GEM TN-92- 53 /PUB

GEM Tracking Meeting
SSCL

January 23, 1992

Abstract:
Transparencies from the Tracking Meeting held at the SSC Lab on January 23, 1992. Included are preliminary specifications for the IPC array, cooling for the IPC's and front end electronics for the IPC. There is a silicon tracker update, simulations results from Yale and Los Alamos, and a section on integration issues.

1/27/92-KM

W. Emmet

The following are preliminary specifications for the GEM interpolating pad chamber tracking array (barrel and endcap sections):

- Four levels of superlayers at two IPC layers per superlayer
- 20 sectors per level of IPC's are in the barrel region
- 10 sectors per level of IPC's are in each endcap
- Each barrel level is rotated 4.5 degrees relative to the adjacent levels
- Each endcap level is rotated 9 degrees relative to the adjacent levels
- The barrel IPC superlayer length is 200 cm
- The barrel inner and outer radii are 35 cm and 70 cm
- The endcap inner and outer radii are 20 cm and 70 cm
- The endcap minimum and maximum z coordinates are 110 and 140 cm
- Each IPC superlayer is 1.6 cm thick, including two layers and the hardback between them
- Each layer is 4 mm deep (cathode to cathode) and the anode wire plane is halfway between the cathode planes
- The pad width is 0.5 cm in the phi coordinate
- The anode wire pitch is 2 mm
- The anode wire diameter is approx. 20 to 40 microns and the material is gold plated tungsten
- The anode potential is 4 KV

The pad (channel) count is the following with the caveat that incomplete pads at the ends of the barrel chambers and along the edges of the endcap chambers are not included:

- Barrel section: 222360 channels
- Each endcap: 87280 channels
- Total: 396920 channels

The "guestimated" power dissipation (Paul O'Connor of BNL) is as follows:

- Three chip set for electronics
- Preamp/shaper (40 pin LCC) at 16 channels per chip is 50 mW per channel
- Analog storage (40 pin LCC) at 16 channels per chip is 10 mW per channel
- Multiplexer chip (? LCC) at 256 channel input, 16 channel output is 1.2 mW per input channel

The "worst case" barrel superlayer has 1664 channels per layer. This would require 104 preamp/shapers (83.2 watts), 104 analog storage chips (16.6 watts) and 6.5 multiplexers (1.95 watts), or a total of 101.75 watts. Since there are two layers per superlayer, the total power dissipation due to the electronics is 203.5 watts per superlayer.

Each endcap superlayer has 1091 channels per layer. The total power dissipation per superlayer is 133.5 watts.

The total electronics power dissipation for the barrel is approximately 13.6 KW; the endcaps dissipate 5.3 KW each.

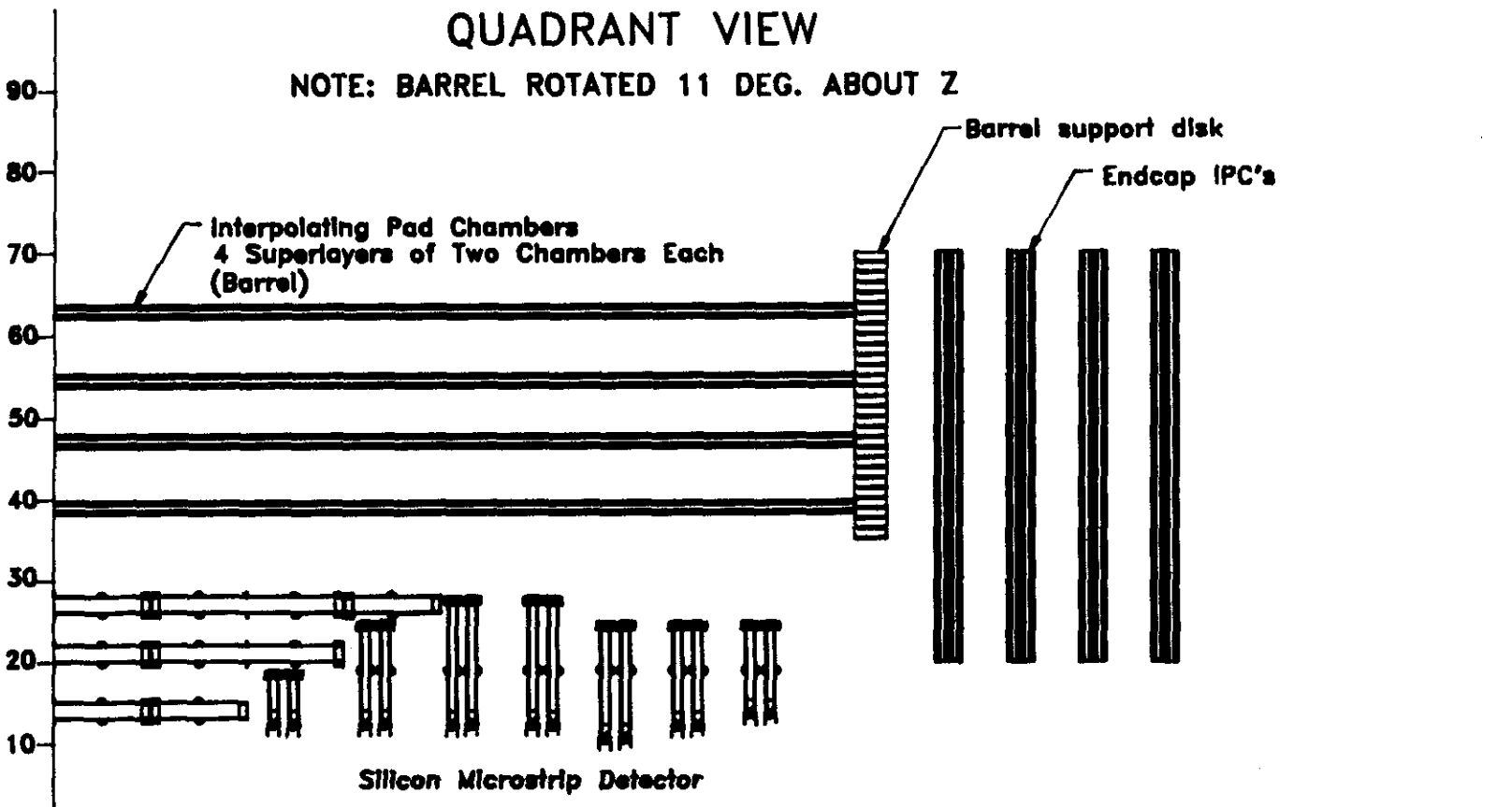
The dimensional stability requirements for the tracker array are as follows:

- 25 microns in phi between superlayer levels
- 100 microns in z between superlayer levels
- 25 microns in phi between endcaps and barrel
- 100 microns in z between endcaps and barrel
- 762 +/- 50 micron maximum superlayer module deflection

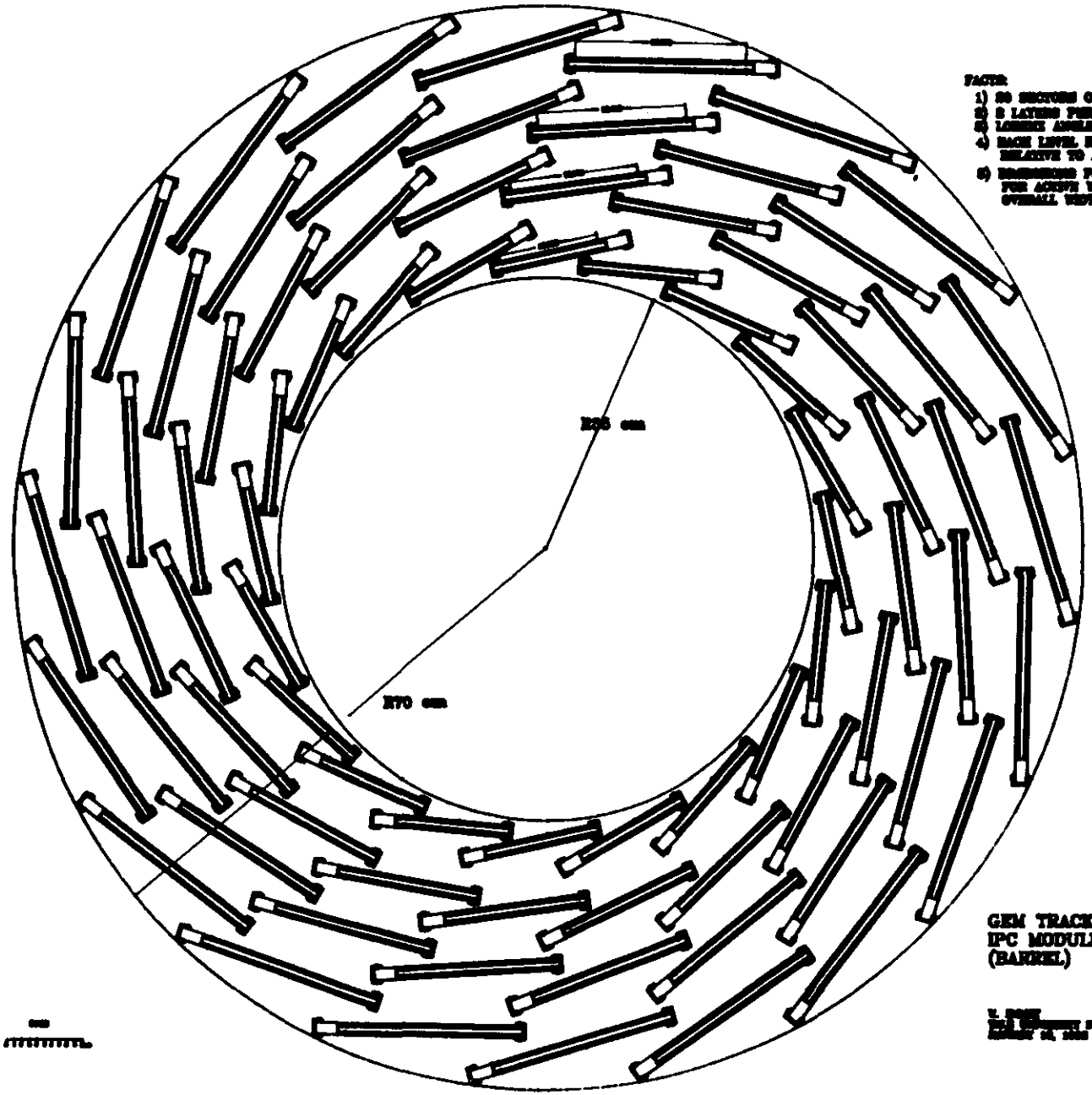
GEM Central Tracking

QUADRANT VIEW

NOTE: BARREL ROTATED 11 DEG. ABOUT Z



W. EMMET
YALE PPG 22-JAN-1992

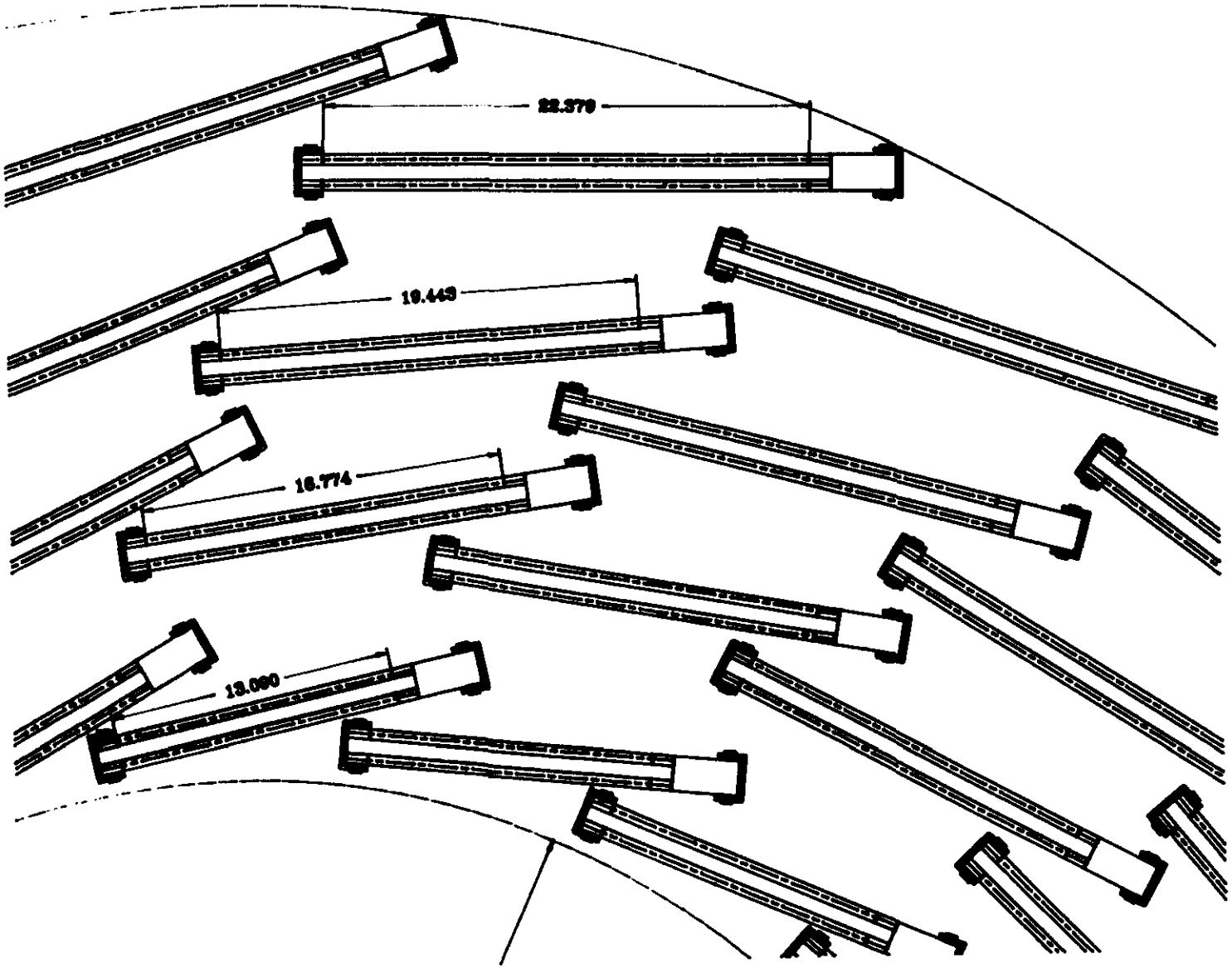


FACTS:

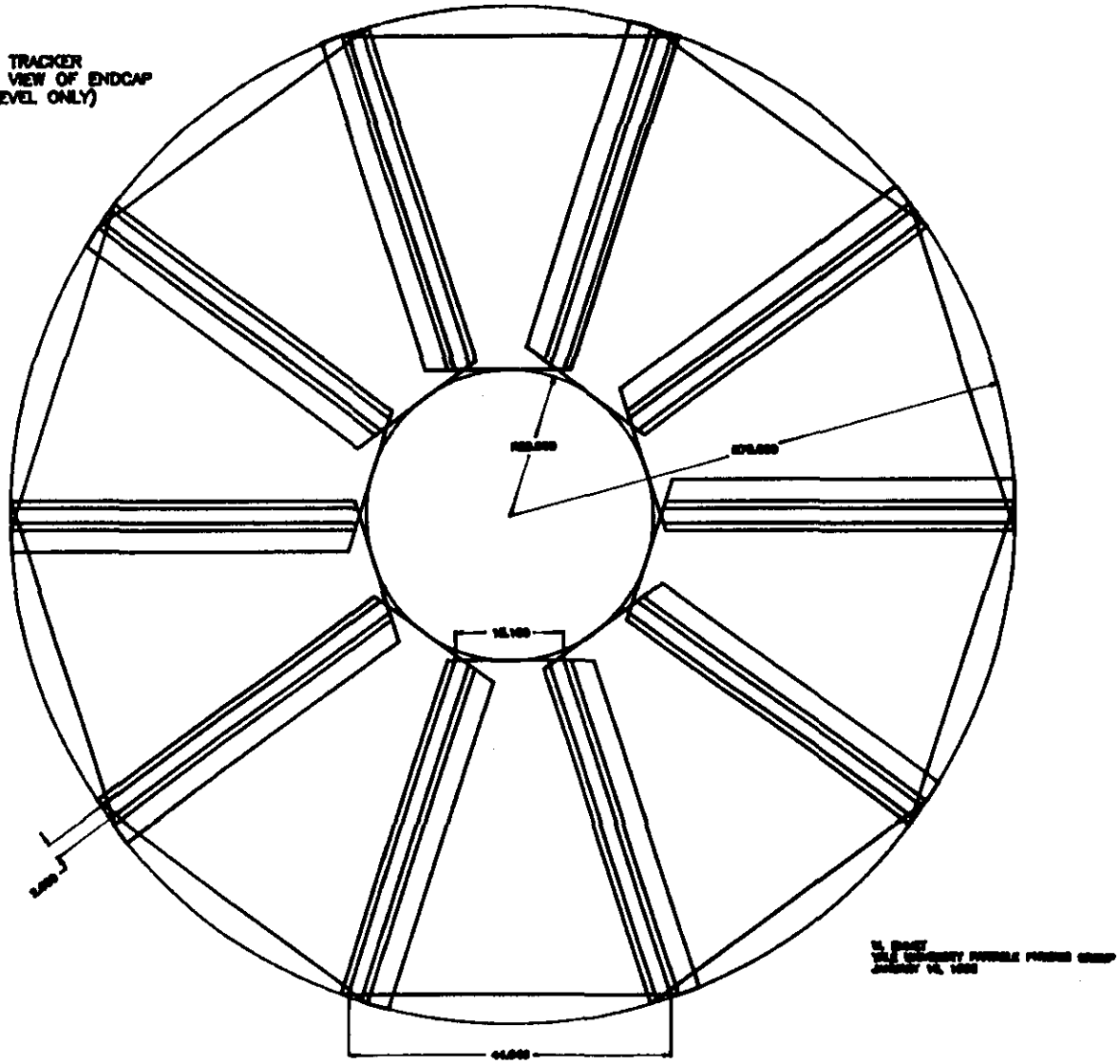
1) [illegible] SECTORS OF 4 SUPERLAYERS EACH
2) 5 LAYERS PER SUPERLAYER
3) LORENTZ ANGLE~15 DEGREES
4) EACH LEVEL ROTATES 4.5 DEGREES RELATIVE TO ADJACENT LEVELS
5) DIMENSIONS FOR CHAMBERS ARE FOR ACTIVE VOLUME (ADD 5 CM FOR OVERALL VOLUME)

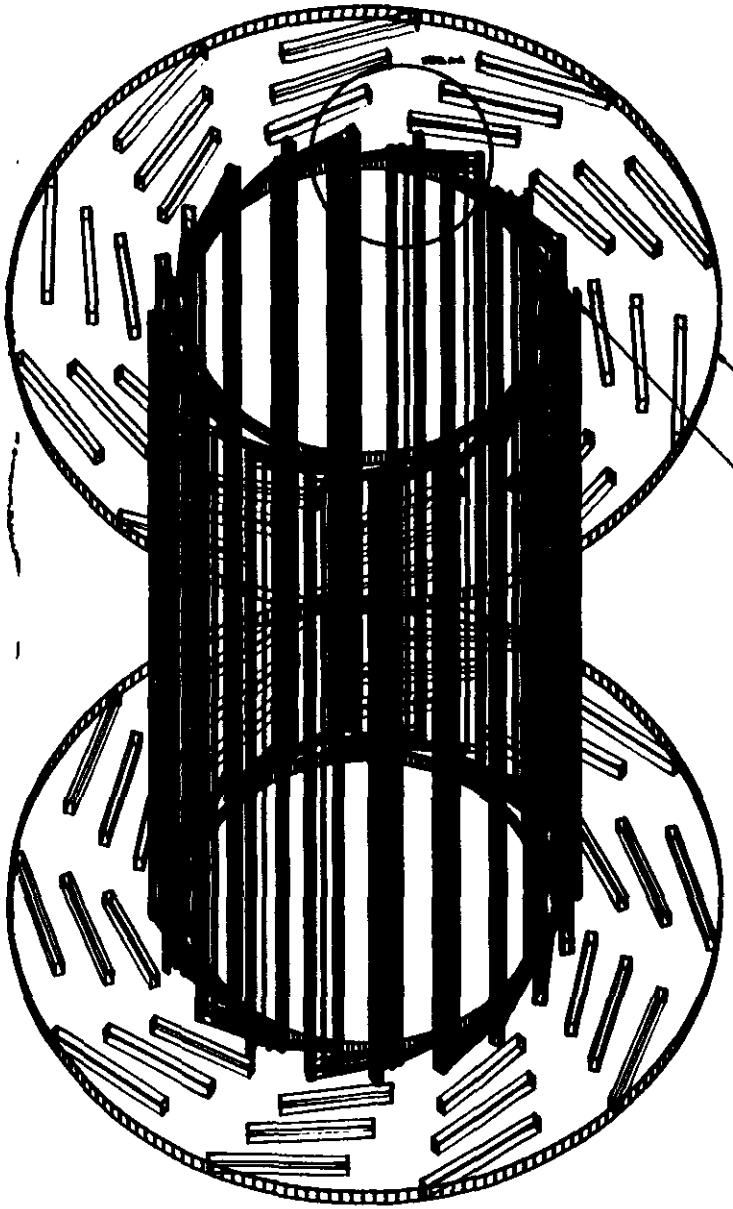
GEM TRACKER
IPC MODULE LAYOUT
(BARREL)

[illegible]
[illegible]
[illegible]


22.370
19.449
16.774
13.090

GEM IPC TRACKER
FRONTAL VIEW OF ENDCAP
(FIRST LEVEL ONLY)





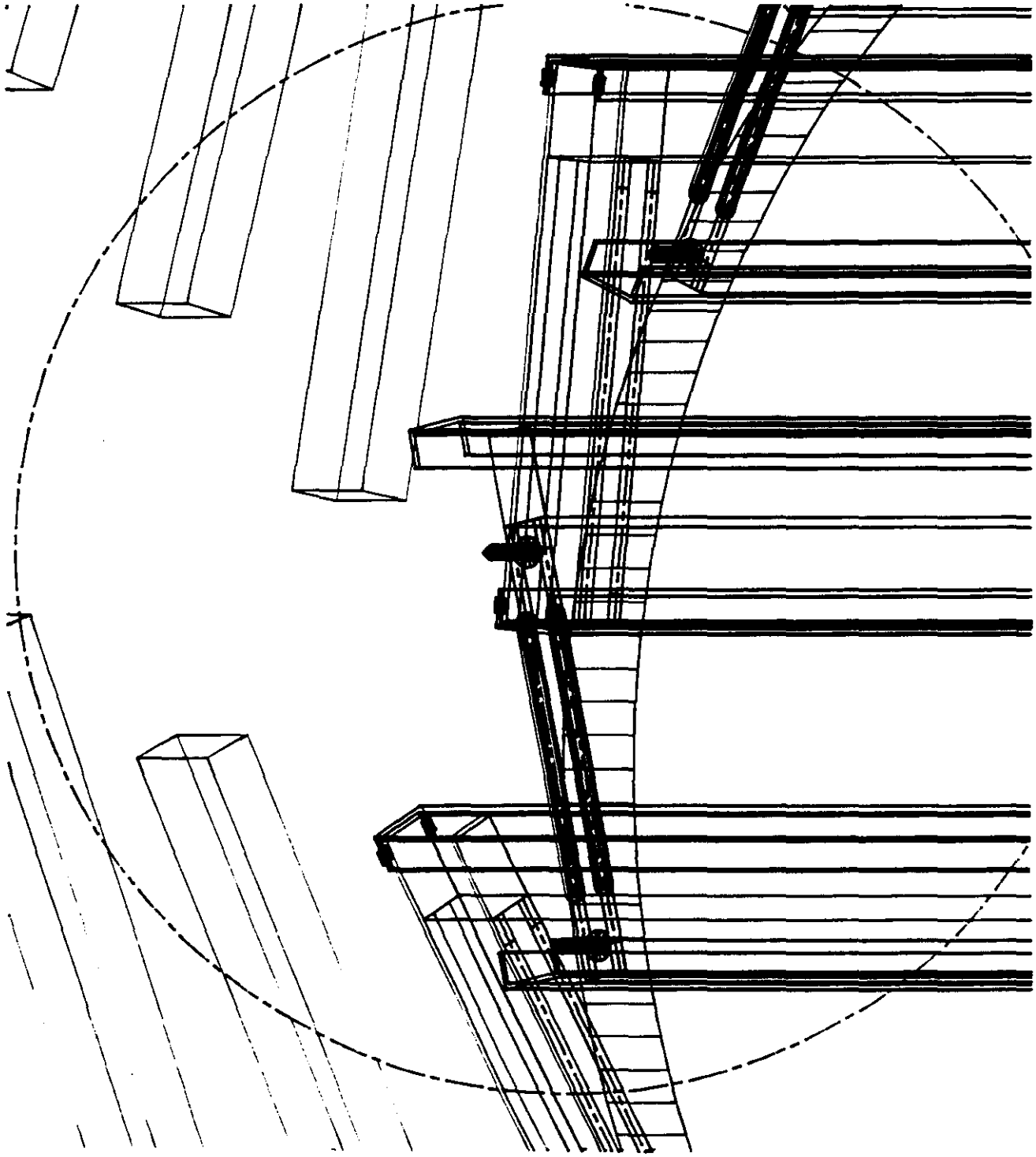
GEM TRACKER
INTERPOLATING PAD CHAMBER ARRAY (BARREL)
20 SECTORS
4 SUPERLAYERS PER SECTOR
2 LAYERS PER SUPERLAYER
LORENZ ANGLE = 12 DEGREES

NOTE: ONLY THE INNERMOST LAYER OF MODULES HAVE BEEN SHOWN FOR PURPOSE OF CLARITY.

HOLLOW GRAPHITE/EPOXY END SUPPORTS DOUBLE AS STRUCTURAL AND GAS CONDUITS
ALTERNATE SECTORS ARE INSTALLED THROUGH ALTERNATE END SUPPORTS

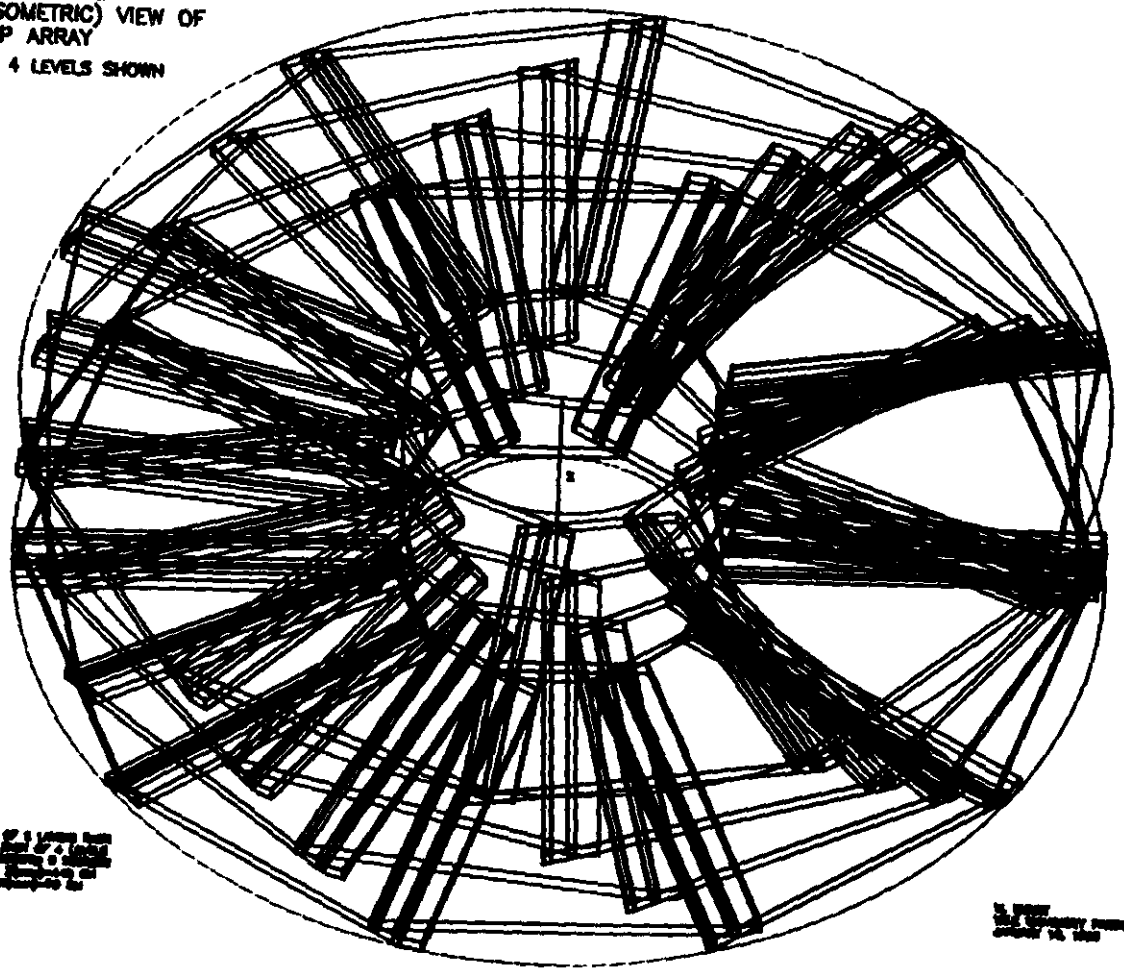
GRAPHITE/EPOXY SLIDES FOR GUIDING MODULES INTO POSITION

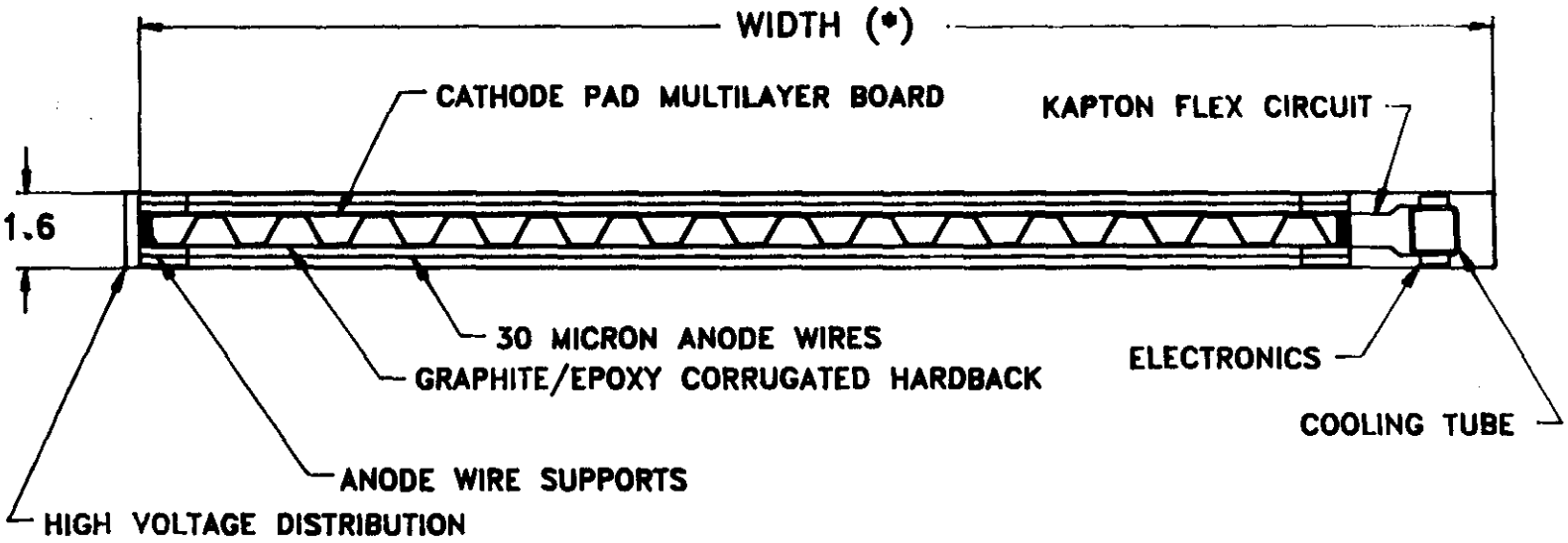
W. ZIMMET
YALE PARTICLE PHYSICS GROUP
JANUARY 19, 1992 (REV. 2)



GEM IPC TRACKER
3-D (ISOMETRIC) VIEW OF
END CAP ARRAY

FIRST OF 4 LEVELS SHOWN





GEM TRACKING IPC SUPERLAYER

SECTIONAL OF TYPICAL BARREL MODULE

W. EMMET
YALE PPG 22-JAN-1992

Keith Woloshun
LANL

GEM IPC COOLING

MEETING OBJECTIVES

1) ALIGN WITH CURRENT CONCEPTION OF IPC GEOMETRY AND COOLING REQUIREMENTS.

   A) ELECTRONIC PACKAGE GEOMETRY AND HEAT LOAD.
   B) LOCATION OF ELECTRONIC PACKAGES.
   C) NUMBER OF ELECTRONIC PACKAGES PER IPC SUPERMODULE.
   D) RESULTING TOTAL HEAT LOAD.

2) PRESENT AND DISCUSS AN OVERVIEW OF THE COOLING OPTIONS BASED UPON THE COOLING REQUIREMENTS AS OF 10/31/91.

GEM IPC COOLING

HEAT SOURCE AND LOAD SPECIFICATIONS

CHANNELS/PACKAGE	6 4
HEAT LOAD/PACKAGE	1.9 W
PACKAGE SIZE	0.6X0.6 TO 1.0X1.0 CM^2
PACKAGE POWER DENSITY	1.9 TO 5.3 W/CM^2
HEAT LOAD/SUPERMODULE	50 W, max
SUPERMODULE LENGTH	2 M (barrel region) 0.5 M (forward region)
PACKAGES/SUPERMODULE	2 7
NET LENGTH OF CHIPS/MODULE	27 CM, max
FAST GAS HEAT LOAD	NEGLIGABLE *

* Based on statement on David Lee 12/91

1/9/92 Update

Power Density	1.1 W/cm^2
Heat Load per Super	210 W
Total Heat Load (120 Supers)	25200 W

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GEM IPC COOLING

COOLING METHODOLOGY

AS SHOWN IN THE 10/31/91 SKETCHES, A COOLING FLUID WILL BE PASSED THROUGH A RECTANGULAR TUBE THAT RUNS THE LENGTH OF THE SUPERMODULE.

THE ELECTRONICS PACKAGES WILL BE MOUNTED DIRECTLY TO THESE TUBES.

ALTERNATIVES:

1) AIR (GAS) COOLING:

Not acceptable due to high ΔT's and high flow velocities. Also, IPC arrangement offers a difficult geometry for introducing a gas flow. Extended surfaces add to system mass and add fabrication problems.

2) FREE EVAPORATION OF A LIQUID INTO THE SURROUNDING SPACES.

Difficult to implement. Requires choice of safe fluid of containment of released vapors.

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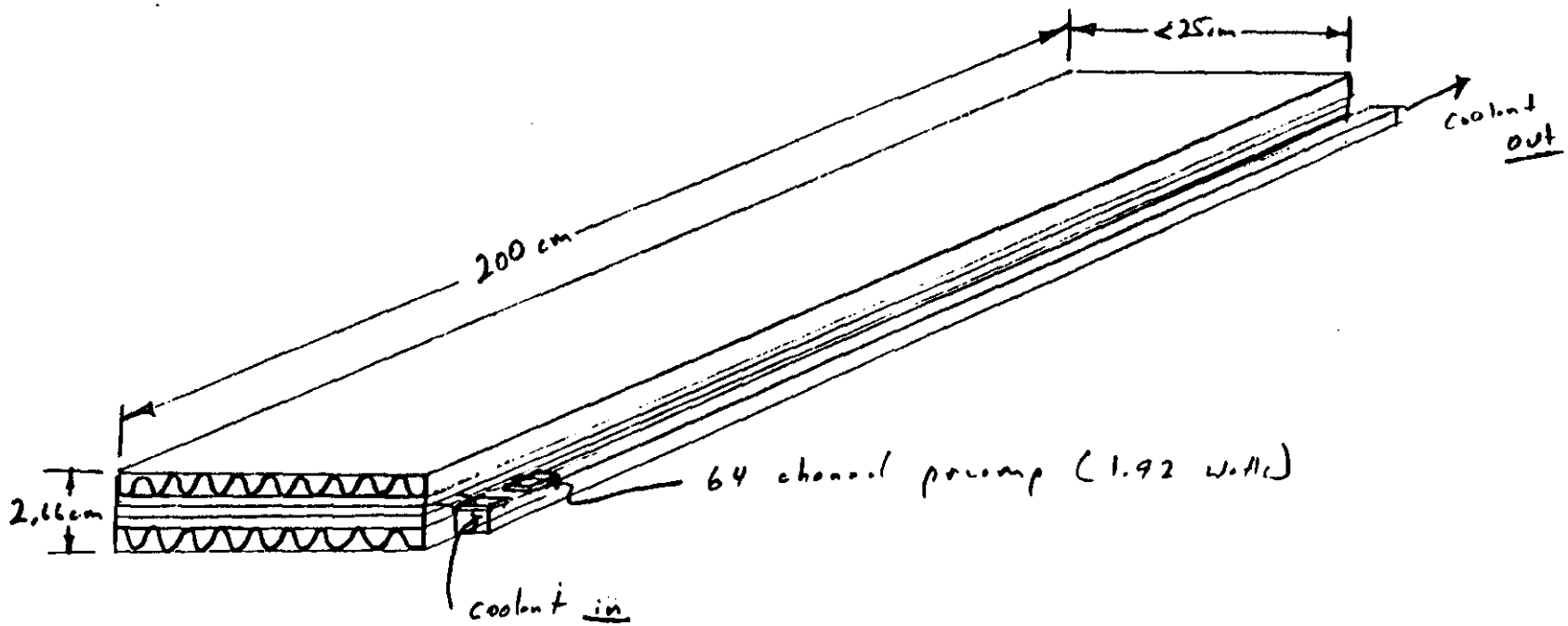
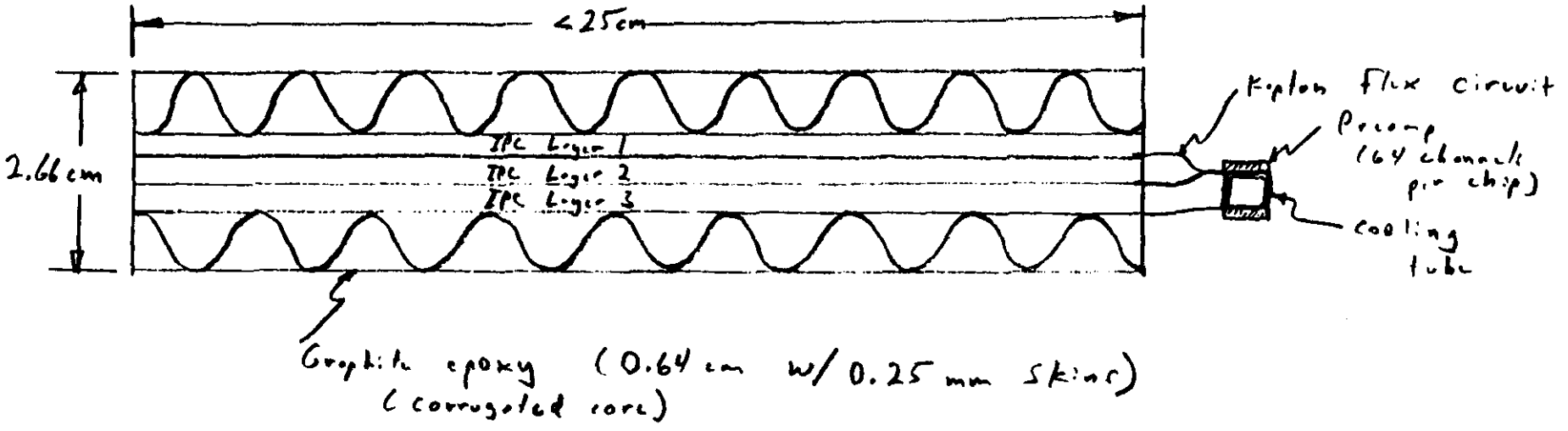


— Isometric View of Typical Barrel IPC Superlayer —

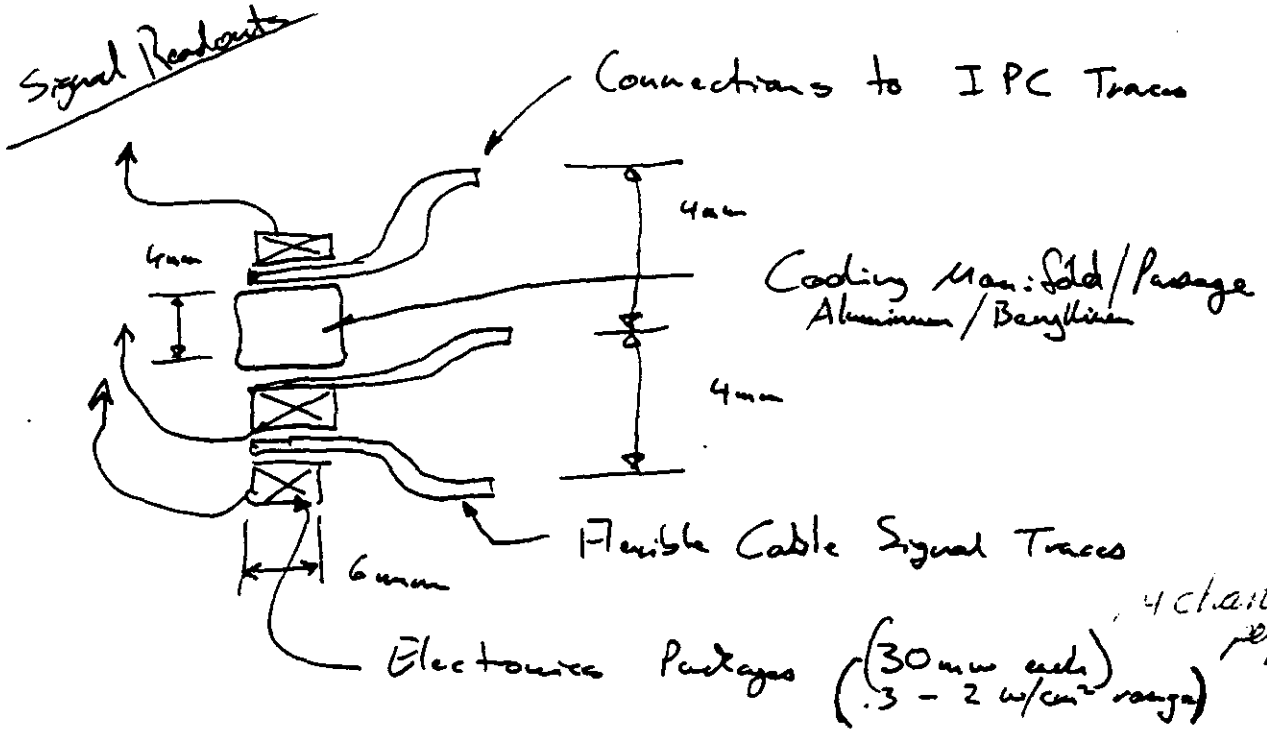


— Sectional View of Typical Barrel IPC Superlayer —

$L_R < 2.38\ \% /$ Superlayer

WTE 10/31/01

Cooling Manifold (Electronics)



Manifold lengths - Max 2 m Barrel Region
Min .5m Fwd Region

Total Heat load/length Max 50 watts ~~[illegible]~~/Super layer
(3 layers/Super layer)

Room Temperature Operation

Self Contained 2 phase evaporative System From 11 74°F

GEM IPC COOLING

COOLING FLUID OPTIONS

1) SINGLE PHASE COOLING WITH WATER

ADVANTAGES

Inexpensive.
Nontoxic.
Nonflammable.
Environmentally safe.
Adequate heat transfer with reasonable ΔT, ΔP.
Symplified system control.

DISADVANTAGES

Leaks may be catastrophic.
Inlet-to-outlet ΔT.
Larger radiation length with all liquid.

WATER COOLING PERFORMANCE "MAP"

GEOM (cm)	V (M/S)	ΔP (kPa)	T_E-T_W (C)	ΔT_W (C)
1 X .2	1.0	11.4	3.3/8.7	0.36
1 X .1	1.0	27.5	2.9/7.7	0.65
1 X .05	1.0	52.8	7.1/19	1.30
1 X .1	2.0	86	1.7/4.4	0.33

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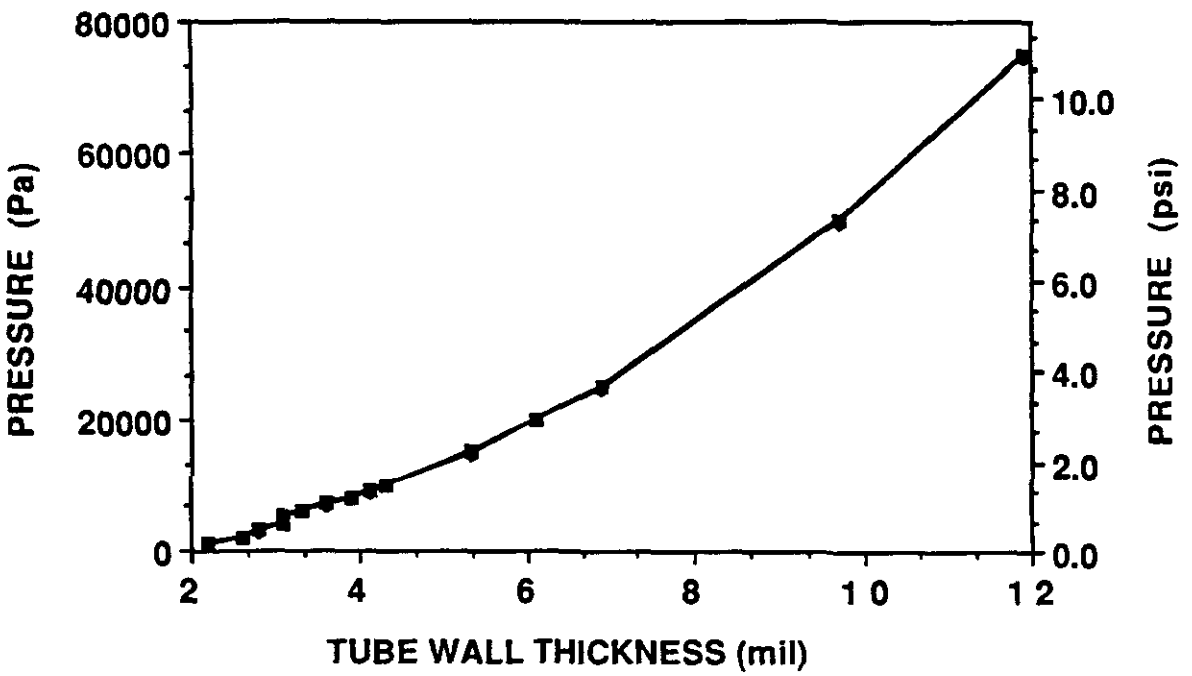
GEM IPC COOLING

COOLING TUBE WALL THICKNESS

Minimum tube wall thickness as a function of gage pressure, based on following assumptions:

Hardened aluminum alloy (i.e. 5052-H38)
Flat plate, all edges fixed approximation.
1.0 cm by ∞ plate dimensions.
Maximum stress = 1/3 yield stress.



LANL 1/9/92

GEM IPC COOLING

COOLING FLUID OPTIONS

2) TWO PHASE (EVAPORATIVE) COOLING.

ADVANTAGES

Inexpensive.*
Nontoxic.*
Nonflammable.*
Environmentally safe.*
Adequate heat transfer with reasonable ΔT, ΔP.
Leaks may be tolerable.
No inlet-to-outlet ΔT.
Minimal radiation length.

DISADVANTAGES

HS&E concerns, depending on fluid.
More difficult to control flow conditions (P, V, x).

* Depends upon fluid selected.

R-11 2-PHASE COOLING PERFORMANCE "MAP"

GEOM (cm)	G (kg/M^2-S)	X	ΔP (kPa)	T_E-T_W (C)
1 X .2	50	0.8	3.5	7.9/14.0
1 X .1	50	0.5	1.7	8.0/14.4
1 X .2	300	0.5	41.0	3.8/8.5
1 X .2	400	0.5	69.4	3.1/7.1

LANL 1/9/92

GEM IPC COOLING

EVAPORATIVE COOLING FLUID OPTIONS

Want a fluid that will evaporate at near ambient temperature and at atmospheric pressure, primarily to keep the gage pressure near zero so that the cooling tube wall thickness can be kept to a minimum.

Some viable candidates are:

R-11 (CCl_3F) B.P. 24°C

Inexpensive, nontoxic, nonflammable, but ozone depleting; use subject to DOE use guidelines.

ISOPENTANE (C_5H_{12}) B.P. 28°C

Inexpensive (?), toxic, flammable, ozone safe; use subject to DOE use guidelines. Bureaucracy associated with flammable hydrocarbons may be easier to satify than that with freons.

DIBROMODIFLUOROMETHANE (Br_2CF_2) B.P.24°C

Expensive, nontoxic, nonflammable, probably ozone depleting but not on DOE hit list.

LANL 1/9/92

TO: GEM TRACKER GROUP
FROM: W. EMMET/YALE PPG
RE: GEM IPC TRACKER "ONBOARD" ELECTRONICS
DATE: JANUARY 9, 1992

I had a telephone conversation with Paul O'Connor at Brookhaven National Labs regarding the onboard electronics for both the barrel and the endcap IPC layers. The following is known:

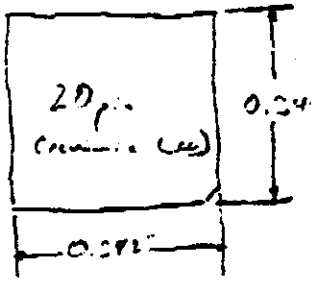
1) Two chips per 16 channels:

   a) Preamp/shaper (PD (estimate) is 50 mW/channel)
   b) Analog storage (PD (estimate) is 10 mW/channel)

2) Multiplexer chip (serves 256 channels; 16 outputs):

   a) PD (estimate) is 300 mW total (or 1.2 mW/channel)

3) The package type will be LSI-sized and will probably be a leadless chip carrier (LCC). Estimated dimensions (WTF) would be 0.342" x 0.342" minimum.



$16 \times 0.05\,W = \frac{0.8\,W}{(.342\,in)^2} = 6.84\ W/in^2$ worst-case power density

$P_D \sim 62\ mW/channel$

$Vol = (0.342)^2(.080) = 0.0094\ in^3$

Assume Alumina (Al_2O_3)

$\rho = \frac{(3.85)(62.4\ lb/ft^3)}{1728\ in^3/ft^3} = 0.14\ lb/in^3$

$Wt/chip = (0.14\ lb/in^3)(0.0094\ in^3) =$
$= 0.0013\ lb\ (0.021\ oz)$

Keith —

<u>Worst case</u> for a "super layer" is <u>210</u> watts

→ 214 chips (107 buffers & 107 analog storage)

+ 14 multiplexer chips

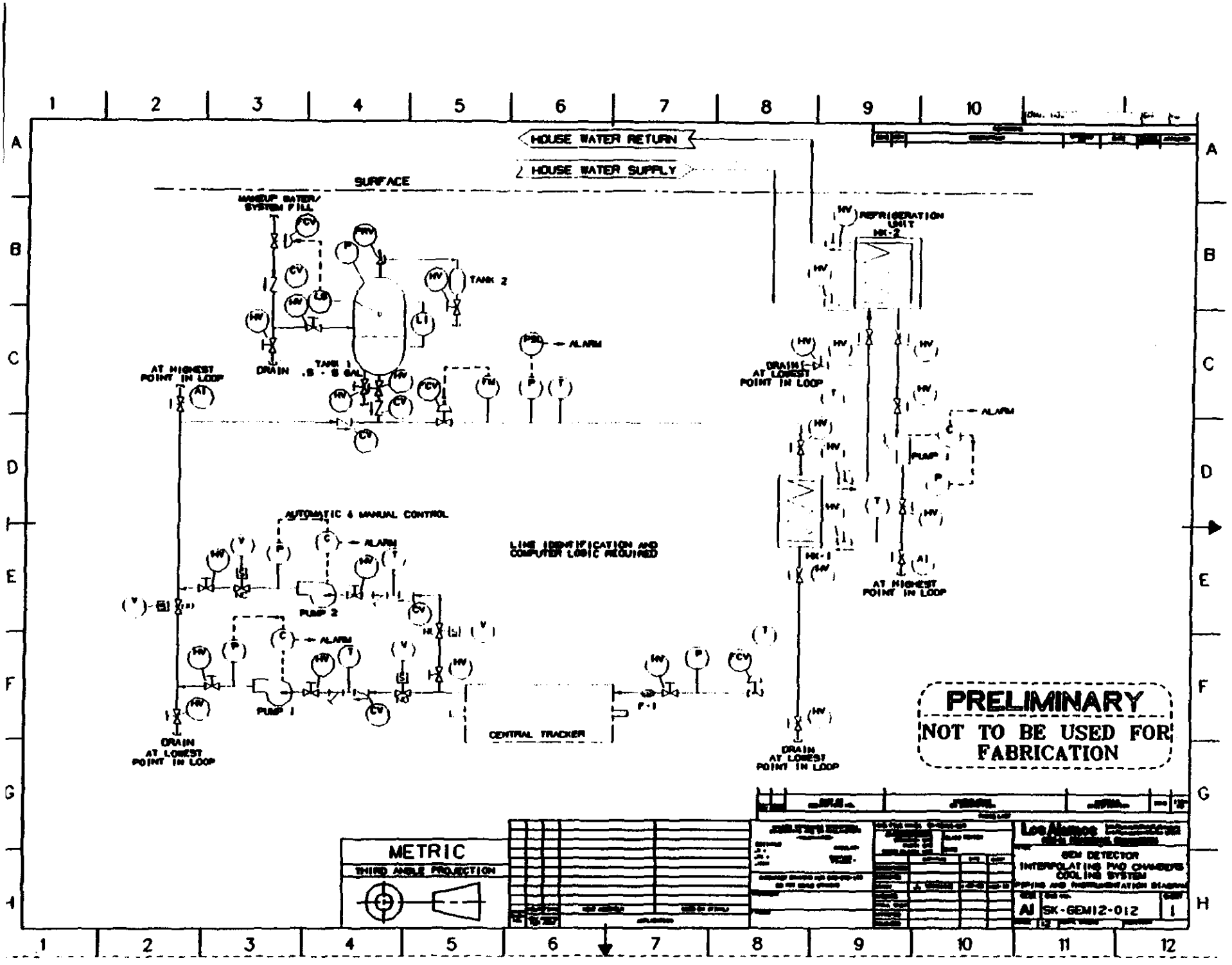
→ Each chip has area of ~ 0.342" × 0.342"

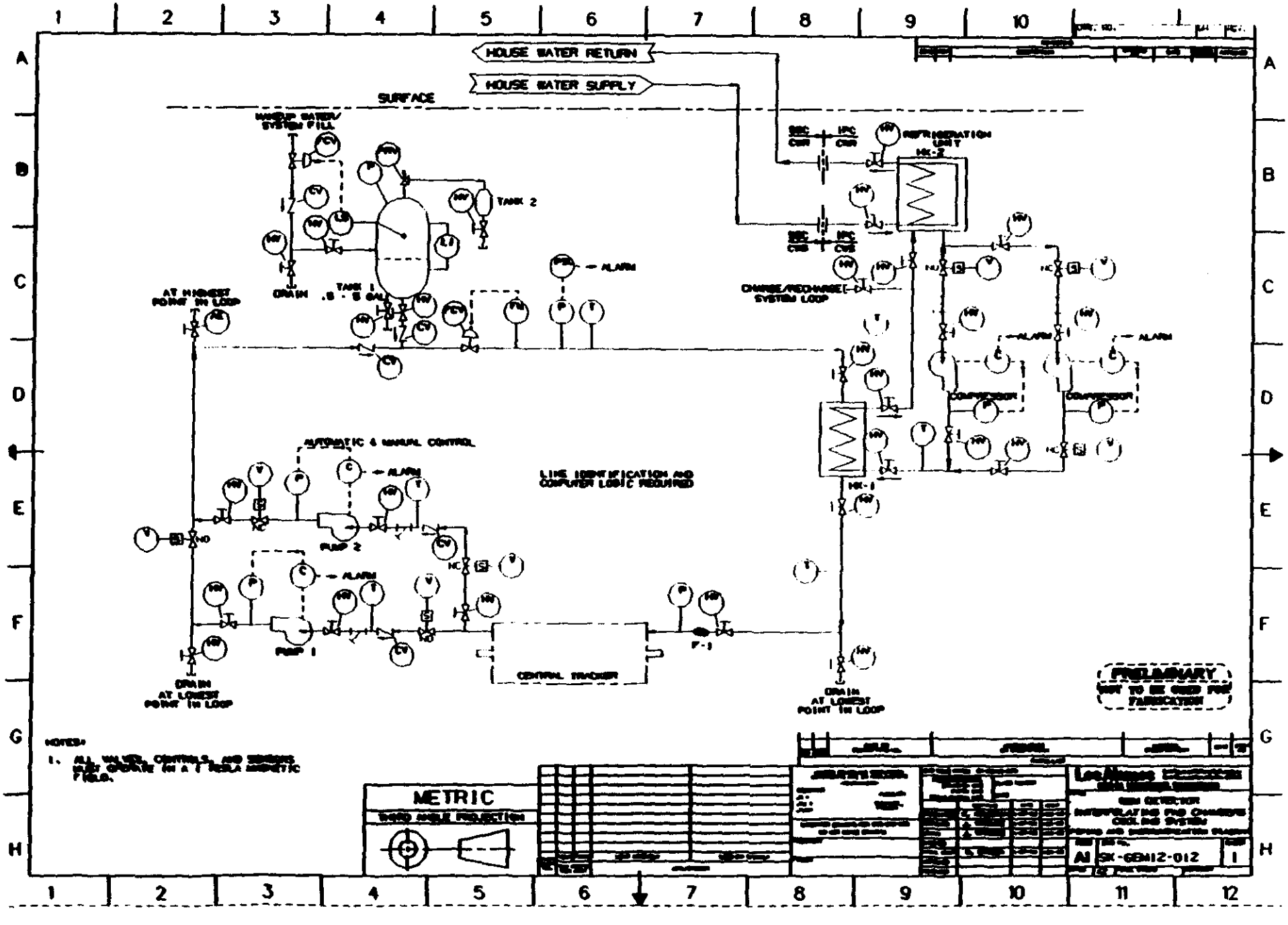
(lead less chip carrier)

Will Emmet

CEM Tracking

Yale University Physics Dept.


HOUSE WATER RETURN
HOUSE WATER SUPPLY
SURFACE
MAKEUP WATER/ SYSTEM FILL
TANK 2
TANK 1 .5 - 5 GAL
DRAIN
AT HIGHEST POINT IN LOOP
ALARM
REFRIGERATION UNIT HX-2
DRAIN AT LOWEST POINT IN LOOP
AUTOMATIC & MANUAL CONTROL
LINE IDENTIFICATION AND COMPUTER LOGIC REQUIRED
PUMP 2
PUMP 1
HX-1
F-1
CENTRAL TRACKER
PRELIMINARY
NOT TO BE USED FOR FABRICATION
METRIC
THIRD ANGLE PROJECTION
Los Alamos
GEM DETECTOR
INTERPOLATING PAD CHAMBERS COOLING SYSTEM
PIPING AND INSTRUMENTATION DIAGRAM
A1
SK-GEM12-012
1


HOUSE WATER RETURN
HOUSE WATER SUPPLY
SURFACE
MAKEUP WATER/ SYSTEM FILL
TANK 2
TANK 1 .5 - 5 GAL
DRAIN
AT HIGHEST POINT IN LOOP
ALARM
REFRIGERATION UNIT
HX-2
CHARGE/RECHARGE SYSTEM LOOP
COMPRESSOR
AUTOMATIC & MANUAL CONTROL
LINE IDENTIFICATION AND COMPUTER LOGIC REQUIRED
PUMP 2
PUMP 1
CENTRAL TRACKER
F-1
HX-1
DRAIN AT LOWEST POINT IN LOOP
PRELIMINARY
NOT TO BE USED FOR FABRICATION
NOTES:
1. ALL VALVES, CONTROLS, AND SENSORS MUST OPERATE IN A 1 TESLA MAGNETIC FIELD.
METRIC
THIRD ANGLE PROJECTION
GEM DETECTOR
INTERPOLATING PAD CHAMBERS COOLING SYSTEM
A1
SK-GEM12-012
1

J. Hausser

IPC Front End Design

Signal to Noise

For C_{in} = 10 pf, 20 ns peaking time, series noise of front end amplifier approx. 1000 e's. (Based on scaling of C_{in} and T from existing designs)

To obtain 50 micron resolution from 5mm pads, need signal/noise greater than 200. Based on simulation performed at BNL.

For 50-50 CF4 - CO2, 60 ion pairs/4mm

Cathode signal signal smaller than full wire signal

- x 3 due to division onto two cathodes, nearby wires
- x 5 due to loss of full induced ion signal due to shaping time.

Gas Gain Required

gain = 1000 * 200 * 5 * 3 / 60 = 50,000

IPC Front End Design

Induced Signal Amplitude vs Shaping Time

$$q(t)/q = (0.5\ln(r_a/r_c))^{-1}\ln(1 - t/t_0) \qquad \text{(Cyl.Symmetry)}$$

$$t_0 = (r_a^2/2\mu_+ V)\ln(r_a/r_c)$$

Present Baseline Parameters

$r_a = 40\mu m$

$r_c = 2000\mu m$

$V = 3000V$

$\mu_+ = 1\text{x}10^3 cm^2/kV - s$

$t_0 = 2.5ns$ using parameters above

$q(20ns)/q = 0.25$

IPC Front End Design

Rate Effects

rate/wire @ 10^{34}
mult/event = $1.2/d\eta d\phi$
events/crossing = 16
x2 for secondaries

tracks/crossing = 720 @ 10^{34}

rate/chamber = $720 \times 62\times10^{6} / 20 = 2 \times 10^{9}\ s^{-1}$

rate/mm wire = $1 \times 10^{4}\ s^{-1}$ <-- Must check whether one can operate at these rates

Aging

$q = (1 \times 10^{5})(1.6 \times 10^{-19})(5 \times 10^{4})(60)(3 \times 10^{7})$
rate/cm gain # pairs
q = 1.4 C/cm-yr

Aging of 50-50 CF_4-CO_2
$(I - I_0) / I_0 = 0.07\ C^{-1}\ cm$

γeμ

IPC Design

Pad Capacitance

For two adjacent conductors, width=w, thickness=t, sep.=d on dielectric material with dielectric constant k.

$$C(pf/in)=0.31\ t/w +0.23(1+k)\ \log_{10}(1+2w/d+(w/d)^2)$$

All dim in.s

For t=0.0006", d=0.006",w=0.2" , k=5

C= 1.6 pf/cm

For w=0.08"

C= 1.25 pf/cm

For chevron pad, edge length = 10 chevron length
chevron length range = 1.7 cm - 11cm
(for 0.5 cm pad width,0.2 cm wire spacing)

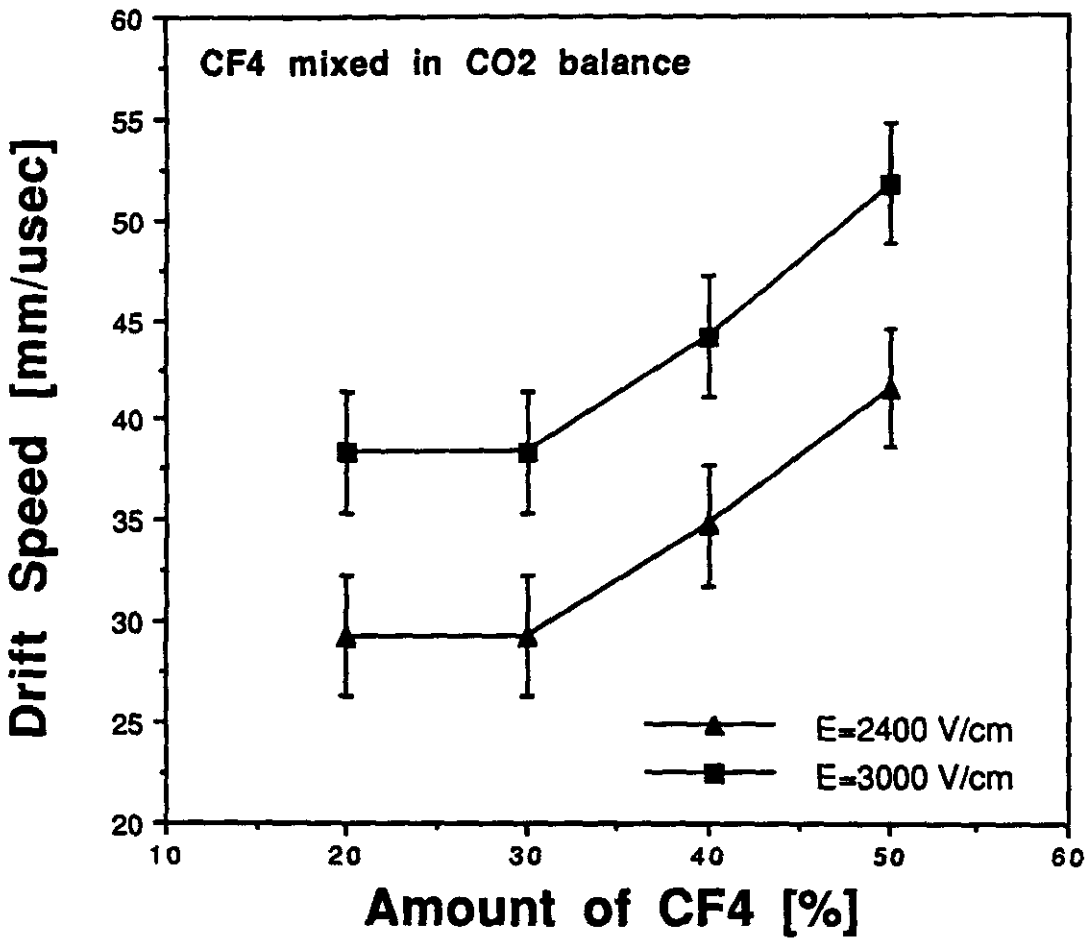
Capacitance Range = 30-177 pf

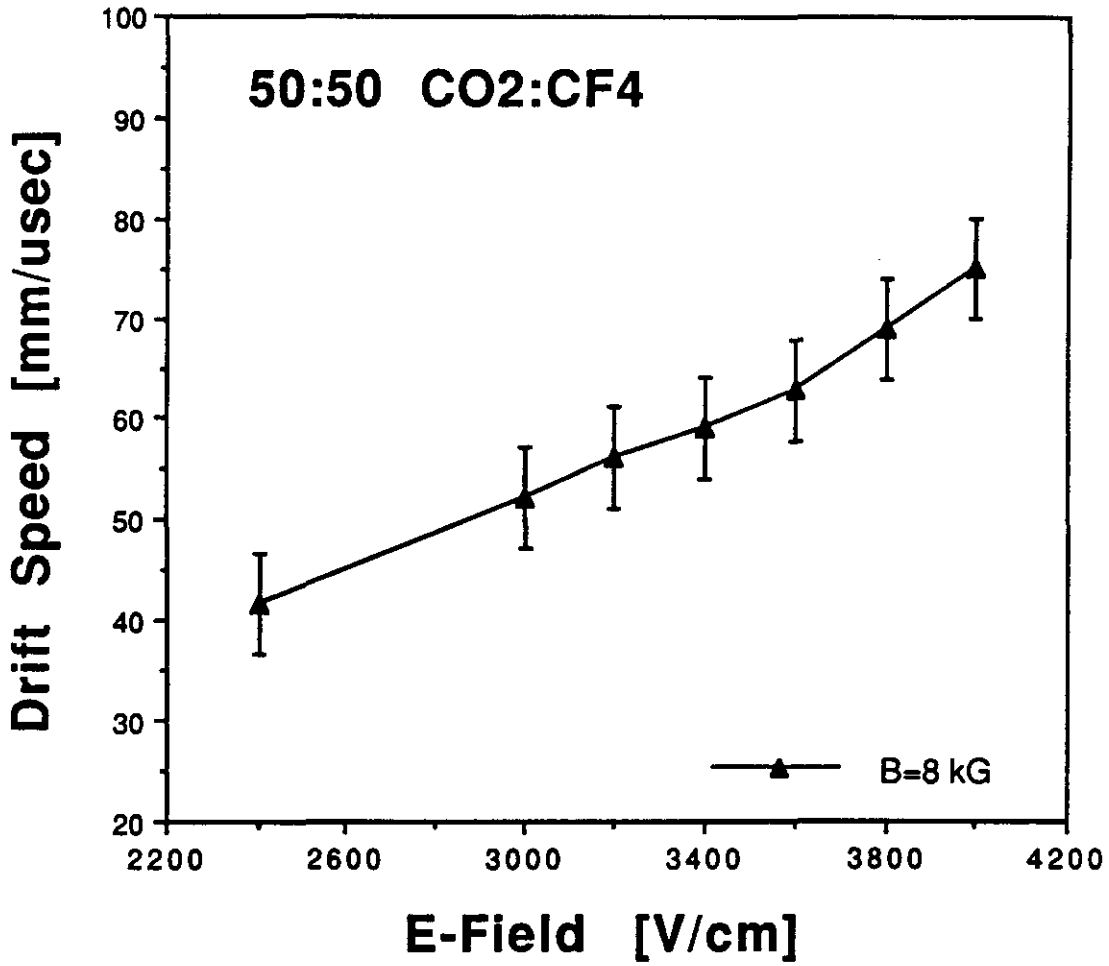
For straight pad, edge length = 2 chevron length, but width must be < 0.2 cm.

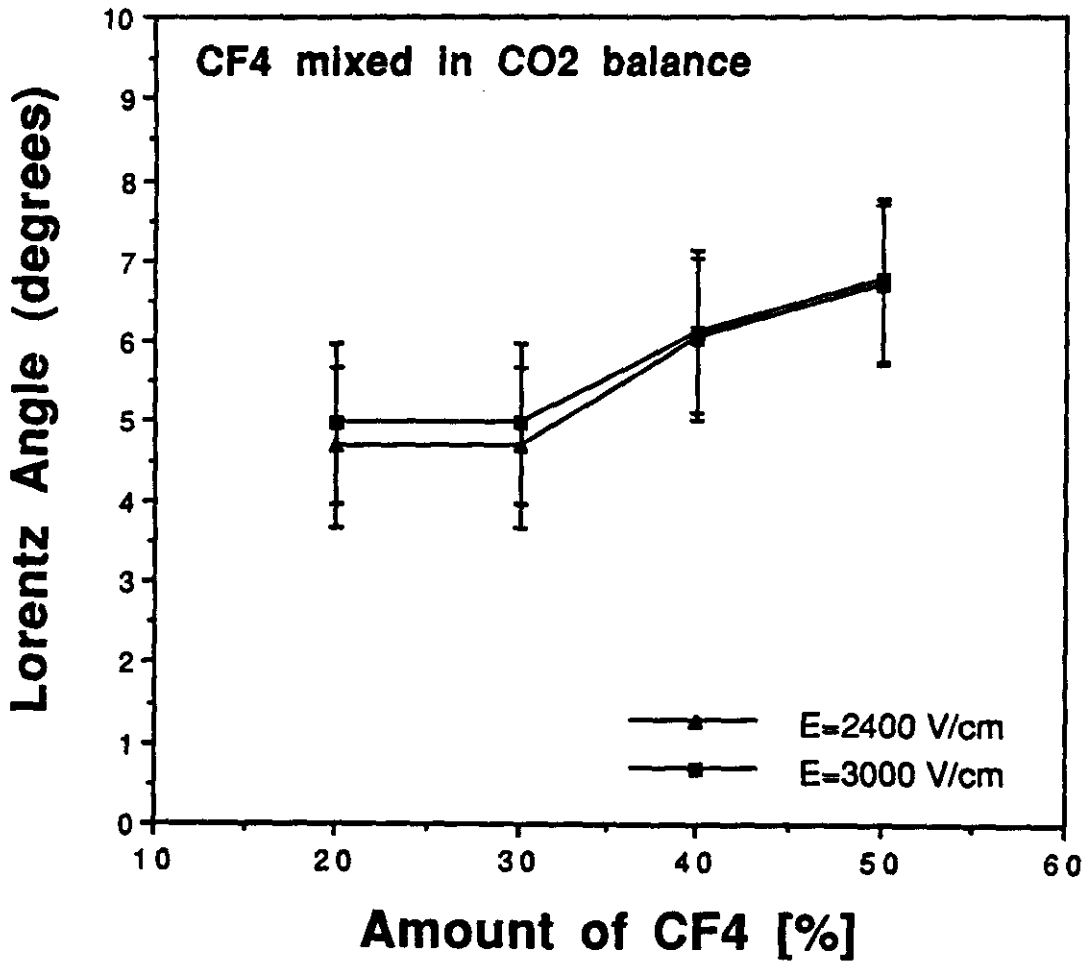
Pad length range = 3.4cm - 22 cm

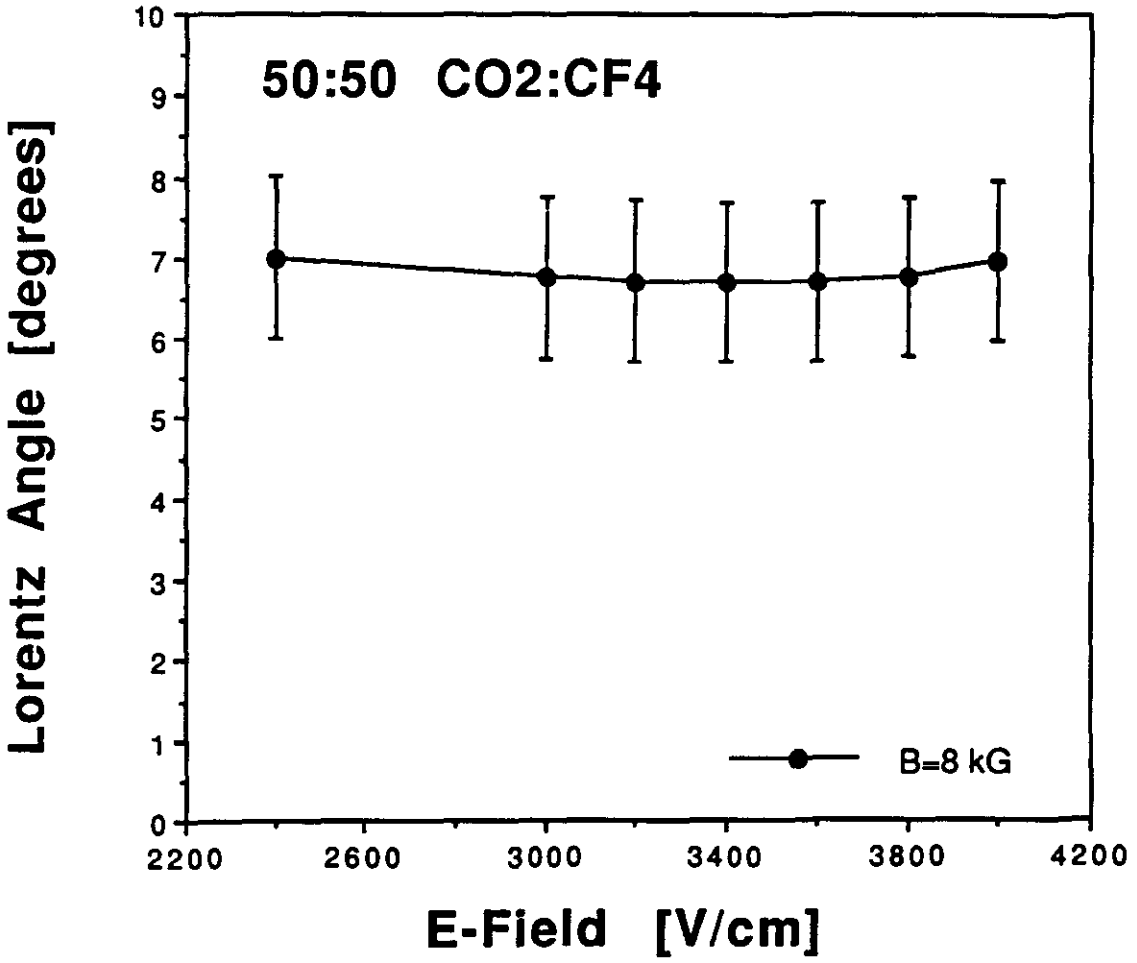
Capacitance Range = 10 pf - 70 pf

γεμ

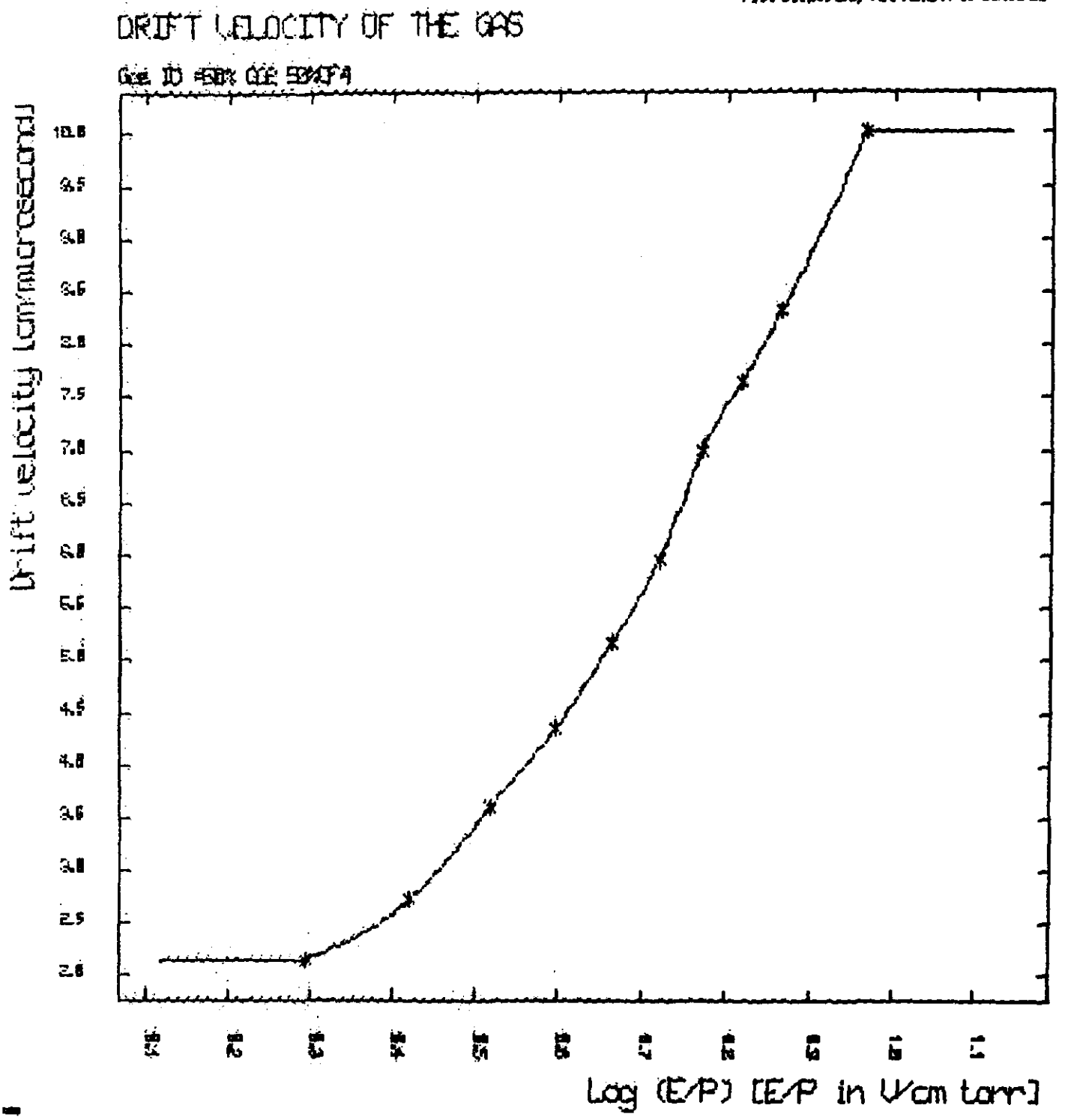

CF4 mixed in CO2 balance
Drift Speed [mm/usec]
Amount of CF4 [%]
E=2400 V/cm
E=3000 V/cm
60
55
50
45
40
35
30
25
20
10
20
30
40
50
60


50:50 CO2:CF4
Drift Speed [mm/usec]
E-Field [V/cm]
B=8 kG
100
90
80
70
60
50
40
30
20
2200
2600
3000
3400
3800
4200

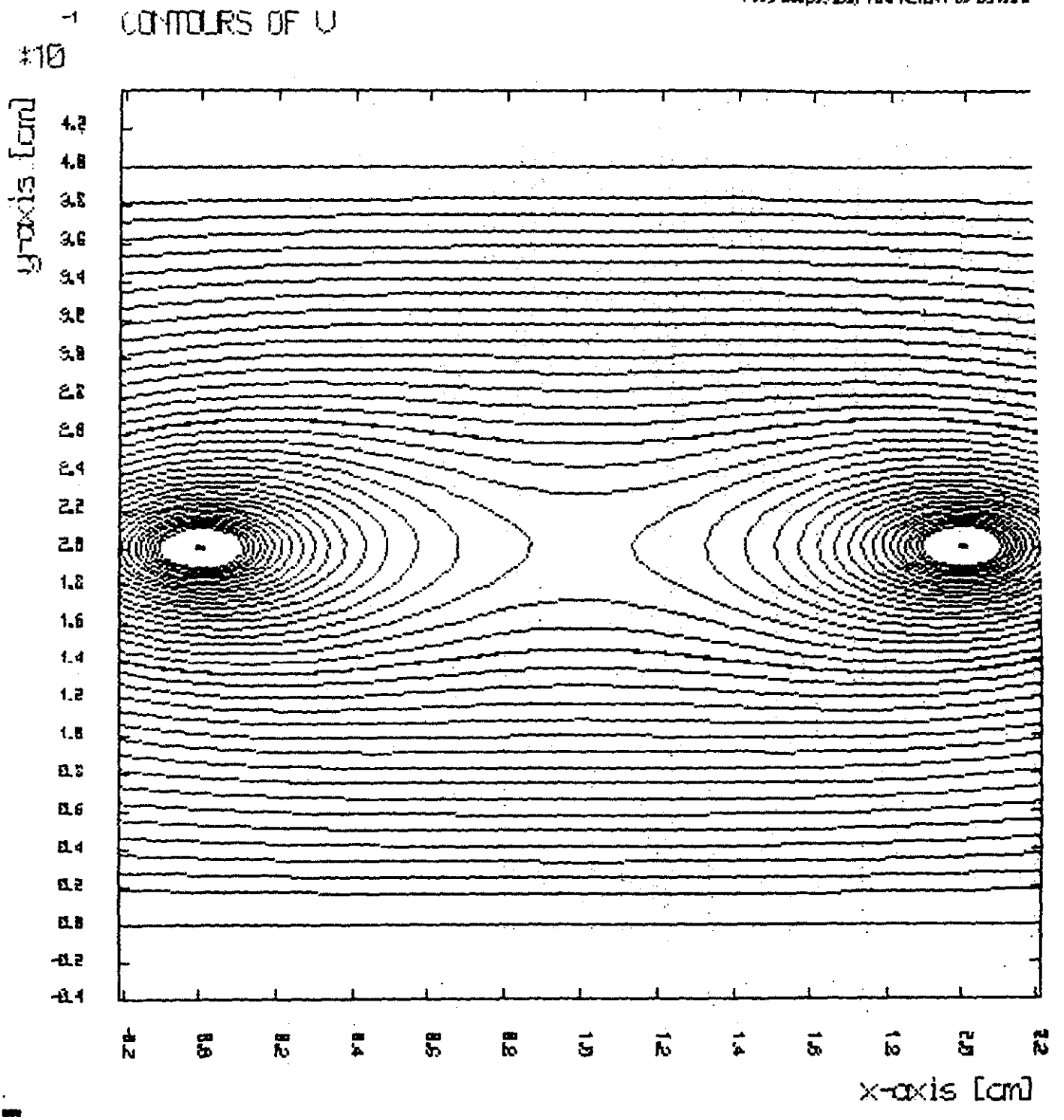

CF4 mixed in CO2 balance
Lorentz Angle (degrees)
Amount of CF4 [%]
E=2400 V/cm
E=3000 V/cm
0
1
2
3
4
5
6
7
8
9
10
10
20
30
40
50
60

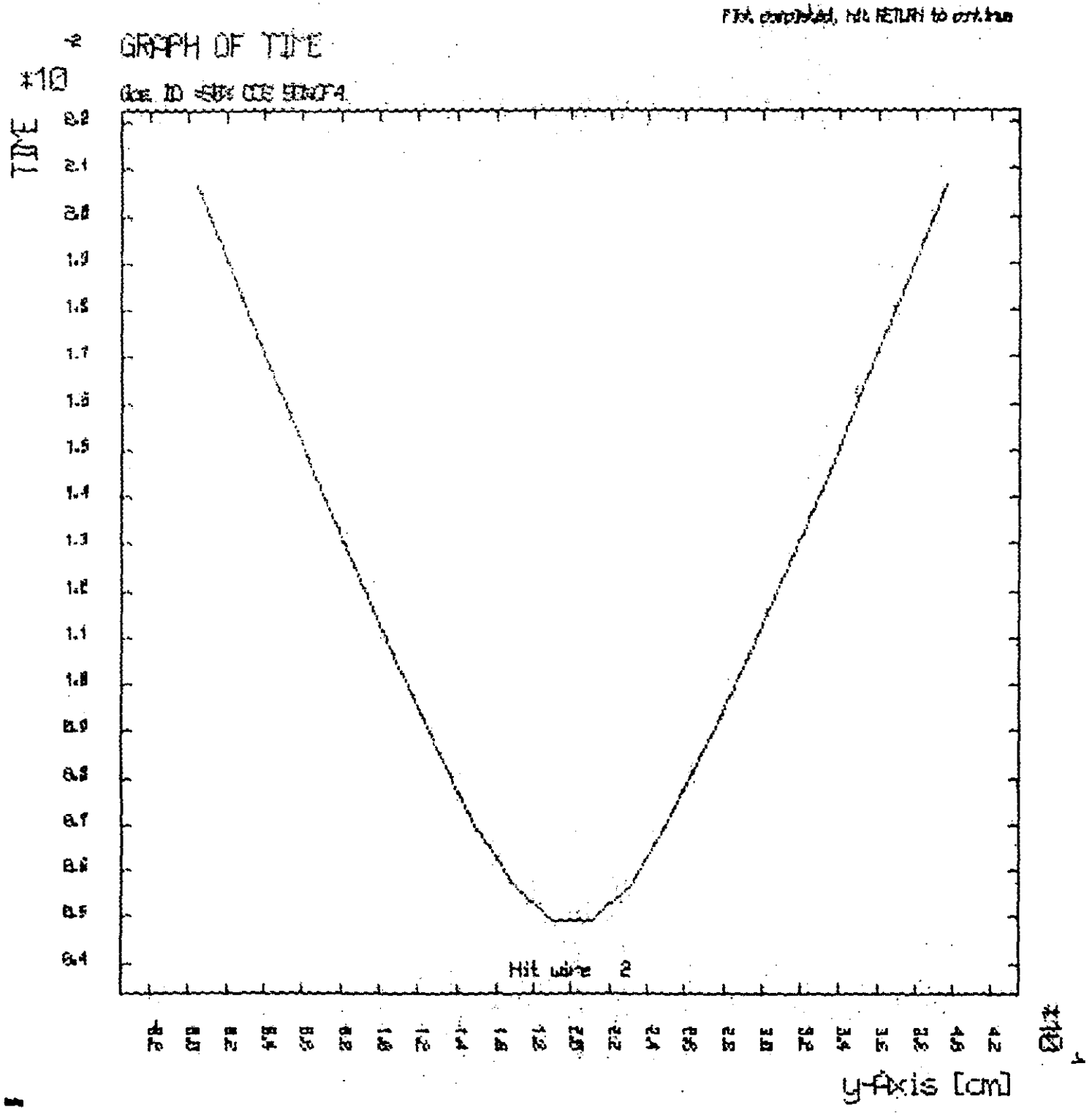

50:50 CO2:CF4
Lorentz Angle [degrees]
E-Field [V/cm]
B=8 kG
0
1
2
3
4
5
6
7
8
9
10
2200
2600
3000
3400
3800
4200

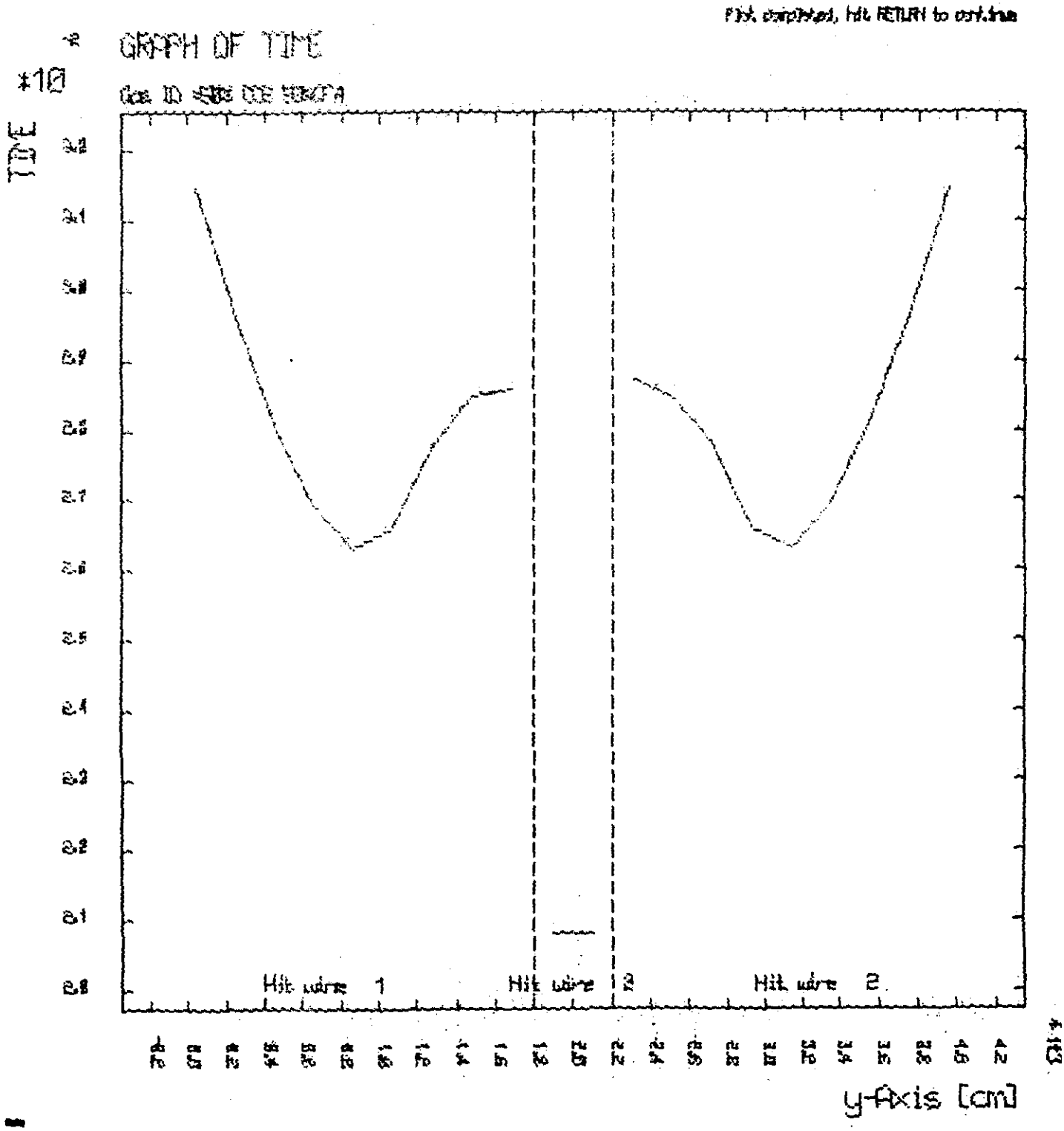
Plot completed, hit RETURN to continue



Plot completed, hit RETURN to continue




GRAPH OF TIME
TIME
*10
Hit wire 2
y-Axis [cm]

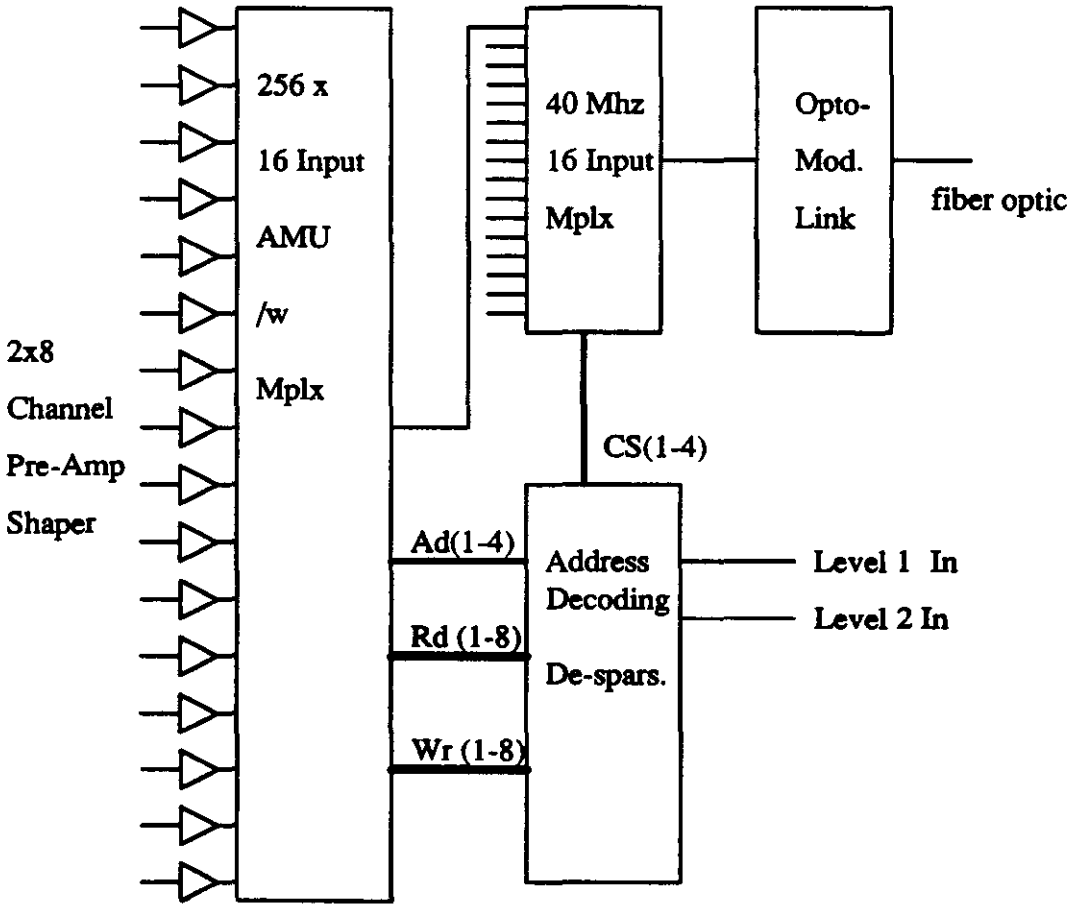

GRAPH OF TIME
TIME
Hit wire 1
Hit wire 3
Hit wire 2
y-Axis [cm]

Preliminary IPC Electonics Cost Estimate

Milestones

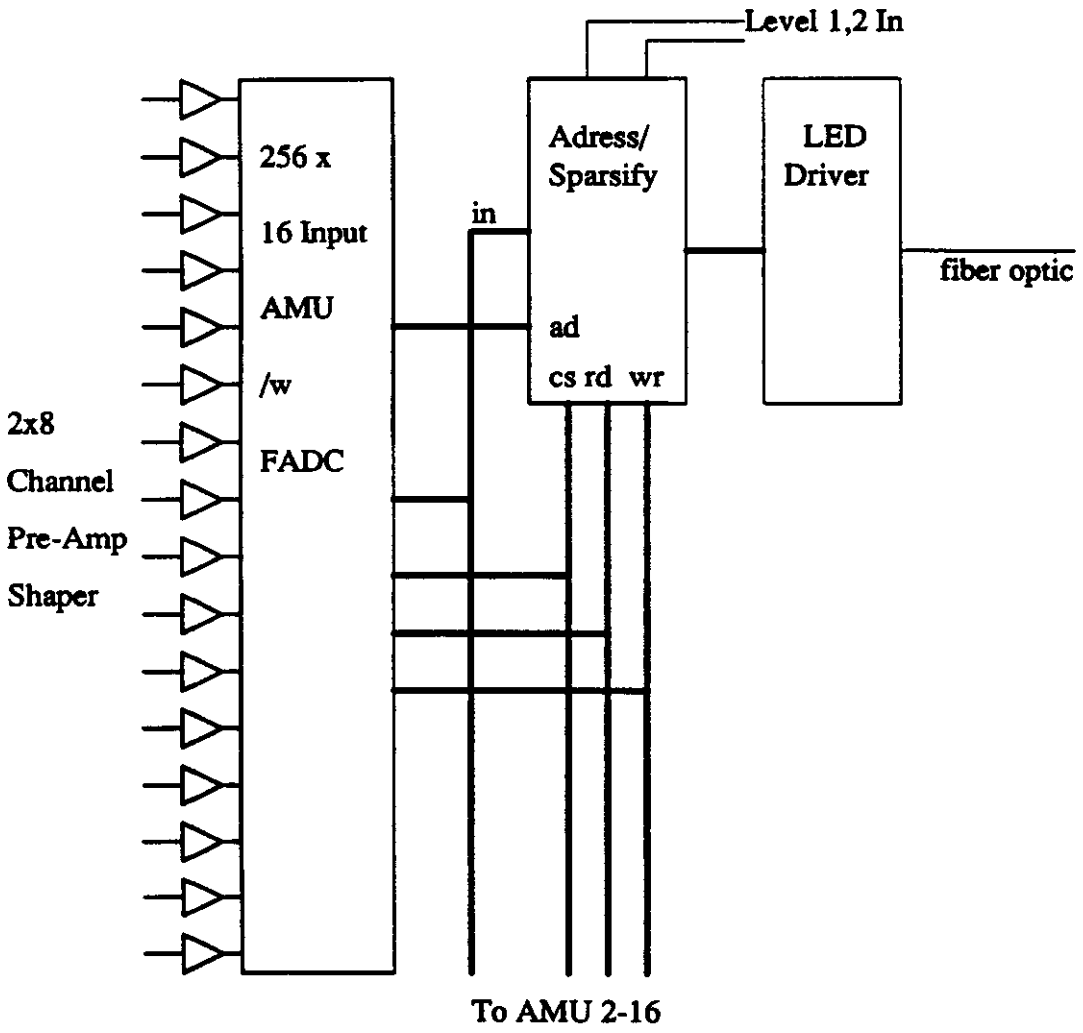
- Baseline Design Costed
  (Paul O'Connor)
  Sept 91
- Baseline Presented to Lecroy for LoI Costing
  Oct 91
- Preliminary LoI Costing Completed by LeCroy
  Dec 91
- LeCroy Costing /w mod.s in WSB format
  mid Feb 91

IPC Electronics Baseline Design



IPC Electronics Baseline Design

On-Chamber Digitization Option



γεμ

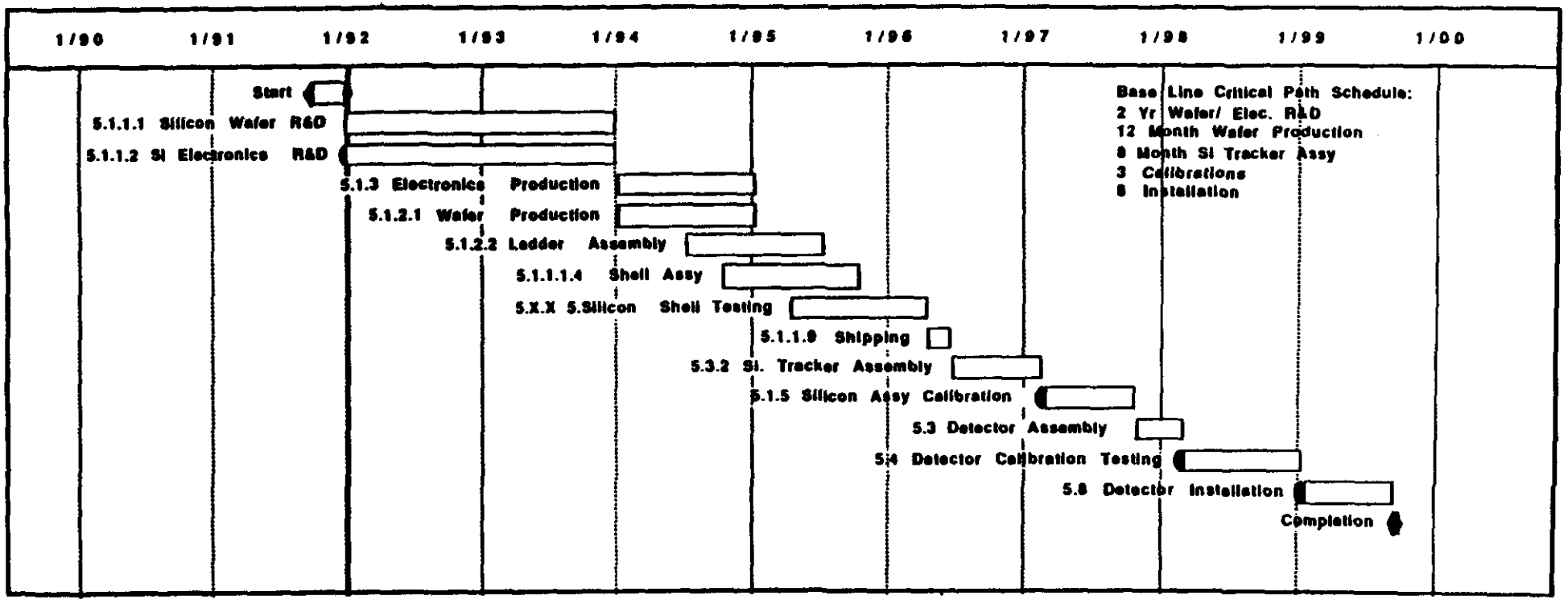
Central Tracker Meeting
1/23/1992 SSCL

Ron Barber

Mechanical Engineering Topics

- Schedule
  - R&D Priorities
- Silicon Tracker
  - Silicon Tracker Layout
  - Wafer Design
  - Ladder Assembly
  - Ladder to Ring Assembly
  - Beam Tube
- IPC Tracker
  - Cooling System
  - External Support
  - IPC Module Panels
- Radiation Length Calculations
  - Silicon Tracker
  - IPC Modules
- Cost Status

GEM Silicon Tracker Critical Path Items



Silicon Tracker Mechanical R&D

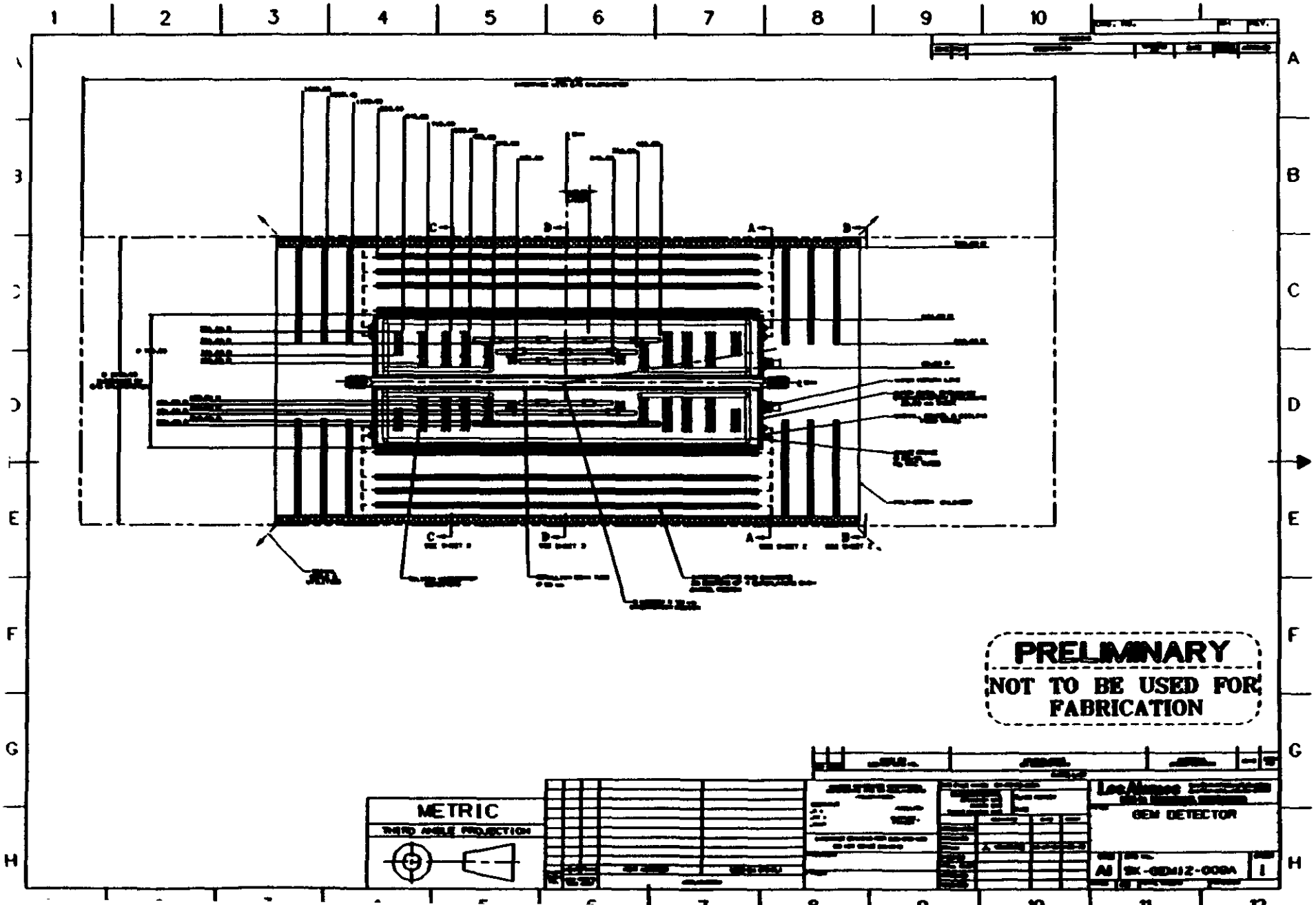
Develop and Test a Silicon Ladder Prototype

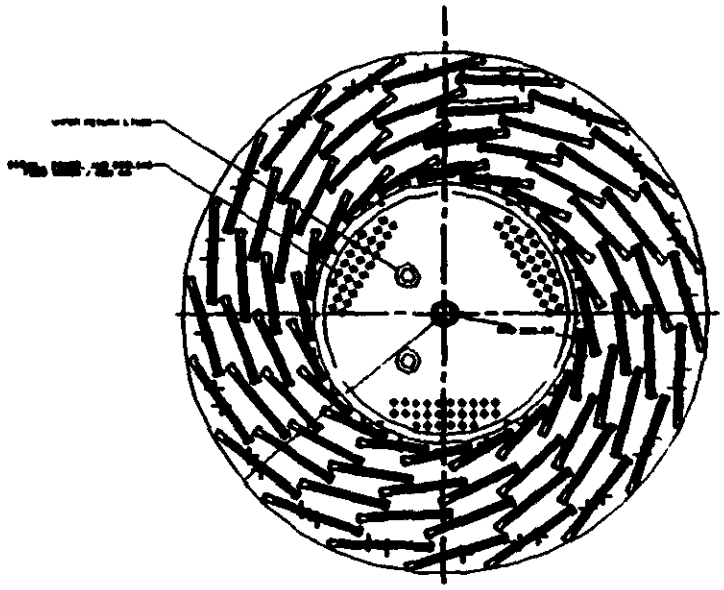
- Ladder Structural design and analysis
- Design and specification of Silicon Wafers
- Evaluation of fabrication sources and production planning
- Prototype development
- Develop assembly and bonding process to maintain back to back alignment
- Wafer bonding adhesive tests
- Assembly tooling fabrication and testing
- Prototype Structural Test
- Thermal modeling of multiple heat sources on the wafer
- Thermal mock up and measurement evaluation
- Power input cabling design for electronics and bias voltage
- Signal cable output and strain relief
- Local power distribution and connections.
- Develop Electronics assembly tooling

GEM Post LOI Silicon Tracker Parameters

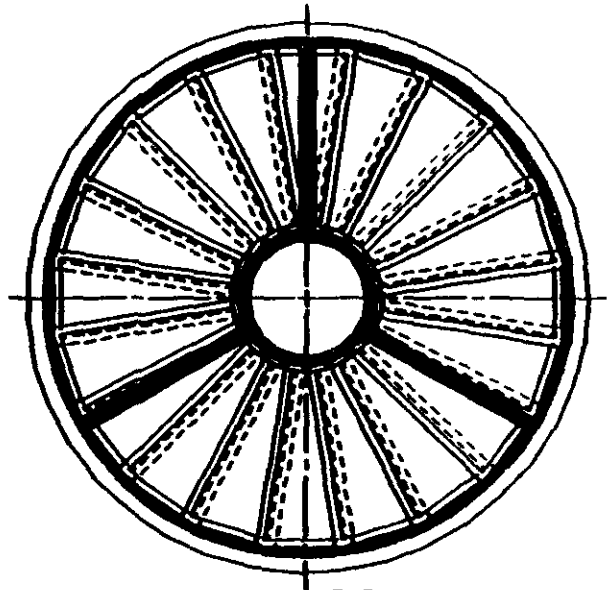
1/19/92

	Radius cm	Wafer size	# C Wafers 2Xπd/3.2	#L Wafers Length	Tot # Waf. #C x #L	Wafer area # 3.4x6/1e4	# Readouts #Waf/2	# strip Elec #RO X640	# Rings
Central Region Barrel (12 cm Ladder)									
Outer Ring	23.1	6x3.5	91	16	1451	2.959387	725	464217.6	
	21	6x3.5	82	16	1319	2.690352	659	422016	10
Middle Ring	17.1	6x3.5	67	12	805	1.643036	403	257731.2	
	15	6x3.5	59	12	707	1.44126	353	226080	6
Inner Ring	12.1	6x3.5	47	8	380	0.775078	190	121580.8	
	10	6x3.5	39	8	314	0.64056	157	100480	6
Central Region Sub Total					**4975**	**10.1497**	**2487.665**	**1.59E+6**	**22**
						61%			
Forward Planar Region (both sides)									
	I. Radius cm.	O. Radius cm	# C Wafers 2xπd/3.2	# L Wafers 4 or 8/sp.	Tot # Waf.	Waf. Area (^2-IR^2)x8	# Ladders(RO) #C.Wafx4	#strip Elec #ROX640	
1a	10	14	55	4	220	0.24	220	140672	4
2a	10	14	55	4	220	0.24	220	140672	4
2b	14	20	79	4	314	0.51	314	200960	4
3a	10	14	55	4	220	0.24	220	140672	4
3b	14	26	102	8	816	1.21	408	261248	4
4a	10	14	55	4	220	0.24	220	140672	4
4b	14	26	102	8	816	1.21	408	261248	4
5a	10	14	55	4	220	0.24	220	140672	4
5b	14	26	102	8	816	1.21	408	261248	4
6b	14	26	102	8	816	1.21	408	261248	4
Forward Region Sub Total					**4678.6**	**6.54**	**3046**	**1.95E+6**	**40**
						39%			
Totals					**9654**	**16.69**	**5533**	**3.54E+6**	62
						(Meter sq. of SS Silicon)			
						8.35	Sq. meters Frontal Area		


PRELIMINARY
NOT TO BE USED FOR FABRICATION
METRIC
THIRD ANGLE PROJECTION
GEM DETECTOR
A1
SK-GEM12-009A
1



SECTION A–A
FROM SHEET 1



SECTION B–B
FROM SHEET 1

PRELIMINARY

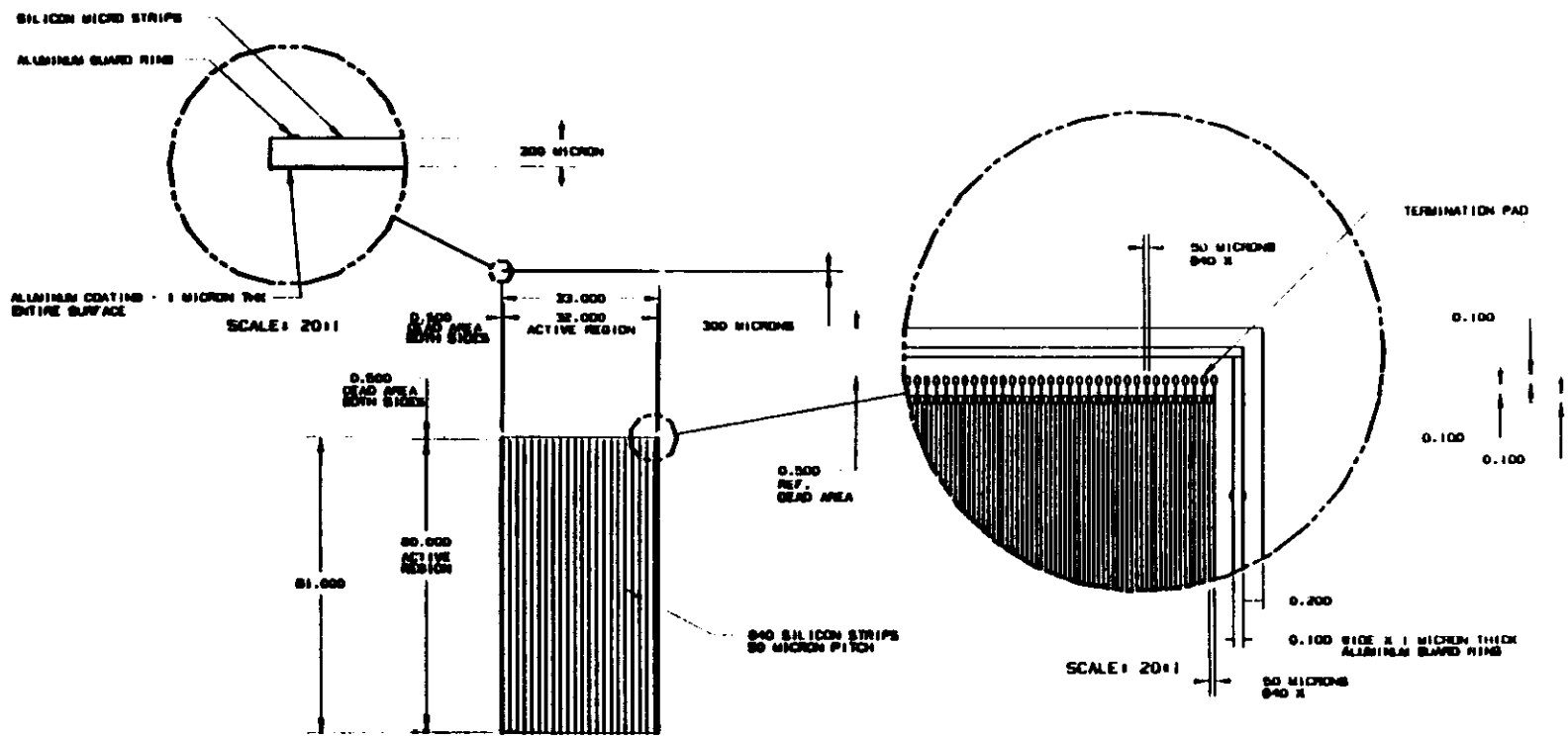
NOT TO BE USED FOR FABRICATION

METRIC

THIRD ANGLE PROJECTION

GEM DETECTOR

A1 SK-GEM12-009A 2



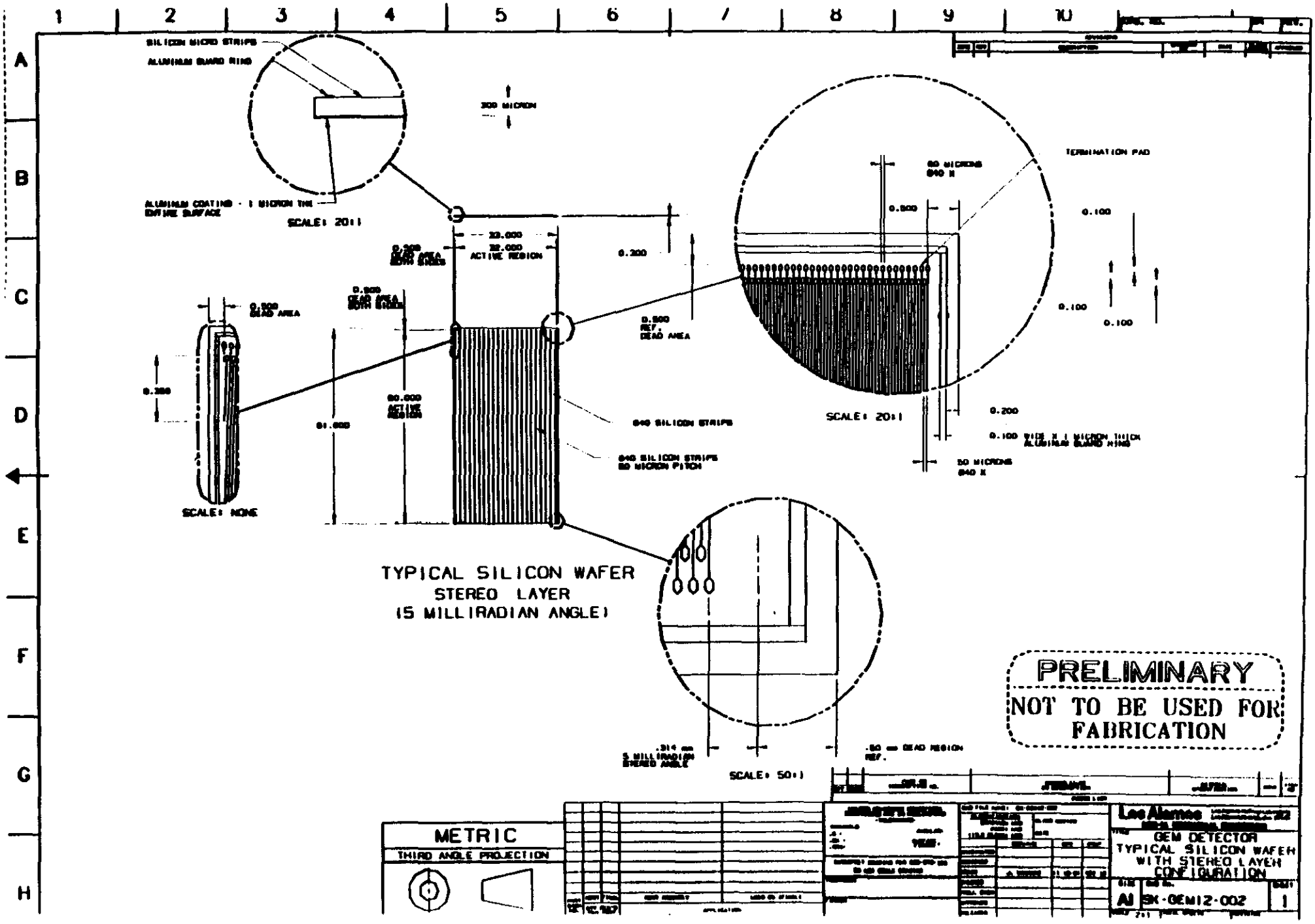
TYPICAL SILICON WAFER
X - LAYER

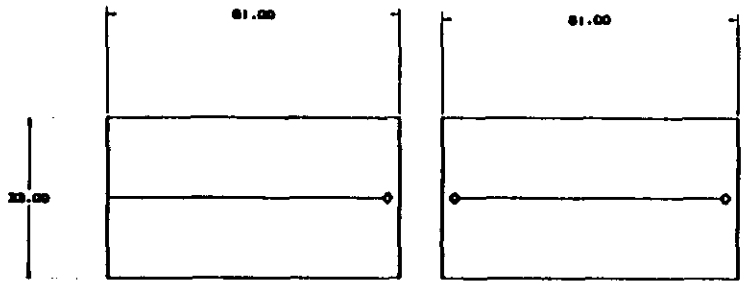
PRELIMINARY
NOT TO BE USED FOR FABRICATION

METRIC
THIRD ANGLE PROJECTION

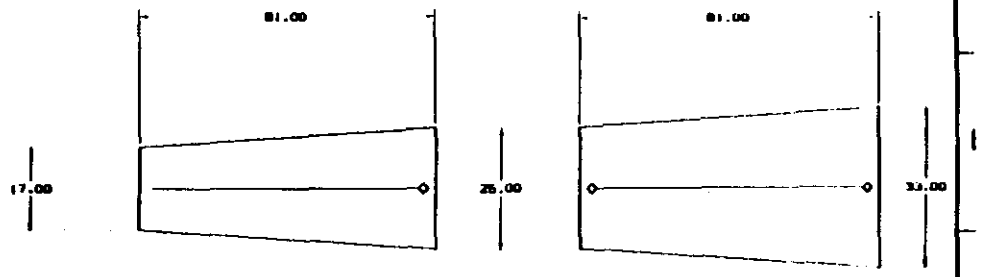
Los Alamos

GEM DETECTOR
TYPICAL SILICON WAFER
WITH X LAYER

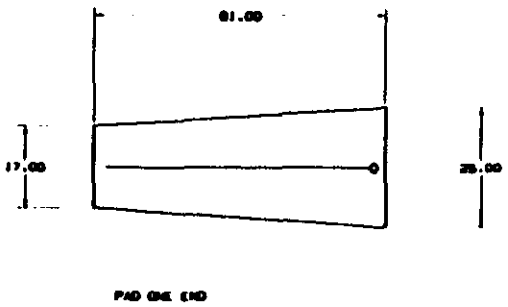

SILICON MICRO STRIPS
ALUMINUM GUARD RING
ALUMINUM COATING - 1 MICRON THK ENTIRE SURFACE
SCALE: 20:1
300 MICRON
0.500 DEAD AREA BOTH SIDES
32.000
32.000 ACTIVE REGION
0.200
0.500 REF. DEAD AREA
0.500 DEAD AREA
0.500 DEAD AREA BOTH SIDES
0.300
81.000
80.000 ACTIVE REGION
SCALE: NONE
840 SILICON STRIPS
840 SILICON STRIPS 50 MICRON PITCH
TYPICAL SILICON WAFER
STEREO LAYER
(5 MILLIRADIAN ANGLE)
TERMINATION PAD
80 MICRONS 840 X
0.500
0.100
0.100
0.100
SCALE: 20:1
0.200
0.100 WIDE X 1 MICRON THICK ALUMINUM GUARD RING
50 MICRONS 840 X
.314 mm 5 MILLIRADIAN STEREO ANGLE
.50 mm DEAD REGION REF.
SCALE: 50:1
PRELIMINARY
NOT TO BE USED FOR FABRICATION
METRIC
THIRD ANGLE PROJECTION
Los Alamos
GEM DETECTOR
TYPICAL SILICON WAFER WITH STEREO LAYER CONFIGURATION
A1
SK-GEM12-002
1



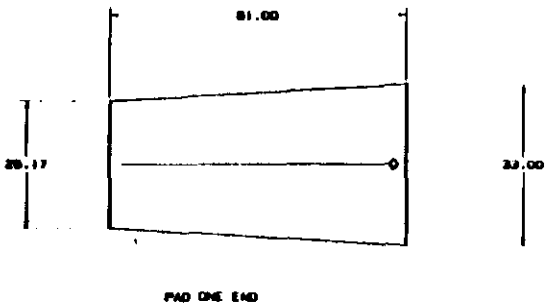
(1) QUANTITY: 1308 EACH FOR X LAYER
QUANTITY: 1308 EACH FOR STERED LAYER
TOTAL OF 6344 WAFERS



(2) QUANTITY: 580 EACH FOR X LAYER
QUANTITY: 580 EACH FOR STERED LAYER
TOTAL OF 2820 WAFERS



(3) QUANTITY: 625 EACH FOR X LAYER
QUANTITY: 625 EACH FOR STERED LAYER
TOTAL OF 1250 WAFERS



(4) QUANTITY: 173 EACH FOR X LAYER
QUANTITY: 173 EACH FOR STERED LAYER
TOTAL OF 346 WAFERS

PRELIMINARY
NOT TO BE USED FOR FABRICATION

NOTES:
1. FOR WAFER SPECIFICATIONS REFER TO WAFER DRAWING SK-SEMI2-001 & SK-SEMI2-002

METRIC
THIRD ANGLE PROJECTION

Los Alamos

SILICON

January 6,1992

Colin D. Wilburn
Micron Semiconductor Inc.
126 Baywood Avenue
Longwood, FL 32750

Dear Mr. Wilburn,

We are seeking your technical assistance in preparing drawings, specifications, cost estimates, and production plans for Silicon Microstrip Detectors for the SSCL GEM Detector. The drawings and specifications provided are for a still evolving conceptual design with numerous details undefined. We would appreciate you reviewing our current understanding of the design and providing assistance in refining the design details.

Electrical Specifications

The Electrical Specifications are for a Single Sided A/C coupled Totally Depleted Silicon Microstrip Detector.

Active Dimensions:	60mm x 32mm
Tolerance:	± 50μm
Thickness:	300μm ± 15μm
Flatness:	± 10μm
# of Strips:	640 (1280)
Strip Pitch:	50 (25) μm
# of Readouts:	640
Readout Pitch:	50 μm
Substrate:	n type, high resistivity silicon
C(interstrip):	> 5 x C(backplane) < 1.5 pf/cm
C(coupling):	> 10 x C(interstrip)
Depletion Voltage:	< 50 Volts
Maximum leakage/strip:	10 nA
Metalization:	Aluminum
Radiation Hardness:	$5x10^{13}$ neutrons/cm^2 ; 5 Mrad
Strip faults (dead):	< 1% of total Strips
C(coupling) faults:	none

Could you identify the cost leaders and possible modifications to the specifications that will result in a less costly Silicon Microstrip detector. In addition to providing cost estimates for single sided detectors, please provide costs for double sided detectors with similar specifications. Could you also identify an existing detector with similar electrical specifications that may be purchased for radiation hardness evaluation.

Mechanical Specifications

Drawing SK-GEM12-001 shows our current baseline design wafer configuration which is nominally 33 mm wide x 61 mm in length x 300μm thick with 640 strips at a 50 μm pitch. The wire bonding pads would be staggered at the ends, but may be elongated or doubled for redundant wire bonding. A single or double guard ring with wire

bonding pads would enclose the microstrips. Half of the wafers will have the microstrips slanted at a 5 milliradian angle as shown on drawing SK-GEM12-002. The dimensions as well as the strip and pad features mentioned above would be as identical as possible. The various locations of the wafers in the tracker will require the wafers to made in several geometries as shown in drawing SK-GEM12-007. In all cases the maximum width of the wafers will be 33 mm, this is to standardize the Electronics packaging. Below each configuration is the quantity of wafers required for the X layer and Stereo Layer, the total number of wafers is 10,460. The drawing also shows the location of the wire bonding pads on the wafer, some require pads at both ends others require pads at one end.

Could you review the design specifications and provide us with some technical guidance from the fabrication aspect, specifically: tolerances of the outer wafer dimensions, wire bonding pad details, guard ring details, thickness tolerances, microstrip to wafer edge placement tolerance, and acceptance qualification tests. Could you provide fabrication cost and production time estimates, for planning purposes, for both single and double sided detectors.

If you need additional information or have any design suggestions please contact the following individuals:

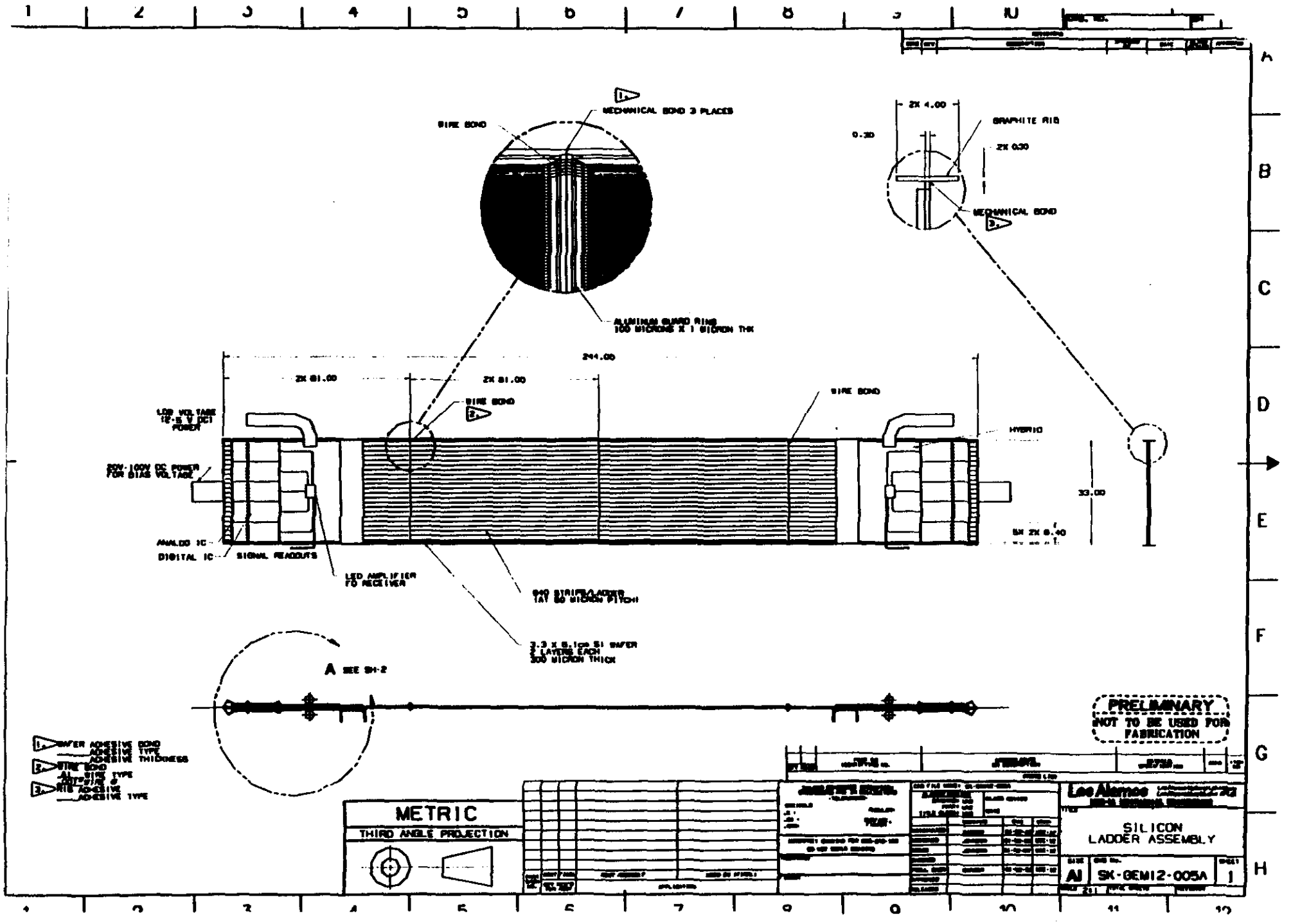
Electrical Specifications:	Geoffery Mills	(505) 665-5510
	Dave Lee	(505) 667-8888
Mechanical Specifications:	Ron Barber	(505) 667-0958
	Chuck Johnson	(505) 665-4415

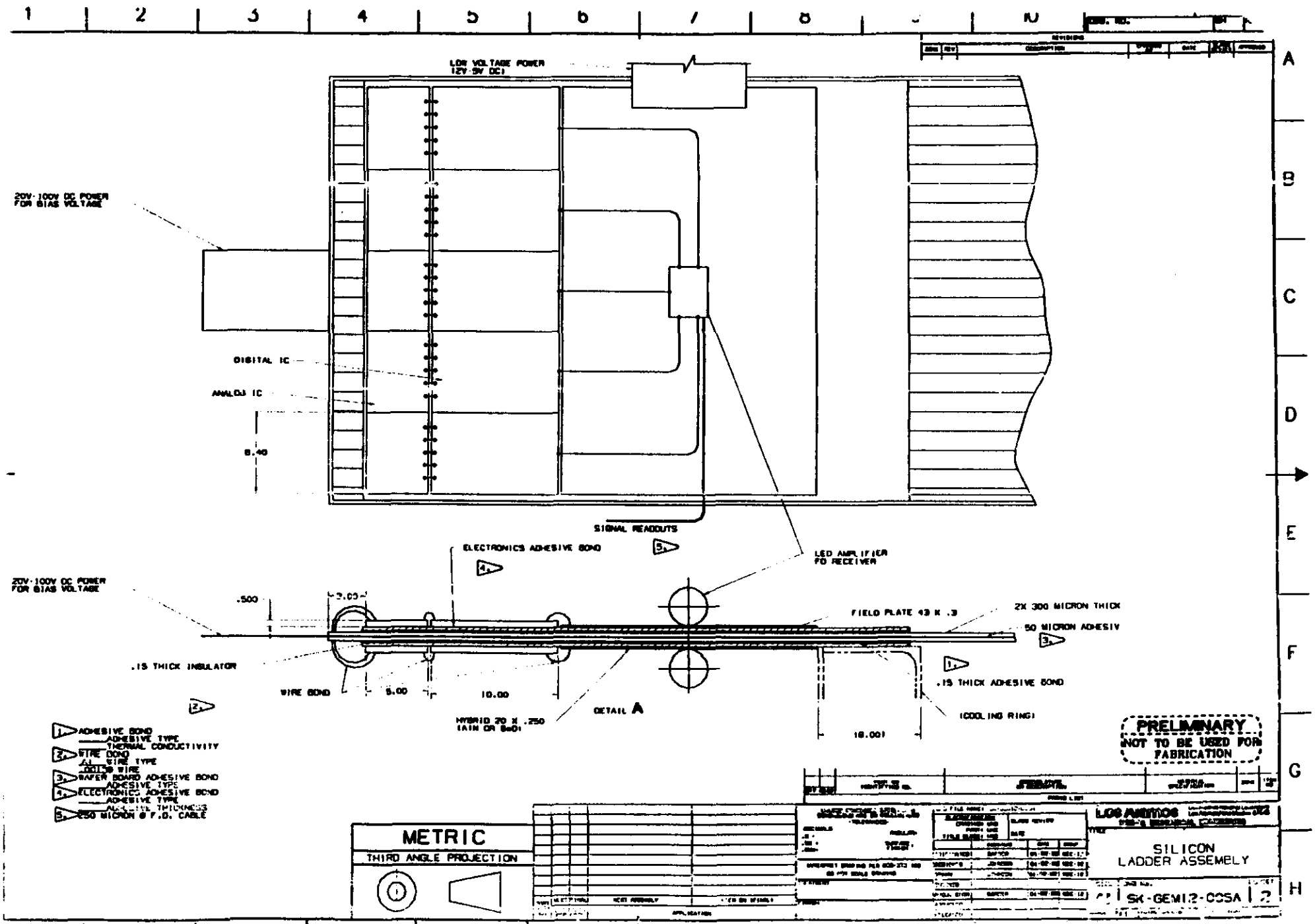
Sincerely

Ron L. Barber

Ron L. Barber MS E533
Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545

Fax (505) 667-3559


MECHANICAL BOND 3 PLACES
WIRE BOND
ALUMINUM GUARD RING
100 MICRONS X 1 MICRON THK
2X 4.00
0.30
GRAPHITE RIB
2X 0.30
MECHANICAL BOND
244.00
2X 81.00
2X 81.00
WIRE BOND
WIRE BOND
LOW VOLTAGE
12-5 V DC1
POWER
HYBRID
20V-100V DC POWER
FOR BIAS VOLTAGE
33.00
ANALOG IC
DIGITAL IC
SIGNAL READOUTS
LED AMPLIFIER
TO RECEIVER
3.3 X 6.1cm SI WAFER
2 LAYERS EACH
300 MICRON THICK
A SEE SH-2
WAFER ADHESIVE BOND
ADHESIVE TYPE
ADHESIVE THICKNESS
WIRE BOND
AL WIRE TYPE
WIRE Ø
RIB ADHESIVE
ADHESIVE TYPE
PRELIMINARY
NOT TO BE USED FOR
FABRICATION
METRIC
THIRD ANGLE PROJECTION
Los Alamos
SILICON
LADDER ASSEMBLY
A1
SK-GEM12-005A
1


LOW VOLTAGE POWER
12V-5V DC)
20V-100V DC POWER
FOR BIAS VOLTAGE
DIGITAL IC
ANALOG IC
8.40
SIGNAL READOUTS
ELECTRONICS ADHESIVE BOND
LED AMPLIFIER
PD RECEIVER
20V-100V DC POWER
FOR BIAS VOLTAGE
.500
3.00
FIELD PLATE 43 X .3
2X 300 MICRON THICK
50 MICRON ADHESIV
.15 THICK INSULATOR
WIRE BOND
5.00
10.00
.15 THICK ADHESIVE BOND
DETAIL A
HYBRID 20 X .250
(AIN OR BeO)
(COOLING RING)
18.001
1. ADHESIVE BOND
ADHESIVE TYPE
THERMAL CONDUCTIVITY
2. WIRE BOND
WIRE TYPE
3. WAFER BOARD ADHESIVE BOND
ADHESIVE TYPE
4. ELECTRONICS ADHESIVE BOND
ADHESIVE TYPE
5. 250 MICRON @ F.O. CABLE
PRELIMINARY
NOT TO BE USED FOR
FABRICATION
METRIC
THIRD ANGLE PROJECTION
LOS ALAMOS
SILICON
LADDER ASSEMBLY
SK-GEMI2-COSA
2

Ladder Assembly Heat Sources

Front End Electronics - total power 3.99 W/Ladder end

2.5 - 4 mWatts/strip (60%in Analog IC,40% in Digital IC)
Analog IC Area - 5 chips .5 cm x .64 cm
.32 cm^2 each
An. Power Density -128 strips x 60% x 3 mW/.32 cm^2
1.2 W/cm^2
Digital IC Area- 5 chips 1.0 cm x .64 cm
.64 cm^2 each
Dig. Power Density-128 strips x 40% 3mW / .64 cm^2
.24 W/cm^2

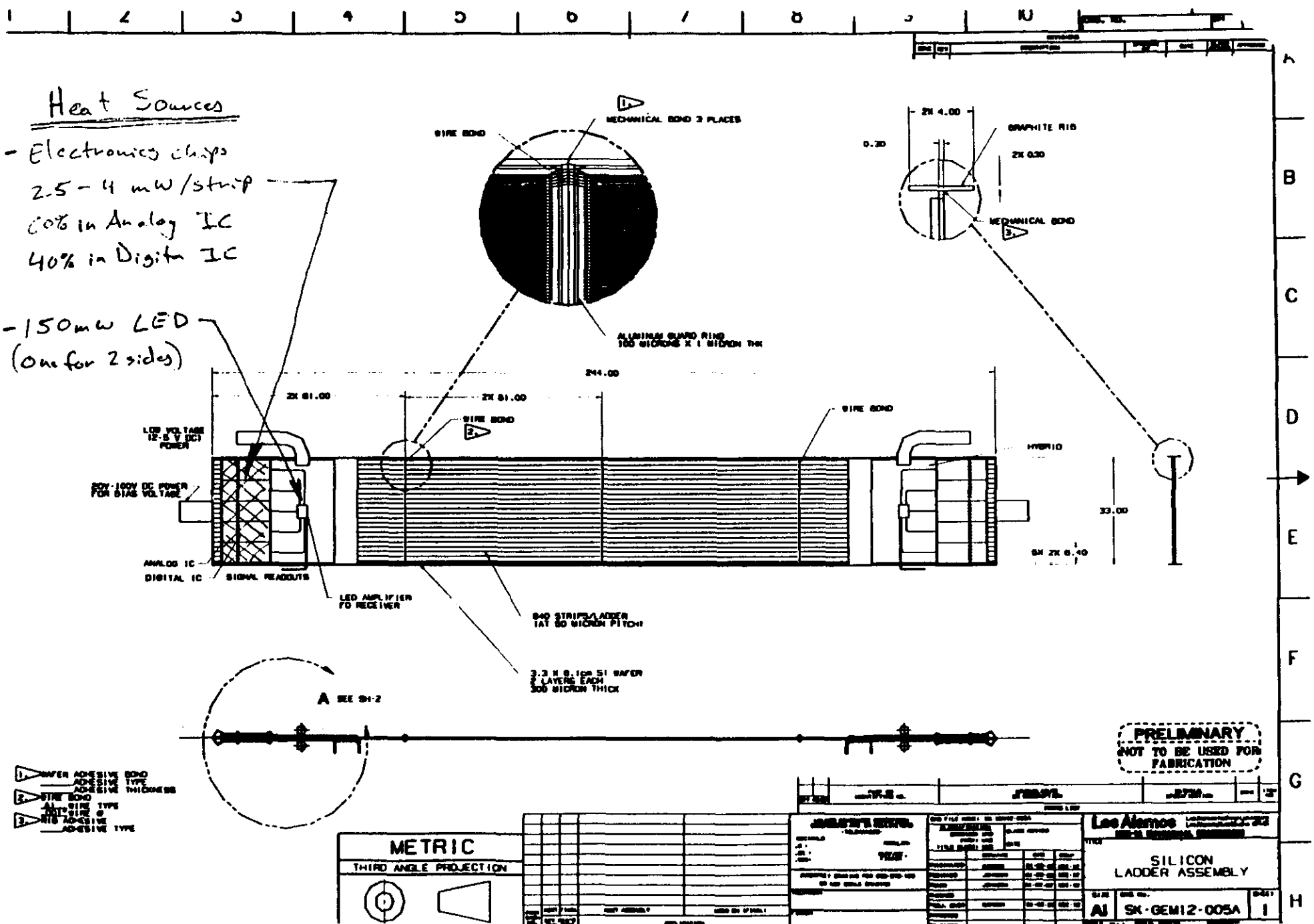
LED Readout Driver- 150 mW each

Cooling Ring Power Density
3 mW/strip x 1280 strips + 150 mW LED / 2.23 cm^2 = 1.8 W/cm^2

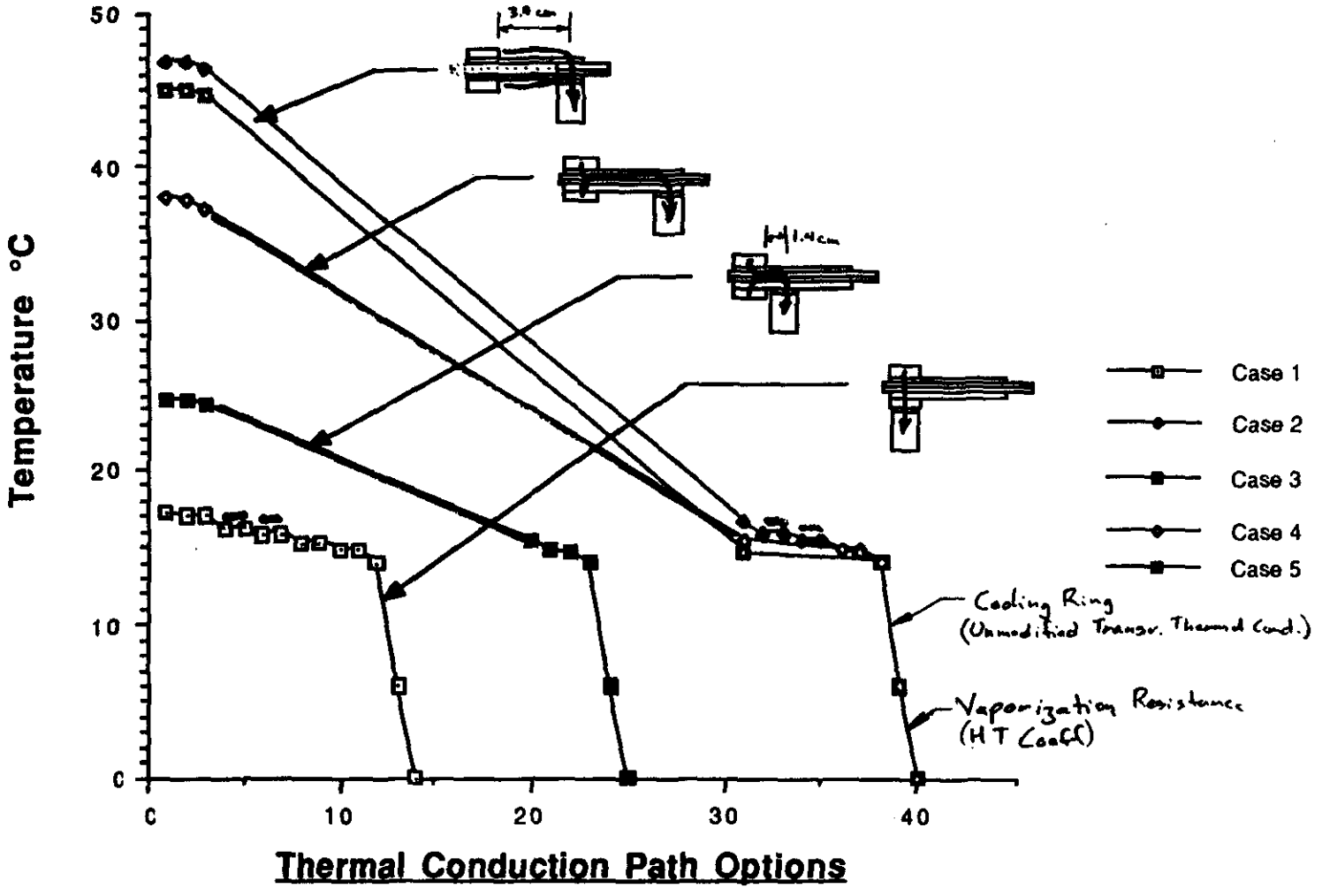
Heat Sources

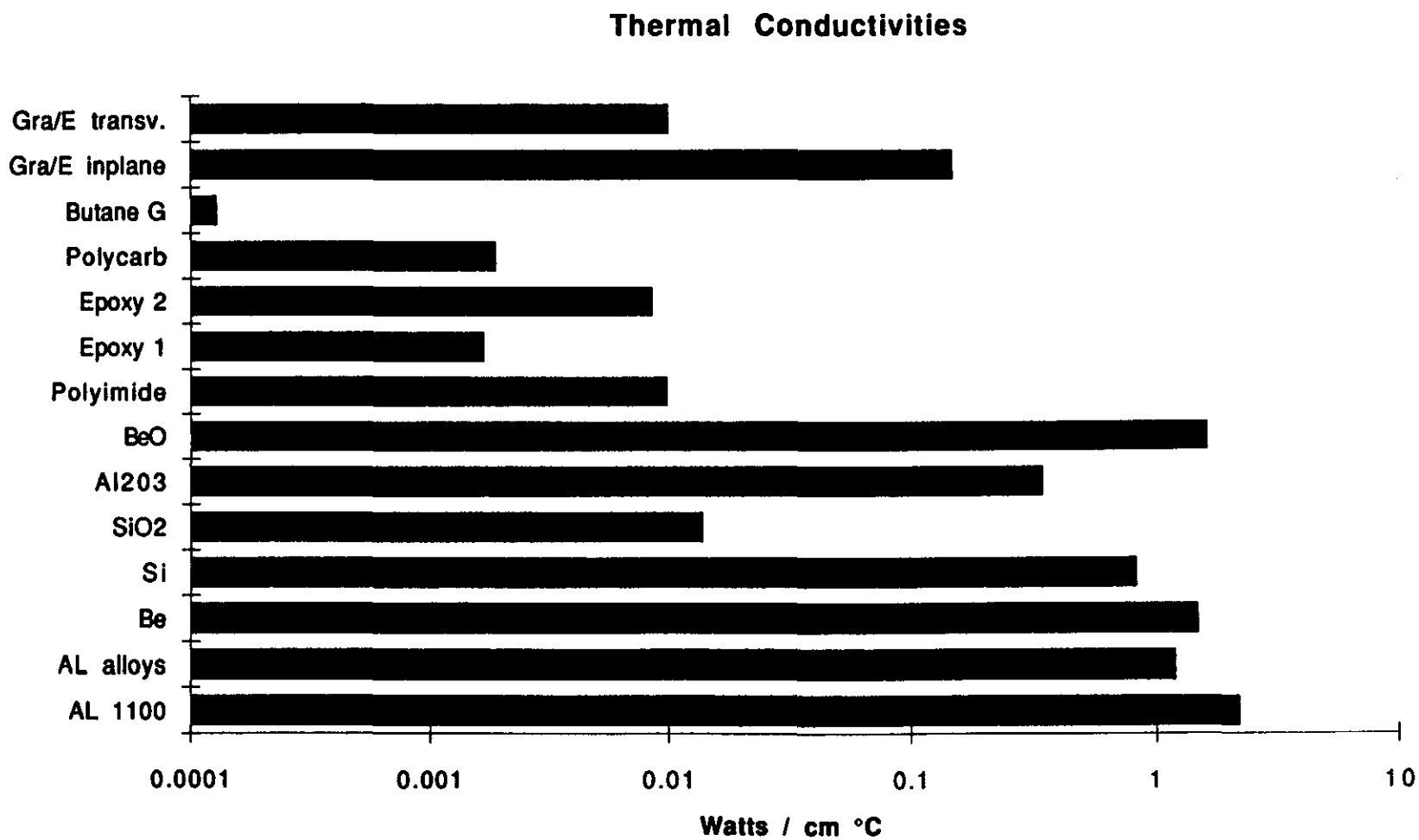
- Electronics chips
  2.5 – 4 mW/strip
  60% in Analog IC
  40% in Digital IC

- 150mW LED
  (One for 2 sides)

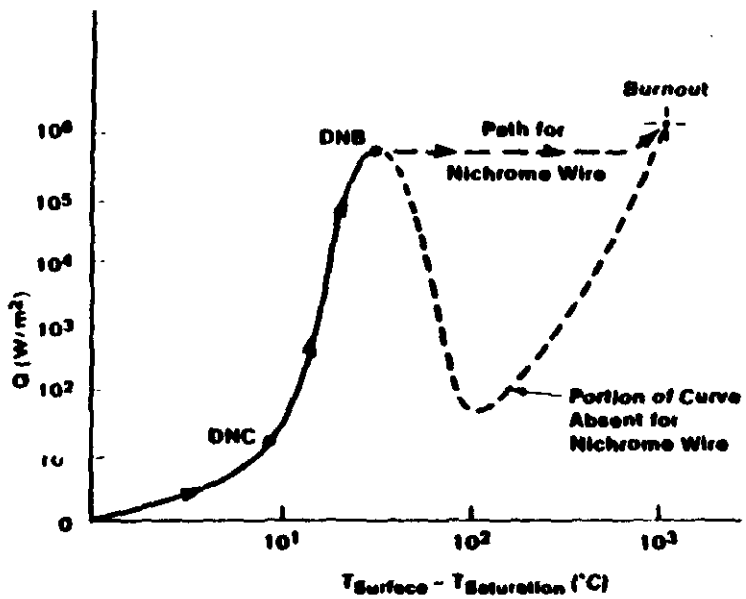


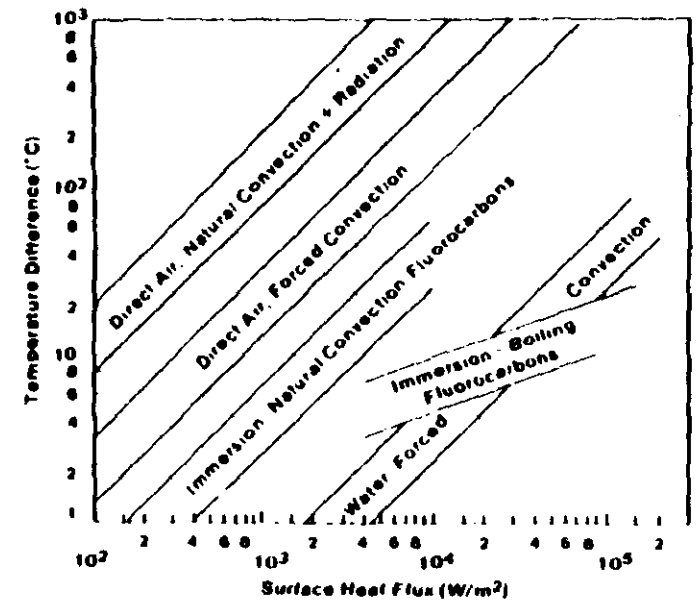
Silicon Electronics Thermal Gradients



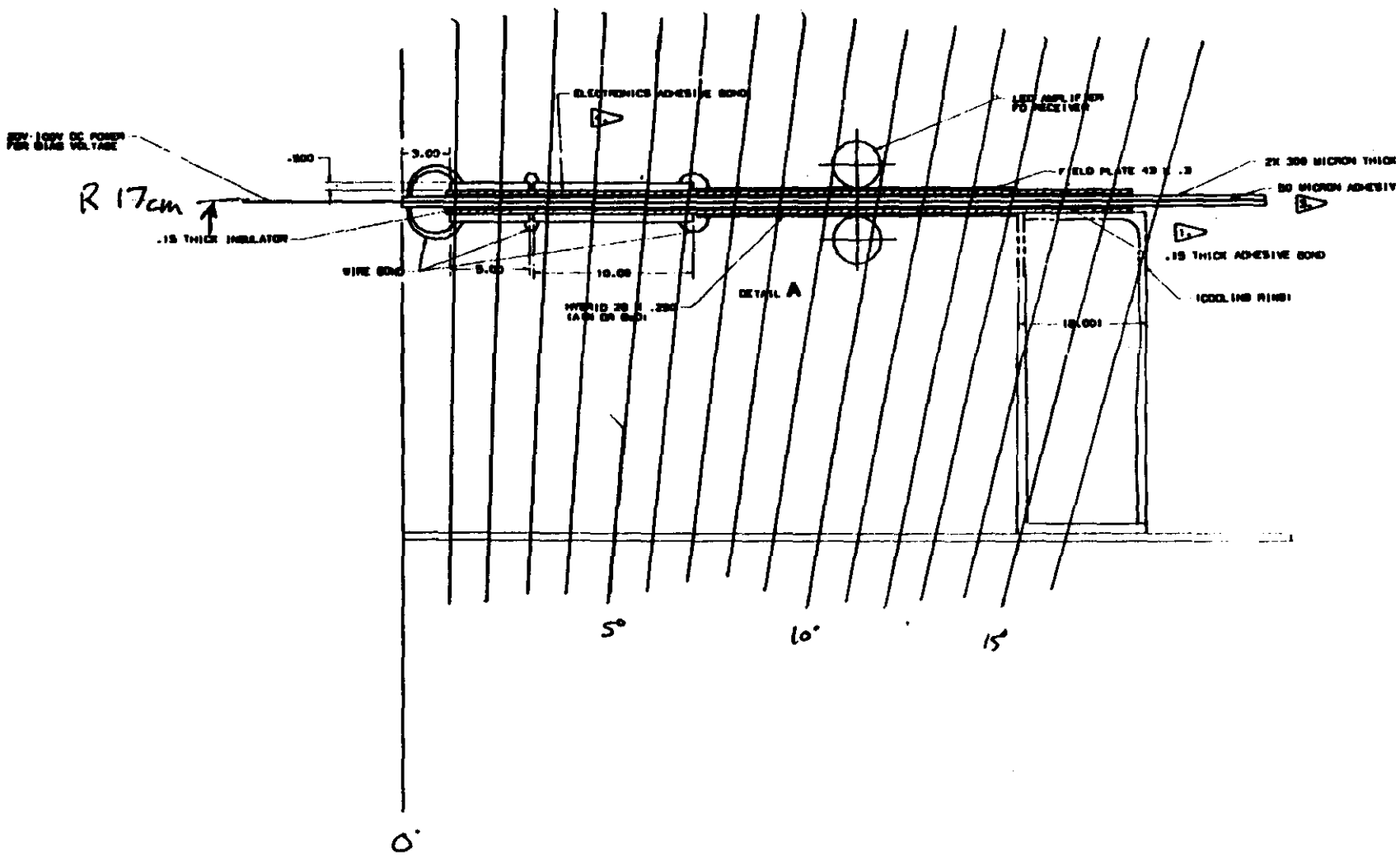

Thermal Conductivities
Gra/E transv.
Gra/E inplane
Butane G
Polycarb
Epoxy 2
Epoxy 1
Polyimide
BeO
Al203
SiO2
Si
Be
AL alloys
AL 1100
0.0001
0.001
0.01
0.1
1
10
Watts / cm °C

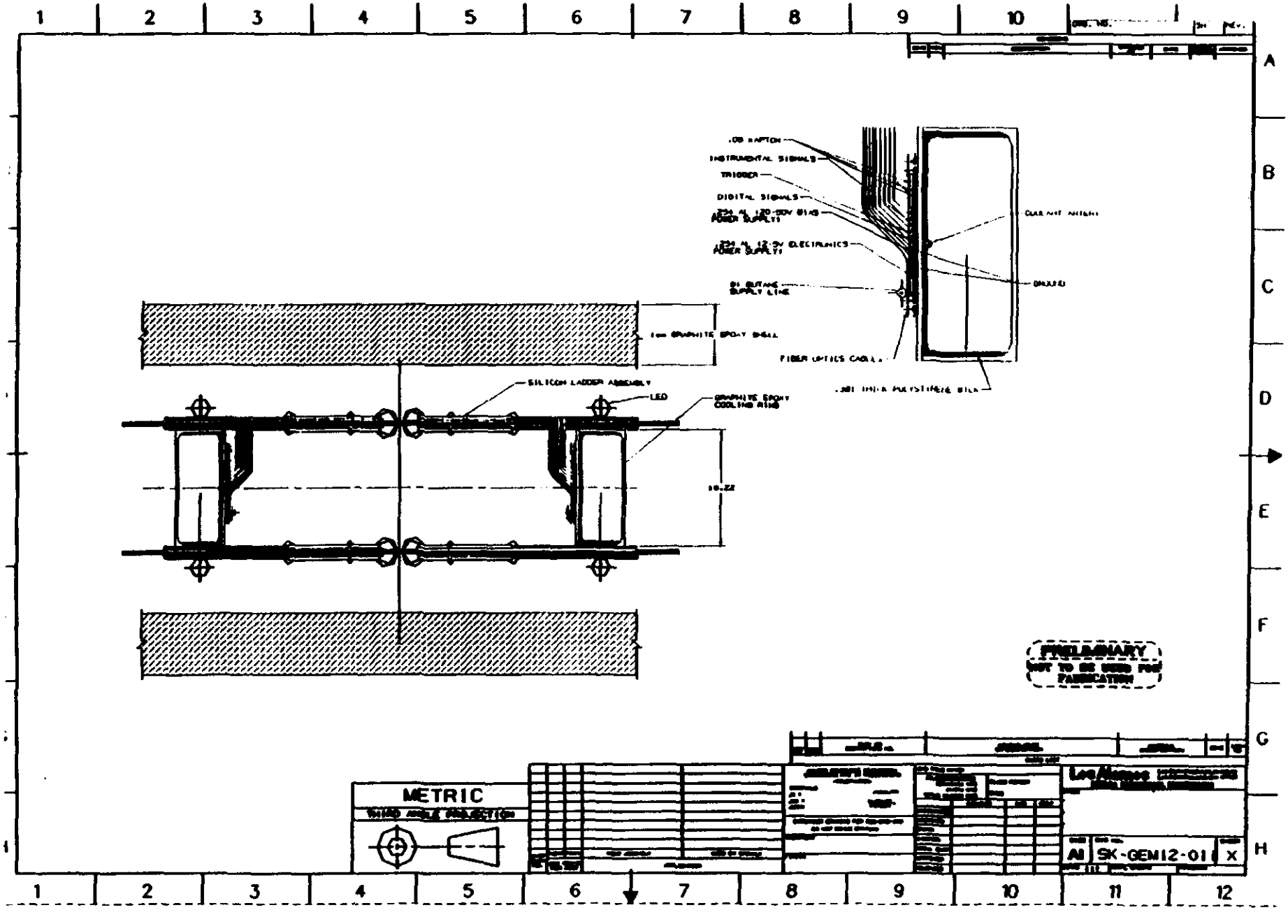
Evaporative Heat Transfer

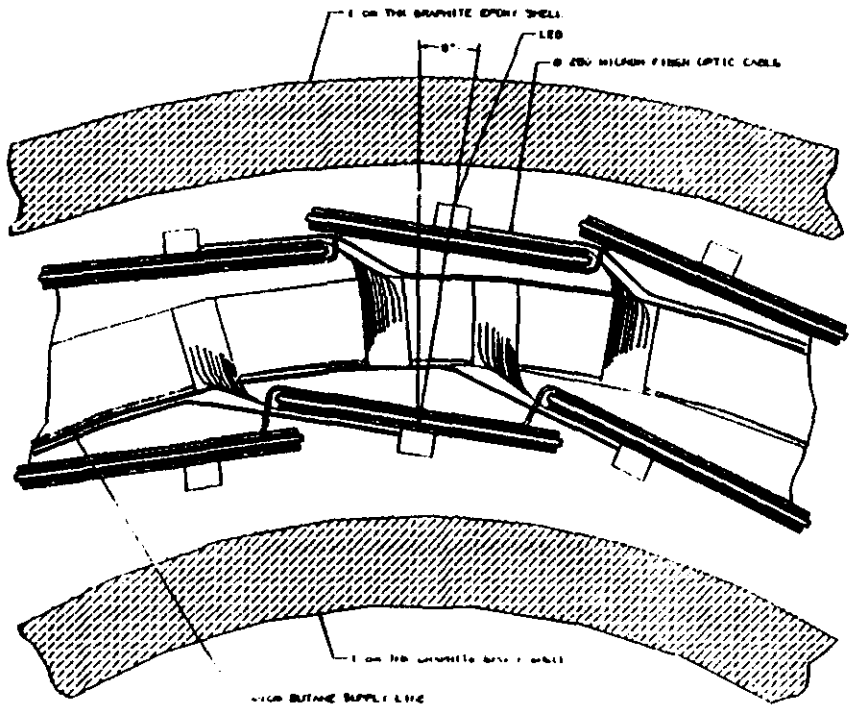




Front End Electronics Rad. Length




INSTRUMENTAL SIGNALS
TRIGGER
DIGITAL SIGNALS
FIBER OPTICS CABLE
SILICON LADDER ASSEMBLY
LED
PRELIMINARY
NOT TO BE USED FOR FABRICATION
METRIC
THIRD ANGLE PROJECTION
SK-GEM12-01
X

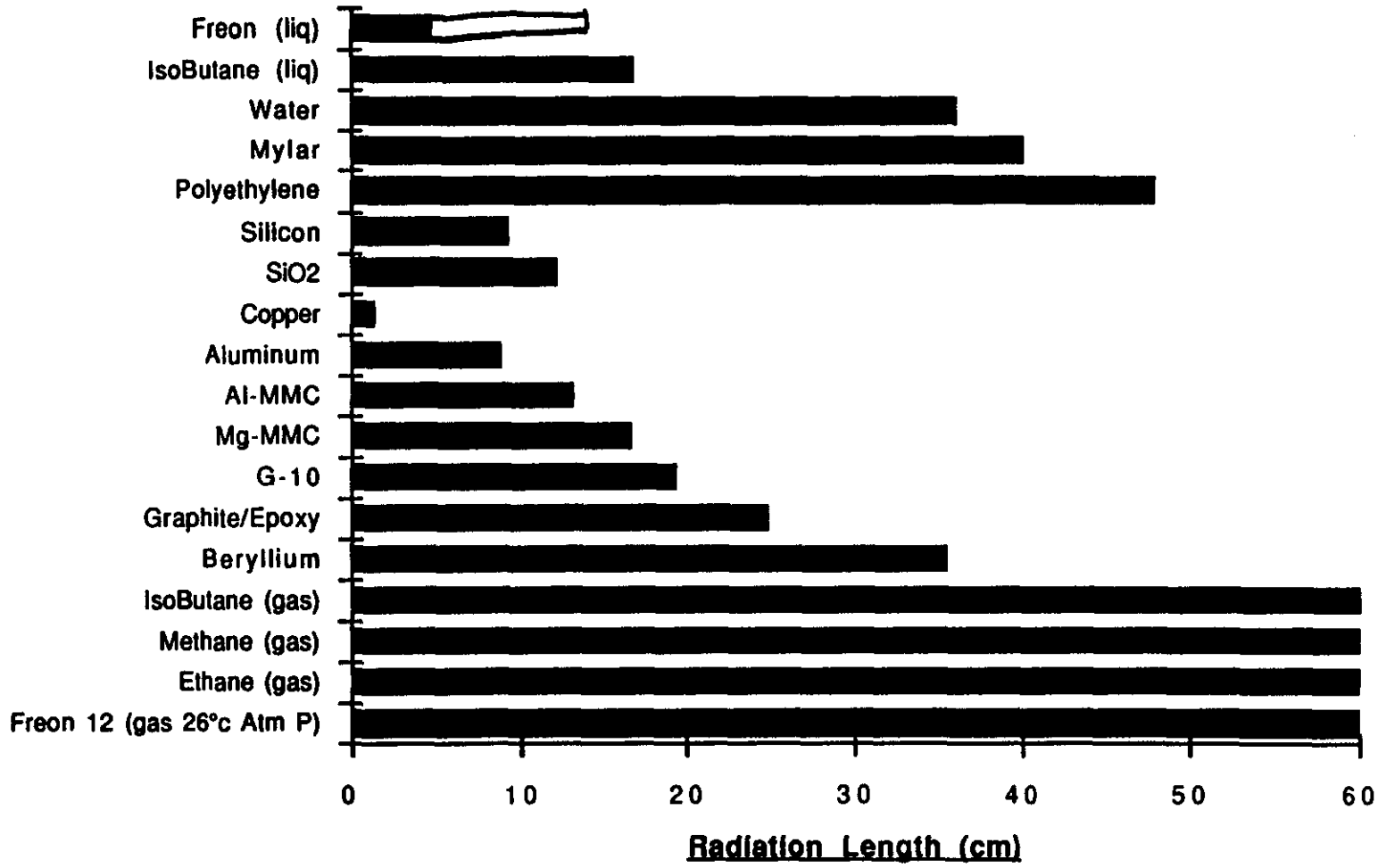


PRELIMINARY
NOT TO BE USED FOR FABRICATION

METRIC
THIRD ANGLE PROJECTION

A1 SK-GEM12-01 X

Material Radiation Lengths

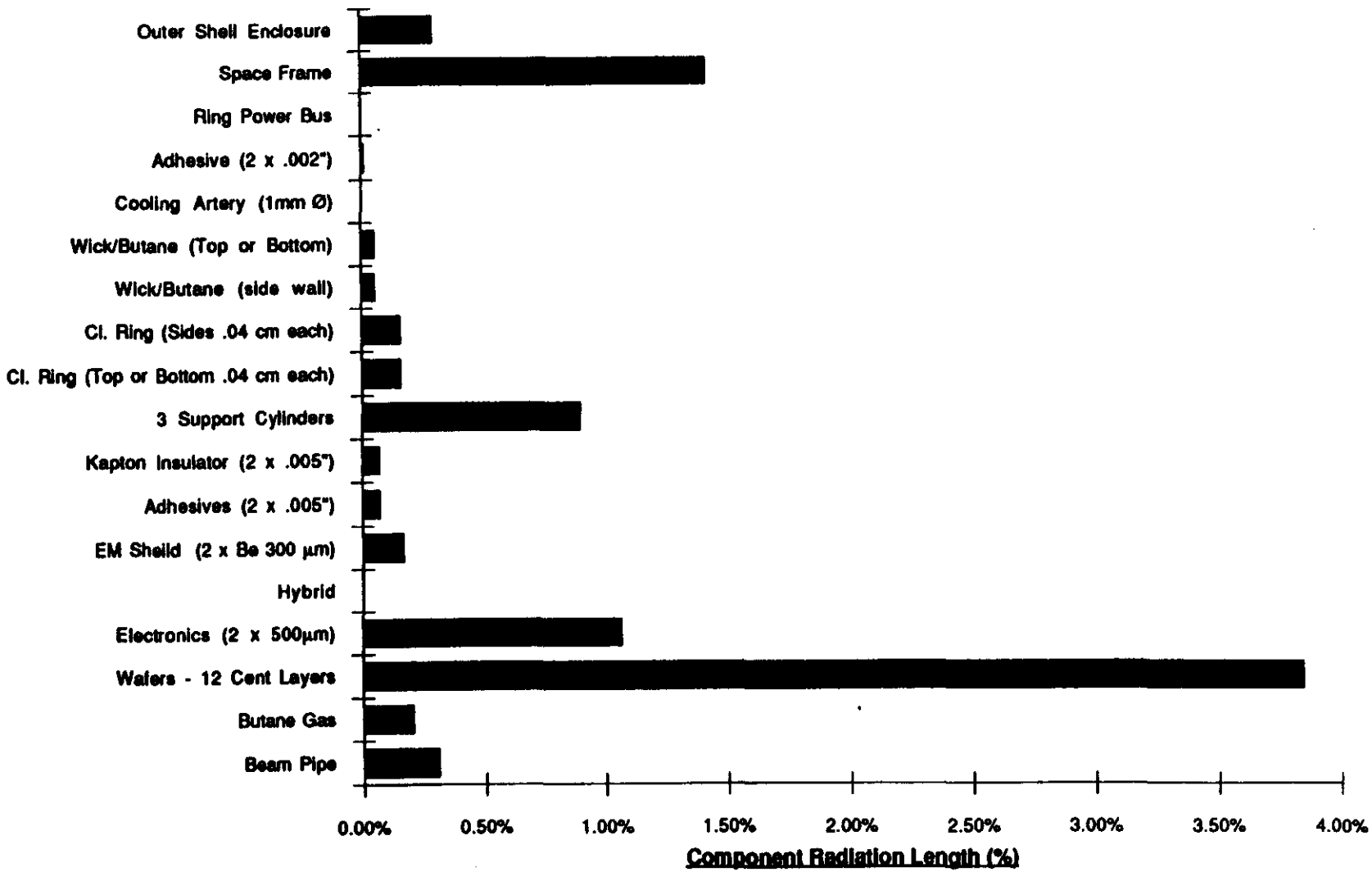


SILICON TRACKER DATA BASE

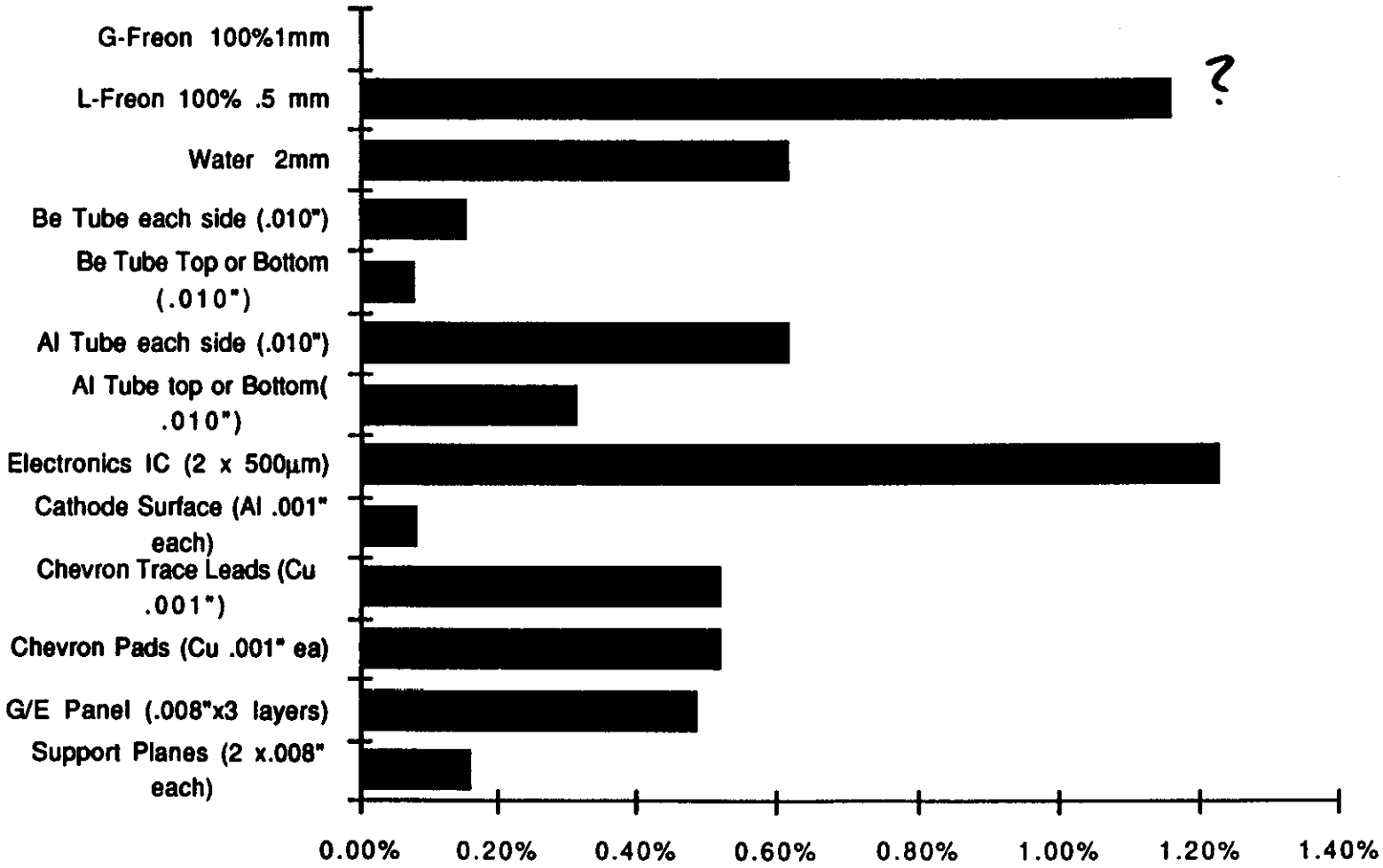
Item	Material	Rad Length cm	Thickness cm	Axial Length	#Layers	% Rad Length					
	0				Angle Ø°	0.1	0.1	1	2	4	6
					1/Cos Ø	1	1.00	1.00	1.00	1.00	1.01
Beam Pipe	Beryllium	35.43	0.1100		1	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%
Butane Gas	IsoButane (ga	16930	35.0000		1	0.21%	0.21%	0.21%	0.21%	0.21%	0.21%
Cen. Reg. Wafer Assy											
Wafers - 12 Cent Layers	Silicon	9.37	0.0300		12	3.84%	3.84%	3.84%	3.84%	3.85%	3.86%
Wafer Electronics (EL number of penetrated layers)									2	2	2
Electronics	Silicon	9.37	0.0500		2	1.07%	0.00%	0.00%	2.14%	2.14%	2.15%
Hybrid						0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
EM Sheild	Beryllium	35.43	0.0300		2	0.17%	0.00%	0.00%	0.34%	0.34%	0.34%
Adhesives	(Lucite)	34.4	0.0150		2	0.09%	0.00%	0.00%	0.17%	0.17%	0.18%
Kapton Insulator	Lucite	34.4	0.0150		2	0.09%	0.00%	0.00%	0.17%	0.17%	0.18%
Support Cylinders											
3 cyl. x 3 layers/cyl	Gra /Epoxy	25	0.0250		9	0.90%	0.90%	0.90%	0.90%	0.90%	0.90%
Cooling Ring (CL number of penetrated layers)									0	0	0
Top or Bottom .04 cm eac	Gra /Epoxy	25	0.0400		1	0.16%	0.00%	0.00%	0.00%	0.00%	0.00%
Sides .04 w cm each	Gra /Epoxy	25	2.9000	0.04	1	0.16%	0.0%	0.0%	0.0%	0.0%	0.0%
Wick/Butane 1mm w (sid	(Water)	36.1	2.1000	0.01	1	0.03%	0.0%	0.0%	0.0%	0.0%	0.0%
Wick/Butane Top or Bottc	(Water)	36.1	0.0100		1	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%
Cooling Artery 1mm Ø							0.00%	0.00%	0.00%	0.00%	0.00%
Adhesive (2 x .002")	Lucite	34.4	0.0050		1	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
Ring Power Bus	Aluminum	8.89				0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Space Frame	Mg-MMC	16.8	0.2380		1	1.42%					
(.076 cm wall- SDC)							0.00%	0.00%	0.00%	0.00%	0.00%
Outer Shell Enclosure	Gra /Epoxy	25	0.0250		3	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%
3 x .008" layers											

Total Radiation Length

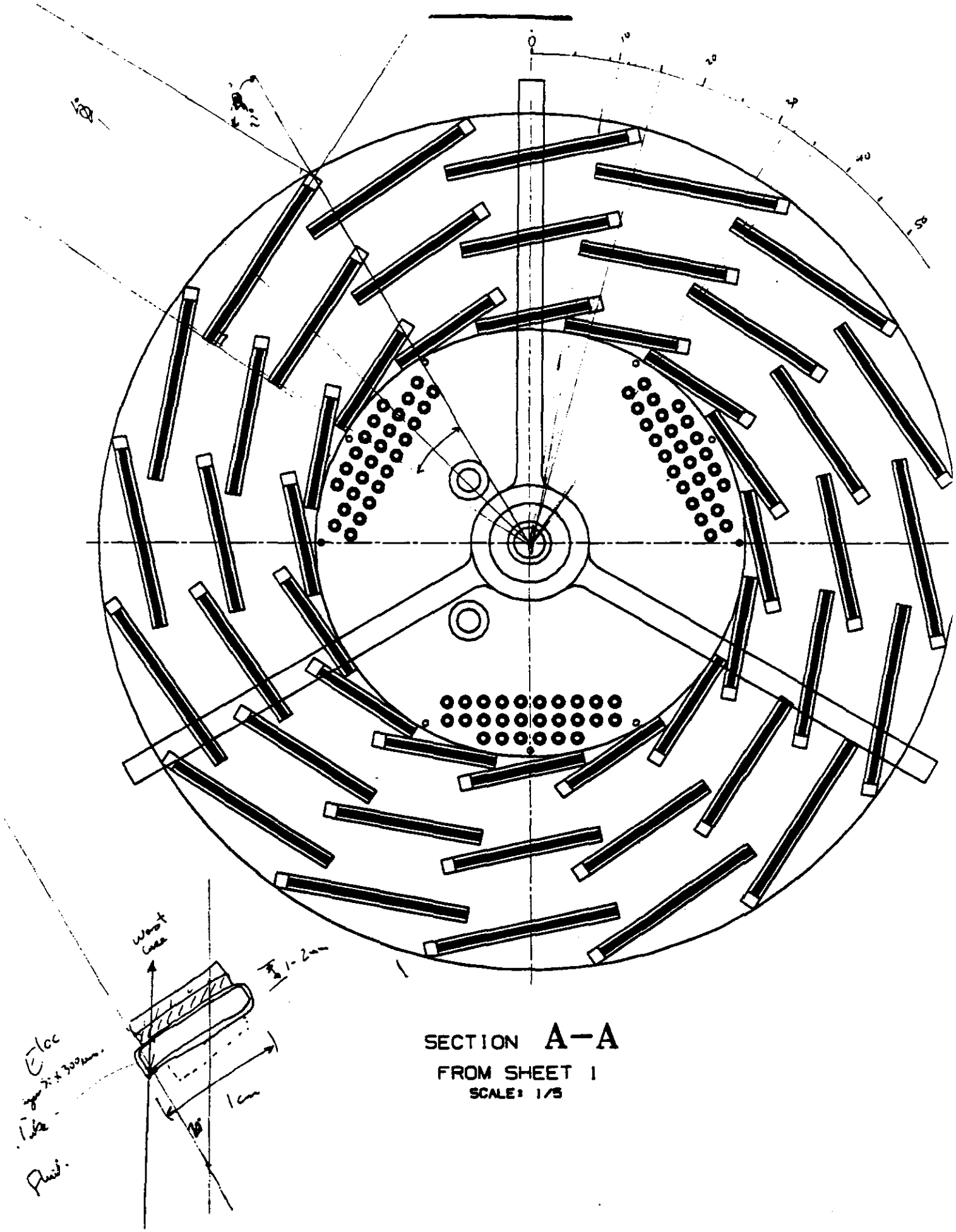
Silicon Tracker Radiation Lenghts



IPC Module Radiation Lengths



360°/16 modules = 22.5°

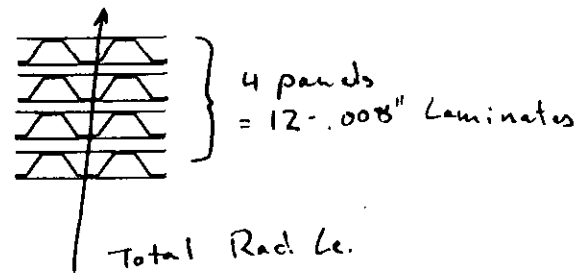


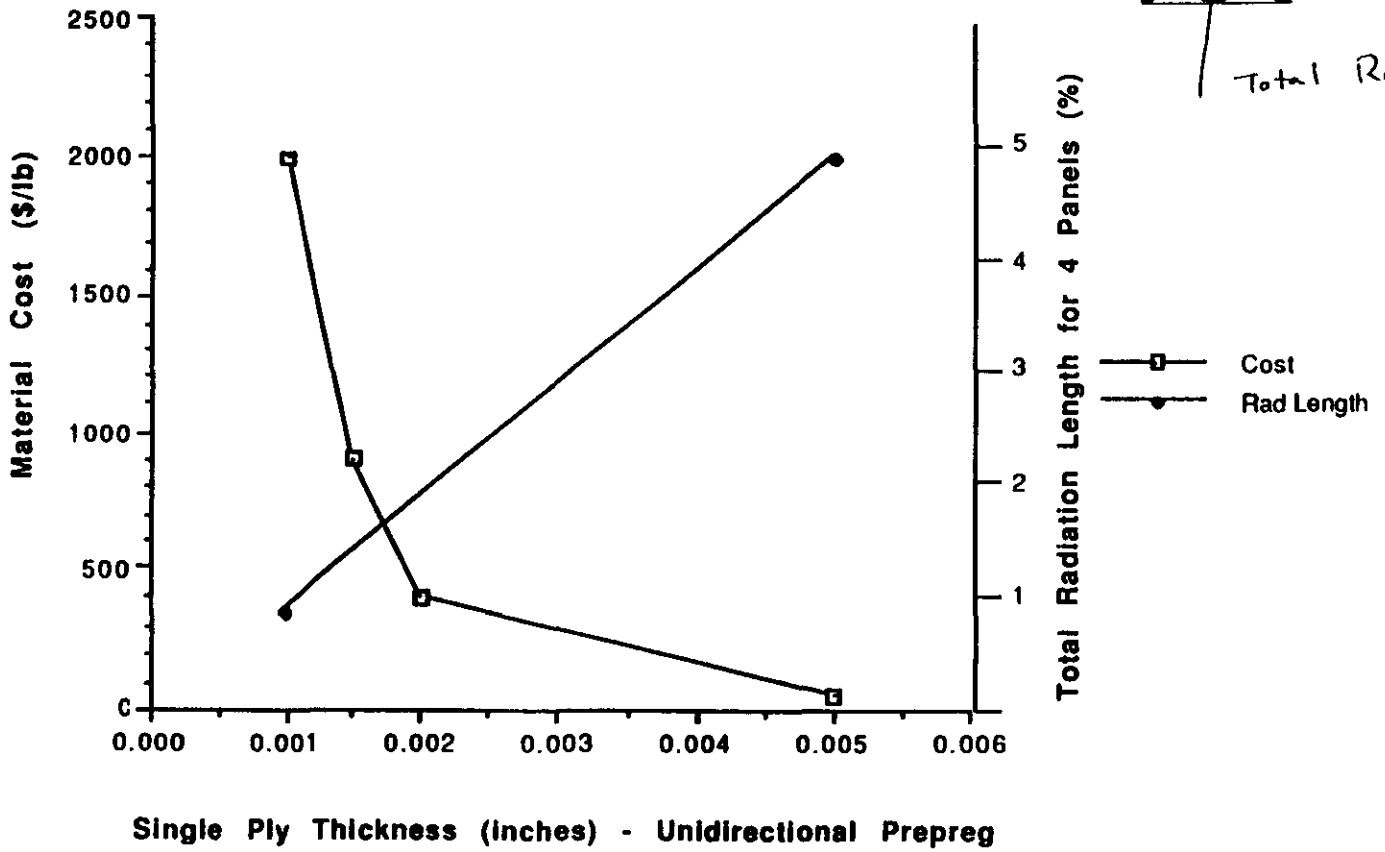
SECTION A—A

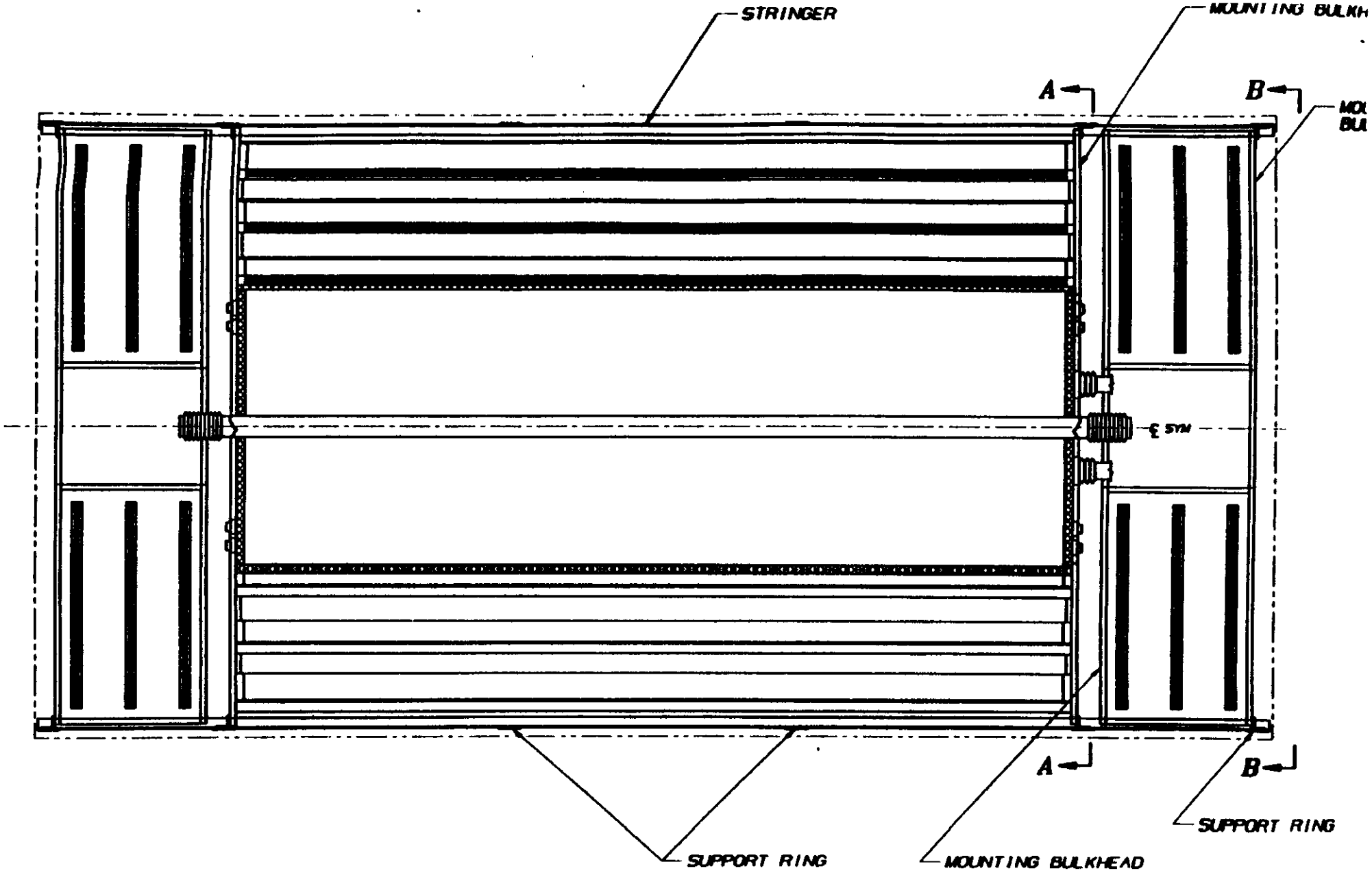
FROM SHEET 1

SCALE: 1/5

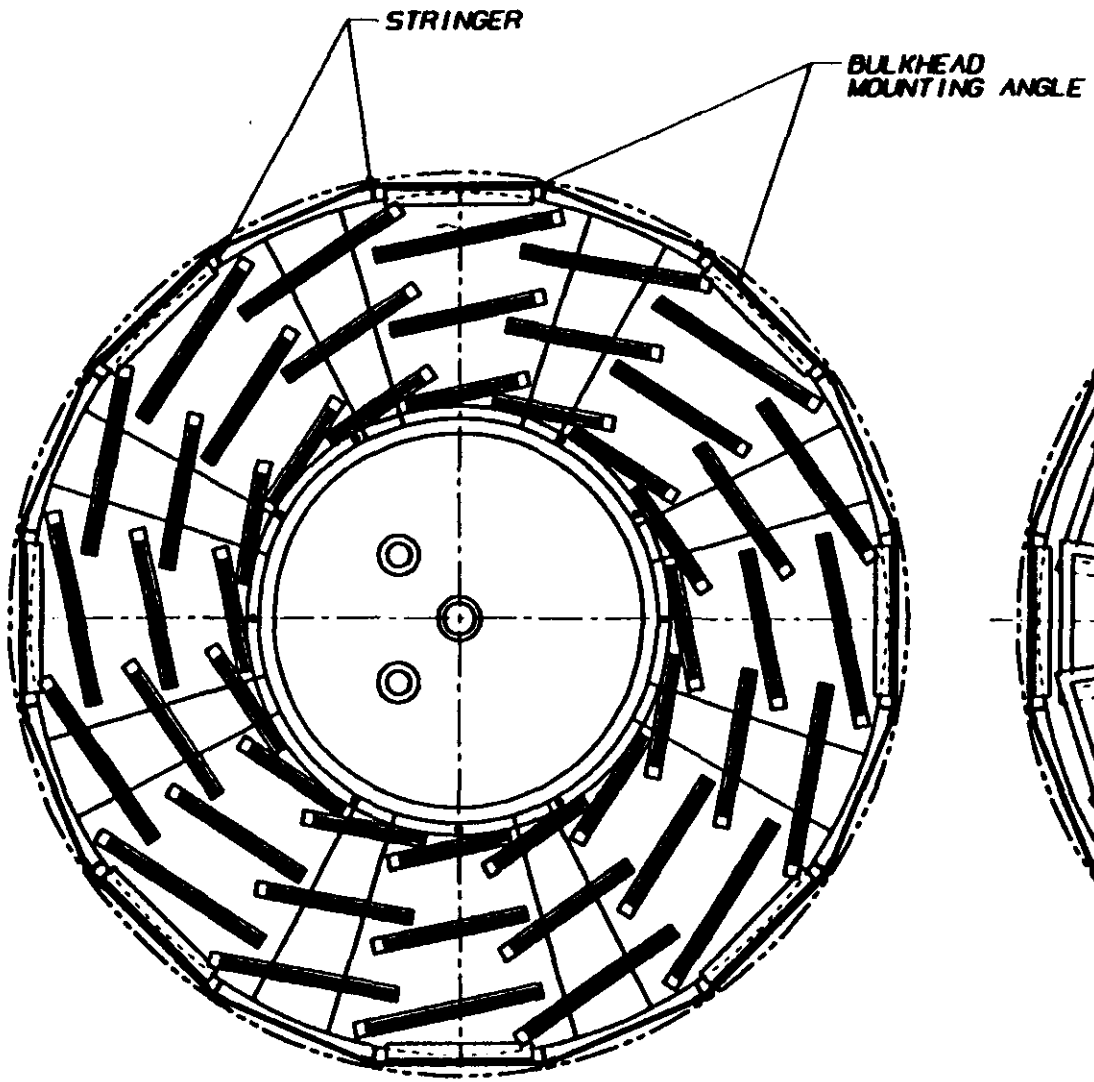
Cost / Radiation Length Trade-off



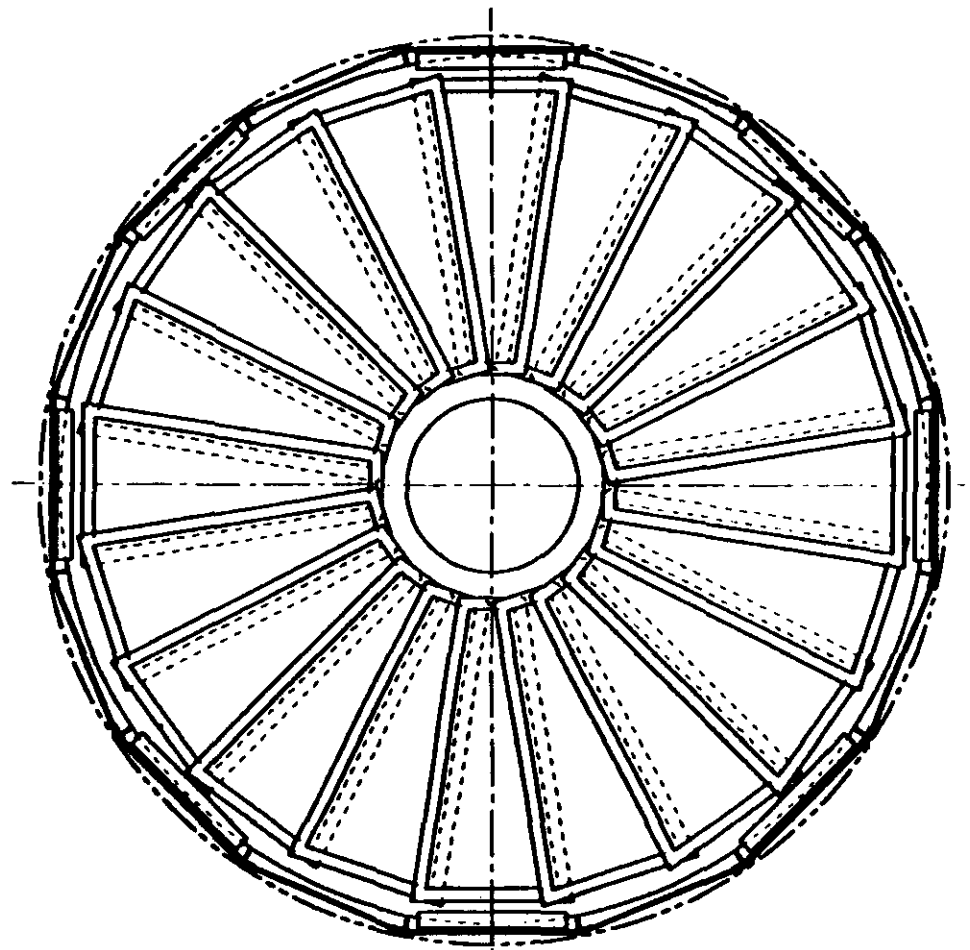




IPC SUPPORT STRUCTURE

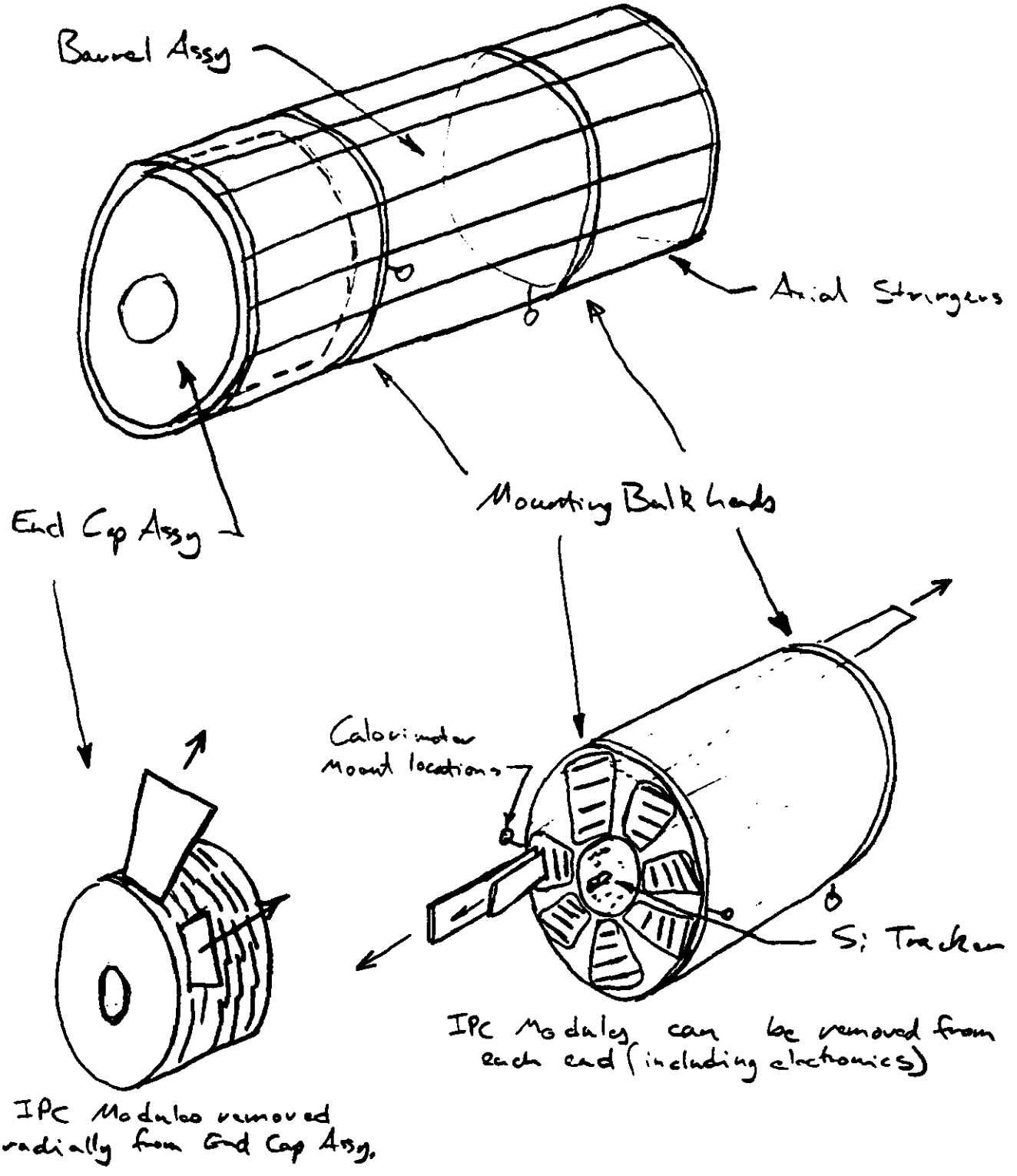


SECTION A–A

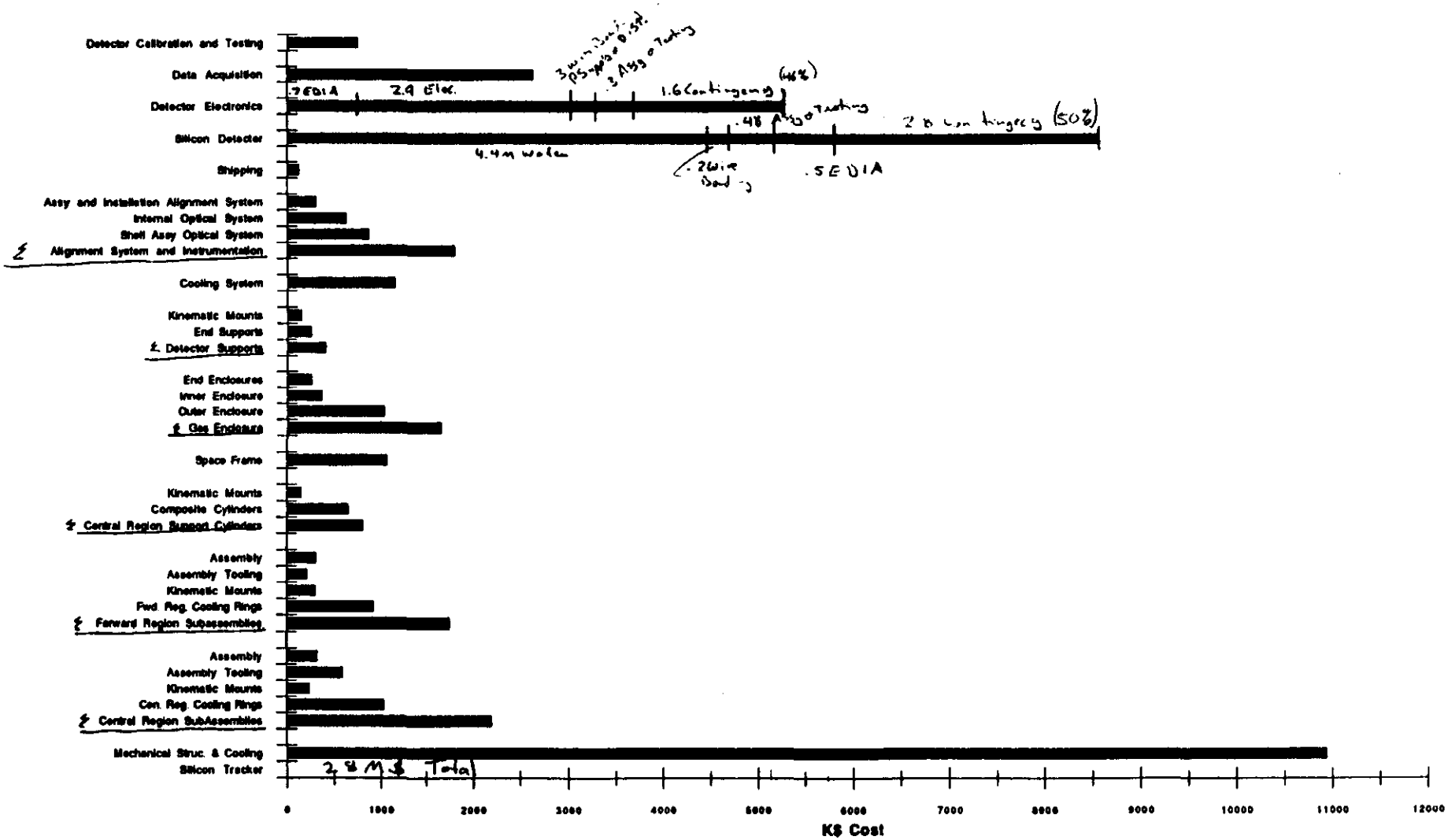


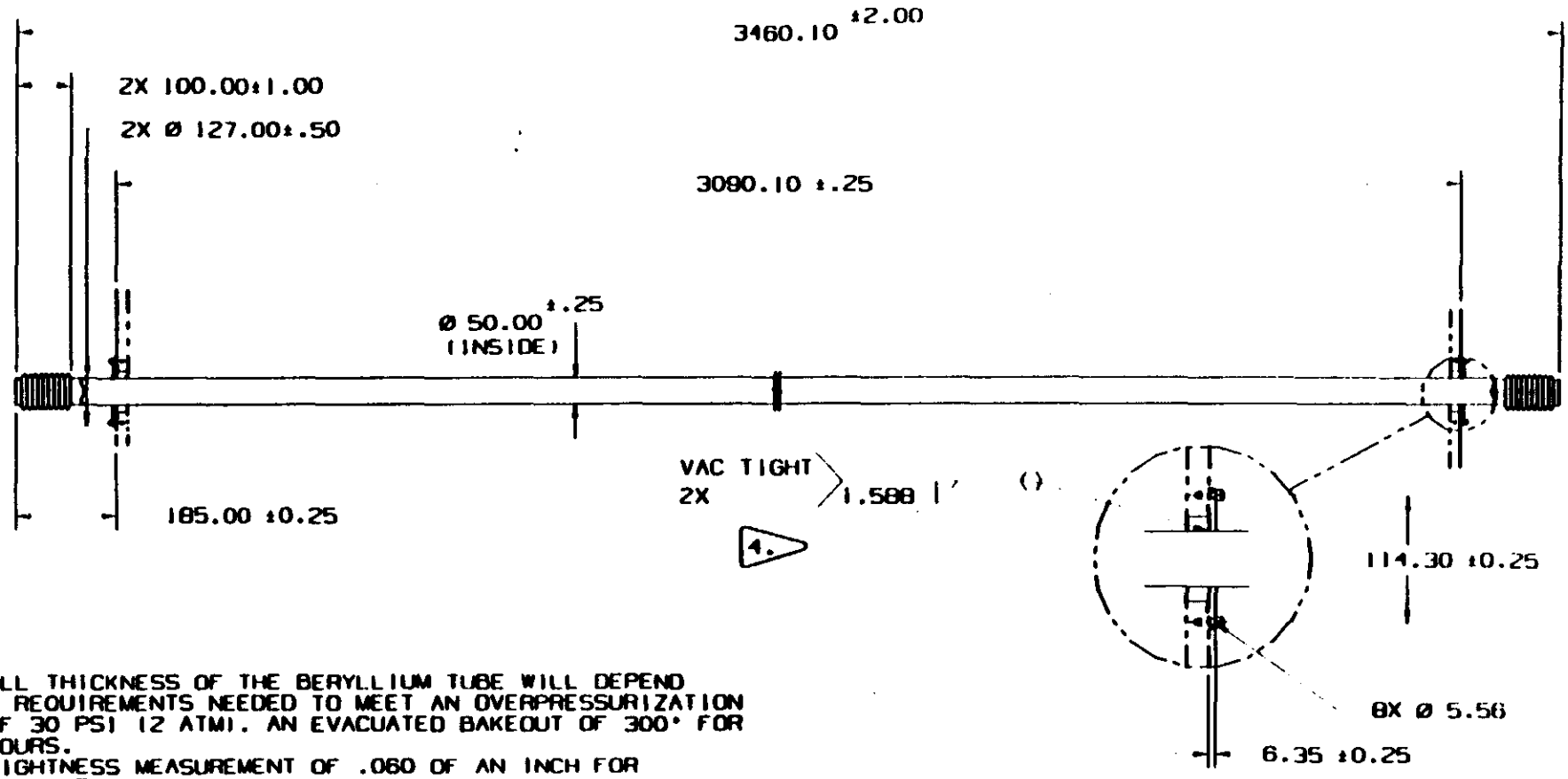
SECTION B–B

External Support Frame



Component Cost Scale





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2. A STRAIGHTNESS MEASUREMENT OF .060 OF AN INCH FOR THE TOTAL LENGTH.
3. MASS SPECTROMETER LEAK TEST WHERE THE LEAK RATE MUST NOT EXCEED 2×10^{-10} ATM CC/SEC OF HELIUM WITH ONE ATMOSPHERE OF DIFFERENTIAL PRESSURE.
4. MASS SPECTROMETER LEAK TEST TO 2×10^{-8} ATM CC/SEC OF HELIUM WITH ONE ATMOSPHERE OF DIFFERENTIAL PRESSURE.
5. MATERIALS: TUBE IS BERYLLIUM S200E OR OTHER GRADE OF 98% BERYLLIUM BELLOWS-ALUMINUM PREFERABLY OR STAINLESS STEEL

PRELIMINARY
NOT TO BE USED FOR FABRICATION

METRIC
THIRD ANGLE PROJECTION

Los Alamos
GEM
CENTRAL TRACKER
BERYLLIUM BEAM TUBE
A1 SK-GEM12-004 1

Proposed MEE Division GEM Detector Support Assignments 1/7/92

Tasks	Engineering								Design				
	Barber	Thompson	Michaud	Hanlon	Smith	Gamble	Reid	Woloshun	Johnson	VanAnne	Wilds	Others	Totals
Central Detector													
Proj Planning	0.05	0											0.05
Systems Integration*	0.25	0							0.15	0.1			0.5
Silicon Tracker													
Silicon Ladders R&D	0.4								0.2				0.6
Elec. Conn.													
Power Dist													
Signal Routin													
Gas Enclosure*	0.2									0.2			0.4
Beam Tube													
Feed Thrus													
Cooling Rings		0.2	0.05							0.1			0.35
Support Cylinders													
Space Frame		0.2								0.1			0.3
Shell Assy Fixtures			0.1										0.1
Kinematic Mounts			0.05										0.05
Alignment Systems*				0.15									
Ladder/shell assy sys													0
Tracker Assy sys										0.1			0.1
Align. Monitoring sys										0.1			0.1
·ne Cooling System*							0.1						0.1
al	0.9	0.4	0.2	0.15	0	0	0.1	0	0.35	0.7	0	0	2.8
K$ Totals (140 K$/SM, 120K$/GR)	126	56	28	21	0	0	14	0	42	84	0	0	371
Interpolating Pad Chambers													
Pad Chamber Modules		0.1											0.1
Support Structure		0.1											
Cooling System								0.2					0.2
Total	0	0.2	0	0	0	0	0	0.2	0	0	0	0	0.4
K$ Totals (140 K$/SM, 120K$/GR)	0	28	0	0	0	0	0	28	0	0	0	0	56

VI. Schedule Milestones

Work performed to accomplish the above tasks shall support the following schedule of overall GEM activities:

Collaboration Executive Meeting	January 22, 1992
Facilities Requirement Report	February 29, 1992
Baseline Confirmation (Tucson Meeting)	March 11, 1992
Technical Proposal Magnet Section Outline Complete	March 23, 1992
Detector Cost Review	April 6, 1992
1st. Draft of Magnet Technical Proposal Complete	May 18, 1992
Magnet Design Review Meeting	July 2, 1992
2nd. Draft of Magnet Technical Proposal Complete	August 3, 1992
Final Magnet Procurement Plan Complete	September 1, 1992
Final Magnet Technical Proposal Complete	September 21, 1992
Technical Proposal Review	October 1992

VII. Deliverables

- Documentation supporting the integration of the Muon Chambers with the GEM detector and facilities.
- Surface and underground facilities Requirements Report:

First issue for Title 1	February 29, 1992,
Maintained up-to-date through	December 31, 1992.

- Muon Chamber parameter data sheets:

First issue	March 11, 1992,
Second issue	September 21, 1992,
Third issue	December 31, 1992.

- Installation Plan:

First issue	March 11, 1992,
Second issue	September 21, 1992
Third issue	December 31, 1992.

VIII. Revisions to SOW

The Statement of Work and its associated deliverables and estimated costs must be considered on a level of effort basis. It is believed that, based on an engineering appraisement, the deliverable can be achieved within the projected cost. The task descriptions and milestones will be regarded as goals and not as deadlines that must be met independent of the level of effort required.

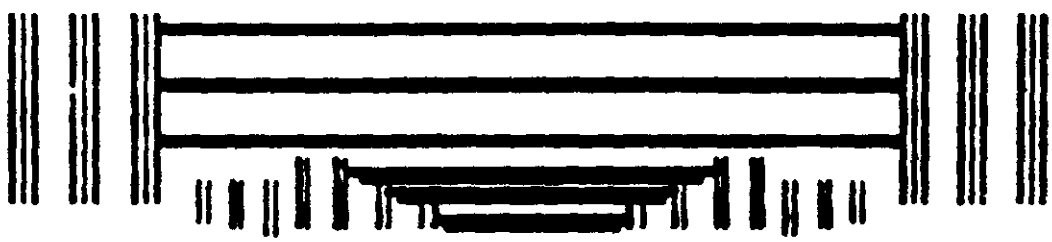
It is further understood that items of work and/or level-of-effort may need to be revised from time to time. If and when such revisions are deemed necessary, they will be accomplished by mutual consent of LANL, the GEM Collaboration management and PRD. Revisions which result in a change in the scope of the work provided for under this SOW or in the items to be delivered may require adjustment to the funding and/or schedule for performance.

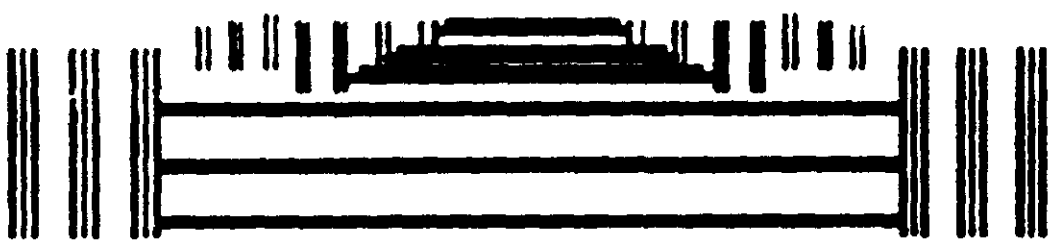
Requirements For The Technical Proposal

- Complete list of Subsystems Specifications and Design Requirements.
- Complete Assembly, Systems, and Component drawings that meet the requirements.
- Documentation of analysis including thermal, structural, and dynamic calculations that demonstrates the component design meets the requirements.
- 80 % of the Subsystems procurement estimates based on vendor ROM estimates from documented drawings.
- Complete R&D and Construction Project Plan and Control System.
- Demonstration that R&D plan will address design issues.
- Completed Preliminary Hazards Analysis and Preliminary Safety Analysis Report of each Subsystem.

Melinda Brooks
1/23/92

LSDT RUN NR 1
EVENT NR 0 4/12/91





Los Alamos

GEANT Simulation Includes:

1) A fairly complete geometry of the silicon tracker, down to the wafer/strip level. The support structure is included just as an overall increase in density.

2) The resolution of the Si that is produced by the code is approximately 10 microns.

3) The pad layers are represented by copper tubes that are 0.6% radiation length thick.

4) The input resolution of the pads is 50 microns in r/phi and 1 mm in z in the barrel region. There is nothing in the code that takes into account charge sharing among pads, occupancy problems, efficiency, etc.

5) All physics processes suchs as multiple scattering, Bremsstraahlung are turned on.

6) A helical fit of tracks is done after pattern recognition to get the momentum of the particles and the impact parameter.

7) Tracking efficiency and charge measurement efficiency plots are available for pattern recognition.

Questions Being/To Be Addressed at Los Alamos

1) How are impact parameter and momentum resolution affected by geometry of tracker, i.e. radii of layers, number of layers and spacing?

2) How is pattern recognition affected by tracker geometry?

3) What is forward tracking region capable of doing in present configuration?

4) What is charge determination efficiency of tracker?

5) What tracking capabilities are necessary to match particles in calorimeter or muon chambers with tracker?

6) Put in dead time and backgrounds from previous events and look at how the pattern recognition is affected.

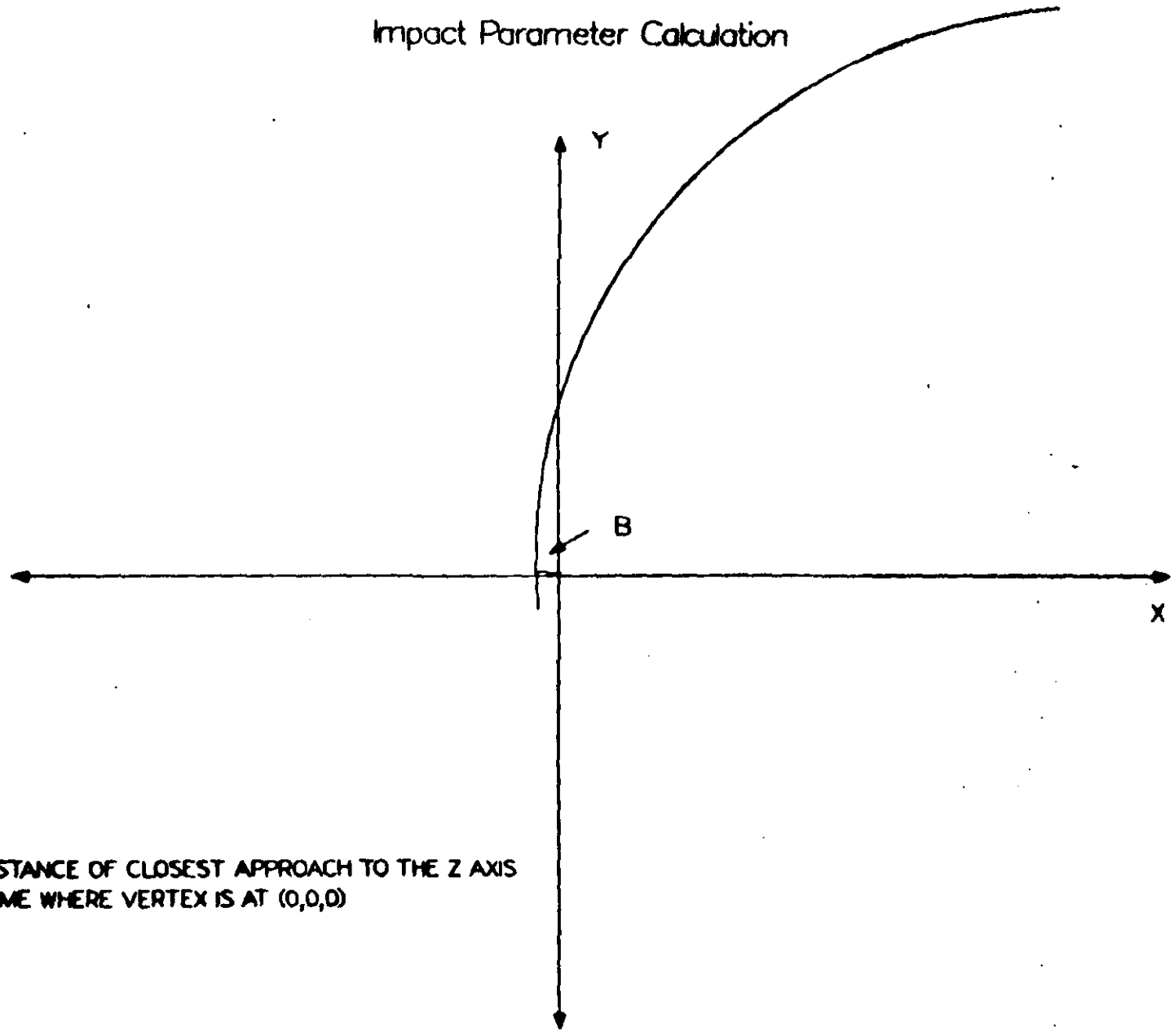
Progress on GEANT

1) Impact parameter and momentum resolutions in barrel region for various geometries have been calculated.

2) Beginning to study pattern recognition in barrel region. Charge and track efficiencies produced.

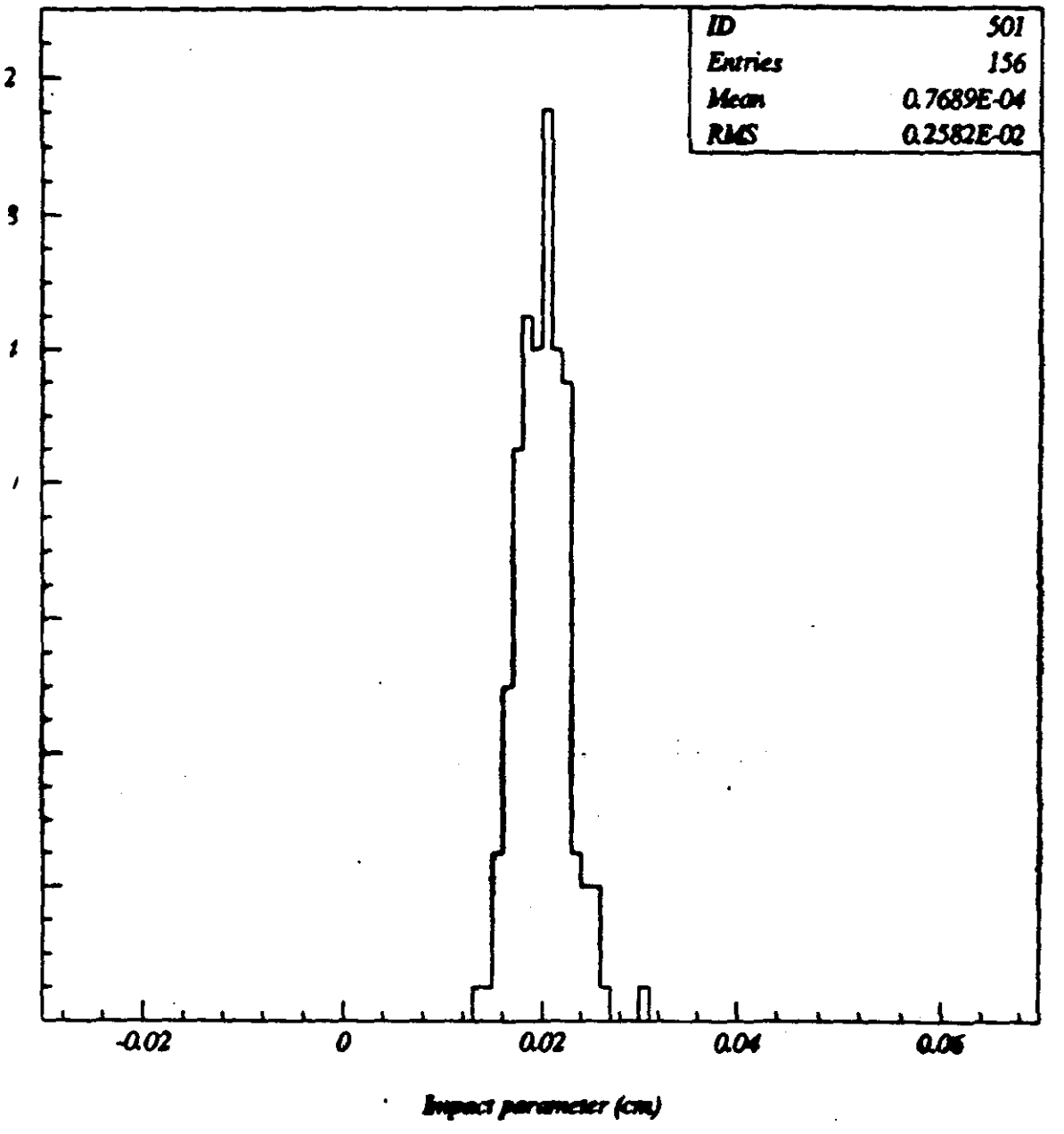
3) Much of forward region is complete but tracking from silicon to pads is not possible yet.

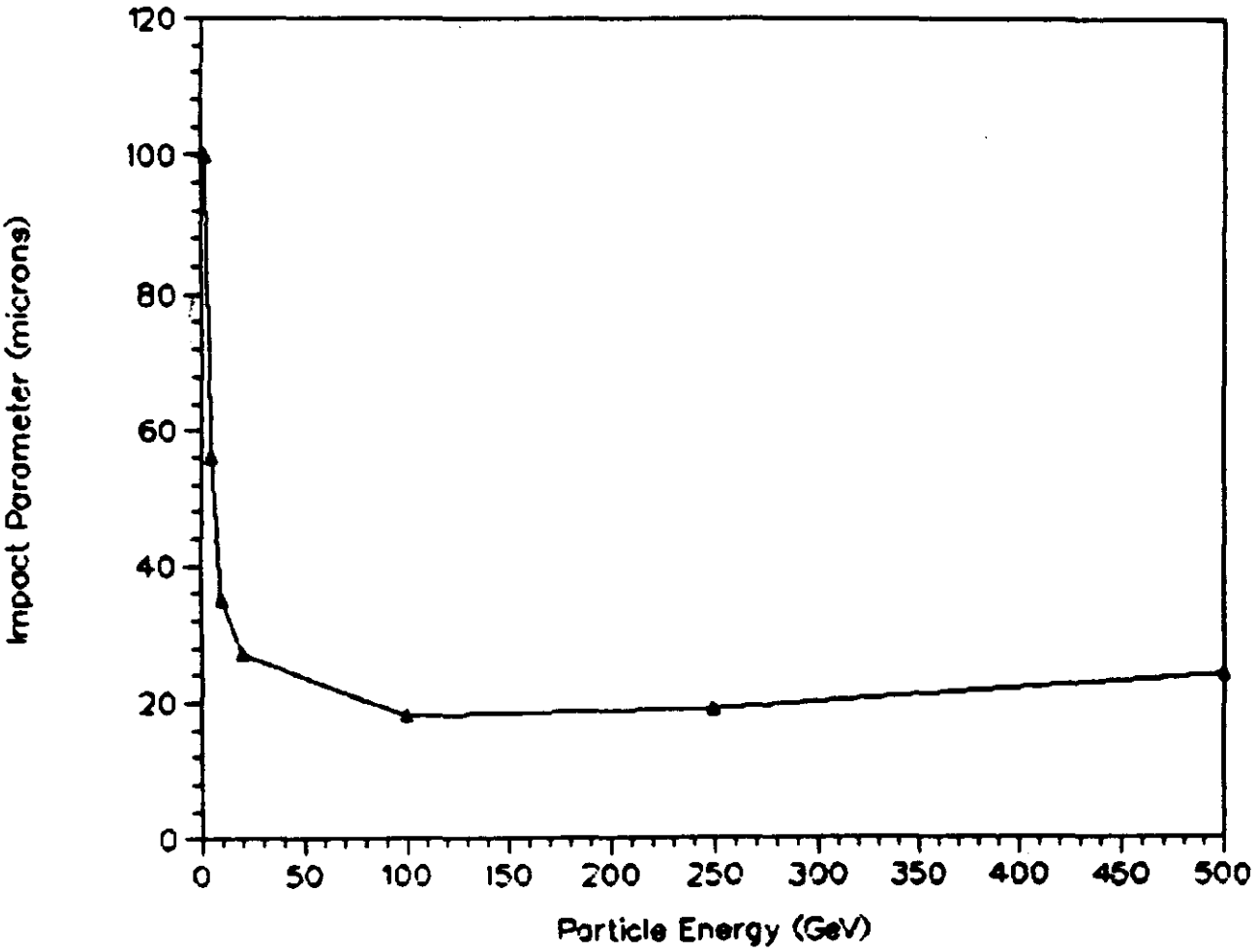
Impact Parameter Calculation

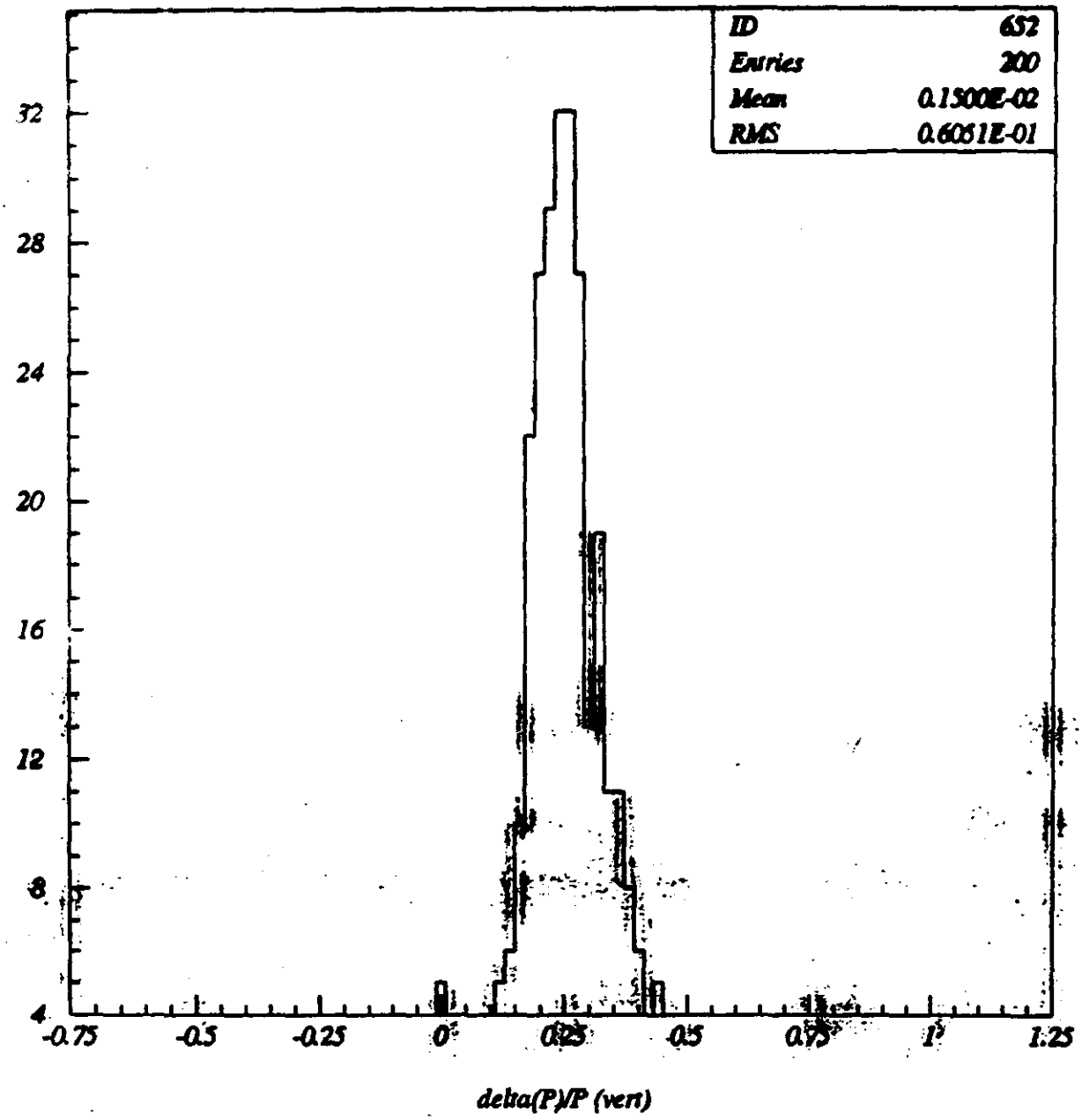


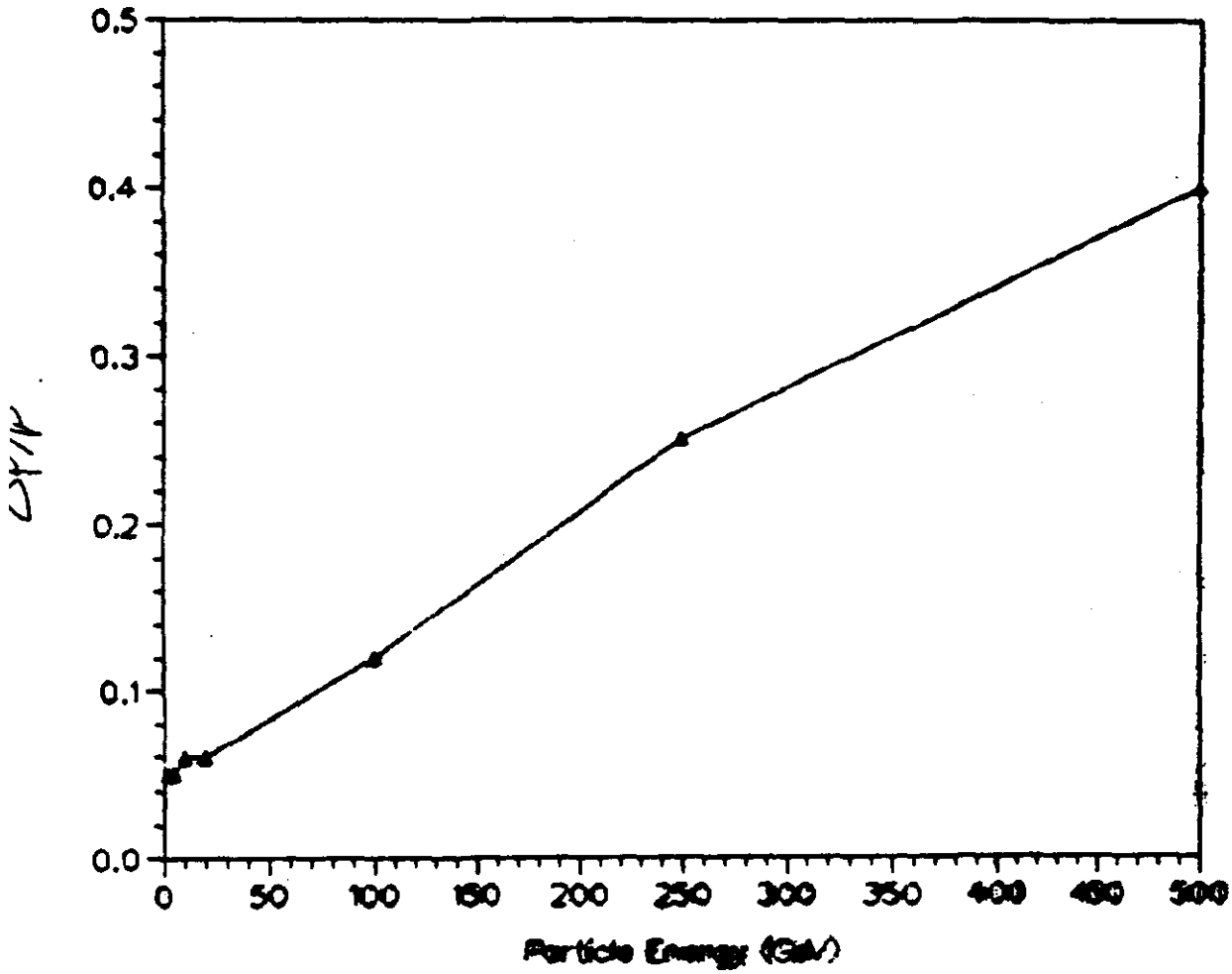
B = DISTANCE OF CLOSEST APPROACH TO THE Z AXIS
IN FRAME WHERE VERTEX IS AT (0,0,0)

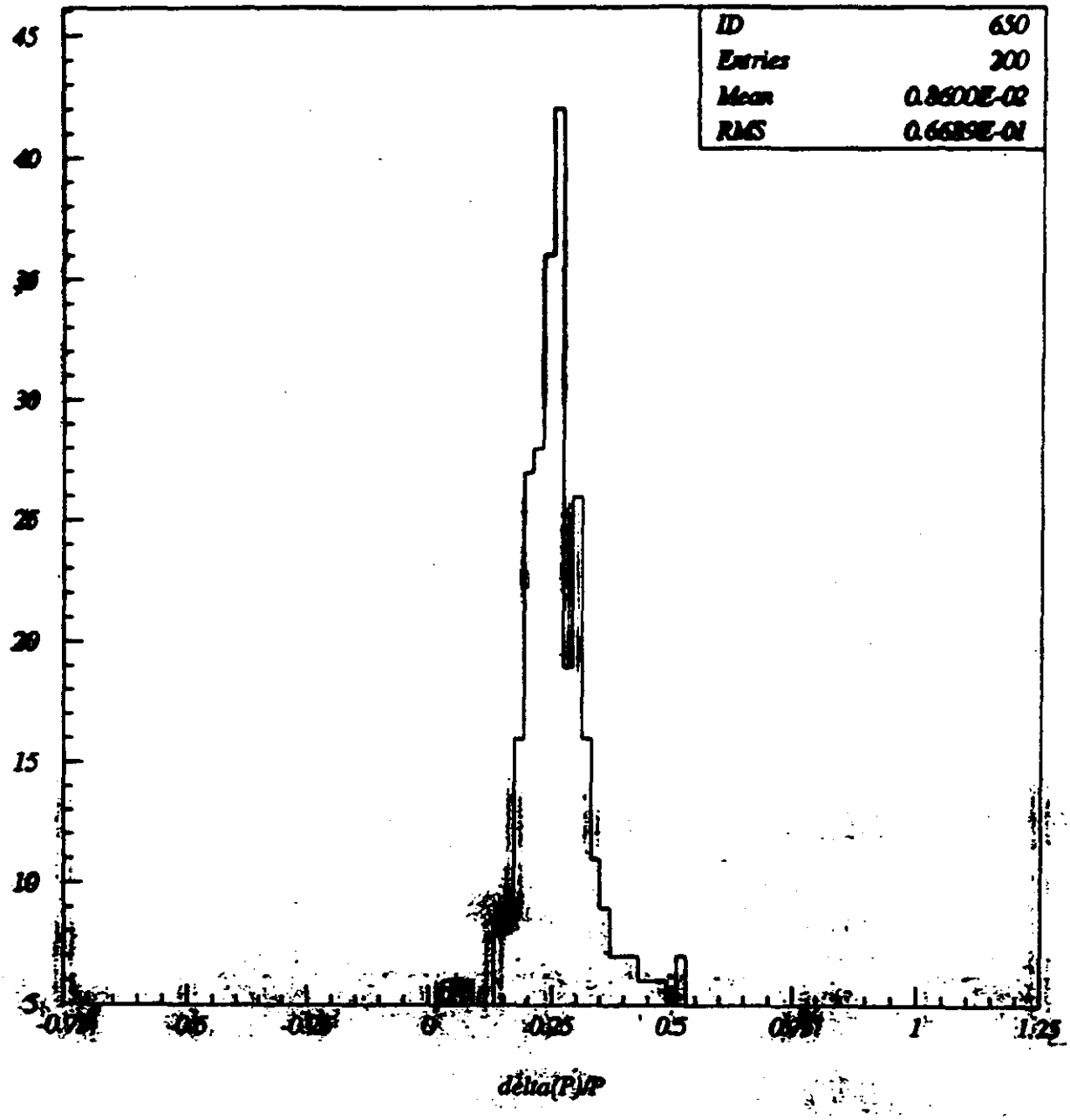
20 GeV Muons
Si: r = 10, 22 cm
Pixels: r = 35, 67 cm
5μm vertex




120
100
80
60
40
20
0
Impact Parameter (microns)
0
50
100
150
200
250
300
350
400
450
500
Particle Energy (GeV)


ID 652
Entries 200
Mean 0.1500E-02
RMS 0.6051E-01
32
28
24
20
16
12
8
4
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
1.25
delta(P)/P (vert)


0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
350
400
450
500
Particle Energy (GeV)


ID 650
Entries 200
Mean 0.8600E-02
RMS 0.6689E-01
45
40
35
30
25
20
15
10
5
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
1.25
delta(P)/P

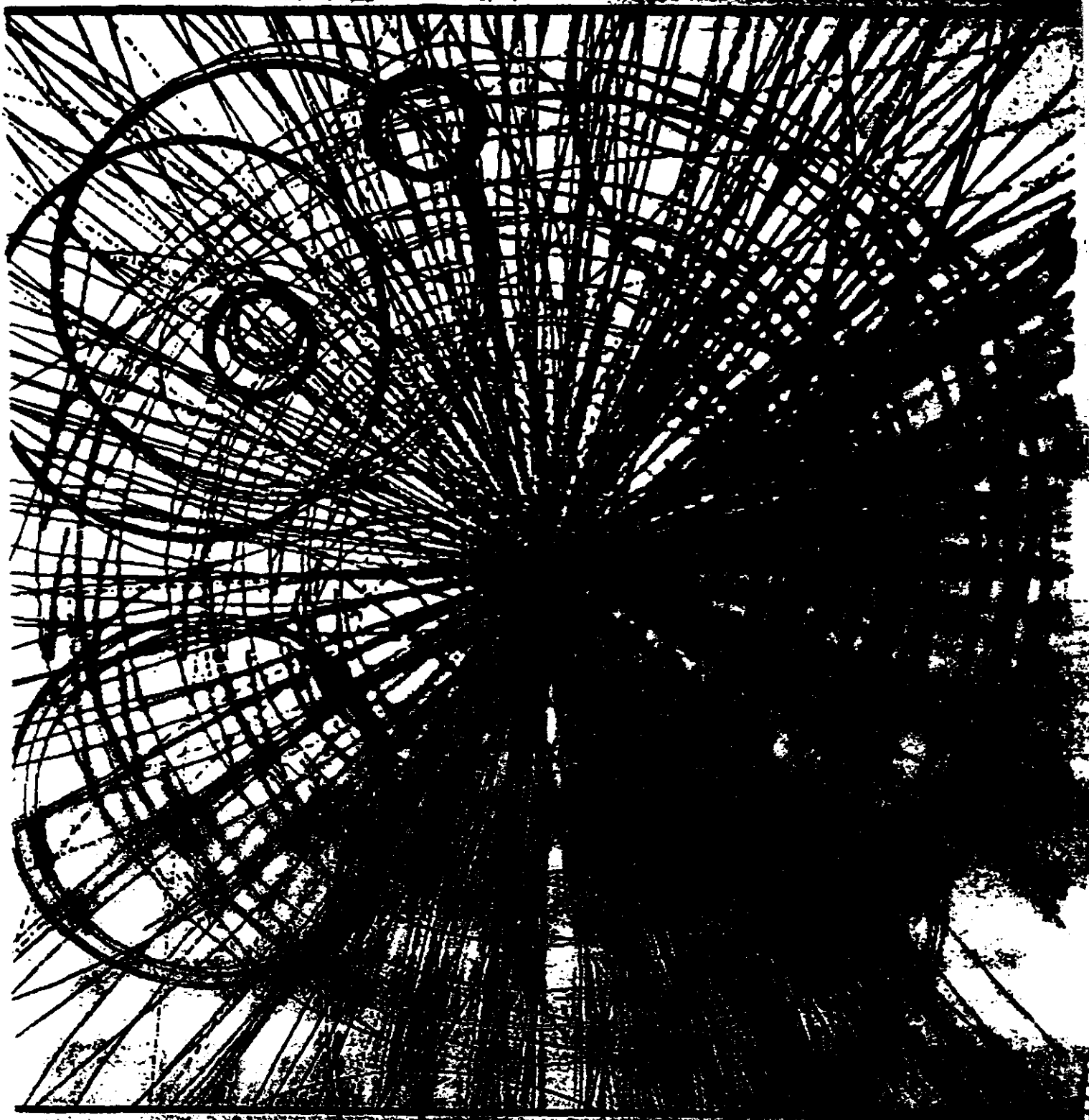
Impact Parameter and Momentum Resolution for Various Geometries

(Single track muons at 20 GeV)

Si layers	Si radii*	Pads layers	Pads radii	Impact param.**	$\Delta p/p$	$\Delta p/p$ w/ [illegible]
6	13,20,28	0	—	79	0.31	0.12
[illegible]	—	[illegible]	[illegible]	400	[illegible]	[illegible]
[illegible]	—	[illegible]	[illegible]	100	[illegible]	[illegible]
4	13,20	4	[illegible]	[illegible]	[illegible]	[illegible]
6	13,20,28	4	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	28	0.07	0.[illegible]

* in cm
** microns

THESE POINTS ARE NECESSARY FOR IMPACT PARAMETER RESOLUTION. TOTAL [illegible] AND SPACING MUST BE DETERMINED BY PATTERN RECOGNITION CAPABILITIES.



Higgs Event with 1.6 minimum bias events overlayed in Silicon detectors

Efficiency Definitions

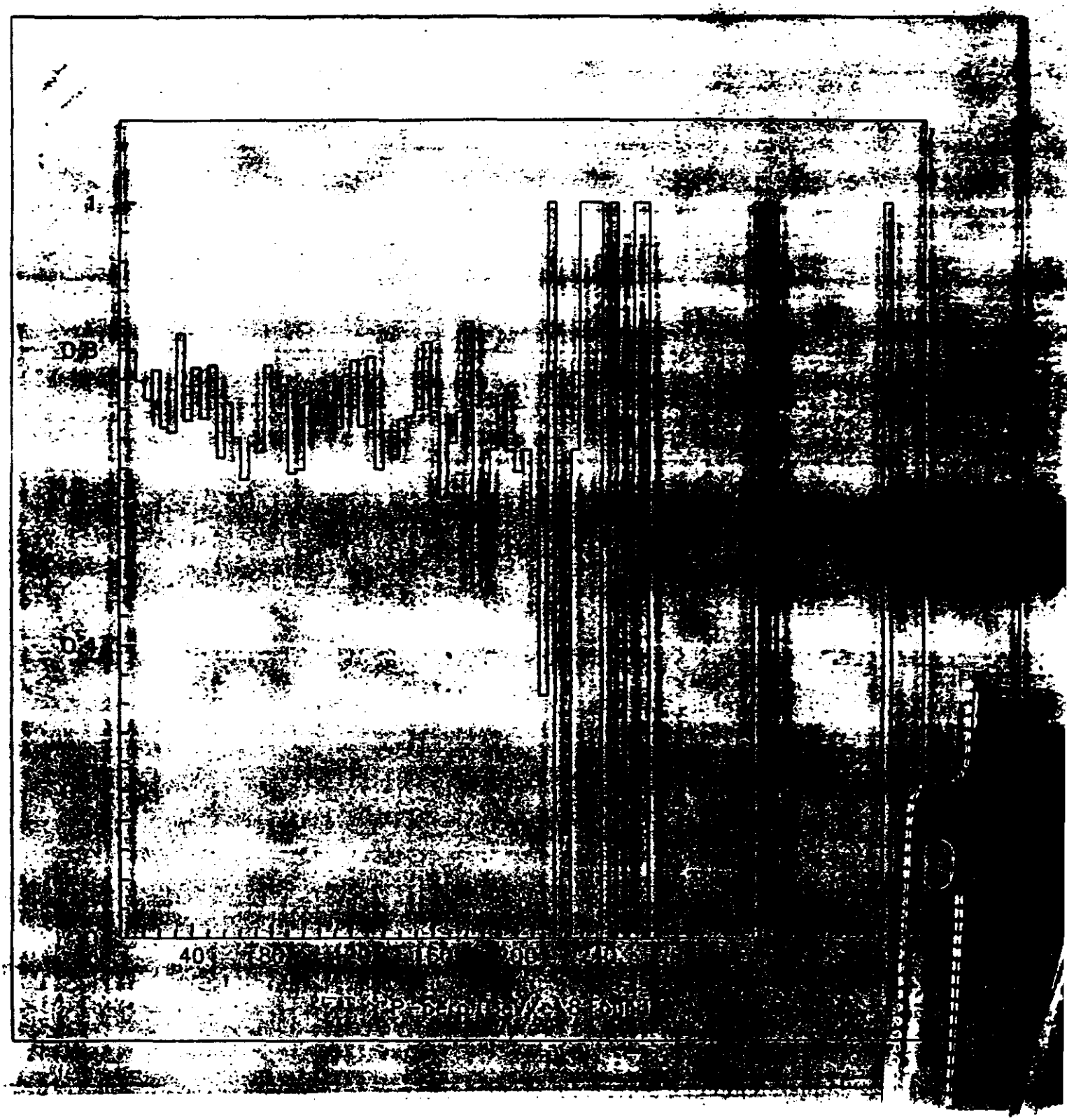
Tracking Efficiency Definition:

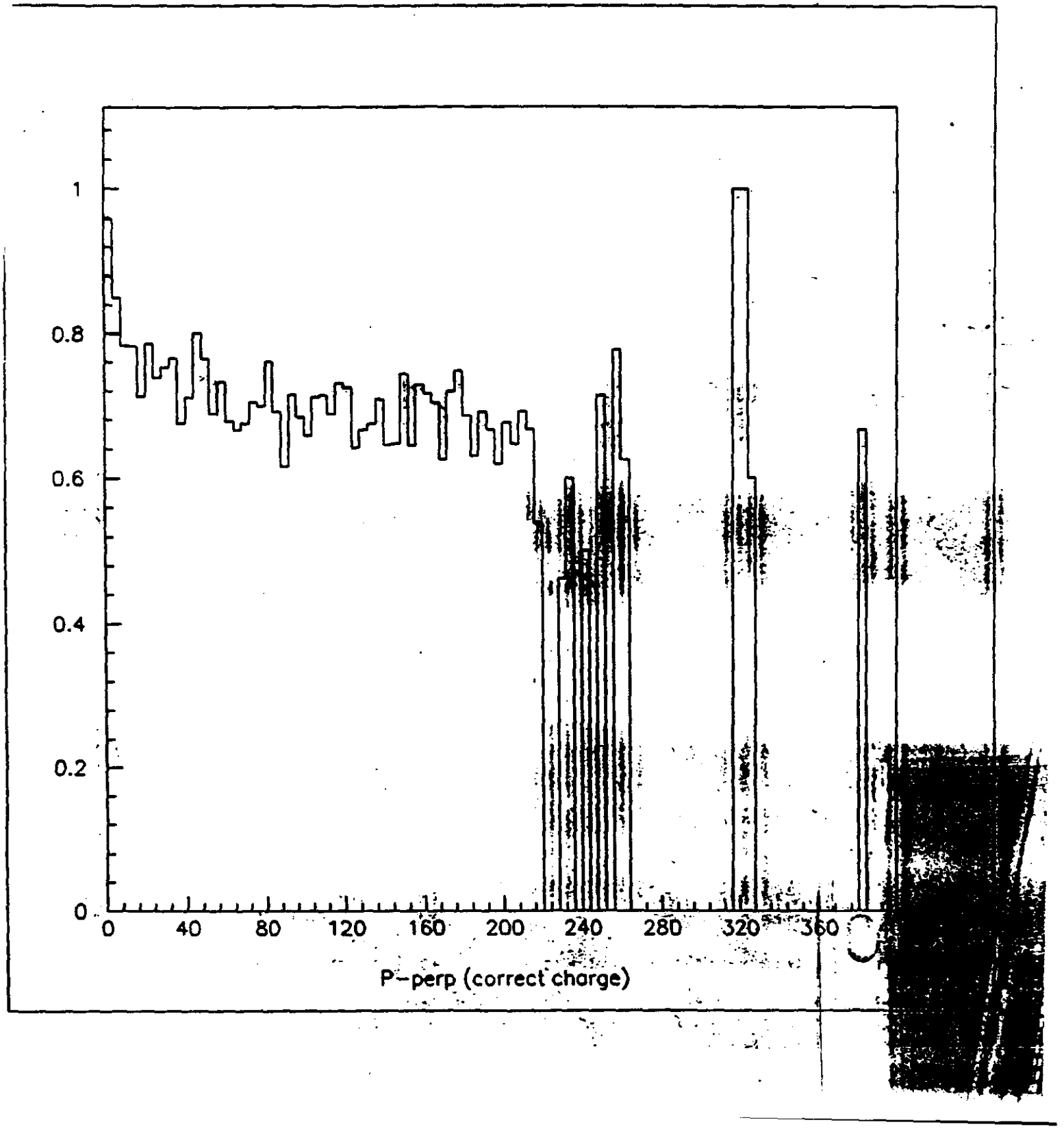
$$E = \frac{\text{\# found tracks with 5 or more correct hits}}{\text{\# tracks that produced 5 or more hits in detectors}}$$

Charge Efficiency:

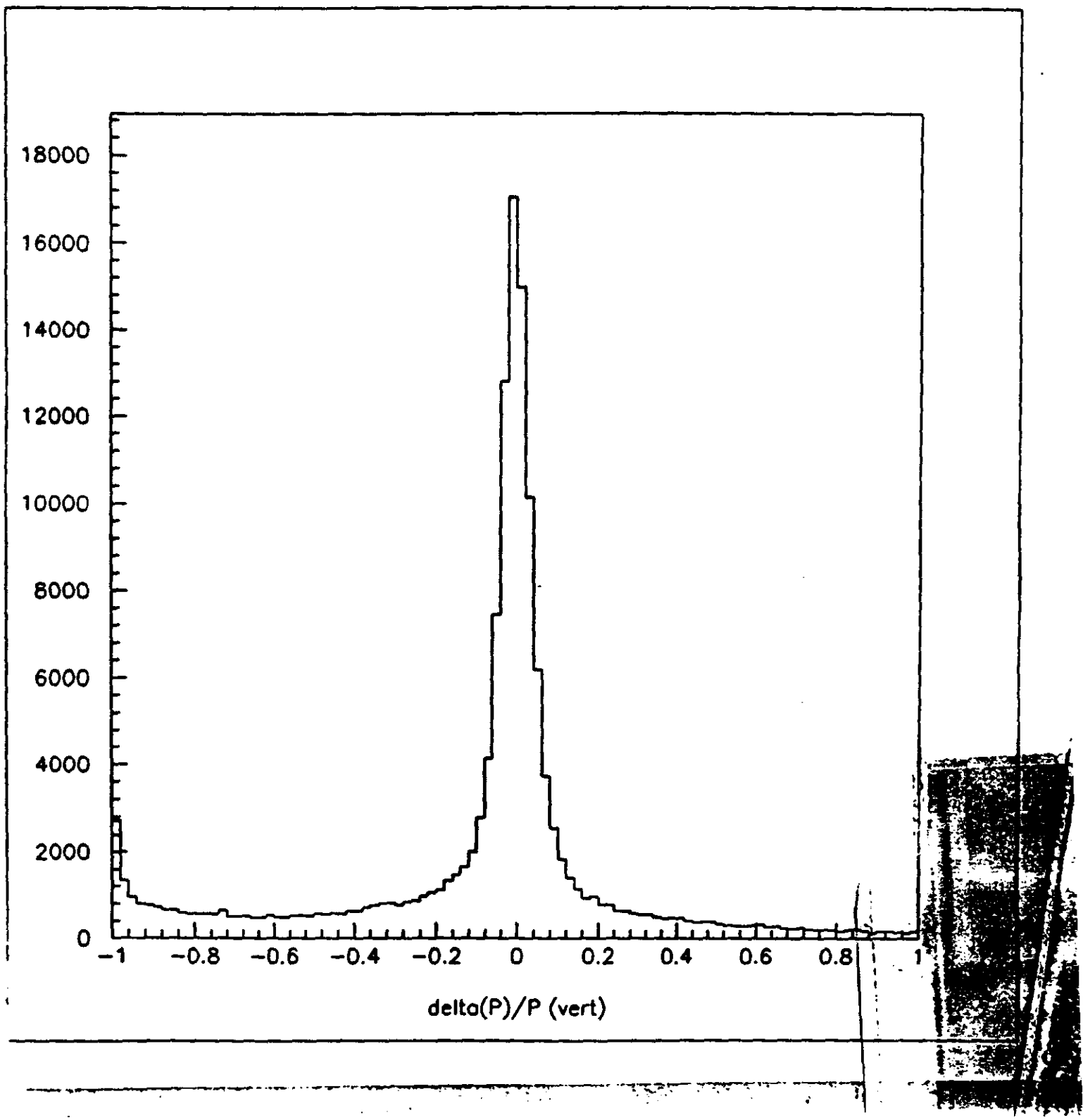
$$E = \frac{\text{\# tracks with measured charge = true charge}}{\text{\# found tracks}}$$

[illegible]
minimum bias events [illegible]
with Higgs.
8 or more out of 14 hits correctly
identified

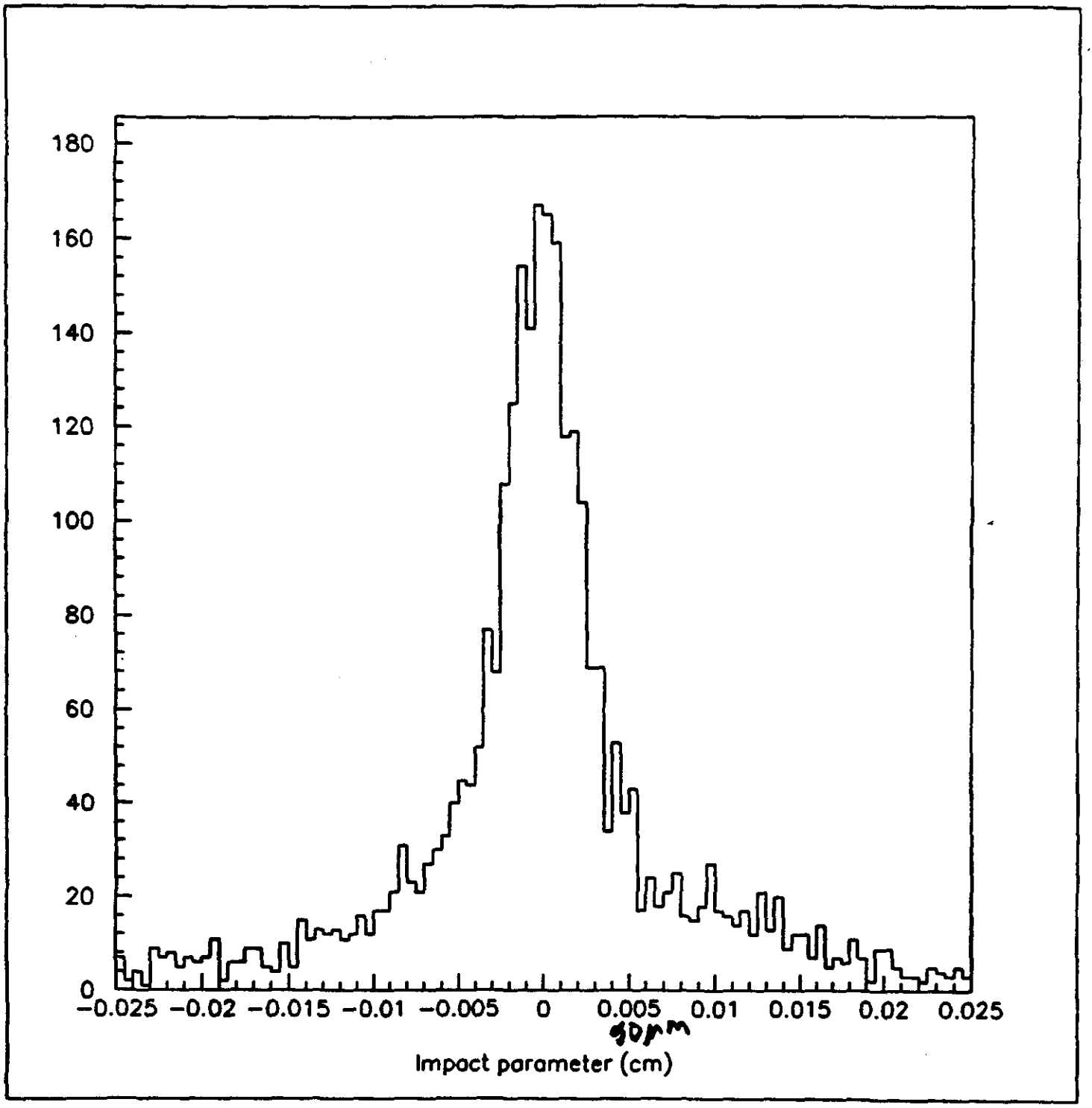



1
0.8
0.6
0.4
0.2
0
0
40
80
120
160
200
240
280
320
360
P−perp (correct charge)

Higgs with 1.6 minimum bias events overlayed. Momentum resolution for all tracks



Higgs events with 1.6 minimum bias events overlayed
Impact parameter resolution for all tracks



K. Morgan

Integration Issues
(Global and Specific)

1 - Assembly Scenarios for GEM

Fixed Magnet vs Mobile Magnet (2 or 3)

CT installation Jan 96 Dec

CT installation last overall flexibility GEM

→ Is Quick Access necessary? useful?

→ Is access to only 1 end of CT useful?

2 - Beam Pipe Design

diameter - Xray scan

$\phi = 50$ mm

how close do we expect to measure anything?

constant?

material and thickness Be ≤ 1 mm

decoupling via 2nd wall?

Vacuum Quality? 10^{-8} torr? WIP

Coordination w/ 1) Rest of GEM installation

2) Surveyors min ϕ aligning

3) Accelerator vacuum Qlty

Alignment

Beam pipe fixed to CT, CT mobile in B. Cal

3 - CT - dimensions (clearance + alignment in B. Cal)

4 - CT alignment wrt Muon System

Defend our space: inner radius outer radius

5 - B field of 1 Tesla?

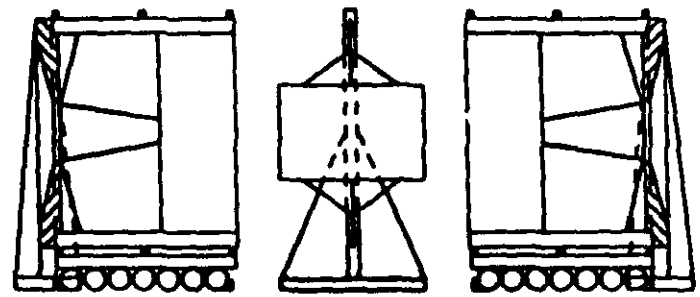
6 - Surface Facilities being defined today

Requires knowledge of construction details testing details etc.

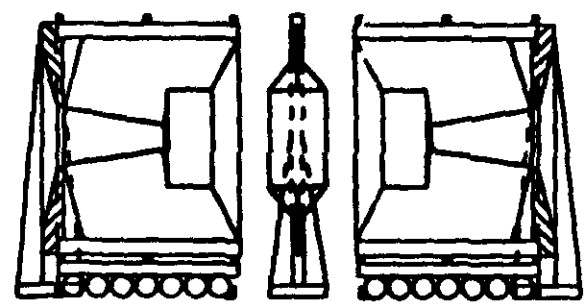
Assume Magnet Hall available

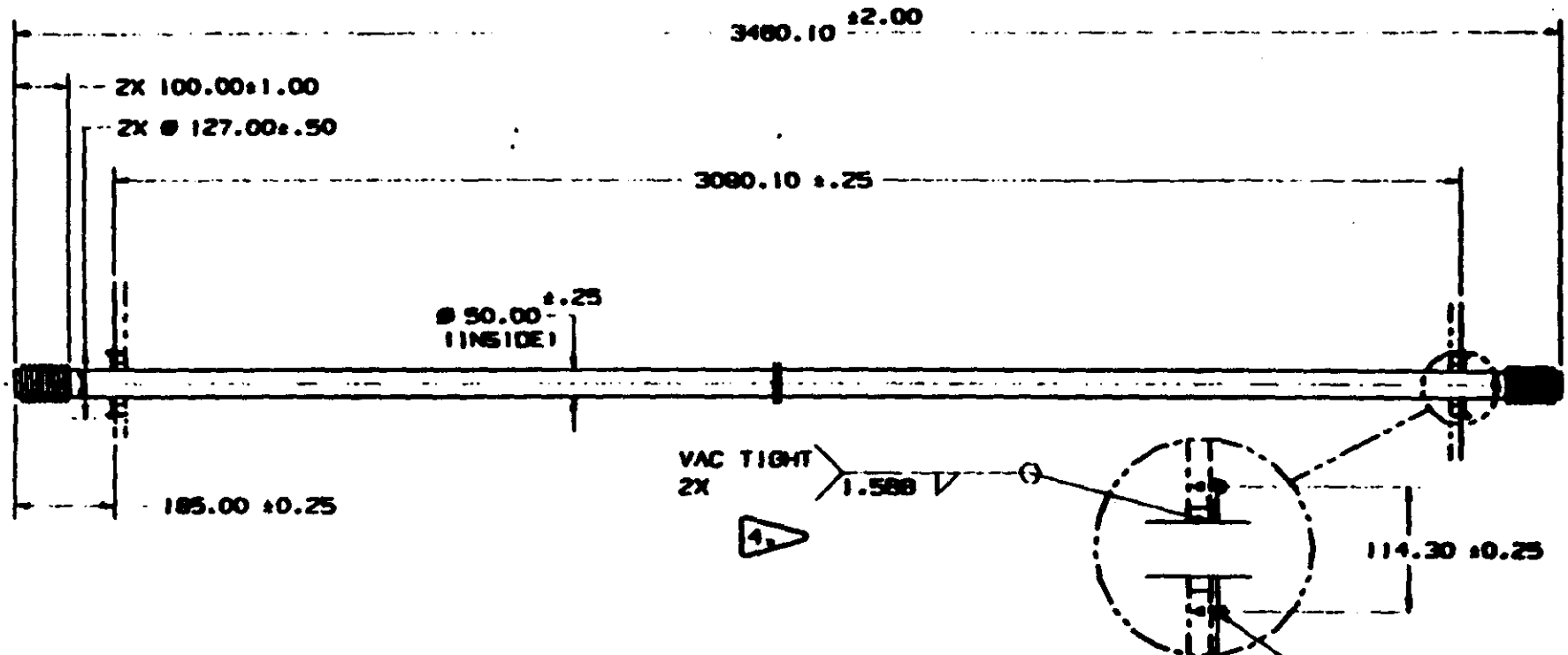
CALORIMETER SUPPORT:

INTEGRAL



OR SPLIT?





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2. A STRAIGHTNESS MEASUREMENT OF .080 OF AN INCH FOR THE TOTAL LENGTH.
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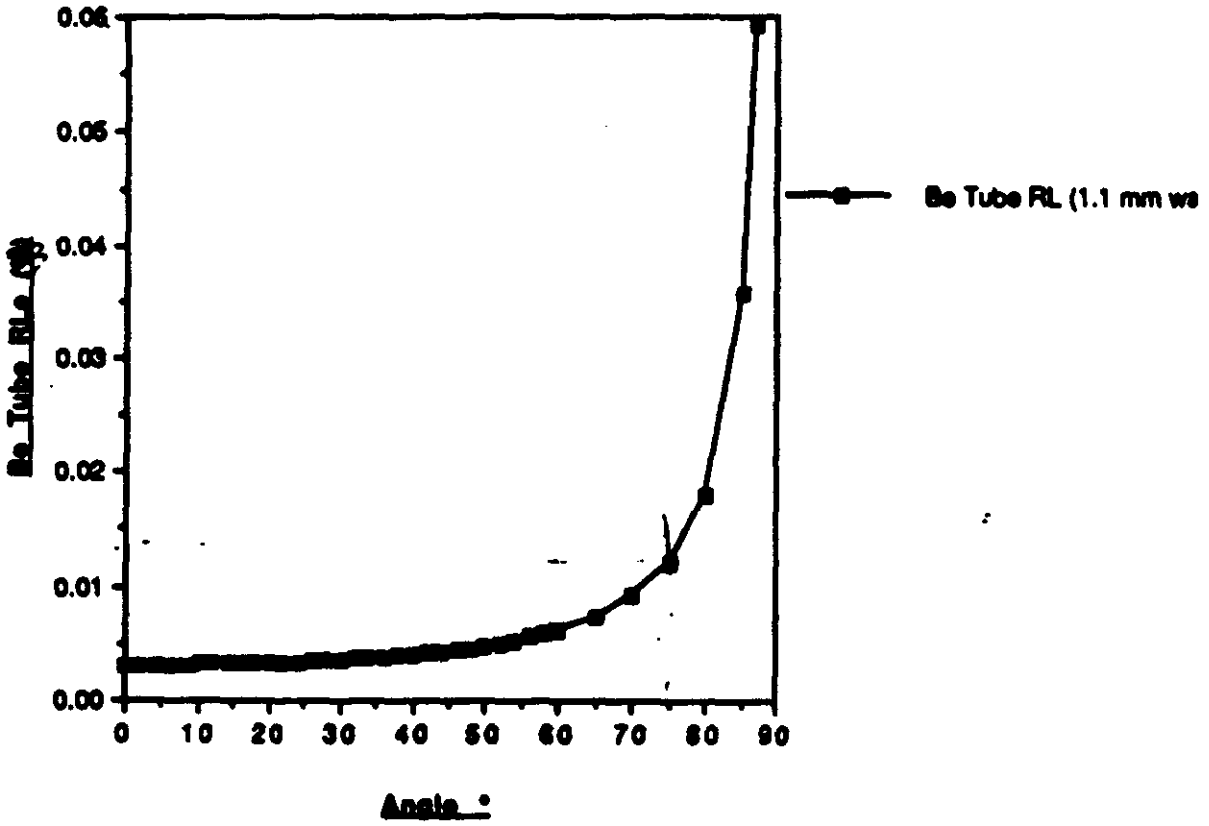
   OR OTHER GRADE OF 98% BERYLLIUM
   BELLOWS-ALUMINUM PREFERABLY
   OR STAINLESS STEEL

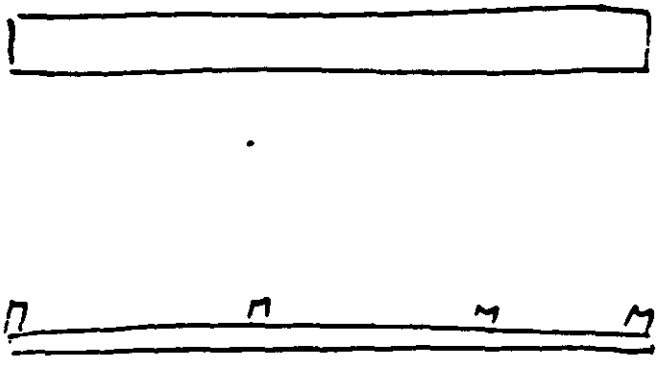
PRELIMINARY
NOT TO BE USED FOR FABRICATION

METRIC
THIRD ANGLE PROJECTION

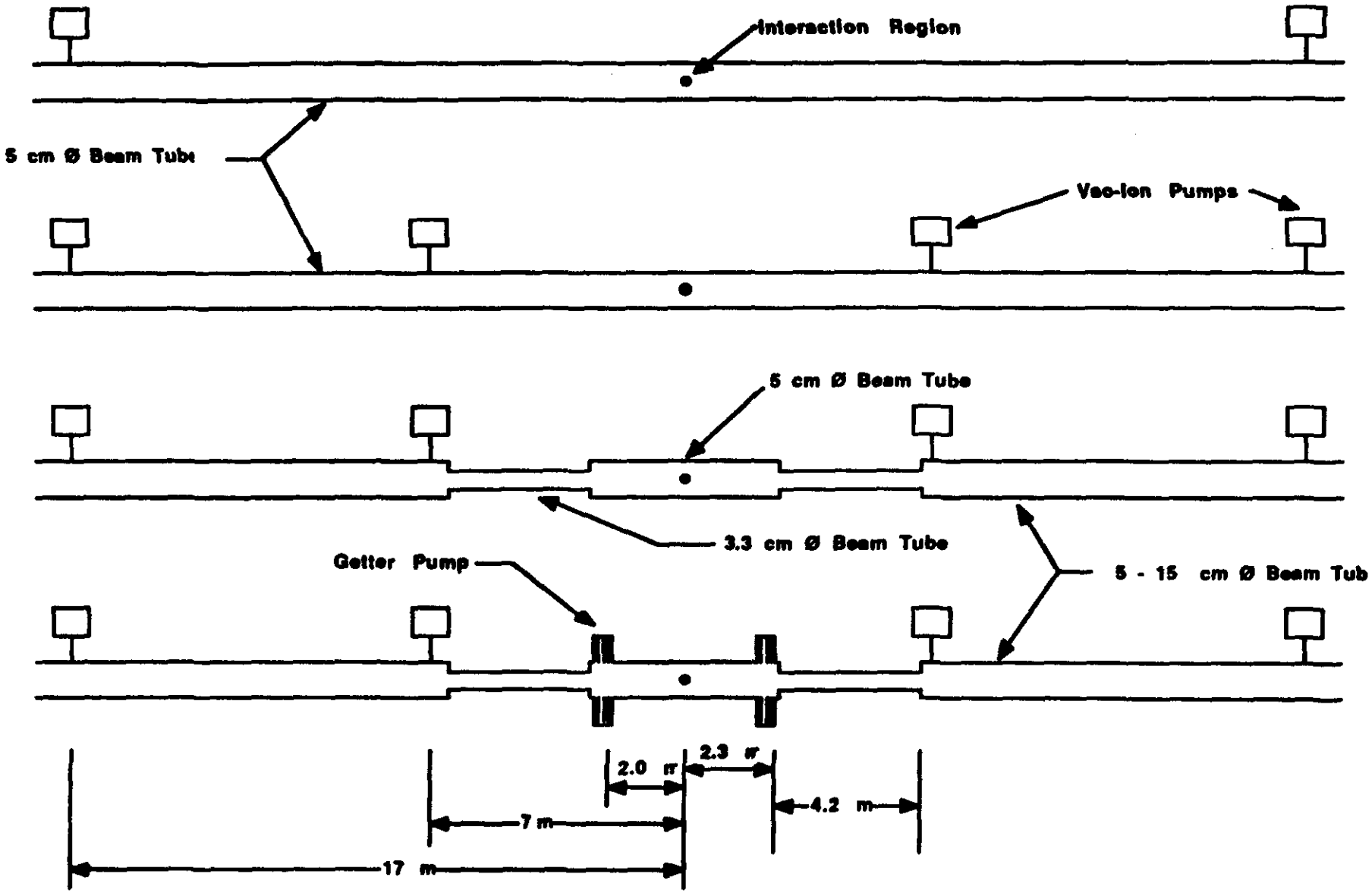
GEM
CENTRAL TRACK
BERYLLIUM BEAM
BK-GEM12-00

Be Beam Tube Radiation Length





Vacuum Beam Tube Configurations



1/22/92 RLB

Vacuum Beam Line Specifications

- **Alignment**
  - Need a large enough aperture to optically align through
  - 3 mm of radial misalignment between the Detector and Beam centerline should be accommodated.
  - The IR Beam tube centerline may be optically located to only 2mm.

- **Radiation Length**
  - Minimum Radiation Length through the Tracker eta < 2.7
  - Flanges of minimum radiation length may be acceptable between eta > 3.0 and 3.3 cm Ø beam tube.

- **Vaccum Level**
  - 1×10^{-8} Torr at the Interaction Region
  - Some higher pressure (1×10^{-7}) may be tolerated in the 3.3 cm Ø Tube.

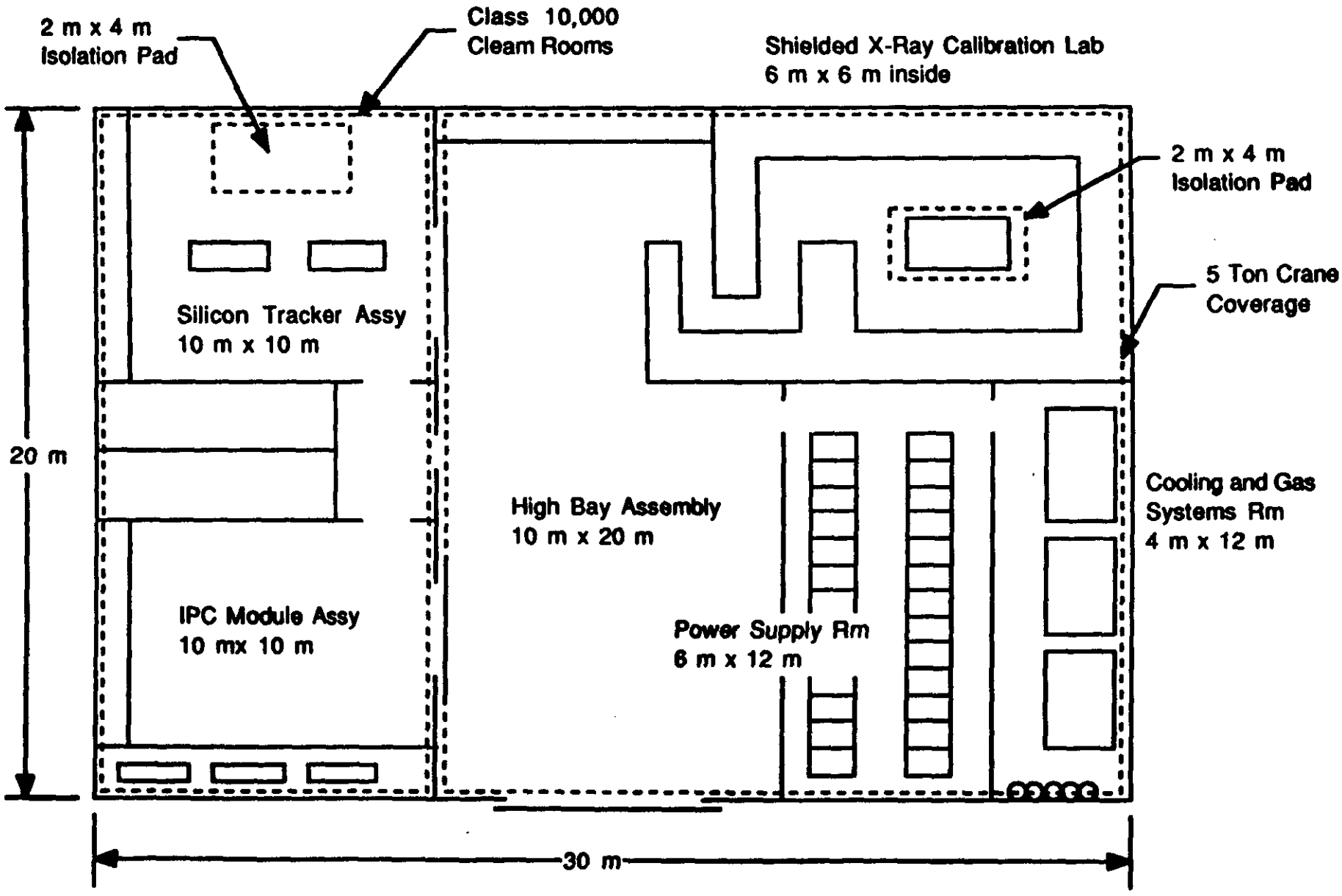
- **Assembly and Installation**
  - Sections of the beam pipe may be baked out at ____°C inside the installed detector.
  - Beam line sections will be assembled sequentially as successive detector layers are added.
  - Bolted flanges are preferable, field welded joints should be kept to a minimum.

- **Beam Tube Diameter**
  - Nominal Beam Tube diameter is 5 cm inside the Tracker.
  - Forward Calorimetry requires a 4.0 cm inside diameter of active detector; this translates to about 3.3 cm Ø beam tube.

- The Beam Tube in the forward region between 7 m and 17 m is limited to the clearance required for the flux sucker, which is about 15 cm Ø.
- Changes in diameter should be through gradual transitions to minimize impedence mismatch.

12/22/92 K. Morgan

Central Tracker Assembly and Maintenance Facility



CENTRAL TRACKER SIMULATION AT YALE

GEANT 3.15 code currently consists of:

- detailed pad chamber geometry in the barrel region (for 3 superlayer design)
- simple geometry for pad chamber endcaps and for silicon
- simple hit mechanism — no simulation of pad chamber response

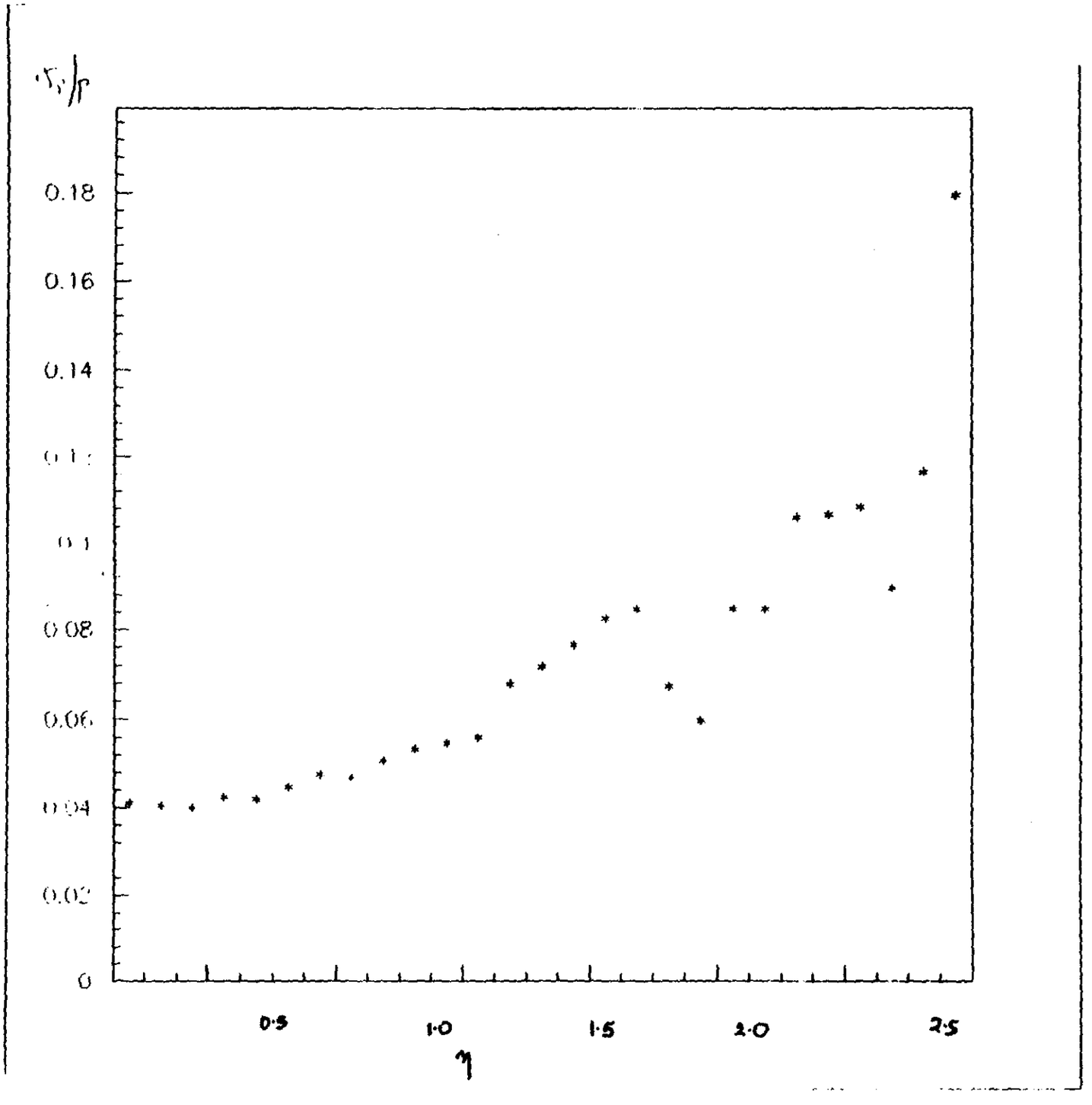
Changes to be implemented:

- insert 4 superlayer geometry
- make a realistic endcap geometry
- make better estimates of materials in the pad chambers
- import realistic Si geometry from LANL.

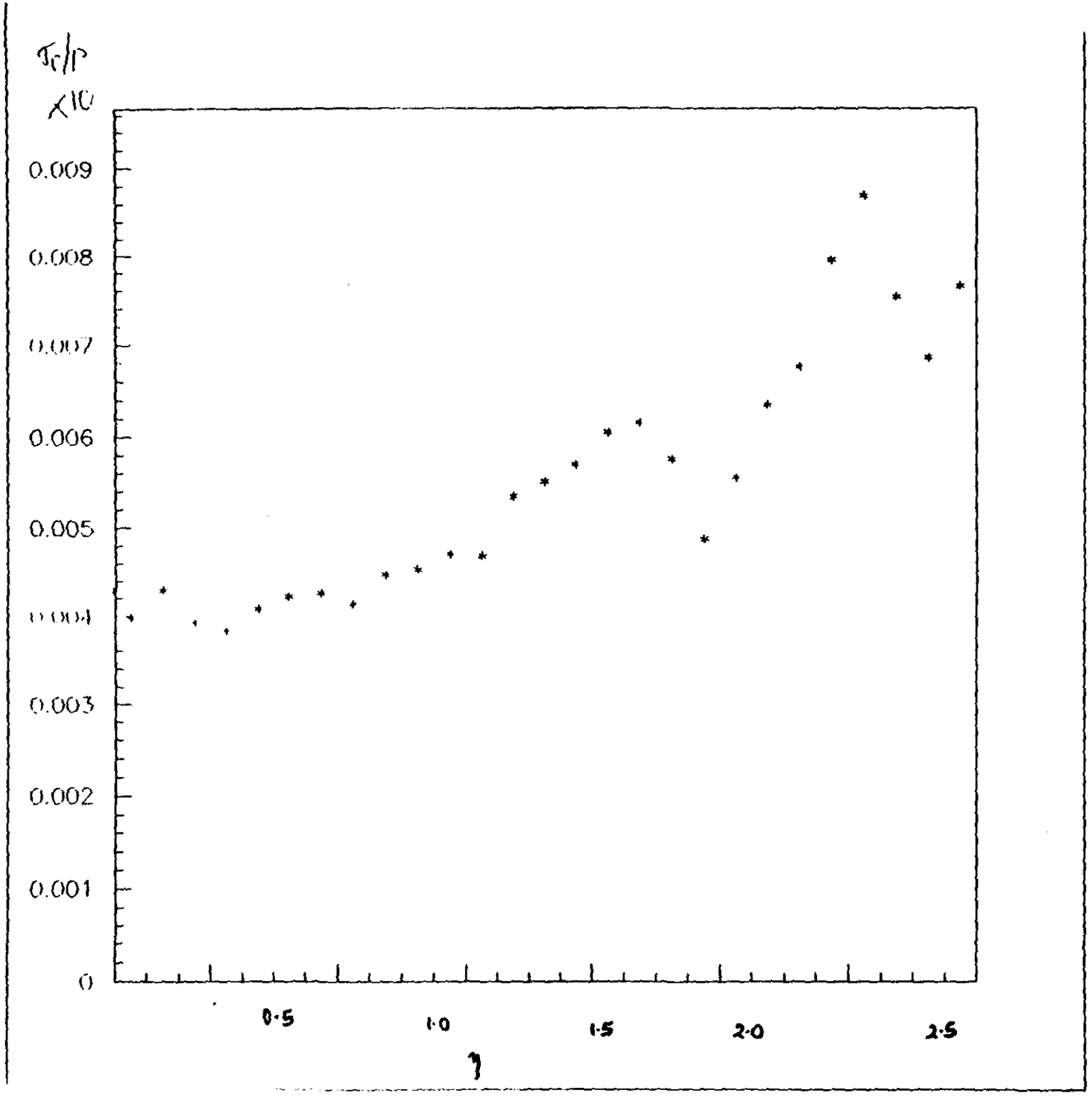
TOPICS STUDIED SO FAR

- momentum resolution:

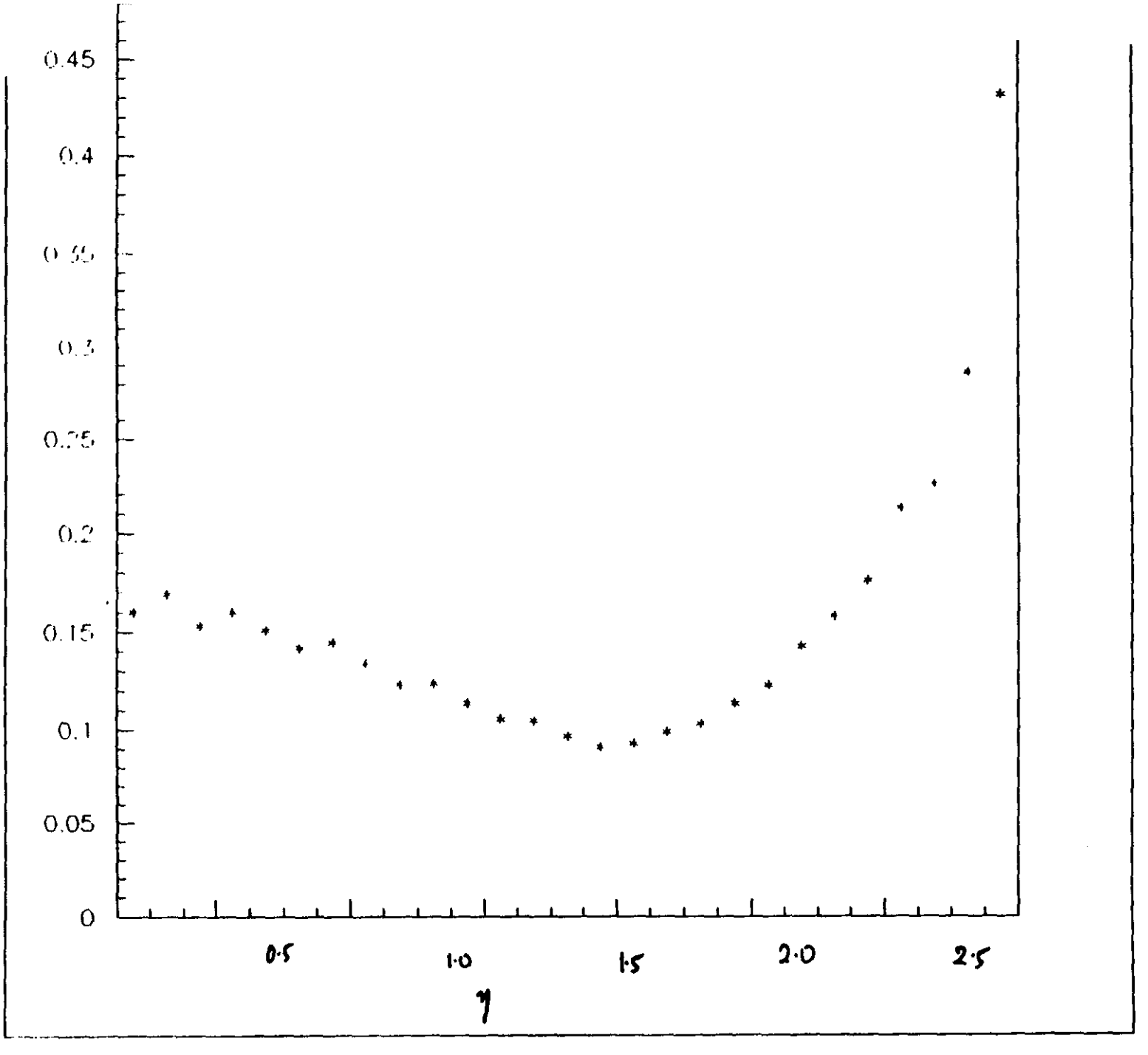
  multiple scattering and energy loss accounted for, but not considered in track reconstruction at present — should give better resolution



1 GeV


σ_c/p
$\times 10$
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0·5
1·0
1·5
2·0
2·5
η

10 GeV


0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.5
1.0
1.5
2.0
2.5
η

$\frac{dn}{d\eta} \sim 6$ tracks/event

$\frac{dn}{d\eta\, d\phi} \sim 1$ track/event

$\Delta\eta\, \Delta\phi = 0.00071$ per pad

$\therefore$ expected occupancy/event/pad $= 0.00071$

$\mathcal{L} = 10^{33} \Rightarrow 1.6$ event/crossing
$\mathcal{L} = 10^{34} \Rightarrow 16$ event/crossing
} expect to collect from 2 crossing.

$\therefore$ $\mathcal{L} = 10^{33}$ occupancy $= 0.23\%$

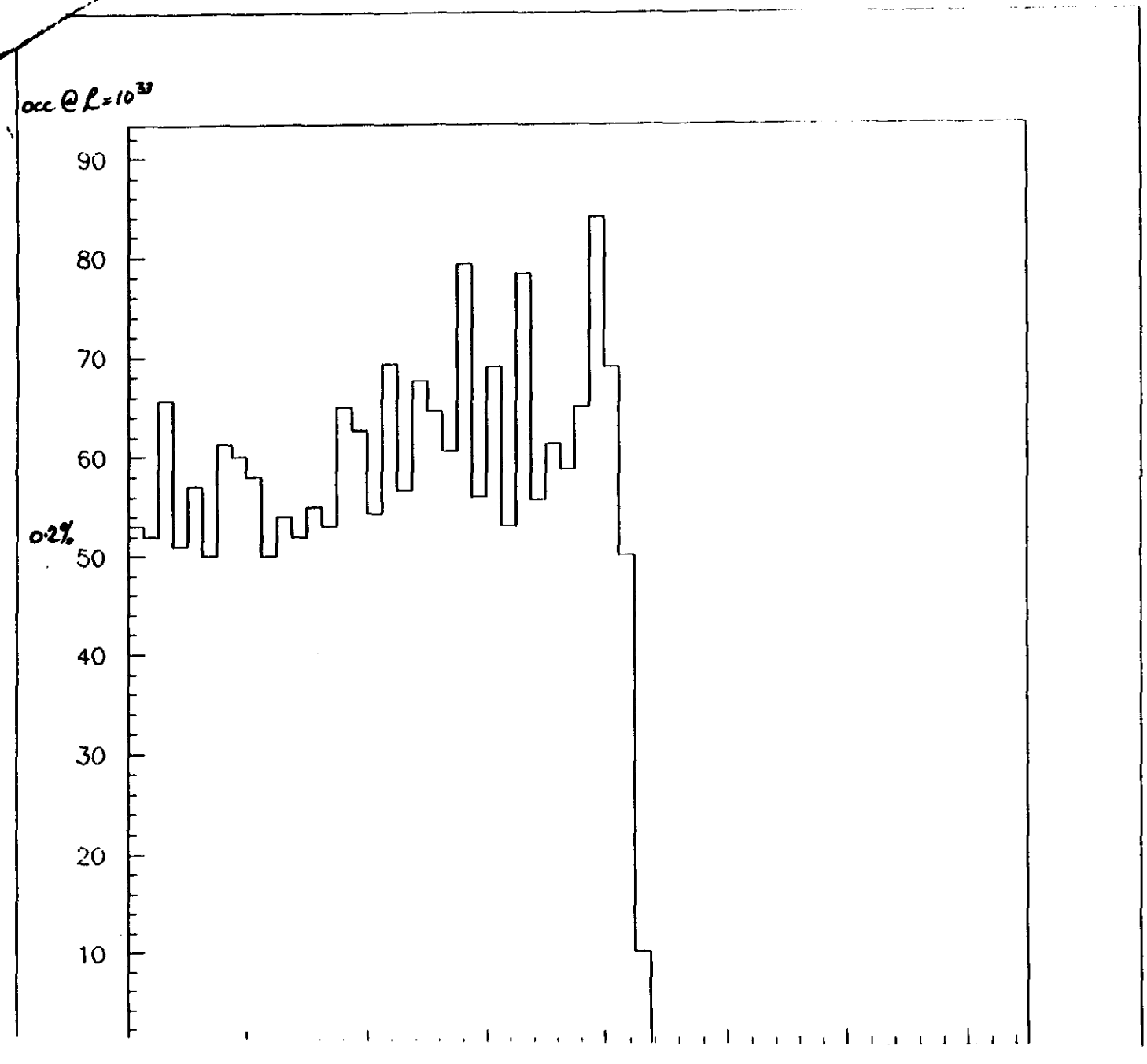
$\mathcal{L} = 10^{34}$ occupancy $= 2.3\%$

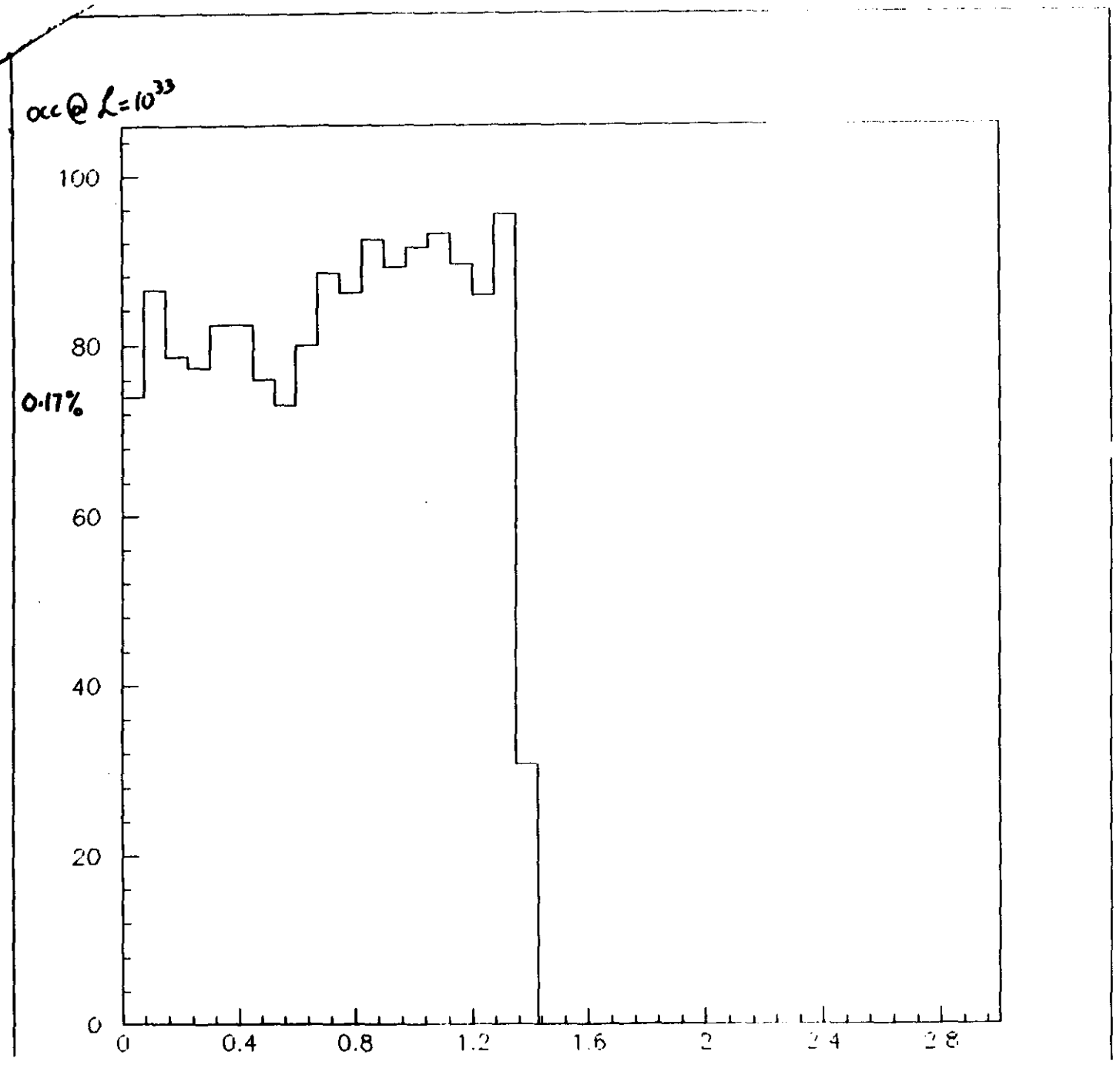
<u>SIMULATION</u> : 3 superlayer design
16 pad chambers/superlayer

3200 MIN BIAS events.

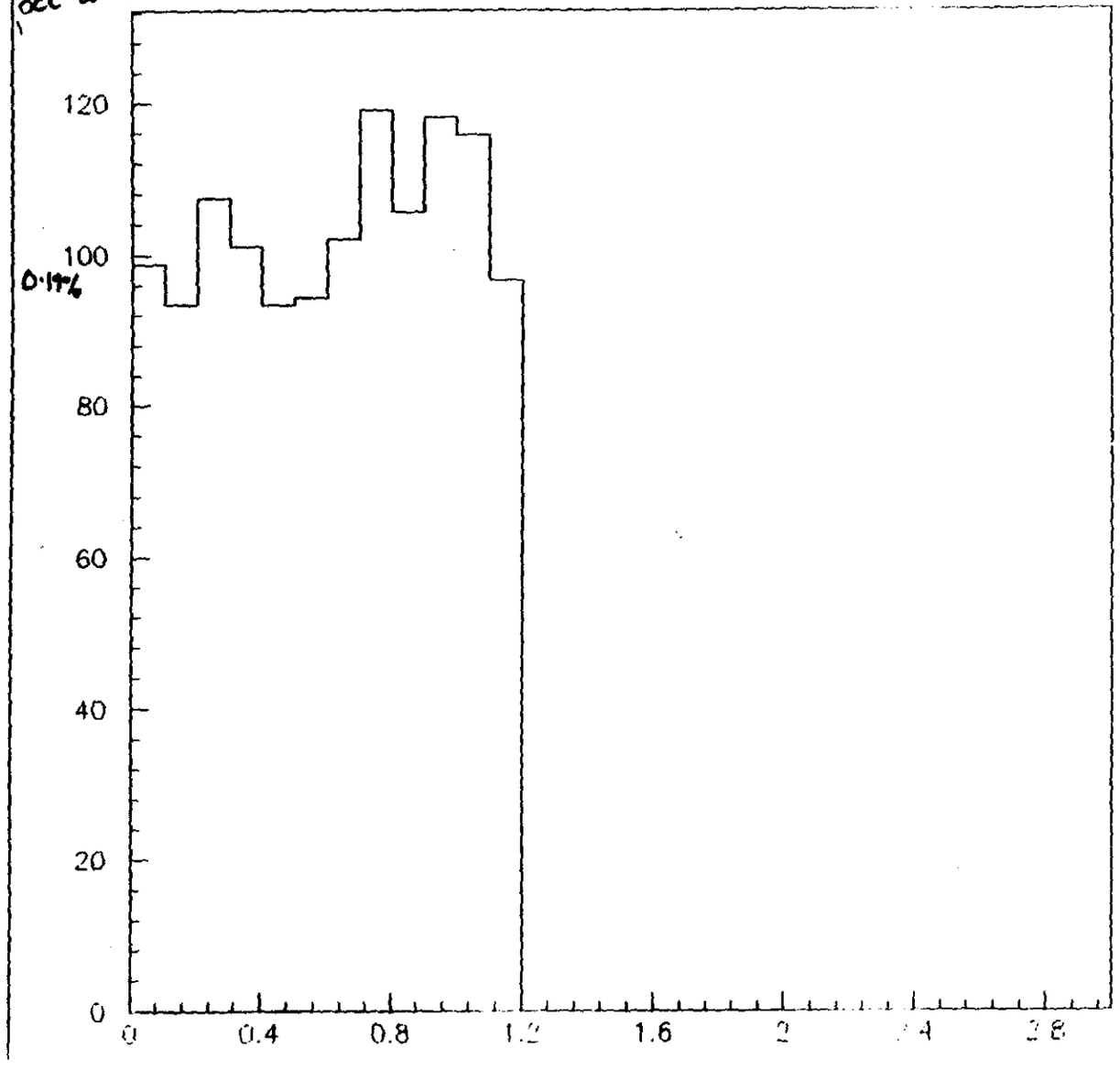
<u>OCCUPANCY</u> <u>@ $\mathcal{L} = 10^{33}$ @ $\eta = 0$</u>

	1st superlayer	2nd superlayer	3rd sup
NO SECONDARIES	0.2%	0.17%	0.1
W/ SECONDARIES	0.28%	0.37%	0.31

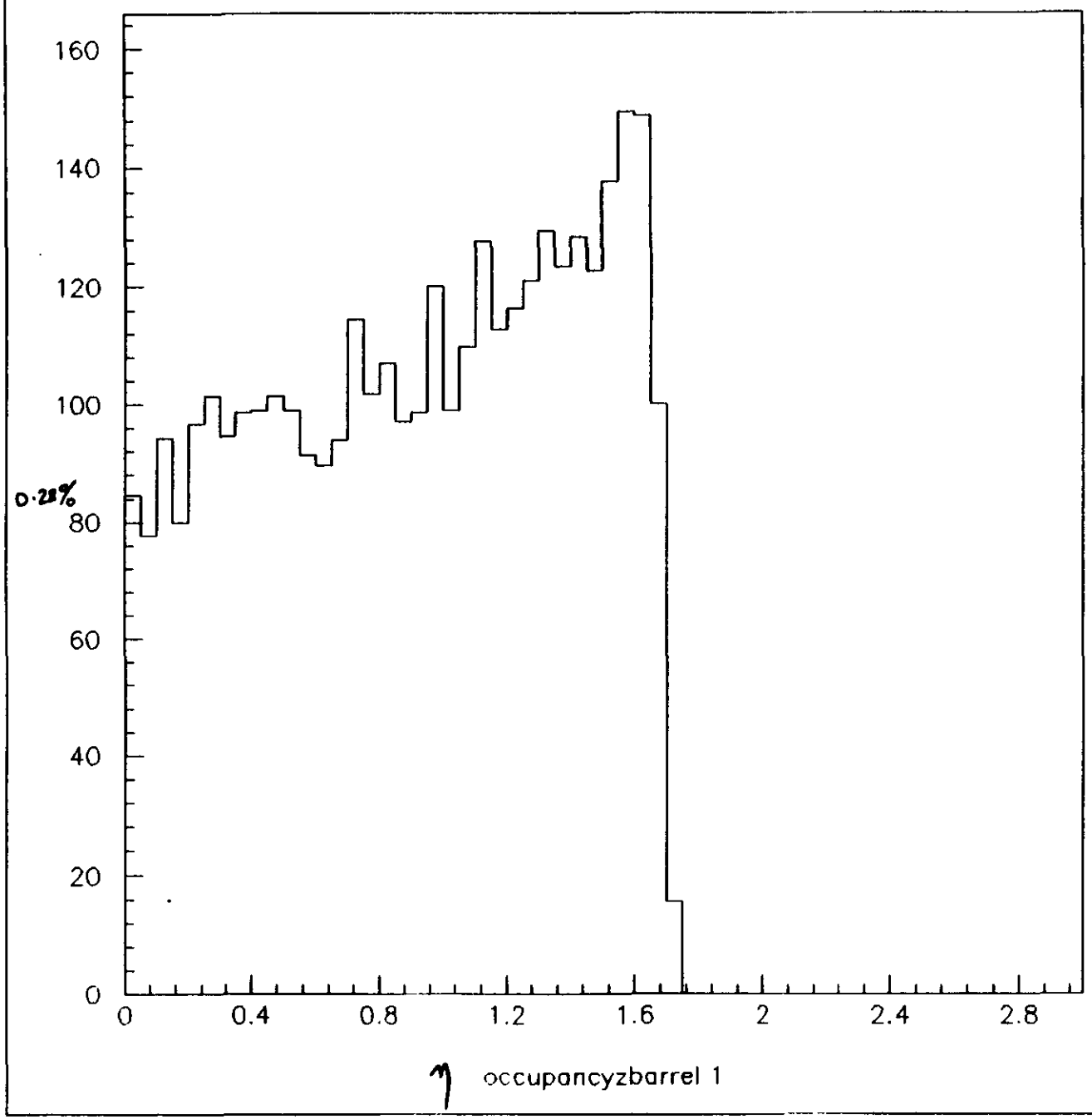

occ @ $\mathcal{L}=10^{33}$
90
80
70
60
0.2%
50
40
30
20
10

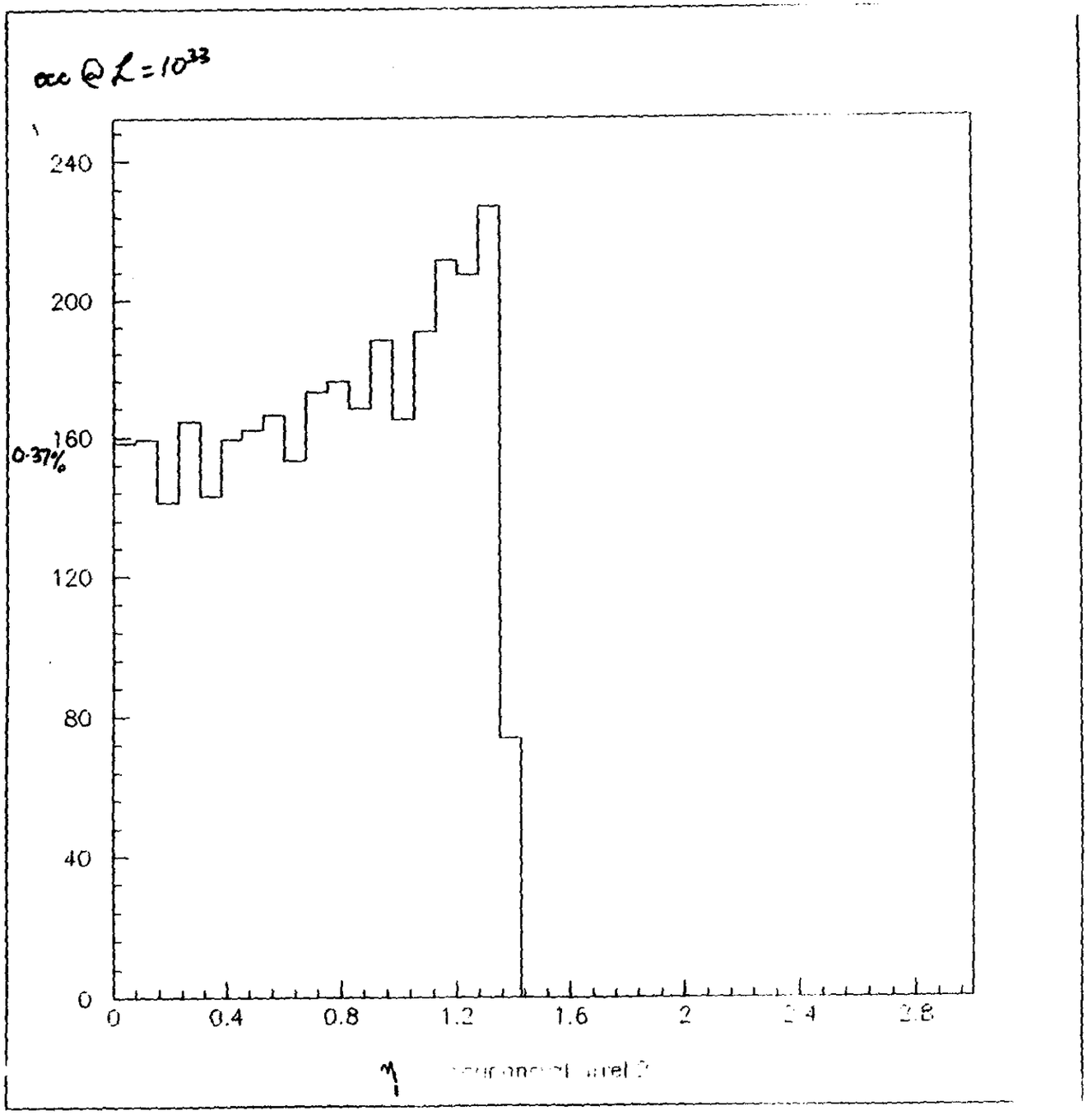

acc @ $\mathcal{L}=10^{33}$
100
80
0.17%
60
40
20
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8

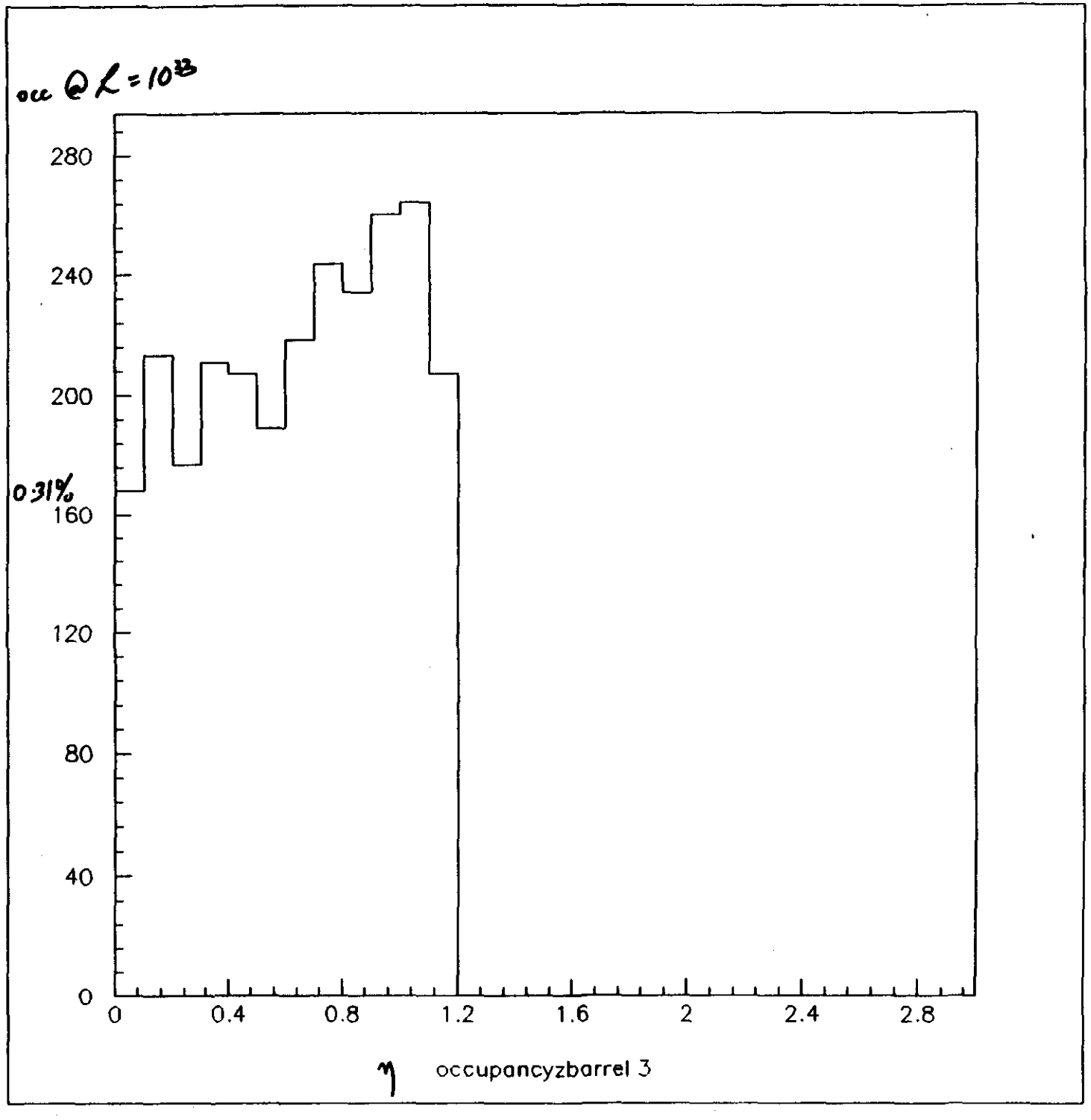
occ at $\ell = 10^{33}$



occ @ $\mathcal{L} = 10^{33}$




acc @ $\mathcal{L} = 10^{33}$
240
200
160
0.37%
120
80
40
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8


occ @ $\mathcal{L} = 10^{33}$
280
240
200
0.31%
160
120
80
40
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
η
occupancyzbarrel 3