GEM TN-92-238

# Collaboration Council Meeting - Brookhaven National Laboratory

November 3-6, 1992

Abstract:

Agenda and presentations of the GEM Collaboration Council Meeting held at Brookhaven National Laboratory on November 3-6, 1992.

# AGENDA

GEM Collaboration Meeting – Nov. 3-6, 1992

Tuesday Nov 3

Registration — BNL Center
Informal meetings all day
Informal get-together with refreshments 3-8 PM
Dinner on your own
Magnet Meeting - G. Deis - Orange Room - Physics Building

Wednesday Nov 4

| | |
|---|---|
| 7:30 AM | Breakfast and registration - BNL Center |
| | Chairman – Frank Plasil |
| 9:00 | Welcome - H. Gordon/G. Yost - BNL Center - North Room |
| 9:30 | News of the GEM collaboration, plans for Baseline 2 - B. Barish |
| 10:30 | Project Manager's Report and Discussion of TDR plans - G. Sanders |
| 11:00 | Break |
| 11:15 | Status of Simulation Effort - K. McFarlane |
| 5:00 ~~11:45~~ | Tracker status - J. Brau |
| 12:15 PM | Lunch at BNL Center |
| | Chairman – Larry Rosenson |
| 1:15 | Calorimetry status, progress toward TDR in December - W. Willis |
| 11:45 ~~2:15~~ | Magnet status - R. Stroynowski |
| 2:15 | Status of IR5 Facilities - D. Moeller, IR5 Design Manager, The PB/MK Team |
| ~~3:15~~ 2:45 | Break |
| 3:00 | Muon system: V. Polychronakos |
| | F. Taylor, G. Mitselmakher, ~~S. Whitaker~~, L. Osborne, C. Bromberg, C. Wuest |
| | Open discussion - M. Marx moderator (30 min) |
| 5:30 | The Importance of $t\bar{t}$ Associated Production at the SSC - W. Marciano |
| 5:50 | The Search for the Supersymmetric Higgs - A. Stange |
| 6:30 | Adjourn |
| 7:00 | Cocktail Hour at Berkner Hall |
| 8:00 | Dinner Buffet at Berkner Hall |

The simulation/physics group will meet at 2 PM (K. McFarlane/F. Paige, conveners) in Room 2-160 in the Physics Building.
The evening after dinner is also available for groups to meet.

8:45 GEM Software Week (I. Shapiro)
Code Distribution (T. Wenaus)
9:45 TDR Online Software (G. Yost)
Simulation



Thursday Nov 5

| | |
|---|---|
| 7:30 AM | Breakfast at Berkner |
| 8:30 AM | **Subsystem Meetings** |
| 8:30 | Muon subsystem (F. Taylor, convener) - Room B, Berkner Hall |
| | Calorimetry subsystem (W. Willis, convener) |
| | I. Engineering - Instrumentation/Annex |
| | II. Simulation - Small Seminar Room (AM) - Physics Building |
| | II. Simulation - Large Seminar Room (PM) - Physics Building |
| | III. Baseline - Definition - Room 2-160 - Physics Building |
| | IV. Common Meeting - Large Seminar Room - Physics Building |
| | Trigger group (D. Marlow, convener) - Room D, Berkner Hall |
| | Physics/simulation (K. McFarlane, convener) - ~~Room A, Berkner Hall~~ Lunch Room BNL Center |
| | Tracker - AGS (Snyder Auditorium) (C. Baltay, convener) |
| | Magnet - 2-187 - Physics (G. Deis, convener) |
| 12:30 | R. Fischer R&D Lunch - Room A - Berkener Hall |
| 12:30 | Lunch at Berkner Hall |
| 1:30 PM | Continuation of morning groups, plus |
| | TDR planning session (G. Sanders, convener) - Orange Room, Physics Building |
| | To be attended by spokesman, lead authors of each chapter, to discuss TDR. |
| 6:00 | Adjourn |
| 6:30 | Dinner at Berkner |
| 8:00 | Round Table discussion on role of university groups in GEM - |
| | Berkner Hall/Theater(G. Yost, convener; panelists plus audience participation) |
| 9:30 | Adjourn |

Friday, Nov 6

| | |
|---|---|
| 7:30 AM | Breakfast, Berkner Hall |
| | Chairman – George Yost |
| 8:30 | Summaries of Working Groups' Results – Theater |
| | F. Taylor |
| 9:30 | W. Willis |
| 10:00 | D. Marlow |
| 10:30 | Break |
| 10:45 | K. McFarlane |
| 11:15 | C. Baltay |
| 11:45 | Summary of the Meeting - B. Barish/W. Willis/G. Sanders |
| 12:30 PM | Lunch at Berkner Hall |
| 1:30 | Executive Committee - Room C, Berkner Hall |
| | Chairman – Howard Gordon |
| 1:30 | Progress in Technical and Model Building - S. Dawson - Theater |
| 2:30 | Adjourn |

gem

$\gamma e \mu$

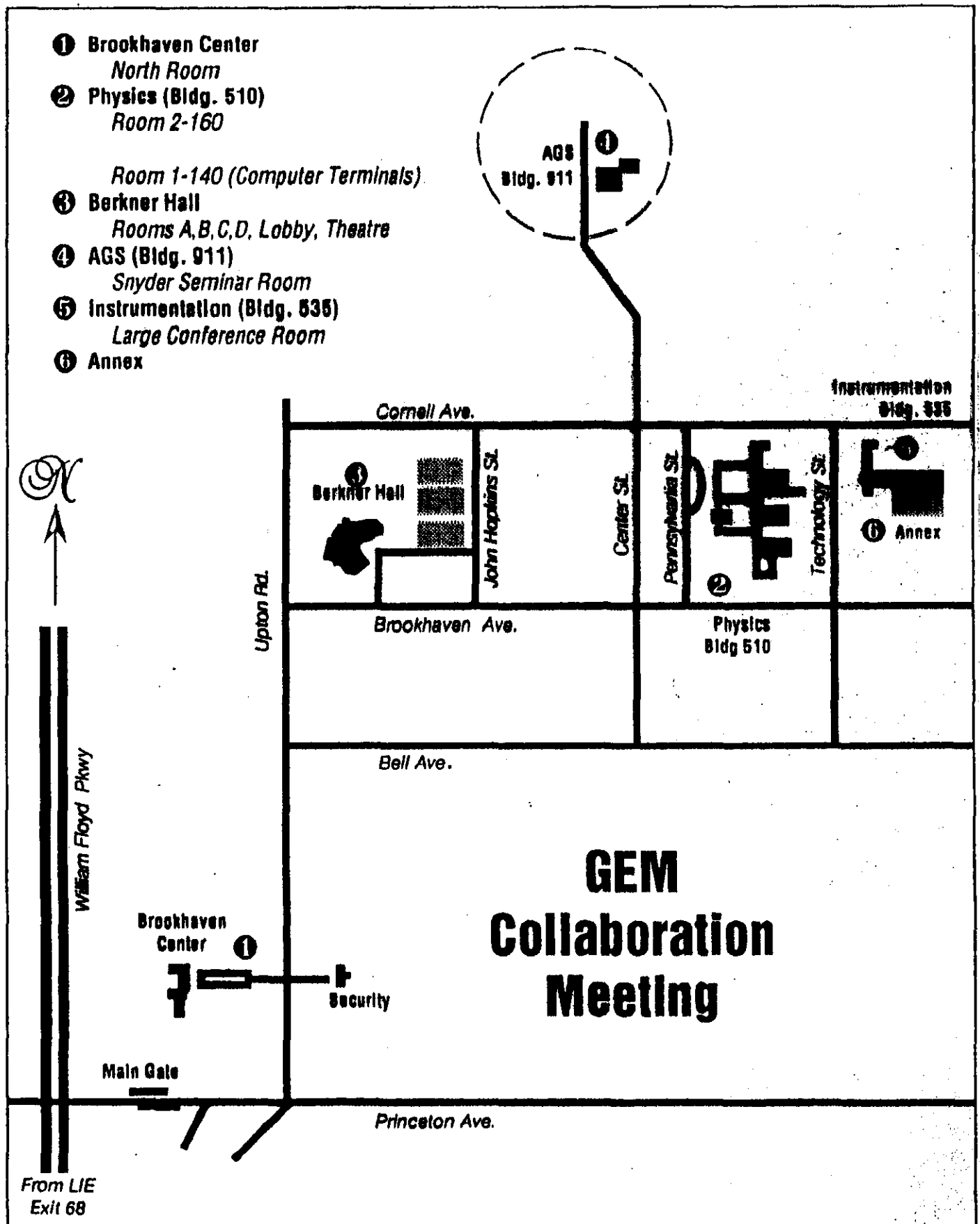
Howard Gordon

George Yost

Welcome

❶ **Brookhaven Center**
*North Room*
❷ **Physics (Bldg. 510)**
*Room 2-160*

*Room 1-140 (Computer Terminals)*
❸ **Berkner Hall**
*Rooms A,B,C,D, Lobby, Theatre*
❹ **AGS (Bldg. 911)**
*Snyder Seminar Room*
❺ **Instrumentation (Bldg. 535)**
*Large Conference Room*
❻ **Annex**




# GEM Collaboration Meeting

information, technology, or Special Nuclear Material; or

- You believe that you may be the target of attempted exploitation (blackmail) by a foreign entity.

E. Travel to a Sensitive Country

Travelers who hold, or have held within the last 5 years, a DOE Access Authorization are required to complete "Request for Approval of Foreign Travel," DOE Form 1512.1, when proposing travel to a sensitive country. This form must be submitted to the Budget Office at least 45 days in advance of the departure date. An Access Authorization is designated as "Q," "L," "Top Secret," or "Secret."

Travelers planning unofficial travel to a sensitive country who hold, or have held, a DOE Access Authorization are also required to submit form DOE F 1512.1 to the BNL Safeguards and Security Division 30 days prior to departure. DOE will not dissuade unofficial travel to sensitive countries unless such travel is judged to endanger the security of sensitive programs or the personal safety of the traveler.

Sensitive Countries include:

Afghanistan
Albania
Algeria
*Andorra
Angola
Argentina
Benin, Peoples Republic of
Brazil
Bulgaria
Burma (Myanmar)
Chile
China, People's Republic of
*Comoro Islands
Cuba
*Djibouti
El Salvador
*Estonia
Ethiopia
*Guyana
India
Iran
Iraq
Israel
Kampuchia (Cambodia)
Korea, North (Democratic People's Republic of)
Korea, South (Republic of)
Laos
*Latvia
Lebanon



Libya
*Mauritania
*Monaco
Mongolia
Mozambique
Namibia
Nicaragua
*Niger
*Oman
Pakistan
Romania
South Africa
Soviet Republics (see below)
Surinam
Syria
Tanzania
*United Arab Emirates
*Vanuatu
Vietnam
Yemen
Yugoslavia

1. The responsibility to notify BNL-SSD of travel to a sensitive country continues for 5 years after a person's Access Authorization is terminated.
2. Travel relating to Taiwan is handled under the policies and procedures which apply to Sensitive Countries.
3. "Soviet Republics" include the republics which constituted the Soviet Union in 1990 (except for Estonia, Latvia, and Lithuania), whether or not now independent or joined in a union with other republics, and any component territories of these republics which may consider themselves independent.

* Countries so marked appear on this list for reasons related to 10 CFR 810, "Assistance to Foreign Atomic Energy Activities." If the subject matter of the travel is not related to nuclear energy, the traveler is not professionally involved in nuclear energy matters in his/her work, and the element of the facility or the people to be visited are not involved in nuclear energy, the country so marked may be treated as non-sensitive for purposes of this particular foreign travel.

## IV. RESPONSIBILITY OF EMPLOYEES NOT POSSESSING ACCESS AUTHORIZATION TO CLASSIFIED INFORMATION

Any employee who does not possess Access Authorization to classified information and who receives or finds classified written material must immediately notify the Security Office. Classified written material may be identified by the official classification marking "Top Secret," "Secret," or "Confidential," which is located on the top and bottom of each page of a document containing classified information. The Security Officer is responsible for reporting to DOE the details of the security infraction.



## V. PRINCIPLES GOVERNING COMMUNICATION OF CLASSIFIED INFORMATION

## Computing at GEM Collaboration Meeting

There are 12 terminals in Room 1-240 in the Physics Building (also 6 phones). Enter by pushing 5-3-1. (May need to do this twice)

The terminals or PC's are on a terminal server

- user > XXX
- local > C BNLCL6
- User: > BNL

This account will give you access to your home system. There are additional terminals in Room 2-84 in the Physics Building.

YOST - Welcome

SPEAKERS - PLEASE ADD COVER SHEET TO YOUR PACKET OF SLIDES AND GIVE THEM ALL TO Jim Reidy

COLLABORATION COUNCIL - NEXT MEETING DEC 10 IN TEXAS.

DUNCANVILLE HOLIDAY INN.

PARTICIPANTS ARE REQUESTED TO REGISTER THERE (WE HAVE GUARENTEED A BLOCK OF ROOMS)

THERE WILL BE A BANQUET THE EVENING BEFORE.

(214) 298-8911 $45/night

(1)

CALL FOR PAPERS TO BE PRESENTED @ COUNCIL.

- GEM - RELATED
- 15-20 MIN FORM FACTOR
- ANYBODY ELIGIBLE

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THURSDAY EVENING (BERENER HALL)

ROUND-TABLE DISCUSSION 8 PM

SUBJECT: THE ROLE OF UNIVERSITY GROUPS IN GEM

PANELISTS + AUDIENCE PARTICIPATION



(2)

# News of the GEM Collaboration, plans for Baseline 2

Barry Barish

B. BARISH

# GEM

## GENERAL COLLABORATION Meeting

NOV 4, 1992

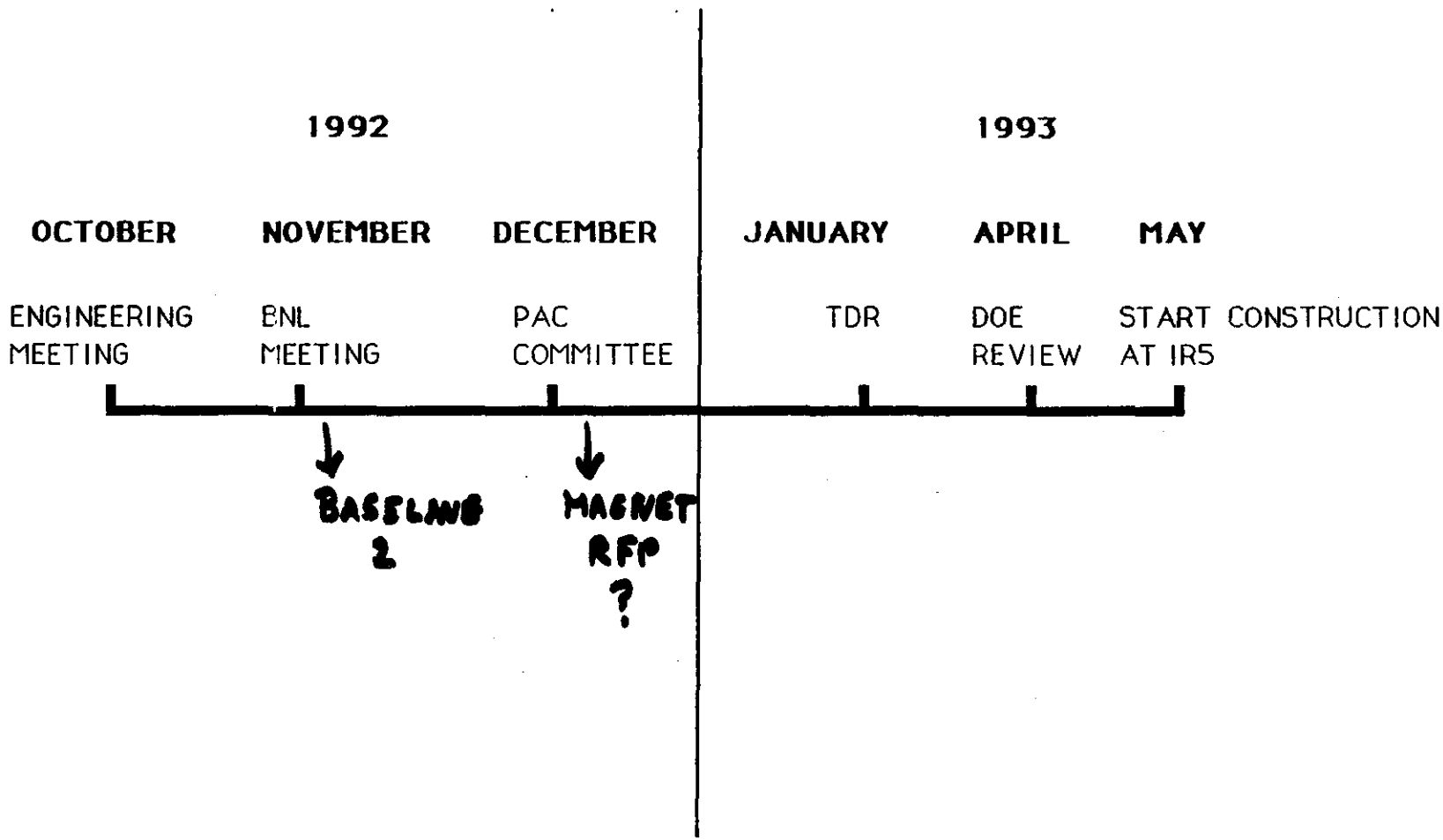
BROOKHAVEN LAB

MARCH '92 TUCSON

: ESTABLISHED BASELINE 1

NOVEMBER '92 BNL

: ESTABLISH BASELINE 2


1992
1993
OCTOBER
NOVEMBER
DECEMBER
JANUARY
APRIL
MAY
ENGINEERING MEETING
BNL MEETING
PAC COMMITTEE
TDR
DOE REVIEW
START CONSTRUCTION AT IR5
BASELINE 2
MAGNET RFP ?

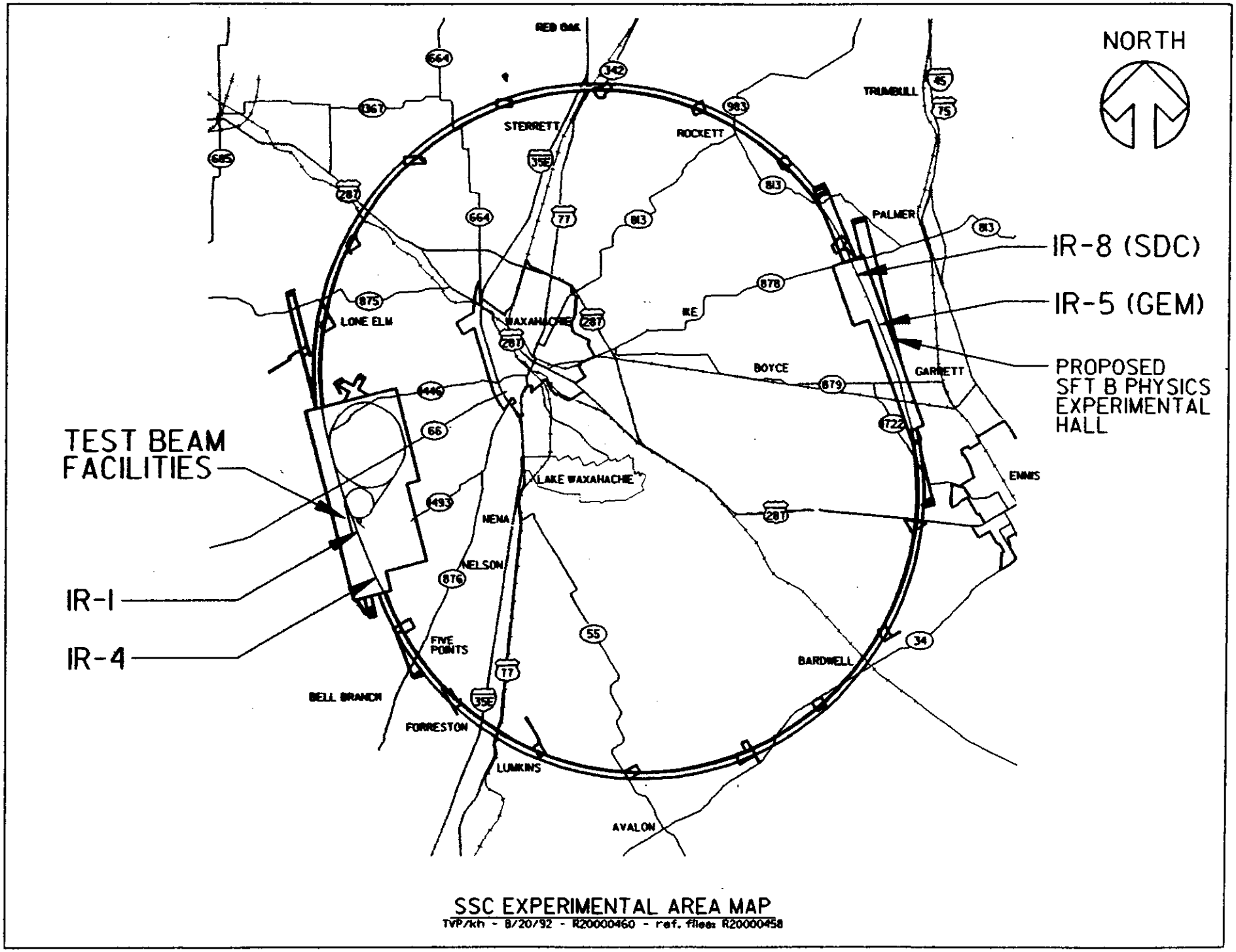
# BASELINE 2
# DESIGN
# as
# of
# NOV 4, '92

# GEM FACILITIES

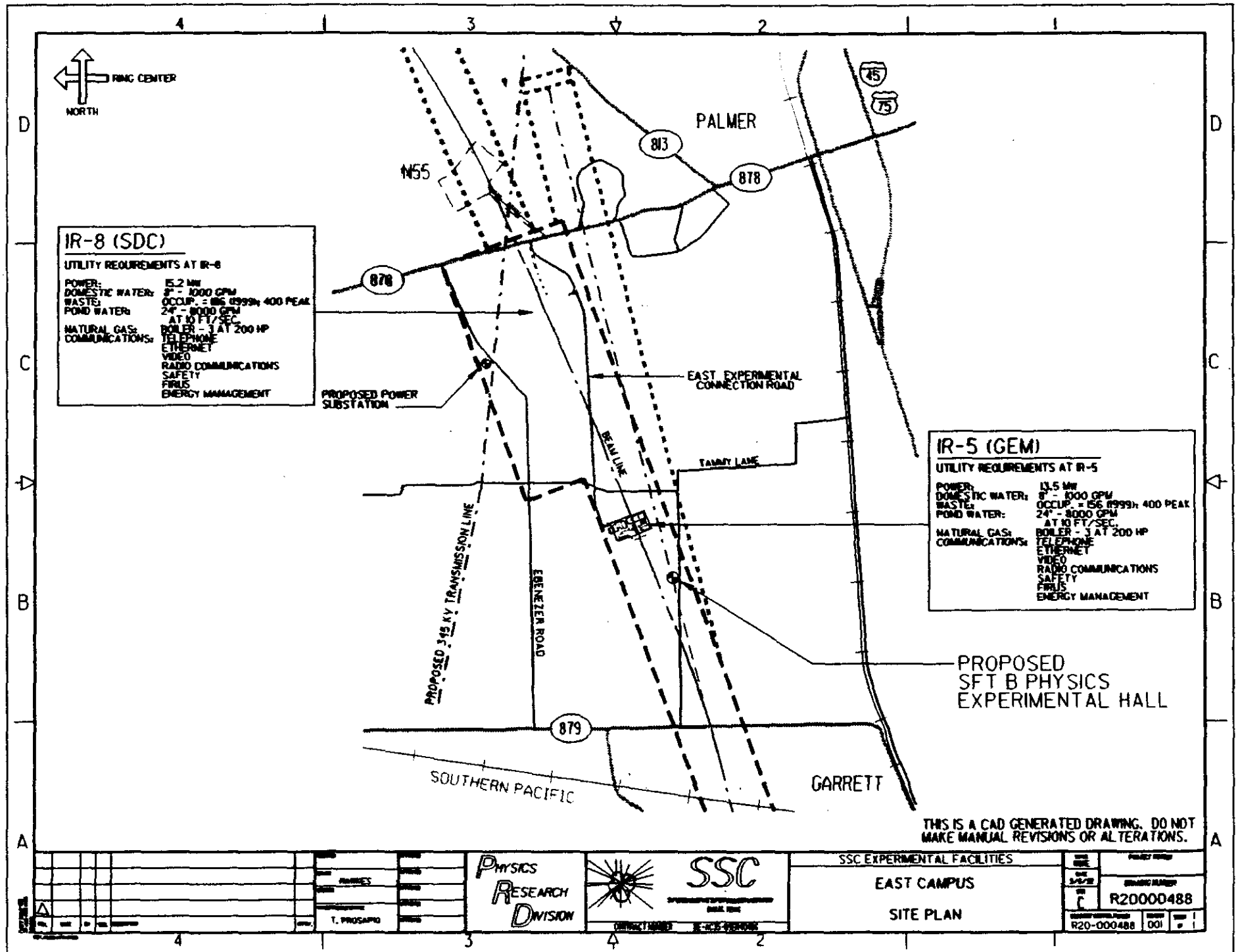
TITLE I

Bill Wisniewski / GEM
Mike Harris

TODAY = D. Moeller
IRS Design Manager
PB/MK




SSC EXPERIMENTAL AREA MAP
TVP/kh - 8/20/92 - R20000460 - ref. files: R20000458


RING CENTER
NORTH
PALMER
N55
813
878
876
45
75
IR-8 (SDC)
UTILITY REQUIREMENTS AT IR-8
POWER: 15.2 MW
DOMESTIC WATER: 8" - 1000 GPM
WASTE: OCCUP. = 186 (1999); 400 PEAK
POND WATER: 24" - 8000 GPM AT 10 FT/SEC.
NATURAL GAS: BOILER - 3 AT 200 HP
COMMUNICATIONS: TELEPHONE
ETHERNET
VIDEO
RADIO COMMUNICATIONS
SAFETY
FIRUS
ENERGY MANAGEMENT
PROPOSED POWER SUBSTATION
EAST EXPERIMENTAL CONNECTION ROAD
BEAM LINE
TAMMY LANE
PROPOSED 345 KV TRANSMISSION LINE
EBENEZER ROAD
IR-5 (GEM)
UTILITY REQUIREMENTS AT IR-5
POWER: 13.5 MW
DOMESTIC WATER: 8" - 1000 GPM
WASTE: OCCUP. = 156 (1999); 400 PEAK
POND WATER: 24" - 8000 GPM AT 10 FT/SEC.
NATURAL GAS: BOILER - 3 AT 200 HP
COMMUNICATIONS: TELEPHONE
ETHERNET
VIDEO
RADIO COMMUNICATIONS
SAFETY
FIRUS
ENERGY MANAGEMENT
PROPOSED SFT B PHYSICS EXPERIMENTAL HALL
879
SOUTHERN PACIFIC
GARRETT
THIS IS A CAD GENERATED DRAWING. DO NOT MAKE MANUAL REVISIONS OR ALTERATIONS.
T. PROSAPIO
PHYSICS RESEARCH DIVISION
SSC
SSC EXPERIMENTAL FACILITIES
EAST CAMPUS
SITE PLAN
R20000488
R20-000488
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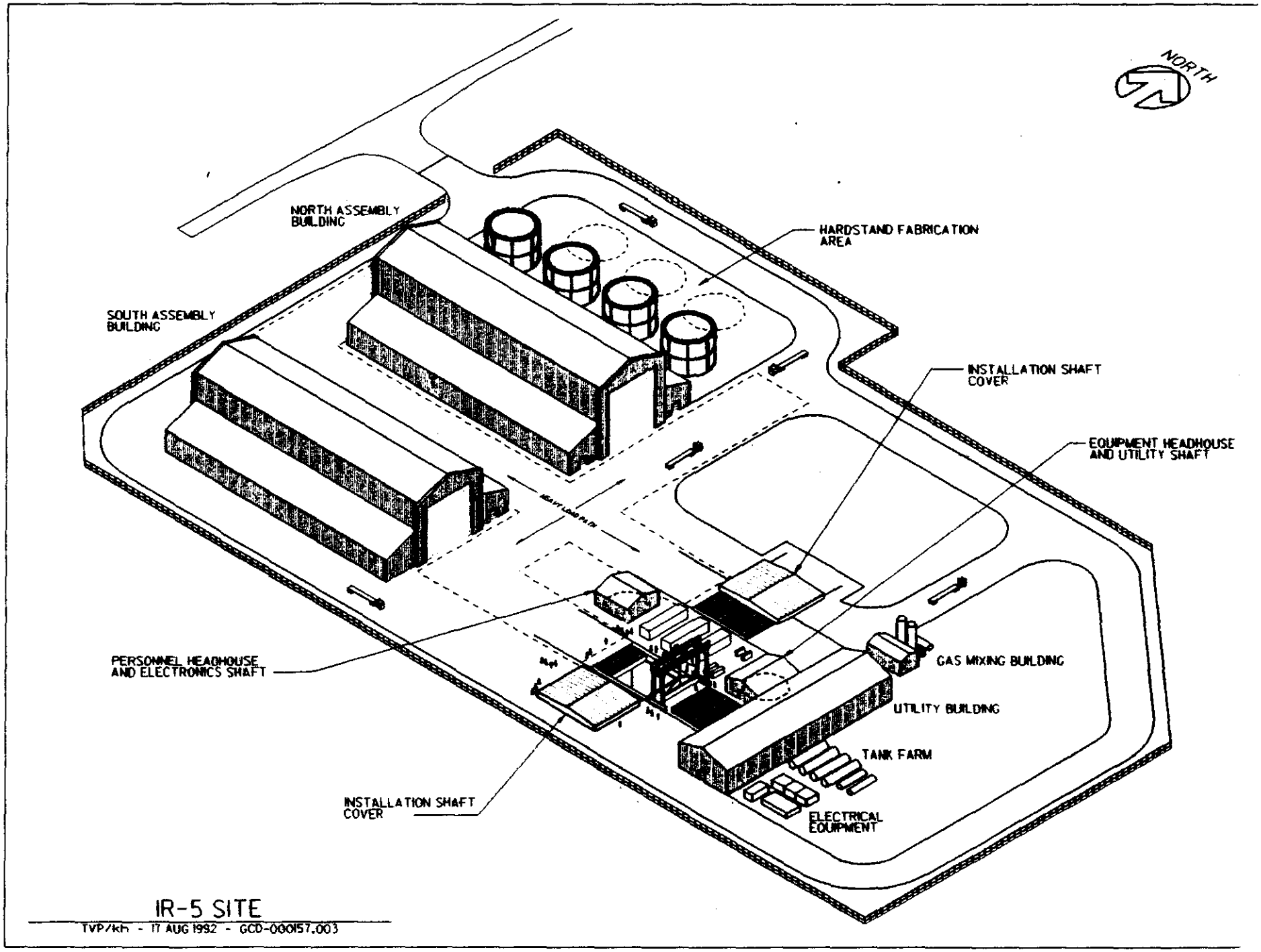
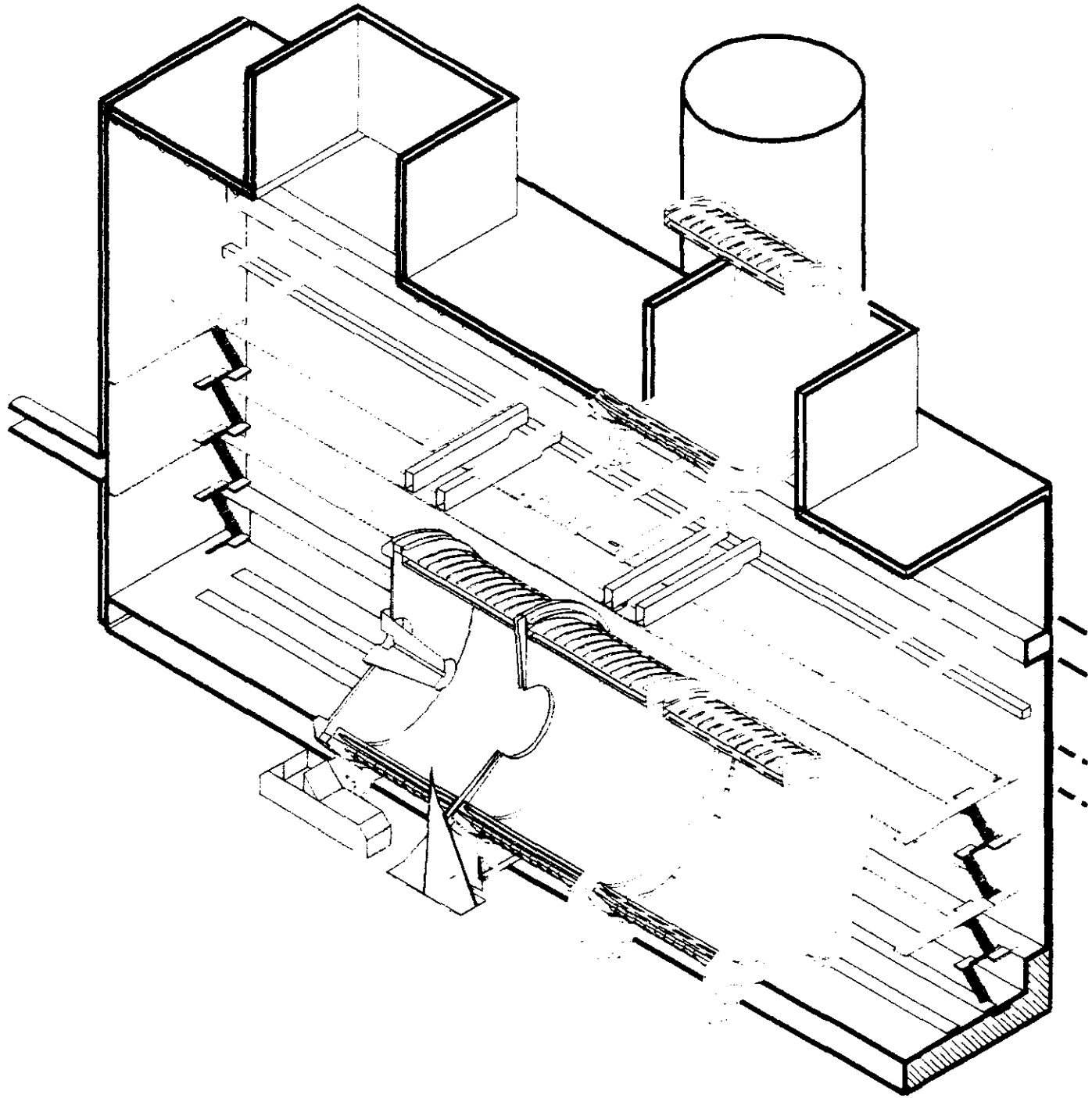
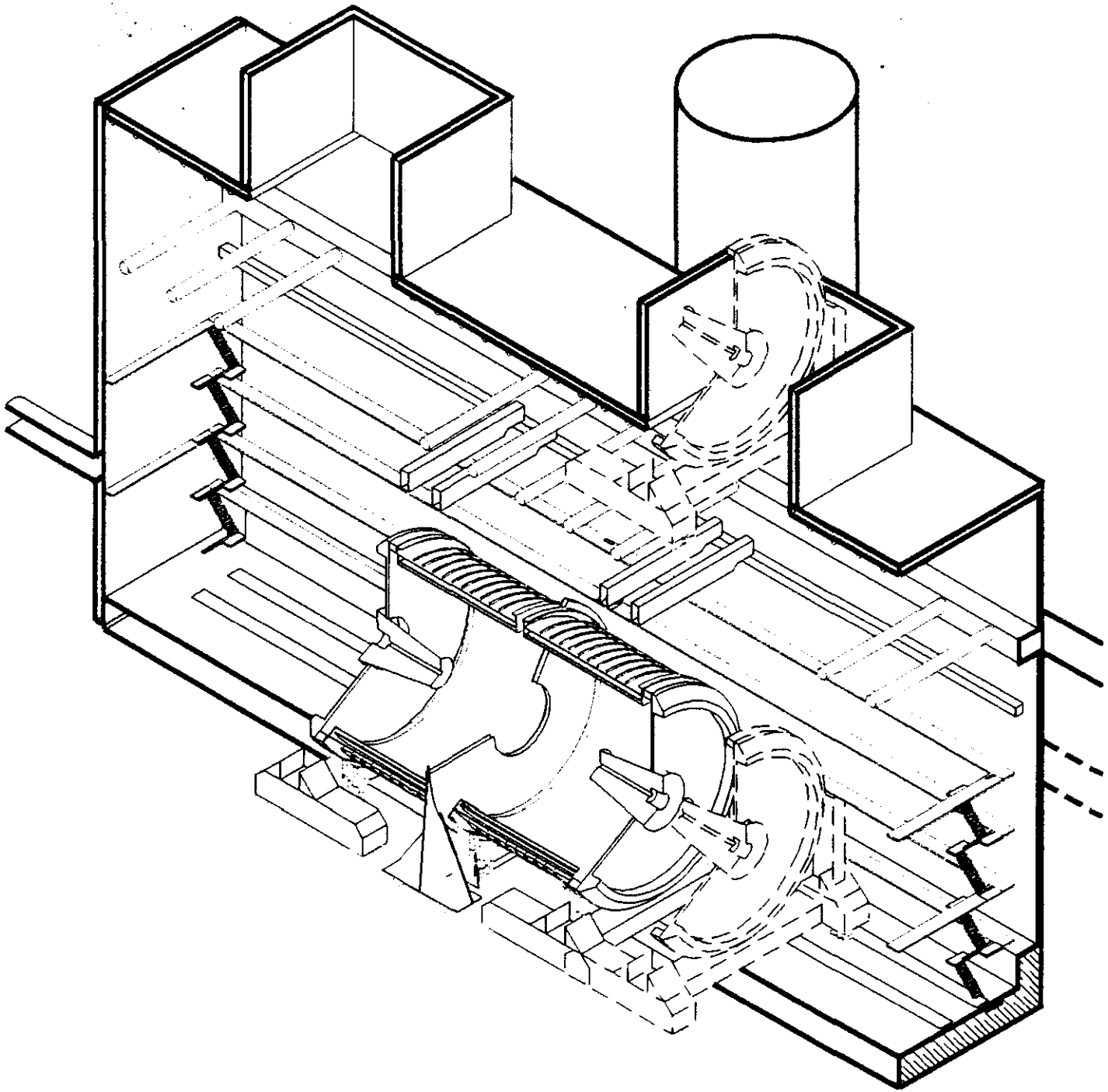
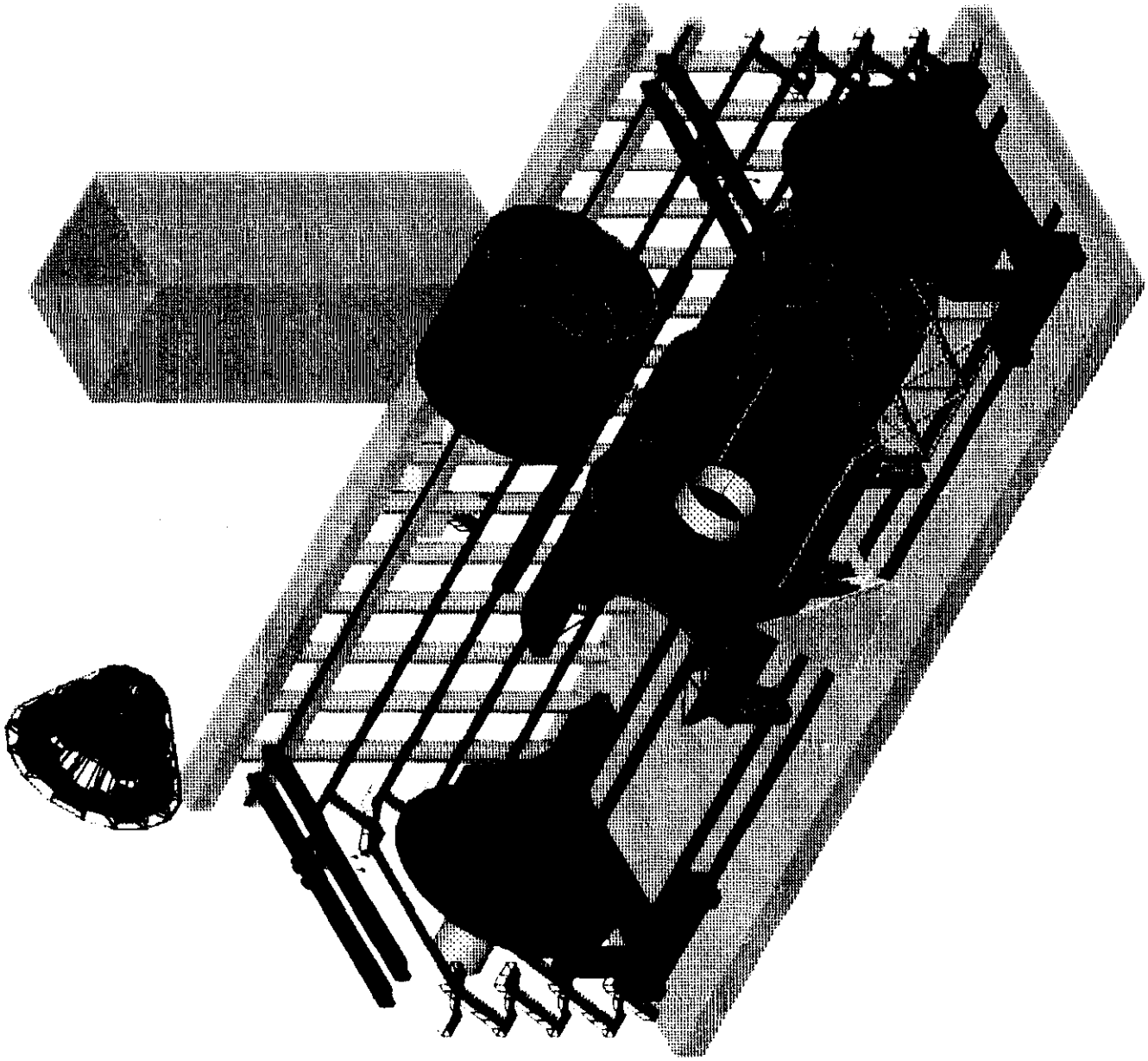

NORTH
NORTH ASSEMBLY BUILDING
SOUTH ASSEMBLY BUILDING
HARDSTAND FABRICATION AREA
INSTALLATION SHAFT COVER
EQUIPMENT HEADHOUSE AND UTILITY SHAFT
PERSONNEL HEADHOUSE AND ELECTRONICS SHAFT
GAS MIXING BUILDING
UTILITY BUILDING
TANK FARM
ELECTRICAL EQUIPMENT
INSTALLATION SHAFT COVER
IR-5 SITE
TVP/kh - 17 AUG 1992 - GCD-000157.003

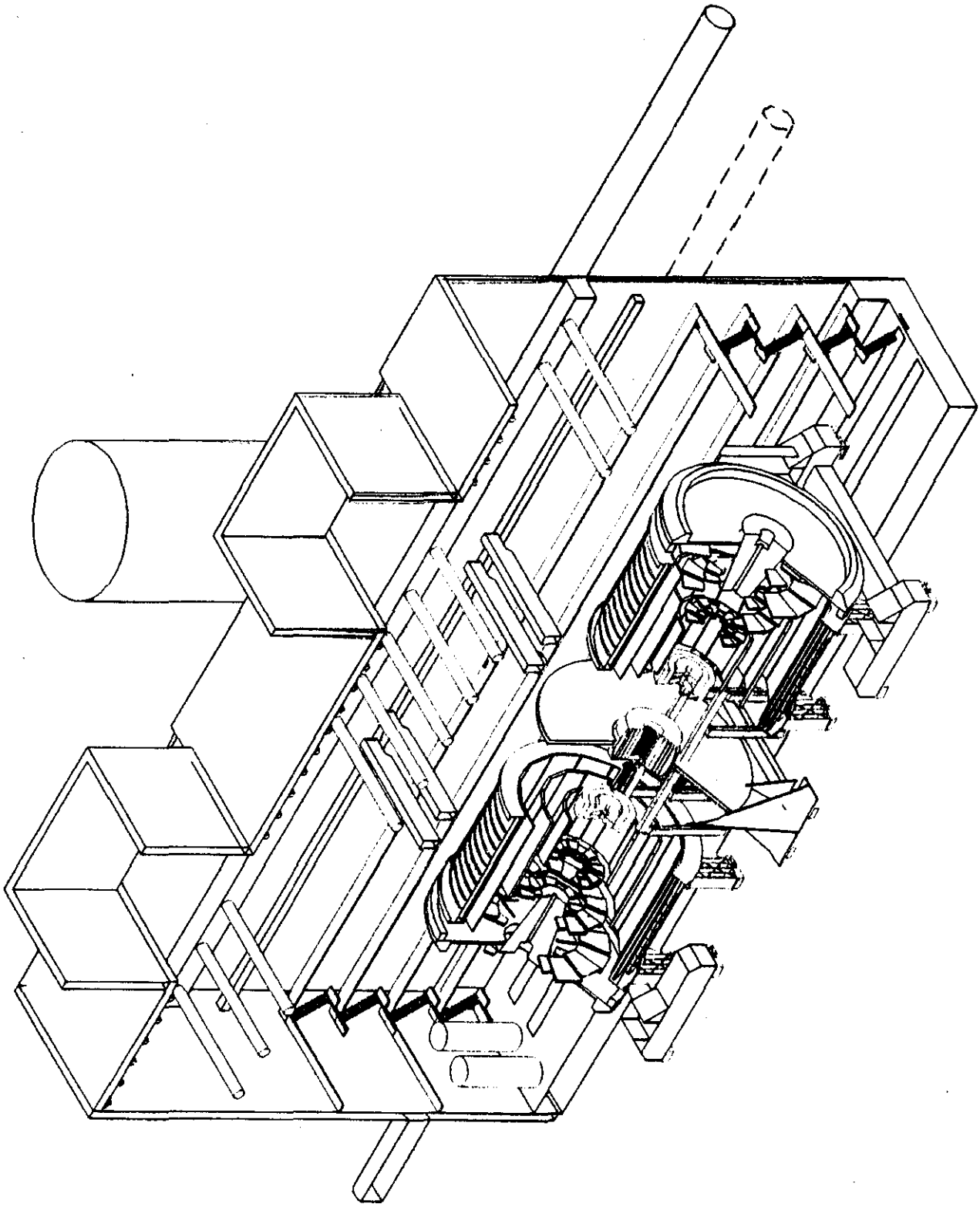
# PHASE 5



# PHASE 6



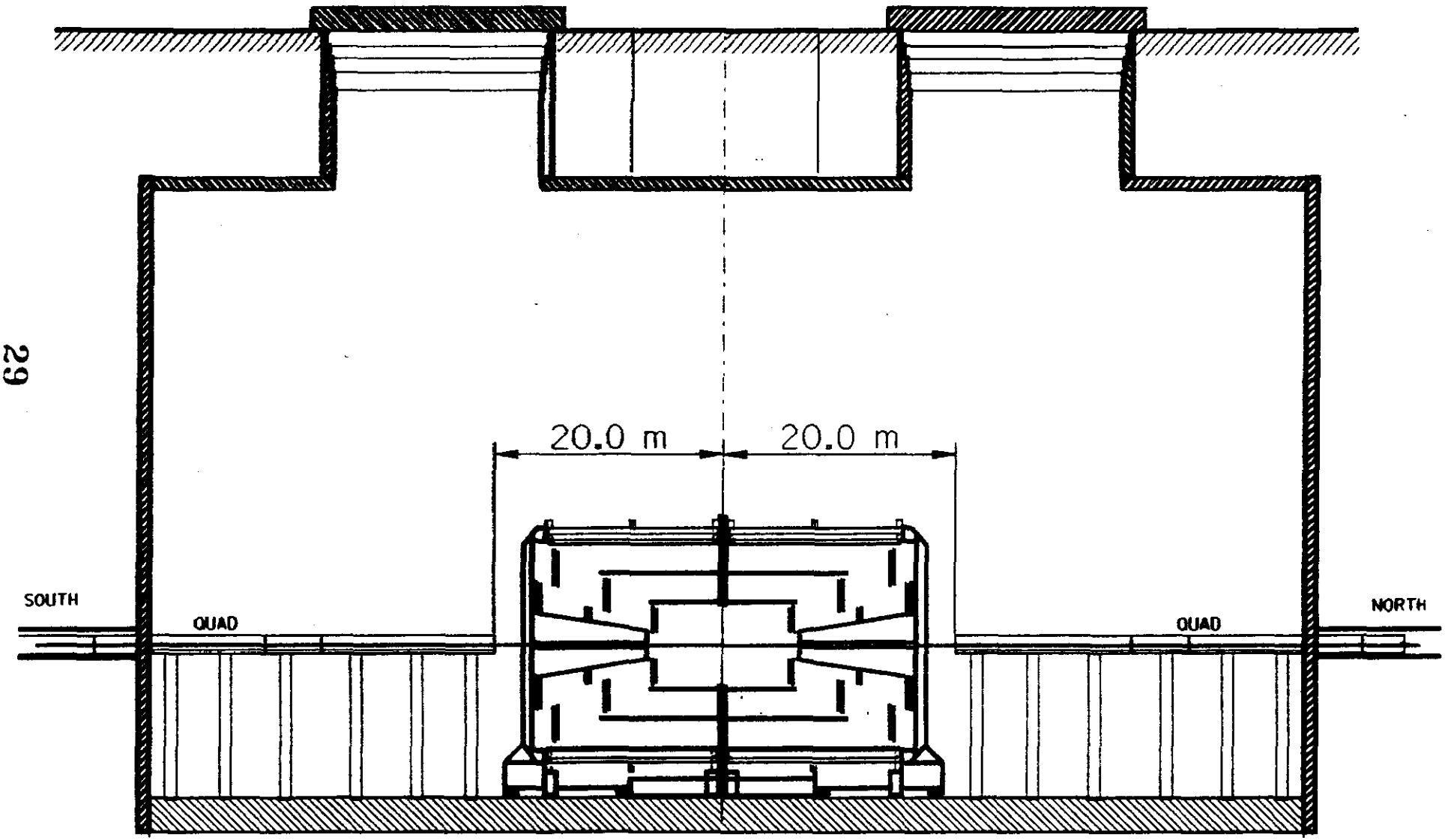


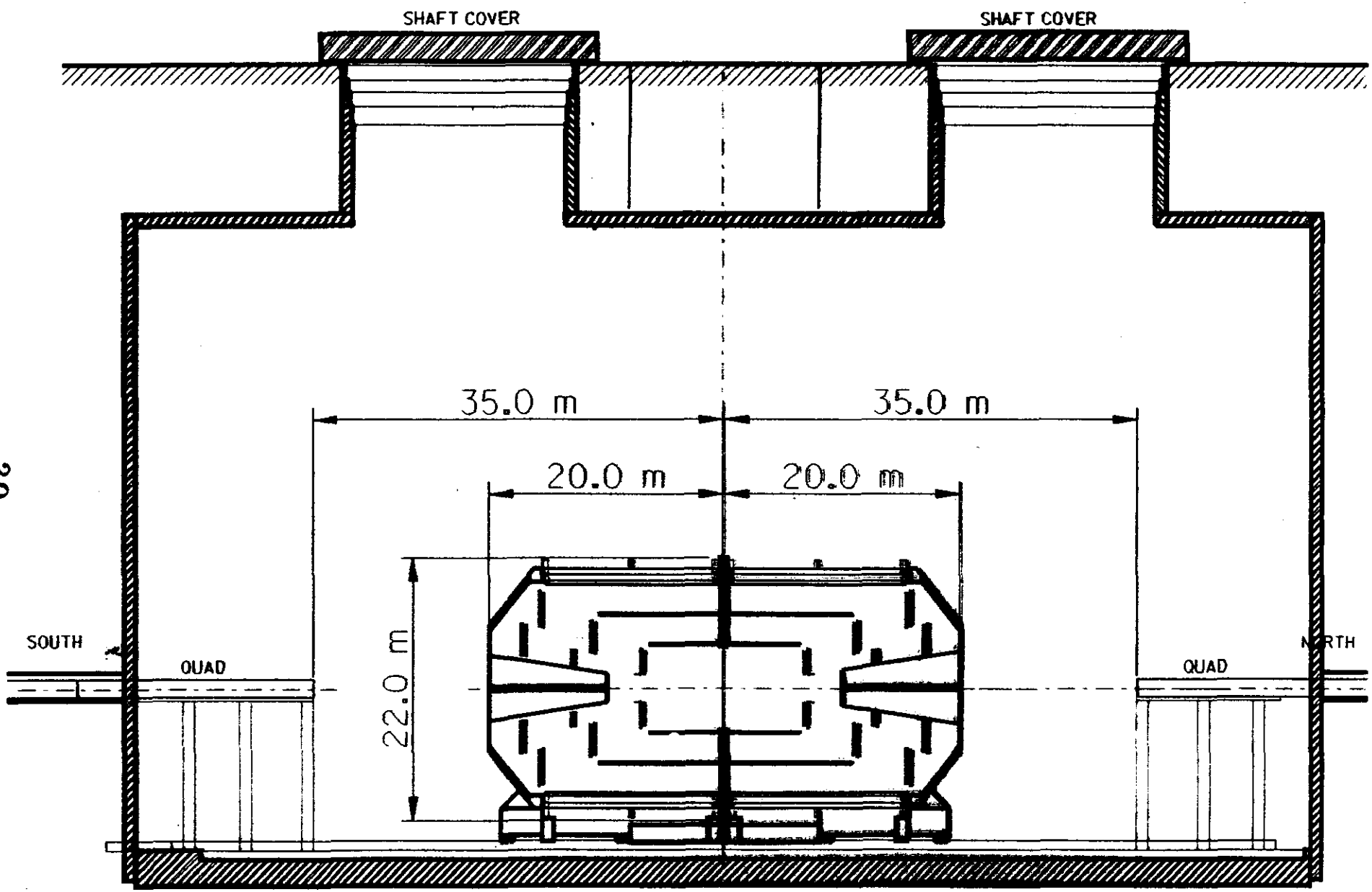


# BASELINE 2

MOVE QUAD TO 35m.

**POSITION QUADRUPOLE OPTION B**
**20 m FROM I.P.**




SHAFT COVER
SHAFT COVER
35.0 m
35.0 m
20.0 m
20.0 m
22.0 m
SOUTH
QUAD
QUAD
NORTH

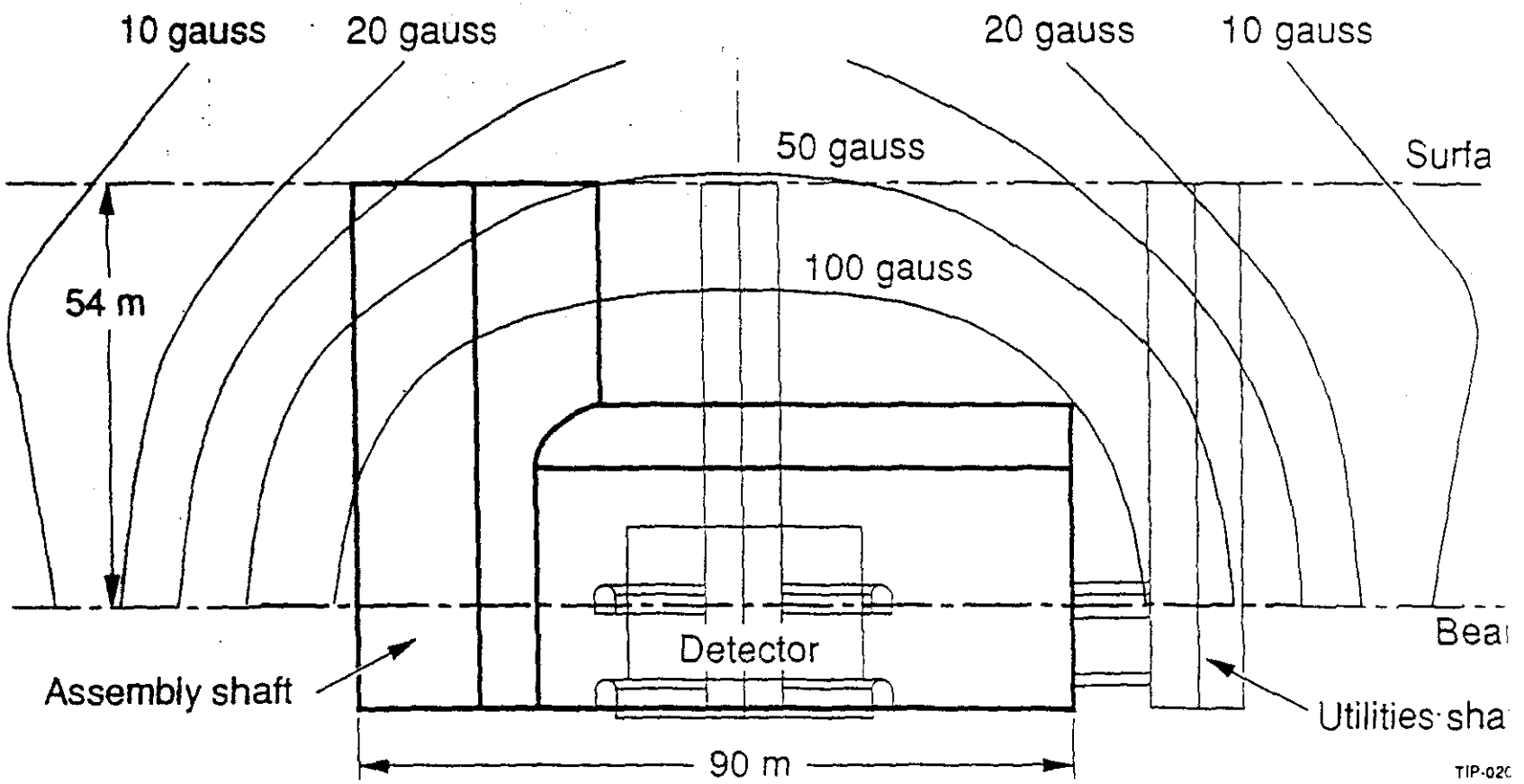
16-OCT-1992

GEM

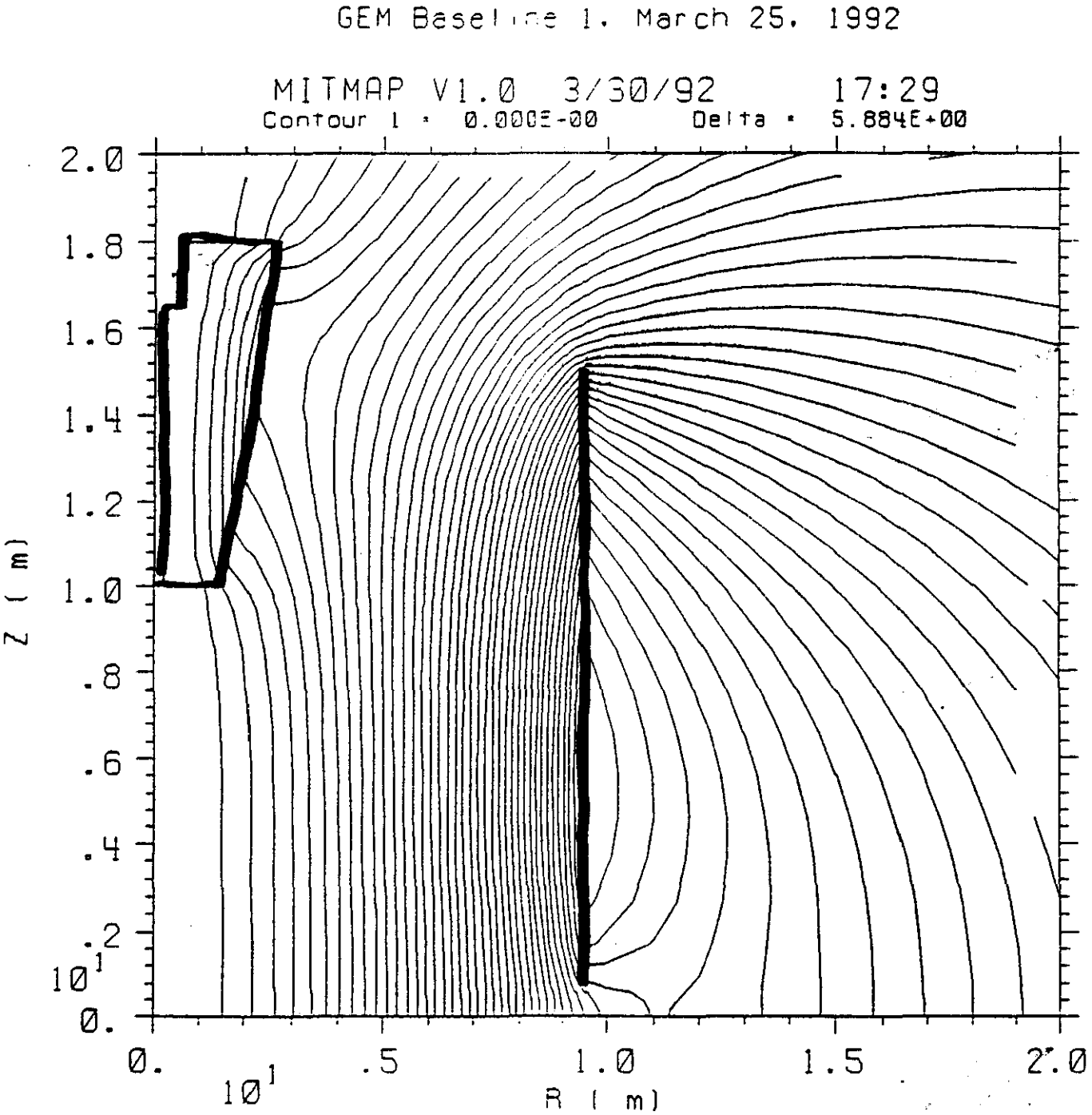
MAGNET

# GEM Magnet

| | |
|---|---|
| Central field | 0.8 T |
| Outer radius of outer cryostat vessel | 10.15 m |
| Mean radius of windings | 9.5 m |
| Inner radius of inner cryostat vessel | 9.1 m |
| Inner radius of magnet subsystem | 9.0 m |
| Magnet axis height above hall floor | 13.0 m |
| Half Cryostat vessel length | 15 m |
| Half Coil length | 14.44 m |
| Total conductor length | 27.2 km |
| Total mass of half magnet subsystem | 1,300 t |
| Total mass of half coil | 153 t |
| Total mass of half cryostat vessel | 851 t |
| Total mass of half FFS | 1,265 t |




ENVIRONMENTAL REPORT = APPROVED




CONTOURS OF CONSTANT FLUX

Figure 1: Lines of constant magnetic flux in a meridional half-plane; the figure is rotationally symmetric about the horizontal axis and has mirror symmetry about $Z = 0$. Note: the beam axis, $Z$, is vertical while the transverse axis, $R$ is horizontal. Both axes extend from 0 to 20 m and the field is in gauss. A sketch of the superconducting winding and the forward field shaper is also shown.

**Figure 22**

# MAGNET STATUS

TECHNICAL REVIEW
COST REVIEW
ENVIRONMENT
ACQUISITION PLAN
} APPROVED

RFP DRAFT OK

MANAGEMENT/TECHNICAL (E. Siskind) ok.

- APPOINT SOURCE SELECTION BOARD
- RFP ISSUE - FOLLOWING DEC. PAC MTG.

No magnet review at that meeting

Comment Tuesday with. Before Friday morning

*Superconducting Super Collider Laboratory*
*2550 Beckleymeade Avenue, Mail Stop 2005*
*Dallas TX 75237-3946*
*(214) 708-6207*
*Fax: (214) 708-6088*

***GEM Project Department***

***Memorandum***

**To:** Gary Sanders
**From:** Paul Reardon, Gary Deis, Ryszard Stroynowski, Bill Wisniewski
**Subject:** Magnet System Paramter Freeze
**Date:** **DRAFT**

---

The GEM Magnet Project has now reached the stage at which it is necessary to freeze the major system parameters of the coil assemblies. This is required to support the overall schedule, which necessitates that the detailed design be advanced quickly in the next six months, and that major procurement actions be initiated immediately. At least one of these procurements, the conductor purchase, will be firm fixed price, so any design changes which would affect the conductor specifications in any way must be strictly avoided.

The Magnet Project recommends an immediate freeze of the following magnet parameters:

| Magnet System Parameter | Value | Unit |
|---|---|---|
| Magnet subsystem inner radius | 9.0 | m |
| Magnetic field at IP | 0.8 | T |
| Vacuum vessel minimum z | 0.4 | m |
| Vacuum vessel maximum z | 15.1 | m |
| Winding mean radius | 9.5 | m |
| Winding minimum z | 0.75 | m |
| Winding maximum z | 15.0 | m |

15.4 ? by Mike Harris

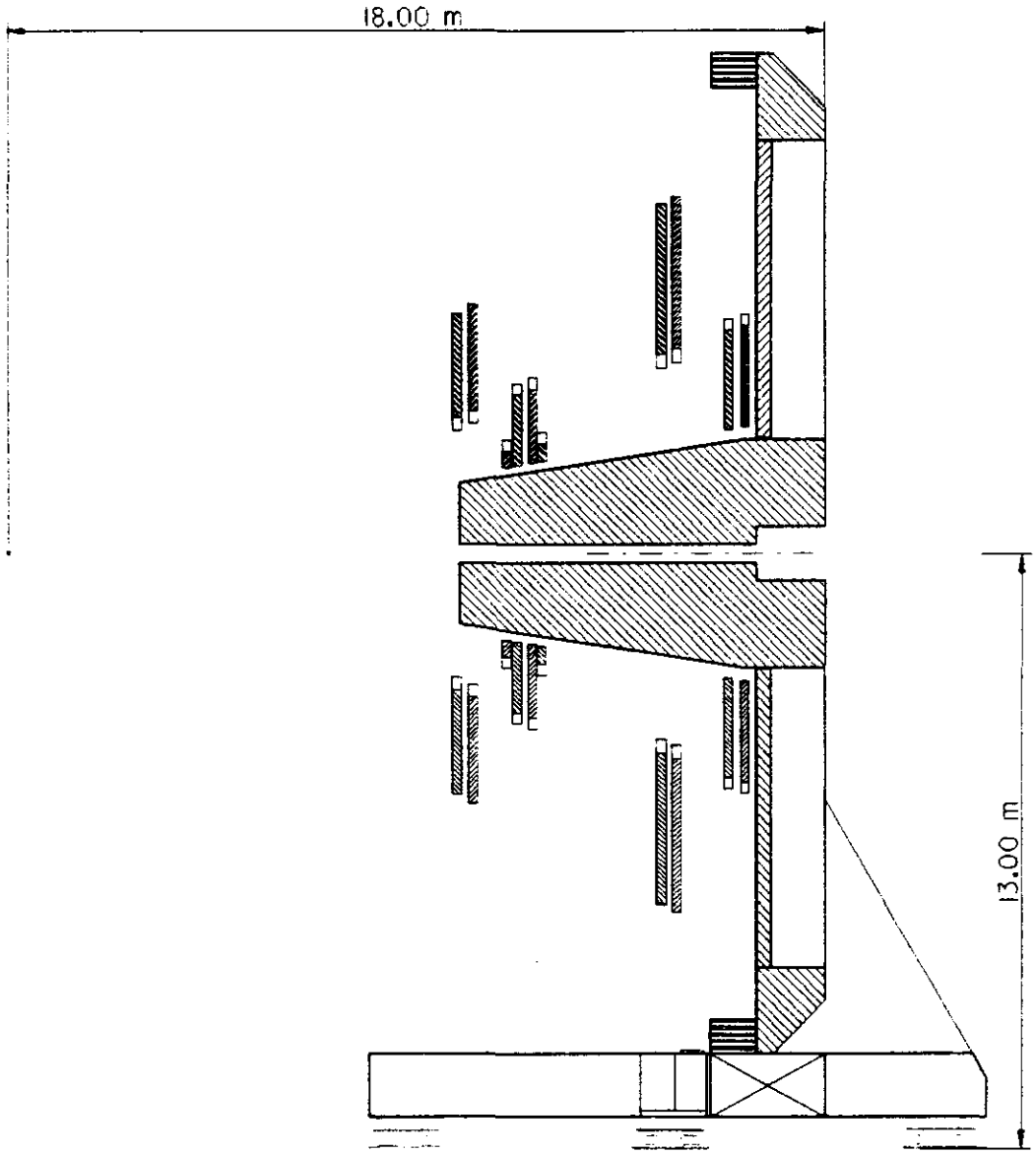
Freezing these system parameters will result in a freeze of many other derived parameters, such as number of turns, current, conductor cross section, etc. Many other parameters relating to the detailed design of the coil assemblies will be frozen as the design progresses.

The magnet project would also like to freeze the design of the FFS. However, in view of the ongoing discussions related to the designs of the tracker, calorimeters, and muon system, together with the slightly less critical schedule for the FFS design and construction, we do not request that the design be frozen at this time. However, please note that uncertainty in the design of the FFS will impede our ongoing discussions with potential foreign suppliers of these components, so an early freeze will be required. We anticipate requesting this freeze within 2 months.

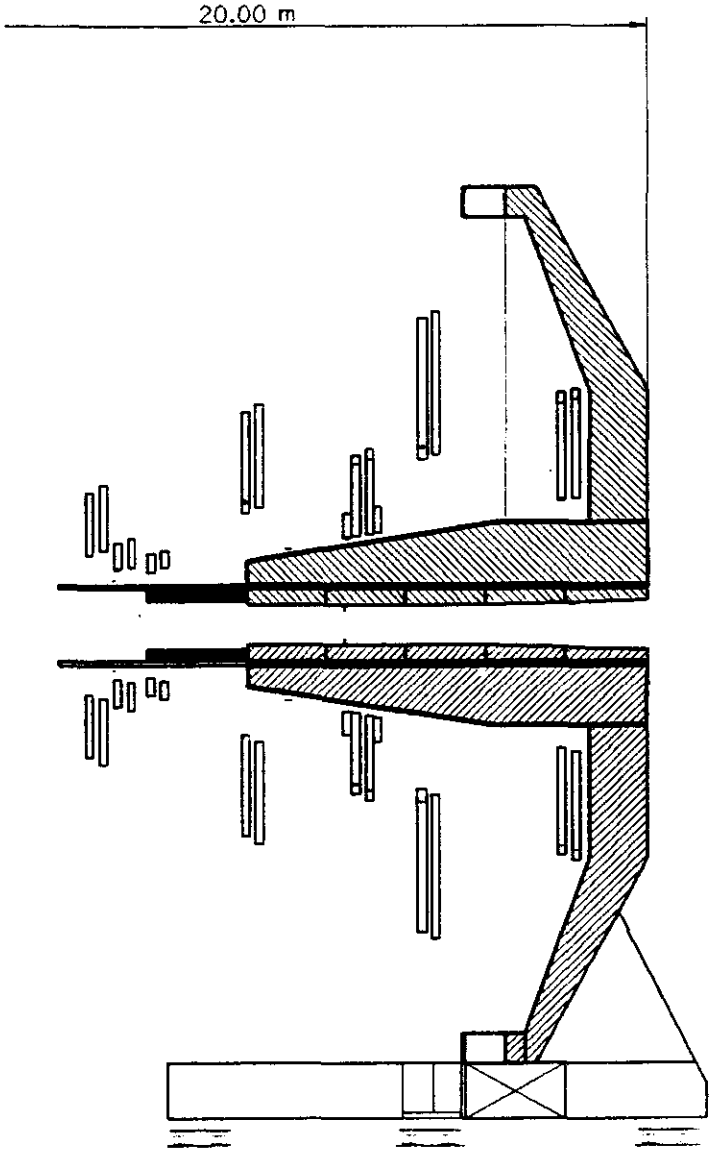
The details of the magnet interfaces with the Central Detector Support, the Muon Subsystem, and the facility, as well as the interface between the FFS and the coil assemblies are being evolved as a normal part of the detailed design process. These details will not affect the magnet design in a significant "system" manner (as would changes in the parameters listed above); therefore we do not regard these interfaces as frozen, and we will continue to work with the other systems to develop the details as a part of our design effort.

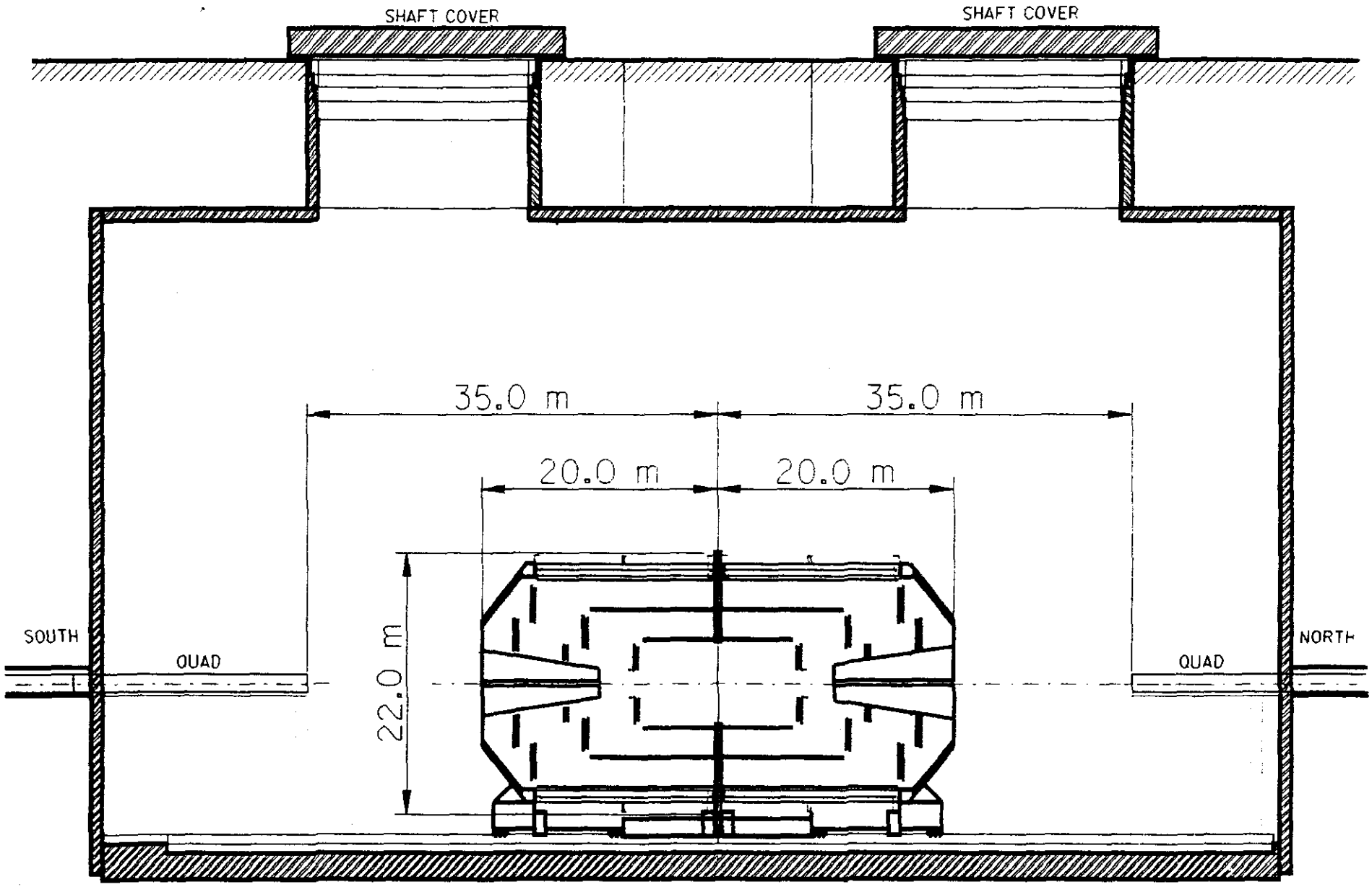
Freezing of the major magnet system parameters, now, is essential in keeping the magnet project on schedule, in minimizing the overall cost, in maintaining project momentum, and in demonstrating the

# F.F.S OPTION B



# F.F.S OPTION A




SHAFT COVER
SHAFT COVER
35.0 m
35.0 m
20.0 m
20.0 m
22.0 m
SOUTH
QUAD
QUAD
NORTH

13-OCT-1992

BEAM PIPE

(G. Chapman)

BASELINE 2.

8 cm. pipe.

Warm Beam Pipe.

flared?

# GEM DETECTOR PARAMETERS

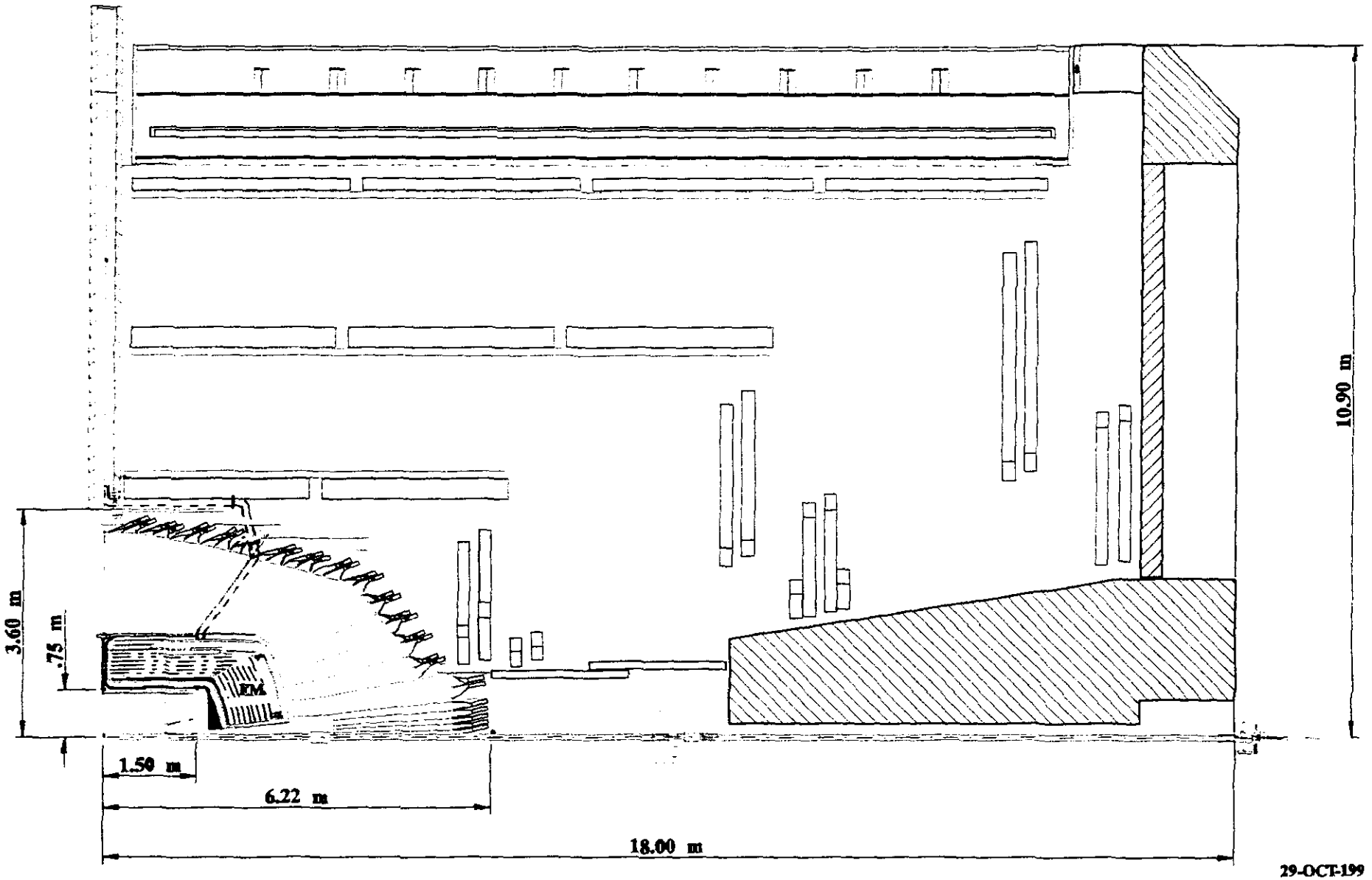
OPTION 1

E.M. CALORIMETER: Liq Kr

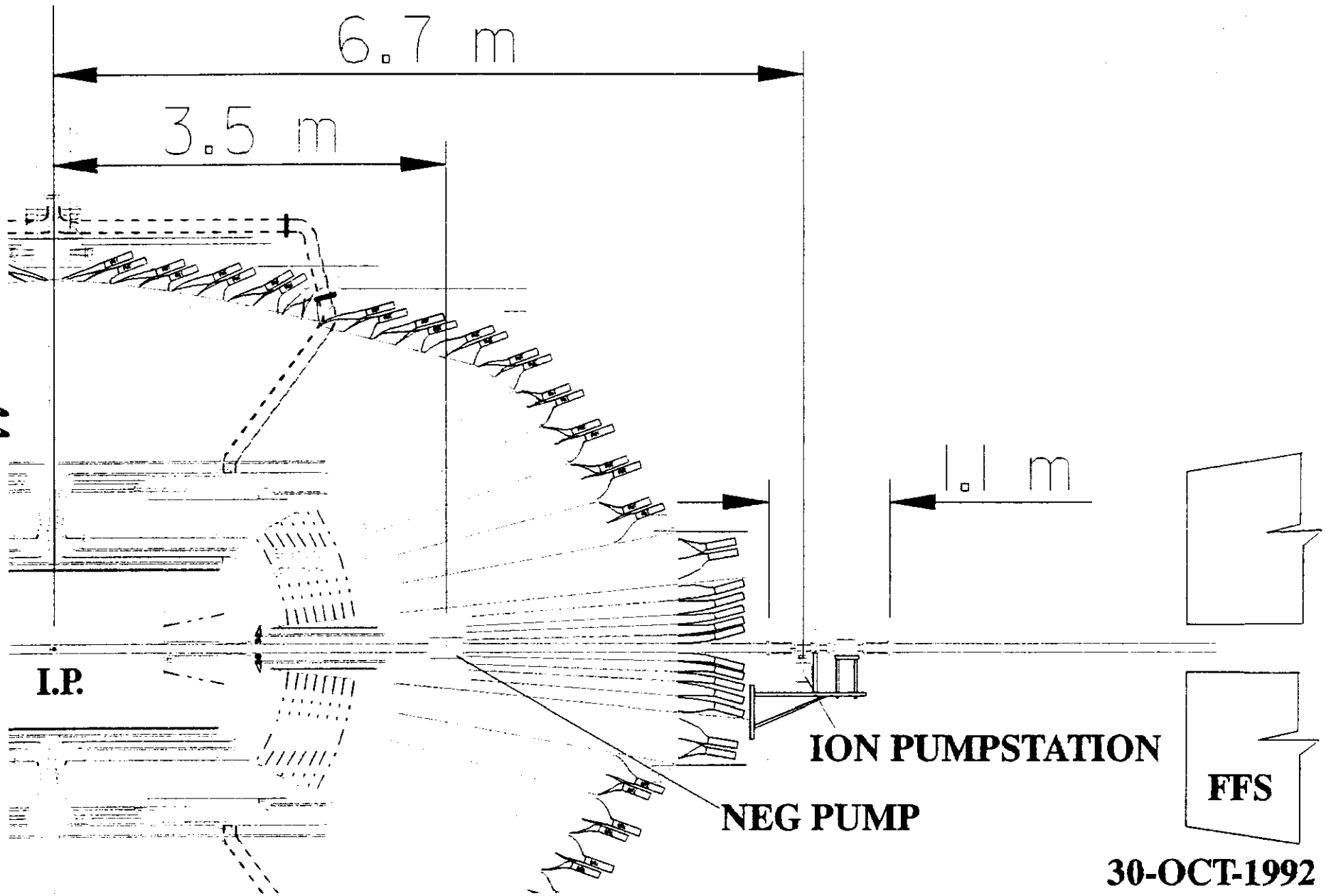
FORWARD CALORIMETER: SCINTILLATING FIBER

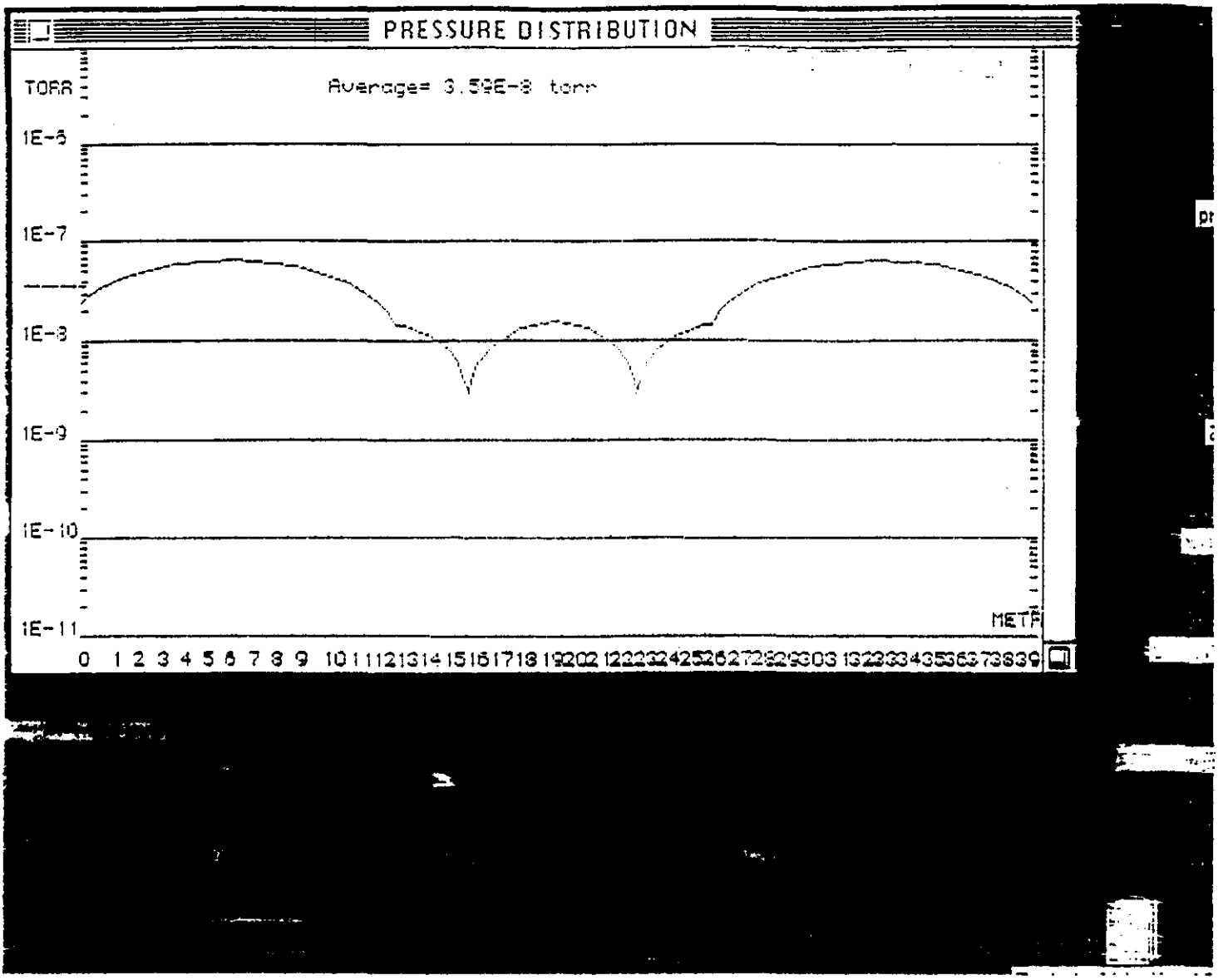
BARREL CALORIMETER: FIBER

VACUUM SYSTEM: OPTION 1 or 3



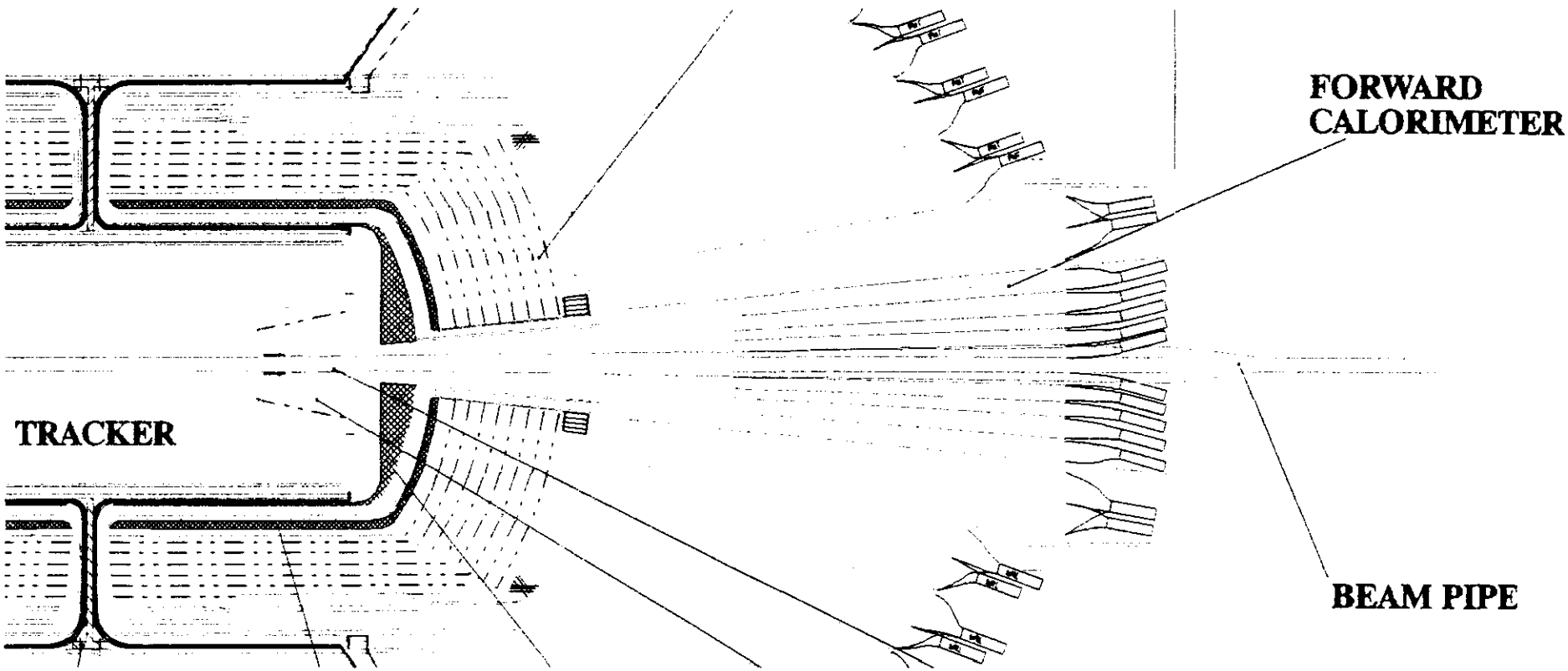

29-OCT-199


6.7 m
3.5 m
1.1 m
I.P.
ION PUMPSTATION
NEG PUMP
FFS
30-OCT-1992



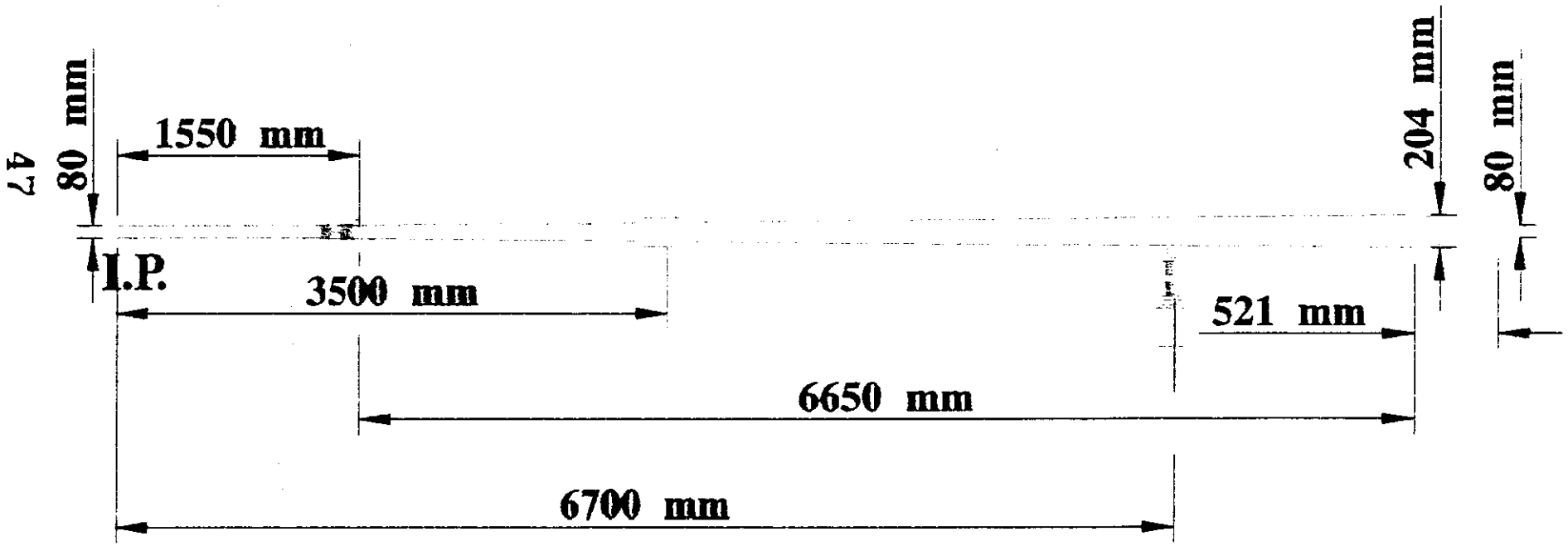

(B) 60 L/S. 60 L/S. NEG. 60 L/S. 60 L/S

φ 8 cm.


FORWARD
CALORIMETER
TRACKER
BEAM PIPE

# GEM DETECTOR BEAMLINE LAYOUT

## OPTION 1-B




30-OCT-1992

# TRACKER

Electron/photon identification

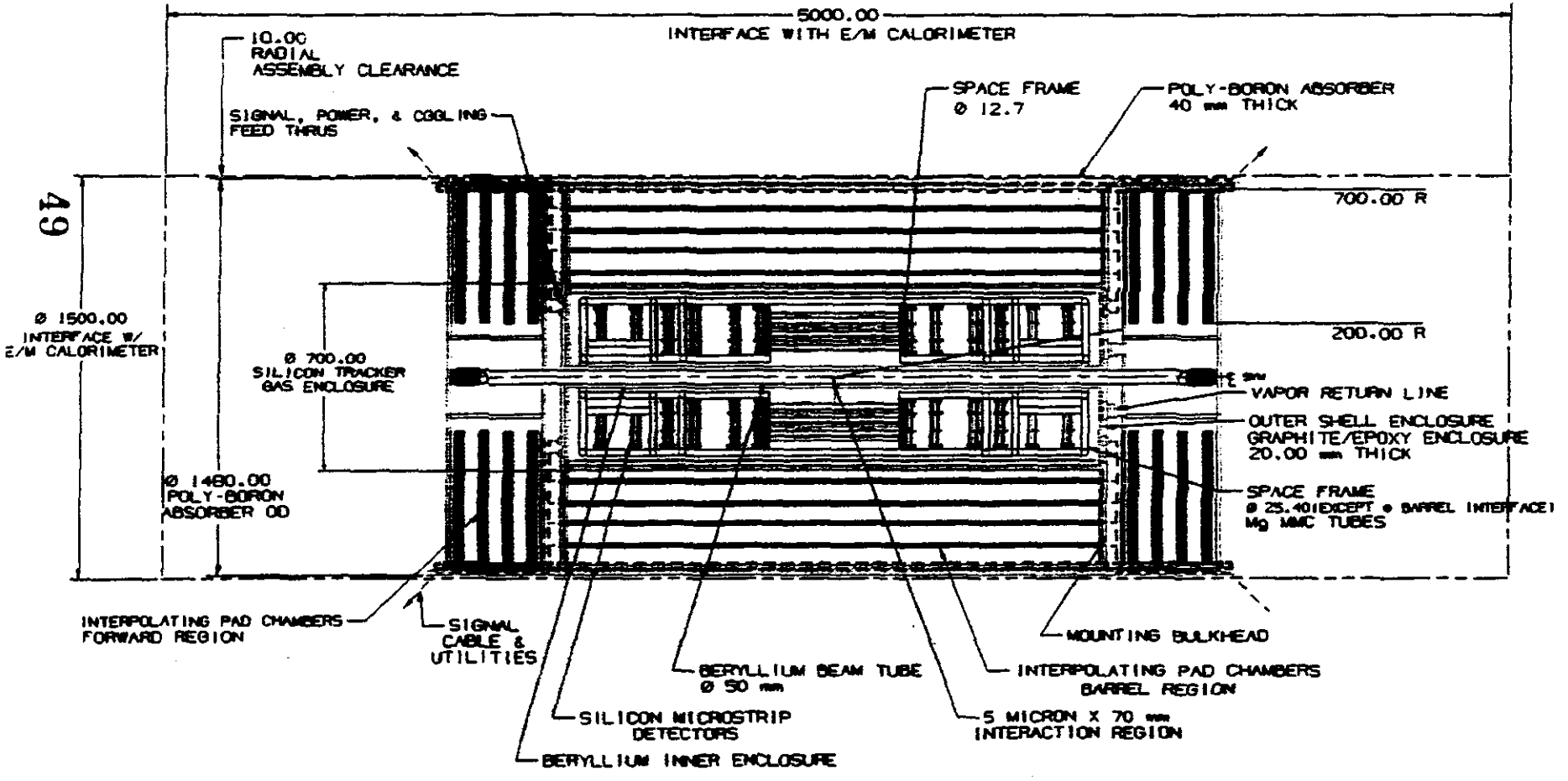
Isolation cuts

Primary vertex

Electron/hadron identification

Electron sign

Background rejection




# GEM CENTRAL TRACKER

GEMVG-126-JV

# The Physics Goals of the Central Tracker

## First Category

1. Required to support primary objectives of GEM: detection of $\gamma$s, $e$s and $\mu$s at high $p_T$.

- Identify the primary vertex of an event:
  separate from pileup events
- Separate electrons and gammas:
  charged track pointing to an EM shower
- Provide track information for $e, \mu$ or $\gamma$:
  isolation cuts
  rejection of conversions and Dalitz pairs
- Electron-hadron separation:
  momentum compared with energy in calorimeter
- Rejection of $\mu$ background:
  match tracker $\mu$ momentum with $\mu$ chambers
- Determine the electron sign up to 400 GeV/c

---

Fulfill these goals well at $10^{33} cm^{-2} s^{-1}$
→ Survive up to $10^{34} cm^{-2} s^{-1}$.
(met by looking for hits in a specific road extrapolated from calorimeter or $\mu$ system)

# The Physics Goals of the Central Tracker

## Second Category

- Full reconstruction of the charged tracks in the event.
- Secondary vertex finding.
- Tracking at low momenta with good resolution.

Enhance GEM's ability on $b$ and top physics.

More demanding in pattern recognition requirement and vertex resolution.

Expect to meet up to $10^{33} cm^{-2} s^{-1}$, but probably not much higher.
(satisfactory due to large $\sigma$s)

## The Silicon Microstrip inner tracker

6 layers of silicon strip ladders
Each ladder ⇒ two back-to-back
single sided silicon sensors
5 mrad stereo angle between the two sensors
Each sensor is 300 $\mu$m thick
Strip pitch of 50 $\mu$m
Each pair of sensors provides a space point
resolution of 10 $\mu$m in the $r - \phi$ plane
and 3 mm in the $r - z$ projection
The 6 layers of ladders ⇒ 3 superlayers
Each superlayer ⇒ track stub

Forward region: Silicon disks -
strips projecting radially inward
toward the beam axis

| | |
|---|---|
| Length | 200 cm |
| Radius | 10 to 35 cm |
| Area of silicon ladders | 7 $m^2$ |
| Number of strip | $3.5 \times 10^6$ |
| Strips per fiber optic readout channel | 1028 |
| Readout channels | 3500 |

## The Interpolating Pad outer tracker

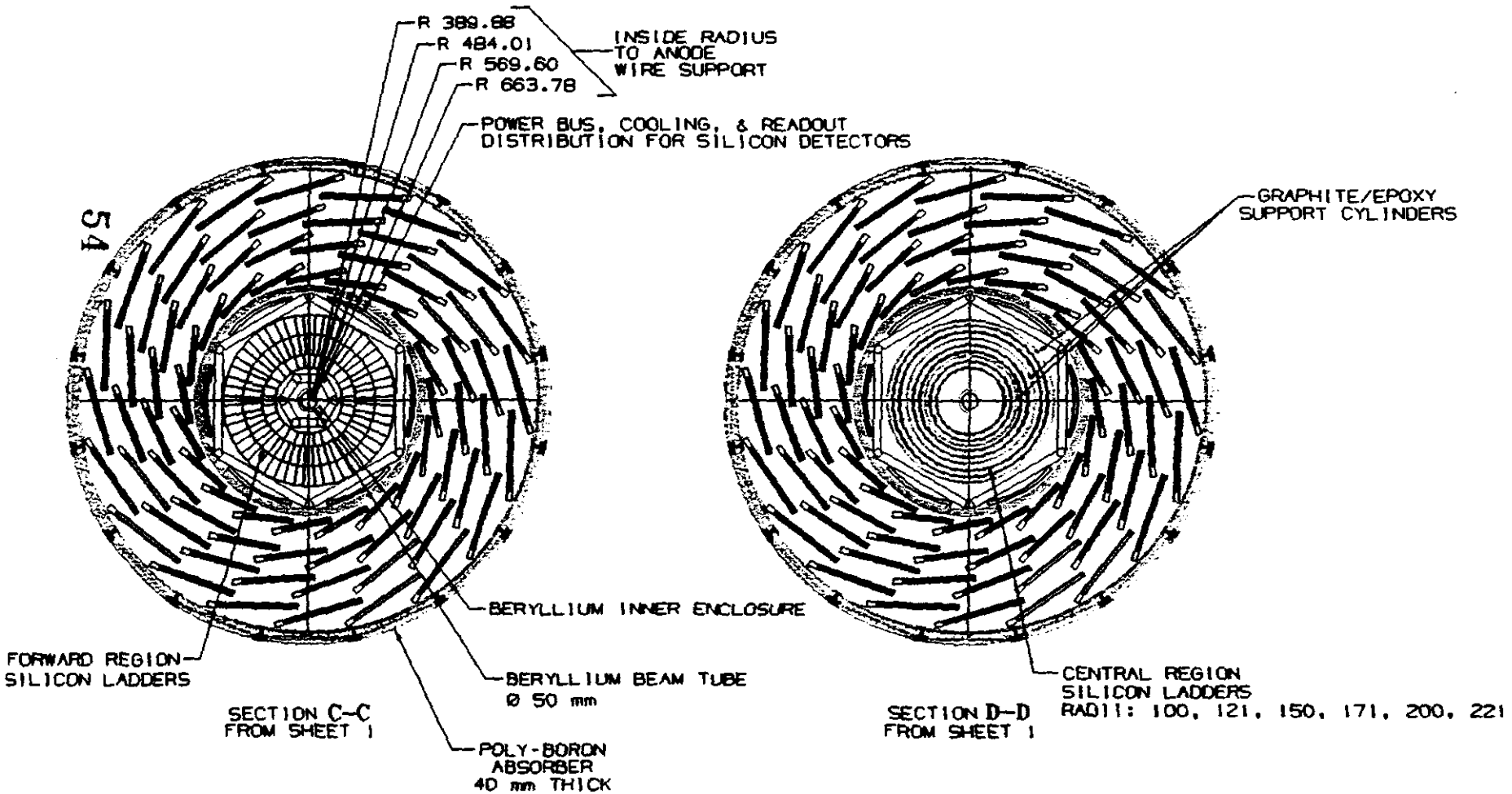
8 layers of pad chambers in the barrel
at radii 35 - 70 cm,
AND in the forward region,
radius 20 - 70 cm

8 layers $\Rightarrow$ 4 superlayers

Each barrel layer: 20 chambers,
each chamber covering 18° in azimuth,
largest chamber 30 cm $\times$ 200 cm

Forward layers: disks of 10 trapezoidal chambers,
about 50 cm x 50 cm each

Silicon & IPC
— Stereo Double Layers
"Space Points"
Low Occupancy

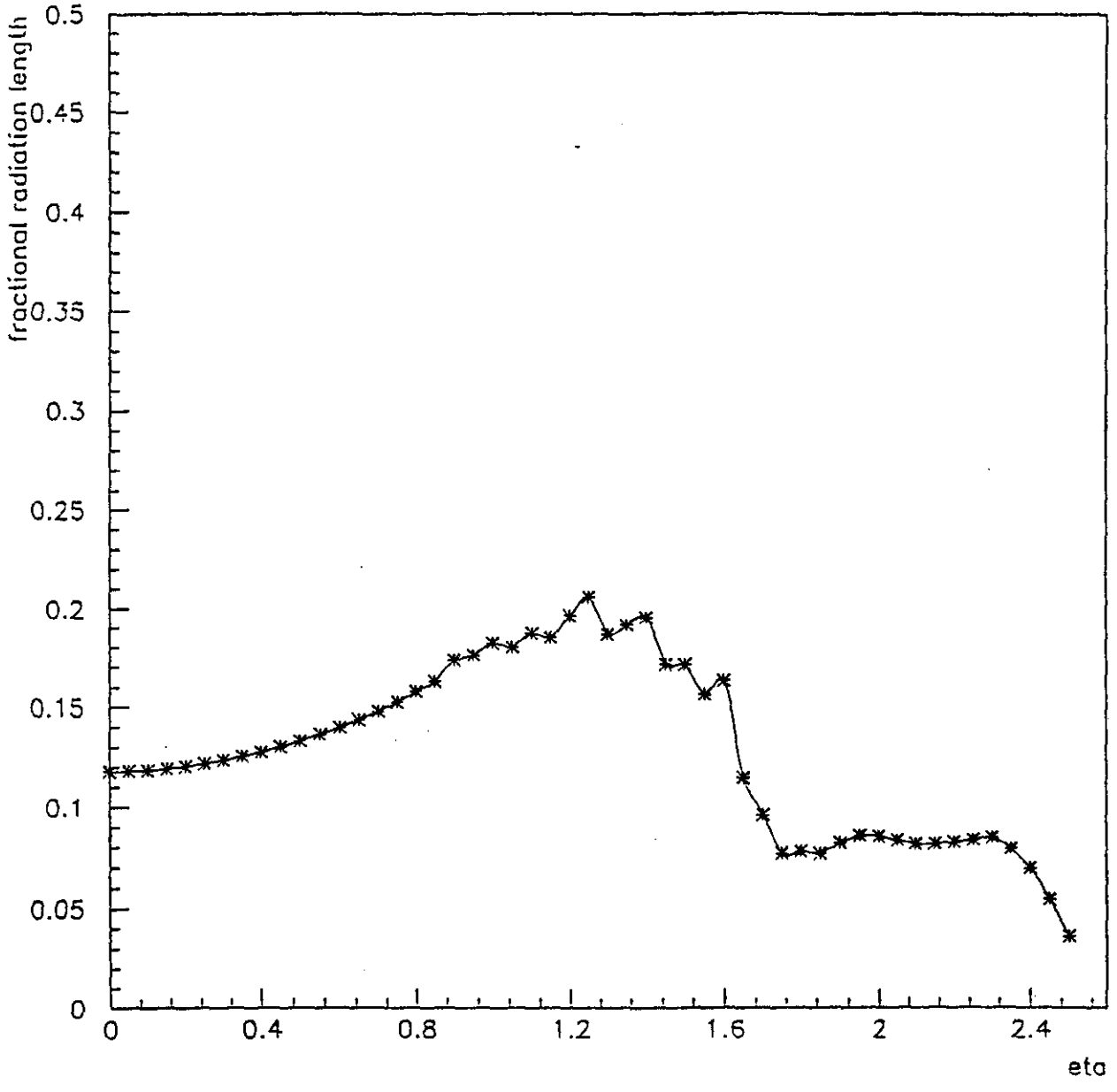



GEMVG-1098-JV 3-23-92

# GEM Central Tracker

| | | |
|---|---|---|
| Magnetic field | | 0.8 T |
| Length (from IP to outer faces) | | ±150 cm |
| Outer radius | | 70 cm |
| Location of neutron shield | | $70 < R < 75$ cm |
| Occupancy | $\mathcal{L} = 10^{33}$ cm$^{-2}$ s$^{-1}$ | $\leq 1\%$ |
| | $\mathcal{L} = 10^{34}$ cm$^{-2}$ s$^{-1}$ | $\leq 10\%$ |
| Charge separation at 95% c.l. | | $\leq 400$ GeV |
| $\Delta p/p$ | High p | 0.0015 $p_T$, $p_T$ in GeV/c |
| | Low p | $\sim 4\%$ |
| Vertex | Beam direction | $\delta z \sim 1$ mm |
| (> 10 GeV/c) | Impact parameter | $\delta b \sim 30$ $\mu$m |

MATERIAL BEFORE LAST TRACKING LAYER

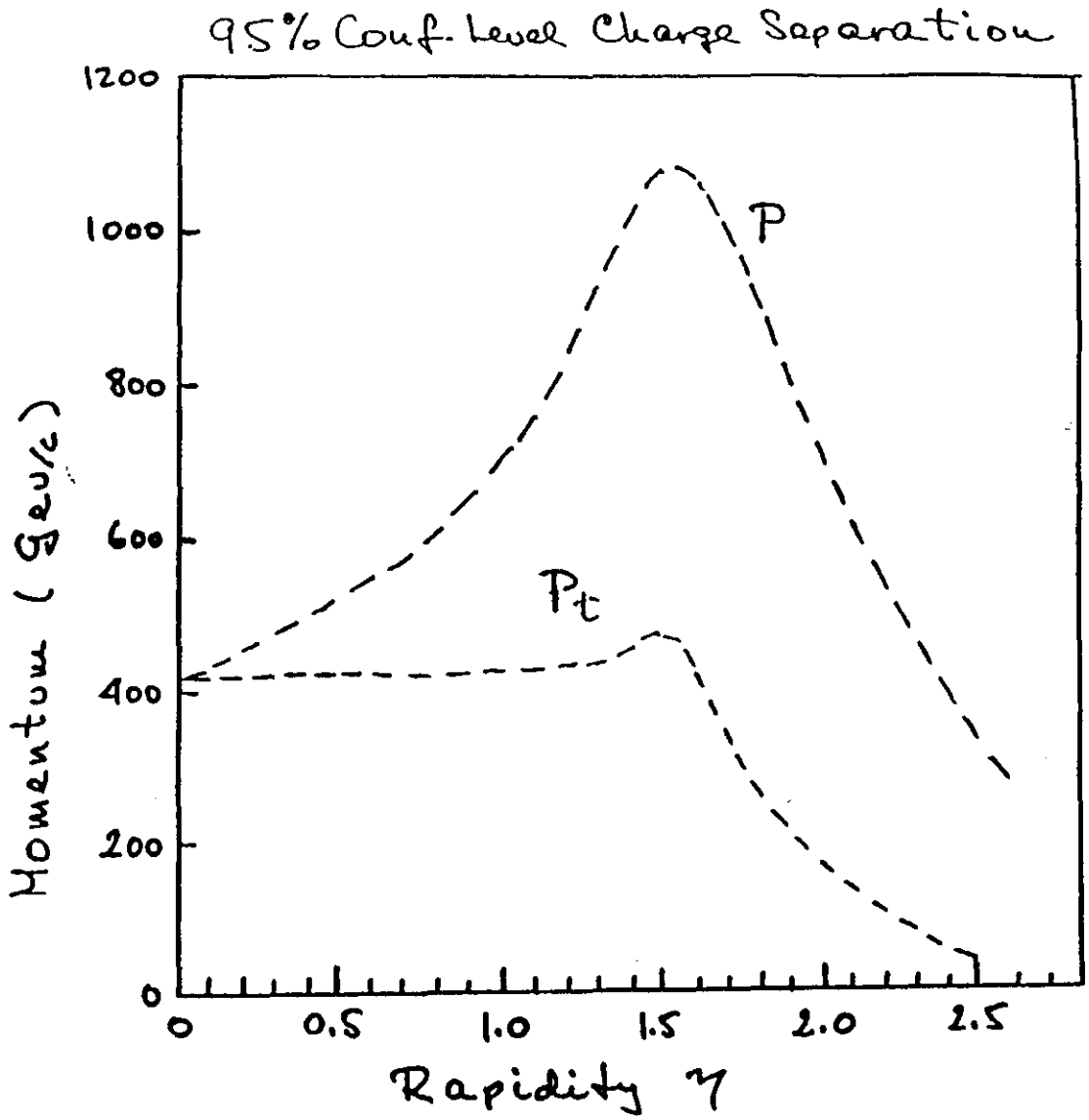


# BASELINE 2

INCREASED DIAMETER

→ D = 1.9 m ←

sensitive


95% Conf. Level Charge Separation
1200
1000
800
600
400
200
0
Momentum (GeV/c)
P
Pt
0
0.5
1.0
1.5
2.0
2.5
Rapidity η

# 2 M VS. 1.5 M CENTRAL TRACKER

LITTLE CHANGE IN THE SI TRACKER (2CM FOR LONGER LADDER)

CURRENT IPC MODULE PACKAGING QUITE TIGHT

CURRENT OUTER SUPPORT STRUCTURE INTERFERES

TWO TIMES IMPROVEMENT IN THE IPC RESOLUTION

OPTION #1 FOR MOUNTING TO A BARREL CALORIMETER

10-20-92

N

IPC TRACKER

SILICON TRACKER
700 OD X 2000 LONG

INNER ENCLOSURE
100 ID

50 BORON-POLY

BEAM TUBE
80 ID

200 THK BORON POLY
THIS SURFACE TO CONFORM TO
END CAP CAL. CONTOUR

20.000
CABLE
ROUTING

1520
CALORIMETER ID
BORON POLY OD

1380.00
CENTRAL TRACKER OD

3000.00
CENTRAL TRACKER LENGTH

MIN 50 GAP

3500.00
MINIMUM TOTAL LENGTH

PRELIMINARY
NOT TO BE USED FOR
FABRICATION

NOTE:

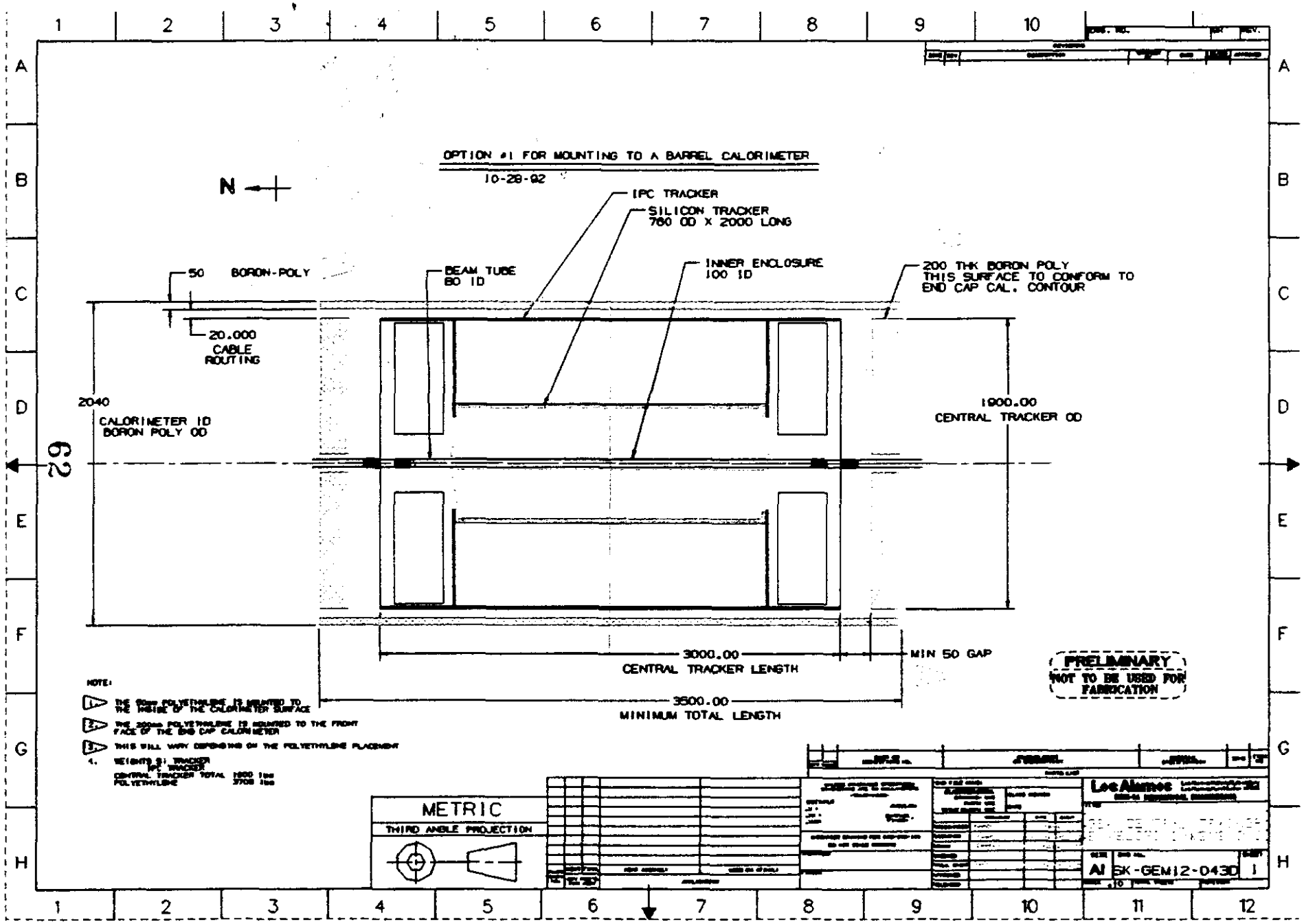
1. [illegible] POLYETHYLENE IS MOUNTED TO THE INSIDE OF THE CALORIMETER SURFACE
2. THE [illegible] POLYETHYLENE IS MOUNTED TO THE FRONT FACE OF THE END CAP CALORIMETER
3. THIS WILL VARY DEPENDING ON THE POLYETHYLENE PLACEMENT
4. WEIGHTS: TRACKER [illegible] LBS
   CENTRAL TRACKER TOTAL [illegible] lbs
   POLYETHYLENE [illegible] lbs

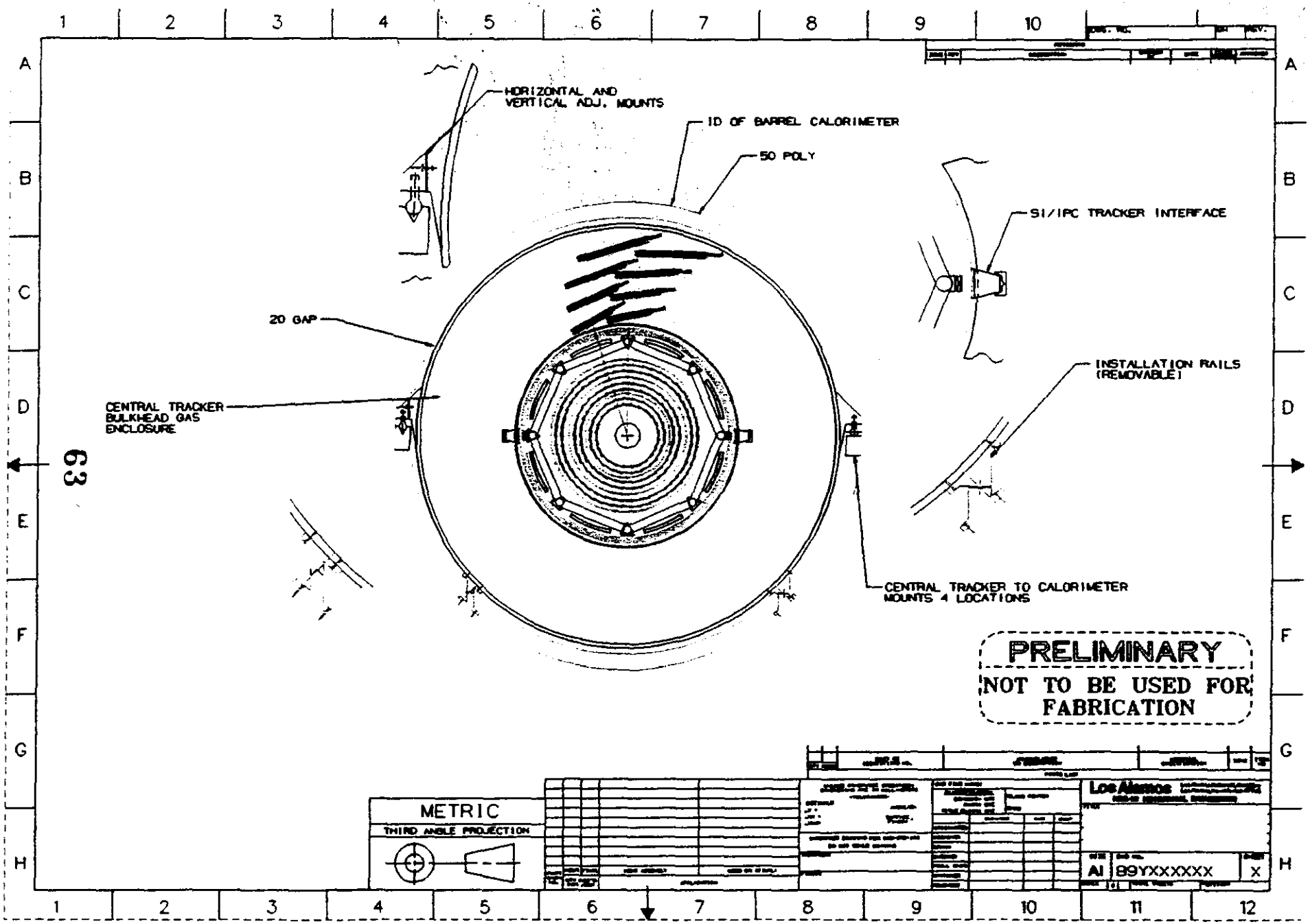
METRIC

THIRD ANGLE PROJECTION

Lee Alonso

AI SK-GEM12-0438 1


OPTION #1 FOR MOUNTING TO A BARREL CALORIMETER
10-28-92
N
IPC TRACKER
SILICON TRACKER
760 OD X 2000 LONG
INNER ENCLOSURE
100 ID
BEAM TUBE
80 ID
50
BORON-POLY
200 THK BORON POLY
THIS SURFACE TO CONFORM TO
END CAP CAL. CONTOUR
20.000
CABLE
ROUTING
2040
CALORIMETER ID
BORON POLY OD
1900.00
CENTRAL TRACKER OD
3000.00
CENTRAL TRACKER LENGTH
MIN 50 GAP
3500.00
MINIMUM TOTAL LENGTH
PRELIMINARY
NOT TO BE USED FOR
FABRICATION
NOTE:
1. THE 50mm POLYETHYLENE IS MOUNTED TO THE INSIDE OF THE CALORIMETER SURFACE
2. THE 200mm POLYETHYLENE IS MOUNTED TO THE FRONT FACE OF THE END CAP CALORIMETER
3. THIS WILL VARY DEPENDING ON THE POLYETHYLENE PLACEMENT
4. WEIGHTS: IPC TRACKER
SIL TRACKER
CENTRAL TRACKER TOTAL 1900 lbs
POLYETHYLENE 3700 lbs
METRIC
THIRD ANGLE PROJECTION
Los Alamos
A1
SK-GEM12-043D
1


HORIZONTAL AND
VERTICAL ADJ. MOUNTS
ID OF BARREL CALORIMETER
50 POLY
SI/IPC TRACKER INTERFACE
20 GAP
CENTRAL TRACKER
BULKHEAD GAS
ENCLOSURE
INSTALLATION RAILS
(REMOVABLE)
CENTRAL TRACKER TO CALORIMETER
MOUNTS 4 LOCATIONS
PRELIMINARY
NOT TO BE USED FOR
FABRICATION
METRIC
THIRD ANGLE PROJECTION
Los Alamos
AI
89YXXXXXX
X

## Central Tracker Cost Scaling to 2 m diameter

Assumed Dimensions:

| | | |
|---|---|---|
| Silicon Tracker | 4 cm inside radius | + 1 cm rad. |
| | 38 cm outside radius | + 3 cm rad. |
| | 200 cm long | same |
| IPC Tracker | 39 cm inside radius | + 3.5 cm rad. |
| | 95 cm outside radius | + 26 cm rad. |
| | 300 cm long | same |
| Polyethylene | Barrel Section | |
| | 97 cm inside radius | + 26 cm rad |
| | 102 cm outside radius | +26 cm rad |
| | End Sections | |
| | 310 cm inside | same |
| | 350 cm outside | same |

**Cost Scaling**

| Si Tracker | June 10 Cost Est. Current Design | New Design | Increment |
|---|---|---|---|
| * Note: These cost increases reflect a larger diameter that would allow for an 18 cm fwd region if the design were to evolve in that direction. | | | |
| Electronics | | | |
| Power Cable & FO readout | These cost options are documented in the 12 vs 18 cm ladder cost sheet. | | |
| Si Det. & Assy | | | |
| Cooling Rings | | | |
| Mechanical Structure* | | | |
| Support Shells | these probably don't change significantly either way | | 0 |
| Outer & End Gas encl | 35 cm r | 38 cm r | 10% |
| | 431 k$ | 474 k$ | 43k$ |
| Inner Gas Enclosure | 8 cm r | 10 cm r | 25% |
| | 60 k$ | 75 k$ | 15 k$ |
| Space Frame | Hex. < 35 cm | Oct. < 38 cm | 10 % |
| | New design is not yet costed, but the central spoke and complex joints may increase the cost 10% | | 33 k$ |
| External Systems | No cost difference in the external cooling and safety systems is expected. | | Ok$ |
| Si Mech. Structure Total | | | 91 k$ |

| IPC Tracker | Current Design | New Design | Increment |
|---|---|---|---|
| Electronics | | | |
| Fwd Mod. Panels | Assume these costs increase by the ave. radius which is | | 30 % |
| | 360 k$ | 468 k$ | 108 k$ |
| Cent Mod Panels | Assume these costs increase by the ave. radius squared | | 68% |
| | 204 k$ | 342 k$ | 138 k$ |
| Cathode pads | | | — |
| Module Frames | | | — |
| Windows & Wires | | | — |
| Cooling Channels | Since the number of channels and heat load is not expected to change there would be no cost differential. | | 0 k$ |
| Ext Gas & Cooling Sys. | There is no expected cost increase for either one of these systems. | | 0 k$ |
| Support Structure | | | |
| Bulkheads | 25 sq ft | 46 sq ft | 84 % |
| | 15 k$ | 28 k$ | 13 k$ |
| Cylinders | 69 cm r | 95 cm r | 38% |
| | 44 k$ | 61 k$ | 17 k$ |
| End Cap Gas Encl. | | | |
| Boron Poly. | 3.7 k lbs | 5.7 k lbs | 54 % |
| | 39 k$ | 60 k$ | 21 k$ |
| IPC Total | | | 300K w/o 3 items |
| Total Incremental costs | | | — |

Note: there may be many small additional added costs such as increased power cable lengths, cooling distribution lines and gas manifolds lengths that should be accounted for.

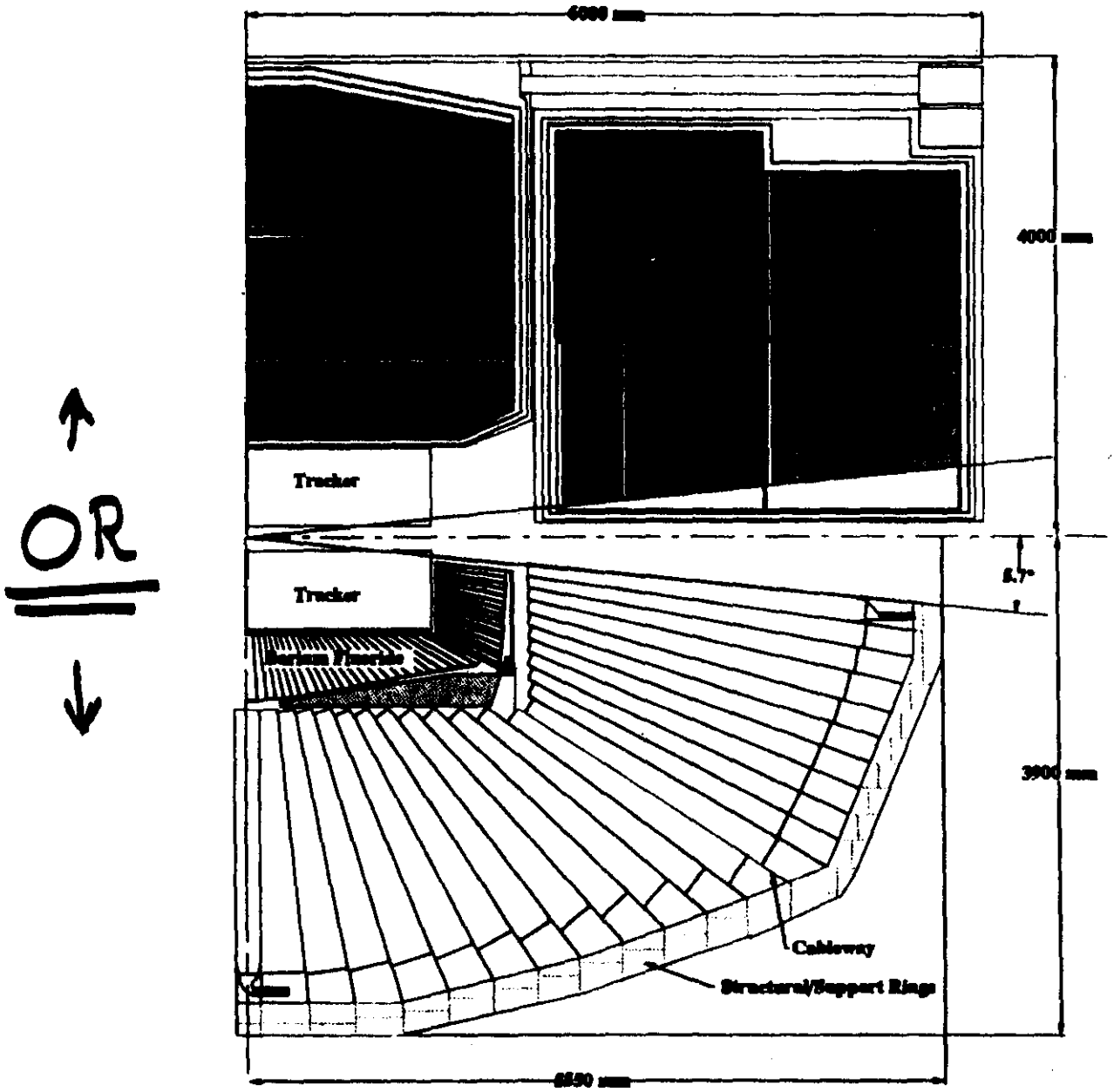
# CALORIMETER

EM - Precision electron/photon energy
Electron/photon position/direction
Electron/photon identification (shape, hadron veto)
Trigger

Hadron (includes forward) - Jet energy
Missing energy
Absorber
Muon identification, energy loss
Trigger

Liquid Argon/Krypton

Liquid Argon Calorimeter




OR

BaF2 EM with Scintillating Fiber Hadron Calorimeter

$BaF_2$ + Spaghetti

# BASELINE 2

EM: Liquid Krypton Accordion

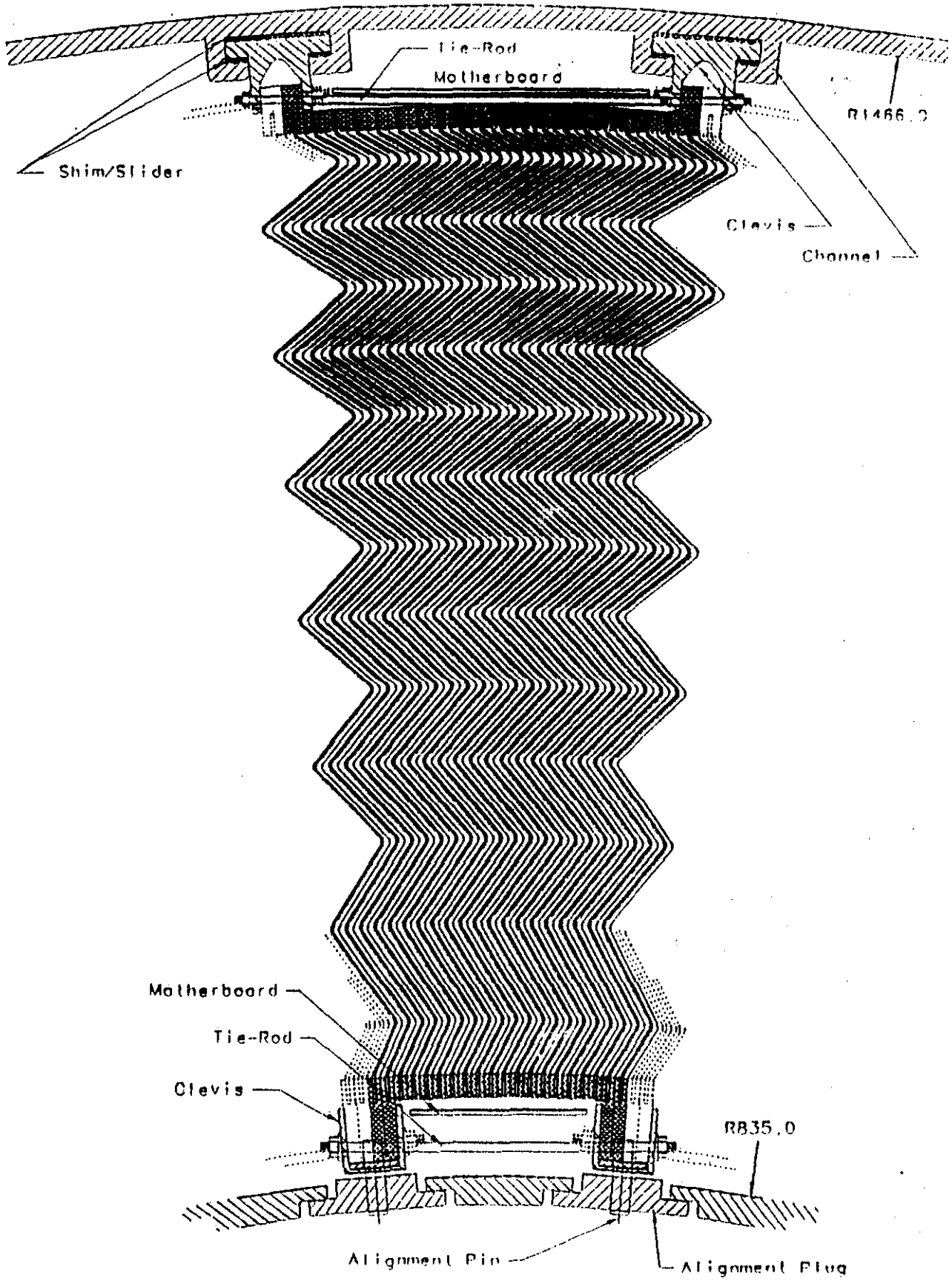



Figure 1-3a. Typical Module Lay-up in Section

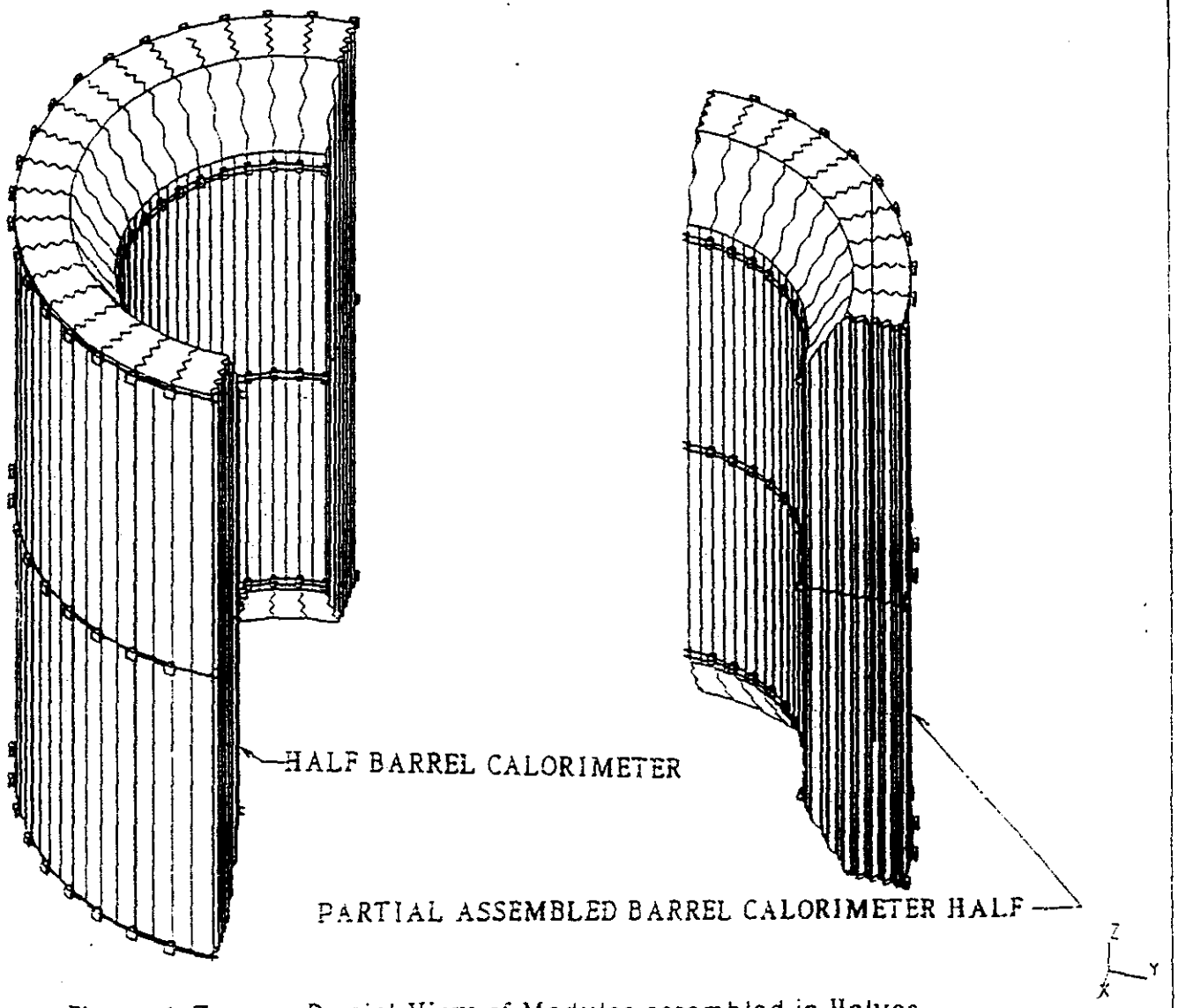
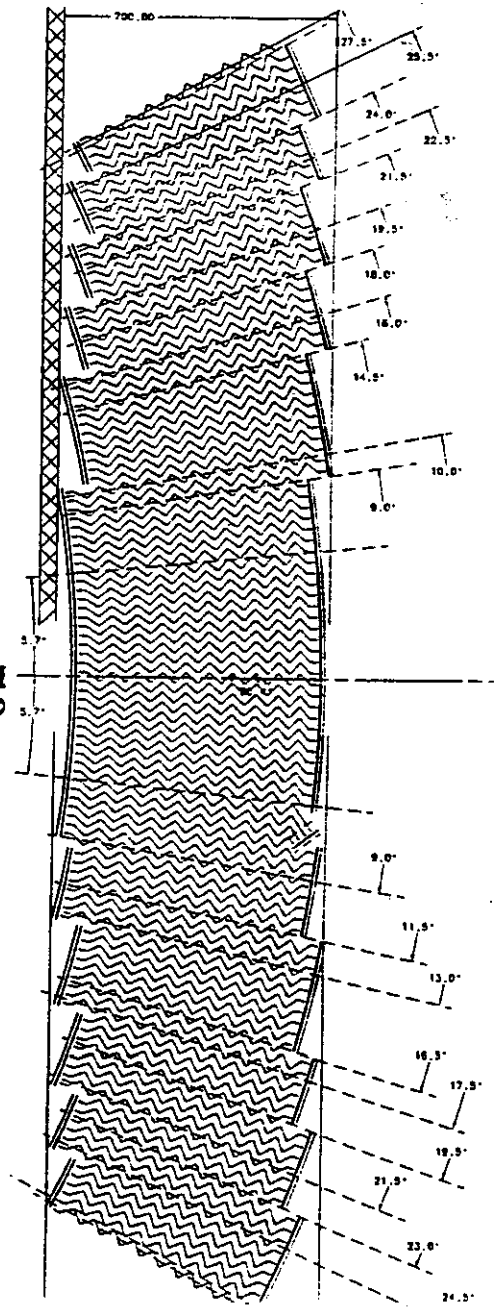
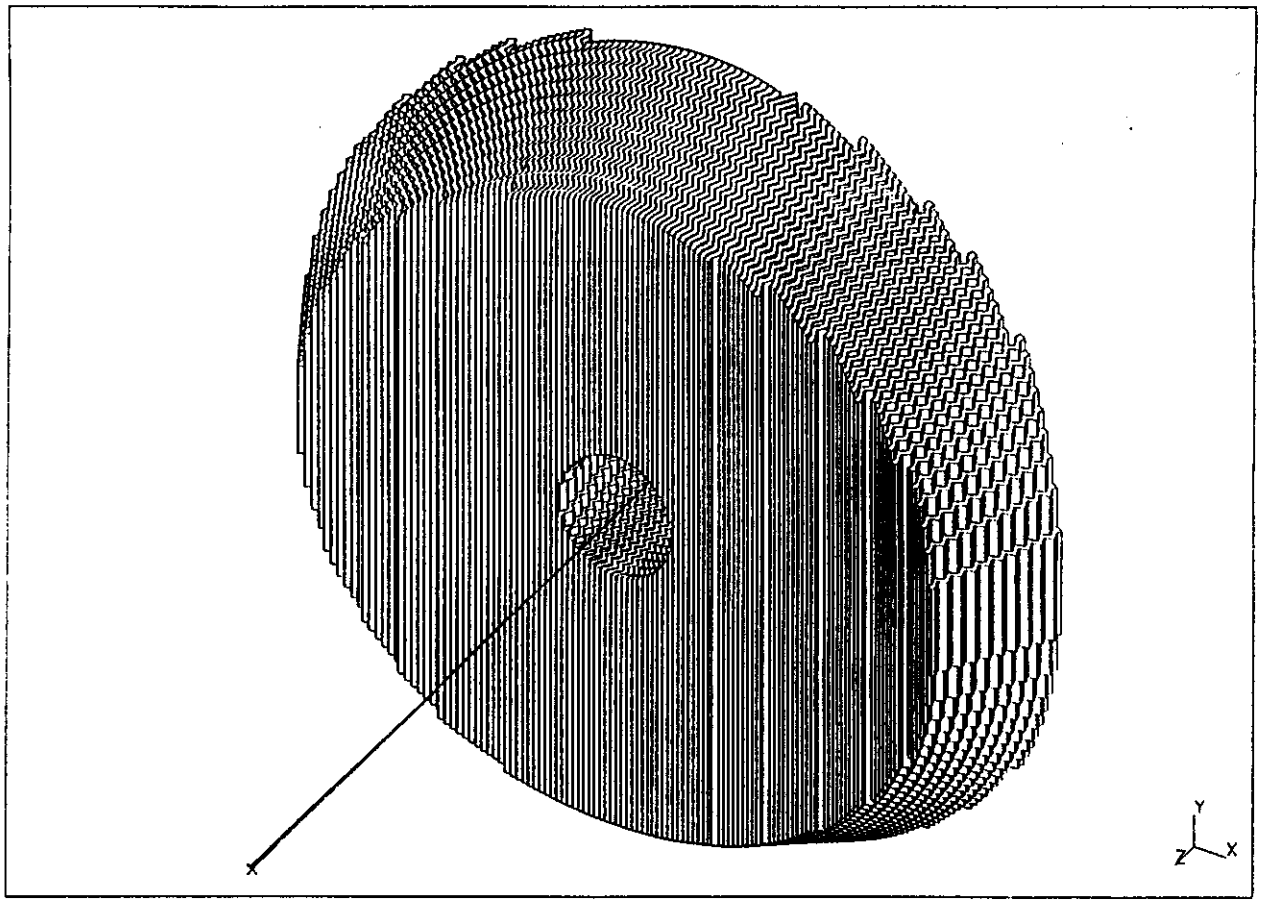



Figure 1-7 Partial View of Modules assembled in Halves

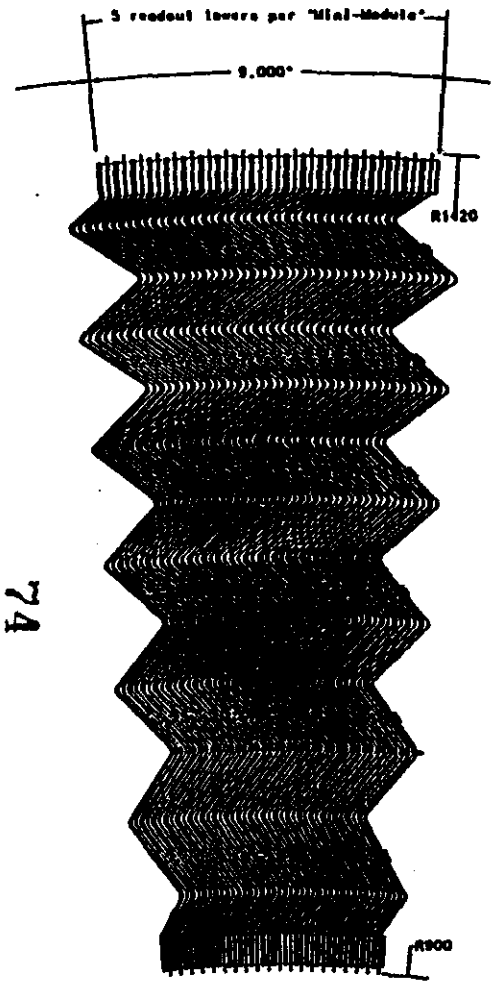
# Endcap Accordion EM

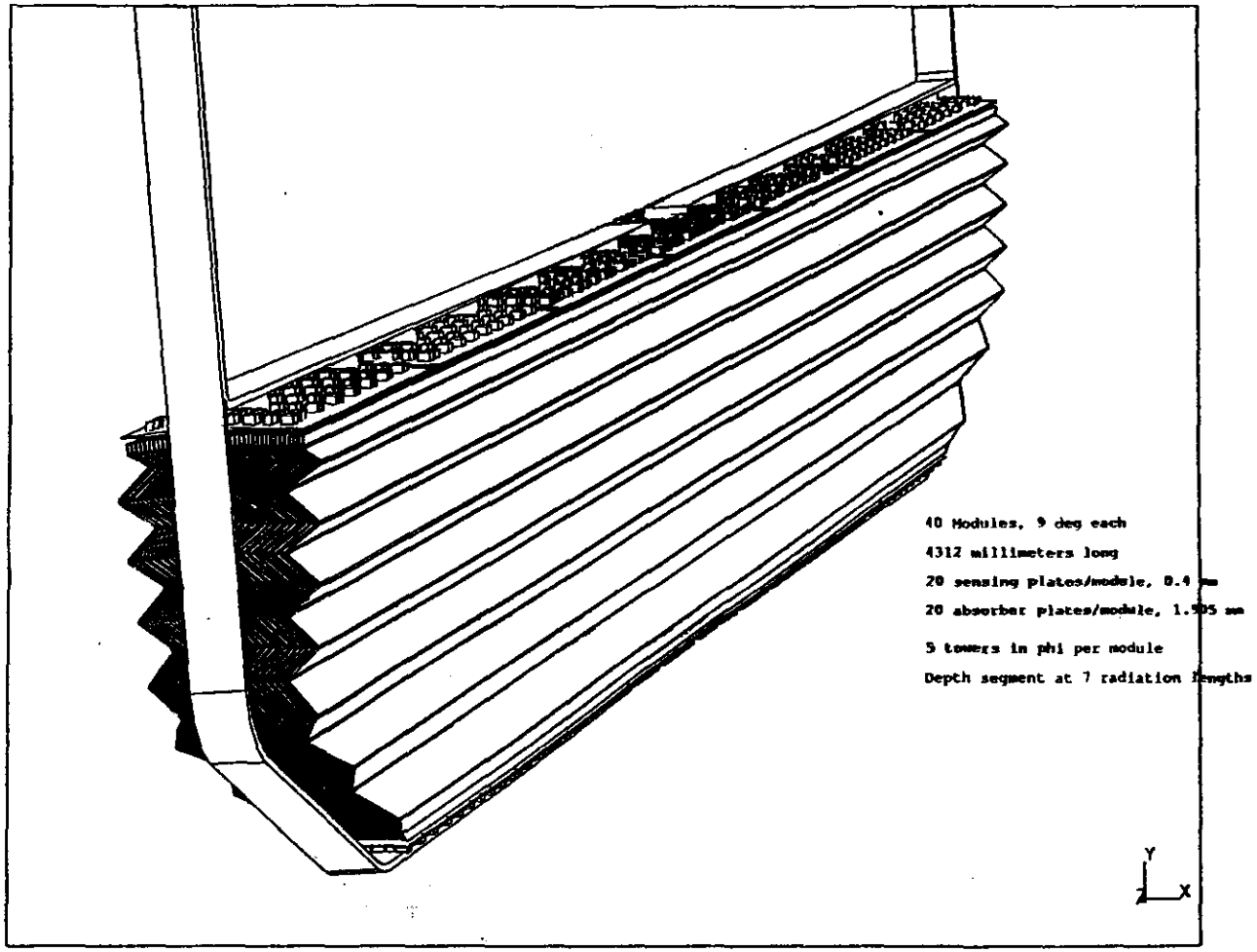




Fully Projective $\eta, \phi$
Crackless

# EM BARREL MODULE with Electronics and Cables



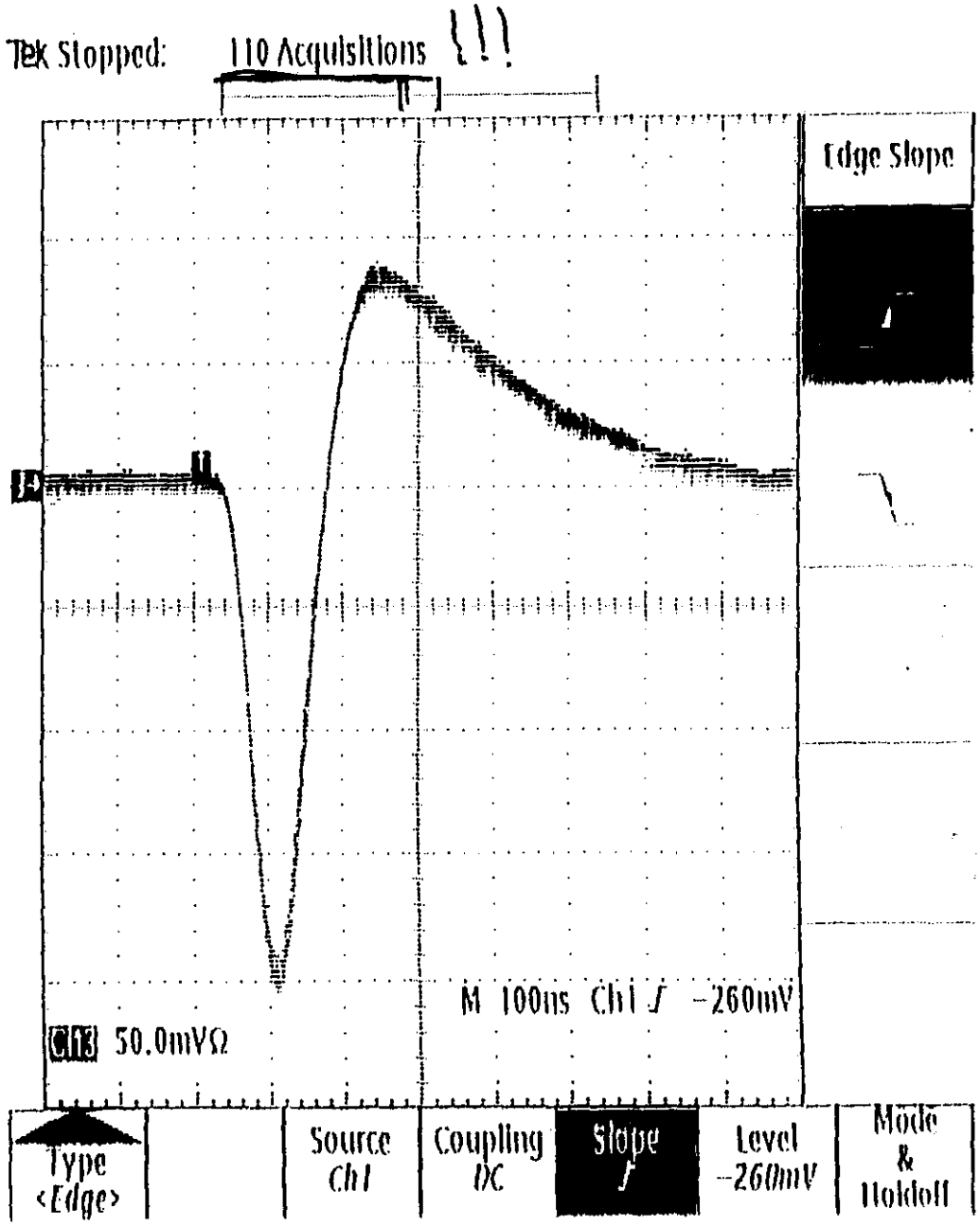




Each "Mini-Module" contains:
20 Absorber plates
20 Sensing Plates
40 spacers on the inner radius
40 spacers on the outer radius

In BNL Test Beam NOW < LAr / LKr

# Liquid Krypton Beam Test

7/22/92



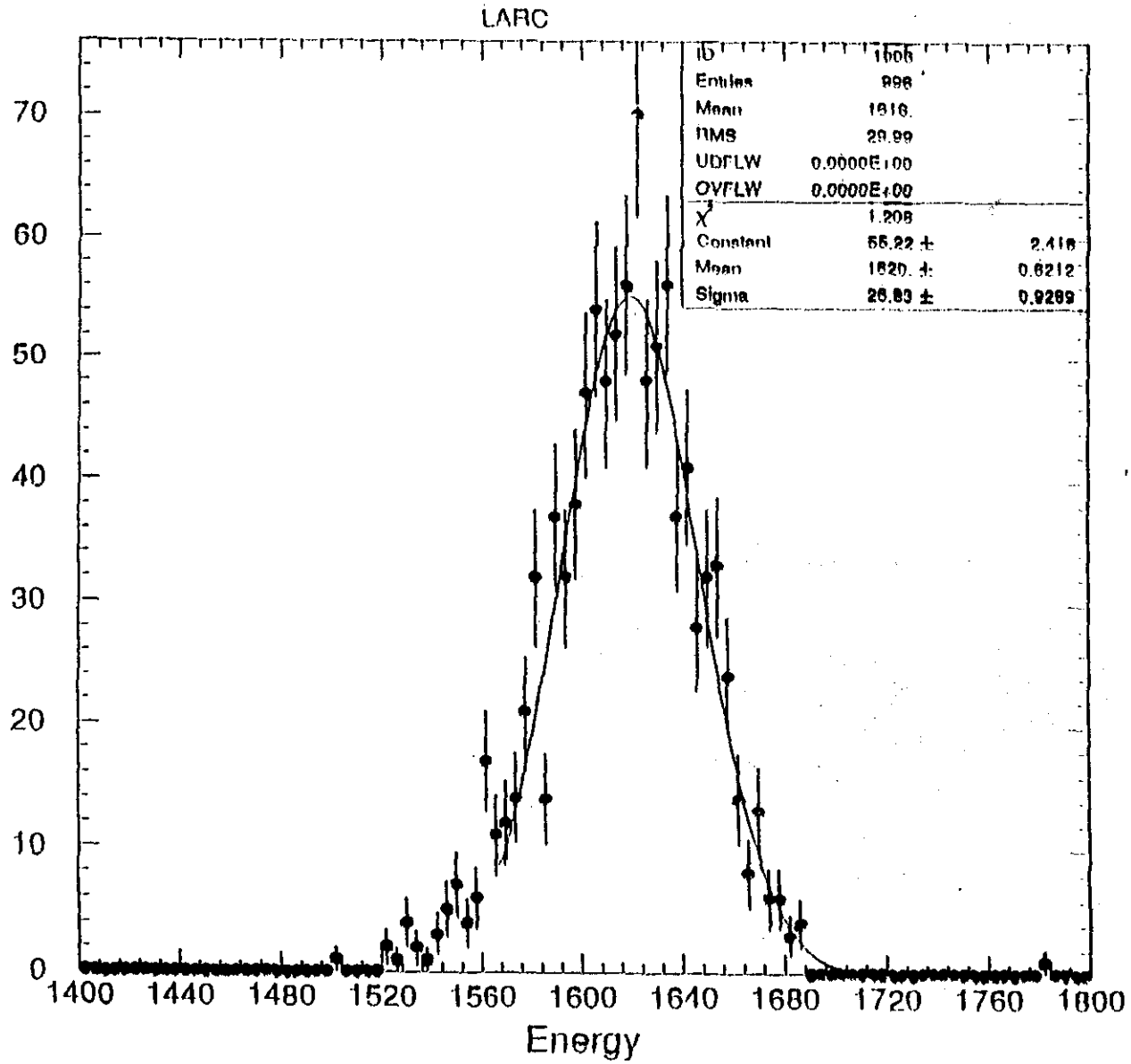

LKr , 2 mm stack , 1.5 kV

206eV

Sum of ~150 channels

Multiple trace - variable persistence

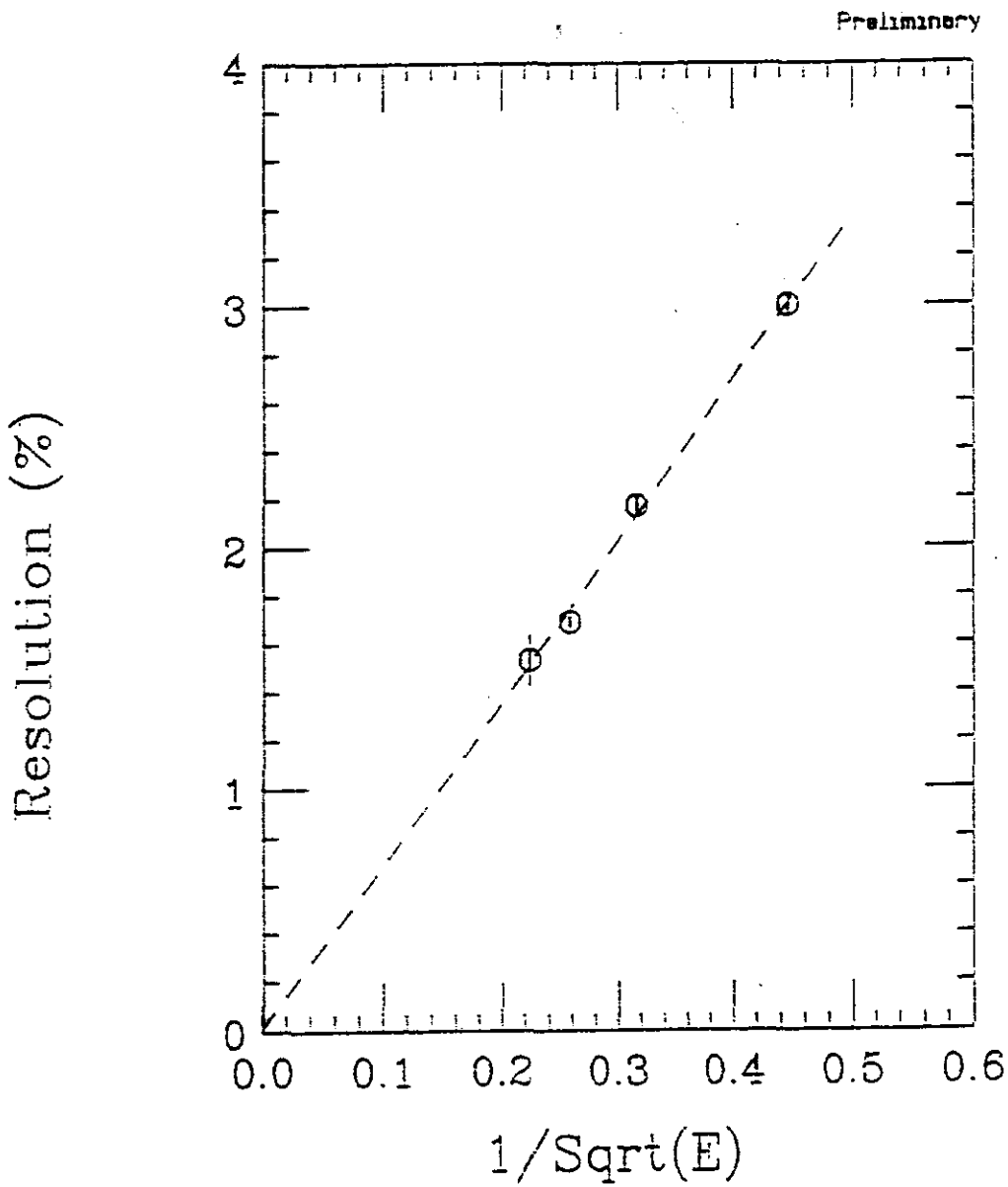
Beam size : 2.5 x 5 cm$^2$




20 Gev

$(1.61 \pm 0.1)\%$ $\frac{\Delta P}{P} = 1/2\%$ $(1.53 \pm 0.1)\%$

$7.2\%/\sqrt{E} + \frac{0.08}{E}$ $\frac{6.84}{\sqrt{E}} + \frac{0.08}{E}$




$$\frac{\Delta E}{E} = \frac{a\%}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

$$c = (0.0 \pm 0.2)\%$$

$$\frac{b}{E} = 0.08 \text{ Gev}/E$$

$$\frac{a}{\sqrt{E}} = \frac{(6.72 \pm 0.35)\%}{\sqrt{E}}$$

| Energy Resolution $\sigma/\sqrt{E}$ | | |
|---|---|---|
| Stack | Measurement* | Monte Carlo |
| 1 mm Ar | 6.1 - 5.8 | 6.25 |
| 2 mm Ar | 7.5 - 7.8 | 7.3 |
| 2 mm Kr | 6.3 - 6.9 | 6.3 |

After
subtracting beam spread of 0.5-0.7%

| Energy Resolution $\sigma/\sqrt{E}$ | | |
|---|---|---|
| Stack | Measurement* | Monte Carlo |
| 1 mm Ar | 6.1 - 5.8 | 6.25 |
| 2 mm Ar | 7.5 - 7.8 | 7.3 |
| 2 mm Kr | 6.3 - 6.9 | 6.3 |

After
subtracting beam spread of 0.5-0.7%

Fig. 2 Wrong vertex selection at different luminosity

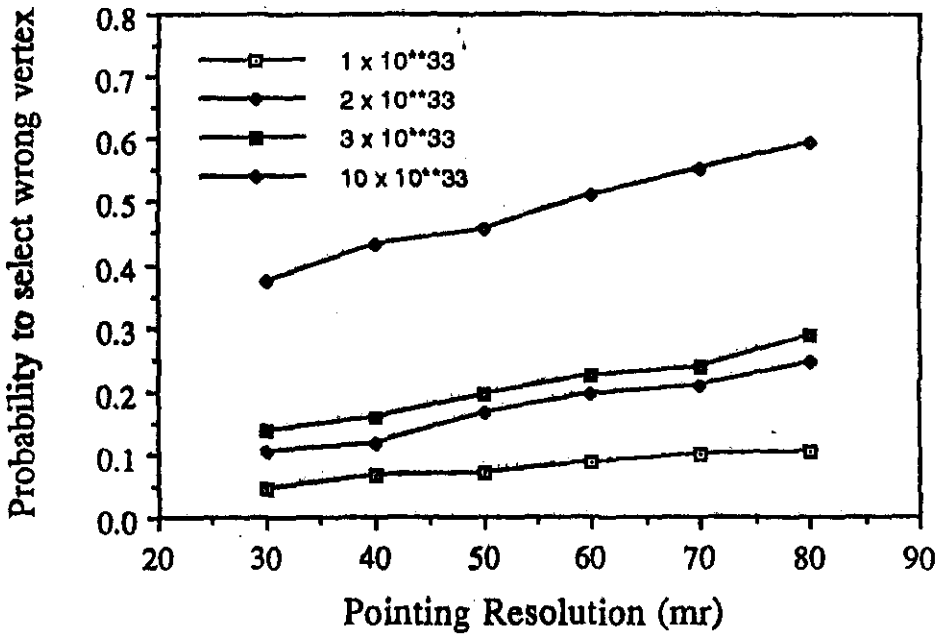
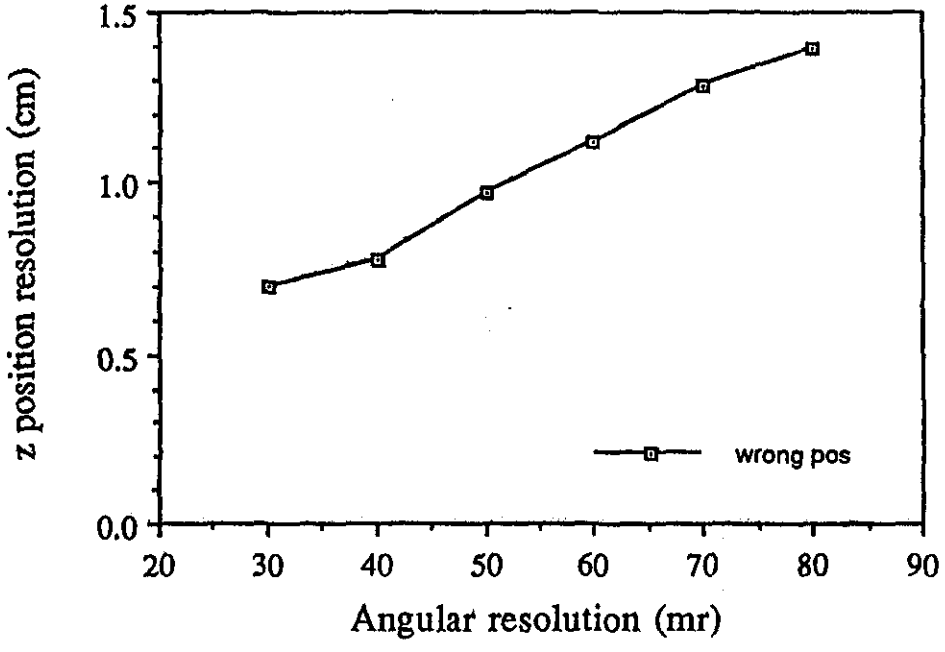



Fig. 3 vertex distribution when wrong one is selected



# Event vertex resolution

## Event sample used

120 GeV Higgs $\rightarrow \gamma + \gamma$ (500 events)

## Detector

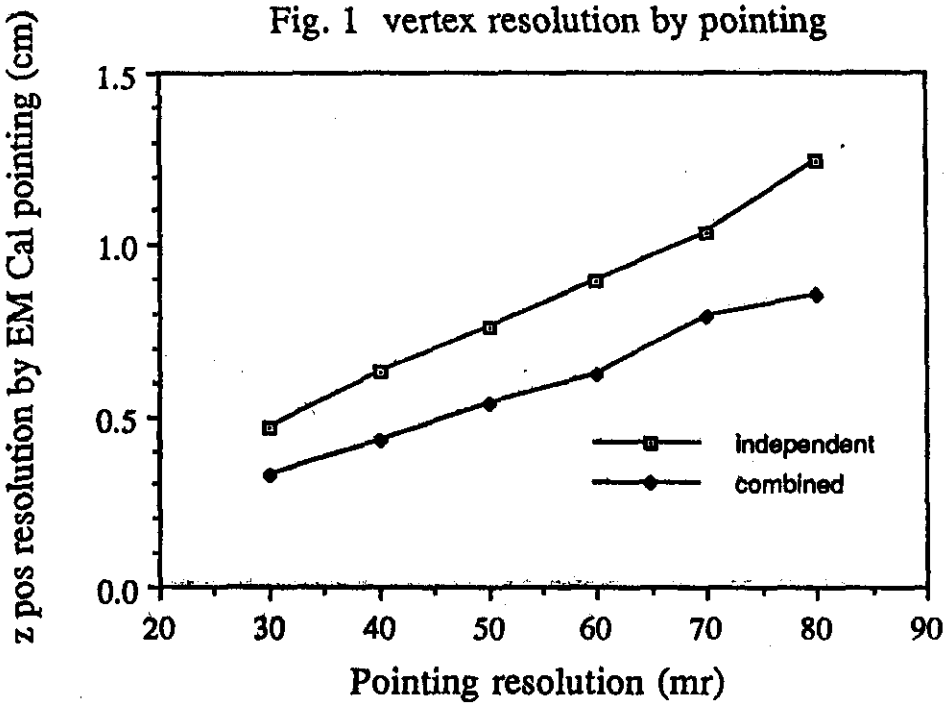
150 cm (half length) x 75 cm (radius) cylinder EM Cal
Pointing resolution = AR / $\sqrt{E}$
Vertex resolution by CT = 1 mm
Event vertex - Gaussian distribution with $\sigma$ = 5 cm

## Vertex determination

1. Pointing by one EM cell
2. Combination of pointings of two EM cells
3. Combined pointing and CT vertex determination

## Result

Fig. 1 vertex resolution by pointing



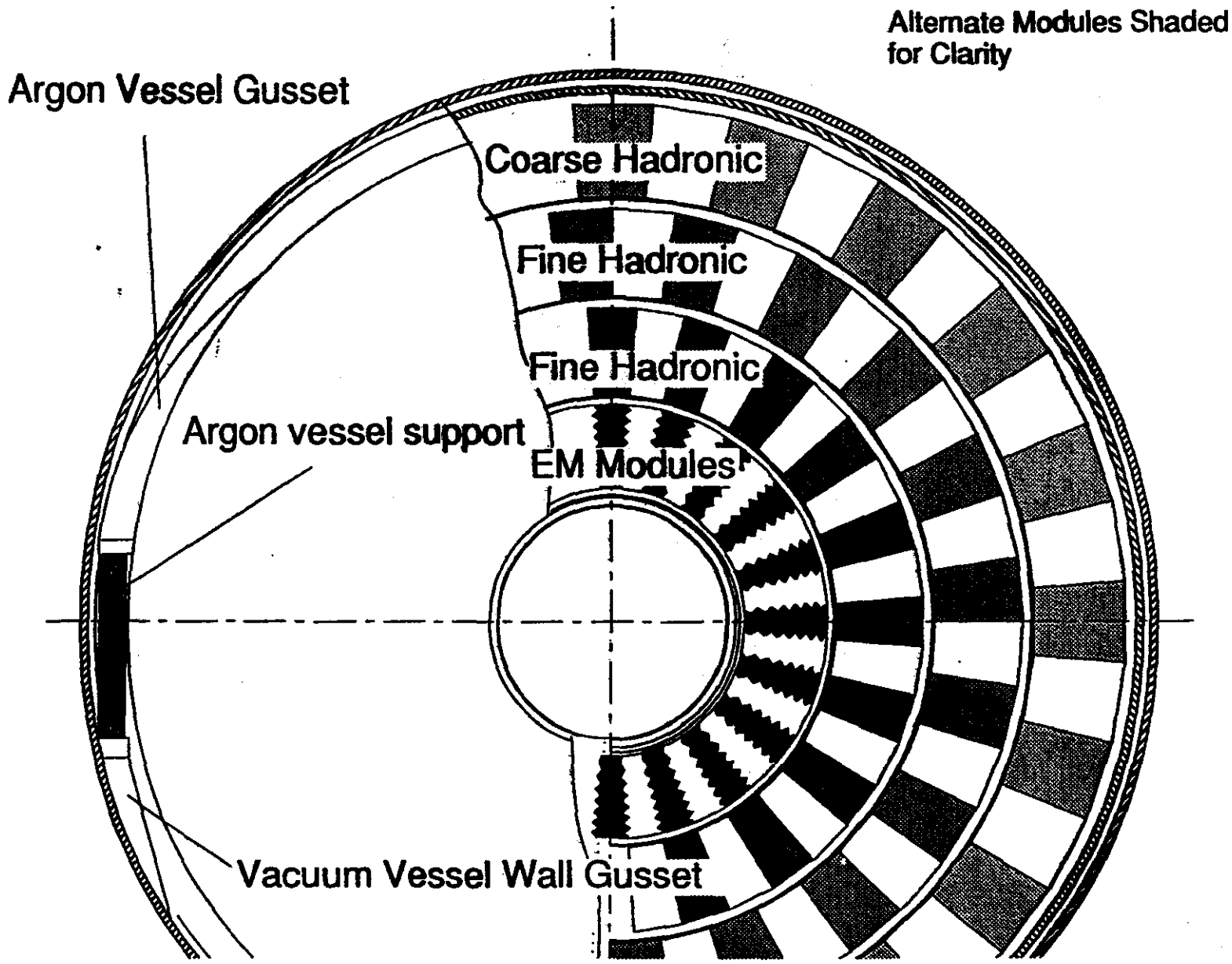
# BASELINE 2

EM + Hadron

## HYBRID CALORIMETER

- Two Technology Calorimeter.
  Liq Kr
  +
  Scint.

# Barrel Cross-Section (looking down beam line)

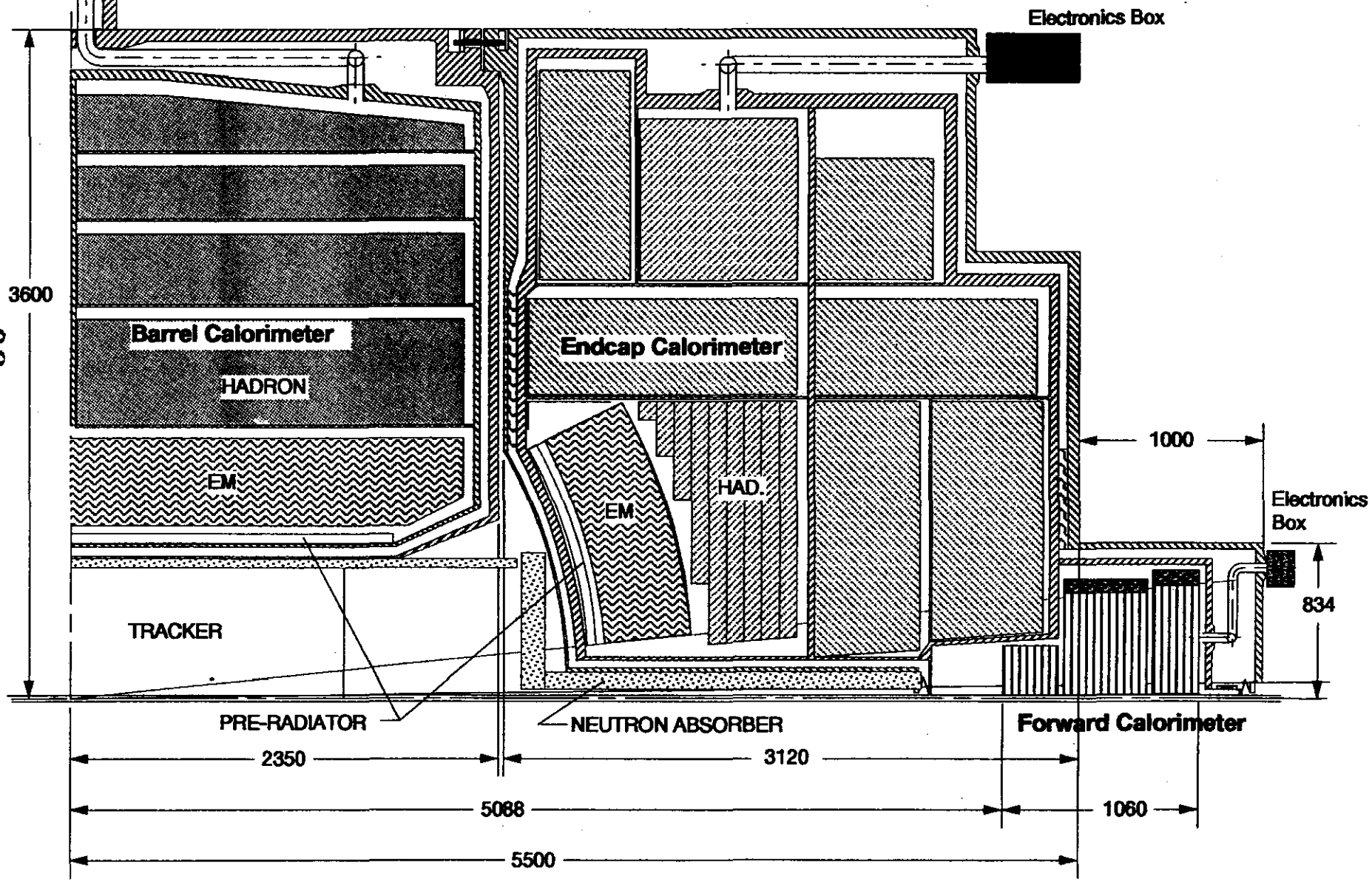


# GEM Liquid Argon Calorimeter

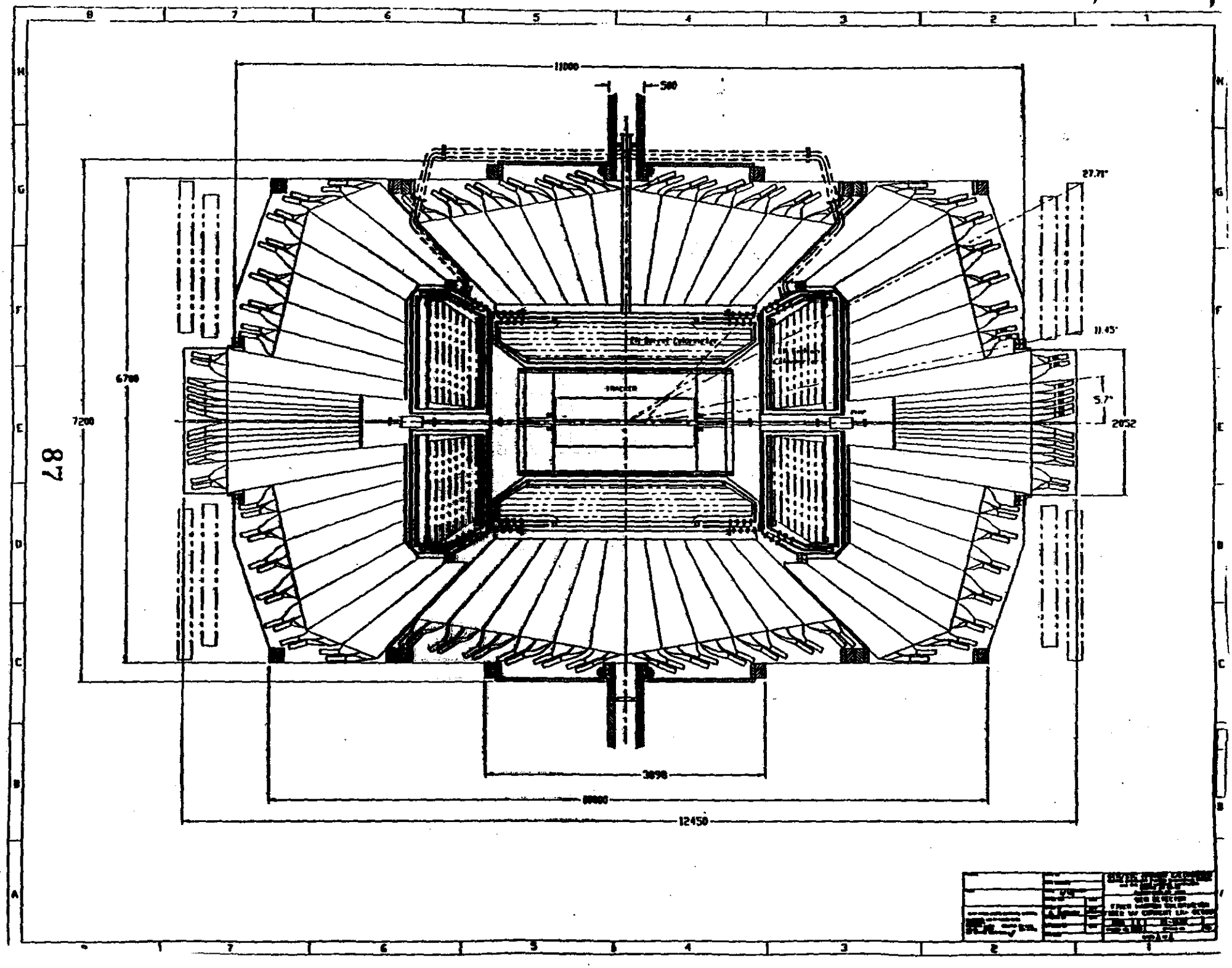
**1/4 Section "Off Vertical"**
**Copper Hadron Absorber**

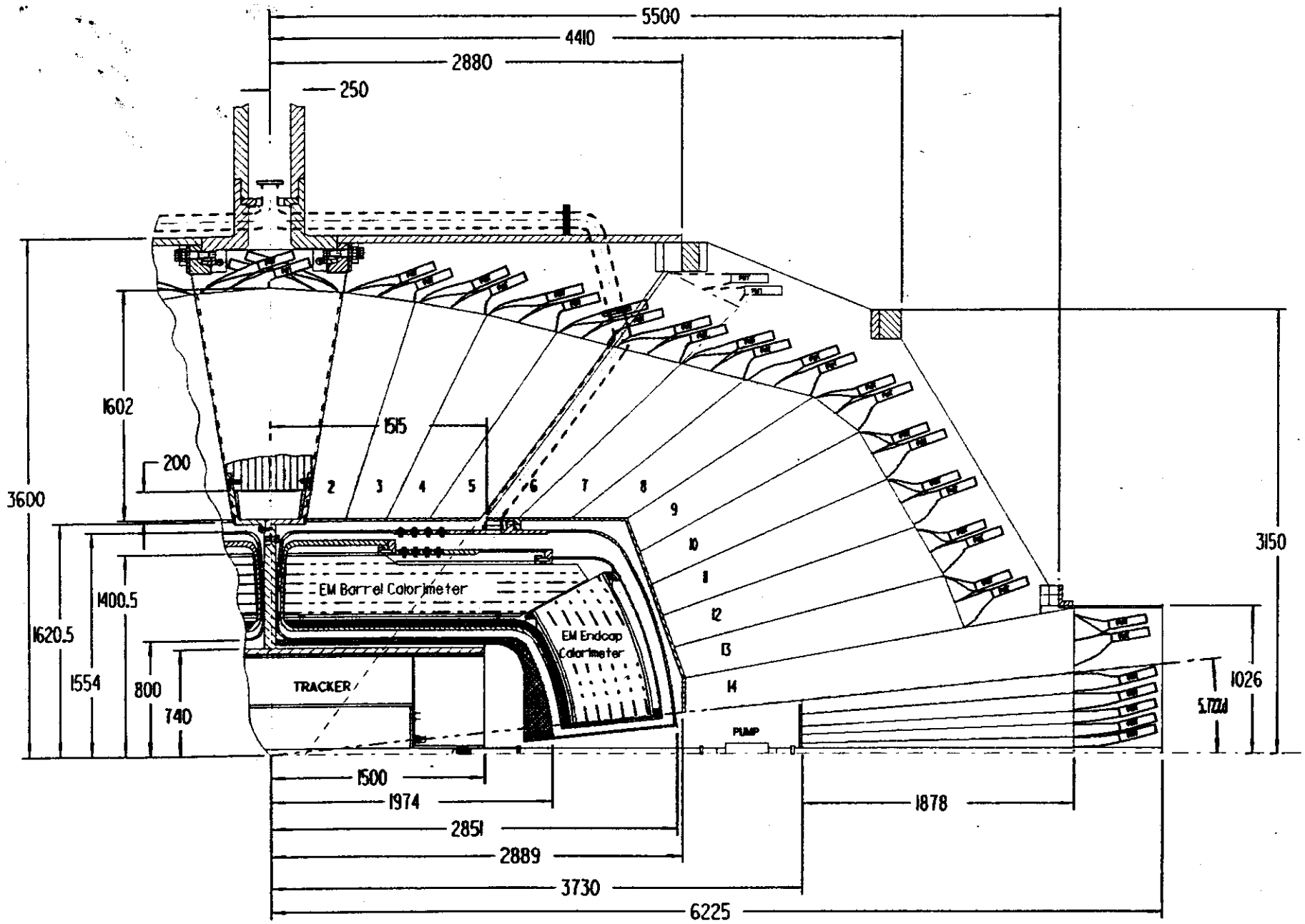
Shows General Configuration with Electronic feed throughs

In Base-line Design




LLMason 3/23/92


11000
500
27.71°
11.45°
5.7°
2052
6700
7200
3090
12450


5500
4410
2880
250
1602
1515
200
3600
2
3
4
5
6
7
8
9
10
11
12
13
14
3150
EM Barrel Calorimeter
EM Endcap Calorimeter
1400.5
1620.5
1554
800
740
TRACKER
PUMP
1026
1500
1974
2851
2889
3730
6225
1878

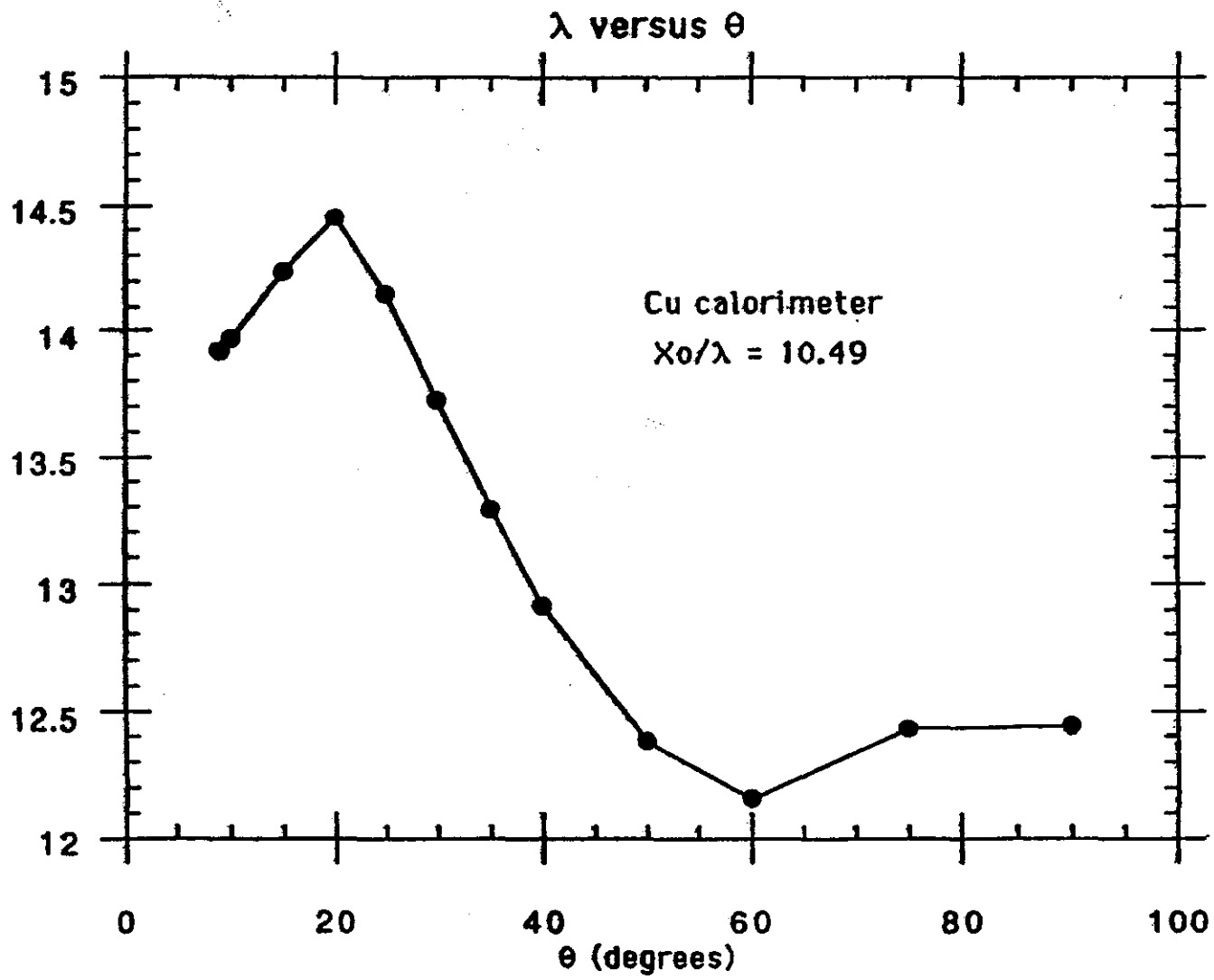

λ versus θ
15
14.5
14
13.5
13
12.5
12
0
20
40
60
80
100
θ (degrees)
Cu calorimeter
Xo/λ = 10.49

Fig. 4.2.1

# BASELINE 2

## HYBRID OPTIMIZATION

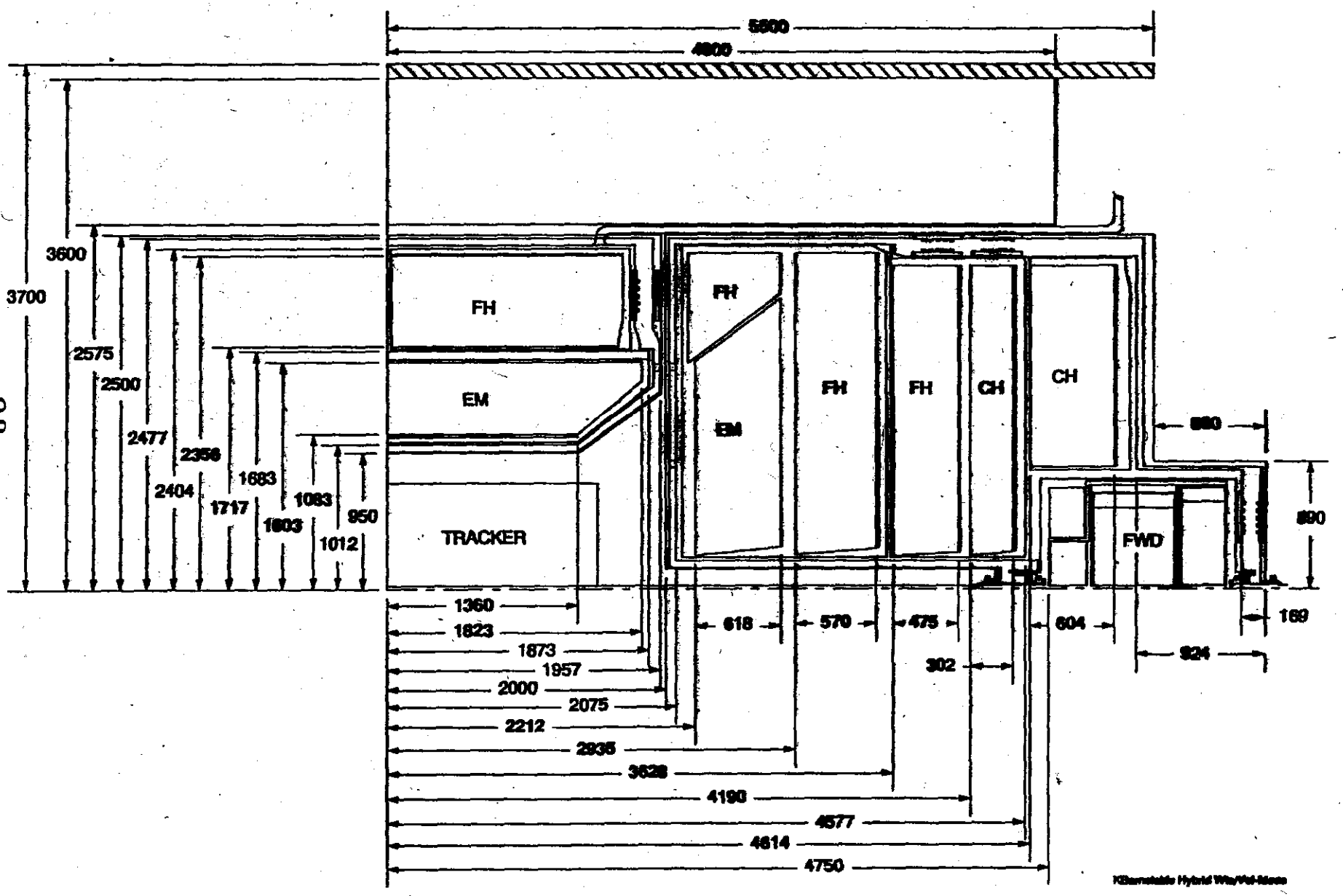
- ORGANIZATION : LEADER - WILLIS
  LEAD ENG - ORNL

- **INCLUDE SHORT HADRONIC SECTION IN LIQ CALORIMETER**
  - services
  - optimize thickness
  - scint had configuration
  - forward direction (eg. access, beam pipe)

  etc.

# Preliminary Hybrid Concept

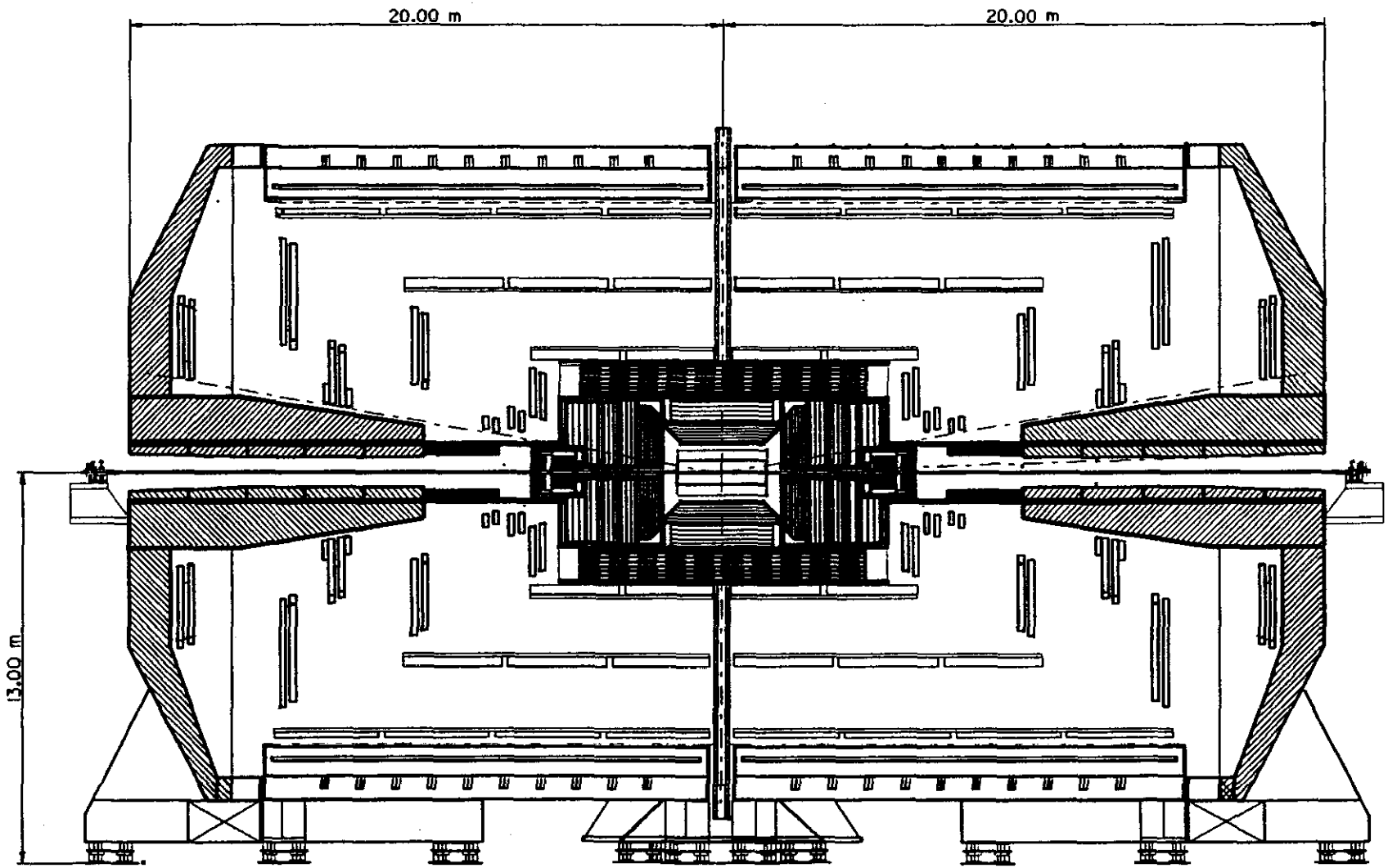
**Dimensions (All dimensions are in mm)**
**Note: All bold dimensions are to active areas.**



# GEM DETECTOR OPTION 2

**E.M. CALORIMETER : INTEGRATED / BARREL CALORIMETER : SCINTILLATING FIBER**

**END CAP CALORIMETER : INTEGRATED / FORWARD CALORIMETER : INTEGRATED**
**TRACKER : 1.5 M VACUUM SYSTEM ; 3 POSSIBILITIES**



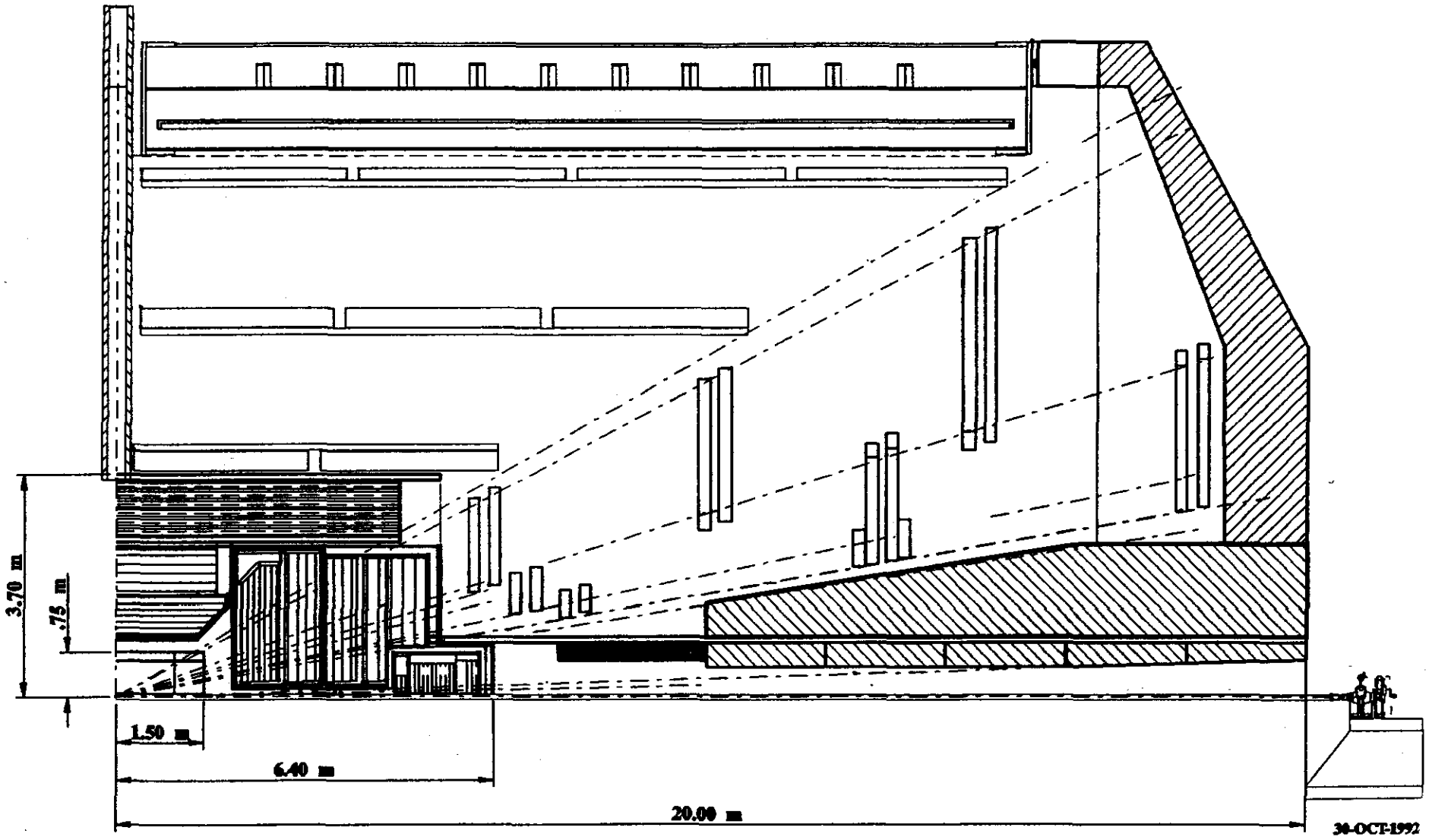
# GEM GETECTOR PARAMETERS

## OPTION 2

E.M. CALORIMETER: INTEGRATED; BARREL CALORIMETER: SCINTILLATING FIBER

ENDCAP CALORIMETER: INTEGRATED; FORWARD CALORIMETER: INTEGRATED

TRACKER: 1.5M; VACUUM SYSTEM: 3 POSSIBILITIES



# THE GEM MUON SYSTEM

## FUNCTIONS:

- Muon Identification
  Track outside 12 to 14 $\lambda$ calorimeter
  (146 $X_0$ of Cu)

- $P_T$ trigger ( $P_T$ > 10 GeV/c typical)
  Segmentation: 1.3 cm. - barrel
  5 mm. - endcaps

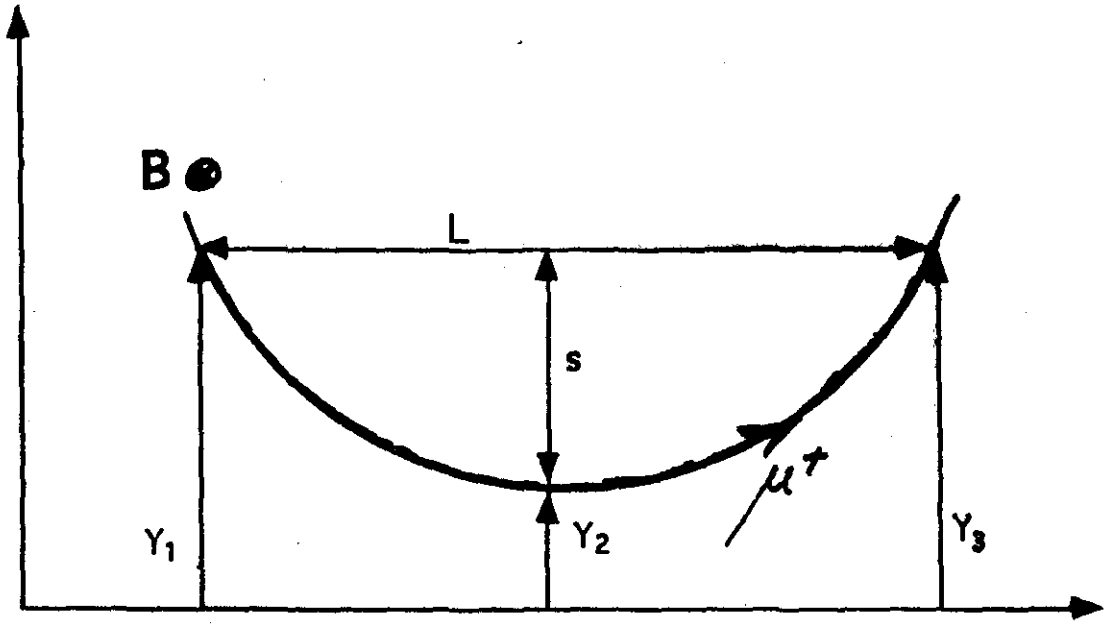
  Rates - Level 1: $10^4$ Hz @ $10^{33}$
  Level 2: $3 \times 10^2$ Hz @ $10^{33}$

- Beam crossing tag: ($\tau$ < 5 ns. )

- Tracking
  - $P_T$ resolution:
    $\delta P_T/P_T \approx 5\%$
    for 500 GeV/c & $\eta \approx 0$ (90°)
    $\delta P_T/P_T \approx 10\%$
    for 500 GeV/c & $\eta \approx 2.5$ (9.47°)

  - Muon charge assignment:
    95 % confidence level
    for $P_T$ < 2.8 TeV/c for $0 < \eta < 2.5$

# WE USE 3 POINT SAGITTA MEASUREMENT




$$S = \frac{y_1 + y_3}{2} - y_2 = \frac{1}{8}\frac{q\,B\,L^2}{P}$$

Optimize Magnet with large L and weak B

$S \approx 1500\ \mu m$

for:

$B \approx 0.8$ tesla

$L \approx 5$ m.

$P \approx 500$ GeV/c

To keep $\frac{\delta P}{P} \leq 0.05 \Rightarrow \delta S \leq 75\ \mu m.$

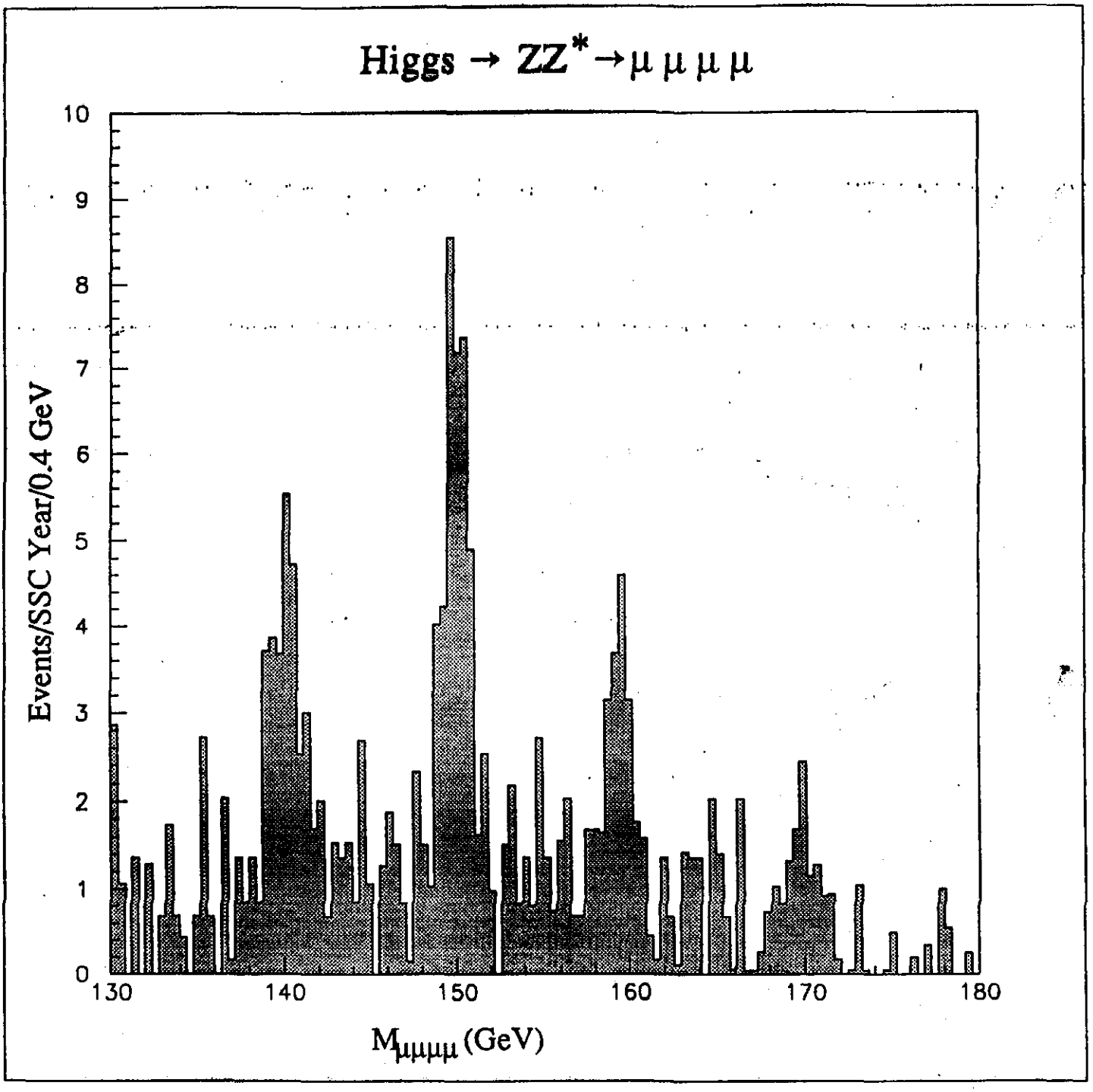
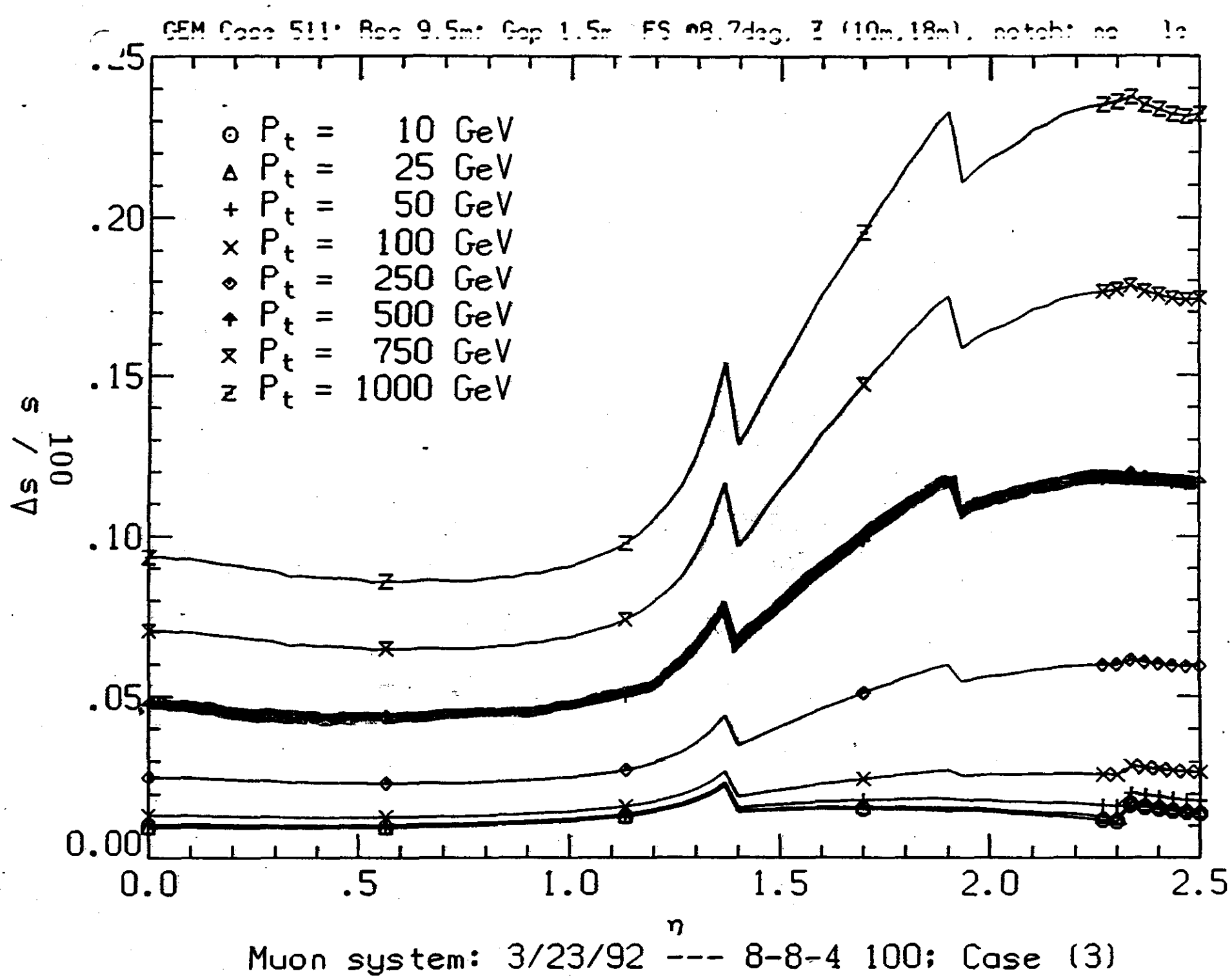


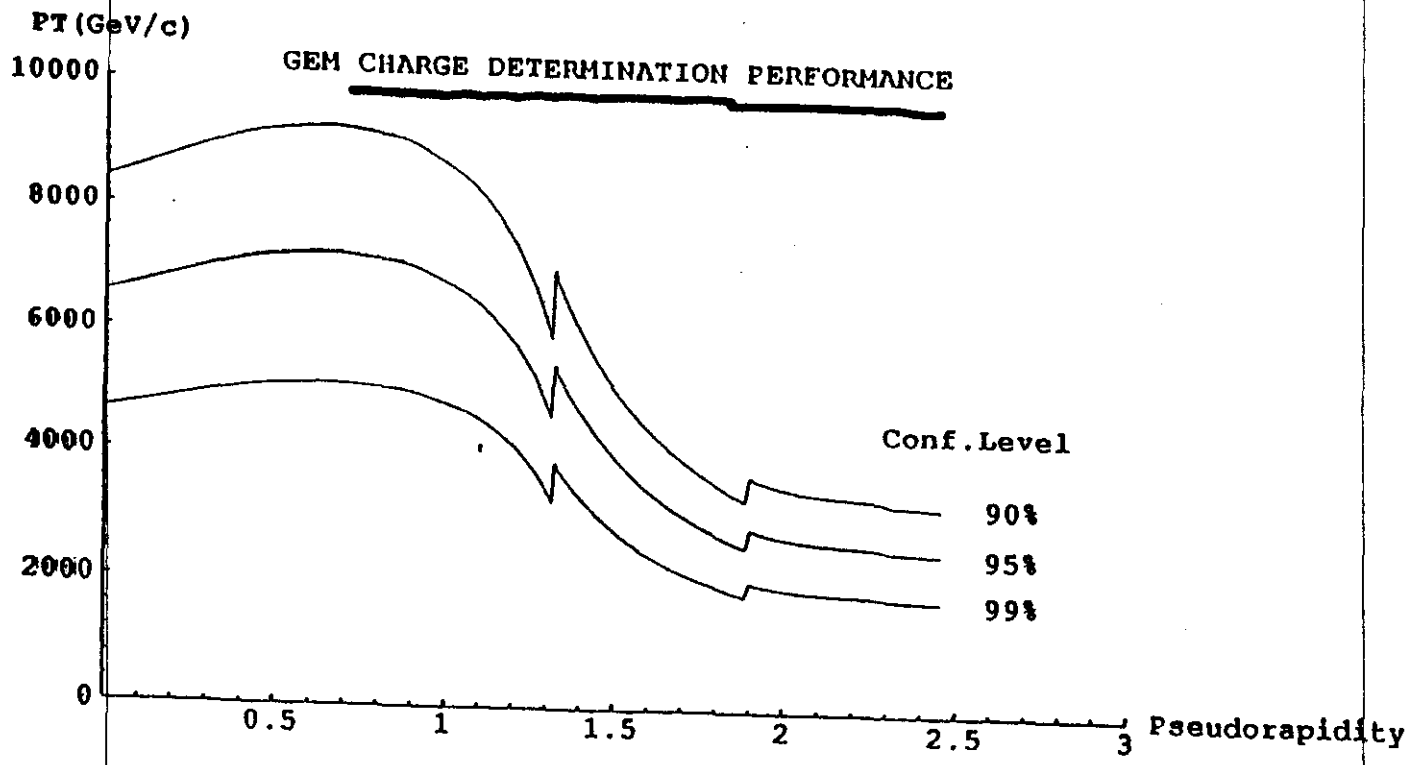

**Figure 2: H→ $ZZ^* \rightarrow \mu^+\mu^-\mu^+\mu^-$ mass ditribution for $M_H$ = 140, 150, 160 and 170 GeV, superimposed on all backgrounds for GEM.**

# GEM Muon System

| | |
|---|---|
| Central field | 0.8 T |
| Length of magnet | 30 m |
| Inner radius of magnet | 9.0 m |
| Outer radius of calorimeter system | 3.6 m |
| Location of neutron shield | $3.6 < R < 3.7$ m |
| Pseudorapidity coverage in barrel | 0.074 – 1.33 |
| Pseudorapidity coverage in endcaps | 1.40 – 2.46 |
| Intrinsic single layer resolution | 100 $\mu$m |
| Alignment accuracy in a superlayer | 50 $\mu$m |
| Alignment accuracy between superlayers | 25 $\mu$m |
| Global alignment accuracy | 200 $\mu$m |


GEM Case 511: Rec 9.5m: Gap 1.5m FS 08.7deg. Z (10m,18m), notch: no
⊙ $P_t$ = 10 GeV
△ $P_t$ = 25 GeV
+ $P_t$ = 50 GeV
× $P_t$ = 100 GeV
◇ $P_t$ = 250 GeV
↑ $P_t$ = 500 GeV
x $P_t$ = 750 GeV
z $P_t$ = 1000 GeV
$\Delta s / s$ 100
.25
.20
.15
.10
.05
0.00
0.0
.5
1.0
1.5
2.0
2.5
η
Muon system: 3/23/92 --- 8-8-4 100; Case (3)

Figt 4.1.1


PT(GeV/c)
GEM CHARGE DETERMINATION PERFORMANCE
10000
8000
6000
4000
2000
0
Conf.Level
90%
95%
99%
0.5
1
1.5
2
2.5
3
Pseudorapidity

Prototype Cathode Strip Chamber

Choice for End Caps:

Option for Barrel

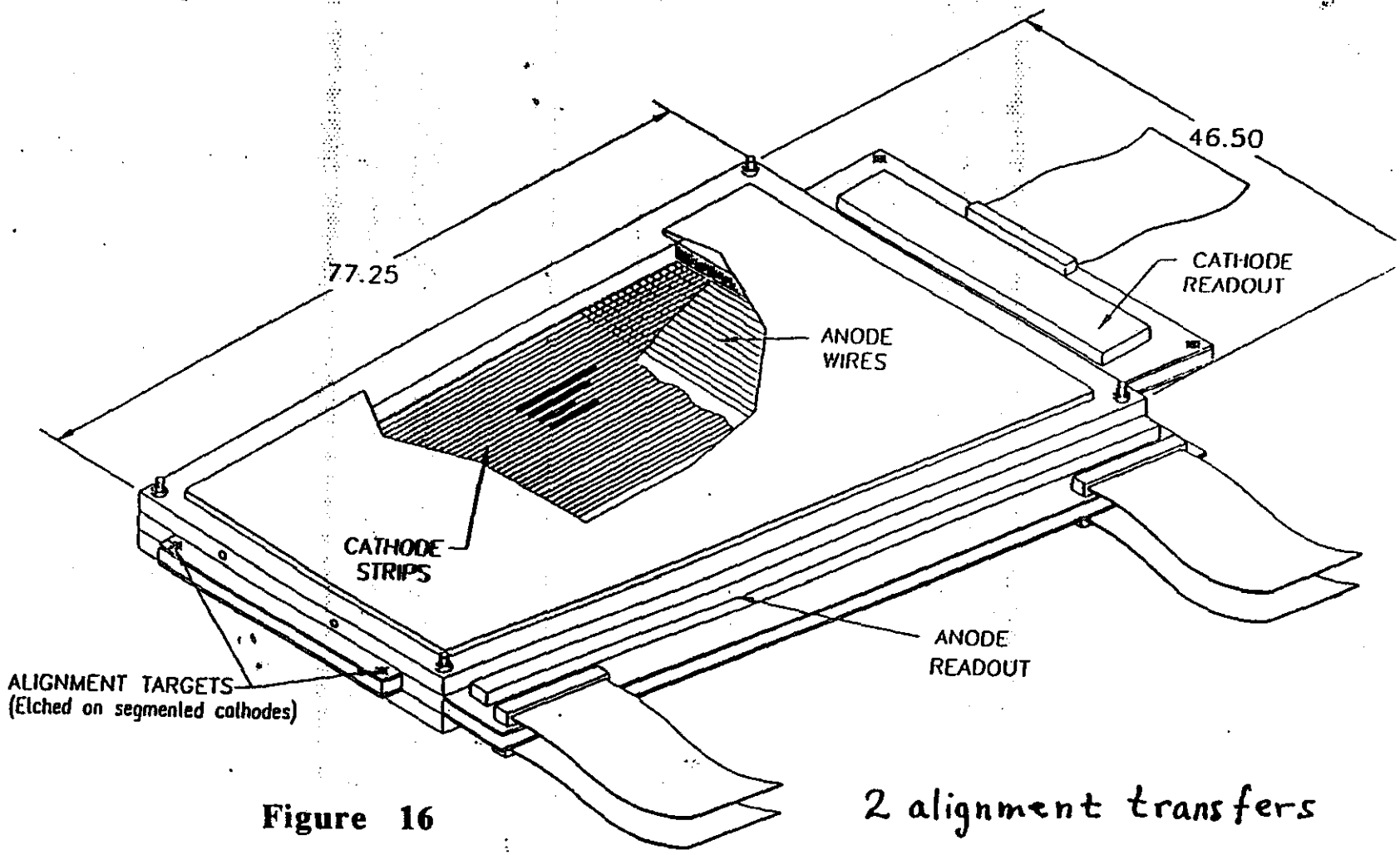



**Figure 16**

2 alignment transfers

# Proposed Technologies for GEM Muons

## ENDCAP REGION
$9.5° < \Theta < 30°$ $(1.3 < \eta < 2.5)$

| Measurement | Technology |
|---|---|
| $P_T$ (r-$\phi$) | Cathode Strip Chambers |
| Second Coordinate ($\theta$) | Cathode Strip Chambers |
| Trigger | Cathode Strip Chambers |
| Beam Crossing Tag | Cathode Strip Chambers |

**Also Under Consideration for Central Region**

**OR**

## CENTRAL REGION
$\Theta > 30°$ $(0.0 < \eta < 1.3)$

| Measurement | Technology |
|---|---|
| $P_T$ (r-$\phi$) | Proportional Tubes or Limited Streamer Tubes in Drift Mode |
| Second Coordinate ($\theta$) | Resistive Plate Chambers |
| Trigger | Resistive Plate Chambers |
| Beam Crossing Tag | Resistive Plate Chambers |

# BASELINE 2

END CAPS : CSC

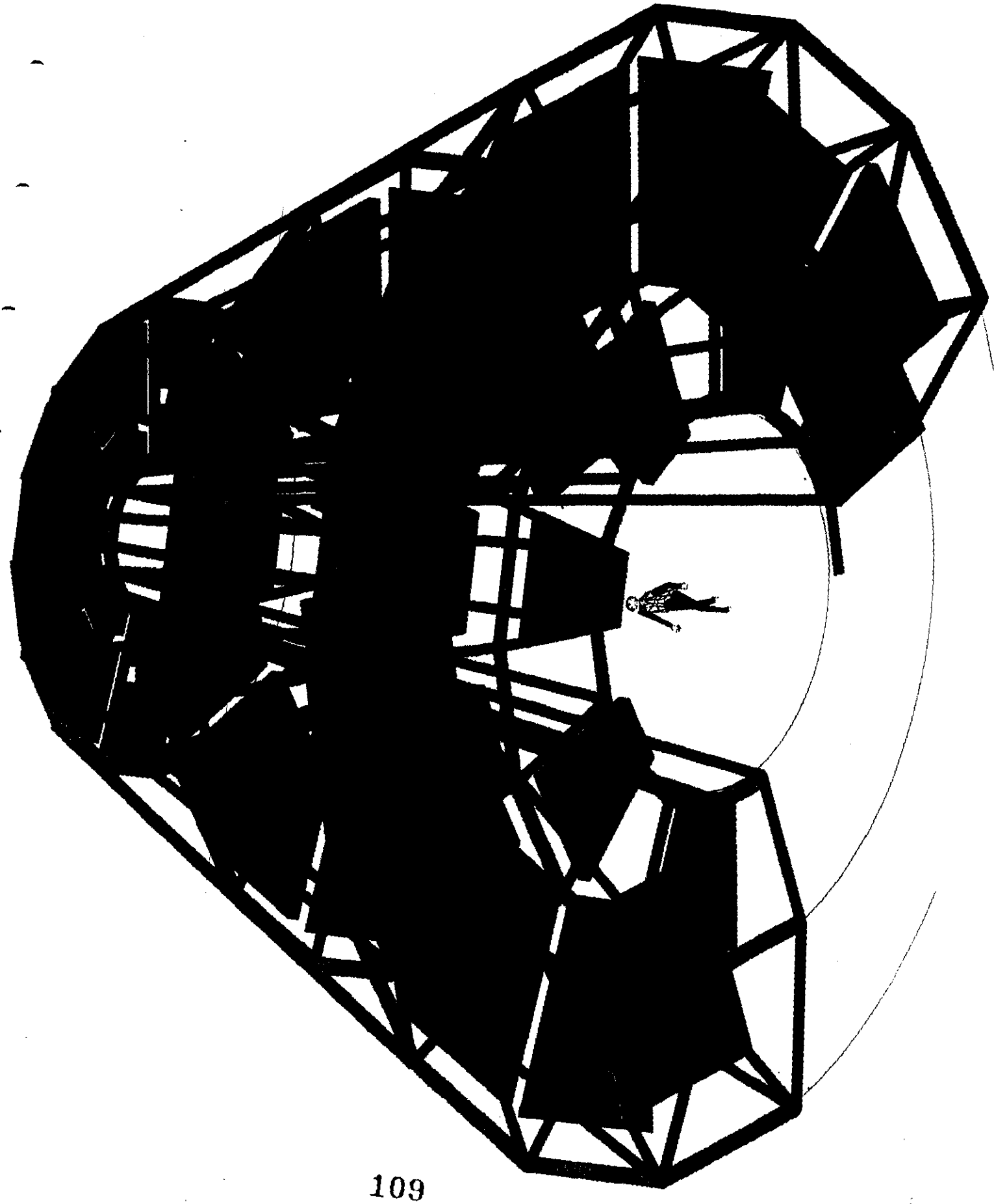
BARREL : Determine this Meeting

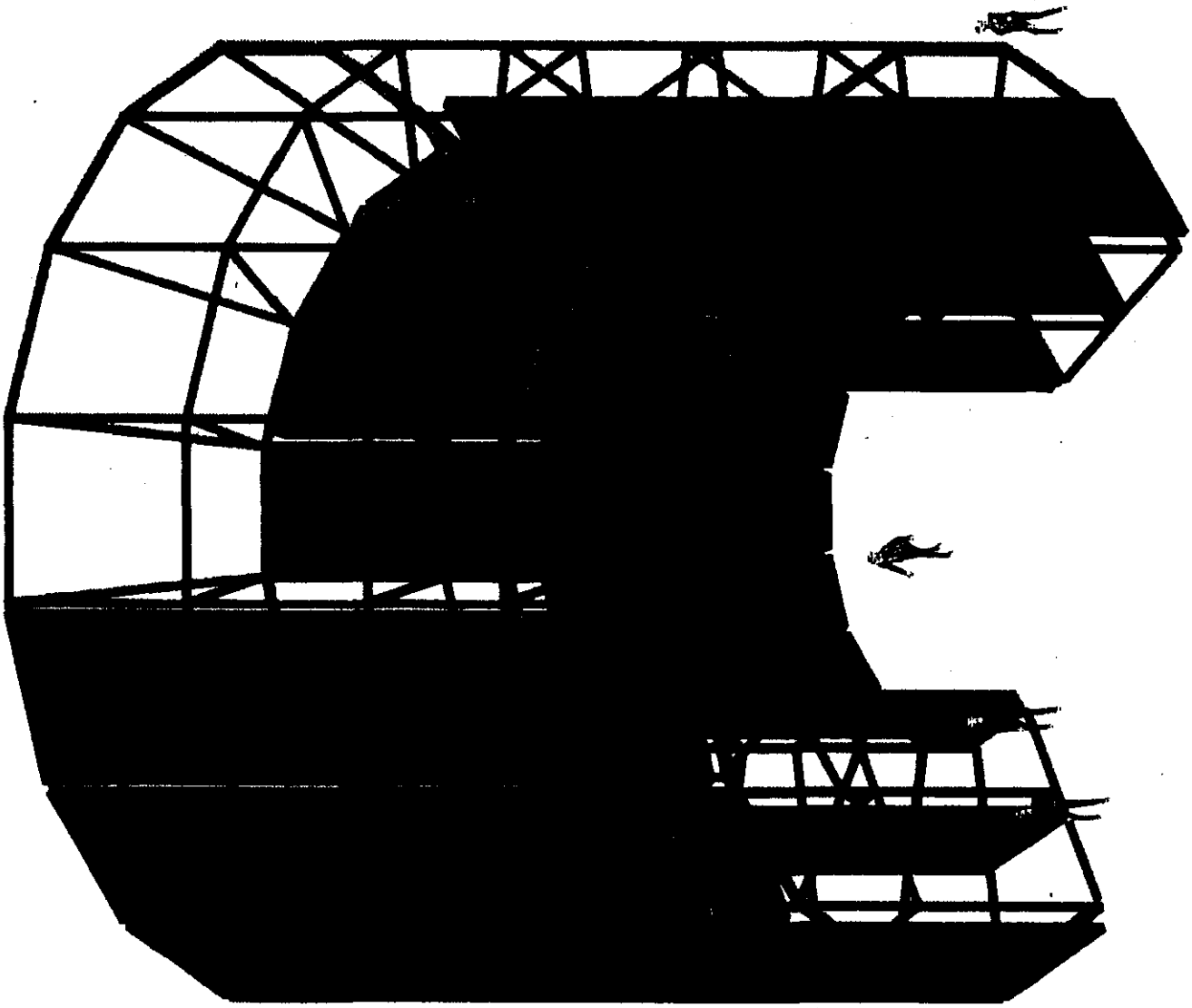
# BASELINE 2

## BIG WHEEL VS SECTOR APPROACH

- Eng. Recommendation Nov. 20.

  Based on Performance !!
  Stability





for the counter light attenuation properties, and by discriminating on analog signals proportional to event energies.

2) It digitizes and stores waveforms (100 $MHz$ 8 equivalent bits) from one particular counter only when an "ET" has occurred.*

3) It measures with high accuracy ($\sigma \approx 1\ ns$) the time of each event relative to the experiment atomic clock standard time; it measures, with the same accuracy, the time difference between the signals from the two counter ends.

4) Each time an ET is obtained from one counter (from now on: "primary event"), the PHRASE energy threshold ("secondary threshold") for that counter (and for the adjacent counters) is lowered (in $\approx 80\ ns$) to a different programmable value for a presettable time interval ST ("special time"); PHRASE goes on recording any (lower energy) event which might occur during this time interval (from now on: "secondary" event).

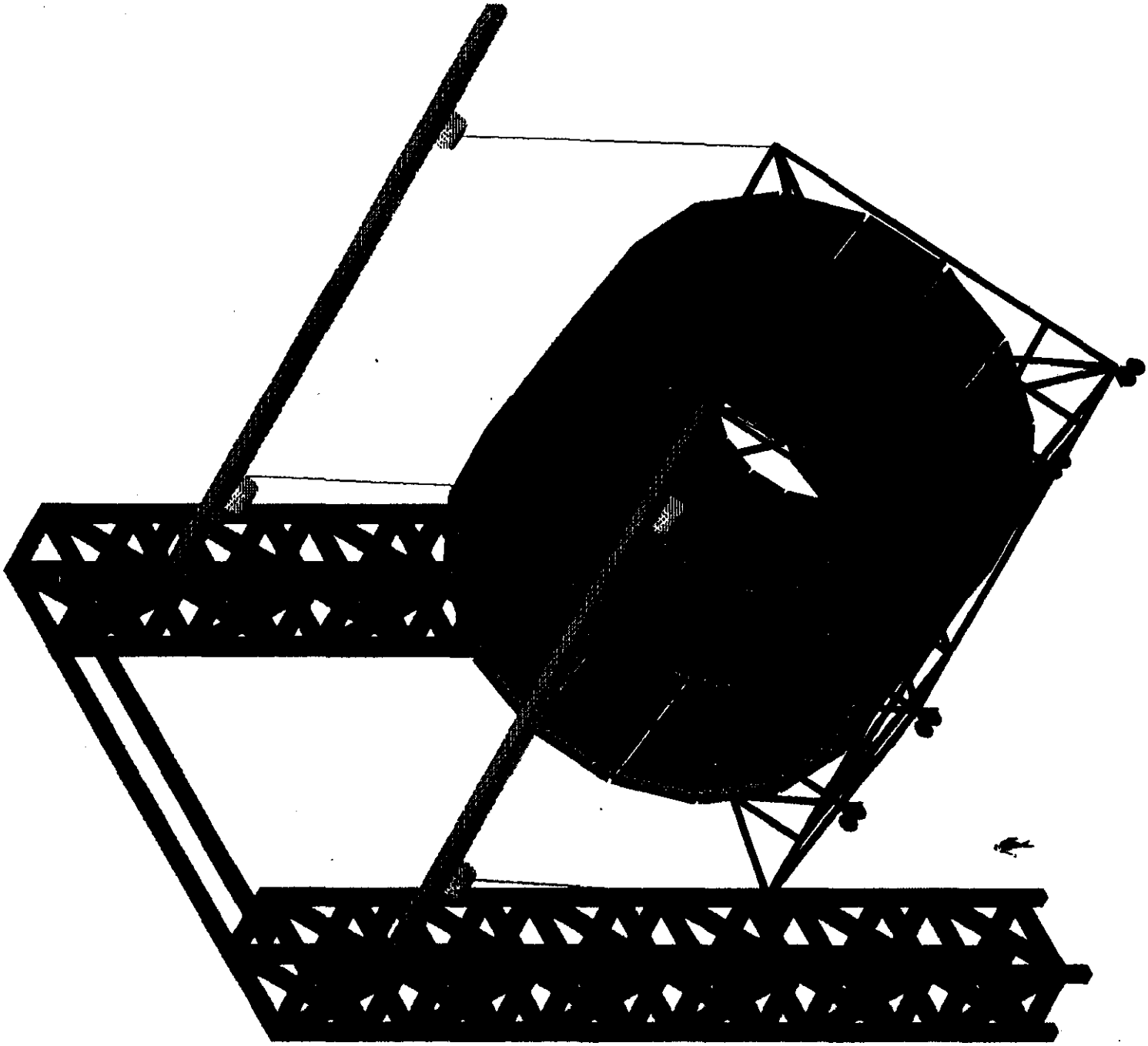
5) A maximum of 14 secondary events can be stored during the "special time".

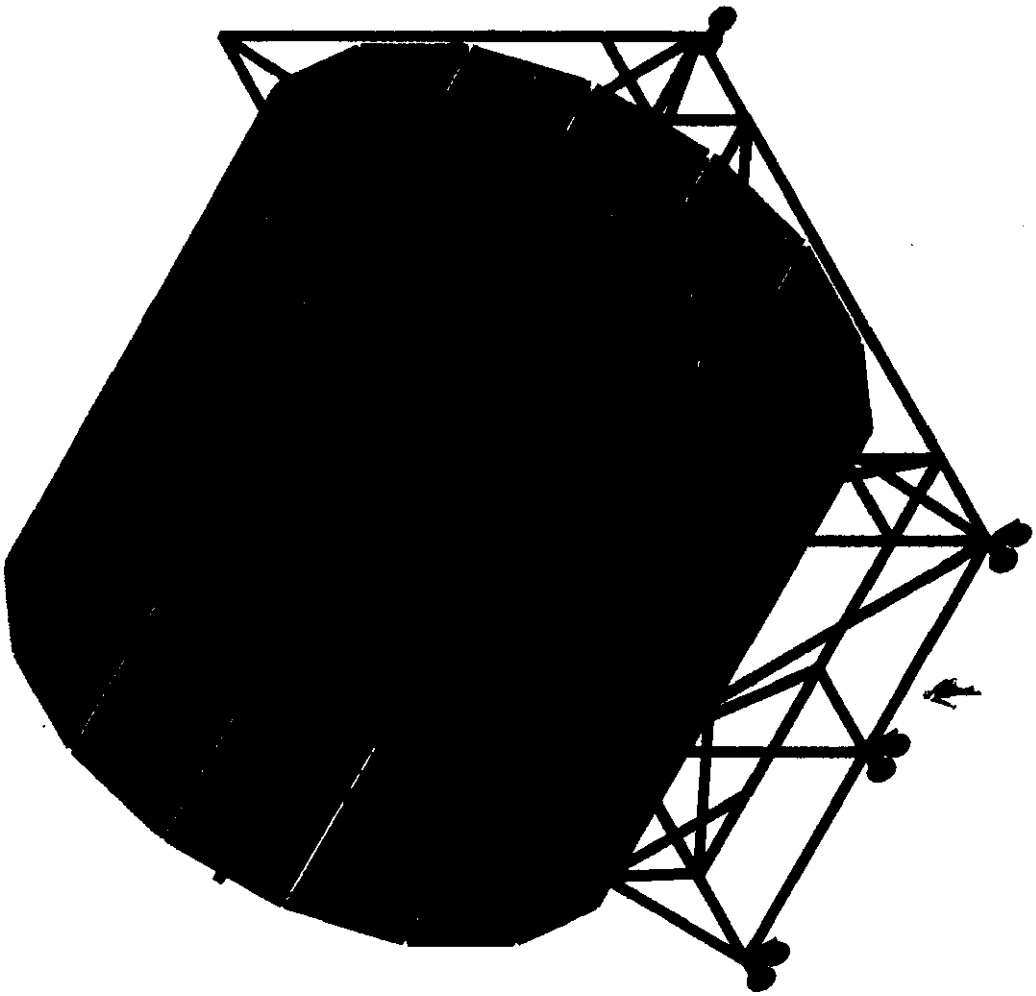
$5 \cdot 10^5 \cdot 1 < 14$

*6.2 The Energy Trigger*

The energy trigger works along the following principles. If $L$ is the MACRO counter length and one chooses a longitudinal coordinate axis $x$ with origin at the counter center, the two counter ends are identified by the $x$-values $x = -L/2$ for the "Left"-end and $x = +L/2$ for the "Right"-end. Since light attenuation in the counter is exponential with very good approximation (apart from the last meter close to the PMT's), if one calls $\lambda$ the attenuation length ($\lambda \approx 12\ m$), the pulse amplitudes for of the "Left" and "Right" PMT's

* waveform digitization is based on techniques developed for the circuit GATHER by François Bourgeois at CERN.





THIS MEETING

Discuss

Evolve

Optimize

&

BASELINE 2.

ON TO THE TDR !!!

gem

$\gamma e \mu$

# Project Manager's Report
# Discussion of TDR Plans

Gary Sanders

# SOME TOP LEVEL FY93 GEM MILESTONES

1. December PAC review of GEM calorimetry and TDR readiness. Magnet RFP release scheduled immediately afterwards.

2. Technical Design Report Submission end of January...

3. March PAC review of TDR - a fixed point.

4. Major Stage I review of GEM in July PAC meeting - a fixed point.

5. Lehman review by DOE for Stage II approval.

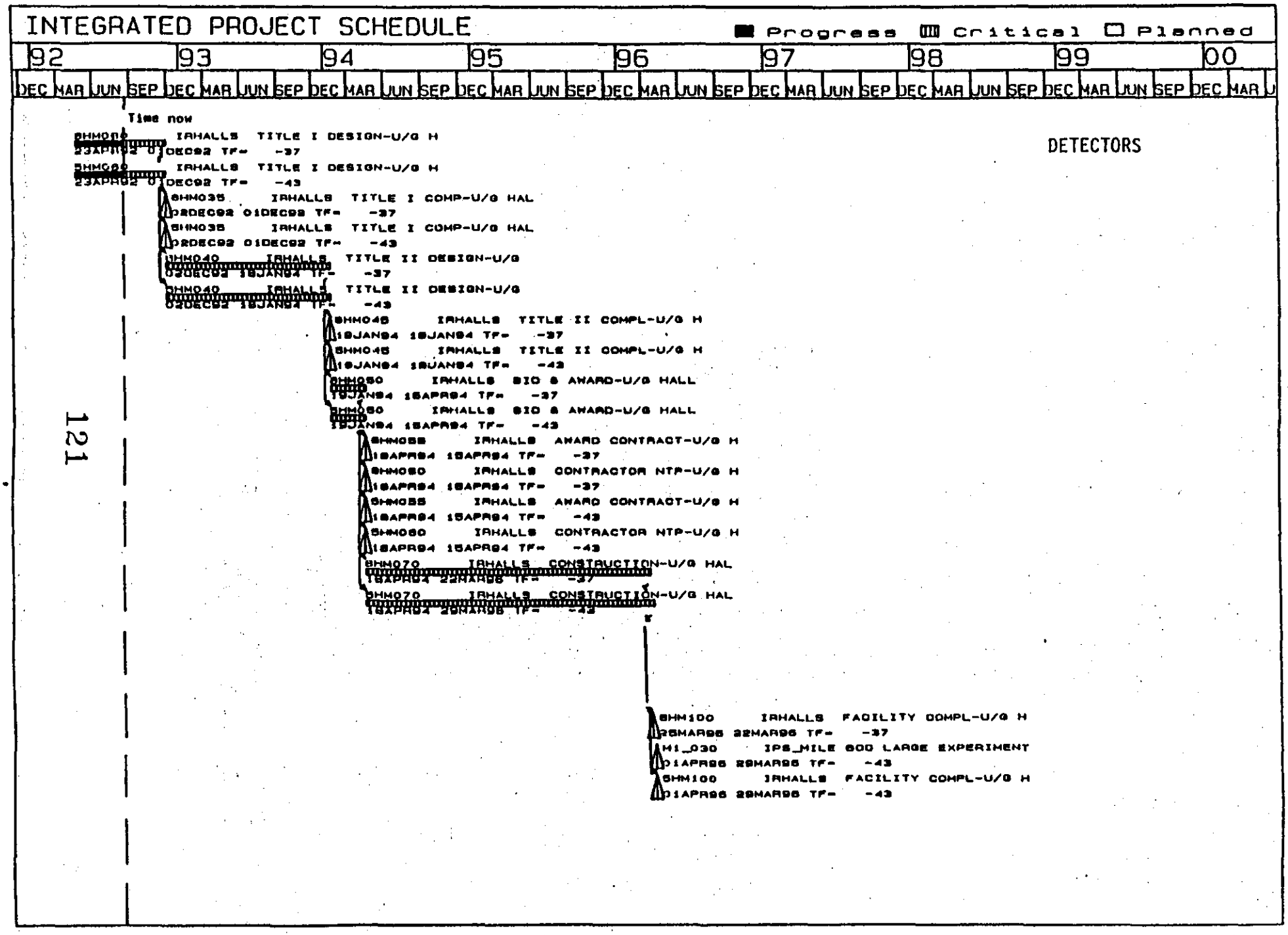
Other key waypoints:

1. GEM magnet and conductor procurement.
2. Presidential and Congressional influence.
3. Foreign participation in SSC Project, SDC, GEM to be examined in spring '93. Real construction start for GEM and SDC depends upon this status.

# FY93 GEM WORKPLAN ACTIVITIES

1. Physics requirements of detector and subsystems.
2. Top level physical, cost, schedule, functional requirements.
3. Specifications which meet these requirements.
4. Design in detail.
5. Design reviews (Critical design review, Preliminary...)
6. Integration.
7. Interface definition and design.
8. Assembly plan.
9. Installation, test and commisioning plan.
10. Cost estimate.
11. Schedule.
12. Resource loaded baseline.
13. Responsibility assignments.
14. Validation of requirements.
15. Planning and replanning tools and infrastructure.
16. Integration into SSC Integrated Project System (IPS)/Performance Measurement Baseline (PMB).

Our work has two customers - the scientific community and the SSC Project.


INTEGRATED PROJECT SCHEDULE
Progress
Critical
Planned
92
93
94
95
96
97
98
99
00
DEC MAR JUN SEP DEC MAR JUN SEP DEC MAR JUN SEP DEC MAR JUN SEP DEC MAR JUN SEP DEC MAR JUN SEP DEC MAR JUN SEP DEC MAR JUN SEP DEC MAR
Time now
DETECTORS
5HM000 IRHALLS TITLE I DESIGN-U/G H
23APR92 01DEC92 TF= -37
5HM000 IRHALLS TITLE I DESIGN-U/G H
23APR92 01DEC92 TF= -43
5HM035 IRHALLS TITLE I COMP-U/G HAL
02DEC92 01DEC92 TF= -37
5HM035 IRHALLS TITLE I COMP-U/G HAL
02DEC92 01DEC92 TF= -43
5HM040 IRHALLS TITLE II DESIGN-U/G
02DEC92 18JAN94 TF= -37
5HM040 IRHALLS TITLE II DESIGN-U/G
02DEC92 18JAN94 TF= -43
5HM045 IRHALLS TITLE II COMPL-U/G H
18JAN94 18JAN94 TF= -37
5HM045 IRHALLS TITLE II COMPL-U/G H
18JAN94 18JAN94 TF= -43
5HM050 IRHALLS BID & AWARD-U/G HALL
18JAN94 15APR94 TF= -37
5HM050 IRHALLS BID & AWARD-U/G HALL
18JAN94 15APR94 TF= -43
5HM055 IRHALLS AWARD CONTRACT-U/G H
15APR94 15APR94 TF= -37
5HM060 IRHALLS CONTRACTOR NTP-U/G H
15APR94 15APR94 TF= -37
5HM055 IRHALLS AWARD CONTRACT-U/G H
15APR94 15APR94 TF= -43
5HM060 IRHALLS CONTRACTOR NTP-U/G H
15APR94 15APR94 TF= -43
5HM070 IRHALLS CONSTRUCTION-U/G HAL
15APR94 22MAR96 TF= -37
5HM070 IRHALLS CONSTRUCTION-U/G HAL
15APR94 29MAR96 TF= -43
5HM100 IRHALLS FACILITY COMPL-U/G H
26MAR96 22MAR96 TF= -37
H1_030 IPS_MILE 600 LARGE EXPERIMENT
01APR96 29MAR96 TF= -43
5HM100 IRHALLS FACILITY COMPL-U/G H
01APR96 29MAR96 TF= -43

TOPIC: **IR Halls and Detectors**

| • Level 1 Milestone Impacted | Baseline | Current Projected | Analyzed | Impact |
|---|---|---|---|---|
| BOD Large Experimental Halls | Jan96 | 29Mar96 | 29Mar96 | -43 days |

- Review of Critical Path:

The critical path runs through design, procurement, and construction of the underground halls and the related surface facilities. The relocation of the large halls to the west, to take advantage of better soil conditions for the foundations of the large detectors, results in a 2-month impact to the Level 1 milestone "BOD Large Experimental Halls" as currently defined. The critical path, however, ends at this point since the detectors themselves can still meet all major milestones in spite of the later final BOD. **This path does not impact the "Beam to Experiment" milestone.**

- Analysis/Concerns:

The current formal definition of "BOD Large Experimental Halls" requires that all systems, including mechanical, electrical, HVAC, and other finishes be completed in January 1996. The detector collaborations, however, have indicated that during the initial phases of detector assembly, joint occupancy of the hall is acceptable. Initial occupancy of IR8 is currently projected on October 1, 1995, IR5 on January 14, 1996. Both detector collaborations have indicated that final beneficial occupancy by March 29, 1996 will meet their schedule requirements.

- Recommendations:

A CCB action is being prepared which proposes that either the "BOD Large Halls" milestone date be adjusted to a later date, with no impact to subsequent major milestones, or that BOD is redefined to be the point in time at which Joint Beneficial Occupancy begins. Further review of the CCD schedule durations, contracting methods, and construction methodologies should be completed to provide reasonable "float" in this area of the Integrated Project Schedule.

15-Oct-92

# KEY UPCOMING EVENTS

FEATURE: WARM MAGNET SYSTEMS

| CCU | EVENT | SCHEDULED DATE | STATUS | ISSUE | CRITICAL MILESTONE |
|---|---|---|---|---|---|
| LINAC (A-200) | ■ INTERIOR COMPLETION<br>■ FACILITY COMPLETION | 13 APR 93<br>1 JUL 93 | [Y]<br>[G] | | BOD 23 APR 93<br>BOD 21 JUL 93 |
| LEB (A-300) | ■ BID OPENING | 29 OCT 92 | [G] | ■ BID OPENING RESCHEDULED FOR 29 OCT 92 | BOD TUNNEL & ACCESS 15 JAN 94<br>BOD S1 & A2 BLDGS 01 MAR 94<br>BOD REMAINDER OF FAC 15 APR 94 |
| MEB TUNNEL TO WP-8 (A-400) | ■ 90% DESIGN SUBMITTAL<br>■ IFB<br>■ COOLING POND DAM | 19 OCT 92<br>14 DEC 92 ~~9 NOV 92~~<br>14 DEC 92 ~~9 NOV 92~~ | [Y]<br>[Y]<br>[Y] | ■ SCHEDULE OF MEB UNDER REVIEW | 22 SEPT 94<br>BOD NORTH: 08 JUNE 94<br>BOD SOUTHEAST: 11 FEB 94<br>BOD SOUTH WEST: 11 MAR 94 |
| TEST BEAMS (A-420) | ■ TITLE I REVIEW COMMENTS | | [X] G | ■ PB/MK AWAITING SSCL TITLE I REVIEW COMMENTS | BOD: 29 NOV 94 |

15-Oct-92

# KEY UPCOMING EVENTS

FEATURE: EXPERIMENTAL FACILITIES -- SDC

| C.C.U. | EVENT | SCHEDULED DATE | STATUS | ISSUE | CRITICAL MILESTONE |
|---|---|---|---|---|---|
| IR 8 U/G SHELL E-305 | ■ COMPLETE 90% DESIGN | 12 NOV 92 | [G] | | BOD MAR 96 |
| IR 8 U/G FINISH E-306 | ■ COMPLETE TITLE I DESIGN | 26 FEB 93 | [G] | ■ SCOPE AUTHORIZATION FOR TECHNICAL LOADS | BOD MAR 96 |
| IR 8 ASSEMBLY BUILDING E-308 | ■ COMPLETE 90% DESIGN | 02 DEC 92 | [G] | | BOD APR 94 (HIGH BAY) |
| TIE BACK TEST PROGRAM | ■ INITIAL TEST RESULTS | 12 OCT 92 | [G] | | |



CARMEAN\KEYUPCOMING EVENTS

15-Oct-92

# KEY UPCOMING EVENTS

FEATURE: EXPERIMENTAL FACILITIES -- GEM

| CCU | EVENT | SCHEDULED DATE | STATUS | ISSUE | CRITICAL MILESTONE |
|---|---|---|---|---|---|
| IR 5 U/G SHELL E-405 | ■ COMPLETE 90% DESIGN | 12 NOV 92 | [G] | | BOD MAR 96 |
| IR 5 U/G FINISH E-406 | ■ COMPLETE TITLE I DESIGN | 26 FEB 93 | [G] | ■ SCOPE AUTHORIZATION FOR TECHNICAL LOADS | BOD MAR 96 |
| NORTH ASSEMBLY BUILDING E-408 | ■ COMPLETE TITLE I DESIGN | 20 NOV 92 | [G] | | BOD 19 AUG 94 |
| SOUTH ASSEMBLY BUILDING E-409 | ■ COMPLETE TITLE I DESIGN | 20 NOV 92 | [G] | | JOD (HIGH BAY) 7 FEB 94 |
| UTILITY BUILDING (PHASE I) E-413 | ■ COMPLETE TITLE I DESIGN | 11 DEC 92 | [G] | ■ EARLY UTILITY BLDG VS SPLIT UTILITY BUILDINGS | SAB JOD (HIGH BAY) 7 FEB 94 |

# KEY UPCOMING EVENTS

FEATURE: PROJECT WIDE AND INFRASTRUCTURE FACILITIES

| CGU | EVENT | SCHEDULED DATE | STATUS | ISSUE | CRITICAL MILESTONE |
|---|---|---|---|---|---|
| WC & EC MAIN SUBSTATION | ■ RFP COMPLETION | 12 JAN 93 | [G] | PERMANENT POWER ACQUISITION BY DOE | WC POWER REQ JAN 95 |
| | ■ ISSUE RFP | 17 JAN 93 | [G] | | EC POWER REQ JUN 96 |
| | ■ RECEIVE PROPOSALS | 02 MAR 93 | [G] | | |
| | ■ AWARD CONTRACT | 23 JUN 93 | [G] | | |
| EAST COMPLEX CONNECTOR ROAD IR 5 & IR 8 SITE GRADING (S-445) | ■ PRE BID MEETING | 13 OCT 92 | | INSUFFICIENT NTP FUNDING S-410 (IR8) & S-412 (IR5) COMBINED WITH S-445 | NTP 07 DEC 92 |
| | ■ BID OPENING | 27 OCT 92 | [Y] | | |
| | ■ CONTRACT AWARD | 30 NOV 92 | [Y] | | |
| N15 COMMUNICATION (S-225) | ■ IFB | 12 OCT 92 | [G] | REDUCTION IN SCOPE BY SSCL | BOD 2 QTR 93 |
| | ■ BID OPENING | 17 NOV 92 | [G] | | |

*Superconducting Super Collider Laboratory*
2550 Beckleymeade Ave., Suite 125 MS-7000
Dallas, TX 75237-3997

***PROJECT MANAGEMENT OFFICE MEMORANDUM***

**To:** **Distribution** **92 5160 E B**

**From:** **J. Rees/E. Siskin**

**Date:** **October 21, 1992**

**Subject:** **PRELIMINARY FY93 COST AND COMMITMENTS FUNDING TARGETS**

---

Attached are the preliminary FY93 Cost and Commitment Funding Targets. These targets are based on the IPS FY93 schedule impact study and on input from Machine Leaders and Division personnel. Results of the schedule impact study will be provided to the WBS Managers and Division personnel by the PMO Cost and Schedule Department. These targets are supported by the total funds available for FY93, but are in some areas significantly lower than information currently in the PMB. The project plans for the fiscal year need to be consistent with the funds available, therefore modifications will be required to the schedule, the PMB, or the funding targets to fit within the funds available. Costs and Commitments should be planned to be equal for FY93 which is the same direction as in FY92.

The Machine Leaders/Detector Project Managers have the responsibility to manage all actions required to modify the project plans to be consistent with the fiscal year constraints. As specified in the PMCS, FY93 budget allocations will be determined at the second-digit WBS level. As a first step in this process, the Machine Leaders/Detector Project Managers will define targets at the next lower level (three digit) WBS consistent with the attached list of funding targets by two-digit WBS. In the case of WBS elements not associated directly with a machine or detector, other individuals have been assigned to carry out this function in the planning process. The attached table indicates the responsible WBS managers. After establishing the targets at the three-digit WBS level, these individuals will then work with the Divisional Cost Account Managers to allocate the target funds among the cost accounts for each three-digit WBS. As noted above, this may lead to cost account allocations different from (in general, less than) those currently in the PMB (COBRA). In some cases, this may result in significant impact on the work planned for FY93. For each three-digit WBS, the Divisions will provide to the Machine Leaders/Detector Project Managers a statement discussing the impact of the proposed target funding on the work planned for FY93 and on the total project schedule for the activities associated with this part of the WBS. The project will utilize the Estimate at Completion features of COBRA for the above process. This process should be completed by November 11.

The resulting information will be analyzed and utilized by Project Management to alter funding targets or update the project schedule (IPS) as necessary to satisfy the FY93 funding constraints with minimum impact on the project. Once a final set of funding targets have been established, the information in the PMB for each work package may be modified to form the baseline for performance measurement per the attached instructions.

## RESPONSIBLE WBS MANAGERS

| WBS | DESCRIPTION | WBS MANAGER |
|---|---|---|
| | | |
| 11 | Management | J. Rees/F. Gilman |
| 21 | LINAC | W. Funk |
| 22 | LEB | R. York |
| 23 | MEB | R. Gerig |
| 31 | HEB | D. Johnson |
| 32 | Collider | R. Meinke |
| 41 | Global | D. Gurd |
| 51 | Experimental Systems R&D | F. Gilman |
| 52 | Detectors | T. Kirk/G. Sanders |
| 53 | Experimental Systems Computing | P. Leibold |
| 54 | Experimental Facilities/Support Facilities | T. Kirk/G. Sanders |
| 55 | Experimental System Support | R. Richardson |
| 56 | Test Beams | J. McGill |
| 57 | PRD Project Coordinator | F. Gilman |
| 71 | West Complex | J. Clifton |
| 72 | E1 Complex | R. Meinke |
| 73 | East Complex | J. Clifton |
| 74 | Collider Infrastructure | J. Clifton |
| 75 | Off-Site Infrastructure | J. Clifton |
| | Indirects | E. Siskin |

# FY93 FUNDING TARGETS

PRELIMINARY - FOR PLANNING PURPOSES ONLY

| | FUNDING ($K) |
|---|---|
| DOE | 517,000 |
| Texas | 74,000 |
| Foreign | 20,000 |
| | 611,000 |
| SSCPO | -18,000 |
| Contingency | -20,000 |
| | 573,000 |
| 1992 Carryover | 180,000 |
| FY93 Total Project | 753,000 |

PRELIMINARY - FOR PLANNING PURPOSES ONLY

| | |
|---|---|
| 21 | 22,000 |
| 22 | 20,000 |
| 23 | 38,500 |
| 31 | 63,000 |
| 32 | 308,000 |
| 41 | 19,000 |
| 51 | 1,500 |
| 52 | 68,000 |
| 53 | 7,000 |
| 54 | 23,000 |
| 55 | 9,500 |
| 56 | 9,000 |
| 57 | 7,500 |
| 71 | 11,000 |
| 72 | 5,750 |
| 74 | 5,750 |
| | **618,500** |
| 11 | 32,500 |
| 8 | 100,000 |
| **Total** | **751,000** |



(Note - All Numbers in 93$)

## DIVISION TOTALS
($K)

| | IPS Cost | Request ** |
|---|---|---|
| Accelerators | 128,000 | 136,000 |
| Magnets | 218,000 | 236,000 |
| Physics | 95,000 | 100,000 |
| Construction | 179,000 | 188,000 |
| Project Management | 31,000 | 31,000 |
| Indirects | 100,000 | 140,000 |
| TOTAL | 751,000 | 831,000 |

** Based on Input From COBRA or Divisions
(Note - All Numbers in 93$)

FY93 Cost Plan

| DESCRIPTION | WBS | ASD | MSD | PRD | CCD | PMO Accel | OTHER | TOTAL | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| Generic Detector R&D | 511 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Detector Subsys. R&D | 512 | 0 | 0 | 1,424 | 0 | 0 | 0 | 1,424 | |
| **ExpSys R&D Total** | **51** | **0** | **0** | **1,424** | **0** | **0** | **0** | **1,424** | |
| Detector I-SDC | 521 | 0 | 0 | 33,561 | 0 | 0 | 0 | 33,561 | |
| Detector II-GEM | 522 | 0 | 0 | 33,980 | 0 | 0 | 0 | 33,980 | |
| Other Detectors | 523 | 0 | 0 | 491 | 0 | 0 | 0 | 491 | |
| **Detectors Total** | **52** | **0** | **0** | **68,032** | **0** | **0** | **0** | **68,032** | |
| Administration | 531 | 0 | 0 | 4,691 | 0 | 0 | 0 | 4,691 | |
| Off-Line Sys Devel. | 532 | 0 | 0 | 2,392 | 0 | 0 | 0 | 2,392 | |
| On-Line Sys. Support | 533 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **ExpSys Computing Total** | **53** | **0** | **0** | **7,083** | **0** | **0** | **0** | **7,083** | |

FY93 Cost Plan

| DESCRIPTION | WBS | ASD | MSD | PRD | CCD | PMO Accel | OTHER | TOTAL | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| Exp. Facilities IR1 | 541 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | CCD Requires 23M |
| Exp. Facilities IR4 | 542 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Exp. Facilities IR8 | 543 | 0 | 0 | 0 | 16,489 | 0 | 0 | 16,489 | |
| Exp. Facilities IR5 | 544 | 0 | 0 | 0 | 6,569 | 0 | 0 | 6,569 | |
| Support Facilities | 545 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **ExpFac & Sppt Fac Total** | **54** | **0** | **0** | **0** | **23,058** | **0** | **0** | **23,058** | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Admin. Eng. Resources | 551 | 0 | 0 | 1,400 | 0 | 0 | 0 | 1,400 | |
| Engineering Support | 552 | 0 | 0 | 7,680 | 0 | 0 | 0 | 7,680 | |
| Test Beam Instrum. Support | 553 | 0 | 0 | 129 | 0 | 0 | 0 | 129 | |
| SDC Support | 554 | 0 | 0 | 140 | 0 | 0 | 0 | 140 | |
| GEM Support | 555 | 0 | 0 | 140 | 0 | 0 | 0 | 140 | |
| Other Detector Support | 556 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Physics Support | 557 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **ExpSys Support Total** | **55** | **0** | **0** | **9,489** | **0** | **0** | **0** | **9,489** | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| MEB Proton Beam | 561 | 1,653 | 0 | 0 | 0 | 121 | 0 | 1,774 | |
| Targets & Target Hall | 562 | 205 | 0 | 0 | 0 | 52 | 0 | 257 | |
| Secondary Beams | 563 | 1,243 | 0 | 413 | 0 | 59 | 0 | 1,715 | |
| Calibration Hall | 564 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Test Beam Conv. Const. | 565 | 0 | 0 | 0 | 5,467 | 0 | 0 | 5,467 | |
| **Test Beams Total** | **56** | **3,101** | **0** | **413** | **5,467** | **232** | **0** | **9,213** | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| PRD Project Coord | 571 | 0 | 0 | 7,593 | 0 | 0 | 0 | 7,593 | |
| **PRD Project Coord Total** | **57** | **0** | **0** | **7,593** | **0** | **0** | **0** | **7,593** | |

*Superconducting Super Collider Laboratory*
*2550 Beckleymeade Avenue, Mail Stop 2001*
*Dallas TX 75237-3946*
*(214) 708-9000*
*Fax: (214) 708-0006*

***Physics Research Division***

## *Memorandum*

**To:** T. Kirk, M. Gilchriese, George Trilling, G. Sanders, B. Barish, and W. Willis

**From:** Fred Gilman

**Subject:** Texas Funding of Research and Education Activities

**Date:** October 23, 1992

---

Lynn Bowers from the TNRLC staff called yesterday to inform me of the results of the meeting of the Commission on October 21st with respect to their research and education activities. This was the first meeting under the new chairman, Mr. Perry, and with Mr. Williams, the new member also present.

Recall that with the SSC Fellowships (at a level of about $2M per year), 1990 activities in research and education were $3.4M, rising to $11.7M in 1991. With the supplemental R&D proposals this past spring 1992 activities came to $13.6M. At the meeting this past Wednesday a target of $15M for 1993 was set. There was also informal discussion of what should happen in succeeding years. Rather than the level funding in previous planning, a peak level of about $25M in 1995 was projected, with a drop to zero in 1998.

cc: R. Schwitters
V. Luth
H. Lynch

# GEM FY93 PLANNING IN NEAR FUTURE

1. TNRLC proposals submitted.
2. Tentative list of endorsements of TNRLC proposals recommended by Webb and Sanders will be discussed at GEM Executive Committee on Friday.
3. R&D/Engineering work plan and budget information have been provided by subsystem leaders to Webb, Sanders and Harris. Discussion draft budget which matches SSC IPS plan to be reviewed by Executive Committee Friday. Final SSC budget not yet available, thus GEM discussion draft quite preliminary.
4. Expect final SSC budget by late November. Revised GEM budget will then be reviewed by subsystem leaders, PM, Executive Committee, Spokesmen.
5. However, 40% to 50% of conservative budget now being released as funds to GEM institutions. This release will keep work moving forward, but will not constrain final FY93 budget if managed prudently.
6. TNRLC technical review in December. GEM endorsements solicited at that time, following merit review. Full Commission meets in January, but they have not downsized awards in past. Decisions in December, funds released starting January. HOW DO WE COPE WITH THIS TIMESCALE?

# TDR

1. We have 10 weeks left to produce TDR.
2. Probably two weeks eaten by printing and production.
3. Each subsystem leader and chapter lead should now have a week-by-week schedule of activities:

   a. scope and outline
   b. writing
   c. calculations and design
   d. TBD list
   e. draft release dates
   f. review team identified
   g. review periods defined
   h. figures being selected and done now when possible!
   i. date for final version and production
   j. plan for coordinating with overall document and cost/schedule, physics, R&D/engineering/test beam, and overview books

## TDR PLANNING MEETING
## THURSDAY 1:00 - 2:00
## ATTENDEES: BARISH, WILLIS, REARDON, STROYNOWSKI, TAYLOR, MARX, BALTAY, MARLOW, SHAEVITZ, MCFARLANE, HARRIS, YOST, FISCHER, SANDERS, DURDEN

GEM MAGNET RFP RELEASE
ENABLED WEEK OF DECEMBER 7
BY SSCL MANAGEMENT

THIS IS A MAJOR MILESTONE!
KUDOS TO MAGNET GROUP (SSCL, LLNL, MITPFC),
GEM BUSINESS GROUP,
AND PETER KLEE, BOB JOHNSON, BILL FLICK
AND ABB!

The FY92 magnet effort showed that with an investment of 20 FTE engineers and $5 million, GEM can bring a major subsystem to readiness for industry involvement in the fabrication. This is a model for the calorimeter and muon groups in FY93.

# Status of Simulation Effort

Ken McFarlane

0

- Simulations
- Future efforts in simulations
- Future efforts in computing
- TDR

# Status of Simulations

Purposes:

- Assist in design of a sub-detector
- Evaluate complete detector

A great deal of work has been done for the first purpose in the sub-detector groups (trigger, tracker, calorimetry - forward, EM, HAD, muons). Features are:

- Partial detector (e.g. accordion section)
- simplified geometry (e.g. no support)
- specific studies (e.g. EM resolution)
- No correlations between sub-detectors

This has been important for the evolution of the GEM design and has provided input to complete simulations.

This talk focusses on the second purpose.

Basis for simulations are:

- the GEANT pachage
- Transport codes such as CALOR89, MORSE, EGS4....
- Parameterizations of measurements on detectors (beam tests, the Bock parameterization of showers..)

The apparatus can be described at a range of levels of detail:

- In extreme detail (every fiber, the readout electronics..)
- In an overall way (a calorimeter)
- anything in between

■ Detail + transport → realistic description of any aspect of detector performance
Cost is execution time (hours/event)

■ Overall + parameterization → Description of <u>chosen</u> aspects. (seconds/event).

In GEM we have developed two packages which attempt to describe the whole detector:

- SIGEM – a detailed, HIT level, GEANT description
- gemfast – an overall parameterized description

SIGEM can be found in the SSCL facility PDSF under ~gemlib/sourse/sigem and e.g. ~gemlib/hpx/sigem
gemfast can be found under /gem

That's the good news; the bad news is that both packages describe <u>Baseline 1</u>

It takes time to prepare a description of a detector.

<u>gemfast</u> (version 1)

Adaptation of 'FAST1' to a new framework
Contributors include K. Lane, S. McKee, S. Sen, M. Brooks, H. Ma, R. Carey, X. Shi, P. Dingus, J. Sullivan, M. Shupe, C. Allen, T. Skwarnicki, I. Sheer.

FAST1 (and its components) was used for:

- July PAC Report Physics section
- trigger issues
- $H \to \gamma\gamma$ studies
- jet rejection studies $(e, \gamma)$
- $\eta = 0$ crack (modification!)

Secondary Purpose:

Develop a GEM approach to software:

- Use Unix
- Code management and distribution
- Program structure — modular
- documentation built-in

gemfast summary

CT provides $\Delta p/p$ based on position resolution, charge separation

EC provides smearing of energy (no fluctuation of shower distribution) based on Bock

HC provides smearing, longitudinal distribution fluctuation of conversion point, based on Bock

FC provides smearing based on GEANT

MU provides $\Delta p/p$ based on posn. resolution and non-uniform field; energy loss, acceptance and trigger efficiency based on GEANT.

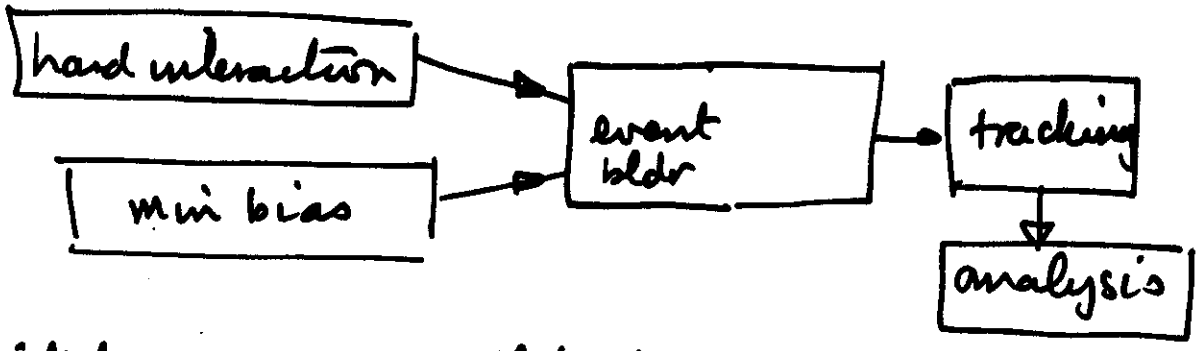
TR provides trigger primitives from EC, HC based on early model of trigger

Particles are transported in helices (no scatterings, no photon conversion ..) and decay

Data structures are basically common blocks

Pileup included.

There are cluster finding routines.
Structured as separate tasks:




Limitations – no ability to study correlations, shower fluctuations, dead material, $\gamma$ conversions..

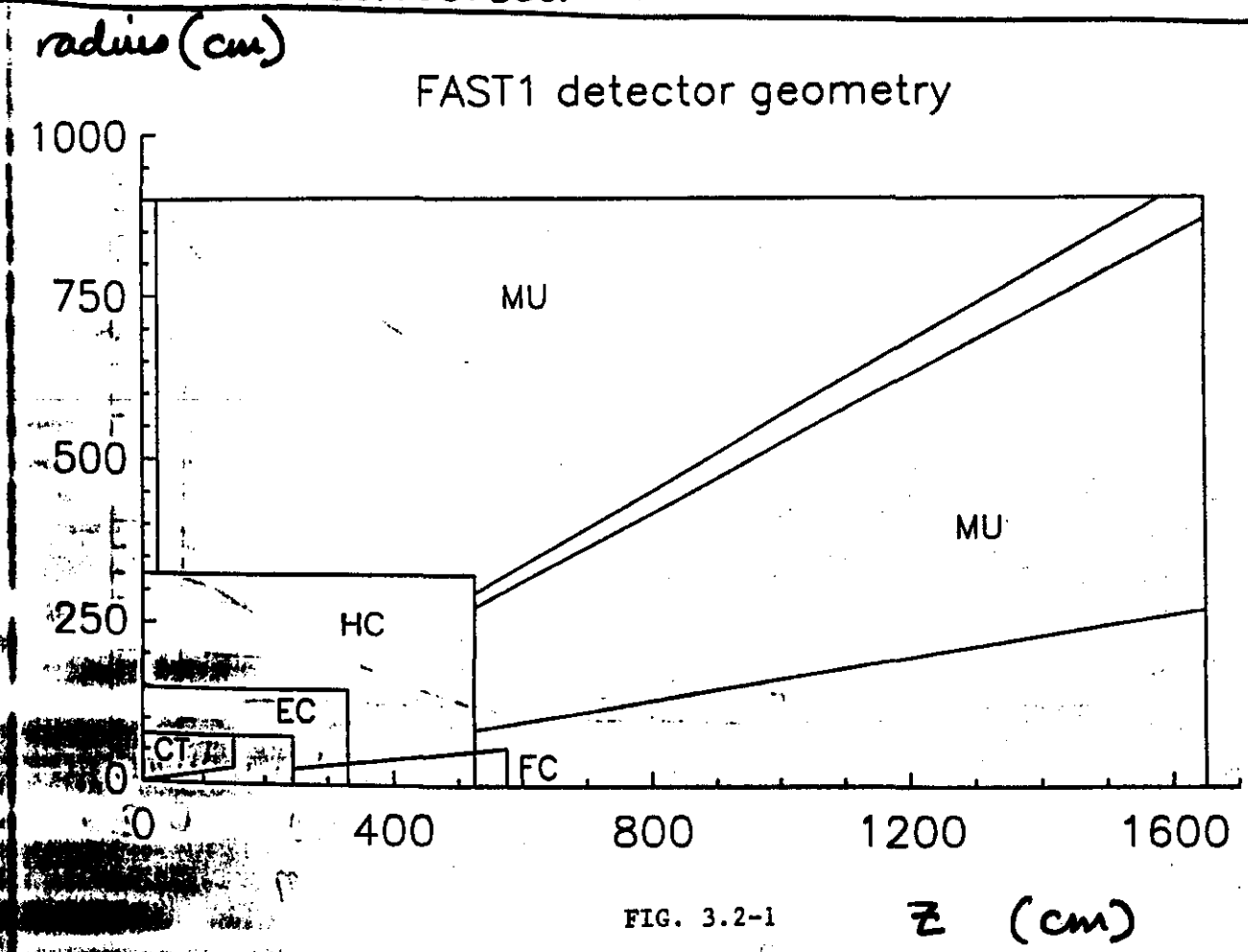



FIG. 3.2-1

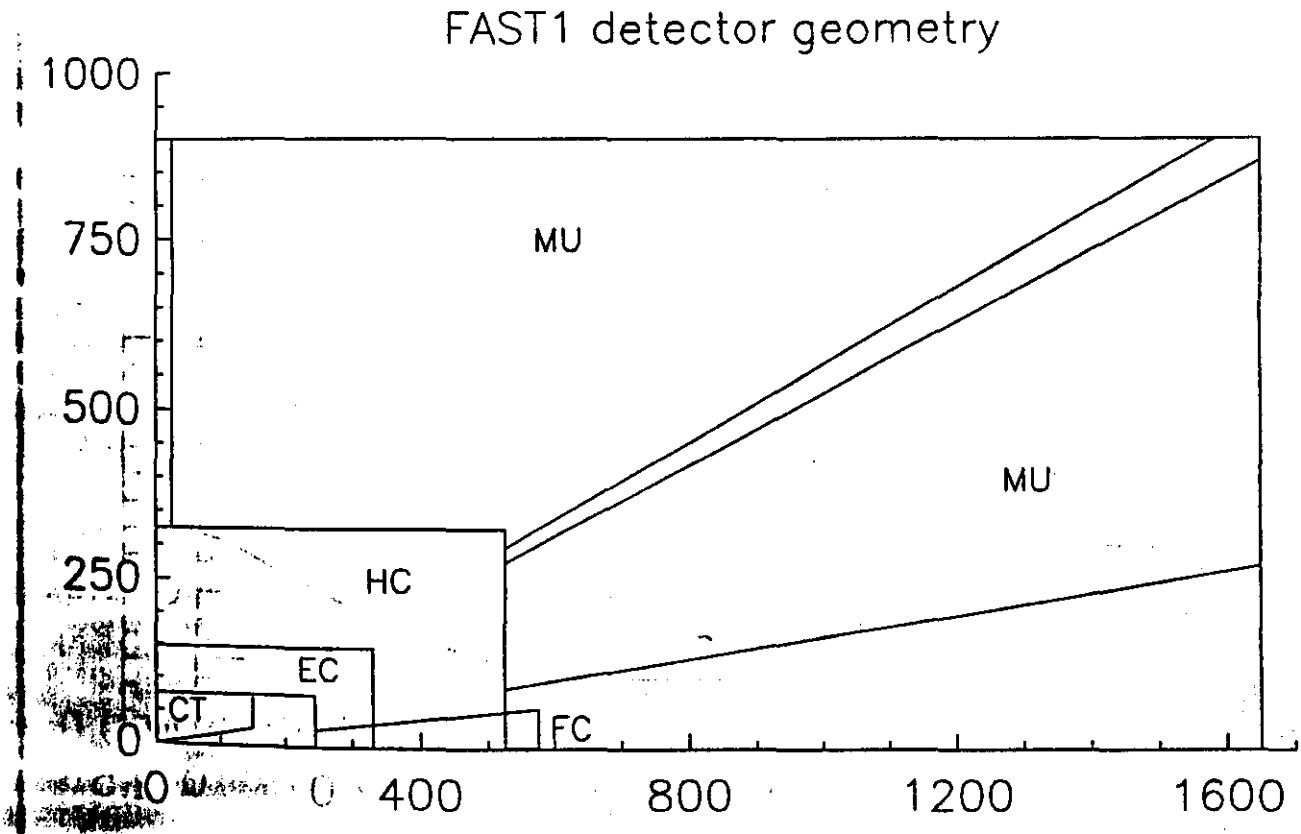

FAST1 detector geometry
1000
750
500
250
0
0
400
800
1200
1600
MU
MU
HC
EC
CT
FC

FIG. 3.2-1

7

gemfast has some degree of detail, as shown in this & and following slides.

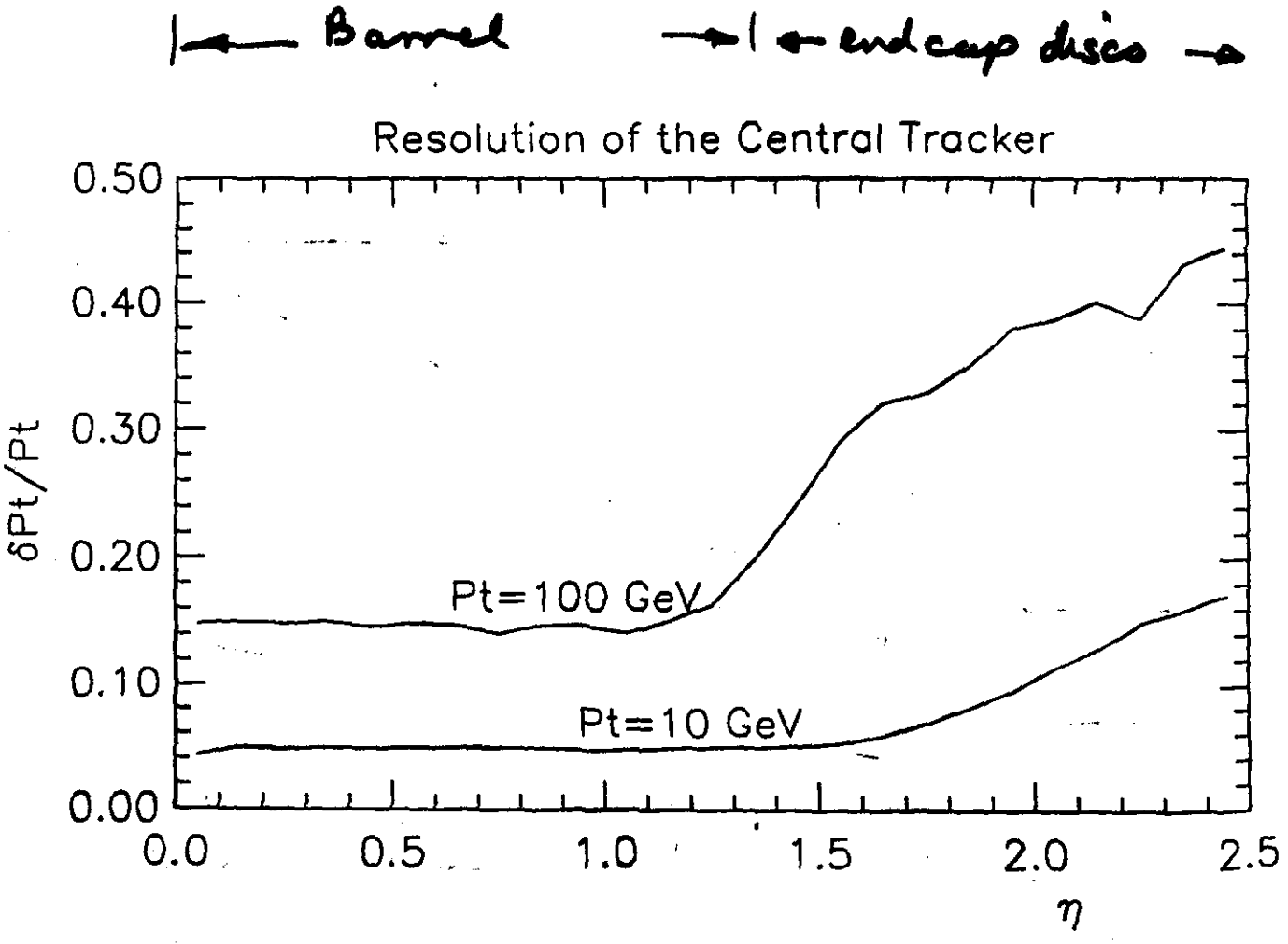



FIG. 3.2-2

(8)

EM resolution

loss of resolution at barrel/endcap transition

'end'

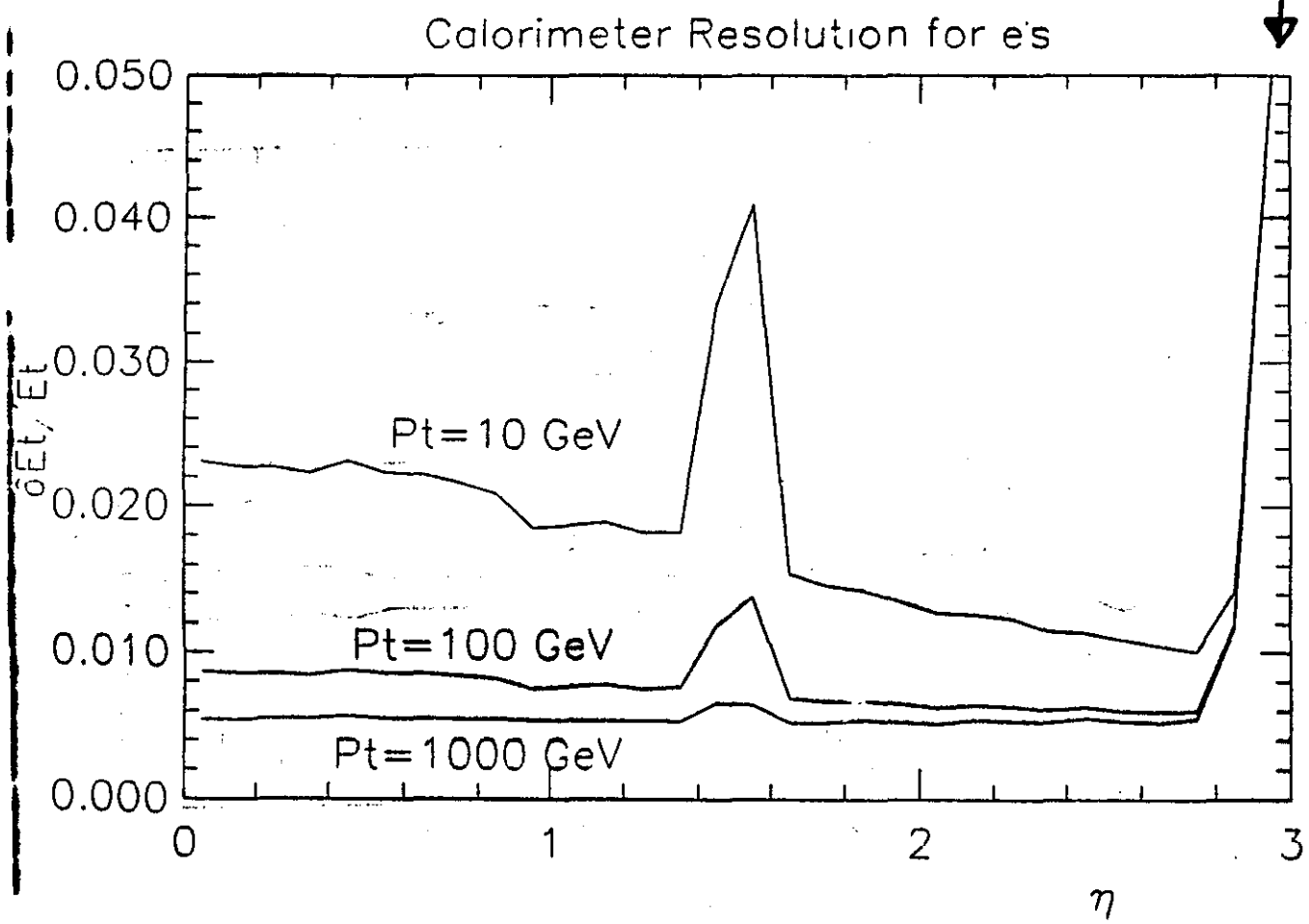



FIG. 3.2-3

9

# Hadronic Resolution

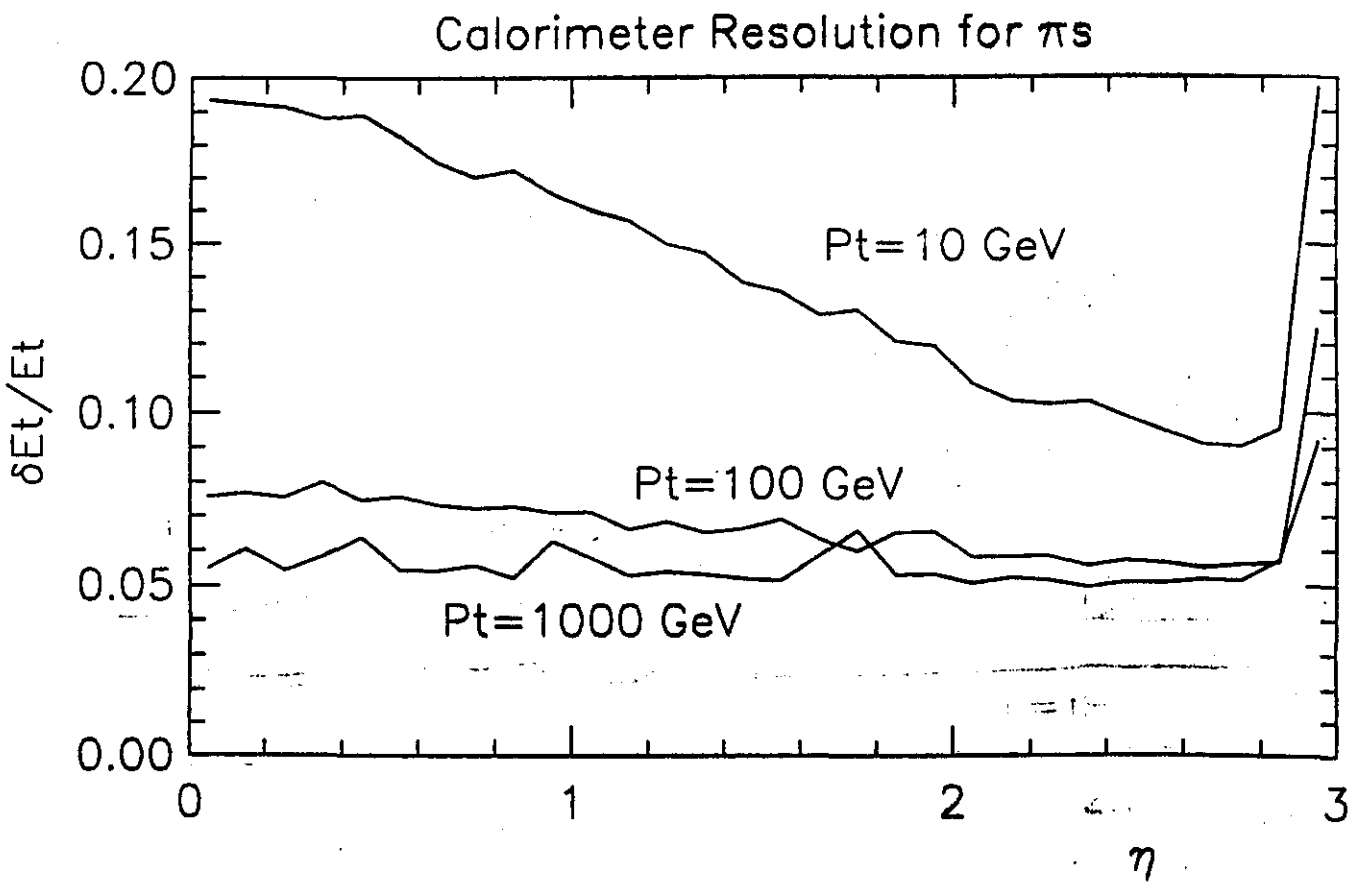



FIG. 3.2-4

# Forward calorimeter

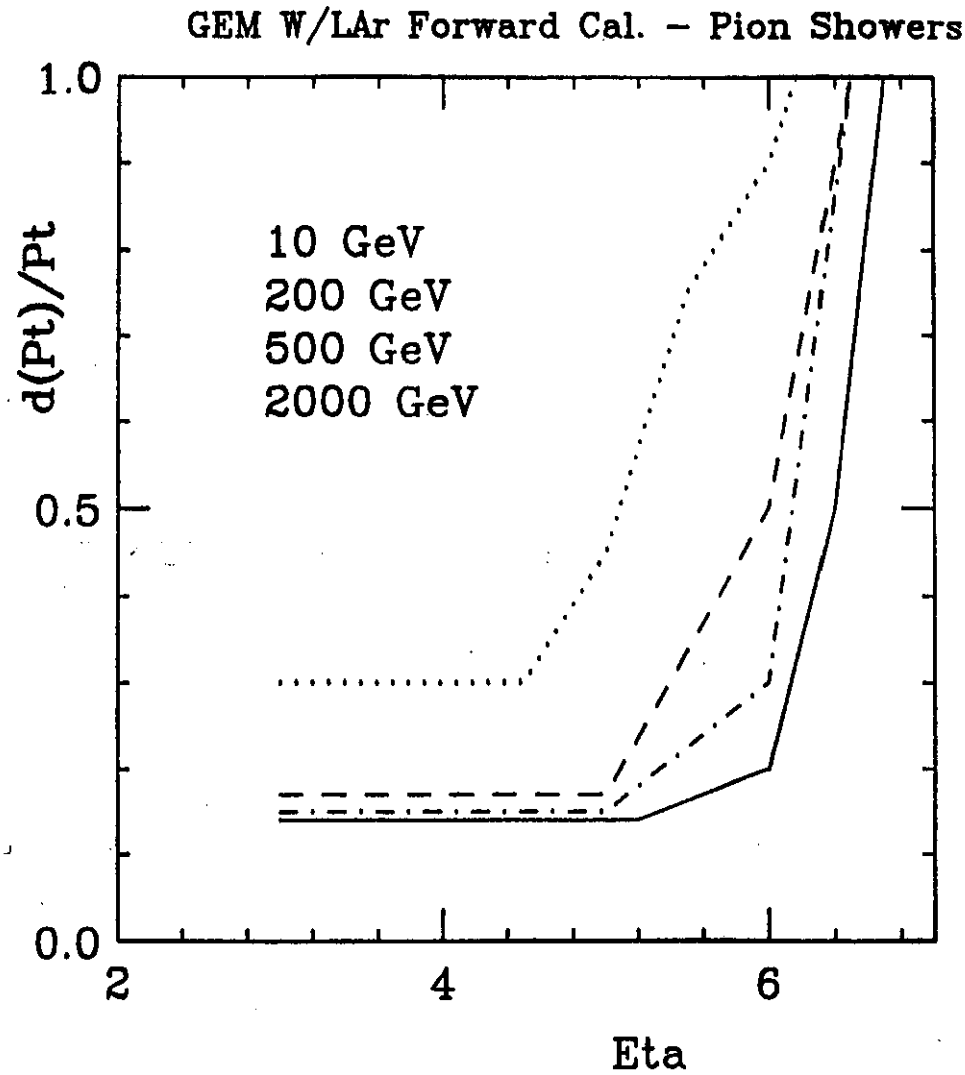



FIG 3.2-6

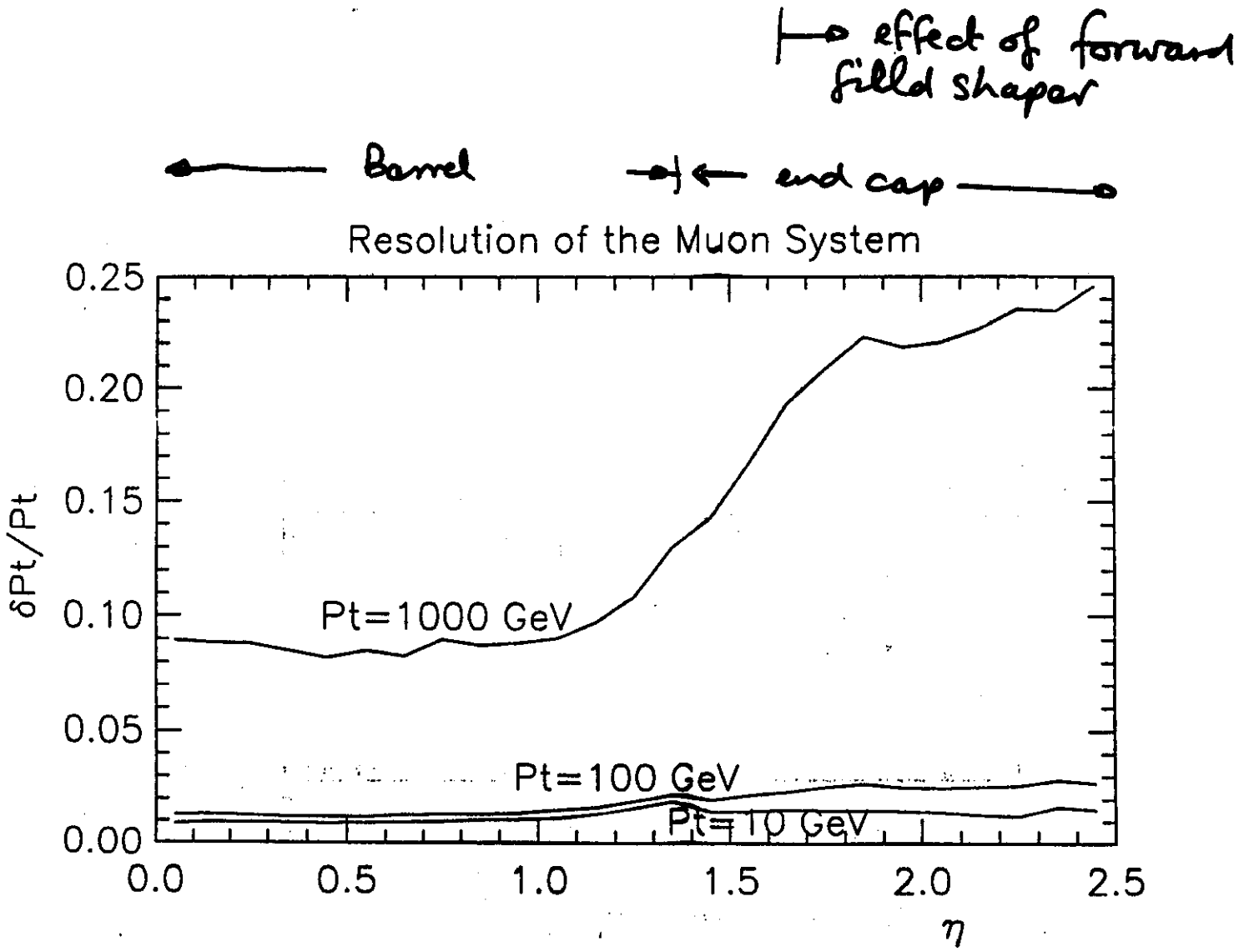

effect of forward field shaper
Barrel
end cap
Resolution of the Muon System
0.25
0.20
0.15
0.10
0.05
0.00
δPt/Pt
Pt=1000 GeV
Pt=100 GeV
Pt=10 GeV
0.0
0.5
1.0
1.5
2.0
2.5
η

FIG. 3.2-6

Next task – New version for Baseline 2 for studies for TDR.

Tasks for sub-system groups

- Define subsystem
- Create parameterizations

gemfast team tasks

- integrate parameterizations
- provide sample jobs, other support

Physics group tasks

- Study performance on specific reactions
- Prepare report for PAC, TDR

These steps all take time!

Need commitment from sub-system groups:

- Provide parameterizations
- Support them (debug ...)
- Defend them.

Meeting after Bill Wilkis talk.

## Full Simulation – SIGEM

Described in GEM TN-92-162.
Built on L3 model by Yu. Fisyak in GEANT framework to HITs level.

- Define a GEOMetry (materials, volumes, sensitive volumes)
- Define HITs (relations between energy deposit in sensitive vol. and information recorded). $(x, y, z, E, t)$
- Define DIGitizations (relation between HITs and information as processed by electronics
- ~~track~~ generate event in KINE structure
- take tracks through detector
- analyze hits or digitizations

Uses ZEBRA for data structures; can be written out at any stage.

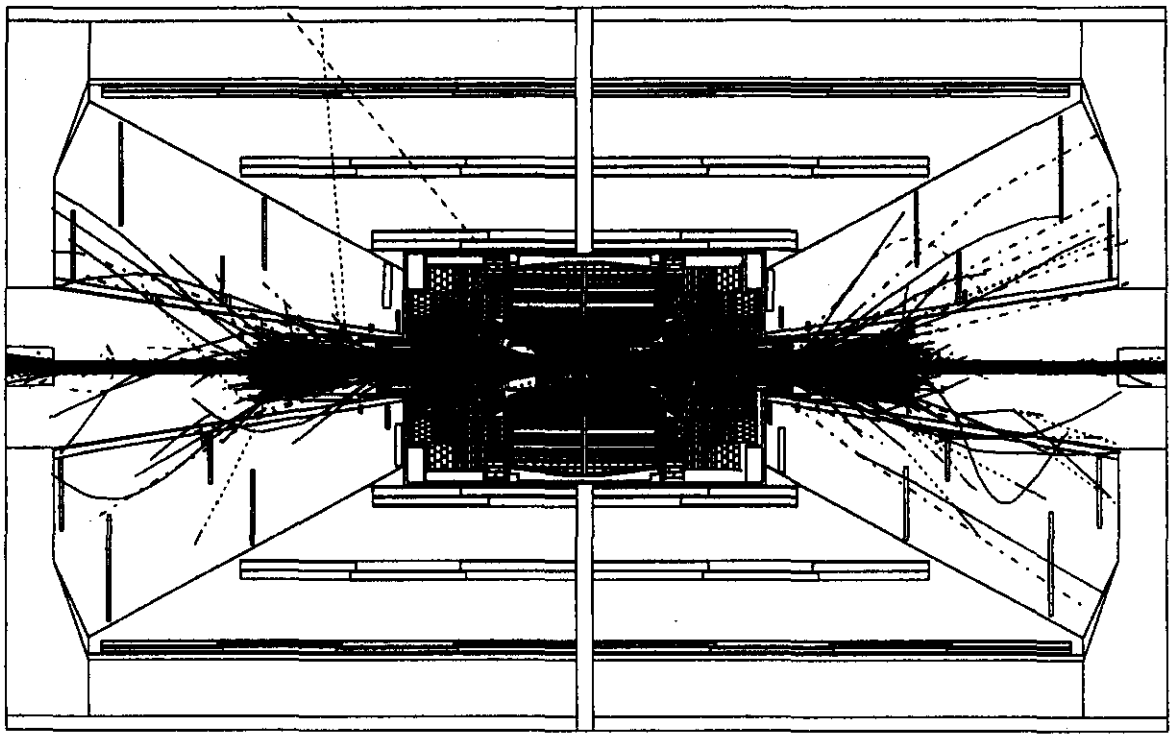
Intention is to use HITs → DIGitization to include pileup

Notable uses so far:

- raised awareness of $n, \gamma$ backgrounds
- raised awareness of material in CT
- "parts" for muon studies
- Full accordion geometry for cal. studies

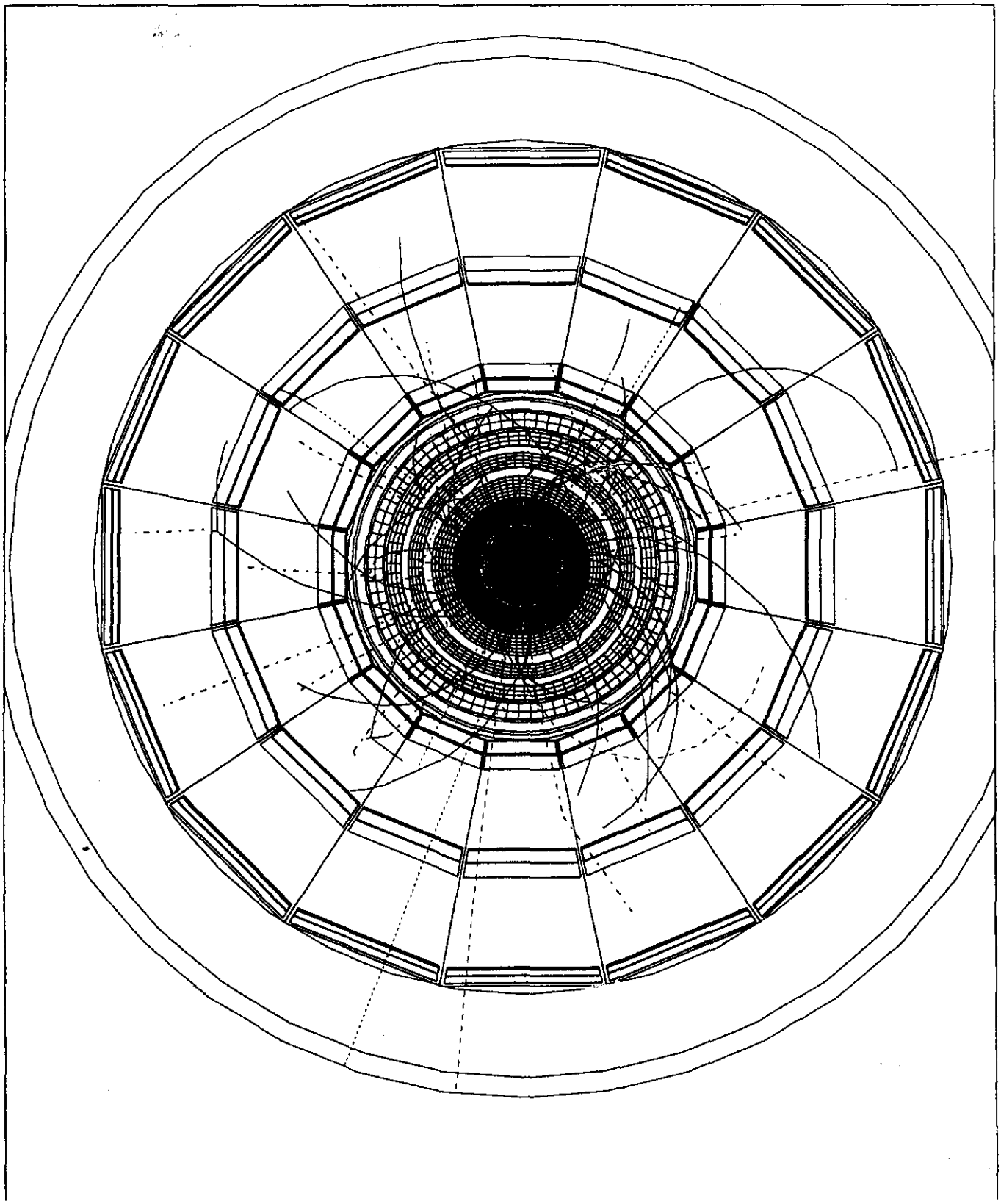
Illustrations follow.

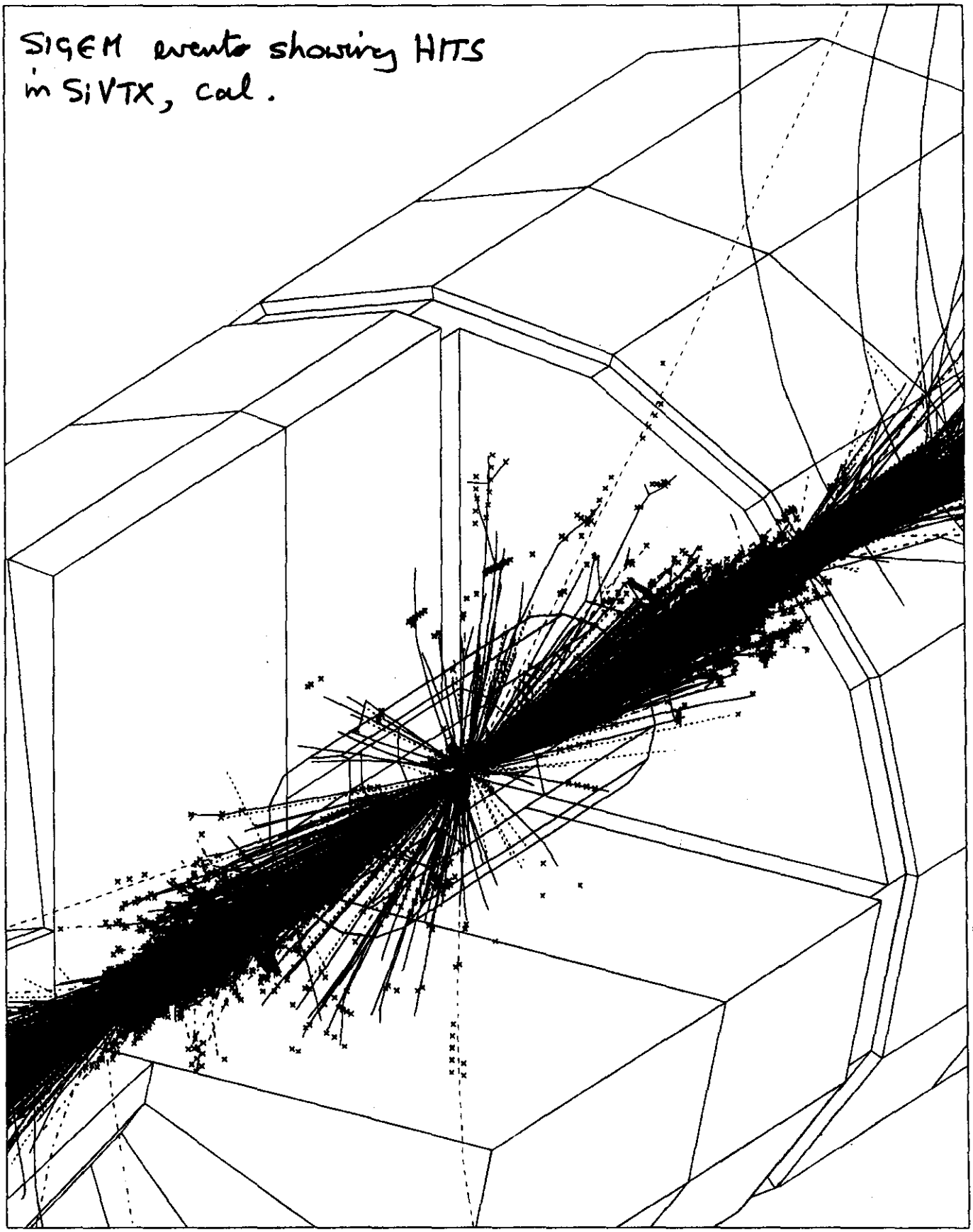
Event in Baseline 1 SIGEM



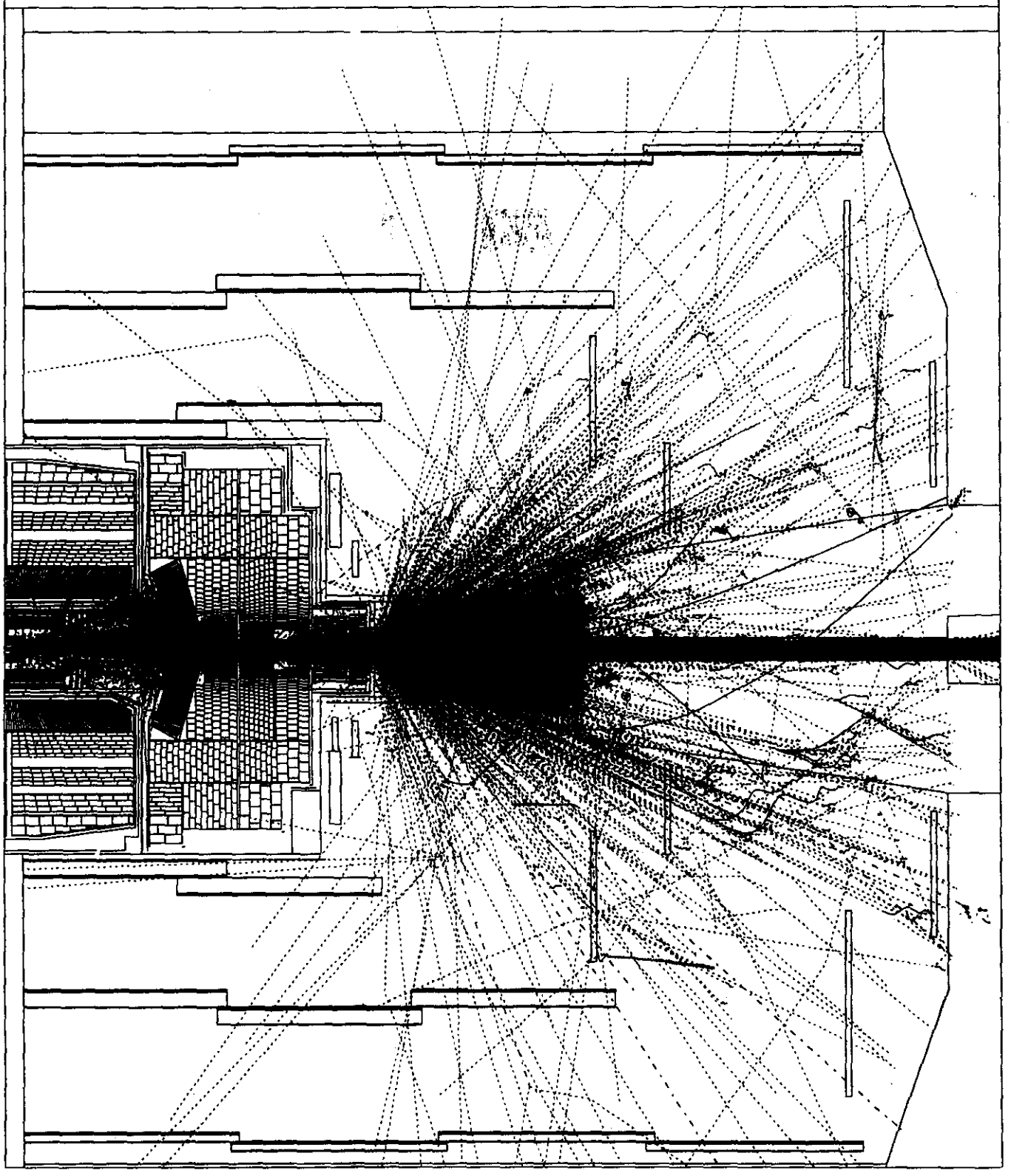
17

SIGEM- cut through Baseline 1




SIGEM events showing HITS
in SiVTX, cal.
8

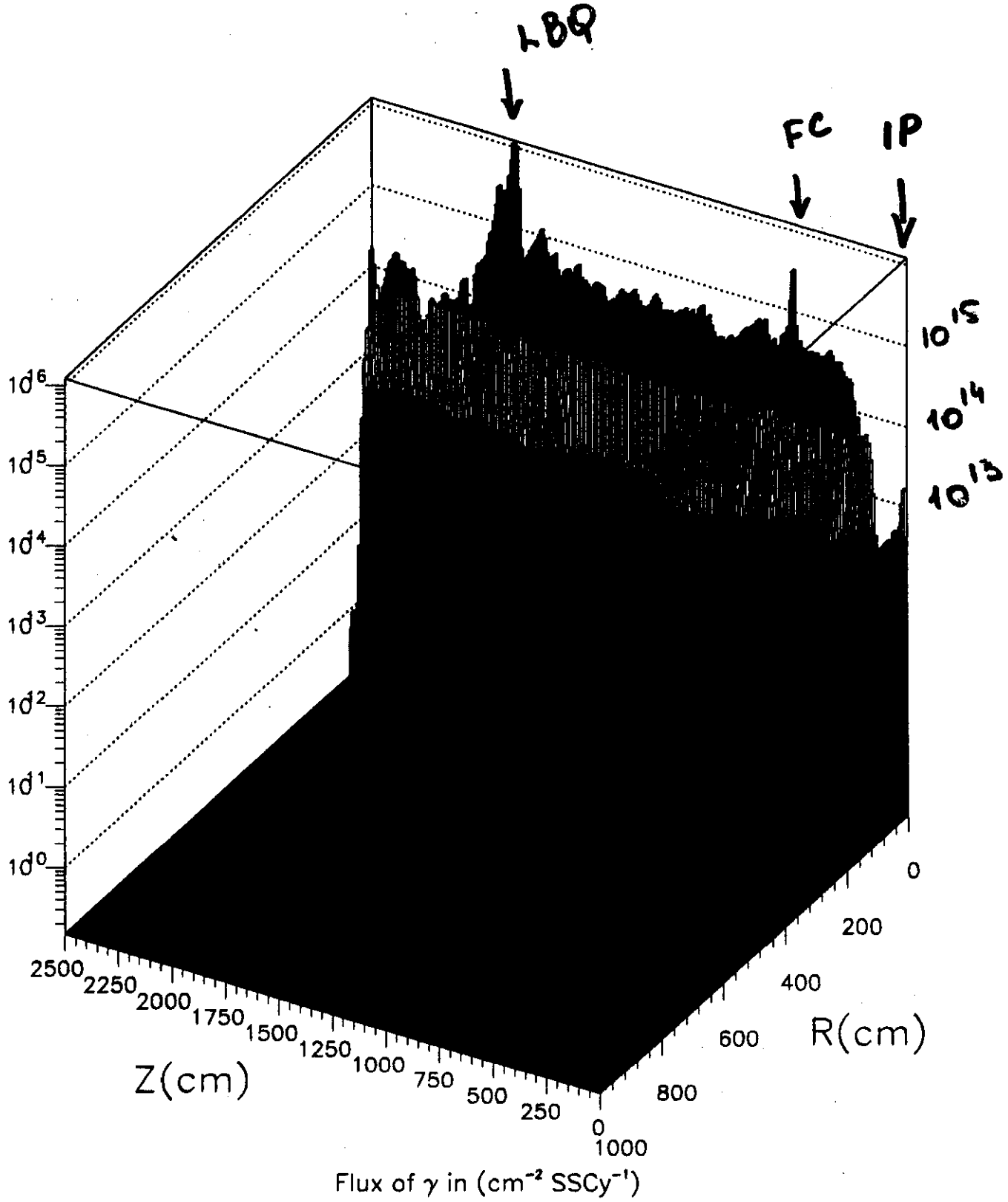
SIGEM event showing low energy (>10 MeV) photons + electrons



H (150 GeV) → WW', (cut 10 MeV)

SIGEM study of photon backgrounds

(20)



Future for SIGEM

☆ Need effort to make Baseline 2 version (volunteers beyond present ~~person~~ people – from subsystems) and more to Unix framework

☆ Adopt as starting point for all GEM detailed simulations.

☆ Define data structures, esp. HITs and DIGitizations.

☆ Pileup

☆ Provide the different levels of description (for Baseline 2):

- dead
- mixture
- detailed

☆ Optimize

☆ H1-style fast shower

☆ Shower libraries

Uses for SIGEM (full simulation)

- Occupancy
- Backgrounds
- Pattern recognition
- Track fitting
- Correlations

Need input from:

Electronics
Sub-Detectors
Beam Tests

Need ~~wide~~ participation of a few good people; wide input -

Advantage of collaboration-wide effort on use of common packages:

- Level of effort
- Level of understanding of issues
- Common framework for discussions
- Credibility of studies

---

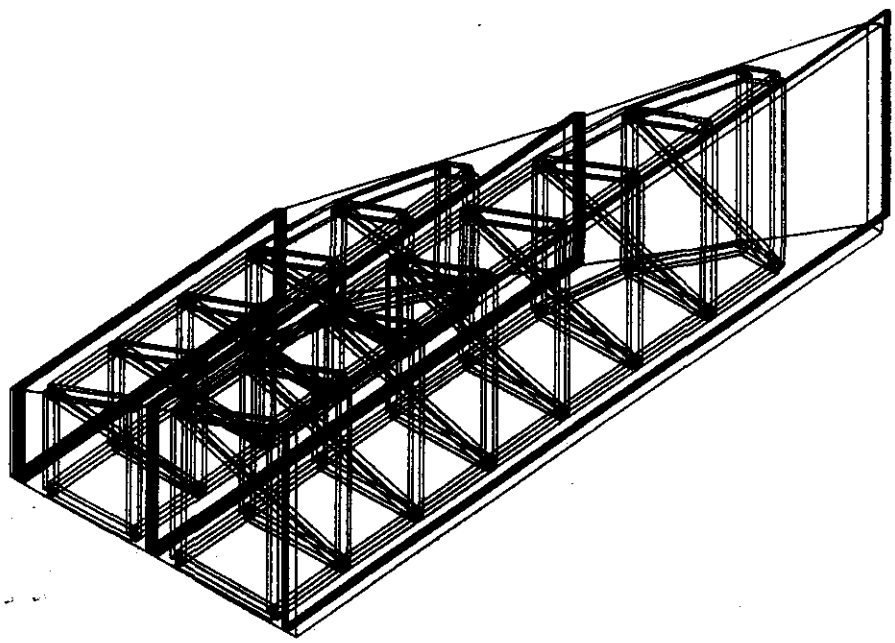
Need sub-systems and institutions to commit effort to a <u>common</u> goal.

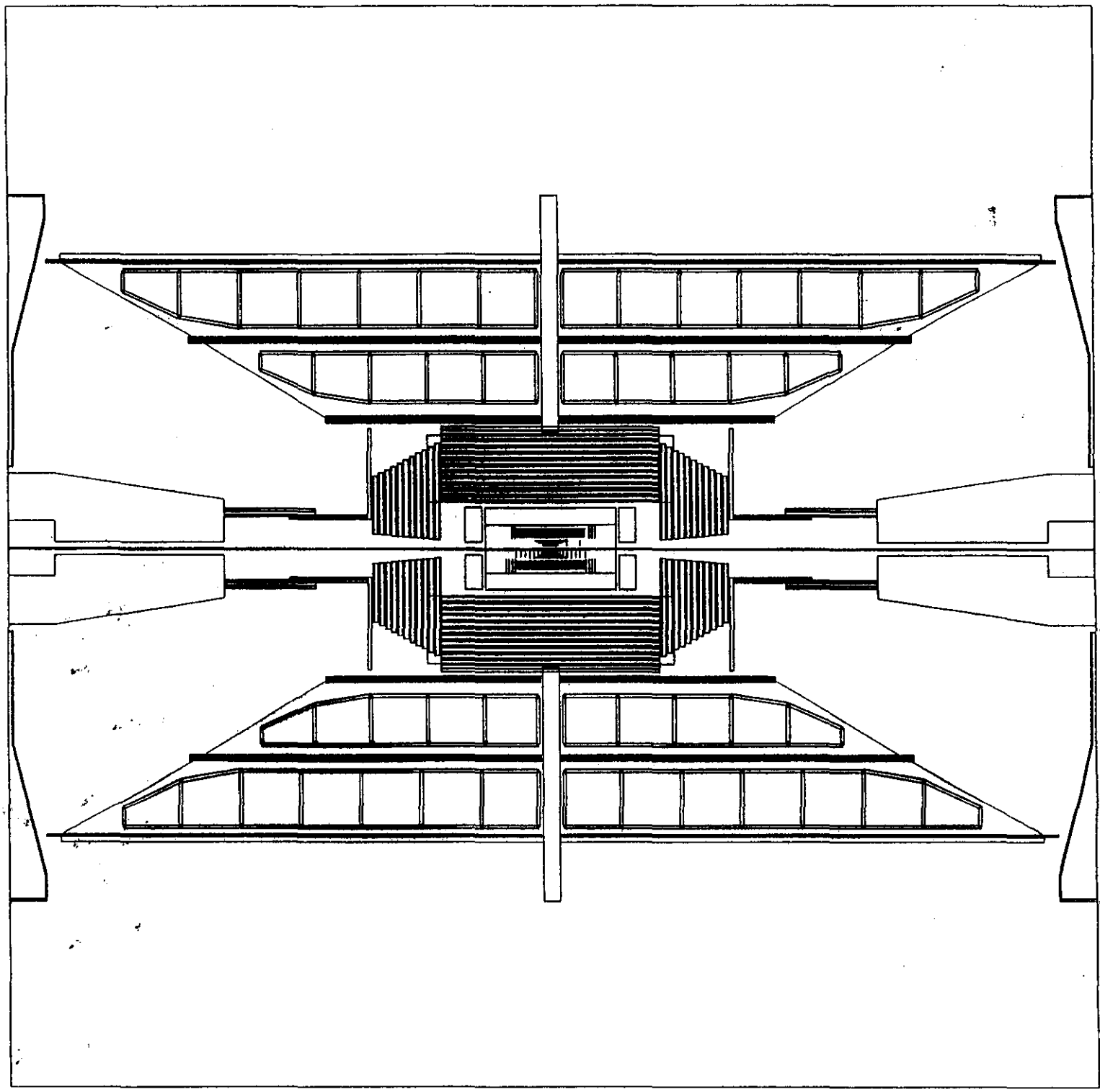
It takes as long to build a ~~computing~~ simulation system as it does to build a detector; many choices to be made.

SIGEM and gemfast provide starting points

Dec meeting → (calorimetry) and others must provide effort, at least beginning.

M. Shupe proposed simplified GEANT model Baseline 2.





## Computing in general

Slow Controls

On-line

Off-line

- pattern recognition
- fitting
- simulation
  - fast
  - full
  - shower techniques
  - pileup

Storage systems

Databases

Data transfer, networks

⋮

---

~~Fund~~ Need TDR section; need plan for detector.

Funding is available for some efforts. Let me know! Thursday a.m.

Physics | Simulation after Bill Willis's talk. TODAY
Physics 2-160

- Status of gemfast
- Discussion of work to be done for Baseline 2.

Computing Thursday Nov. 5th

8:30 am. K. McF Introduction
8:45 am GEM software base – I. Sheer
9:15 am Code Distribution – T. Wenaus
9:45 am TTR offline software – G. Yost
10:15 am Full simulation – T. Wenaus
10:45 am Discussions Full simulation, TDR.

# Magnet Status

Ryszard Stroynowski

K. STROYNOWSKI / SMU
NOV. 4, 1992

# MAGNET

PROGRESS SINCE LAST COLLABORATION MEETING AT TUCSON

AT TUCSON: MODIFICATIONS OF GLOBAL PARAMETERS OF THE MAGNET

- INCREASE OF RADIUS
- ADDITION OF FORWARD FIELD SHAPER
- FREE STANDING CENTRAL DETECTOR SUPPORT
- MOBILE COILS

SINCE THEN:

- CONCEPTUAL DESIGN HAS BEEN COMPLETED
- TECHNICAL DESIGN REPORT (BASELINE I) COMPLETED (6/29/92)
- TECHNICAL DESIGN AND COST ESTIMATES HAVE BEEN REVIEWED (AND CONFIRMED) BY SEVERAL INDEPENDENT GROUPS, PANELS AND ORGANIZATIONS
- PROCUREMENT AND MANAGEMENT PLANS HAVE BEEN FORMULATED AND APPROVED BY DOE
- ENVIRONMENTAL ASSESSMENT OF MAGNET FRINGE FIELD (NO SIGNIFICANT EFFECT) APPROVED BY DOE
- REQUEST FOR PROPOSALS HAS BEEN PREPARED AND COMMENTS FROM INDUSTRY INCORPORATED
- DETAILED ASSEMBLY PLAN HAS BEEN PREPARED IN ORDER TO PROCEED WITH THE DESIGN OF SURFACE BUILDINGS AND FACILITIES

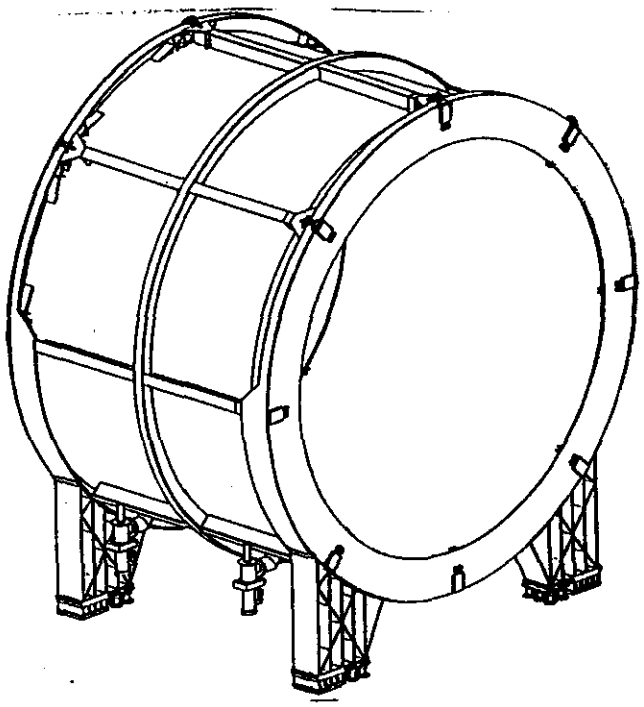
**LAST 3 MONTH** : MAIN EMPHASIS ON DETAILED PLANNING OF INDUSTRIAL CONTRACTS AND FURTHER EXPLORATION OF COMPONENTS WHICH CAN BE MANUFACTURED/PURCHASED BY NATIONAL LABS.

**PROBLEM** : THE SUBMISSION OF RFP (REQUEST FOR PROPOSALS) TO INDUSTRY HAS BEEN SCHEDULED FOR SEPTEMBER IT HAS BEEN DELAYED BY ROY SCHWITTERS PENDING THE REVIEW (BY ED SISKIN - SSC PROJECT MANAGER) OF THE MAGNET TECHNICAL ASPECTS AND OF ITS MANAGEMENT.

THIS REVIEW HAS NOW BEEN COMPLETED AND AS OF FRIDAY LAST WEEK WE ARE TOLD THAT RFP IS FURTHER <u>DELAYED PENDING PAC REVIEW OF GEM IN DECEMBER.</u>

→ MAGNET PROCUREMENT HINGES ON STATUS OF CALORIMETRY AND MUON SYSTEM DESIGN IT IS STILL POSSIBLE TO SATISFY OVERALL SCHEDULE

SSC Lab Review



Siskin's Management Review

US Cost, Inc. Review
SAIC

PAC,
Magnet Technical Panel

# TECHNICAL DESIGN PROGRESS – IN MANY AREAS

- DETAILED DESIGN OF COLD MASS SUPPORT RODS
- COMPRESSION PADS FOR FFS-VACUUM VESSEL INTERFACE TO ACCOUNT FOR MOVEMENT AT POWER-UP
- DETAILED DESIGN OF STIFFENING RINGS OF THE VACUUM VESSEL
- NEW IDEAS ON JOINT DESIGN
- DETAILED ASSEMBLY PLAN FOR BOTH HORIZONTAL AND VERTICAL ASSEMBLY

# R&D PROGRAM MODIFICATIONS

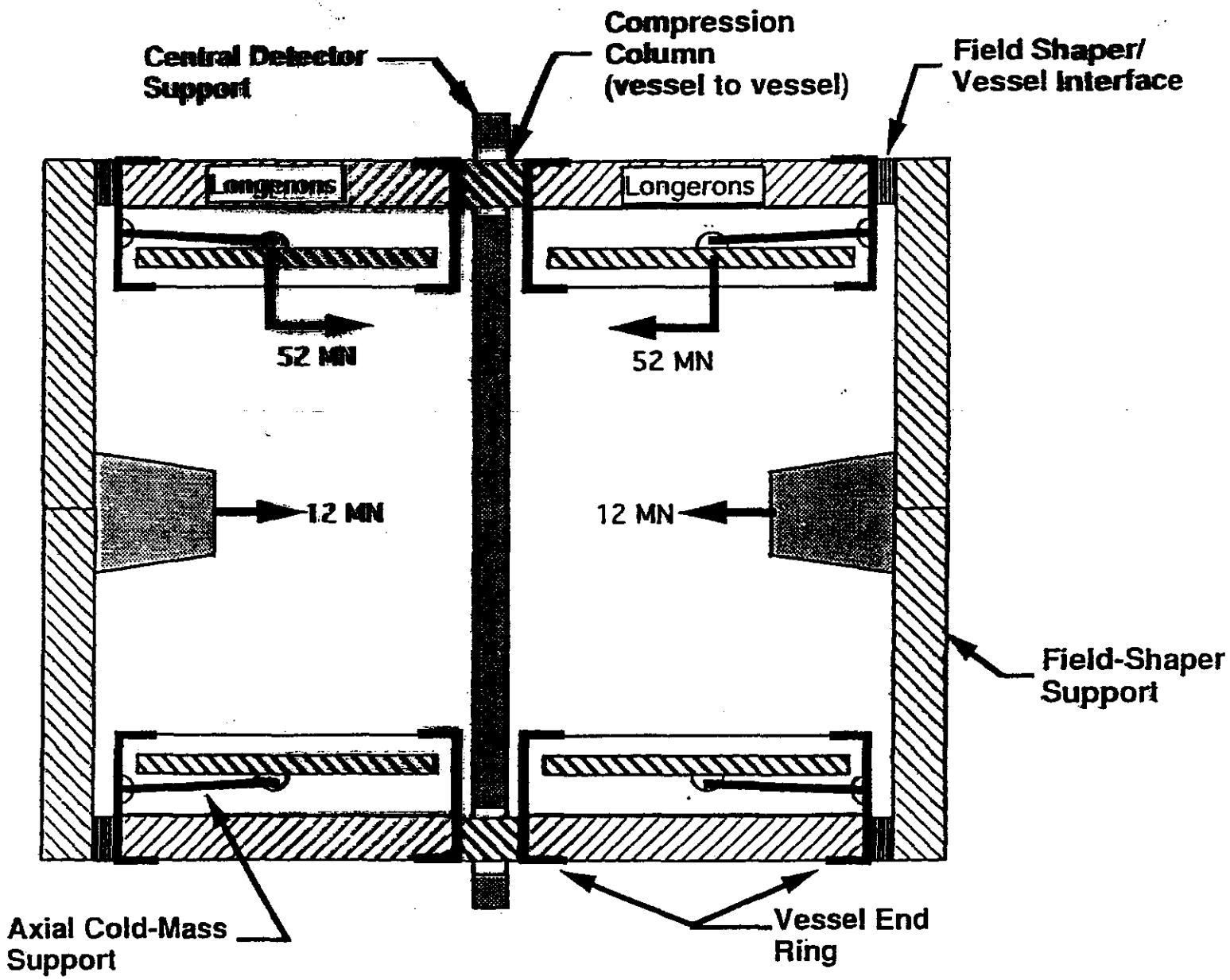
- CONDUCTOR WORK SHIFTED FROM "R&D" TO 'VERIFICATION'

  PEOPLE ARE CONFIDENT THAT CONDUCTOR CAN BE MANUFACTURED IN REQUIRED LENGTH AND WITH SUFFICIENT QUALITY ASSURANCE

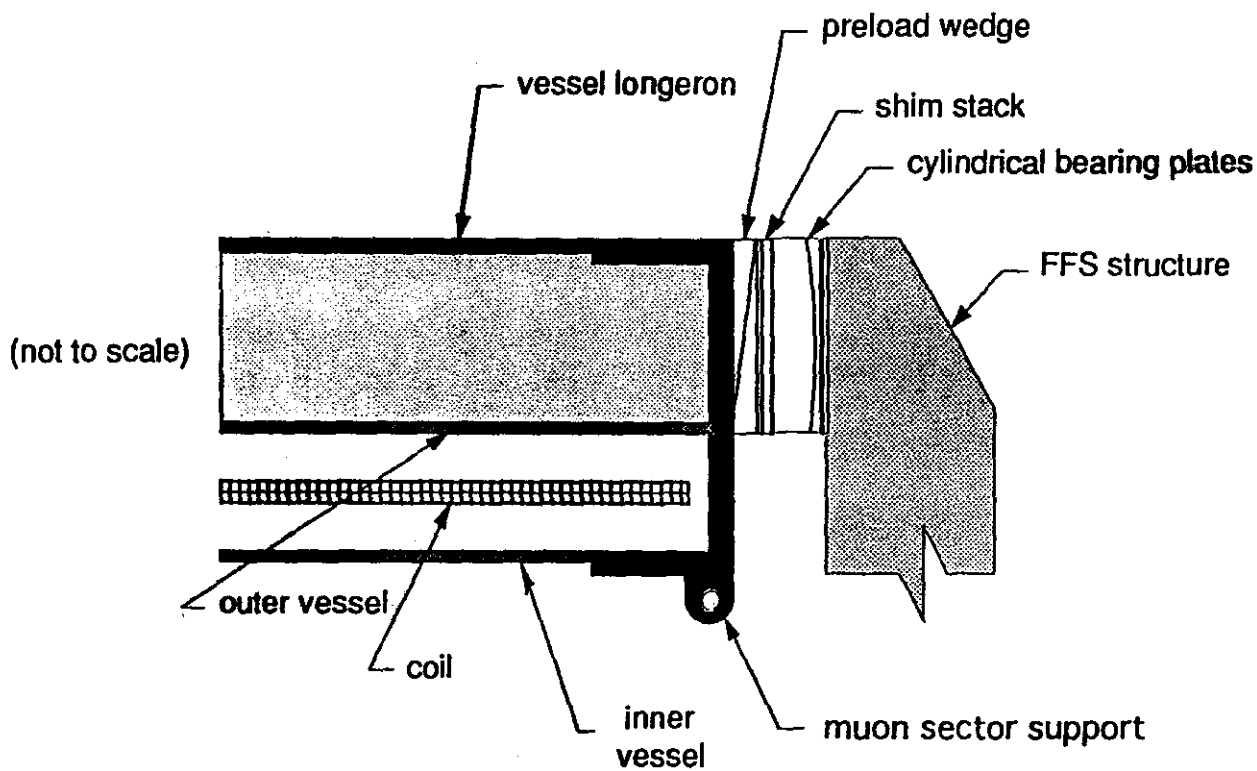
  CONDUCTOR PERFORMANCE AND JOINTS PERFORMANCE NEEDS TO BE TESTED

  → HAIRPIN TEST – 60 m OF CONDUCTOR AND A FULL SCALE JOINT WILL BE TESTED AT FULL CURRENT USING STRING TEST MAGNET CRYOSTATS
- MAIN R&D EFFORT SHIFTED TOWARDS DEVELOPMENT OF TOOLING FOR COIL WINDING.

# Axial Magnetic Load Paths



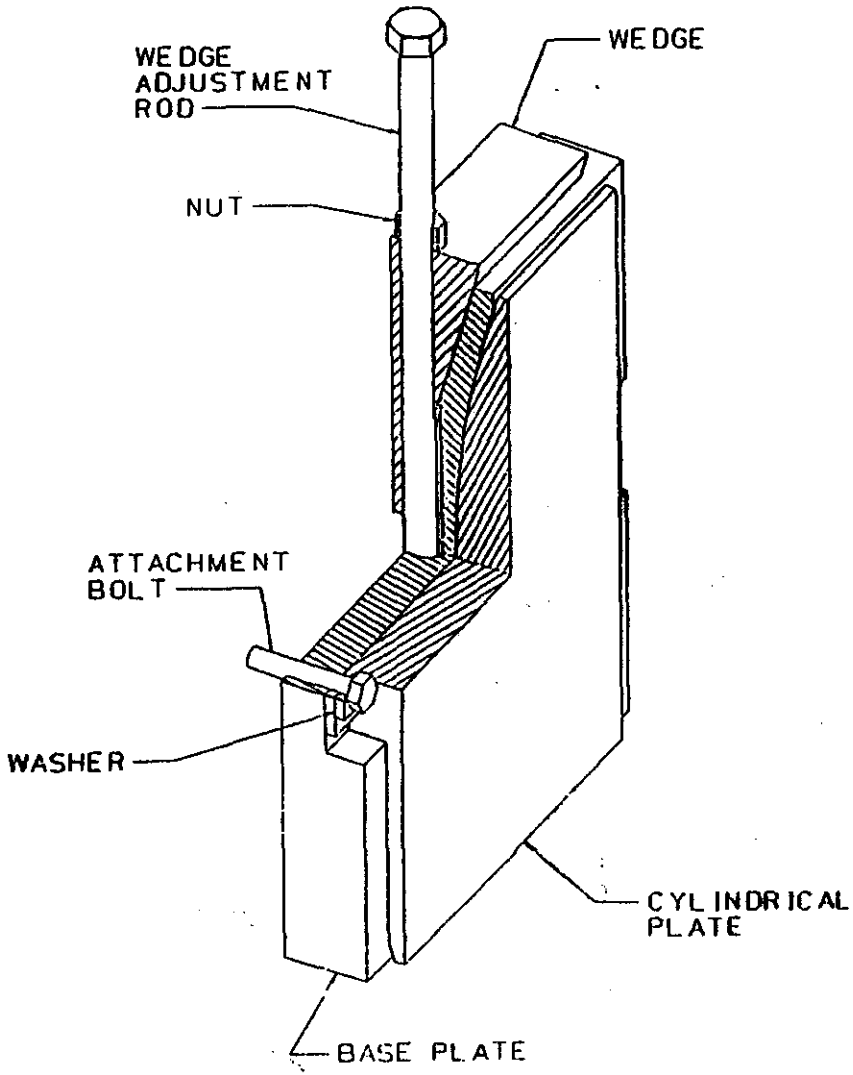
# FFS / vacuum vessel interface




- vessel/ FFS structure interface is preloaded with large wedges, assuring contact at eight load points

JMB-20
10/12/92

# Compression pad



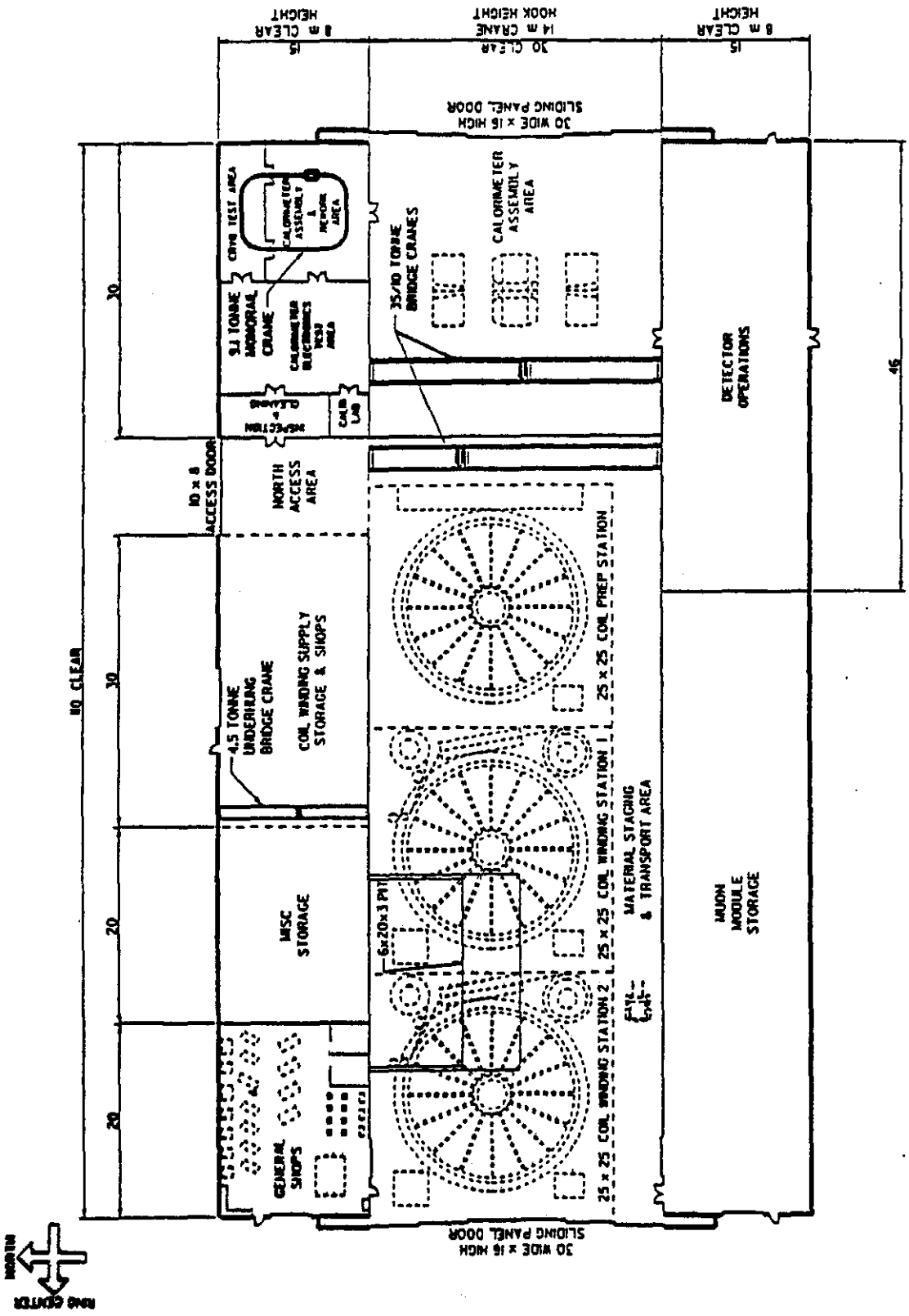
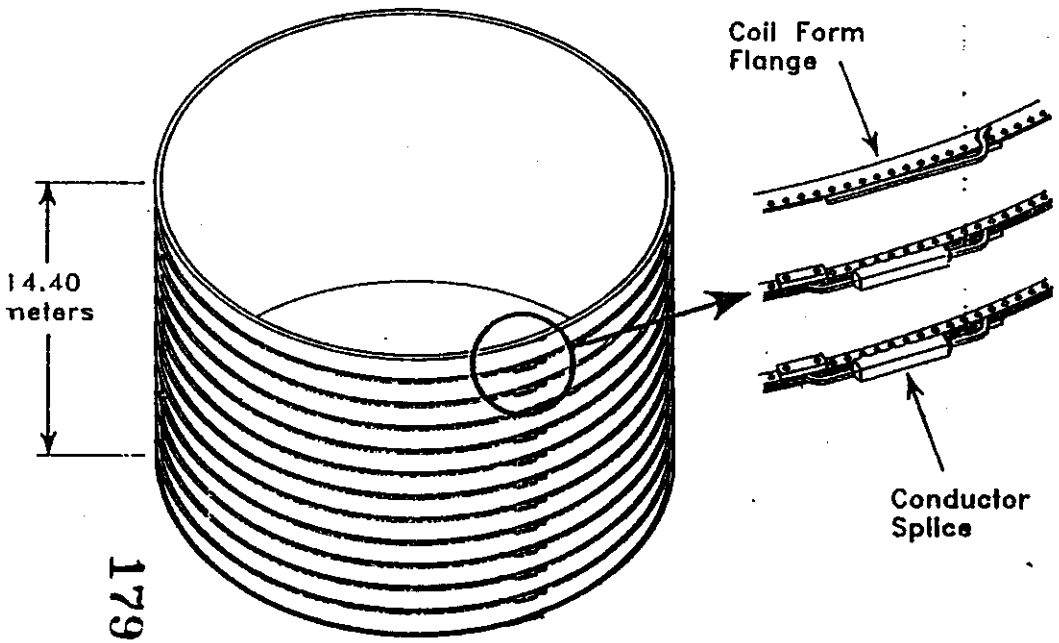


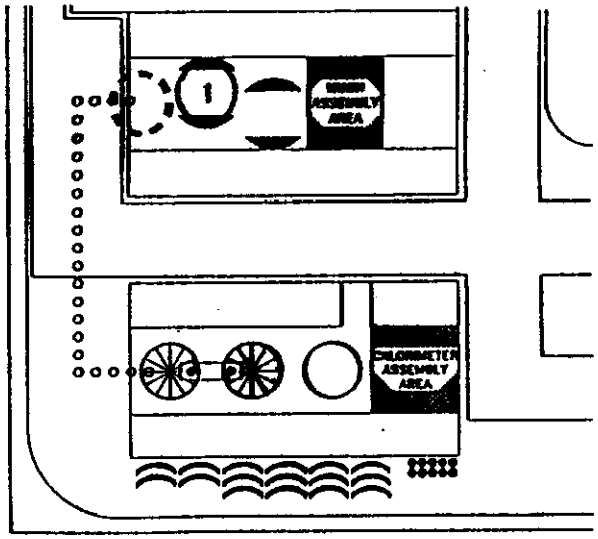

Figure 6-2 South Assembly Building Floor Plan.

# Assemble the Half Coil

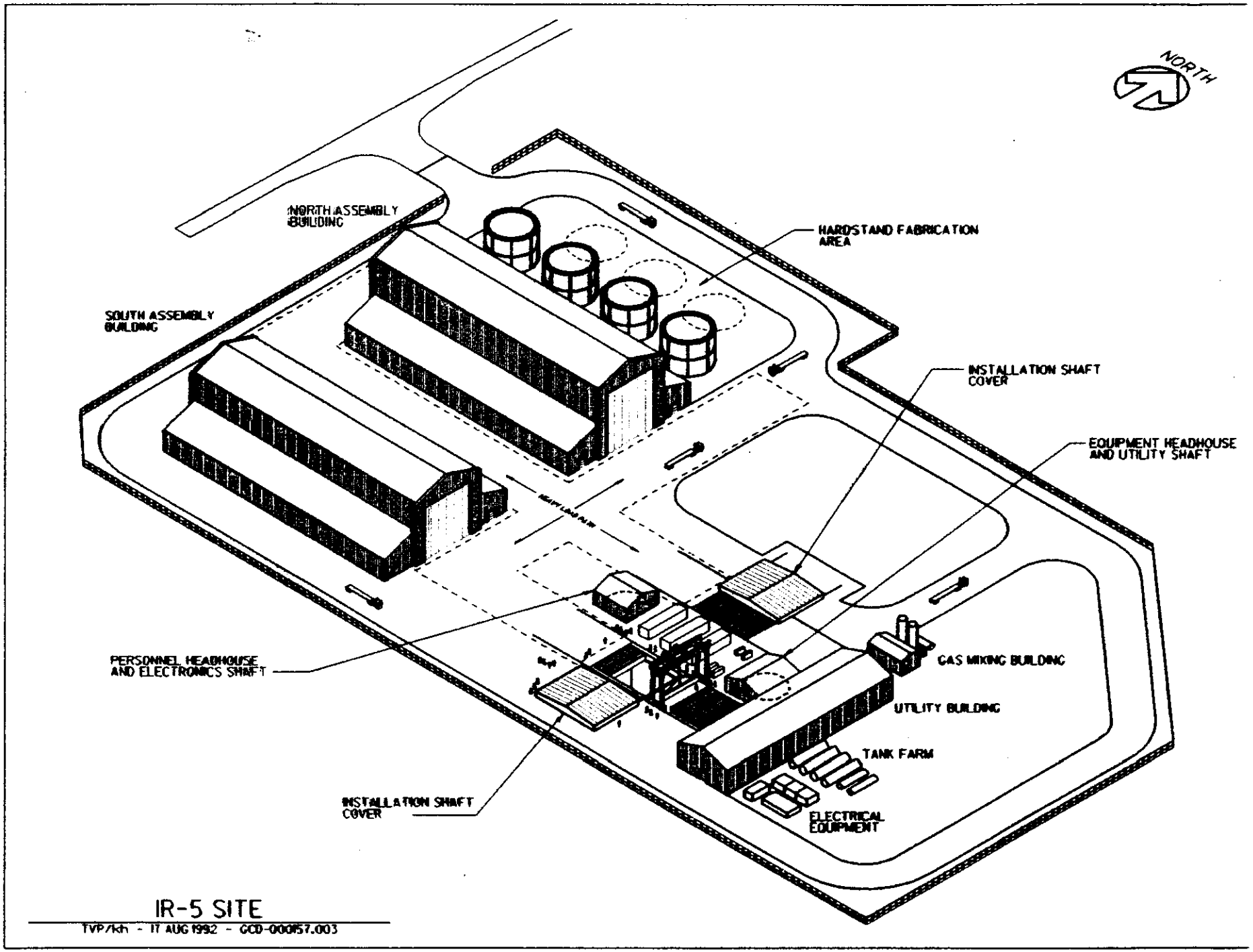



In the North Assembly Building high bay;

1. Transport to NAB with straddle lifter.
2. Lift to top of ass'y with crane
3. Make conductor joint
4. Bolt bobbin flanges
5. Install voltage taps, strain gauges, etc.
   (Repeat 12 times...)
6. Install cryogenic manifolds
7. Certify ready for assembly
8. Protect from weather
9. Lift with "heavy hauler"



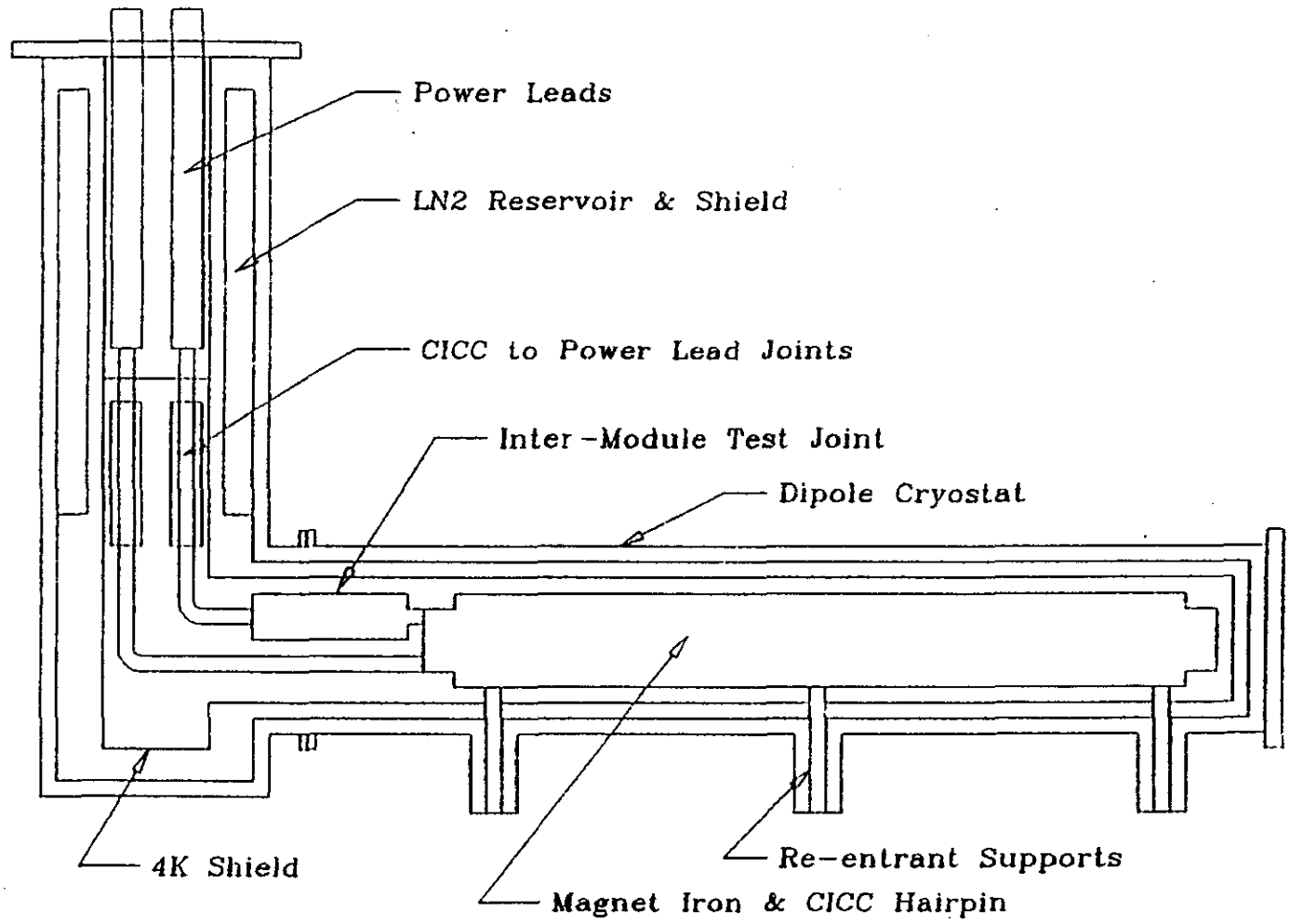

VG-GEM-92-010-10




IR-5 SITE

TVP/kh - 17 AUG 1992 - GCD-000157.003

# TWO TURN CICC HAIRPIN in IRON




NOTE: 4K Circulating Lines
Not Shown

MIT-PFC
9/20/92
RJCJr

# GEM MAGNET DATES

| | |
|---|---|
| Magnet Subcontract Award | March 12, 93 |
| Conductor Subcontract Award | March 19, 93 |
| Test full scale SC joint | February 1, 93 |
| Built hairpin sample: | |
| Strand (66 km) | Dec 14, 92 |
| Cable (120 m) | Jan 27, 92 |
| Pull into 60 m conduit | May 5, 93 |
| Sheath | March 30, 93 |
| Built test facility and Assemble hairpin sample (60 m) | Oct. 4, 93 |
| Test hairpin sample | Dec. 14, 93 |
| Winding Building (South Assembly Building) Ready | February 8, 94 |
| Shipping of the 1st piece of the conductor | March 25, 94 |
| Winding of the 1st coil start | April 12, 94 |
| Shipping of the 24th piece | January 1, 96 |
| Assemble the 2 nd magnet half | June 6, 96 |
| Test and map magnet | March 24, 97 |

gem

$\gamma e \mu$

# Status of IR5 Facilities

Dale Moeller

THE PB/MK TEAM
ARCHITECTS • ENGINEERS • CONSTRUCTION MANAGERS

# CONVENTIONAL EXPERIMENTAL FACILITIES STATUS
# GEM DETECTOR AT IR 5 SITE, EAST COMPLEX, SSC

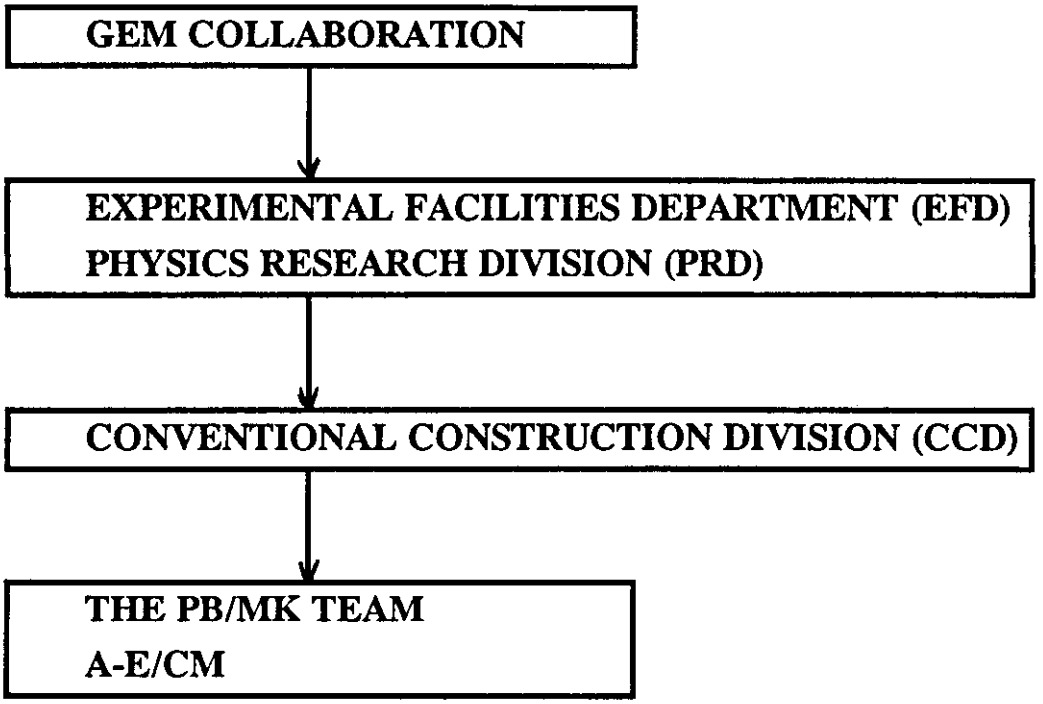
Presentation at GEM Collaboration Meeting at BNL, Upton, New York
November 4, 1992

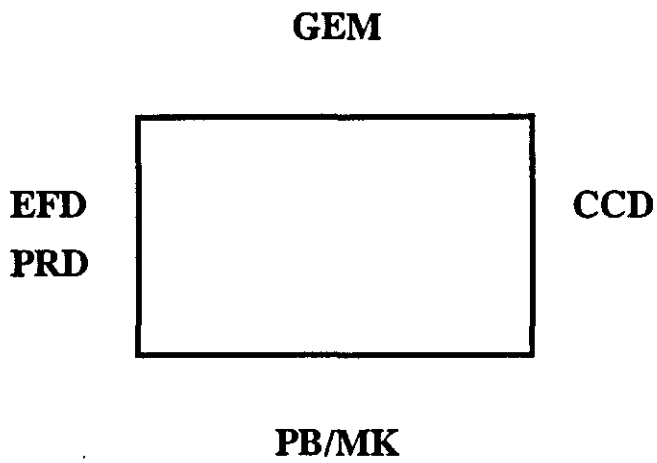
Presentation by Dale T. Moeller, IR 5 Design Manager, The PB/MK Team

- INTRODUCTION
- ORGANIZATION & WORK FLOW
- DESIGN PROCESS
- CONSTRUCTION PACKAGING & DESIGN CONCEPTS
  - SITE & INFRASTRUCTURE
  - SURFACE BUILDINGS
  - U/G HALL
- SCHEDULE



A JOINT VENTURE OF PARSONS BRINCKERHOFF AND MORRISON KNUDSEN
7220 South Westmoreland Road, Dallas, Texas 75237 • (214) 709-0900 • FAX (214) 709-0014


GEM COLLABORATION
EXPERIMENTAL FACILITIES DEPARTMENT (EFD)
PHYSICS RESEARCH DIVISION (PRD)
CONVENTIONAL CONSTRUCTION DIVISION (CCD)
THE PB/MK TEAM
A-E/CM


GEM
EFD
PRD
CCD
PB/MK

- DESIGN PROCESS

RECEIVE DESIGN REQUIREMENTS

TITLE I DESIGN (PRELIMINARY)

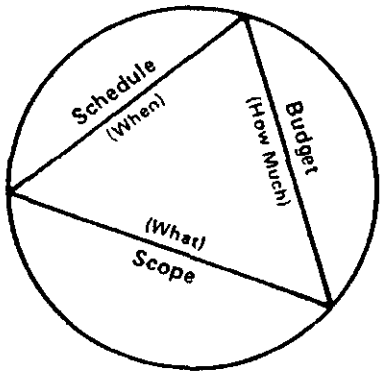
REPORT
DESIGN REVIEW
COST ESTIMATE
VALUE ENGINEERING (VE)

TITLE II DESIGN (FINAL IFB DOCUMENTS)

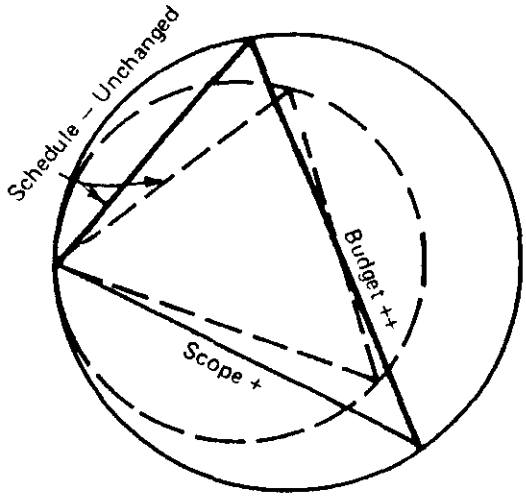
90% SUBMITTAL
DESIGN REVIEW
100% DESIGN
DESIGN BOARD
IFB
COST ESTIMATE
ADDENDUM PREPARATION

TITLE III (DESIGN SERVICES DURING CONSTRUCTION)

SHOP DRAWING REVIEW
DESIGN CHANGE NOTICES
RESPOND TO RFI's




**4.1A**
**The Project**




**4.1B**
**The Changed Project**

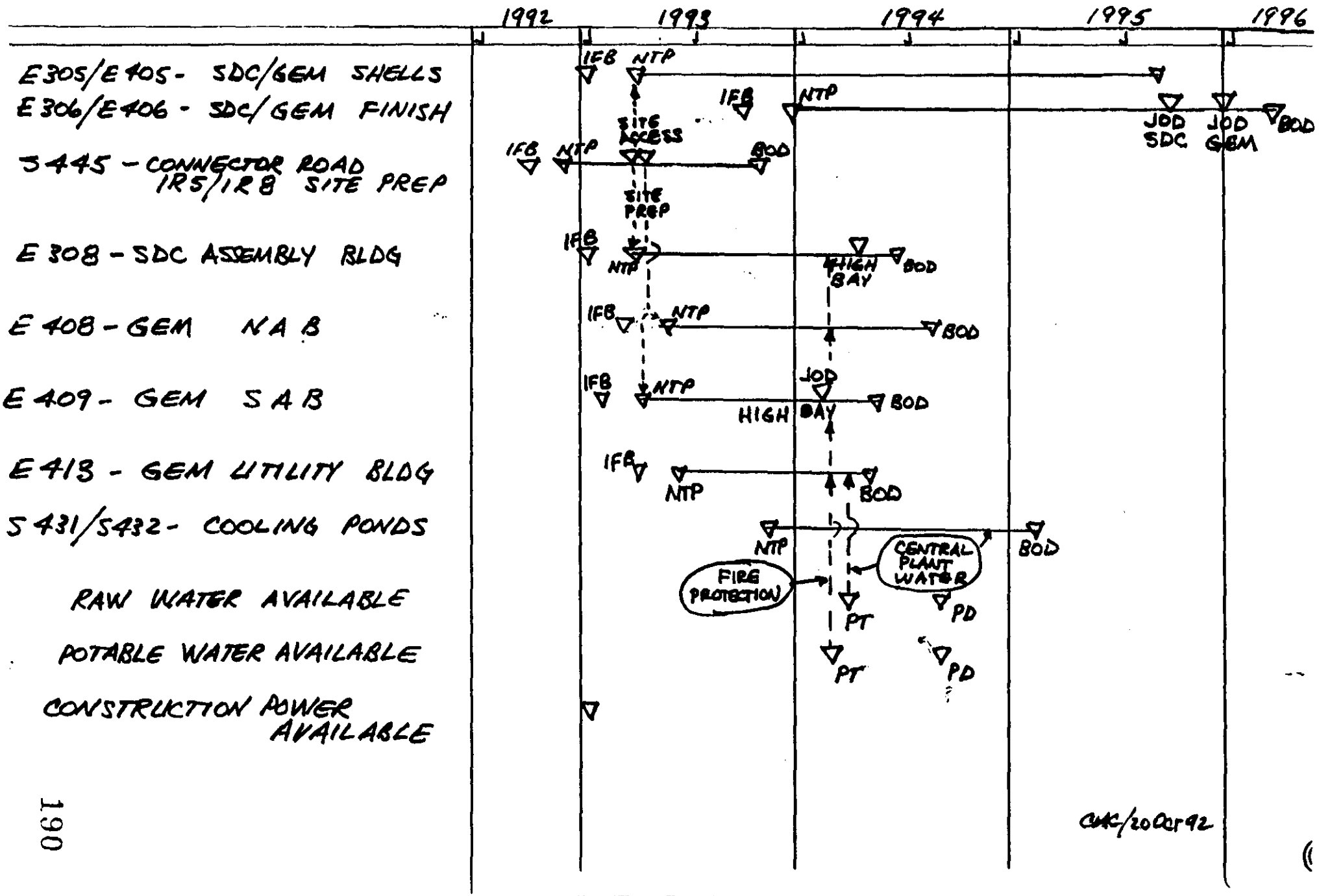
Notes:

1. The variables can change within a project but, by definition, a change to one variable must result in a change to at least one other.
2. Inherent in the scope, the schedule and the budget is the quality of the services the client has contracted for. A material change in quality requirements will also result in a material change to the primary variables.

An enlarged scope held to the same schedule requires an enlarged budget, i.e., a changed project.

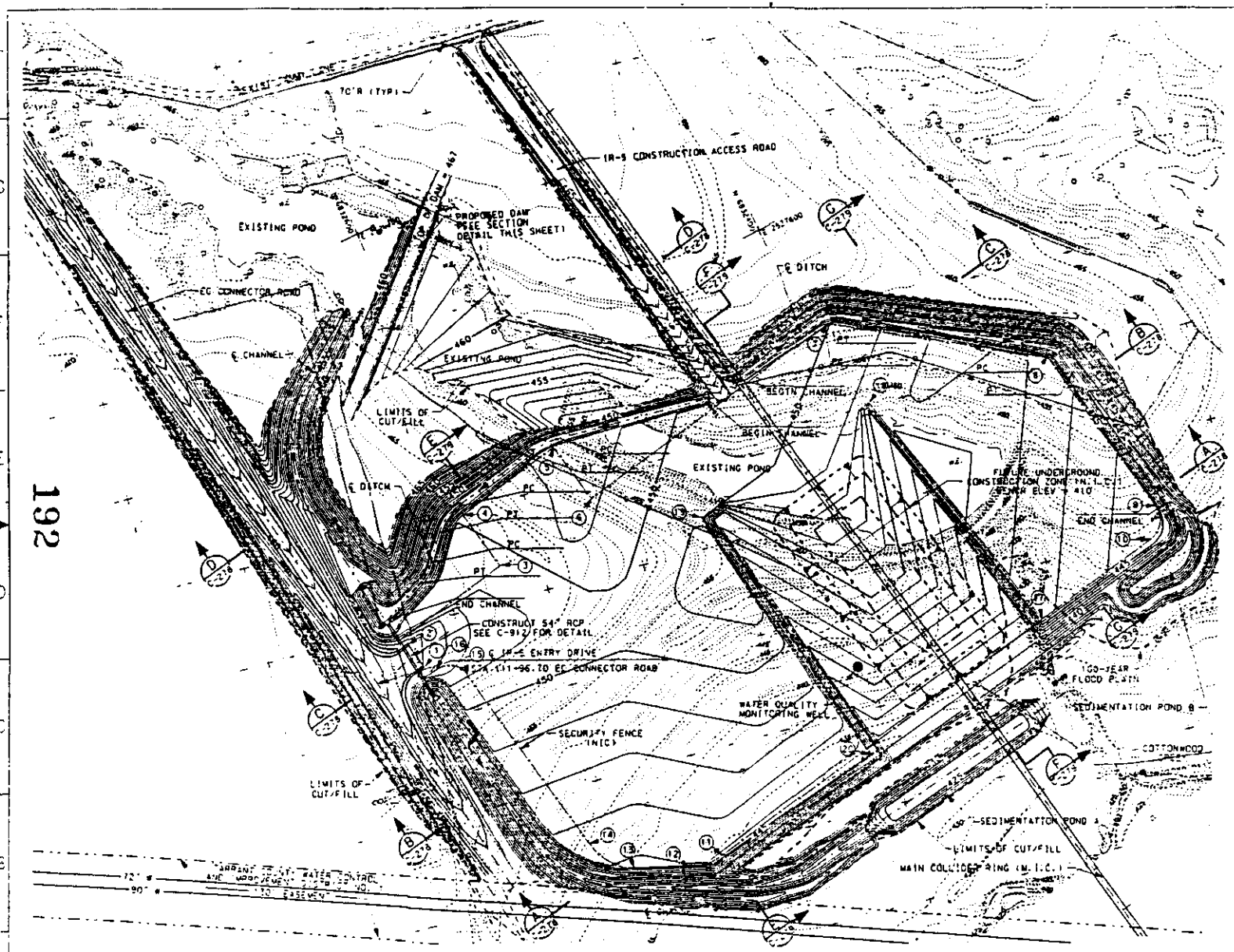
oject _____ Contract No. _____ File No. _____
ature _____ Designed _____ Date _____
m _____ Checked _____ Date _____

# EAST COMPLEX FACILITIES – CURRENT RELATIONSHIPS



# CONSTRUCTION PACKAGES

- ROADS AND SITE PREPARTION
- HALL SHELLS
- HALL FINISHES
- UTILITY BUILDING
- OTHER BUILDINGS AND INFRASTRUCTURE

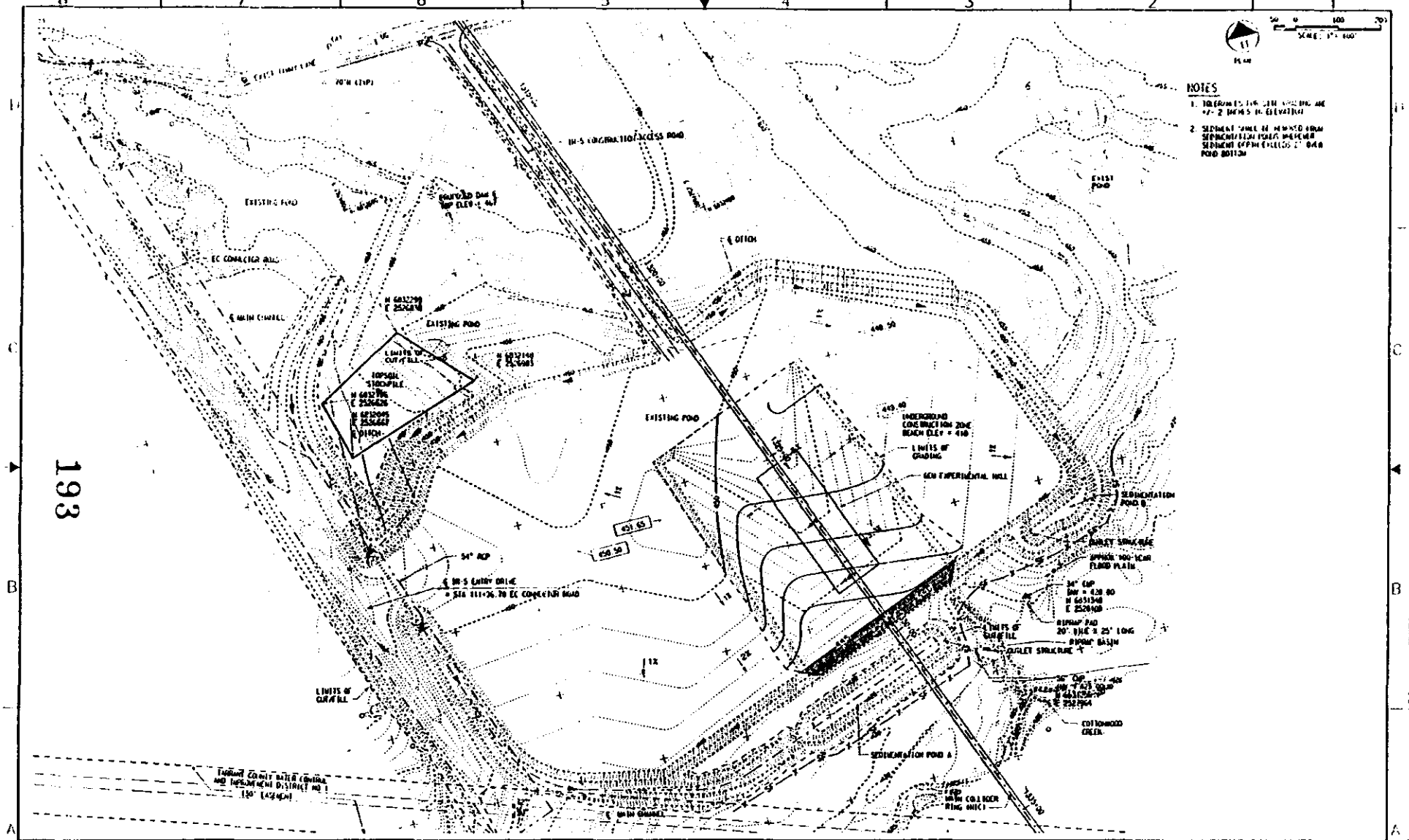



SUPERCONDUCTING SUPER COLLIDER LABORATORY

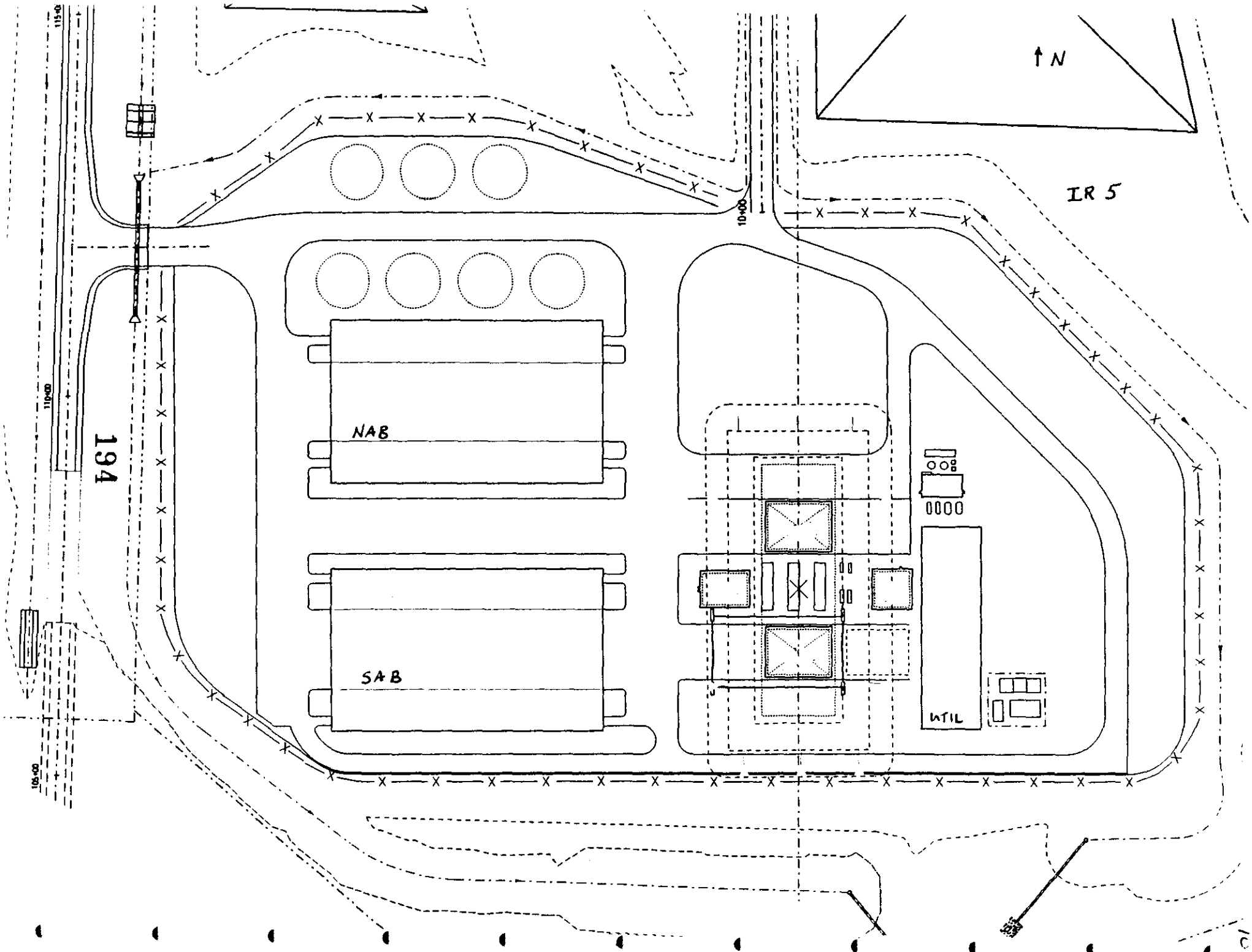
IR5 SITE GRADING

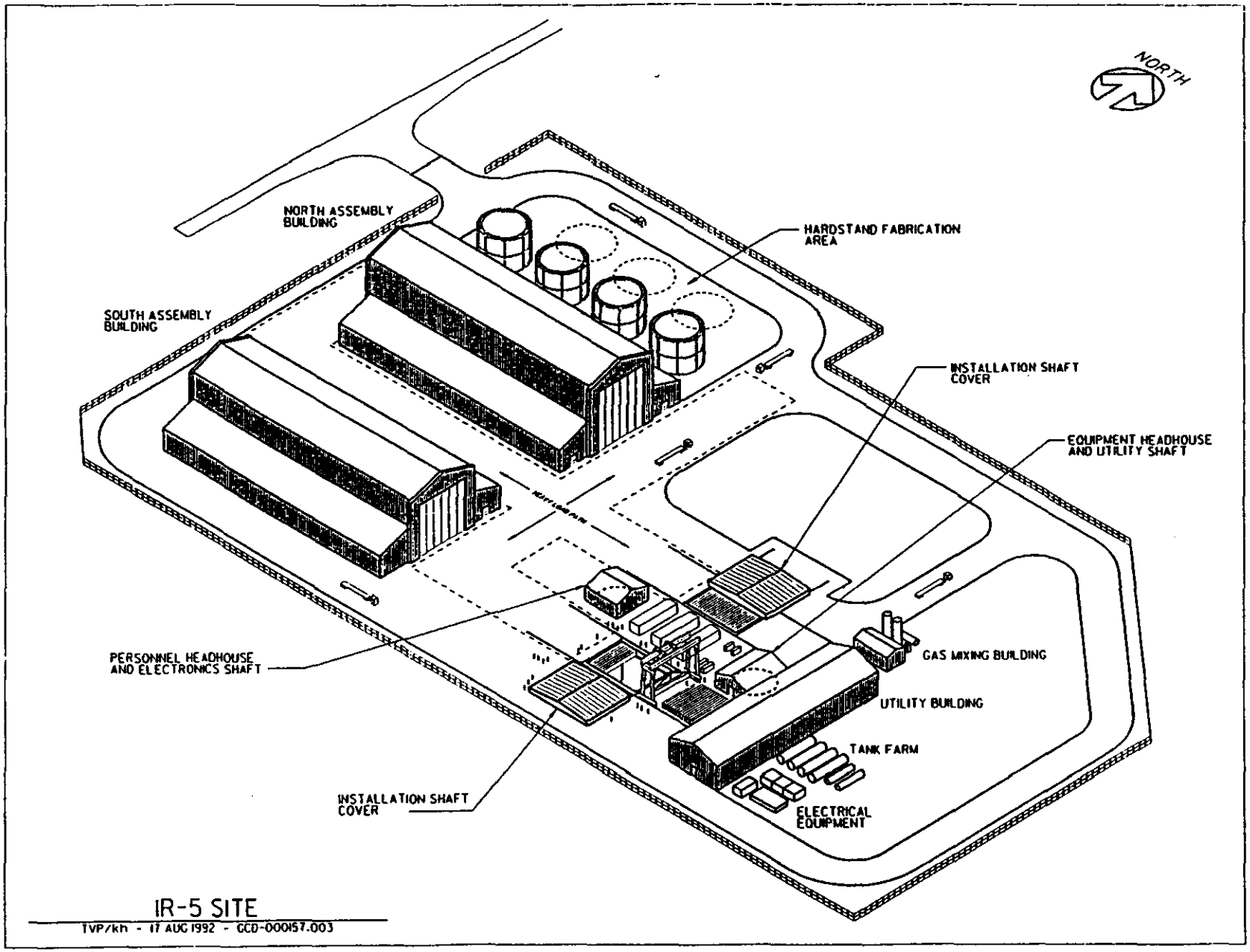
SITE GRADING PLAN

192




| | | | |
|---|---|---|---|
| SUPERCONDUCTING SUPER COLLIDER LABORATORY | THE PB/MK TEAM | SITE GRADING PLAN | E-405 |
| | | CIVIL | C-101 |
| | | | 09 25 92 |
| | | | 0 C24-001606 A |


N
IR 5
194
NAB
SAB
UTIL
115+00
110+00
105+00
100+00


NORTH
NORTH ASSEMBLY BUILDING
SOUTH ASSEMBLY BUILDING
HARDSTAND FABRICATION AREA
INSTALLATION SHAFT COVER
EQUIPMENT HEADHOUSE AND UTILITY SHAFT
PERSONNEL HEADHOUSE AND ELECTRONICS SHAFT
GAS MIXING BUILDING
UTILITY BUILDING
TANK FARM
ELECTRICAL EQUIPMENT
INSTALLATION SHAFT COVER
IR-5 SITE
TVP/kh - 17 AUG 1992 - GCD-000157.003

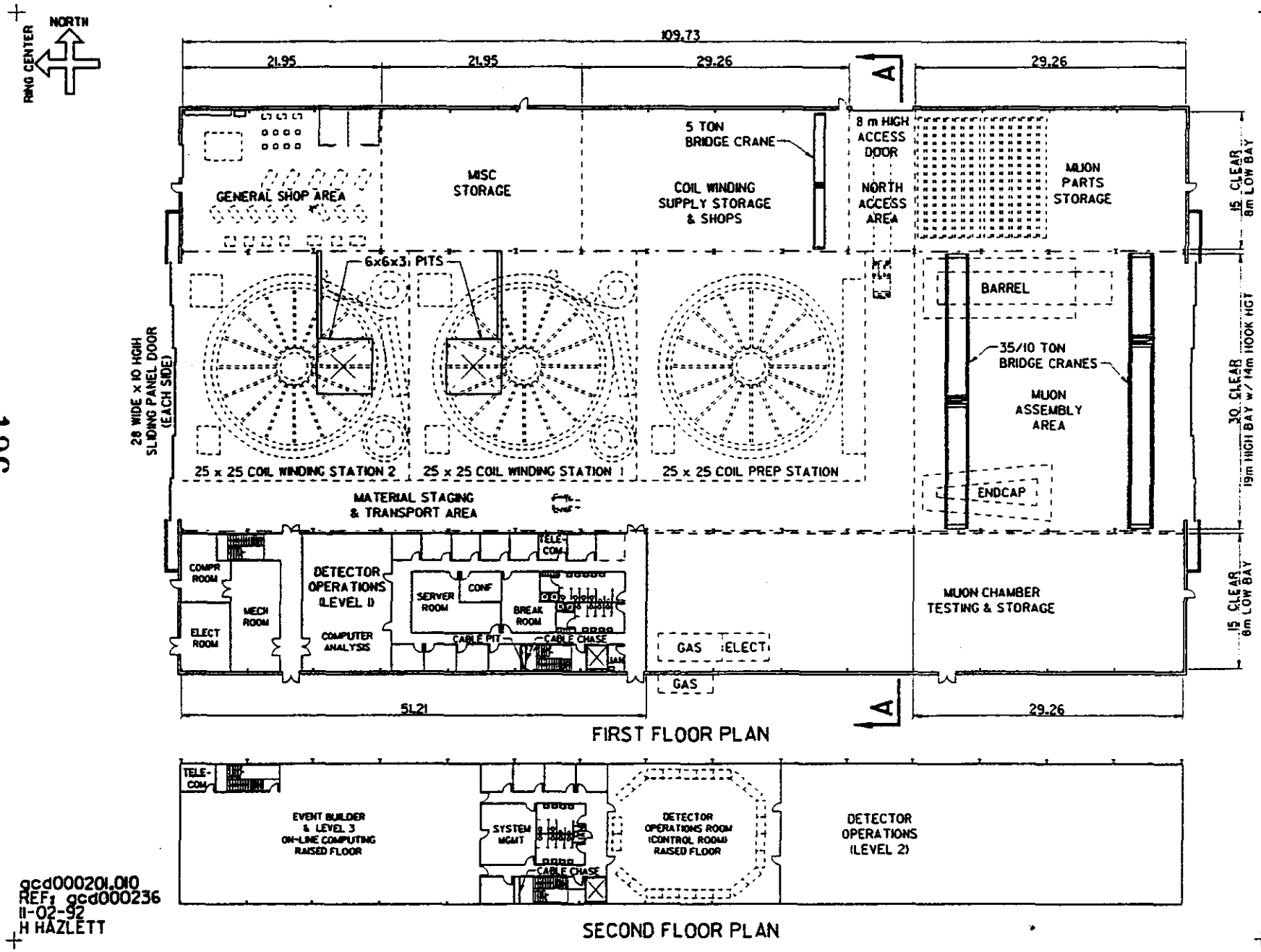
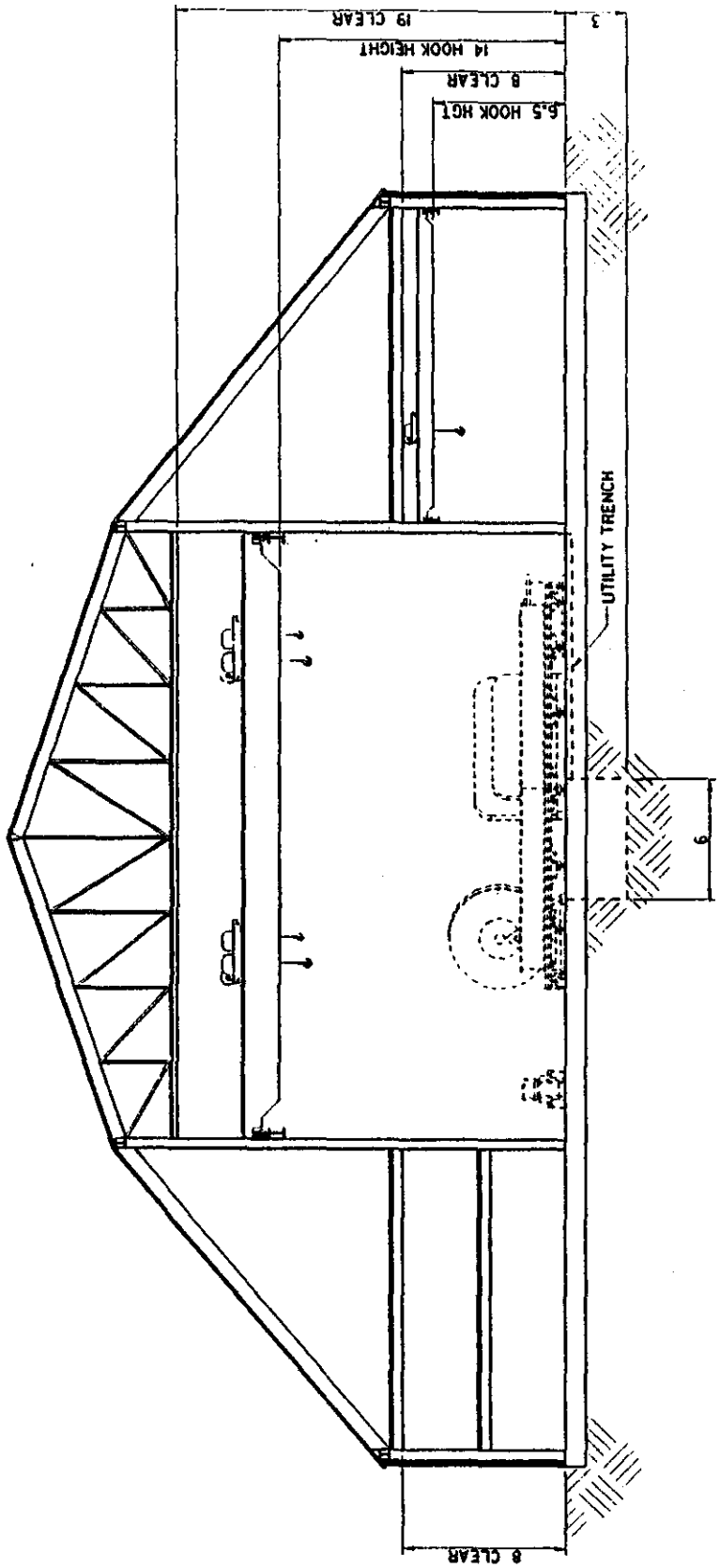



Figure 6-2 South Assembly Building Floor Plan

gcd000201.010
REF: gcd000236
11-02-92
H HAZLETT



Document Control No. E21-000046
SCN No. B010




SECTION A-A

Figure 6-3 South Assembly Building Section

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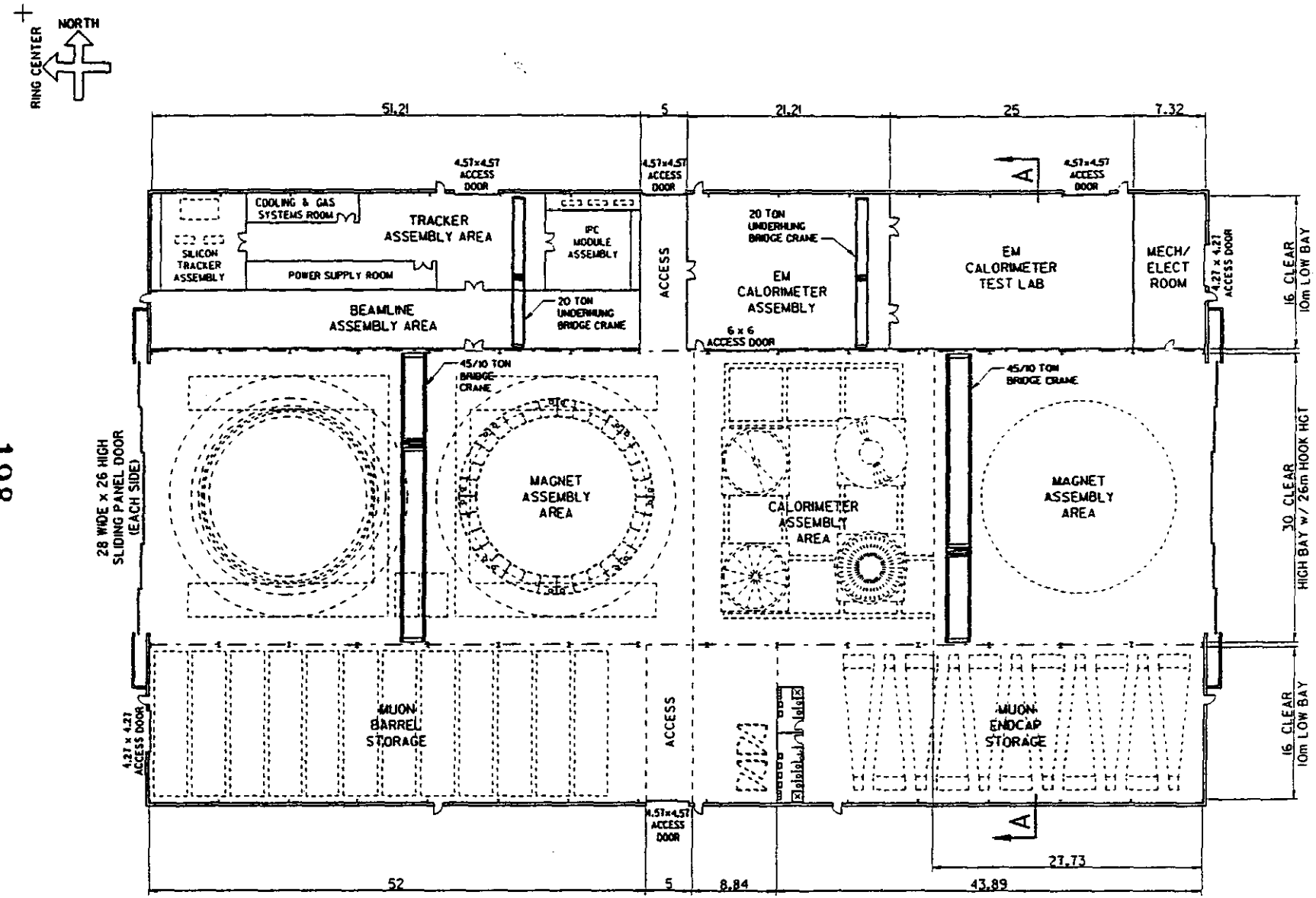
REF: gcd000237
11-02-92
H HAZLETT



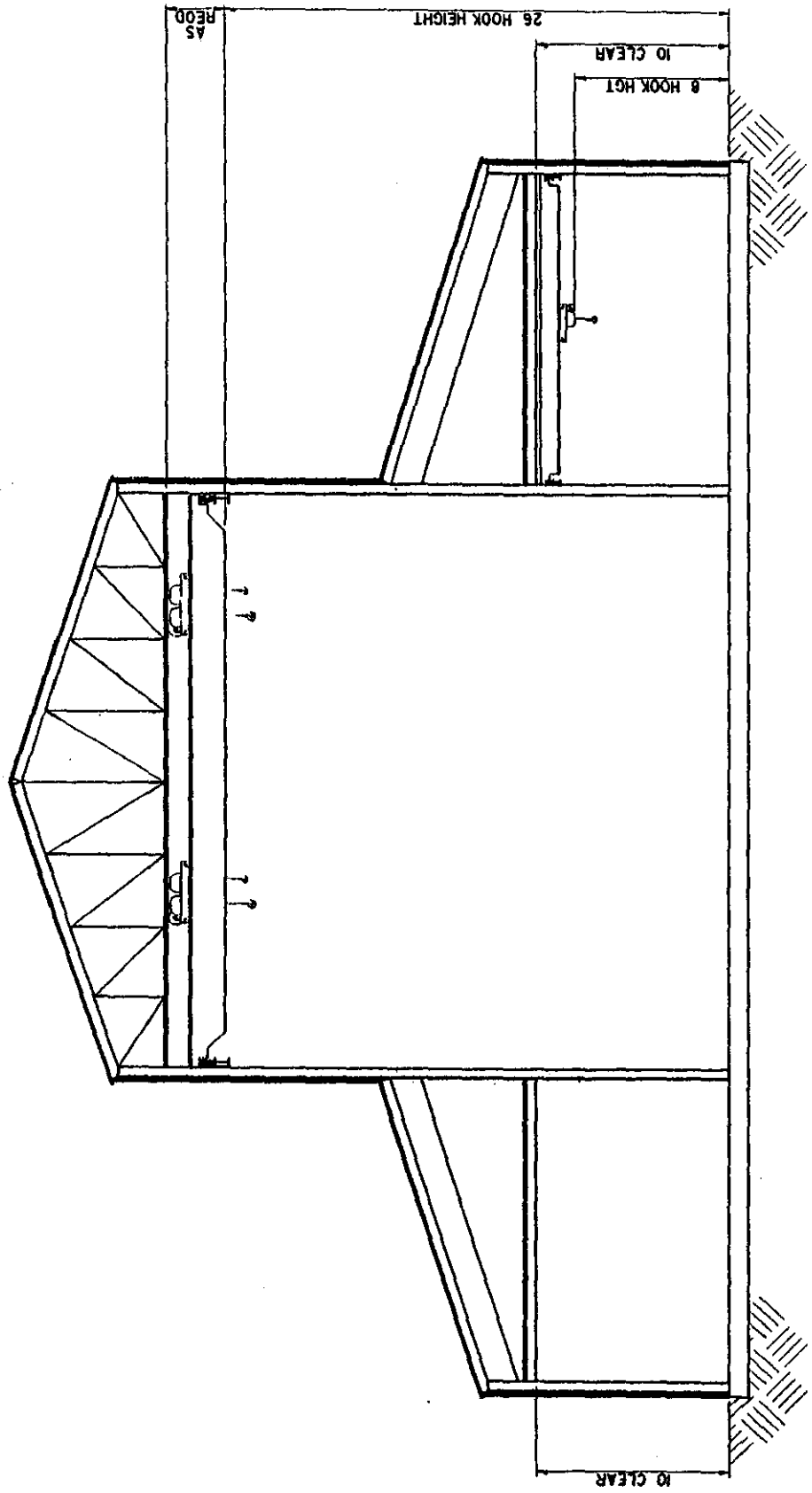

gcd000130.007
REF: gcd000240
11-02-92
H HAZLETT

Figure 7-2 North Assembly Building Floor Plan



Document Control No. E21-000046
SCN No. B010

14




SECTION A-A

Figure 7-3 North Assembly Building Section

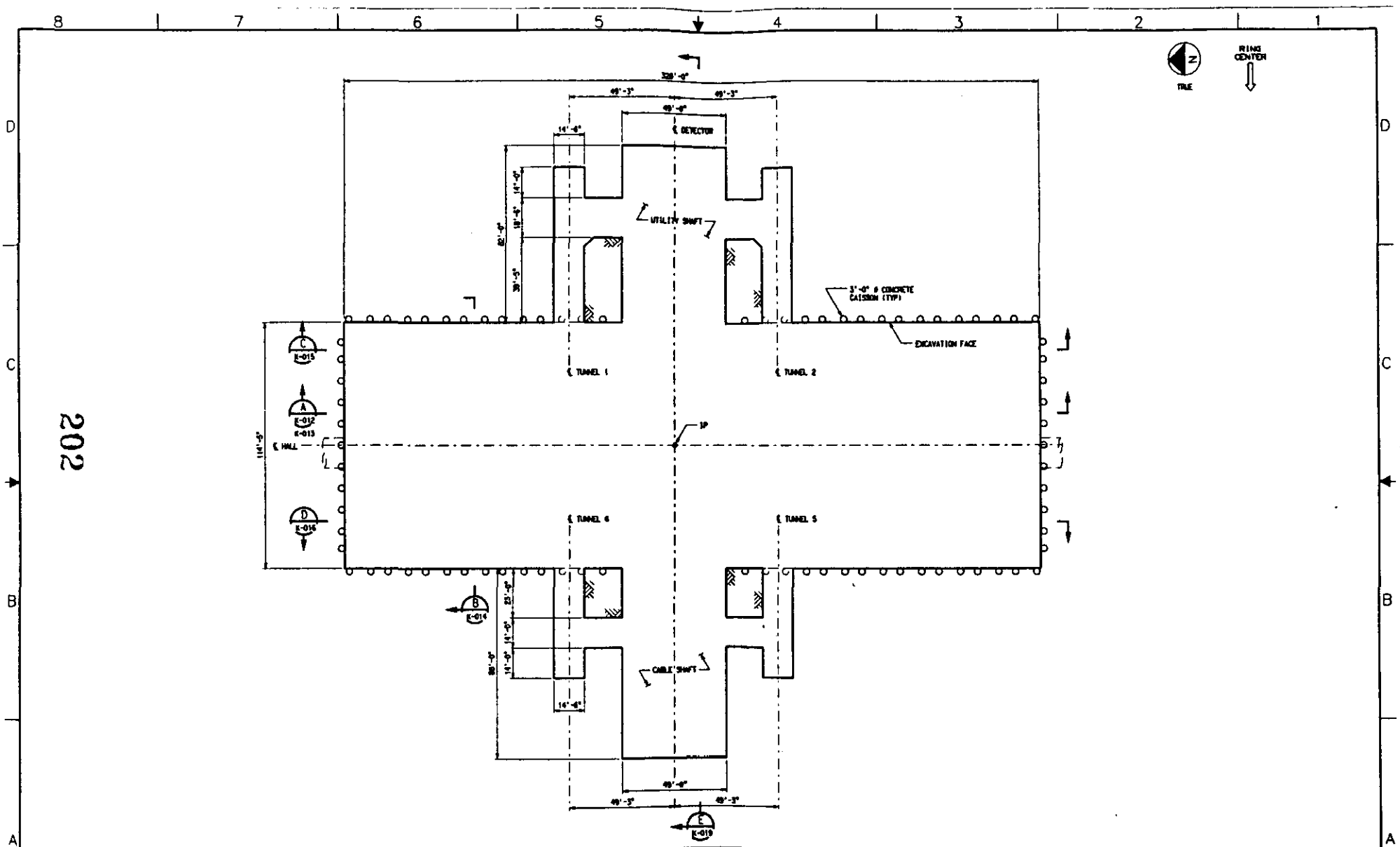
gcd00013.004
REF: gcd000241
11-02-92
H HAZLETT

# GEOLOGIC CONDITIONS

- TAYLOR MARL - A SOFT SHALE
- AUSTIN CHALK - A COMPETENT FOUNDATION MATERIAL

# HALL DESIGN COMPONENTS

- WALLS SUPPORTED BY TIEBACKS
- ROOF ON COLUMNS
- SHAFTS AND TUNNELS




| REV | DATE | DRN | DES | CHK | DESCRIPTION | REV | DATE | DRN | DES | CHK | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 09-25-92 | | | | TITLE I - 30% DESIGN SUBMITTAL | | | | | | |

DESIGNED J. SAMANIAMI
DRAWN K. QUADE
CHECKED
IN RESPONSIBLE CHARGE P. DAS

SUPERCONDUCTING SUPER COLLIDER LABORATORY

THE PB/MK TEAM

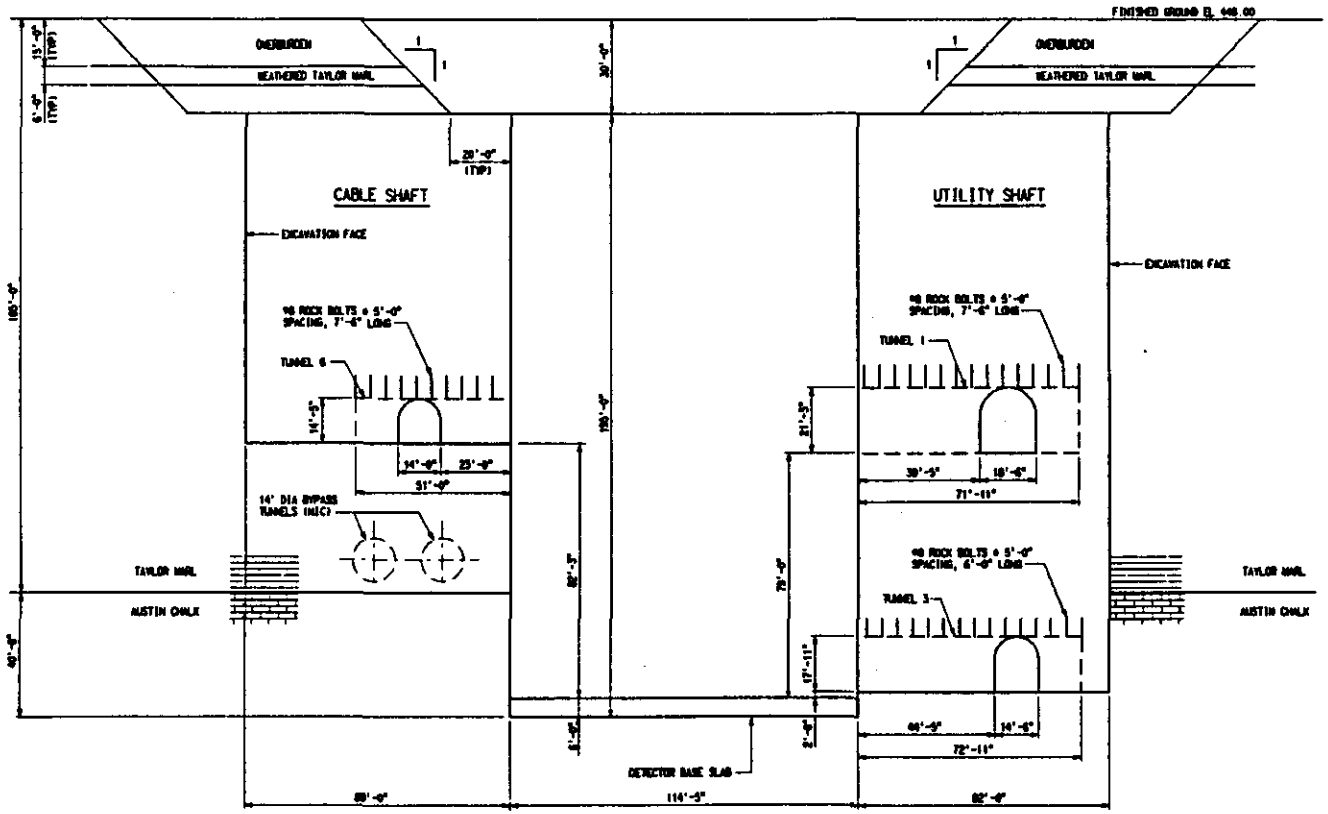
IRS - GEM EXPERIMENTAL FACILITY

# EXPERIMENTAL HALL

EXCAVATION PLAN
LEVEL 5

GEOTECHNICAL

PROJECT NUMBER E-405
DRAWING NUMBER K-010
SCALE 1"=20' | RELEASE DATE 09-25-92 | SHEET NO OF
SIZE D | DRAWING CONTROL NUMBER C24-001575 | REVISION A




E K-016 SECTION
SCALE: 1" = 20'

203

| | | | |
|---|---|---|---|
| TITLE I - 30% DESIGN SUBMITTAL | R. BANERJEE | SUPERCONDUCTING SUPER COLLIDER LABORATORY | 105 - GEM EXPERIMENTAL FACILITY |
| | D. RHOADS | THE PB/MK TEAM | EXPERIMENTAL HALL |
| | P. DAS | | EXCAVATION SECTION E |
| | | | GEOTECHNICAL |

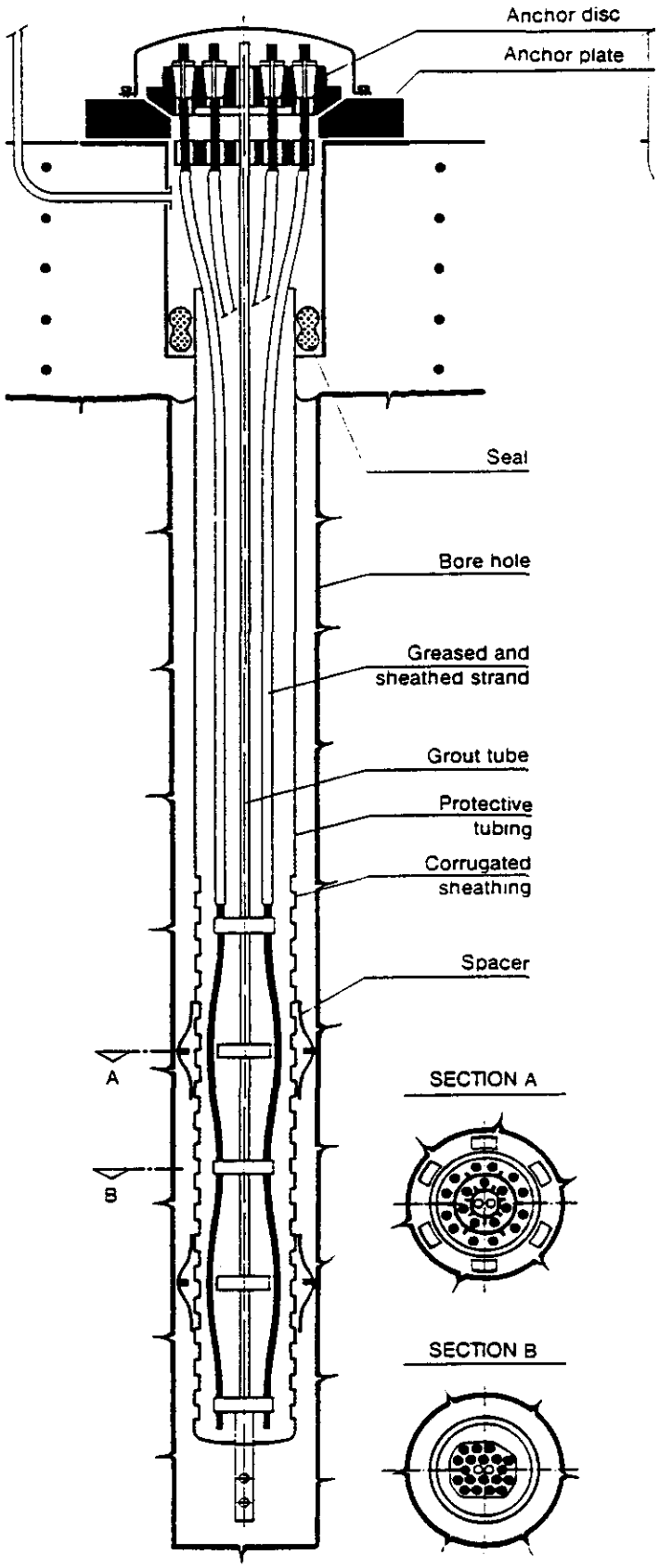
E-405 | K-017 | 1"=20' | 09-25-92 | D | C24-001587 | A

# TIEBACKS

- DOUBLE PROTECTION AGAINST CORROSION
- ALL PROOF TESTED
- TIEBACK TEST PROGRAM
- PRINCIPLES OF DESIGN

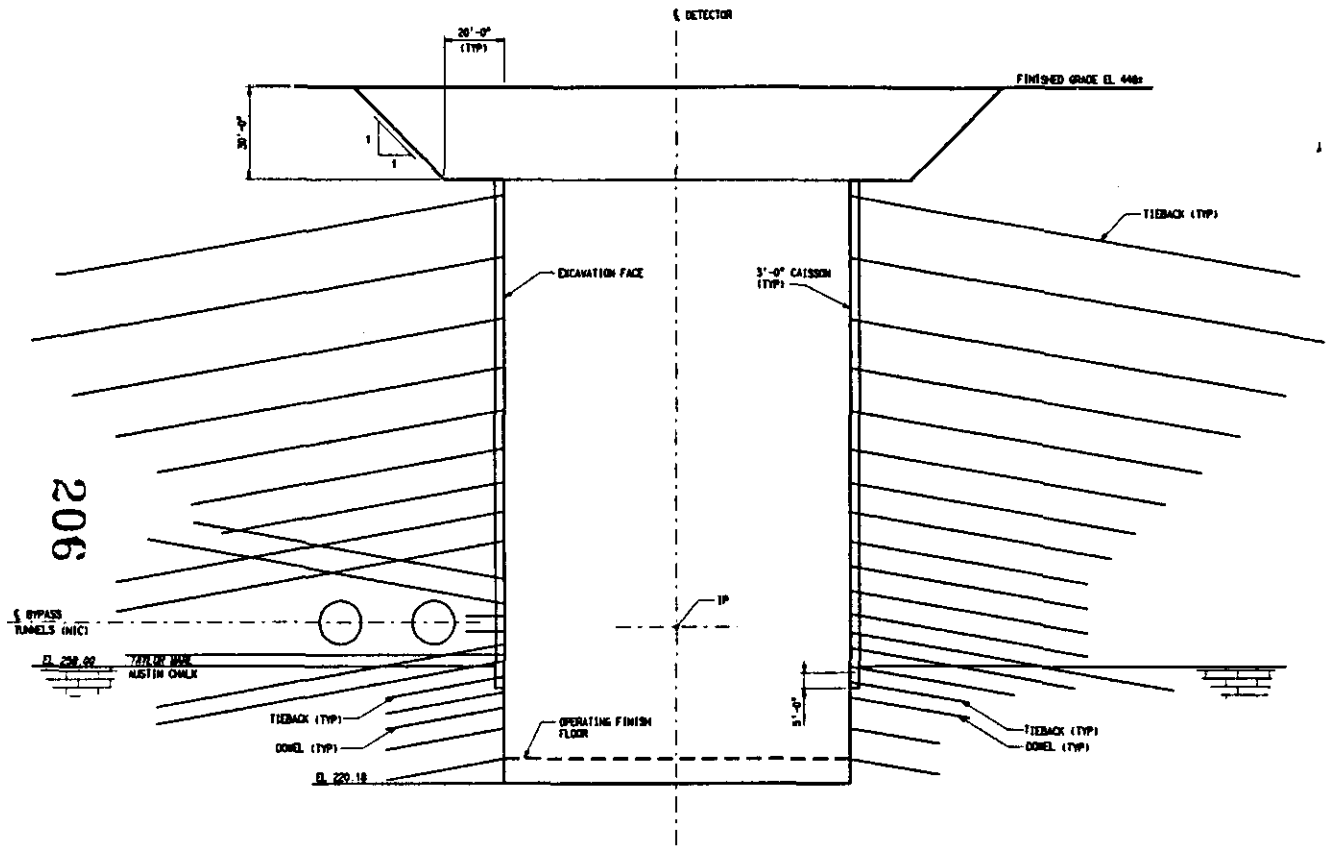
*Fig. 42*
*Multistrand anchor*

42






with double corrosion protection




B
K-010
K-011
ELEVATION LOOKING NORTH
SCALE: 1" = 20'

206

| REV | DATE | DRN | DES | CHK | DESCRIPTION | REV | DATE | DRN | DES | CHK | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 09-25-92 | | | | TITLE I - 30% DESIGN SUBMITTAL | | | | | | |

DRAWN: M. HASEK
CHECKED: K. GUADE
IN RESPONSIBLE CHARGE: P. DAS

SUPERCONDUCTING SUPER COLLIDER LABORATORY

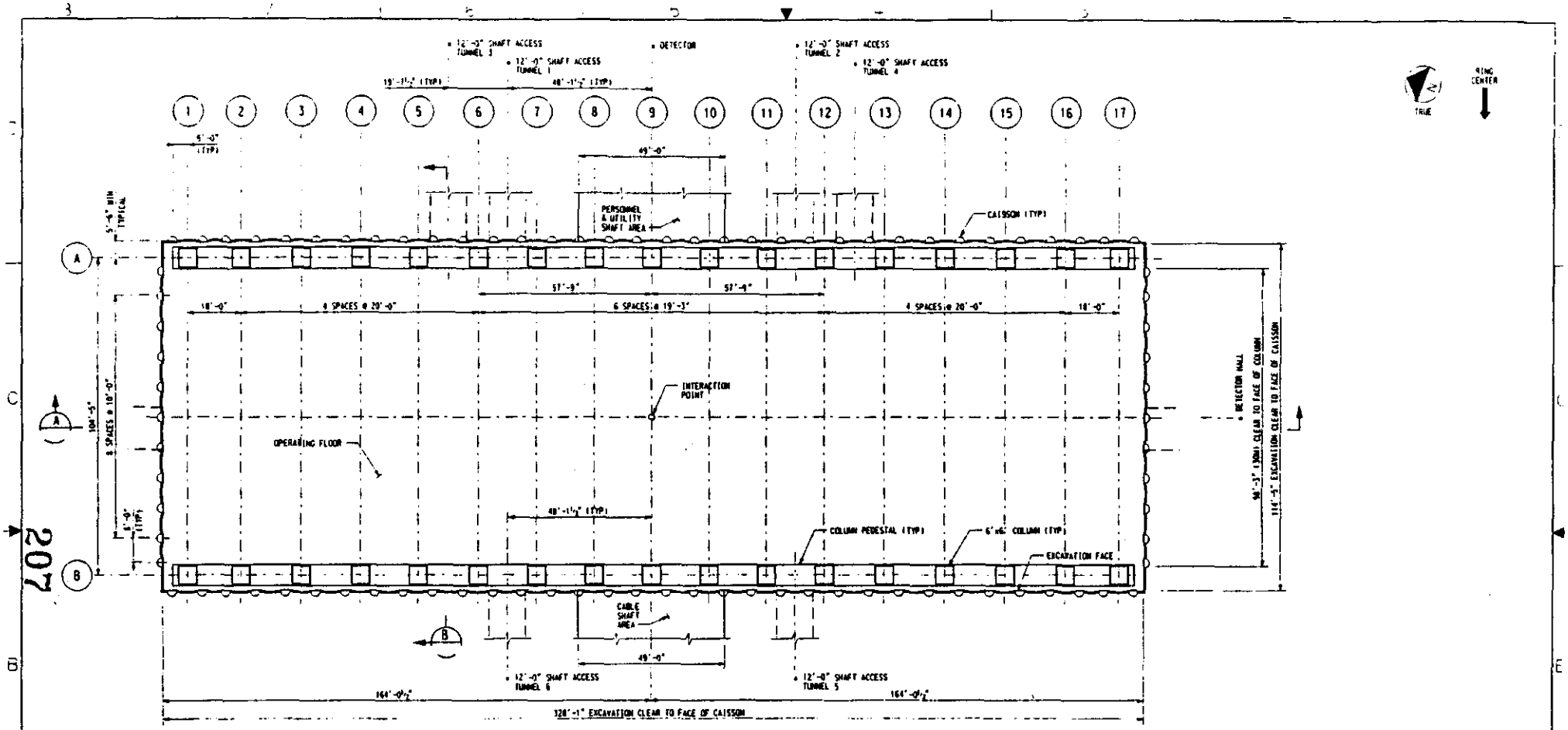
THE PB/MK TEAM

TBS - GEN EXPERIMENTAL FACILITY

EXCAVATION SECTION B

GEOTECHNICAL

PROJECT NUMBER: E-405
DRAWING NUMBER: K-014
SCALE: 1"=20'
RELEASE DATE: 09-25-92
SHEET NO. OF
SIZE: D
DRAWING CONTROL NUMBER: C24-001579
REVISION: A




SUPERCONDUCTING SUPER COLLIDER LABORATORY

THE PB/MK TEAM

EXPERIMENTAL HALL
FLOOR PLAN
AT OPERATING LEVEL

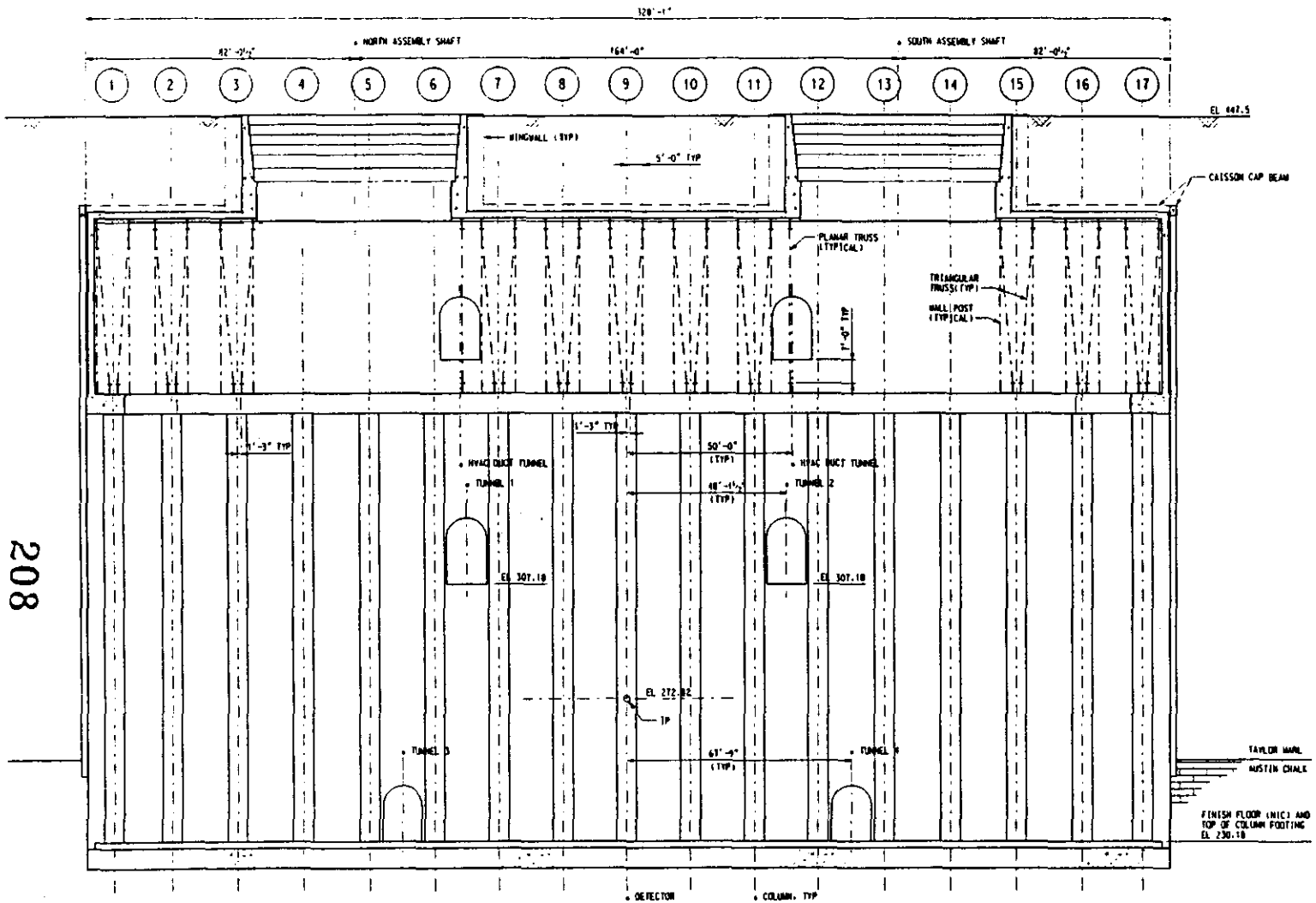
STRUCTURAL

E-4015

S-010

0 C24-001511 A

207




SECTION A
SCALE: 1/16" = 1'-0"

208

| | | | |
|---|---|---|---|
| SUPERCONDUCTING SUPER COLLIDER LABORATORY | THE PB/MK TEAM | EXPERIMENTAL HALL<br>SECTION A<br>STRUCTURAL | PROJECT NUMBER E-405<br>DRAWING NUMBER S-011<br>SIZE D<br>C24-001515<br>REV B |

24

gem

$\gamma e \mu$

# The importance of $t\bar{t}$ associated production at the SSC

Marciano

W. Marciano
11/4/92

# Higgs Discovery Signatures

(View From The Top)

**SSC Goal** - Elucidate Origin of Electroweak Symmetry Breaking - Mass Generation

## Find the Higgs or Whatever takes its place

LEP I $\rightarrow m_H \sim 60\,GeV$ LEP II $\rightarrow \sim 80\,GeV$ (90 GeV?)

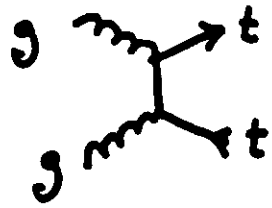
SSC $m_H \simeq 80 - 800\,GeV$

H couples to mass (study Heavy Particles)

$m_\tau$ (1.78 GeV), $m_b$ (4.5 GeV), $m_W$ (80 GeV), $m_Z$ (91 GeV)

$m_t$ (145 ± 40 GeV) top couples most strongly

The SSC is a top factory




$\mathcal{L} = 10^{33}\,cm^{-2}s^{-1}$ $T = 10^7 s$

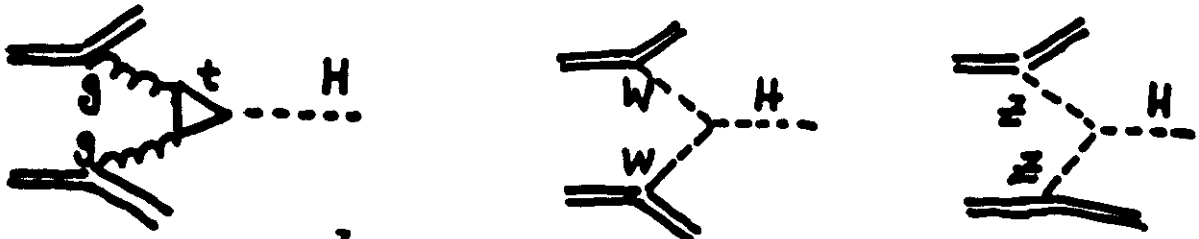
$10^8\, t\bar{t}$ /yr !

Concentrate on top physics

Mass, Decays, etc. Other? (Rare or unusual decays)

$t \rightarrow Wb\,(x)$?

## Higgs Production at the SSC (Direct)




$\sigma \simeq 10^2 \sim 10\,pb$

Decay $180 \lesssim m_H \lesssim 800$ GeV $H \to ZZ \to 4\ell$ $\ell: e, \mu$

$130 \lesssim m_H \lesssim 180$ GeV $H \to ZZ^* \to 4\ell$

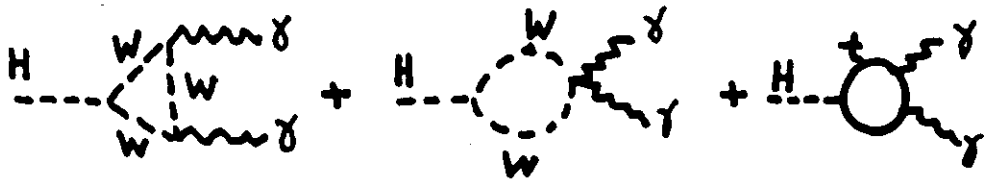
$H \to W^+W^-$ hard but important ($H \to ZZ \to \ell^+\ell^-\nu\bar{\nu}$)
Confirmation!

$m_H \simeq 80 - 130$ GeV Very Hard

Production $\simeq 10^6$ / SSC yr. !

$H \to b\bar{b}$ (90%) ; $H \to \tau^+\tau^-$ (8%) dominate (large backgrounds)

Look for rare decay $H \to \gamma\gamma$




$B(H \to \gamma\gamma) \simeq 1\text{-}2 \times 10^{-3}$

Background $q\bar{q} \to \gamma\gamma$ $\sim 10^7$/yr Need outstanding resolution

(After cuts) signal $\sim 500$ events/yr (GEM)

-66- 7c-

From C. Barter et al.
Snowmass 1988

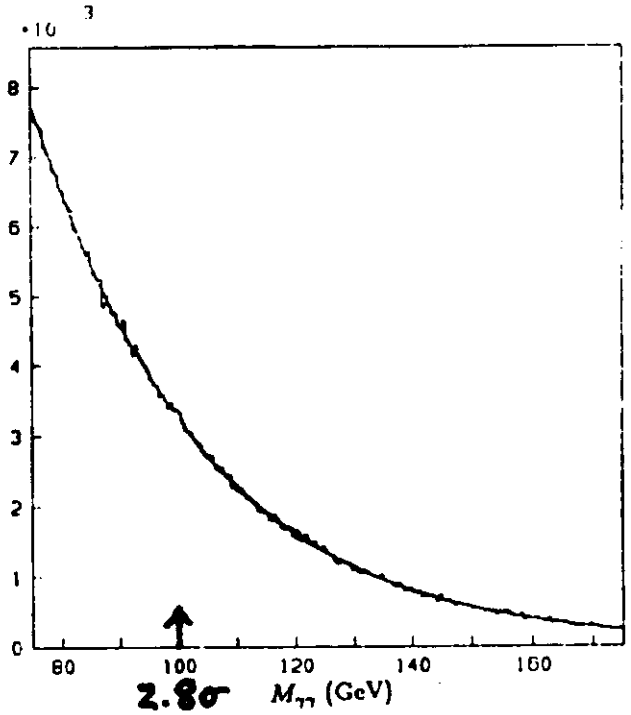



FIG. 6. Simulated mass distribution for 100 GeV Higgs in detector with extraordinary resolution.

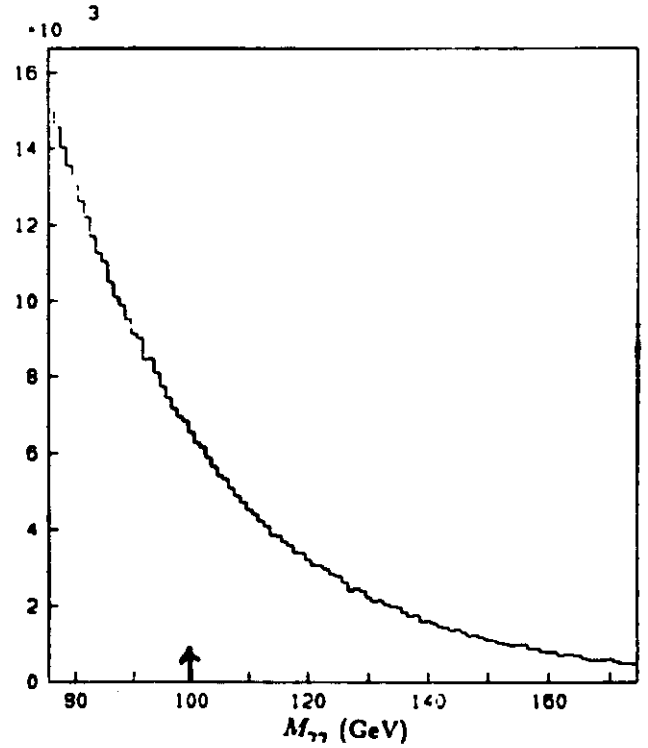



FIG. 4. Simulated mass distribution for 100 GeV Higgs in detector with excellent resolution.

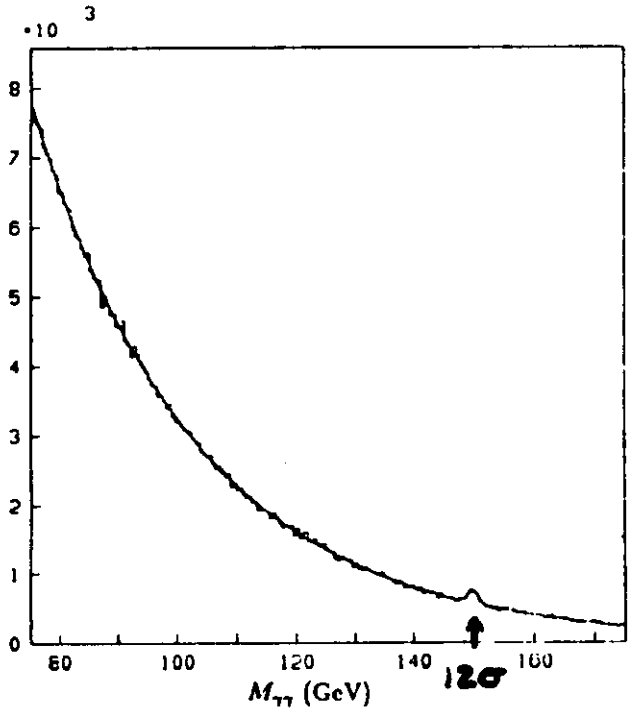



FIG. 7. Simulated mass distribution for 150 GeV Higgs in detector with extraordinary resolution.

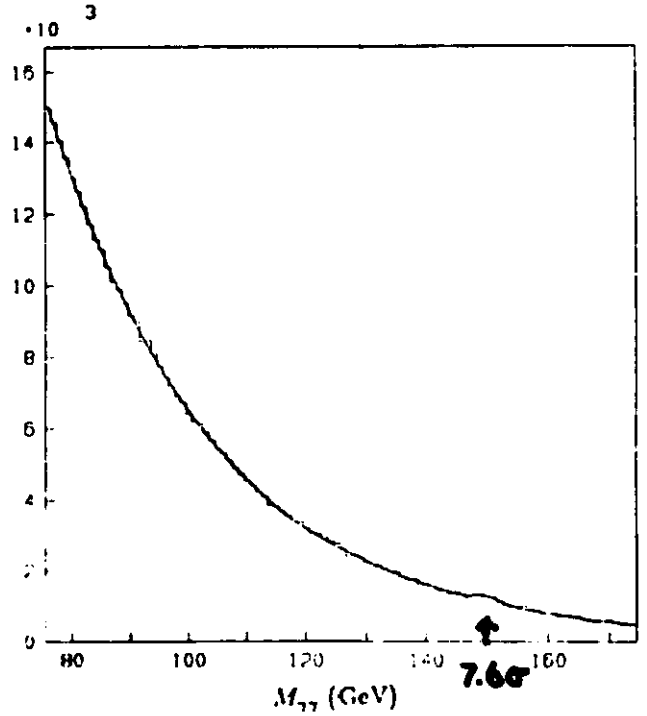



FIG. 5. Simulated mass distribution for 150 GeV Higgs in detector with excellent resolution.

Extraordinary Resolution

$$\frac{\sigma_E}{E} = \frac{3\%}{\sqrt{E}} + 0.5\%$$

Excellent Resolution

$$\frac{\sigma_E}{E} = \frac{10\%}{\sqrt{E}} + 1\%$$

<u>Other rare decays?</u> $H \to \gamma Z \to \underline{\gamma \ell^+ \ell^-}$

(Produce) $\simeq 250$/SSC yr $m_H \sim 130$GeV

<u>How well can GEM do?</u> $\underline{\ell^+ \ell^- \gamma}$

(In general) Interesting signal for spin 0 particles

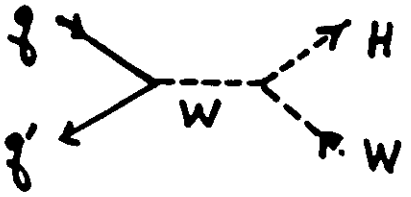
$\underline{H \to \mu^+ \mu^-}$ also about 250 /SSC yr (Produced)

(No $e^+e^-$ events)

Backgrounds? $Z \to \mu^+\mu^-$ Drell-Yan?

## <u>Good Exercises For GEM</u>

### <u>Associated Higgs Production</u>

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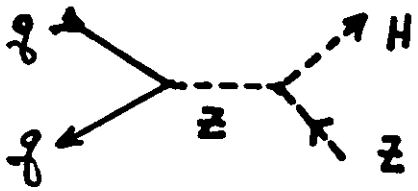
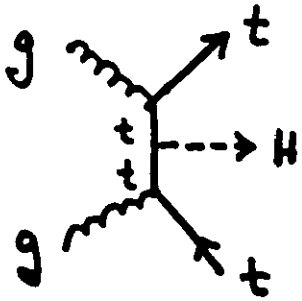
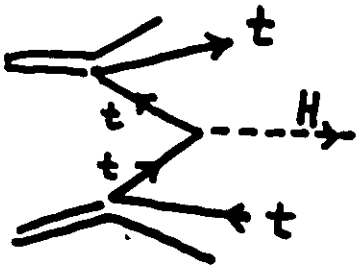



or

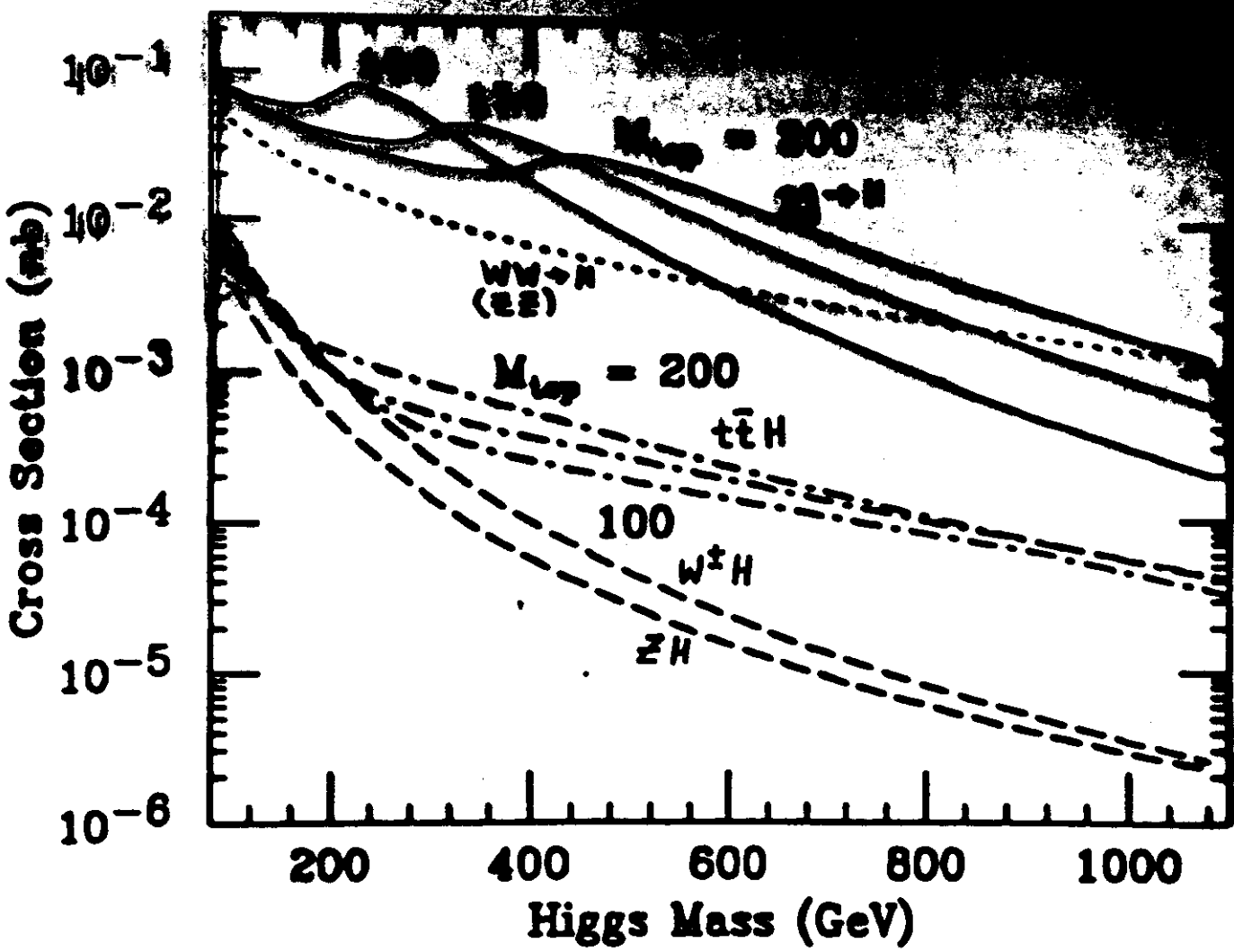



<u>large!</u>

Expect $\sim \underline{10^5\, t\bar{t}H}$ + $W^\pm H$ /SSC yr

Big SSC advantage over LHC

From SDC

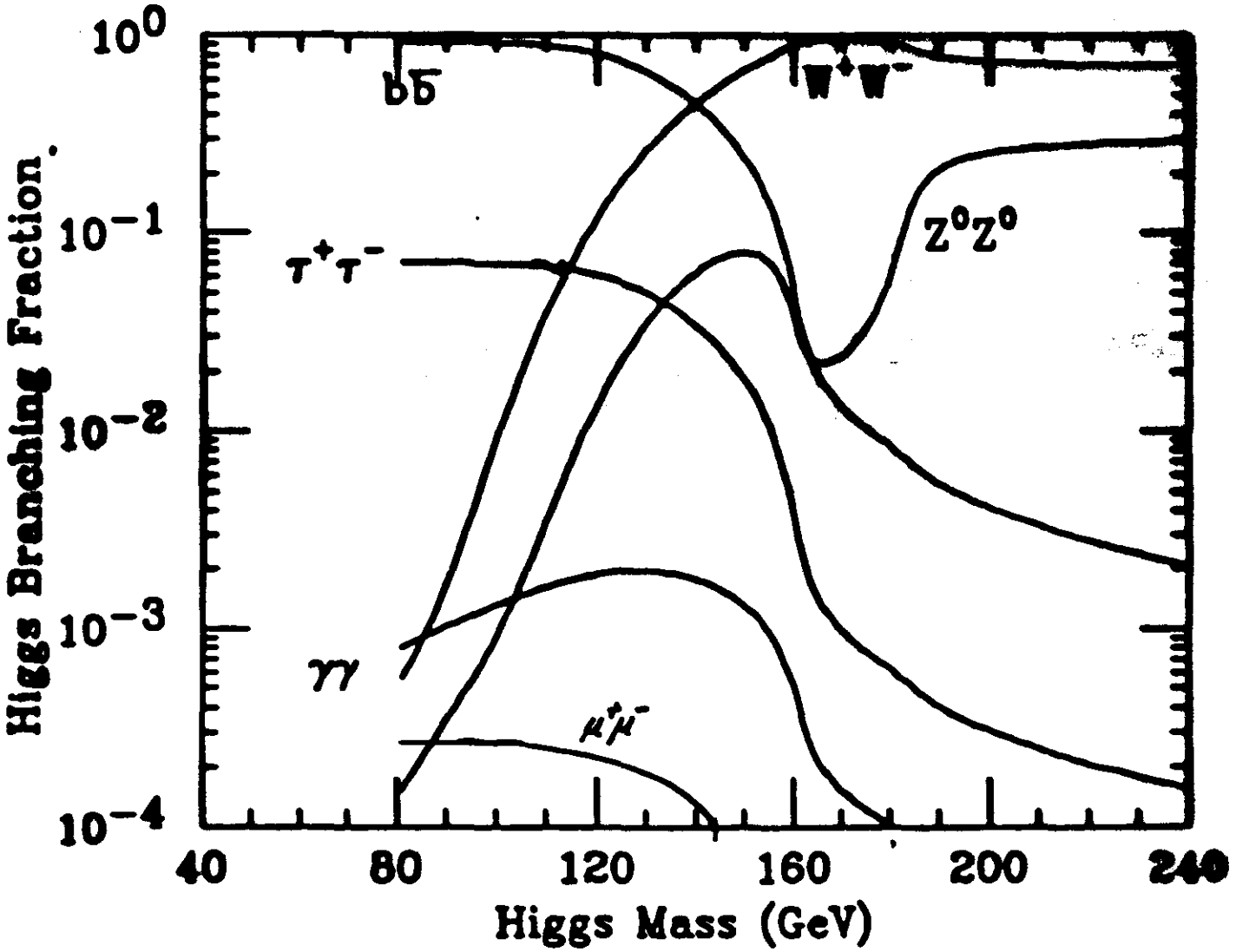



Higgs production cross-section at SSC

1 SSC yr → $L = 10^7 nb^{-1}$

From SDC




$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
Higgs Branching Fraction
$b\bar{b}$
$W^+W^-$
$Z^0Z^0$
$\tau^+\tau^-$
$\gamma\gamma$
$\mu^+\mu^-$
40
80
120
160
200
240
Higgs Mass (GeV)

0.001 of $t\bar{t}$ pairs have a Higgs! $10^5$/yr!

$t \to Wb$, $W \to \ell\nu$ } 0.22 BR → 40% of all $t\bar{t}H$ have lepton tag

Options look for $H \to b\bar{b}$ ~ 90% BR } Should be examined!
$H \to \tau^+\tau^-$ ~ 8% BR
$H \to \gamma\gamma$ $1\text{-}2 \times 10^{-3}$ BR
$H \to \mu^+\mu^-$ $3 \times 10^{-4}$

(Perhaps $H \to \ell^+\ell^-\gamma$) Under Study

$H \to \gamma\gamma$ Studied by SDC

| $M_H$(GeV) | $t\bar{t}H \to \ell\gamma\gamma$ | $\ell\gamma\gamma$ detected |
|---|---|---|
| 80 | 42 | 9 |
| 100 | 39 | 10 |
| 120 | 38 | 10 |
| 140 | 24 | 7 |

QCD corrections probably increase signal. By how much? (25-50%)

$W^\pm H$ ~ 2.5 /SSCyr after cuts

SDC claims 3σ in one SSC yr (Too Pessimistic)

GEM should do better (5σ for $m_H \simeq 80$GeV) F. Paige

Background ≃ 8 events/yr (M. White & W.M.)

## Other Associated Production Modes

**Study** $t\bar{t}Z$ $Z \to \ell^+\ell^-$ (Background)

try $t\bar{t}H$ $H \to \mu^+\mu^-$ or $\ell^+\ell^-\gamma$ (low background)

(High Luminosity) $t\bar{t}H_{\hookrightarrow \tau^+\tau^-}$ ?

## Heavy Higgs $m_H \gtrsim 200$ GeV

$10^4$ $t\bar{t}H$ /SSC yr $\to$ $W^+W^-b\bar{b}\,W^+W^-$ $7\times10^3$/yr

$W^+W^-b\bar{b}\,ZZ$ $3\times10^3$/yr

Can you find $10^4$ $W^+W^-W^+W^-$ events /yr ?

After you discover the Higgs you will want to study it.

---

Conclusion: $t\bar{t}X$ window to origin of mass

$X = H$ or other, $H \to \gamma\gamma, \mu^+\mu^-, \tau^+\tau^-$ ?

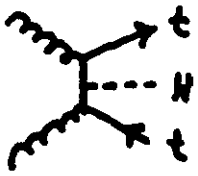
Start by doing top studies ($\mathcal{L} \simeq 10^{30}$ at turn-on) $\to 10^{33} \to 10^{34}$?

Top is not Boring!

Should be fully exploited

# Associated Higgs Production at the SSC

$pp \to t\bar{t}HX$ (W. Marciano + F. Paige)




$\to 10^4 \sim 10^5$ $t\bar{t}H$ /yr at SSC

$t \to Wb \to \ell\nu_\ell$ $\ell = e, \mu$ isolated lepton tag

Search for rare decays $H \to \gamma\gamma$ (BR $\sim 10^{-3}$ intermed. Higgs)

Backgrounds $pp \to t\bar{t}\gamma\gamma$, $t\bar{t}\gamma$, $t\bar{t}$ other $\gamma$ from decays $W \to e\nu\gamma$

( M. White Yale Ph.D. Thesis + W. Marciano )

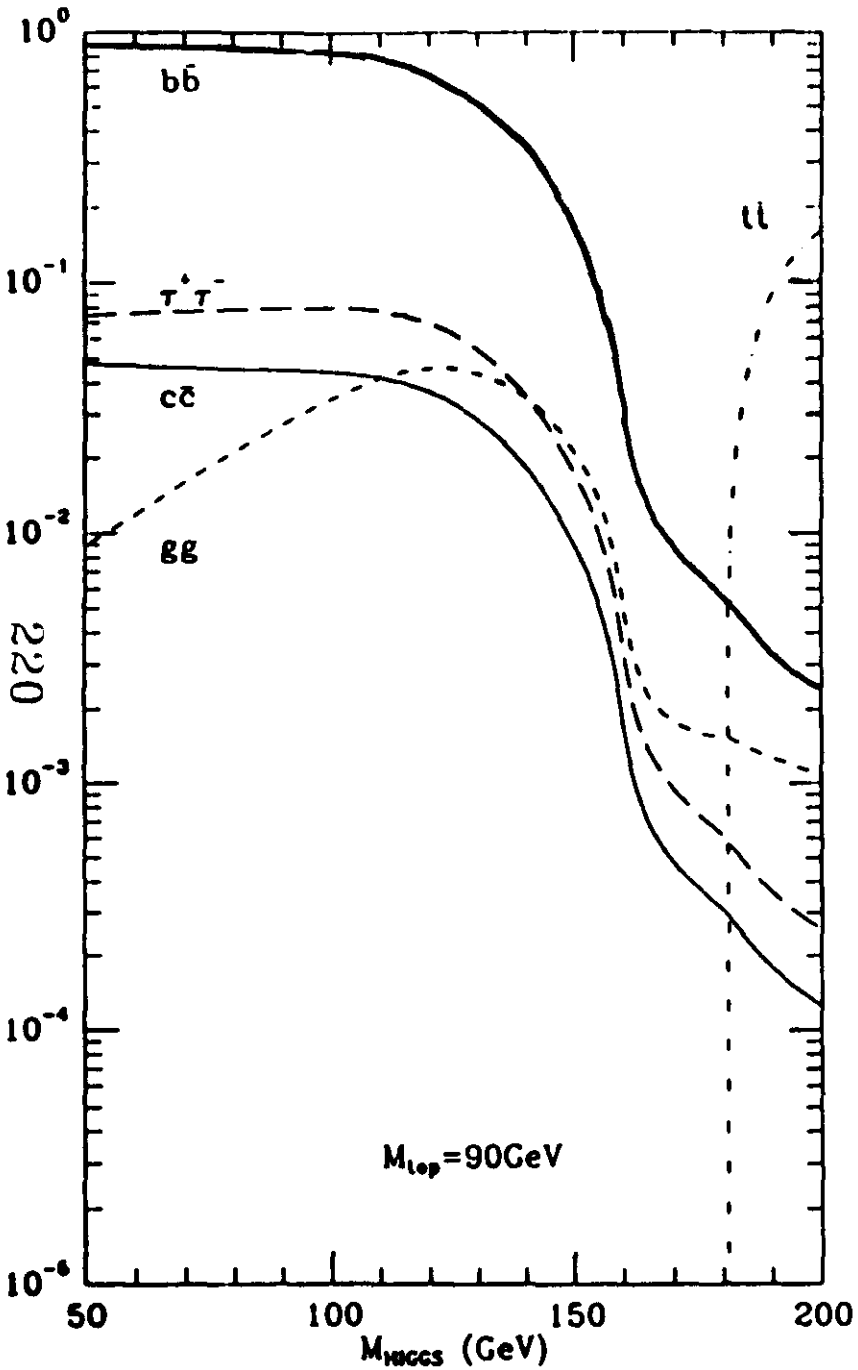
| $m_H$ (GeV) | Signal $t\bar{t}H \to \gamma\gamma\ell$ | Real $\gamma\gamma\ell$ Background ±1.5% Resolution |
|---|---|---|
| 80 | 17 | 8 |
| 90 | 18 | 9 |
| 100 | 19 | 9 |
| 110 | 18 | 8 |
| 120 | 17 | 8 |
| 130 | 15 | 7 |
| 140 | 12 | 7 |
| 150 | 8 | 6 |

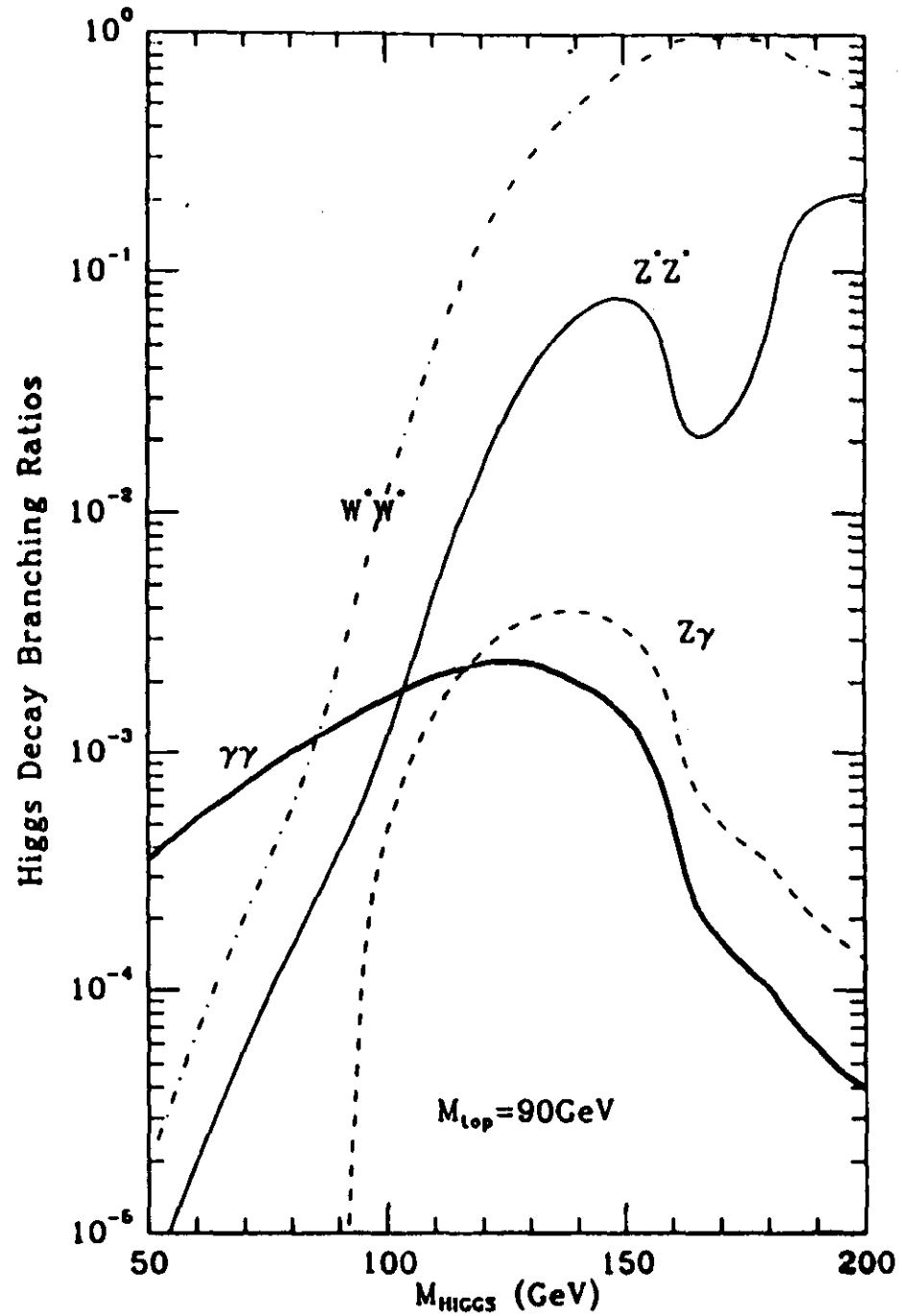
Covered by GEM in 1 SSC yr.

Working on other decays $H \to \mu^+\mu^-$, $b\bar{b}$, $\tau^+\tau^-$

From Kleiss, Kunszt + Stirling

Higgs branching ratios



gem

$\gamma e \mu$

# Calorimetry Status, progress toward TDR in December

Bill Willis

# GEM CALORIMETER

* E.M. PERFORMANCE

* ENHANCE POINTING AND $\pi^0$ REJECTION

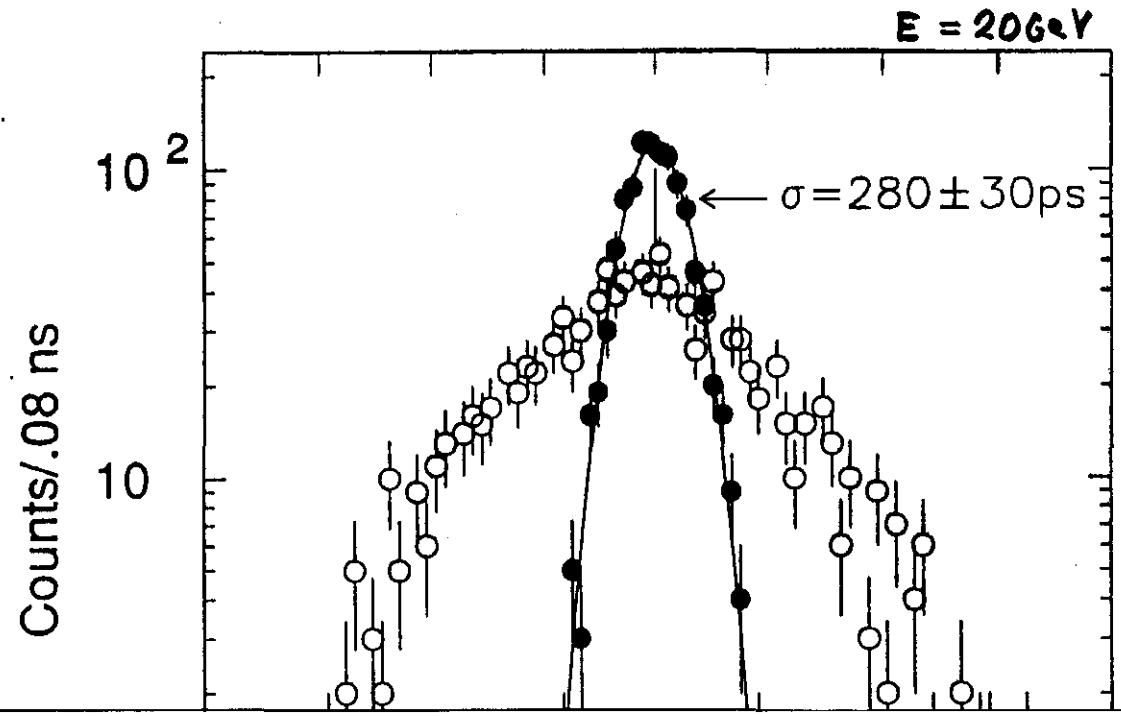
* HADRONIC CALORIMETER

Timing Distribution

5x5 towers

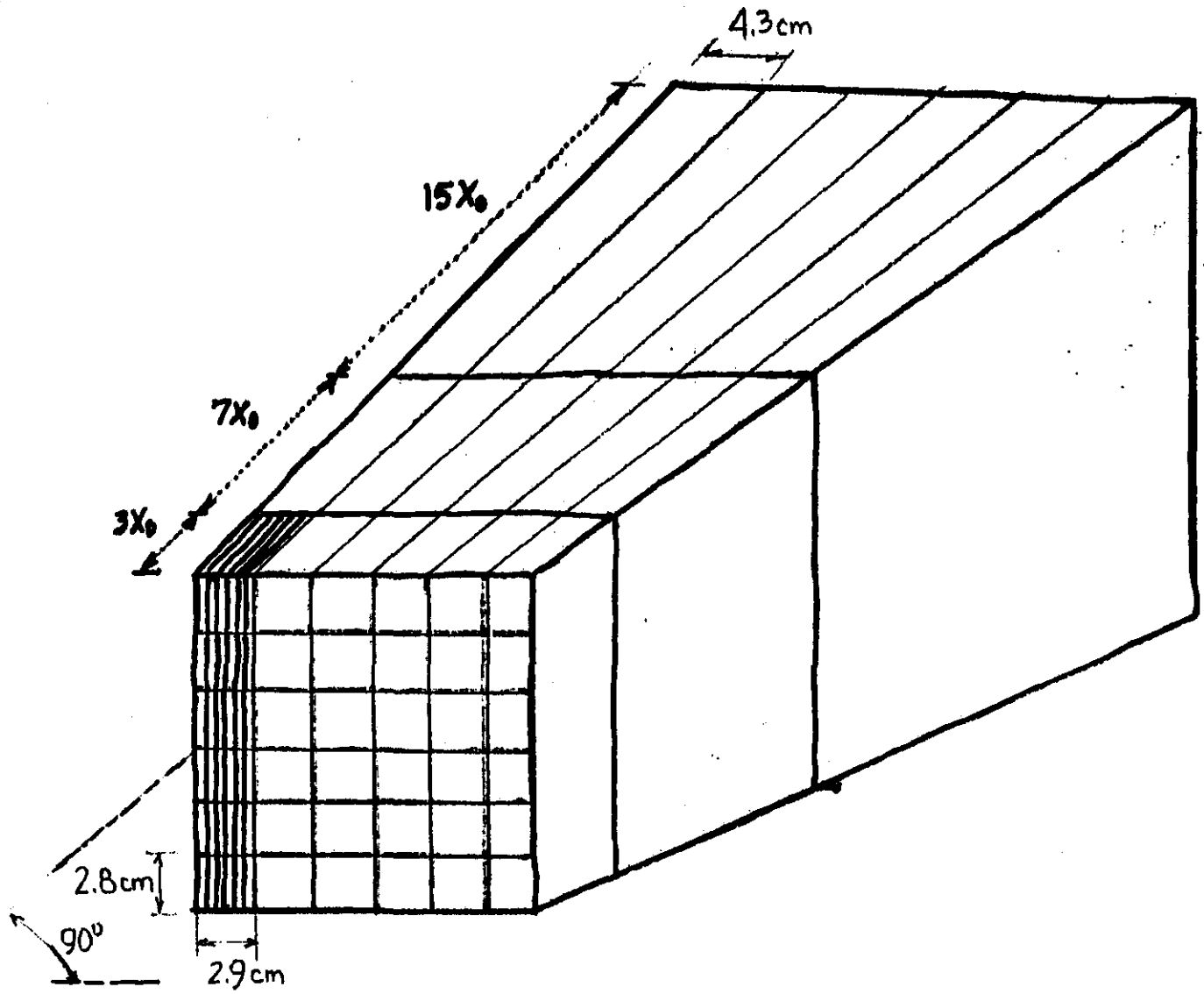
o - discriminator output

● - corrected for timing differences of individual channels




* γ-POINTING GOOD ENOUGH IN ANY CHARGED TRACK CONFUSION

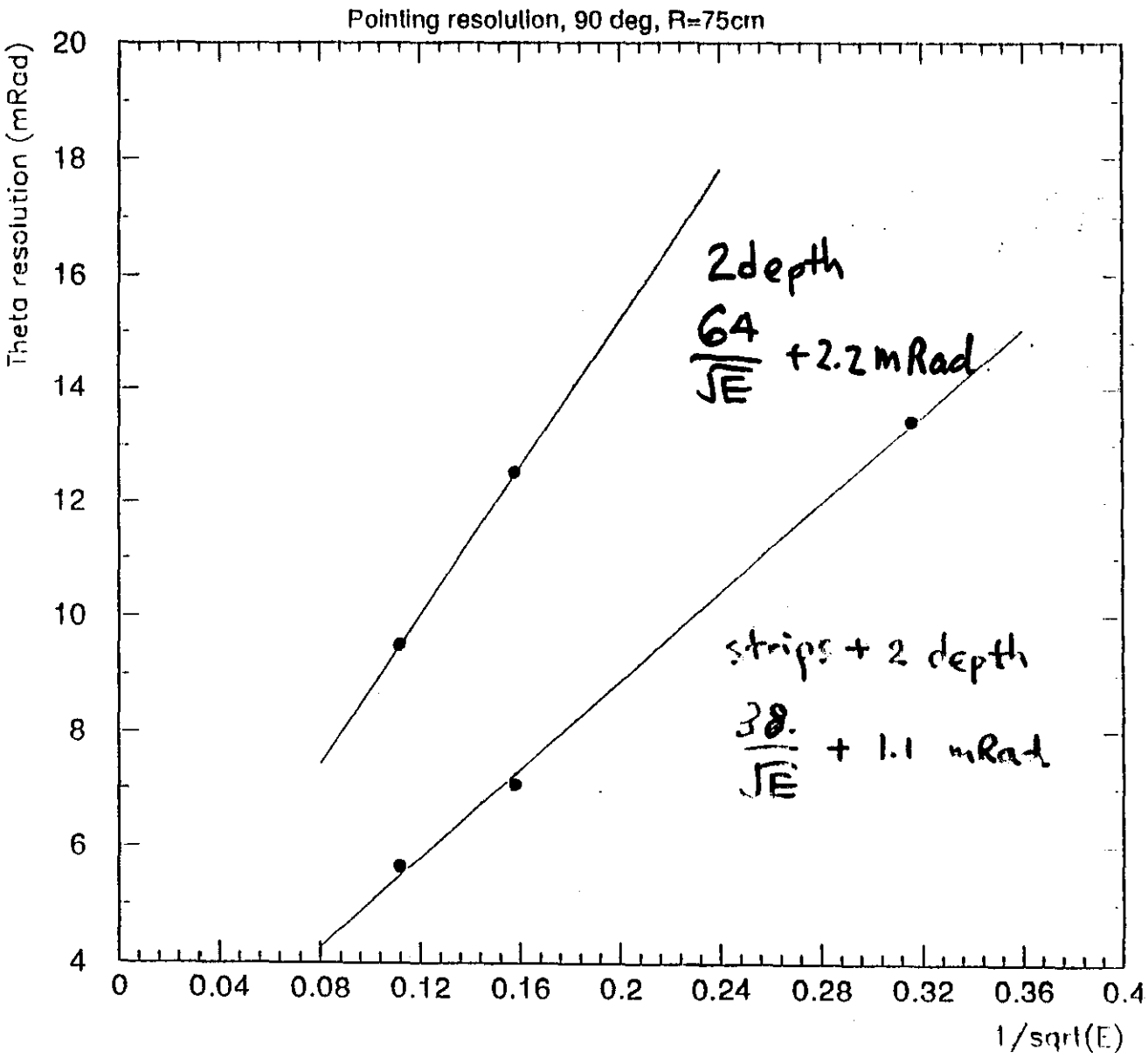
$\sigma_\theta < 50$ milliradian


4.3cm
15X₀
7X₀
3X₀
2.8cm
90°
2.9cm

$$\Delta\eta = \Delta\varphi = \frac{2\pi}{240} = 0.026$$

18720 towers in Barrel

2 x 7938 towers in Endcaps


Pointing resolution, 90 deg, R=75cm
Theta resolution (mRad)
20
18
16
14
12
10
8
6
4
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.4
1/sqrt(E)
2depth
64/√E +2.2 mRad
strips + 2 depth
38./√E + 1.1 mRad

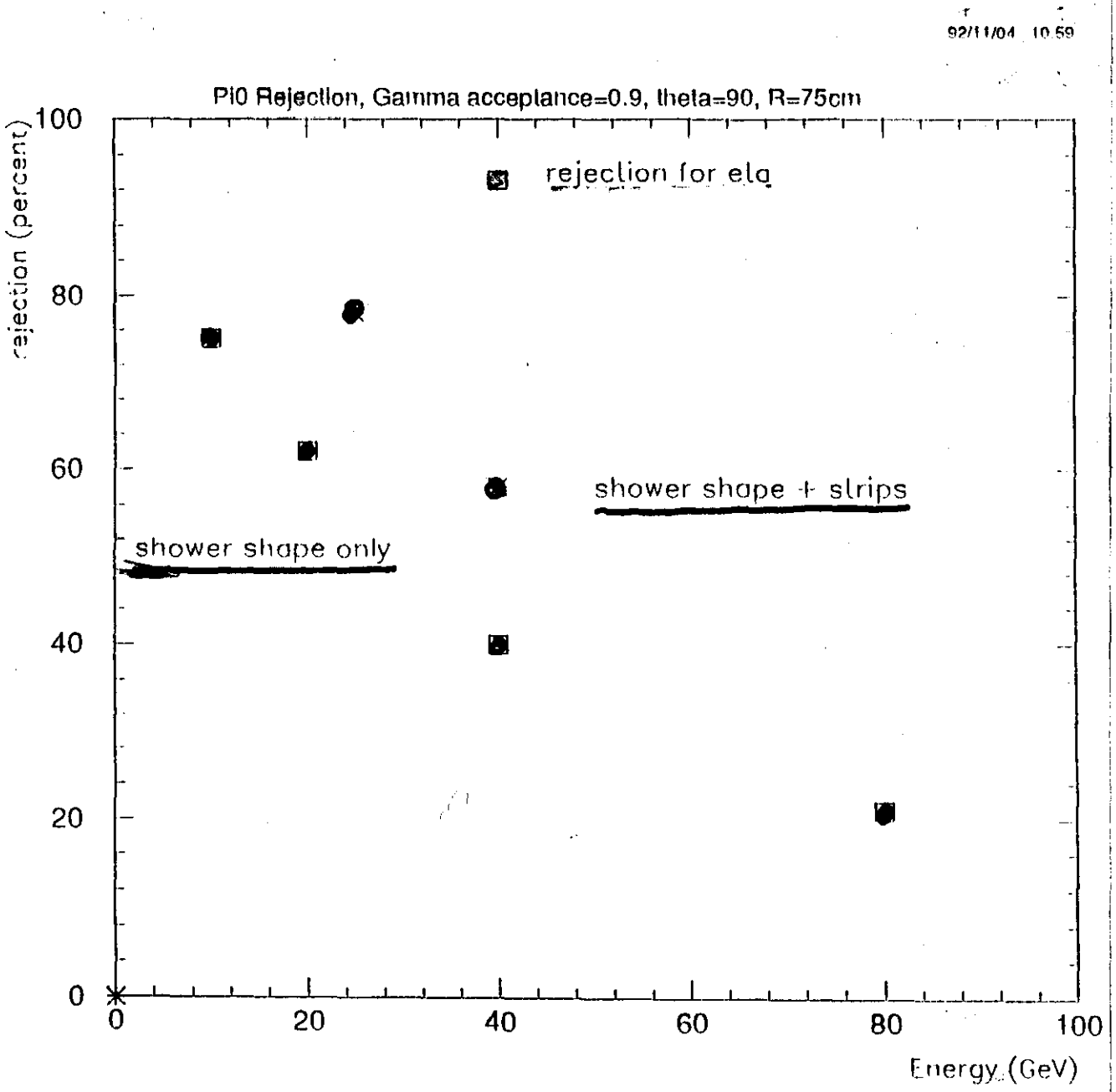
THETA strips

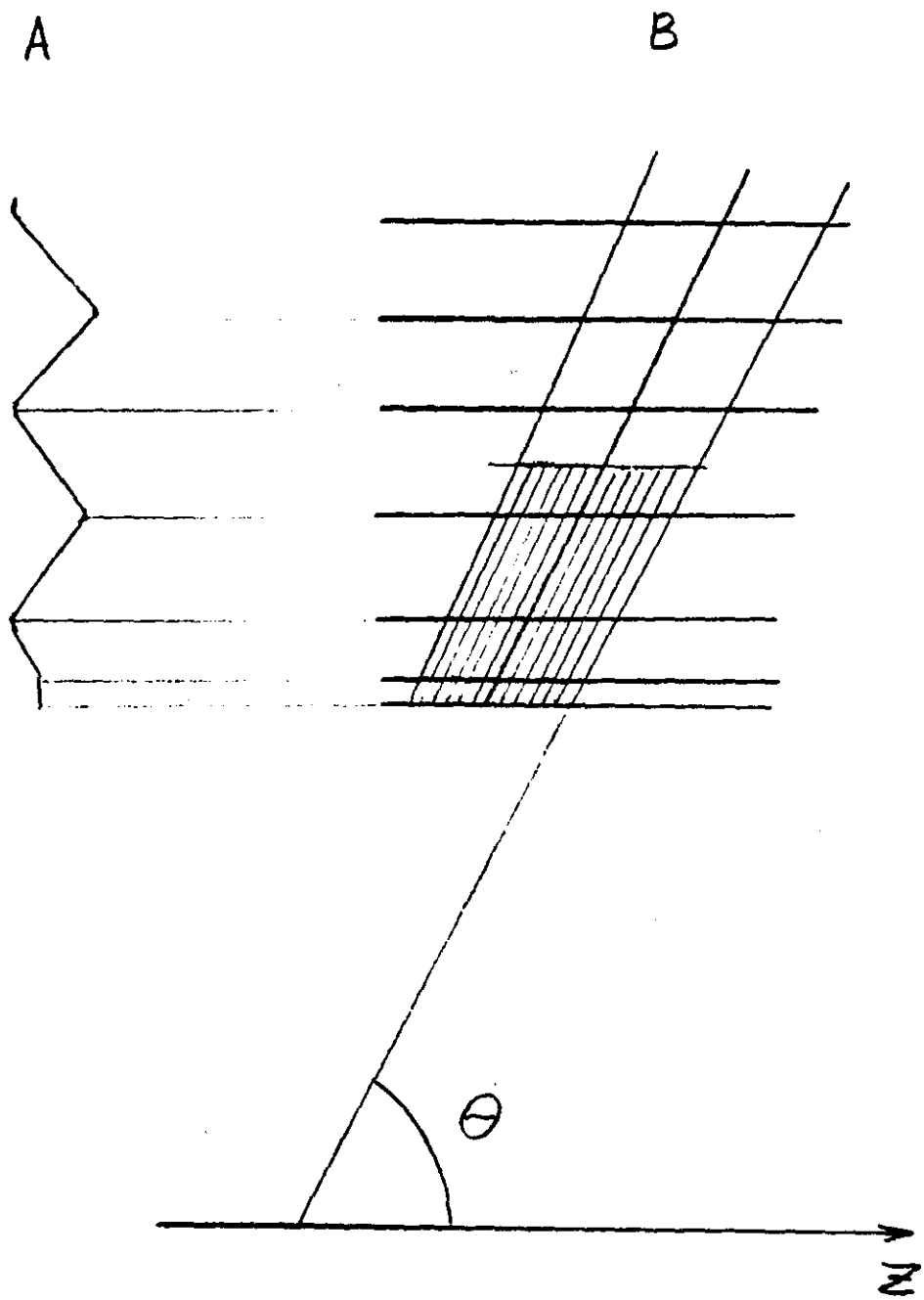
pi-zero acceptance at 90% gamma acceptance (efficiency)
for $E_t$ = 25 GeV (only lateral energy distribution used)

inner cryostat radius at 95 cm

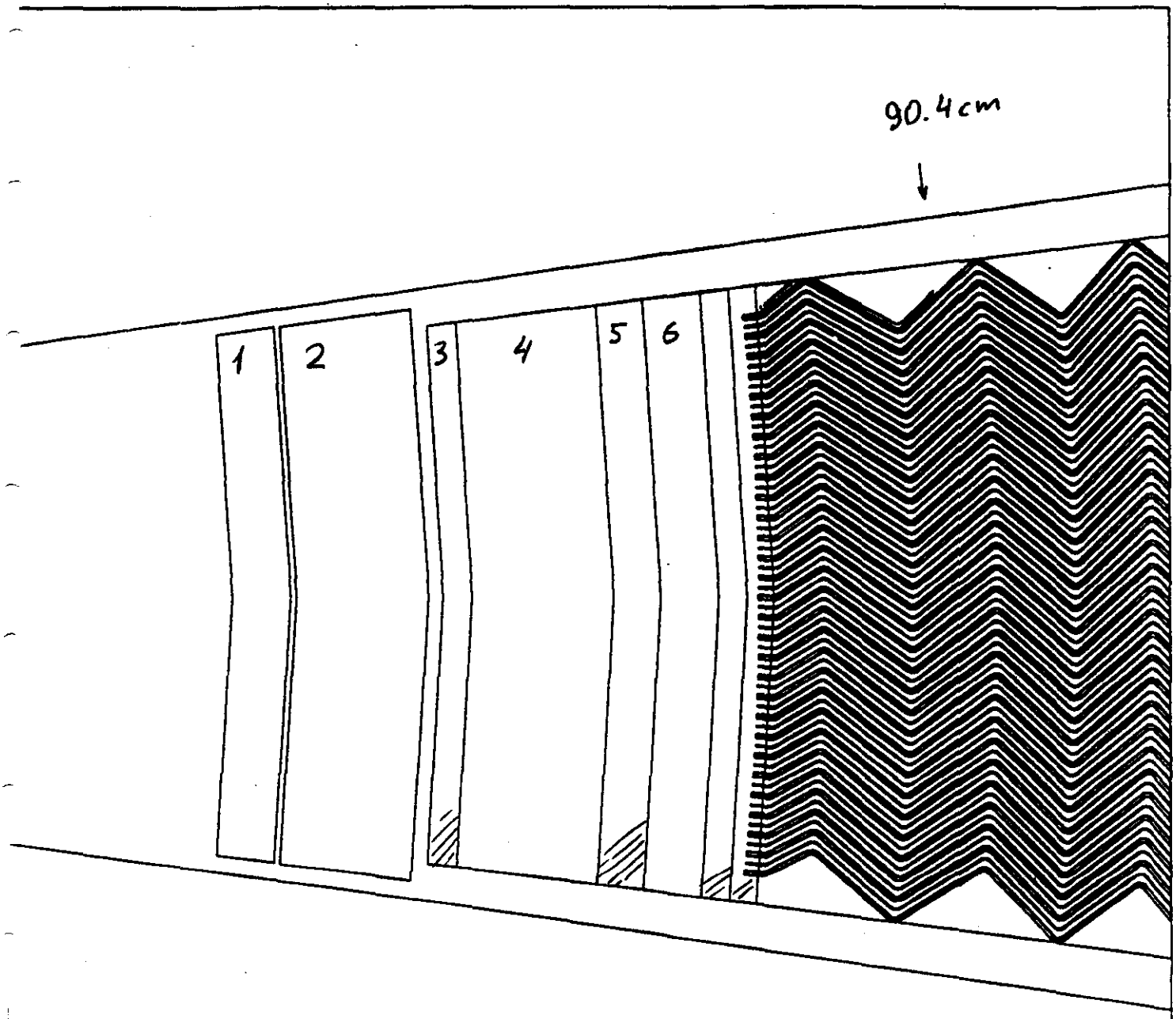
| Strip width mm | Noise sigma MeV | Strip length cm | 25 GeV, 90 deg | 35 GeV, 45 deg |
|---|---|---|---|---|
| 5.0 | 0 | 8.6 | 22% | 24% |
| 5.0 | 3 | 8.6 | 23% | 24% |
| 5.0 | 0 | 5.8 | 28% | 24% |
| 2.5 | 0 | 8.6 | 20% | |
| 2.5 | 3 | 8.6 | 24% | |

* Uncorrelated Gaussian noise was added to each strip signal
** 200 - 500 events per run
*** Strip width = tower width divided by 6 (or 12)
Tower width → 0.02618 rapidity units at the radius of the middle of 3-d stack (114 cm) → 3 cm


92/11/04 10.59
Pi0 Rejection, Gamma acceptance=0.9, theta=90, R=75cm
rejection (percent)
100
80
60
40
20
0
rejection for elq
shower shape + strips
shower shape only
0
20
40
60
80
100
Energy (GeV)


A
B
θ
z

$\beta/\delta = 2.88$

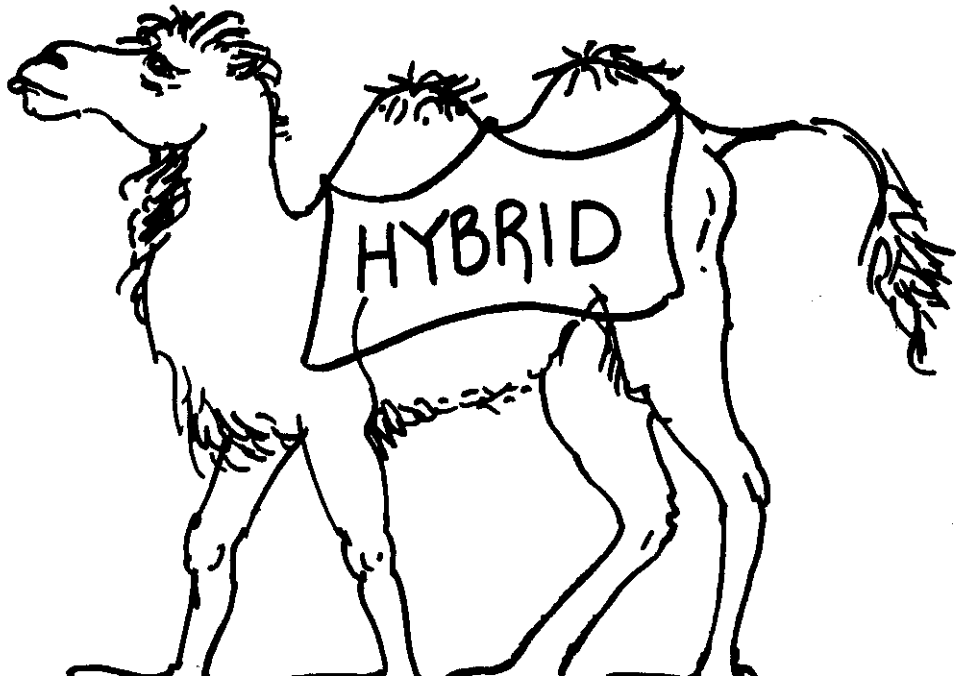


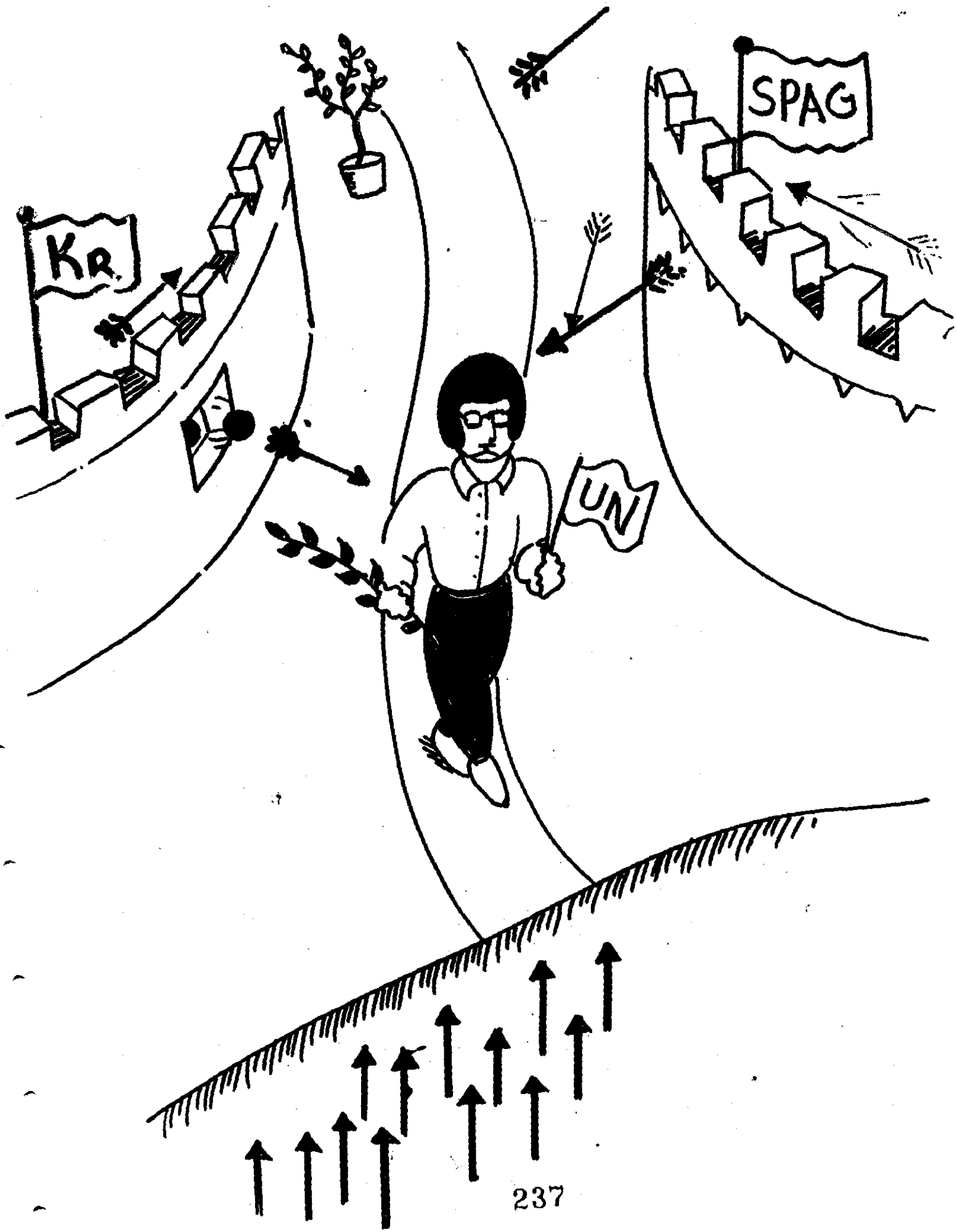
# THE GEM SPOKESMEN

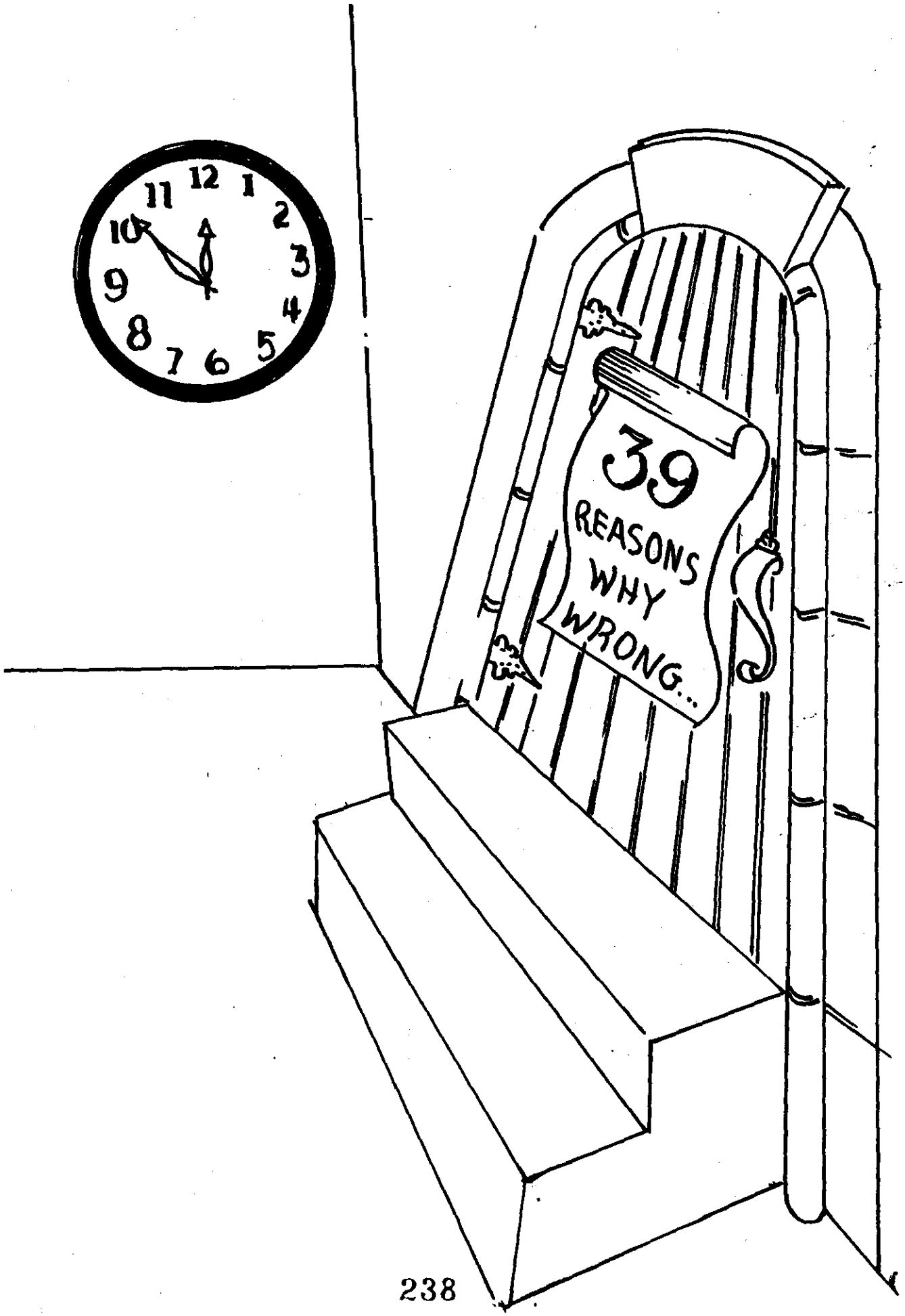
"WE DECIDE FOR A HYBRID CALORIMETER:

1. TO REDUCE THE SIZE OF THE LARGE CRYOSTAT REQUIRED FOR 12 λ INTEGRATED
2. TO GIVE A CHANCE FOR THE MOST FAVORABLE E.M."

A HYBRID INVOLVES COMPROMISE

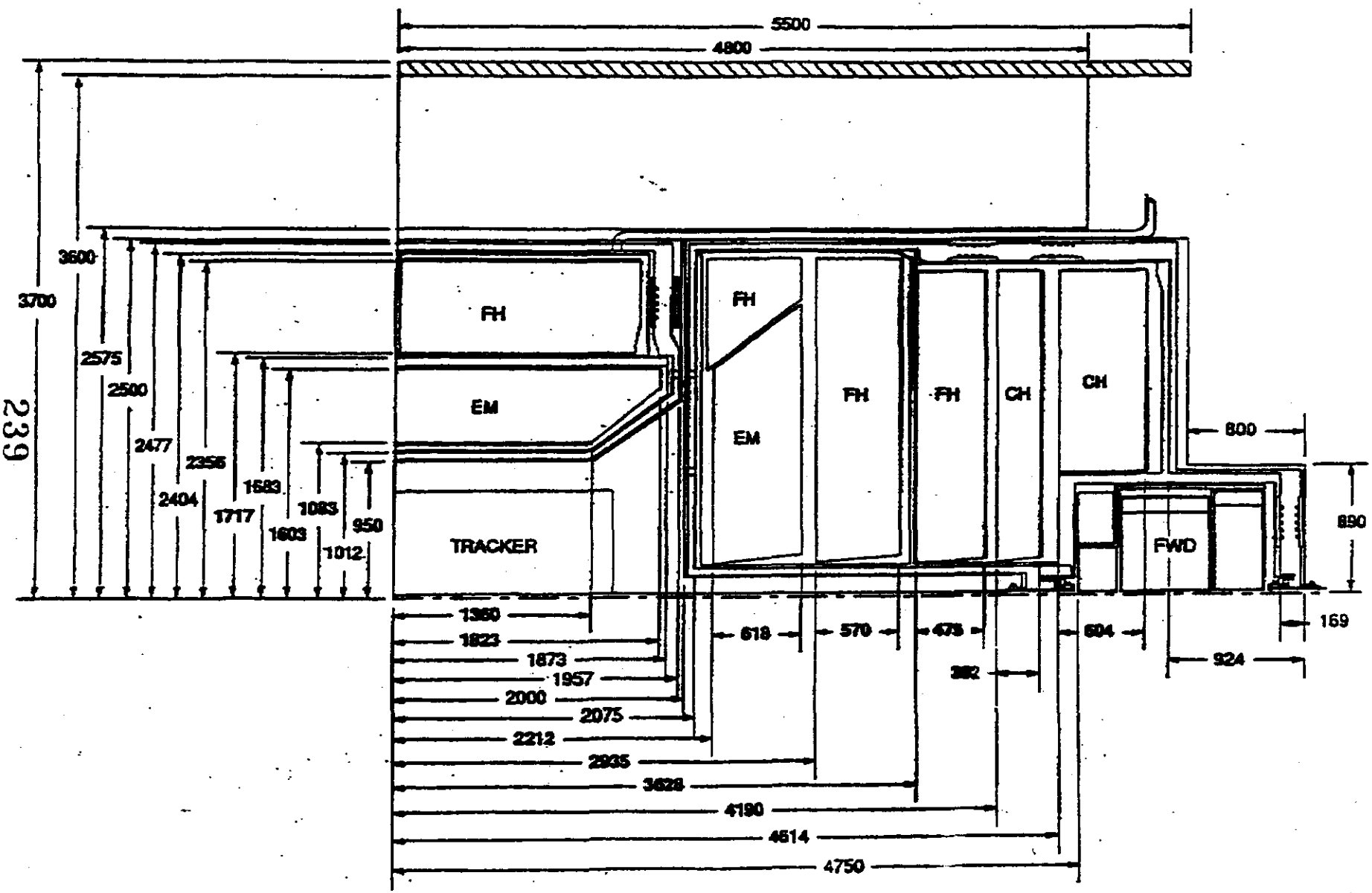


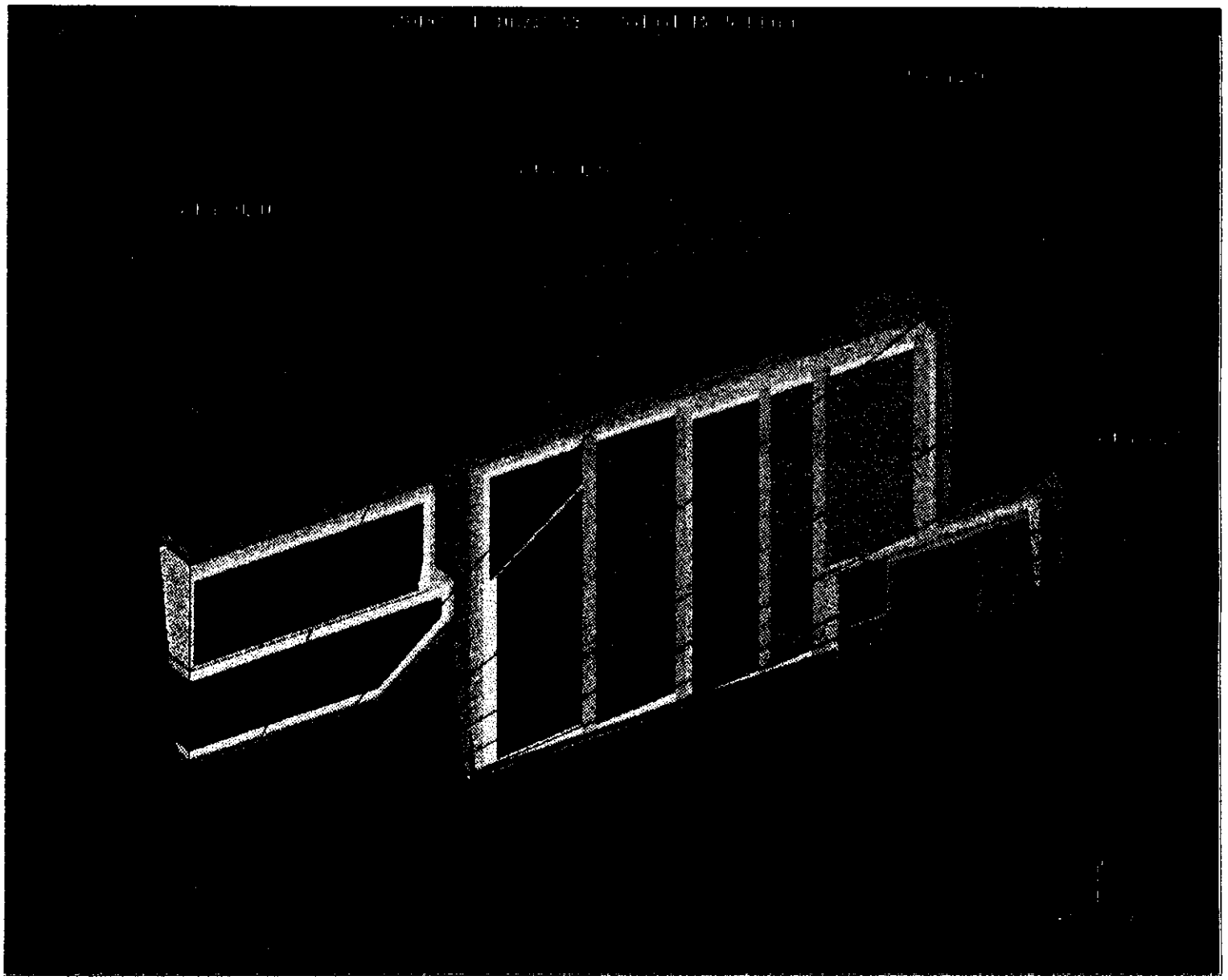

KR.
SPAG
UN

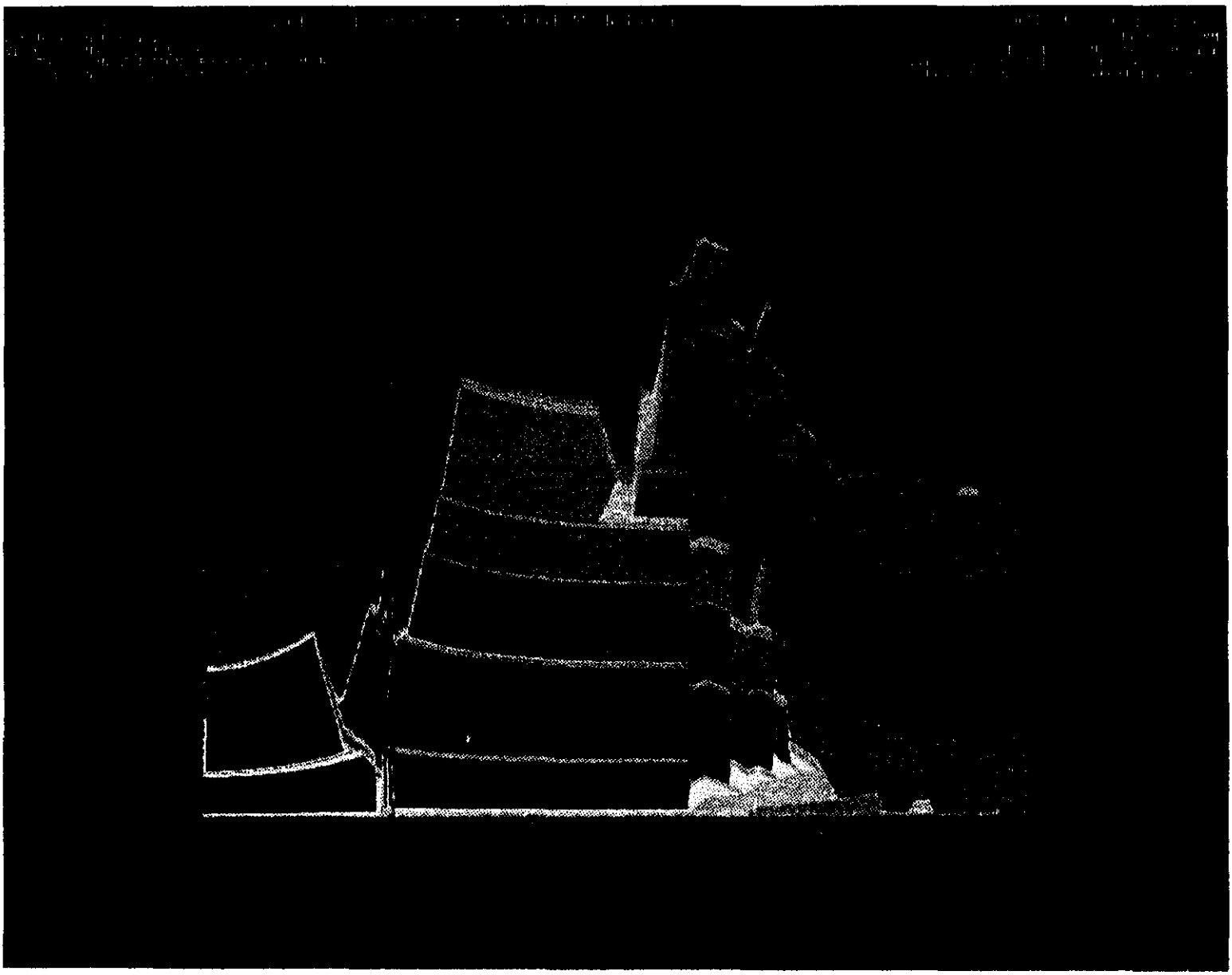

39
REASONS
WHY
WRONG...

# Preliminary Hybrid Concept

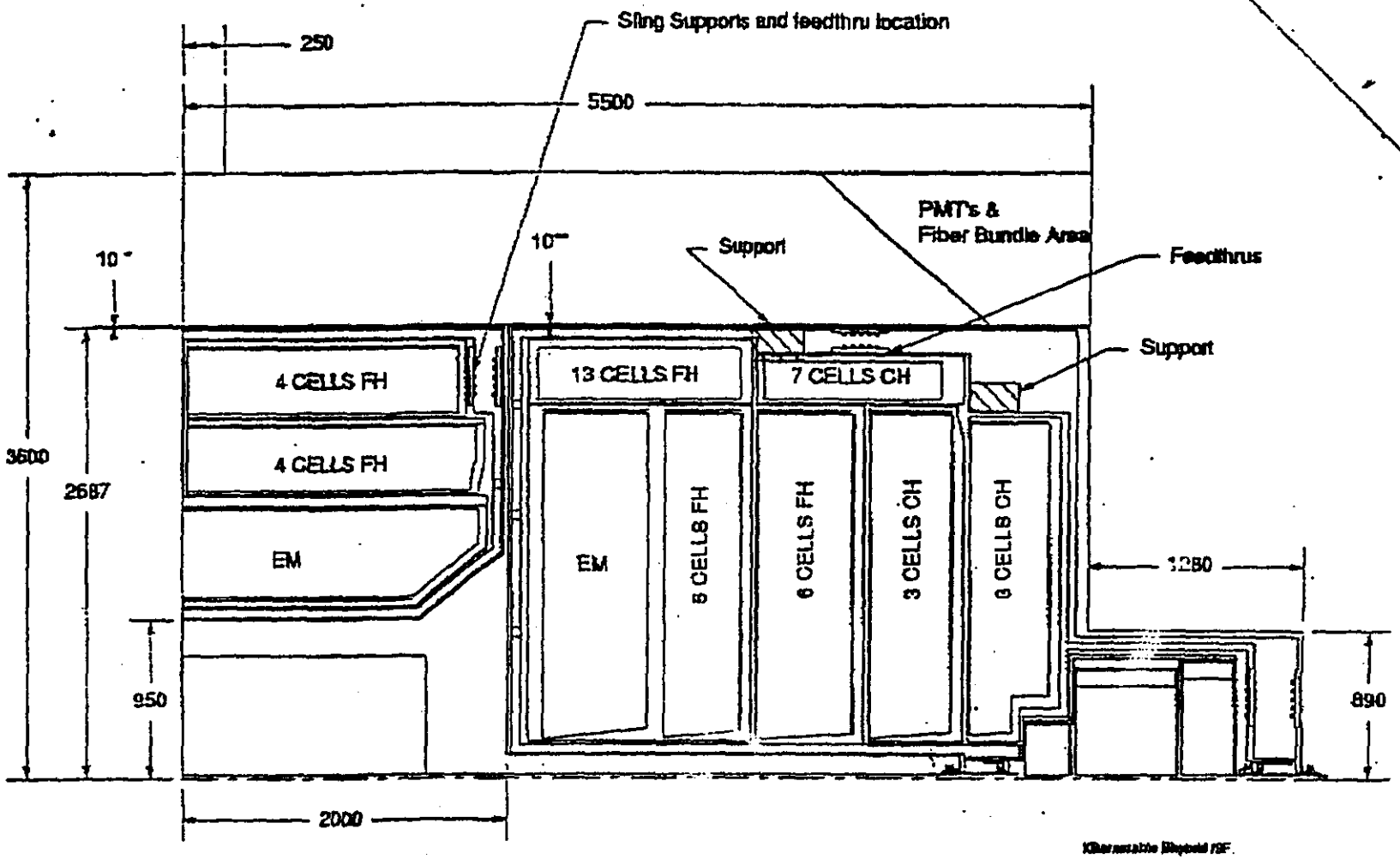
Dimensions (All dimensions are in mm)
Note: All bold dimensions are to active areas.







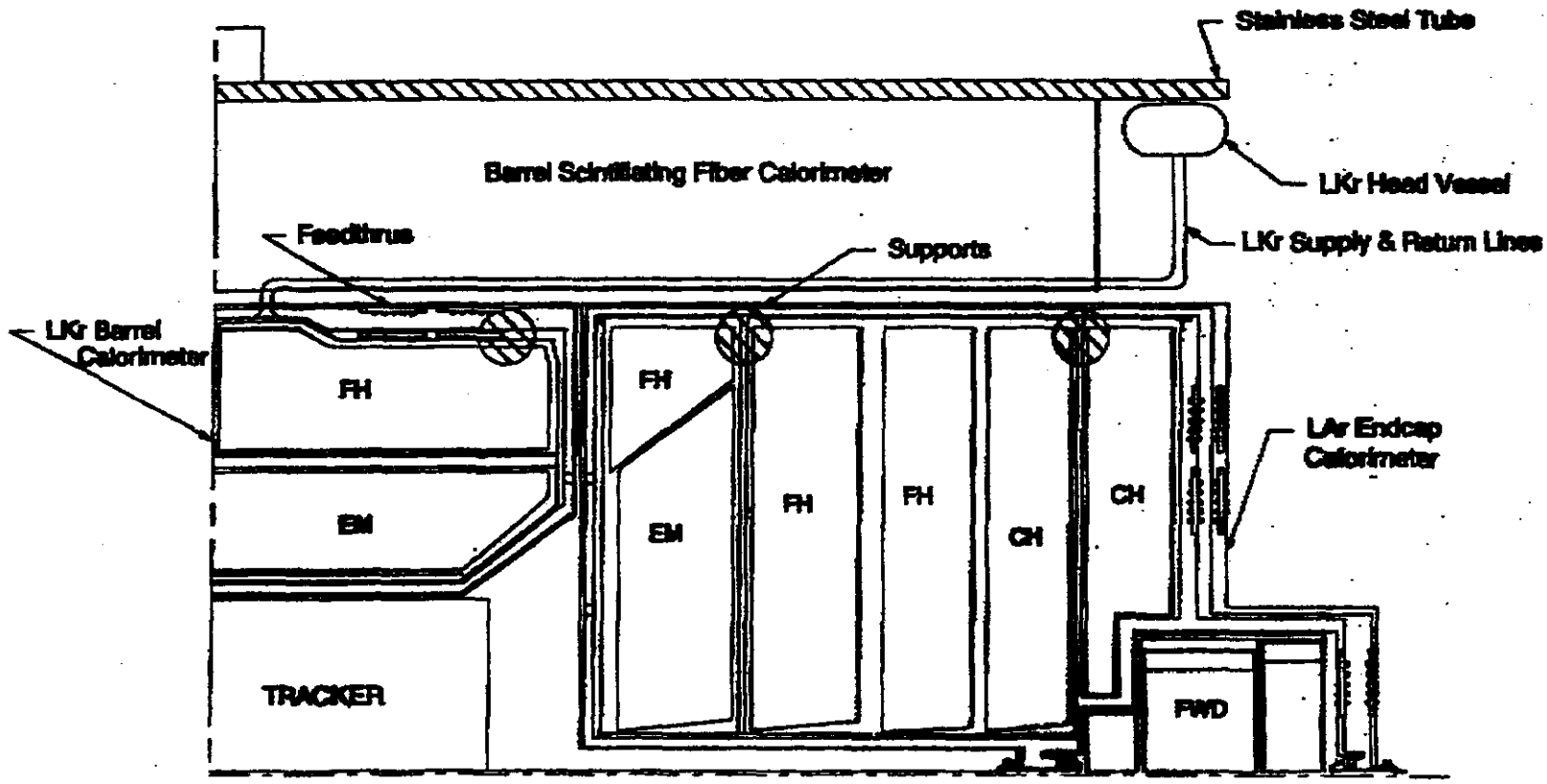
# Preliminary Hybrid Concept EM + 4 Lambda




* Only 1 cm. Probably not enough space.

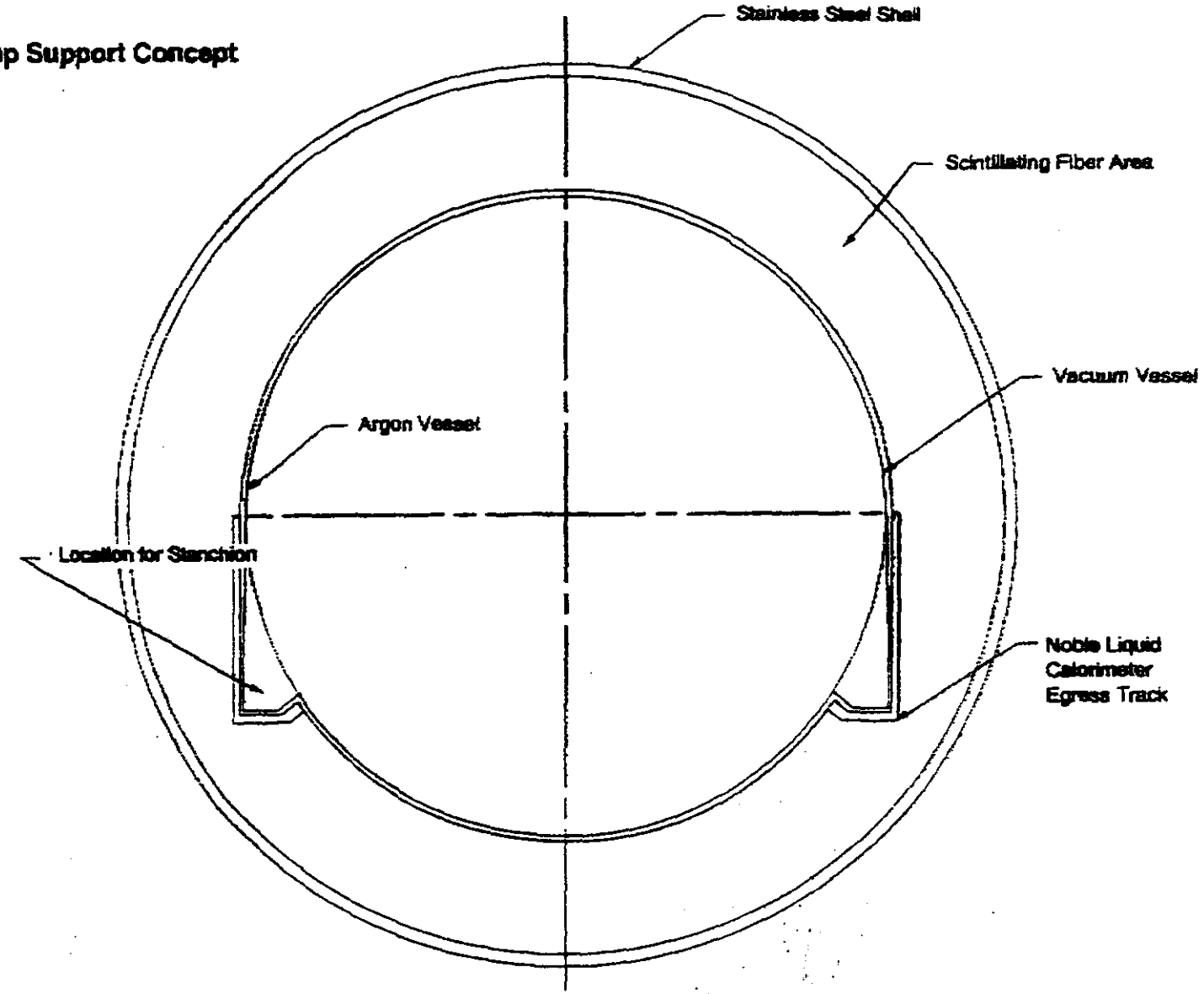
** Only 1 cm. Definitiely not enough space for tracker and calorimeter cabling.

# Preliminary Hybrid Concept



# *Preliminary Hybrid Concept*

**Endcap Support Concept**

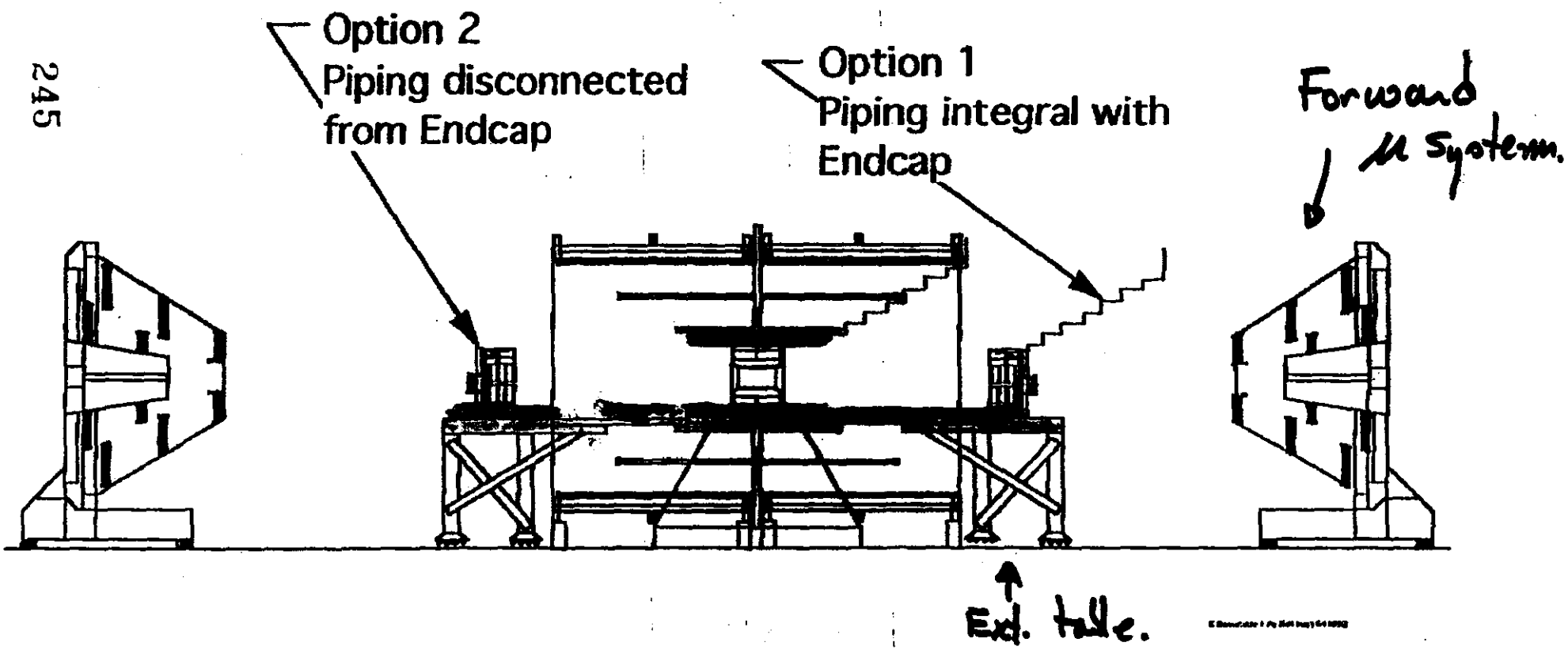


# Tracker Maintenance - 1 Piece Support Tube Calorimeter

Tracker access is similar with each cabling and piping option:

1. With Option 1, the roll transfer cradle will include provisions for supporting the cabling and piping while accessing the tracker.

2. With Option 2, all cabling and utilities must be disconnected.



# SCINTILATION CALORIMETER

- PROJECTIVE TOWERS

---P.M.T.s AT ENDS ? : :

- TILES + FIBERS

- LONGITUDINAL FIBERS/ BARS .... T.P.C. READOUT FROM ENDS IN 0.5 m BINS
  ⇒ FEWER P.M.T.s OR MORE SPACE POINTS

- WANT TO SPOT MUONS?

1. BASELINE 2 CALORIMETER OUTLINE DEFINED

TOMORROW PARALLEL

1. PRE - ENGINEERING MEETING: FINER DEFINITION
2. SIMULATION MEETING
3. OPTIMIZATION AND SCINTILLATION CALORIMETER OPTIONS

3. ENGINEERING
INTEGRATION
SIMULATION
R&D

4. PAC - TDR

gem

γeμ

**Presentation by:**

**G. Mitselmakher**

# Chambers to be delivered to TTR:

| | Technology | Chamber size | TTR delivery date |
|---|---|---|---|
| • ✔ | PDT-JINR | 1 m x 4 m x 8 layers | 7/28/92 (delivered) |
| • ✔ | PDT-MSU | 1.3 m x 3.8 m x 4 layers | 9/11/92 9/30 |
| • ✔ | LSDT | 1 m x 4 m x 4 layers | 9/20/92 9/23 |
| • | RPC | 1 m x 2 m x 2 layers | 9/20/92 9/30 |
| | CSC-BU | 0.5 m x 0.6 m x 3 x 2 layers | 9/16/92 |
| • ✔ | CSC-BNL | 0.6 m x 0.6 m x 2x4 layers | 9/15/92 10/25 |
| | CSC-BNL | 1 m x 1.8 m x 4 layers | --------- |
| • ✔ | CSC-UH | 0.5 m x 1 m x 3 layers | 9/15/92 9/15 |
| • ✔ | CSC-JINR | 1.1 m x 1.5 m x 2 layers | 9/28/92 + 10/21 |

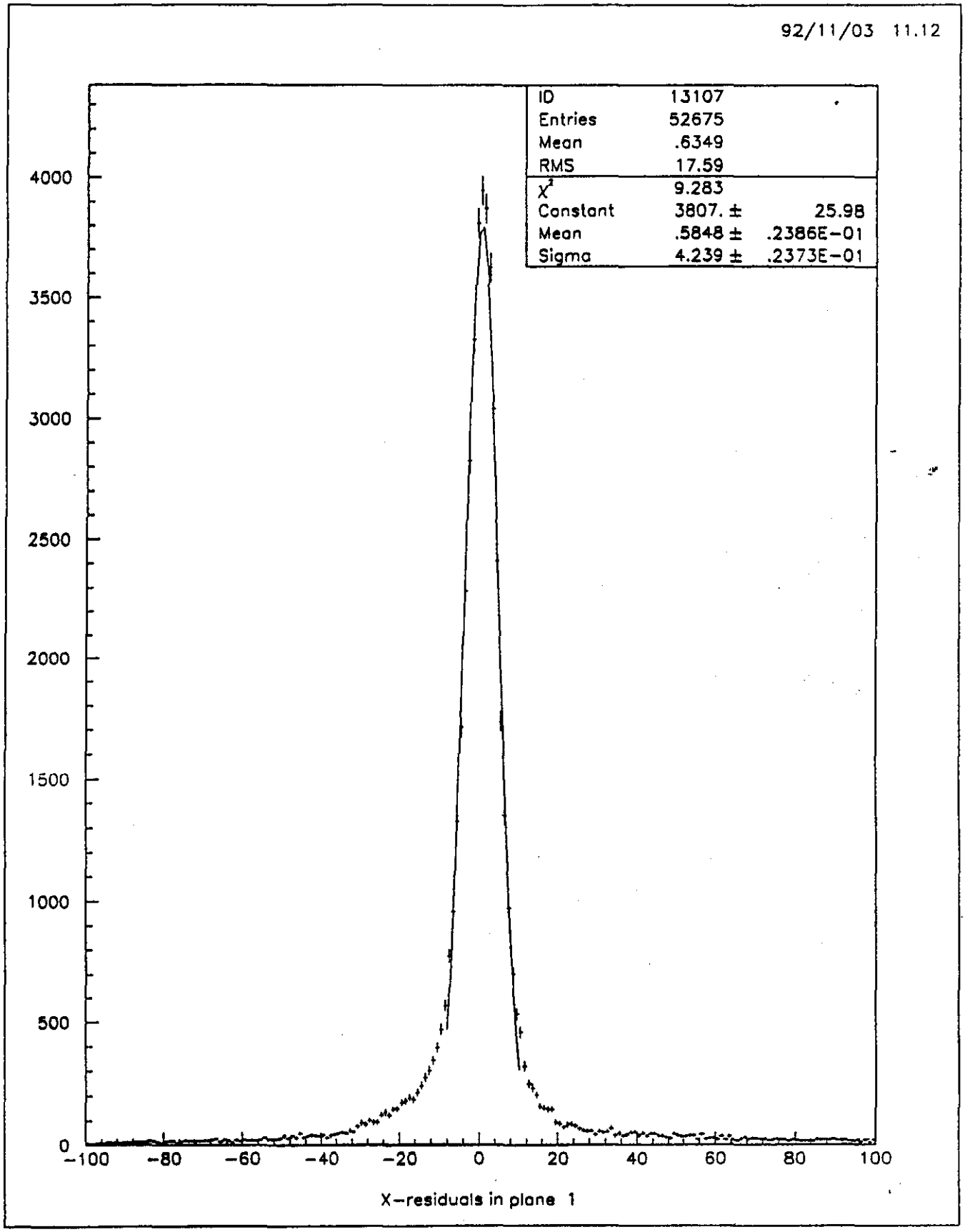
## • Barrel Issues:

1. Which is the more attractive drift technology - PDT or LSDT ?
2. Will the RPCs perform in terms of jitter, background sensitivity ?
3. In case RPCs are not accepted, is there an alternative trigger ?
4. Will the CSCs perform in barrel in terms of alignment, costs ?

## • Endcap Issues:

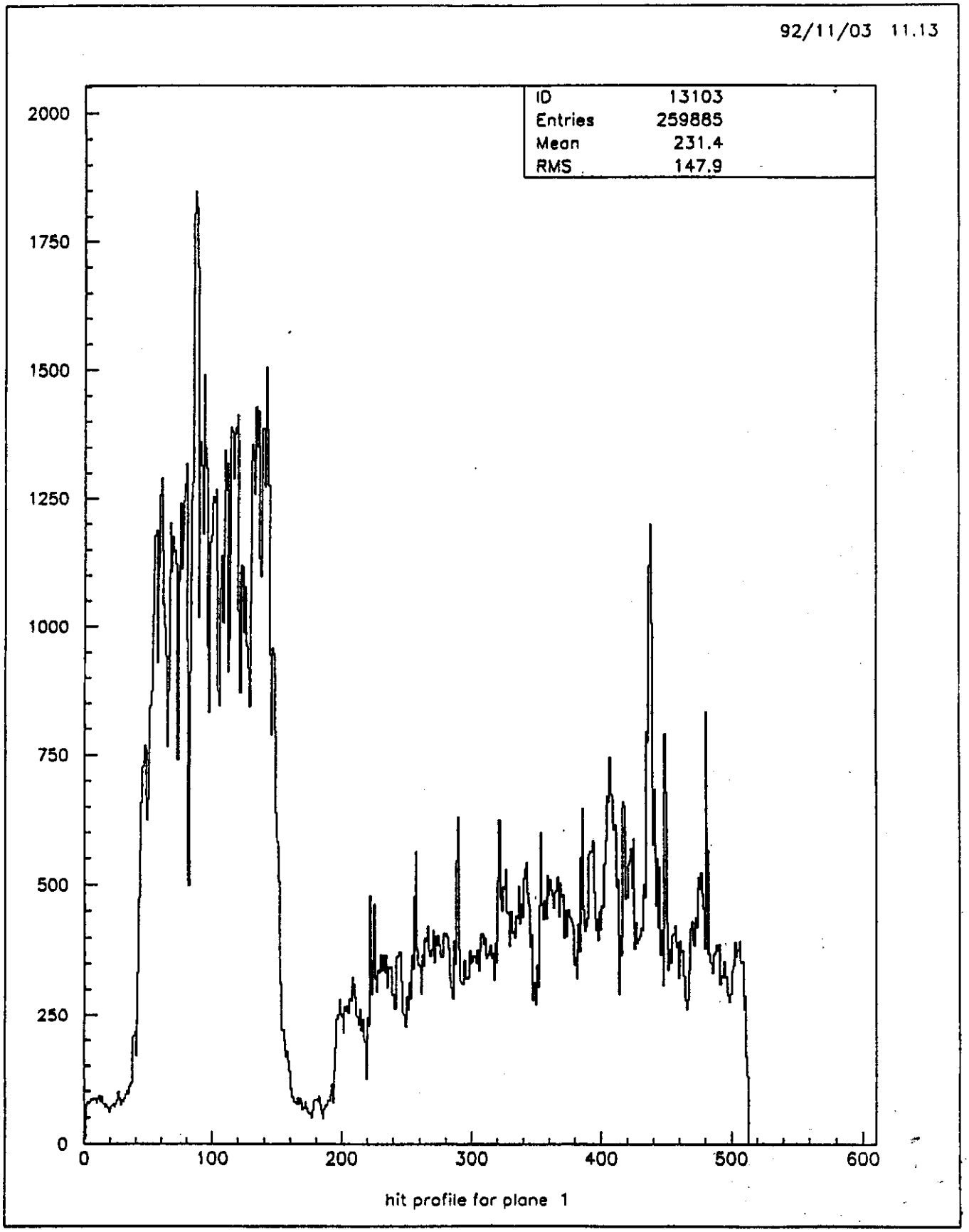
1. Will the CSCs perform in terms of resolutions, background, costs ?

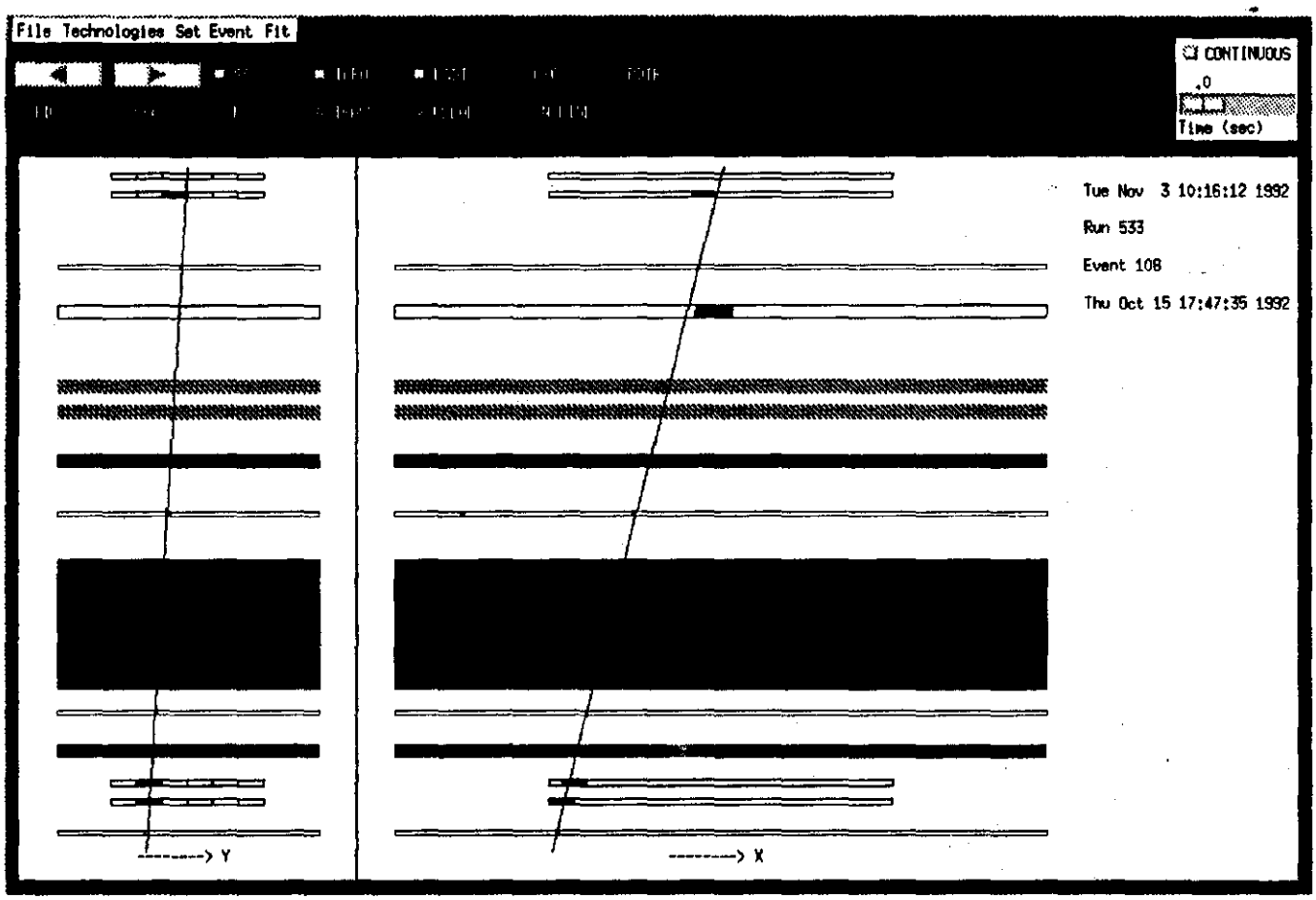
TTR Iarocci + sci. counters

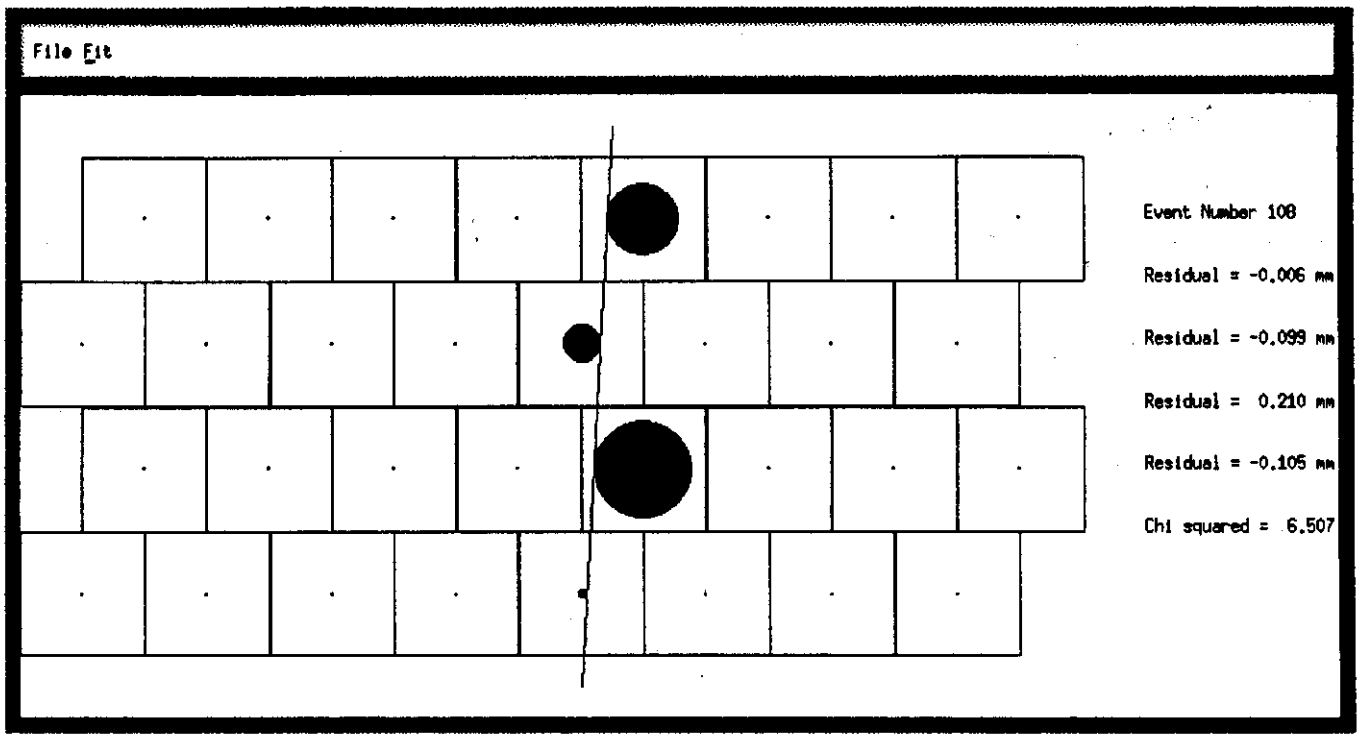



$\sigma = 4.2$ cm (~300ps).

VATOCCI


92/11/03 11.13
ID 13103
Entries 259885
Mean 231.4
RMS 147.9
2000
1750
1500
1250
1000
750
500
250
0
0
100
200
300
400
500
600
hit profile for plane 1


File Technologies Set Event Fit
CONTINUOUS
.0
Time (sec)
Tue Nov 3 10:16:12 1992
Run 533
Event 108
Thu Oct 15 17:47:35 1992
Y
X

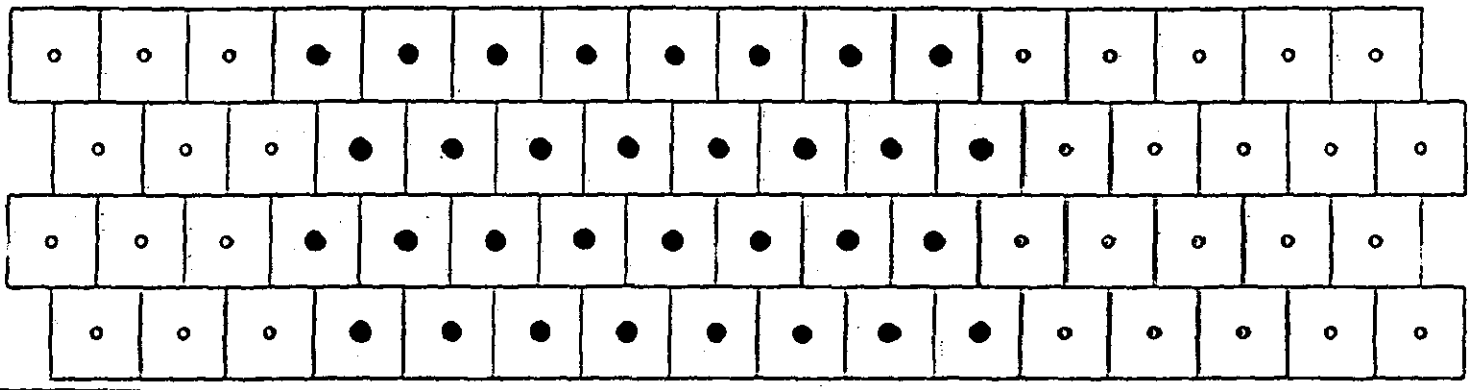

File Fit
Event Number 108
Residual = -0.006 mm
Residual = -0.099 mm
Residual = 0.210 mm
Residual = -0.105 mm
Chi squared = 6.507

11/4/92

# LSDT Status

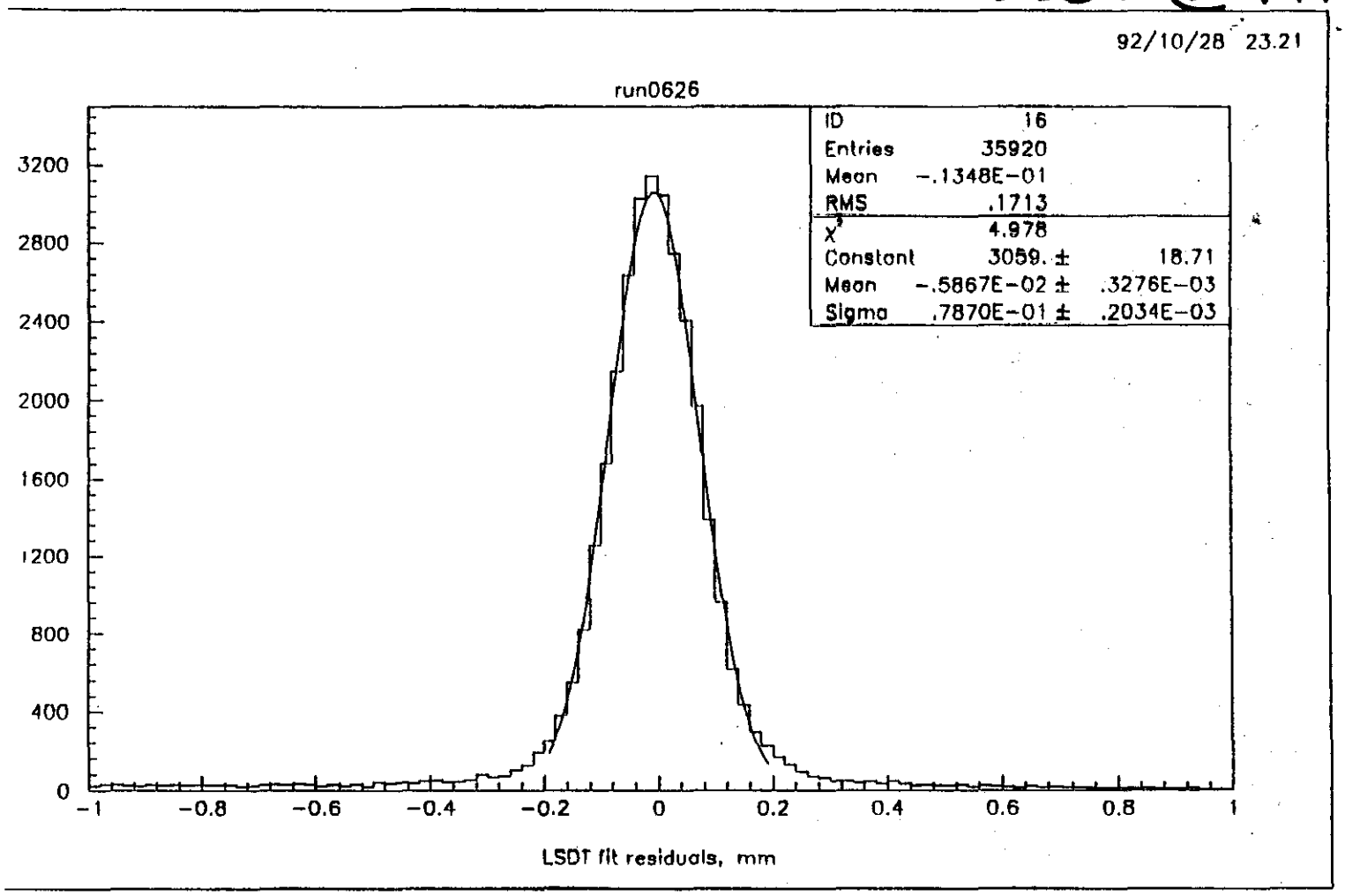
(preliminary results from TTR)

LSDT @ TTR



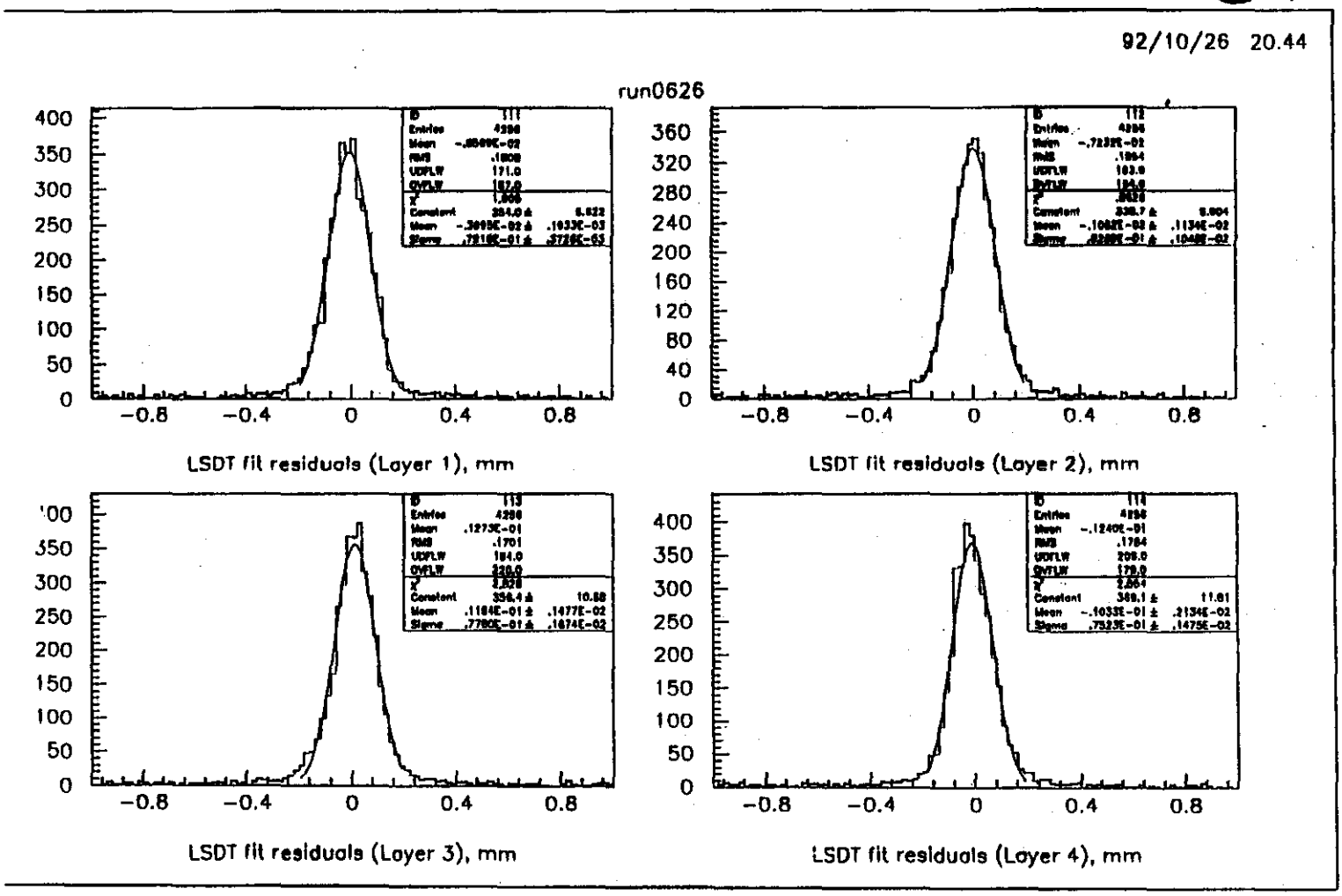
$\sigma = 79\ \mu m$

LSDT @ TTR



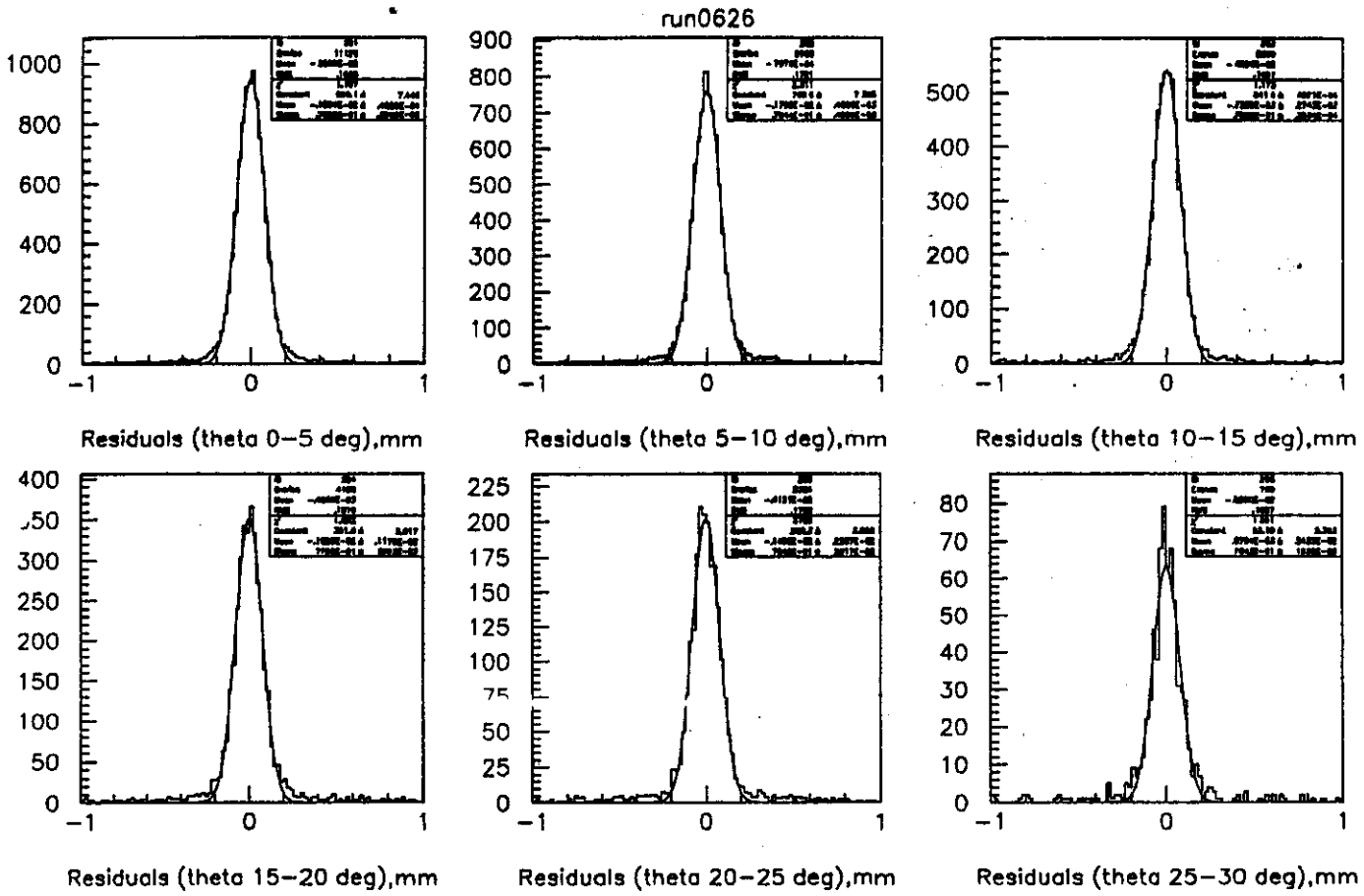
| Layer | σ (μm) | Δ (μm) |
|---|---|---|
| #1 | 79 | −4 |
| #2 | 83 | −1 |
| #3 | 78 | +12 |
| #4 | 75 | −10 |

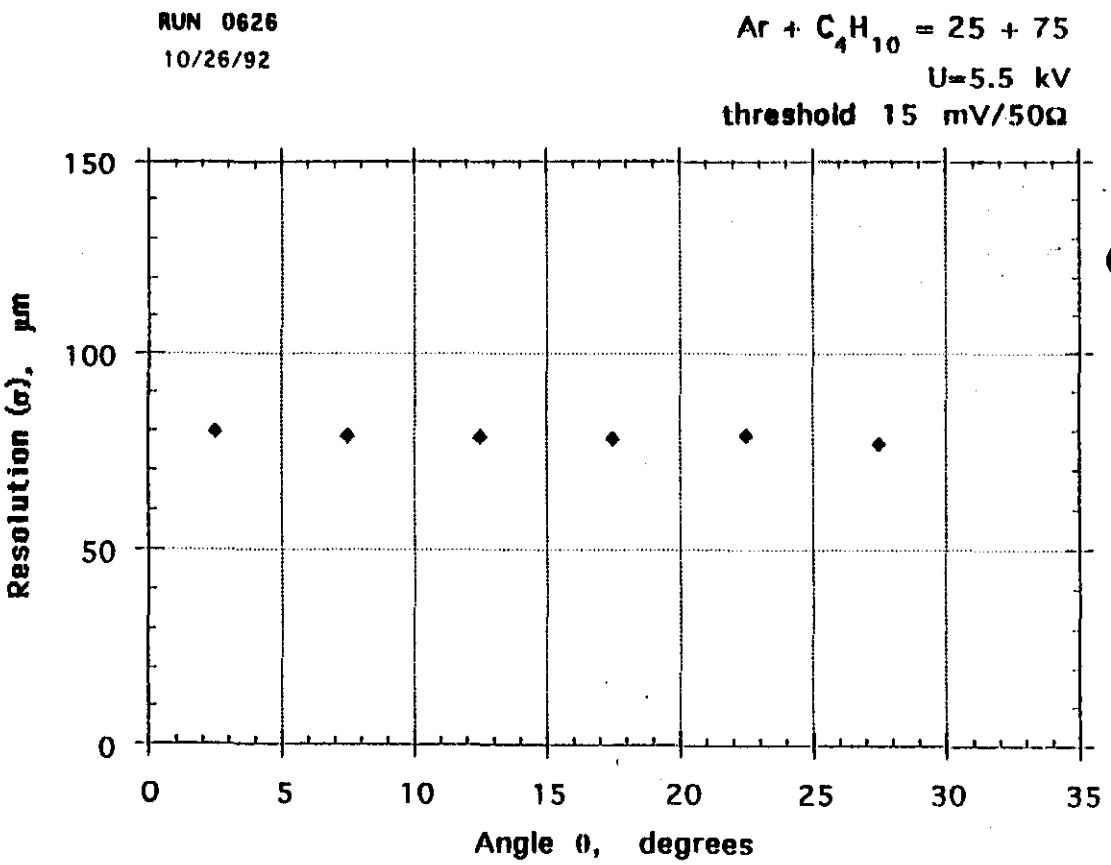
LSDT @ TTR



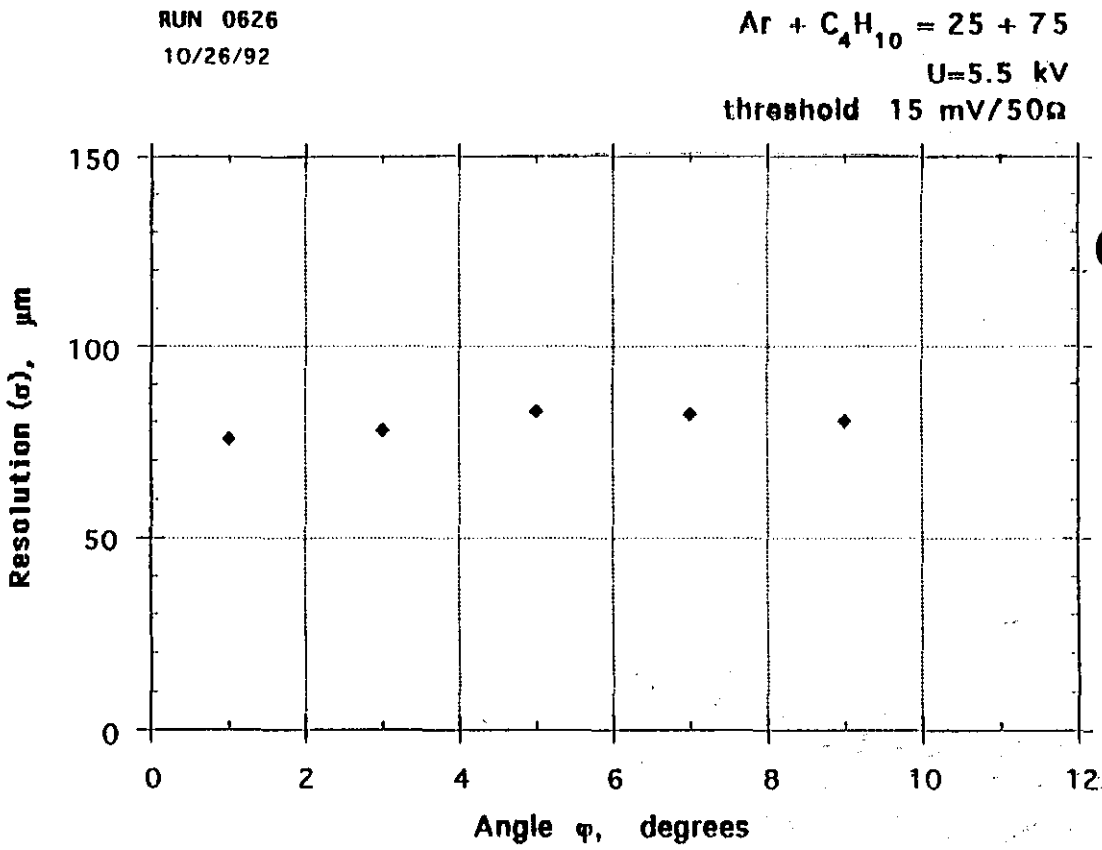
LSDT @ TTR

92/10/29 13.48

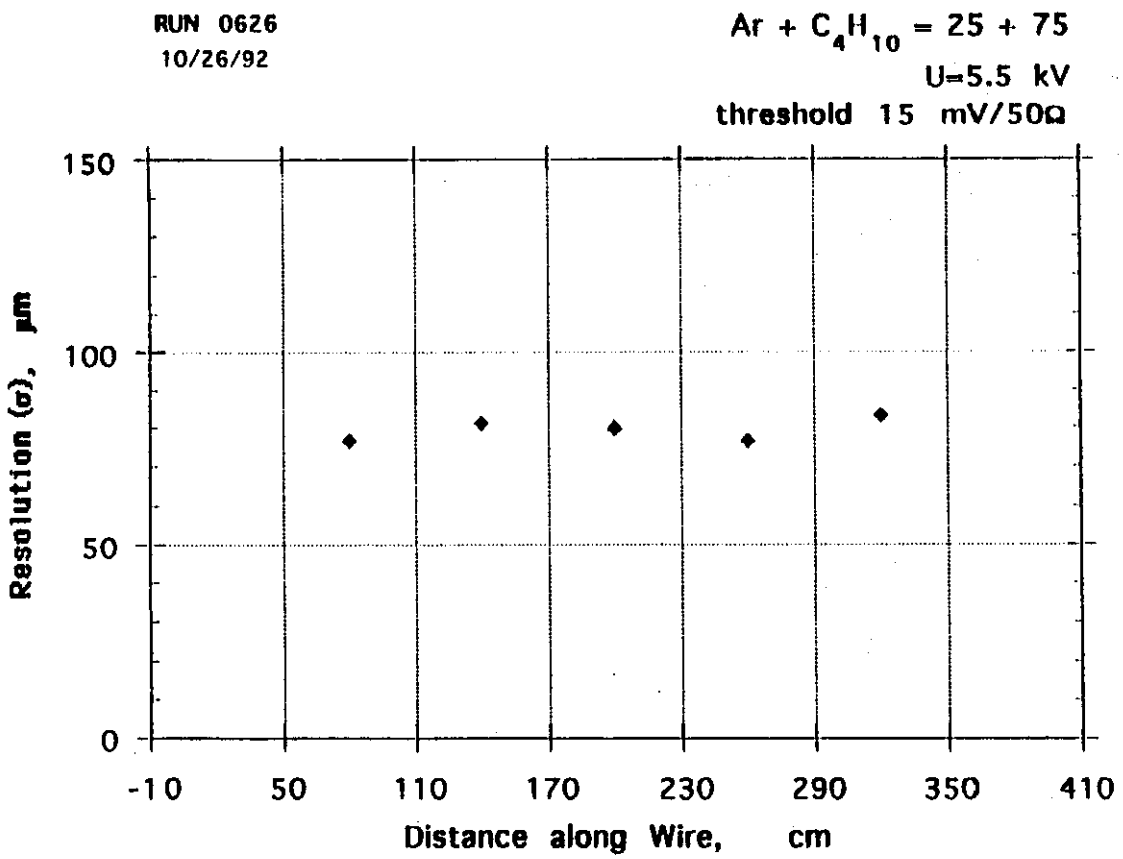



RUN 0626
10/26/92
Ar + C4H10 = 25 + 75
U=5.5 kV
threshold 15 mV/50Ω
150
100
50
0
Resolution (σ), μm
0
5
10
15
20
25
30
35
Angle θ, degrees

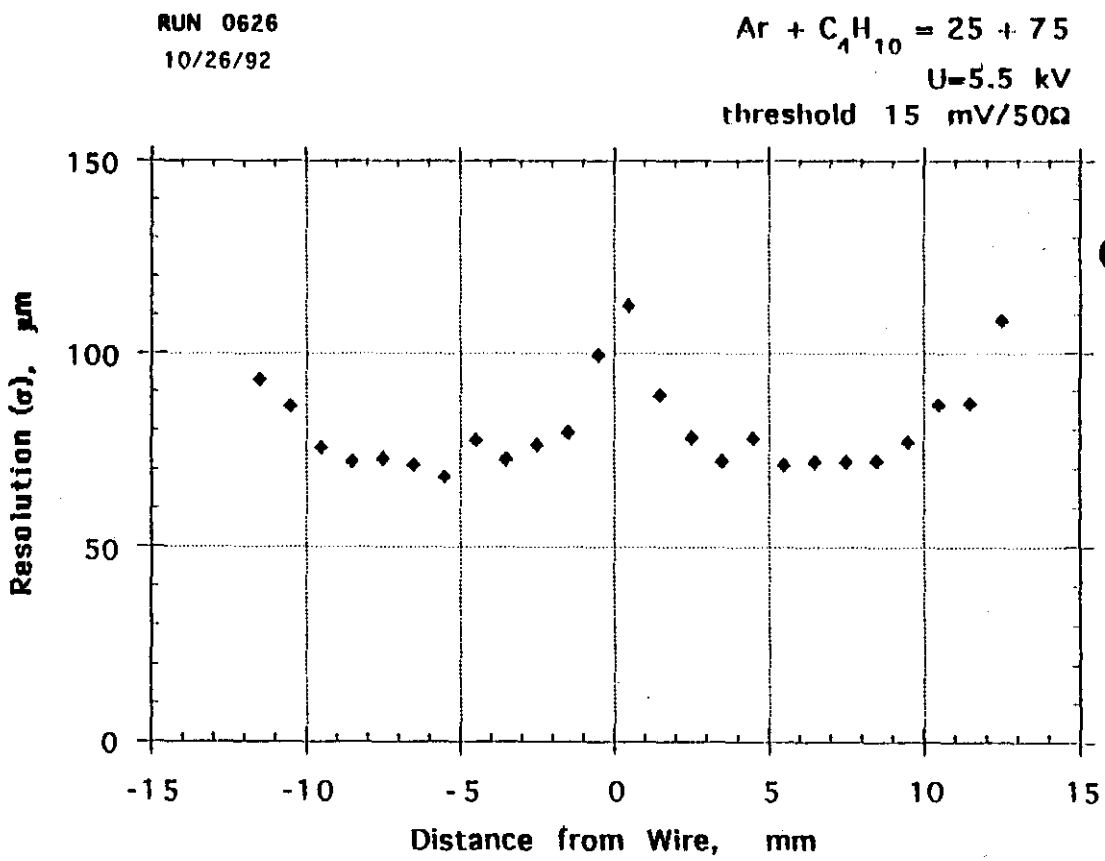
LSDT @ TTR


RUN 0626
10/26/92
Ar + $C_4H_{10}$ = 25 + 75
U=5.5 kV
threshold 15 mV/50Ω
150
100
50
0
Resolution (σ), μm
0
2
4
6
8
10
12
Angle φ, degrees

LSDT @ TTR


RUN 0626
10/26/92
Ar + C4H10 = 25 + 75
U=5.5 kV
threshold 15 mV/50Ω
150
100
50
0
Resolution (σ), μm
-10
50
110
170
230
290
350
410
Distance along Wire, cm

LSDT @ TTR


RUN 0626
10/26/92
Ar + C4H10 = 25 + 75
U=5.5 kV
threshold 15 mV/50Ω
150
100
50
0
Resolution (σ), μm
-15
-10
-5
0
5
10
15
Distance from Wire, mm

LSDT @ TTR

# STATUS OF DUBNA PDT PROTOTYPE

JINR /DUBNA/

ITEP /MOSCOW/

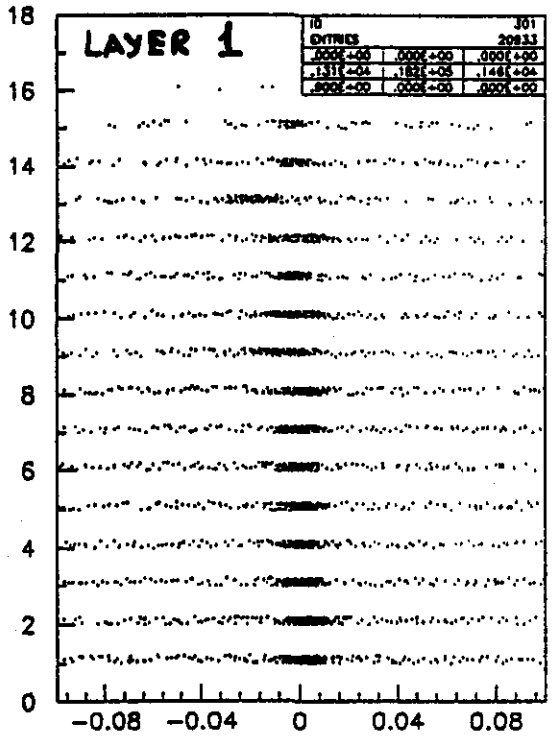
SSCL /DALLAS/



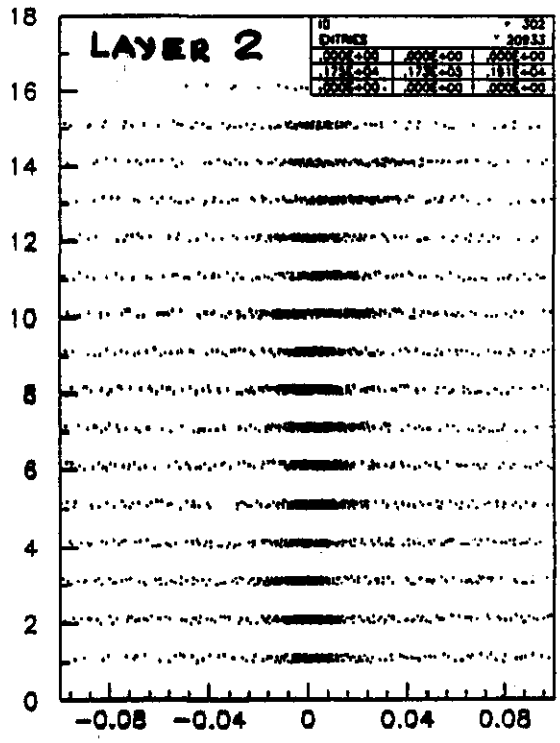
ed / 51

# RESIDUALS VS TUBE NUMBER

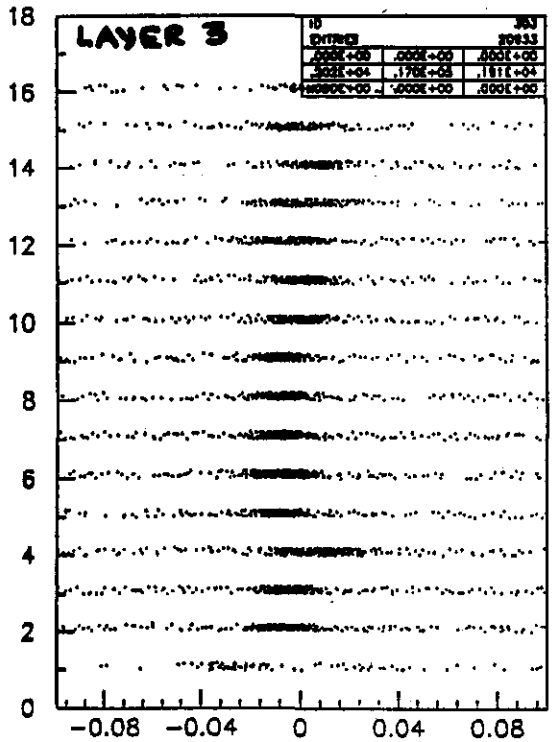
92/11/02 22.33



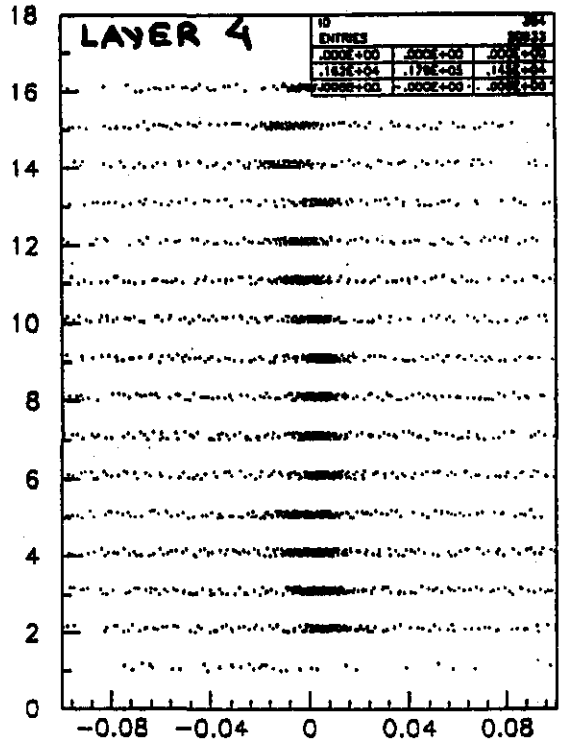

delta(Y) vs tube number for layer 1



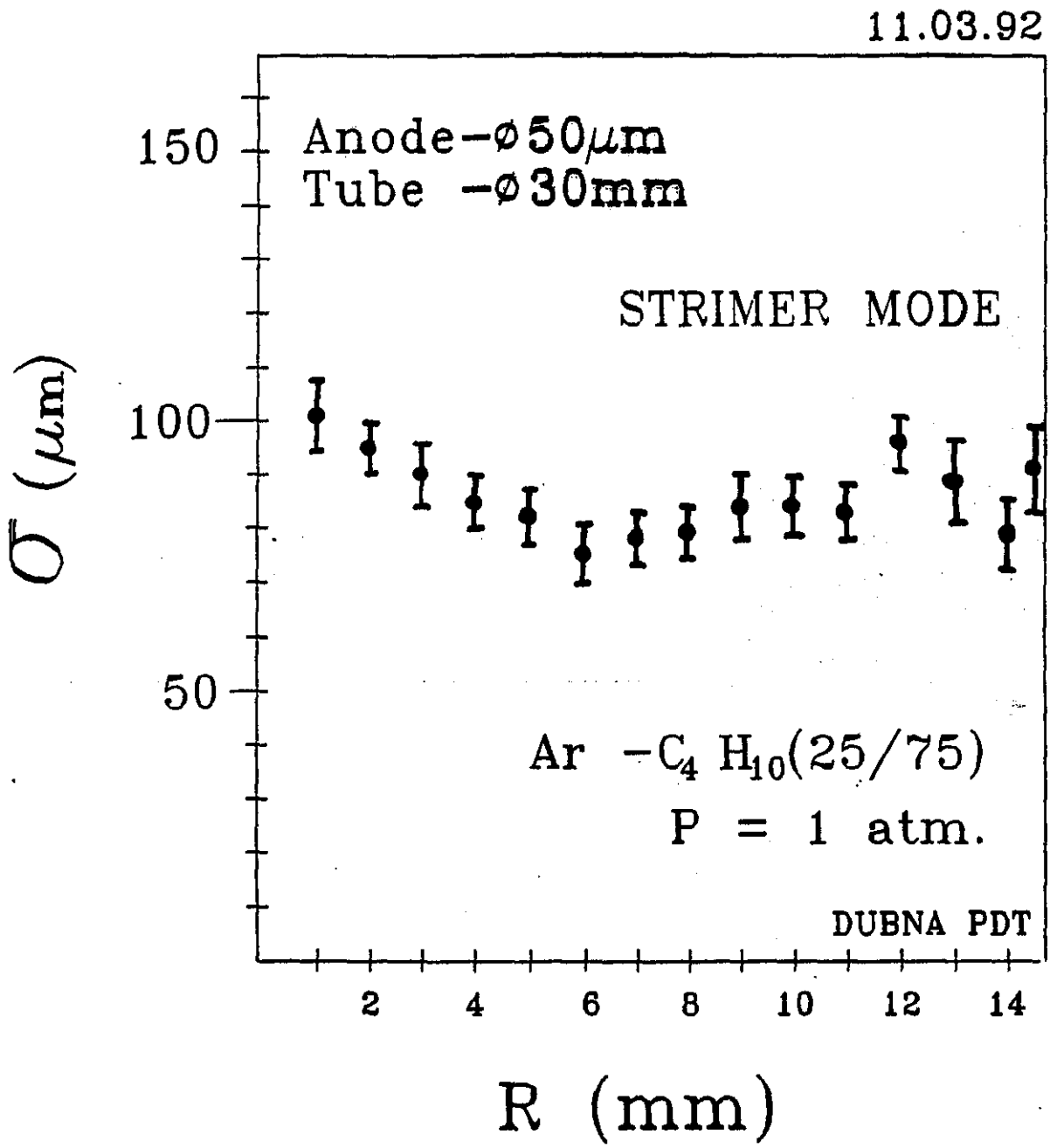

delta(Y) vs tube number for layer 2

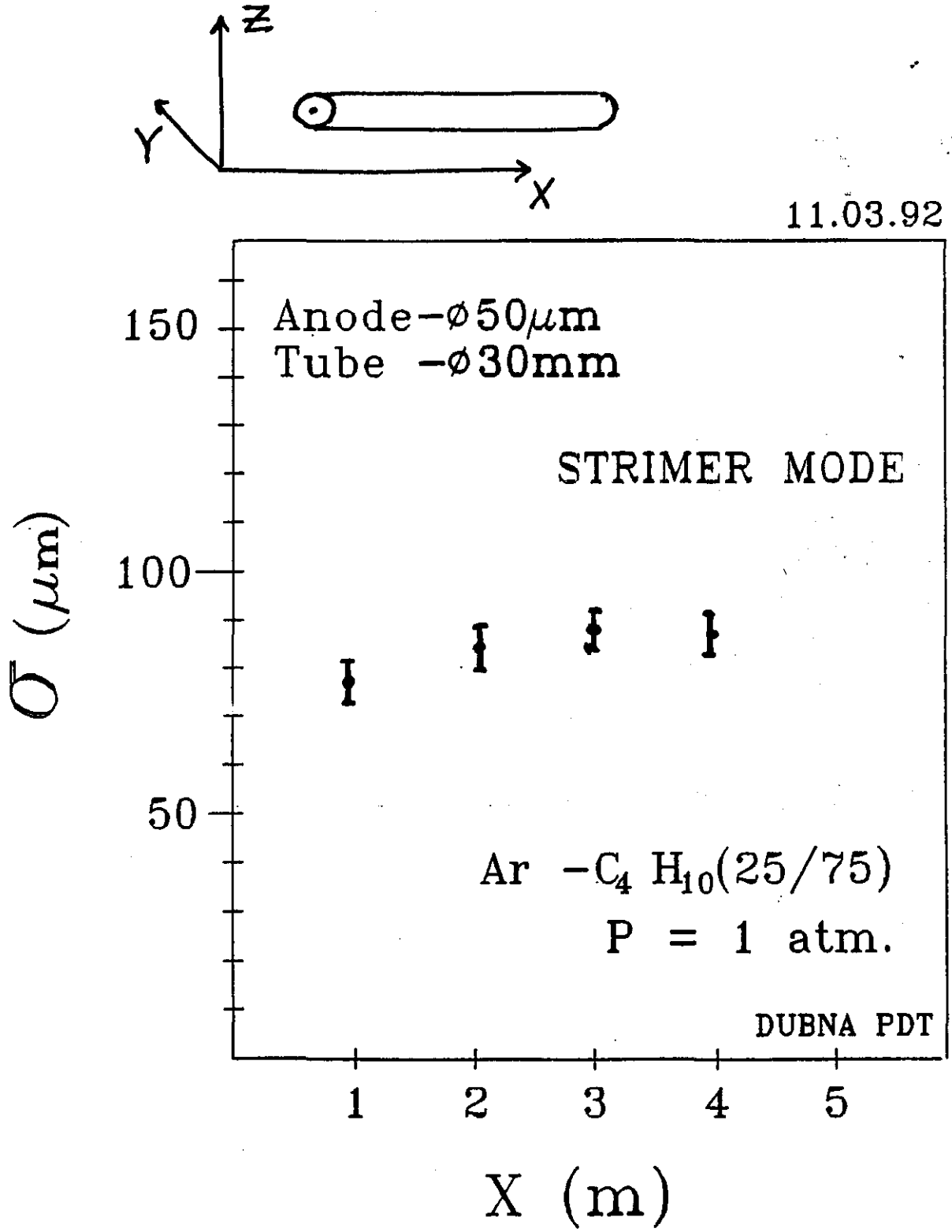


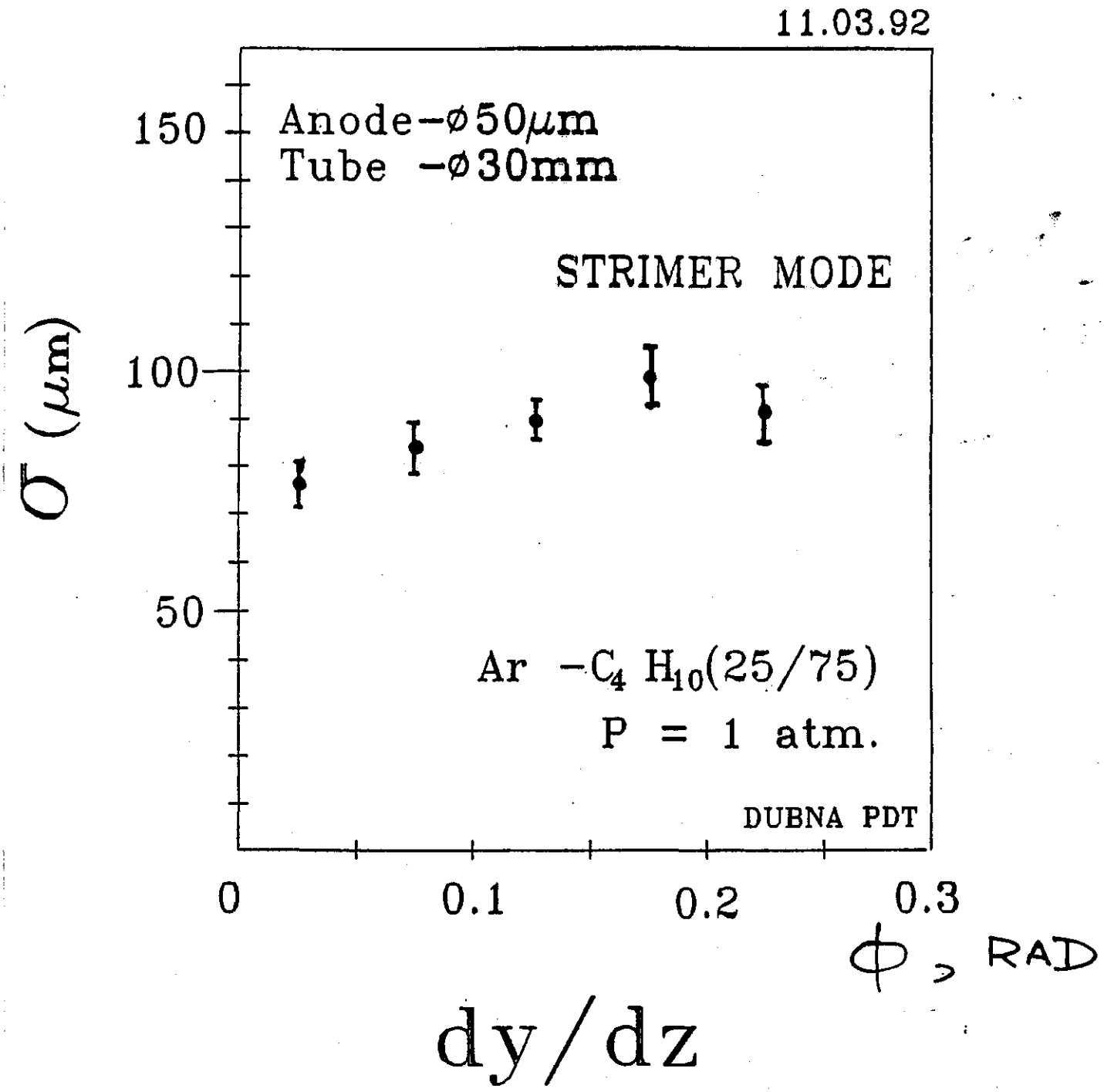

delta(Y) vs tube number for layer 3

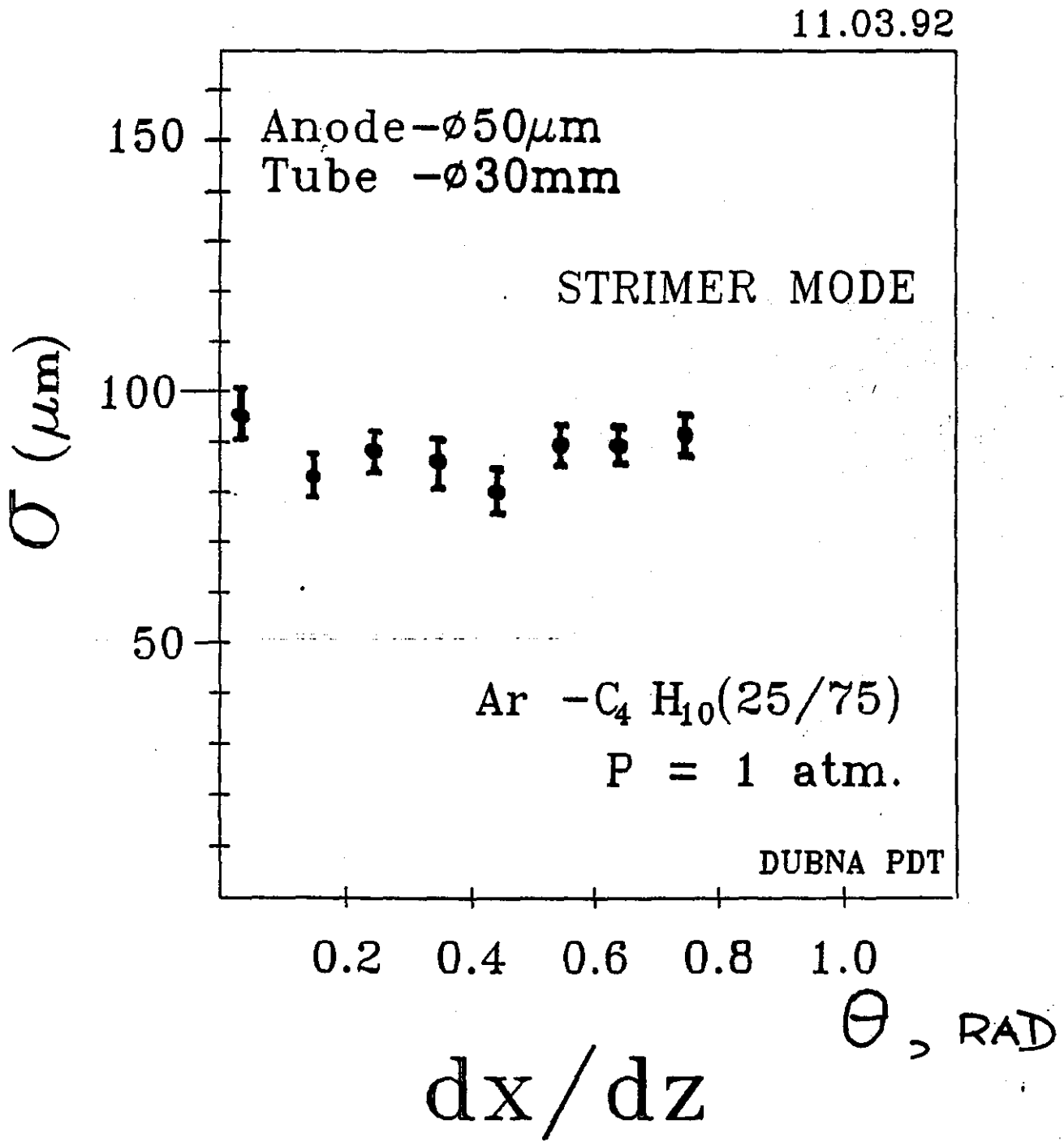



delta(Y) vs tube number for layer 4


11.03.92
Anode-ø50μm
Tube -ø30mm
STRIMER MODE
Ar -C4 H10(25/75)
P = 1 atm.
DUBNA PDT
150
100
50
σ (μm)
2
4
6
8
10
12
14
R (mm)


Z
Y
X
11.03.92
Anode-ø50μm
Tube -ø30mm
STRIMER MODE
Ar -C4 H10(25/75)
P = 1 atm.
DUBNA PDT
150
100
50
σ (μm)
1
2
3
4
5
X (m)


11.03.92
Anode-ø50μm
Tube -ø30mm
STRIMER MODE
Ar -C4 H10(25/75)
P = 1 atm.
DUBNA PDT
σ (μm)
150
100
50
0
0.1
0.2
0.3
φ, RAD
dy/dz


11.03.92
Anode-ø50μm
Tube -ø30mm
STRIMER MODE
Ar -C4 H10(25/75)
P = 1 atm.
DUBNA PDT
σ (μm)
150
100
50
0.2
0.4
0.6
0.8
1.0
θ, RAD
dx/dz

# $Ar - C_2H_6(50/50)$

PROP. MODE

| $U_A$ kV | Layer / $P_{atm}$ | 1 | 2 | 3 | 4 | 1...4 |
|---|---|---|---|---|---|---|
| | | Δ | Δ | Δ | Δ | σ |
| 3.1 | 1 | (+26) | (−47) | (+8) | (+10) | 110 |
| 4.3 | 2 | (+32) | (−52) | (+10) | (+10) | 92 |
| 5.9 | 4 | (+36) | (−59) | (+8) | (+10) | 76 |

σ −space resolution (μm)

Δ −systematic shift (μm)

# $Ar - C_4H_{10}(25/75)$

P = 1 atm

| $U_A$ kV | Layer / Mode | 1 | 2 | 3 | 4 | 1...4 |
|---|---|---|---|---|---|---|
| | | Δ | Δ | Δ | Δ | σ |
| 4.1 | prop. | (+34) | (−52) | (+12) | (+10) | 95 |
| 4.5 | strimer | (+34) | (−57) | (+10) | (+12) | 82 |

σ −space resolution (μm)

Δ −systematic shift (μm)

MSU PDT

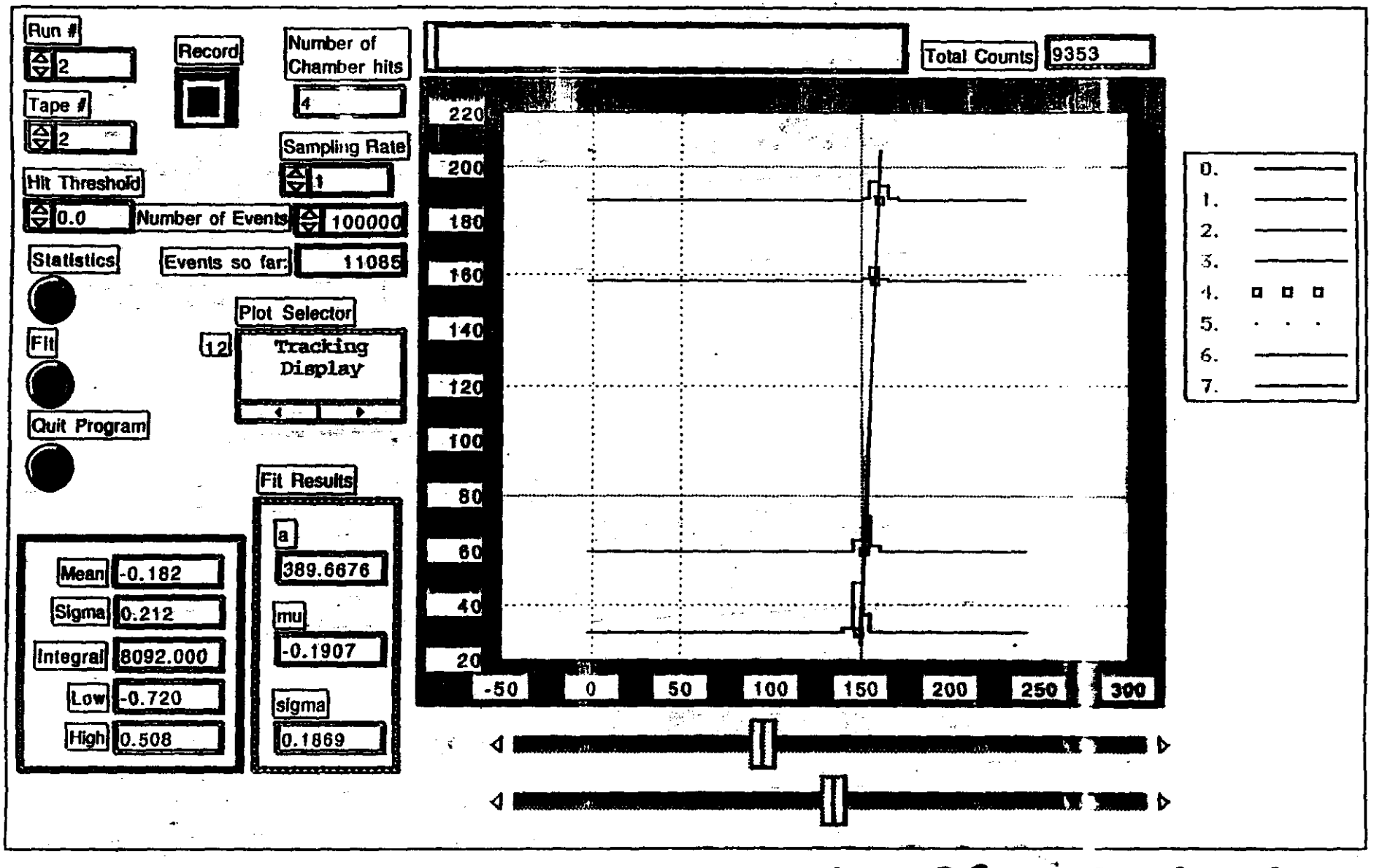
Take Track Data (8mm)
Monday, October 19, 1992 01:43

Run #2



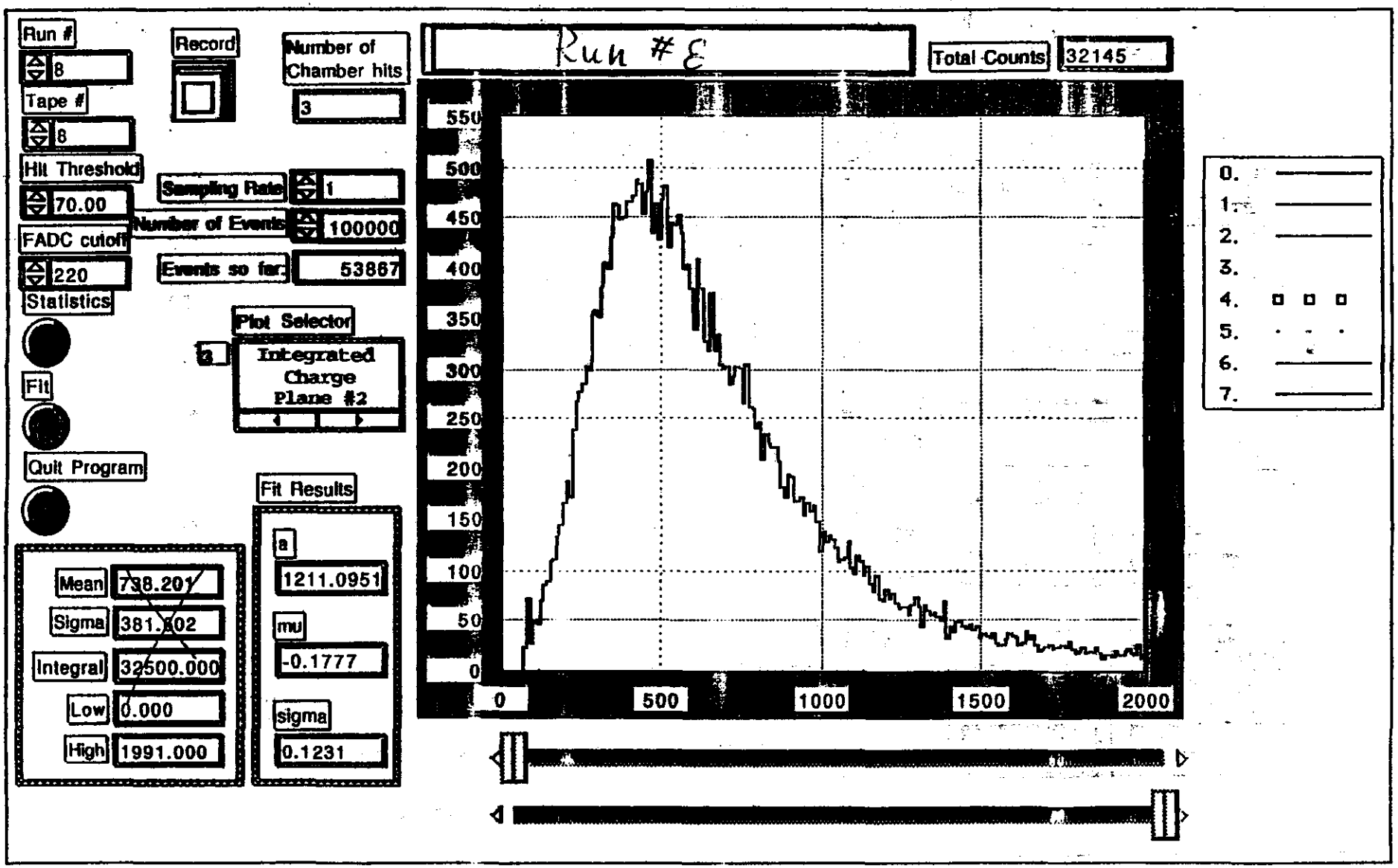
Run 2

Front Panel



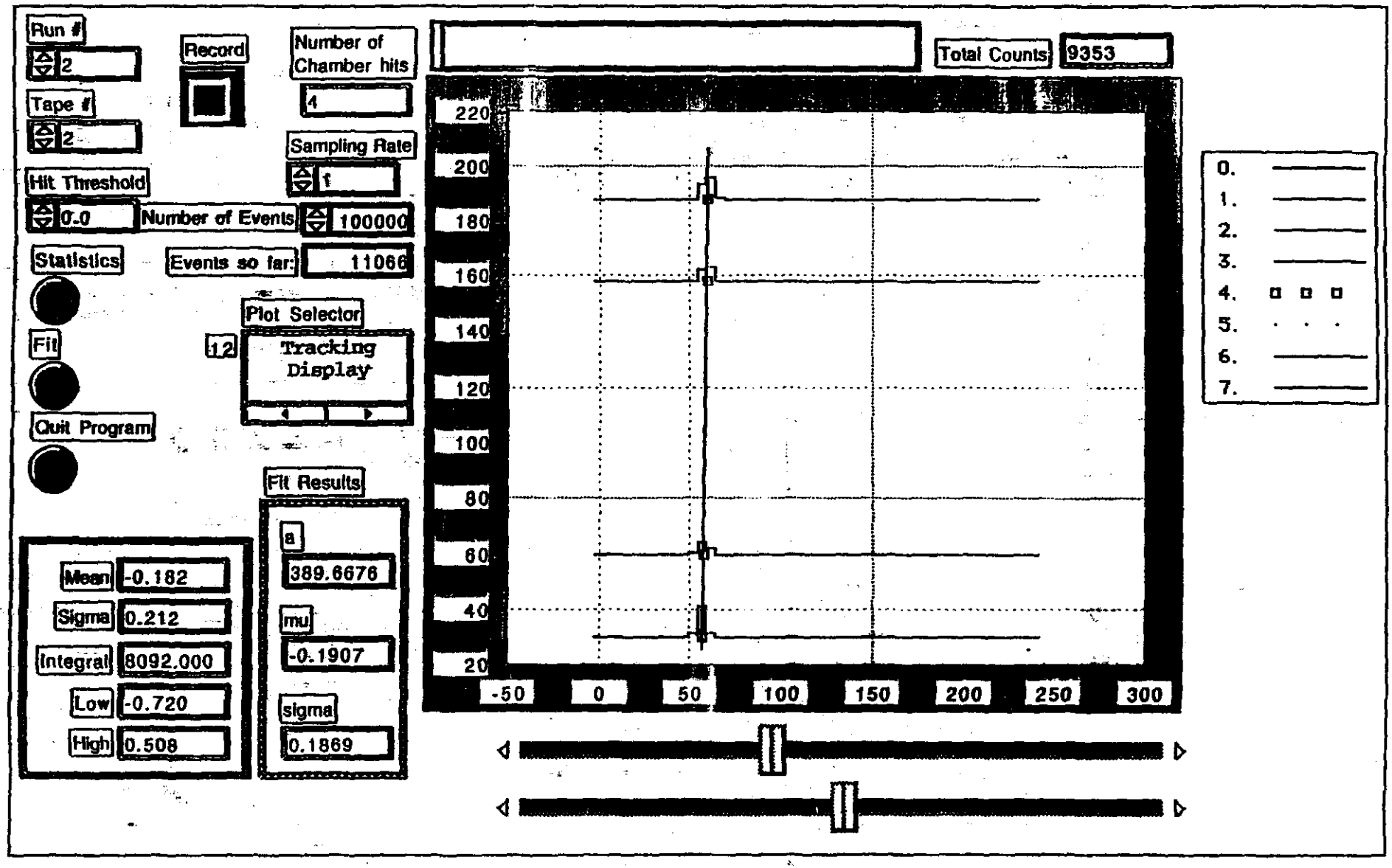

$CF_4$-Ar-$CO_2$ 20:30:50

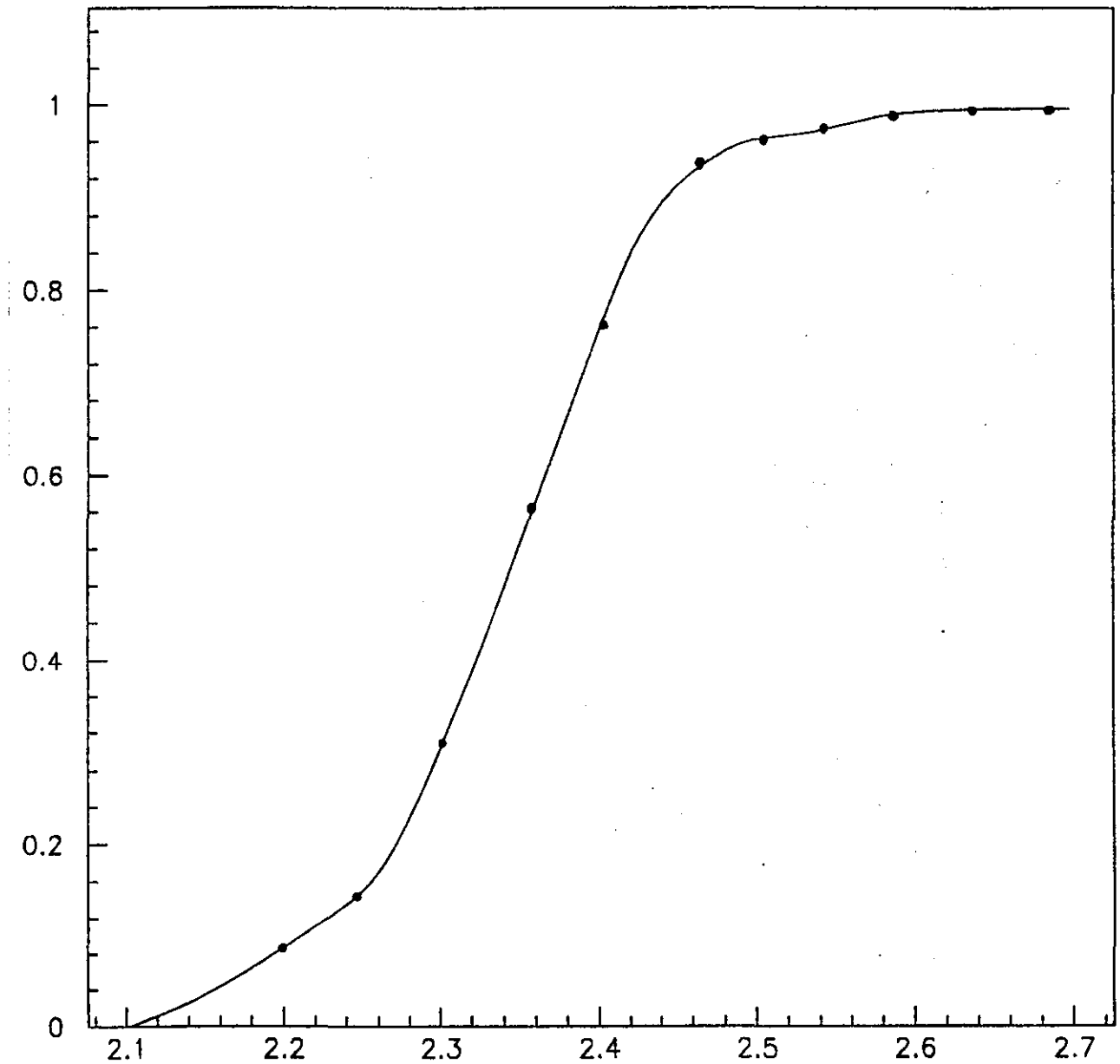
Front Panel


Run #
8
Tape #
8
Hit Threshold
70.00
FADC cutoff
220
Statistics
Fit
Quit Program
Record
Number of Chamber hits
3
Sampling Rate
1
Number of Events
100000
Events so far
53867
Plot Selector
3
Integrated Charge Plane #2
Fit Results
a
1211.0951
mu
-0.1777
sigma
0.1231
Mean
738.201
Sigma
381.102
Integral
32500.000
Low
0.000
High
1991.000
Run #ε
Total Counts
32145
550
500
450
400
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
0.
1.
2.
3.
4.
5.
6.
7.

Take Track Data (8mm)
Monday, October 19, 1992 01:43

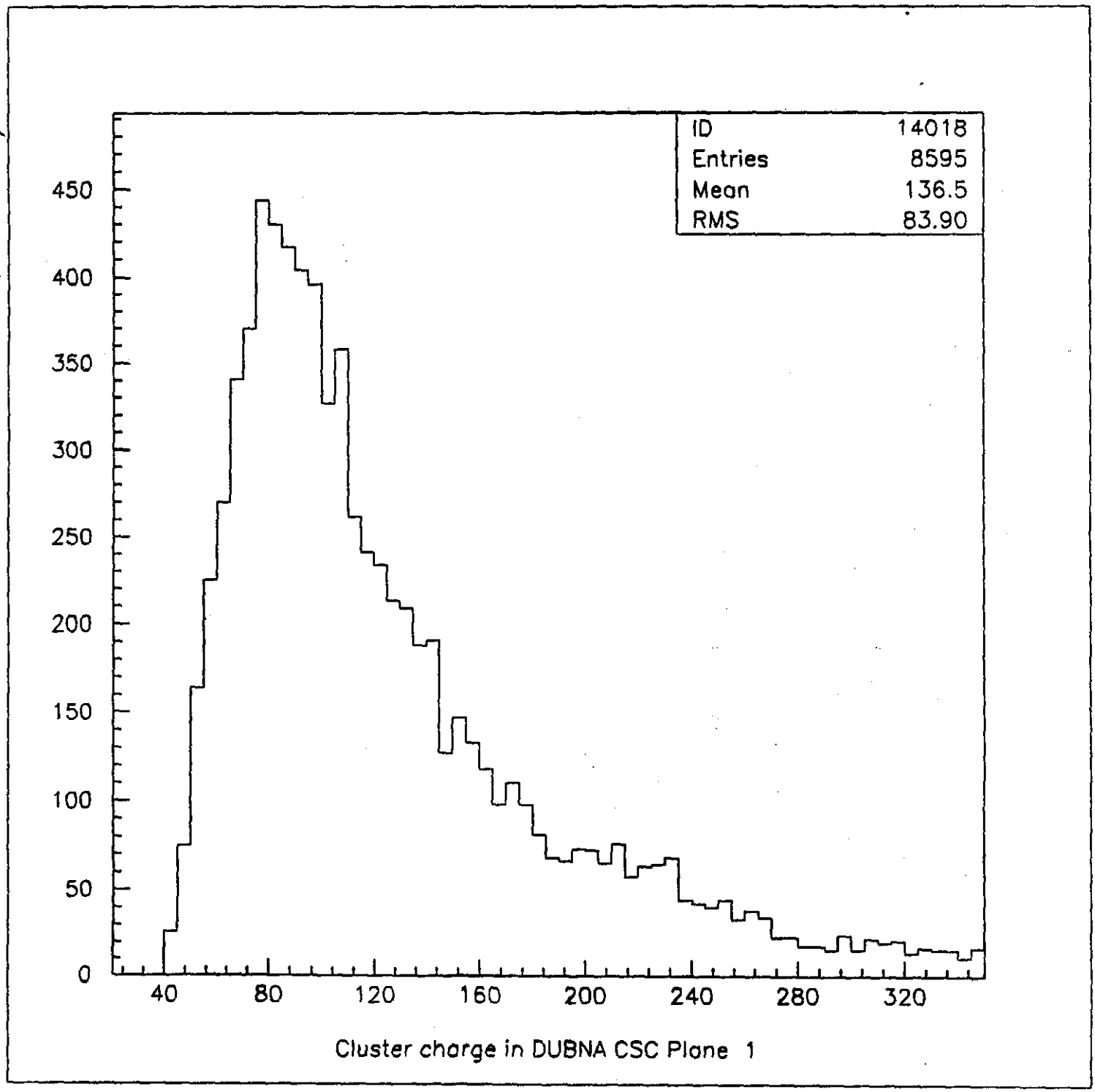
Front Panel

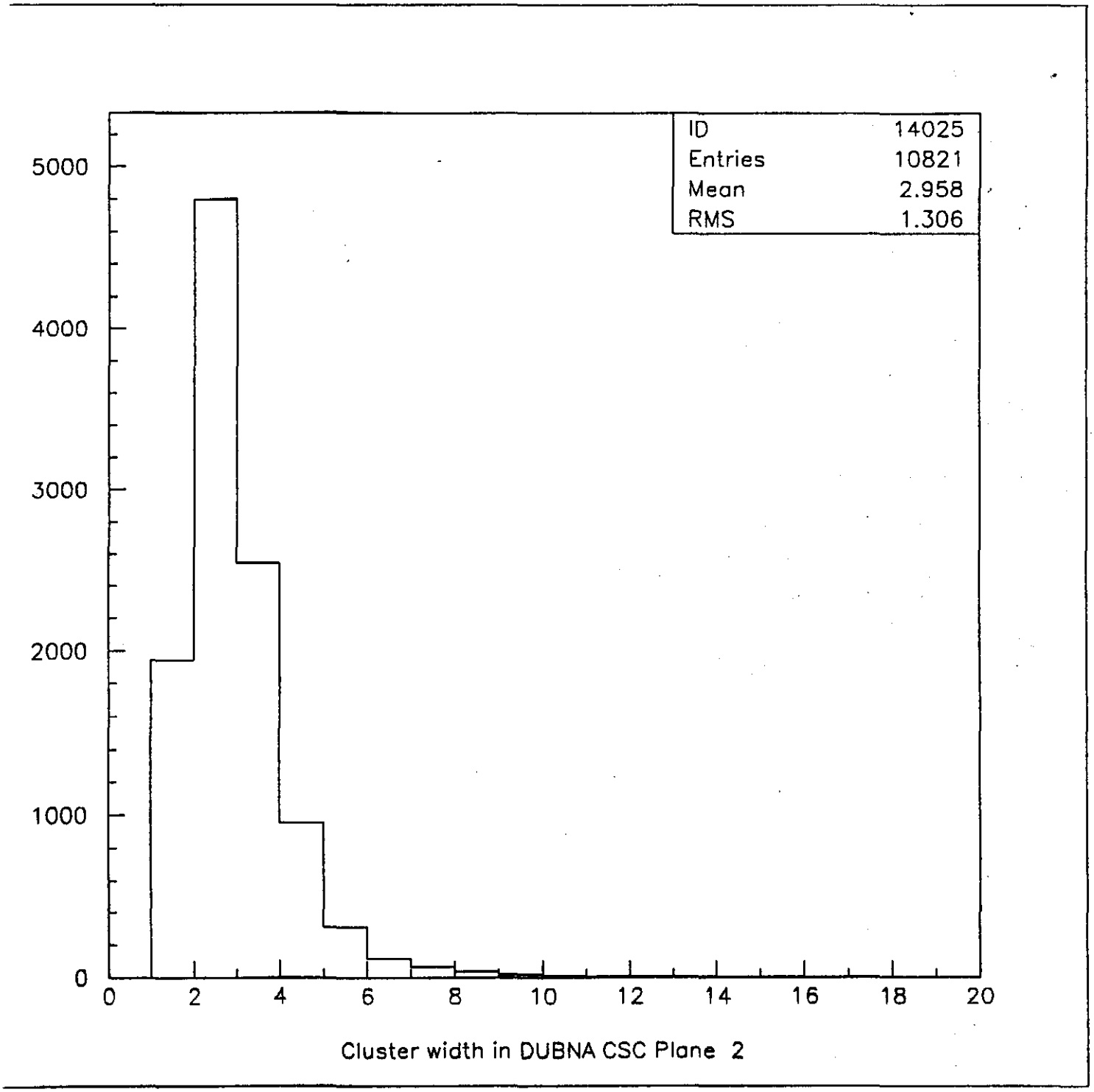





Dubna CSC Efficiency. Plane1 Plane2 Coincidence. No cuts.

37


ID 14018
Entries 8595
Mean 136.5
RMS 83.90
450
400
350
300
250
200
150
100
50
0
40
80
120
160
200
240
280
320
Cluster charge in DUBNA CSC Plane 1


ID 14025
Entries 10821
Mean 2.958
RMS 1.306
5000
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
16
18
20
Cluster width in DUBNA CSC Plane 2

## Conclusions

- PDT and LSDT big prototypes are precise within specifications ($\sigma < 100\mu$) for a wide range of $\theta, \varphi, z$.

- CSC prototypes are operational, tests in progress

gem

γeμ

**Presentation by:**

**V. Polychronakos**

V. POLYCHRONAKOS (5
BNL 4 Nov. '92

## Proportional Chambers with Segmented Cathodes
## CSC

Segmentation in strips (pads) of varying lengths:

- Width 0.5 cm to achieve $\approx 50 - 75\mu m$ resolution.
- Length 20-300 cm.
- Integration time 300-500 ns to keep rms noise to $\approx$1500 electrons.

These chambers allow:

- Flexibility of segmentation for rapidly varying rates at high $\eta$.
- One device used for :
  - Precision measurement (momentum)
  - Z-coordinate (R in endcaps)
  - Level 1 Trigger
  - Bunch crossing assignment
- Insensitivity to variations in gas gain, ambient pressure, temperature, electric and magnetic field, etc.
- Low current proportional mode, No aging effects
- Easy, straightforward alignment.
- Alignment verification in situ

**Emphasis on Readout. Has to be:**

- **simple**
- **affordable**
- **highly integrated**

## Institutions involved in CSC R&D

Beijing Institute for High Energy Physics

Boston University

Brookhaven National Laboratory

Draper Laboratory

Hofei University

Institute for Theoretical and Experimental Physics, Moscow

Joint Institute for Nuclear Research, Dubna

Minsk Institute for Nuclear Problems

Oak Ridge National Laboratory

Princeton University

St Petersburg Nuclear Physics Institute

SSC Laboratory

State University of New York at Stony Brook

Tsinghua University

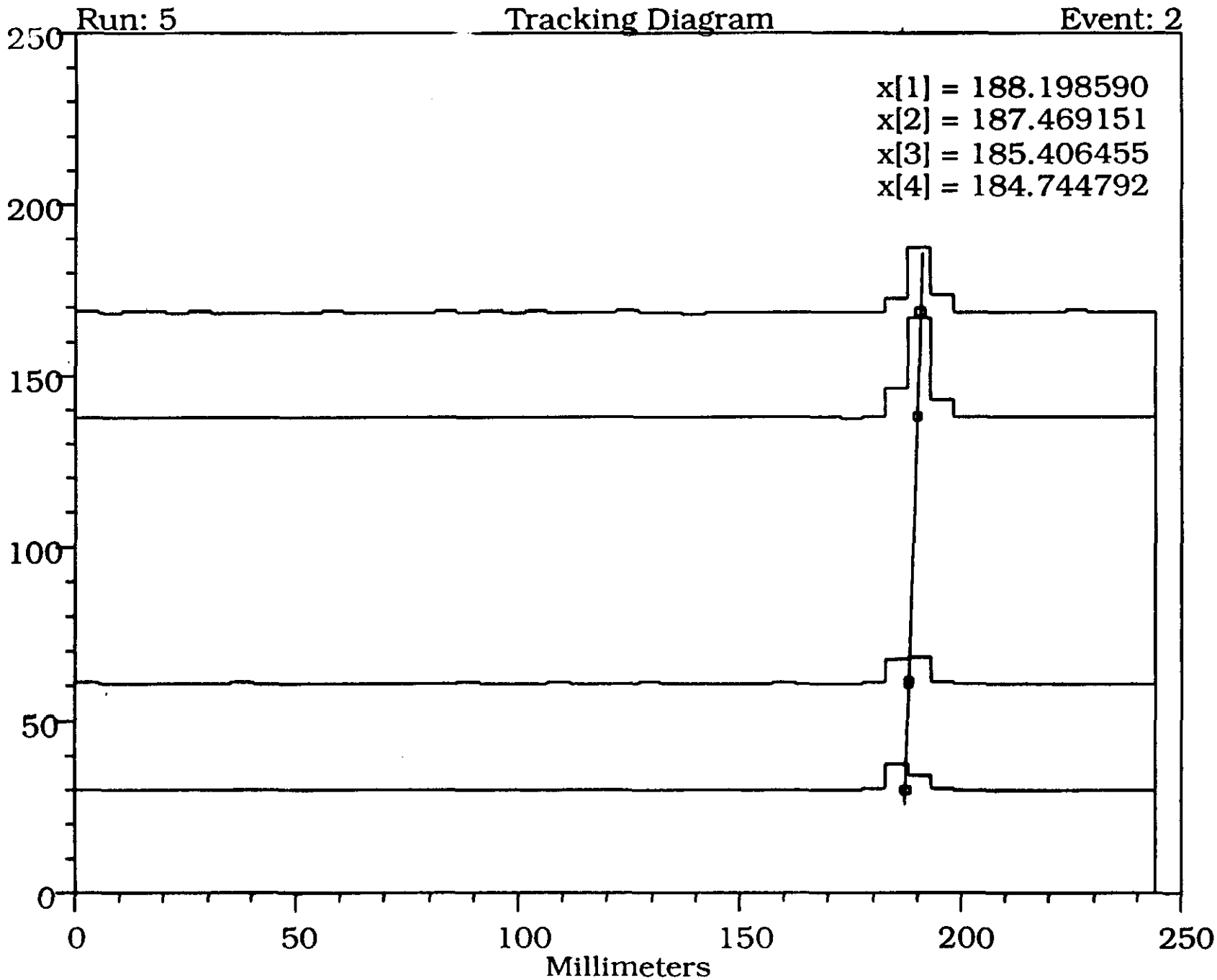
University of Houston

**R&D Activities:**

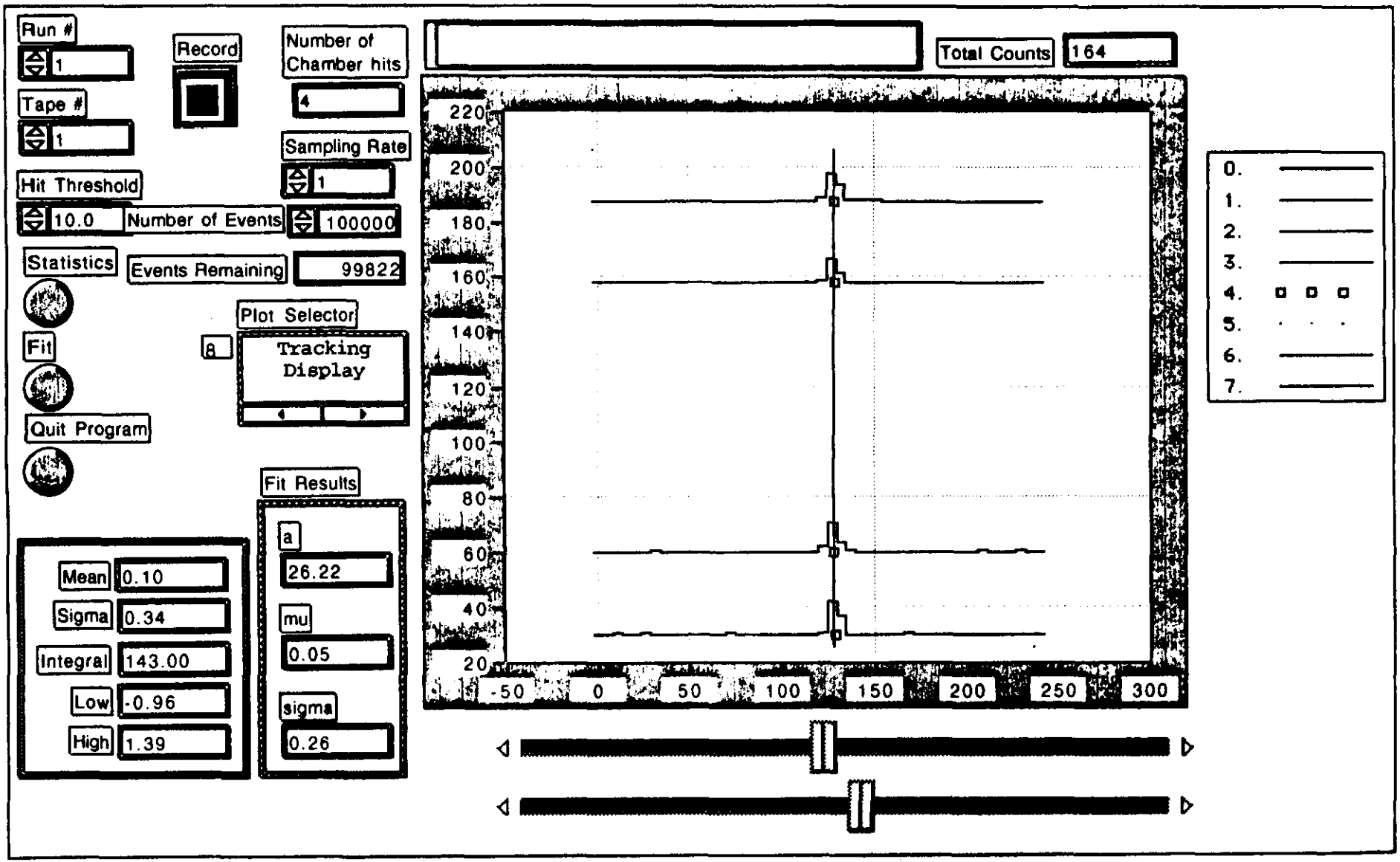
1. Prototype Development and Tests
2. Chamber Performance Simulations
3. Studies and choice of operating Gas
4. Electronics Develpment
5. Alignment
6. Neutron Sensitivity Studies
7. System Performance
8. System Layout and Engineering

**Prototype Development**

- BU Prototype (0.5x0.5m$^2$) undergoing tests in RD5, CERN
- Houston (1x0.5m$^2$–Iarocci tubes) being tested at TTR
- Dubna prototype(1x1.5m$^2$) being tested at the TTR
- BNL prototype (0.5x0.5m$^2$) taking data at the TTR
- BNL,BU,ORNL,PNPI,SB large prototype being constructed. Expected to be delivered at the TTR later this month.


Run: 5
Tracking Diagram
Event: 2
x[1] = 188.198590
x[2] = 187.469151
x[3] = 185.406455
x[4] = 184.744792
250
200
150
100
50
0
0
50
100
150
200
250
Millimeters

Front Panel


Run #
1
Tape #
1
Record
Number of Chamber hits
4
Sampling Rate
1
Hit Threshold
10.0
Number of Events
100000
Statistics
Events Remaining
99822
Fit
Quit Program
Plot Selector
8
Tracking Display
Fit Results
a
26.22
mu
0.05
sigma
0.26
Mean
0.10
Sigma
0.34
Integral
143.00
Low
-0.96
High
1.39
Total Counts
164
220
200
180
160
140
120
100
80
60
40
20
-50
0
50
100
150
200
250
300
0.
1.
2.
3.
4.
5.
6.
7.

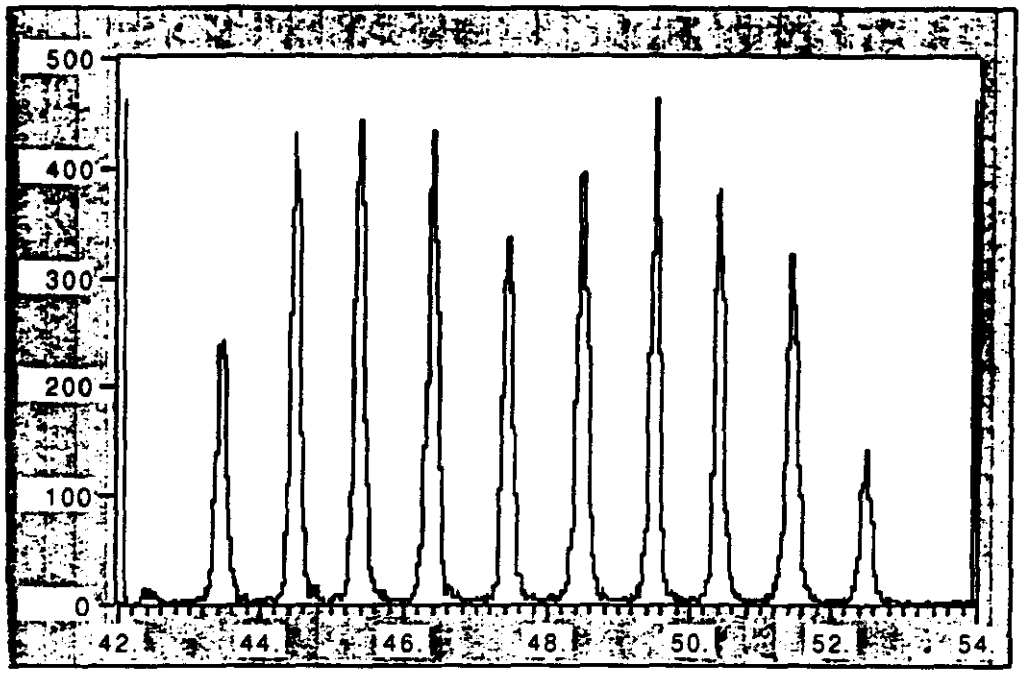



Figure 14a

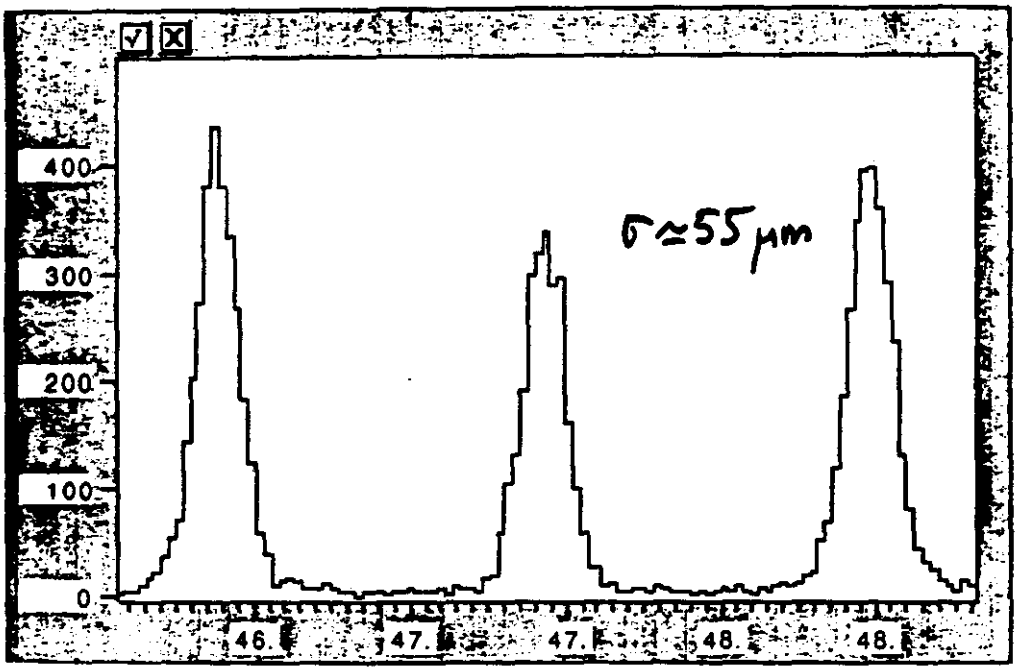



Figure 14b

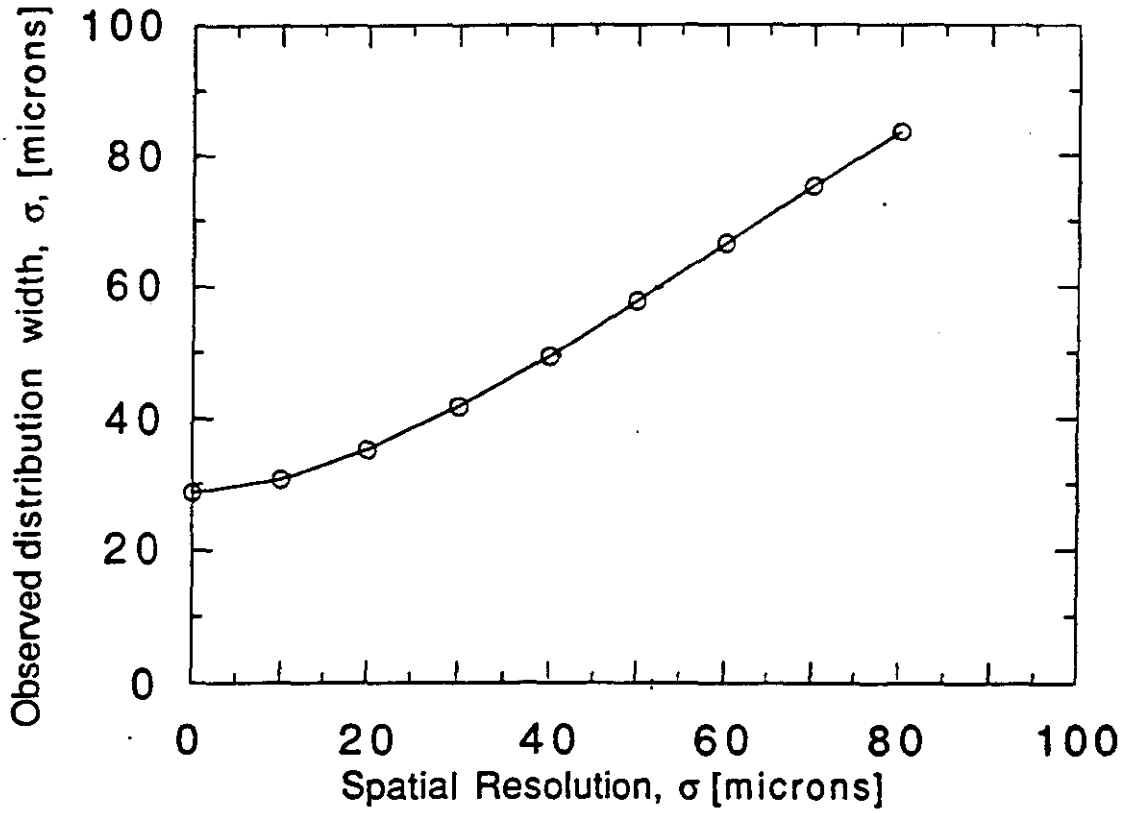

Observed distribution width, σ, [microns]
100
80
60
40
20
0
0
20
40
60
80
100
Spatial Resolution, σ [microns]

Figure 15

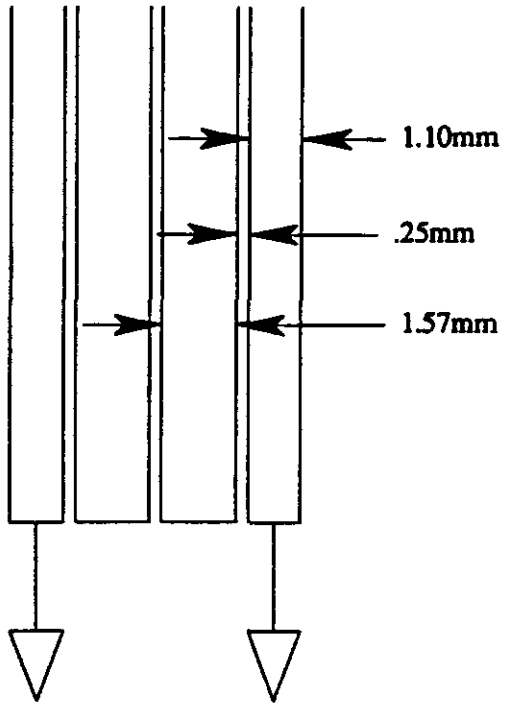



Figure 5a

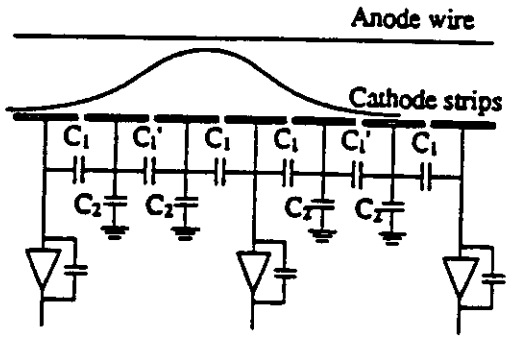



Figure 5b

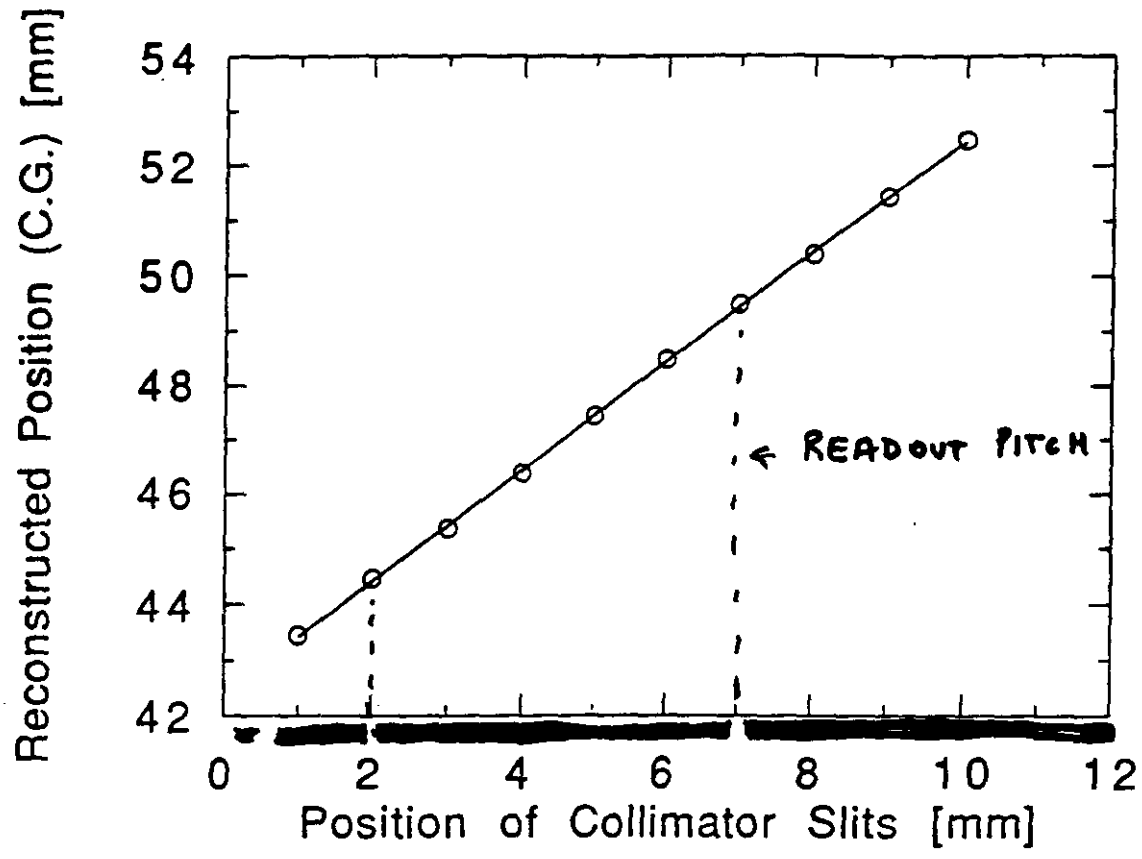



Figure 16a

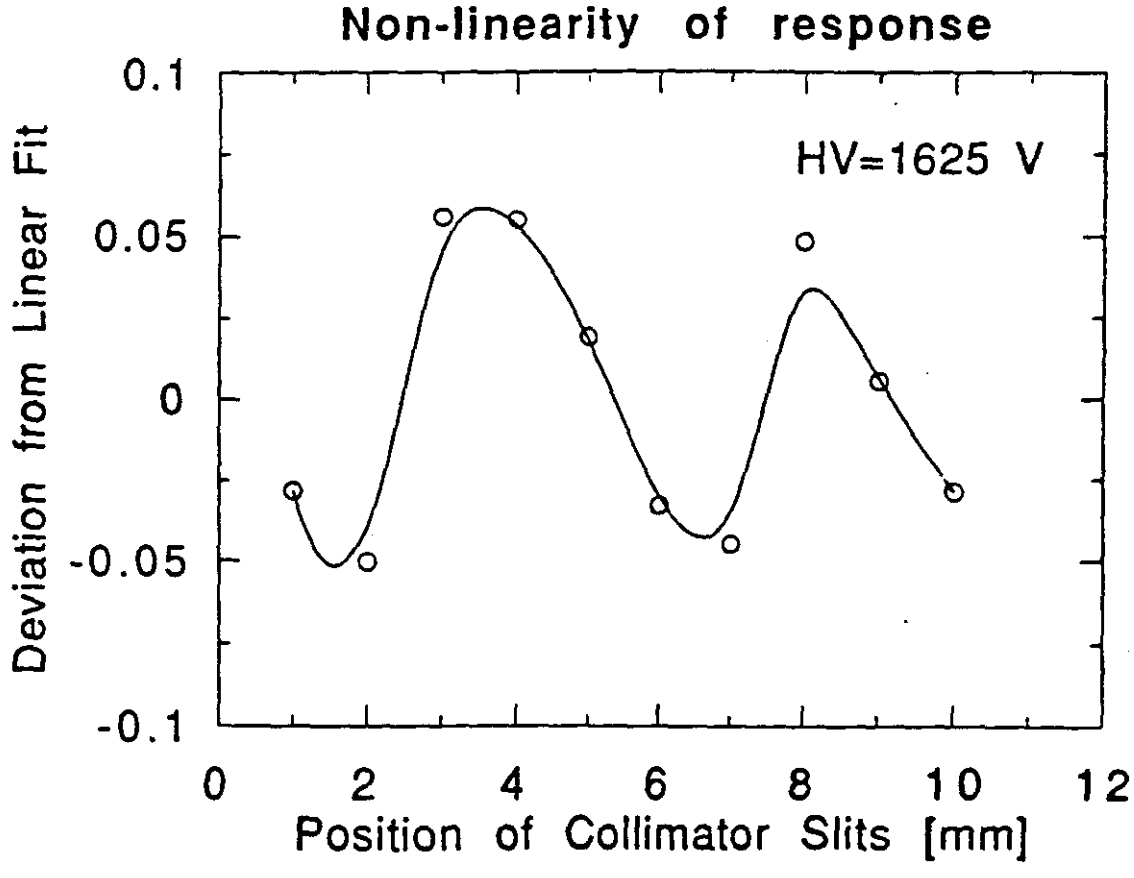
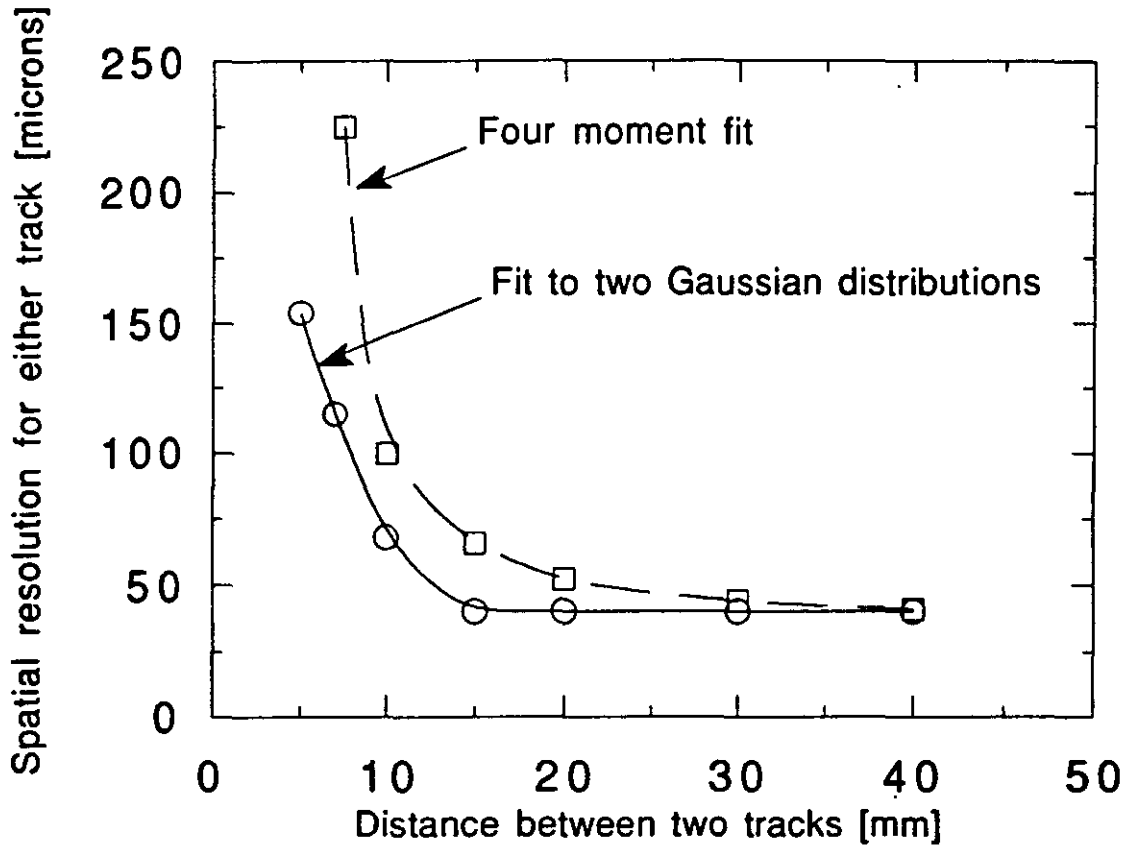



Figure 16b

## Chamber Performance Simulations

Detailed Monte Carlo developed to study/optimize design. It takes into account:

- Electronic Noise contribution
- Channel-to-channel intercalibration
- Diffusion of the Electrons
- Range of $\delta$-electrons
- Lorentz effect
- Differential nonlinearity
- The effect of anode wires that are not at right angles wrt cathode strips.


Spatial resolution for either track [microns]
250
200
150
100
50
0
Four moment fit
Fit to two Gaussian distributions
0
10
20
30
40
50
Distance between two tracks [mm]

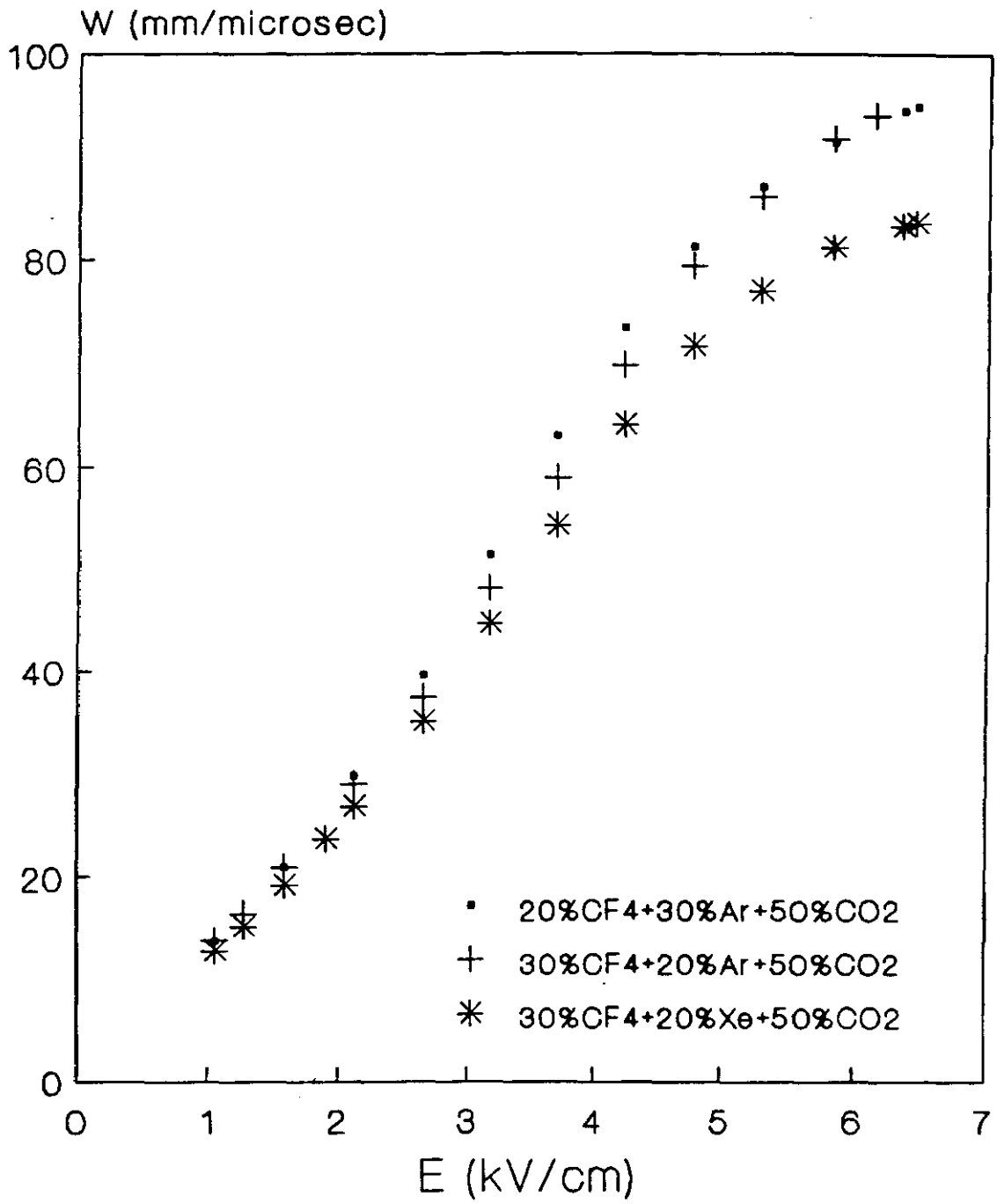
**Gas Requirements**

- High Drift Velocity
- Low ($< 8°$) Lorentz angle
- Nonflammable, nontoxic

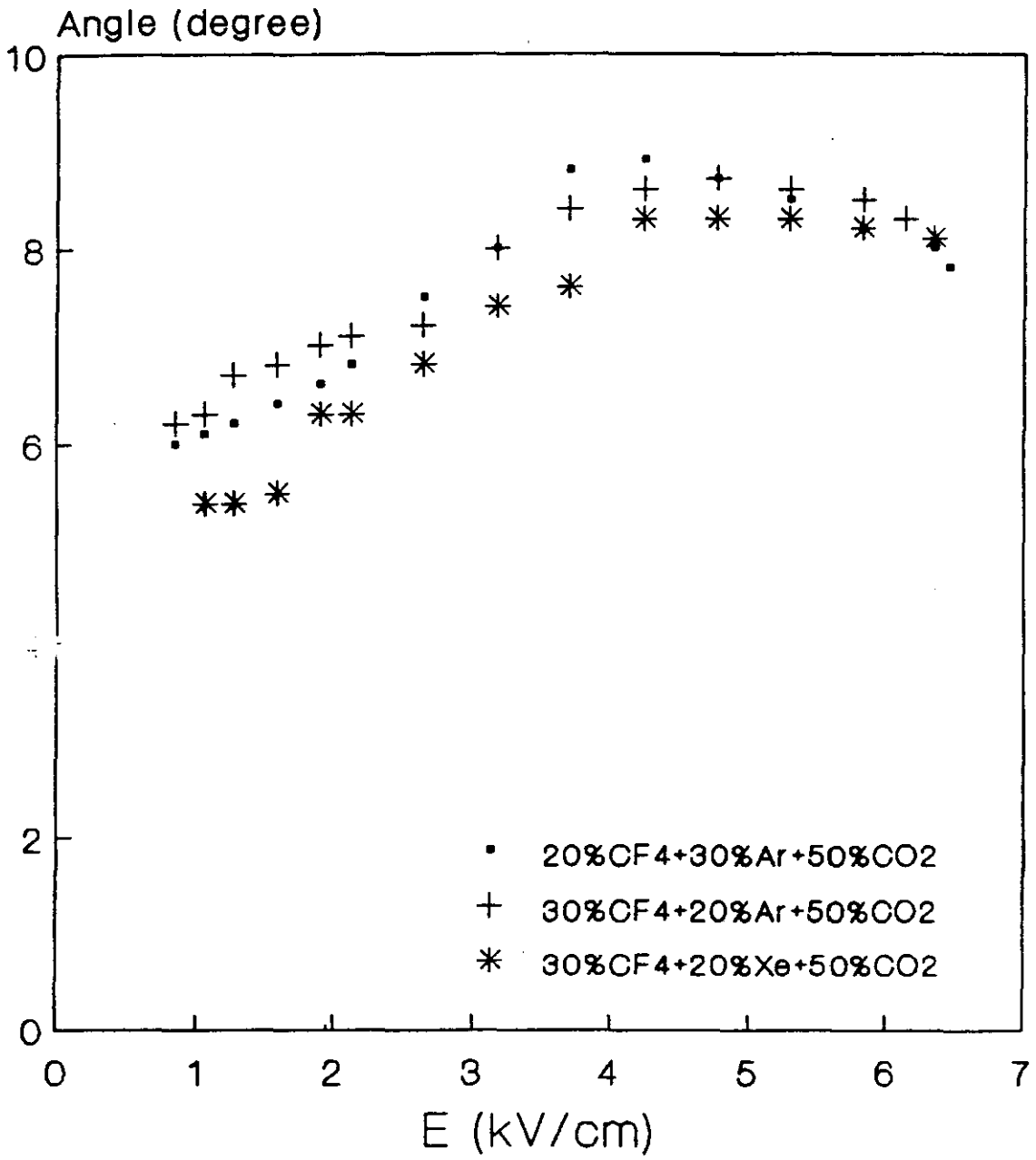
20%$CF_4$, 30%Ar, 50%$CO_2$ current choice.

All chambers being tested with min. ionizing particles operate with gas that could be used in GEM.

# Drift velocity



# Lorentz angle
## B = 0.8 T



## Electronics Development

- Prototypes fully instrumented. Small prototype at the SSC/TTR has 1/4 of channels of largest module. Full size prototype will have as many channels as the actual experiment modules.
- Compact, high performance readout using existing ICs implemented.
- Monolithic Developments at BNL, Minsk, PNPI, Princeton under way for the production version. For some IC's prototypes already fabricated.

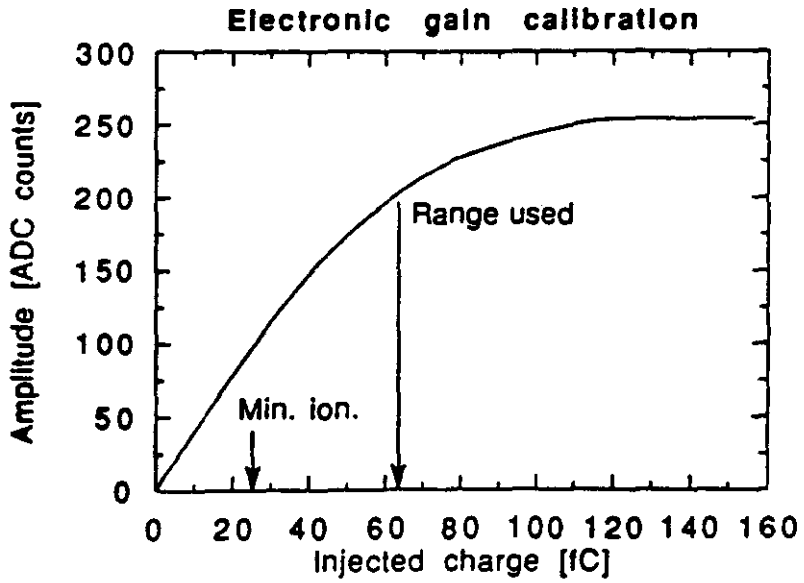



Figure 9a

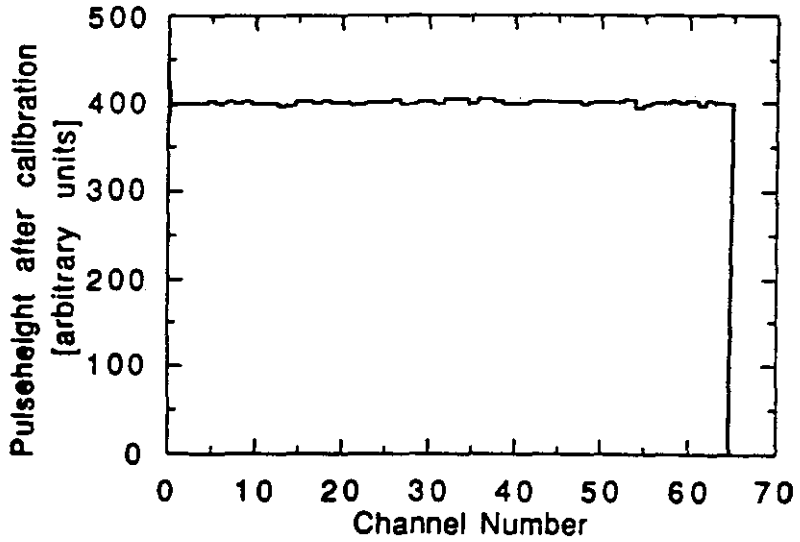



Figure 9b

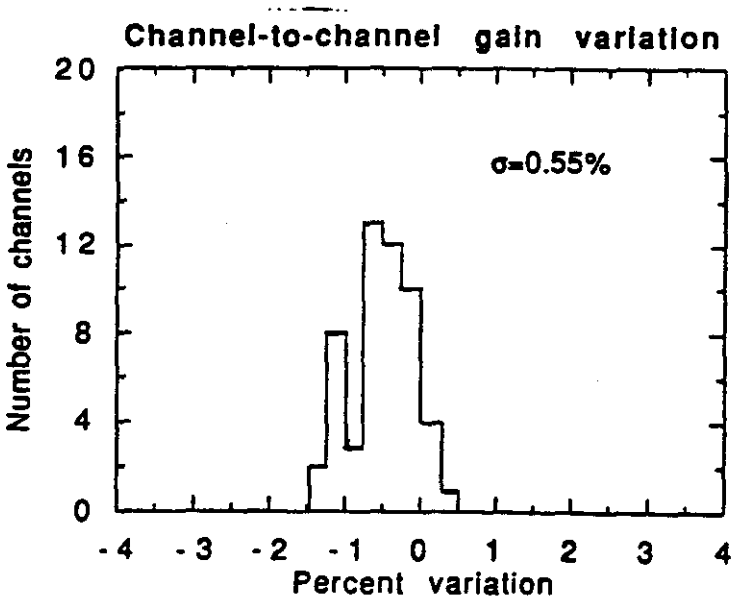
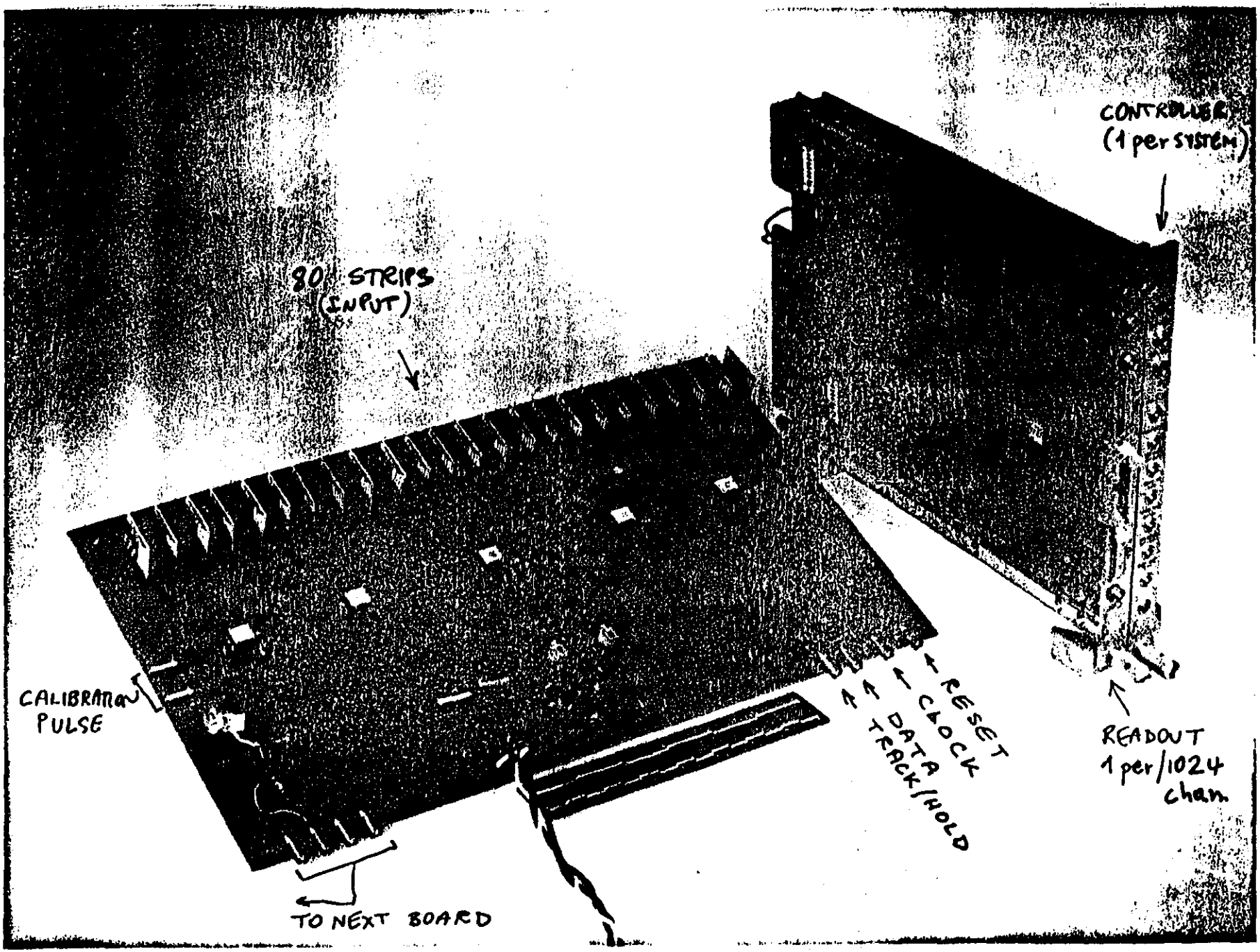
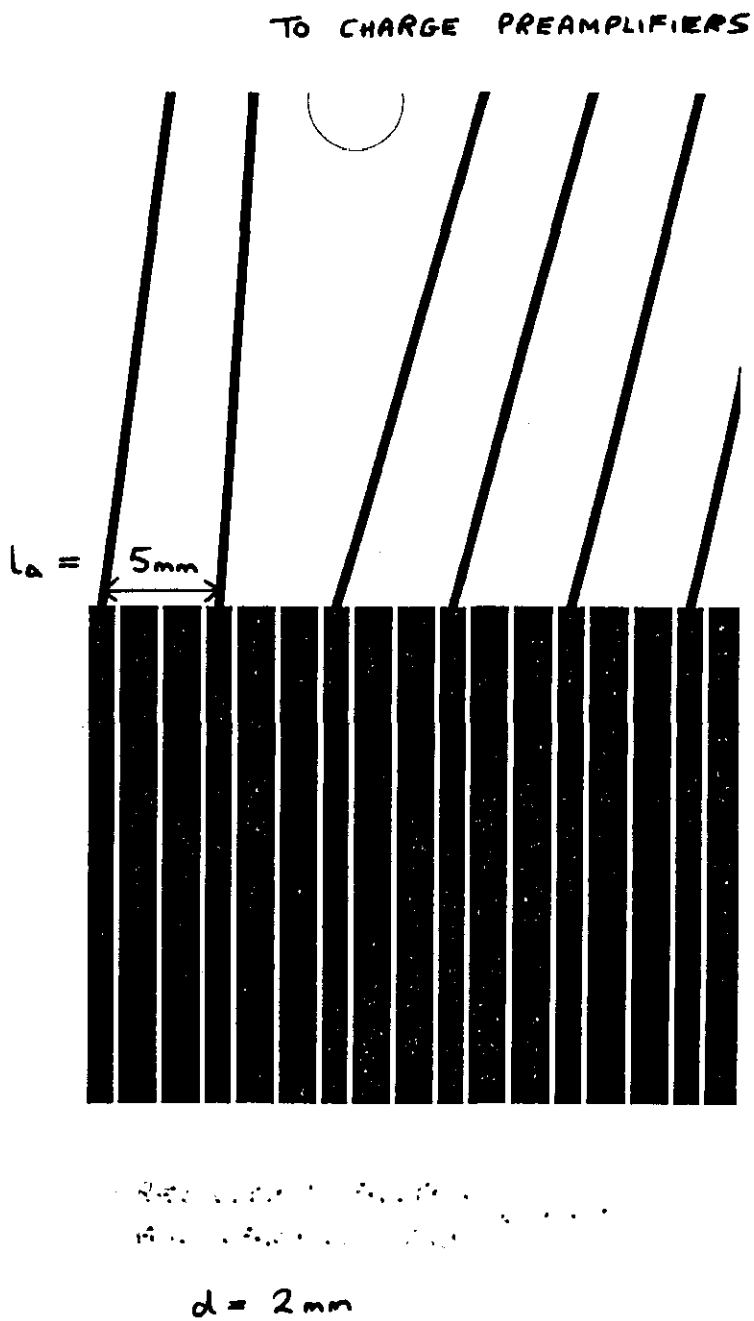


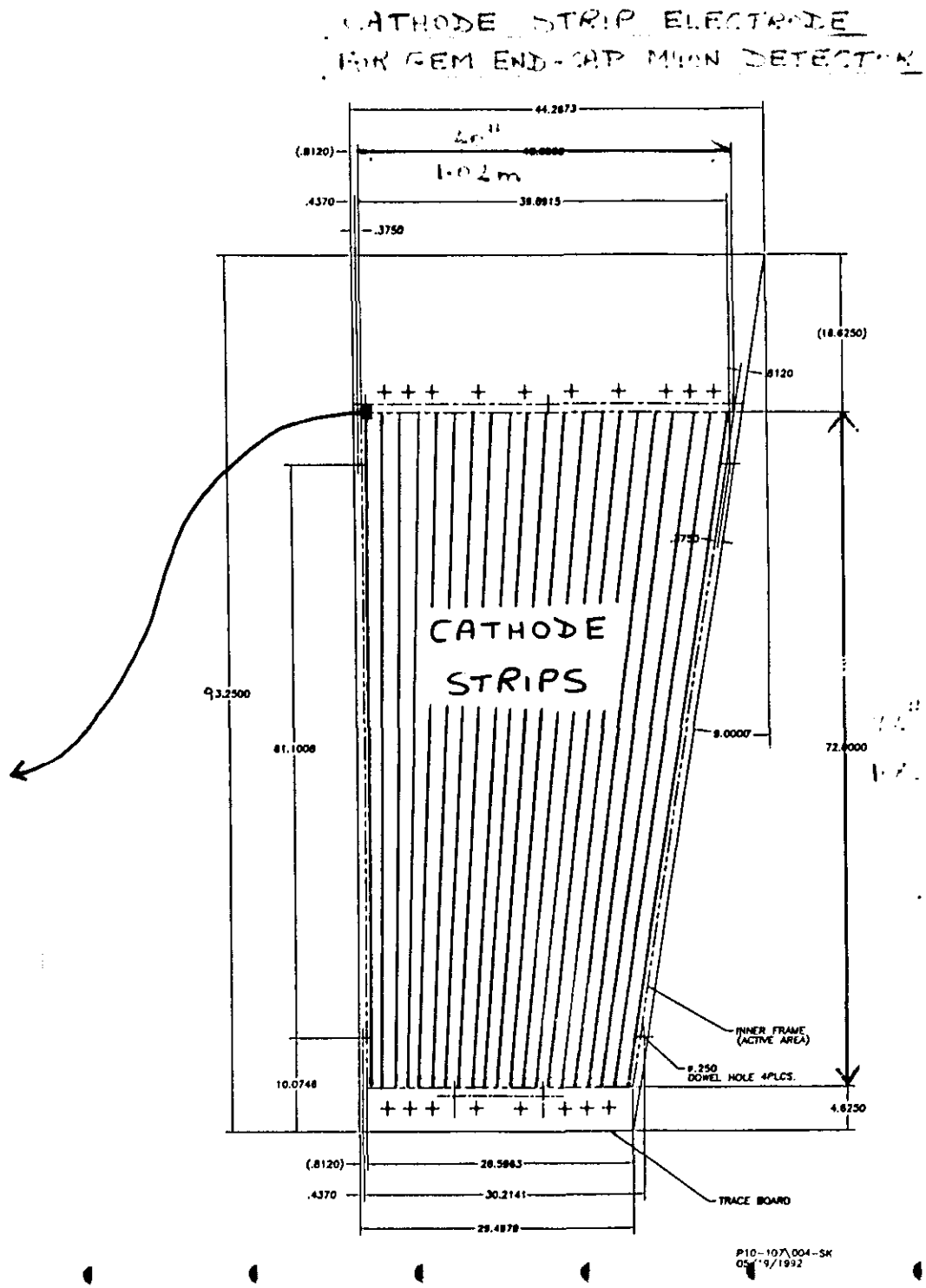

Figure 9c

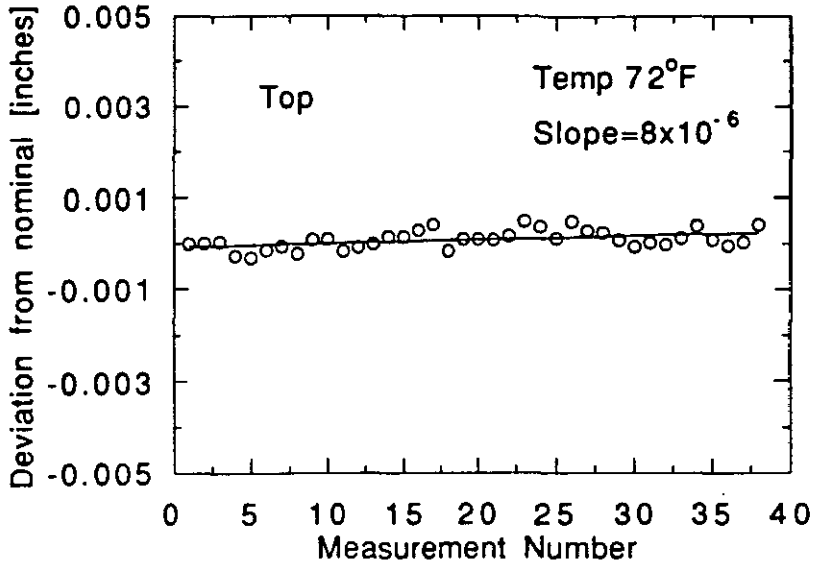

CONTROLLER
(1 per SYSTEM)
80 STRIPS
(INPUT)
CALIBRATION
PULSE
RESET
CLOCK
DATA
TRACK/HOLD
READOUT
1 per/1024
chan.
TO NEXT BOARD

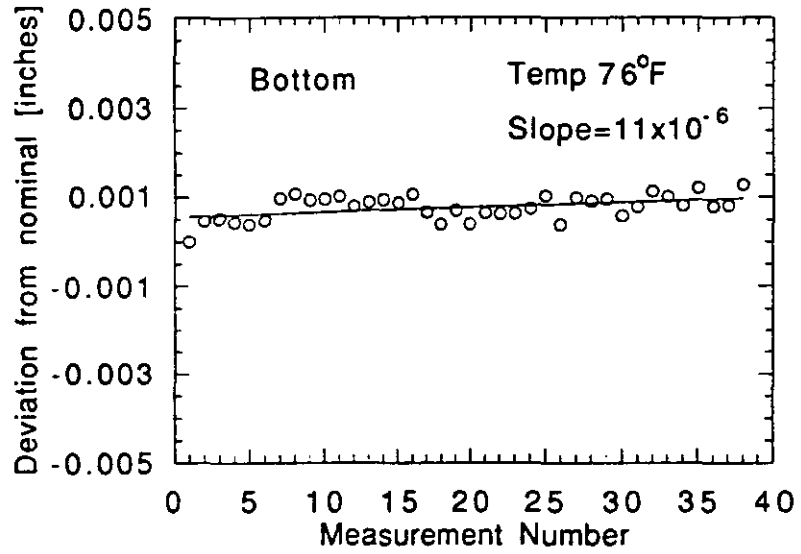
## Alignment

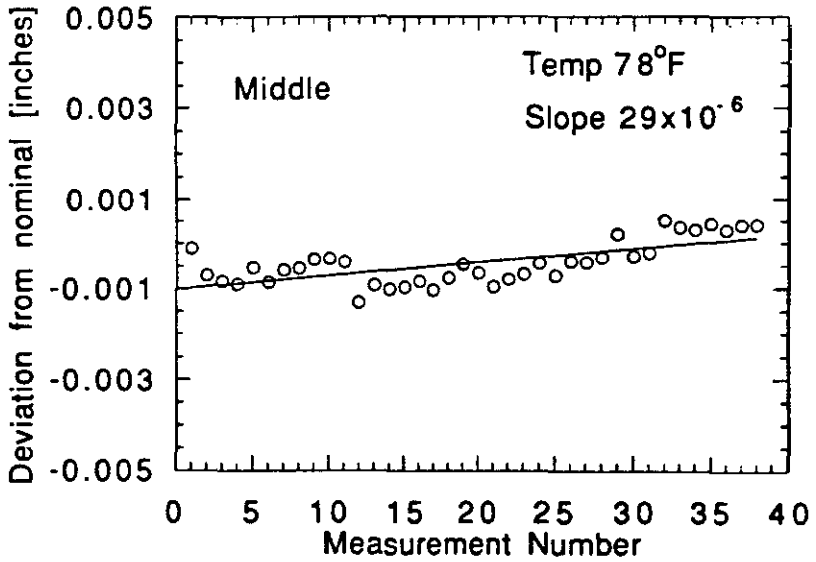
- Internal Chamber Alignment is integral to the cathodes. Externally visible alignment marks etched along with strips with photolithography.
- CSCs have minimum number of alignment transfers.
- X-ray diagnostic techniques can be used to verify strip position in situ (work in progress at PNPI, BNL).


TO CHARGE PREAMPLIFIERS
$L_a$ = 5mm
d = 2mm


CATHODE STRIP ELECTRODE
FOR GEM END-CAP MUON DETECTOR
44.2873
40"
1.02m
(.8120)
.4370
38.8915
.3750
(18.6250)
.8120
CATHODE
STRIPS
93.2500
81.1008
9.0000
72.0000
INNER FRAME (ACTIVE AREA)
9.250 DOWEL HOLE 4PLCS.
10.0748
4.6250
(.8120)
28.5863
.4370
30.2141
29.4878
TRACE BOARD
P10-107\004-SK
05/19/1992

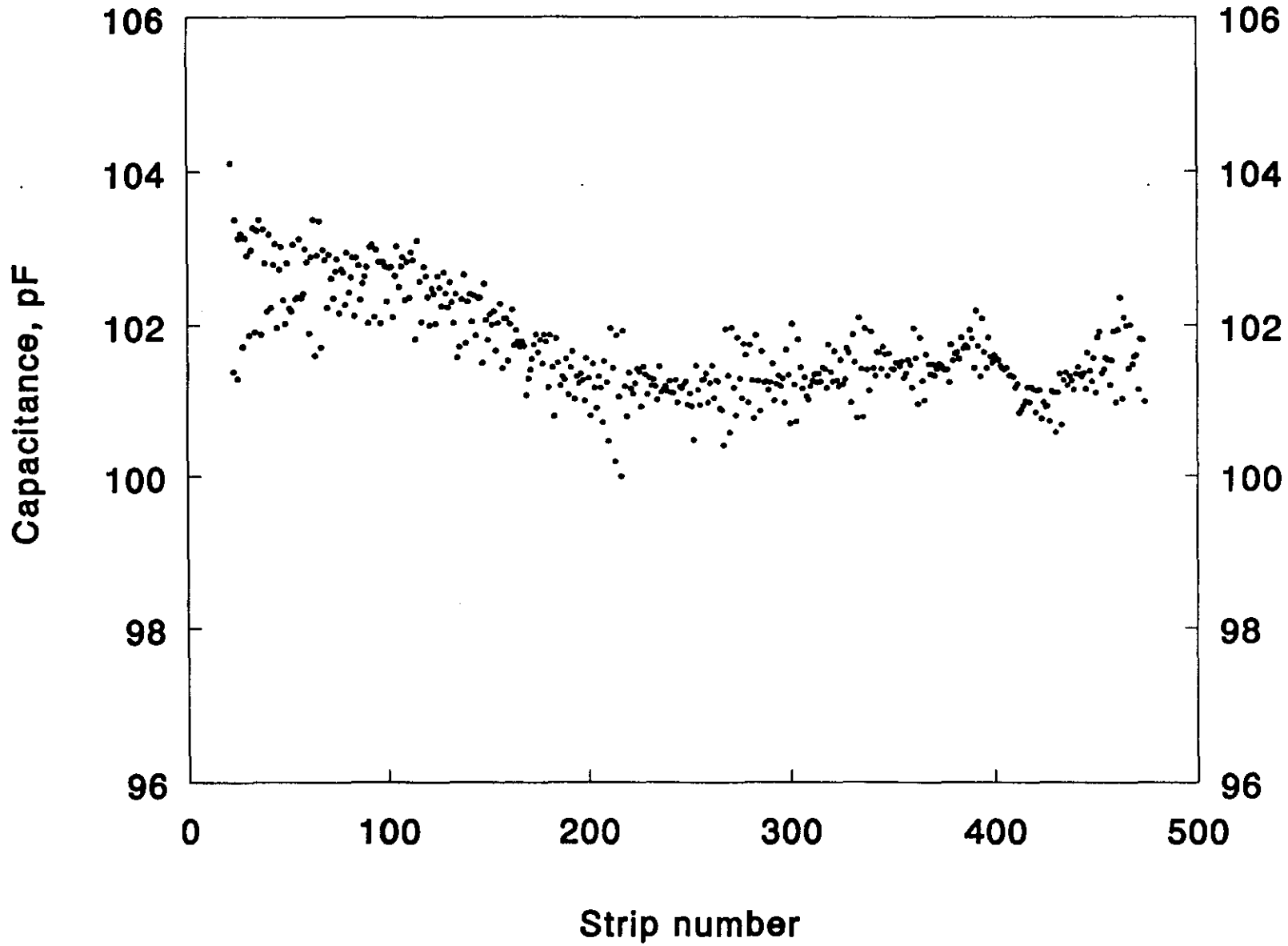

Top
Temp 72°F
Slope=8x10^-6
Deviation from nominal [inches]
0.005
0.003
0.001
-0.001
-0.003
-0.005
0 5 10 15 20 25 30 35 40
Measurement Number

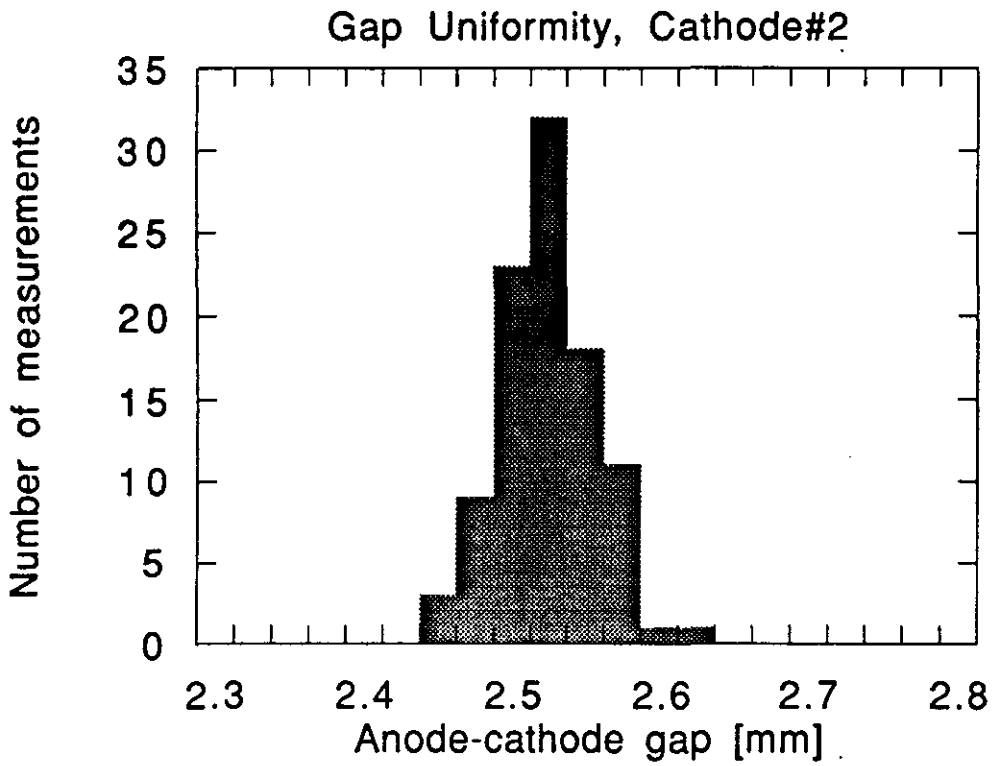

Bottom
Temp 76°F
Slope=11x10^-6
Deviation from nominal [inches]
0.005
0.003
0.001
-0.001
-0.003
-0.005
0 5 10 15 20 25 30 35 40
Measurement Number

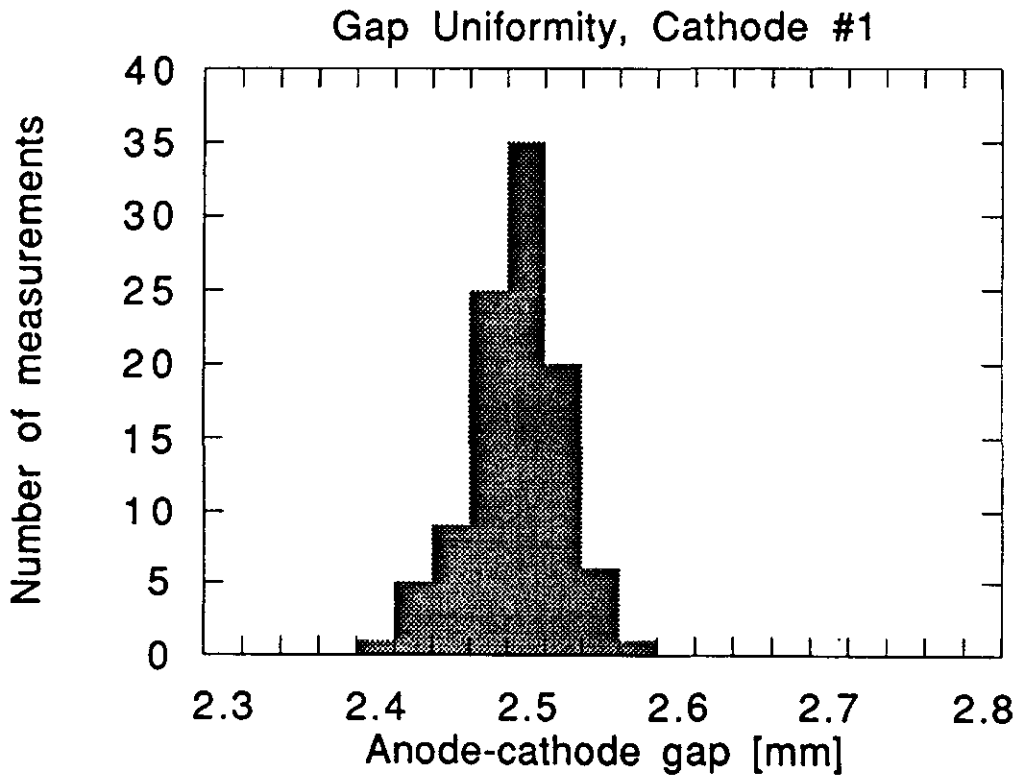

Middle
Temp 78°F
Slope 29x10^-6
Deviation from nominal [inches]
0.005
0.003
0.001
-0.001
-0.003
-0.005
0 5 10 15 20 25 30 35 40
Measurement Number

# Capacitance between strips

## Big prototype CSC




Gap Uniformity, Cathode#2
Number of measurements
35
30
25
20
15
10
5
0
2.3
2.4
2.5
2.6
2.7
2.8
Anode-cathode gap [mm]


Gap Uniformity, Cathode #1
Number of measurements
40
35
30
25
20
15
10
5
0
2.3
2.4
2.5
2.6
2.7
2.8
Anode-cathode gap [mm]

## Neutron Studies

Boston U. studies at MIT Cf source along with the other Technologies. Results reported at several Muon Meetings).

gem

$\gamma e \mu$

# Muon System Technology Options

LSDT—L. Osborne

# LIMITED STREAMER DRIFT TUBES FOR THE GEM MUON SYSTEM


LSDT R & D Group

**R. Sumner**

*LeCroy Corp., Chestnut Ridge, NY*

**R. McNeil, W. Metcalf**

*Louisiana State Univ., Baton Rouge, LA*

**W. Busza, H. W. Kendall, A. Korytov, J. Kelsey, L. S. Osborne, L. Rosenson, F. E. Taylor, R. Verdier, B. Wadsworth**

*Massachusetts Institute of Technology*

*Cambridge, MA*


We expect that whatever technologies are chosen most of the present GEM muon group will coalesce around the chosen one(s). Many groups here who have expressed a definite interest in pursuing LSDT's were they selected. Among them:

**Joint Institute for Nuclear Research, Dubna, Russia**

**Institute of High Energy Physics, Beijing, P. R. China**

**Superconducting Super Collider Lab, Dallas, Texas**

**University of Houston, Houston, Texas**

# Serendipity

*For LSDT*

Streamer Mode

↓

Measuring accuracy; 50 to 100 $\mu$m

+

Modern Machine Tools

Typical accuracies; 2/10,000" = 5 $\mu$m

↓

Accurate Wire Placement

# Gases Considered

Argon(A), Isobutane(IB) Safety!!
A(few %),IB(10 %), $CO_2$
A(few %),IB(10%),$CO_2$,$CF_4$

IB($\leq$10%)-non-flammable
$CO_2$-ohmic,slow,cool
$CF_4$-flat,fast

## Merits of Streamer-Drift System

1. Preservation of the fast rise time in pulse transmission. ~10 nsec. ~ 100 mV
2. Open structure for laying down wires-allows multiple wire placement and placement checking for ease of construction.
3. Precision wire positioning.
4. Minimum scattering material.
5. No restriction on chamber length.
6. Parts and assembly amenable to mass production.
7. Stiffness in the final chamber to minimize support points.
8. Single wire resolution of $\sim 100\mu$m.
9. Qne tube per one wire minimizes efficiency loss in wire breakage.

# Streamer Pulse

**Fast: 10 nsec rise time**

**Large: $\sim$ 100 mv**

| Table X.1: Resolution* and $T_{max}$ for Drift Readout in 2.5 cm. cells | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Gas → | A-IB 25 – 75 | | A-IB-$CO_2$ 2.5 – 9.5 – 88 | | $CO_2$ – $CF_4$ – IB 20 – 69 – 11 | | $CO_2$ – $CF_4$ – IB 40 – 50 – 10 | |
| Ioniz. Source ↓ | $\sigma$ ($\mu m$) | $T_{max}$ (n sec) | $\sigma$ ($\mu m$) | $T_{max}$ (n sec) | $\sigma$ ($\mu m$) | $T_{max}$ (n sec) | $\sigma$ ($\mu m$) | $T_{max}$ (n sec) |
| Laser-no mag. field | 35 | 260 | 55 | 830 | 70 | 280 | 70 | 460 |
| Laser-mag. field(0.8 T) | 45 | 278 | 60 | 835 | 75 | 295 | | |
| 0.5 TeV Muons | 55 | | | | 95 | | 75 | |

* Averaged over all drift times

| Table X.2: Resolution* for Pick-up Strip Readout ( 1.0 cm. strips) | | |
|---|---|---|
| GasAmpl.Mode → Ioniz.Source ↓ | Proportional | Limited Streamer |
| Laser | 45 $\mu m$ | 100 $\mu m$ |
| 0.5 TeV Muons | 85 $\mu m$ | |

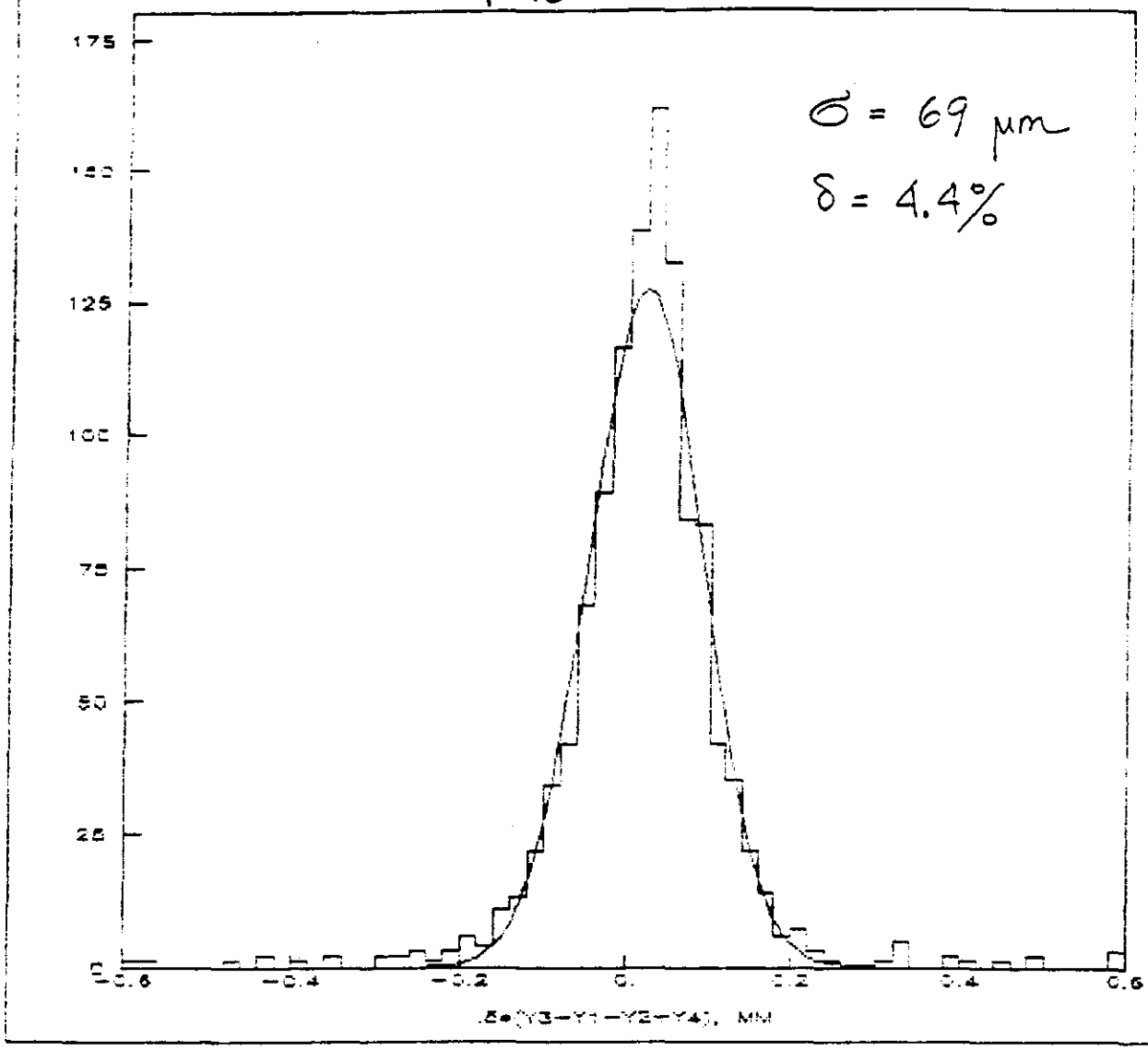
* Averaged over all ionization positions

## Worries Over Cathode Strips

1.) Measuring to 100 $\mu$m with 1 cm strip requires a 1% measurement.
   a.) Superb amplifiers though mass produced.
   b.) Very accuratly made strips.
2.) Thermal noise requires long ($\sim$ 1 $\mu$sec integrating times.
3.) Thermal noise places upper limits on the size of the strips and, therefore the chambers.
   a.) Needs many small chambers.
   b.) Large number of electronics channels.
4.) Man made noise will be present to some extent; this will not be known quantitatively until turn on day.

PRELIMINARY 9/20/92

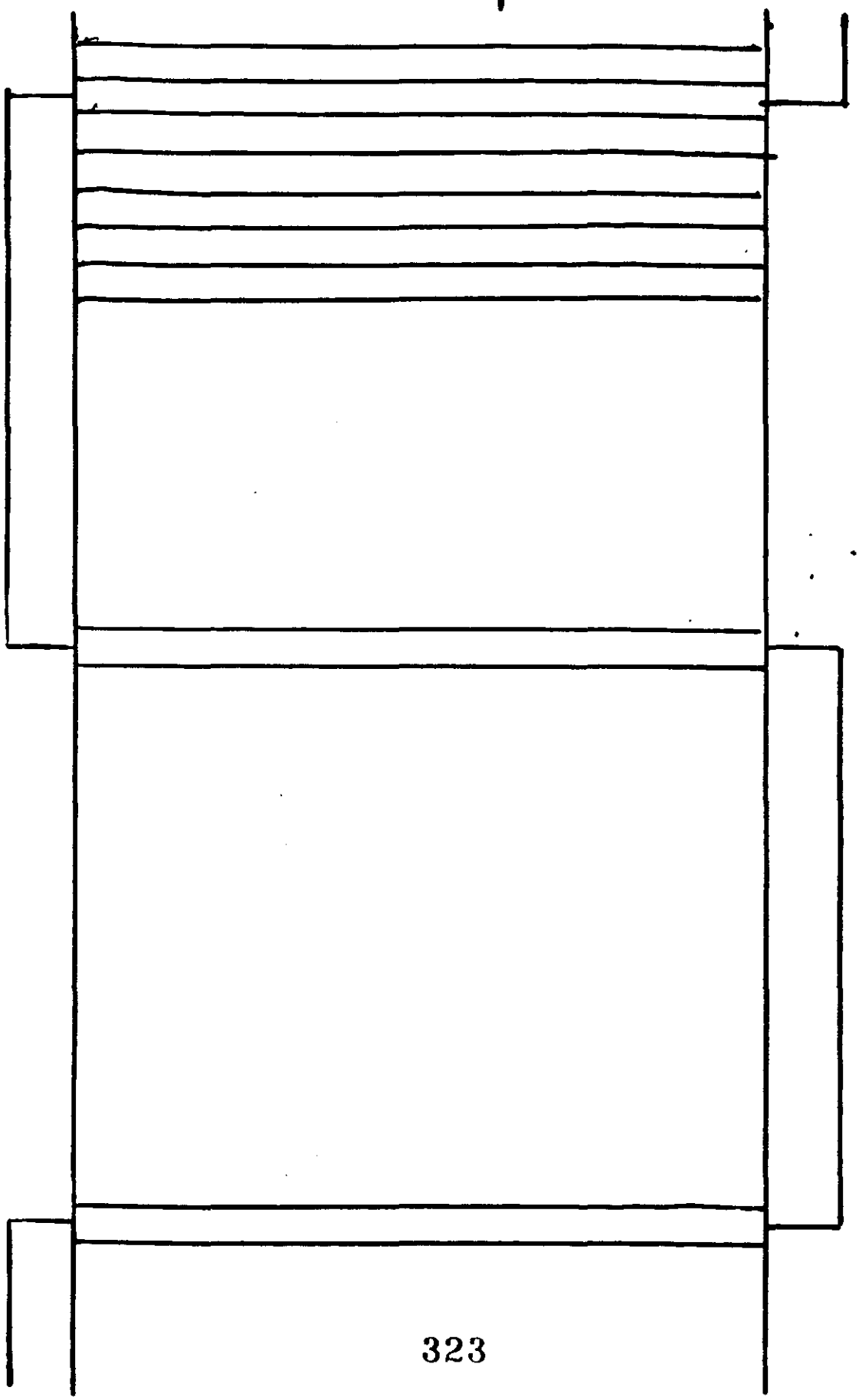
$Ar + C_4H_{10} = 25 + 75$




ALL TRACKS GOING BETWEEN WIRES

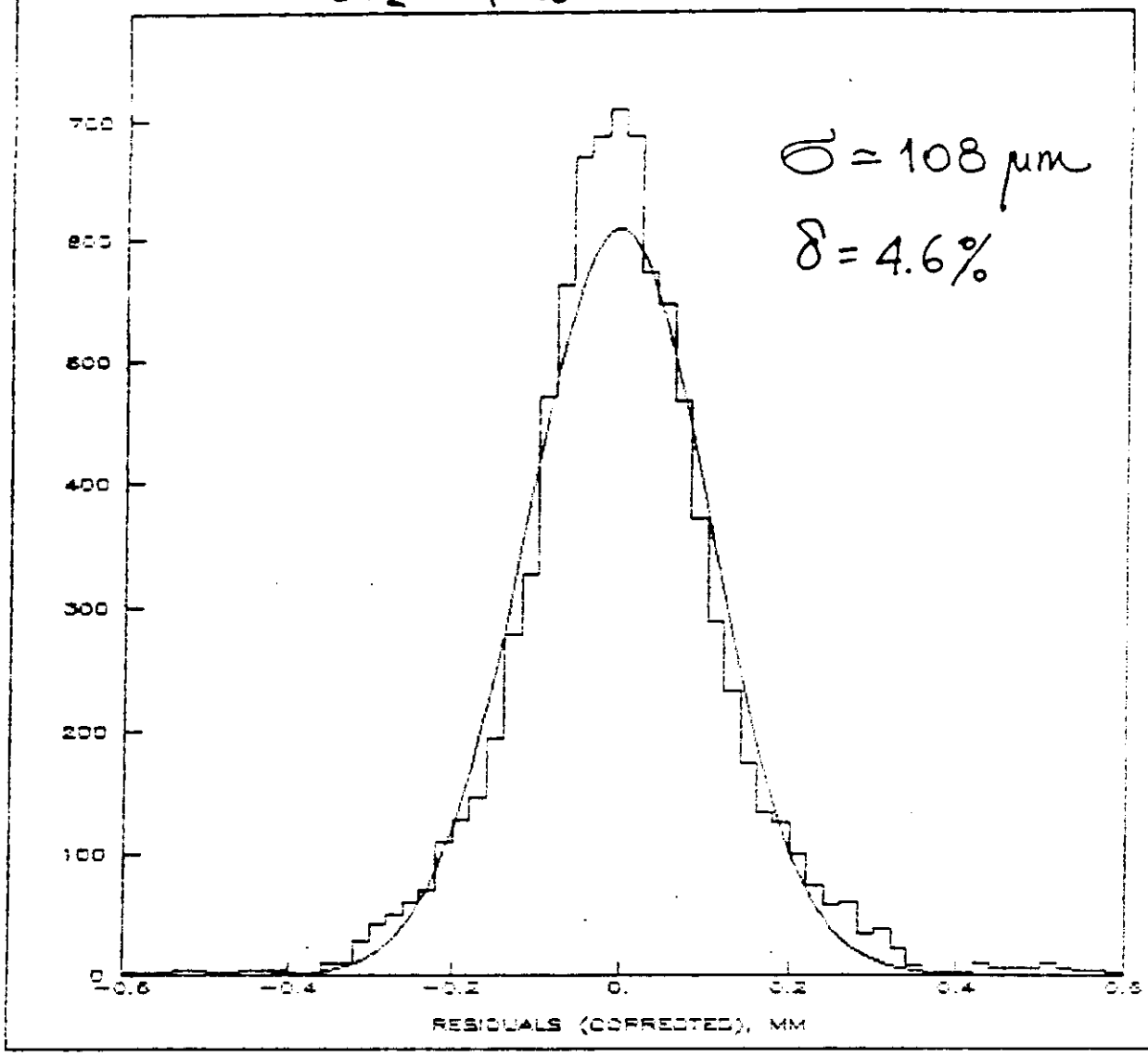
($\sigma_\alpha \sim 4°$)

Z- strips



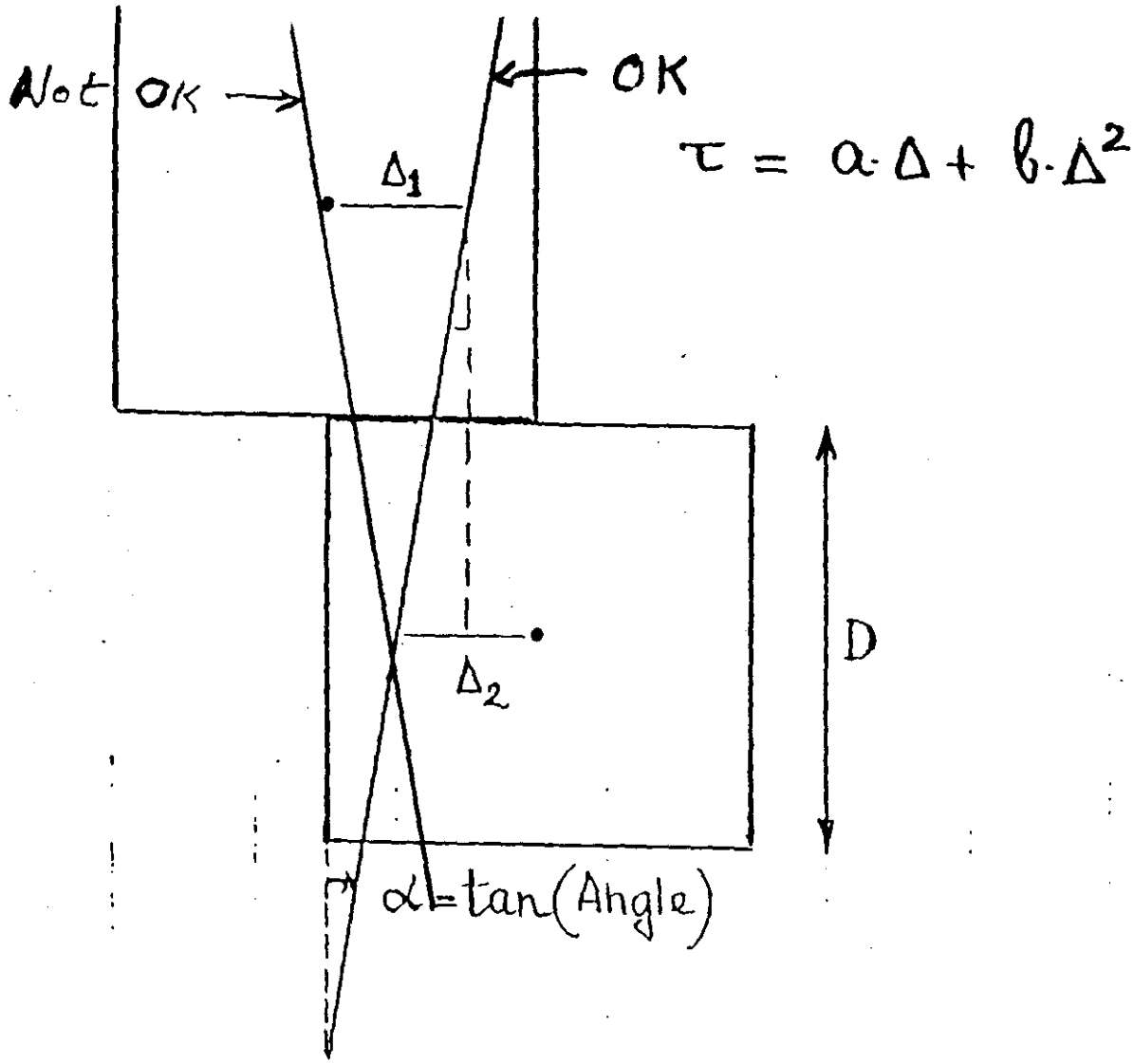
PRELIMINARY 9/18/92

$Ar + CO_2 + C_4H_{10} = 2.5 + 88 + 9.5$






$|\alpha| \leq 5°$ $\sigma = 108$ μm




$$\tau = a \cdot \Delta + b \cdot \Delta^2$$

$$T_0 = \frac{T_1 + T_2}{2} - \frac{a \cdot C_0}{2} - \frac{b}{4}\left(C_0^2 + \frac{(\Delta T)^2}{(a + bC_0)^2}\right)$$

$$C_0 = \frac{D}{2} + \alpha \cdot D$$

Fig.A.IV.5

SL2

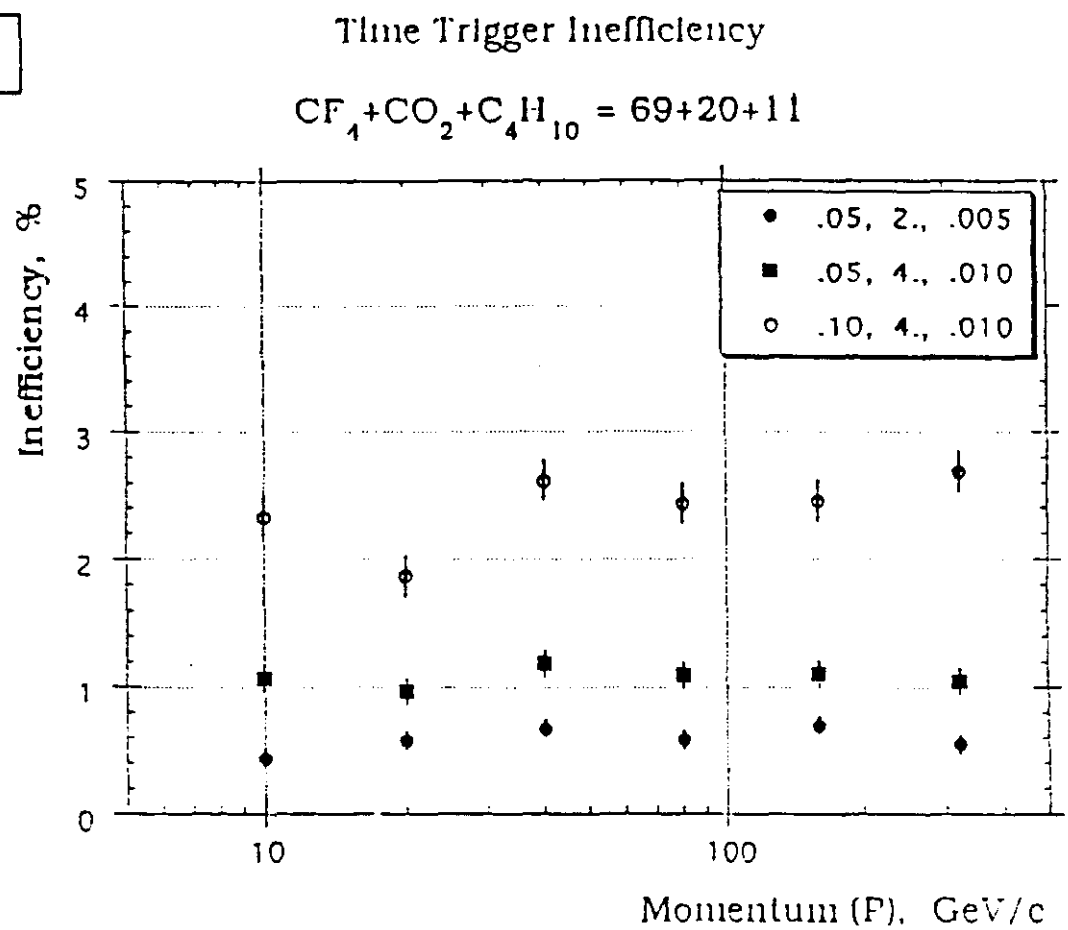
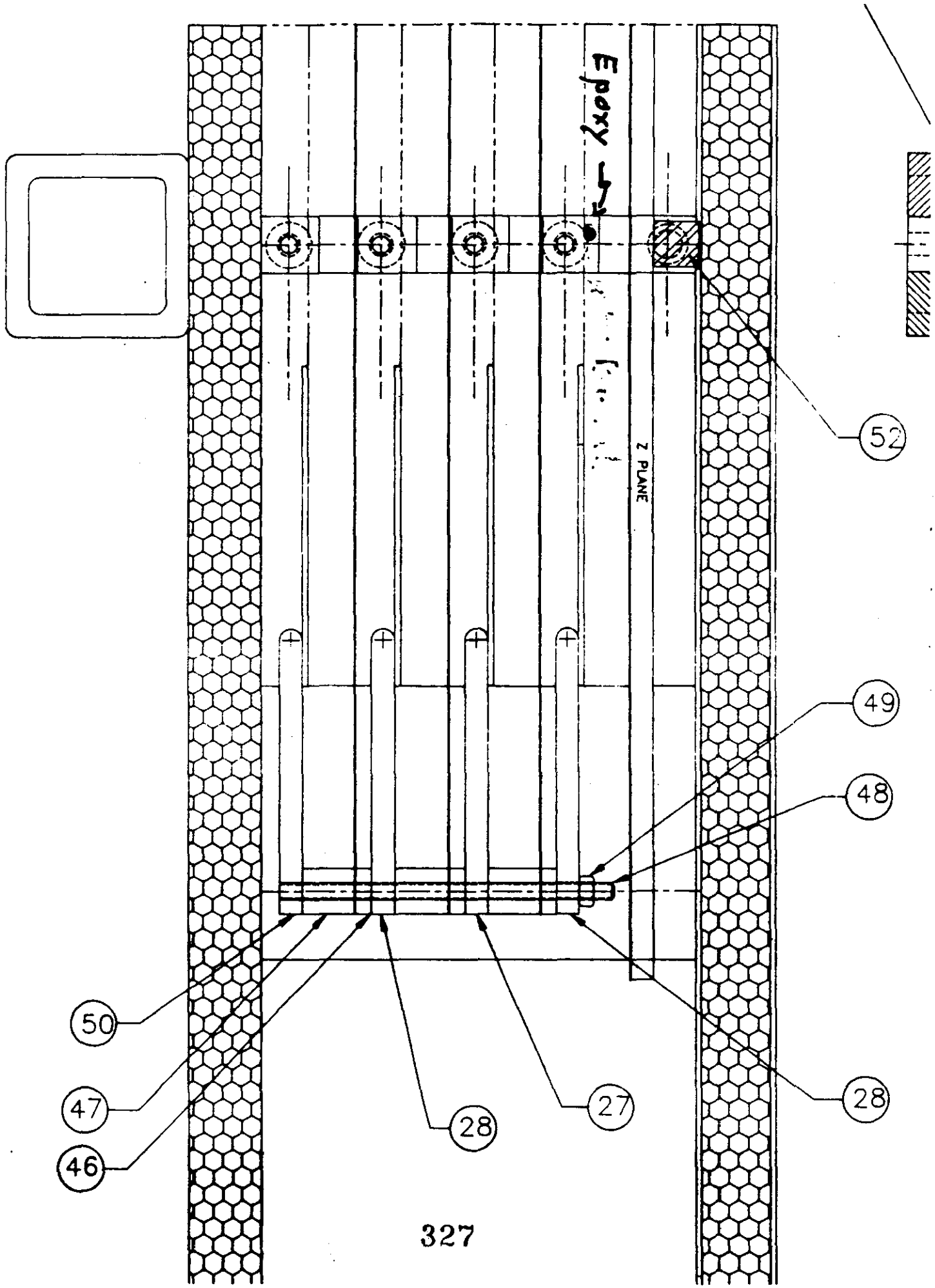
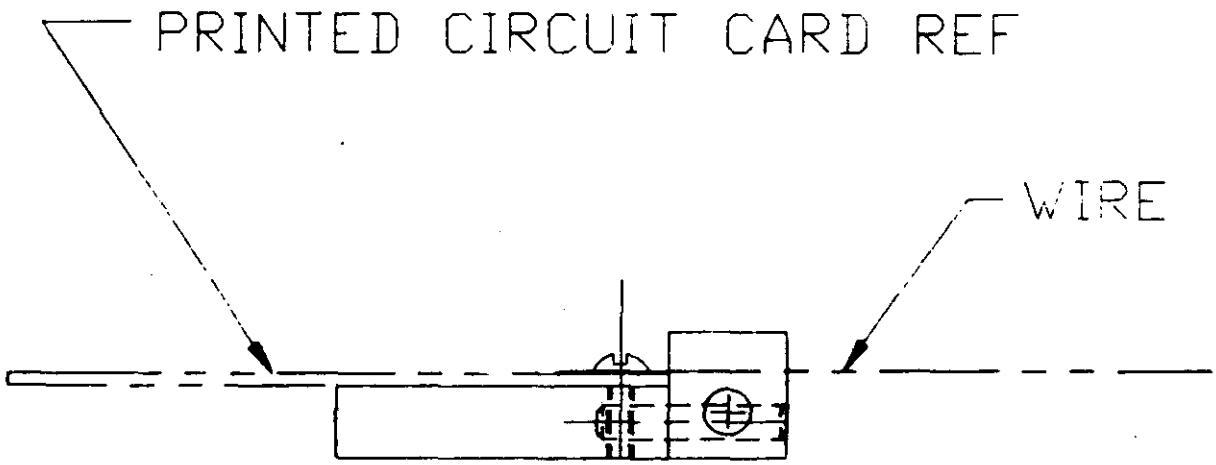
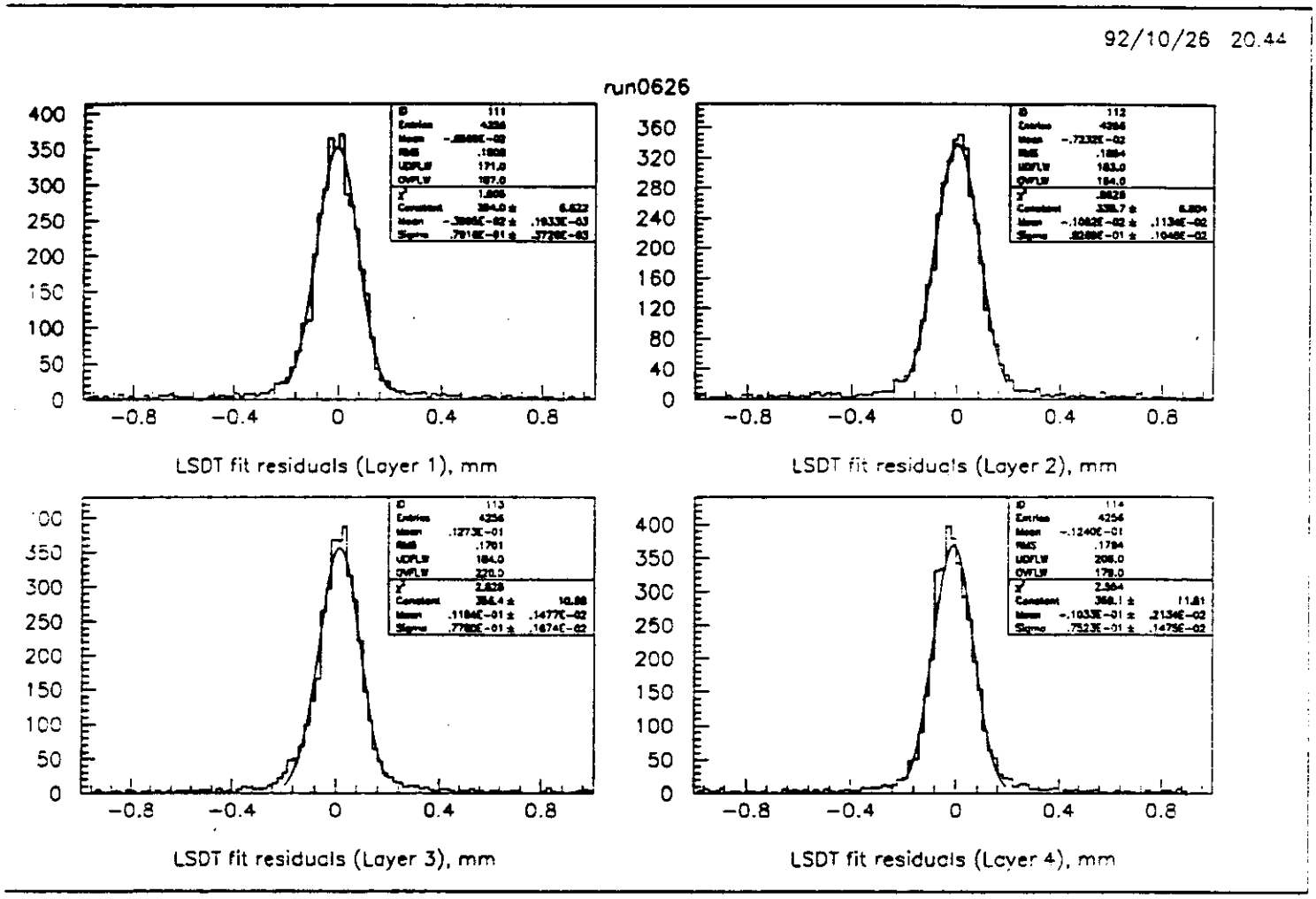

Time Trigger Inefficiency
$CF_4+CO_2+C_4H_{10}$ = 69+20+11
Inefficiency, %
5
4
3
2
1
0
10
100
Momentum (P), GeV/c
.05, 2., .005
.05, 4., .010
.10, 4., .010

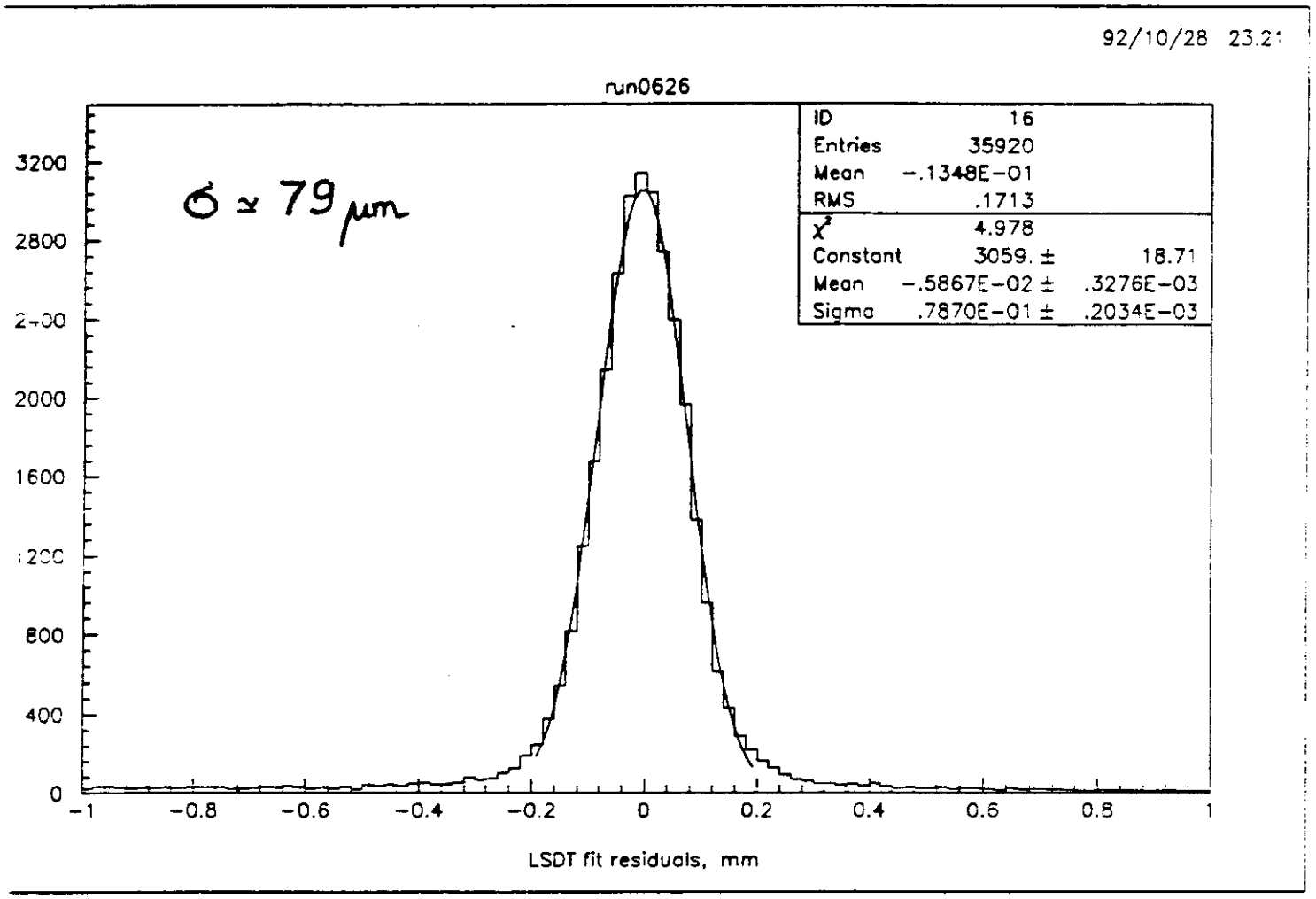
Fig.A.IV.8


Epoxy
Z PLANE
52
49
48
50
47
46
28
27
28


PRINTED CIRCUIT CARD REF
WIRE

| Layer | Sigma (μm) | Displacement (μm) |
|---|---|---|
| #1 | 79 | −4 |
| #2 | 83 | −1 |
| #3 | 78 | +12 |
| #4 | 75 | −10 |




92/10/28 23.21
run0626
ID 16
Entries 35920
Mean −.1348E−01
RMS .1713
χ² 4.978
Constant 3059. ± 18.71
Mean −.5867E−02 ± .3276E−03
Sigma .7870E−01 ± .2034E−03
σ ≈ 79 μm
3200
2800
2400
2000
1600
1200
800
400
0
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
LSDT fit residuals, mm

## What are we waiting for?

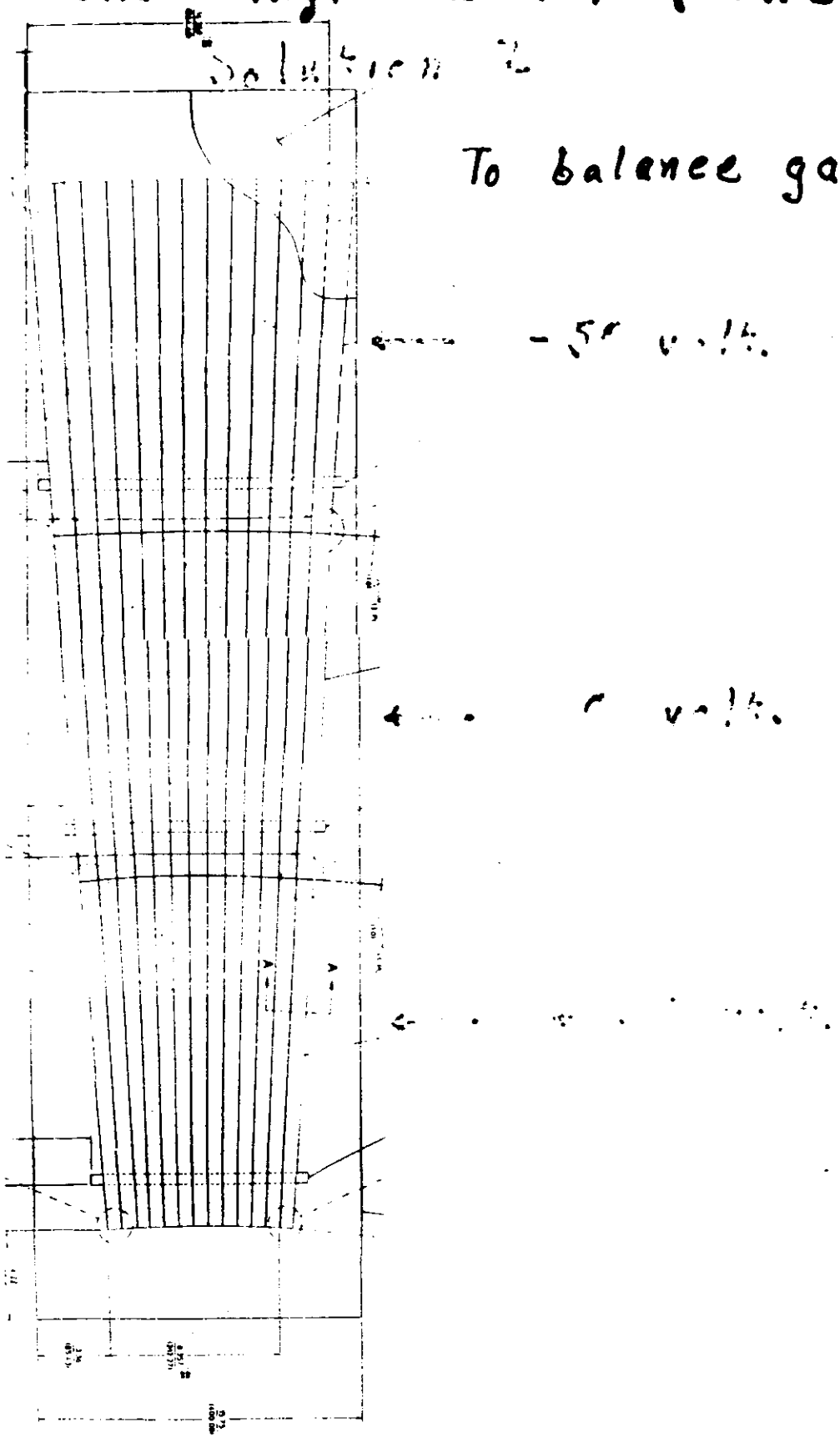
**LSDT have:**

1.) Baseline accuracy ($CF_4$ yet to be measured)
2.) Triggering ability
3.) $r\phi$ - z measurement
4.) Documented drawings
5.) Documented costs
6.) Exportability
7.) Conservatism-e.g. less susceptible to noise

**What more do you want?**

Usable at small angles? One technology?

Small Angle LSDT (Checked)



IEEE Transactions on Nuclear Science, Vol. 36, No. 1, February 1989

# WIRE CHAMBER AGEING WITH $CF_4$/ISOBUTANE AND ARGON/ETHANE MIXTURES

R. Henderson+, R. Openshaw, W. Faszer, M. Salomon G. Salomons and G. Sheffer

TRIUMF, 4004 Wesbrook Mall, Vancouver, B.C., Canada V6T 2A3
+ also associated with University of Melbourne, Australia

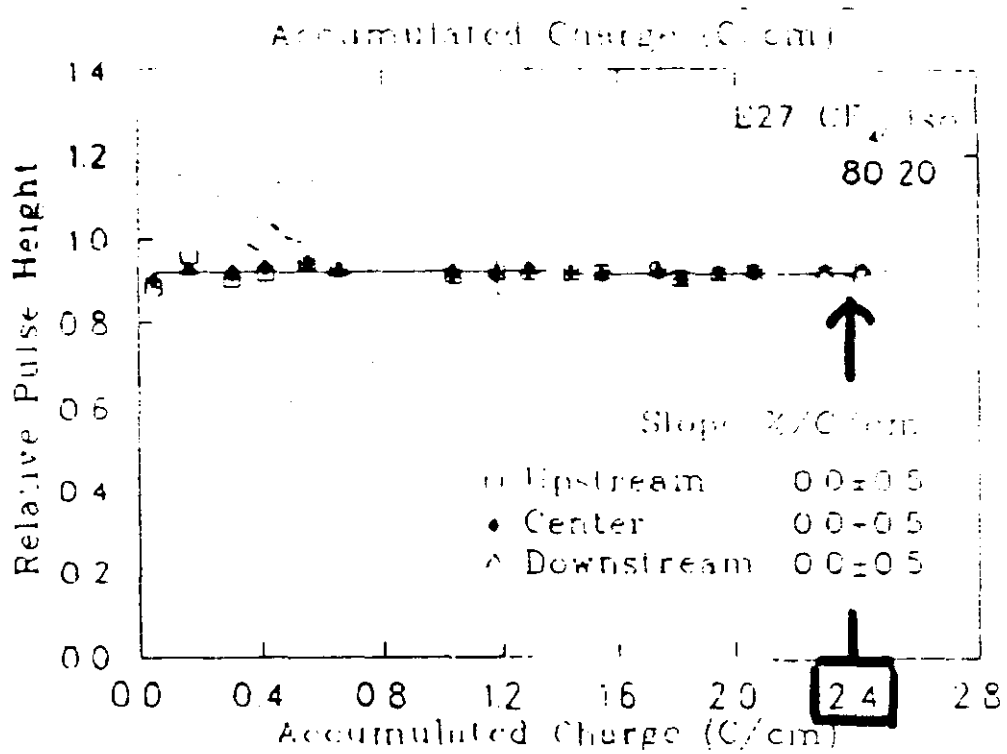
4) The ability of $CF_4$/Iso chambers to withstand accumulated charges exceeding 10 C/cm without suffering large changes in pulse height and exhibiting only small dark currents up to at least 6 C/cm indicates this gas mixture is an excellent candidate for small high flux chambers. We believe this remarkable hardiness is likely related to the chemical activity and radical scavenging ability of flourine

Transactions on Nuclear Science, Vol. 36, No. 1, February 1989

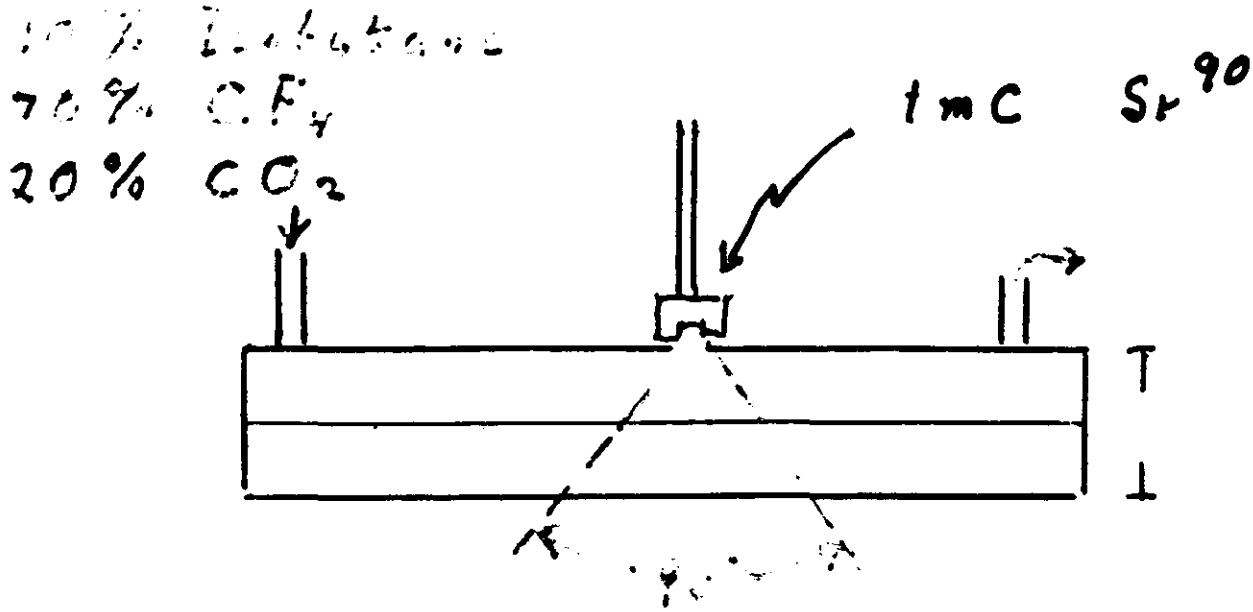
# TESTS OF WIRE CHAMBER AGEING WITH $CF_4$/ISOBUTANE (80:20), ARGON/ETHANE (50:50), AND ARGON/ETHANE/$CF_4$ (48:48:4)

R. Openshaw, R. Henderson+, W. Faszer, D. Murphy, M. Salomon and G. Sheffer

TRIUMF, 4004 Wesbrook Mall, Vancouver, B.C., Canada V6T 2A3
+ also associated with University of Melbourne, Australia



# Aging Test




Total Charge = 8.6 Coulombs over ~ 1 cm.

Loss in Sensitivity < 5%

gem

$\gamma e \mu$

# Muon System Technology Options

## RPC—Craig Wuest

335

# RESISTIVE PLATE CHAMBER TECHNOLOGY REVIEW

**November 4, 1992**

M. Widgoff
Brown University

E. D. Alyea
Indiana University

E. Ables, R. Bionta, M. Haro, D. Makowiecki, G. J. Mauger, M. McKernan, K. Miller, P. Ramsey, C. R. Wuest*
Lawrence Livermore National Laboratory

D. Chen, E. S. Hafen, P. Haridas, M. Lee, I. A. Pless*, S. Yunus
Massachusetts Institute of Technology

R. Santonico
University of Rome and Instituto Nazionale di Fisica Nucleare

S. Berridge, W. Bugg, P. Y. C. Du
University of Tennessee

*Co-spokesmen

# Resistive Plate Counter Design

- Resistive Plate Chambers (RPCs) have been in operation in experiments throughout the world since 1981.

- The current standard (Italian) design is two meters long by one meter wide with a sensitive gas gap of 2 millimeters.

- There are no wires or conductors anywhere in the sensitive region.

- The walls of the chamber - in contact with the gas of the sensitive volume - consists of a semi-conductor (Bakelite, for example) with a bulk resistance of about 10**11 ohm-centimeters.

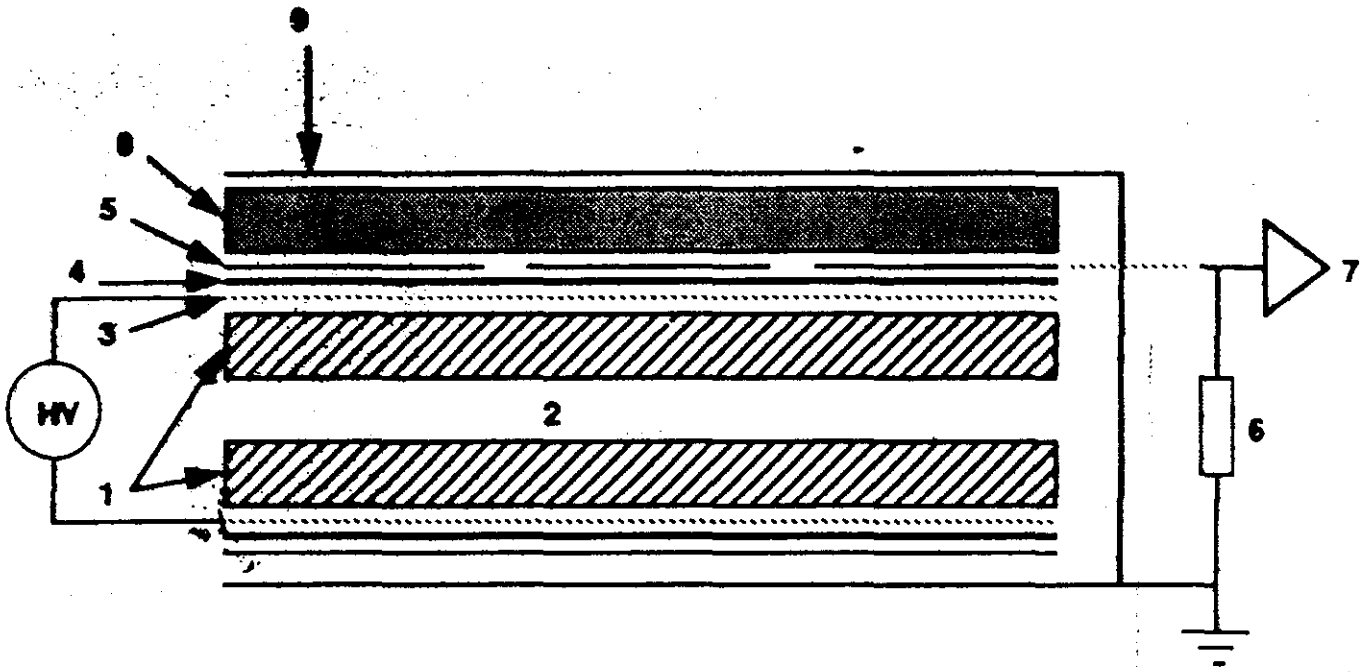
- An ioniz ing particle passing through the sensitive volume (2 m x 1 m x 2 mm) breaks down the gap and creates an electrical discharge.

- This discharge is very fast (a few nanoseconds).

- The discharge is capacitively coupled to pick-up strips which are located outside the semiconductor walls of the gas cell.

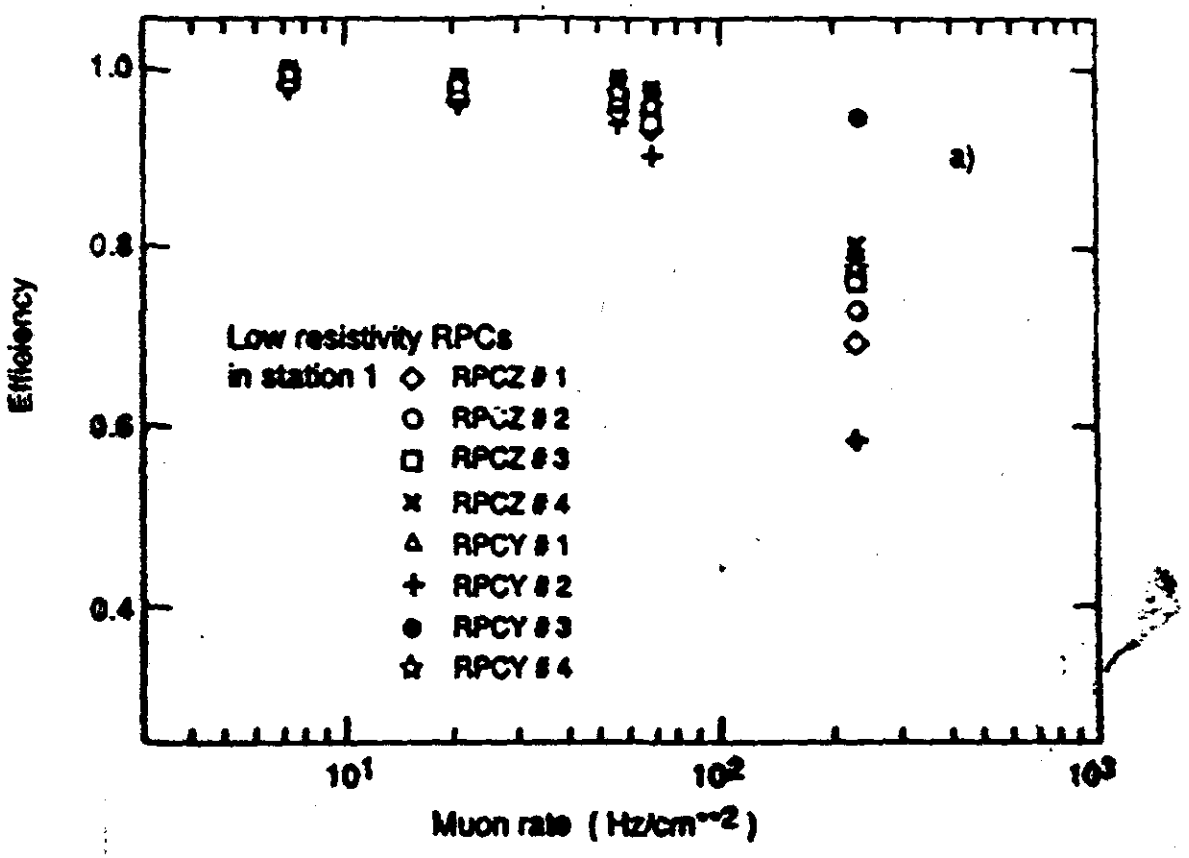
## Resistive Plate Counter Design

- Hundreds of these chambers have been produced and are operating in experiments all over the world.
- A set of these chambers have operated at Frascati for 7 years.
- Such chambers are currently being used in E-771 at Fermilab.
- Recently L3 at CERN has ordered 400 of these chambers from General Technica, Colli, Italy, a company that is a commercial supplier of RPCs.
- Not a new technology, but rather a mature technology which is well understood and for which the manufacturing technology has already been transferred to industry.




1 Bakelite plate
2 gas
3 graphite coating
4 insulating foil
5 aluminum strips
6 line termination
7 discriminator
8 foam
9 aluminum ground plane

**Figure 1**


1.0
0.8
0.6
0.4
Efficiency
a)
Low resistivity RPCs
in station 1
RPCZ # 1
RPCZ # 2
RPCZ # 3
RPCZ # 4
RPCY # 1
RPCY # 2
RPCY # 3
RPCY # 4
$10^1$
$10^2$
$10^3$
Muon rate ( Hz/cm$^{**2}$ )

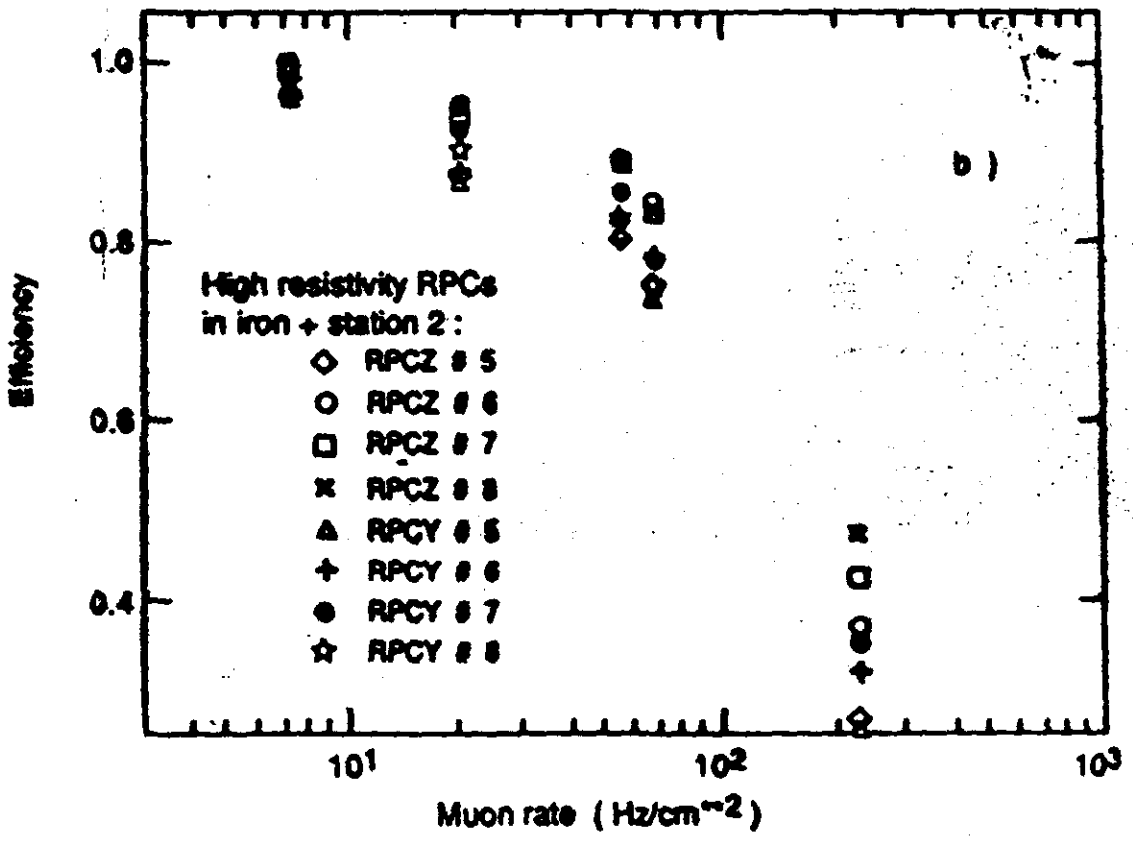

1.0
0.8
0.6
0.4
Efficiency
b )
High resistivity RPCs
in iron + station 2 :
RPCZ # 5
RPCZ # 6
RPCZ # 7
RPCZ # 8
RPCY # 5
RPCY # 6
RPCY # 7
RPCY # 8
$10^1$
$10^2$
$10^3$
Muon rate ( Hz/cm$^{**2}$ )

FIG. 20

- In November 1991, the RPC Collaboration submitted its R&D program for the GEM Muon Beam Tagging Trigger and Z-coordinate Measuring System using Resistive Plate Counters.

- Properties of RPCs that have been measured include:

  - Pulse rise-time jitter
  - Maximum counting rate
  - Efficiency
  - Lifetime
  - Noise
  - Response to neutrons and gammas

- A number of RPC prototypes have been fabricated using new materials:

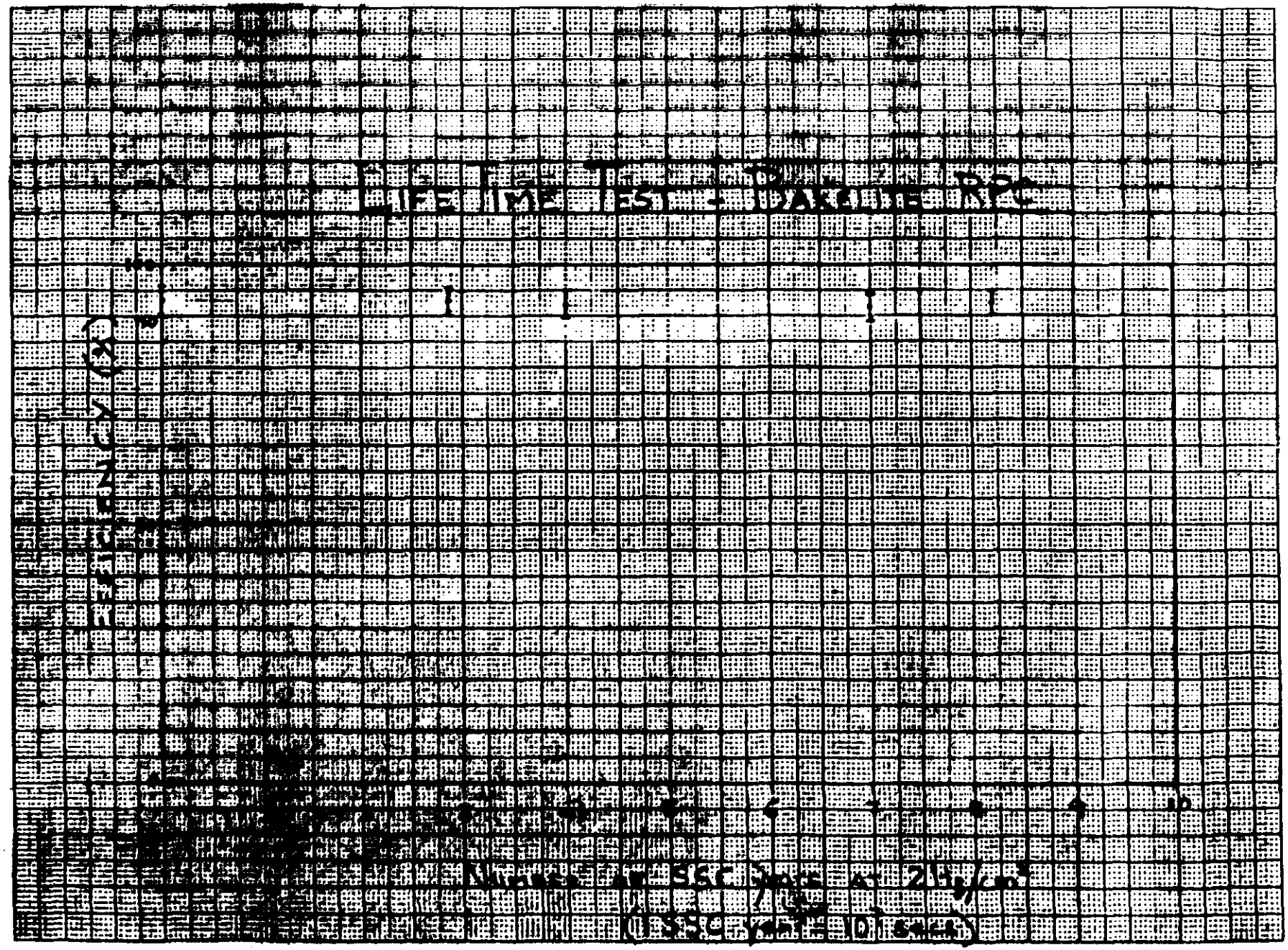
  - Glasses
  - Cermets
  - Plastics

- Results from the RPC R&D program:
  - Pulse rise-time jitter measured on 1m x 2 m Italian RPC - 1.4 ns
  - Pulse rise-time -2.5 ns
  - Pulse width - 50 ns
  - Pulse height - 200-500 mV into 50 ohms without amplification.
  - Saturated counting rate -
    - Glasses - 50-75 Hz/cm^2
    - Bakelite - 560 Hz/cm^2
    - Static-dispersive plastics - 15 KHz/cm^2
  - Efficiency – 95% using cosmic ray scintillator telescope.
  - Lifetime – 1% decrease in efficiency measured for 8.2 SSC years exposure.
  - Noise – 10 x cosmic rays.
  - Neutron sensitivity (1-10 MeV) – 4.8 x 10^-3, same as other technologies.
  - Photon sensitivity (1-10 MeV) – 6.6 x 10^-3.

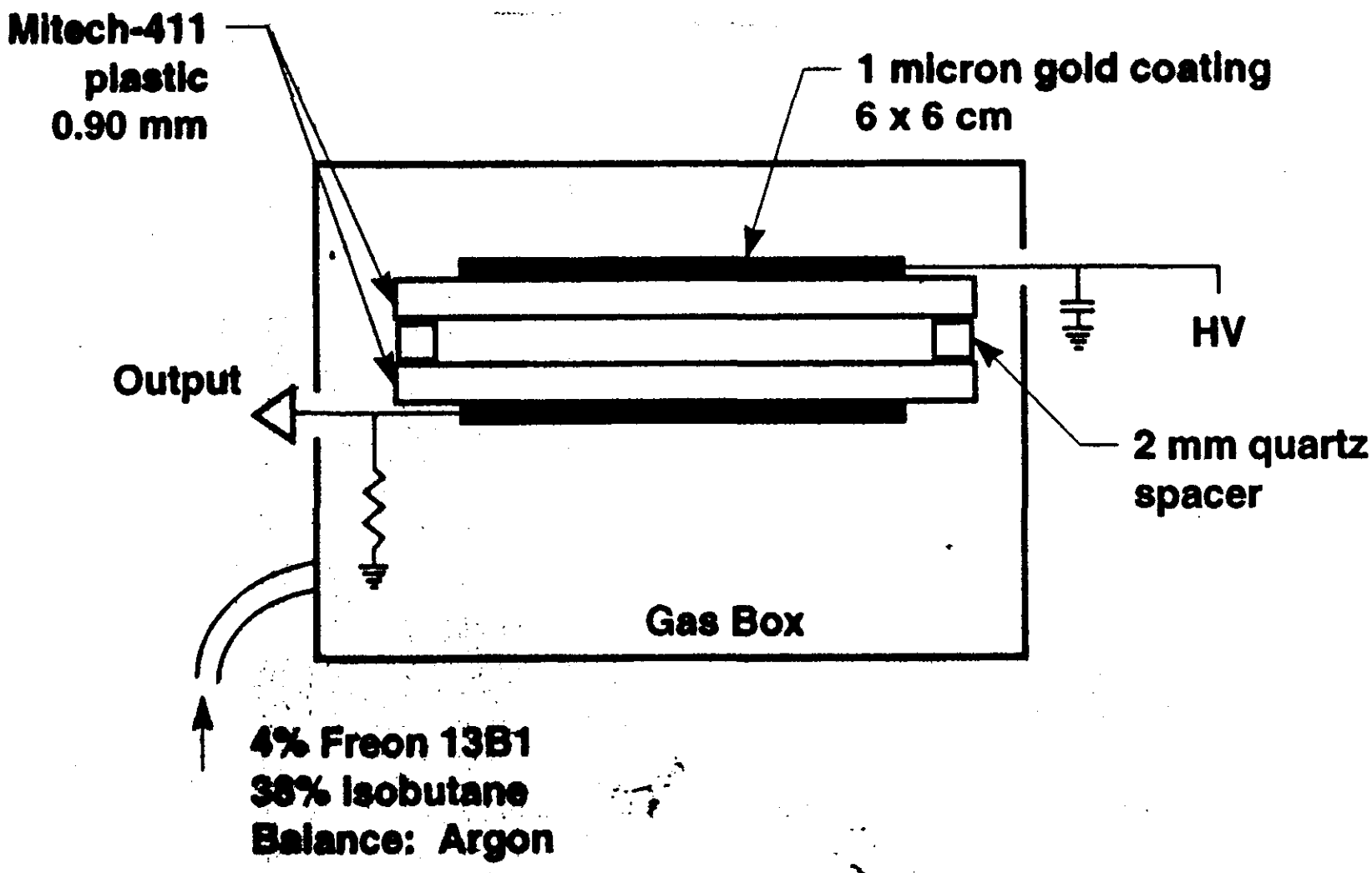
- Conclusions:
  - The R&D program has successfully addressed the major concerns of RPC counting rate, aging/lifetime, neutron sensitivity, and noise.

**Figure 16**

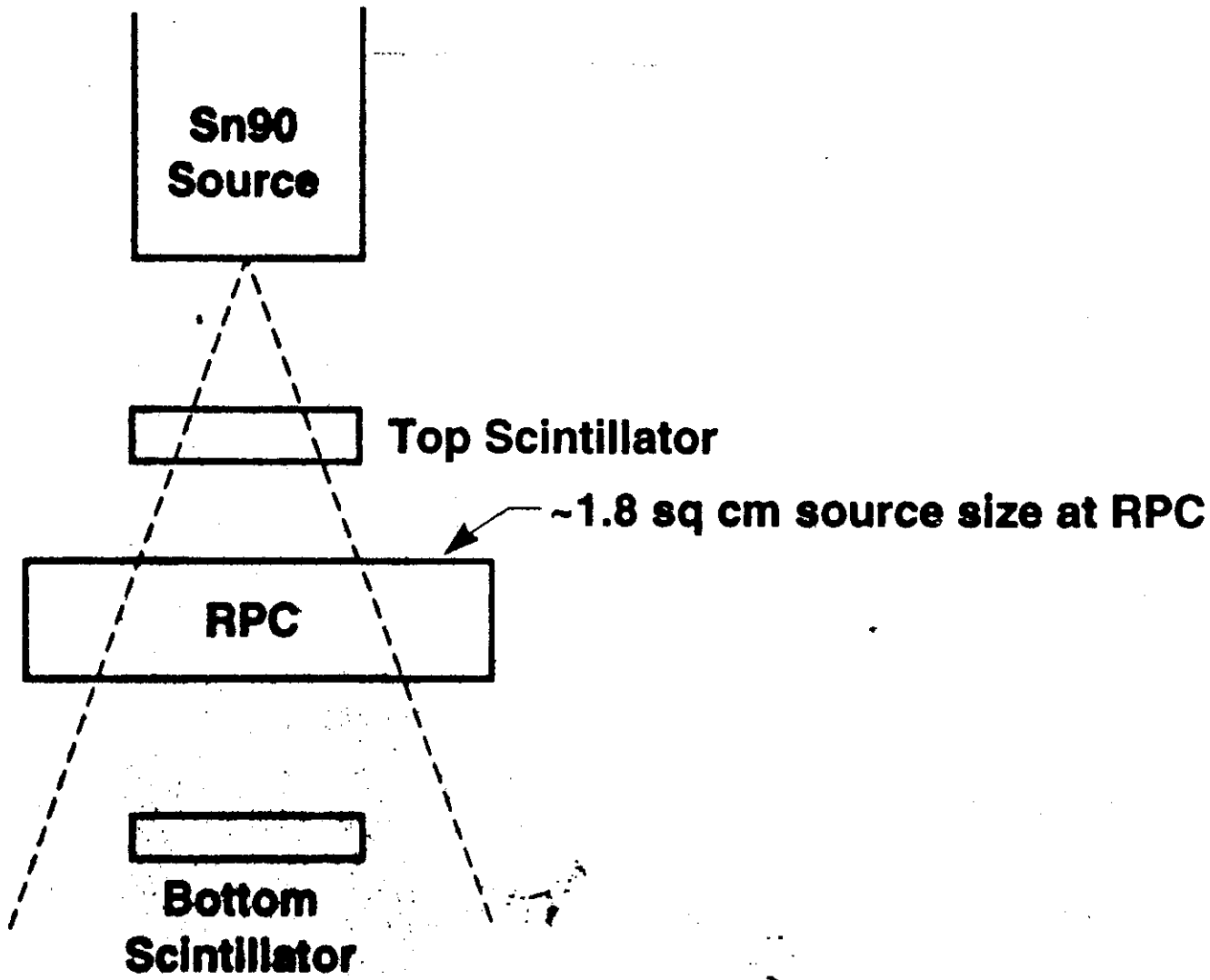




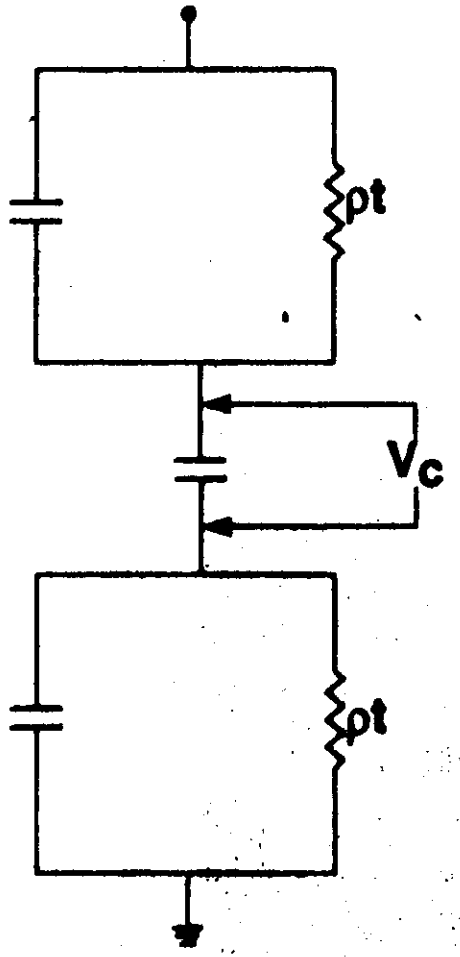
# Materials Test Detector

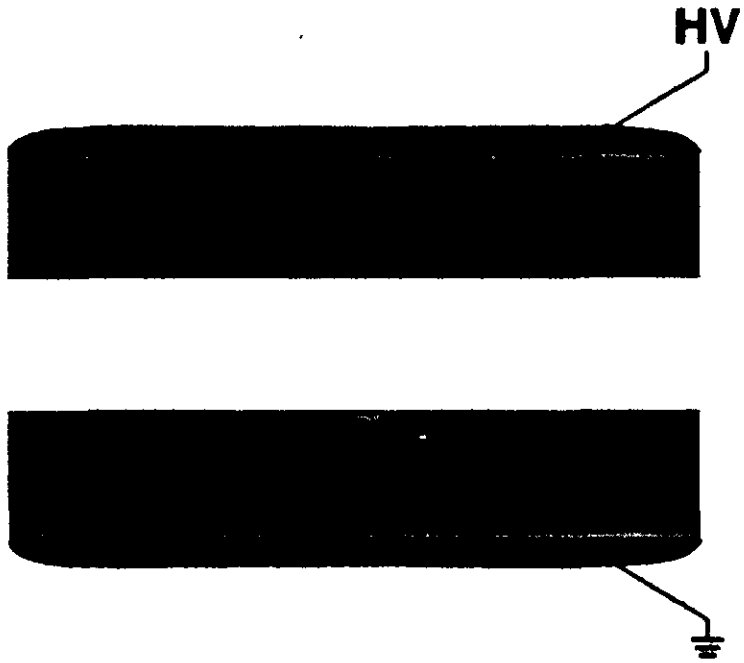


# RPC Source Test



# Spice RPC Model



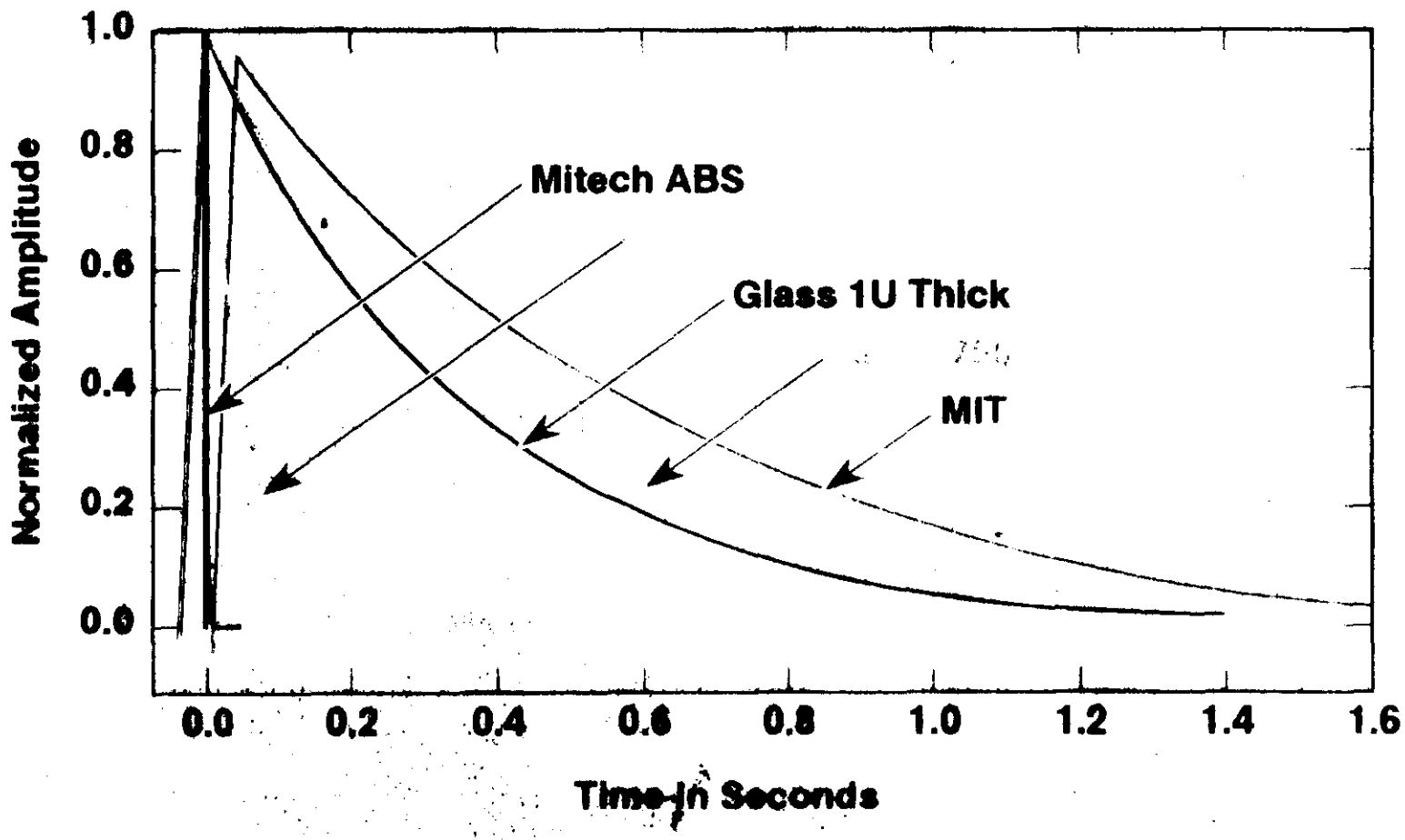

BAKKA-01/RMB

# RPC Candidate Material

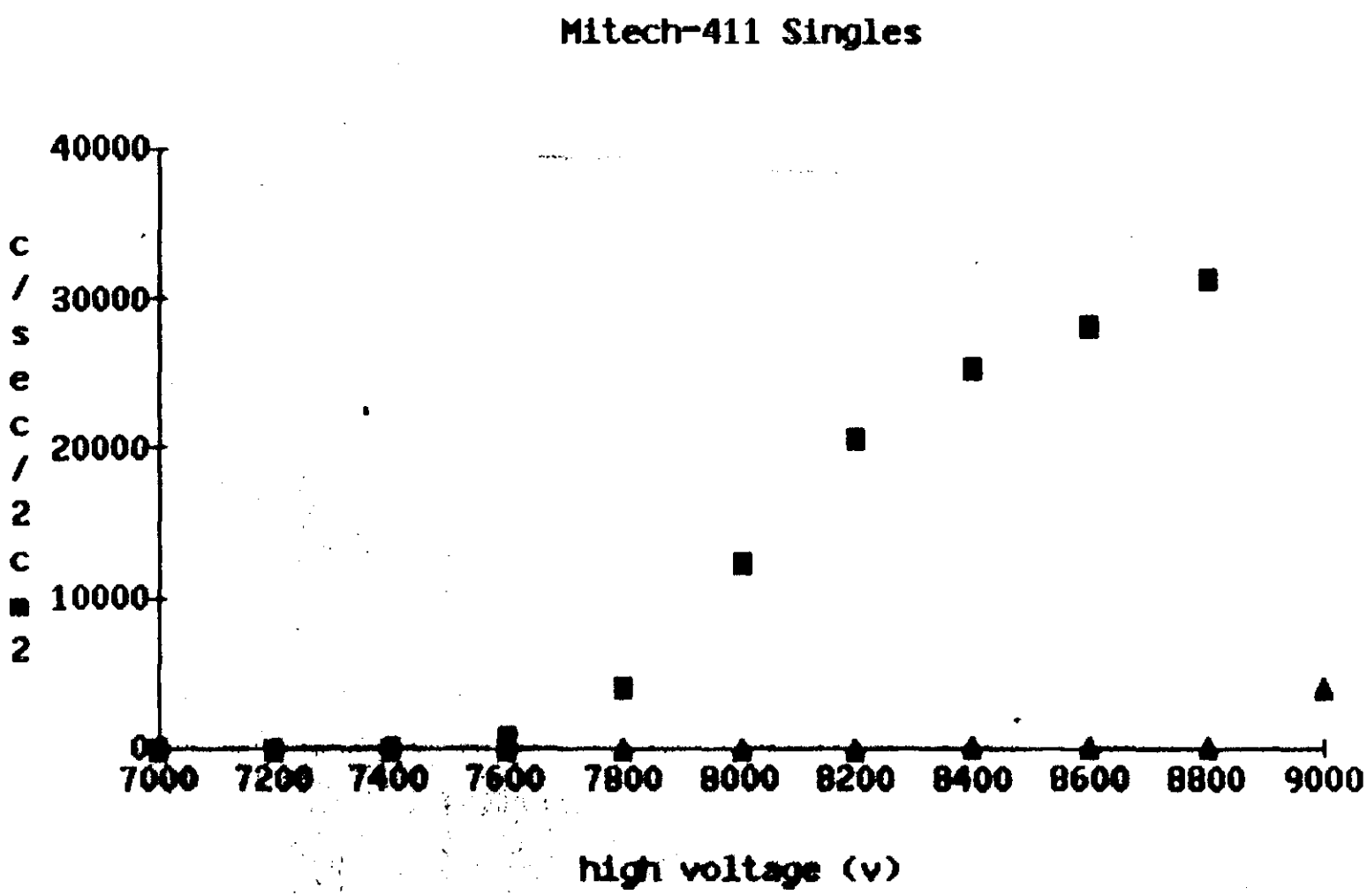
| Material | Thickness (cm) | Bulk Resistivity (Ωcm) | Arc Resistivity ($\Omega cm^2$) |
|---|---|---|---|
| MIT mirror | .300 | $5.0 \times 10^{12}$ | $1.5 \times 10^{12}$ |
| 750 micron mirror | .066 | $4.9 \times 10^{12}$ | $3.23 \times 10^{11}$ |
| Kodak projector glass | .123 | $6.42 \times 10^{11}$ | $7.89 \times 10^{10}$ |
| Italian RPC | .200 | $1.0 \times 10^{11}$ | $2 \times 10^{10}$ |
| Bakelite | .161 | $4.5 \times 10^{9}$ | $7.24 \times 10^{8}$ |
| ABSTAT–M310 | .072 | $5.78 \times 10^{9}$ | $4.16 \times 10^{8}$ |
| ABSTAT–M310 | .060 | $5.78 \times 10^{9}$ | $3.47 \times 10^{8}$ |
| Mitech–410 | .090 | $2.03 \times 10^{9}$ | $1.83 \times 10^{8}$ |
| Mitech–410 | .030 | $2.03 \times 10^{9}$ | $6.19 \times 10^{7}$ |
| Corning 0211 glass | .056 | $6.7 \times 10^{7}$ | $3.75 \times 10^{6}$ |
| Boron | .0001 | $1 \times 10^{6}$ | $1 \times 10^{2}$ |

BAK.XA-14/PMB

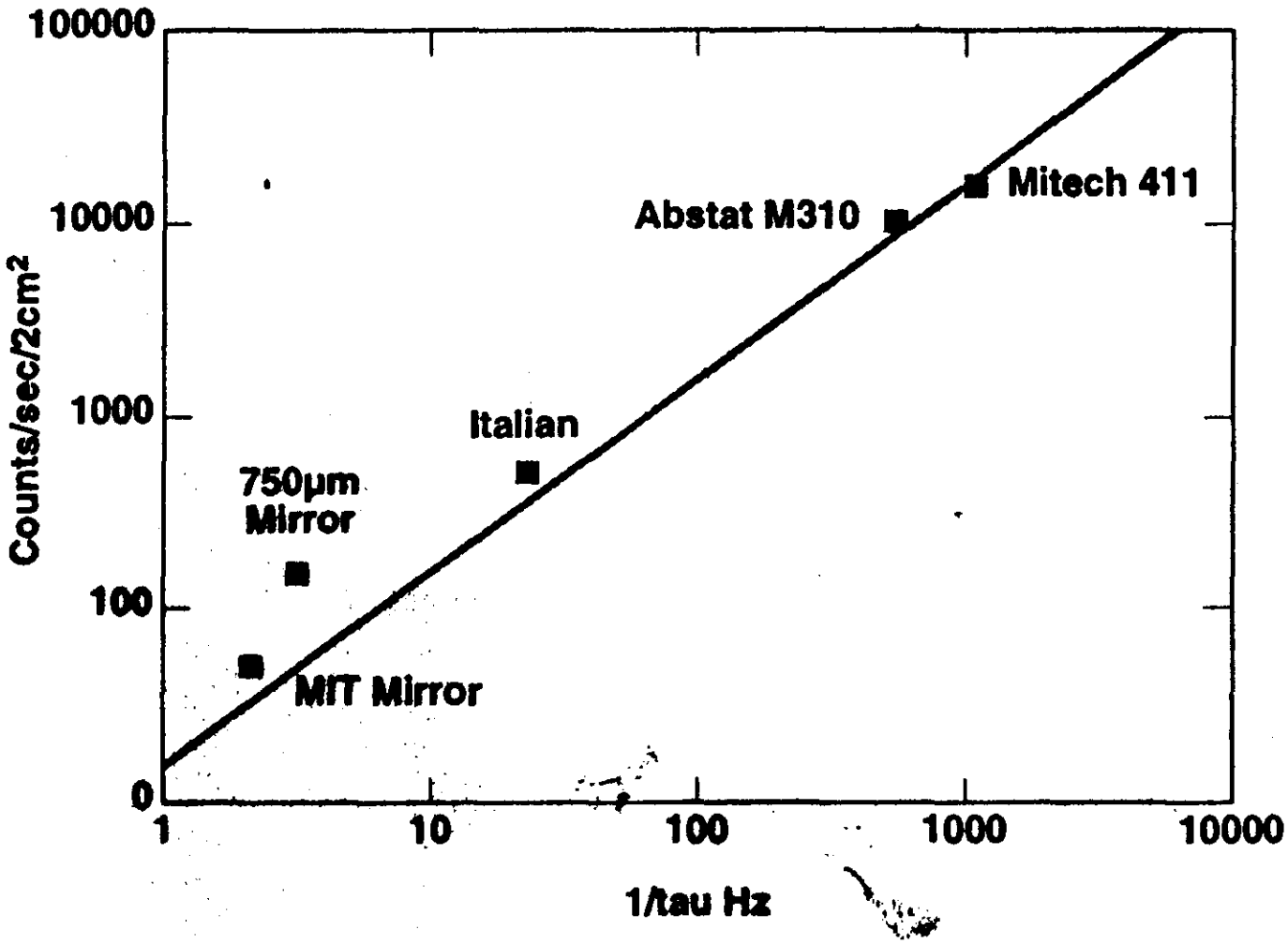
# Spice Calculations of Recharge




HAK KA 18/RMB

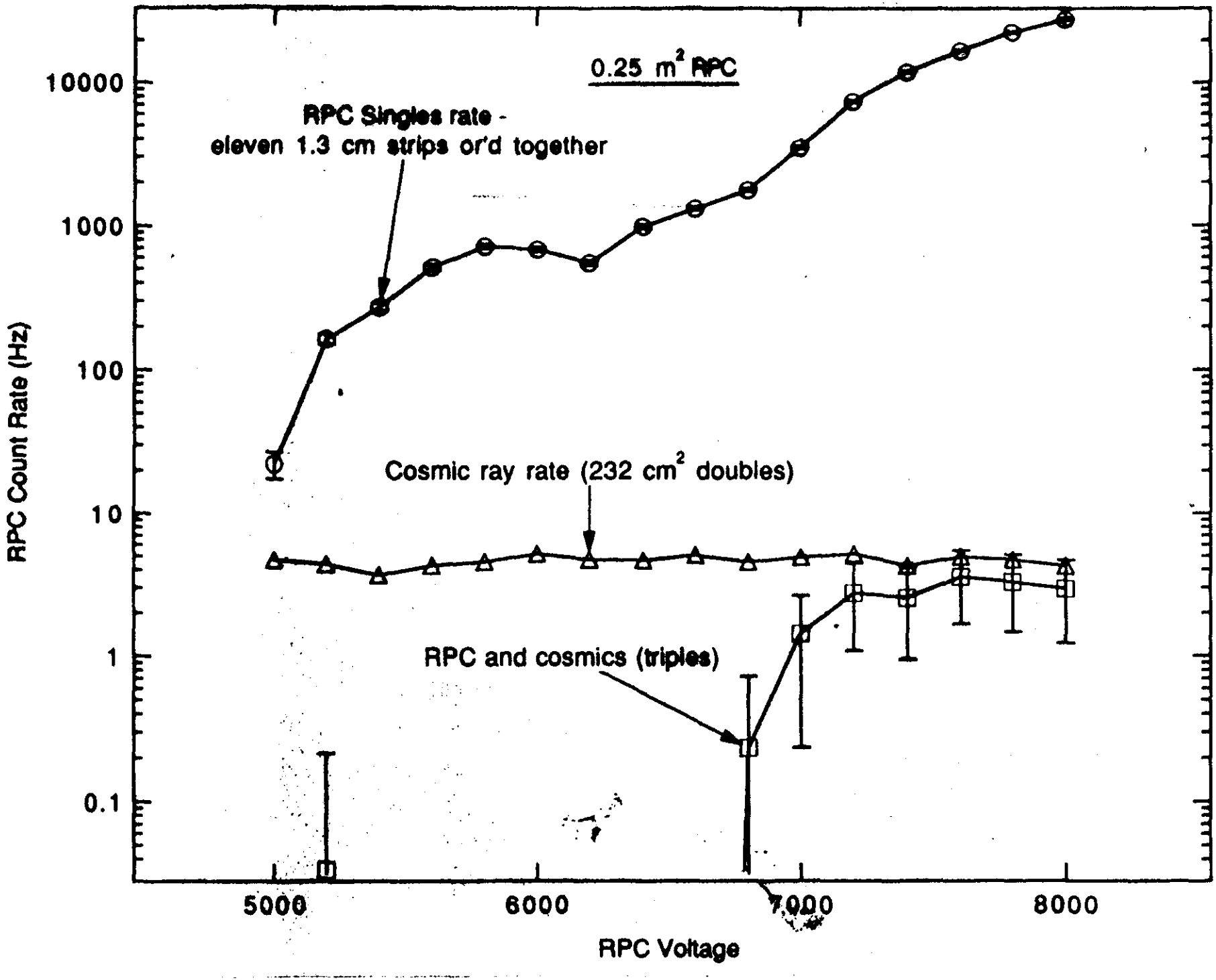

Mitech-411 Singles
c/sec/2cm2
40000
30000
20000
10000
0
7000
7200
7400
7600
7800
8000
8200
8400
8600
8800
9000
high voltage (v)

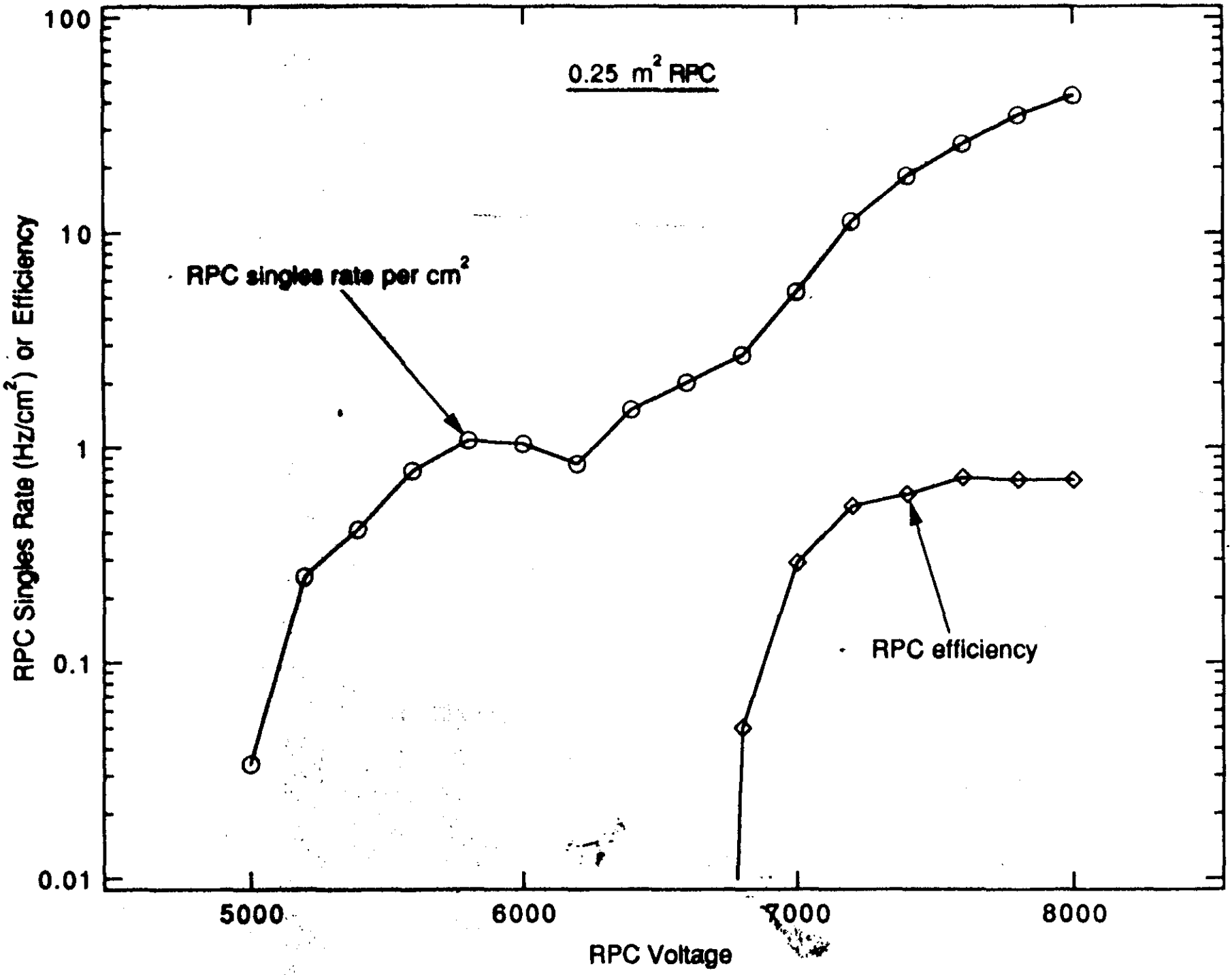
# Saturated Singles Rate vs SPICE 1/tau

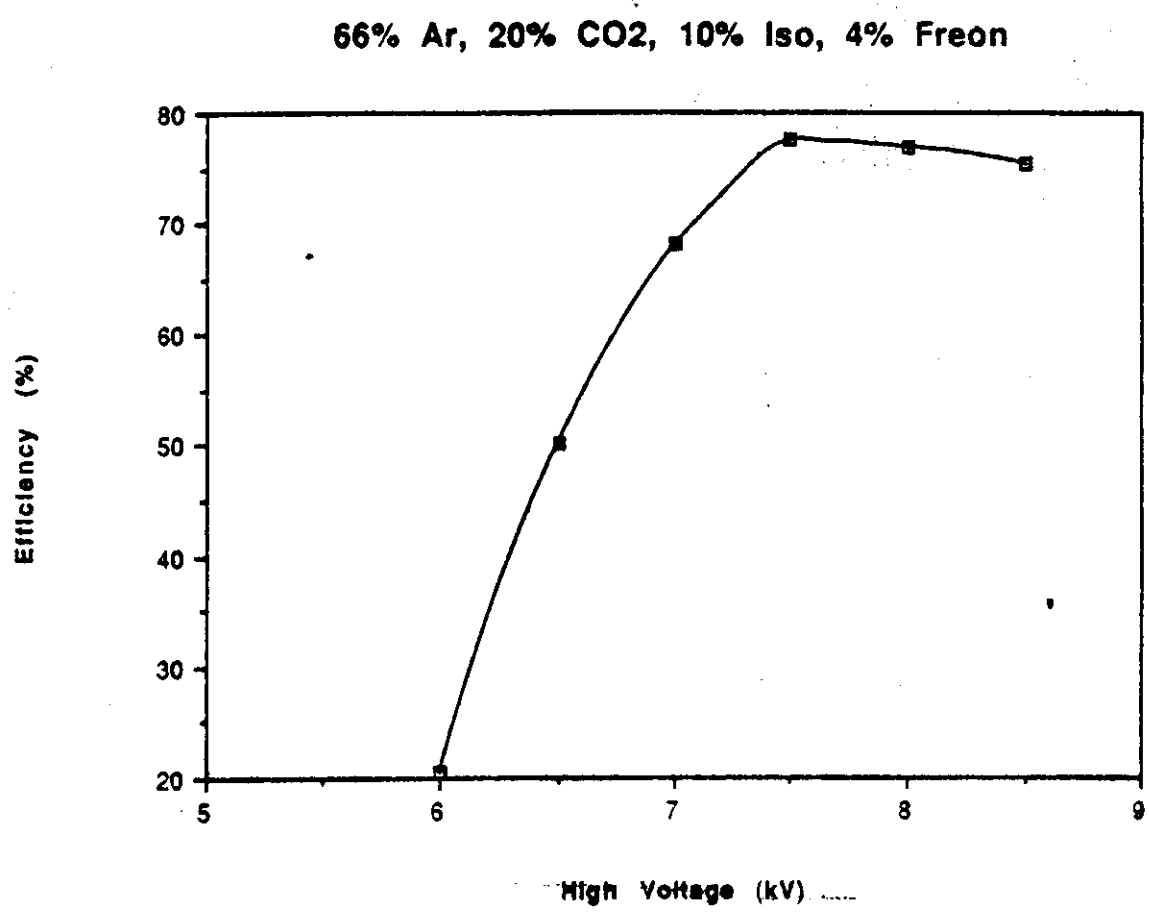



BAKKA-17/RMB

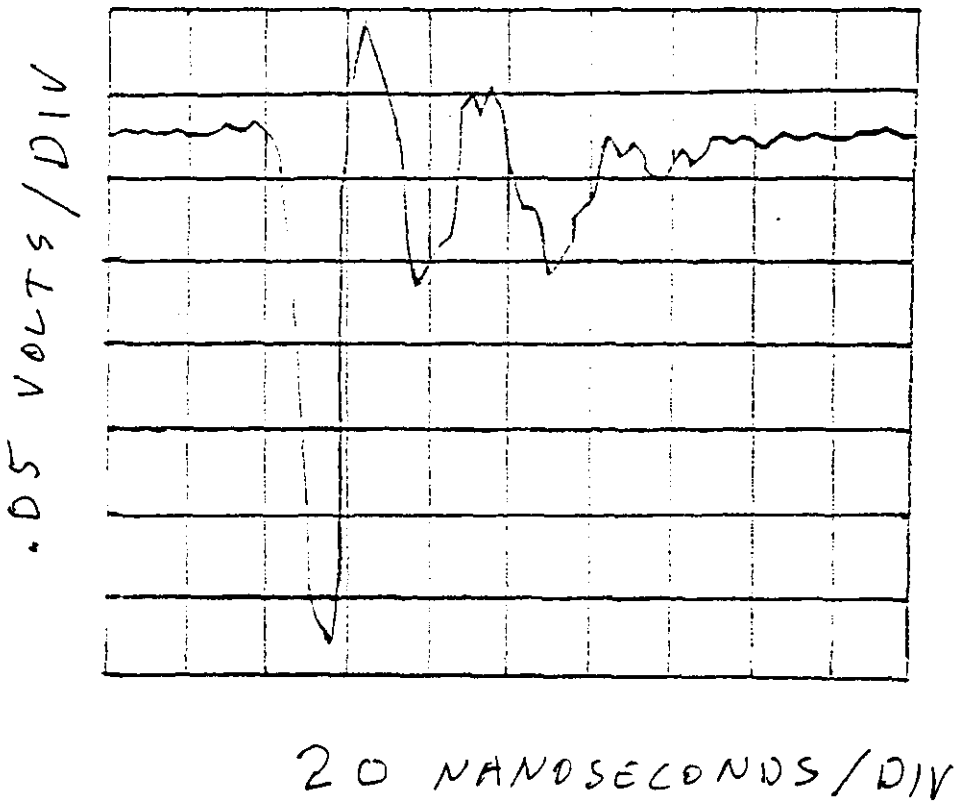
- Results since October 6, 1992:
  - We have built 3 RPCs from low resistivity ABS plastics:
    - Two 51 cm x 51 cm (0.25 square meters each).
    - One 76 cm x 127 cm (0.96 square meters).
  - Measurements have been made on efficiency, noise rate, rate capability, jitter.
  - Noise - 20 Hz/cm**2
  - Pulse Height - 200-500 mV
  - Plateau > 800 Vwide (measured with two-fold cosmic ray coincidence)
  - Rate capability - 10-20 KHz/cm**2 (measured with 36 cm**2 RPC)
  - Jitter - less than 5 ns (measured with 36 cm**2 RPC)
- Single layer 1 m**2 RPC weighs 0.4 g/cm**2 (4.1 kg)
- Ar/CO2/isobutane/freon and CO2/CF4 gas mixes tested in RPCs.


0.25 m² RPC
RPC Singles rate -
eleven 1.3 cm strips or'd together
Cosmic ray rate (232 cm² doubles)
RPC and cosmics (triples)
RPC Count Rate (Hz)
10000
1000
100
10
1
0.1
5000
6000
7000
8000
RPC Voltage


0.25 m² RPC
RPC singles rate per cm²
RPC efficiency
RPC Singles Rate (Hz/cm²) or Efficiency
RPC Voltage
100
10
1
0.1
0.01
5000
6000
7000
8000


66% Ar, 20% CO2, 10% Iso, 4% Freon
Efficiency (%)
80
70
60
50
40
30
20
5
6
7
8
9
High Voltage (kV)

60% AR, 20% $CO_2$, 10% ISO,
4% FREON



gem

γeμ

**Presentation by:**

**Frank Taylor**

Frank Taylor 11/4/92

# Muon System Technology Choice

## • R&D Program for FY92

R&D program for FY92 focused on building a number of prototypes of several technologies to determine properties and assess applicability for GEM Muon System.

**Baseline 1:**

| | Barrel | Endcaps |
|---|---|---|
| L-1 Triggering: | RPC | CSC |
| Tracking: | PDT or LSDT | CSC |

## • Oct. 6-7 Technology Review Meeting:

Intended to define the TDR baseline (Baseline 2)

-proponent reports (CSC, LSDT, PDT, RPC)

-independent engineering assessment (R. Savick; et al.)

-outside reviewers (Branson, Fabjan, Foley, (Nygren))

But at that time not all of the prototype chambers had been delivered to the TTR and there was little performance data.

# Issues Listed for Oct. 6-7 Meeting

- Barrel Issues:

1. Which is the more attractive drift technology - PDT or LSDT ?
2. Will the RPCs perform in terms of jitter, background sensitivity, and longevity ?
3. In case RPCs are not accepted, is there an alternative trigger for the drift option ?
4. Will the CSCs perform in barrel in terms of resolution, alignment, and costs ?

- Endcap Issues:

1. Will the CSCs perform in terms of resolutions, background, and costs ?
2. Are there any alternatives to the CSCs in the Endcaps ?

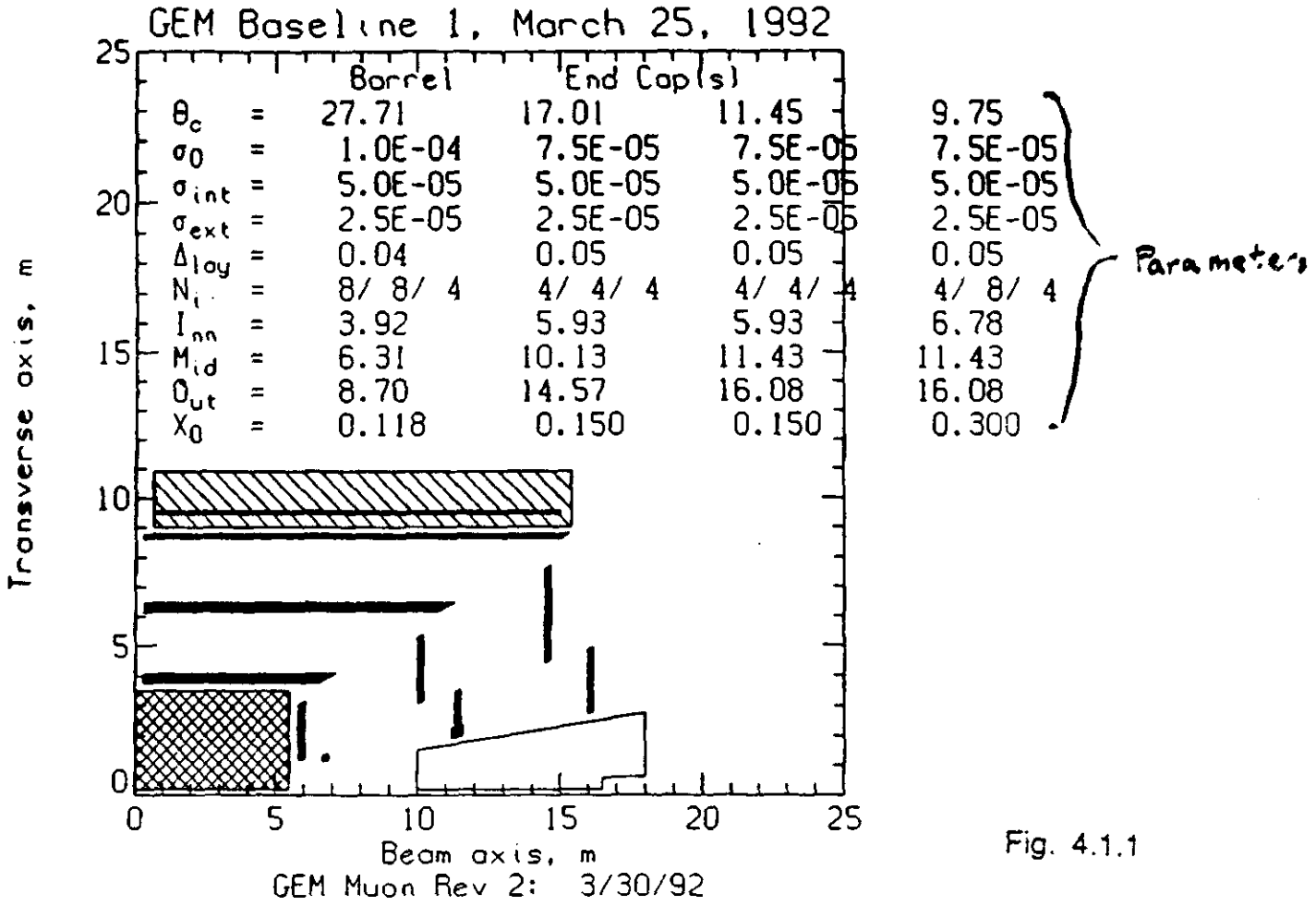
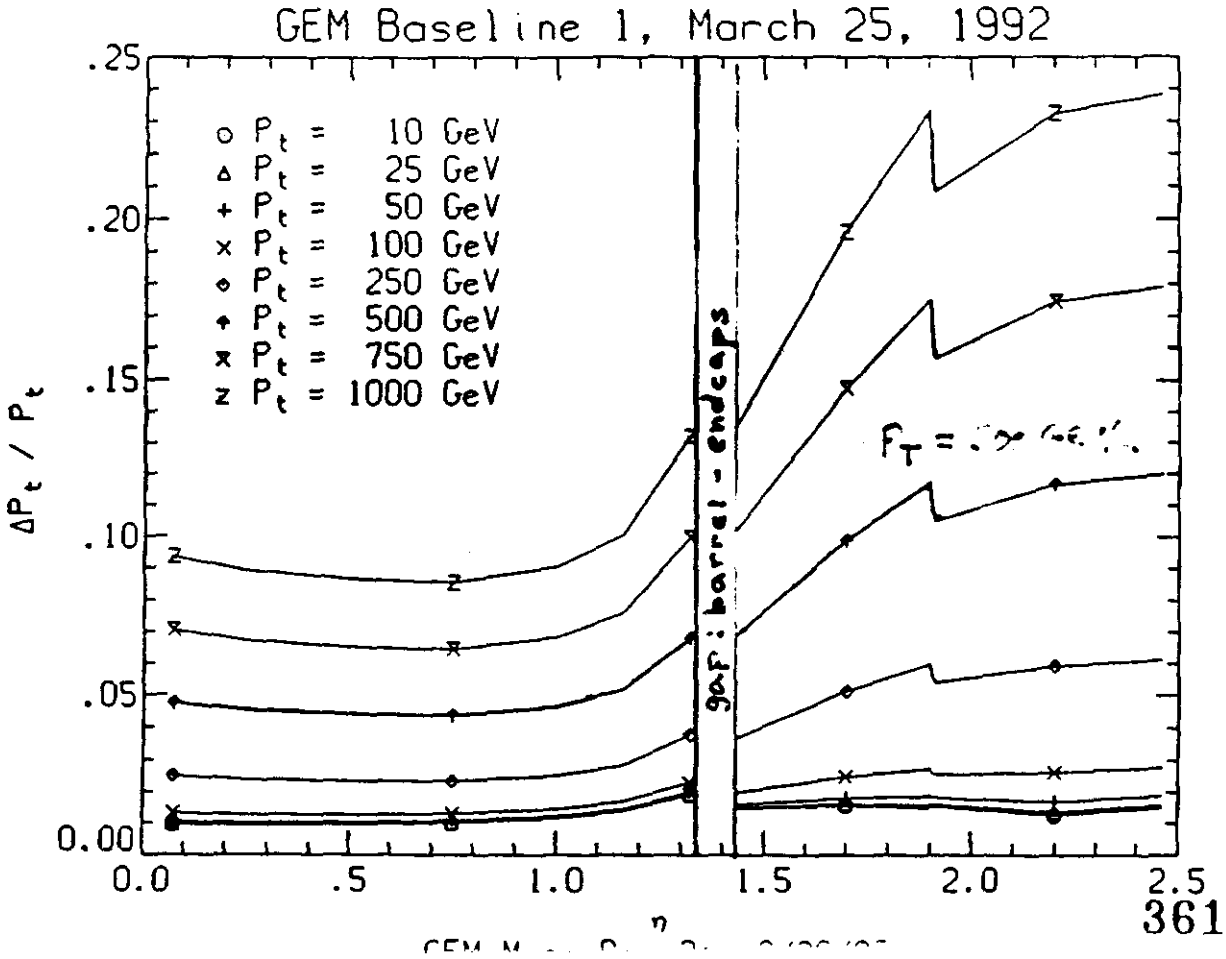



Fig. 4.1.1

Resol'n w/o $\Delta E_\mu$ Fluctuation



# Baseline 1 Resolutions

## Cathode Strips:

| | |
|---|---|
| Configuration (SL1:SL2:Sl3) | 8:4:4<br>8:8:4 forward angles |
| Single layer resolution | 75 $\mu$m RMS |
| Alignment (internal random) | 50 $\mu$m RMS |
| Alignment (external SL-to-SL) | 25 $\mu$m RMS |

## Drift:

| | |
|---|---|
| Configuration (SL1:SL2:Sl3) | 8:8:4 |
| Single layer resolution | 100 $\mu$m RMS |
| Alignment (internal random) | 50 $\mu$m RMS |
| Alignment (external SL-to-SL) | 25 $\mu$m RMS |

# Muon Chambers at the TTR

As of 11/3/92

| Technology | Chamber size | TTR delivery date |
|---|---|---|
| PDT-JINR | 1 m x 4 m x 8 layers | 7/28/92 (delivered) |
| PDT-MSU | 1.3 m x 3.8 m x 4 layers | 9/29/92 (delivered) |
| LSDT | 1 m x 4 m x 4 layers | 9/22/92 (delivered) |
| LSDT | 1 m x 4 m x 4 layers | 10/23/92 (delivered)<br>10/28/92 (sent back) |
| RPC | 1 m x 2 m x 2 layers | 9/29/92 (delivered) |
| CSC-BU | 0.5 m x 0.6 m x 3 x 2 layers | RD5-CERN (delivered) |
| CSC-BU | 0.5 m x 0.6 m x 3 x 2 layers | |
| CSC-BNL | 0.6 m x 0.6 m x 2x4 layers | 10/20/92 (delivered) |
| CSC-BNL | 1 m x 1.8 m x 4 layers | |
| CSC-UH | 0.5 m x 1 m x 3 layers | 9/92 (delivered) |
| CSC-JINR | 1.1 m x 1.5 m x 2 layers | 10/10/92 (delivered) |

more details from G. Mitselmakher

## Result of Oct. 6-7 Meeting:

- Attempted to rate drift technologies in barrel:

  -LSDT with stand-alone trigger (without RPC) seemed attractive.

  =====however====

  -PDT (actually operated in limited streamer mode at 1 ATM.) would have essentially the same operation properties.

  -RPC low resistivity plastic looks attractive (high rate possible).

- CSC was not rated for barrel application (no performance data was available.)

- A number of questions were identified:

  -showering from material inside the chambers

  -acceptance coverage

  -location of alignment paths and affect on acceptance

  -comparative costs of chamber construction and electronics

## • Present Situation:

- Examples of all chamber technologies have been delivered and tested at the TTR.

- Cost comparisons have been refined.

- Performance data available from all technologies.

For today:

- summary of TTR results Mitselmakher
- description of each technology

  CSC Polychronakos

  LSDT Osborne

  PDT Bromberg

  RPC Wuest

- discussion of pros/cons of each technology
  Marx - convener

gem

$\gamma e \mu$

# Tracker Status

Jim Brau

7983

# GEM Tracker Status Report

Jim Brau

November 4, 1992

BNL Meeting

Review Tracker Parameters

Proposal to Increase Radius
(75 cm → ~100 cm)

Choice of Silicon Microstrip Length
(18 centimeters?)

Taiwanese Engineering

| | |
|---|---|
| Outer Radius | 70 cm |
| Length | $\pm$150 cm |
| Rapidity Coverage | $\lvert\eta\rvert \leq 2.5$ |
| Magnetic Field | 0.8T |
| Occupancy | |
| at $\mathcal{L} = 10^{33} cm^{-2} sec^{-1}$ | $\leq$1% |
| at $\mathcal{L} = 10^{34} cm^{-2} sec^{-1}$ | $\leq$10% |
| Charge separation at 95% C.L. | $p \leq$400 GeV/c |
| Momentum Resolution at 90° | |
| at high momenta | |
| (measurements limited) | $\Delta p/p^2 \sim (1 - 3) \times 10^{-3} (GeV/c)^{-1}$ |
| at low momenta | |
| (multiple scattering limited) | $\Delta p/p \sim$ [redacted] 4% |
| Vertex Resolution | |
| along beam direction | $\delta z \sim$1mm |
| impact parameter | $\delta b \sim 30 \mu m$ |
| | above 10 GeV/c |

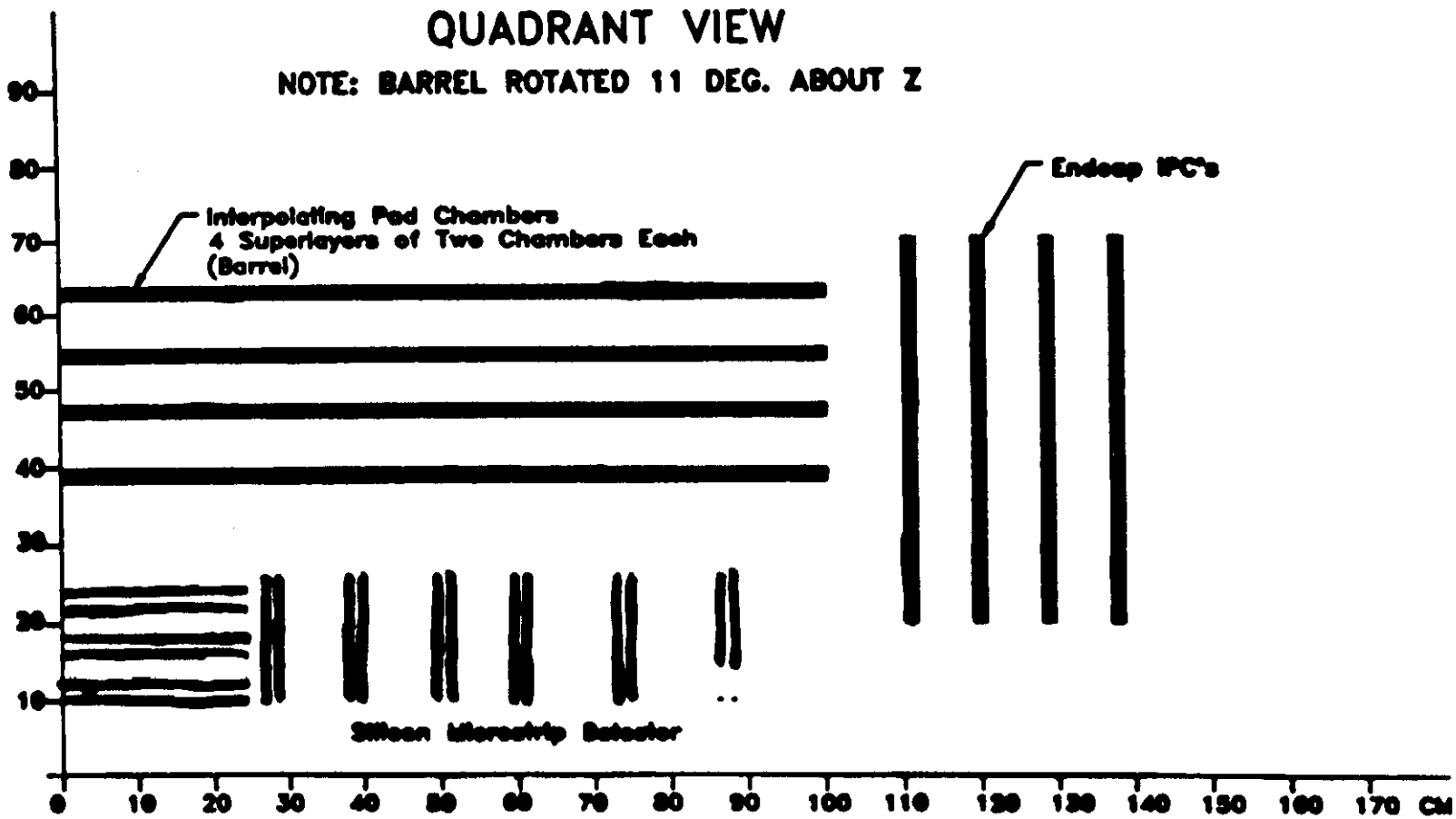
**Design Parameters for the Central Tracker**

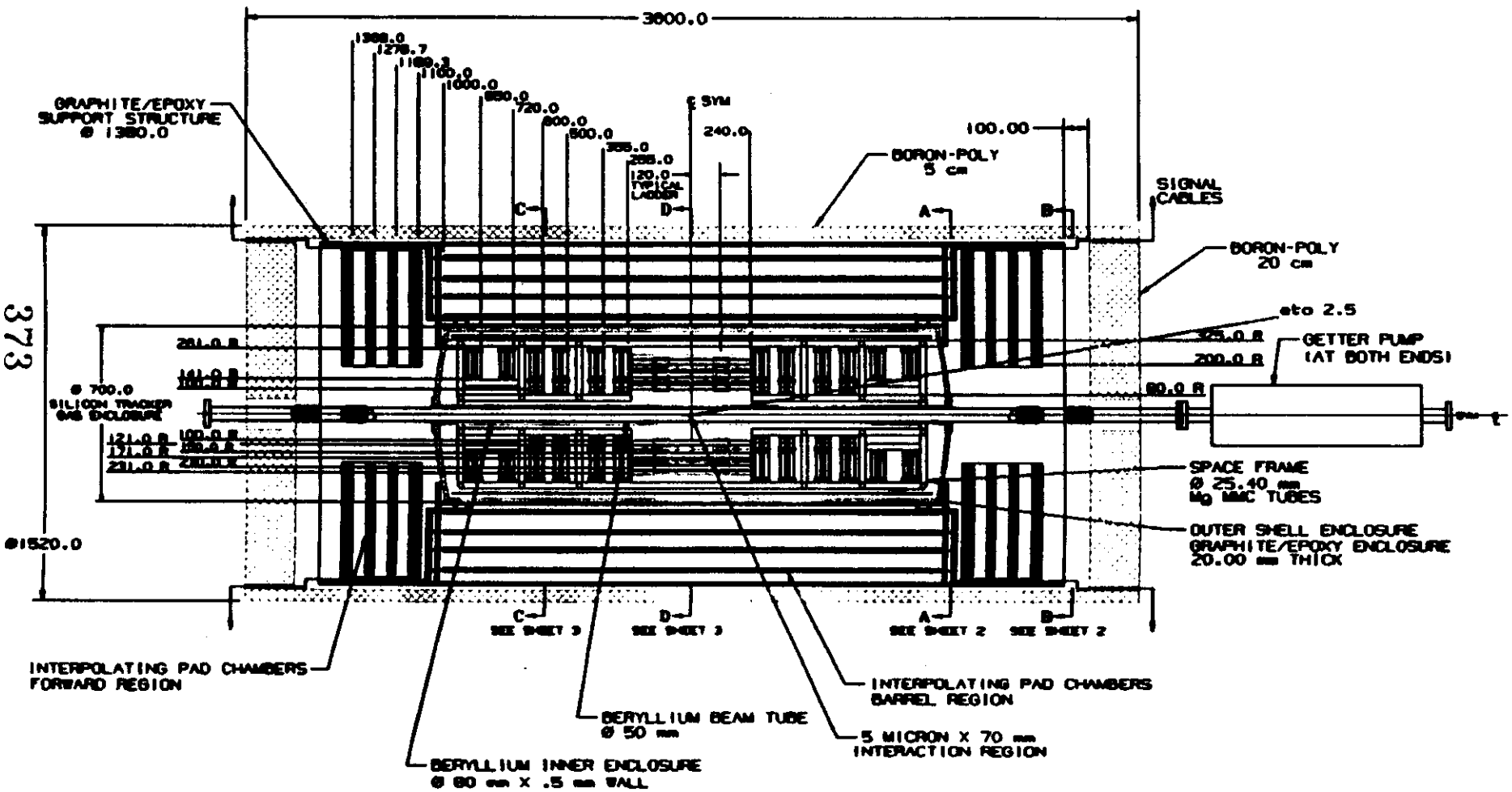
FIGURE 1

# GEM Central Tracking

## QUADRANT VIEW

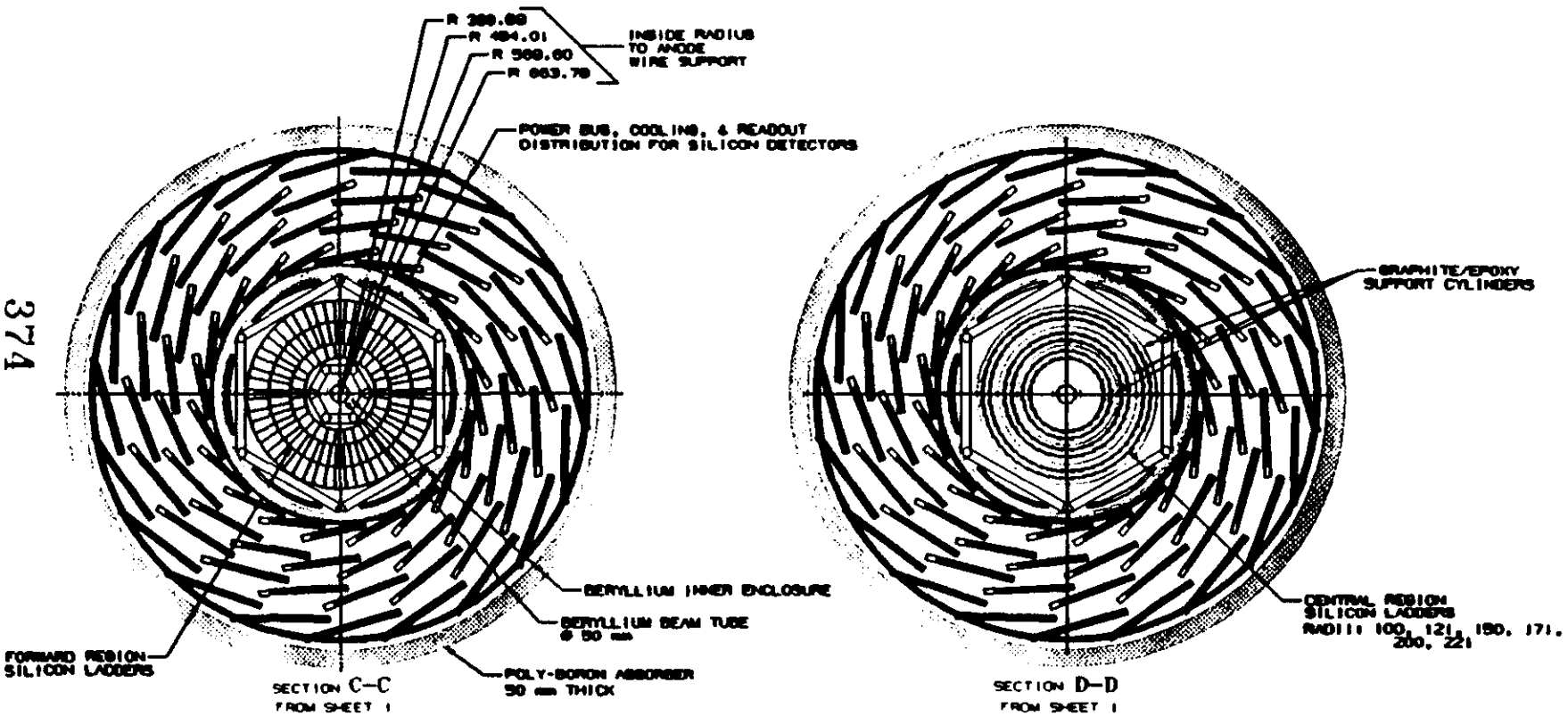
NOTE: BARREL ROTATED 11 DEG. ABOUT Z



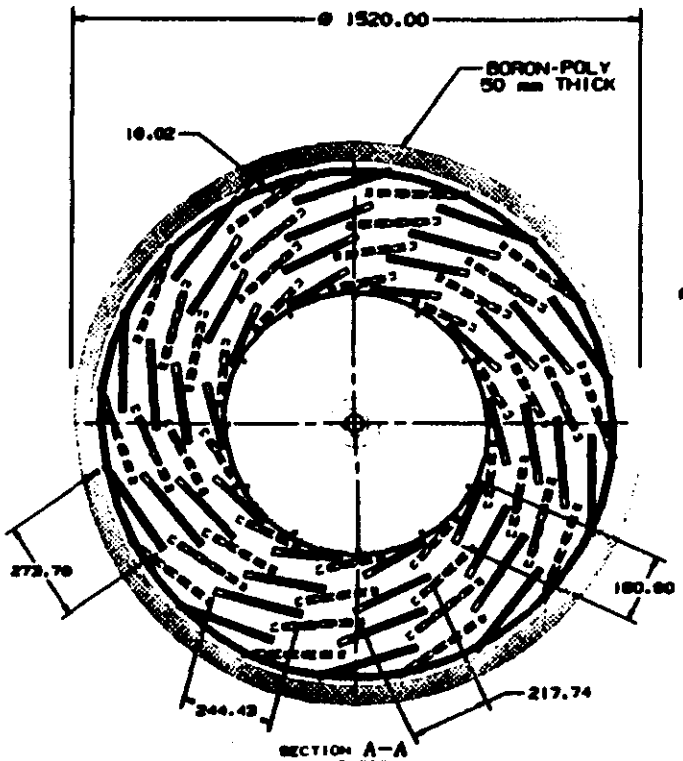



# GEM CENTRAL TRACKER

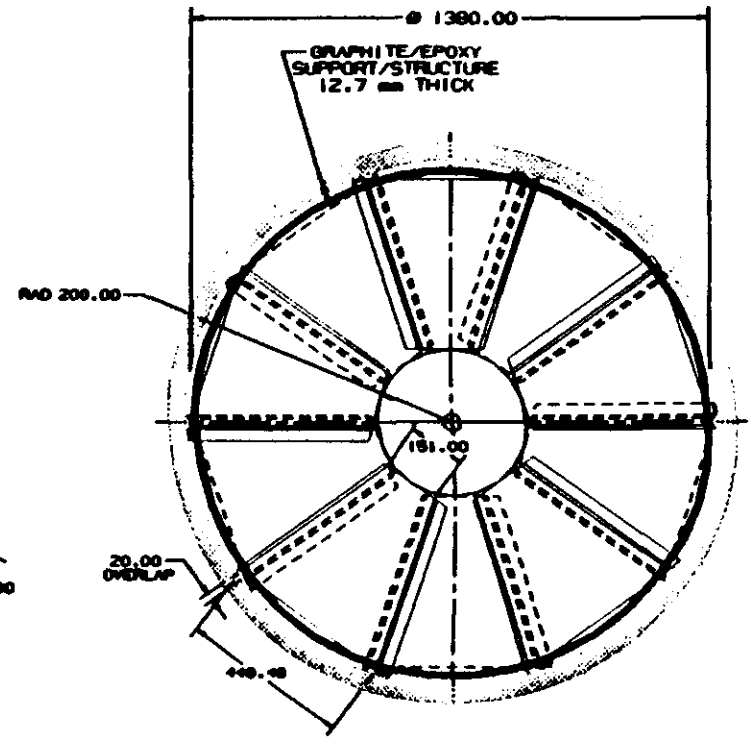
GEMVG-126A-JV




GEMVG-109E-JV 6-17-92




SECTION A–A
FROM SHEET 1




SECTION B–B
FROM SHEET 1

NOTE: EACH LEVEL OF 10 SECTORS ROTATED 9 DEGREES
RELATIVE TO ADJACENT LEVELS (4 LEVELS IN TOTAL)

METRIC

Los Alamos

GEM CENTRAL TRACKER
WORKING LAYOUT

A1 | SK-GEM12-0006 | 2

375

| Silicon Wafer Design Parameters | |
|---|---|
| Thickness | 300 μm ± 15 μm |
| Number of strips | 640 |
| Strip pitch | 50 μm |
| Number of readouts | 640 |
| Readout pitch | 50 μm |
| Substrate | n type high resistivity silicon, 4 - 8 kΩ |
| C (interstrip | 5 x C(backplane) < C < 1.5 pf/cm |
| C (coupling) | > 10 x C(interstrip) |
| Depletion voltage | 60 volts max. prior to irradiation<br>140 volts max. after 5 MRads of irradiation |
| Breakdown voltage | 150 volts min. prior to irradiation<br>180 volts min. after 5 MRads of irradiation |
| Leakage/strip | 10 nA max. prior to irradiation<br>90% strips ≤ 2 nA prior to irradiation |
| Leakage/Wafer | 3.5 μA max. prior to irradiation<br>(assume 90% @ 2nA + 7% @ 10 nA + 3% @ 100 nA |
| Metalization | Aluminum |
| Radiation Hardness | $5 \times 10^{13}$ neutrons/cm$^2$; 5 Mrad |
| Strip faults/wafer | Maximum of 3% of the strips (19 strips) due to a combination of capacitive coupling faults or P-N junction faults. No more than 3 faulty strips in 10 adjacent strips. |

Source: K. Morgan/R. Barber
Updated: 6/25/92

# Interpolating Pad Chamber Parameters

| | |
|---|---|
| Anode to cathode distance | 2 mm |
| Anode wire diameter | 40 μ |
| Anode wire spacing | 2 mm |
| Anode wire voltage | 3000 Volts |
| Gas gain | $5 \times 10^4$ |
| Pad size | 2.5 mm × a few cm |
| Input Capacitance to Preamp | 5 – 35 pF |
| Shaping time | 20 nsec |
| Typical signal on pad | $2 \times 10^5$ e |
| Typical noise on pad | 1000 e |
| Signal to noise | 200:1 |
| Accumulated charge on wire | 1.4 Coul/cm/yr at $10^{34}$ |
| Chamber Gas | $CO_2 - CF_4$ (50:50) |

# A Re-examination of the Tracker Design driven by Physics Requirements

J.Brau, C.Baltay, L.Rosenson, R.Stroynowski

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

# ATTRACTIVE IMPROVEMENT IN CEN. TRACKER.

(OVERALL DETECTOR OPTIMIZATION)

1. Increase outer tracker radius

   75cm → 100cm

   improves resolution $\frac{\sigma_p}{p_t} = 1.3\times10^{-3} \rightarrow .7\times10^{-3}$

   95% charge separation 400 GeV → 800 GeV

   decreased neutrons in tracker

2. Increase calorimeter inner radius

   75cm → 100cm

   X too costly for BaF

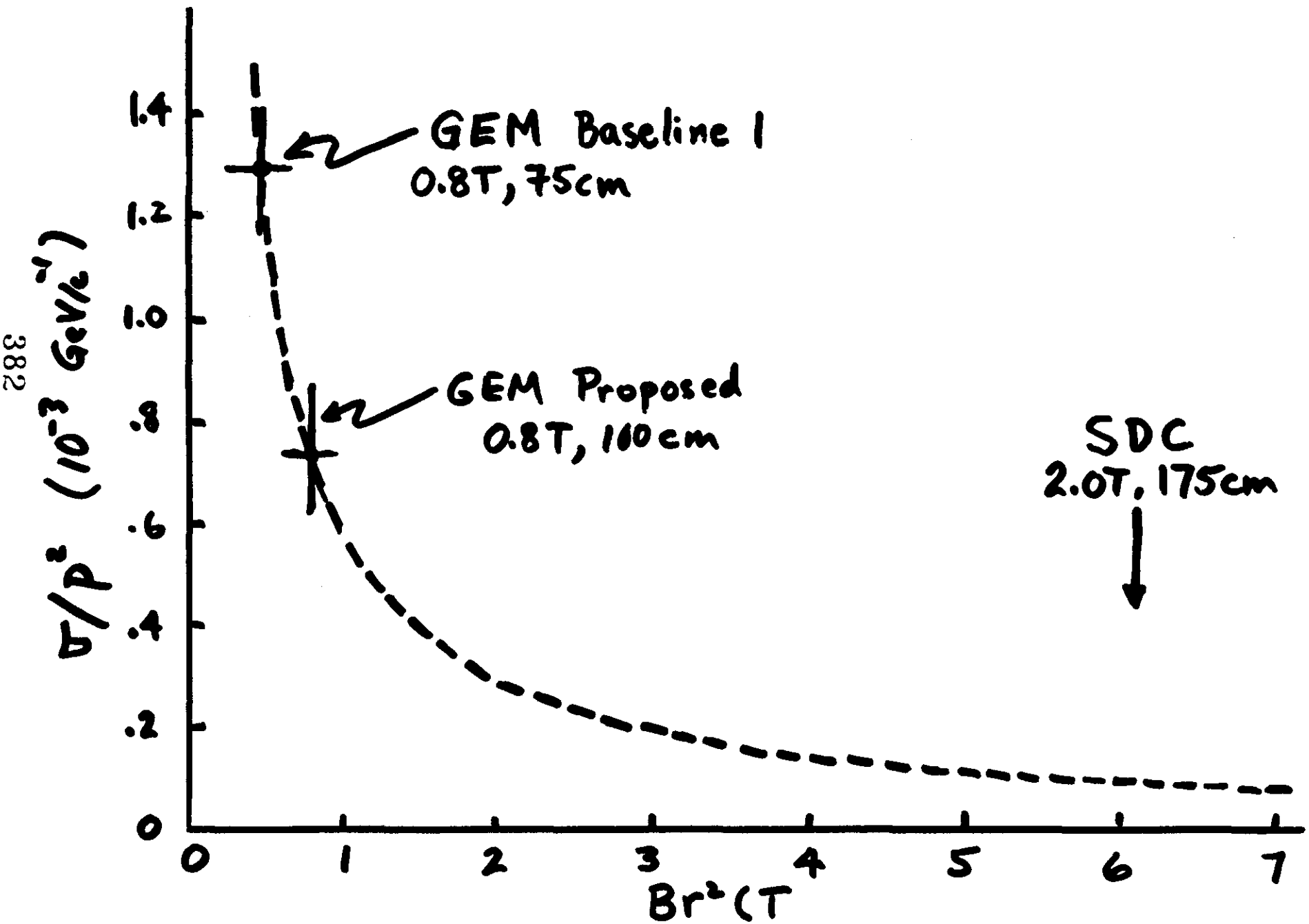
   Liq. Argon:

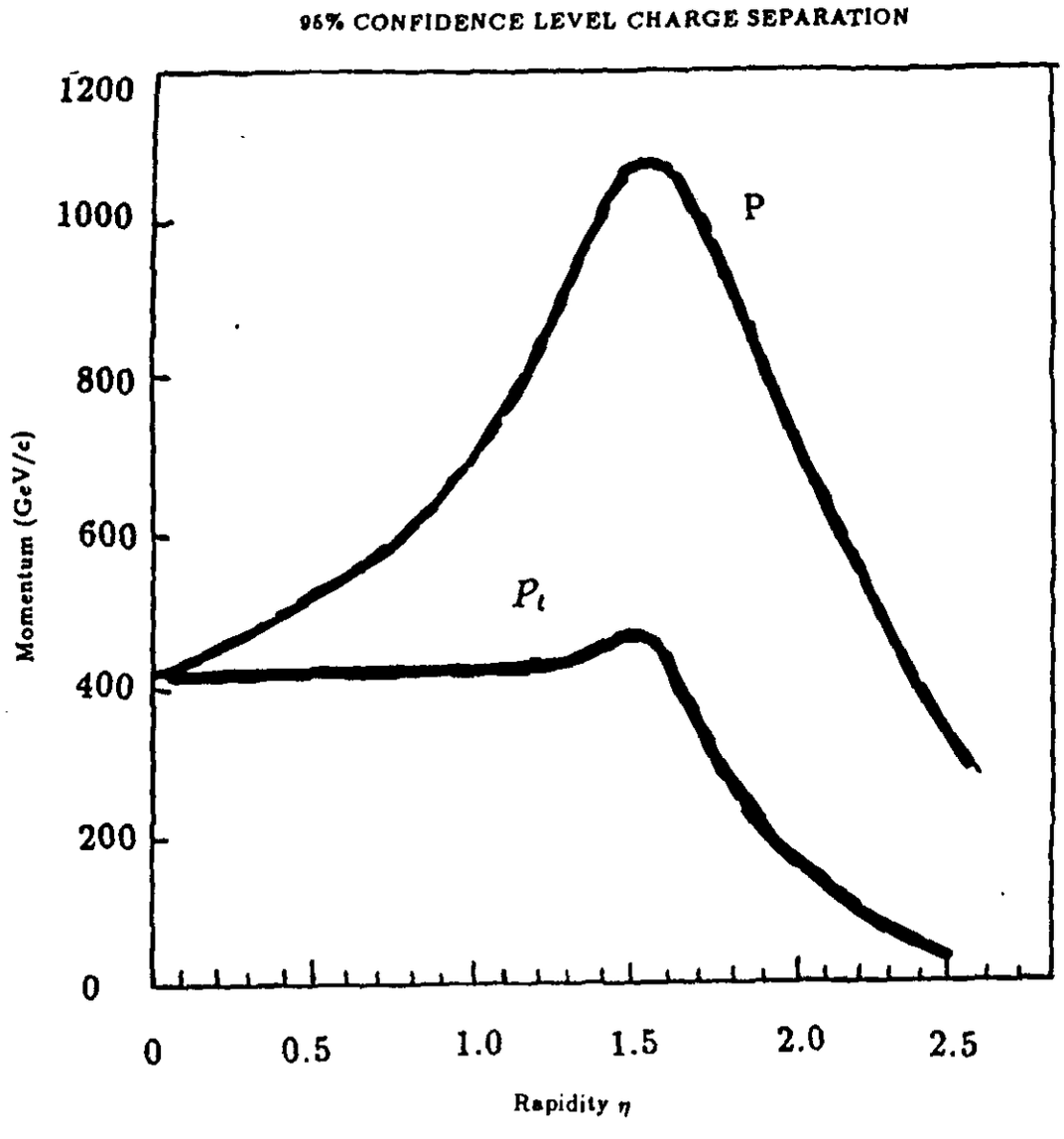
   cracks have smaller consequences

   showers less overlap (jets etc.)

   accordion slightly simpler (bends)

   cost +10M $ (if same thickness)


GEM Baseline I
0.8T, 75cm
GEM Proposed
0.8T, 100cm
SDC
2.0T, 175cm
$\Delta/p^2$ ($10^{-3}$ GeV/c$^{-1}$)
1.4
1.2
1.0
.8
.6
.4
.2
0
0
1
2
3
4
5
6
7
$Br^2$ (T$^2$)


95% CONFIDENCE LEVEL CHARGE SEPARATION
1200
1000
800
600
400
200
0
Momentum (GeV/c)
P
$P_t$
0
0.5
1.0
1.5
2.0
2.5
Rapidity $\eta$

Tucson, Mar '92

Proposal:

SINCE THIS LOOKS ATTRACTIVE FOR L.A. OPTION, BUT NOT FOR B&F OPTION:

IN AUGUST (COORDINATED WITH CALORIMETER CHOICE)

- If B&F → NO CHANGE IN TRACKER
- If LA → IMPLEMENT IMPROVEMENTS

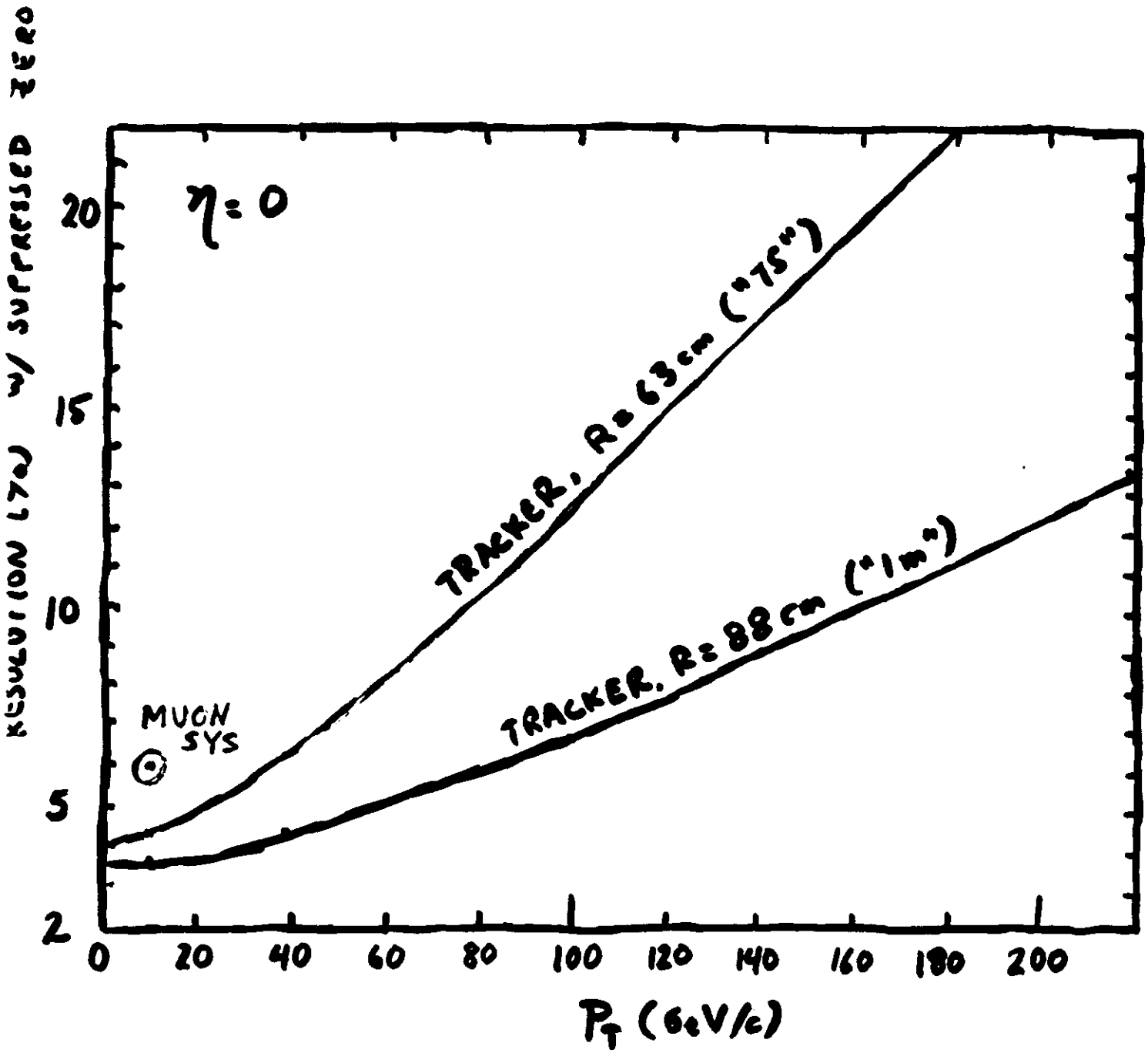
IN MEANTIME – DETAILED STUDIES OF PHYSICS IMPACT TO FIRM UP CASE

# PHYSICS JUSTIFICATION FOR PROPOSED R = 1 m

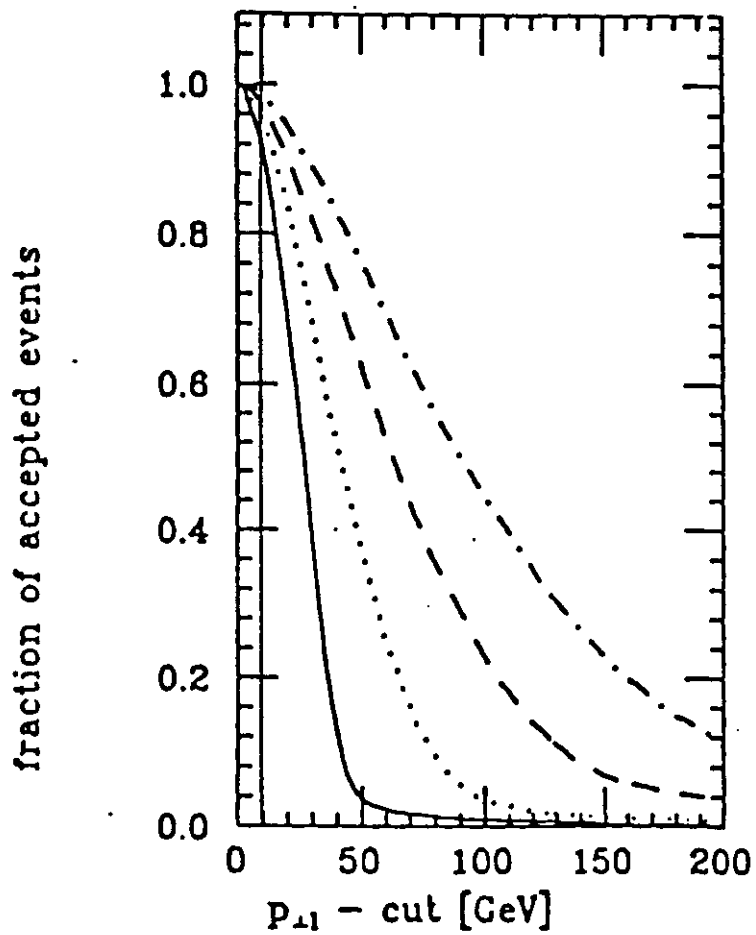
GENERALLY BETTER PERFORMANCE
(BUT NO SILVER BULLET)

## EXAMPLES

- LOW $P_T$ MUONS ($H \to Z^* Z$)
- HIGH $P_T$ ELECTRON SIGN
  - GLUINOS $\to \ell^\pm \ell^\pm$
  - $W_L^+ W_L^+$ SCATTERING


RESOLUTION (%) w/ SUPPRESSED ZERO
η = 0
TRACKER, R = 63 cm ("75")
TRACKER, R = 88 cm ("1m")
MUON SYS
20
15
10
5
2
0
20
40
60
80
100
120
140
160
180
200
$P_T$ (GeV/c)

Higgs Acceptance for Various Lepton $P_t$ cuts.




solid: $M_H$ = 200 GeV, dotted: $M_H$ = 400 GeV
dashed: $M_H$ = 600 GeV, dashed-dotted: $M_H$ = 800 GeV

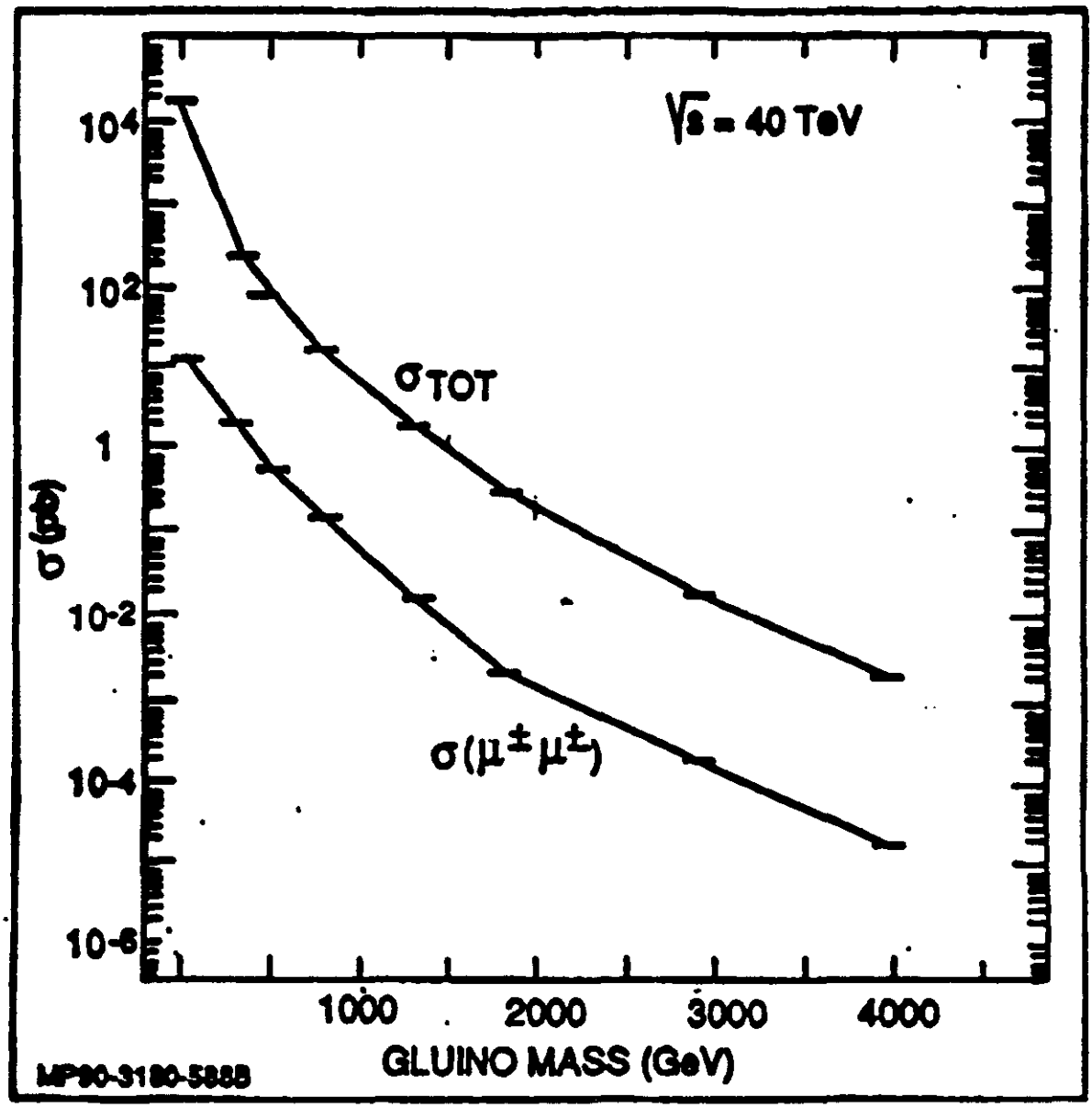
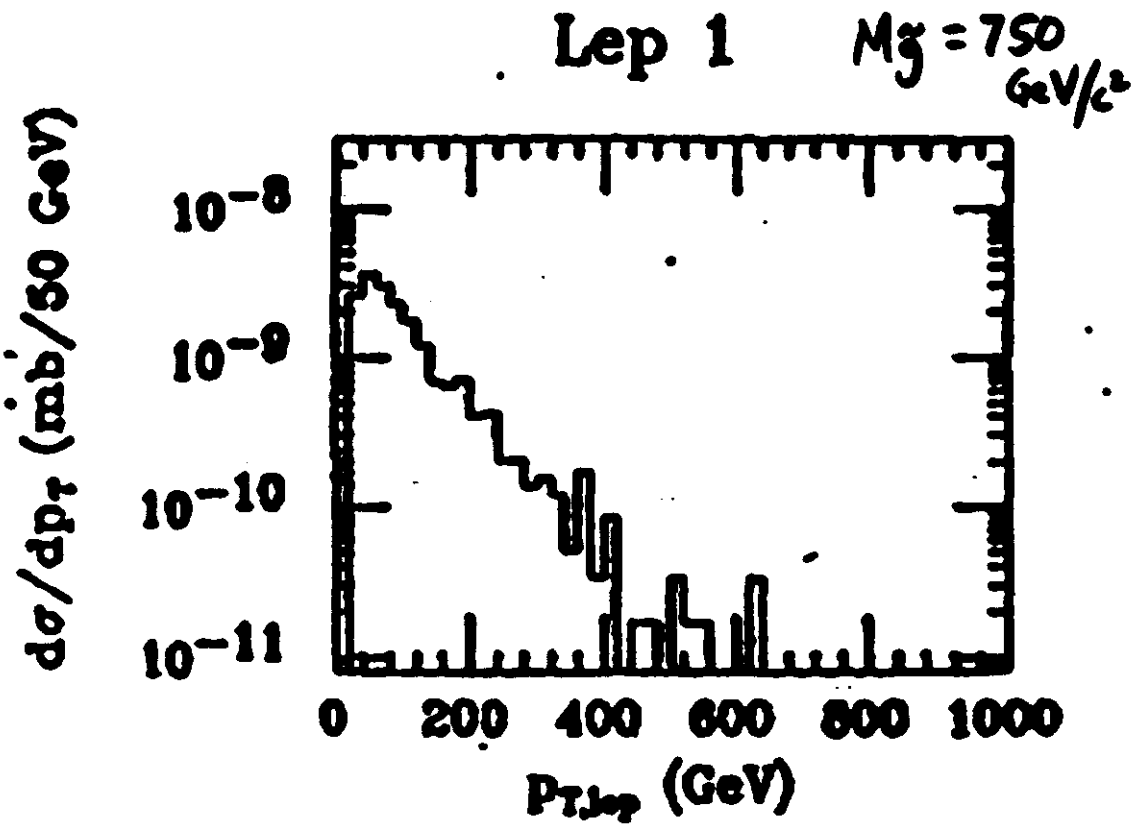



**Fig. 6-19** Gluino Cross Section as a Function of Gluino Mass. Lower curve for Two and Only Two Muons with $p_T$ (μ) >20 GeV/c and $\eta_\mu$ < 2.5


Lep 1
Mg = 750 GeV/c²
dσ/dp_T (mb/50 GeV)
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
0
200
400
600
800
1000
p_T,Jet (GeV)

J.Thomas, E.Wang

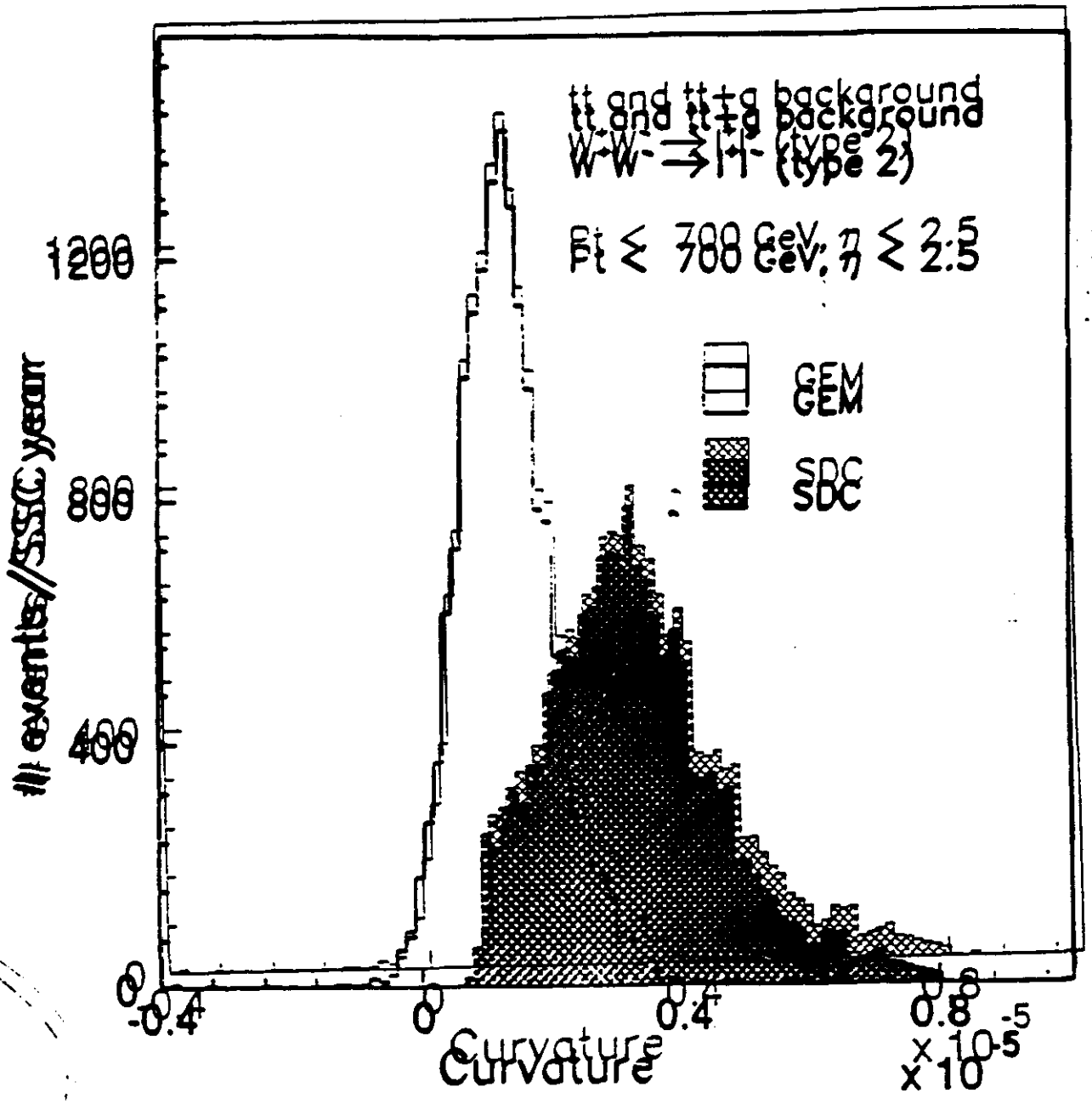
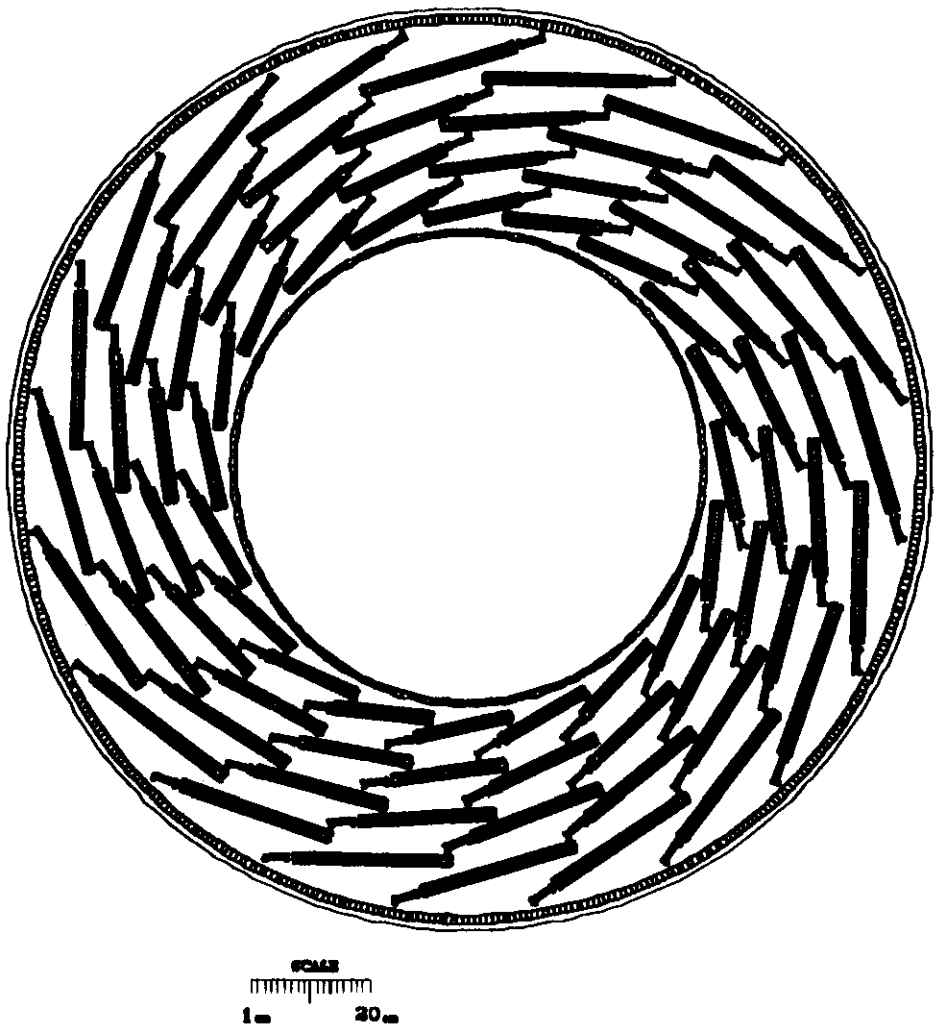



Figure 16: Curvature for type 2 tt background for the SDC and GEM geometries

Figure 16: Curvature for type 2 tt background for the SDC and GEM geometries

# GEM TRACKER IPC
# MODULE LAYOUT (BARREL)

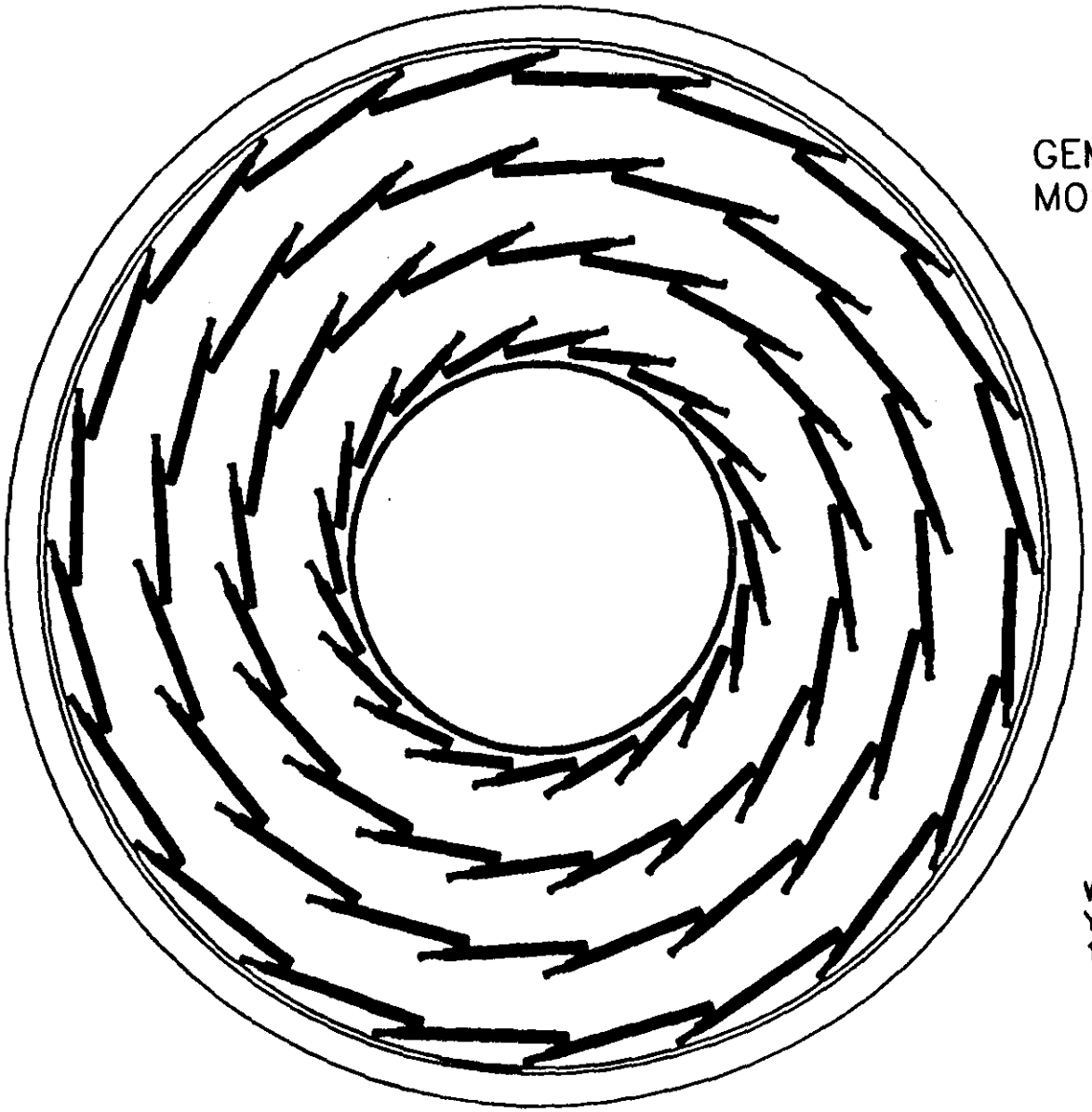



FACTS:

1) 30 SECTORS OF 4 SUPERLAYERS
2) 2 LAYERS PER SUPERLAYER
3) EACH LEVEL ROTATED 4.5 DEG. RELATIVE TO ADJACENT LEVELS

HARDBACK WIDTH:

LEVEL 1 14.76 cm
LEVEL 2 17.26 cm
LEVEL 3 20.60 cm
LEVEL 4 24.06 cm



GEM TRACKER IPC
MODULE LAYOUT (BARREL)

1 METER OUTSIDE RADIUS
20 SECTORS OF 4 SUPERLAYERS
2 IPC LAYERS PER SUPERLAYER
EACH LEVEL ROTATED 4.5 DEG.
RELATIVE TO ADJACENT LEVELS

W. EMMET
YALE UNIVERSITY PPG
11/3/92

# WHAT ARE THE COSTS?

TRACKER

estimate ~0.5 M$

CALORIMETER

under investigation

MUONS

loss of 25 cm of 500 cm

↳ 10% in resolution

WE ARE NOW PROPOSING THIS CHANGE

→ EXECUTIVE COMMITTEE

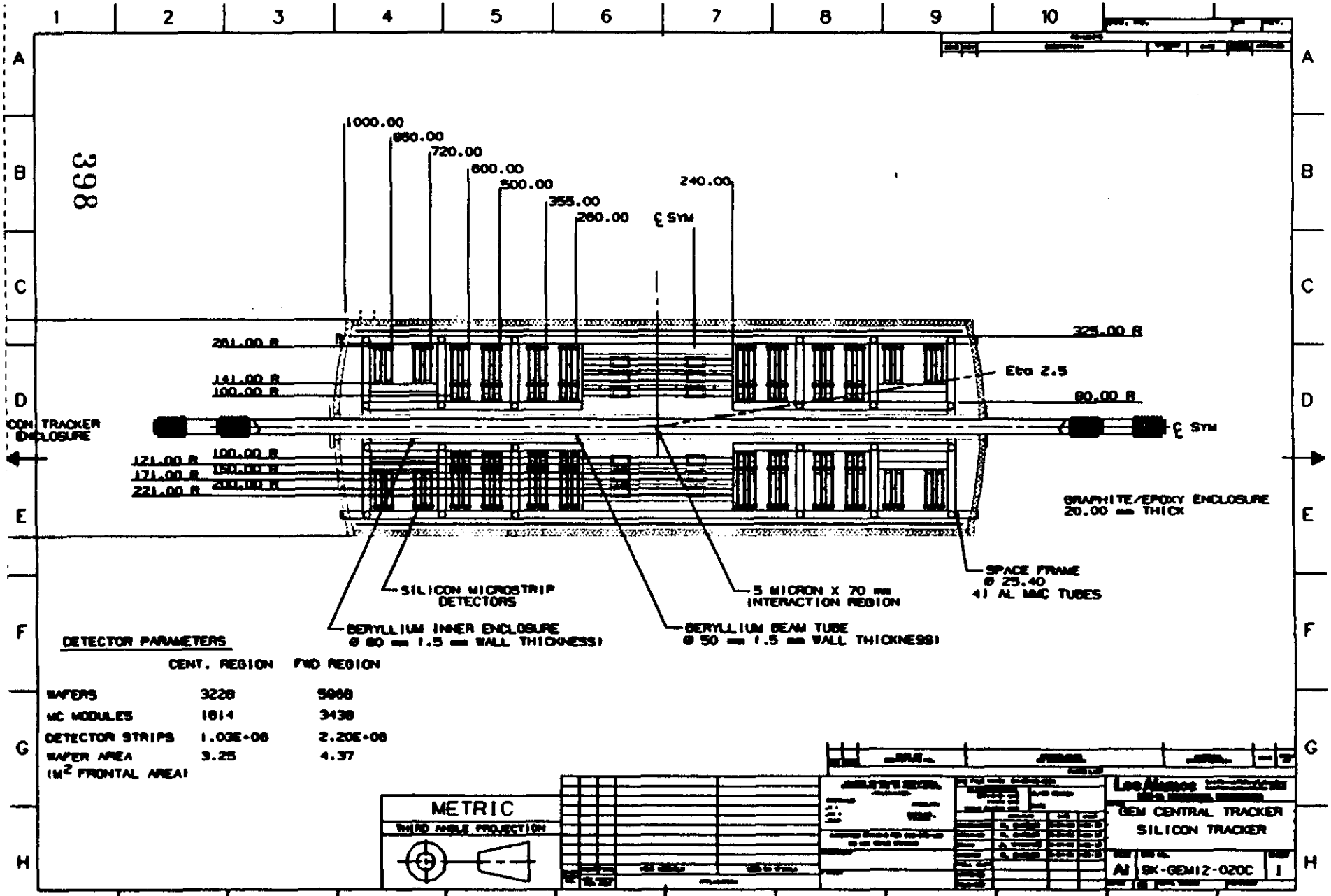
# SILICON MICROSTRIP LENGTH

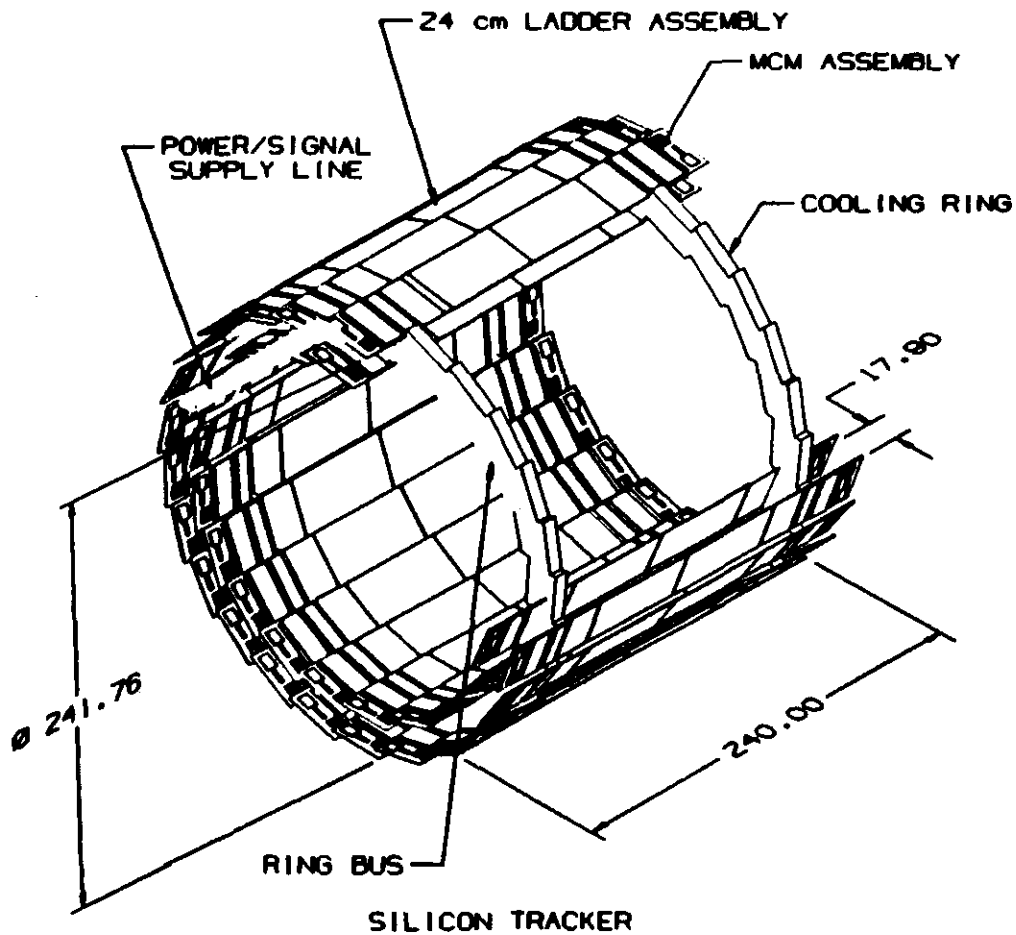
GEM Baseline 1 Assumes 12cm Silicon Microstrips.

Four such strips are assembled into the barrel, leaving the electronics/cooling deep in the barrel.

If we could operate 18cm microstrips, We could build a 36cm long barrel, moving electronics/services to end of barrel.

SIGNIFICANT SIMPLIFICATION OF MECHANICAL CONSTRAINTS


1000.00
880.00
720.00
600.00
500.00
355.00
260.00
240.00
℄ SYM
281.00 R
141.00 R
100.00 R
325.00 R
Eta 2.5
80.00 R
CON TRACKER ENCLOSURE
℄ SYM
121.00 R
171.00 R
221.00 R
100.00 R
150.00 R
200.00 R
GRAPHITE/EPOXY ENCLOSURE
20.00 mm THICK
SPACE FRAME
Ø 25.40
41 AL MMC TUBES
SILICON MICROSTRIP DETECTORS
5 MICRON X 70 mm INTERACTION REGION
BERYLLIUM INNER ENCLOSURE
Ø 80 mm 1.5 mm WALL THICKNESS)
BERYLLIUM BEAM TUBE
Ø 50 mm 1.5 mm WALL THICKNESS)
DETECTOR PARAMETERS
CENT. REGION FWD REGION
WAFERS 3228 5968
MC MODULES 1814 3438
DETECTOR STRIPS 1.03E+08 2.20E+08
WAFER AREA 3.25 4.37
(M2 FRONTAL AREA)
METRIC
THIRD ANGLE PROJECTION
Los Alamos
GEM CENTRAL TRACKER
SILICON TRACKER
A1
SK-GEM12-020C
1




SILICON TRACKER
INNER LAYER 24 cm SHELL ASSEMBLY

METRIC
THIRD ANGLE PROJECTION

Los Alamos
SILICON TRACKER
INNER LAYER
24 cm SHELL ASSEMBLY
A1 SK-BEM12-044 1

# 10 cm strips

## Advantages

- simplify cooling
- reduce heat load
- reduce channel count
- reduce scattering in barrel (cables/electron

## Issues

- occupancy (NO!)
- S/N → efficiency
- silicon detector optimization
  (eg. metal resistance)

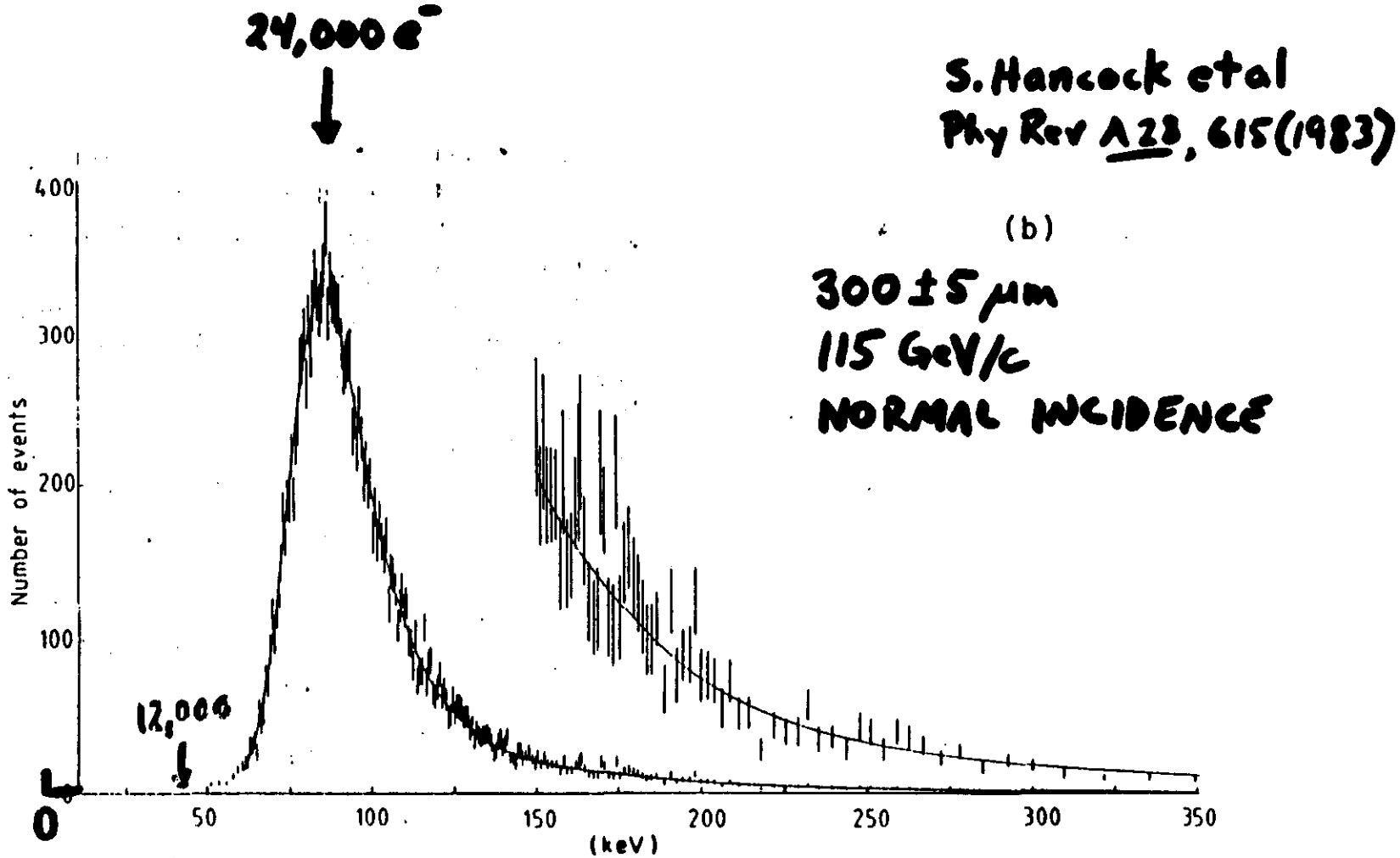
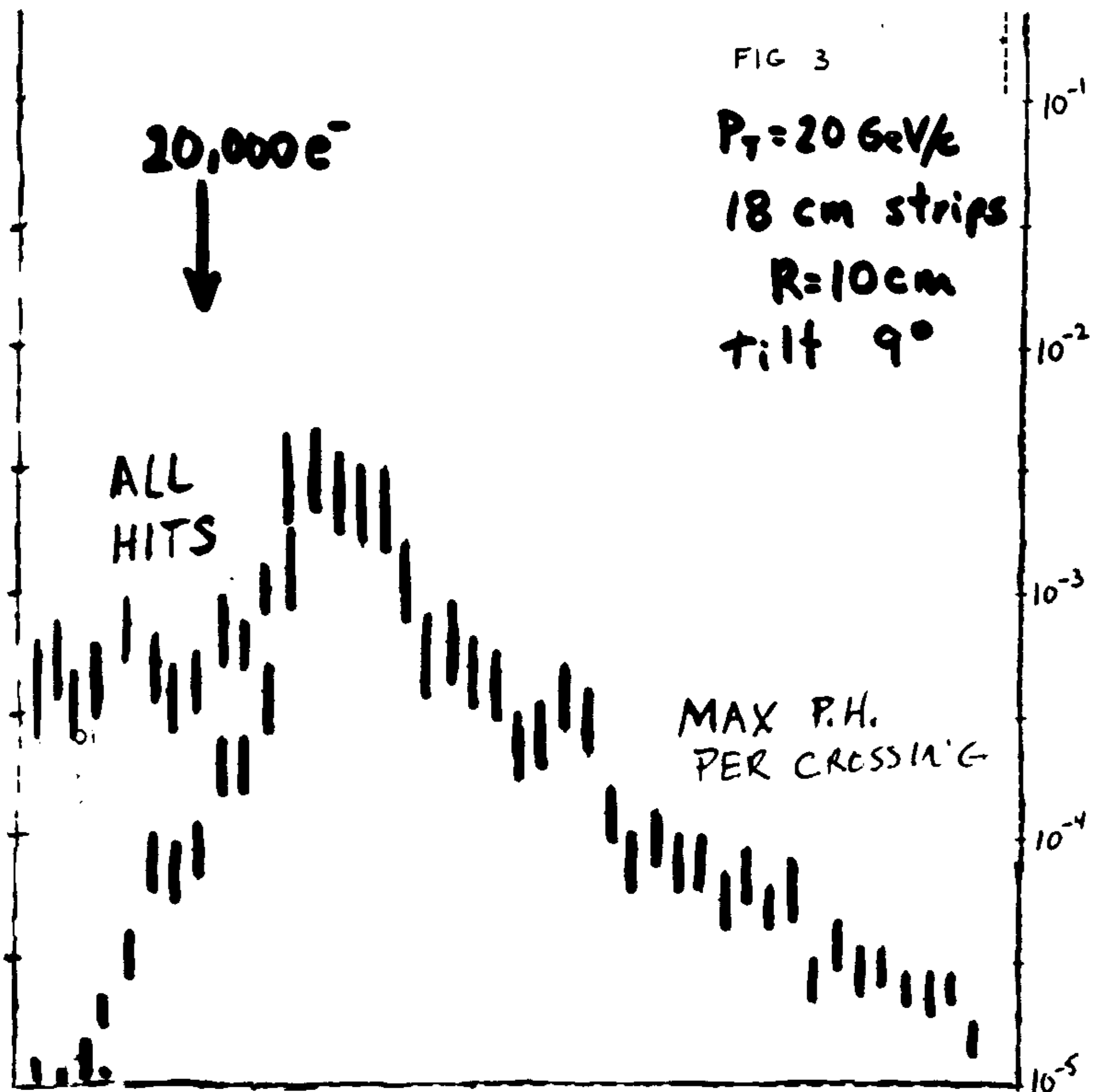
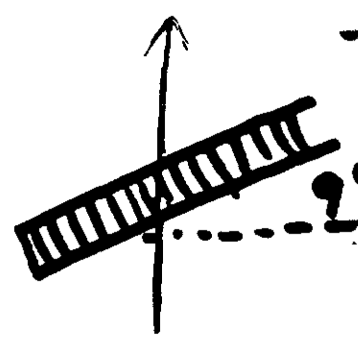



FIG. 2. (a) and (b) show the energy-loss spectra at 0.736 and .115 GeV/$c$ of incoming proton momenta, respectively. Continuo curves are the complete fits to the experimental data. Values of $\xi$ are $14.9\pm0.8$ and $5.5\pm0.3$, respectively (the corresponding values the best fit are $15.0\pm0.8$ and $5.6\pm0.3$). Values of $\sigma=\sqrt{\delta_2}$ are $11.3\pm1.4$ and $5.5\pm1.1$, respectively (the corresponding values of t best fit are $10.2\pm1.3$ and $5.7\pm1.1$). In (b) the tail is also shown with the vertical scale multiplied by ten.

FIG 3

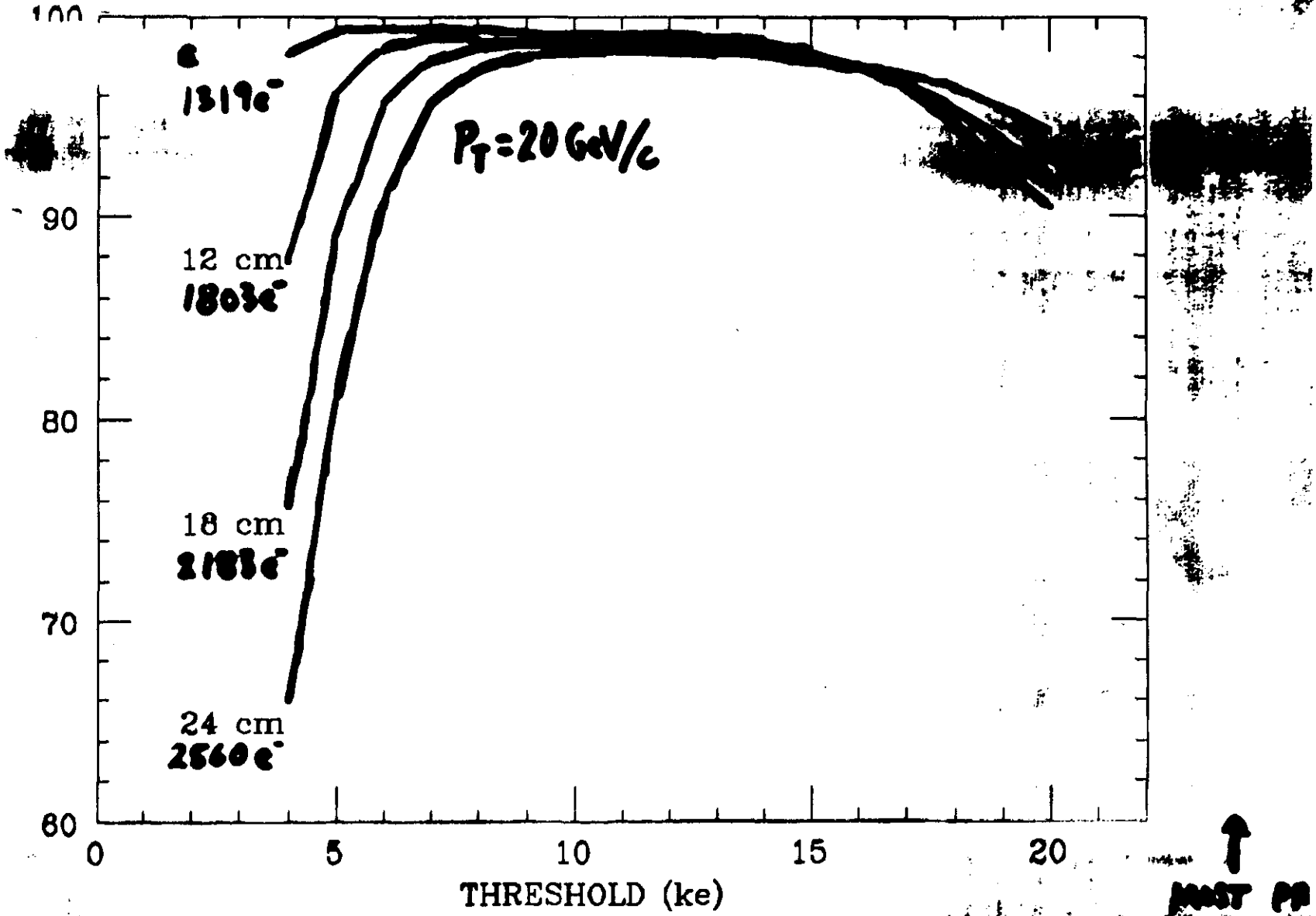



| | | | | keV |
|---|---|---|---|---|
| | [illegible] | 69 | 9.4 | 60 |
| 9 | 278 | 85 | 9.2 | 65 |
| 10 | 375 | 97 | 9.8 | 70 |
| 11 | 504 | 129 | 11.4 | 75 |
| 12 | 634 | 130 | 11.4 | 80 |
| 13 | 793 | 159 | 12.6 | 85 |
| 14 | 1004 | 211 | 14.5 | 90 |
| 15 | 1254 | 250 | 15.8 | 95 |
| 16 | 1493 | 239 | 15.5 | 100 |
| 17 | 1729 | 236 | 15.4 | 105 |
| 18 | 1964 | 235 | 15.3 | 110 |
| 19 | 2169 | 205 | 14.3 | 115 |
| 20 | 2344 | 175 | 13.2 | 120 |
| 21 | 2524 | 180 | 13.4 | 125 |
| 22 | 2693 | 169 | 13.0 | 130 |
| 23 | 2855 | 162 | 12.7 | 135 |
| 24 | 2994 | 139 | 11.8 | 140 |
| 25 | 3137 | 143 | 12.0 | 145 |
| 26 | 3295 | 158 | 12.6 | 150 |
| 27 | 3442 | 147 | 12.1 | 155 |
| 28 | 3552 | 110 | 10.5 | 160 |
| 29 | 3643 | 91 | 9.5 | 165 |
| 30 | 3744 | 101 | 10.0 | 170 |
| 31 | 3835 | 91 | 9.5 | 175 |
| 32 | 3925 | 90 | 9.5 | 180 |
| 33 | 4001 | 76 | 8.7 | 185 |
| 34 | 4086 | 85 | 9.2 | 190 |
| 35 | 4159 | 73 | 8.5 | 195 |
| 36 | 4239 | 80 | 8.9 | 200 |
| 37 | 4283 | 44 | 6.6 | 205 |
| 38 | 4340 | 57 | 7.5 | 210 |
| 39 | 4386 | 46 | 6.8 | 215 |
| 40 | 4436 | 50 | 7.1 | 220 |
| 41 | 4477 | 41 | 6.4 | 225 |
| 42 | 4514 | 37 | 6.1 | 230 |
| 43 | 4553 | 39 | 6.2 | 235 |
| 44 | 4575 | 22 | 4.7 | 240 |
| 45 | 5000 | 425 | 20.6 | OVR |
| | E 0 | E 0 | E 0 | E 0 |

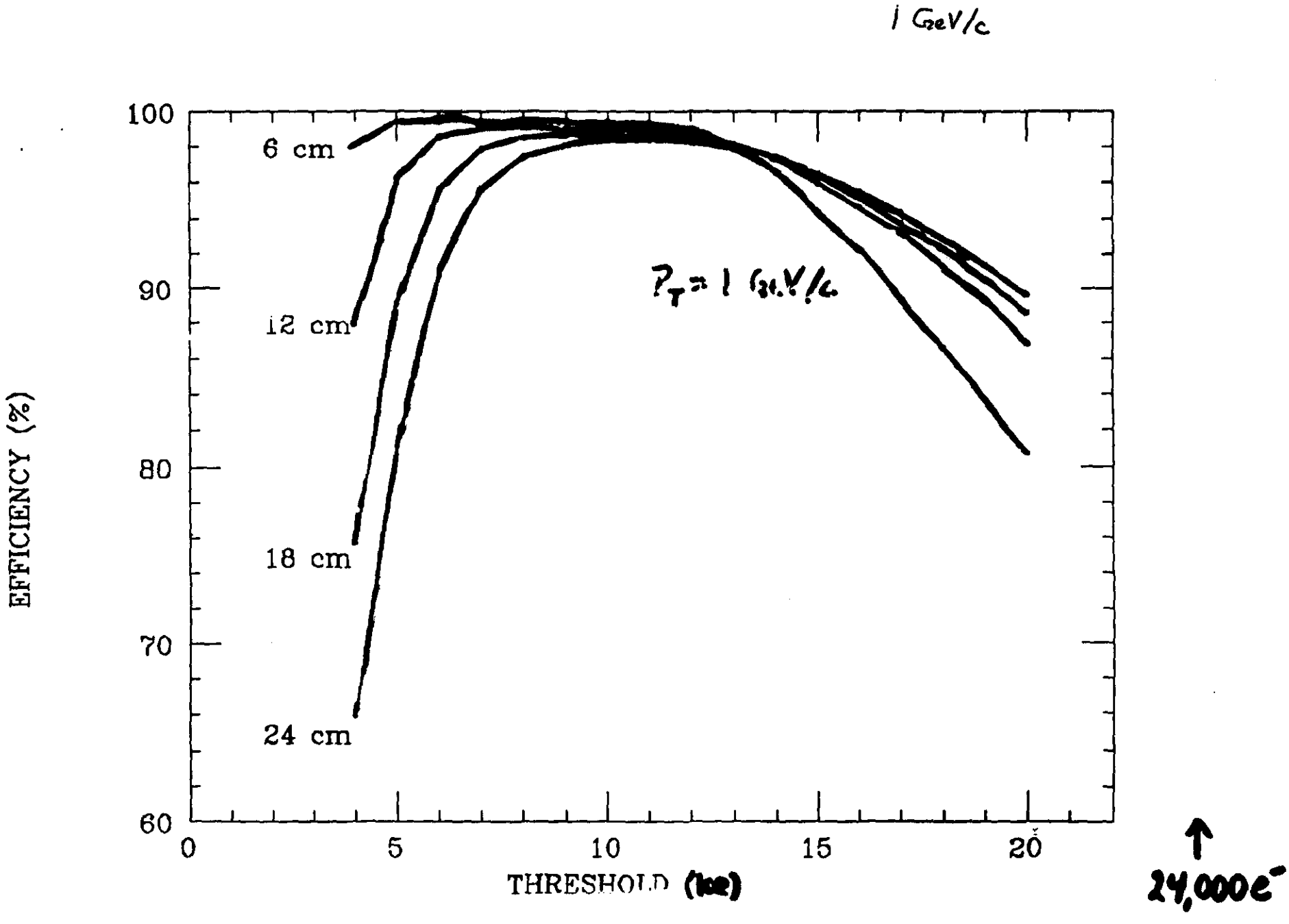



PLAN TO
REDUCE ANGLE
~2° TO MATCH
LORENTZ ANGLE

FIG 6


100
90
80
70
60
0
5
10
15
20
EFFICIENCY (%)
THRESHOLD (ke)
12 cm
18 cm
24 cm
$P_T$=20 GeV/c

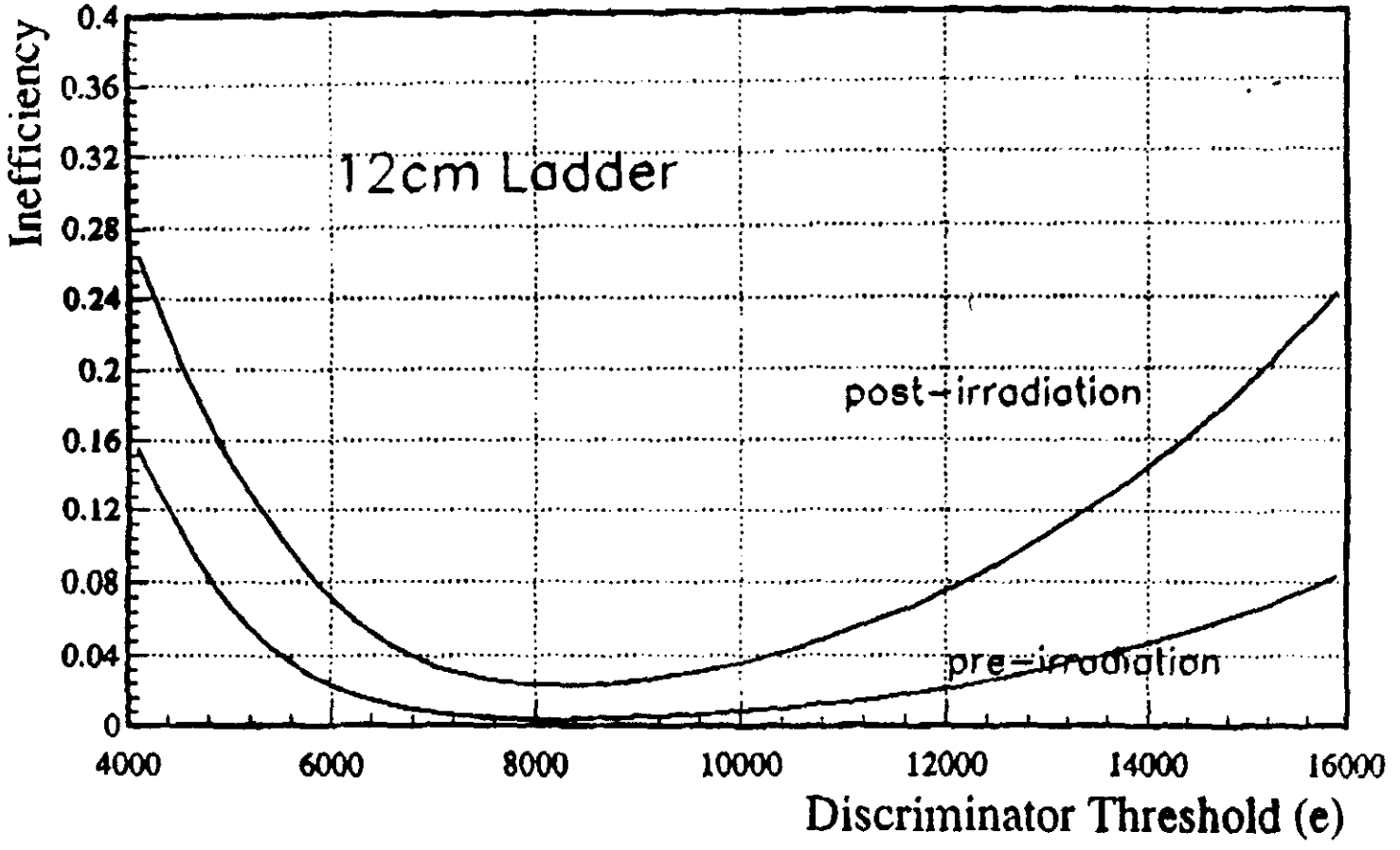
403

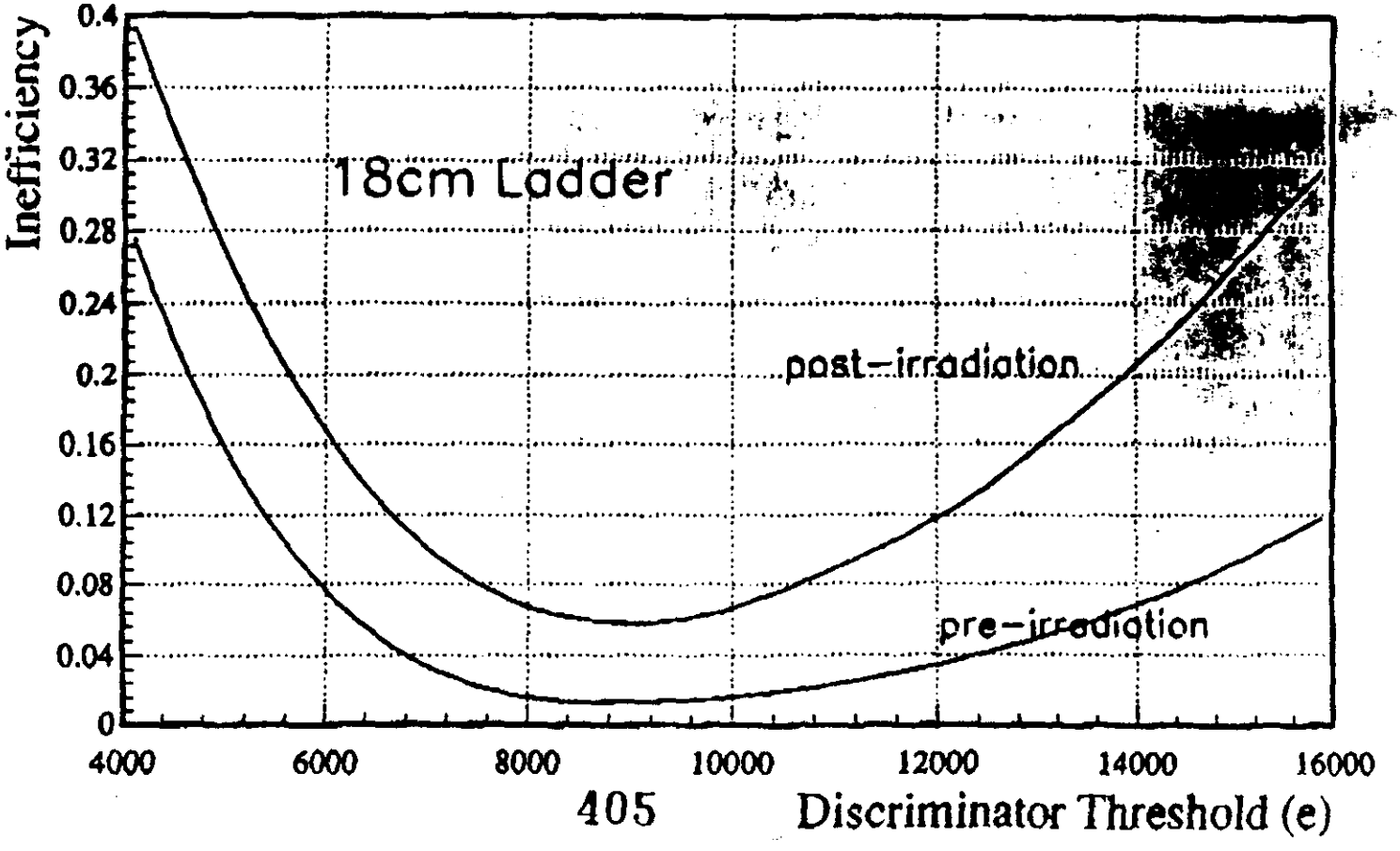

1 GeV/c
100
90
80
70
60
EFFICIENCY (%)
6 cm
12 cm
18 cm
24 cm
$P_T$ = 1 GeV/c
0
5
10
15
20
THRESHOLD (ke)
24,000e⁻

# Hit Ineff. for muons $P_t$=20

12cm BARREL + FORWARD

50Ω/cm

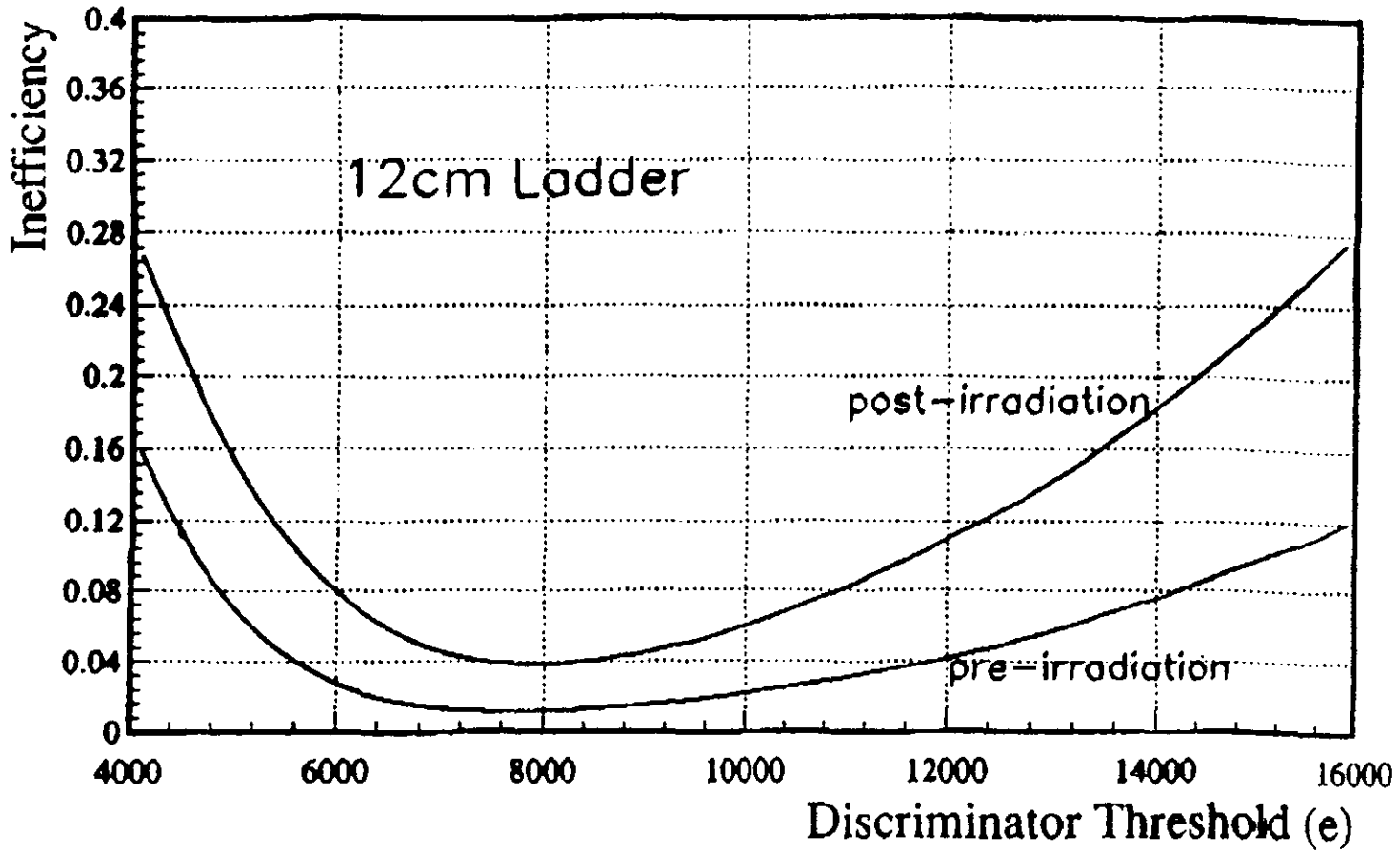


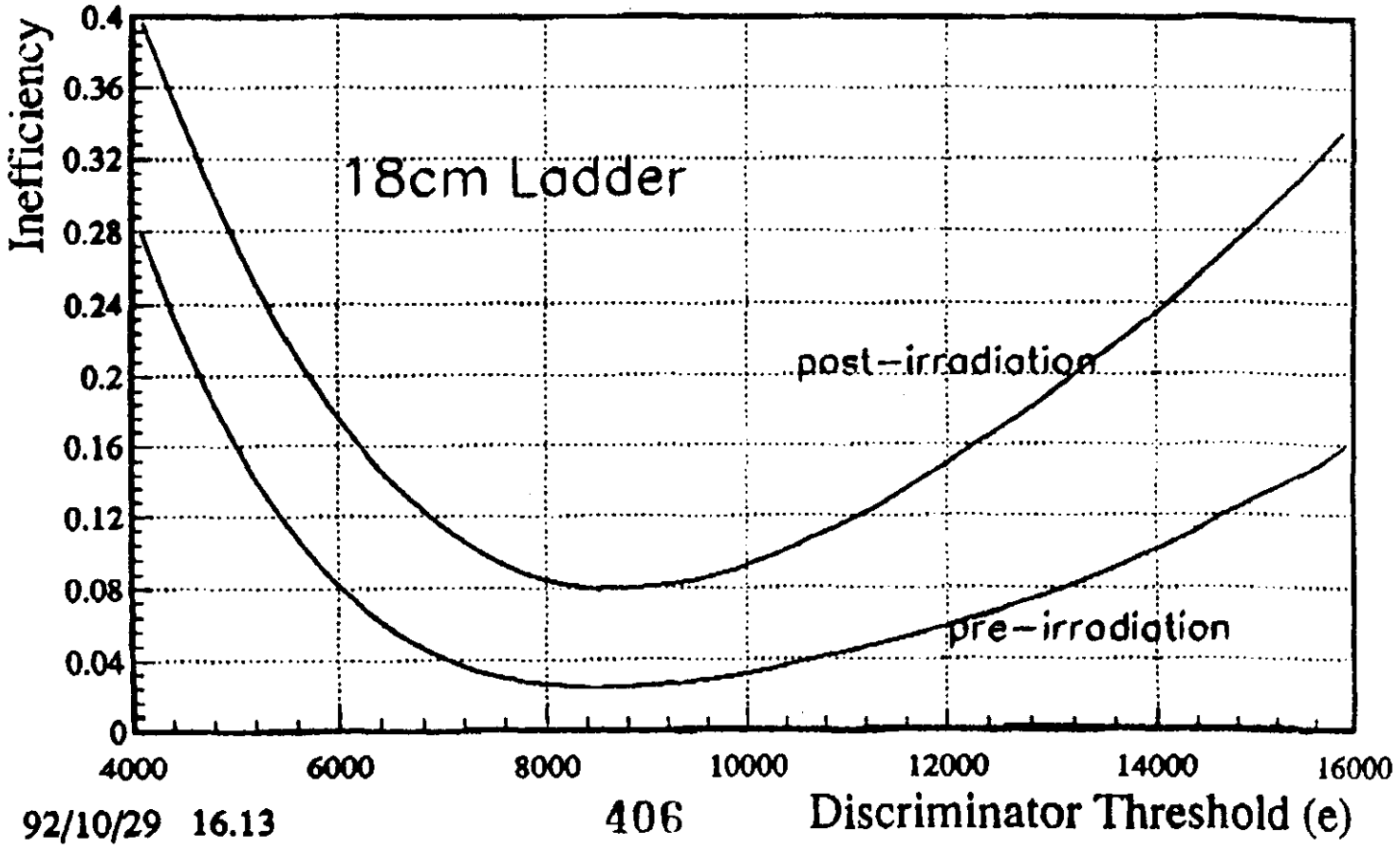



# Hit Ineff. for Higgs+MB (1Gev $P_t$ cut)

18cm BARREL + FORWARD

50Ω/cm

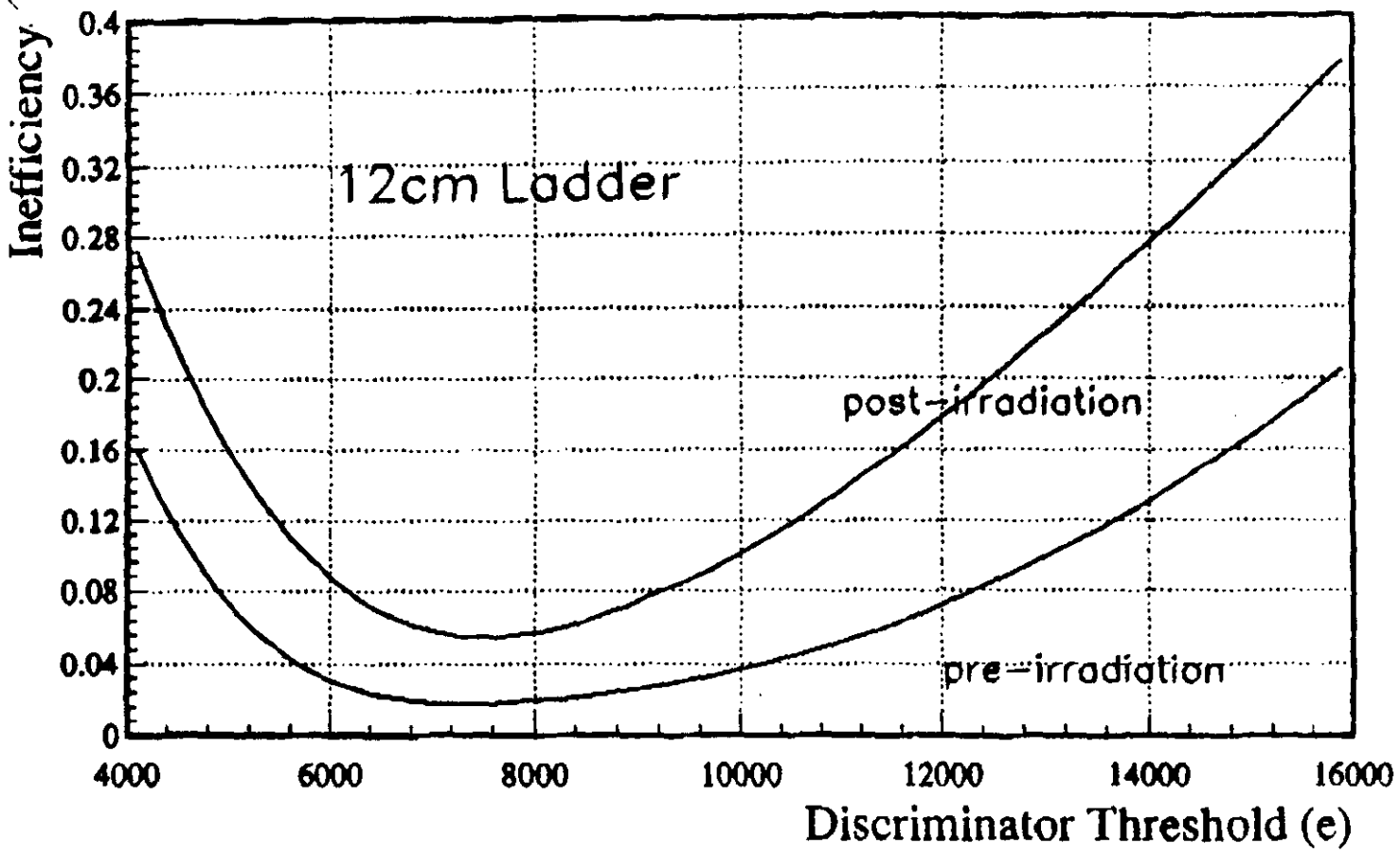


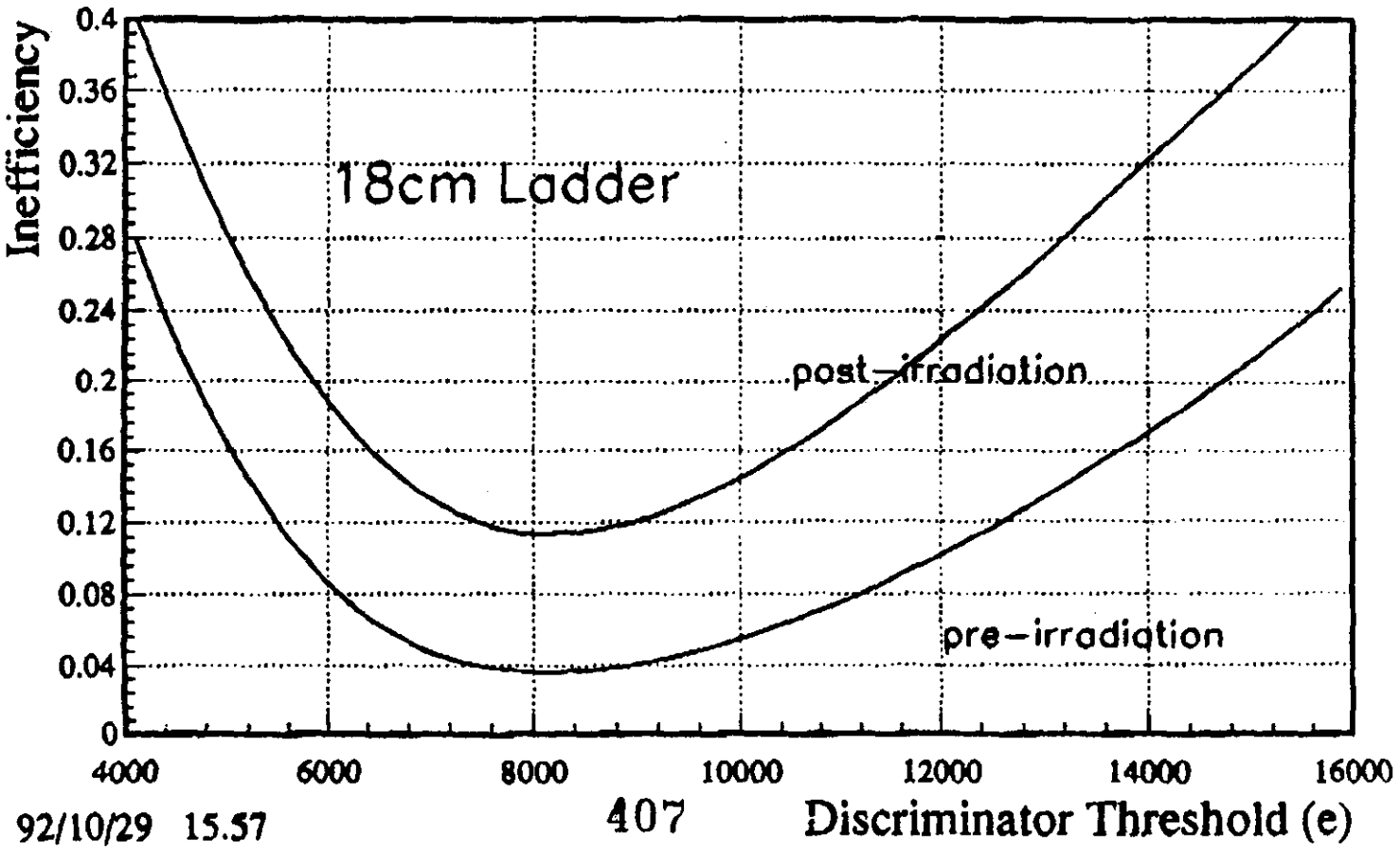



# Hit Ineff. for Higgs+MB (1Gev $P_t$ cut)

18cm BARREL

50Ω/cm



# SIGNIFICANT DIFFERENCES BETWEEN GEM + SDC

| GEM | SDC |
| --- | --- |
| single-sided | double-sided |
| B = 0.8 T | B = 2 T |
| induced charge concentrated on p-side over small distance | induced charge spread on both sides over ~50 μm |
| outer radius = 22 cm makes 36 cm long barrel possible | outer radius = 36 cm demands 60 cm long barrel |
| ⇓ | ⇓ |
| 18 cm strips | 12 cm strips |

# STATUS OF 18 cm DECISION

WE ARE NOW PURSUING THE DESIGN OF AN 18 cm SYSTEM, BUT WILL NOT MAKE FINAL DECISION UNTIL:

1. NEWLY SUGGESTED DETRIMENTAL EFFECTS ARE CONTROLLED
   - STRIPLINE DISPERSION
   - INFLUENCE OF ADJACENT STRIPS AND PREAMPS
   - CHARGE SHARING (GEANT)

OR

2. TEST IN LAB DEMONSTRATES PERFORMANCE

# TWO RECENT VISITS TO TAIWAN

## INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE ACADEMY OF SCIENCE

OCT 4-8

RON BARBER, JIM BRAU,
BRAD COCKE, WILL EMMET,
SANGKOO HAHN, R.T. KOLLIPARA
TAYE LEE, PAUL [illegible]
[illegible]

OCT 27-30

T.D. LEE, C. BALTAY, B. [illegible]

# GEM Central Tracker
# Proposed Plan for Collaboration on R&D and Engineering Design

Approximately two-year period - 1993 & 1994

1. Sign Agreement to formalize Phase I collaboration on R&D effort and engineering design.

2. Consolidate project-oriented working groups to start collaboration

   a) Identify U.S. and Chinese group leaders
   b) Group members

3. Each working group (in coordination with overall Central Tracker Management) should start in November 1992 to

   a) Set up schedule of short and long visits back and forth
   b) Develop work plan of activities
   c) Propose a schedule for the work plan
   d) Define milestones for "Deliverables" i.e. measureable signs of progress such as specific designs, prototypes, test results, etc.

4. Define Subsystem Prototype program

   a) Identify person in charge
   b) Institutional responsibilities
   c) Develop schedules & milestones

5. Sign Phase II of the Agreement

6. Develop Fabrication Plan for the Central Tracker

   a) Define subsystems or tasks
   b) Identify persons in charge of each subsystem
   c) Propose institutional responsibility for each subsystem
   d) Develop fabrication schedule for each subsystem
   e) Define milestones to measure progress

# GEM Central Tracker

Project-oriented working groups to collaborate on R&D and Engineering Design

**Mechanical - Group A**

| | |
|---|---|
| 1. Silicon Tracker | Ron Barber/C. L. Wu |
| 2. IPC Tracker | Will Emmet/L.S. Lee |

**Electronics - Group B**

| | |
|---|---|
| 1. Silicon Tracker | Dave Lee/J. Fu-Su |
| 2. IPC Tracker | Jim Musser/Peter Chou |

**Test Beam Work - Group C**

| | |
|---|---|
| 1. Silicon Tracker | Geoff Mills, Jim Brau/ |
| 2. IPC Tracker | Kate Morgan/ |

# GEM Central Tracker R&D and Design Working Groups

## Mechanical--Group A

### Overall Coordination: R. Barber/C. Hsu (CMS)

| TASK | U.S.A. | TAIWAN | |
|---|---|---|---|
| | | ITRI Engineers | Physicists |
| 1) Silicon Tracker | R. Barber | C.L. Wu | A. Chen |
| a) Support & cooling rings, ladders, etc. | T. Thomson, R. Barber | Chung-Lin Wu, Larry C.C. Tang | P.K. Teng |
| b) Support frame | T. Thomson | Y.C. Chen | P.K. Teng |
| c) Cooling & gas flow | R. Barber | Chung-Lin Wu, Larry Tang, Ping-Ho Sam Shih | P.K. Teng |
| d) Alignment & monitoring | R. Barber | Li-Shing Lee | M.T. Cheng |
| e) Cabling | R. Barber | Jong-Ming Liu | M.T. Cheng |
| 2) IPC Tracker | W. Emmet | L.S. Lee | A. Sumarokov |
| a) Chamber modules | W. Emmet | Chung-Lin Wu, Jau-Liang Chen, Larry Tang | A. Sumarokov |
| b) Support structure | W. Emmet, T. Thomson | Chung-Lin Wu | A. Sumarokov |
| c) Cooling and gas flow | D. Neeper | Ping-Ho Sam Shih | A. Sumarokov |
| d) Alignment & monitoring | R. Barber | Li-Shing Lee | M.T. Cheng |
| e) Cabling | W. Emmet | Jong-Ming Liu | M.T. Cheng |

# GEM Central Tracker R&D and Design Working Groups

## Electronics--Group B

### Overall Coordination: Jim Musser/Julia Fu-Su

| TASK | U.S.A. | TAIWAN | |
|---|---|---|---|
| | | ITRI Engineers | Physicists |
| 1) Silicon Detector | Dave Lee | Julia Fu-Su | A. Chen |
| a) Detectors | J. Brau | W.C. Tsai | M.J. Wang |
| b) Front end amplifiers | S. Hahn | S.W. Chang, Sebastian Liau | S.Y. Chao |
| c) Digital pipeline (CMOS1) | B. Cooke | Steven Yang, Peter Chou | M.T. Cheng |
| d) Readout controller (CMOS2) | J. Brau | | M.T. Cheng |
| e) Multichip module (MCM) | B. Cooke | Fang-Lin Chao, H.C. Chang, Mei-Ling Chou | M.T. Cheng |
| f) Fiber optics | J. Mills | W.S. Chan | P.K. Teng |
| 2) IPC Electronics | Jim Musser | S.K. Peter Chou | J. Antos |
| a) Front end amplifiers | P. O'Connor | S.W. Chang, Sebastian Liau | S.Y. Chao |
| b) Switched capacitor array | C. Britton | Peter Chou | M.T. Cheng |
| c) ADC, Multiplexer | J. Musser | | M.J. Wang |
| d) A to D pipeline | G. Haller | Steven Yang | M.T. Cheng |
| e) Readout controller | C. Bender | | M.T. Cheng |
| f) Fiber optics | C. Bender | W.S. Chan | P.K. Teng |

# Silicon Microstrip Detectors

J. Brau
Oct 26, 92

## R&D Schedule and Milestones

Proposed ERSO GEM Silicon Microstrip R&D Plan

| | |
|---|---|
| Fabricate 1st Microstrips based on 7.93 x 4.01 cm2 design (minimize strip resitance) | 8/92-12/92 |
| Develop back-to-back 2 chip bonding with 5 micron precision | 12/92-3/93 |
| Develop rad-hard poly resitance of 500kOhm | 1/93-4/93 |
| Study effects of edge defects on wafer yield and strip reliability | 1/93-4/93 |
| Fabricate 1st GEM specific microstrip prototype | 3/93-5/93 |
| Study microstrip characteristics (leak current, depletion voltage, breakdown voltage, poly resist, etc) vs. radiation exposure and develop hardening procedures | 4/93-9-93 |
| Fabricate 2nd GEM specific microstrip prototype | 9/93-11/93 |
| Study microstrip characteristics (leak current, depletion voltage, breakdown voltage, poly resist, etc) vs. radiation exposure and develop hardening procedures | 11/93-4-94 |
| Fabricate Final GEM specific microstrip prototype | 4/94- 6/94 |

MILESTONES

| | |
|---|---|
| Deliver 7.93 x 4.01 cm2 microstrip detector to Oregon (goal: strip res: 10 ohm/cm) | Jan 15, 1993 |
| Define GEM silicon detector design | Feb 31, 1993 |
| Deliver 1st GEM specific prototype | May 1, 1993 |
| Define revised GEM detector design | Oct 15, 1993 |
| Deliver 2nd GEM microstrip prototype | Jan 1, 1994 |
| Define Final GEM detector design | June 15, 1994 |
| Deliver Final GEM Prototypes | Aug 1, 1994 |

# Prototype Program

1. Silicon Tracker

    a) 18 cm Barrel Ladder
    b) Forward Disc

2. IPC Tracker

    a) Barrel Chamber
    b) Endcap Chamber

3. Test Beam Setups

    a) Silicon Ladders
    b) IPC Chambers

# GEM Central Tracker Subsystems for Fabrication

1. Silicon Detector Mechanical

   a) Barrel Detector

      i) Ladder Assemblies

      ii) Support and Cooling Rings

      iii) Barrel Assembly

   b) Forward Detector

      i) Detector Discs

      ii) Support and Cooling Rings

      iii) Two Forward Assemblies

   c) Support Structure Space Frame

   d) Cooling and Gas Flow Systems

   e) Alignment and Monitoring System

2. IPC Tracker Mechanical

a) Barrel Region

i) Chamber Modules

ii) Support Structure

b) Forward Detectors

i) Chamber Modules

ii) Support Structure

c) Overall Support Structure and Kinematic Mounts

d) Cooling and Gasflow Systems

e) Alignment and Monitoring System

3. **Silicon Tracker Electronics**

   a) Silicon Detectors

   b) Front End Preamplifiers

   c) Digital Pipeline Buffer

   d) Readout Controller

   e) Multichip Module

   f) Fiber Optics

4. **IPC Electronics**

   a) Front End Amplifier

   b) Pipeline Buffer

   c) Analog to Digital Converter

   d) Readout Controller

   e) Fiber Optics

Increase in Tracking Volume
70 cm → 95 cm

Increasing Silicon Microstrip Length
12 cm → 18 cm

Moving ahead with R+D
and Engineering Collaboration
with Taiwan

Tomorrow – 8:30 am
Tracker Meeting
AGS Snyder Auditorium

# Discovery Limits for Supersymmetric Higgs Bosons

Alan L. Stange

Nov. 4, 1992

V. Barger
M. Berger
K. Cheung
R.J.N. Phillips

Li, sher

J. Gunion A. Turski

M. Berger

Y. Okada et. al.

Haber R. Hempfling

J. Ellis et. al.

Barbieri et. al.

J. Lopez. D. V. Nanopoulos

A. Yamada

M. Drees M. Nojiri

R. Hempfling

M. Diaz H. Haber

D. Pierce et. al.

A. Brignole et. al.

H. Baer et. al.

J. Gunion et. al.

F. Zwirner

A. Djouadi et. al.

P. Zerwas

Espiniosa, Quiros

Krasnikov, Pokorski

Kalinowski

Chankowski et. al.

I. Introduction
- Radiative Corrections

II. Experiments
- LEP I and II
- SSC

III. What Collider covers MSSM?

IV. Summary and Conclusions

# I. Introduction

## Minimal SUSY Model

- 2 Higgs boson doublet

$$H_1 = \begin{pmatrix} \phi_1^0 \\ -\phi_1^- \end{pmatrix}, \quad H_2 = \begin{pmatrix} \phi_2^+ \\ \phi_2^0 \end{pmatrix}$$

- 5 physical particles

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

$$\begin{pmatrix} h \\ H \end{pmatrix} = \sqrt{2} \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} \mathrm{Re}\phi_1^0 - v_1 \\ \mathrm{Re}\phi_2^0 - v_2 \end{pmatrix}$$

- 2 free parameters

$$m_A, \quad \tan\beta = v_2 / v_1$$

$$m_{h,H}^2 = \frac{1}{2}\left[M_Z^2 + m_A^2 \pm \sqrt{(M_Z^2 + m_A^2)^2 - 4m_A^2 M_Z^2 \cos^2 2\beta}\right]$$

$$m_{H^\pm}^2 = M_W^2 + m_A^2$$

$$m_h \leq M_Z \qquad m_H \geq M_Z \qquad m_{H^\pm} \geq M_W$$

Could be ruled out or verified at LEP II

- Radiative Corrections

$\rightarrow$ masses, couplings, mixing angles

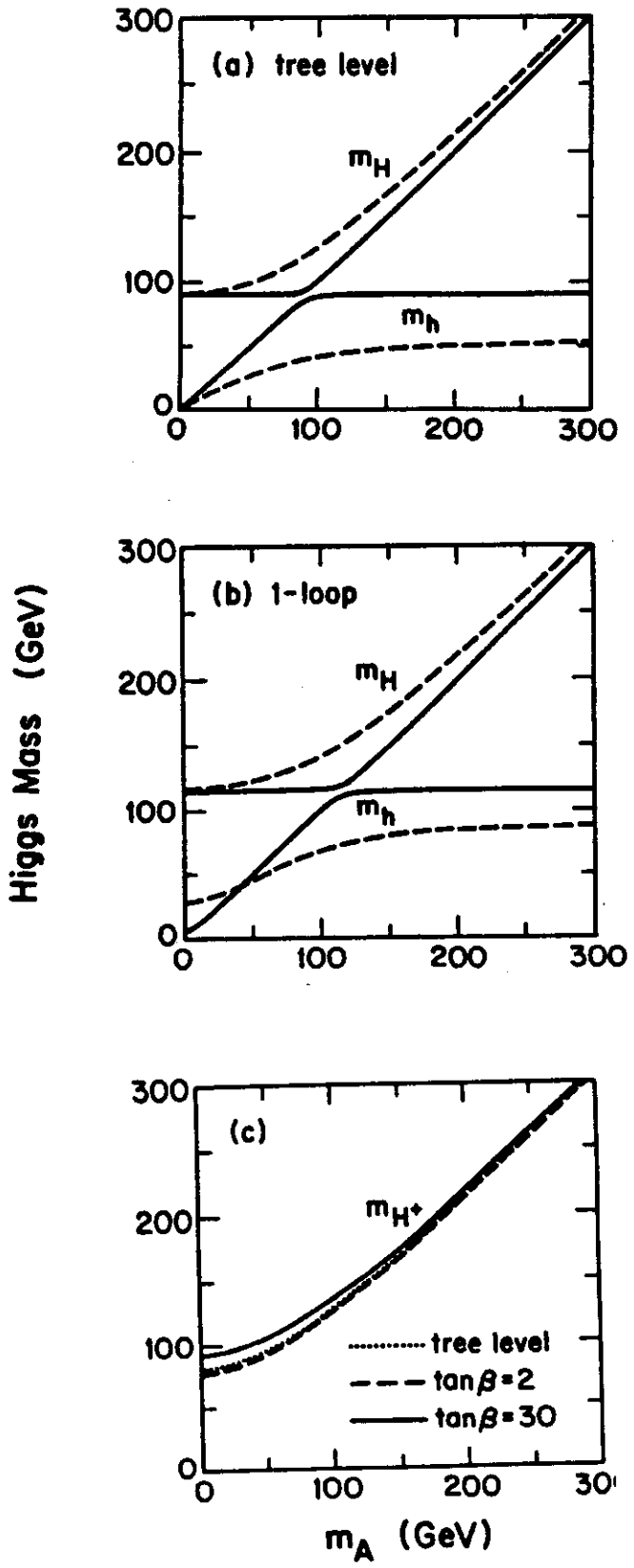
Effective potential formalism

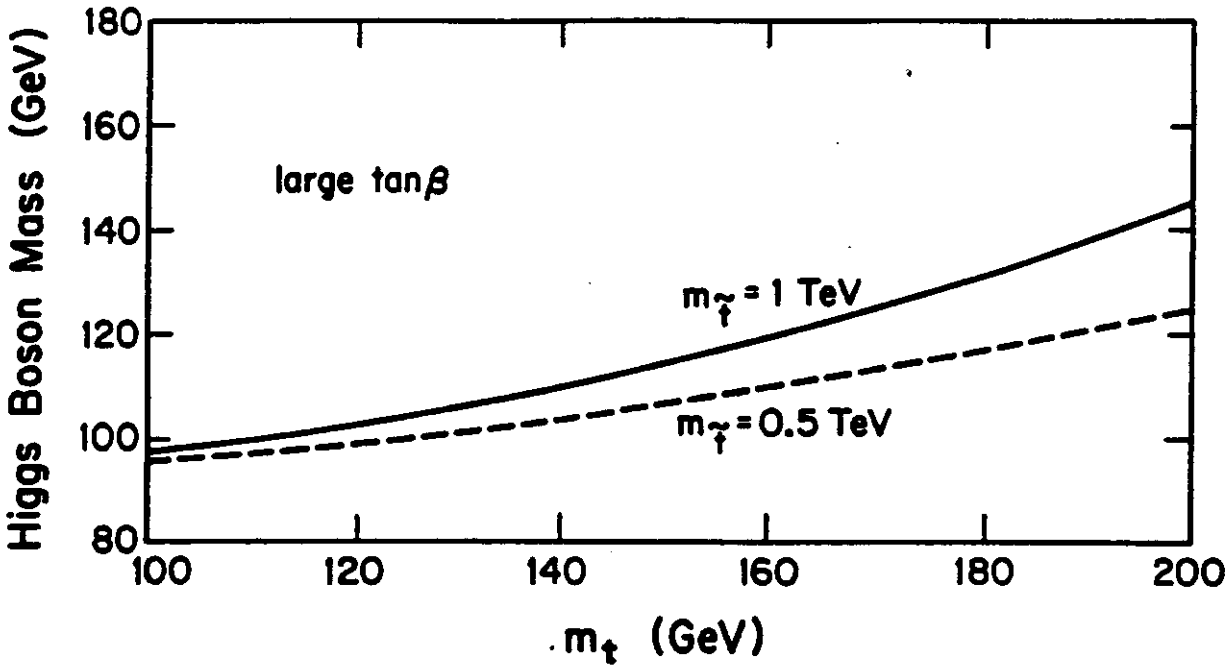
Schwinger; Goldstone, Salam, Weinberg;
Nambu; Coleman, Weinberg; Li, Sher;

* Expand in Loops, not couplings
* Include top quark, bottom quarks and squarks

Ellis, Ridolfi, Zwirner
PLB 262, 477 (1991)

$$m_t = 150 \text{ GeV}$$
$$m_Q = m_U = m_D = m_{susy}$$
$$A_t = A_b = 2\mu = m_{susy} / 2$$
$$m_{susy} = 1000 \text{ GeV}$$


(a) tree level
$m_H$
$m_h$
(b) 1-loop
$m_H$
$m_h$
(c)
$m_{H^+}$
tree level
tan β = 2
tan β = 30
Higgs Mass (GeV)
$m_A$ (GeV)
0
100
200
300


Higgs Boson Mass (GeV)
180
160
140
120
100
80
large tanβ
$m_{\tilde{t}}$ = 1 TeV
$m_{\tilde{t}}$ = 0.5 TeV
100
120
140
160
180
200
$m_t$ (GeV)

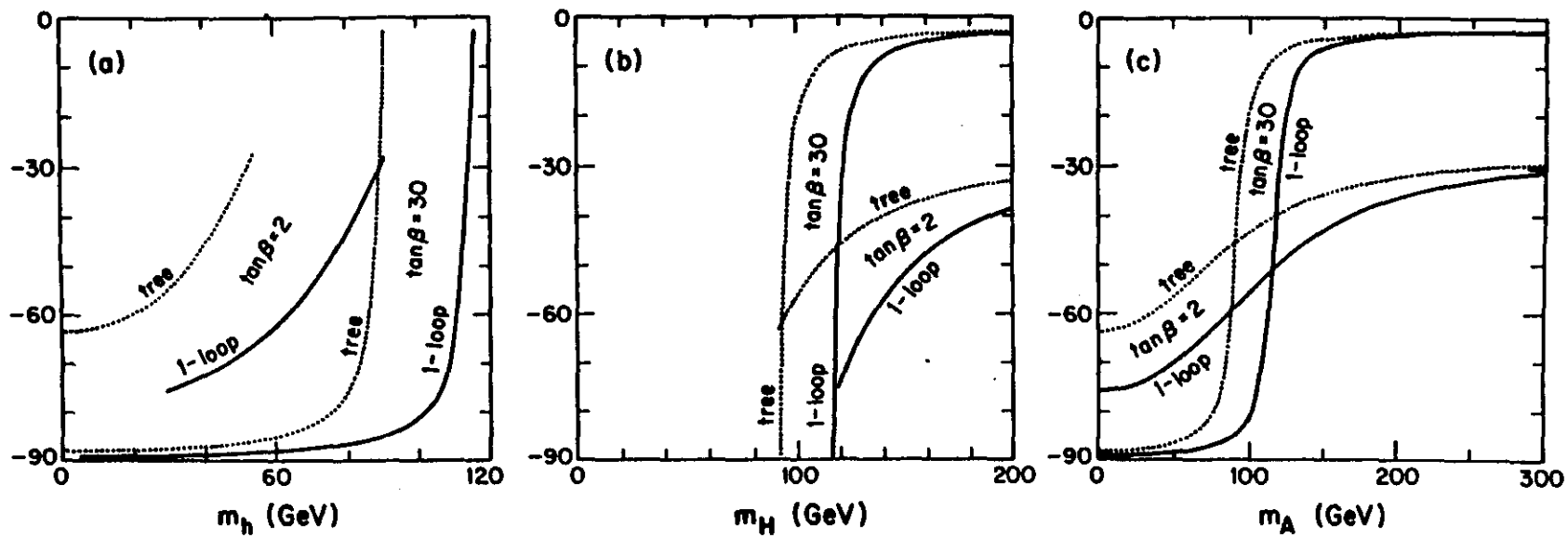
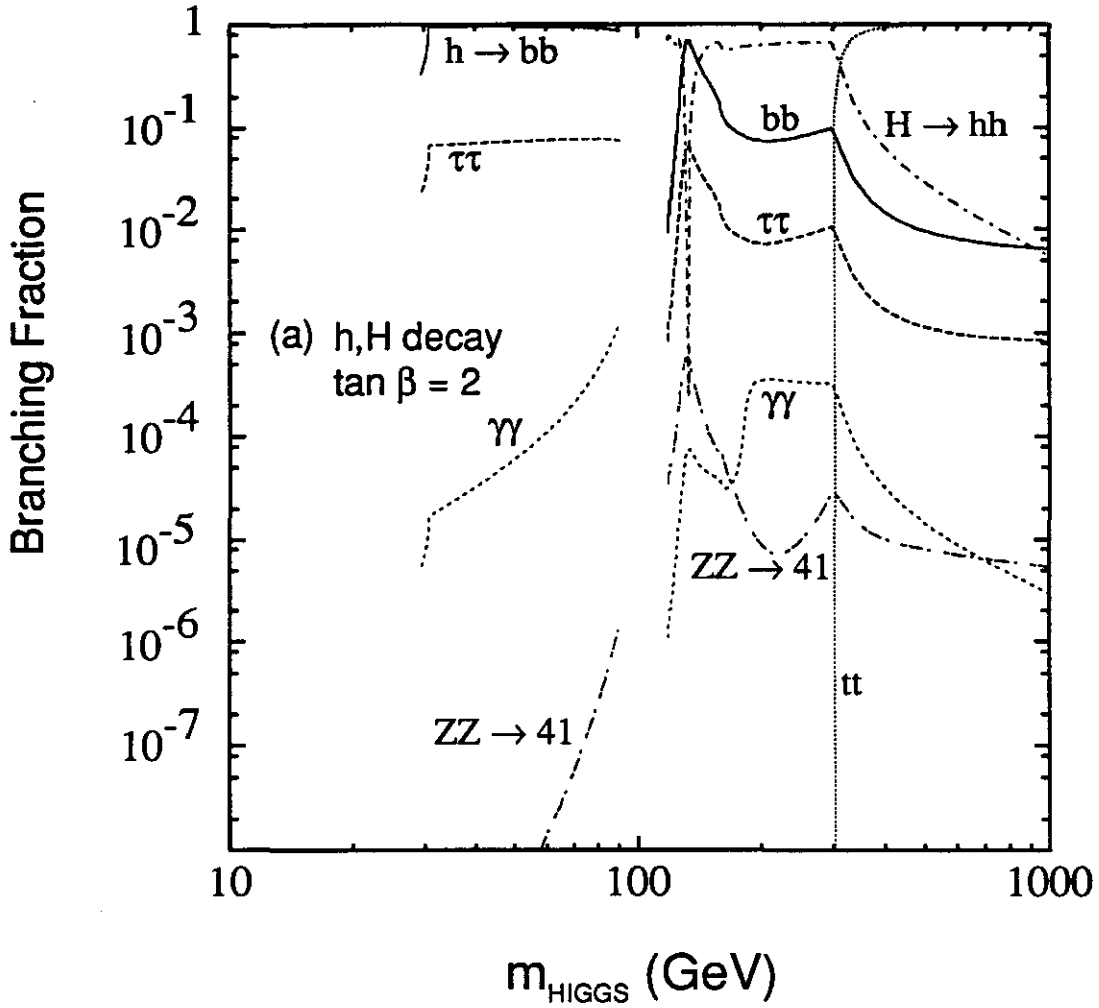
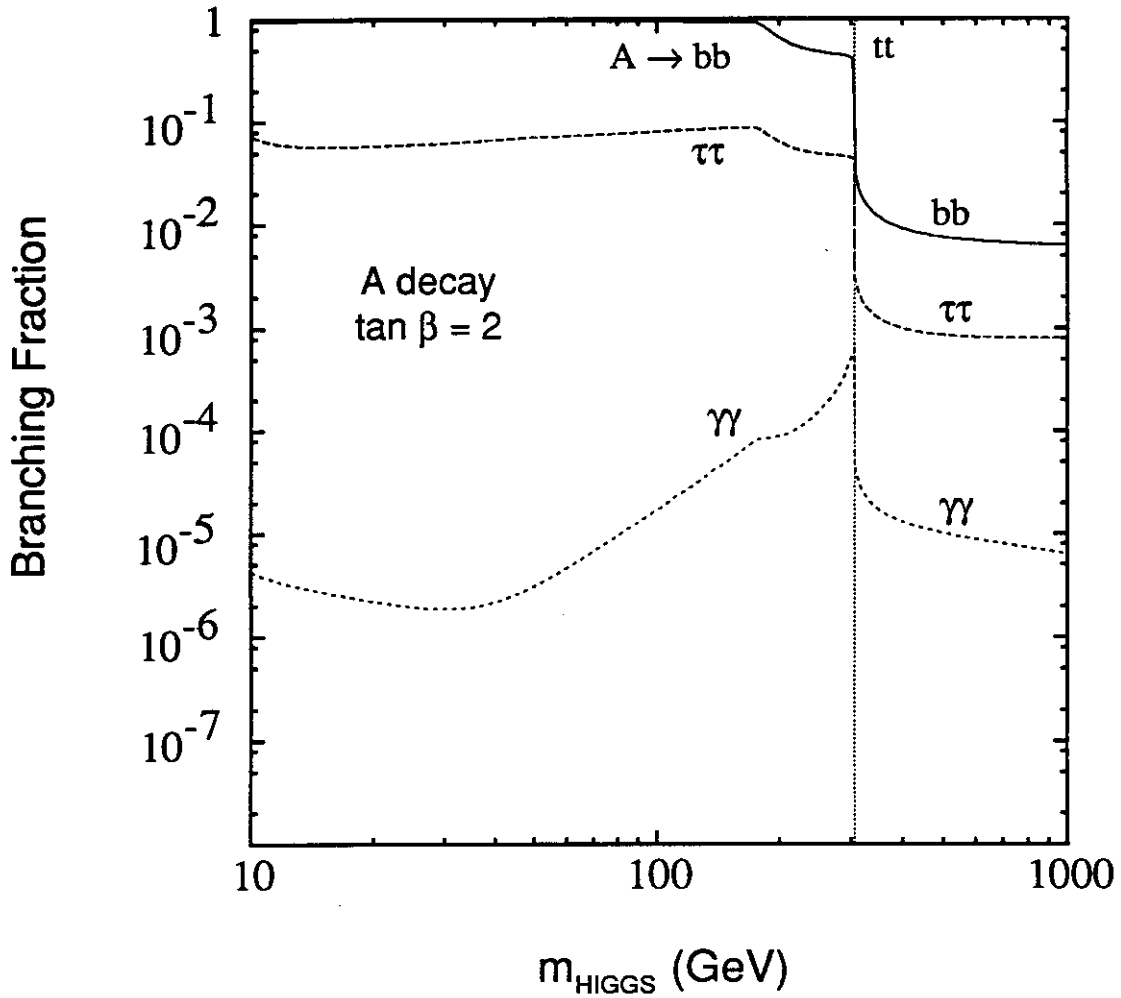
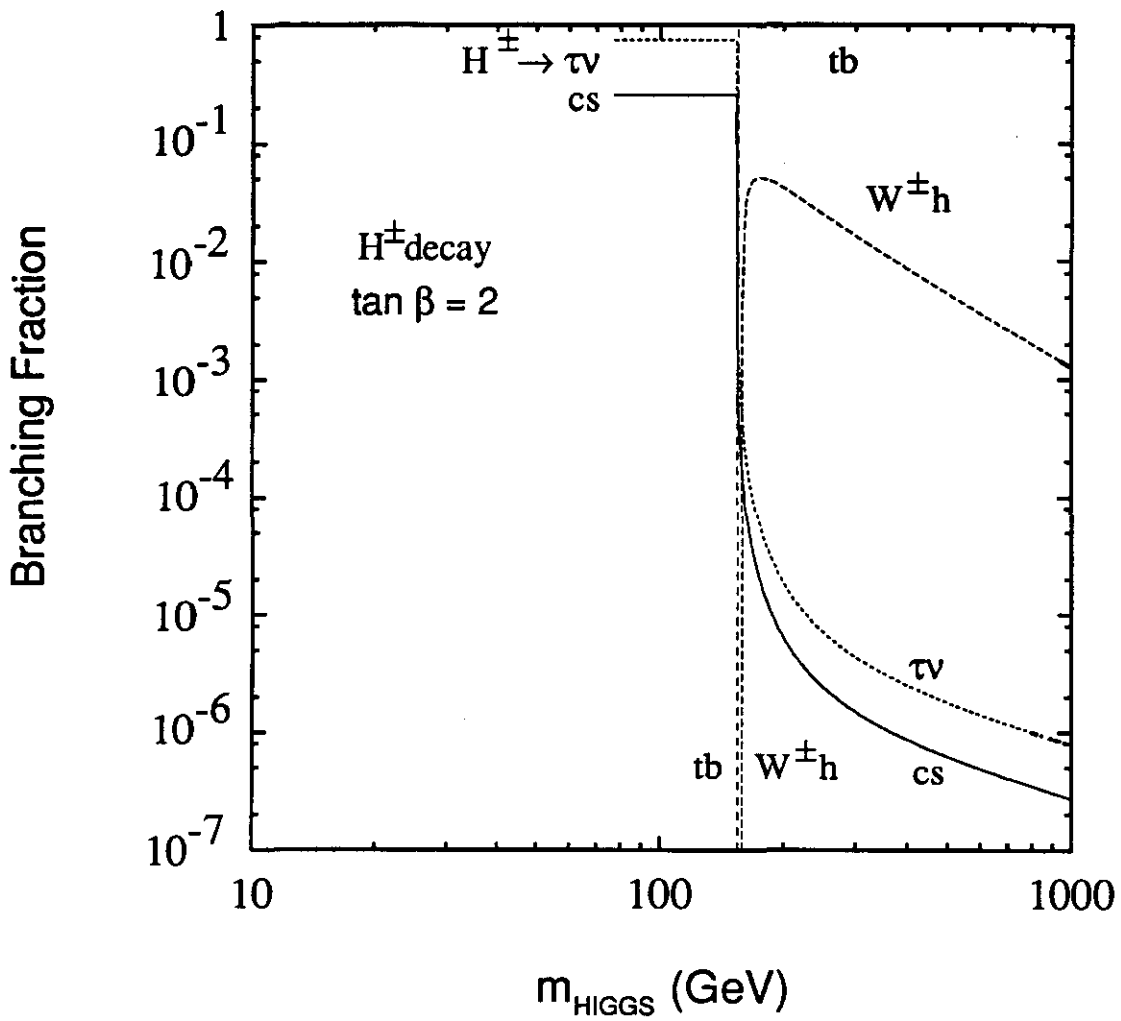

(a)
(b)
(c)
tree
1-loop
tanβ=2
tanβ=30
0
-30
-60
-90
0
60
120
100
200
300
$m_h$ (GeV)
$m_H$ (GeV)
$m_A$ (GeV)

Fig. 5

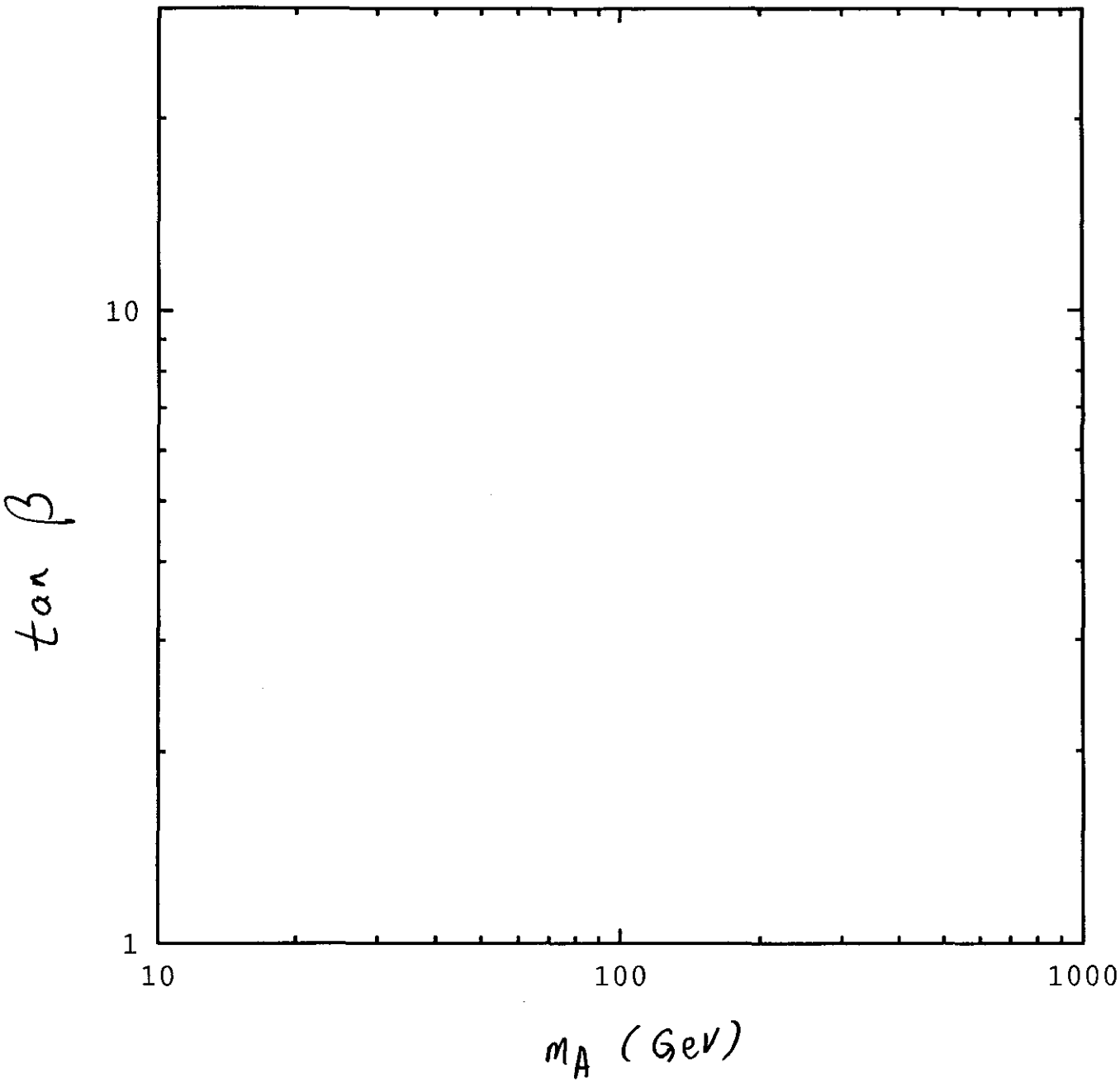

Branching Fraction
1
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
10
100
1000
$m_{HIGGS}$ (GeV)
h → bb
ττ
γγ
ZZ → 41
(a) h,H decay
tan β = 2
bb
H → hh
ττ
γγ
ZZ → 41
tt


Branching Fraction
1
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
10
100
1000
$m_{HIGGS}$ (GeV)
A decay
tan β = 2
A → bb
tt
ττ
bb
ττ
γγ
γγ


Branching Fraction
1
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
10
100
1000
$m_{HIGGS}$ (GeV)
$H^{\pm} \to \tau\nu$
cs
tb
$W^{\pm}h$
$H^{\pm}$decay
tan β = 2
$\tau\nu$
tb
$W^{\pm}h$
cs

What do these changes mean for the SUSY Higgs Search ?

Consider search potential in $m_A$-tan$\beta$ plane for several $m_t$ values


10
1
10
100
1000
tan β
$m_A$ (GeV)

# II. Experiments

## •LEP I and II

### »LEP I

Aleph limits $\cos^2(\beta-\alpha)$, $\sin^2(\beta-\alpha)$

### »LEP II

a) rescale $Zh \rightarrow$ jets

$Zh \rightarrow (ee,\mu\mu)$+jets

S. L. Wu *et. al.*

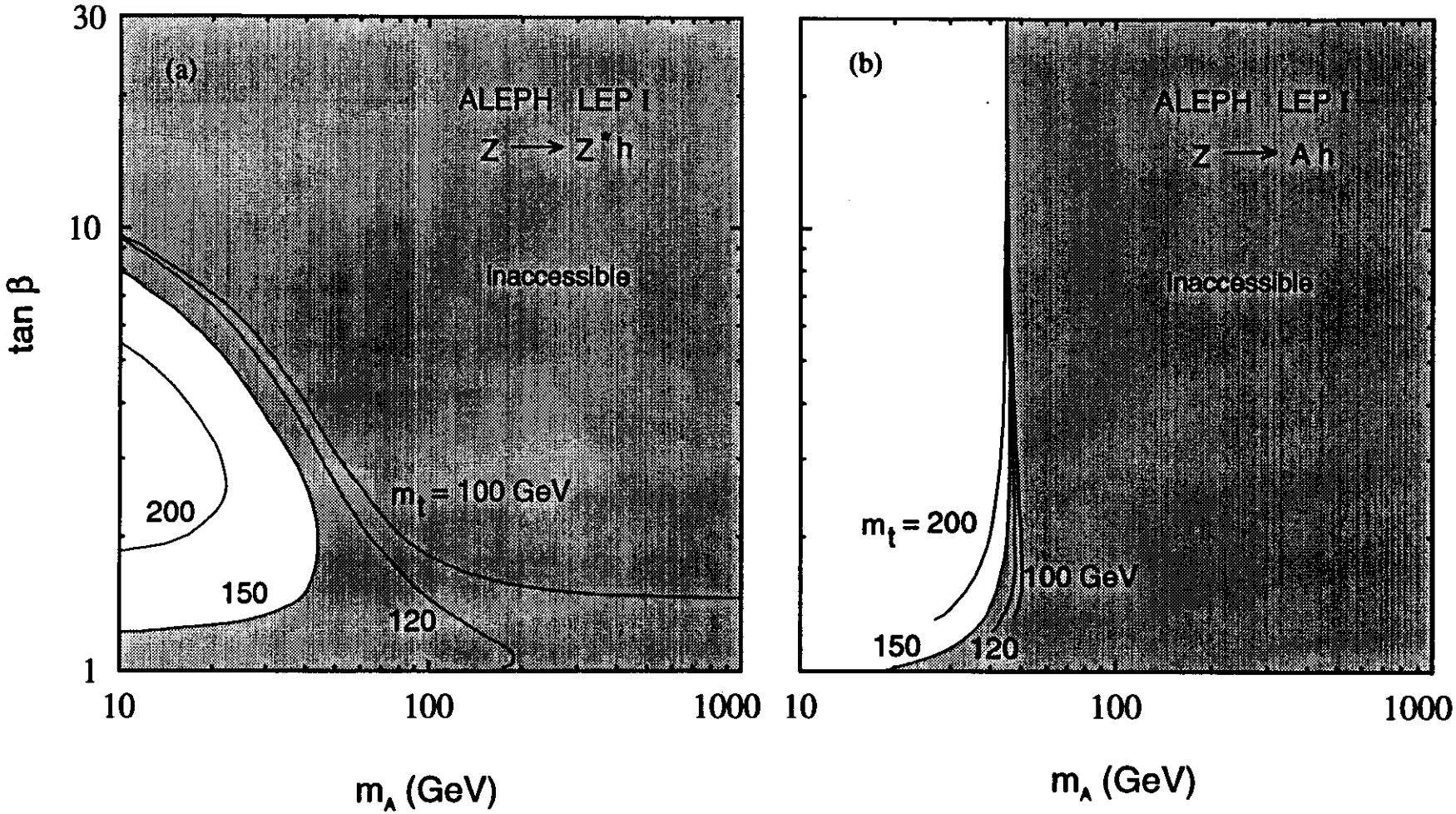
ECFA workshop on LEP 200

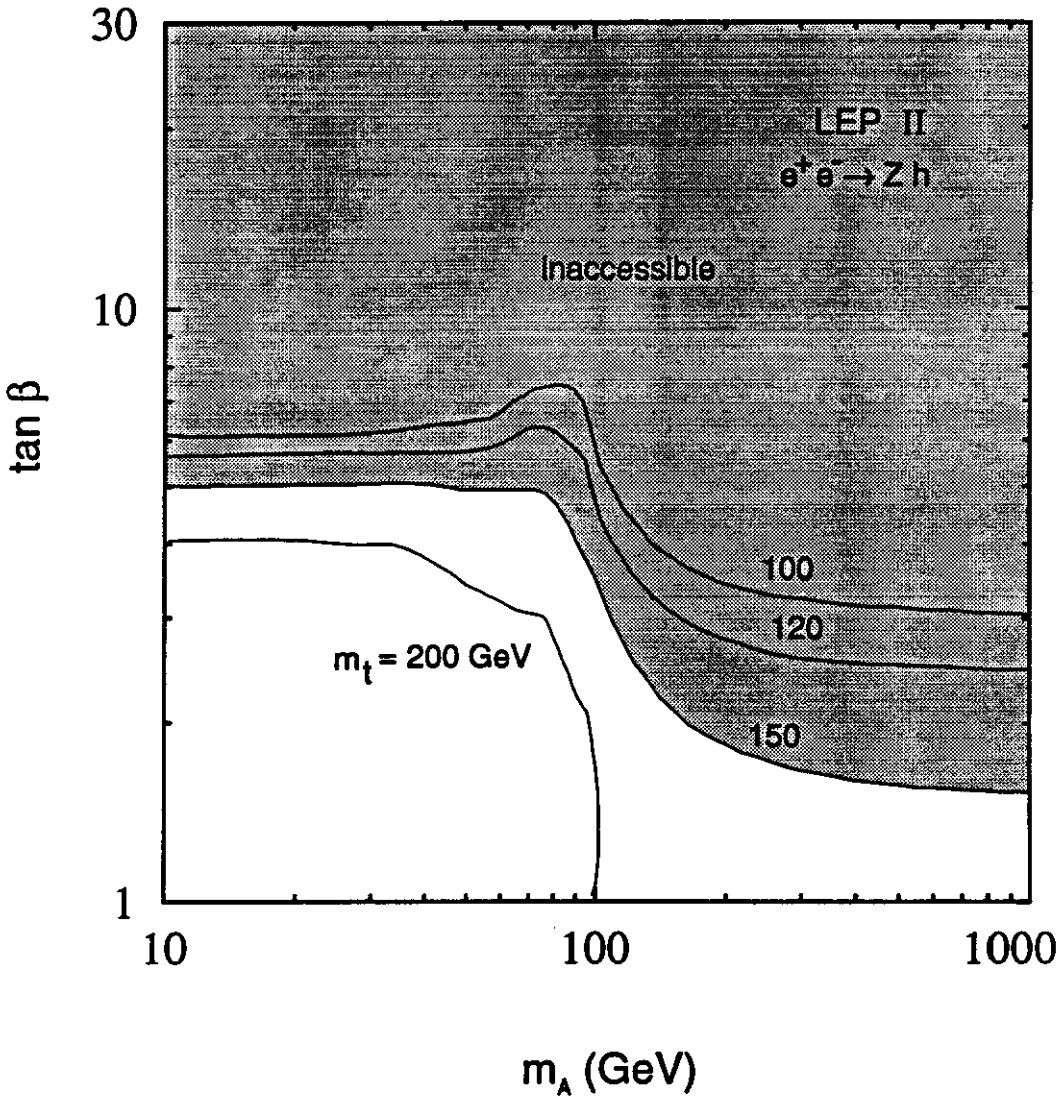
b) rescale $Zh$, $Ah$, $AH \rightarrow \tau\tau$+jets

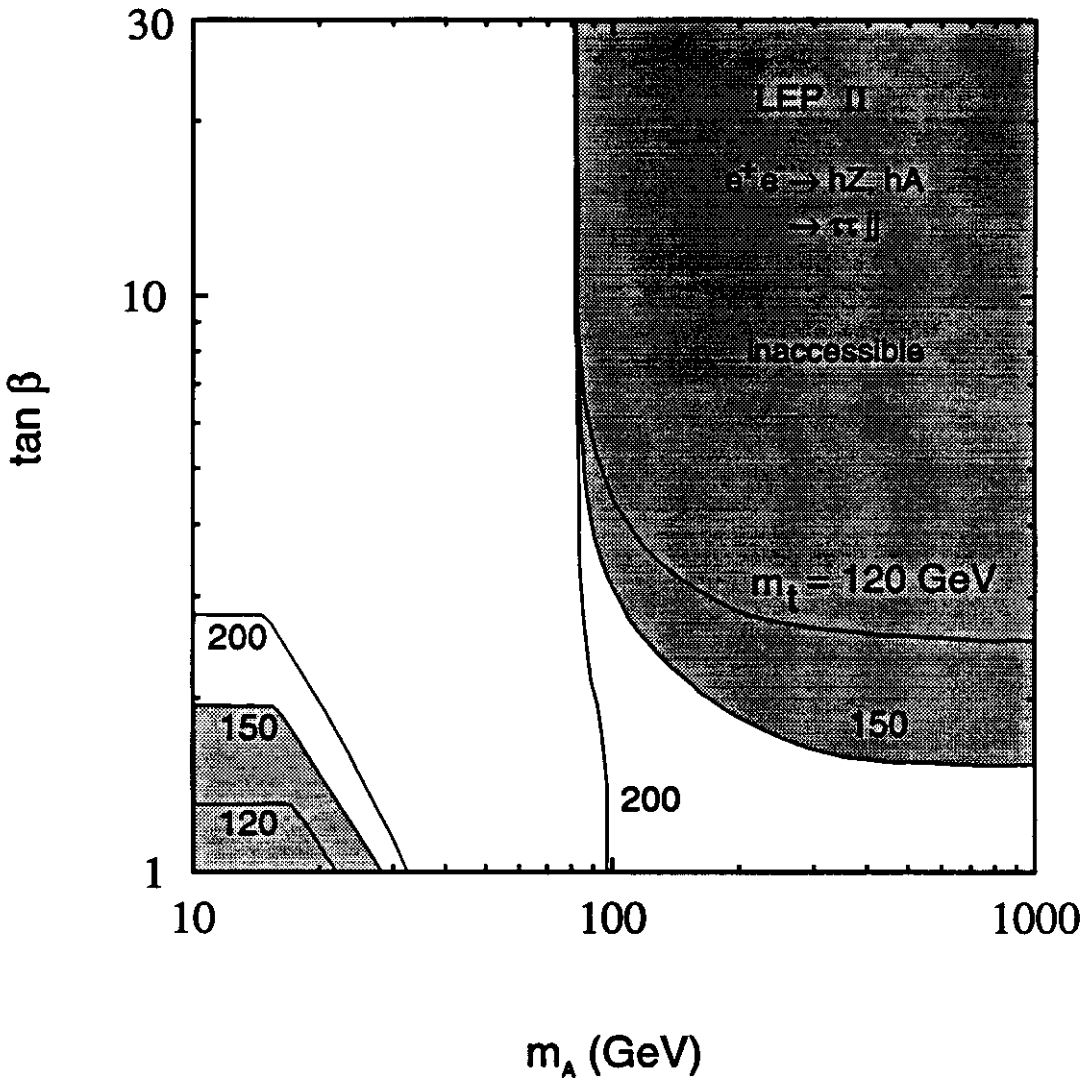
P. Janot LAL 91-61

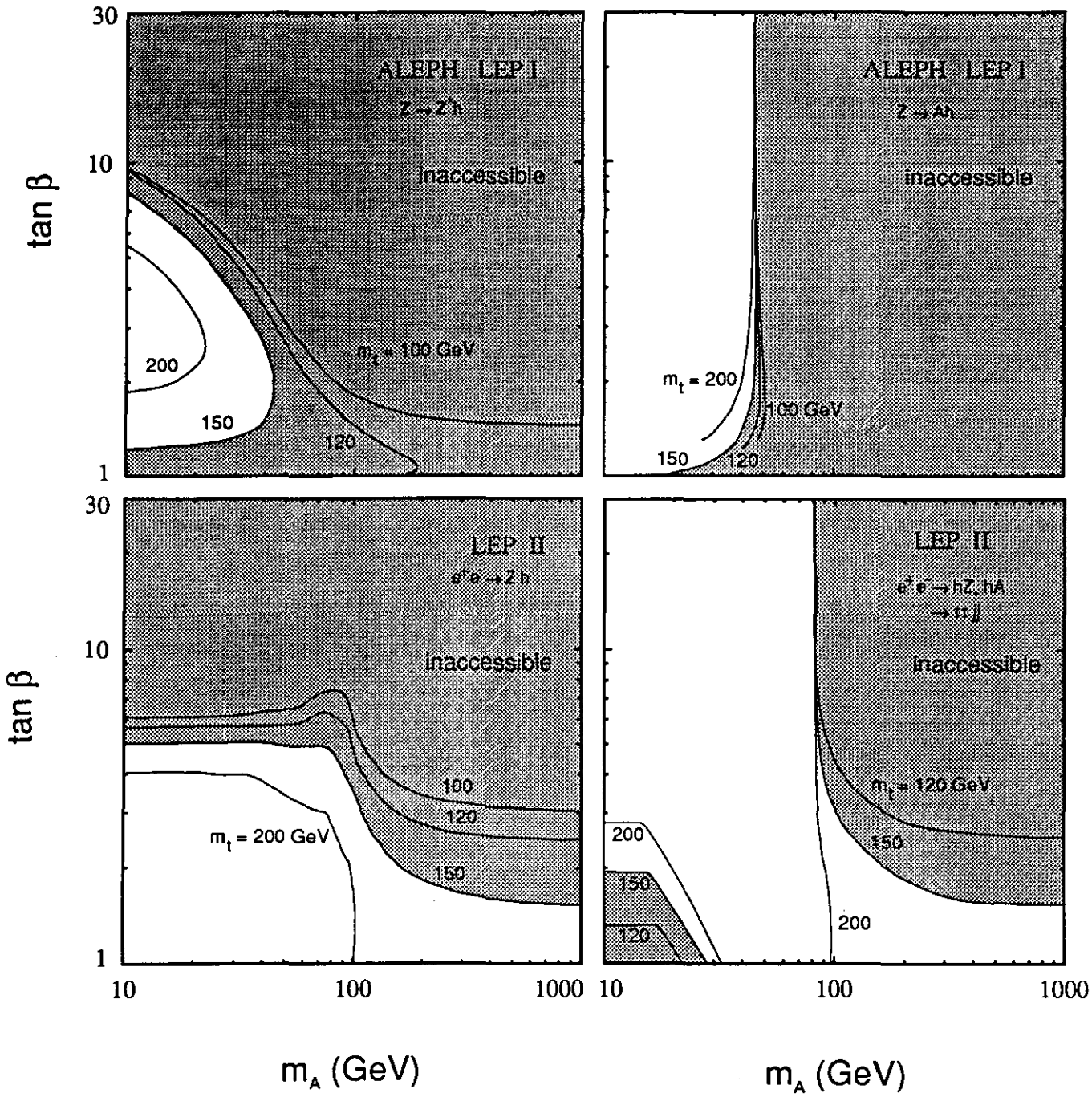
J.-F. Grivaz LAL 91

$S/\sqrt{B} > 4$


(a)
ALEPH LEP I
Z → Z*h
Inaccessible
m_t = 100 GeV
200
150
120
tan β
30
10
1
10
100
1000
m_A (GeV)
(b)
ALEPH LEP I
Z → Ah
Inaccessible
m_t = 200
100 GeV
150
120
10
100
1000
m_A (GeV)


30
10
1
tan β
10
100
1000
m_A (GeV)
LEP II
e+e- → Z h
Inaccessible
100
120
150
m_t = 200 GeV


30
10
1
10
100
1000
tan β
m_A (GeV)
LEP II
e+e- → hZ, hA
→ τ+ℓ
haccessible
m_t = 120 GeV
150
200
200
150
120


ALEPH LEP I
Z → Z*h
inaccessible
m_t = 100 GeV
200
150
120
ALEPH LEP I
Z → Ah
inaccessible
m_t = 200
100 GeV
150
120
LEP II
e⁺e⁻ → Z h
inaccessible
m_t = 200 GeV
100
120
150
LEP II
e⁺e⁻ → hZ, hA
→ τ τ j j
inaccessible
m_t = 120 GeV
150
200
200
150
120
tan β
tan β
30
10
1
30
10
1
10
100
1000
10
100
1000
m_A (GeV)
m_A (GeV)

# IV. SSC (LHC)

---

$H_{SM} < \sim 800$ GeV is detectable at SSC

Differences from Standard Model
- » couplings
- » mixing
- » extra final state decays

consider the most interesting channels

- $gg \to h,H,A \quad \to \gamma\gamma$
- $qq,gg \to tt(h,H,A) \to (e,\mu)\gamma\gamma$
- $gg \to h,H \quad \to$ leptons
- $qq,gg \to tt \quad \to bbWH^{\pm}$

$L = 20\ \mathrm{fb}^{-1} \quad S/\sqrt{B} > 4 \quad S > 10$

- SSC

  » $gg \to h,H,A \quad \to \gamma\gamma$

  » $qq,gg \to tt(h,H,A) \to (e,\mu)\gamma\gamma$

  » $gg \to h,H \quad \to$ leptons

  » $qq,gg \to tt \quad \to bbWH^{\pm}$

$L = 20\ \mathrm{fb}^{-1} \quad S/\sqrt{B} > 4 \quad S > 10$

- $gg \rightarrow h,H,A \rightarrow \gamma\gamma$

---

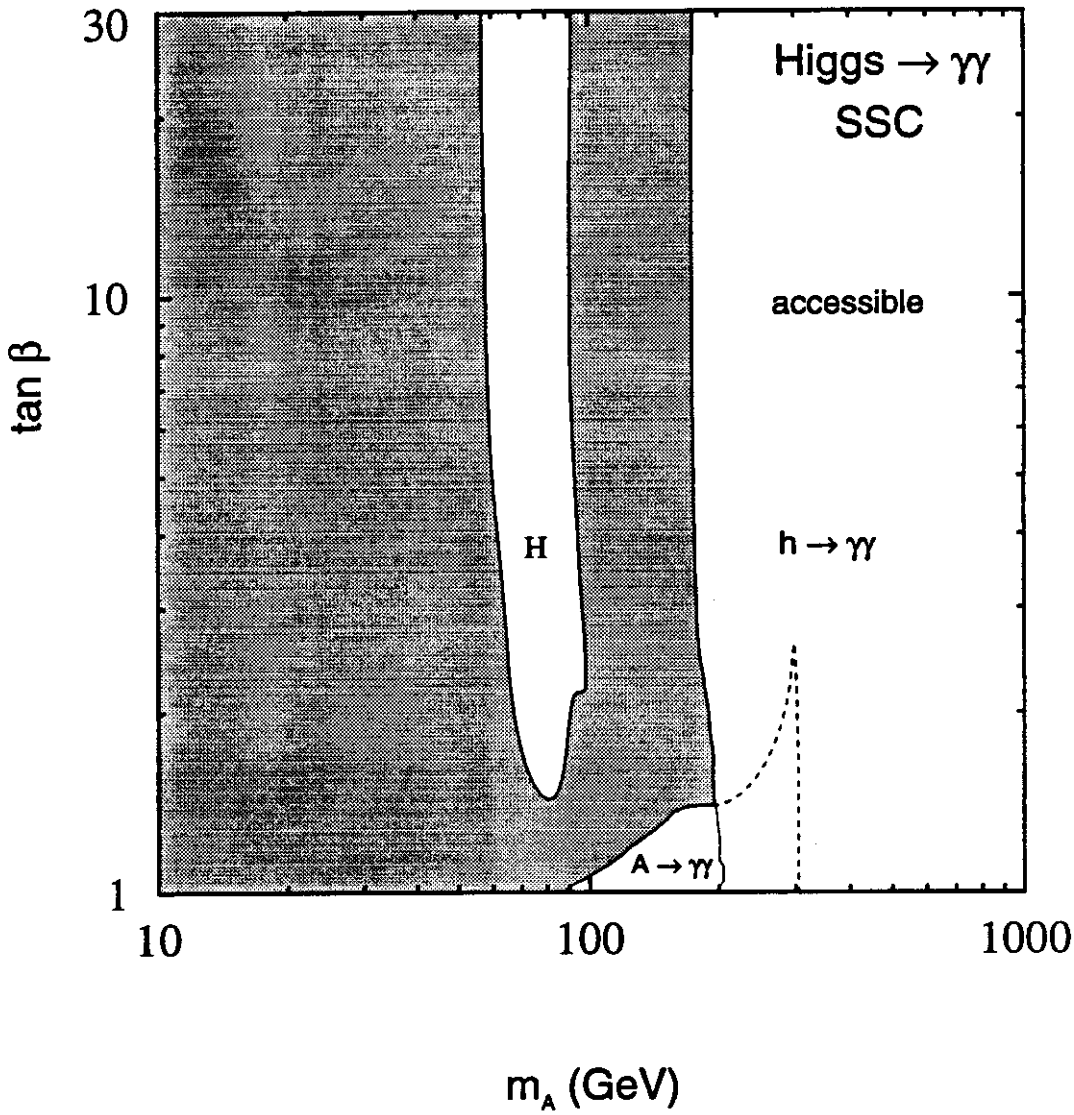
- Largest production cross section
- Important for intermediate masses

GEM to have $\Delta m/m(\gamma\gamma) \approx 1\%$
to beat $qq,gg \rightarrow \gamma\gamma$ backgrounds

GEM simulation of LAr calorimeter
$|\eta_\gamma| < 2.5$, $E_T > 20$ GeV, $|\eta_{\gamma\gamma}| < 3.0$,
$|\cos\theta^*_\gamma| < 0.9$, $\pi-\gamma$ rejection
isolation: $\Delta R = 0.6$ $E_T < 10$ GeV

55% efficiency

B = # events in mass bin $m_h \pm 1\%$


Higgs → γγ
SSC
accessible
H
h → γγ
A → γγ
30
10
1
tan β
10
100
1000
m_A (GeV)

- $qq,gg \rightarrow tt(h,H,A) \rightarrow (e,\mu)\gamma\gamma$

---

» "tagged" lepton $\gamma\gamma$ events

$Wh \rightarrow (e,\mu)\ \gamma\gamma$
largest source is tth with decay

potentially large backgrounds:
$W\gamma\gamma$, $tt\gamma\gamma$, ttjj, $bb\gamma\gamma$

Use SDC simulation
$|\eta| < 2.5$, $p_T > 20$ GeV, $\Delta R > 0.4$
isolation: $\Delta R < 0.3$, $E_T < 10$ GeV
» 0.93 Wh
» 0.73 tth

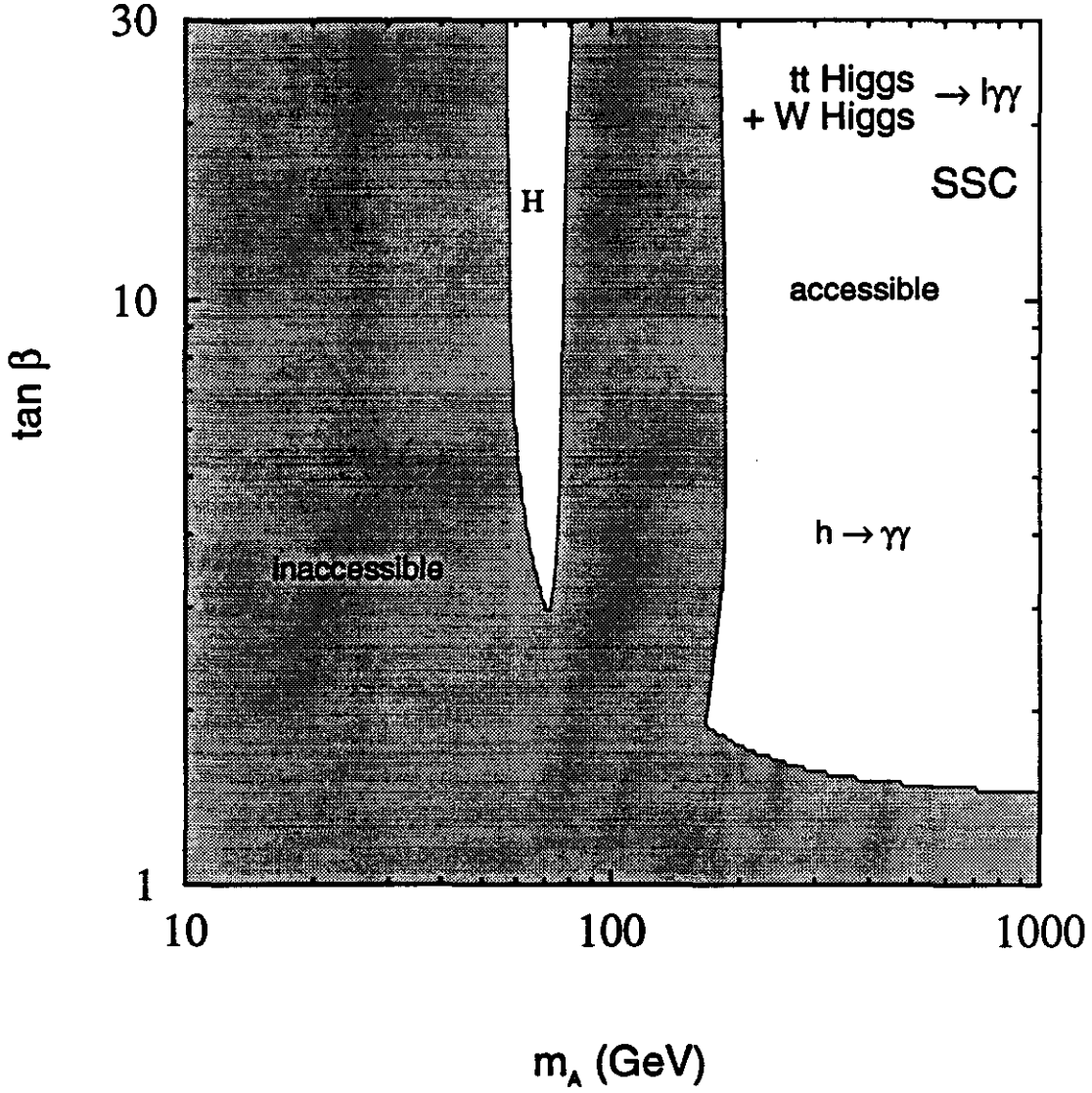
$(0.85)^3$ detection efficiency

Gaussian resolution:

| $m_h$ | $\sigma_{\gamma\gamma}$ (GeV) |
|---|---|
| 80 | 1.23 |
| 100 | 1.44 |
| 120 | 1.65 |
| 140 | 1.81 |
| 160 | 2.00 |

B = # events in mass bin $m_h \pm 2\sigma_{\gamma\gamma}$

Att doesn't meet detectability requirments


30
10
1
tan β
10
100
1000
m_A (GeV)
tt Higgs
+ W Higgs
→ lγγ
SSC
H
accessible
h → γγ
inaccessible

- $gg \rightarrow h,H \rightarrow$ leptons

---

"gold-plated" mode

background: $qq,gg \rightarrow ZZ \rightarrow$ leptons

$K=1.65$: $O(\alpha_s)$ corrections

tt, Ztt, Zbb are eliminated by cuts

Follow SDC:

$p_T > 20$ GeV, $|\eta| < 2.5$, $\Delta R > 0.4$

$|M_Z - M(ll)| < 10$ GeV one pair

isolation: $\Delta R < 0.3$ $E_T < 5$ GeV

» $(0.9)^4$

detection efficiency: $(0.85)^2(0.95)^2$

Mass resolution:

- not dominated by Higgs width

» generate real Higgs→ZZ→4l events

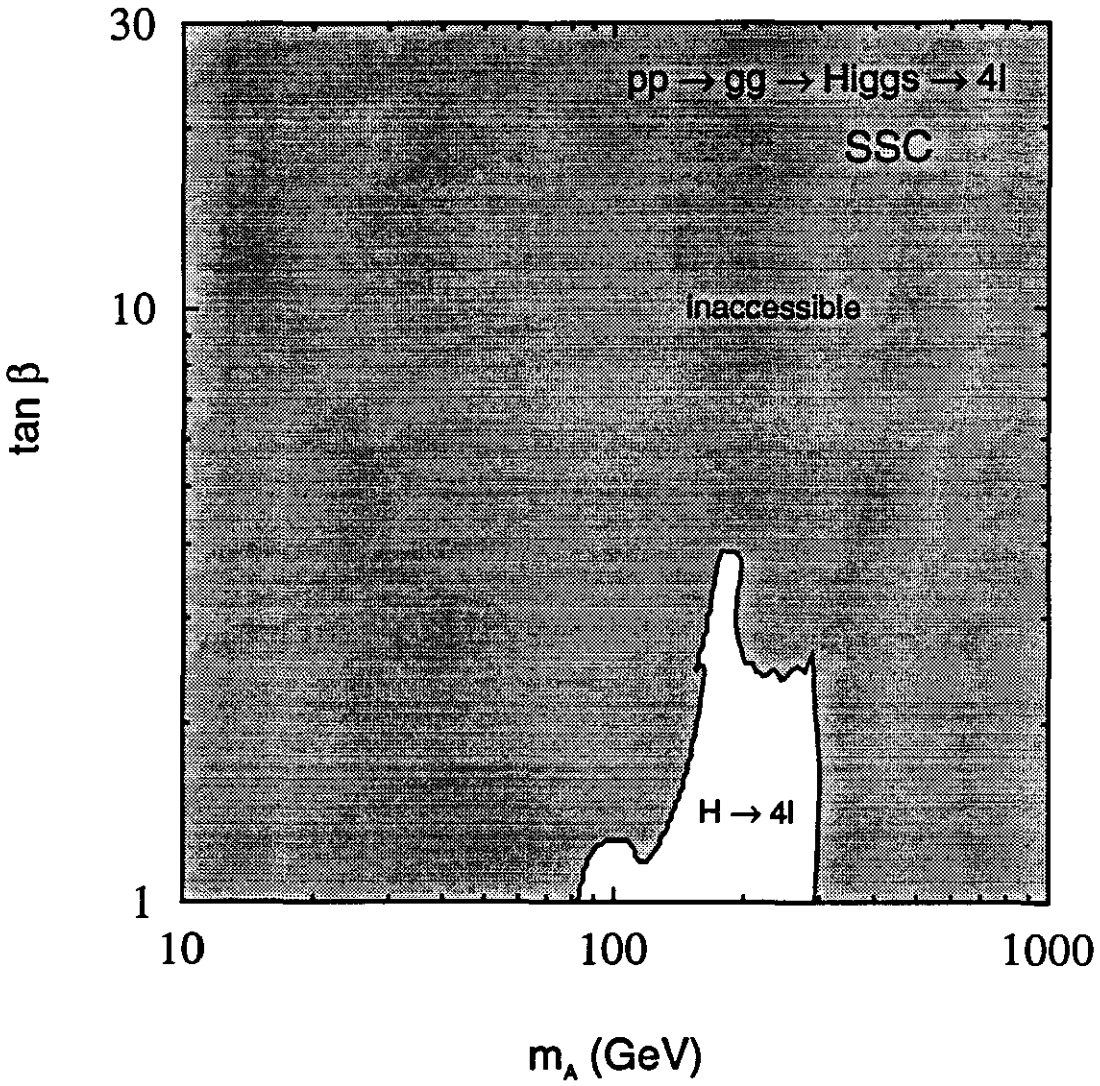
» smear lepton energies

$$\sigma(E)/E = \left[(0.14/\sqrt{E})^2+0.01^2\right]^{0.5}$$

» fit resulting invariant mass to obtain $\sigma_{41}$

» $\sigma_{eff} = \left[(\sigma_{41})^2+ (\Gamma_H/2)^2\right]^{0.5}$

B = # ZZ events in bin $m_h \pm 2\sigma_{eff}$


30
10
1
tan β
pp → gg → Higgs → 4l
SSC
inaccessible
H → 4l
10
100
1000
m_A (GeV)

- $qq,gg \rightarrow tt \rightarrow bbWH^{\pm}$

---

signal: excess of $\tau + (e,\mu)$ final states in tt events

- violation of lepton universality in W decays

Follow SDC:

1-prong $\tau$ decay: $\tau \rightarrow \pi\nu$

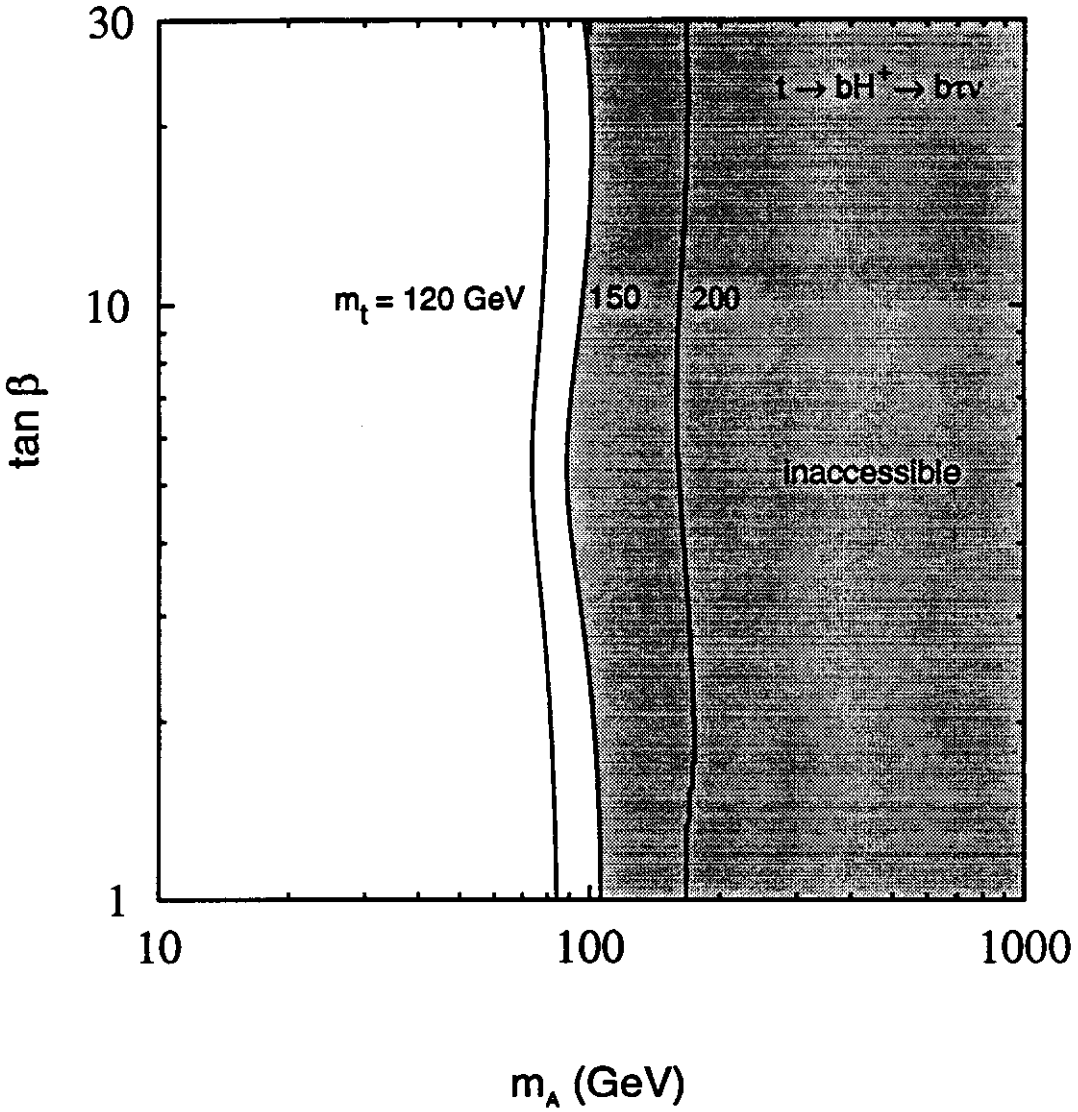
BF = 11.5%

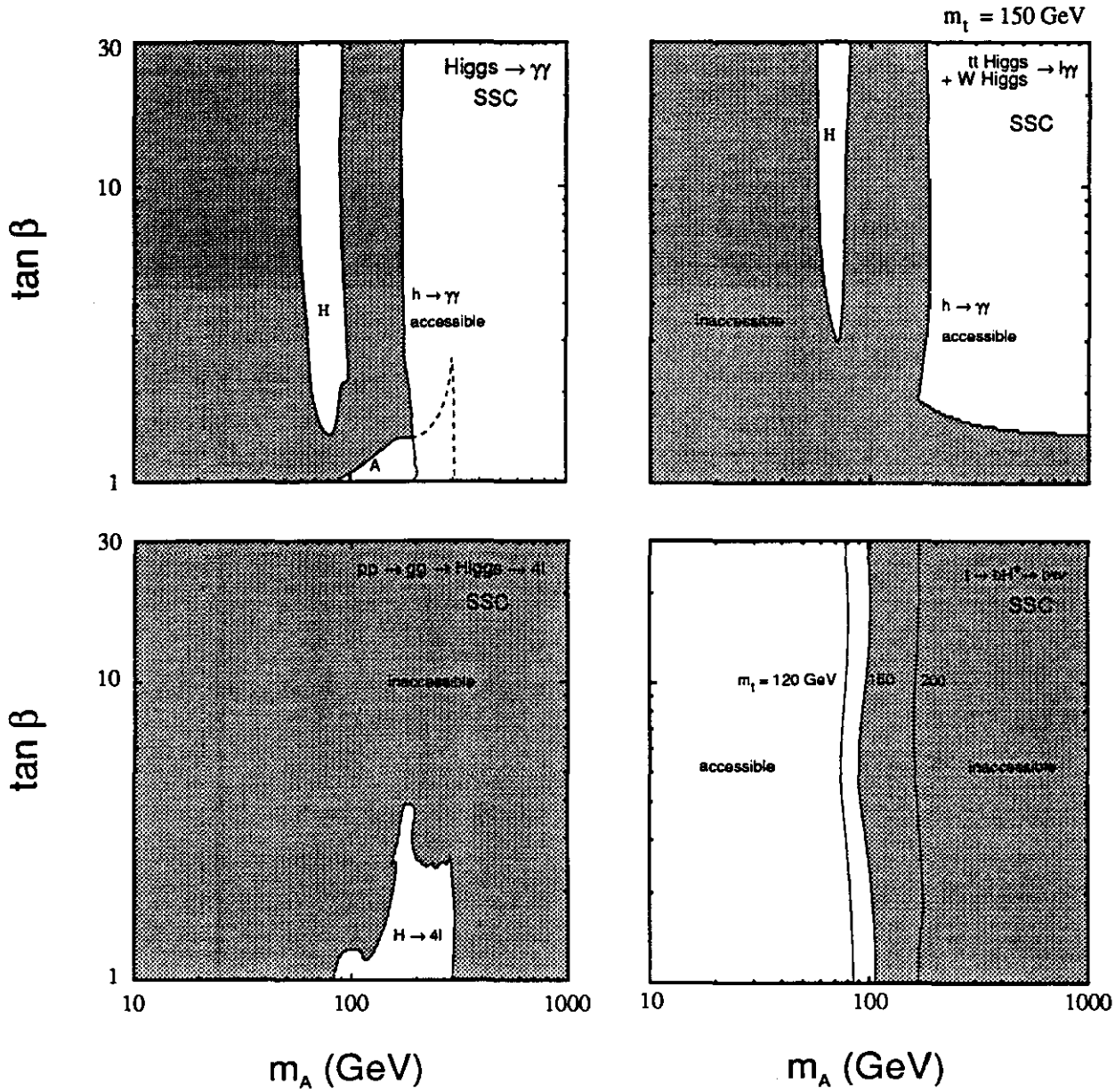
$p_T(\pi) > 100$, $p_T(1) > 40$, $p_T(b) > 30$

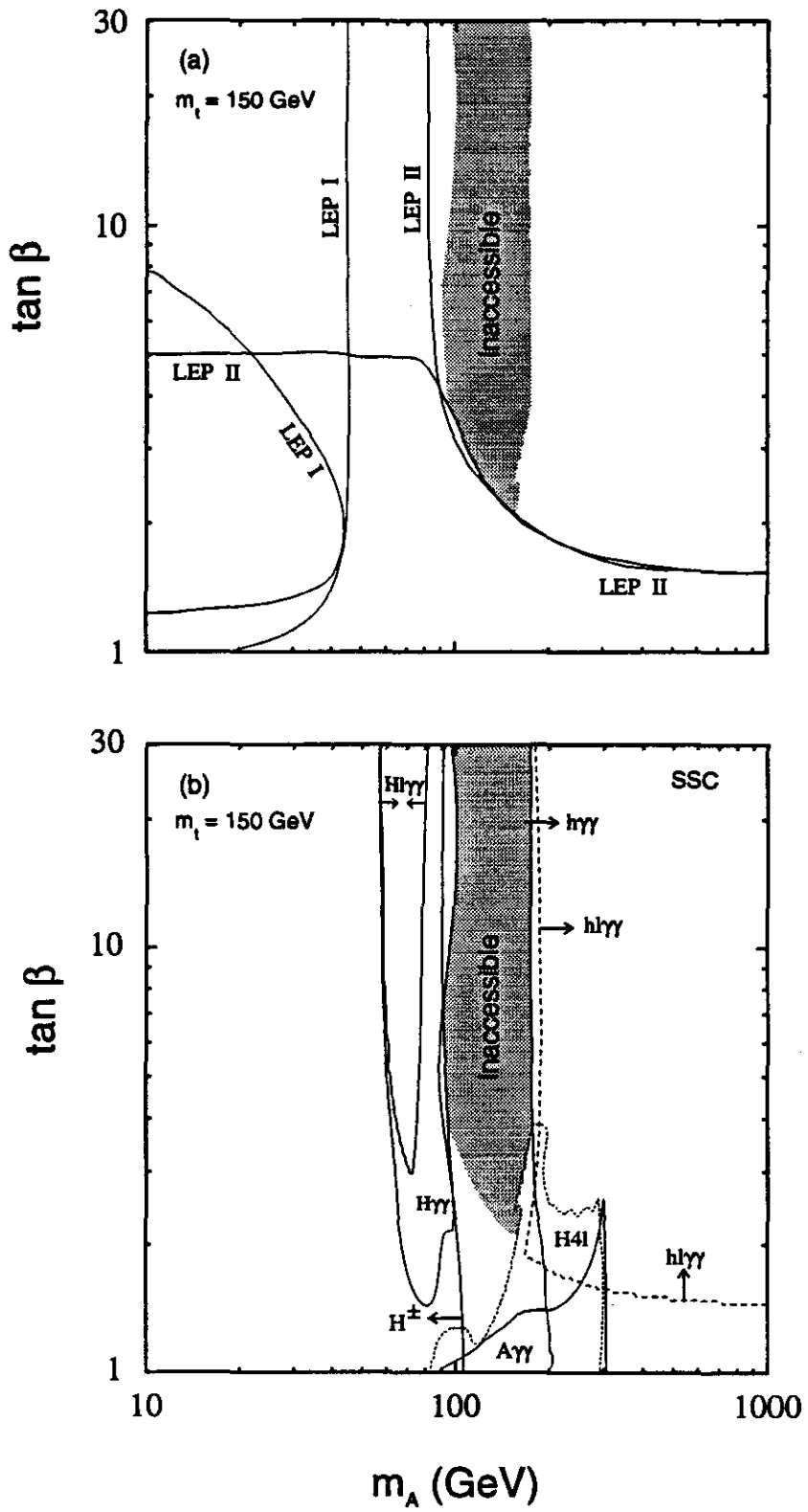
$|\eta(1)| < 2.5$, $|\eta(b)| < 2.0$

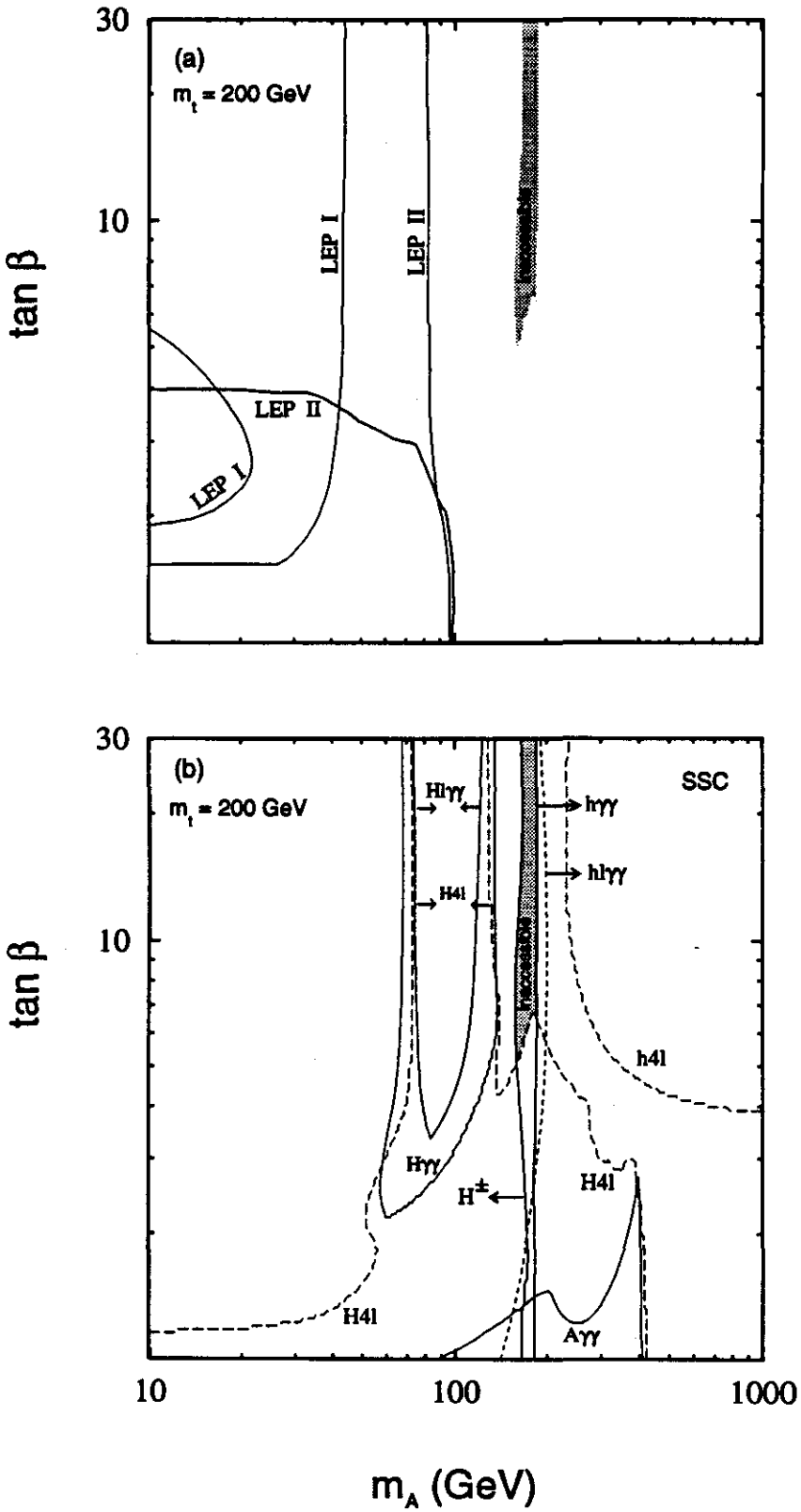
isolation: $\Delta R < 0.4$ $E_T < 0.25E_T(1,b)$

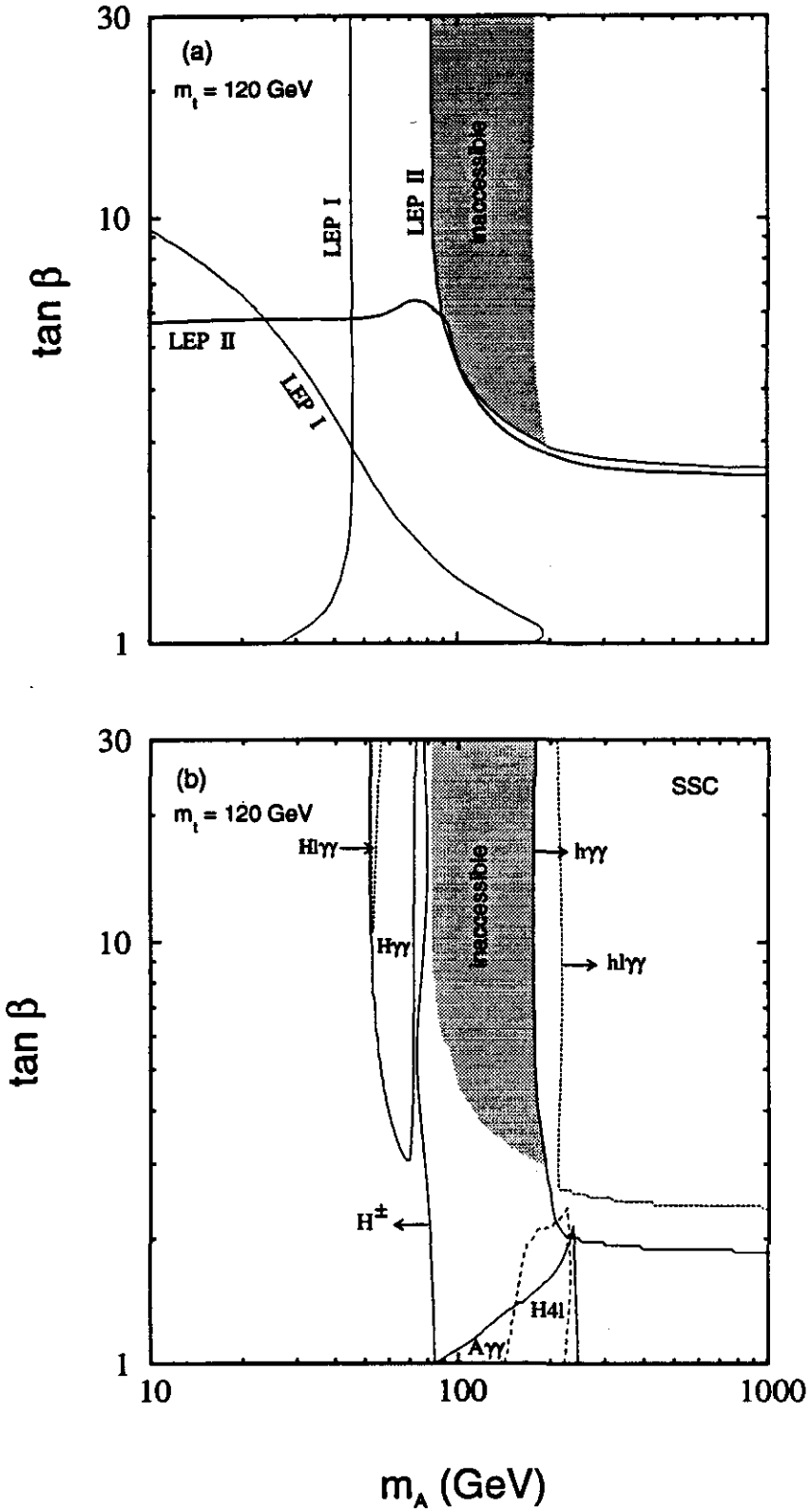
- Require $S/\sqrt{(S+B)} > 5$
- No sure way to reconstruct $H^{\pm}$ mass

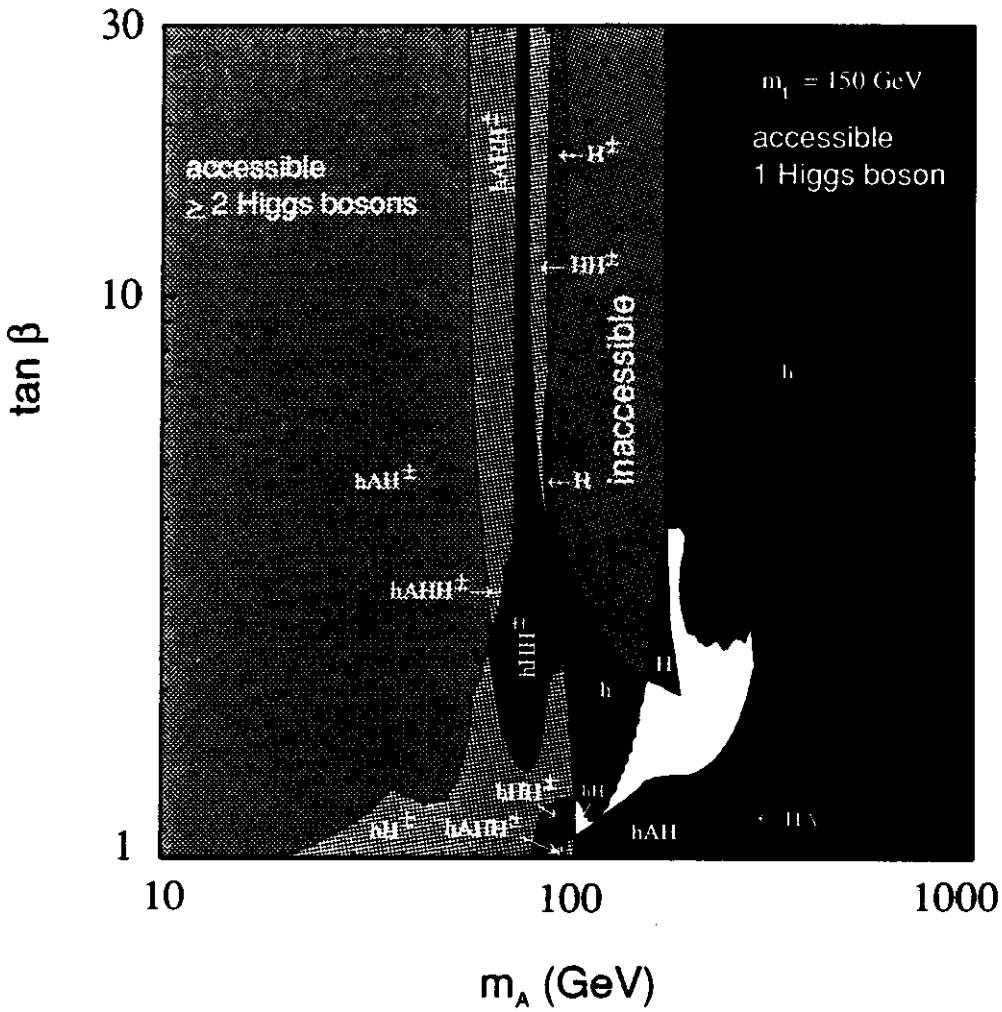

30
10
1
tan β
10
100
1000
m_A (GeV)
m_t = 120 GeV
150
200
t → bH⁺ → bτν
inaccessible


$m_t$ = 150 GeV
Higgs → γγ
SSC
H
h → γγ
accessible
A
tt Higgs
+ W Higgs → hγγ
SSC
H
inaccessible
h → γγ
accessible
pp → gg → Higgs → 4l
SSC
inaccessible
H → 4l
$m_t$ = 120 GeV
150
200
accessible
inaccessible
tan β
30
10
1
10
100
1000
$m_A$ (GeV)


(a)
$m_t$ = 150 GeV
LEP I
LEP II
inaccessible
LEP II
LEP I
LEP II
tan β
30
10
1
(b)
$m_t$ = 150 GeV
SSC
Hlγγ
hγγ
hlγγ
inaccessible
Hγγ
H4l
hlγγ
$H^{\pm}$
Aγγ
tan β
30
10
1
10
100
1000
$m_A$ (GeV)


(a)
$m_t$ = 200 GeV
LEP I
LEP II
LEP II
LEP I
tan β
30
10
(b)
$m_t$ = 200 GeV
SSC
Hlγγ
hγγ
hlγγ
H4l
h4l
Hγγ
$H^{\pm}$
H4l
H4l
Aγγ
tan β
30
10
10
100
1000
$m_A$ (GeV)


(a)
$m_t$ = 120 GeV
LEP I
LEP II
inaccessible
LEP II
LEP I
tan β
30
10
1
(b)
$m_t$ = 120 GeV
SSC
Hlγγ
hγγ
Hγγ
inaccessible
hlγγ
$H^{\pm}$
H4l
Aγγ
tan β
30
10
1
10
100
1000
$m_A$ (GeV)

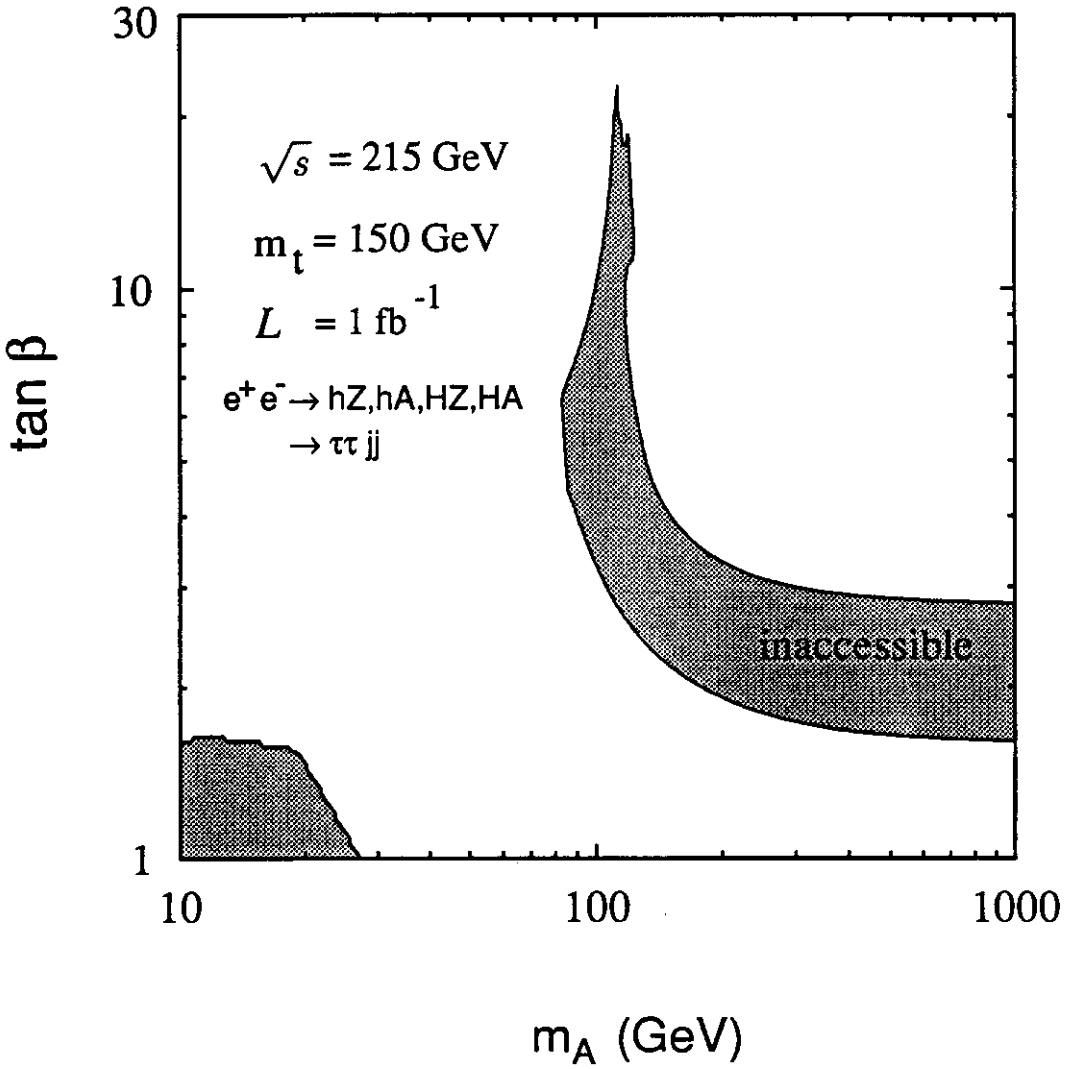

30
10
1
tan β
10
100
1000
m_A (GeV)
m_1 = 150 GeV
accessible
1 Higgs boson
accessible
≥ 2 Higgs bosons
inaccessible
hAHH±
←H±
←HH±
←H
hAH±
hAHH±
hHH
hHH±
hAHH
h
H

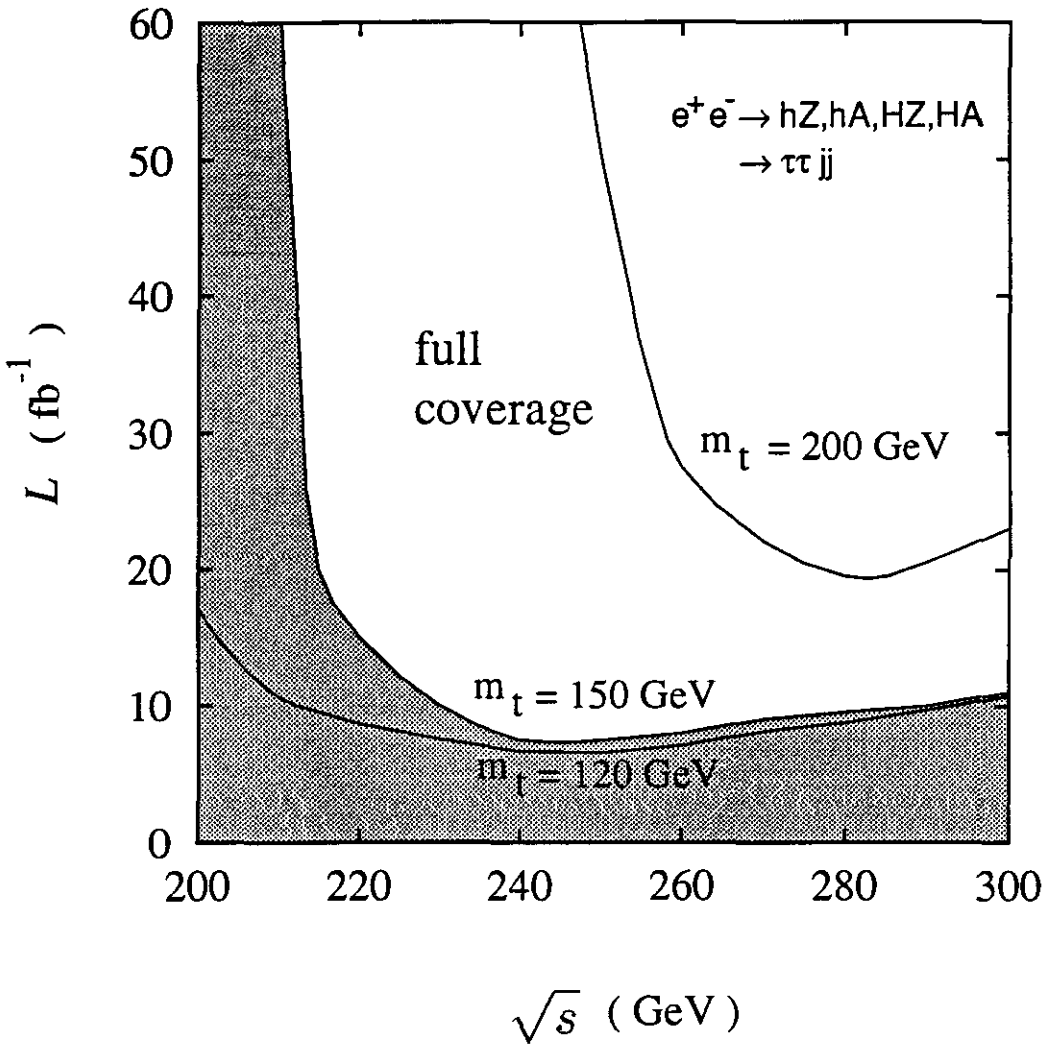
# III. What Collider covers MSSM?

What $e^+e^-$ collider can rule out MSSM Higgs sector?

» repeat $\tau\tau jj$ analysis in $\sqrt{s}$-L plane

require $m_A$-$\tan\beta$ plane be "covered" for given $m_t$ value


30
10
1
10
100
1000
tan β
$m_A$ (GeV)
$\sqrt{s}$ = 215 GeV
$m_t$ = 150 GeV
$L$ = 1 fb$^{-1}$
$e^+e^- \to hZ,hA,HZ,HA$
$\to \tau\tau\, jj$
inaccessible


60
50
40
30
20
10
0
200
220
240
260
280
300
$L$ ( $fb^{-1}$ )
$\sqrt{s}$ ( GeV )
$e^+e^- \to hZ,hA,HZ,HA$
$\to \tau\tau jj$
full
coverage
$m_t$ = 200 GeV
$m_t$ = 150 GeV
$m_t$ = 120 GeV

## IV. Summary

Major factors:

a) $\alpha,\beta$ dependent couplings

b) higgs boson masses

c) acceptance, luminosity, background estimates

a), b) included exactly in all cases

c) included to the best degree possible given understanding and resources

» parameter space NOT covered by existing/proposed colliders/detectors

» large regions where only one Higgs boson in detectable. How to distinguish from SM Higgs?

Future Directions

» detailed detector simulations

» b-tagging to help reject backgrounds

» exotic Higgs $\rightarrow$ SUSY decays

(Baer *et. al.*)

» build the experiments!

gem

γeμ

**Presentation by:**

**Frank Taylor**

Frank Taylor 11/6/92

# Status of GEM Muon System

- Triggering and Tracking Technology:

  - o system performance
  - o complexity
  - o cost
  - o manufacturability

- Design of support structure:

  - o alignment to 25 μm and stable
  - o sector approach attractive for initial installation and alignment
  - o monolithic structure more stable
  - o coverage
  - o endcaps

Decision [illegible]

# Results of Nov. 5, 1992 Muon Meeting:

- Discussed Chamber R&D program:

  - Highlights

    o Test results obtained from 1m x 4m PDT and LSDT prototypes.
    (Dubna - Movchan, MIT - Korytov)

    In limited streamer mode: $\sigma$ = 80 microns
    Flammable gas (3:1 IB: A)

    o CSC prototypes delivered to TTR.

    With safe gas $\sigma$ = 109 microns (preliminary)
    (BNL - Polychronakos)

    o X-ray alignment of chambers
    (PNPI-Vorobyov)

    o RPC with low resistivity plastic constructed

    Expected characteristics promising. Rate limit is calculated to be 15 kHz/cm$^2$
    (LLNL-Wuest, MIT-Pless)

- Discussed backgrounds

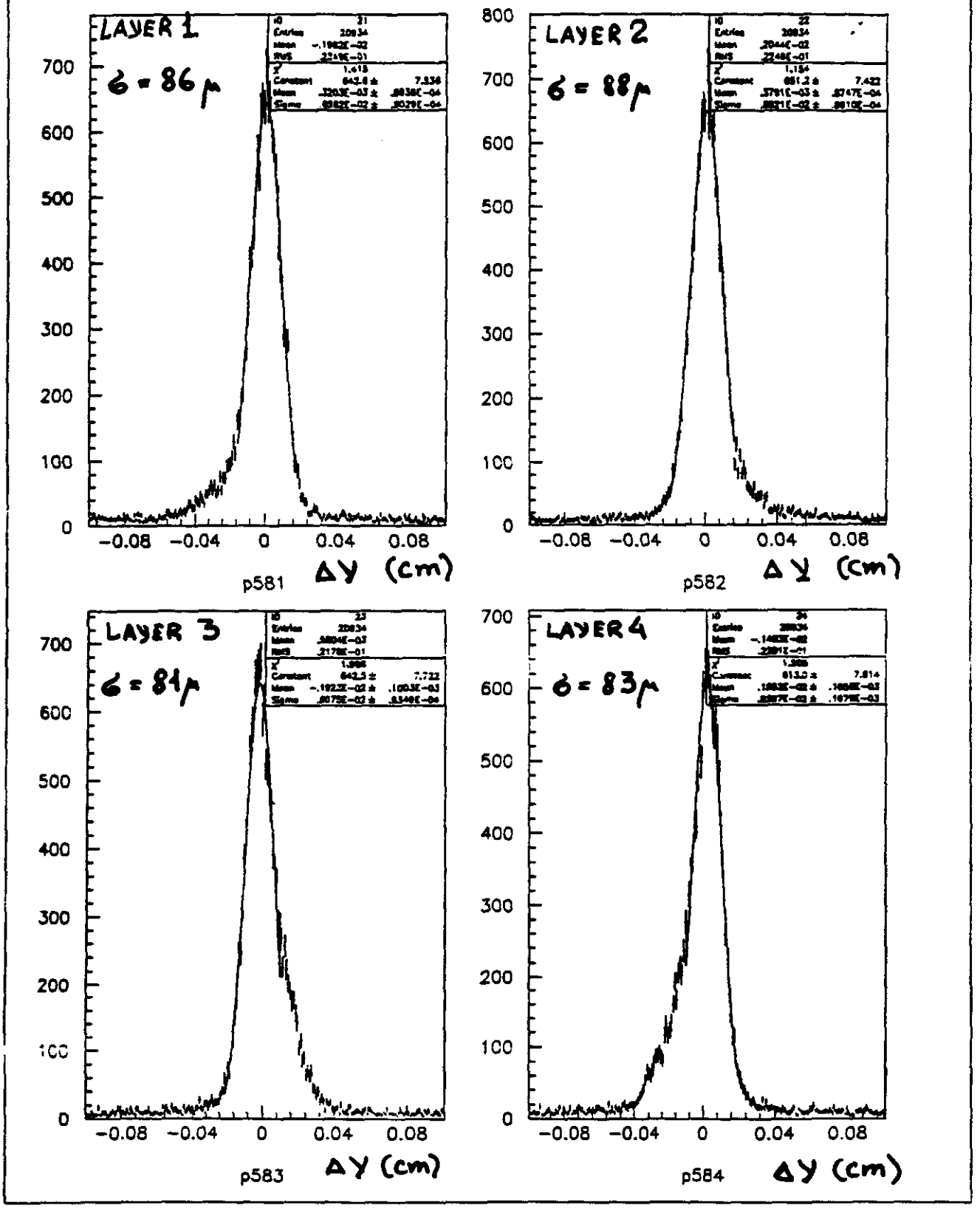
  - Muon associated background for CSC geometry in EC 8:4:4 geometry with 0.7 X0 in front of chambers get 90% of time [redacted] only 1 extra hit within 8 mm.
    (SB-Yanagasawa, SSCL-Dingus, and Ostapchuk)

  - Neutron background may force CF4 gas if LS mode
    (SSCL-Glebov)

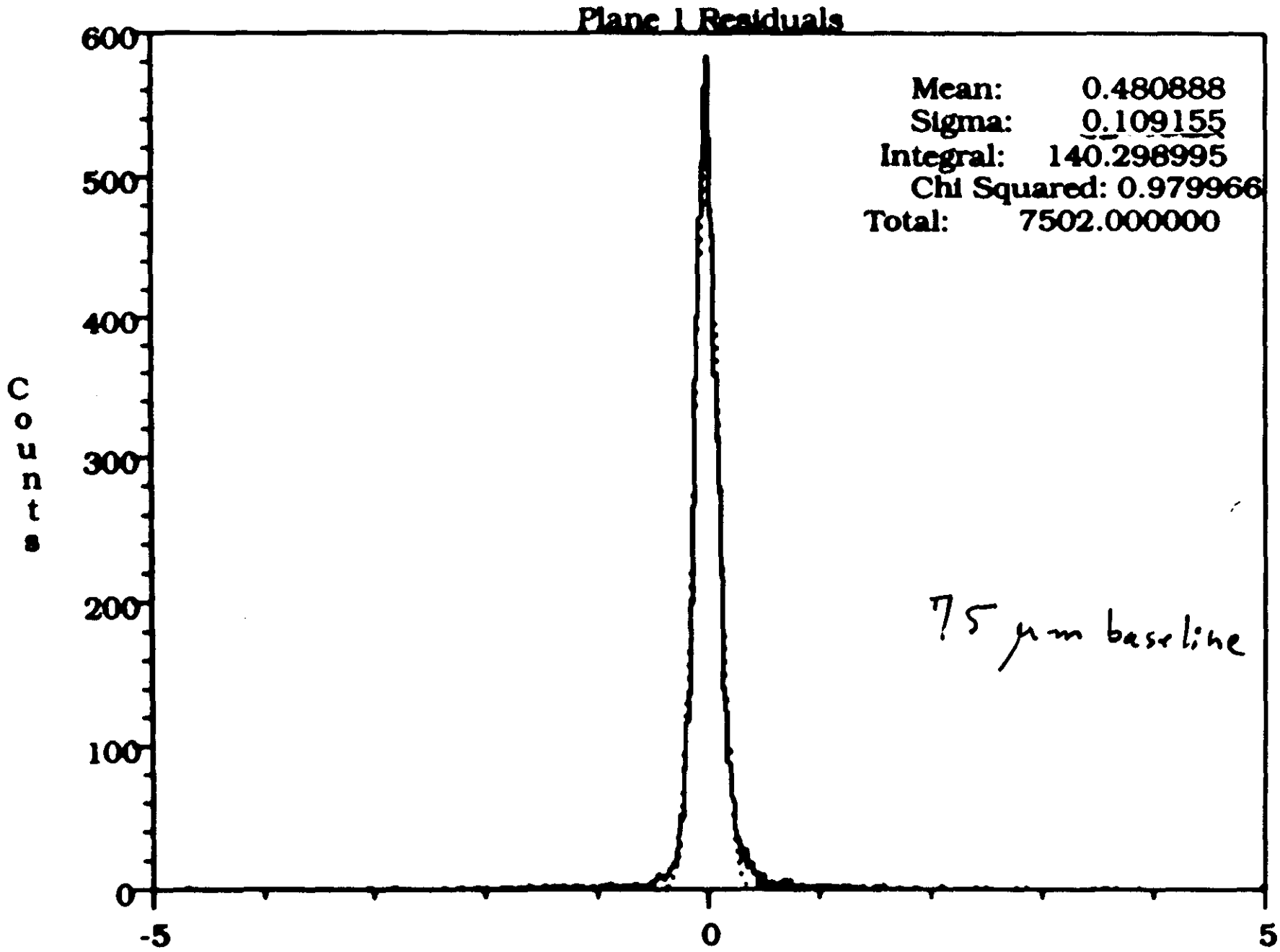
# RESIDUALS FROM THE TRACK

$\langle \sigma \rangle = 85\mu$

92/11/03 00.57




100 μm baseline


Plane 1 Residuals
Mean: 0.480888
Sigma: 0.109155
Integral: 140.298995
Chi Squared: 0.979966
Total: 7502.000000
Counts
600
500
400
300
200
100
0
-5
0
5
75 μm baseline

# Technology Decisions

- Process

  - Listed all questions which need answers before TDR

  Mental Game was to assume that given technology was the chosen one.

| Technology: | Number of Questions |
|---|---|
| CSC | 22 |
| LSDT | 16 |
| PDT | 16 |
| RPC | 10 |

- Questionare for comparative ranking of technologies

  All members of Muon Group were asked to respond. Results (24 respondents)
  (Low # is GOOD)

| Technology | Rating |
|---|---|
| CSC | 68 ± 15 |
| PDT | 54 ± 12 |
| LSDT | 72 ± 13 |

CSC ≈ LSDT

PDT 1σ better

# CSC

1) Demonstration of full scale prot
2) Correlation of pad/wire trigger in multihit
3) Working electronics
4) Take chamber to working collide → noisey environment.
5) Engineering design ready for mat's
6) Test in humid environment – cycle
7) Full cost estimate
8) η efficiency
9) Measure operation in $\vec{B}$
10) Support design
11) Optimization channel/chamber. – Vorobyov
12) 75 μm from existing chamber.
13) Test of endcap bent wire.
14) Measure double track
15) Produce full size cathode/panel
16) Calibration scheme proof
17) Broken wire mitigation.

CSC cont

18) Timing res'l/rate (bunch)

19) Measure rate capability @ n hits

20) Fix operating params barrel ends

21) Resolution f(rate)

22) Alignment transfer/scheme.

# LSDT

1) Wire pos'n ?
2) Alignment transfer/design design, build
3) Design for manuf/robustness done
4) Stand alone trigger design, cost, manufacture → suggested RED
5) End cap geometry design & build (?)
6) After Pulsing - more RED + present GEM notes
7) Coating/signal prop/ σ will do
8) Operation of Full Scale Prototype done at MIT
   ↳ align
9) Non flammable gas will do
10) η efficiency redo
11) Rate capability incl σ, eff will do
12) Lifetimes doing
13) ~~Distortion~~ Stability on design support/align
14) Occupancy/pattern recognition
15) Operation w/RPC will do
16) Acceptance

# RDT

1) Wire sag — $\delta T \sim 1\%$ — Lifetime

2) Trigger?

3) End cap Geometry → Trigger

4) Pattern Recognition – n hits
no 2nd coord.

5) Diameter / DT / Trigger / Cost / tolerance sag wire $\phi$

6) Alignment transfer / thermal / support

7) Tube to wire tolerance

8) Afterpulsing rate

9) Non flammable gas

10) n efficiency – vs P, gas

11) Monitoring scheme

12) Optimization mode / wire $\phi$

13) $\sigma$ vs P

14) Acceptance
Optimization / limitation of the width.

15) Resolution vs rate

# RPC (✓) done

1) Demonstrate rate capability at n $10^5/cm^2/s$

2) Noise below 10 Hz/(cm)$^2$ and stable

3) Working ~~large~~ full scale prototype in conjunction with DT at high rate

4) Specification for end cap

5) Lifetime measurement.

6) Rad hardness

7) n efficiency

8) Non flammable gas.

9) Time Resol at high rate. slewing, efficiency, pos dep.

10) Design of mech. liner

GEM TN-92-207
Draft

# Mechanical Engineering Evaluation of the Muon Chamber Technology Options

R. Sawicki (Chairman) - Lawrence Livermore National Laboratory
M. Gamble, C. Johnson - SSC Laboratory
F. Nimblett - C. S. Draper Laboratory
R. Humphreys - Martin Marietta Science Systems

October 1, 1992

Abstract:

This report summarizes an engineering evaluation of the technologies that are being proposed for the barrel muon subsystem of the GEM detector. A summary of the status of each option is presented along with a comparison of the relative strengths and weaknesses of each design.

**DRAFT**

# Muon Cost Estimating Status
# (Barrel region only)

Richard Sawicki
Lawrence Livermore National Laboratory
November 4, 1992

# Cost estimating contributors

- Cost coordinator
  - R. Gustavson, Draper
- Chamber material and assembly costs
  - CSC, C. Johnson, LLNL/SSCL
  - LSDT, J. Kelsey, MIT
  - PDT, C. Bromberg, MSU
- Assembly costs- foreign
  - I. Golutvin, Dubna
  - Y. Xie, IHEP
- Structural and cooling system costs
  - F. Nimblett, Draper
- Gas system costs
  - M. MacKernan, LLNL
- Electronic system
  - D. Marlow, Princeton
  - S. Calhoun, US Cost
  - MEOAD ATIYA
- Alignment system costs
  - R. Sawicki, LLNL

# Material cost status

- Bottom-up mechanical system costs have been developed for all technologies

- LSDT and PDT costs, in general, are based on actual costs of prototy parts or vendor estimates for production parts

- CSC material costs now have supporting quotations for major structu components
  - cathode strips (CCT Marketing)
  - honeycomb panel with cathode plain attached (MC Gill)

# Assembly cost assumptions

- Assembly labor rates and task times are US estimates
  - labor rates based on GEM Cost Estimating Plan
  - task times estimated by US estimators

- Work force makeup

| | | Percent of workforce | | |
|---|---|---|---|---|
| Discipline | K$/yr | CSC | LSDT | PDT |
| Engineer/physicist | 133 | 13.4 | 10.6 | 12.8 |
| Senior technician | 107 | 46.3 | 44.7 | 55.3 |
| Junior technician | 82 | 40.3 | 44.7 | 31.9 |
| Average rate K$/yr | | 100.4 | 98.6 | 102.4 |

- Does not include facility operation costs

- Costs based on number of hours to build an average size chamber

# Assembly time comparison

Time (hr) to fabricate average chamber

| | USA | Dubna | IHEP | Average | Average/ USA | Cost delta (K$)** |
|---|---|---|---|---|---|---|
| CSC | 200 | 424 | 282 | 302 | 1.51 | 6029 |
| LSDT | 197 | 256* | 357 | 270 | 1.37 | 2375 |
| PDT | 418 | 424 | 858 | 567 | 1.36 | 2691 |

* time estimate that was provided contained some operations assumed to be performed in US. These times were subtracted out to provide for a fair comparison
**Cost delta equals increase in cost if USA cost times are increased to average times

# Electronic cost evaluation

- A bottom-up estimate for CSC, LSDT and PDT electronic cost (barrel only) has been assembled

more mature

- CSC evaluation has evolved over the last few months and is documente in cost reports by D. Marlow

less mature

- LSDT and PDT electronic designs (which are assumed to be the same) were quickly assembled in the last two weeks and are consequently much less defensible

- RPC costs have not been evaluated and are assumed to be the same as the LSDT and PDT on a $/channel basis

- CSC total cost is the greatest of any of the technologies because of the high channel count (877,000 in the barrel)

- Drift tube channel cost is higher than the CSC because five electronic boards are required for each module (only 1 for CSC)
  - further evaluation may evolve a more optimized design

# Contingency assumptions

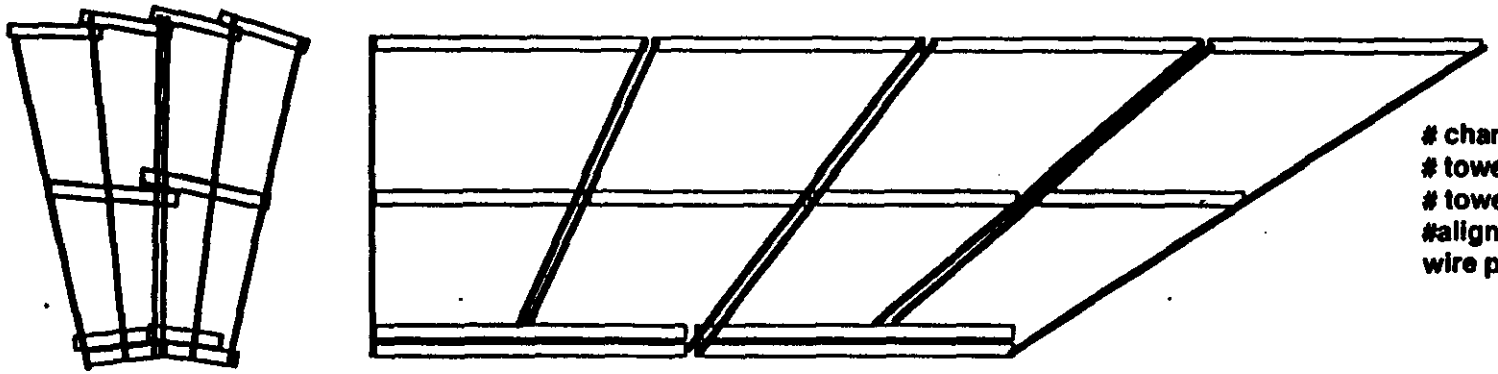
- Mechanical hardware
  - 30% contingency for PDT, LSDT and RPC technologies
  - 36% contingency for CSC technology

- Electrical hardware
  - 20% of PDT, LSDT and RPC technologies
    - -- although design is primitive it is conservative
  - 30% for CSC technology
    - -- design concept is agressive

| | CSC | LSDT | PDT | RPC |
|---|---|---|---|---|
| Mechanical contingency | 13891 | 8471 | 7389 | 1552 |
| Electronic contingency | 2894 | 905 | 780 | 226 |
| Total contingency | 16785 | 9376 | 8169 | 1778 |
| Total if contingency = 30% | 14469 | 10503 | 9064 | 2058 |
| Difference | -2316 | +1127 | +895 | +280 |

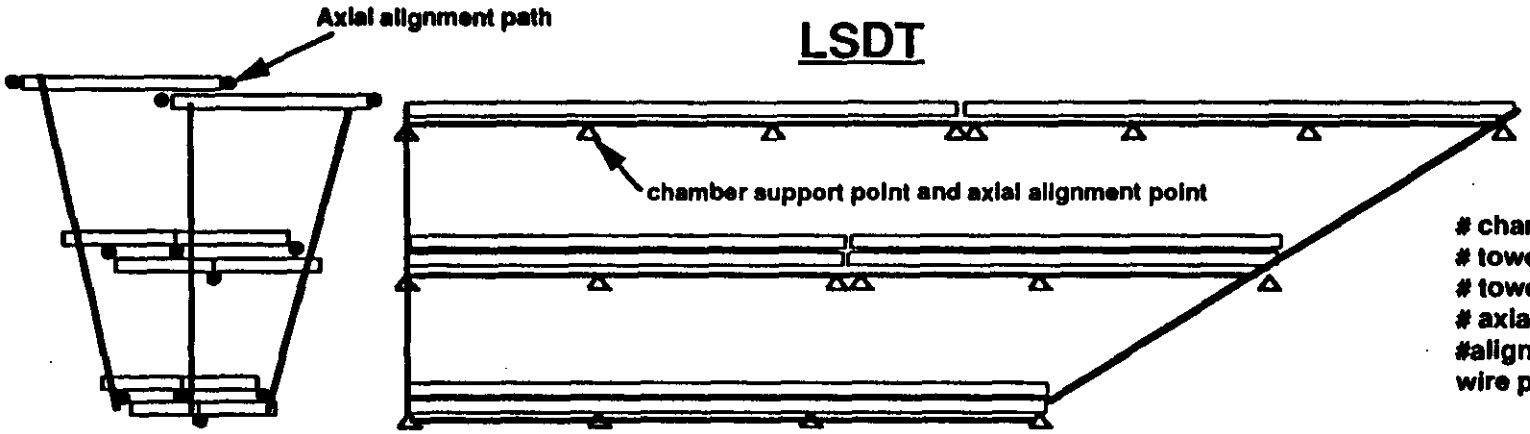
# Alignment system comparison per sector

## CSC



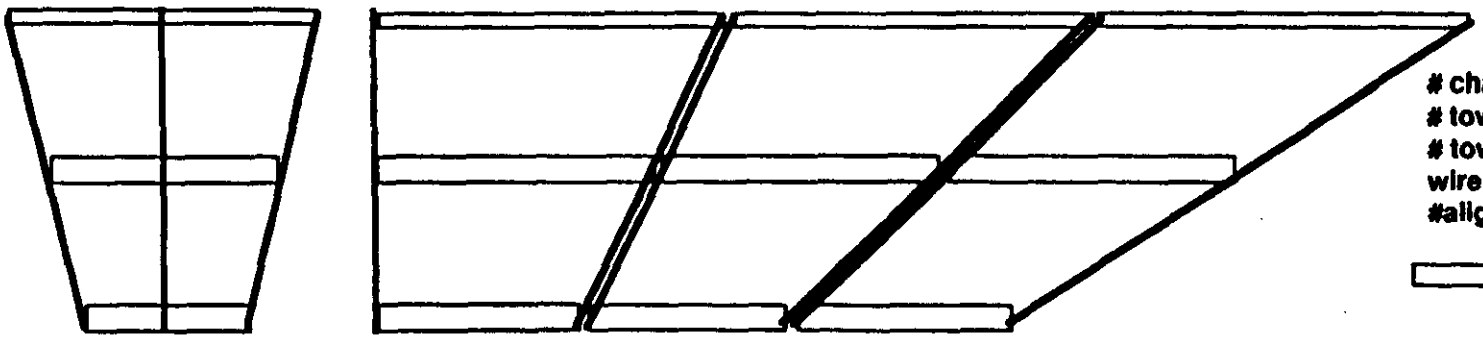
# chambers = 32
# towers = 8
# tower alignment paths = 4
#alignment points = 144
wire plane configuration = 8

## LSDT




# chambers = 16
# towers = 1
# tower alignment paths = 6
# axial alignment paths = 1
#alignment points = 90
wire plane configuration = 8

## PDT



# chambers = 9
# towers = 3
# tower alignment paths = 1
wire plane configuration = 8
#alignment points = 54

= chamber

= alignment pat

## Alignment system costs (K$)

| | CSC | LSDT | PDT |
|---|---|---|---|
| **Material costs** | | | |
| (1) # projective alignment paths | 48 | 6 | 18 |
| (2) # axial alignment paths | 0 | 12 | 0 |
| (3) # axial alignment points | 0 | 72 | 0 |
| (4) # axial alignment sensors | 0 | 48 | 0 |
| (5) # temperature monitors | 48 | 56 | 18 |
| (6) # SLM = (1) + (4) | 48 | 54 | 18 |
| Total SLM cost = $750* (6) * 32 | 1152 | 1296 | 432 |
| Total temp monitor cost = (5)*$70*32 | 108 | 125 | 40 |
| Alignment test equipment | 300 | 300 | 300 |
| Total material cost | 1560 | 1721 | 772 |
| **Installation and assembly labor costs** | | | |
| (7) Fiducialization = (6) *32 * 8 hr/SLM * $~~28.28~~ 25.57/hr | 314 | 353 | 118 |
| (8) Alignment = (6) *32 * 10 hr/SLM * $~~28.28~~ 25.57/hr | 393 | 442 | 147 |
| Inspection and administration = .06((7)+(8)) | 42 | 48 | 16 |
| Total installation and assembly labor costs | 749 | 843 | 281 |
| **Total costs** | 2309 | 2564 | 1053 |

Labor rates assume following work group composition at SSCL job shop rates
- 10% engineer @ $49.97/hr
- 45% Jr. Tech @ $19.14/hr
- 45% Sr. tech @ $26.58/hr
- Average rate = $25.57/hr

PDT alignment costs ½ of CSC & LSDT

## GEM MUON ELECTRONICS COST ESTIMATE

| Item | CSC $/Chan | LSDT w/Trig $/Chan | LSDT w/RPC $/Chan | PDT $/Chan | PDT w/RPC $/Chan |
|---|---|---|---|---|---|
| IC's (see sumemry table) | $4.39 | $12.32 | $5.72 | $5.72 | $5.72 |
| Capacitors | $0.00 | $1.00 | $1.00 | $1.00 | $1.00 |
| PCB Fab. ($0.96/in^2) | $0.75 | $5.42 | $5.06 | $5.06 | $5.06 |
| Connectors (Male & Female) | $1.00 | $0.25 | $0.25 | $0.25 | $0.25 |
| Cables | $0.00 | $6.25 | $6.25 | $6.25 | $6.25 |
| Misc. Parts (S.W.A.G.) | $0.32 | $0.32 | $0.32 | $0.32 | $0.32 |
| Assembly (1500 leads @ $0.06/ea) | $1.41 | $2.53 | $2.53 | $2.53 | $2.53 |
| Q/A @ 20 min/board | $0.16 | $0.39 | $0.39 | $0.39 | $0.39 |
| Test @ 1 man-hour/board | $0.47 | $1.17 | $1.17 | $1.17 | $1.17 |
| Rework 20% @ 2hrs/board | $0.19 | $0.47 | $0.47 | $0.47 | $0.47 |
| LVPS (200 mW/chan @ $5.00/W) | $1.00 | $1.00 | $1.00 | $1.00 | $1.00 |
| Mounting Hardware (S.W.A.G.) | $0.31 | $0.31 | $0.31 | $0.31 | $0.31 |
| Packing & shipping | $0.31 | $0.31 | $0.31 | $0.31 | $0.31 |
| Additional Front End Elements | $0.69 | $9.40 | $9.40 | $9.40 | $9.40 |
| Subtotal Cost/Channel | $11.00 | $41.14 | $34.18 | $34.18 | $34.18 |
| *Channel Count* | *877,000* | *110,000* | *143,000* | *114,000* | *147,000* |
| Subtotal Channel Cost | $9,647,000 | 4,525,400 | 4,887,740 | 3,896,520 | 5,024,460 |
| Contingency (30% CSC; 20% others) | $3.30 | $8.23 | $6.84 | $6.84 | $6.84 |
| Cost/Channel w/Contingency | $14.30 | $49.37 | $41.02 | $41.02 | $41.02 |
| Channel Cost w/ Contingency | $12,541,100 | $5,430,700 | $5,865,880 | $4,678,280 | $6,029,940 |
| *Channels/ Board* | *64* | *128* | *128* | *128* | *129* |
| Total Cost/Board | $915 | $6,319 | $5,251 | $5,251 | $5,292 |
| Fixed Cost (Prototype Development) | $0 | $2,246,000 | $2,246,000 | $1,686,000 | $2,246,000 |
| Grand Total | $12,541,100 | $7,676,700 | $8,111,860 | $6,362,280 | $8,275,940 |

# Muon Technology Cost Summary

**(Barrel only)**

| | CSC | LSDT (w/trig) | PDT | (+) RPC | LSDT w/RPC | PDT w/RPC |
|---|---|---|---|---|---|---|
| | | | | | | |
| Design | 367 | 526 | 369 | 369 | 895 | 738 |
| Material/Fabrication | 13579 | 10179 | 6990 | 1995 | 12174 | 8985 |
| Shipping | 371 | 243 | 187 | 187 | 430 | 374 |
| Facility Preparation | 594 | 834 | 594 | 474 | 1308 | 1068 |
| Assembly/Test | 15157 | 8950 | 10785 | 1867 | 10817 | 12652 |
| Support Structure | 3267 | 3267 | 3120 | 0 | 3267 | 3120 |
| Alignment | 2309 | 2564 | 1063 | 15 | 2579 | 1078 |
| Gas System | 1467 | 1652 | 1496 | 242 | 1894 | 1738 |
| Cooling System | 1475 | 25 | 25 | 25 | 50 | 50 |
| Electronics | 9647 | 6771 | 5583 | 1687 | 7134 | 7270 |
| SUBTOTAL | 48233 | 35011 | 30212 | 6861 | 40548 | 37073 |
| | | | | | | |
| Contingency | 16785 | 9377 | 8169 | 1778 | 11002 | 9946 |
| | | | | | | |
| TOTAL | 65018 | 44388 | 38381 | 8639 | 51550 | 47019 |

$\Delta = \$18m$

However

* Does not include 1.3M$ to attach electronic boards to bridges -LSDT

Does not include increased cost for decreasing tube diamter to 2.5 cm - PDT = ↑ ~~5882~~ 7069 K$

(52% increase in sone
(52% increase in tracka
(32% increase in ease

| | | | | | |
|---|---|---|---|---|---|
| NOMINAL | 65018 | 44388 | | 51550 | 47019 |
| ADD 1.3M$ FOR LSDT MOD | | +1300 | | +1300 | |
| ADD 5,882K$ FOR PDT MOD | | | | | Smaller dia. PDT (2.5 ~~+5882~~ 7069 |
| UNIFORM CONTINGENCY ≈ 30% | −2316 | +1127 | | +1127 | +895 |
| | | | | +280 | +280 PDT |
| CSC | 62,702 | 46,815 | $\Delta \sim \$16m$ | 54,257 | ~~57,076~~ 55,26 |

# Muon Steering Committee Meeting

- Discussed several questions

  - Are we prepared to accept CSC chambers in Barrel?

    Solid yes (with no reservations) 2
    Qualified yes (more R&D needed) 6

    Solid no (too risky, too costly...) 8

  - Which is the better drift technology: LSDT or PDT ?

    LSDT 5
    PDT 1 0 Hence PDT for more R&D.

    (one not voting)

  - CSC vs PDT ? As a better technology everywhere

    CSC 7
    PDT 9

  - Baseline 2 for TDR

| | Barrel | Endcaps |
|---|---|---|
| (1) | CSC<br>[PDT & RPC | CSC<br>PDT & RPC backup] |
| (2) | PDT & RPC<br>[CSC | CSC (hybrid!)<br>PDT & RPC backup] |

Votes: (1) 7
(2) 9

# Summary

Recommendations from Muon Group:

- Drift Technology: PDT favored No more LSDT R&D
- CSC looks attractive
  - need to demonstrate resolution
  - trigger timing
  - large scale prototype
  - costing
- RPCs look promising with low resistivity plastic
  - need to demonstate jitter, rate, slewing,....
- Need to develop alternative to CSC in EC as backup

With PDT and RPC:

- how to trigger?
- how to deploy tubes ?
- baseline resolutions obtainable?

- More work needed on costing
  - electronics
  - chamber fabrication
- Baseline 2:
  - hybrid slightly favored (Base line 1)
  - universal agreement that more R&D needed

Process now before Exec. Com. & Spokesmen.

# Summary of Calorimetry Working Group

Bill Willis

# Nov. 5, Calorimeter Meetings

I. Calorimeter Engineering -

David Lissauer/Bill Wisniewski Chair

**Instrumentation/Annex**

i)Calorimeter Facilities at the SSC — Cliff Eberle

ii)Interface to central detector support. — Brian Smith

iii)Overview of the Scint. Design — Mark Rennich

iv)Overview of the Liquid Design. — Lyle Mason

v)Module structure. — Brian Easom

vi)Electrode structure design — Don Makowiecki.

vii)Cryogenic Facilities — Don Rishied

viii) Beam line interface — Garry Chapman

ix) FNAL Test: Prototype calorimeter. — D.Lissauer

4:30 P.M: Joint session of all groups. Bill Willis - Chair
Physics Building - Large Seminar Room

## II. Simulation / Optimization Working Group

Bob McCarthy Chair

Morning Session: Mulitphoton Rejection and Pointing -

Physics Building/Small Seminar Room

Sasha Vanyashin - "Gamma/Jet Rejection by Isolation"

Misha Leltchouk - "Narrow Strips in the Projective Accordion"

Hong Ma - "Pointing and Shower Shape Analysis in the Accordion"

Yuri Efremenko - "How to Improve Pointing by the L-Kr EM Calorimeter"

Kostya Shmakov - "Optimization of a Massless Gap for the Accordion"

Afternoon session:

Tomasz Skwarnicki/John Womersley Chair

Physics Building/Large Seminar Room

Description of present code and needs: Tomasz S.

Integration of the calorimeter simulation in to the Overall GEM software.

Simulation tools.

4:30 P.M: Joint session of all groups. Bill Willis - Chair Physics Building - Large Seminar Room

III) Baseline Calorimeter

Morning session. Chair: Bill Willis

Physics Building - 2-160

a)Status of the Liquid section.

b) Function of the Scintillator section.

c) Depth optimization. Frank Paige

d) e/pi: Discussion.

Afternoon Bill Willis - Chair

Physics Building - 2-160

Scintillator Design questions. Larry Sulak

a) Fibers Solution; Bars Jim Reidy??

b) Photomultiplier: readout questions.

c) Trigger Bill Cleland.

4:30 P.M: Joint session of all groups. Bill Willis - Chair
Physics Building - Large Seminar Room

# CALORIMETER GROUP MEETINGS

## OPTIMIZATION SECTION

1. LARGER DEGREE OF CONSENSUS ON MANY ISSUES

2. "BASLINE 2 HYBRID": NOT THIS ONE!

3. TWO REASONABLE HYBRIDS:

   i) LKR $>\sim 6-7\lambda \Rightarrow$ BASELINE 1 PHYSICS PERFORMANCE*

   ii) LKR $\lesssim 2\lambda \Rightarrow$ <u>COMPENSATED</u> <u>PROJECTIVE</u> TOWERS

4. CALORIMETER GROUP DOES NOT CONSIDER THE 25% INCREASE IN INNER RADIUS WORTH THE EXTRA COST

5. WIGMANS PREDICTED INCREASE IN $(e/\mu)_{LKR} / (e/\mu)_{LA}$ : OBSERVED IN AGS TEST $\Rightarrow e/\pi$ LKR Cu $= 1.9$

   $\Rightarrow$ <u>UNCORRECTED</u> CONSTANT TERM

   $\sigma_{E\,JET} \gtrsim 5\%$ (2% REQUIRED)

   CORRECTED = ??

6. THIS "REQUIRES" HIGH-Z ABSORBER THROUGHOUT LKR, EG $\underline{\Delta R(Pb\text{-}Cu)}$ = 8-10 cm. ETC.

7. LIQUID CALORIMETERS REQUIRE EXTENSIVE TEST BEAM SURVEY IN CORNERS AND CRACKS

8. POLL FINDS

a) FRACTION FAVORING IMPROVED PERFORMANCE ON JETS WITH 2λ HYBRID; ENGINEERING PROBLEMS WILL BE SOLVED.

b) FRACTION BELIEVING IN STABILITY ETC OF LKR; ENGINEERING OF 2λ NOT YET SOLVED.

c) SIGNIFICANT FRACTION MOVED BY ENGINEERING ARGUMENTS, WOULD PREFER 2λ HYBRID BUT NOTE DESIGN OF IT HAS NOT CONVERGED.

# gem

$\gamma e \mu$

## Physics/Simulation

Ken McFarlane, Convener

Physics | Simulation after Bill Willis's talk. TODAY
Physics 2-160

- Status of gemfast
- Discussion of work to be done for Baseline 2.

Computing Thursday Nov. 5th

8:30 am. K. McF Introduction
8:45 am GEM software base – I. Sheer
9:15 am Code Distribution – T. Wenaus
9:45 am TTR offline software – G. Yost
10:15 am Full simulation – T. Wenaus
10:45 am Discussions Full simulation, TDR

GEM Physics/Simulation meeting 11/4/92

| Name | Institute | email |
|---|---|---|
| Hong Ma | BNL | ~~HMA~~ HMA@BNLCL6.BNL.GO |
| CRISTINA BERISSO | U. MASSACHUSETTS | FNAL::MCHRISE |
| Alexandre Savine | UTK | ORPH1::SAVIN |
| Alexei SOUHAKOKOV | Academia. Sci Taiwan | PHA\|EXEI@TWNAS86C |
| CINDY SCHWARZ | VASSAR COLLEGE | SCHWARZ @ VASSAR |
| Steve KAHN | BNL | ~~KAHN1@~~ BNLDAG::KAHN1 |
| HENK UITERWAAL | SSCL | HENK @ PDSF. SSC. gov |
| STEVE MRENNA | CALTECH | MRENNA@ CITHEX. CITHEP. PHA. EDU |
| JENNY THOMAS | SSCL | JTHOMAS @ SSCVX1 |
| Melynda Brooks | LANL | BROOKS@ LAMPF. LANL. GOV |
| Shawn McKee | U of Michigan | MCKEE@ TARLE3. PHYSICS. LSA. UMICH. E |
| Tony Johnson | Boston Univ | TONYJ@SLACVX.SLAC.STANFORD.ED |
| Gary Ward | Rutgers Univ. | WARD@Ruthep.Rutgers.edu |
| Jin Chu Wu | SSCL | jcwu@sscvxl.ssc.gov |
| Nasser Danesh | SSCL | danesh@sscvxl.ssc.gov |
| Sasha Vanyashin | SSCL | vanyashin@sscvxl.ssc.gov |
| DAVID LEE | LANL | LEE @LAMPF. LANL. GOV |

GGM BNL | 11/4/92

# Physics Simulation Meeting

| Name | Institution | Email Address |
|---|---|---|
| Kenneth Lane | Boston Univ. | LANE@BUPHYC.BU.EDU |
| Saj Alam | U. at Albany | MSA90@ALBNY1VX |
| ZHICHAO LING | SUNY at ALBANY | L63634@ALBNYVMS |
| Lee A. Roberts | SSCL | lroberts@sscvx1.ssc.gov |
| Charles C Allen | UTexas-Austin | callu@uthep2.ph.utexas.edu |
| Elliott Wolin | Yale Univ | wolin@Yalphz.physics.Yale.edu |
| Ick Joh Kim | SUNY at Albany | IK348@ALBNYVMS |
| Henry Kasha | Yale Univ. | kasha@yalehep.bitnet |
| Frank Paige | SSCL | paige@SSCVX1.SSC.gov |
| Irwin Sheer | SSCL | Irwin_Sheer@SSC.gov |
| Hiroaki Yamamoto | Caltech | Yamamoto@CITHEX |
| Ren-yuan Zhu | CALTECH | ZHU@CITHEX |
| Jean-Yves HOSTACHY | BNL | HOSTACHY@BNLCL1 |
| ROBERT STEINER | ADELPHI UNIV. | STEINER@BNLCL6 |
| Bing-xin Yang | SSCL | SSCVX1::BYANG |
| RICHARD HEINZ | INDIANA UNIV. | HEINZ@IUBACS |
| Konstantin Shmakov | ORNL | shmakov@ORPHO1 |
| BRENT MOORE | UNIV. OF MISSISSIPPI | moore@higgs1.phy.olemiss.edu |
| TORRE WENAUS | LLNL | WENAUS@SSCVX1 |
| Bob Panvini | Vanderbilt Univ. | RSP@SLACVX or SLACVX::RSP |
| JOHN O'NEILL | UNIV. at Albany | JJO619@albnyvm |
| Horst Severini | Univ. at Albany | HS7786@ALBNYVMS |

11/4/92

1. Report by T. Skwarnicki on status of gemfast.

   - Needs definition of Baseline 2
   - Needs participation of calorimeter group.

2. Discussion of time scale:

   1 month for parameterization + time to put into gemfast.
   1 month for study
   1 month for report.

2/28/93 ~~3/1/93~~ would be more realistic than 1/31/93

This was communicated by B. Barish

Responsibilities assigned:

CT – S. McKee
EC – H. Ma
FC – M. Shupe
HC – W. Willis will provide
MU – P. Dingus
TR – H. Uijterwaal

Schedule was set for parameterizations: End of November.
gemfast volunteers to communicate with tomasz@sscvx1.ssc.gov

physics volunteers to communicate with lane@buphyc.bu.edu

Discussion on software base

C. Allen –

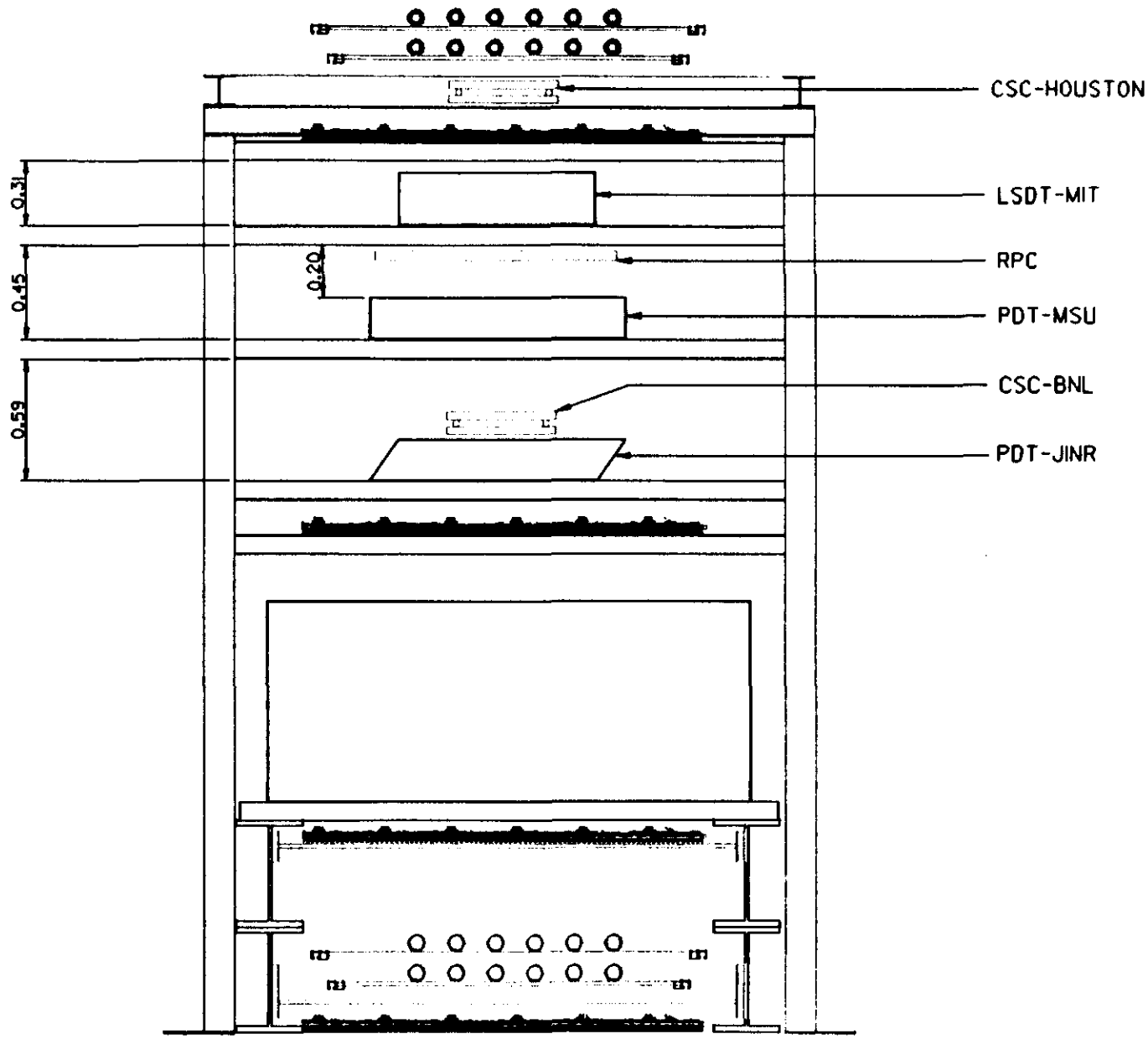
- cpp is not standard. May not be a separate program in future. Can ~~be~~ result in problems in pathological cases (e.g. /* ...). May not work with debugger.

- Should not add layers if not needed (use FORTRAN 'include' etc.)

- Keep it simple

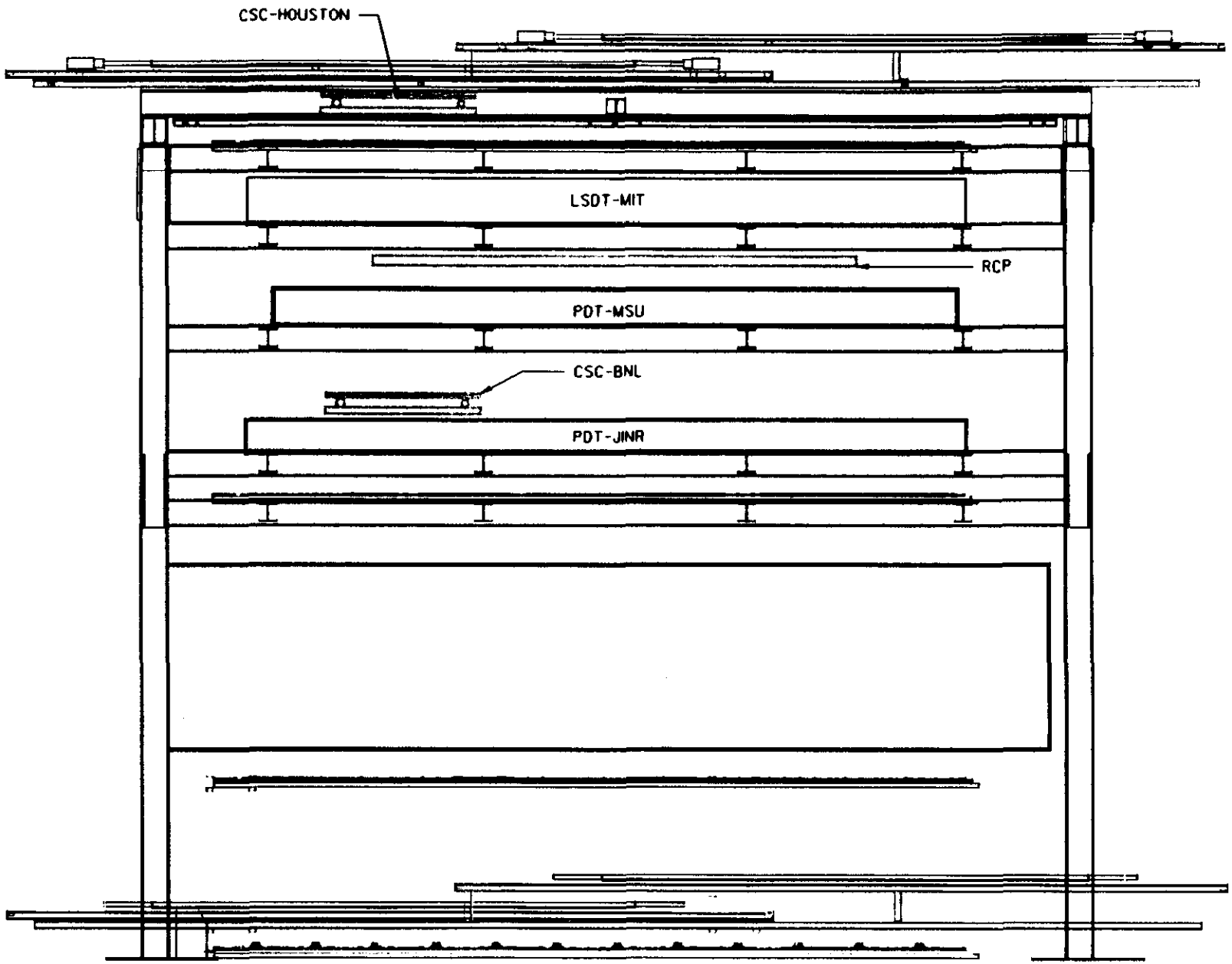
# TTR OFF-LINE SOFTWARE

- SINGLE BASIC APPARATUS (TTR)
  - INCLUDES SCINTILLATOR TRIGGER
  - INCLUDES IARCCI TUBES FOR MOMENTUM DETERMINATION
  - HAS POTENTIALITY OF DOING SAME TRACKS IN MULTIPLE TECHNOLOGIES → GLOBAL FITS
- MULTIPLE USERS
  - EVERYBODY CAME AT ONCE
  - EVERYBODY HAD SOME FORM OF SOFTWARE, BUT NEEDED AT LEAST THE SCINTILLATOR INFO (EXCEPT CSC'S!)
  - ALL THE S/W WAS ABOUT AS DIFFERENT AS POSSIBLE




INSTALLATION IN TTR - EAST FACE

EZ/kh - 29 OCT 1992 - TTRJ




INSTALLATION IN TTR

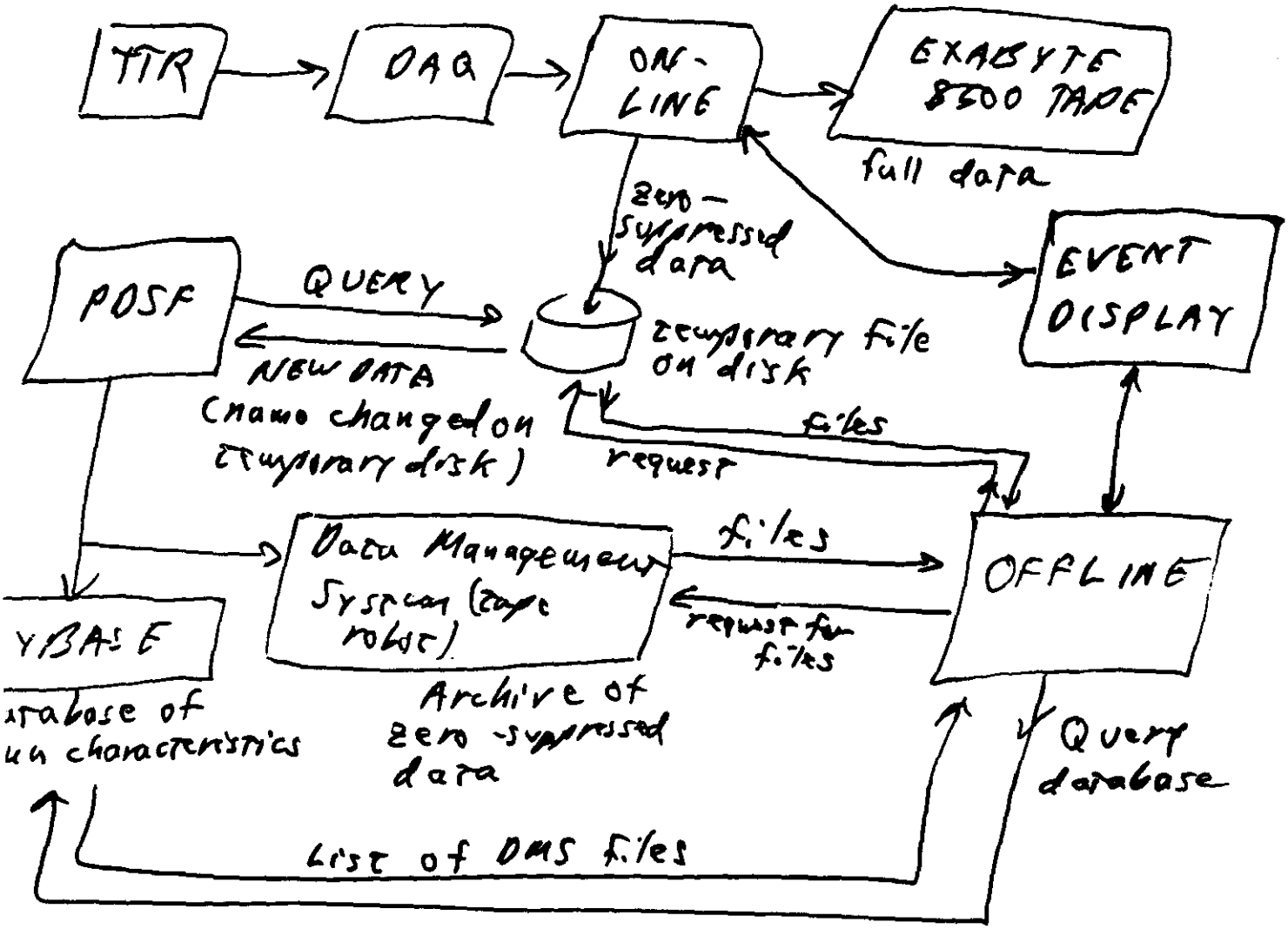
EZ/kh - 29 OCT 1992 - TTR.2

- INSTANT GRATIFICATION REQUIRED
  THIS MEANT WE HAD TO OPERATE
  IN KLUDGE MODE.

A RATHER NICE SET OF OFF-LINE S/W HAS BEEN DEVELOPED, BUT IS NOT IN PRODUCTION. EXPECTED TO BE SOON.

THIS IS THE STORY OF THAT SOFTWARE...

# DATA COLLECTION AND ANALYSIS CHAIN.



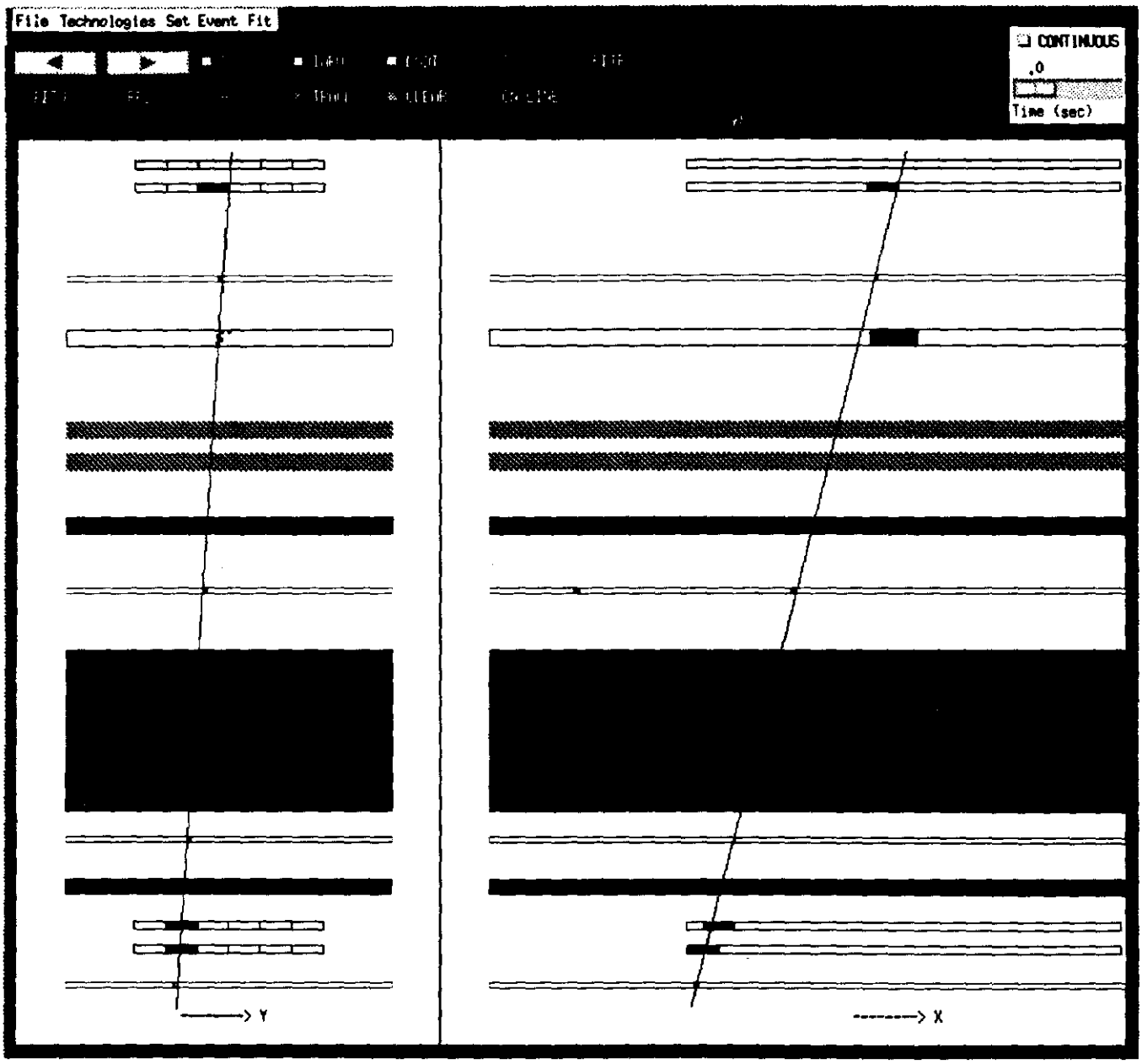

ALL The Green Stuff is operational.
The Black Stuff works, but only part is operational.



3

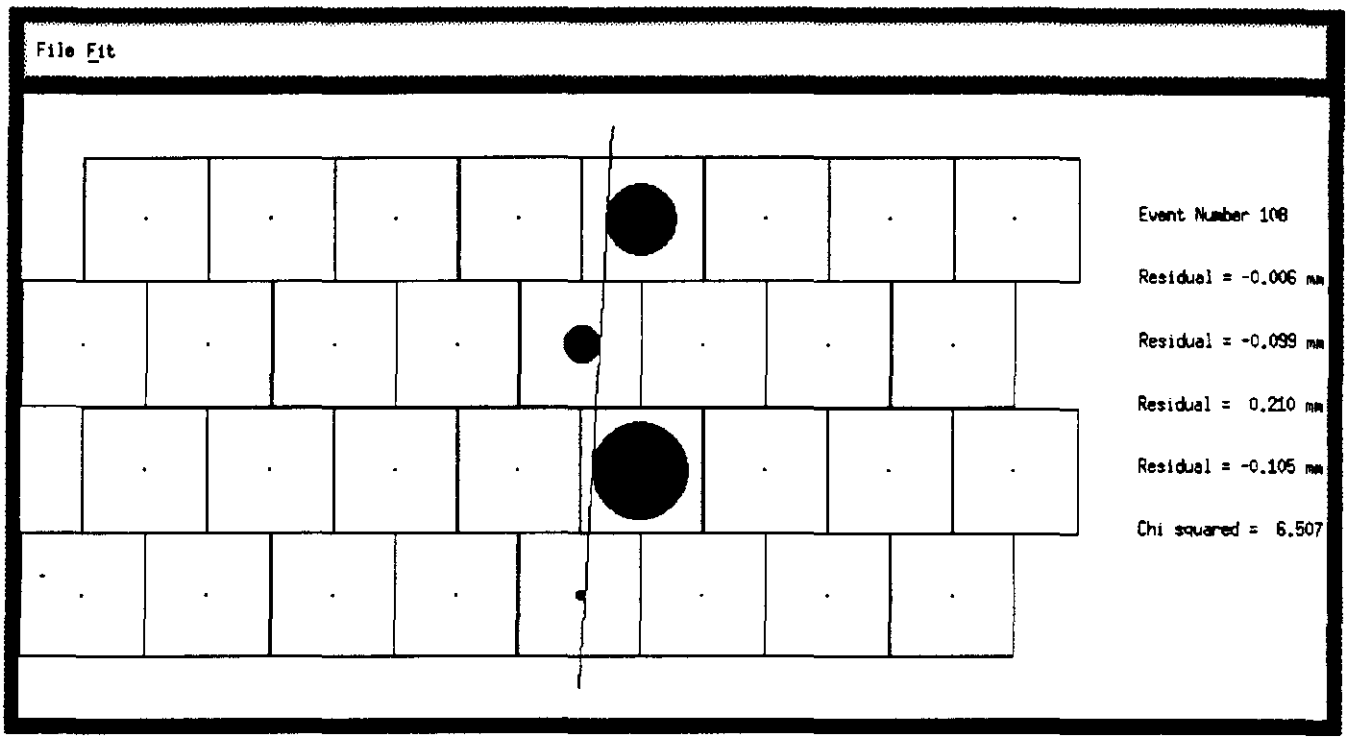
TEKTRONIX TEKTRONIX TEKTRONIX TEKTRONIX

EVENT DISPLAY






(Luis Villasenor)


File Fit
Event Number 108
Residual = -0.006 mm
Residual = -0.099 mm
Residual = 0.210 mm
Residual = -0.105 mm
Chi squared = 6.507

THE OFFLINE WAS DEVELOPED ON AN HP 730, USING THE SOFTBENCH DEVELOPER'S PACKAGE.

- FORTRAN, EXCEPT FOR I/O ROUTINES (Ken McFarlane)
- REAL*8, EXCEPT WHERE CALLING HBOOK.

SOFTBENCH CONTAINS POINT-AND-CLICK FUNCTIONALITY:

FILE MANAGER
EDITOR
COMPILER/LINKER
DEBUGGER

ALLOWS FAST COMPILATIONS, FIXING ERRORS

ALLOWS FAST EDITING, INCLUDING PASTING FROM ONE FILE TO ANOTHER.

DEBUGGER SIMPLE TO USE, FAST FINDING OF MOST BUGS. SIMPLY STEP THROUGH NEW ROUTINE AND CHECK EVERY VARIABLE.

(4)

IT ALL WORKS OVER THE N/W, SO SEVERAL PEOPLE CAN WORK AT ONCE, USING DEBUGGER, ETC.

MACHINE IS PLEASANTLY FAST:
10K LSOT EVENTS IN 1 MINUTE
<u>VS</u> 1/2 DAY OF PC!

SOFTBENCH HAS A FEW LIMITATIONS
- MEMORY "LEAKAGE"
- DEBUGGER DOES NOT HAVE FULL FUNCTIONALITY.

BUT IT'S REAL EASY TO LEARN.

KEY OPERATIONAL PROBLEM IN MULTI-USER ENVIRONMENT, EACH WITH HIS OWN CODE, HIS OWN SCHEDULE:

<u>HOW TO ISSUE UPDATED VERSIONS</u>

Friday

Change name

to B. Barish

# Summary of the Meeting

Barry Barish
Bill Willis
Gary Sanders

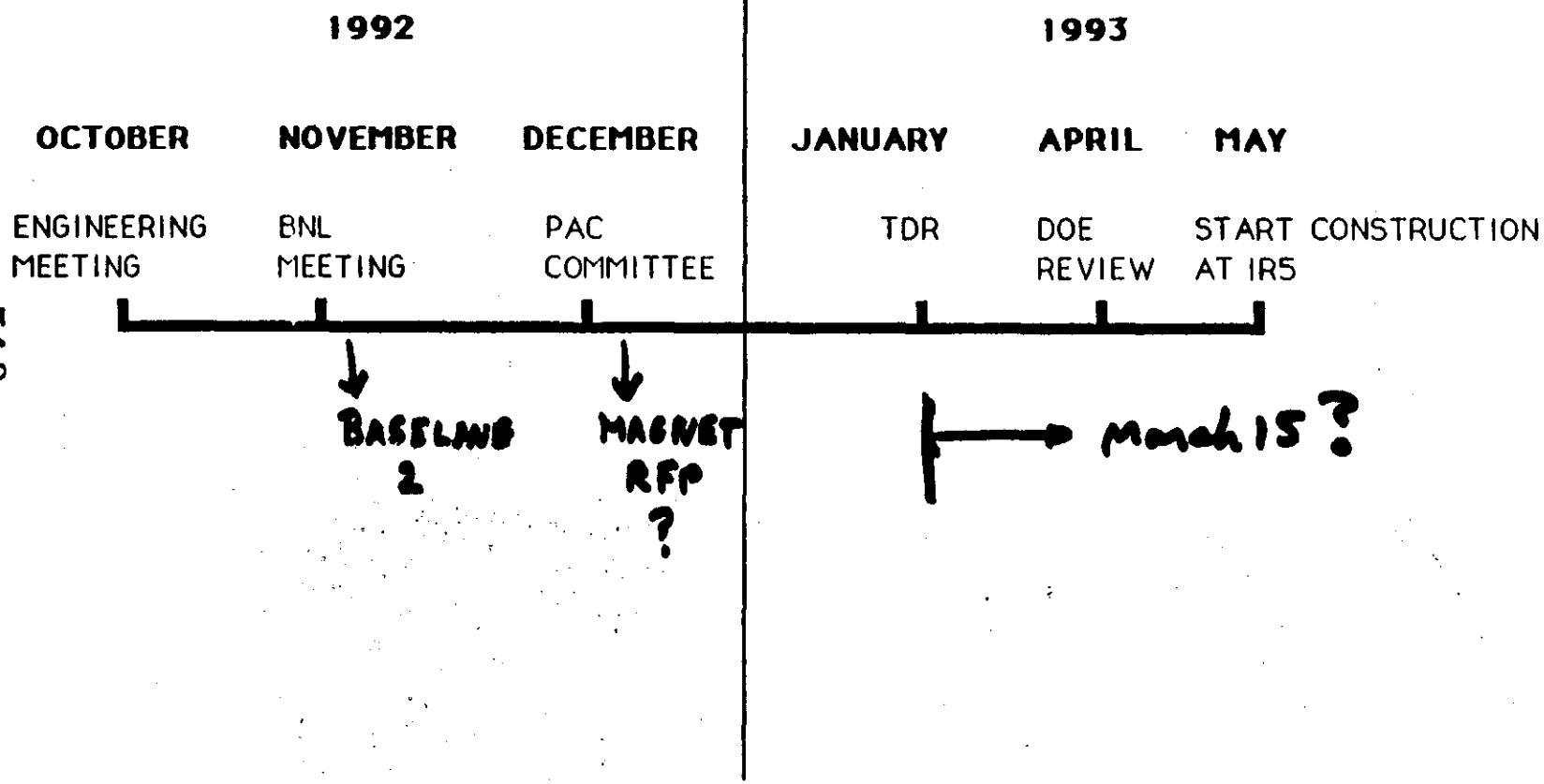
MARCH '92 TUCSON

: ESTABLISHED BASELINE 1

NOVEMBER '92 BNL

: ESTABLISH BASELINE 2

# Timeline

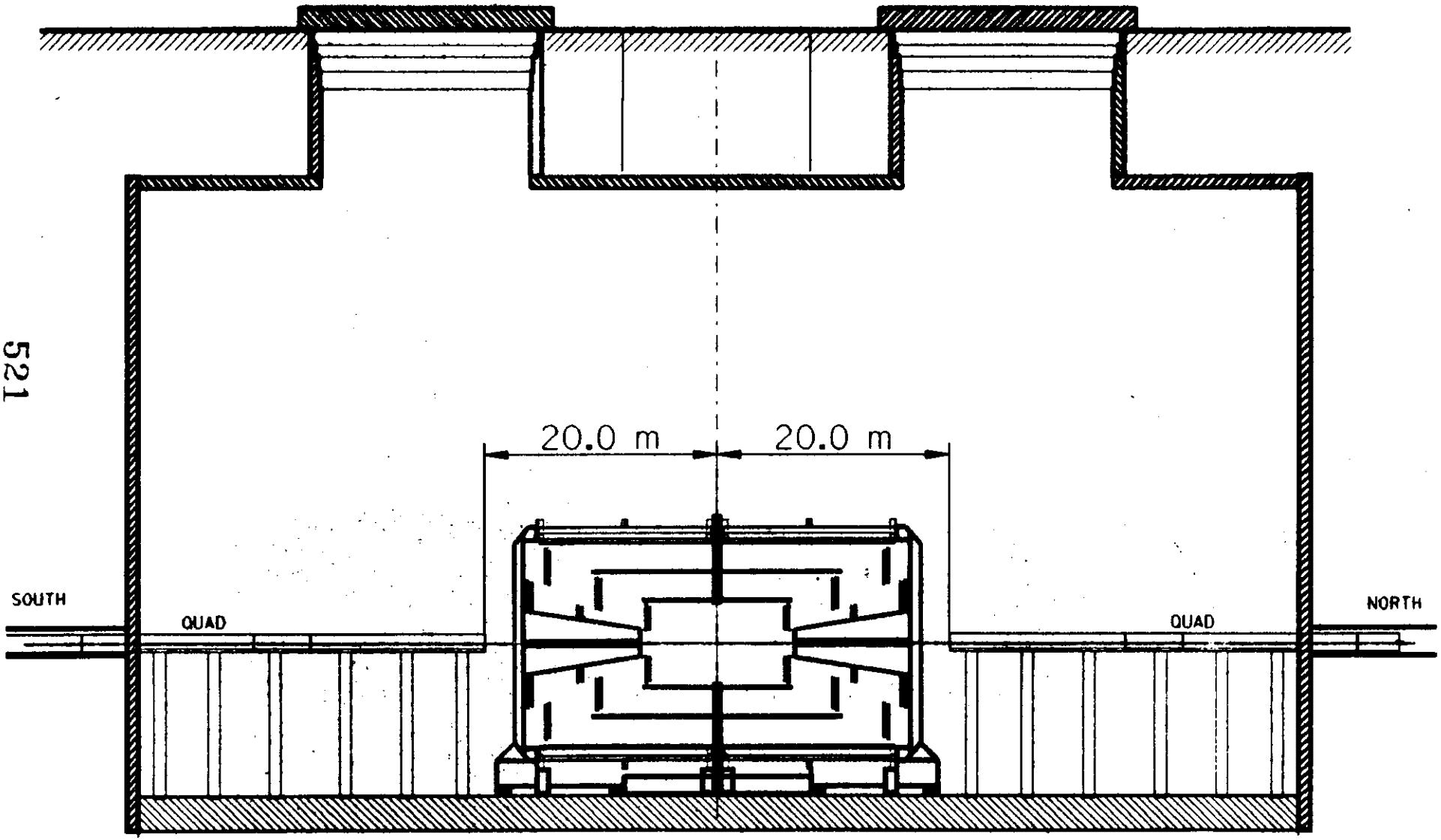

1992
1993
OCTOBER
NOVEMBER
DECEMBER
JANUARY
APRIL
MAY
ENGINEERING MEETING
BNL MEETING
PAC COMMITTEE
TDR
DOE REVIEW
START CONSTRUCTION AT IR5
BASELINE 2
MAGNET RFP ?
March 15 ?

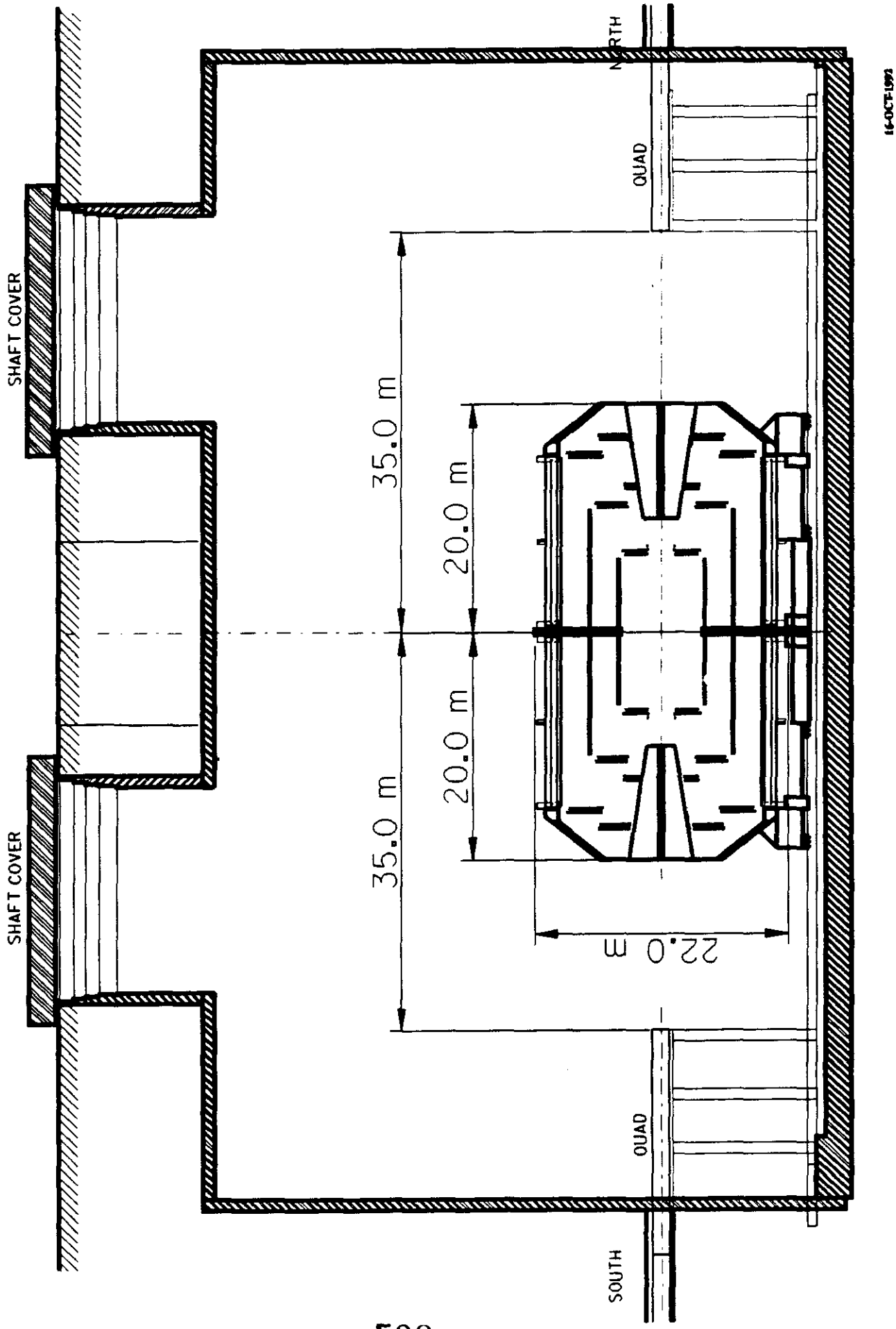
# BASELINE 2
# DESIGN
# as
# of
# NOV 4, '92

# BASELINE 2

MOVE QUAD TO 35m.

**POSITION QUADRUPOLE OPTION B**
**20 m FROM I.P.**




SHAFT COVER
SHAFT COVER
35.0 m
20.0 m
20.0 m
35.0 m
22.0 m
QUAD
QUAD
SOUTH
NORTH
16-OCT-1992

Comment Tomorrow with.
Before Friday morning

*Superconducting Super Collider Laboratory*
*2550 Beckleymeade Avenue, Mail Stop 2005*
*Dallas TX 75237-3946*
*(214) 708-6207*
*Fax: (214) 708-6088*

***GEM Project Department***

***Memorandum***

**To:** Gary Sanders
**From:** Paul Reardon, Gary Deis, Ryszard Stroynowski, Bill Wisniewski
**Subject:** Magnet System Paramter Freeze
**Date:** **DRAFT**

---

The GEM Magnet Project has now reached the stage at which it is necessary to freeze the major system parameters of the coil assemblies. This is required to support the overall schedule, which necessitates that the detailed design be advanced quickly in the next six months, and that major procurement actions be initiated immediately. At least one of these procurements, the conductor purchase, will be firm fixed price, so any design changes which would affect the conductor specifications in any way must be strictly avoided.

The Magnet Project recommends an immediate freeze of the following magnet parameters:

| Magnet System Parameter | Value | Unit |
|---|---|---|
| Magnet subsystem inner radius | 9.0 | m |
| Magnetic field at IP | 0.8 | T |
| Vacuum vessel minimum z | 0.4 | m |
| Vacuum vessel maximum z | 15.1 | m |
| Winding mean radius | 9.5 | m |
| Winding minimum z | 0.75 | m |
| Winding maximum z | 15.0 | m |

15.4 ? by Mike Harris

Freezing these system parameters will result in a freeze of many other derived parameters, such as number of turns, current, conductor cross section, etc. Many other parameters relating to the detailed design of the coil assemblies will be frozen as the design progresses.

The magnet project would also like to freeze the design of the FFS. However, in view of the ongoing discussions related to the designs of the tracker, calorimeters, and muon system, together with the slightly less critical schedule for the FFS design and construction, we do not request that the design be frozen at this time. However, please note that uncertainty in the design of the FFS will impede our ongoing discussions with potential foreign suppliers of these components, so an early freeze will be required. We anticipate requesting this freeze within 2 months.

The details of the magnet interfaces with the Central Detector Support, the Muon Subsystem, and the facility, as well as the interface between the FFS and the coil assemblies are being evolved as a normal part of the detailed design process. These details will not affect the magnet design in a significant "system" manner (as would changes in the parameters listed above); therefore we do not regard these interfaces as frozen, and we will continue to work with the other systems to develop the details as a part of our design effort.

Freezing of the major magnet system parameters, now, is essential in keeping the magnet project on schedule, in minimizing the overall cost, in maintaining project momentum, and in demonstrating the

Collaboration's ability to make timely decisions. Would you please present this issue to the executive committee for their concurrence?

BEAM PIPE

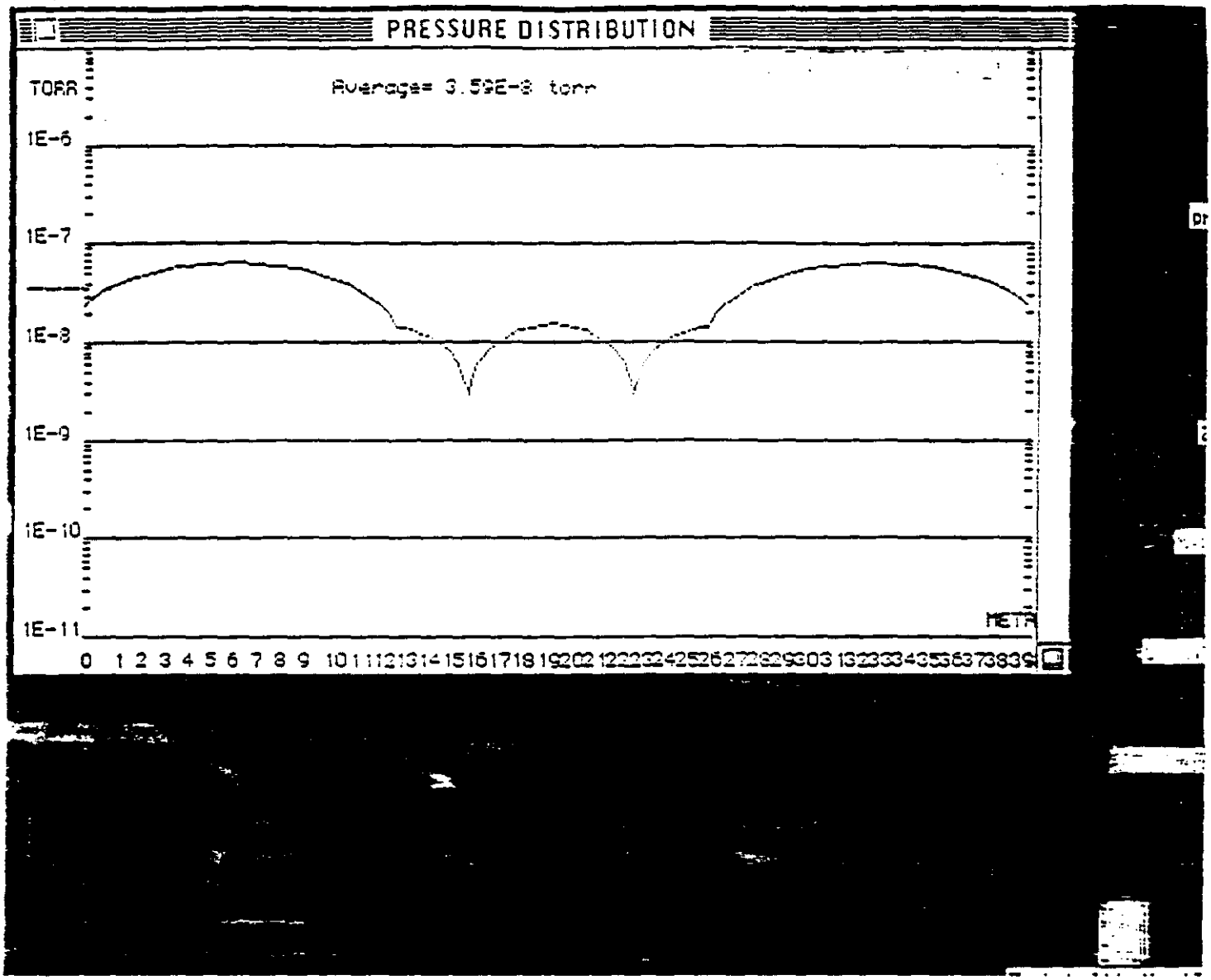
(G. Chapman)

BASELINE 2.

8cm pipe

Warm Beam Pipe

flared?

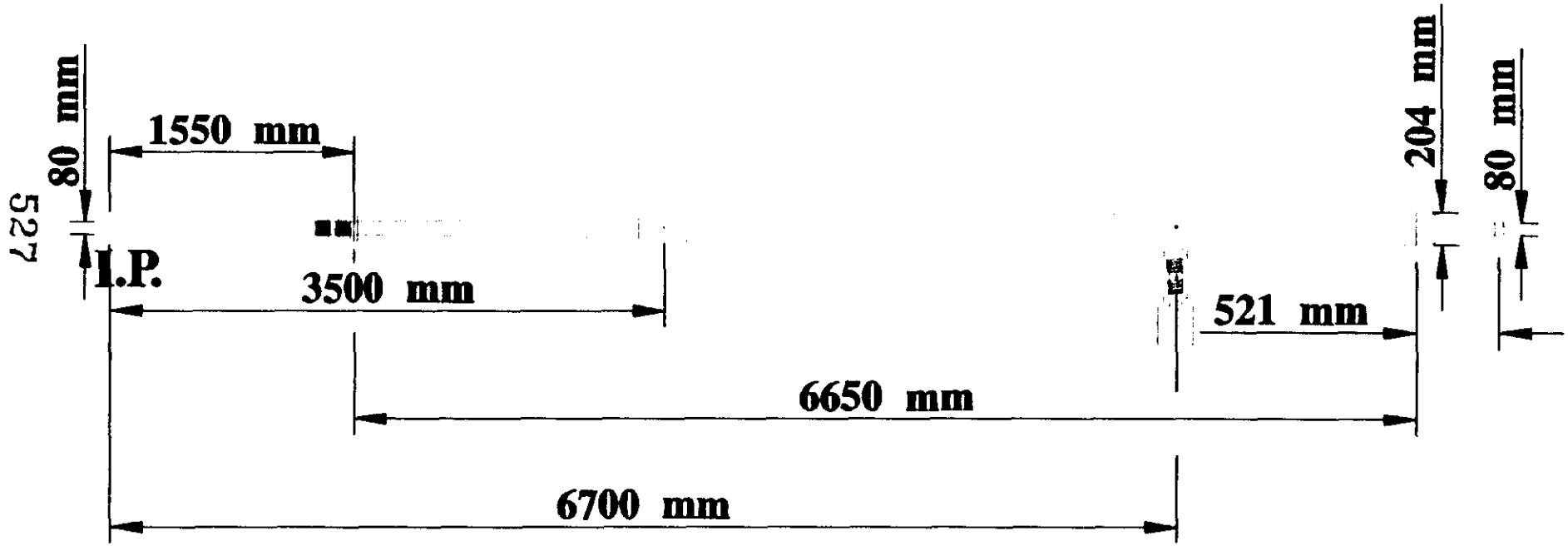



(B) 60 L/S. 60 L/S. NEG. 60 L/S. 60 L/S

φ 8 cm.

# GEM DETECTOR BEAMLINE LAYOUT

## OPTION 1-B

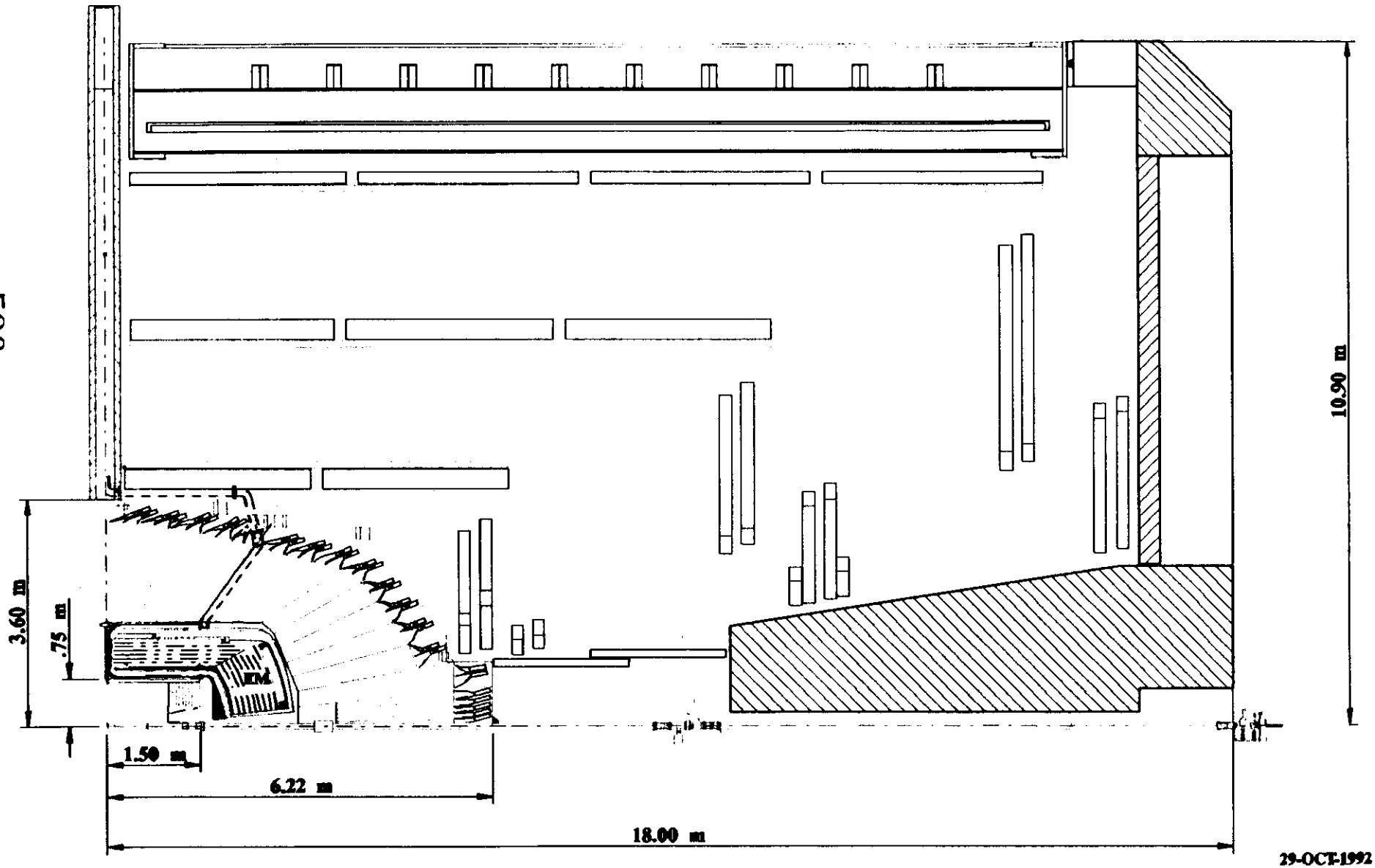



30-OCT-1992

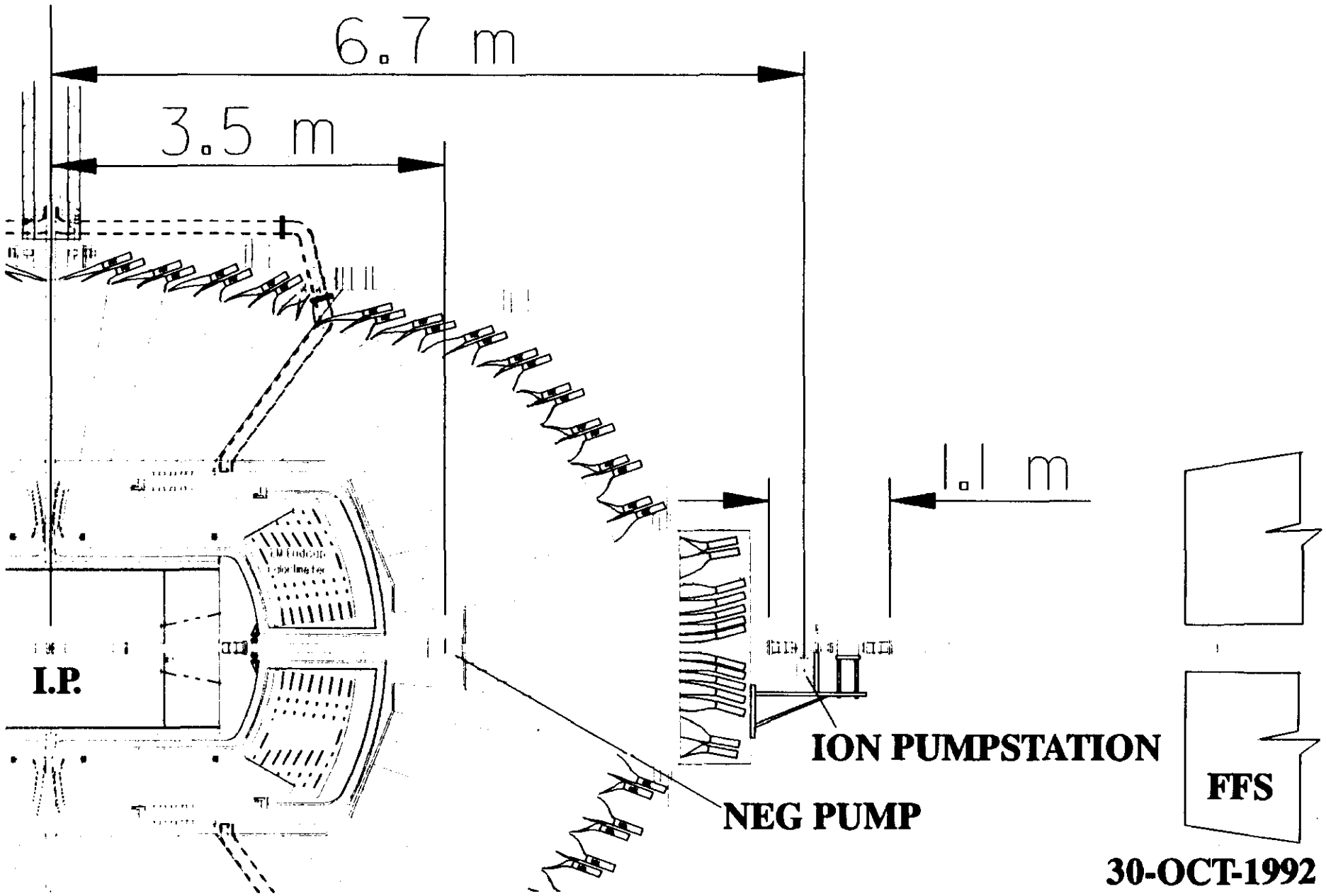
# GEM DETECTOR PARAMETERS

**OPTION 1**

**E.M. CALORIMETER: Liq Kr**
**FORWARD CALORIMETER: SCINTILLATING FIBER**
**BARREL CALORIMETER: FIBER**
**VACUUM SYSTEM: OPTION 1 or 3**




29-OCT-1992

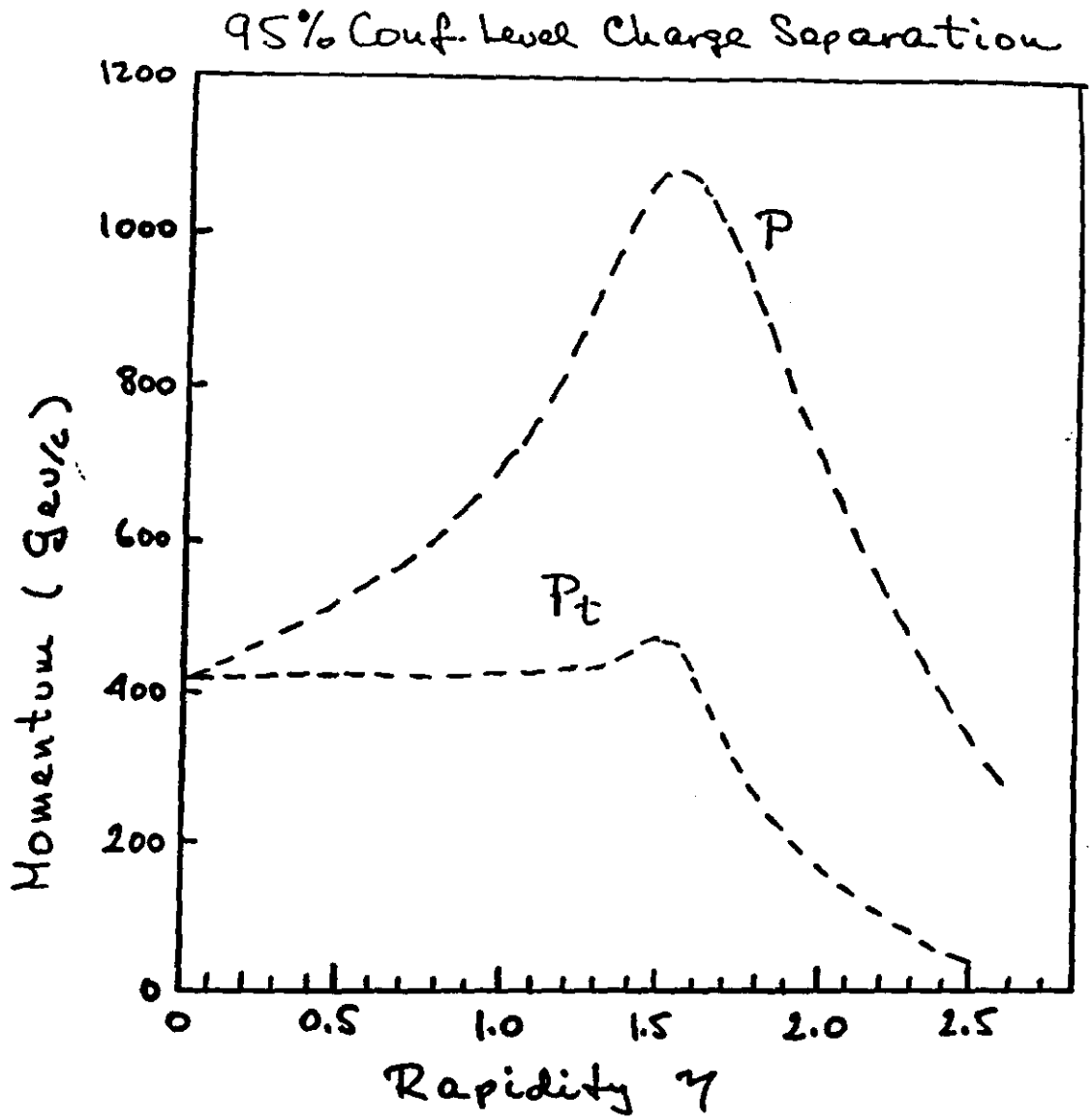

6.7 m
3.5 m
1.1 m
I.P.
ION PUMPSTATION
NEG PUMP
FFS
30-OCT-1992

# BASELINE 2

INCREASED DIAMETER

→ D = 1.9 m ←

sensitive


95% Conf. Level Charge Separation
1200
1000
800
600
400
200
0
Momentum (GeV/c)
P
Pt
0
0.5
1.0
1.5
2.0
2.5
Rapidity η

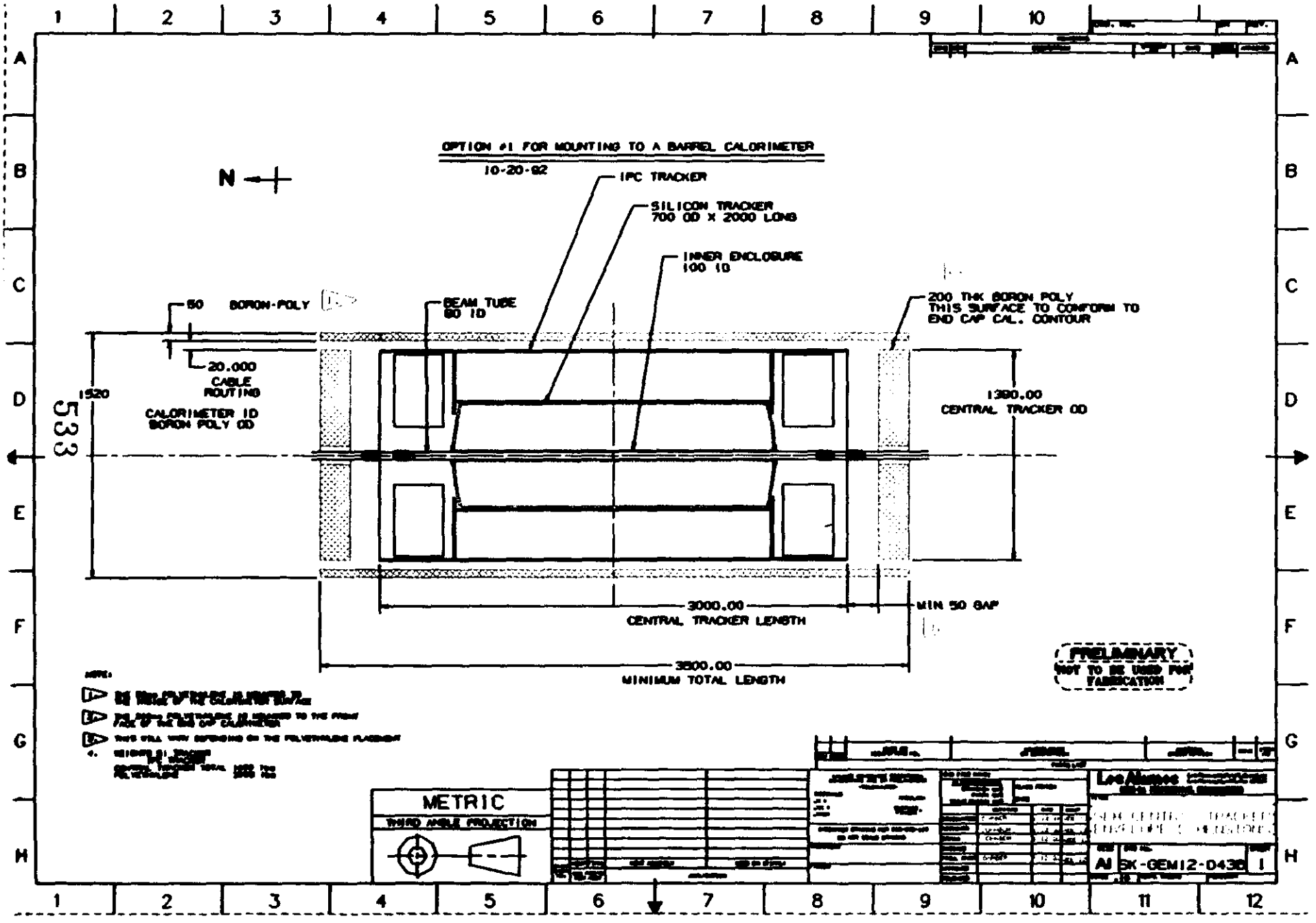
# 2 M VS. 1.5 M CENTRAL TRACKER

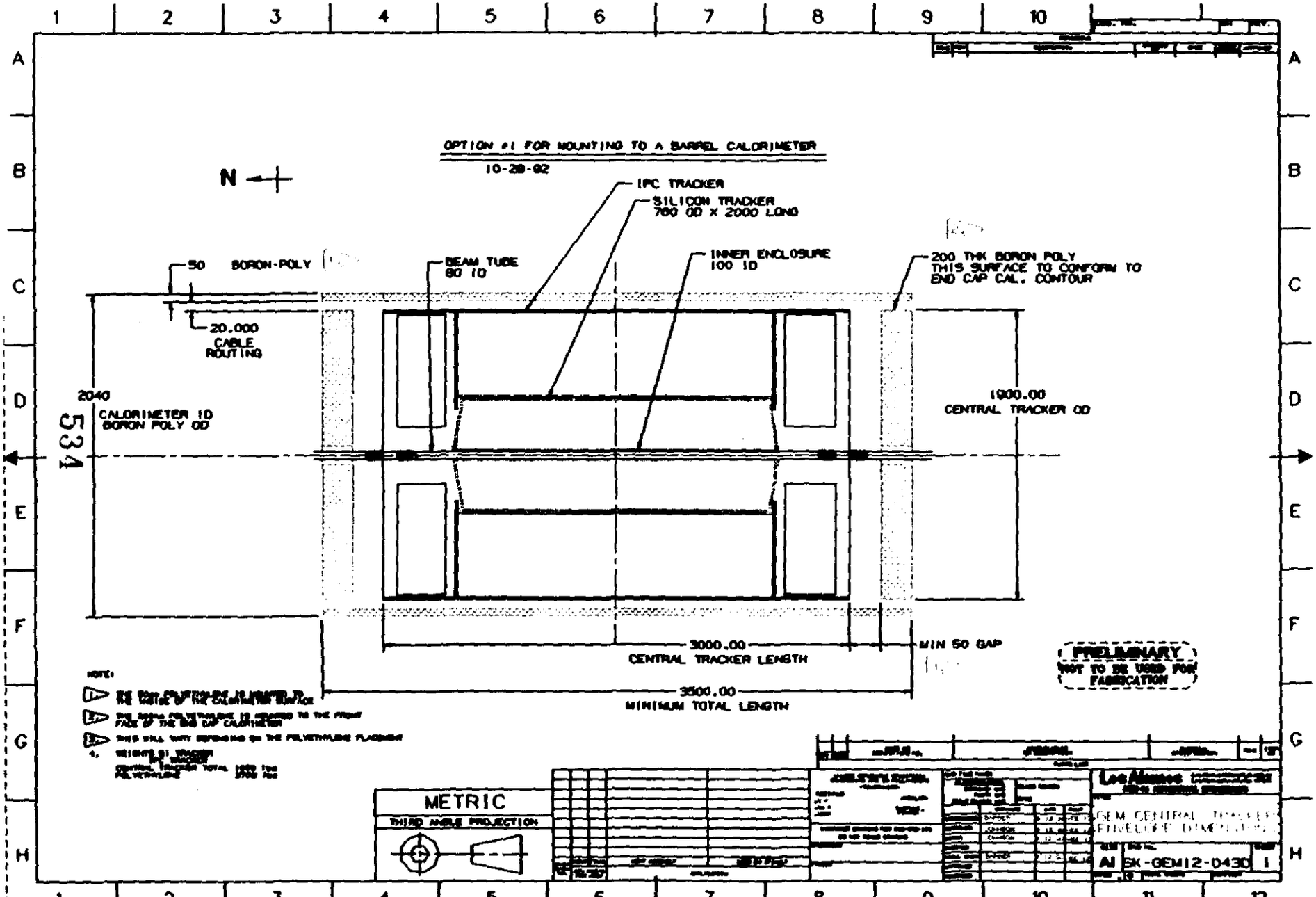
LITTLE CHANGE IN THE SI TRACKER (2CM FOR LONGER LADDER)

CURRENT IPC MODULE PACKAGING QUITE TIGHT

CURRENT OUTER SUPPORT STRUCTURE INTERFERES

TWO TIMES IMPROVEMENT IN THE IPC RESOLUTION


OPTION #1 FOR MOUNTING TO A BARREL CALORIMETER
10-20-92
N
IPC TRACKER
SILICON TRACKER
700 OD X 2000 LONG
INNER ENCLOSURE
100 ID
50 BORON-POLY
BEAM TUBE
60 ID
200 THK BORON POLY
THIS SURFACE TO CONFORM TO
END CAP CAL. CONTOUR
20.000
CABLE
ROUTING
1520
CALORIMETER ID
BORON POLY OD
1380.00
CENTRAL TRACKER OD
3000.00
CENTRAL TRACKER LENGTH
MIN 50 GAP
3500.00
MINIMUM TOTAL LENGTH
PRELIMINARY
NOT TO BE USED FOR
FABRICATION
METRIC
THIRD ANGLE PROJECTION
Los Alamos
A1
SK-GEM12-D430
1


OPTION #1 FOR MOUNTING TO A BARREL CALORIMETER
10-28-92
N
IPC TRACKER
SILICON TRACKER
760 OD X 2000 LONG
50 BORON-POLY
BEAM TUBE
80 ID
INNER ENCLOSURE
100 ID
200 THK BORON POLY
THIS SURFACE TO CONFORM TO
END CAP CAL. CONTOUR
20.000
CABLE
ROUTING
2040
CALORIMETER ID
BORON POLY OD
1900.00
CENTRAL TRACKER OD
3000.00
CENTRAL TRACKER LENGTH
MIN 50 GAP
3500.00
MINIMUM TOTAL LENGTH
PRELIMINARY
NOT TO BE USED FOR
FABRICATION
METRIC
THIRD ANGLE PROJECTION
Lockheed
GEM CENTRAL TRACKER
ENVELOPE DIMENSIONS
A1
SK-GEM12-0430
1

# BASELINE 2

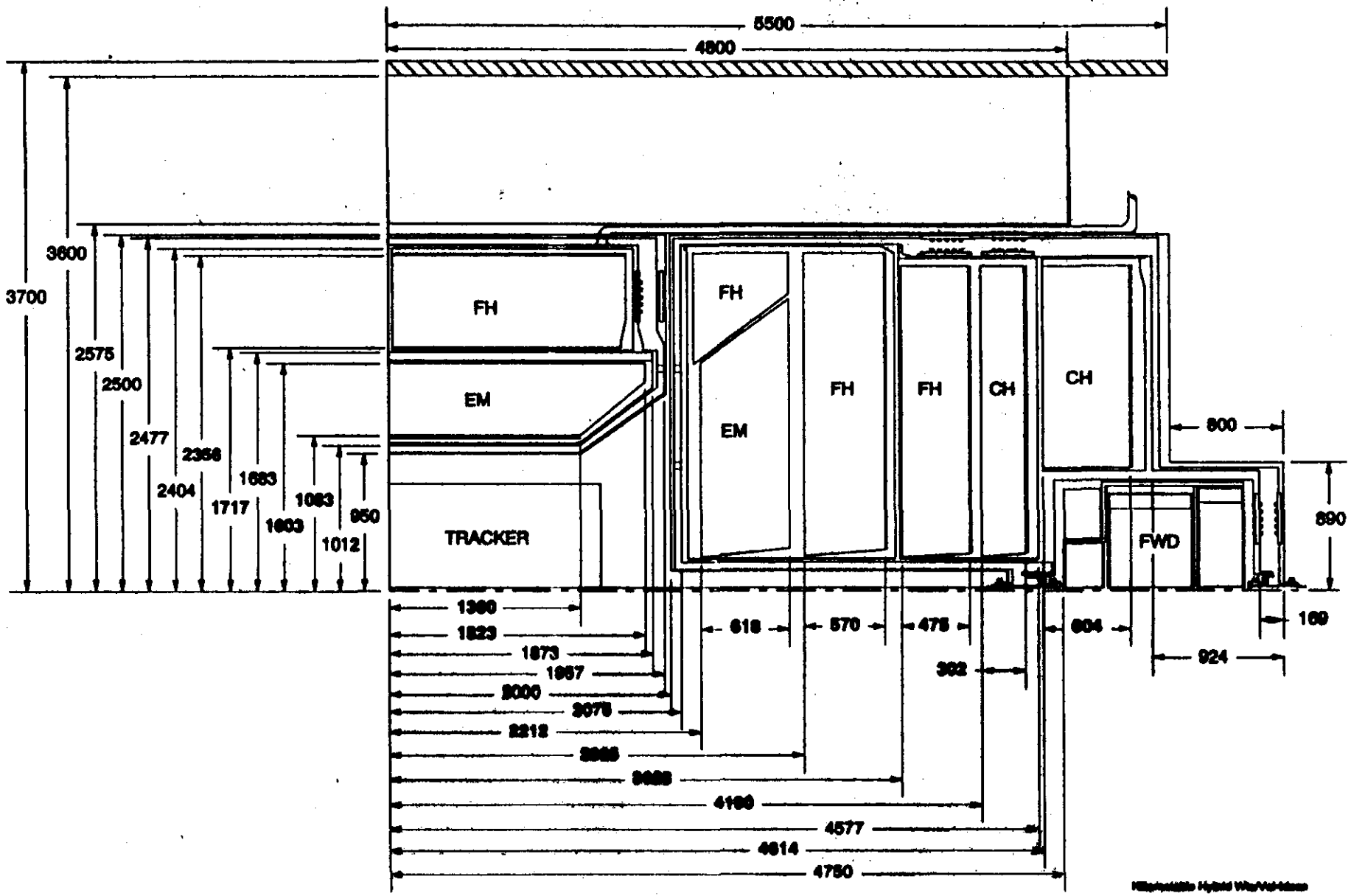
## HYBRID OPTIMIZATION

- ORGANIZATION : LEADER - WILLIS
  LEAD ENG - ORNL
- INCLUDE SHORT HADRONIC SECTION IN LIQ CALORIMETER
  - services
  - optimize thickness
  - scint fad configuration
  - forward direction (e.g. access, beam pipe)

etc.

# Preliminary Hybrid Concept

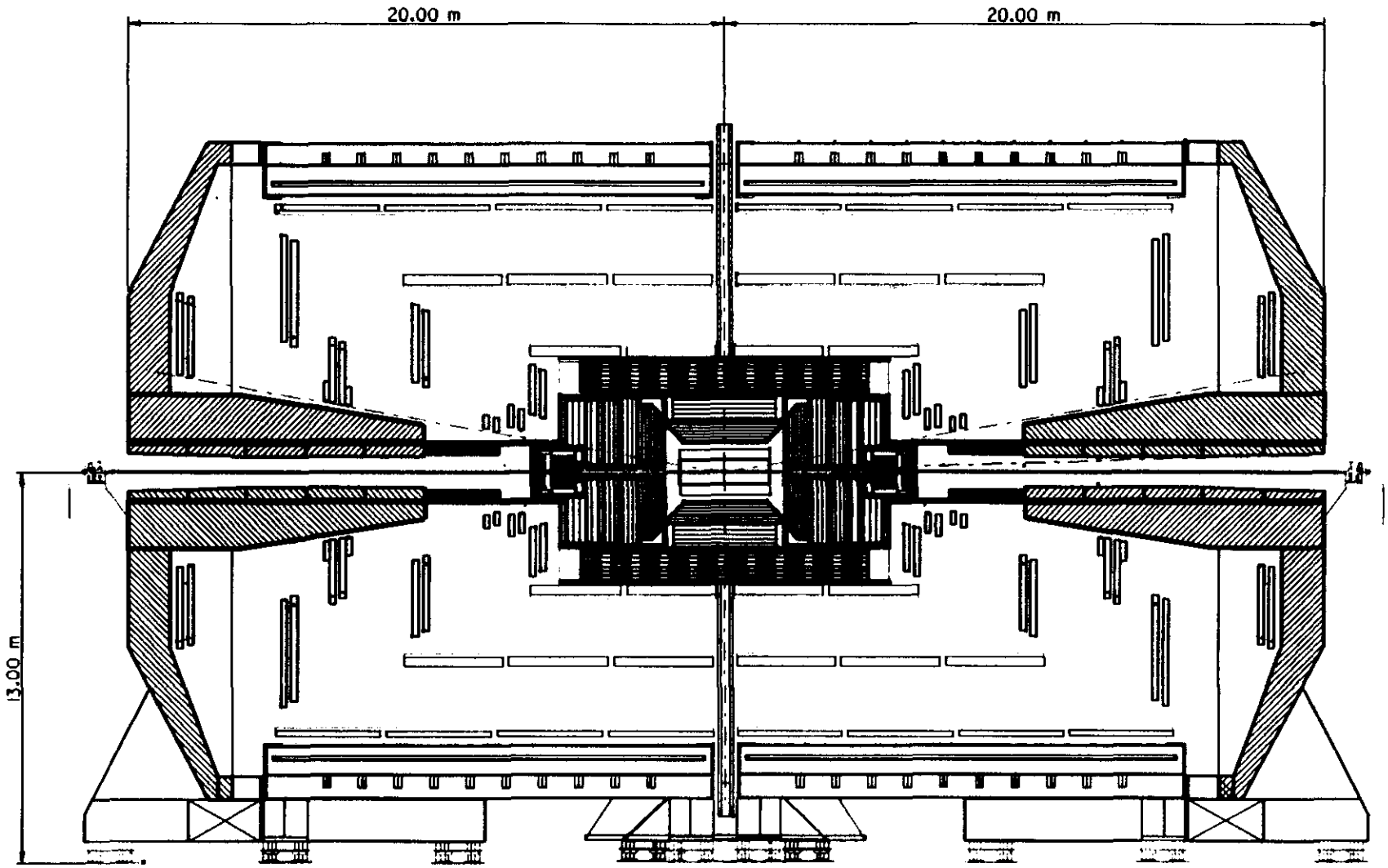
**Dimensions (All dimensions are in mm)**
**Note: All bold dimensions are to active areas.**



# GEM DETECTOR OPTION 2

**E.M. CALORIMETER : INTEGRATED / BARREL CALORIMETER : SCINTILLATING FIBER**

**END CAP CALORIMETER : INTEGRATED / FORWARD CALORIMETER : INTEGRATED**
**TRACKER : 1.5 M VACUUM SYSTEM ; 3 POSSIBILITIES**



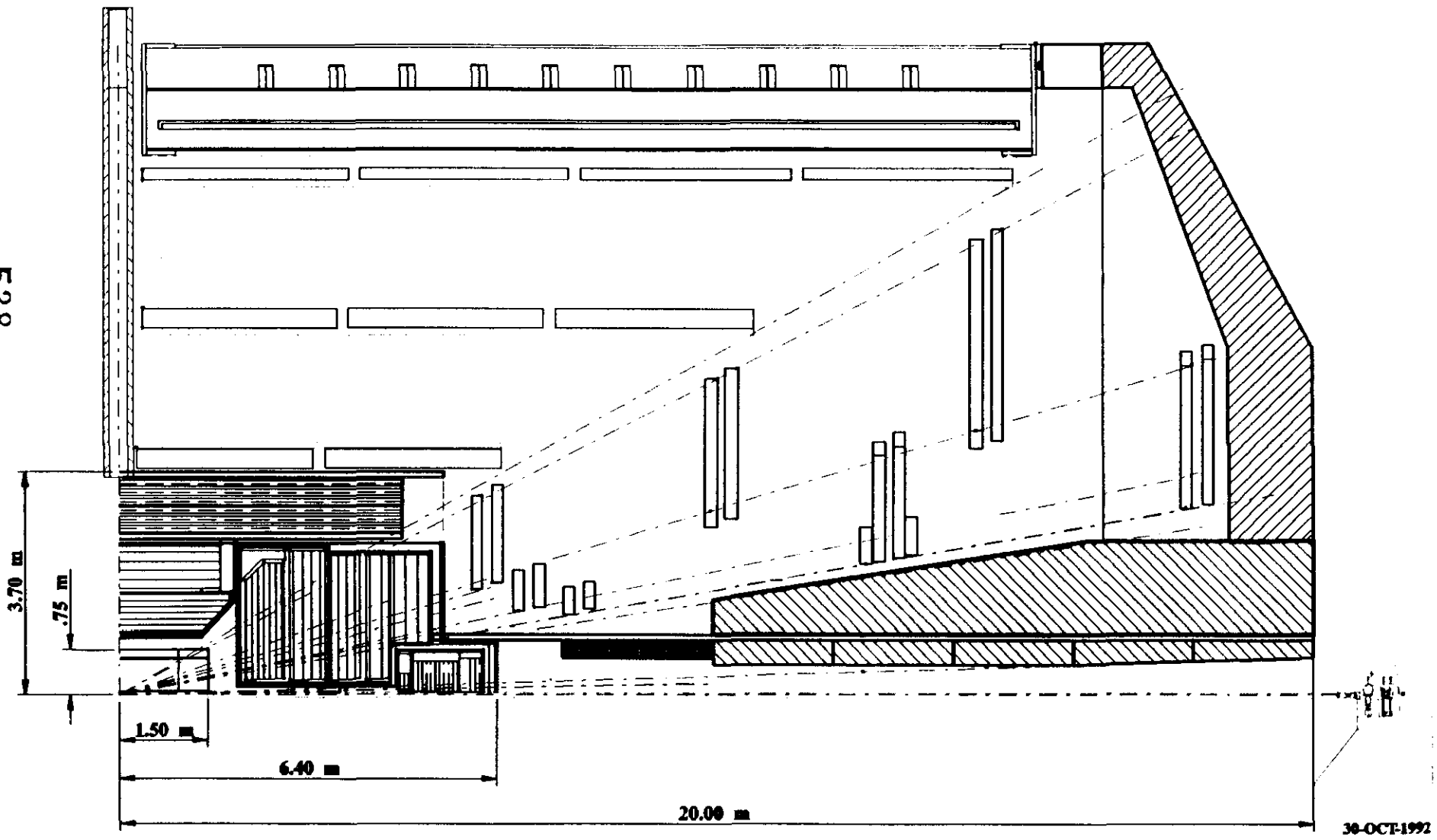
# GEM GETECTOR PARAMETERS

## OPTION 2

**E.M. CALORIMETER: INTEGRATED; BARREL CALORIMETER: SCINTILLATING FIBER**

**ENDCAP CALORIMETER: INTEGRATED; FORWARD CALORIMETER: INTEGRATED**

**TRACKER: 1.5M; VACUUM SYSTEM: 3 POSSIBILITIES**



# BASELINE 2

END CAPS : CSC

BARREL : Determine this Meeting

# Proposed Technologies for GEM Muons

## ENDCAP REGION
$9.5° < \Theta < 30°$ $(1.3 < \eta < 2.5)$

| Measurement | Technology |
|---|---|
| $P_T$ (r-$\phi$) | Cathode Strip Chambers |
| Second Coordinate ($\theta$) | Cathode Strip Chambers |
| Trigger | Cathode Strip Chambers |
| Beam Crossing Tag | Cathode Strip Chambers |

**Also Under Consideration for Central Region**

**OR**

## CENTRAL REGION
$\Theta > 30°$ $(0.0 < \eta < 1.3)$

| Measurement | Technology |
|---|---|
| $P_T$ (r-$\phi$) | Proportional Tubes or Limited Streamer Tubes in Drift Mode |
| Second Coordinate ($\theta$) | Resistive Plate Chambers |
| Trigger | Resistive Plate Chambers |
| Beam Crossing Tag | Resistive Plate Chambers |

# BASELINE 2

BIG WHEEL VS SECTOR APPROACH

- Eng. Recommendation Nov. 20.
  Based on Performance !!
  Stability

# THIS MEETING

Discuss

Evolve

Optimize

&

BASELINE 2.

ON TO THE TDR !!!

gem

γeμ

**Presentation by:**

**J. Thomas**

# Agenda for Tracker Meeting

J. Thomas

| | | |
|---|---|---|
| Scott Nutter | IPC Cathodes<br>How to make the cathode pads | 9:00 – 9:20 |
| Tim Thompson | IPC Composites<br>Carbon Fibre no good, Kevlar hard, Teflon maybe | 9:20 – 9:40 |
| George B. | Silicon Detectors<br>Resistivity Issues | 9:40 – 9:55 |
| Jim Musser | IPC Electronics<br>Simulation of Front End, Dan Marlow | 9:55 – 10:25 |
| C. Baltay | General Comments<br>TAIWAN: Working Groups, Schedules & Milestones | 10:30 – 11:30 |
| Shawn McKee | Simulation Status<br>Working towards a better GEMFIST ... | 11:30 – 12:00 |
| Irwin Shear | $H \to \gamma\gamma$ Vertex Find.<br>Initial studies look promising at finding correct Vertex | 12:00 – 12:30 |
| Jenny Thomas | IPC Two track Res. | 12:30 – 1:00 |
| LUNCH | | |
| A Sumerokov | Work in Taiwan<br>HUGE amount of work, Independent checks, track-ECAL matching | 2:00 – 2:45 |
| G. Hills/J. Brau | Si Strip Length<br>Resistivity Issues, No decision yet, Item are being seriously studied | 2:45 – 3:45 |
| Tracker Steering Committee | | 4:00 – 6:00 |

# MULTI-TRACK RESOLUTION OF INTERPOLATING PAD CHAMBERS.

- MOTIVATION FOR MULTI-TRACK RECONSTRUCTION
- DESCRIPTION OF SIMULATION PROGRAM
- PROCEDURE USED FOR 1 TRACK, 1 CO-ORDINATE RECONSTRUCTION
- TWO TRACK RESOLUTION
- THREE TRACK IDENTIFICATION
- IMPLICATIONS ON PHYSICS ABILITY

# TWO TRACK RESOLUTION OF IPCs

1 • WHY IS 2 TRACK RESOLUTION IMPORTANT?

- DEGREDATION OF RESOLUTION OF ISOLATED TRACKS WHEN MIN-BIAS TRACK NEARBY

- CAN WE IDENTIFY FOR $e^{\pm}$ IN HEAVY JETS

  - CHARGE — b- PHYSICS, t- PHYSICS

  - MOMENTUM — b- JETS SOMETIMES VERY COLLIMATED – HARD TO DISENTANGLE IN THE EMCAL

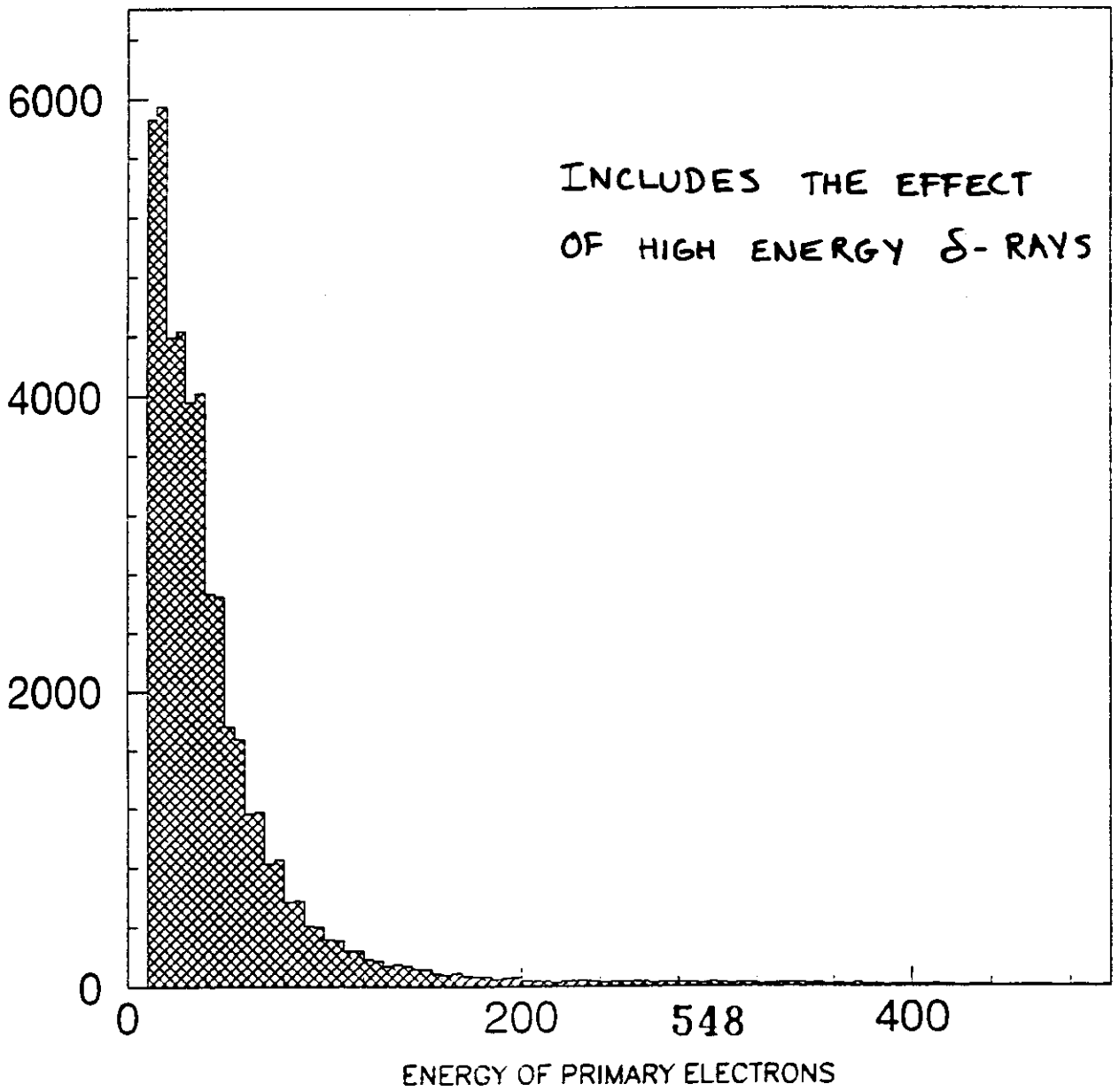
2. • IN SILICON, 10μm RESOLUTION, 50μm PITCH

- TRACKS CLOSER THAN 50μm NOT RESOLVED

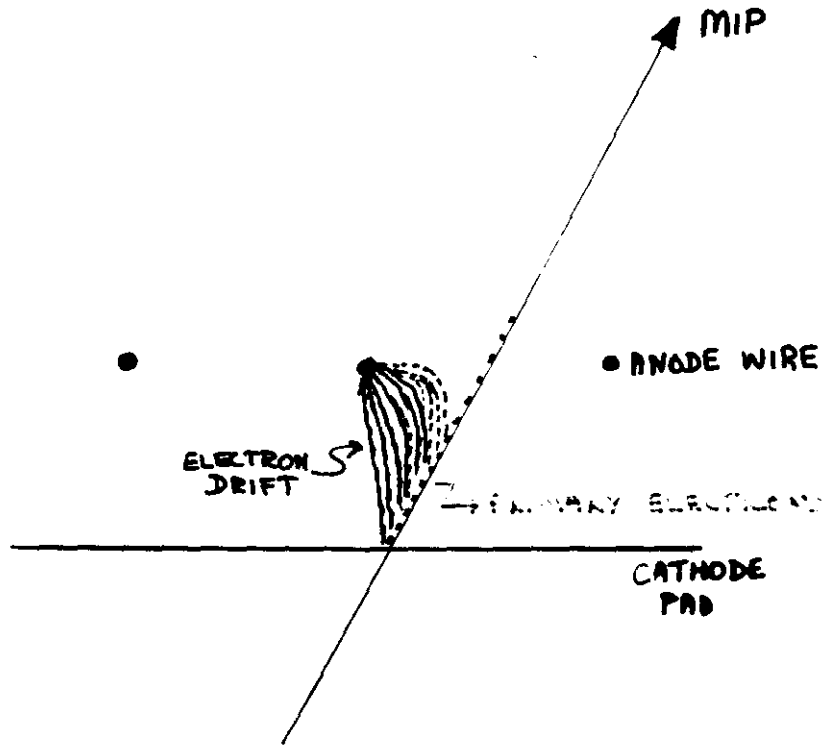
- OTHERWISE, VERY GOOD 2 TRACK RESOLUTION

5. V. CHERNIATIN & A. CHICKANIAN AT BNL (GEM CSC μ-CHAMBERS) HAVE WRITTEN A PROGRAM TO SIMULATE CSC IN $CO_2CF_4$ (50:50)

- PRIMARY ELECTRONS PRODUCED ALONG TRACK (15/mm) ACCORDING TO A MEASURED DISTRIBUTION (RUSSIA)



- ELECTRONS STEP ACCORDING TO THEIR MFP (55μm) INCLUDING DIFFUSION (51μm/mm DRIFT) ALONG THE FIELD LINES INCLUDING E × B OF 8KG FIELD.

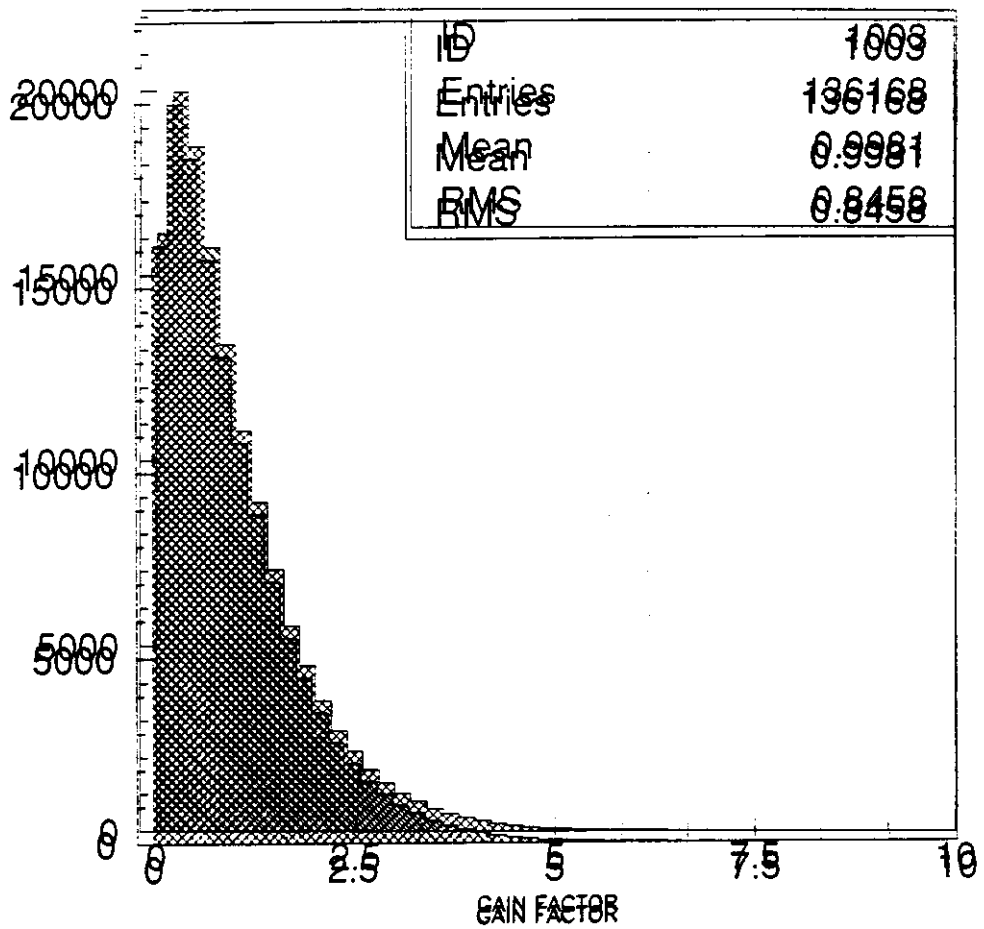


- ANODE GAIN IS FOLDED WITH A POLYA DISTRIBUTION

$$\ln M = 2CV_a B \left\{ \ln(r_0/r_a) - 1 + r_a/r_0 \right\}$$

$r_0 = 2CV_a/pS_0$ $\quad$ $B, S_0$ – GAS CONSTANT $\quad$ $P$ – PRESSURE (TORR)

$r_0$ IS RADIUS




IS GAIN OF $2 \times 10^4$ * POLYA CORRECT ?

- CHARGE SIGNAL INDUCED ON THE PADS ACCORDING TO ~~[illegible]~~ MATHIESON'S RECIPIE.

- NOISE OF 1500 $e^-$ RMS IS ADDED TO EACH PAD

- NOISE CONTRIBUTION OF 1% OF SIGNAL THEN ADDED FOR CALIBRATION.

HOPEFULLY THE NOISE IS CONSERVATIVE

- GEM TRACKER GEOMETRY

  2·5 mm PAD WIDTH

  2·0 mm ANODE-CATHODE SPACING

  2·0 mm ANODE PITCH

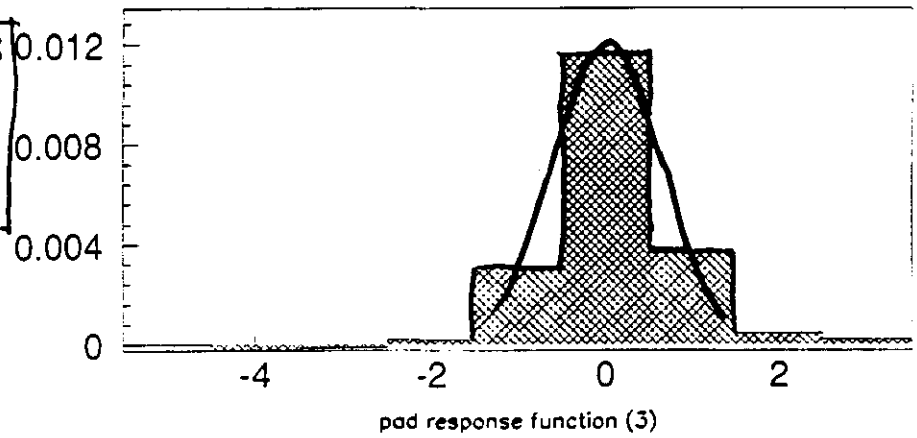
- 20% OF SIGNAL ACCEPTED DUE TO 20 nsec COLLECTION TIME

# 4. ONE TRACK PROCEDURE

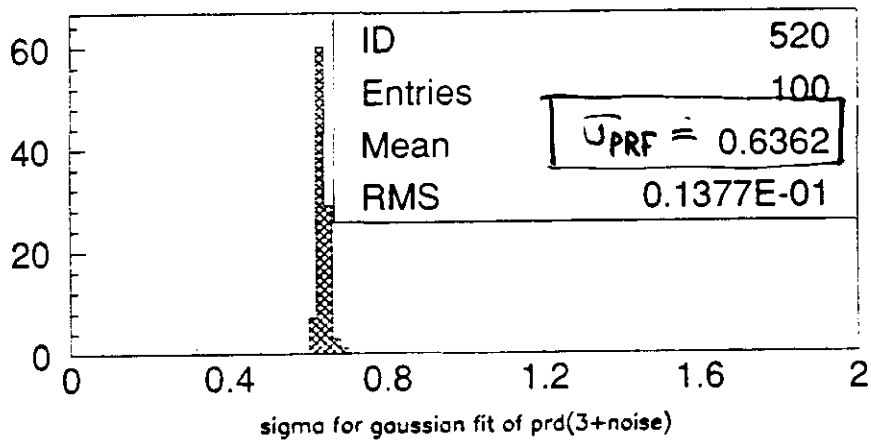
GAUSSIAN APPROACH

- MEASURE "PAD RESPONSE FUNCTION" FOR 1 TRACK

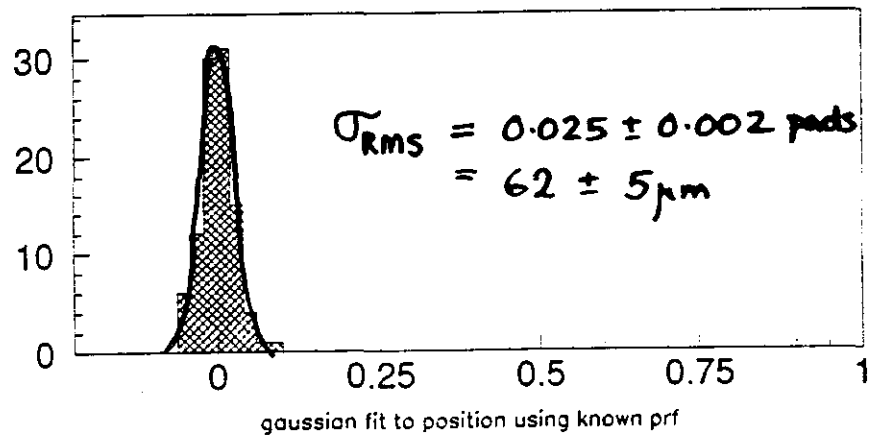
USE ONLY 3 PADS
NOISE HURTS MOST
IN THE TAILS




PLOT FITTED VALUE
OF $\sigma_{PRF}$ FOR
MANY TRACKS



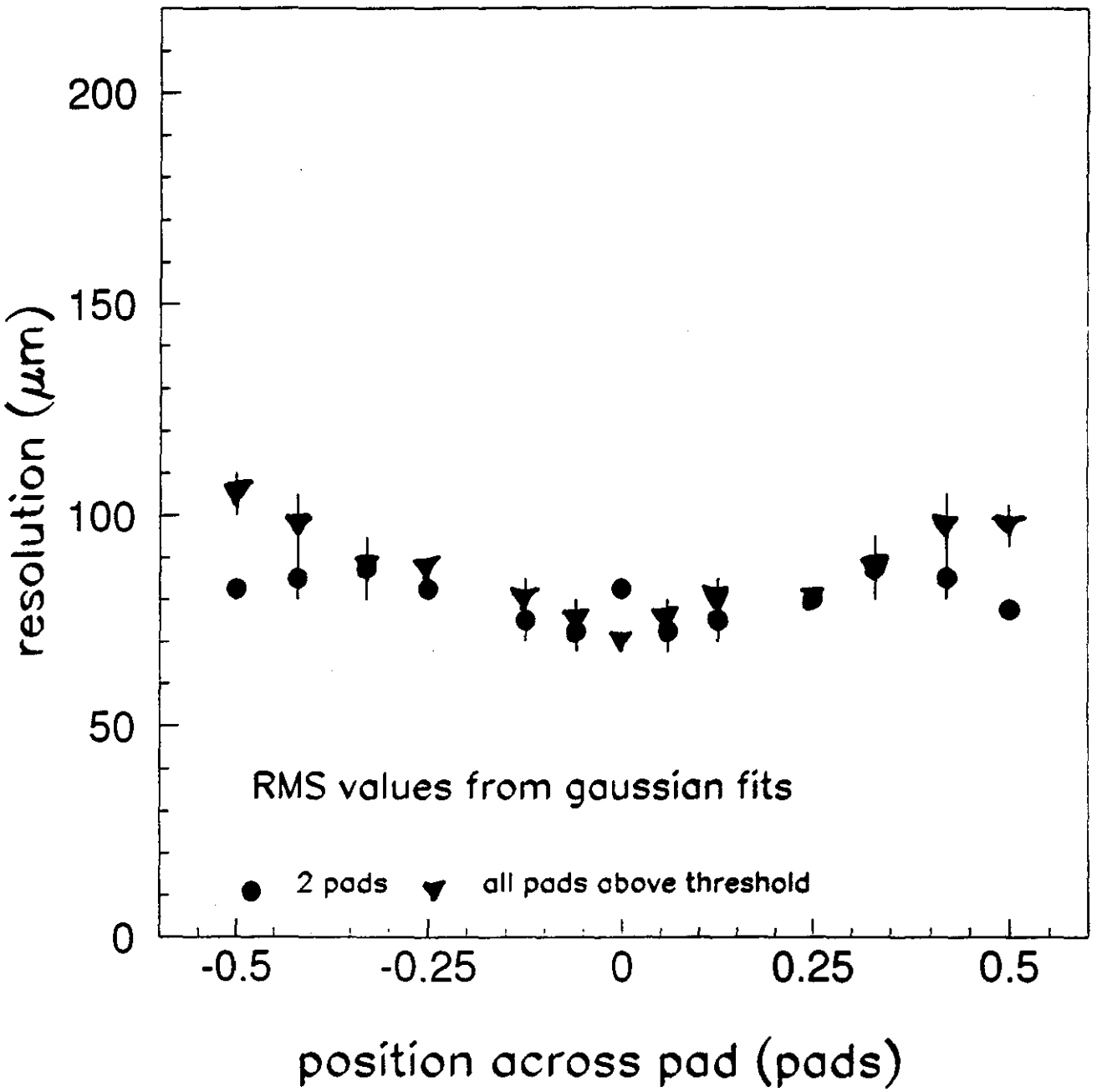

USE KNOWN $\sigma_{PRF}$
AND FIT FOR
POSITION

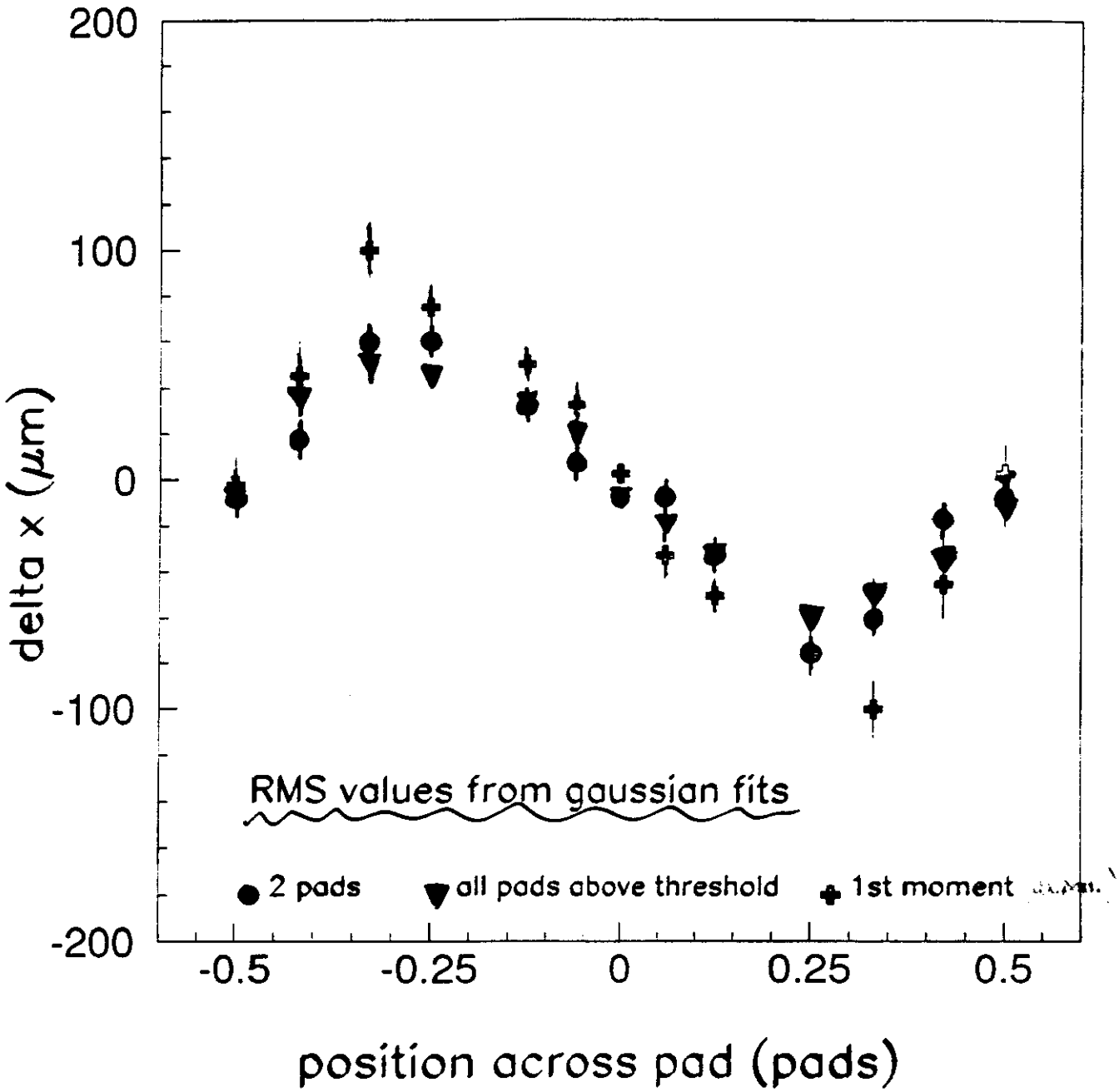



- ASSUME PRF IS THE SAME FOR ALL TRACKS IRRESPECTIVE OF ANGLE

EITHER, LOOK AT ALL PADS ABOVE THRESHOLD

OR, 2 LARGEST PADS

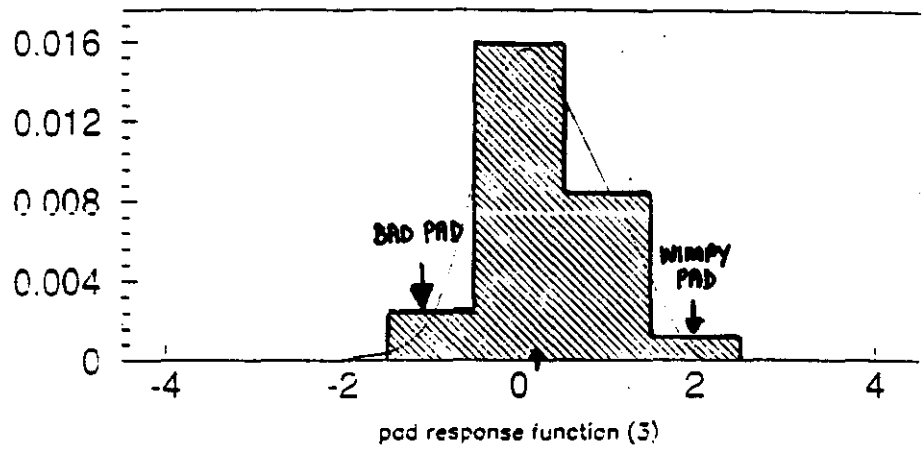





- SHIFTS ARE SMALLER FOR GAUSSIAN FITS EXCEPT AT CENTRE & EDGES

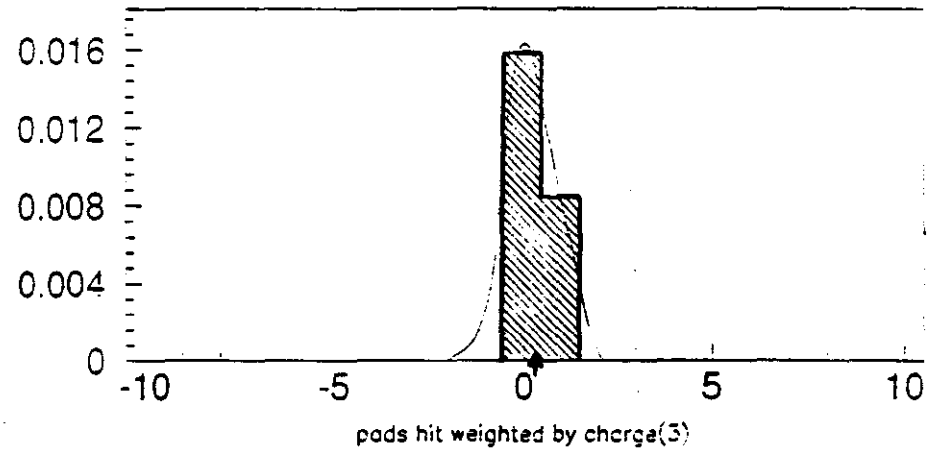
- FOR SINGLE TRACKS, SYSTEMATIC OFFSETS CAN EASILY BE UNDERSTOOD, & REDUCED (NOT ELIMINATED)

→ CONSPIRACY OF END PADS CAUSES SHIFT TO LEFT IN THIS CASE — LESS SEVERE IF WIMPY PAD IS USED




IN SOME CASES, 2 PADS ARE

→ BETTER, BUT MOSTLY WHEN TRACK IS BETWEEN PADS.




- A GOOD INDICATOR IS RATIO OF

$$\frac{\text{PEAK CHARGE}}{\text{SUM CHARGE}}$$

FOR ALL PADS ABOVE THRESHOLD

(I USED 0.001 pC, 4 × NOISE)

# 5. TWO TRACK RESOLUTION

- FIRST PROBLEM IS TO IDENTIFY THAT THERE ARE 2 TRACKS

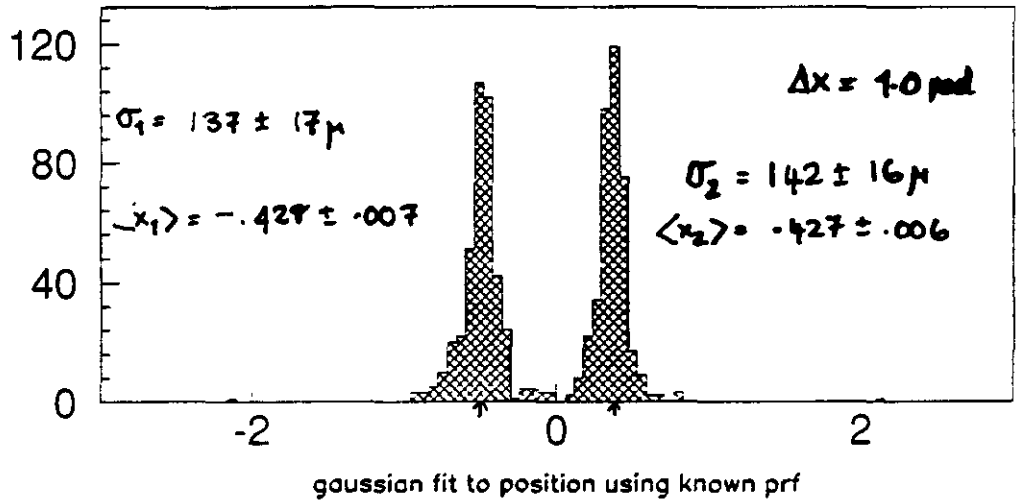
- WHEN TRACKS ARE SEPARATED BY $> 1/2$ PAD, SHAPE DIFFERENCE IS APPARENT + $\frac{dE}{dx}$ : $\chi^2$ TEST ALSO

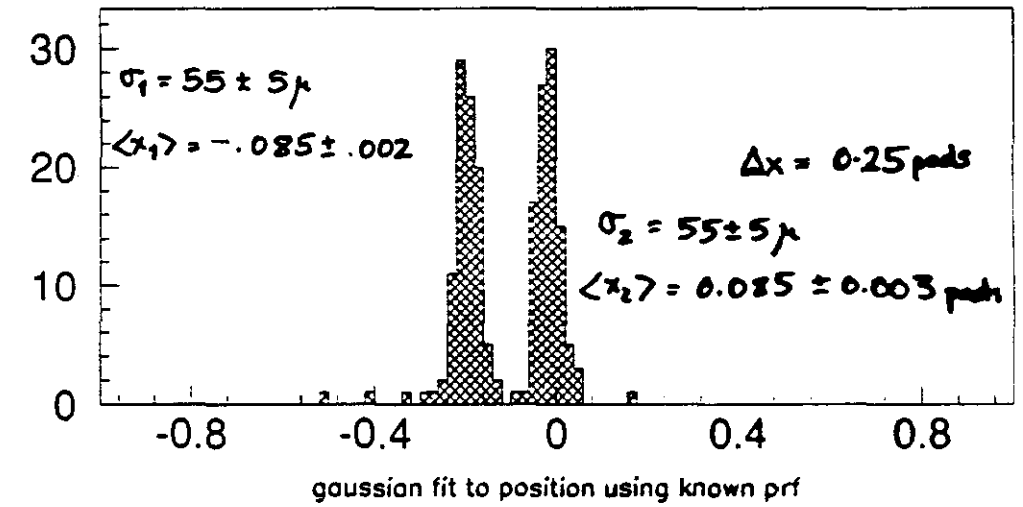
- $< 1/2$ PAD SEPARATION, ONLY $\frac{dE}{dx}$ IS AVAILABLE

- FIT TO TWO GAUSSIANS OF WIDTH $\sigma_{PRF}$ :

$$A e^{-\left(\frac{x-\bar{x}_1}{2\sigma_{PRF}}\right)^2} + B e^{-\left(\frac{x-\bar{x}_2}{2\sigma_{PRF}}\right)^2}$$

- RESULT OF FITTING TWO GAUSSIANS WITH KNOWN $\sigma_{PRF}$ YIELDS TWO POSITIONS

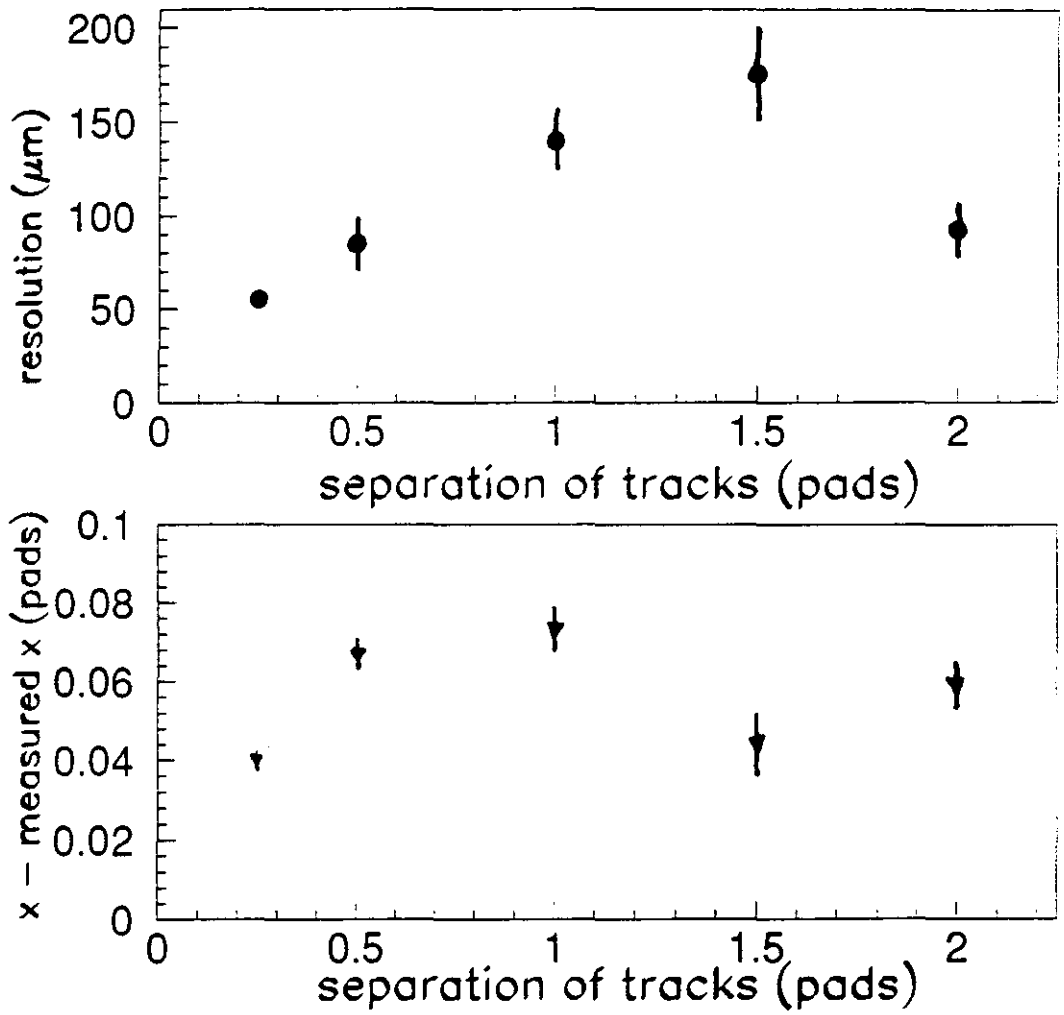



- A SYSTEMATIC OFFSET IS APPARENT

  CAN PROBABLY BE CORRECTED FOR

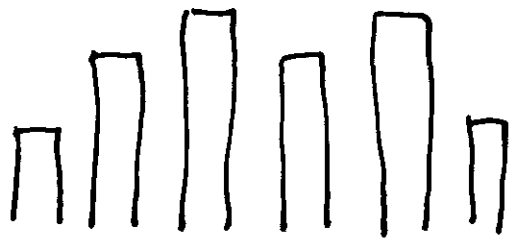
- SUMMARY OF TRACK SEPARATION VS RESOLUTION & SYSTEMATIC OFFSET



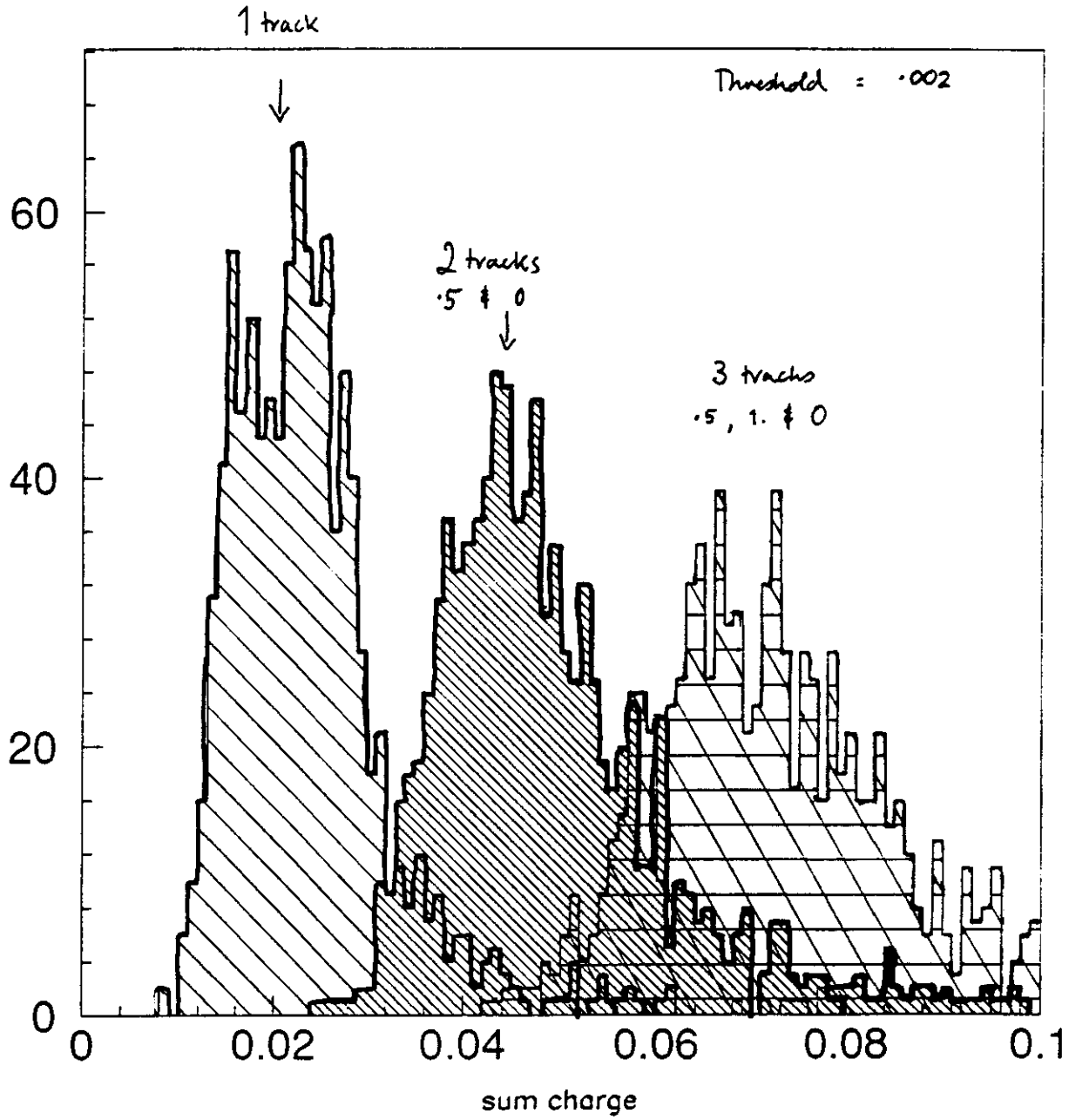

- OFFSET NEEDS TO BE UNDERSTOOD

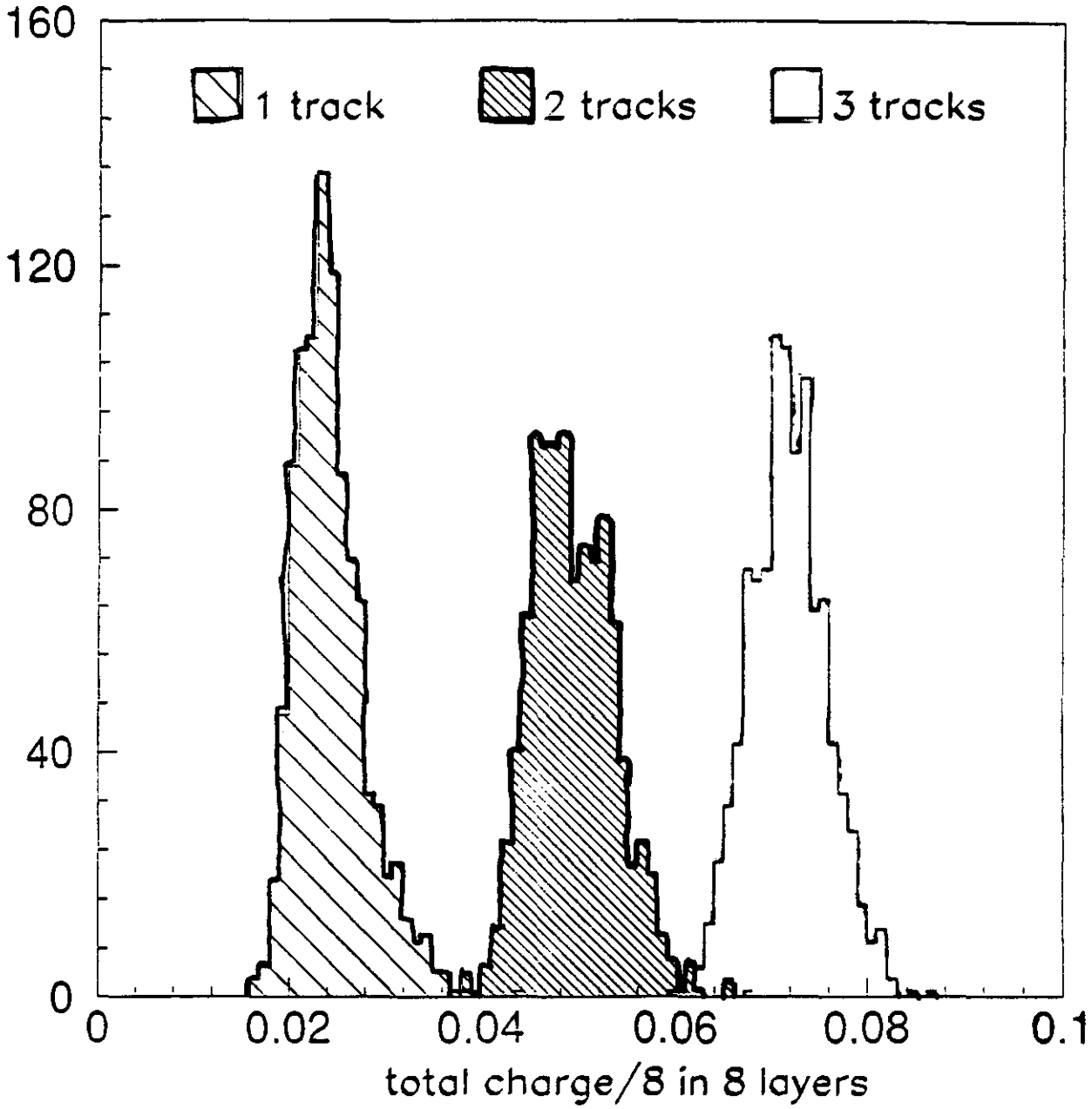
# 3 TRACK RESOLUTION

- WHEN TRACKS ARE SEPARATED BY MORE THAN ONE PAD, EASY TO RECOGNISE

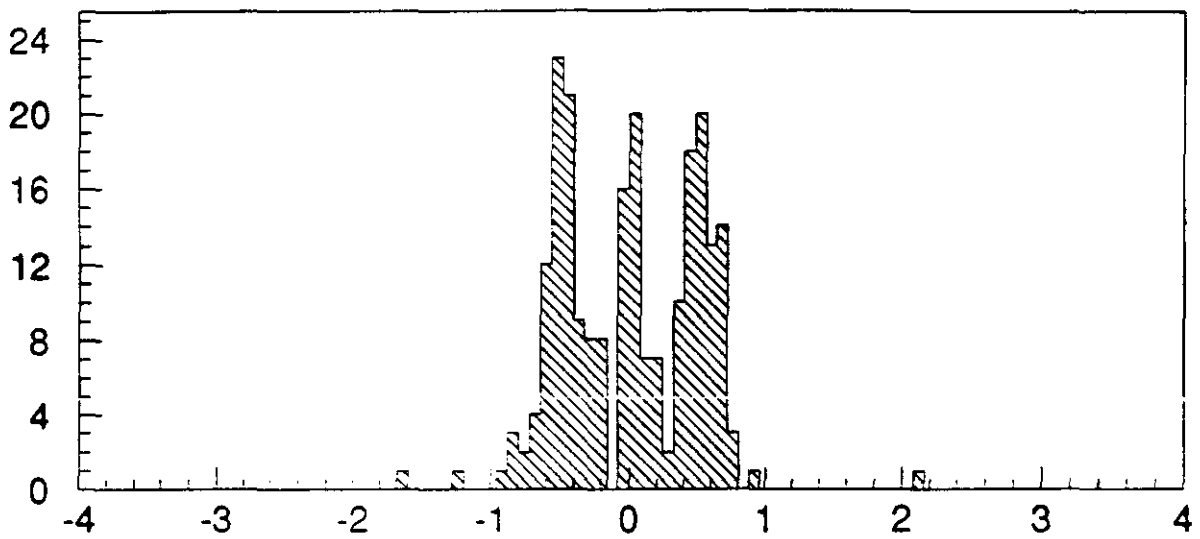


- WHEN TRACKS ARE CLOSE TOGETHER NOT SO OBVIOUS - LOOK AT TOTAL CHARGE ON ALL PADS ABOVE THRESHOLD


1 track
Threshold = ·002
2 tracks
·5 & 0
3 tracks
·5, 1. & 0
60
40
20
0
0
0.02
0.04
0.06
0.08
0.1
sum charge




TOTAL_CHARGES.PS




gaussian fit to x1,x2,x3 using known prf

- THIS LOOKS LIKE THE LIMIT OF MULTI-TRACK RESOLUTION

- $\frac{dE}{dx}$ IS A VERY POWERFUL TOOL FOR 3-PRONG $\tau$ DECAYS

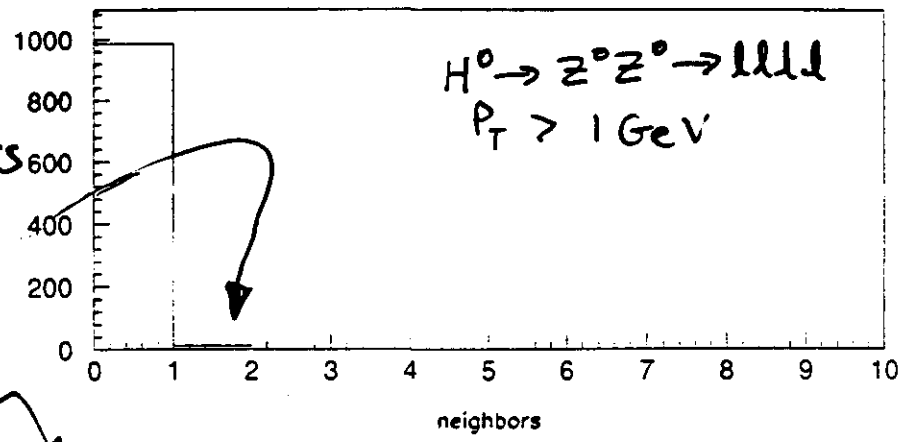
- MAKE SURE ELECTRONICS' DYNAMIC RANGE IS UP TO THE TASK

- ~~TO ACHIEVE THIS $\frac{dE}{dx}$, ES MUST SPREAD OUT OVER 3 ANODE WIRES, GO ANODE SATURATION GAIN FOR~~

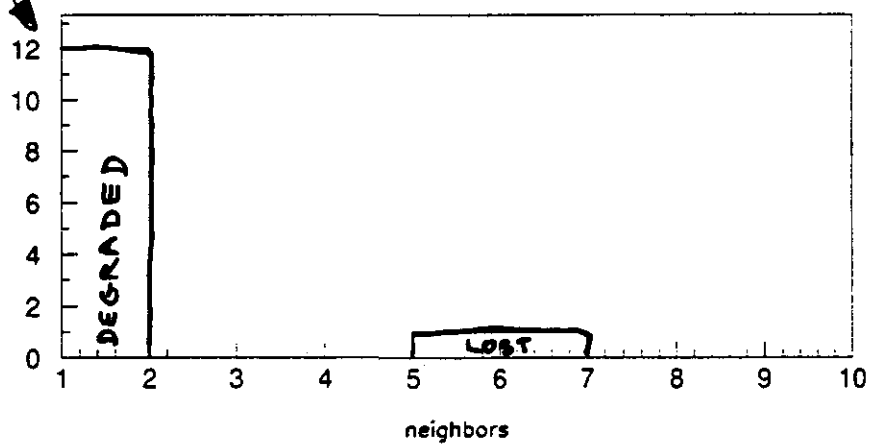
# 6. PHYSICS IMPLICATIONS

- SIGNAL TRACKS ARE AFFECTED BY A NEARBY* MIN-BIAS OR SIGNAL EVENT TRACKS.

~1% OF TRACKS ARE DEGRADED



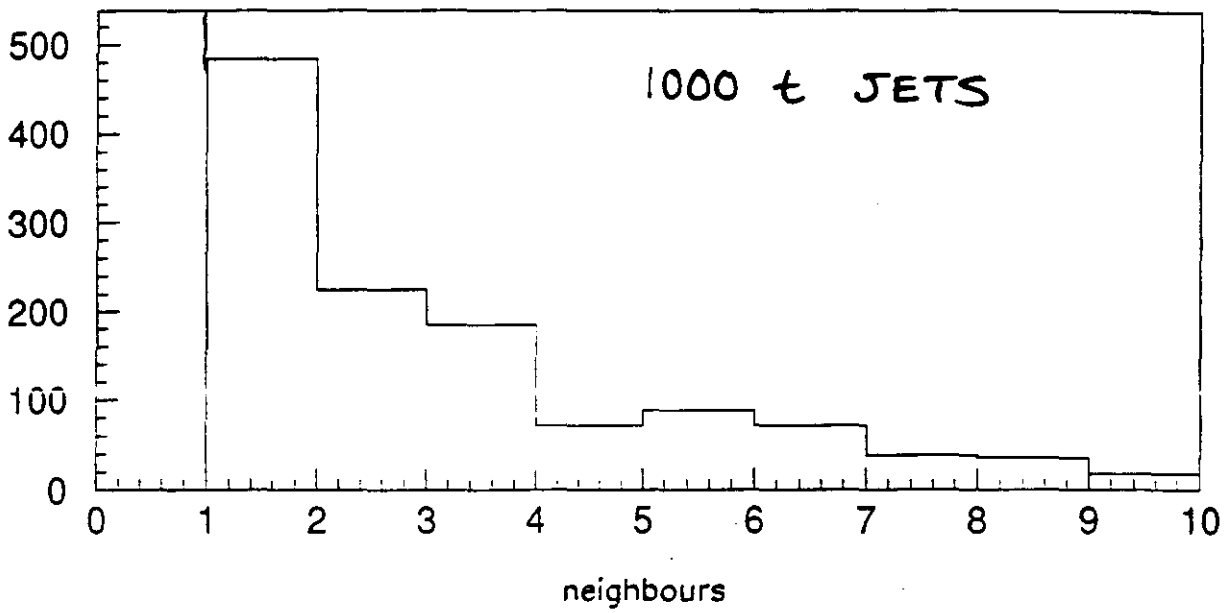

~1‰ ARE LOST




- * NEARBY MEANS INSIDE 3 PADS

- FOR b OR t JETS . . .

LOOK AT ALL TRACKS ABOVE 1 GeV




ESTIMATE!!

- $\sim 2/3$ OF T JETS SHOULD BE COMPLETELY RECONSTRUCTABLE

- $\frac{dE}{dX}$ IS IMPORTANT TO RECOGNISE & MEASURE # TRACKS IN A JET.

gem

γeμ

**Presentation by:**

**Sally Dawson**

Sally Dawson

# PROGRESS (?) IN

# TECHNICOLOR

# MODEL BUILDING

GEM Collaboration
Nov. 6, 1992

# I. Generic Technicolor

Copy QCD: $\langle u\bar{u} + d\bar{d} \rangle \Rightarrow m_\pi \neq 0$

$SU(2)_L \times SU(2)_R \Rightarrow SU(2)_V$

Simple model:

- Technifermions: $\begin{pmatrix} U \\ D \end{pmatrix}$

- Strongly interacting TC gauge group, $SU(N)_{TC}$

Global $SU(2)_L \times SU(2)_R \Rightarrow SU(2)_V$

→ 3 Goldstone Bosons, $W_L^\pm, Z_L$

→ Scaled up $\rho, \omega, \eta$ etc

$\rho \cdot 1$ automatically

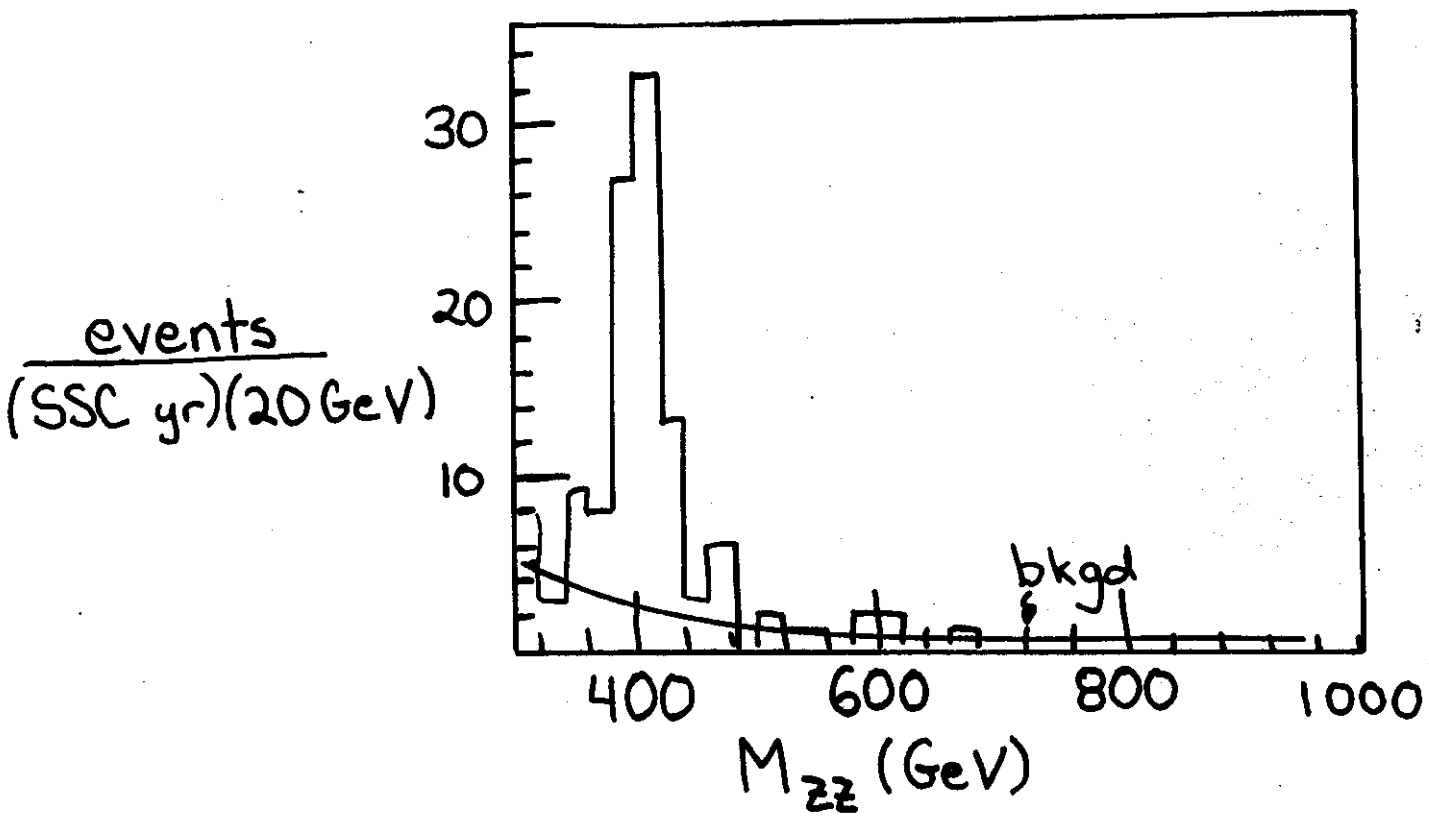
| QCD | TC |
| --- | --- |
| $SU(3)_c$ | $SU(N_{TC})$ |
| Quarks $\begin{pmatrix} u \\ d \end{pmatrix}$ | Techni-quarks $\begin{pmatrix} U \\ D \end{pmatrix}$ |
| $\langle u\bar{u} + d\bar{d} \rangle \sim \Lambda^3_{QCD}$ | $\langle U\bar{U} + D\bar{D} \rangle \sim \Lambda^3_{TC}$ |
| $\boxed{SU(2)_L \times}$ | $\boxed{SU(2)_R \rightarrow SU(2)_V}$ |
| $\pi^\pm, \pi^0$ | $\pi^\pm, \pi^0 \rightarrow W^\pm_L, Z_L$ |
| $f_\pi = 93$ MeV | $F_\pi = v = 246$ GeV |
| $\Lambda_{QCD} \sim 160$ MeV | $\Lambda_{TC} \sim 1$ TeV |

# Searching for new physics...

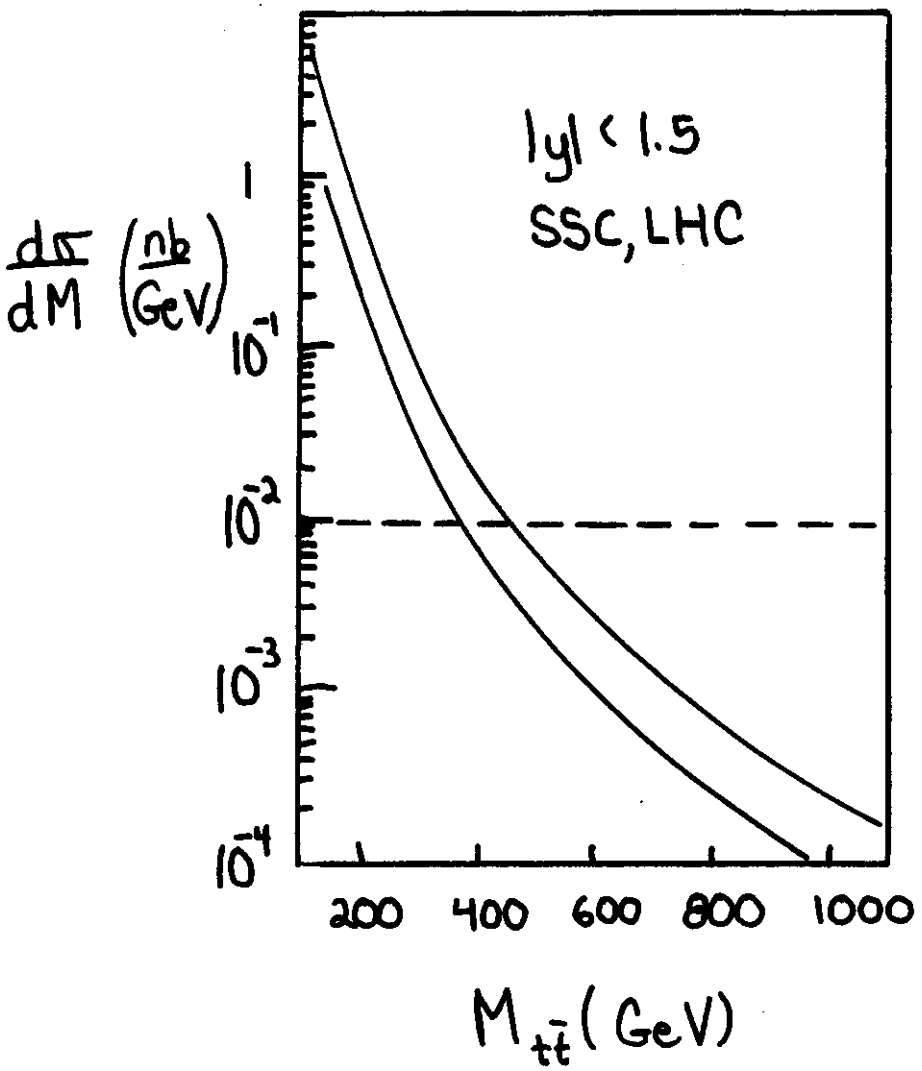
Best cases: a) Resonance

b) Large rate

Ex: Higgs → ZZ, $M_H = 400$ GeV



# Ex: Top quark Production

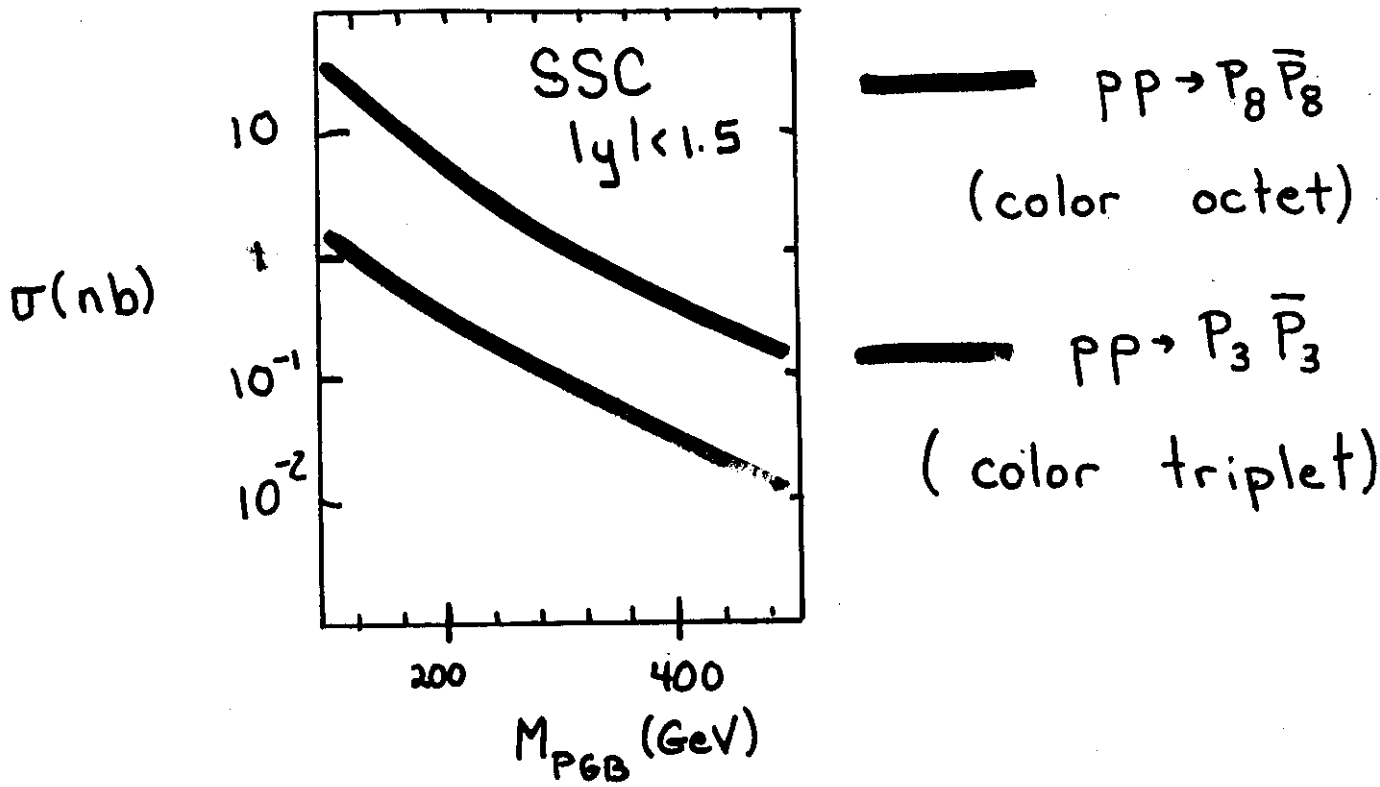



$10^5$ events/yr

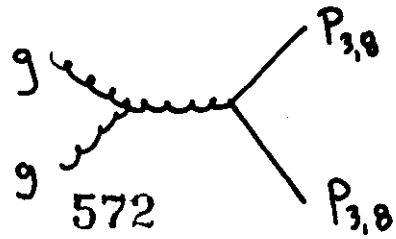
@ $\mathcal{L} = 10^{33}/cm^2/sec$

# Many Testable Consequences

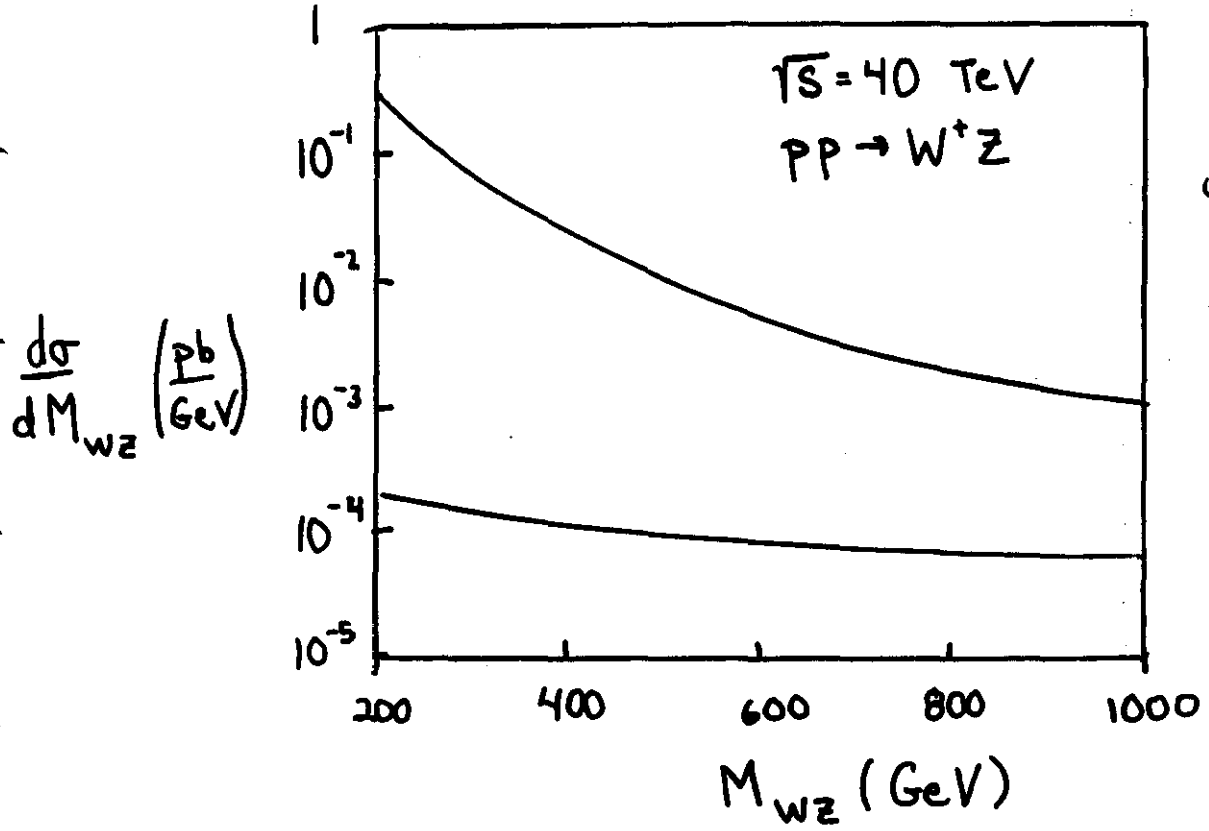
- Broken global symmetries ⇒
  Pseudo-goldstone Bosons (PGBs)



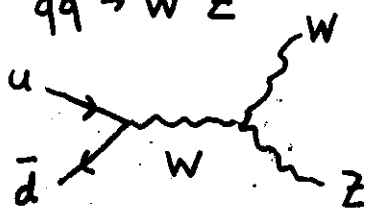

- Large Rates
- Relatively Independent of Model



# Resonant vs Non-Resonant $\mathcal{L}$'s:




$q\bar{q} \to W^+Z$

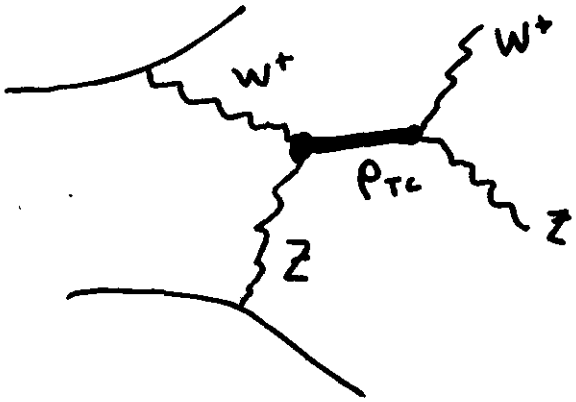


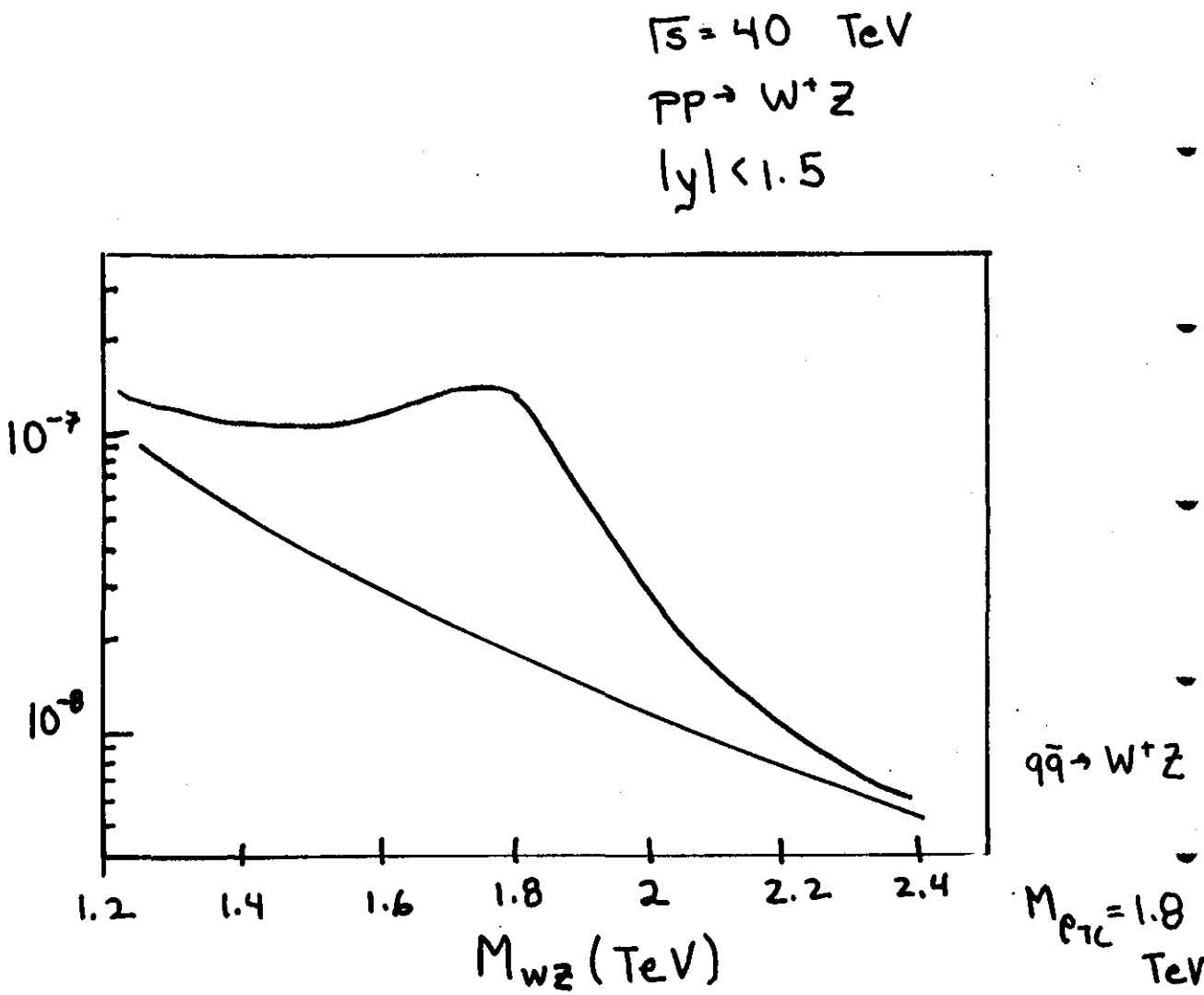

$M_{\rho_{TC}} \sim 1.5$ TeV

$N_{TC} = 3$

$N_{TF} = 4$

$W^+Z \to W^+Z$




$\sqrt{s} = 40$ TeV
$pp \to W^+ Z$
$|y| < 1.5$
$10^{-7}$
$10^{-8}$
1.2
1.4
1.6
1.8
2
2.2
2.4
$M_{WZ}$ (TeV)
$q\bar{q} \to W^+ Z$
$M_{\rho_{TC}} = 1.8$ TeV

Standard Model: $\mathcal{L} \sim c \frac{H}{v} \bar{\Psi}\Psi$

fermion masses $\longrightarrow m_f \approx c$

Introduced Extended TC group

$$G_{ETC} \rightarrow G_{TC} \rightarrow SM$$

$$\Lambda_{ETC} \qquad \Lambda_{TC}$$

$$\mathcal{L} = \underbrace{\frac{1}{\Lambda_{ETC}^2} \bar{Q} Q \bar{q} q}_{m_f = \frac{\langle \bar{Q} Q \rangle}{\Lambda_{ETC}^2} \sim \frac{\Lambda_{TC}^3}{\Lambda_{ETC}^2}} + \underbrace{\frac{1}{\Lambda_{ETC}^2} \bar{s} d \bar{s} d}$$

$$\Delta M (K_L - K_S) \rightarrow \Lambda_{ETC} \gtrsim$$

500 Tel

# OLD PROBLEMS

Top Quark mass: $M_{TOP} \sim \dfrac{\Lambda_{TC}^3}{\Lambda_{ETC}^2}$

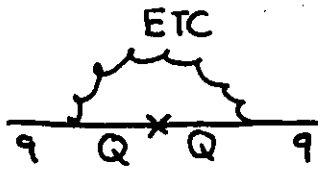
$M_{TOP} \sim 100$ GeV , $\Lambda_{TC} \sim 1$ TeV

$\rightarrow \Lambda_{ETC} \sim 3$ TeV

$\Rightarrow$ FCNC

Solutions: Walking, crawling TC

Enhance $\langle Q\bar{Q} \rangle \sim \Lambda_{TC}^3 \left( \dfrac{\Lambda_{ETC}}{\Lambda_{TC}} \right)^{\gamma}$

$m_f \sim$ 

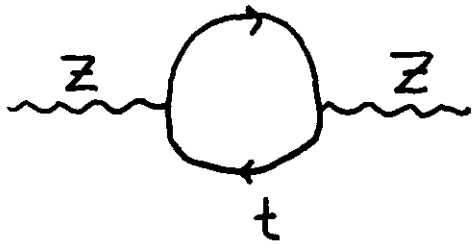

$\rightarrow$ Can increase $\Lambda_{ETC}$ & still get big $M_{TOP}$

- Multi-scale models

# The Alterative...

## PRECISION MEASUREMENTS

cf. LEP




$M_{TOP} = 150^{+23}_{-26}$ GeV

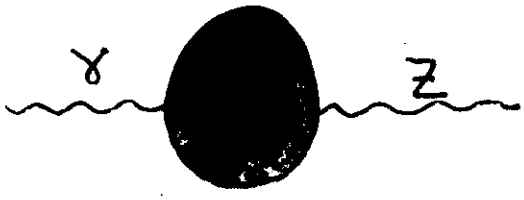
[Langacker, PDG]

$$\mathcal{L}_{eff} = -\frac{\alpha}{2\sin(2\theta_W)} S \, B^{\mu\nu} W_{\mu\nu}$$

Do Similar analysis for 3, 4 gauge boson couplings

# PRECISION MEASUREMENTS

## confront TECHNICOLOR




$$\Delta\mathcal{L} = -\frac{\alpha}{2\sin(2\theta_W)}\, S\, \mathrm{Tr}(\Sigma B^{\mu\nu} \Sigma^{+} W_{\mu\nu})$$

U(1) gauge field

SU(2) gauge field

Precision EW data ⇒ (Altarelli)

$$S = .15 \pm 1.6 \qquad (@ M_Z)$$

S runs....

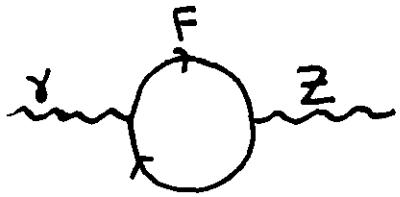
$$S(\mu_1) - S(\mu_2) = \frac{1}{6} \ln\left(\frac{\mu_1}{\mu_2}\right)$$

eg: $S(1.5\ \mathrm{TeV}) = .5$

# What is S in TC Models?

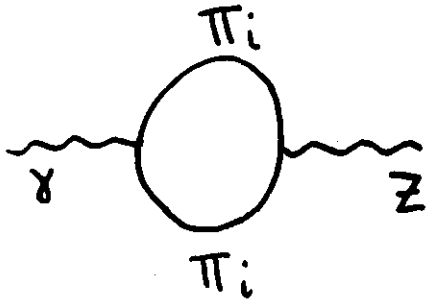
Consider $N_{TC} = 4$, $N_{DOUBLETS} = 4$

**1.**




$$S(M_Z) = \frac{N_{TC} N_D}{6\pi} \rightarrow \underline{.85}$$

**2.**




$$S(M_Z) \sim \frac{8}{3\pi} \ln\left(\frac{\Lambda_{TC}}{M_\pi}\right) \rightarrow \underline{1.7}$$

$(\Lambda_{TC} \sim 1.5 \text{ TeV}, M_\pi \sim 200 \text{ GeV})$

**3.** Just rescale QCD..... $\pi \rightarrow e \nu \gamma$

$$S \sim \underline{2.}$$

cf. exp $S(M_Z) = .15 \pm 1.6$

Close squeeze...

# But... ambiguity in computing S in TC models

Contributions from heavy $\rho$
+ large-N scaling:

$$F_\rho = 246 \text{ GeV} \sqrt{\frac{2}{N_{TF}}}$$

$$M_{\rho_{TC}} = 2 \text{ TeV} \sqrt{\frac{6}{N_{TC} N_{TF}}}$$

$$S(\mu) = \left(\frac{4\pi F_\rho^2}{M_\rho^2}\right) + \frac{1}{6\pi} \ln\left(\frac{M_\rho}{\mu}\right)$$

Ex: $N_{TC} = 3,\ N_{TF} = 2 \Rightarrow S(M_Z) = .35$

$N_{TC} = 4,\ N_{TF} = 8 \Rightarrow S(M_Z) = .37$

Dugan and Randall: S negative in models with large mass splittings.

# But.... Walking TC changes things.....

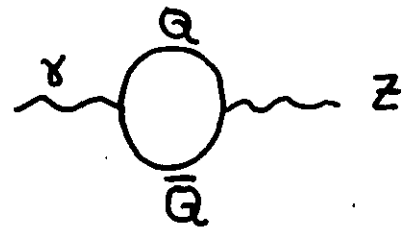
"Old TC"

$$S_{QCD}^{TC} \sim \left(\frac{4.5\,v^2}{N_D M_{TF}^2} - .015\right) N_D N_{TC} - .03N$$

$$\rightarrow \underline{.1\, N_D N_{TC}}$$

Walking TC: (Sundrum & Hsu)

$\langle Q\bar{Q} \rangle$ enhanced $\rightarrow$

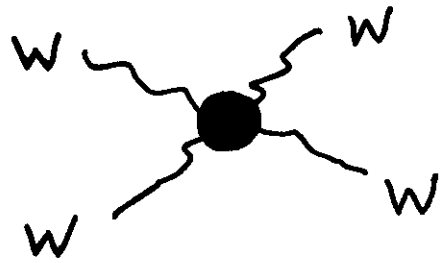



$$S_{Walking}^{TC} \sim \left(\underbrace{\frac{4.5\,v^2}{N_D M_{TF}^2}}_{\sim .1} - \underbrace{.07c}_{c \sim 1}\right) N_D N_{TC} - .03N$$

Big Cancellation

- TC models severely restricted by S

- SSC measures



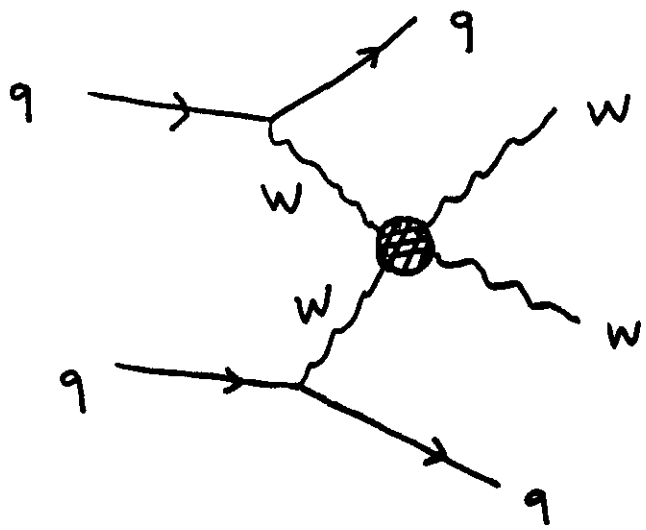

5 New terms @ $\frac{S^2}{\Lambda_{TC}^4}$

- Measure $\begin{cases} W^+W^+ \\ W^+Z \\ W^+W^- \\ ZZ \end{cases}$

- Restrict Coefficients

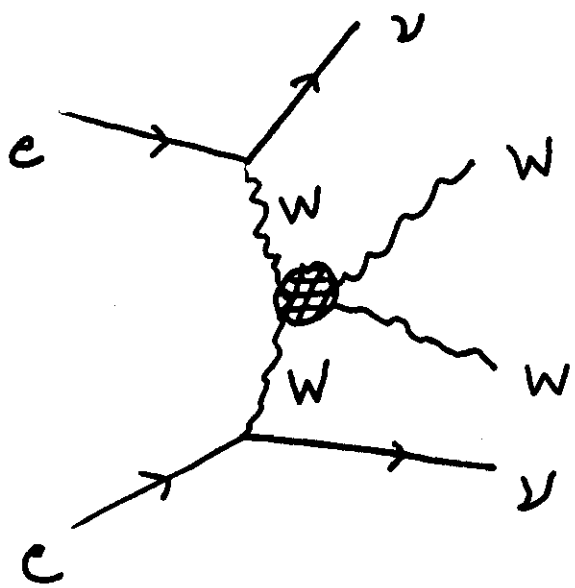
- Match with theory

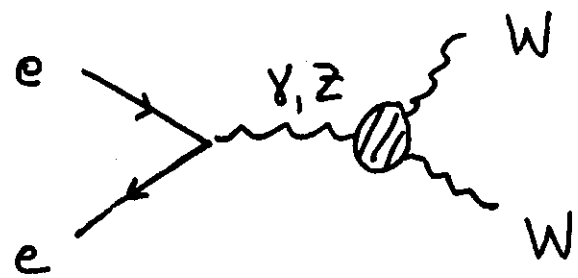
# Hadron Colliders




Strong Interaction

# $e^+e^-$ Machines



**Problem:** Some partial waves grow with $N_{TC}$ (Cahn & Suzuki)

Singlet: $a_0 = \frac{N_{TC}^2}{64\pi} \frac{s}{v^2}$

$N_{TF} = 8$, $a_0 = \frac{1}{2}$ @ $\sqrt{s_c} = 310$ GeV

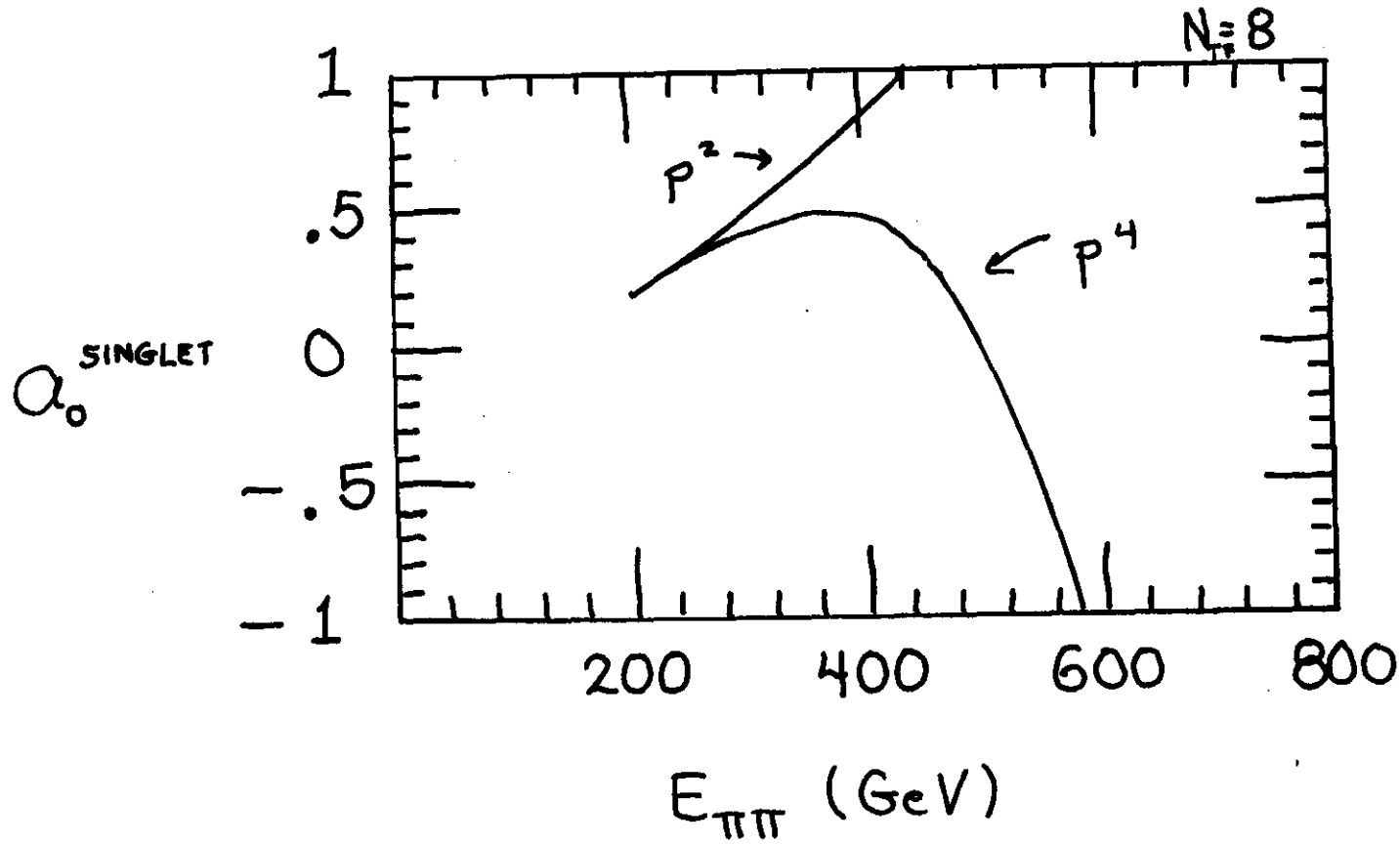
Compare: SM has global $SU(2) \times SU(2)$

$\rightarrow \sqrt{s_c} \sim 1.2$ TeV

TC $\Rightarrow$ New physics at lower scales than SM.

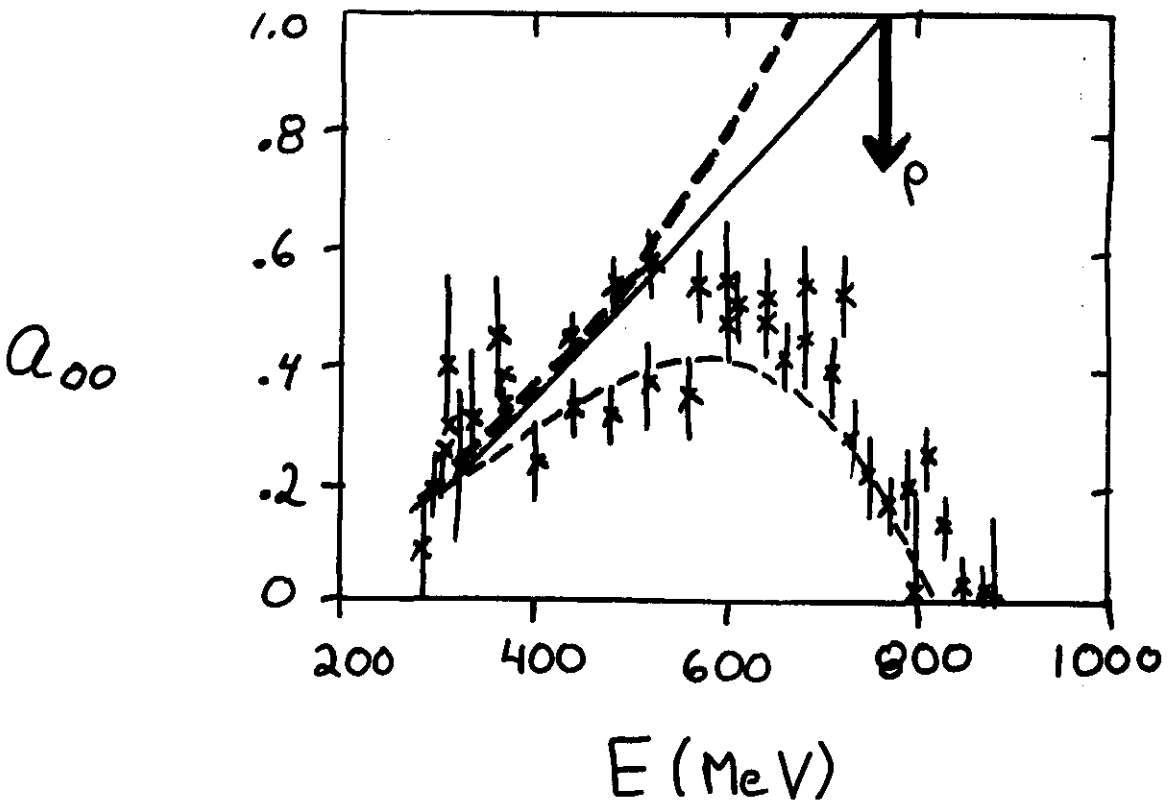
[cf: $m_{\rho_{TC}} \sim 800$ GeV $N_{TF} = 8$, $N_{TC} = 4$]

Unitarity problems NOT cured by adding more terms in energy expansion.



Remember $\pi\pi$ Scattering.....

(Donoghue, Ramirez, Valencia)




— $O(s)$

— $O(s^2)$ w/ $L_1 > 0$, $L_2 = 0$ "Scalar"

— $O(s^2)$ w/ $L_1 = -L_2$ "vector"

OPTIMIST: Can distinguish between "ρ" and "σ" theories in QCD

## Technicolor $\mathcal{L}$'s:

$$SU(N_{TF}) \times SU(N_{TF}) \to SU(N_{TF})$$

- Global symmetry + embedding of SM gives all

- Goldstone bosons, $\pi_i$, ($N_{TF}^2 - 1$ of them)

  Non-linear realization, $\Sigma = e^{\left(\frac{2i\pi \cdot T}{F}\right)}$.

Expand in $\frac{s}{\Lambda_{TC}^2}$:

$$\mathcal{L}_2 = \frac{F^2}{4} \mathrm{Tr}\left(D_\mu \Sigma D^\mu \Sigma^\dagger\right)$$

$M_W$ fixes $F = (246 \text{ GeV}) \sqrt{\frac{2}{N_{TF}}}$

$$D_\mu \Sigma = \partial_\mu \Sigma + \frac{i}{2\sqrt{\frac{N_{TF}}{2}}} g W_\mu \Sigma - \frac{i}{2\sqrt{\frac{N_{TF}}{2}}} g' B_\mu \Sigma \tau_3$$

- Valid below resonances

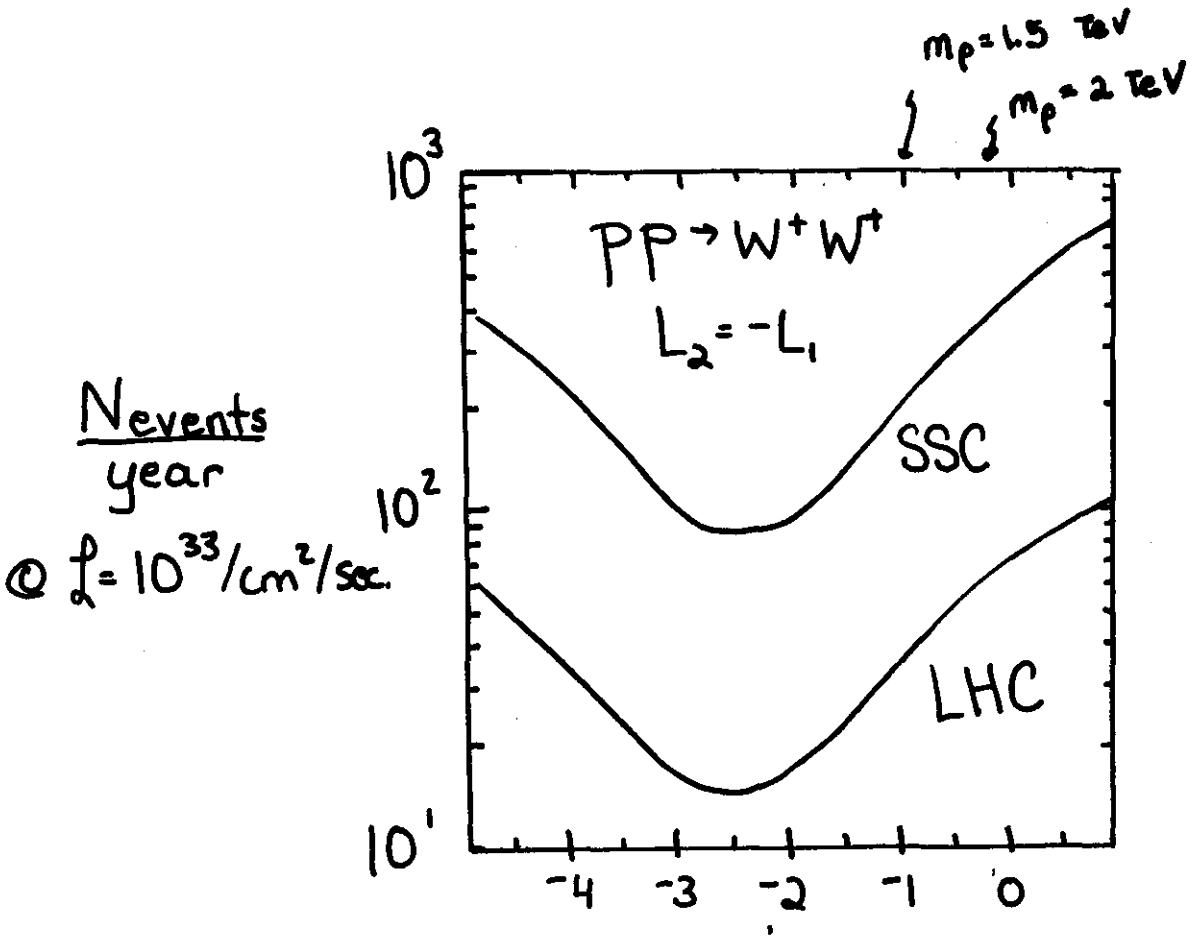
• Assume global $SU(2)_L \times SU(2)_R$ broken only by hypercharge

5 new terms at $O(s^2)$:

$$\frac{L_1}{16\pi^2}\left[\mathrm{Tr}\left(D^\mu \Sigma D_\mu \Sigma^\dagger\right)\right]^2 + \frac{L_2}{16\pi^2}\left[\mathrm{Tr}\left(D^\mu \Sigma D_\nu \Sigma^\dagger\right)\right]^2$$

---

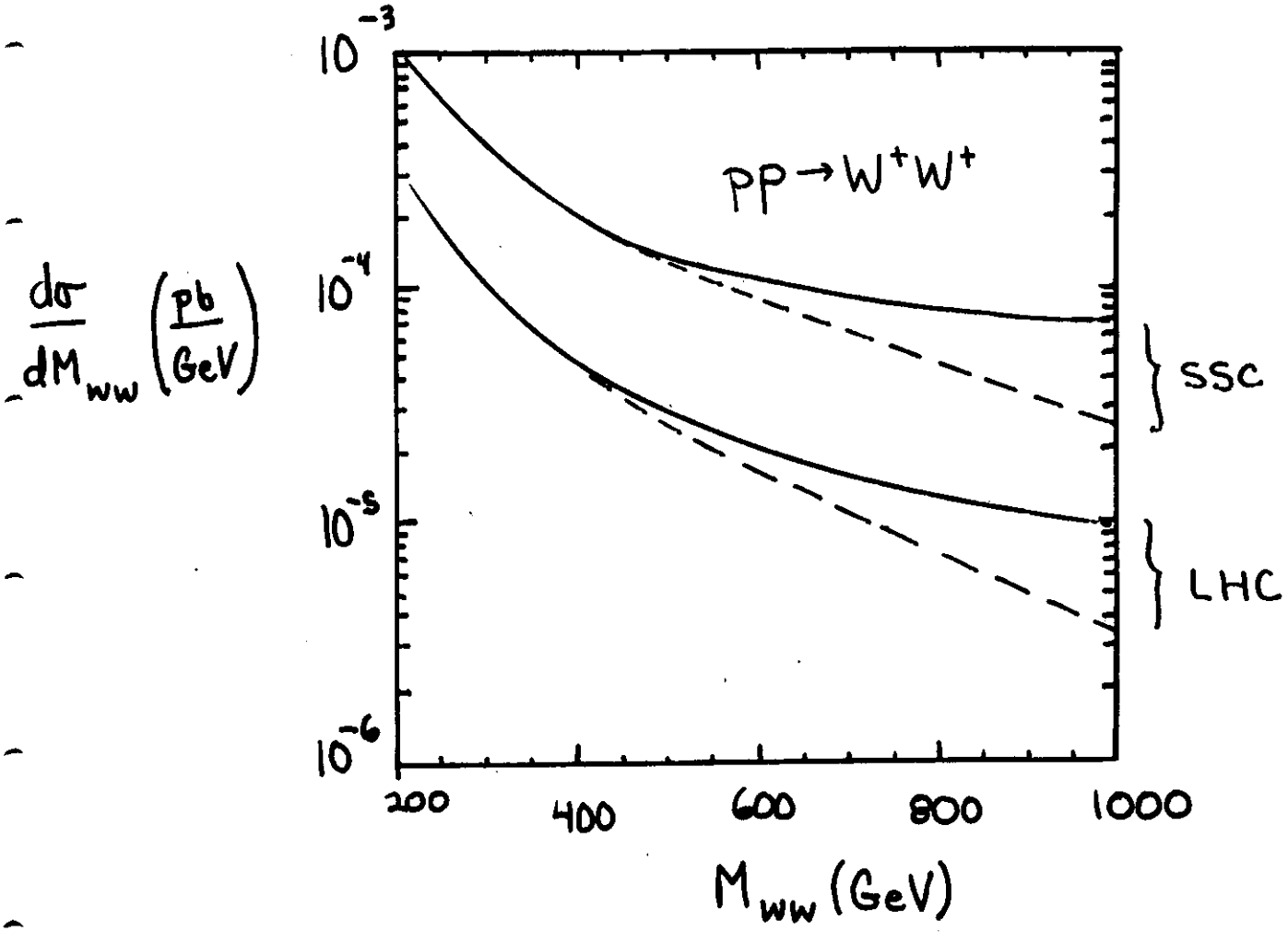
$W^+W^+ \to W^+W^+$ sensitive to $|L_1, L_2| \gtrsim 1$.




[Bagger, Dawson, Valencia]

$.5\ \mathrm{TeV} < M_{WW} < 1\ \mathrm{TeV}$

"Reasonable" models vary within ~ factor of 2 at 1 TeV




- $\frac{s}{v^2}$ $\mathcal{L}_{CHIRAL}$
- $\left(\frac{s}{v^2}\right)^2$ $\mathcal{L}_{CHIRAL}$ w/ $L_1 = -L_2$

~ "2 TeV $\rho$"

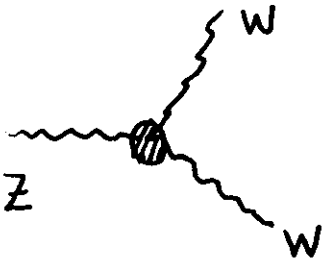
$$gg' \frac{L_{10}}{16\pi^2} \mathrm{Tr}\left(\Sigma B^{\mu\nu} \Sigma^{+} W_{\mu\nu}\right)$$

$$L_{10} = -\pi S$$

Altarelli: $L_{10}(1.5\ \mathrm{TeV}) = .5 \pm 1.6$

$$-ig \frac{L_{9L}}{16\pi^2} \mathrm{Tr}\left(W^{\mu\nu} D_\mu \Sigma\, D_\nu \Sigma^{+}\right)$$

$$-ig' \frac{L_{9R}}{16\pi^2} \mathrm{Tr}\left(B^{\mu\nu} D_\mu \Sigma^{+} D_\nu \Sigma\right)$$



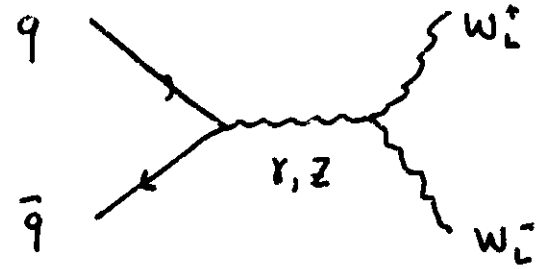

$$\mathcal{L} = -ig_V \Big[ g_1^Z \left(W^{+}_{\mu\nu} W^{\mu} - W^{+\mu} W_{\mu\nu}\right) Z^{\nu} + \kappa_V W^{+}_{\mu} W^{-}_{\nu} Z^{\mu\nu} \Big] \ldots$$

Same old couplings...

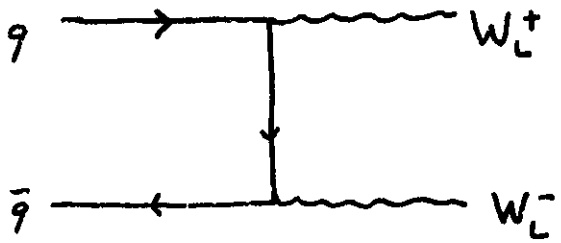
$$g_V - 1 = g^2 L_9 (\ldots) - 1 \quad \text{etc.}$$

[Holdom]

## Remember Tree Level:




$$a_s \sim \frac{g^2 s}{4M_W^2}$$




$$a_t \sim -\frac{g^2 s}{4M_W^2}$$

CANCELLATION → NO rising $\sigma$!

Changing gauge boson vertices spoils cancellation

"Delayed Unitarity" (Ahn, Peskin, Lynn, Selipsky)

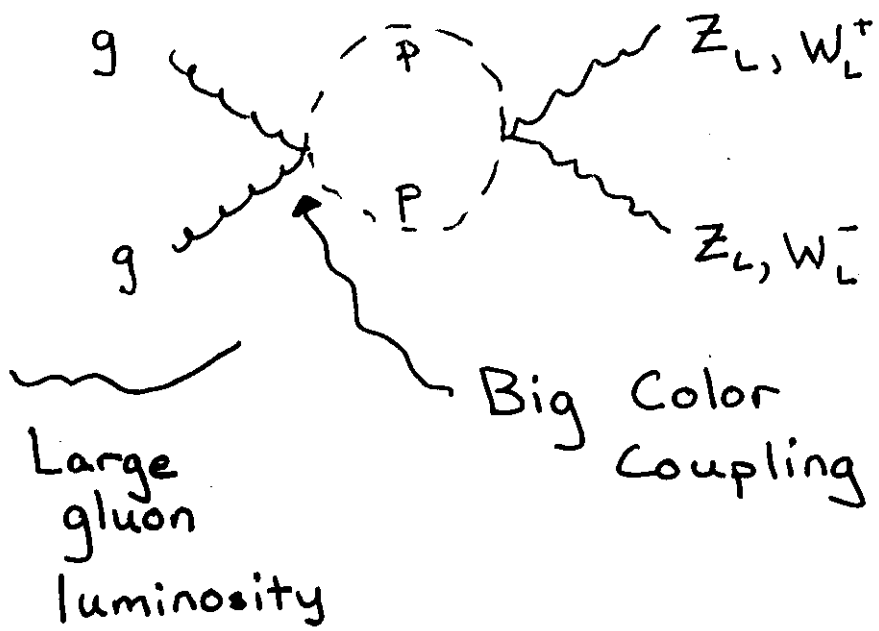
# Gluon Fusion as TC Probe

Ex: Farhi-Susskind

Global symmetry: $SU(8)_L \times SU(8)_R$

$\rightarrow 8^2 - 1 = 63$ Goldstone Bosons

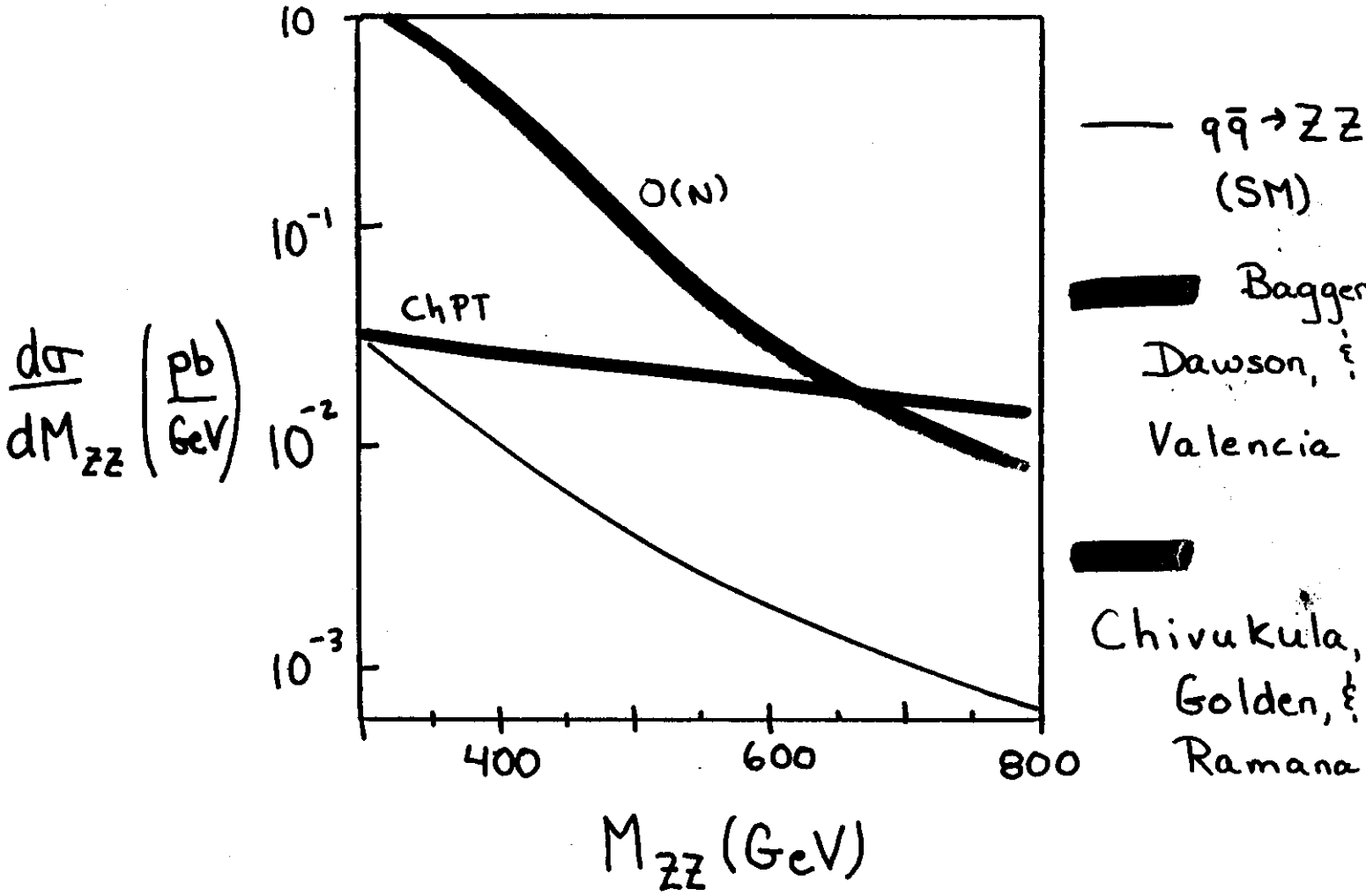
$P_3, P_8$ $\begin{cases} \text{Color triplet, octet GB's} \\ \text{Mass} \sim 200 \text{ GeV} \end{cases}$




But.... hard to calculate reliably

# Colored Goldstone boson loops:

SSC, $pp \to ZZ$, $|y_Z| < 2.5$




Perhaps.... ZZ channel good for non-resonant signals

# CONCLUSIONS:

1. Radiative Corrections (S) restrict TC models severely.

2. TC models have enhanced signal in $ZZ$ channel from $gg \to ZZ$.