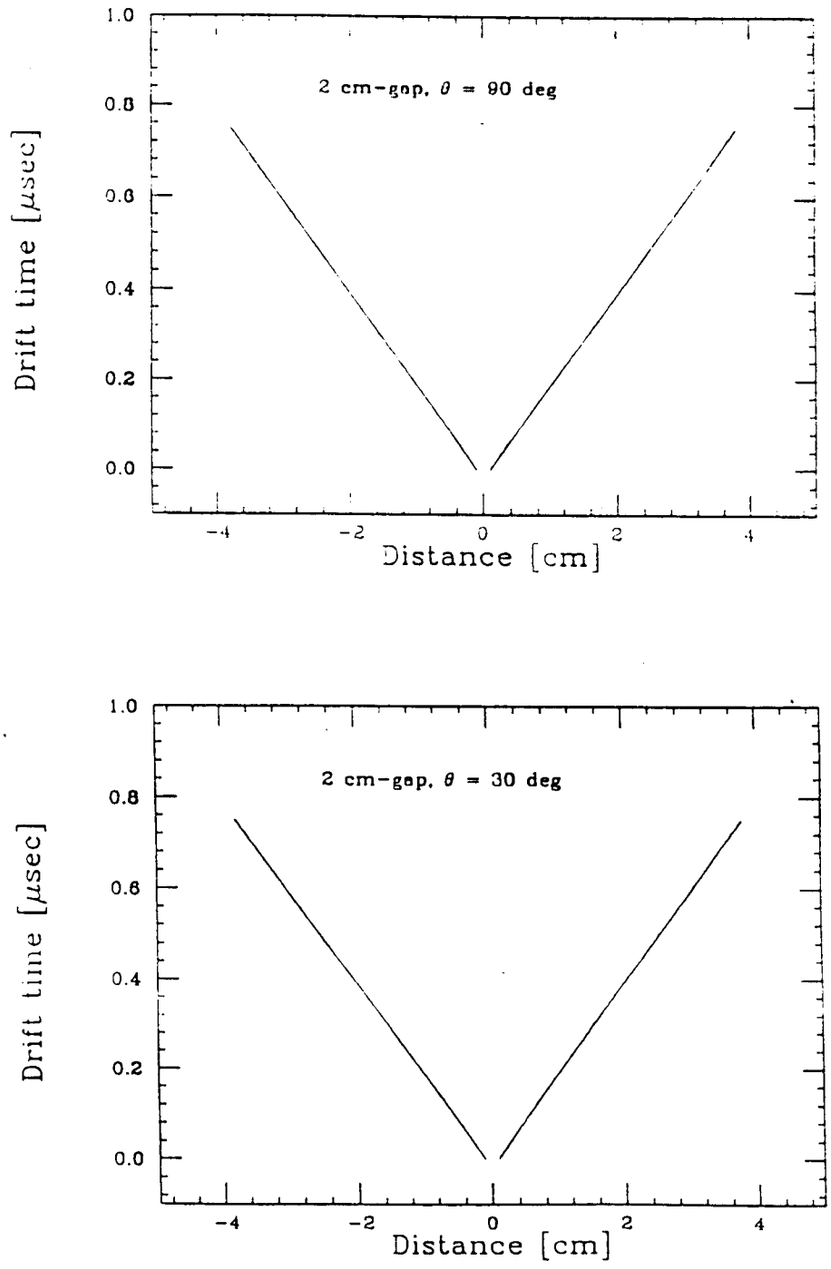



Fig. 4.1.5. The time-to-distance relations obtained as the results of the drift simulation. Results for 3 sense wires in a cell are drawn in each figure.

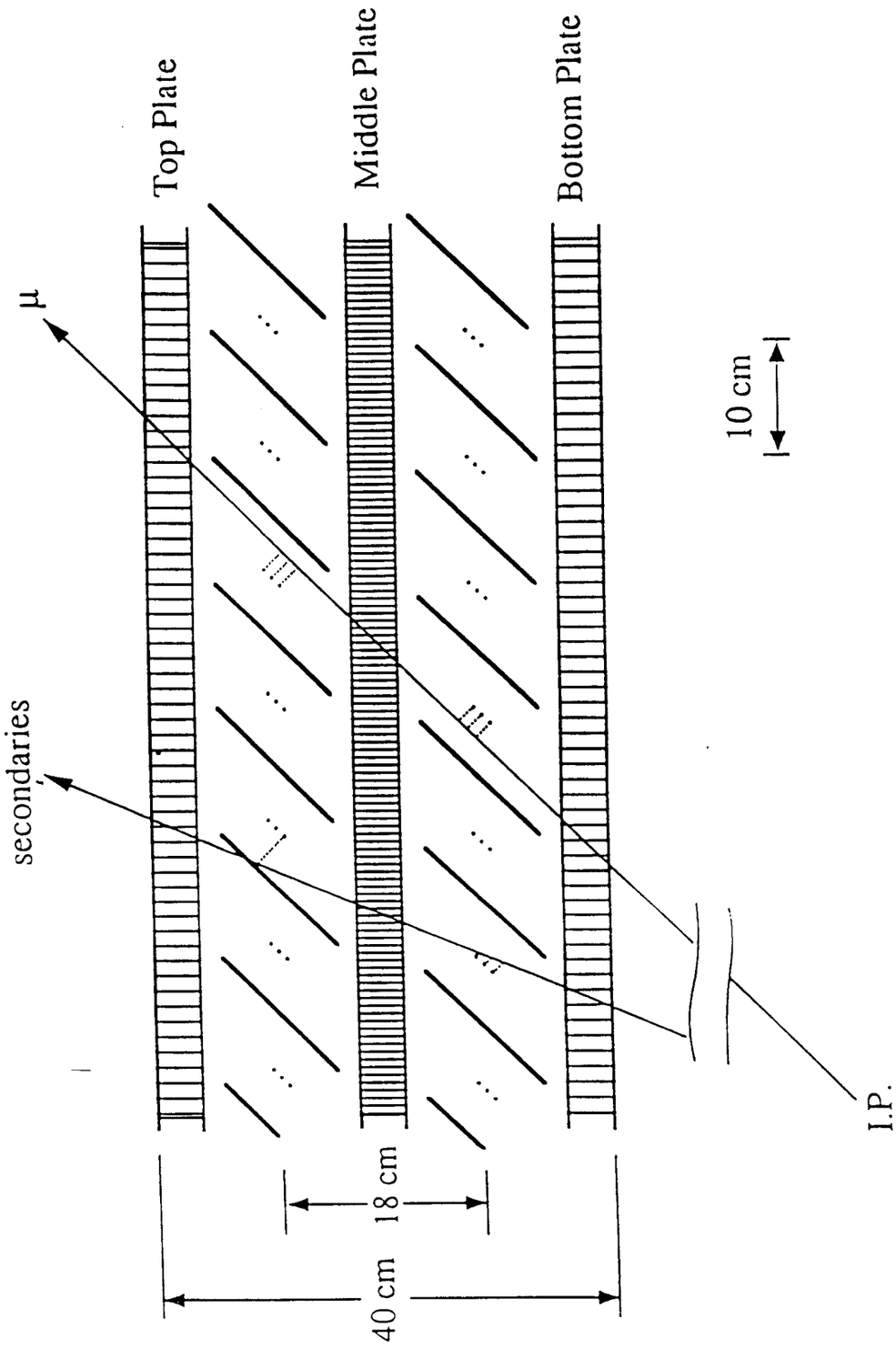



Fig. 1.2 Schematic picture of proposed jet-type drift chambers.

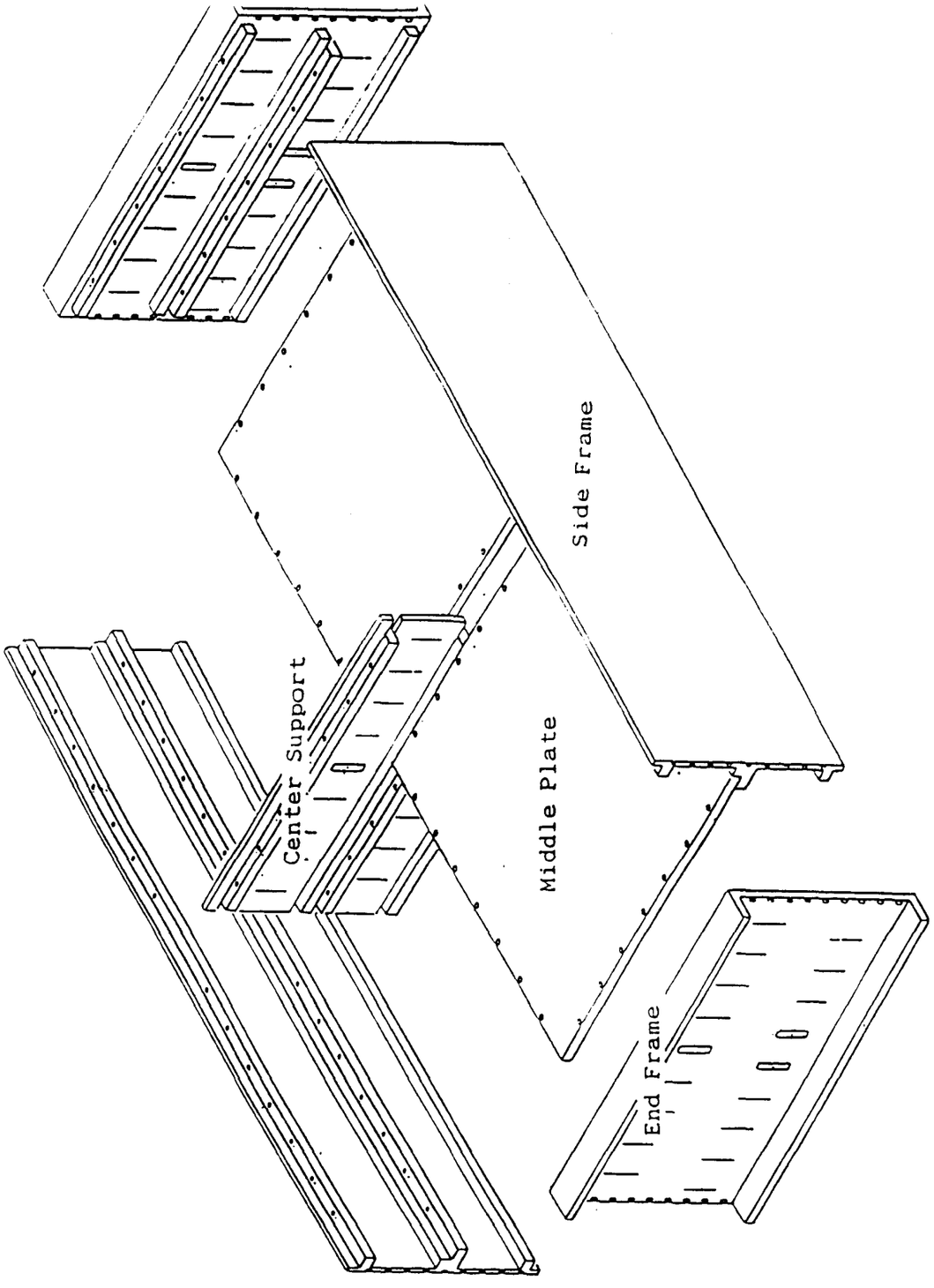



Fig. 2.3. A cutaway view of the jet chamber module.

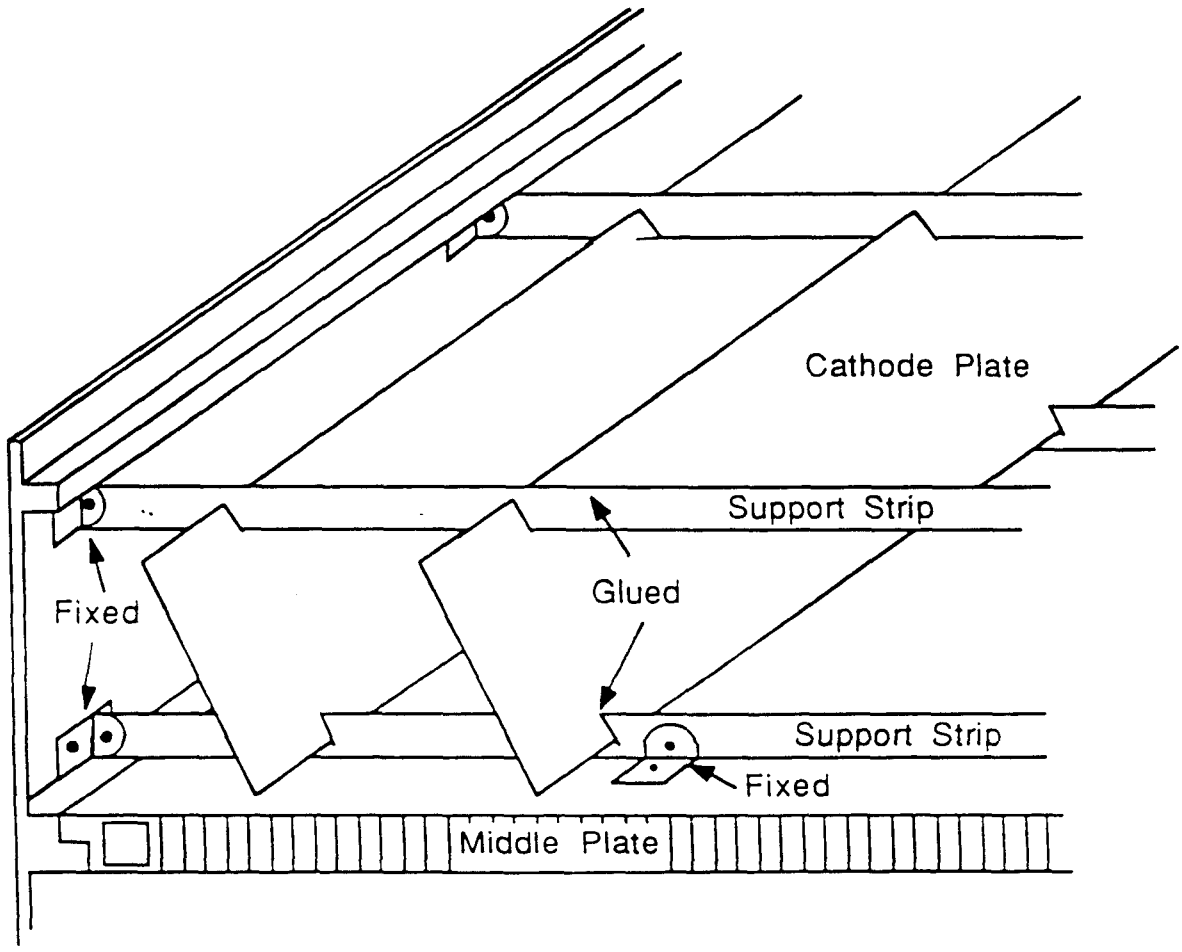
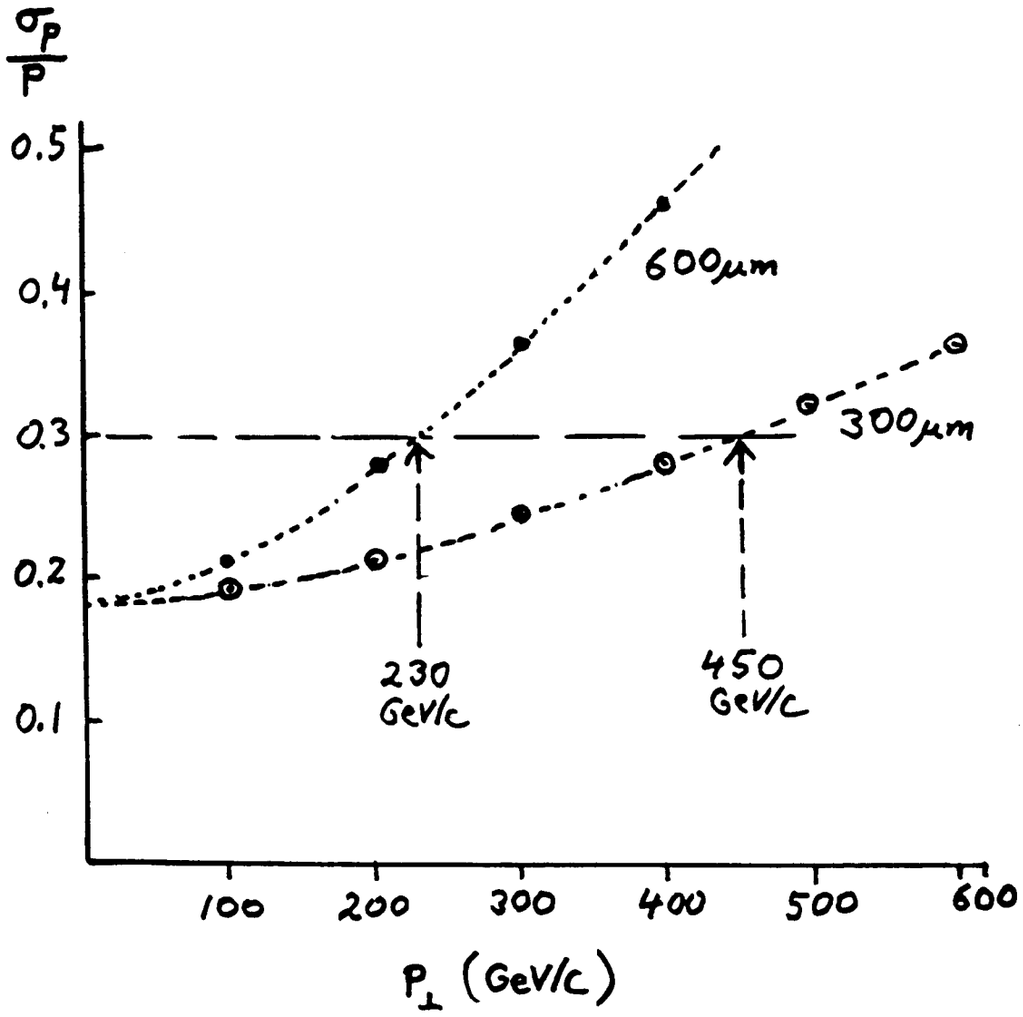


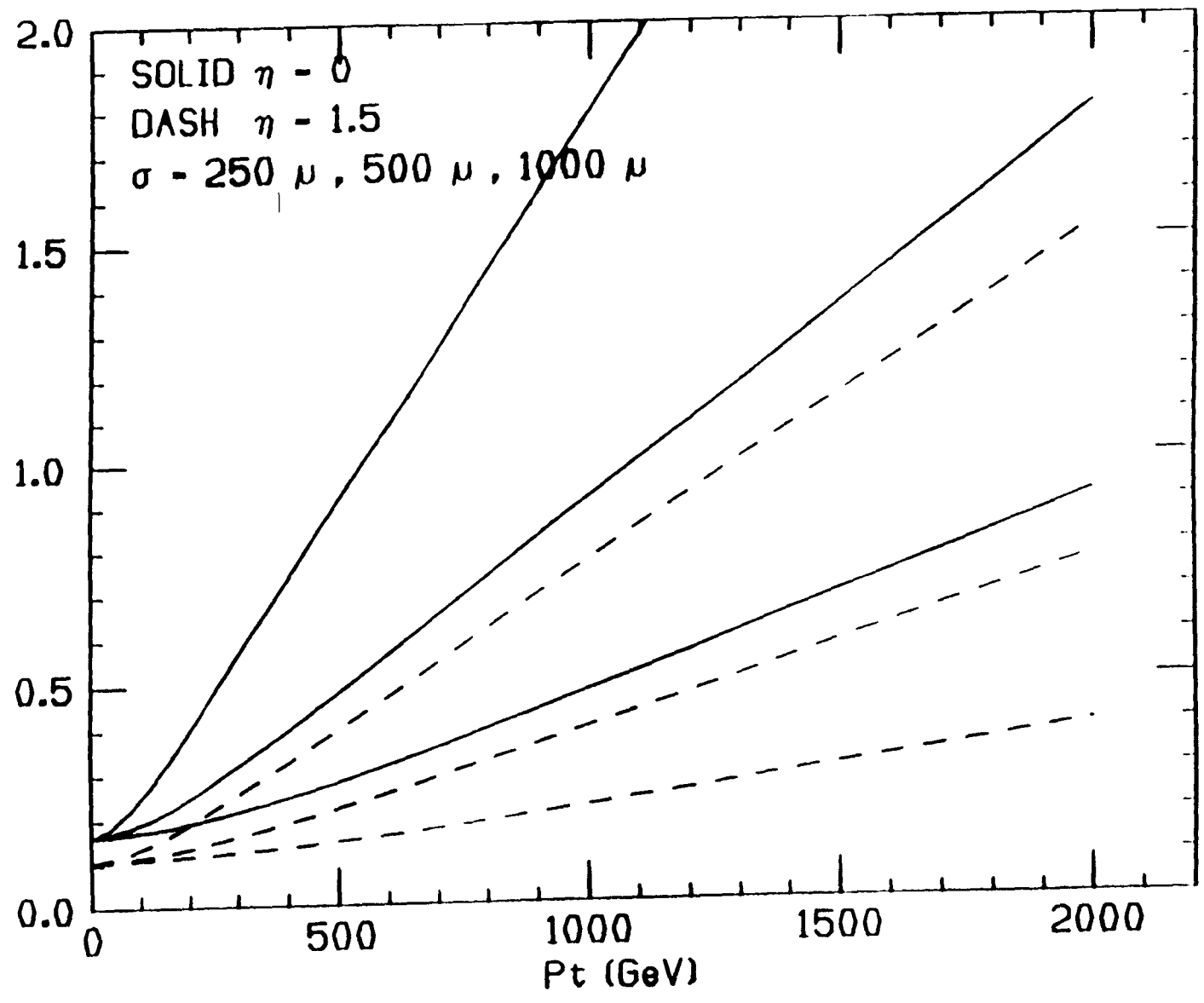

Fig. 2.4. A picture to show the cathode support structure.

## SDC BARREL MUON SYSTEM




MOMENTUM RESOLUTION
VS
DRIFT CHAMBER RESOLUTION

Fig 4 -- SA : MUON ONLY



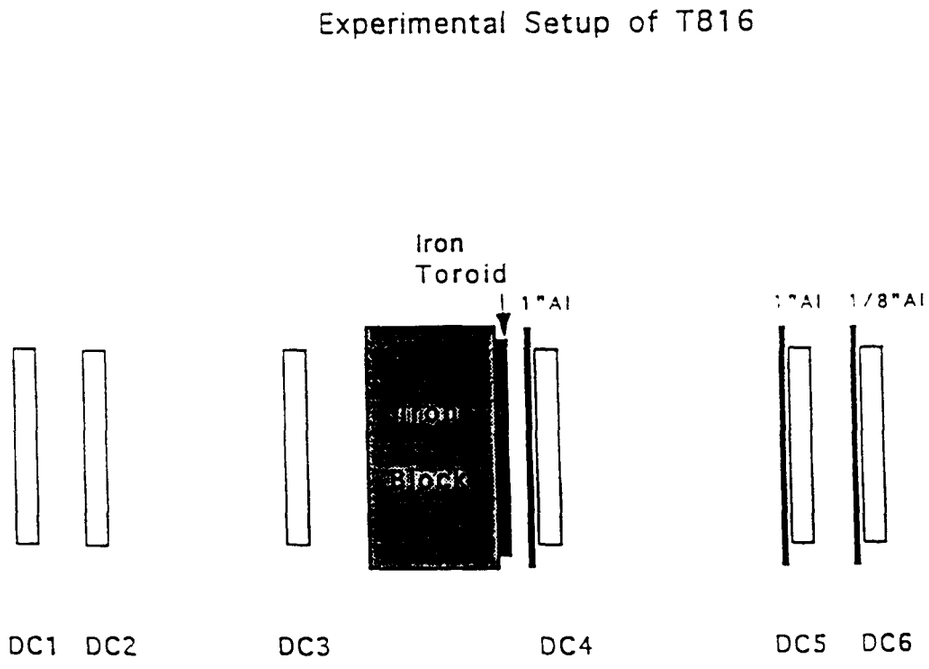



Fig. A3.1. A schematics of the experimental setup. This shows the test materials for the "extra-material condition". Muon beams are coming from left.

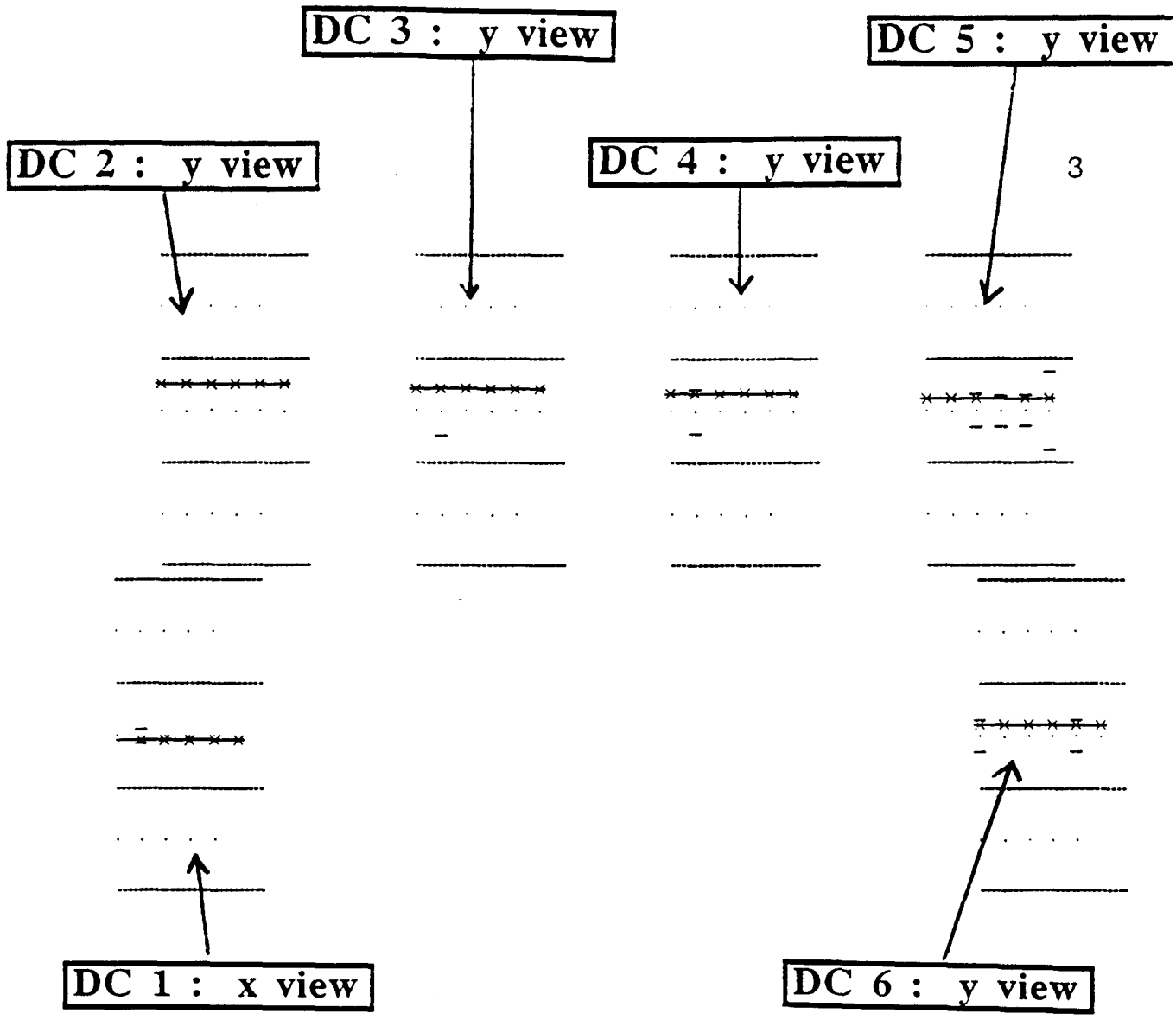

DC 3 : y view
DC 5 : y view
DC 2 : y view
DC 4 : y view
DC 1 : x view
DC 6 : y view

FIG.A.2.3 Event with Delta-Rays at Downstream

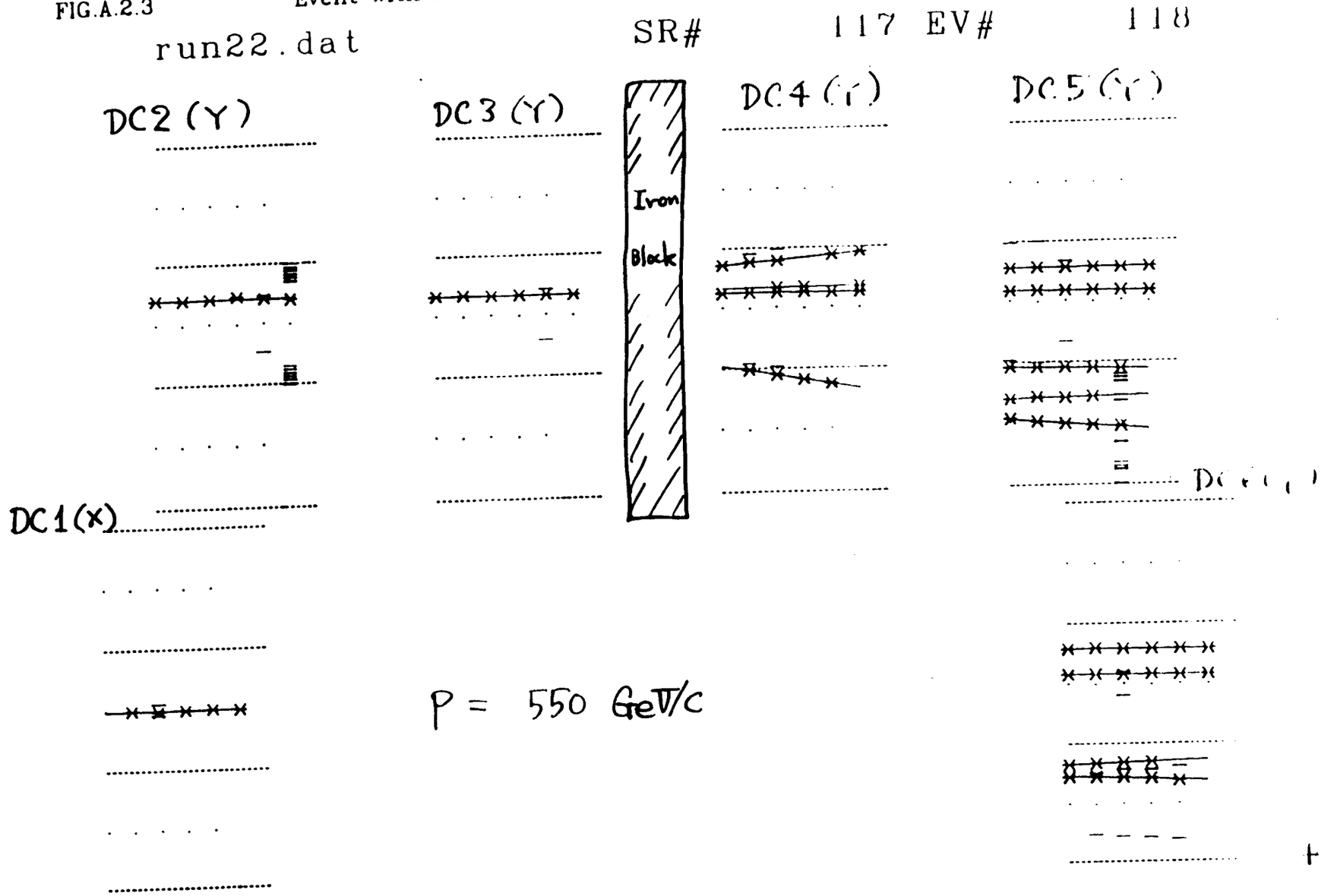
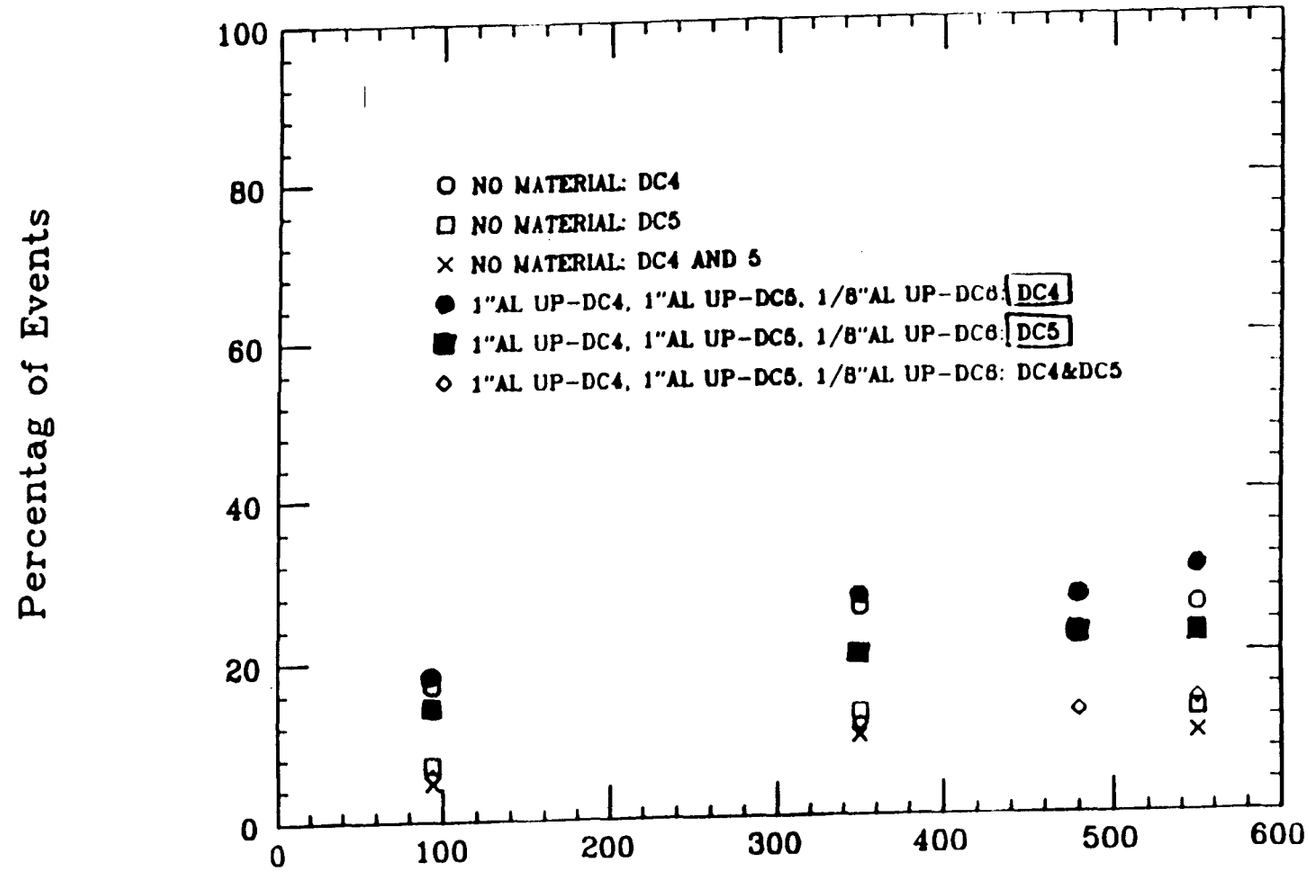
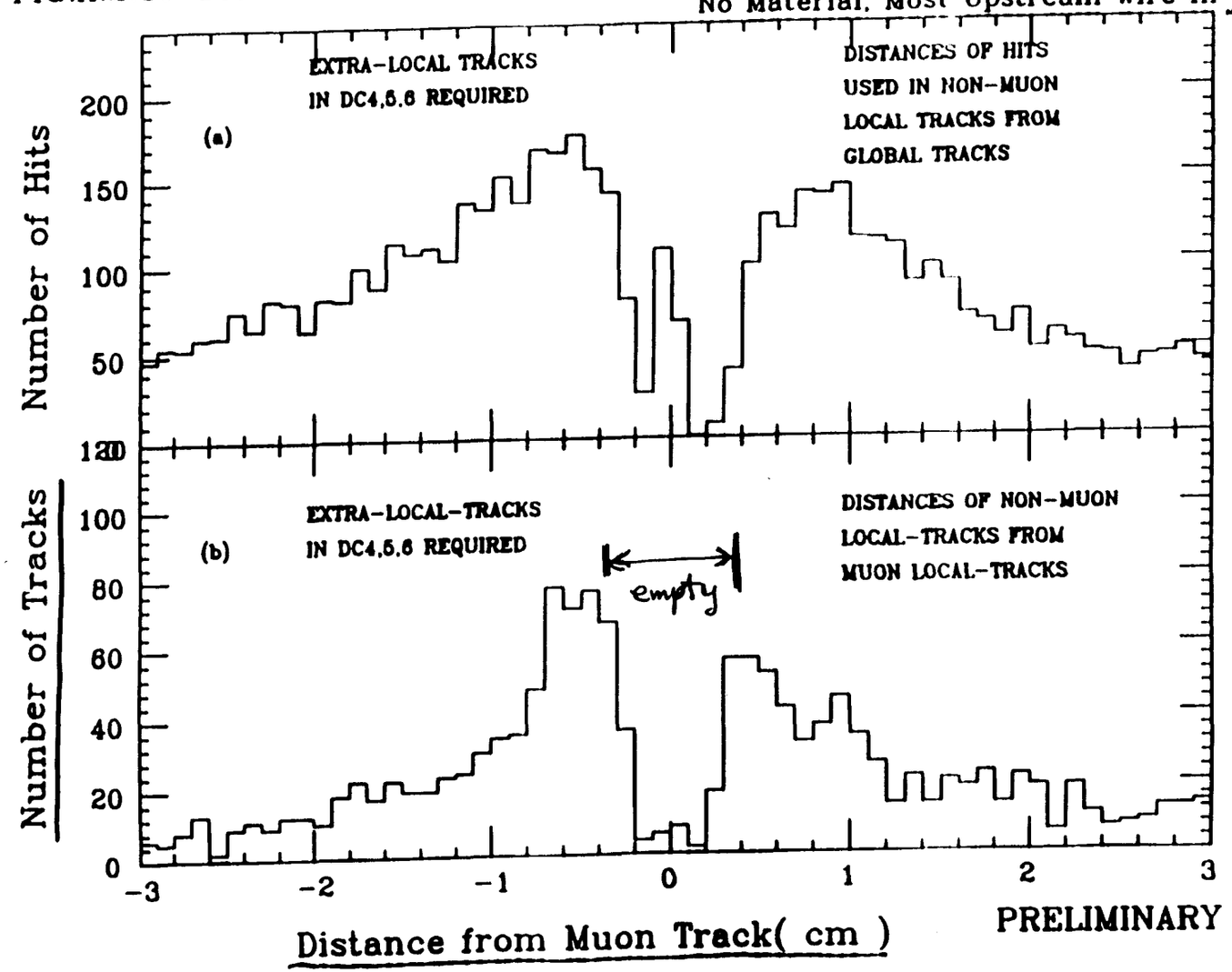


FIG.A.2.4. Percentages of Events with Tracks other than Muons




PRELIMINARY

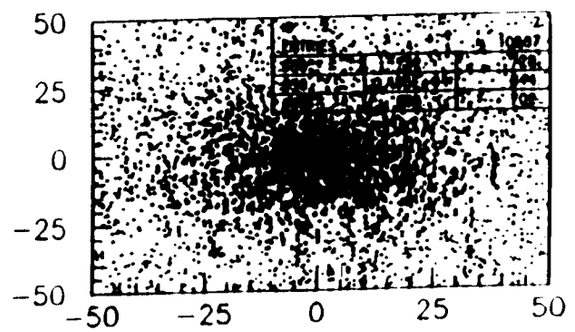
FIG.A.2.19. Distance of Non-muon Tracks from Muon Tracks, 550 GeV.
No Material, Most Upstream Wire in DC4



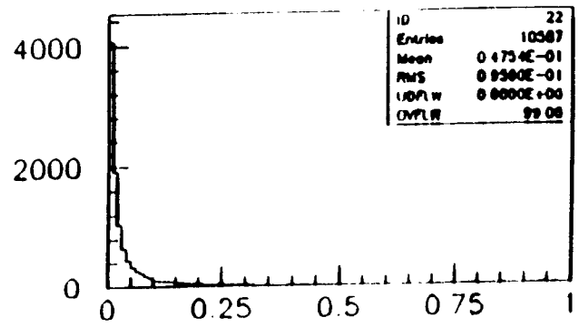

2-track sep
~ 5 mm

no walls , $E_\mu = 500$ GeV , $cut_{e,\gamma} = 1$ MeV

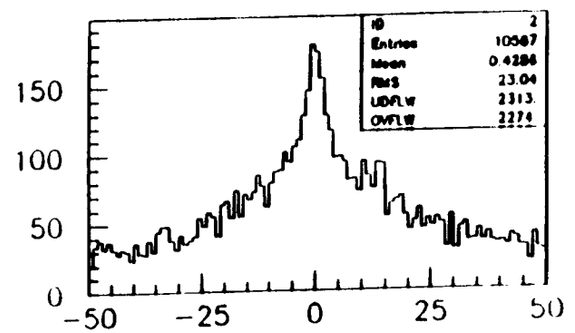
BW1



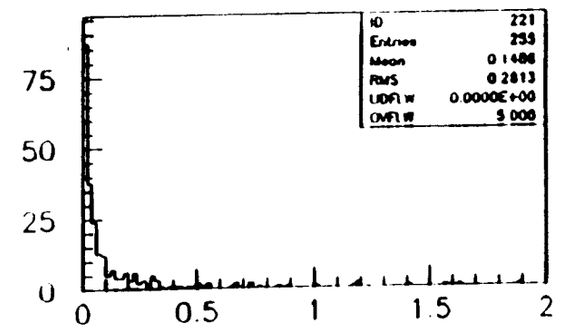

back hits around mu (muc2 enter)



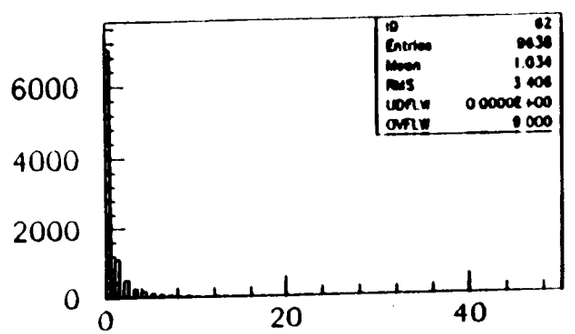

mom of back hits (muc2 enter)



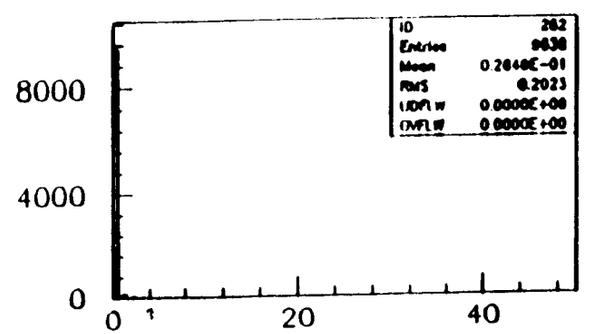

back hits around mu (muc2 enter)




mom back hits R<muc2 enter

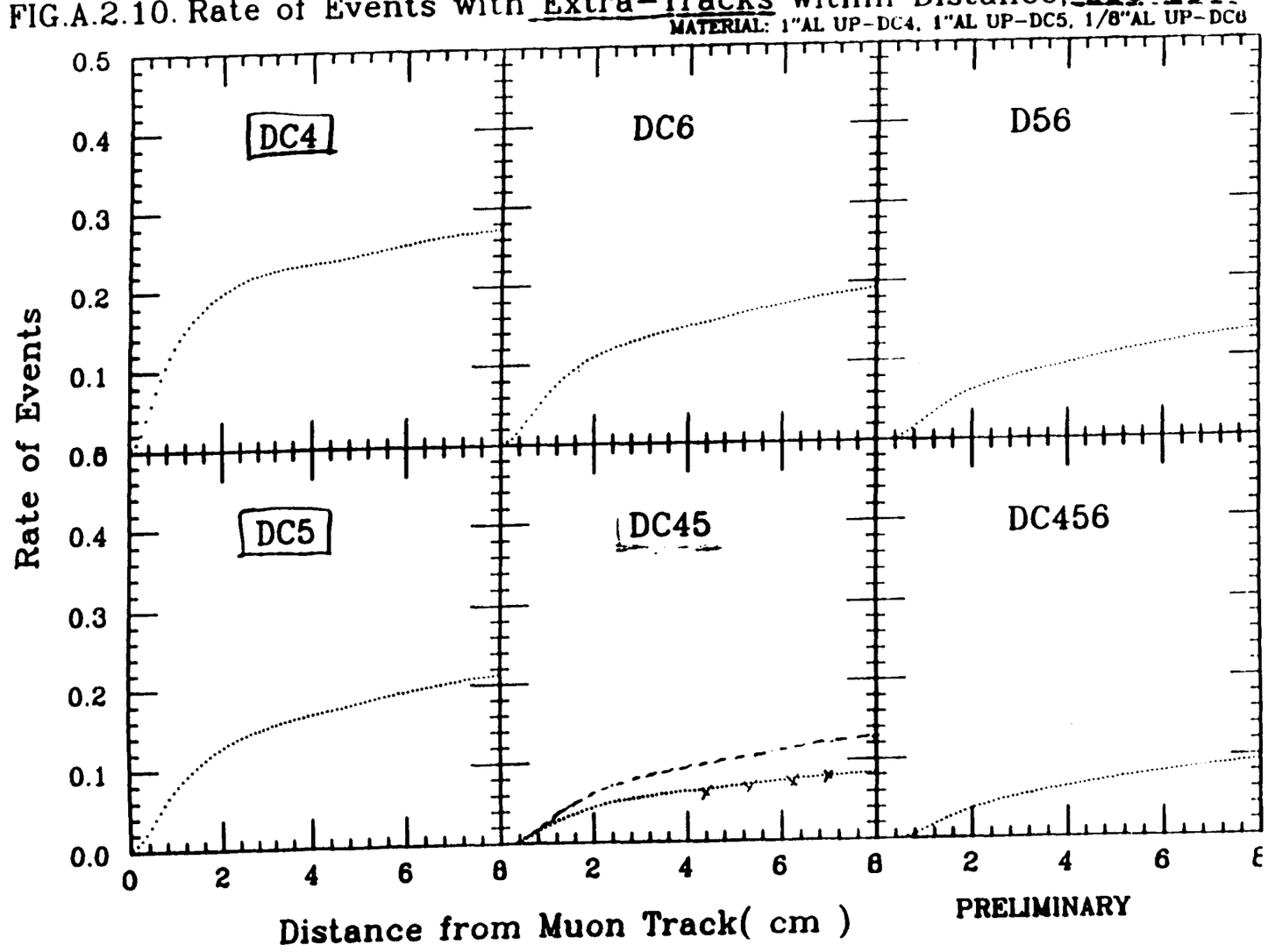


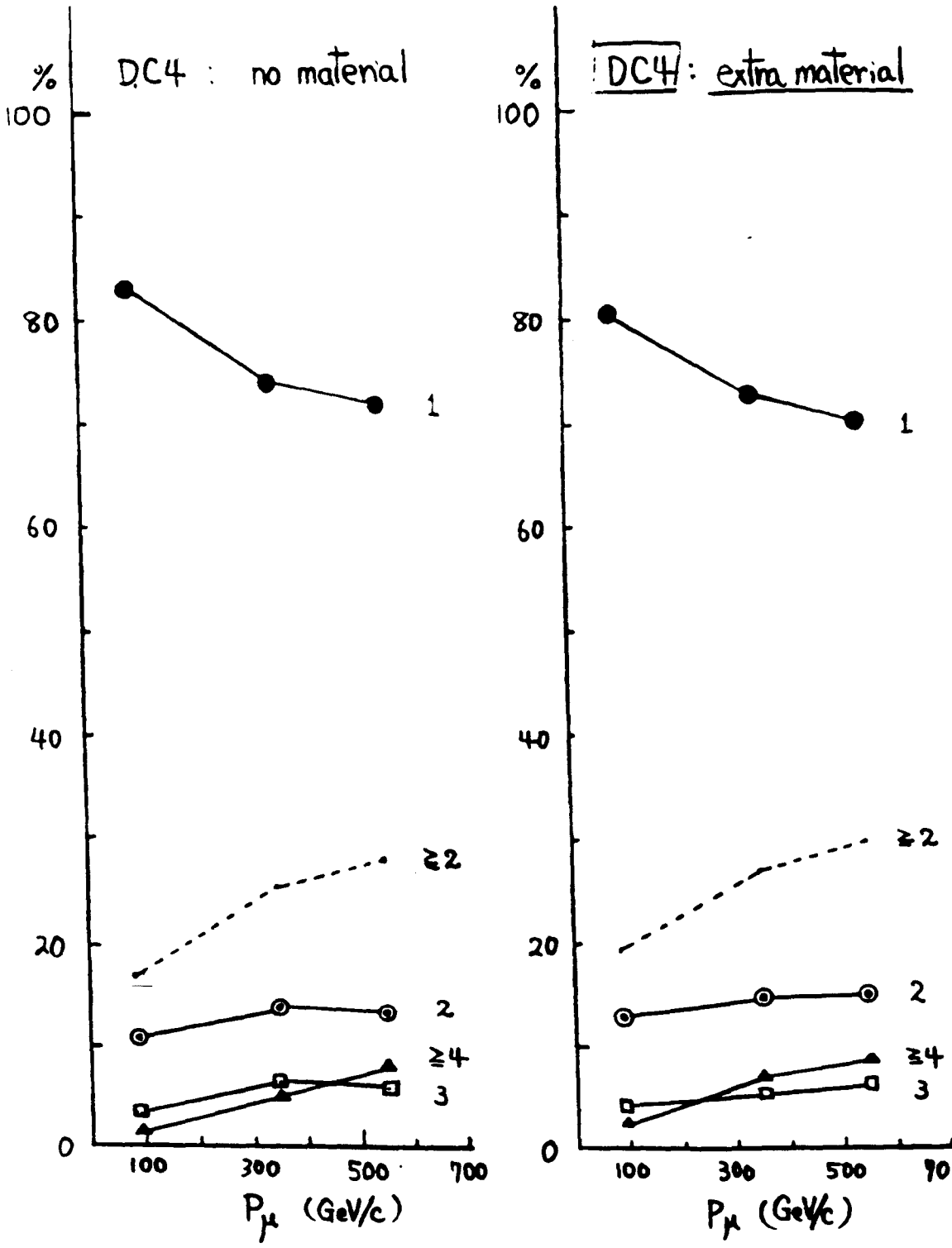

num of back hits (muc2 enter)

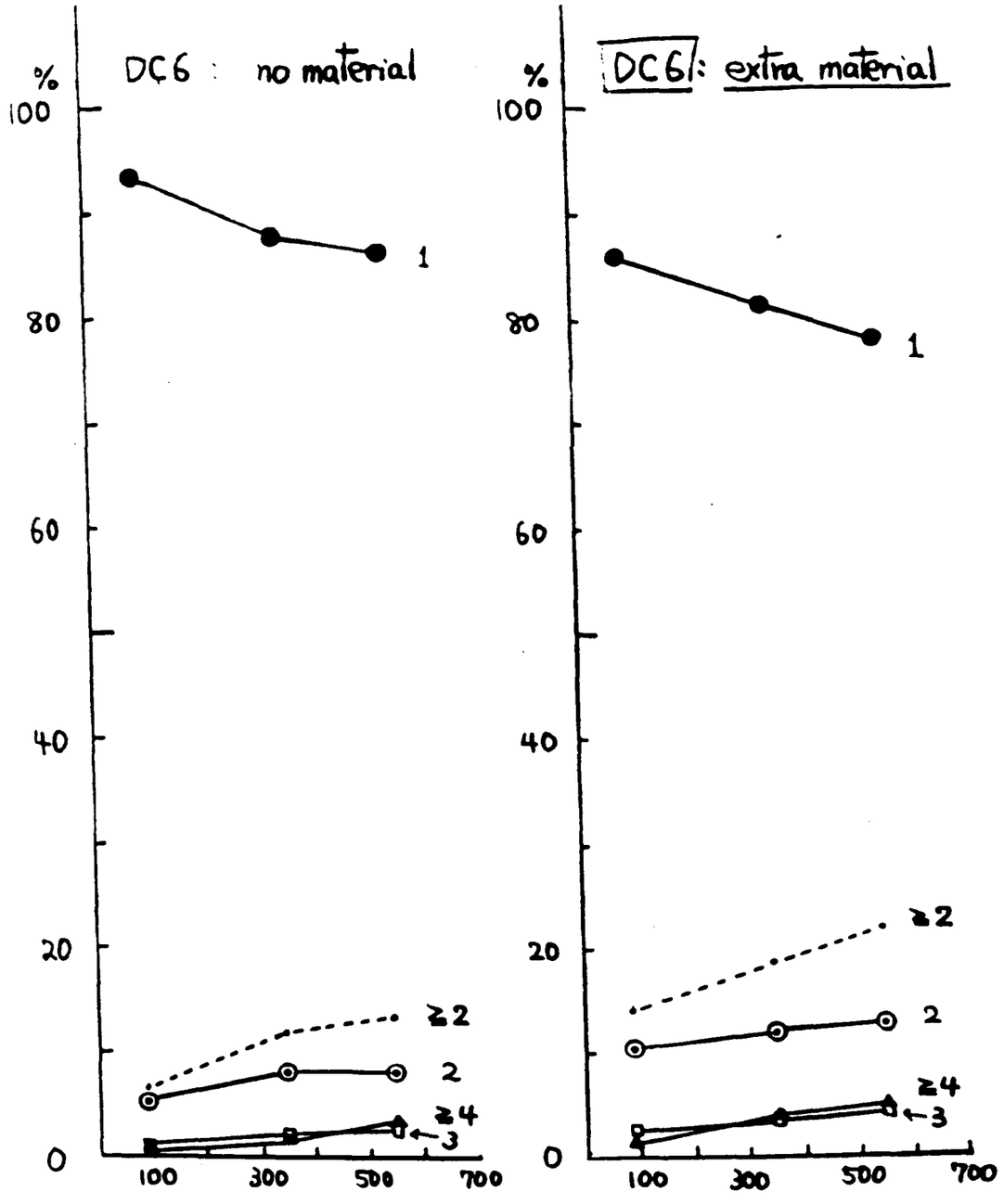



num of back hits R<muc2 enter

FIG.A.2.10. Rate of Events with Extra-Tracks within Distance, 550 GeV.

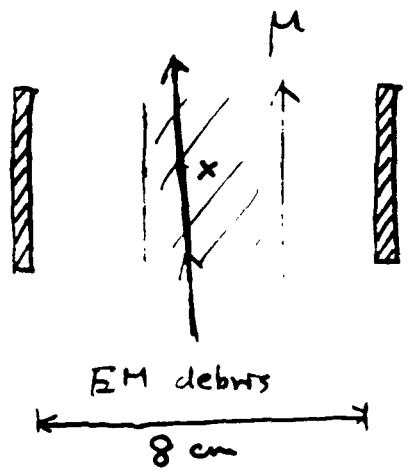



%
DC4 : no material
100
80
60
40
20
0
1
≥2
2
≥4
3
100
300
500
700
$P_\mu$ (GeV/c)
%
DC4 : extra material
100
80
60
40
20
0
1
≥2
2
≥4
3
100
300
500
700
$P_\mu$ (GeV/c)


DC6 : no material
%
100
80
60
40
20
0
100
300
500
700
1
≥2
2
≥4
3
DC6 : extra material
%
100
80
60
40
20
0
100
300
500
700
1
≥2
2
≥4
3

Dependence on <u>2-track separation</u>

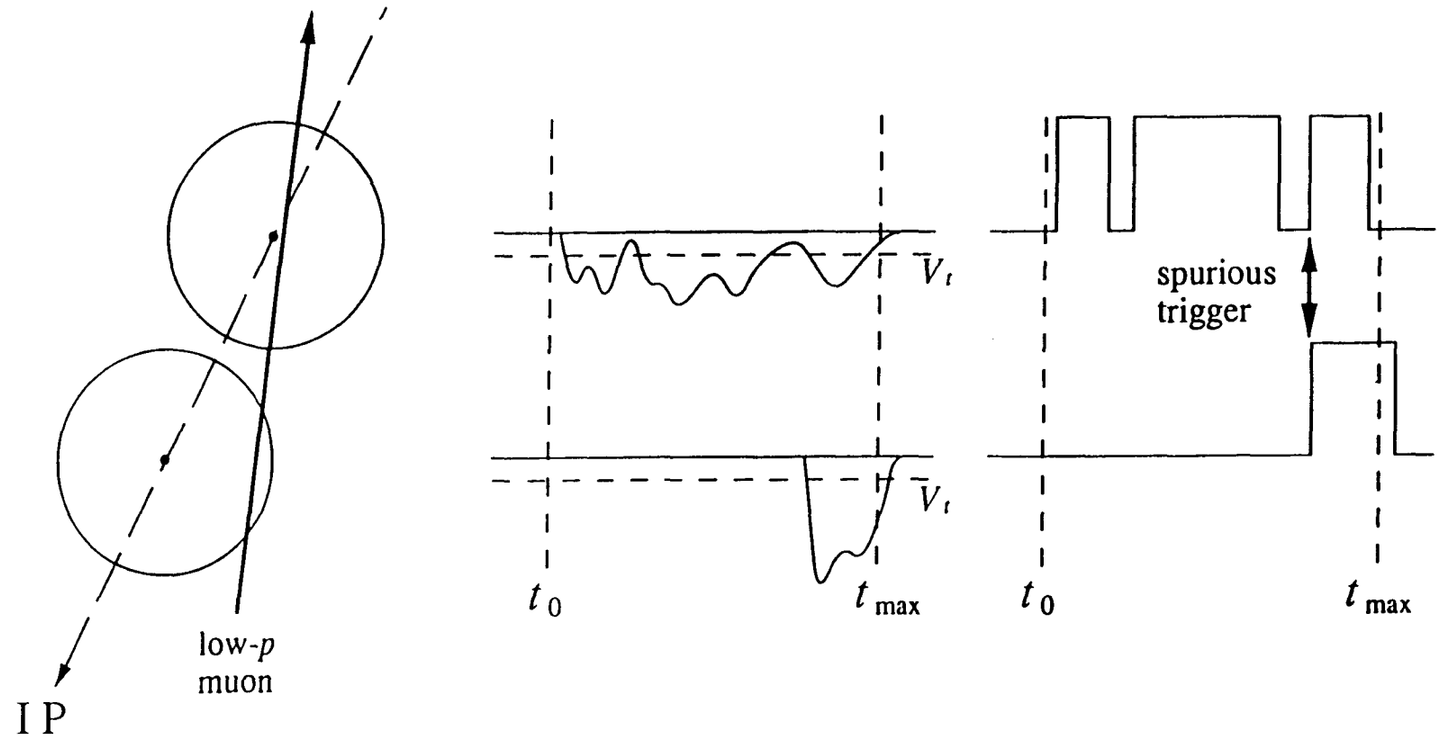
of $\varepsilon$ (detect $\mu$)




| P (GeV/c) | chamber | Two-track separation 5 mm | without |
|---|---|---|---|
| 94 | DC 4 | 96 % | 92 % |
| | DC 5 | 98 % | 95 % |
| 550 | DC 4 | 93 % | 86 % |
| | DC 5 | 96 % | 91 % |

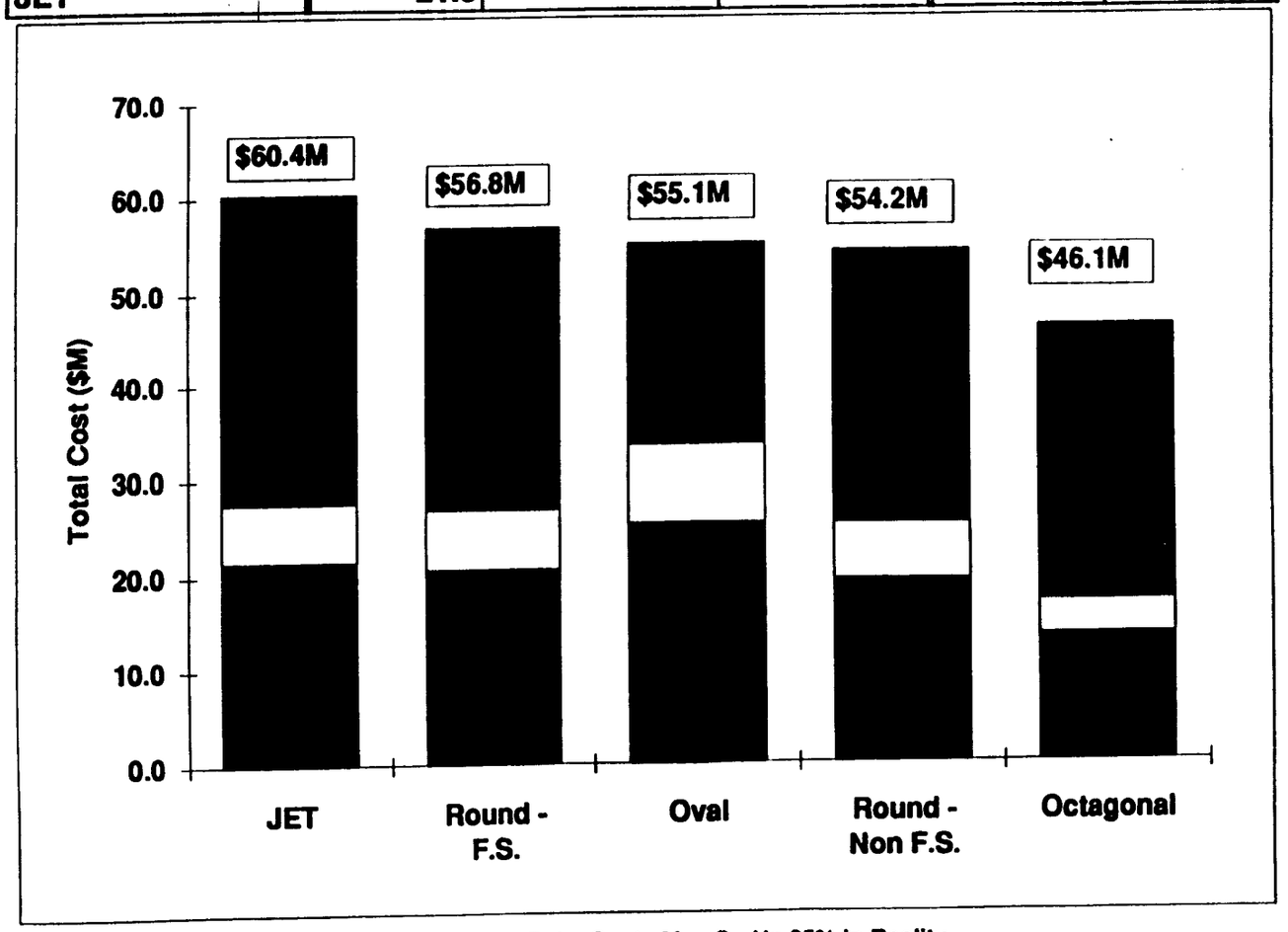
Inefficiency (w/o 2-track) $\simeq$ Inefficiency (5 mm, 2-trac

$\times 2$


low-p
muon
I P
$V_t$
$V_t$
$t_0$
$t_{max}$
spurious
trigger
$t_0$
$t_{max}$

# SDC Muon Chamber Cost Comparisons

| | Barrel ($M) | Intermediate ($M) | Electronics ($M) | Total ($M) | Delta ($M) |
|---|---|---|---|---|---|
| Octagonal | 13.5 | 3.6 | 29.0 | 46.1 | 0.0 |
| Round - F.S. | 20.6 | 6.3 | 29.9 | 56.8 | 10.7 |
| Round - Non F.S. | 19.3 | 6.0 | 28.9 | 54.2 | 8.1 |
| Oval | 25.4 | 8.1 | 21.6 | 55.1 | 9.0 |
| JET | 21.5 | 6.2 | 32.7 | 60.4 | 14.3 |




Note: Costs Based on Actual Work Performed, Delta Costs May Go Up 25% in Reality

## Baseline Muon Chamber Layout

| Layer | Type | #L | #D | #O | LDO | Width | Length | Radius | Ang Fact | Octagonal T/L | Octagonal Total # | Round T/L | Round Total # | Jet LM | Jet T/L | Jet Total # | Oval Eff w | Oval T/L | Oval Total # |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BW1 | φ | 4 | 3 | 8 | 96 | 4739 | 7381 | 5720 | 0.973 | 63 | 6048 | 62 | 5952 | 1.50 | 86 | 8256 | 155 | 29 | 2784 |
| | θ | 4 | 1 | 8 | 32 | 22144 | 5091 | 6145 | 0.750 | 295 | 9440 | 292 | 9344 | 1.50 | 311 | 9952 | 155 | 107 | 3424 |
| BW2 | θ | 4 | 1 | 8 | 32 | 29032 | 7025 | 8480 | 0.763 | 387 | 12384 | 383 | 12256 | 1.50 | 415 | 13280 | 142 | 156 | 4992 |
| BW3 | φ+σ | 6 | 5 | 8 | 240 | 8276 | 6006 | 9990 | 0.973 | 110 | 26400 | 109 | 26160 | 1.33 | 134 | 32160 | 154 | 52 | 12480 |
| | θ | 4 | 1 | 8 | 32 | 30032 | 8773 | 10590 | 0.810 | 400 | 12800 | 396 | 12672 | 1.50 | 456 | 14592 | 142 | 171 | 5472 |
| Total barrel | | | | | | | | | | | 67072 | | 66384 | | | 78240 | | | 29152 |
| IW2 | θ | 4 | 1 | 16 | 64 | 2180 | 6495 | 7840 | 0.816 | 29 | 1856 | 28 | 1792 | 1.50 | 33 | 2112 | 142 | 12 | 768 |
| IW3 | φ+σ | 6 | 1 | 16 | 96 | 10216 | 6025 | 12332 | 0.973 | 136 | 13056 | 134 | 12864 | 1.33 | 165 | 15840 | 154 | 64 | 6144 |
| | θ | 4 | 1 | 16 | 64 | 6025 | 7721 | 9320 | 0.850 | 80 | 5120 | 79 | 5056 | 1.50 | 95 | 6080 | 142 | 36 | 2304 |
| Total intermediate | | | | | | | | | | | 20032 | | 19712 | | | 24032 | | | 9216 |
| Total | | | | | | | | | | | 87104 | | 86096 | | | 102272 | | | 38368 |
| | | | | | | | | | | | | | | | | | | CDR | (38752) |

| | Width | Area | L (km) | V (m^3) |
|---|---|---|---|---|
| Octagonal tube | 75.0 | 4789 | 581 | 2781 |
| Round tube | 75.7 | 4072 | 574 | 2338 |
| Jet cell | 80.0 | | 682 | 3770 |
| Oval tube (width nominal) | 160.0 | 4229 | 256 | 1082 |

Notes: Units are mm unless stated otherwise

Ang Fact is an angle factor which accounts for the spread out as the angle increases. It is calculated analytically. It only affects the jet cell and oval tube options.

LM accounts for the increased layer count in the jet cell option.

Eff w is the effective width of the oval tubes. It is smaller than the nominal width because of overlap.

CDR values should be used for oval option because Eff w is only approximate.

| | BOSTON | WISCONSIN | WASH./SSC | | KEK |
|---|---|---|---|---|---|
| $\sigma$ ($\mu$m) | 300 | 550 | 460 | 250 | 240 |
| 2-HIT $\sigma$ (mm) | 5 | ? | ? | 5-10 ? | 5 |
| TRIGGER (%) EFFICIENCY | 93<br>99 ← OVERLAP | 93<br>99 | 93<br>99 | | 93<br>99 |
| RECONSTRUCTION EFFICIENCY % | ~ 94 | ~ 88 | ~88 | ~94 | ~ 94 |
| WIRE SAG (mm) | 0.125 | 1.5 | 1.3 | 1.3 | 0.6 |
| MODULE SAG (mm) | TUBE SAG 1.0 | 1.0 | 1.0 | | < 1.0 |
| SURVEY/ ALIGNMENT POINTS | ~ 3200 | 320 | 240 | | 840 |
| CHANNELS BARREL + INT. | 38 368 | 87104 | 86096 | | 102 27 |
| COST M$ | 55.1 | 46.1 | 54.2 | 56.8 | 60.4 |

PRESENTATION BY:

ANDRIS SKUJA

Criteria & Constraints
Forward Muon System
$1.5 \lesssim \eta \lesssim 2.5$ (9.4° to 25°)

Andris Sumja Jan 27, '92
Sat pm

Goals

- Stand alone momentum measurement $\left(\frac{\delta\theta_{MS}}{\theta_B} \approx \frac{\delta\theta_B}{\theta_B}\right)$
  Better than 10% at 1TeV ⇒ 100μm / station
  Need FW1, FW2, FW4 and FW5 for stand alone system
  Need FW2, FW4, FW5 if Gmicrostrips and Silicon CTD work as advertised
- Muon i.d. in CTD
  Need FW1 and FW2
  Study underway for amount of confusion at $10^{33}$ and $10^{34}$
- Level 1 trigger
  Need FW4 and FW5
- Level 2 and Level 3 trigger
  Need FW2 (and FW1?) as well
- Stand alone capability at high luminosity ($10^{34}$)
  Need FW1, FW2, FW4 and FW5

FW3 needed to help distinguish and recover from large angle scatters in FT1 or FT2
It does not add much to capability otherwise
It also aids in momentum reconstruction if em shower in FT2 wipes out FW4 and FW5

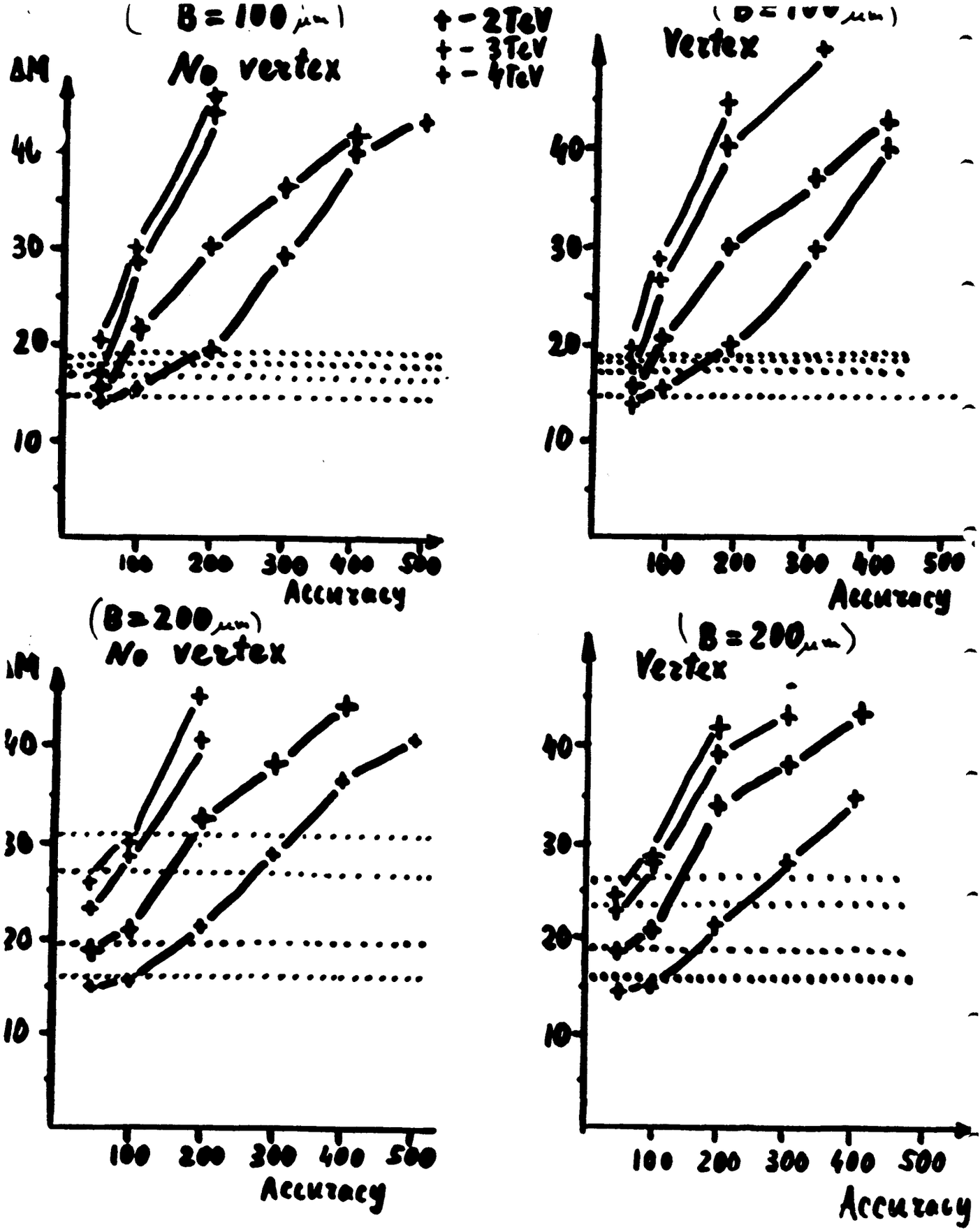
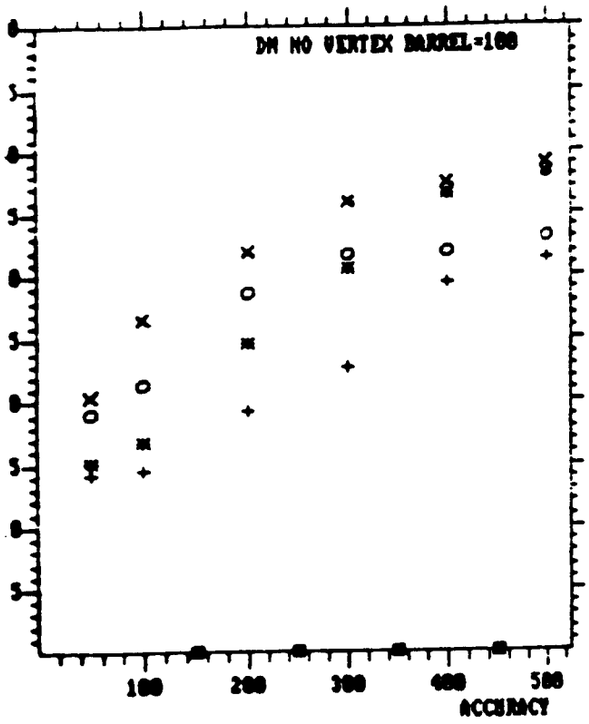
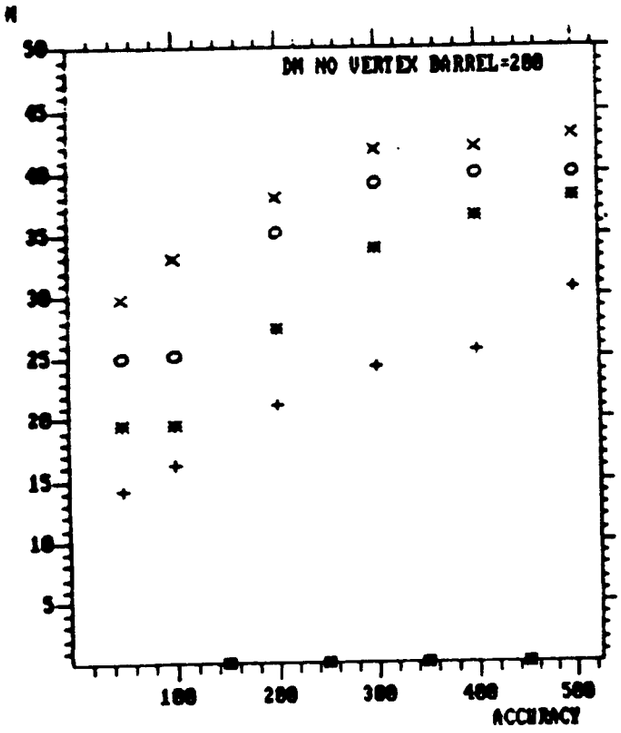

( B = 100 μm )
No vertex
+ - 2TeV
+ - 3TeV
+ - 4TeV
ΔM
40
30
20
10
100
200
300
400
500
Accuracy
Vertex
(B = 200 μm)
No vertex
Vertex

fig 5


DM NO VERTEX BARREL=100
100
200
300
400
500
ACCURACY


DM NO VERTEX BARREL=200
5
10
15
20
25
30
35
40
45
50
100
200
300
400
500
ACCURACY

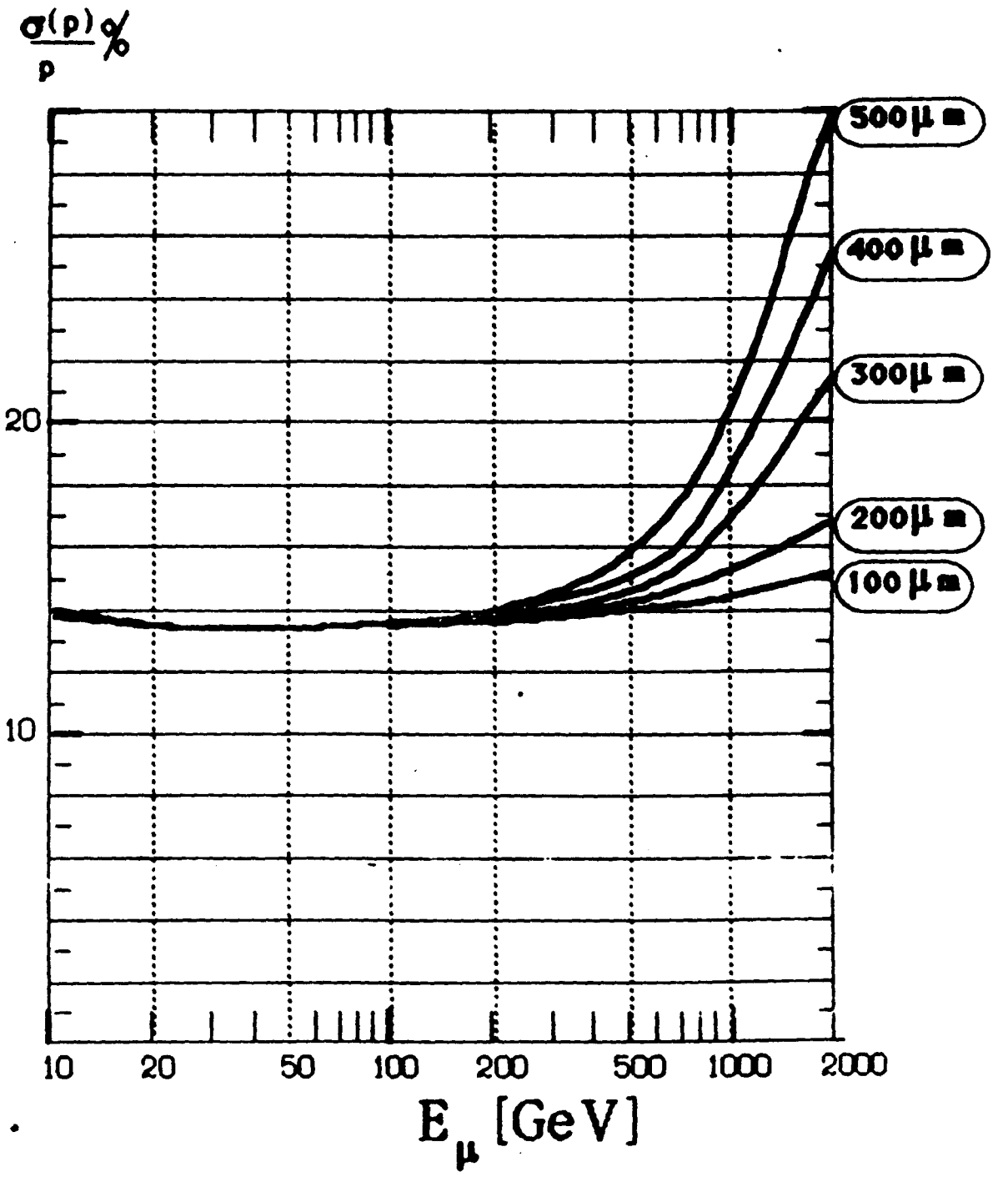
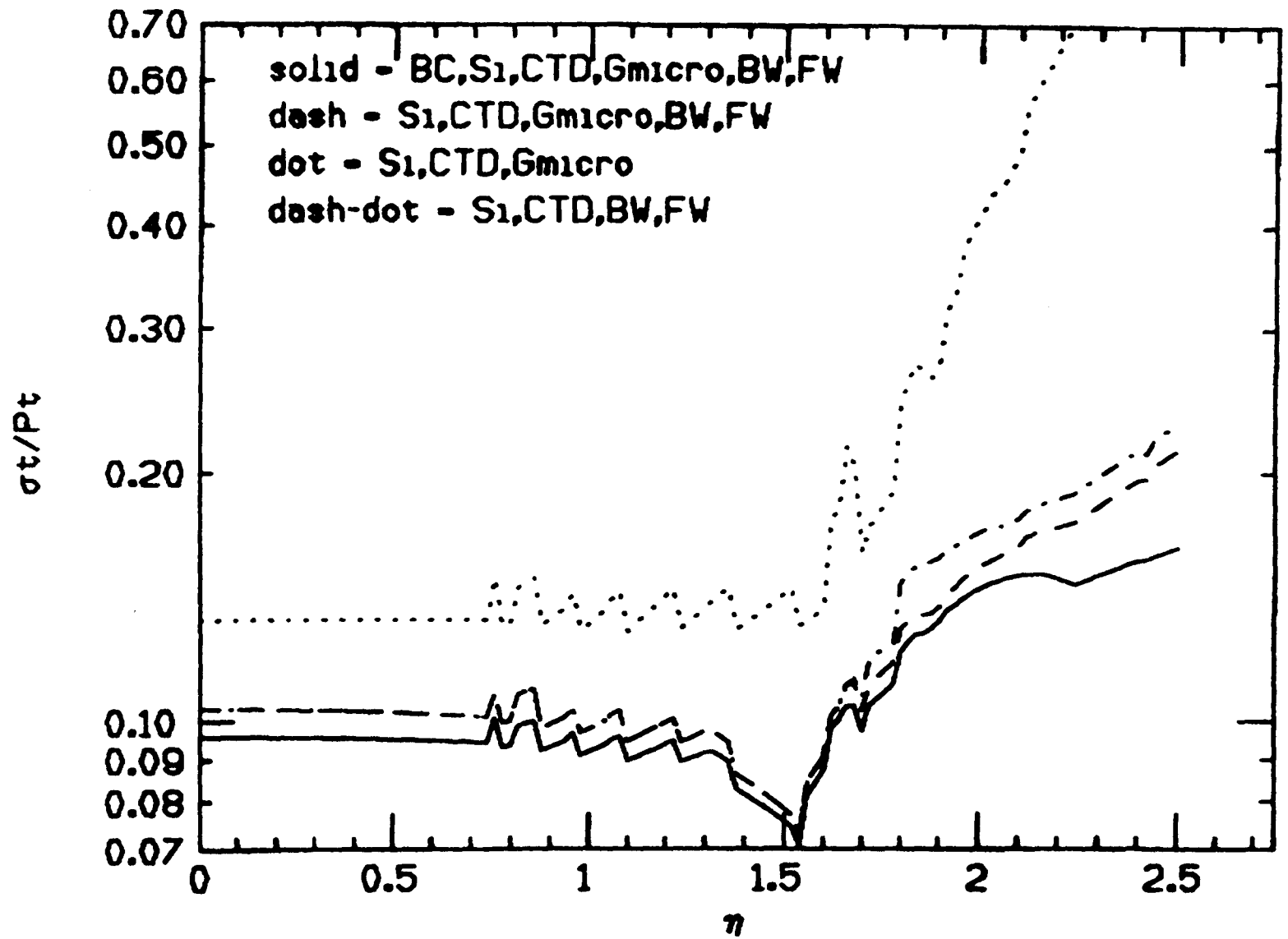

σ(p)/p %
500μm
400μm
300μm
200μm
100μm
20
10
10
20
50
100
200
500
1000
2000
E_μ [GeV]

Figure 14

Jim Wiss
Jan 30, '92

# Fig 4a Pt = 1000

160μm/doublet
Δxs ~ 2m



150 μm / doublet
Δus ~ 2m

# FIG 4c Pt - 1000

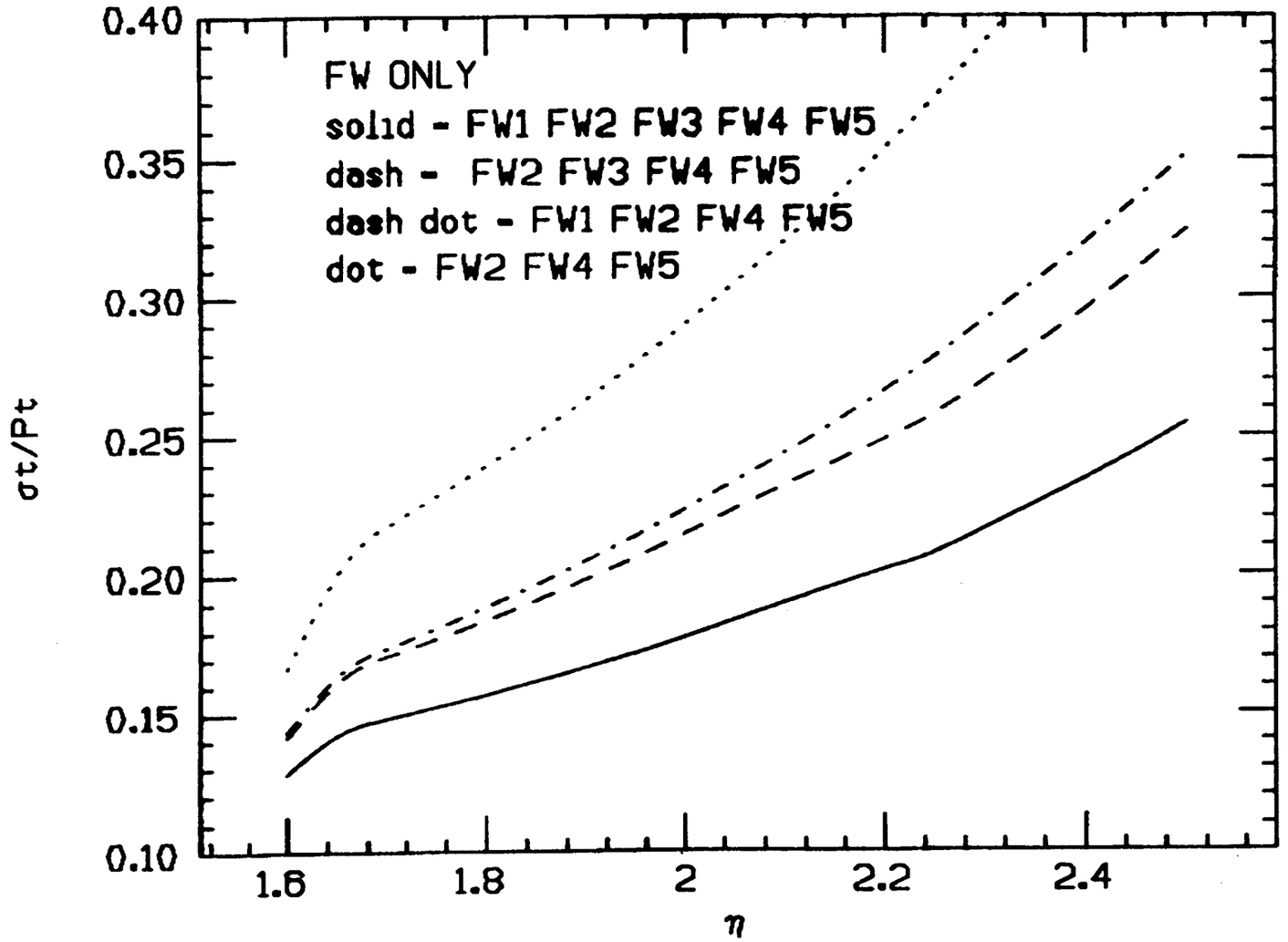
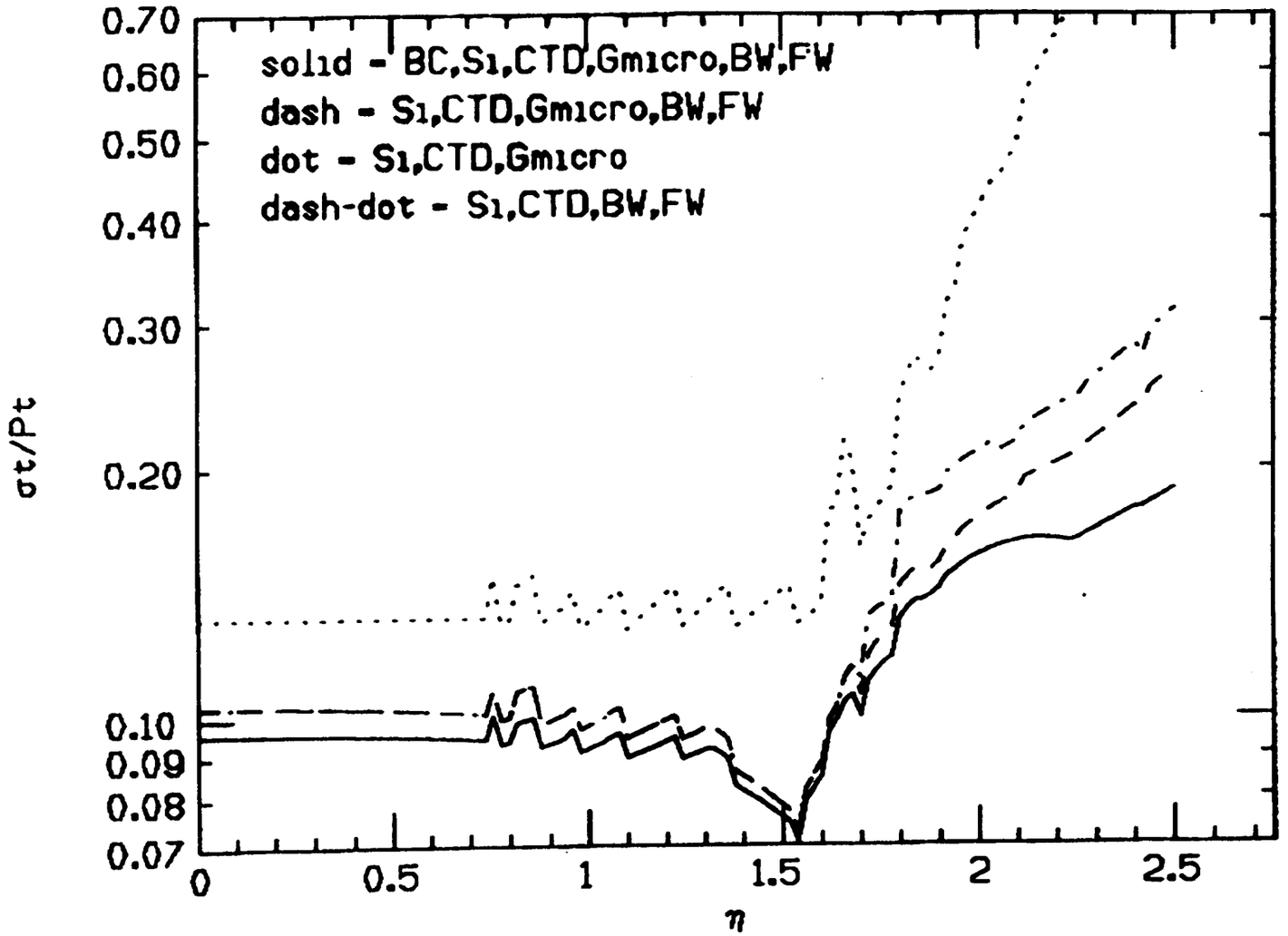


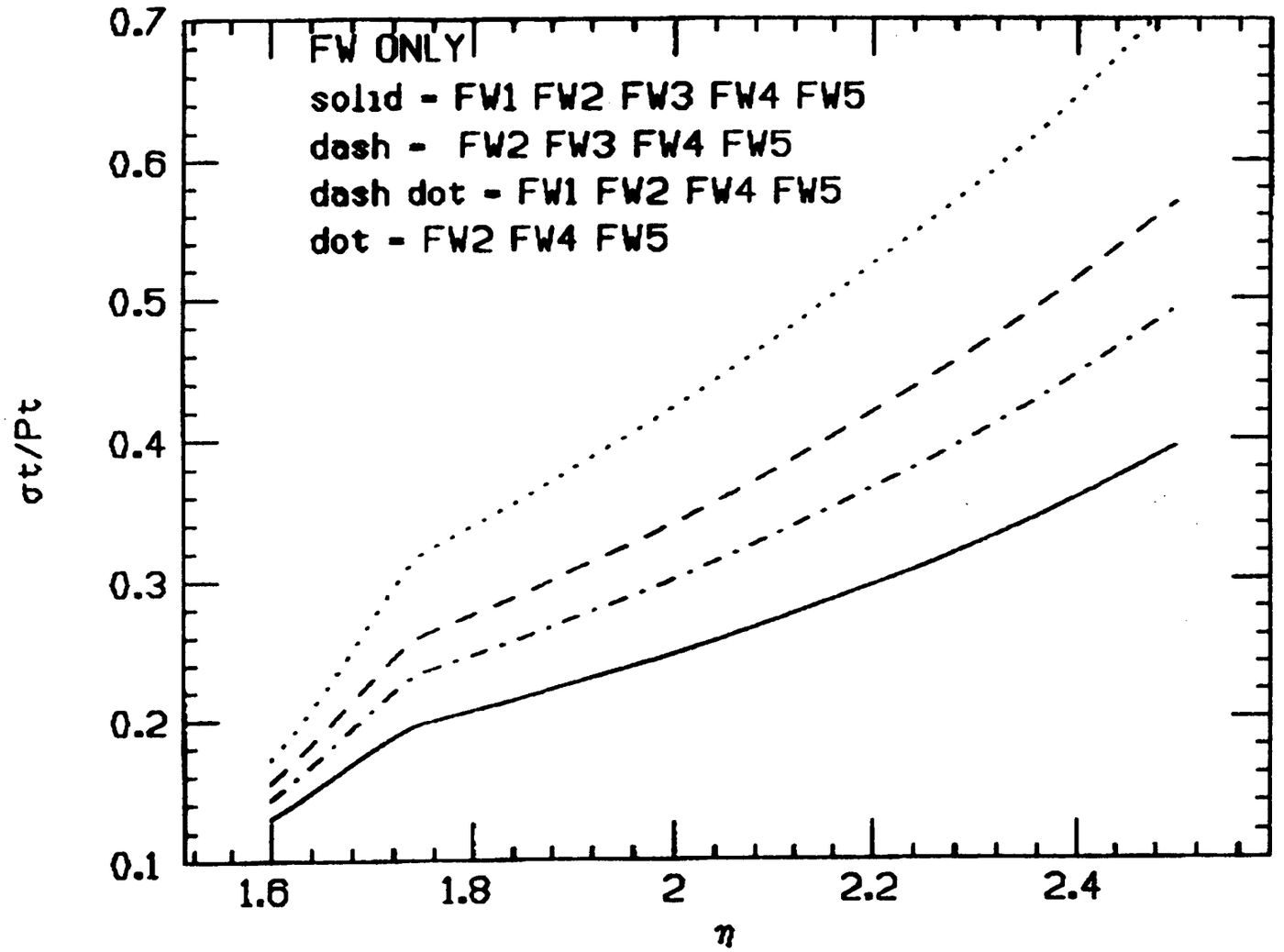
Fig 8a Pt = 1000

300μm/doublet
Δ45 ~ 4m



# FIG 8c Pt = 1000

300 μm / doublet
Δy5 ~ 4m



# LOI Layout of coordinates

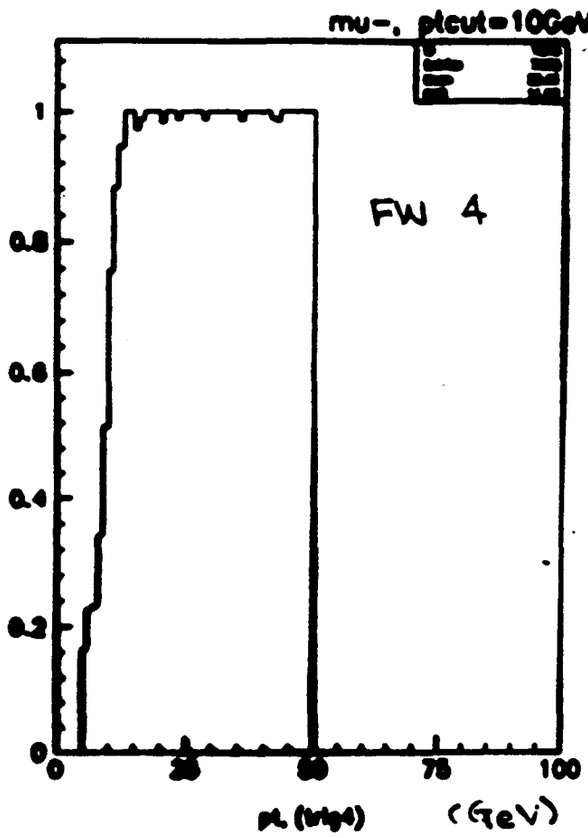
Coordinates measured (Trigger requirements imply some re-ordering — Kunori)

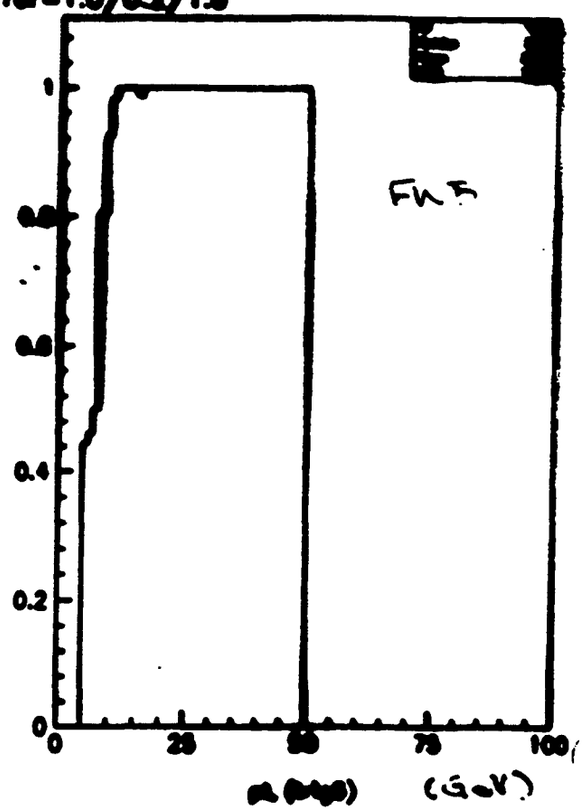
| | | | | |
|---|---|---|---|---|
| FW1 | 4θ | | | |
| FW2 | 2θ | | | |
| | $2S_1$ | + 7.5° | stereo | |
| | $2S_2$ | − 7.5° | stereo | |
| | 2θ | | | |
| FW3 | 4θ | | | |
| FW4 | 2θ ] 35 cm | | 6 cm cells | wire trigger yields |
| | 2θ | | 6.15 cm cells | $P_t = 10$ GeV cut |
| FW5 | 2θ ] 42 cm | | 6 cm cells | (multi muon trigger requirement) |
| | $2S_1$ | | | |
| | $2S_2$ | | 6.15 cm cells | |
| | 2θ | | | |

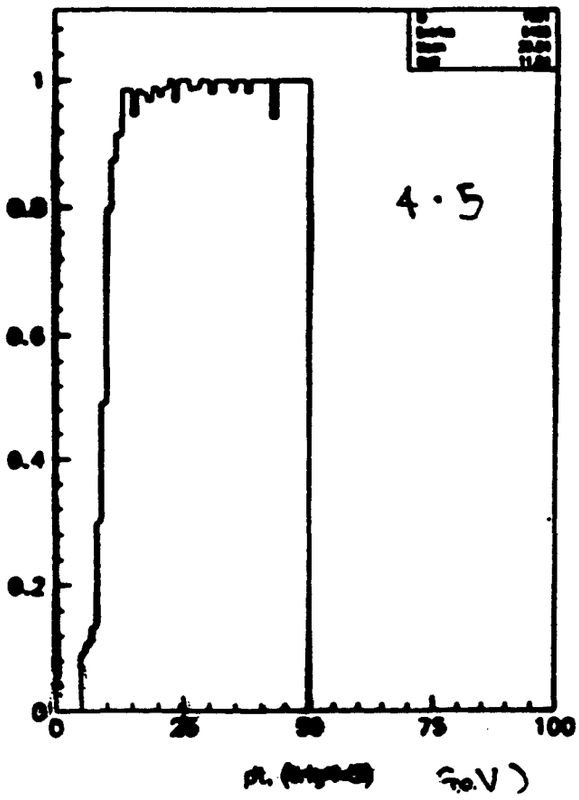
FW3 provides a handle on large angle scatters in toroids

# Trigger Efficiencies

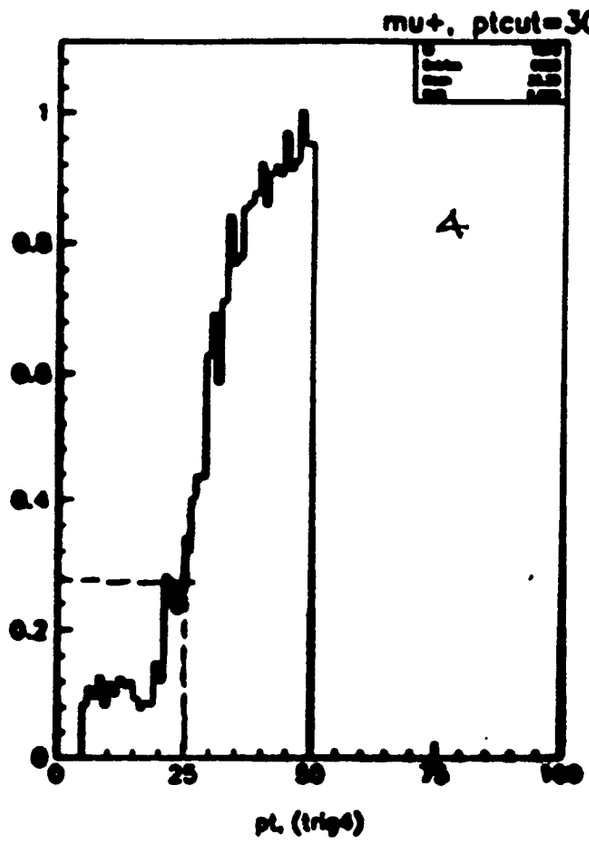
$P_T^{cut} = 11$ GeV

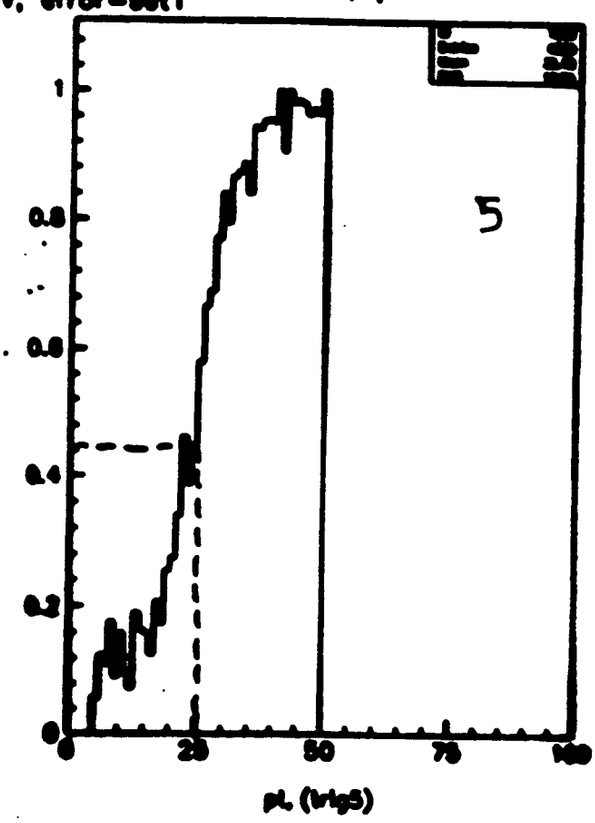


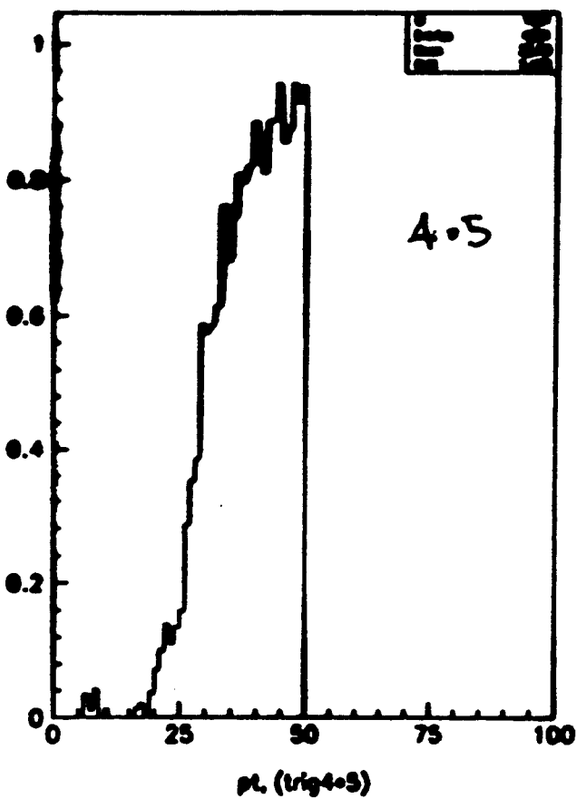



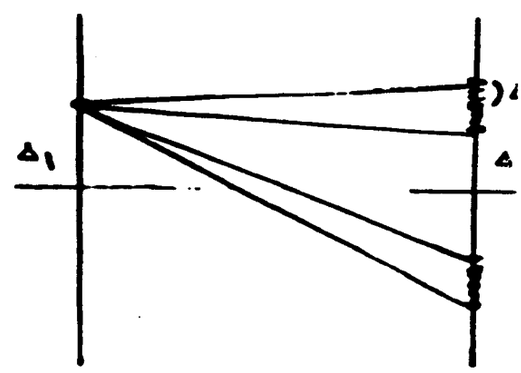



$P_T^{cut} = 30\,GeV$



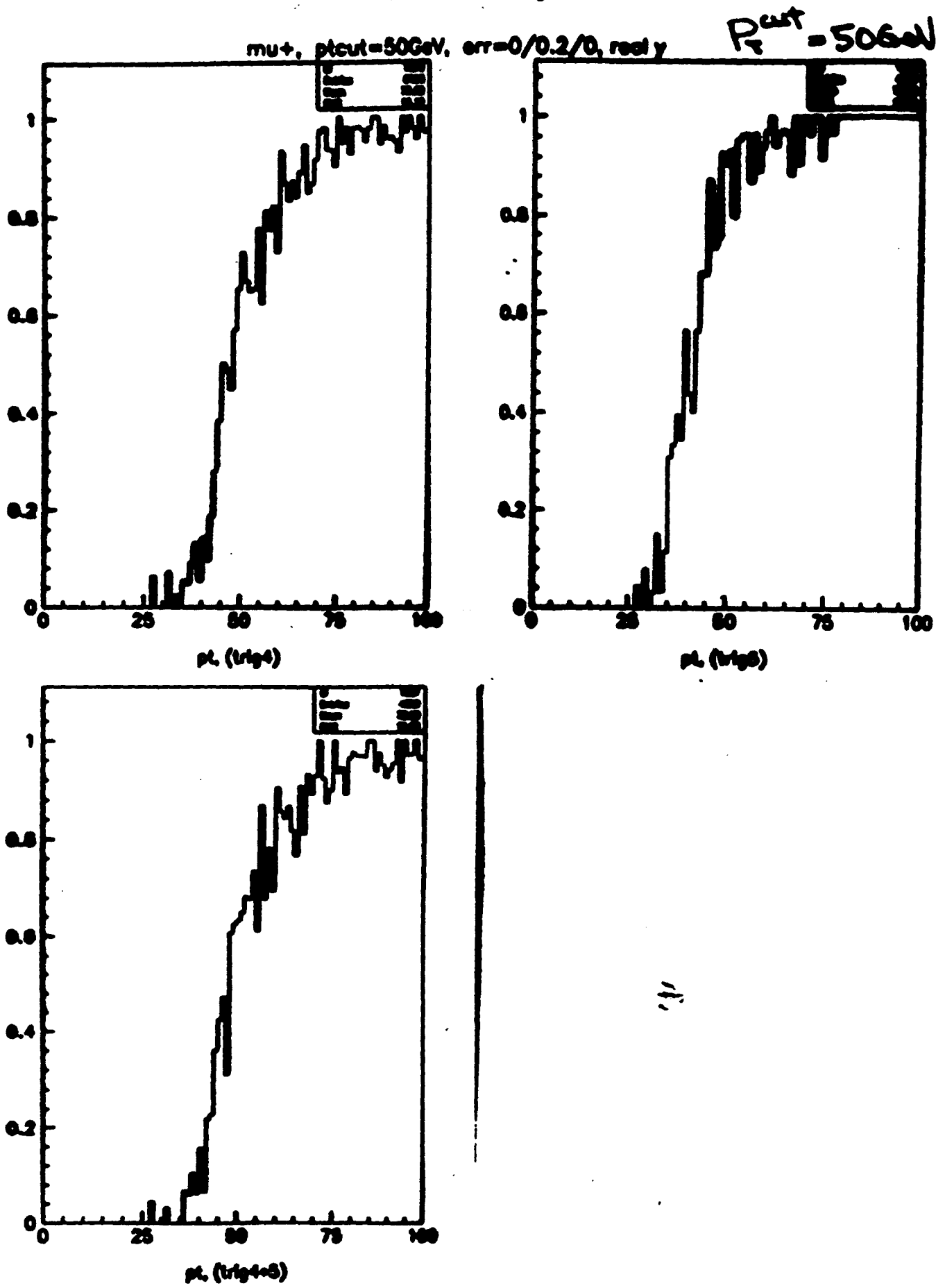



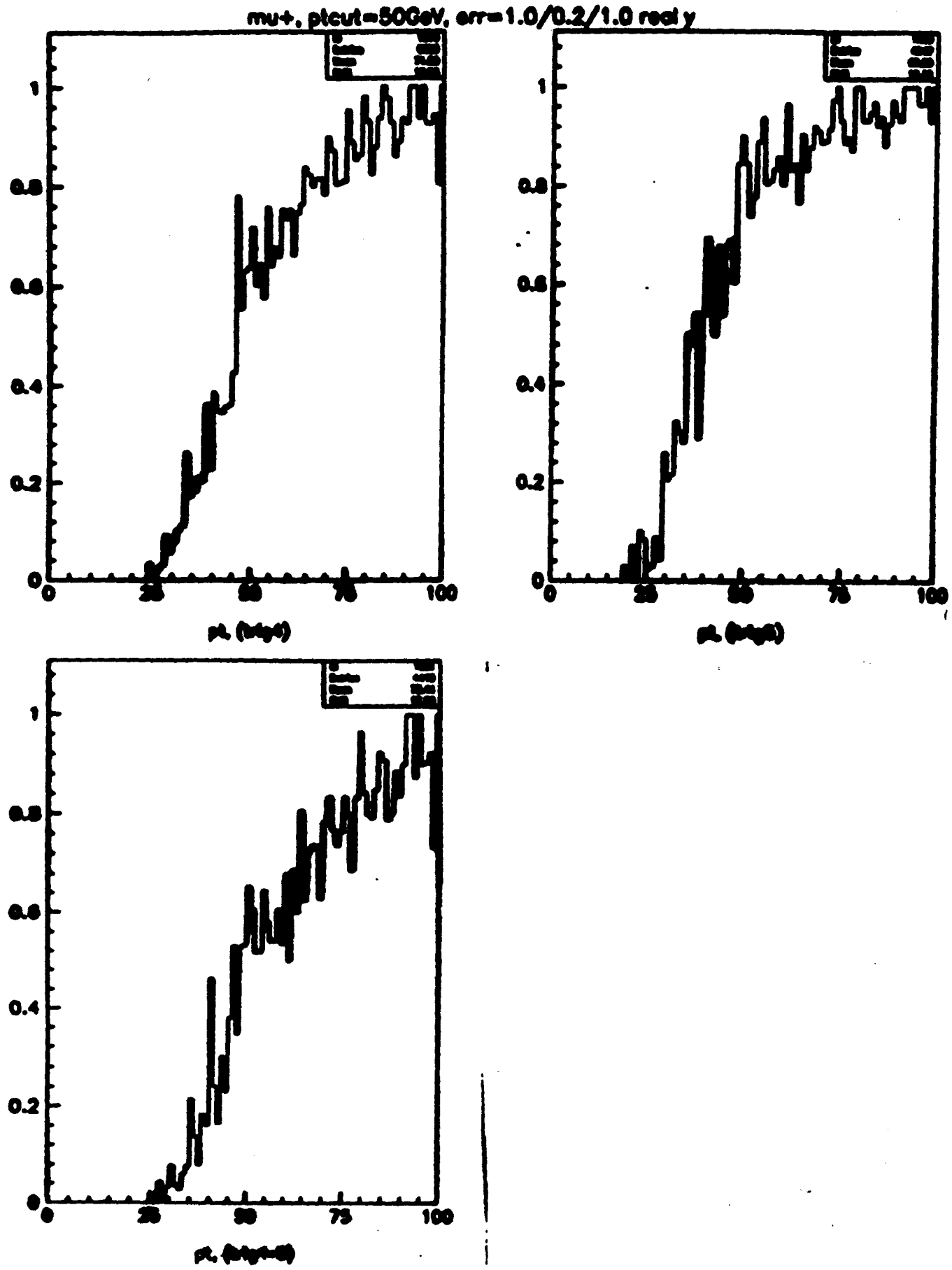

$\big|\,|\Delta_1| - |\Delta_2|\,\big| < \Delta t$

Δ (alignment) = 0

Δ (drift) = 200μm



Δ (alignment) = 1mm
Δ (drift) = 200 μm



# Summary

1. Need ~ 6 cm wide chamber for $P_T^{Trig} \gtrsim 10 GeV$.

2. • Need Two types of chambers

   6 cm wide , 6.15 cm wide

   for projection geometry.

   • distance between $\theta_1$ and $\theta_2$ are related to the ratio of widths.

3. Trigger acceptances for FW4 and FW5 are different with same trigger road width.

4. Tail at lower $P_T$ due to particles on another side of wire.

   Solution : ① FW4 · FW5

   ② use check sum.

5. Misalignment : ~ 1 mm is ok upto $P_T^{cut} \sim 50 GeV$

Under Review

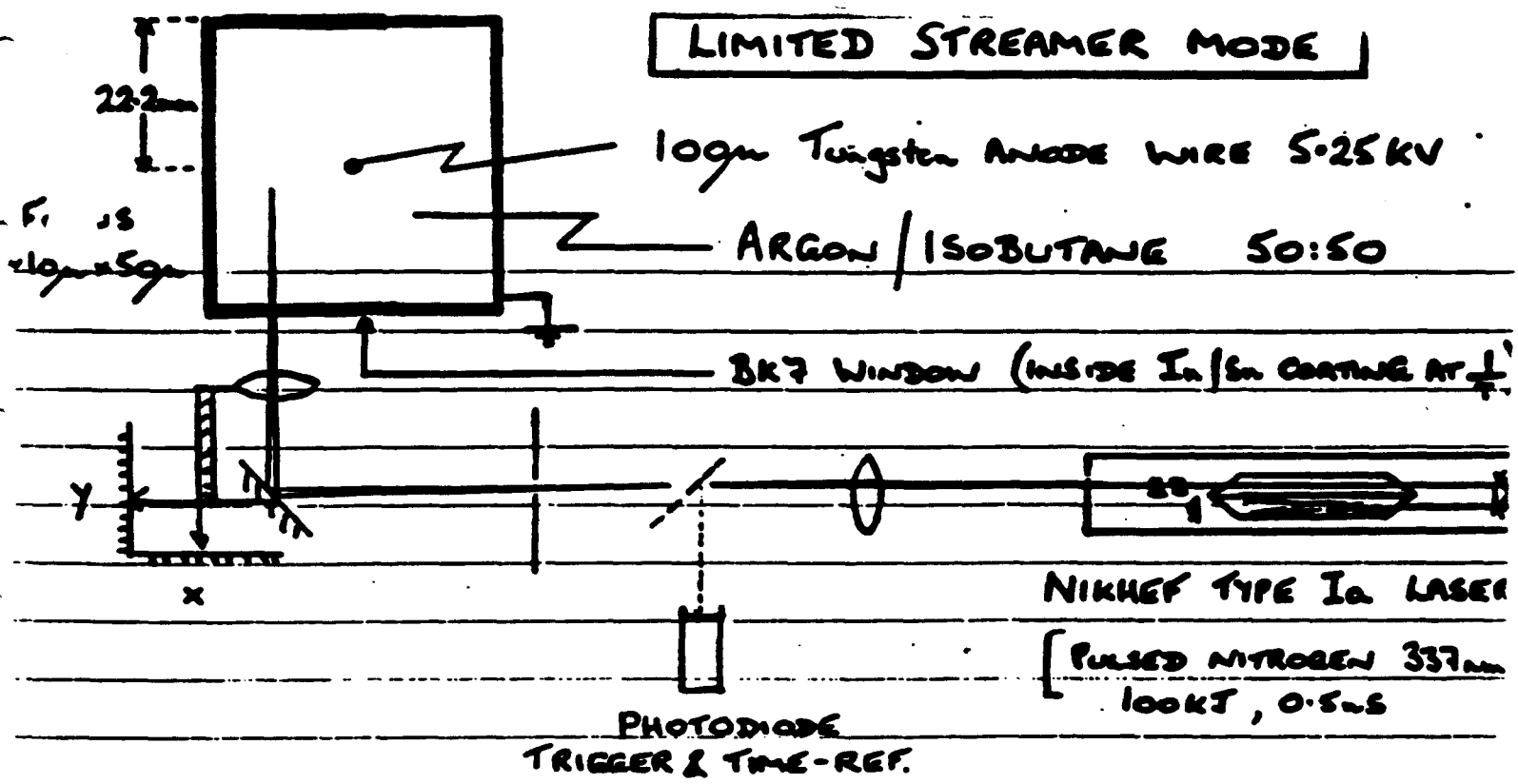
- Disposition of FS1 and FS2 (response on Wednesday ?)
- Review of Cherenkov counter trigger took place last Tuesday. ~~My impression is that~~ Review Committee will recommend that Cherenkov should be kept and scintillator removed in forward region.
  - ⇒ Cherenkov design should be modified to incorporate 4 tubes.
- FW3 becomes a future upgrade.
  - ⇒ Lose capability for reconstructing true momentum if large angle scatter occurs in FT1 or FT2
  - ⇒ Lose capability for reconstructing true momentum if e.m. shower occurs in FT2

Drift Cell requirements

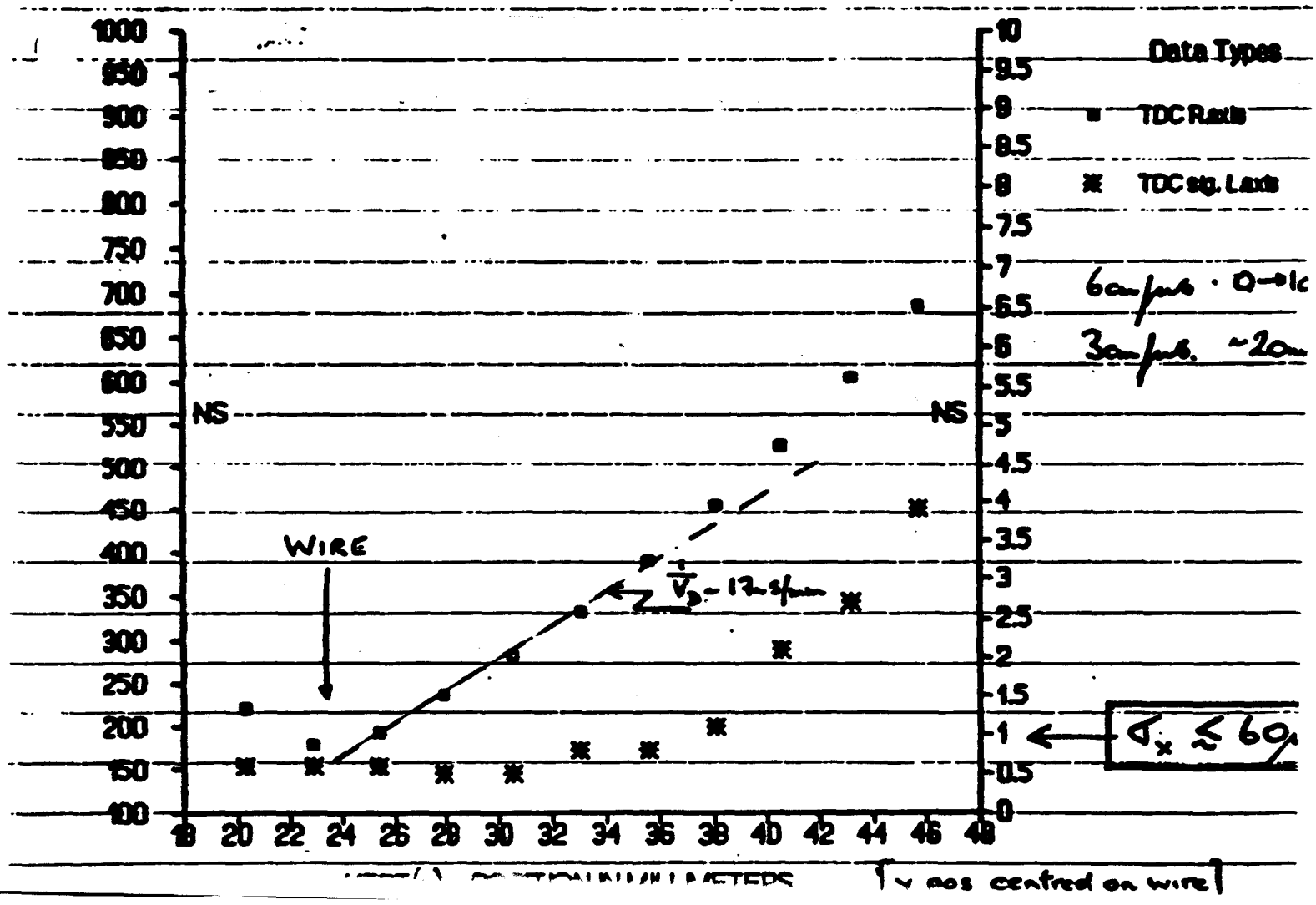
- Good resolution ( $\lesssim$ 150 $\mu$m / cell)
- Good 2 track resolution
  ( 5mm probably O.K. ) (see Kubanovsky's talk)
- Non - flammable gas
  ( 90 : 10 argon : ethane probably O.K.)
- 6 cm drift cells ( actually 2 sizes 6 and 6.15 for PGT)
  $P_t$ = 10 GeV multi muon trigger requirement
  ( see Kunori's talk)
- 50 $\mu$m wire placement

Cost minimization

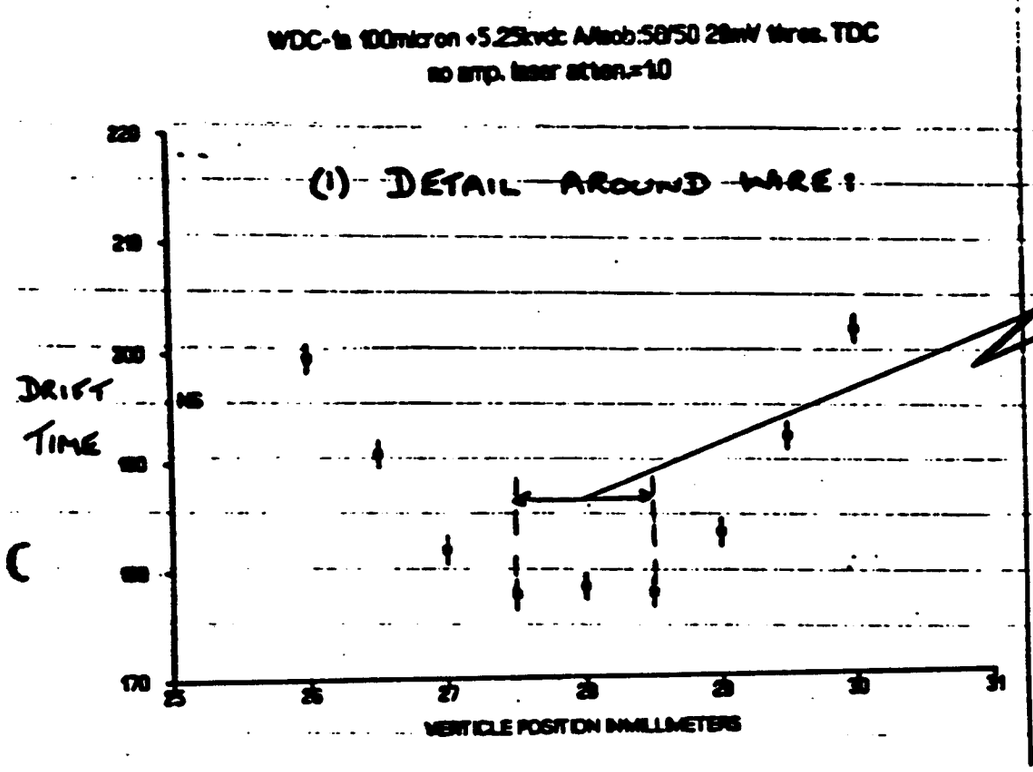
- Reduce channel count to minimize cost
  but not sacrifice capability
  6 cm cells reduce LOI channel count by 1/3




WDC-1a 100micron A/Isob:50/50 +5.25kvdc 20mV threshold TDC & TDC sigma
no amplifier, laser attenuation= 1.0 O.D., 62mm lens



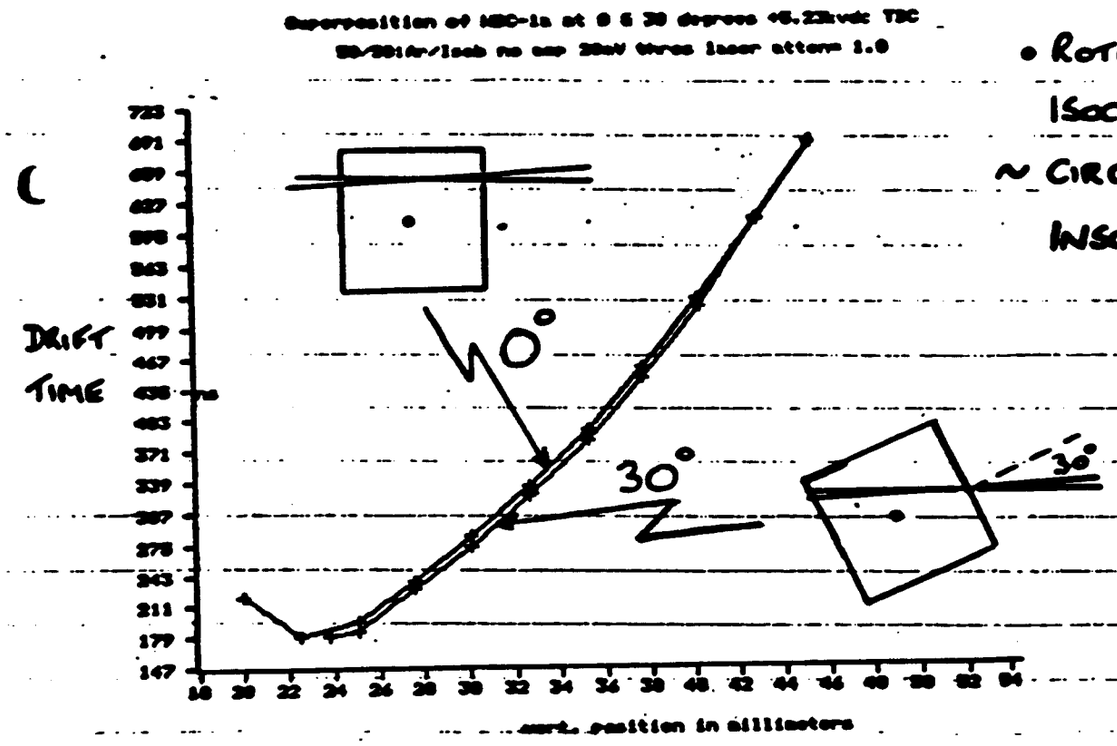
# FURTHER TESTS :—



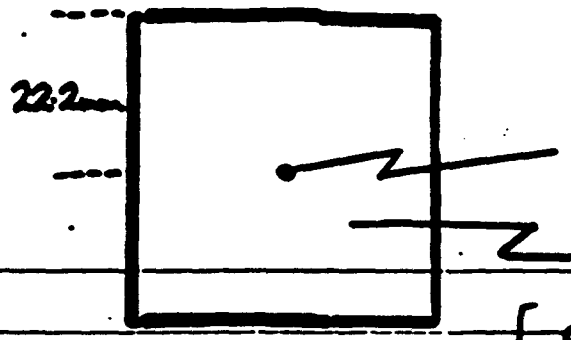

ZONE OF ~ CONSTA
DRIFT TIME

[• EXTENDED FOCUS
• IMPERFECT ALIGNME
+
• EXTENT OF STREAM
(previously reported by
DELPHI O.D. group

(II) ROTATION




• ROTATION TESTS SHO
ISOCHRONES ARE
~ CIRCULAR UP TO
INSCRIBED CIRCLE.
[CURIOUS ??]



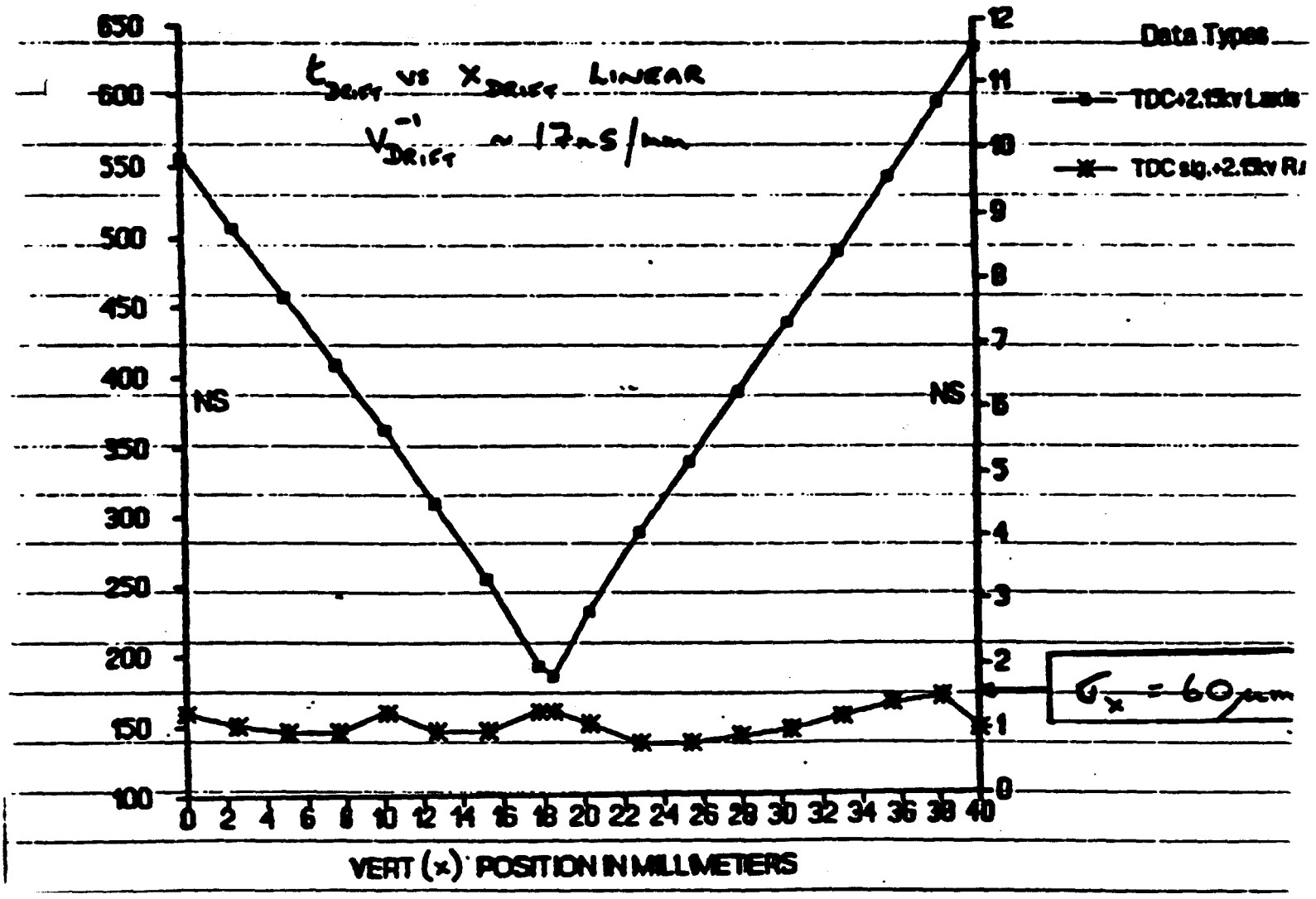

PROPORTIONAL MODE

50μ Tungsten ANODE WIRE 2.15KV

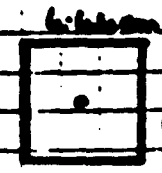
ARGON / ETHANE 90:10

[ a prop mode, long drift path chamber gas with a long track-record in muon systems of JADE, OPAL.

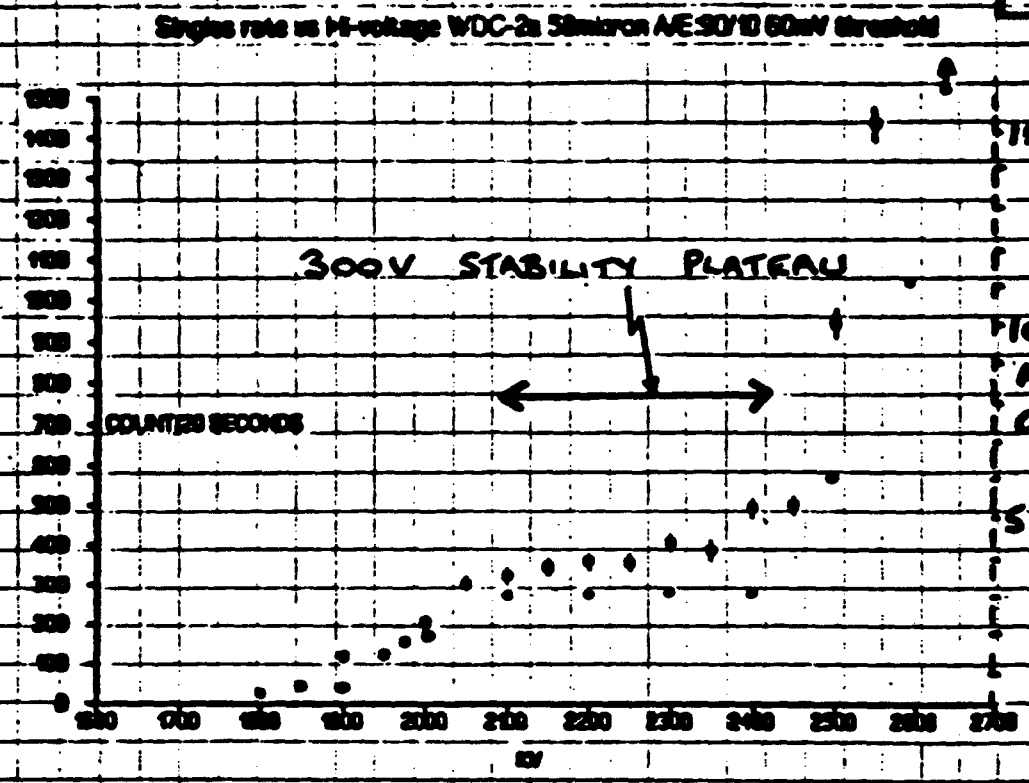
WDC-2a 50micron +2.15kvdc A/Ethane:90/10 20mV thres. TDC & TDC sigma
laser atten.=0.03 50mm lens LeCroy amp. TRA402 gain= 100

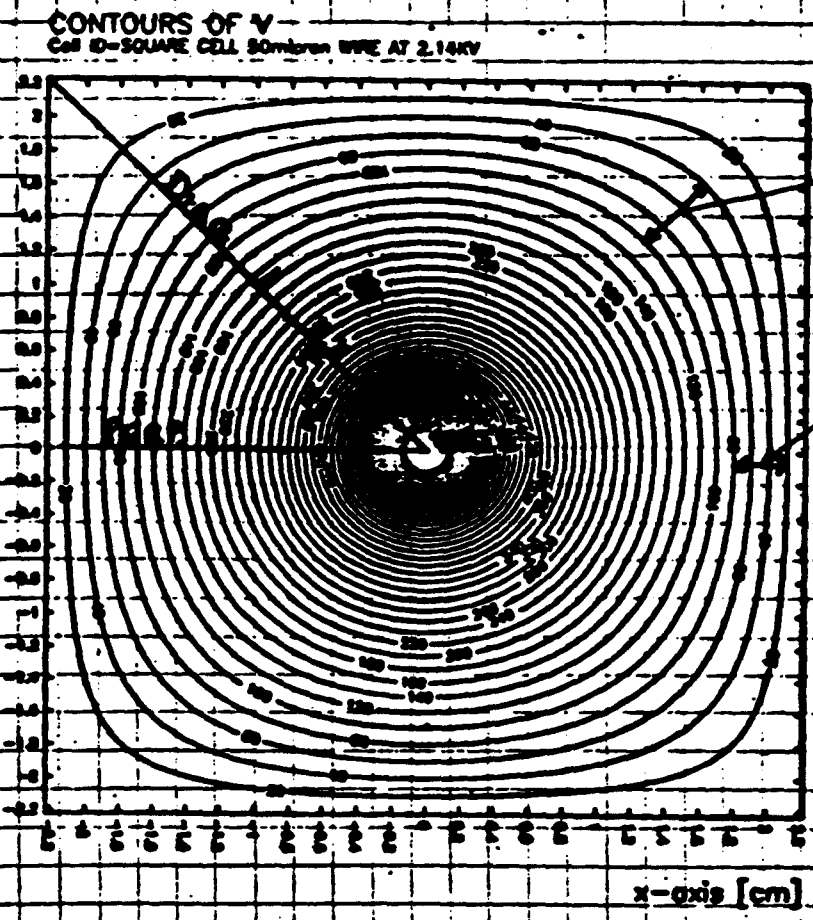


# SOME FURTHER REMARKS ON THIS CELL:




5cm
90Ar 10C4H10
PROP MODE
$V_A$ = 2.15 kV




E = 120 V/cm

E = 200 V/cm

- BETTER THAN A+
ISOCHRONES CIRCULA
~EVERYWHERE

- SATURATED $V_D$ AT
LOWER E FIELD
THAN EXPECTED.

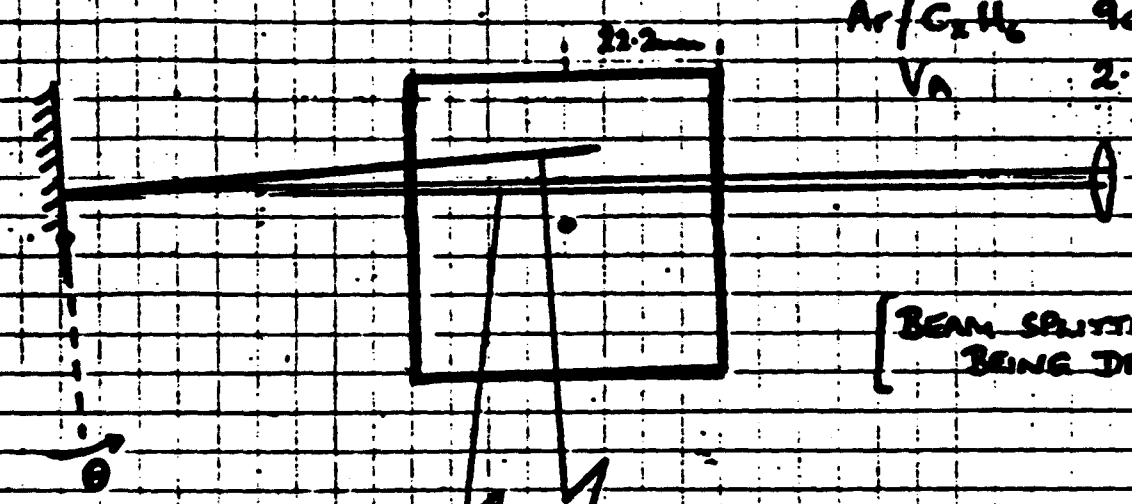
BUT SEE REMARKS

# DOUBLE TRACK RESOLUTION

QUALITATIVE PRELIMINARY MEASUREMENT :-

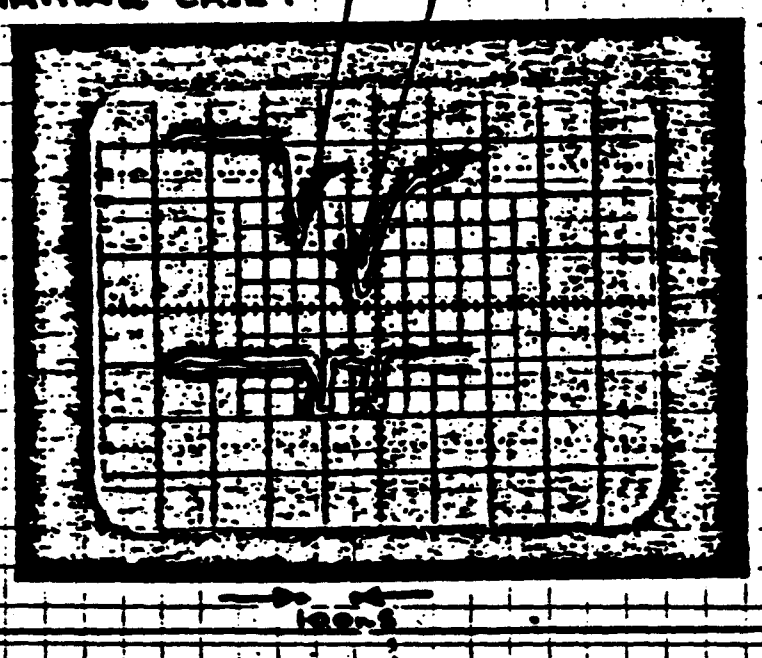
$Ar/C_2H_6$ 90 : 10

$V_A$ 2·15 kV.




[BEAM SPLITTING PRISM BEING DESIGNED]

LIMITING CASE :

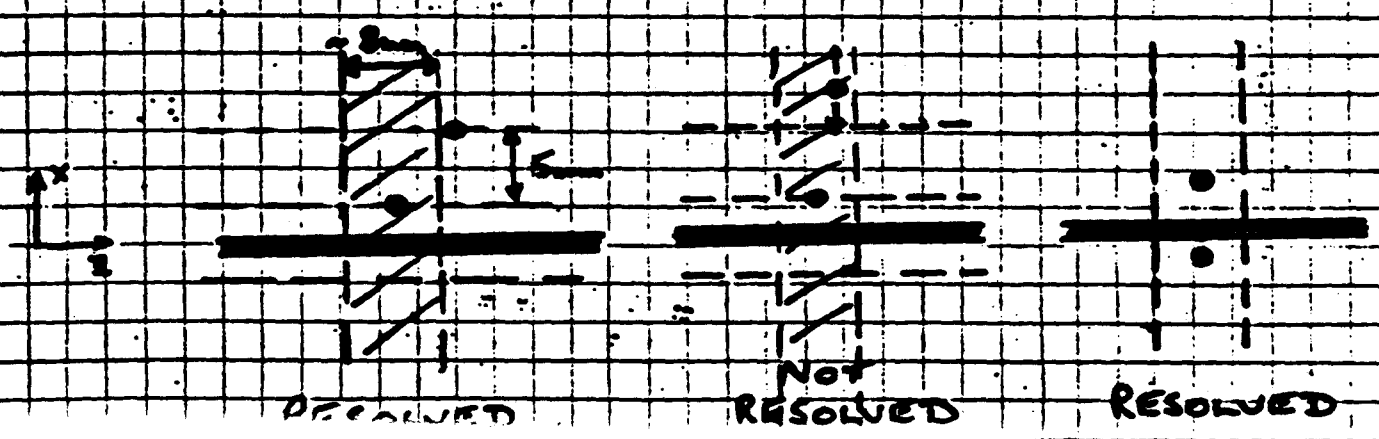


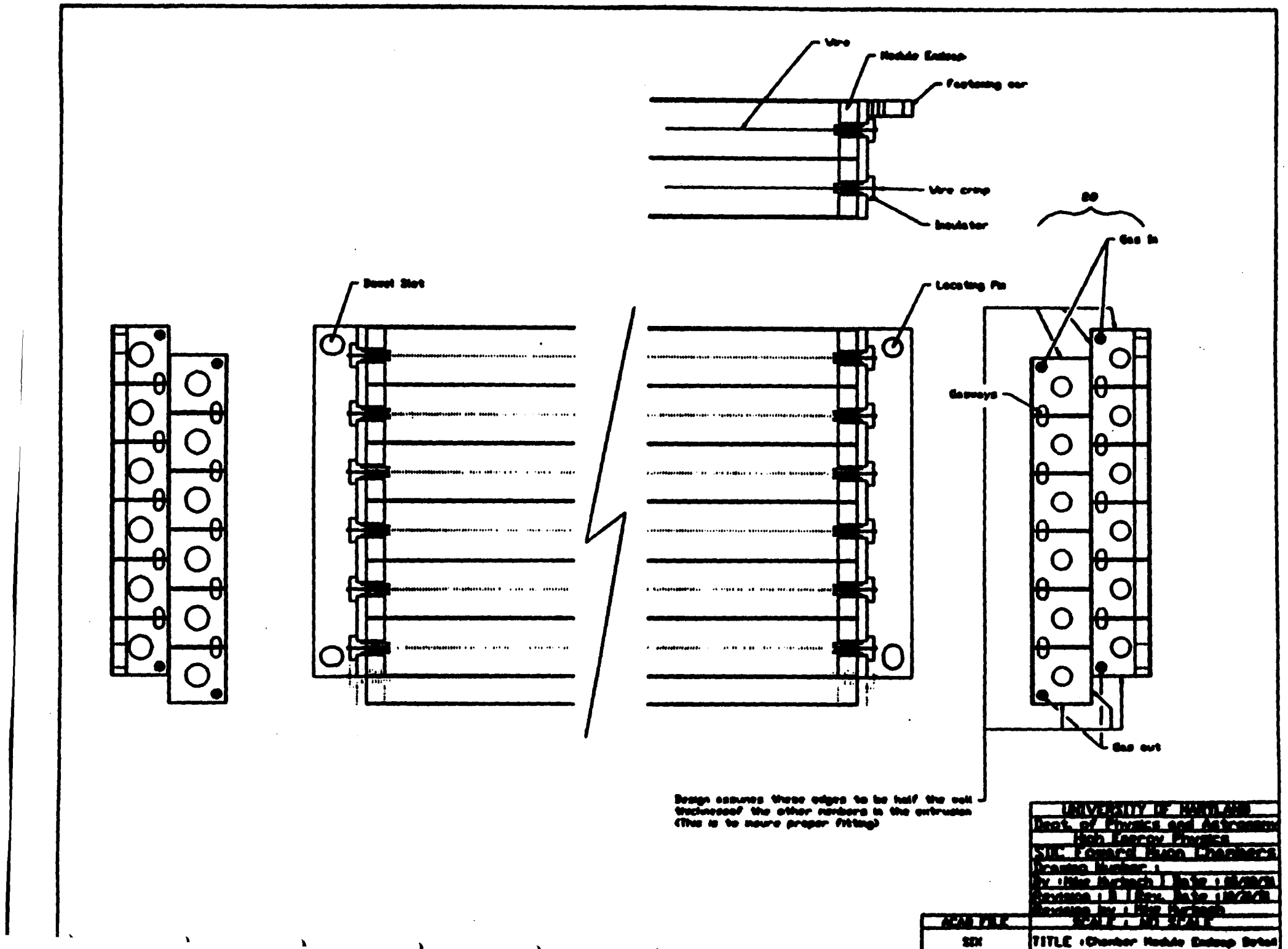

ANODE RESPONSE

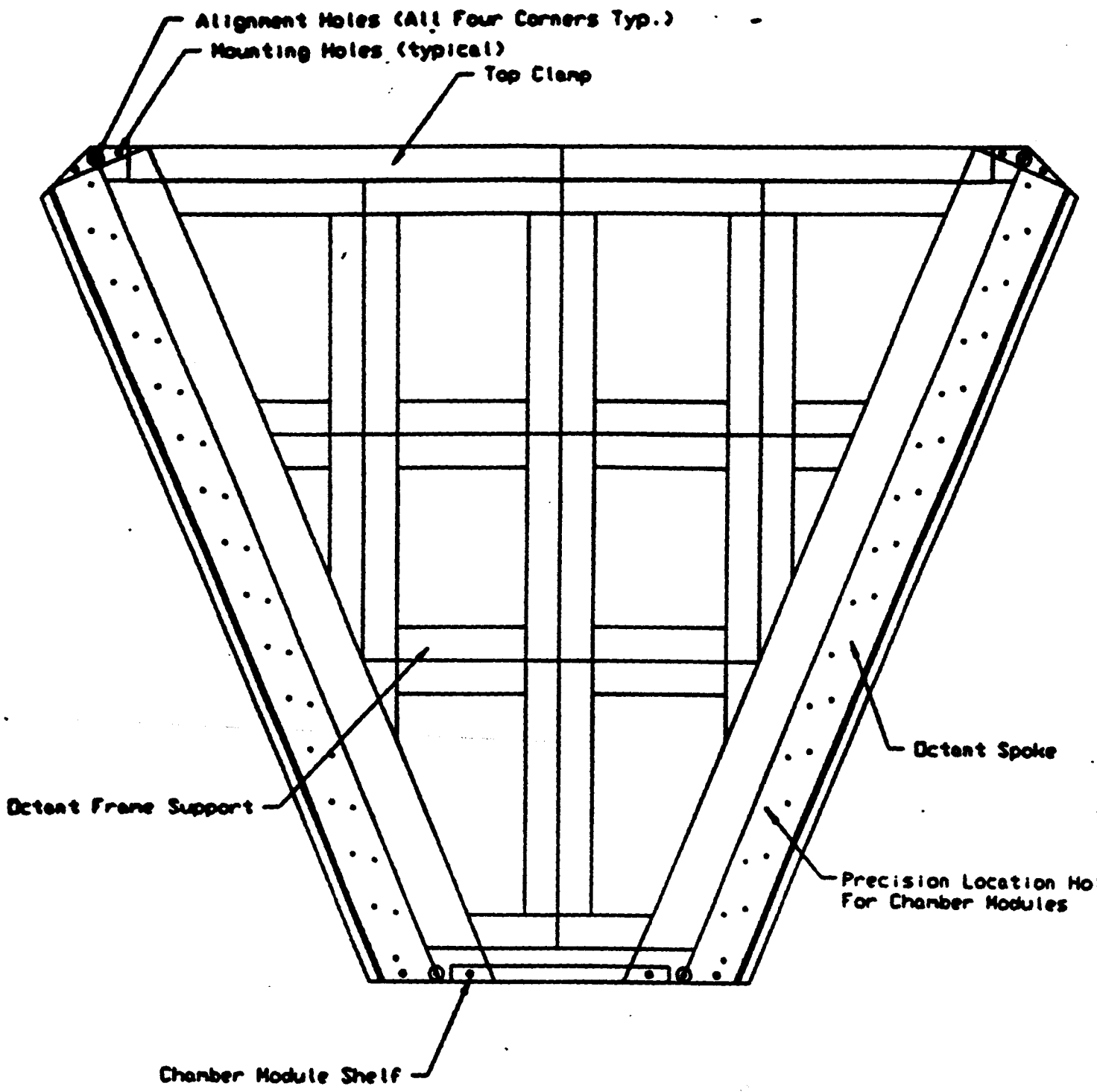
DISCRIMINATOR (63μ

BEAM SEPARATION ≥ 5mm (x & z) : TRACKS ARE RESOLVED.

ION CHARGE CLOUD ⟶ PLANAR DEAD ZONE ONE SIDE OF W

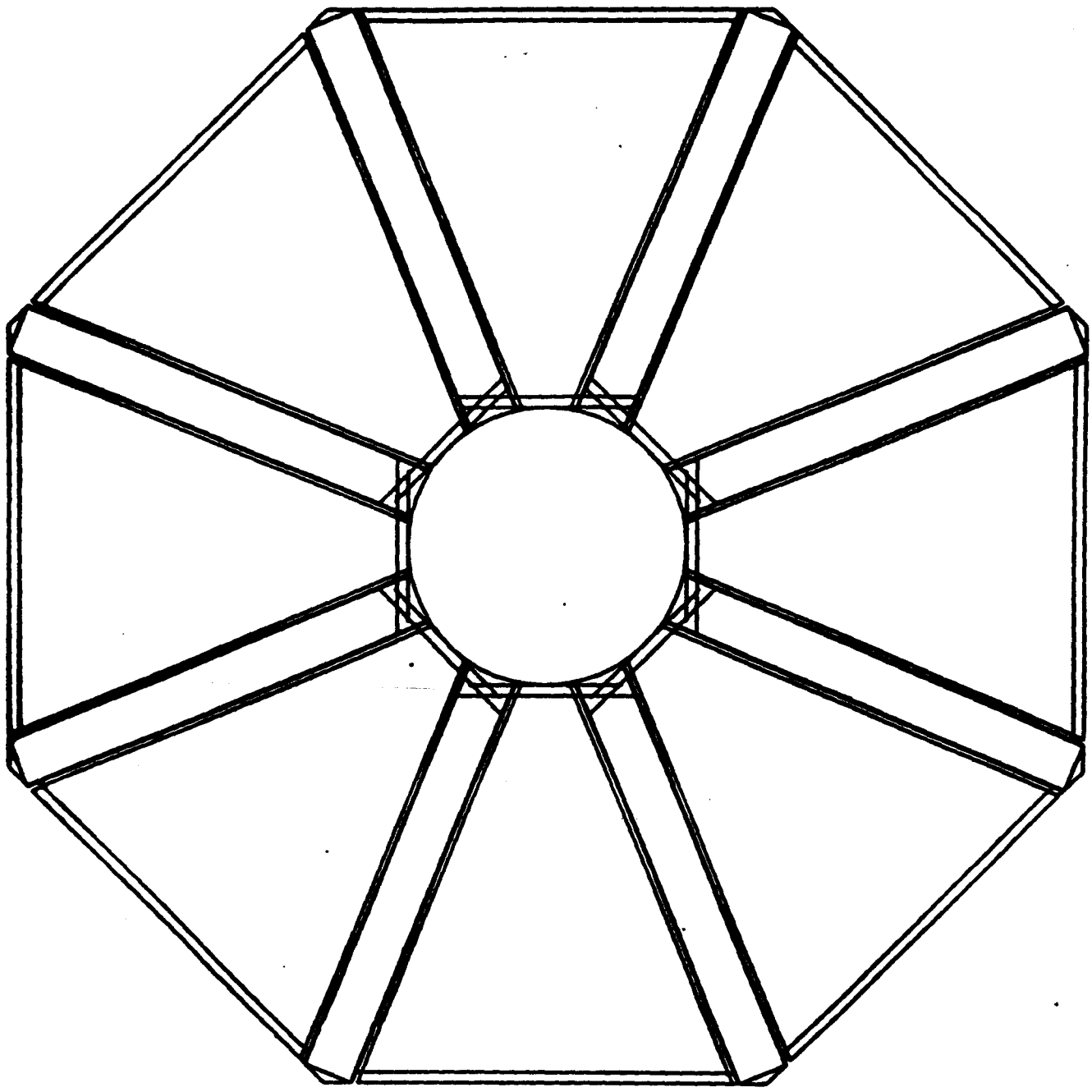



Wire
Module Endcap
Fastening ear
Wire crimp
Insulator
Dowel Slot
Locating Pin
Gas In
Gasways
Gas out
Design assumes these edges to be half the wall thickness of the other members in the extrusion (This is to insure proper fitting)
UNIVERSITY OF MARYLAND
Dept. of Physics and Astronomy
High Energy Physics
STC Lepton Beam Chambers
(Cosmic Muons)
SIZE
TITLE :Chamber Module Endcap Detail



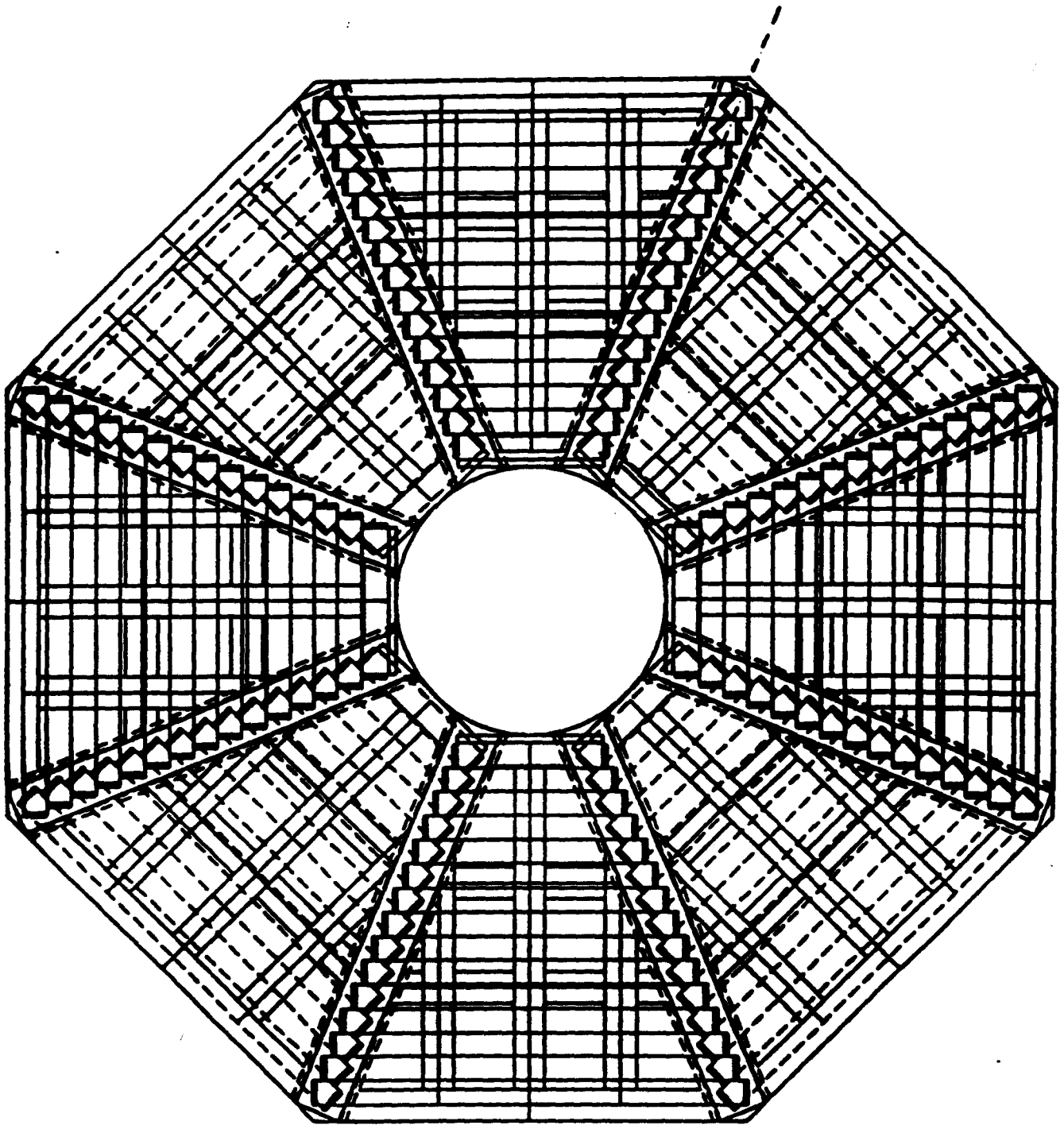

OCTANT MODULE TRAPEZOIDAL FRAME (TYPICAL)

| | |
|---|---|
| | UNIVERSITY OF MARYLAN |
| | Dept. of Physics and Astr |
| | High Energy Physics |
| | SDC Forward Muon Chan |
| | Drawing Number : |
| | By : Mike Marbach \| Date : |
| | Revision : \| Rev. Date : |
| | Revision by : Mike Marbach |
| ACAD FILE | SCALE : NO SCALE |
| SDXSET2 | TITLE : Octant Frame |



μFW1

| | |
|---|---|
| | UNIVERSITY OF MARYLAND |
| | Dept. of Physics and Astro |
| | High Energy Physics |
| | SDC Toward Muon Chamb |
| | Drawing Number : |
| | By : Mike Murbach \| Date : 11/2 |
| | Revision : A \| Rev. Date : 8/2 |
| | Revision by : Mike Murbach |
| ACAD FILE | SC |
| SIXSTRUC | TITLE : Super Module Support Str |



$\mu$FW1 — 4$\theta$

OCTANTS ARE STAGGERED AND ELECTRONICS ARE LOCATED
ON FACES OPPOSITE WIRE MODULES

| | |
|---|---|
| | UNIVERSITY OF MARYLAN |
| | Dept. of Physics and Astro |
| | High Energy Physics |
| | SDC Forward Muon Chamb |
| | Drawing Number : |
| | By : Mike Murbach \| Date : |
| | Revision : A \| Rev. Date : |
| | Revision by : Mike Murbach |
| ACAD FILE | SCALE : NO SCALE |
| SIXSET2 | TITLE : Supermodule |

Protvino design
of tube

# The design
# of drift tube mounting

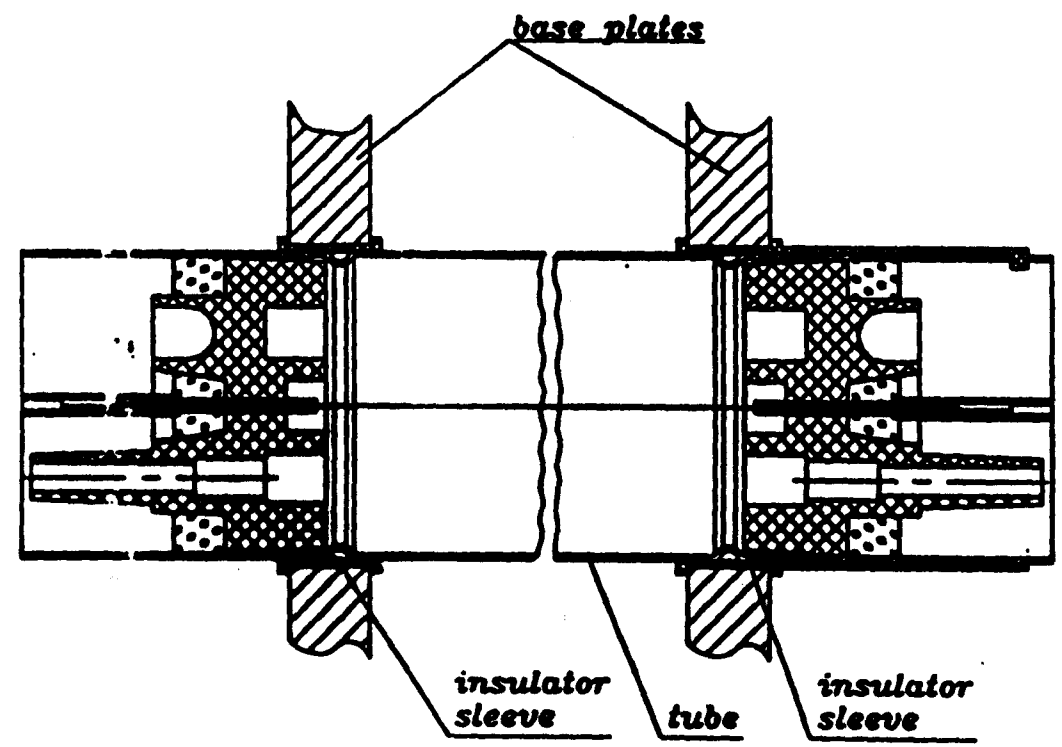



**Figure 7**

| |
|---|
| MMS designing group |
| Proposal from 19.12.91 |
| Originator: L.Baliev |
| Scale: No scale |
| № 1016 |

## The design of quadrant module

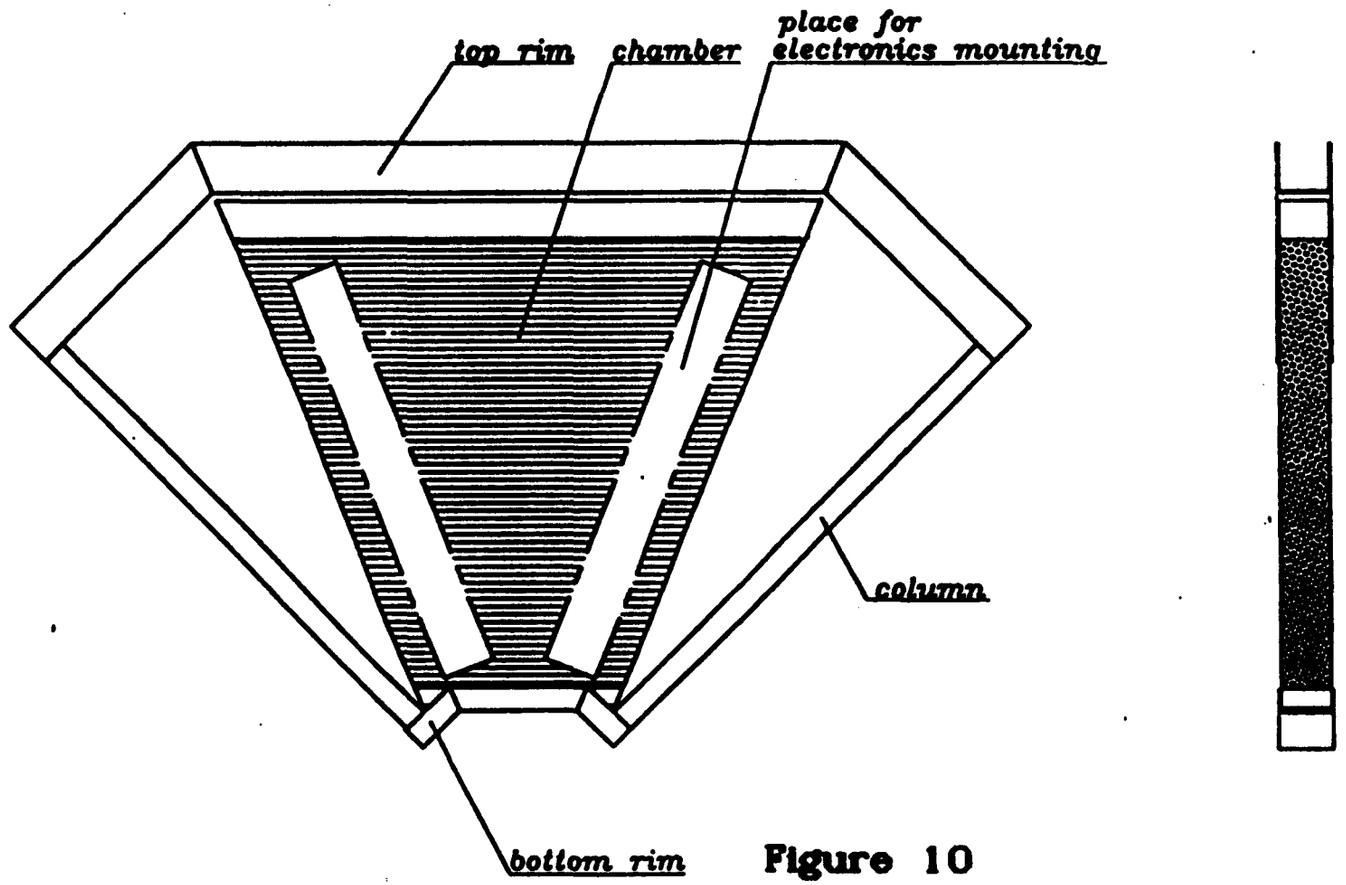
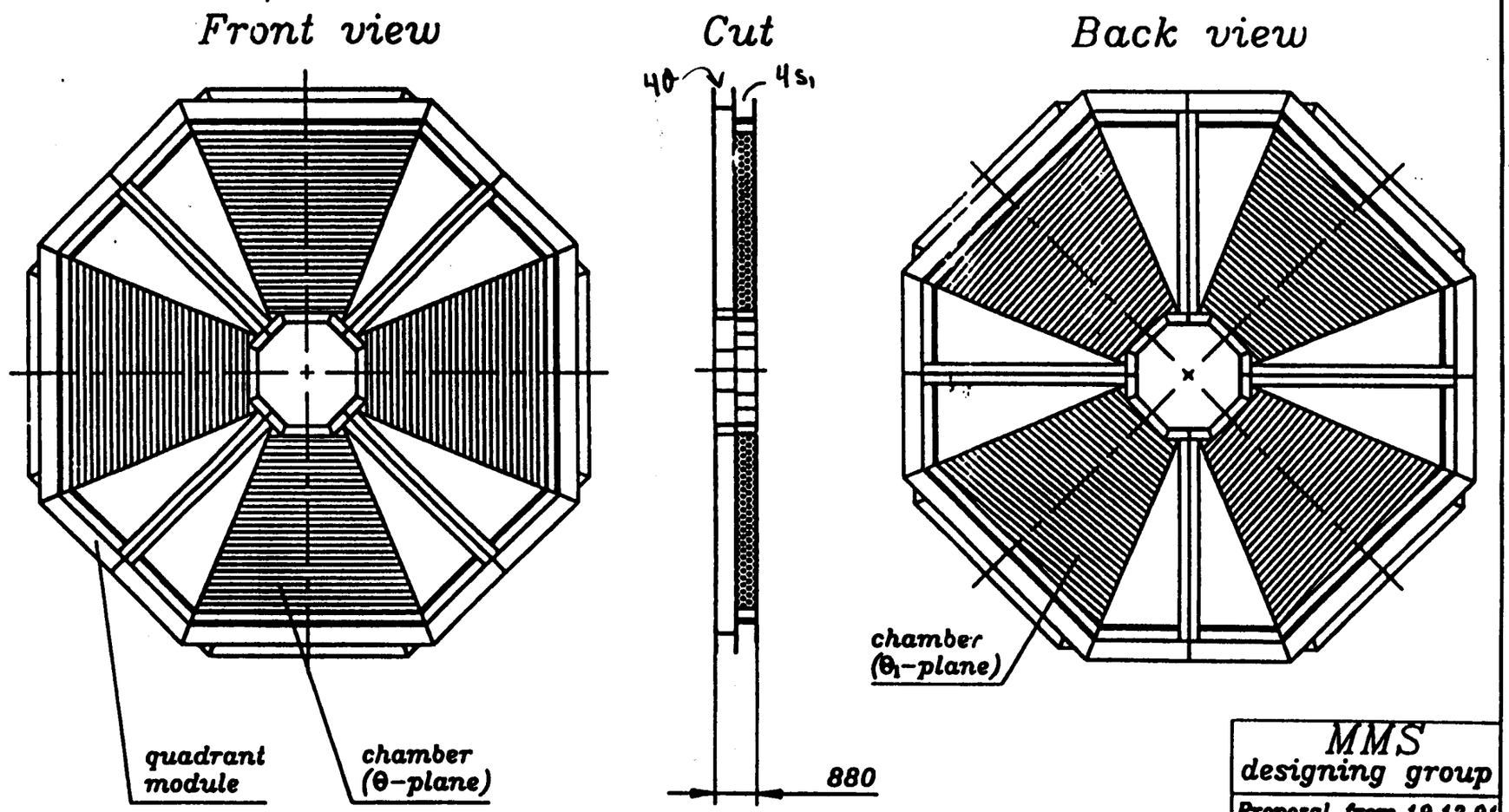



**Figure 10**

| |
|---|
| MMS designing group |
| Proposal from 23.12.91 |
| Originator: L.Baliev |
| Scale: No scale |
| № 1018 |

# FMS Station




| | |
|---|---|
| MMS designing group | |
| Proposal from 19.12.91 | |
| Originator: L.Baliev | |
| Scale: No scale | |
| NOTE: All dimensions are in millimetrs | № 1016 |

## Backgrounds

Neutrons

Difficult to calculate below 10 MeV

GEANT + GEISHA calculation for $E_n > 10$ MeV

(see presentations on Tuesday afternoon + Kulik's paper)

⇒ Neutrons produce 1-3 charged particles / neutron

Shielding proposals + flared (projective) beam pipe

Tuesday afternoon

## E-m debris

Knock on electrons (δ-rays)

Calculations (Kusarovsky)

Measurements from FNAL (Thursday)

High energy bremsstrahlung and pair production.

more catastrophic

more numerous so more important

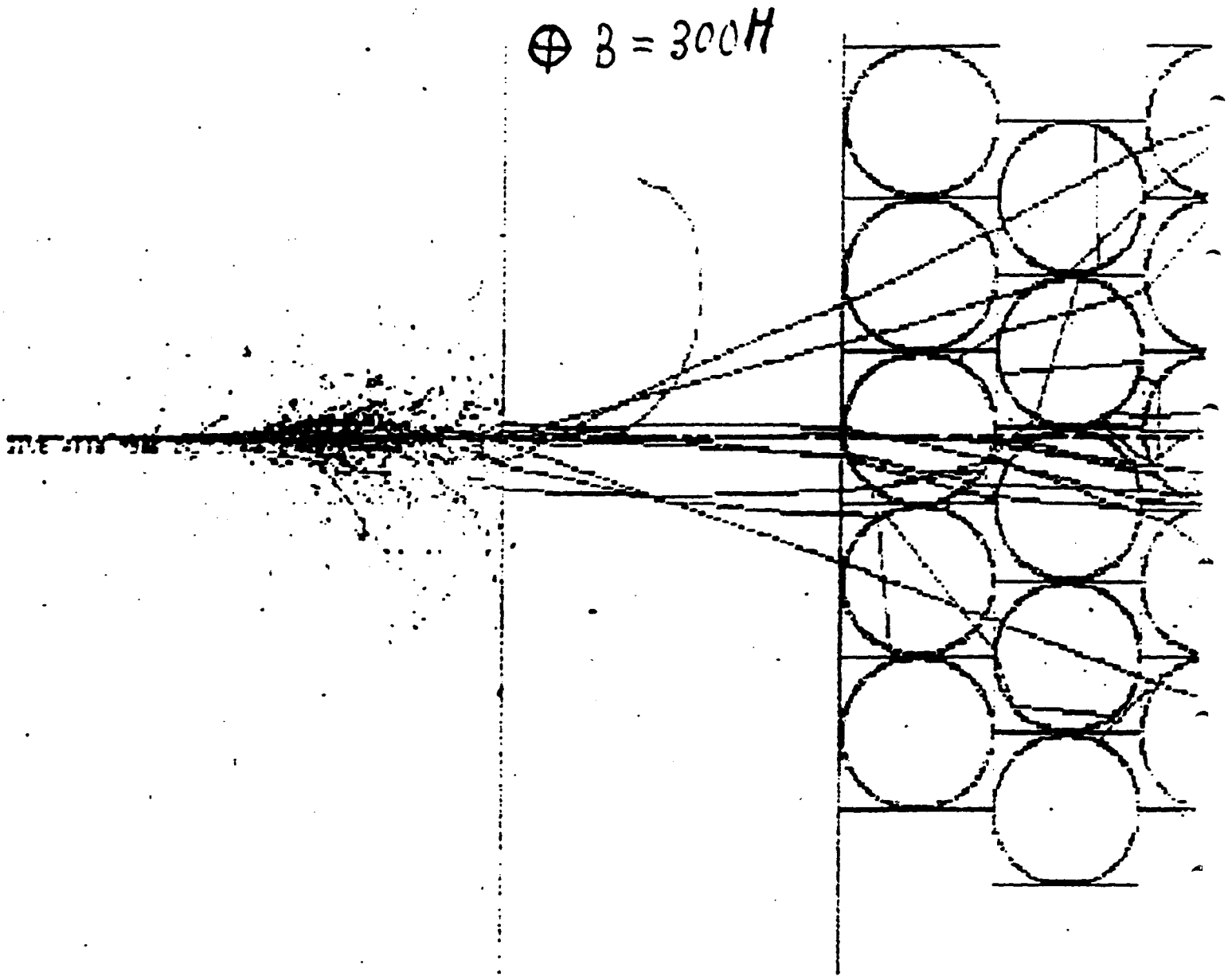
(Antipov and Kubarovsky today)

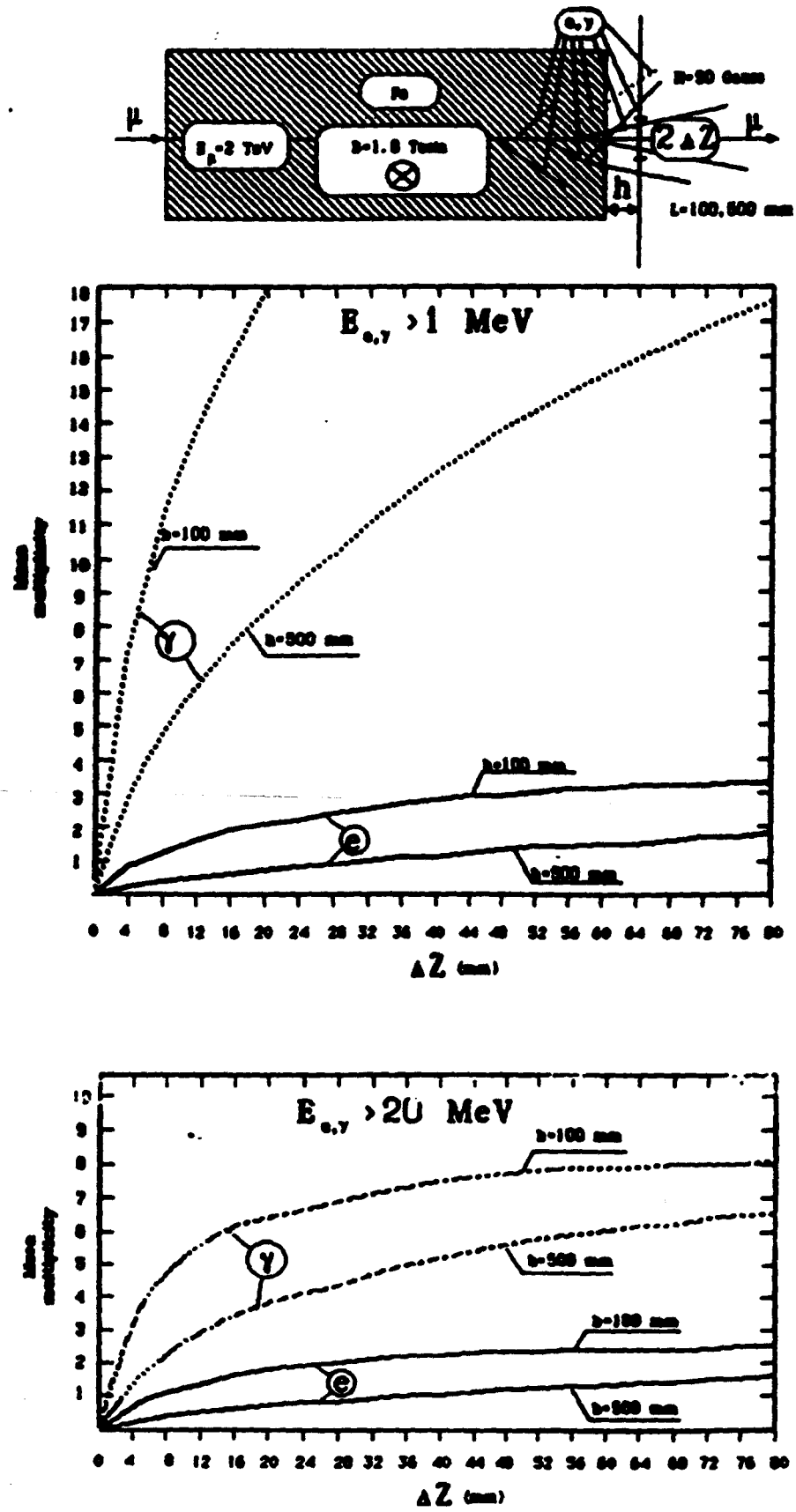
Both neutron and e-m. backgrounds imply as light a structure as possible

All aluminum (no stainless steel) if possible

uncorrelated background (δ-rays) independent of cell size if good 2 track efficiency

Random background (neutrons) increases with 1-½ time


B = 300H




inefficiency

Anikeev, Kirsanov

**Figure 1**

```
1D   35 TYPE  1 MODA 1000
      nchar, L=50, E > 1 MeV

                 0            999            1
1000*I----,----I----,----I----,----I----,----I----,----I
    I                                                  I
    I                                                  I
    I                                                  I
    I                                                  I
 875*                                                  *
    II                                                 I
    II                                                 I
    II                                                 I
    I.                                                 I
 750*.                                                 *
    I.                                                 I
    I.                                                 I
    I.                                                 I
    I.                                                 I
 625*.                                                 *
    I.                                                 I
    I.                                                 I
    I.                                                 I
    I.                                                 I
 500*.                                                 *
    I.                                                 I
    I.                                                 I
    I.                                                 I
    I.                                                 I
 375*.                                                 *
    I.                                                 I
    I.                                                 I
    I.                                                 I
    I.                                                 I
 250*.                                                 *
    I.                                                 I
    I.                                                 I
    I.                                                 I
    I.                                                 I
 125*.                                                 *
    I.                                                 I
    I.I                                                I
    I.II                                               I
    I...II                                             I
   0*I____.____I____.____I____.____I____.____I____.____I
    0        10        20        30        40        50
    I____.____I____.____I____.____I____.____I____.____I
    8
    26411
    53672655 433 3 1 1  1  1  1 11
    ..................................................
    00000000000000000000000000000000000000000000000000
```

**Figure 2**

ID 29 TYPE 1 MODA 1000
ngamma, L=50, E > 1 MeV

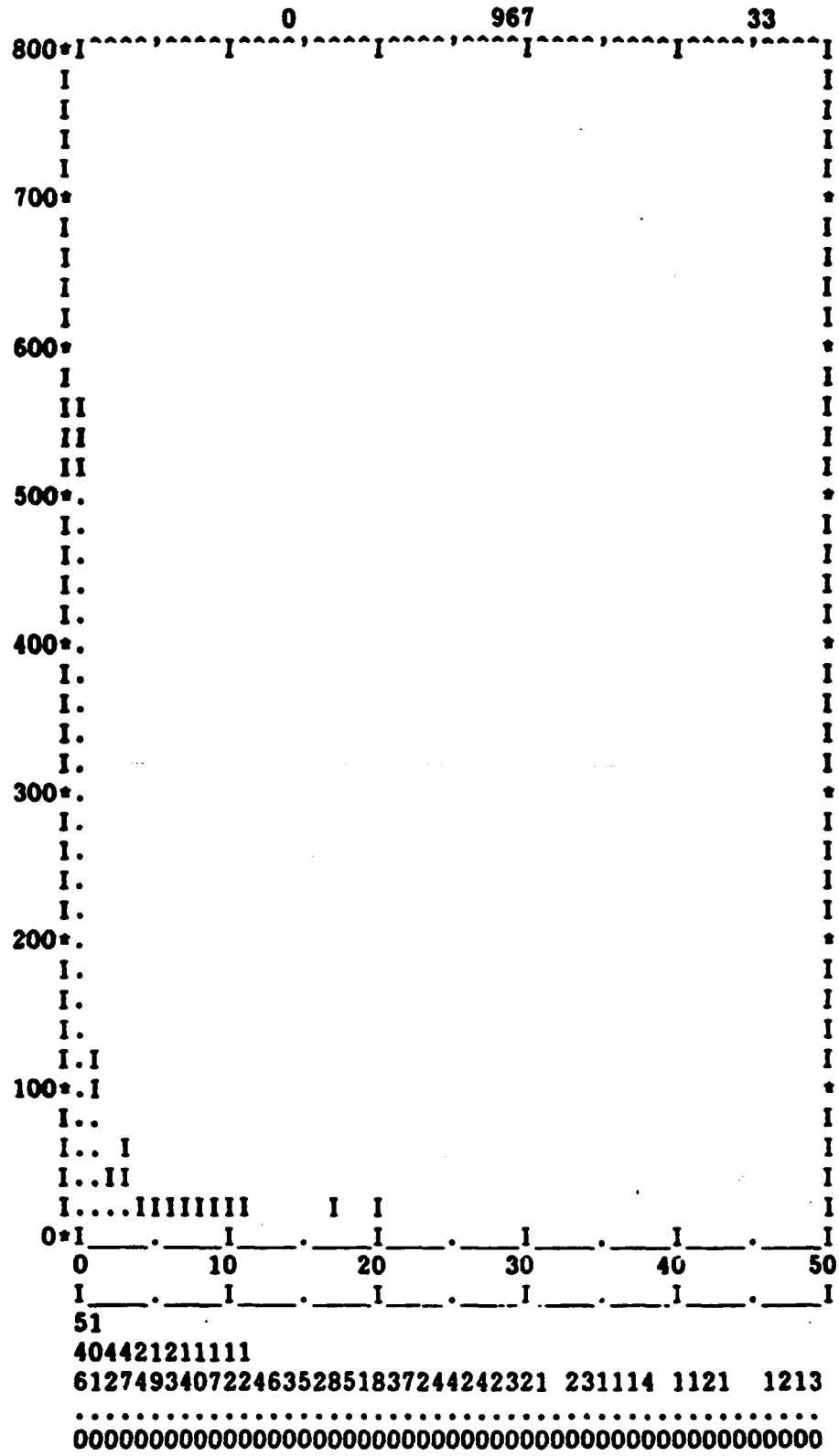
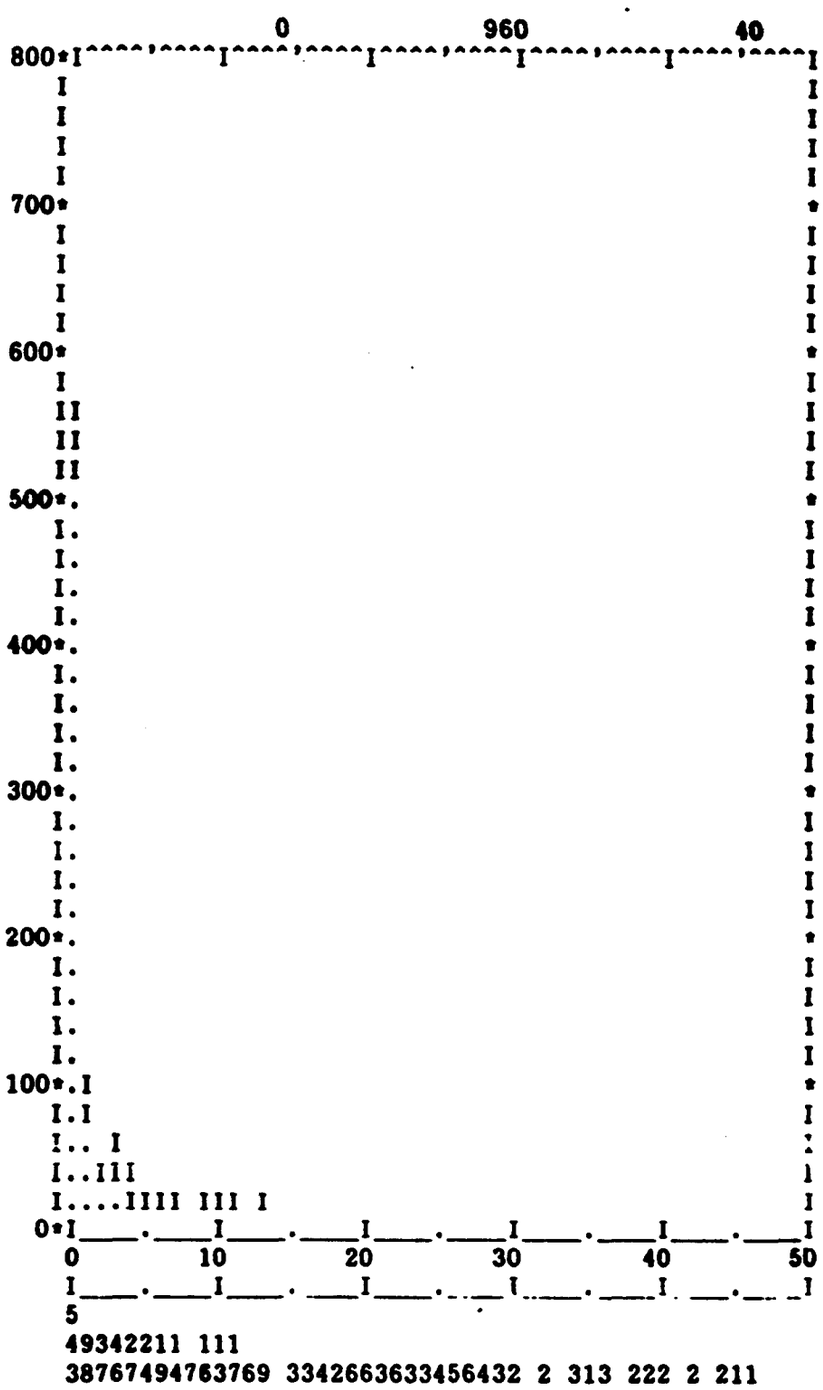



Figure 3

nuhba

SDS test

ID 23 TYPE 1 MODA 1000
ntot, L=50, E > 1 MeV



Kulik

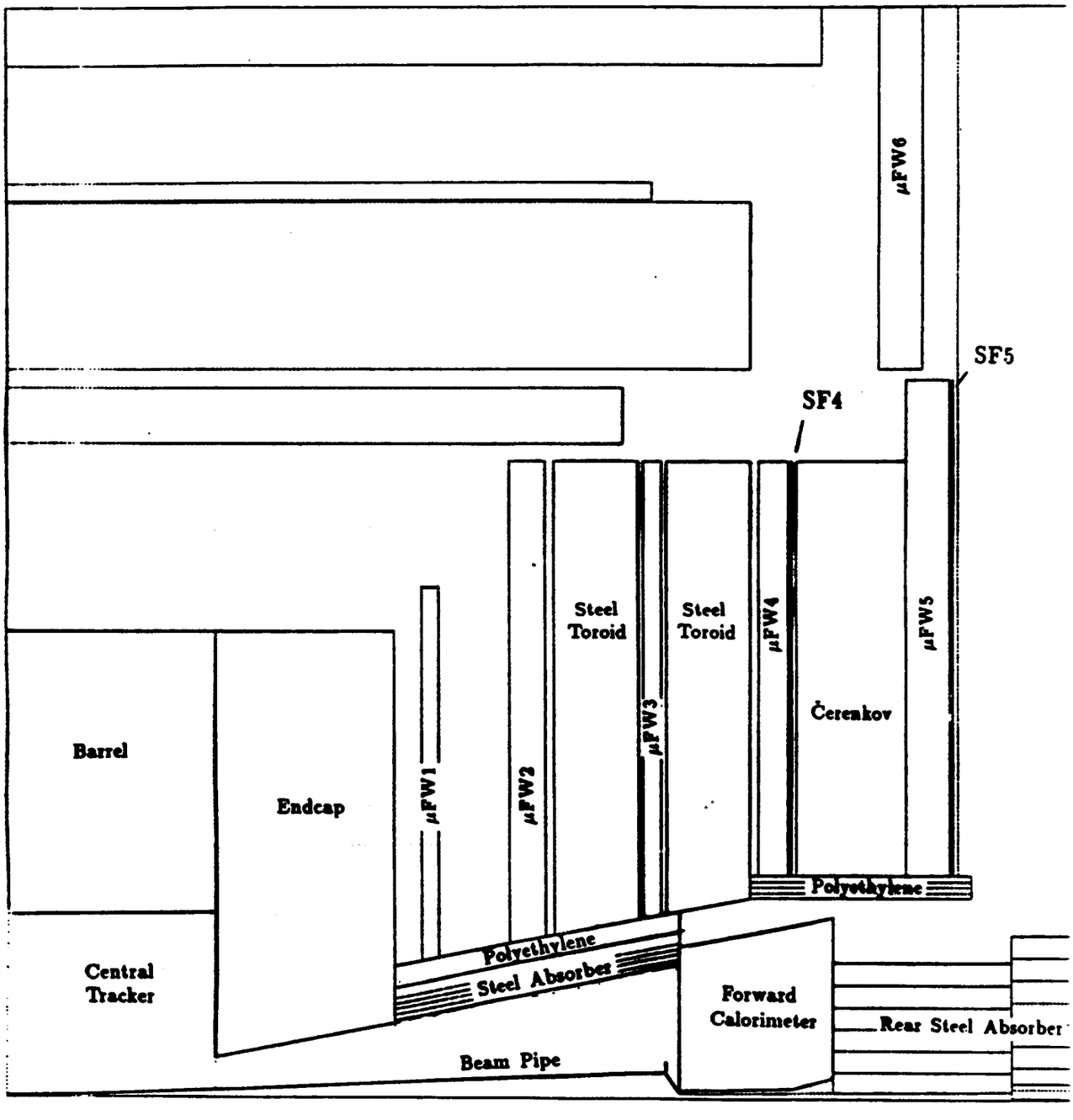



Figure 0.1: $\frac{1}{4}$ of the set-up

Kulik

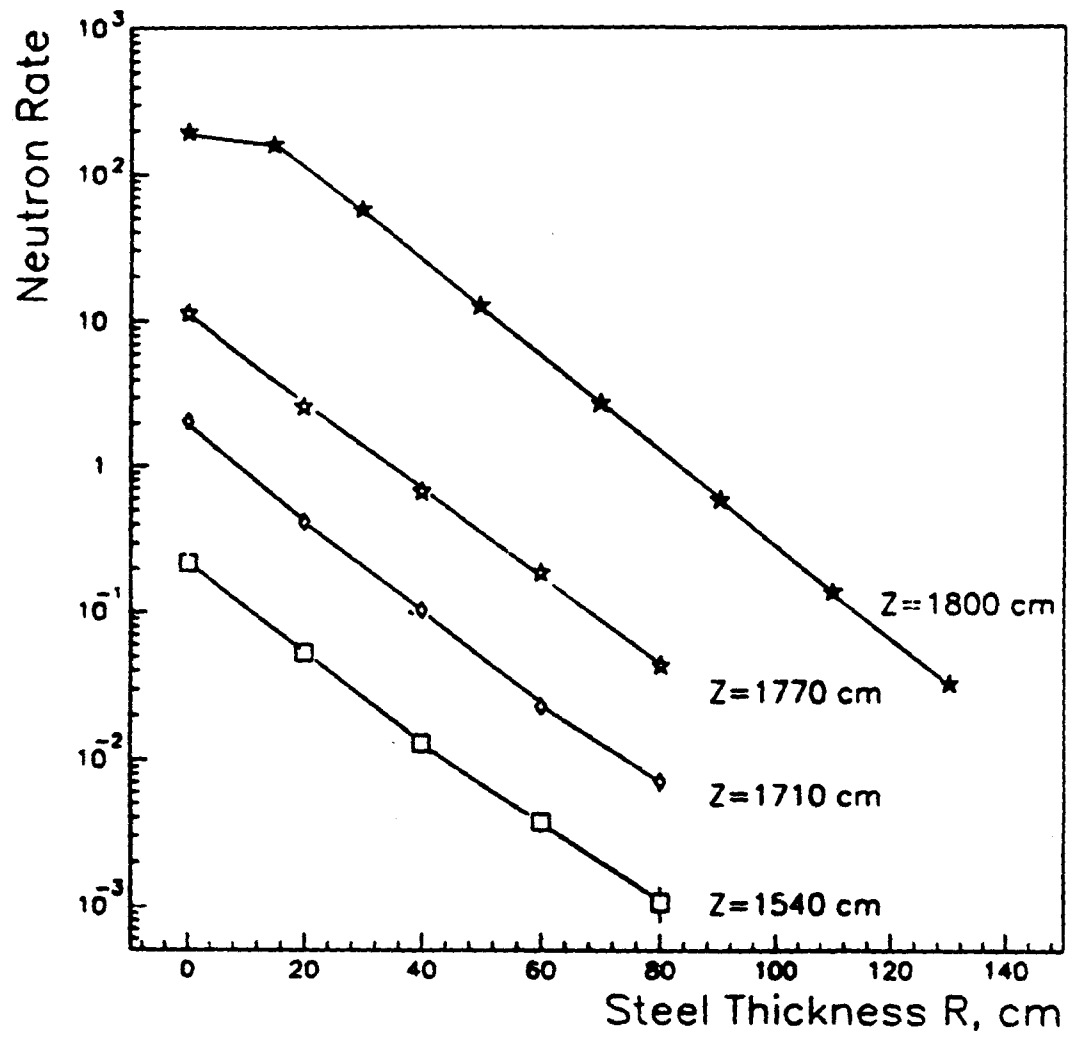



**Figure 0.3: The distribution of neutrons in the Rear Absorber vs. radius. Sets of points correspond to various cuts in Z.**

## Alignment (Difficult and unsolved)

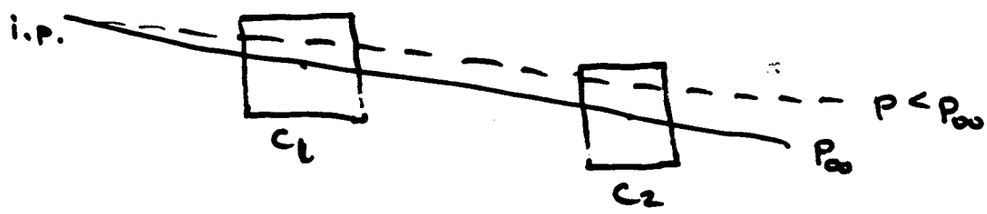
## Momentum Resolution

Need to Know

⇒ 100 μm resolution / station
- 1 mm in z
- 1 mm vertical tilt
- 50 μm drift cell placement
  50 μm radial chamber mount placement } ~ 100 μm
  50 μm wire placement
- temperature effects (?)

## Trigger

⇒ Projective Geometry Wire Trigger




$|\Delta t_1| < |\Delta t_2|$

- Local measurement of $||\Delta t_1| - |\Delta t_2|| \approx \Delta t$ at FW4 and
- And of FW4 . FW5 (or check sum)
- Sum of drifts should be constant for overlapping cells ⇒ gets rid of out of time hits

Alignment Must be positioned accurately w.r.t. Interaction Point
- 1 mm OK. even at $p_t \approx 50$ GeV
- must be better for higher $p_t$

Good alignment is easier for light structure.
All aluminum if possible

## Trigger

Need to identify correct beam crossing

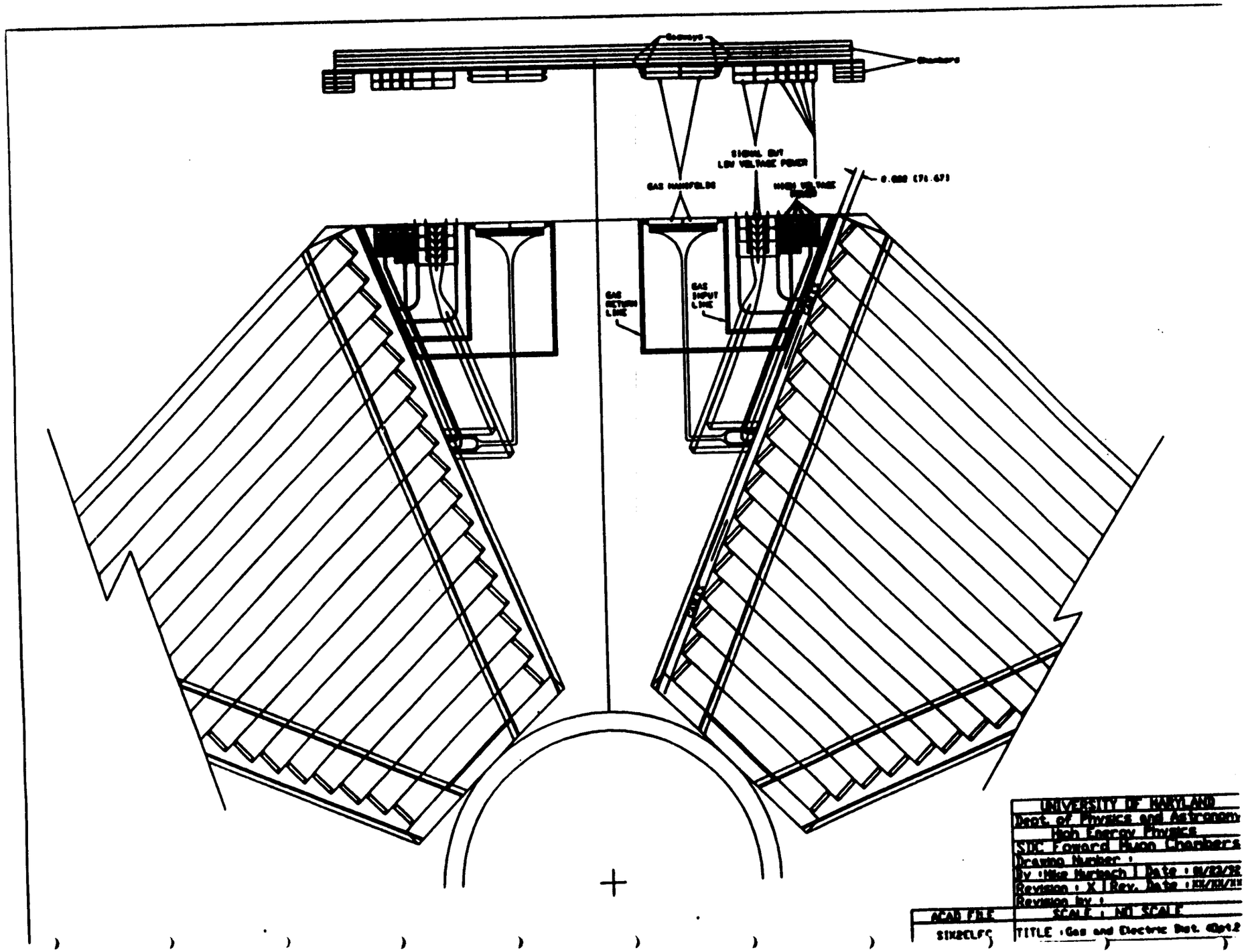
- Scintillator (but neutrons)
- Cherenkov (probably OK with 4 tubes/cell)

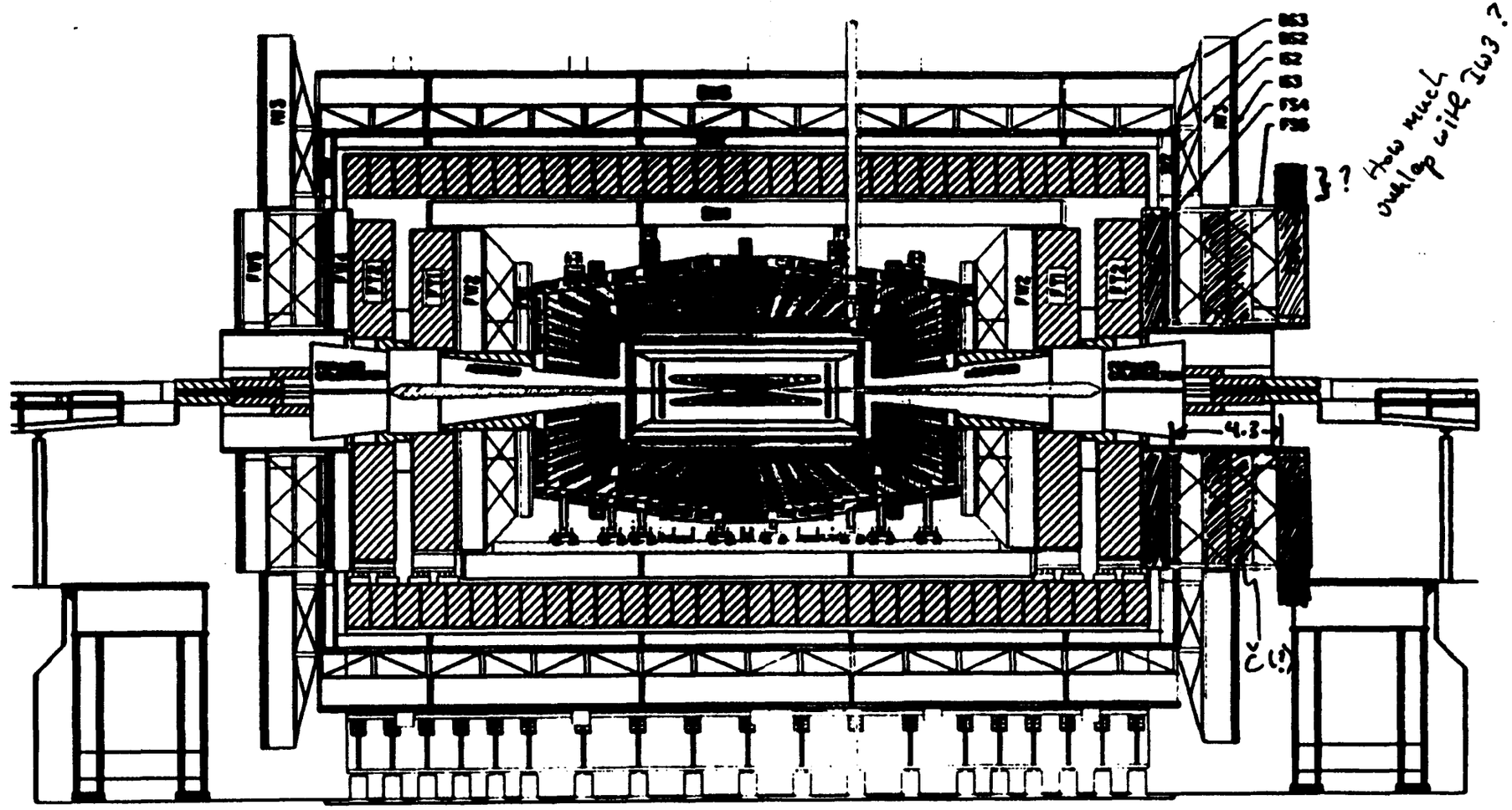
## Considerations and Constraints

- Access to electronics
  HV Distribution, trigger electronics, power distribution, gas distribution
  ⇒ Distribution points on periphery of detector
- Minimization of dead channels
  ⇒ Highly parallel distribution system
- Access to front-end electronics
  ⇒ All front end electronics on outer faces of FW1, FW2, FW4 and FW5 (FW3 is difficult to access under any scenario)
- Access to Calorimeter photo tubes
  FW1 must move independently toward FW2
- Access to [redacted] CTD electronics
  FW1 + Calorimeter End cap move toward FW2 by ~ 1.2 m
- Access to FW4 and FS1
  FS1, Č and FW5 + FS2 move backward
- Access to Č
  FW5 moves backward independently
- Trapping of FW1 through FW4
  Cable runs, etc along inner radius

  } increase space between FW4 and F from 2 m to 4 m

- Radial dimensions of FMS ≲ 7 m to allow splitting of FMS to move around quads and other machine elements


SIGNAL OUT
LOW VOLTAGE POWER
GAS MANIFOLDS
HIGH VOLTAGE
GAS
RETURN
LINE
GAS
INPUT
LINE
UNIVERSITY OF MARYLAND
Dept. of Physics and Astronomy
High Energy Physics
SSC Forward Muon Chambers
Drawing Number :
By : Mike Marinach | Date :
Revision : X | Rev. Date :
Revision by :
ACAD FILE
SCALE : NO SCALE
SINGLEFS
TITLE : Gas and Electric Dist. Opt.2




? How much overlap with IW3 ?

Shield scintillator planes with poly (especially if no Cherenkov)

## Protvino Original Proposal

Single tubes (5% bad after shipment)
- Round 4.5 cm in diameter
- No field shaping

} Difficult to manufacture "new" extrusions

Integration engineering work

## Present Agreement

Test beam work at Serpukhov at BNL

Cells must have good single track resolution
~ 150 μm

and good 2 track resolution
~ 5 mm

Both simple cells and Washington / SSCL type tubes with field shaping will be tested at Serpukhov

Maryland will test rectangular cells with various field shaping options at BNL

Protvino will investigate possibility of making non-standard round extrusions
(Dies from US or EC)

We will investigate possibility of making composite structures of ~ 1m in radial dimension both at Maryland and Protvino

We will investigate wire replacement in tubes which are part of composite structure

Integration work at Protvino will concentrate on
- Moving support for FW1 & FW2
- Beam pipe support
- Absorbers and absorber support

Maryland will continue its integration work

SSCL will investigate setting up Link between Protvino and SSCL

SSCL will provide INTERGRAPH PC software and liscence

SSCL will investigate possibilit of sending PC with MATH hardware to PROTVINO

## Cherenkov Counter

Specs for mirrors and tubes

50/50 % split of mirrors if both pass specs

All tubes from Serpukhov if pass specs

Electronics from US

Alignment device designed by Colorado

## Scintillator Counters

?

## Long Term Goals

75% of drift tubes and composite modules assembled in Russia, using as many components from Russian industry as is possible ⇐ {we will investigate in '92 what this means}

25% of drift tubes, etc constructed in US

All other assembly in US.

Protvino may be able to provide support structure forward toroids, and absorber

Italy may contribute real resources to help pay for some of the hard currency expenses

PRESENTATION BY:

DON REEDER

Reeder
Sat pm

# Report of the Cerenkov Review Committee


**D. Hedin,**
**H. Lubatti,**
**M. Miller,**
**D.D. Reeder, Chairman**


**21 January 1992**

## Charge to the Cerenkov Review Committee

The review committee is to determine if a forward Cerenkov counter is to be included in the Technical Proposal either in the "baseline" design or as a potential upgrade option. Review criteria include:

- additional capability provided by the Cerenkov counter beyond what can be achieved with the scintillation counters
- uniformity of response of the Cerenkov counter as a function of various variables like Pt, longitudinal source point position etc.
- tunability(in Pt) of the Cerenkov counter. This should include consideration of how reliably trigger efficiency can be determined
- cost

The committee may wish to include other factors.

The committee is requested to compare the trigger and timing capabilities of the following three configurations for the forward muon system, considering potential operation at 10**33 and 10**34 luminosity, and to recommend the most cost-effective direction.

1. Cerenkov counter only
2. Two layers of scintillator only
3. One layer of scintillator and Cerenkov counter.

# Scintillators

Assume at each end

- 2 planes of 700 counter each
- trigger ≡ coincidence of 2 proj counters

From FNAL (Hedin)

$\langle$occupancy$\rangle \simeq 2\%$ per crossing $\begin{cases} 1/2 \text{ charged part.} \\ 1/2 \text{ neutrons} \end{cases}$

Prob. of coinc. per crossing $\simeq 0.25$!

- must be combined with wire chamber trigger! (?)

Q Escalation FNAL $\rightarrow$ SSC ($10^{33}$) ?

Q. Upgrade to $10^{34}$ ?

Conclusion; scintillators accomplish little (except $t_0$)

caveat; $\begin{cases} \text{geometry dependent} \\ \text{calculation calibrated at FNAL soon.} \end{cases}$

~~2~~ Simple 2 plane scintillator trigger [ uncertain / no safety factor

~~1+C~~ Serves no function

Cost

$\left.\begin{array}{l} 120\ m^2 \text{ per layer } \{1K\$/m^2\} \\ 700 \text{ tubes " " } \{\$250/\ ?\} \end{array}\right\} \Rightarrow \sim 600\ K\$$ per end

COST: mechanical 2.7 M$
electronic .7
3.4 M$ both ends 1.7 M/end (x3 s

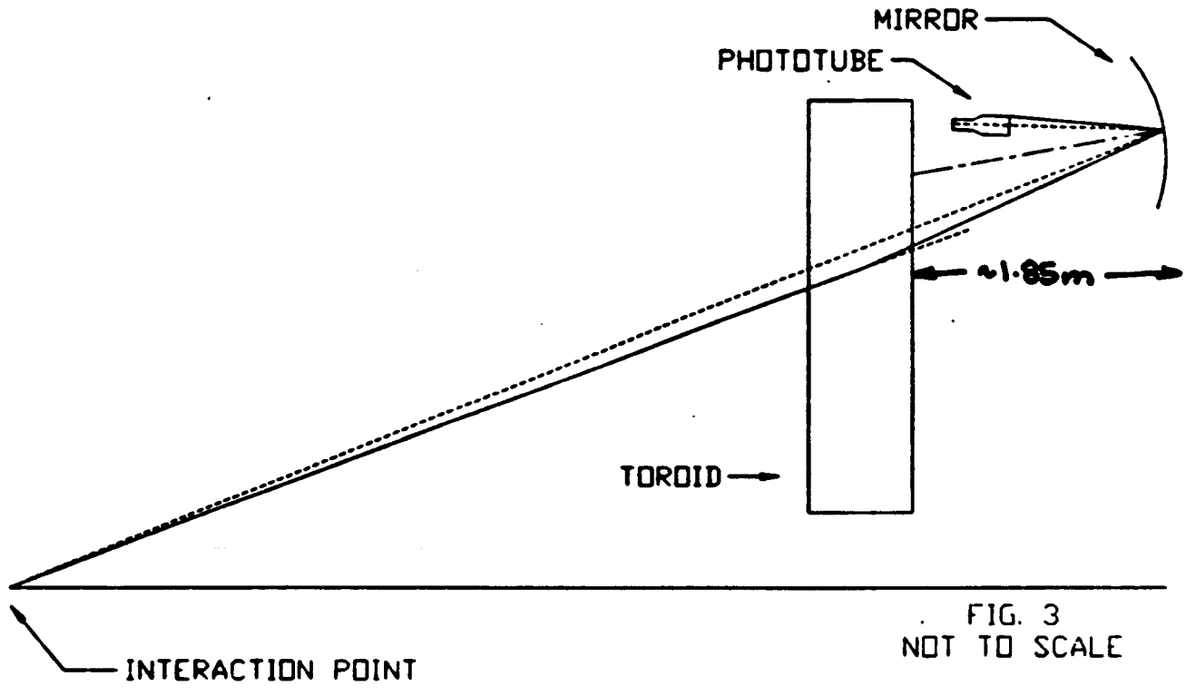



FIG. 3
NOT TO SCALE

- Good timing ($t_0$)
- insensitive { n's, δ-ray < 20 MeV }
- limited angular acceptance
- Rad. hard – might work @ $10^{34}$
- no tunability in $P_t$ { wire ch, trigger }
- Cost (engineering)
- with single tube
  - ⊕ noise
  - ⊕ Variation of $P_t$ thresh $\eta$

## Design Parameters of the Gas Čerenkov Counter

| Parameter | Value |
|---|---|
| Gas Medium | $N_2$ |
| Gas Pressure | 1 Atmosphere |
| Index of Refraction ($\lambda$=3500 A°) | 1.000309 |
| Width of Counter | 2.00 meters |
| Inner Radius | 2.15 meters |
| Outer Radius | 6.55 meters |
| Width of Cerenkov Medium | 1.85 meters |
| Mirror Reflectivity | 85 % |
| Phototube | 5″ BURLE 8854 (?) |
| Expected # of Photoelectrons | 17.5 |
| # of Cells per Counter | 200 |
| # of Mirrors per Cell | 4 |
| Size of Each Mirror | $\approx 40\times45$ cm$^2$ |
| Focal Length of Each Mirror | 1.40 meters |
| Čerenkov Light Ring Radius at Phototube | $\approx$3.73 cm |
| Momentum Threshold for muons | 4.25 GeV/c |

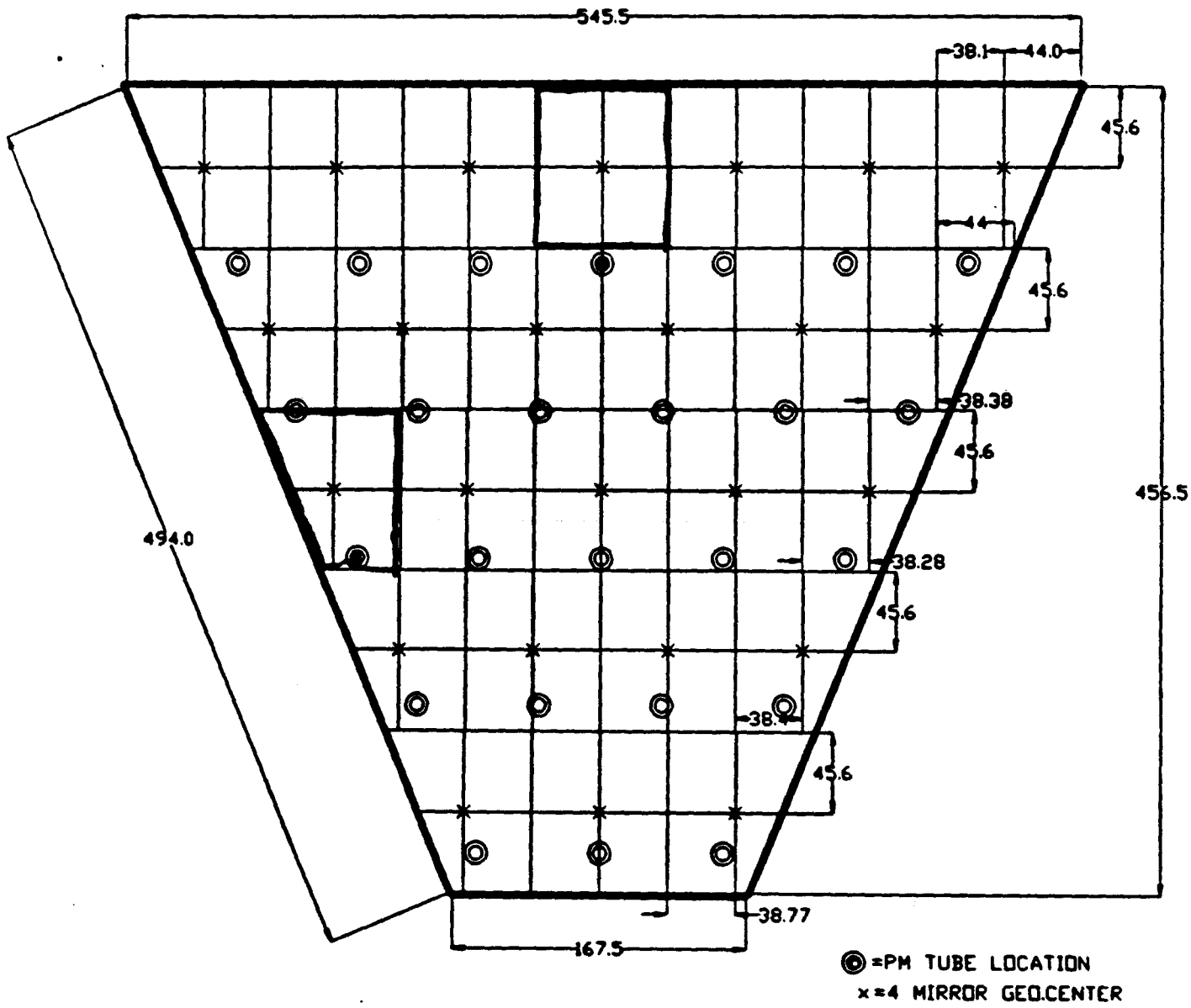
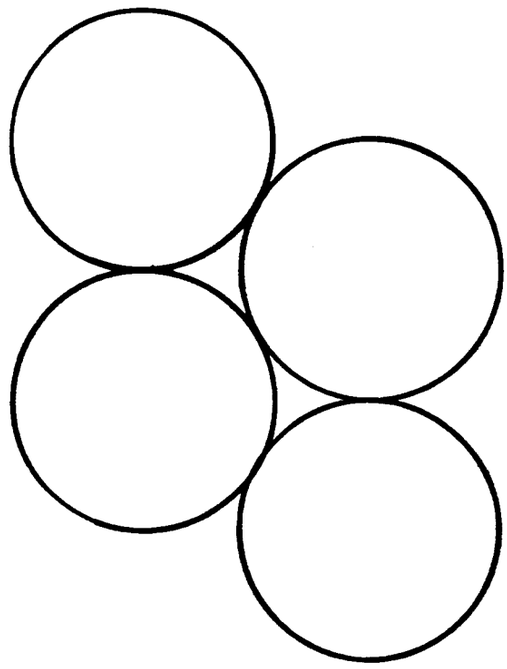

545.5
38.1
44.0
45.6
44
45.6
38.38
45.6
456.5
494.0
38.28
45.6
38.4
45.6
38.77
167.5
=PM TUBE LOCATION
x=4 MIRROR GEO.CENTER

FIG.8

3" tubes



## TRIGGER EFF. VERSUS MOMENTUM

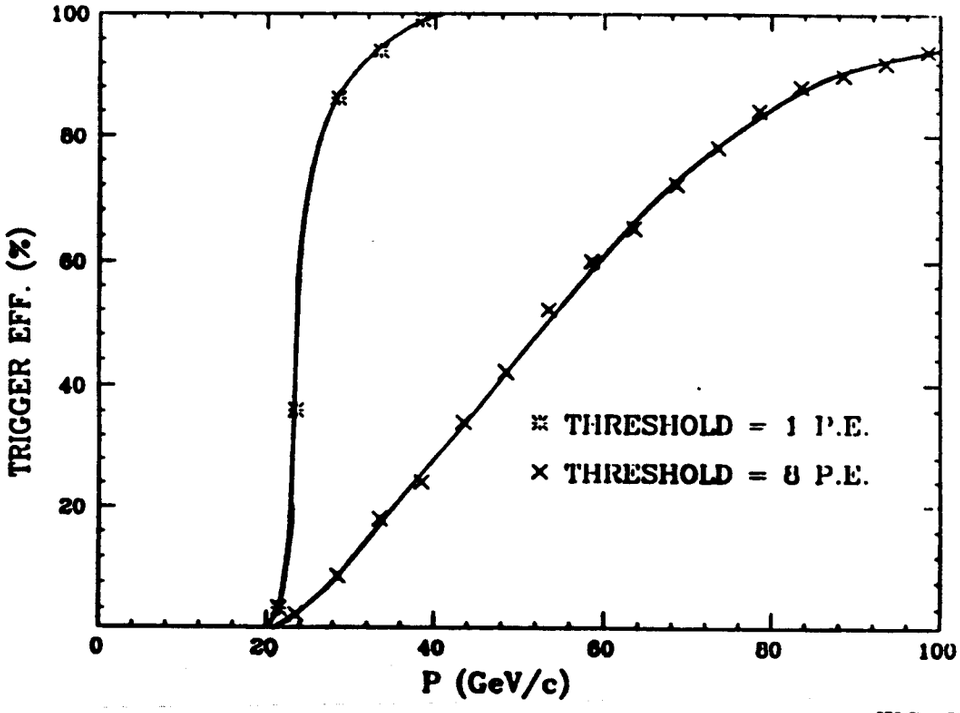
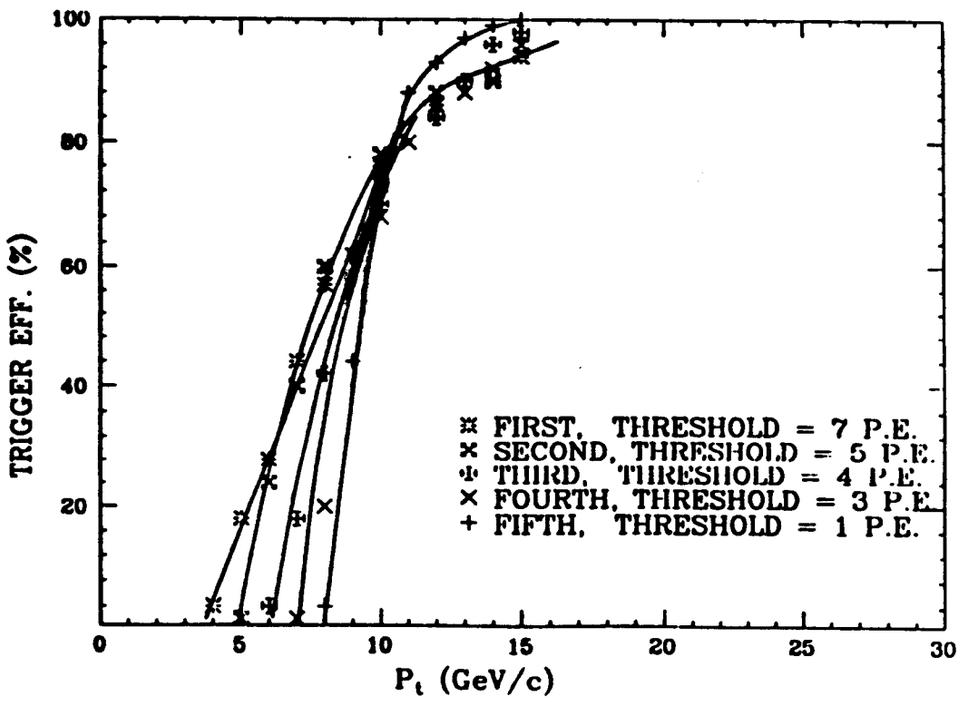



FIG. 7a

## TRIGGER EFF. VERSUS TRANS. MOMENTUM



Simulation:
Optics
Multiple Scattering
not δ-ray

# CERENKOV LIGHT SIMULATION

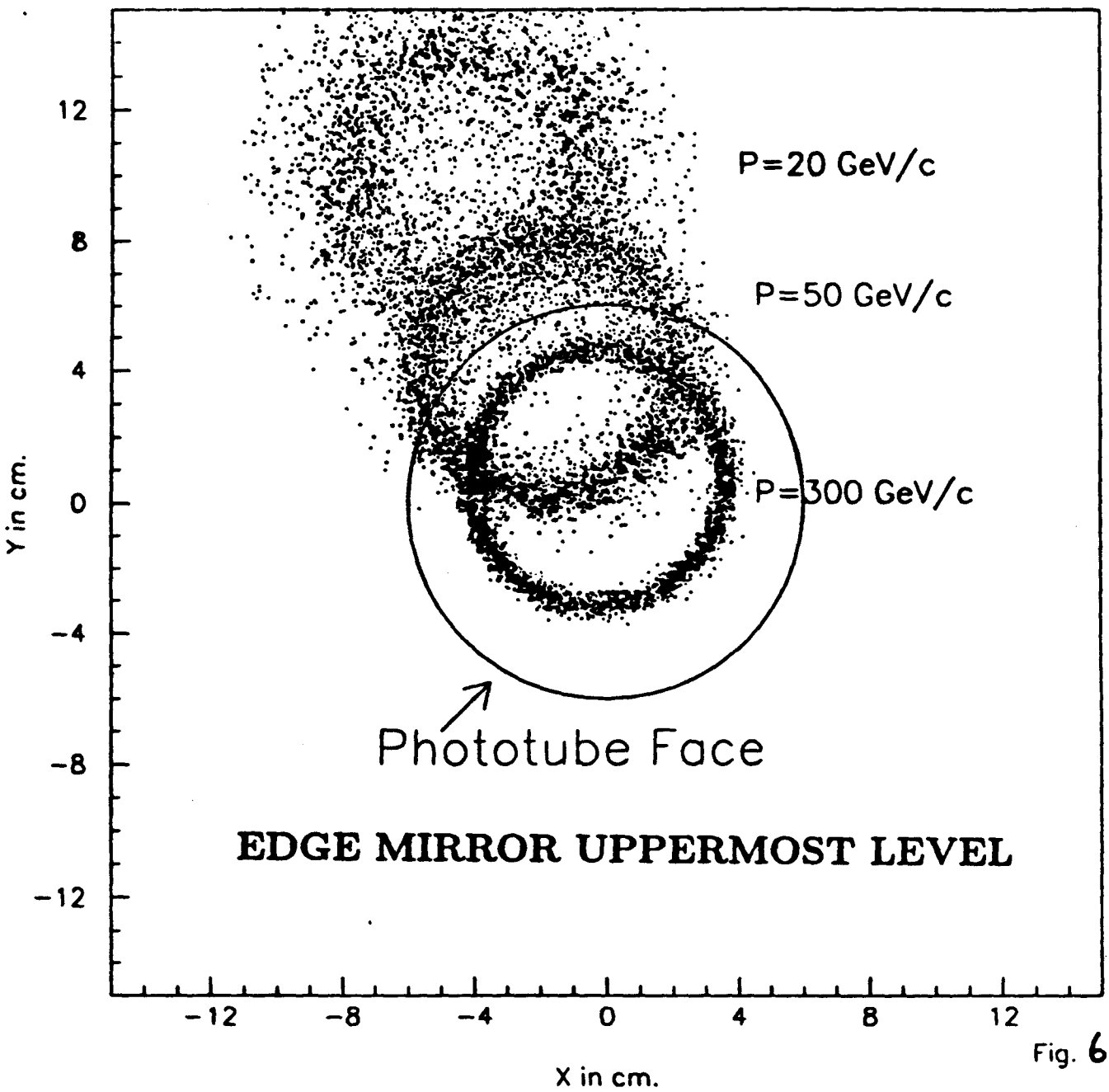
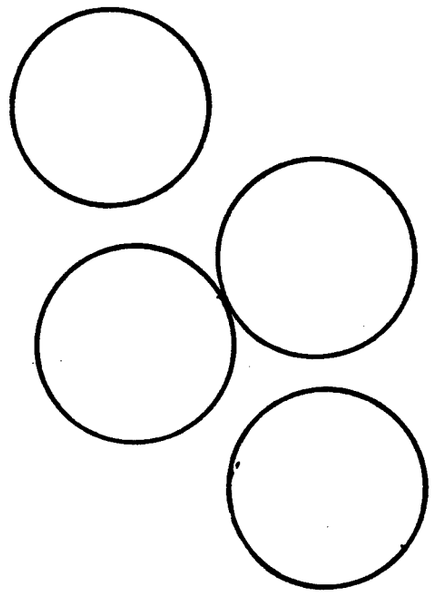



Fig. 6b

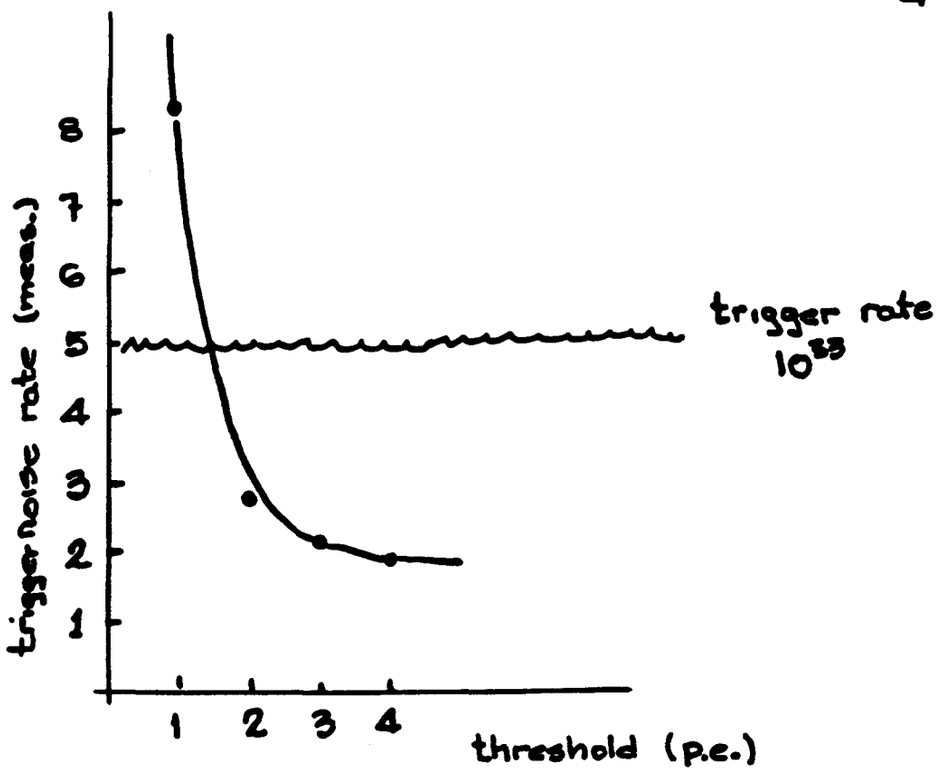
2¼" tubes



Single tube

Trigger noise rate:

(measured per tube)(200)($\frac{1}{4}$ beam crossing)




Zero with tubes in coincidence

## The Design and Engineering Program

- The basic design of the cerenkov array incorporating multiple tubes should be completed.

- The design, specification and engineering of the support system should be done in parallel with the array design and in consultation with the design of the forward drift chamber supports.

- Restudy the division into octants (quadrants? whole?)

- The procedures, tooling *etc.* needed to align the array must be designed engineered and included in the costs. The space required should be defined and identified.

- The installation procedures and equipment must be defined in coordination with the integration group in order to insure the space, line of sight, time, *etc.* is compatible with the overall installation plan.

## Costs

Estimation:

- Installation and alignment not included.
- Electronic readout is expensive ($ 2,500 per channel)
- There is an equal number of PMT's per unit area.
- Boundary between forward and intermediate trigger?
- Number of mirrors imaged on a single tube (4?)
- The use of Winston cones to 'tune' the effective diameter of the photo cathode.

## RECOMMENDATIONS

- We recommend that the cerenkov trigger array (as modified for guard or anti- tubes) for the forward muon system be incorporated as part of the Technical Proposal. (perhaps as an option?)

- We recommend that the scintillator array in the forward muon system which overlaps the acceptance of the cerenkov array be eliminated.

- We recommend that the design and engineering effort directed toward the cerenkov array be increased with the goal of a detailed definition of the device, of its construction and alignment, and of its installation. As discussed below we believe that the potential exists for significant cost savings compared to the current configuration.

- We recommend that the costs be reestimated according to the common standards used elsewhere in the collaboration.

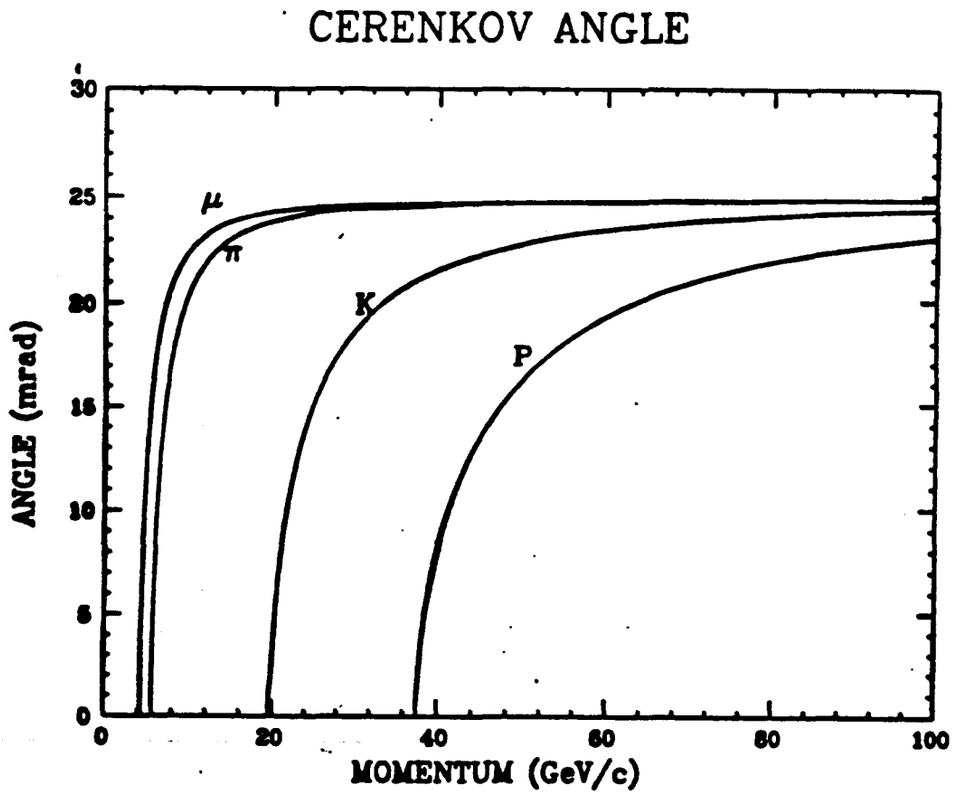
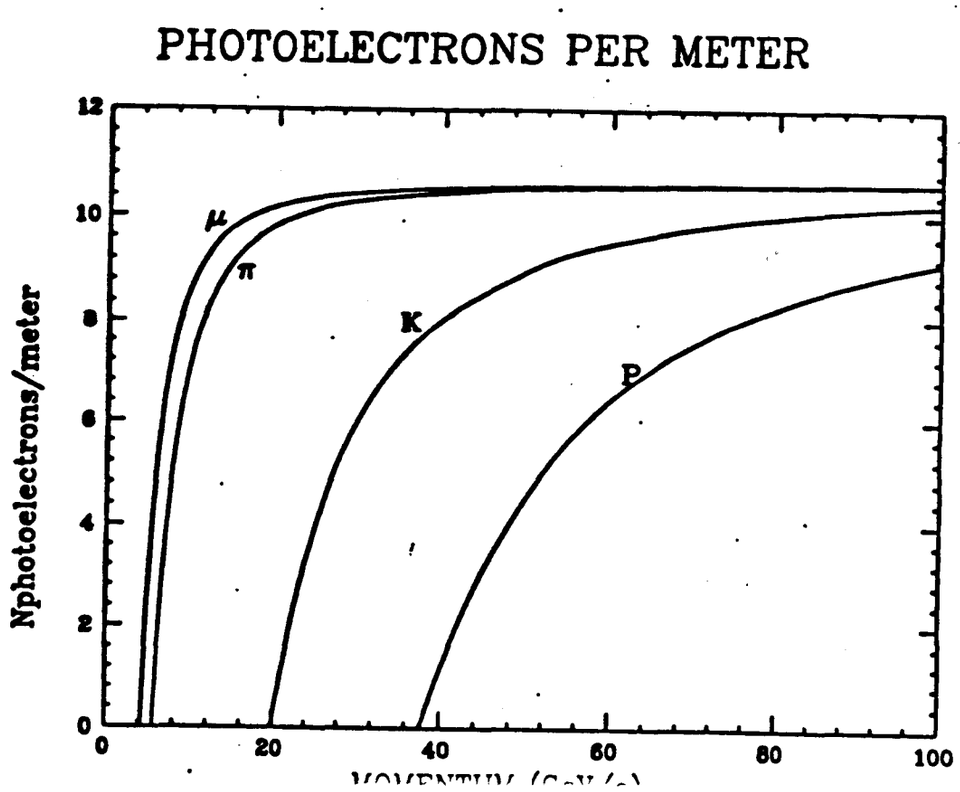

CERENKOV ANGLE
ANGLE (mrad)
MOMENTUM (GeV/c)
μ
π
K
P
0
5
10
15
20
25
30
0
20
40
60
80
100

FIG. 1


PHOTOELECTRONS PER METER
Nphotoelectrons/meter
μ
π
K
P
0
2
4
6
8
10
12
0
20
40
60
80
100

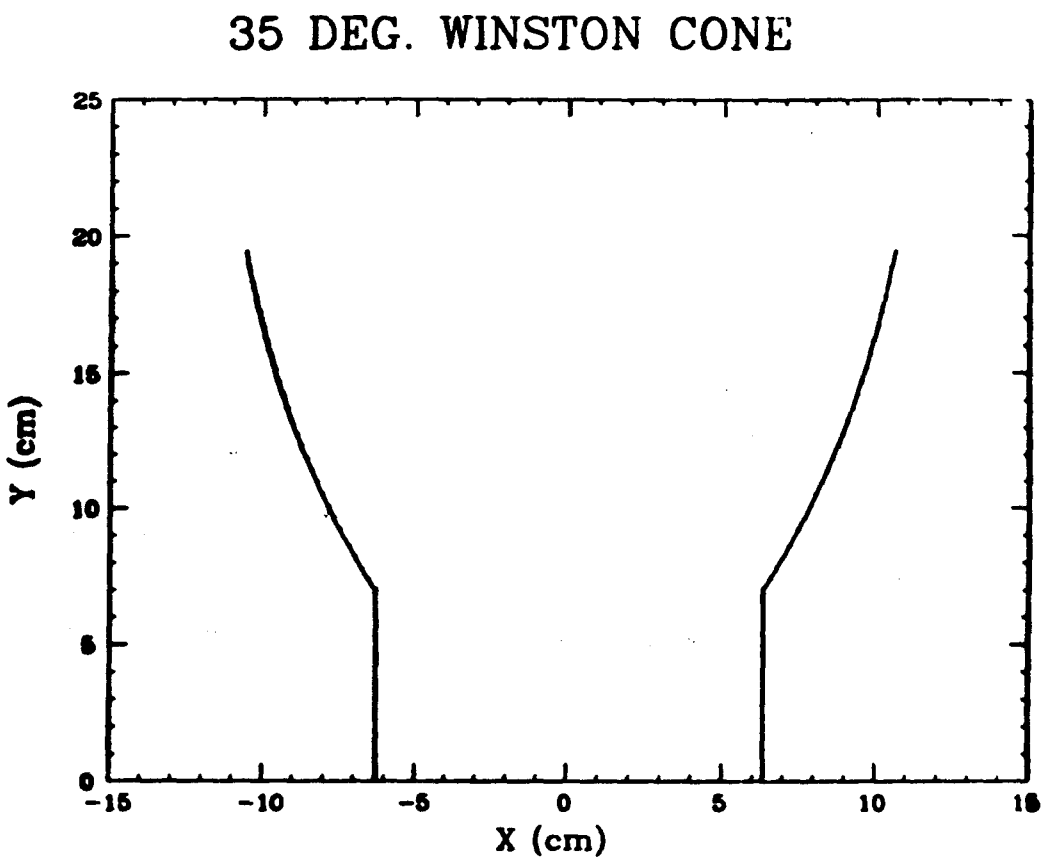



FIG. 13

# Report of the Cerenkov Review Committee

D. Hedin, H. Lubatti, M. Miller, D.D. Reeder, Chairman

January 29, 1992

On 21 January, 1992 the Committee met at the SSCL together with A. Skuja. The cerenkov trigger option for the forward muon system was presented by U. Nauenberg. Unfortunately, there was no presentation by an advocate of the scintillation counter trigger option, nor did the Russians attend. The charge to the committee is appended, but in brief it is to recommend to the Collaboration whether to include the cerenkov trigger option in the Technical Proposal.

## 1 Introduction

The forward muon system is designed to detect muons in the $\eta$ range $1.5 < \eta < 2.8$. Since wire chambers with drift times $t_d \sim 500$ $n$sec are the primary recording devices, it is necessary to tag the crossing time with a fast counter. We assume that the necessity of a low $p_t$ trigger in the forward muon system has been established *e.g.* to participate in a combined element trigger to select rare multilepton events. Candidate technologies for the fast counter are: cerenkov counters and scintillation counters. The scintillation counters are simpler and perhaps less expensive, but they are sensitive to neutrons and, individually, they are omnidirectional. The cerenkov on the other hand is more difficult to construct and operate, but it signals only particles with relativistic velocity moving in a selected direction.

This committee has been charged with comparing the performance of the Cerenkov counter trigger to that of two layers of scintillation counters. We have been hampered in doing this by the lack of a design for the forward muon trigger scintillation system and, more importantly, any estimate of its performance. However, based upon experience at the Fermilab collider, it is questionable whether two layers of scintillation counters could meet the trigger specification ($\sim 10^4$ level 1 muon triggers per sec of the total level 1 rate $10^4$ to $10^5$ at a luminosity of $10^{33}$ $cm^{-2}$). Its effectiveness would be severely reduced, perhaps to zero, at a luminosity of $10^{34}$ $cm^{-2}$. In order to be used as a trigger, the scintillators would need to be combined with a trigger formed using the drift chambers. The overall rate is impossible to estimate at this time, when so little is known concerning the performance of the drift chambers or the environment. However, the credibility of the monte carlo calculation of the background radiation will be evaluated experimentally during the next running period of the Tevatron and results might be expected before Fall 92.

As an illustration of the limitations of the scintillation counter trigger, we calculated the trigger rate using a very simple model. We started with 2 layers of counters behind the forward toroid; each layer having 700 counters. We then assumed that there were 14 hits per layer per pp interaction - these hits could be from either charged particles or from neutron interactions - and that the segmentation is such that each counter has a 2%

occupancy. This number of hits is comparable to what is seen at the Tevatron (CDF) and is predominately caused by beam scraping at small angles. The flux is greatly dependent upon the specific geometry and will be greater at smaller radii. Finally, we assumed that the trigger was formed by requiring the coincidence of a single counter from each of the layers (ignoring inefficiencies due to edges). This model together with the 2% occupancy leads to a prediction of 0.28 level 1 triggers per pp interaction for each end of the forward system (*i.e.* $1-2\ MHz$)! The background fluxes are quite likely to be greater at SSC than at the Tevatron, so perhaps the average rate is conservative! Given this, admittedly crude, result, the performance of the scintillator at the initial luminosity is marginal. Certainly the luminosity upgrade to $10^{34}$ would render much of the scintillator useless as a trigger. Thus, the two scintillator plane configuration, as we understand it, seems inadequate.

The cerenkov counter array, potentially, can meet the desired trigger specification. The design is not completely defined, so that the performance and cost remain uncertain. Nevertheless, it seems to provide the margin of safety needed to meet the increased luminosity and still provide a muon trigger at large $\eta$.

Cerenkov counters intrinsically have a sharp threshold in $p$ rather than $p_t$. The value of the threshold is inherent in the design – optics photocathode diameter *etc.* – and is not 'tunable'. It may, however, be possible to use different effective photocathode diameters and achieve a sharper $p_t$ threshold. The combination of the cerenkov and the wire chamber trigger can provide the desired on line 'tunability' in $p_t$ while also reducing tube noise. It appears that the trigger rate from the cerenkov alone might be a fraction of the 10 $KHz$ max rate input to the second level trigger. But in order to achieve this the noise rate must be eliminated, either thru a coincidence between two tubes or between one tube and the wire chambers. Also the momentum threshold must be sharpened by the addition of 'guard' tubes on either side of the trigger tube, which can be used to veto lower momentum particles, eliminating this source of false triggers. (See Fig. 1) It will always be difficult to reduce the first level single muon trigger to an acceptable level (*i.e.* about 10% of the 10 $KHz$ total rate) – even using the wire chambers to increase the $p_t$ threshold. So the forward muons will mostly be used in multicomponent triggers.

We were asked to address a potential option of cerenkov counters and a single layer of scintillator. The scintillator would not reduce the trigger rate from real particles, and there are other ways to reduce the noise rate as mentioned above. Furthermore, the scintillator is not needed to tag the beam crossing since the cerenkov response time is well under 16 nsec. We conclude that the extra expense and complexity of adding a layer of scintillator yields no improvement in physics capability and is unnecessary. Depending on the space required, its inclusion might even hazard the cerenkov system.

In summary, we believe the cerenkov option of triggering the forward muon system, despite its current incomplete design, can meet the necessary requirements of the first level trigger and the challenges anticipated at the maximum luminosities.

# 2 RECOMMENDATIONS

• We recommend that the cerenkov trigger array (as modified for guard or anti- tubes) for the forward muon system be incorporated as part of the Technical Proposal.

• We recommend that the scintillator array in the forward muon system which overlaps the acceptance of the cerenkov array be eliminated.

• We recommend that the design and engineering effort directed toward the cerenkov array be increased with the goal of a detailed definition of the device, of its construction and alignment, and of its installation. As discussed below we believe that the potential exists for significant cost savings compared to the current configuration.

• We recommend that the costs be reestimated according to the common standards used elsewhere in the collaboration.

# 3 The Design and Engineering Program

1. The basic design of the cerenkov array should be completed. The guard tube feature must be incorporated to sharpen the $p_t$ threshold. The items and questions listed under the section on costs should be addressed.

2. Little has been done in regard to the specification and design of the support system. This should proceed together with the completion of the counter design and be integrated with the engineering of the support *etc.* of the forward muon drift chambers. The division of the cerenkov counter into octants may be unnecessary, if the outer radius is reduced, thus eliminating fractional mirrors.

3. The procedures, tooling *etc.* needed to align the array must be designed and costed. The space required should be defined and identified.

4. The definition of the installation procedures and equipment must be done in coordination with the integration group in order to insure the space, line of sight, time, *etc.* is compatible with the overall installation plan.

# 4 Costs

The estimation of costs for the cerenkov option have not been done according to the standards used in estimating other components. The sign of the difference is not immediately apparent. For example, the cost of installation is not included, nor are the alignment costs. On the other hand, the specification of the electronic readout seems unnecessarily expensive. The requirement of 8-bit flash ADC's has not been justified ($ 1000 per channel). There may be double counting of these cerenkov readout electronics costs and those of the DAQ and trigger tasks. More generally, we were unable to identify the increased functionality that would justify the order of magnitude increase in per channel cost of electronics for the cerenkov counter as compared to those of the calorimeter.

There are a number of design details which should be reexamined in order to minimize costs and still meet the functional goals. A few of these are listed below, in no priority order, and we note that it is likely that some suggestions may be incompatible with others.

1. The current design incorporates an equal number of PMT's per unit area. Since the background is significantly greater at small radii (distance to the beam pipe), it may be desirable to increase the density there.

2. The radius which separates the scintillator trigger counter system used in the barrel and intermediate regions and the cerenkov system now occurs, by default, at the boundary between the forward and intermediate systems. However, it may be cost effective to continue the scintillator system at large radii. This would decrease the number of channels for the cerenkov system and diminish the design problem of the supports. Knowledge of the background rates as a function of radius in a realistic environment is of obvious importance in this optimization.

3. The current design has four mirrors imaged on a single 5" PMT. Could the number of the mirrors on a single tube be increased (particularly at large radii)? This would also result in economies.

4. The use of Winston cones to obtain an effective diameter of the photo cathode approximately twice the true diameter is suggested by the proponents as a method of lowering the cerenkov threshold near $\eta \sim 1.5$. Whether or not this is optimal in the final design, it may be that this arrangement is satisfactory throughout the array. This means that a smaller (perhaps 2-3") PMT could be used with resultant savings. By varying the acceptance of the tubes at different radii (*i.e.* $\eta$) using Winston cones, the $p_t$ threshold could be tuned to the same value.

5. The integration of the electronics design effort with those of the other components might lead to standardization, simplification and less expensive unit costs.

# Charge to the Cerenkov Review Committee

The review committee is to determine if a forward Cerenkov counter is to be included in the Technical Proposal either in the "baseline" design or as a potential upgrade option. Review criteria include:

1. additional capability provided by the Cerenkov counter beyond what can be achieved with the scintillation counters
2. uniformity of response of the Cerenkov counter as a function of various variables like Pt, longitudinal source point position etc.
3. tunability(in Pt) of the Cerenkov counter. This should include consideration of how reliably trigger efficiency can be determined
4. cost

The committee may wish to include other factors.

The committee is requested to compare the trigger and timing capabilities of the following three configurations for the forward muon system, considering potential operation at 10**33 and 10**34 luminosity, and to recommend the most cost-effective direction.

1. Cerenkov counter only
2. Two layers of scintillator only
3. One layer of scintillator and Cerenkov counter.

# CERENKOV LIGHT SIMULATION

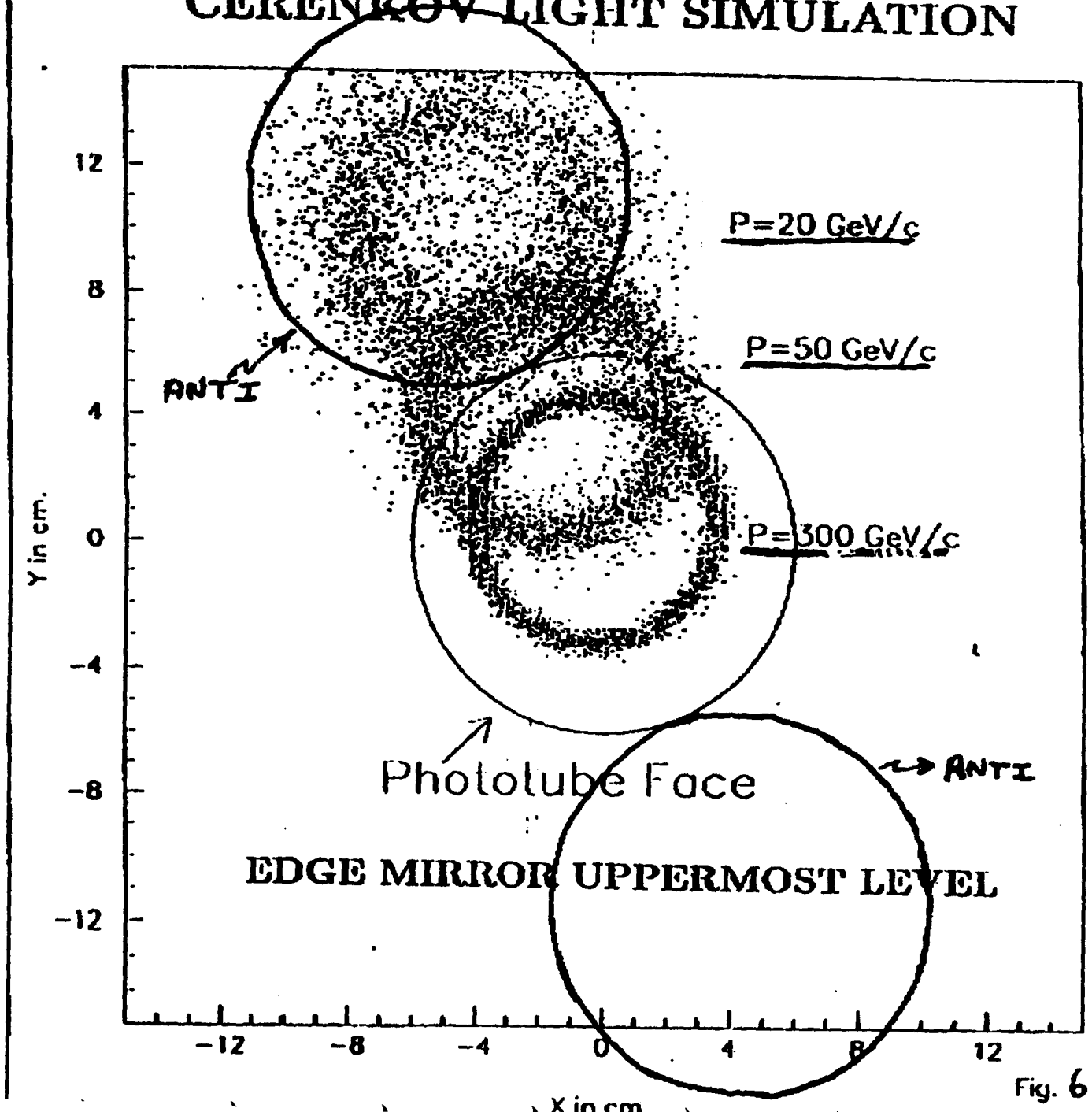



Fig. 6b

PRESENTATION BY:

JIM BENSINGER

Bensinger
Sat pm

# Magnet Status

1) Meeting with Izhora Engineers / DUBNA of Barrel Toroid Jan 20-24.

2) Meeting with ITEP /IHEP on Forward Toroids - Jan 29.

# Design Activities

1) An analyses group has been formed and is active doing detailed design of the barrel magnet.

2) Conceptual designs of the forward toroids will continue both in the US and in Russia

3) Coil design is in progress at PSL.

4) Russian colleagues are forming an engineering group which will oversee magnet production (single project).

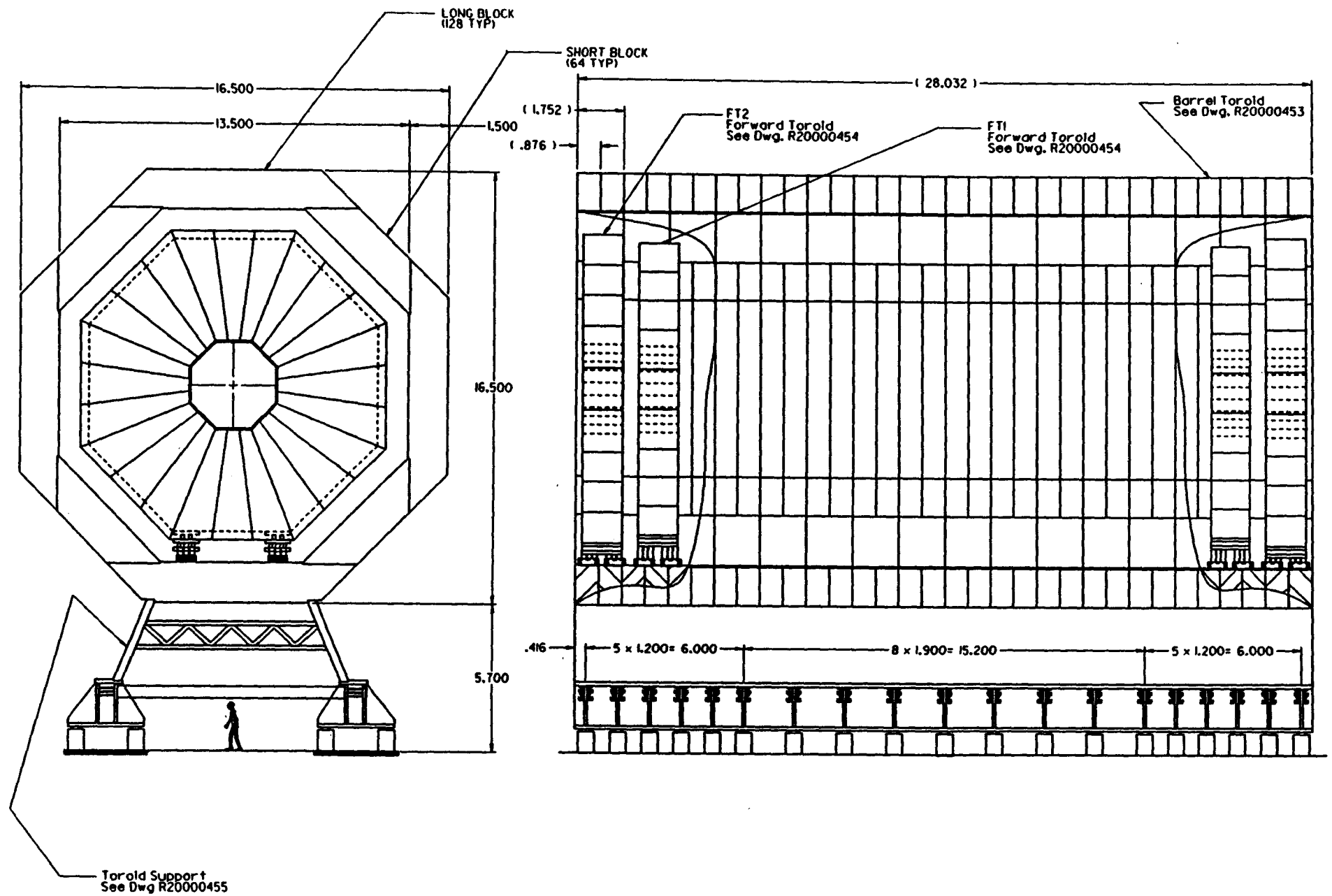
5) Future meetings on magnet design:
   - At the SSCL at the end of April.
   - In Moscow before the Japan SDC meeting.

6) We would like to bid the rigging contract ASAP.

# Milestones

## SDC Muon Barrel Toroid (MBT)

| | |
|---|---|
| Complete Preliminary Design | 8/92 |
| Begin Fabrication | 1/93 |
| First Group (12) of Blocks Complete | 7/93 |
| Vertical Ring Assembly | 12/93 |
| Deliver First batch of Blocks (24) | 2/94 |
| Complete Block Delivery | 12/95 |
| U/G Hall BOD | 1/96 |
| Complete MBT Installation | 8/96 |



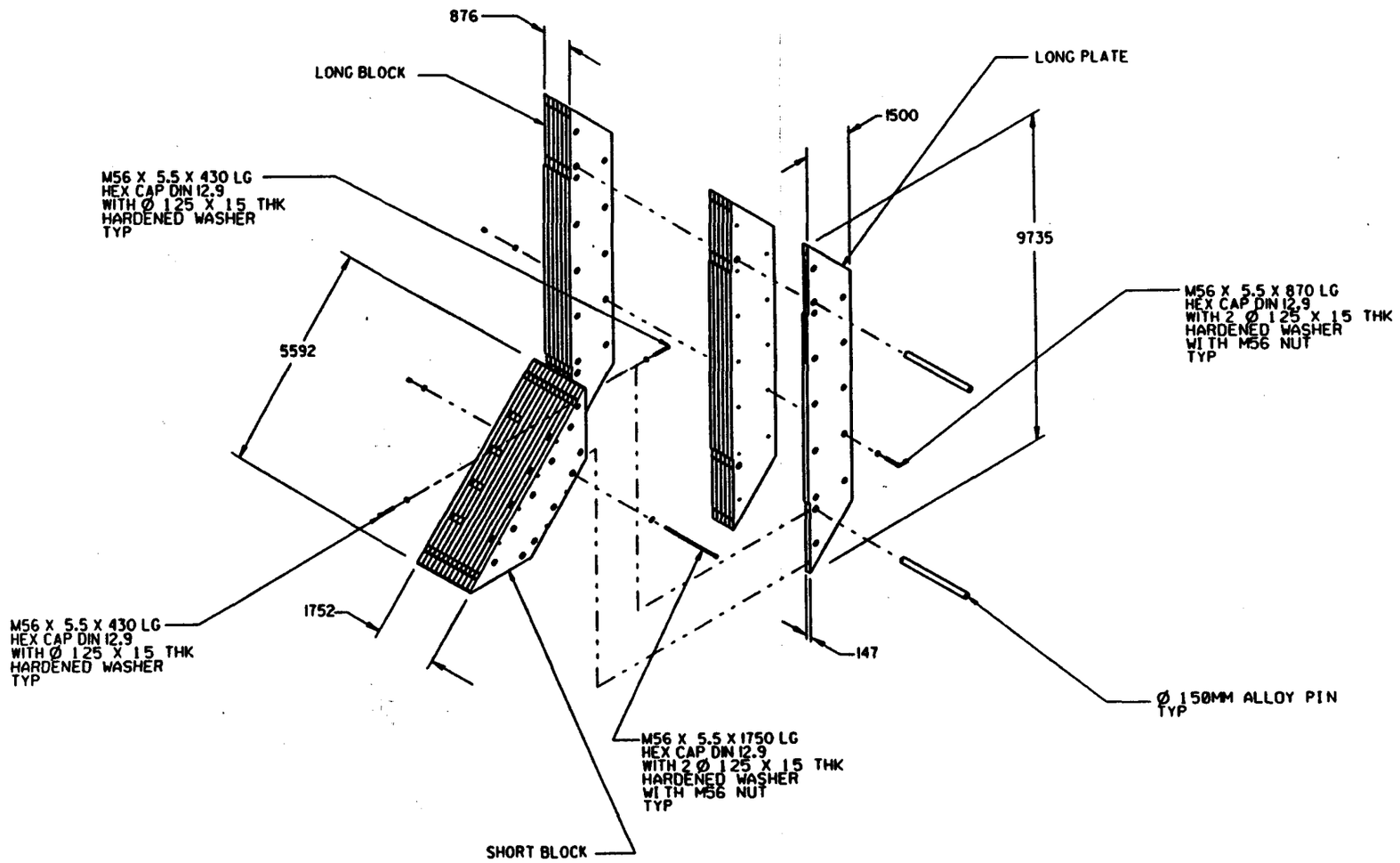

SDC MUON MAGNET ASSEMBLY

DRAWING NUMBER R20000452

J.L.W/R.G.
1-23-92

FINAL ASSEMBLY IN HALL

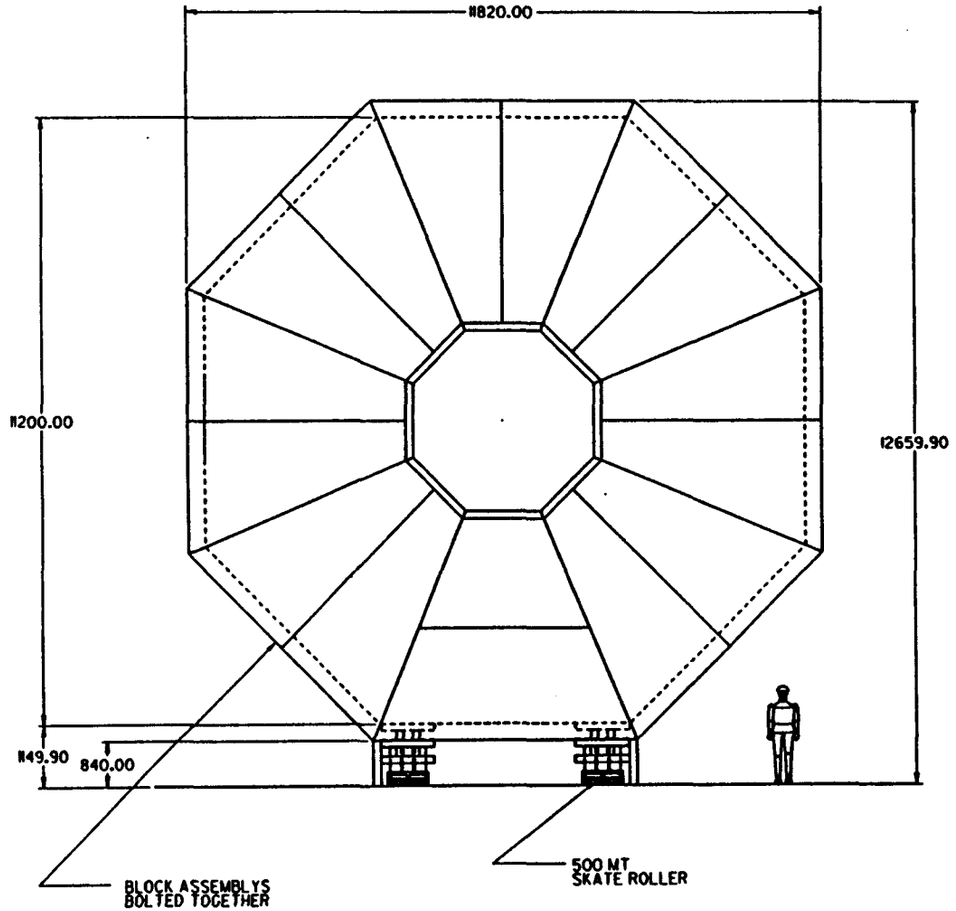
BLOCK ASSEMBLY AT MANUFACTURER

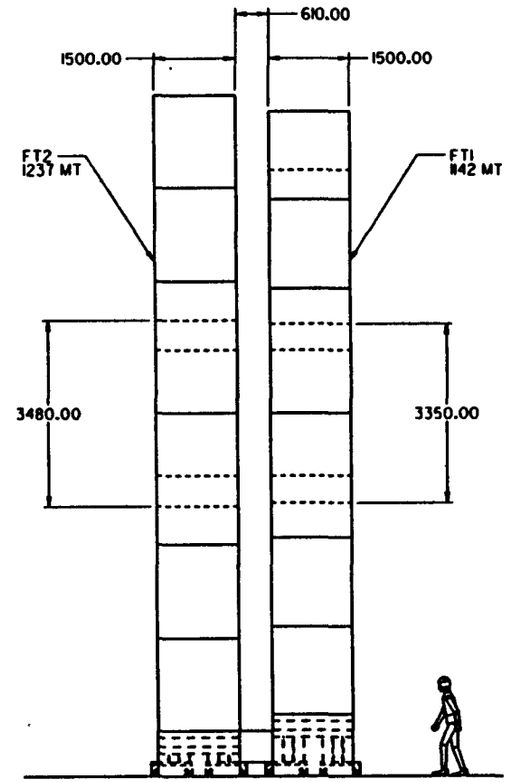



MUON BARRREL BLOCK ASSEMBLY

DRAWING NUMBER R20000453

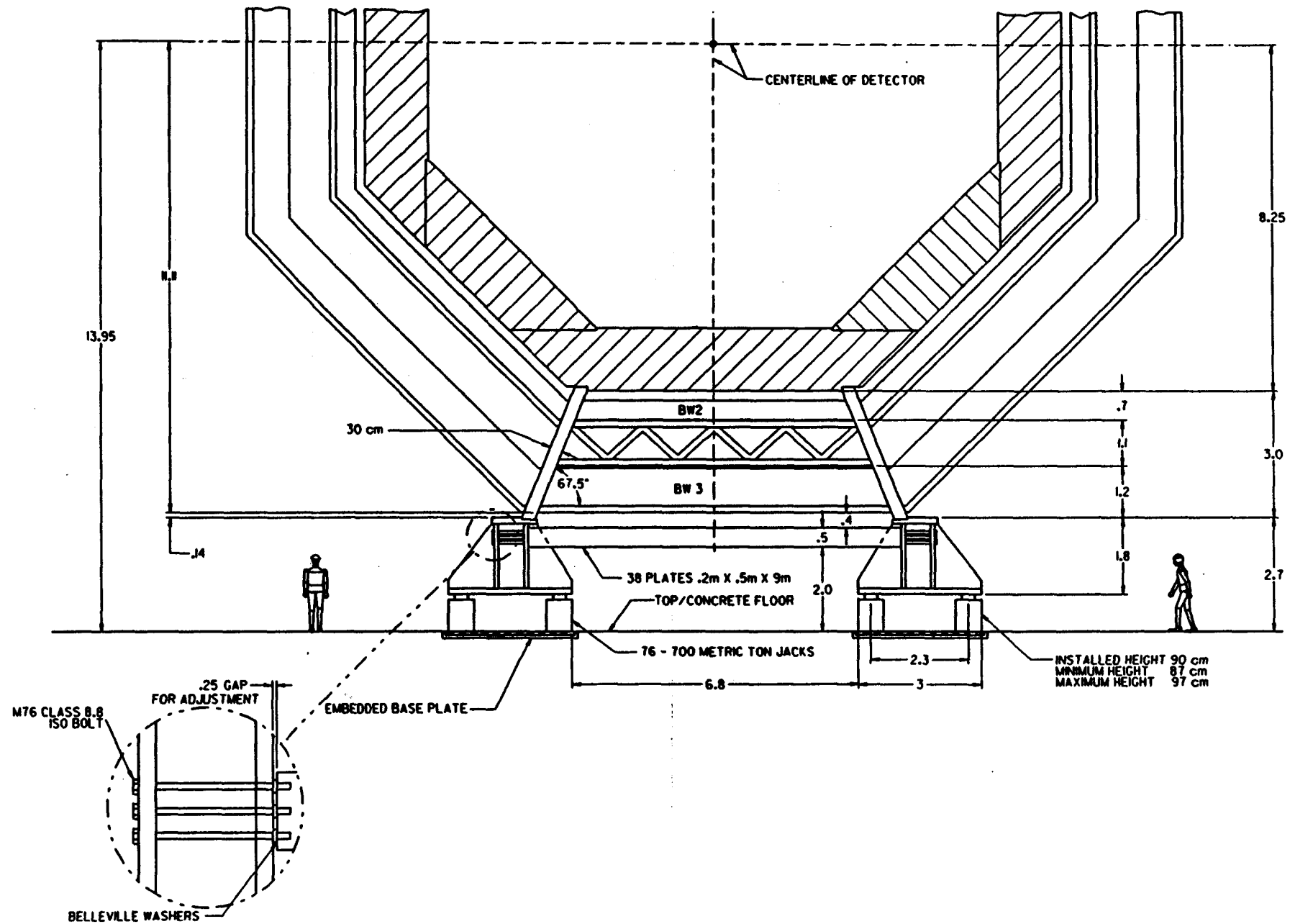
J.J.C/L.J.C.
1-23-92



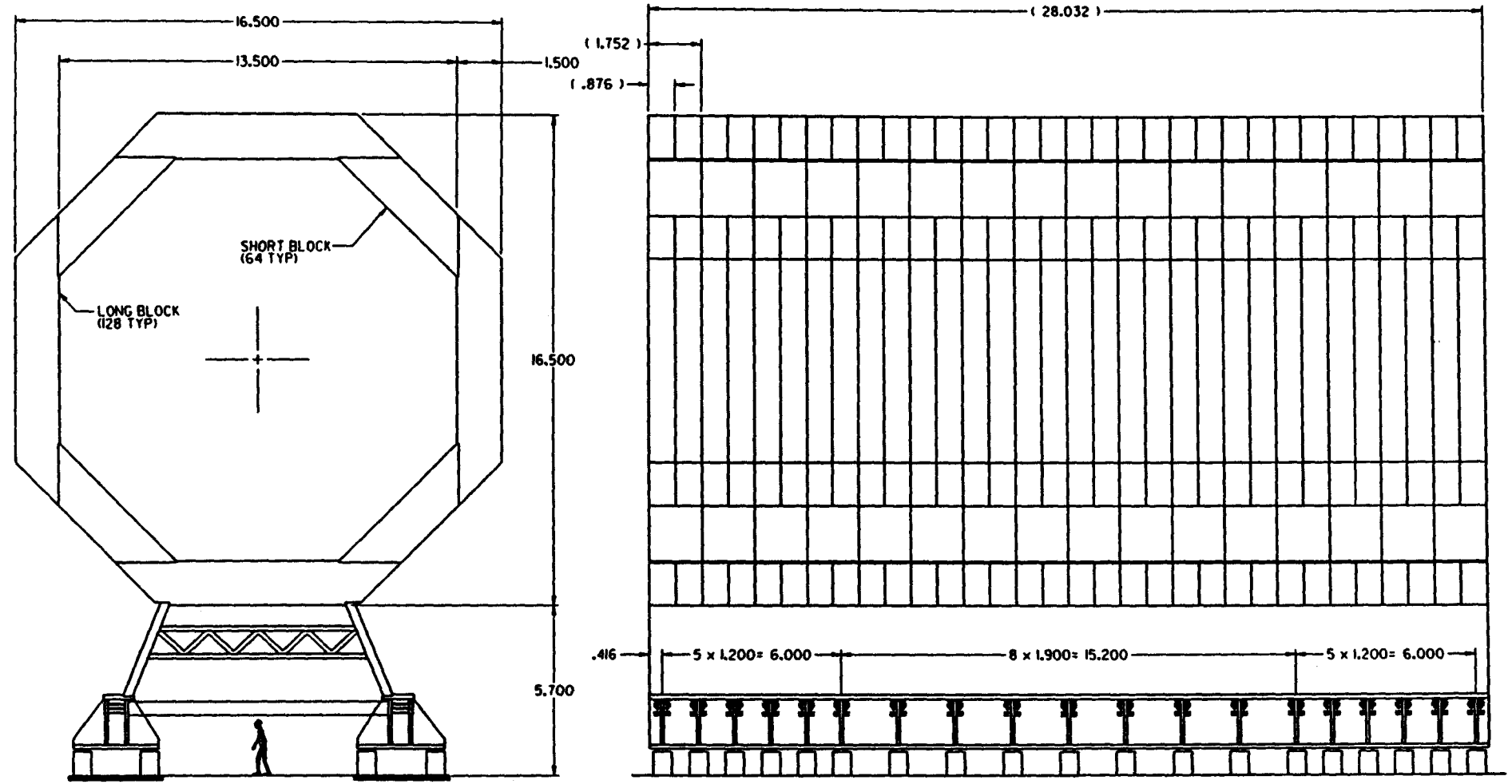

FORWARD MUON TOROID ASSEMBLY
DRAWING NUMBER R20000454

J.L.W/R.G.
1-23-92



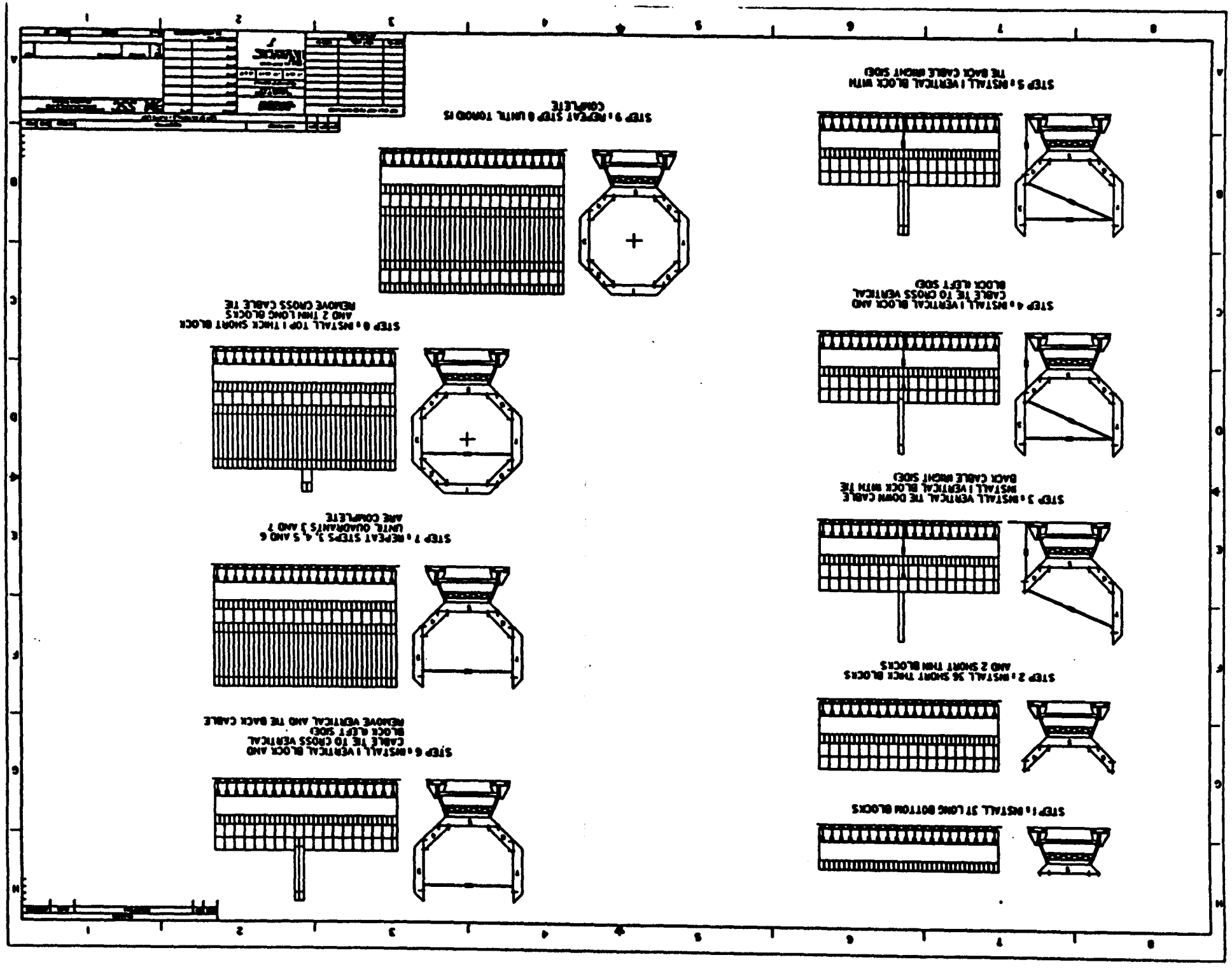

SDC TOROID SUPPORT ASSEMBLY
DRAWING NUMBER R20000455

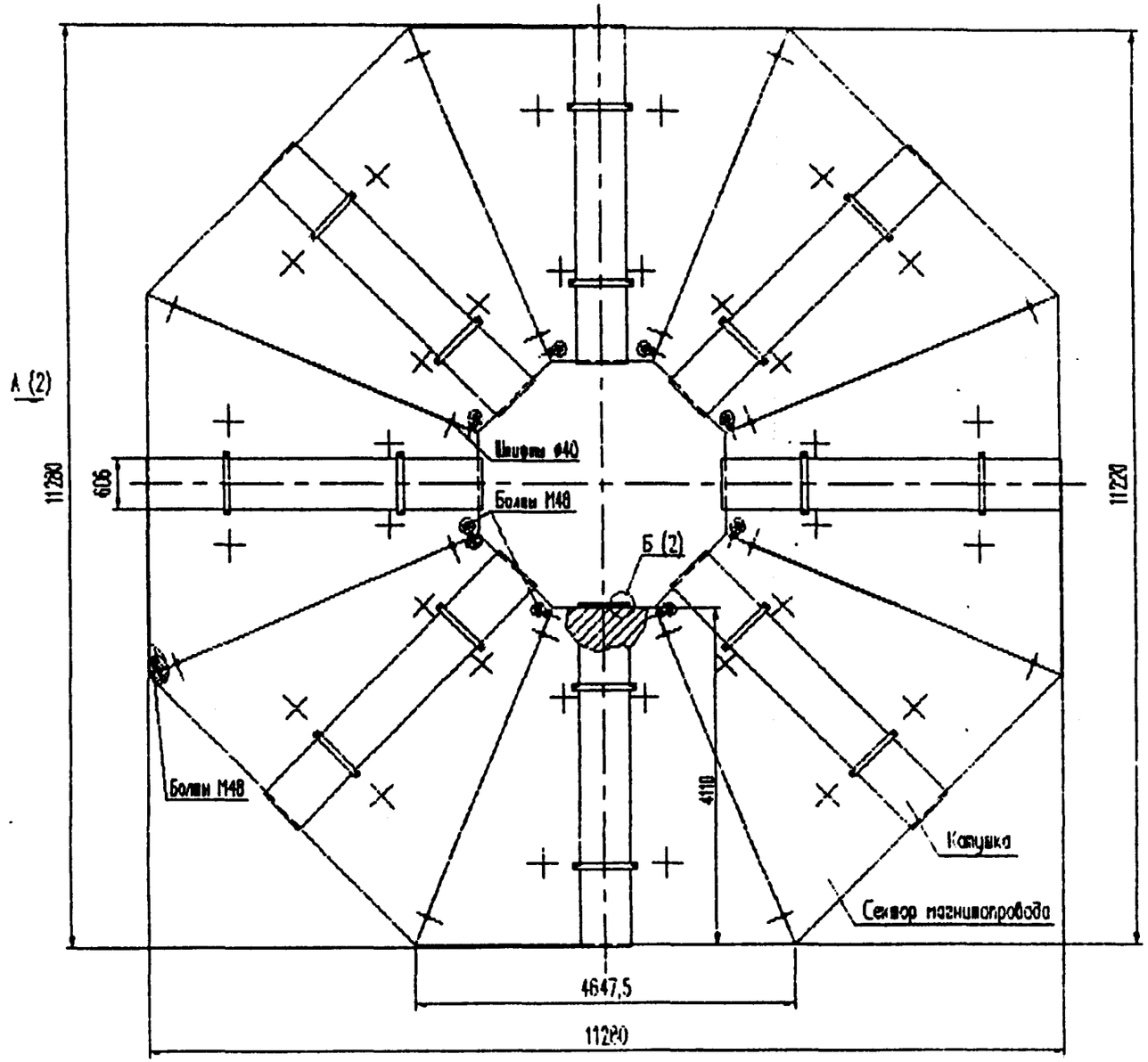
J.L.W/R.G.
1-23-92




SDC MUON MAGNET ASSEMBLY
DRAWING NUMBER R20000456

J.L.W/R.G.
1-23-92


STEP 1 • INSTALL 37 LONG BOTTOM BLOCKS
STEP 2 • INSTALL 36 SHORT THICK BLOCKS AND 2 SHORT THIN BLOCKS
STEP 3 • INSTALL VERTICAL TIE DOWN CABLE INSTALL 1 VERTICAL BLOCK WITH TIE BACK CABLE MIDDLE SIDED
STEP 4 • INSTALL 1 VERTICAL BLOCK AND CABLE TIE TO CROSS VERTICAL BLOCK LEFT SIDED
STEP 5 • INSTALL 1 VERTICAL BLOCK WITH TIE BACK CABLE MIDDLE SIDED
STEP 6 • INSTALL 1 VERTICAL BLOCK AND CABLE TIE TO CROSS VERTICAL BLOCK LEFT SIDED REMOVE VERTICAL AND TIE BACK CABLE
STEP 7 • REPEAT STEPS 3, 4, 5 AND 6 UNTIL QUADRANTS 3 AND 7 ARE COMPLETE
STEP 8 • INSTALL TOP 1 THICK SHORT BLOCK AND 2 THIN LONG BLOCKS REMOVE CROSS CABLE TIE
STEP 9 • REPEAT STEP 8 UNTIL TOWOD IS COMPLETE




| Наименование показателей | Величина |
|---|---|
| 1.Среднее магнитное поле, Тл | 1,67 |
| 2.Рабочий ток, А | 450 |
| 3.Активное напряжение на обмотке, В | 115 |
| 4.Энергопотребление, кВт | 52 |
| 5.Число катушек в обмотке | 8 |
| 6.Число витков в катушке | 26 |
| 7.Средняя длина витка, м | 11,2 |
| 8.Проводник – труба алюминиевая | |
| 9.Размеры проводника, мм | 22x22 |
| 10.Площадь сечения проводника, мм² | 330 |
| 11.Диаметр отверстия в проводнике,мм | 14 |
| 12.Перепад давления охл. воды, МПа | 0,5 |
| 13.Расход воды, л/мин | 8 |
| 14.Перегрев воды в обмотке, К | 12 |
| 15.Число ветвей охлаждения в обмотке | 8 |
| 16.Масса магнитопровода, т | 1150 |
| 17.Масса алюминия обмотки, т | 2,1 |

Электромагнит I детектора SDC
Чертеж общего вида
1:2

Fig. 1

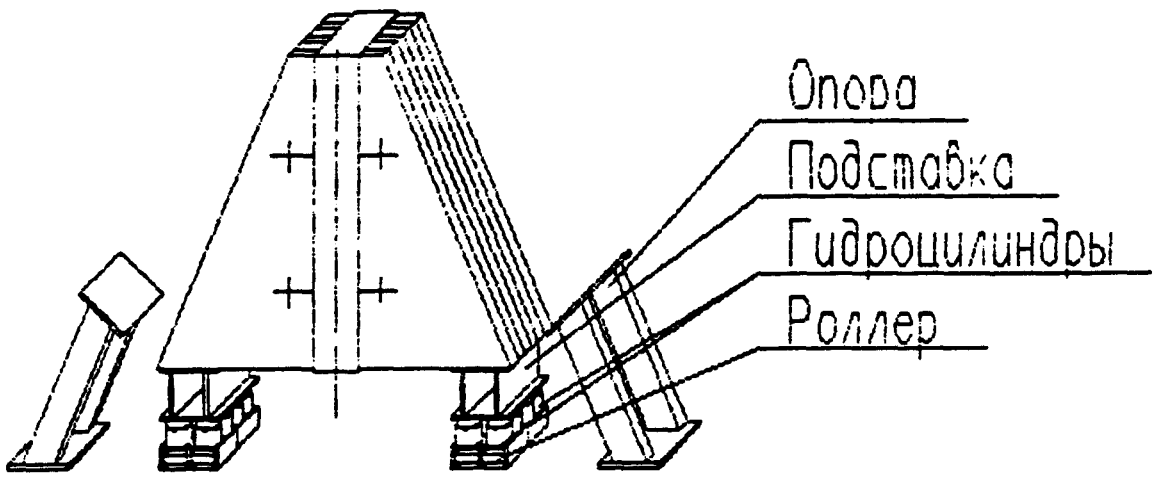



Fig. 2

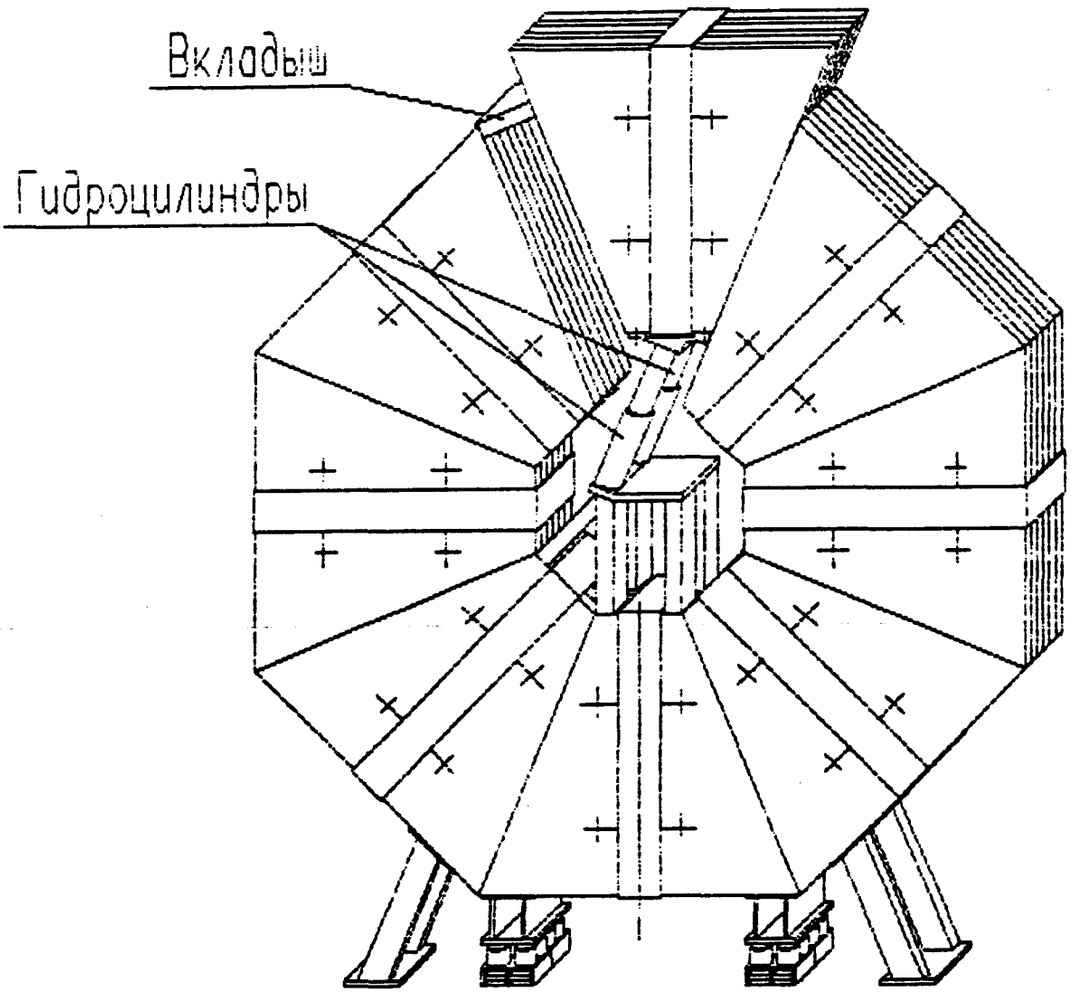



Fig. 7

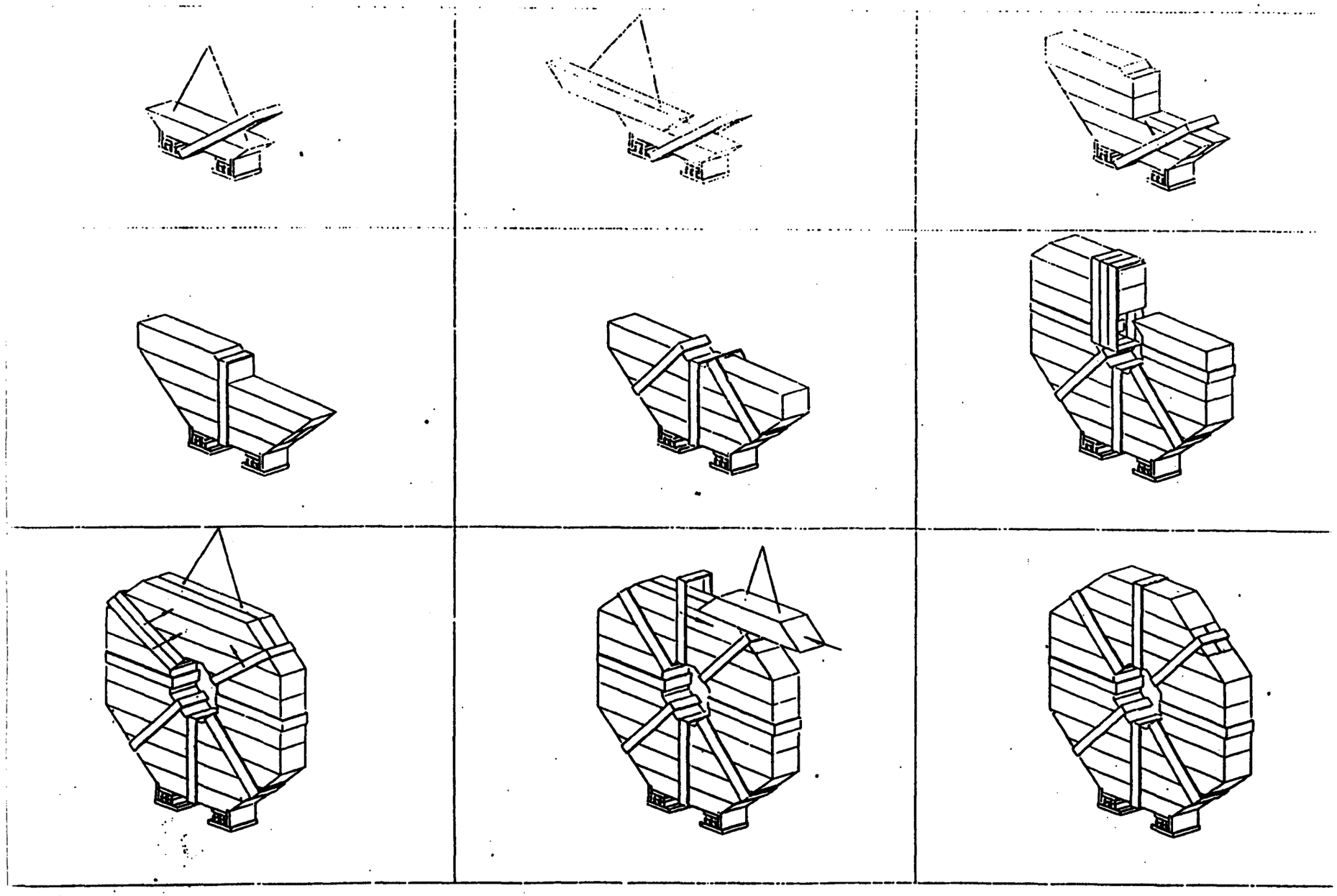
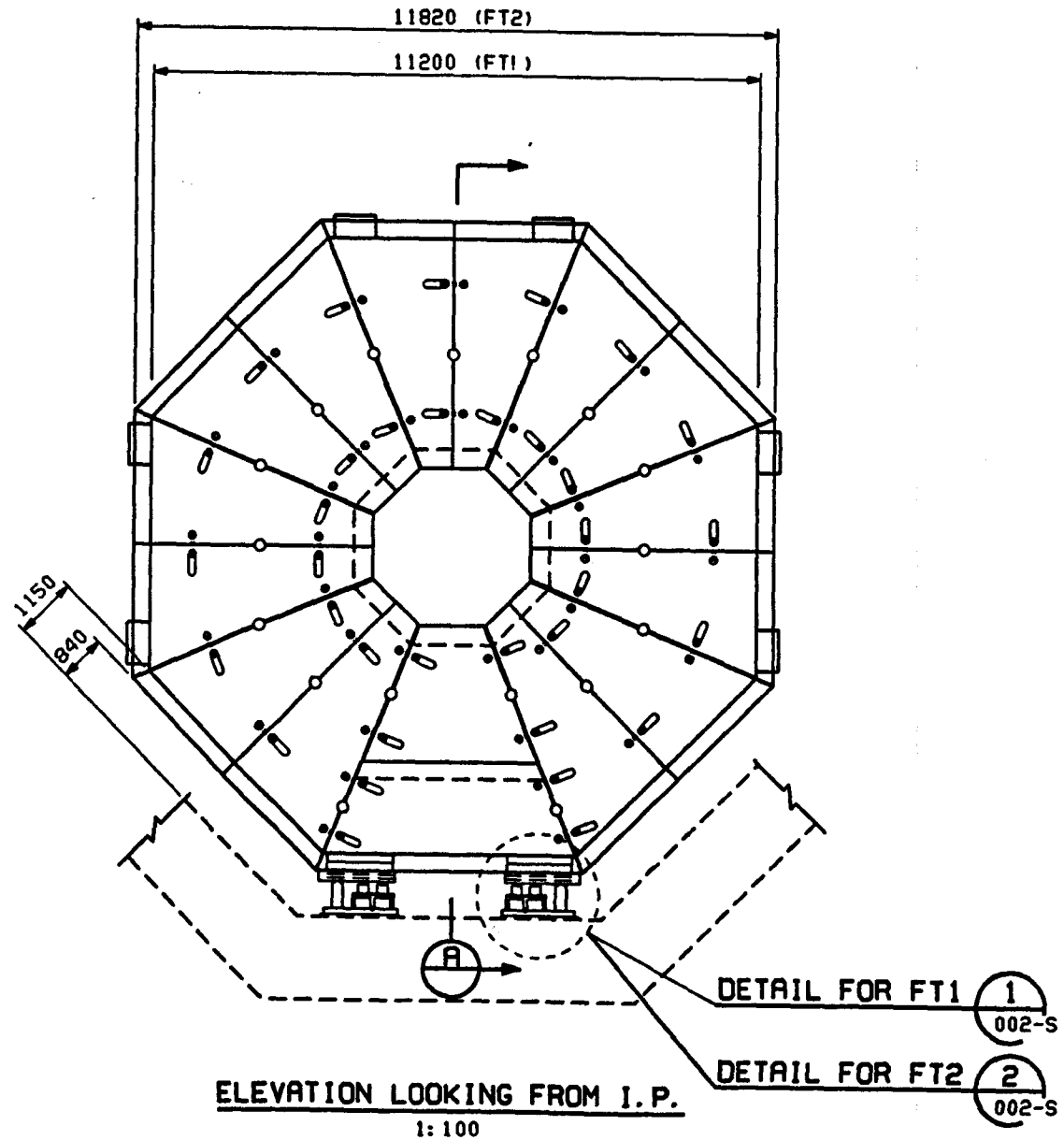
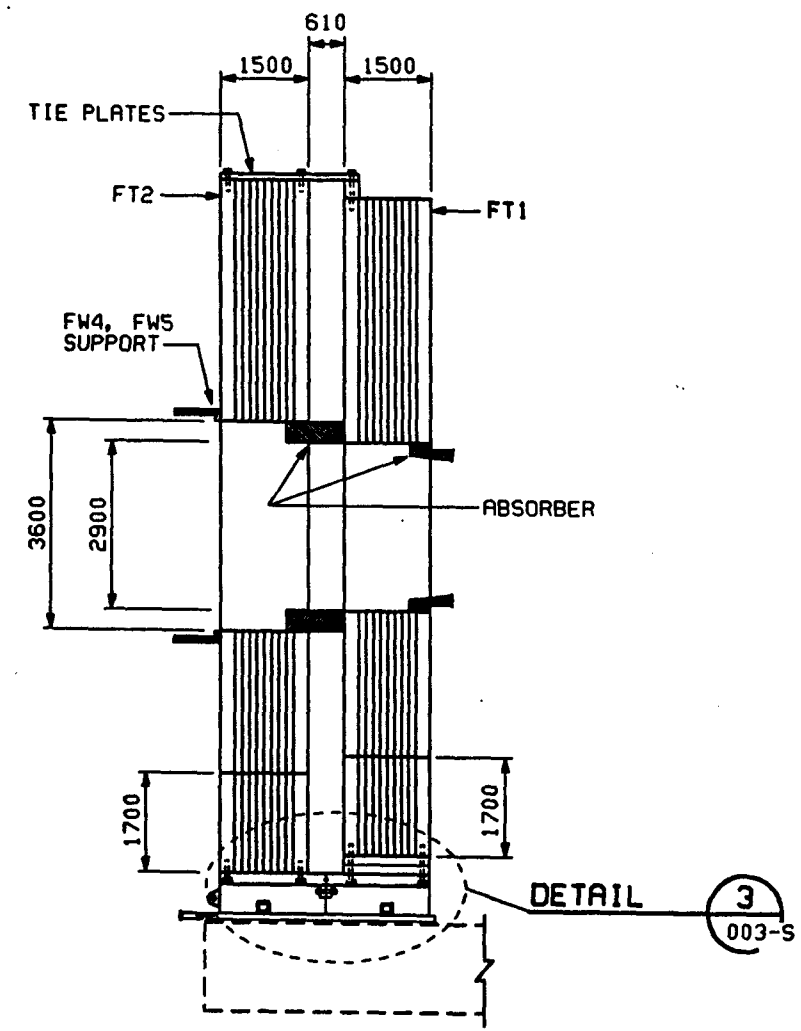


Схема сборки электромагнита.




ELEVATION LOOKING FROM I.P.
1:100




SECTION A
1:100

| NO. | DATE | REVISION | BY | APP. | APP. | FOR CODE |
|---|---|---|---|---|---|---|

NOTES

APPROVAL | DATE

SCALE: AS SHOWN

DESIGNED BY L. DITTERT 1/7/92
DRAWN BY B. FLEMETIS 1/9/92
CHECKED BY
APPROVED BY
APPROVED BY

PROFESSIONAL SEAL

ICF KAISER ENGINEERS

SDC DETECTOR

MUON FORWARD TOROID ASSEMBLY

JOB NO. 92150-001 DWG NO. 001-S REVISION R-0

PRESENTATION BY:

RUDOLPH THUN

# MUON TRIGGER COUNTERS

R. THUN 6 DEC

#2
Sat. PM

1.) SCINTILLATORS
2.) CERENKOV COUNTERS

## FUNCTION

1.) IDENTIFY BEAM CROSSING
2.) PROVIDE $P_t$ THRESHOLD
3.) MAKE MUON TRIGGER MORE ROBUST
4.) PROVIDE POSITION INFORMATION FOR CORRELATING MUON TRIGGER WITH OTHER DETECTOR ELEMENTS

# SCINTILLATOR GEOMETRY

CONSIDERED:

1.) TWO LAYERS - ONE PMT / COUNTER
2.) ONE LAYER - TWO PMT'S / COUNTER
3.) THREE LAYERS

PICK OPTION 1.)

WHY?

NOT POSSIBLE WITH 2.)
- PROVIDES $P_t$ THRESHOLD
- INSENSITIVE TO LOCAL BACKGROUNDS e.g. neutrons
- DIRECTIONALITY REDUCES COSMICS

OPTION 2 WOULD REDUCE COST ~25%

OPTION 3 NOT NECESSARY
TOO EXPENSIVE

R. THUN
3 FEB 92

# REPORT TO TECHNICAL BOARD ON MUON SCINTILLATORS

1.) BASIC IDEA

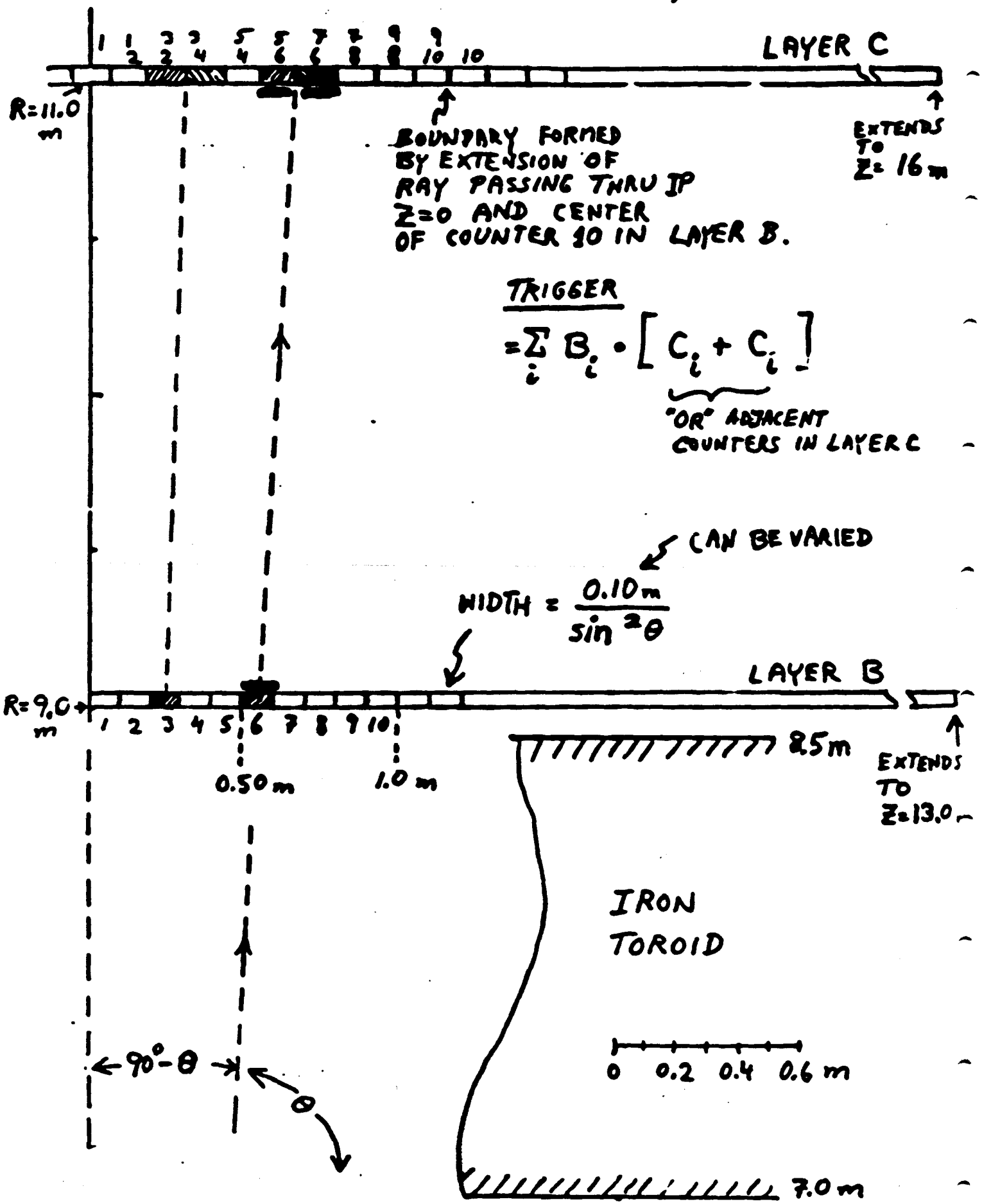
2.) MEASUREMENTS + SIMULATIONS

3.) MEETING (29 JAN 92)

K. DE (Mich)
B. ROE (Mich)
V. RYKALIN (IHEP)
R. THUN (Mich)

4.) RECOMMENDATIONS

FIG 5 CENTRAL MUON TRIGGER SCINTILLATORS
(FORWARD LAYOUT IS SIMILAR)



# COUNTER SIZE

1.) WIDTH – DETERMINED BY $P_t$ THRESHOLD REQUIREMENT

2.) LENGTH – DETERMINED BY ATTENUATION ($\lambda \sim 2m$)
LIGHT TRANSIT TIMES
$V_{eff} \sim 0.16 m/nsec$

3.) THICKNESS – $\langle n \rangle_{p.e.}$
ROBUSTNESS AGAINST SURFACE DEFECTS

WIDTH: varies { BARREL: 20 → 60 cm
INTERMED: 7 → 40 cm

LENGTH: $\lesssim 2m$

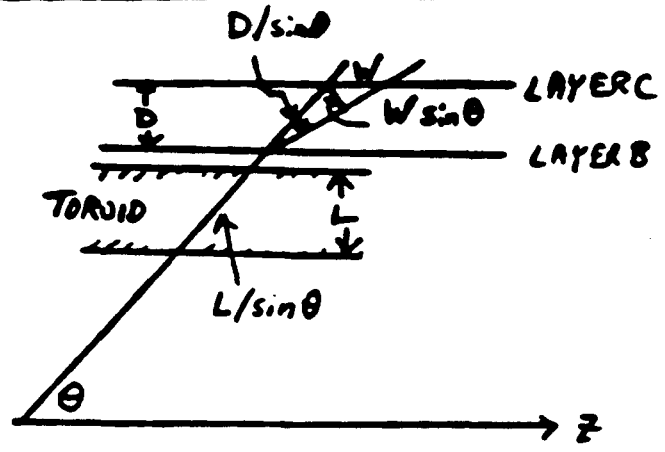
THICKNESS: $\sim 1.0$ cm $\langle n \rangle > 20$

FIG 6

# Scintillator Segmentation for Uniform $P_\perp$ Thresholds

Naively:

## 1.) CENTRAL REGION




Counter width W defines a bend-angle

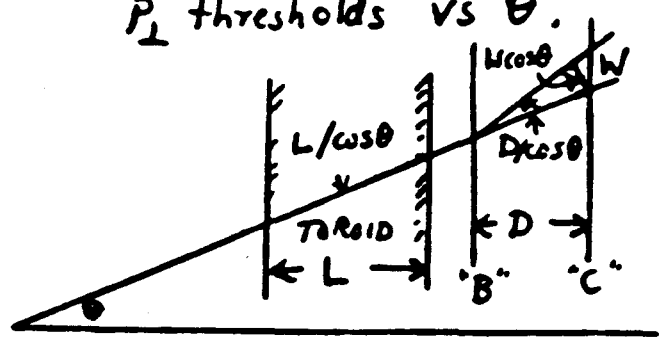
$$\alpha \approx \frac{W\sin\theta}{D/\sin\theta} = \frac{W}{D}\sin^2\theta$$

$$P_\perp = P\sin\theta \approx \frac{0.3B\frac{L}{\sin\theta}}{\alpha}\sin\theta = \frac{0.3BLD}{W\sin^2\theta}$$

so want $\boxed{W \approx \frac{0.3BLD}{P_\perp \sin^2\theta}}$

In the Monte Carlo $W = \frac{\text{const}}{\sin^2\theta}$ does give uniform $P_\perp$ thresholds vs $\theta$.

## 2.) FORWARD REGION

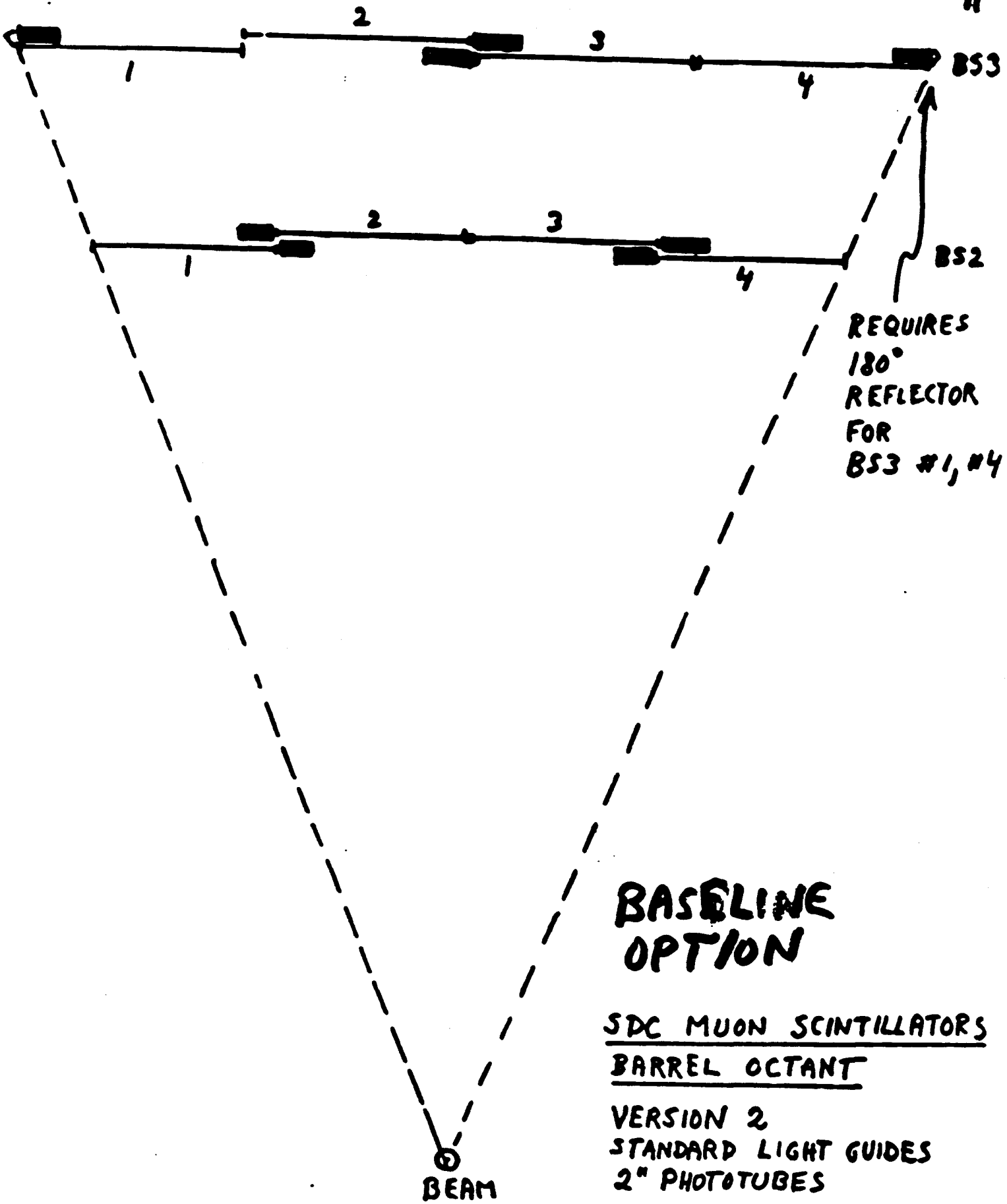



$$\alpha \approx \frac{W\cos\theta}{D/\cos\theta} = \frac{W}{D}\cos^2\theta$$

$$P_\perp = P\sin\theta \approx \frac{0.3B\frac{L}{\cos\theta}}{\frac{W}{D}\cos^2\theta}\sin\theta = \frac{0.3BLD}{W}\frac{\sin\theta}{\cos^3\theta}$$

or $\boxed{W \approx \frac{0.3BLD}{P_\perp}\frac{\sin\theta}{\cos^3\theta}}$

In the Monte Carlo, this gives a somewhat <u>non-uniform</u> response. <u>Empirically</u> $W \approx [\sin\theta]^{1.35}$ <u>works ok.</u>




# BASELINE OPTION

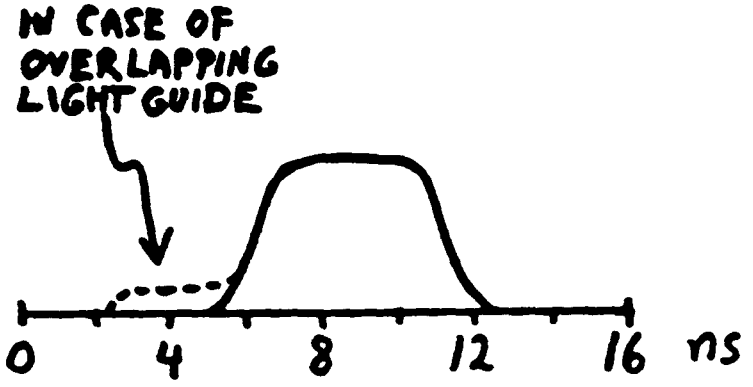
SDC MUON SCINTILLATORS

BARREL OCTANT

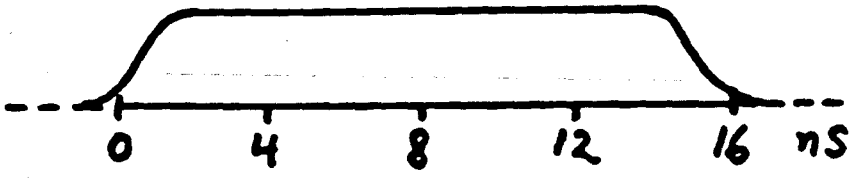
VERSION 2
STANDARD LIGHT GUIDES
2" PHOTOTUBES

6100 PMts IN BARREL

12-NOV-91



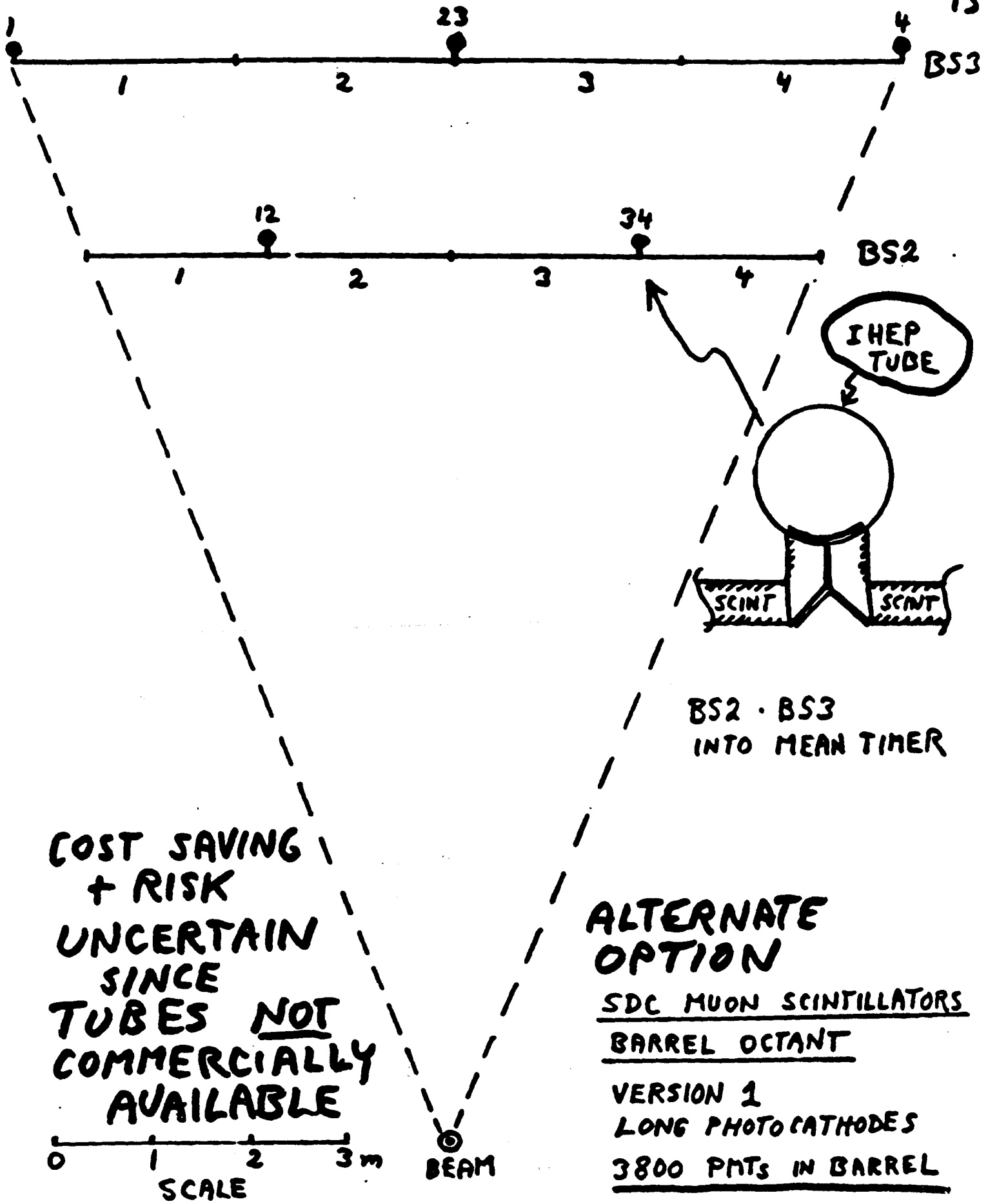

BS2 · BS3
MEAN-TIMER
OUTPUT




BS2

BARREL MUON TIME DISTRIBUTIONS

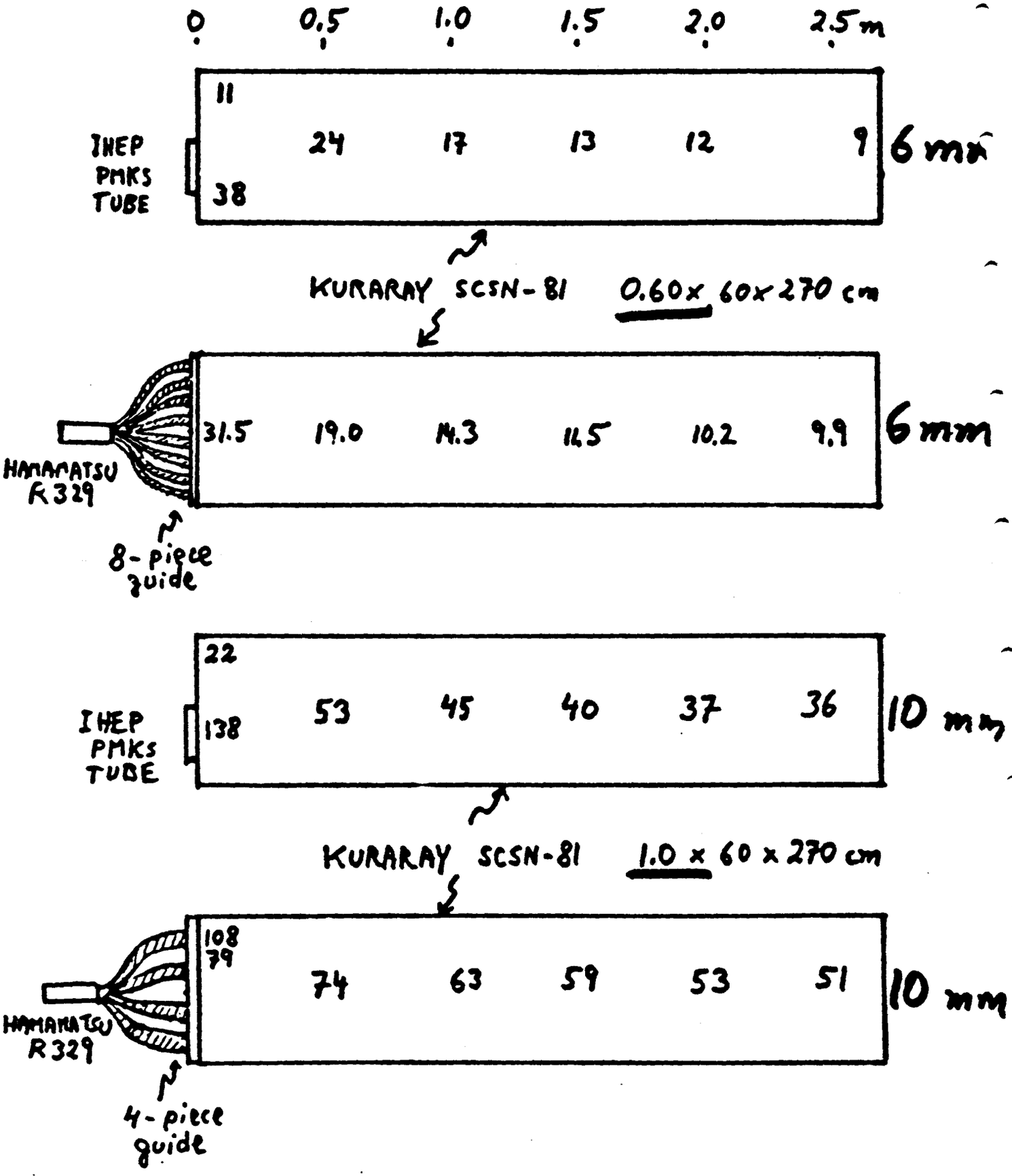
12 NOV 91


1
23
4
BS3
1
2
3
4
12
34
BS2
1
2
3
4
IHEP TUBE
SCINT
SCINT
BS2 · BS3
INTO MEAN TIMER
COST SAVING
+ RISK
UNCERTAIN
SINCE
TUBES NOT
COMMERCIALLY
AVAILABLE
0
1
2
3 m
SCALE
BEAM
ALTERNATE
OPTION
SDC MUON SCINTILLATORS
BARREL OCTANT
VERSION 1
LONG PHOTOCATHODES
3800 PMTs IN BARREL

12 NOV 91

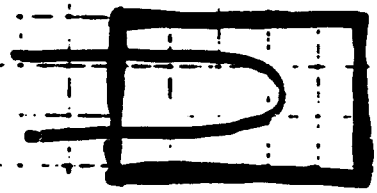
12 NOV 91

# SOME RESULTS ON PHOTOELECTRON YIELDS



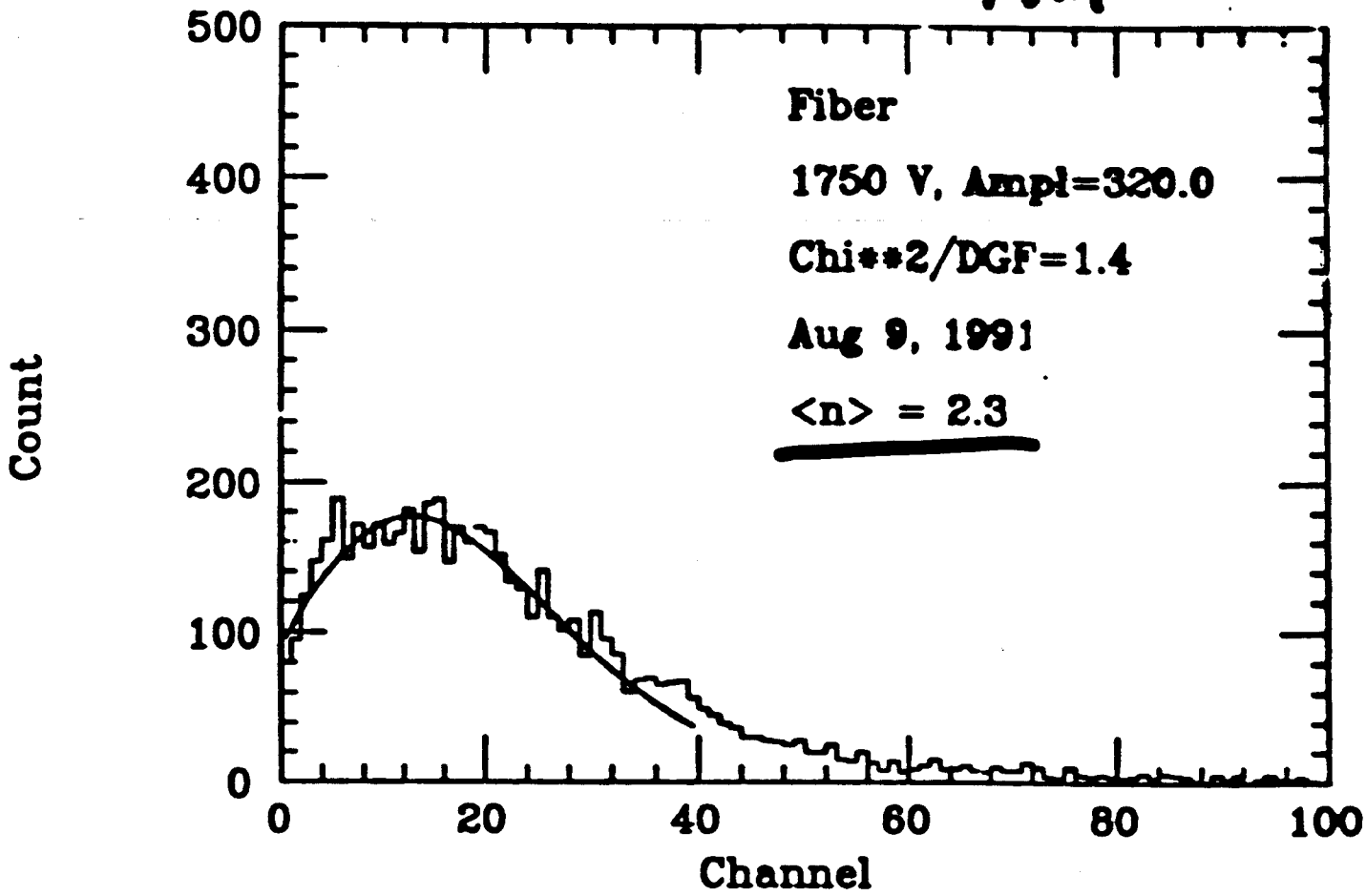
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 501-510 | 20 | 601-610 | 9 | 701-710 | 8 | 801-810 | 3 | 901-910 | 15 |
| 510 | 20 | 610 | 11 | 710 | 13 | 810 | 4 | 910 | 9 |
| 520 | 25 | 620 | 15 | 720 | 10 | 820 | 6 | 920 | 9 |
| 530 | 15 | 630 | 9 | 730 | 4 | 830 | 3 | 930 | 2 |
| 540 | 14 | 640 | 9 | 740 | 3 | 840 | 6 | 940 | 2 |
| 550 | 20 | 650 | 11 | 750 | 10 | 850 | 5 | 950 | 2 |
| 560 | 13 | 660 | 8 | 760 | 5 | 860 | 4 | 960 | 2 |
| 570 | 8 | 670 | 7 | 770 | 4 | 870 | 1 | 970 | 4 |
| 580 | 4 | 680 | 10 | 780 | 5 | 880 | 0 | 980 | 1 |
| 590 | 7 | 690 | 8 | 790 | 4 | 890 | 5 | 990 | 0 |
| | | | | | | | | 1000 | 1 |
| | | | | | | | | 1010 | 1 |
| | | | | | | | | 1020 | 1 |

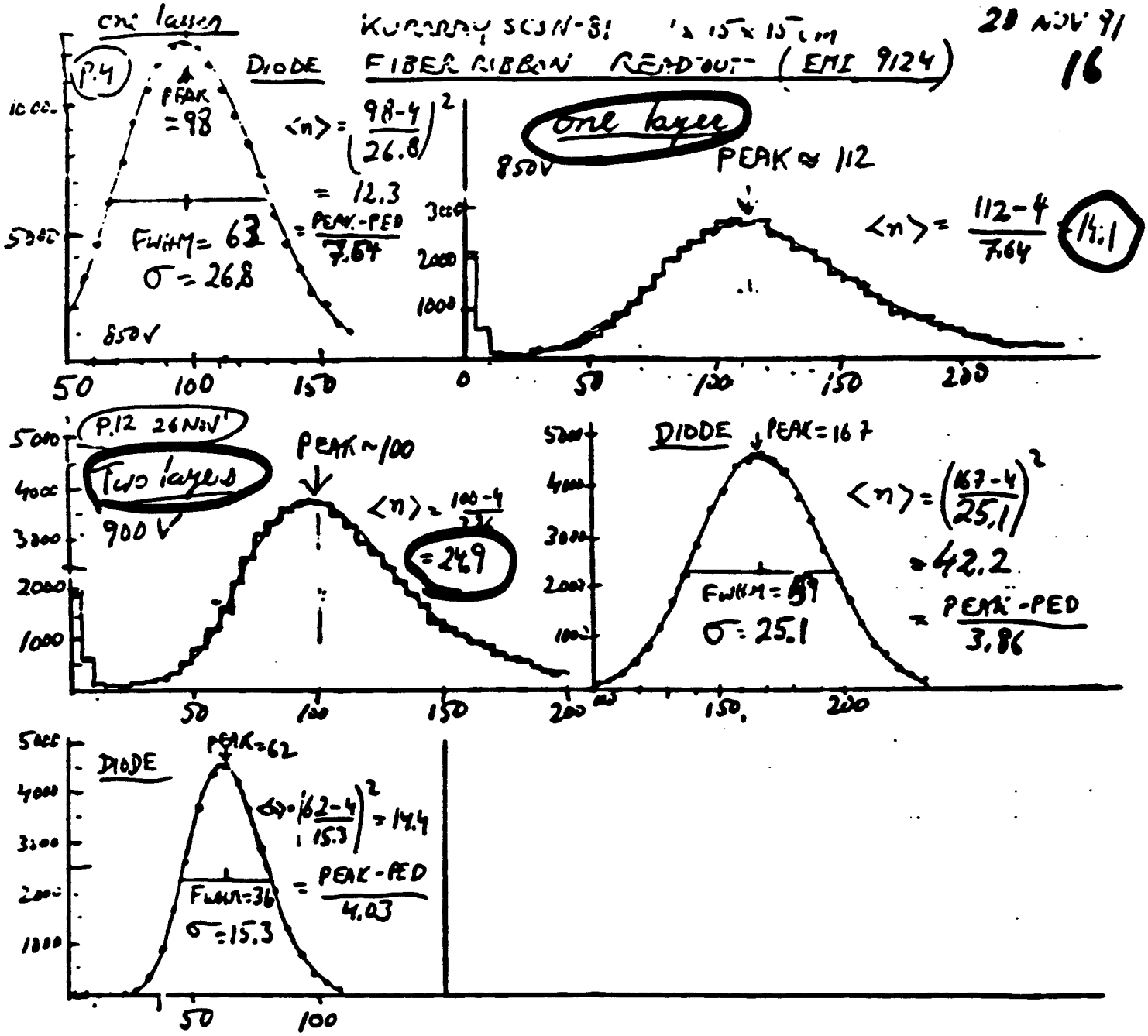
BCF 91A

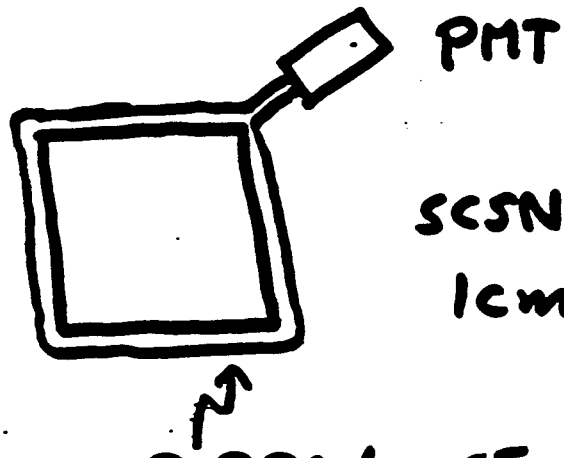


SCSN-81

1 cm

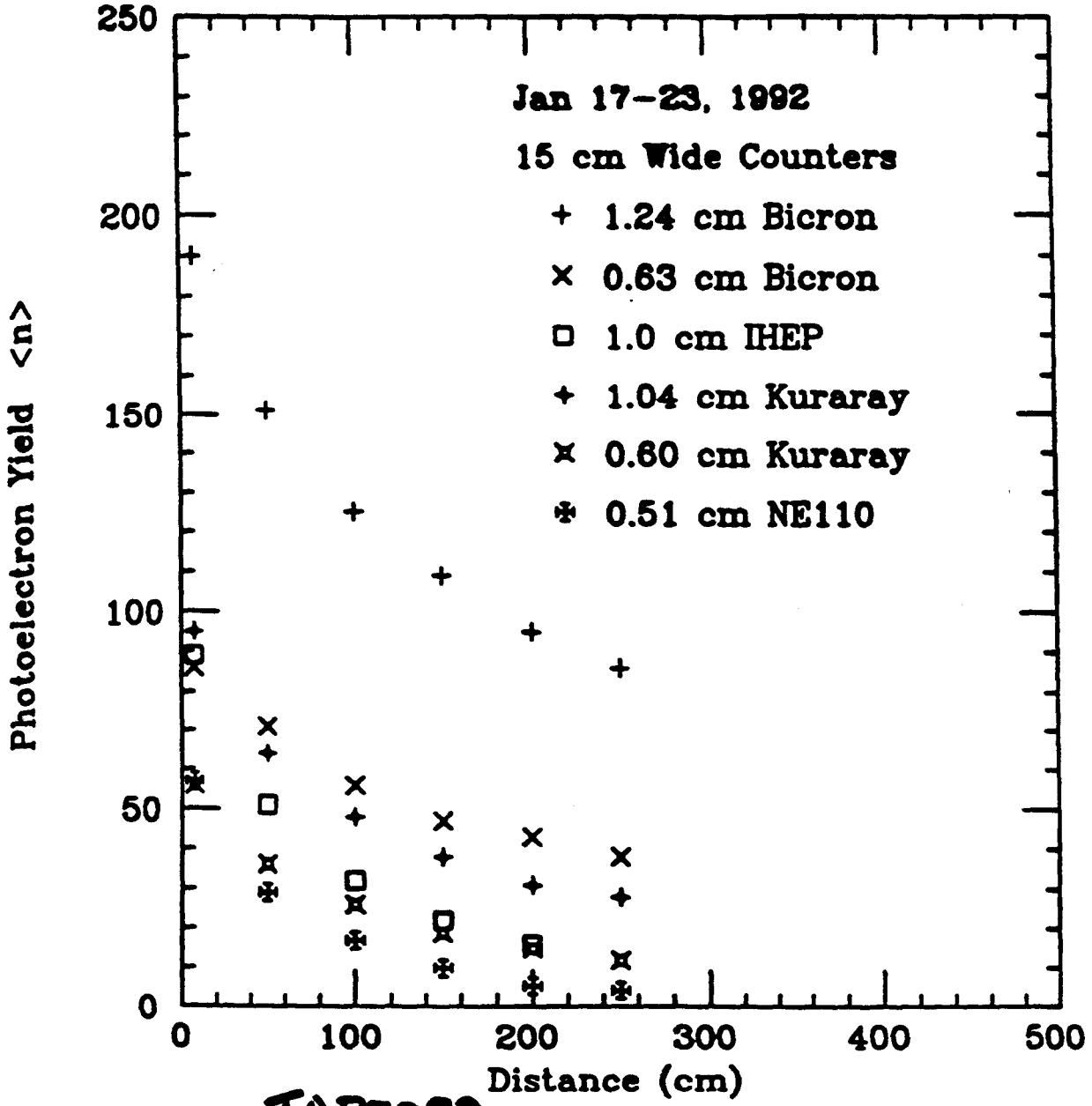


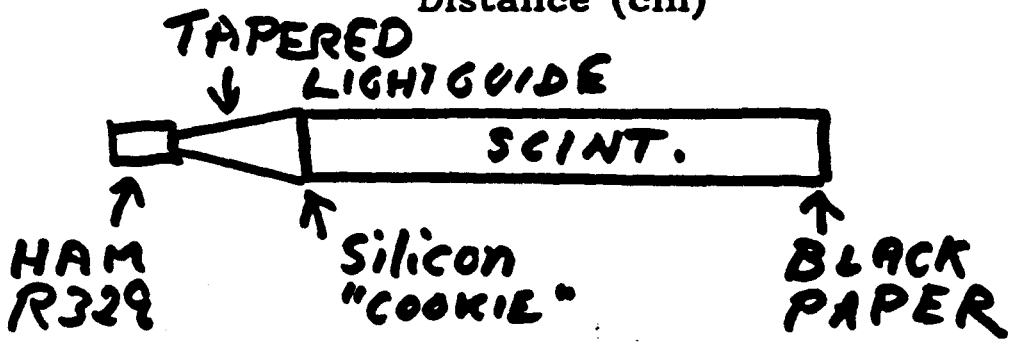


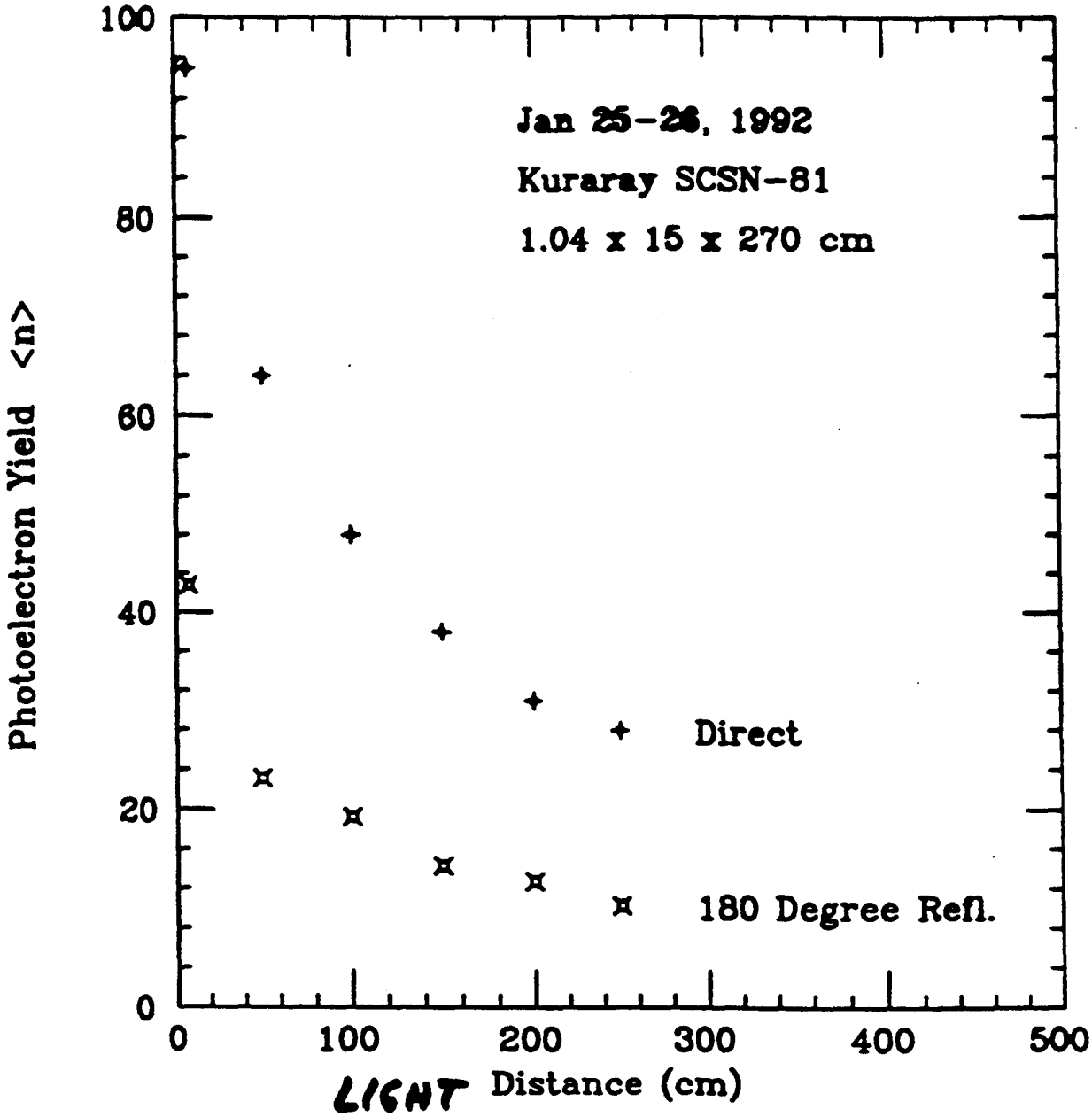



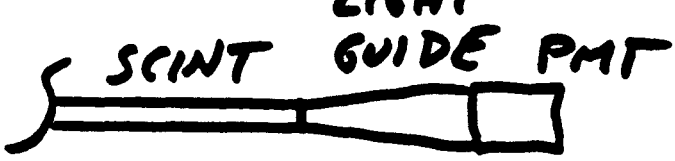

$\langle n \rangle = 14$
for one layer

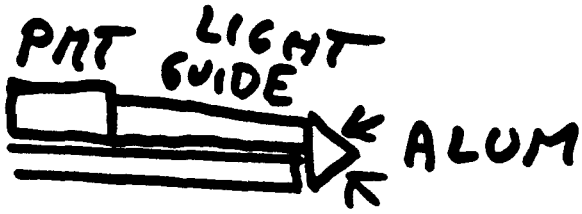
$\langle n \rangle = 25$
for two layers

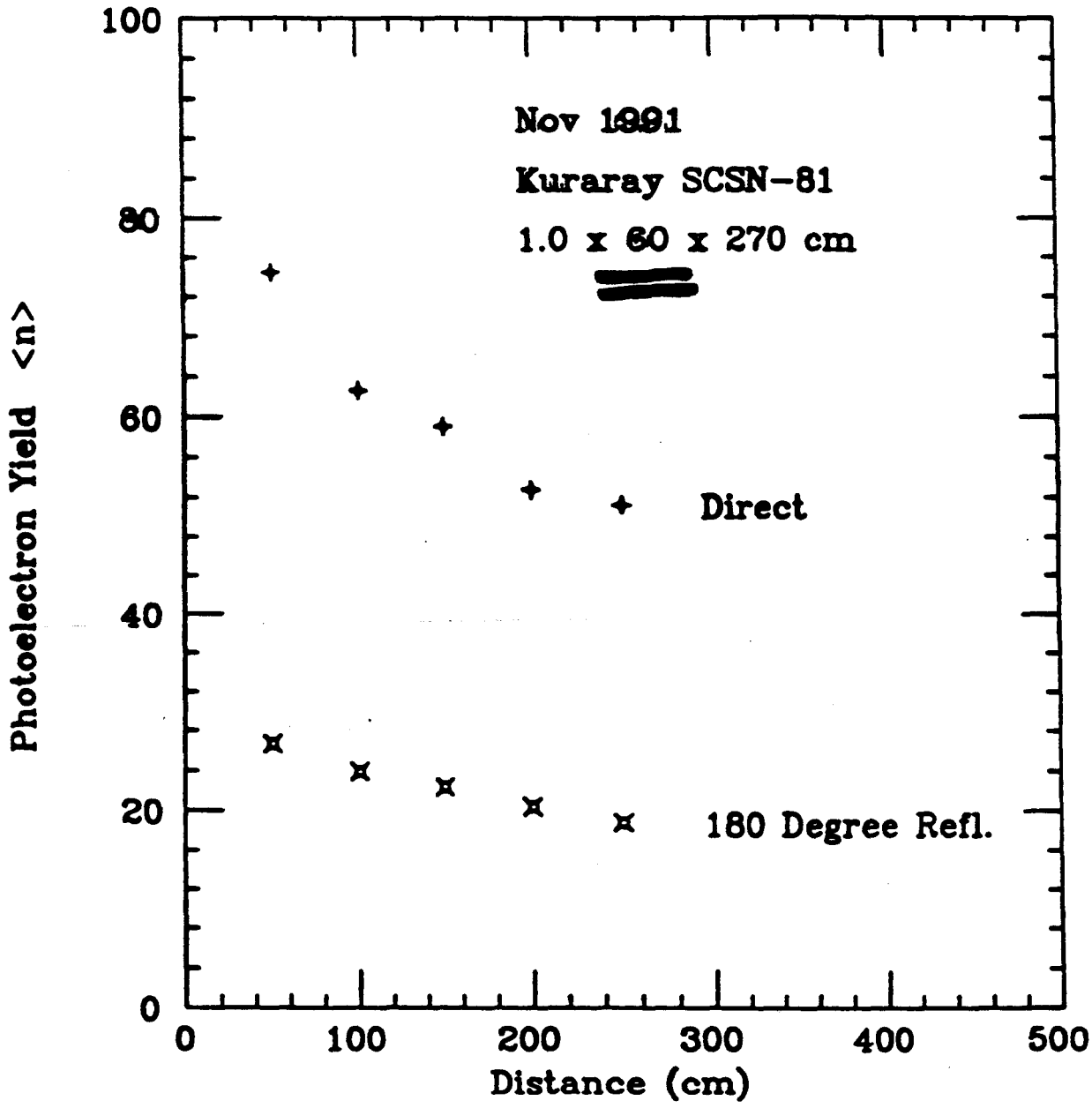

Jan 17–23, 1992
15 cm Wide Counters
1.24 cm Bicron
0.63 cm Bicron
1.0 cm IHEP
1.04 cm Kuraray
0.60 cm Kuraray
0.51 cm NE110
Photoelectron Yield <n>
Distance (cm)
0
50
100
150
200
250
0
100
200
300
400
500


TAPERED
LIGHTGUIDE
SCINT.
HAM
R329
Silicon
"COOKIE"
BLACK
PAPER

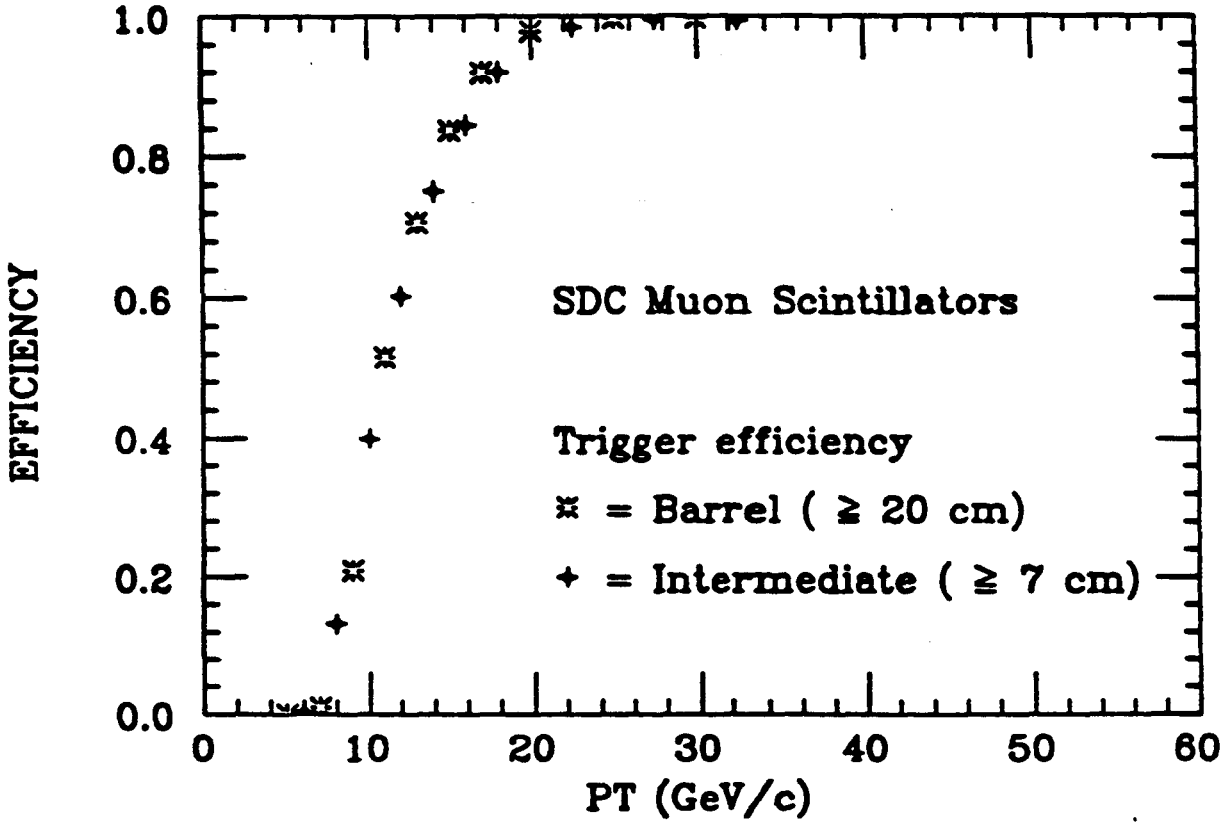

Jan 25-26, 1992
Kuraray SCSN-81
1.04 x 15 x 270 cm
Direct
180 Degree Refl.
Photoelectron Yield <n>
Distance (cm)
0
20
40
60
80
100
0
100
200
300
400
500


SCINT
LIGHT GUIDE
PMT


PMT
LIGHT GUIDE
ALUM



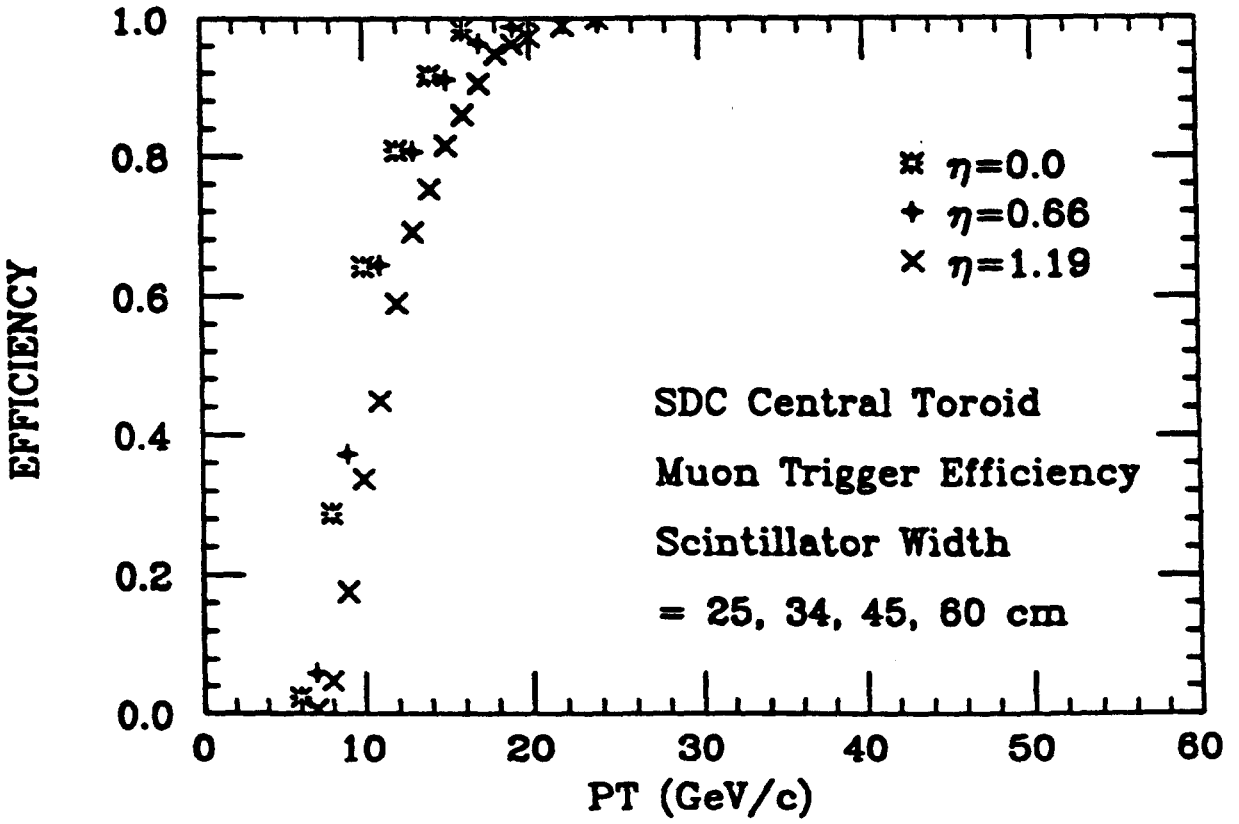

4- PIECE TWISTED-STRIP LIGHT GUIDE




Barrel $W = \frac{20\,cm}{\sin^2\theta}$

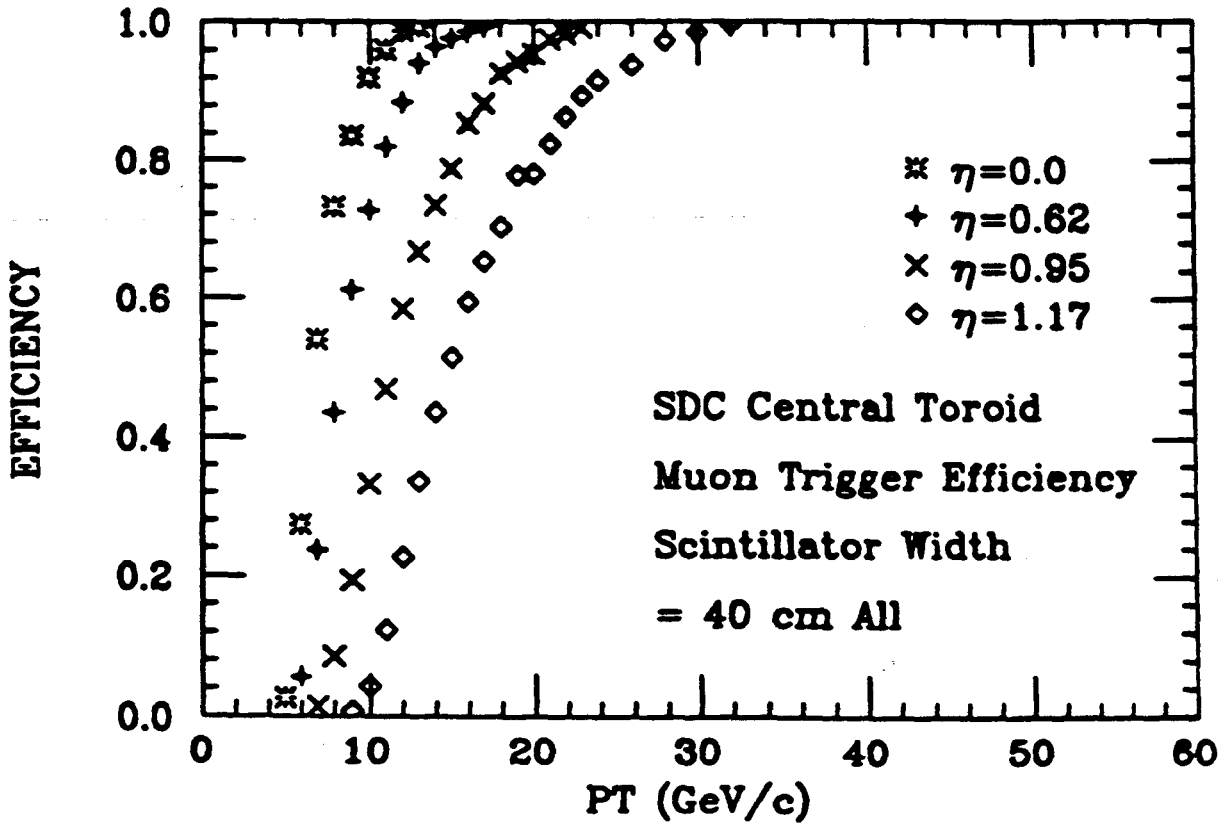
INTERM. $W \sim CONST\,(\sin\theta)^{1.35}$

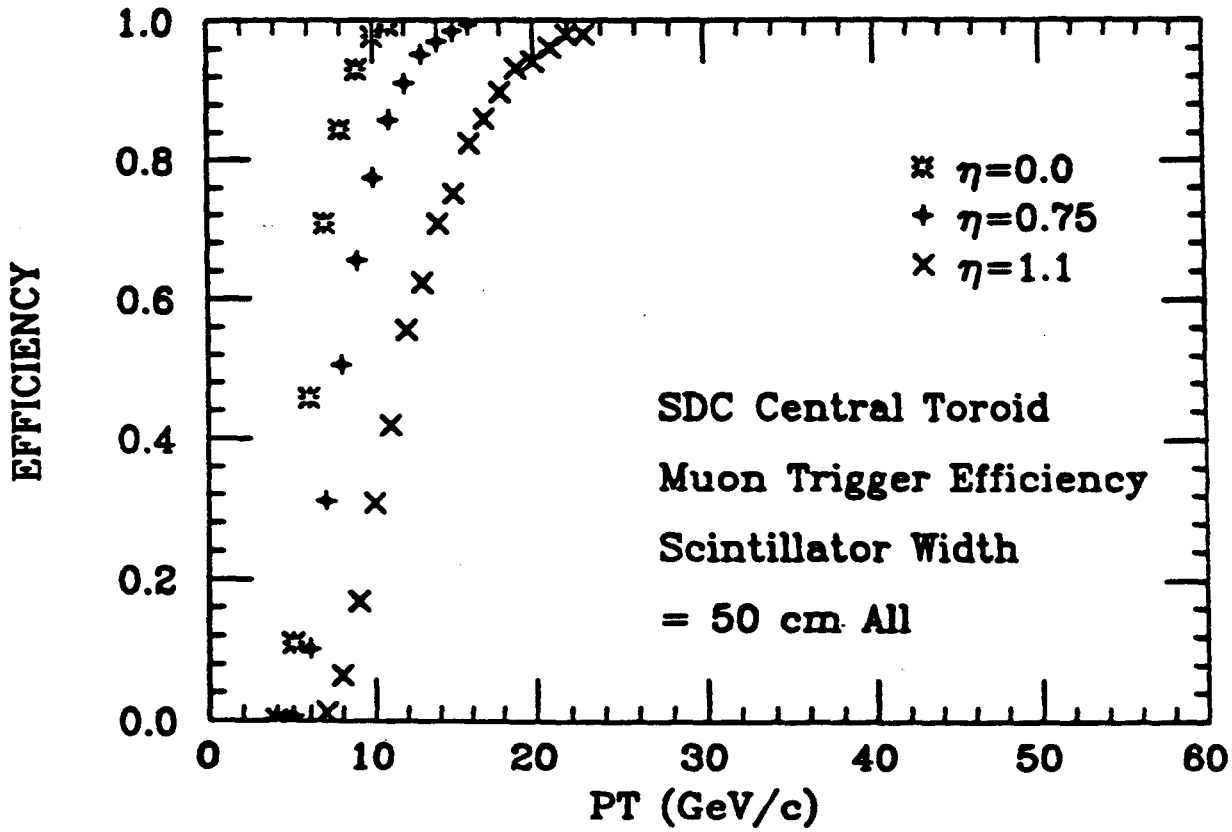
$= 7\,cm$ at $\eta = 2.5$




WIDTHS STEPPED

20 x 25cm
12 x 34 cm
6 x 45cm
5 x 60 cm


1.0
0.8
0.6
0.4
0.2
0.0
EFFICIENCY
0
10
20
30
40
50
60
PT (GeV/c)
η=0.0
η=0.62
η=0.95
η=1.17
SDC Central Toroid
Muon Trigger Efficiency
Scintillator Width
= 40 cm All


1.0
0.8
0.6
0.4
0.2
0.0
EFFICIENCY
0
10
20
30
40
50
60
PT (GeV/c)
η=0.0
η=0.75
η=1.1
SDC Central Toroid
Muon Trigger Efficiency
Scintillator Width
= 50 cm All

# BARREL OPTIONS

| | WIDTHS (m) | CHANNEL COUNT |
|---|---|---|
| 1.) | $\frac{0.20}{\sin^2\theta}$ | 6144 |
| 2.) | 0.25, 0.34, 0.45, 0.60 | 5504 |
| 3.) | 0.40 | 4736 |
| 4.) | 0.50 | 3840 |

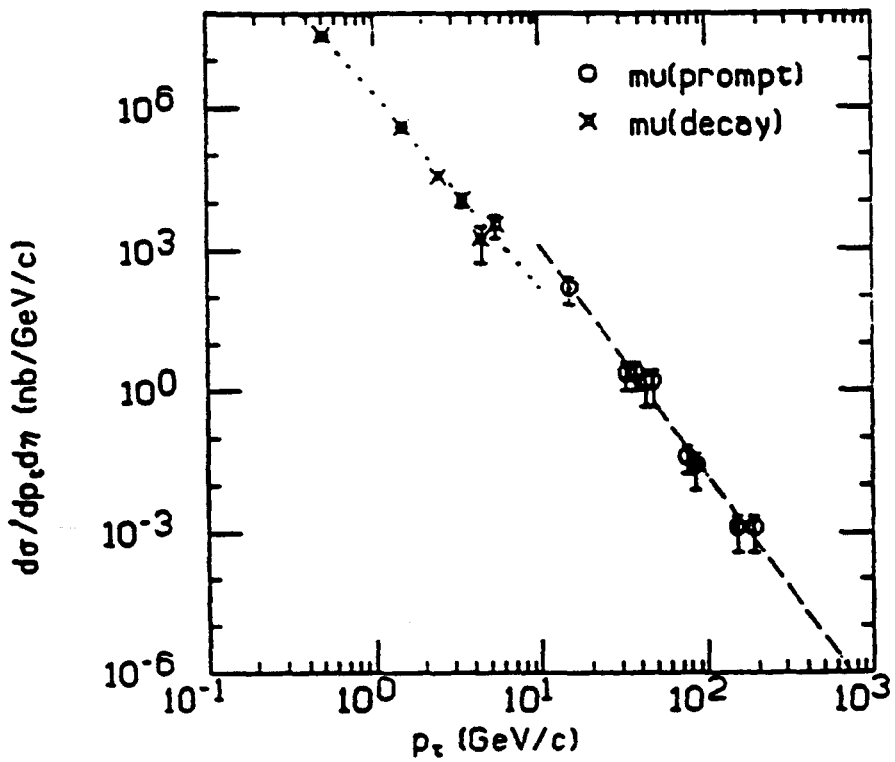
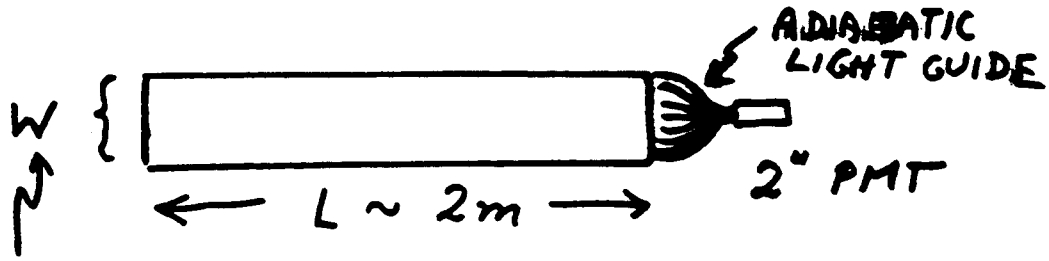



Fig. 3.2.1 Differential cross section, $d\sigma/dp_t\, d\eta$ as a function of $p_t$ for prompt muons (open circle) and decay muons (x-mark). These points are calculated by using PYTHIA5.3. The dashed and dotted lines are the best fitted functions given in the text.

# RECOMMEND:

## 1.) FOR 1 APRIL 92 TECHNICAL PROPOSAL:

### a.) "BASELINE" DESIGN (BARREL)



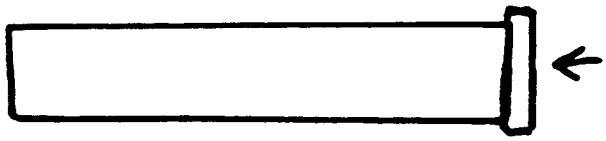

VARIES FROM ~ 0.25 → 0.60 m
IN DISCRETE STEPS TO PROVIDE
UNIFORM $P_\perp$ RESPONSE (4 OR 5 SIZES)

REQUIRE $\langle n \rangle_{p.e} > 20$ EVERYWHERE

→ SCINT. THICKNESS ~ 1.0 cm

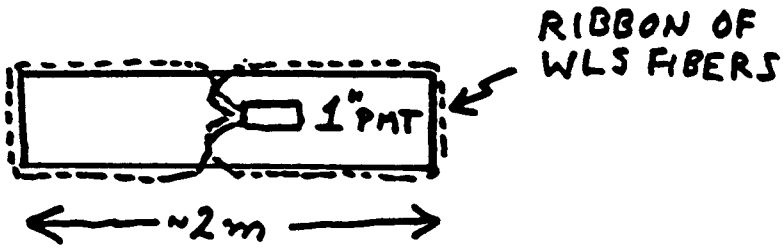
### b.) TWO ALTERNATE OPTIONS

(i)

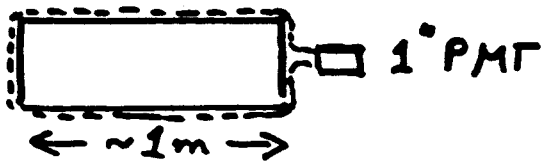



(AT PRESENT NOT INDUSTRIALLY AVAILABLE)

(ii)




OR



2.) MORE R&D BEFORE COMMITTING TO FINAL DESIGN

a.) OPTIMIZE "BASELINE" DESIGN AND BUILD COUNTERS

b.) TEST WLS FIBER READOUT ON LARGE COUNTER

c.) FURTHER WORK ON PMT WITH LARGE PHOTOCATHODE

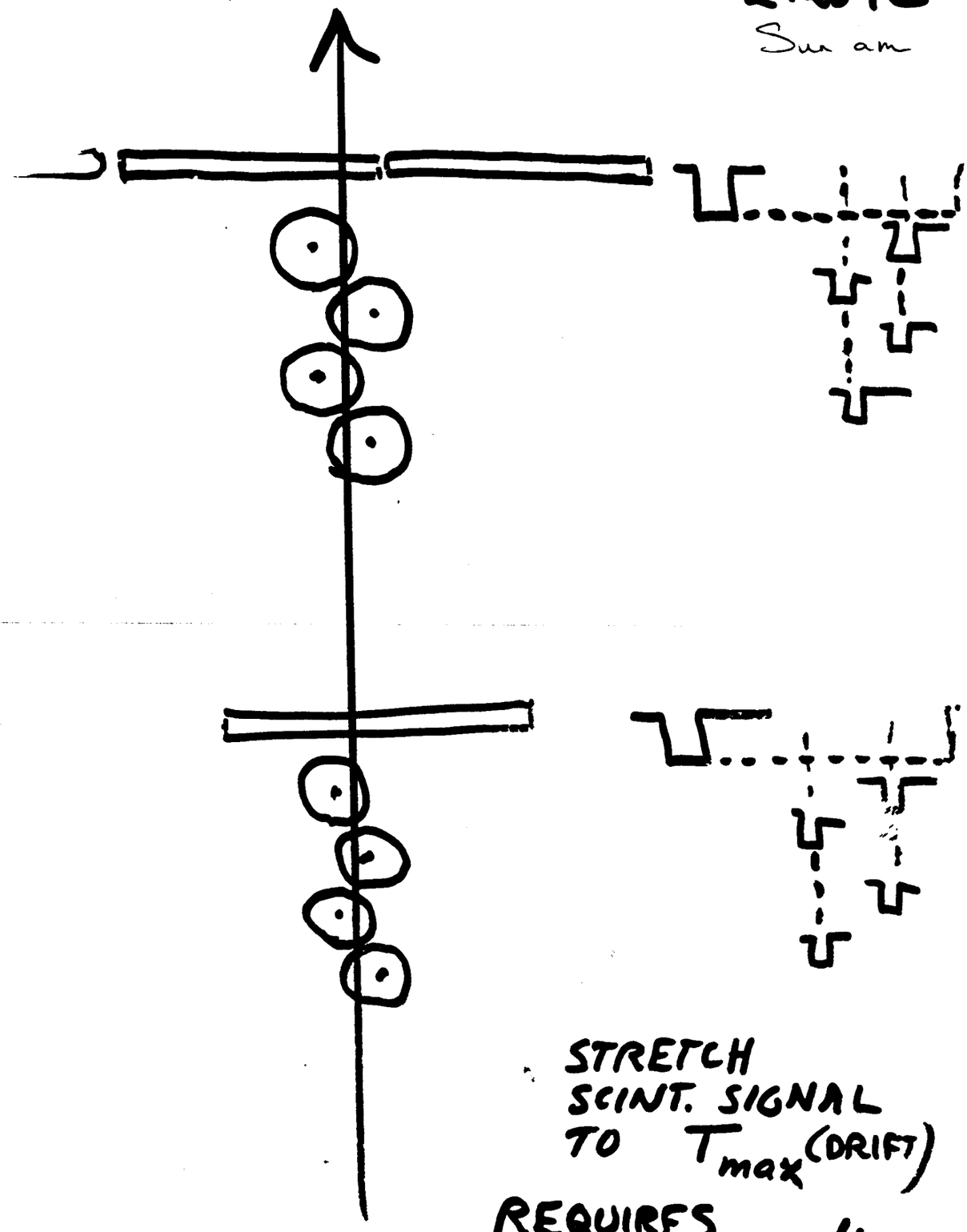
d.) SCINTILLATOR R&D (IHEP)
$\gamma$-YIELD, $\lambda_{ATT}$

e.) INTEGRATION WITH WIRE-CHAMBER DESIGN

PRESENTATION BY:

RUDOLPH THUN

R THUN
2 Feb 92
Sun am



STRETCH
SCINT. SIGNAL
TO $T_{max}$ (DRIFT)

REQUIRES
RATE $\lesssim 10^4$
PER SEGMENT

COSTS K$

| | PROCURE | EDIA | CONTINGENCY | TOTAL |
|---|---|---|---|---|
| BS2 | 3185 | 335 | 1006 | 4527 |
| BS3 | 3413 | 359 | 1078 | 4850 |
| IS2 | 349 | 37 | 147 | 533 |
| IS3 | 888 | 93 | 373 | 1354 |
| FS4 | 1001 | 105 | 421 | 1527 |
| FS5 | 1335 | 140 | 561 | 2037 |
| | 10171 | | | 14828 |

BICRON "QUOTE"

SCINT $860/m^2$

AREA BS2 = $1800\ m^2$ = 1.550 M$

EDIA DOES NOT SCALE SINCE BS2 AND BS3 HAVE SAME DESIGN

IF COST IS TO BE REDUCED:

1.) DO <u>NOT</u> GET RID OF 2 LAYERS

<u>BUT RATHER</u>

2.) REDUCE SEGMENTATION
e.g. in BARREL

| WIDTH (m) | CHANNEL COUNT |
|---|---|
| 0.25, 0.34, 0.45, 0.60 | 5504 |
| ALL 0.50 | 3840 |
| | 1664 |

PMT \$300
LIGHT GUIDE \$100
HV, CABLES \$100
CALIBRATION, MISC \$100
EDA/CONT \$200

\$800 /CH × 1664 = 1.34 M\$
IN BARREL

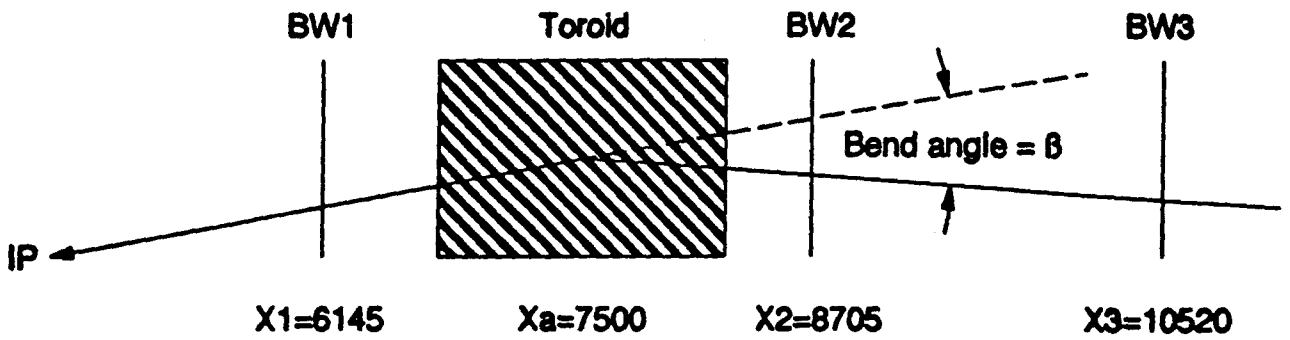
PRESENTATION BY:

JIM BENSINGER

Bensinger
Sept pm

# Muon System Stand Alone

## Measurements at 90° in BW1, BW2, and BW3 only




- Resolution for the point-line method:

$$\beta\,(\text{radians}) = \frac{810 \times 10^{-6}}{P_t\,(\text{TeV})}$$

- Measurement only:

$$\frac{\delta P_t}{P_t} = \frac{\sigma(\text{wire})}{1.62 \times 10^{-3}} \cdot \frac{\sqrt{(x_3-x_2)^2+(x_3-x_1)^2+(x_2-x_1)^2}}{(x_a-x_1)\cdot(x_3-x_2)} \cdot P_t = 1.36\,\sigma(\text{mm})\,P_t(\text{TeV})$$

Multiple scattering: $\frac{\delta P_t}{P_t} = .2$

- ~~Combined error~~:

for $\sigma = .25$ mm

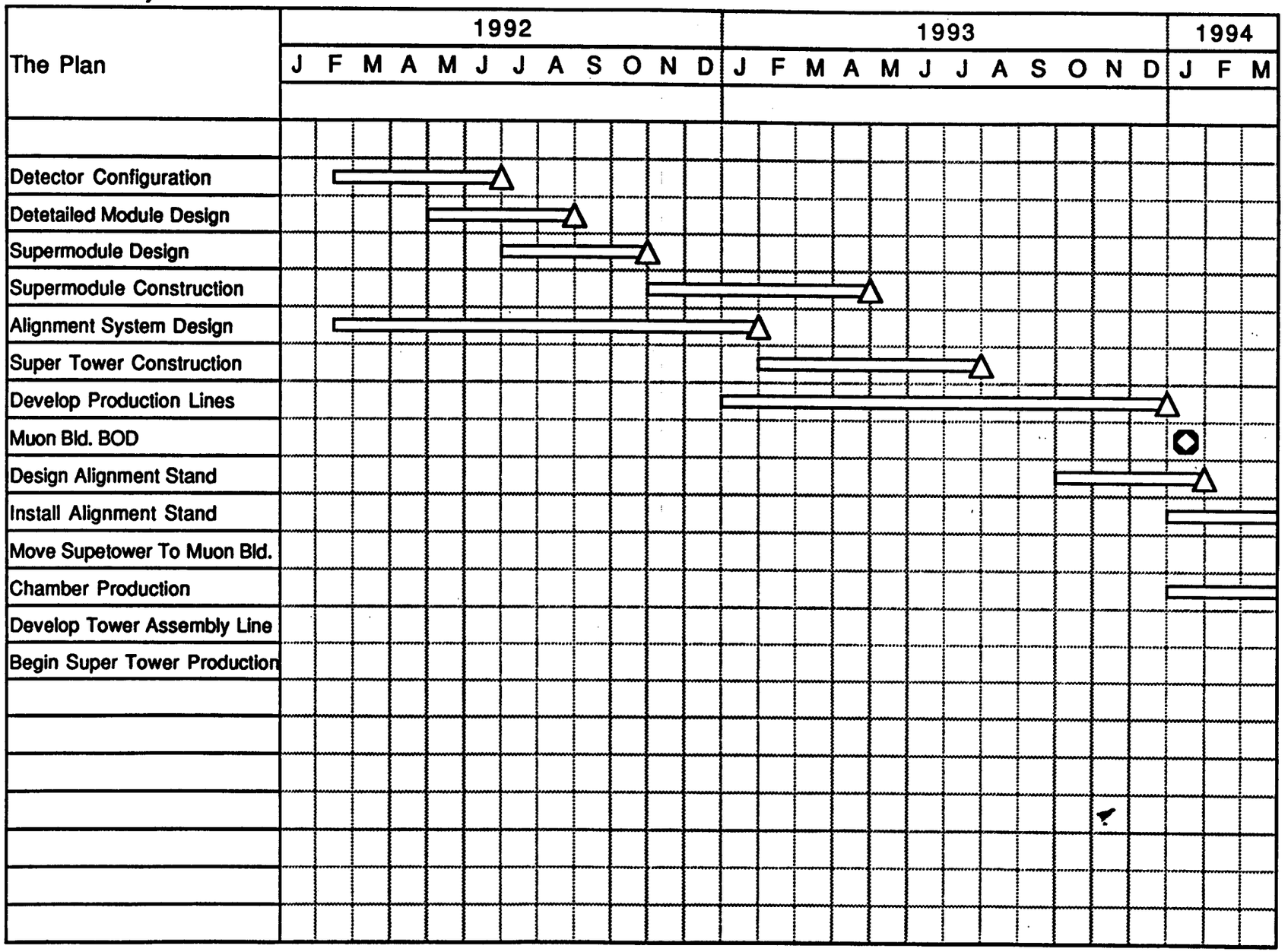
$$\frac{\delta P_t}{P_t} = .54\,P_t$$

$= .29\,P_t$ for BW3 + .5 m

$= .27\,P_t$ for BW3 + 1 m

$= .25\,P_t$ for BW3 + 1.5 m

SDC Muon System



## SDC Muon System WBS (Baseline for 1/17/92 Cost Roll-Up)

| WBS # | | Base ($k) | Contingency % | Total with Contingency ($k) |
|---|---|---|---|---|
| 3.1 | Magnet System | | | |
| 3.1.1 | Barrel Toroid | 33,472 | 19.1% | 39,851 |
| 3.1.2 | Forward Toroids | 8,581 | 31.3% | 11,268 |
| 3.1.3 | Utilities | 976 | 30.0% | 1,269 |
| 3.1.4 | Forward Absorber | 1,137 | 34.0% | 1,523 |
| | Total Magnet System | 44,166 | 22.1% | 53,911 |
| 3.2 | Muon Measurement System | | | |
| 3.2.1 | Tracking Chambers | 15,212 | 20.3% | 18,304 |
| 3.2.2 | Support Structure | 2,559 | 31.9% | 3,375 |
| 3.2.3 | Alignment System | 4,266 | 34.0% | 5,717 |
| 3.2.4 | Handling Fixtures | 2,017 | 30.0% | 2,622 |
| 3.2.5 | Local Utilities | 303 | 30.0% | 394 |
| 3.2.6 | Trigger Counters | 11,242 | 31.9% | 14,827 |
| 3.2.7 | Super-Module Assembly | 6,146 | 34.0% | 8,233 |
| 3.2.8 | Global Utilities | 2,182 | 24.0% | 2,706 |
| 3.2.9 | Transportation | 566 | 13.0% | 639 |
| 3.2.10 | Spares | 504 | 24.0% | 625 |
| 3.2.11 | Prototype | 1,566 | 24.0% | 1,942 |
| | Total Muon Measurement System | 46,563 | 27.5% | 59,385 |
| 3 | Total Muon System | 90,728 | 24.9% | 113,296 |

| | Total | Barrel | Inter. | Forward | Tooling |
|---|---|---|---|---|---|
| Chambers | 18.301 | 9.111 | 2.135 | 6.425 | .631 |
| Support | 3.380 | 2.438 | .348 | .594 | |
| Alignment | 5.716 | | | | |
| Assy. Tooling | 2.616 | .244 | .265 | | 2.106 |
| Scint Counters (PM) | 14.828 (2.769) | 9.377 (1.751) | 1.886 (.223) | 3.565 (.795) | |
| Assembly | 8.227 | 4.463 | 1.393 | 2.371 | |
| Utilities | 3.090 | | | | |
| Transportation | .640 | | | | |
| Spares | .627 | | | | |
| Prototypes | 1.951 | | | | |

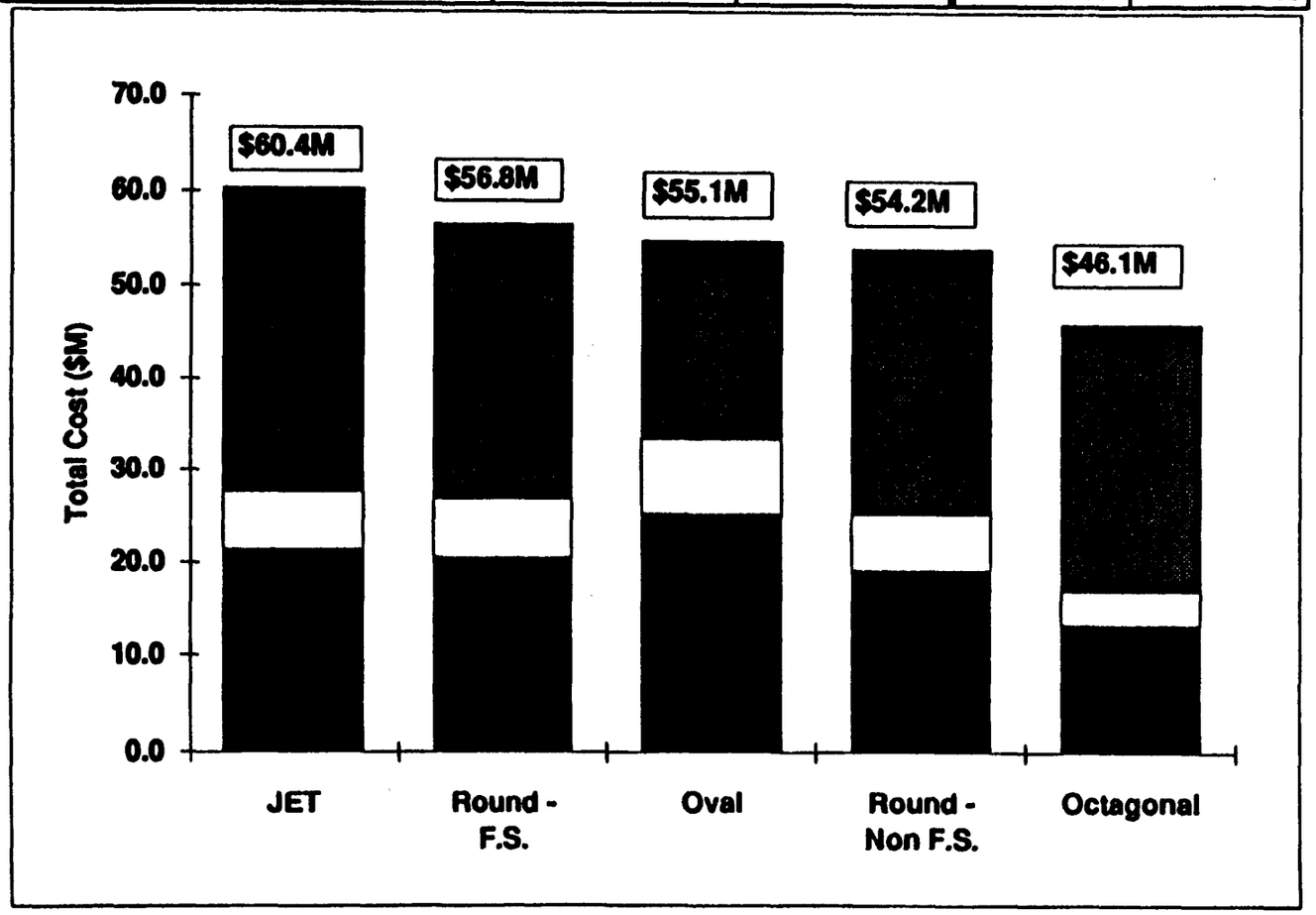
JRS 2/2/92

## SDC Muon System WBS (Baseline for 1/17/92 Cost Roll-Up)

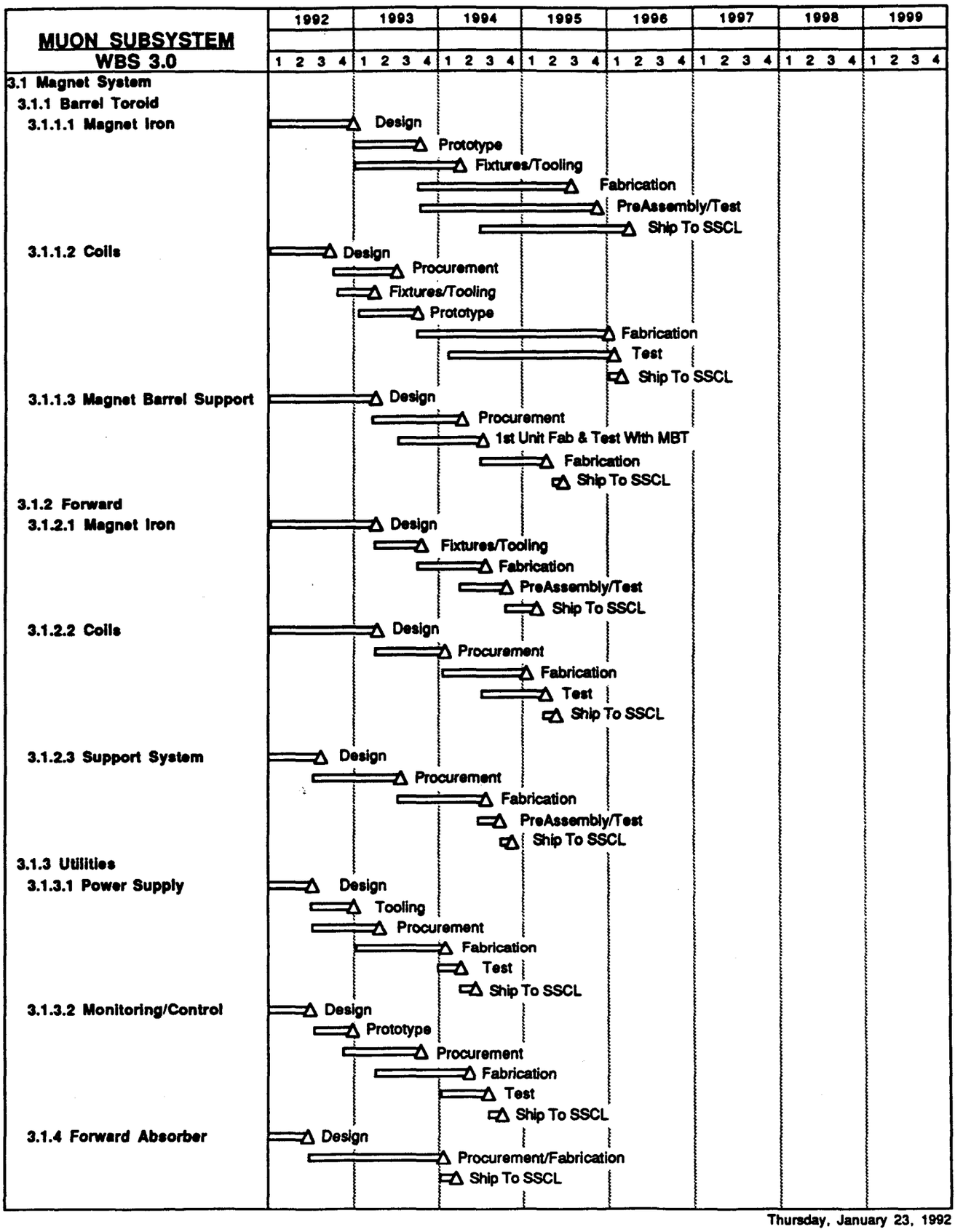
| | Procurement ($k) | Mfg Labor ($k) | EDIA ($k) | Total ($k) | Cont. ($k) | Total with Cont. ($k) |
|---|---|---|---|---|---|---|
| **Barrel** | | | | | | |
| BT | 22,087 | 5,764 | 6,397 | 34,247 | 6,585 | 40,832 |
| BW1 | 1,772 | 1,147 | 1,542 | 4,460 | 1,045 | 5,506 |
| BW2 | 1,709 | 876 | 1,188 | 3,773 | 834 | 4,607 |
| BW3 | 5,353 | 2,569 | 3,434 | 11,356 | 2,465 | 13,821 |
| BS2 | 3,185 | 0 | 335 | 3,520 | 1,006 | 4,527 |
| BS3 | 3,413 | 0 | 359 | 3,772 | 1,078 | 4,850 |
| **Total Barrel** | 37,518 | 10,356 | 13,254 | 61,128 | 13,014 | 74,142 |
| **Intermediate** | | | | | | |
| IW2 | 239 | 158 | 169 | 566 | 154 | 720 |
| IW3 | 1,718 | 1,087 | 1,176 | 3,981 | 1,081 | 5,062 |
| IS2 | 349 | 0 | 37 | 386 | 147 | 533 |
| IS3 | 888 | 0 | 93 | 981 | 373 | 1,354 |
| **Total Intermediate** | 3,193 | 1,245 | 1,476 | 5,914 | 1,754 | 7,668 |
| **Forward** | | | | | | |
| FT1 | 2,758 | 694 | 767 | 4,219 | 1,333 | 5,552 |
| FT2 | 2,982 | 750 | 830 | 4,562 | 1,441 | 6,003 |
| FW1 | 527 | 460 | 485 | 1,472 | 489 | 1,961 |
| FW2 | 1,410 | 1,078 | 1,138 | 3,627 | 1,193 | 4,820 |
| FW3 | 0 | 0 | 0 | 0 | 0 | 0 |
| FW4 | 893 | 562 | 593 | 2,048 | 663 | 2,711 |
| FW5 | 1,729 | 1,124 | 1,186 | 4,039 | 1,312 | 5,351 |
| FS4 | 1,001 | 0 | 105 | 1,107 | 421 | 1,527 |
| FS5 | 1,335 | 0 | 140 | 1,476 | 561 | 2,037 |
| CC | 0 | 0 | 0 | 0 | 0 | 0 |
| Absorber | 1,060 | 0 | 77 | 1,137 | 386 | 1,523 |
| **Total Forward** | 13,695 | 4,668 | 5,323 | 23,687 | 7,799 | 31,486 |
| **Total Muon System** | 54,407 | 16,268 | 20,053 | 90,728 | 22,567 | 113,296 |

# SDC Muon Chamber Cost Comparisons

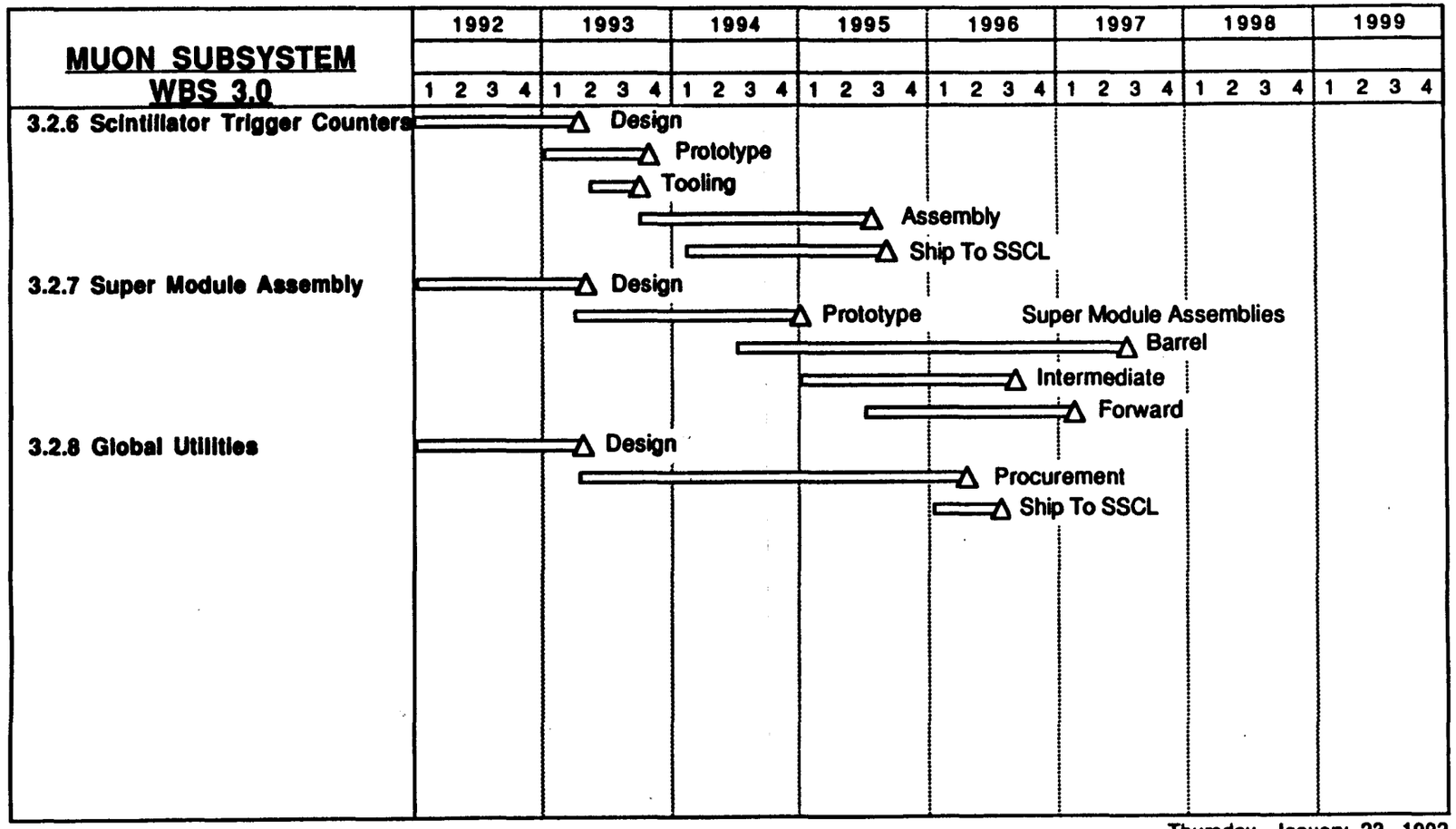
| | Barrel ($M) | Intermediate ($M) | Electronics ($M) | Total ($M) | Delta ($M) |
|---|---|---|---|---|---|
| Octagonal | 13.5 | 3.6 | 29.0 | 46.1 | 0.0 |
| Round - F.S. | 20.6 | 6.3 | 29.9 | 56.8 | 10.7 |
| Round - Non F.S. | 19.3 | 6.0 | 28.9 | 54.2 | 8.1 |
| Oval | 25.4 | 8.1 | 21.6 | 55.1 | 9.0 |
| JET | 21.5 | 6.2 | 32.7 | 60.4 | 14.3 |



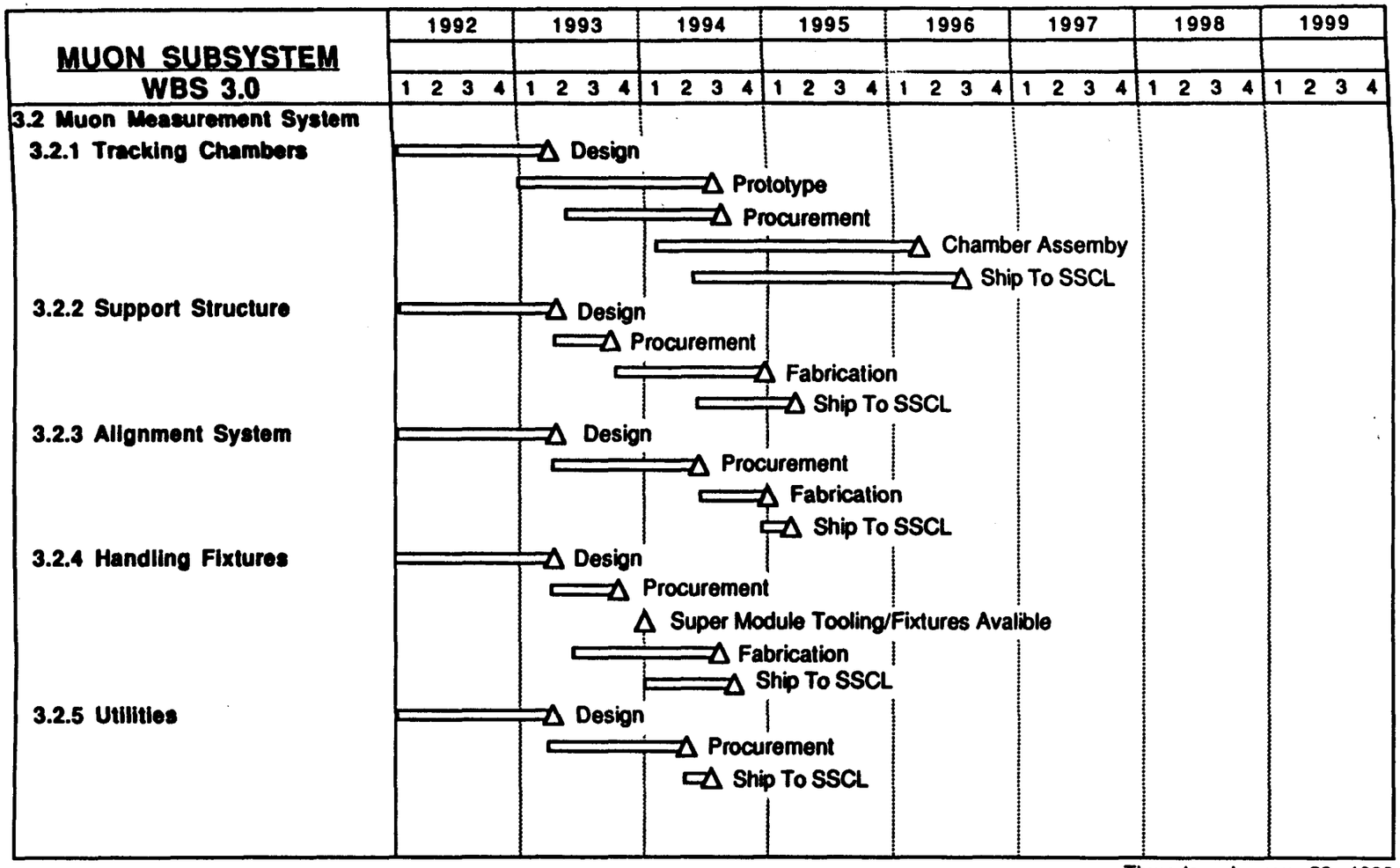

Note: Costs Based on Actual Work Performed, Delta Costs May Go Up 25% in Reality



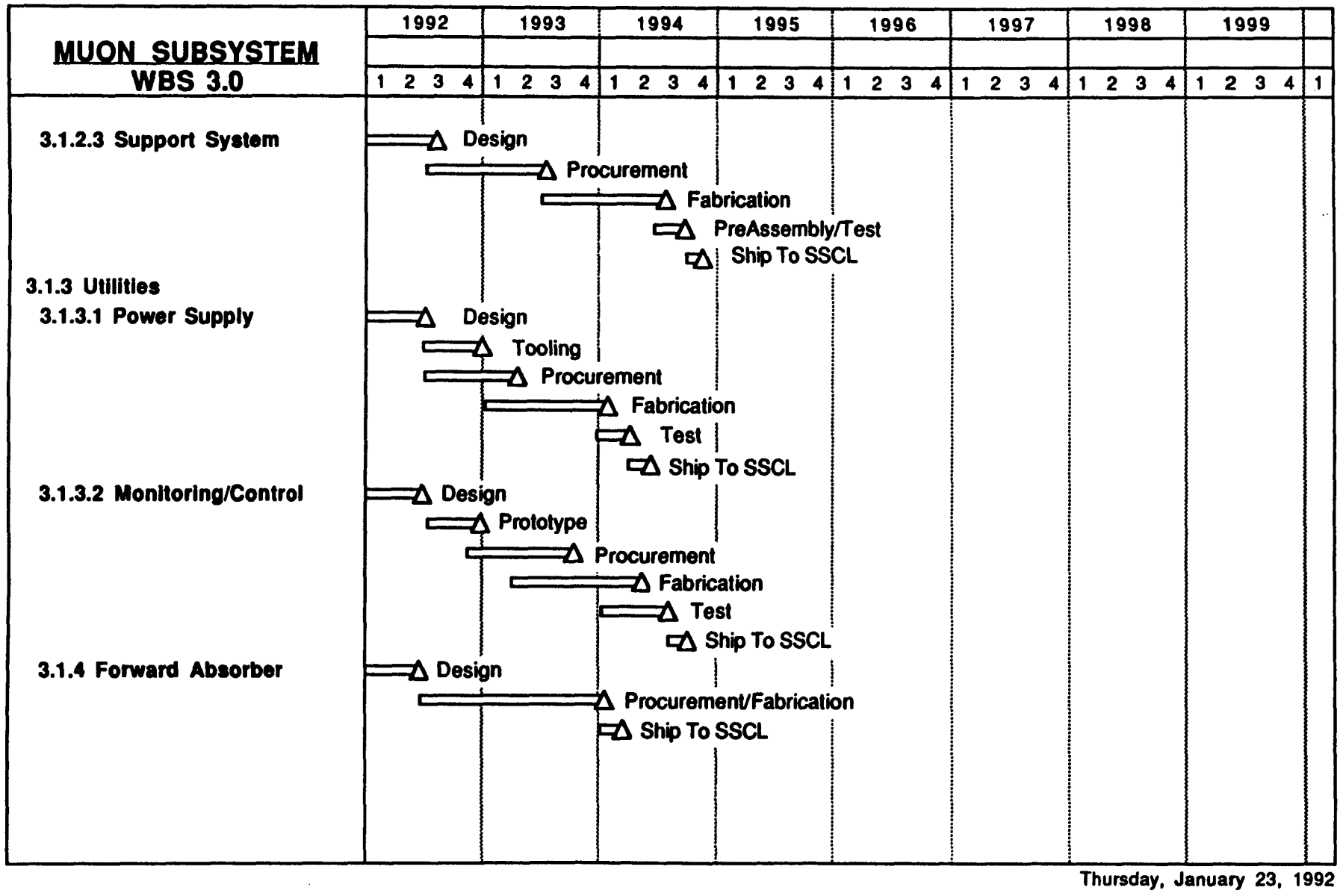

Thursday, January 23, 1992

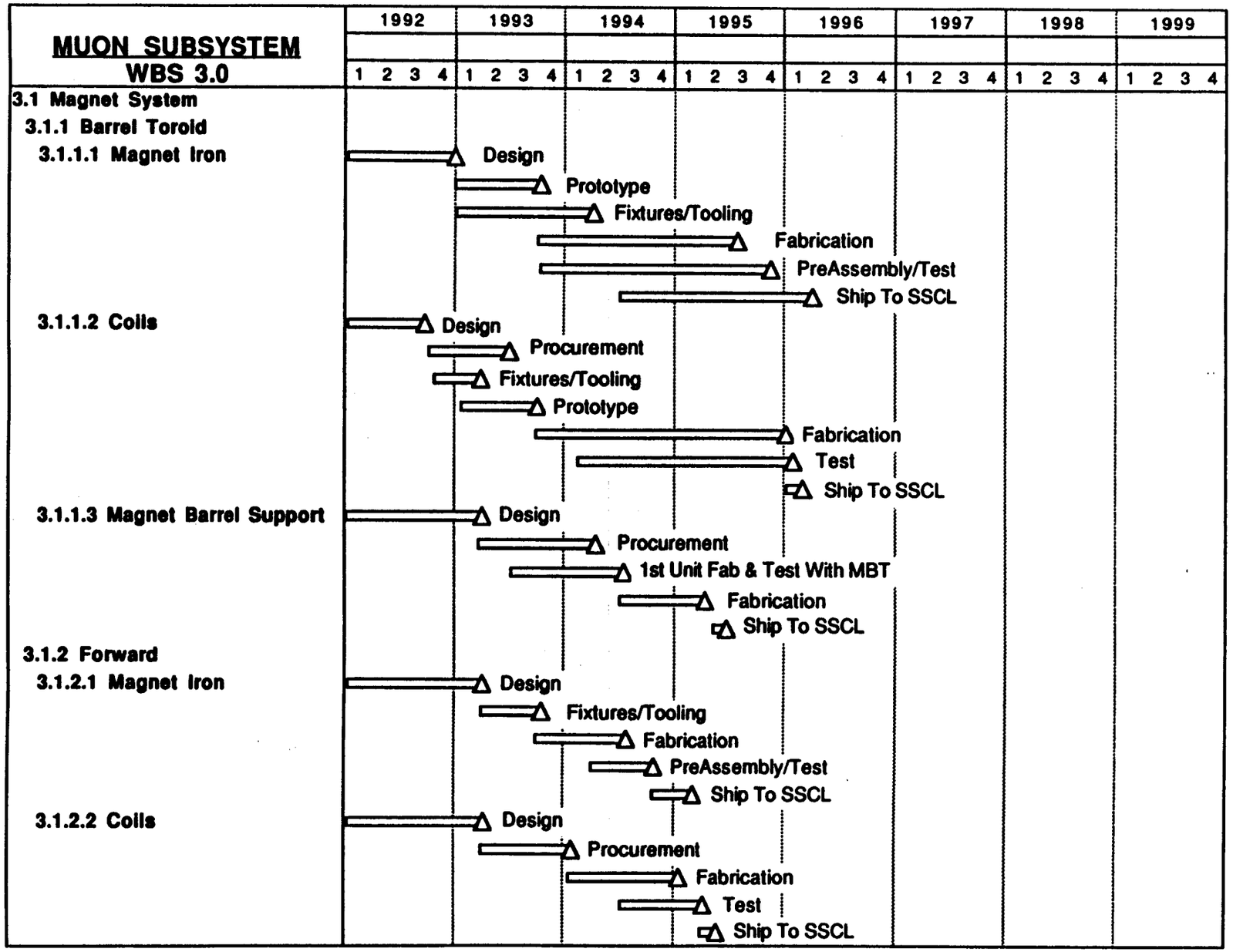



Thursday, January 23, 1992




Thursday, January 23, 1992


MUON SUBSYSTEM
WBS 3.0
1992
1993
1994
1995
1996
1997
1998
1999
1 2 3 4
3.1.2.3 Support System
Design
Procurement
Fabrication
PreAssembly/Test
Ship To SSCL
3.1.3 Utilities
3.1.3.1 Power Supply
Design
Tooling
Procurement
Fabrication
Test
Ship To SSCL
3.1.3.2 Monitoring/Control
Design
Prototype
Procurement
Fabrication
Test
Ship To SSCL
3.1.4 Forward Absorber
Design
Procurement/Fabrication
Ship To SSCL
Thursday, January 23, 1992




Thursday, January 23, 1992

OPEN PLAN (R)

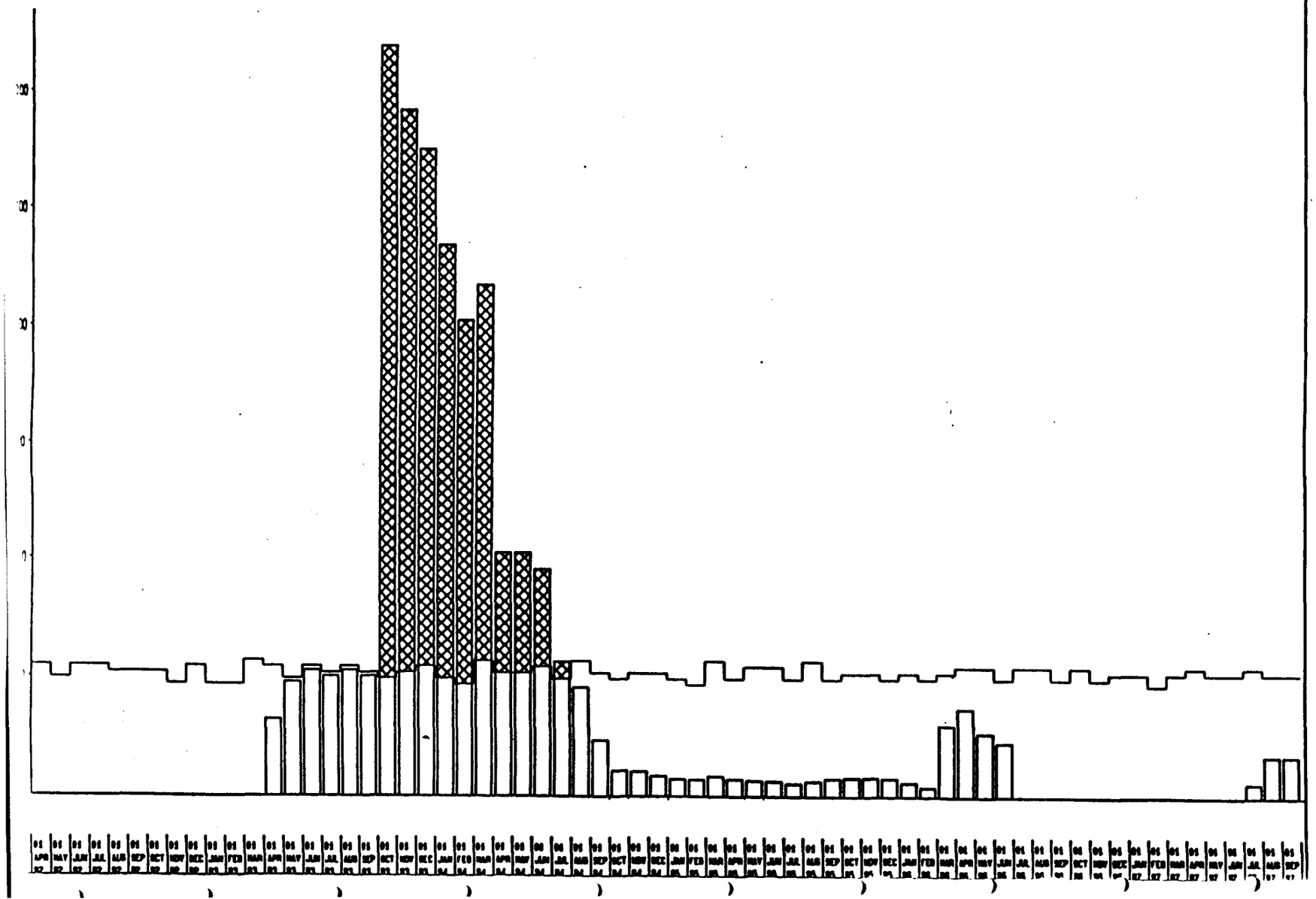
Report : GRAPRES1
Project : MUON
Time Now: 01JAN92
Date : 20JAN92
Time : 11:52:49

EARLY DATES Major <$50K: $MAJOR

# SDC MUON SYSTEM

## Resource Histogram

HISTOGRAM KEY
Required EARLY Dates
Available
Overload EARLY Dates
Each Bar = 600 Time Units



PRESENTATION BY:

MARK STROVINK

Strovink
Sun am

# REPORT

## SDC Forward Calorimeter Review Committee

31 January 1992

## INTRODUCTION

The committee reviewed plans for the SDC Forward Calorimeter ("FCal") in a meeting on 24-25 Jan 92 at the SSC Laboratory. We were charged by the SDC Technical Manager to recommend (*i*) one geometrical configuration ("backstop" *vs.* "inverted cone") for the FCal, and (*ii*) no more than two technologies for support of continued SDC FCal R&D. We heard presentations on physics requirements, detailed GEANT simulation of geometries, motivation and design of the inverted cone, and beam pipe layout. There followed thorough presentations on warm liquid, high pressure gas, and liquid scintillator technologies. The agenda is appended.

The committee consisted of C. Blocker, A. Bodek, G. Brandenburg, W. Frisken, N. Giokaris, P. Limon, B. Roe, and M. Strovink (chairman). The full committee discussed and voted on the geometrical configuration. After the first phase of technology discussion, three members identified with particular technologies (Brandenburg, Frisken, and Giokaris) were excused. The remainder of the committee further discussed the technologies, voted on them, and drafted this report.

## GEOMETRY RECOMMENDATION

With one dissent (Frisken), we recommend the backstop geometry in preference to the inverted cone. (Recall that the Forward Calorimeter Task Force, co-chaired by Frisken, expressed a preference for the inverted cone geometry in its Nov 91 meeting.)

### Discussion

The reasons for this committee's recommendation are:

- The backstop FCal can be calibrated by studying a small subset of its towers in a beam. To measure the energy loss due to albedo at grazing incidence, a major fraction of the inverted cone FCal would need a beam test. GEANT simulations show that the correction for this loss in the inverted cone geometry is important.

- The use of towers that are not tapered, *i.e.* with axes parallel to the beam, has the potential to reduce the FCal cost. The $\Delta\eta$ subtended by the axis of an unsegmented paraxial hadronic tower is about 0.3 if the front face is at $z = 7.5$ m, where the inverted cone would begin. This is not small compared to the $\eta$ segmentation (0.2) desired at

that point. The subtended $\Delta\eta$ would be about 0.15-0.2 in the backstop, depending on its location. A smaller $\Delta\eta$ could be achieved by longitudinally segmenting the hadronic towers, but this would add significantly to the cost, except perhaps for the warm liquid FCal.

- Proponents of the technologies did not exhibit inverted cone layouts for which it seemed straightforward to measure separately the electromagnetic ("EM") and the hadronic energy. This would be desirable if it became necessary to monitor and correct for radiation damage and/or space charge distortions that are most severe in the EM region. The inverted cone layouts shown had towers arranged in steps approximating a true conical face. Depending on where a photon entered a particular EM tower, it seemed possible that much of its energy could register in an immediately adjacent hadronic tower. This problem would not exist in the backstop geometry.

The relative performance of the forward calorimeters with each geometry was not a strong factor in our recommendation. After examining in detail the results of GEANT simulations presented by John Hauptman (Fig. 1), we could find no compelling difference in performance between the two geometries, provided that the inverted cone half angle did not fall below 0.1 rad. We note that the backstop does not shield the muon chambers, while the inverted cone design at least partly shields them. The muon group should be asked whether they would concur with our recommendations.

## TECHNOLOGY RECOMMENDATION

The subset of the committee involved in our final discussions on technologies recommends unanimously that R&D toward the high pressure gas and the liquid scintillator options should continue to be pursued.

### Discussion

**1. Requirements.**

We accepted the FCal requirements as formulated by the Forward Calorimeter Task Force and illustrated by the simulations due to several authors presented in Michael Barnett's talk. These requirements include:

- There must be in place a strategy (including recycling, replacement, and disposal) to withstand a lifetime radiation dose of 10's of gigarads at $\eta = 6$, and correspondingly less at lower $\eta$.
- The calorimeter signal should be able to be timed to $\approx$5 nsec and should persist for less than $\approx$50 nsec.
- Space charge effects must not make the constant term in the resolution unacceptably large (see below).
- The $\eta$ coverage should be $3 < |\eta| < 5$ (fully active) at startup, $3 < |\eta| < 4$ (fully active) at $\mathcal{L} = 10^{34}$. ("Fully active" implies that the corrected reconstructed energy

of a shower having an axis within that range satisfies the resolution requirements.)

- The segmentation should be $d\eta = d\phi = 0.2$ at $\eta = 3$, growing to $d\eta = d\phi = 0.4$ at $\eta = 5$.
- The energy resolution should be no worse than $dE/E = \sqrt{1\text{GeV}/E} \oplus 0.1$.

For all but the energy resolution, good arguments were presented on the basis of simulations. For the energy resolution, Barnett and Kevin Einsweiler (through a statement on his transparency) expressed the opinion that the constant term should be smaller, for example 5%. However, since neither author varied the constant term in his simulations, we were unable to react to that opinion. We feel that more investigation of the effect of varying the constant term is urgently needed.

**2. High pressure gas FCal.**

We were impressed with the excellent recent progress in R&D on the high pressure gas technique. A sample EM calorimeter using parallel steel plates has been tested in an electron beam at Fermilab. It shows linear response at 100 atm and resolution consistent with an EGS4 simulation. Furthermore, the signal *vs.* high voltage at 100 atm saturates at the comfortably low gradient of 700 V/mm and is linear *vs.* pressure from 0 to over 100 atm. The resolution for 50 GeV/c electrons essentially saturates at 80 atm for the 2.5 cm plates used in this prototype. With the addition of 5% methane to the argon gas, the limiting drift velocity of electrons is 50 $\mu$m/nsec. With a fast preamplifier and a gap of 2 mm, electron signals with $\approx$15 nsec risetime and a base width of order 60 nsec were observed.

Some of the outstanding questions about the applicability of high pressure gas have been answered by the recent R&D, but major questions still remain. An exposure to at least 16 Mrad of $^{60}$Co radiation showed no deleterious effects, but it was conducted with the high voltage off. We are anxious to see definitive tests of radiation damage under high voltage as soon as possible. At least one of these tests should be conducted using the coaxial geometry proposed for the final device.

The high pressure gas group has calculated that a dose rate of 12 rad/sec should produce only a 10% distortion by space charge of the electric field in a parallel plate geometry. (Space charge effects would diminish slightly in a coaxial geometry.) This dose rate is slightly smaller than that calculated for EM shower maximum at $\eta = 5.5$ and $\mathcal{L} = 10^{33}$. While this level of distortion may be acceptable, the possible degradation of positive ion mobility with accumulated dose was not taken into account. This effect should be measured or estimated, and the necessary rate at which fresh gas must be introduced should be computed.

The proposed FCal using high pressure gas is conceptually different from the tested design. It would use steel tubes arranged approximately parallel to the beam in a steel matrix. This design has not been tested. A GEANT Monte Carlo simulation was presented. It shows that the stochastic terms for both electrons and hadrons, and the constant term for the hadrons, are adequate for the SDC FCal. However, the constant term for electrons

is unacceptably large. It is felt that this term is due to shower channeling in the large gas tubes that are spaced rather far apart, and that a device with smaller and closer tubes oriented a few degrees to the beam axis will perform better. We are concerned by this large constant term in the simulated resolution for electrons, and we urge that new simulations of full jets and of added preradiators be pursued vigorously.

It appears that the high pressure gas calorimeter would be straightforward to construct, particularly in the backstop geometry, and would be relatively uncomplicated, inexpensive, and flexible in terms of transverse and longitudinal segmentation. A prototype with the proposed design should be built and tested soon, with particular attention devoted to the constant term in the resolution. Engineering cost estimates based on realistic conceptual designs also need to be made.

### 3. Liquid scintillator FCal.

The liquid scintillator technique offers the possibility of FCal time resolution comparable to that of the central calorimeter. Materials testing is underway, but no proof of principle and no clear conceptual design are yet available.

The liquid scintillator option consists of rad hard transparent tubes (e.g. quartz), which are roughly parallel to the beam line and filled with liquid scintillator. The technology is at a very early stage of development. It is essential that long tubes (e.g. 3 m) of various materials be filled with the various choices of liquid scintillator and irradiated in the 20 to 200 Mrad range. The light yield and attenuation length must be determined before and after irradiation in order to determine how often the scintillator needs to be replaced, and if there is any permanent damage or wall deposits that affect the optical transmission in the tubes. If such a test is successful, this would be the only proposed technology that could provide very fast (<20 nsec) pulses.

Issues such as energy calibration and monitoring need to be addressed, and a conceptual design needs to be developed. The present cost estimate of the order of $15M is rather crude and needs to be firmed up with a real design. Although extrapolation from solid fiber test beam results can be made, the liquid scintillator tubes are thicker and will require a beam test of a realistic prototype in order to determine the energy resolution for electrons and pions and the $e/h$ ratio. The $e/h$ ratio needs to be reasonable in order keep the constant term in the resolution small. Unless the device is longitudinally segmented, this implies that the attenuation length must remain in the several meter range. The constant term in the resolution for electrons will be large for zero degree incidence on the fiber. The addition of a passive preradiator, or designs with a several degree incident angle, should be investigated.

The management of the group needs to be developed. We encourage close cooperation between the gas tube and scintillator tube efforts. For example, the tower geometries of the two types of tube calorimeter might share a similar layout.

### 4. Warm liquid FCal.

The warm liquid R&D is furthest advanced, as the result of an extensive and excellent

program. The warm liquid group has made considerable and commendable progress on studying the feasibility of such a calorimeter for the forward region. In particular, they have demonstrated that the required purity can be achieved, that a variety of materials do not compromise the purity, and that a "swimming pool" style calorimeter will work. Since warm liquid has been considered seriously for the SDC central calorimeter, it seems clear that FCal energy resolution and segmentation requirements could easily be met, leaving aside radiation effects peculiar to the forward region. The warm liquid proponents are well aware of both the potential benefits and the risks. We relied heavily on their tests and calculations in order to formulate our recommendations.

The warm liquid calorimeter option would consist of iron plates perpendicular to the beam direction with very small (0.5 to 1 mm) gaps containing TMP, a room-temperature liquid. It would have several advantages. First, the transverse and longitudinal segmentation necessary in the FCal is easy. Second, since it is a unity gain ionization device like the high pressure gas FCal, its response is inherently stable, and maintaining the calibration should be relatively straightforward. Third, the spatial uniformity should be very high (except perhaps for space-charge effects noted below).

Although, as in the high pressure FCal, the signals are slow compared to a scintillating calorimeter, they should be fast enough that large energy depositions can be accurately measured and properly associated with the correct beam crossing.

There are several disadvantages to a warm liquid calorimeter. The major disadvantage is that the low positive ion mobility (a few % of that in high pressure gas) could lead to space-charge effects causing a nonuniform response, as a function of both of $\eta$ and of depth. These effects have been calculated by the warm liquid group, assuming a drift gap $G$ that is small (1 mm) and an unperturbed electric field $E$ that is large (5000 V/mm). (For the TMP module recently tested, $G$ was 2 mm and the breakdown $E$ was $\approx$3500 V/mm. It is hoped that raising the pressure will improve the breakdown characteristics by suppressing bubble formation.) The space charge distortion of the field is proportional to $(G/E)^2$.

With these assumptions, for a dose rate of 40 rad/sec (corresponding to $\mathcal{L} = 10^{33}$ and $\eta = 6$ at EM shower maximum) the ratio of minimum to maximum field in the gap is calculated to be >0.75. Because both the ionization rate and the drift velocity increase with electric field, such a field distortion is calculated to have a negligible effect on the collected signal. A similar calculation also concludes that the effects of space charge distortion in TMP and in high pressure gas are nearly the same. To reach this conclusion in spite of the much greater ion mobility in high pressure gas, this calculation assumes that the drift gap would be 2 mm in gas rather than 1 mm in TMP, and that the operating field would be 1000 V/mm in gas rather than 5000 V/mm in TMP.

The space charge distortion is further complicated by evidence that the positive ion mobility decreases significantly with radiation damage to the liquid. For the highest $\eta$ module in the warm liquid FCal design, our rough estimate is that the dose at $\mathcal{L} = 10^{33}$, averaged over all the liquid in the module, would be at least 1 Mrad/$10^7$ sec. It is known that the positive ion mobility in TMP decreases by $\approx$1 order of magnitude after a 10 Mrad

exposure. More detailed investigation is needed, but it seems, even if the TMP remains perfectly mixed, that radiation-induced deterioration of positive ion mobility is a serious concern.

In addition, as in high pressure gas, there is the possibility that intense radiation causes substances to "plate out" onto the electrodes (this needs to be investigated further). Another concern is whether the required TMP purity can be maintained in the high radiation field over the long life of the calorimeter. Also, TMP is a flammable liquid, which leads to safety problems (although it has low enough volatility and high enough flash point that this is not an overriding concern). Finally, this option is expensive (at least $25M, assuming no need for repurification of the TMP).

**5. Reasons for technology recommendation.**

We feel that the unresolved issues outlined above represent substantial risks for all three of the technologies considered. We would be extremely reluctant to see any single technology chosen at this time. If resources would permit, we would prefer to see R&D continued on all three technologies.

Given our charge to recommend only two technologies for support of continued R&D aimed at the SDC FCal, we prefer to improve the odds of finding at least one acceptable solution by recommending two approaches for which the risks are somewhat independent. Broadly speaking, most risks can be classified into (*i*) radiation damage, (*ii*) not yet proven principle, (*iii*) inadequate performance, and (*iv*) difficulty of implementation, including cost.

With respect to radiation damage, the most important risk for high pressure gas and for warm liquid seems to be space charge. In our opinion, the warm liquid design has been stretched further than has the high pressure gas design in order to achieve comparable calculated tolerance to space charge effects. If it should prove necessary to refresh the ionization medium to avoid space-charge-induced deterioration of positive ion mobility, in our opinion this would be easier for gas than for TMP. All three technologies could suffer from radiation-induced contaminants "plating out" on surfaces, building up opaque or insulating layers. In this respect, liquid scintillator is probably more different from either TMP or gas than the latter are from each other. All in all, we feel that the risk from radiation damage would be minimized by choosing high pressure gas and liquid scintillator.

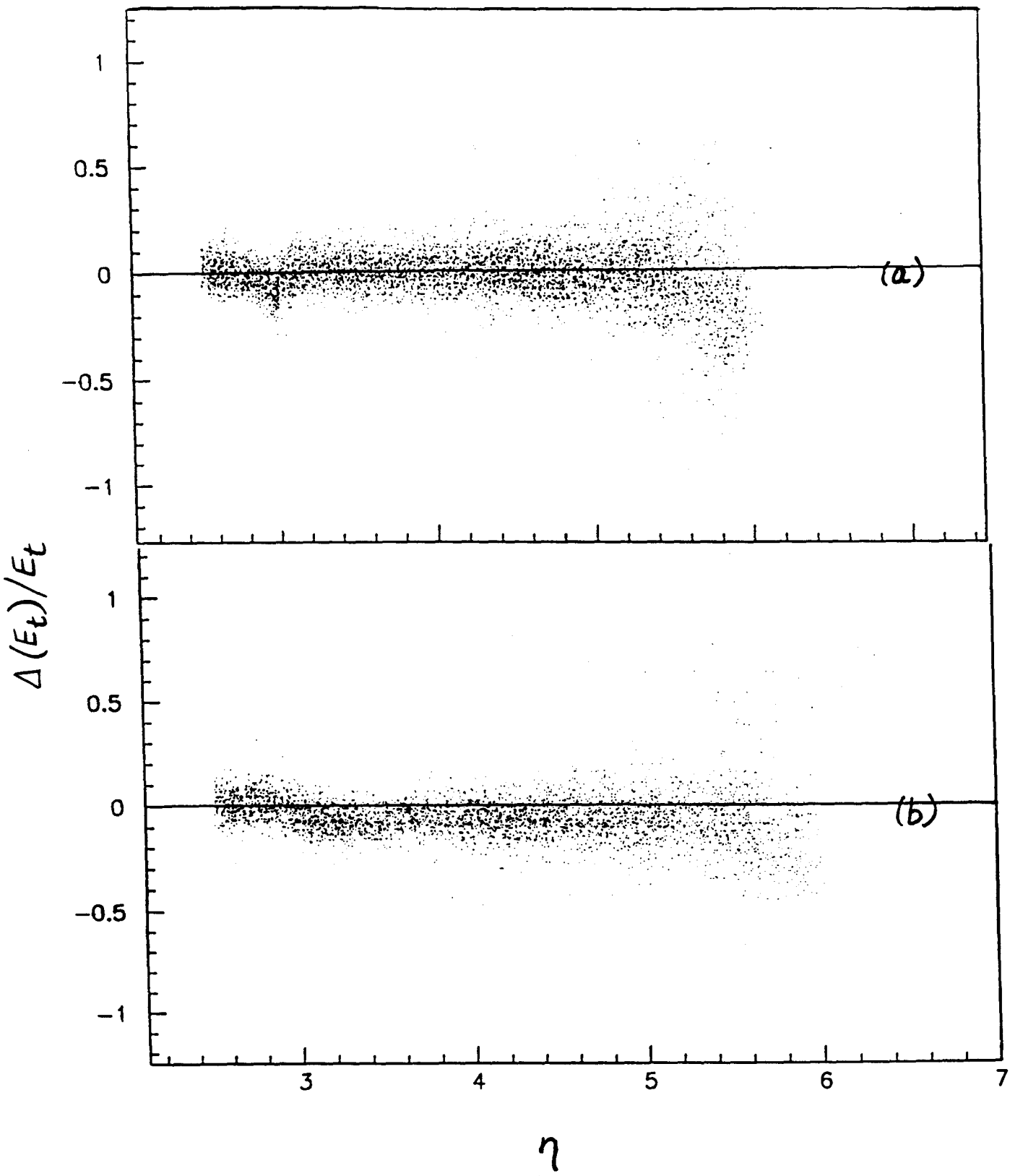
With respect to principle, as a result of recent R&D accomplishments, we feel that (except for radiation tolerance) reasonable proof is in hand for warm liquid and for high pressure gas, but not yet for liquid scintillator. (Specifically, we are unaware of any example of an unirradiated liquid-scintillator-filled tube that has achieved a few meter attenuation length.) With respect to performance, the two main risks appear to be (*a*) resolution tails that are not easily modeled, and (*b*) inadequate uniformity leading to a high constant term. A possible contributor to (*a*) is pileup, which is exacerbated in the FCal region by shower overlap. Liquid scintillator has a unique advantage there because of its faster response. Warm liquid may have a unique advantage in uniformity (in the absence of radiation damage).

With respect to implementation, the simplicity and possible cost-effectiveness of the high pressure gas design, particularly in the backstop version, are viewed with enthusiasm by the committee. In the absence of detailed cost assessments, we guess that high pressure gas would probably be more cost effective than liquid scintillator, and almost surely more so than warm liquid.

As seen from the above, from the viewpoint both of risk and of other factors, important arguments exist which favor each of the technologies. Since only two can be recommended, it is our opinion that the overall risk to SDC of the forward calorimeter would be minimized if high pressure gas and liquid scintillator R&D were to proceed.

## Figure Caption

Fig. 1. Scatter plot of GEANT simulated fractional error in reconstructed $E_t$ *vs.* $\eta$, for (a) backstop and (b) inverted cone (half-angle = 0.1 rad) geometries (from John Hauptman and Myungyun Pang).


1
0.5
0
−0.5
−1
(a)
1
0.5
0
−0.5
−1
(b)
3
4
5
6
7
$\Delta(E_t)/E_t$
$\eta$

AGENDA
SDC Forward Calorimeter Review
SSCL, 24-25 Jan 92

FRIDAY 24 JAN -- Bldg. 3 Physics Research Conference Room

| | | |
|---|---|---|
| 10:30-11:30 | M. Barnett | Physics requirements for FCAL (includes Einsweiler's work) |
| 11:30-11:45 | J. Hauptman | Requirements from WW scattering |
| 11:45-12:15 | J. Hauptman | GEANT study of FCAL geometries |

Lunch

| | | |
|---|---|---|
| 1:30-1:45 | B. Roe | IR beam pipe |
| 1:45-2:30 | Frisken/Thur | Inverted cone geometry |
| 2:30-3:00 | J. Kadyk | Recent results on warm liquid FCAL |
| 3:00-3:30 | W. Thur | Mechanical design of warm liquid FCAL |

Break

| | | |
|---|---|---|
| 4:00-5:00 | N. Giokaris | High pressure gas FCAL |
| 5:00-6:00 | R. Orr | Liquid fiber FCAL |

7:00- Closed session dinner (no host, place TBA) for review committee members (Blocker, Bodek, Brandenburg, Frisken, Giokaris, Limon, Roe, Strovink)

SATURDAY 25 JAN -- Bldg. 4 Physics Research Conference Room
(NOTE Friday was Bldg. 3)

| | | |
|---|---|---|
| 9:00-9:30 | J. White | Test beam results on liquid fiber FCAL |
| 9:30-9:50 | D. Winn | Liquid spaghetti FCAL w/heavy absorber |

End of open sessions

10:30-12:30 Review committee members (closed session)

12:30-1:00 Working no-host box lunch for review committee members (closed session)

1:00-5:00 Review committee members (closed session). Part of the membership will be excused during a portion of this last session.

PRESENTATION BY:

WILLIAMS

Williams
Sun pm

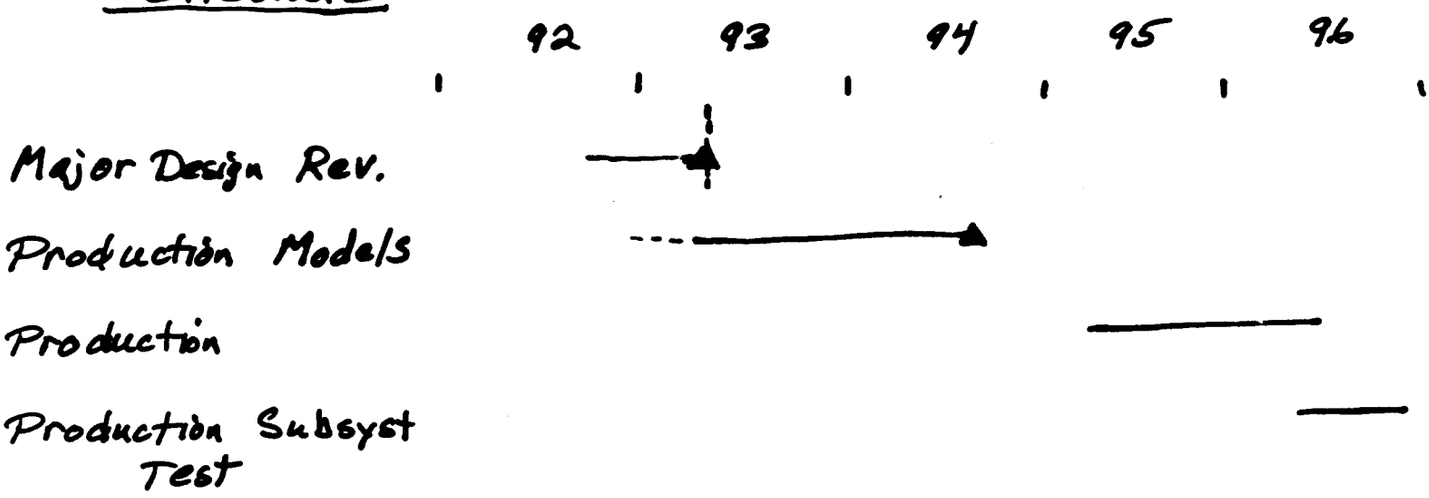
| Proposal | Design | Text |
|---|---|---|
| Triggering | ✓- | ✓ |
| Front End Electronics | | |
| SCA Calorim. Readout | ✓ | ✓ |
| Flash ADC Readout | ✓ | |
| Shower Maximum | ✓ | ✓ |
| Straw Tubes | ✓ | ✓ |
| Muon Chamber | ✓- | |
| Scint. Fibers | ✓ | ✓ |
| Intermediate Tracking | ✓ | ✓ |
| Silicon Tracking (off-detector) | ✓ | ✓ |
| DAQ | ✓ | ✓ |

## Decision Process

Status report & "Light" Review — Feb 26-28

Critical review & Decision on Calorim. Readout — June - Sept

## Schedule



## Electronics Activities

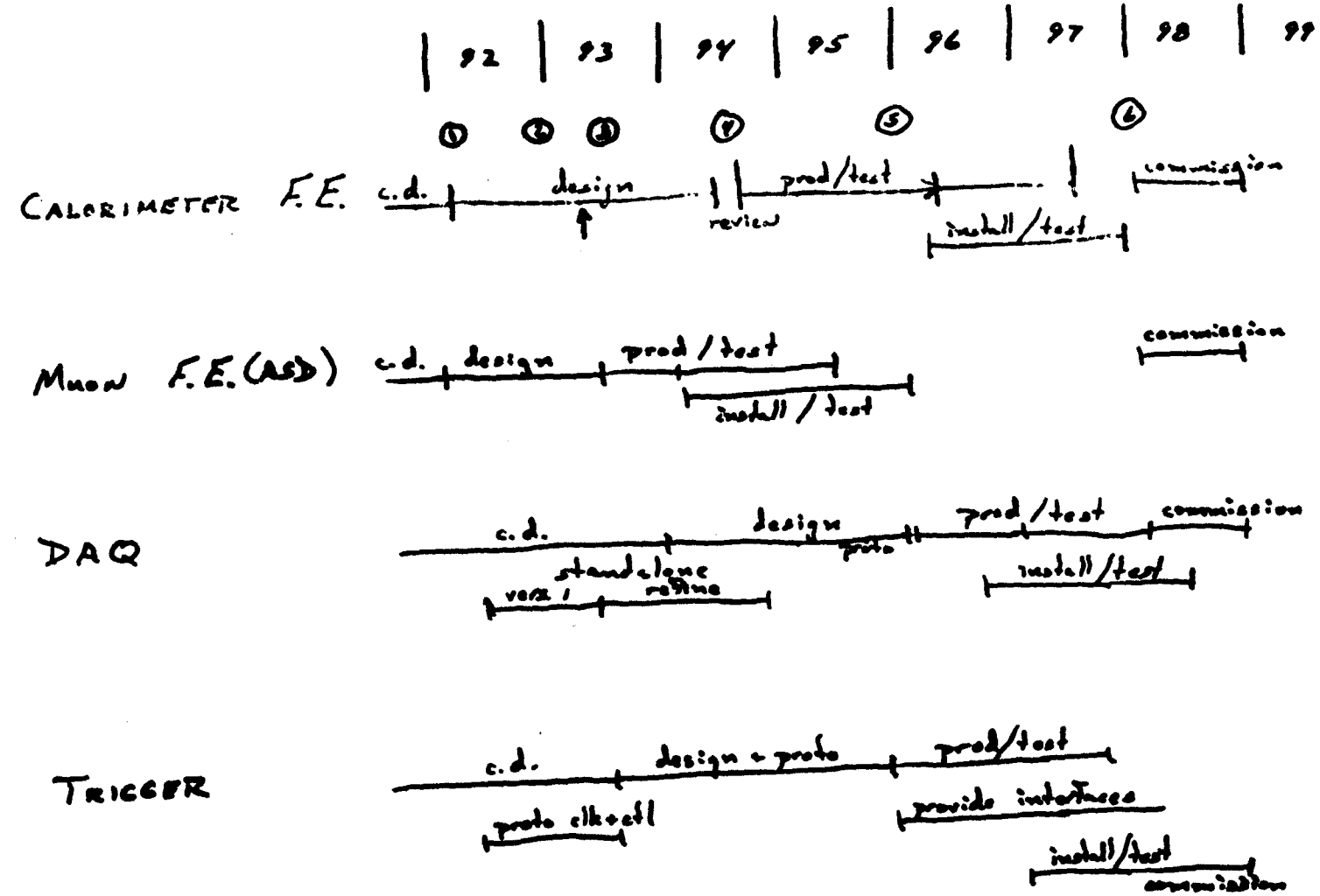
NOW: CHIPS → SUBSYSTEMS

THIS YEAR: SYSTEMS ENGINEERING, SUBSYSTEM DESIGNS, PROTOTYPES

SOON ENOUGH: DESIGN REVIEWS, PRODUCTION

## Milestones

| | | |
|---|---|---|
| 1 | Proposal + Design Reports | 92 |
| 2 | Electronics System Tests | 92, 93 |
| 3 | Detector Prototype Beam Tests | 93 |
| 4 | Design Reviews/Production Start | 93, late 94, 95 |
| 5 | Detector/Electronics Delivery Begins | μ: 94 cal: 96 |
| 6 | Commissioning in Hall Starts | 98 |




1. T.D.R.
2. Elex Sys Tests
3. Beam Tests
4. Design Revisions
5. Install / Test
6. Commissioning

# Cost Review

Jan 16-17 — Calorimeter, Scint Fiber, Straws, Muons, DAQ — "line by line" through the WBS

Jared, Oliver, Yarema, Foster, Baumbaugh, Van Berg, Wms, Lankford, Hess, Moore, Oberst, Weissxamp, Emory, Barsotti

~~Feb~~
Jan 30 — Trigger, Muons

Some more work on DAQ & Trigger necessary

* μ strip gas - not reviewed but may exist signif. uncertainty in cost of Front End & L1 trigger

Tried to establish consistency in

* Design Document
* Project Management
* PC Boards
* ASICS
* Engineering
* Testing

## Summary

* All estimates improved
* SCA & straw cost largely unchanged
* Small increase in FADC & scint. fiber
* Significant decrease in muon (1-3 million?)
* Significant decrease in trigger (≈ 6 million mainly due to better understanding / reduction in scope)
* Will try to "scrub" DAQ further.

## Electronics Systems Parametric Cost Summary

| WBS & Subsystem | Scaling Parameters | Total Cost | Cost Formula |
|---|---|---|---|
| 5.1.2 Straw Tracker * | 117,024 Ch. | $11.1M | $3.5M + $65/Ch. |
| 5.1.3.1 Calorimeter (SCA) | 24,960 Ch.** | $8.8M | $3.4M + $215/Ch. |
| 5.1.3.2 Shower Max (SCA) | 47,104 Ch. | $5.3M | $2.4M + $61/Ch. |
| 5.1.4.1 Muon Wire Chamber | 100,790 Ch. | $7.4M | $1.4M + $59/Ch. |
| 5.1.4.2 Muon Scintillator Cntr. | 9,472 Ch. | $1.6M | $0.3M + $134/Ch. |
| 5.1.4.4 Regional Electronics | 110,262 Ch. | $9.2M – 2-3 | $2.7M + $59/Ch. |
| 5.1 Front-End Subtotal | | $43.4M | |
| 5.2 DAQ | 218 Sources | $34.9M – ? | $9.1M + $72K/Source |
| 5.3 Trigger | 220 Sources | $31.1M – 5-6 | $25.4M + $26K/Source |
| 5.4 Ancillary Systems Controls | Per Subsystem | $4.0M | Varies with subsystem (150K+>450K ea.) |
| 5.0 Electronics Total | | $163.4M | |
| *5.1.1 Sci-Fi Tracker Option | 674,000 Ch. | $4.5M | $2.0M + $3.75/Ch. |

** Channel Count differs from parameters book because of the Barrel Trigger towers that are projected onto the End-Cap Calorimeter.

# Summary of Significant Technical Issues

- Front End

SCA Calorimeter Readout

system level test (individ. pieces OK)

Flash ADC

gated integrator + comparator + ADC
(emitter splitting looks OK)

Straw Tubes

packaging of elec on Front End Board,

straw + ASD + Trigger + Time meas operation together
(indiv pieces OK)

Rad Hard TMC in Japan (not a problem in US)

Scint Fiber

ASD + VLPC + demonstration of ~~the~~ interconnect
(indiv pieces OK)

Muons

no signif. technical issue

Shower Max

settle on photodetector (elec OK)

Gas $\mu$ strip

not reviewed; similar to silicon
but Level 1 trigger!?

PRESENTATION BY:

IRWIN GAINES

Gaines
Sun pm

# SDC Data Acquisition System
## Cost Summary

**WBS 5.2 (Requirements Through Production):**

| Item | Material Costs | Manpower Costs | Total |
|---|---|---|---|
| Infrastructure | $1075.00K | $186.32K | $1261.32K |
| Prototypes | $345.20K | $3380.35K | $3725.55K |
| Pre-Production Units | $768.50K | $459.00K | $1227.50K |
| Production Units | $9960.30K | $2460.60K | $12420.90K |
| Spare Units | $1007.15K | $212.88K | $1220.03K |
| Project Management | $0.00K | $912.00K | $912.00K |
| Design Reviews | $0.00K | $554.24K | $554.24K |
| **Totals (no contingency)** | **$13156.15K** | **$8165.39K** | **$21321.54K** |

with conting $24.9M

**WBS 8.2.1.5.2 (Installation):**

| Item | Material Costs | Manpower Costs | Total |
|---|---|---|---|
| Installation | $0.00K | $902.76K | $902.76K |

**WBS 8.2.2.5.2 (Integration & Testing):**

| Item | Material Costs | Manpower Costs | Total |
|---|---|---|---|
| Integration & Testing | $0.00K | $2299.22K | $2299.22K |

# SDC Data Acquisition
# Descoped Costing Summary
# (November 14, 1991)

| M&S | Estimated Cost |
|---|---|
| - Infrastructure | $865.0K |
| - DAQ Control/Monitoring Network | 70.0K |
| - Crates, Power Supplies, Etc. | 40.0K |
| - Event Data Readout & Control/Monitoring Network Interfaces | |
| - DAQ CPU Modules | 1510.0K |
| - Crate Adapter/Interface Modules | 120.0K |
| - Event Data Links | 137.0K |
| - (Other Items) | 15.0K |
| - Event Builder Subsytem & Links To The Online Processor Subsystem | 1100.0K |
| - Event Data Flow Control Subsytem | 11.0K |
| - Online Processor Subsystem | 6640.0K |
| - DAQ Offline Analysis Interface | 250.0K |
| - Electronics Rack Protection Subsystem | 1782.0K |
| **M&S Total** | **12540.0K** |

| Manpower | Estimated Cost |
|---|---|
| **Manpower Estimated Total** | **12460.0K** |
| + contingency | |
| **Overall Totals** | **25000.0K** |

# DAQ - Cost & Scope Issues

- Infrastructure
- Spares
- Contingency (16%)
- Size of level 3 Farm
- # of crates and data sources (now 252/412)
- subsystem crates

PRESENTATION BY:

ABE SEIDEN

Seiden
Sunpm

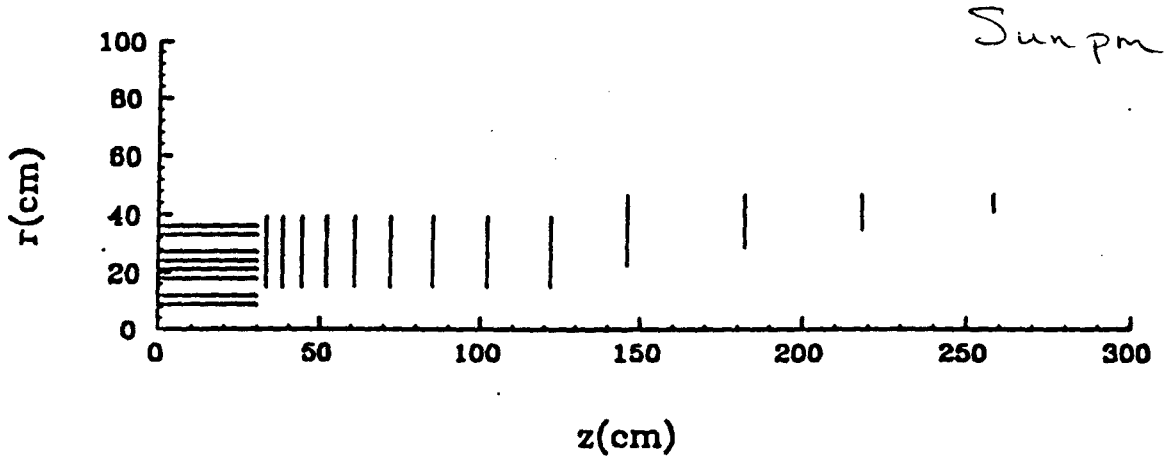



**Fig. 1.** Silicon tracker design.

**Table 2.** Dimensions for tracker

| Barrel | r | z | |
|---|---|---|---|
| (1) | 9 cm | 30 cm | |
| (2) | 12 cm | 30 cm | |
| (3) | 18 cm | 30 cm | 6.78 $m^2$ for Barrel. |
| (4) | 21 cm | 30 cm | |
| (5) | 24 cm | 30 cm | |
| (6) | 27 cm | 30 cm | |
| (7) | 33 cm | 30 cm | |
| (8) | 36 cm | 30 cm | |
| **Disks** | $r_{in}$ | $r_{out}$ | z |
| (1) | 15 cm | 39 cm | 33 cm |
| (2) | 15 cm | 39 cm | 38 cm |
| (3) | 15 cm | 39 cm | 44 cm |
| (4) | 15 cm | 39 cm | 52 cm |
| (5) | 15 cm | 39 cm | 61 cm |
| (6) | 15 cm | 39 cm | 72 cm |
| (7) | 15 cm | 39 cm | 85 cm |
| (8) | 15 cm | 39 cm | 102 cm |
| (9) | 15 cm | 39 cm | 122 cm |
| (10) | 22.5 cm | 46.5 cm | 146 cm |
| (11) | 28.5 cm | 46.5 cm | 182 cm |
| (12) | 34.5 cm | 46.5 cm | 218 cm |
| (13) | 40.5 cm | 46.5 cm | 258 cm |
| | | Total Area = 16.94 $m^2$ | |

10.16 $m^2$ for Disks (both sides)

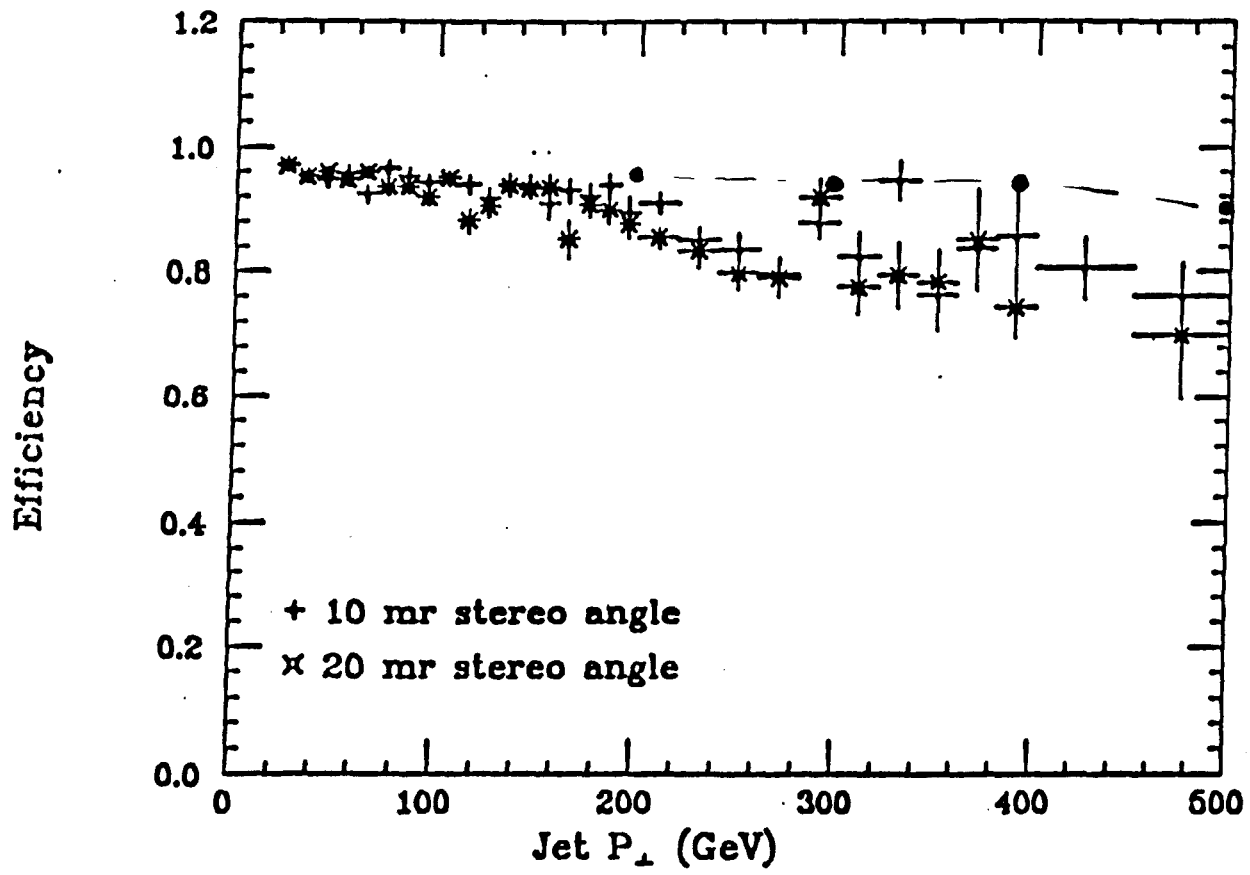



**Fig. 11. Efficiency for reconstructing tracks with $P_\perp > 1$ GeV inside jets as a funct of the jet transverse momentum, for two values of the stereo angle.**

- ~ 9 Layers on average.
- ~ 7 " " "

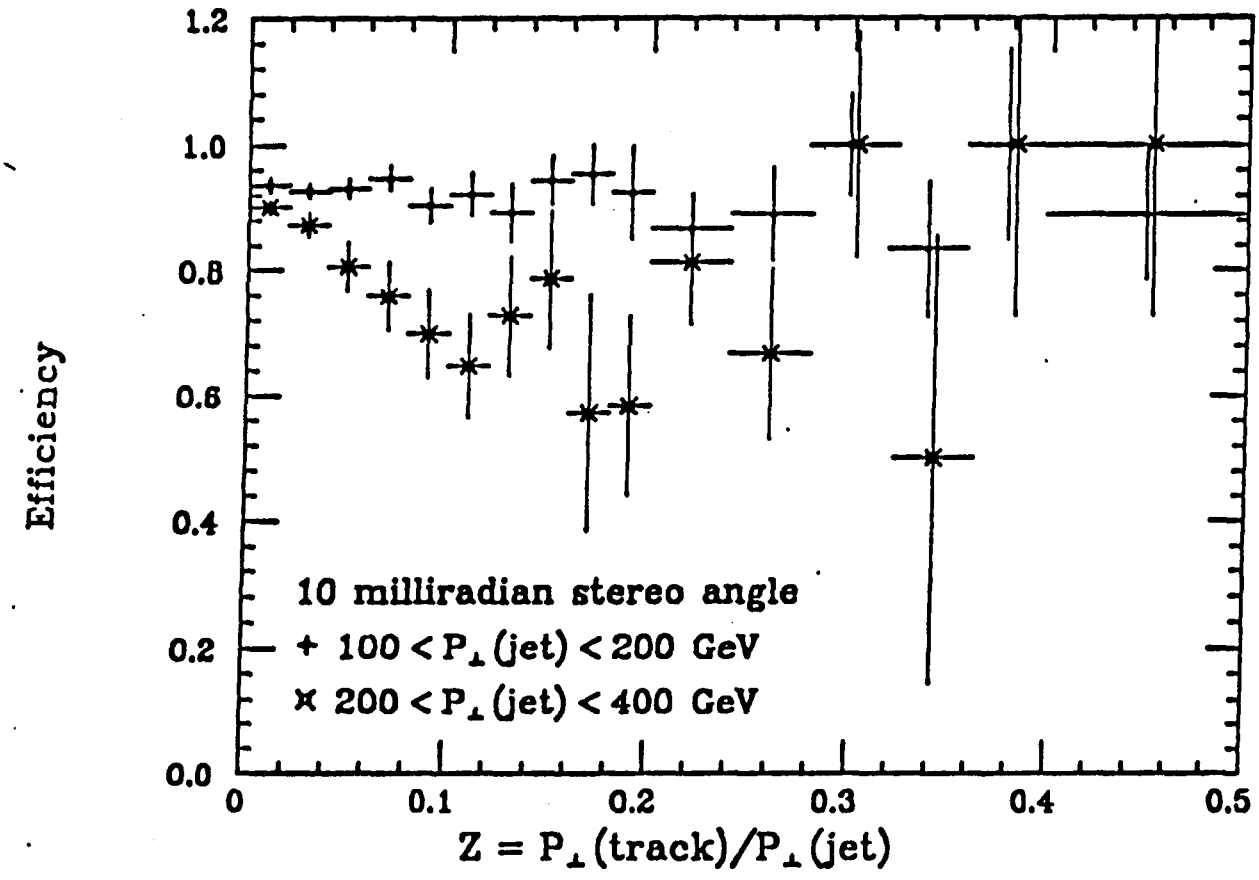



**Fig. 12.** Track reconstruction efficiency as a function of the fragmentation variable $z$ (for two intervals of jet $p_\perp$). The stereo angle used was 10 milliradians.

Probably best plot to look at effect of stereo ∡. Need to still do this.

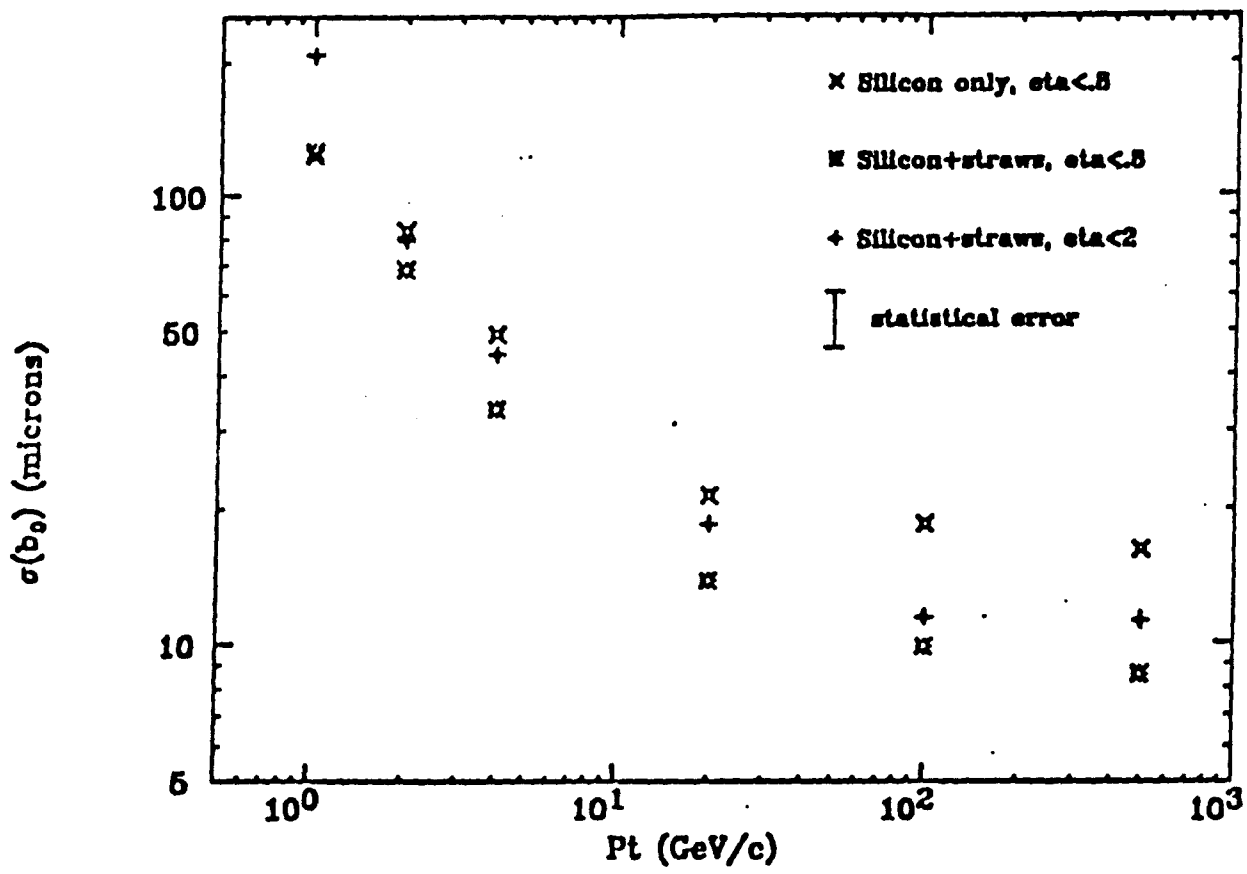
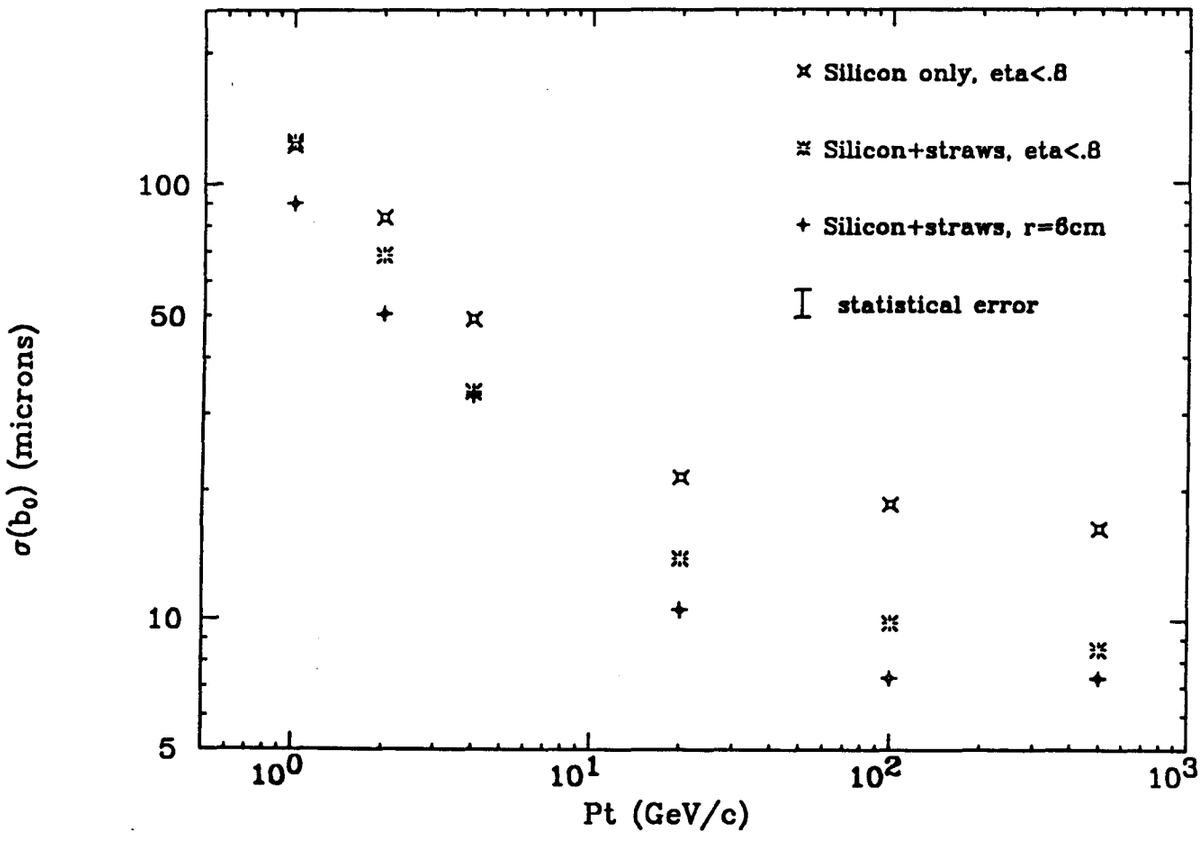
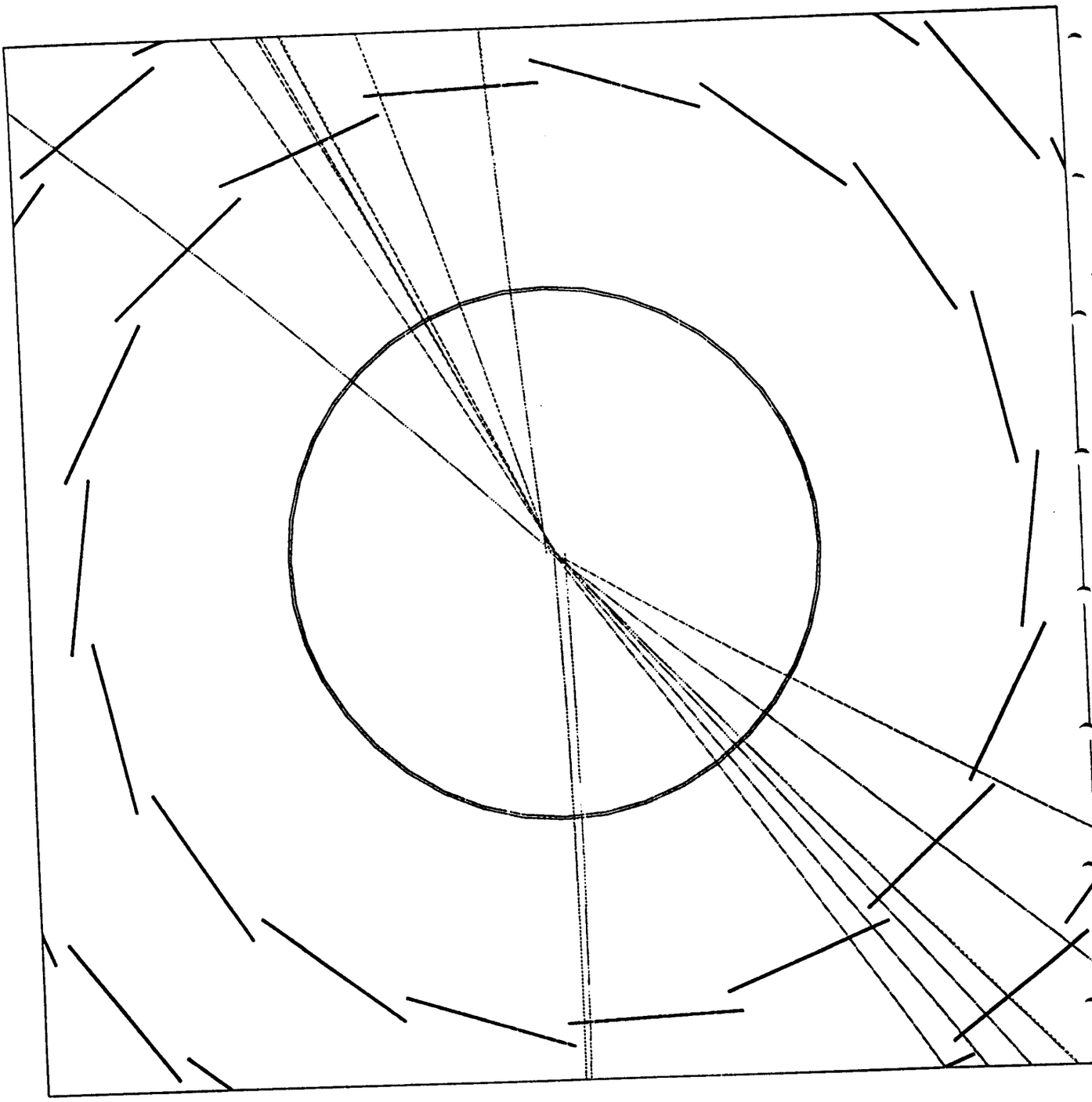
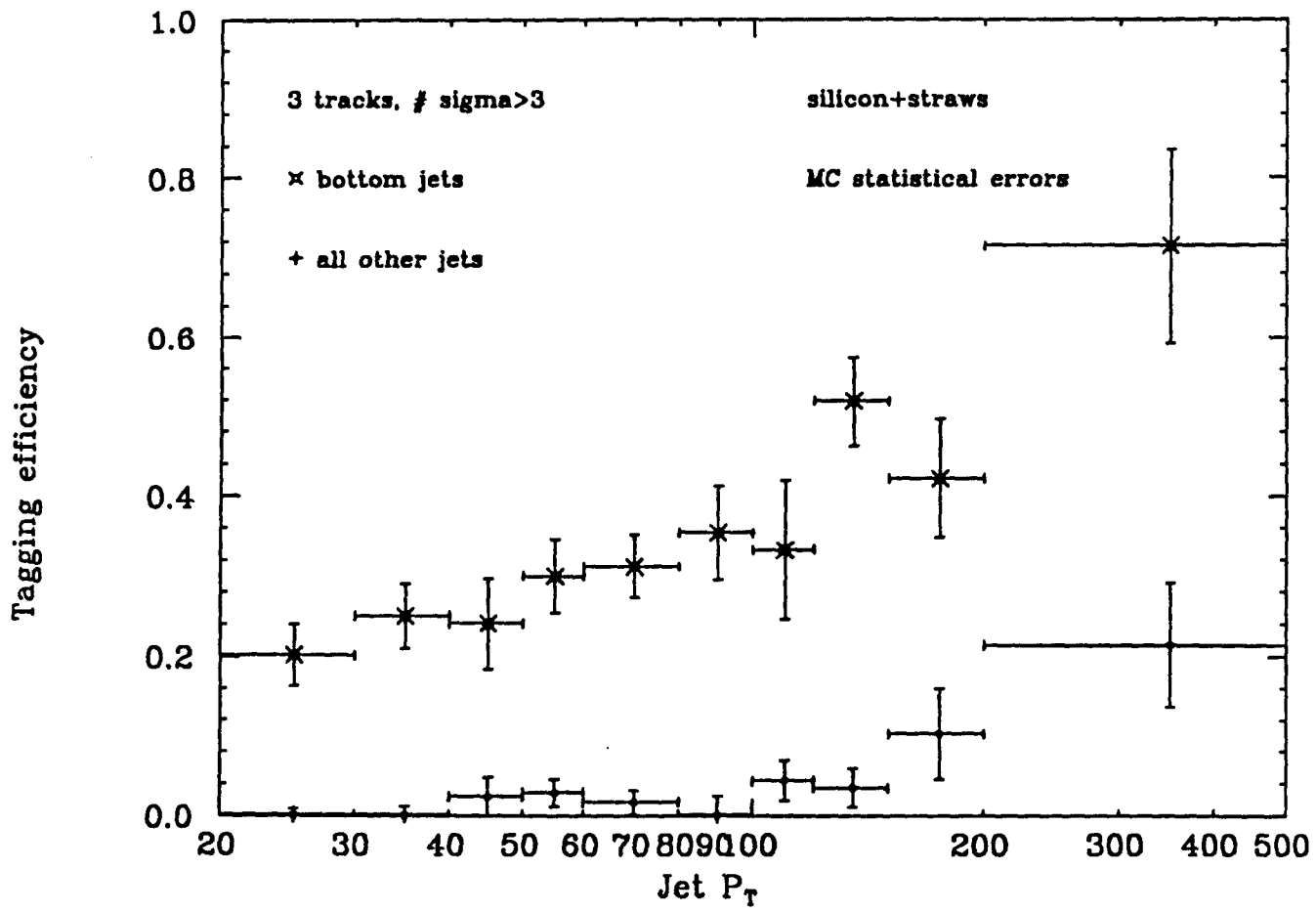



Fig. A. Impact parameter resolution for single muons as a function of $P_\perp$ over diff $\eta$ ranges. Note that the resolution of the combined system is $\sim 9$ $\mu$m, compared $\mu$m for the silicon system alone.


Silicon only, eta<.8
Silicon+straws, eta<.8
Silicon+straws, r=6cm
statistical error
100
50
10
5
$10^0$
$10^1$
$10^2$
$10^3$
Pt (GeV/c)
$\sigma(b_0)$ (microns)




3 tracks, # sigma>3
silicon+straws
× bottom jets
MC statistical errors
+ all other jets
Tagging efficiency
1.0
0.8
0.6
0.4
0.2
0.0
20
30
40
50
60
70
80
90
100
200
300
400
500
Jet $P_T$

# Z Resolution With Pixels

| Geometry: | | Radii |
|---|---|---|
| | Pixels | 6 and 9 cm |
| | Silicon Strips | 18, 24, 27, 33, 36 cm |
| | Stereo Straws | 135 and 148 cm. |

$\sigma_{pixels} = 30\,\mu m$, vary $\sigma_{si}$ and $\sigma_{str}$.

| $\sigma_{z_0}$ | $\sigma_{si}$ | $\sigma_{str}$ | |
|---|---|---|---|
| 35 μm | 1.5 mm | .7 mm | |
| 43 μm | 1.5 mm | 1 mm | ← Can we get to here? |
| 55 μm | 1.5 mm | 1.5 mm | |
| 65 μm | 1.5 mm | 2.0 mm | |
| 41 μm | .5 mm | 1.0 mm | |
| 37 μm | .25 mm | 1.0 mm | |

Worried about beam alignment and trigger. Track trajectory:

$$\phi = \phi^0 + kr + b/r$$

Misalignment produces an impact parameter b.

Trigger measures:

$$\frac{d\phi}{dr} = k - \frac{b}{r^2}.$$

Want:

$$\frac{b}{r^2} < \sigma_k.$$

Goals: $\sigma_k = 3 \times 10^{-3}\, m^{-1}$ level 1

$1.5 \times 10^{-3}\, m^{-1}$ level 2.

Typical radii:

| | |
|---|---|
| 25 cm | Silicon |
| 50 cm | Gas microstrips |
| 150 cm | Straws. |

These imply for b:

$b < 7$ mm for straws at level 1.

$b < 800\,\mu m$ for gas microstrips at level 1.

$b < 100\,\mu m$ for silicon alone at level 2

MAJOR ITEM COST
(After R & D)

VQ - Vendor quote
EE - Engr est
C - Catalogue

| ITEM | UNIT COST | UNIT | NUMBER | TOTAL, k | BOE |
|---|---|---|---|---|---|
| Barrel detector | $750 | each | 3600 | $2,700 | VQ |
| Frwd detector | $1,500 | each | 3384 | $5,076 | VQ |
| Barrel readout | $36 | each | 18000 | $642 | VQ |
| Frwd readout | $36 | each | 30456 | $1,086 | VQ |
| Barrel modules | $193 | each | 1800 | $348 | VQ/EE |
| Frwd modules | $234 | each | 1692 | $395 | VQ/EE |
| Data cable | $33 | each | 1925 | $64 | EE |
| Bus selector chip | $10 | each | 6042 | $60 | EE |
| Optical trans/rec | $500 | set | 1248 | $624 | C |
| Optical fiber | $160 | run | 624 | $100 | EE |
| Enclosure | $633 k | each | 1 | $633 | EE |
| Space frame | $599 k | each | 1 | $599 | VQ |
| Ctrl cooling ring | $30 k | each | 16 | $480 | EE |
| Ctrl support cyl | $108.3 k | each | 2 | $217 | EE |
| Ctrl mount | $0.7 k | each | 72 | $50 | EE |
| Ctrl coolant dist | $0.7 k | each | 16 | $107 | EE |
| Ctrl align/assy/tst | $11.4 k | each | 12 | $137 | EE |
| Disc cooling ring | $15.7 k | each | 44 | $691 | EE |
| Disc support ring | $4.2 k | each | 24 | $101 | EE |
| Disc mount | $1.5 k | each | 144 | $216 | EE |
| Disc coolant dist. | $1.5 k | each | 44 | $66 | EE |
| Disc align/assy/tst | $31.2 k | each | 24 | $749 | EE |
| Power cable/bus | $177 k | each | 1 | $177 | EE |
| Int. optical sys | $300 k | system | 1 | $300 | EE |
| Slow control | $40 k | system | 1 | $40 | EE |
| Heat rejection sys | $595 k | system | 1 | $595 | EE/C |
| Gas system | $35 k | system | 1 | $35 | EE |
| | | | TOTAL | $16,288 | |

Total w/o contingency = $32,830 k
Total with contingency = $43,963 k

MAJOR ITEM COST
(After R & D)

VQ - Vendor quote
EE - Engr est
C - Catalogue

| ITEM | UNIT COST, k | UNIT | NUMBER | TOTAL, k | BOE |
|---|---|---|---|---|---|
| Barrel detector | $0.750 | each | 3600 | $2,700 | VQ |
| Frwd detector | $1.500 | each | 3112 | $4,668 | VQ |
| Barrel readout | $0.053 | each | 18000 | $954 | VQ |
| Frwd readout | $0.053 | each | 32640 | $1,730 | VQ |
| Barrel modules | $0.164 | each | 1800 | $296 | VQ/EE |
| Frwd modules | $0.265 | each | 1632 | $433 | VQ/EE |
| Data cable | $0.022 | each | 2008 | $44 | EE |
| Bus selector chip | $0.010 | each | 6102 | $61 | EE |
| Optical trans/rec | $0.500 | set | 1236 | $618 | C |
| Optical fiber | $0.160 | link | 618 | $99 | C |
| FEE Labor | $3,215 | effort | 1 | $3,215 | EE |
| DAT Labor | $146 | effort | 1 | $146 | EE |
| Enclosure/supports | $881.0 | each | 1 | $881 | VQ |
| Space frame/mounts | $501.0 | each | 1 | $501 | VQ |
| Ctrl cooling ring | $12.5 | each | 20 | $250 | VQ |
| Ctrl support rings | $12.5 | each | 4 | $50 | VQ |
| Ctrl support cyl. | $122.5 | each | 2 | $245 | VQ |
| Ctrl ring/shell mt | $1.0 | each | 72 | $75 | EE |
| Ctrl coolant dist | $2.1 | each | 20 | $42 | VQ |
| Ctrl align/assy/tst | $10.0 | each | 12 | $120 | EE |
| Disc cooling ring | $11.3 | each | 48 | $542 | VQ |
| Disc support ring | $16.9 | each | 22 | $372 | VQ |
| Disc Array mount | $3.1 | each | 78 | $242 | EE |
| Disc coolant dist. | $4.6 | each | 26 | $120 | VQ |
| Disc align/assy/tst | $8.6 | each | 26 | $224 | EE |
| Power cable/bus | $5.6 | each | 68 | $381 | VQ/EE |
| Int. optical sys | $9.0 | each | 30 | $270 | EE |
| Heat rejection sys | $180.0 | each | 2 | $360 | VQ/EE |
| Gas system | $17.5 | each | 2 | $35 | EE |
| Pwr Sppls/Cables | $0.9 | each | 164 | $148 | EE |
| Trker assy/test | $879.0 | each | 1 | $879 | EE |
| In-situ alignment | $250.0 | sys | 1 | $250 | EE |
| 1.1 Prog Man | $989.0 | each | 1 | $989 | EE |
| | | | TOTAL | $21,939 | |

Total w/o contingency = $32,860 k
Total with contingency = $41,743 k

PRESENTATION BY:

HAROLD OGREN

# 1 METER MODULE TESTS

a) Assembled 159 straws

wire supports (3)

Bonded lid

Bonded endcaps

Ground connections to straws

Strung wires

Measured tension

Flushed chamber with He

Chamber now running on cosmic ray stand

pictures

# Modular straw outer tracker

## Developments since December, 1991

- 1 meter long tests
  - efficiency
  - signals
  - pictures of events
  - resolution studies
- 4 meter shell
  - review of old schedule
  - pictures of shells
  - measurements of shells
- " Pisa compromise" Configuration
- Performance studies
- Trigger simulation
- Costing changes

## Recommendations II of Tracking Evaluation committee Nov. 17, 1991

3) The committee would like to see an all-straw design for the Technical Proposal with robust capabilities in the following areas:

a) Good pattern recognition and efficient linkage to the silicon system to exploit fully the large magnetic field volume for measurements of momentum.

b) A L1 trigger that uses more than a single axial superlayer and is both highly efficient and has good fake rejection.

c) Measurements of the Z coordinate and polar angles that are well matched to the requirements of the extrapolation to the outer detectors.

d) The understanding of the capabilities of the system e.g. pattern recognition, trigger, and radiation damage, as the luminosity rises beyond the design luminosity of $10^{33}$ up to $10^{34}$.

## Engineering Review on Modules, B. Miller December 5, 1991

Carbon-fiber shell module approach for a straw based outer tracker was selected.

TEC

4) On the mechanical design, the committee notes:

a) A modular approach provides a credible way to make stereo straws.

b) Any credible design must address the issue of replacing the inner layers for higher luminosity operation.

Demonstrations by next review. If answers cannot be provided by the next review a timetable should be produced:

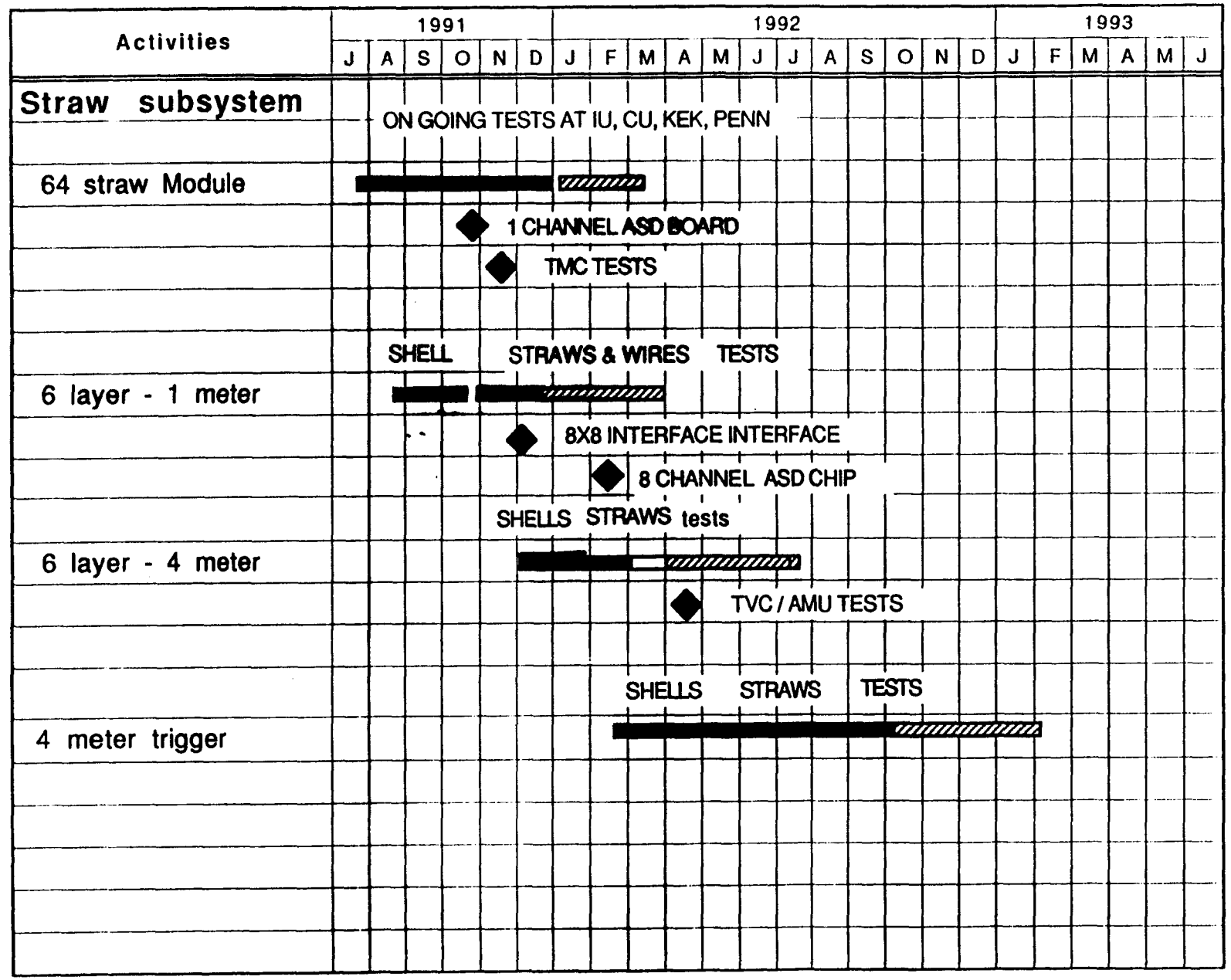
straws:

1)Demonstrate a four meter straw with the prototype readout at radiation levels (e.g. rate and current draw) corresponding to the SSC operation.

2) Demonstrate a four meter module loaded with straws and readout.

3) Demonstrate electronics robustness to noise and oscillations at operating conditions.in a large scale test.

4)Provide the integrated mechanical design of the packaging for the electronics and the cabling.


Activities
1991
1992
1993
J A S O N D J F M A M J J A S O N D J F M A M J
Straw subsystem
ON GOING TESTS AT IU, CU, KEK, PENN
64 straw Module
1 CHANNEL ASD BOARD
TMC TESTS
SHELL
STRAWS & WIRES
TESTS
6 layer - 1 meter
8X8 INTERFACE INTERFACE
8 CHANNEL ASD CHIP
SHELLS
STRAWS
tests
6 layer - 4 meter
TVC / AMU TESTS
SHELLS
STRAWS
TESTS
4 meter trigger

# 1 meter module
# Testing with cosmic rays

Using Penn Amplifier\
John Oliver shaper\disc
layout board for 16 ch.

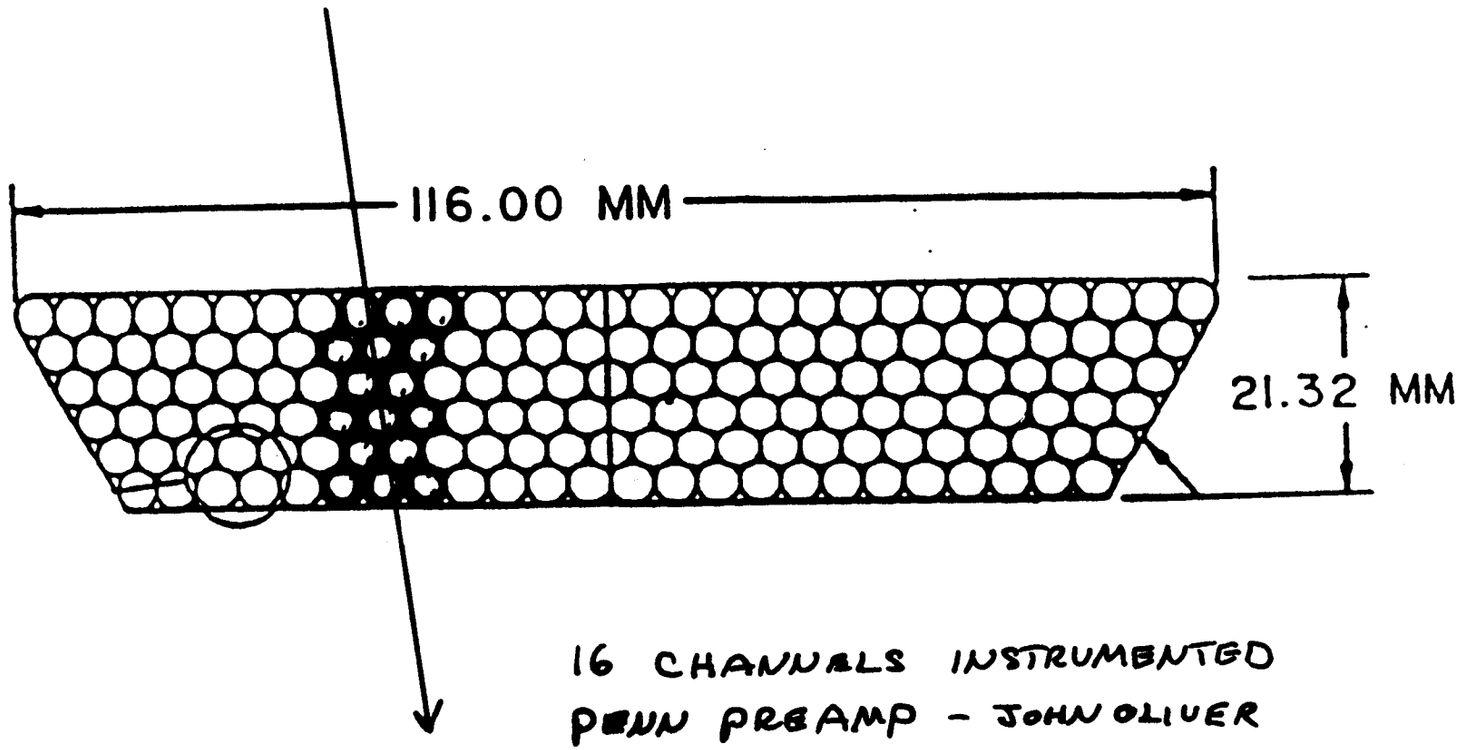
Operating at a threshold of about 4 fC.
(Approximately one cluster)

With HV from 1800- 2000 volts

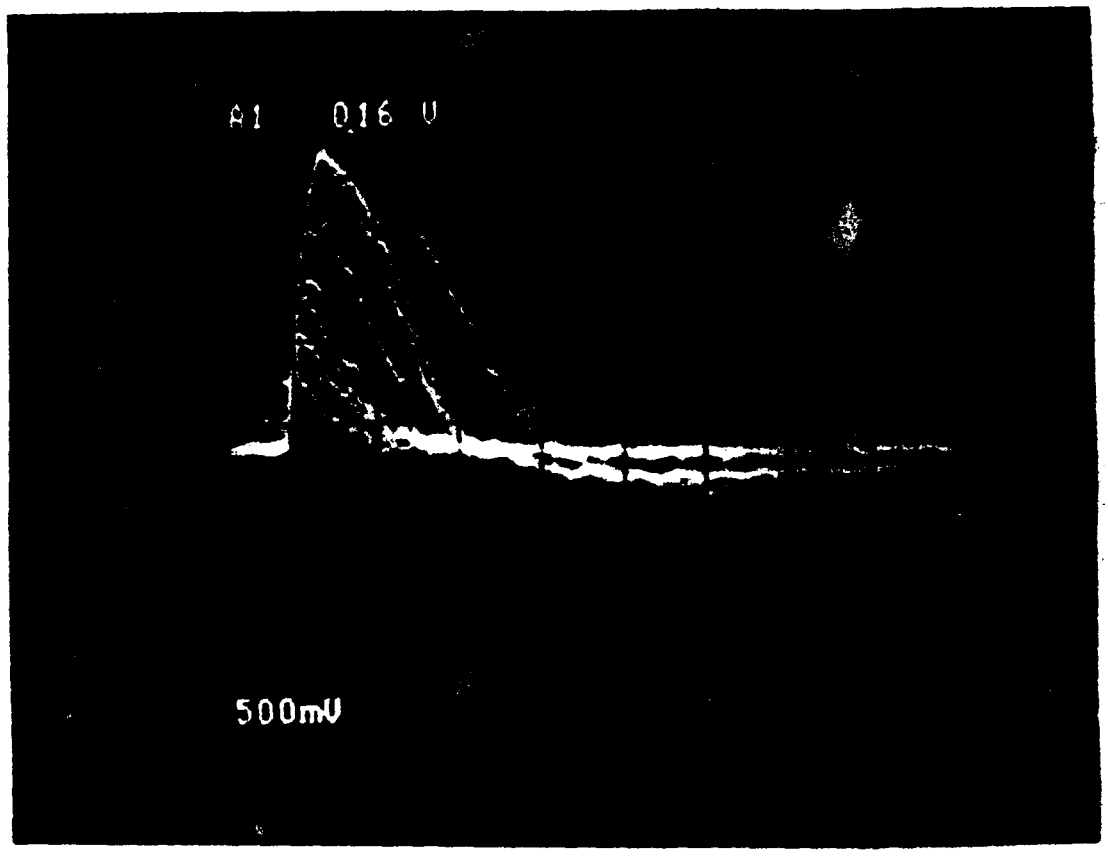
Signals from amplifiers

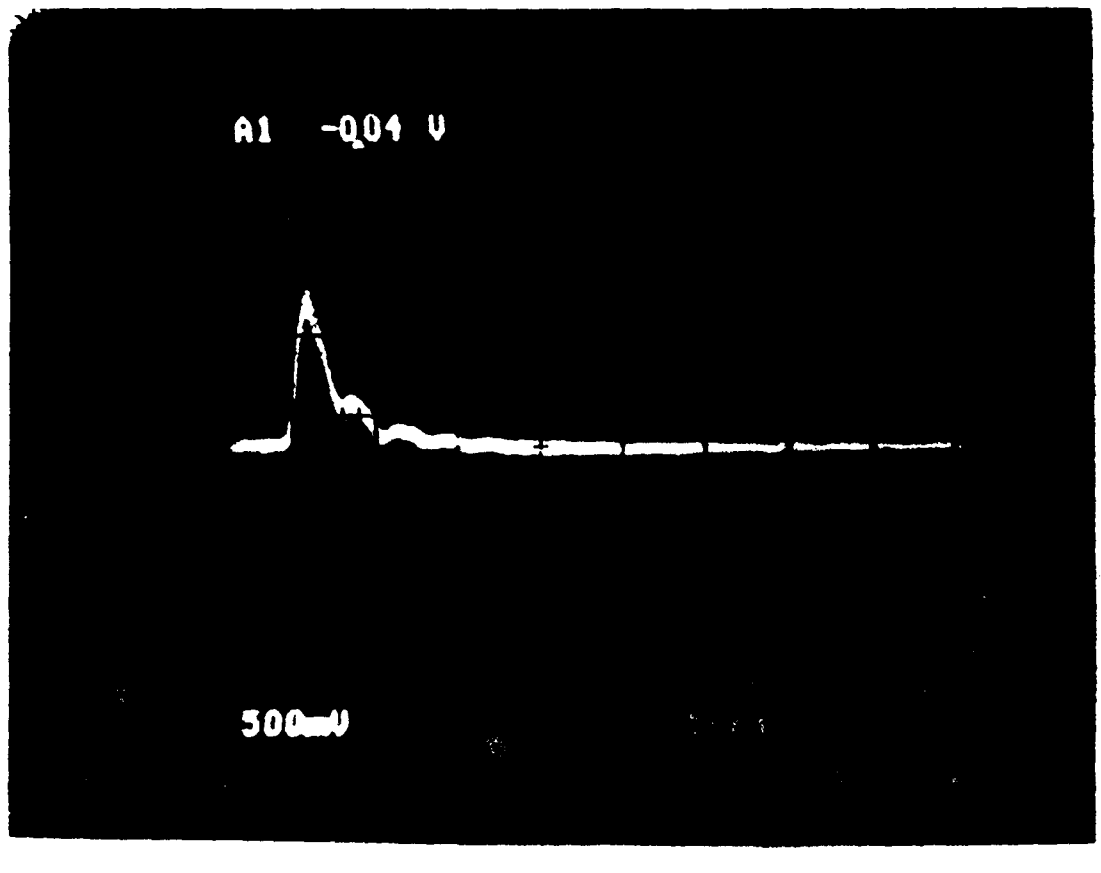
Efficiency- at low threshold

Resolution measurements-




16 CHANNELS INSTRUMENTED
PENN PREAMP - JOHN OLIVER
SHAPER - DISC BOARD
ALL WIRES TERMINATED - BOOR


A1 0.16 V
500mV




$Fe^{55}$ 1700V

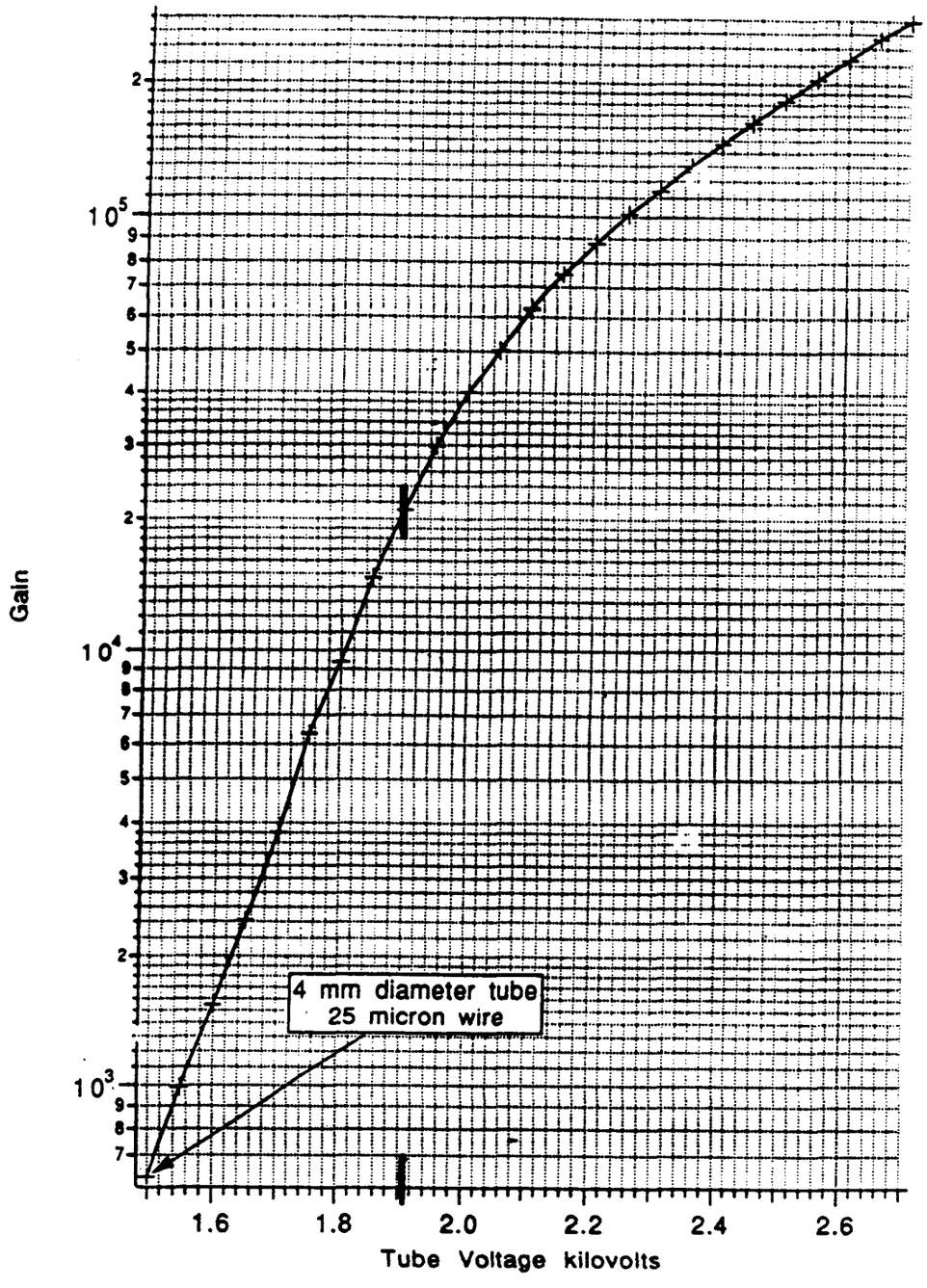
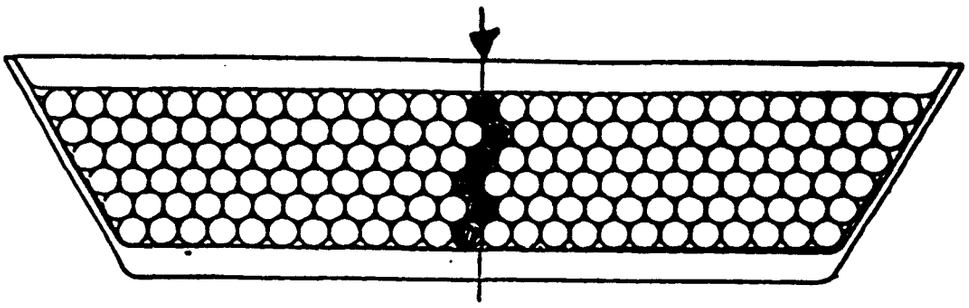
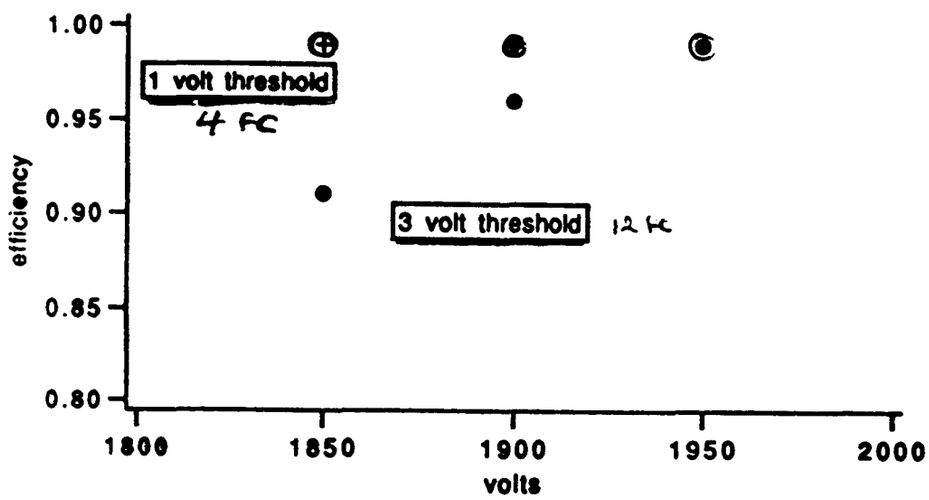



Fig. III.3. The gain curve of a 4 mm straw drift tube with $CF_4$ -isobutane 80:20 gas. The absolute calibration of the curve is accurate to about 15% but the shape of the curve reflects the true dependence of the gain on voltage.

COSMIC RAY EFFICIENCY MEASUREMENTS





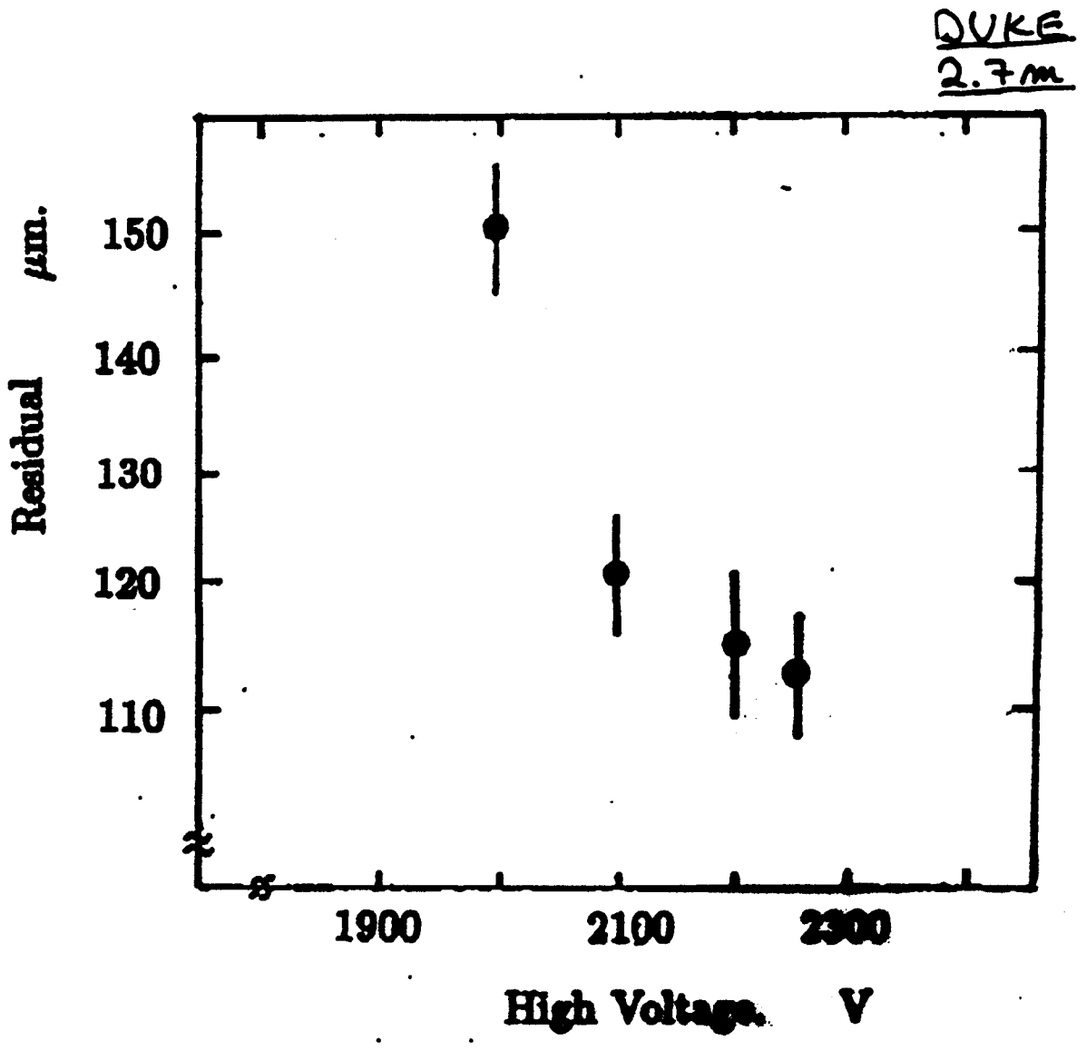



Fig.III. 6. Dependence of efficiency of a straw tube as a function of voltage in cosmic ray tests.

DUKE
2.7 METER

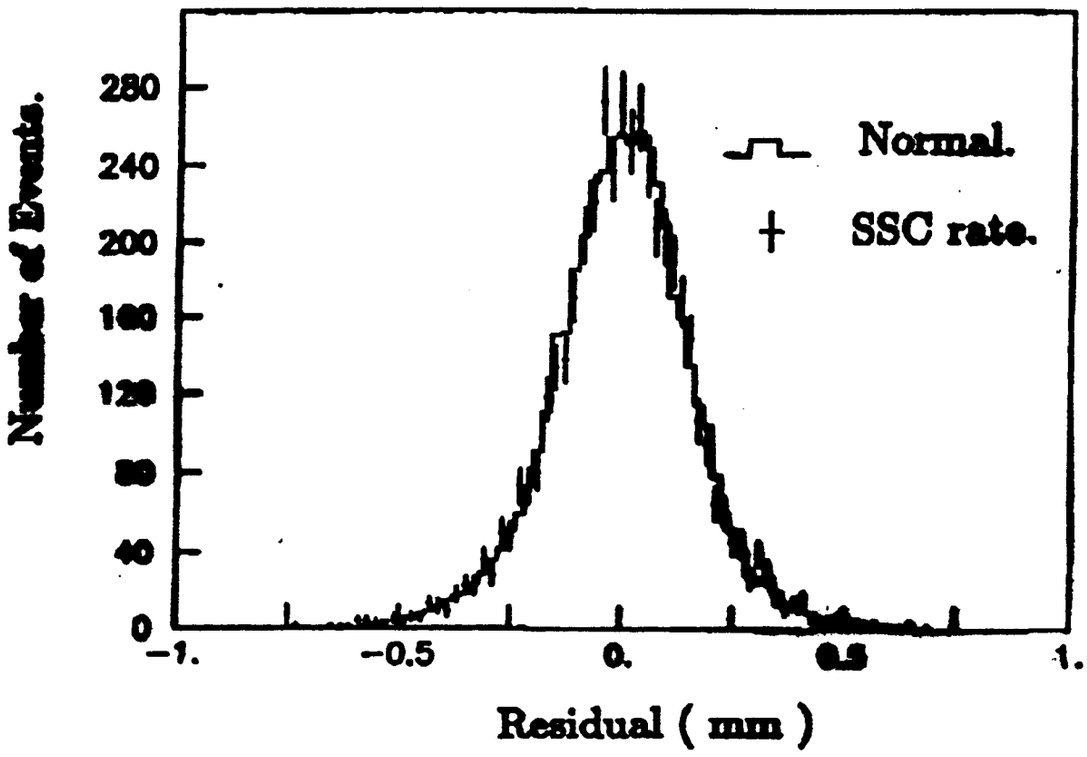



Fig.III. 7. Plot of the residuals of fits to cosmic ray tracks in a module from data taken under two different background conditions. One free of extra background and the other with a background similar to what is expected in an SSC environment.

# 4 meter shell

**Review of schedule**

**Graphite molds were finished on**

**December 19.**

**First base assembly finished**

**December 24**

**First lid finished**

**December 31, 1991.**

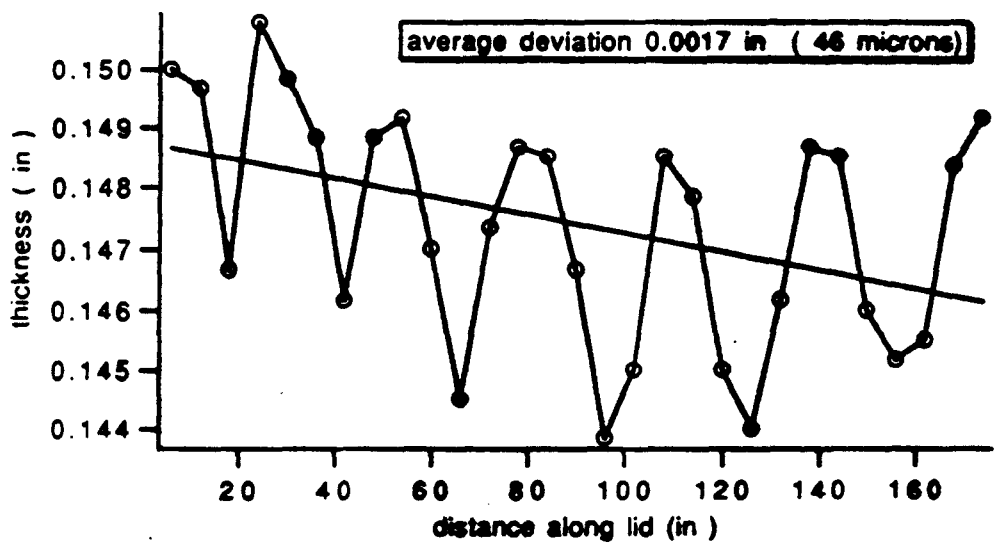
**Shipped to Bloomington**

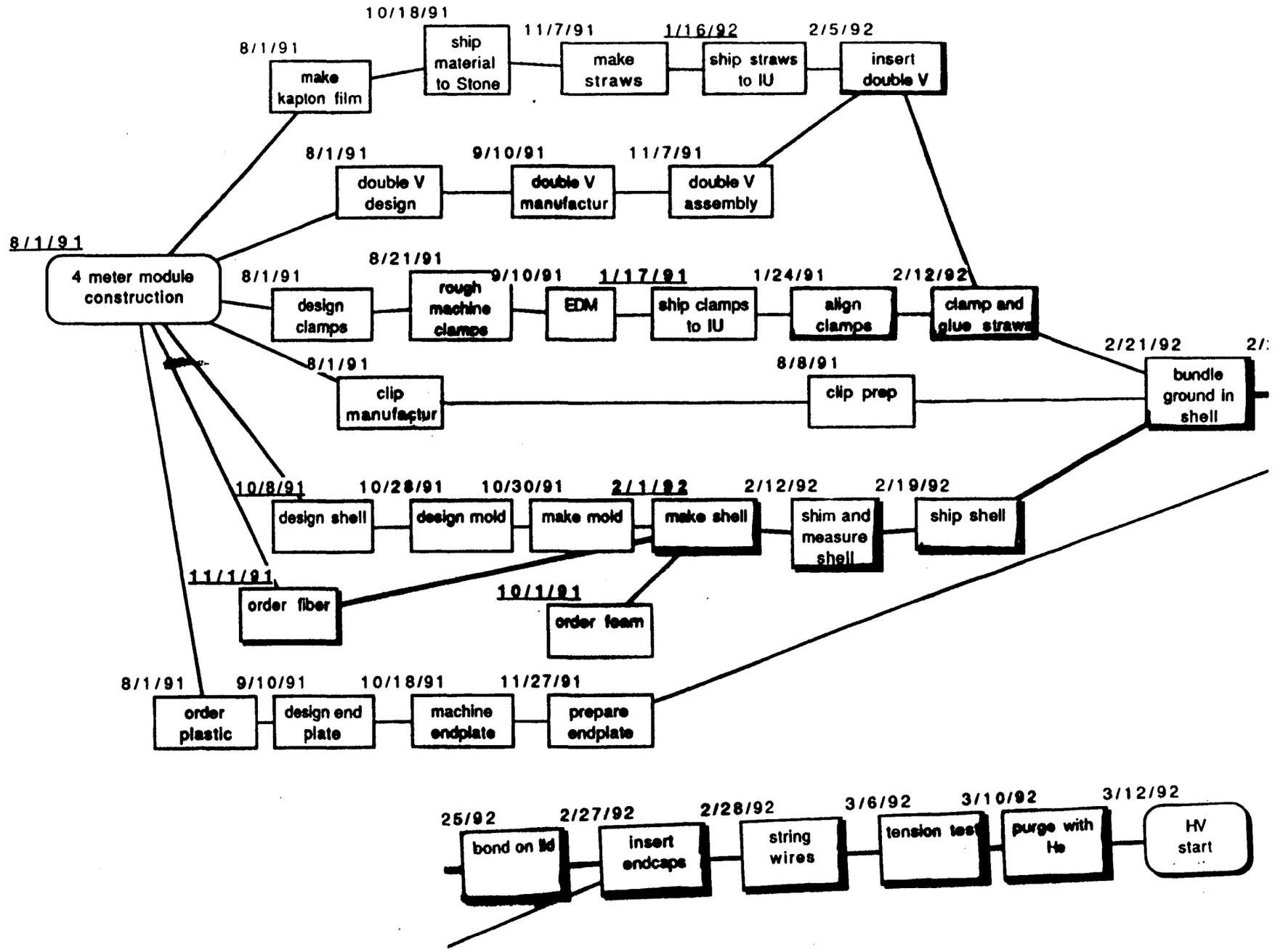
**Jan. 14, 1991**

**Pictures**

**First measurements of the shell made in Bloomington and CHI.**

**Measurements proceeding.**
**Second shell produced this week at CHI.**


average deviation 0.0017 in ( 46 microns)
0.150
0.149
0.148
0.147
0.146
0.145
0.144
thickness ( in )
20
40
60
80
100
120
140
160
distance along lid (in )


8/1/91
4 meter module construction
8/1/91
make kapton film
10/18/91
ship material to Stone
11/7/91
make straws
1/16/92
ship straws to IU
2/5/92
insert double V
8/1/91
double V design
9/10/91
double V manufactur
11/7/91
double V assembly
8/1/91
design clamps
8/21/91
rough machine clamps
9/10/91
EDM
1/17/91
ship clamps to IU
1/24/91
align clamps
2/12/92
clamp and glue straws
8/1/91
clip manufactur
8/8/91
clip prep
2/21/92
bundle ground in shell
10/8/91
design shell
10/28/91
design mold
10/30/91
make mold
2/1/92
make shell
2/12/92
shim and measure shell
2/19/92
ship shell
11/1/91
order fiber
10/1/91
order foam
8/1/91
order plastic
9/10/91
design end plate
10/18/91
machine endplate
11/27/91
prepare endplate
25/92
bond on lid
2/27/92
insert endcaps
2/28/92
string wires
3/6/92
tension test
3/10/92
purge with He
3/12/92
HV start

# SOME R&D MILESTONES

| MILESTONE | DATE |
|---|---|
| <u>Straw R&D</u> | |
| Develop final wire support design | Sep. 92 |
| Develop resistive terminator | Sep. 92 |
| Develop fabrication technique | Feb. 93 |
| <u>Module R&D</u> | |
| Complete construction of first 4-meter nontrigger module | Mar. 92 |
| Complete construction of 5 more nontrigger modules | Aug. 92 |
| Complete construction of 4-meter trigger shells (two types) | Sep. 92 |
| Complete construction of 4-meter trigger modules | Nov. 92 |
| Complete construction of 4 more trigger modules, for a total of six | Feb. 93 |
| <u>Detector and Electronics Evaluation</u> | |
| Develop cross-talk free connection from wires to electronics | Sep. 92 |
| Establish operating condition for modules with prototypes of final electronics (~ 100 μm resolution at $2 - 5 \times 10^4$ gain) | Feb. 93 |
| <u>Aging Studies</u> | |
| Study materials | Feb. 93 |
| Study wire chamber lifetime (neutrons, etc.) | Feb. 93 |
| Rate studies | Feb. 93 |

Engineering R&D

| | |
|---|---|
| Develop the spaceframe support design | Sept 92 |
| build and test strut and joint prototypes | Aug 92 |
| Develop cylinder engineering | Sept 92 |
| build and test flat prototype | May 92 |
| build and test small cylinder | Sept 92 |
| Develop layout for trigger and stereo modules | April 92 |
| Develop shim rings | Sept 92 |
| build and test prototype | June 92 |
| Develop module attachment | Sept 92 |
| build and test attachment prototype | July 92 |
| Develop tracker support | Sept 92 |
| design support fixtures | May 92 |
| build and test model | July 92 |
| design silicon mount | July 92 |
| Develop stability test program,temp,moisture | July 92 |
| Develop assembly concepts | Sept 92 |
| Develop alignment requirements | Sept 92 |
| Develop alignment techniques | Sept 92 |
| Carry out structural analysis on structure | Sept 92 |
| Design support structure for multilayer beam test | Sept 92 |
| Build multilayer structure | Jan 93 |
| Develop the Outer tracker Utilities | Sept. 92 |
| Design the electronics distribution | July 92 |
| Design the electronics cooling | Aug 92 |
| Design the gas distribution and recovery systems | Sept 92 |
| Design the tracker diagnostic instrumentation | Sept 92 |
| Develop the Outer tracker surface faculties | April 93 |

Computer Simulation

| | |
|---|---|
| Determine final configuration of outer tracking system | May 92 |
| Establish performance of combined tracking system | Feb. 93 |

components of the proposed outer tracking system. There are a total of $1.30 \times 10^5$ straws in the system.

Table I.1. Modular Straw Outer Tracker Design

| Superlayer | Mean Radius (m) | Modules | Channel Count | Layers/Super layer | $z_{max}$ (m) | Stereo Angle (°) |
|---|---|---|---|---|---|---|
| 1 | 0.710 | 80 | 12,720 | 6 | 2.00 | 0 |
| 2 | 1.067 | 120 | 19,080 | 6 | 3.20 | +3 |
| 3 | 1.351 | 152 | 32,224 | 8 (trigger) | 3.90 | 0 |
| 4 | 1.488 | 168 | 26,712 | 6 | 3.95 | -3 |
| 5 | 1.631 | 184 | 39,008 | 8 (trigger) | 3.95 | 0 |

We have made considerable progress during the past year in straw module design and construction, as described in Section IV. The module shell is composed of a carbon fiber composite and foam laminate, which is very rigid with low mass. The first one-meter full-cross-section module (159 straws) with a shell of this design has been completed and is now being tested. Six short modules of an earlier design, containing 64 straws, were built and are now being tested at several institutions. The first full-length 4-meter shell has been constructed and will soon be assembled into a complete module.

The modules are supported on cylinders of a design similar to the module shells, so that they too have excellent structural properties with low material. Section VI presents the tracking system support structure and assembly procedures for the tracking system. The cylinders are supported by a carbon composite space frame. Results of finite element analyses are given.

The conceptual designs of the front end and trigger electronics are summarized from the individual conceptual design reports in Section V.

Integration of the tracking system with the rest of the detector is described in Section VII. The remaining R&D is discussed in Section VIII. The schedule for construction and checkout of the tracking system and the cost estimate are presented in Section IX.

Table II.3. Parametric Resolutions

| Track Parameter | Si + 4 Superlayers | Si + 5 Superlayers | Si Only | STRAW only CBC |
|---|---|---|---|---|
| $\sigma_{p_T}/p_T$ @ 1 TeV (BC) | 0.150 | 0.150 (9) | 1.343 | .35 |
| $\sigma_{p_T}/p_T$ @ 1 TeV (No BC) | 0.166 | 0.165 (12) | 2.023 | |
| $\phi_0$ (mrad) | 0.066 | 0.066 (4) | 0.277 | |
| $\cot\theta$ (mm/m) | 1.311 | 1.310 (5) | 7.054 | 5.5 |
| $b$ (μm) | 13.1 | 13.0 (2) | 28.6 | |
| $z_0$ (mm) | 0.77 | 0.77 (2) | 1.70 | |
| $r\phi$ @ shower max. (mm) | 0.14 | 0.14 (18) | 2.5 | |
| $z$ @ shower max. (mm) | 2.5 | 2.5 (6) | 14 | 5mm |

For the parametric resolutions presented in Table II.3, we take 6 (8) layers per superlayer, configured as in Table II.2, intrinsic resolution of 120 μm per straw measurement, internal alignment of wires within a superlayer of 30 μm, error from lack of straightness of the module of 45 μm, and from placement of the modules of 45 μm. We assume 90% efficiency for hits included on segments. The results of adding these in quadrature are 87 (83) μm for 6 (8) layer superlayers. The stereo angles of superlayers 2

MONTE CARLO SIMULATION OF TRACKER - SDCSIM

6 — 100 GeV (NO INTERACTIONS)

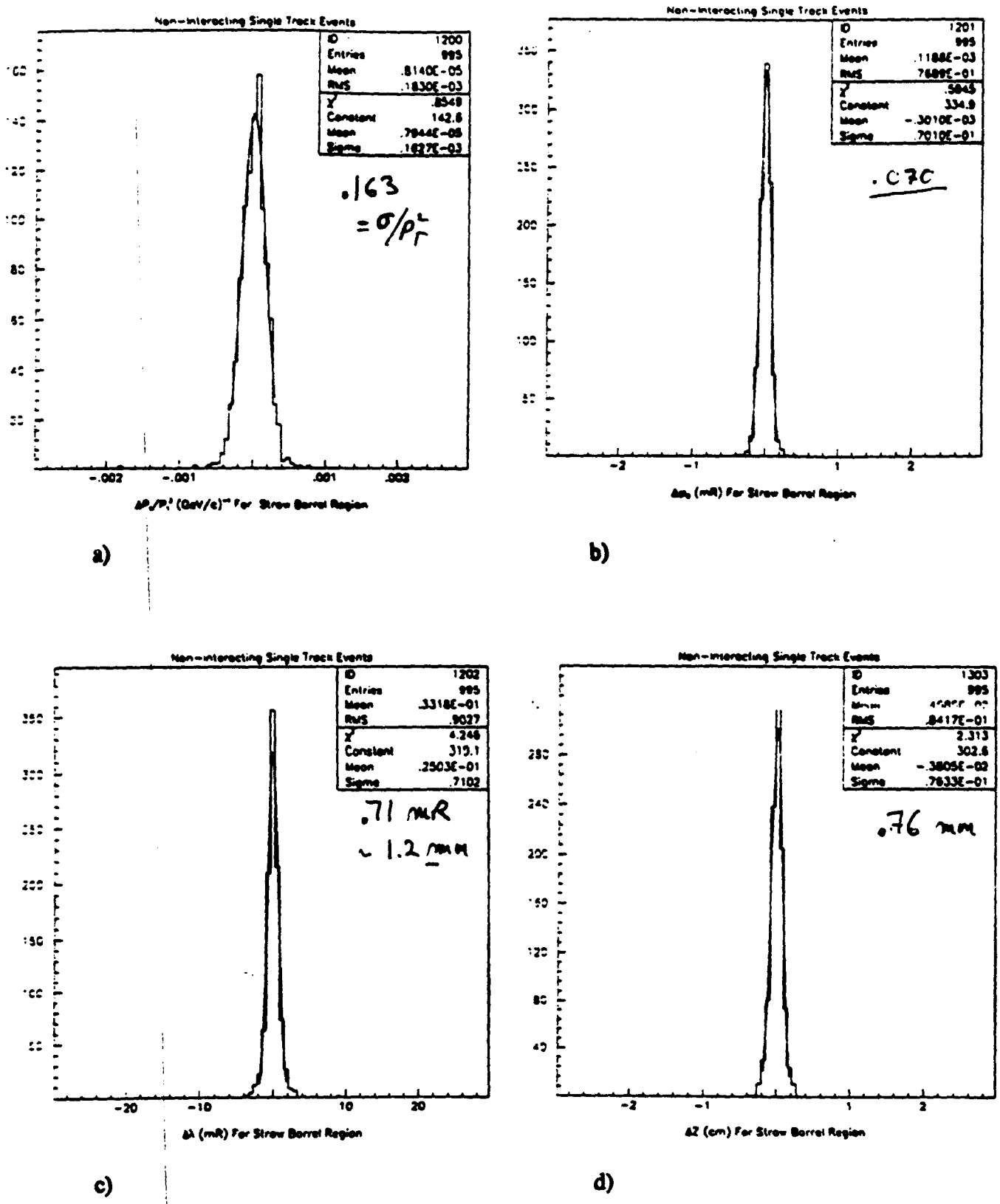



Fig. II.9 The resolutions of $P_T$, $\phi_0$, $\lambda$, $Z_0$ for non interacting particles

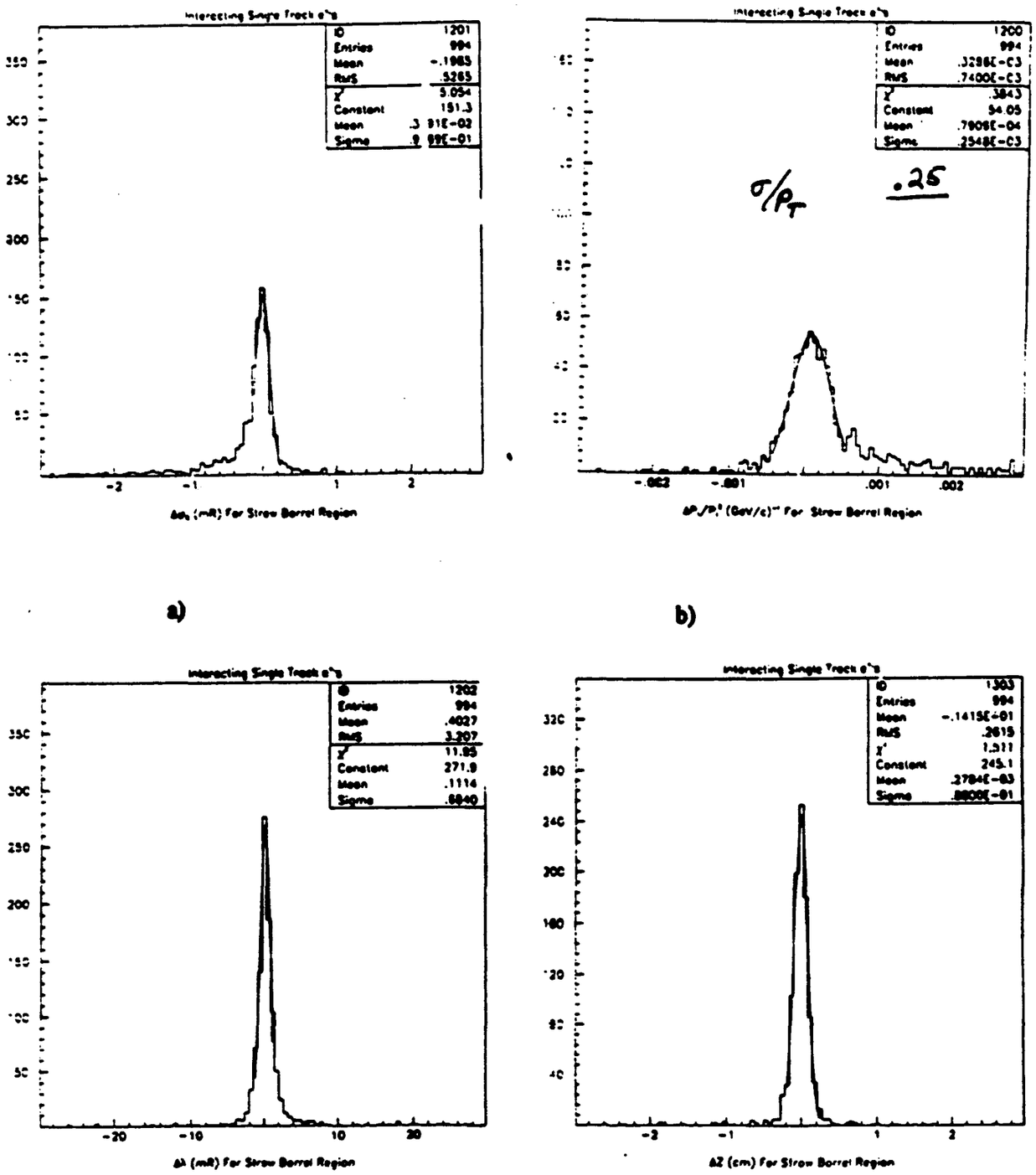
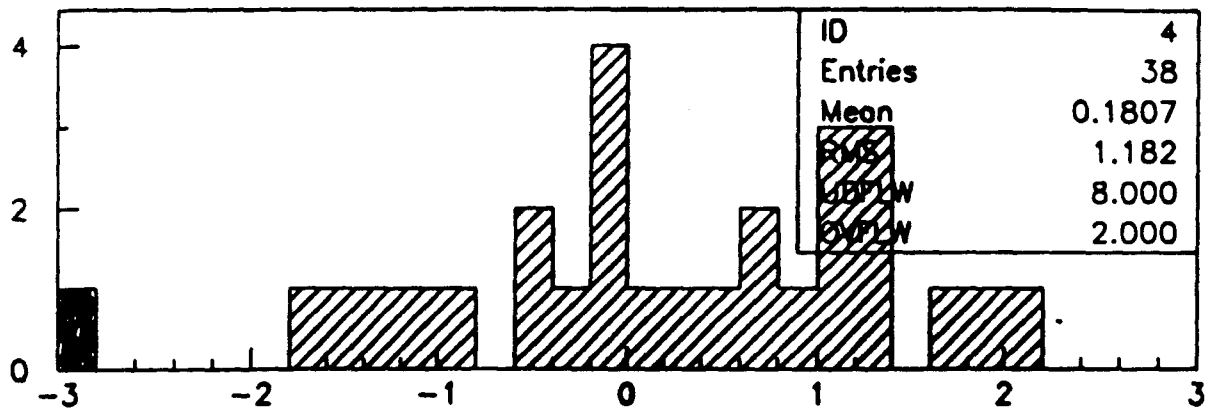


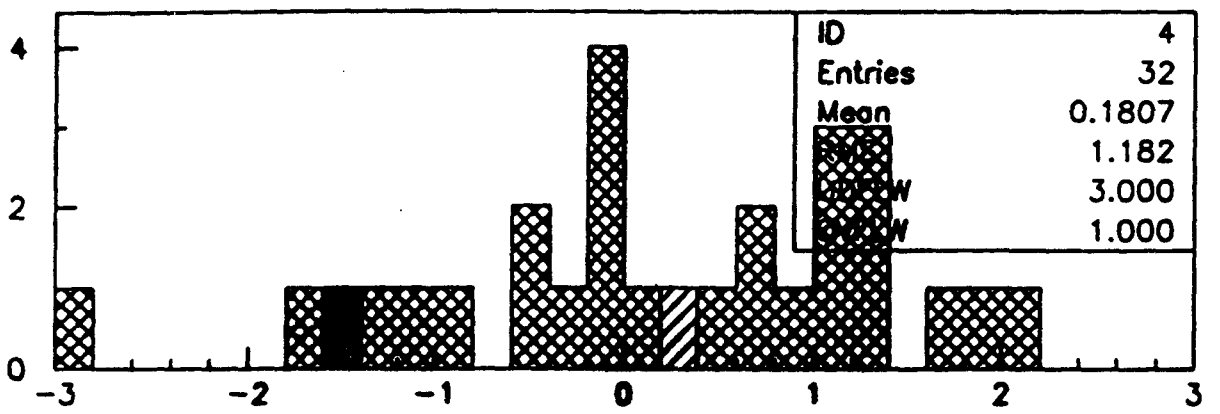

Fig. II.10 The resolution in $P_T$, $\phi_0$, $\lambda$, $Z_0$ for a muon with all interactions turned on.

TRACK FINDING VS η

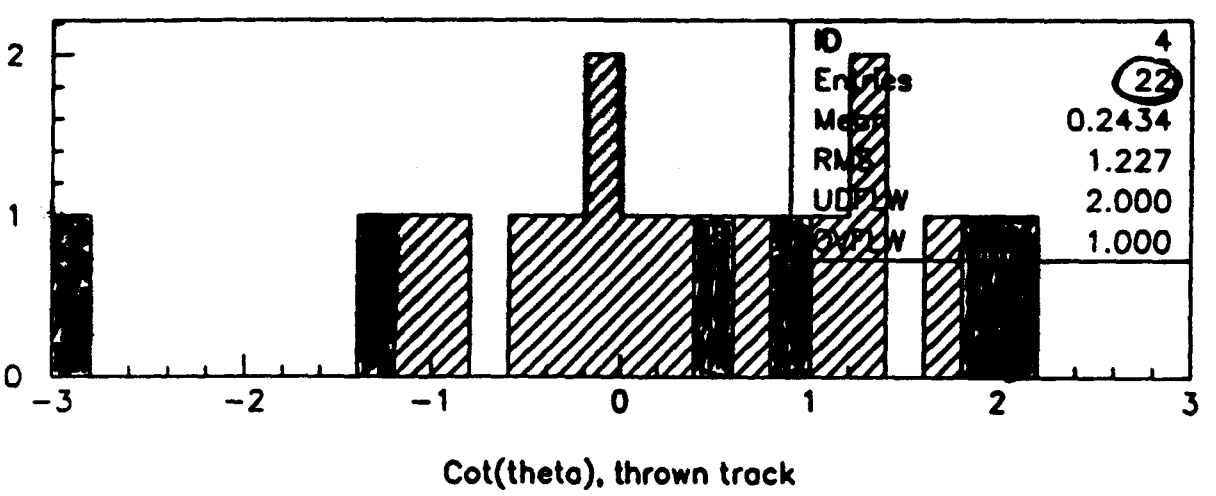
Higgs → 4



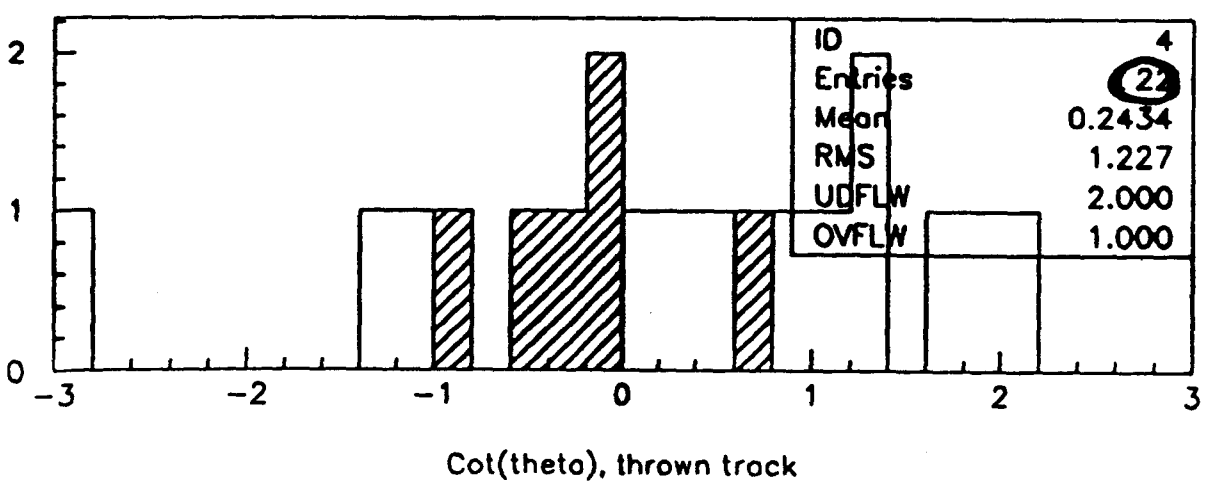

NO MUONS



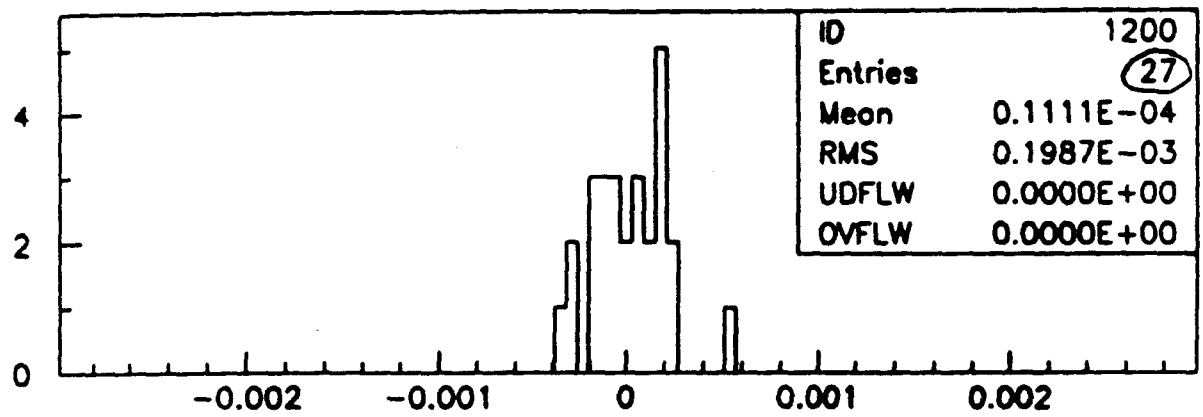

$10^{33}$




$3 \times 10^{33}$

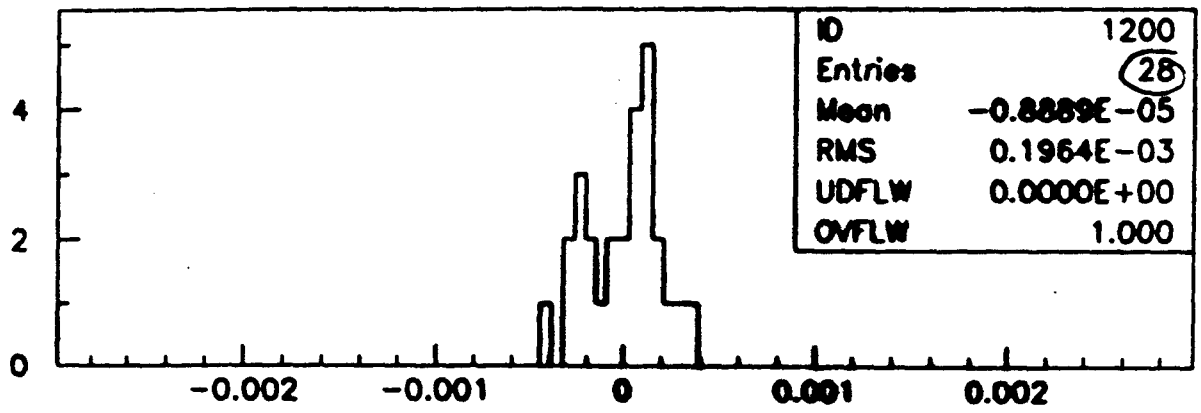



$6 \times 10^{33}$

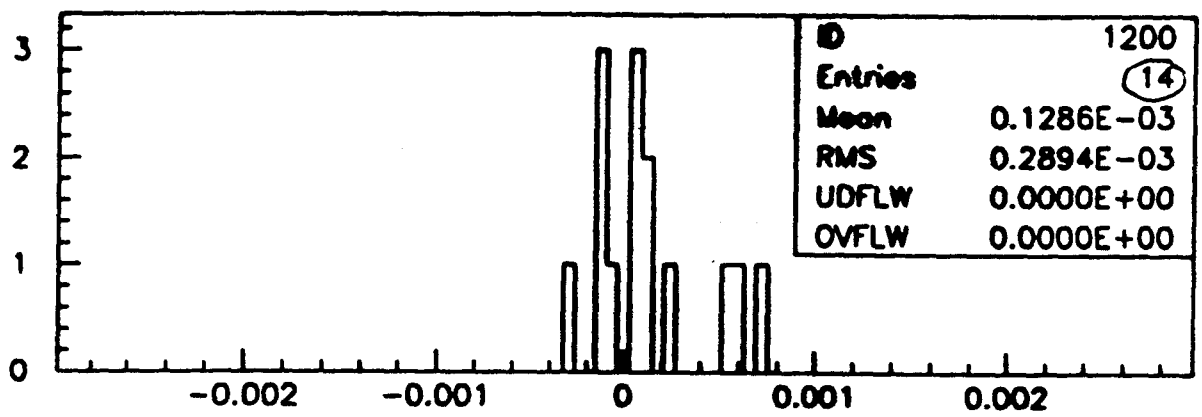



Higgs → 4l

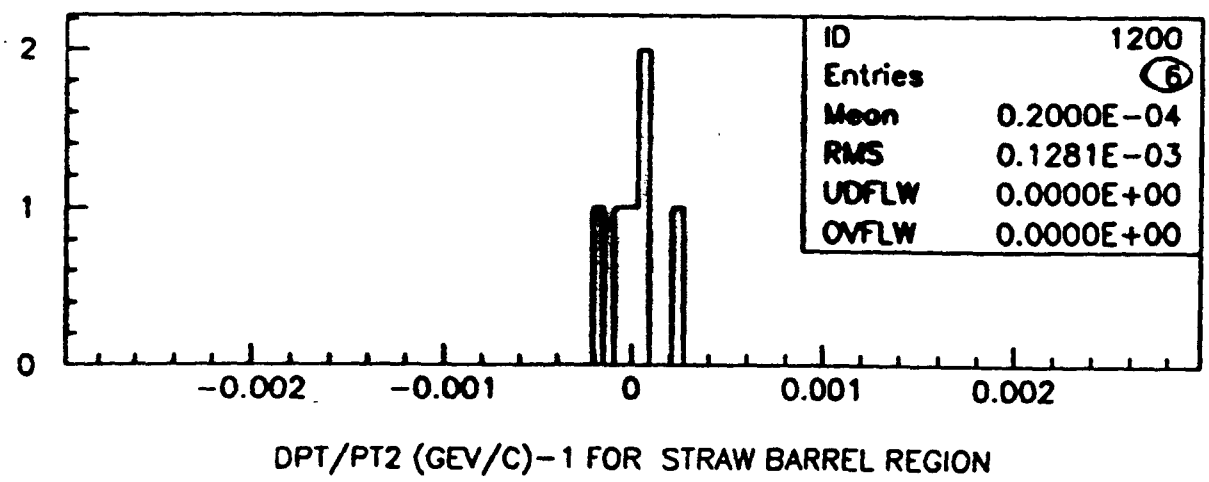
No MUBA




$10^{33}$




$3 \times 10^{33}$




$6 \times 10^{33}$

TRIGGERING STUDIES

JAY CHAPMAN

One of Eight Patterns

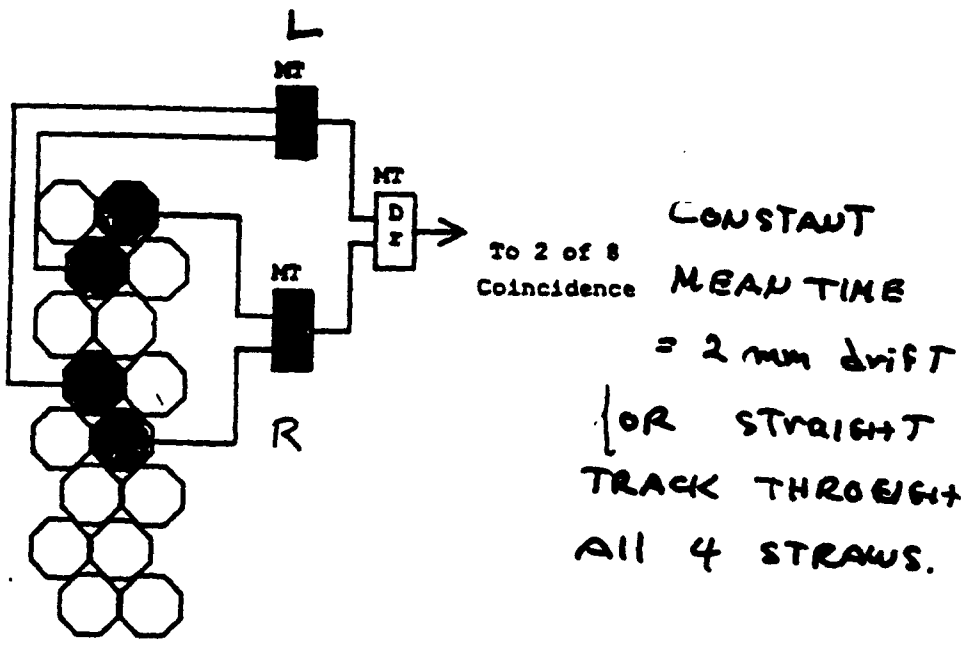



Fig. V.22. A representative mean timer connection for an 8 tube superlayer. The connection shows two mean timers each requiring hits to be consistent with a preset momentum lower limit and output pulses averaged in time to a common radial position. The third mean timer averages these output pulses to arrive at a final pulse whose timing is fixed relative to the particle passage time plus the signal propagation time from its z position to the end of the straws. The pattern shown is one of 8 used in a two-fold coincidence to produce a stiff track trigger.

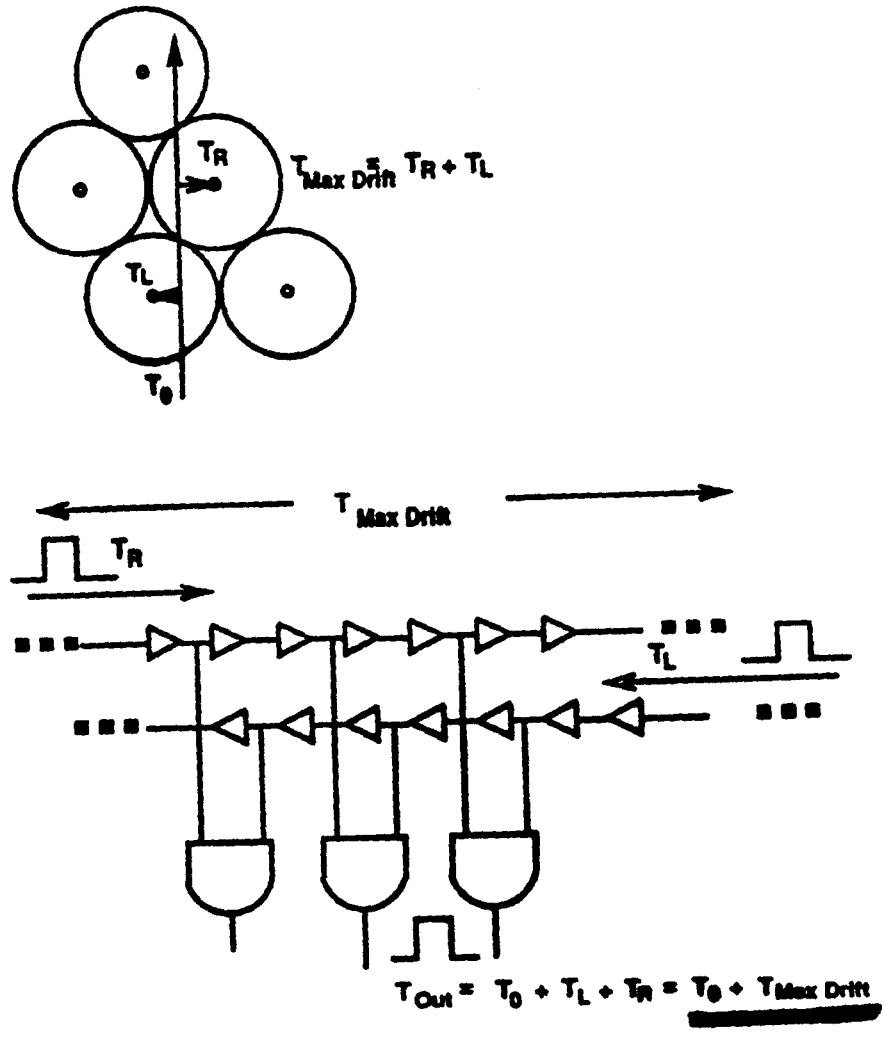



Fig. V.8. Mean time method of segment finding.

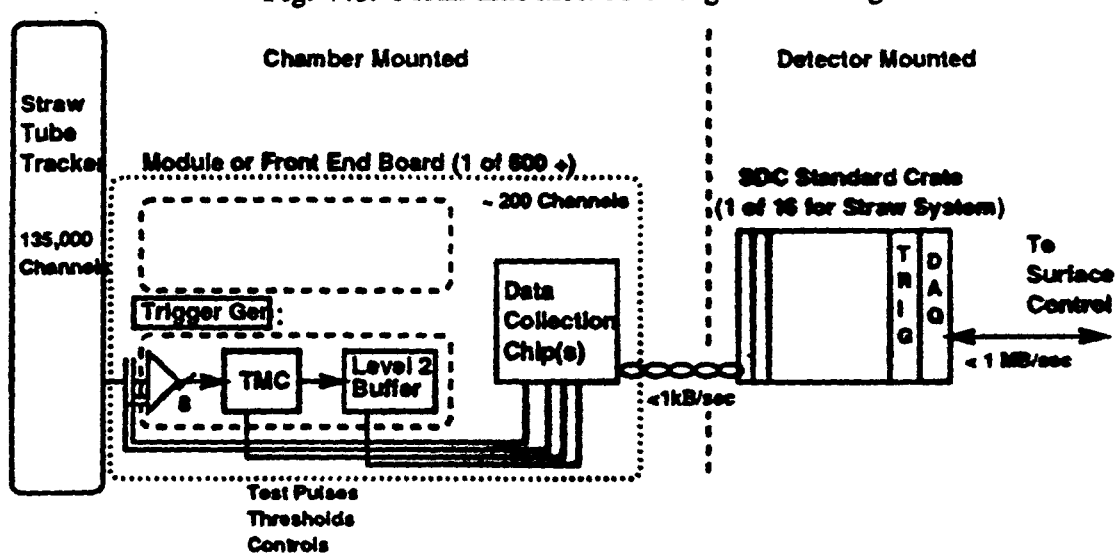



Fig. V.9. Control path to the straw electronics.

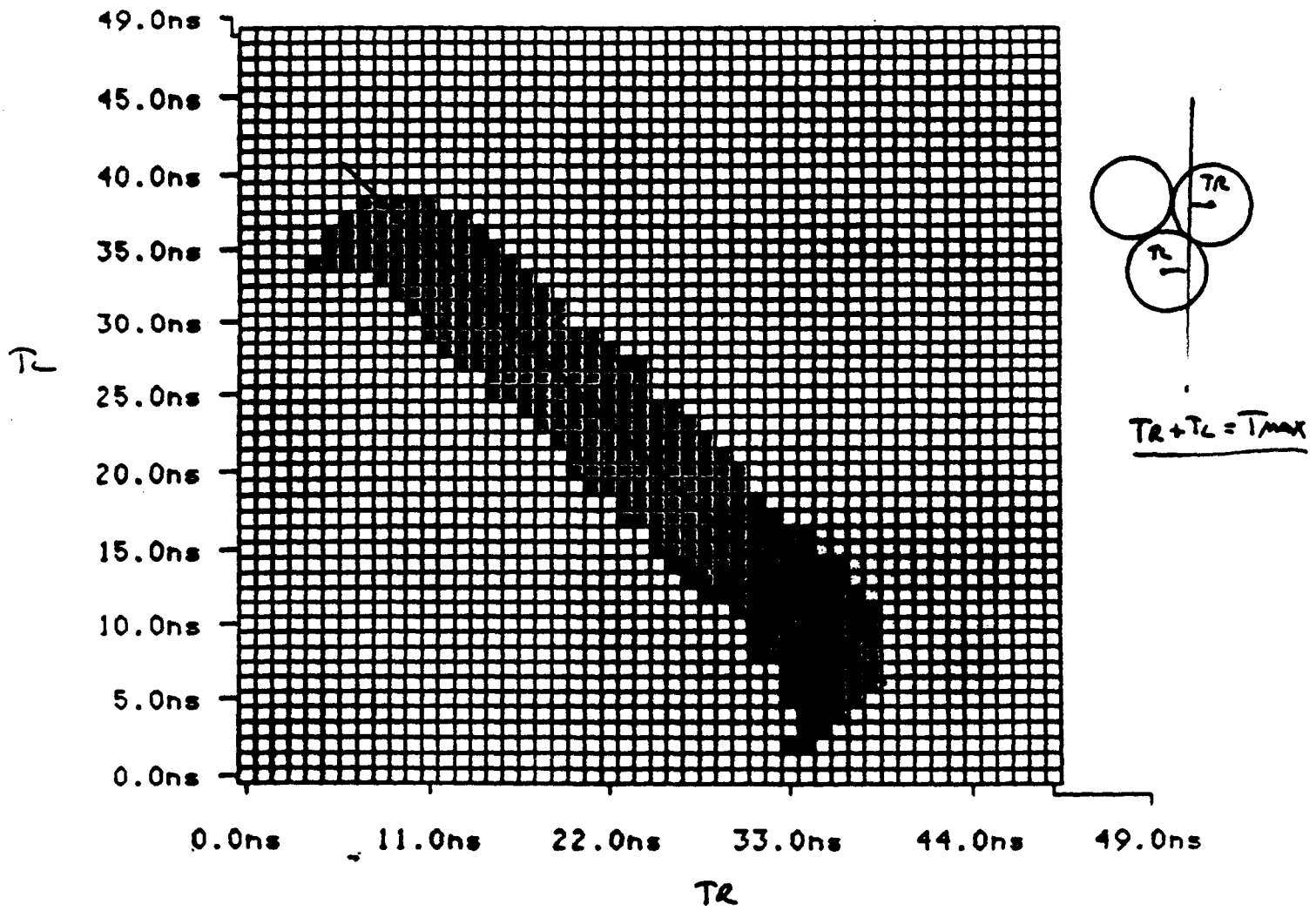



Fig. V.24. A test plot of the $p_T$ cut portion of the mean timer IC. The axes are the times of the aligned wire inputs and the plotted points are those values of the axis coordinates for which an output was generated at a predetermined value. A falling 45° is expected for correct averaging of the input times. The cutoff of the line at large coordinate differences is due to the time difference restriction (momentum cut).

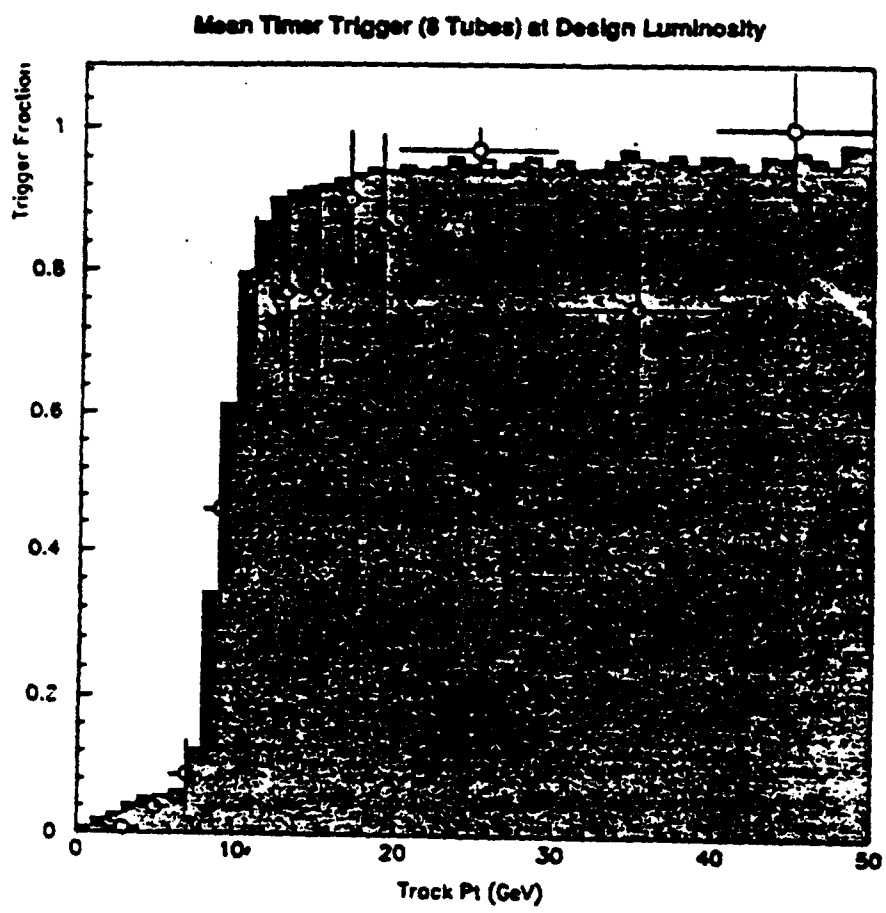



Fig. V.23. The efficiency as a function of $p_T$ for a digital mean timer based trigger operating on signals from an 8 tube deep superlayer of packed straw cells. The points are from a GEANT simulation of Higgs $\rightarrow Z\,Z$ events at $10^{33}$ cm$^{-2}$ s$^{-1}$ luminosity, and the shaded histogram is for a fast parametrized simulation tuned to match the GEANT points.

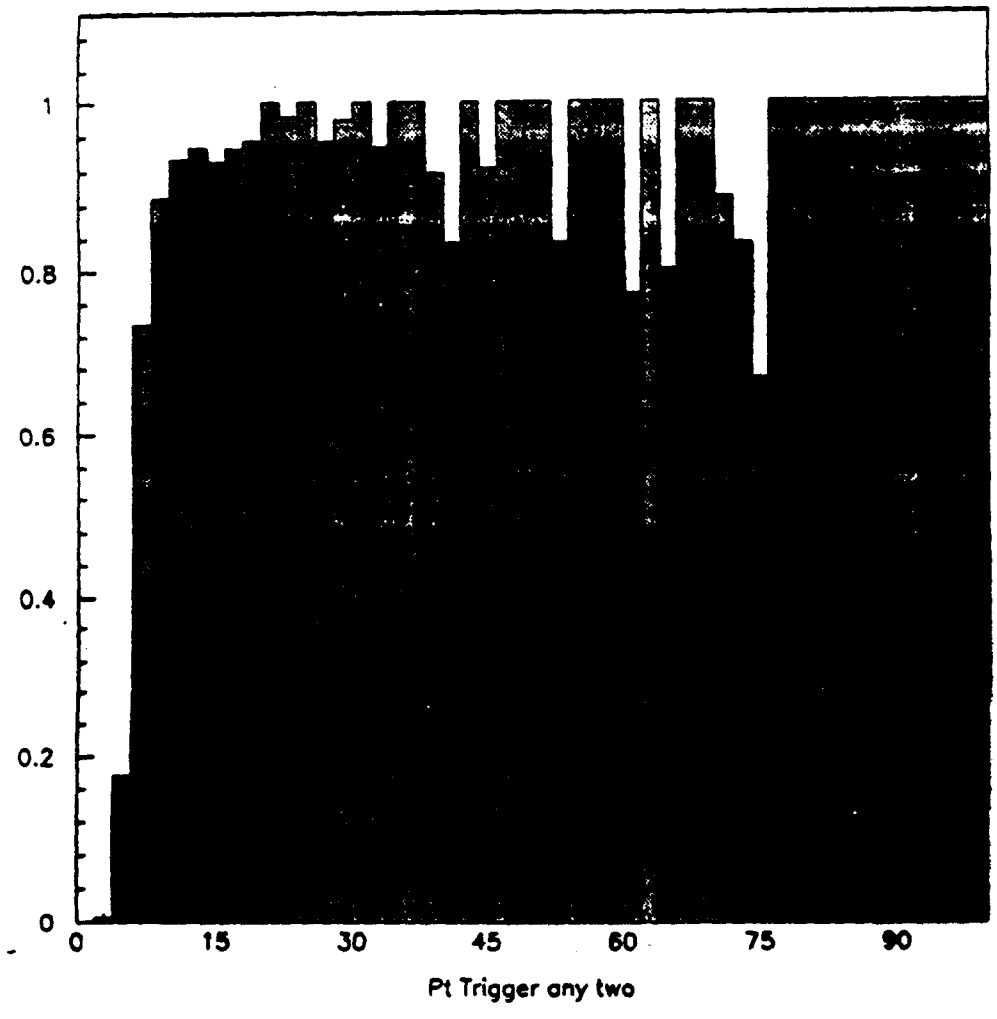



Fig. V.24. The trigger efficiency as a function of $p_T$ for a digital mean timer based trigger operating on signals from three six layer superlayers of packed straw cells. Two out of the three layers are required for a trigger.

# Multi superlayer triggering

1) mean timer selection of stiff track segment

6 combinations for a six layer superlayer
select two out of 6 for "stiff segment trigger primitive"

about 93% efficient
worst case for inner layer (C1) is three primitives per crossing at design luminosity. FAKE RATE

Momentum turn on is about 6 Gev.

2) Form 2/3 trigger requirement using layers C1, C3, C5
about 97% efficient

no false triggers in 500 events

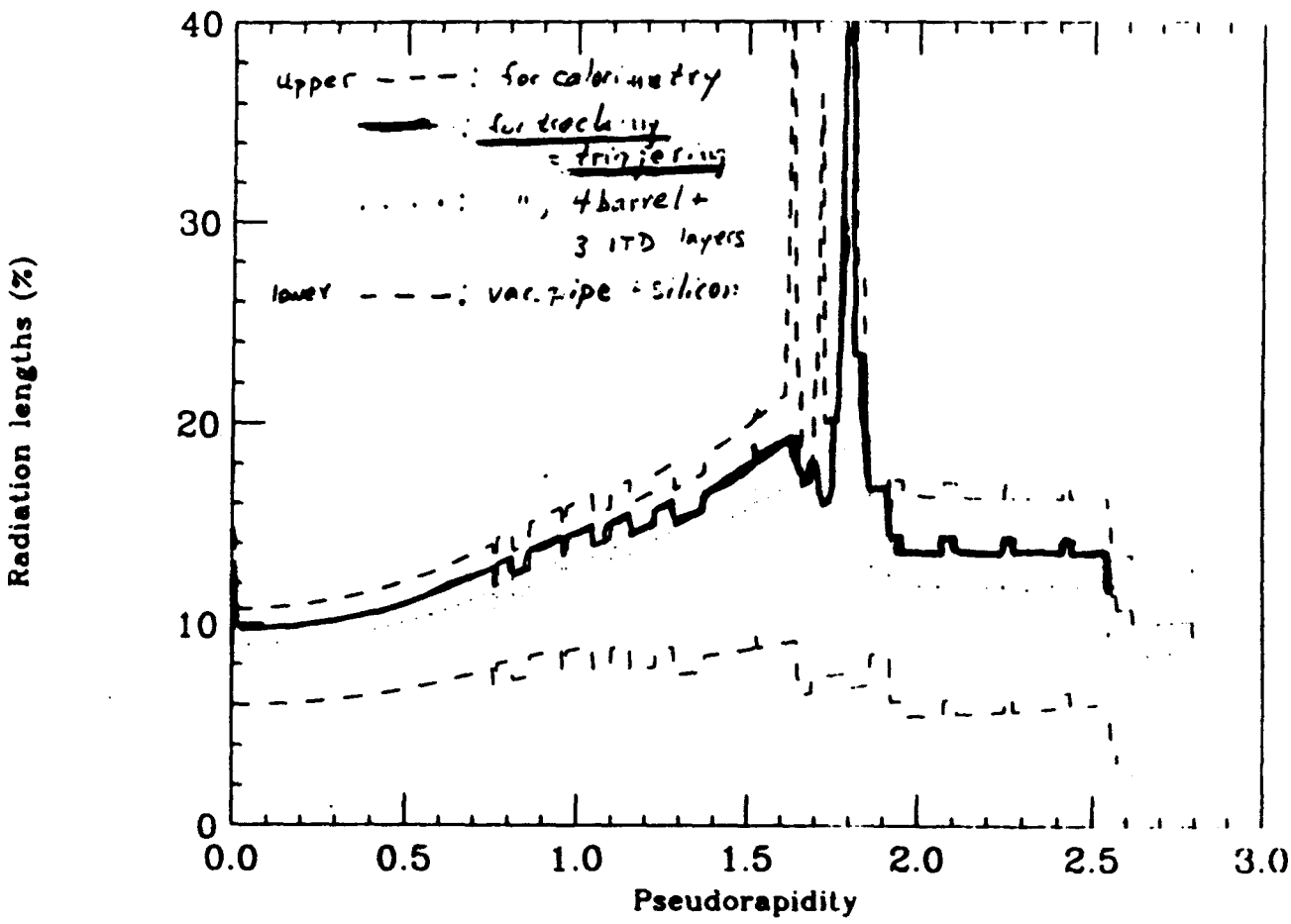
momentum turn on is set by Phi segment selection at about 10 GeV. Very clean at low momentum.

LOTS OF WORK GOING ON

64 segmentation
L2 read out of stiff segments
6 straw superlayers.

# MATERIAL - Si + STRAWS + ITD

Material in Si + wire Tr[illegible]




INTEGRATED MATERIAL FOR TRACKING
~ 14% $X_0$

Technical REQUIREMENTS - < 15%

NOVEMBER 91

TABLE NUMBER 1 11-08-91

DATA SHEET FOR FUNCTIONAL COST BREAKDOWN FOR MODULAR STRAW TRACKER

| TITLE | OBS · OD | EN | ENM | EA | EAM | DR | DRM | TE | TEM | LA | LAM | EXP | K$ MINOR | K$ MAJOR | EDIAS | EDIA+C$ | MFALS | MFAL+C$ | TMATS | TMAT+C$ | BASES | BAS+C$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TRIGGER STRAW TOTALS | | 131 | 0 | 0 | 0 | 60 | 0 | 0 | 740 | 0 | 0 | 0 | 282 | 384 | 79891 | 92176 | 216153 | 249903 | 675500 | 774445 | 971544 | 1116226 |
| TRIGGER SHELL TOTALS | | 124 | 0 | 68 | 0 | 120 | 0 | 0 | 609 | 0 | 0 | 0 | 114 | 840 | 118264 | 158474 | 177828 | 238290 | 953750 | 1278025 | 1249642 | 1674790 |
| TRIGGER ASSEMBLY TOTALS | | 20 | 0 | 368 | 0 | 20 | 0 | 0 | 2268 | 0 | 0 | 0 | 49 | 0 | 141820 | 162149 | 662256 | 760123 | 49000 | 59185 | 853076 | 981456 |
| AXIAL & STEREO STRAWS TOTAL | | 110 | 0 | 47 | 0 | 45 | 0 | 0 | 1037 | 0 | 0 | 0 | 170 | 350 | 80610 | 92899 | 382998 | 348274 | 894367 | 1137197 | 1377846 | 1578472 |
| AXIAL & STEREO SHELLS TOTAL | | 98 | 0 | 150 | 0 | 90 | 0 | 0 | 736 | 0 | 0 | 0 | 70 | 850 | 122256 | 163823 | 214812 | 287992 | 920000 | 1232900 | 1257168 | 1684003 |
| AXIAL & STEREO ASSEMBLIES TOTAL | | 360 | 0 | 1140 | 0 | 20 | 0 | 0 | 2231 | 0 | 0 | 0 | 40 | 0 | 536350 | 611663 | 653222 | 743731 | 39887 | 44881 | 1231440 | 1400296 |
| CYLINDERS | | 196 | 60 | 28 | 0 | 302 | 38 | 50 | 50 | 0 | 0 | 0 | 0 | 4450 | 183776 | 226044 | 69210 | 85128 | 4450000 | 5473500 | 4702986 | 5784673 |
| SHIM RINGS | | 29 | 54 | 50 | 0 | 30 | 5 | 96 | 161 | 0 | 0 | 0 | 8 | 0 | 39369 | 48618 | 102147 | 126162 | 8000 | 9920 | 149516 | 185403 |
| SPACEFRAME | | 8 | 14 | 20 | 0 | 10 | 1 | 10 | 45 | 0 | 0 | 0 | 0 | 1800 | 13436 | 16529 | 22639 | 28092 | 1800000 | 2337000 | 1936277 | 2361621 |
| ASSEMBLY & MACHINING | | 134 | 118 | 1 | 0 | 80 | 25 | 60 | 206 | 0 | 0 | 0 | 5 | 0 | 78349 | 90101 | 140195 | 161224 | 5000 | 5750 | 223544 | 257074 |
| MODULE INSTALATION | | 175 | 123 | 1 | 0 | 120 | 30 | 296 | 826 | 0 | 0 | 0 | 10 | 0 | 120000 | 150621 | 394661 | 497363 | 10000 | 10900 | 524661 | 656602 |
| MOUNTS | | 87 | 23 | 7 | 0 | 80 | 21 | 8 | 71 | 0 | 0 | 0 | 125 | 0 | 66362 | 87829 | 40496 | 51896 | 125000 | 160000 | 233878 | 299866 |
| FINAL ASSEMBLY | | 63 | 49 | 5 | 0 | 100 | 25 | 37 | 160 | 0 | 0 | 0 | 40 | 0 | 69166 | 83362 | 86238 | 116474 | 40000 | 52800 | 191406 | 252869 |
| STRAW TOOLING | | 224 | 24 | 24 | 24 | 400 | 82 | 6 | 16 | 0 | 0 | 0 | 20 | 120 | 241064 | 296919 | 42188 | 52313 | 140000 | 173800 | 423252 | 524830 |
| SHELL TOOLING | | 263 | 52 | 64 | 36 | 480 | 86 | 42 | 70 | 0 | 0 | 0 | 363 | 136 | 267763 | 356095 | 67226 | 108871 | 486000 | 611840 | 862989 | 1078802 |
| MODULE ASSEMBLY TOOLING | | 86 | 38 | 5 | 23 | 100 | 17 | 90 | 45 | 0 | 0 | 0 | 92 | 896 | 74693 | 93183 | 69636 | 87013 | 486000 | 611840 | 634631 | 791834 |
| MANDRELS | | 40 | 15 | 5 | 0 | 5 | 0 | 25 | 0 | 0 | 0 | 5 | 80 | 1998 | 21690 | 29496 | 14215 | 19332 | 1561000 | 2122960 | 1986605 | 2171799 |
| TAPING MACHINE | | 34 | 11 | 12 | 0 | 46 | 0 | 23 | 23 | 0 | 0 | 0 | 10 | 861 | 84199 | 45143 | 20453 | 26896 | 271000 | 357720 | 325862 | 429861 |
| SUPPORT STRONGBACK | | 12 | 0 | 2 | 0 | 24 | 4 | 2 | 0 | 0 | 0 | 0 | 25 | 0 | 13862 | 16701 | 1884 | 2212 | 26000 | 29800 | 40886 | 48714 |
| SUPPORT ALIGN TOOL | | 26 | 5 | 5 | 7 | 0 | 0 | 36 | 23 | 0 | 0 | 0 | 16 | 175 | 14533 | 17440 | 22292 | 26670 | 193000 | 231600 | 228825 | 278806 |
| MACHINING STATION | | 36 | 12 | 12 | 0 | 48 | 0 | 24 | 24 | 0 | 0 | 0 | 10 | 297 | 36096 | 46203 | 21496 | 27517 | 307000 | 392960 | 364594 | 466680 |
| S/L ASMB TOOLING | | 14 | 0 | 1 | 0 | 26 | 4 | 0 | 0 | 0 | 0 | 0 | 46 | 89 | 15679 | 20325 | 1300 | 1684 | 96000 | 121600 | 112179 | 136062 |
| FINAL ASMB TOOLING | | 15 | 0 | 0 | 30 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | 0 | 7860 | 10089 | 6750 | 12960 | 37000 | 47360 | 54640 | 69839 |
| TRANSPORT TOOLING | | 30 | 0 | 3 | 0 | 60 | 9 | 10 | 0 | 0 | 0 | 0 | 36 | 100 | 34306 | 43910 | 5946 | 7481.8 | 136000 | 172800 | 175180 | 224183 |
| ERECTION TOOLING | | 45 | 0 | 2 | 0 | 90 | 11 | 10 | 0 | 0 | 0 | 0 | 46 | 100 | 56945 | 67296 | 6495 | 8670.8 | 148000 | 187800 | 202140 | 263767 |
| TEST EQUIPMENT | | 72 | 27 | 0 | 30 | 0 | 0 | 0 | 56 | 0 | 0 | 0 | 62 | 875 | 33192 | 42966 | 36549 | 56378.8 | 437000 | 576400 | 506741 | 666736 |
| TRACKER UTILITIES | | 309 | 0 | 14 | 7 | 465 | 56 | 10 | 545 | 0 | 0 | 0 | 237 | 0 | 304824 | 363962 | 182536 | 236257 | 237000 | 297760 | 724156 | 911717 |
| TESTING FUNCTION | | 26 | 5 | 0 | 0 | 20 | 3 | 0 | 336 | 0 | 0 | 0 | 0 | 75 | 18496 | 24864 | 101362 | 132968 | 79000 | 102000 | 194678 | 256853 |
| FINAL ALIGNMENT WORK | | 17 | 5 | 2 | 4 | 24 | 4 | 10 | 16 | 0 | 0 | 3 | 15 | 0 | 16287 | 22936 | 13081 | 16779.1 | 19000 | 25020 | 47368 | 66734 |
| TRACKER TRANSPORTATION SYSTEM TOT. | | 15 | 0 | 0 | 0 | 20 | 3 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 13415 | 19654 | 975 | 1443 | 10000 | 14800 | 24390 | 36097 |
| ERECTION SOCL | | 61 | 41 | 0 | 0 | 33 | 10 | 5 | 90 | 0 | 0 | 0 | 0 | 0 | 36846 | 54384 | 46891 | 69247.A | 0 | 0 | 88737 | 124231 |
| DRIFT GAS SYSTEM | | 184 | 10 | 50 | 0 | 79 | 19 | 5 | 56 | 0 | 0 | 0 | 115 | 360 | 89889 | 133008 | 28305 | 41881.A | 475000 | 703000 | 583174 | 877889 |
| MODULE FACILITIES | | 9 | 750 | 6 | 0 | 16 | 378 | 0 | 750 | 0 | 0 | 0 | 40 | 275 | 11949 | 14100 | 687600 | 811368 | 315000 | 371700 | 1014549 | 1197167 |
| SUPPORT FACILITIES | | 13 | 750 | 8 | 0 | 26 | 379 | 0 | 750 | 0 | 0 | 0 | 0 | 315 | 17043 | 20782 | 687825 | 838886 | 315000 | 384300 | 1019966 | 1244361 |
| COST & SCHEDULE | | 154 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 54 | 0 | 0 | 70884 | 79083 | 0 | 0 | 54000 | 60400 | 124884 | 139486 |
| TECHNICAL MGR | | 2300 | 500 | 675 | 0 | 630 | 0 | 0 | 0 | 0 | 0 | 325 | 0 | 0 | 2E+06 | 2E+06 | 230800 | 256865 | 325000 | 360750 | 2104925 | 2336466 |
| R & D EFFORTS | | 400 | 0 | 0 | 0 | 500 | 0 | 400 | 0 | 0 | 0 | 40 | 80 | 360 | 444400 | 506906 | 140160 | 188011 | 470000 | 620400 | 1084560 | 1368020 |
| INSTALLATION & TEST | | 87 | 119 | 2 | 5 | 71 | 32 | 69 | 268 | 0 | 25 | 67.5 | 0 | 0 | 63632 | 84796 | 156684 | 201366 | 67500 | 86325 | 287356 | 374610 |
| | | | | | | | | | | | | | | | | | | | | | 27713706 | 34365170 |

34,365,170

TARGET ← $30M

JAN 27, 1992

TABLE NUMBER 3

DATA SHEET FOR FUNCTIONAL COST BREAKDOWN FOR MODULAR STRAW TRACKER — 5 SUPERLAYER

RLS(W)STC 01-28-91

ORIGINAL/COM1/CON1/09-23-91 REVISED/COM1/CON2/11-2-91 REVISED/COM2/CON3/01-24-92

| WBS | TITLE | CONTS | MY | MFAL | MA | EAM | DR | DRM | TE | TEM | LA | LAM | MY EDA | MY MFAL | EDA$ | MFAL$ | TMA$ | CONT$ | BASE$ | BAS+C$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MD | | | | | | | | | | | | | | | | | | | |
| 1.2.1 | MODULES(336 TRG 365 A&B) | 0.2 | 476 | 0 | 0 | 2,735 | 308 | 120 | 0 | [illegible] | 0 | 0 | 3.3 | 45.3 | 318,838 | 3,182,155 | 3,017,800 | 1,046,350 | 6,469,191 | 7,534,521 |
| 1.2.2 | STRUCTURE COMPONENTS | 0.2 | 496 | 147 | 86 | 0 | 370 | 55 | 108 | 0 | 0 | 0 | 4.1 | 0.8 | 630,600 | 222,599 | 4,421,002 | 1,162,534 | 5,274,201 | 6,436,735 |
| 1.2.3 | STRUCTURE ASSEMBLY | 0.3 | 146 | 86 | 11 | 0 | 116 | 34 | 108 | 113 | 30 | 0 | 1.7 | 1.0 | 189,708 | 221,563 | 184,000 | 166,409 | 589,271 | 737,880 |
| 1.2.4 | INSTALL MODULES | 0.3 | 88 | 199 | 0 | 0 | 40 | 10 | 291 | 93 | 0 | 86 | 1.5 | 1.7 | 99,696 | 212,634 | 8,000 | 73,743 | 289,622 | 363,365 |
| 1.2.5 | EQUIPMENT & TOOLING | 0.3 | 844 | 100 | 116 | 135 | 555 | 113 | 346 | 168 | 0 | 0 | 6.9 | 2.5 | 597,103 | 355,071 | 3,555,385 | 1,404,366 | 4,907,529 | 6,311,915 |
| 1.2.6 | FINAL ASSEMBLY | 0.3 | 231 | 0 | 14 | 7 | 347 | 46 | 19 | 494 | 0 | 0 | 2.5 | 2.0 | 223,616 | 143,653 | 327,000 | 199,341 | 604,769 | 774,110 |
| 1.2.7 | FACTORY ASSEMBLY | 0.3 | 38 | 5 | 2 | 0 | 34 | 4 | 0 | 351 | 0 | 0 | 0.2 | 1.3 | 23,656 | 91,741 | 50,000 | 65,118 | 195,427 | 250,545 |
| 1.2.8 | TRACKER TRANSPORTATION | 0.3 | 6 | 6 | 5 | 0 | 10 | 1 | 0 | 4 | 0 | 0 | 0.1 | 0.0 | 13,833 | 7,469 | 20,000 | 19,825 | 41,302 | 61,127 |
| 1.2.9 | INSPECTION | 0.3 | 125 | 41 | 24 | 0 | 58 | 30 | 10 | 70 | 0 | 0 | 1.0 | 0.5 | 92,400 | 48,761 | 655,000 | 218,584 | 796,161 | 1,011,745 |
| 1.2.10 | PACKING | 0.2 | 18 | 1,000 | 12 | 0 | 26 | 289 | 0 | 1,000 | 0 | 0 | 0.3 | 10.0 | 33,462 | 1,062,657 | 560,000 | 301,700 | 1,676,119 | 1,977,819 |
| 1.2.11 | PROJECT COORDINATION | 0.1 | 3,085 | 344 | 280 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14.0 | 1.4 | 2,123,019 | 158,564 | 358,000 | 350,508 | 2,669,603 | 3,060,111 |
| 1.2.12 | FUTURE R&D | 0.3 | 260 | 0 | 0 | 0 | 240 | 0 | 260 | 0 | 0 | 0 | 3.2 | 0.0 | 333,360 | 142,360 | 738,000 | 367,758 | 1,211,740 | 1,599,498 |
| 1.2.13 | INSTALLATION & TEST | 0.3 | 52 | 115 | 3 | [illegible] | [illegible] | [illegible] | [illegible] | 154 | 0 | 25 | 0.9 | 1.4 | 72,711 | 142,358 | 67,000 | 65,878 | 282,536 | 355,412 |
| | TOTAL MD | 0.3 | 5,822 | 2,107 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 30 | 123 | | | [illegible] | [illegible] | 14,219,257 | 5,490,112 | 25,007,471 | 30,497,583 |
| | TOTAL MY | | 23 | 9 | 2 | [illegible] | [illegible] | [illegible] | [illegible] | 43 | 0 | 1 | 39.6 | 66.0 | | | | | | |
| 240 | PERCENT | | | | | | | | | | | | | | 19.3% | 23.9% | 58.5% | | | |

$ 30,497,583

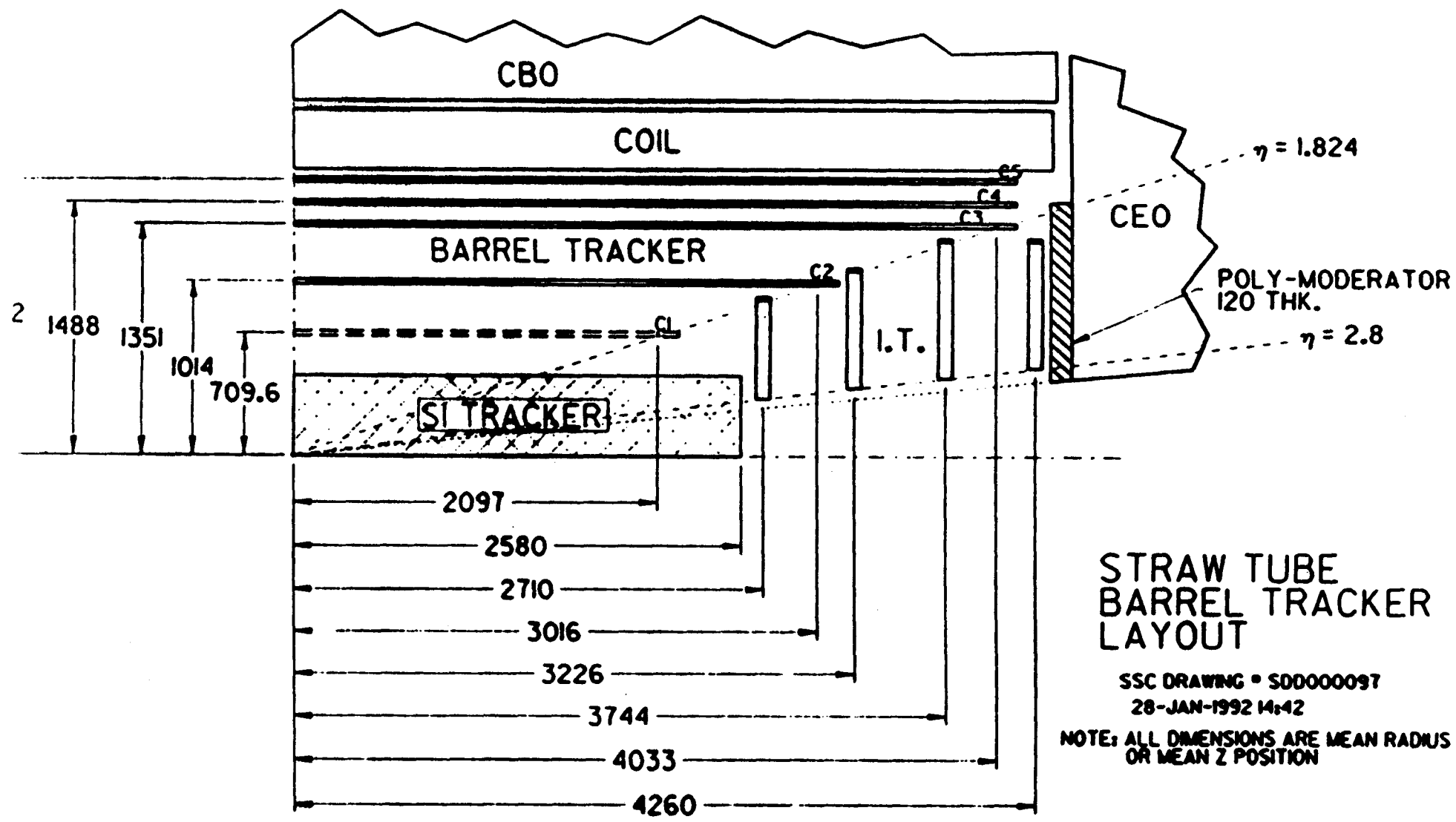
electronics 11,100,000

CD(COM24CON9)01-24-92

| WBS | TITLE | EDIA$ | MFAL$ | TMAT$ | CONT$ | BASE$ | BAS+C$ |
|---|---|---|---|---|---|---|---|
| 1.2.1 | MODULES(336 TRK 368 A&S) | 319,536 | 3,152,155 | 3,017,500 | 1,045,330 | 6,489,191 | 7,534,521 |
| 1.2.2 | STRUCTURE COMPONENTS | 630,600 | 222,599 | 4,421,002 | 1,162,534 | 5,274,201 | 6,436,735 |
| 1.2.3 | STRUCTURE ASSEMBLY | 193,708 | 221,563 | 154,000 | 168,409 | 569,271 | 737,680 |
| 1.2.4 | INSTALL MODULES | 68,968 | 212,634 | 8,000 | 73,743 | 289,622 | 363,365 |
| 1.2.5 | EQUIPMENT & TOOLING | 697,103 | 355,071 | 3,856,355 | 1,404,386 | 4,907,529 | 6,311,915 |
| 1.2.6 | FINAL ASSEMBLY | 223,816 | 143,953 | 237,000 | 169,341 | 604,769 | 774,110 |
| 1.2.7 | FACTORY ASSEMBLY | 23,686 | 91,741 | 80,000 | 65,118 | 195,427 | 260,545 |
| 1.2.8 | TRACKER TRANSPORTATION | 13,833 | 7,469 | 20,000 | 19,825 | 41,302 | 61,127 |
| 1.2.9 | ERECTION | 92,400 | 48,761 | 655,000 | 215,584 | 796,161 | 1,011,745 |
| 1.2.10 | FACILITIES | 33,462 | 1,062,657 | 580,000 | 301,700 | 1,676,119 | 1,977,819 |
| 1.2.11 | PROGRAM COORDINATION | 2,123,019 | 158,584 | 388,000 | 390,508 | 2,669,603 | 3,060,111 |
| 1.2.12 | FUTURE R&D | 333,380 | 142,360 | 736,000 | 387,758 | 1,211,740 | 1,599,498 |
| 8.2 | INSTALLATION & TEST | 72,711 | 142,325 | 67,500 | 85,876 | 282,536 | 368,412 |
| | TOTAL MD | 4,828,242 | 5,961,872 | 14,219,357 | 5,490,112 | 25,007,471 | 30,497,583 |
| 240 | TOTAL MY | | | | | | |
| | PERCENT | 19.3% | 23.8% | 56.9% | | | |

BIG REDUCTIONS IN STRUCTURES

New vendor quotes from
Hercules
Kaiser Aerotech



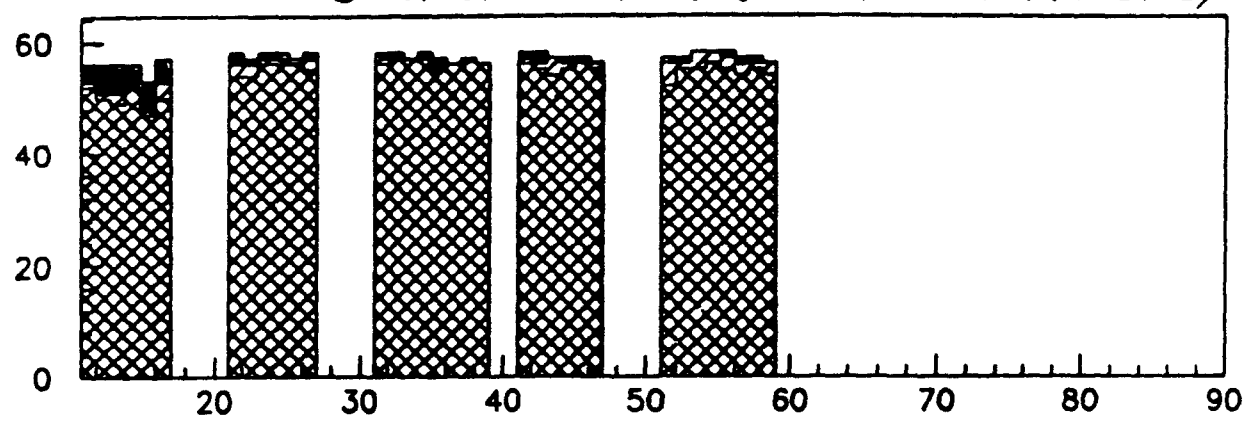

STRAW TUBE
BARREL TRACKER
LAYOUT

SSC DRAWING • SD0000097
28-JAN-1992 14:42

NOTE: ALL DIMENSIONS ARE MEAN RADIUS
OR MEAN Z POSITION

SEGMENT FINDING – STRAW EFFICIENCY

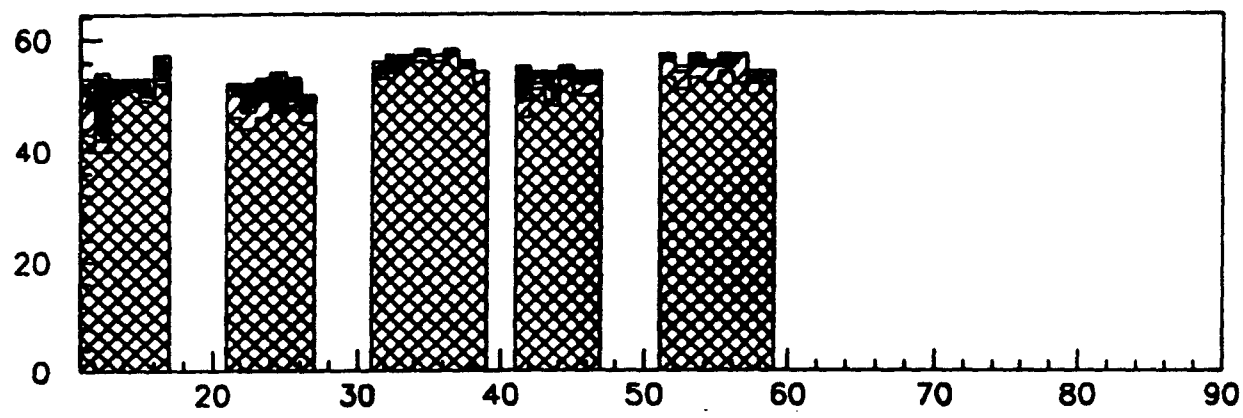
HIGGS → 4




0 MIN BIAS

$P_T > 2$ GeV

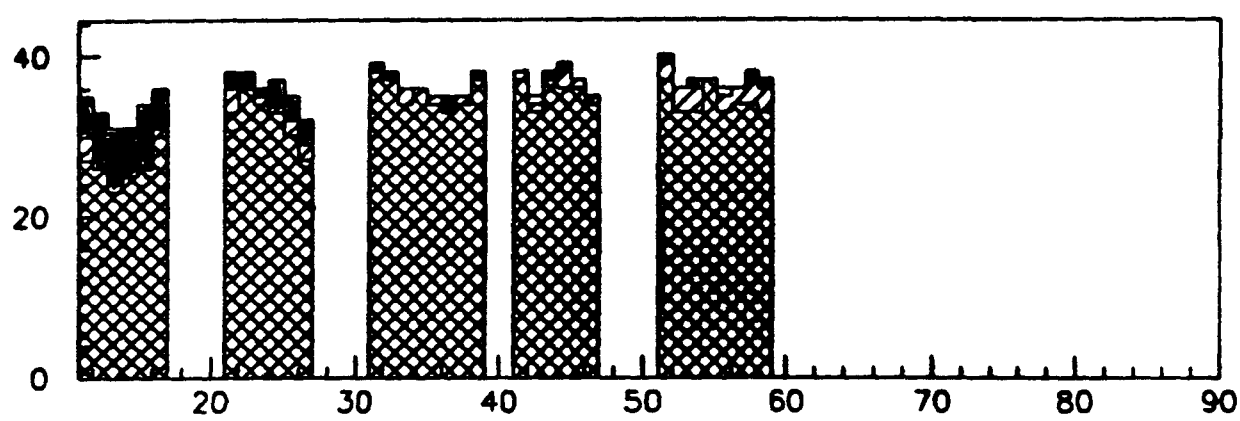
10*(Superlayer No.)+(Layer No.)




LUMINOSITY

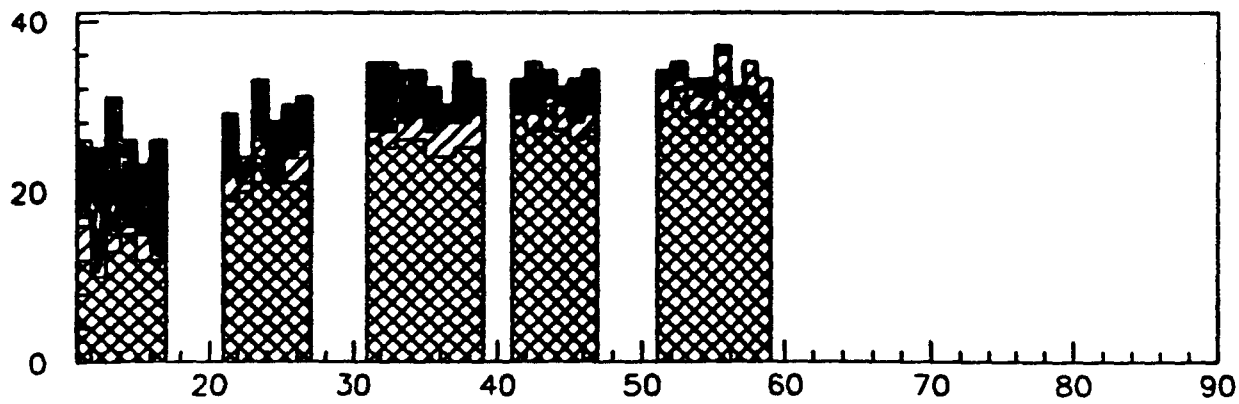
$10^{33}$

10*(Superlayer No.)+(Layer No.)




$3 \times 10^{33}$

10*(Superlayer No.)+(Layer No.)




$6 \times 10^{33}$

10*(Superlayer No.)+(Layer No.)

# The position of the the inner superlayer

In the TDR the first layer is positioned at the minimum radius boundary for the outer tracker. The optimum position of C1 and C2 will be determined by an on-going simulation study.

But the present position is defensible in the TDR:

a) the occupancy is 11% at design luminosity

b) segment finding is nearly fully efficient in the inner layer at design luminosity.

c) the inner layer is as effective as the outer four layers in track finding at design luminosity.

d) triggering efficiency in the inner layer is high, and the fake rate is acceptable at design luminosity.

# Five layer outer tracking system

1) Provides a robust and logical superlayer configuration

Risk tolerance:

It has just enough redundancy to tolerate the random ( but hopefully rare) loss of modules in either the stereo or trigger superlayers without serious degradation of resolution and pattern recognition.

Trigger flexibility and robustness:

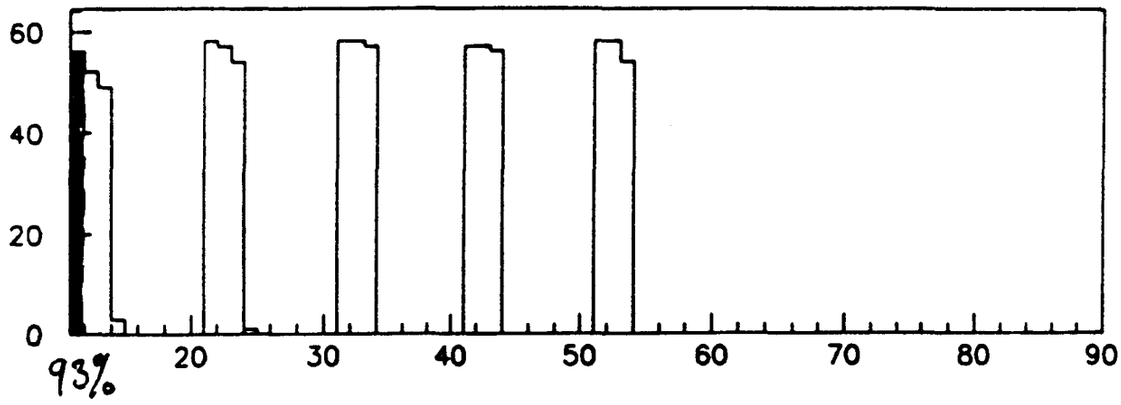
The five layer configuration gives us the possiblity of using a 2/3 trigger configuration and a two level trigger in the region of 1.65 to 1.8 eta.

c)The inner axial layer is positioned close to the maximum sagitta point to maximize the backup capabilities of the straw system. ( random loss of Si wafers or modules)

HIGGS → 4l

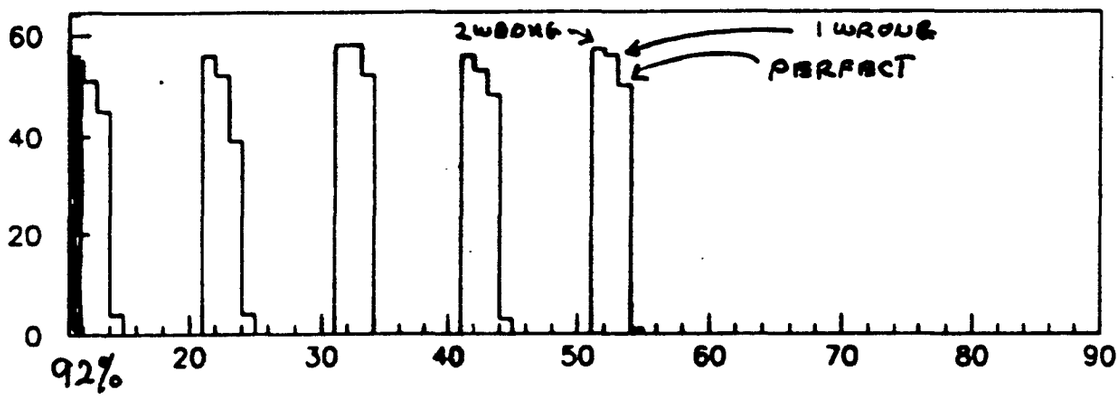
NO MINBIAS

$P_T > 2$ GeV



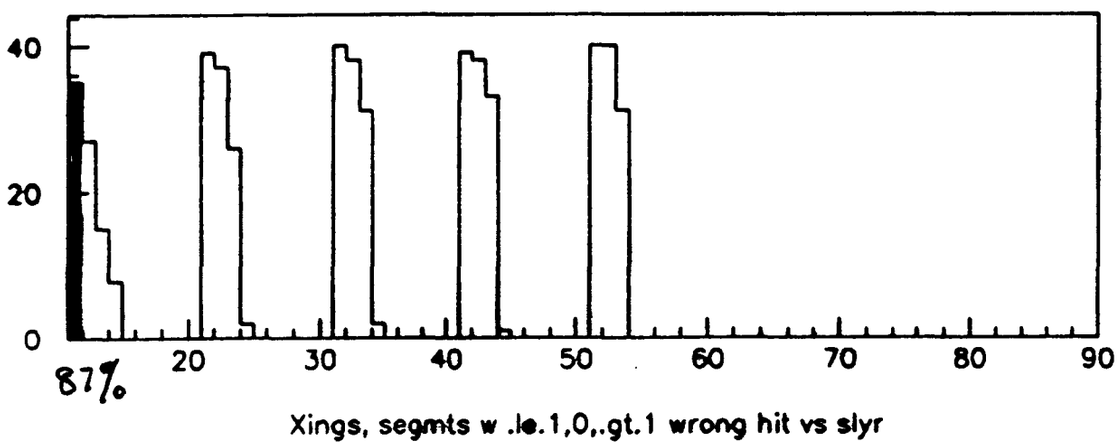

LUMINOSITY

$10^{33}$

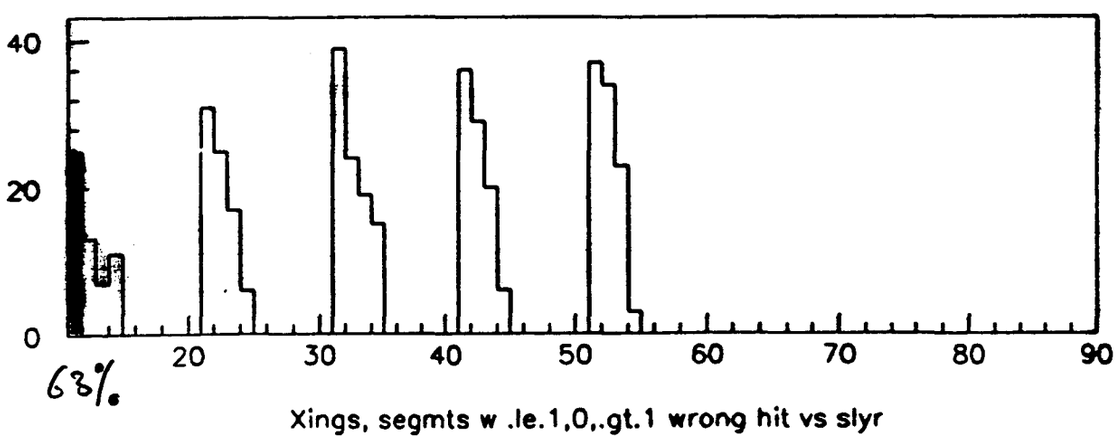



LUMINOSITY

$3 \times 10^{33}$




$6 \times 10^{33}$



PRESENTATION BY:

RANDY RUCHTI

Ruchti
Sunpm

# UPDATE ON SCINTILLATING FIBER OUTER TRACKING

R.Ruchti/J.Elias
Fiber Tracking Group
2-2-92

I. REVISION OF THE FIBER TRACKER DESIGN

- A. DESIGN STRATEGY
- B. IMPLEMENTATION
- C. REQUIREMENTS SUMMARY
- D. COSTING
- E. INTEGRATION ISSUES

II. PROGRESS ON FIBER TRACKING TECHNOLOGY

- A. PHOTOSTATISTICS ISSUES
- B. RADIATION DAMAGE STUDIES
- C. VLPC R & D
- D. BEAM TEST AT FERMILAB (T-839)

III. SUMMARY

IV. SYSTEMS STUDIES FY92-93

V. R & D AND ENGINEERING REQUEST

- A. MECHANICAL ENGINEERING
- B. VLPC AND CRYOSTAT DEVELOPMENT

# Conceptual Design
# Scintillating Fiber Outer Tracking


Fiber Tracking Group (FTG)

B.Abbot[k], D.Adams[l], M.Adams[c], E.Anderson[m], T.Armstrong[i], M.Atac[a,b], A.Baumbaugh[b], B.Baumbaugh[g], P. Besser[n], M.Binkley[b], F.Bird[o], J.Bishop[g], N.Biswas[g], A.D.Bross[b], C.Buchanan[a], N.Cason[g], R.Chaney[p], D.Chrisman[a], D.Cline[a], C. Collins[o], M.Corcoran[l], R.Davies[k], J.Elias[b], E.Fenyves[p], D.Finley[b], G.W.Foster[b], R. Fox[o], H.Goldberg[c], H.Hammack[p], A.Hasan[i], M. Hechler[o], S.Heppelmann[i], K.Hess[o], J.Jaques[g], J.Kauffman[j], R.Kehoe[g], C.Kelley[e], M. Kelly[g], C.Kennedy[m], V.Kenney[g], R.Kephart[b], D.Koltick[k], J.Kolonko[a], K.Kondo[q], J.Kubic[a], R.A.Lewis[i], R.Leitch[h], J.LoSecco[g], B.Lowery[p], J.Marchant[g], R.McCutcheon[m], R.McIlwain[k], S.Margulies[c], H.Mendez[c], F.Miere[d], H.Miettenen[l], R.Moore[i], R.J.Mountain[g], B.Oh[i], J.Orgeron[p], H.Paik[d], J.Park[a], J.Passaneau[i], K.Pennington[o], M.Petroff[n], J. Piles[o], A.Pla-Dalmau[b], C.Rivetta[b], R.Ruchti[g], R.Scalise[i], J.Schmitz[k], W.Shephard[g], E.Shibata[k], J.Skeens[l], G.A.Smith[i], J.Solomon[c], K.Takikawa[q], C. Talmadge[k], T.Thurston[o], S.Tkaczyk[b], W.Toothacker[i], Balamurali V[g], D.Vandergriff[h], K.Vasavada[d], R.Wagner[b],, M.Wayne[g], and J.Whitmore[i]

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Philadelphia College of Pharmacy and Science[j]
Purdue University[k]
Rice University[l]
Rockwell International, Electro-Optical Center[m]
Rockwell International, Science Center[n]
Superconducting Super Collider Laboratory[o]
University of Texas at Dallas[p]
Tsukuba University[q]



Presented to the SDC Collaboration
Tracking Review Committee
January 20, 1992



Compiled and Edited by
D. Adams, A. Baumbaugh, F. Bird, R. Chaney, C. Collins, K. Hess,
D. Koltick, R. Leitch, and R. Ruchti

# I. DETECTOR DESIGN REVISION

## A. DESIGN STRATEGY:

1. EXPLOIT LONG-BARREL APPROACH (4.3m HALF LENGTH).

2. A SEAMLESS LEVEL-1 TRIGGER CONCEPT OVER THE FULL RAPIDITY INTERVAL.

3. CAPABILITY OF SUCCESSFUL TRIGGERING AND TRACKING AT HIGH LUMINOSITY.

4. MECHANICAL SIMPLICITY IN THE SUPPORT STRUCTURE FOR THE SUPERLAYERS.

5. NO PROJECTIVE CRACKS FILLED WITH MATERIAL FROM DETECTOR ELEMENTS, SUPPORTS OR SERVICES.

6. KEEP THE MATERIAL BUDGET LOW IN FRONT OF THE TRIGGER LAYERS FOR ELECTRON TRIGGERING.

7. REDUCE COSTS FOR THE OVERALL OUTER TRACKING SYSTEM.

## B. IMPLEMENTATION

### 1. ALL BARREL CONFIGURATION

#### a. COVERAGE FOR TRACKING

$0.6m \leq R \leq 1.65m$
$0 \leq |\eta| \leq 2.5$ including combined Silicon and Fiber Systems
$0 \leq |\eta| \leq 2.3$ for Fiber System

#### b. COVERAGE FOR TRIGGERING

$0 \leq |\eta| \leq 2.3$ for $L = 10^{33}$
$0 \leq |\eta| \leq 2.1$ for $L = 10^{34}$

#### c. SUPERLAYER CONFIGURATION

6 Superlayers for Tracking (B1-B6)
Separated Fiber Doublet Structure on Each Layer - i.e. Vector Layers
Two superlayers have small angle stereo (B3 and B6) of $15^{o}$.
Three Superlayers for Triggering (B1-B3) at $0 \leq |\eta| \leq 2.3$ for $L = 10^{33}$
Four Superlayers for Triggering (B1-B4) at $0 \leq |\eta| \leq 2.1$ for $L = 10^{34}$

#### d. CHANNEL COUNT

439K Fiber/VLPC Channels

### 2. NO INTERMEDIATE TRACKER

In this design, no intermediate tracking has been implemented. This does not preclude an option for a staged intermediate tracker.

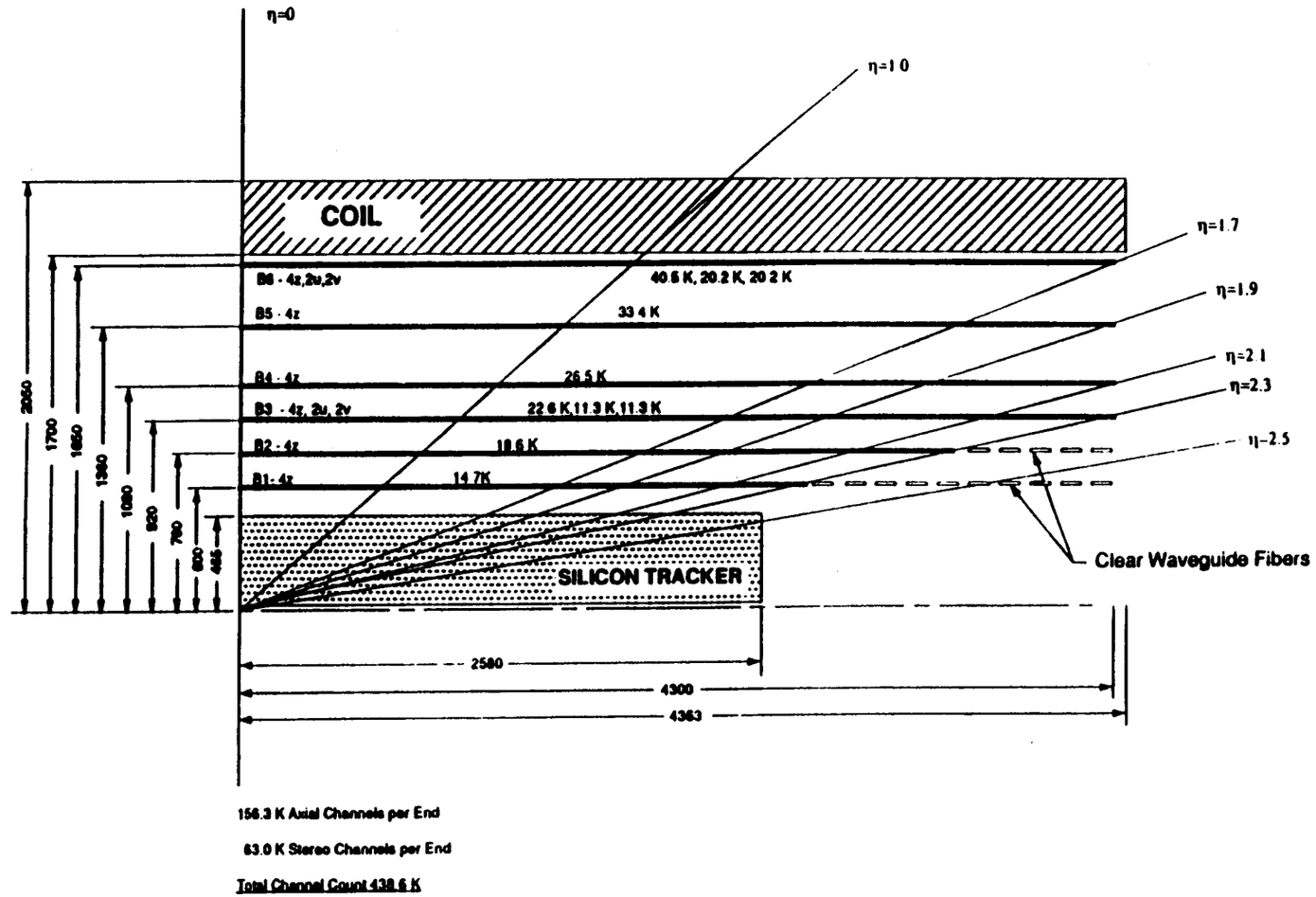
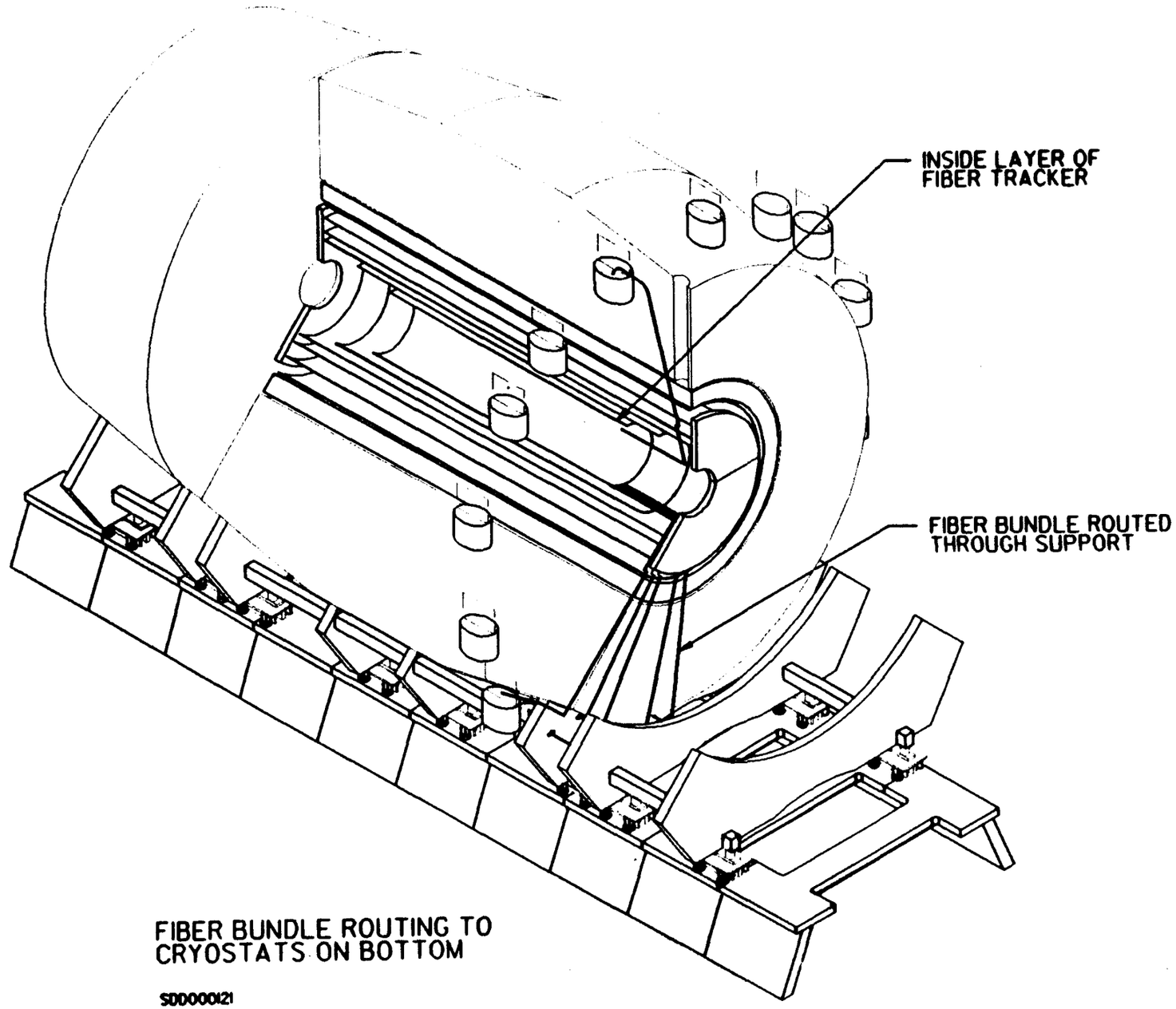



Figure 3.1-1. Schematic of the central tracker exhibiting the fiber superlayers.




FIBER BUNDLE ROUTING TO
CRYOSTATS ON BOTTOM

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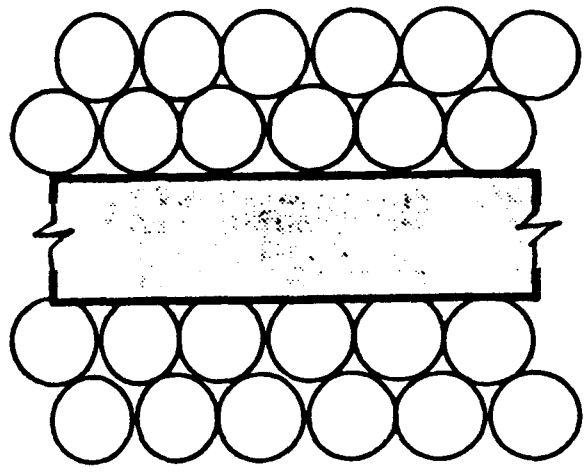


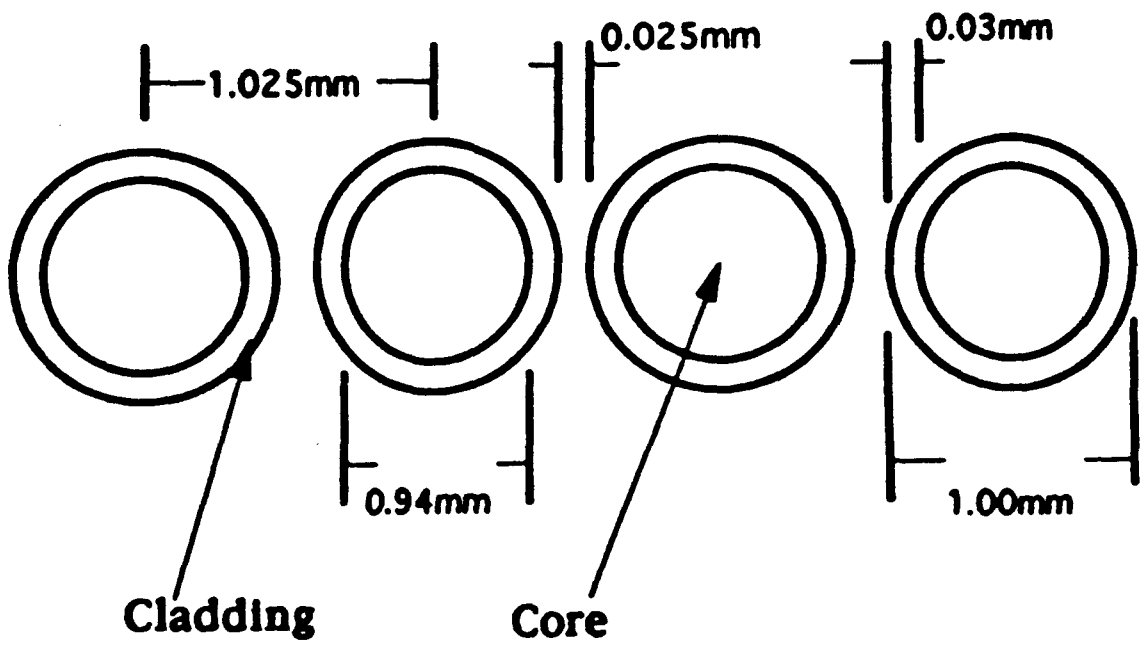




Figure 5.3.1-1. Schematic of a superlayer of fibers, composed of two double-layer ribbons of 1mm diameter and 1.025mm pitch, separated by 1.6cm.

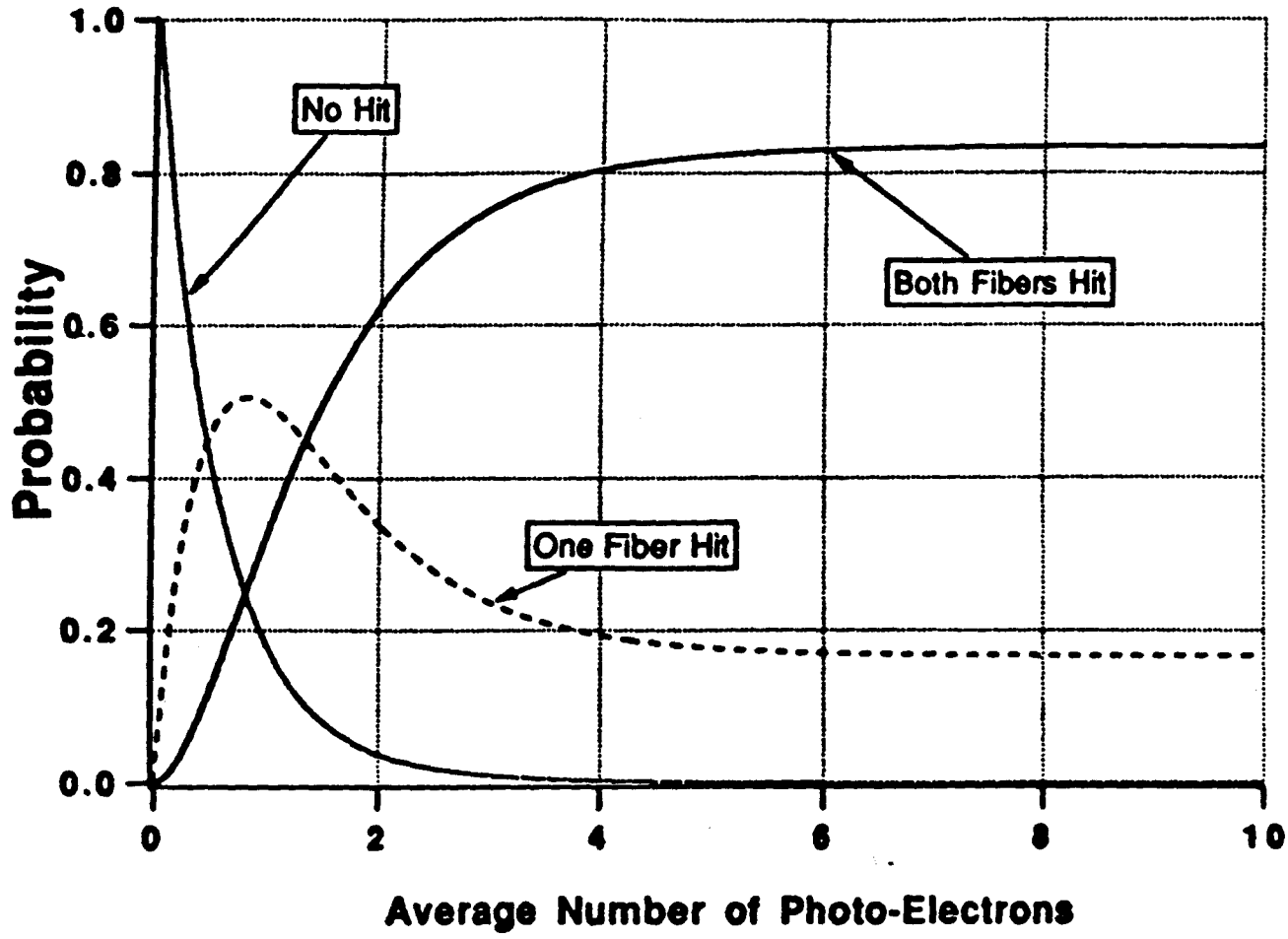



**Figure 5.3.3-2** Probability of observing zero, one, and two fiber hits per minimum ionizing particle per fiber doublet layer as a function of detected photoelectron yield per fiber.

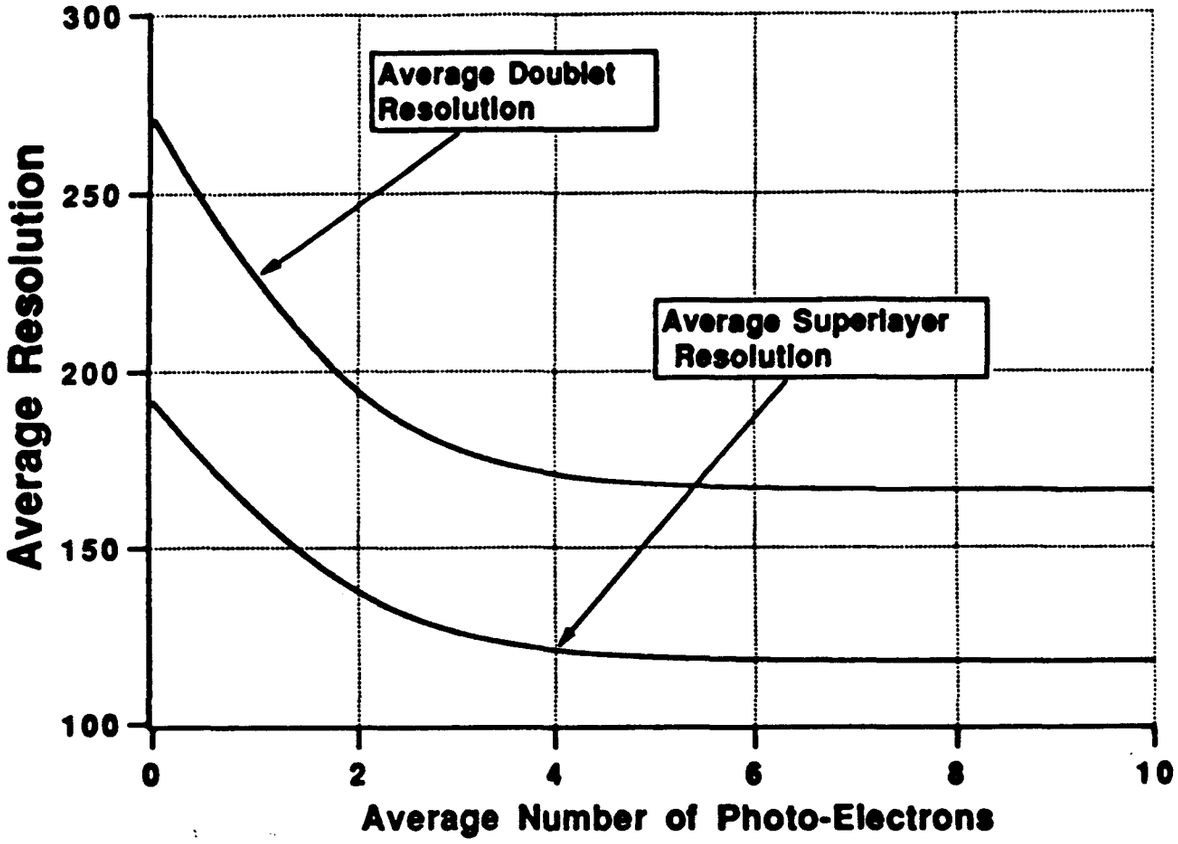
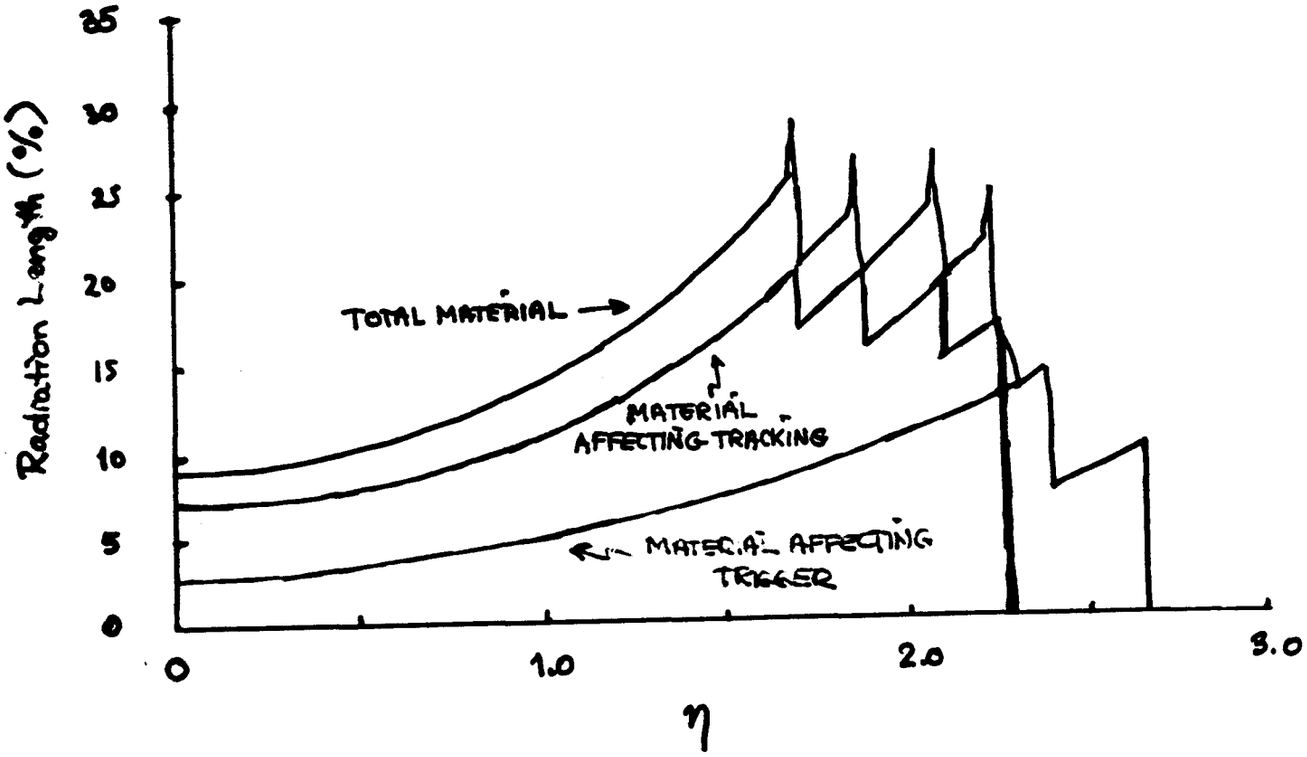
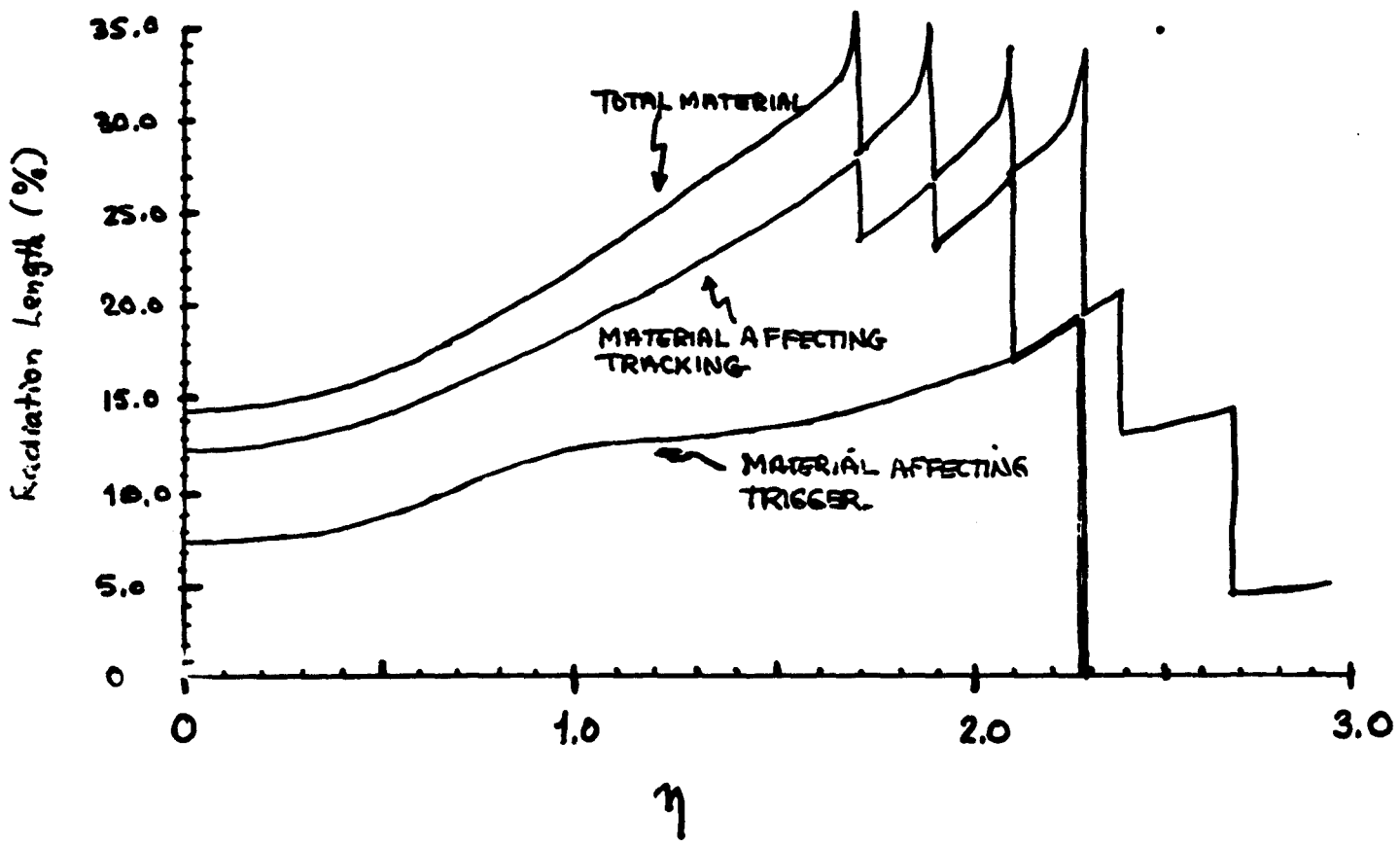



Figure 5.3.4-1 Resolution of a fiber doublet layer and a fiber superlayer (two doublets, assumed uncorrelated) as a function of detected photoelectron yield. (Worst case for the SDC fiber tracker is ~5 photoelectrons at $\eta$=0.)

TOTAL MATERIAL
SCINTILLATING FIBER TRACKER (ONLY)
1-31-92



TOTAL MATERIAL
SILICON + SCINTILLATING FIBER TRACKERS
1-31-92



## C. REQUIREMENTS SUMMARY

**Scintillating Fiber Outer Tracker**

**Conceptual Design Report SDC-92-174**

| | | | |
|---|---|---|---|
| (1) | Acceptance and resolution | | |
| | \|eta\| acceptance | \|eta\| < 2.3 | |
| | $P_t$ resolution, \|eta\|<1.8 | 16 % $TeV^{-1}$ | |
| | \|eta\|>1.8 | <75 % $TeV^{-1}$ (parametric) | |
| (2) | Reconstruction efficiency @ $L = 10^{33}$ | 99 % | |
| (3) | Reconstruction efficiency @ $L = 10^{34}$ | 99 % ( eta < 1, $L = 0.6*10^{34}$) | |
| (4) | Reconstruction efficiency jets < 100 GeV/c | TBD ( > 90 % ) | |
| (5) | Material in radiation lengths (includes silicon & pipe) | at 90° | $0 \leq \|\eta\| \leq 2.3$ |
| | for tracking | 12.5 % | (19.6 % average) |
| | for triggering | 7.7 % | (12.2 % average) |
| (6) | Spatial resolution | | |
| | shower max z | 1.2 mm | |
| | shower max r-phi | 1.1 mm | |
| (7) | Spatial resolution | | |
| | muon system z | ~3 mm, no multiple scatt. | |
| | muon system r-phi | TBD | |
| (8) | Jet Charged Multiplicity jets up to 500 GeV | >85 % track efficiency (preliminary, $p_t$ > 5) | |

| | | |
|---|---|---|
| (9) | b - tagging efficiency | TBD |
| | impact parameter resolution: | |
| | stiff tracks | 13 microns |
| | at $p_t$ = 3 GeV/c | multiple scattering limited |
| | track finding efficiency | TBD |
| (10) | Z - vertex resolution | 0.8 mm |
| (11) | Trigger $p_t$ resolution - Level 1 | 6.0 $TeV^{-1}$ |
| (12) | Level 1 trigger | |
| | efficiency @ L = $10^{33}$ | > 99 % |
| | false rate per 1/64 in Phi | 0.0002 |
| (13) | Level 2 trigger | TBD |
| | $p_t$ resolution | (depends on silicon scheme) |
| (14) | Discovery potential | |
| | leptons in jets | TBD |
| (15) | Survivability @ L = $10^{33}$ | > 50 years |
| (16) | High luminosity | |
| | survivability | > 5 years |
| | triggerability | \|eta\| < 2.1 |

## D. COSTING (WITH CONTINGENCY)

ASSUMES A 439K CHANNEL SYSTEM

| | | |
|---|---|---|
| 1. | MECHANICAL STRUCTURE | $24.1M |
| 2. | VLPC/CRYO/ASD<br>Includes all Electronics Through Amplifier/Shaper/Discriminator | $15.2M |
| 3. | ELECTRONICS<br>Includes L1 and L2 Pipelines<br>Includes L1 Trigger | $ 3.7M |
| TOTAL | | $43.0M |

### BREAKDOWN OF ITEMS 1. AND 2.

| | Estimated Cost (Millions) | Cost and Contingency (Millions) |
|---|---|---|
| Scintillating Fiber | $3.9 | $5.1 |
| Support Structure | 2.7 | 3.5 |
| Assembly | 1.3 | 1.8 |
| Tooling | 5.2 | 6.8 |
| Utilities | 0.4 | 0.5 |
| Photon Transducer | 11.4 | 15.2 |
| Shipping/Assembly | 0.5 | 0.6 |
| Tests/Installation | 1.2 | 1.6 |
| Facilities | 0.5 | 0.6 |
| Management/7 years | 3.1 | 3.6 |
| Total Costs | $30.1 | $39.3 |

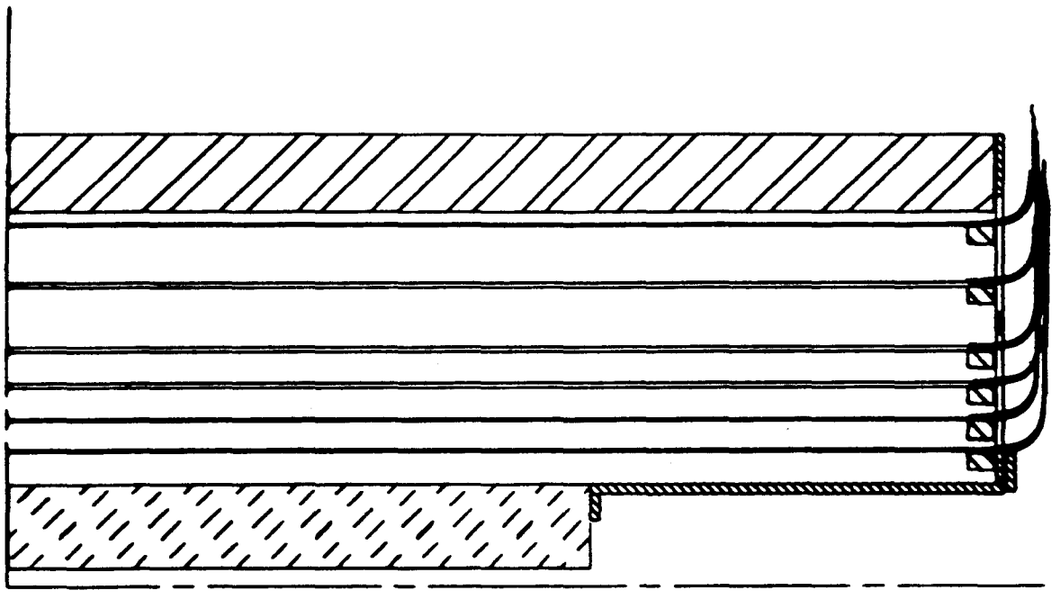


Figure 4.2-1 Close-up view of the support structure for the out tracker showing the interface between the outer tracker and the silicon system. The flow of the wave guide fiber from all of the tracking elements is also shown. No bending radii are smaller than 10 cm.

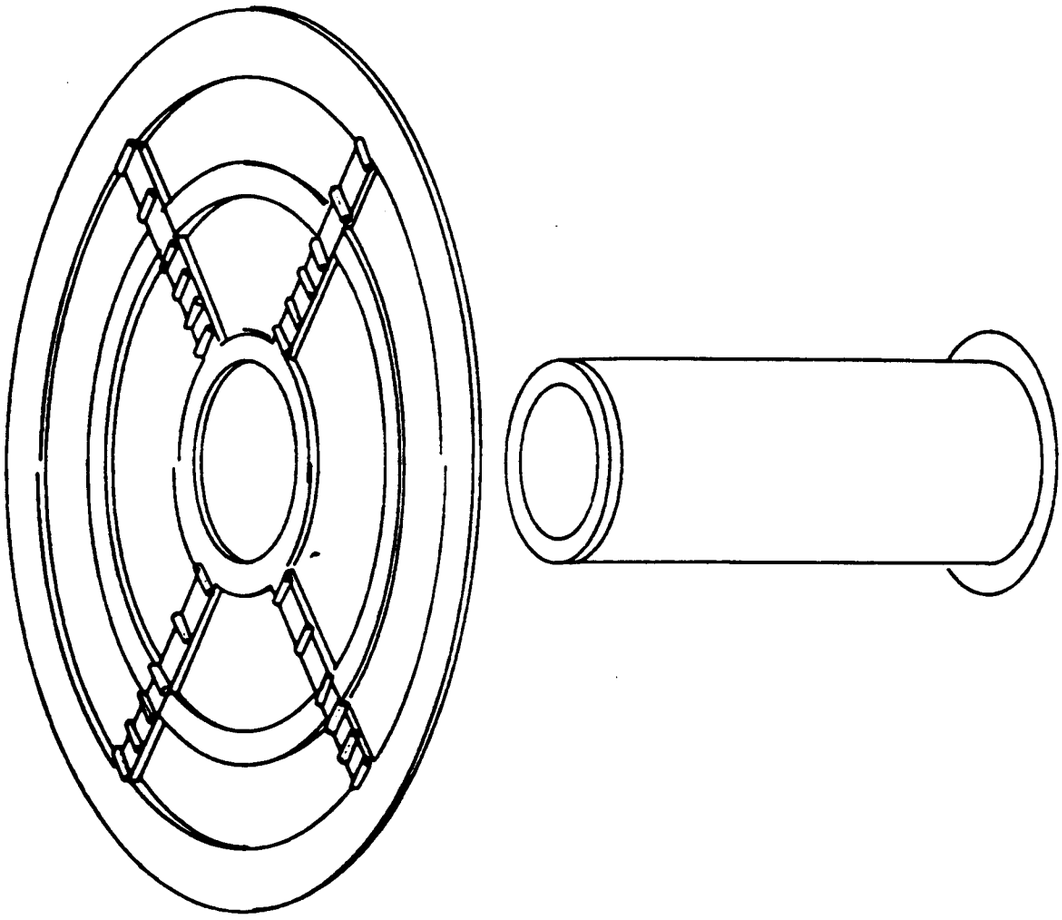


Figure 4.2-2 a.) the simple thin panel forms the backbone of the tracking system. b) The nose which connects to the silicon system to the outer tracking system.

# COST THE FIBER TRACKING SYSTEM

The cost of the fiber tracker can be parameterized

$$14.5 + 0.48 \cdot 10^{-2} \times n + 0.175 * N + 0.525 \times \Sigma R^2$$

A B C D

Where:

n= number of channels
N=number of superlayers
R= The radius of the superlayer

Terms:

A. The fixed cost which consists of engineering design. Does not very to 1st order with the number of channels.

B. The per channel cost ~80% due to electronics and 20% due to mechanical.

C. Assembly costs

D. Cylinder costs.

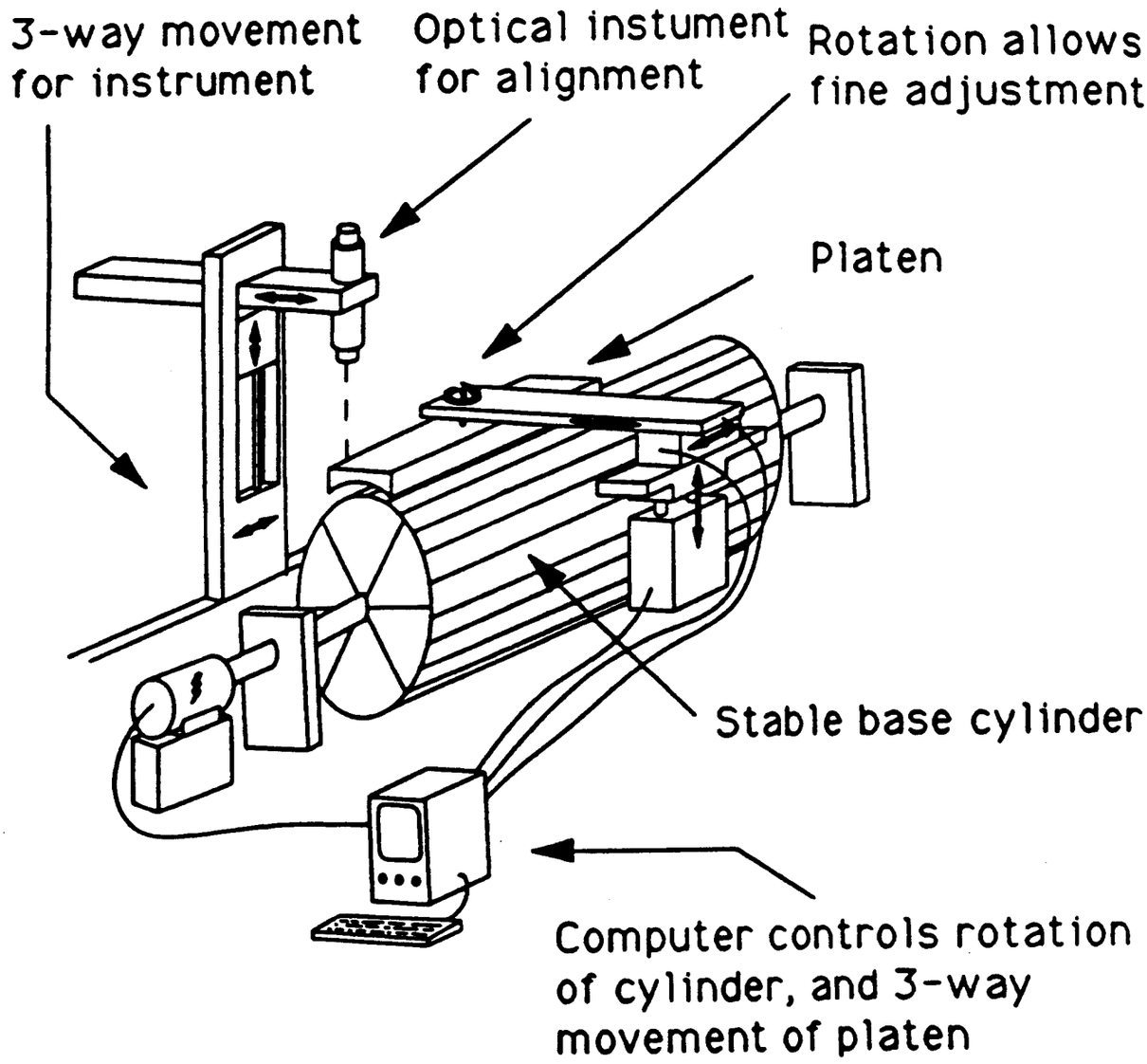



**Figure 12.2-3** Attaching the ribbons will require a large, stable, computer controlled are for the placement. The cylinder is indexed. An optical instrument is used to check the alignment.

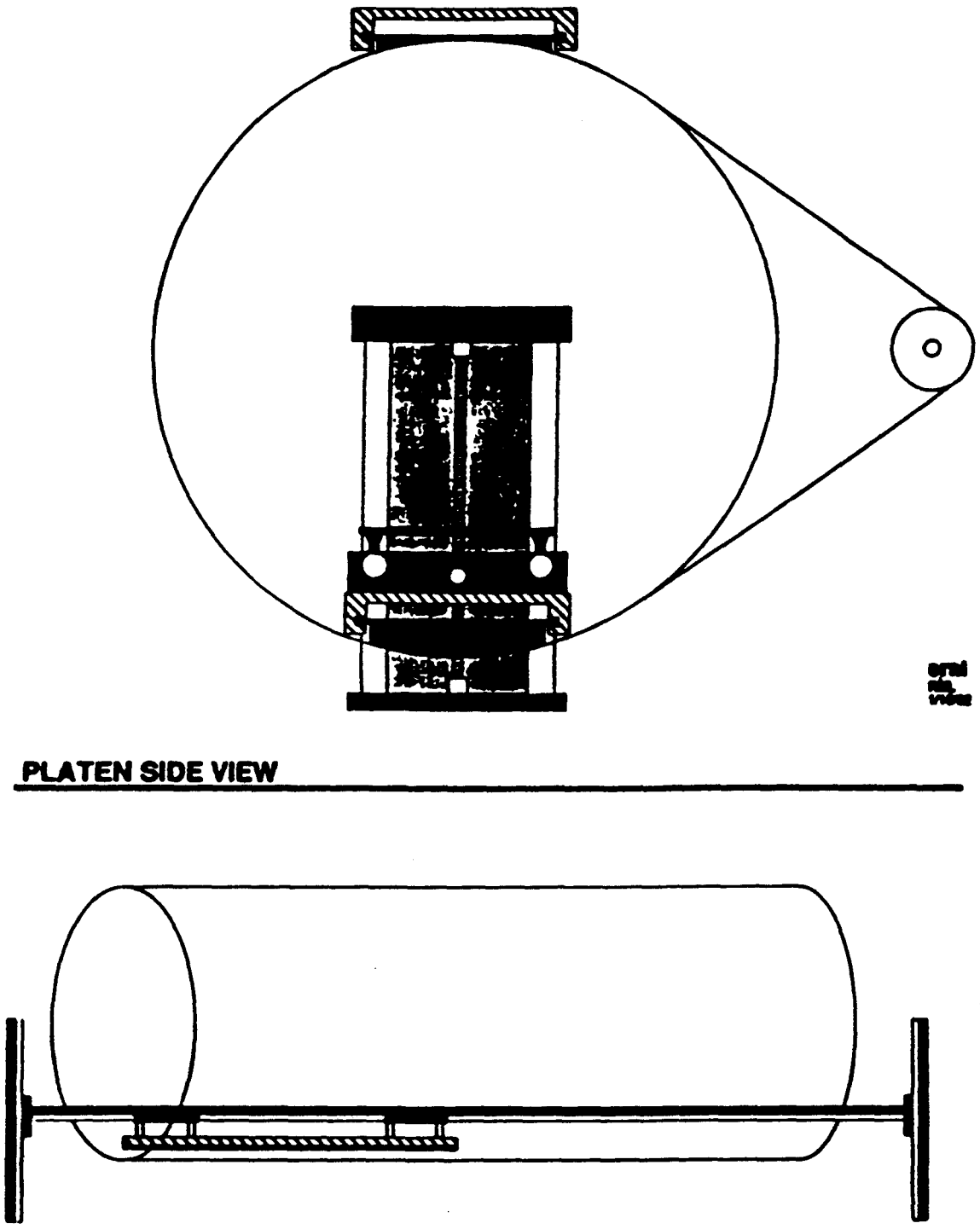
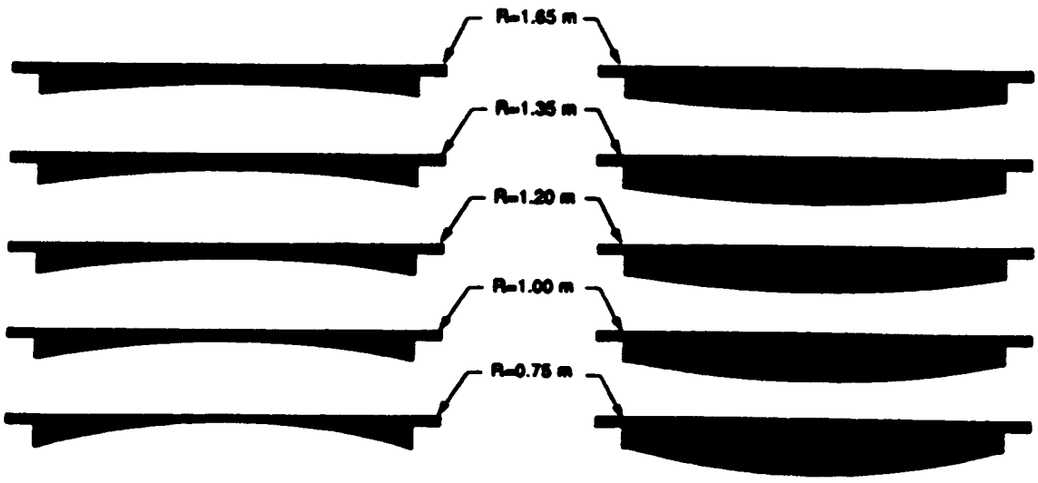



Figure 12.2-2 Concept drawings of the inner and outer platen placement machine.




**PLATEN INSERT**

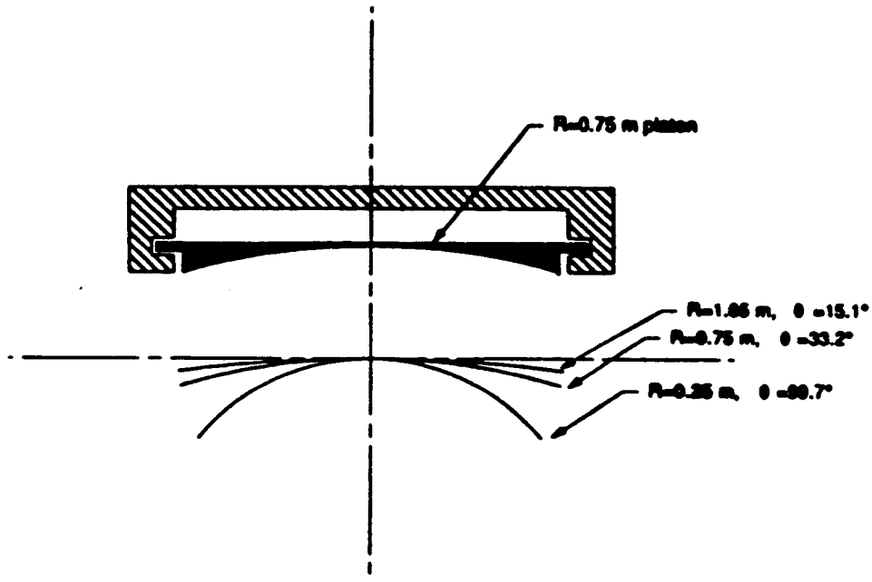



Figure 12.2-1 Platens used to accurately place ribbons on the cylinders. Platens are needed for placement on the inner and outer diameter of the ribbons.

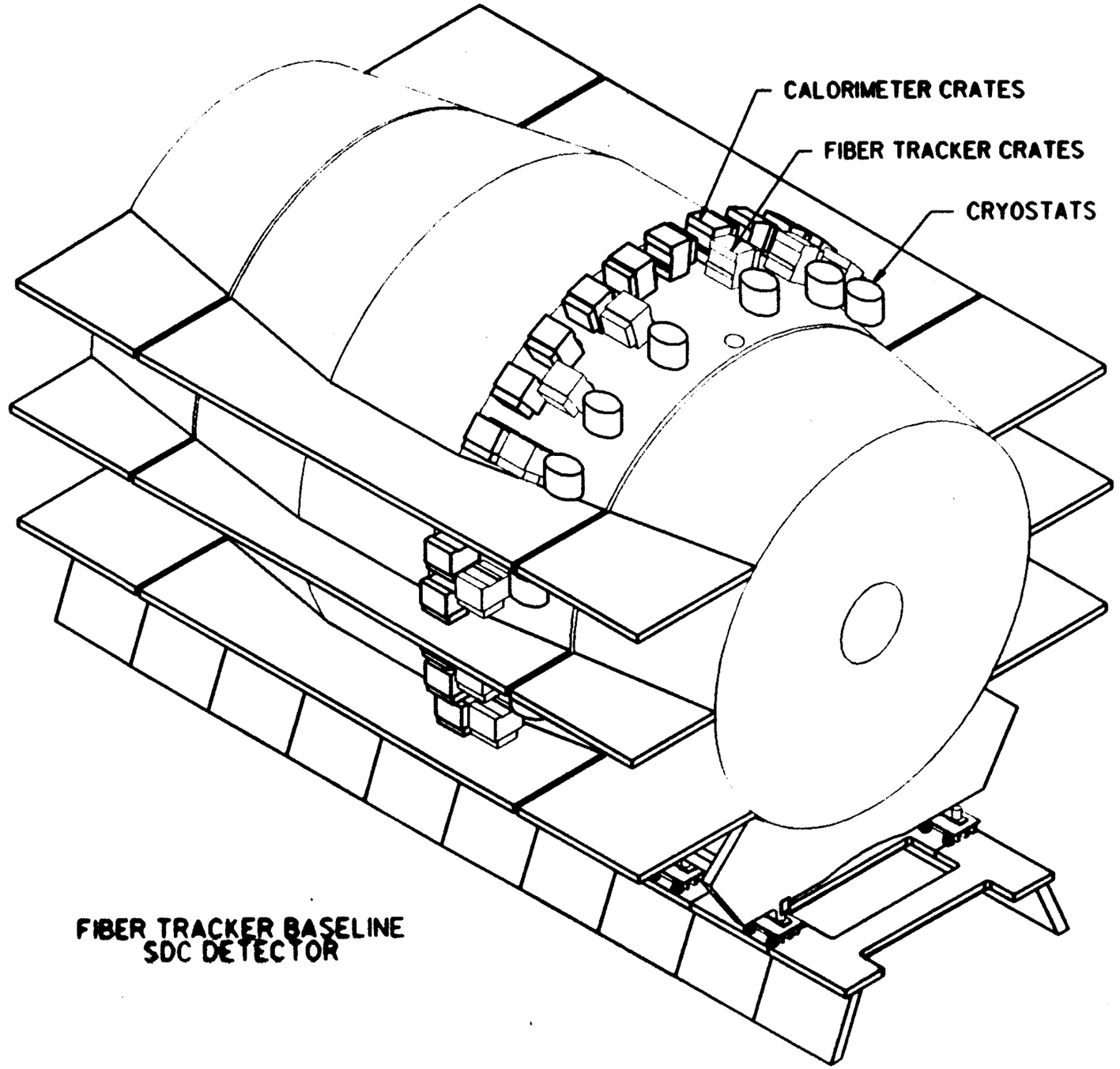
## E. INTEGRATION ISSUES:

### 1. REDUCED CRYOSTAT/CRATE INVENTORY

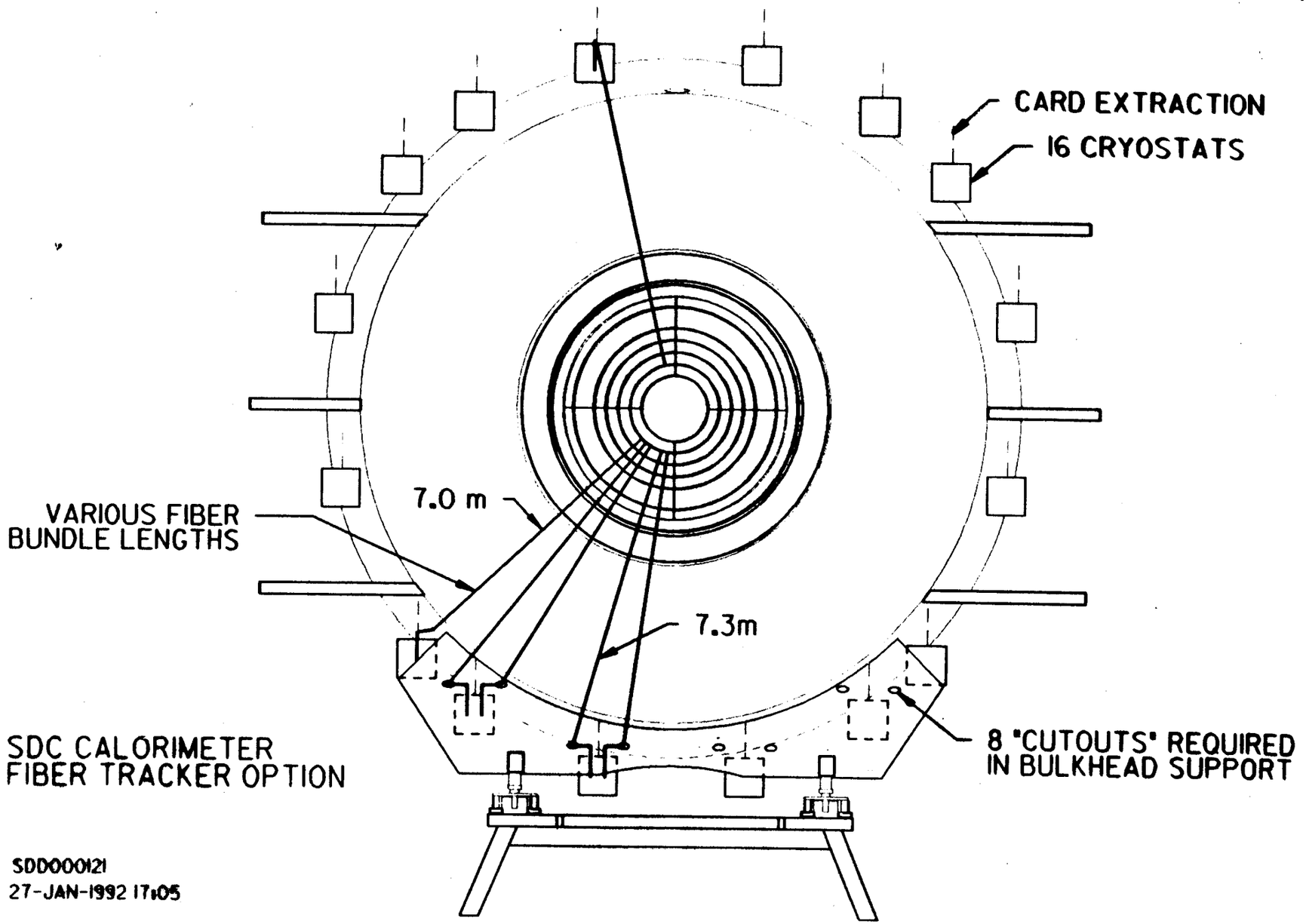
Was 96 total in the November CDR Draft
Now 32 total in the current design,
16 at each end of the detector.

### 2. FIBER OPTIC WAVEGUIDE RUNS ARE LONG

Lengths $\leq$ 7m
It would be important to keep these lengths at a minimum, and to reduce the lengths if possible




FIBER TRACKER BASELINE
SDC DETECTOR




SDC CALORIMETER
FIBER TRACKER OPTION

SDD000121
27-JAN-1992 17:05

# II. PROGRESS ON FIBER TRACKING TECHNOLOGY

## A. STUDIES OF PHOTOSTATISTICS

Using "baseline" scintillator composition
Polystyrene + pterphenyl + 3hydroxyflavone

### 1. MOTIVATION:

Increased length of tracking volume.
Increased fiber lengths from integration studies.
Concern for improved efficiency per fiber doublet layer, since the design now uses the doublet as the basic sense element for tracking and triggering.

### 2. METHOD:

Based on bench tests at UCLA using cosmic rays.
830micron scintillating fibers of 4m length
830micron waveguide fibers of 3m length
No mirroring

Correcting the measurements to SDC configuration for the various layers and then scaling to 1mm diameter fibers.

### 3. CONCLUSION:

To have a factor of 2 safety margin in photoelectron statistics, 1mm diameter fibers are now needed to assure efficient fiber doublet layers.

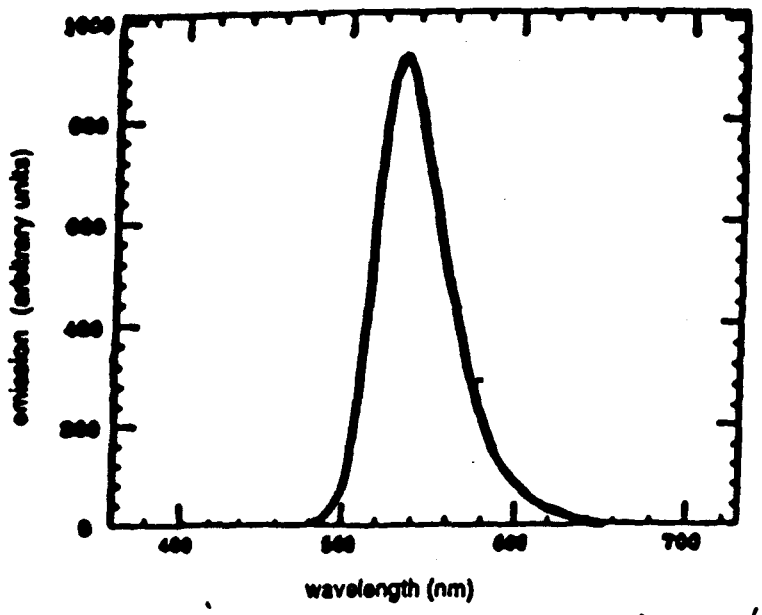



FIG.2.2-1 EMISSION SPECTRUM OF PS/PTP/3HF

Emission Spectrum

Figure 2.2-1 Absorption curve for polystyrene/PTP/3HF , reference-air. The vertical scale is in absorption units, AU=-log ($I/I_O$), path length = 1 meter

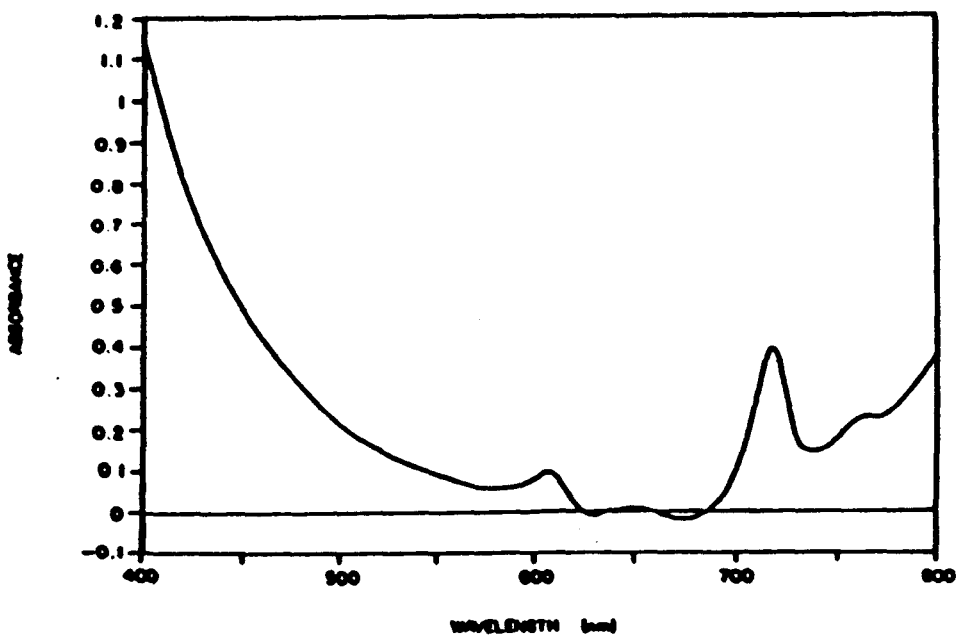
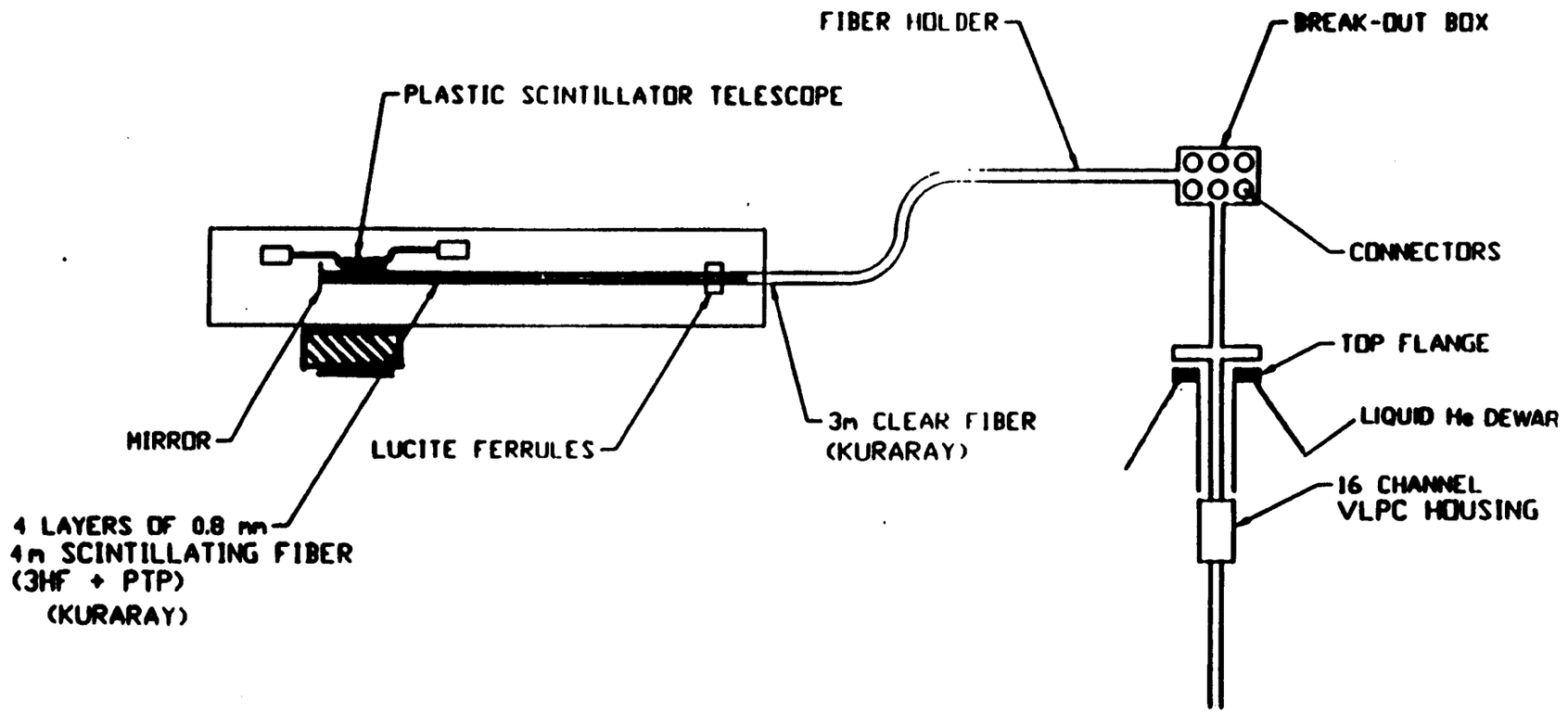



Figure 2.2-2 Absorption in unirradiated polystyrene as a function of wavelength.


FIBER HOLDER
BREAK-OUT BOX
PLASTIC SCINTILLATOR TELESCOPE
CONNECTORS
TOP FLANGE
LIQUID He DEWAR
MIRROR
LUCITE FERRULES
3m CLEAR FIBER
(KURARAY)
16 CHANNEL
VLPC HOUSING
4 LAYERS OF 0.8 mm
4m SCINTILLATING FIBER
(3HF + PTP)
(KURARAY)

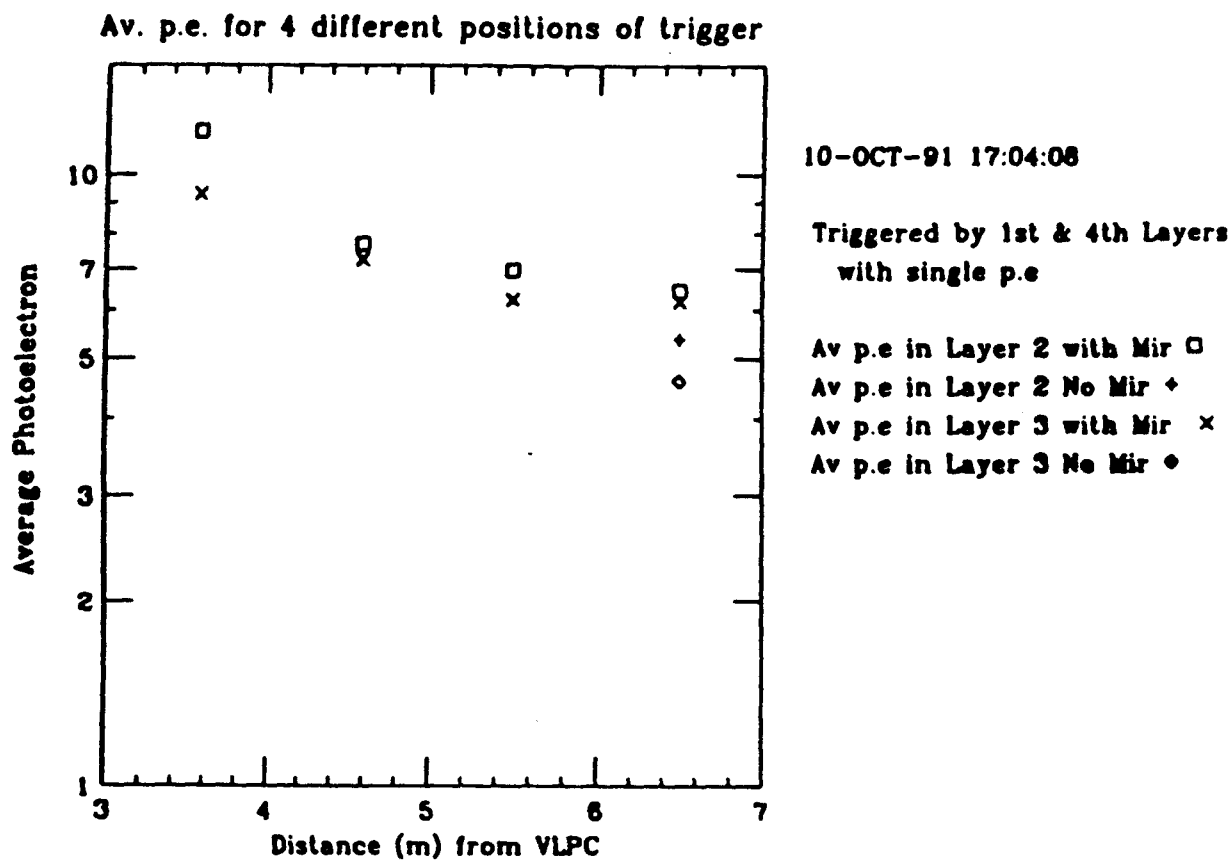



**Figure 2.2-11** Average number of detected photoelectrons per fiber layer in the cosmic ray tests using HMC VLPC photodetectors. Distance indicates the physical separation of the trigger counter telescope from the VLPCs, and includes 3 meters of clear fiber-optic waveguide, an optical splice, and then up to 4 meters of scintillating fiber.

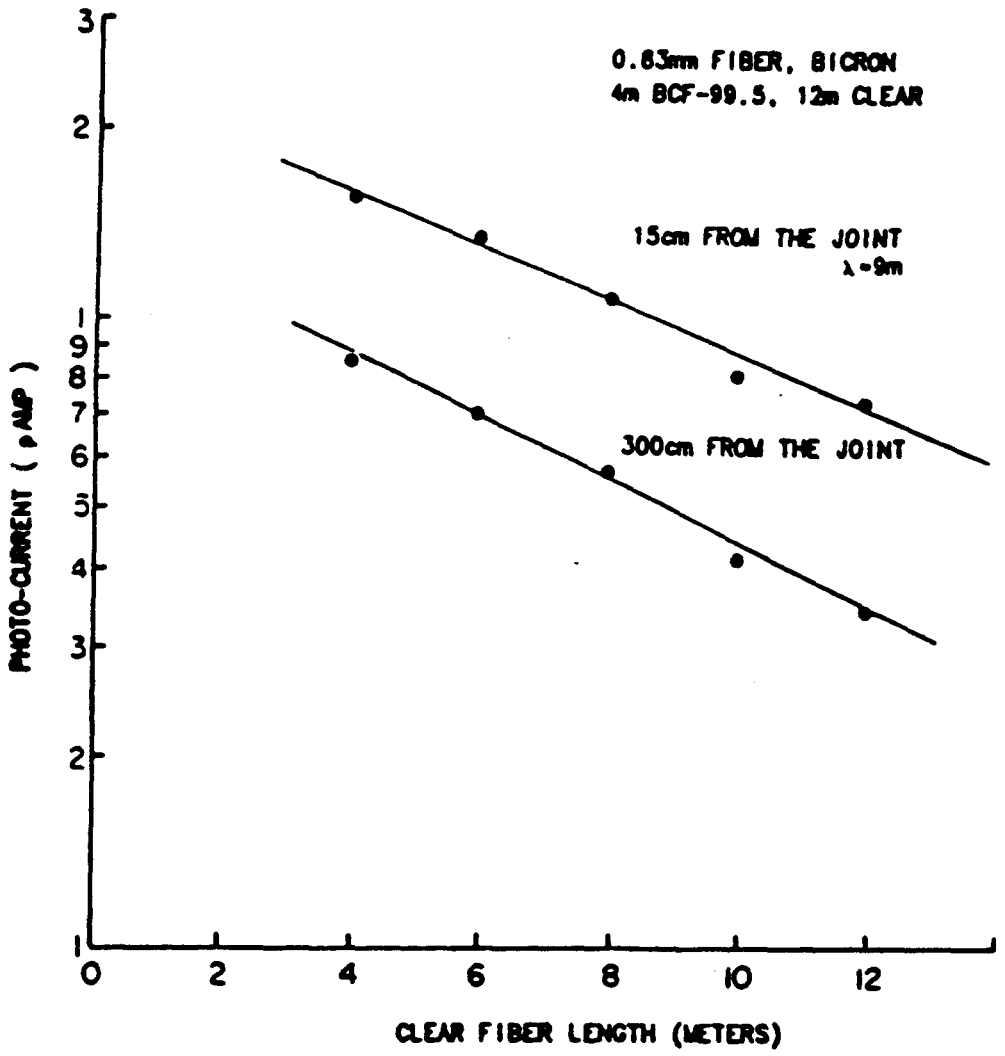



**Figure 2.2-12** Attenuation length of clear waveguide fiber of 830μm diameter. Source is UV excitation. Photodetector is a silicon photodiode, which has spectral response similar to the VLPC.

**Table 2.2-1**

**Photoelectron Yields in the Scintillating Fiber Tracker**

| Fiber Super Layer | Scifi length | Wave-guide length | Total fiber length | Correct-ion factor from data from Fig. 2.2-11 | Corrected p.e. for 830μm diameter ($\eta$ =0) | Scale up to 1mm diameter | Expected p.e. for 1mm diameter ($\eta$ =0) |
|---|---|---|---|---|---|---|---|
| B1 | 3.00m | 6.93m | 9.93m | .61 | 3.4 | 1.47 | 5.0 |
| B2 | 3.65m | 6.12m | 9.77m | .67 | 3.4 | 1.46 | 4.9 |
| B3 | 4.30m | 5.31m | 9.61m | .73 | 3.3 | 1.46 | 4.8 |
| B4 | 4.30m | 5.15m | 9.45m | .75 | 3.4 | 1.45 | 4.9 |
| B5 | 4.30m | 4.87m | 9.17m | .77 | 3.5 | 1.44 | 5.0 |
| B6 | 4.30m | 4.58m | 8.88m | .80 | 3.6 | 1.44 | 5.2 |

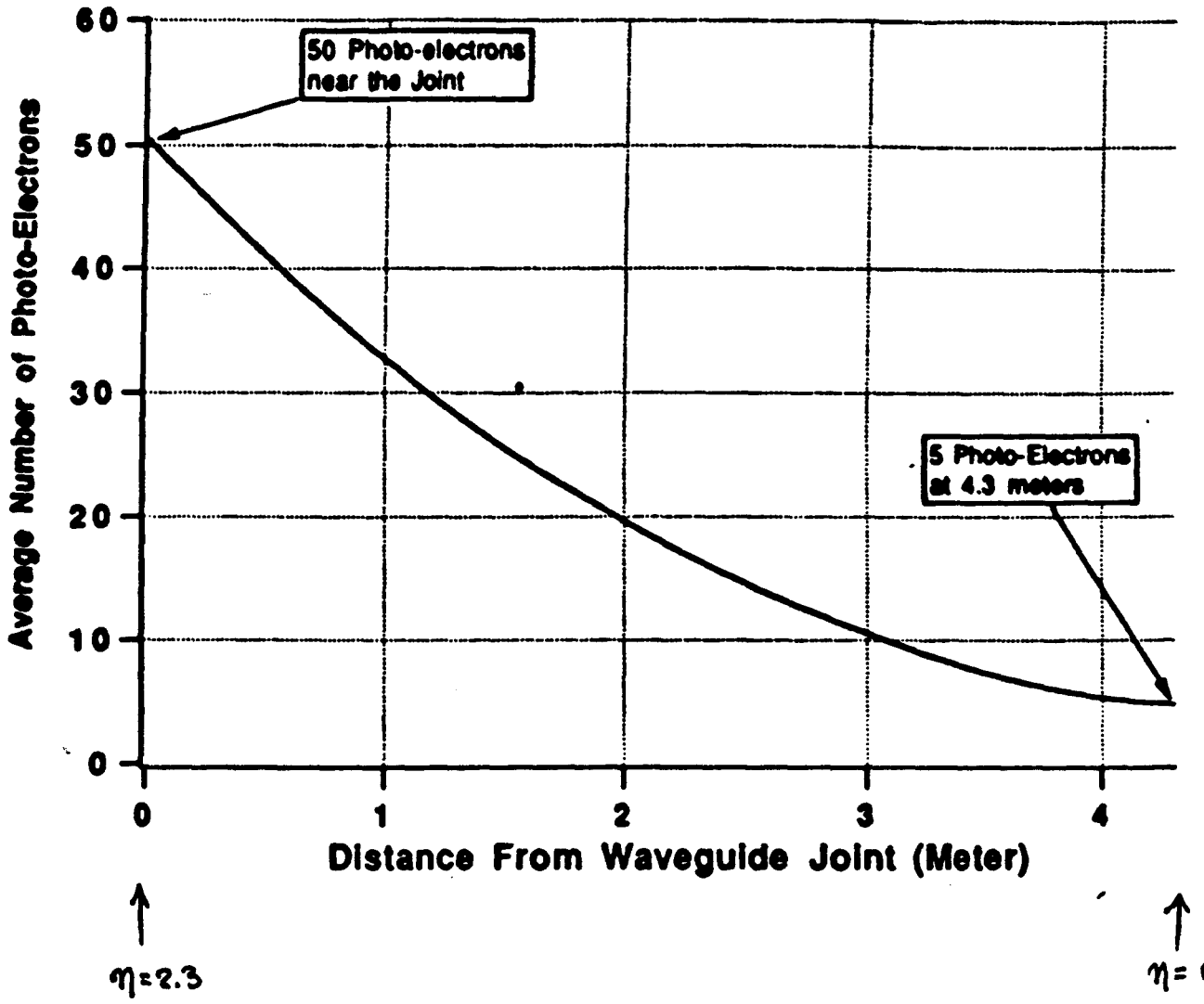



**Figure 5.3.3-1** Mean detected photoelectron yield as a function of position along a scintillating fiber in layer B3 of the tracker (at R= 92 cm)

## B. RADIATION DAMAGE STUDIES

### 1. HIGH DOSE/HIGH DOSE RATE:

$^{60}Co$ 1MRad - 10MRad
Various Atmospheres
Annealing

Bulk Boules 1cm dia x 10cm length

### 2. LOW DOSE RATE:

Tevatron C0 Area 15KRad - 120KRad
Various Atmospheres
Annealing

Fiber Samples 830micron dia x 4m length

### 3. CONCLUSION:

Baseline composition shows excellent radiation resistance characteristics in the high dose rate boule studies. No observable damage to 1MRad (>50 Standard SSC years at the inner tracking radius). Some damage observed at 10MRad.

Studies in progress on slow damage. Initial results are favorable, indicating that inert atmosphere during irradiation is important.

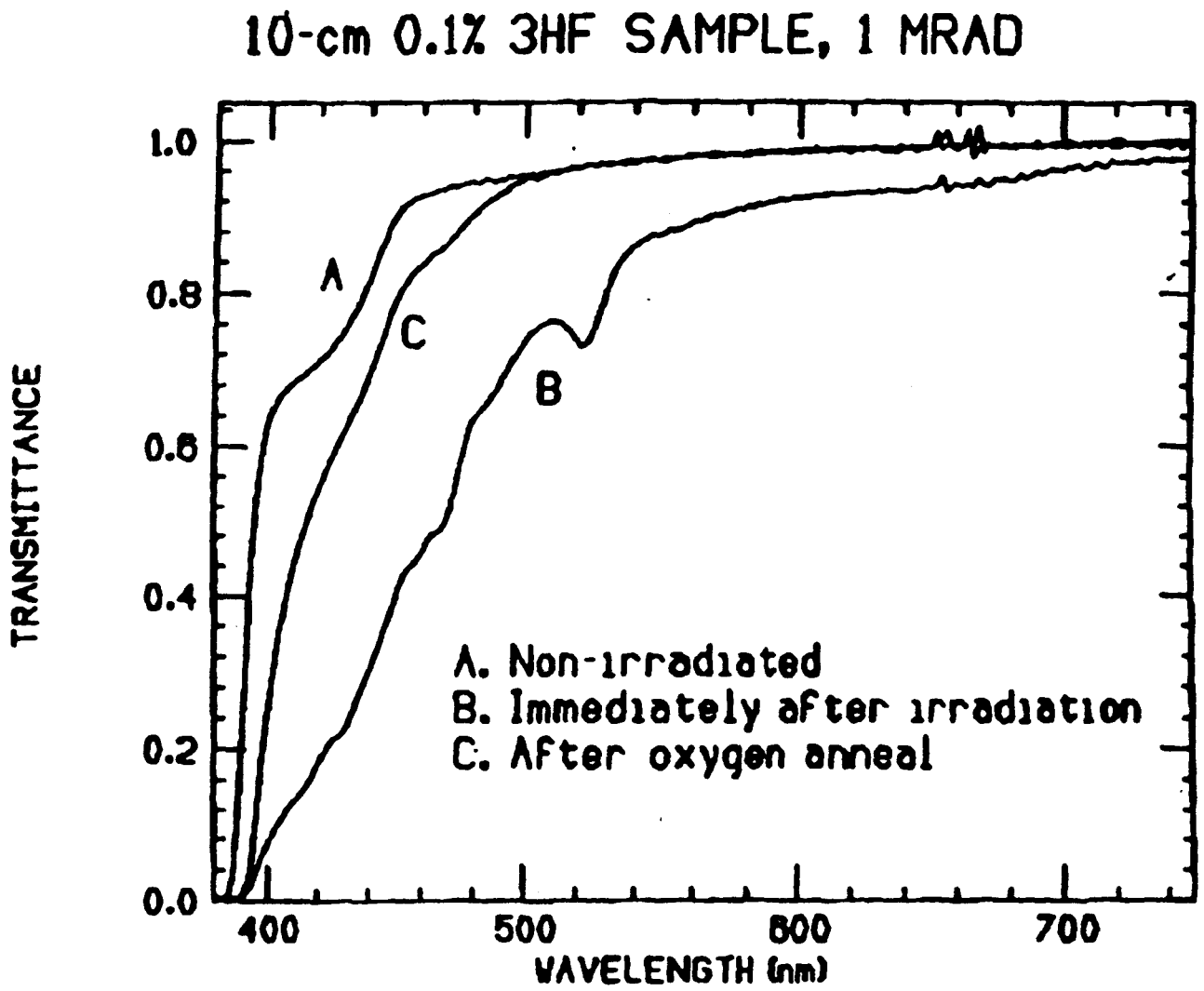



**Figure 5.2-1** Transmission in polystyrene/PTP/3HF scintillator as a function of wavelength. Before and after irradiation by $^{60}Co$ to 1 MRad, and after annealing.

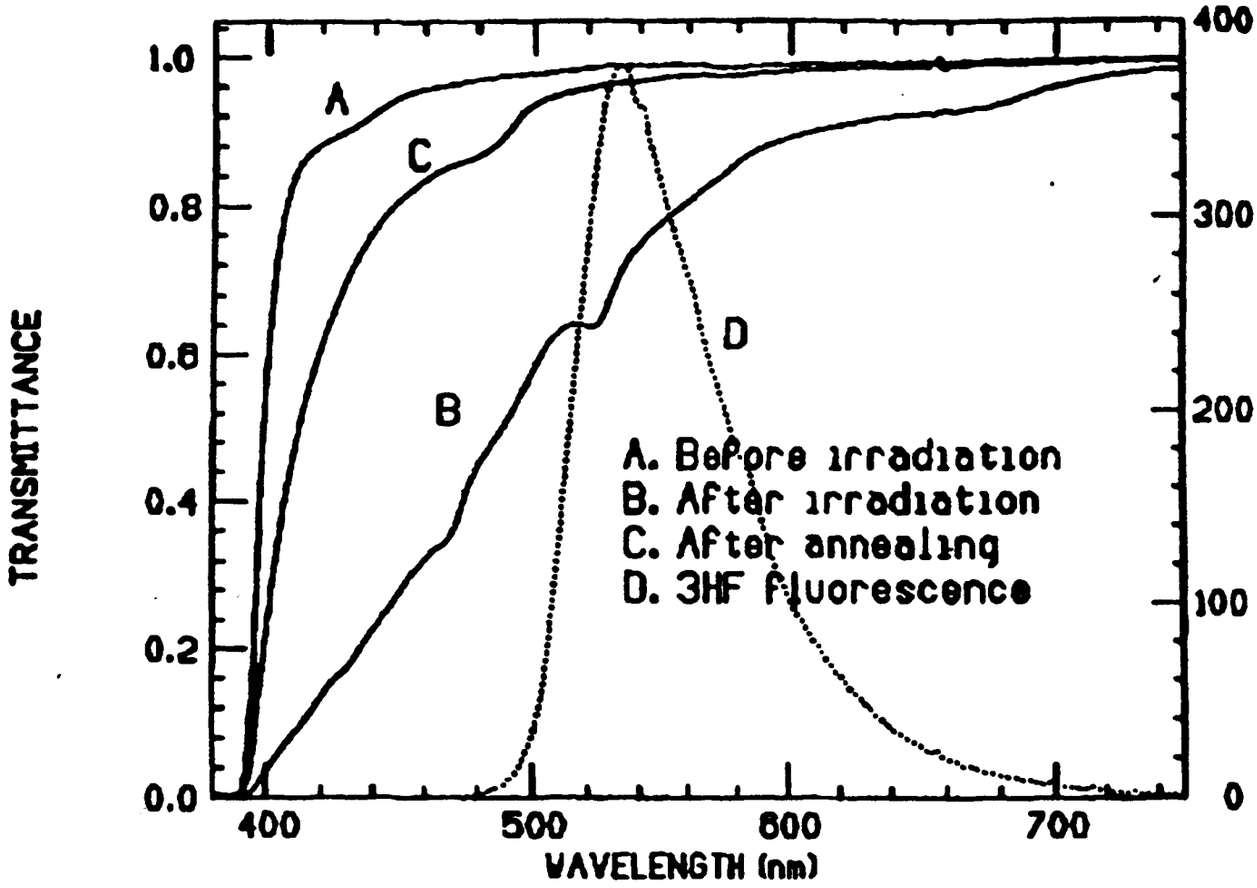
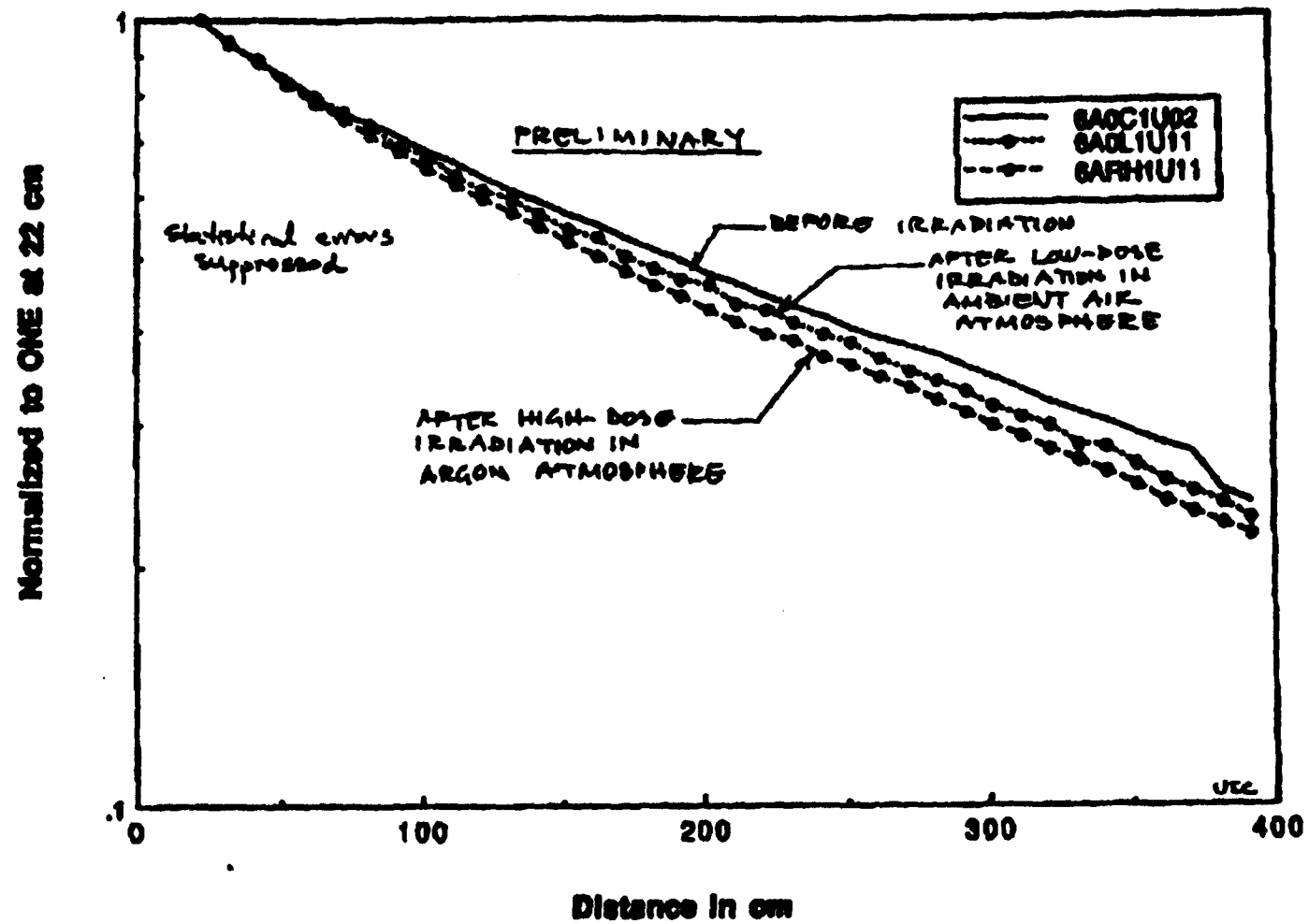



Figure 5.2-2 Transmission in polystyrene/PTP/3HF scintillator as a function of wavelength. Before and after irradiation by $^{60}Co$ to 10 MRad, and after annealing.

UI-CHICAGO




# pT + 3HF

FIBER TRANSMISSION BEFORE IRRADIATION, AFTER LOW-DOSE IRRADIATION IN AMBIENT AIR, AND AFTER HIGH-DOSE IRRADIATION IN ARGON ATMOSPHERE. (ARBITRARY NORMALIZATION AT 22 CM.)

## C. VLPC RESEARCH AND DEVELOPMENT

### 1. HISTE-II DECLARED "ITAR-FREE"

Letters to J. Peoples and R. Schwitters indicating availability for unrestricted use.

### 2. PREPARATION OF A SMALL, COMPACT CRYOSTAT FOR 32-CHANNEL BEAM TEST AT FERMILAB (T-839)

Small 5 liter dewar fabricated.
Small compact cryostat fabricated by Rockwell to support 32 VLPC channels (HISTE-II), with associated fiber waveguides and fiber-optic coupler.
Implementation of warm preamps.

### 3. HISTE-III CHARACTERIZATION BY THE END OF FEBRUARY 92

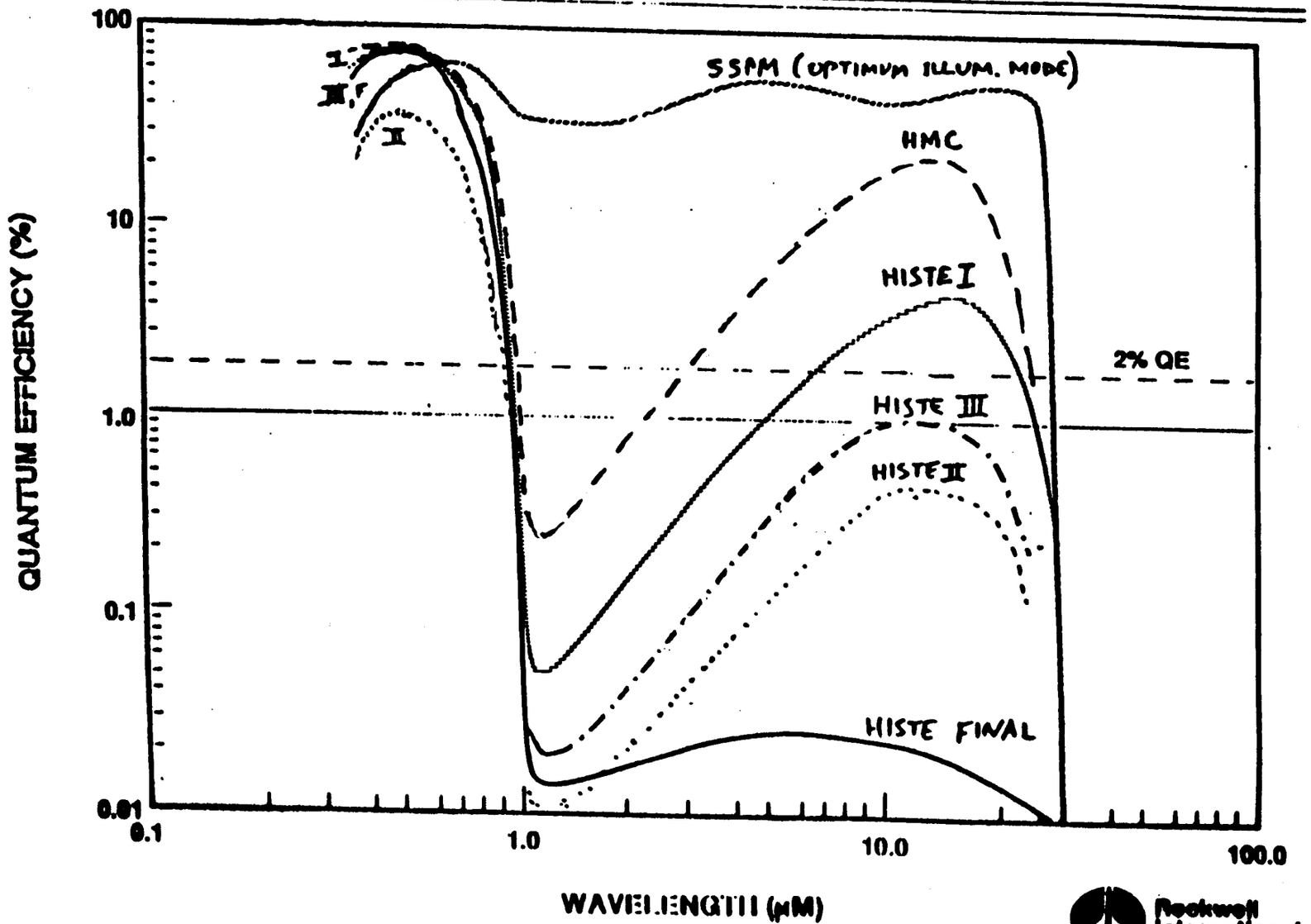
Material has been prepared.
Layer thicknesses appear to be as expected.
Device fabrication steps underway.

### 4. CANISTER CONCEPTUAL DESIGN REPORT TO BE PRESENTED 2-12-92 AT ROCKWELL, ANAHEIM, CA.

### 5. CONCLUSION:

VLPCs are now available for general laboratory use.
Compact cryostat is able to maintain adequate temperature stability for multiple channel systems.
Performance in the beam test for the HISTE-II is described in the next section.

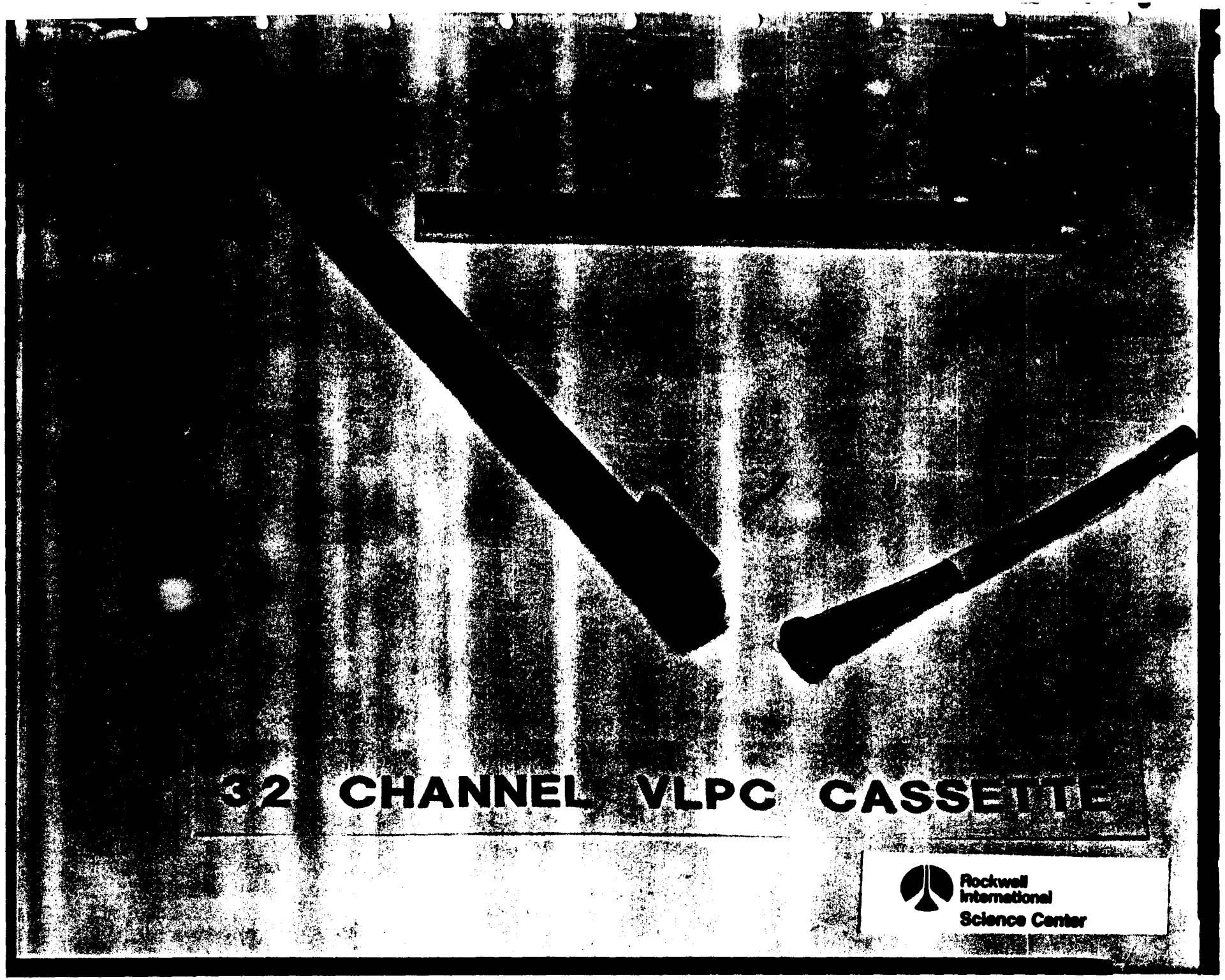
# VLPC SPECTRAL QUANTUM EFFICIENCY

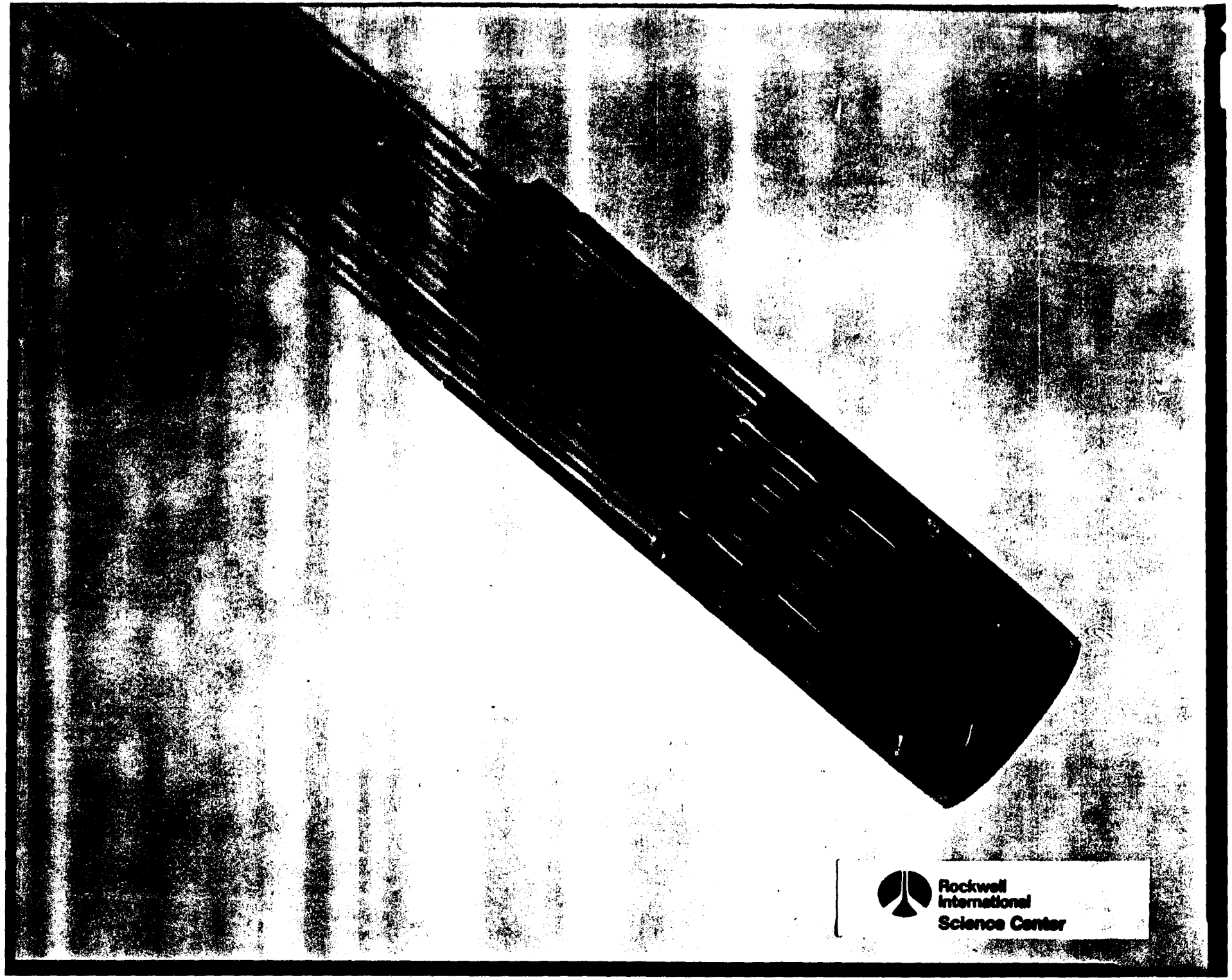



EP9.16386 D30

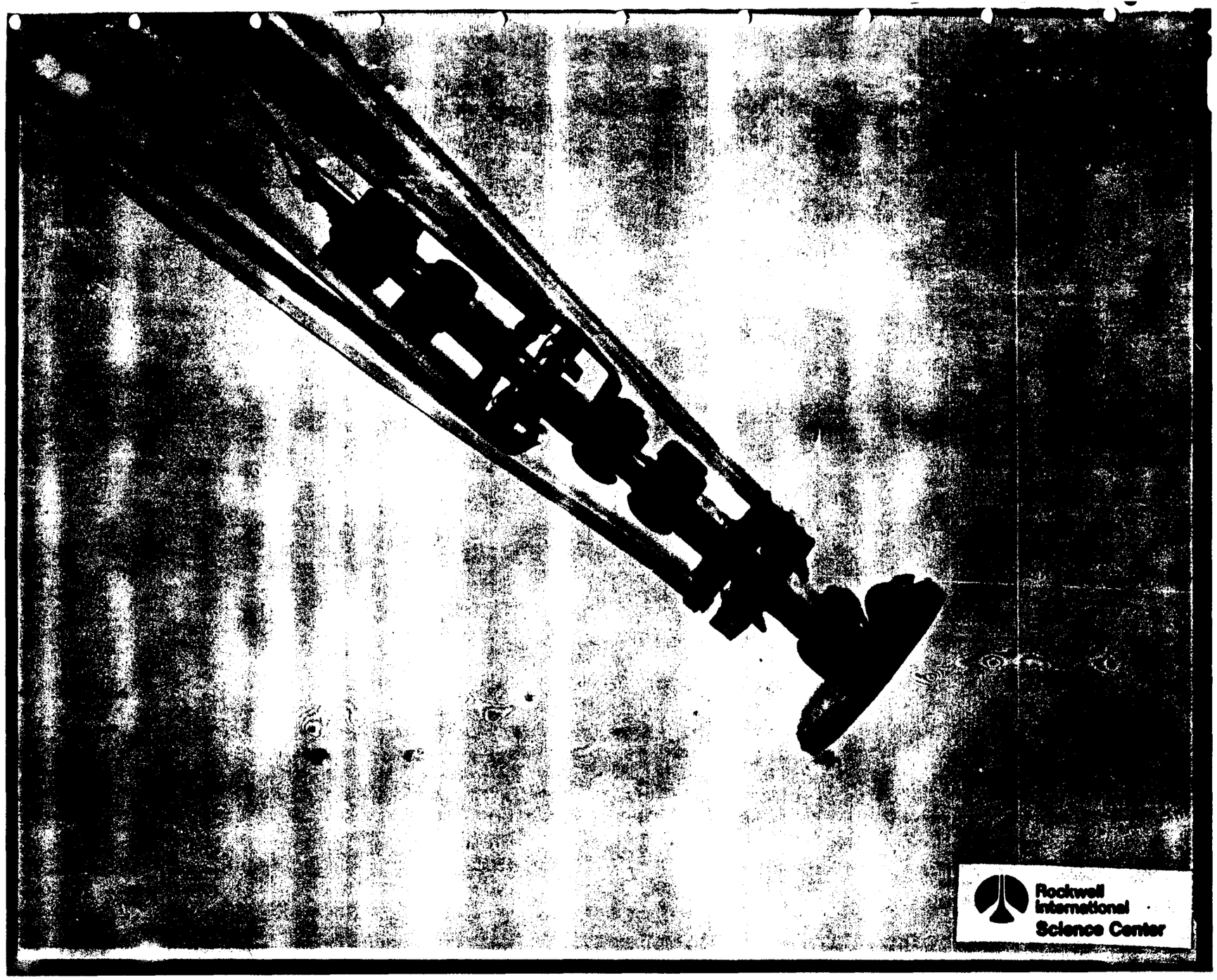
Rockwell International Science Center

32 CHANNEL VLPC CASSETTE
Rockwell
International
Science Center


32 CHANNEL VLPC CASSETTE
Rockwell International
Science Center



Rockwell International
Science Center



Rockwell International Science Center

Figure 7. Helium Bottle for Multiple Channel VLPC Cassette

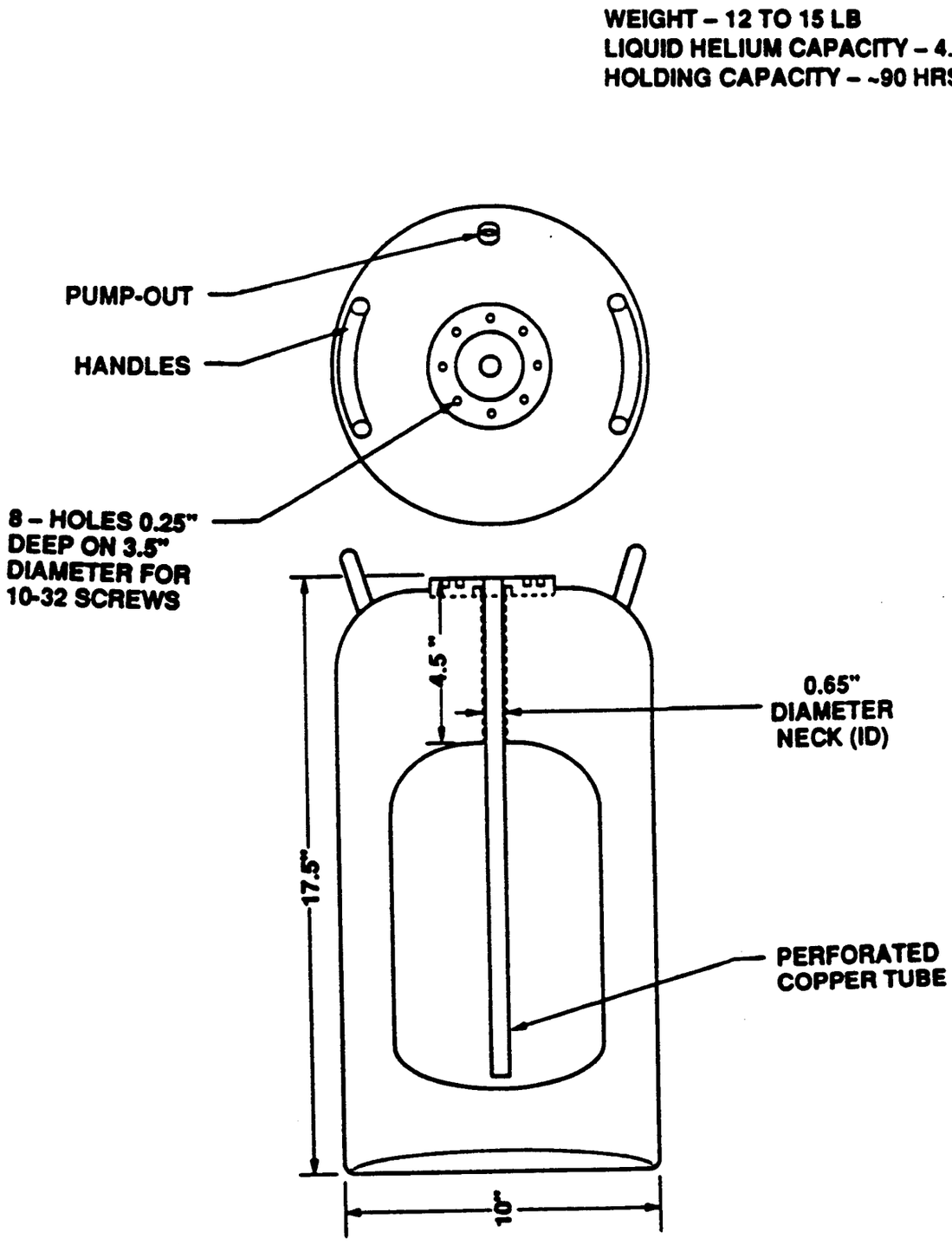
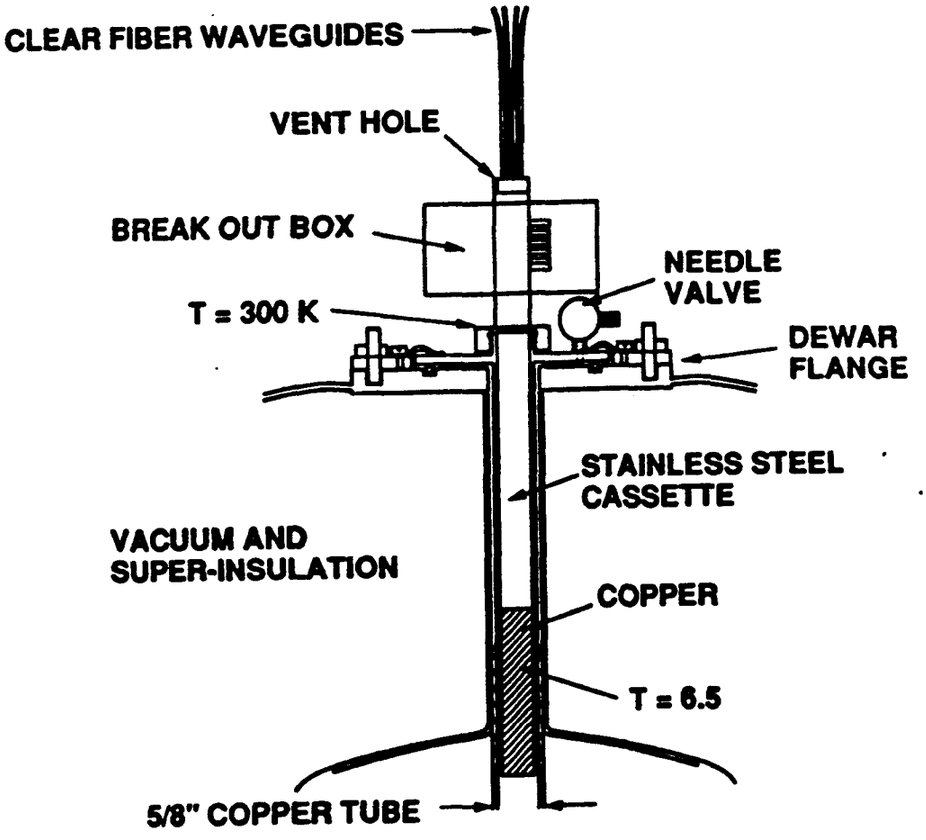


Figure 8. Multiple Channel VLPC Cassette Installed in Helium Bottle.



## D. BEAM TEST (T839)

### 1. MOTIVATION:

To study the performance of a scintillating fiber/VLPC system comprised of 32 channels using fast, room temperature preamplifiers.

To study doublet fiber layer resolution.

### 2. IMPLEMENTATION:

The beam test was performed at Fermilab New Muon Laboratory (NM Beam) during December '91 and January '92.

The test arrangement consisted of 4 superlayers of fibers having 1/4 fiber offset in the ribbons and arranged as:

32-channels readout with HISTE-II VLPCs and using:
- VTX preamps (Warm)
- New compact cryostat
- Low capacitance strip cable

96-channels readout with MAPMT

### 3. CONCLUSIONS:

The VLPC system was quickly brought on line and performed well. Notably:

The small compact cryostat system operated stably, and 32 channel test went smoothly. Cooldown from room temperature to 9K took 5-10min. Stable operation could be maintained for 24-36 hours.

**The HISTE-II and VTX preamplifier combination exhibited <5ns pulse rise and excellent signal to noise characteristics. These results indicate that cryogenic preamps will not be necessary for SDC operation.**

**Tracks have been recorded with the system in the muon beam (NM) at Fermilab.**

**Doublet layer resolution is in accord with expectation (~120microns) based on tracking measurements using the multianode pmt.**

**Beam tests are essential to assess overall system performance.**

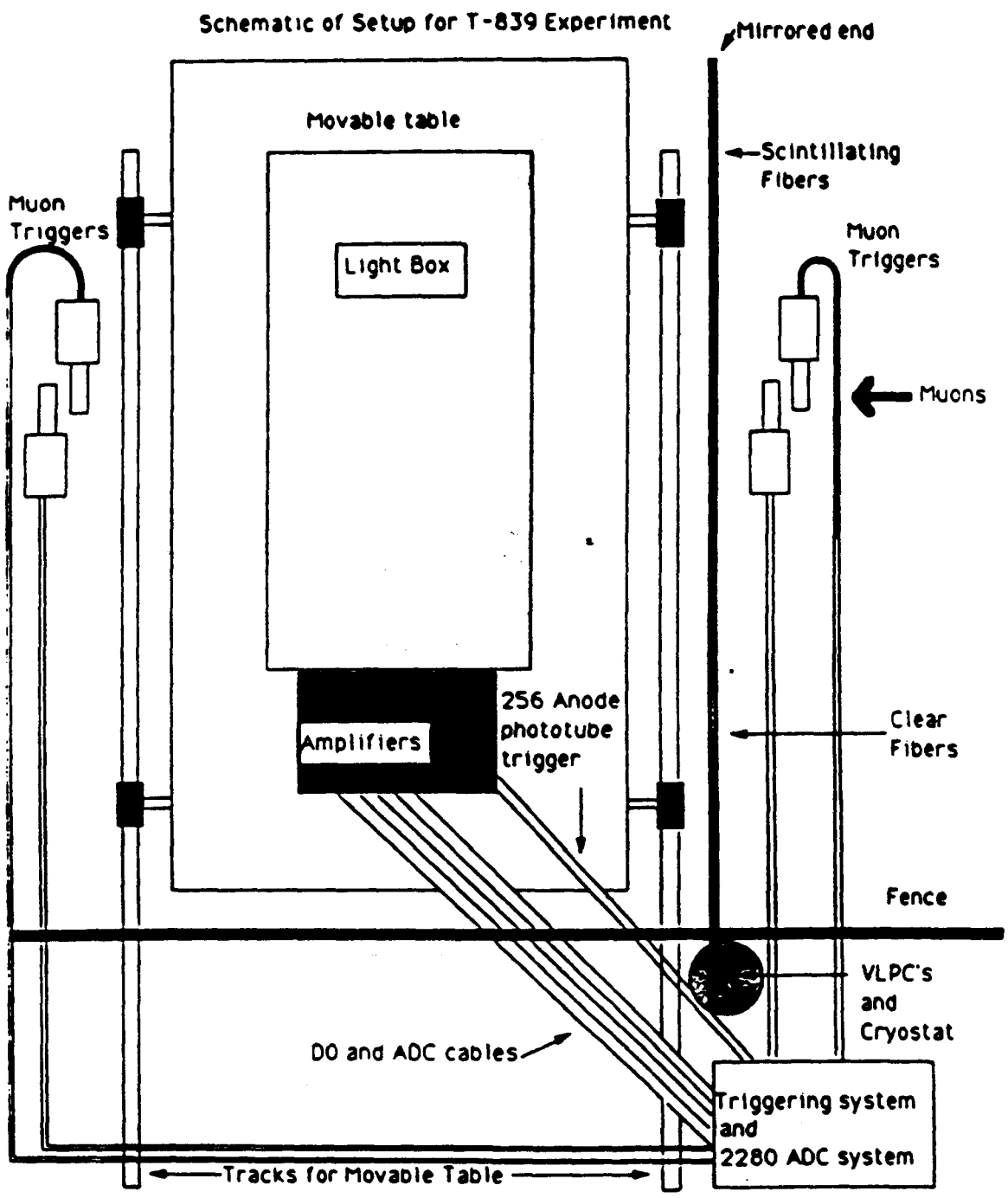
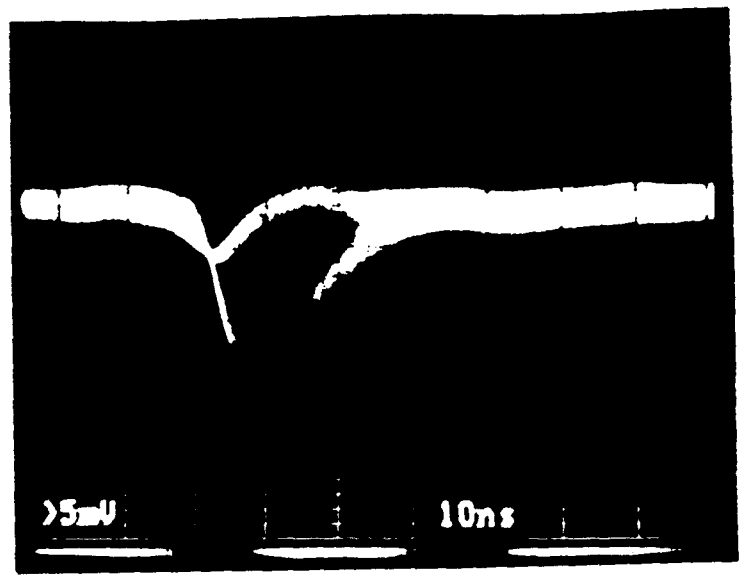



Figure 2.2-13 Schematic of the arrangement of detectors in the NM (muon) beam at Fermilab.




1/2/1992

Tests with HISTE-II VLPCs

Using VTX amplifiers

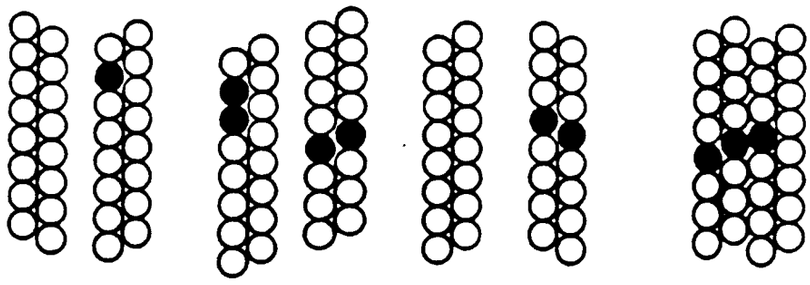
Bias Voltage : 7.8 volts

Temperature: 9.5 K

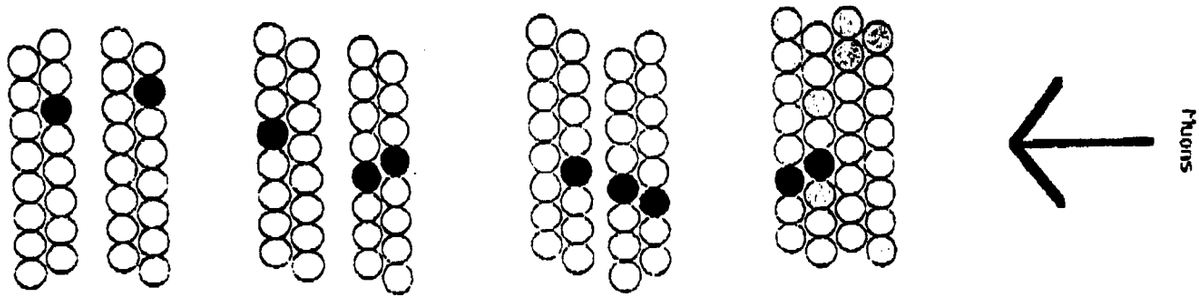
Looking at thermal electron pulses

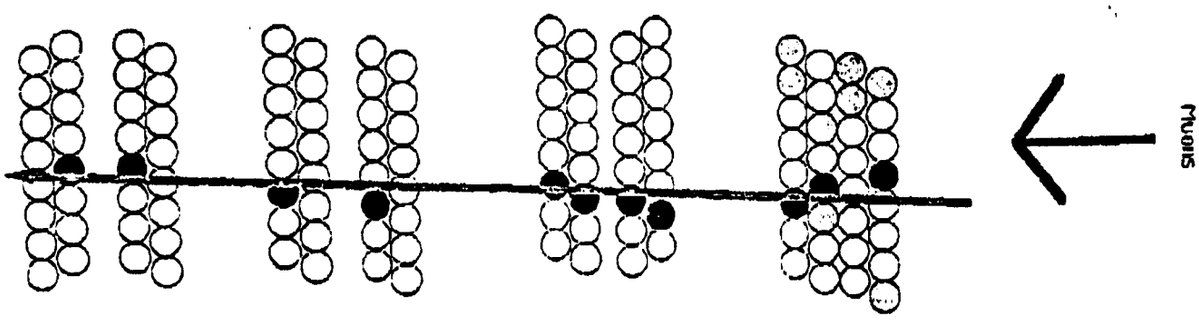
Location of fiber hits for Multianode Phototube

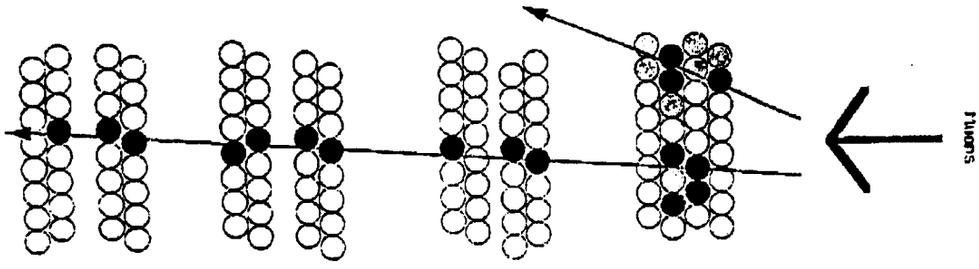
Location of fiber hits for VLPC



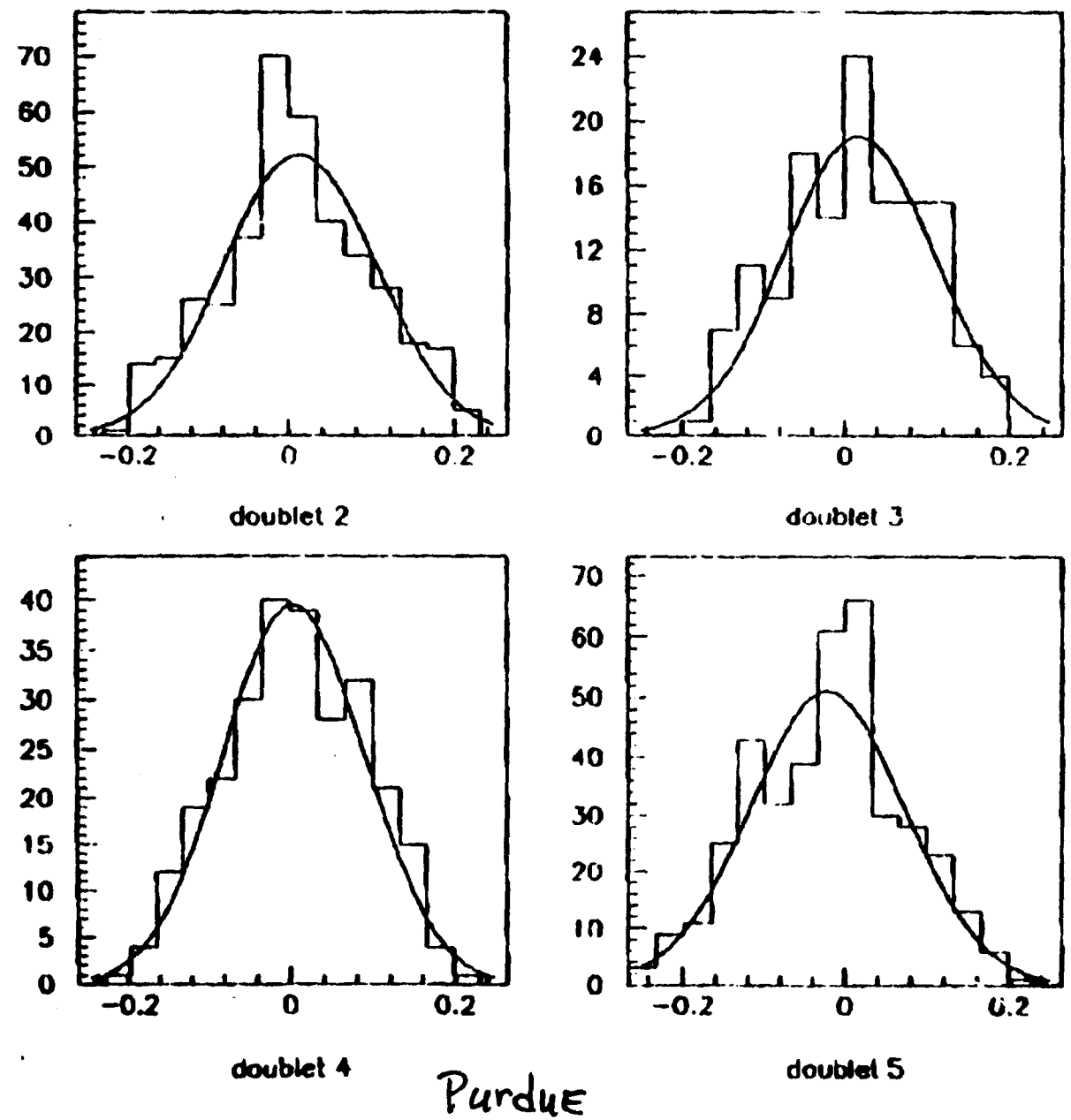
Blackened circles represent fibers hit
Note: Location of fibers not to scale



Test Beam T-637




Purdue

## III. SUMMARY

1. A scintillating fiber outer tracker is proposed which exploits the low-occupancy and fine granularity of the fibers and the intrinsically prompt response of the scintillator to:

   cover the range $0 \leq |\eta| \leq 2.3$ with a uniform triggering and tracking approach using

   cylindrical geometry
   vector superlayers
   two small-angle stereo measurements (U and V)
   currently set at $15^{o}$.

2. The tracker meets all of the tracking performance requirements at $L = 10^{33}$.

3. The tracker meets or exceeds all of the tracking performance requirements at $L = 10^{34}$.

4. Triggering is straightforward, implemented in ASIC, and is capable of reporting a momentum value (4bits) at Level 1. At design luminosity, this utilizes the inner three superlayers (B1-B3) and covers $0 \leq |\eta| \leq 2.3$. At high luminosity B1-B4 will be utilized, with slightly reduced $\eta$ coverage: $0 \leq |\eta| \leq 2.1$.

5. The lower channel count of the current design (439K fibers) enables a much more efficient crate/cryostat utilization - now 16 per end. The tracker cost has been substantially reduced.

6. As designed, the fiber + silicon tracker system exceeds the average material budget in radiation lengths over the the rapidity interval $0 \leq |\eta| \leq 2.5$ as specified in the tracking requirements (19.6% vs 15%). However this is not an issue for triggering, in which the three inner superlayers B1-B3 are utilized. While we intend to examine ways to reduce the material budget further, we will endeavor to maintain the simple elegance of the current fiber tracker design.

## IV. SYSTEMS STUDIES FY92-FY93:

1. 128 CHANNEL TEST OF FIBERS AND HISTE-III VLPC - SPRING 1992

2 256 CHANNEL TEST OF FIBERS AND HISTE-III VLPC - SUMMER 1992

3 1024 CHANNEL TEST IN EARLY FY93 HISTE-III OR IV.

# V. R & D AND ENGINEERING REQUEST

A. MECHANICAL ENGINEERING

B. VLPC AND CRYOSTAT DEVELOPMENT

**Engineering for Scintillating Fiber Tracking**

12/17/91
David Koltick & Randy Ruchti

**1. Relevant to 1024 channel test.**

**a. Cylinder Development**

| | |
|---|---|
| i. Thin Cylinder (using existing mandrel) | 50K |
| ii. Sandwich Cylinder (using existing mandrel) | 80K |
| iii. Survey of Cylinder Manufacturers | 5K |
| iv. Design of Pre-prototype Ribbon Laying apparatus (built at university) | 16K |
| | --- |
| | 151K |

**b. Cordax Machine**

| | |
|---|---|
| i. Refurbish Cordax Machine at ORNL | 20K |
| ii. Locate and Prepare Clean Space for Cordax at Y-12 or K-25 | 20K |
| iii. Move Cordax to new space and install | 15K |
| iv. Camera Probe for Cordax | 15K |
| | --- |
| | 70K |

c. Ribbon Manufacturing Apparatus (Design) 32K

**2. Assembly of Fibers on Superlayers**

i. Design of a "Universal" Platen to Place Fibers on the inside and outside of Cylinders
ii. Tooling to place fibers on cylinders
iii. Tooling to mount cylinder and ancillary hardware on Cordax
iv. Instrumentation to rotate cylinder and diagnostics for cylinder positioning
v. Placement of fiber on inner and outer walls (platen to cylinder operation)

| | |
|---|---|
| 4 mo. engineering design | 64K |
| drafting | 36K |
| 3mo. parts fabrication (1.25FTE tech) | 125K |
| 3mo. asembly and check (0.25FTE engr. and 0.25FTE tech.) | 75K |
| | --- |
| | 300K |

**3. VLPC Cannister Prototype Fabrication**

Further Design Refinements and Fabrication of a Pre-production Prototype 300K

**4. VLPC R and D Contract** 245K

Per attachment

**5. Engineering Support at SSCL and ORNL**

i. ORNL Cost and Schedule and Mechanical Design (1FTE)
ii. Cryo Engineering and Integration (0.5FTE)

PRESENTATION BY:

EDWARDS

Edwards
Sun pm

# LAYOUT OF THE ITD.

LAYOUT IN BODY OF OUR CDR COVERS
$1.7 < \eta < 2.8$.

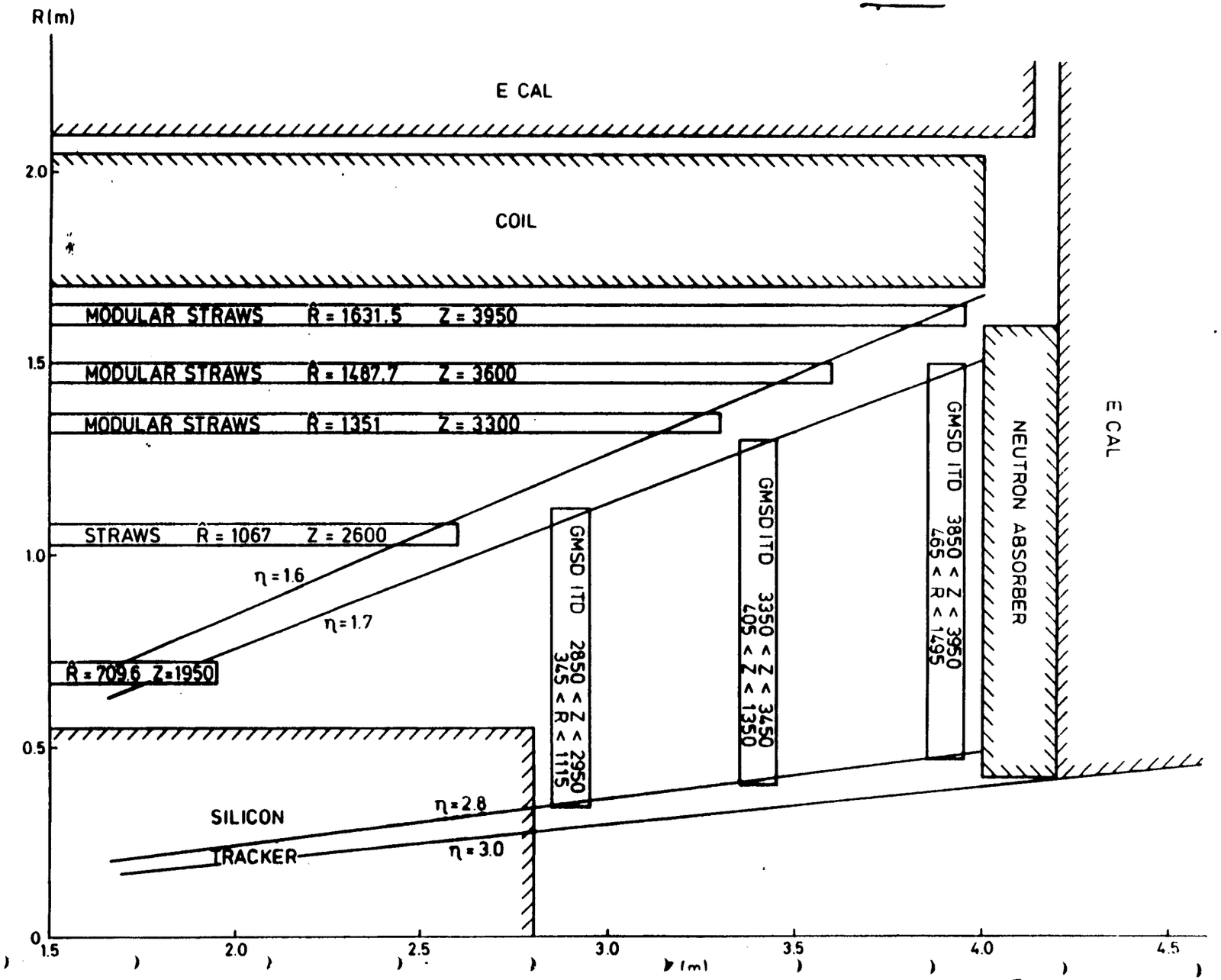
IT HAS 2 MAJOR DRAWBACKS

1) GAP IN RAPIDITY COVERAGE 1.6 - 1.7 BETWEEN CTD AND ITD.

2) ALL SUPPORT STRUCTURES AND ELECTRONICS ARE IN THIS GAP

IN PISA A SUB-GROUP OF ITD AND CTD GOT TOGETHER AND WORKED OUT A NEW LAYOU

ssc DRAWING sdd 000079 rev 11-5-91 CDR. 22/11/91



SHOWN IS THE ACTIVE REGIONS OF THE TRACKERS PLUS ELECTRONICS AT END OF STRAWS AND SPACE FOR H.V. FEED AND GAS SEALING OF TILES OF ITD

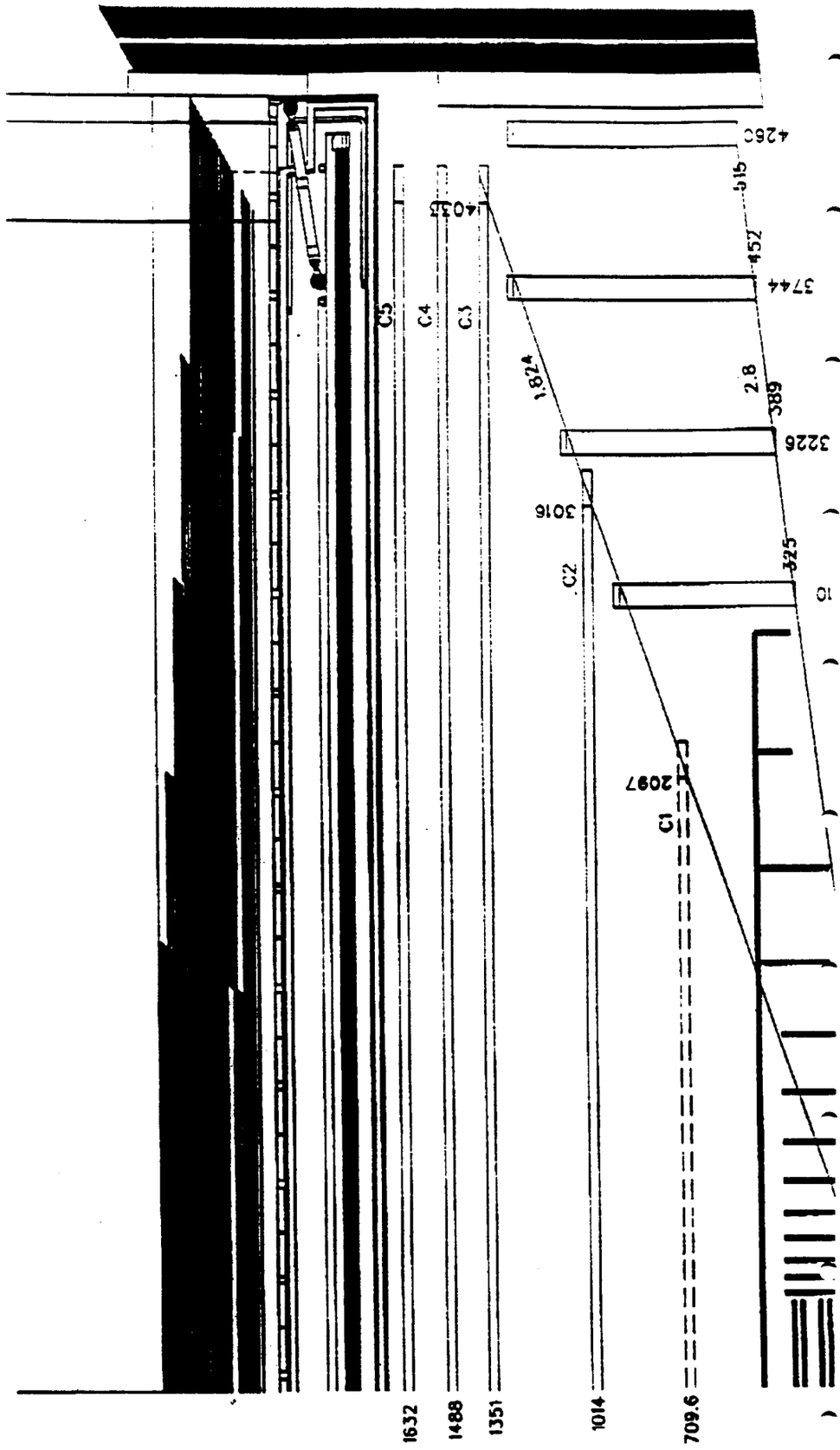
THERE IS A 2CM CLEARANCE BETWEEN ITD AND CTD.

FOR CTD ELECTRONICS AND SPACE FRAME ARE INTERLEAVED SO TAKE UP SAME SPACE ON DRAWING.

C3 AND C2 HAVE STRENETHENED CYLINDER AT ENDS TO CARRY C2 AND C1 AND SILICON RESPECTIVELY.

SUPPORT FOR ITD PLUS ITS ELECTRONICS AND SERVICES ARE NOW ON INNER DIAMETE

SERVICES FOR SILICON ALSO ON INNER DIAMETER WITH IF NECESSARY, LOOP IN BORE OF END CAP TO ALLOW IT AND ITD TO ROLL BACK.


1632
1488
1351
1014
709.6
C5
C4
C3
C2
C1
2097
3016
1,874
4260
3744
3226
10
325
389
2.8
452
515

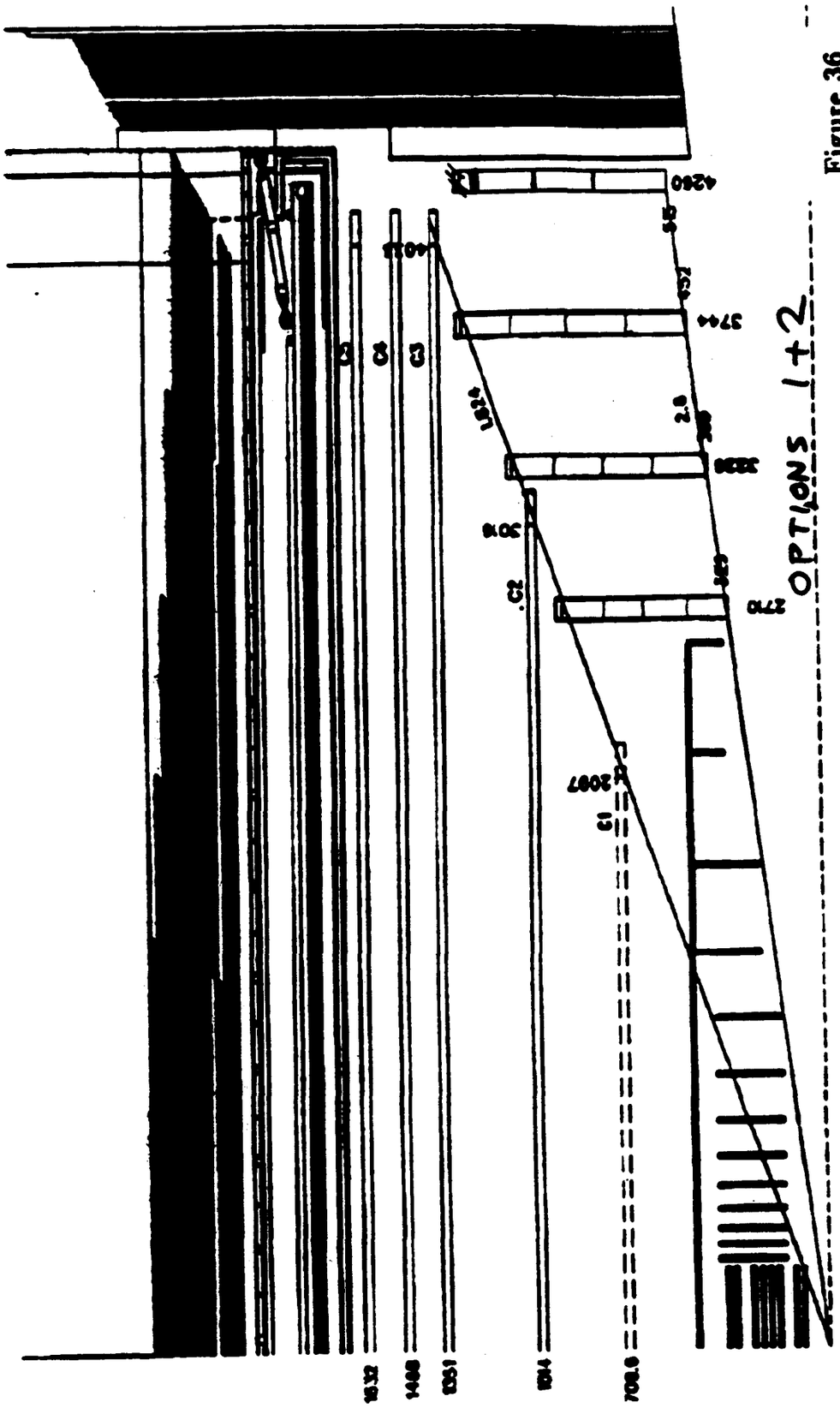
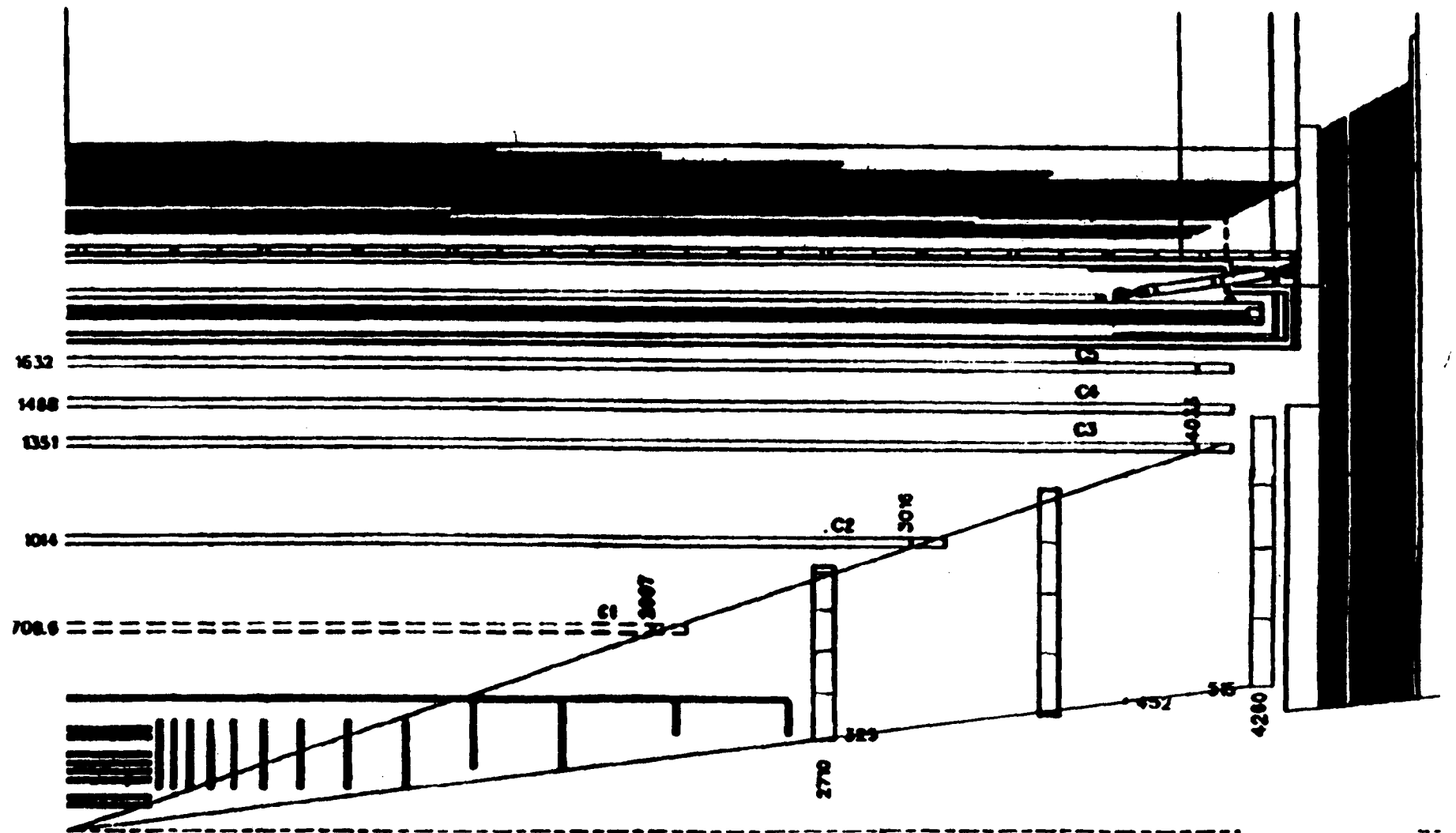

OPTIONS 1+2
4260
3744
3228
2712
2087
C2
C3
C4
C1
1632
1468
1351
1014
708.6

Figure 36




OPTION 3

Figure 36

AN ENGINEERING STUDY OF THIS LAYOUT HAS STARTED – NO CONCLUSIONS YET.

IN THIS LAYOUT THE ITD HAS
4 SUPERLAYERS EACH OF 4 LAYERS.
TOTAL TILE COUNT 3808
TOTAL CHANNELS 1.95 M.
ESTIMATED COST $17.2M

THE 4th SUPERLAYER DOES NOT COVER THE FULL $\eta$ (IT STARTS AT $\eta = 2.0$)

2 OBVIOUS WAYS TO "IMPROVE" LAYOUT.

PRESENTATION BY:

TAKAHIKO KONDO

T. Kondo
Mon am

# Agenda

JAN. 30 [Building #4 Auditorium]

| | | |
|---|---|---|
| 9:00 ~ 9:40 | ITD | presentation + Q & A |
| 9:40 ~ 10:20 | Si | |
| 10:40 ~ 11:20 | Straw | |
| 11:20 ~ 12:00 | SFT | |

| | |
|---|---|
| 14:00 ~ 14:30 | Simulation (D. Adams) |
| 14:30 ~ 15:20 | Simulation Summary (D. Coupal) |
| 16:00 ~ 17:30 | Discussion (open) |
| 20:00 ~ | Discussion (closed) |

JAN. 31 [Building #4, Directorate #1]

| | |
|---|---|
| 10:00 ~ 12:00 | Discussion on recommendations ~~consultants~~ (closed) |
| 14:00 ~ 18:00 | Writing recommendations |

# ISSUES YET TO BE ADDRESSED

and time run out.

1. innermost straw layer (C1)
2. pixels
3. # of silicon layers
4. # of ITD superlayers

# Summary of Tracking Simulation Results

presented by Dave Coupal

work done by: D. Adams
F. Bird
D. Coupal
W. Ford
B. Hubbard
F. Luehring
K. O'Shaughnessy

- General
- Algorithms

| | straw | Fiber |
|---|---|---|
| • Segment Finding | x | |
| • Resolutions | x | previous talk |
| • Higgs | x | " " |
| • Jets | x | x |
| • b-tagging | x | |
| • Top | | x |
| • Other | | |

# Track Finding Algorithms

① TR (D. Adams)

Start with pairs of hits, project outward (and/or inward), refit each time a hit is added

② TS (Hubbard & O'Shaughnessy &...)

Segments between layers in Silicon clustered in phi-curvature. Found silicon tracks projected to outer tracker to pick up straw segments or fiber coordinates.

③ RW (Luehring)

Overlapping bins of phi and curvature, fit all combinations of si and straw segments.

Warning:

- Algorithms still evolving and optimizing.
- Comparing different detectors with different algorithms is difficult.

- D. Coupal

# Summary

- No definitive test yet of straw vs fiber with the <u>same</u> algorithm ... but close.

- <u>Si + Straws</u>

Resolutions: consistent with parametrization

Segment finding: current algorithm shows problems in layer 1 @ $3 \times 10^{33}$, in layers 1-4 @ $6 \times 10^{33}$.

Higgs: A pattern recognition program based on silicon tracker shows good efficiency up to $3 \times 10^{33}$. Electron efficiency is lower - will need special treatment in track fitting and, probably, track finding.

Jets: Silicon-based pattern recognition shows good efficiency (~95%) for jets below 300 GeV, falling off to ~70% at 1 TeV.

4-layer vs 5-layer: No significant effect on Higgs (high $p_T$ isolated tracks) at design luminosity.
In jets, efficiency improved with 4-layer (<u>but</u> algorithm could be changed to be less dependent on layer 1 of straws).

Non-silicon-based pattern recognition just beginning to get results. Still needs some tuning

Si + Straw (cont'd)

b-tagging: 20-40% for b jet $P_T = 20-200$ GeV.
Needs more work.

- **Si + Fiber**

Resolutions: Consistent with parametrization

Higgs: Road search track finding algorithm shows good efficiency up to $6 \times 10^{33}$.

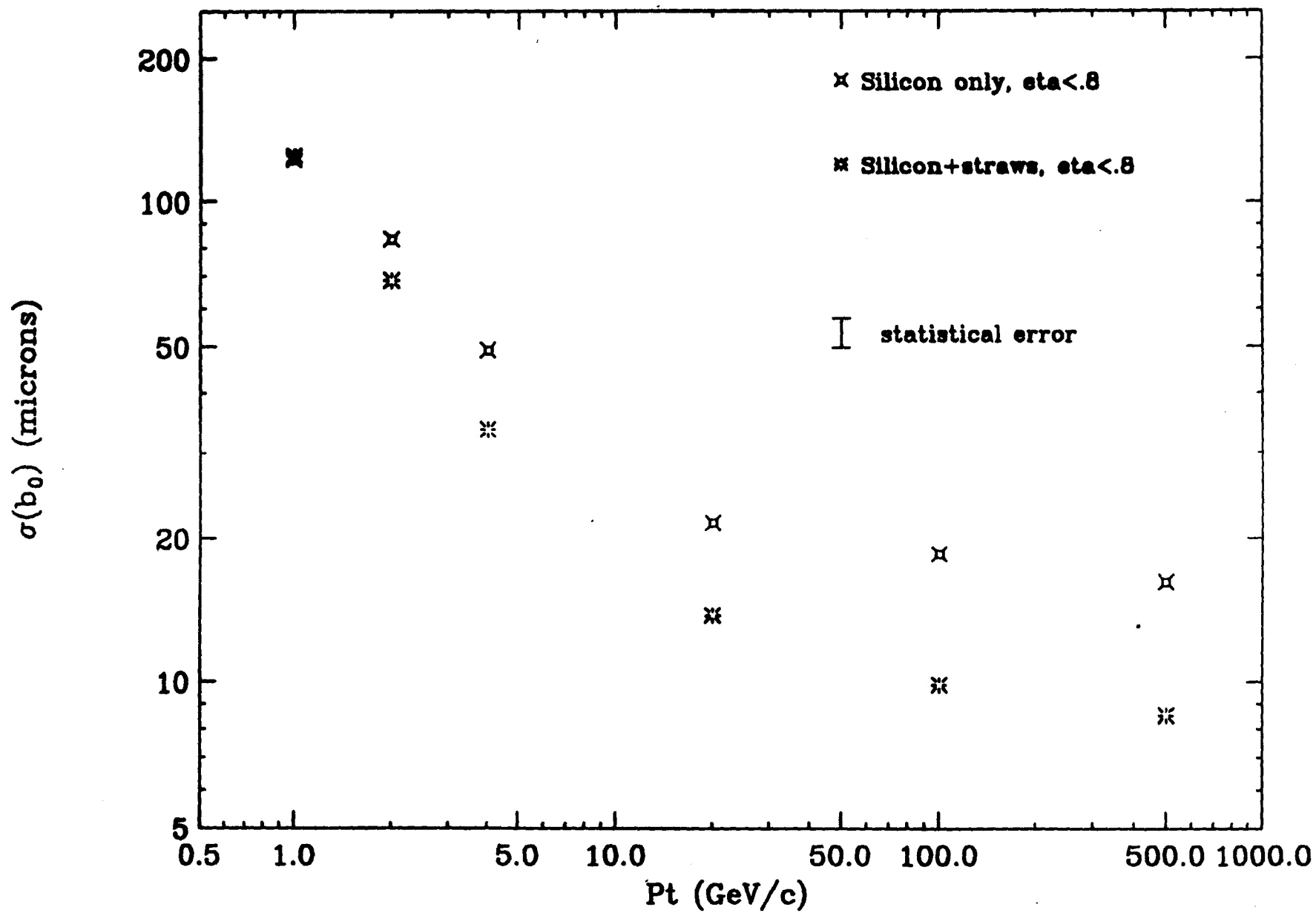
Jets: Lower overall efficiency than Si + Straws (may be algorithm needs tuning). Shows no sagging for jet $p_T$ up to 1 TeV

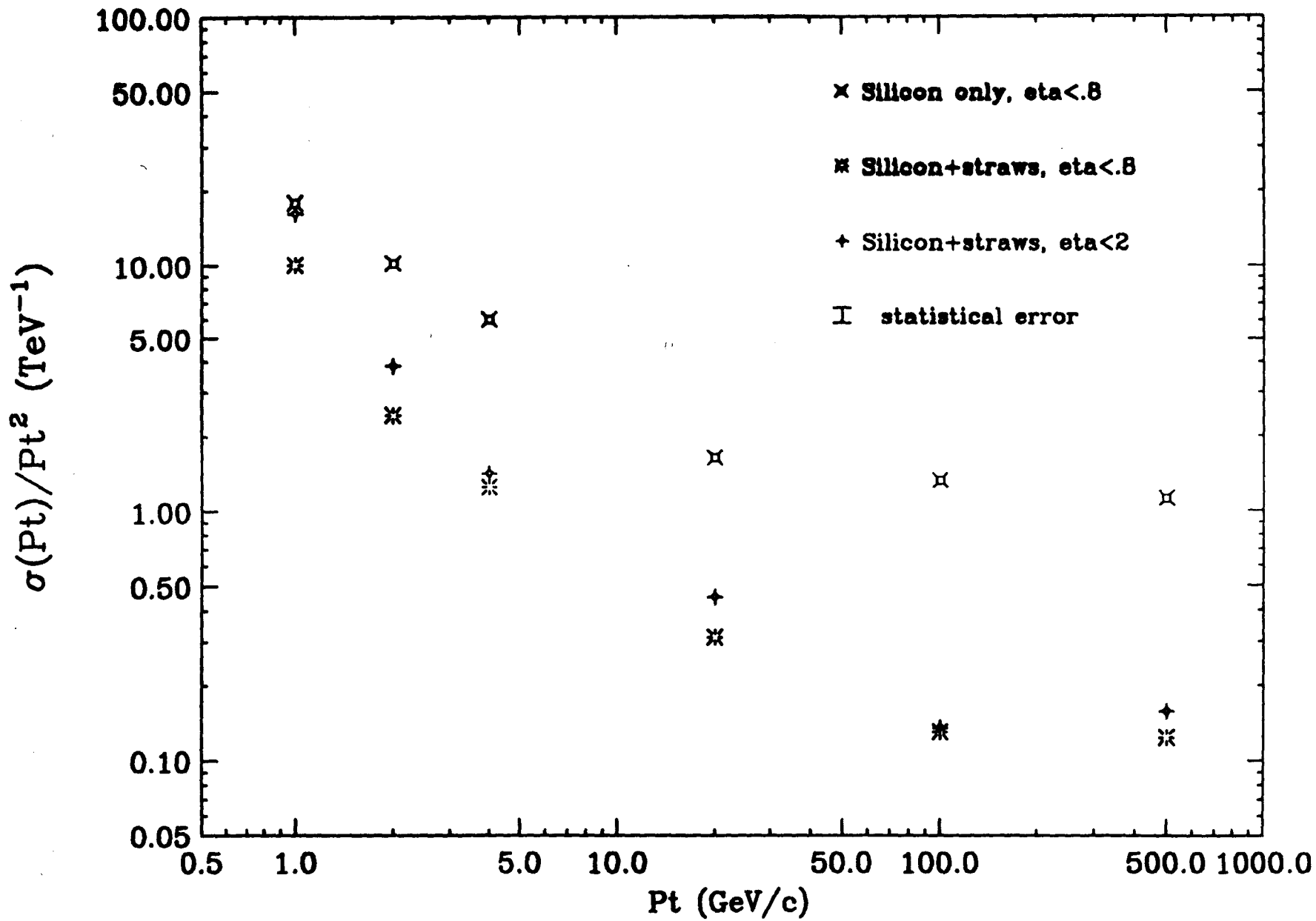
Top: Preliminary work done on $\mu$'s from top decay

Segment finding: Code written to construct segments with the split fiber layer design. Should be straight-forward to incorporate into segment linking algorithms

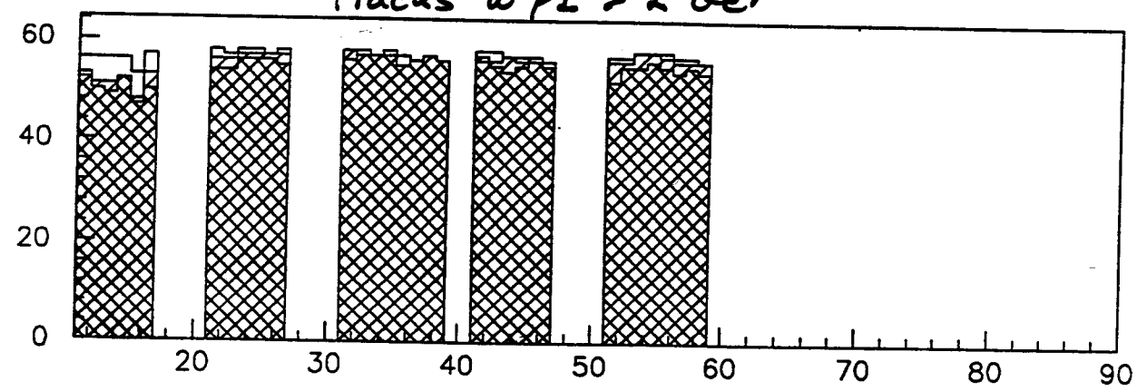
- ITD

see ITD presentation

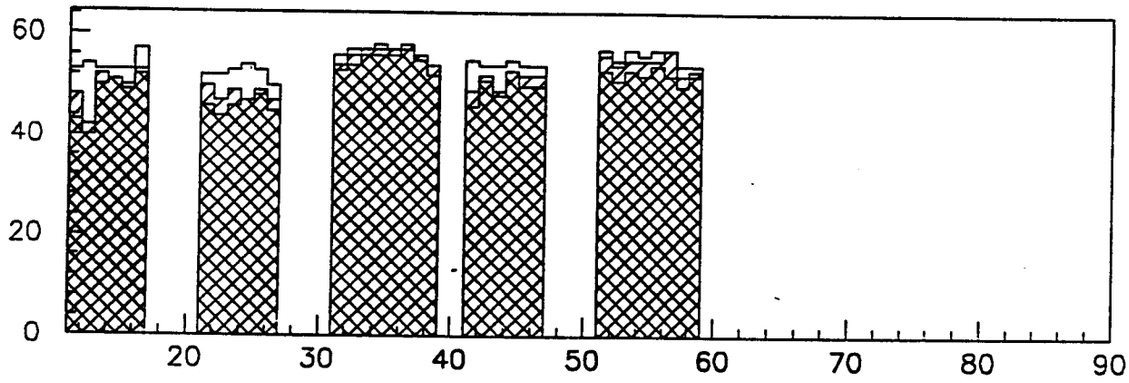

Silicon only, eta<.8
Silicon+straws, eta<.8
statistical error
σ(b₀) (microns)
200
100
50
20
10
5
0.5
1.0
5.0
10.0
50.0
100.0
500.0
1000.0
Pt (GeV/c)


100.00
50.00
10.00
5.00
1.00
0.50
0.10
0.05
σ(Pt)/Pt² (TeV⁻¹)
0.5
1.0
5.0
10.0
50.0
100.0
500.0
1000.0
Pt (GeV/c)
Silicon only, eta<.8
Silicon+straws, eta<.8
Silicon+straws, eta<2
statistical error

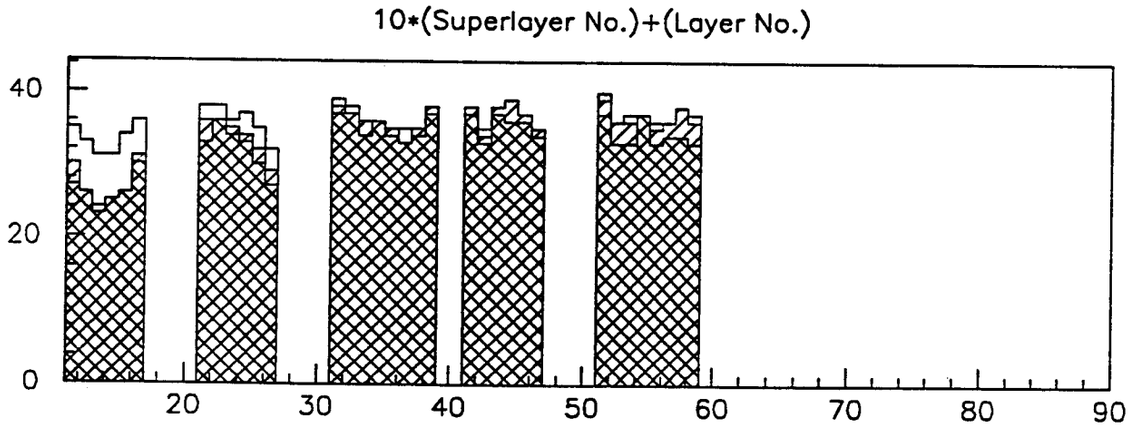
Straw segment finding efficiency
Tracks w $p_\perp > 2$ GeV



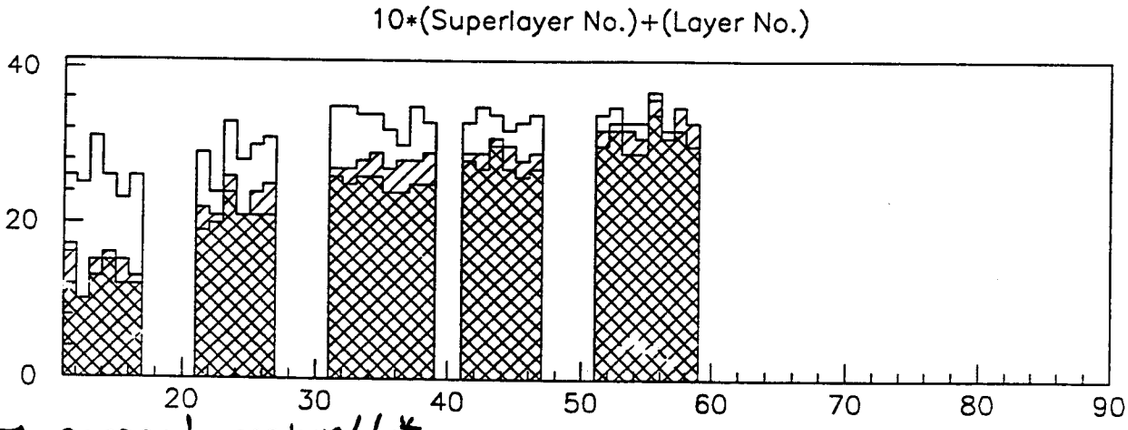

$H \to 4\mu$
(10 evts)




+ bg
$\mathcal{L} = 10^{33}$
(10 evts)



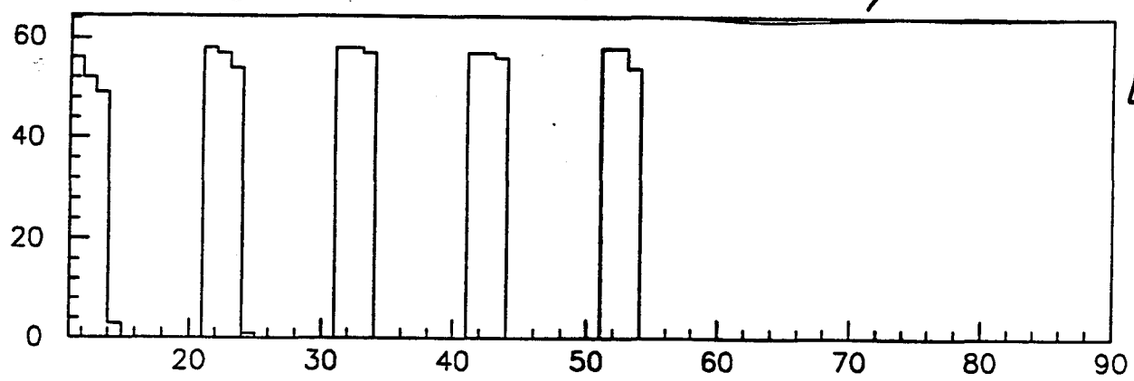

$3 \times 10^{33}$
(7 evts)




$6 \times 10^{33}$
(7 evts)

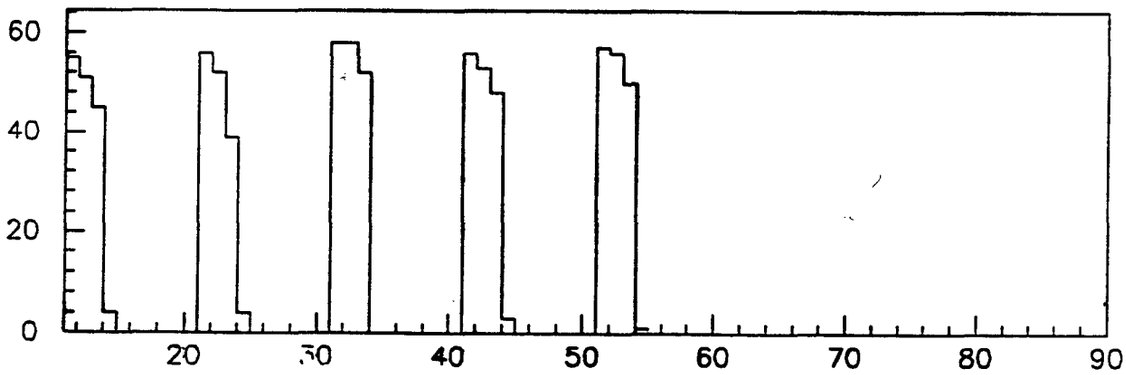
properly assigned hit
" w correct ambiguity

Straw segment finding efficiency



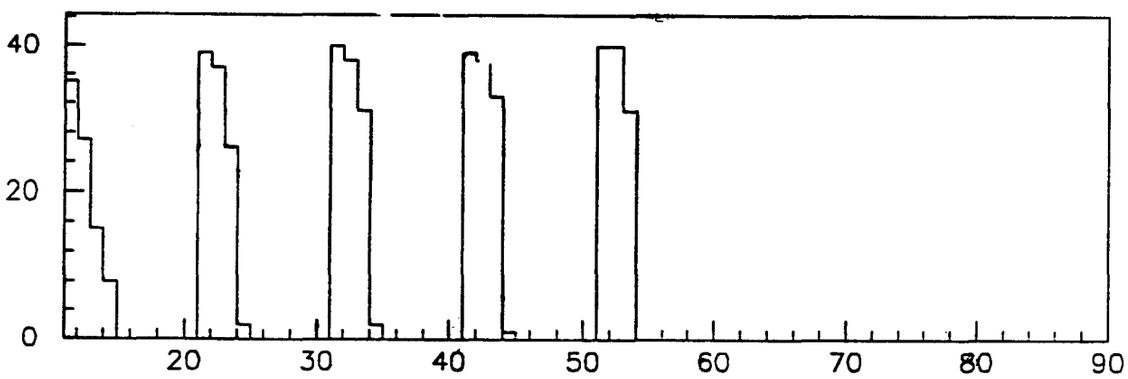

$H \to 4\mu$

Xings, segmts w .le.1,0,.gt.1 wrong hit vs slyr



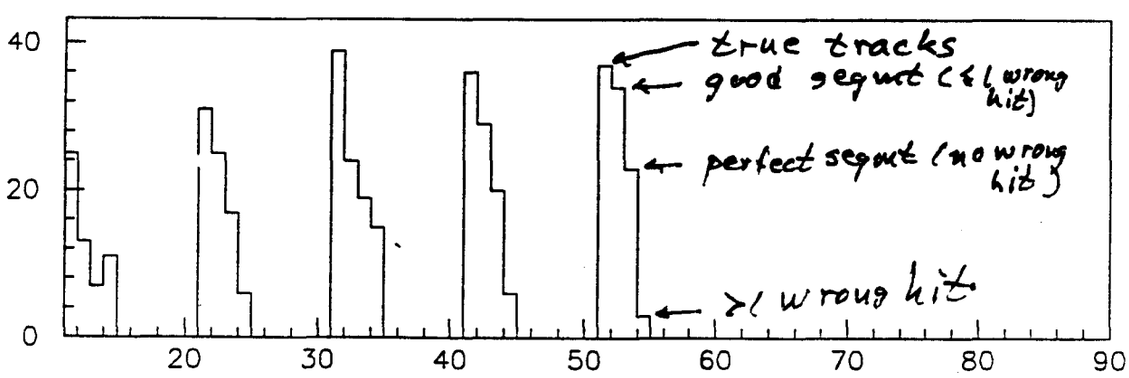

+bg
$\mathcal{L} = 10^{33}$

Xings, segmts w .le.1,0,.gt.1 wrong hit vs slyr




$3 \times 10^{33}$

Xings, segmts w .le.1,0,.gt.1 wrong hit vs slyr




$6 \times 10^{33}$

Xings, segmts w .le.1,0,.gt.1 wrong hit vs slyr

KO

Table 1. Summary of efficiencies and number of fake tracks for $H^0 \rightarrow e^+e^-\mu^+\mu^-$ events for various configurations.

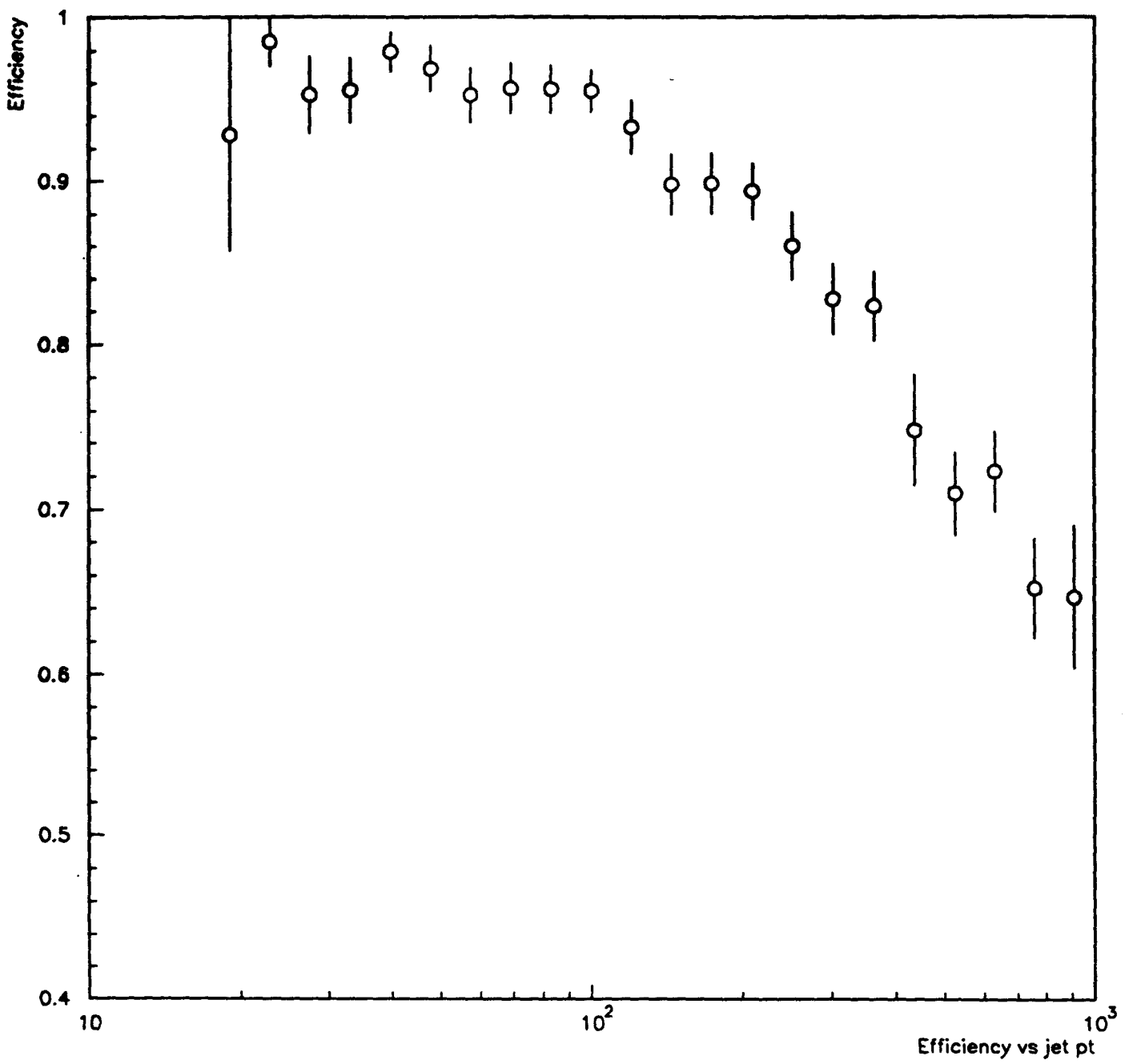
| Luminosity/ Configuration | Fakes per event with $P_\perp > 5$GeV | Track Efficiency $P_\perp > 20$GeV | Electron E/p Efficiency $0.7 < E/p < 1.4$ | $M_Z$ cut Efficiency $e$ | $M_Z$ cut Efficiency $\mu$ | Higgs Reconstruction Efficiency |
|---|---|---|---|---|---|---|
| $1 \times 10^{33}$ ST 8 layer + straw | $0.03 \pm 0.01$ | 0.991 | $0.94 \pm 0.01$ | $0.81 \pm 0.03$ | $0.98 \pm 0.01$ | $0.74 \pm 0.04$ |
| $1 \times 10^{33}$ ST 6 layer + straw | $0.02 \pm 0.01$ | 0.965 | $0.93 \pm 0.01$ | $0.78 \pm 0.03$ | $0.98 \pm 0.01$ | $0.64 \pm 0.04$ |
| $3 \times 10^{33}$ ST 8 layer + straw | $0.04 \pm 0.02$ | 0.989 | $0.94 \pm 0.01$ | $0.81 \pm 0.04$ | $0.95 \pm 0.02$ | $0.74 \pm 0.04$ |

Goal: ~.1

Efficiency - Si + Straw

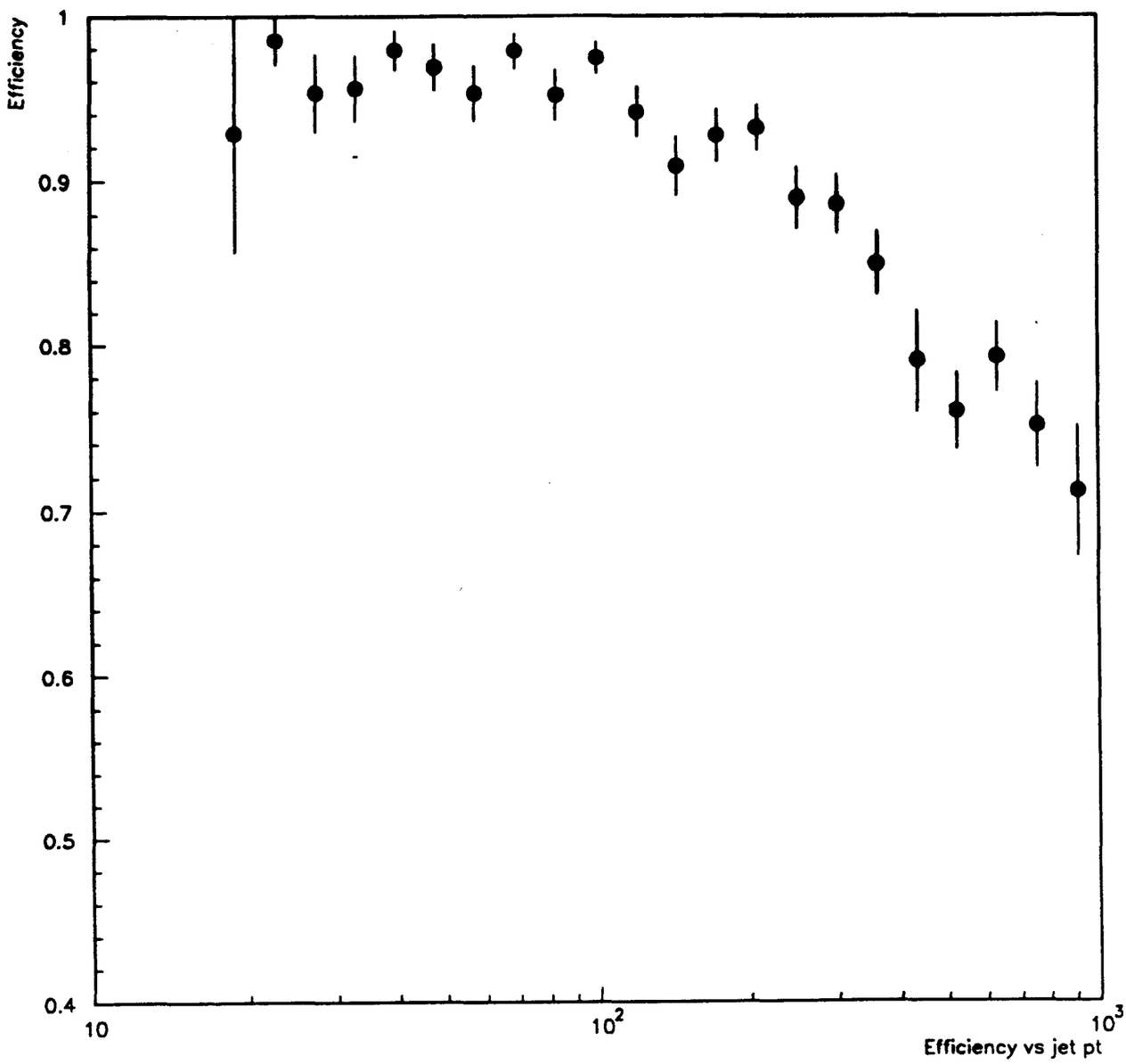
$P_T > 4$

$|\eta| < 1.5$



Efficiency Si + 4-layer Straw, TS alg.

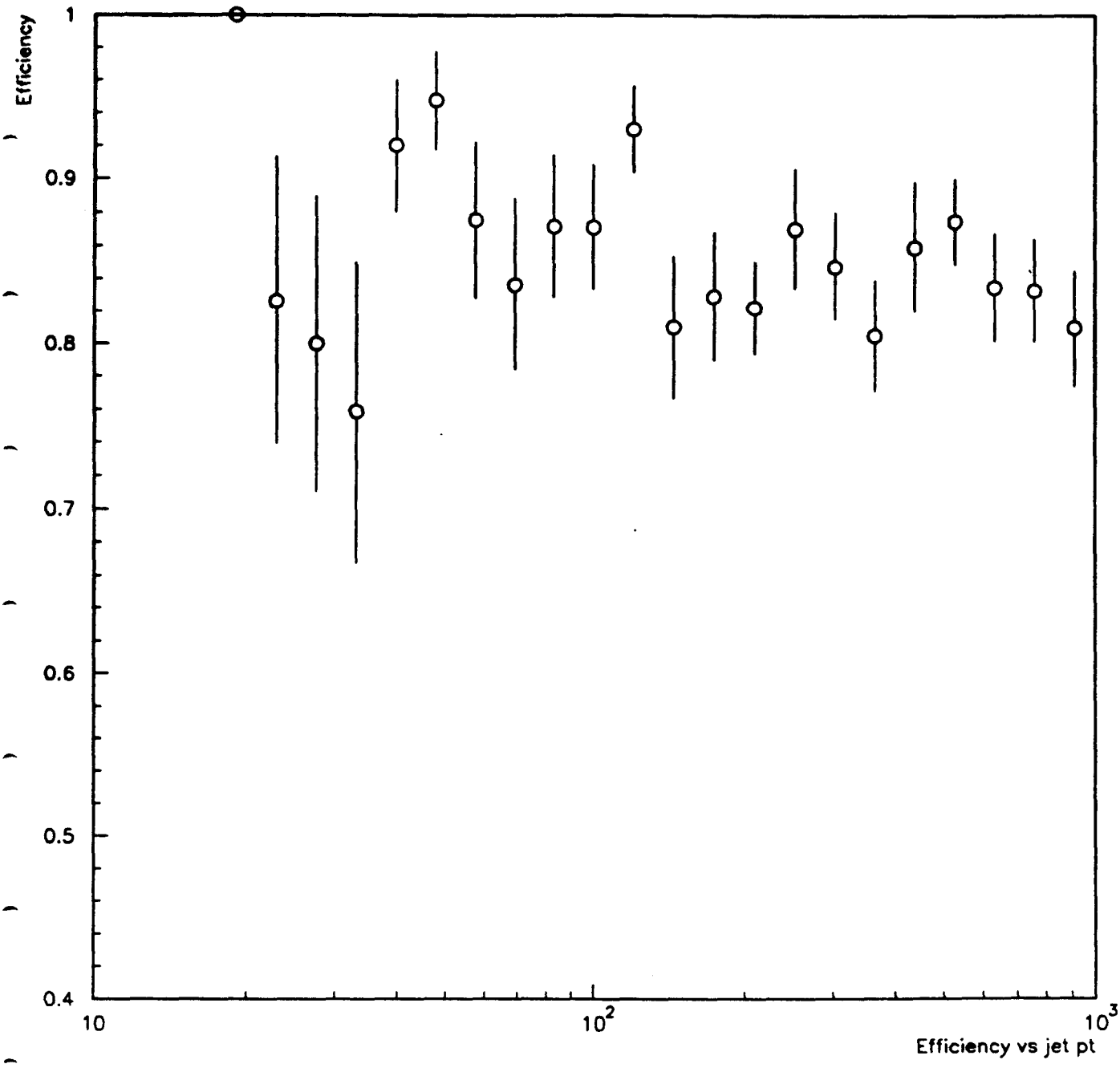
(same cuts)



Si + 5-layer Fiber TR algorithm

$P_T > 5$

$|\eta| < .7$



A

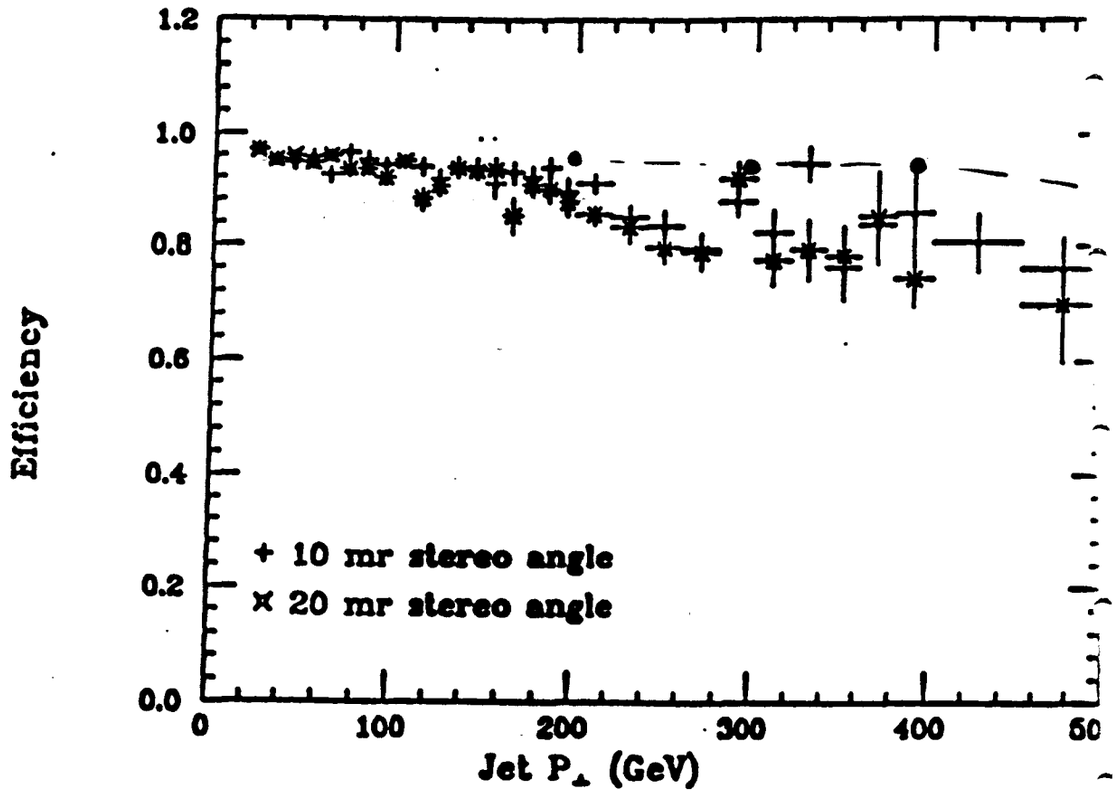



**Fig. 11.** Efficiency for reconstructing tracks with $P_\perp > 1$ GeV inside jets as a f of the jet transverse momentum, for two values of the stereo angle.

- ~ 9 Layers on average.
- ~ 7 " " "

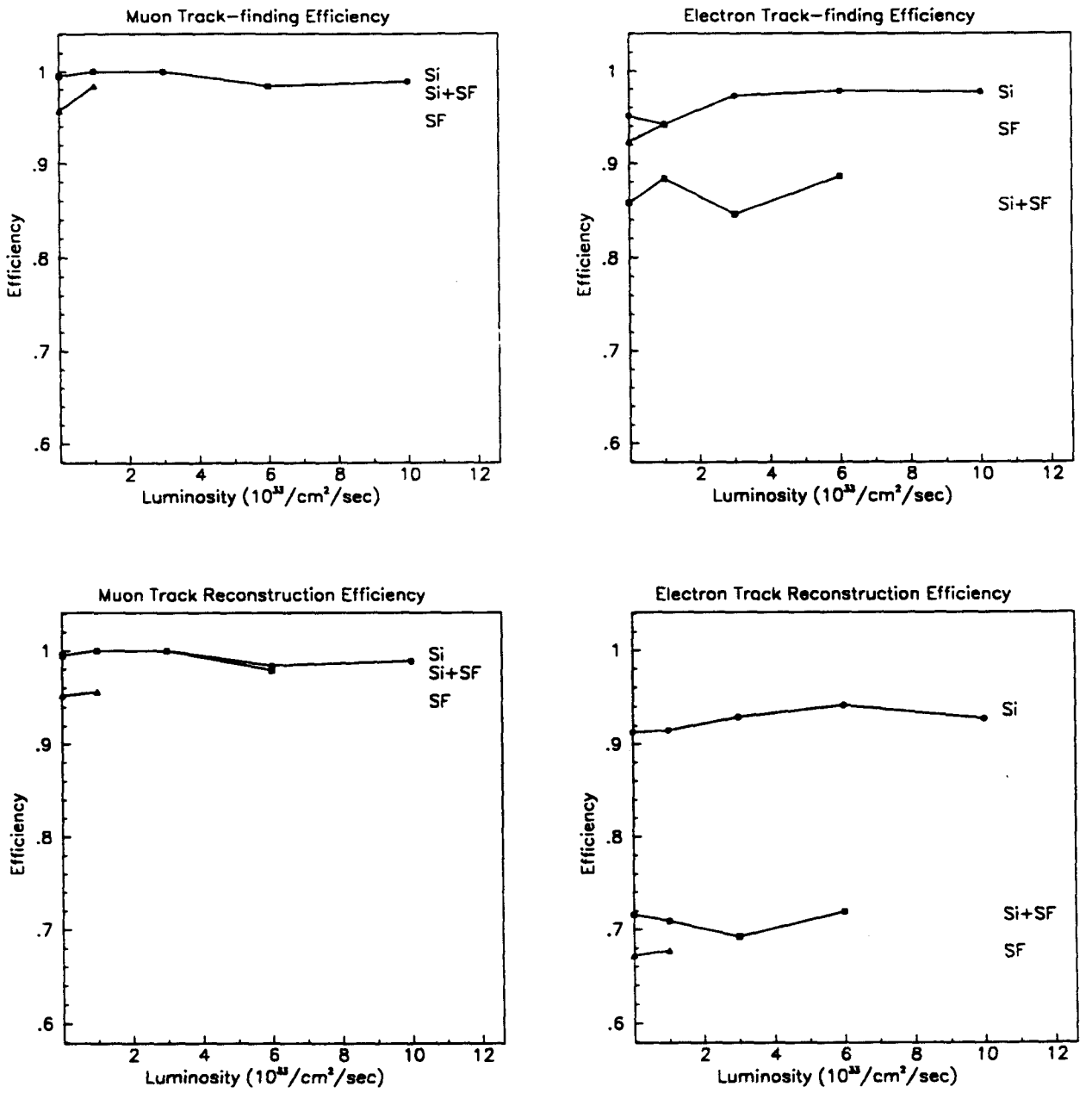



**Figure 5. Track-finding and reconstruction efficiencies for muons and electrons. Each plot shows results at all luminosities for silicon alone (Si) and silicon extrapolated into the fibers (Si+SF). Fibers alone are shown for low luminosity.**

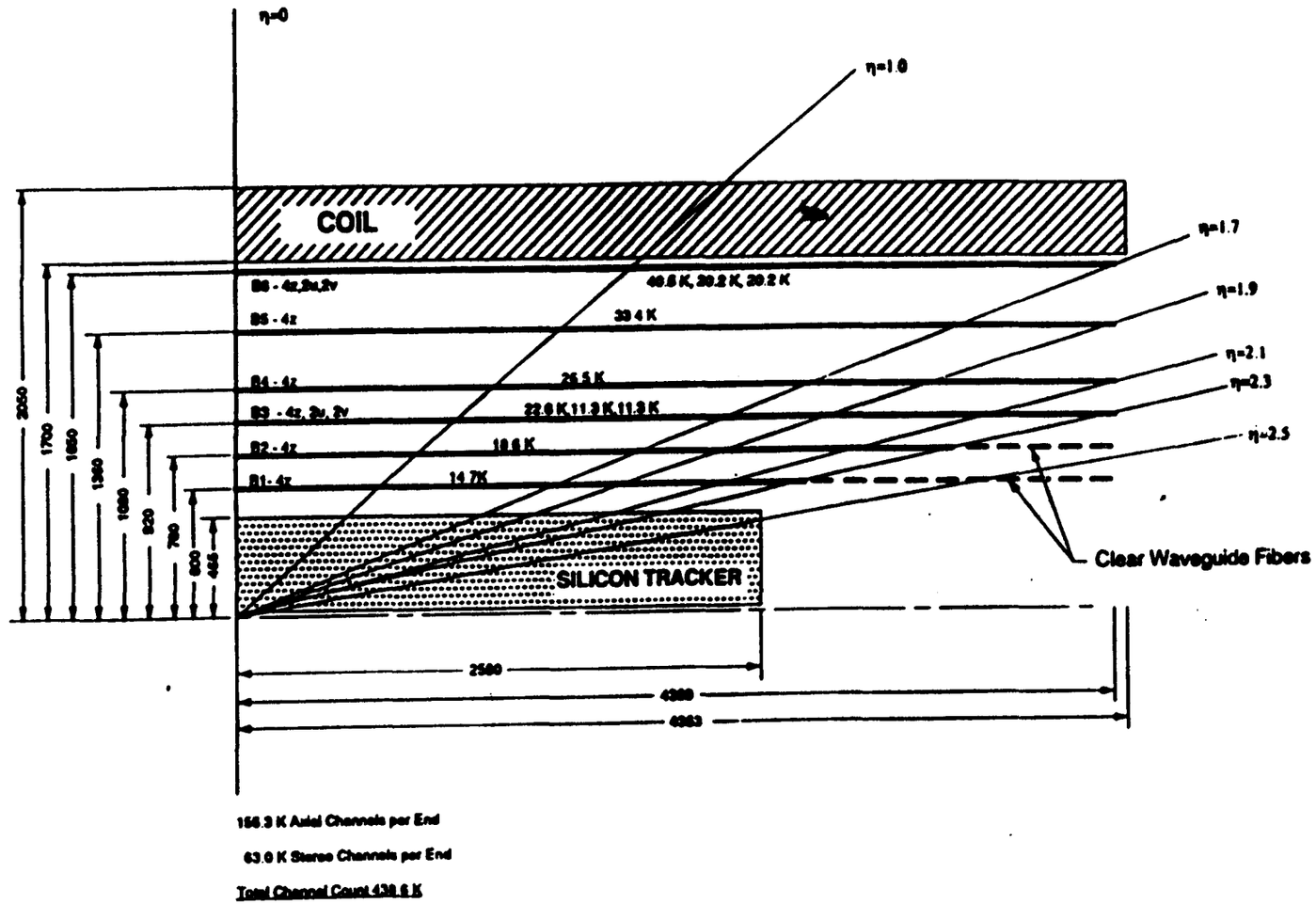
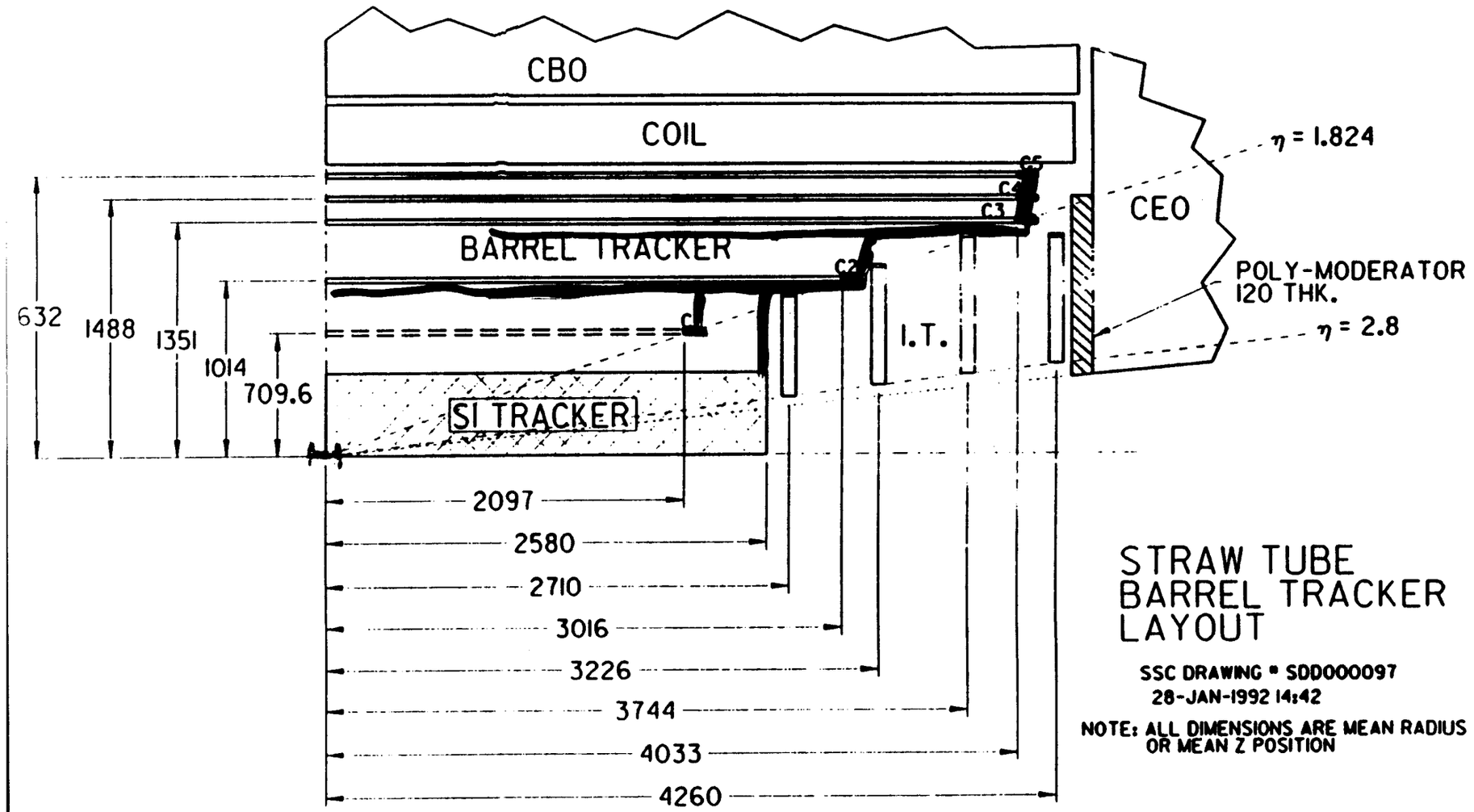



Figure 3.1-1. Schematic of the central tracker exhibiting the fiber superlayers.




STRAW TUBE
BARREL TRACKER
LAYOUT

SSC DRAWING # SDD000097
28-JAN-1992 14:42

NOTE: ALL DIMENSIONS ARE MEAN RADIUS
OR MEAN Z POSITION

H.C

# Tracking Requirements

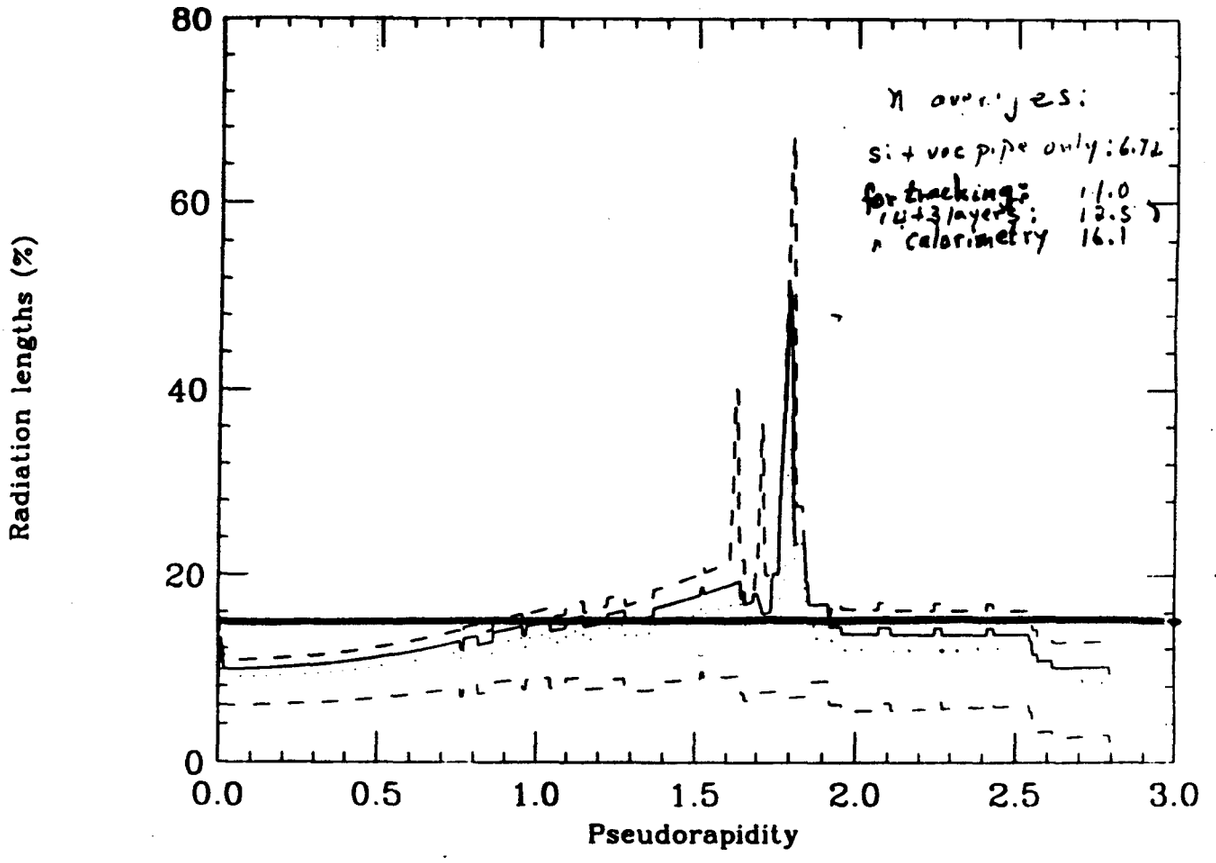
| Requirement | Si + Straw + ITD | Si + Fiber |
|---|---|---|
| (1) Acceptance $\|\eta\| < 2.5$ | $\|\eta\| < 2.8$ | $\|\eta\| < 2.3$ |
| Resolution $\sigma_{p_T}/p_T^2$ | | |
| $< 20\%\,\mathrm{TeV}^{-1}$ ($\|\eta\| < 1.8$) | $15\%\,\mathrm{TeV}^{-1}$ ($\eta < 1.6$) | $17\%\,\mathrm{TeV}^{-1}$ ? ($\eta < 1.8$) |
| $\rightarrow 100\%\,\mathrm{TeV}^{-1}$ ($\|\eta\| \rightarrow 2.5$) | $40\%\,\mathrm{TeV}^{-1}$ ($\eta < 2.5$) | $< 75\%\,\mathrm{TeV}^{-1}$ ($\eta < 2.3$) |
| | $200\%\,\mathrm{TeV}^{-1}$ ($\eta < 2.8$) | |
| (2) Reconstruction efficiency | | |
| $\geq 97\%$ (isolated, $p_T > 10$) | 99% | 99% (300GeV Hig |
| $\leq 0.1$ fake/trigger | | |
| @ $10^{33}\,\mathrm{cm}^{-1}\mathrm{s}^{-1}$ | | |
| (3) Reconstruction efficiency | no loss @ $3\times10^{33}$ | 99% @ $6\times10^{33}$ |
| $\geq 90\%$ @ $10^{34}$ | | |
| (4) Reconstruction efficiency in jet | ~ 97% | ~ 89% |
| $\geq 80\%$ ($p_T > 5\,\mathrm{GeV}$) | | |
| 10% fake in jet (100GeV) | | |
| (5) Material 15% $X_0$ | 15% averaged over | 12.5% @ 90° |
| average over $\|\eta\| \leq 2.5$ | $\eta < 2.5$ | 7.7% @ 90° trigg |
| 7% $X_0$ inside 50cm | | |

( Requirements )

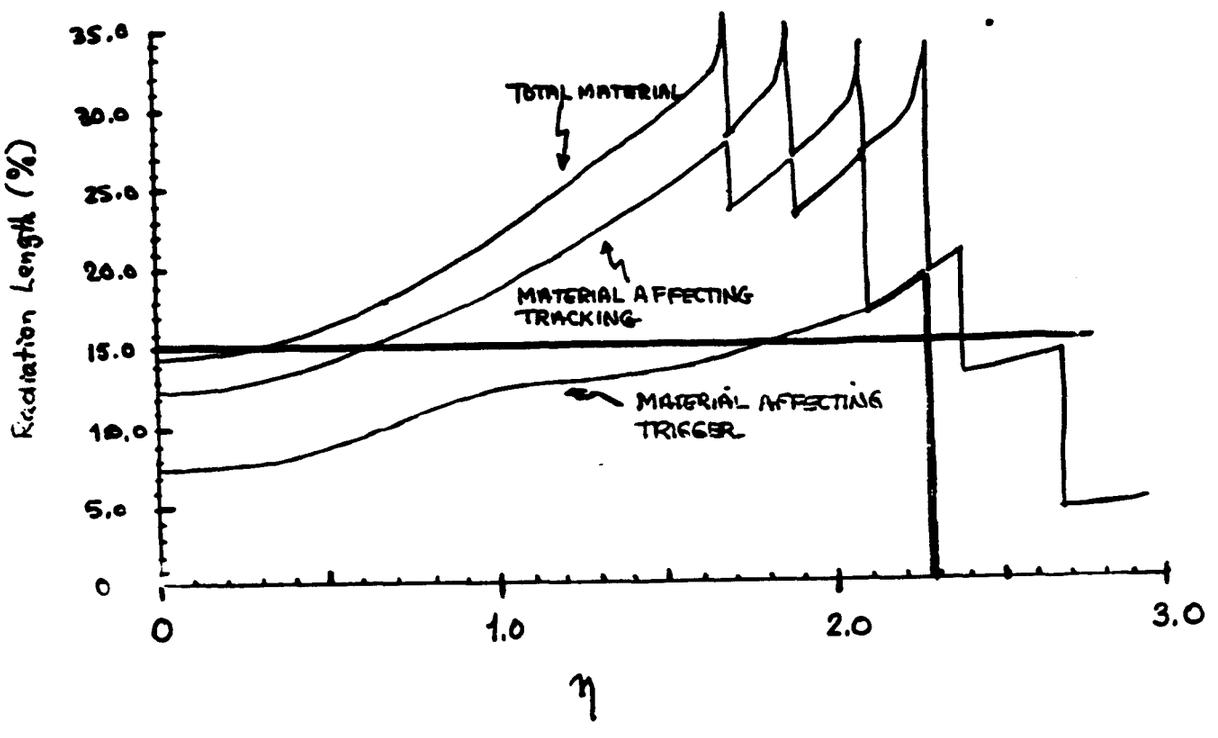
| | Si + Straw + ITD | Si + Fiber |
|---|---|---|
| (6) Position res. at SMX<br>$\sigma_{r\phi} \leq 5$mm<br>$\sigma_z \leq 2$mm | ? 0.14 mm ($\eta$<2.8)<br>[redacted]<br>2.5 mm | 1.2 mm<br>1.1 mm |
| (7) Position resolution and alignment to $\mu$<br>$\sigma_{r\phi} \leq 100\,\mu$m, $\sigma_z \leq 2$mm | need work | need work |
| (8) jet charge multiplicity<br>< ±15%<br>($p_T^{jet}$ = 500 GeV) | ~ 80%<br>($p_T$ > 4 GeV) | ~85%<br>($p_T$ > 5 GeV) |
| (9) B tagging eff. ≥ 50%<br>with ≥ 90% purity<br>$\sigma_b \leq 20\,\mu$m | ~30%<br>$\sigma_b$ = 13 $\mu$m | ~30%<br>$\sigma_b$ = 13 $\mu$m |
| (10) $\sigma_z^{vertex}$ < 2mm | $\sigma_z$ = 0.8 mm | $\sigma_z$ = 0.8 mm |
| (11) 1st level trigger<br>$\sigma_{p_T}/p_T^2 \leq 1000\%$ TeV$^{-1}$ | 10 TeV$^{-1}$ (1.8<$\eta$<2.8) | 6 TeV$^{-1}$ ($\eta$<2.3) |
| (12) 1st level trigger<br>eff. ≥ 98%<br>≤ 5% false trigger | 97%<br>false < 1/500/64<br>(2/3 s.l. Trigger) | > 99%<br>false 0.01/64/crossing |

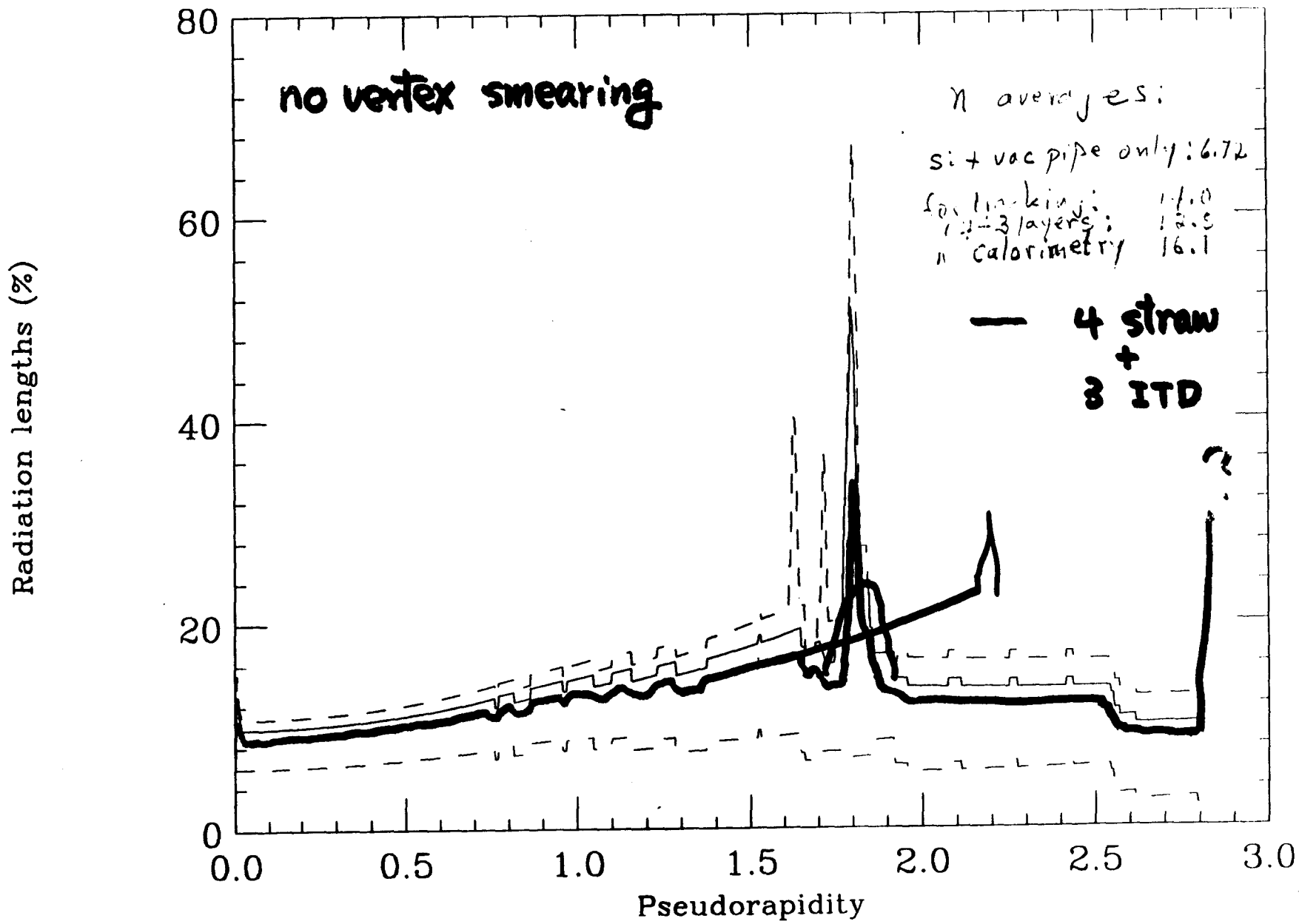
( Requirements )

| | Si + Straw + ITD | Si + Fiber |
|---|---|---|
| (13) 2nd level Trigger $\sigma_{p_T}/p_T^2 = 5\ \mathrm{TeV}^{-1}$ | TBD (Si) | TBD (Si) |
| (14) Discovery potential leptons in jets | | > 50% ? |
| (15) Survivability @ $10^{23}$ | 0.21 C/cm @ 70 cm 10 yr<br>Si [ < 10 yr (1st layer)<br>> 10 yr (other layer) ] | > 50 yrs (bulk test) |
| (16) Natural path for upgrading with survivability @ $10^{34}$ | < 1 C/cm @ 160 cm 10 yr<br>upgrade inner superlayer with fibers | > 5 yrs (bulk test) |




SILICON + SCINTILLATING FIBER TRACKERS
1-31-92




no vertex smearing
η averages:
si + vac pipe only: 6.72
for tracking: 11.0
" 1-3 layers: 12.5
" calorimetry 16.1
4 straw
+
3 ITD
Radiation lengths (%)
Pseudorapidity
0
20
40
60
80
0.0
0.5
1.0
1.5
2.0
2.5
3.0

PRESENTATION BY:

PAUL MANTSCH

Mantsch
Moncam

# CENTRAL CALORIMETER PARAMETERS FOR TECHNICAL PROPOSAL

Parameters of 12/9/92 have not changed significantly (some inconsistencies corrected, some remain)

Design issues under consideration:

- Removable endplug for replacement of radiation damaged tiles.
- Revised support system.
- Descoped source calibration system.
- HAD1 with upgrade path from 0.1 x 0.1 to 0.05 x 0.05.

# CALORIMETER COST FOR TECHNICAL PROPOSAL

Cost refinement activities

- Update cost for FY 1992 labor rates ↑
- Phototube assembly ↓
- HAD1 upgrade path costs ↑
- Endplug costs ↑
- Calibration descope cost adjustment ↓
- Reduction in scintillator cost ↓
- Correction of errors ↓
- Prototype Estimate ↑

| SDC | 2/1/92 | E. Larson | FNAL | D. Scherbarth | WSTC | | | |
|---|---|---|---|---|---|---|---|---|
| CALORIMETER | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Comparison of | | | | | | | | |
| Case 31 & 32 | | | | | | | | |
| | Case 31 | All Units K$ | | | Case 32 | | | |
| | Barrel | End Cap | Totals | | Barrel | End Cap | End Plugs | Totals |
| | | | | | | | | |
| Components | 50,148 | 31,268 | 81,416 | Components | 49,798 | 25,544 | 5,081 | 80,423 |
| Module Assy | 4,946 | 3,277 | 8,223 | Module Assy | 6,984 | 3,703 | 1,034 | 11,721 |
| Support Structure | 4,844 | 3,980 | 8,824 | Support Structure | 4,208 | 3,303 | 500 | 8,011 |
| Tooling | 10,675 | 2,812 | 13,487 | Tooling | 11,143 | 2,626 | 500 | 14,269 |
| Facility | 4,268 | 426 | 4,694 | Facility | 4,677 | 442 | 400 | 5,519 |
| Surface Assy | 2,326 | 1,520 | 3,846 | Surface Assy | 2,216 | 1,809 | 500 | 4,525 |
| Project Mgmt | 16,911 | 4,460 | 21,371 | Project Mgmt | 13,381 | 4,763 | 1,500 | 19,644 |
| R&D Prototype | 1,340 | 2,873 | 4,213 | R&D Prototype | 3,589 | 1,500 | 500 | 5,589 |
| Installation | 404 | 650 | 1,054 | Installation | 414 | 650 | 0 | 1,064 |
| Test | 52 | 49 | 101 | Test | 54 | 49 | 0 | 103 |
| | | | | | | | | |
| | | | | | | | | |
| Totals | $95,914 | $51,315 | $147,229 | | $96,464 | $44,389 | $10,015 | $150,868 |

E. Larson 2/1/92

## POTENTIAL CHANGES IN FUTURE CASES

Reduce piece part cost on PMT's.

Reduce Granularity in Hac 1 to 0.1 x 0.1 reducing tiles from 691 K Tiles to 542 K tiles, Est savings $ 3 Million.

Refine estimate on absorber from vendors, impact unknown.

Refined Shower Max Tile design and estimate.

Refined End Plug design and estimate.

PRESENTATION BY:

DICK HUBBARD

Hubbard
Moran

# SM Granularity

## Baseline design

Strip width = $\frac{1}{2}$ × Moliere radius

8 strips / tower $(2^n)$

$\pi^0/\gamma$ separation

2 peaks $E_T \leq 15$ GeV

Shower shape $E_T \leq 30$ GeV

## Improvements ?

Narrow core { Kevin $t\bar{t}H \to \gamma\gamma$; Bonamy GEANT; Melèse PS @ $6X_0$

1) Remove bulkheads $\Delta \approx \phi$

$\varphi$ strips $\frac{.05}{16} \times .10$ gang by 4

2) Double $\varphi$ strip count gang by 8 Problem

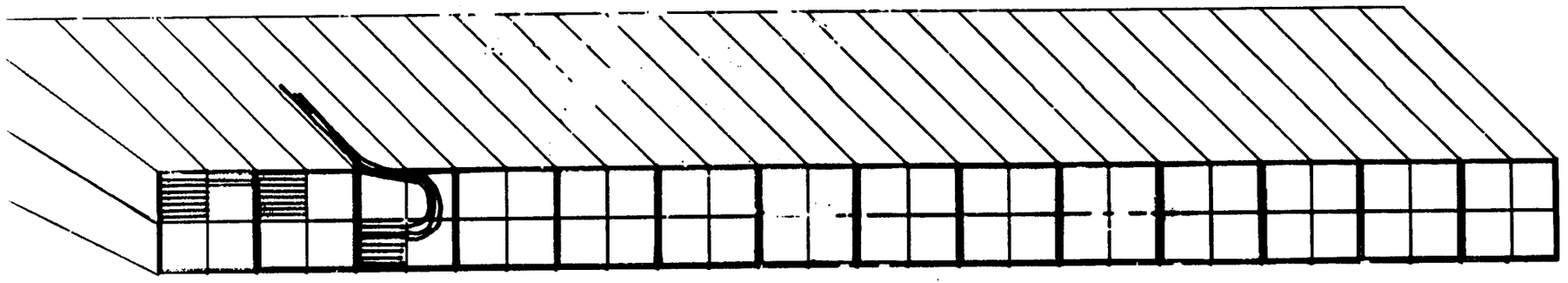
a) Drop $\eta$ strips Pixels × 1/32

b) Increase strip count $\Delta \approx 3.5$ M$\not{\xi}$

OR 3) Instrument massless Gap $\Delta \approx$ ? M$\not{\xi}$

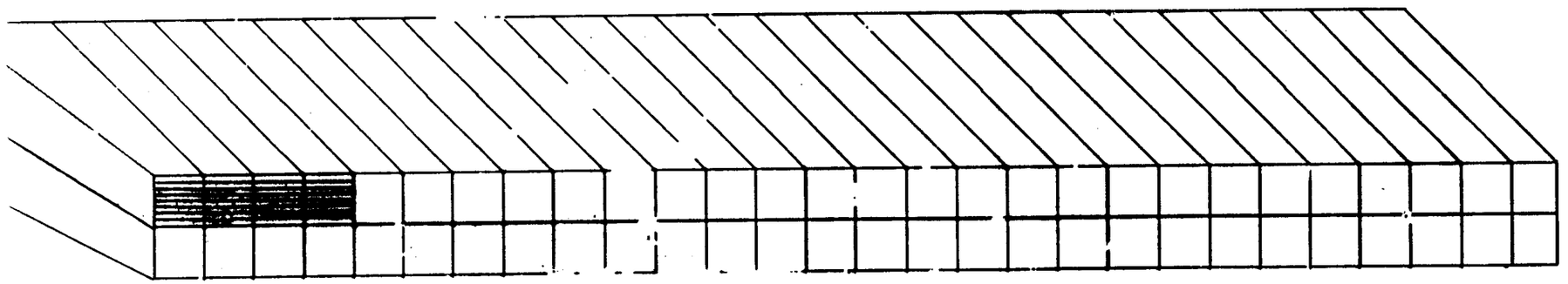
$\Rightarrow$ statistical $\pi^0/\gamma$ separation.

# Shower Max $\varphi$ Strips - Barrel



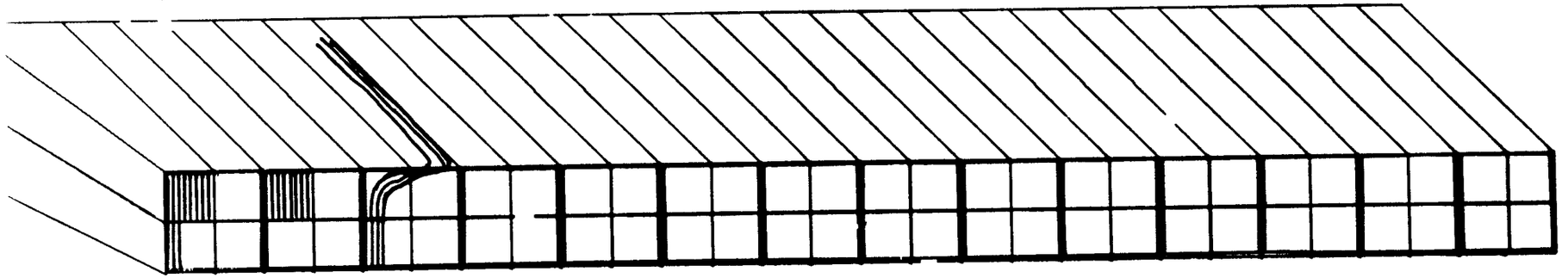
Physical strips $\frac{.05}{8} \times .05$ limited by bulkheads in cast Pb

Electronic channels $\frac{.05}{8} \times .20 \xrightarrow{\text{Upgrade}} \frac{.05}{8} \times .10$



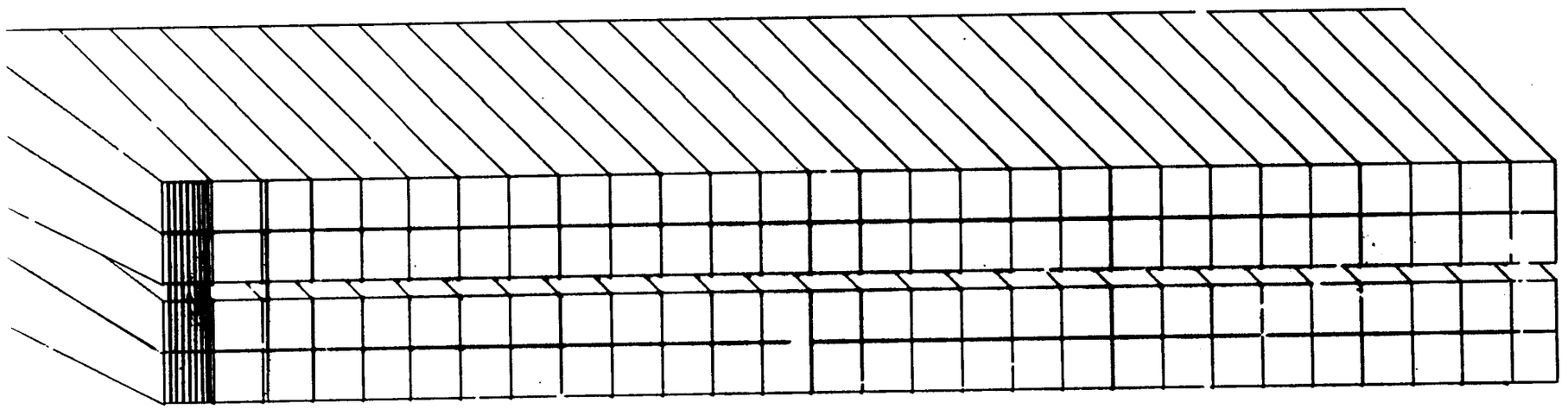
64-channel MCPMT pixel $2 \times 2$ mm$^2$ 4 fibers per pixel

# Shower Max η Strips - Barrel



Physical strips $\frac{.05}{8} \times .05$ limited by wedges

Electronic channels $\frac{.05}{8} \times .20$ $\xrightarrow{\text{upgrade}}$ $\frac{.05}{8} \times .10$

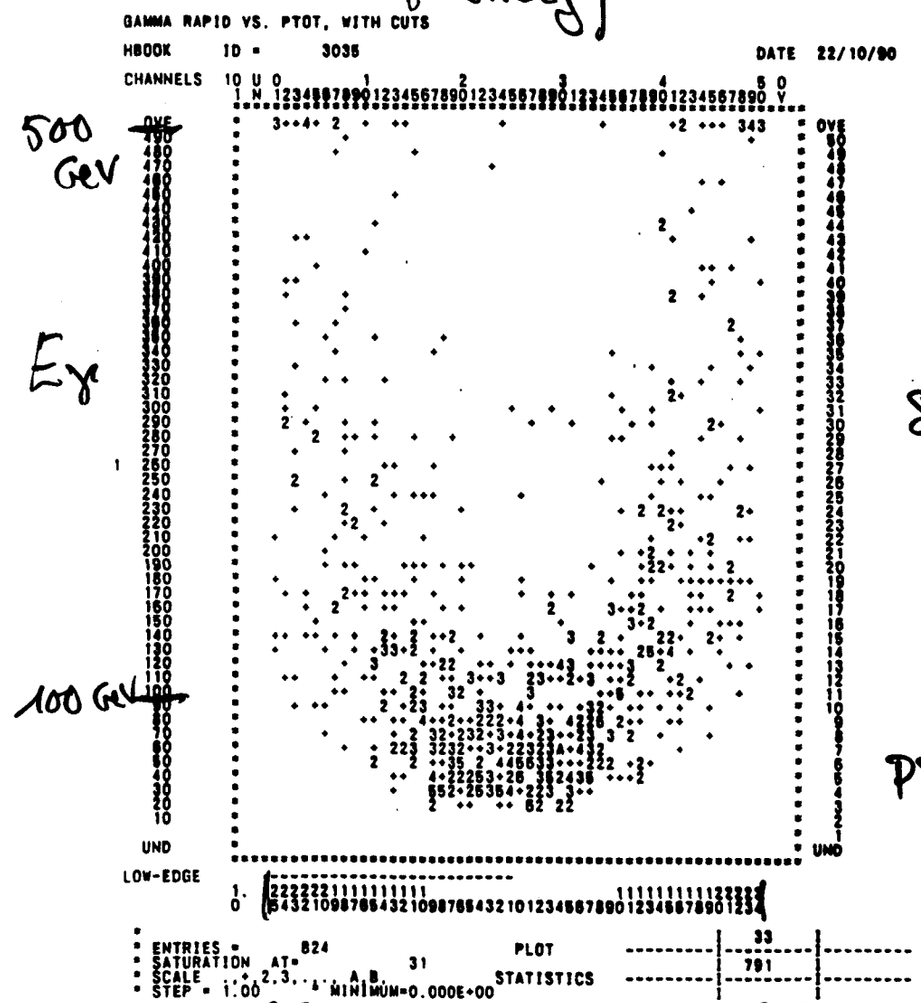


| | | | |
|---|---|---|---|
| Barrel total strips | 114688 | | |
| Barrel total channels | 28672 | $\xrightarrow{\text{upgrade}}$ | 57344 |
| Barrel total PMT's | 448 | $\longrightarrow$ | 896 |

# $WH \to l\nu\ \gamma\gamma'$

$M_H = 120$ GeV

$\gamma$ energy

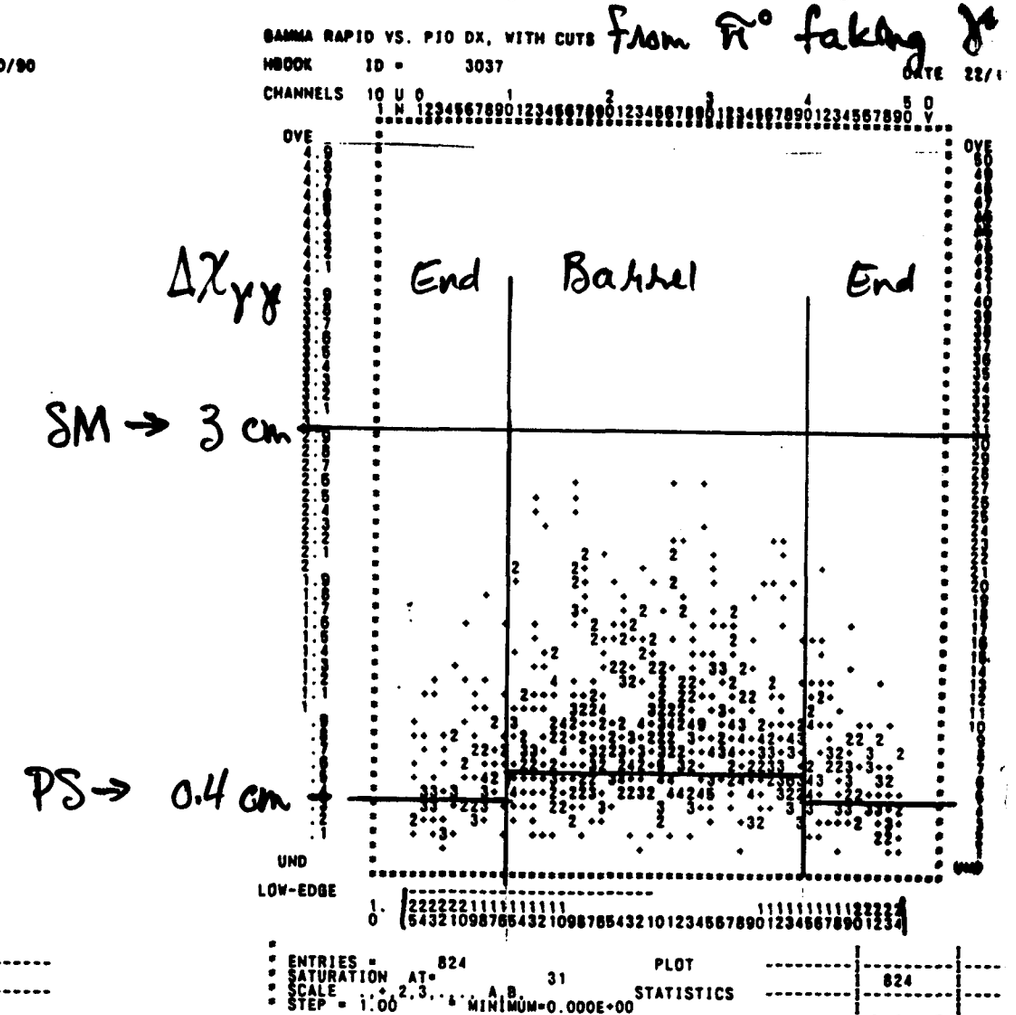



$\eta \to$

WH
$\hookrightarrow \gamma\gamma$

$M_H = 120$

Distance Between $\gamma$'s from $\pi^0$ faking $\gamma$




$\eta \to$

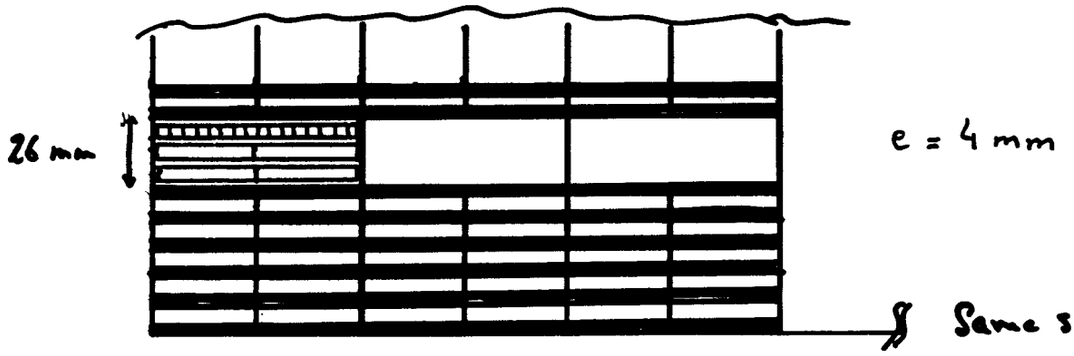
$\Rightarrow$ SM useless here

PS $\pi^0 \times$ [redacted] 2/3

# BARREL

* = 64 wedges of 2 × 28 towers. in ½-barrel

* Cast lead structure.




$\Delta E(\eta)/\Delta E(\varphi)$

Same slot .90 ± .16

Different slots .88 ± .27

⇒ choose same slot

The SMD tiles are placed:

- after lead plate # 7 for $0.0 < \eta < 0.6$ (12 towers)
- # 6 $0.6 < \eta < 0.8$ (4 towers)
- # 5 $0.8 < \eta < 1.0$ (4 towers)
- # 4 $1.0 < \eta < 1.2$ (4 towers)
- # 3 $1.2 < \eta < 1.4$ (4 towers)

SM @ 10 GeV ⟷ depth = $6.1\ X_0$ at $\eta = 0$
$7.2\ X_0$ at $\eta = 1.4$

(with the coil).

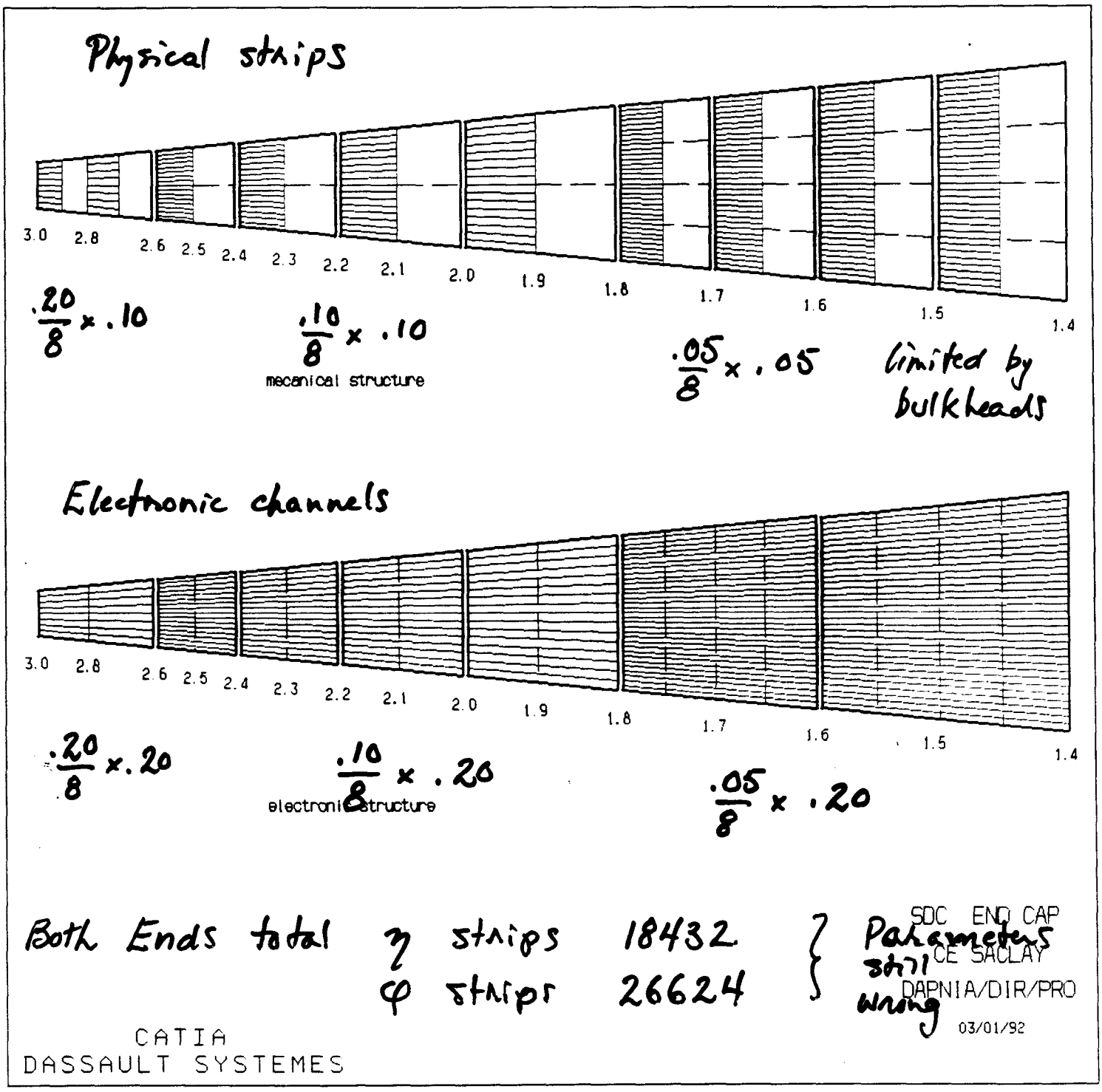
⇒ limited dynamic range

⇒ 12 bits O.K.

* 1 tile = 8 strips

* 1 elementary module = 4 × 2 tiles in a box

# SM Ends : φ Strips

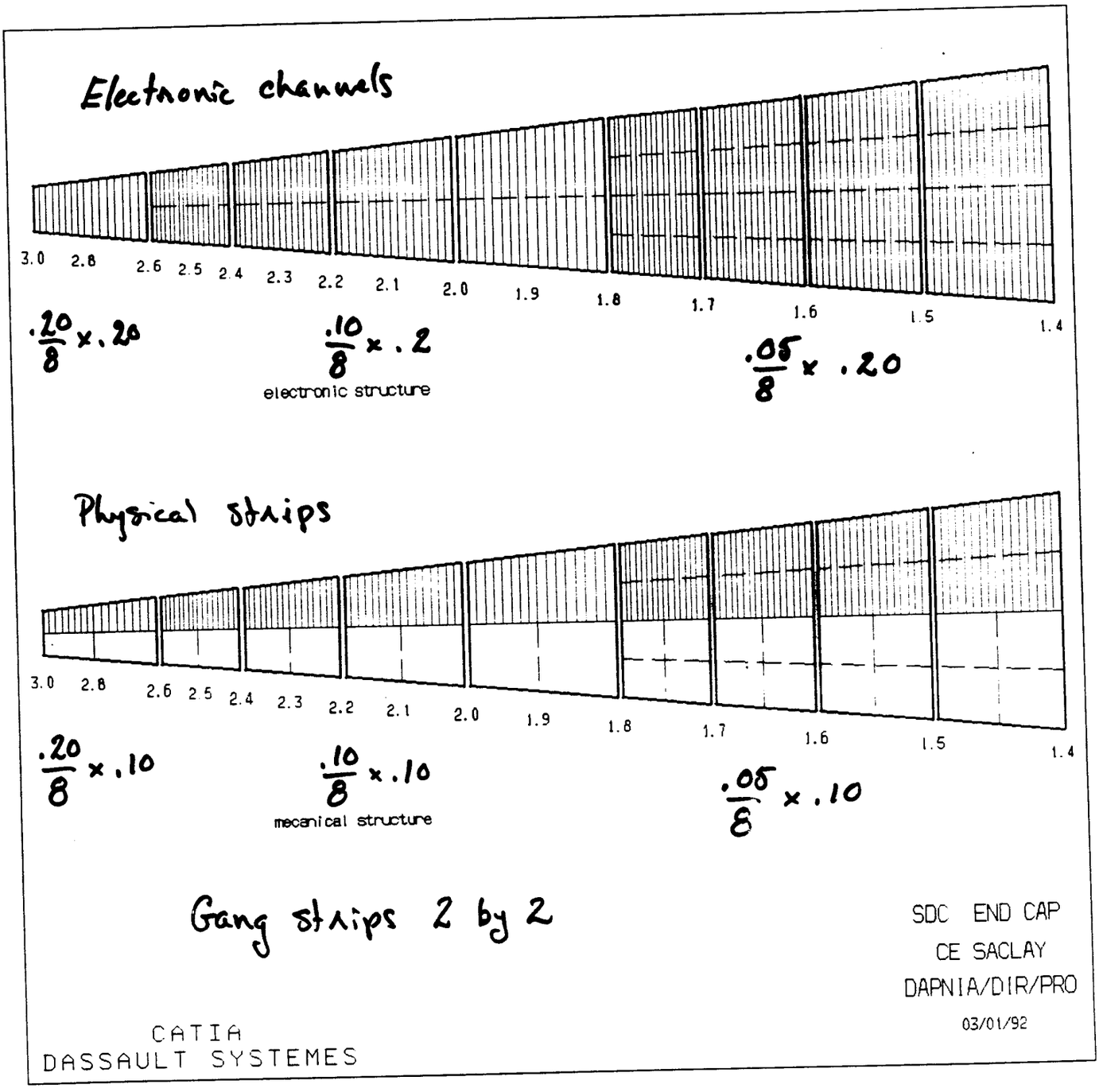



Both Ends total channels 18432 → 36864

total PMT's 320 → 576

upgrade

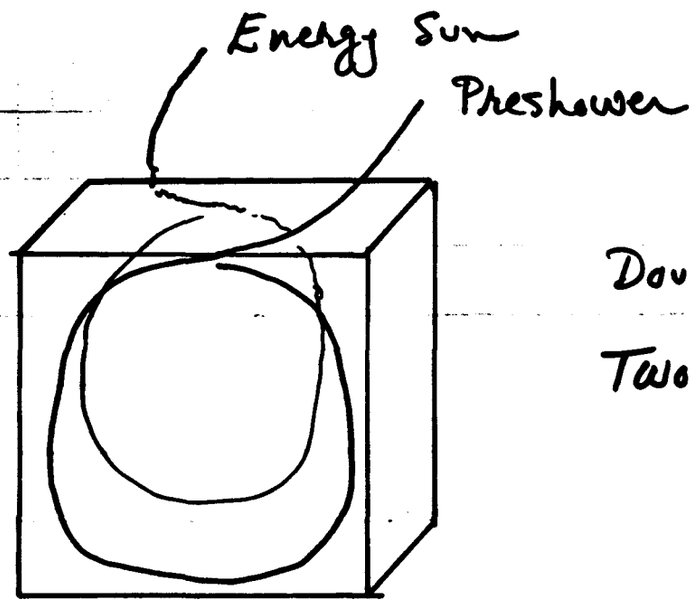
# SM Ends : η Strips




Overlap tower $1.3 < \eta < 1.4$

IGNORED BY SHOWER MAX !

# Massless Gap




Double thickness

Two fibers

Start-up: 1 fiber → energy sum

⇒ Energy correction

Upgrade: 2nd fiber → MCPMT (64-channel)

NOW! ⇒ Preshower

Barrel: 128 wedges × 56 towers

⇒ 128 MCPMT's

Both ends: 64 wedges × 50 towers

⇒ 64 MCPMT's

# Calibration

SM Problems:

4 strips → single photodector cell

Non-uniformity can't be corrected

Source tubes don't scan $\phi$ strips

During fabrication

Measure strips → optical disconnect

Use $\beta$ source (Underwood $\beta$ spectro?)

During installation

Scan SM strips with $\beta$ source

before EMC tile installed in SM slot

or source tubes in $\phi$ at SM?

In-situ

$\gamma$ source ⇒ Live Vs. Dead

PRESENTATION BY:

DAN GREEN

DRG
2/92

Green
Monam

# CALORIMETER PARAMETERS AND PHYSICS PERFORMANCE

1. BASIC RESULTS IN SIEGRIST DOCUMENT AND CAL CDR OF 9/91

2. LOOSE ENDS OF HAD SEGMENTATION AND EM RESOLUTION

3. EVOLUTION OF HAD $\Delta$ $\perp$ SEGMENTATION WITH REALISTIC SHOWER SHAPE

LoI ? → CDR
⋮
WICKLUND ⟹ HAD $\Delta = (0.1)^2$
⋮ (151 mB → 147 mB)
EINSWEILER

4. EM RESOLUTION?

SEE KEVIN EINSWEILER, THIS MEETING, EXPENSIVE

S/N ?

USE PS TILE READOUT? CHEAP & IMP

# CALORIMETER RESOLUTION SCALE

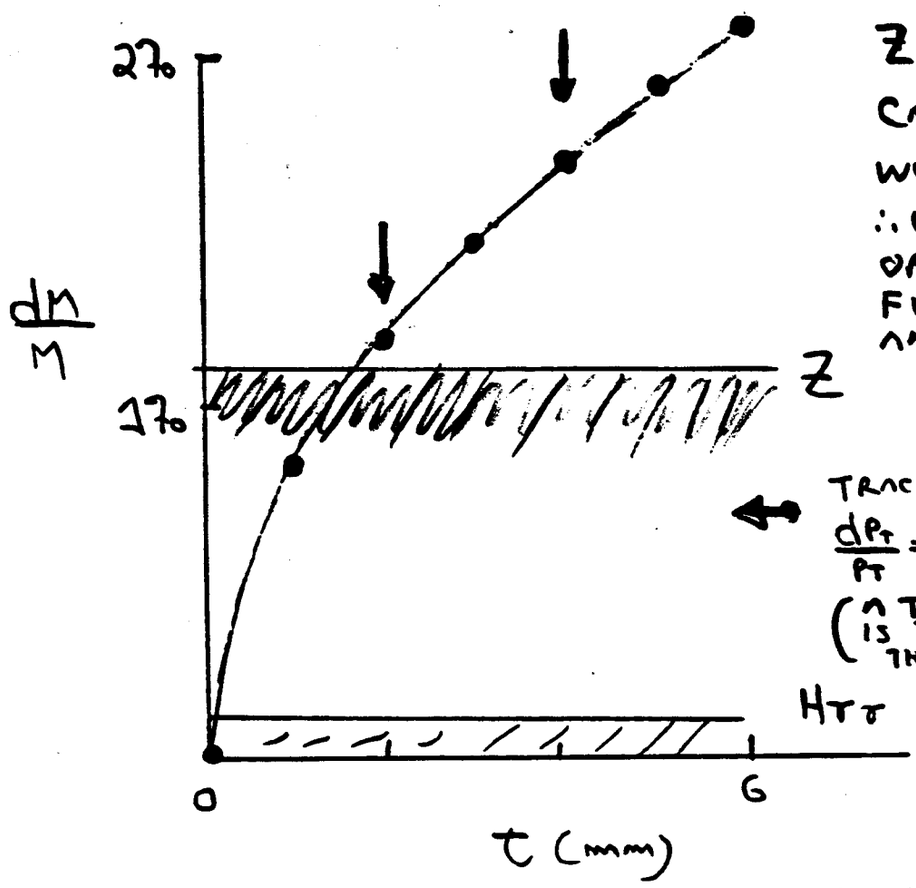
(A)

$$\frac{\Gamma(H\to\gamma\gamma)}{M_H} \sim 0$$

$$\frac{\Gamma_Z}{2.4\,M_Z} \sim 1.1\%$$

$$\frac{dM}{M} \sim \frac{1}{\sqrt{2}}\, dE/E$$

$$\frac{dE}{E} = \frac{a\sqrt{\tau/\tau_0}}{\sqrt{E_T}}, \quad E_T \equiv M/2$$




$Z \to ee$

CAL RESOLUTION WORSE THAN $\Gamma$

∴ USE TRACKING OR FIND Z (BKGND) AND FIT

TRACKING

$\frac{dp_T}{p_T} = 0.2$ @ 1 TeV

(A TRACKING GOAL IS TO DO BETTER THAN $\Gamma$)

FOR $e$ TRACKING IS CRUCIAL. NEED A GLOBAL OPTIMIZATION OF HIGGS → $e$ OR GENERAL PURPOSE - E.G. JETS

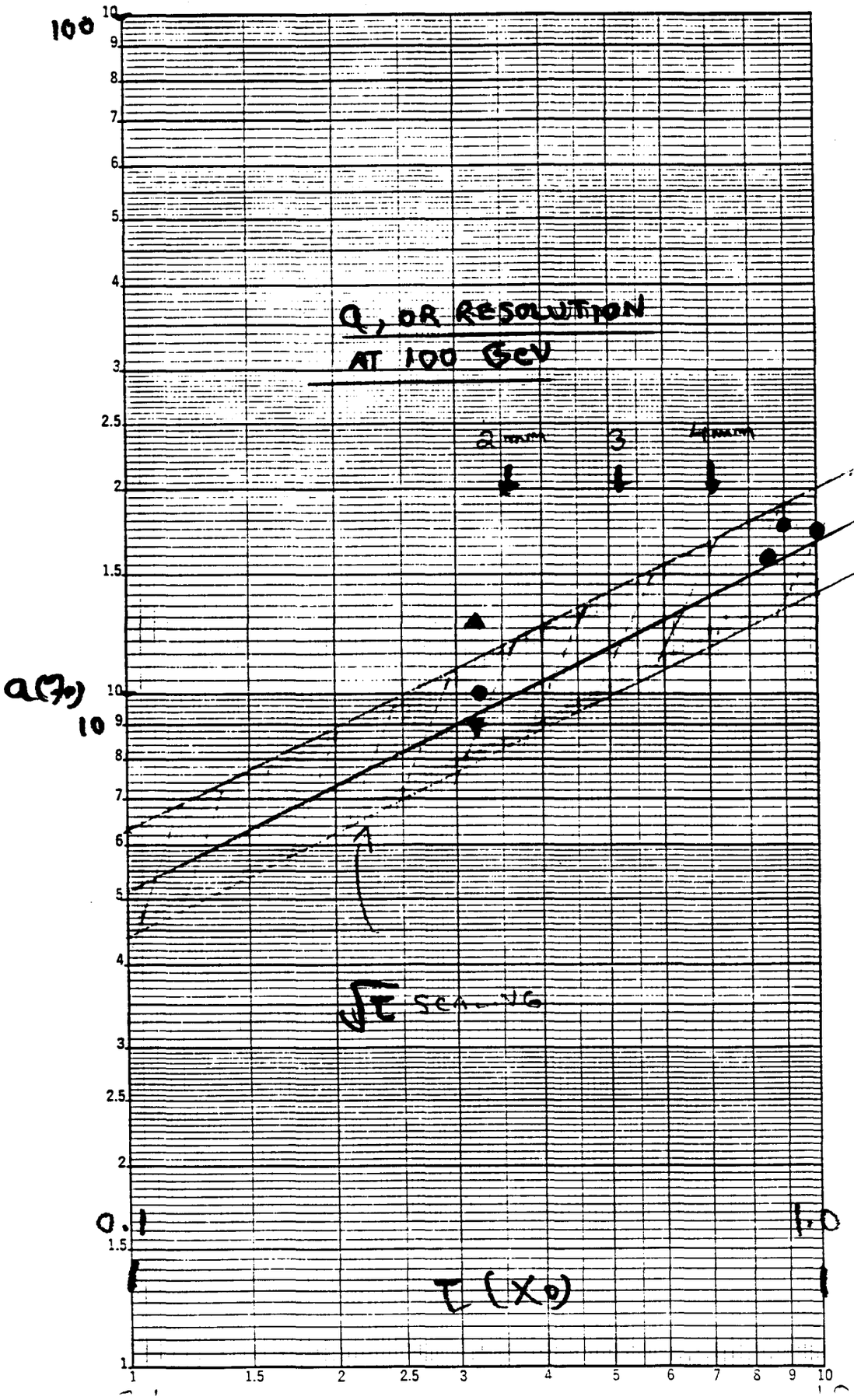
HOW DOES STOCHASTIC SCALE WITH t?

→ C. HEARTY, THIS MEETING WITH EGS4

$$dE/E = a/\sqrt{E} \oplus b$$

→ DATA

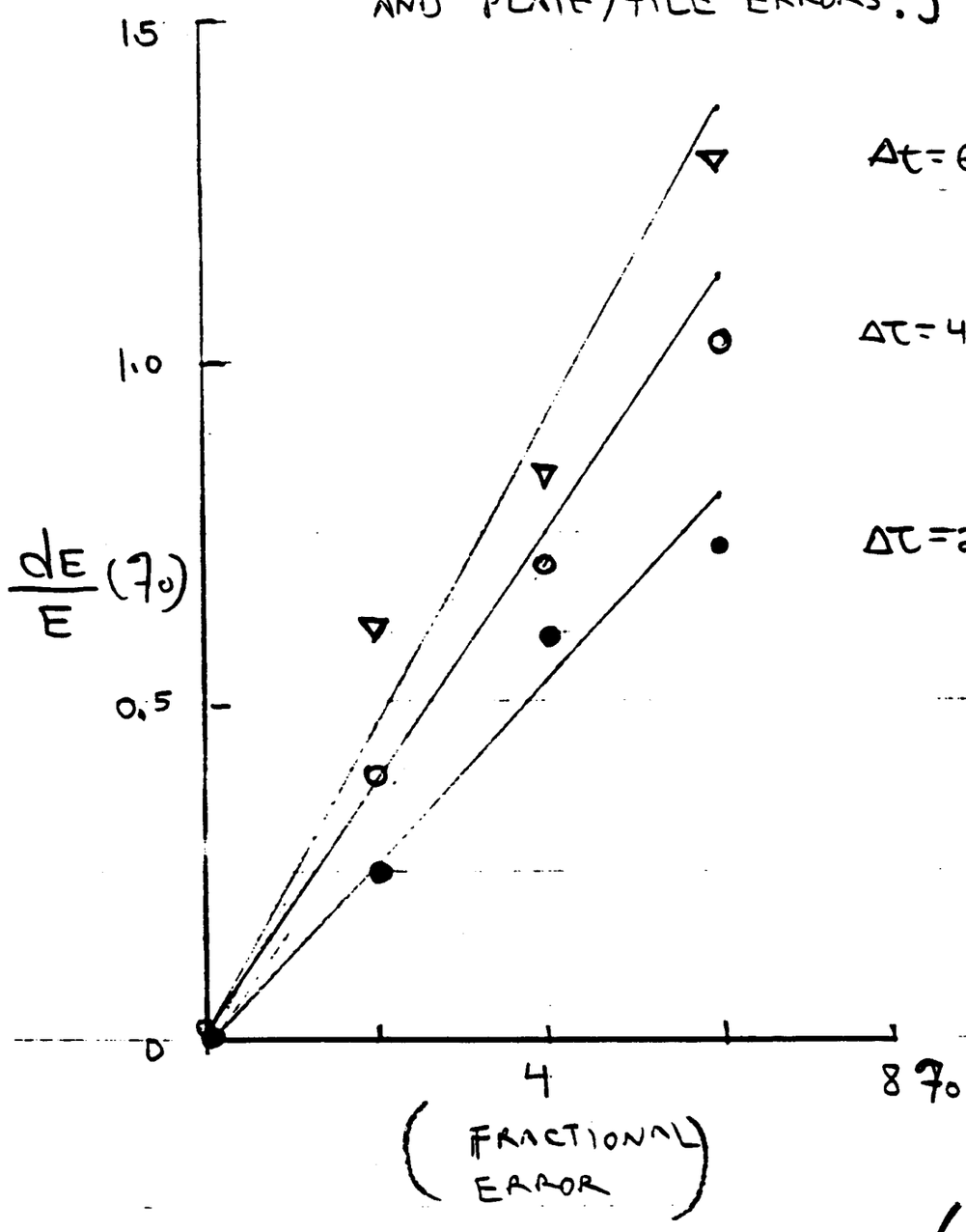
| COLLAB | a(%) | b(%) | COMMENT |
|---|---|---|---|
| ZEUS | 18 | — | 1 $X_0$ DU (3.3 mm)<br>2.6 mm PLASTIC |
| DØ (ECHAD)<br>(ECEM) | 20<br>15.5 | — | 6.0 mm U<br>LA<br>4.0 mm DU<br>LA (CRYOSTAT) |
| ACCORDIAN | 10 | 0.2 | 1.8 mm Pb<br>+0.2 mm STAINLESS<br>LA (CRYOSTAT) |
| NA31 | 7.5 | 0.5 | 2.3 mm Pb } 0.32 $X_0$<br>LA<br>(0.9 $X_0$ CRYOSTAT) |
| H1 | 13 | — | 2.4 mm Pb<br>LA<br>(2 $X_0$ COIL CRYOSTAT) |
| ANL/WSTC | 18 | — | 5 mm Pb<br>2.5 mm PLASTIC |
| CDF PLUG | 16 | — | 4.8 mm Pb<br>4.0 mm PLASTIC |




K+E LOGARITHMIC 46 7080
2 X 1 CYCLES MADE IN U.S.A.
KEUFFEL & ESSER CO.

DOES CONSTANT TERM SCALE?

EM CONSTANT TERM AND PLATE/TILE ERRORS: } γ CONVERSION POINT ERRORS SIMPLE MODEL

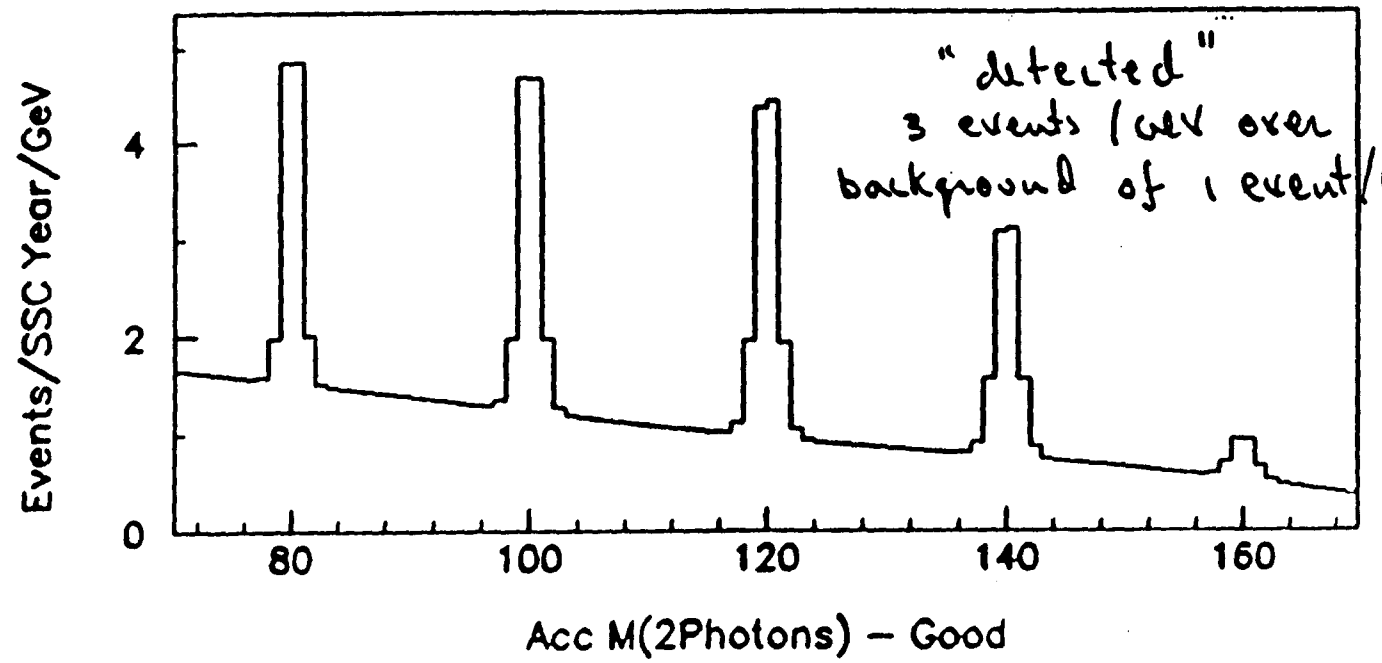



(GLOBAL CALIB)

$$-\left(\frac{dE}{E}\right) = (\%\ \text{RMS})\sqrt{\frac{\Delta T}{2\text{mm}}}\ (0.13)$$

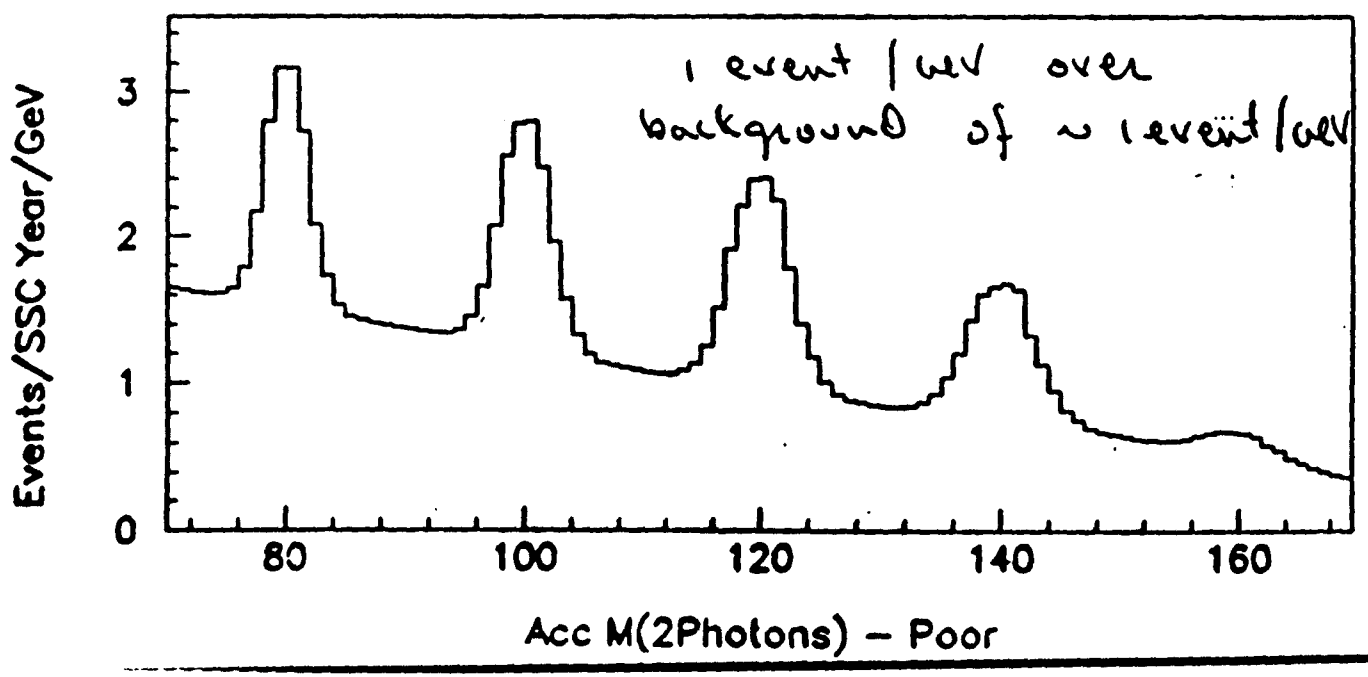
- SIGNIFICANCE GOES AS $\sqrt{dM}$ OR $(\tau)^{1/4}$ - TIME TO DISCOVERY

$PP \rightarrow t\bar{t}H \rightarrow e/\mu + (\gamma\gamma)$ (COMPETITION ?) GOES AS $dM$ OR $\sqrt{\tau}$ •




$\frac{10\%}{\sqrt{E}} \oplus 0.25\%$

THE PRESENT DESIGN DOES NOT COMPROMISE THE PHYSICS CAPABILITIES OF SDC




$\frac{20\%}{\sqrt{E}} \oplus 2\%$

[EINSWEILER]

PRESENTATION BY:

ROBERTO AMENDOLIA

Amendolia
Mon. PM

# TEST BEAMS AT CERN

Report by S.R.Amendolia
EB meeting, February 1, 1992

**Investigation based on:**

a) discussion between G.B. and E. Iarocci (chairman of the CERN Committee for R&D and Test Beam allocation) on January 13, 1992

b) meeting at CERN (January 23, 1992) of SRA with Jurgen Schukraft (SPS Coordinator) and Per Grafstrom (aide, beam expert of Accelerator Division). Also two members of the GEM Collaboration were present.

c) phone call of SRA to Nicholaus Haman (PS Coordinator) on January 21, 1992

**Schedule:**

PS operation (for users) will start around April 15. There are approximatively 25 weeks in 1992 in which PS beams will be available.

SPS test beams' operation will start (see attached schedule) on May 25 (Period P1 devoted to Heavy Ions Physics). Period P3D (December 10-18) will probably be suppressed, so test beams will close on December 7, 1992.

**Beam availability and status:**

Max momentum:

Beams in the North Area (NA) can go up to max accelerator momentum (450 Gev/c), though most are allocated to experiments. H6 cannot (it is a secondary beam of target T4), it is limited to 205 Gev/c pions (can also have electrons, though not stated in the tables). Also, in the future, H8 (now at 450 Gev/c because of NA12), even if NA12 desappears will not run at 450 Gev/c since 1994 because NA48 needs the protons (will be located in P0 from 1994). So H8 can possibly run at 450 Gev/c only in 1993 (for 1992 it is entirely booked).

Beams in the West Area (WA) which can be used as test beams now reach 100 Gev/c maximum. NOTE: there is a serious plan of upgrading (if requested) X5 or X7 to 200 Gev/c (this will be a candidate to become the dedicated SSC test beam line, see below). The upgrade can take place during the 1992-93 shut down. The upgrade affect (negatively) the X1 beam line, which owns the beam elements needed to perform the operation. The cost of the upgrade was guessed of the order of 0.5 MSF. There is a chance that X3 will be discontinued, as a result of the upgrade.

Low momentum:

WA beams can go to very low momenta, but this may be tricky. For example X3 can operate as low as 2-3 Gev/c, but very unstably (1-2 $\pi$/burst, a little more $e^-$).

Beams in the PS are suited for low momentum tests. Their max momentum is limited to 15 Gev/c. These beams do not undergo changes and upgrades, usually.

Location and availability:

WA is the place traditionally used as a test beam area (LEP test beam lines were located there). Also H6 (NA) will mostly operate as a test beam in the next years. Note that H6 is the beam where the NAxx test experiment (Pisa group - SRA) was located until 1991. We "own" an electrically powered barrack and some equipment overthere.

NOTE: WA will close in 1996 at the latest time, because the injection elements are needed for LHC. The statement reads "there is no committment to go any further". It could be earlier eventually, but LHC schedule seems today a little more relaxed.

PS beams suitable for us are located in the East Area of PS (see list). South Area's beams are weak, low momentum stuff.

**Status of beam allocation:**

PS has not yet started to collect beam requests. Forms will be distributed soon (SRA will act ad interim as a contact). Beams are allocated by the PS Coordinator, in case of great conflicts the issue will be reported to the SPSC (there is no longer a PS Committee, I understood).

SPS has already a draft schedule (attached) which accounts for the major experiments' requests. Test beam allocation is yet to be discussed, however specific requests (GEM included) have already been forwarded. We (and GEM) are expected to state our needs as soon as possible (first week in February?).

**Policy for beam allocation:**

The policy for test beam allocation to SSC groups has not yet been discussed. Rumors on a high "participation fee" to be payed by SSCLAB originate from an "incident" (a non-CERN group showing up at a test beam previously - cheating? - allocated for CERN related test activity) and from Director's General strong attitude versus SSC in view of the problems with LHC approval by the CERN Council. Iarocci's temptative statement is that there is no reason for a "punitive" behaviour, especially if European groups are involved in the tests.

At the meeting with SPS coordinator, it was stated that a possible plan for 1992 is to charge SSC groups with "operating costs" only, which seems fair, but it is not clear what operating costs mean: it could range from the crane's operator intervention to displace a magnet, to the salary of the Accelerator's control room crew... Note that things like electrical works, experimental barracks' setting-up etc. are normally charged to groups working at CERN.

Referring to the upgrade of X5 or X7 beams (see above), SSC would be charged for example with the cost of the operation, una tantum, which seems reasonable.

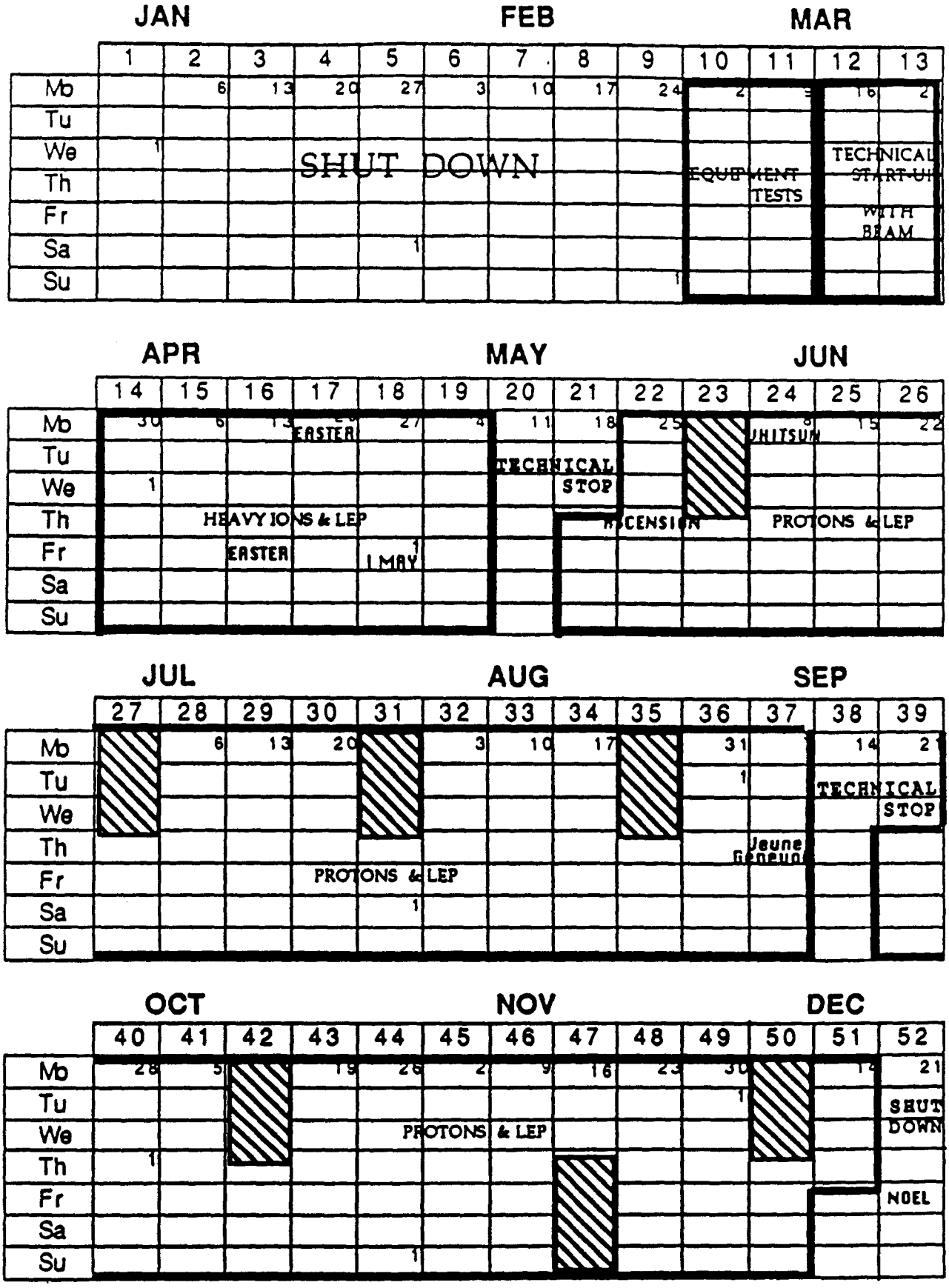
It was felt by the SPS coordinator that the long term policy will be to allocate a test beam line to SSC for the forthcoming years, and SSC groups would manage the sharing between them (as was successfully done for LEP experiments, and will possibly be done for LHC as well).

The fact that SDC has a large European component, while GEM has none, could play in our favour in case of a separate approach; it would be waved away if a beam line is labeled "SSC". There has not been an extensive discussion on this issue, for sake of fair play.

GEM is requesting at least 2-4 weeks of SPS test beam time for 1992, with 5-100 Gev/c $e^-$ and 2-4 weeks in 1993 with 5-100 Gev/c $\pi$ or $e^-$. They test a Liquid Xe and Kr Calorimeter (MIT group). SDC has placed a verbal preliminary request for about 4 weeks of beam time, waiting for technical details by the physicists involved, and pending decisions by SDC boards.

# 1992 SPS SCHEDULE

PROVISIONAL
POST RESEARCH BOARD
28 NOVEMBER 1991




VERSION 11 1 December 1991

CPS & SPS MD

NOTE. LEP MDs in alternate second weeks

# 1992 SPS Fixed Target Programme (draft)

17th December 1991

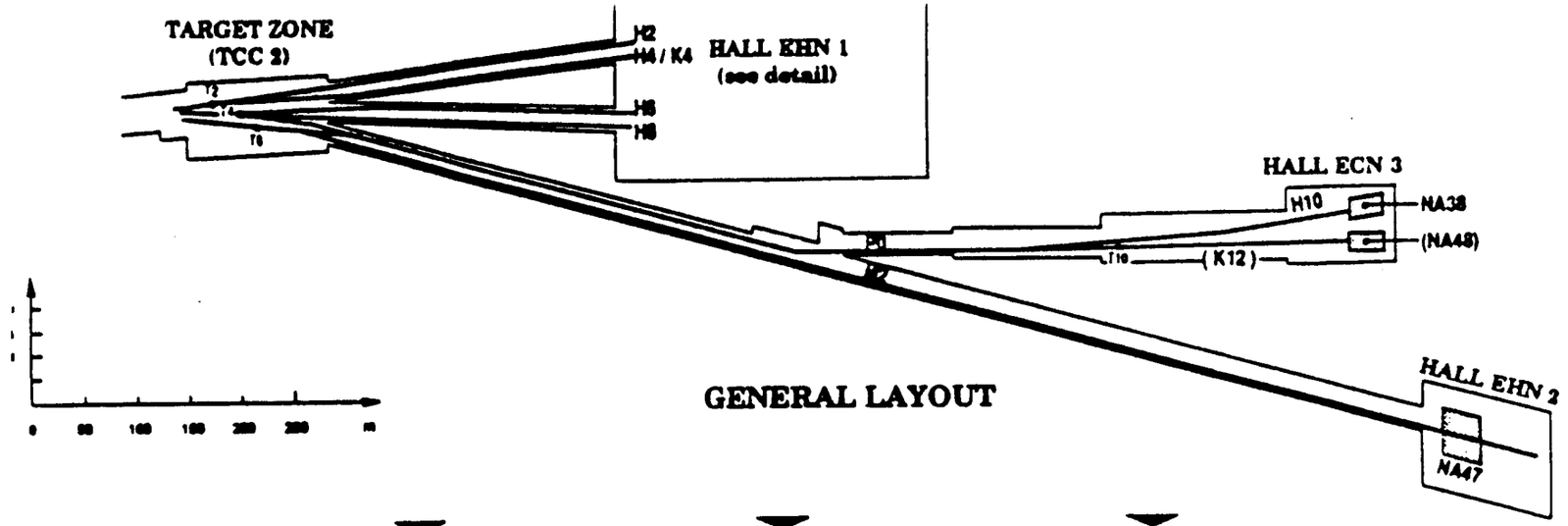
| Date | | 30/3 10/5 | | 21/5 01/6 | 04/6 29/6 | | 02/7 27/7 | 30/7 24/8 | | 27/8 13/9 | 24/9 12/10 | | 15/10 19/11 | | 23/11 07/12 | | 10/12 18/12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Target Beam | | P1 HEAVY IONS 42 days | | P2A 10 | P2B 24 | | P2C 24 | P2D 24 | | P2E 17 | P3A 17 | | P3B 34 | | P3C 14 | | P3D 7 |
| T9 | N1 | | | | | | | | | | | | | | | | |
| T1 | H1 | WA94 | | WA92 | WA92 | | WA92 | WA9~~1~~2 | | WA9~~1~~2 | WA~~89~~ 97 | | WA~~89~~ 17 | | WA89 | | WA89 |
| T1 | H3 | WA93 | | | | | | | | | | | | | | | |
| T1 | X1 | | | Pb-glass | RD8 10 | DELPHI 14 FCA | | | | RD8 10 | | | RD8 10 | | DELPHI 7 FCA | | |
| T1 | X3 | | | | WA89 | | WA89 | WA89 10 | | | | | | L3 14 | L3 | | |
| T1 | X5 | | | RD20 | DELPHI 14 SSDD | | | GEM | | | RD20 10 | GEM 7 | GEM 17 | ZEUS 17 | RD20 10 | | |
| T1 | X7 | | | UA4 | DELPHI (HPC) | | UA4 10 | | | | | | | WA95 14 | WA95 | | |
| T2 | H2 | NA35 | | RD2 | RD2 9 | RD1 15 | RD2 10 | RD5 14 | RD2 10 | RD1 | NA35 | | RD5 10 | 18 10 | 1 7 | 2 7 | RD5/18 | RD5/18 |
| T2 | H4 ~~X4~~ | NA44 | | NA44 | ~~NA44~~ NA48 | | NA44 | NA44 | | NA44 | NA48 | | NA48 | | | | |
| T4 | H6 | | | RD3/RD6 | RD3/RD6 | | RD3/RD6 14 | TIS 3 | NA48 14 | H1 | | | | H1 11 | H1 | | |
| T4 | H8 | NA45 | | NA12/2 1,2) | NA12/2 | | NA12/2 | NA12/2 | | SL 5 | RD3 | | RD3 | | RD21 | | RD21 |
| T6 | H10 | NA38 Sulphur | Deuterons | | — | | — | — | | — | — | | — | | — | | — |
| T6 | M2 | | | NA47 | TIS 1 | NA47 | NA47 | NA47 | | NA47 | NA47 | | NA47 | | NA47 | | NA47 |

1) NA45 running parasitically 2) 5 days bent crystal test RD22

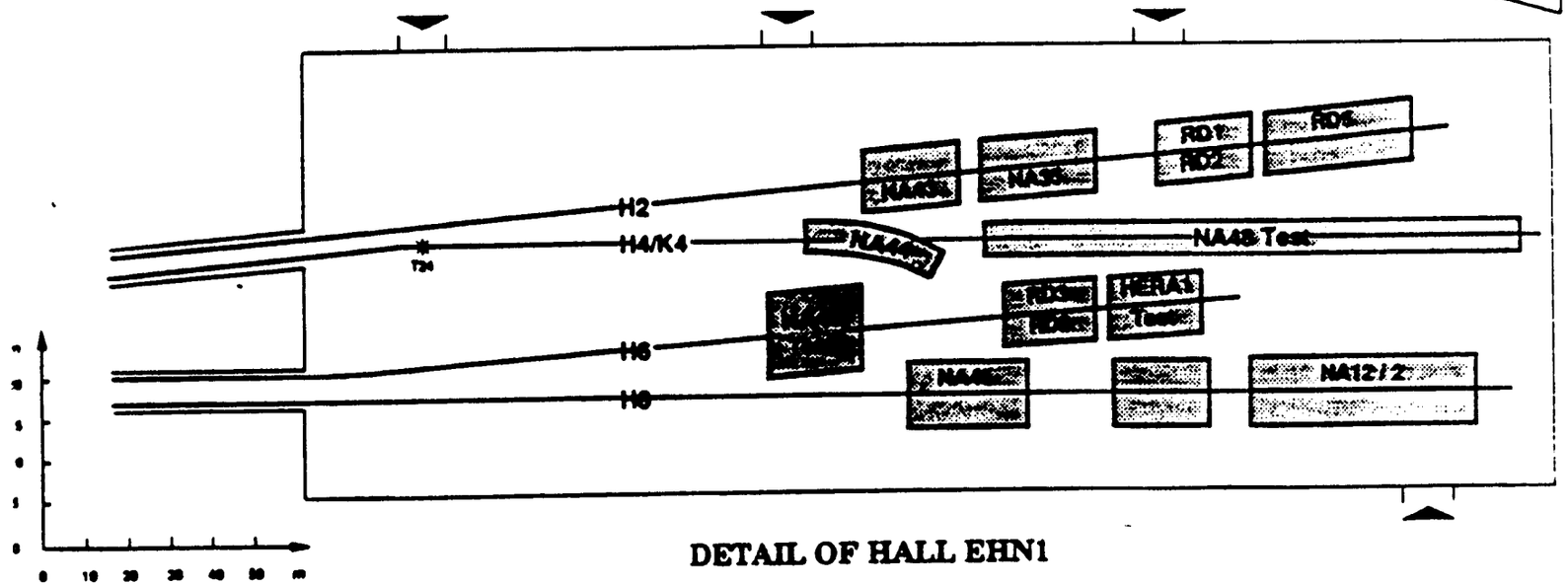
## LIST OF SPS BEAMS

### 1A. BEAMS IN THE NORTH AREA (Situation for 1991)

| Beam name | Maximum momentum (GeV/c) | Intensity of beam for $10^{12}$ incident protons at 450 GeV/c | Beam Type |
|---|---|---|---|
| H2 | 450 | $9\ 10^7\ \pi^+$ at 200 GeV/c<br>$3\ 10^7\ \pi^-$ at 200 GeV/c<br>$4\ 10^6\ e^\pm$ at 150 GeV/c<br>$\sim 10^5\ {}^{32}S$ at 200 GeV/A | 1) high energy hadron or electron beam (also used as test beam);<br>2) heavy ion beam |
| K4 | 450<br><br>360 | $\sim\ 1\ 10^6\ K^0_L > 50$ GeV for $10^{11}$ inc. p (2•5 mrad)<br>$\sim\ 2\ 10^2\ K^0_S$ for $2\ 10^7$ inc. p (4•5 mrad) | alternate $K^0_L$ and $K^0_S$ beams |
| H6 | ~~250~~<br>205 | $1\ 10^8\ \pi^+$ at 150 GeV/c<br>$4\ 10^7\ \pi^-$ at 150 GeV/c | medium energy hadron beam, also used to produce tertiary test beam |
| H8 | 450 | $\sim\ 10^6$ p at 450 GeV/c<br>$2\ 10^8\ \pi$ at 200 GeV/c<br>$7\ 10^7\ \pi^-$ at 200 GeV/c<br>$\sim\ 10^6\ {}^{32}S$ at 200 GeV/A | 1) attenuated primary p or high energy hadron (e) beam;<br>2) heavy ion beam |
| M2 | 280 | $2\ 10^7\ \mu^+$ at 200 GeV/c<br>$8\ 10^6\ \mu^-$ at 200 GeV/c | high intensity muon beam |
| PO | 450 | $\leq\ 10^{13}$ p at 450 GeV/c<br>$\geq\ 10^7\ {}^{32}S$ at 200 GeV/A | primary proton beam, used to transport hadrons or heavy ions to H10 or E12 |
| H10 | 450 | $\sim 10^8$ p at 450 GeV/c<br>$\sim\ 1\ 10^7\ \pi^+$ at 200 GeV/c<br>$\sim\ 3\ 10^6\ \pi^-$ at 200 GeV/c<br>$\geq 10^7\ {}^{32}S$ at 200 GeV/A | 1) attenuated primary proton or high energy hadron beam (via PO);<br>2) high intensity heavy ion beam |
| E12 | 450 | hadron fluxes similar to H10 | beam available for tests |




GENERAL LAYOUT




DETAIL OF HALL EHN1

**SPS NORTH EXPERIMENTAL AREA**

(situation for 1991)

LIST OF SPS BEAMS

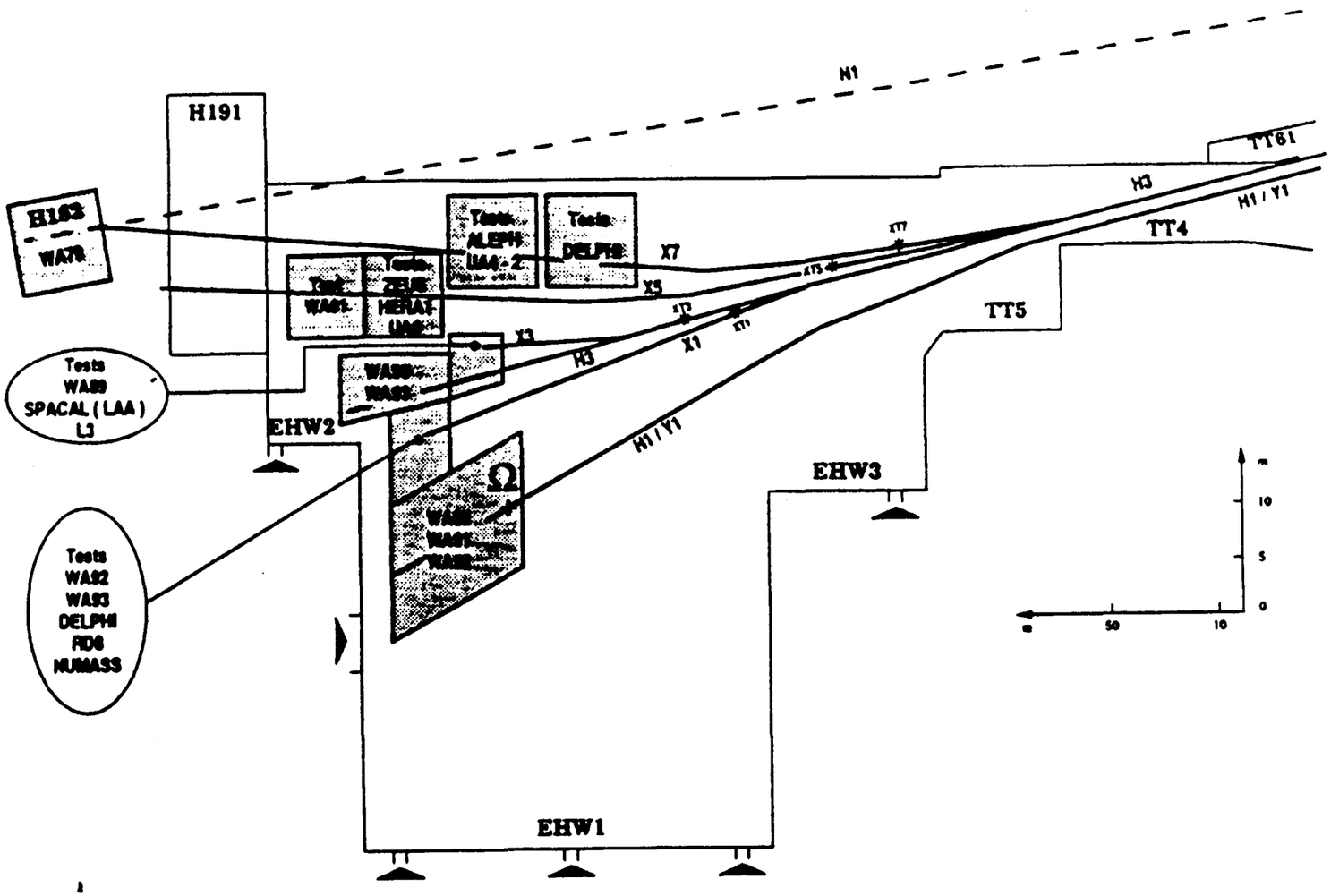
## 1B. BEAMS IN THE WEST AREA (Situation for 1991)

| Beam name | Maximum momentum (GeV/c) | Intensity of beam for $10^{12}$ incident protons at 450 GeV/c | Beam Type |
|---|---|---|---|
| H1/Y1 | 450 | ~ $10^6$ $\pi^-$ at 350 GeV/c<br>~$10^8$ $\pi^+$ at 200 GeV/c<br>$10^6$ e at 200 GeV/c<br>~$10^5$ $\Sigma^-$ at 350 GeV/c<br>(for $2 \cdot 10^{10}$ inc. p)<br>~ $10^6$ $^{32}S$ at 200 GeV/A | 1) high energy hadron or electron beam<br>2) high energy hyperon beam<br>3) heavy ion beam |
| H3 | 200<br>(400)* | ~ $10^8$ $\pi^+$ at 200 GeV/c<br>~ $10^7$ $\pi^-$ at 200 GeV/c<br>$10^6$ e at 200 GeV/c<br>~ $10^6$ $^{32}S$ at 200 GeV/A | 1) hadron or electron beam; serves to produce test beams X1,X3,X5,X7<br>2) heavy ion beam |
| X1 | 70 | $10^2$ - $10^4$ tertiaries / $10^7$ incident H3 particles | test beam: tertiary electrons + hadrons |
| X3 | 50 | $10^2$ - $10^4$ tertiaries / $10^7$ incident H3 particles | test beam: tertiary electrons + hadrons |
| X5 | 100 | $10^2$ - $10^4$ tertiaries / $10^7$ incident H3 particles | test beam: tertiary electrons + hadrons |
| X7 | 100 | $10^2$ - $10^4$ tertiaries / $10^7$ incident H3 particles | test beam: tertiary electrons + hadrons |

## 2. BEAMS IN THE WEST AREA NEUTRINO FACILITY

| Beam name | Parent momentum (GeV) | $\langle E_\nu \rangle$ (GeV) | Intensity of beam and/or event rate for $10^{13}$ incident protons (870m from tgt, inside 1.75m radius) | Beam type |
|---|---|---|---|---|
| N1 | 450 GeV protons | ~ 24<br>~ 20 | $1.3 \times 10^{10}$ $\nu/m^2$ ~ 0.13 ev/ton<br>$0.7 \times 10^{10}$ anti-$\nu/m^2$ ~ 0.03 ev/ton | Wide band spectrum up to 450 GeV/c |

*) Beam H3 can operate at momenta up to 400 GeV/c provided the test beams X1, X3, X5 and X7 are not used.




**SPS WEST EXPERIMENTAL AREA**

**(situation for 1991)**

LIST OF PS BEAMS (as from September 1990)

Some in November 1991

I. EAST AREA (primary beam)

| Beam | Ejection | Momentum | Particles/magnet cycle | Remarks |
|---|---|---|---|---|
| $e_{17}$ | SE62 | 8.-24.GeV/c | p: $2\times10^{11}$ (for test beams) | primary beam split in 2 branches |

II. EAST AREA (counter beams)

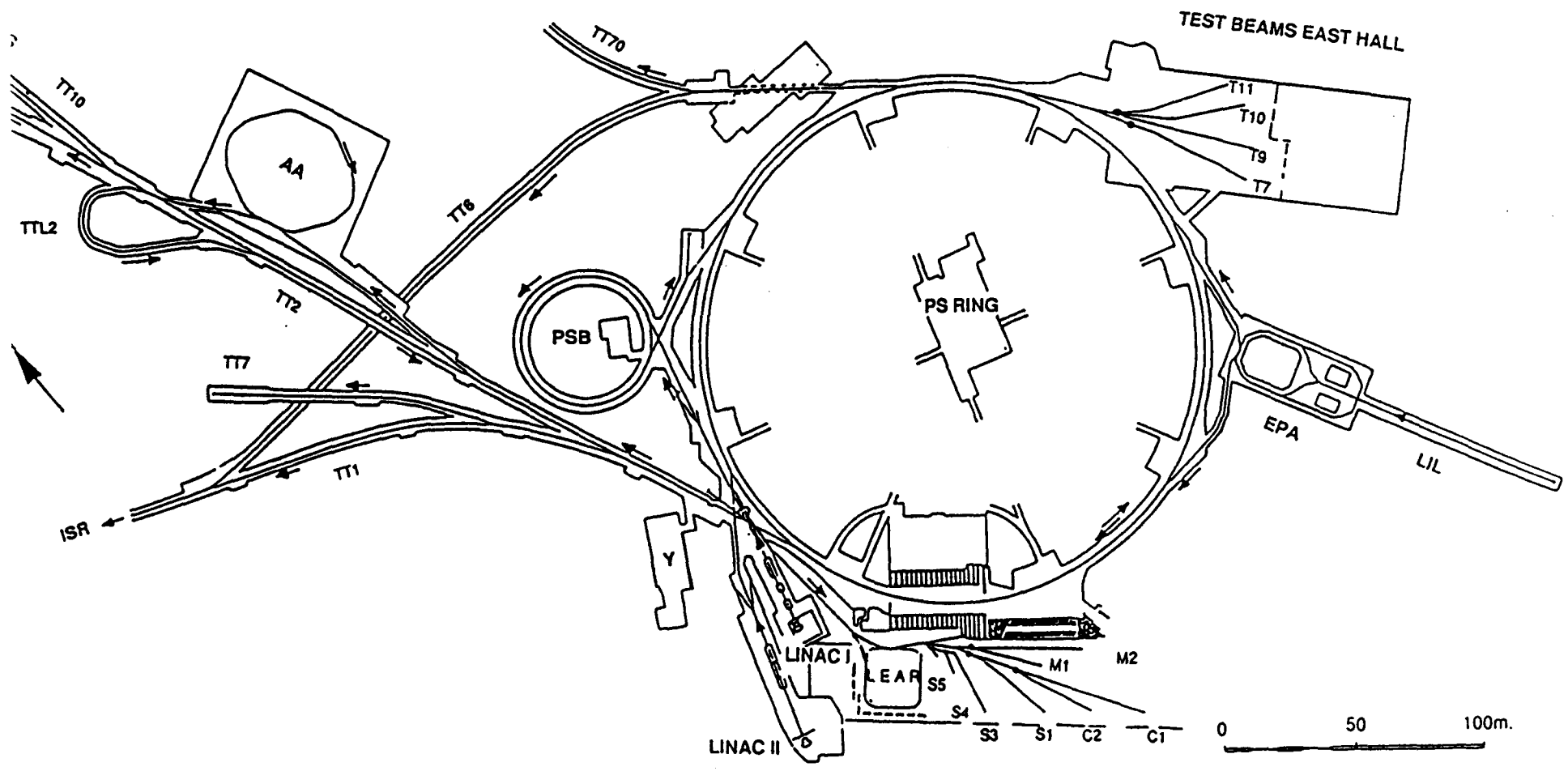
| Beam | Ejection | Momentum | Particles and flux/cycle | Remarks |
|---|---|---|---|---|
| $t_7$ | SE62 (South branch) | ≤ 10 GeV/c | p,$\pi^+$,$e^+$ or $\pi^-$,$e^-$<br>$e^+$ 7% of + beam (5 GeV/c)<br>~50% of + beam (2 GeV/c) | production angle: 0 degree<br>beam height 1.28m<br>beam switched between 2 branches |
| $t_9$ | SE62 (North branch) | ≤ 15 GeV/c | $\pi^-$ 15 GeV/c ≈ $10^5$<br>$e^-$ ≈ 1-3%*)<br>pos. beam ≈ $10^6$ | production angle: 0 degree<br>beam height 2.28 m |
| $t_{10}$ | SE 62 (North branch) | ≤ 5 GeV/c | $\pi^-$ 5 GeV/c ≈ $3\times10^5$<br>$e^-$ ≈ 10%*)<br>pos. beam ≈ $6\times10^5$ | production angle: 3.53 degrees<br>beam height 2.5 m |
| $t_{11}$ | SE62 (North branch) | ≤ 3.5 GeV/c | $\pi^-$ 3.5 GeV/c ≈ $2\times10^5$<br>$e^-$ < 10%*)<br>pos. beam ≈ $4\times10^5$ | production angle: 8.55 degrees<br>beam height 2.5 m<br>*)The percentage of $e^-$ in the negative beam is depending on the external target used (converter) |

III. SOUTH AREA (LEAR design values)

| Beam | Ejection | Momentum | Particles and flux | Remarks |
|---|---|---|---|---|
| LEAR external beam | ultra-slow ≈ 1 hour | 0.06-1.9 GeV/c | pbar: ≤ $3\times10^6$/s for 1 hour spill | spill length: 15' to 4 hrs |

pbar beam split in 3 branches (8 experimental areas)

# THE PS ACCELATOR COMPLEX




LEAR AND EXPERIMENTAL AREAS

PRESENTATION BY:

DAN GREEN

ORG
2/92

Green
Mon pm

# CENTRAL CALORIMETER PROTOTYPE

1. THE NEXT STEP FOR SDC CALORIMETRY IS THE "PREPRODUCTION PROTOTYPE"

2. THIS DEVICE ADDRESSES BOTH;
   MECHANICAL ISSUES
   COLLABORATION ISSUES
   AND
   TEST BEAM ISSUES

3. WE MUST RAMP UP FUNDING IN FY93 IF THE OFFICIAL SSC SCHEDULE IS TO BE MET.

   + GEM
   + LHC

   NEED TO KEEP MOMENTUM

Description : Technical Board Meeting, Pisa, Italy, Jan. 10, 1992
From : CSA::BAUTZ date : 21-JAN-1992

# SUMMARY OF TECHNICAL BOARD MEETING

## PISA, ITALY

January, 10, 1992

MEMBERS PRESENT: K. Amako, M. Edwards, J. Elias, I. Gaines, M. Gilchriese, D. Green, R. Hubbard, T. Kondo, A. Lankford, L. Price, A. Seiden, W. Smith, G. Trilling

OTHERS PRESENT: L. Bautz

The meeting began at 12:15 PM.

## PAC REPORT AND TECHNICAL PROPOSAL

Trilling outlined his impressions of the reaction from the SSC Program Advisory Committee to the SDC presentation in December. Their response seemed positive on technical progress, including the process for technical decisions. There was support for the SDC fiscal year 1992 budget request, concern about insufficient SDC management presence at the SSC Lab, and concern about costs. The PAC and the SSCL desire to see a vigorous defense of all detector parameters and the relationship to physics performance in the Technical Proposal.

It is expected that the proposal will be subjected to intensive review over several days sometime during the first two weeks of May. It will consist of plenary sessions covering the overall detector, physics, costs, schedules, and management followed by parallel sessions covering each subsystem in detail. The reviewers will include PAC members, additional technical experts, and, possibly, some DOE representatives and HEPAP members.

## STATUS OF THE TECHNICAL PROPOSAL

Gilchriese indicated that there will be a draft of the proposal distributed for comment at the next meeting. He called attention to the SDC Parameters book, noting the need for consistency with the proposal.

## TEST BEAM NEEDS AND PLANS

Building a wedge prototype for the central calorimeter to be tested by the summer of 1993 was discussed.

Green pointed out that the prototype will be a major undertaking and that setting up for testing will involve cranes, rails, electronics, etc. There will also be a need to test wedges as they come off the production line in 1994-96. He is looking into possibilities for testing at Fermilab. Testing at CERN would need to be explored. Gilchriese asked Green, Mantsch, Hubbard, and Takikawa to define the prototype, including cost and schedules, by Feb. 1. ?

The feasibility of testing the prototype at either Fermilab or CERN will be explored and a preliminary report presented at the next EB/TB meeting.

## PREPARATION FOR NEXT EB/TB MEETING

From: FNAL::DGREEN 21-JAN-1992 17:56:54.63
To: PLAVALLIE
CC: DGREEN
Subj: Pat, please send out to FERMISSC.DIS AND SDC_CALOR.DIS first thing Wed am, thanks. Dan

CALORIMETER PROTOTYPE '93

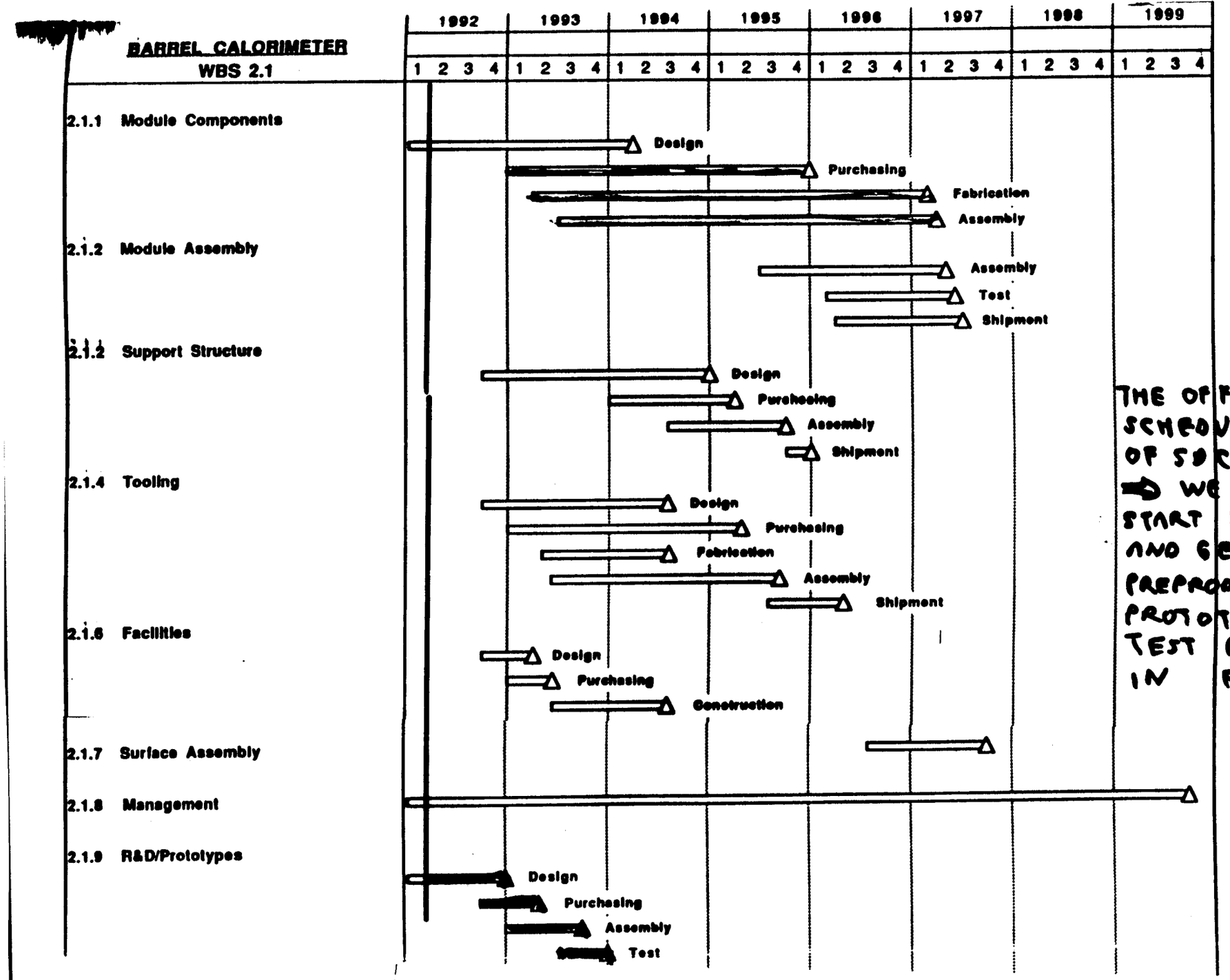
AGENDA

Jan 22, Wednesday 3-5 pm, Fermilab, Curia II (WH2SW)

| | | |
|---|---|---|
| 3:00 - 3:10 | Where do we test SDC calorimetry? | D. Green |
| 3:10 - 3:30 | What test beams are available @ FNAL? | G. Bock/ C. Hojvat |
| 3:30 - 4:00 | What would a "preproduction prototype" look like,cost,weigh, ... ? | S. Gourlay |
| 4:00 - 4:20 | What did we learn from EM tests in MP? | J. Proudfoot |
| 4:20 - 4:40 | What did we learn from SM tests in MP? | D. Hubbard |
| 4:40 - 5:00 | What did we learn from HF tests in MT? | B. Foster |
| 5:00 - 5:15 | Where are we going in RADDAM studies? | A. Byon |
| 5:15 - 5:30 | Can we build a "PPP" in 1993 ? | D. Green |

Adjourn

MEETING AFTER: FIXED TARGET RUN
SACLAY, FSA




THE OFFICIA
SCHEDULE
OF SDC
⇒ WE MUST
START NOW
AND GET A
PREPROTOTYP
PROTOTYPE
TEST DONE
IN FY93

S. Gourlay
Fermilab
January 22, 1992

# First Look At A Preproduction Prototype Barrel Calorimeter for SDC

- FY91 TEST BEAM WORK

**What have we done so far?**

- Argonne EM prototypes EM
- Fermilab hadron test wedge + HAD
- + many, many R&D efforts

**Where are we?**

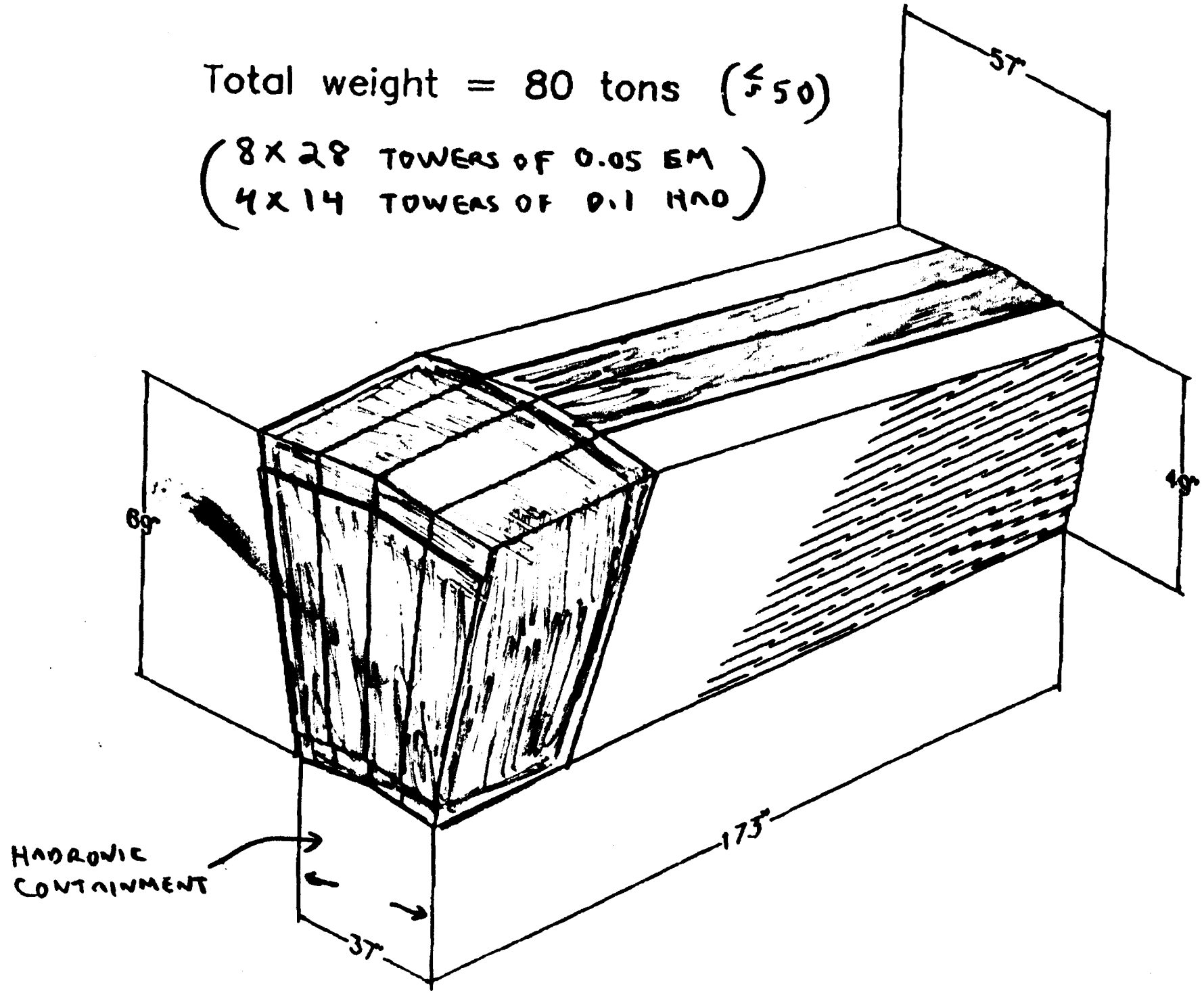
- Efforts are now directed at finalizing the design parameters and producing a viable cost estimate

**Still need to....**

- Confront basic construction/design details
- Calibration *
- Compare performance with design expectations
- Exercise upgrade scenarios

Total weight = 80 tons ($\frac{4}{5}$50)

(8 X 28 TOWERS OF 0.05 EM
4 X 14 TOWERS OF 0.1 HAD)



# SDC Calorimeter Prototypes — GOALS

| | Small Scale | Beam Test Module (8x8) (SCINT) | Full Wedge PROTOTYPE |
|---|---|---|---|
| **Organization** | | | |
| Resource integration (JAPAN, FRANCE, ITALY) | | X | X |
| **Procurement** | | | |
| Source development | | X | X |
| Inspection procedure development | | X | X |
| **Design verification** | | | |
| Absorber fabrication (including tolerance control) | | X | X |
| Barrel assembly (wedge/wedge/had-EM) | | | X |
| Mechanical properties of the absorber and EM | | | X |
| **Manufacturing and assembly verification** | | | |
| Tile preparation | X | X | X |
| Fiber insertion and fiber connections | X | X | X |
| Fiber routing | | X | X |
| PMT installation | | X | X |
| Assembly procedures | | X | X |
| Source tube installation and operation | | X | X |
| QA/QC procedures | | X | X |
| **Performance (with beam)** | | | |
| Crack scans in both eta and phi | | X | X |
| Linearity | | X | X |
| Resolution | | X | X |
| Calibration (source, muons) | | X | X |
| PMT monitoring | | X | X |

MODULE / TILE CRACK-SCANS

WE HAVE ASKED TSUKUBA FOR 8X8 (~4000 TILES) PLASTIC FOR THIS TEST

# Barrel Prototype Cost Estimate

Barrel cost breakdown from the current WBS

| | |
|---|---|
| Components | $55,000k |
| Assembly | 7,000k |
| Tooling | 11,000k |
| Facilities | 5,000k |
| Proj. mgt | 20,000k |
| | $98,000k |

EXPERIENCE FROM EM AND HAD TEST BEAM MODULES

There are 128 half-wedges (h-w), therefore each h-w is $760k

To get absorber cost subtract tile and PMT costs TSUKUBA

3000 tiles/h-w @ $40/tile installed = $120k

83 channels of PMT per h-w @ $540/channel = $50k

So production cost of absorber for 1 h-w is $600k

Assume cost of first prototype module is 3X production cost and subsequent modules are 2X production cost

(UP FRONT TOOLING AND INVESTMENT)

**Scintillator**

| Tiles | | Average Size |
|---|---|---|
| 1920 | EM | 13 X 13 cm |
| 1792 | Had1 | 18 X 18 cm |
| 240 | Had2 | 39 X 39 cm |
| 3,952 | Total | approx. 130 $m^2$ |

**Fiber**

| | |
|---|---|
| Clear Fiber | 13,000 m |
| WLS Fiber | 3,000 m |

**Channel Count**

Primary configuration - 96

Upgrade configuration - 208

EM -> EM1/EM2

Had1 (0.1 X 0.1) -> Had1 (0.05 X 0.05)

EXERCISE

Need a total of 224 PMTs

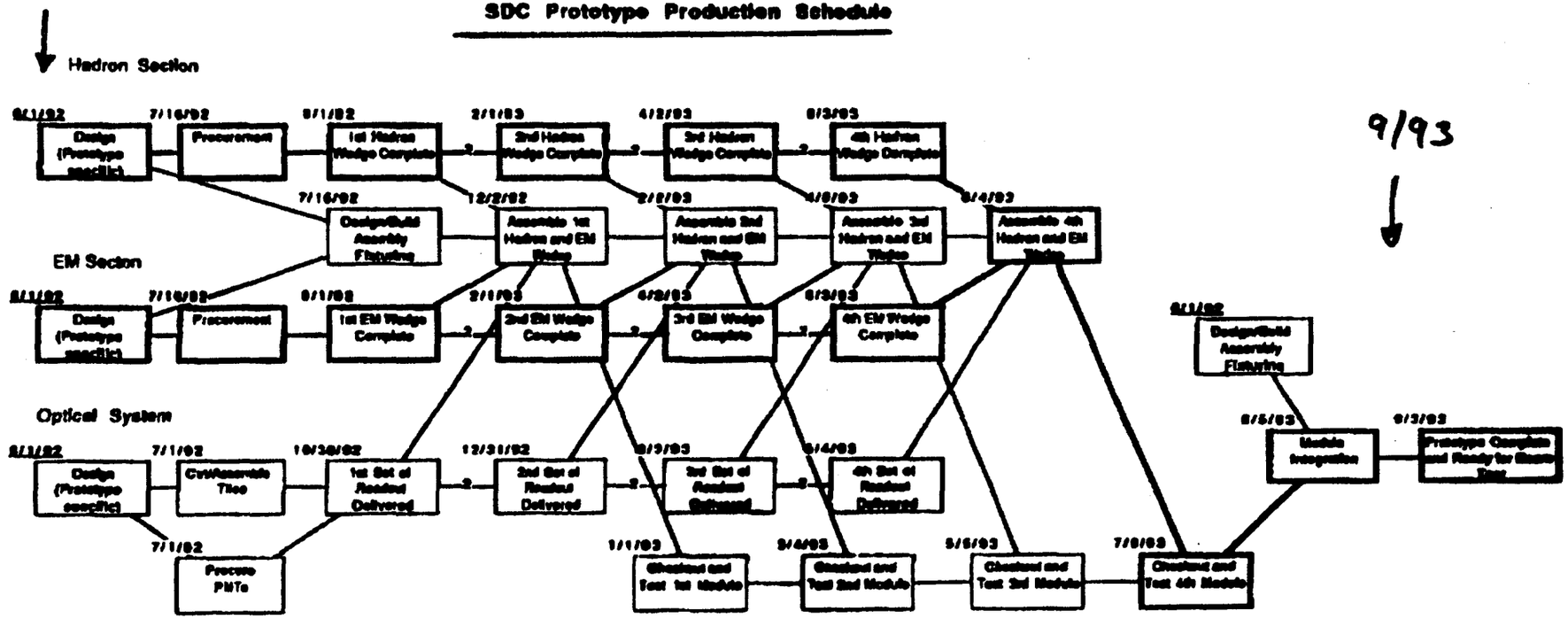
WT (PS)
EM1/EM2
TO MAKE SURE
IT WORKS

Total cost for 4 half-wedges with 8 X 8 section at eta = 1.4 ? instrumented is then:

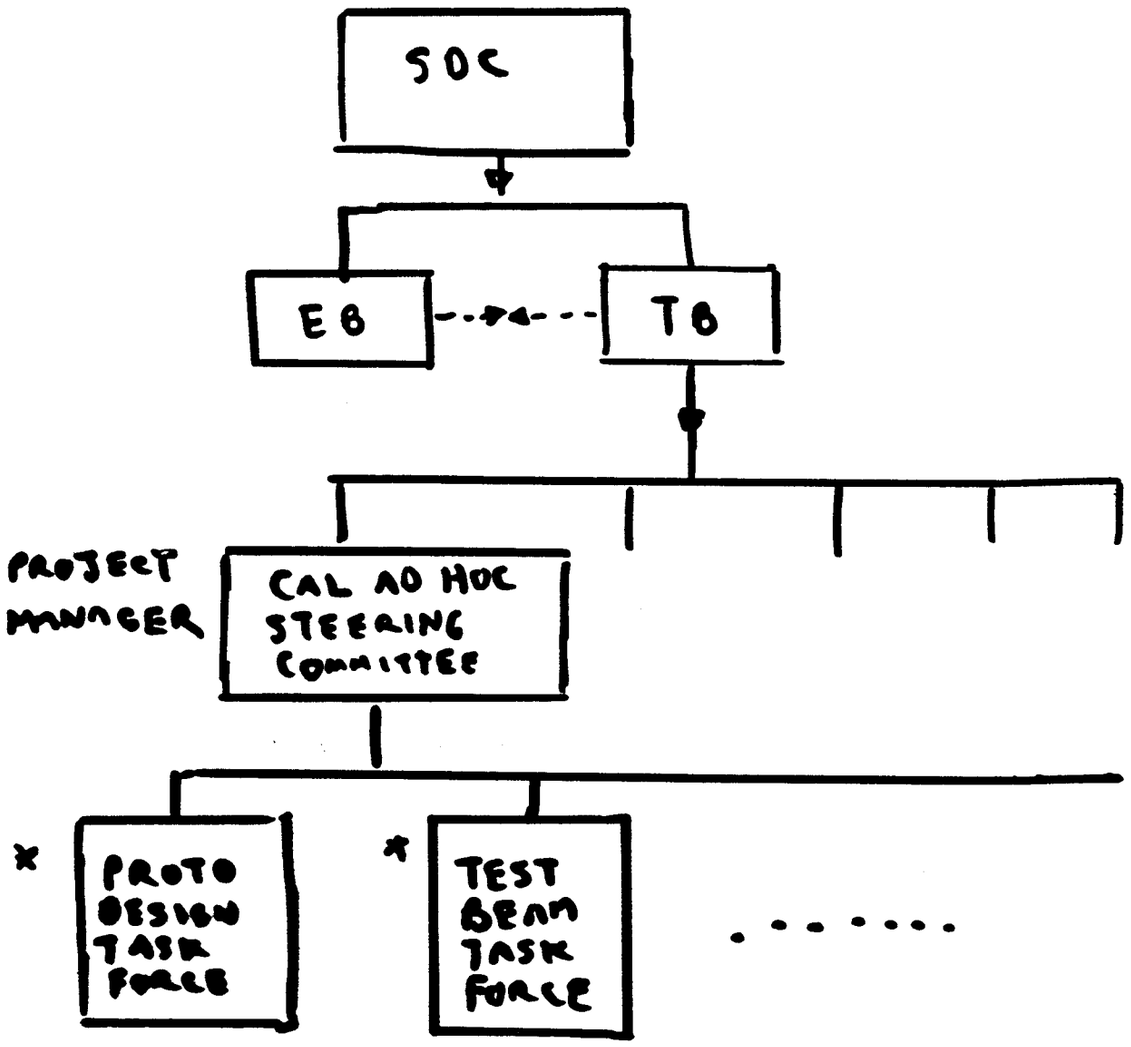
Absorber

| | | |
|---|---|---|
| | $4,000k | Components,assembly,tooling |
| | $1.400k* | Facilities, proj. mgt |
| | $5,400k | |
| Tiles/PMTs | $180k* | (not installed) |
| Install readout | $200k | |
| SM (SACLAY) | $500k* | (includes all components and installation) |
| Test Fixturing | | |
| Beam Test | | |
| Total | $6,280k | (-0.8M// WITH OPTION OF "OUTRIGGERS") |

## SDC Prototype Production Schedule



# 1 MODEL FOR CALORIMETER MANAGEMENT




* WE AIM TO GET THE "YOUNG TURKS" INVOLVED IN DESIGN AND TEST

WHILE THE

TDR, COST/SCHEDULE AND "REVIEW DE JOUR" GOES ON

DRG
2/92

# TEST BEAMS (2)
# FNAL FOR SDC

1. THEY WILL BE USED IN ~ 94 - 98 TO TEST WEDGES OFF THE ASSEMBLY LINE

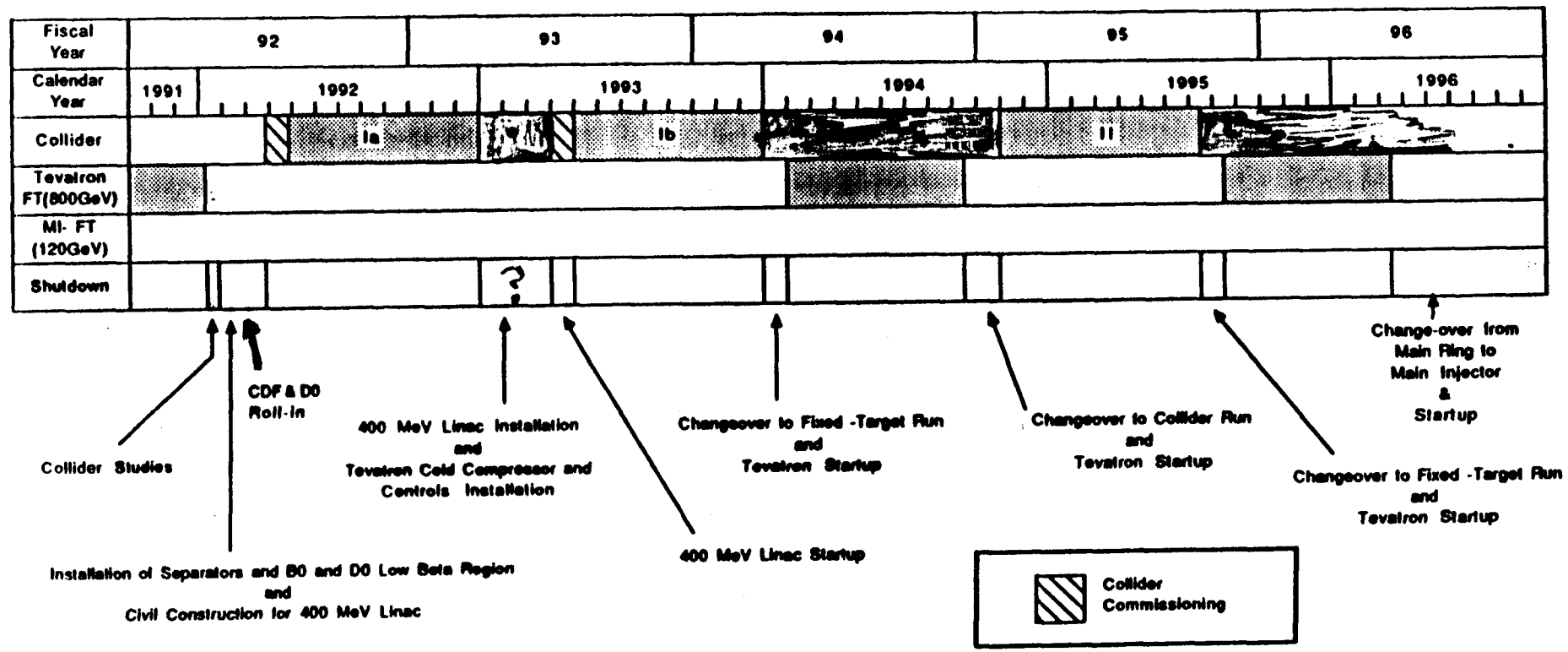
2. IT IS AN EXPENSIVE PROPOSITION TO SET UP A TEST FACILITY

3. ∴ IT SEEMS "OPTIMAL" TO USE FNAL FOR <u>BOTH</u> '93 PROTOTYPE TESTS AND LATER TESTS.

January 1992

# DRAFT LONG-RANGE SHCEDULE

**(For Budget Purpose Only)**



# MAIN RING EXTRACTION @ FNAL?

- V = 19
  LAMBERTSON/SEPTUM @ A0
- B1 → B2 IN OVERPASS ALREADY
  ⇒ NEED 3" x 5" IN OVERPASSES
  - NON PLANAR MACHINE -
  VERTICAL APERTURE RESTRICTIONS

≤150 GeV

LOW INTENSITY, NEED ℓ? TERTIARY BEAM

NEEDS A FEASIBILITY STUDY
IN ACCELERATOR DIVISION

ADVANTAGES:

TEST BEAM @ FNAL IN '94
ANYWAY - SET UP ONCE

CERN COSTS (TRAVEL, INFRASTRUCTURE)
CERN CHARGES (?)

NO ROLLOUT OF CDF 100

GEM AND SDC HAVE BEEN ASKED FOR REQUIREMENTS FOR THE NEXT FIXED TARGET RUN

# Letter of Intent*

for the

# Test of Prototype Detectors for the SDC**

at Fermilab

September 1990

** Listing of SDC members in Appendix A

*Correspondents: J. Bensinger
(617)647-2835
BENSINGER@BRANDEIS

D. Green
(708)840-3104
DGREEN@FNAL

WHAT DO CDF AND D~~Ø~~ BEAMLINES COST TO FNAL?

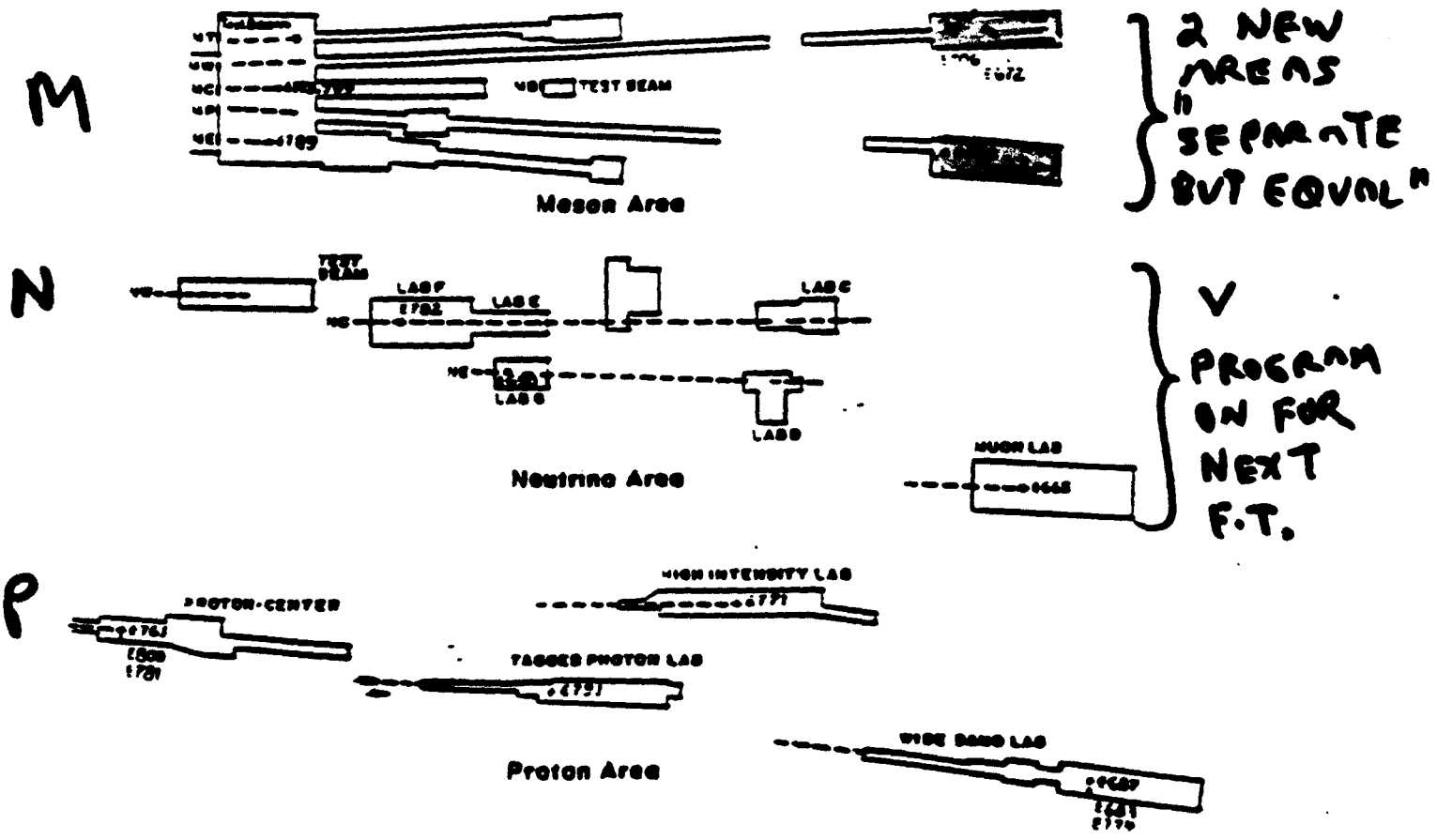
| | Experiment | FY85 | FY86 | FY87 | FY88 | FY89 | Total Costs |
|---|---|---|---|---|---|---|---|
| | E775 (E741)(9/84) | | | | | | |
| MT | Oper | 0.0 | 0.0 | 2.5 | 1.9 | 0.4 | 4.8 |
| | Equipt | 17.1 | 5.5 | 262.0 | 181.9 | 82.0 | 548.5 |
| | MT beamline | • • | 0.3 | 81.2 | 3.0 | 5.7 | 90.2 |
| | Total | 17.1 | 5.8 | 345.7 | 186.8 | 88.1 | 643.5 |
| | E740 (3/88) | | | | | | |
| NWA | Oper | 0.0 | 0.0 | 51.8 | 0.0 | • 153.9 | 205.7 |
| | Cryo OP | 0.0 | 0.0 | 0.0 | 30.6 | 9.4 | 40.0 |
| | Equipt | 0.0 | 0.0 | 158.0 | 99.1 | • 621.1 | 878.2 |
| | Cryo Equipt | 0.0 | 0.0 | 0.0 | 91.7 | 230.8 | 322.5 |
| | NW beamline | 7.2 | 2.5 | 6.9 | 0.1 | 0.0 | 16.7 |
| | Total | 0.0 | 0.0 | 209.8 | 221.4 | 1015.2 | 1446.4 |

GUESS 0.5 M$/YEAR

| | | |
|---|---|---|
| FY90 | E775 | 166. |
| | E740 | 1304. |

WHERE IN FNAL?

UNCLEAR NOW ⇒ SUMMER PAC




*Schematic drawing of the fixed-target experimental areas with locations of major experiments still to be completed. The drawings are not to scale.*

1/22/92
C. HOJVAT

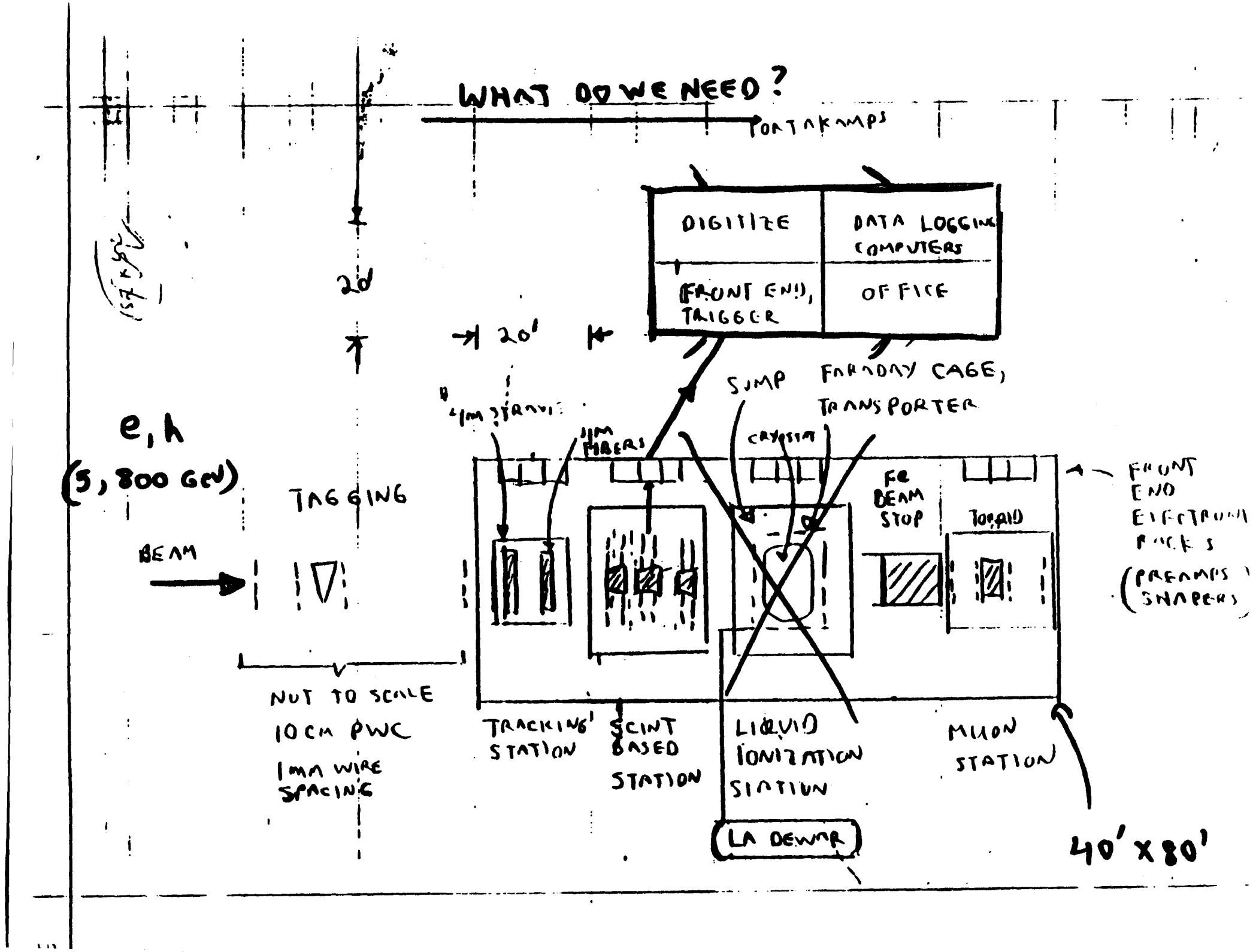
# EXPERIMENTAL HALLS DIMENSIONS AND CRANES

WHERE?

| AREA | LOCATION | DIMENSION | CRANE | TONS |
|---|---|---|---|---|
| | | | | |
| MESON | | | | |
| MDB | DETECTOR BLD. | 133' X 190' | CRANE | 20 |
| ME7 | MESON EAST | | CRANE | 30 |
| MW 9 | MESON WEST LAB | 200' X 63' | CRANE | 25 |
| MP 9 | MESON POLARIZED LAB | 198' X 62' | CRANE | 25 |
| | | | | |
| | | | | |
| NEUTRINO | | | | |
| NWA | OLD MUON | 200' X 40' | CRANE NORTH | 7.5 |
| | | " | CRANE SOUTH | 7.5 |
| LAB E | LAB E & F | 124' X 40' | CRANE | 12.5 |
| NCE | LAB F | 145' X 80' | CRANE HOIST | 7.5 |
| NEE | LAB G | 80' X 50' | CRANE | 20 |
| NMS | NEW MUON | 243' X 83' | CRANE NORTH | 25 |
| | " | " | CRANE SOUTH | 25 |
| | " | " | CRANE HOIST | 7.5 |
| NCH | LAB C | 110' X 40' | CHAIN HOIST | 2 |
| | " | " | MONORAIL | 7.5 |
| NEH | LAB D | 64' X 46' | CRANE | 5/5 |
| | | | | |
| | | | | |
| PROTON | | | | |
| PC4 | PROTON CENTRAL LAB. | 176' x 36 | CRANE | 10 |
| TPL | TAGGED PHOTON LAB. | 158' X 36' | CRANE | 10 |
| HIL | HIGH INTENSITY LAB. | 226' X 30' | CRANE | 20 |
| PB7 | WIDE BAND LAB. | 224' X 34' | CRANE SOUTH | 15 |
| | " | " | CRANE NORTH | 15 |
| | | | | |
| CDF | | | | |
| AH | CDF ASSEMBLY HALL | | CRANE | 50/10 |
| | | | | |
| D0 | | | | |
| D0 HALL | DO EXP. HALL | | CRANE | 15/15 |

D0-

CDF?


WHAT DO WE NEED?
PORTA KAMPS
DIGITIZE
DATA LOGGING COMPUTERS
FRONT END, TRIGGER
OFFICE
20'
20'
SUMP
FARADAY CAGE, TRANSPORTER
e, h
(5,800 GeV)
TAGGING
BEAM
1mm FIBERS
CRYOSTAT
Fe BEAM STOP
TOROID
FRONT END ELECTRONICS PACKS (PREAMPS SHAPERS)
NOT TO SCALE
10 cm PWC
1mm WIRE SPACING
TRACKING STATION
SCINT BASED STATION
LIQUID IONIZATION STATION
MUON STATION
LA DEWAR
40' x 80'

PRESENTATION BY:

JIM SIEGRIST

1-23-92

Siegrist
Mon pm

# 14. SDC Test Beam Needs

## 14.1 Requirements

### 14.1.1 Introduction and Basic Assumptions

Experience with detectors at hadron Colliders at Fermilab and CERN has shown that the calibration beam needs of the SDC will be substantial. We anticipate that the SSC Laboratory will have at least one calibration beam dedicated to SDC for a period starting several years before and extending to several years after first collisions. In addition, beam time will be needed for prototype and initial production tests at other labs, before beams will be available at SSC. We plan for low energy beams (1-200 Gev) from the Medium Energy Booster (MEB) to be available for system verification and calibration. Beam (2 TeV) from the High Energy Booster (HEB), if available, will be used primarily for detector calibration and response studies. Testing needs are driven by the overall detector schedule, and the need to carry out checks of subsystem performance with beam at various stages of design and construction. The next sections outline the testing needs by subsystem, and the beam and hall parameters required to meet the needs. Section 14.2 describes the proposed test plan and its cost.

### 14.1.2 Detector Schedule Overview

The overall detector schedule has been described in section _____. The schedule is driven by the underground installation activities. Figure 14.1 shows the schedule of underground installation activities. Muon system work begins first and finishes last. The calorimeter surface work is to be completed in 1997 and the assembly lowered into the underground hall. Tracking systems are to be installed in 1998. For each subsystem, fabrication of components must be completed in order to meet the required underground assembly schedule. Various levels of test will occur throughout component design, fabrication, and installation. Those tests that require particle beams to carry out can be somewhat arbitrarily divided into prototype tests, pre-production tests, production verification tests, and detector calibration and response studies. The needs for such testing and calibration work depend on the individual subsystems, as outlined in the next section.

### 14.1.3 Testing Needs by Subsystem

- Calorimeter

The calorimeter systems will require the most extensive and elaborate beam tests. Figure 14.2 shows an overview of the calorimeter construction and installation schedule.

Experience with large, multi-purpose detectors at high-energy hadron colliders has shown that the calorimeter is an essential part of nearly all physics measurements of high transverse momentum processes. These processes are characterized by the presence of high Pt jets, leptons, (electrons, muons, taus), and/or neutrinos detected by the

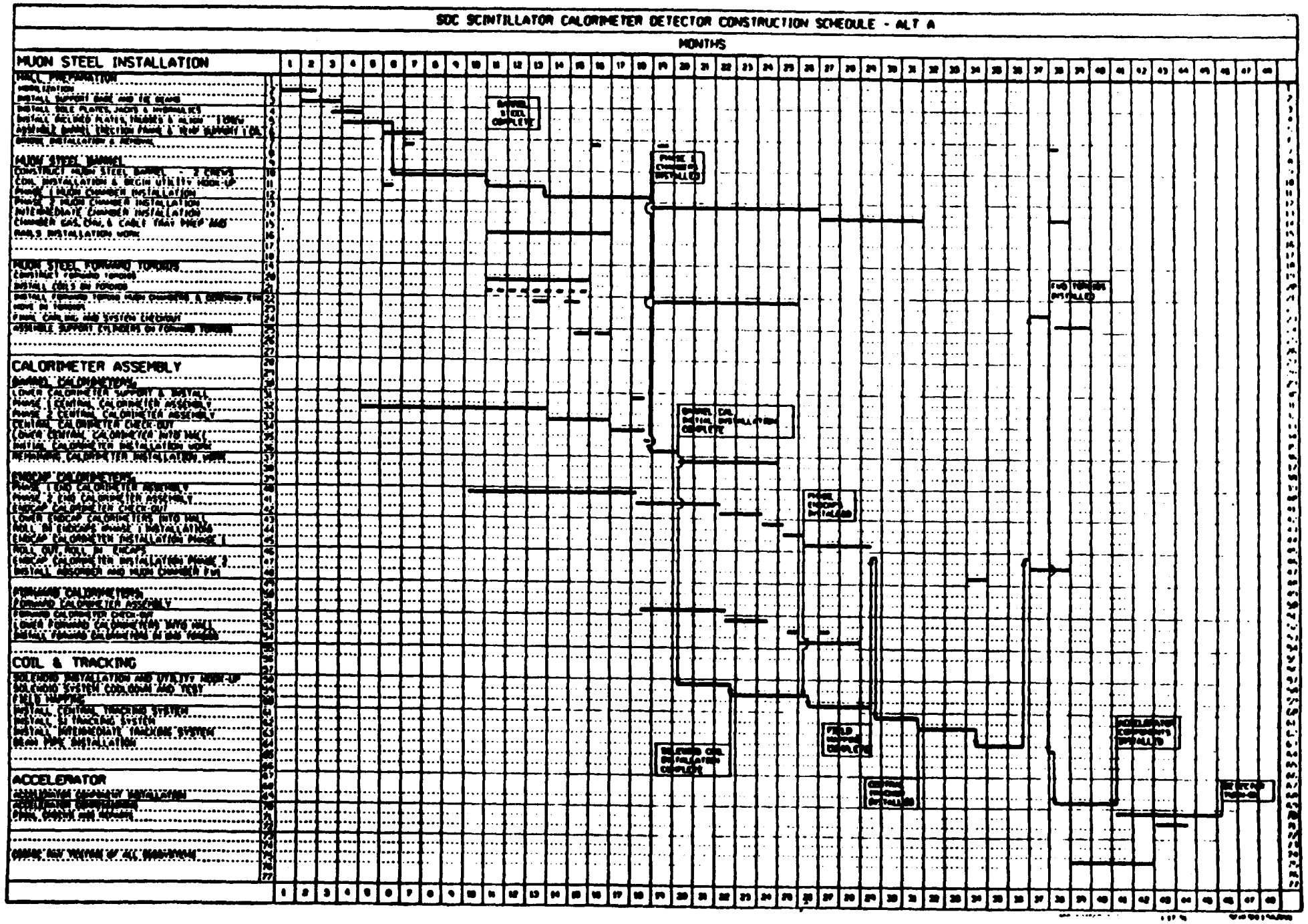



Figure 4. Construction schedule for the SDC detector.

# SDC Calorimeter Preliminary Schedule

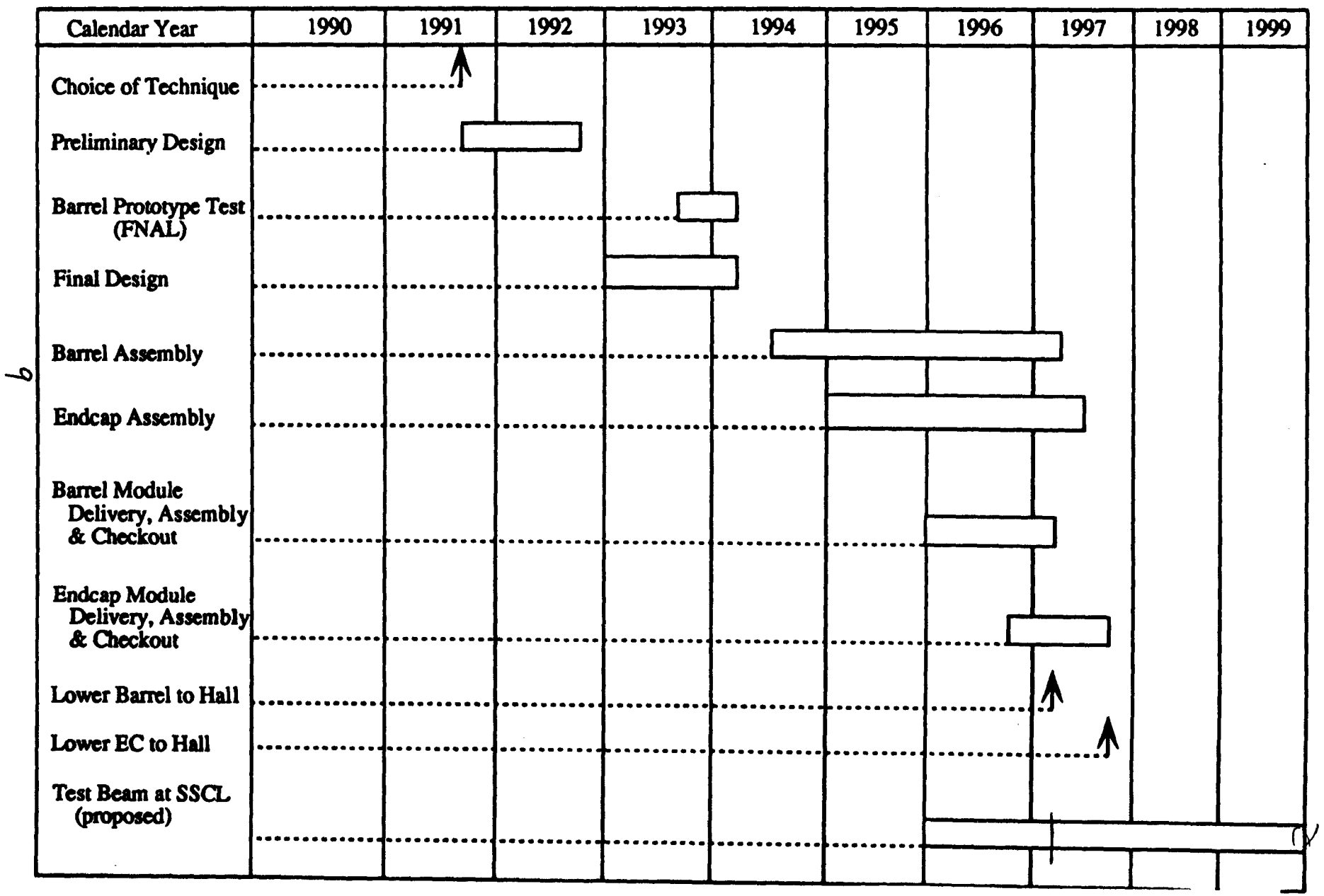



Figure 2. Preliminary schedule for the SDC calorimeter design, construction, and

technique of missing transverse energy). The calorimeter is central to the identification and measurement of jets, electrons, and neutrinos and is of lesser, but not insignificant, importance in the identification of muons and taus.

Most QCD cross sections are steeply falling functions of the jet energy. This implies that relatively small errors in the jet energy scale correspond to fairly large errors on the cross section. This can be particularly important for looking for evidence of quark substructure as signaled by an increase in the rate of production of very high transverse energy jets.

The ability to identify neutrinos via the missing transverse energy of events is totally dependent on the calorimetry. Module-to module errors in the calibration lead to increased fluctuations in the missing transverse energy, although it is difficult to quantify the impact on physics since it depends on the physics process and on the algorithm for calculating missing transverse energy )for example, whether clustered or unclustered energy is used).

Many important physics processes at the SDC will be studied via their production of high Pt leptons. We mention just a few here, namely, production of a high-mass Higgs, production of a low-mass Higgs, and production of a high-mass Z'.

The primary objective of the SDC program is the study and understanding of Electroweak symmetry breaking. A crucial part of this is the search for the Higgs particle postulated by the Standard Model. If the Higgs exists and is sufficiently massive, then its primary decay is into a pair of intermediate vector bosons (WW or ZZ), of which the Z-pair mode with the Z's decaying to leptons is thought to be the cleanest discovery channel. Obviously, measurement of leptons is crutial here, with the main requirement being that the resolution on the Z mass be of the order of the Z width or better so that separation of Z's from the background is not compromised. This is a relatively modest requirement.

If the Higgs mass is low, then its decays are complicated and usually contain heavy quarks or taus. Separation of these modes from QCD backgrounds is very difficult, so that it is thought that the primary discovery channel would be decay to a pair of photons. It is imperative in this case to have good energy resolution in the EM calorimeter so that a narrow Higgs can be identified in the presence of a substantial continuum background.

If a Z' is discovered, it will be essential to measure its width. The calorimeter resolution for high energy electrons must be sufficient so that the mass resolution does not compromise this measurement.
Consideration of the physics processes above and others has led the SDC collaboration to require that the energy resolution of the EM calorimeter have a stochastic term that is 15% or less and a constant term that is 2% or less (the energy resolution is a sum in quadrature of a constant term and a stochastic term that varies as the inverse of the square root of the energy). Also, it is required that the hadron calorimeter have a stochastic term of 60% or better and a constant term of 4% or less.

There are several contributions to the constant term in the energy resolution. One of these is a module-to module variation in the energy scale. SDC intends to have an extensive source monitoring system on each module which may be able to determine the energy scale sufficiently well. However, there is at present no proof that this will work, and there will be no proof until a significant fraction of the production modules have been studied in a test beam. For the EM calorimeters, there will be an *in situ* calibration using inclusive electrons and/or electrons from Z and W decays. This calibration will take time, meaning that the performance of the calorimeter will be compromised initially unless a separate calibration is done. Calibration *in situ* of the hadron calorimeter to the required precision is much more difficult.

Some of the contributions to the constant term are intrinsic to the calorimeter modules, such as transverse and longitudinal spatial nonuniformity. We feel it is important to measure these contributions on the production modules as part of the quality assurance that they meet the design criteria. The energy resolution for electrons and hadrons as a function of energy is shown in Figure 14.3. As can be seen, in order to separate a constant term of the magnitude of interest from the stochastic term, it is necessary to measure the resolution at a sufficiently high energy. For electrons, this implies an energy of at least 50-100 GeV. For hadrons, a 200 GeV beam is minimal. Furthermore, in order to feed back to the production-line techniques in case of problems, it is necessary to do this testing as the modules are constructed.

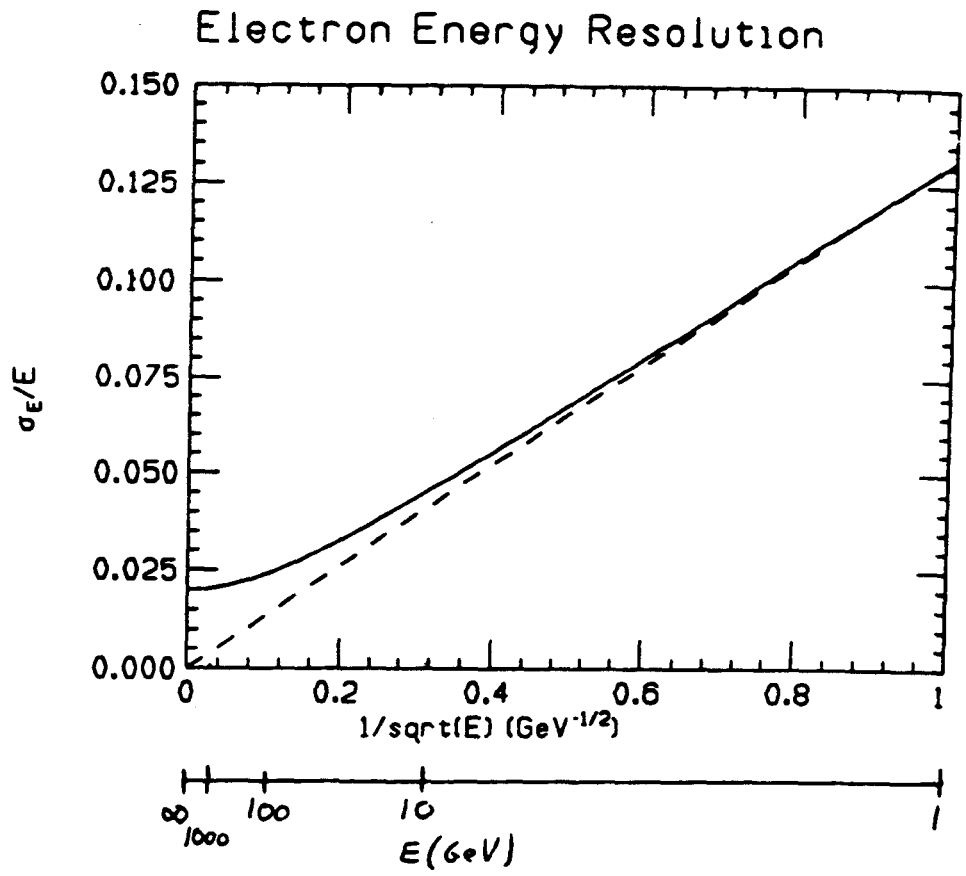
For low energies, the energy resolution becomes sufficiently broad that many particles are required to accurately determine the mean response, making the systematic study of problems very difficult. This is particularly a problem for hadrons, where the resolution is greater.

Since we are aiming for a 1% calibration, the effects of material in front of the calorimeter can be significant for low energy beams. Figure 14.4 shows this effect in a simulation for a liquid argon module. Although the material is significantly more than we would have for the test beam (although we may want to emulate the 1 radiation length coil), the figure illustrates the effect. This further emphasized the need for high-energy calibration beams.

It is very useful to have muons as a check on the calibration. Muons are minimum ionizing throughout the calorimeter, giving signal levels that are straight-forward to relate to first principles. Also, the signal from muons is sensitive to variations in scintillator thickness and light production but is insensitive to variations in absorber thickness, allowing a separation of these effects that is not possible with electrons or pions.

In conclusion, we prefer electrons of 150 GeV or greater to calibrate and test the EM calorimeter, but 50-100 GeV may be adequate. We also require hadrons of at least 200 GeV in order to calibrate and test the hadron calorimeter. As a cross check, we require muons (these may be mixed with the electron and/or pion beams).

Once the SDC calorimeter has been assembled, we will continue detailed studies of spare calorimeter modules in the test beam to understand questions of spatial uniformity, response near cracks, energy linearity, energy leakage, energy resolution, position resolution in the shower max detector, etc. This ongoing program will need



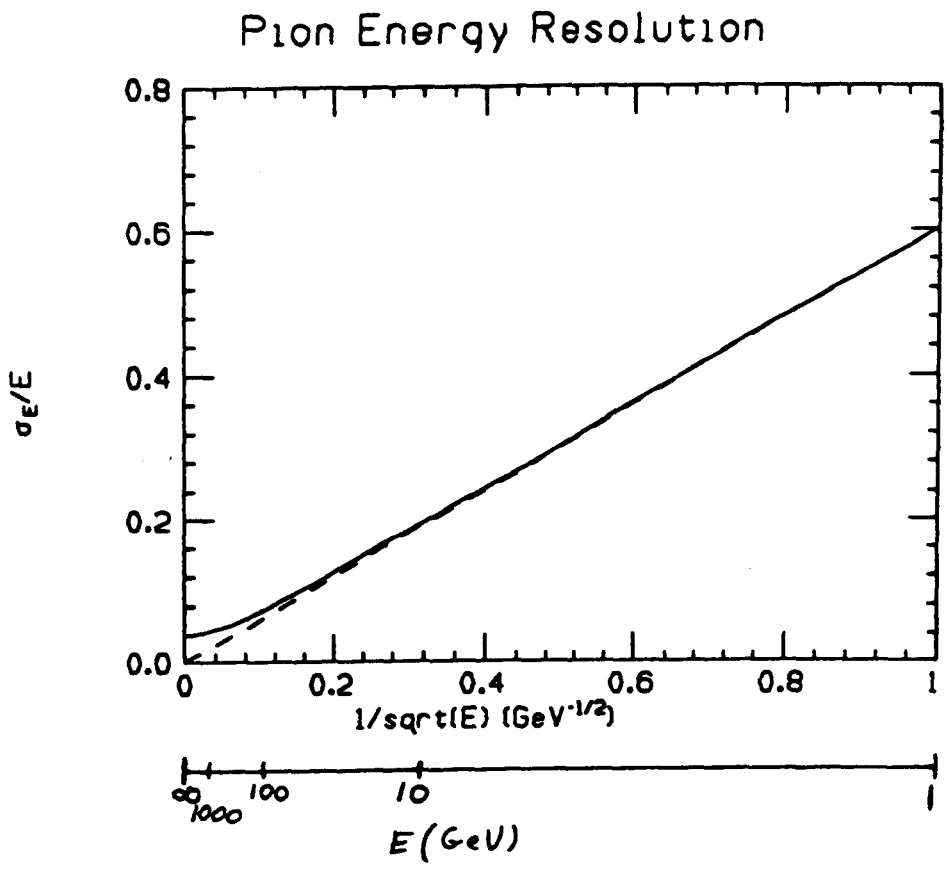




Figure 1. Energy resolution as a function of the particle energy for (a) electrons and (b) hadrons. For electrons, the resolution is a 2% constant term added in quadrature with a 13% stochastic term. For hadrons, the constant term is 4% and the stochastic term is 60%.

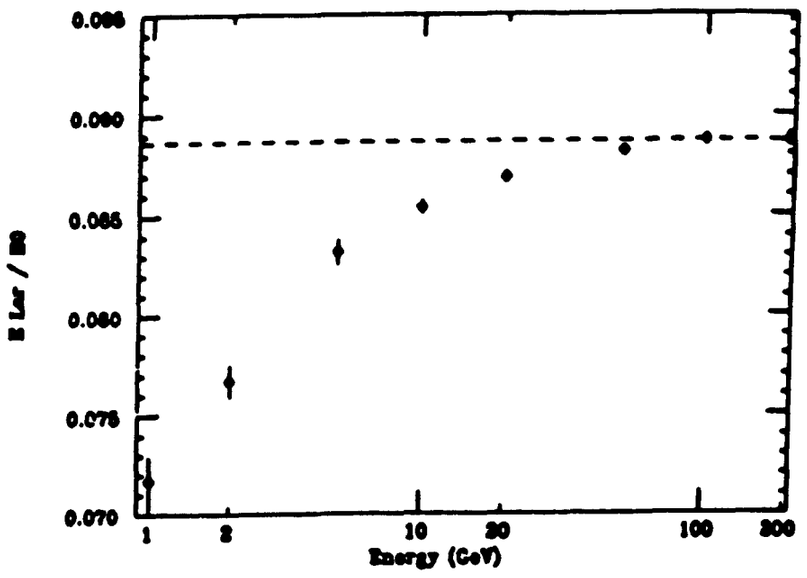



Figure 2. Fraction of total energy deposited in the liquied argon vs incident energy, with no massless gap correction. Total energy is incident energy less leakage (~0.5%). The amount of material in front of the calorimeter is 2 $X_0$.

higher energy beams (several hundred GeV) in order to study the linearity of both the EM and hadron calorimeters and to accurately measure the constant term in the hadron energy resolution.

The above considerations and a look at the assembly schedule shown in Figure 14.1 leads to a calorimeter testing schedule with the following elements:

Prototype test, 92-93
Preproduction tests, 93-96
Production verification/calibration, 96-97
Response studies, 97 and beyond

Exact running times for such tests are to be determined later, but a minimum testing period can be expected to be on the order of three months, based on past calibration and test experience at FNAL and CERN. More details on the beam requirements are discussed in the next section.

- Tracking Systems

Two types of tracking system tests and measurements are anticipated at this time. One would use a low intensity direct beam through the tracking detectors to measure their resolution and double hit separation capabilities. A test beam with precise knowledge of the particle trajectories is essential for these measurements. Of course, simulations can and will be done, but the measurements cannot be eliminated if there is to be no doubt that the tracking system will work correctly and on schedule. All three types of particle tracking detectors can be tested at the same time; that is, the silicon devices, the straw tubes and the scintillating fibers. An upstream beam telescope comprised of silicon strips is required to define the particle trajectories to better than 5 mm. The beam spot over which the particle trajectories are distributed should measure about 2 cm in both transverse dimensions and the divergence should be less than about 2 milliradians. A rotating table would put the particles through different regions of the detectors at different angles to check resolution as a function of those two variables.

The second type of tracking system measurement is intended to test the high rate capabilities of both the tracking devices themselves and the track recognition hardware which must be included in either the first or second level trigger. For this, it is desirable to have an intense radiation flux, but one that is spread out over as much of the area of the detectors as possible. This will approach the distribution of particles in the tracking region of the SDC detector. A target can be placed in the beam at some upstream point and the energy of the beam can be run at a moderately low energy where the particle flux becomes less highly collimated, but still there is a high multiplicity of produced particles. An adaptable mounting and moving mechanism would allow the flux to pass through the tracking devices in ways to match the typical trajectories in the SSC. The rotating table could be fitted with various mounting fixtures and linear translators and lifters to change the configurations with minimal access to the beam line. Beam quality here is not an issue, but the beam intensity must be on the order of 50 MHz.

No extensive calibration and response runs are foreseen to be needed at this time. Thus, we expect tracking prototype testing in 1993-95, and preproduction tests in 1997.

- Muon Systems

Requirements for muon tests are very similar to those for tracking. Again, high rate and multi-track resolution studies require beam time. The bulk of the muon tests are foreseen to be made in a series of cosmic ray tests that rely on various alignment system test stands through the design and production cycle. Muon tests can be mounted during the calorimeter and tracking system tests.

- DAQ/Trigger

Data acquisition and trigger system tests, especially at high rate, are planned to be made with the calibration beams. Large scale tests of these systems will occur in the 1996 time frame, when production calorimeter modules become available. Earlier prototype tests will occur in conjunction with the prototype calorimeter and tracking tests.

### 14.1.4 Required Beam Parameters

Two important issues to be addressed in calibration beams then are lepton identification (both electron and muon), and jet energy measurement and resolution. For leptons, the full energy range available will be studied. Jets are a collection of low energy hadrons; thus, careful measurement of the calorimeter response at low energies is important. Jets up to 10 Tev will be produced in the first year's exposure at SSC. Since the mean momentum fraction carried by the fragmentation products of such jets is n.2, pions with momentum of 2 Tev or so are appropriate for study. As with the leptons, pion beams of the highest available energy will be required for study. To provide the required dynamic range in beam energy, facilities that can target 200 Gev from the MEB, as well as the 2 Tev beam from the HEB, will be needed.

To study lepton identification the beams should transport the highest possible energy, with fluxes of 100 to 1000 Hz for each particle type (electron, muon, pion) at that energy. The minimum flux at which useful data can be taken is about 1 Hz. In addition, for calibration of the beamline components, the magnets should be able to transport particles up to the fully energy of the primary beam. For hadrons, most studies will need fluxes similar to those given above for lepton studies, except when studying issues of pileup. For this, fluxes of $10^7$ per pulse will be needed. For a 100 GeV electron beam with a flux of $10^7/cm^2/sec$, an electromagnetic calorimeter will receive a dose at shower maximum of $10^3$ rad/sec or a Mrad in 1000 seconds of exposure.

Since the resolution expected for the Em calorimeter is $15\%/\sqrt{E} + 1\%$, absolute momenta should be known better than .3% and relative momenta (given by the beam tagging system) should be known to better than .05%. Since the $e/\pi$ separation in the calorimeters is expected to be in the 100 to 1000 range, the beam particle types should be identified to better than 1000:1. In particular, the misidentification of pions as electrons should be below this

level. This means that particle rejection equal to 1000 divided by the fraction of the desired particle in the beam will be required.

For muons, studies are made of how often pions look like muons in the detector, either by not interacting or via hadronic shower punch through. Again, the misidentification of pions as muons should be below 1000:1. During calorimeter calibration there should be no muons in the calorimeter in the measurement time window. This can be achieved by using a veto counter to reject any muons entering the calorimeter just before or after the beam particles pass through. If during low flux operations of the beams, the muon fluxes are less than 150 KHz/m$^2$, this procedure will not incur substantial dead time. Beam requirements are summarized in Table 14.1.

Table 14.1 Calibration Beam Requirements

A. Lepton ID
   1. beams of highest possible energy at 100 Hz of $e,\mu,\pi$
   2. particle ID 1000:1
   3. energy resolution absolute 1/3%
      relative .05%

B. Hadron Response/Calibration
   1. beams in 1 to 200 GeV range
   2. flux to $10^7$/sec
   3. particle ID 1000:1

C. Stray muon flux in detector hall < 150 KHz/m$^2$
   Summary of calibration beam requirements

### 14.1.5 Required Support Facilities

The general requirements for the test stands are that they move to cover the full range of particle angles that a particular type of detector might see in the actual experiment. Further, the stands should retract from the beam line while not being tested so that components in downstream positions may be tested. To calibrate the calorimeter energy response over the entire detector, there must be a sufficient portion of the calorimeter available to test so that all particle trajectories can be simulated with the beam. The calorimeter will be mounted on a table with sufficient degrees of motion to allow the beam to go directly down each tower in the calorimeter.

To calibrate the forward calorimeter requires a smaller range of motion so it can be mounted on rails with jacks to give the correct position. The forward calorimeter is placed so that it and the endcap test module can have the correct orientation to study the transition between the central and forward calorimeter.

A muon chamber stand is located behind a block of iron so that energy losses by high energy muons are properly simulated. The chamber is mounted on rails so that one can scan the entire length of the chamber. It can also be rotated so that particles traverse the chamber at the correct angle.

The tracking chamber stand, located in front of the calorimeter, can be used as a general purpose stand for whatever small testing needs arise.

A total floor space of about 40' (transverse) by 120' (along beam) appears to be adequate for SDC needs. A control room roughly the size of four Fermilab trailers (12' x 80') should be adequate. Many services will be required. Rigging of full scale calorimeter modules will be needed. Crane coverage of 50T appears adequate to the task. Survey will also be periodically needed. Consumables for the various detectors are another obvious necessity. Wire tracking systems will need gases, mixing stations and exhaust systems.

Since we foresee to perform the initial acceptance and testing of calorimeter modules at the calibration hall site, considerable floor space, enough to accommodate some 20% of the modules, will be needed outside the beamline area for module testing and repair. The climate should be controlled in this area.

## 14.2 Implementation Plan

### 14.2.1 Proposed Test Plan

The possible test beam sites are determined by many requirements. These include the beam energy and type requirements and the schedule requirements given above. In addition, there are other considerations affecting the choice of site.

It will be necessary to eventually have test beam facilities at the SSC Lab to do the ongoing, long term study of the calorimeters necessary to maximize their performance and hence maximize the physics output of the detector.

If the calibration is not done at the SSC Lab or at Fermilab (assuming that is where the modules are assembled), then there will be additional shipping of the modules. This may not be trivial or inexpensive since modules are heavy (32 tons each) and may be relatively fragile (they contain a large number of delicate optical fibers). In addition, each module has a fairly high dose source (probably Co-60 or Sr-90) attached to it. Restrictions on shipping these sources, particularly overseas, may lead to delays. In general, it would be wise to limit the amount of transportation of these modules as much as possible. Overseas sites have the additional problem that close and timely communications of needs and results is difficult.

In addition to the general consideration such as diverting money and manpower, shipping, etc., we now consider various specific sites:

BROOKHAVEN-Beam energies are too low. It is not clear what beam availability might be in 1996.

SLAC-Pion beam energies are too low. It is not clear whether SLAC will be running test beams in 1996.

ACCELERATORS IN RUSSIA-Beam energies are too low. Long term schedules are uncertain. Currently, there is no Russian interest in the SDC calorimeter group.

CERN-Cern has the required beam and it is likely that they will be running at the appropriate time. However, there are the problems of shipping and of being so far from the production line.

FERMILAB-Fermilab also has the required beams, but it is not clear the the lab will be running fixed target mode at the appropriate time, particularly given that the highest priority at that time will be the Tevatron collider.

SSC LAB-The test beams from the MEB would be adequate for initial calibration, but the current schedule has them turning on too late. It might be possible to get test beams from the LEB, but the beam energies would be too low.

We plan to invest in test facilities for use of SDC at FNAL and SSC Lab. Once beam becomes available, we intend to carry out our test activities primarily at SSC Lab. For earlier periods when beam is not available at FNAL, tests will have to be conducted at CERN, or the scope of the tests restricted in order that they may be mounted elsewhere.

### 14.2.2 Schedule for Tests

We plan to mount the beam tests for all subsystems during periods when beam is needed for calorimeter tests. The 92-93 prototype tests are planned for a 3 month run at FNAL or CERN. The preproduction tests in the 93-96 time period are to be carried out during two or three three-month running periods at FNAL the remainder of the studies will be carried out at SSC Lab, depending on beam availability.

### 14.2.3 Costs

Cost estimates to carry out beam test activities are included in the overall detector costs. These estimates include costs for fixturing, test beam DAQ systems, and the direct test operations of the systems under test. Costs for test not at SSC Lab (offsite beam tests) have been estimated and included. No costs for actual beam operations have been included, as those costs are expected to be covered elsewhere. Costs incurred before calorimeter installation in the hall are tabulated separately from those incurred during the calorimeter response studies before collider operations. Table 14.2 tabulates the results.

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BY: FSS

12/6/91

Example

## SDC TEST BEAM PROGRAM

## ESTIMATE SUMMARY

| | | BASE K$ | CONTINGENCY 20% | TOTAL K$ |
|---|---|---|---|---|
| 8.1.1 | FIXTURING | 1,383 | 277 | 1,659 |
| 8.1.2 | DAQ SYSTEM | 6,500 | 1,300 | 7,800 |
| 8.1.3 | TEST OPERATIONS | 468 | 94 | 562 |
| 8.1.4 | OFF-SITE BEAM TESTS | 3,905 | 781 | 4,686 |
| | SUB-TOTAL | 12,256 | 2,451 | 14,707 |
| 8.1.5 | PRE-OPS RESPONSE STUDIES | 3,128 | 626 | 3,753 |
| | TOTAL FOR TEST BEAM PROGRAM | 15,383 | 3,077 | 18,460 |

Table 14.2 Summary of Beam Test Costs

PRESENTATION BY:

DAVE ETHERTON

Etherton
Moniam



## Conventional Systems
## WBS 7

- **WBS Totals:**

| Current | TDR | |
|---|---|---|
| $13.4M | $11.5M | Base |
| 3.6M | 3.5M | Contingency |
| $17.0M | $15.0M | Total |

- 7.1 Mechanical Systems = $2.5M
  - 7.1.1 Deionizing Station
  - 7.1.2 HTLCW System
  - 7.1.7 Detector Duct Work
  - 7.1.5 MCHW System
  - 7.1.3 LTLCW System
  - 7.1.10 Detector Venting Systems

- 7.2 Electrical Systems = $2.7M
  - 7.2.1 400 Hz Power
  - 7.2.2 Cable Trays
  - 7.2.3 60 Hz Distribution Power
  - 7.2.4 Grounding System
  - 7.2.5 IR Region Comm.
  - 7.2.6 Conv. Const. Interface

## Conventional Systems (cont.)

- 7.3 Safety Systems = $5.5M → $3.5M
  - 7.3.1 Oxygen Mngt System
  - 7.3.2 Flammable Gas Mgnt System
  - 7.3.3 Personnel Access Safety System
  - 7.3.4 Emergency Centers
  - 7.3.5 Fire Protection System
  - 7.3.6 Misc Safety System
  - 7.3.7 Safety Systems Control and Integration

- 7.4 Structures and Access = $6.3M
  - 7.4.1 Structural Support for Detector Systems
  - 7.4.2 Detector Access Systems
  - 7.4.3 Mechanical Shops
  - 7.4.4 Electrical/Electronic Shops
  - 7.4.5 Storage Facilities

## Test Beam Program
## WBS 8.1

- WBS Estimate is:

| Current | TDR | |
|---|---|---|
| $8.4M | $8.3M | Base |
| 1.7M | 1.7M | Contingency |
| $10.1M | $10.0M | Total |

- 8.1.1 Fixtures & Facilities = $1.7M
- 8.1.2 Test Beam DAQ = $3.2M
- 8.1.3 SSCL Test Operations = $.6M
- 8.1.4 Off-Site Beam Tests = $4.7M
- 8.1.5 Pre-Operations Response Studies = $0M
- Still need to reallign costs with known activities - set aside

## Installation & Test
## WBS 8.2

- WBS Estimate is:

| Current | TDR | |
|---|---|---|
| $28.8M | $25.0M | Base |
| 3.2M | 5.0M | Contingency |
| $32.0M | $30.0M | Total |

- Takes system components from "Top of Hole" and assembles, installs, integrates, and tests.
- Finishes with commissioning of detector - Ready to receive beam in October 1999.
- Strategy is to identify common facility tasks like crane operators, some riggers, tool crib personnel, clean-up crews, etc. and have those provided by SSCL.

20 people in UG hall X 4 years = Facility Operations Staff

## Project Management
## WBS 9.0

- Current estimate is

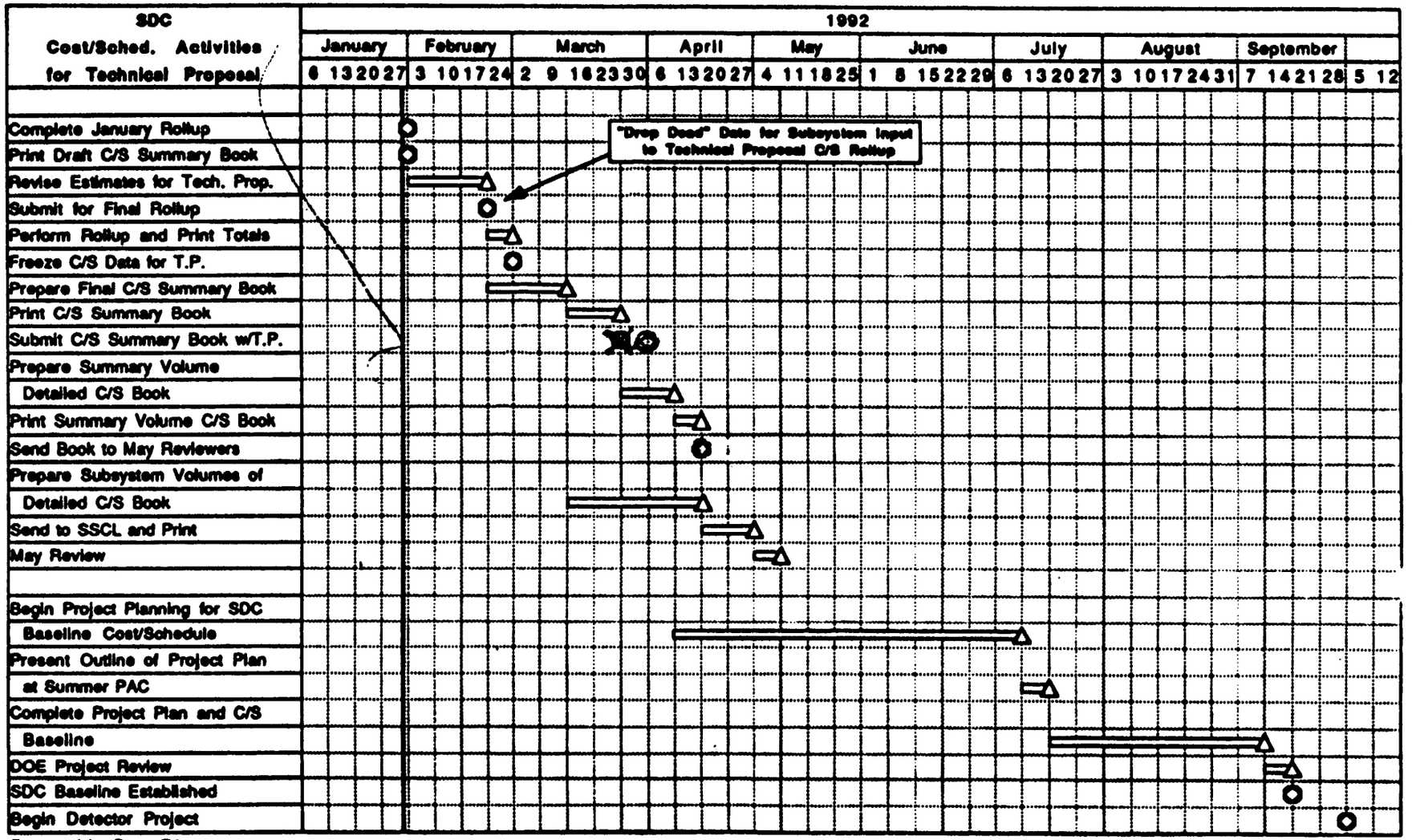
| | | |
|---|---|---|
| $15.8M | $13.7M | Base |
| 4.7M | 4.3M | Contingency |
| $20.5M | $18.0M | Total |

- Defined as overall SDC project management at SSCL and designated institutions supporting total project planning, tracking, administration, coordination, and integration.

- Includes: SDC project manager, chief engineer & staff.
  Project planning, tracking, and reporting.
  Detector integration.

- 30 FTE's x 7 Years = 210 FTE's = $20.5M

  less 2 FTE's x 7 Years = 14 FTE's = -$2.5M




Prepared by Dave Etherton

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