GEM TN-93-304

Collaboration Council Meeting - Duncanville, Tx.

February 4, 1993

Abstract:

Agenda and presentations of the GEM Collaboration Council Meeting held at the Holiday Inn in Duncanville, Texas on February 4, 1993.

Collaboration Council Meeting
February 4, 1993
9:00

9:00	Greetings, Announcements	Yost
9:10	News of the GEM Collaboration	Barish
9:50	Neutron Flux Working Group Report	Diwan
10:00	Visiting Congress in Support of the SSC	Barnett
10:15	*Break*	
10:30	Project Manager's Report	Sanders
11:00	Muon System Decision Report	Taylor
11:40	Tracker System Report	Baltay
12:00	*Lunch*	
1:00	Calorimetery System Report	Wisniewski
1:30	TDR	Newman
2:00	A Prototype Silicon Preradiator	R. Frey
2:20	Using the Scintillating Tail Catcher as a Muon Trigger	Yu. Efremenko
2:40	DAQ Architecture for Virtual Level 2 Trigger	M. Bowden
3:00	Adjourn	

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Presentation by:

George Yost

THE GEM COLORS

- A CERTAIN AMOUNT OF UNHAPPINESS ABOUT THE SALMON
- WE COULD STICK WITH THE SALMON OR GO WITH SOMETHING ELSE
- NOW'S YOUR CHANCE. VOTE OUTSIDE. VOTES WILL BE TALLIED AND THE RESULTS ANNOUNCED TODAY.

VOTE FOR THE PRIMARY COLOR ONLY. ACCENT COLOR WILL BE CHOSEN TO GO WITH IT.

GEM Computing

We need institutional responses on computing needs for the near term (6/93) and for FY94. This is to get simulations done for the TDR and PAC meeting, and to predict need for upgrapde of PDSF (planning NOW). It may be necessary to begin to ration CPU time and disk space on PDSF in the near term. Please select an institutional contact who will provide (to mcfarlan@sscvx1):

- ☐ Estimates of CPU and disk space needs on PDSF from now till 10/93 and for FY94. No estimate will be interpreted as zero.
- ☐ Local CPU time that could be used by others between now and the TDR (Unix or VMS, >100 MIPS)
- ☐ A response as to whether the institution is interested in working on controls, event filters, database, software frameworks, etc. for the future. There are projects, and there is funding!

GEM Council

Feb 4, 1993

Next meeting: March 17, SSCL

General Collaboration Meeting:

May 10, 11, 12

San Diego

(IISSC May 6-8 in San Francisco)

Following Council meeting:

June 30 (Wednesday)

SSCL

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Presentation by:

B. Barish

4 Feb 93 ①
B. BARISH

GEM News/Status

- **MUON TECHNOLOGY DECISION**

  Recommendation: MUON Steering Comm
  CSC Everywhere

- **BASELINE 2**

  Frozen for TDR simulations, etc
  (engineering evolution)

- **Cost Roll-up**

  $500M ++ (Sanders)

- **TDR APRIL 30** (will not change)

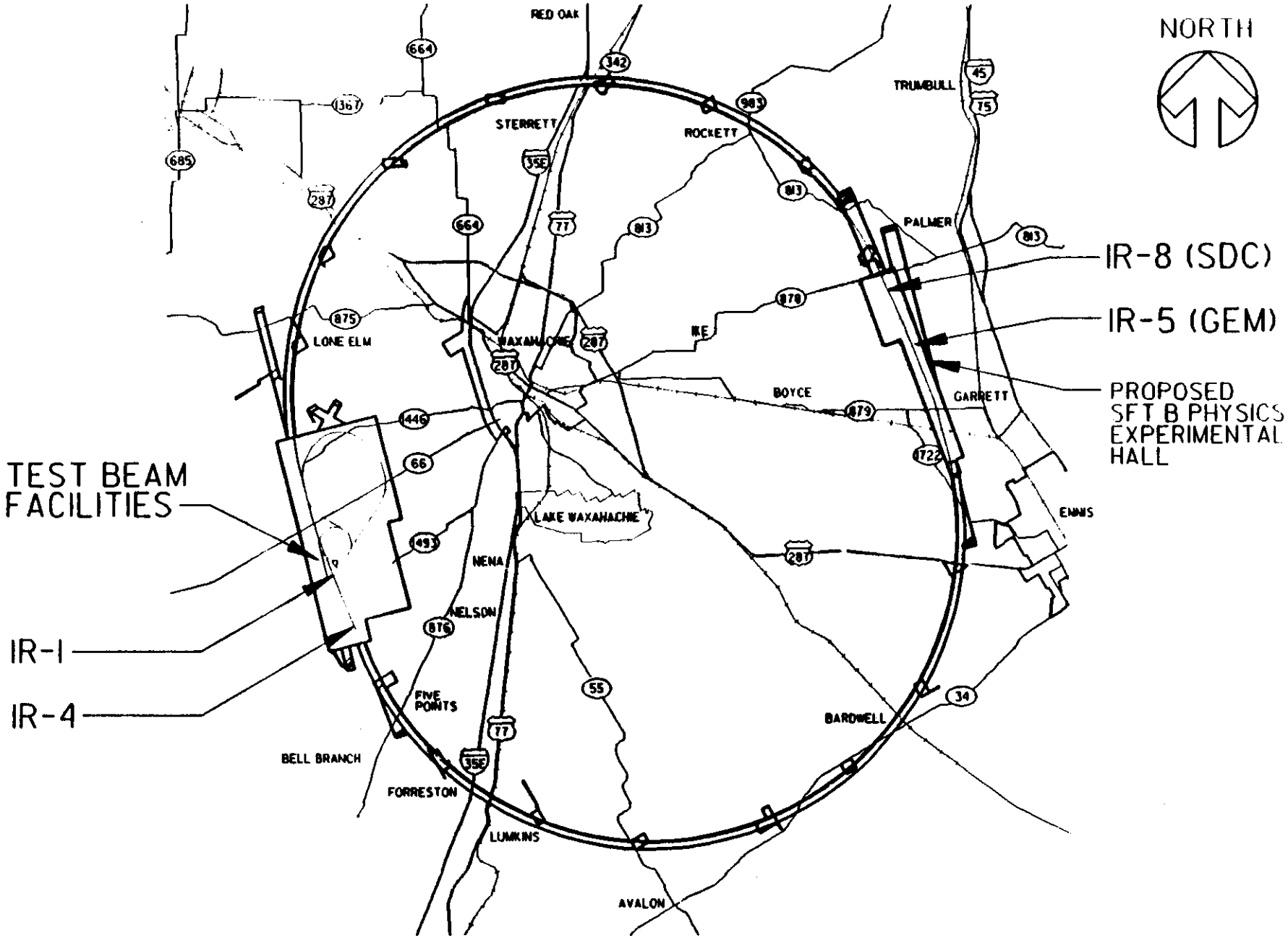
  Turn in on deadlines (Newman)

- <u>China Visits</u> "Leading Group" Min Lin
  - Calorimeter (Jan)
  - Muons (Feb)

- FY93 R+D / Engineering Budgets
  - planning ~$34M

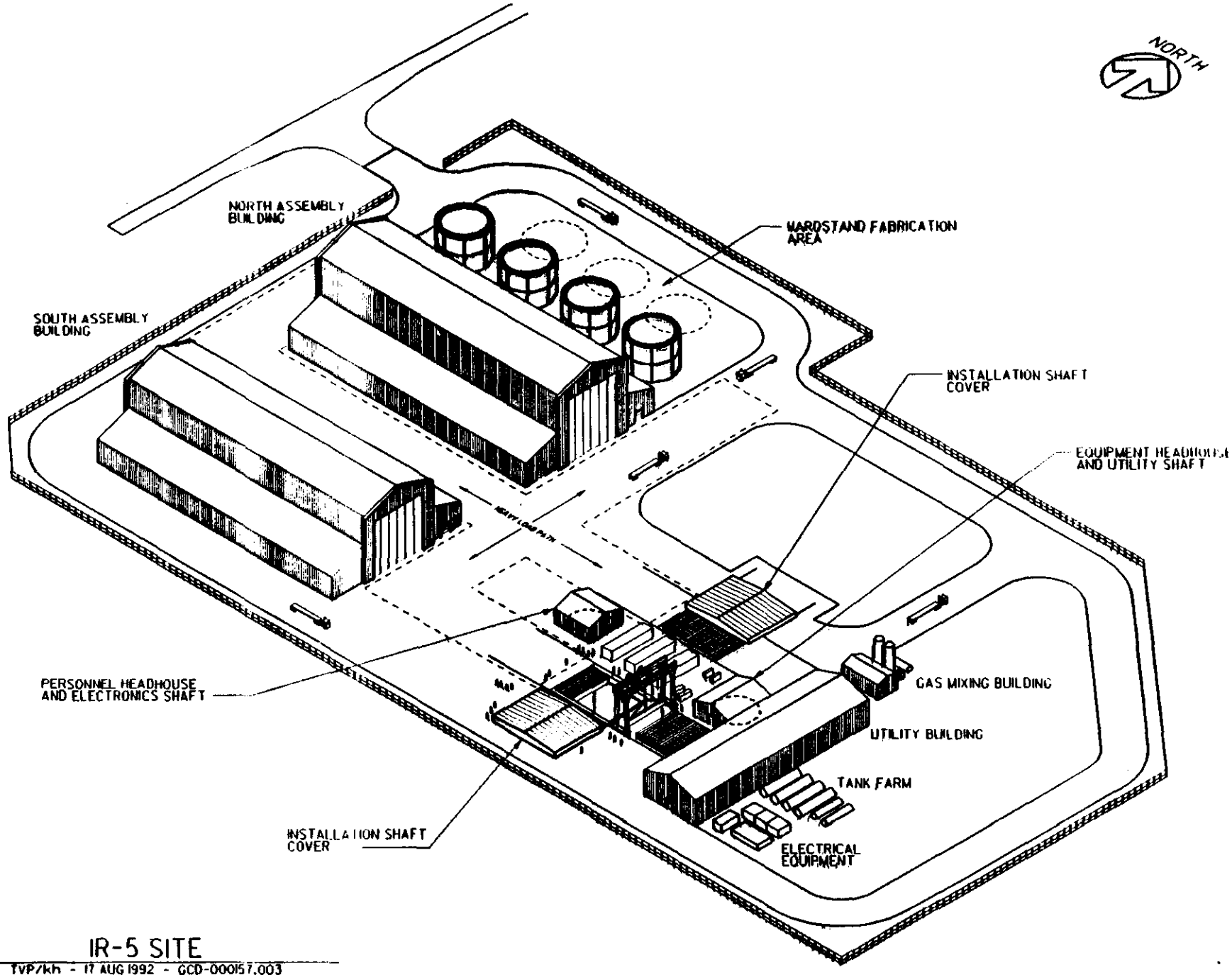
- Campus / Bldgs.
  - M. Safdie
  - "Vocabulary"
  - Site
  - Feb 10 1:30 - 3:00 GEM Mtg.

- Institutional Roles / Responsibilities
  - Sanders - letter.



SSC EXPERIMENTAL AREA MAP

TVP/kh - 8/20/92 - R20000460 - ref. files: R20000458



IR-5 SITE

TVP/kh - 17 AUG 1992 - GCD-000157.003

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Presentation by:

M. Diwan

Free space vs. collimator ID

- Increasing free space

	20m	35m	50m
$\mathcal{L}$	1.0	0.76	0.65

- n fluence is a weak function of z
  - no $1/r^2$ dependence because of hall walls
  - energy intercepted by collimator changes weakly
    20m → 35m with ID = 42 $\frac{\Delta E}{E} \sim 30\%$
- more space is available at 35m for shielding

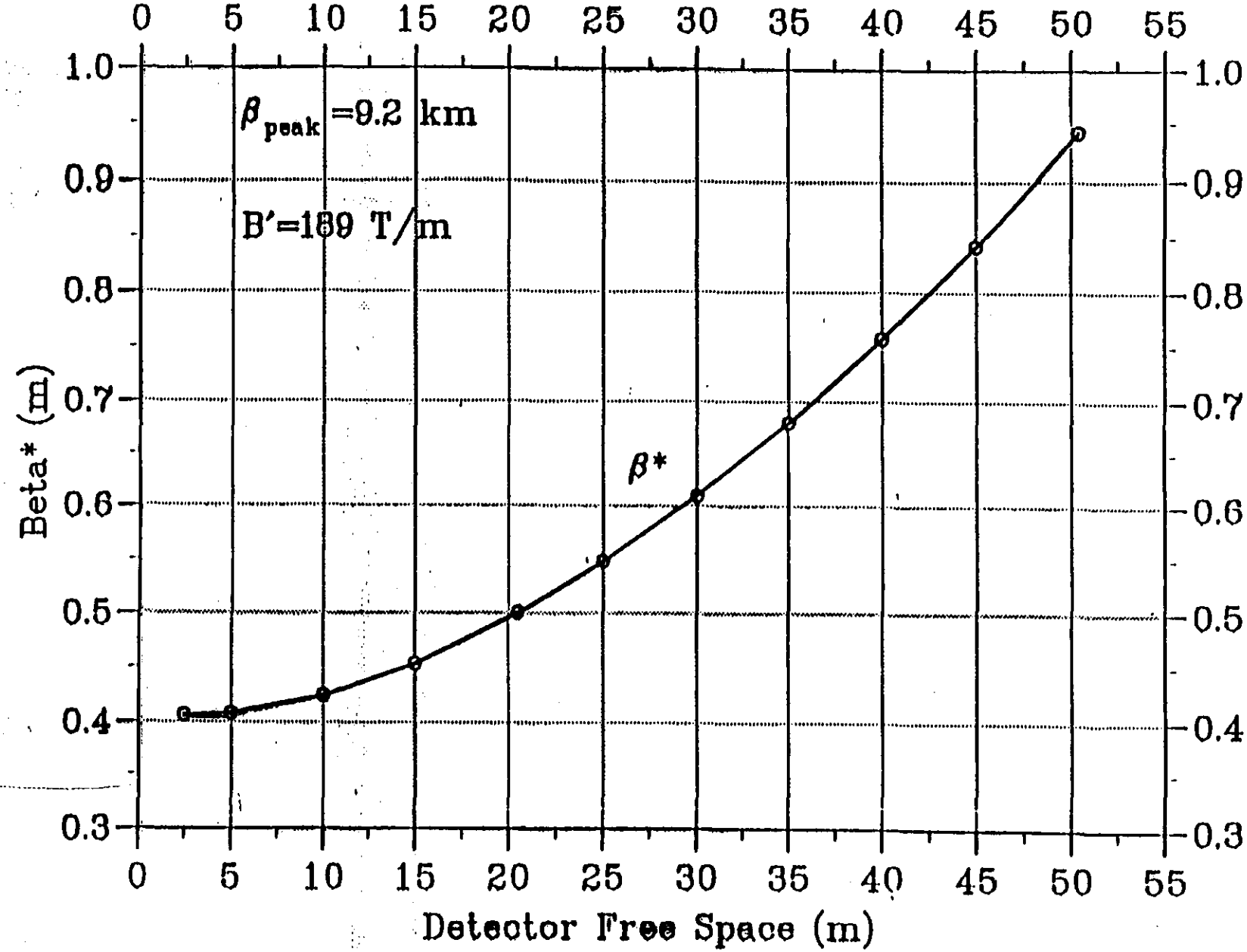
- collimator effects

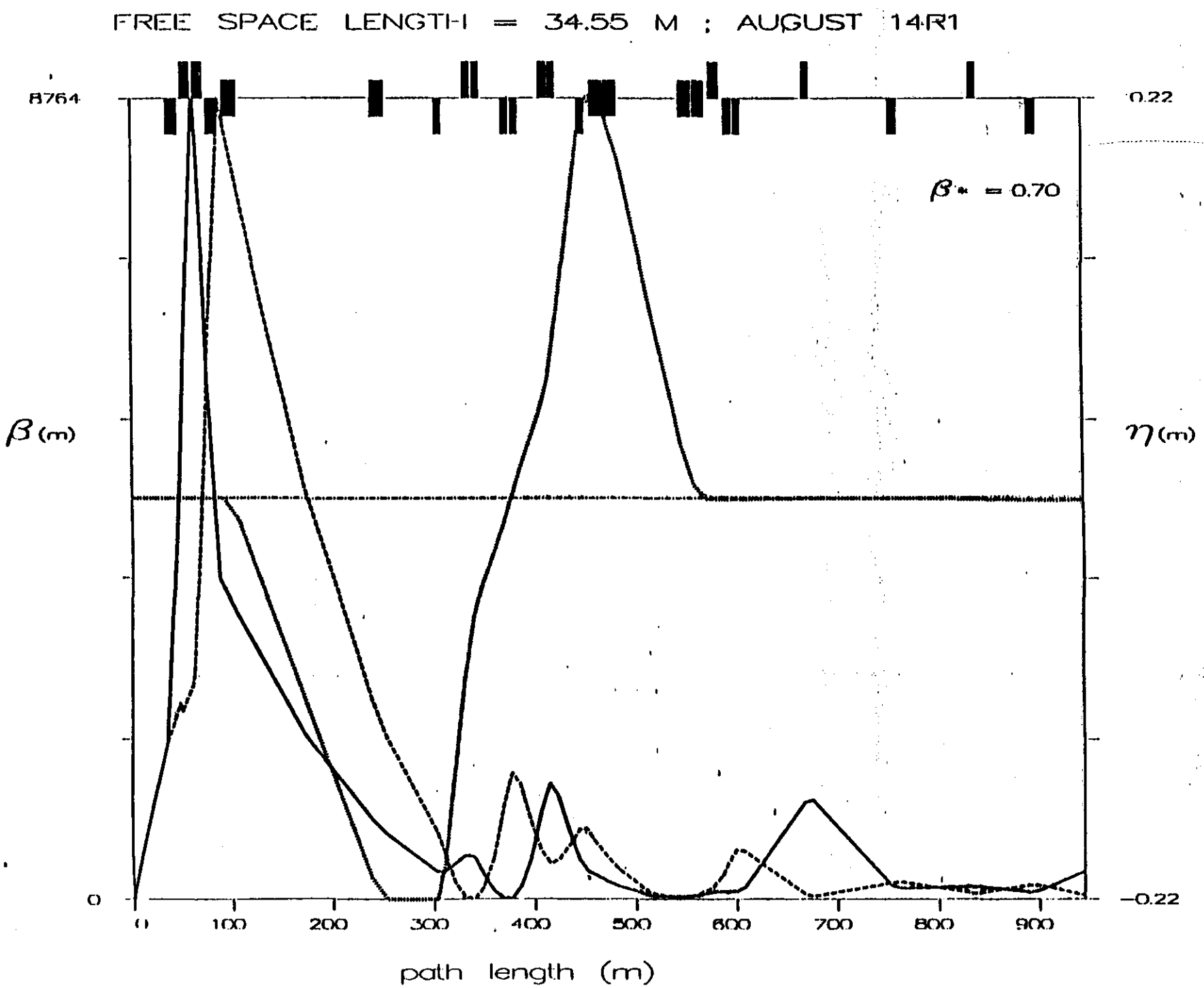
collimator at 32-35m
QLI > 35.5m
$\mathcal{L} = 10^{33}\ cm^{-2}\ s^{-1}$

Aperture	25	42	∞
QLI (watts)	21	40	85
Lifetime (yr)	7	5	1.5
QLI n leakage 10^{13} n/cm²/yr	2.6	3.8	4

Maximum power input allowed ~50 watts
In Arcs 0.4 - 4 watts/magnet

Beta* vs Detector Free Space.




FREE SPACE LENGTH = 34.55 M ; AUGUST 14R1
8764
0
β (m)
0.22
−0.22
η (m)
β* = 0.70
0
100
200
300
400
500
600
700
800
900
path length (m)

N. Mokhov

NEUTRON BACKGROUND

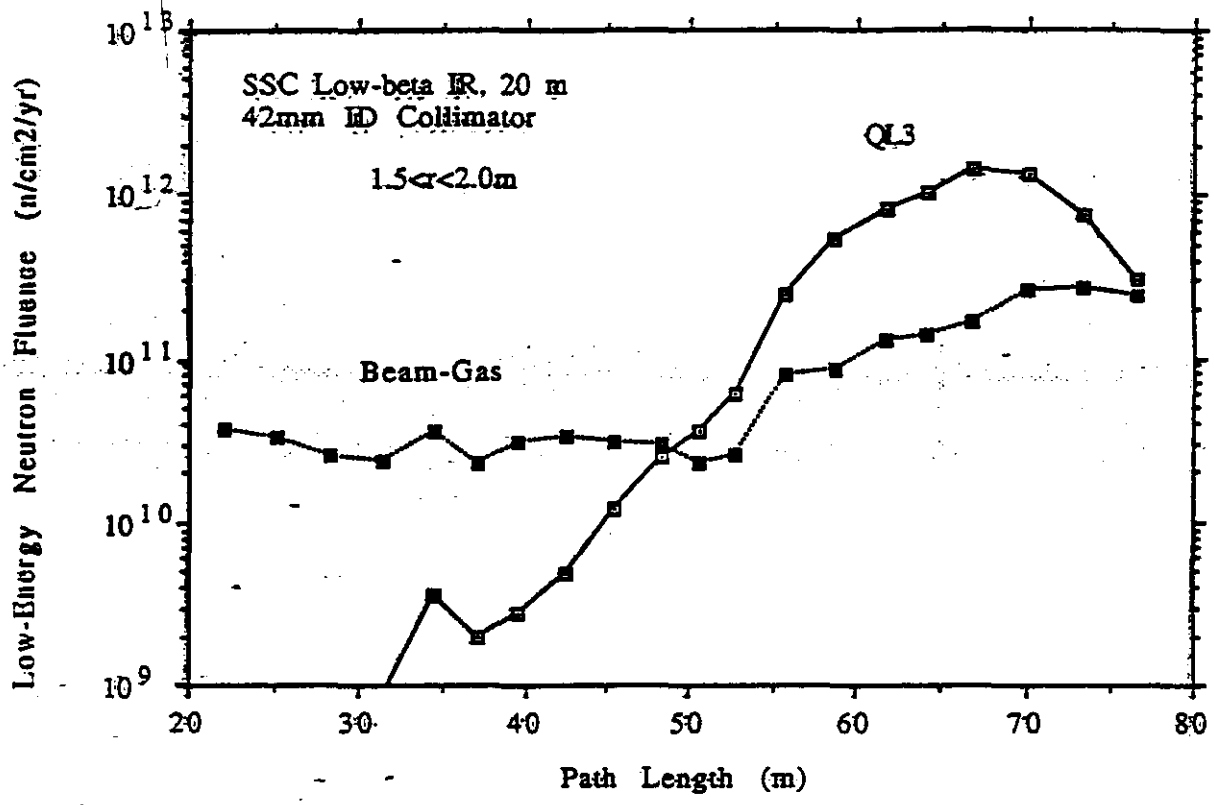
Neutron Fluence at L=20m and R=2m per the SSC year

- **pp-collisions** (10^{33} @ 20 m): 2×10^{12} cm^{-2}

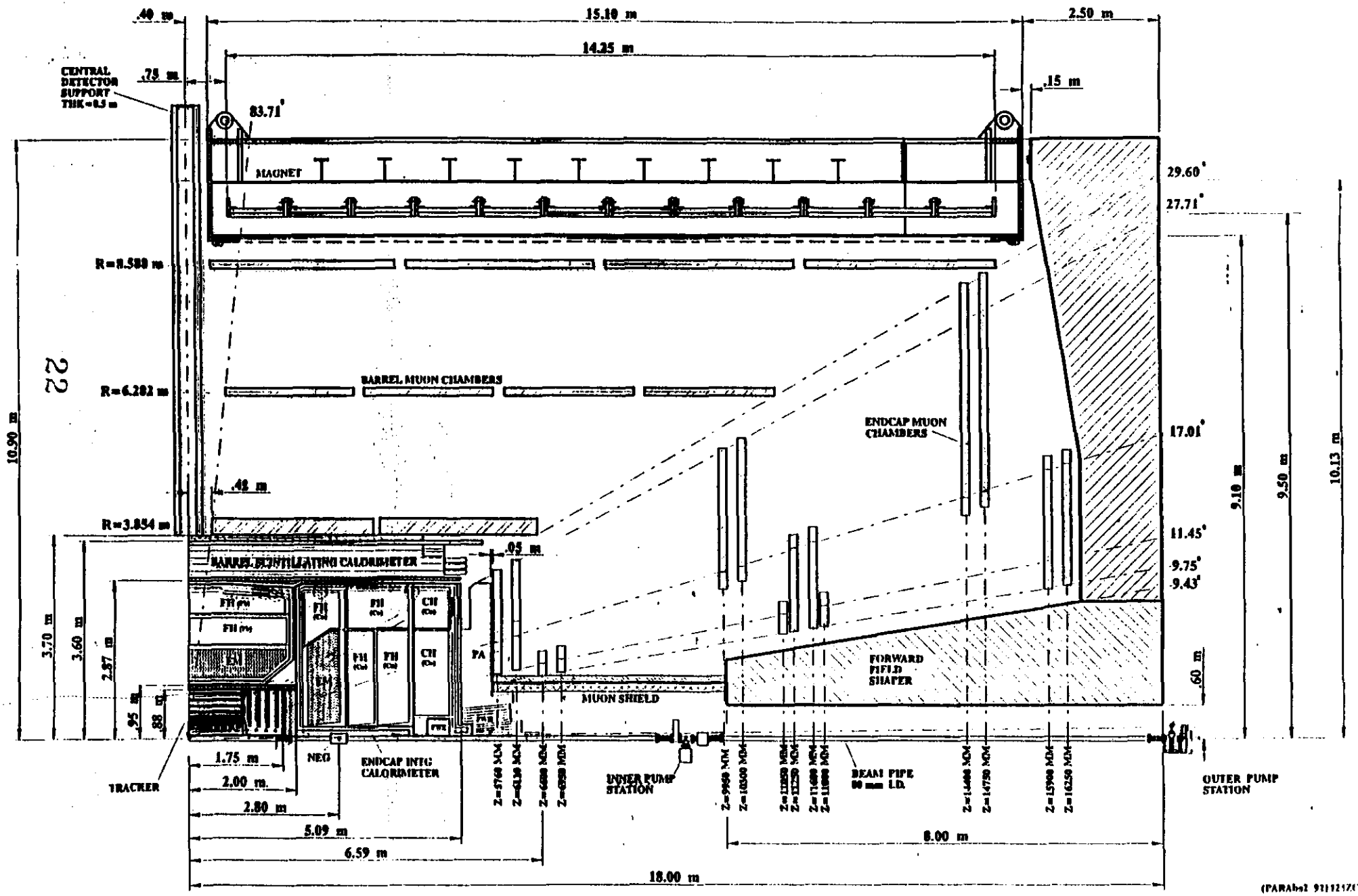
  (can be significantly reduced @ 35 m)

- **Local Beam Loss** (Normal Operation): 1×10^{9} cm^{-2}
- **Beam-Gas** (cold+10^{-8} torr in warm): 5×10^{10} cm^{-2}

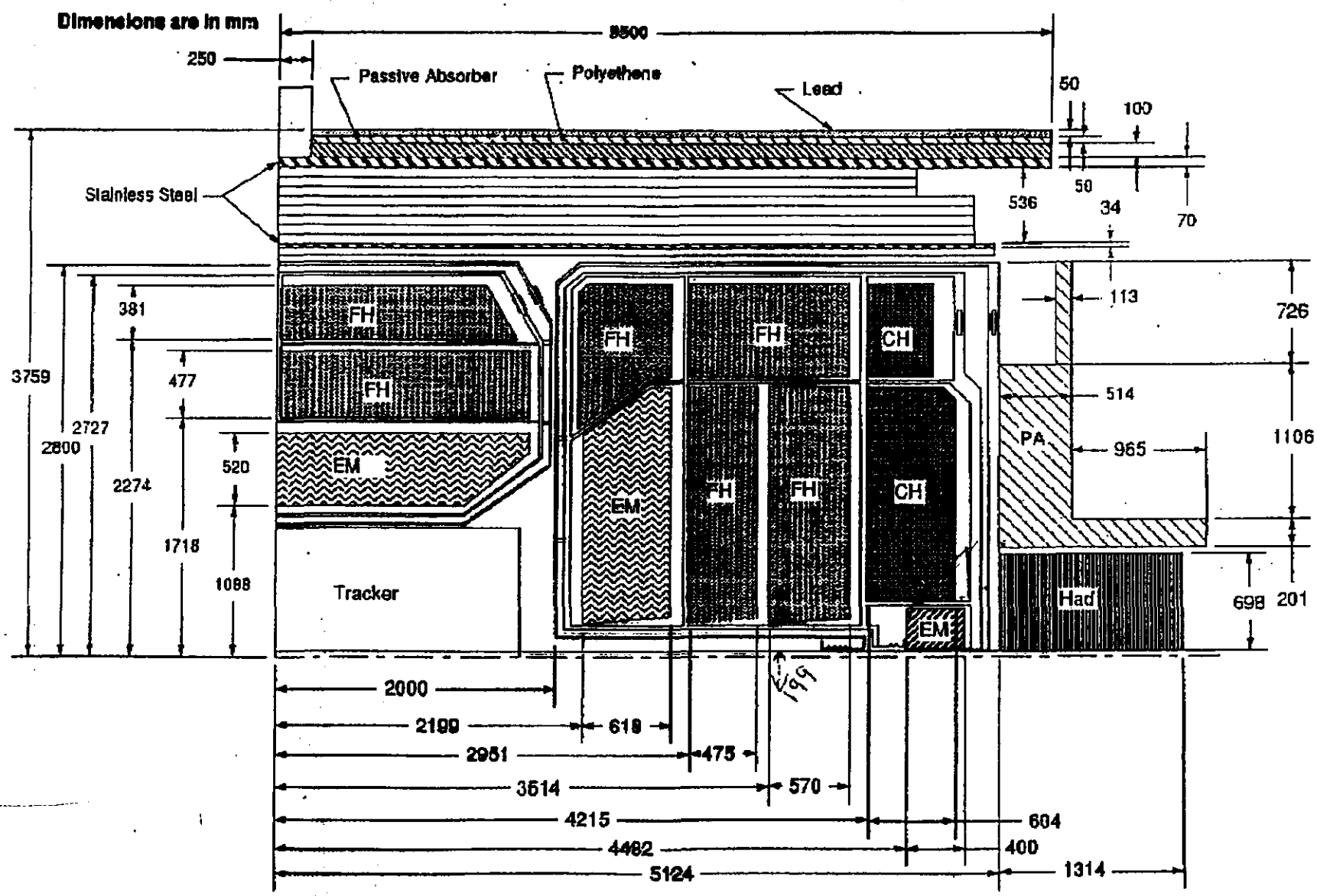
  around beam pipe: 3.5×10^{12} cm^{-2}

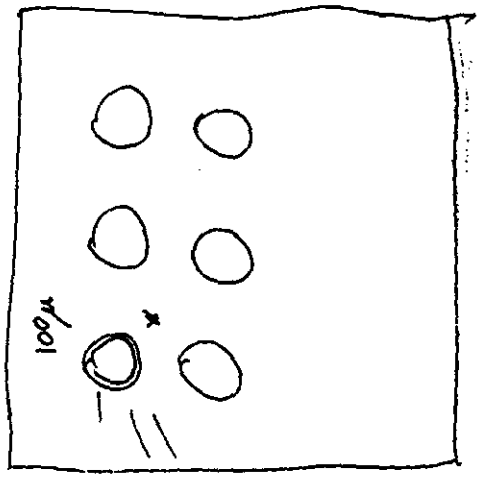

SSC Low-beta IR, 20 m
42mm ID Collimator
1.5<r<2.0m
QL3
Beam-Gas
Low-Energy Neutron Fluence (n/cm2/yr)
Path Length (m)
10^13
10^12
10^11
10^10
10^9
20
30
40
50
60
70
80

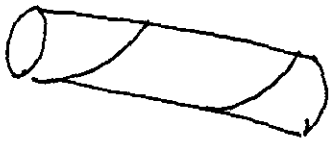
GEM DETECTOR PARAMETERS
BASELINE 2

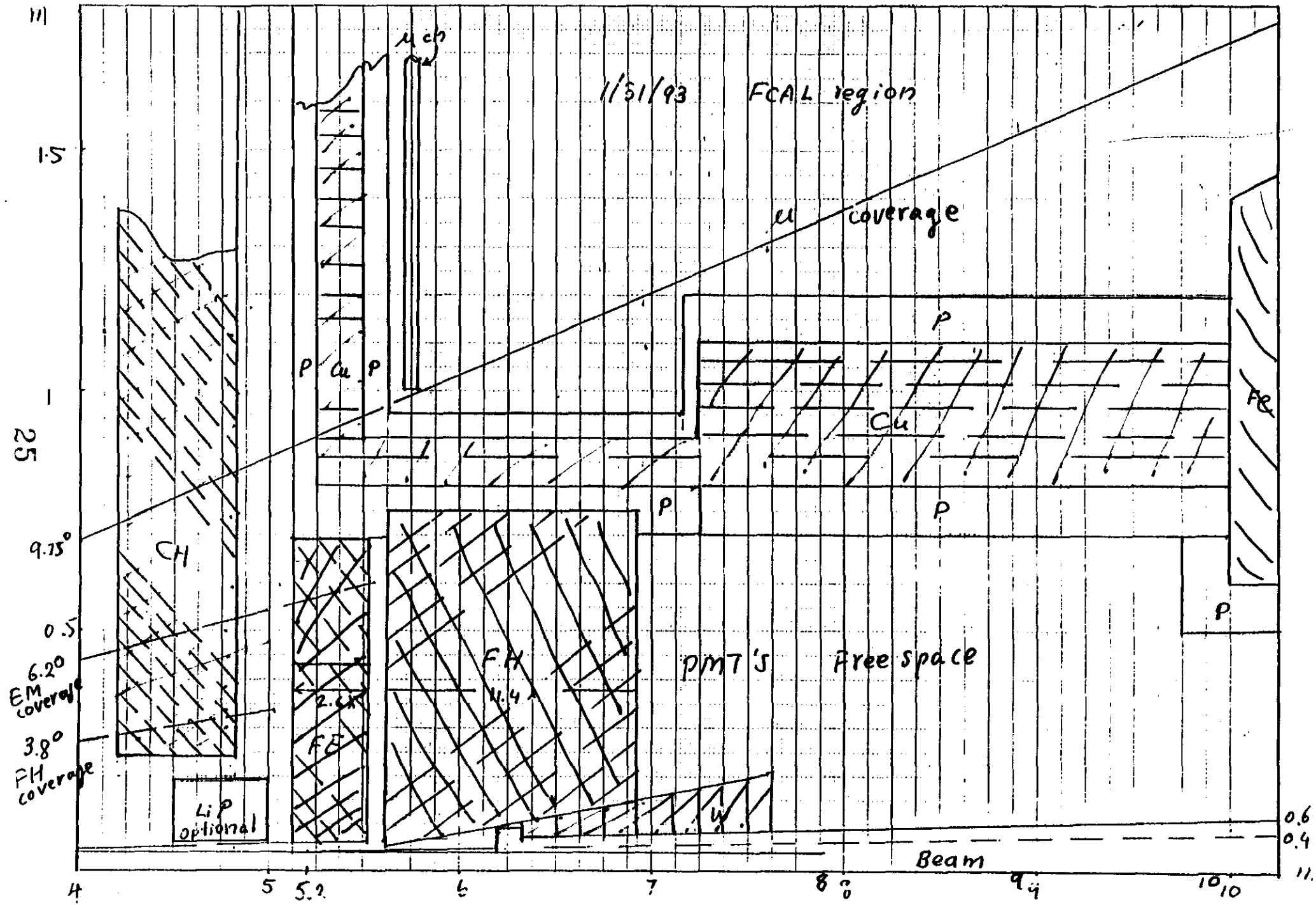


GEM Calorimeter - Dimensions

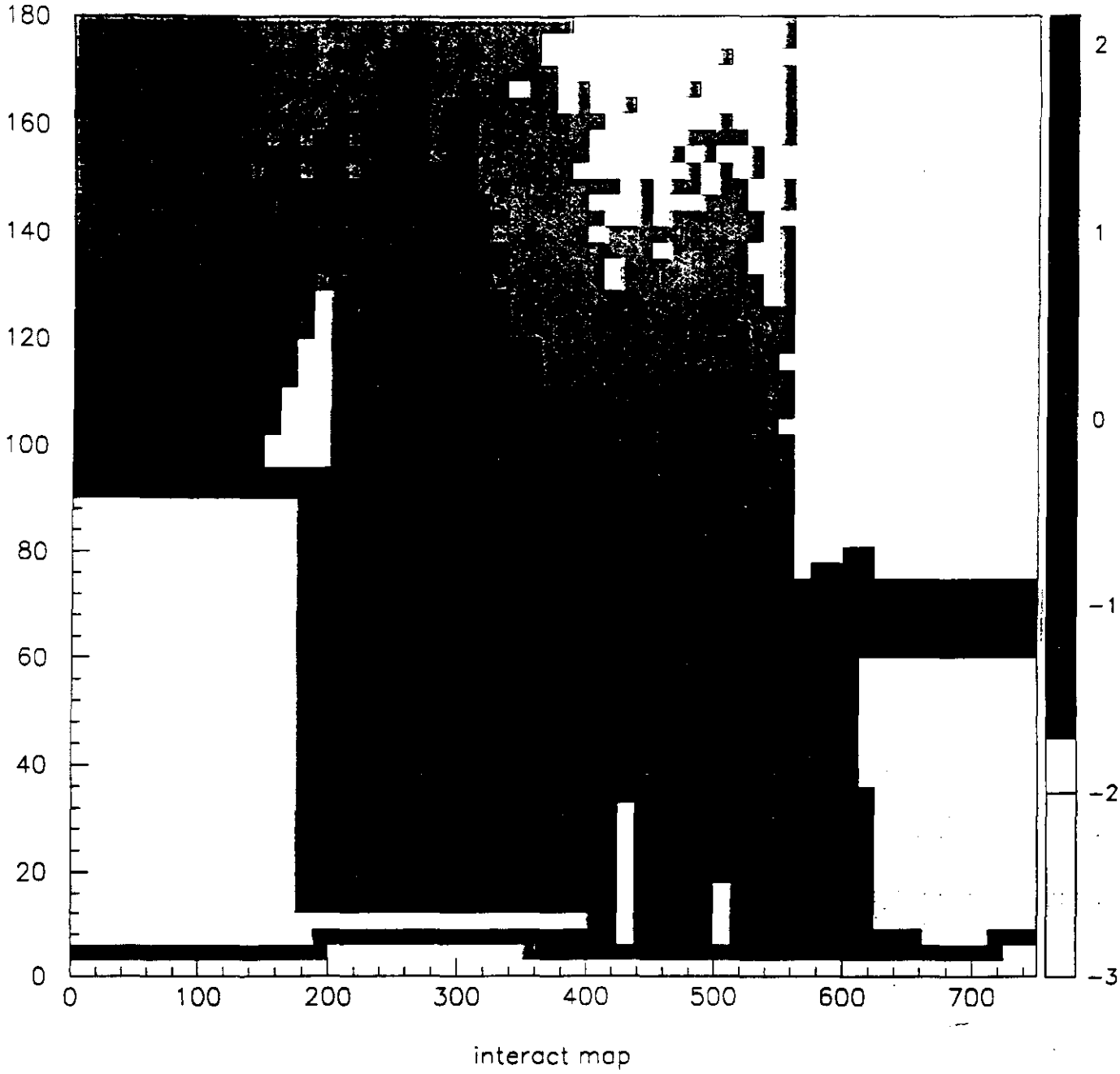



100μ

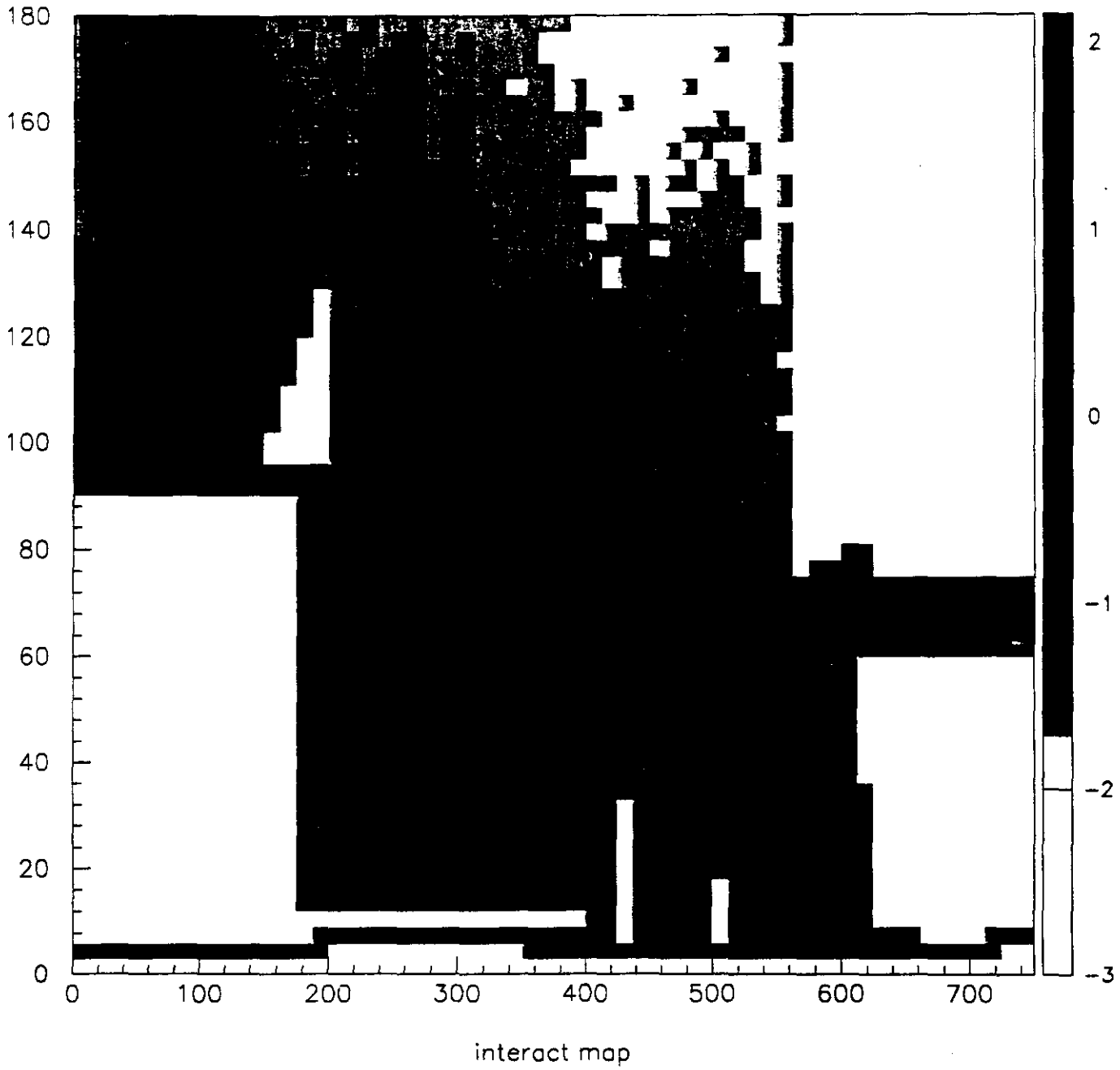



11/31/93 FCAL region
μ coverage
μ ch
P
Cu
P
P
Cu
P
P
Fe
P
CH
FH
4.4λ
PMT's
Free space
2.4λ
Fe
W
Li P
optional
Beam
9.75°
6.20°
EM coverage
3.8°
FH coverage
0.5
1
1.5
0.6
0.4
4
5
5.2
6
7
8
9
10
25

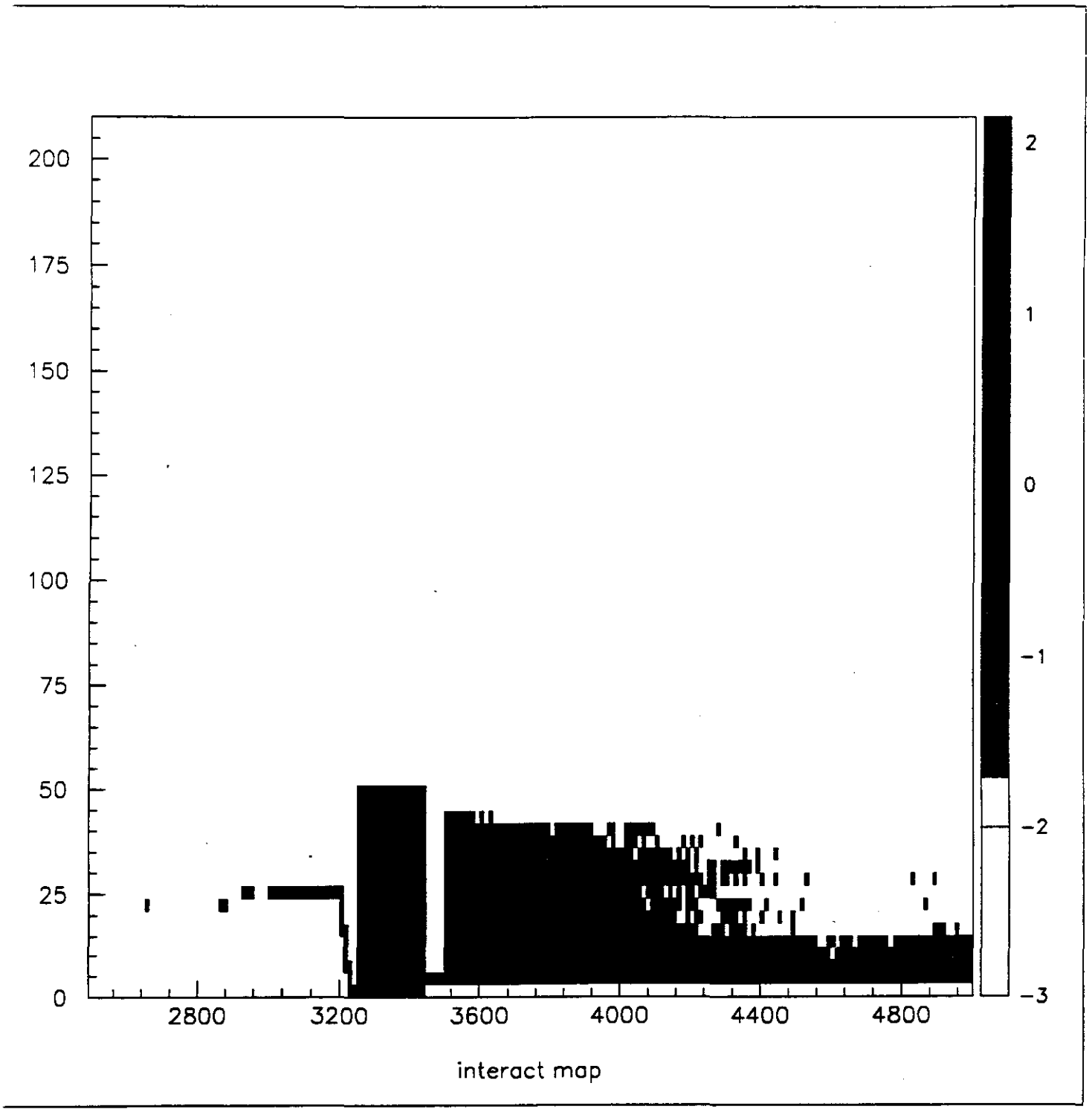
interaction map with no shielding



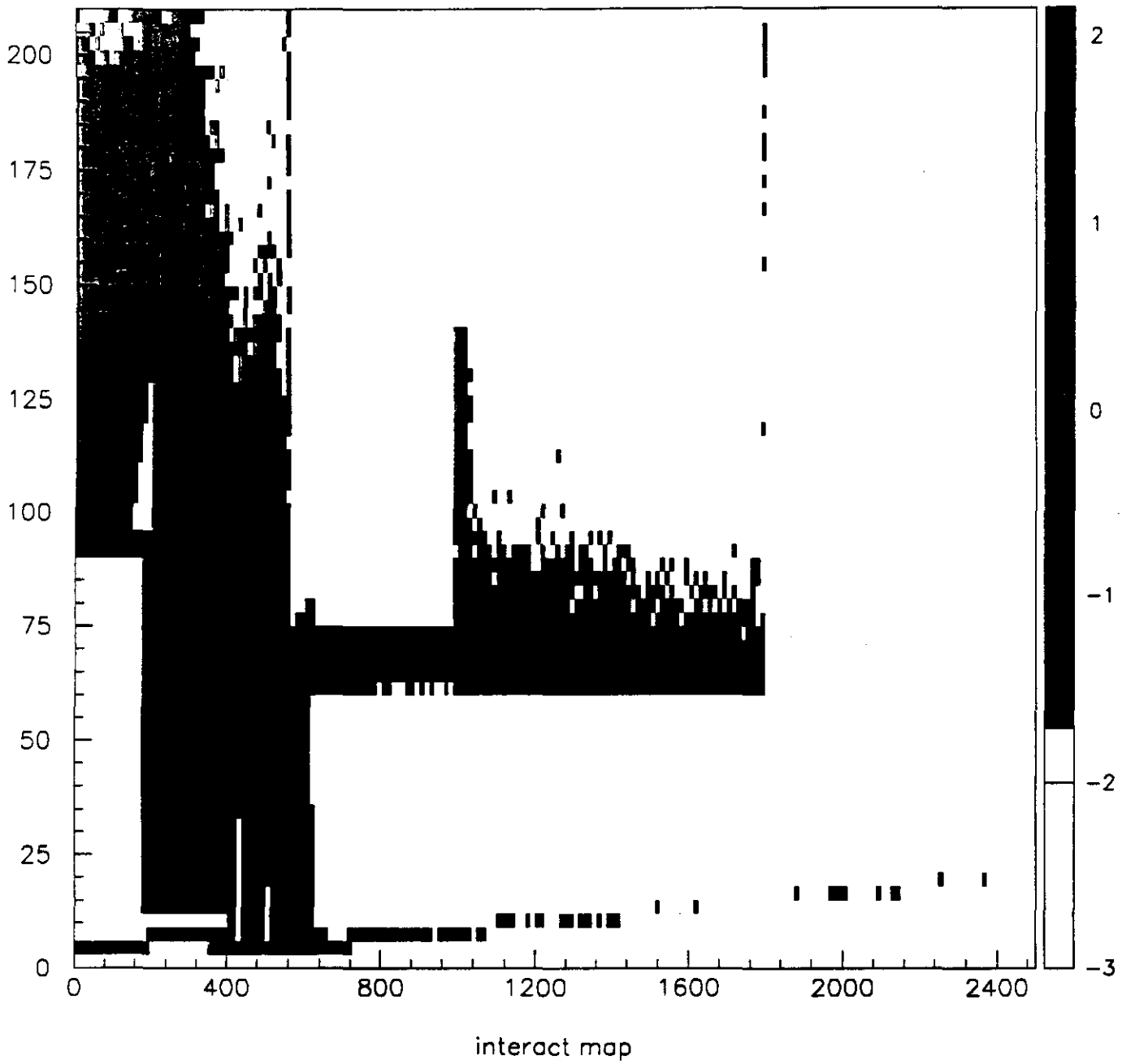
Interaction map with no shielding



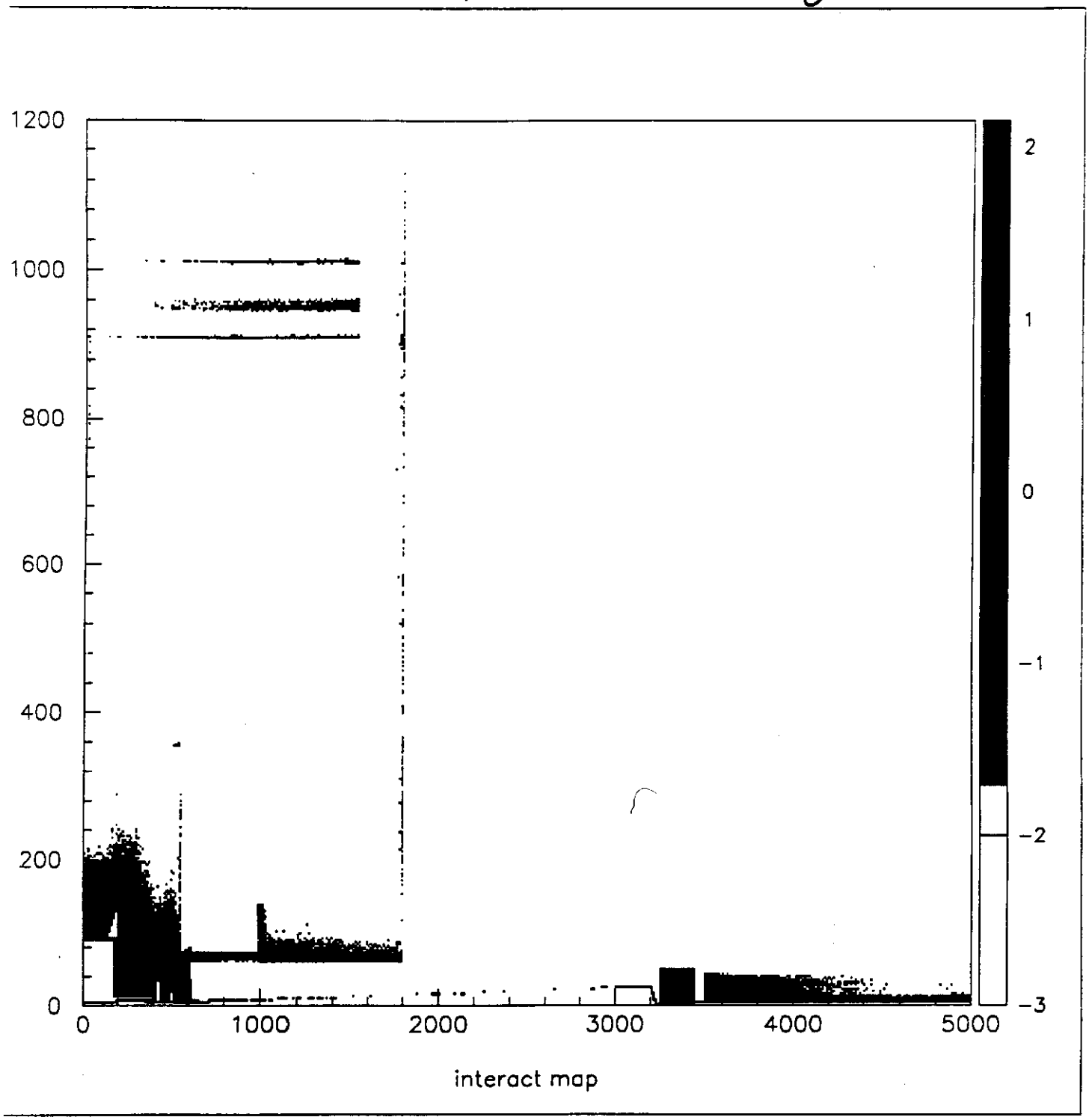
Interaction map with no shielding



Interaction map with no shielding

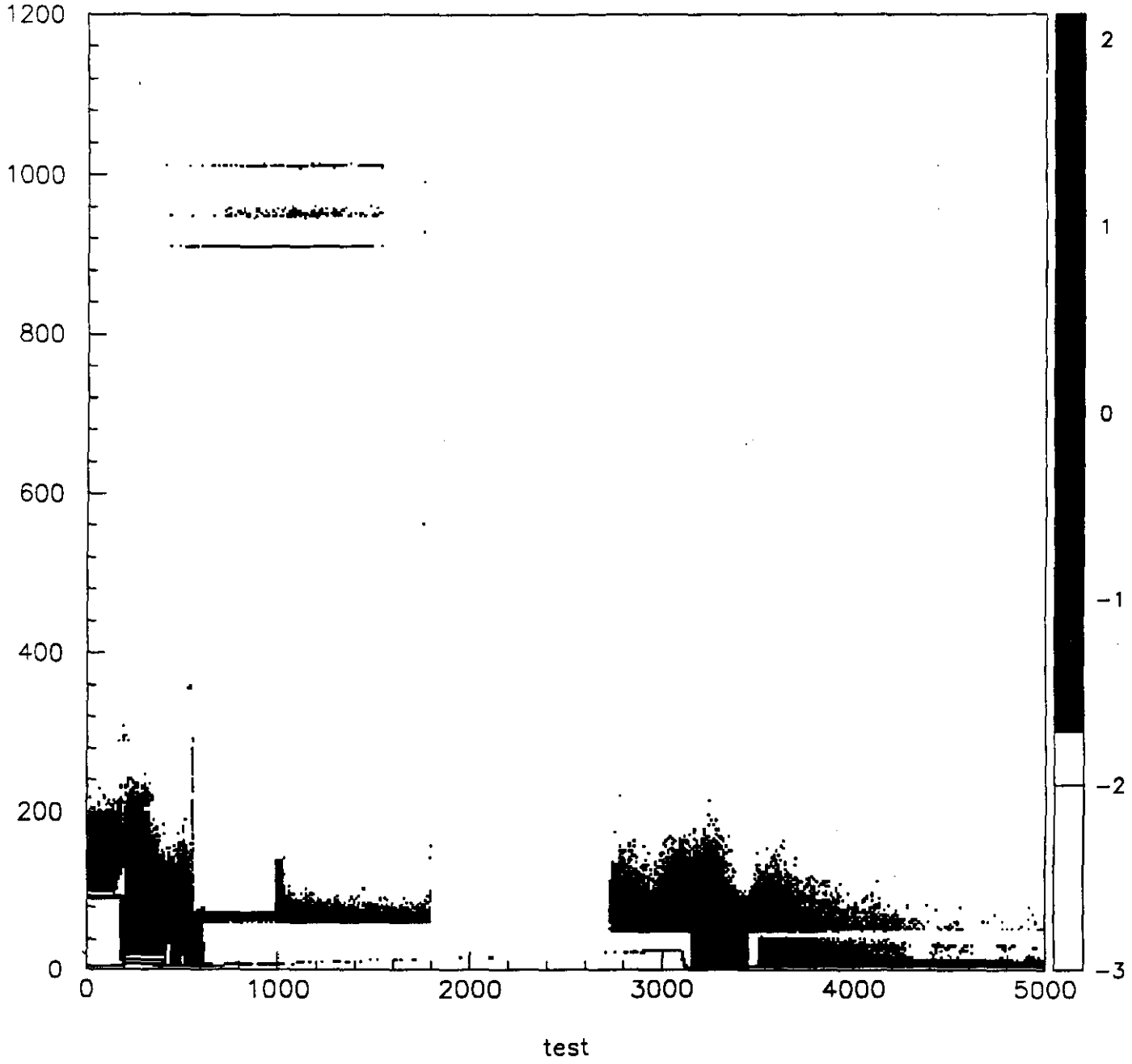


Interaction map with no shielding

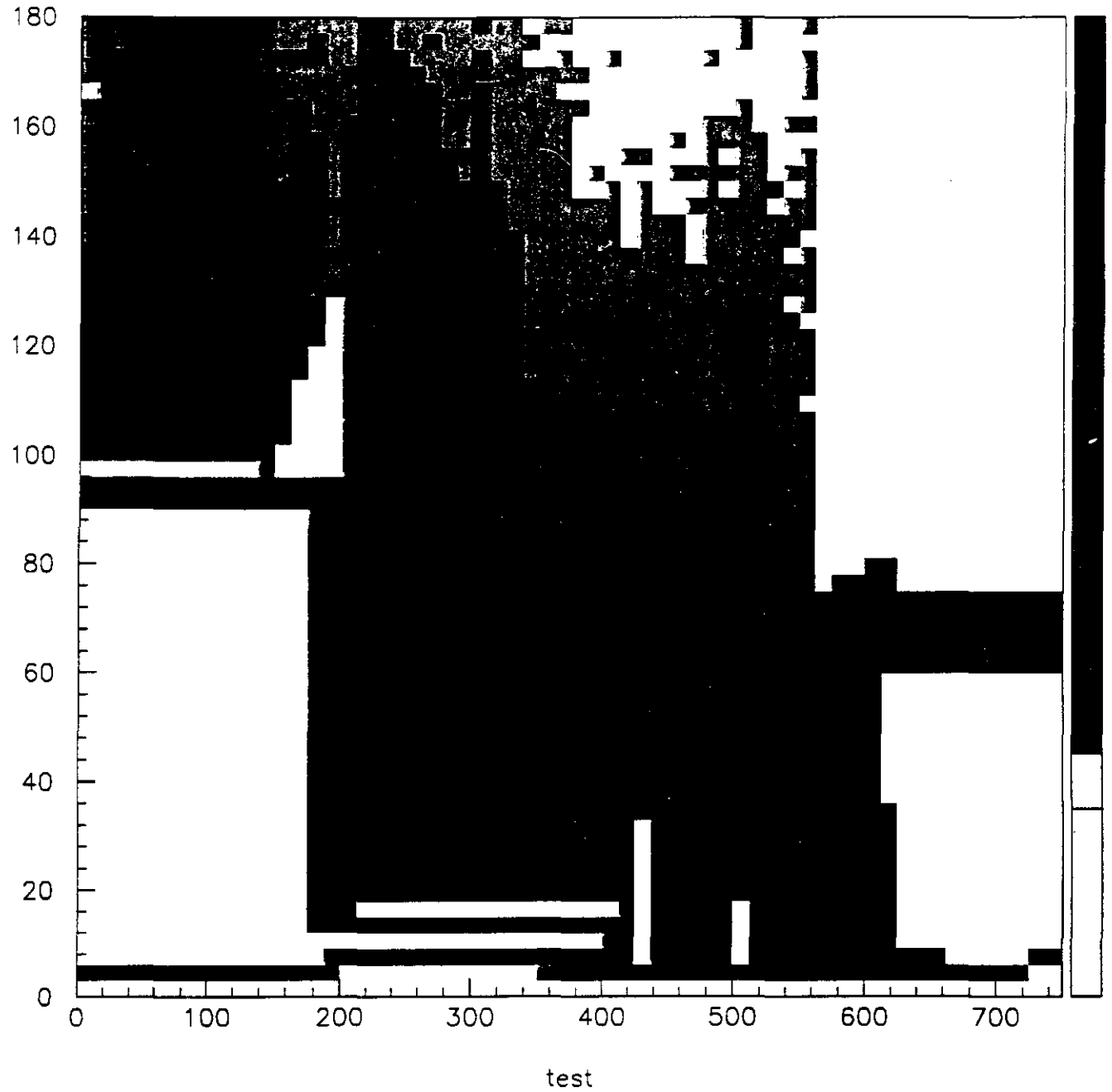


units are interactions per SSC min b event in r-z slice 3cm x 12.5 cm

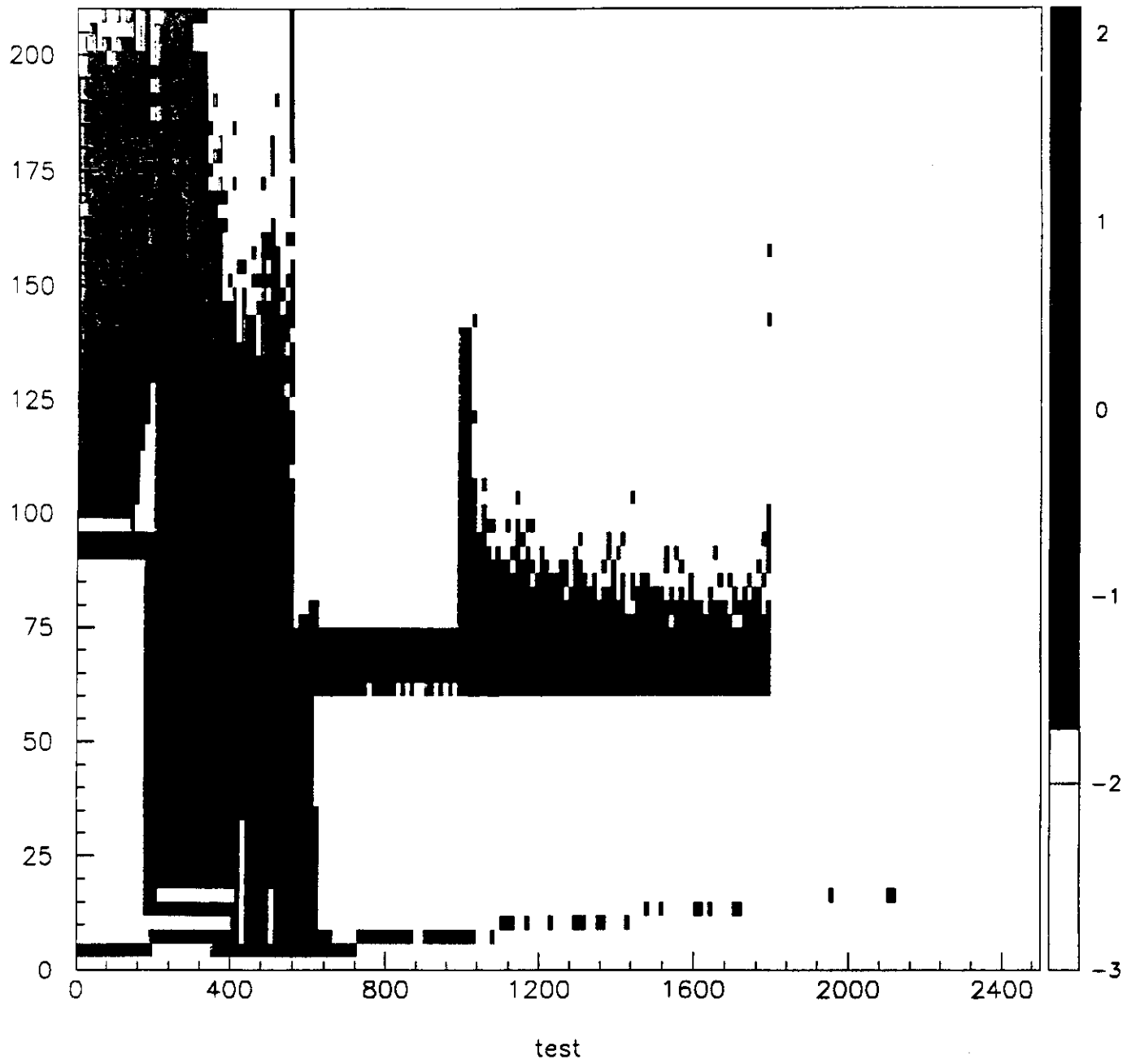
Interaction map with Quad shield



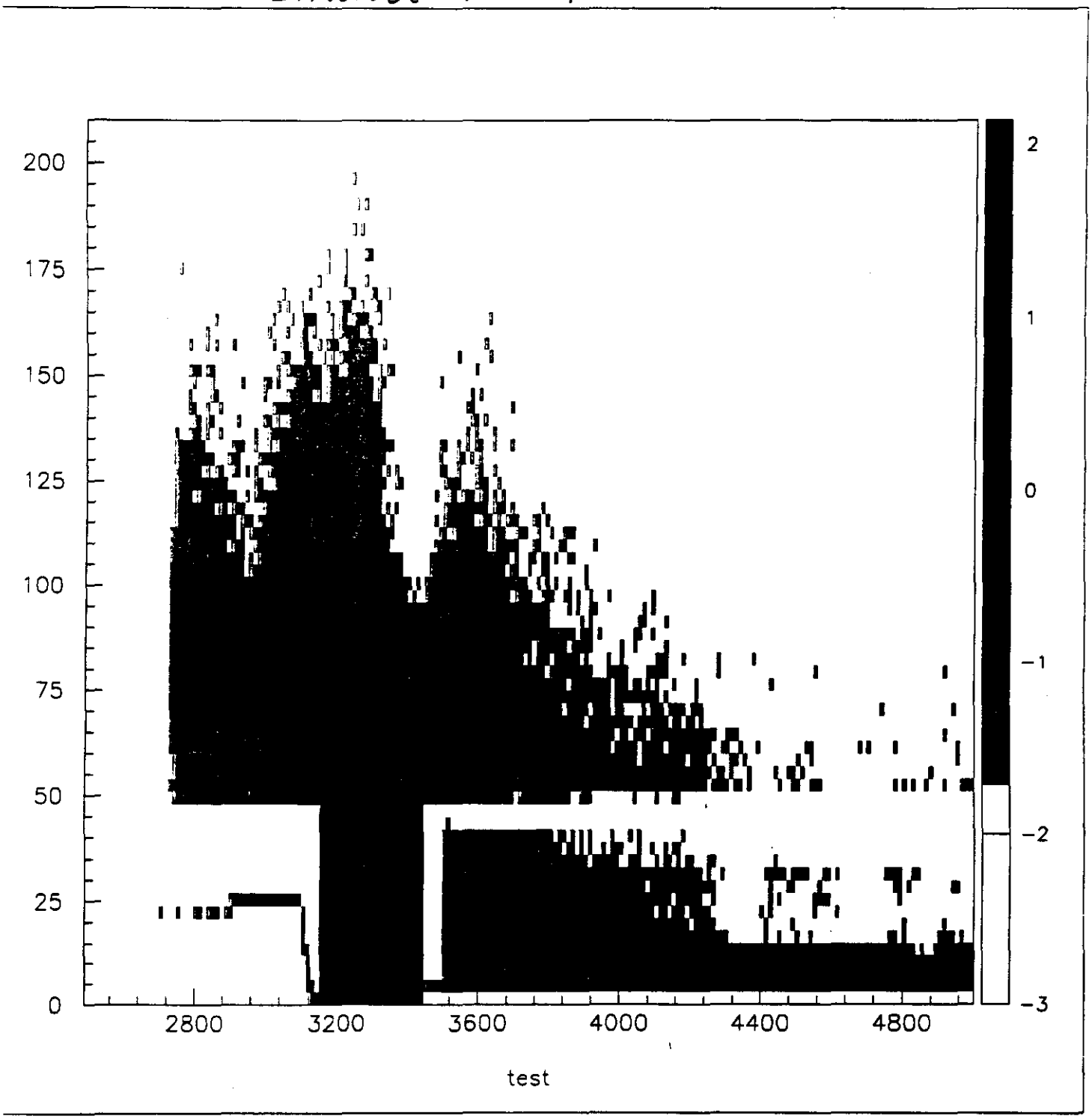
Interaction map with Quad shield



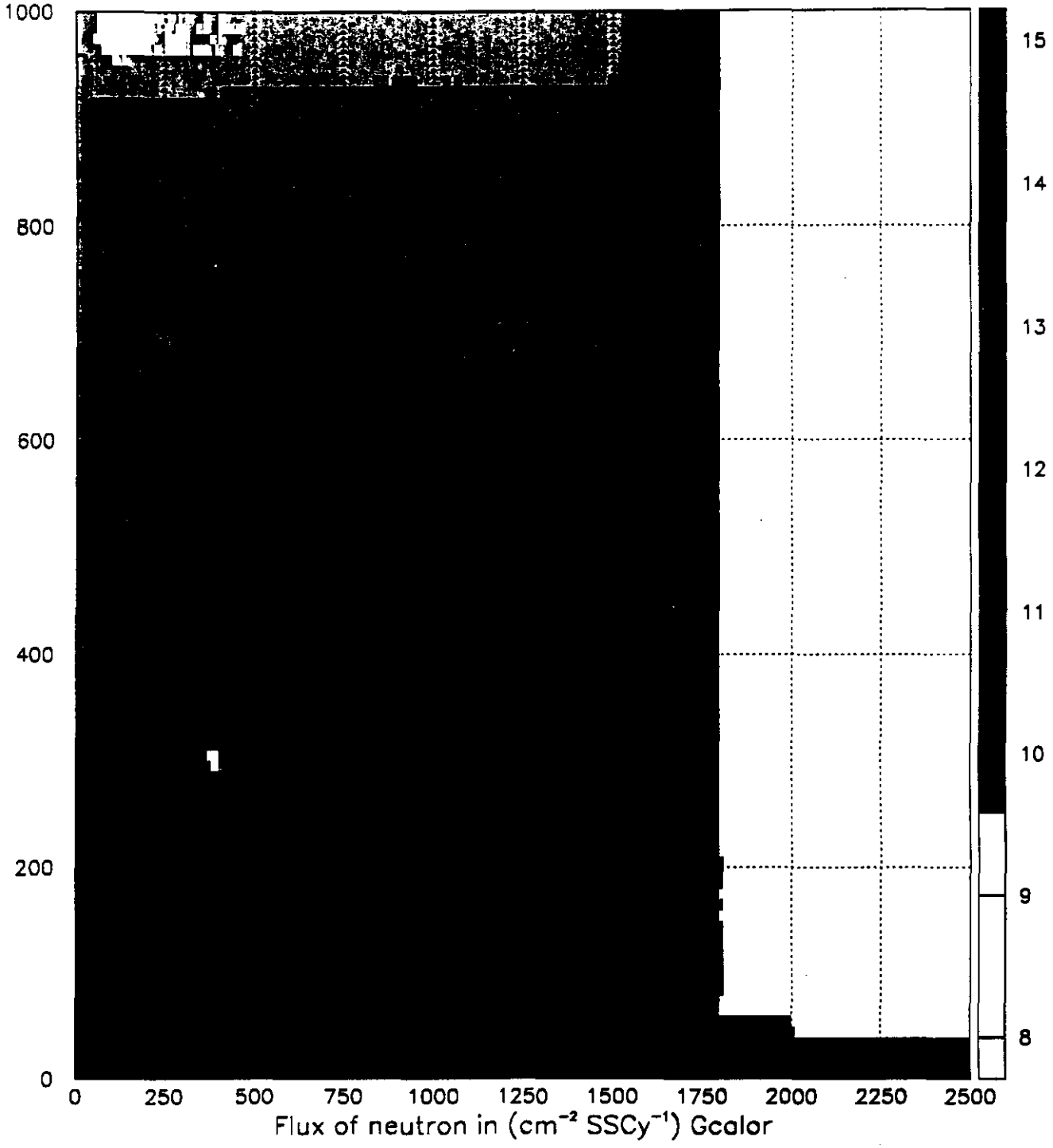
Interaction map with Quad Shield



Interaction map with Quad shield

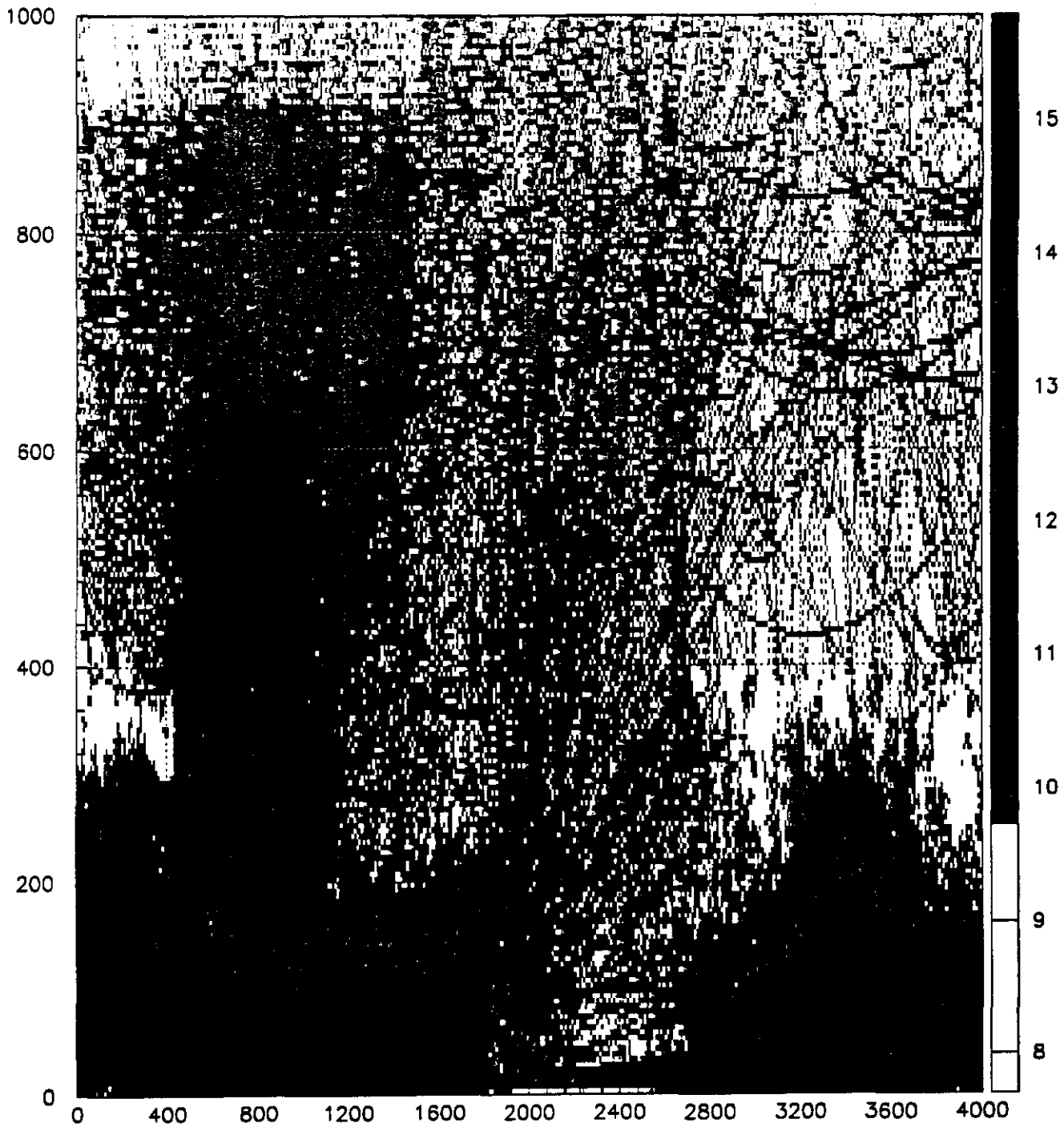


Baseline 1 Interaction map



FISYAK

neutron
~~Interaction~~ map concrete quad, FCAL shield



Flux of neutron in (cm^{-2} $SSCy^{-1}$) Gcalor

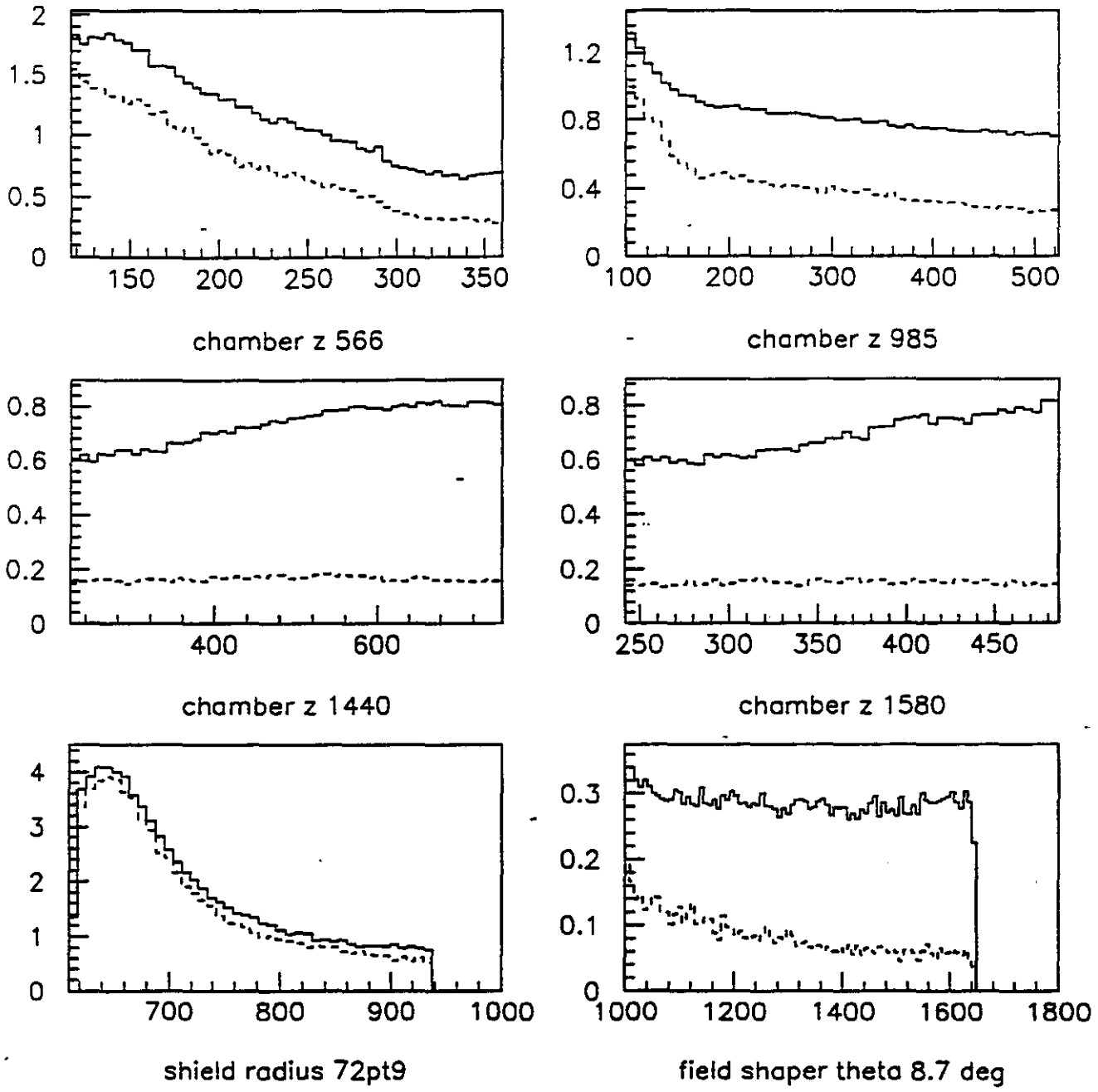
$E_n > 10\,eV$

FISYAK

4 dtujet events

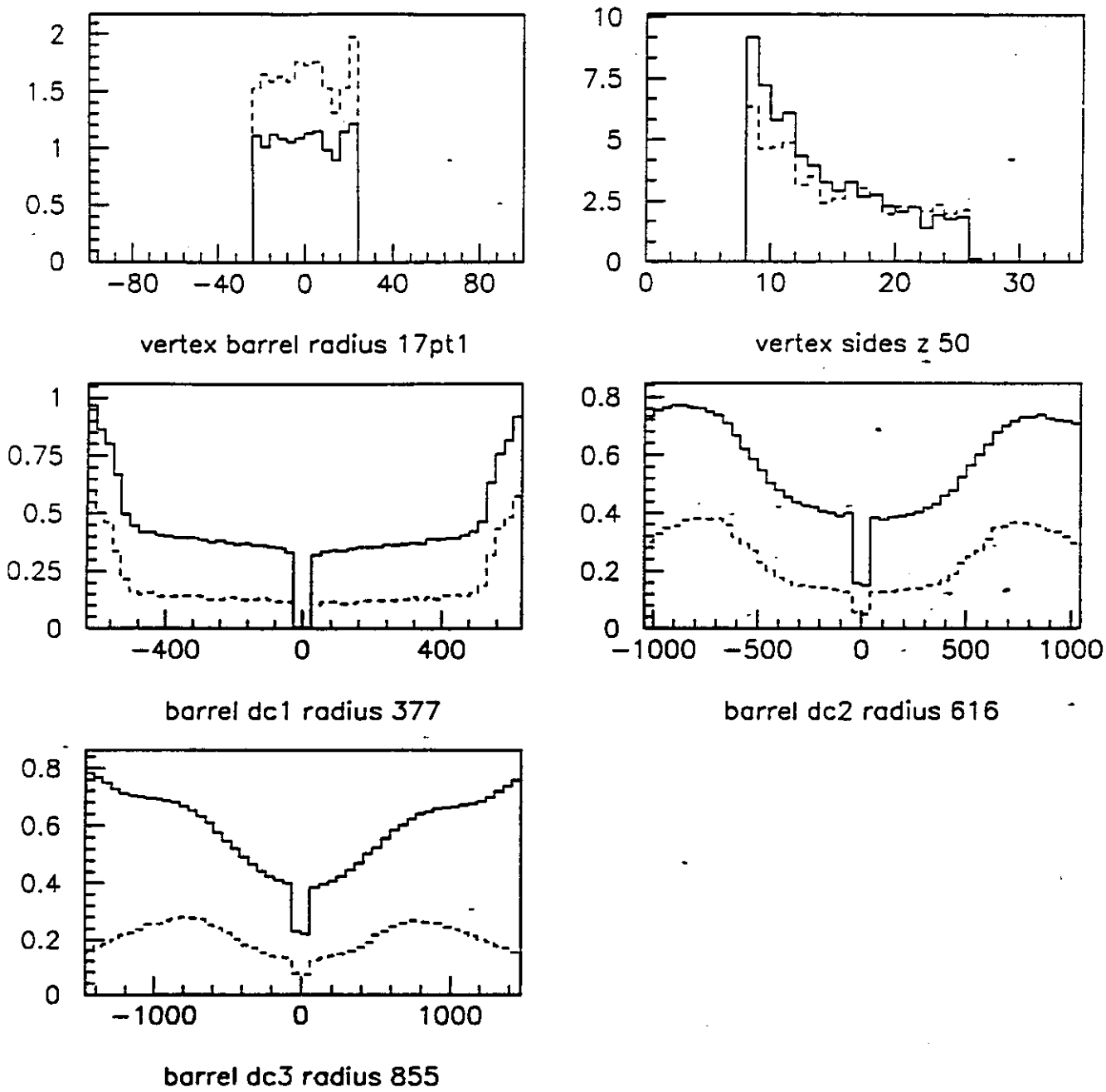
n currents all tin 10^{-1} /cm²/sscy

—— no shield ---- with quad shield



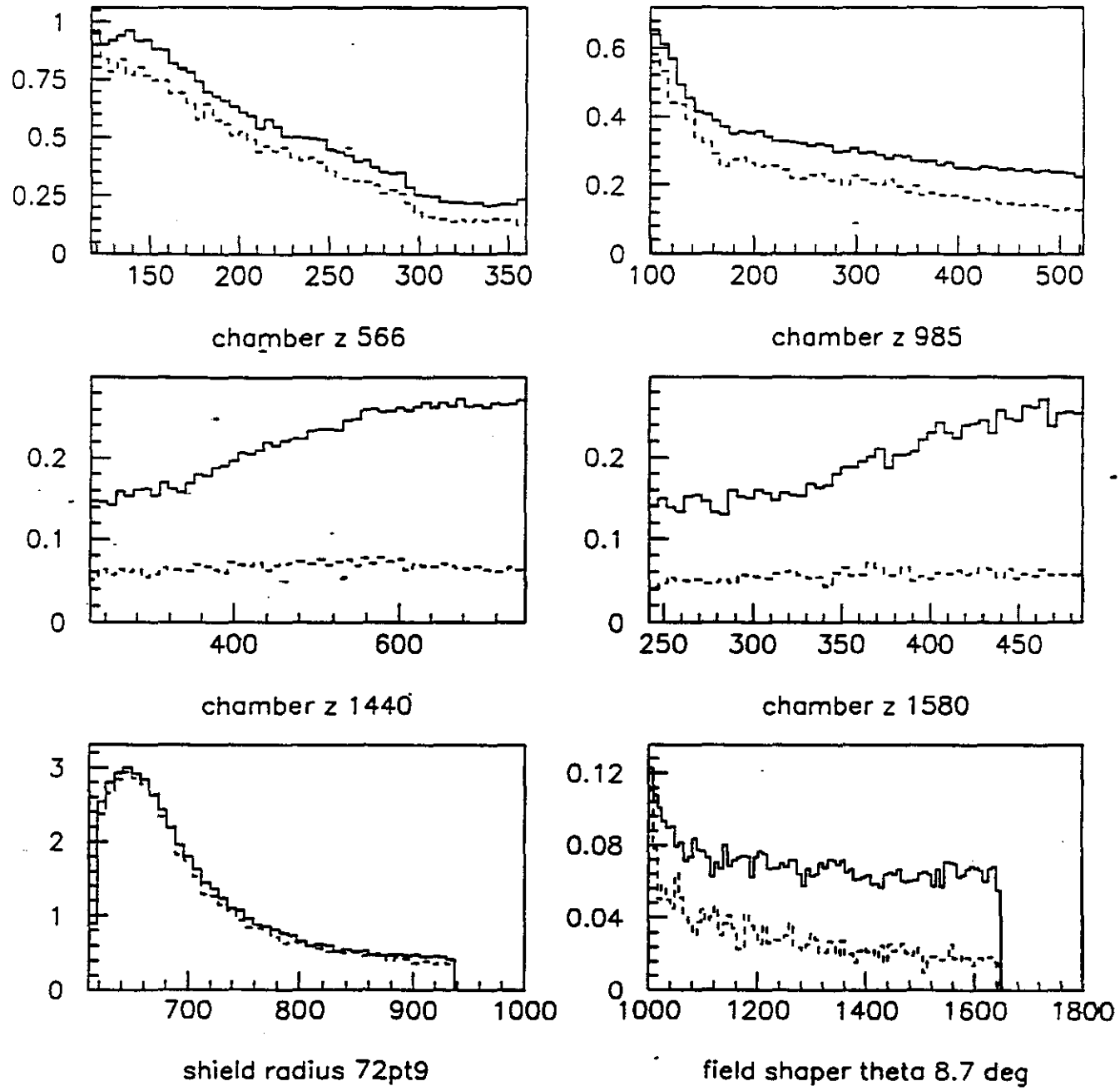
n currents all E_n $10^{12}/cm^2/ssc y$

—— no shield .... with quad shield



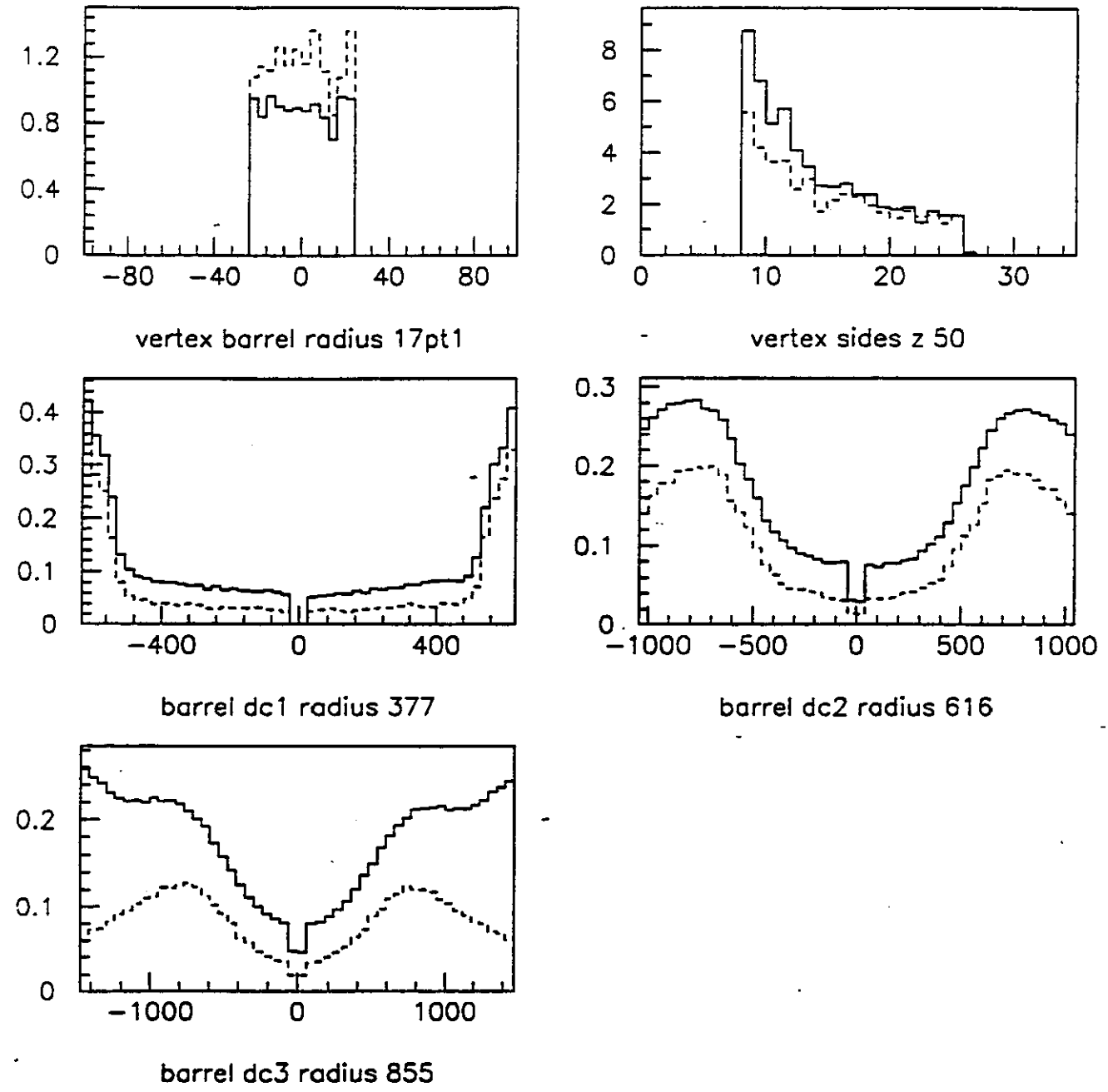
n currents $E_n > 100$ keV $10^{12}/cm^2/ssc\gamma$

— no shield ---- with quad shield



n currents $E_n > 100$ keV $10^{12}/cm^2/SSCy$

— no shield ---- with quad shield



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Presentation by:

Barnett

NO TRANSPARENCIES FOR THIS PRESENTATION

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Presentation by:

Gary Sanders

INTERNATIONAL AGREEMENTS

1. GOVERNMENT TO GOVERNMENT

2. INTERLABORATORY AGREEMENTS

3. ATTACHMENTS TO ILA

4. MEMORANDA OF UNDERSTANDING BETWEEN GEM AND THE INSTITUTION, DOMESTIC OR FOREIGN

FIRST ILA'S AND ATTACHMENTS FOR NEAR TERM ARE IN PREPARATION.

TNRLC FUNDING TO UNIVERSITIES

1. TNRLC ACTIONS WILL BE PUBLIC DURING FEBRUARY.

2. GEM WILL MAKE UP SHORTFALLS TO THE GROUPS NOT FULLY FUNDED IN OUR BASELINE FY93 R&D PLAN.

3. I WILL SEND THAT MONEY TO UNIVERSITIES THROUGH DIEBOLD AND O'FALLON AT DOE BY WRITING A LETTER THROUGH FRED GILMAN.

4. I WILL SIMULTANEOUSLY SEND EACH GRANTEE A FAX WITH INSTRUCTIONS FOR A BRIEF PROPOSAL TO BE SENT TO DOE, WITH AN ENDORSEMENT LETTER FROM ME.

5. MONEY SHOULD BE AVAILABLE ON SAME SCHEDULE AS TNRLC MONEY.

PLEASE PROVIDE ME INPUT ON WHETHER GEM SHOULD PUT ALL UNIVERSITIES ON AN APRIL 1 FISCAL YEAR TO MATCH TNRLC CYCLE SO WE DO NOT EXPERIENCE THE DROUGHT WE HAVE JUST HAD. THEN I WILL BRING YOUR INPUT TO THE EXECUTIVE COMMITTEE.

GEM RESPONSIBILITY MATRIX

1. BARRY AND I SENT ABOUT 85 LETTERS OUT TO ALL GEM INSTITUTIONS TO KICK OFF DISCUSSION OF GEM DETECTOR CONSTRUCTION RESPONSIBILITIES, RESOURCES AND COSTS.

2. LARGE FRACTION OF RESPONSES ARE IN, BUT MANY ARE STILL IN PROCESS.

3. FINAL RESULT OF THIS PROCESS WILL BE INDIVIDUAL MOU'S WITH EACH INSTITUTION.

PROJECT MANAGEMENT PLAN

1. DRAFT COMPLETED.

2. COLLABORATION ORGANIZATION AND GOVERNANCE UNDER DISCUSSION. DRAFT BEING REVIEWED FIRST BY SPOKESMEN, COLLAB. COUNCIL CHAIR AND CHAIRMAN OF ORGANIZATION COMMITTEE. WHEN COMMENTS ARE INCLUDED, DRAFT WILL BE CIRCULATED TO EXECUTIVE COMMITTEE AND MORE WIDELY.

3. ROLE OF MANAGEMENT, REPORTING TO LAB AND DOE, MECHANISM FOR REVIEWING AND MODIFYING DESIGN, PROCESS OF INTERNATIONAL CONTRIBUTIONS DEFINED.

SCHEDULE STATUS

1. MAGNET RFP WAS 4 MONTHS LATE DUE TO SSCL REVIEW. MAGNET GROUP IS USING SEVERAL SCHEDULE RECOVERY STRATEGIES TO REGAIN THIS CRITICAL PATH.

2. PB/MK IS DOING EVERYTHING IT CAN TO DELAY THE UNDERGROUND HALL 3-9 MONTHS!!!

3. MIKE HARRIS IS BEING QUITE RIGID IN FIGHTING THESE DELAYS.

4. MAGNET SCHEDULE LAST WEEK REWORKED TO RECOVER 3 MONTHS IN NEGATIVE SLACK. THIS INVOLVES ADOPTING MINIMAL MAGNET MAPPING INTO BASELINE PLAN WITH ANALYTIC USE OF SENSORS AFTER COMMISSIONING. WE ARE AWAITING FIELD REQUIREMENTS DEFINITION TO CHECK THIS DECISION.

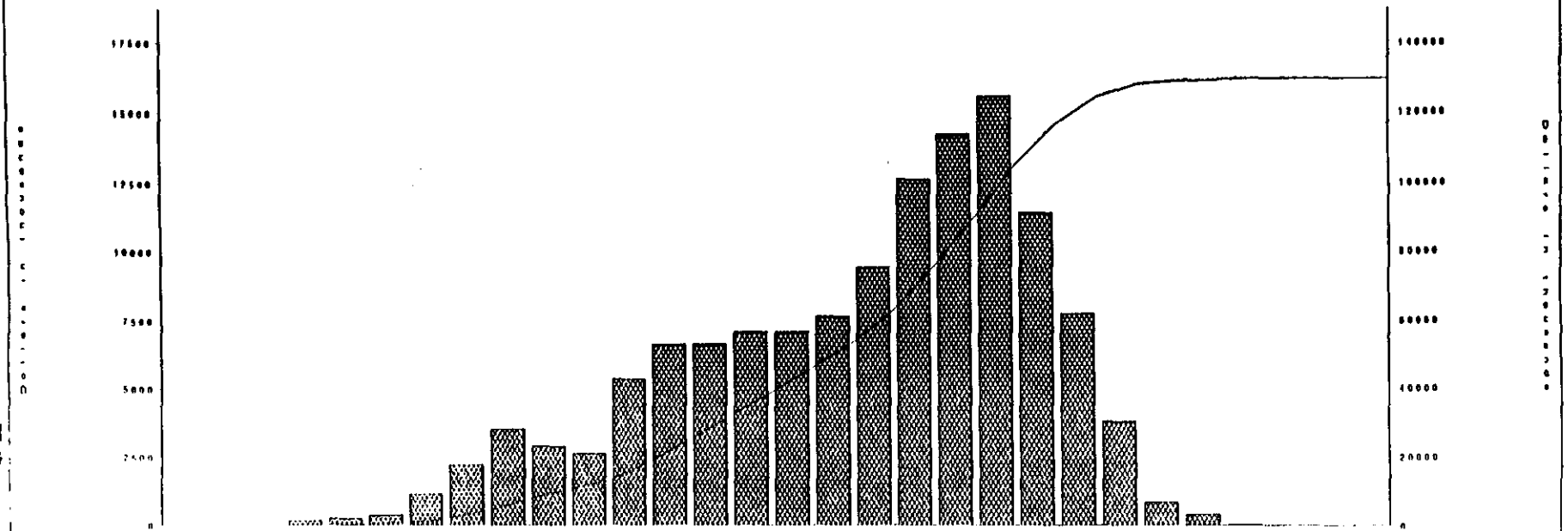
5. DELAY IN INSTALLATION OF FFS HAS BEEN ADOPTED TO RECOVER EARLY FUNDS ALLOCATION TO OTHER SYSTEMS ALLOWING ADVANCE IN OTHER ACTIVITIES AND ADDITIONAL UNDERGROUND SPACE DURING INSTALLATION.

6. CALORIMETER AND MUON SCHEDULES MAY WELL BE CRITICAL AND ARE UNDER VIGOROUS STUDIES. TRANSITION FROM TDR TO PROTOTYPE TESTS TO CONSTRUCTION APPEARS CRITICAL.

OPEN PLAN (R)
Report: GEM_COS1

GEM DETECTOR
WBS 40 - GEM MAGNET

Date: 3FEB93
Project: MAGNET



	01 OCT 90	01 JAN 91	01 APR 91	01 JUL 91	01 OCT 91	01 JAN 92	01 APR 92	01 JUL 92	01 OCT 92	01 JAN 93	01 APR 93	01 JUL 93	01 OCT 93	01 JAN 94	01 APR 94	01 JUL 94	01 OCT 94	01 JAN 95	01 APR 95	01 JUL 95	01 OCT 95	01 JAN 96	01 APR 96	01 JUL 96	01 OCT 96	01 JAN 97	01 APR 97	01 JUL 97	01 OCT 97	01 JAN 98
Incr Bud $10k				10	26	37	115	220	352	280	241	532	450	602	707	707	763	849	1202	1422	1557	1130	778	377	83	41	3			
Cum Bud $100k				2	4	8	20	42	77	100	132	185	251	317	388	458	535	620	755	897	1063	1195	1266	1281	1290	1294	1294	1294	1294	1294

WBS 40.01.1	$2,042,615	CONDUCTOR DEVELOPMENT R&D	14SEP92	25FEB94
WBS 40.01.2	$ 527,919	JOINT DEVELOPMENT R&D	15JUL92	22JUN93
WBS 40.01.3	$2,377,402	WINDING DEVELOPMENT R&D	01MAY92	19MAR93
WBS 40.01.4	$ 231,511	COMPOSITE DEVELOPMENT R&D	18JAN93	04JUN93
WBS 40.02.1	$2,097,671	COIL ASSEMBLIES DESIGN	01JUN93	31DEC93
WBS 40.02.2	$ 797,416	FORWARD FIELD SHAPER ASSEMBLY DESIGN	26APR93	20OCT93
WBS 40.02.3	$ 428,819	CENTRAL DETECTOR SUPPORT	04FEB93	22DEC93
WBS 40.02.4	$ 222,121	POWER PROTECTION SYSTEM DESIGN	31MAR93	15DEC93
WBS 40.02.5	$ 857,056	CRYOGENICS DESIGN	30JUL93	05MAY94
WBS 40.02.6	$ 279,539	MAGNET VACUUM SYSTEM DESIGN	01JUN93	01DEC93
WBS 40.02.7	$ 181,864	MAGNET CONTROL SYSTEM DESIGN	04MAY93	21APR94
WBS 40.02.8	$ 148,759	RETURN FIELD MITIGATION DESIGN	01JUN93	04NOV94
WBS 40.02.9	$1,774,554	INSTALLATION AND TESTING DESIGN	19AUG93	02APR96
WBS 40.03.1	$59,033,189	COIL ASSEMBLIES	04MAR93	09SEP96
WBS 40.03.2	$16,523,968	FORWARD FIELD SHAPERS/SPPTS	21OCT93	01MAY96

COST REDUCTION

1. GEM WILL SUBMIT A $500 m FY90$ ESTIMATE ($535 FY92$).

2. VALUE ENGINEERING AND REDUCTIONS IN CONSTRUCTION COSTS MUST BE STUDIED IN MUON, CALORIMETER AND ELECTRONICS, WITH NO SCOPE REDUCTIONS.

3. ITEMS MUST BE IDENTIFIED AS UPGRADES TO BE POSTPONED BEYOND COMMISSIONING. EXAMPLES: LEAVE OUT SOME COOLING ON MAGNET, SOME IRON ON FFS, GANG ELECTRONICS CHANNELS, POSTPONE KRYPTON.

4. STAGING MUST BE STUDIED. LEAVE OUT FFS AND/OR END CAP MUON SYSTEM.

5. EXECUTIVE COMMITTEE WILL DISCUSS NEW SUBSYSTEM TARGETS.

GEM Project Department

GEM June, 1992 Cost Summary
FY92 $

		Electronics	Total
Tracker	31	25	56
LAC	104	21	125
FCAL	15		
Muon	87	24	111
Magnet	127		
Electronics	109		
Comp./Comm.	20		
Interface	15		
PM	16		

These figures are the cost targets in FY92 $ for the TDR exercise.

gs/1-20-93

STATUS OF BASELINE 2 COST ROLLUP

TRACKER	$28.1 million
CALORIMETERS	$147.8 m
MUON	$110.1 m
MAGNET	$129.4 m
ELECTRONICS	$90 m
COMPUTER/CONTROLS	$20 m
INTERFACE SYSTEMS	$25 m
PROJECT MANAGEMENT	$28.8 m
	$579.2 m FY92

FY90$ $500 m = FY92$ $535.5 m

RECALL JUNE, 1992 ROLLUP $524 m FY92$

CALORIMETER + CALORIMETER ELECTRONICS HAS GROWN ABOUT $27 m. ABOUT HALF OF THIS FROM TRACKER RADIUS INCREASE AND IMPROVED EM PERFORMANCE

ELECTRONICS REDUCED $18m

INTERFACE SYSTEMS GREW $10 m DUE TO SHIELDING AND OTHER ITEMS.

PM AND SUBSYSTEM MANAGEMENT AT SSC GREW $10 m AFTER CORRECTION IN APPLICATION OF SSC LABOR BURDEN.

GEM Project Department

GEM Technical, Cost, Schedule Baseline Reviews for TDR

1/20	GEM Cost/Schedule
1/21	GEM Eng./Integration
1/22	GEM Services
1/27	Magnet Cost/Schedule
2/18	GEM Cost/Schedule
2/19	GEM Eng./Integration
2/23	Calorimeter Cost/Schedule
2/24	Electronics ~~Cost/Schedule~~ Design
2/25	GEM ES&H
2/26	Muon Cost/Schedule → may change
3/4	Interface Systems Cost/Schedule
3/8	Tracker Cost/Schedule
3/9	Tracker Design Review
3/10	Electronics Cost/Schedule
3/15	GEM Engineering/Integration
3/16	Muon Design Review
3/17	Calorimeter Design Review
3/23	GEM ES&H

Design and ES&H Reviews will be attended by outside reviewers

gs/1-20-93

OFFICE SPACE AT SSC

1. GEM Project and Group B have had less than 50 cubicles during 1992. No consistent space was available for the Collaboration.

2. GEM now has space assigned of nearly 110 very small cubicles (8'x10').

3. Mike Marx and I have pooled our space for the Project, local physics group and Collaboration.

4. We will arrange for all engineers, visitors, physicists, commuters to have contiguous space organized by activities (calorimeter, computing, muon,...).

5. Space will be provided for commuting collaborators as shared space. Our goal is that those who are hear with reasonable duty factor will have consistent space so things can be left in a drawer, and so we will know where people are.

6. Additional conference rooms and meeting space will be developed.

7. A single reception and coffee pot area will be developed for all GEM.

8. Census developed by Mike and Dorothy and Holly and I shows about 150 spaces needed through 1993.

9. We have requested Gilman provide additional space. He agrees to try this quickly.

PROJECT MANAGER'S REPORT

FEBRUARY 4, 1993

gem

γeμ

Presentation by:

Frank Taylor

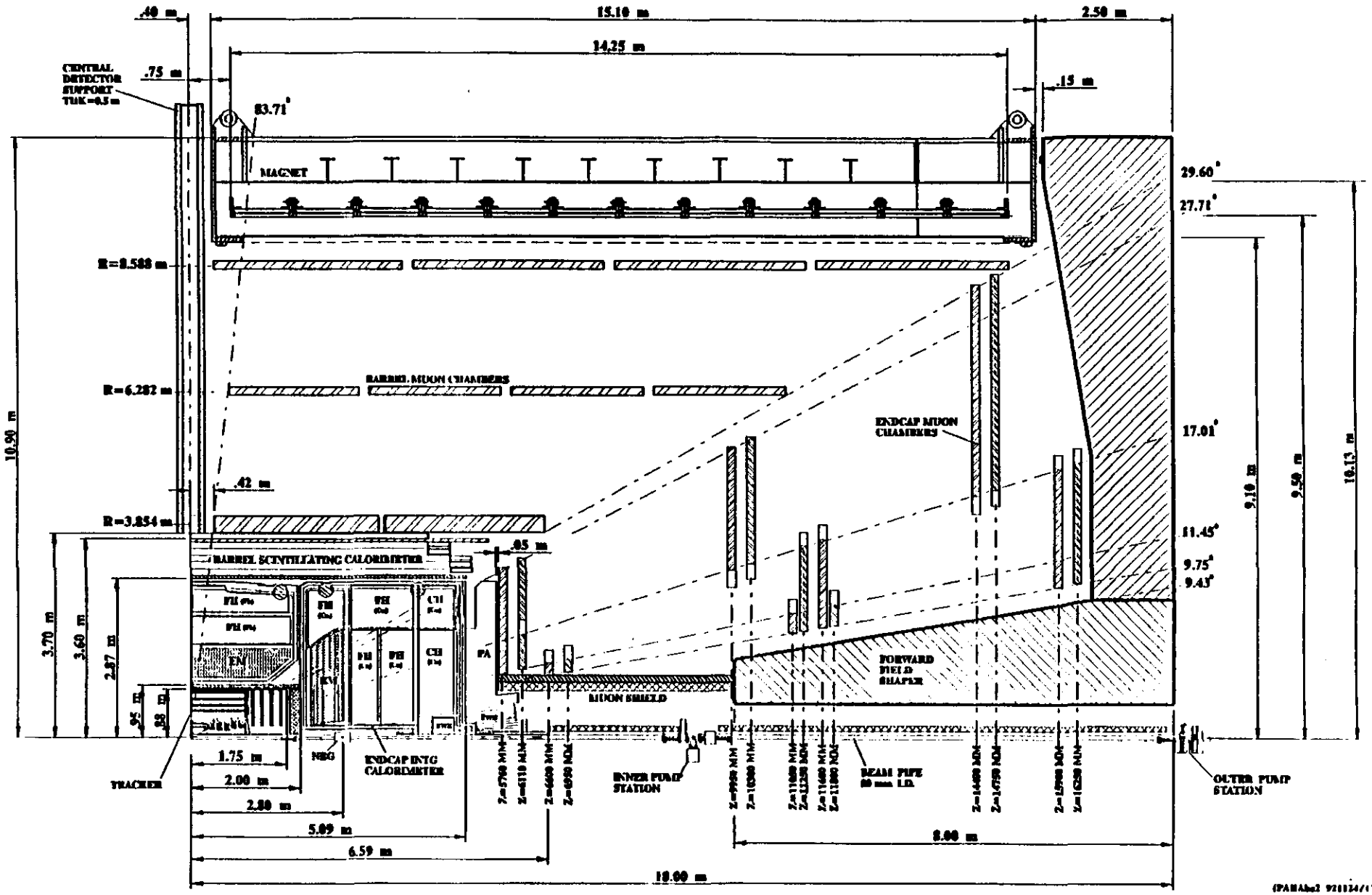
Frank Taylor

FET 1/31/93

The GEM Muon System Technology Choice

- General considerations
- Describe the choices
- Compare performances
- Compare costs

GEM DETECTOR PARAMETERS
BASELINE 2



Elements considered

(1) System Performance

(a) pattern recognition capability
(b) Pt - resolution
(c) Θ and ϕ resolution
(d) Trigger resolution (T_0 and P_t)
(e) Intrinsic rate capability

(2) Technical Risk of System

(a) How well has the R&D program validated the design ?
(b) Any major risks with out feasible backup ?
(c) Complexity of system (number of chambers and channels)
(d) Construction required (e.g. chambers, support structure)

(3) Cost of System

(a) Cost of chambers and contingency
(b) Cost of electronics and risk
(c) Cost of support structure & alignment
(d) Foreign contributions & interests

(4) Strength of the R&D Effort

(a) Short-term R&D effort strong enough (T < TDR) ?
(b) Enough effort invested in backups - if needed ?

(5) Strength of TDR Case

(a) Credible design which meets baseline performance, costs ?
(b) Any unanswered questions ?

Muon Chambers - R&D FY92

Technology	Chamber size	TTR date
Round Drift Tubes:		
RDT-JINR	1 m x 4 m x 8 layers	7/28/92
RDT-MSU	1.3 m x 3.8 m x 4 layers	9/29/92
Limited Streamer Drift Tubes:		
LSDT	1 m x 4 m x 4 layers	9/22/92
LSDT	1 m x 4 m x 4 layers	10/23/92
Resistive Plate Chambers:		
RPC-INFN	1 m x 2 m x 1 pair (x-y)	9/29/92
RPC-LLNL	1.2 m x 2.4 m x 1 pair (x-y)	1/10/93
Cathode Strip Chambers:		
CSC-BU	0.3 m x 0.4 m x (2x2) layers	RD5-CERN
CSC-BNL	0.5 m x 0.5 m x (2x2) layers	10/20/92
CSC-BNL	1 m x 1.8 m x 2 layers	1/10/93
CSC-UH	0.5 m x 1 m x 3 layers	9/92
CSC-JINR	1.1 m x 1.5 m x 2 layers	10/10/92

Duncanville 1/16-18/93

Recommended Cathode Strip Chambers:

For:

- Barrel and endcap
- Trigger
- Track reconstruction

Effectively made a choice of what problems to solve.

Challenges:

- How to make inexpensive enough to preserve baseline ?
- How to build practical system with good Ω-coverage ?

Rejected the RDT/RPC option:

Why ?

- How to trigger ?
  - RPCs still have rate problems, but promising R&D.
  - No interest in group for a PWC trigger.
- Majority interest in developing the CSCs.

Look at evidence:

Compare technologies:

(1) Chamber operating principle and construction

(2) Layer resolution and factors affecting it

(3) Layout of Baselines 2 (CSC) and 2A (RDT/RPC)

- deployment of chambers
- alignment paths and support structure

(4) Vital statistics - number of chambers, channels

(5) Momentum reconstruction resolution

- low Pt
- high Pt

(6) Trigger resolution (T_0 and P_t)

(7) Rate effects

(8) Major technical risks

(9) Comparison of costs

Cathode Strip Chamber Design:

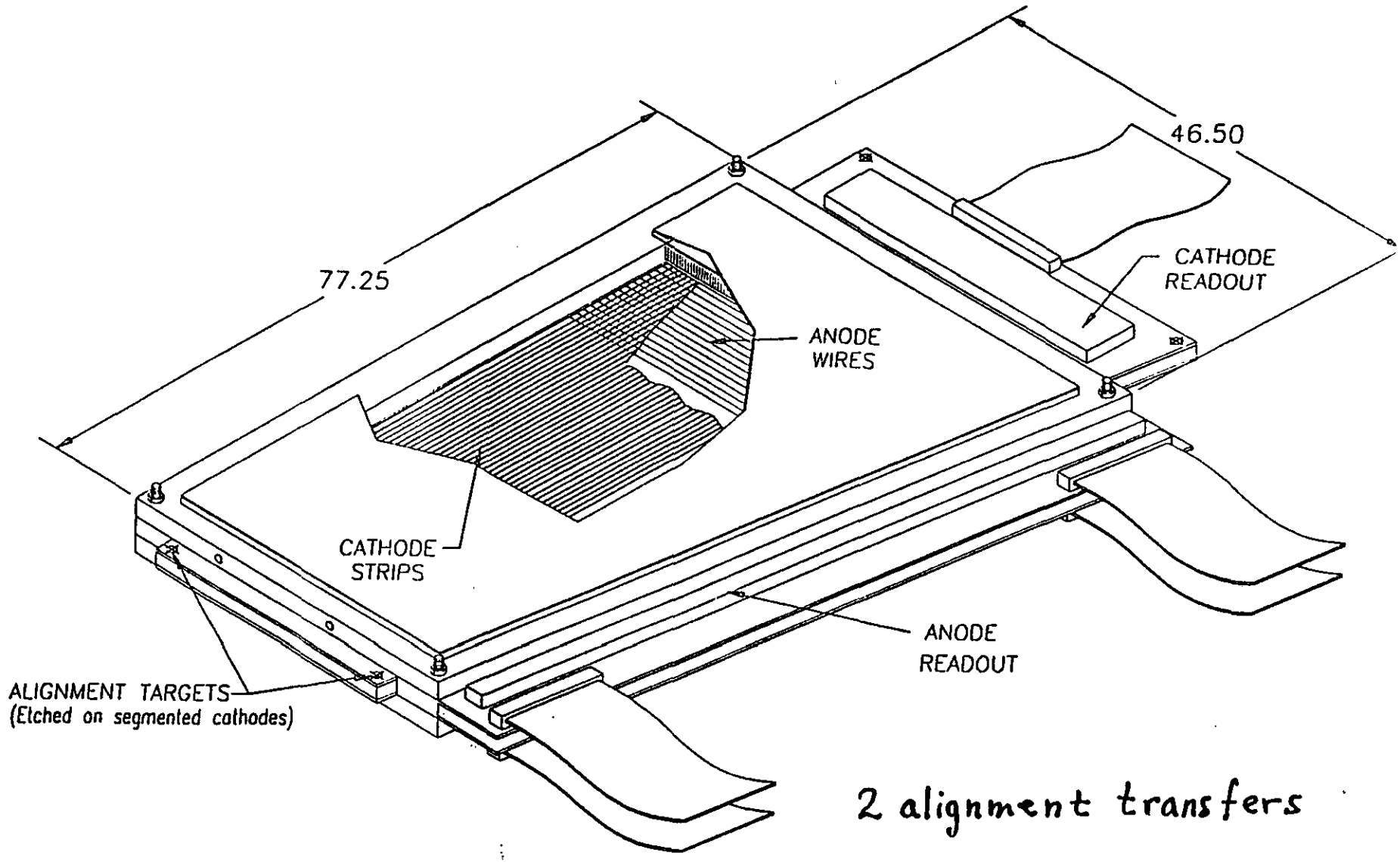
Features:

- anolog readout (noise/channel < few x 10^3 electrons)
- precision cathodes with alignment fixturing
- anode wires for timing and orthogonal coordinate
- position resolution: $\sigma_x < 75$ μm and $\sigma_y < 5$ cm
- ch. - size limited to 1.2 m (wires) x 3.4 m (cathodes)
- radial strip geometry possible for endcaps
- performs all muon functions (triggering and tracking)

Challenge for GEM application:

- implementing elegant concept to scale needed for GEM

Prototype Cathode Strip Chamber



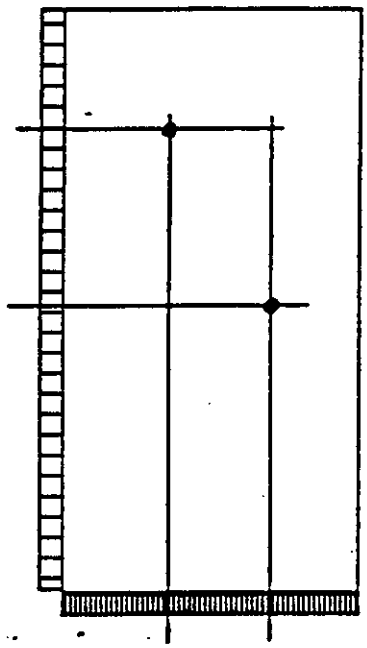
2 alignment transfers

CSC Readout Concept

orthogonal readout
(wires, or dip strips)

fast (30 ns peaking) output
for timing, θ measurement

Could also measure charge to
resolve ambiguities for multimuons
by charge correlation



strip readout

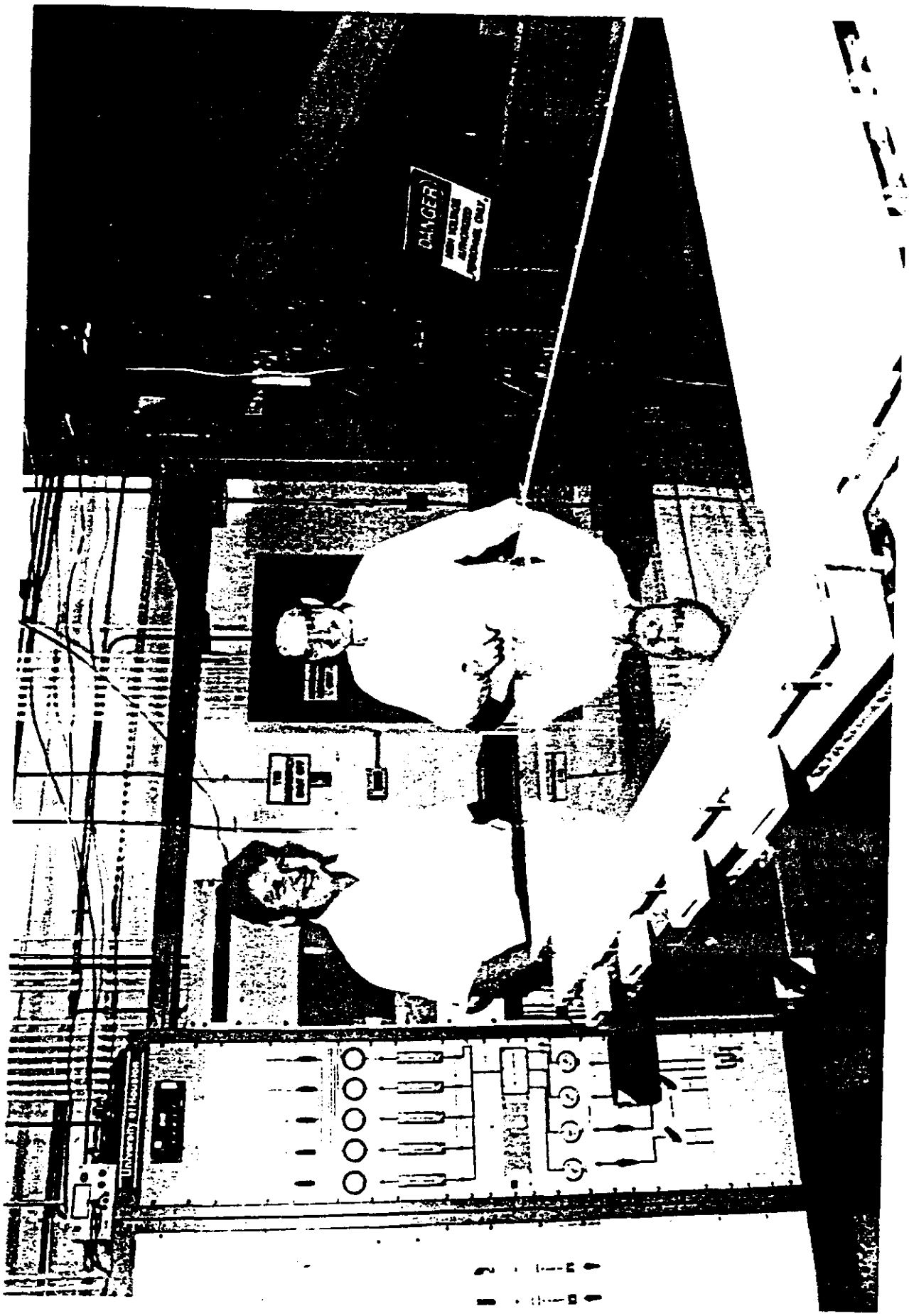
fast (30 ns peaking) output for trigger, timing

slow (300 ns -- 1 μsec peaking) output for
precision charge measurement

- track-and-hold
- Switched capacitor array

3. – energetic dimuons with small opening
le could be produced by a wide range of
resting physics:
energetic Z's
Drell-Yan
decay of neutral scalars

mple: a 500 GeV Z → μμ has a typical
ning angle between the muons of
9 radians, or a separation of 1.1 m at 6 m,
hese muons will frequently hit the same
on detector module.


DANGER

Cathode Strip Chamber

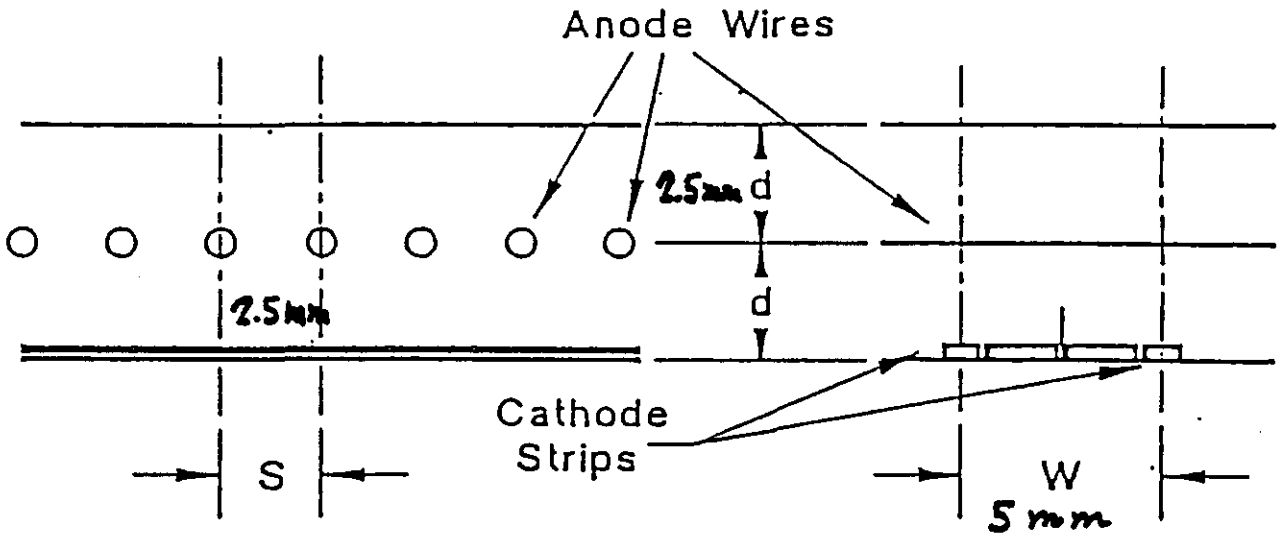
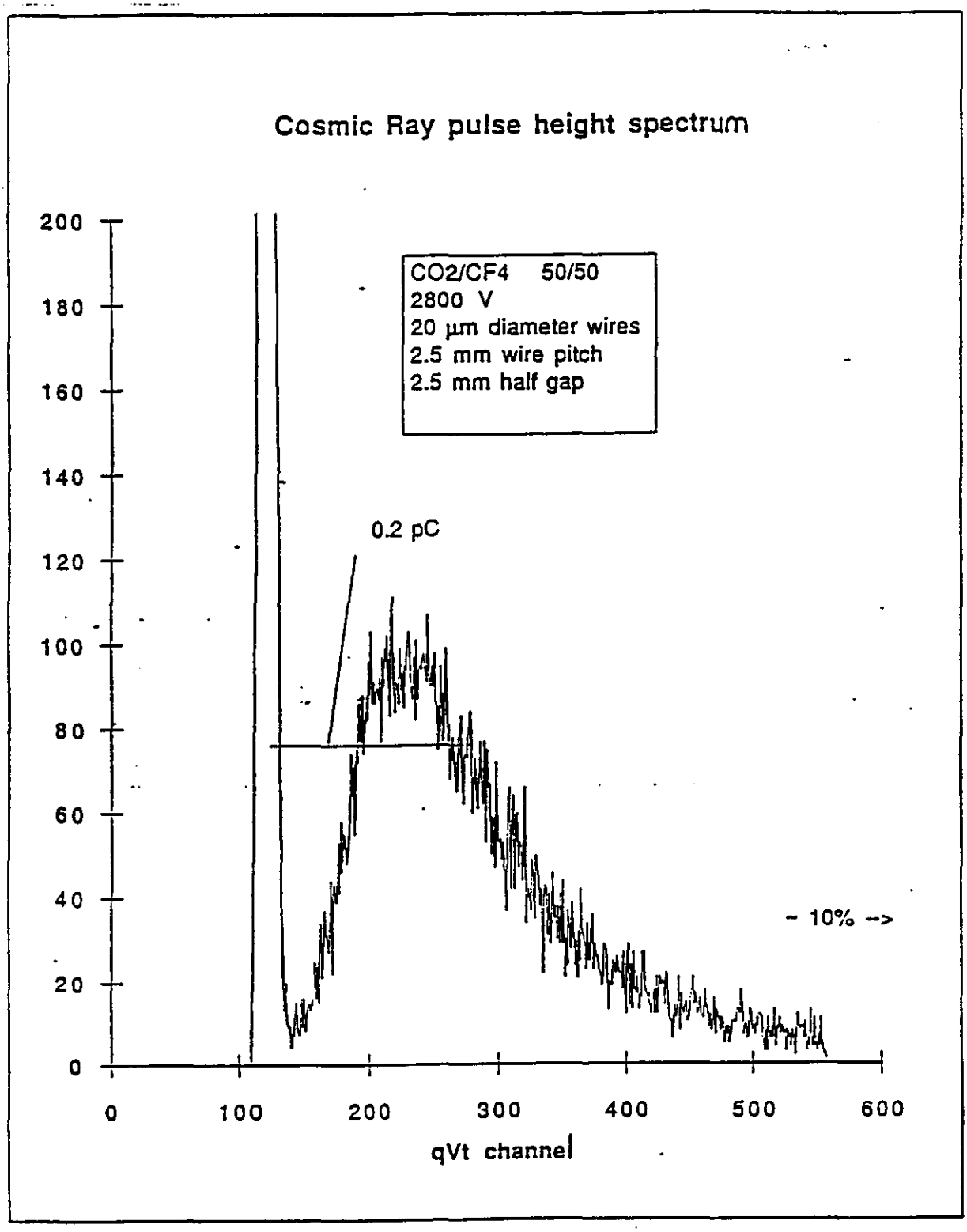
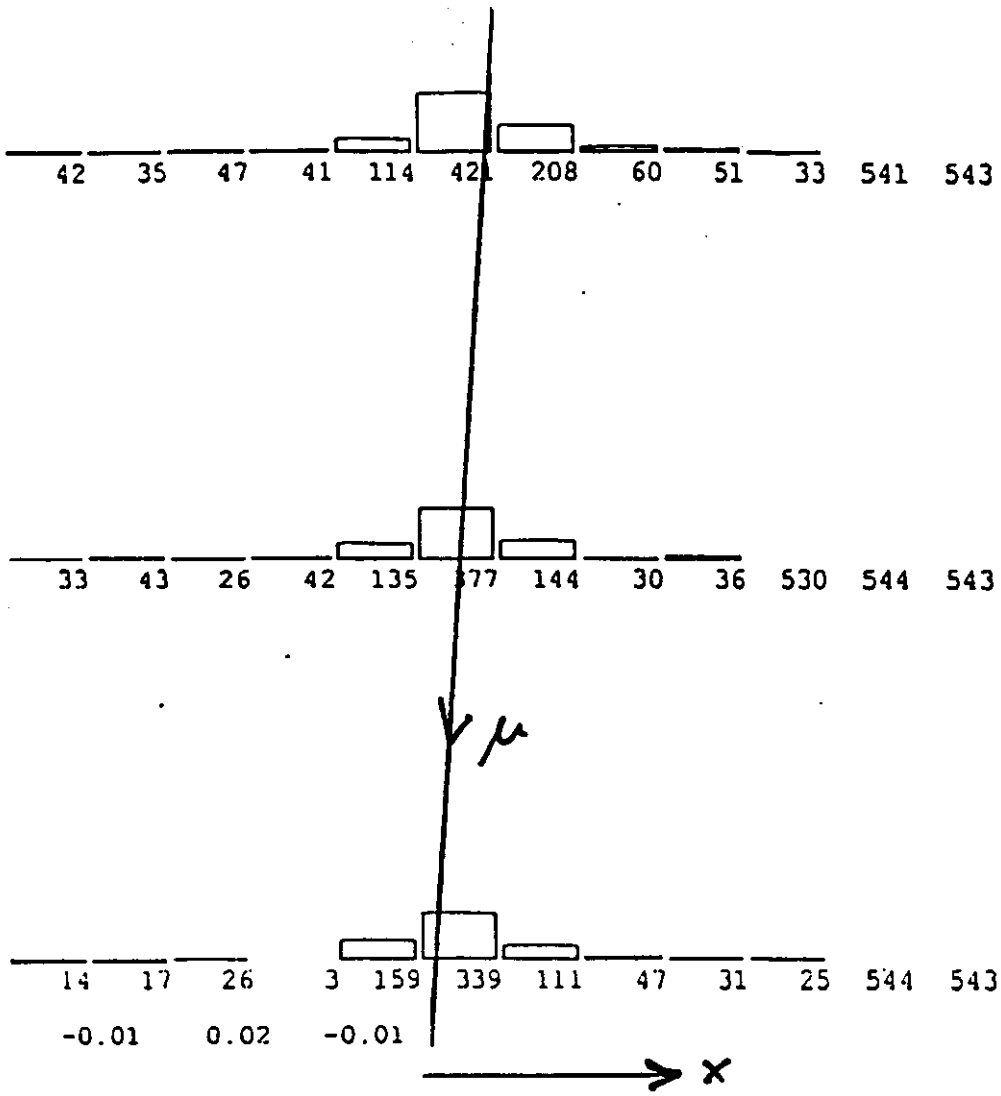


Figure 1: Geometry of the basic cell of the CSC


Cosmic Ray pulse height spectrum
CO2/CF4 50/50
2800 V
20 µm diameter wires
2.5 mm wire pitch
2.5 mm half gap
0.2 pC
~ 10% -->
200
180
160
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
qVt channel

Run#: 666 Events on File: 45442 groups on file: 2
Event#: 4200 Fri, Oct 23, 1992 17:45

UH prototype



position: $x_{cg} = \frac{\sum x_i q_i}{\sum q_i}$ $\qquad x_i = (i)\,\ell_a$

resolution: $\sigma_{cg} \simeq \ell_a \frac{\sigma_{noise}}{Q}\sqrt{2}$ for 3 strips

Round Drift Tube Design:

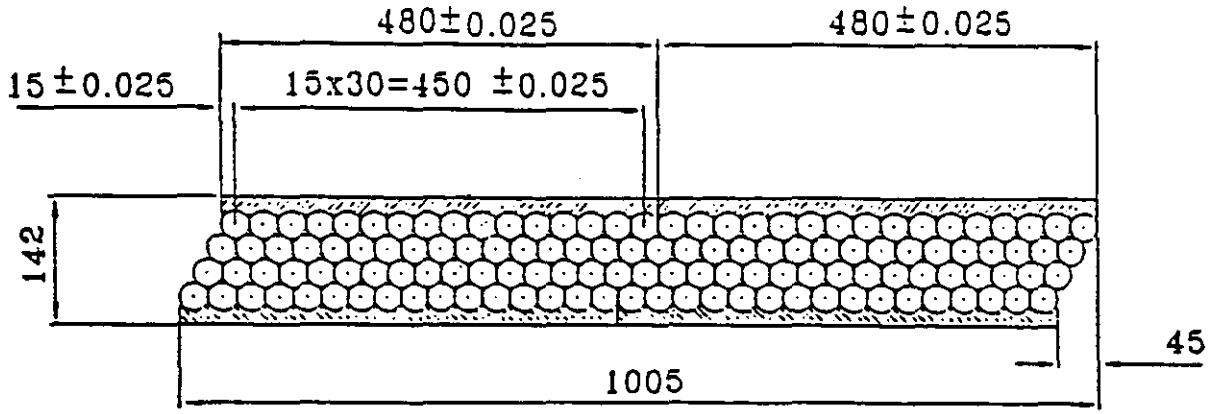
Features:

- drift time measured with cross-checks ($t_1+t_2=T$)
- cylindrical symmetry => L-angle corrections tractable
- rigid light-weight chamber package
- precision possible - wire tension and positioning
- size limitation: 2 to 3 m (endplates) x 4 m (wires)

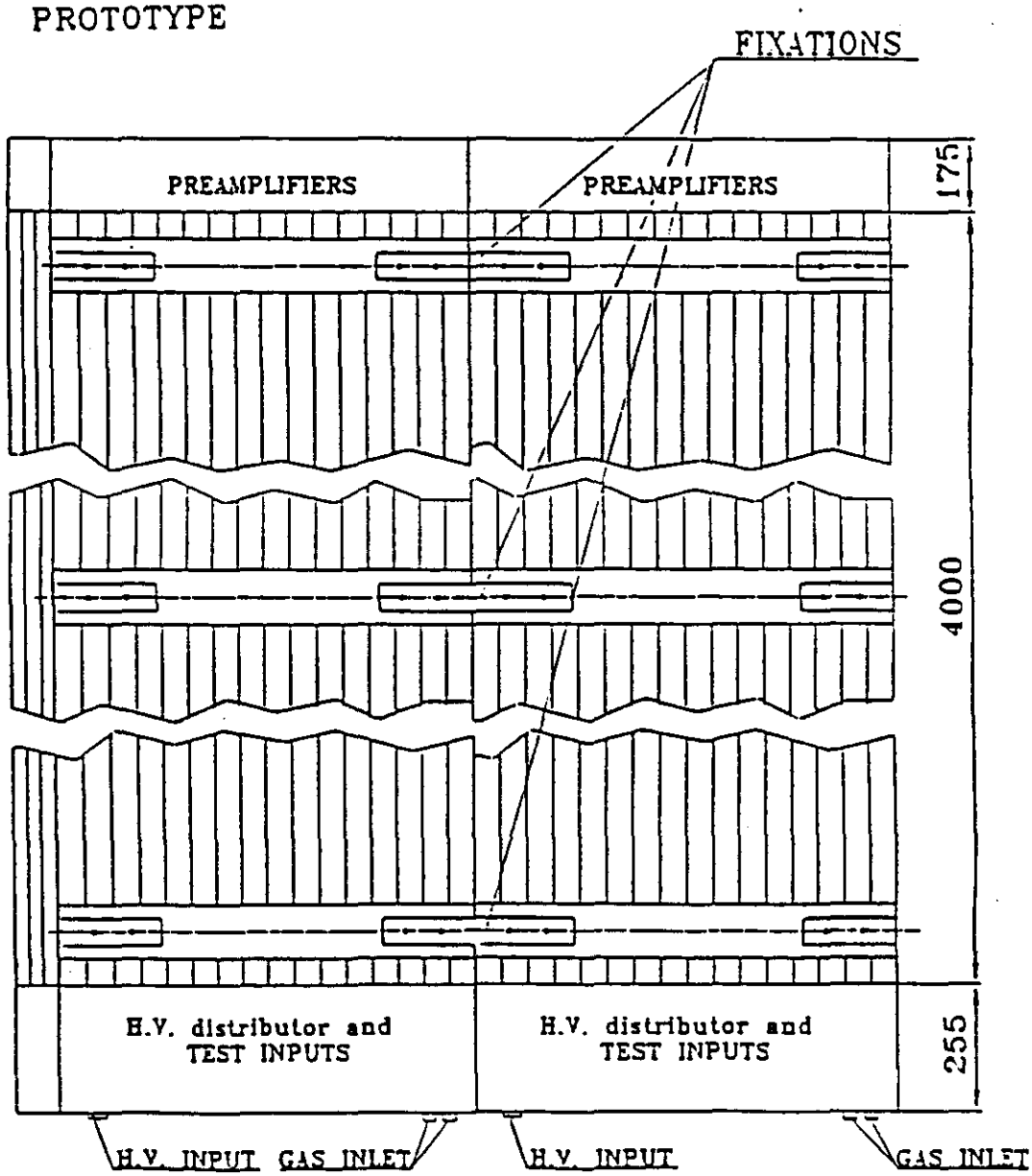
Challenge for GEM application:

- controlling the mechanical alignment error budget

Round Drift Tube



DUBNA PDT PROTOTYPE



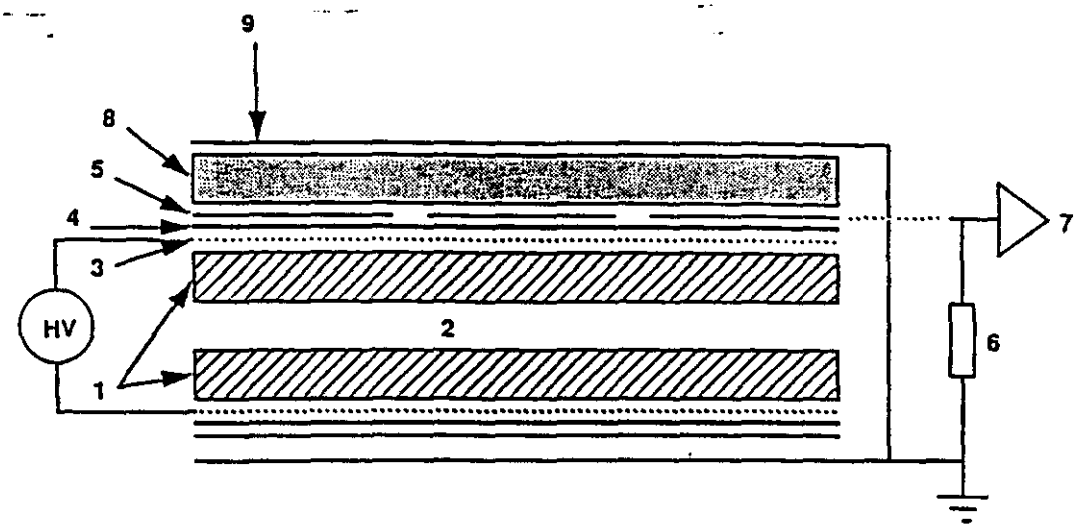
Resistive Plate Chambers:

Features:

- intrinsically fast (at low rates)
- simple construction
- inexpensive
- X-Y readout from gas gap

Challenge for GEM application:

- rate capability < 100 Hz/cm^2 (timing and efficiency)



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

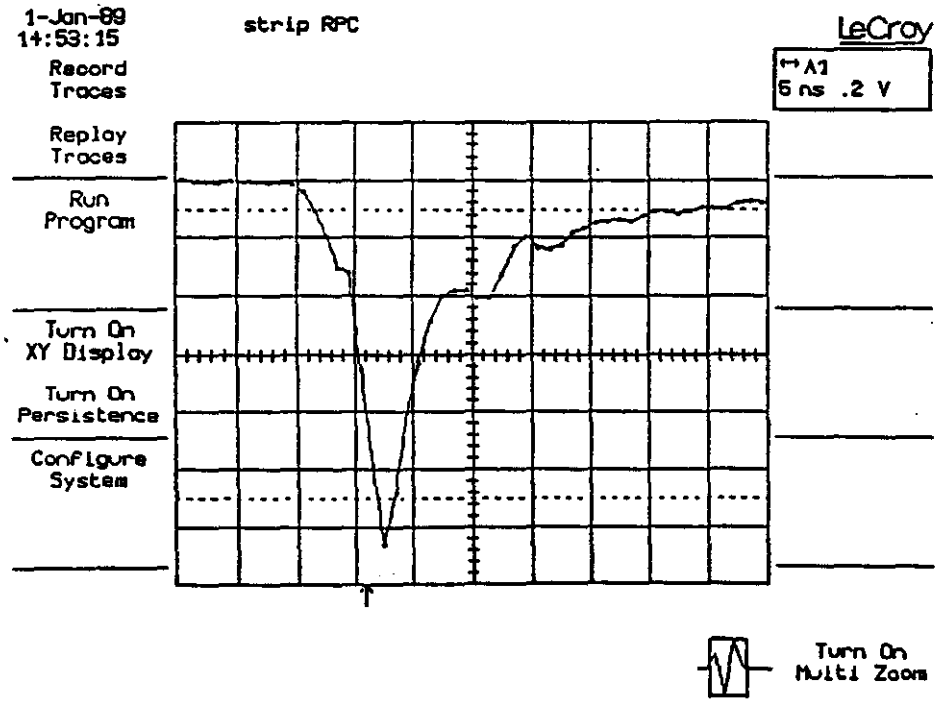
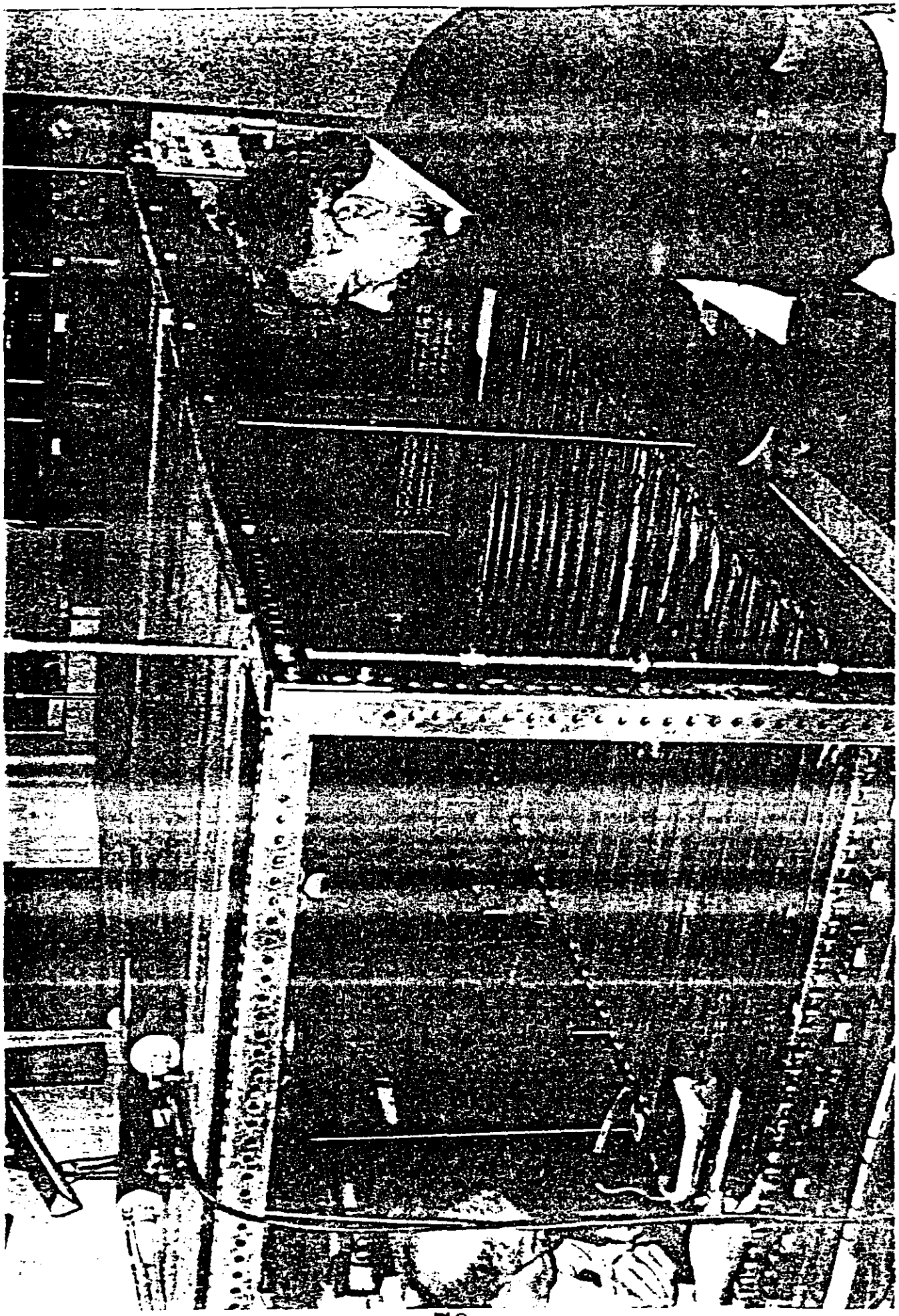


Fig. 5.1



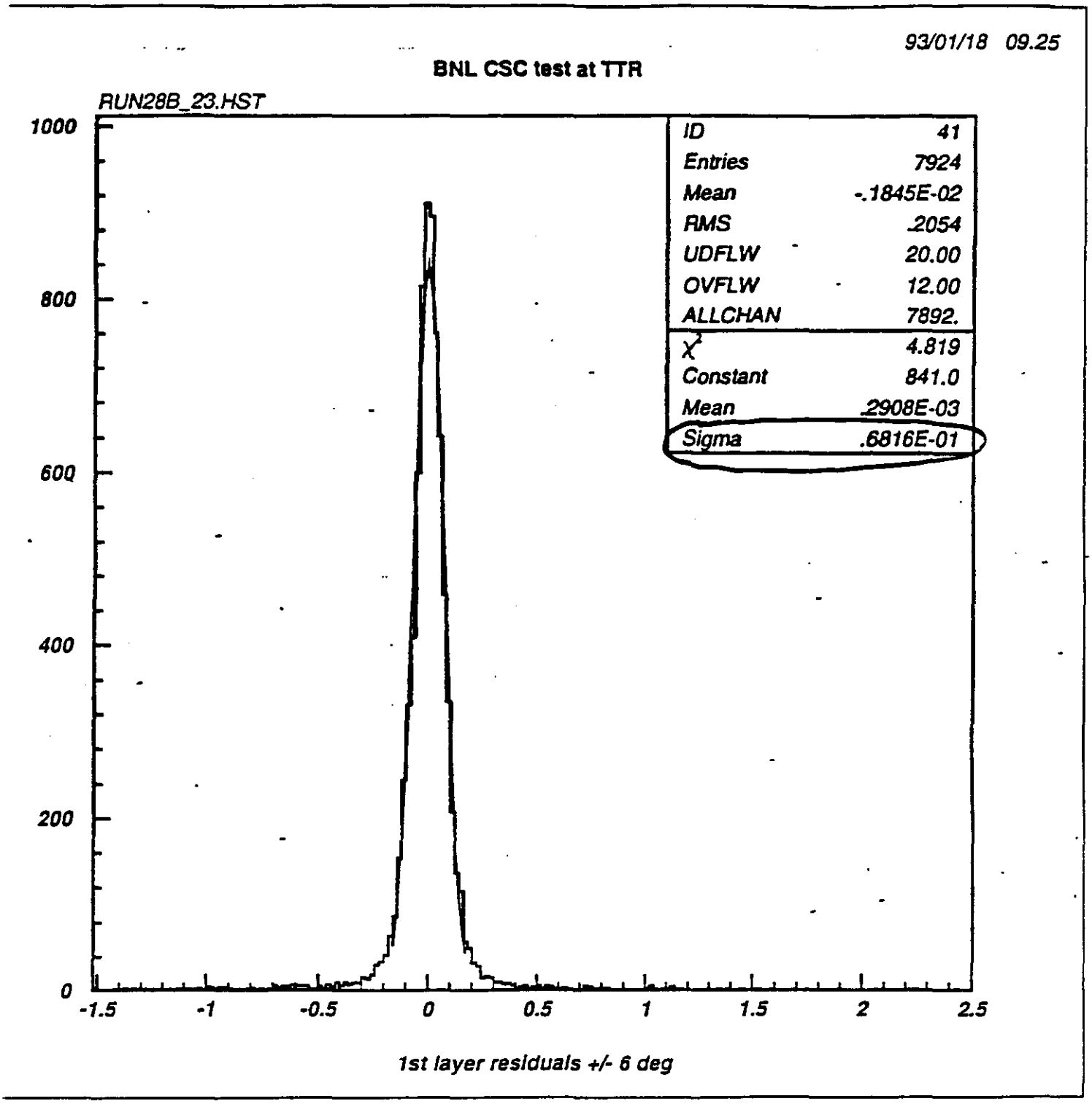
Summary of CSC Resolutions/R&D FY92:

Data on:

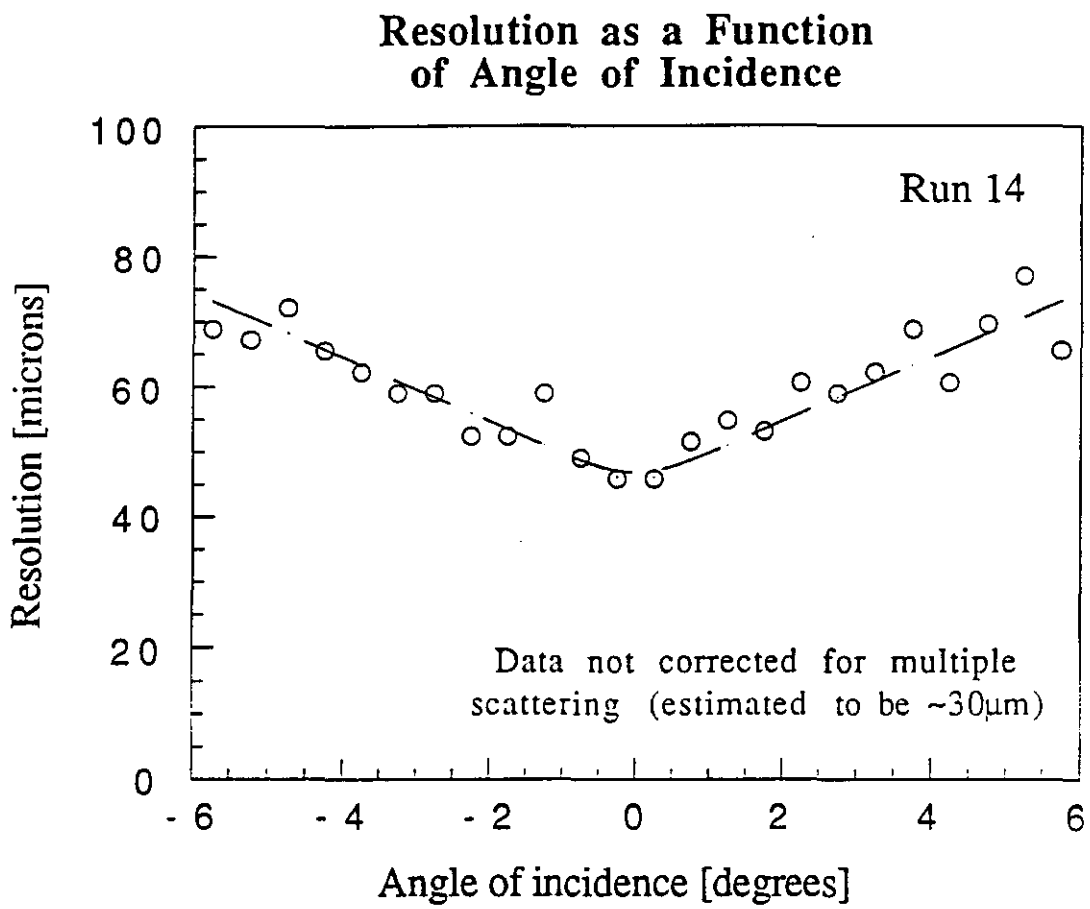
- layer resolution for sagitta measurement
- timing resolution for T_0

Factors affecting resolution:

(1) small (noise limit) and large pulse height
(2) angle of incidence
(3) Lorentz angle effects


93/01/18 09.25
BNL CSC test at TTR
RUN28B_23.HST
ID 41
Entries 7924
Mean -.1845E-02
RMS .2054
UDFLW 20.00
OVFLW 12.00
ALLCHAN 7892.
χ² 4.819
Constant 841.0
Mean .2908E-03
Sigma .6816E-01
1000
800
600
400
200
0
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
1st layer residuals +/- 6 deg

Data from TTR



U H Prototype

Summary of Results (Preliminary)

- Averaged over $\pm \simeq 6°$

HV(kV)	$\sigma(\mu m)$
3.1	74.8 ± 3.9
3.2	72.0 ± 3.5
3.3	56.4 ± 2.0

meets baseline resol'n

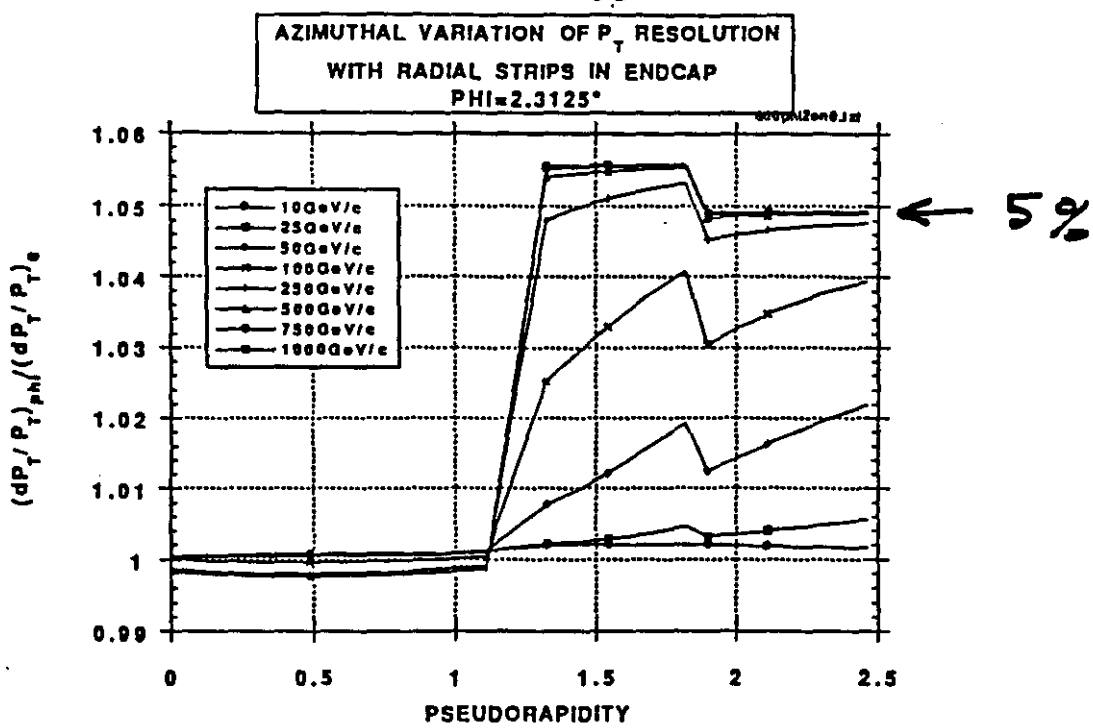
- Averaged over all angles $\pm \simeq 8°$

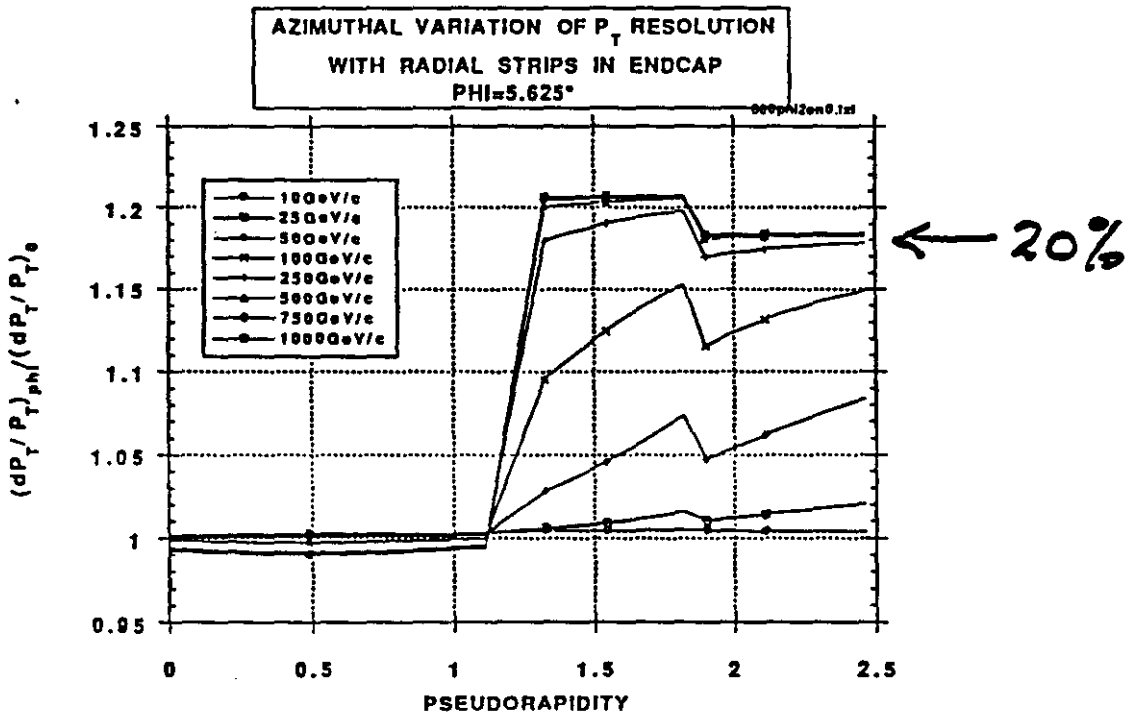
HV(kV)	$\sigma(\mu m)$
3.1	78.9 ± 3.6 (96.3)
3.2	73.2 ± 3.0
3.3	59.7 ± 1.9

- Normal incidence ± 2.0°

HV(kV)	$\sigma(\mu m)$
3.1	66.4 ± 10.7
3.2	62.8 ± 8.6
3.3	37.9 ± 3.0

Geometric Effect for EC





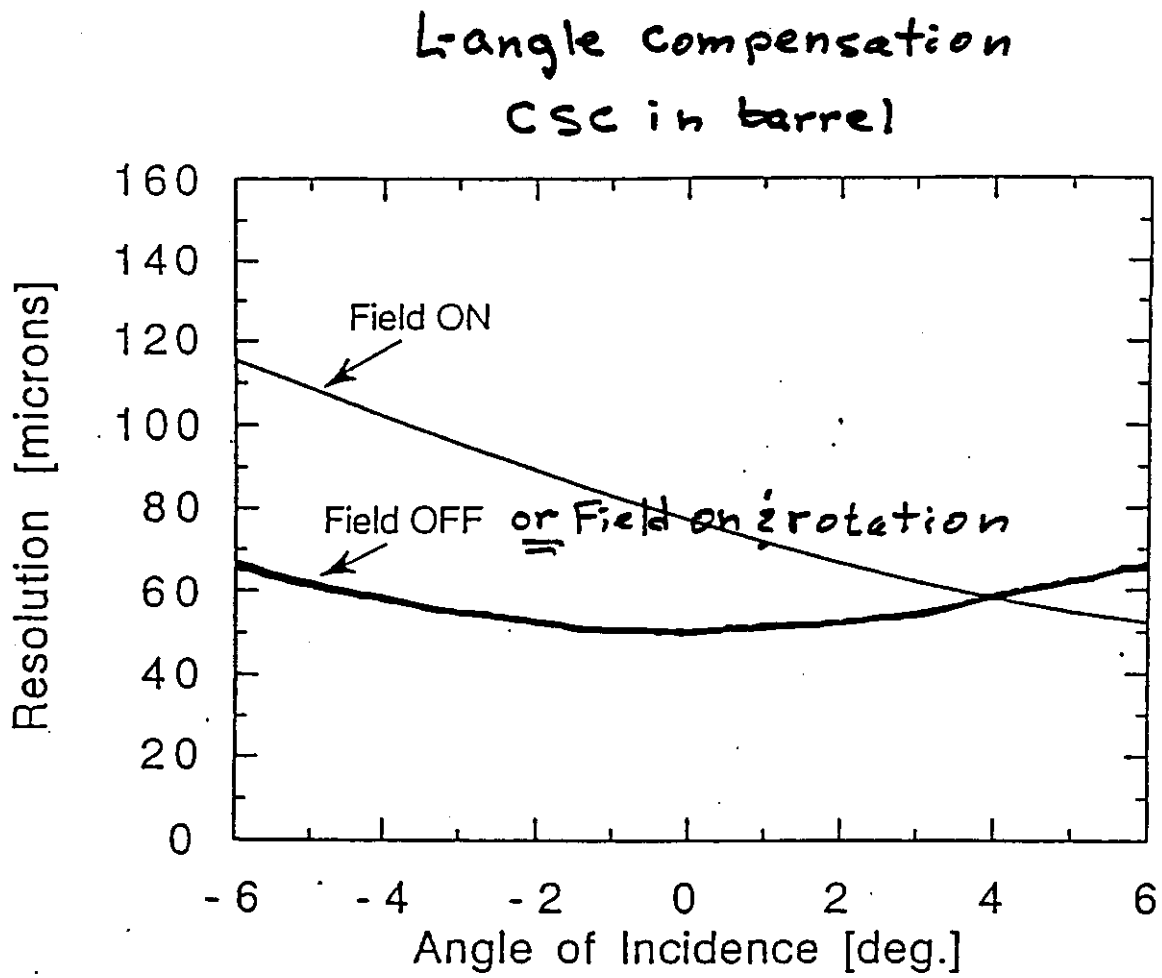


Figure 3: Resolution as a function of incident angle within a sector in a system with a 32-fold symmetry.

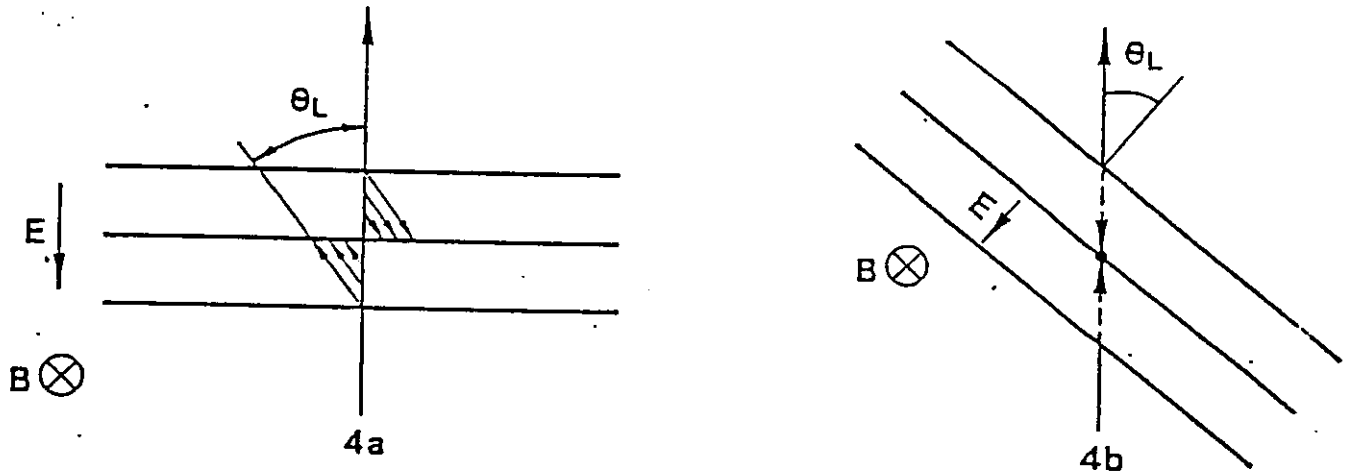


Figure 4: Normal incidence (4a) and compensation by tilting (4b)

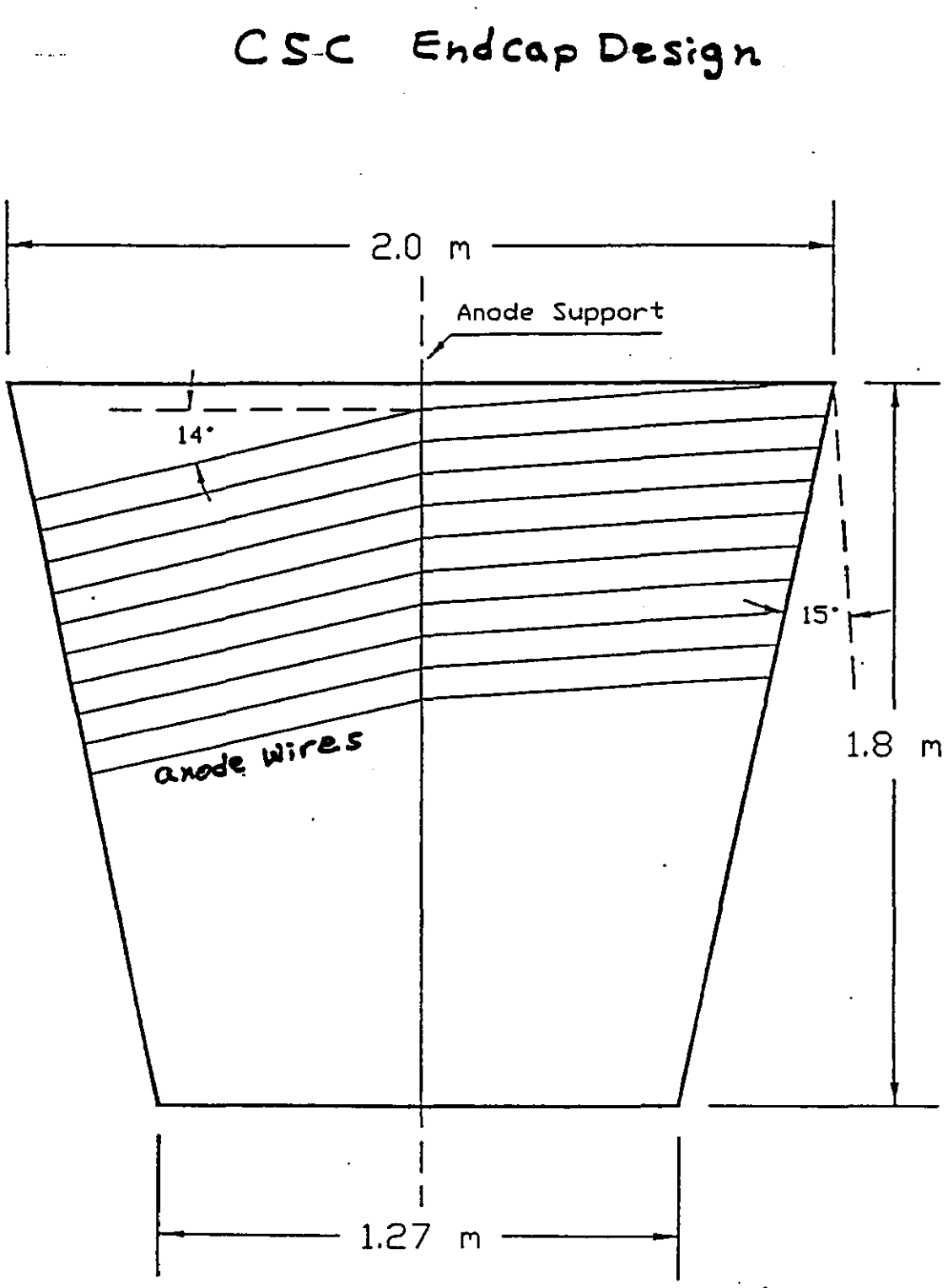
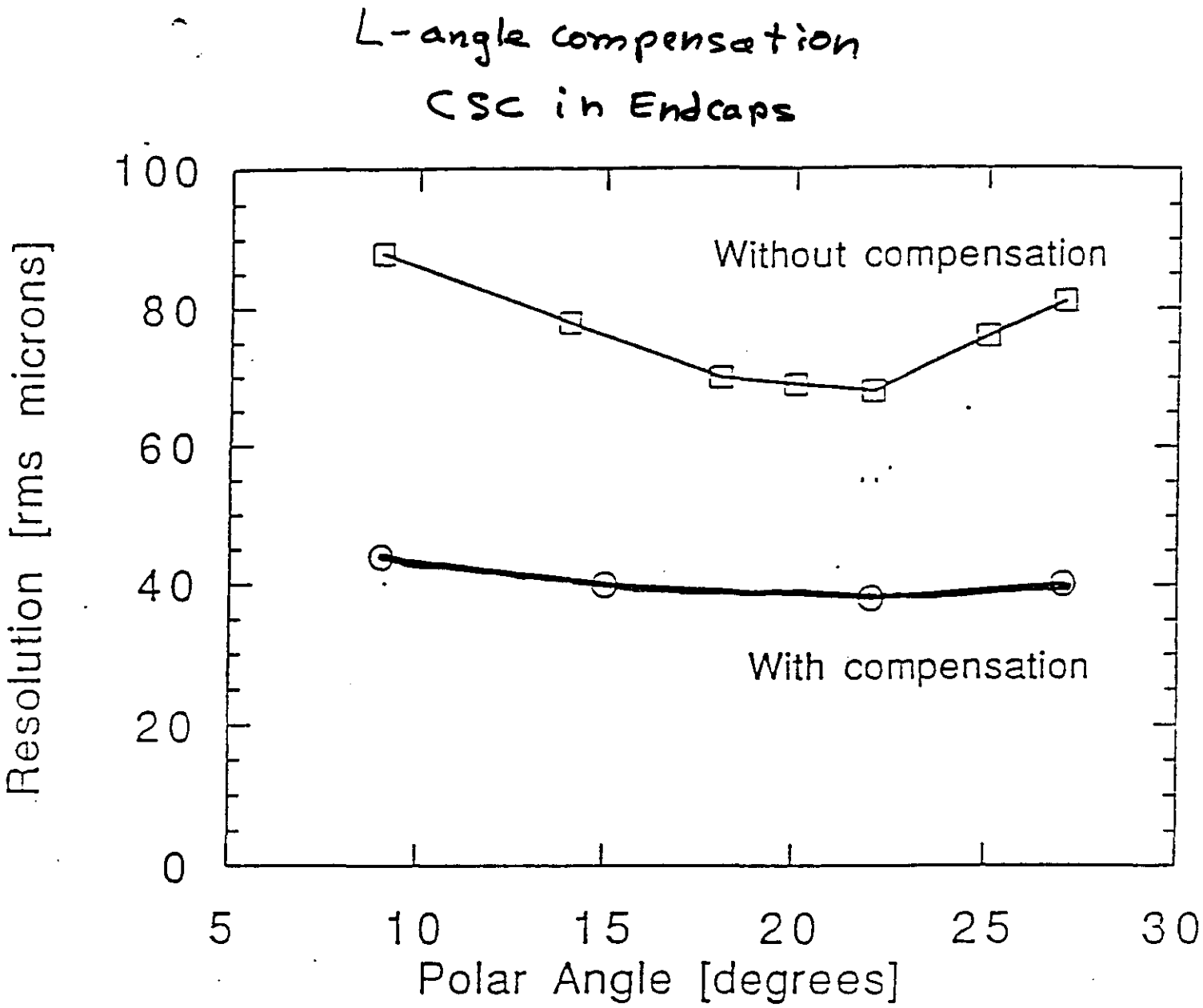
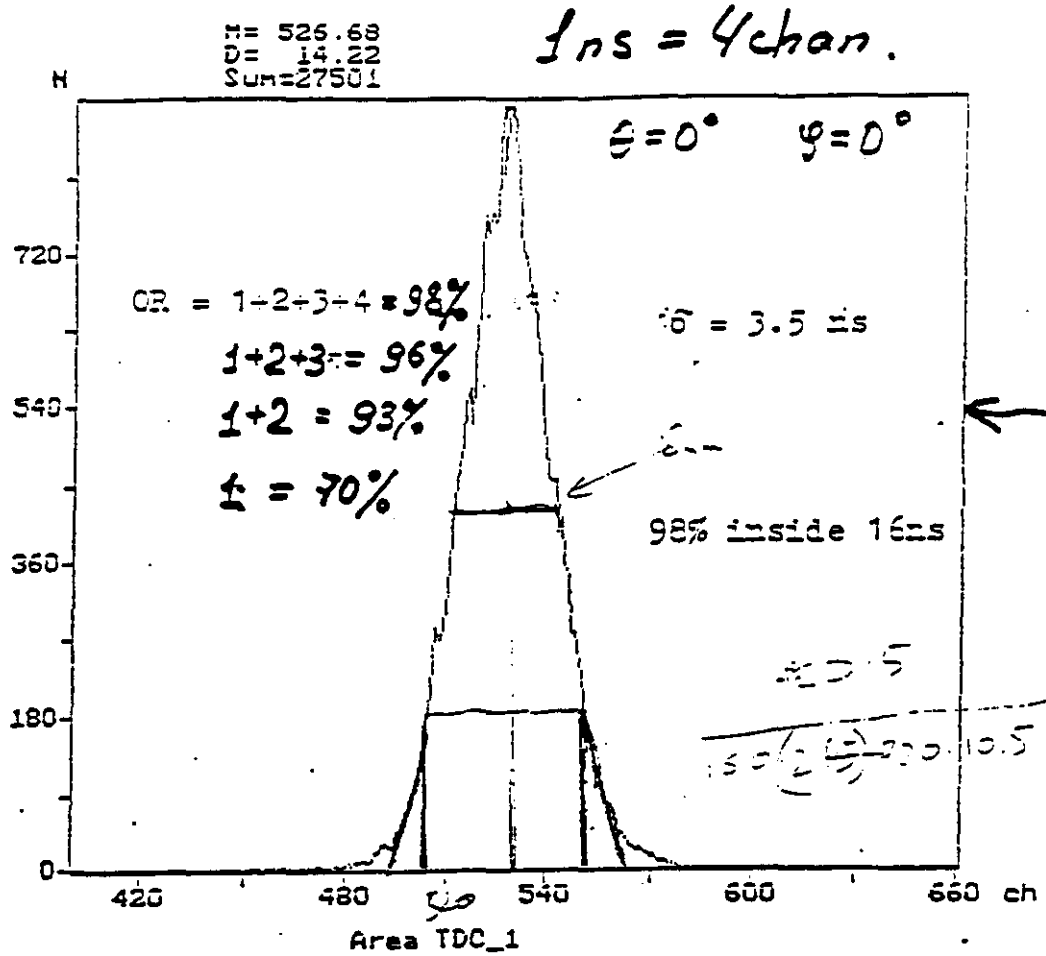
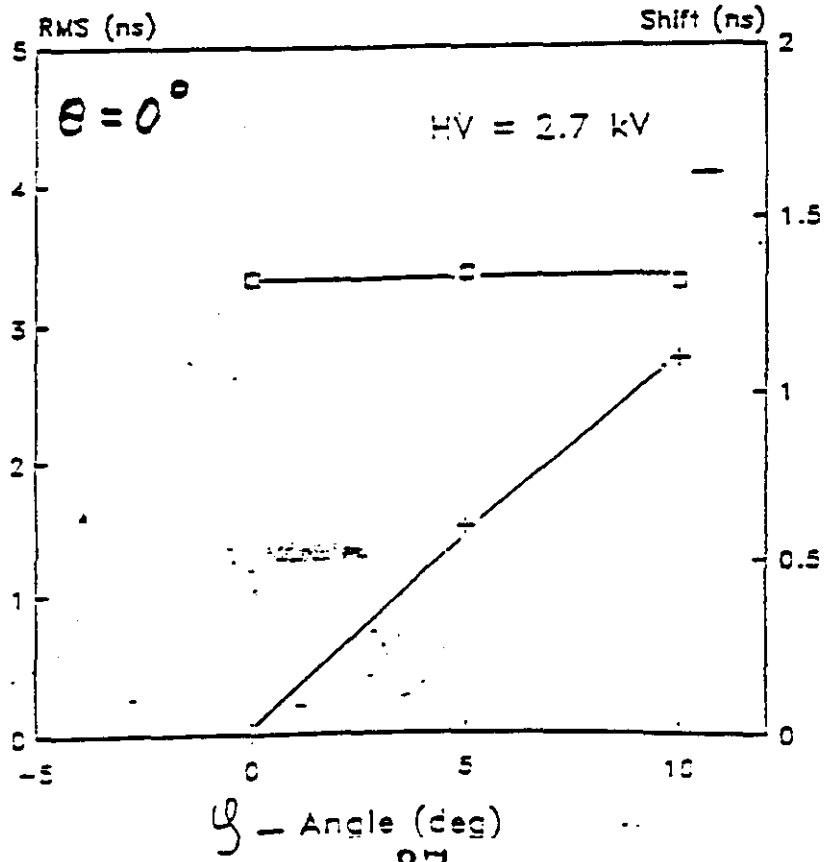


Figure 7: Wire placement to minimize effect of the angle between the anode wires and radial strips and the effect of the magnetic field.


L-angle compensation
CSC in Endcaps
Without compensation
With compensation
Resolution [rms microns]
Polar Angle [degrees]
100
80
60
40
20
0
5
10
15
20
25
30





HV = 2.7 kV
σ = 3.5 ns

CSC

$\sigma_x \lesssim 75 \mu m$

$\sigma(T_0) \approx 3.5 ns$ OR $4 \leq BCross \approx 98\%$

Low noise electronics demonstrated

φ-incidence mitigated

L-angle effect controlled

Summary of RDT Resolutions/R&D FY92:

X - resolution (drift direction)
Y - resolution (wire direction)

Factors affecting resolution:

(1) wire tension and concentricity in tube
(2) misalignments
(3) Lorentz -angle correction

Dubna RDT

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	(+28)	(−47)	(+8)	(+10)	110
4.3	2	(+32)	(−52)	(+10)	(+10)	92
5.9	4	(+36)	(−59)	(+8)	(+10)	76

Ar – C_4H_{10} (25/75)

P = 1 atm

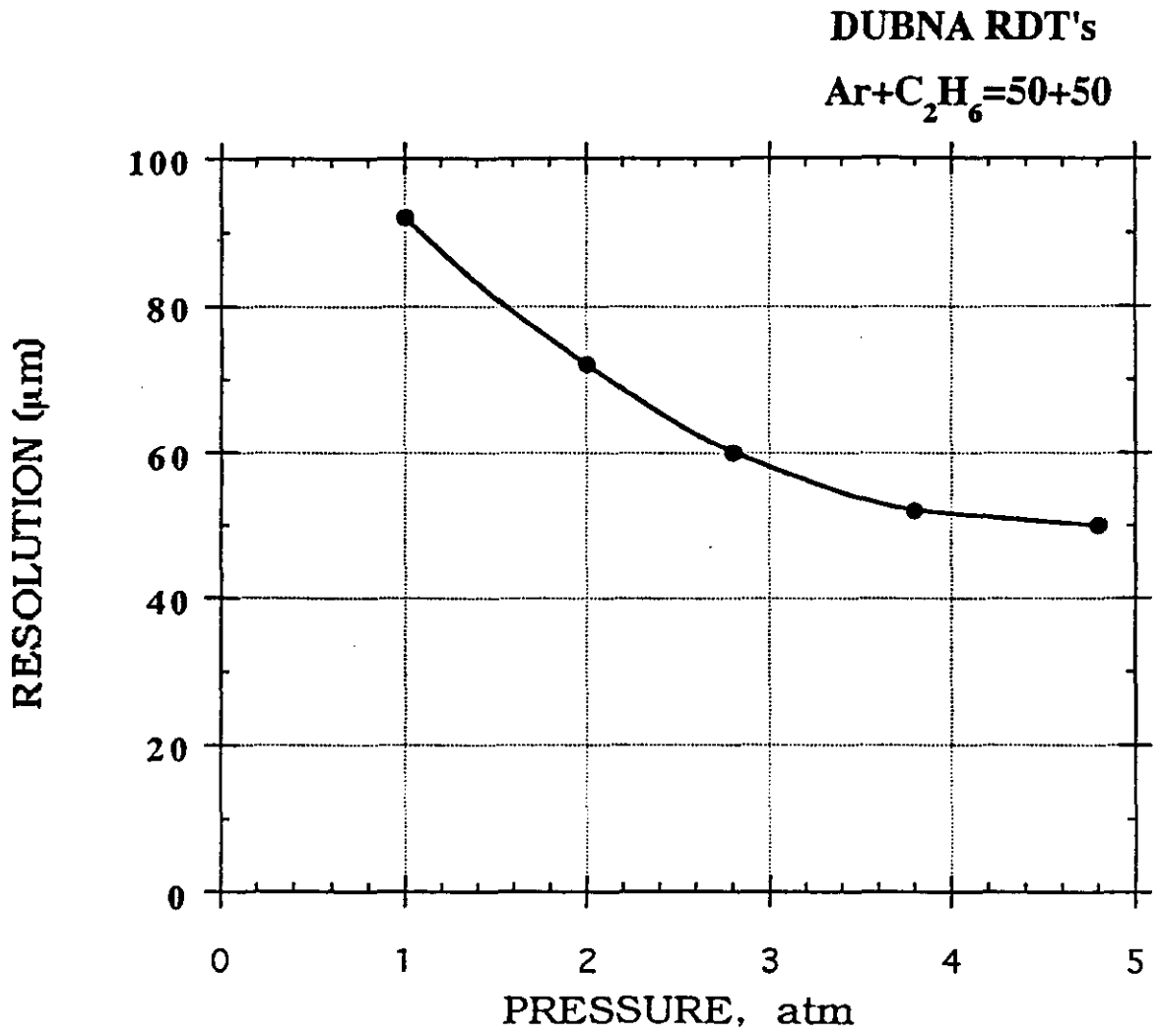
U_A kV	Layer / Mode	1	2	3	4	1...4
		Δ	Δ	Δ	Δ	σ
4.1	prop.	(+34)	(−52)	(+12)	(+10)	95
4.5	streamer	(+34)	(−57)	(+10)	(+12)	82

$\sigma_x \lesssim 100\,\mu m$

σ – space resolution (μm)

Δ – systematic shift (μm)

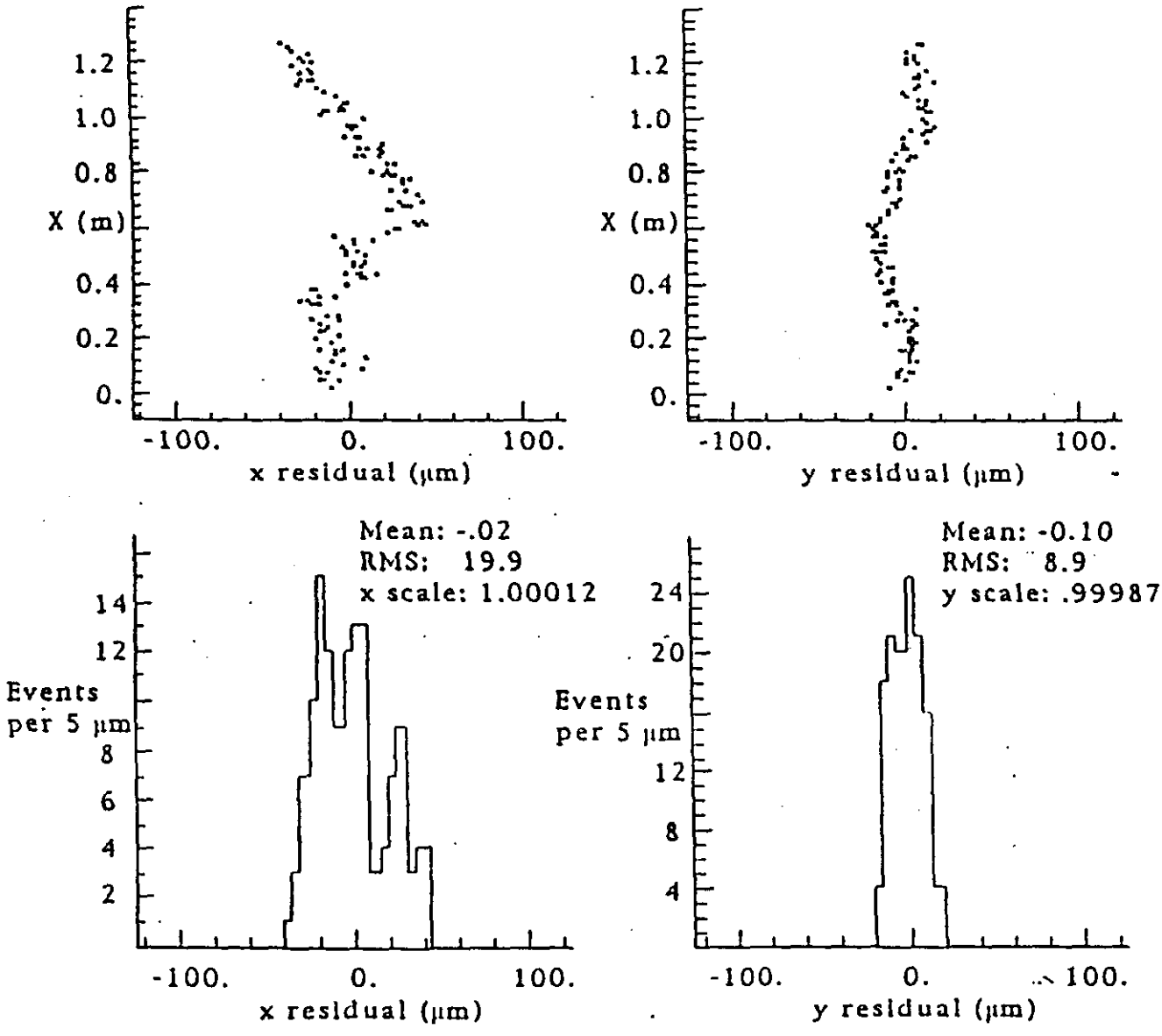
TTR Results


DUBNA RDT's
Ar+C2H6=50+50
RESOLUTION (μm)
100
80
60
40
20
0
0
1
2
3
4
5
PRESSURE, atm

MSU RDT Prototype

Manifold Plate Hole Placement

Aug. 4, 92



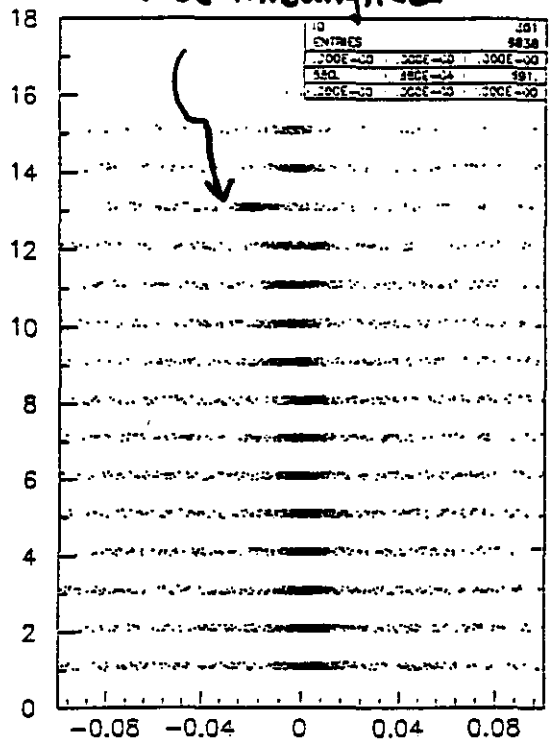
92

Fig. 6.1.4

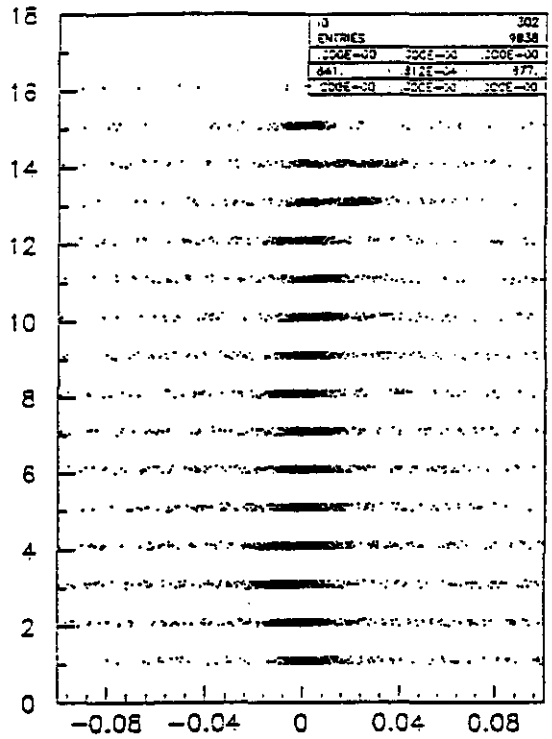
Analysis by ITEP Collaboration

92/12/01 17.20

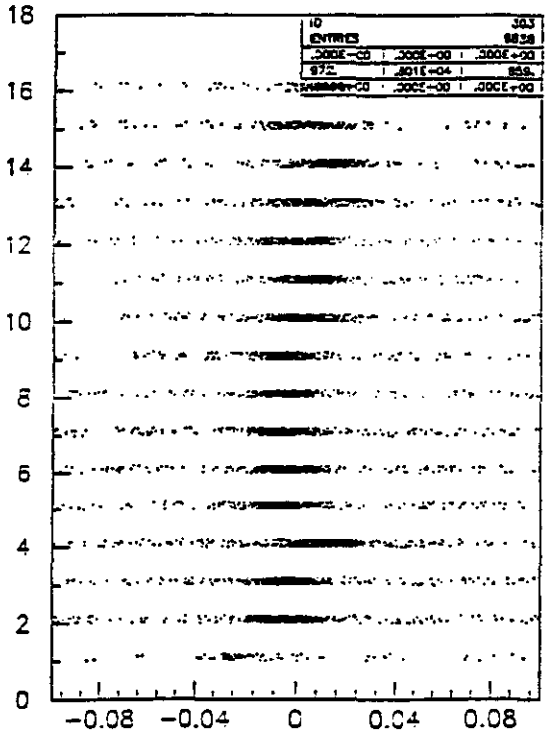
tube misaligned



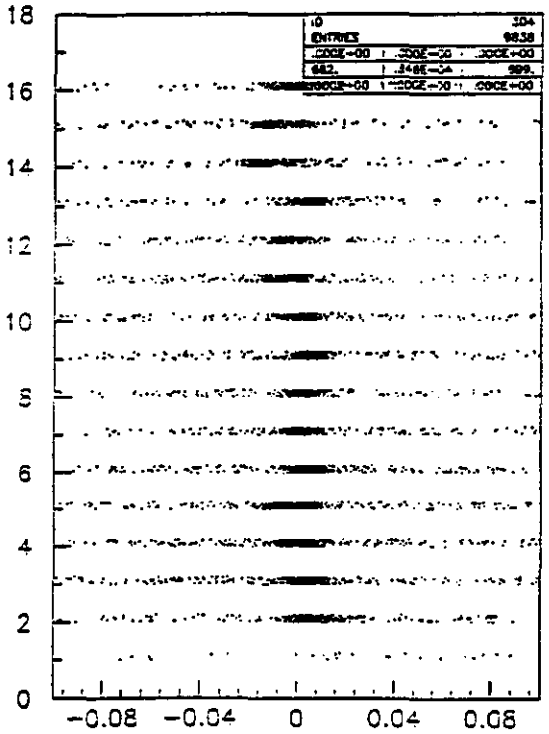
delta(Y) vs tube number for layer 1



delta(Y) vs tube number for layer 2



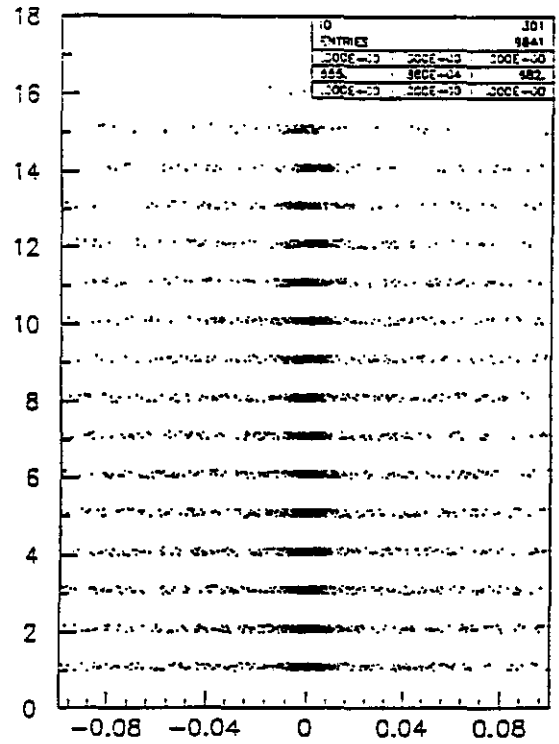
delta(Y) vs tube number for layer 3



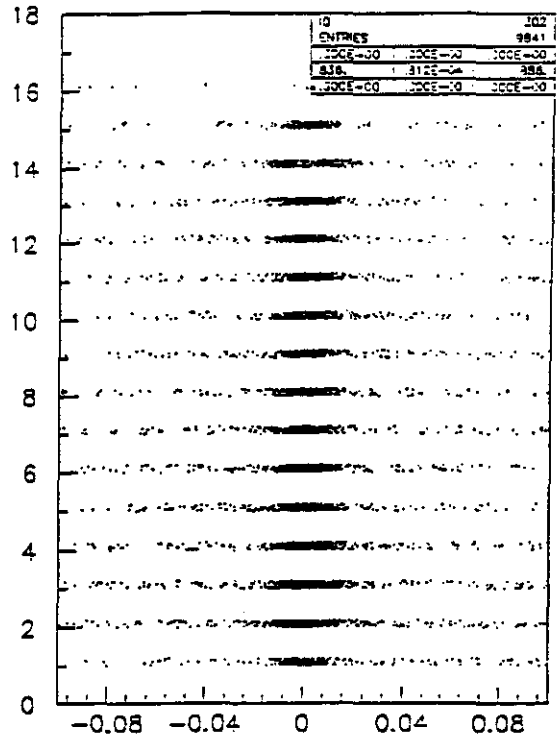
delta(Y) vs tube number for layer 4

Tubes now aligned (11 - shift)

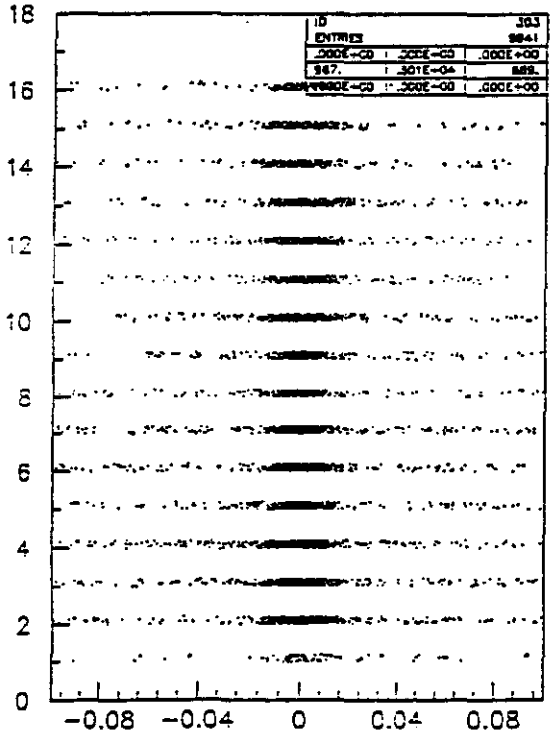
92/12/01 17.33



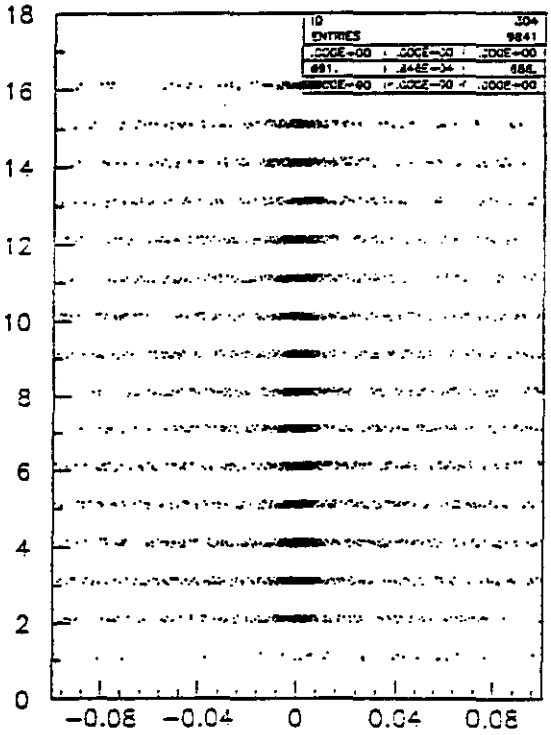
delta(Y) vs tube number for layer 1



delta(Y) vs tube number for layer 2

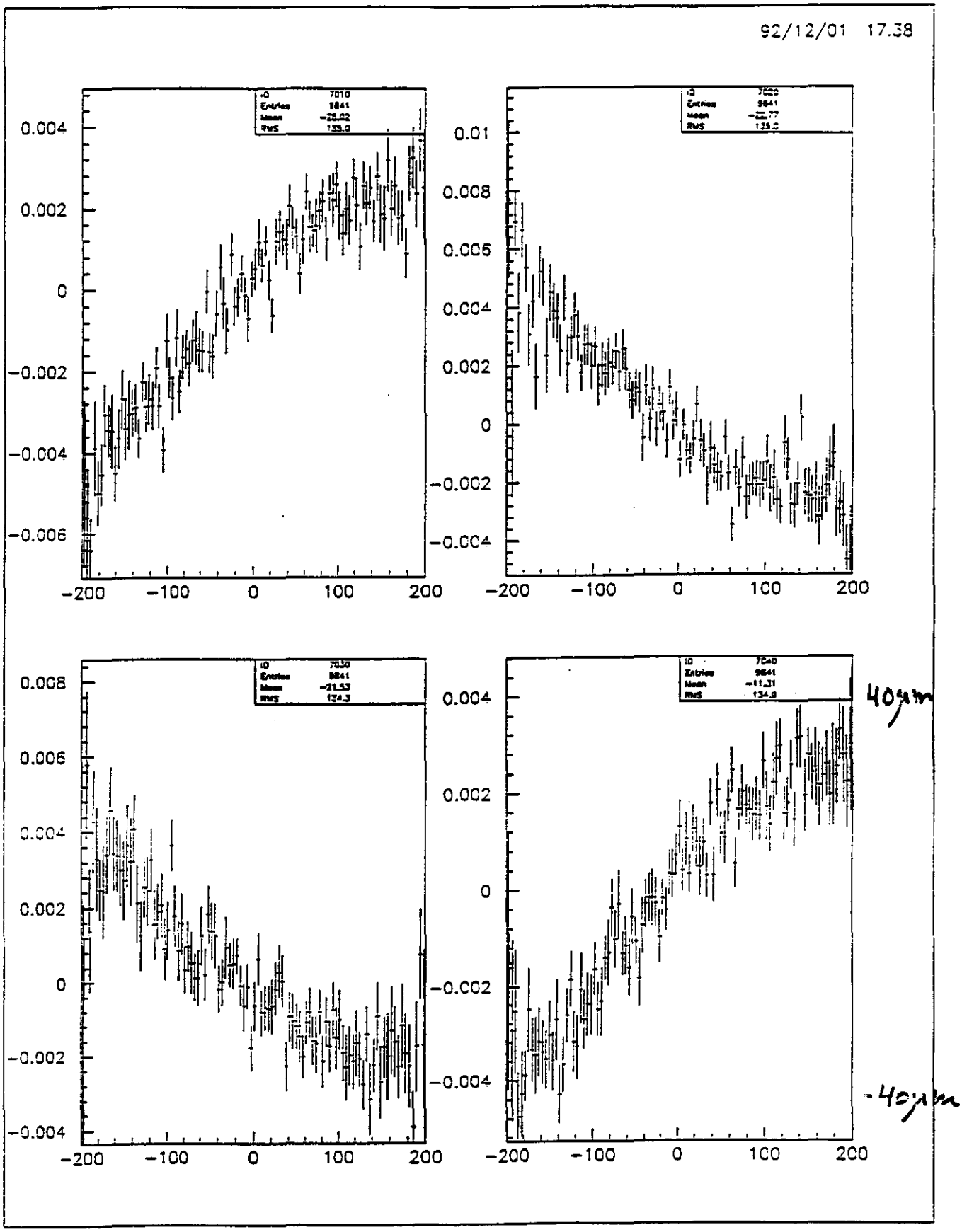


delta(Y) vs tube number for layer 3

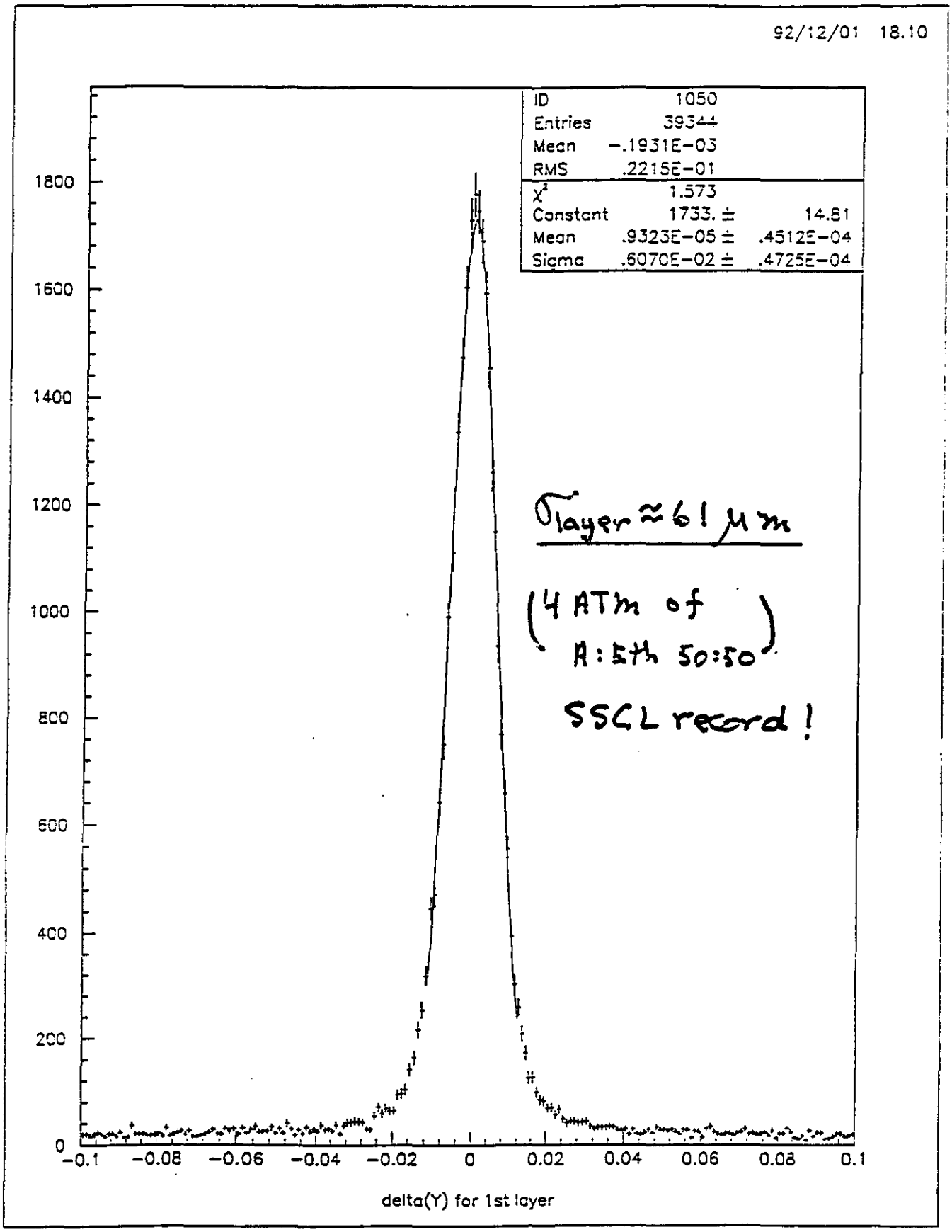


delta(Y) vs tube number for layer 4

Tubes have "crossed" misalignments

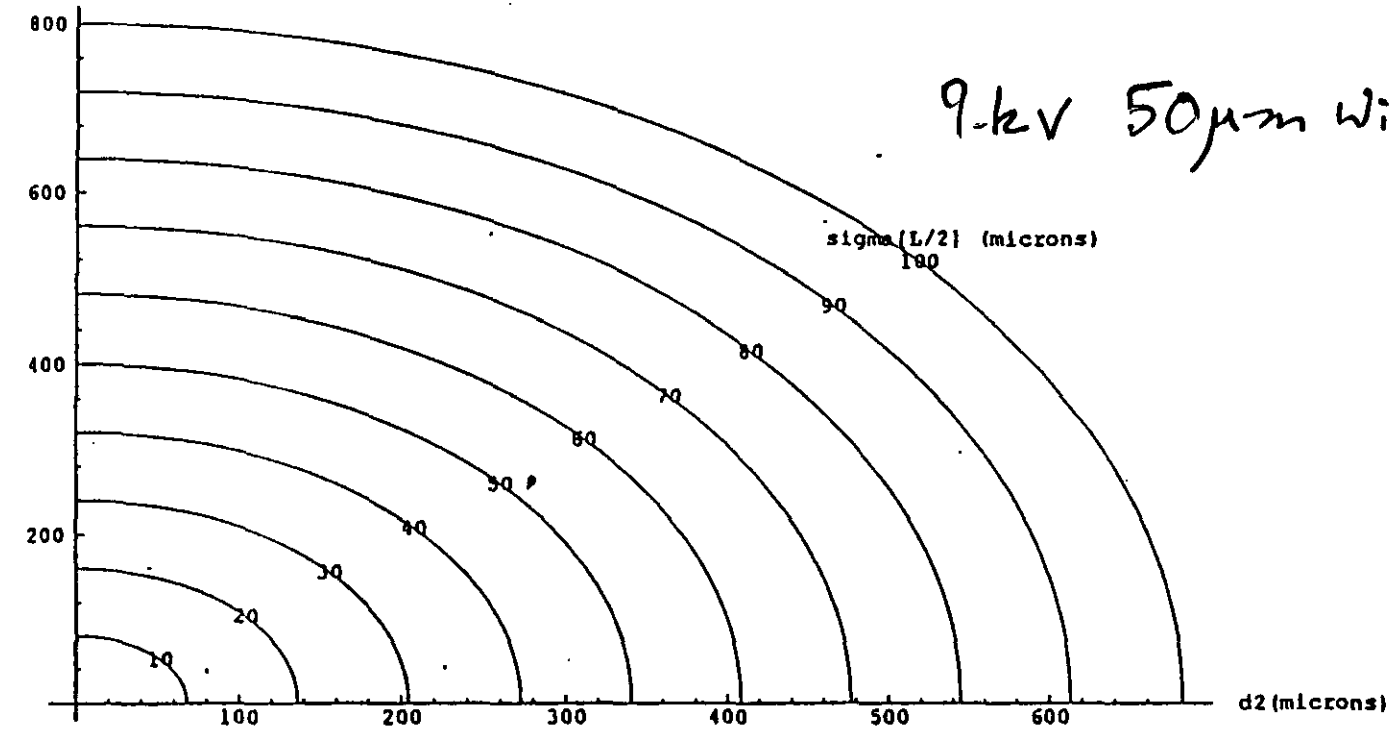


RDT Resolution - all corrections



Data can be used to calibrate & align

CONTOURS OF CONSTANT MEASUREMENT SIGMA(L/2) FOR VARIOUS VALUES OF SIGMA OF WIRE OFFSET,'d1' AND CENTRAL TUBE OFFSET,'d2'.

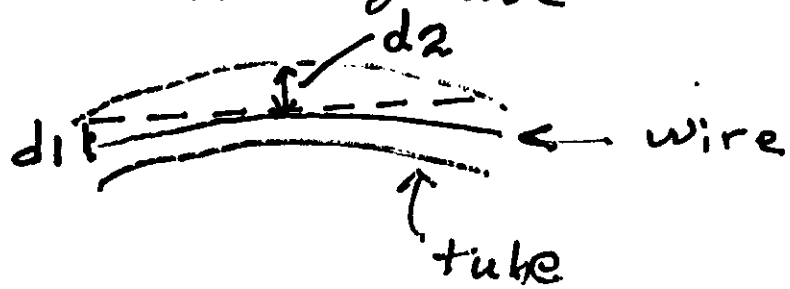


9-kV 50μm wire

Wire Sag

2nd order Term

d1 = "offset of wire in tube
d2 = "Bow" of tube



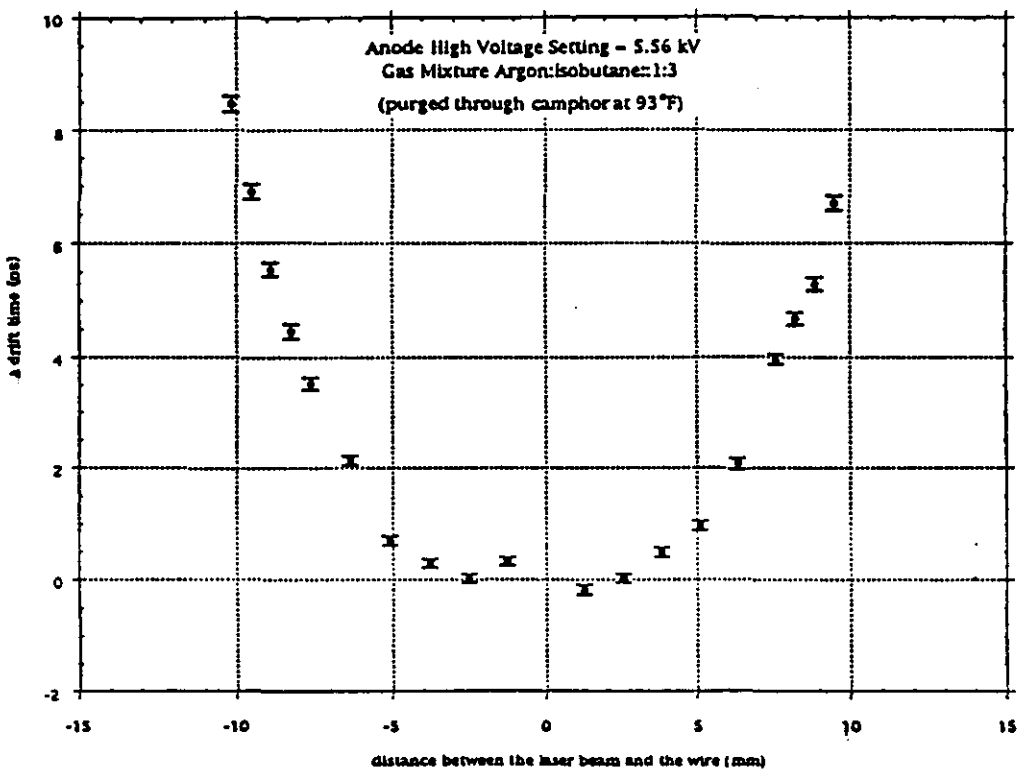
$d_1 \& d_2 < 250\mu m$

1st order Term

Wire sag $\lesssim 250\mu m$

Lorentz Angle Effect RDT

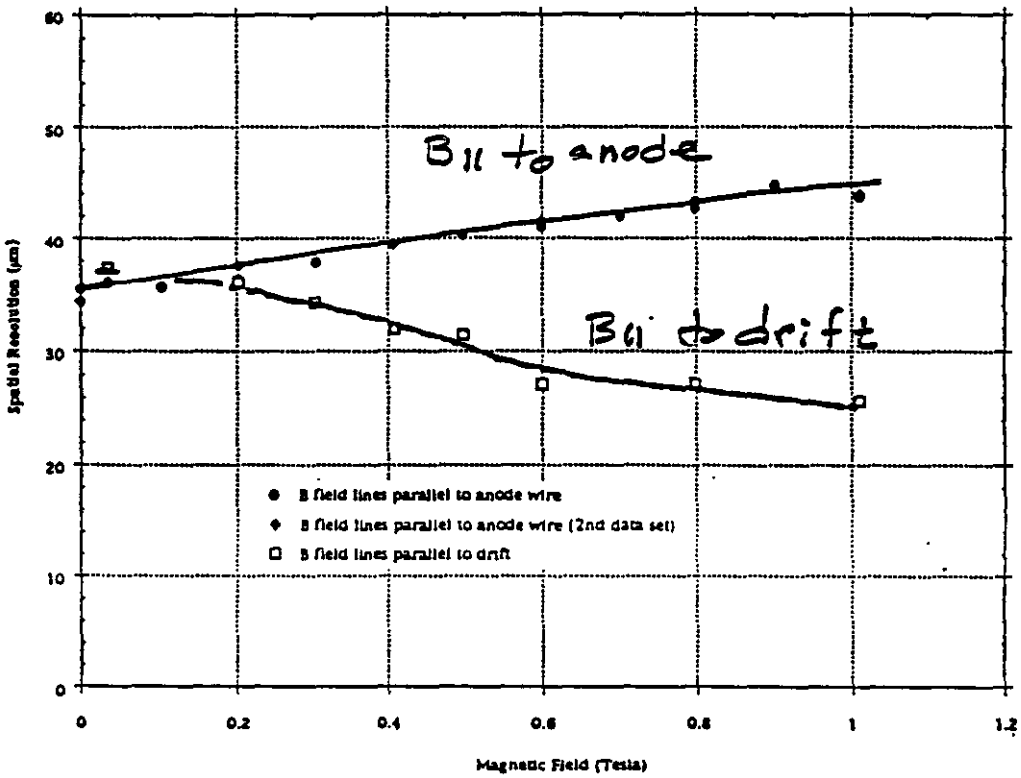
Figure 20. Plot of the Δ drift time in nanoseconds versus the distance between the laser beam and the wire. Δ drift time = Gaussian mean drift time (B=0.8T) - Gaussian mean drift time (B=0T).



$\Delta T = 8ns$ for 10 mm

No correction $\delta r \lesssim 400\mu m$

Figure 22. Plot of the spatial resolution in μm as a function of the strength and direction of the applied, external magnetic field, in Teslas.
Anode High Voltage Setting = 5.40 kV
Gas Mixture Argon:Isobutane::1:3



RPC Timing Resolution:

time resolution:

rate capability :

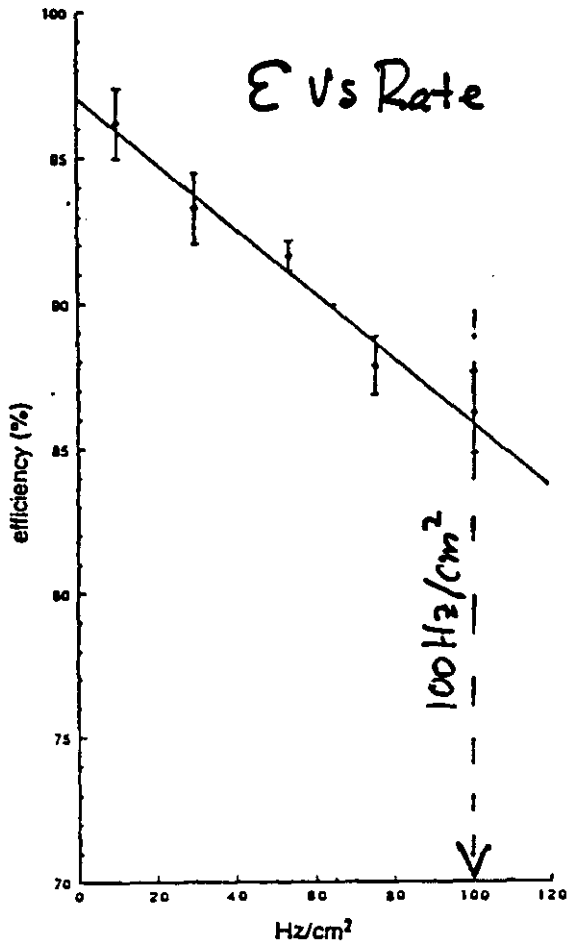


Fig. 4. Plateau values of the efficiencies of fig. 3 as a function of the beam rate.

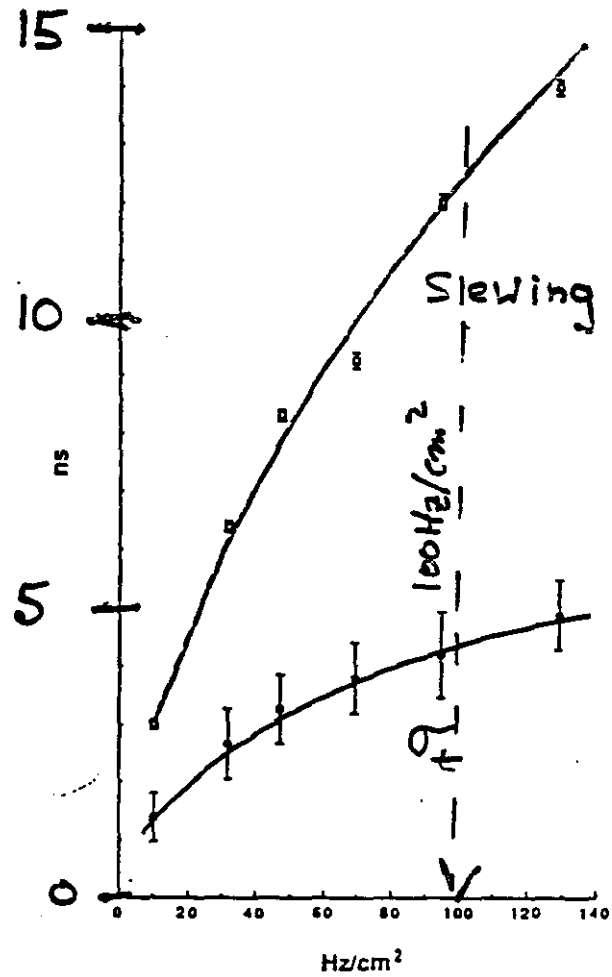
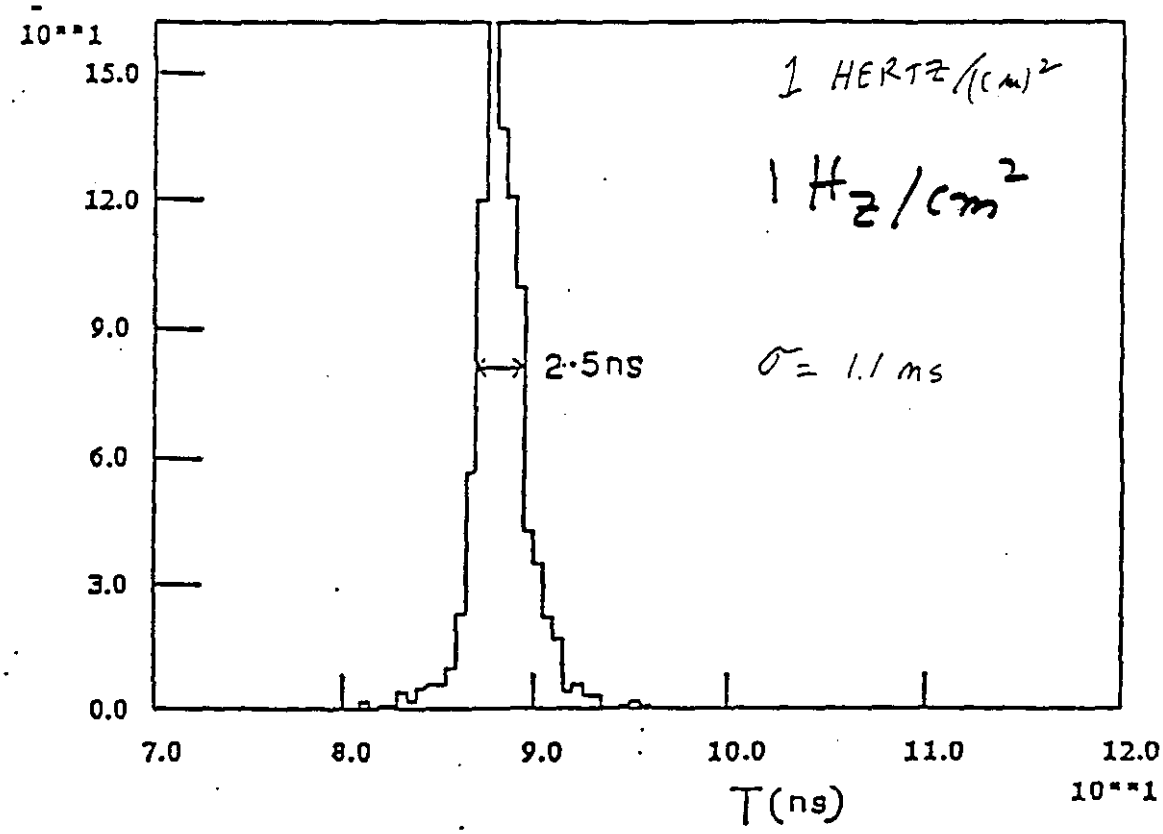
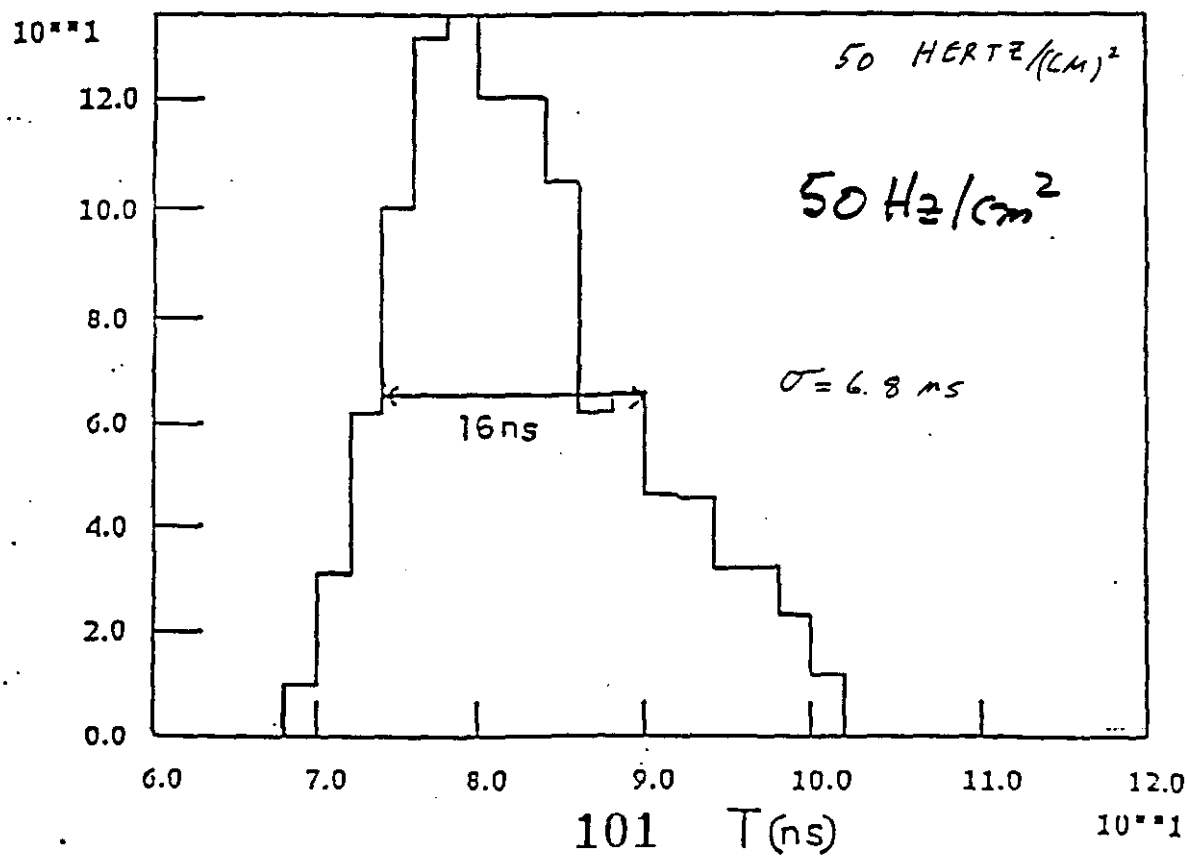
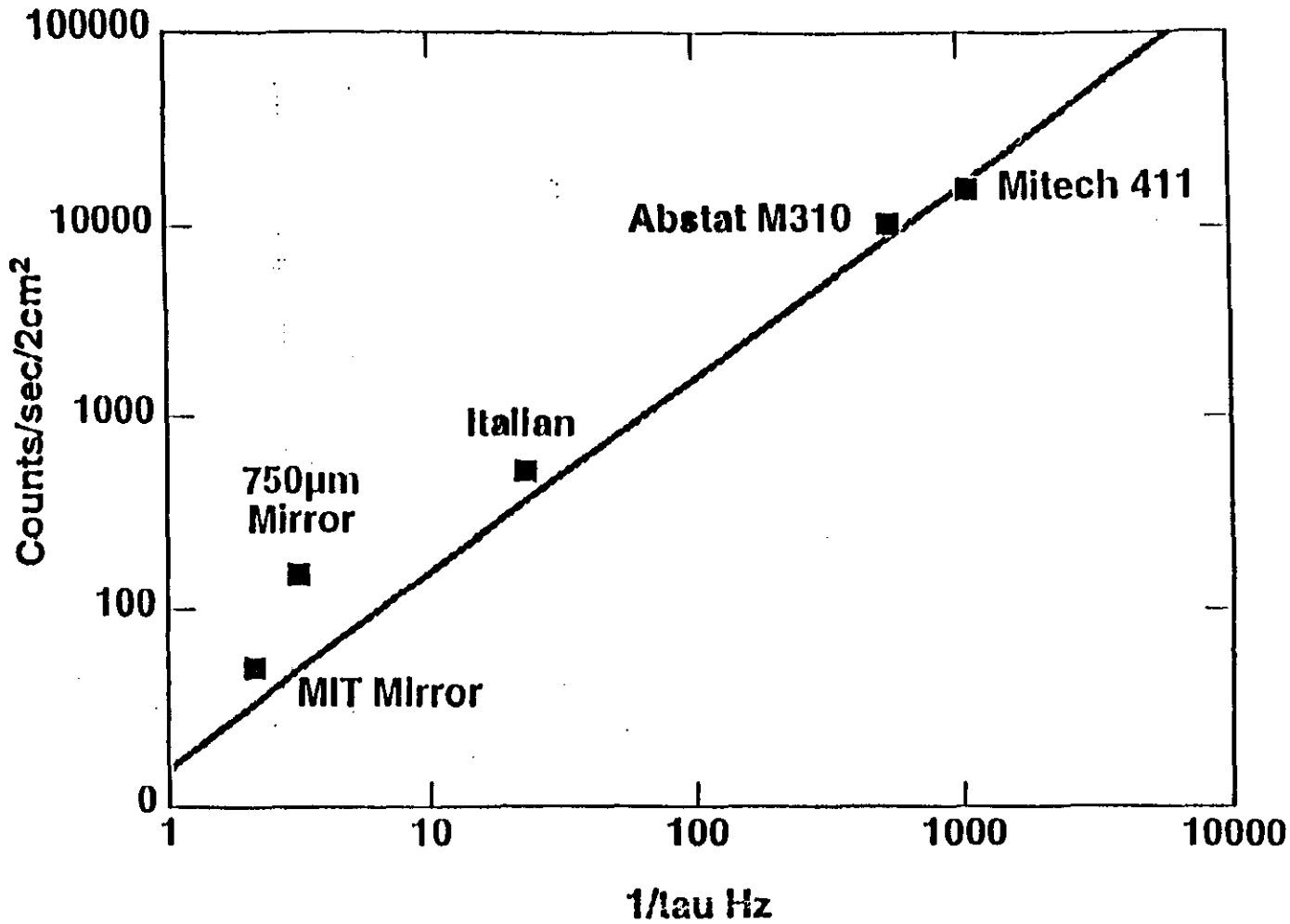


Fig. 6. Mean value (open points) and standard deviation (full points) of the time-of-flight between the RPC #2 and a beam counter versus beam flux. The standard deviation was calculated by evaluating the interval around the most probable value of the time distribution containing 68.3% of the total area. The contribution of the scintillator counter time resolution has been subtracted. The mean values of the time distributions contain a common arbitrary additive constant.


10**1
15.0
12.0
9.0
6.0
3.0
0.0
7.0
8.0
9.0
10.0
11.0
12.0
10**1
T(ns)
1 HERTZ/(CM)²
1 Hz/cm²
2·5ns
σ = 1.1 ns


10**1
12.0
10.0
8.0
6.0
4.0
2.0
0.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
10**1
T(ns)
50 HERTZ/(CM)²
50 Hz/cm²
σ = 6.8 ns
16ns

Saturated Singles Rate vs SPICE 1/tau



Comparison of Rate Capabilities

neutrons @ 104 Hz/cm2:

- **CSC:**

Require 3 strips to have 1 hit within T-integration

T-drift < 1.25 mm/50μm/ns = 25 ns (normal incidence)
T-integration = 550 ns (BNL prototype)
typical large strip A = 1 cm x 340 cm = 340 cm^2
E-neutrons = 0.5 %

$$Occ = 10^4 \times 0.5 \times 10^{-2} \times 3 \times 1 \times 340 \times 550 \times 10^{-9}$$

$$= 2.8\ \%$$

- **RDT:**

Require 2 tubes to have 1st hit good within T-drift

probability 1st hit is neutron = 0.5
T-drift = 250 ns
typical tube size = 2.5 cm x 400 cm = 1000 cm^2

$$Occ = 0.5 \times 10^4 \times 0.5 \times 10^{-2} \times 2 \times 2.5 \times 400 \times 250 \times 10^{-9}$$

$$= 1.3\ \%$$

- **RPC:**

Neutron fluence where single layer E = 90%

rate = 65 Hz/cm2
neutron efficiency = 0.5 %

$$\text{n-fluence} = [65\ Hz/cm^2]/0.5 \times 10^{-2} = 1.3 \times 10^4\ Hz/cm^2$$

But slewing, ε, σ_T at high rates degrades

Being updated

MUON SYSTEM

(1) Physics Goals:

(1) Provide muon identification-track penetrating 12 to 14 λ of calorimeter
(2) Charge assignment of muons
(3) P_t trigger - both levels 1 and 2
(4) Beam crossing time marker
(5) Muon momentum determination from a few GeV/c to a few TeV/c. Design goal: $\delta P_t/P_t = 5\%$ (12%) at $\eta = 0$ (2.5), for $P_t = 500$ GeV/c.

(2) System Parameters

Barrel Region:

Geometry:

Rmagnet (inner radius of cryostat)	9.0 m
B-field at the IP	0.8 T
Rcalorimeter (outer radius of calorimeter)	3.60 m
Calorimeter thickness at $\eta = 0$	12 λ
Assumed calorimeter material (hadronic section)	Cu
Number of sectors in Φ	16
Location of neutron shield	3.60 m < R < 3.70 m
Chamber stay-clear (from neutron shield or magnet cryostat)	6 cm

Chamber Parameters:

Cathode Strip Chambers (CSC for both tracking and triggering)

Spatial resolutions:

Chamber single-layer resolution	75 µm (σ)
Chamber internal alignment	50 µm
Superlayer-to-superlayer alignment	25 µm
Radiation length/chamber layer	3.75%
Chamber thickness	5 cm / layer
Timing resolution (for trigger)	< 10 ns for "OR" of 4

Channel segmentation and count:

For all θ-segments

Bend plane segment width	5 mm
Bend plane channel count	754,000
Nonbend plane segment width	10 cm
Nonbend plane channel count	124,000

MUON SYSTEM

Spatial resolutions:	
Chamber single-layer resolution	75 μm (σ)
Internal chamber alignment	50 μm
Superlayer-to-superlayer alignment	25 μm
Radiation length/chamber layer	3.75 %
Chamber thickness	5 cm/layer
Chamber configuration	8:4:4
Radii of superlayer midplanes	SL 1 = 3.854 m
	SL 2 = 6.282 m
	SL 3 = 8.588 m
Barrel lever arm	4.74 m
Half-lengths of superlayers along axis of magnet (Z)	SL 1 = 6.319 m
	SL 2 = 10.426 m
	SL 3 = 14.750 m
Φ Widths of sectors	SL 1 = 1.485 m
	SL 2 = 2.390 m
	SL 3 = 3.296 m
Coverage:	
Polar angle	$29.6° < \theta < 85.8°$
Pseudorapidity	$0.074 < \eta < 1.33$
Azimuthal angle	95.3%

MUON SYSTEM

Endcap region:

Geometry:

B-field at IP	0.8 T
Length of magnet cryostat	15 m
Z-separation of coils	1.5 m
Forward Field Shaper (FFS):	
Z_{front}	10.0 m
Z_{rear}	18.0 m
OD-half angle of steel	9.4°
ID	1.2 m
$Z_{calorimeter}$ (half-length of calorimeter along beam axis)	5.50 m
Calorimeter thickness at $\eta = 2.5$	14 λ
Z_{max}	16.5 m
Number of sectors in Φ	16
Location of neutron shield 10 cm behind calorimeter	5.50 m < Z < 5.60 m
Chamber stayclear	6 cm

Chamber Parameters:

Cathode Strip Chambers (CSC for both tracking and triggering)

Spatial resolutions:	
Chamber single-layer resolution	75 μm (σ)
Chamber internal alignment	50 μm
Superlayer-to-superlayer alignment	25 μm
Radiation length/chamber layer	3.75%
Chamber thickness	5 cm / layer
Timing resolution (for trigger)	< 10 ns for "OR" of 4

Channel segmentation and count:

For all θ-segments	
Bend plane segment width	5 mm (at middle)
Bend plane channel count	294,000
Nonbend plane segment width	5 cm
Nonbend plane channel count	35,000
Single channel rate at $L = 10^{33}/cm^2sec$	< 100 Hz
Occupancy for "OR" of 7 strips at $L = 10^{34}/cm^2sec$	< 3 %

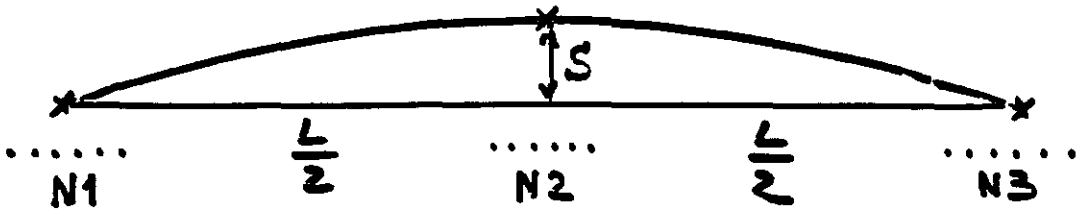
Coverage:

Polar angle	$9.75° < \theta < 27.71°$
Pseudorapidity	$1.40 < \eta < 2.46$
Azimuthal angle	100%

Endcaps - Tracking and Triggering:

(a) <u>Forward angle region:</u>	$9.75° < \theta < 11.45°$	$(2.30 < \eta < 2.46)$
Chamber configuration		8:8:4
Average Z location of chambers		SL 1 = 6.78 m
		SL 2 = 11.43 m
		SL 3 = 16.08 m
Average lever arm		9.3 m
(b) <u>Intermediate angle region:</u>	$1.45° < \theta < 17.01°$	$(1.90 < \eta < 2.30)$
Chamber configuration		8:4:4
Average Z location of chambers		SL 1 = 5.94 m
		SL 2 = 11.43 m
		SL 3 = 16.08 m
Average Lever arm		10.14 m
(c) <u>Outer angle region:</u>	$17.01° < \theta < 27.71°$	$(1.40 < \eta < 1.90)$
Chamber configuration		8:4:4
Average Z location of chambers		SL 1 = 5.94 m
		SL 2 = 10.13 m
		SL 3 = 14.58 m
Average lever arm		8.64 m

(B)



$$\frac{\Delta P}{P} = \frac{\Delta S}{S} = \frac{27\, p\left[\frac{TeV}{c}\right]}{BL^2\,(Tm)} \sqrt{\frac{\sigma_{s1}^2}{2} + \sigma_{s2}^2 + \frac{\sigma_{s3}^2}{2}} + \frac{0.1}{BL\,(Tm)} \sqrt{X_2/X_0}$$

$\sigma_{s1}, \sigma_{s2}, \sigma_{s3}$ — RESOLUTION OF SUPERLAYERS 1, 2, 3

$$\sigma_{si}^2 = \frac{\sigma_i^2}{N_i\, \epsilon_i}$$

σ_i - SINGLE LAYER RESOLUTION IN SUPERLAYER i

N_i - NUMBER OF LAYERS IN SUPERLAYER i

X_2/X_0 - RAD. LENGTH OF SUPERLAYER 2

ϵ_i - SINGLE LAYER EFFICIENCY

(1) RESOLUTION OF SUPERLAYER 2 SHOULD BE OPTIMIZED

$$\rightarrow \mathrm{MIN}\left\{\frac{\sigma_2^2}{N_2\, \epsilon_2}\right\}$$

(2) MULTIPLE SCATTERING IN SUPERLAYER 2 SHOULD BE MINIMIZED

$$\mathrm{MIN}\left\{X_2/X_0\right\}$$

NUMBER OF SECTORS ?

DOMINATING CONSTRAINS:

→ MINIMUM NUMBER OF CHAMBERS IN THE MIDDLE PLANE

↓

MINIMUM NUMBER OF FRAMES

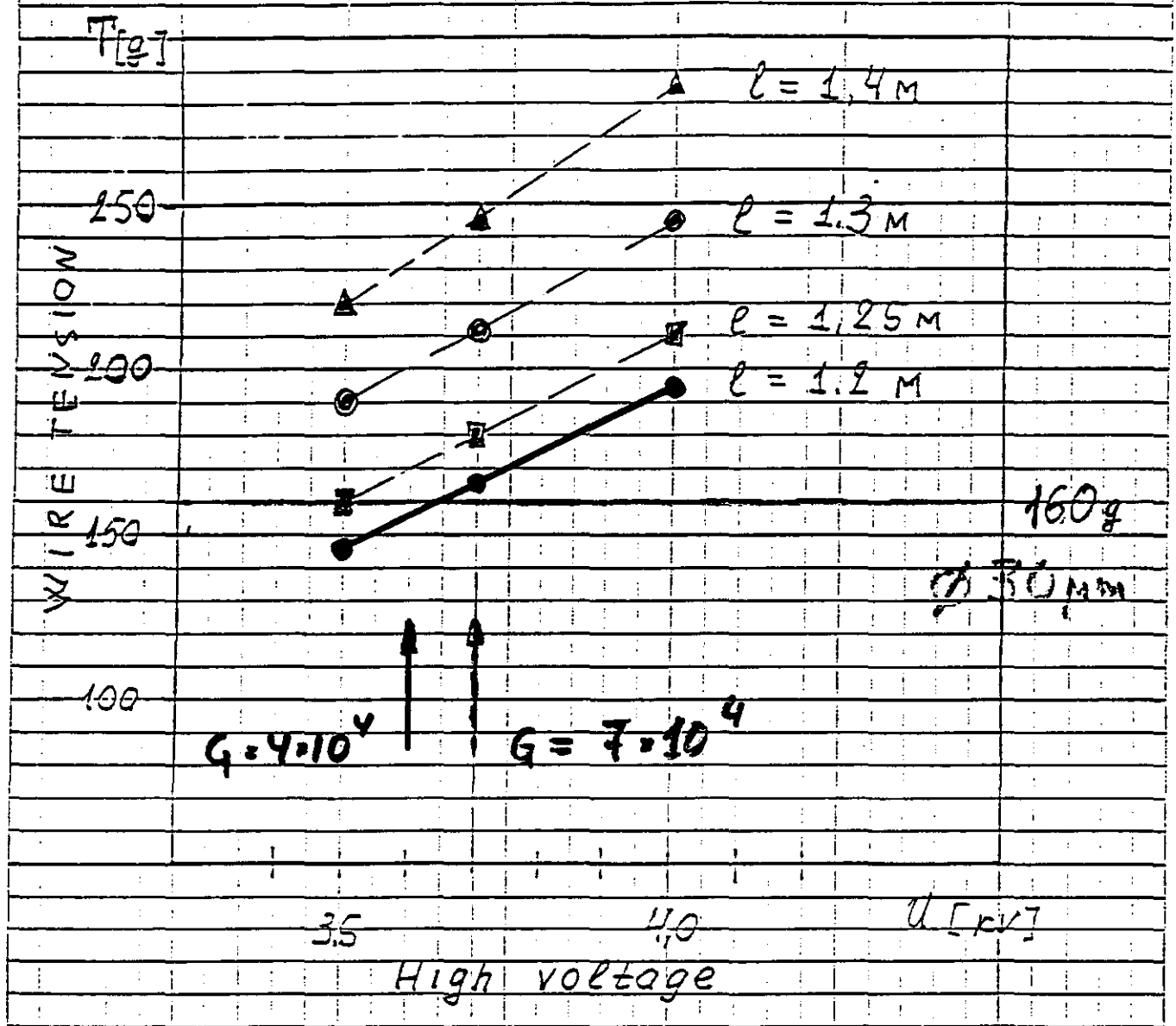
↓

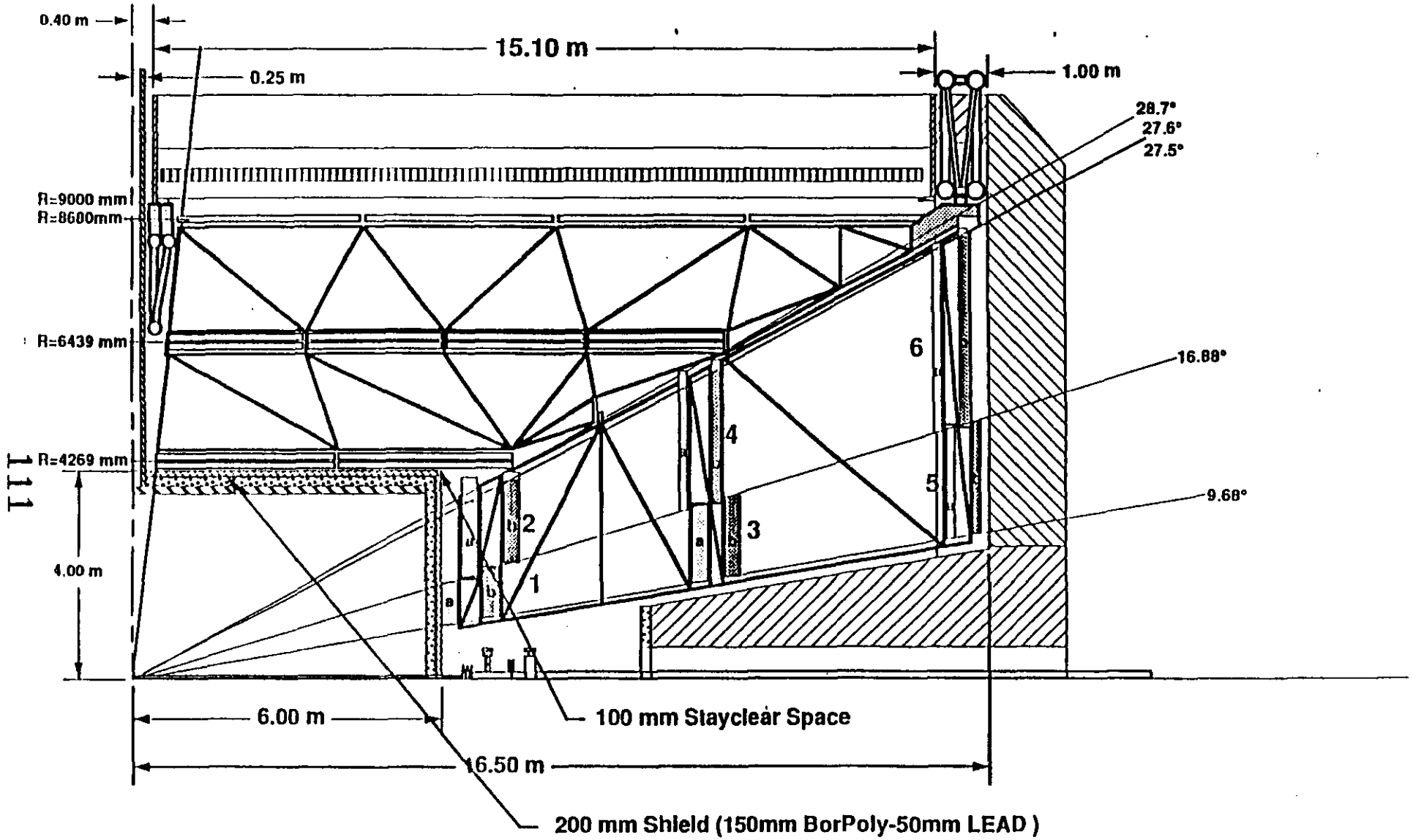
MINIMIZE MULTIPLE SCATTERING

→ MAXIMUM POSSIBLE LENGTH OF ANODE WIRES

→ ANGLE RANGE IN THE MIDDLE CHAMBER

MAX ANODE WIRE LENGTH





GEM CSC Muon System Layout

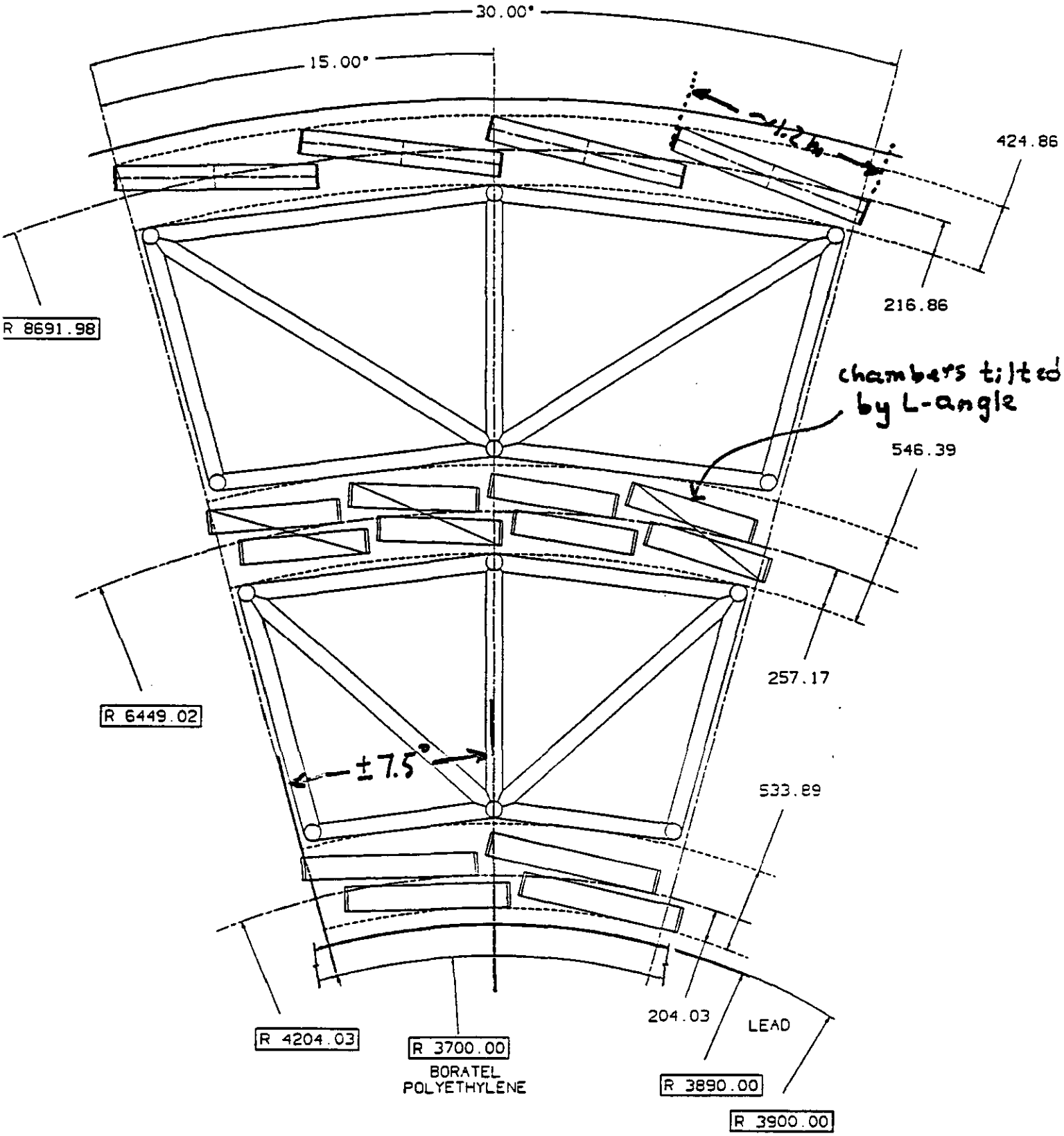
(6-6-4 Gaps per Superlayer Barrel)
(Version "h" Endcap)

6-6-6 -2/3/93

Frank Nimblett
18 January '93

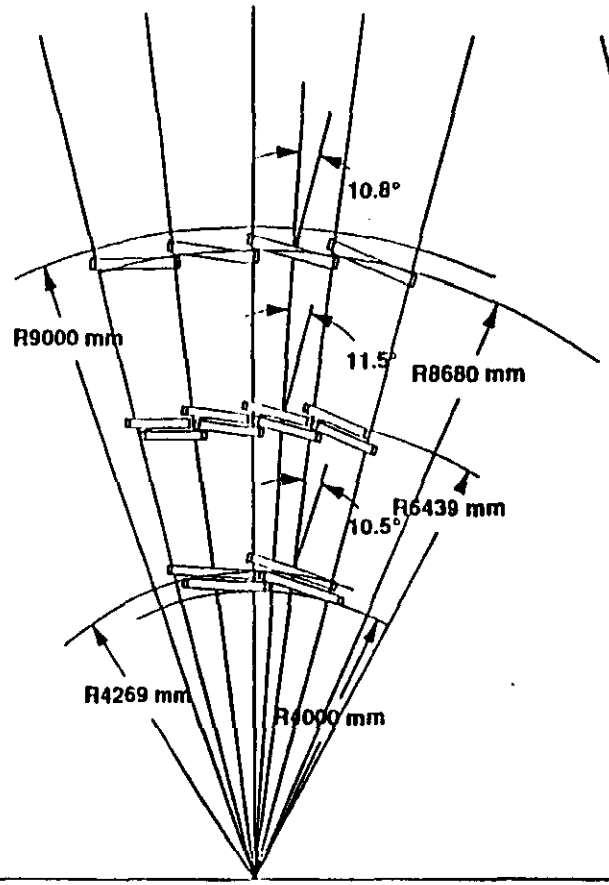
111

Layout of CSC in barrel

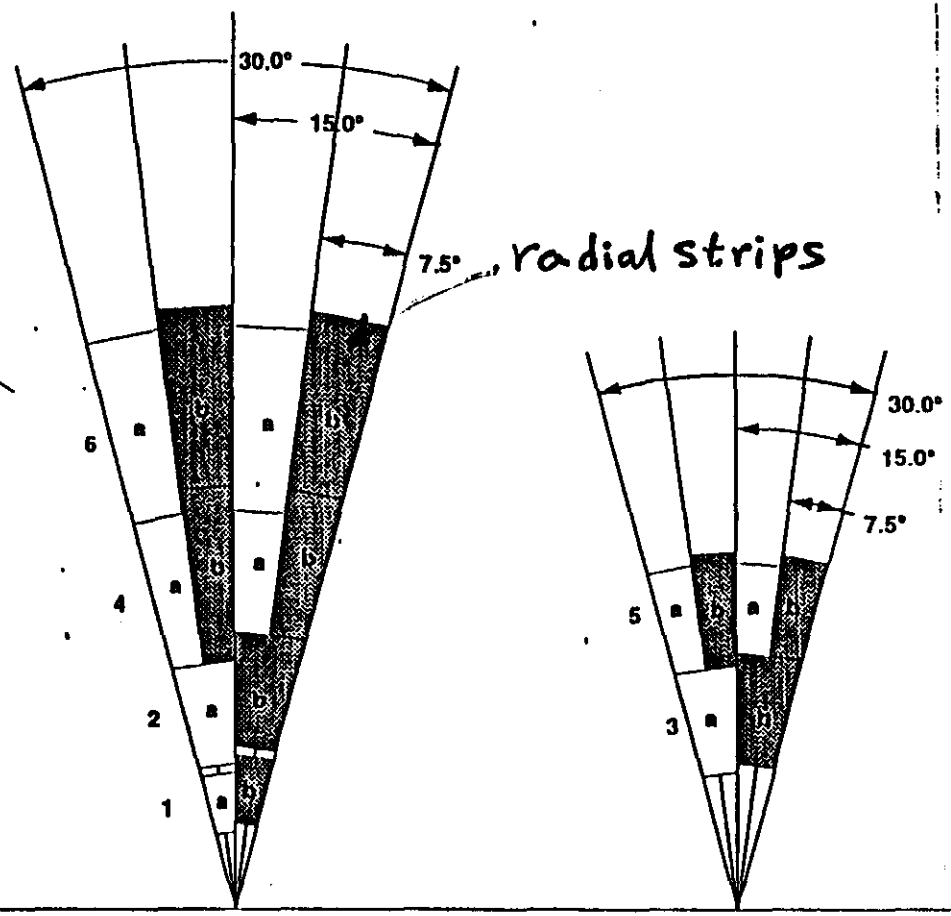


6° BARREL MODULE
12 SECTORS-4000MM MIN R
SUPPORT
T.HINES 5/JAN/93

DIMS=MM

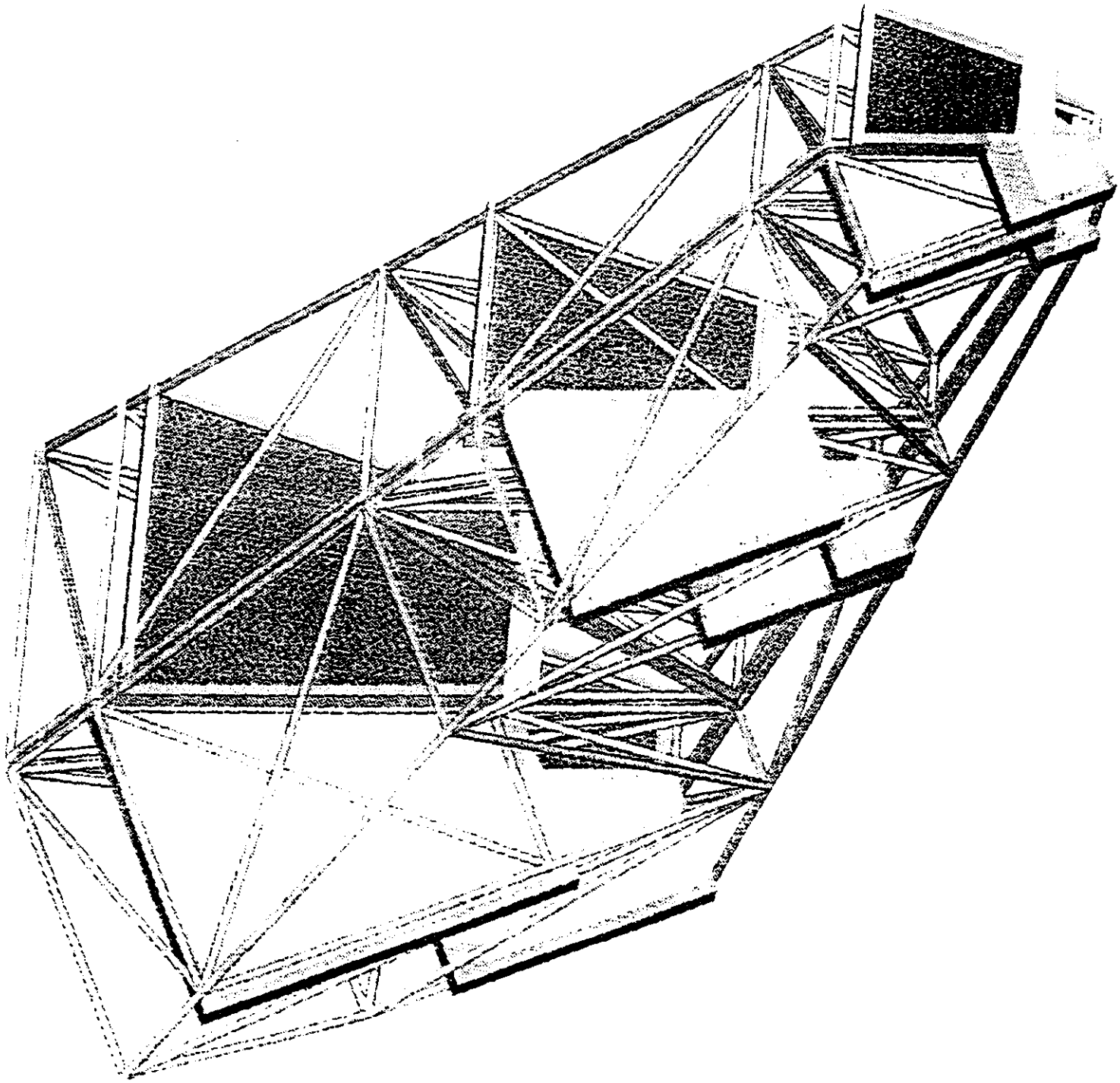


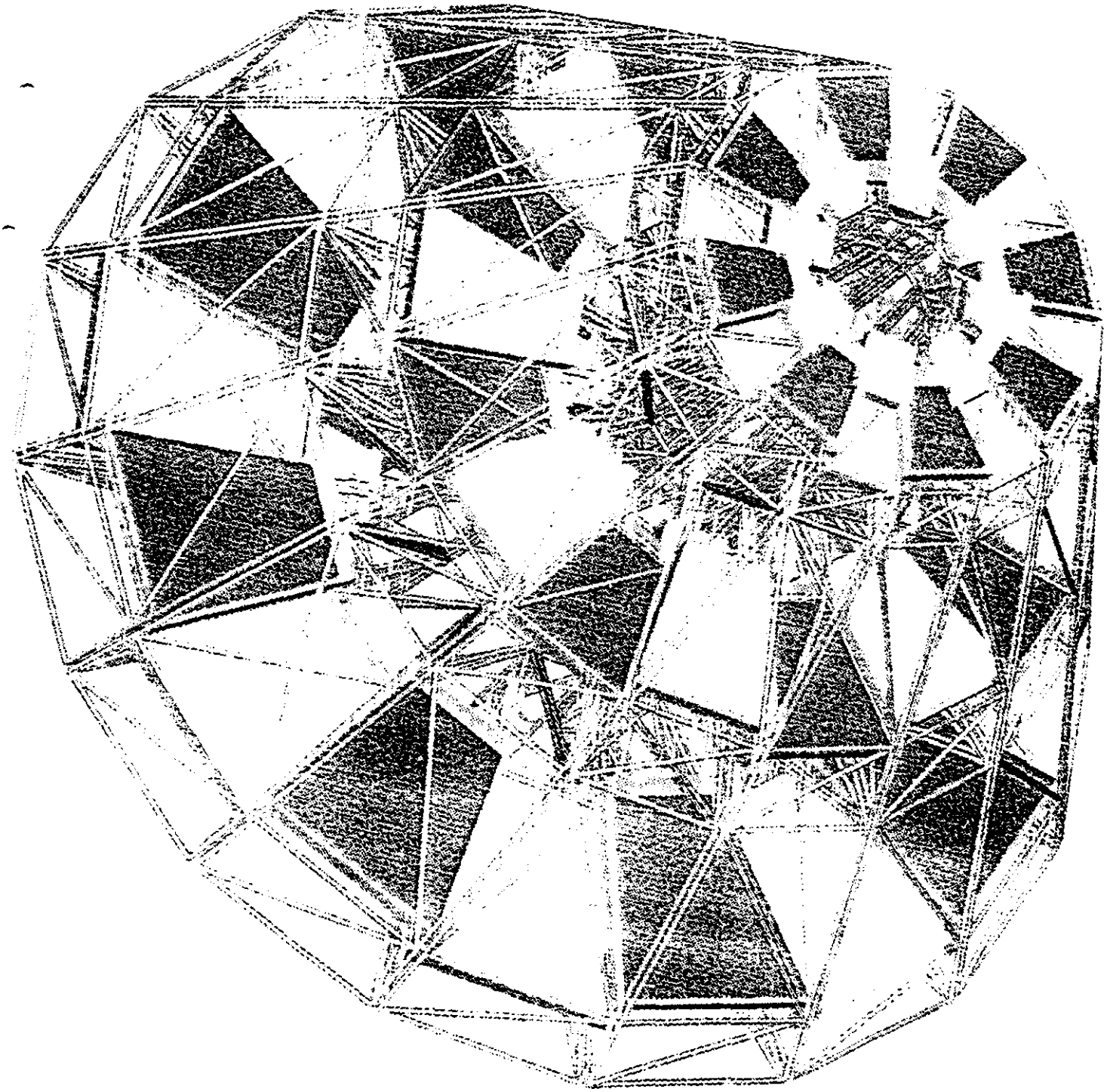
Barrel Region 100% Phi Overlap**
(6-6-4 Gaps per Superlayer)



CSC Endcap Version "h" Chamber Layout
(segmentation of each group)

Frank Nimblett
18 January '93





Baseline 2A RDT/RPC

Physics Goals:

(1) Provide muon identification - track penetrating 12 to 14 λ of calorimeter
(2) Charge assignment of muons
(3) Pt trigger
(4) Beam crossing time marker
(5) Muon momentum determination from a few GeV/c to a few TeV/c.
Design goal: $\delta P_t/P_t = 5\%$ (12%) at $|\eta| = 0$ (2.5), for $P_t = 500$ GeV/c.

Information per Incident Muon Track:

	Bend plane		Non-bend plane		
	Trigger	Tracking	Trigger	Tracking time	stereo
Sl1	3	8	3	4	4
Sl2	3	10	3	6	4
Sl3	3	8	3	4	4
	Total 35		Total 35		

System Parameters:

Barrel Region:

Geometry:

Rmagnet (inner radius of cryostat)	9.0 m
B-field at the IP	0.8 T
Rcalorimeter (outer radius of calorimeter)	3.70 m
Calorimeter thickness at $|\eta| = 0$	11 λ
Assumed calorimeter material	Pb/Cu/Sc/Kr
Number of sectors in ϕ	16
Location of neutron shield (20 cm B-Poly)	3.70 m < R <3.90 m
Chamber stay-clear (neutron shield or magnet cryostat)	10 cm

RDT Chamber Parameters:

(a) Tracking - bend plane:

Spatial resolutions (baseline assumption):	
Chamber single-layer resolution	< 100 μm (RMS)
Internal chamber alignment	< 50 μm
Superlayer-to-superlayer alignment	< 25 μm
Tube wall thickness	300 μm
Radiation length/tracking chamber layer	1.14 % (Al-tubes)
Tube diameter	2.54 cm
Chamber layers/SuperLayer (SL1:SL2:SI3)	8:10:8
Stereo configuration:	
SL1	4 axial-2 U-2V
SL2	6 axial-2 U-2V
SL3	4 axial-2 U-2V
Angle of stereo (α)	4 mr
Radii of barrel superlayer midplanes:	
	SL 1 = 4.2 m
	SL 2 = 6.4 m
	SL 3 = 8.6 m
Barrel lever arm	4.4 to 4.5 m
Half-lengths of superlayers along (Z) (approx.)	
	SL 1 = 7.0 m
	SL 2 = 10.8 m
	SL 3 = 14.4 m
ϕ Widths of sectors (approx.)	
	SL 1 = 1.67 m
	SL 2 = 2.55 m
	SL 3 = 3.42 m
Coverage:	
Polar angle: (gaps not included)	$29.6^\circ < \theta < 85.8^\circ$
Pseudo-rapidity:	$0.074 < \lvert\eta\rvert < 1.33$
Azimuthal angle: (goal)	94 %
Number of alignment paths	768
Number of drift tubes in barrel:	229,376

(b) Tracking - nonbend plane: (RPC)

Number of RPC gaps/superlayer	3
Information/RPC gap	X and Y
Radial locations of RPCs (chamber midplanes) (approx.)	
	SL 1 = 4.35 m
	SL 2 = 6.55 m
	SL 3 = 8.45 m
RPC Radiation length/superlayer (2 gaps)	1.66 %
Chamber thickness for 2 gap package	3.3 cm

Nonbend plane RPC segment widths:	SL1 = 3.9 cm SL2 = 6.5 cm SL3 = 8.9 cm
Nonbend plane electronic channel count:	15,936

(c) Tracking-nonbend plane: (RDT)

Number of RDT stereo layers/superlayer	SL1: 4 axial - 2U-2V SL2: 6 axial - 2U-2V SL3: 4 axial - 2U-2V
Angle of stereo	4 mr
Information per superlayer from stereo	2 Y
Resolution/Y measurement	1.8 cm RMS

(d) Triggering: Resistive Plate Chambers (RPC)

Measurements - Bend plane:	
Segment width	1.3 cm
Number of electronic trigger channels:	25,056
Time jitter of chamber	< 1.5 ns
Time jitter of T0 determination	< 8.3 ns

(e) Triggering: Round Drift Tubes (RDT)

Bend plane segment size	1.25 cm
Non-bend plane segment (by timing)	10 cm RMS

Endcap region:

Geometry:	
B-field at IP	0.8 T
Length of magnet cryostat	15 m
Z-separation of coils	1.5 m
Flux concentrator (FC):	
Zfront	10.0 m
Zrear	18.0 m
OD-half angle of steel	9.4° non-projective
ID	1.2 m
Zcalorimeter (half-length of calorimeter along Z)	5.70 m
Calorimeter thickness at $\lvert\eta\rvert = 2.5$	$< 17\,\lambda$
Zmax	16.5 m
Number of sectors in ϕ	16
Location of neutron shield	$5.70\text{ m} < Z < 5.90\text{ m}$
Chamber stayclear	10 cm

Chamber Parameters (RDT):

Spatial resolutions (baseline assumption):	
Chamber single-layer resolution	< 100μm (RMS)
Internal chamber alignment	< 50 mm
Superlayer-to-superlayer alignment	< 25 μm
Tube wall thickness	300 μm
Radiation length/tracking chamber layer	1.14 % (Al-tubes)
Tube diameter	2.54 cm
Chamber layers/SuperLayer (SL1:SL2:Sl3)	8:10:8
Stereo configuration:	
SL1	4 axial-2 U-2V
SL2	6 axial-2 U-2V
SL3	4 axial-2 U-2V
Angle of stereo	4 mr
Polar angle regions:	
	$9.75^\circ < \theta < 16^\circ$
	$16^\circ < \theta < 29^\circ$

Channel count:

Number of RDT channels	118,784
Nonbend plane: Small angle stereo	

Coverage:

Polar angle:	$9.75^\circ < \theta < 29^\circ$
Pseudo-rapidity:	$1.35 < \lvert\eta\rvert < 2.46$
Azimuthal angle:	94 %
Number of alignment paths	288

(a) Forward angle region: $9.75^\circ < \theta < 16^\circ$ $(1.96 < \lvert\eta\rvert < 2.46)$

Chamber configuration: segmented in ϕ:

Segment A:
Z location of chambers:

SL 1 = 6.05 m
SL 2 = 10.6 m
SL 3 = 15.4 m

Segment B:
Z location of chambers:

SL 1 = 6.45 m
SL 2 = 11.0 m
SL 3 = 15.8 m

(b) Outer angle region: $16^\circ < \theta < 30^\circ$ $(1.32 < \lvert\eta\rvert < 1.96)$

Segment C:
Average Z location of chambers:

SL 1 = 6.65 m
SL 2 = 11.2m
SL 3 = 15.85m

Segment D:
Average Z location of chambers:

	SL 1 = 7.05 m
	SL 2 = 11.6 m
	SL 3 = 16.25 m

Triggering: Resistive Plate Chambers (RPC)

Bend plane:

Segment width $9.75^\circ < \theta < 16^\circ$ $(1.96 < \lvert\eta\rvert < 2.46)$	0.44 cm
Segment width $16^\circ < \theta < 29^\circ$ $(1.32 < \lvert\eta\rvert < 1.96)$	0.60 cm
Number of trigger channels:	71,104

Nonbend plane:

Segment width $9.75^\circ < \theta < 16^\circ$ $(1.96 < \lvert\eta\rvert < 2.46)$	
SL1	3.8 cm
SL2	6.5 cm
SL3	9.3 cm
Segment width $16^\circ < \theta < 30^\circ$ $(1.32 < \lvert\eta\rvert < 1.96)$	
SL1	3.8 cm
SL2	6.5 cm
SL3	9.3 cm
Number of nonbend plane trigger channels:	6,336

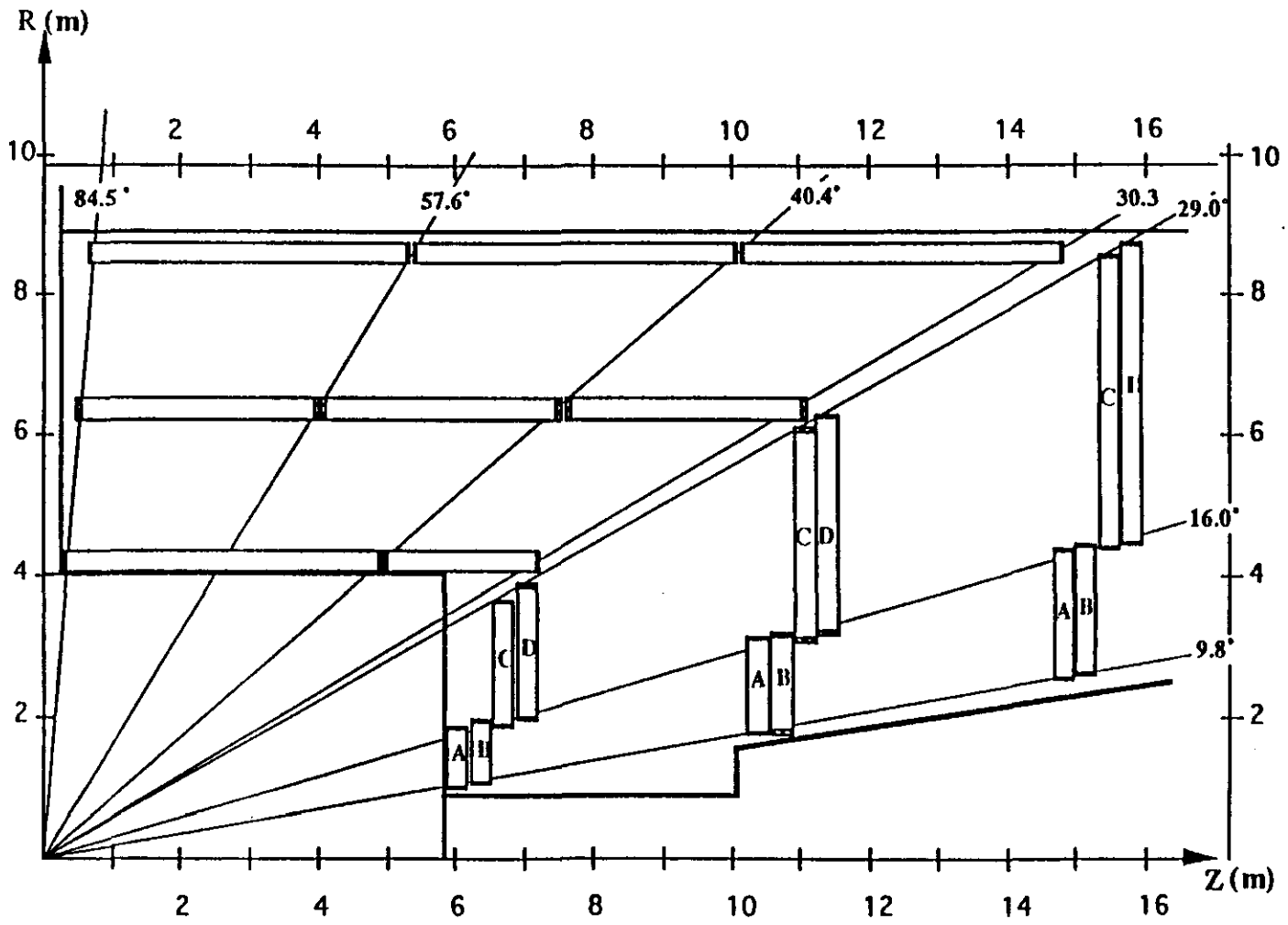
Time jitter of chamber	< 1.5 ns
Time jitter of T0 determination	< 8.3 ns

Note that a backup trigger based on RDTs is envisioned.

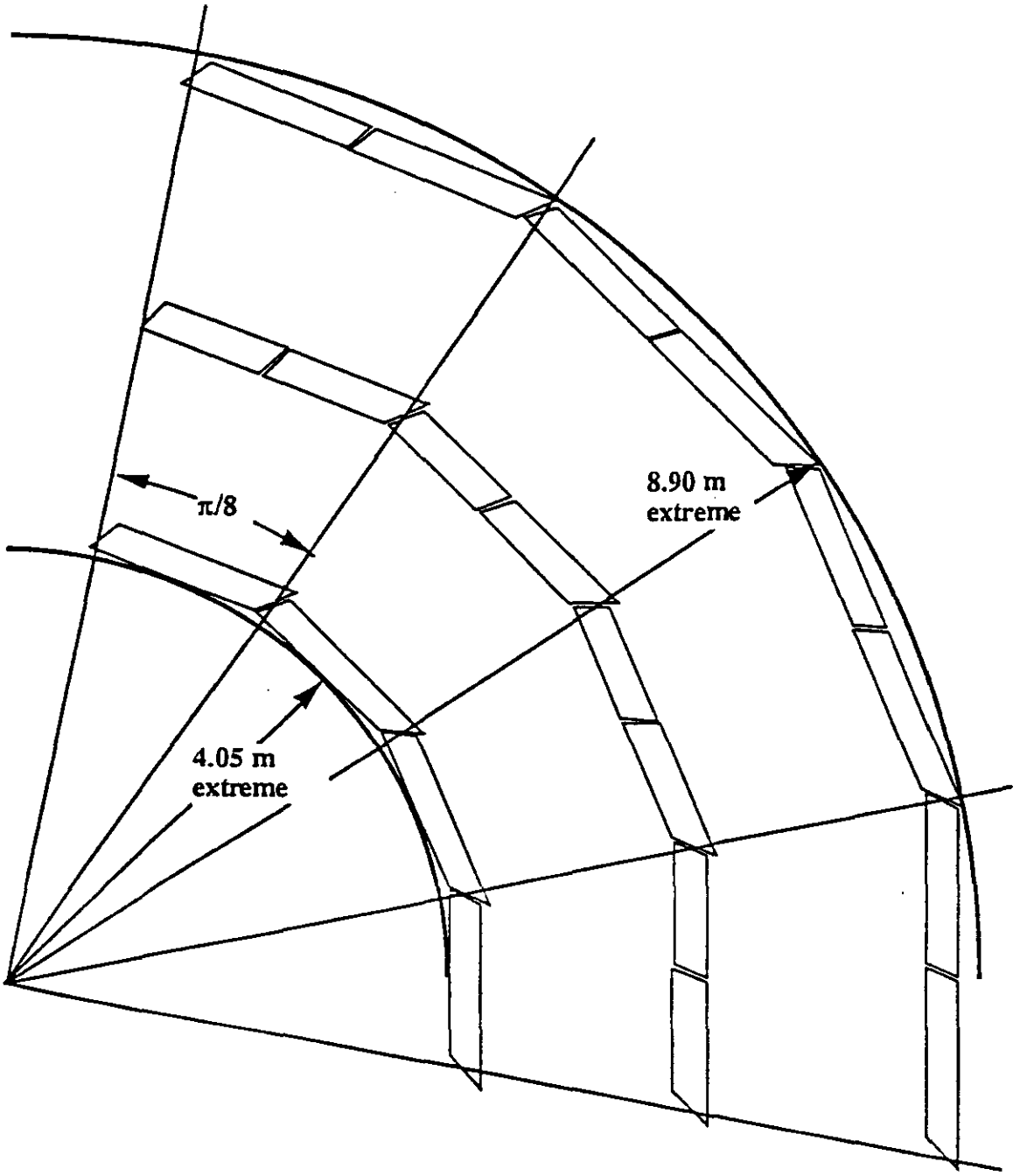
Grand Totals:

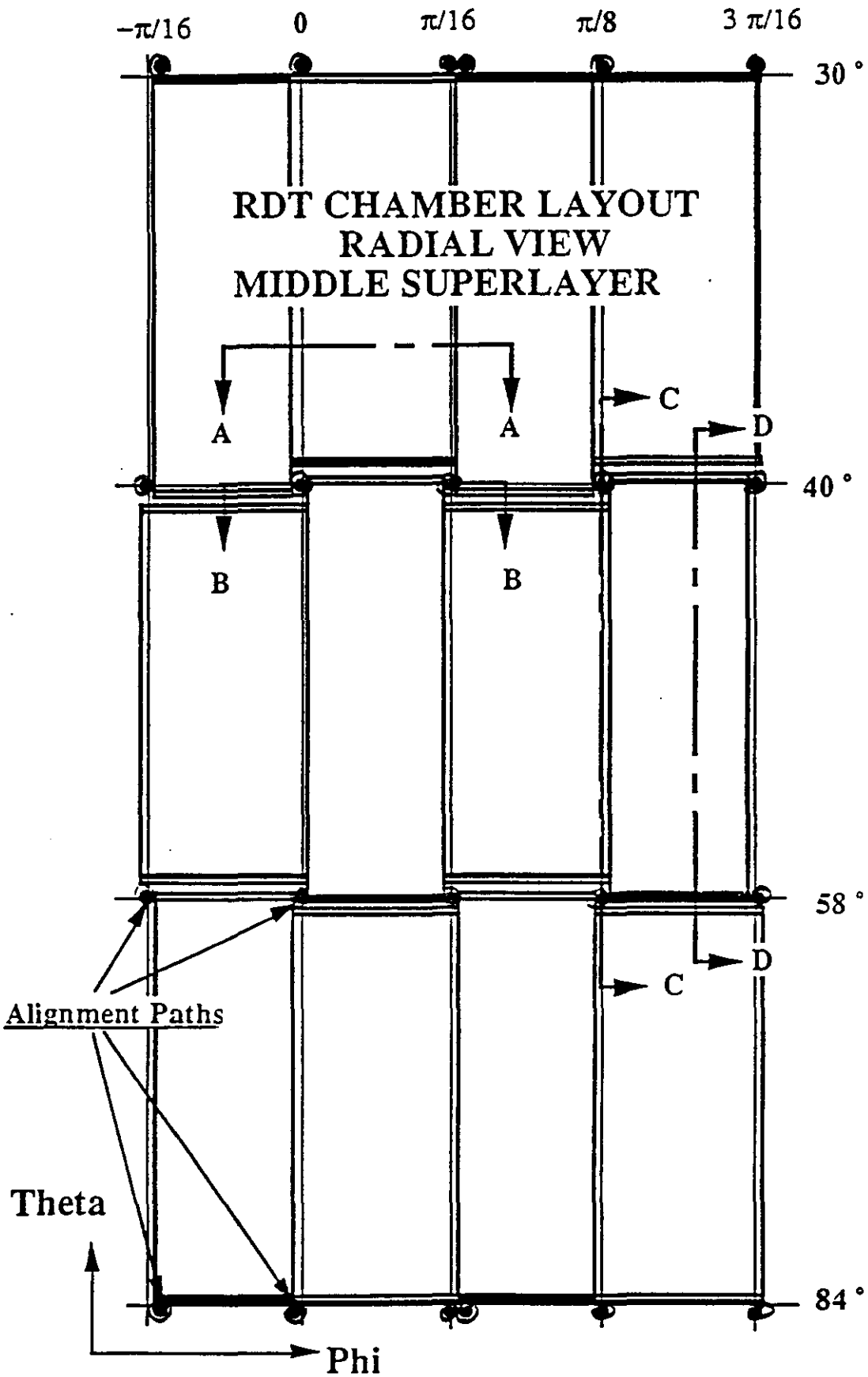
Number of RDT tubes(Channels)	348,160
Number of RPC channels	118,432
Number of alignment paths	1056
Coverage (within Muon System)	94 %

RDT QUADRANT LAYOUT
ELEVATION VIEW

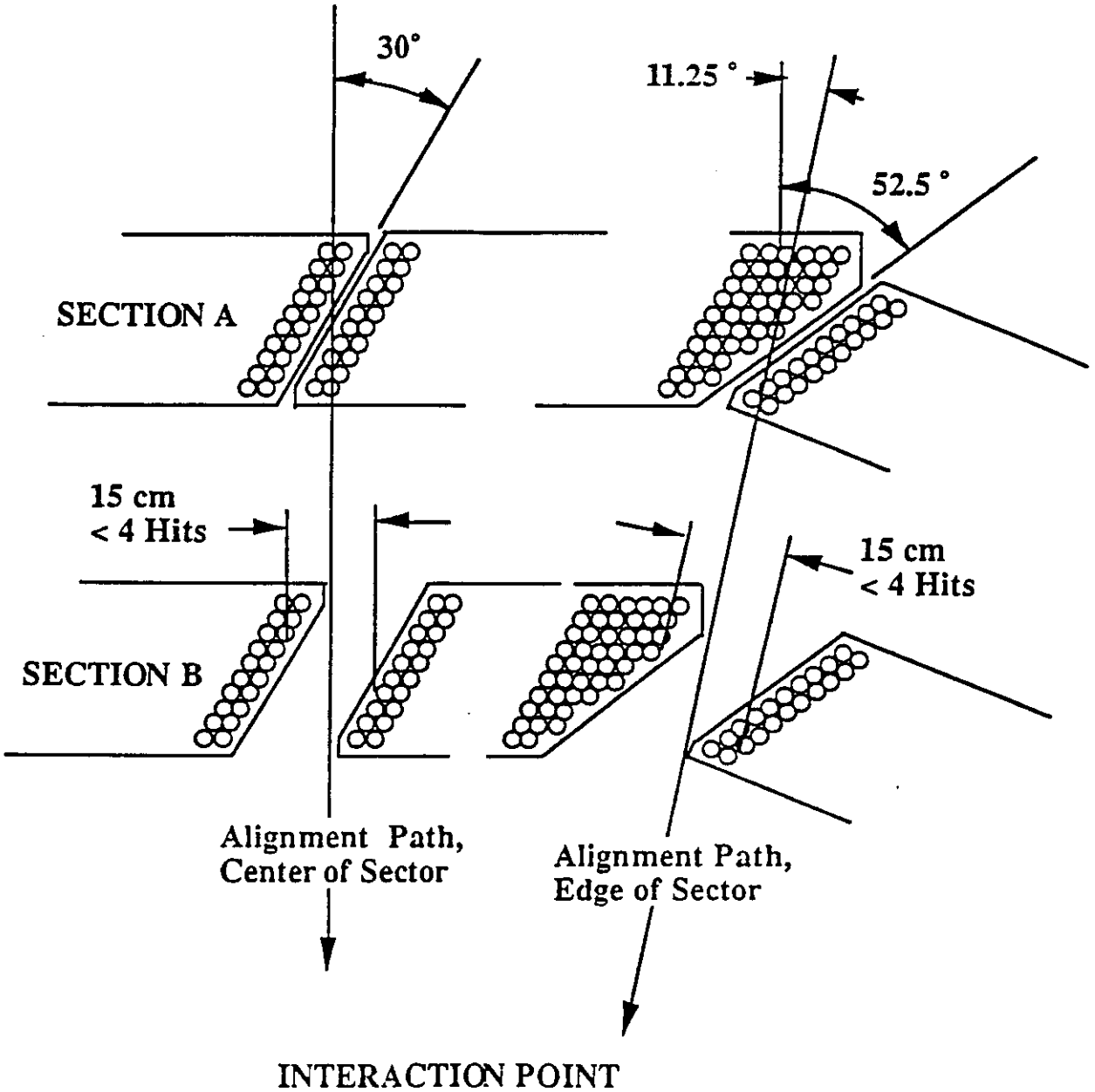


RDT BARREL QUADRANT
AXIAL VIEW

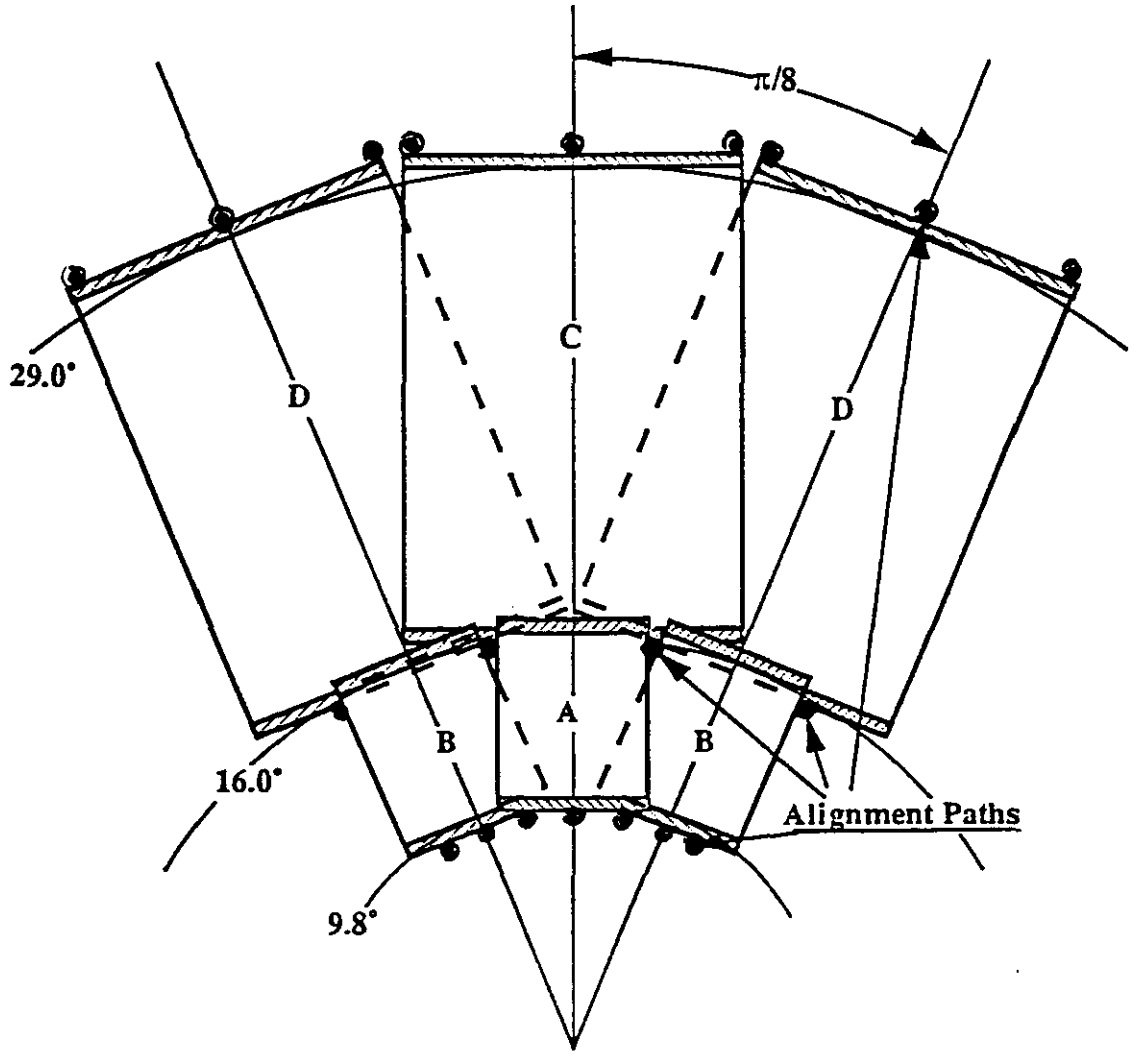



−π/16
0
π/16
π/8
3 π/16
30 °
RDT CHAMBER LAYOUT
RADIAL VIEW
MIDDLE SUPERLAYER
A
A
C
D
40 °
B
B
58 °
D
C
Alignment Paths
Theta
84 °
Phi

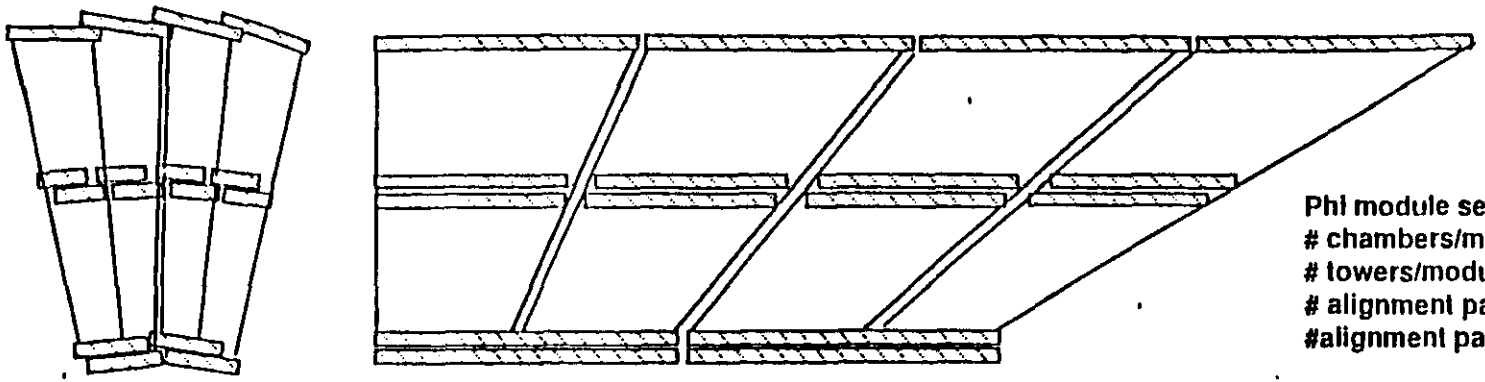
RDT BARREL, MIDDLE SUPERLAYER
PHI OVERLAP DETAIL



RDT ENDCAP LAYOUT
PROJECTIVE VIEW

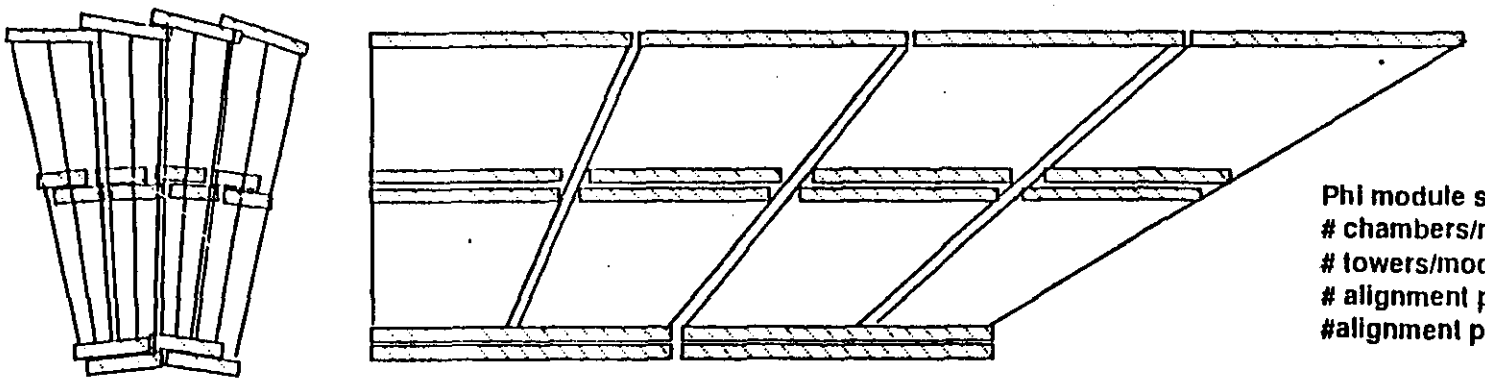


CSC barrel alignment configuration



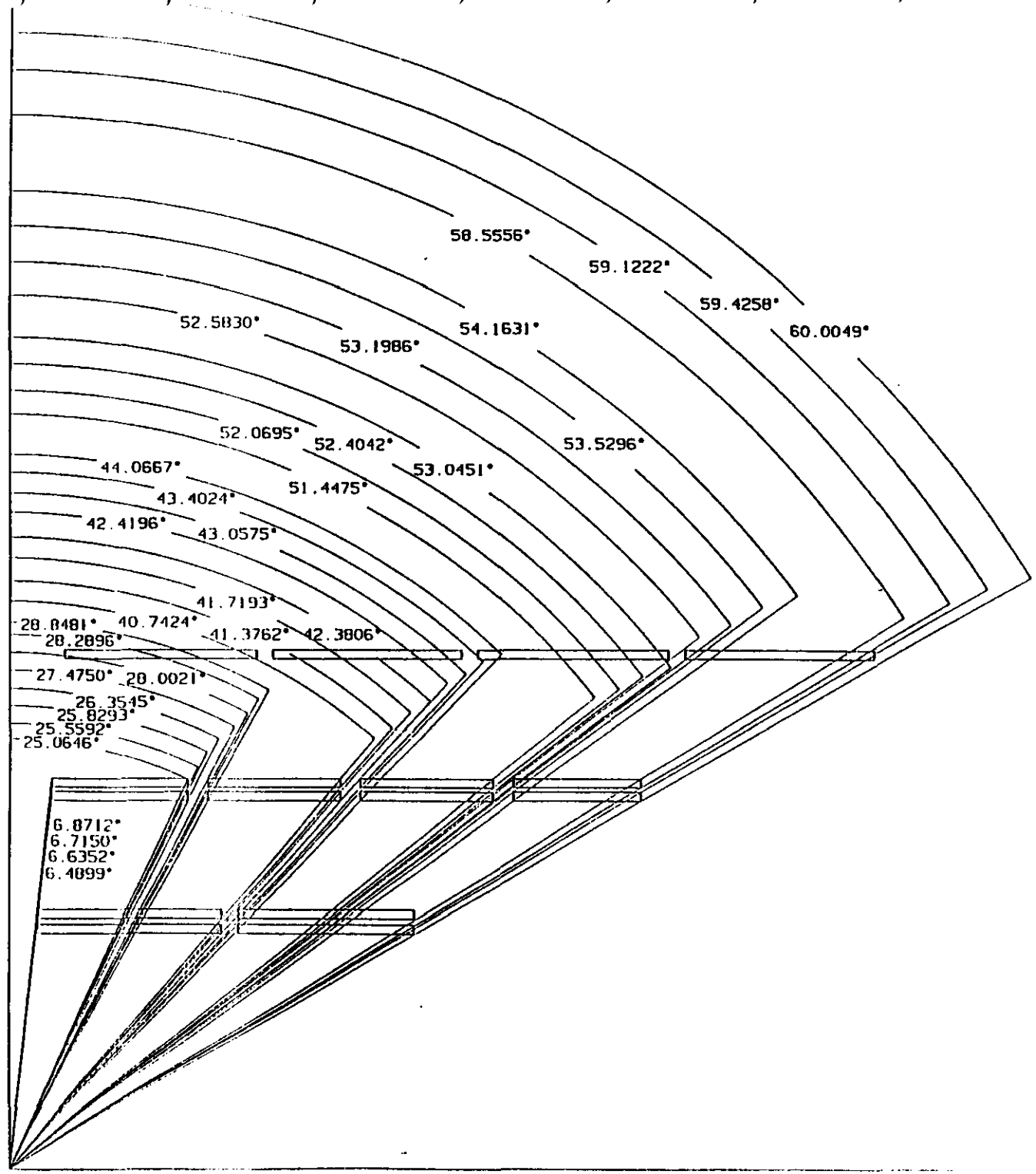
Phi module segmentation = 12
chambers/module = 56
towers/module = 8
alignment paths/module = 48
#alignment paths/GEM = 1152

Configuration with rigid chamber coupling in phi direction

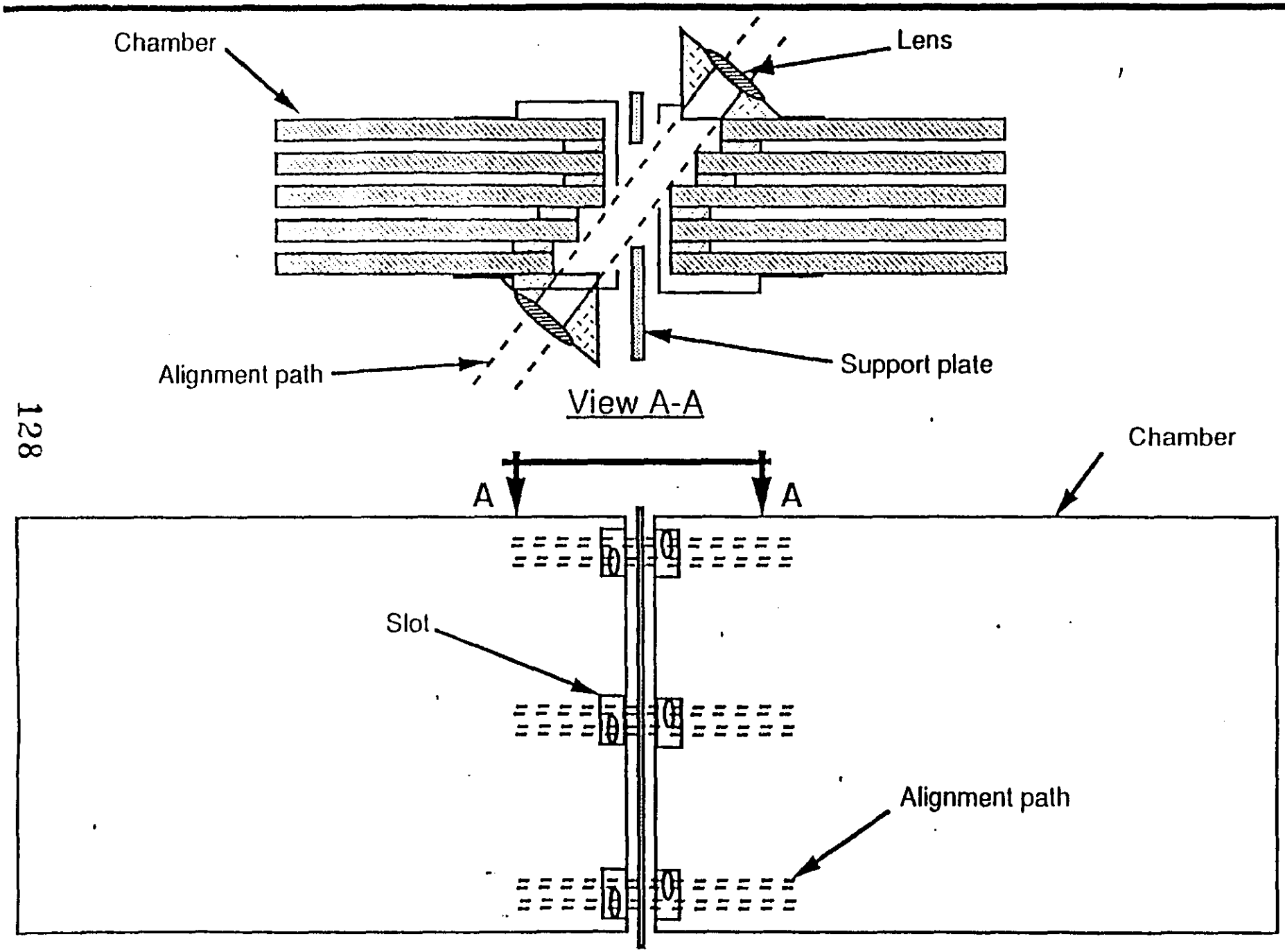


Phi module segmentation = 12
chambers/module = 56
towers/module = 16
alignment paths/module = 96
#alignment paths/GEM = 2304

Configuration with no rigid chamber coupling in phi direction

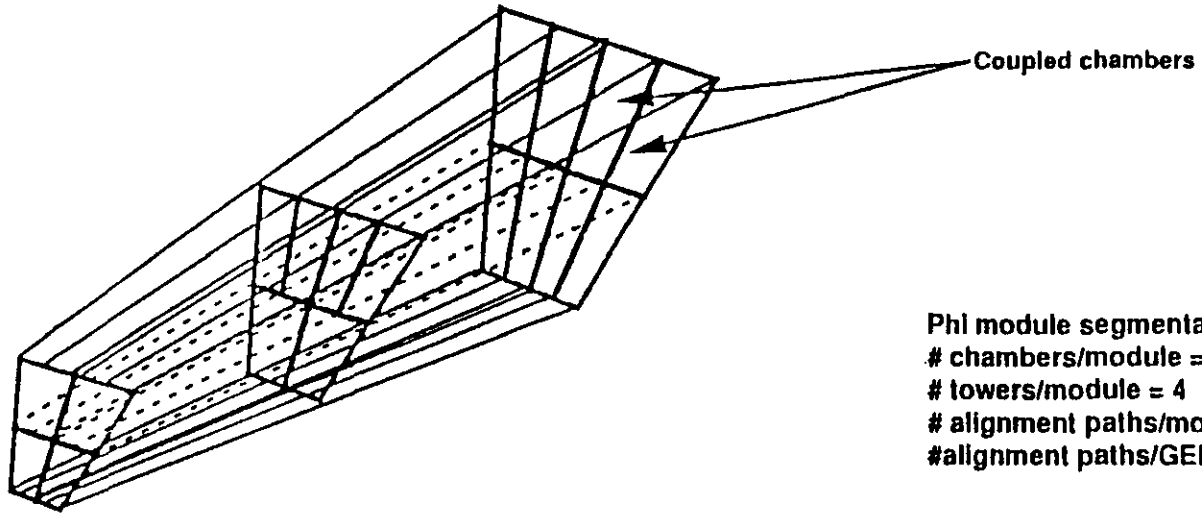

58.5556°
59.1222°
59.4258°
60.0049°
52.5830°
54.1631°
53.1986°
52.0695°
52.4042°
53.5296°
44.0667°
53.0451°
51.4475°
43.4024°
42.4196°
43.0575°
41.7193°
28.8481°
40.7424°
28.2896°
41.3762°
42.3806°
27.4750°
28.0021°
26.3545°
25.8293°
25.5592°
25.0646°
6.8712°
6.7150°
6.6352°
6.4099°

Barrel region alignment slots



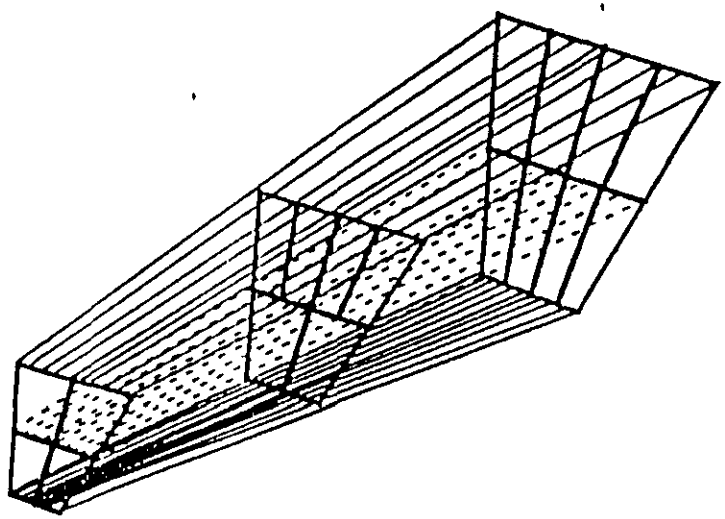
Not drawn to scale

CSC endcap alignment configuration



Phi module segmentation = 12
chambers/module = 24
towers/module = 4
alignment paths/module = 24
#alignment paths/GEM = 1152

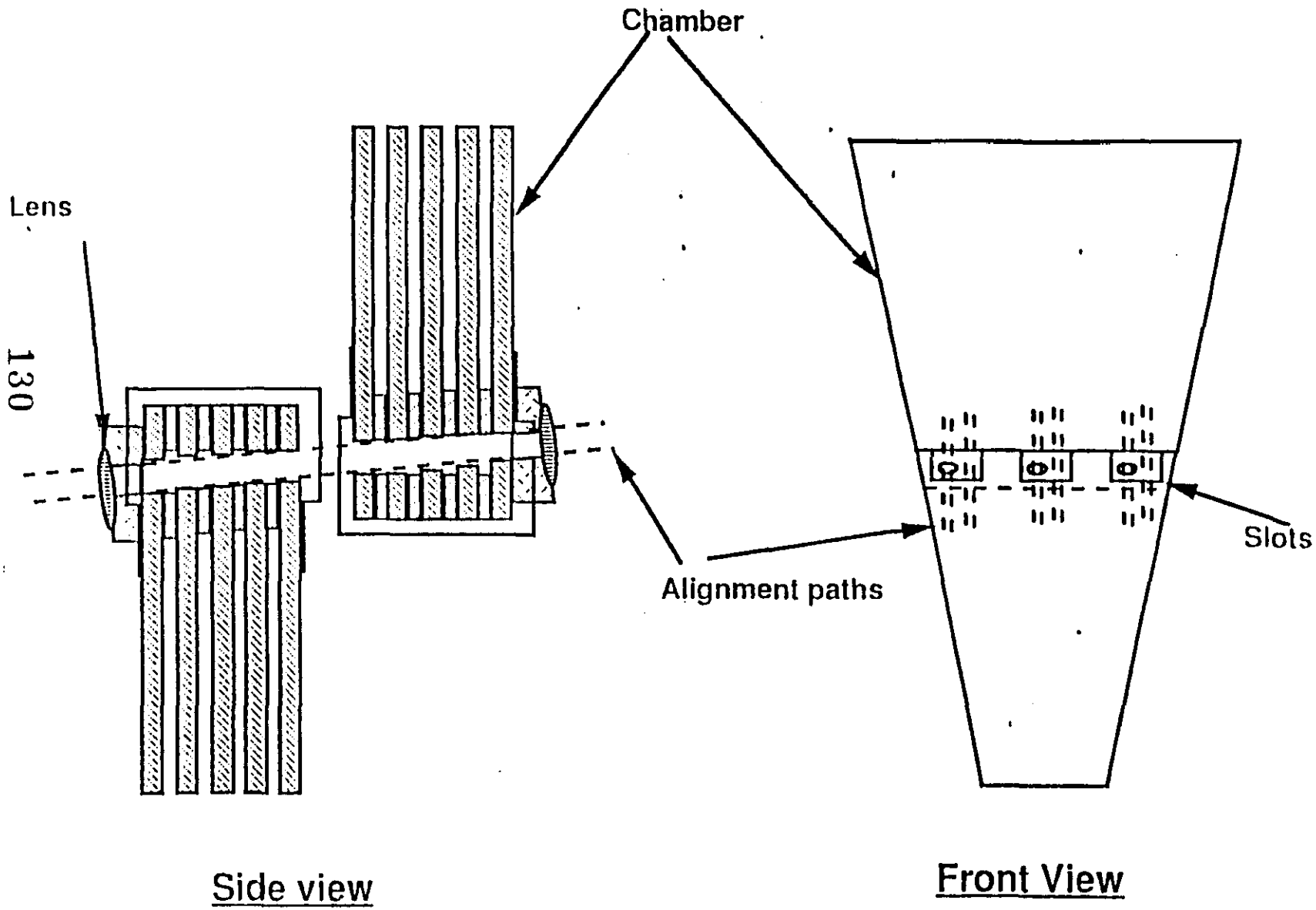
Configuration with rigid chamber coupling in phi direction



Phi module segmentation = 12
chambers/module = 24
towers/module = 8
alignment paths/module = 48
#alignment paths/GEM = 2304

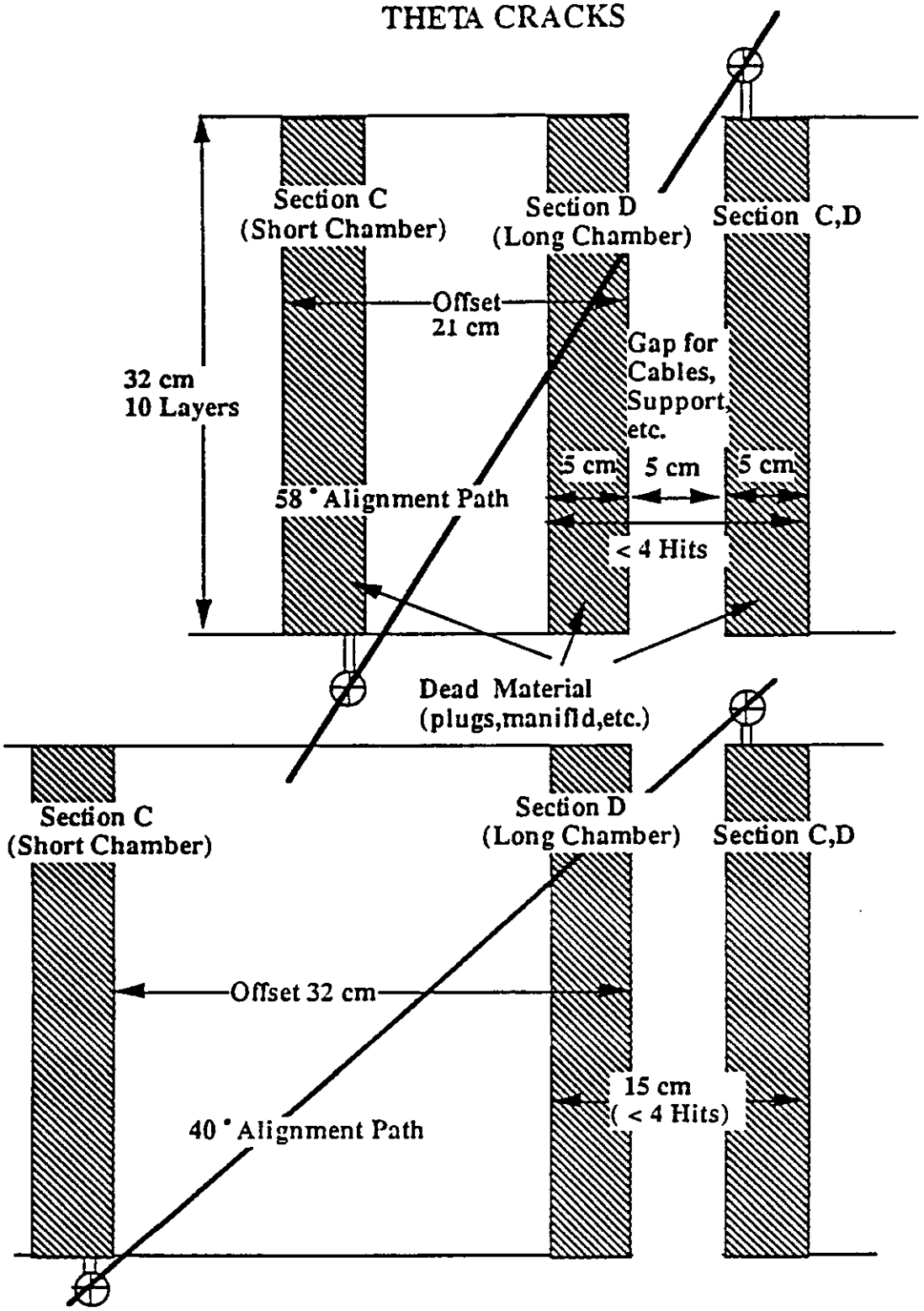
Configuration with no rigid chamber coupling in phi direction

Endcap region alignment slots

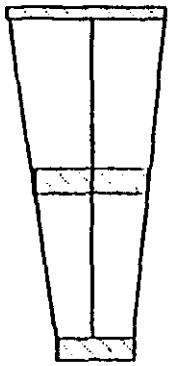


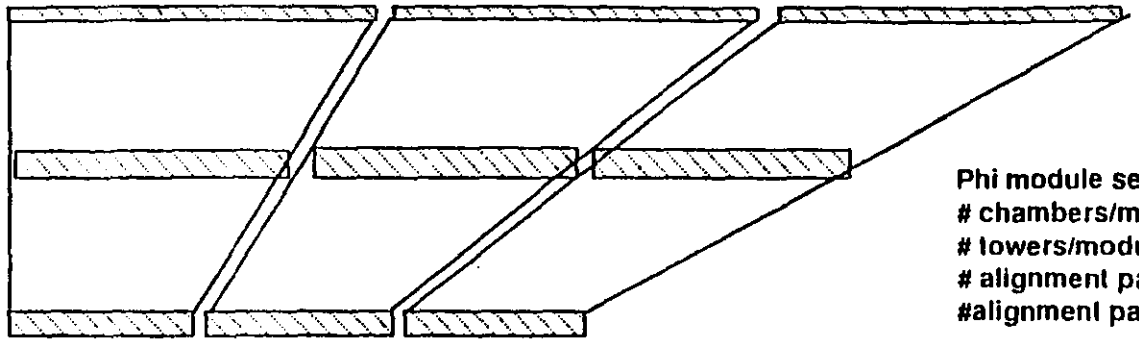
Not drawn to scale

RDT BARREL, MIDDLE SUPERLAYER
THETA CRACKS



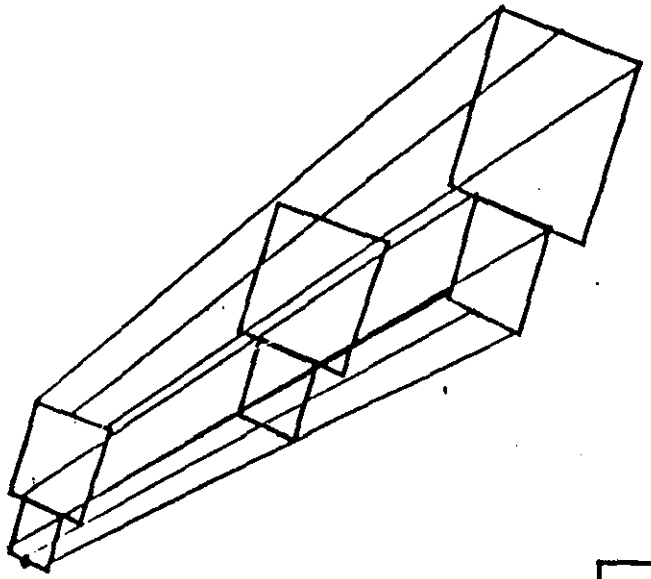
RDT alignment configurations





Phi module segmentation = 16
chambers/module = 9
towers/module = 3
alignment paths/module = 18
#alignment paths/GEM = 576

Barrel configuration with rigid chamber coupling in phi direction



Phi module segmentation = 16
chambers/module = 6
towers/module = 2
alignment paths/module = 9
#alignment paths/GEM = 288

Endcap configuration

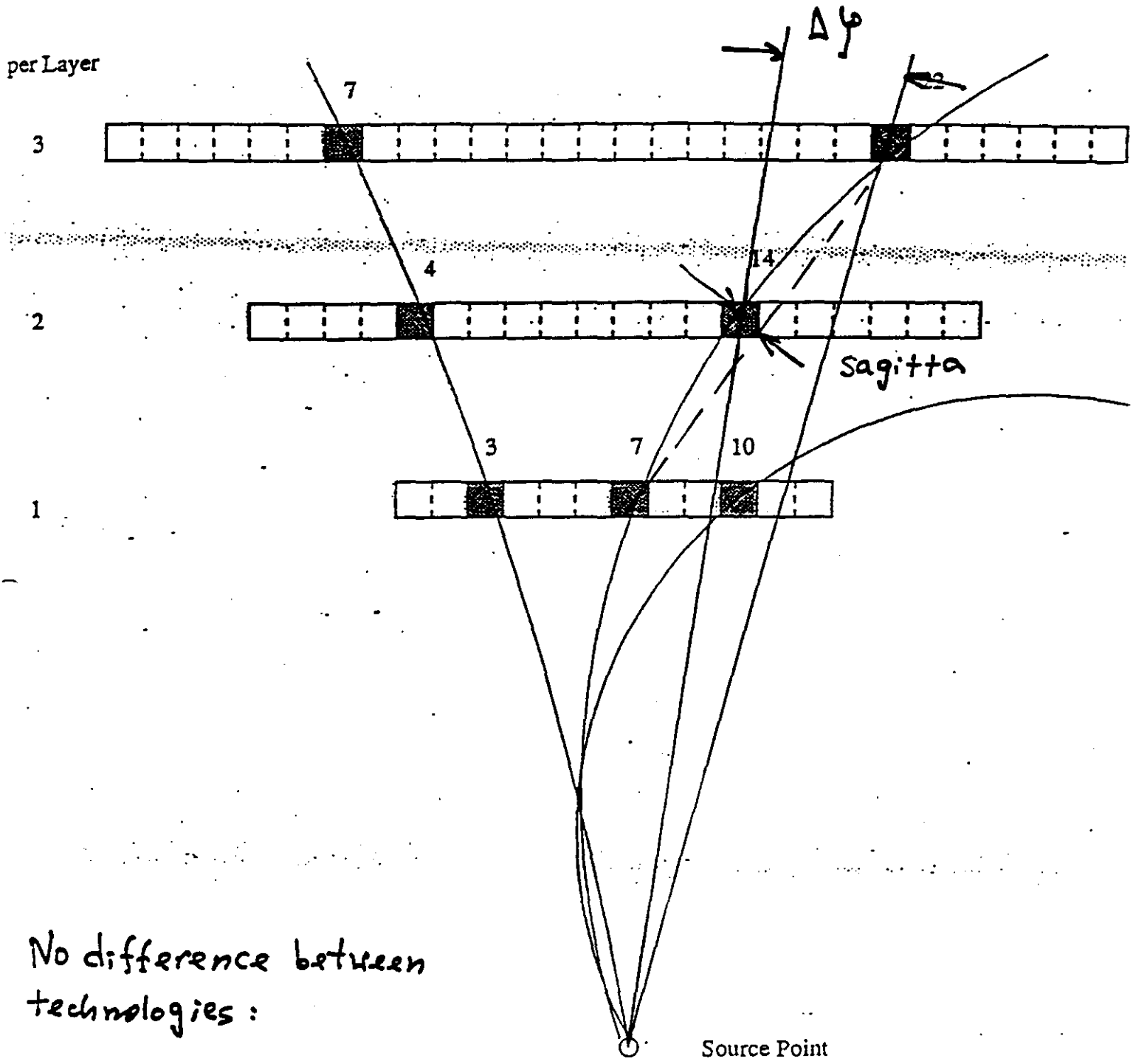
Note: Resolution and 6 degree of freedom rigid body motion discrimination has not been verified with fewer than 6 projective alignment paths in endcap

Alignment path comparison

	#Alignment paths	Alignment channel cost - K$
CSC (no chamber coupling)	4608	2995
CSC (with chamber coupling)	2304	1497
RDT (with chamber coupling)	864	561

Notes:
1) alignment channel cost = $650
2) Endcap towers have fewer than 6 alignment paths

Trigger



No difference between technologies:

Δφ in barrel

Sagitta in Endcaps

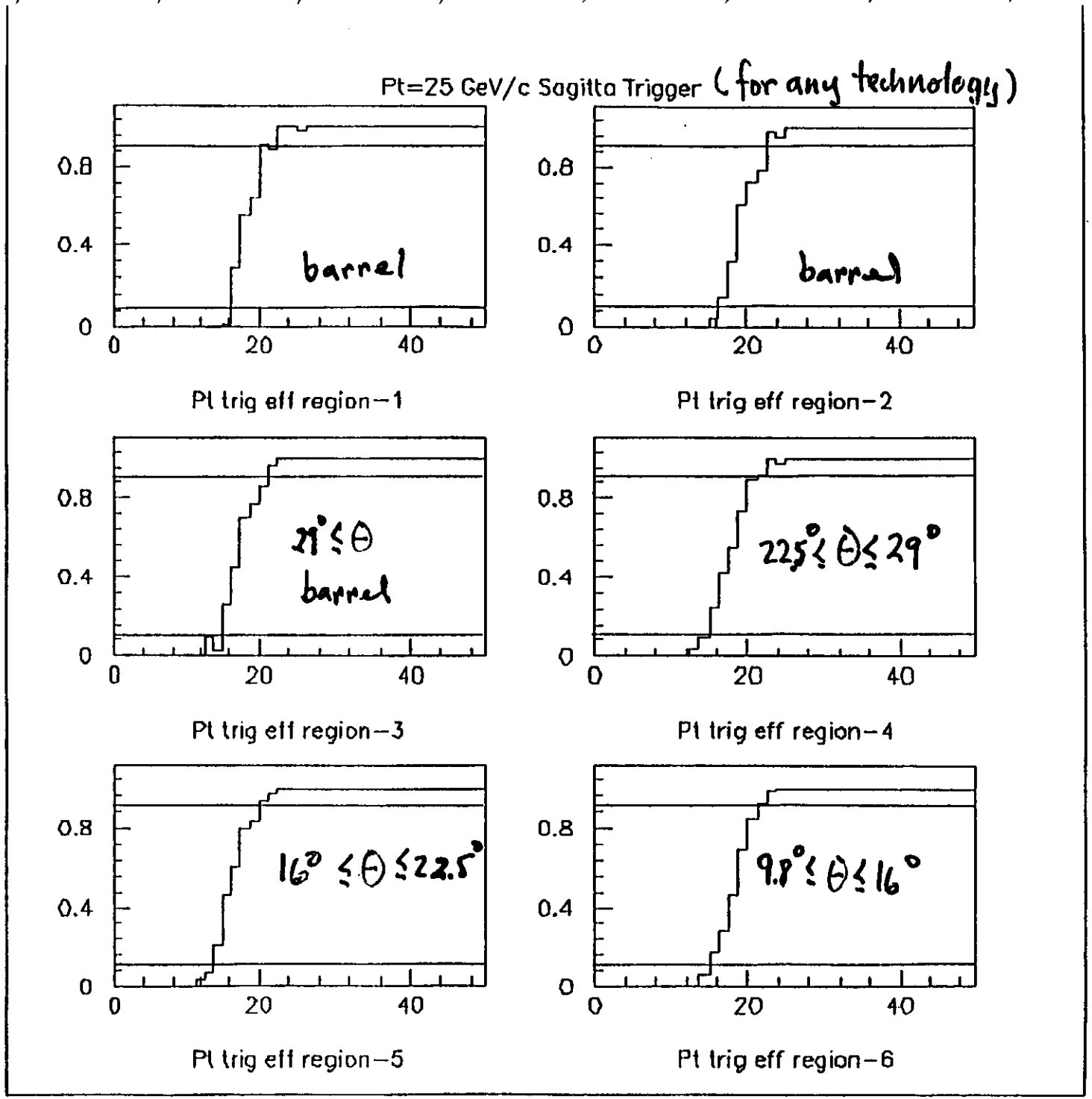

Pt=25 GeV/c Sagitta Trigger (for any technology)
0.8
0.4
0
0
20
40
barrel
Pt trig eff region−1
barrel
Pt trig eff region−2
29° ≤ θ
barrel
Pt trig eff region−3
22.5° ≤ θ ≤ 29°
Pt trig eff region−4
16° ≤ θ ≤ 22.5°
Pt trig eff region−5
9.8° ≤ θ ≤ 16°
Pt trig eff region−6

Fig. 8.1.1.b

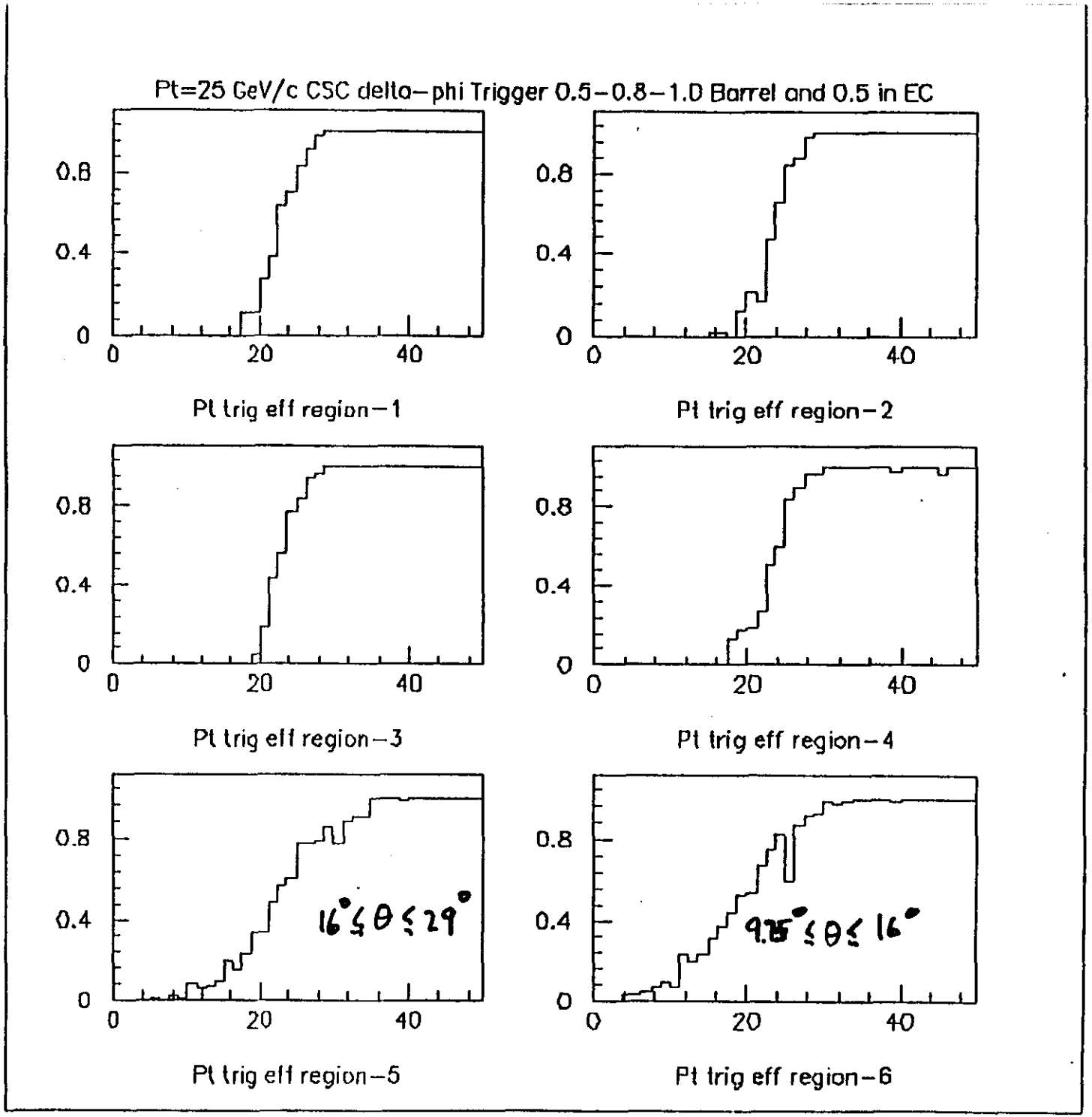

Pt=25 GeV/c CSC delta-phi Trigger 0.5-0.8-1.0 Barrel and 0.5 in EC
0.8
0.4
0
0
20
40
Pt trig eff region-1
Pt trig eff region-2
Pt trig eff region-3
Pt trig eff region-4
Pt trig eff region-5
Pt trig eff region-6
16° ≤ θ ≤ 29°
9.25° ≤ θ ≤ 16°

Fig. P.1

$P_\perp$ resolution

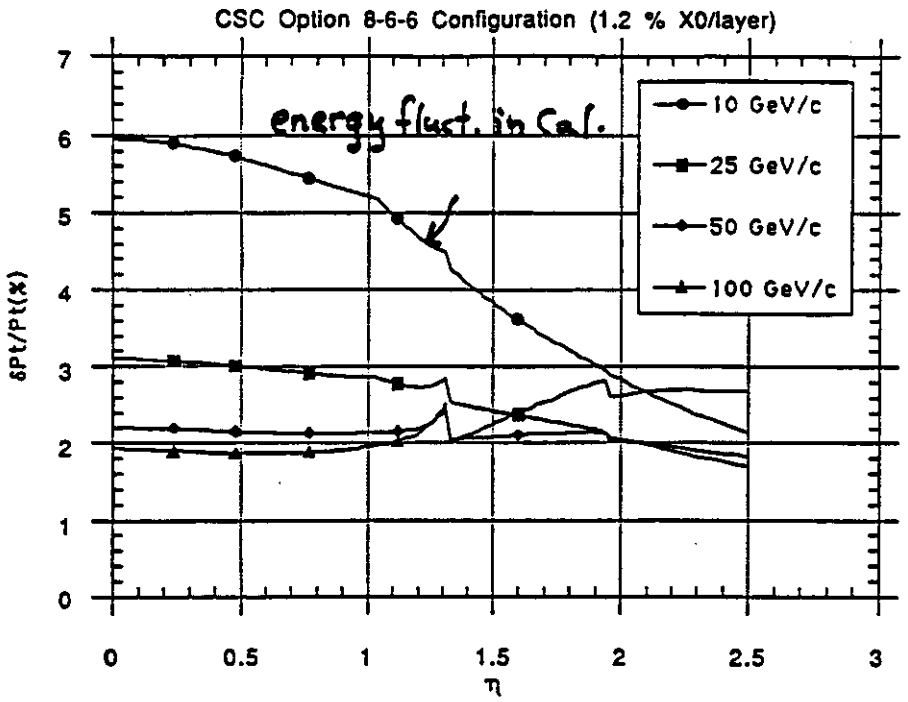


Fig. 8.2.1a

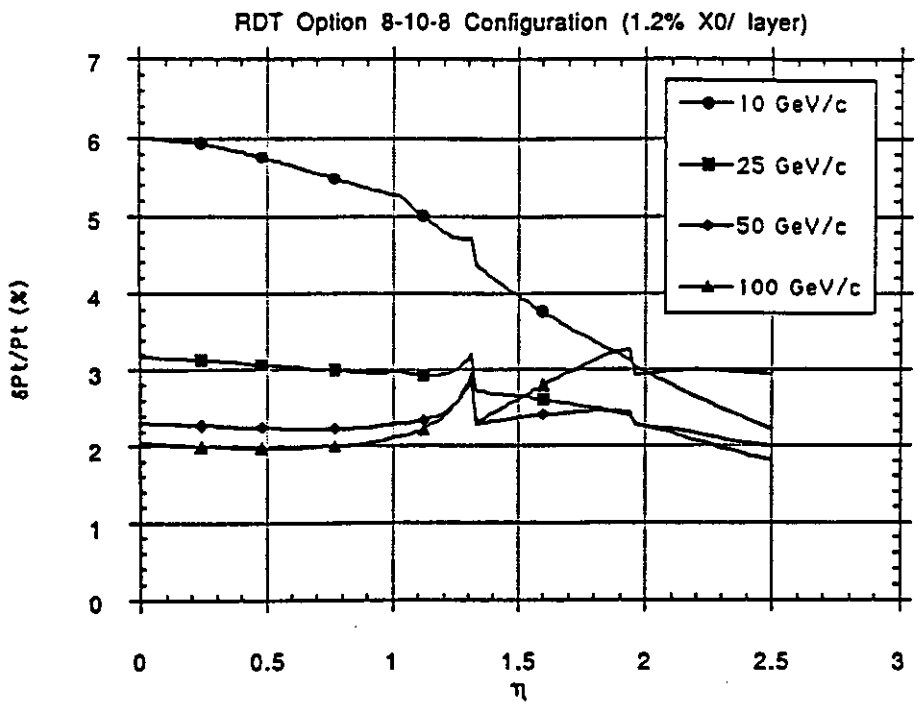


Fig. 8.2.1 a

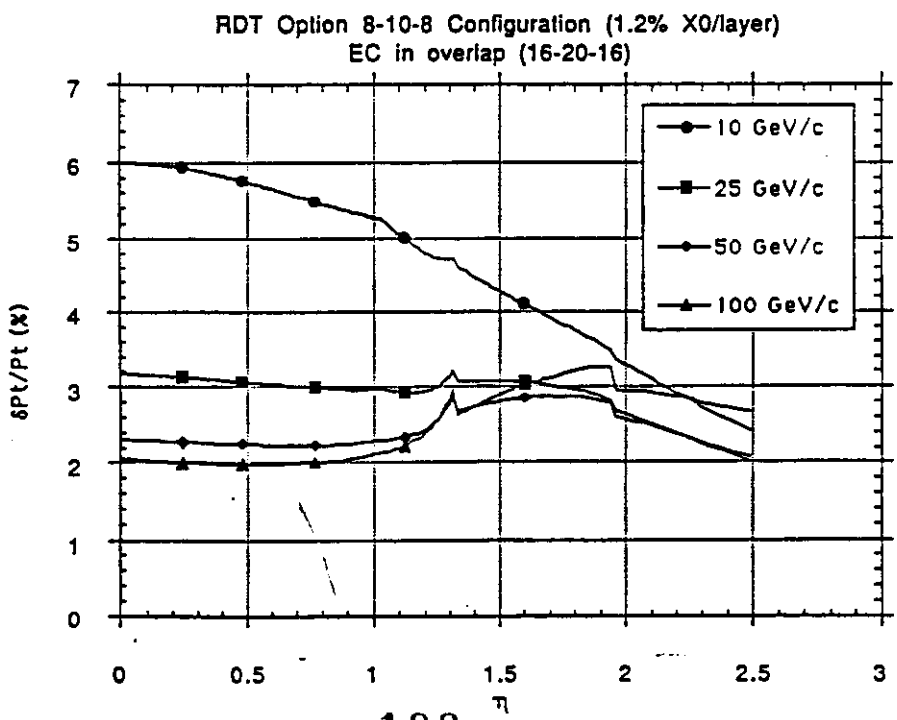
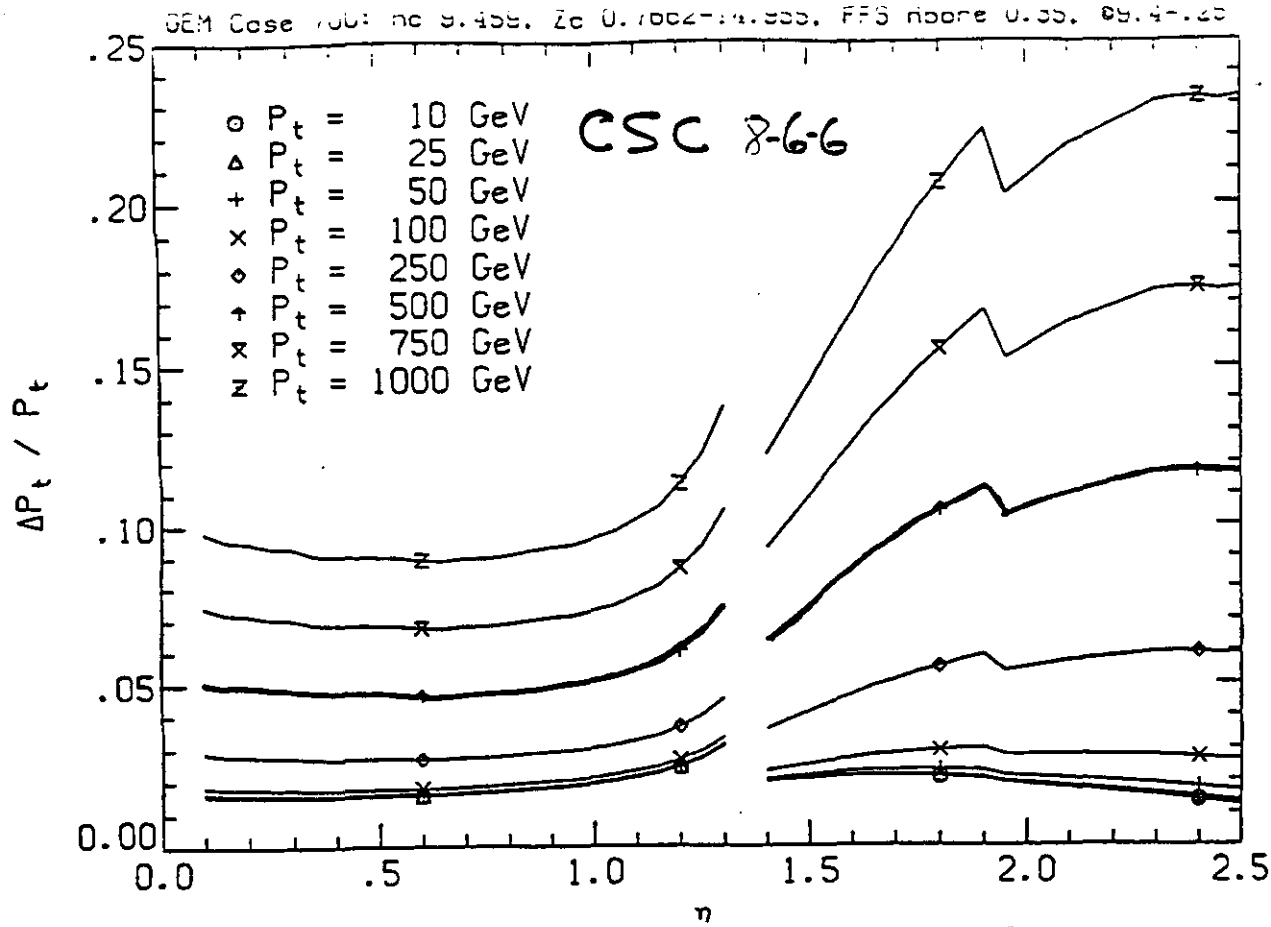


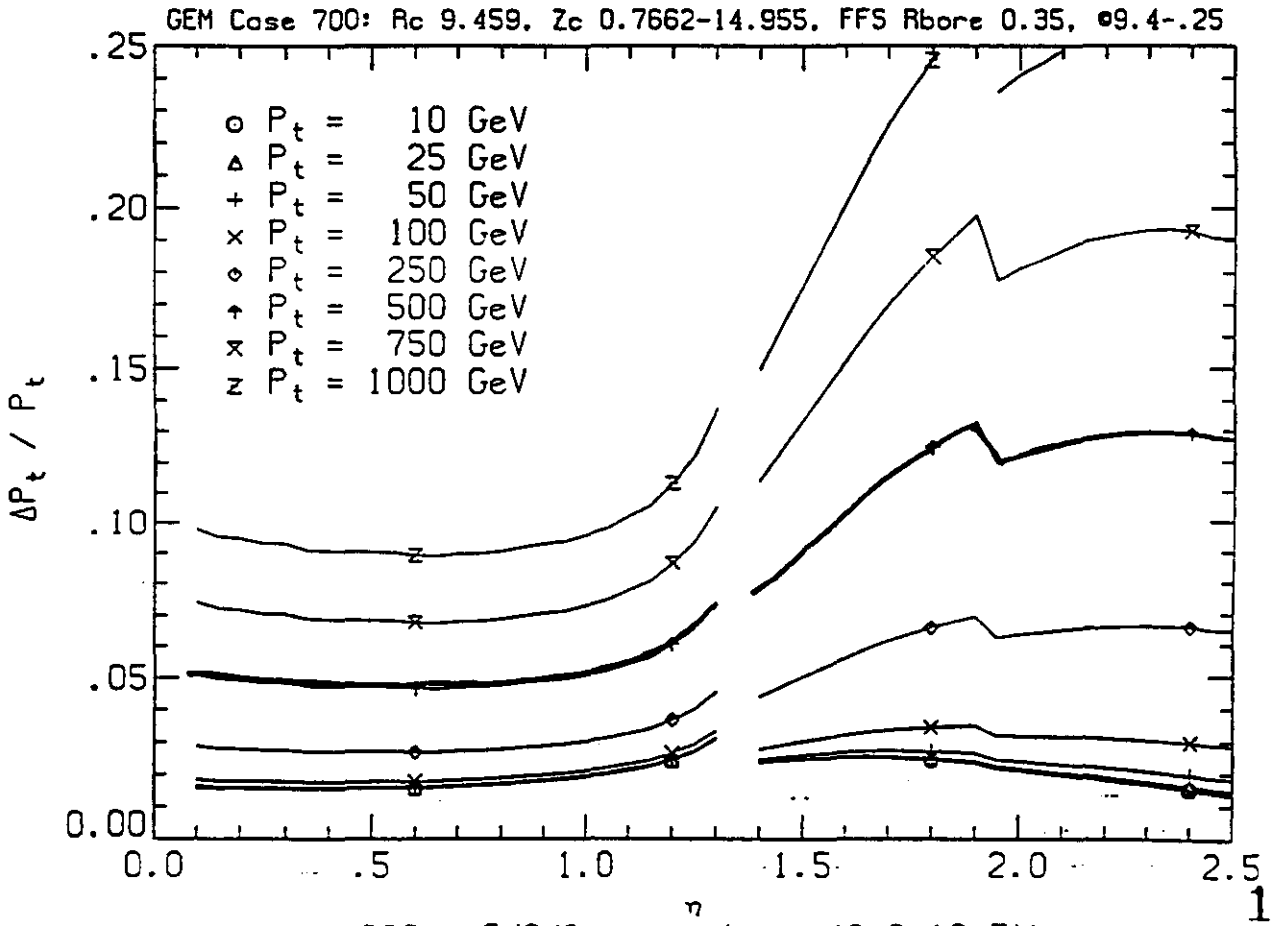
Fig. 8.2.1 b

FEB-01-1993 14:49 FROM MIT PLASMA FUSION-2 TO 31755 P.19

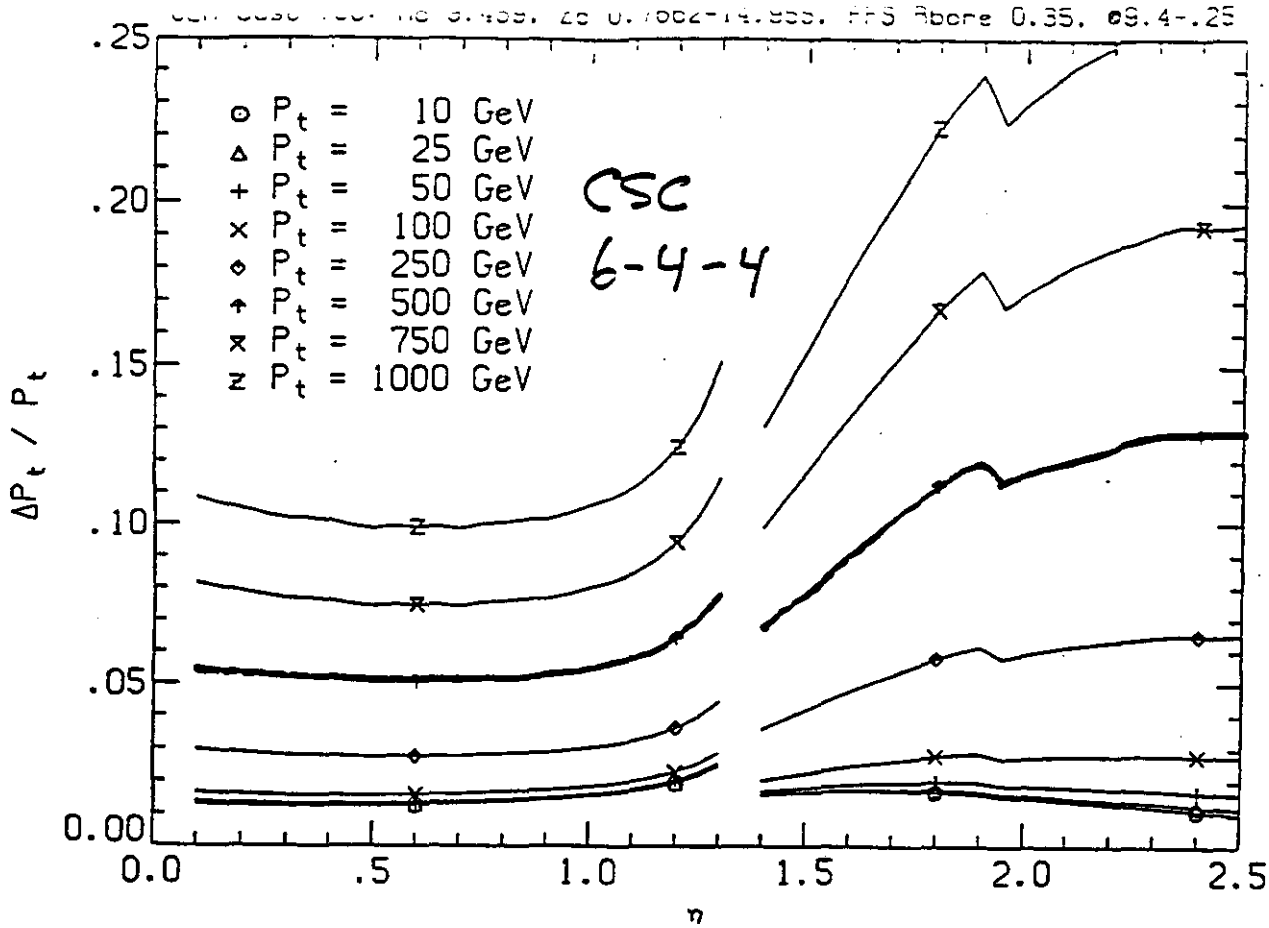


CSC: 8/6/6 everywhere (6.0-16.5)a

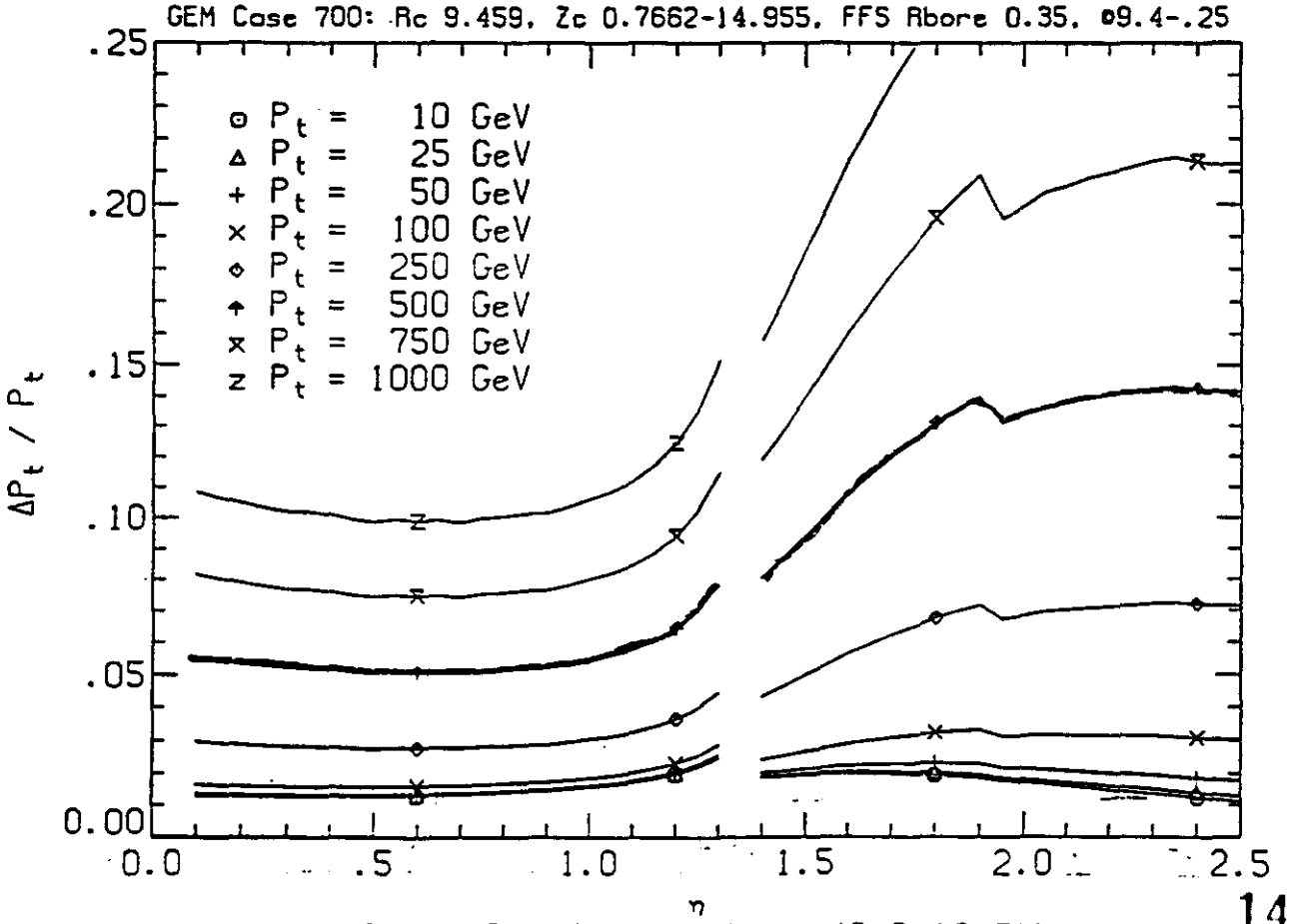
FEB-01-1993 14:40 FROM MIT PLASMA FUSION-2 TO 31755 P.08



CSC: 8/6/6 everywhere (6.0-16.5)b



CSC: 6/4/4 everywhere (6.0-16.5)a



CSC: 6/4/4 everywhere (6.0-16.5)b

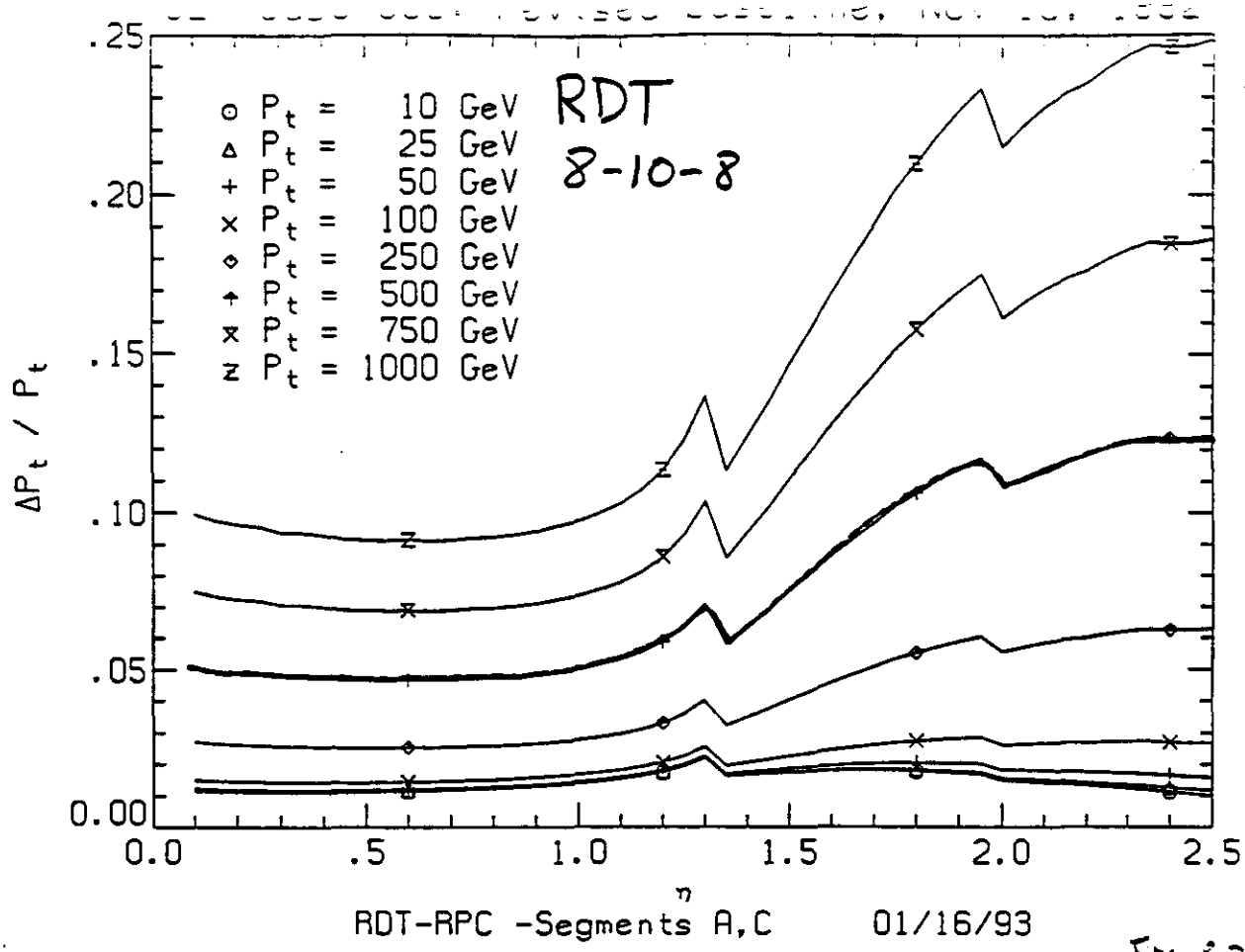


Fig. 8.2.2 a

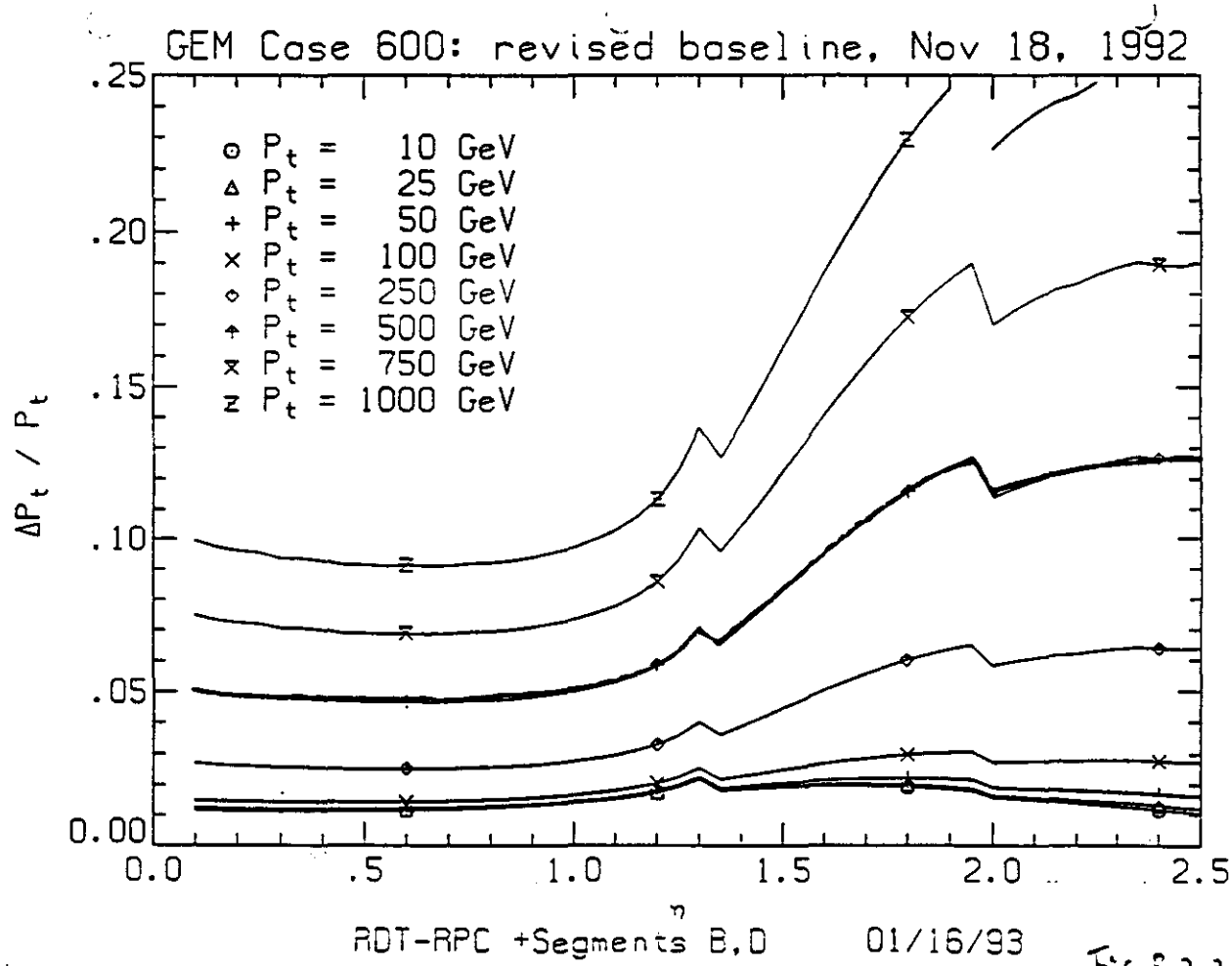


Fig. 8.2.2 b

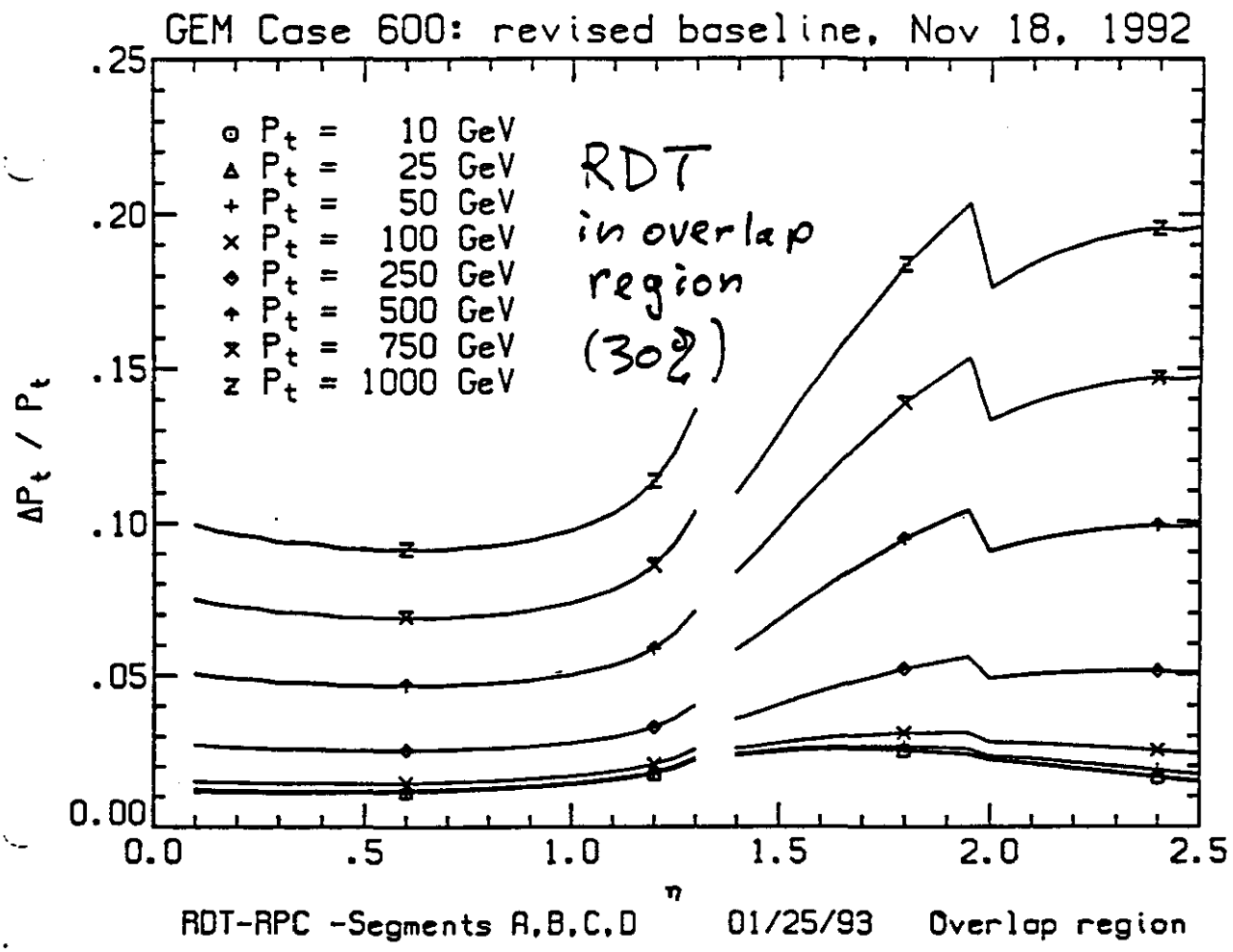
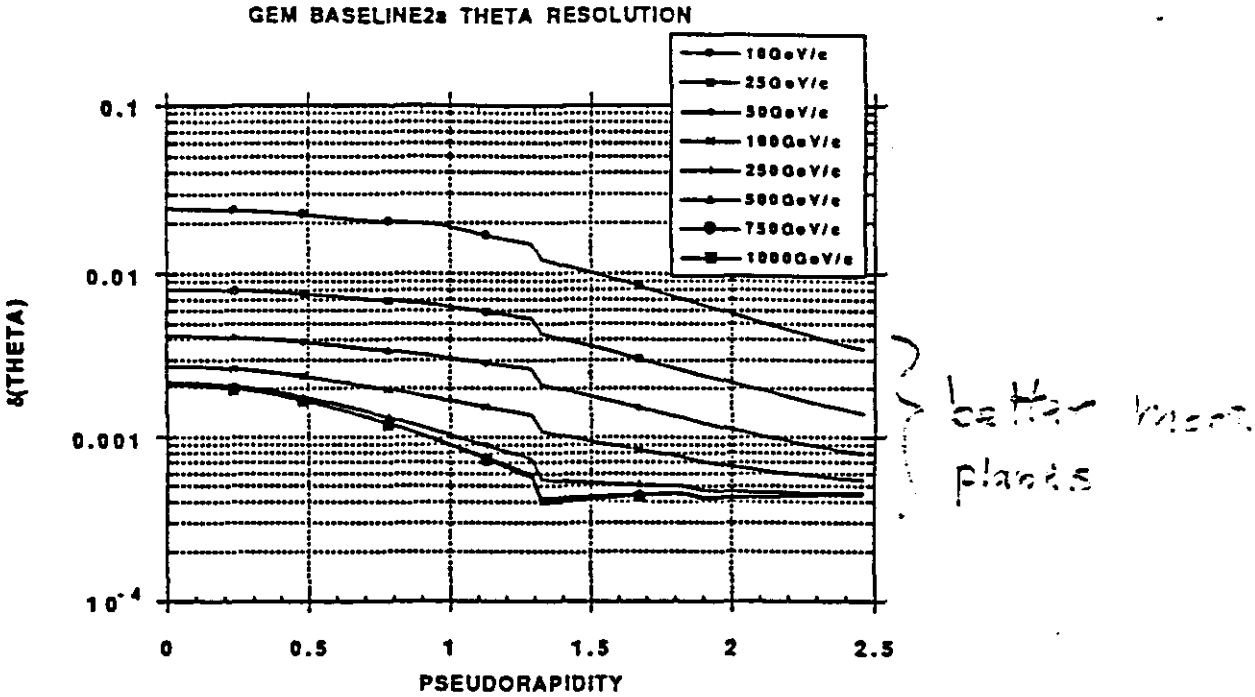
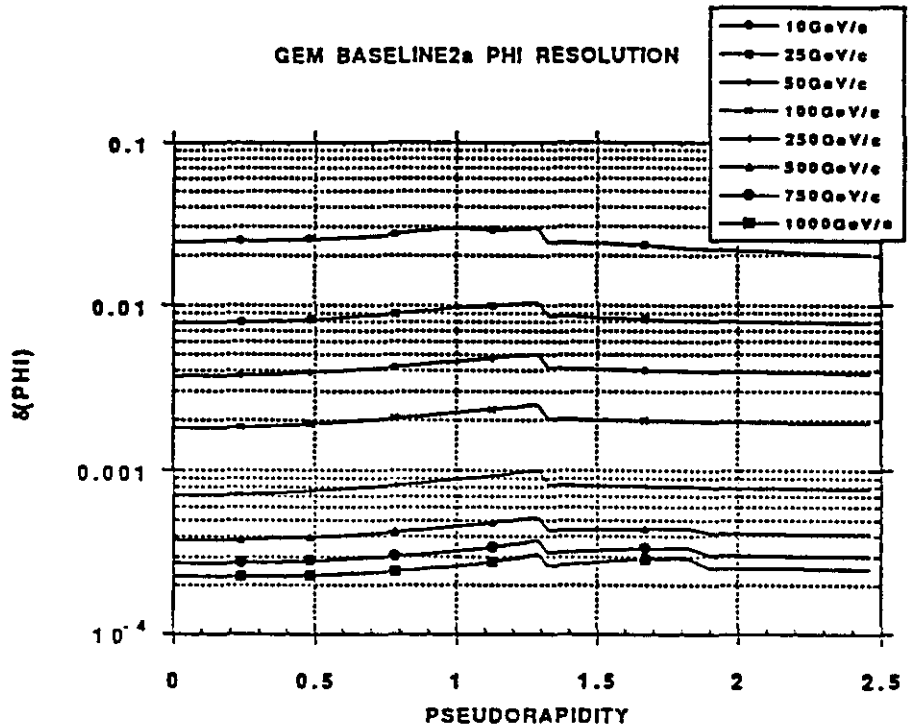

GEM Case 600: revised baseline, Nov 18, 1992
⊙ P_t = 10 GeV
△ P_t = 25 GeV
+ P_t = 50 GeV
× P_t = 100 GeV
◆ P_t = 250 GeV
✦ P_t = 500 GeV
✕ P_t = 750 GeV
z P_t = 1000 GeV
RDT
in overlap
region
(30%)
$\Delta P_t / P_t$
.25
.20
.15
.10
.05
0.00
0.0
.5
1.0
1.5
2.0
2.5
η
RDT-RPC -Segments A,B,C,D
01/25/93
Overlap region

Fig. 8.2.2 c

CSC


GEM BASELINE2a THETA RESOLUTION
10GeV/c
25GeV/c
50GeV/c
100GeV/c
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
0.1
0.01
0.001
10^-4
δ(THETA)
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
resol'n
better meas. planes

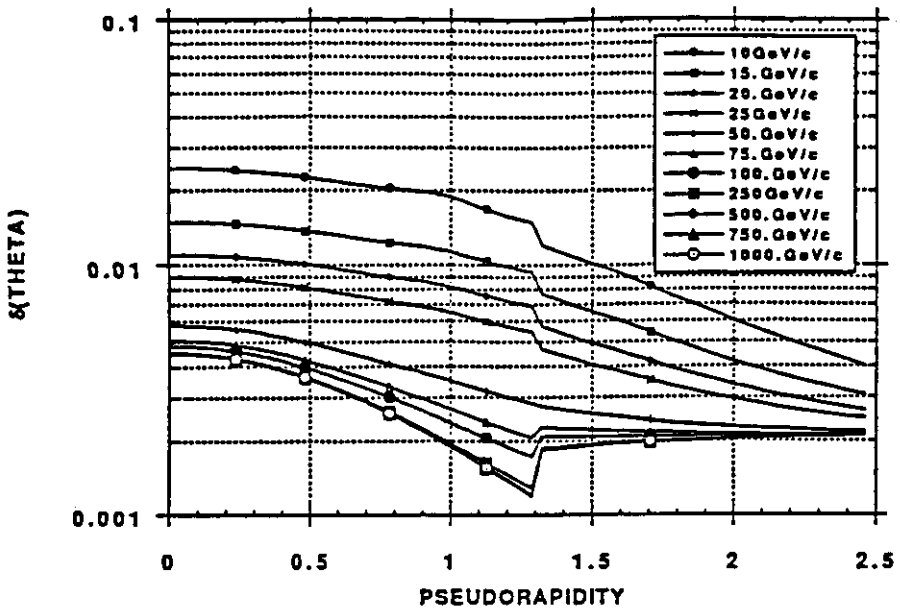

GEM BASELINE2a PHI RESOLUTION
10GeV/c
25GeV/c
50GeV/c
100GeV/c
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
0.1
0.01
0.001
10^-4
δ(PHI)
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
resol'n

RDT

3wayiesilcon.ixl

GEM BASELINE2 THETA RESOLUTION
RDT SYSTEM

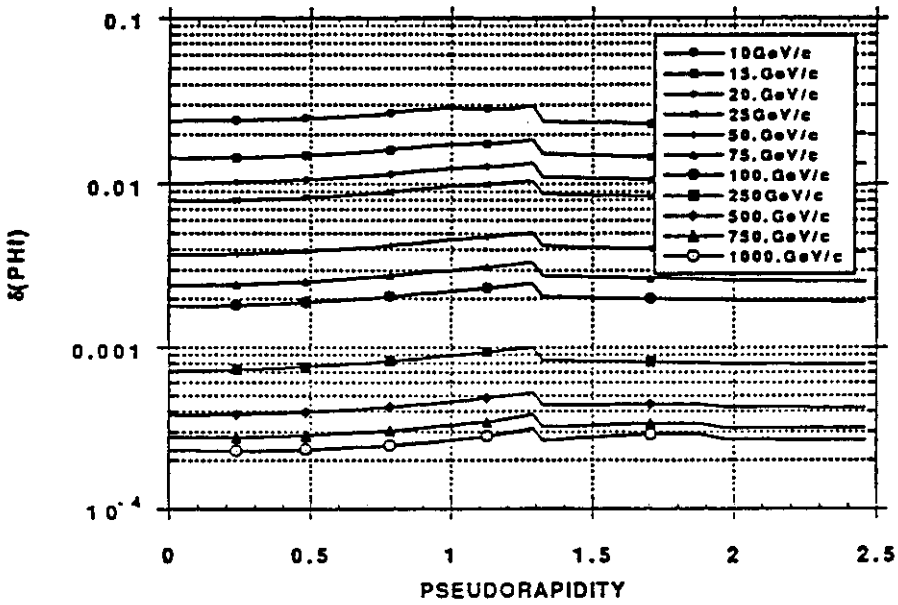
θresol'n



3wayiesilcon.ixl

GEM BASELINE2 PHI RESOLUTION
RDT SYSTEM

resol'n



Costs

GEM Muon Sub-system Chamber Options

(Mechanical only)

		Material Costs (pre DGA)						Estimated (mechanical) System Cost
		Barrel	End Cap	Sum	change from Rev. 15	35% DGA	total change from Rev. 15	
1	CSC 6-4-4 everywhere	14590	2410	17000	-494	-178	-672	107279
2	CSC 8-8-8 everywhere	20707	3483	24190	6896	2411	9107	117058
3	CSC 8-4-4 Barrel 8-8-4 End Cap (1<16) 8-4-4 End Cap (16<1<28)	15265	2696	17961	467	168	635	108586
4	RDT 8-10-8 everywhere	10421	4323	14744	3493	1257	4750	98573
	RPC 3-3-3 everywhere	1092	429	1521	0	0	0	
5	RDT 8-8-6 everywhere	7826	3425	11251	0	0	0	91823
	RPC 3-3-3 everywhere	1092	429	1521	0	0	0	

Barrel CSC data from adaptation of Coleman Johnson's spreadsheet

End Cap CSC data from Scott Whitaker's spreadsheet

Barrel and End Cap RDT data from Bob Miller

Barrel and End Cap RPC data from Craig Wuest

CSC vs RPT/RPC Δ mechanical ≈ 117 - 98.6 = $18.4 M

Note: Change in number of gaps results in materials cost changes only.
(Not enough is known about the specifics of assembly/test to allow cost changes in those categories.)

Subjectives:

- **RDT/RPC** would provide an operating baseline if RPC rate effect could be solved

  - resolutions adequate
  - highly redundant for same cost as CSC system
  - PWC could be substituted for RPCs, but no design.
  - likely to be less expensive

- **CSC** provides all functions needed for muon system Challenge is find a practical design.

gem

γeμ

Presentation by:

Charlie Baltay

CENTRAL TRACKER PROGRESS REPORT

1. Silicon Tracker Design Fine tuning
   - Tilt angle
   - Strip length
2. Pad chamber design progress
   - Double Chamber Modules
   - Pad size optimization
   - Support structure design
3. Silicon & Pad chamber prototypes under construction
4. Increased emphases on Simulation of detector performance & physics
5. TDR preparation
6. Budget preparation
7. Consolidating Taiwanese Collaboration

gem

γeμ

Presentation by:

Bill Wisniewski

Calorimetry System Report (2/93)

- Noble Liquid Calorimeter
- Scintillating Barrel Calorimeter
- Underground Service Concepts
  & Surface Assembly Facilities
- Assembly & Schedule
- China Visit

—Bill Wisniewski

GLM Calorimeter - Weights

Each Endcap Total:
24 Mg EM
40 Mg FH
48 Mg FH
77 Mg FH
50 Mg FH
53 Mg CH
34 Mg CH
5 Mg FWE
331 Mg
50 Mg Other
381 Mg Total

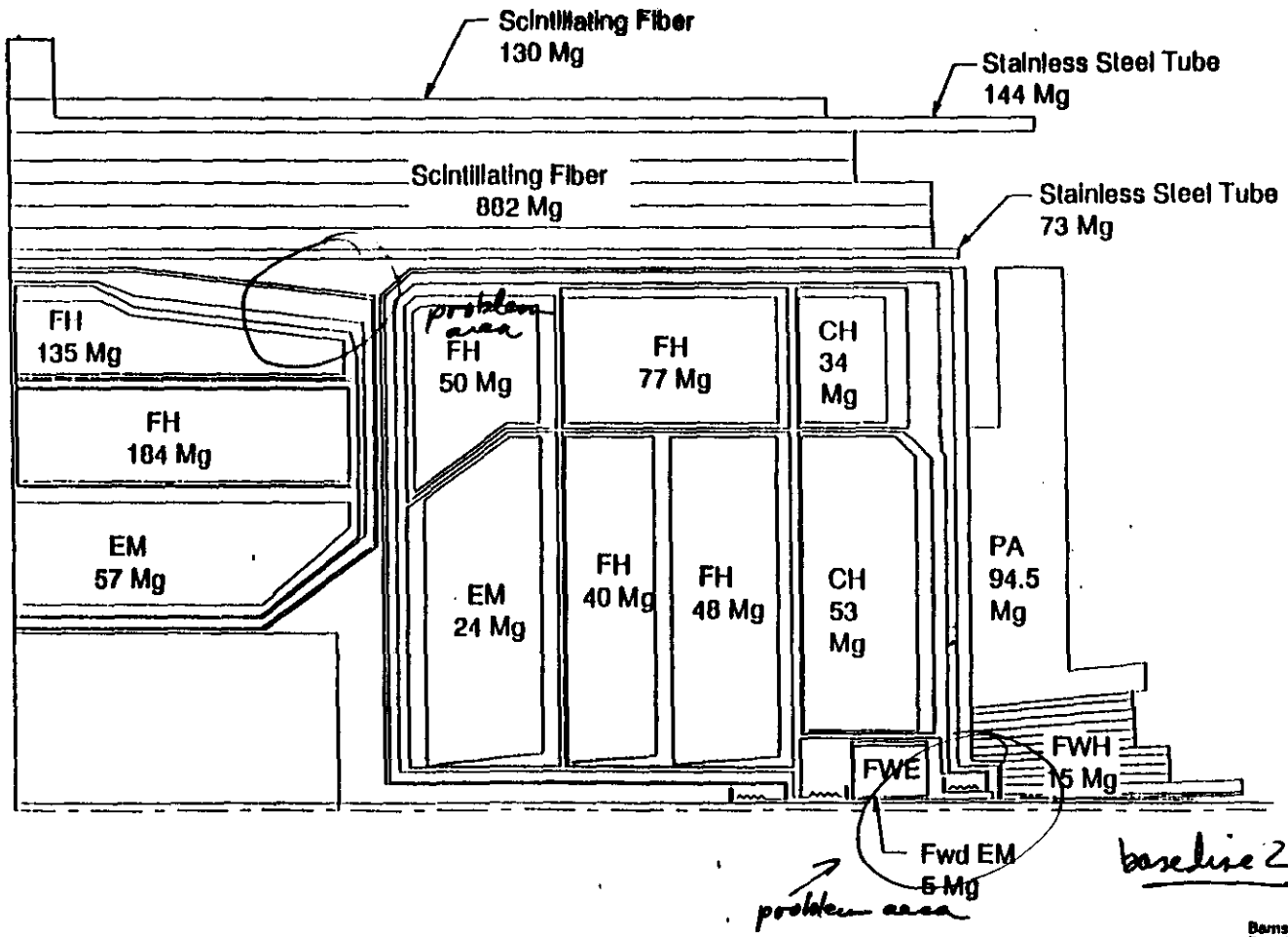
Barrel Totals:
57 Mg EM
184 Mg FH
135 Mg FH
376 Mg
57 Mg Other
433 Mg Total

Other Totals:
217 Mg S.S. Tubes
1012 Mg Sc. Fiber
1229 Mg total

Forward Total:
15 Mg FWH

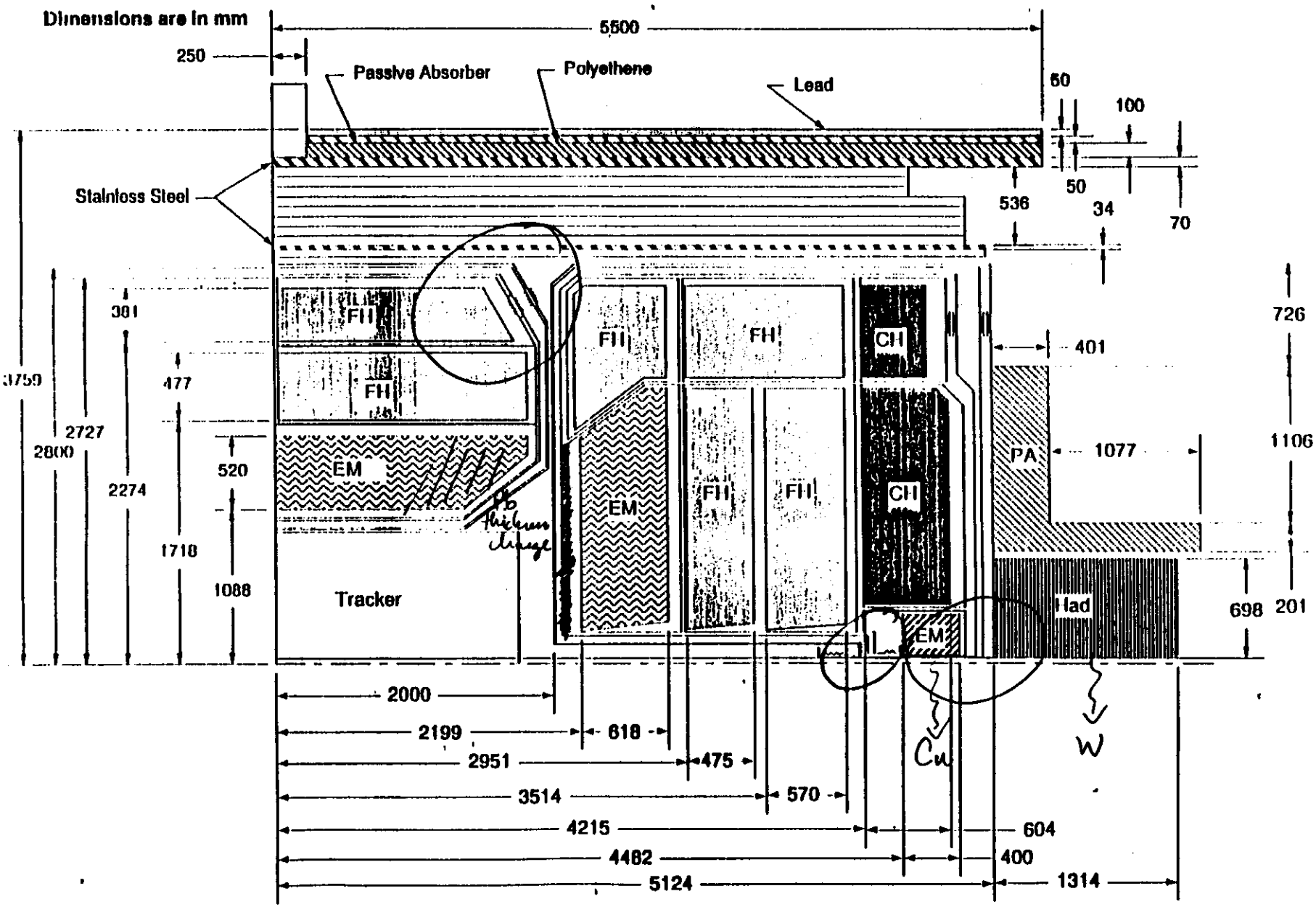
PA Total:
94.5 Mg

Total Calorimeter:
381 Mg Endcap
381Mg Endcap
433 Mg Barrel
1229 Mg Other
15 Mg Fwd
15 Mg Fwd
94.5 Mg PA
94.5 Mg PA
2643 Mg total



Barnstable:gemcalbl2 921123
Barrel 7.0/ Endcap7.0 -Cu

GEM Calorimeter - Dimensions

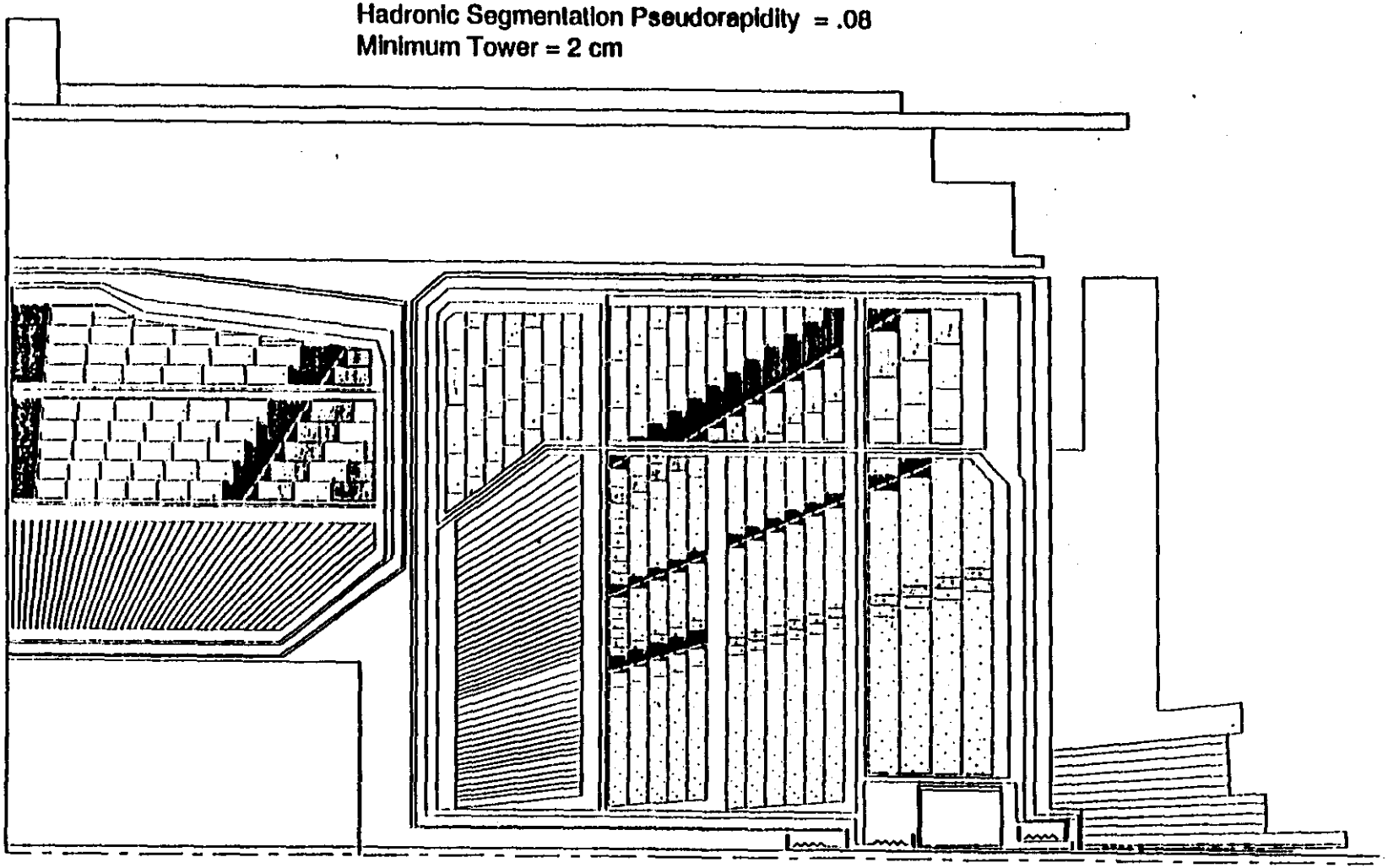


— = "fixes"
— = info
— c neutron concern area
— cryo wall study

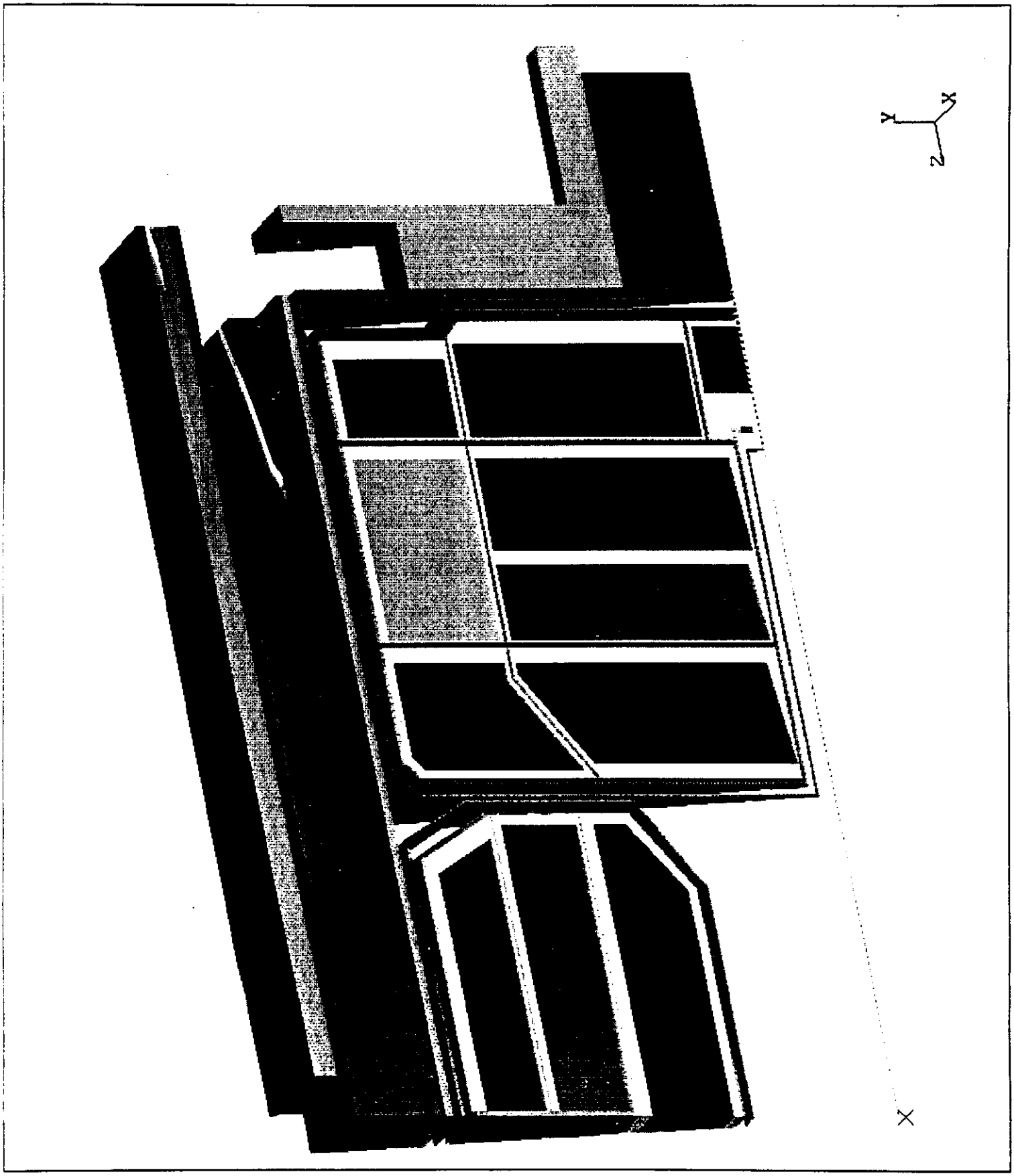
KBernstein:Bt2mod wte/vel:930116

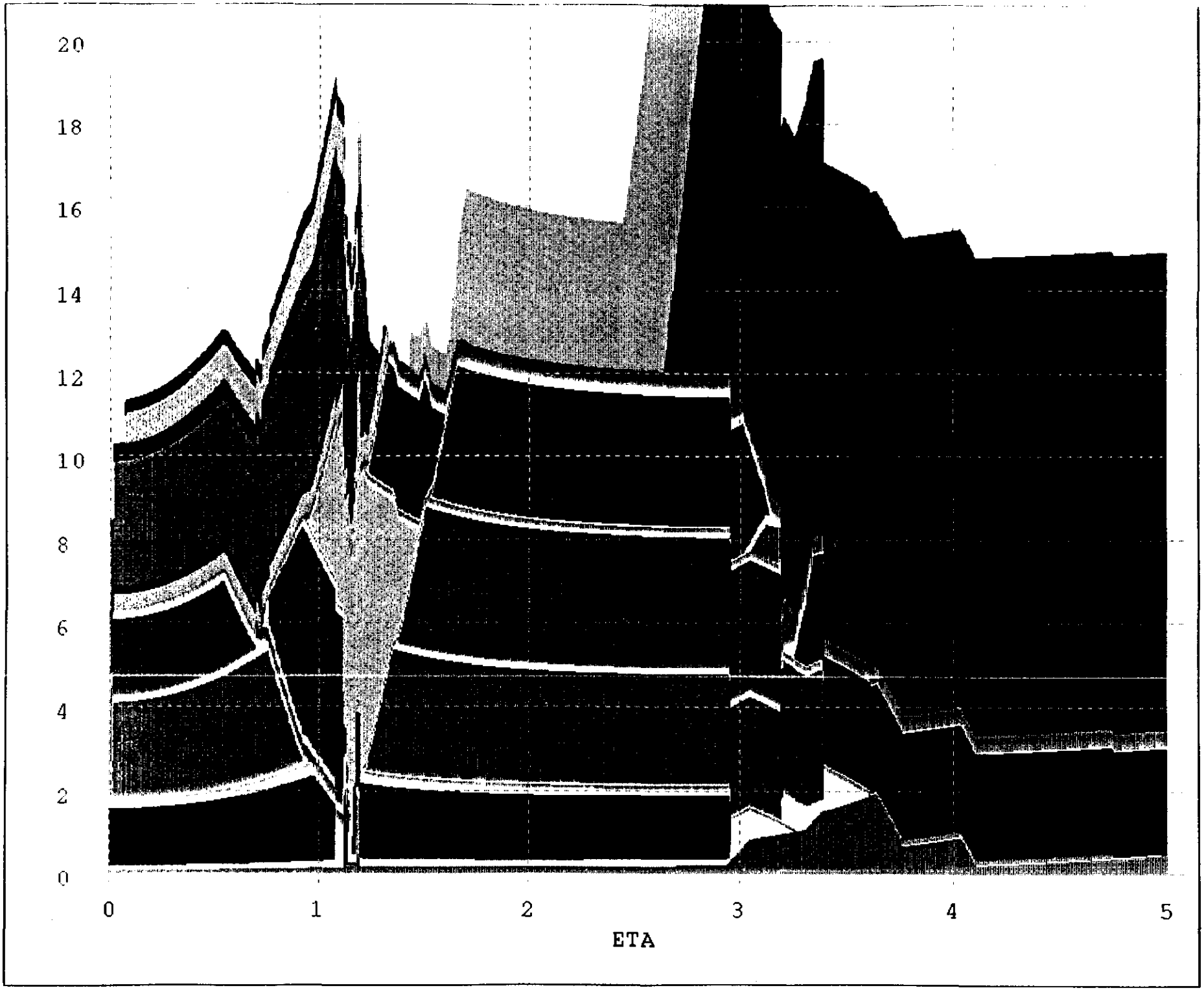
Hadronic Electronic Segmentation

Hadronic Segmentation Pseudorapidity = .08
Minimum Tower = 2 cm

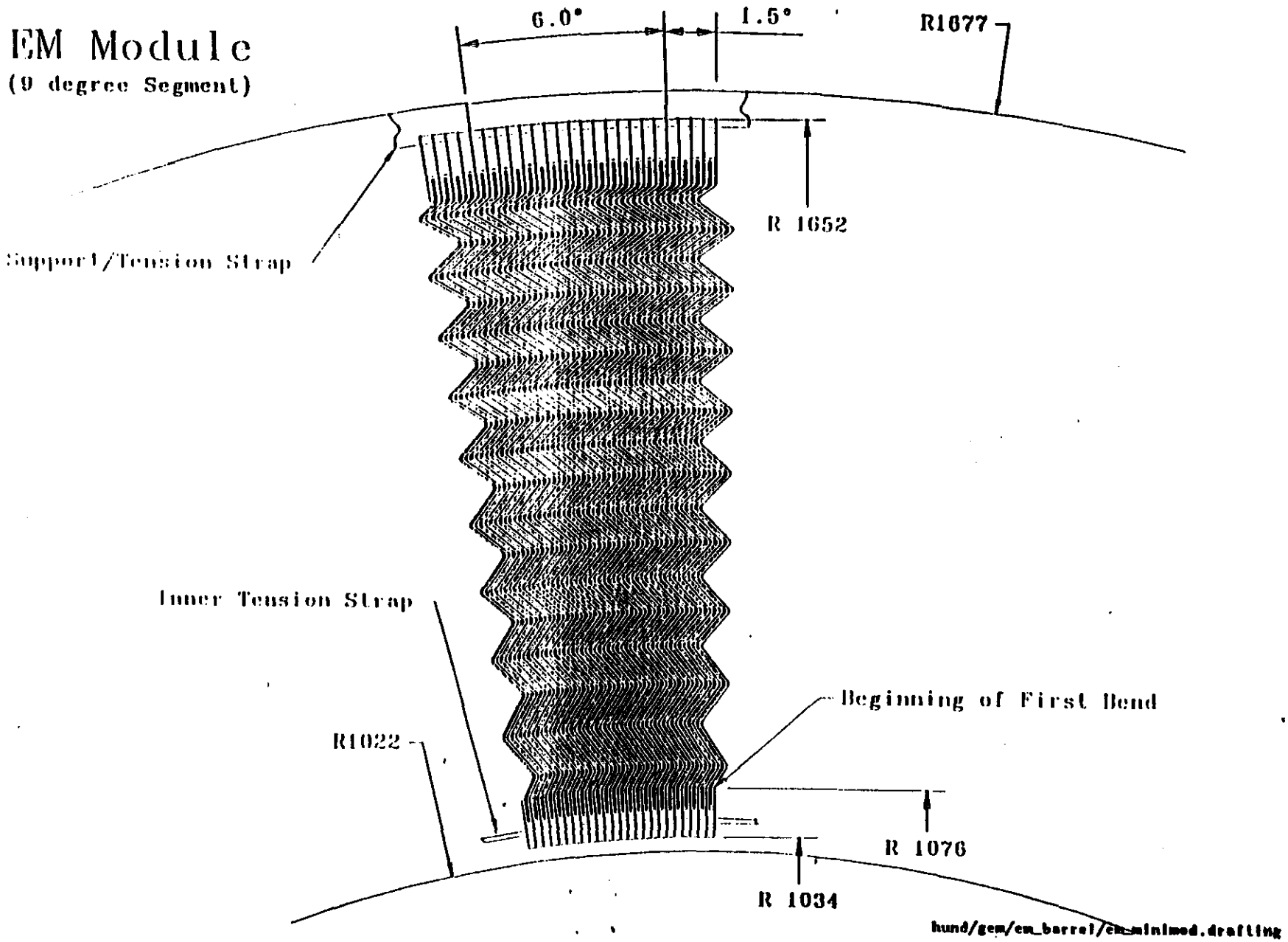


ADAMS:GEMCALSEG3:12/7/92


X
Y
Z

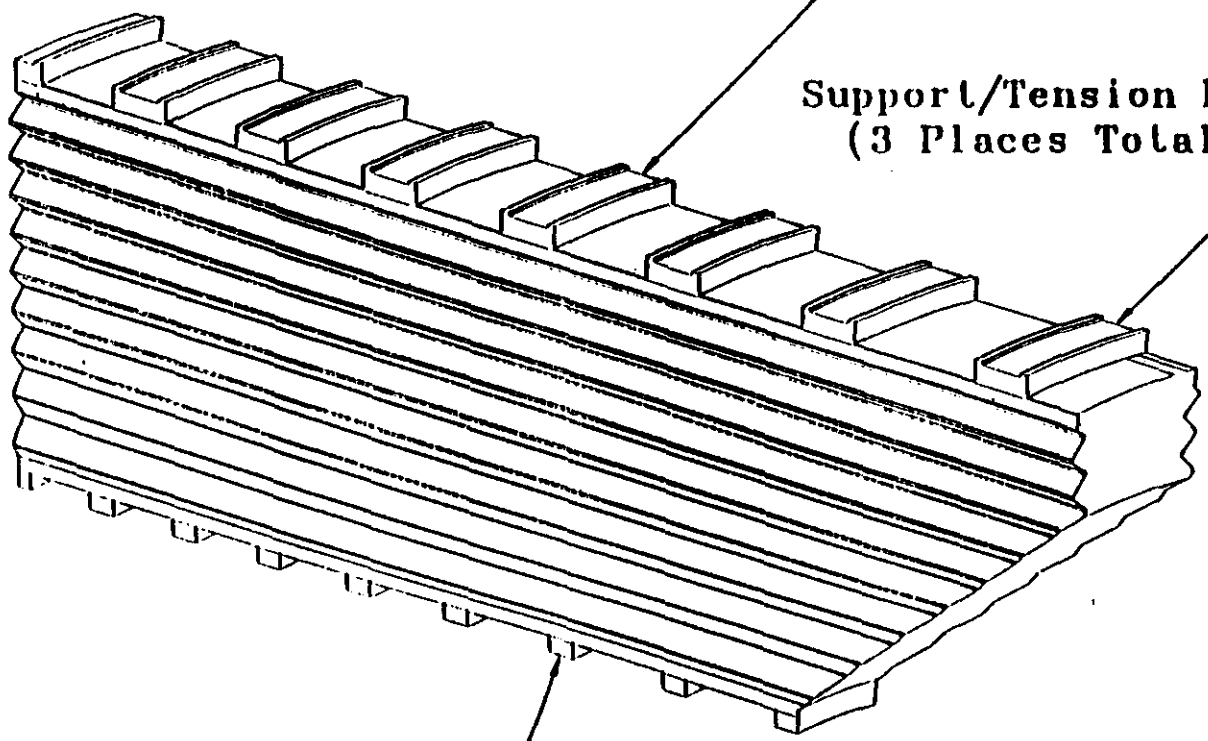

20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
ETA

EM Module
(9 degree Segment)

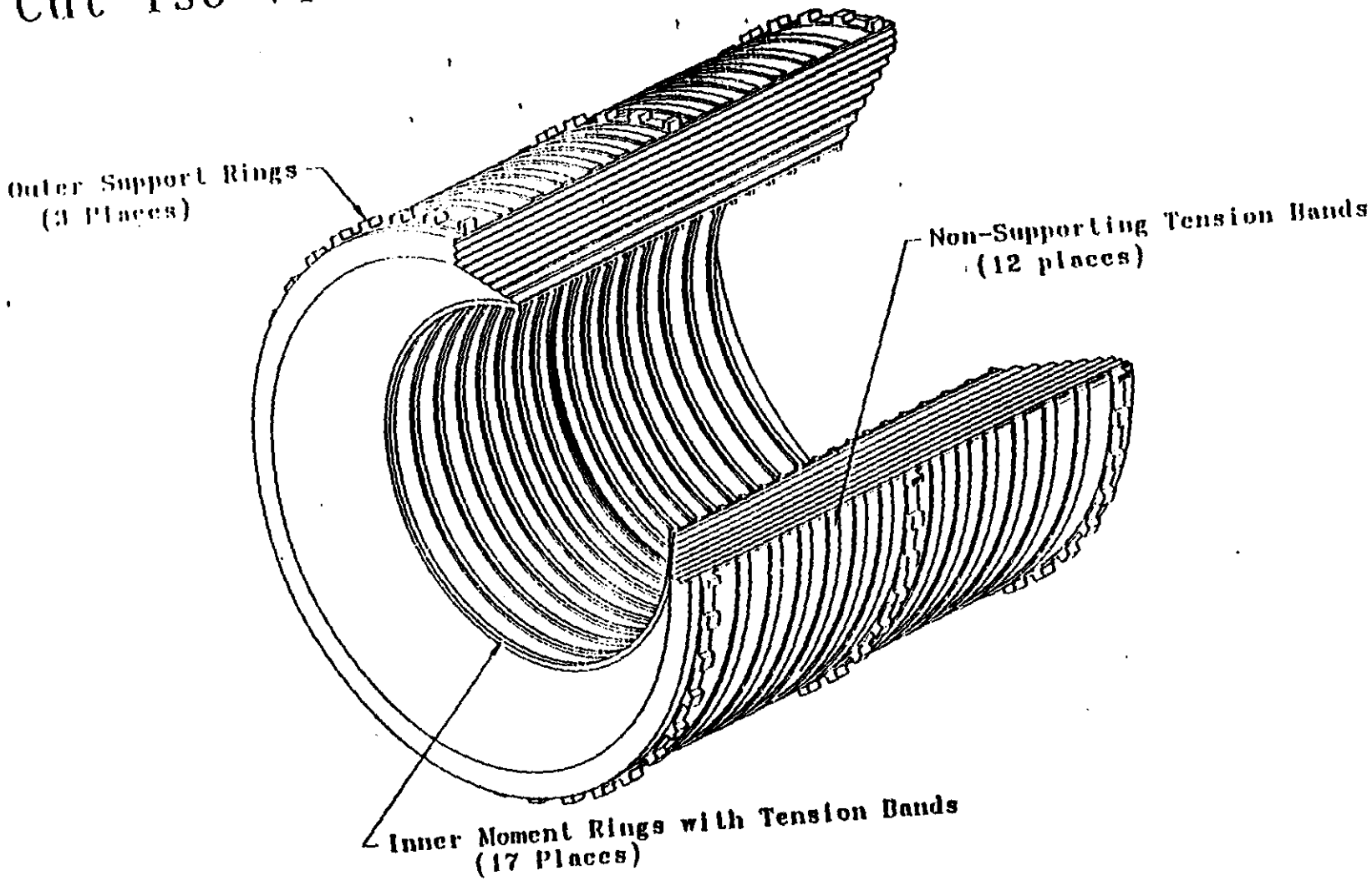


EM Half Module Envelope

(9 Degree Segment)



EM Cut Iso View



hund/gem/em_barrel/EM_cu_iso_view.drafting

Hadronic Module Section 1 Assembly

5 Cells Depth
Segmentation $\Delta\eta \times \Delta\varphi = 0.08 \times 0.08$
80 Modules Required
Wt.=2.30 MT each

Each Module Contains the following:
1-Top Ground Plate
1-Bottom Ground Plate
4-Included Gnd Plates
30-Tile Plates
5-Signal Electrodes
1-Strongback
1-Structural Shell
2-End Plates
Lines and Electronics

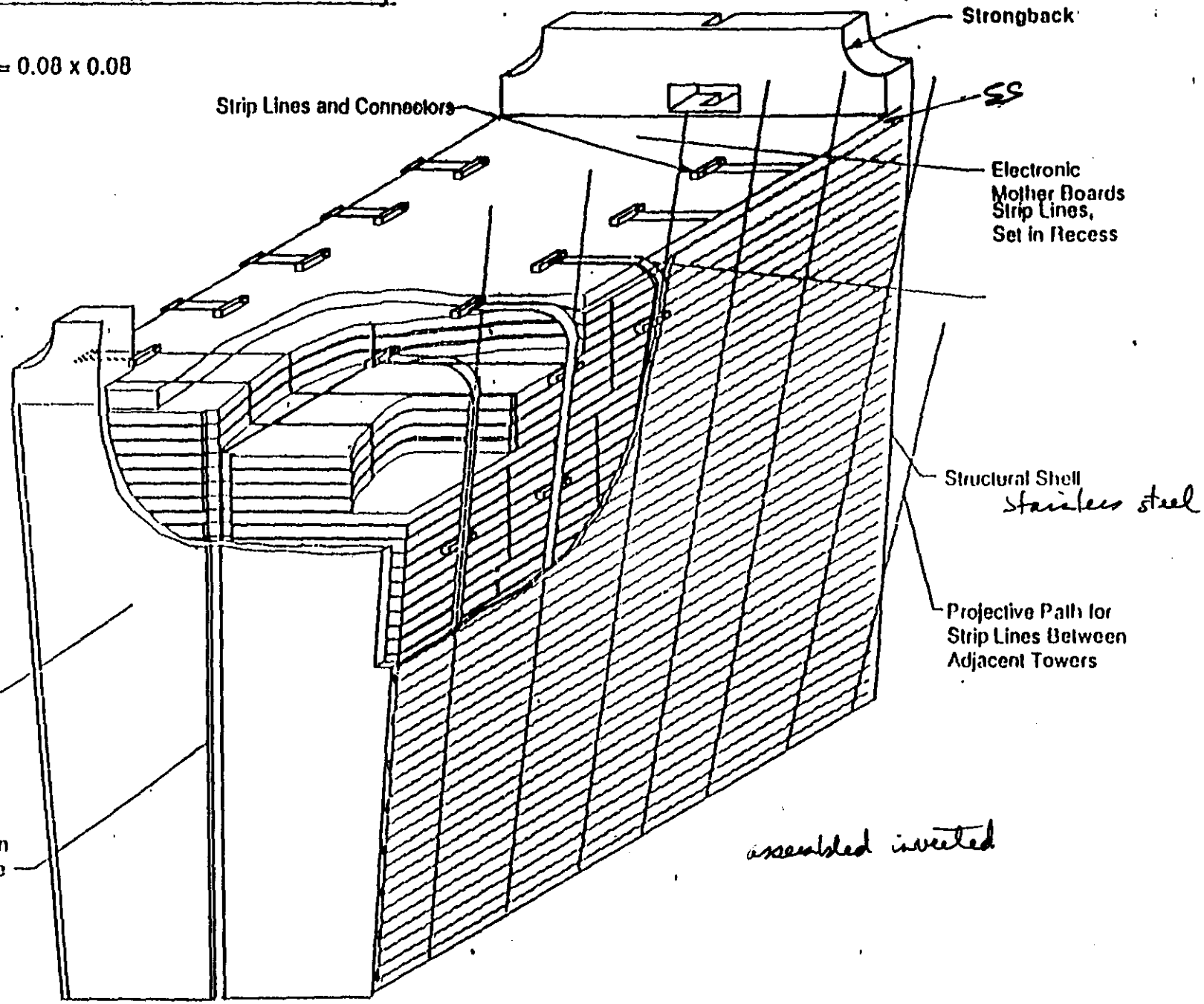


Figure 3.1.1-2

KBarnstable : HadModule 12/11/92

Scintillator Barrel Calorimeter

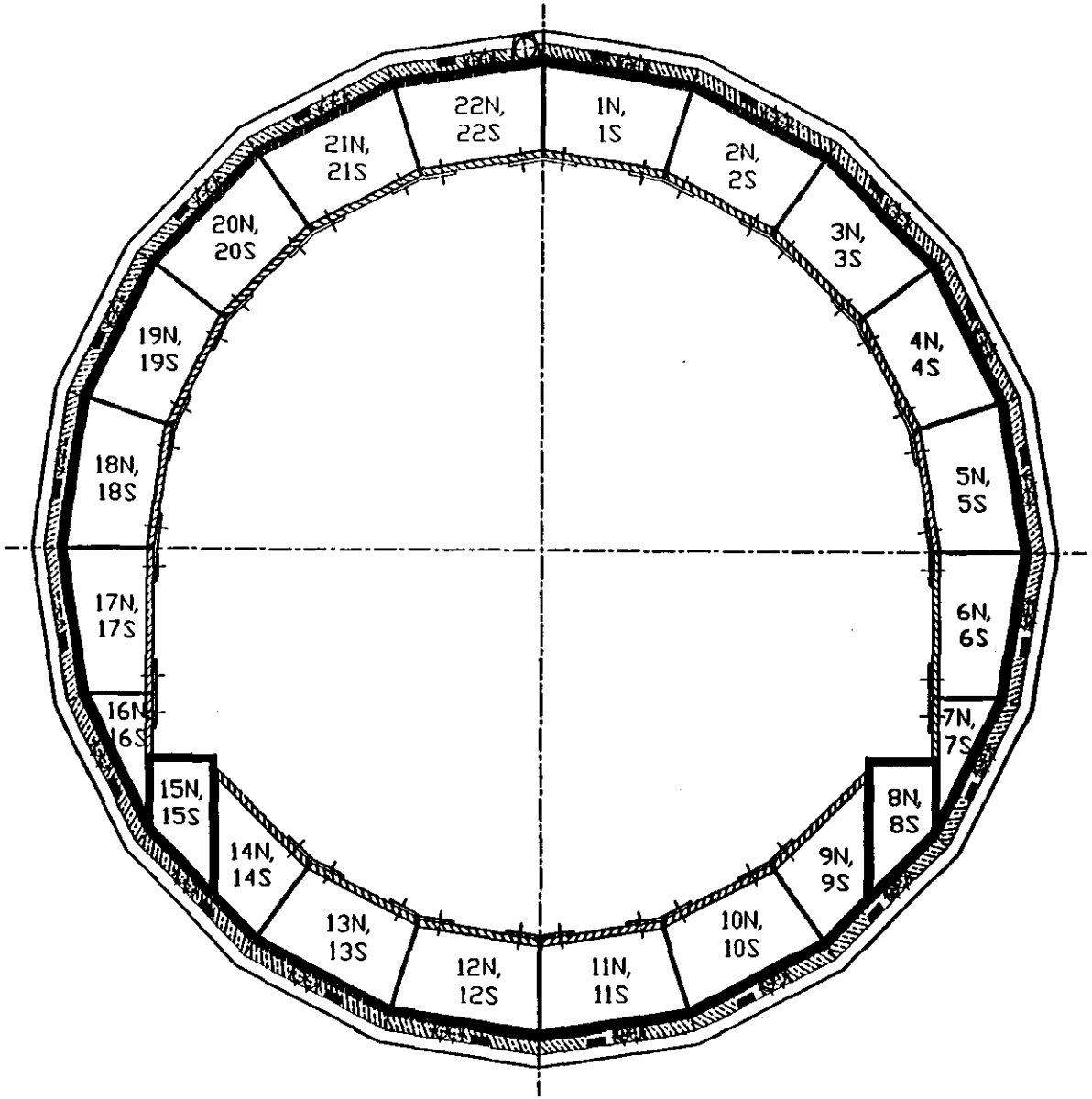
- Conceptual design exists
- It is optimized for :

  a) low cost ($ 26 M US)

  b) detection of had. jets

  c) muons are detectable

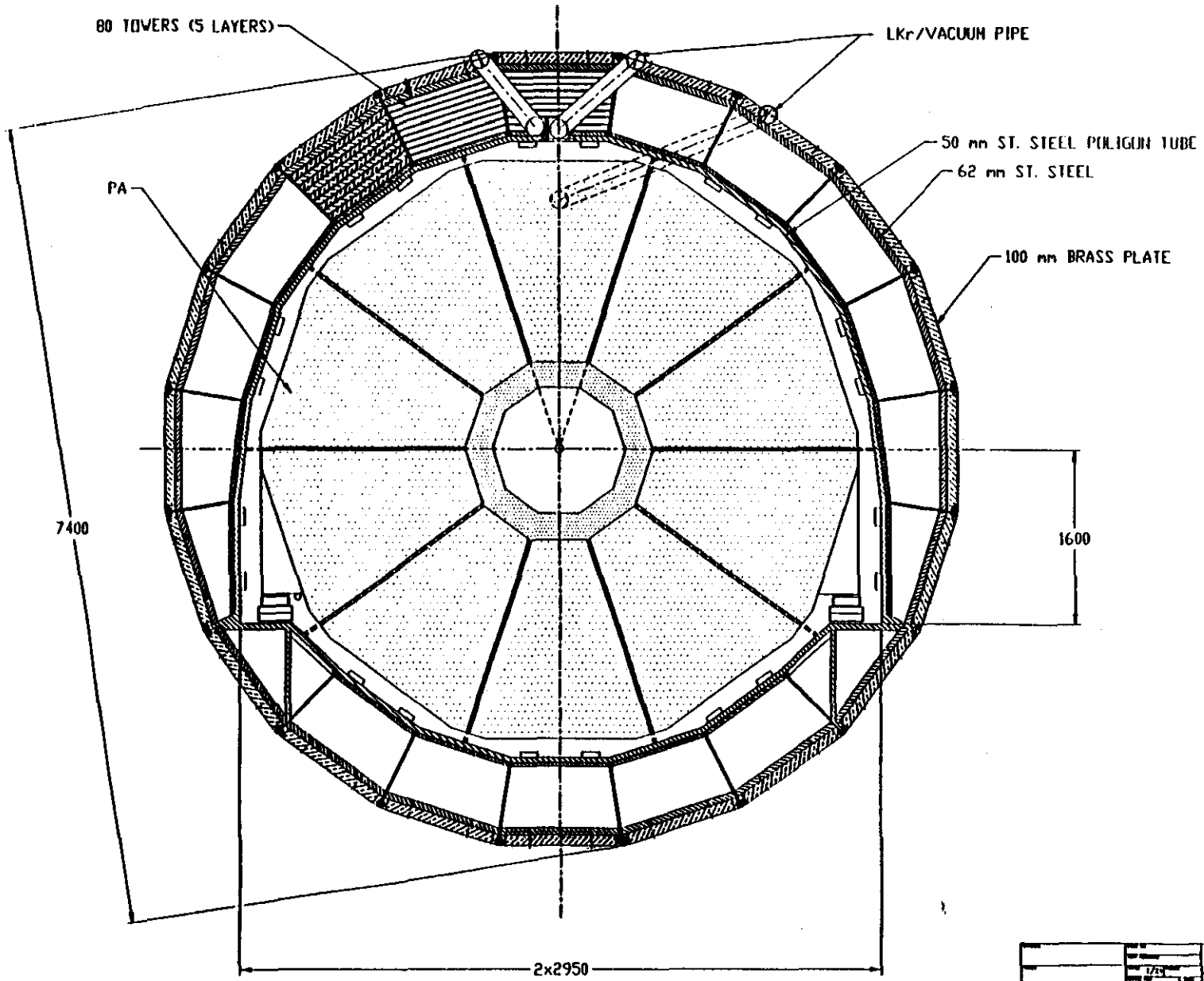
- Option of SB optimized for muon triggerig also exists (+ $ 4-5 M)
- We are working on the Production Plan with China, Albania, Russia ...
- Early SB installation in 1996?
- Update of existing R&D program

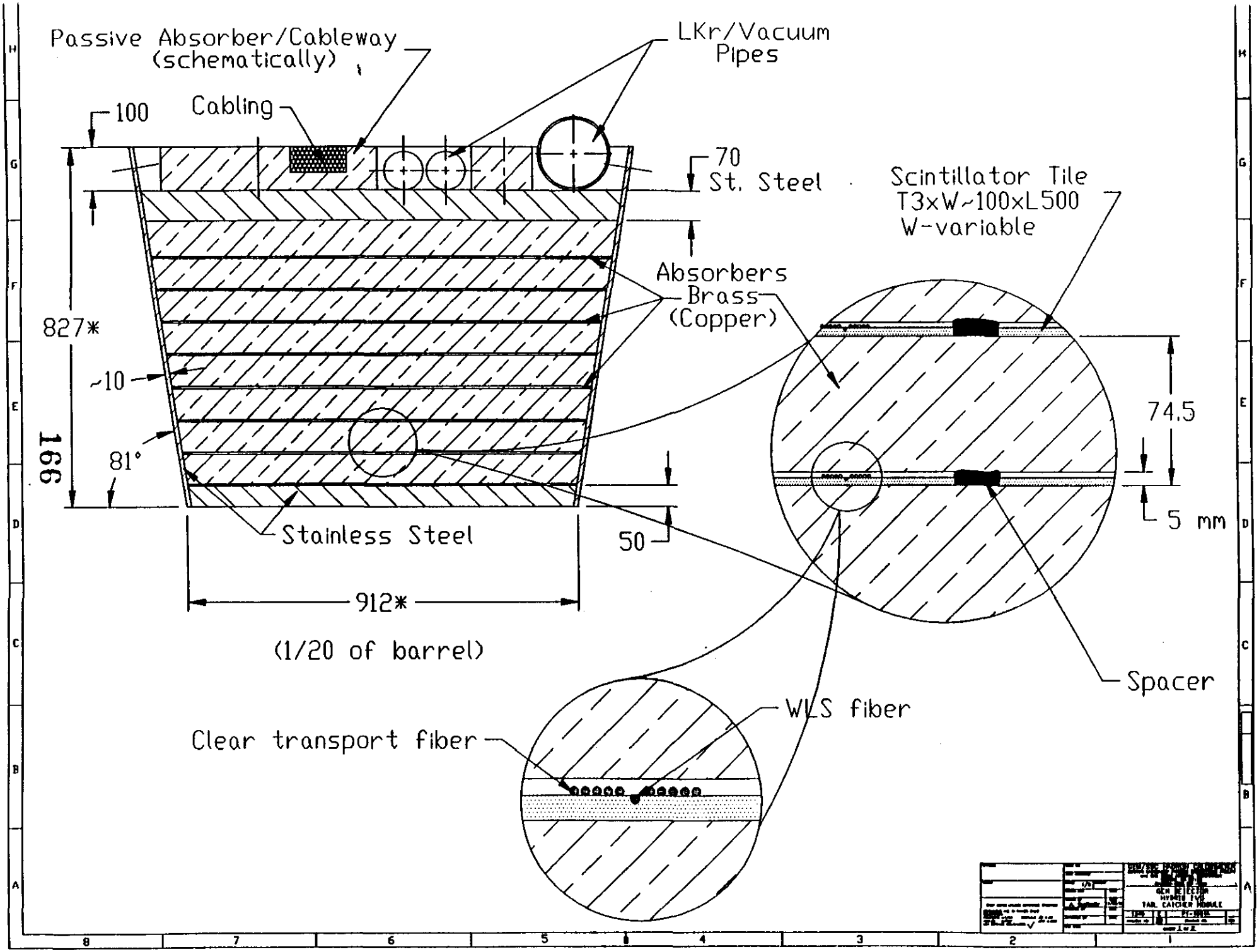


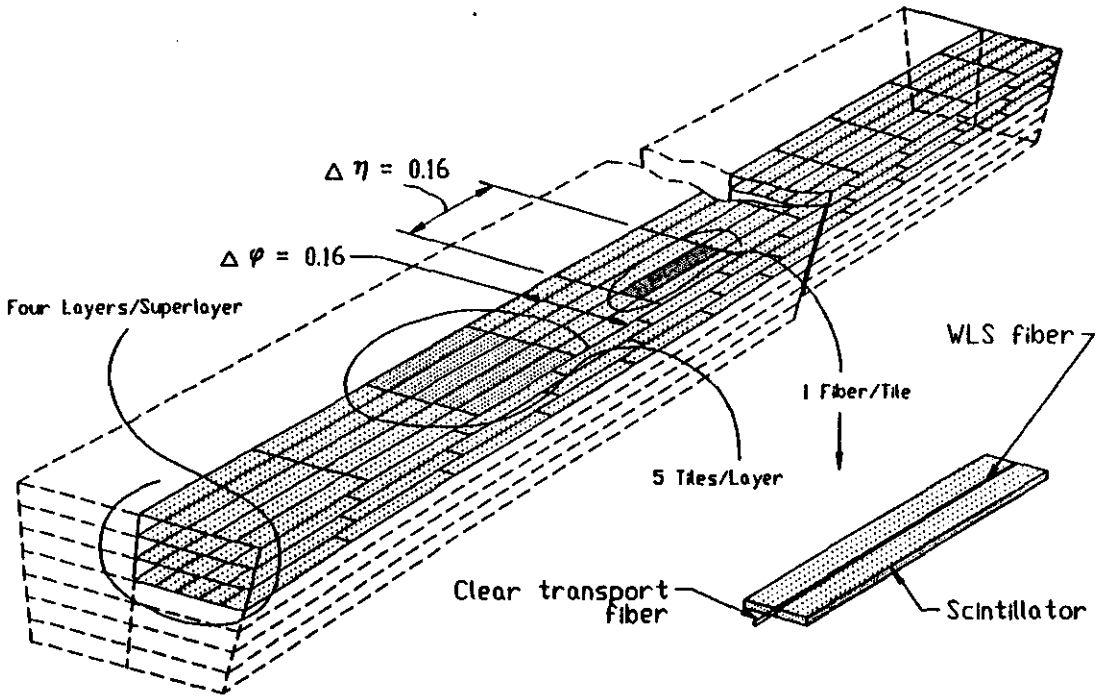
VIEW LOOKING SOUTH FROM NORTH

GEM DETECTOR
BARREL SCINTILLATING CALORIMETER
GEM DETECTOR

X3E017048 A014

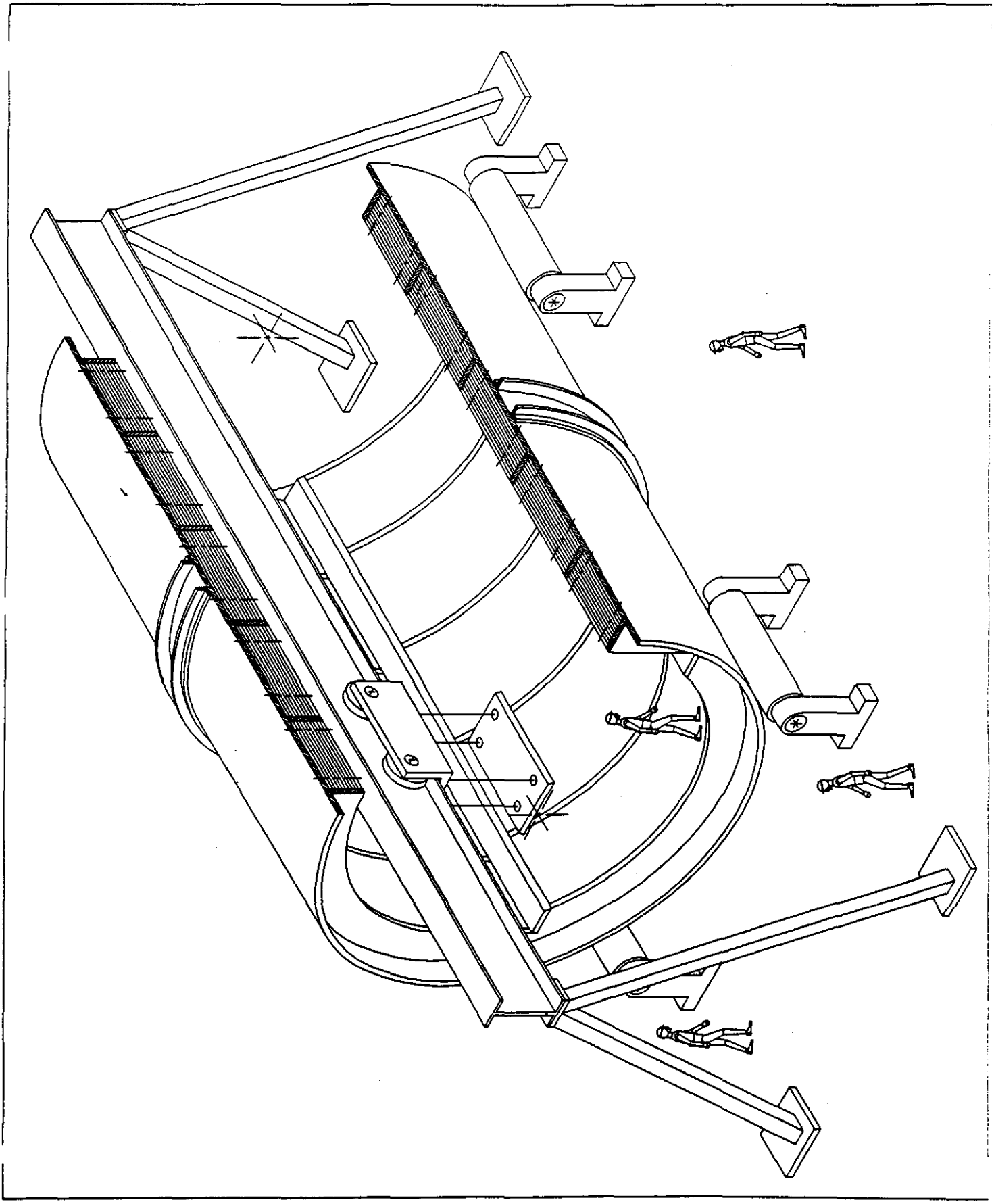

80 TOWERS (5 LAYERS)
LKr/VACUUM PIPE
50 mm ST. STEEL POLIGON TUBE
62 mm ST. STEEL
100 mm BRASS PLATE
PA
7400
1600
2x2950

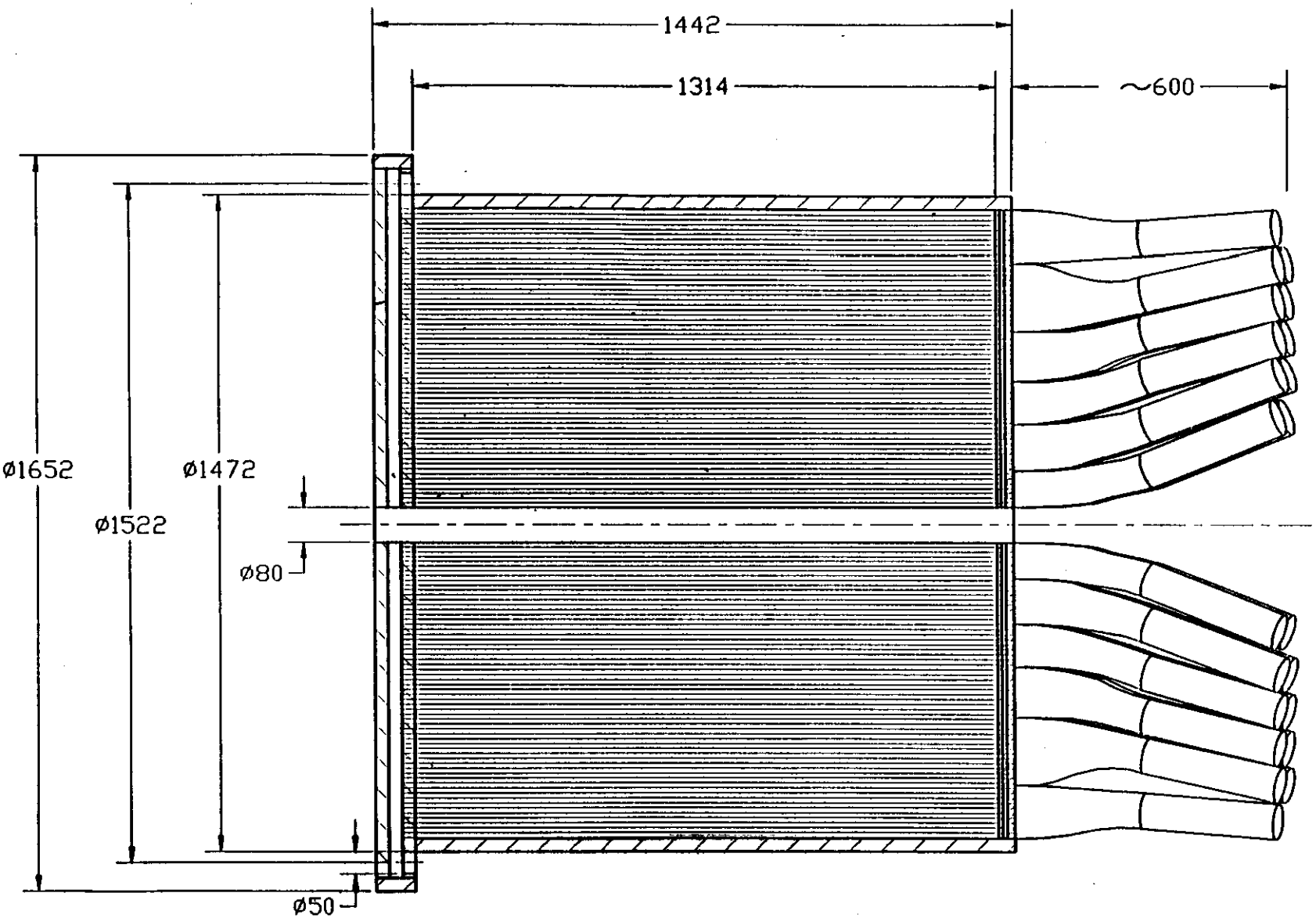

Passive Absorber/Cableway
(schematically)
LKr/Vacuum
Pipes
100
Cabling
70
St. Steel
Scintillator Tile
T3xW~100xL500
W-variable
Absorbers
Brass
(Copper)
827*
~10
166
81°
74.5
5 mm
Stainless Steel
50
912*
(1/20 of barrel)
Spacer
WLS fiber
Clear transport fiber



Readout Configuration

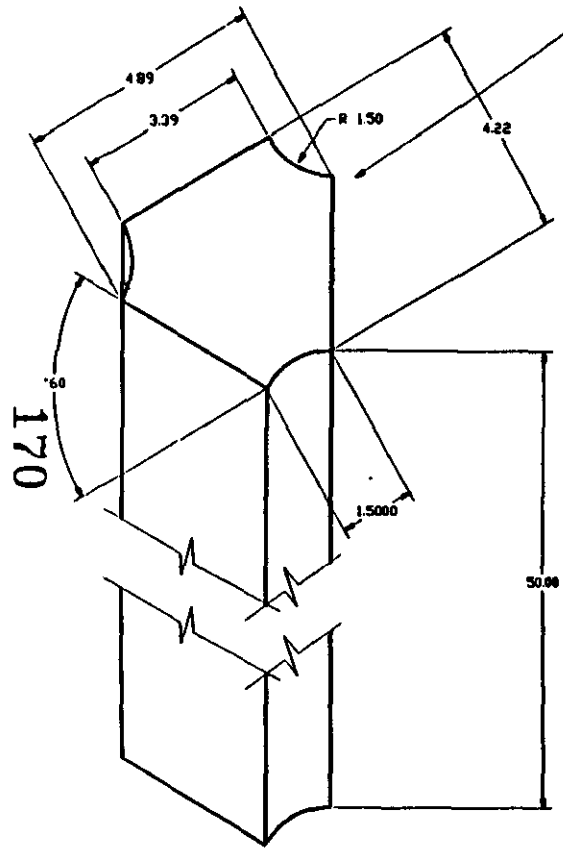
GEM DETECTOR
BARREL SCINTILLATING CALORIMETER
HYBRID TWO-TAIL CATCHER MODULE (ISO)

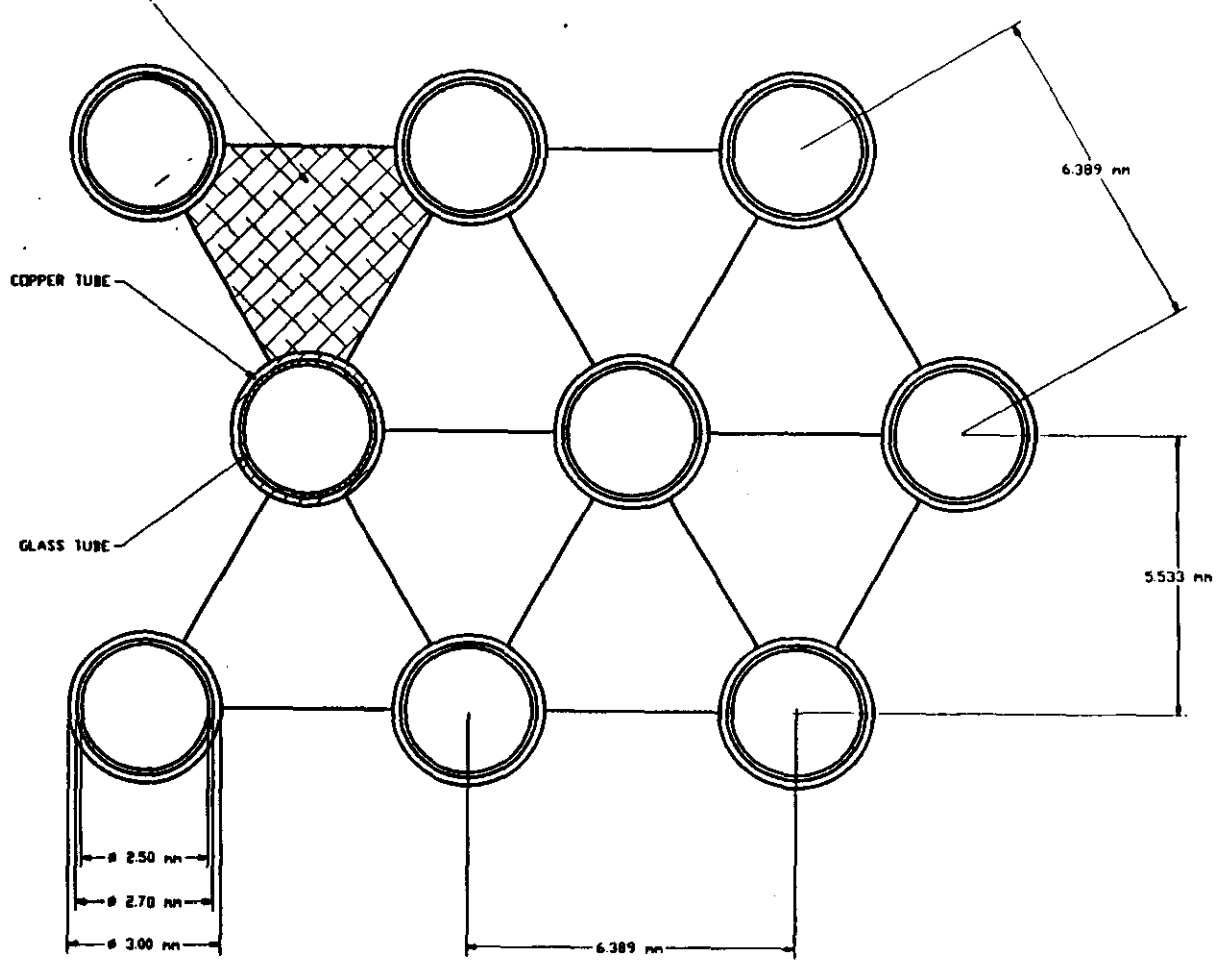




NOTE: DIMENSIONS ARE IN MILLIMETERS.

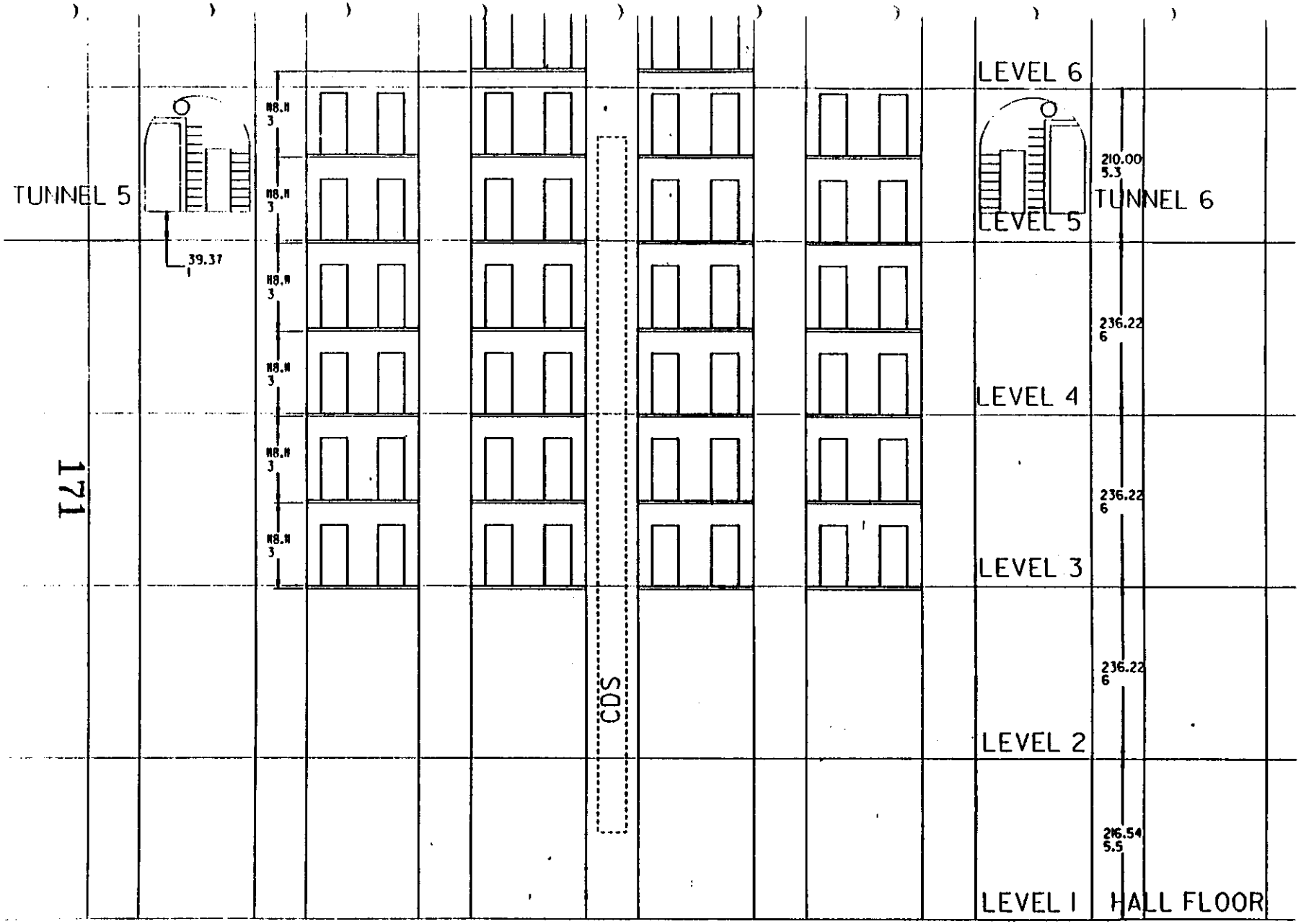
FORWARD CALORIMETER
SCINTILLATING LIQUID
SUPER TOWER FIBER ARRANGEMENT



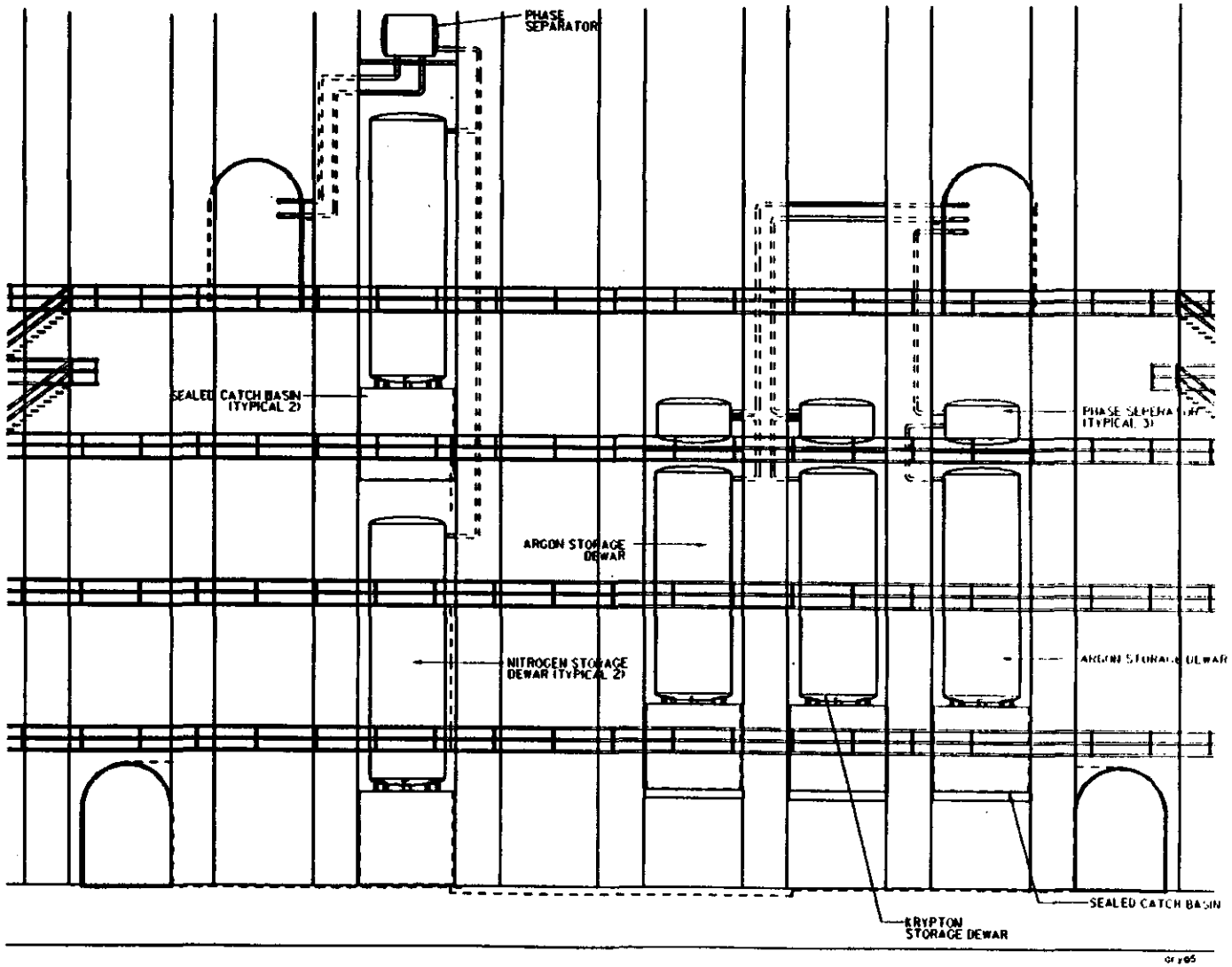


170

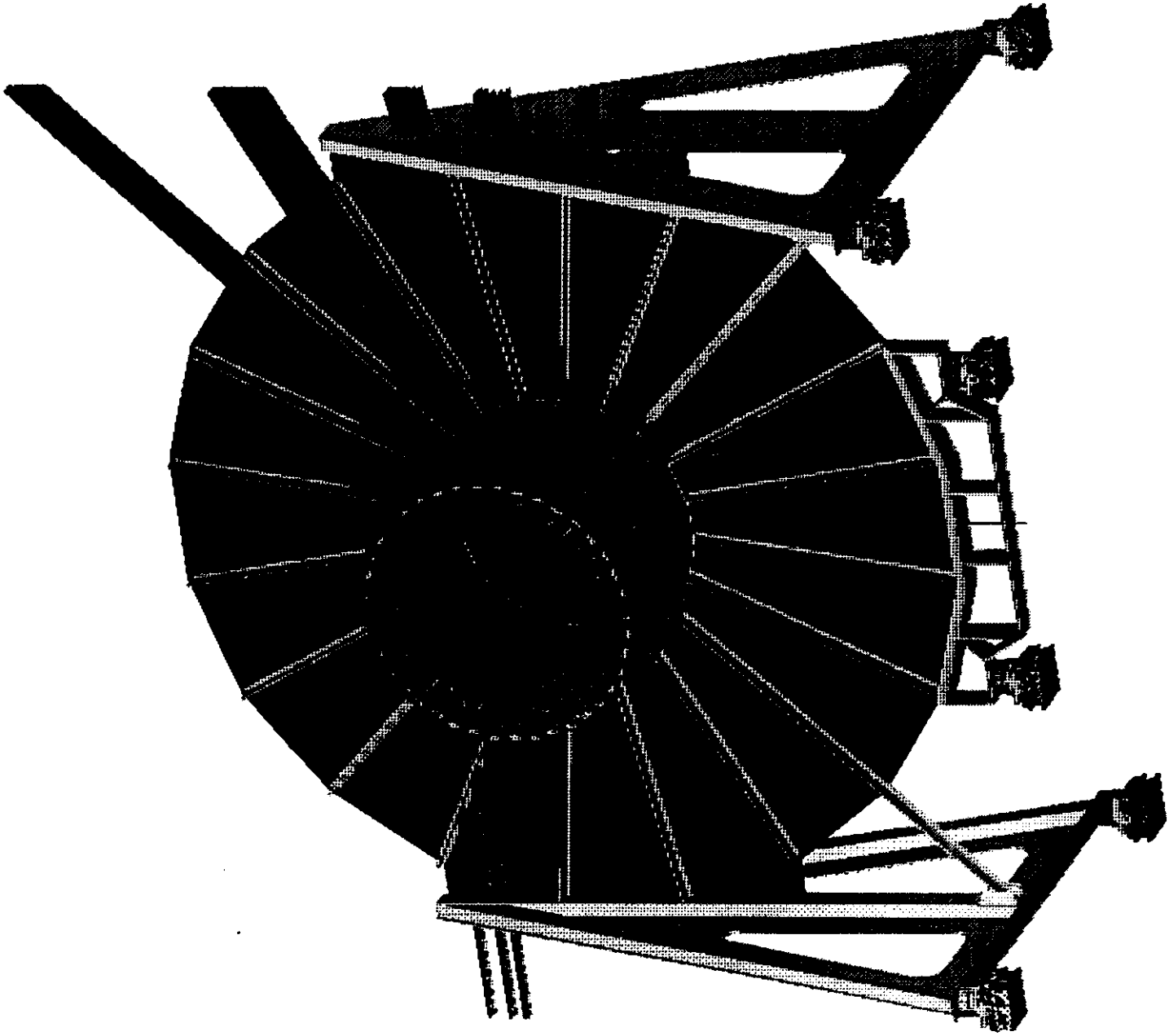
FORWARD CALORIMETER
SCINTILLATING LIQUID
TUNGSTEN PELLETS/TUBE ARRANGEMENTS

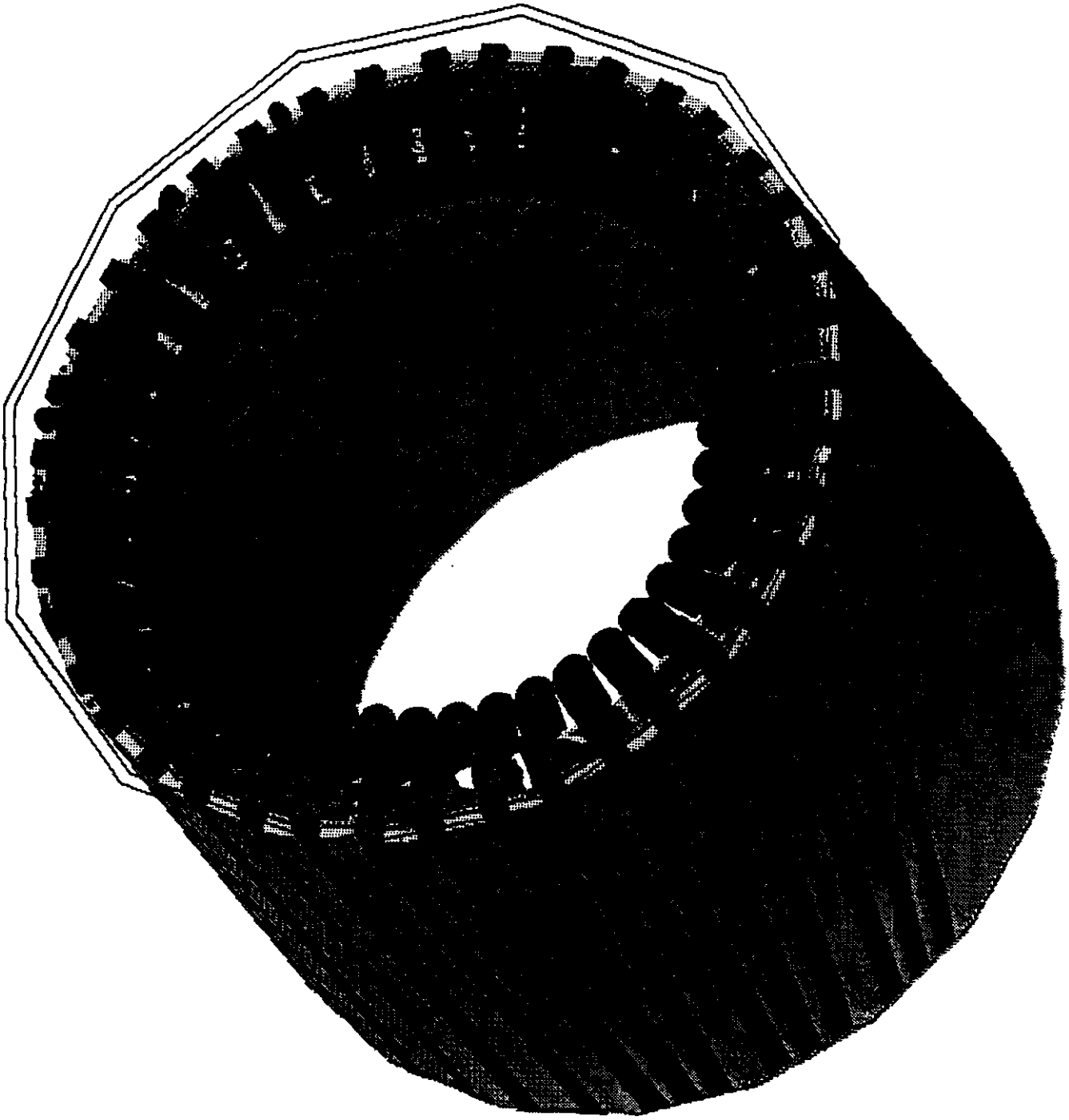


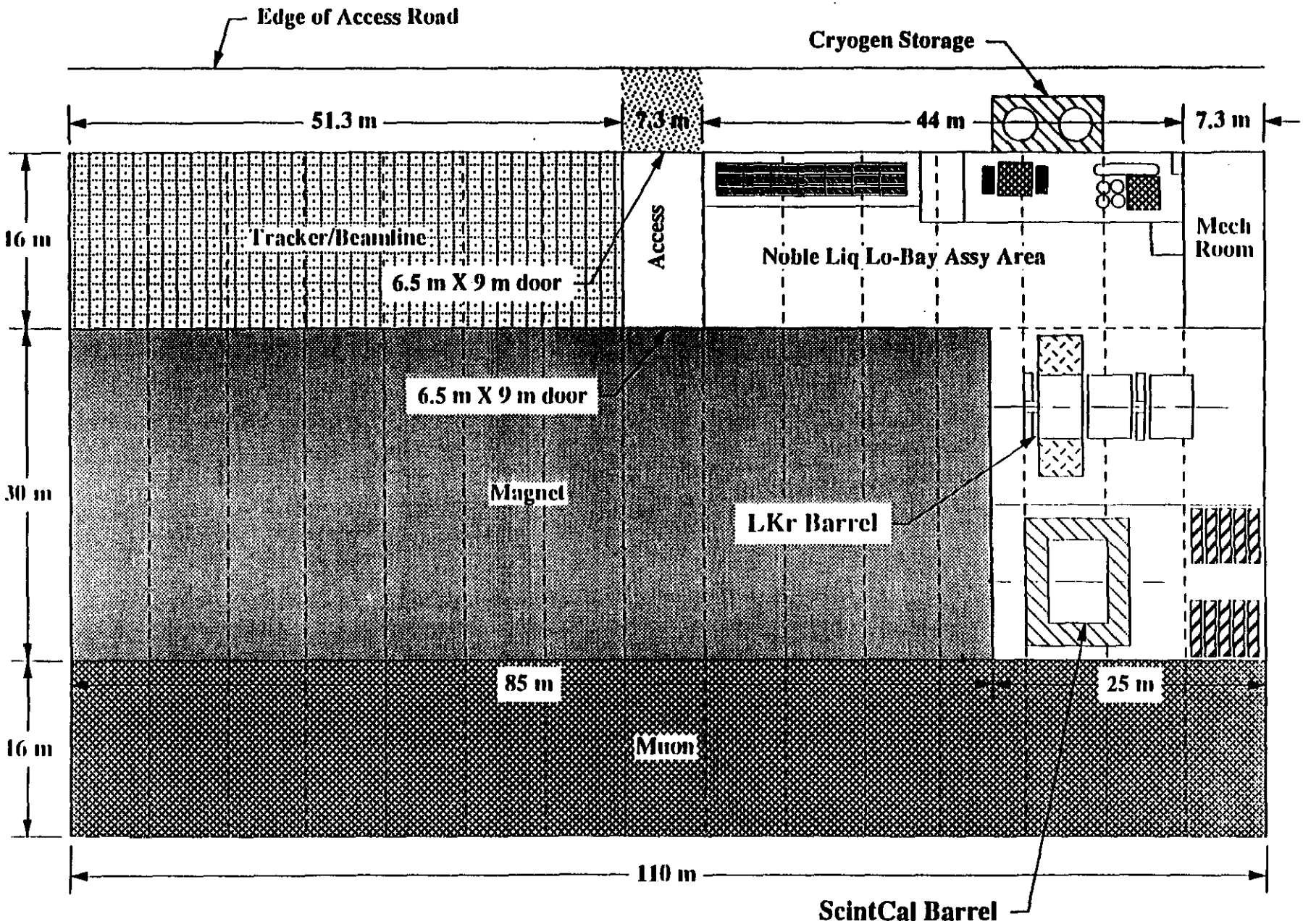
ELECTRONICS PLATFORM PLACEMENT
(156 RACKS)



ARGON/KRYPTON STORAGE LOCATIONS IN EAST WALL

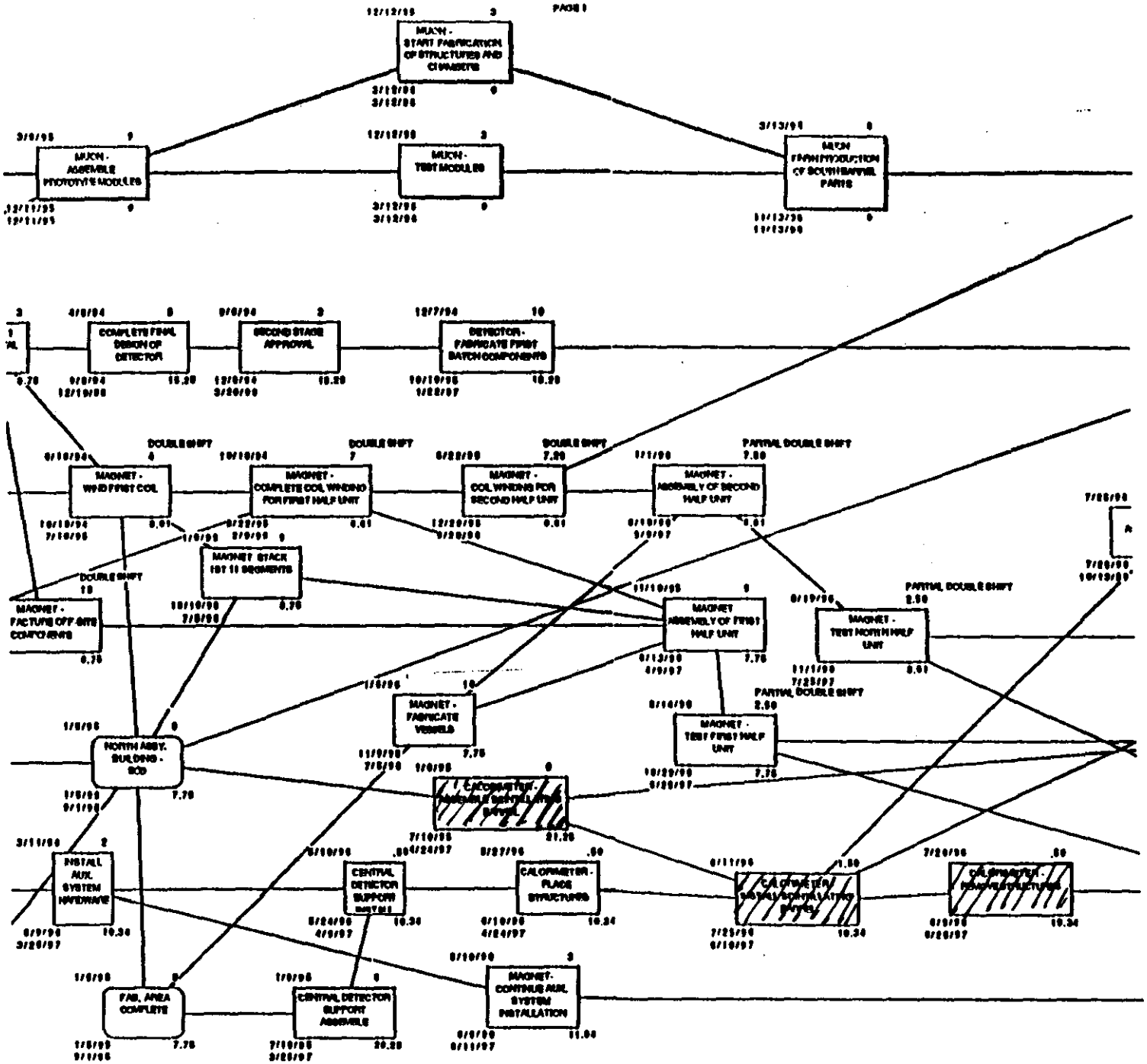


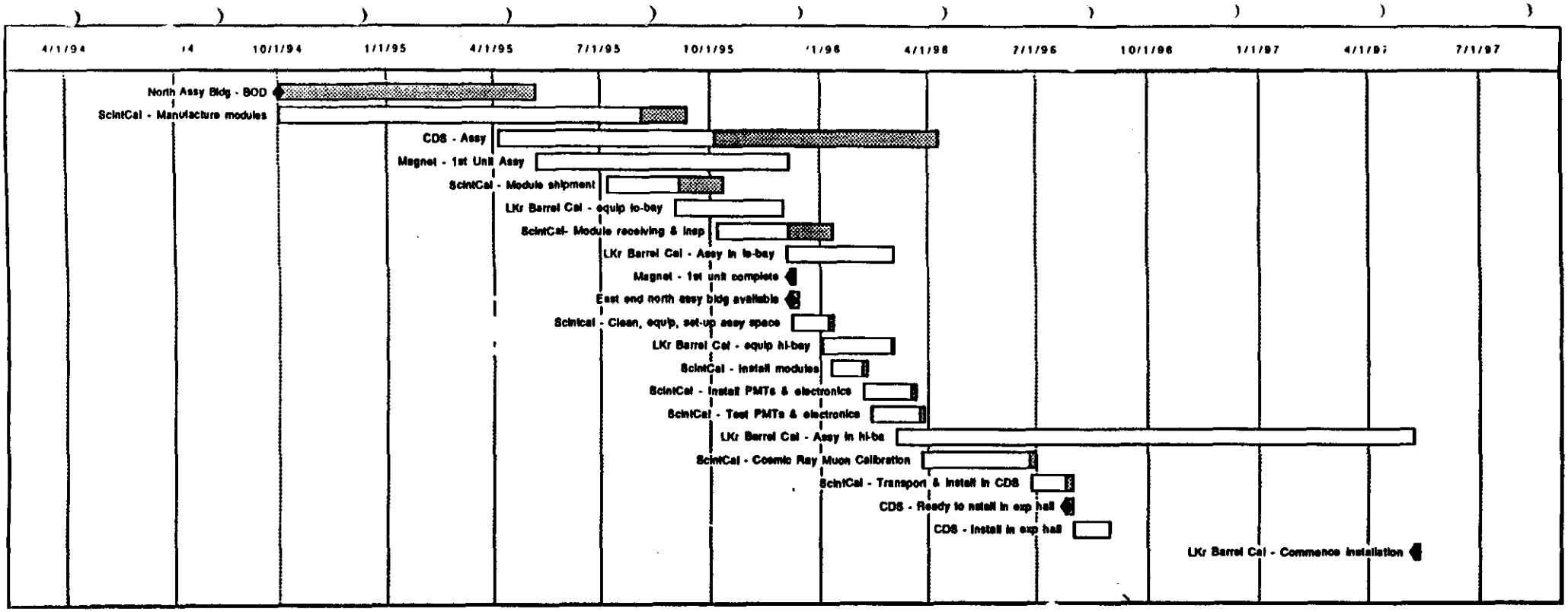


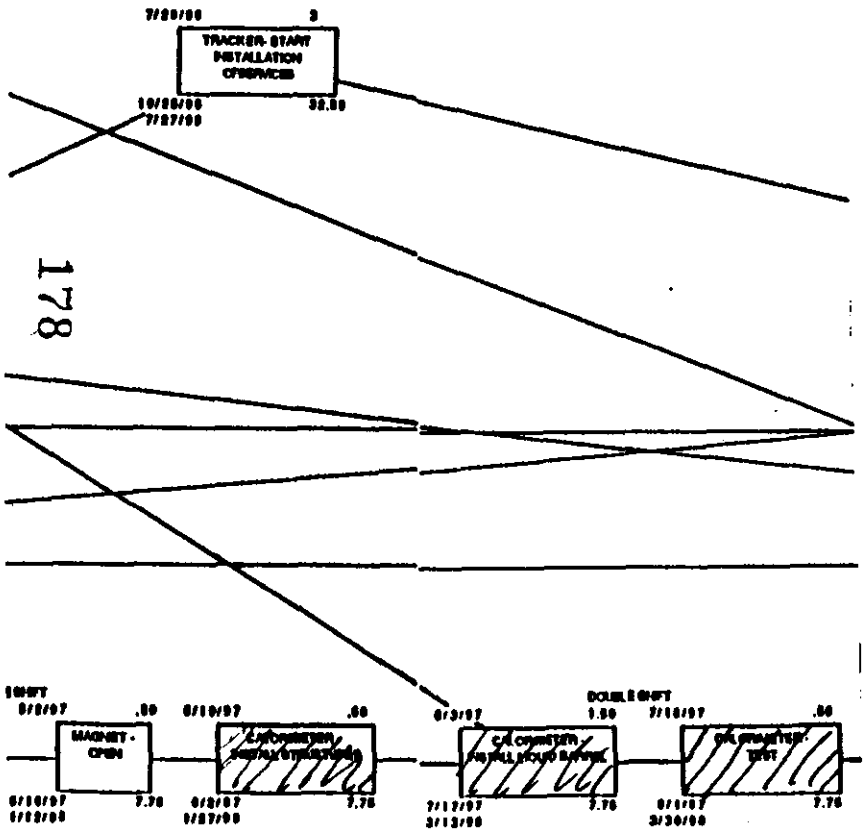


GEM North Assembly Bldg
North Lo-Bay EM Cal Space
Vertical Magnet Assembly
Half-Barrel ScintCal

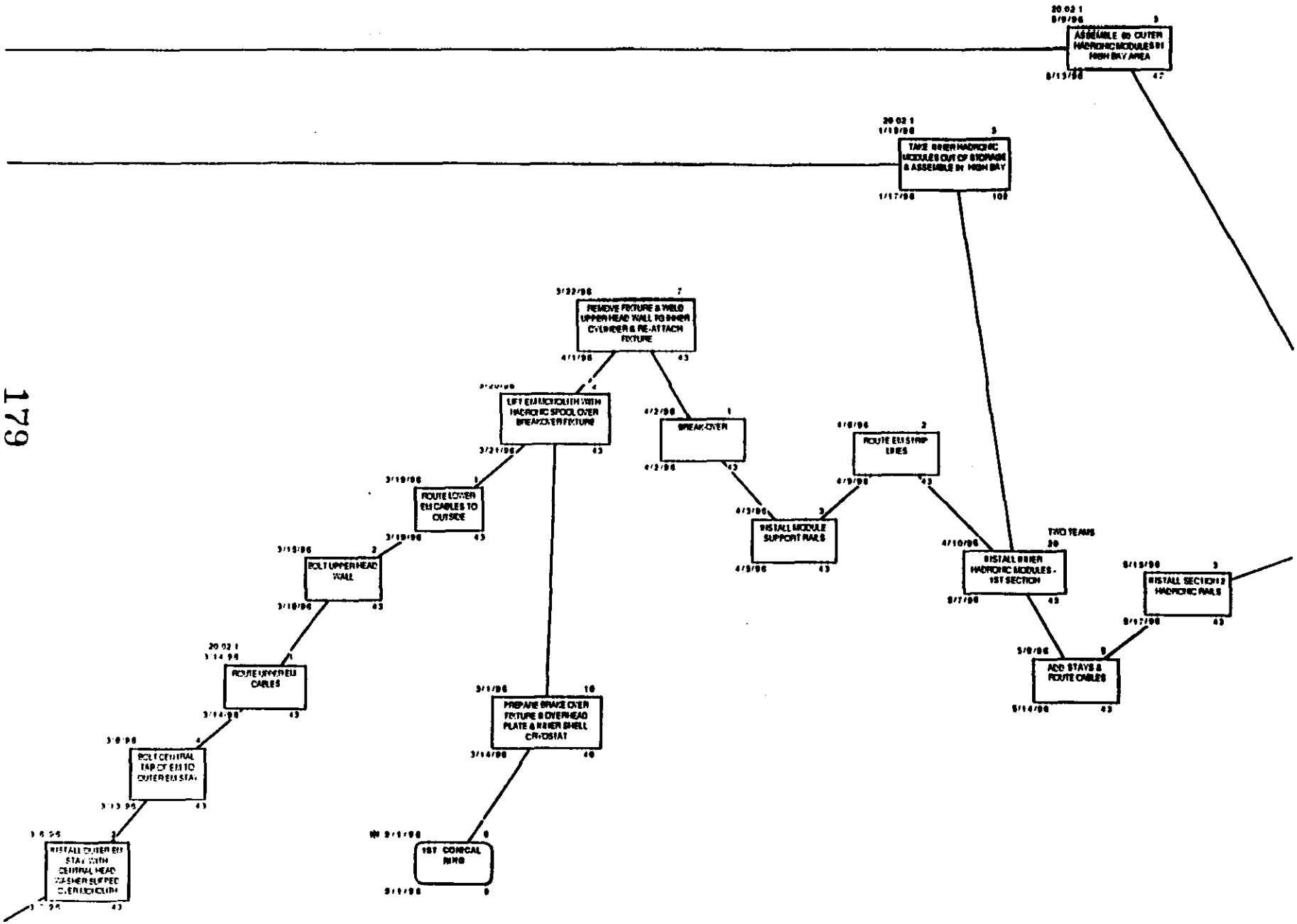
DRAFT
CE.GC.SF.930203.01

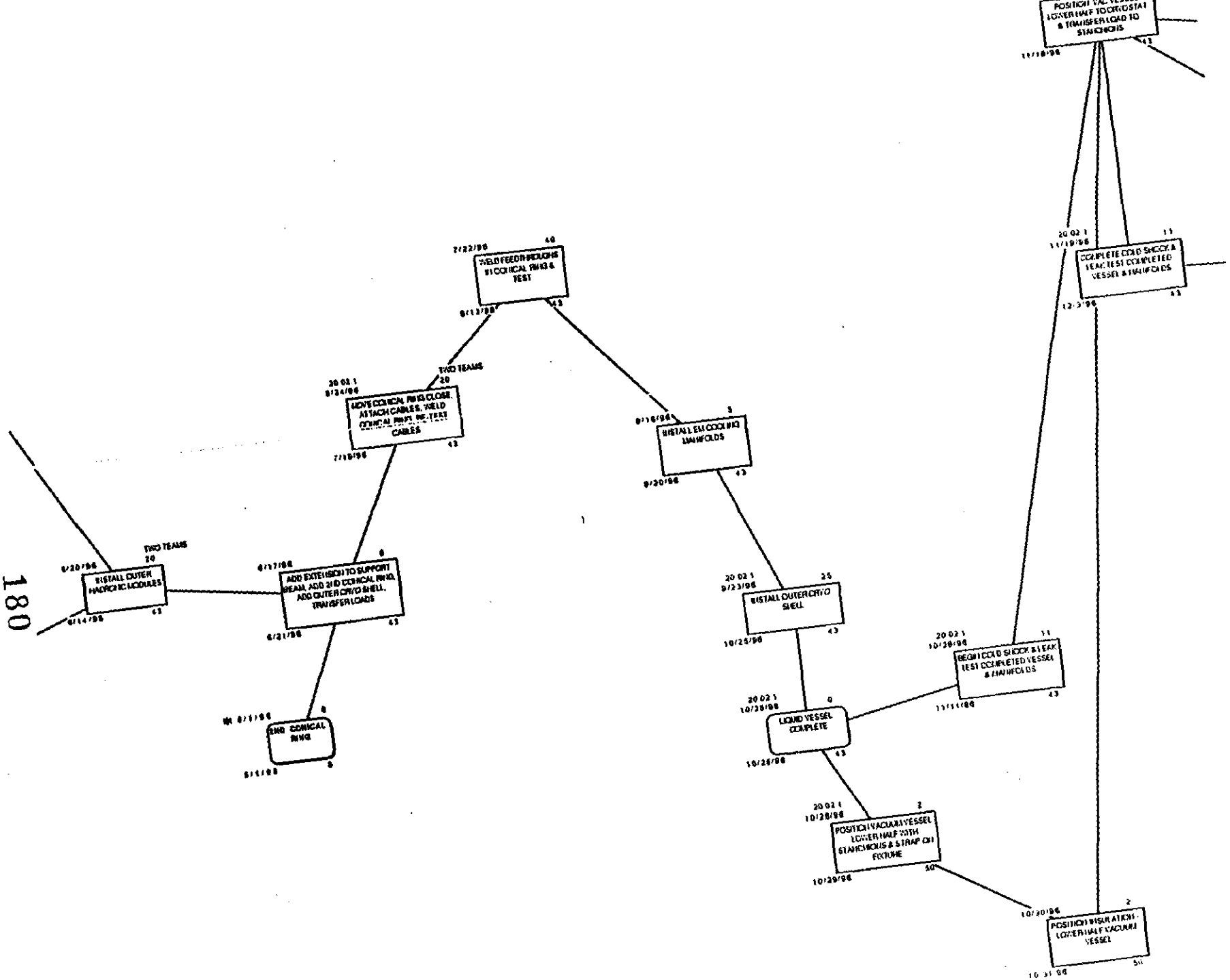

PAGE 1
MUON - START FABRICATION OF STRUCTURES AND CHAMBERS
MUON - ASSEMBLE PROTOTYPE MODULES
MUON - TEST MODULES
MUON - FABRICATION OF SOUTH BARREL PARTS
COMPLETE FINAL DESIGN OF DETECTOR
SECOND STAGE APPROVAL
DETECTOR - FABRICATE FIRST BATCH COMPONENTS
MAGNET - WIND FIRST COIL
MAGNET - COMPLETE COIL WINDING FOR FIRST HALF UNIT
MAGNET - COIL WINDING FOR SECOND HALF UNIT
MAGNET - ASSEMBLY OF SECOND HALF UNIT
MAGNET STACK 1ST 10 SEGMENTS
MAGNET - FACTURE OFF-SITE COMPONENTS
MAGNET ASSEMBLY OF FIRST HALF UNIT
MAGNET - TEST NORTH HALF UNIT
MAGNET - FABRICATE VESSELS
MAGNET - TEST FIRST HALF UNIT
NORTH ASSY. BUILDING - BOD
INSTALL AUX. SYSTEM HARDWARE
CENTRAL DETECTOR SUPPORT INSTALL
CALORIMETER - PLACE STRUCTURES
FAB. AREA COMPLETE
CENTRAL DETECTOR SUPPORT ASSEMBLE
MAGNET - CONTINUE AUX. SYSTEM INSTALLATION
DOUBLE SHIFT
PARTIAL DOUBLE SHIFT

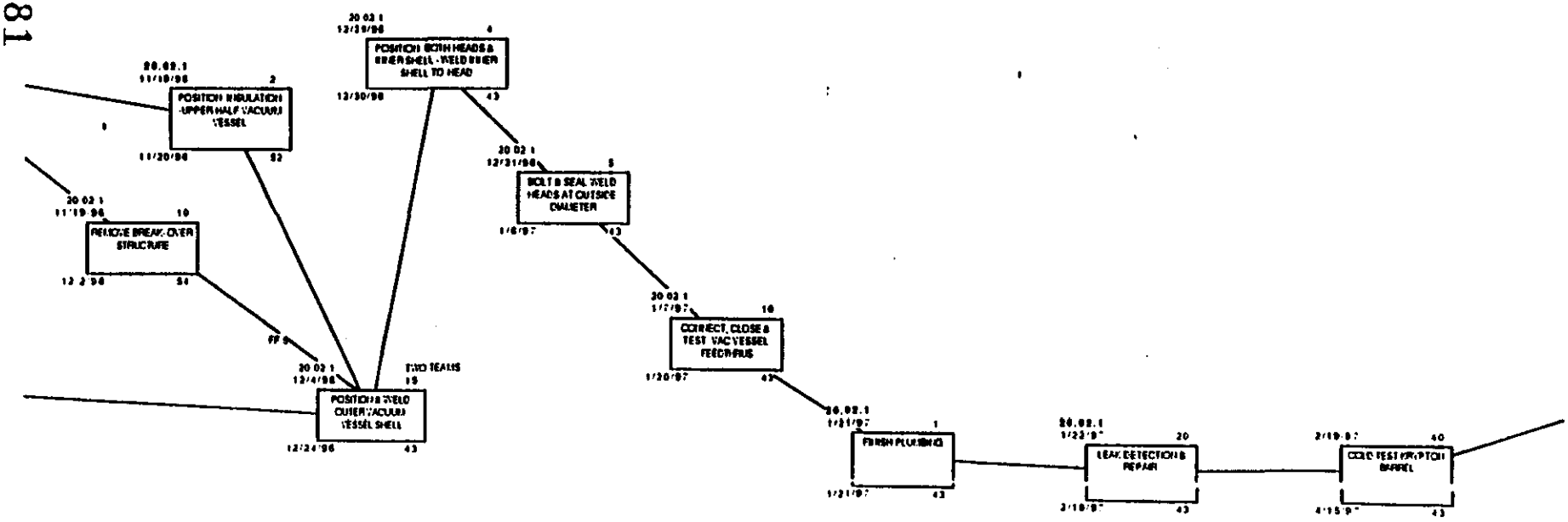

4/1/94
10/1/94
1/1/95
4/1/95
7/1/95
10/1/95
4/1/96
7/1/96
10/1/96
1/1/97
7/1/97
North Assy Bldg - BOD
ScintCal - Manufacture modules
CDS - Assy
Magnet - 1st Unit Assy
ScintCal - Module shipment
LKr Barrel Cal - equip lo-bay
ScintCal- Module receiving & insp
LKr Barrel Cal - Assy in lo-bay
Magnet - 1st unit complete
East end north assy bldg available
Scintcal - Clean, equip, set-up assy space
LKr Barrel Cal - equip hi-bay
ScintCal - Install modules
ScintCal - Install PMTs & electronics
ScintCal - Test PMTs & electronics
LKr Barrel Cal - Assy in hi-ba
ScintCal - Cosmic Ray Muon Calibration
ScintCal - Transport & Install in CDS
CDS - Ready to install in exp hall
CDS - Install in exp hall
LKr Barrel Cal - Commence installation



End Caps after tracker installation!


ASSEMBLE 60 OUTER HADRONIC MODULES IN HIGH BAY AREA
TAKE INNER HADRONIC MODULES OUT OF STORAGE & ASSEMBLE IN HIGH BAY
REMOVE FIXTURE & WELD UPPER HEAD WALL TO INNER CYLINDER & RE-ATTACH FIXTURE
LIFT EM MONOLITH WITH HADRONIC SPOOL OVER BREAKOVER FIXTURE
BREAK-OVER
ROUTE EM STRIP LINES
ROUTE LOWER EM CABLES TO OUTSIDE
INSTALL MODULE SUPPORT RAILS
BOLT UPPER HEAD WALL
TWO TEAMS
INSTALL INNER HADRONIC MODULES - 1ST SECTION
INSTALL SECTION 2 HADRONIC RAILS
ROUTE UPPER EM CABLES
PREPARE BRAZE OVER FIXTURE & OVERHEAD PLATE & INNER SHELL CRYOSTAT
ADD STAYS & ROUTE CABLES
BOLT CENTRAL TAP OF EM TO OUTER EM STAY
INSTALL OUTER EM STAY WITH CENTRAL HEAD WASHER BUFFED EM MONOLITH
1ST CONCAL RING


INSTALL OUTER HADRONIC MODULES
TWO TEAMS
20
6/20/96
6/14/96
43
ADD EXTENSION TO SUPPORT BEAM, ADD 2ND CONICAL RING, ADD OUTER CRYO SHELL, TRANSFER LOADS
6/17/96
6/21/96
43
END CONICAL RING
6/1/96
MOVE CONICAL RING CLOSE, ATTACH CABLES, WELD CONICAL RINGS RE-TEST CABLES
TWO TEAMS
20
20 02 1
6/24/96
7/19/96
43
WELD FEEDTHROUGHS TO CONICAL RING & TEST
40
7/22/96
8/13/96
43
INSTALL EM COOLING MANIFOLDS
5
8/16/96
9/20/96
43
INSTALL OUTER CRYO SHELL
25
20 02 1
9/23/96
10/25/96
43
LIQUID VESSEL COMPLETE
0
20 02 1
10/28/96
10/28/96
43
POSITION VACUUM VESSEL LOWER HALF WITH STANCHIONS & STRAP ON FIXTURE
2
20 02 1
10/28/96
10/29/96
50
POSITION INSULATION LOWER HALF VACUUM VESSEL
2
10/30/96
10/31/96
50
BEGIN COLD SHOCK & LEAK TEST COMPLETED VESSEL & MANIFOLDS
11
20 02 1
10/28/96
11/11/96
43
POSITION VACUUM VESSEL LOWER HALF TO CRYOSTAT & TRANSFER LOAD TO STANCHIONS
11/18/96
43
COMPLETE COLD SHOCK & LEAK TEST COMPLETED VESSEL & MANIFOLDS
11
20 02 1
11/19/96
12/3/96
43


POSITION INSULATION -UPPER HALF VACUUM VESSEL
REMOVE BREAK-OVER STRUCTURE
POSITION BOTH HEADS & INNER SHELL - WELD INNER SHELL TO HEAD
POSITION & WELD OUTER VACUUM VESSEL SHELL
BOLT & SEAL WELD HEADS AT OUTSIDE DIAMETER
CONNECT, CLOSE & TEST VAC VESSEL FEEDTHRUS
FINISH PLUMBING
LEAK DETECTION & REPAIR
COLD TEST CRYOSTAT BARREL

Itinerary for the U.S. Delegation on the China/SSC-GEM Calorimeter Collaboration

Jan. 2

22:20 Arrival of Dr. David Lissauer and Dr. Donald Makowiecki by UA853
Stay at Youhao Guest House

Jan. 3

09:00-12:00 Introduction by Dr. Lissauer and Dr. Makowiecki on GEM, liquid calorimeter, etc. at the Ministry of Aero-Space Industry
13:00-17:00 Continue with the introduction

Jan. 4

09:20 Arrival of Dr. William Wisniewski by Lufthansa 720
09:30 Continue with introduction by Dr. Lissauer and Dr. Makowiecki
13:50 Arrival of Dr. Nicholas Digiacomo and Dr. Lyle Mason by Air Nippon 905
x 14:30 Meeting with Dr. Wisniewski at the Ministry of Aero-Space Industry
13:30 lunch @ Minister
20:40 Arrival of Dr. Yuli Kamychkov and Dr. Lawrence Sulak by UA853

Jan. 5

09:00-12:00 Mr. Lin Zongtang, Minister of Aero-Space Industry meets with the delegation
12:00-13:30 Luncheon hosted by Minister Lin Zongtang
x 14:00 Visit Qinghua University and Beijing Glass Research Institute (Scintillating Calorimeter Group)
all to Qinghua
Visit the Forbidden City (Liquid Calorimeter Group)
17:40 Fly from Beijing to Xi'an
dinner @ XAC

Jan. 6

09:00-12:00 Visit facilities in Xi'an Aero-engine Company
13:00-17:00 Visit ~~and discussion~~ Terra Cotta Museum
19:00 Dinner hosted by the company

Jan. 7

morning Visit the Terra-Cotta Warriors discussion
afternoon Discussions
16:05- Fly from Xi'an to Shanghai

Jan. 8

morning Visit Shanghai Aviation Industrial Corporation
Afternoon Visit and discussion

Jan. 9

morning Discussions
12:30-14:10 Fly from Shanghai to Beijing
15:30-17:00 Minister Lin meets with the delegation (SC Group)
~~19:00 Dinner hosted by Minister Lin~~
late return
visit: Beijing Institute of Aeronautical Material
Jan 10 final meeting with Minister Lin
departures

MINUTES OF MEETING

(Jan. 2 -- 10, 1993)

At the invitation of Mr. Lin Zongtang, Minister of the Ministry of Aero-Space Industry (MAS), People's Republic of China, a group of seven representatives from the GEM collaboration at the U.S. Superconducting Super Collider visited China from Jan. 2 to Jan. 10, 1993. Minister Lin met with this group, and personally arranged and took part in their important activities in China. Minister Lin expressed that the Chinese Government will actively support the project, and that China is willing to make its contributions to the world's biggest, most important international cooperative research project, the SSC. Therefore, MAS has set up a temporary office for the SSC project that will be responsible for the organization of contacts and cooperation.

During its stay in China, the group visited the Institute of High Energy Physics of Academia Sinica, MAS, Qing Hua University, Xi'an Aero-Engine Corporation and Shanghai Aviation Industrial Group Corporation. The group was impressed by the quality of personnel, the manufacturing capability, and the management of Xi'an Aero-Engine Corporation and Shanghai Aviation Industrial Corporation. The group was encouraged by the Ministry's intention to apply the excellent quality control program developed by Shanghai Aviation Industrial Corporation with McDonnell Douglas Corp. to all GEM-SSC related projects.

The calorimeter group representatives participated in detailed discussions about GEM calorimeter design and production, including material, techiniques and fabrication requirements. Experts from Nanjing University, Northwestern Polytechnical University, Baoji Non-ferrous Manufacturing Factory, Luoyang Copper Manufacturing Factory, No. 2 Space Research Academy, Aeronautical Manufacturing Technology

RD3 visit

Orsay/Saclay

- feed throughs
- cryostats & cryogenics
- hadronic accordion

CERN

- e.m. accordion construction
- simulations
- prototype results
- visit test beam set-up
- different endcap em concepts
- hadronic modules

gem γeμ

Presentation by:

Harvey Newman

GEM TDR

THE BASIS For SSCL, DOE REVIEW
THE BASIS For GEM APPROVAL

- (1) A PROPOSAL To SSCL and DOE
- (2) A DESIGN REPORT

- (1) PROOF of PHYSICS CAPABILITY
- (2) PROOF of TECHNICAL FEASIBILITY

- UNIFIED TOP DOWN STRUCTURE

PHYSICS GOALS	$\Longleftrightarrow$	SUBSYSTEM MISSION; PERFORMANCE	$\Longleftrightarrow$	DETECTOR ENVIRONMENT; OPERATIONS

- MISSION ORIENTED
  - Only Sufficient Detail To Make The Case
  - Reference To External Documents For Engineering Details

SUMMARY SCHEDULE FOR REVIEW OF GEM

End March, 1993	**Deadline for Cost and Schedule, draft Project Management Plan**
April 30, 1993	**Submission of GEM TDR**
May 24 - 29, 1993	**Review of TDR and draft plans (at SSCL)**
Focus:	- Scientific merit
	- Technical feasibility
	- Collaboration resources, organization, management
	- Cost and schedule
Projected Results:	- Detailed evaluation of the GEM project
	- Action items for further study and clarification
	- Cost and schedule goals for GEM baseline
July 31 - August 6, 1993	**PAC Meeting (tentative dates)**
Focus:	- Closure on action items from May review
	- GEM in context of total SSC program
Projected Results:	- Recommendation to formulate the GEM baseline and to draft agreements with participating institutions.

If the August review results in a recommendation to proceed with the formulation of the GEM baseline, the tentative schedule is:

October 1, 1993 (tentative date)	**Deadline for proposed baseline Cost and Schedule and final versions of GEM Project Management Plan and Conceptual Safety Analysis Report**
October, 1993	**DOE Project Review (at SSCL)**
Focus:	- Detailed review of GEM the baseline - Management plan (in-depth review) - Status of agreements & plan for institutional assignments (US and foreign) - Operations (plans for QA, safety, acquisitions, detector operating procedures, etc.
Projected Results:	- Report to DOE/ER Management - GEM baseline presented by Laboratory approved by DOE

January 1993

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1 New Year's Day	2 Pay rent
3	4	5	6	7	8	9
10	11 DoE Visit	12 DoE Visit	13	14	15	16
17	18 Martin Luther King Day	19	20	21	22	23 New Year's Day Year of Rooster
24	25	26	27	28	29	30
31 GEM TDR not due						

December 1992

		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

February 1993

	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28						

GEM TDR SCHEDULE:

DUE TO SSCL

APRIL 30, 1993

MILESTONE DUE DATES	
Intermediate Drafts	12/18, 1/20, 2/17
GEM Internal Board Reviews Completed	2/3, 3/1
Final Draft for Review	3/15
Final GEM Internal Review Completed	3/26
Finished Chapters: All Text and Figures	4/9
Document Complete; Submitted To SSCL	4/30

GEM TDR DRAFTS

DECEMBER 18

- Detailed Outlines

JANUARY 20

- Drafts Due For All Sections
- Preliminary Drafts:
  - Complete Section Structure (3 Levels)
  - Summary of All Missing Text, In Place
  - Status Report: Plan, Schedule, Major Tasks for Final Draft

FEBRUARY 17

- Complete Draft for All Sections
- Final Draft for More Advanced Sections
- Status Report and Summary-In-Place of Planned Revisions, For Sections Not In Final Form

MARCH 15 ONWARDS

- All "Final" Drafts Submitted To TDR Team and Internal Review Board;
  As Many as Possible Prior to March 15
- Weekly Working and Review Group Meetings:
  General Status, Problem Areas, Scheduled Focus On Individual Sections

APRIL 9 ONWARDS

- Final Chapters In Hand
- Final Chapter-Editing and Global Editing
- Final Document Processing: Text and Figure Layout

APRIL 27 – 30

- Document Reproduction
- Final Check In Time for Submission

	Section	Pages	Lead Authors
1	Executive Summary; Detector Overview	25	Barish, Willis
2	Physics Goals, Performance, Simulations	80	Lane, Zhou, Barish, Paige
3	Magnet	50	Stroynowski
4	Muon Spectrometer	100	Taylor, Marx
5	Calorimeters	100	Gordon, Willis, Rutherfoord, Lissauer
6	Tracker	80	Baltay, Morgan
7	Electronics	90	Shaevitz, Marlow
8	Computing, Controls, Networking	25	McFarlane,Cormell
9	Facilities, Assembly and Installation	30	Harris
10	Detector Operations, Access and Maintenance	20	Harris, Wisniewski
11	Detector/Beamline Interface	10	Wisniewski, Morgan, Chapman
12	Detector Upgrades; Staging Options	10	Willis, Barish
13	Neutron Particle Backgrounds and Shielding	20	Diwan, Wuest, Waters, Marx
14	Beam Testing and Calibration	20	Yost
15	Project Management Plan Summary	10	Sanders, Baltay
16	Environmental Safety and Health	20	Woolley
17	Cost Estimate Summary; Responsibility Matrix; Funding Plan	10	Sanders, Barish, Willis
		700 Pages	

SEPARATE DOCUMENTS	
Project Management Plan	Sanders, Baltay
Cost/Schedule Baseline and WBS Dictionary	Sanders, Barish, Willis
Preliminary Safety Analysis Report	Woolley

GEM TDR ORGANIZATION

TDR TEAM

- EDITORIAL BOARD:
  H. Newman, N. Baggett, J. Reidy, G. Yost, F. Paige
  O. Fackler, K. Morgan, R. Panvini, J. Womersley

- FIGURE CZARS:
  J. Reidy, O. Fackler

- PRODUCTION GROUP:
  SSC: H. Durden, L. Fowler, C. Thomas, L. Ballard
  Caltech: R. Harder
  Yale: B. Alexy

- INTERNAL REVIEW BOARD:
  C. Baltay, B. Barish, J. Brau, M. Danilov, J. Friedman,
  H. Gordon, Y. N. Guo, M. Harris, Y. Kamyshkov, H. Kendall,
  K. Lane, D. Marlow, M. Marx, K. McFarlane, P. Mockett,
  R. Mount, Y. Onel, F. Plasil, L. Rosenson, J. Rutherfoord,
  J. Russ, N. Samios, G. Sanders, R. Shang, M. Shaevitz,
  P. Slattery, R. Stroynowski, F. Taylor, W. Willis, R. Webb,
  W. Wisniewski, S. Whitaker, C. Wuest

GEM TDR OUTLINE

INTERNAL REVIEWERS

	Section	Internal Reviewers
1	Executive Summary; Detector Overview	Marx, Sanders, Slattery
2	Physics Goals, Performance, Simulations	Baltay, Brau, Marx, Rutherfoord
3	Magnet	Taylor, Barish
4	Muon Spectrometer	Brau, Rosenson
5	Calorimeters	Marx, Shaevitz
6	Tracker	Stroynowski, Whitaker
7	Electronics	McFarlane, Willis
8	Computing, Controls, Networking	Mount
9	Facilities, Assembly and Installation	Wisniewski
10	Detector Operations, Access and Maintenance	Sanders
11	Detector/Beamline Interface	Harris, Plasil
12	Detector Upgrades; Staging Options	Harris, Lane, Plasil
13	Neutron Particle Backgrounds and Shielding	Russ
14	Beam Testing and Calibration	Mockett
15	Project Management Plan	Newman, (15), Gilman
16	Environmental Safety and Health	Harris
17	Cost Estimate Summary; Responsibility Matrix; Funding Plan	Samios, Baltay

GEM TDR: CONCERNS and ISSUES

- PHYSICS CHAPTER (K. Lane, B. Zhou)
  - Unique Physics: $H^0 \rightarrow \gamma\gamma$, Leptons At High $\mathcal{L}$
  - Time To Complete Studies: "3 Months"; Based On FIXED Detector Geometry
  - Depth of Studies: Founded In Subdetector and Specialized Simulations, With Reconstruction
- PROOF OF DETECTOR PERFORMANCE
  - Neutron Fluxes; Hit Rates, Occupancy and Background Energy Spectra
  - Pattern Recognition Studies
  - Reconstruction in Non-Uniform Field, With Background
  - Reliable Estimate of Reconstruction and Particle ID Efficiencies (CT, FFS, Transition Regions)
  - Data Flow: Trigger and Online DAQ Complexity and Cost; Minimum E_T
  - Detector Calibrations: Test Beams and In Situ
- OPTIMIZATION OF PERFORMANCE/COST
- DETECTOR OPERATION, INTERFACE, EVOLUTION
  - Installation Procedure; Relation to Staging
  - Access Procedures, Steps, Time Required; Including Impact of:
    - Magnetic Fringe Field
    - Materials Activation and Handling
  - Beam Pipe and SSC Vacuum Requirements
  - Luminosity: Minibeta Quad; Upgrade
- MAGNETIC FIELD
  - Mapping Accuracy, Time To Map, FFS Region
  - Monitoring Instrumentation

GEM TDR

SPECIAL SUBJECT REVIEWERS

	Section	Reviewer(s)
S1	Optimization of Detector Performance/Cost	Sanders
S2	Detector Subsystem Design Consistency and Schedule	Harris
S3	Pattern Recognition	Gordon, Willis
S4	Particle Identification	Kamyshkov, Danilov
S5	Neutron and Charged Particle Backgrounds: Impact on Performance	Wuest
S6	Detector Simulations	Womersley, Rosenson
S7	Subsystem Chapters (Detector Readout)/ Electronics Chapter Interface	Marlow, Onel
S8	R&D Plans	Webb
S9	Physics and Detector Figures	Guo, Shang
S10	Project Organization and Management	Samios, Baltay

TDR Schedule, Authors, and Submission Dates

X = RECEIVED BY TECHNICAL SUPPORT

* = LEAD AUTHOR

Ch	Title	Pgs	Author(s)	Editor	Reviewer	Intermediate TDR Drafts: Outlines 12/18	1/20	2/17	Internal and Editorial Reviews Completed: 1/8	2/3	3/1	Final Draft 3/15	Final Int/Edt 3/26	Fin'd chaps: text, & figs 4/9	TDR Submit 4/30
1	Executive Summary: Detector Overview	25	Barish*, Willis	Baggett	Marx, Sanders, Slattery	?	2/3								
2	Physics Goals, Performance, Simulations	80	Lane*, Zhou, Barish, Paige	Newman	Baltay, Brau Marx, Rutherfoord	X	X								
3	Magnet	50	Stroynowski*	Baggett	Taylor, Barish	X	New								
4	Muon Spectrometer	100	Taylor*, Marx	Yost	Brau, Rosenson	X									
5	Calorimeters	100	Gordon*, Willis, Rutherfoord, Lissauer	Reidy	Marx, Shaevitz	X	X								
6	Tracker	80	Baltay* Morgan	Panvini	Stroynowski, Whitaker	X	2/9								
7	Electronics	90	Shaevitz*, Marlow	Reidy	McFarlane, Willis	X	X								
8	Computing, Controls, Networking	25	McFarlane*, Cormell	Newman, Womersley	Mount	X									
9	Facilities, Assembly and Installation	30	Harris*	Baggett	Wisneiwski	X	2/5								
10	Detector Operations Access and Maintenance	20	Harris*, Wisniewski	Baggett	Sanders	X	2/5								
11	Detector/Beamline Interface	10	Wisniewski*, Morgan, Chapman	Fackler	Harris, Plasil,	X	2/11								

TDR Schedule, Authors, and Submission Dates

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Ch	Title	Pgs	Author(s)	Editor	Reviewer	Intermediate TDR Drafts Outlines 12/18	1/20	2/17	Internal and Editorial Reviews Completed 1/8	2/3	3/1	Final Draft 3/15	Final Int/Edt 3/26	Fin'd chaps: text, & figs 4/9	TDR Submit 4/30
12	Detector Upgrades/ Installation	10	Willis*, Barish	Baggett	Harris, Lane, Plasil	?									
13	Neutron Particle Backgrounds and Shielding	10	Diwan* Marx, Wuest, Waters	Morgan	Russ	X	X								
14	Beam Testing and Calibration	20	Yost*, Slattery	Fackler	Mockett	X	2/5								
15	Project Management Plan Summary	10	Sanders*, Baltay	Baggett	Newman, Barish, Willis, Baltay, Yost, Fischer, Baggett, Pells, Reardon, Sanders, Friedman (Sub-section reviewers: Harris, Woolley, Leibold, Richardson, Gilman)	X									
16	Environmental Safety & Health	10	Woolley*	Baggett	Harris	X	X		XE						
17	Cost Estimate Summary; Responsibility Matrix; Funding Plan	10	Sanders*, Barish, Willis	Baggett	Samios, Baltay	X									

Revised/rlh: 02/02/93

16. ENVIRONMENT, SAFETY & HEALTH

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GEM TDR

GUIDANCE on SUBMISSIONS

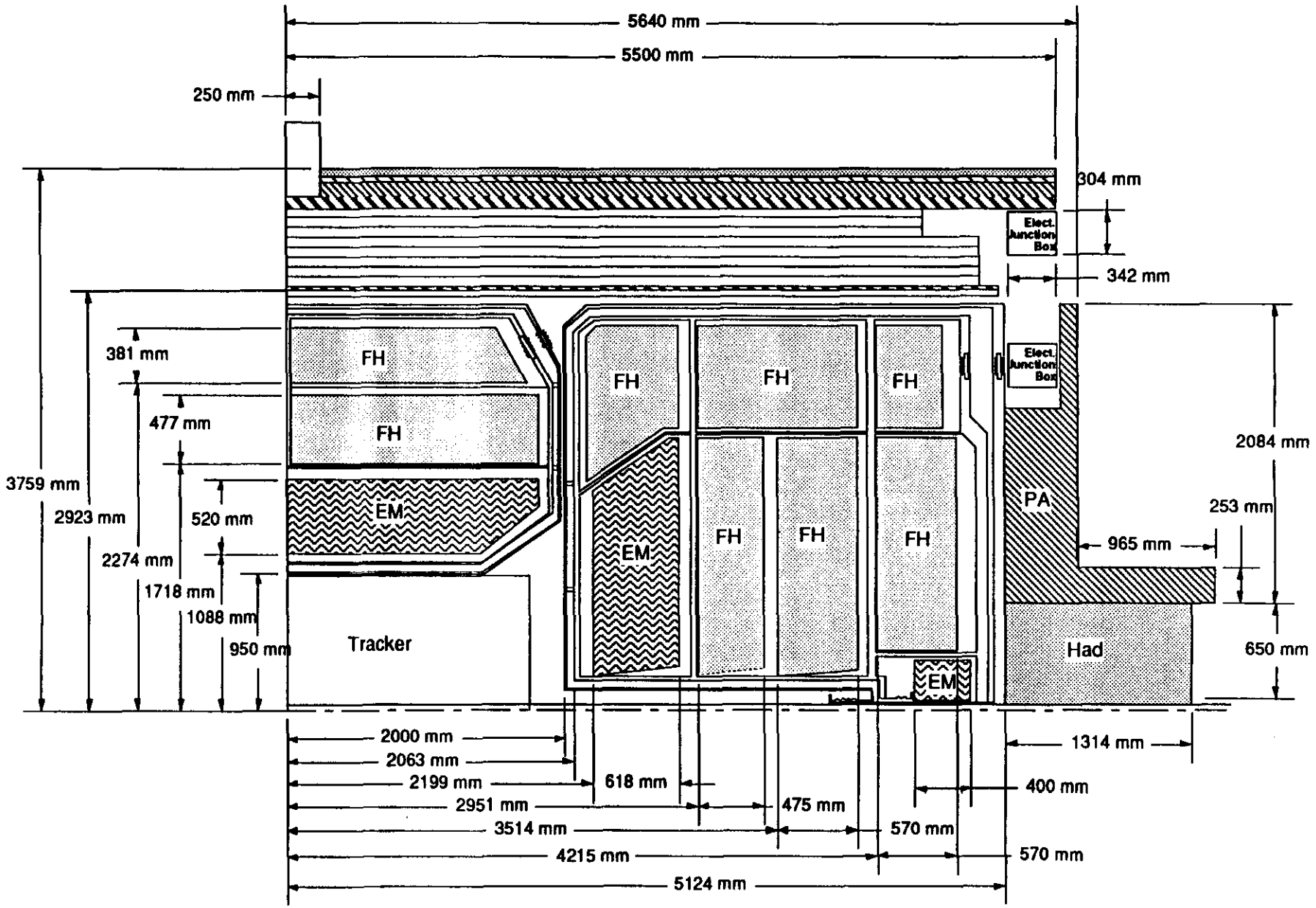
- LEAD AUTHORS Only: Submit drafts on time to Holly Durden, ASAP.
  - -- Additional Authors: Submit text and figures, in advance of the draft deadline, to the Lead Author for first-round review.
  - -- Submissions from Lead Authors (Only) will be made available in the CMS Library on SSCVX1.
- Simple Formatting: (See TDRSTYLES.RTF)
  - -- Single column only.
  - -- No WORD frames or boxes.
  - -- Leave page layout to the Production Staff.
  - -- A plain text file is preferable to a highly stylized document.

GEM TDR

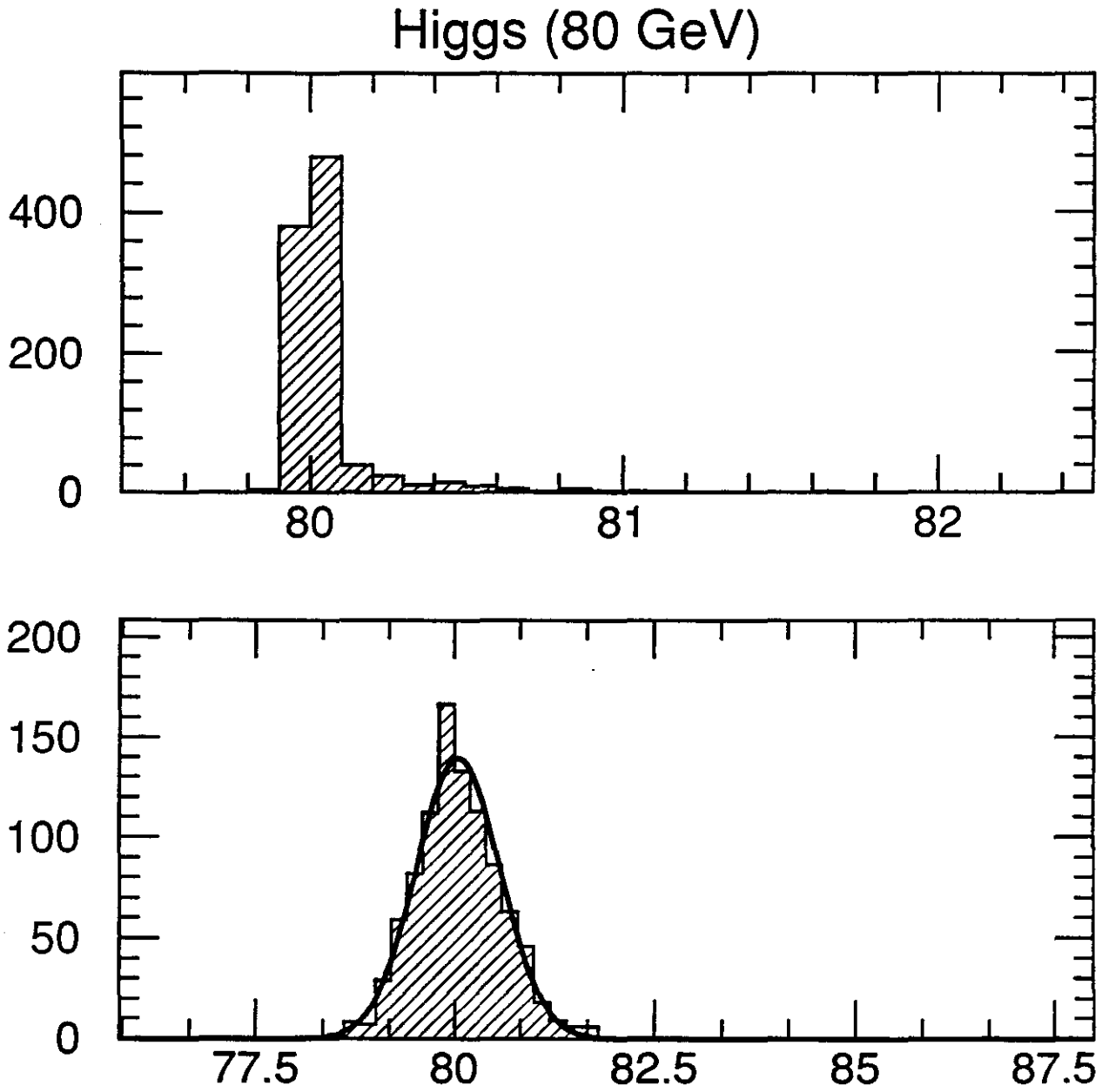
GUIDANCE on SUBMISSIONS (Cont'd) and REVIEW

- LEAD AUTHORS: Submit AS MANY FIGURES AS POSSIBLE, starting now.
  - -- Extra time is needed for handling and/or editing.
  - -- If submitted electronically, figures should be sent as a separate file from the text.
  - -- Check to see if your electronic figures can be imported into WORD.
  - -- A good example (Gordon): Claris CAD → WORD (Import) → .RTF File
- REVIEWERS:
  - -- Use the CMS Library; hard copies will be distributed only as necessary.
  - -- Return detailed comments/corrections to Lead Authors in 2 weeks or less.
  - -- WORD Text Annotations is recommended; try it and report experience/problems.

GEM Calorimeter - Dimensions



From H. Gordon


Higgs (80 GeV)
400
200
0
80
81
82
200
150
100
50
0
77.5
80
82.5
85
87.5

GEM TDR

- *The submission of a TDR of sufficient quality ON TIME is the highest priority for GEM; there are no higher priority activities.*
- *April 30, 1993 is the FINAL Due Date; There can be no further extension.*
- *A TDR which demonstrates fully GEM's unique physics capabilities, and the ability of the Collaboration to build the experiment -- within budget and on schedule -- is required for GEM's continuation.*
- *Until now, the TDR schedule, accepted by the Collaboration in December, has not been met. Many reasoned excuses have been given; these are simply not useful for GEM's future.*
- *The next draft is REQUIRED by the Collaboration within the next 10 days. Failure to submit a well thought out draft BEFORE February 17 will be treated with the gravest concern by the GEM Spokesmen, and the Executive Committee.*

gem

γeμ

Presentation by:

R. Frey

R. FREY
2/4/93
GEM

A Prototype Silicon Preradiator for the SSC

A. Arodzero, U. of Oregon / Moscow State U.

G. Bashindzhagyan, Moscow State

J. Brau, U. Oregon

R. Frey, UO

K. Furuno, UO

H. Hwang, UO (grad. s.)

D. Mason, UO (undergrad.)

D. Strom, UO

R.A. Todd, ORNL

X. Yang, UO (grad.)

- Motivation
- Prototype description
- Beam test results

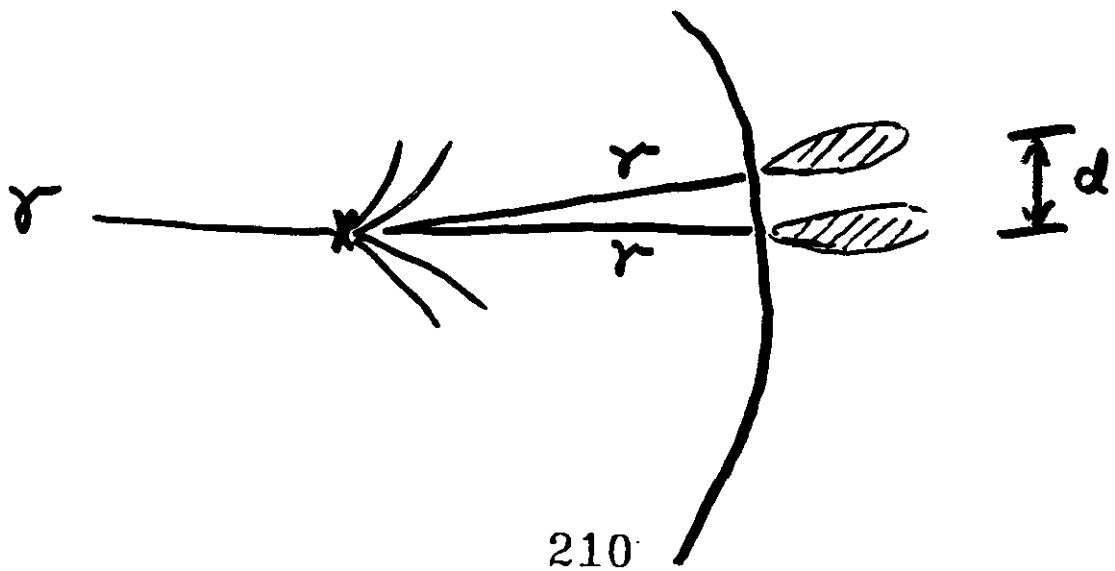
Focus of preradiator for GEM:

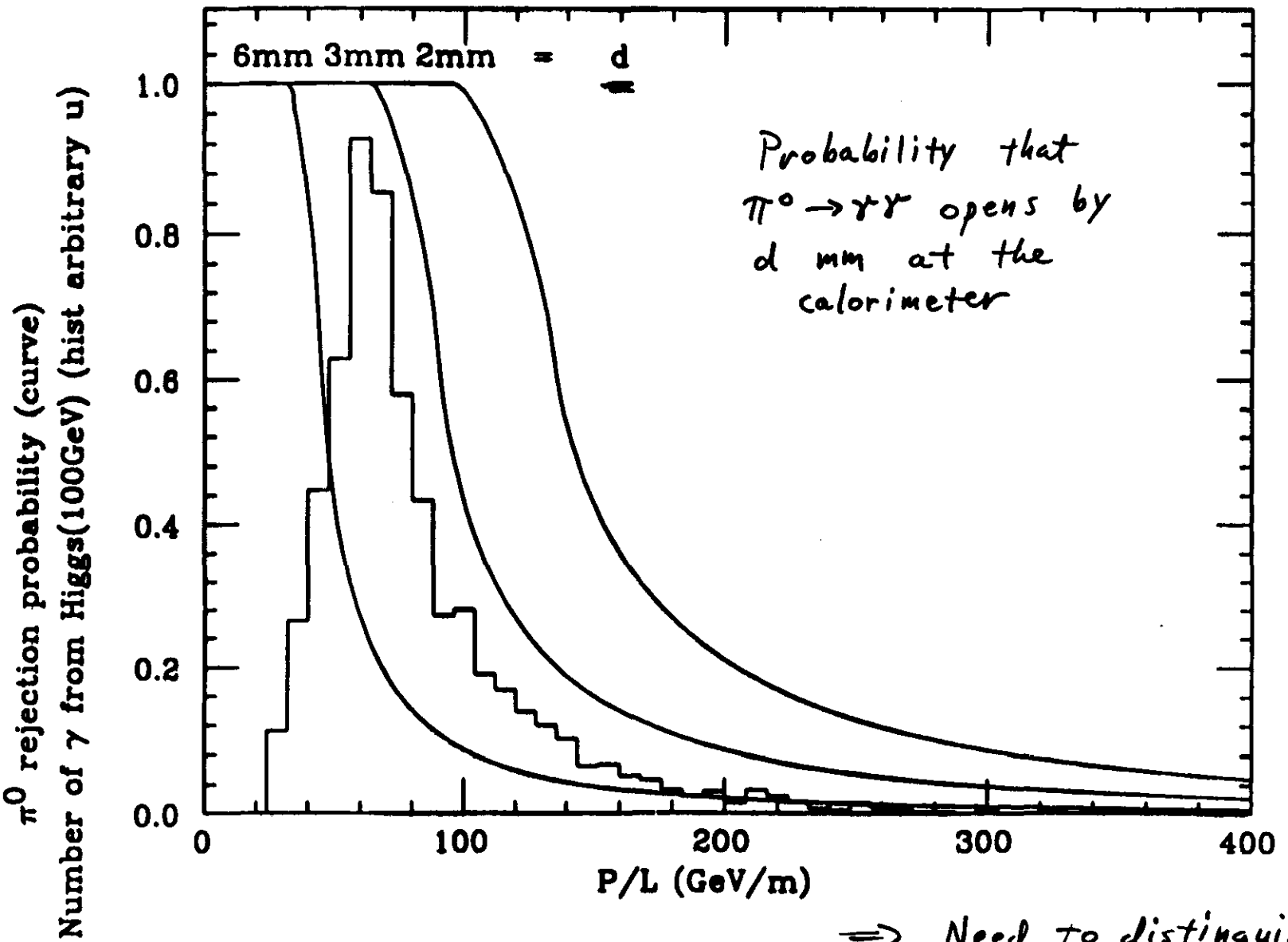
$$H \to \gamma\gamma$$

<u>Backgrounds</u>:

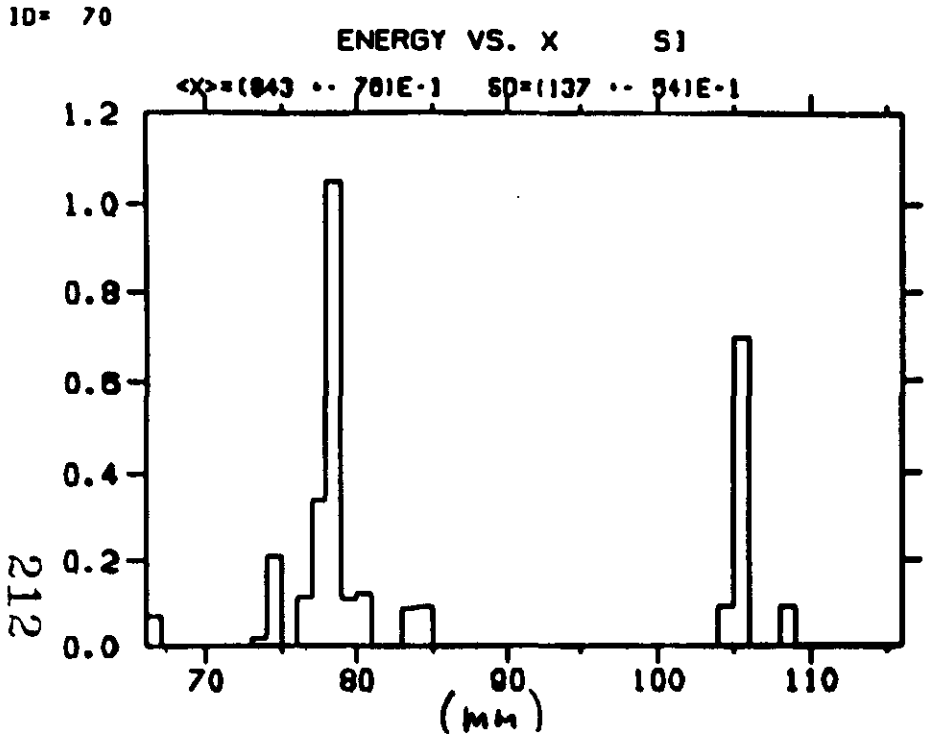
$pp \to \gamma\gamma$ (irreducible)

$$\left.\begin{array}{l} \to \gamma j \\ \to jj \end{array}\right\} \quad j \to n\pi^0 X$$





⇒ Need to distinguish showers for $d \gtrsim 3$ mm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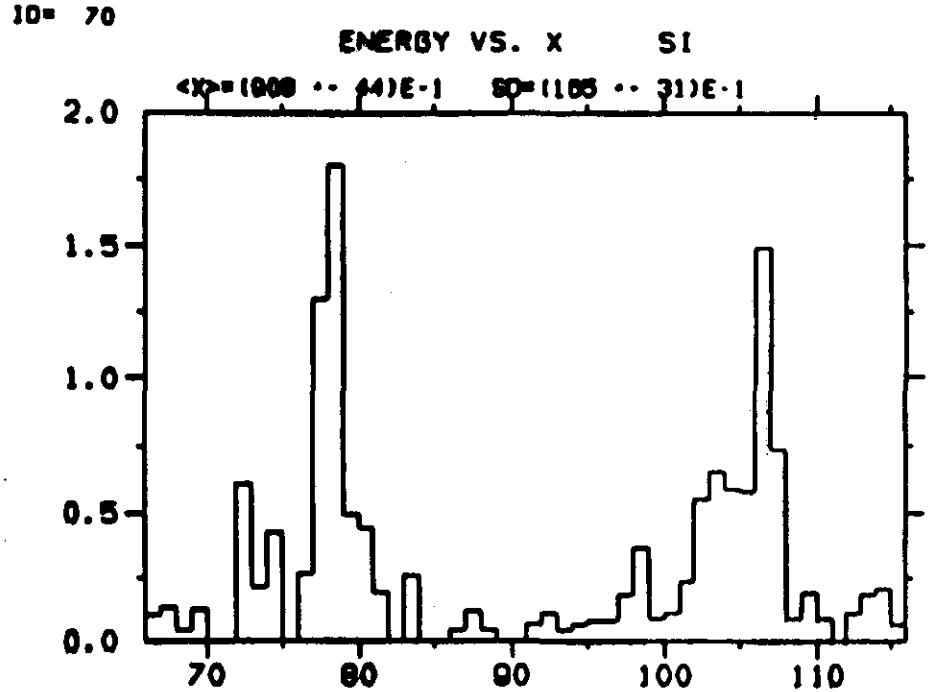
ENERGY VS. X SI
<X>=(843 ·· 78)E-1 SD=(137 ·· 54)E-1
1.2
1.0
0.8
0.6
0.4
0.2
0.0
70
80
90
100
110
(mm)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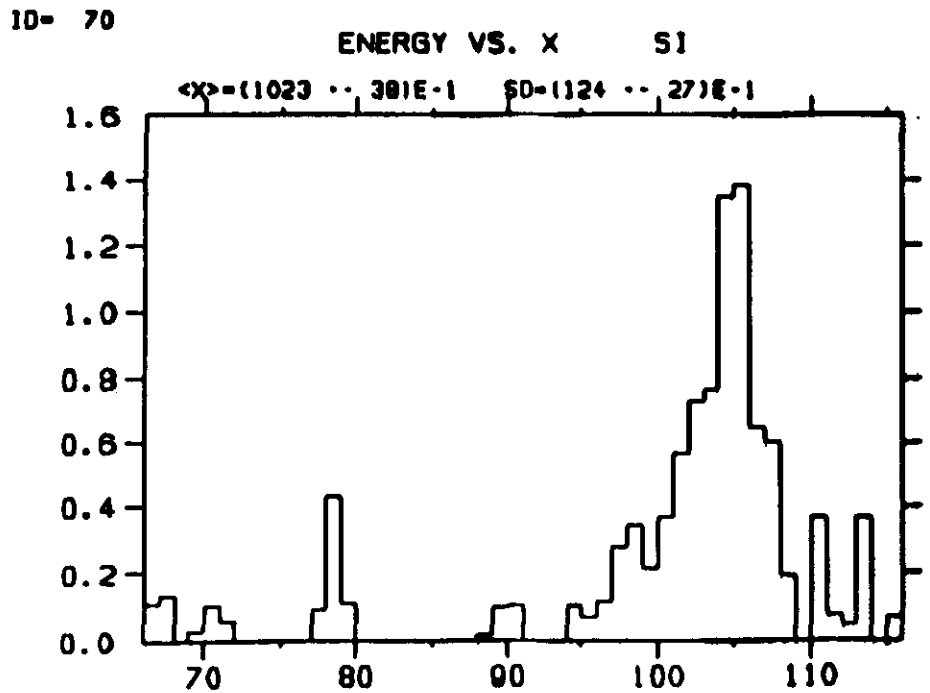
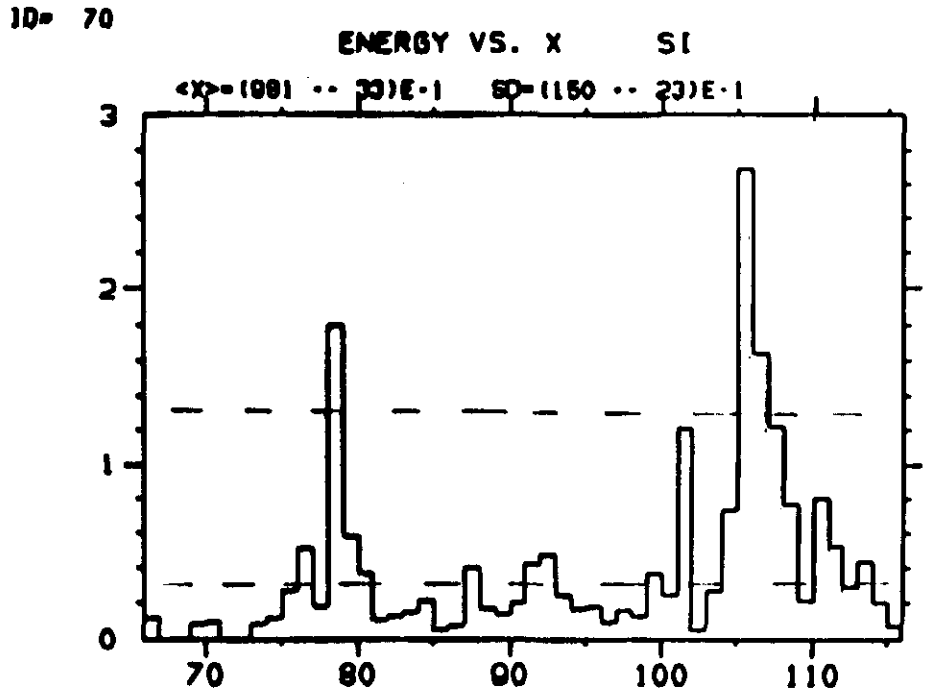
ENERGY VS. X SI
2.0
1.5
1.0
0.5
0.0
70
80
90
100
110


ID= 70
ENERGY VS. X SI
<X>=(1023 ·· 38)E-1 SD=(124 ·· 27)E-1
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
70
80
90
100
110

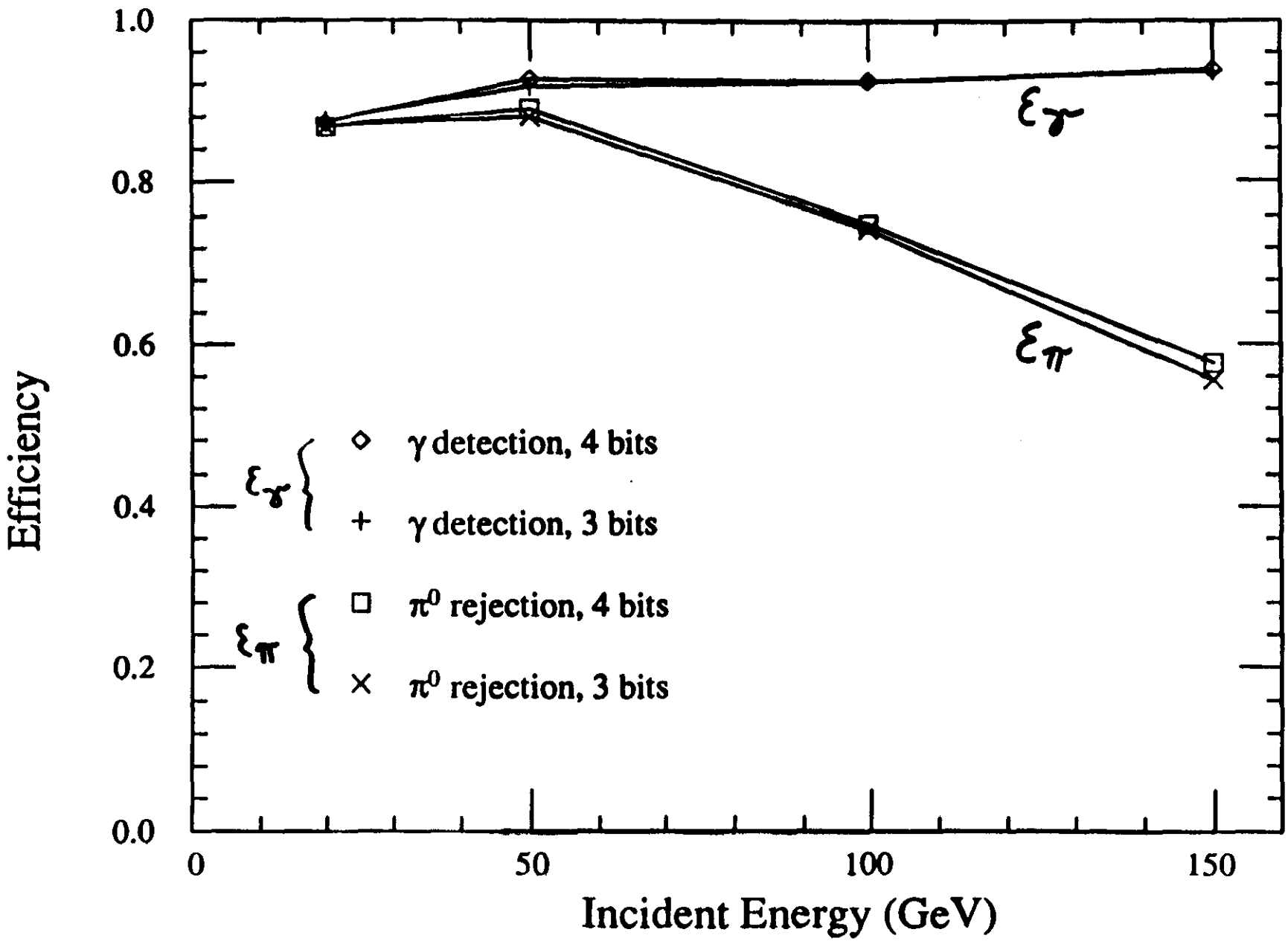

ID= 70
ENERGY VS. X SI
3
2
1
0
70
80
90
100
110

$H \to \gamma\gamma$ significance

$$S = \frac{N \varepsilon_\gamma^2}{\left[\varepsilon_\gamma^2 N_{\gamma\gamma} + \varepsilon_\gamma \bar{\varepsilon}_\pi N_{j\gamma} + \bar{\varepsilon}_\pi^2 N_{jj} \right]^{1/2}}$$

ε_γ photon finding efficiency

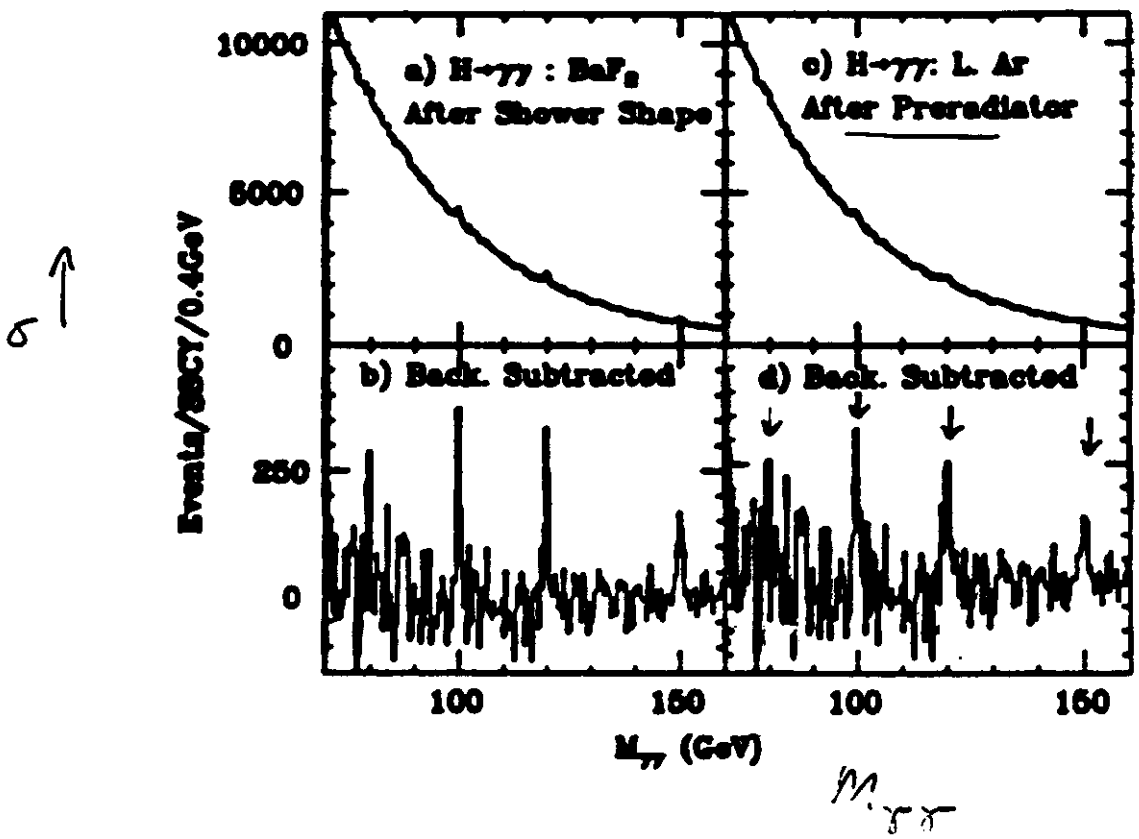
$\bar{\varepsilon}_\pi$ inefficiency of π^0 rejection


1.0
0.8
0.6
0.4
0.2
0.0
Efficiency
0
50
100
150
Incident Energy (GeV)
ε_γ
ε_π
ε_γ
ε_π
γ detection, 4 bits
γ detection, 3 bits
π^0 rejection, 4 bits
π^0 rejection, 3 bits

GEM Calculation $H^0 \to \gamma\gamma$ + ($\gamma\gamma$ + γj + jj)

Backgrounds

	$\sigma_{\gamma\gamma}$	$\sigma_{\gamma j}$	σ_{jj}	*
nematic and olation cuts	34 pb	90 pb	220 pb	
1. shower shape	34	50	120	
eradiator	34	24	20	

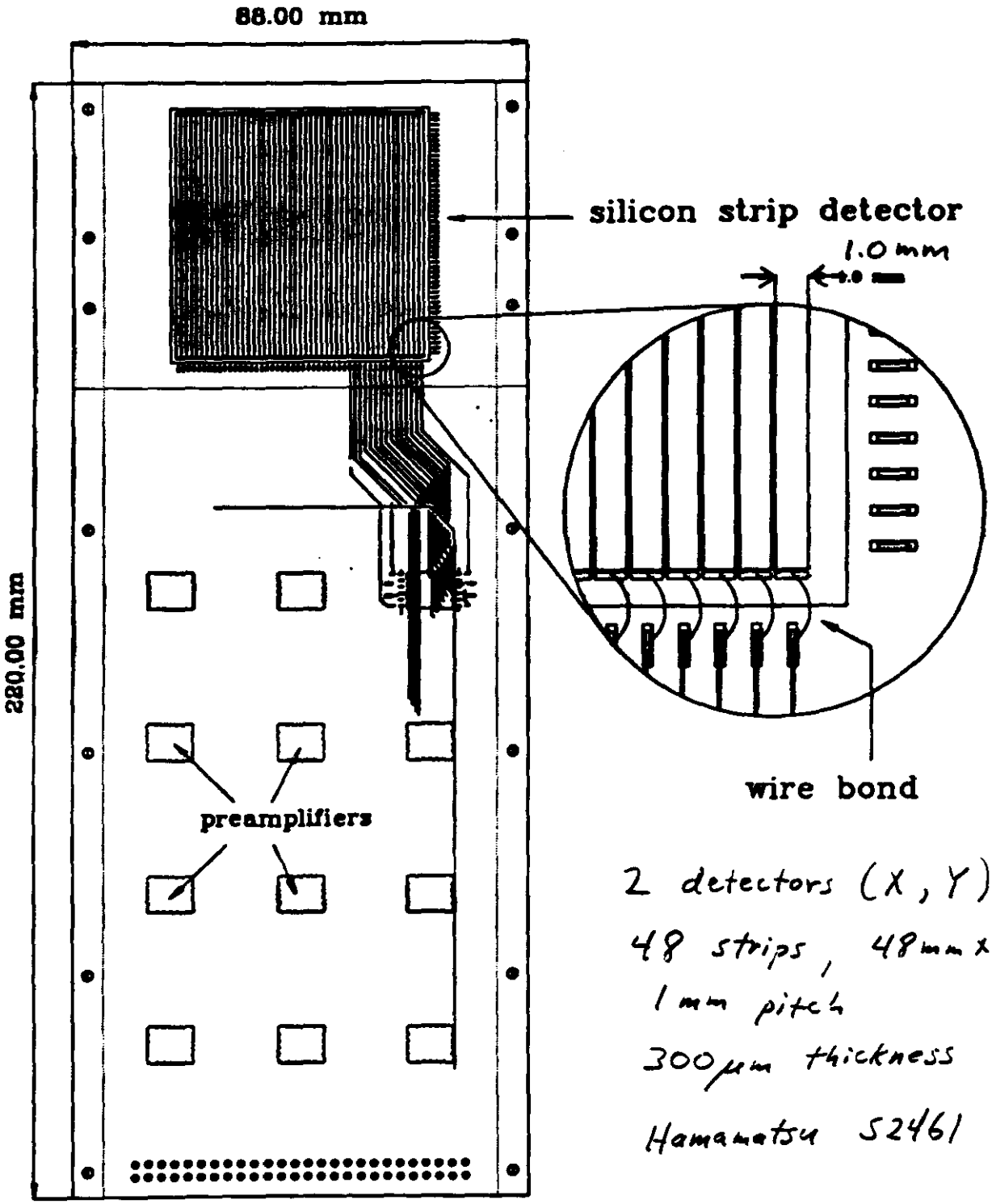


GEM TN-91-32
R.-Y. Zhu

M_H = 80
100
120
150 GeV/c²

* Background calculations very uncertain

Prototype (detectors, mounting, preamps)



2 detectors (X, Y)

48 strips, 48mm x 48mm

1 mm pitch

300 μm thickness (70V depletio

Hamamatsu S2461

preamp Designed by ORNL for Si calorimetry

Bipolar Monolithic quad

Charge sensitive $C_F = 10\,pF$ (100 mV/pC)

ENC ~ 4000 e^- rms (300 K, $C_{DET} \approx 20\,pF$)

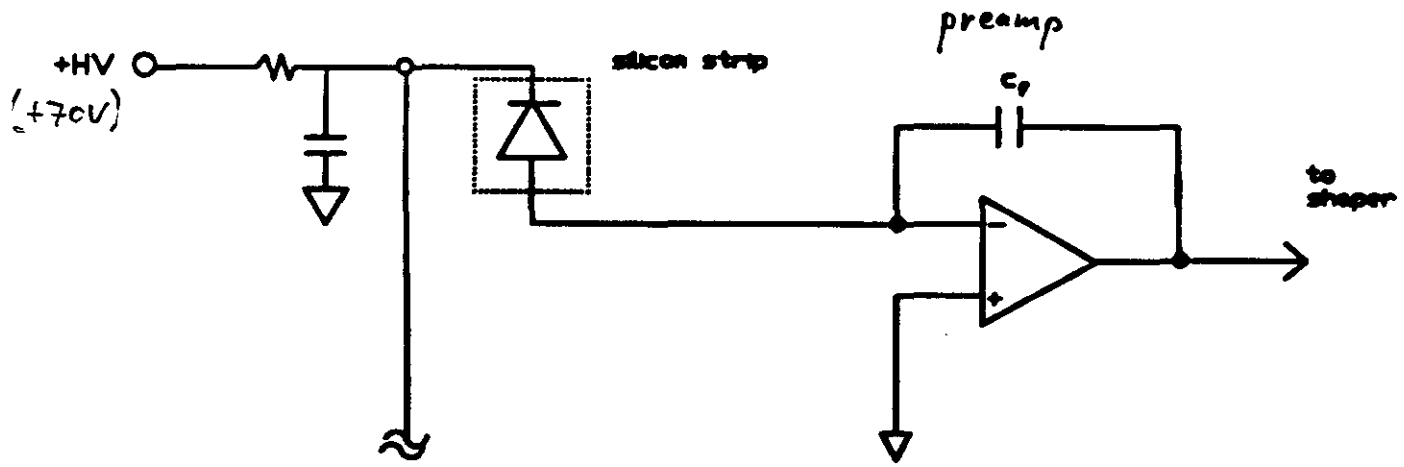
$t_r = 4\,ns$

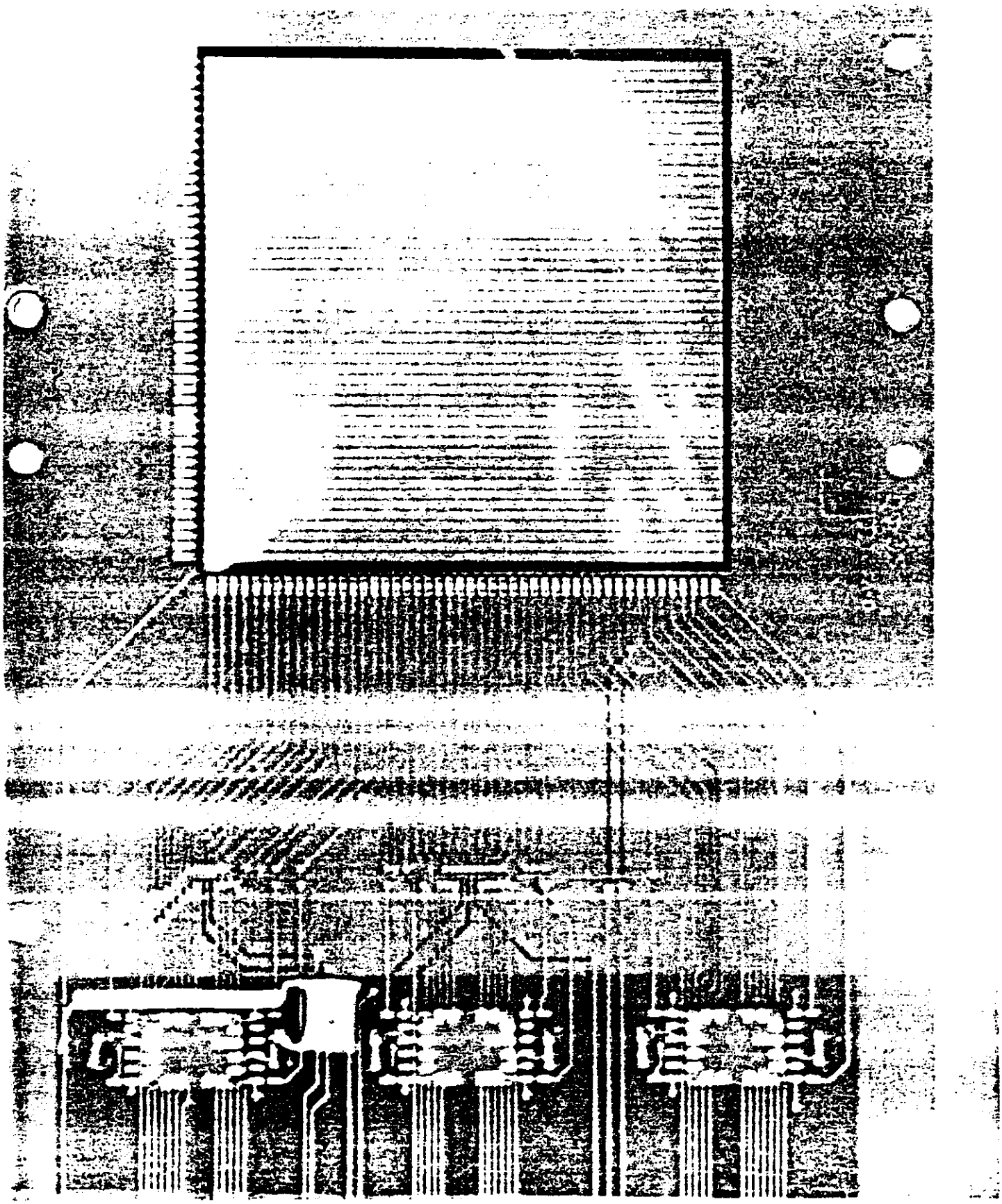
$P = 18\,mW$ per channel

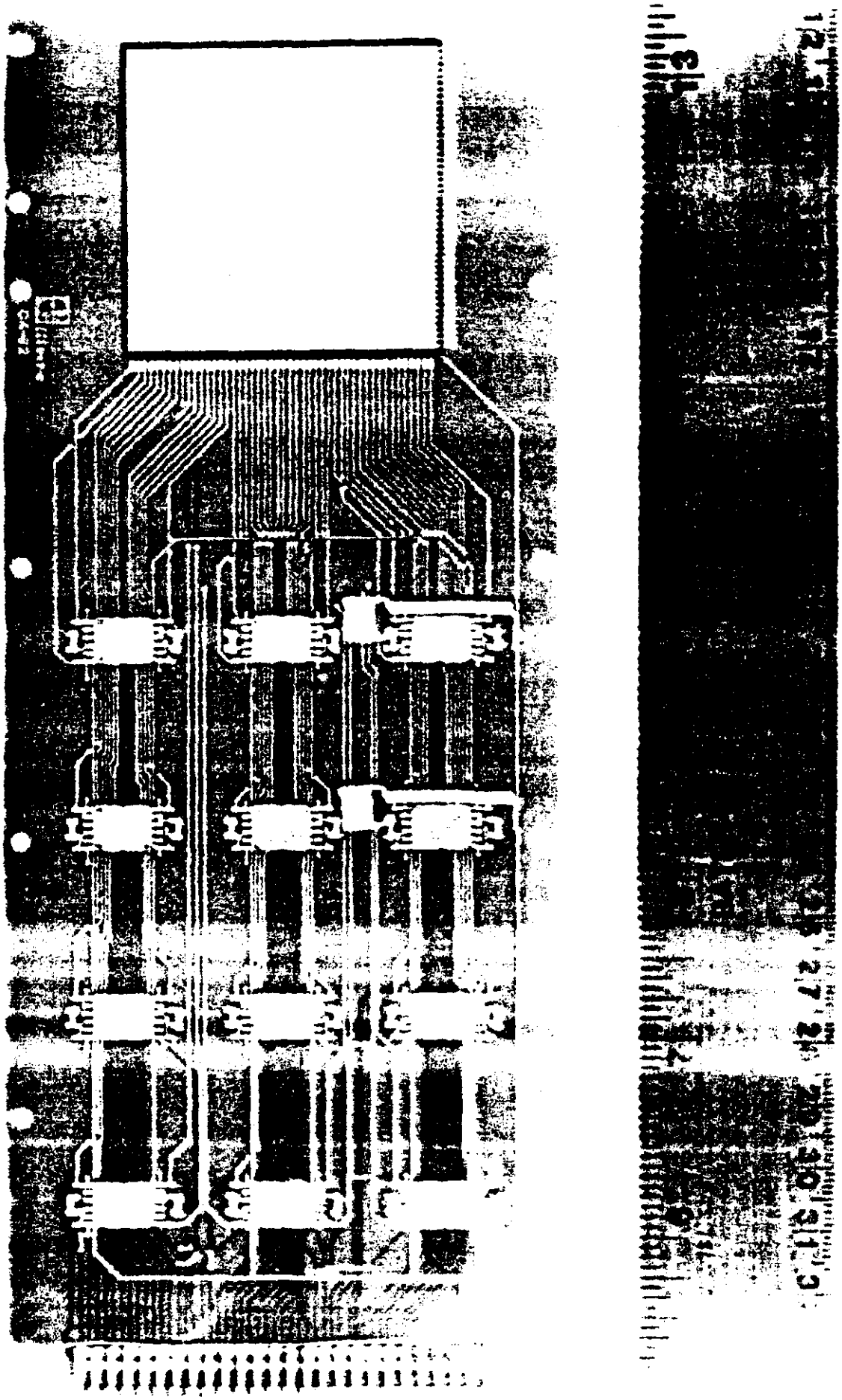
shaper Conventional — compatible with beam test digit.

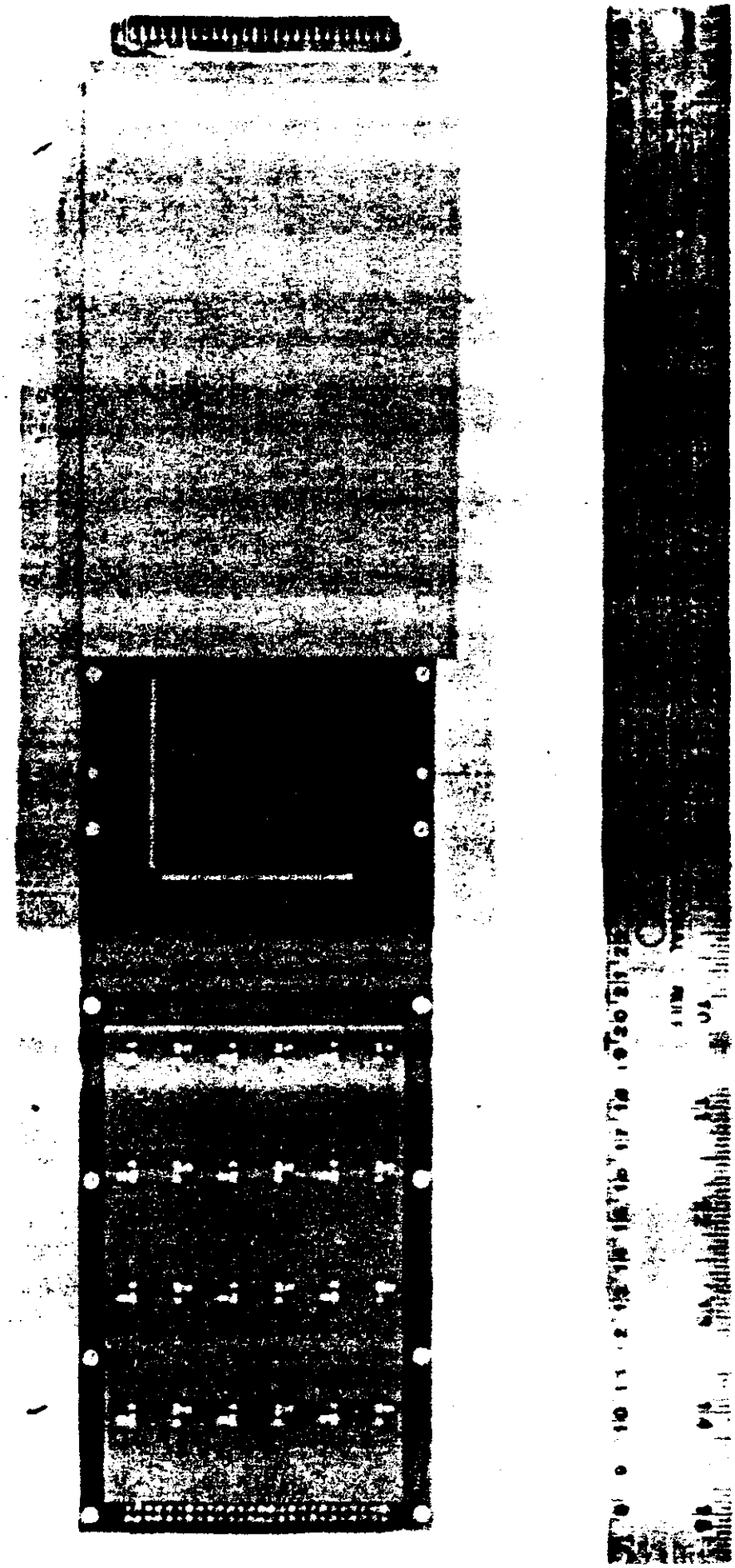
Voltage gain ≈ 40

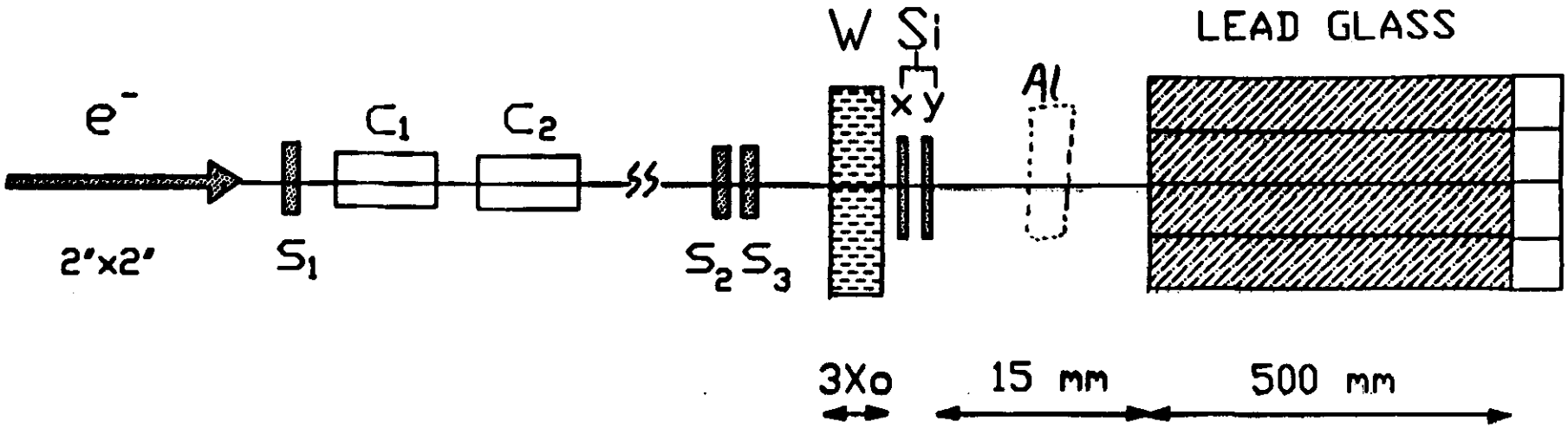
50 ns shaping time











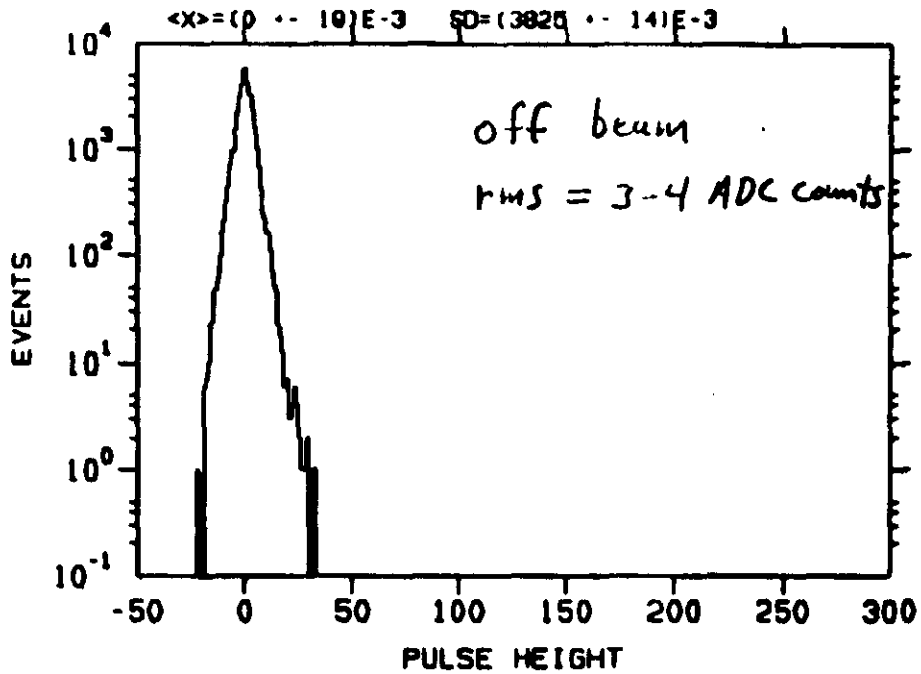
2, 4, 5 GeV electrons (~80% purity)

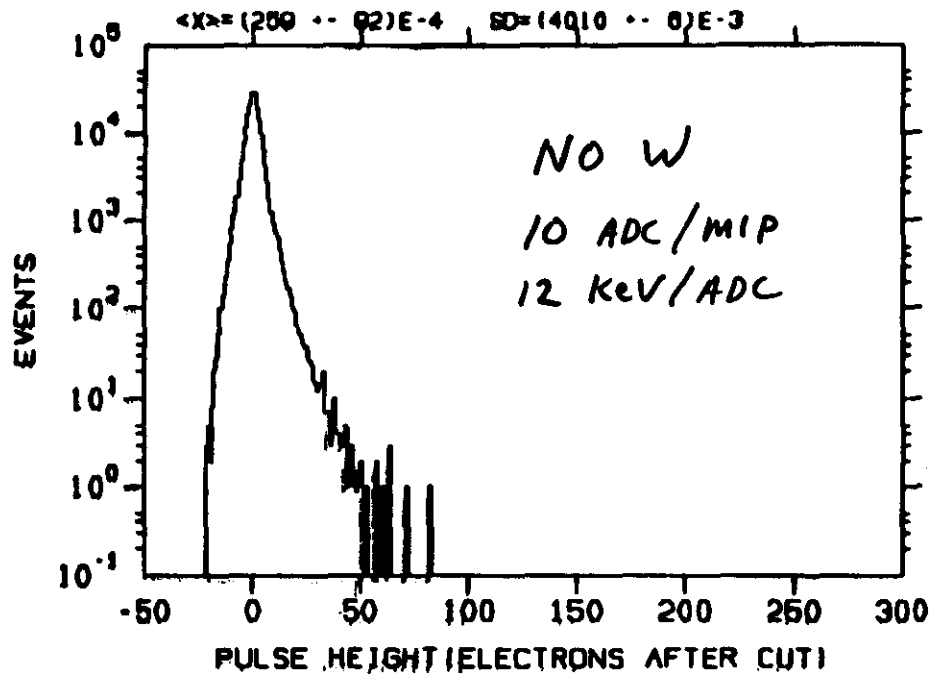
0, 1, 3 X_0 W

3×4 array 6.4cm×6.4cm×50cm Lead Glass (BNL E865)

Primary Goals

- transverse shower shape → multi-γ pattern recognition
- energy resolution compensation





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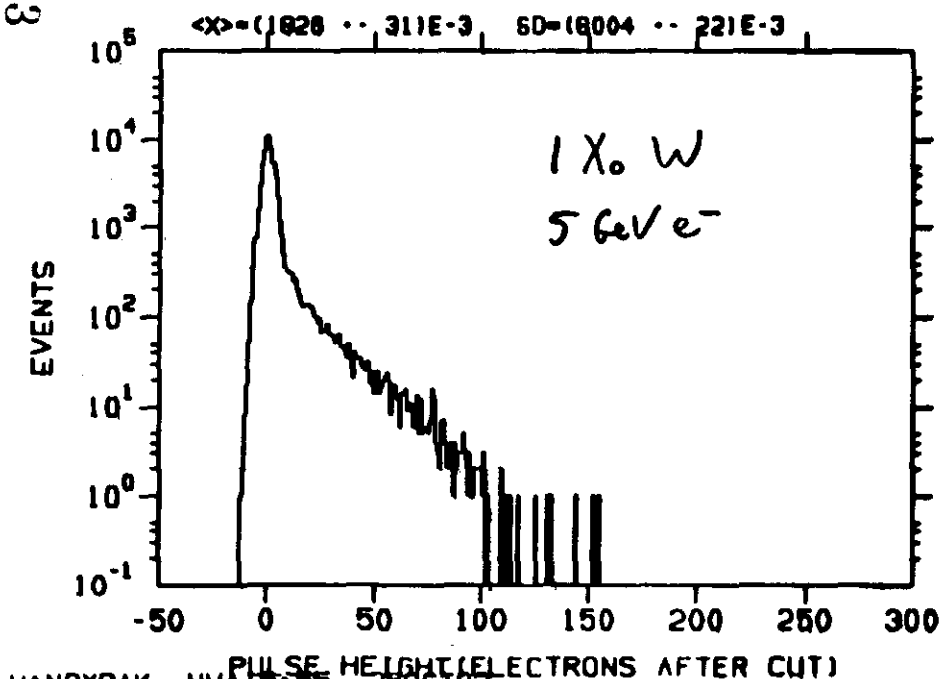
COR DATA OF X STRIPS(1 X0 W:5 GEV)



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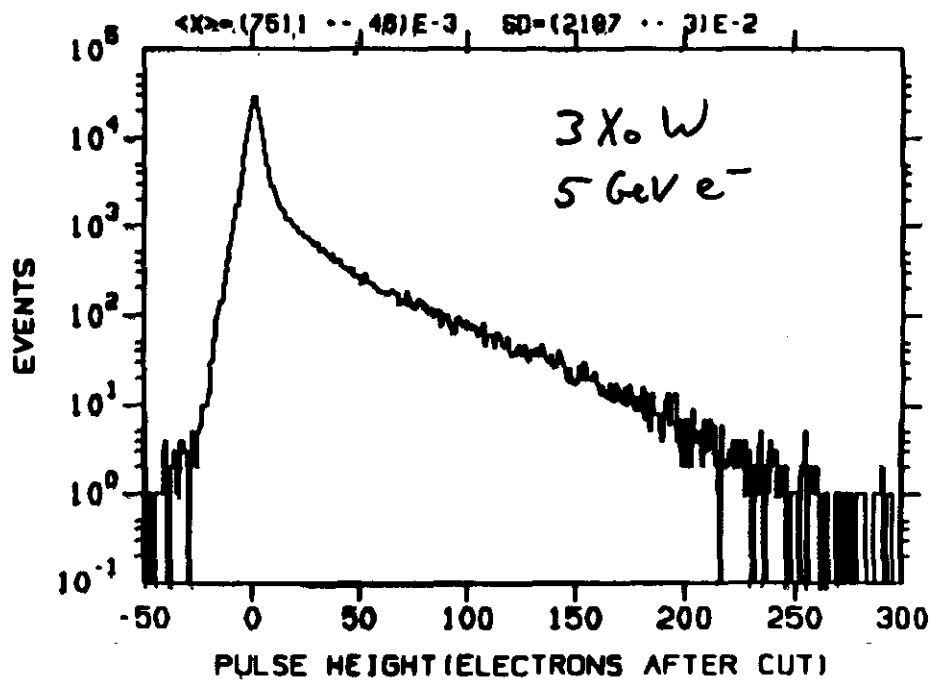
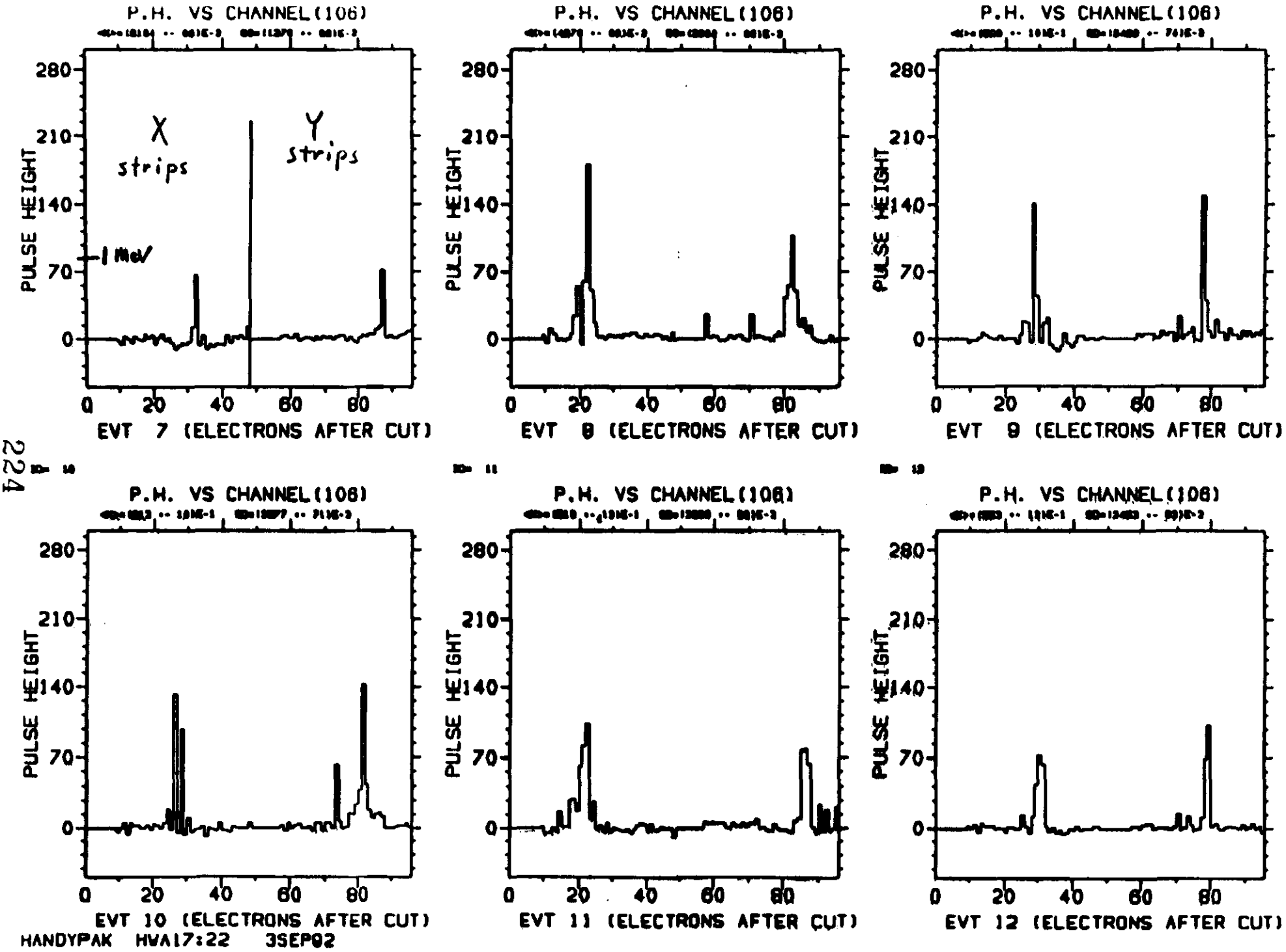
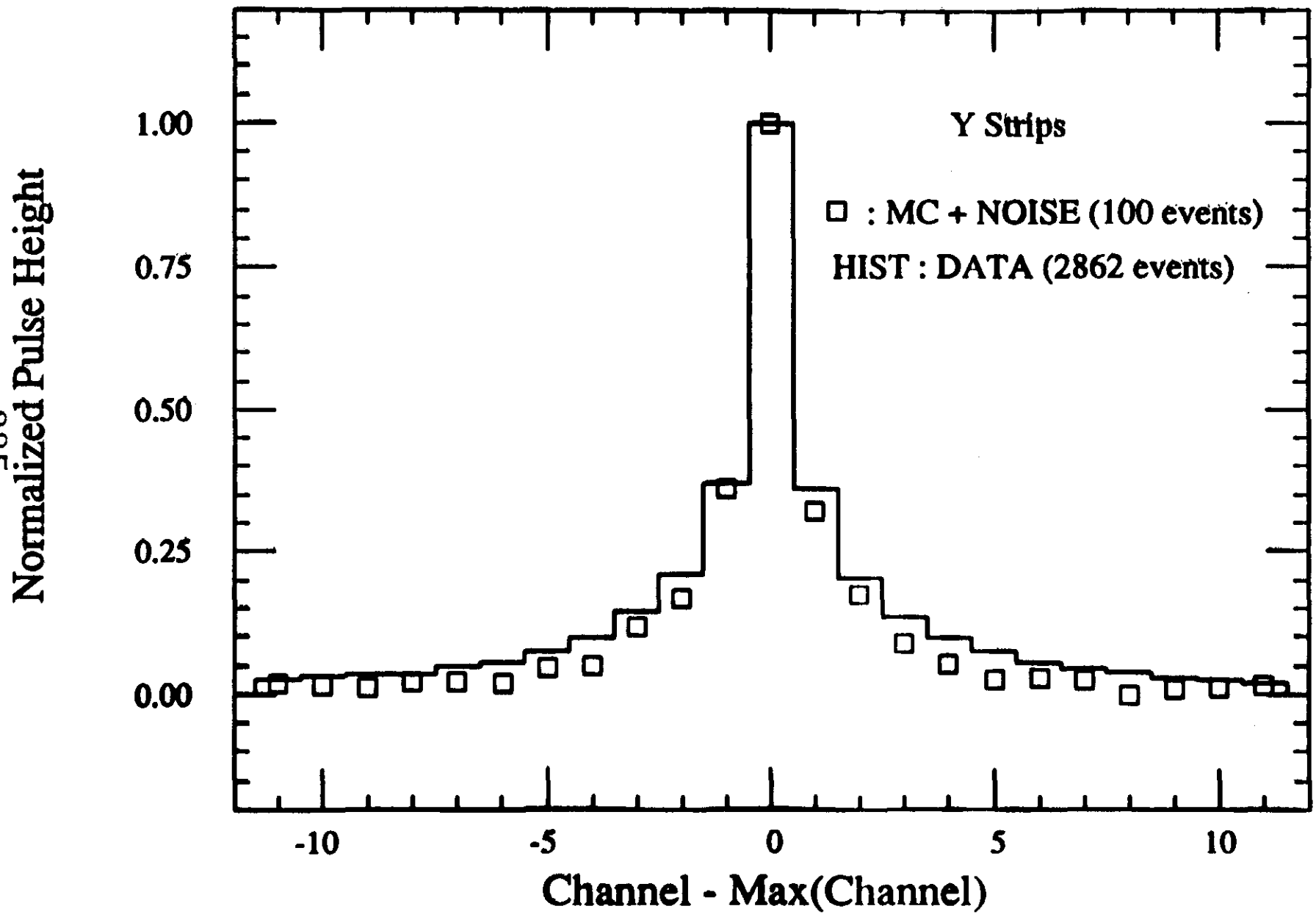
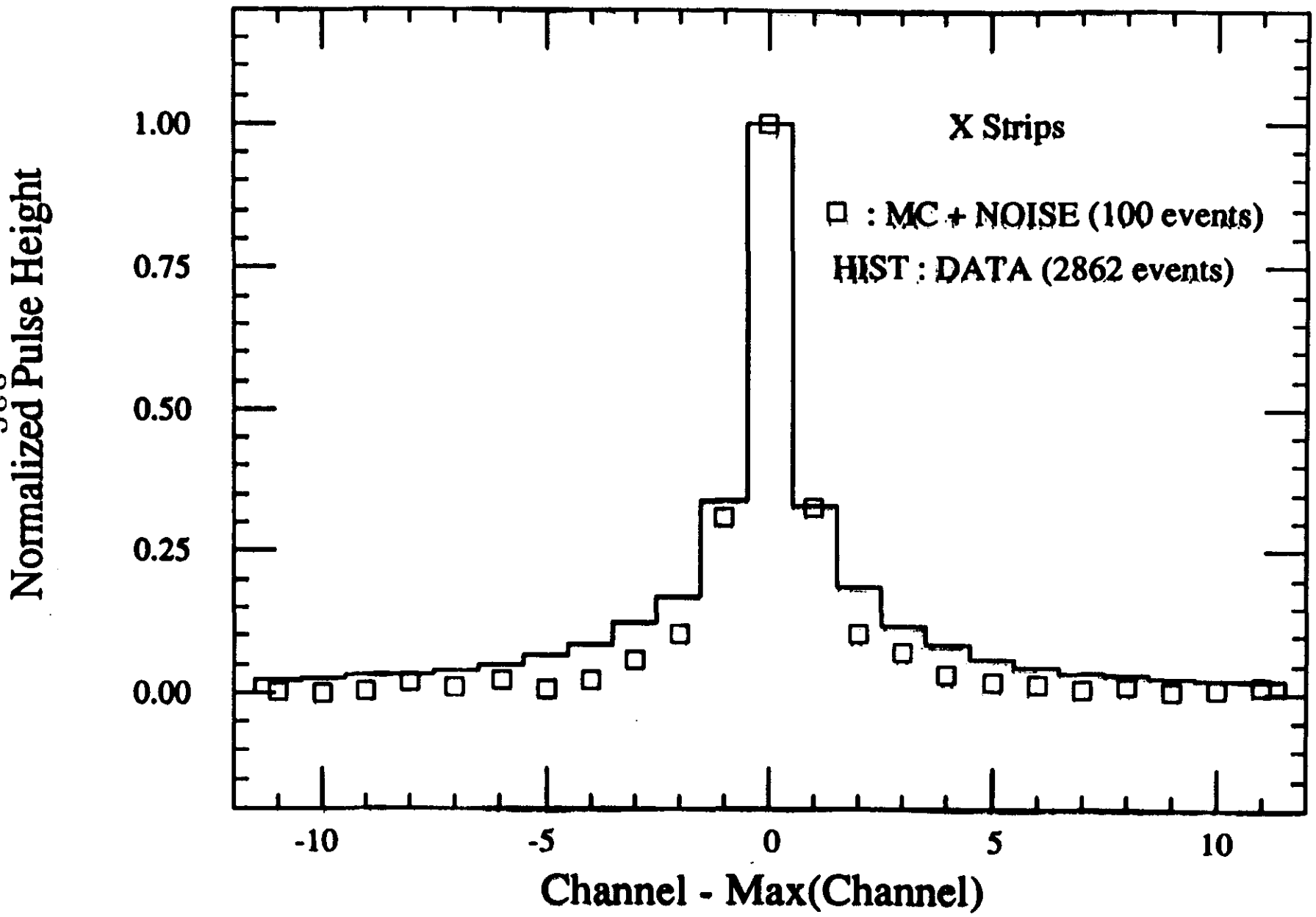
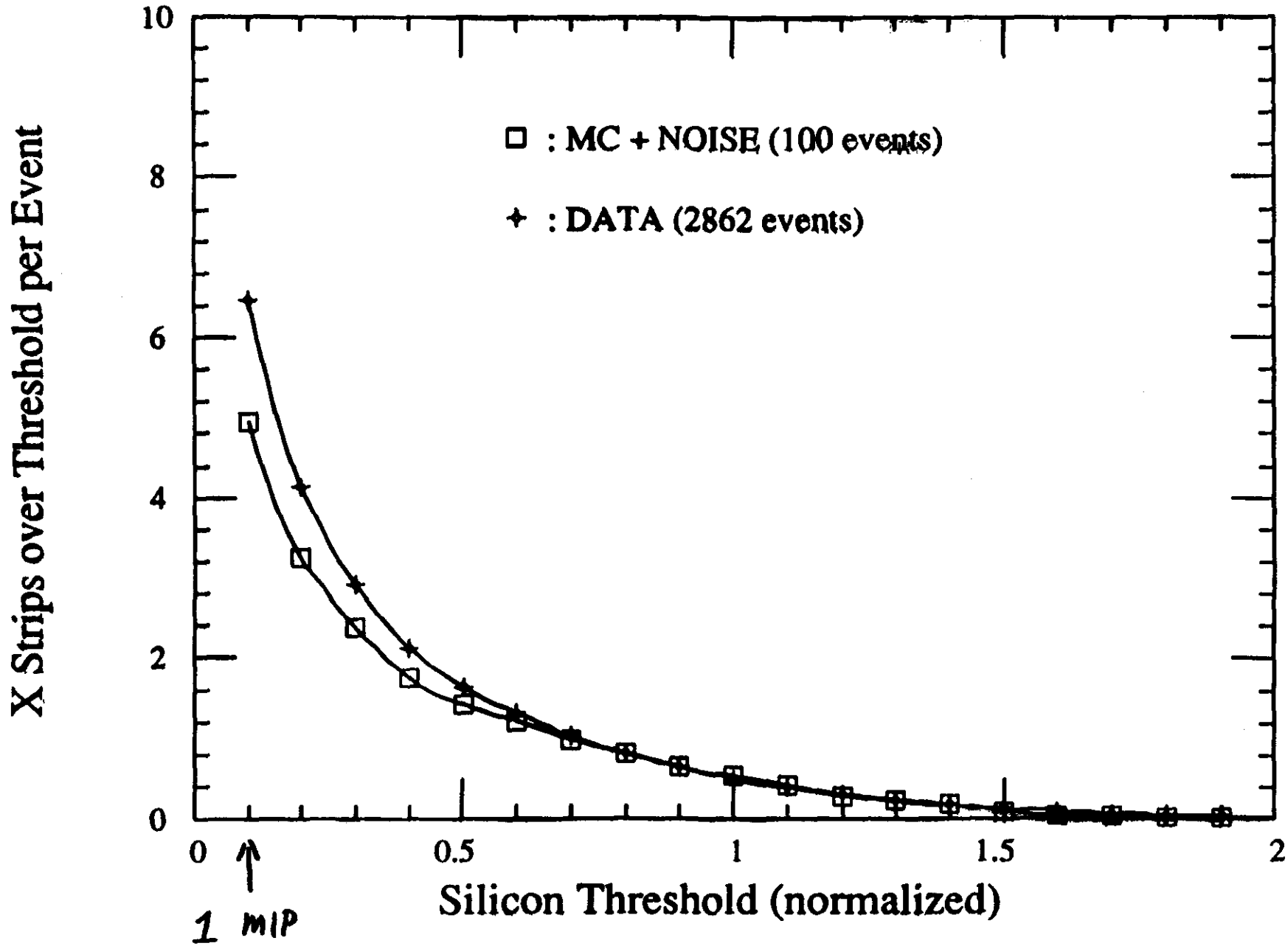


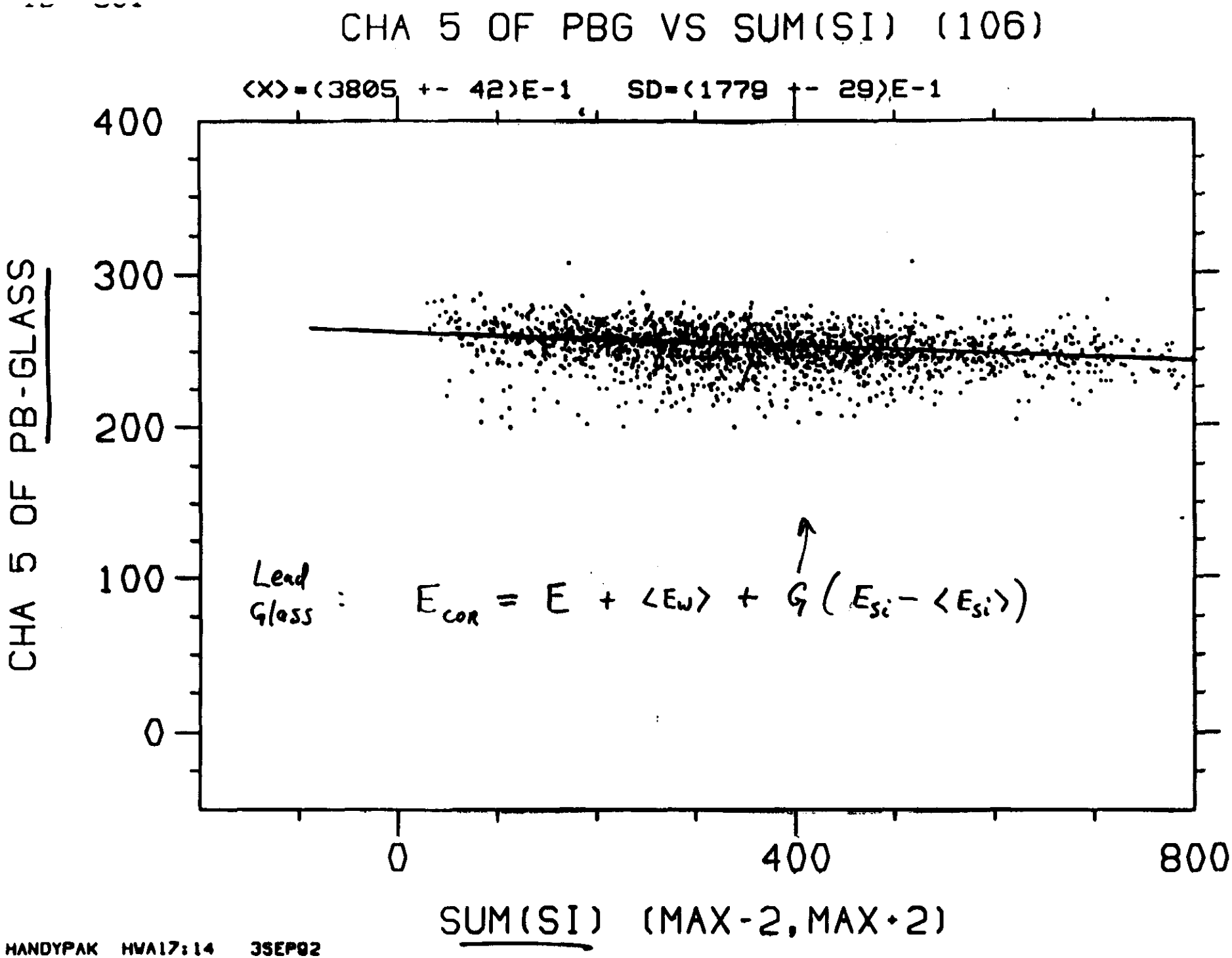
HANDYPAK HWA16:55 26OCT92

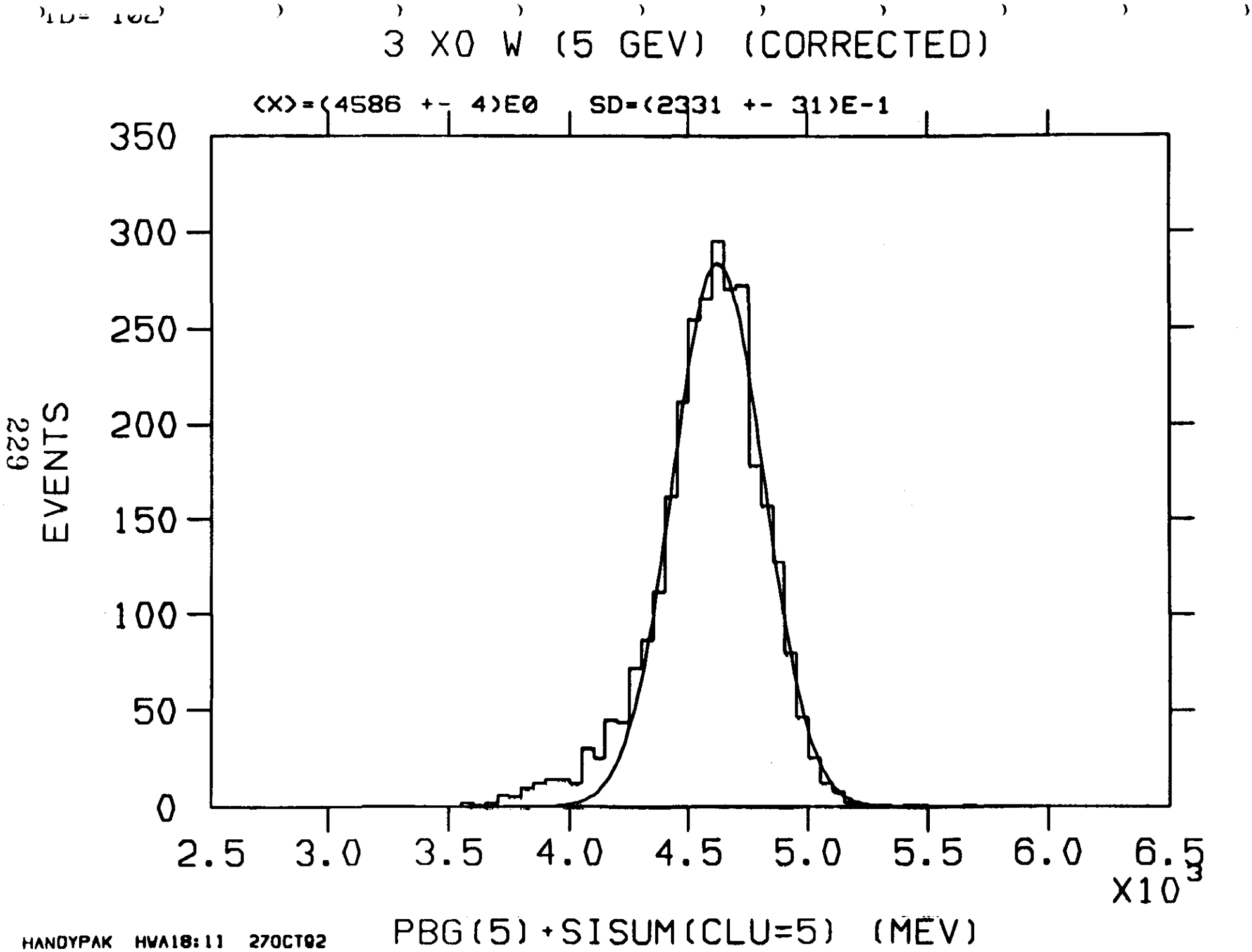

P.H. VS CHANNEL(106)
PULSE HEIGHT
X strips
Y strips
1 MeV
EVT 7 (ELECTRONS AFTER CUT)
EVT 8 (ELECTRONS AFTER CUT)
EVT 9 (ELECTRONS AFTER CUT)
EVT 10 (ELECTRONS AFTER CUT)
EVT 11 (ELECTRONS AFTER CUT)
EVT 12 (ELECTRONS AFTER CUT)
HANDYPAK HWA17:22 3SEP92


Y Strips
: MC + NOISE (100 events)
HIST : DATA (2862 events)
Normalized Pulse Height
1.00
0.75
0.50
0.25
0.00
-10
-5
0
5
10
Channel - Max(Channel)


X Strips
□ : MC + NOISE (100 events)
HIST : DATA (2862 events)
Normalized Pulse Height
1.00
0.75
0.50
0.25
0.00
-10
-5
0
5
10
Channel - Max(Channel)


X Strips over Threshold per Event
10
8
6
4
2
0
0
0.5
1
1.5
2
Silicon Threshold (normalized)
1 MIP
: MC + NOISE (100 events)
: DATA (2862 events)


CHA 5 OF PBG VS SUM(SI) (106)
<X>=(3805 +- 42)E-1 SD=(1779 +- 29)E-1
400
300
200
100
0
CHA 5 OF PB-GLASS
Lead Glass : $E_{cor} = E + \langle E_W \rangle + G(E_{Si} - \langle E_{Si} \rangle)$
0
400
800
SUM(SI) (MAX-2,MAX+2)
HANDYPAK HWA17:14 3SEP82


ID= 102
3 X0 W (5 GEV) (CORRECTED)
<X>=(4586 +- 4)E0 SD=(2331 +- 31)E-1
EVENTS
350
300
250
200
150
100
50
0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
X10^3
PBG(5)+SISUM(CLU=5) (MEV)
HANDYPAK HWA18:11 27OCT92

Lead Glass resolution

One-block lead glass resolution for 5 GeV electrons for data and EGS simulation. Errors are 10% relative.

	σ_E/E (%) – Data	σ_E/E (%) – EGS
No Preradiator	3.2	–
3 X_0 W – no correction	5.0	4.9
3 X_0 W – corrected	4.2	4.0

± 0.1 %

- Correction possible
- Good agreement with EGS

→ Extrapolate to higher energy via EGS :

EGS simulation results for resolutions with and without preradiator correction for a full lead glass array for 5 and 50 GeV electrons. Errors are 10% relative.

	σ_E/E (%), 5 GeV	σ_E/E (%), 50 GeV
3 X_0 W – no correction	3.6	1.1
3 X_0 W – corrected	2.6	0.8

Conclusions

Silicon "strip" preradiator motivated by SSC requirements to separate $\pi^0/\gamma/e$.

→ In particular, $H^0 \to \gamma\gamma$ with GEM

- Simulations show good γ efficiency & π^0 rejection
- Is it needed or not ??

  Background rejection (γj, jj uncertain)
  vs.
  e.m. resolution (compensation)

Silicon preradiator "prototype"

- 1 mm x 48 mm strips (X and Y)
- SSC-like preamp and mounting

→ Tested with ≤ 5 GeV e^- at BNL:

- transverse shower profile
  → multi-γ pattern recognition

  ~ EGS
- energy resolution compensation using preradiator demonstrated with Lead Glass (one block) agrees with EGS

gem

γeμ

Presentation by:

Yu. Efremenko

Muon Trigger based on the Tail Catcher.

Yu. Efremenko
ORNL

4 Feb. 1993, GEM council meeting.

Muons triggering in Tail Catcher

Is it possible ?

Do we really need it?

* cost
* speed
* reliability
* simplicity

Current Tail Catcher Design

Thickness - 4λ

Eta coverage +/- 1.28

Four layers of 3mm tiles

Tower size - 0.16*0.16

640 readout channels

Total weight - 1240 T

Total volume of scintillators - 4 m^3

Cost - 26 M$

Tail Catcher functions:

* improvement of jet energy resolution

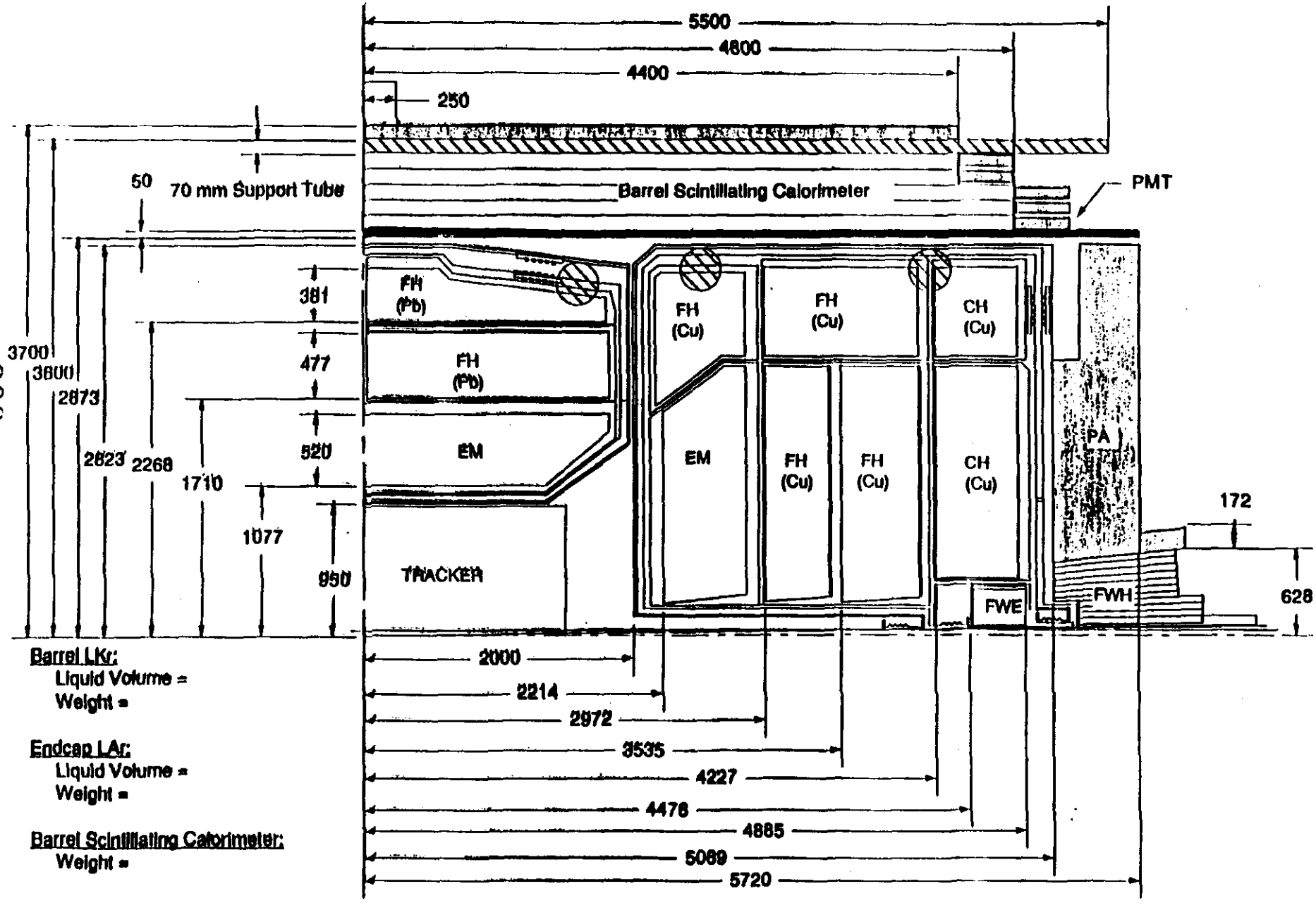
* correction for muons catastrophic energy loss

* usefull for missing Et measurements

* passive shielding of muon system

* muon triggering ?

GEM Calorimeter

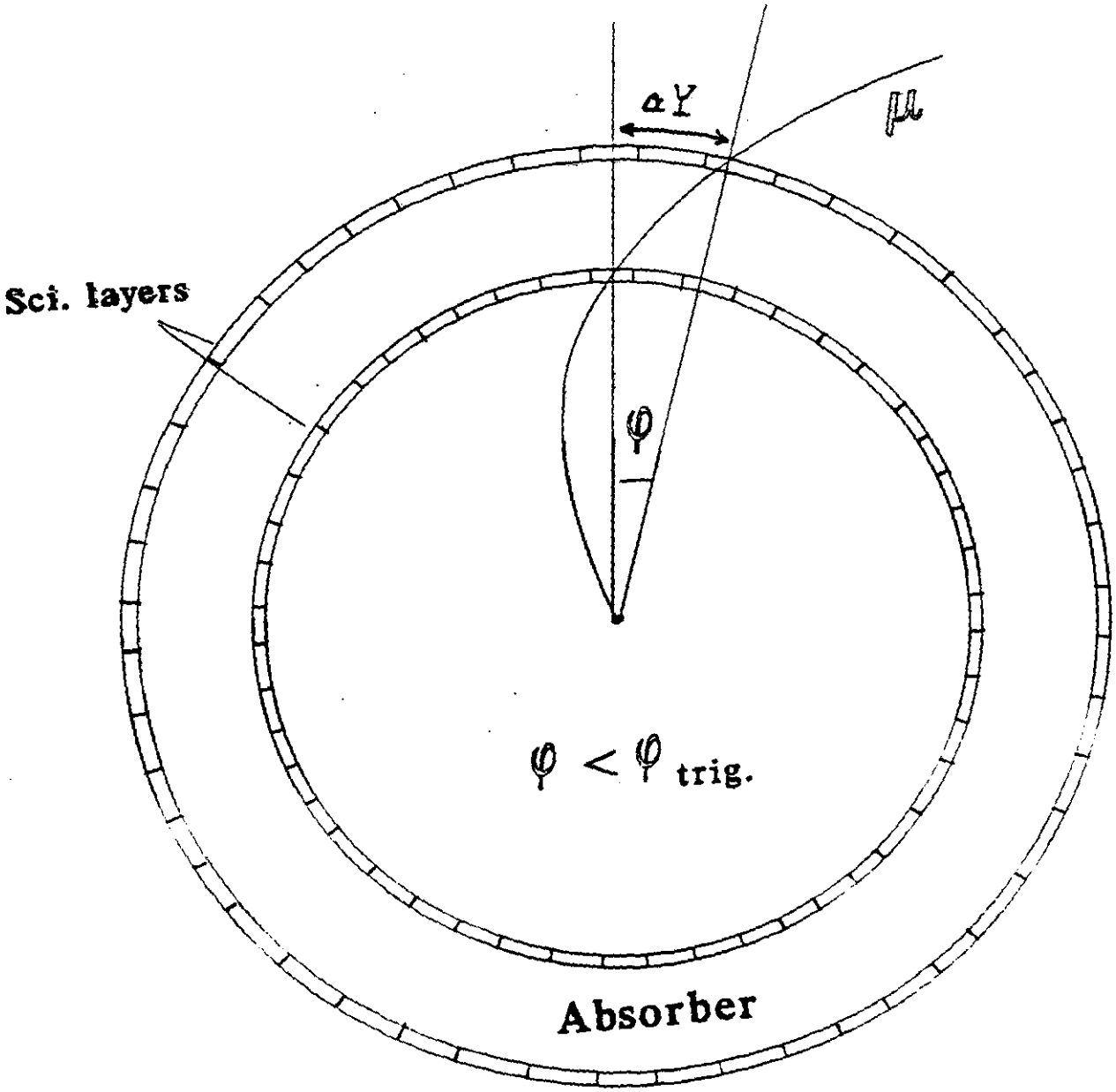


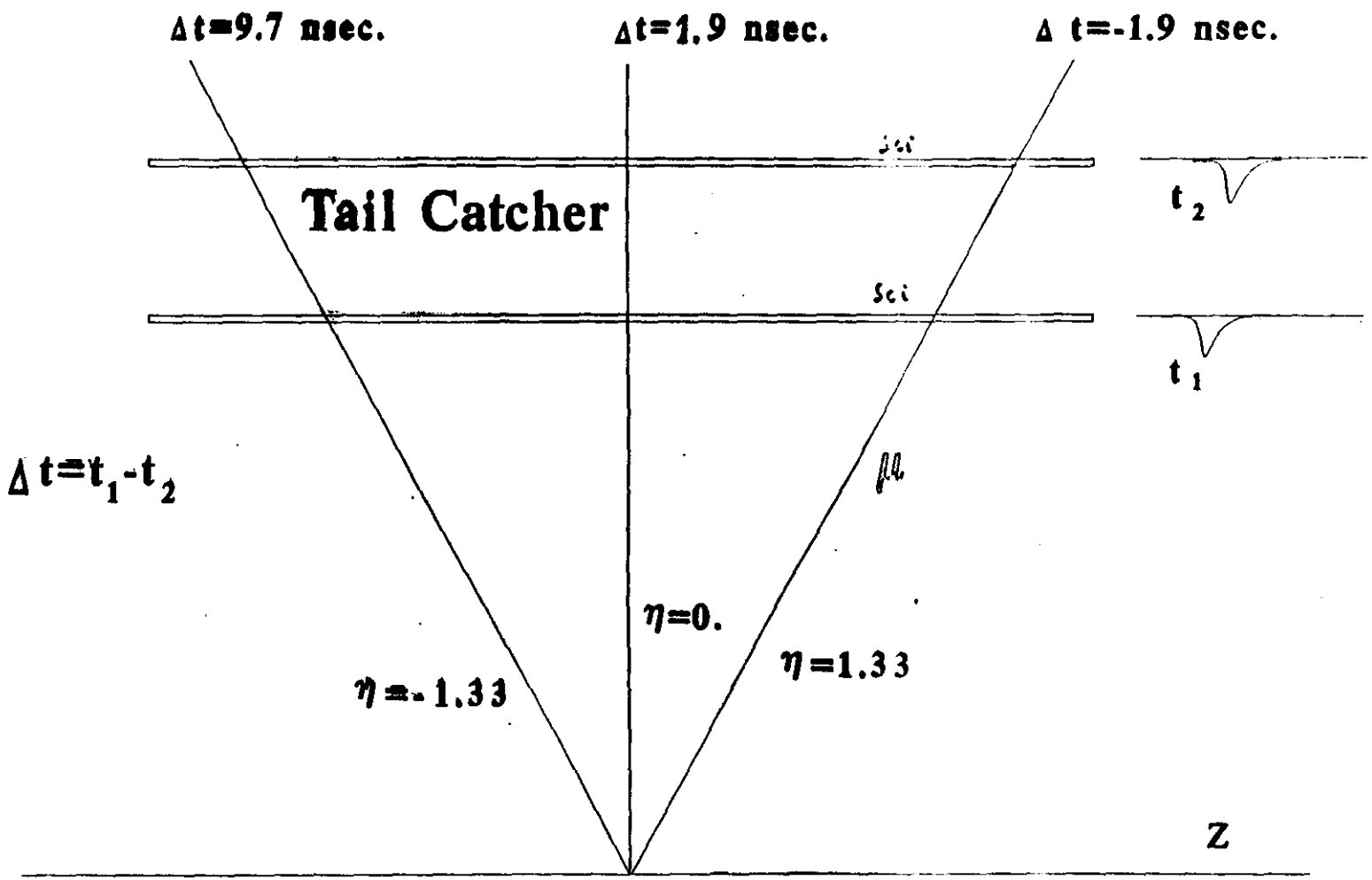
Barrel LKr:
Liquid Volume =
Weight =

Endcap LAr:
Liquid Volume =
Weight =

Barrel Scintillating Calorimeter:
Weight =

KBernstein Hadron Hybrid
Barrel 6.2e-1 / Endcap6.2e-1

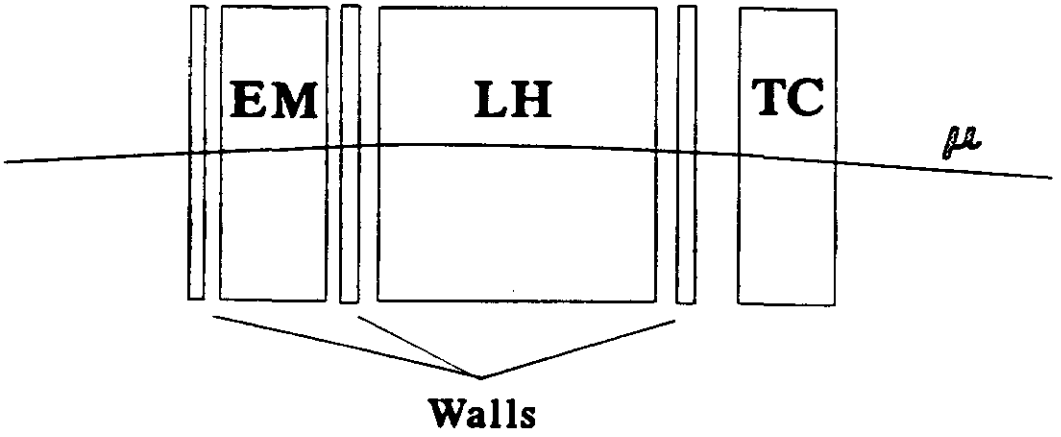

ΔY
μ
Sci. layers
φ
φ < φ trig.
Absorber

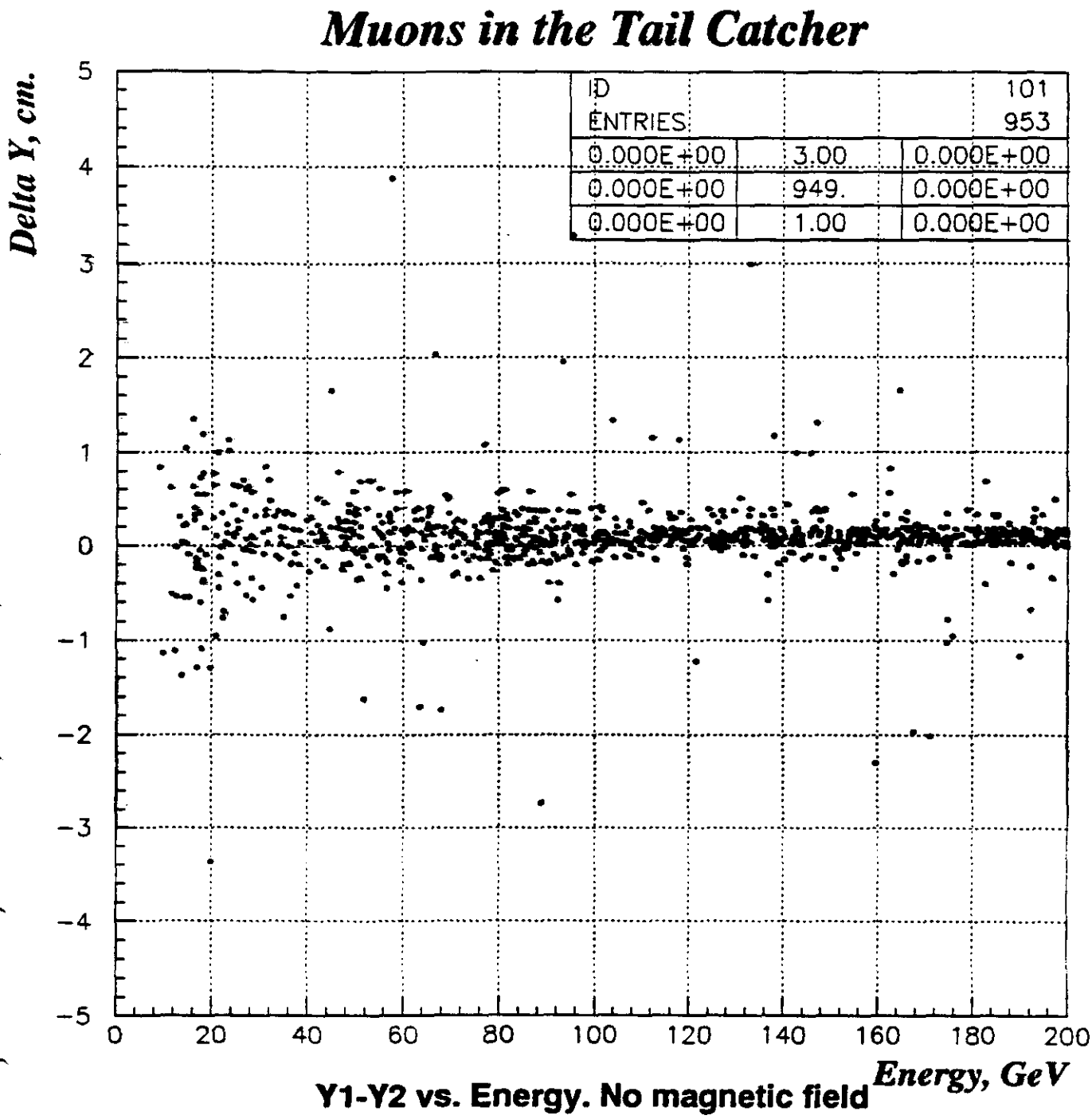


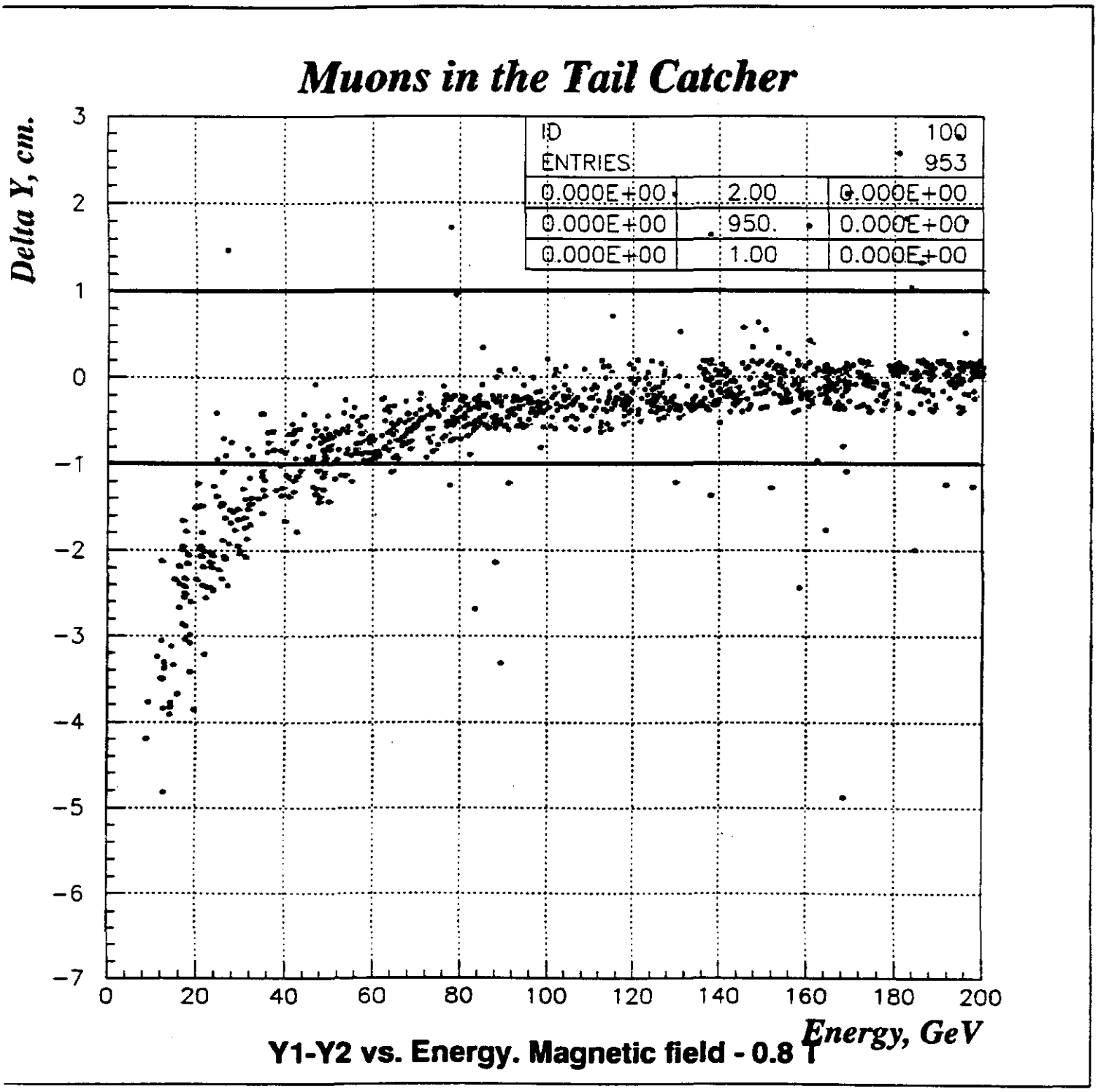
Trigger is coincidence signals from both strips.

Gate is~15 nsec.

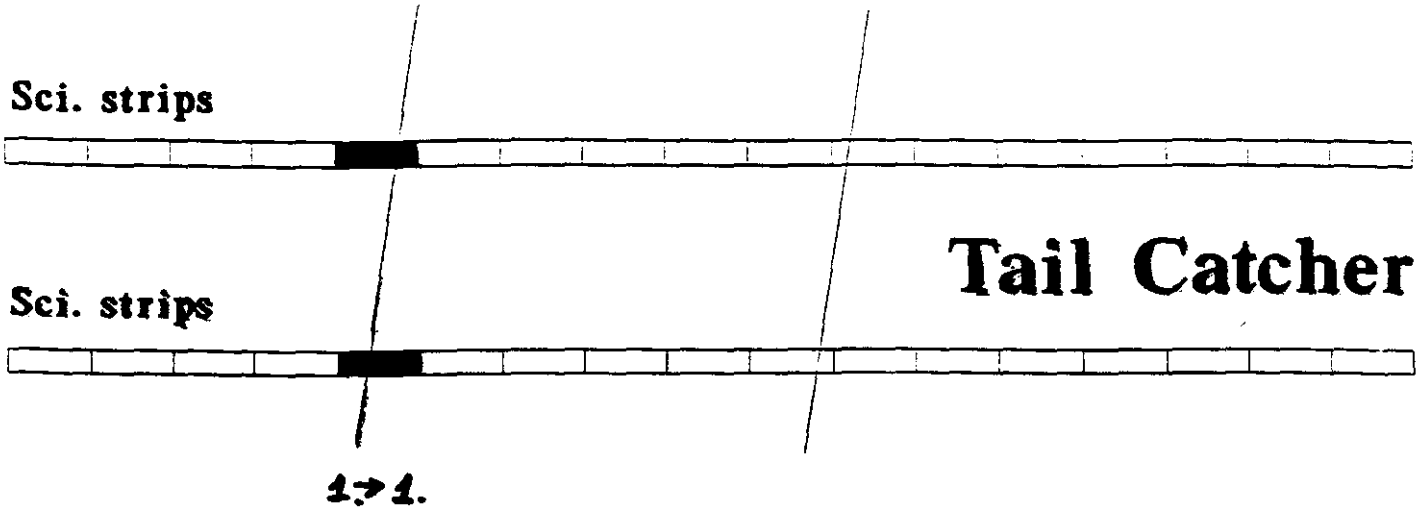
Geant simulation.




Muons in the Tail Catcher
ID 101
ENTRIES 953
0.000E+00 3.00 0.000E+00
0.000E+00 949. 0.000E+00
0.000E+00 1.00 0.000E+00
Delta Y, cm.
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
20
40
60
80
100
120
140
160
180
200
Energy, GeV
Y1-Y2 vs. Energy. No magnetic field


Muons in the Tail Catcher
Delta Y, cm.
ID 100
ENTRIES 953
0.000E+00 2.00 0.000E+00
0.000E+00 950. 0.000E+00
0.000E+00 1.00 0.000E+00
3
2
1
0
−1
−2
−3
−4
−5
−6
−7
0
20
40
60
80
100
120
140
160
180
200
Energy, GeV
Y1-Y2 vs. Energy. Magnetic field - 0.8 T

V1. Nonshifted strips.

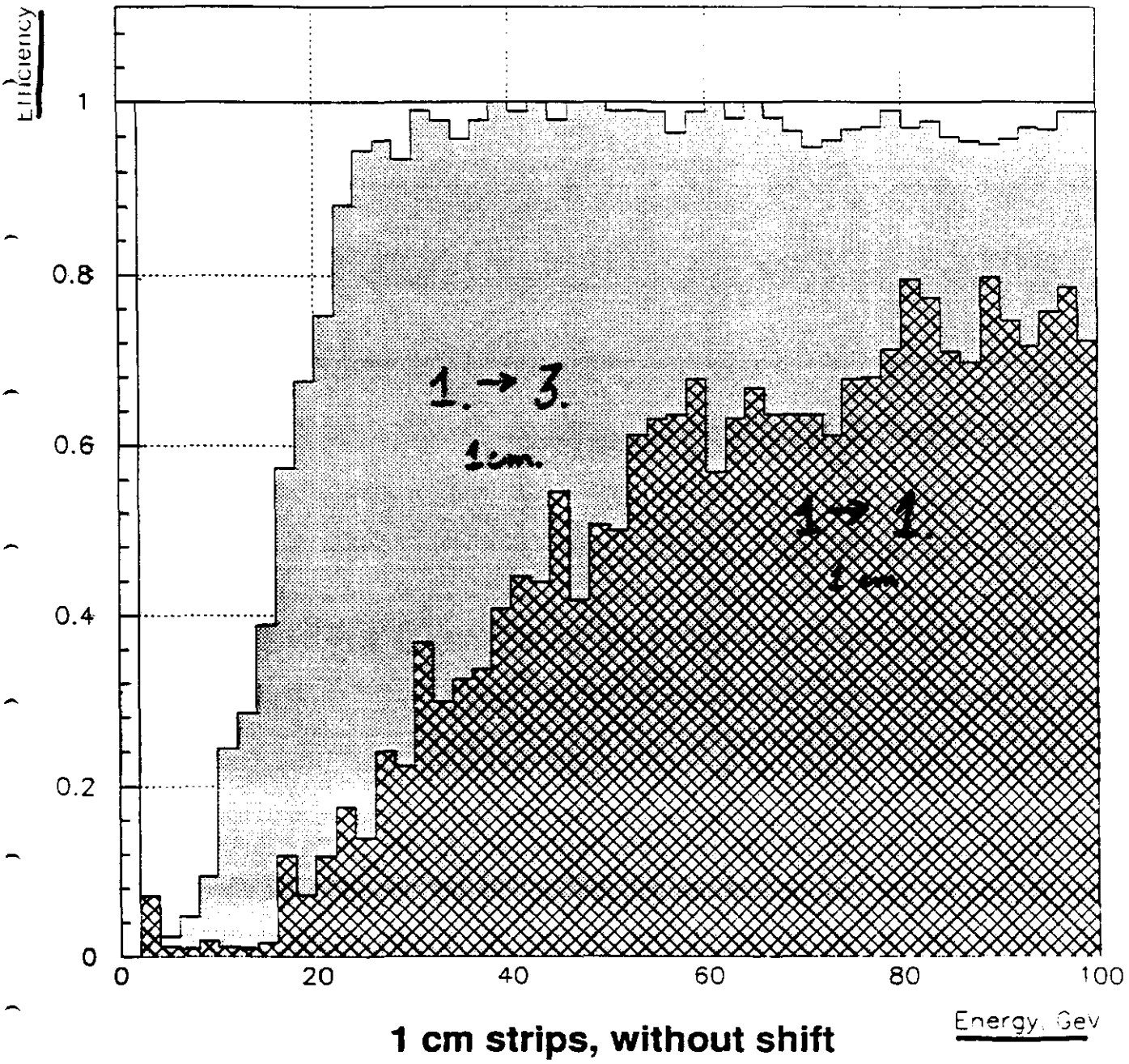


[redacted] [redacted]

[redacted] [redacted]

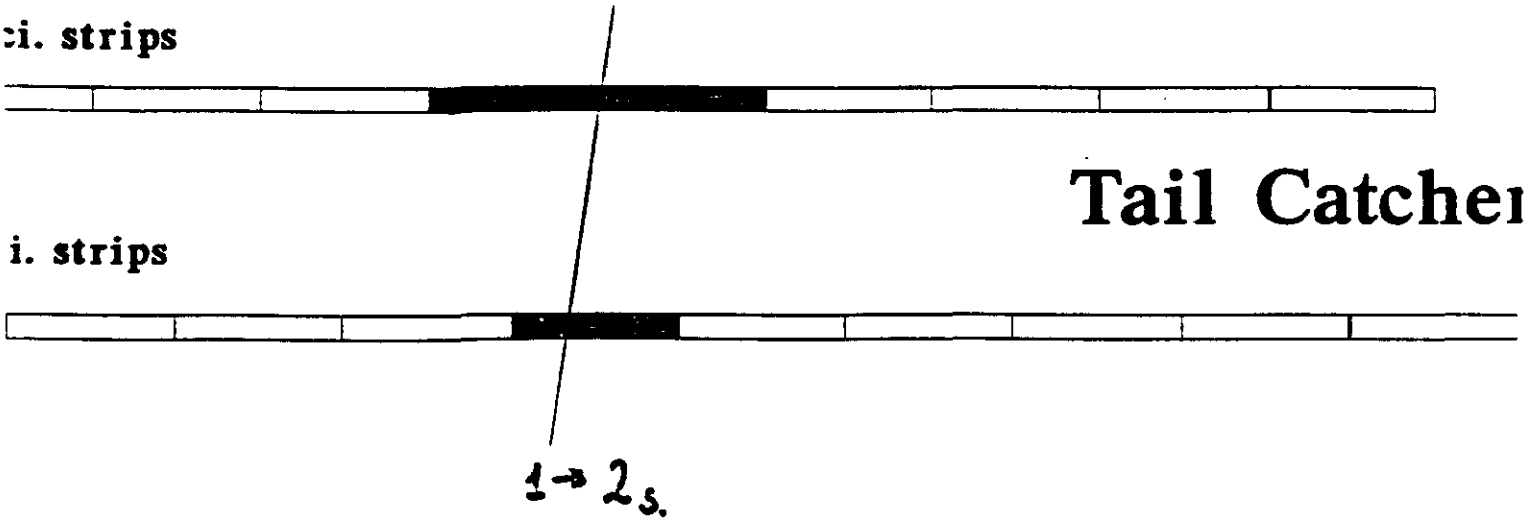
1→3

Muons in the Tail Catcher

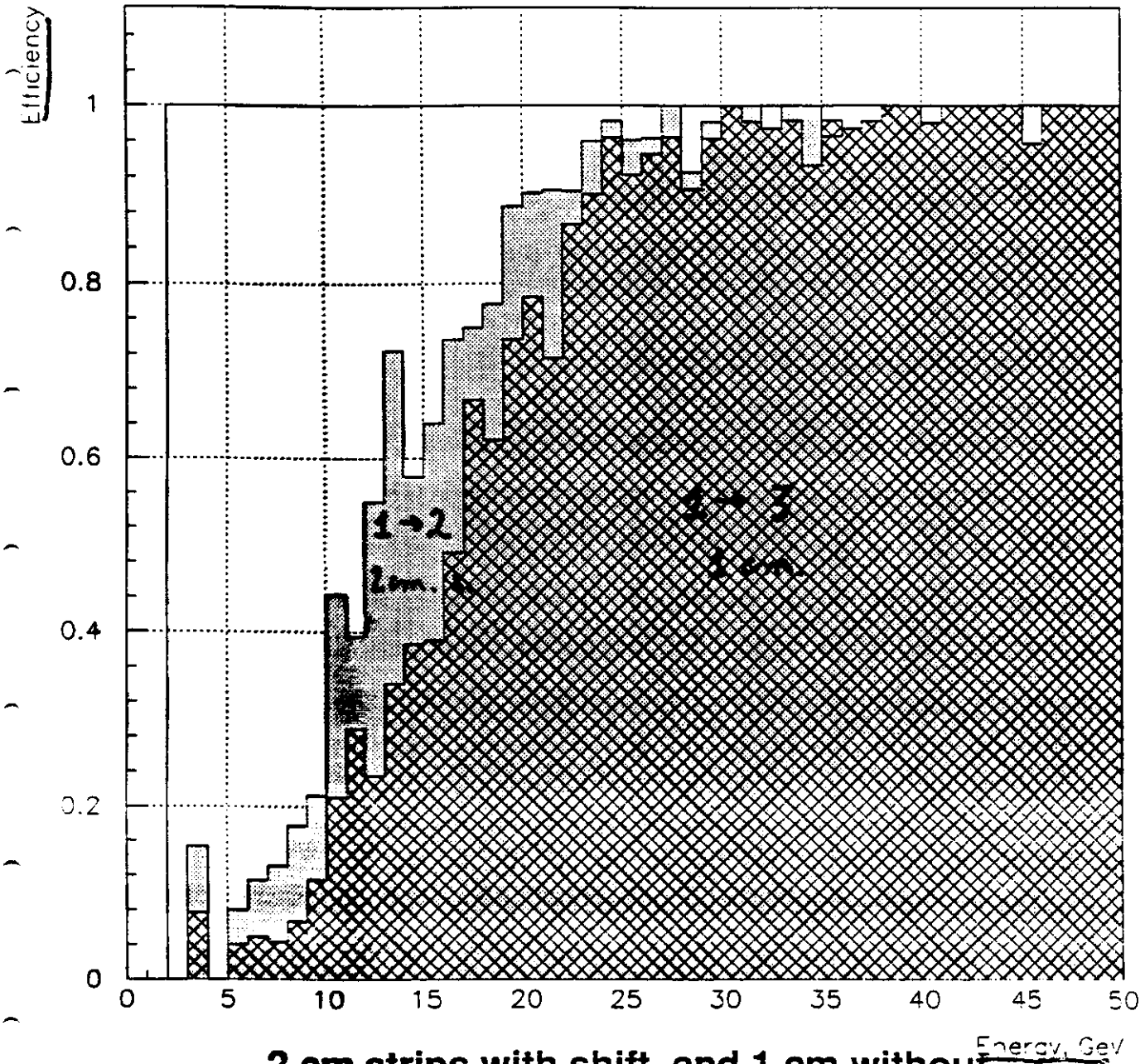


1 cm strips, without shift

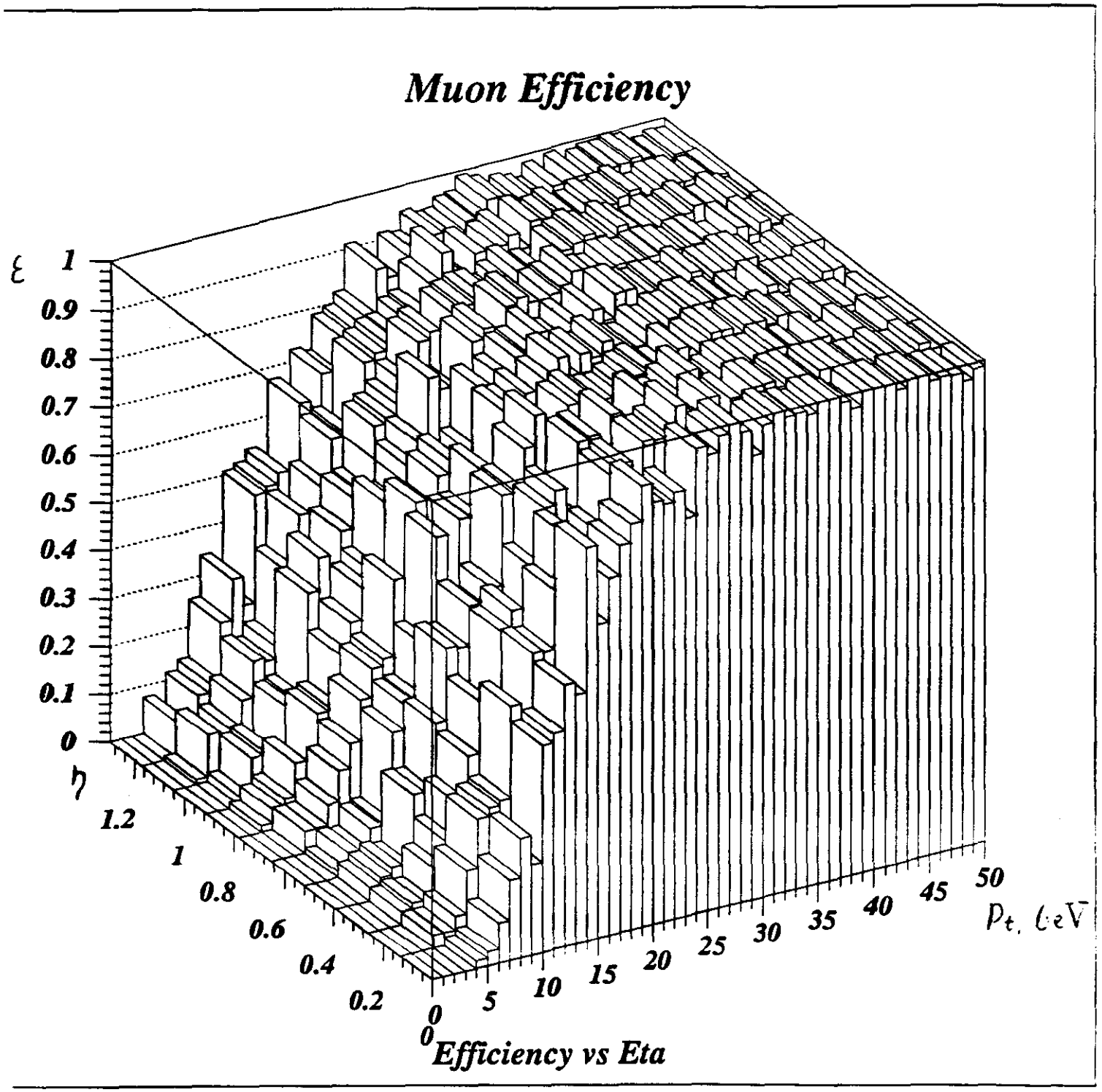
V2. Shifted strips.



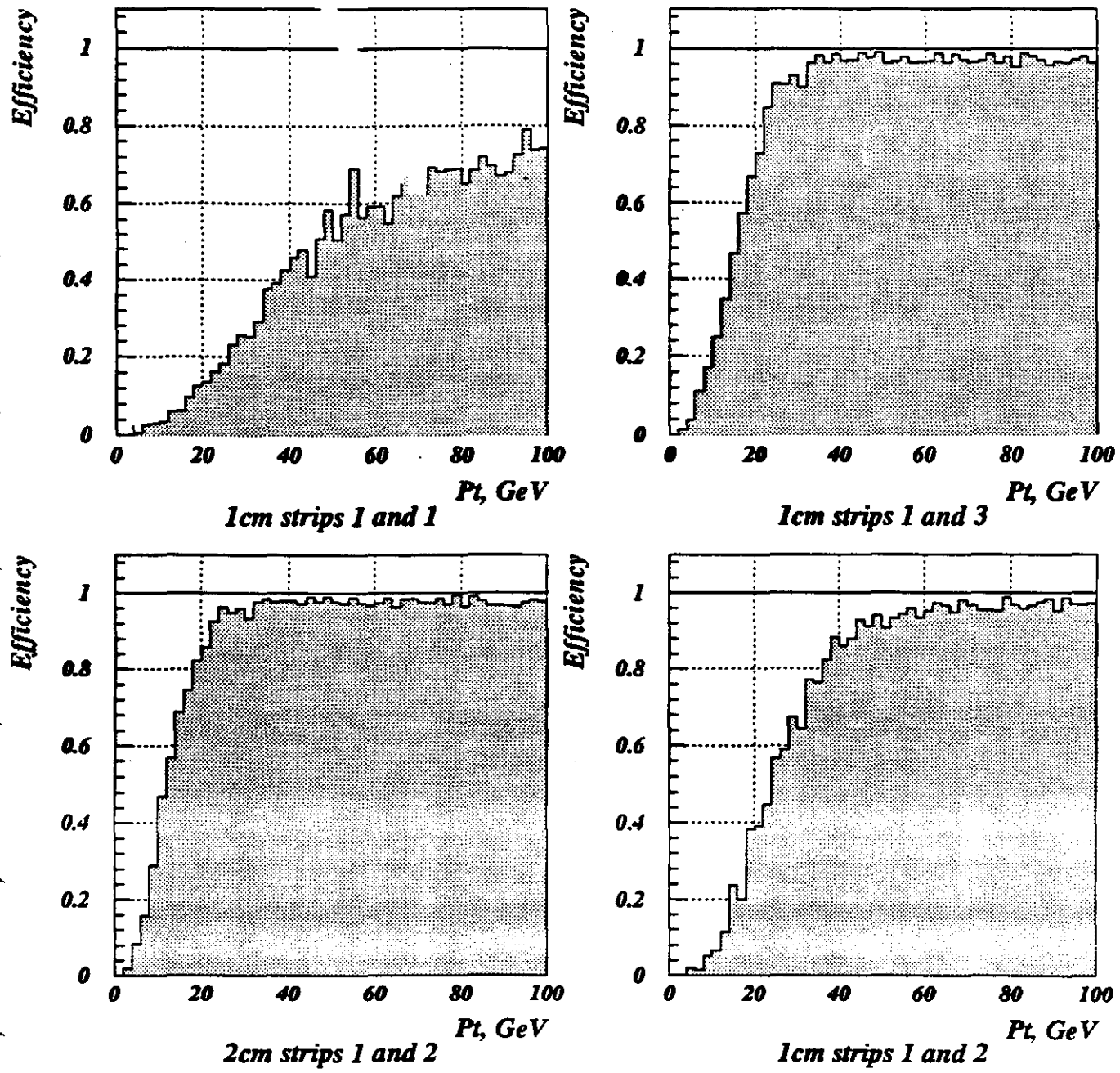
Muons in the Tail Catcher

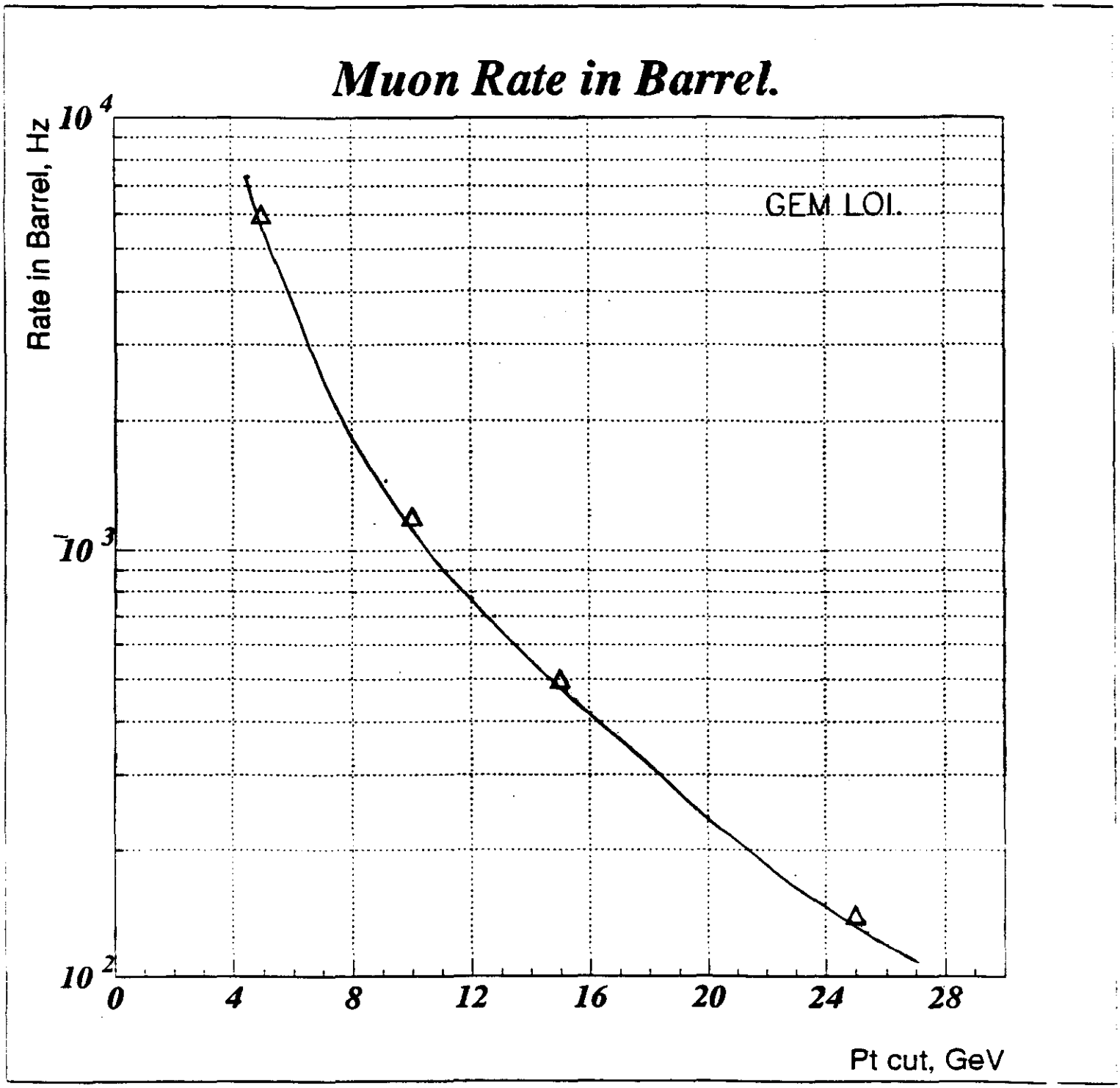


2 cm strips with shift, and 1 cm without


Muon Efficiency
ε
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
η
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
p_t, GeV
Efficiency vs Eta

Muon Efficiency.




Muon Rate in Barrel.
Rate in Barrel, Hz
10 4
10 3
10 2
GEM LOI.
0
4
8
12
16
20
24
28
Pt cut, GeV

For 1 - 2 trigger scheme

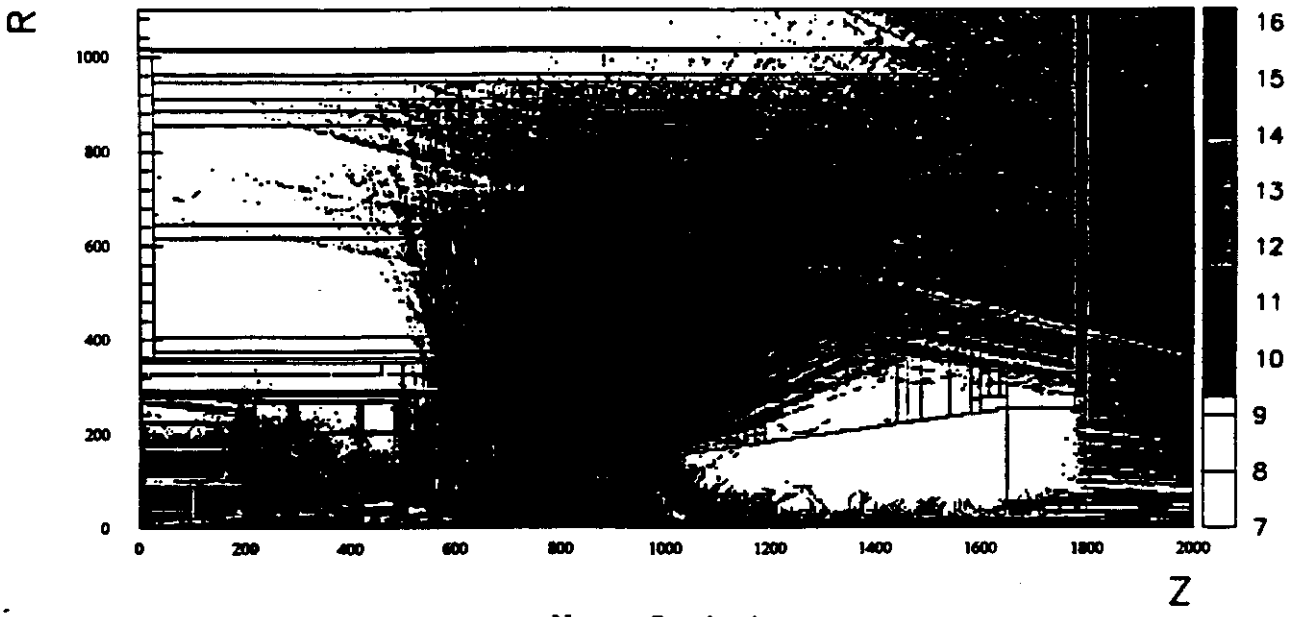
Muon rates in the Barrel

1 cm. strips - 570 Hz

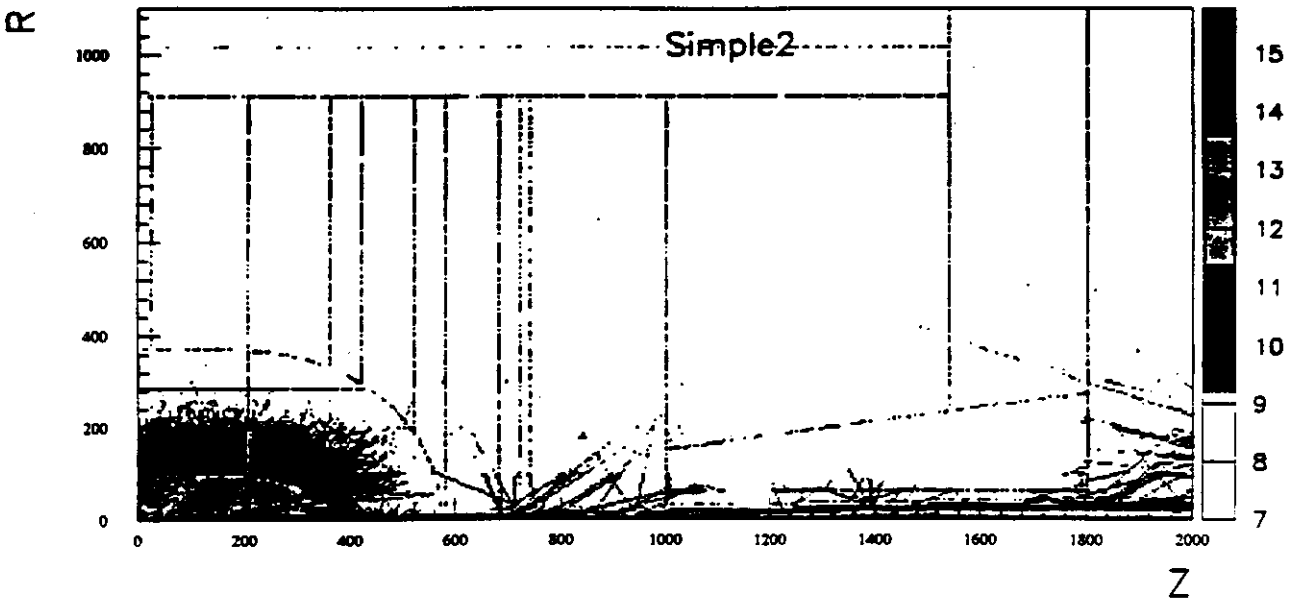
2 cm. strips - 2100 Hz

4 cm. strips - 5500 Hz

93/01/03 11.41



Neutron flux density



NEUTRON FLUX DENSITY

Neutron background

1. Tail Catcher is the most safe place

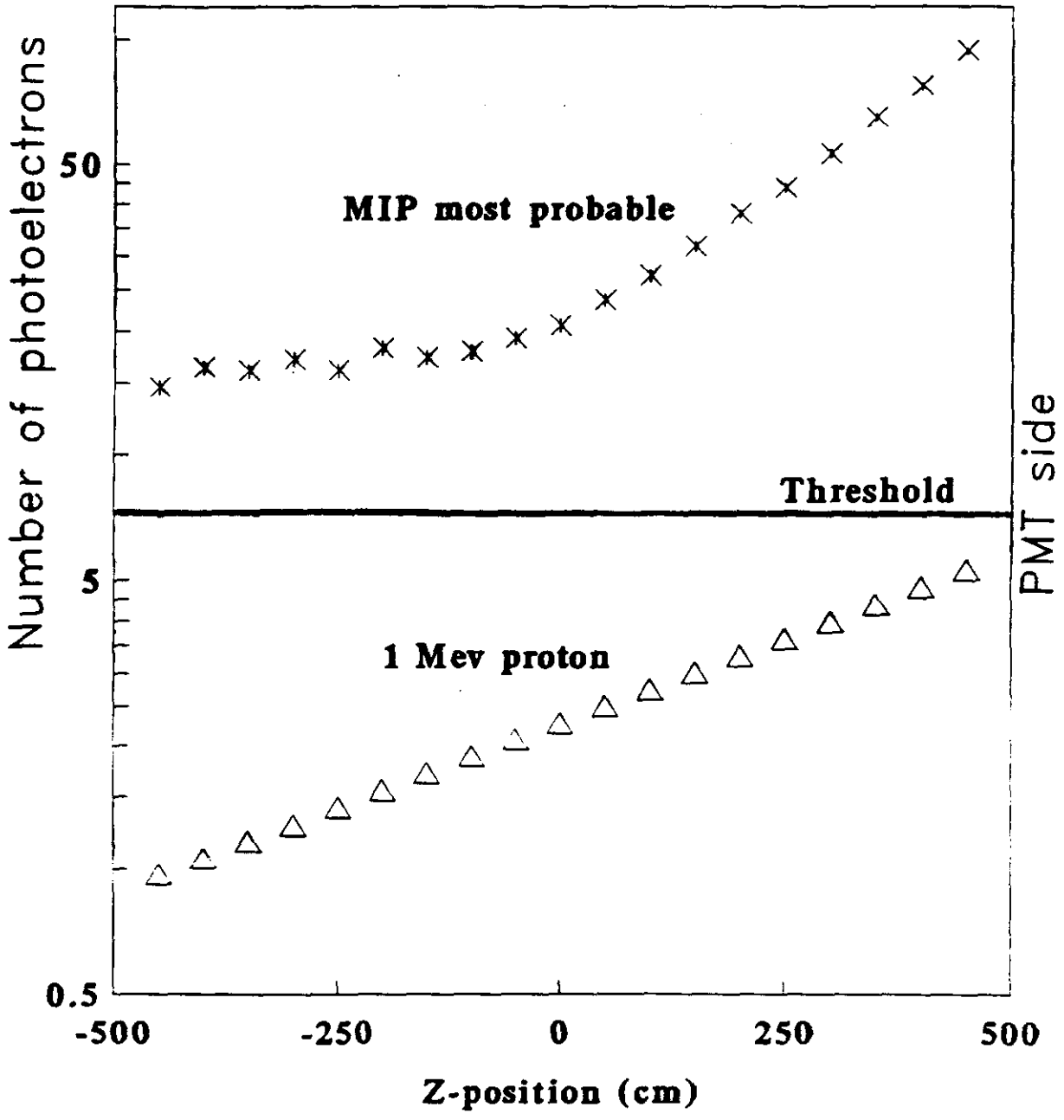
Neutron flux in the Tail Catcher is less than $10^{11}/cm^2/SSCY$

Probability for neutron to have interaction in 2 cm strip during 15 nsec is less than 0.016

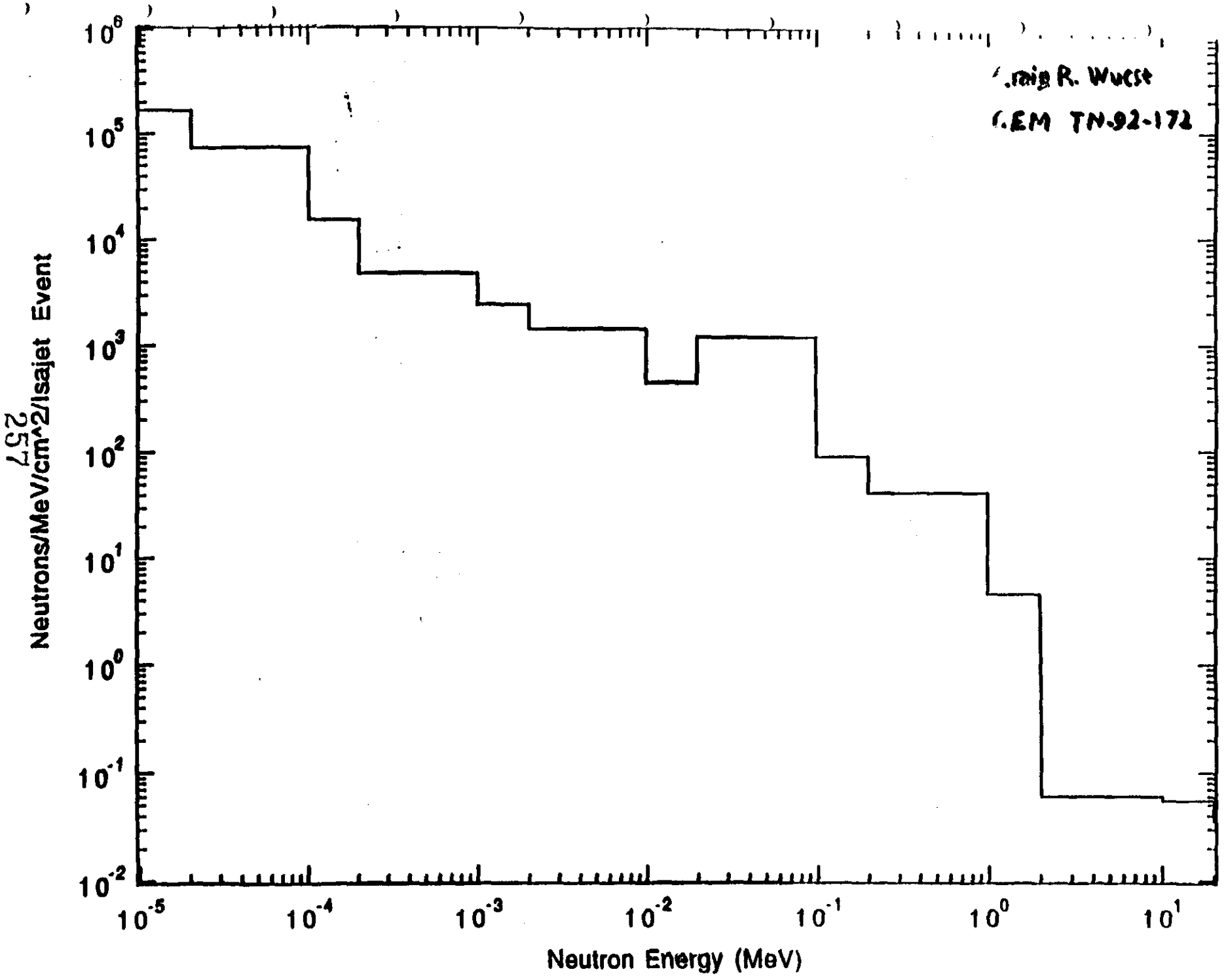
Total $5 \cdot 10^{-8}$

2. Signal from 1 MeV neutron is less than the signal from MIP

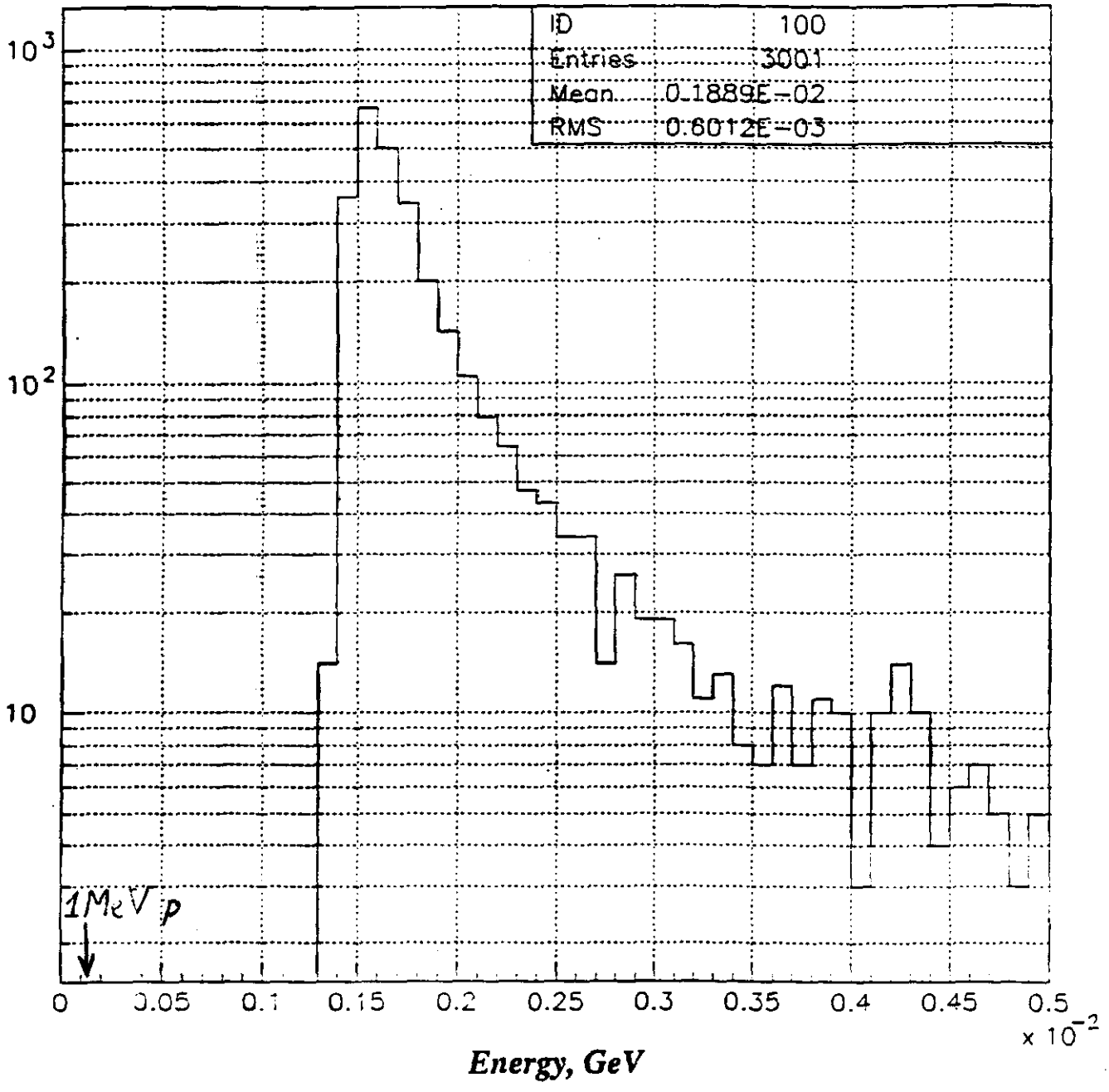
Array of scintillating fibers
1 cm thickness



E.Tarkovsky/ORNL/01-26-93


Neutrons/MeV/cm^2/Isajet Event
Neutron Energy (MeV)
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
Craig R. Wuest
CEM TN-92-172

50.0 GeV Muons in the 9 mm scintillator.

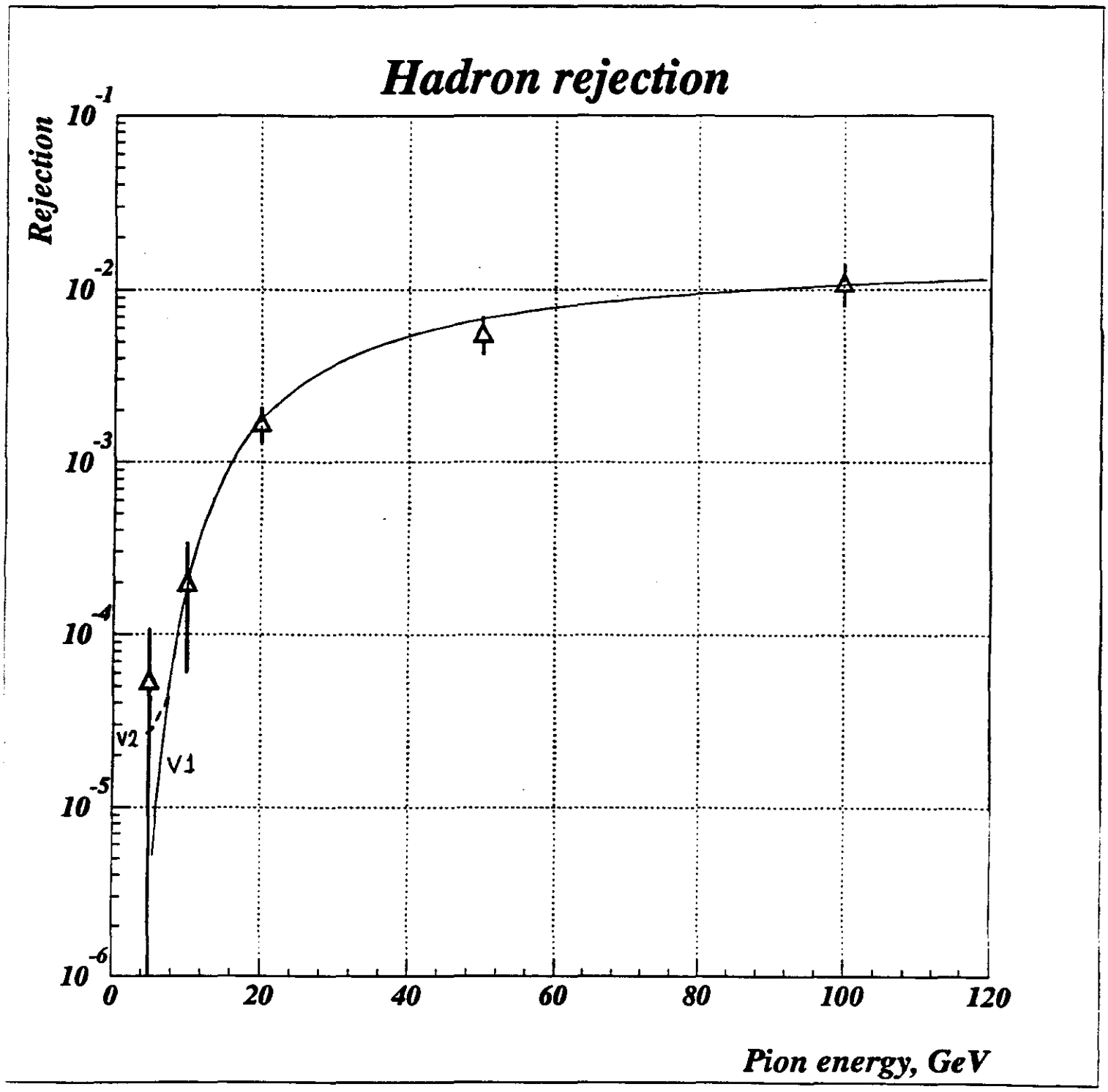


Hadron background:

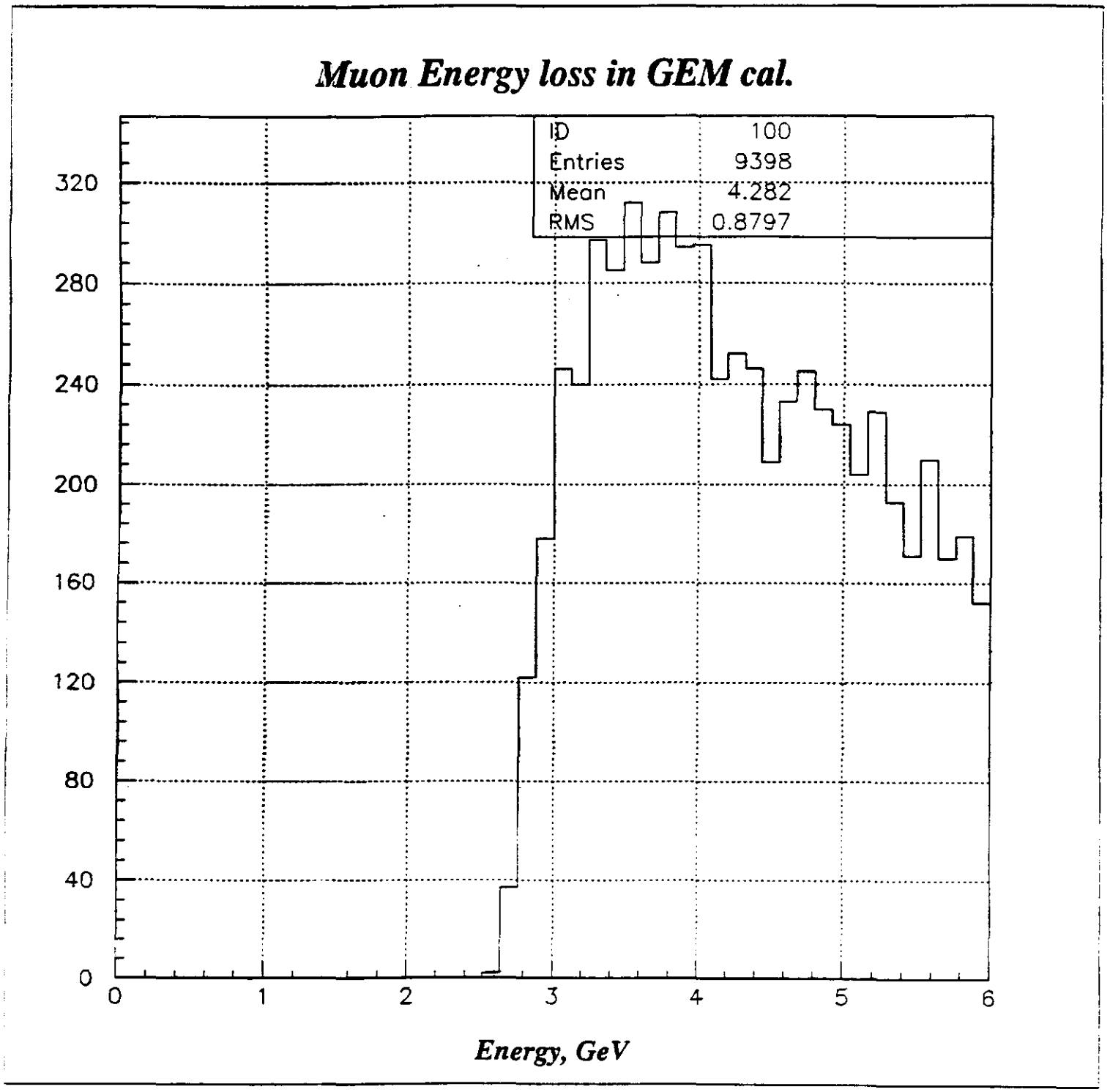
1. Charge hadrons with the E less 2.5 GeV can't pass through Barrel calorimeter.

2. Probability for hadrons to produce muon trigger is 10^{-2} - 10^{-5}

3. Jet the same energy is "better" than pion.

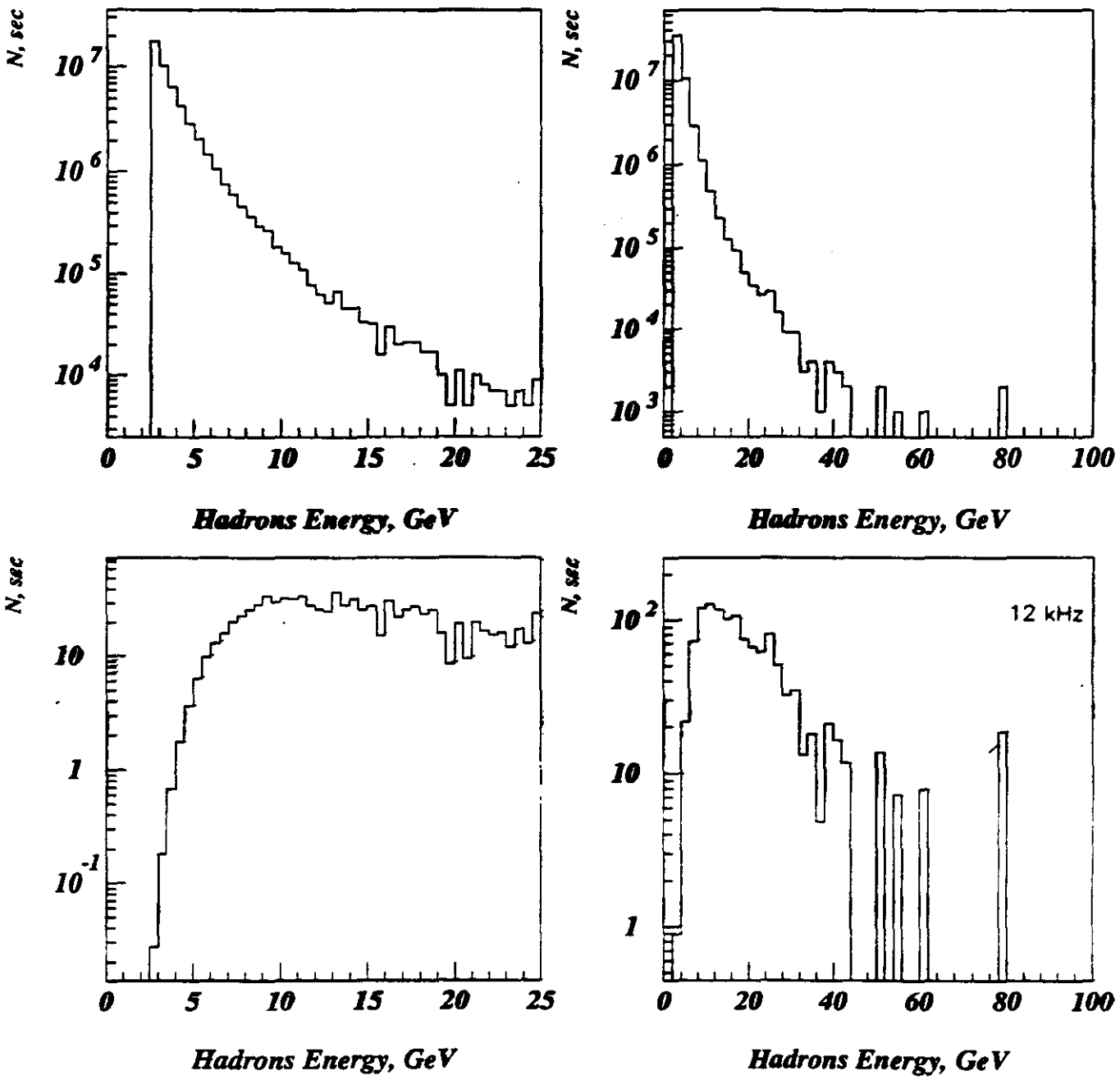

Hadron rejection
Rejection
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
V2
V1
0
20
40
60
80
100
120
Pion energy, GeV

Jet


Muon Energy loss in GEM cal.
ID 100
Entries 9398
Mean 4.282
RMS 0.8797
320
280
240
200
160
120
80
40
0
0
1
2
3
4
5
6
Energy, GeV

V1

Hadrons in the Barrel, $L=10^{33}$

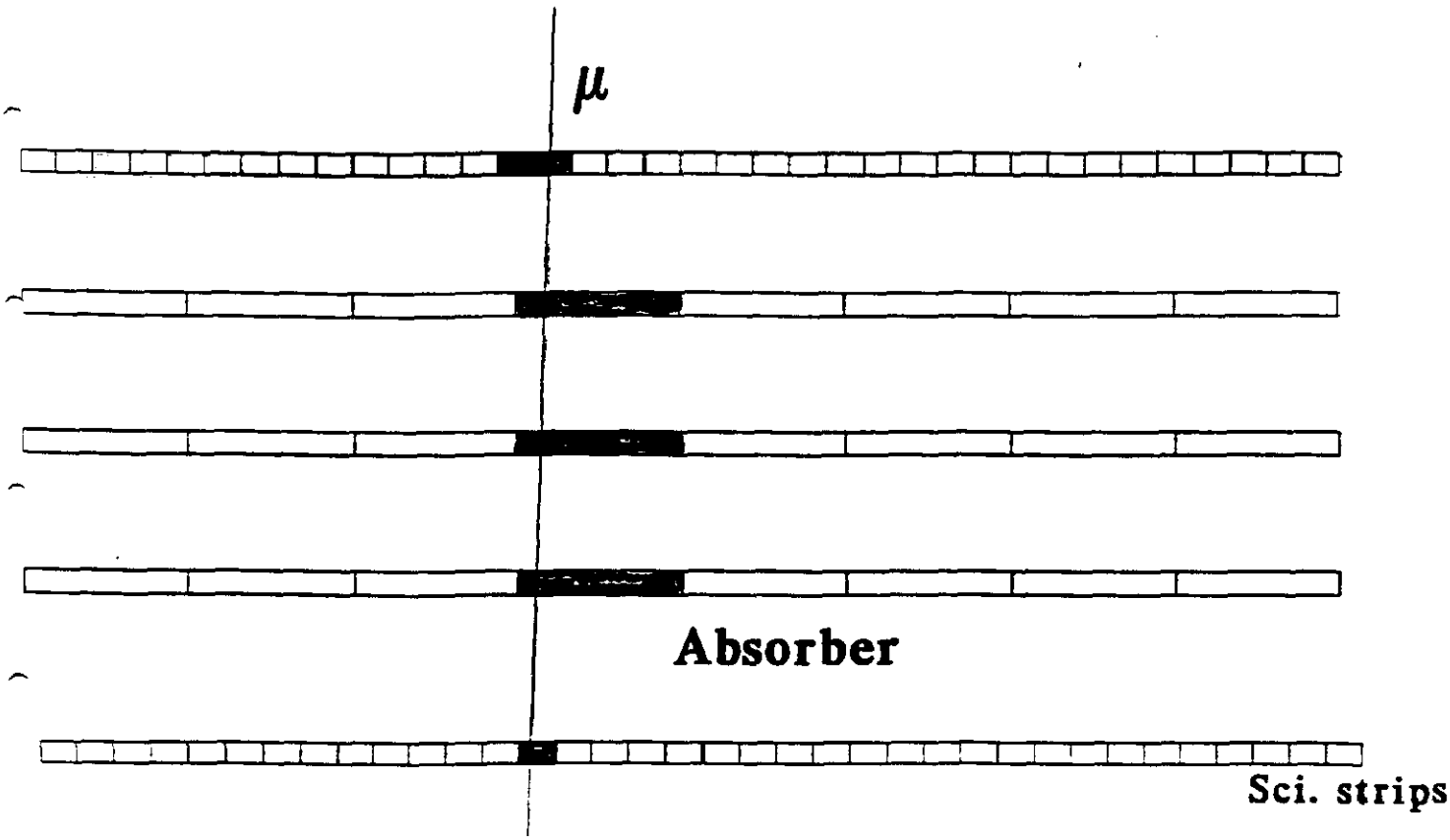


Region eta = 0 +/- 0.1 is not sensitive in the muon system due to CDS

In this region TC calorimeter can provide :

1. Pt > threshold trigger
2. T0 measurement
3. Muon identification (together with tracker and liquid calorimeter section) <-- ?
4. Rought momentum measurement (based on vertex, tracker and TC meas.) <-- ?

Tail Catcher



Disadvantages:

1. 10 m long module need more complicate assembling conception.

2. Completed φ coverage needed for trigger, conflict with mechanical support.

3. Channel count 640 → 4000.

4. Total cost increasing 26 → 30 M$

M. Renich

Advantages :

1. Full eta-phi coverage (for eta < 1.3) is possible (including eta ~ 0.)

2. Intrinsically fast

3. T_0 is possible

4. Stand alone for the first level trig.

5. Simple trigger electronics / algorithm

6. No neutron problems.

Conclusions:

1. Scintillating Tail Catcher can be complete, independent Level - 1 trigger system for muons in barrel $0.< |\eta| < 1.3$

2. Muon threshold 10-40 GeV Pt can be provided.

3. According simulation trigger rate can be less 20 kHz.

4. All this features cost is 4 M$

gem

γeμ

Presentation by:

M. Bowden

DAQ Architecture for Virtual Level 2 Trigger

2/4/93

DAQ System

- Number of input channels

Si	2525
IPC	3125
Cal	3335
CSC/RPC/RDT	1270
Total	~10255 channels

Design allows for 512 Data Collectors X 24 channels
=> 12288 channels

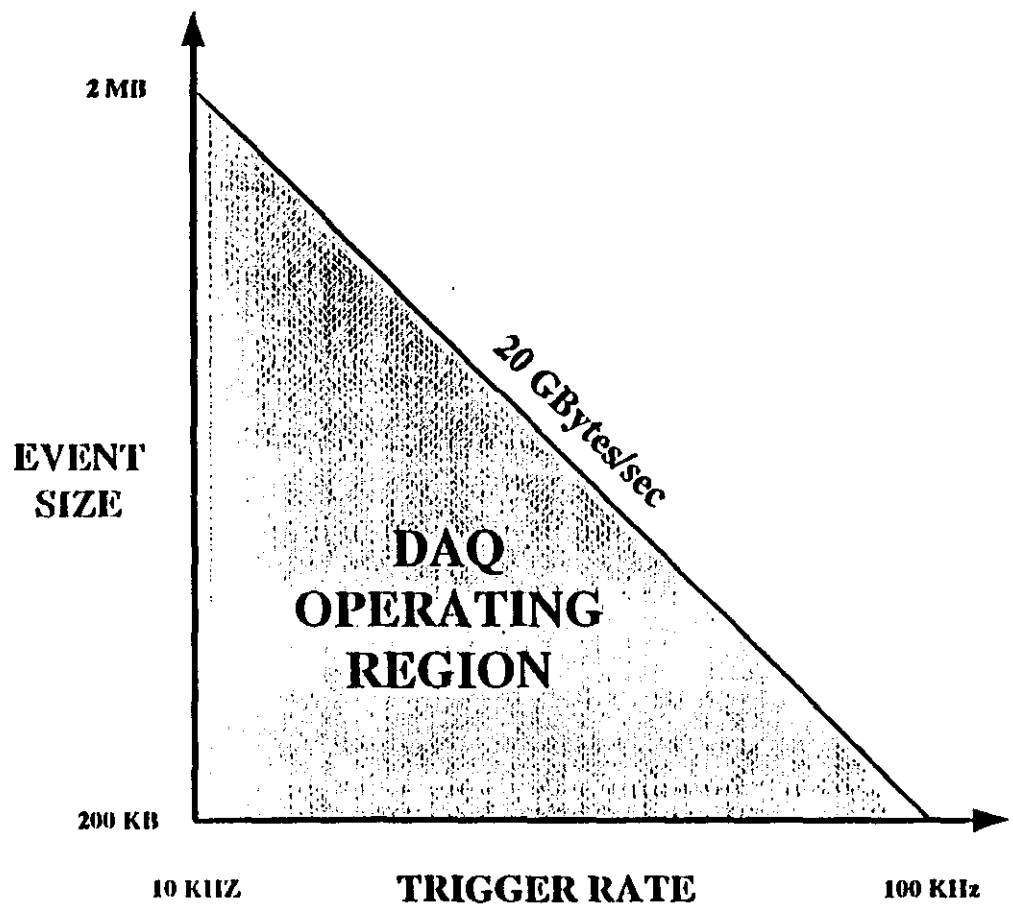
- Data Rate

250 KBytes/event X 100 KHz
=> 25 GBytes/sec
(less with selective readout)

Design allows for 512 X 600 Mbps
=> 30 GBytes/sec

Peak input rate = 12288 channels X 62 Mbps
=> 75 GBytes/sec

DAQ OPERATING REGION



Trigger Philosophy

- Two Basic Trigger Levels

  Low Latency Trigger (L1) is limited by depth of front-end IC buffers (1-2 microseconds).

  High Latency Trigger (L3) is limited by depth of off-detector buffers (can be several hundred milliseconds).

  L1 should reduce data rate per front-end board to the maximum bandwidth of a low-cost serial link (approximately 5 MBytes/sec).

  L2 can be an extension of L1 (L1+) with low latency (100 μsec) or a prelude to L3 (L3-) with higher allowed latency (100 msec).

- Virtual L2 Trigger

  Design should allow implementation of L2 trigger using either L3 processors or dedicated hardware.

  Initial implementation uses L3 processors until L2 trigger is fully characterized.

- Data Readout

  Selective readout approach uses L1 trigger information to point to interesting regions of the detector. L2 algorithm only requests data necessary for trigger. L2 Accept causes all remaining data to be read. Reduces event builder bandwidth requirements.

  Emphasis is on moderate performance, highly parallel readout and trigger processing. Limit use of very high speed processors and datapaths.

- **Comparisons**

SDC

Conventional three level trigger. L2 is implemented in hardware with maximum latency of 100 μsec (may be increased to 1 msec). L2 is currently undefined. Output from front-end boards to L2 trigger system is undefined. L2 may be simple extension of L1 with no additional data.

LHC (proposed)

Very similar to proposed GEM DAQ. Uses both local hardware L2 triggers (LT2) and global software L2 trigger (GT2). Readout is selective (estimated at 1%) using SCI network.

Off-Detector L2 Buffering

Cost;

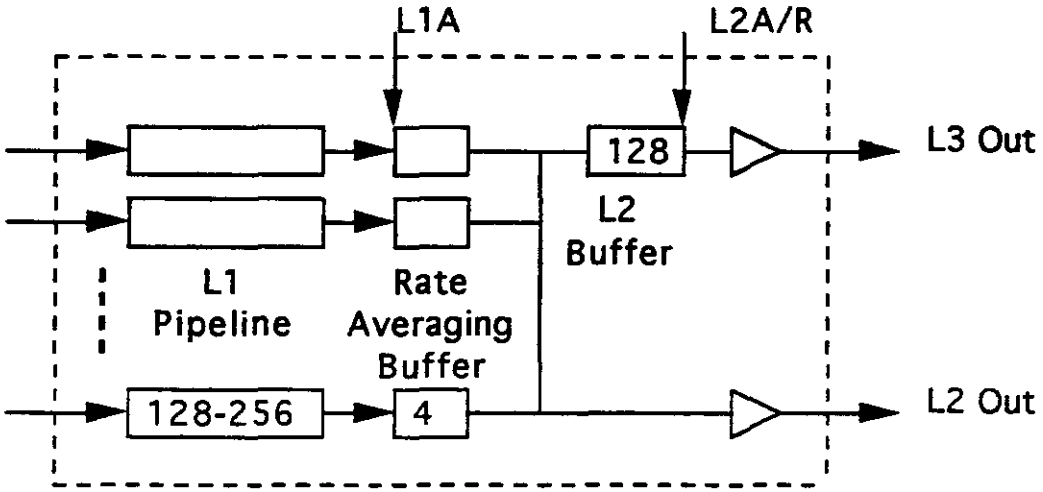
$5,000 per MByte on front-end ICs (rad-hard SRAM)
vs $10 per MByte off-detector (standard DRAM)

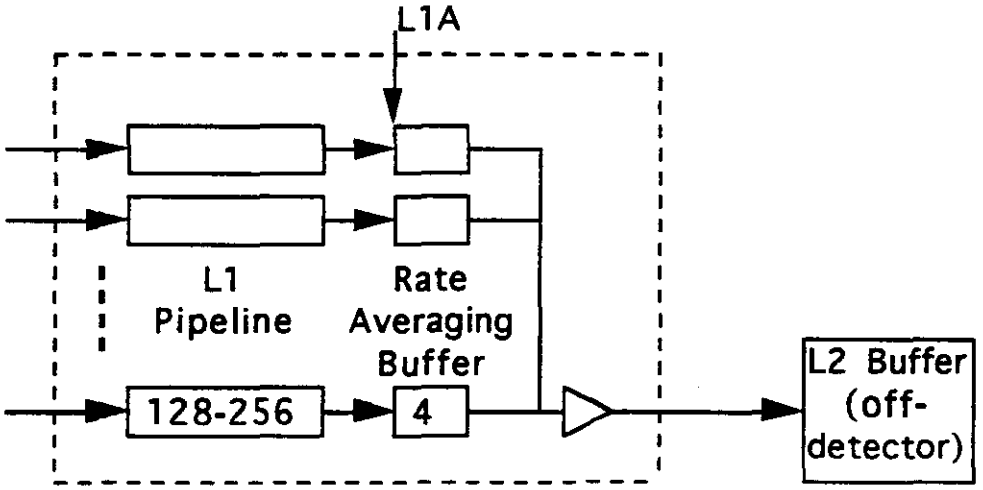
Advantages;

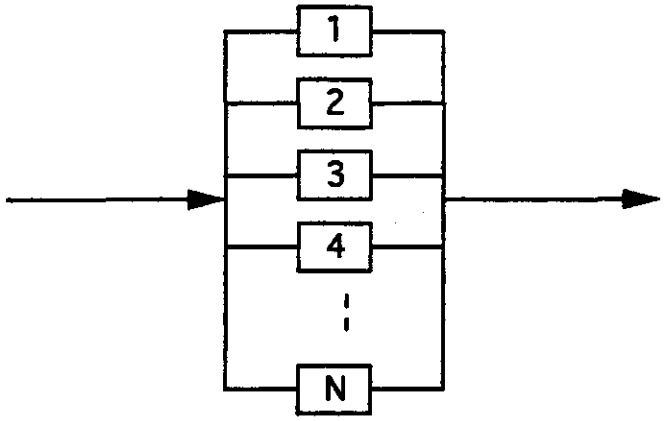
- **eliminates L3 output link**
- **higher buffer memory utilization, lower cost per bit**
- **allows much higher trigger latency**

Disadvantages;

- **need faster L2 output link**
- **need faster A/Ds**





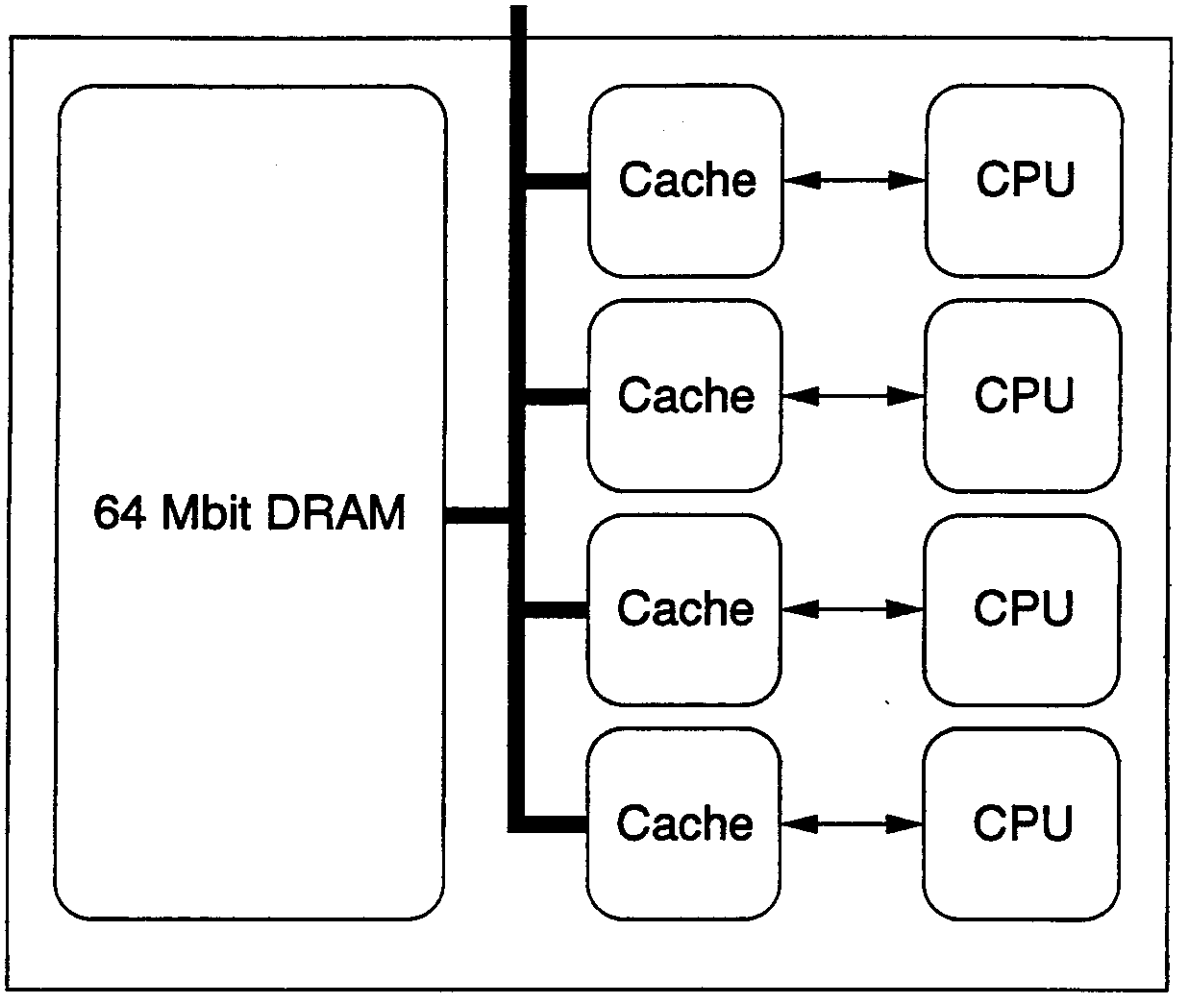


100,000 events/second can be processed by;

1	Processor(s)	@	10	μsec/event	
10	"	@	100	μsec/event	← **Typical**
100	"	@	1	msec/event	
1,000	"	@	10	msec/event	← **Proposed GEM DAQ**
10,000	"	@	100	msec/event	
100,000	"	@	1	sec/event	

Multiple L2 processes per processor to allow for data access time. Example: 10,000 L2 processes on 1,000 physical processors => 10 msec/event processing time + 90 msec/event data access time (100 msec/event L2 trigger latency)

Microprocessor (circa 1999)



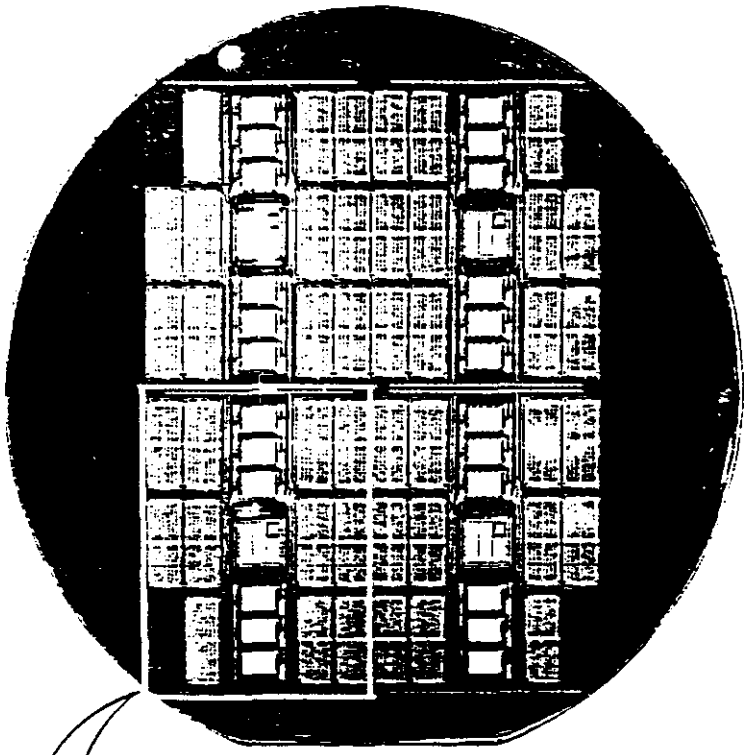
On-chip DRAM (8 MBytes)

1024 bit Cache line

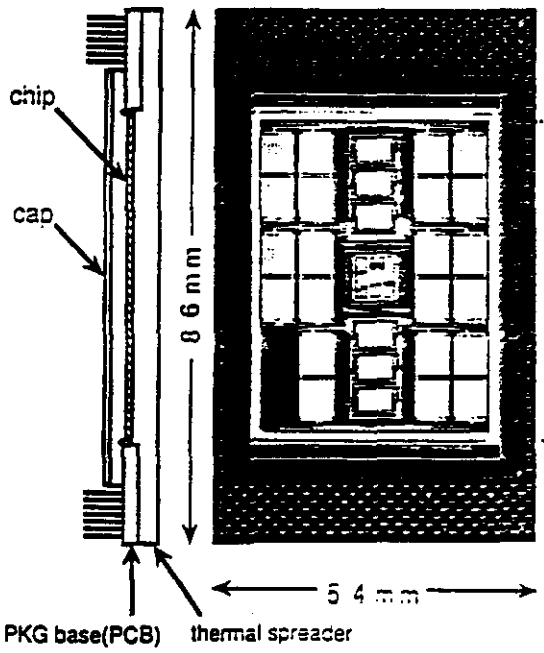
4 X 50 MOPS Processor

< $10 / MOPS (1992 = $100 / MOPS)

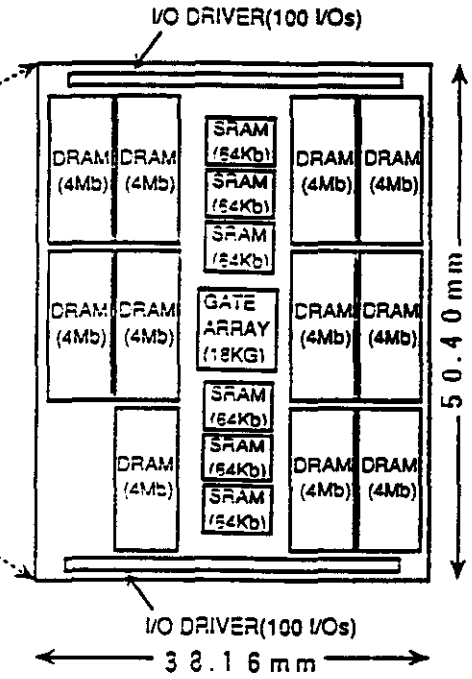
(Continued from page 53)



(a) A fabricated wafer for SYSI-ULSIs

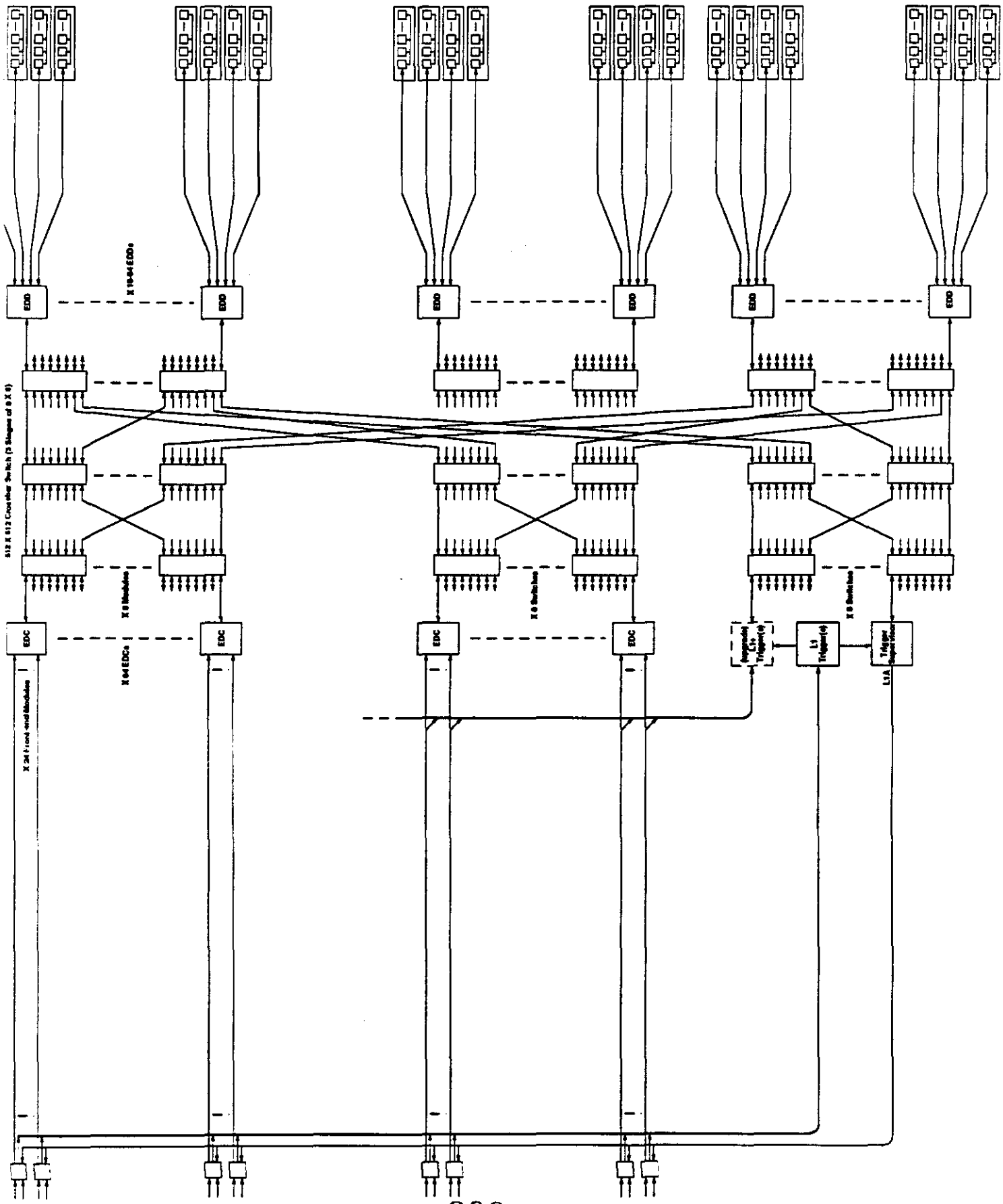


(b) A SYSI-ULSI chip in a 324 pin plastic PGA



(c) A SYSI-ULSI chip configuration

Figure 1: SYSI-ULSI chip configuration and micrographs.


EDD
EDC
L1
Trigger

Data and Control Flow

The following steps are all heavily pipelined to avoid deadtime:

1) Processors with free event buffers issue event requests to the Trigger Supervisor.

2) If there are no pending event requests, L1 Accept is inhibited.

3) If there is a pending event request and an L1 trigger is generated, L1 Accept is sent to all front-end modules and the corresponding L1 event ID is sent to the next requesting processor.

4) The processor sends a message to the L1 trigger buffer requesting an event summary.

5) The L1 trigger returns trigger type information and pointers to regions of interest.

6) The processor sends messages to selected EDCs requesting data.

7) Selected EDCs return data.

8) The processor completes the L2 decision and sends an accept or reject message to the remaining EDCs.

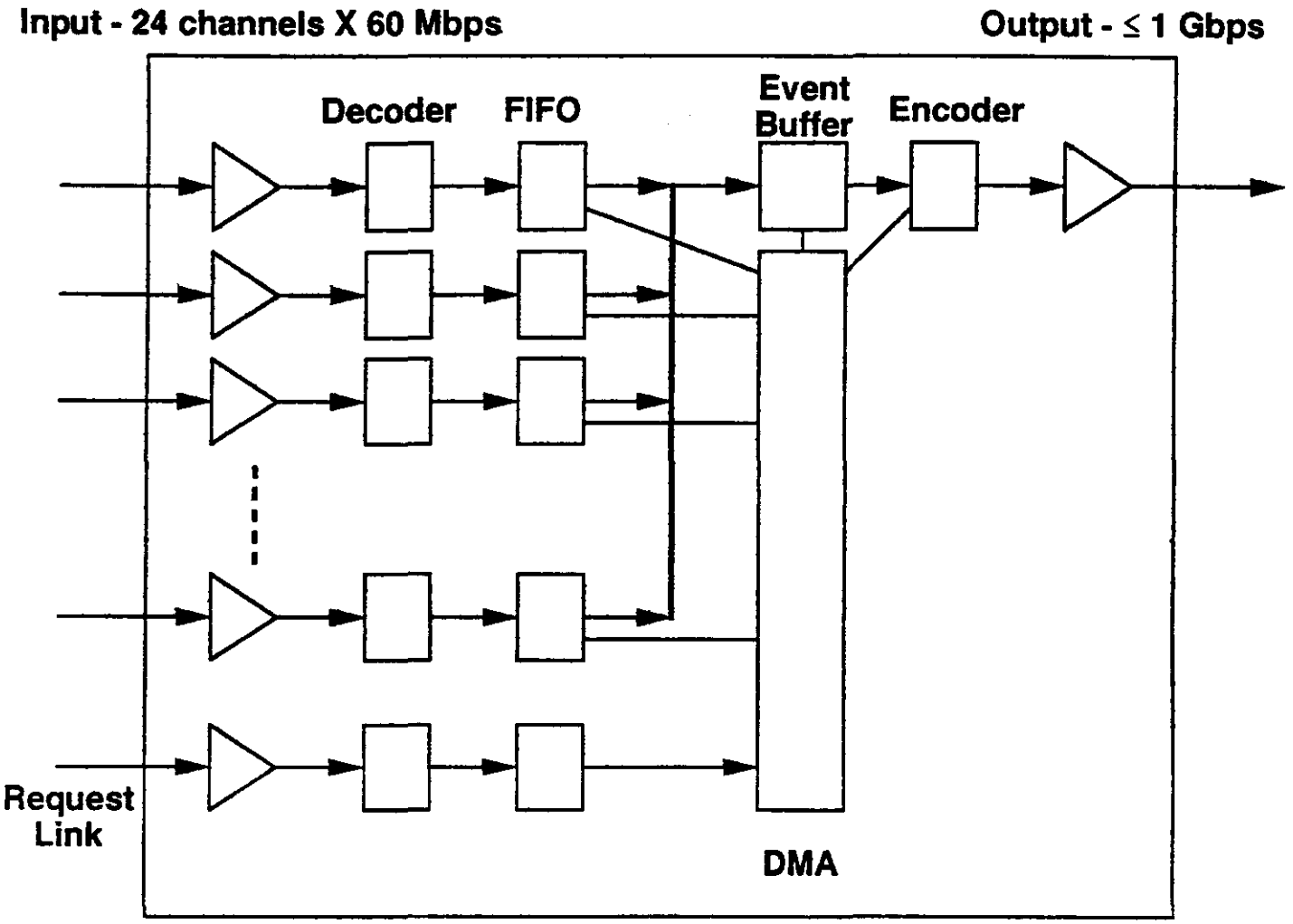
9) Remaining EDCs return or delete data.

10) L3 processing continues for accepted events.

11) When the processor event buffer is free, a new event request is transmitted.

Note: Processor suspends L2 process after sending data request message. L2 process resumes on receipt of data. Multiple L2 processes exist on each processor to avoid deadtime.

Event Data Collector

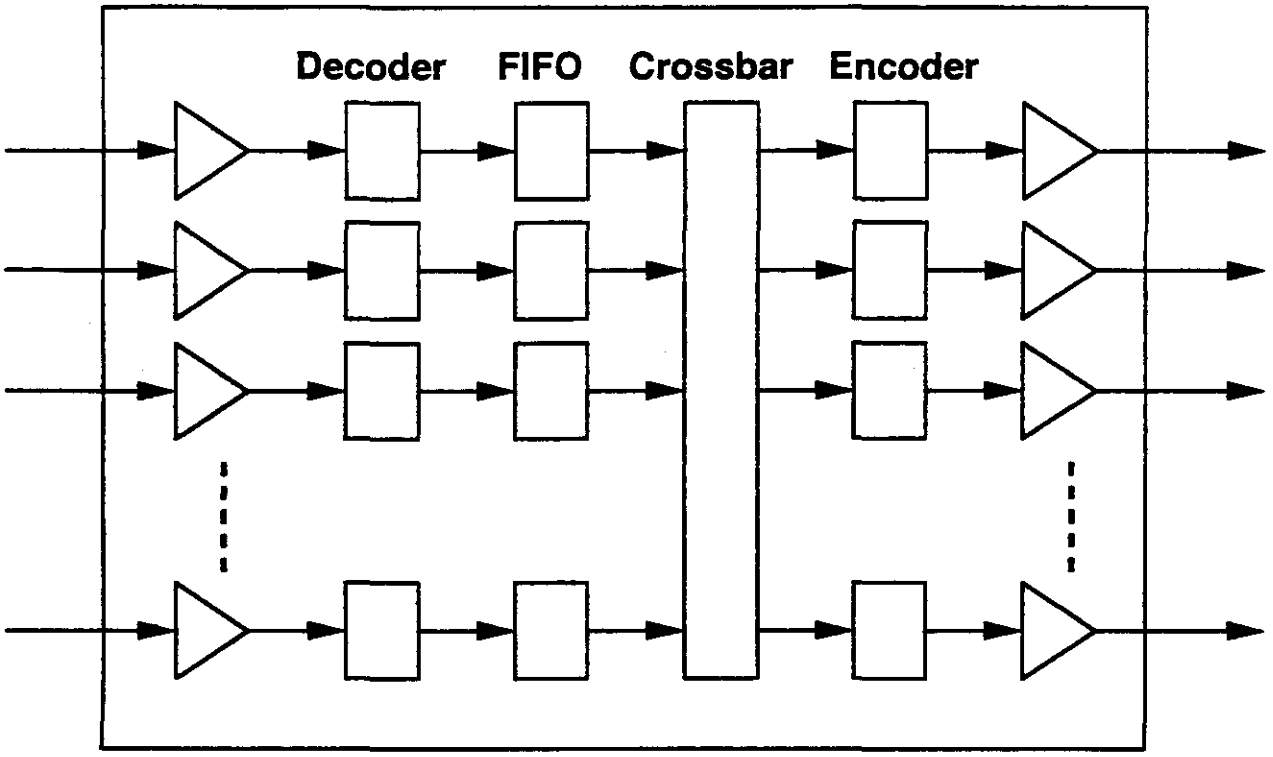


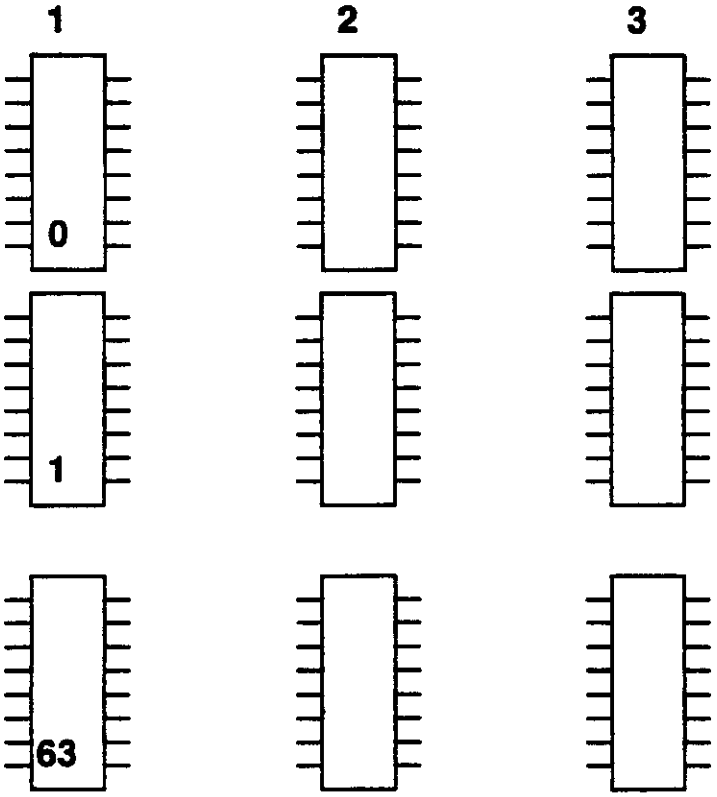
Event Buffer

1 KByte/event X 100,000 events/sec X 1 sec = 100 Mbytes

(May be divided among input channels)

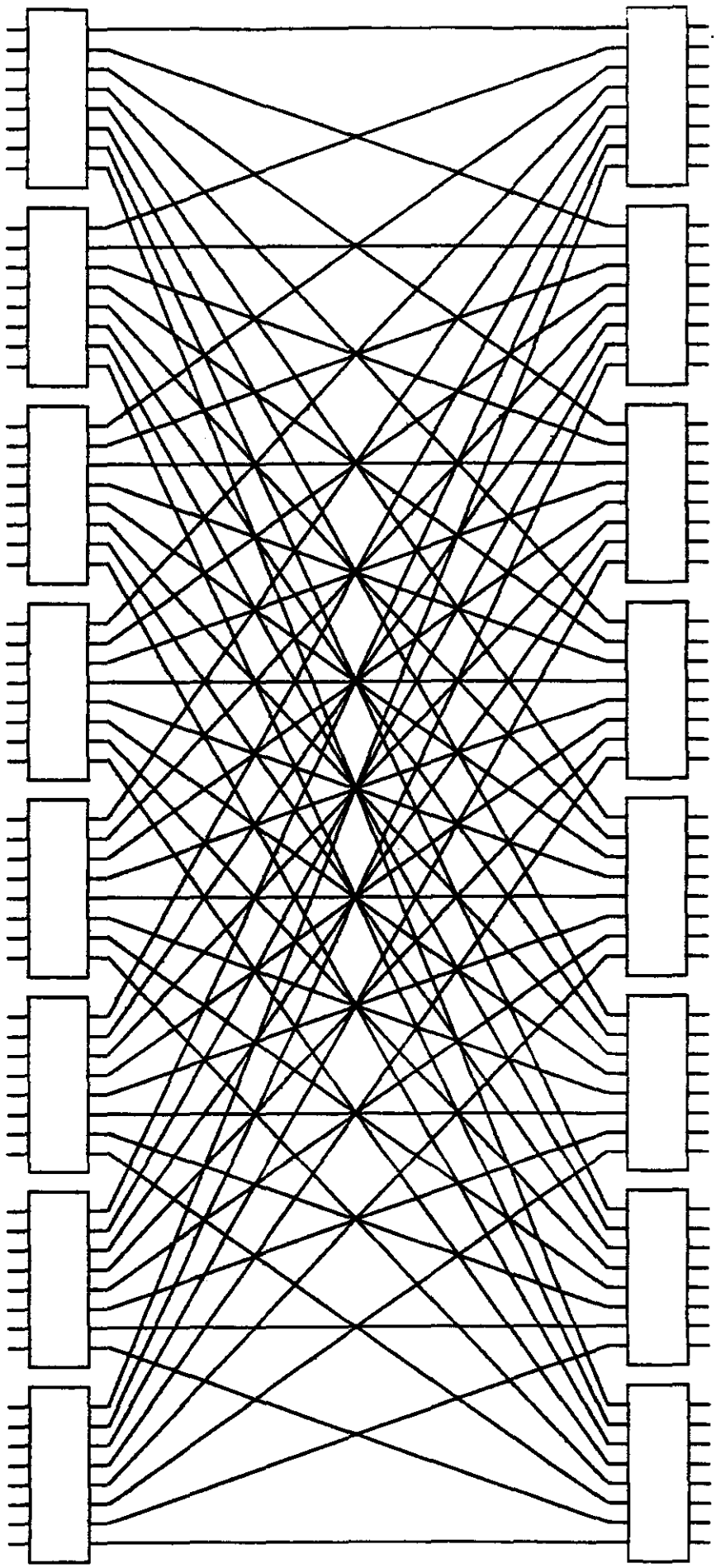
Crossbar Switch





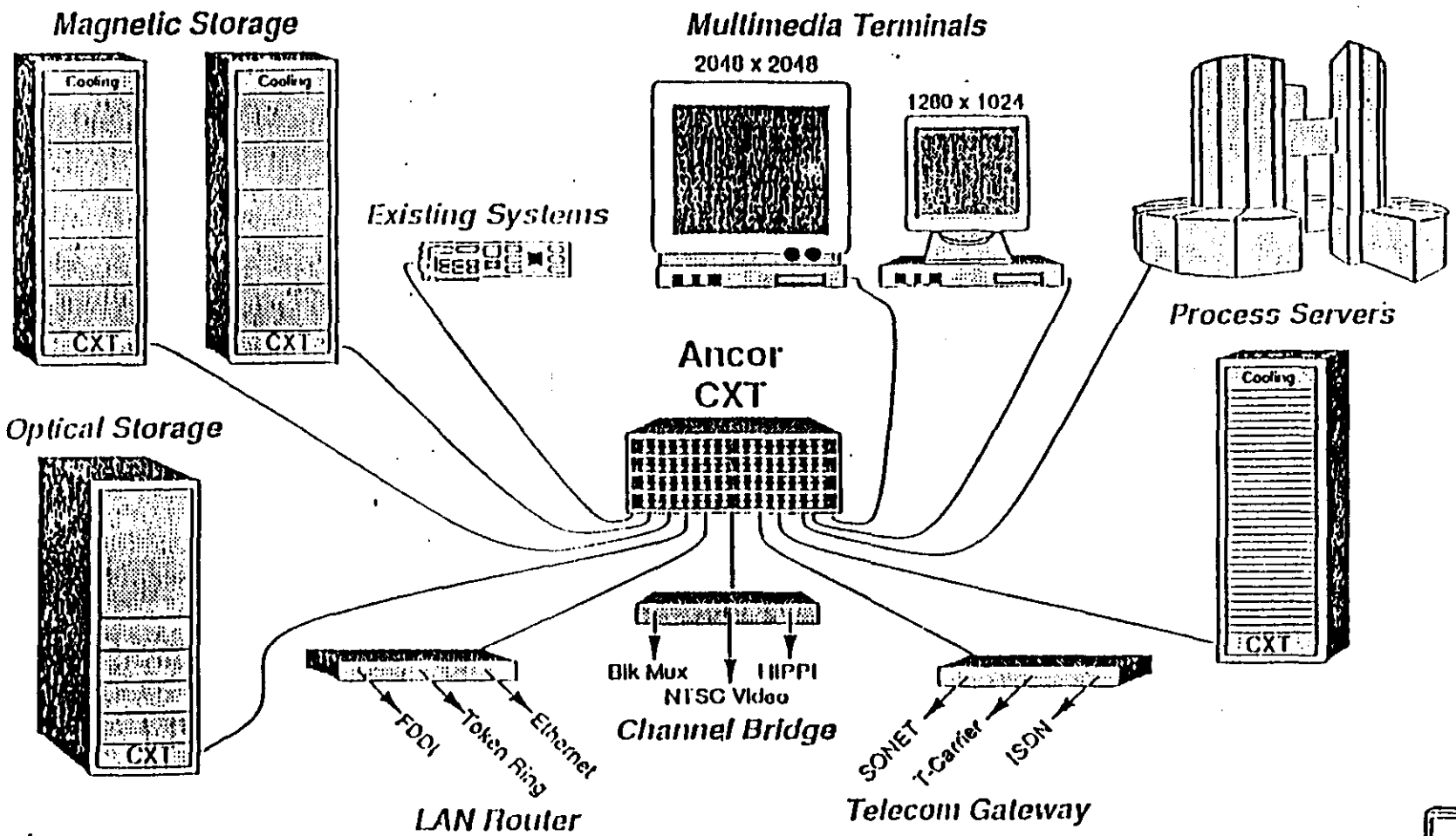
512 X 512
= 192 Modules

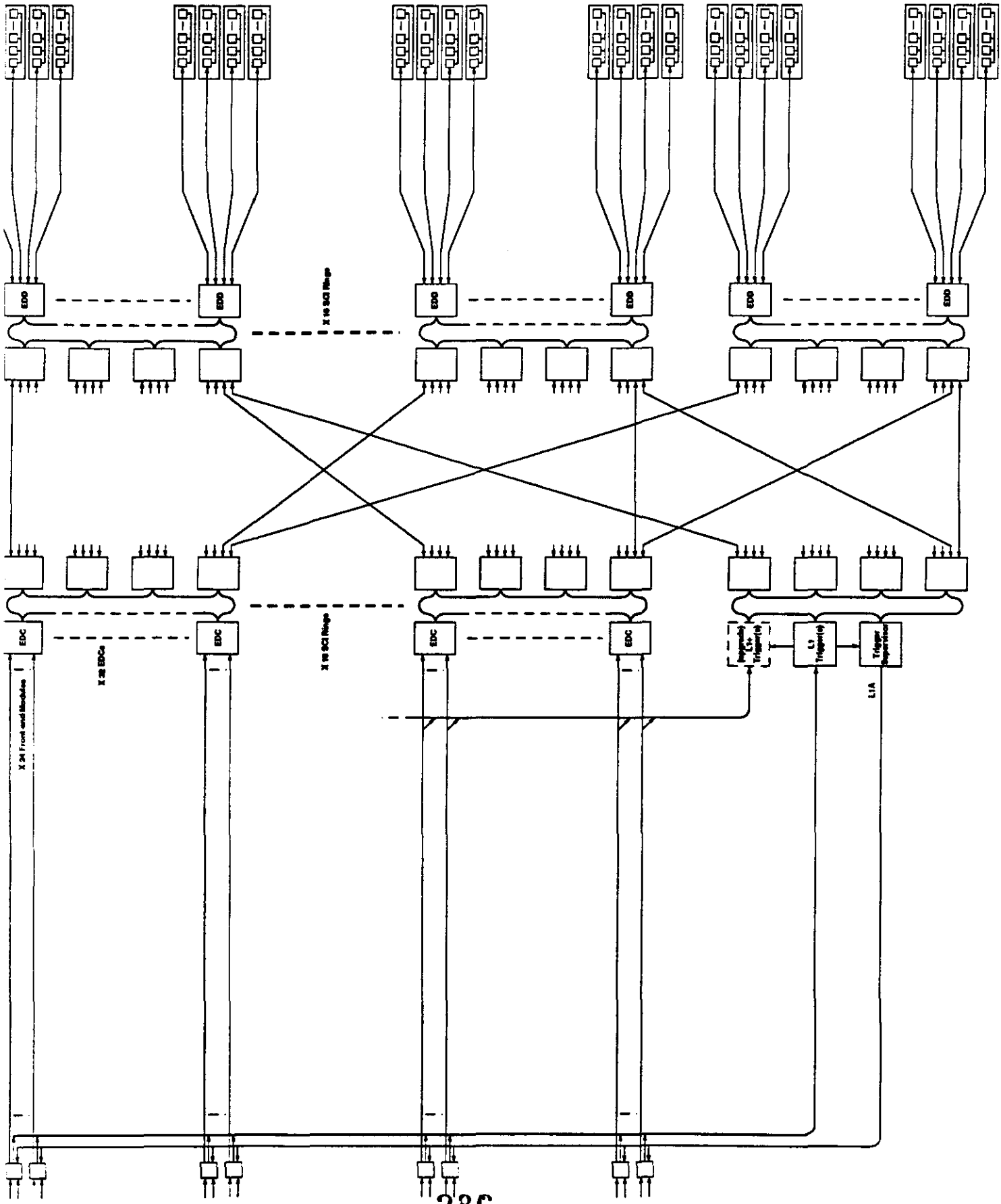
64 X 64 Switch



Ancor Communications

CXT 250/1000 Development Plan




EDO
EDO
EDO
EDO
EDO
EDO
X 16 SCI Rings
EDC
EDC
EDC
EDC
X 32 EDCs
X 16 SCI Rings
X 24 Front-end Modules
L1A

SCI

NodeChip™ Architecture Compared to Conventional Bus Architectures

Feature	Difference
64-bit address	Standard buses support only 32-bit addresses
200-1000 Mbytes/sec	Standard buses achieves less than 100 Mbytes/s
Cache coherence support	SCI cache coherence protocols scale much better than conventional snooping protocols
One VLSI chip	Standard buses require 10-20 chips for the bus interface
256 addressable nodes	Standard buses have less than 32 addressable nodes
Interconnect flexibility	Standard buses are constrained to a backplane, while the NodeChip™ allow protocols to run on cables as well
Multiple senders	Standard buses allow only one sender at a time, while the NodeChip™ allow several simultaneous senders
Serialization	Standard bus protocols can not be directly serialized to run on fiber-optic or coax cables. The NodeChip™ can drive an external parallel-to-serial chip directly to run SCI protocols on fiber or coax cable

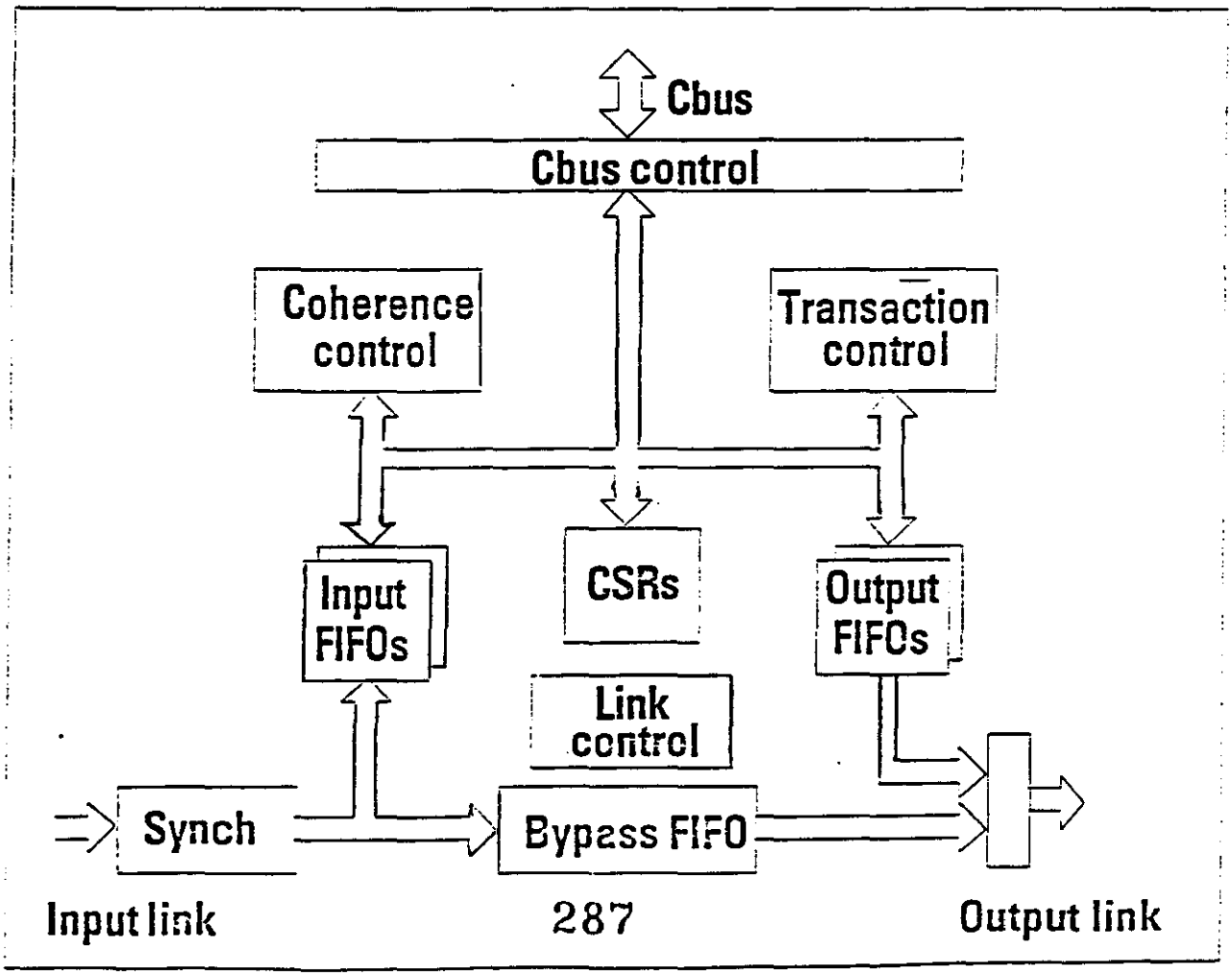
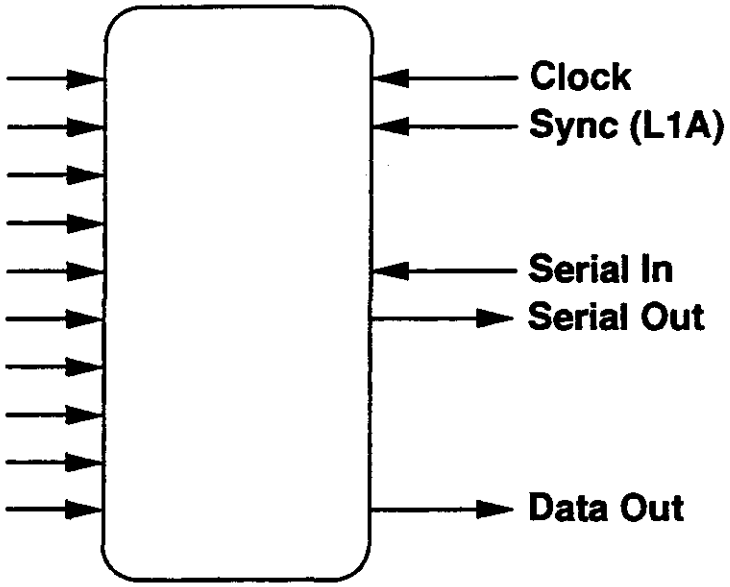


Figure 1. NodeChip™ block diagram

Minimal Front-end Interface



Clock (62 MHz)

Sync (62 Mbps, 31 MHz NRZ, clock synchronous)

Serial I/O (20 Mbps, 10 MHz NRZ, asynchronous using 62 MHz clock for 3X oversampling)

Data Out (62 Mbps, 31 MHz NRZ, clock synchronous)

All signals (except Data Out) are differential copper to/from local fanout board which serves 24 front-end boards. Fanout board connects via fiber to clock, trigger and control network in Electronics Room. Data Out is fiber direct to EDCs in Electronics Room.

Summary Features

- All data is digitized at Level 1
- Level 2 buffers are off-detector
- This allows high latency L2 Trigger
- High latency allows choice of hardware and/or software L2 implementation
- Start with software....migrate to hardware if necessary
- Selective readout to reduce event builder bandwidth
- Bussless architecture....point to point serial interconnects.....easier to scale
- High degree of parallelism & pipelining to reduce need for very fast processors and interconnects