GEM TN-92-56

GEM Calorimeter Meeting
SSCL

January 24, 1992

Abstract:

Transparencies and agenda of the GEM Calorimeter Meeting on Central Calorimeter Systems held at the SSCL on January 24, 1992.

Agenda for GEM Calorimeter meetings

Jan. 24, 1992 at SSCL

(Discussions on Central Calorimeter Systems)

8:30 am	Introduction	Bill Willis	15'
8:45	Summary on preradiator	J.Brau	10'
8:55	Summary on Forward	J.Rutherfoord	10'
9:05	R&D FY92 money	Yu.Kamyshkov	10'
9:15	Engineering	Cliff Eberle	20'
9:35	Summary of calorimetry electronics development	John Parsons	30'
10:05	Task and work of BaF2 Panel	Harvey Lynch	30'
10:35	Break		10'
10:45	Background for BaF2 spesifications	Yuri Kamyshkov	10'
10:55	Non-rad-damage issues of BaF2 R&D plans for 1992	Harvey Newman	30'
11:25	Discussions on BaF2		15'
11:40	Calorimetry simulations	Jim Brau	20'
12:00	LAr e-m calorimeter. R&D plans for 1992	Howard Gordon &Davis Lissauer	30'
12:30 pm	Lunch		
13:30 pm	Plate e-m cal. option	Paul Mockett	20'
13:50	On uniformity,resolution and linearity of LXe/Kr	Fedyakin	10'
14:00	SSCinCAL hadron calorimeter. R&D plans till August 92	Larry Sulak	30'
14:30	1992 beam tests at CERN	Harvey Newman	10'
14:40	Discussions		
15:20	Close meeting		

J. Brau

Preradiator

Physics:
a) π^0 rejection (vs E_π an θ)
b) $\gamma\gamma$ vertex pointing (σz of reconstructed γ direction with beam line vs E_γ, θ)
c) e identification (end caps, high lumi)

Performance:
a) for above processes
b) how much e-m resolution is degraded by preradiator.
Optimum π^0 rejection – resolution

Integration with e-m design

Cost idea

Motivation

Discovery of a Higgs with

$$80 < m_h < 160 \text{ GeV}$$

is difficult!

$H \to b\bar{b}$ looks like background

$H \to \gamma\gamma$ is possible

cut	$\sigma_{H\to\gamma\gamma}$	σ_{jj}	$\sigma_{j\gamma}$	$\sigma_{\gamma\gamma}$
$P_t > 20$	50-200fb	2mb	235nb	275p
$\left.\begin{array}{l} \lvert\eta\rvert<2.5,\ E_t^\gamma > 20\text{GeV} \\ \lvert\cos^*\theta_\gamma\rvert<0.9,\ \lvert\eta_{\gamma\gamma}\rvert<3.0 \\ \text{isolation},\ M_{\gamma\gamma} > 70\text{GeV} \end{array}\right\}$	25-100fb	220pb	90pb	34p
Shower Shape	25-100fb	120pb	50pb	34p
Preradiator	25-100fb	20pb	24pb	34p

highly uncertain

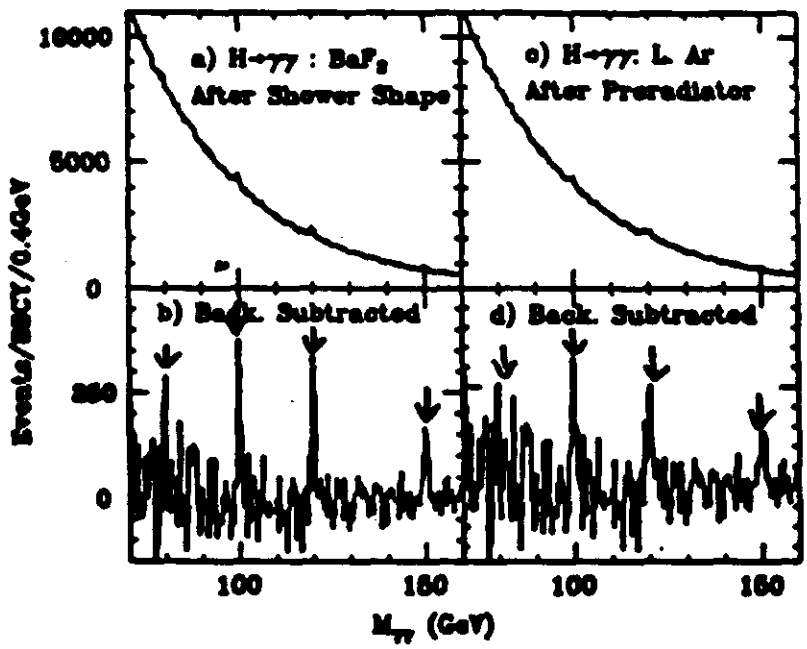
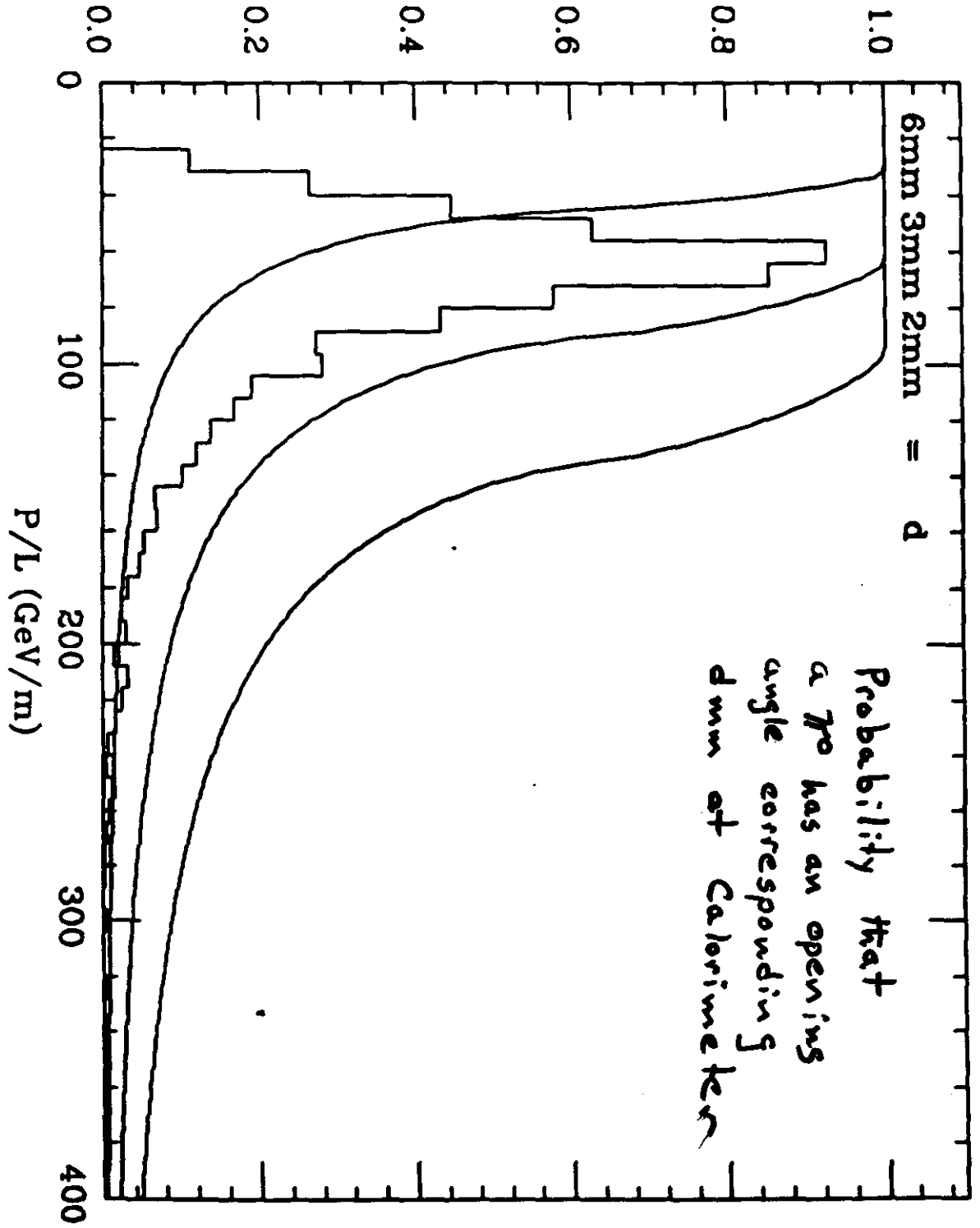


Figure 3.2-1 $H \rightarrow \gamma\gamma$ mass distributions and background-subtracted mass distributions for various Higgs masses. Left: BaF_2 calorimeter. Right: LAr calorimeter

π^0 rejection probability (curve)

Number of γ from Higgs(100GeV) (hist arbitrary u)



Preradiator Options

* accordion strips
* parallel plate strips
* silicon strips (LA)

  European pre-accordion
  sci-fi (NO GEM proponents)

* BaF_2

* discussed Wednesday

Expected Pre-radiator performance (LAr)

γ efficiency $\gtrsim 95\%$

π^0 rejection 80 – >90% at 50 GeV

70 – >80% at 100 GeV

Energy correctable for external

$$\frac{7.5\%}{\sqrt{E}} \rightarrow \sim \frac{8.5\%}{\sqrt{E}}$$

Magnetic field has little effect.

Do we need a pre-radiator?

A scenario exists in which the answer is NO — Barely

<u>BUT</u>

It is based on:

uncertain physics generators ($\sim 10^{-6}$ rej)
optimistic detector performance
assumption of NO surprises

More conservative approach would demand preradiator

Therefore — I propose we take the position that a preradiator is desired.

How can we progress on choice?

For now, try to define baseline

Baseline EM calorimeter = accordion

Which preradiator is best matched to accordion?

- Silicon strip preradiator
  - Straight forward technology
  - Expected performance
  - First cost estimate acceptable (13M
  - Solid interest within GEM (Oregon, Moscow, ORNL et al)

J. Rutherfoord
1/24/92 GEM Mtg SSCL

GEM Forward Calorimetry

Physics Goals (F. Paige)

- Hermetic measurement of global $\vec{p}_T$
- Forward tagging jets

Critical Parameters

- Mean density of calorimeter (High as possible)
- Diameter of beam hole (Small as possible)

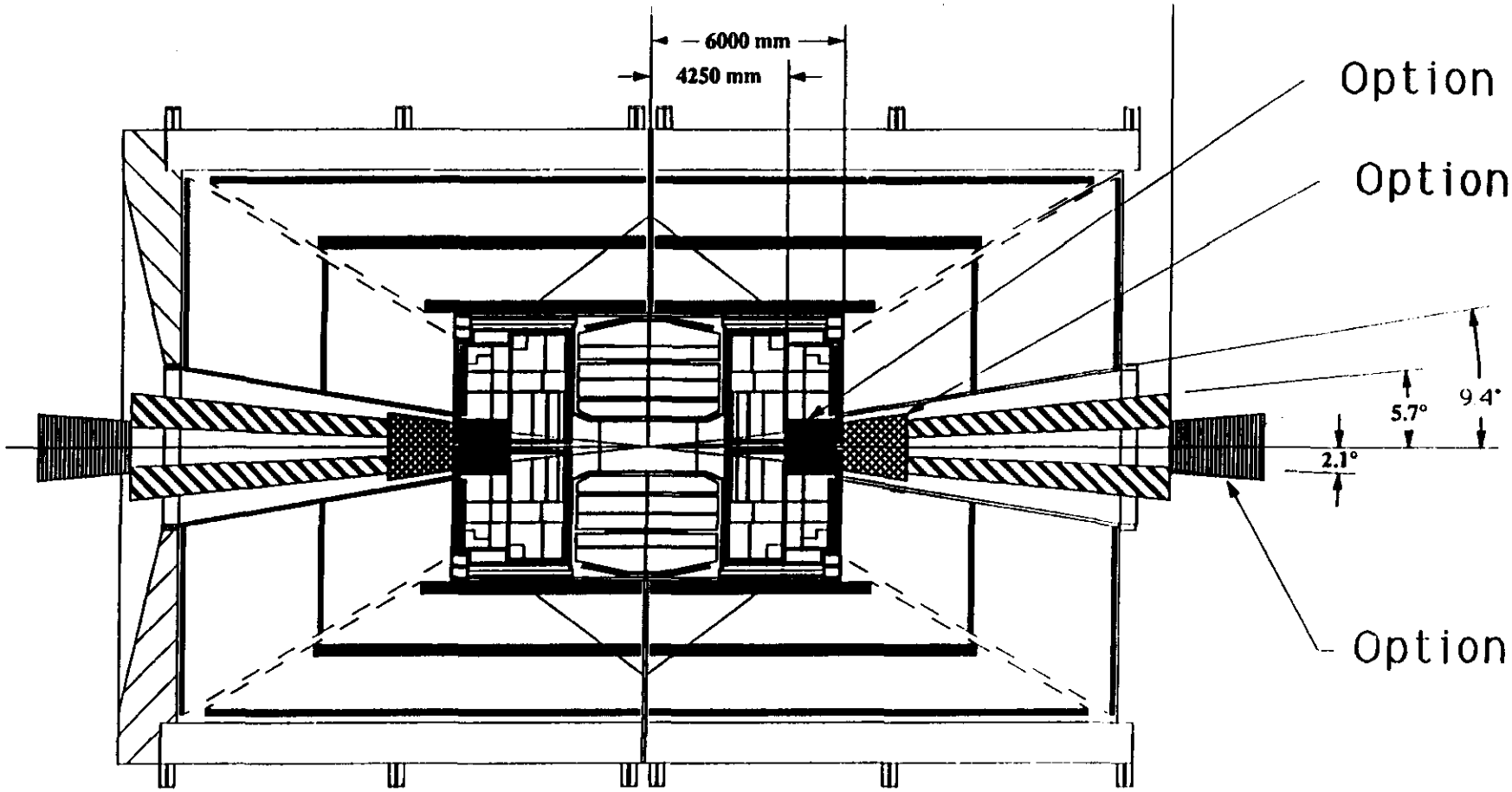
Technologies

- High pressure gas (E. Kistenev, G. Fanourakis)
- Liquid Scintillator spaghetti (R. Webb)
- Liquid Argon (J. Rutherfoord)

General Simulation Results

Integration Issues

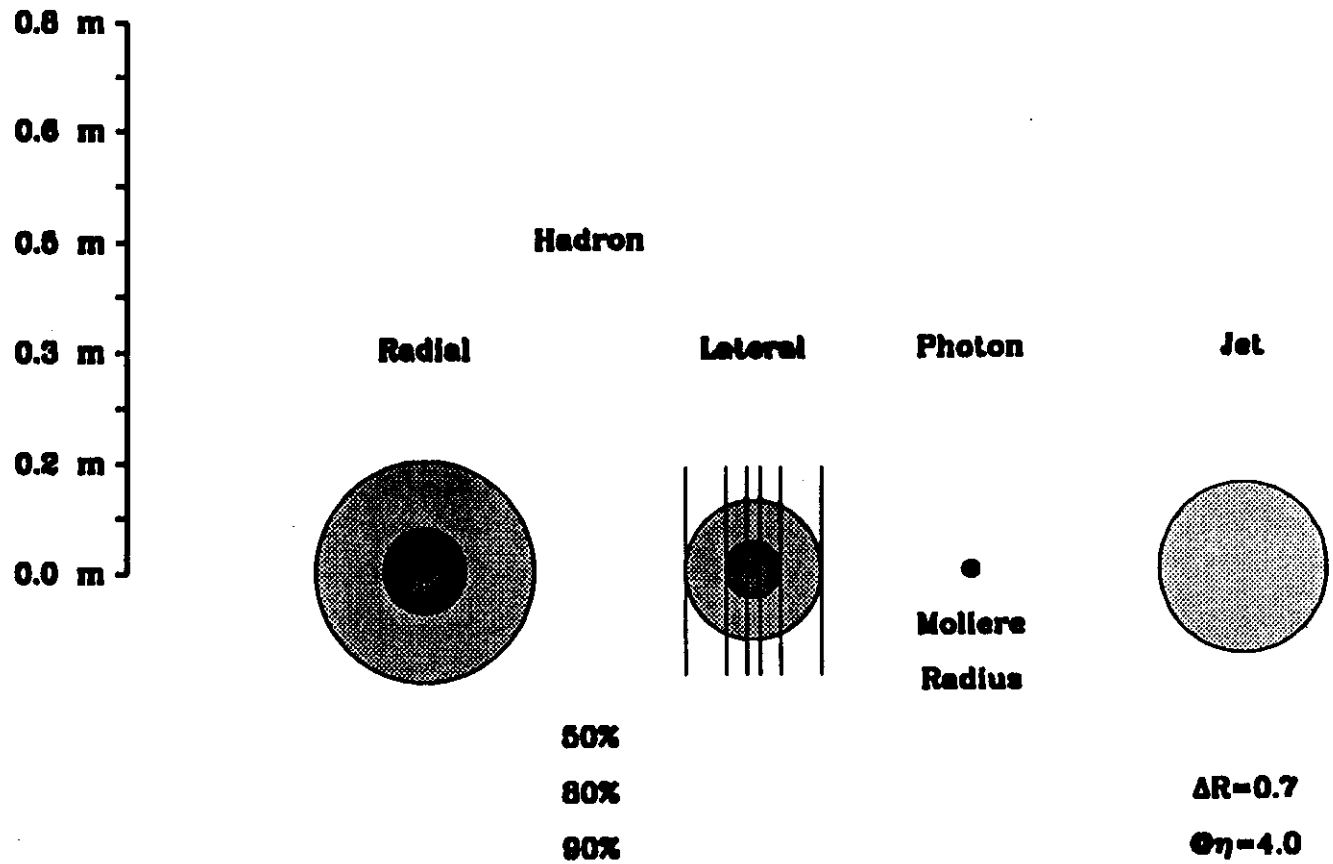
Preliminary Cost Estimates

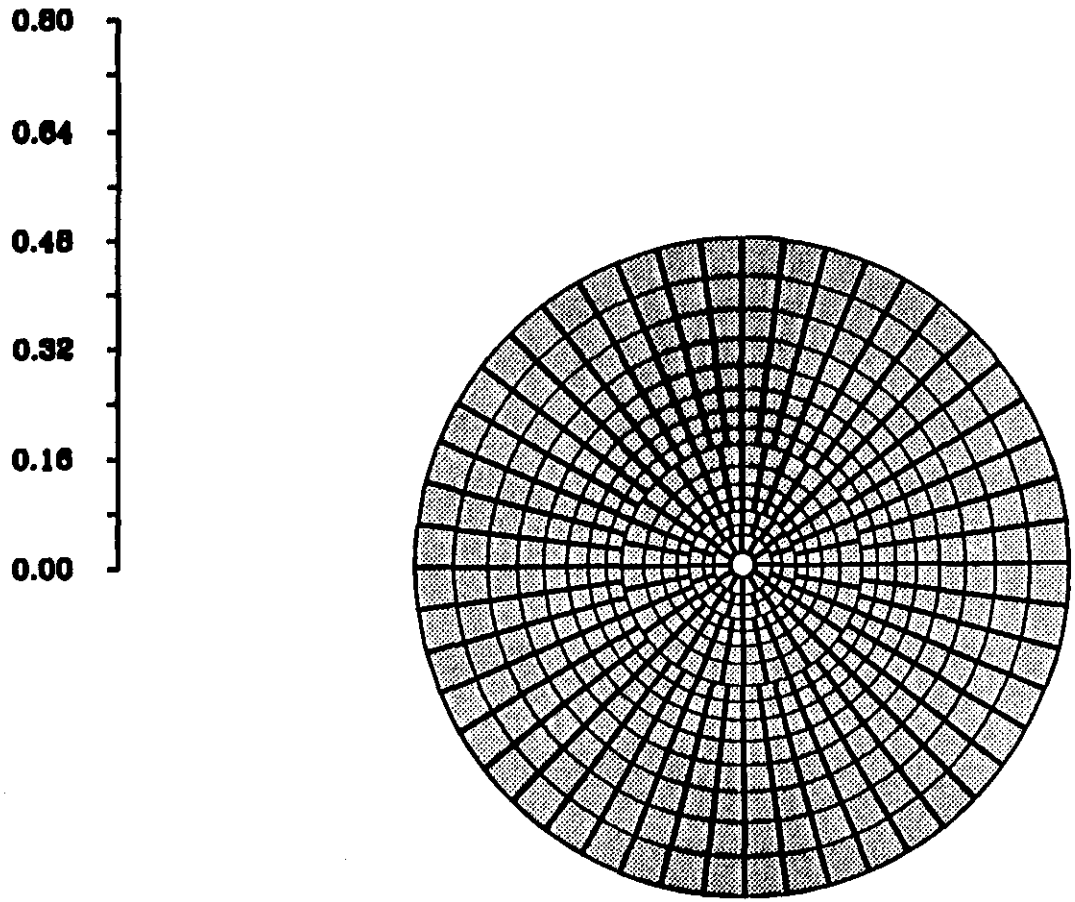


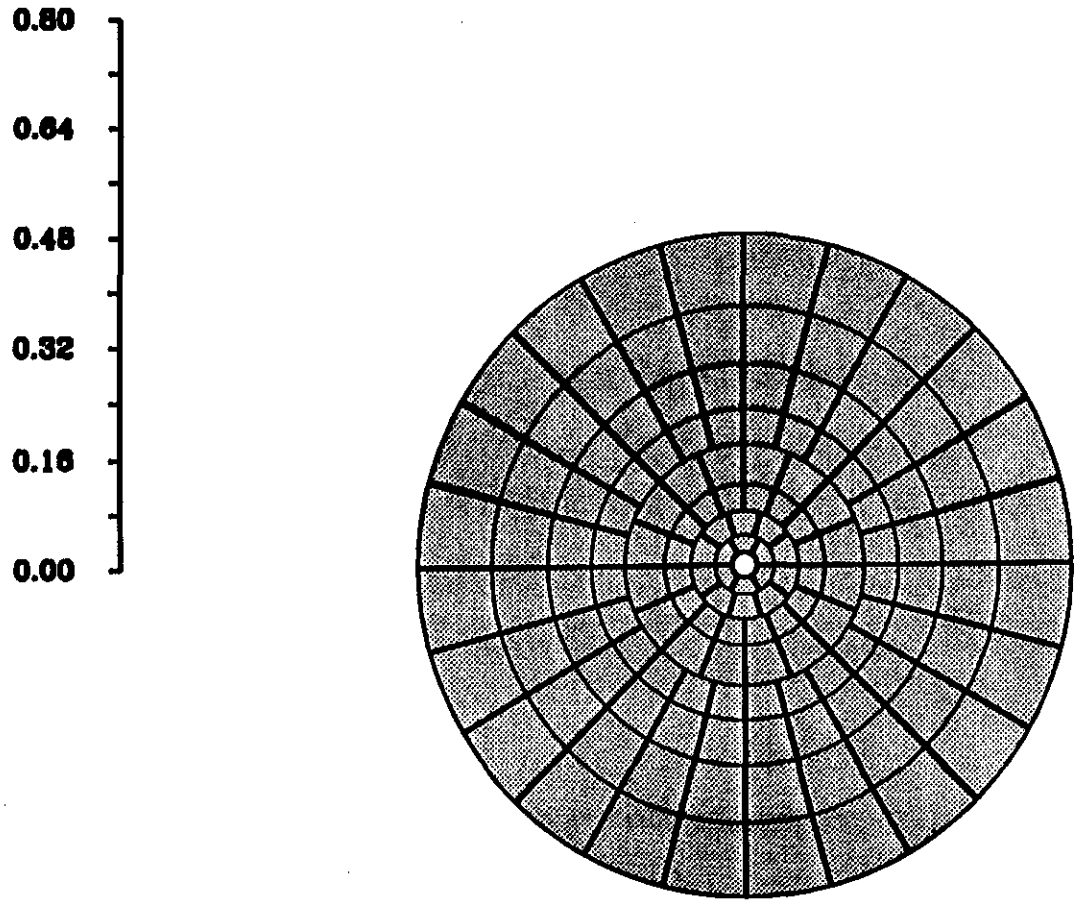
GEM CONFIGURATION OPTION STUDY
FORWARD CALORIMETER
3 LOCATION OPTIONS

G.03.FD.00018

CHAE/RENNICH


0.8 m
0.6 m
0.5 m
0.3 m
0.2 m
0.0 m
Hadron
Radial
Lateral
Photon
Jet
Moliere
Radius
50%
80%
90%
ΔR=0.7
Δη=4.0


0.80
0.64
0.48
0.32
0.16
0.00


0.80
0.64
0.48
0.32
0.16
0.00

GEM FCal Simulation Work

1) Calorimeter performance for

Charged pions	UAZ	nearly complete
Photons	UAZ	will do
Jets	UAZ	will do

2) Radiation effects in the calorimeter

Ion loading in LAr	UAZ	in progress
Poisoning in LAr	UAZ	started
Damage		
Activation	UAZ	will make crude estimate

3) Neutron albedo in tracking volume LANL David Lee

4) Leakage into muon system

Charged particles		
Neutrons	UAZ ?	(Ken Johns)

5) Cracks and cross-over ($\eta = 3$ crack)

GEM FCal
Requirements and Constraints

Coverage for full containment	$3.0 \leq \lvert\eta\rvert \leq 5.0$	
Required resolution over coverage	$\frac{\Delta p_T}{p_T} \lesssim 10\%$	hadrons photons
Signal collection time	$\lesssim 80$ ns	
Distance from IP to front face	4.5 - 9.0 m	
Hole thru FCal	~ 4.0 cm	ID

GEM FCal Technology Decision

Does technology satisfy physics requirements?

Will it work at all?

Will it cover to $|\eta| = 5$ with $\Delta p_T/p_T \lesssim 10\%$?

Cost

Compatibility

Soft Spots

1) LAr will work at some level but not guaranteed to meet physics requirements.

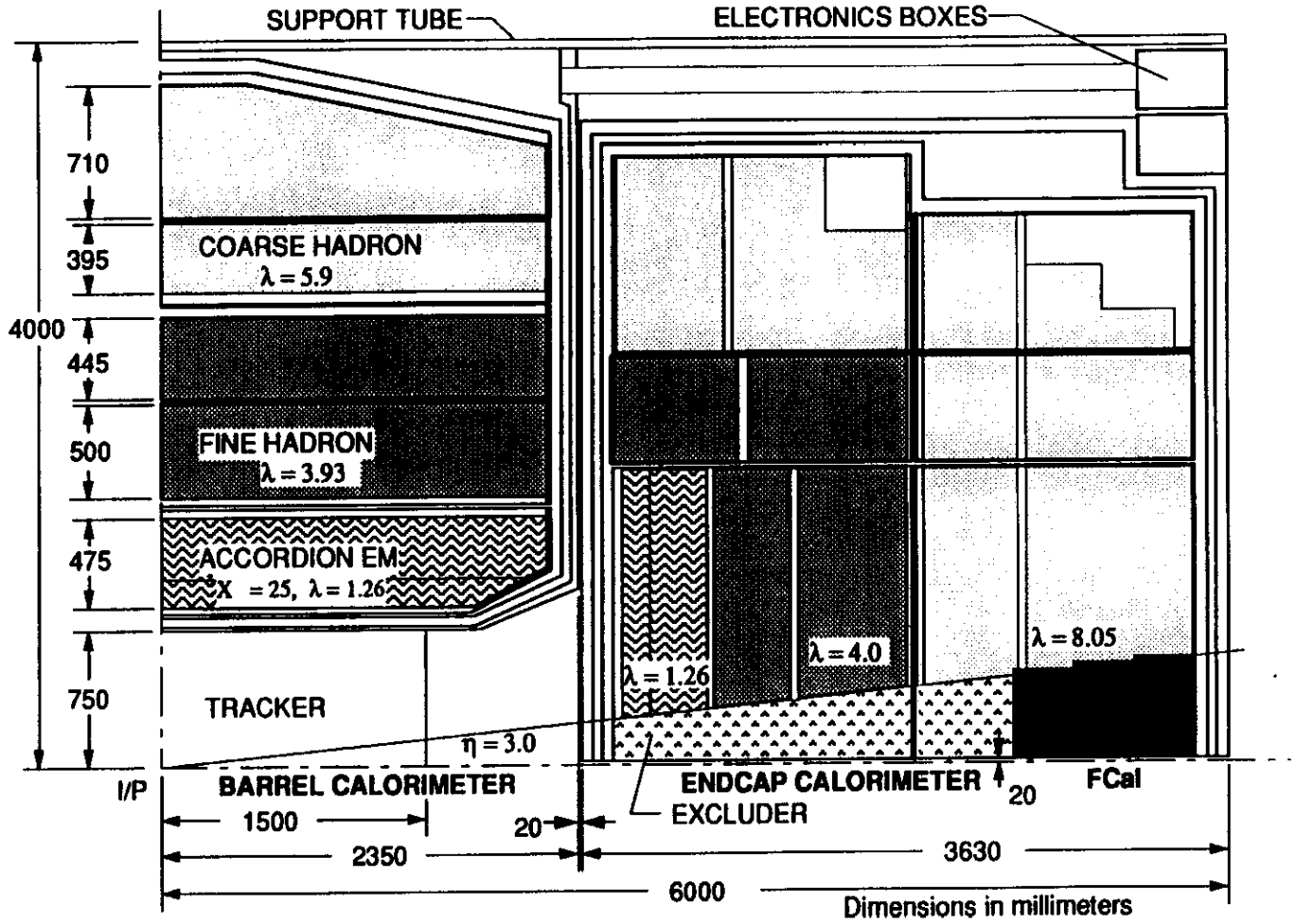
2) HPG and LScint not dense enough?

3) HPG safety and performance?

4) LScint light attenuation, rad damage, light collection, safety

Decision

To be recommended by GEM Cal group when calorimetry choice is made.


SUPPORT TUBE
ELECTRONICS BOXES
710
395
4000
445
500
475
750
COARSE HADRON
λ = 5.9
FINE HADRON
λ = 3.93
ACCORDION EM
X = 25, λ = 1.26
TRACKER
η = 3.0
λ = 1.26
λ = 4.0
λ = 8.05
I/P
BARREL CALORIMETER
ENDCAP CALORIMETER
FCal
EXCLUDER
20
20
1500
2350
3630
6000
Dimensions in millimeters

Y. Kamyshkov

GEM Calorimeter R&D money FY92

	OLD	90%	NEW	
	4,662	→	4,160	+ 100
R&D				(TRNLC)
Liq. Ar	1170		1120	(205)
Ba F_2	1209		1260	(500)
Sci Cal	610		450	(400 appr.)
Forward	75		15	(?)
Si Prerad	140		40	
Total	3204		2885	(90%)

Engineering			
MMA Denver	798	630	(150 BNL, 480 MMA)
ORNL		331	(LAr, Sci Cal, Forw., Prerad)
C.S.D.	250	134	
BaF_2 (ORNL)		180	
Forward	10		
Preradiator	10		
Post decision	350	0	
Total	1418	1275	(90%)

GEM Calorimetry	FY92 K$	
a) Liquid Argon		
Brookhaven N.L.	895	
Uni. of Washington		205 TRLNC
Uni. of Arizona	20	
***	915	(1120)
b) BaF2		
Carnegie Mellon	15	
Princeton	50	
BNL	70	
ORNL	60	
UCSD	144	
CALTECH	421	+ 500 TRLNC
***	760	(1260)
c) Scintillating Fiber-Cal.		
Boston Uni.	195	
Fairfield Uni.	15	
MSU	35	
UCSD	25	
UT	25	
UMiss	45	
ORNL	110	
***	450	
d) Forward Calorimeter		
Texas A&M	15	
***	15	
e) Silicon Preradiator		
Uni. of Oregon	40	
***	40	
f) Engineering		
MMA Denver	630	(150 BNL, 480 MMA)
Draper Lab	134	
ORNL	511	(LAr,SciCal,Forw,Prerad :331,BaF2:180)
***	1275	
g) Support for ITEP engineers and physicists at ORNL :	100	
***	100	
Total :	3555	(4260)

Jan. 24/92

GEM Calorimeter Electronics

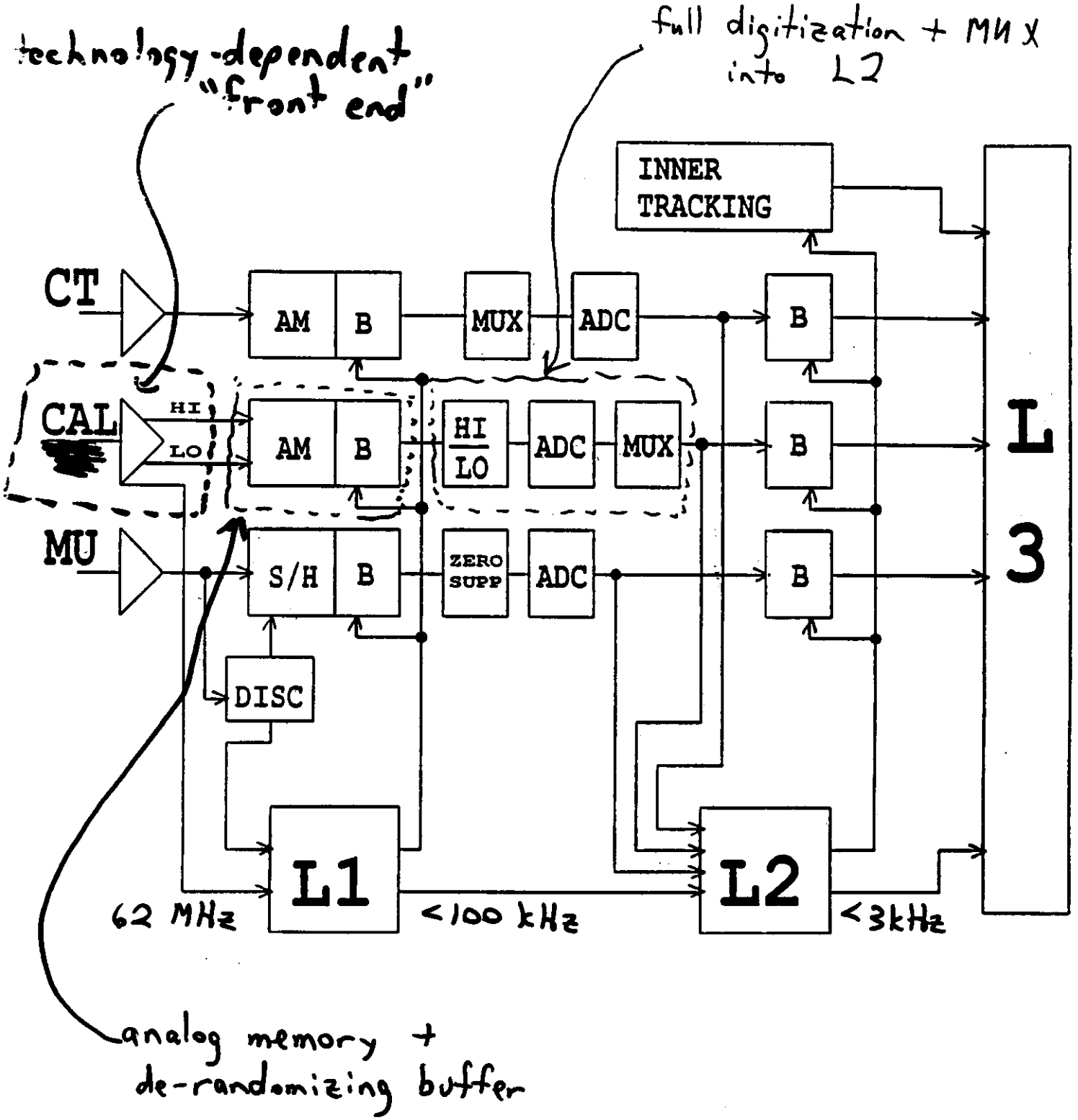
Table from LoI

GEM Trigger/DAQ Design Goals				
Level	Rate In	Rate Out	Latency	Comments
1	62 MHz	10 kHz	3 μs	Synchronous, Pipelined
2	100 kHz	300 Hz	100 μs	Asynchronous, Monotonic
3	3 kHz	10 Hz	—	CPU Ranch

Requirements on CAL Readout

- sample every 16 ns
- fast trigger pick-off for L1 decision
- allow for L1 latency of 2-3 μs
- "deadtimeless" operation at L1 rates of up to 100 kHz, with transfer of fully digitized data to L2
- 17-bit dynamic range
- ~10 bits of precision
- contribution to constant term << 0.5 %, for a system of ~10^5 channels
  - calibration
  - stability
  - reliability
  - access

Overview of GEM Trigger/DAQ System



"Front End" Electronics

① BaF_2

- vacuum phototriode + pre-amp
- 1-3 samples **OR** gated integrator

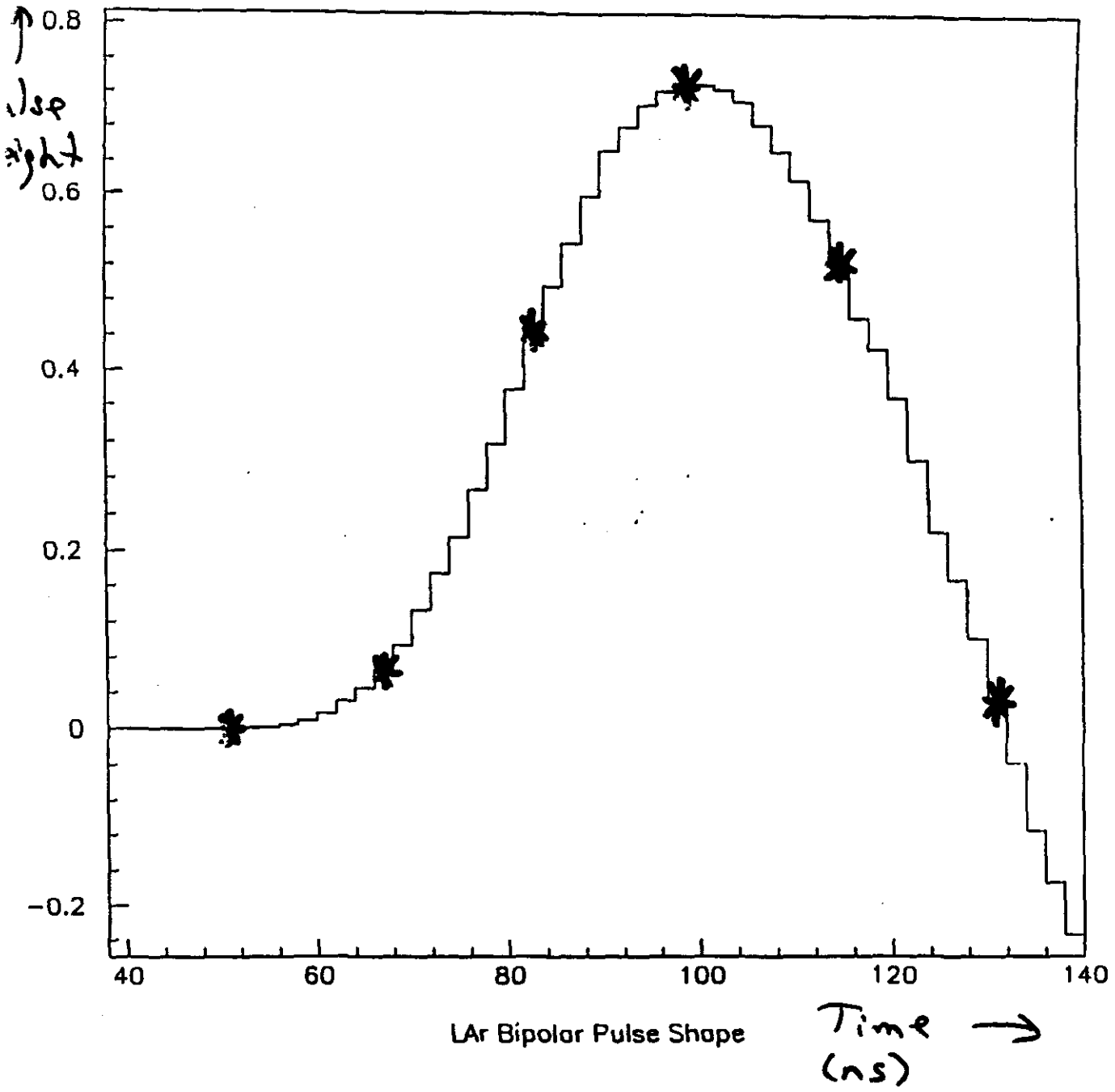
② Spaghetti

- PMT readout
- samples/gated integrator as above
- long. shower info. needs leading edge timing with <1ns resolution

③ LAr

- cold FET-input pre-amp
- bipolar shaping with 40 ns peaking time
- 5 samples.

Sampling of LAr Pulse with 40ns Peaking Time Bipolar Shaping

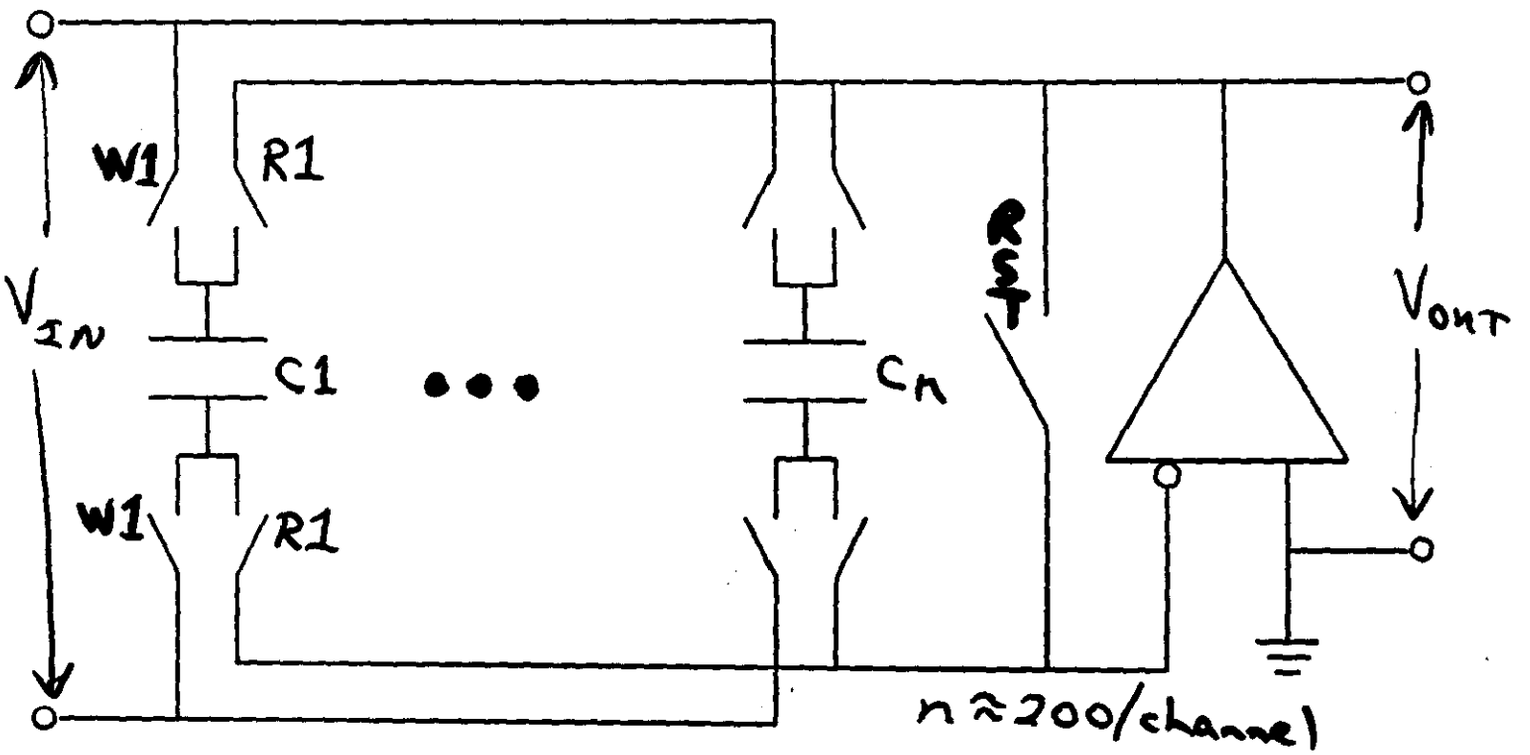


- simulations ⟹ need at least 5 samples for good resolution due to pile-up.

  ↳ energy, time given by weighted means of the 5 samples

Switched-Capacitor Analog Memory

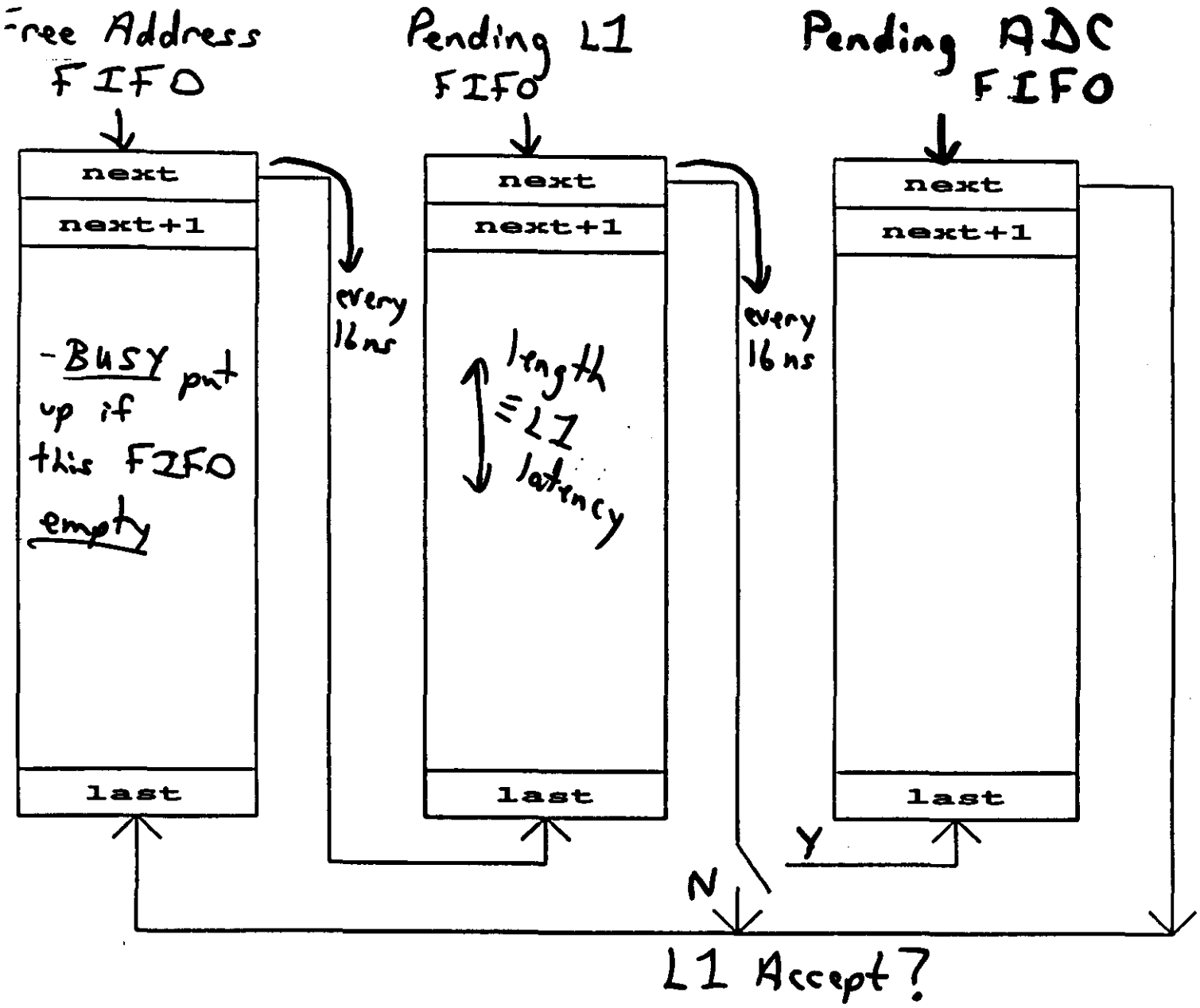
- sample voltage every 16ns and store in switched-cap. array awaiting L1 decision.



- **deadtimeless** through simultaneous R/W capability + virtual buffer
  - ↳ requires complicated address bookkeeping
- existence proof provided by LBL.
- can achieve 12-13 bits of dynamic range
  - ↳ need at least 2 gain scales
- may need to correct for cell-to-cell pedestal differences, especially when adding up large number of channels.

Address List Processor (ALP)

- insufficient time to transfer charge to a buffer
  ↳ just transfer <u>address</u> & leave charge (virtual buffer)



- ALP will probably have to be <u>separate</u> chip (put R/W address decoders on SCA)

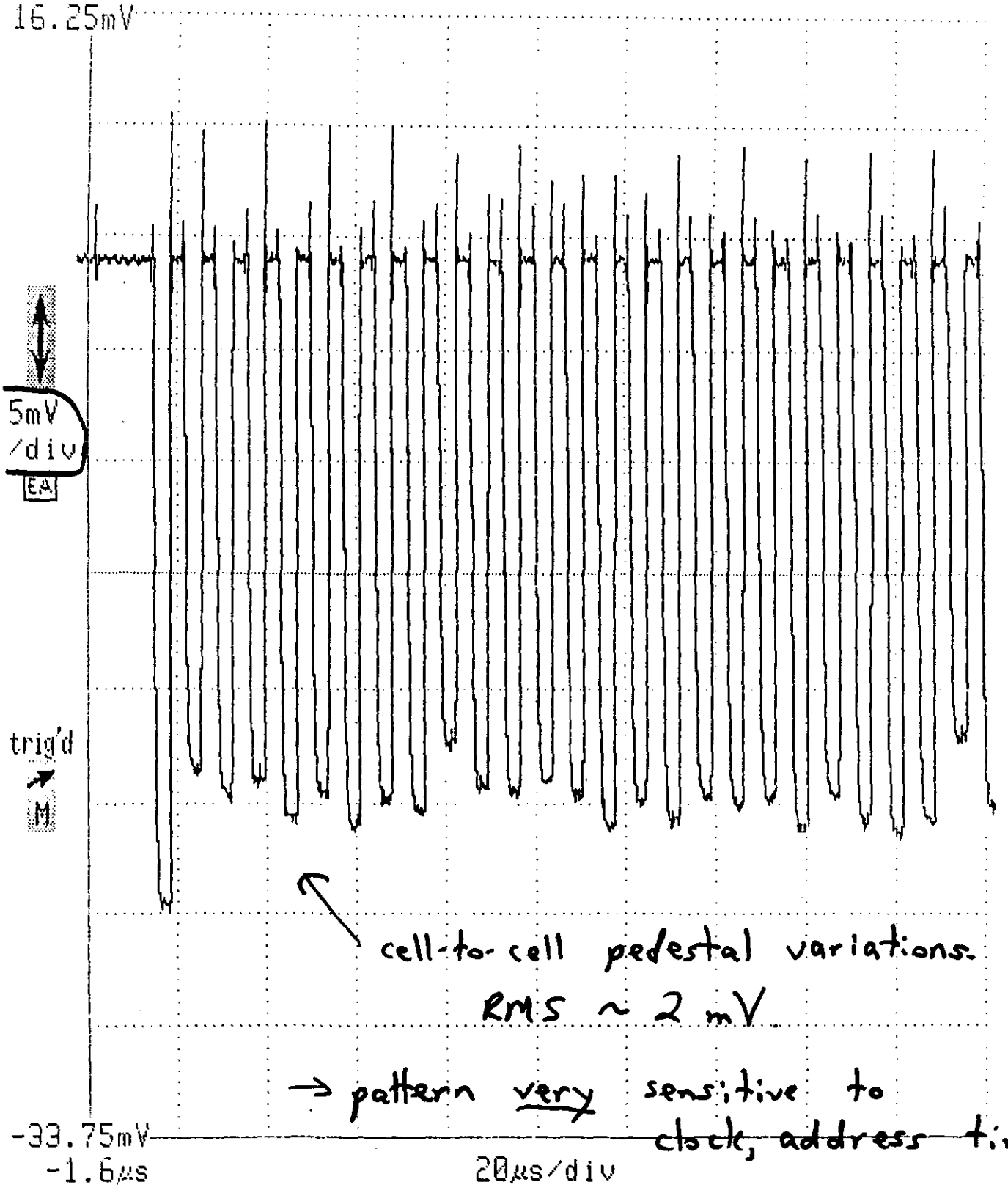
- are investigating different schemes to minimize fast digital signals which need to be sent to SCA chip, due to worries about noise.

LBL Specifications

Analog Store Parameters	Achieved Performance
No. channels/chip	16
No. of elements/channel	256
Power consumption/channel	10 mW
Non-linearity	±0.1% (full scale) ±0.5% (value)
Cell to cell pedestal variation	0.5 mV rms
Charging time constant	1.5 ns
Channel dynamic range	5500
Maximum sample rate	90 MHz
Maximum readout rate	200 KHz
Noise floor	0.7 mV rms
Input voltage range	0.1-4.9 Volts
Capacitor droop rate	0.1 mV/msec
Output settling time (0.02%)	1.2 μsec
Gain variation from unity	+/- 1.5%

Table 3.2. Measured performance parameters of a simultaneous read-write switched capacitor array integrated circuit. The array has been implemented in 1.2 μm CMOS, has 16 channels, and 256 storage cells per channel. Measurements were performed at a 50 MHz acquisition rate.

Ongoing Tests of LBL SCA Chip



cell-to-cell pedestal variations.
RMS ~ 2 mV

→ pattern <u>very</u> sensitive to clock, address timing

→ strong channel-to-channel correlations
↳ use differential structure?

Digitization + MUX into L2

- must digitize up to 5 samples / channel for every L1 trigger.

↳ L1 max. rate of 100 kHz

⇒ 500k samples/s !

① on-chip, one-per-channel, custom ADC followed by digital MUX

↳ need to develop low-power custom 500k samples/s 12-bit ADC.

② analog MUX to off-chip commercial ADC (20 MHz 12-bit ADC's are becoming available)

↳ could MUX 40:1

- worries about <u>precision</u> fast analog MUX due to cross-talk

- higher power + higher cost compared to ①

Some Alternatives Being Pursued

1) CCD's for analog storage. (QDOT, Inc.)

- no "cell-to-cell" problems like SCA
- no need for virtual buffering & ALP
- high I/P bandwidth

- typical dynamic range $\lesssim 10$ bits
- poor linearity
- poor radiation tolerance

- clock fanout problems $\Rightarrow$ need to resonate the clocks (in a magnetic field)

(2) all-digital approach

↳ digitize every 16 ns & use digital pipeline.

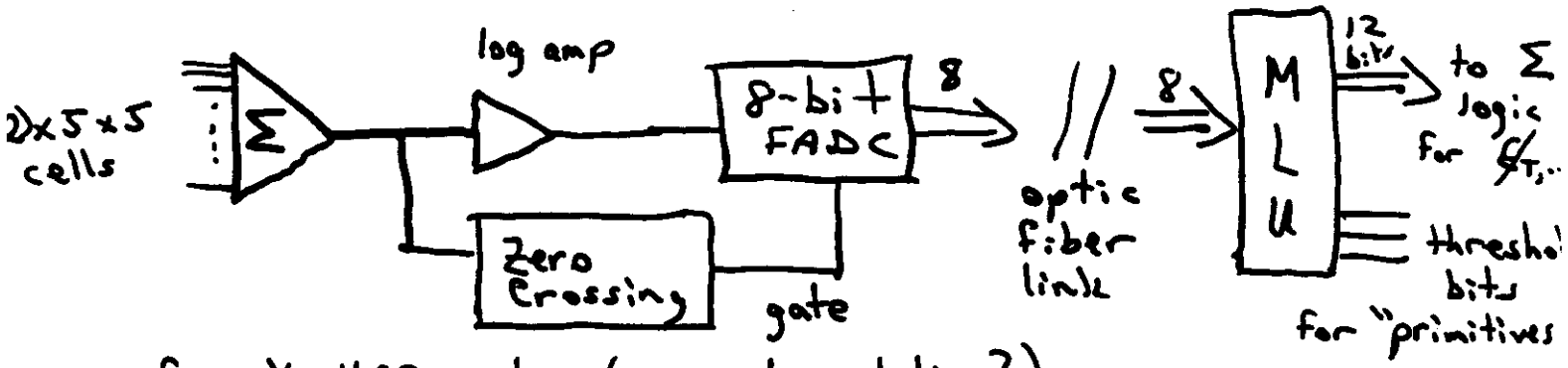
→ need low power, low cost 62 MHz 12-bit ADC!

↳ contact made with Texas Instruments, who are working on a 20 MHz 12-bit GaAs ADC.

GEM CAL Trigger

LEVEL 1
- pipelined, synchronous
- latency 2-3 μs (cable delay ~ 1 μs)
- CAL + MU INFO ONLY.

CAL trigger tower $\Delta\eta\,\Delta\phi = .2 \times .2$



- for e,γ, HAC veto (+ weak isolation?)

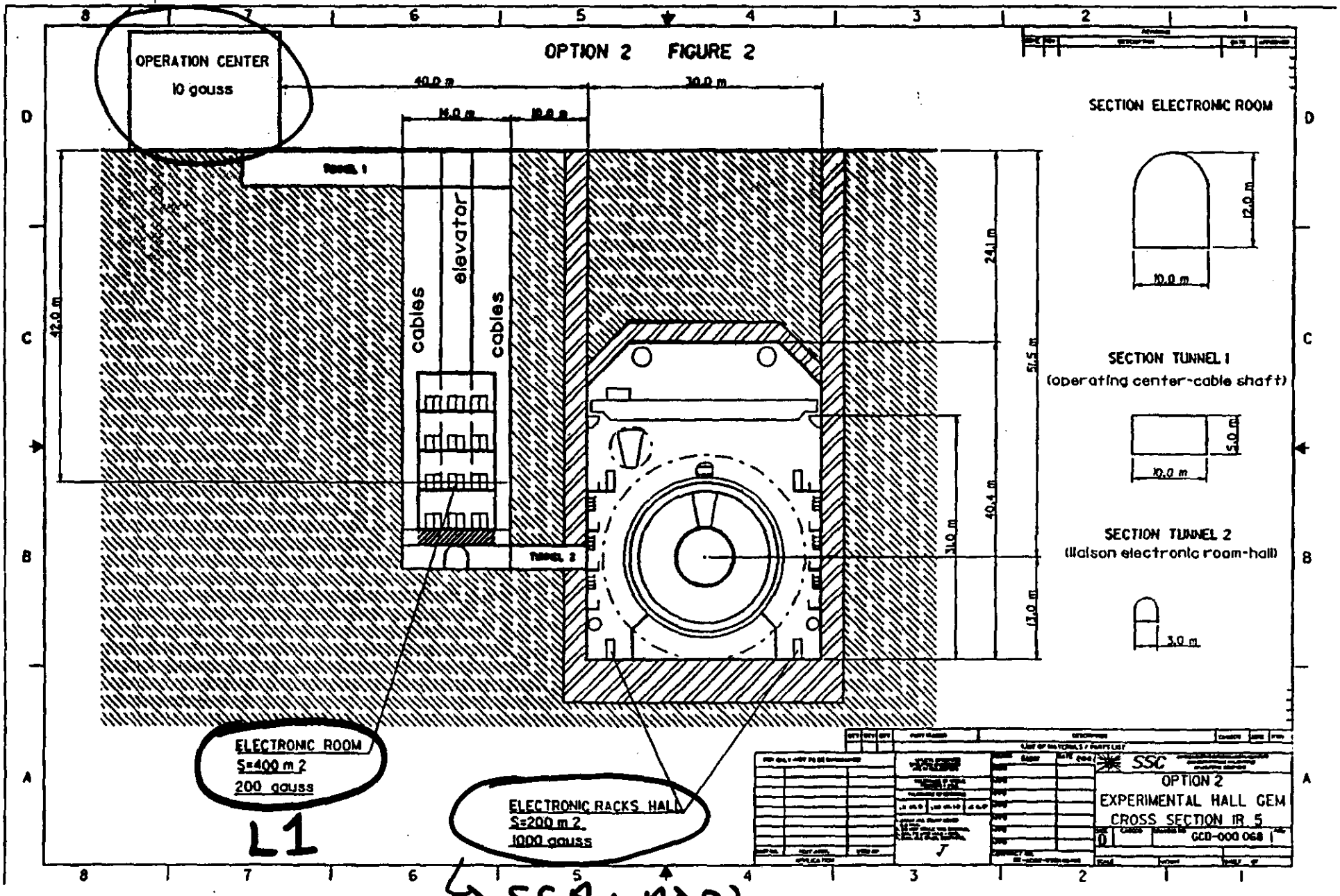
LEVEL 2
- digital, asynchronous, monotonic
- CAL + MU + CT info.

CAL
- fully encoded data with full granularity
- map n channels onto a DSP
  - ↳ select hi/lo gain
  - apply calibration constants on samples
  - calculate energy, time
  - zero suppression?
- for e,γ, apply isolation cut + look for match/veto from CT

LEVEL 3
- processor farm
- full detector info.

XEROX TELECOPIER 295 ; 12-12-91; 5:00 PM;
SENT BY:Xerox Telecopier 7021 ;12-12-91 ; 17:06 ;

L2,L3



Dec 18/92 @ NEVIS

AGENDA

aghetti Calorimeter Readout Issues - Eric Hazen

alibration of Liq. Ionization Calorimeters - Veljko Radeka

nalog Pipelines - John Parsons

FCD's - Bob Wisted

pdate of Studies of Levels 1, (1.5), 2 - Dan Marlow

AL Readout into Level II and Beyond

~~(a) Work at the SSCL~~ ~~Dario Giubetto~~

(b) Overview of the ZEUS CAL readout - Steve Ritz

lectronics Placement - Dan Marlow

uture Plans and Organization

Harvey Lynch

Objectives of BaF2 Review Meeting 21-22 January 1992

* Define what is needed for GEM to make a decision on using BaF2 by August 1992.
  - This panel will make technical recommendations, but GEM must make the decision.
  - Schedule for BaF2 project is not the Panel's problem directly. Panel should offer views on feasibility of production capabilities, R&D, or measurements to meet a schedule defined by GEM.
  - Panel should establish set of new measurements and calculations needed to make a GEM decision possible.

* GEM must define acceptable crystal characteristics for radiation environment.
  - Electron or Photon damage (ionization)
  - Hadron damage (spallation)
  - Variability of attenuation within crystal
  - Degree of saturation required (*i.e.* change of radiation damage over time)

* Review what has been learned about radiation damage mechanism
  - Crystal purity and defects, and their relation to radiation resistance
  - What is role of dose rate?
  - Is saturation real?
  - Surface *vs.* bulk effects and how they are dealt with

* Review ability of potential vendors to produce adequate crystals
  - Purity of raw materials
  - Ability to analyze sample purity
  - Ability to control contamination
  - Production "black magic"--key personnel
  - Liaison between GEM and vendor

* Understand production process for crystals
  - Crystal fabrication
  - Crystal tuning for uniformity of response
  - Test procedures
  - Is pre-radiation for saturation feasible?

H. Gordon
Jan. 24, 1992

Progress and Problems in LAr for GEM

- Meeting at Martin Marietta - Jan. 9-10, 1992
- Pressure from μ-group on radius, Z, thickness and material
- Pb/Fe/DU vs hybrid
- Test beam organization - David Lissauer

Attendance Sheet

MEETING LAr CALORIMETRY MTG. DATE JAN 9 1992

NAME	INSTITUTE	TELEPHONE NO.	EMAIL
RONN WOOLLEY	SSCL	214-708-6079	WOOLLEY@SSCVX1
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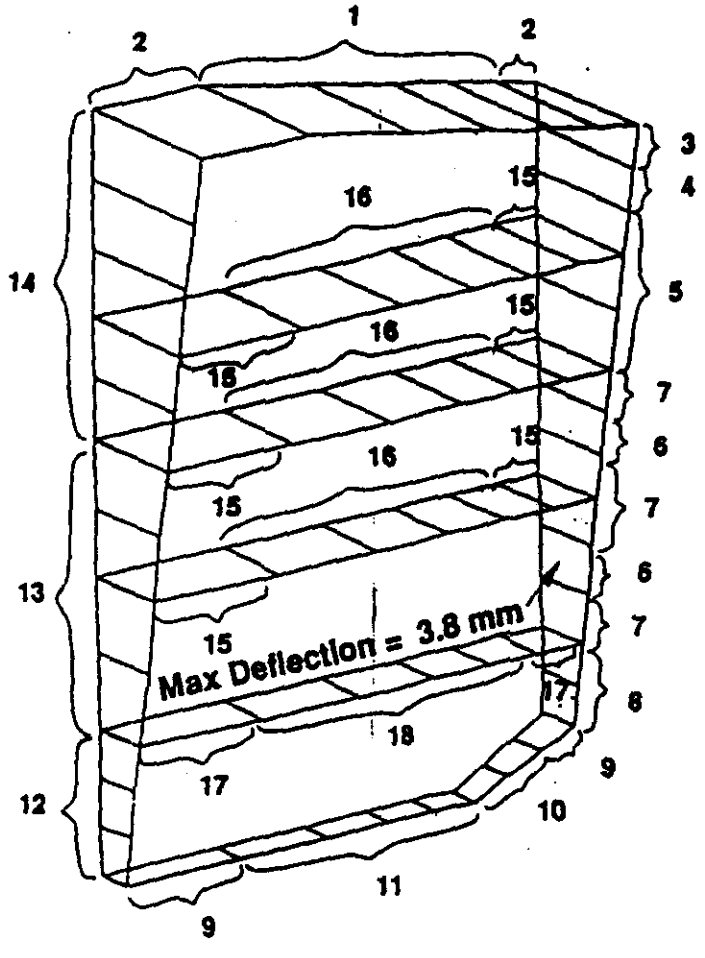
JIM BRAU	U of OREGON	503-346-4766	JIMBRAU@SLACVM
Don Makowiecki	BNL	516-282-4009	Makowiecki@BNLCL6
Howard Gordon	BNL	516-282-3740	GORDONH@BNLCL1

Gem3 Central Calorimeter Argon Vessel Wall Thickness



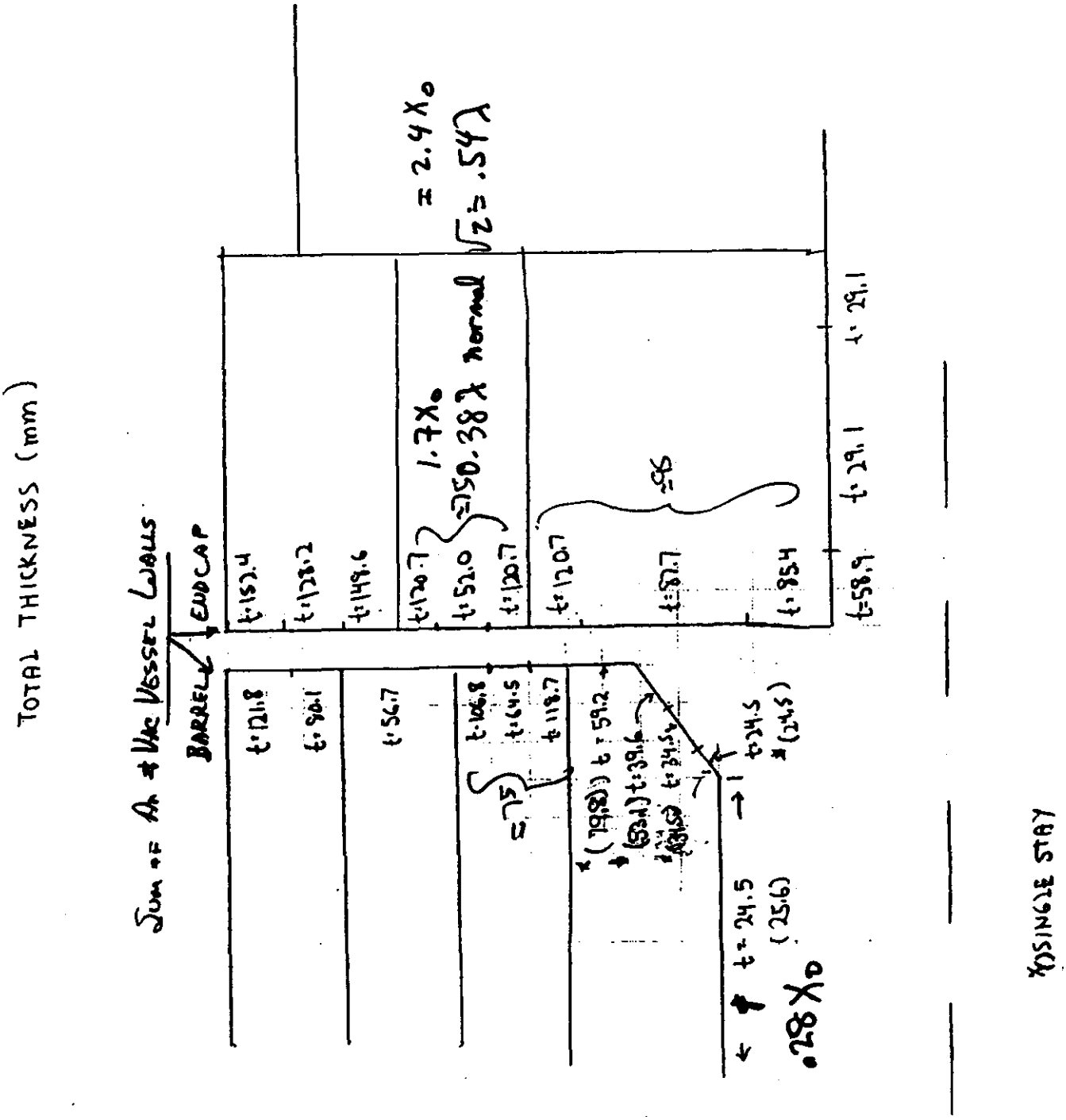
Group	[2]Wall (mm)	[1]ASME Sizing	Pressure (psi)	Von Mises (ksi)
1	(L)22.9	H	-14.7	N/A
2	(L)22.9	H	-14.7	N/A
3	20.2	3.0 Sm	50.0	32.4
4	29.3	1.5 Sm	50.0	17.4
5	18.6	3.0 Sm	50.0	25.4
6	13.7	1.5 Sm	50.0	16.8
7	68.7	3.0 Sm	50.0	4.9
8	8.4	3.0 Sm	50.0	34.2
9	(L)15.5	H	50.0	N/A
10	(L)15.5	H	50.0	N/A
11	(L)15.5	H	50.0	N/A
12	1.00	1.0 Sm	50.0	10.8
13	1.02	1.0 Sm	50.0	13.3
14*	1.57	1.0 Sm	50.0	11.4
15*	2.90	1.0 Sm	50.0	16.7
16*	3.28	1.0 Sm	50.0	14.1
17	9.13	1.0 Sm	50.0	10.6
18	2.73	1.0 Sm	50.0	11.6

[1]ASME Section VIII Division 2
Sm (5083 AL) = 12000 psi for $1.3 \le t \le 38.1$ mm
H = Hoop Buckling
[2](L) = Optimizer reached lower limit
* = Half Thickness

MARTIN MARIETTA

BY MR DATE 1/10/92 SUBJECT SHEET NO. OF

CHKD BY DATE JOB NO.

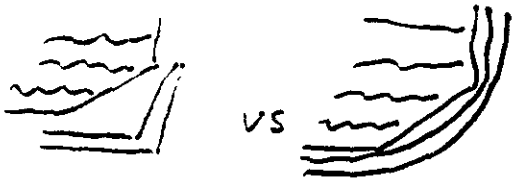


DEN 660160 (04-84)

Action Items from GEM LAr Meeting at MMA
January 9-10, 1992

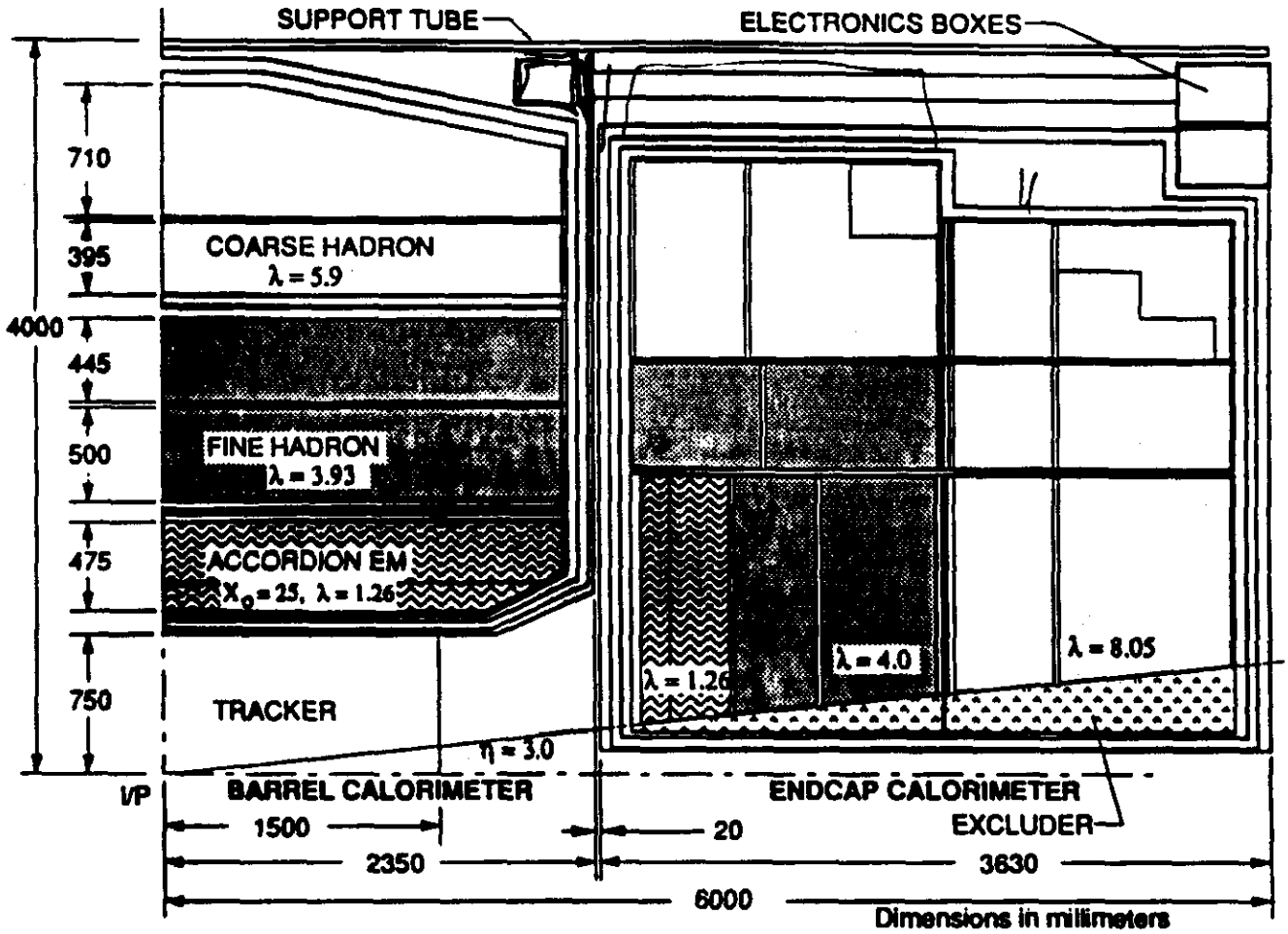
Engineering Tasks

- Tabulate all wall thicknesses
- Check corner of EM Barrel



- Projective Accordion - vary angle and length
- Calculate Support web thickness for split case
- Calculate Liquid Volume
- $r\phi$ View of Calorimeter (η=0) including tolerances, gaps, utilities, cable routing
- Detailed concept of barrel support leg
- Pipe and cable routing, cable count (calibration =10% of signal lines) including feedthrough installation
- Thermal schematic - magnetic field effect on valves, pumps, etc.
- Understand Division 2 ASME Code Approval process
- Detailed concept of Internal Electronics - location, mounting, cooling
- Thermal and structural analysis of accordion

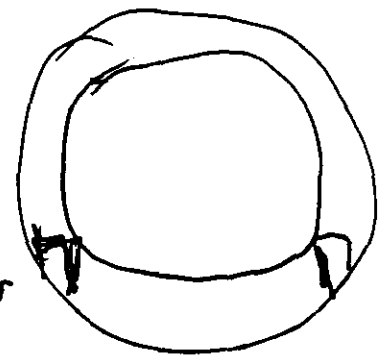
GEM LOI 11/30/91



4→6mm Fe

no washer in EM

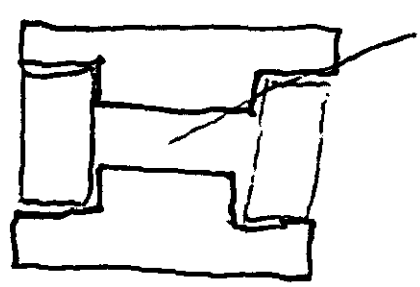
Junction box can be @ barrel + smaller



- Cost of Pb (vs. Fe) 6 mm (extra weight, support...)
- Integrated forward calorimeter - W - Beam tube!!!

<u>Options</u>

- Parallel Plate EM - engineering and cost
- Krypton - separate liquid vessel
- Decrease barrel length
- End cap diameter - larger in split case???
- 4 mm Fe -> 6 mm Pb, Fe -> 6 mm DU
- Bumper technique for vacuum vessel
- Ray trace 6 mm DU model
- Long barrel with large plug



Physics Issues and Simulation Tasks

EM

- $\Delta E/E$, Xo vs. η, projective accordion

- Segmentation for optimal e/π, γ pointing (barrel and endcap)

- Warm preradiator corrections on E, B (massless gap needed?)

- Cold Preradiator

Hadron

- $\Delta E/E$ vs. plate thickness, constant term, stuff escaping behind 12 λ vs. Fe/Pb/DU

- Effect of EC/CC walls

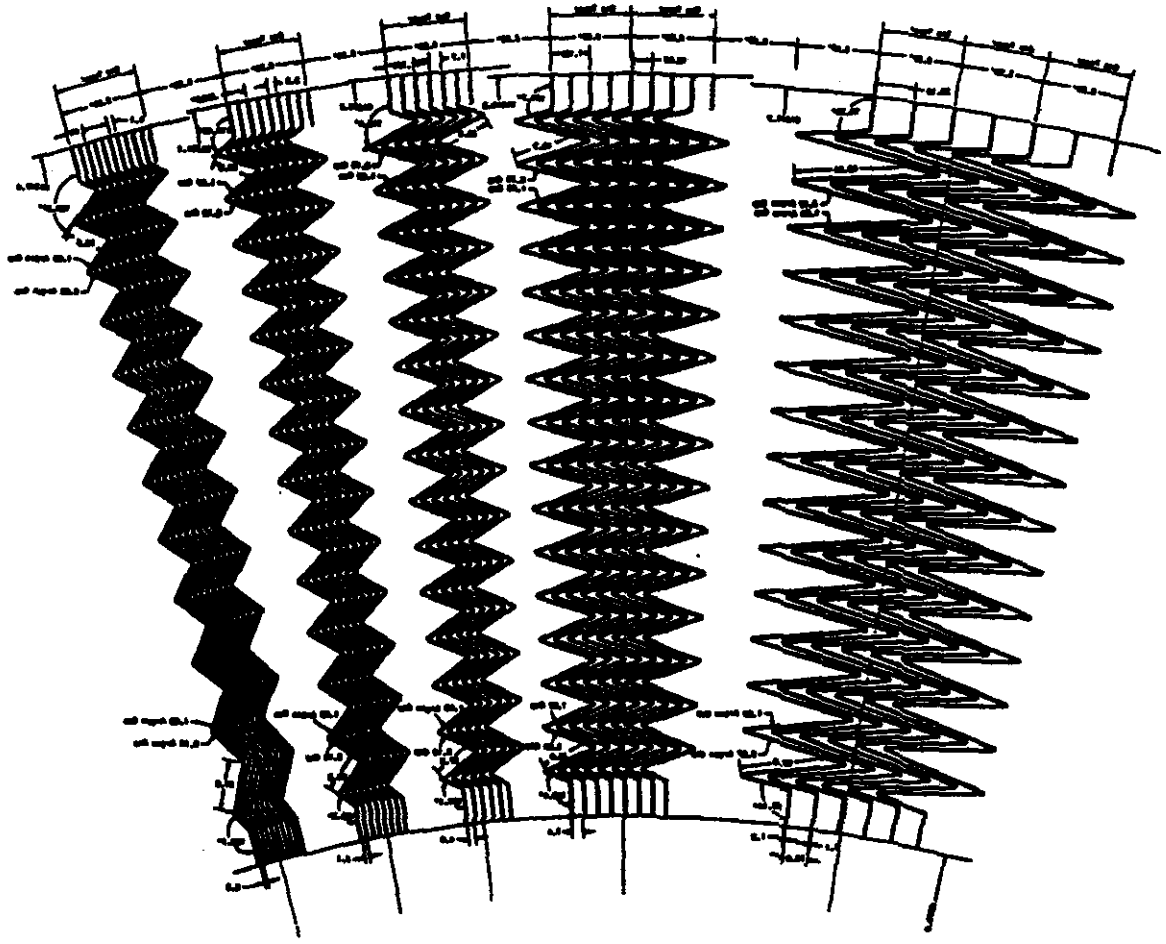
- Noise vs. shaping time in leakage section

- Effect of gaps between tiles in EST, effect of charge non-uniformity

- Explore effect of changing fine to coarse for $\eta = 1$ crack

- Explore long barrel with large plug

- Neutron flux vs Fe/Pb/DU

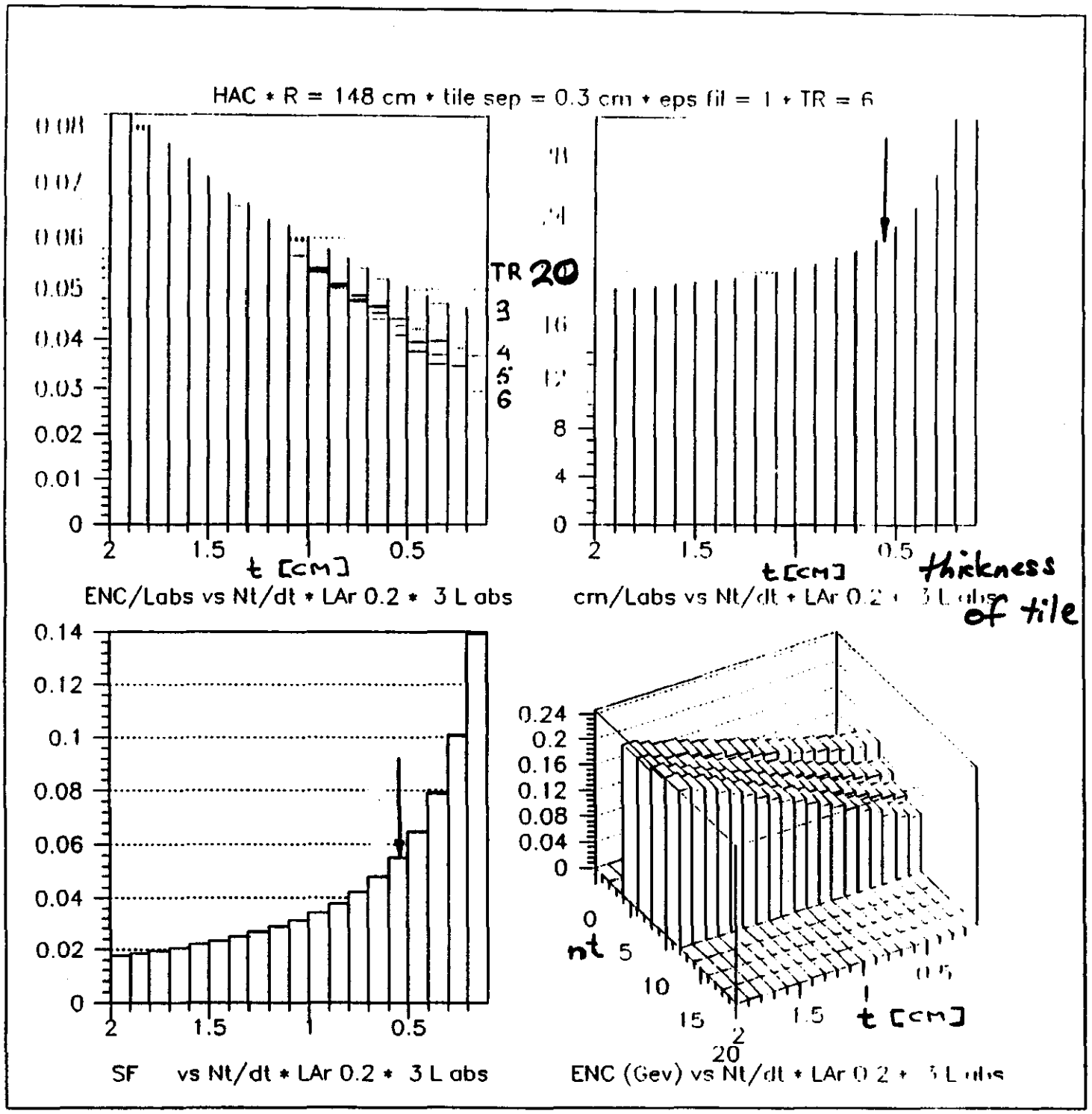


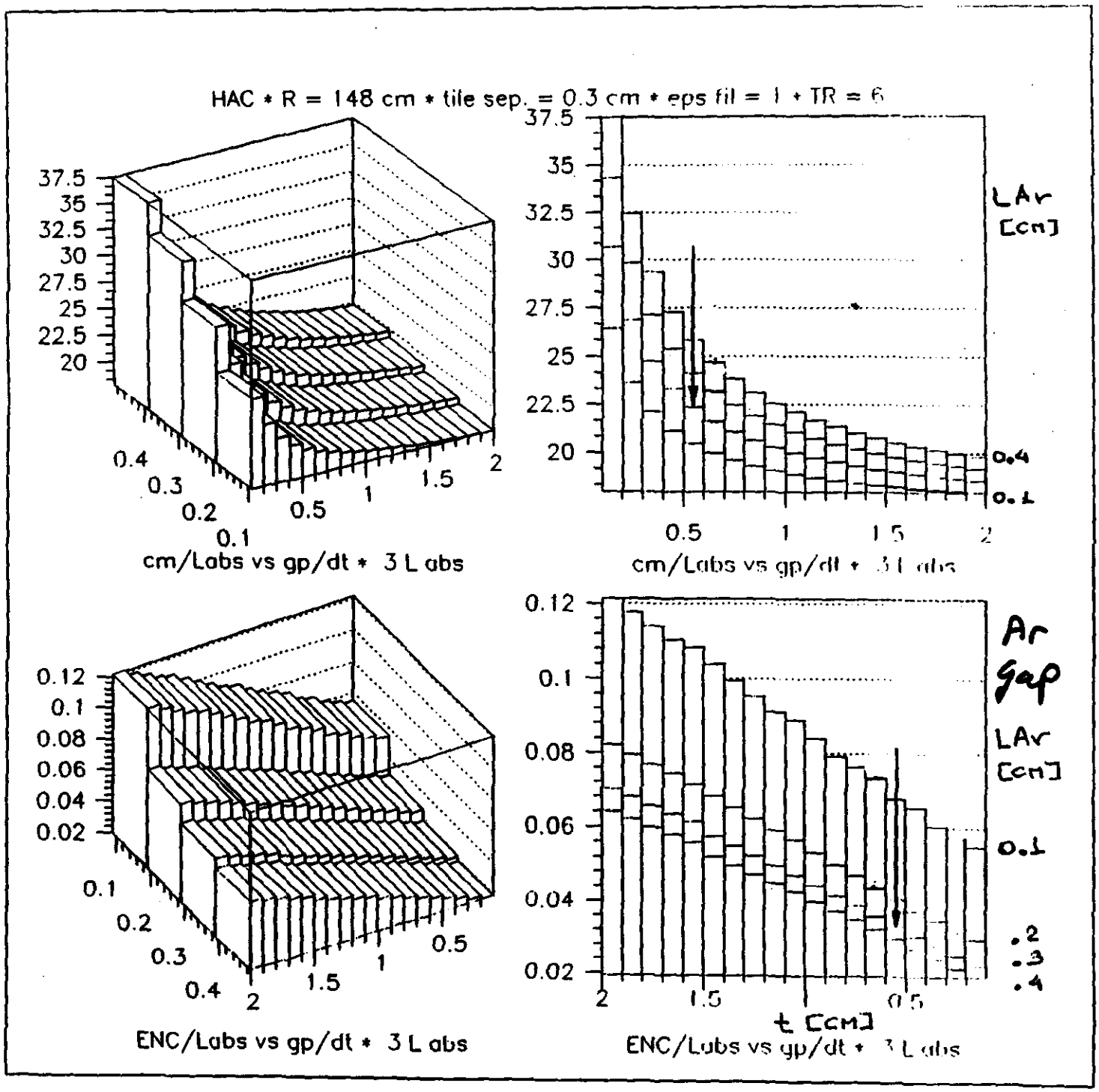
Dimensions are in millimeters

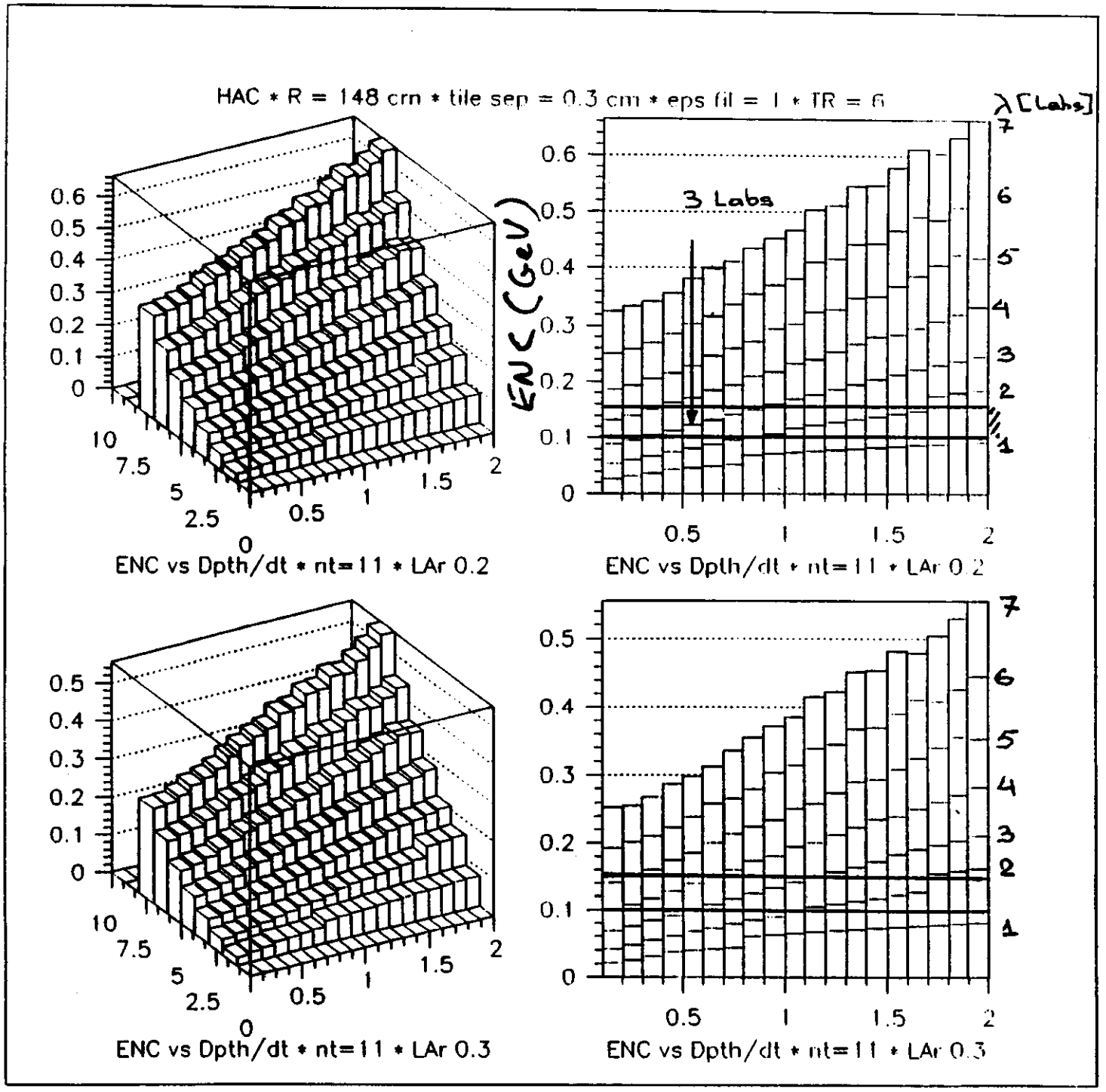
Scale is 1:1

S. Lesser Jan 8, 1992

Edward Kistenev, BNL




HAC * R = 148 cm * tile sep. = 0.3 cm * eps fil = 1 * TR = 6
37.5
35
32.5
30
27.5
25
22.5
20
0.4
0.3
0.2
0.1
0.5
1
1.5
2
cm/Labs vs gp/dt * 3 L abs
LAr
[cm]
0.4
0.1
cm/Labs vs gp/dt * 3 L abs
0.12
0.1
0.08
0.06
0.04
0.02
ENC/Labs vs gp/dt * 3 L abs
Ar
gap
LAr
[cm]
0.1
.2
.3
.4
t [cm]
ENC/Labs vs gp/dt * 3 L abs


HAC * R = 148 cm * tile sep = 0.3 cm * eps fil = 1 * TR = 6
λ [Labs]
3 Labs
ENC (GeV)
ENC vs Dpth/dt * nt=11 * LAr 0.2
ENC vs Dpth/dt * nt=11 * LAr 0.2
ENC vs Dpth/dt * nt=11 * LAr 0.3
ENC vs Dpth/dt * nt=11 * LAr 0.3

CAL-TR-037 12-2-91 M. Nessi et al.

12-2-91 LHC-NESSI

Comparison between few hadronic calorimeter "scenarios"

This summarizes the work of:

- D. Cavalli
- Cl. Fuglesang
- P. Jenni
- F. Nessi
- M. Nessi
- L. Perini
- M. Sciamanna

"Scenarios"

EM calorimeter : LAr - Accordion, like in test beam ($\sim 25 X_0$)

$$\frac{\sigma}{E} = \frac{10\%}{\sqrt{E}} + 0 \quad \text{for electrons}$$

Pb absorber

hadronic calorimeter:

1- Pb - Scintillator, parallel plates

2- Fe - Scintillator, longitudinal plates

3- LAr Accordion

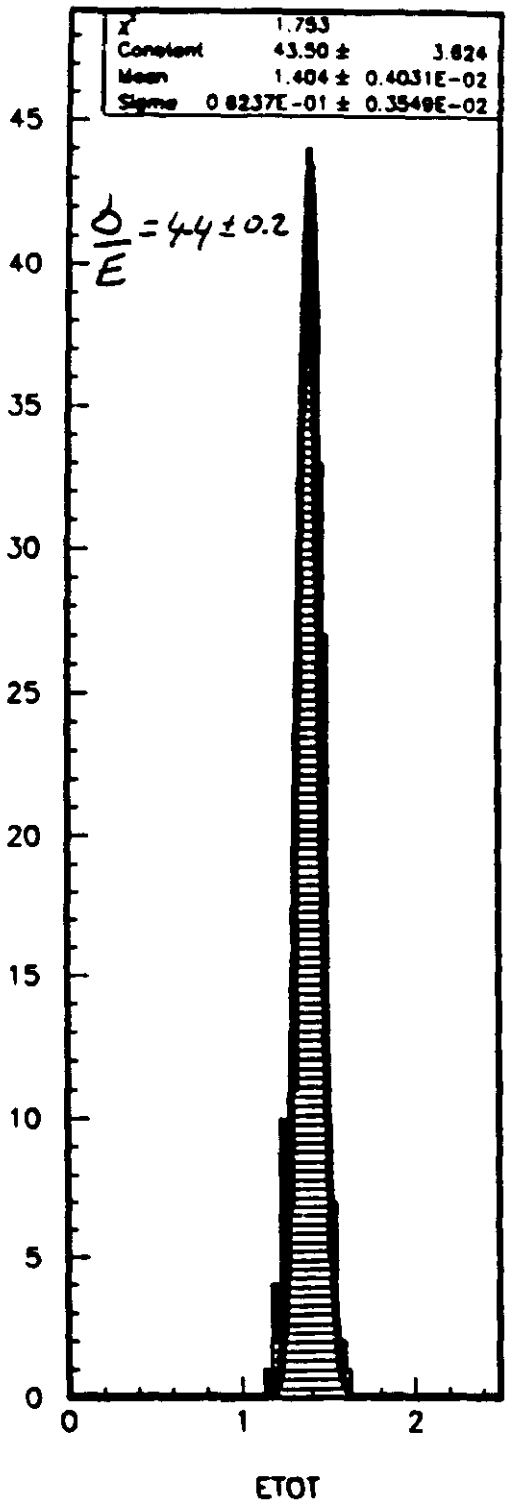
What is new??

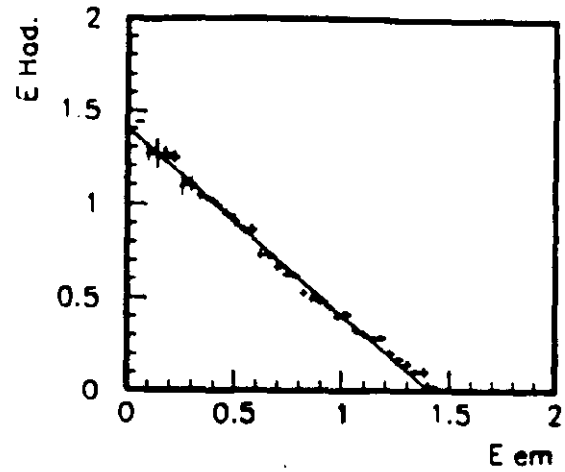
⇒ high statistics for
150 GeV jets
using full shower simulation
(Geant 3.14, 10 keV cuts)

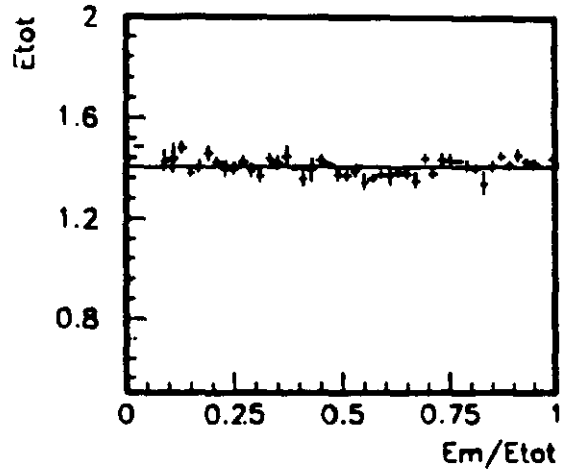
→ generated about
6000 jets at 150 GeV

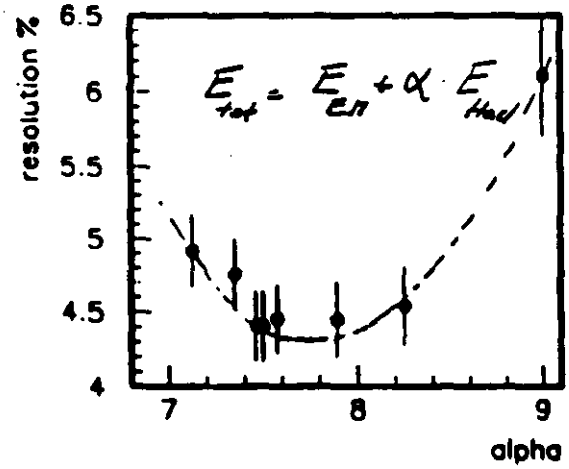
- in Milano (IBM-Cilea), L. Perini et al
- at CERN via SHIFT and HOPEA

u-jets at 150 GeV, $\eta = 0$

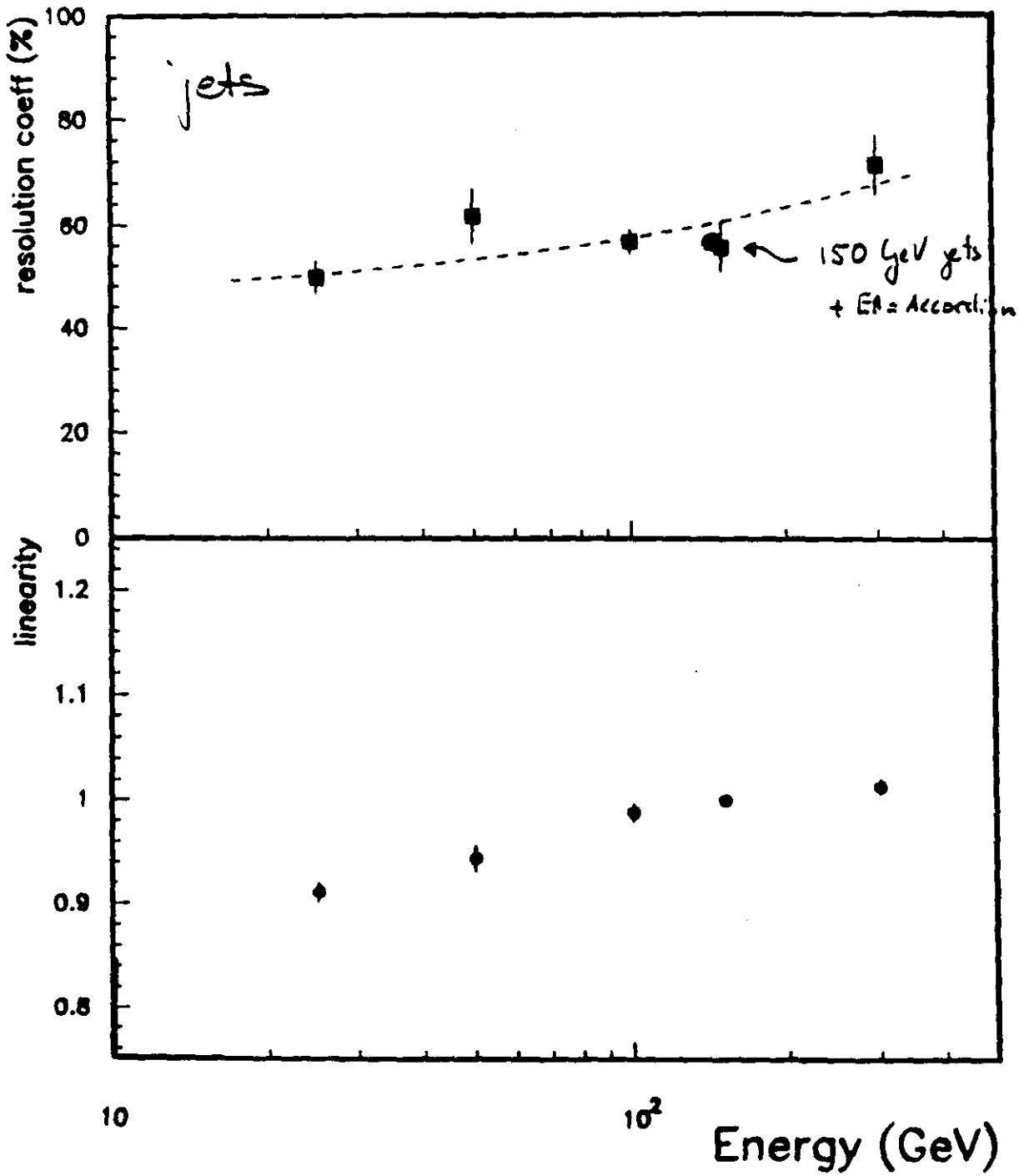








SANDWICH CALO EM Pb 0.3 / LAr 0.4 cm
HAD Pb 1.0 / Sci 0.25 cm



$$R = \frac{43.5 \pm 4.5}{\sqrt{E}}\,\% + (1.4 \pm 0.5)\,\%$$

Conclusions

- Looking at these 3 scenarios for 150 GeV jets, scintillating calorimeters look better*

$$\frac{\sigma}{E} = \frac{0.50}{\sqrt{E}} + 0.02$$ is not a problem in any case (150ns)

- We may have a problem going to 50ns, but it might be just a Geant problem.

- Pb or Fe are similar, but Fe has bigger constant term

- An Accordion geometry is not a problem.

* even better resolutions are expected for a full SPACAL calorimeter

			150GeV σ/E	$\sigma/\sqrt{E}$	
	Pb	$\sigma/E(\%) = \frac{63\pm4}{\sqrt{E}} + (1.6\pm0.4)$	6.7	82	!
1cm	Fe	$\sigma/E(\%) = \frac{62\pm5}{\sqrt{E}} + (2.5\pm0.5)$	7.6	93	!

From: BNLCL6::GORDONH "HOWARD GORDON OR VIA BITNET "gordonH@bnlcl1"" 23-J
To: SSCVX1::HGORDON
CC:
Subj: weighting

From: Jnet%"NESSI@CERNVM" "Marzio" 23-JAN-1992 08:30:59.37
To: GORDONH@BNLCL1
CC:
Subj: Hadr resolution

Received: From CERNVM(MAILER) by BNLCL1 with Jnet id 0186
for GORDONH@BNLCL1; Thu, 23 Jan 1992 08:30 EST
Received: from CERNVM (NESSI) by CERNVM.cern.ch (Mailer R2.08) with BSMTP id 0471; Thu, 23 Jan 92 14:28:25 SET
Date: Thu, 23 Jan 92 14:27:03 SET
From: Marzio <NESSI@CERNVM>
Subject: Hadr resolution
To: GORDONH@BNLCL1

Yes we did try, just to have a first idea about weightng technique .

- we have divided longitudinally the EM accordion in 3 and the HAD in four segments.

_ to each one we apply an energy dependent weight:

alpha(i)=a(i)+b(i)*E(i)

where E(i) is the energy deposited in the i-th compartement.

- The 14 coefficients were calculated using minuit and minimizing the spread of the total measured energy

for jets at 150 GeV this method improves the resolution expressed in sigma/E

$\frac{74\%}{\sqrt{E}}$ from 6.1+-.3 % to 4.5+-.2 % $\frac{55\%}{\sqrt{E}}$

similar results were found at different energies for jets and pions.

This was just a first look. We probably will continue that with the the data we will get from the '92 prototype next summer.

regards, Marzio N.

Budget

Engineering $630K

Preliminary design

Assembly, tooling, transportation, handling

Schedule for R+D, fabrication, installation, test + commissioning

Cost estimates – bottoms up

Trade studies for configurations

Structural analyses

Thermal Analyses

Vessel configurations, support, utility access,

Facility requirements

R+D

2 mm Projective EM accordion + hadron calorimeter (RD3) $150K

Improve EM accordion "2 mm" Kr, "1 mm" Ar 520K

~~Hadronic EST~~

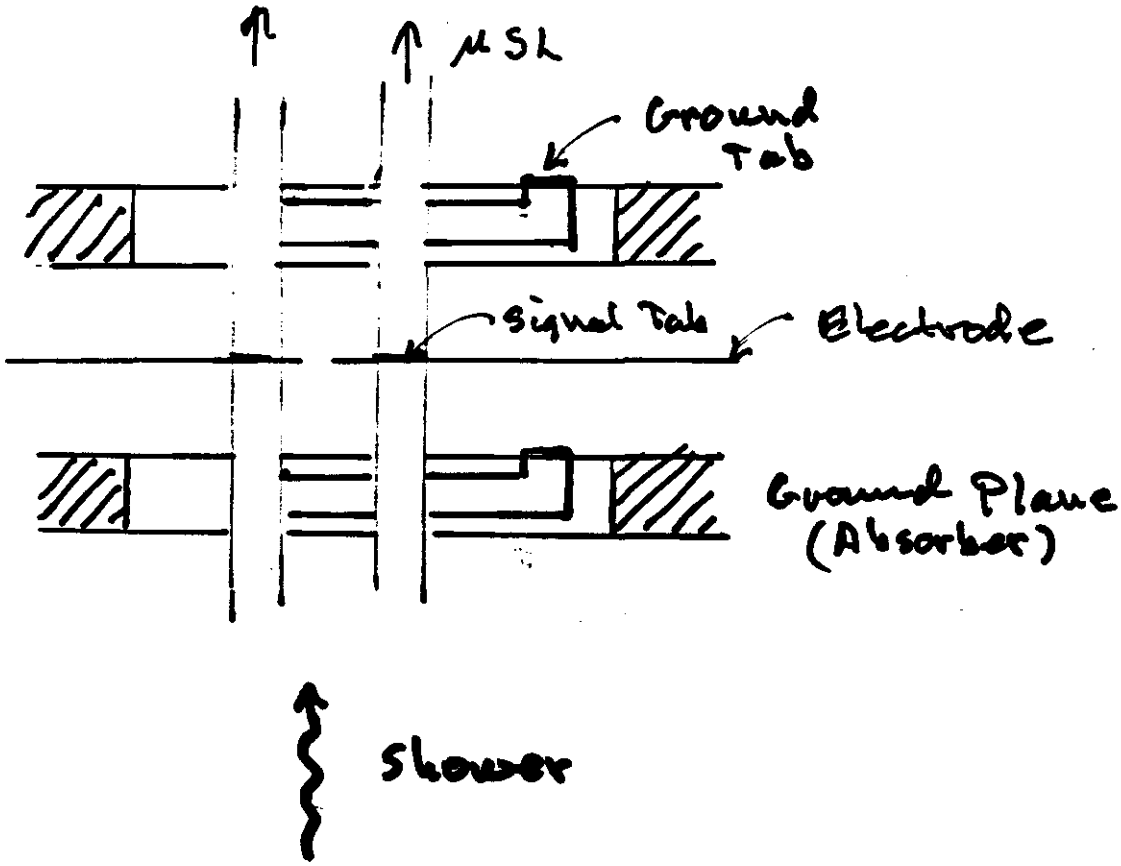
Parallel Plate EM	(205K)
Precision calibration	75K
Operation of Test Beam	50K
Purification	100K
	$1120K

. Mockett
/24/92
SCL
EM

PARALLEL PLATE CALORIMETER

U. Wash. U. Ariz. MIT ORNL

EGS value of $\sigma \leq 7\%/\sqrt{E}$



// Plate Design Based on NA31 with measured good σ

SSC speed Requirements Necessitates μSL signal line

Innovative μSL Design

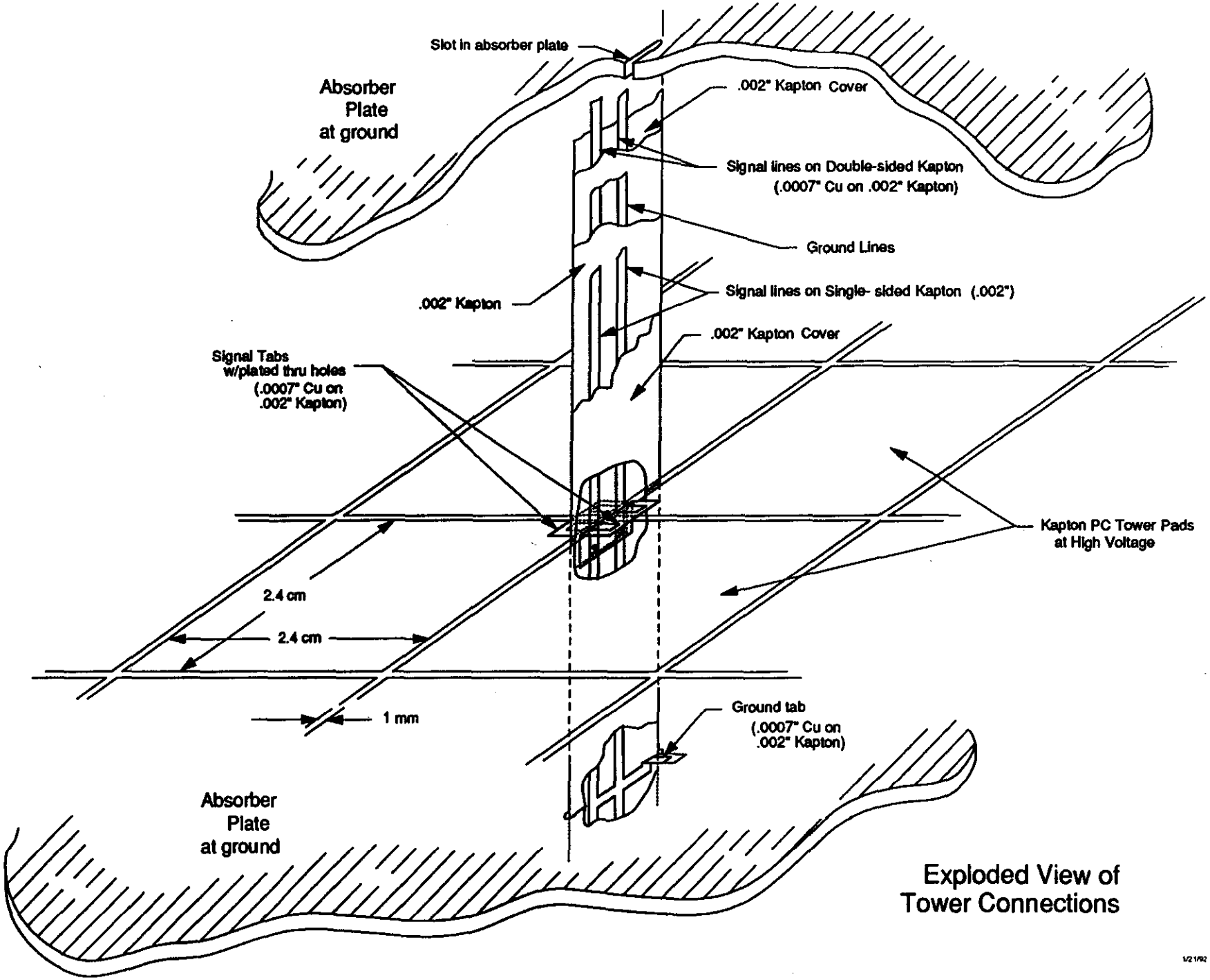
Demonstrated to be more than adequate in speed by Test & Simulation

Next step is to demonstrate constructability

1st protype completed

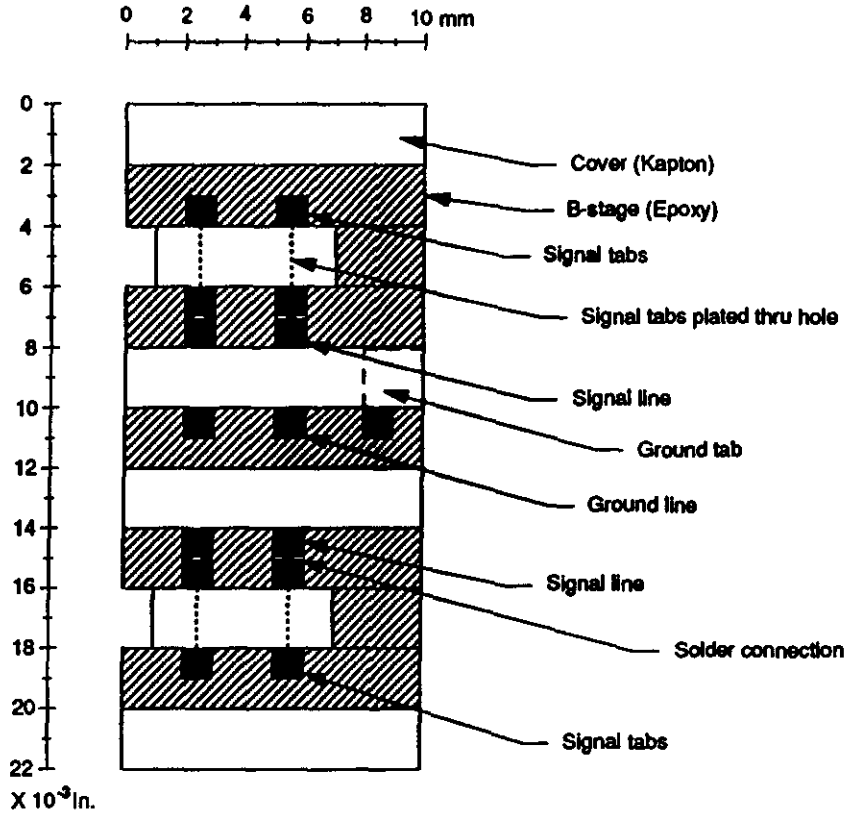
Engineering appraisal phase

Verify performance in Test Beam @ BNL

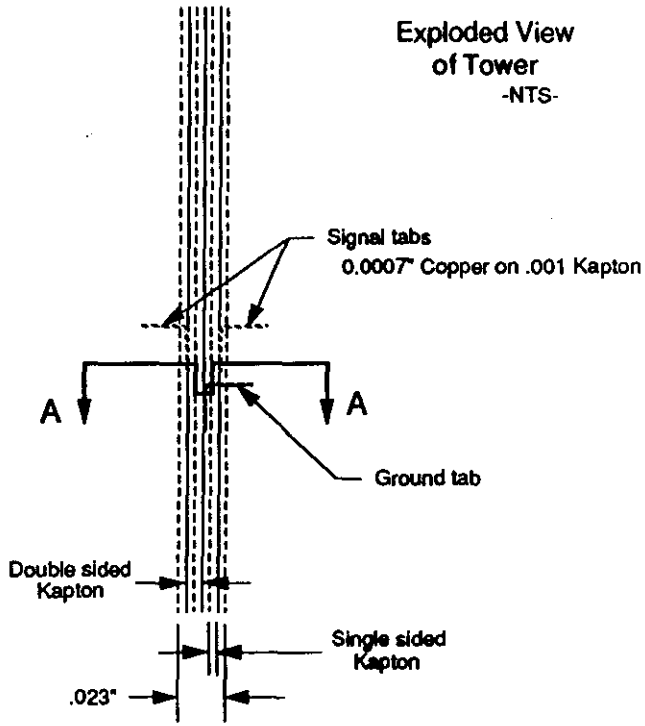


Exploded View of Tower Connections

1/21/92



A - A
(Enlargement)



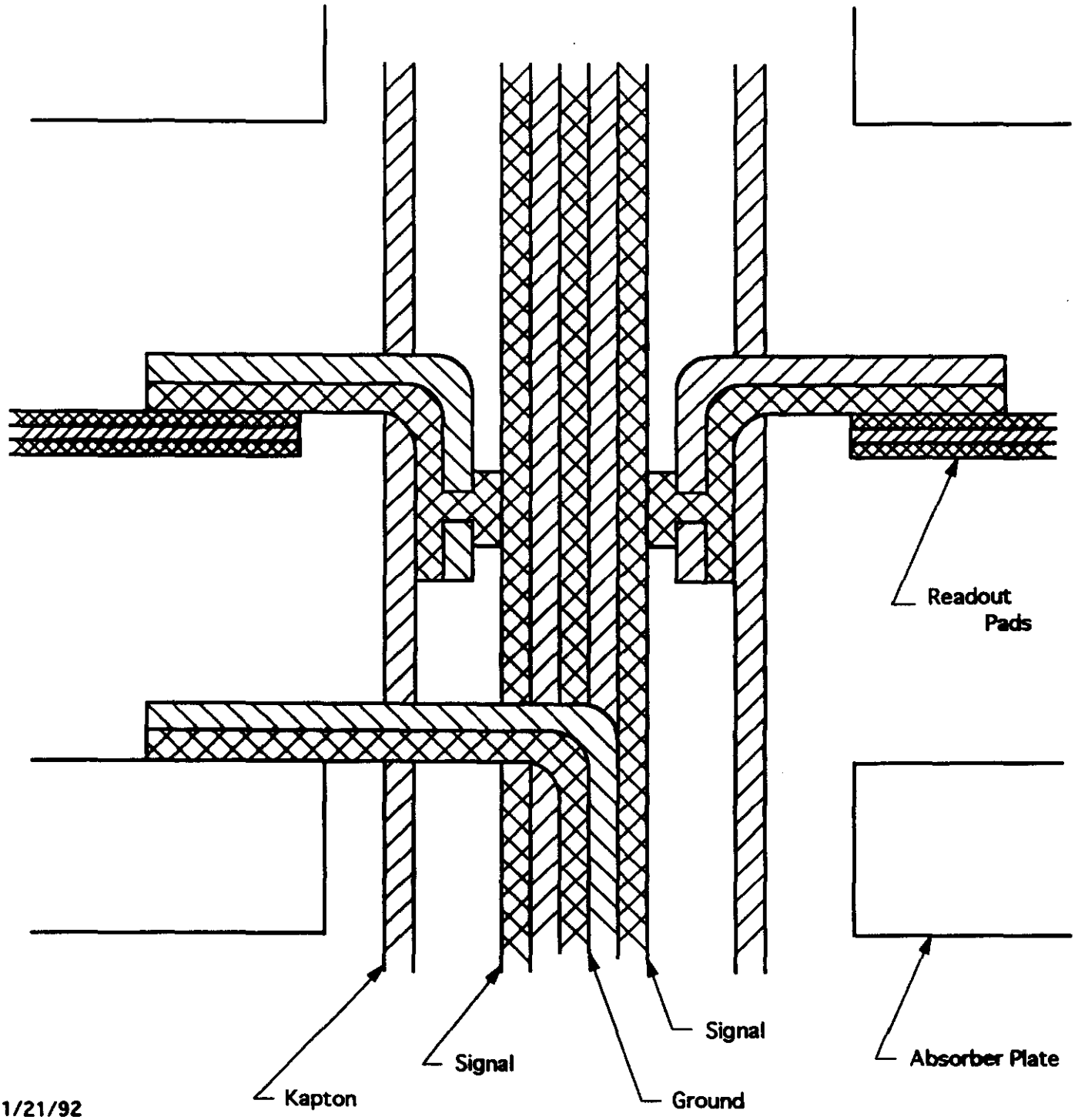
Key

- Kapton
- B-stage Epoxy
- Copper

Cross Section of Signal Line

1/21/92

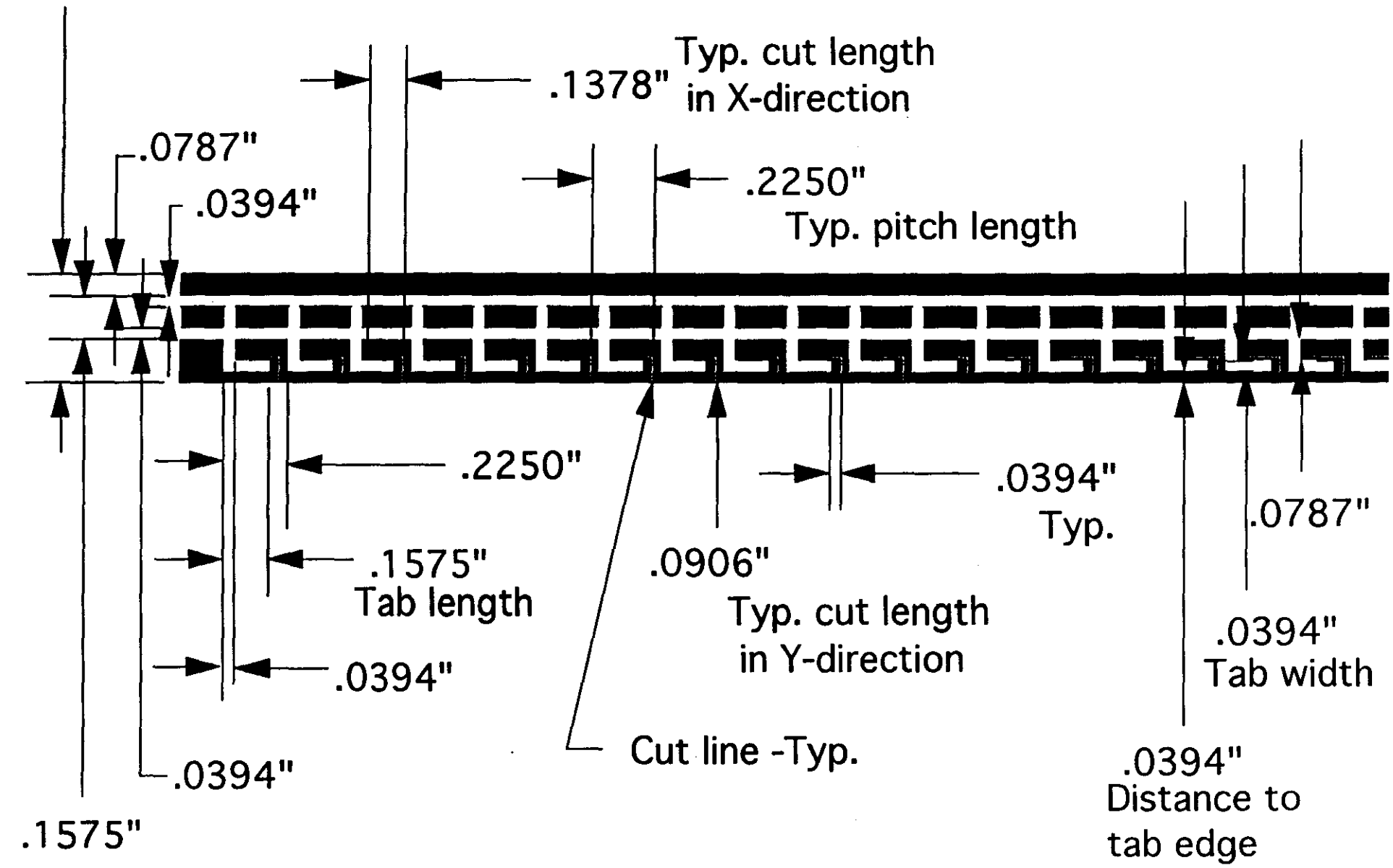
Microstrips for GEM Parallel Plate EM LAC



1/21/92
DAF

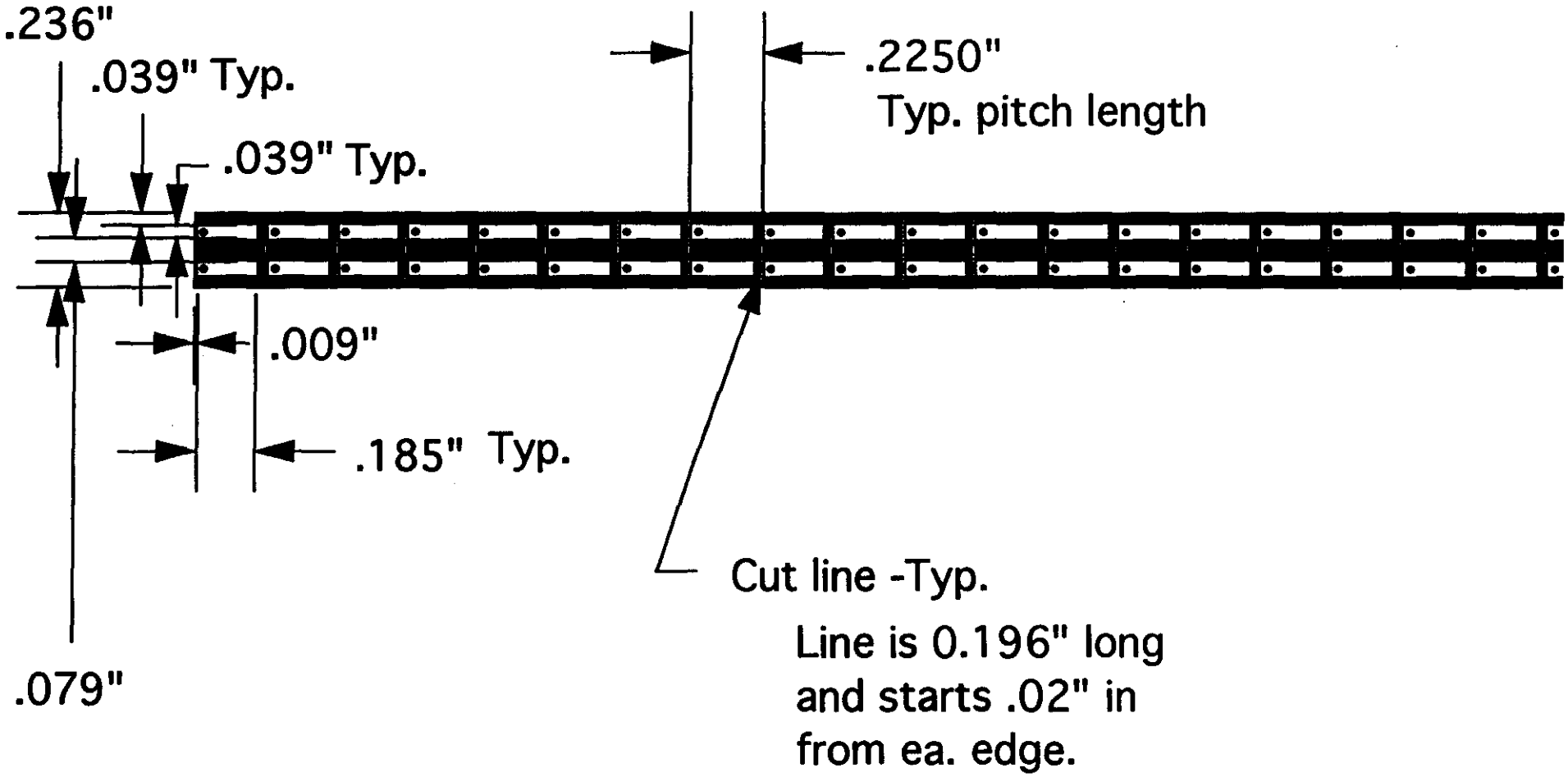
Ground Tab Enlargement

1/21/92

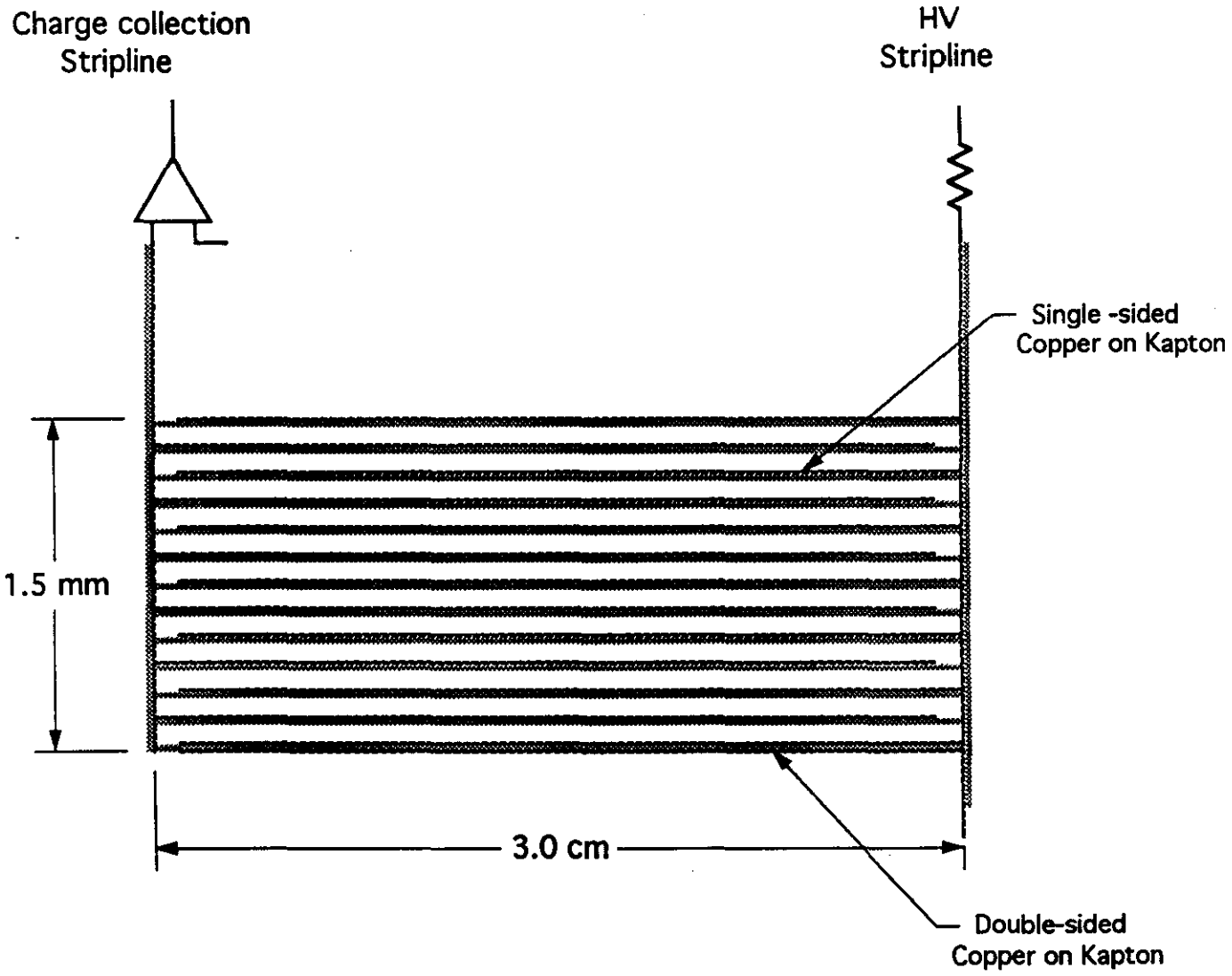


Signal Tab Enlargement

1/21/92

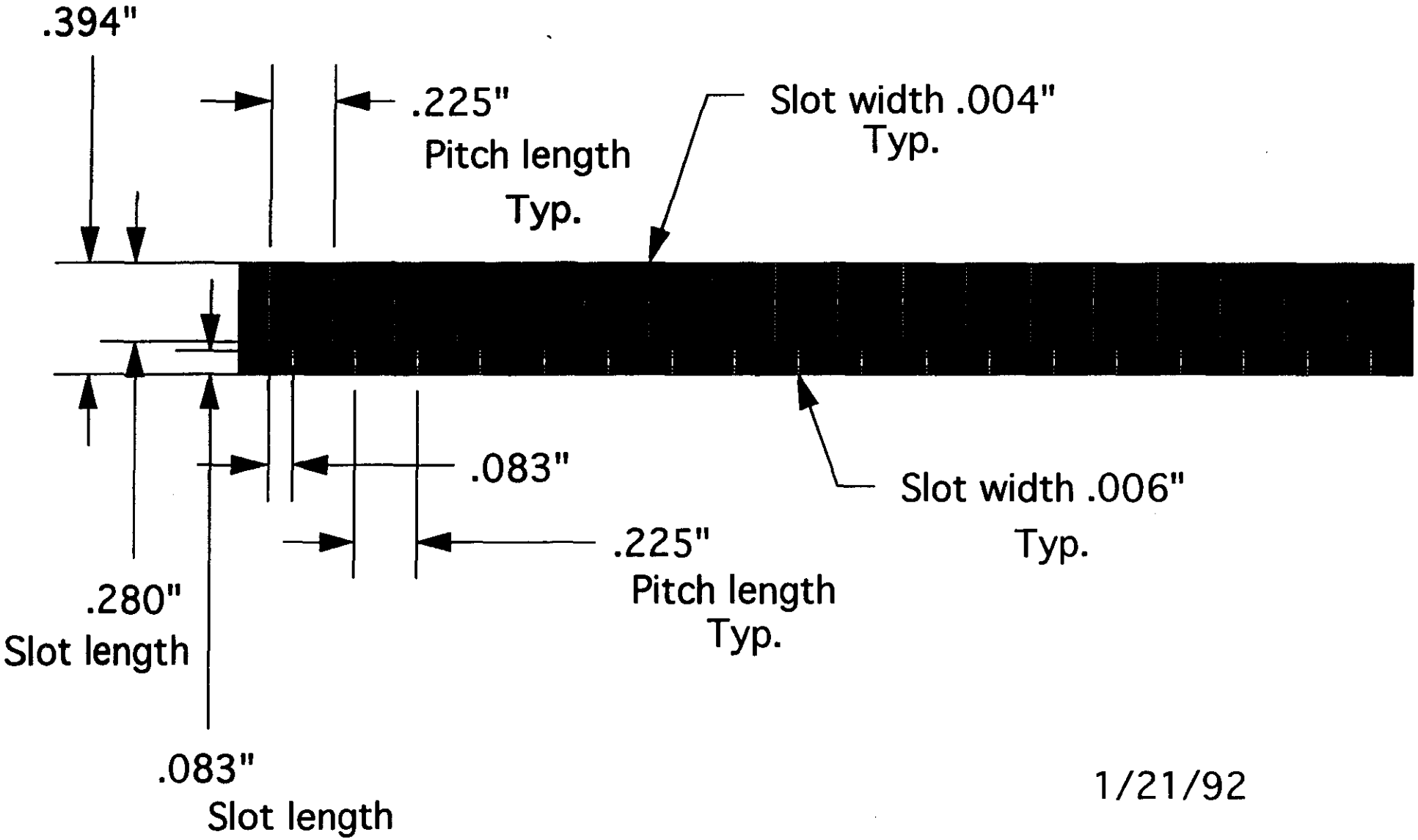


Decoupling Capacitor Schematic

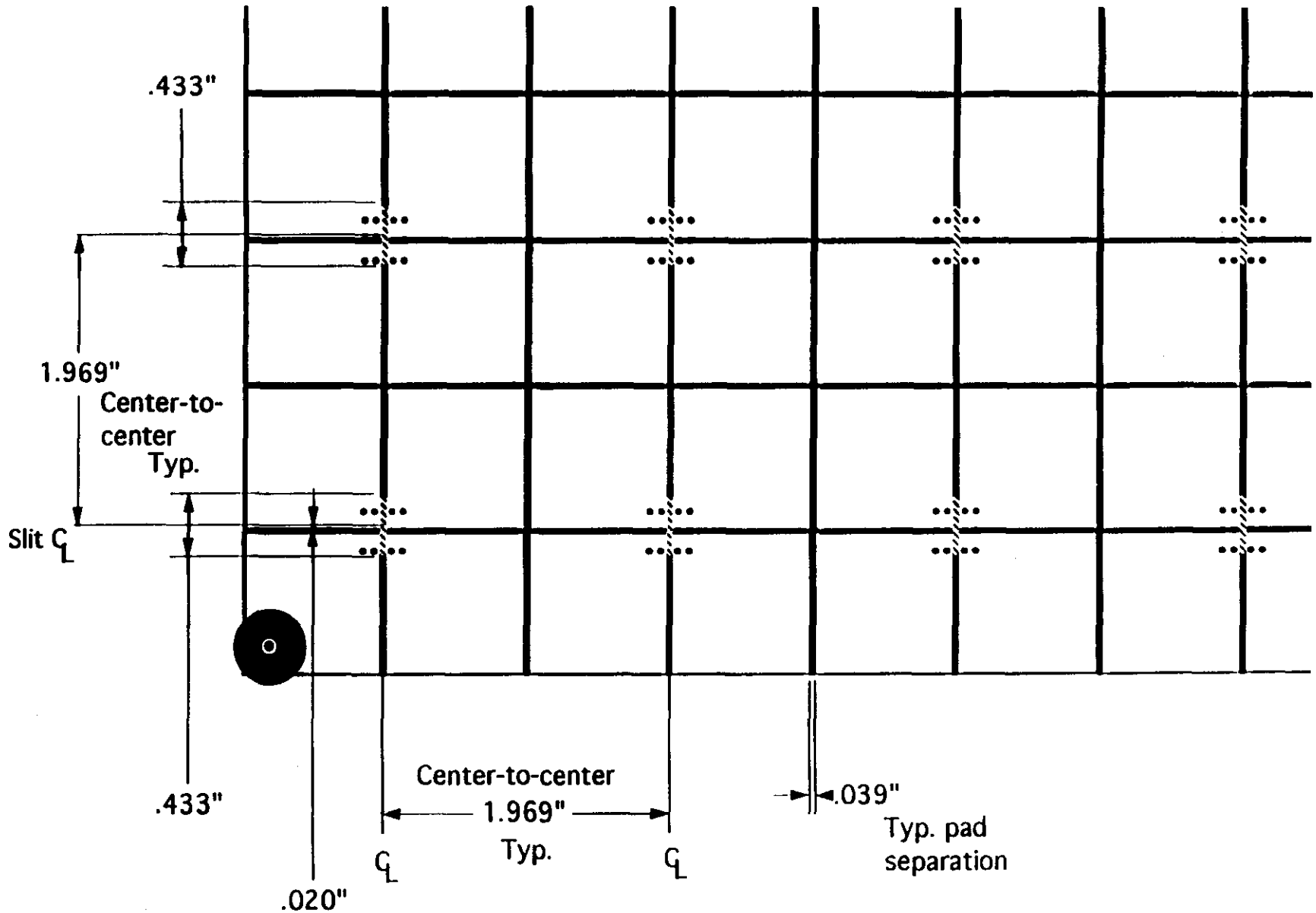


1/21/92

Kapton Cover Slit Pattern

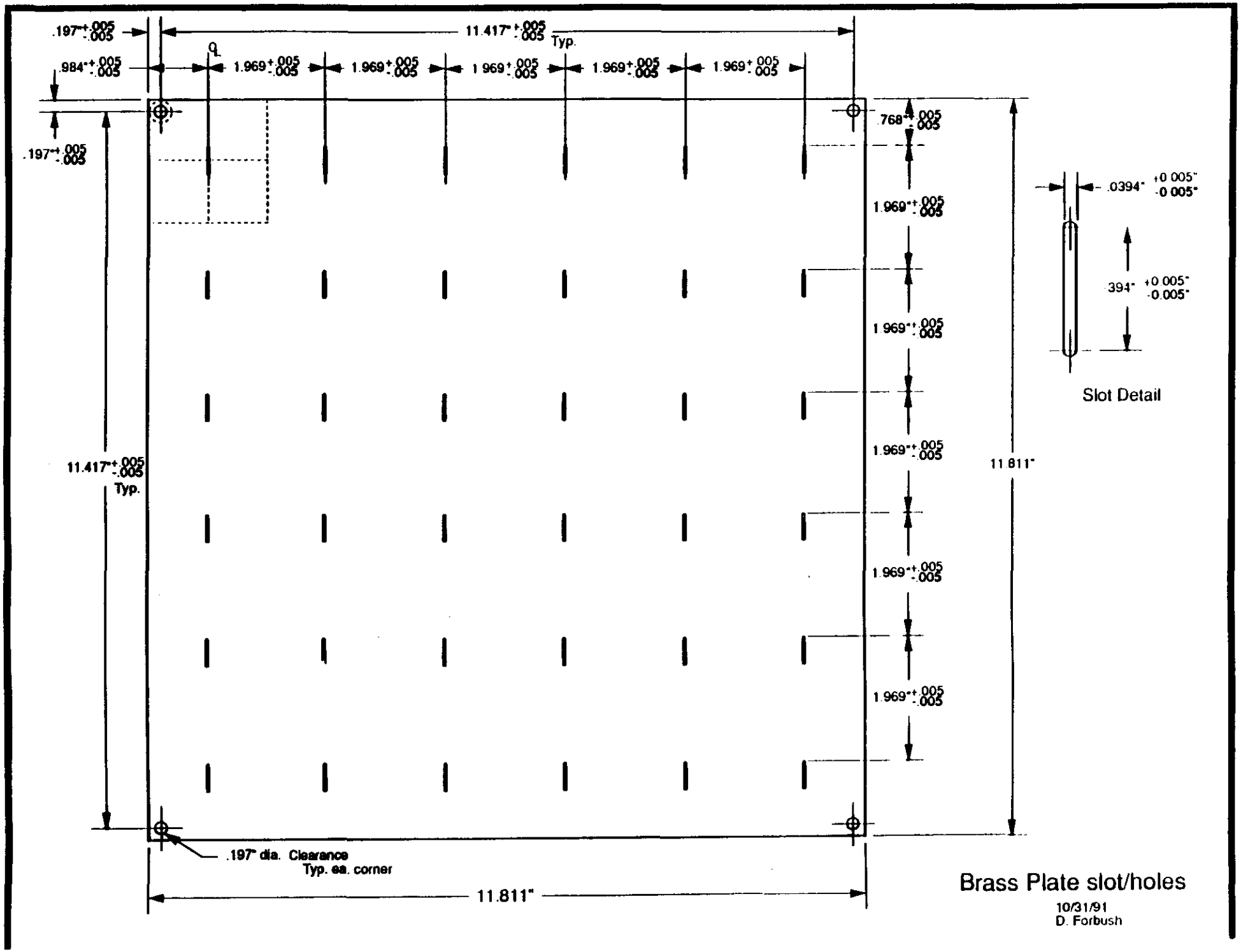


1/21/92

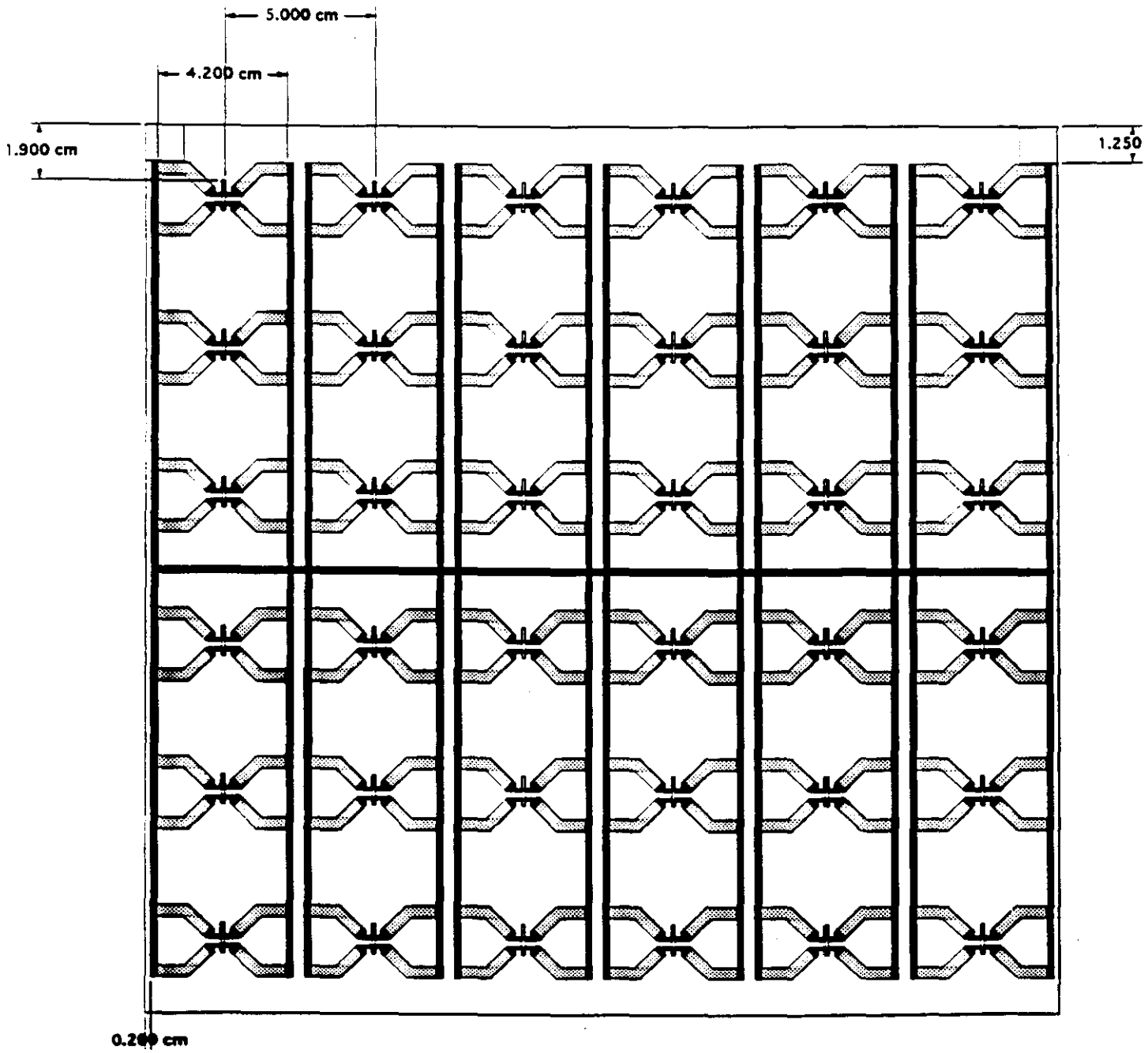


Note:
Slit has a total length of .433" and .039" width.

Pad Slit Pattern

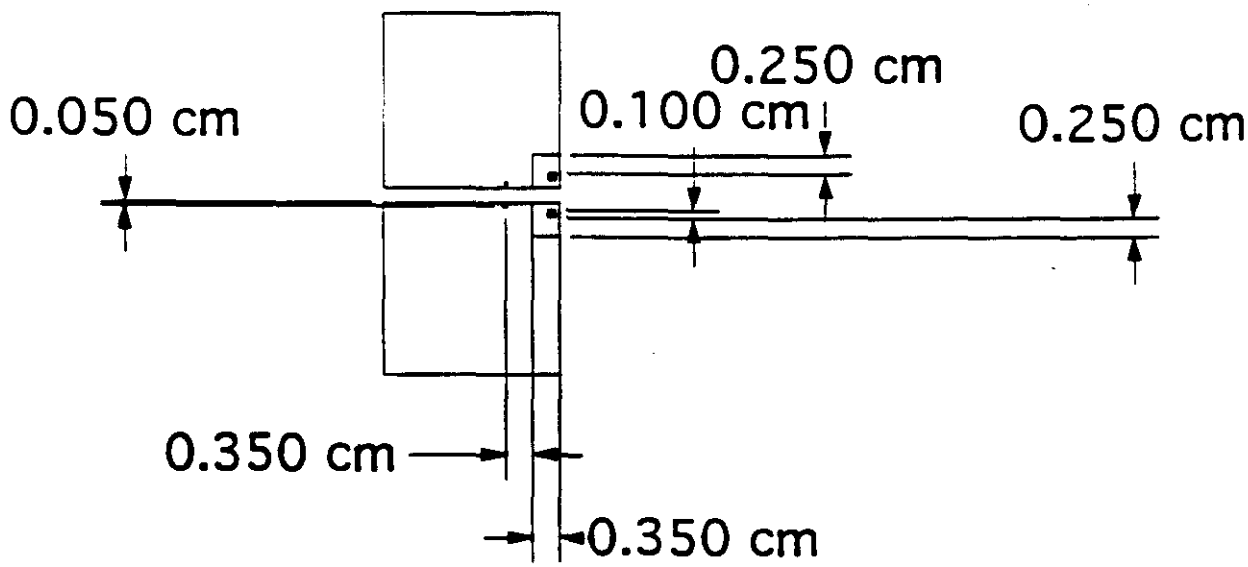

.197" +.005 -.005
11.417" +.005 -.005 Typ.
.984" +.005 -.005
1.969 +.005 -.005
.197" +.005 -.005
.768" +.005 -.005
1.969" +.005 -.005
11.417" +.005 -.005 Typ.
11.811"
.0394" +0.005" -0.005"
.394" +0.005" -0.005"
Slot Detail
.197" dia. Clearance Typ. ea. corner
11.811"
Brass Plate slot/holes
10/31/91
D. Forbush

High Voltage Distribution

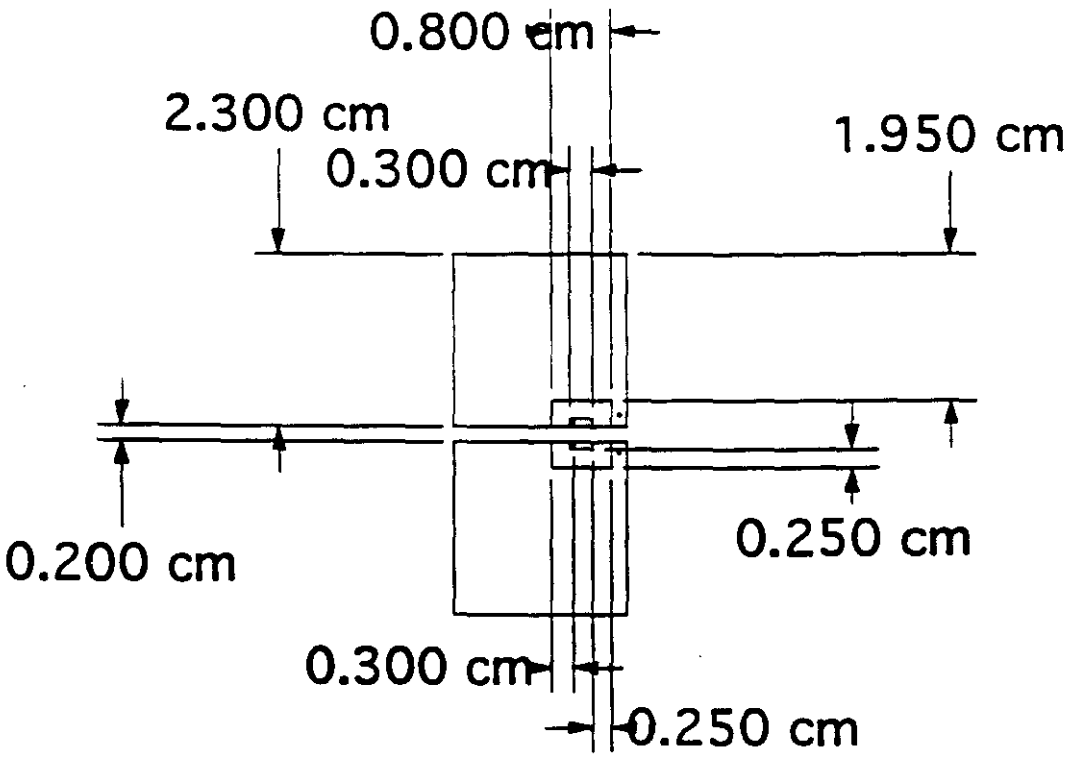


solid = Cu
dotted = resistive coatin

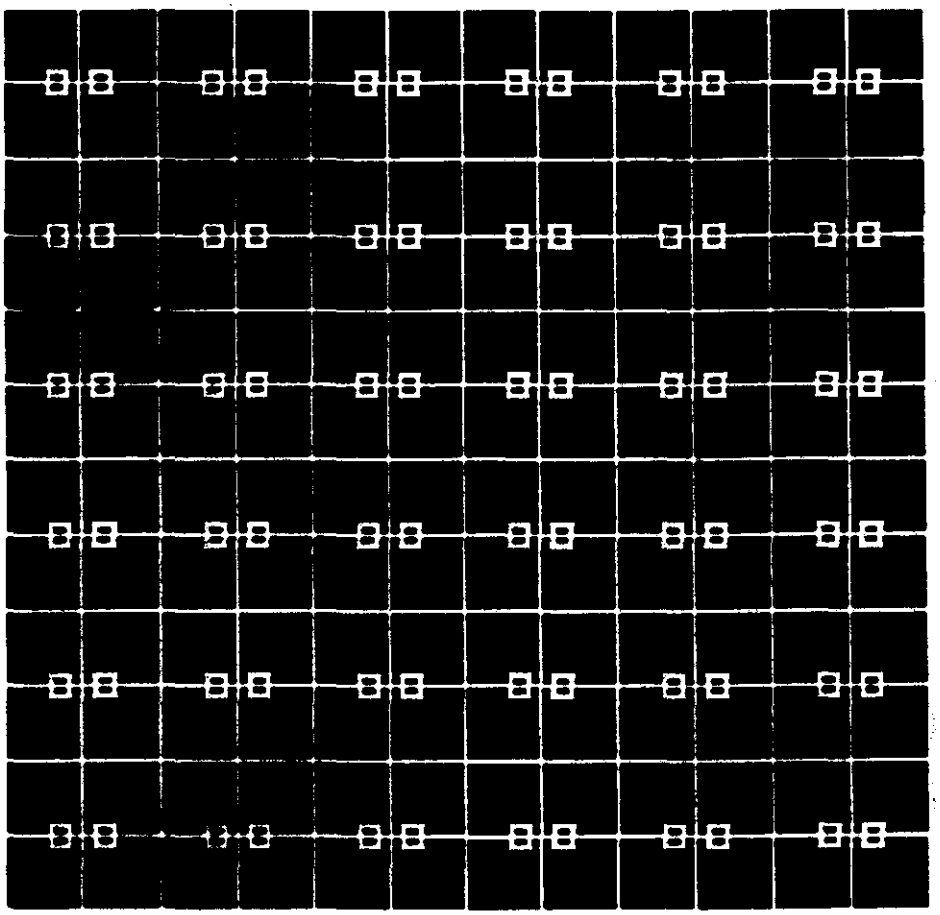
Low voltage
capacitor plate
detail

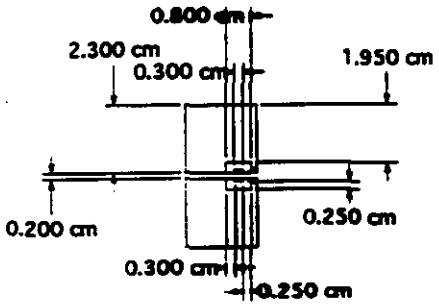


High voltage
capacitor plate
detail

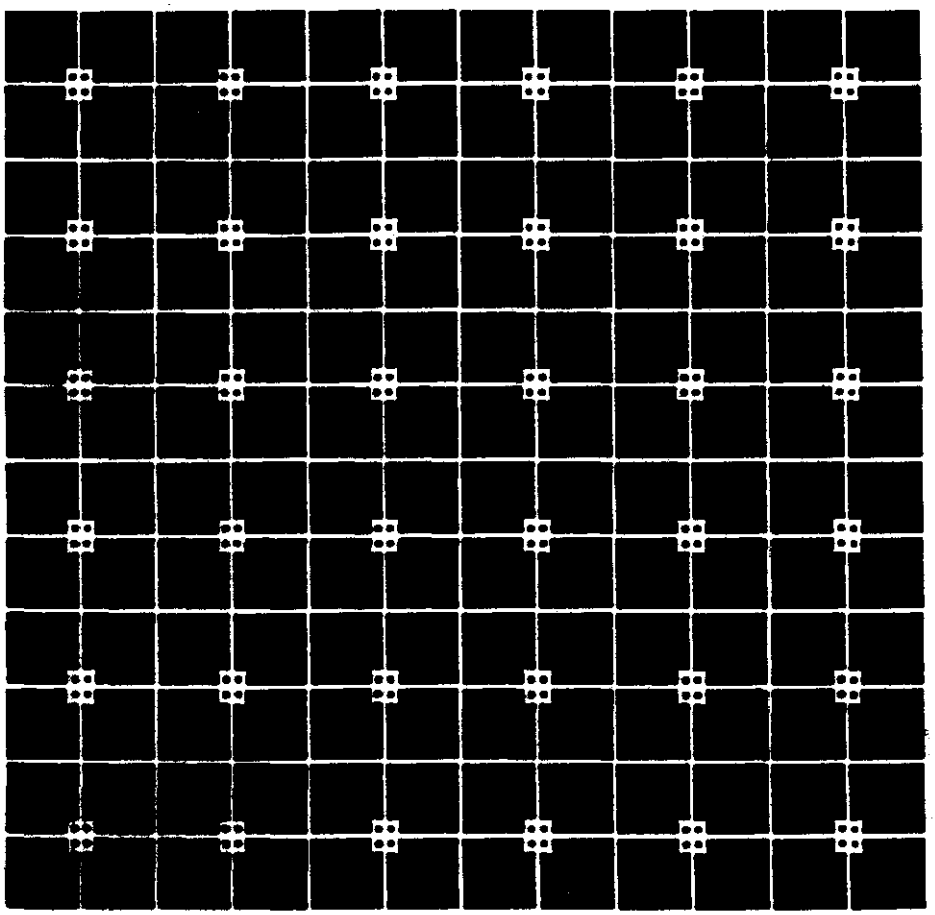


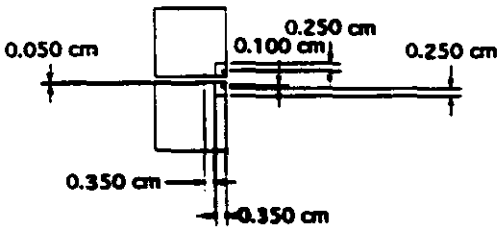
High Voltage Capacitor plate

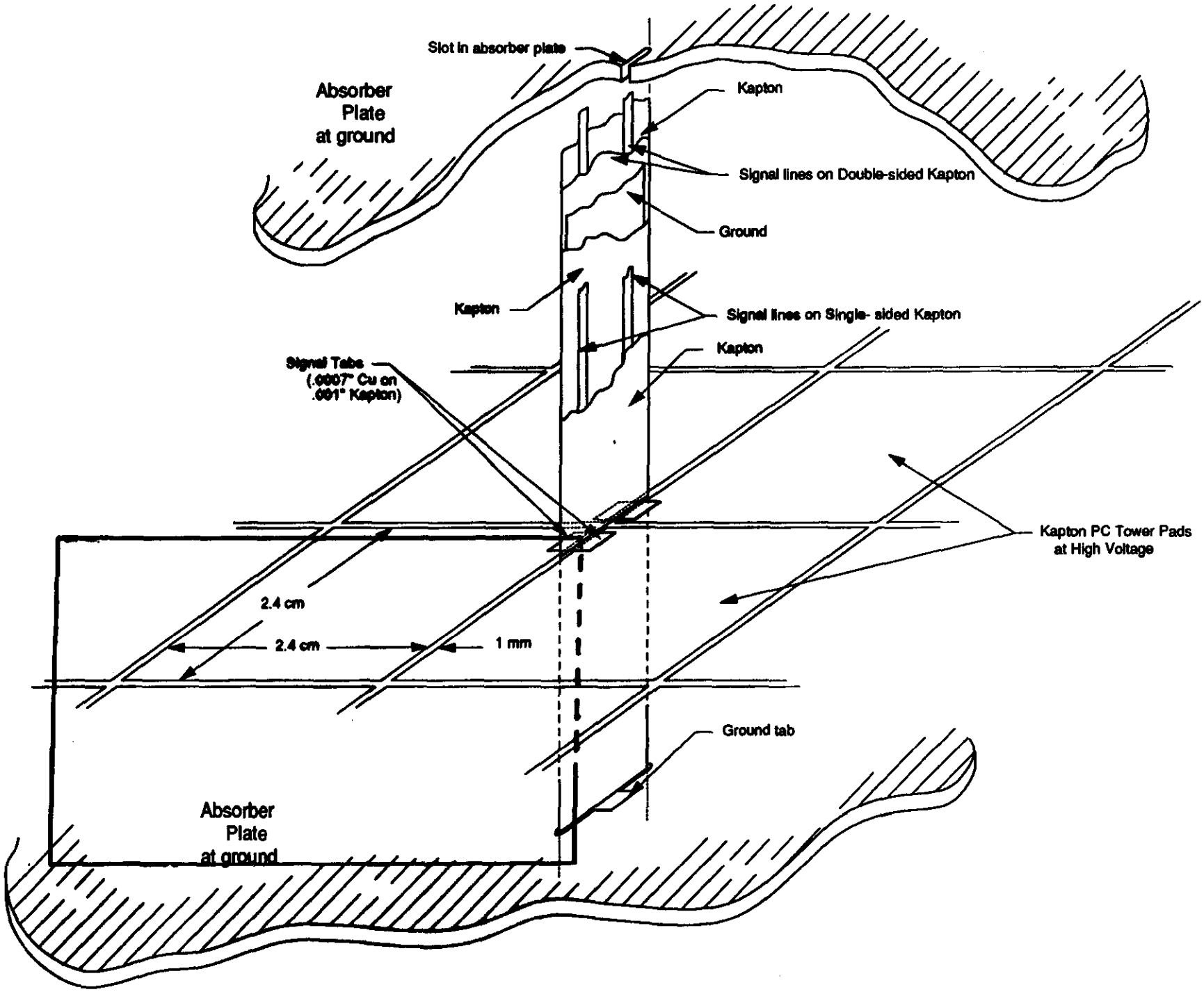




Low Voltage Capacitor plate

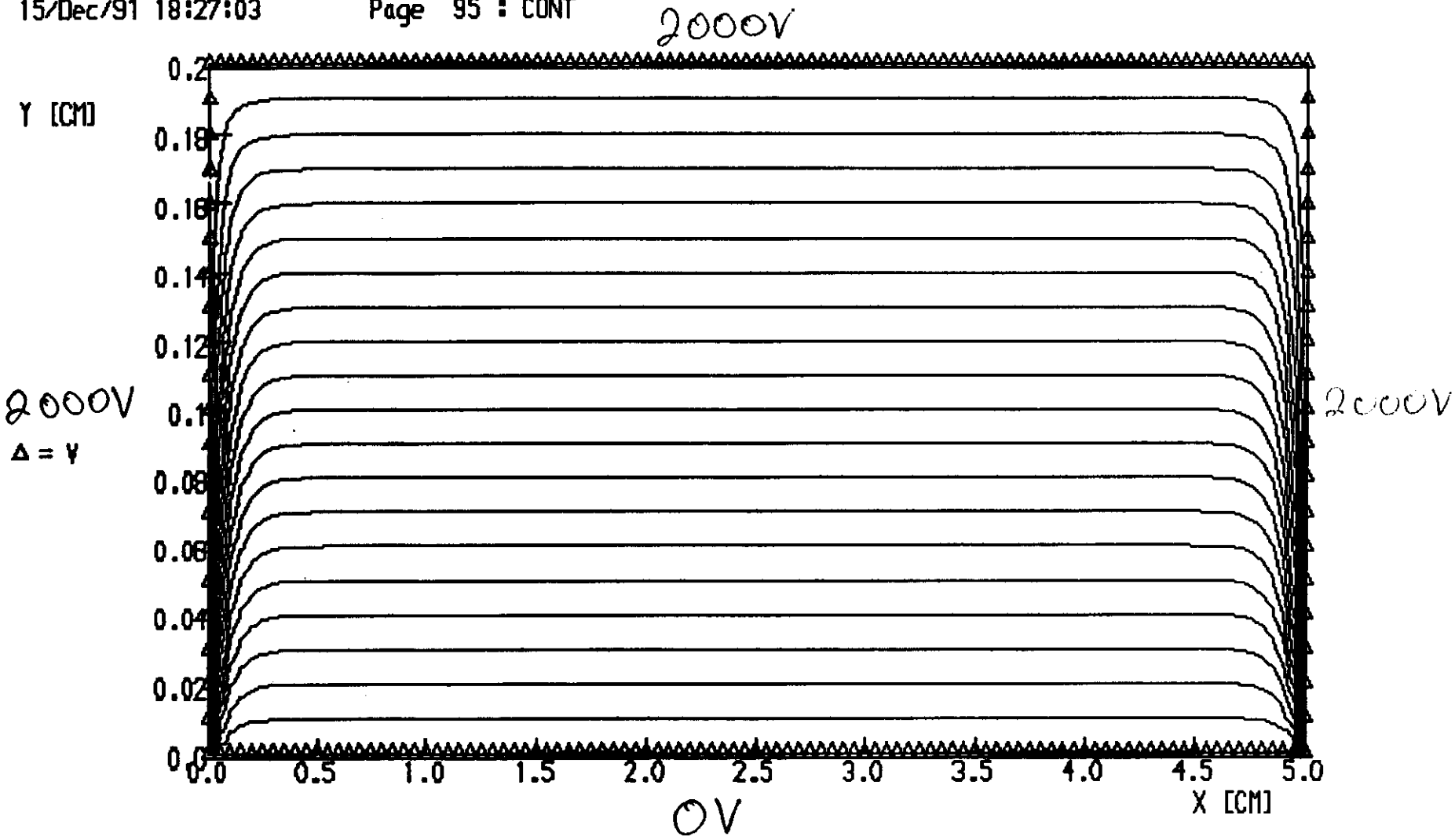





Slot in absorber plate
Absorber Plate at ground
Kapton
Signal lines on Double-sided Kapton
Ground
Kapton
Signal lines on Single- sided Kapton
Kapton
Signal Tabs (.0007" Cu on .001" Kapton)
Kapton PC Tower Pads at High Voltage
2.4 cm
2.4 cm
1 mm
Ground tab
Absorber Plate at ground

Equipotentials

WHOLE_CELL.STRES
15/Dec/91 18:27:03 Page 95 : CONT

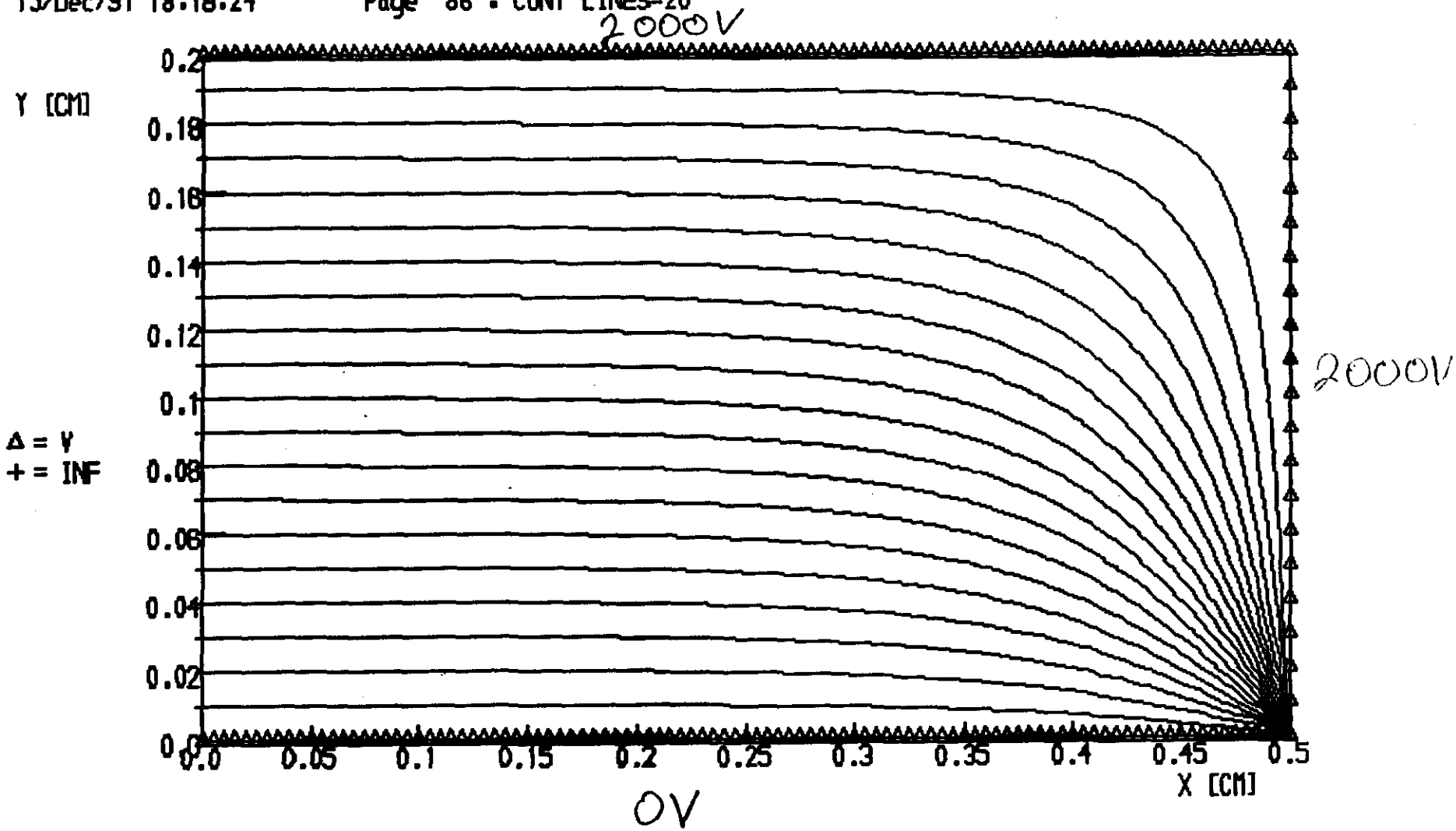


ELEM=LINE SYMM=XY SOLN=V SCALE=1.0 FIEL=ELEC
Static Solution Mesh 4000 Elements 1 Region

VF/PE2D.8

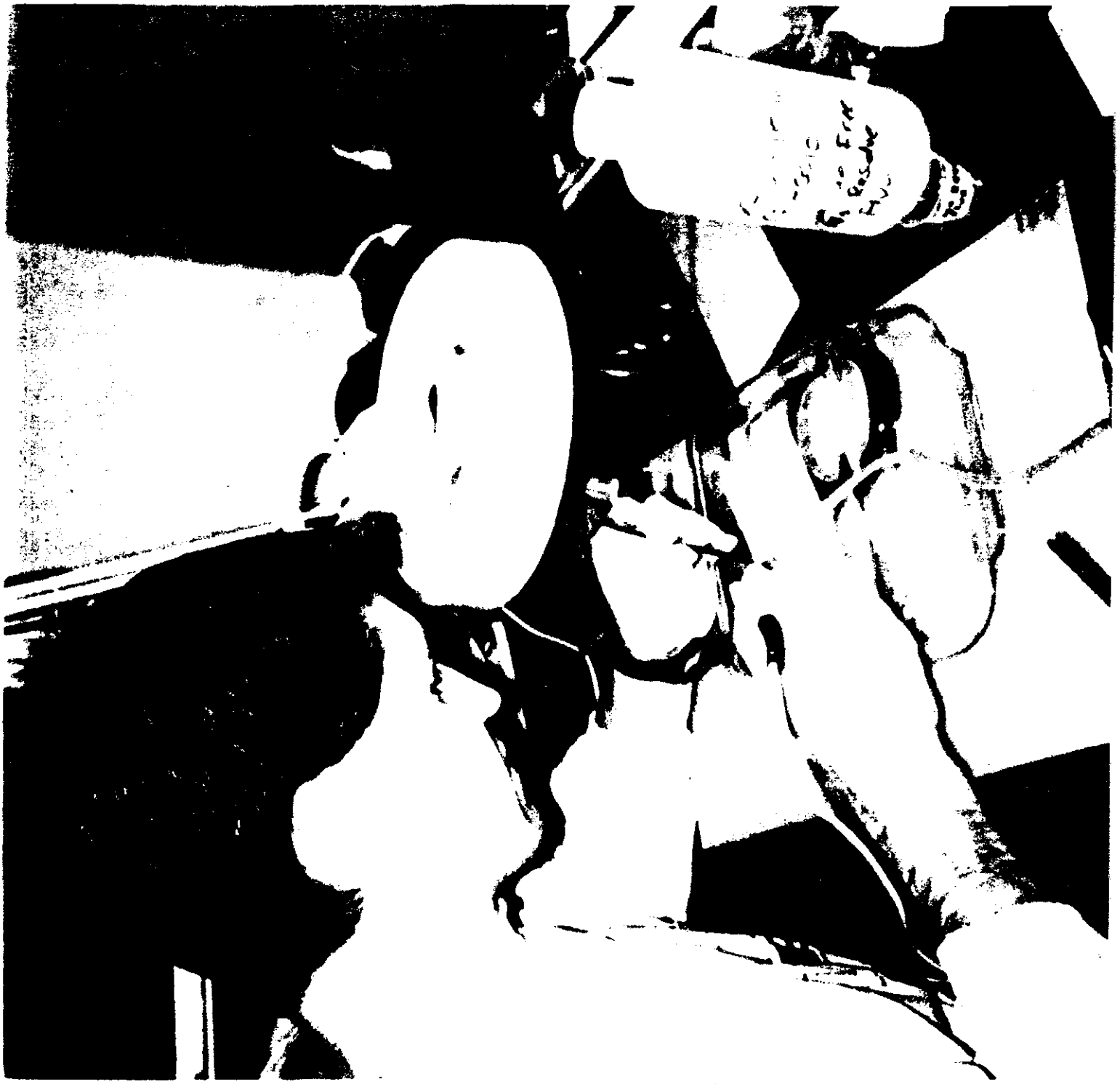
Equipotentials

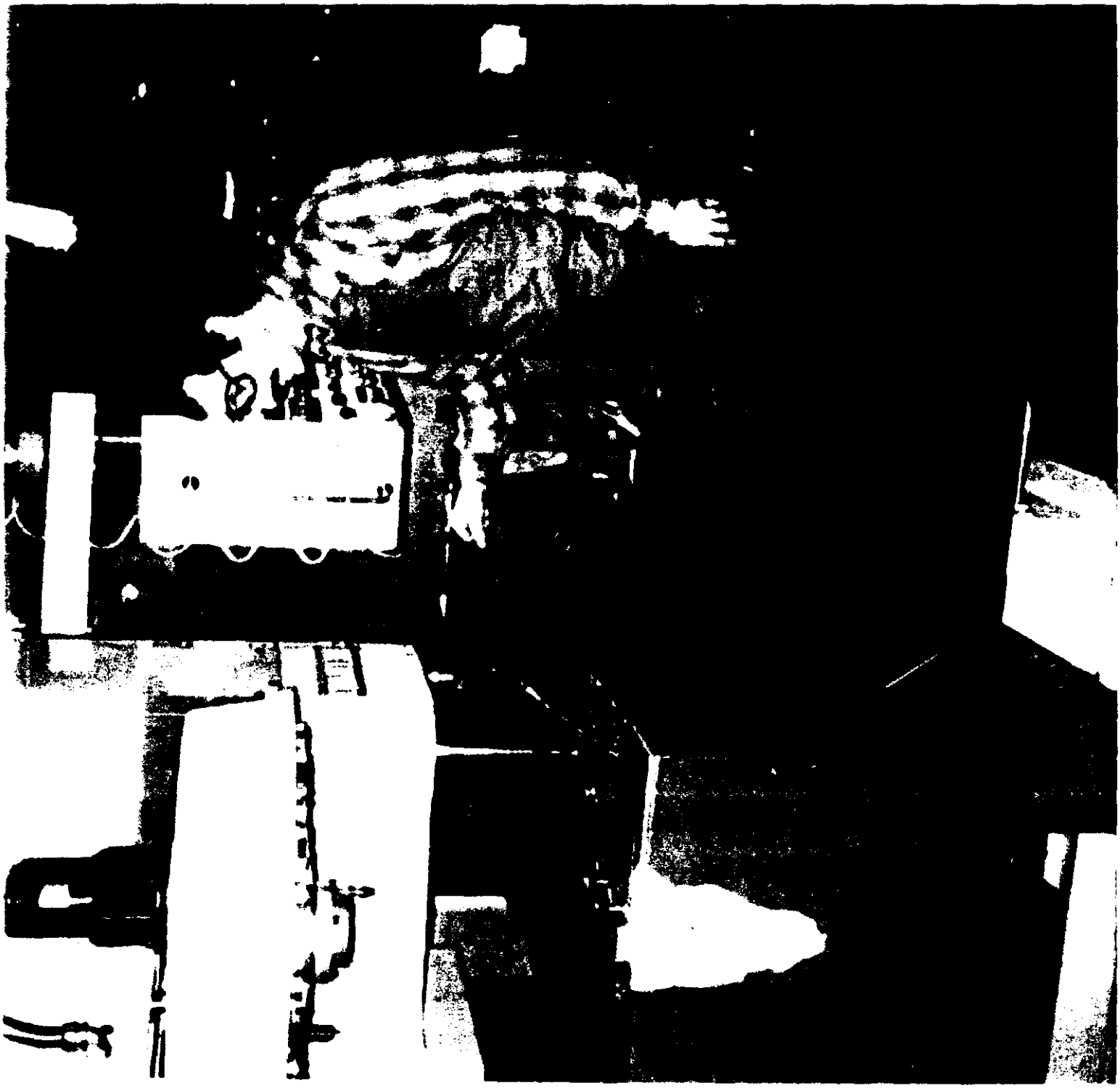
PART_OF_CELL.STRES
15/Dec/91 18:18:24 Page 86 : CONT LINES=20

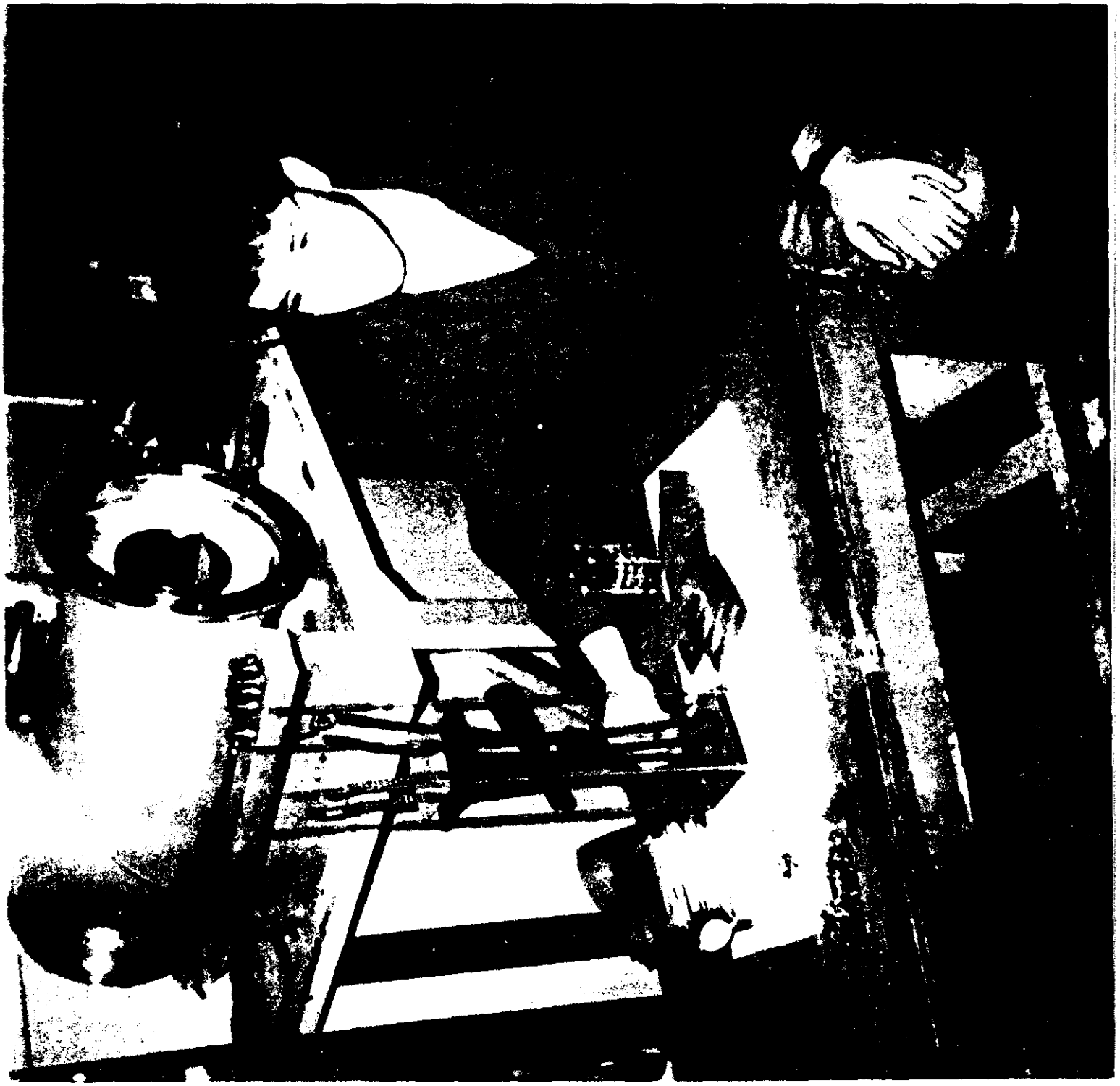


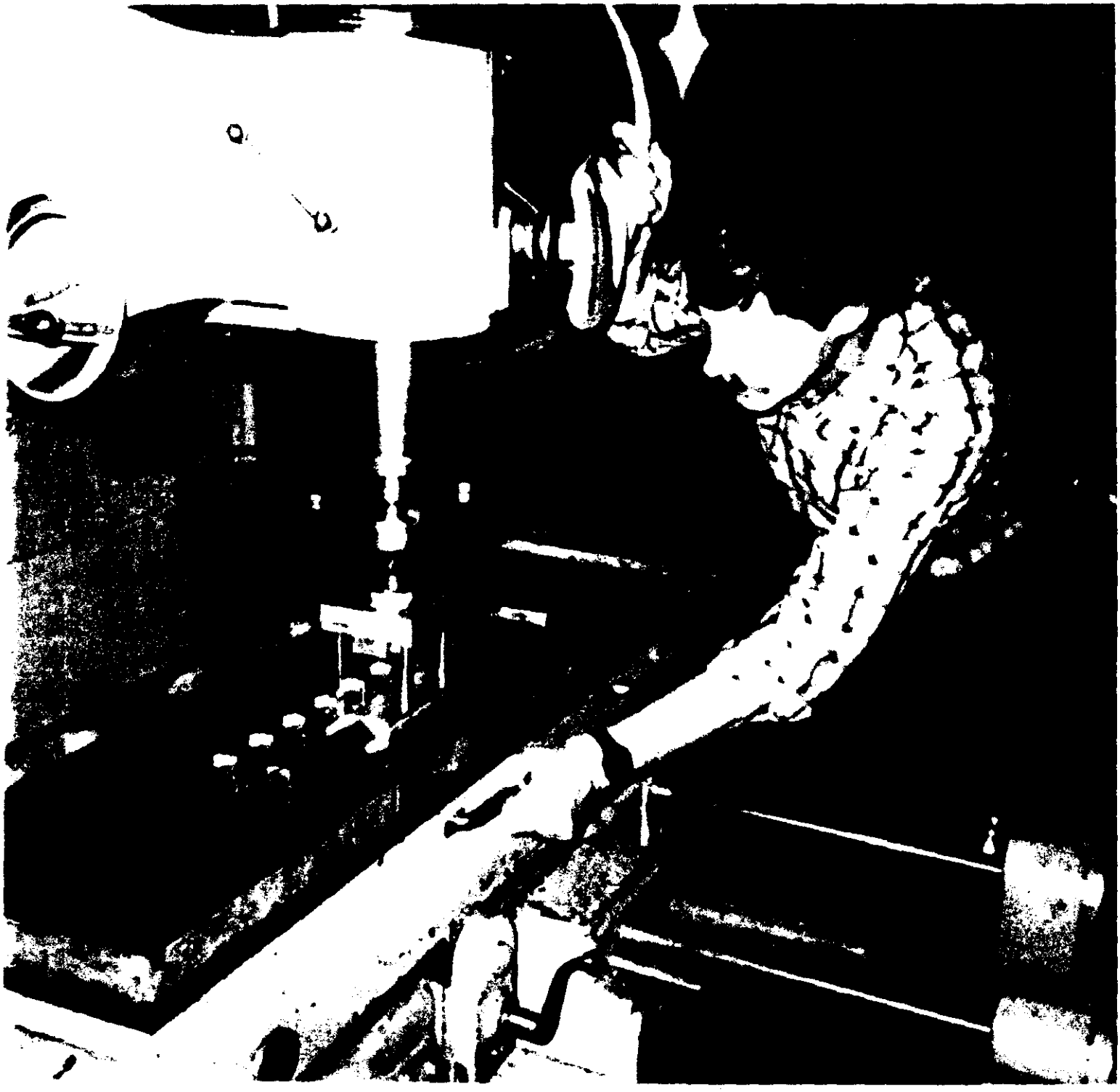
ELEM=LINE SYMM=XY SOLN=V SCALE=1.0 FIEL=ELEC
Static Solution Mesh 4000 Elements 1 Region

VF/PE2D.8

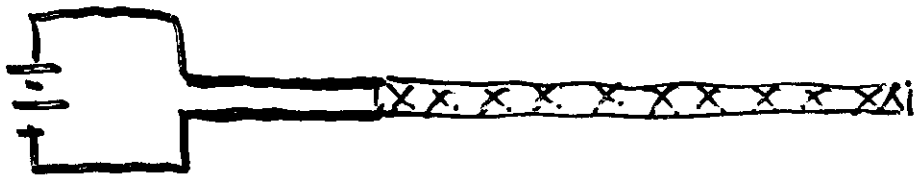








HV Tests of μSL



HV Tests to ± 3 KV

Air (Seattle) ~30 na @3KV

LN_2

Vac

LAr

Threading Test for Barrel

1 Uniformity, Resolution and Linearity of Homogeneous LKr/LXe Calorimeter

MITLNS Technical Report 182, Jan. 24, 1992

M. Chen, D. Pelly, S. Shei, S. Shotkin,
L. Cai, K. Sumorok, X.J. Yan
Laboratory for Nuclear Science, MIT, Cambridge, MA, USA

D. Akyuz, E. Chen, M.P.J. Gaudreau, **D.B. Montgomery**
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2 Fast speed and large signals

- Fast signals in LXe and LKr (+5% Xe):
  decay time is 2ns for αs and 20ns for e/γs;

- Full size, windowless, fast silicon photodiodes with quantum efficiency > 30% and matching fast amplifiers with 10 ns peaking time have been developed and tested in beams. They (as well as cables) work well immersed in liquid xenon and krypton, making 3-D shower measurements possible.

- LXe/Kr detectors have large output (10^7 photoelectrons/GeV), permitting calibration with 5.5 MeV α's.

- Homogeneous LXe detectors achieved $\delta E/E < 0.5\%$ at 1.5 GeV with heavy ion beams;

3 Radiation Hardness

All reflective and support materials of the UV mirrors, shown in Figure 1, are known to be sufficiently radiation hard:

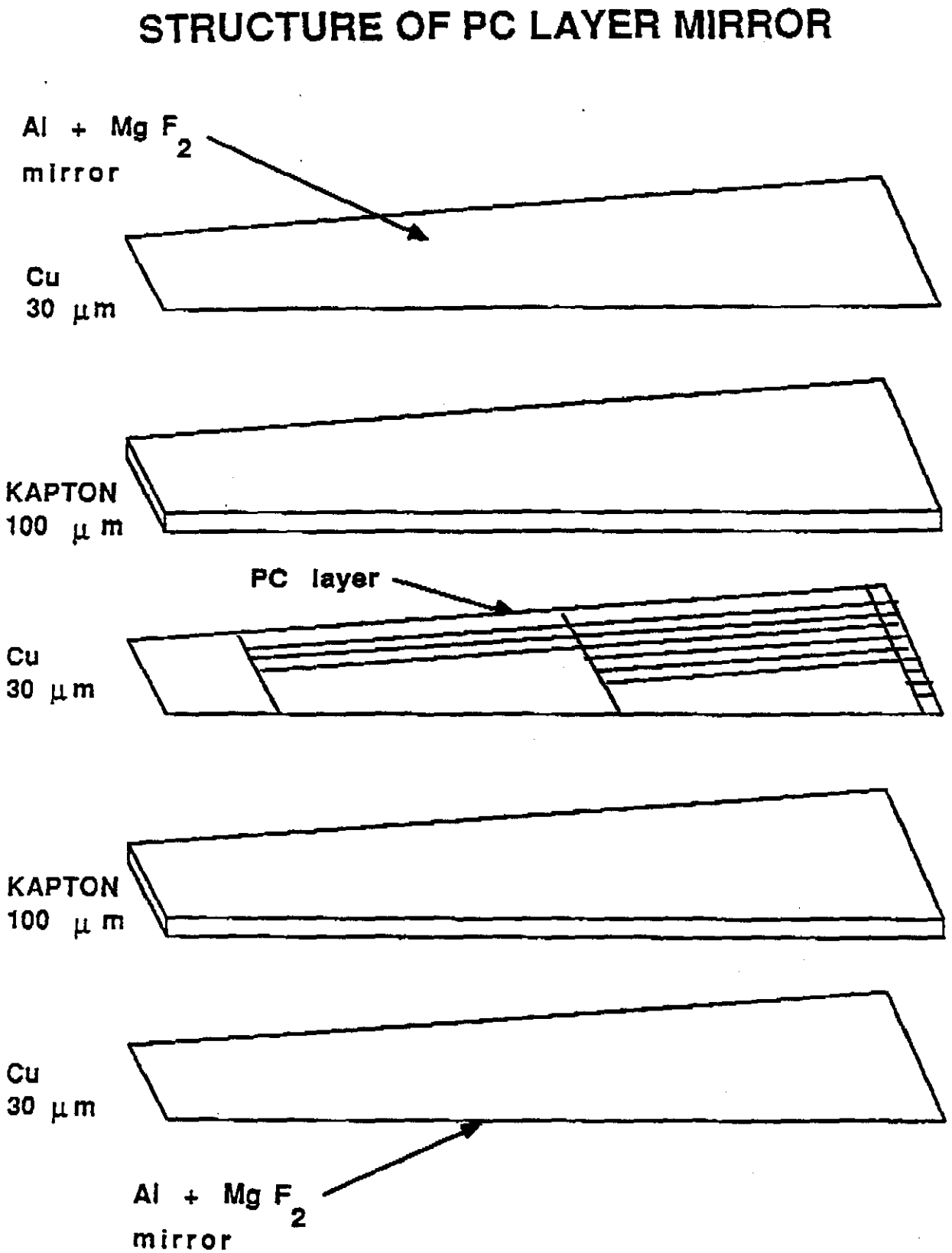


Figure 1: Schematic structure of a UV-reflector made of printed circuit boards and coated with Al and MgF_2.

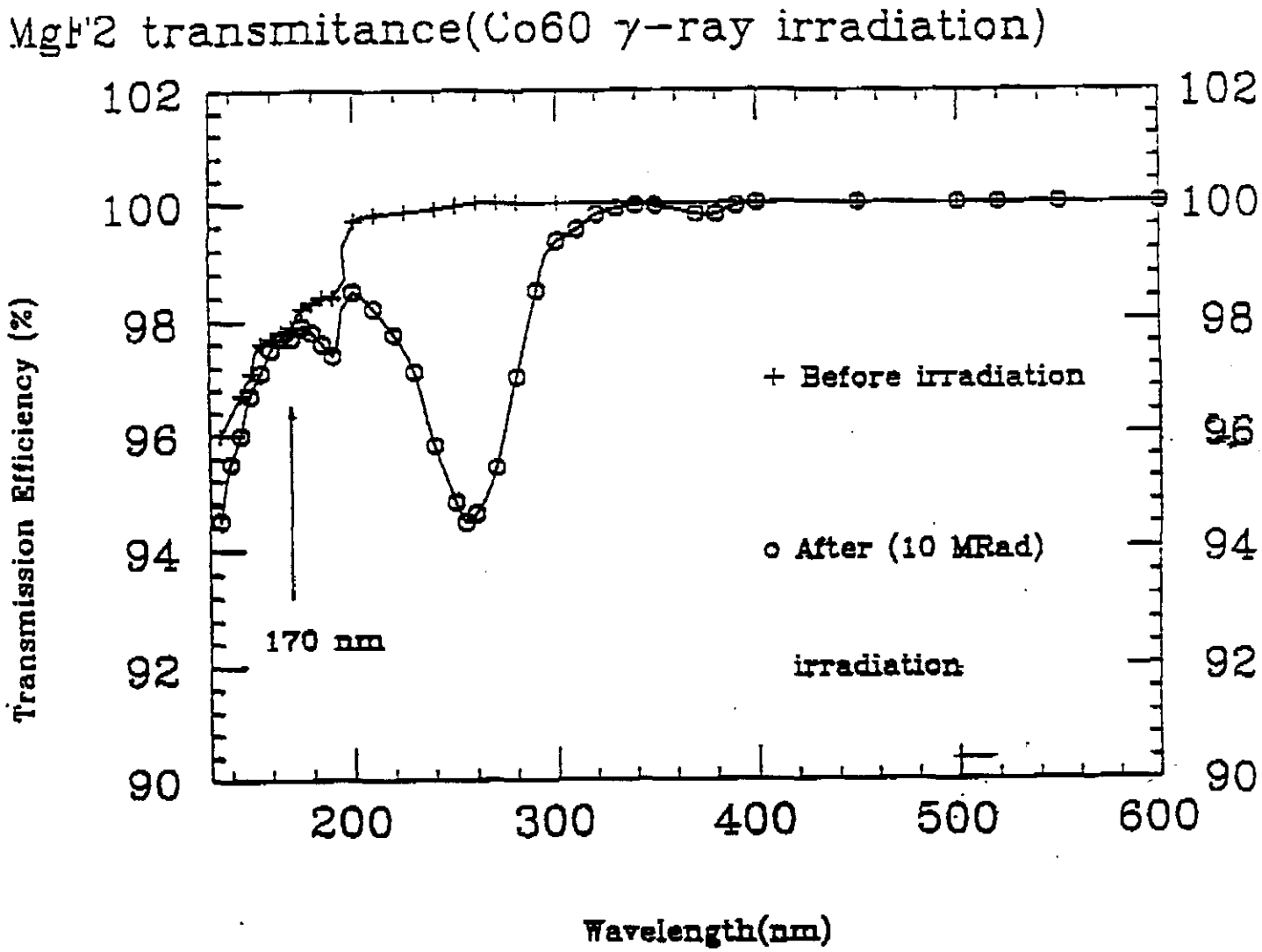


Figure 2: Measured transmission efficiency of a 1500 μ thick MgF_2 window as a function of the wavelength before and after 10 Mrad of radiation from Co^{60}, showing the radiation damage effect for 170 nm UV is negligible (<1%).

1. **Cu, Al, Au and ceramic are all hard;**
2. **MgF_2 is radiation hard up to 10^7 rad.. As seen in Figure 2,**

   the radiation damage effect in the transmission efficiency of 170 nm UV is not visible (<1%) for 1500 μ thick window. Our mirror is < 1 μ thick, so the effect of radiation damage is < 1/1500 of 1%;
3. **Kapton is hard up to $5 \times 10^{8-9}$ rad.;**
4. **Silicon diode can be calibrated and the leakage current is negligible at -100 ° C. The frame of the diode is either ceramic or kapton, both are radiation hard.**

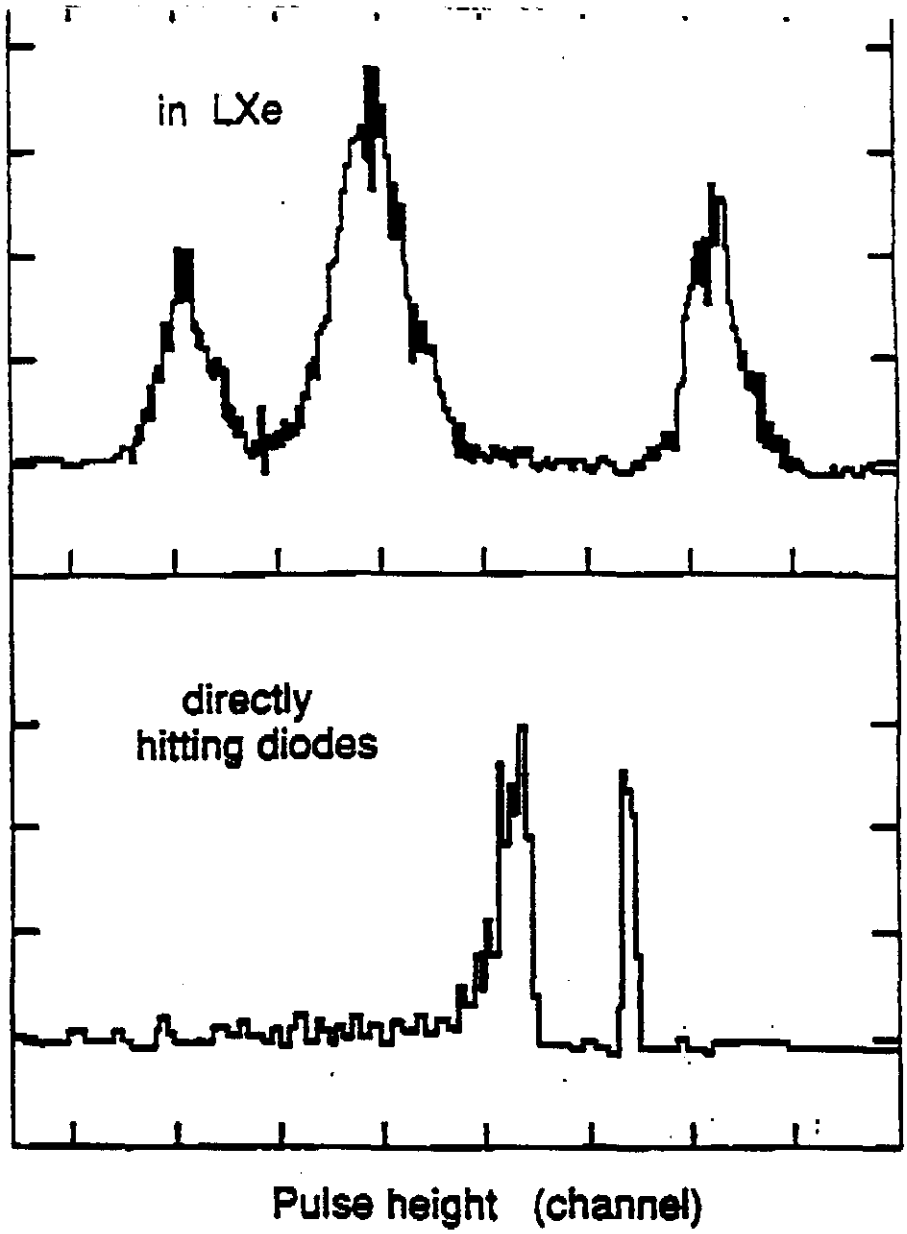


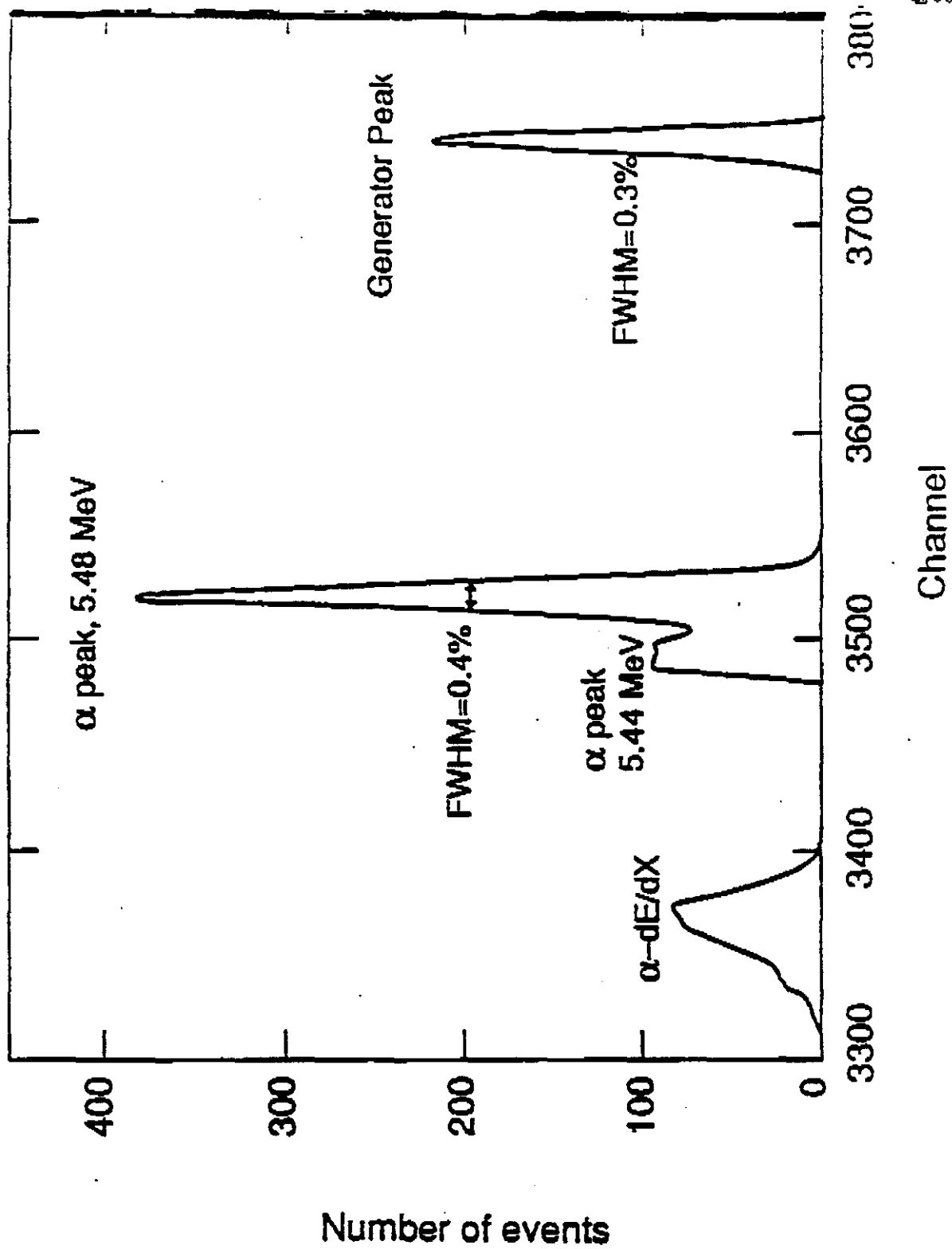
Figure 5: 5.48 MeV α's signals detected using a UV photodiode and fast amplifier: with the α particles stopped in a) liquid xenon (scintillation signal) and b) in the diode directly. The signals in a) are (from left) pedestal, signal and test pulse (to measure the number of photoelectrons in the signals) while the pedestal is suppressed in b).

5 Calibration

One can use α, cosmic μ and MIP for calibration, after the detectors have been calibrated in beams.

Using two α sources: one calibrates the complete detector system using LXe scintillation light, and one calibrates the electronics system using the direct hits of α's. (Figure 5 and Figure 6),

As seen in Figure 6, a resolution of 0.2% per α has been routinely achieved and the signals are stable to 10^{-3} over weeks. This demonstrates how the LXe detectors can be calibrated in situ.



Calibration using 5.44 MeV α's directly hitting a UV photodiode: The signals are (from left) α passing through the metal grids, signal and test pulse (to measure the number of photoelectrons in the signals). A resolution of 0.2% per α has been achieved and is stable over weeks.

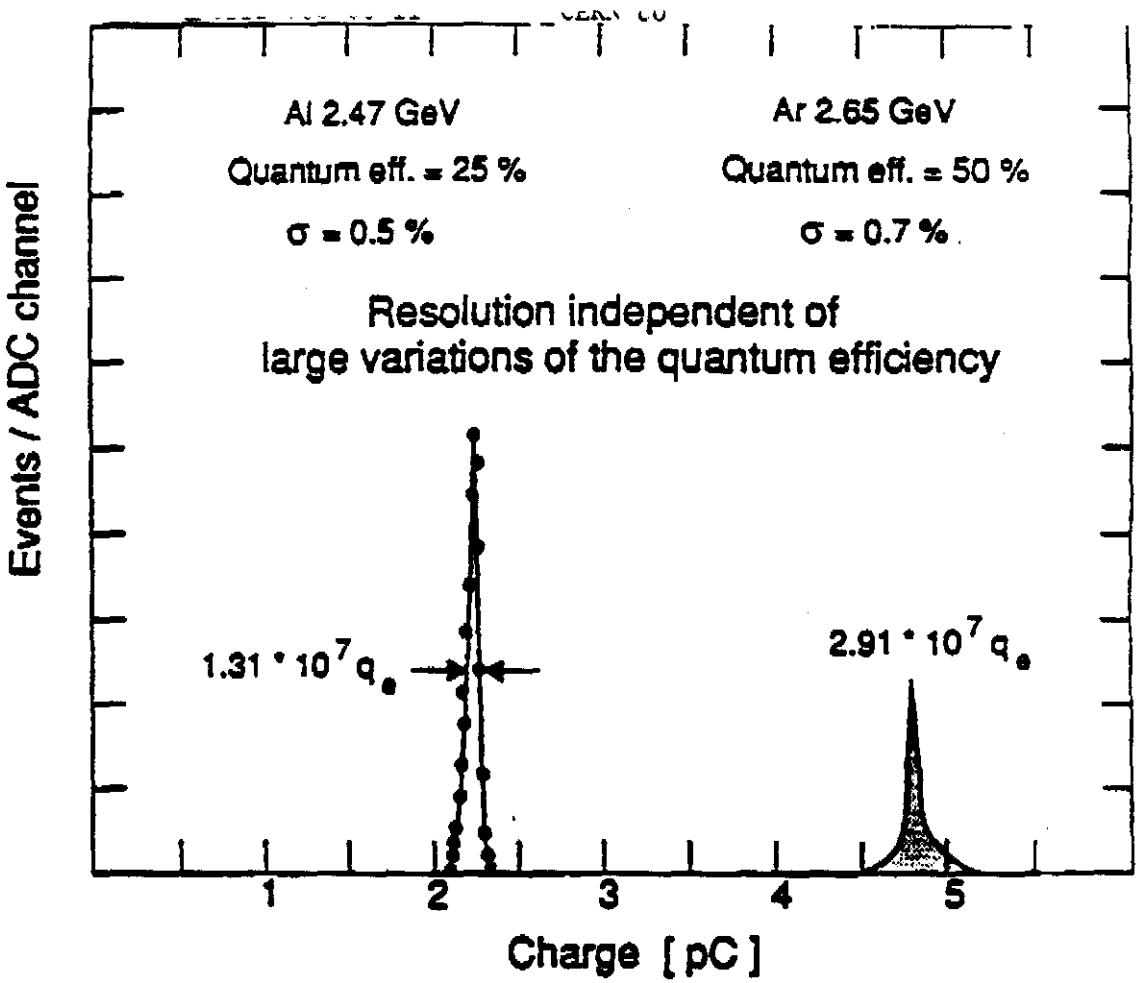


Figure 7: Measured numbers of photoelectrons for 2.65 GeV Ar ions (solid); and 2.47 GeV Al ions with 50% reduced quantum efficiency (points), showing that the resolutions are not limited by photoelectron statistics.

6 Energy Resolution measured with Heavy Ion Beams Calibrated with α's

The observed energy resolution was 0.6% rms for 1.64 GeV ^{14}N, and 0.7% for 2.65 GeV ^{40}Ar. The charge observed is 2.91×10^7 for 2.65 GeV ^{40}Ar.

we baked the same diode used for the above measurements until the quantum efficiency of the diode, calibrated using α's. dropped to 50% of its previous value. We repeated the measurement using 2.47 GeV ^{27}Al ions 2 months after the previous Ar ion tests. Indeed the charge observed is reduced to 1.36×10^7 electrons (Figure 7), exactly corresponding to the decrease in quantum efficiency. The measured energy resolution without corrections improves slightly to 0.5% with 40 ns gate, due to better beam collimation. These results demonstrate that:

- the calibration method with α's does work;
- the measured energy resolution is mainly due to beam energy spread, not electronics or intrinsic photon statistics: the actual intrinsic energy resolution of LXe detectors may be much better than what are quoted above.

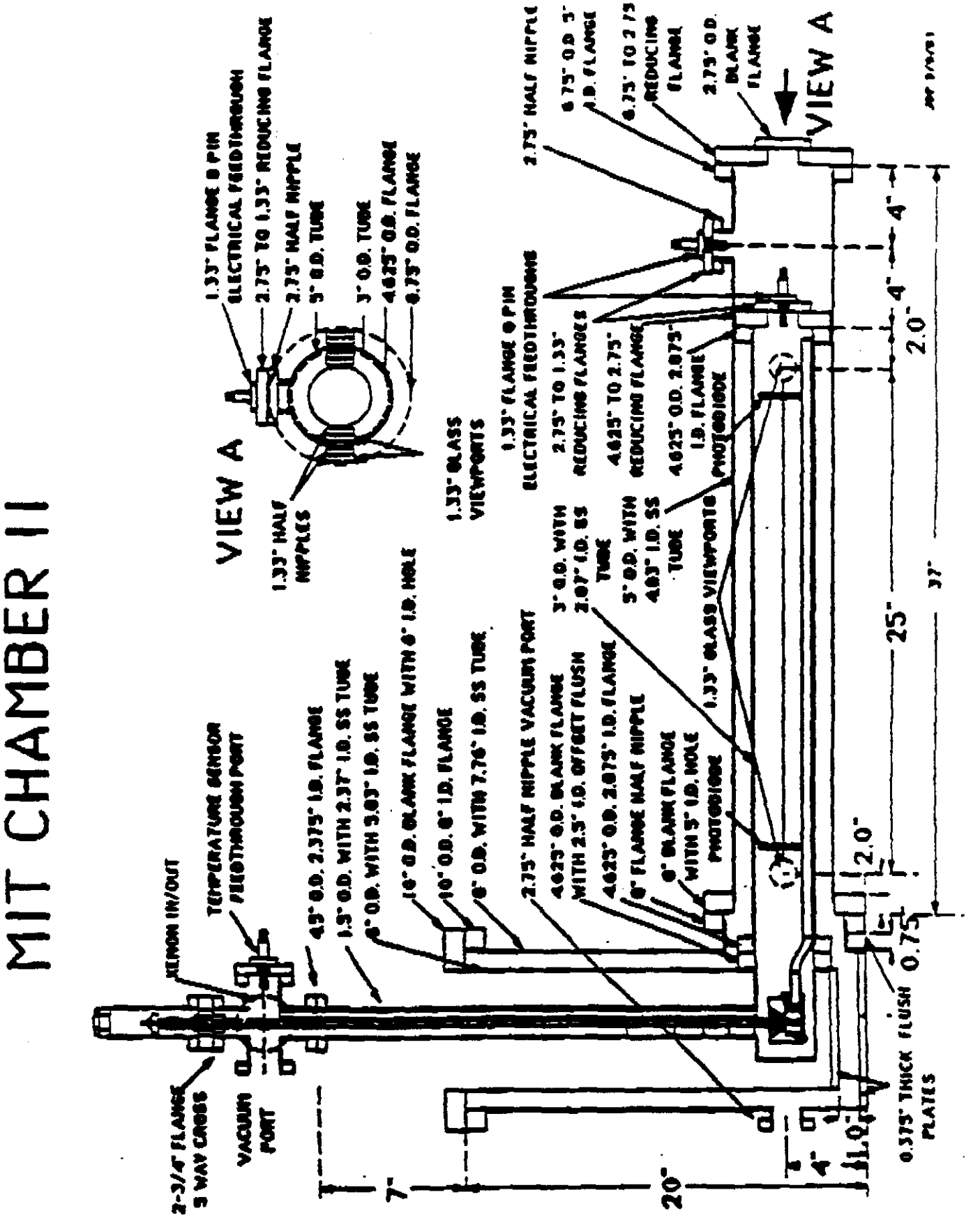


Figure 8: Schematic of a second full length liquid xenon/krypton cell for uniformity tests with improved temperature control.(MIT-2)

8 1x1 scintillating LXe cell: MIT-2

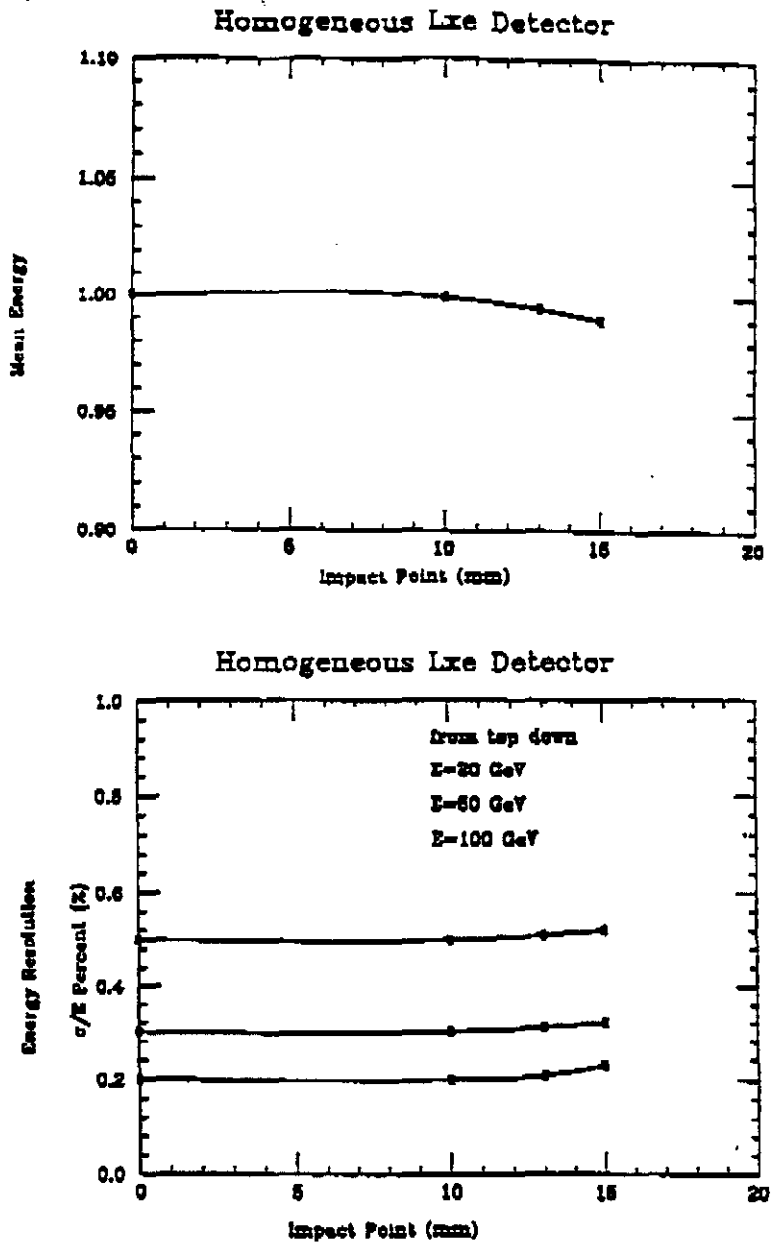


Figure 9: a. Mean energy ; b. energy resolution as function of the impact point of incident particles away from the center of a 3 cm wide front window in 65 cm long LXe cell, as simulated by GEANT.

10 Transverse Uniformity

Transverse non-uniformity due to particles entering at different points across the small end of the cell is very small because:

1. **Liquids are homogeneous due to diffusion.**
2. **Diodes are uniformly covered due to the very large numbers of photons emitted and reflection involved.**
3. **T Little dead material:**

   UV-reflector is 290 nm thin, to be compared with the 900 μ intercell cracks of the L3 BGO.

The nonuniformity is less than 1% at the very edge of the cell, which can be corrected, for isolated particles with known impact points, to retain the energy resolution (<< 0.5%).

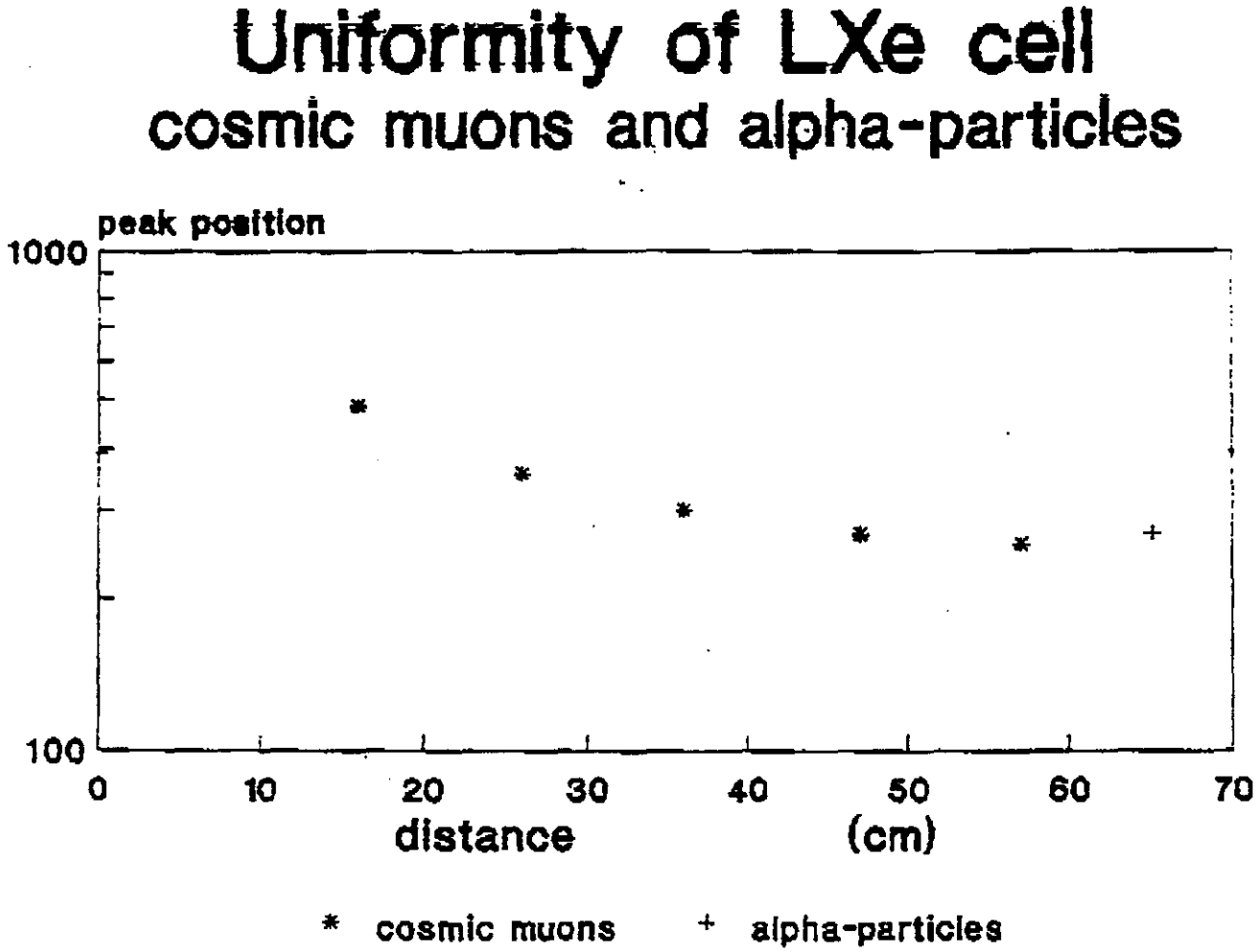
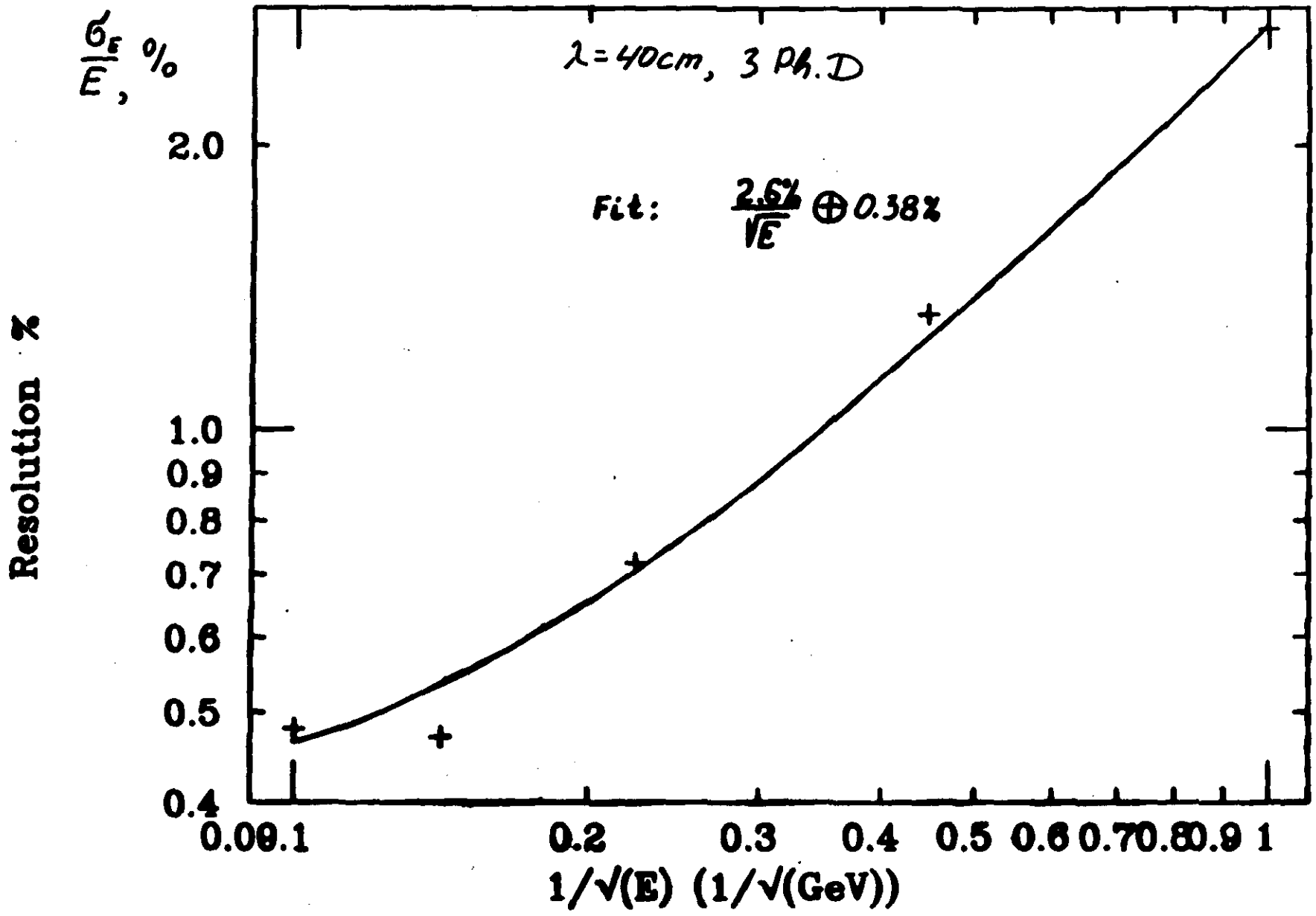


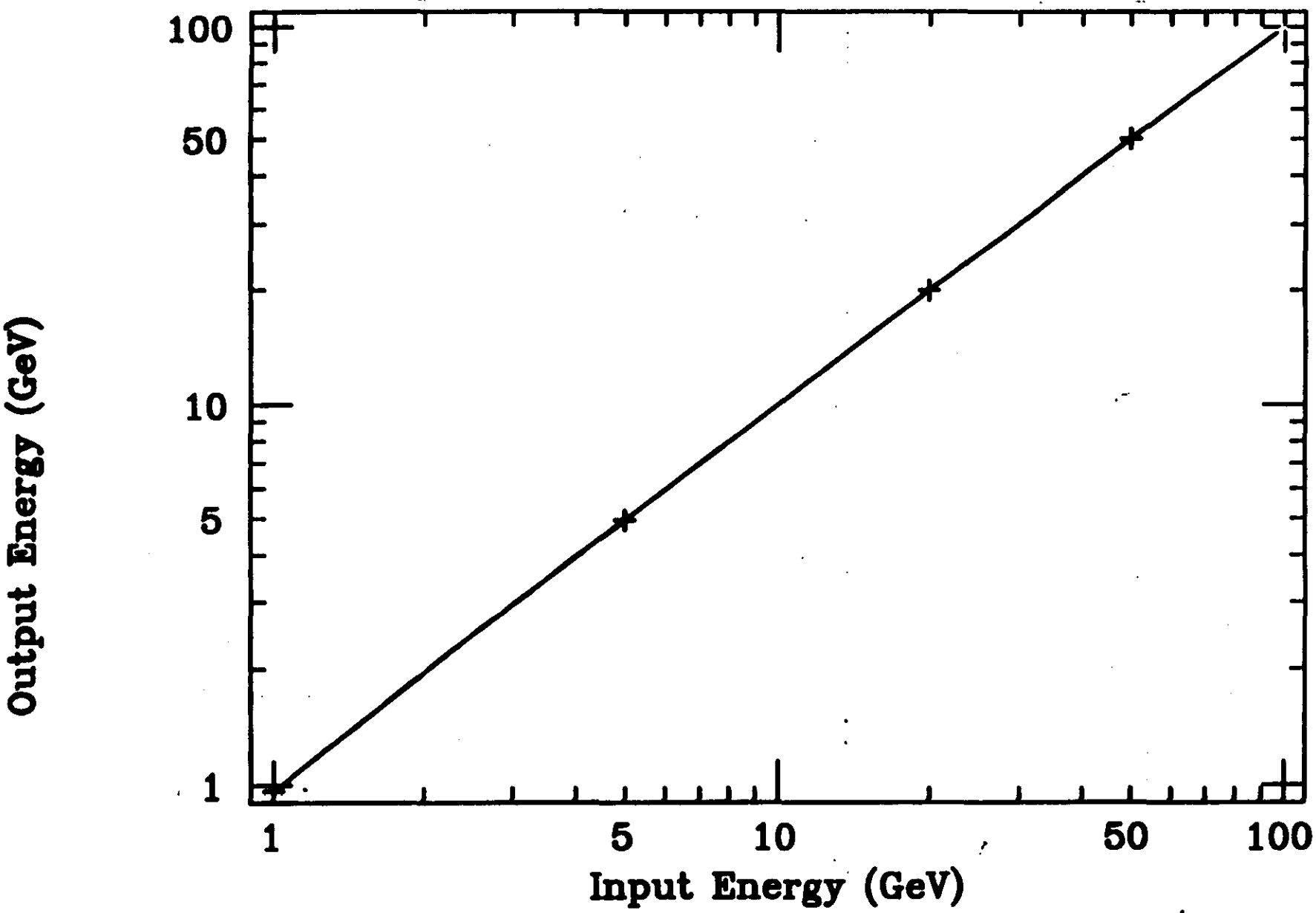
Figure 10: The measured light collection acceptance, using cosmic μs and αs, versus the distance to the photo-detector, in a 65cm long LXe cell MIT-II. The last data point is due to an α source situated on the end mirror, which serves as a calibration point for each cell.

11 Measured Longitudinal Uniformity

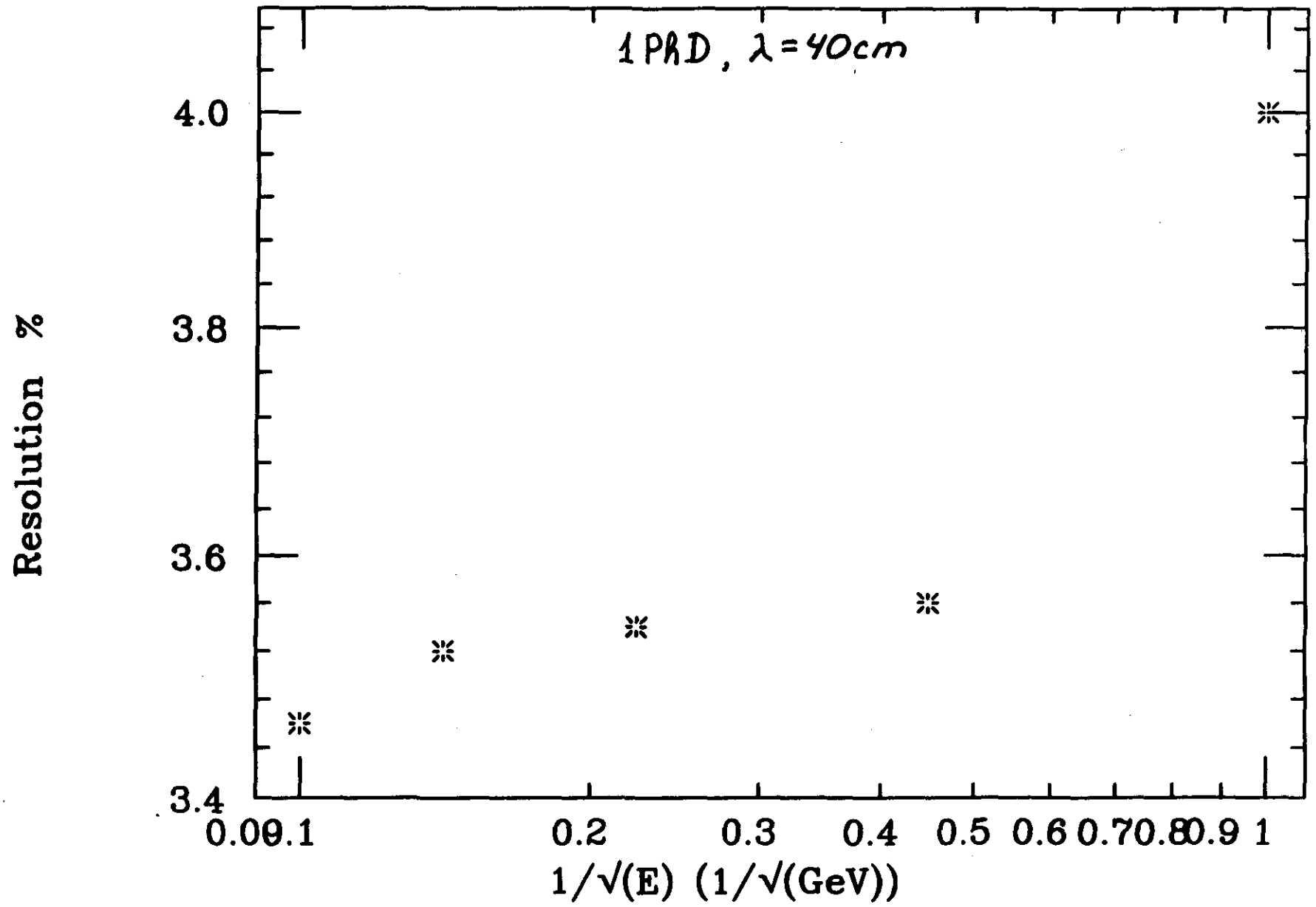
Mirror: (2.4x2.4 + 4.4x4.4) x 65 cm^3.
Without using getters.
The α signal at the far end provides stable calibration in-situ for each cell.

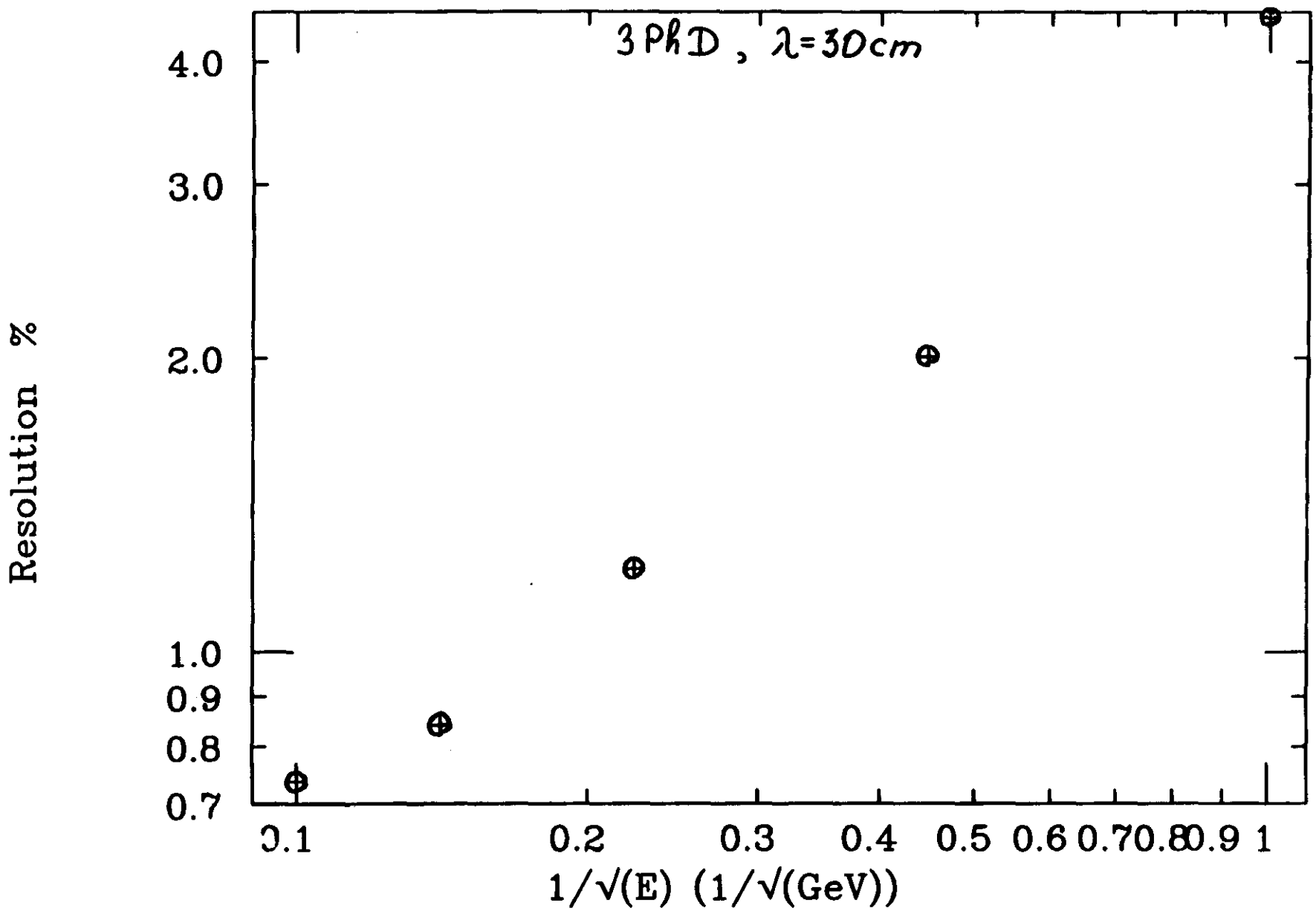

$\frac{\sigma_E}{E}$, %
λ=40cm, 3 Ph.D
Fit: $\frac{2.6\%}{\sqrt{E}} \oplus 0.38\%$
Resolution %
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.0 0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1/√(E) (1/√(GeV))

Input Energy versus output energy Jan.13, 1992



max. deviation ≤ 100MeV


1 PhD, λ=40cm
Resolution %
4.0
3.8
3.6
3.4
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1/√(E) (1/√(GeV))


3PhD , λ=30cm
Resolution %
4.0
3.0
2.0
1.0
0.9
0.8
0.7
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1/√(E) (1/√(GeV))

14 Cell to Cell variation

Cell to Cell variation:

1. cells share the same liquid,

2. the quantum efficiency of each diode is calibrated by α on the diode,

3. the reflectivity is calibrated by α at the far end,

4. the overall effect can be calibrated by beams at one energy,

5. the linearity of the detector ensure calibration at all energies.

16 Checks performed

To check the simulation results, we use some conservative fitted parameters that the effective attenuation length, $\Lambda > 40$ cm and the effective reflectivity of the mirror, $R > 80\%$ (Λ and R are correlated, but our results are sensitive to the product not the individual parameter):

The input light collection efficiencies at a distance d cm away from the photo-device approximately are the follows:

$0.4 * (e^{-d/40cm} + 0.8 * e^{-(8-d)/40cm})$

for the first section,

$0.3 * (e^{-d/40cm} + 0.8 * e^{-(30-d)/40cm})$

for the second and third sections.

We apply such analytic light uniformity curves to the energy distributions of electron showers generated by Geant, and reproduce the results of the original Monte Carlo.

We also fitted the combined cosmic and alpha data (fig.21) using the sum of two exponents

$e^{-d/L} + 0.8 * e^{-(65-d)/L}$

obtained the result for L=46.5±3 cm.

so using L=40 cm is conservative and 30 cm is abs. worst case.

19 Future improvement

Starting Jan. 24, 92,

1. At MIT:

purify with Oxysorb + Molecular Sieves and + Ti-getter.

2. At ITEP:

purify with MOYDODYR:

Using high voltage Ti electrides emmersed in LKr(LXe),
to produce sputtering of Ti
during high voltage dischages,
and absorb impurities.
Earlier, we used MDD
to increase elctron drift length
from 1 cm to more than 100 cm in LKr.

22 Petitions

LXe detectors are:

precise,
homogeneous,
radiation hard;
have natural longitudinal segmentation;
and can be calibrated in situ.
With our major breakthrough in uniformity

we would like to request for a review
of using LXe detectors
for GEM precision EM calorimetes.

Recently, PAC stated that:

"It is, however, concerned about the problems of radiation damage and the lack of longitudinal segmentation of the BaF2 calorimeter, as well as the potential inhomogeneity of response and the difficulty of longitudinal segmentation in the lead/scintillating fiber calorimeter. Also, the effect on the constant term of the hadronic energy resolution, when employing very different compositions for the electromagnetic and hadronic parts, needs to be quantified.

Furthermore, the PAC recognizes that in the accordion design of the liquid argon/krypton calorimeter, a $7\%/\sqrt{E}$ performance has not yet been demonstrated (even for a moderate size prototype) and that a substantial engineering R&D effort will be needed."

Fiber Hadron Calorimeter

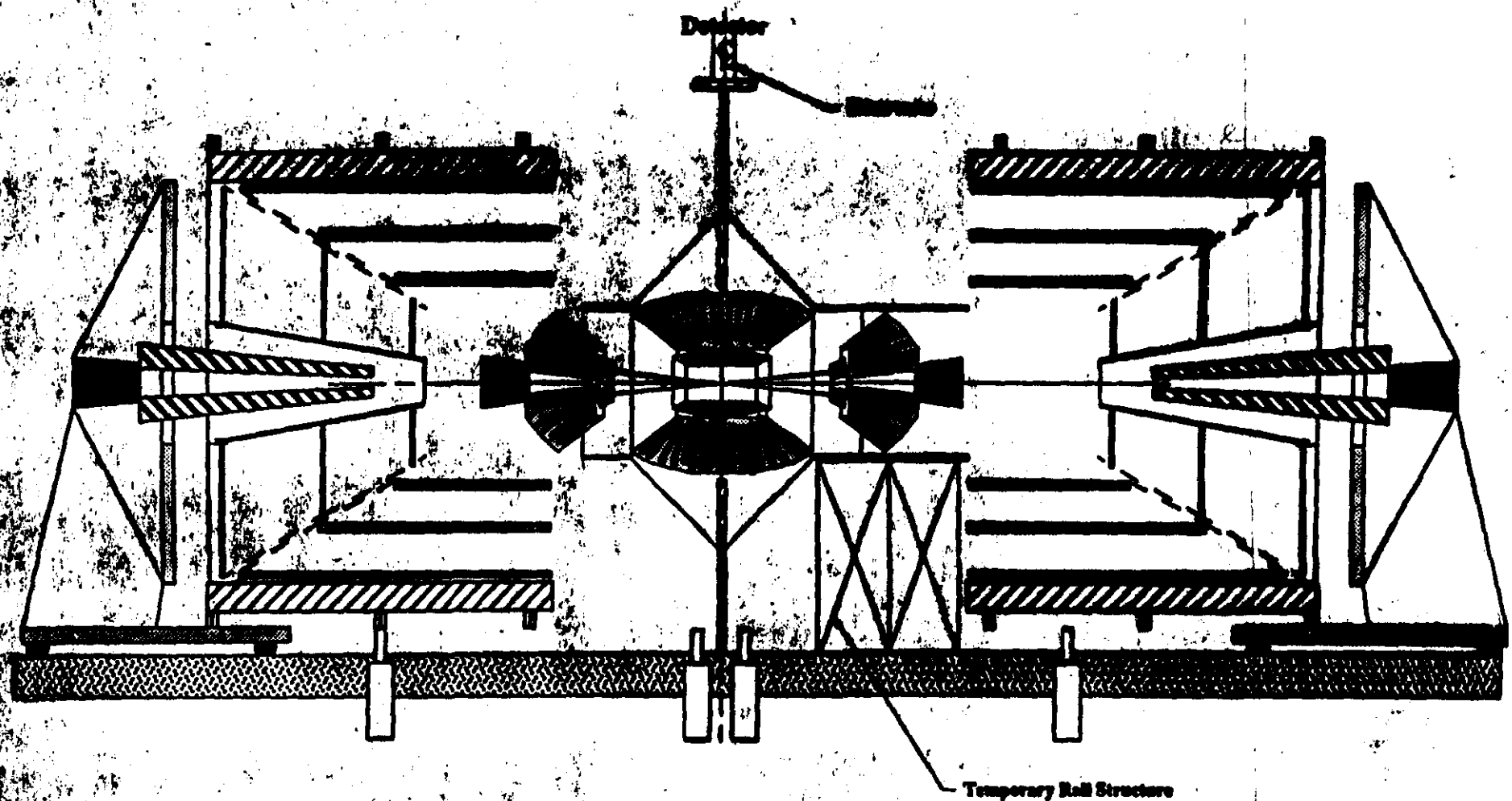
Recent Progress & Test Beam Program

for the SSC inHCAL Collaboration

L. Sulak
GEM Calorimetry

1/24/92

new fiber calorimeter base line design

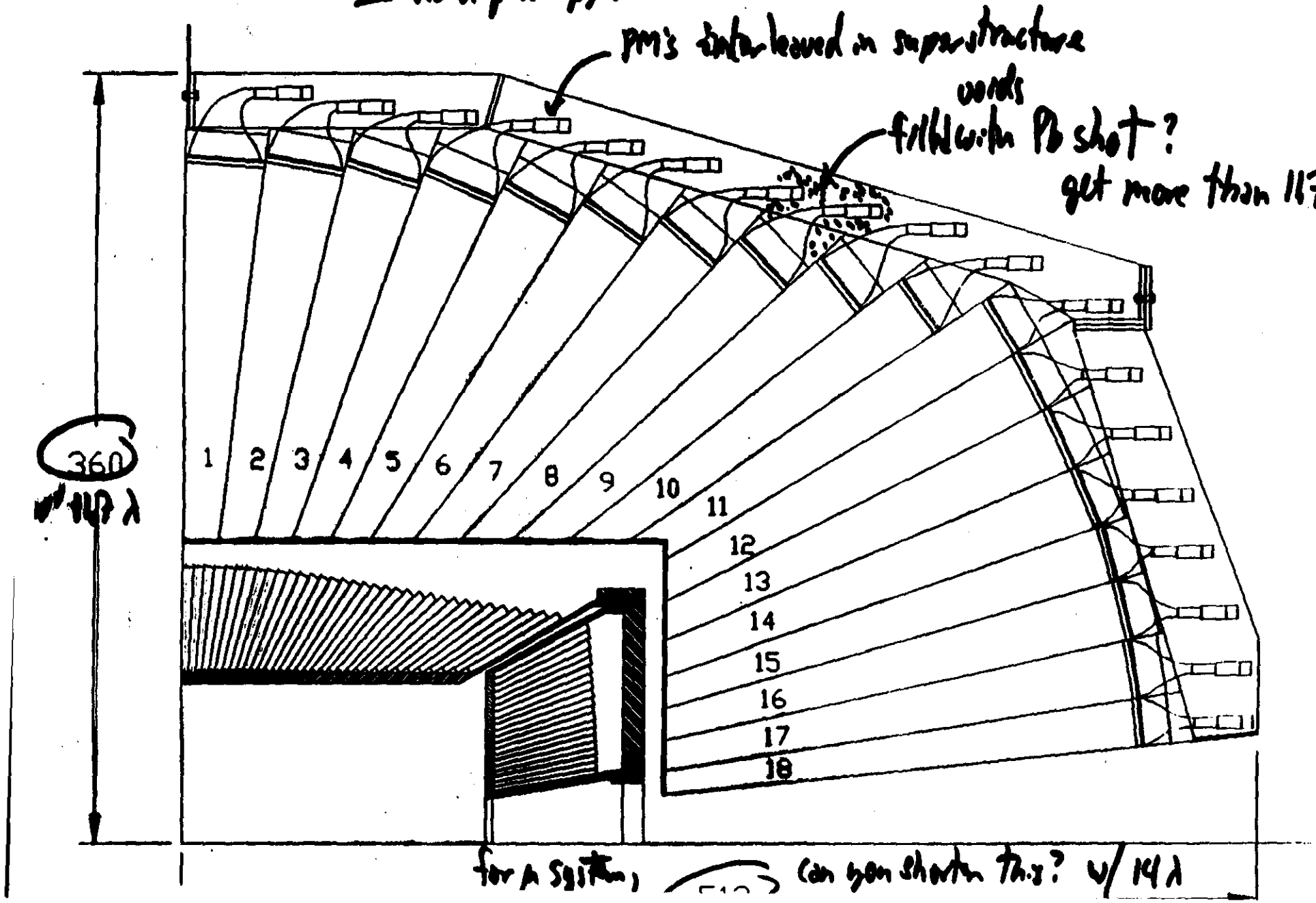


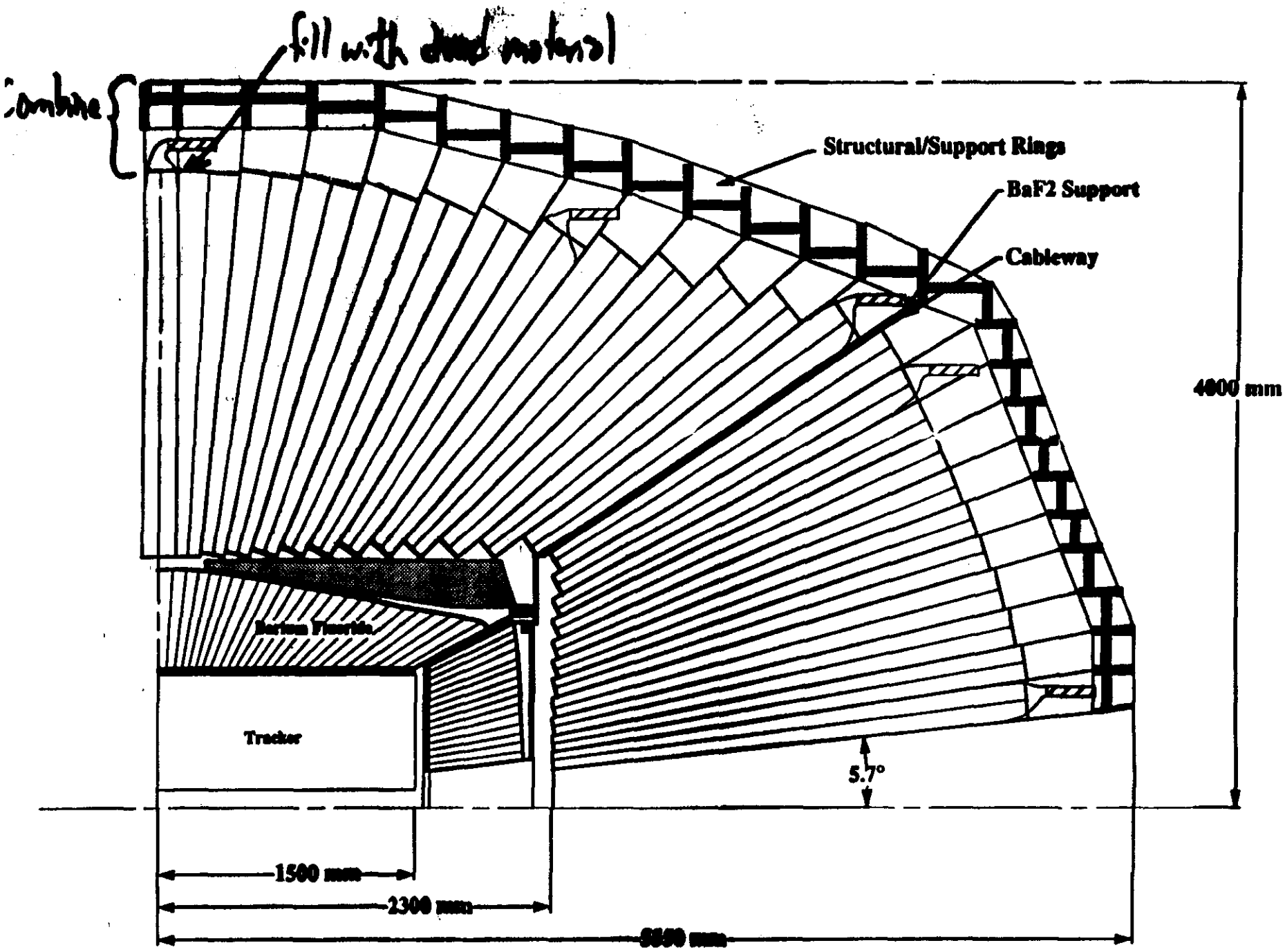
GEM Configuration Option Study
Scintillating Calorimeter
Integral Calorimeter Version

Engineering Design Progress

10 cm = $6.5m in μ & magnet cost

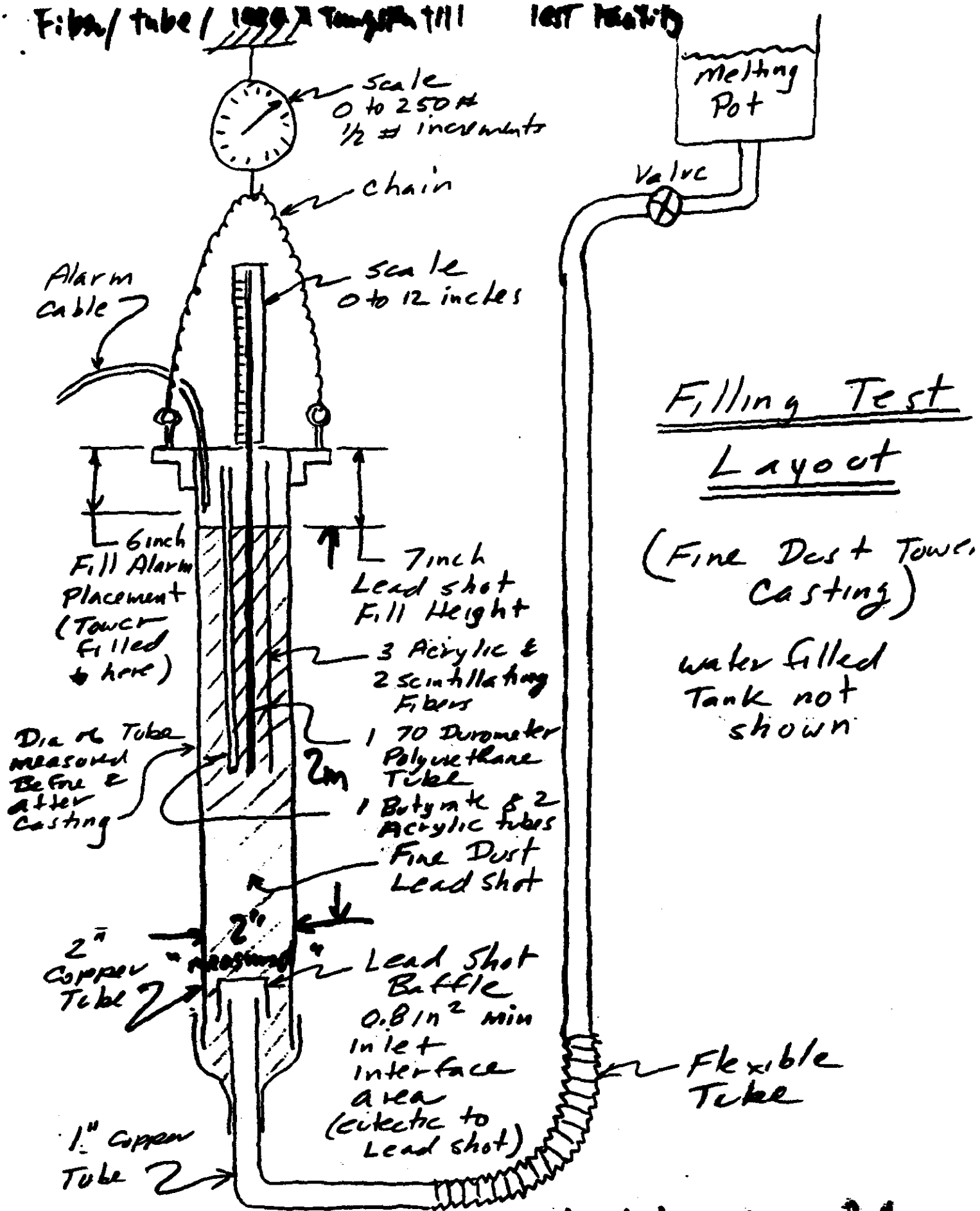
constructed as a wedge on a flat table
... not as a pineapple slice





Spaghetti Hadron Calorimeter
Eutectic Fill/0.10 or 0.05 Segmentation

Fiber/tube/ [illegible] Tungsten till Test Facility



Filling Test Layout

(Fine Dust Tower Casting)

water filled Tank not shown

... show cylinder of eutectic + 0.5mm shot with [illegible] fiber and 3mm tube [illegible]

Tube vs Fiber

Engineers : Unanimous for tubes

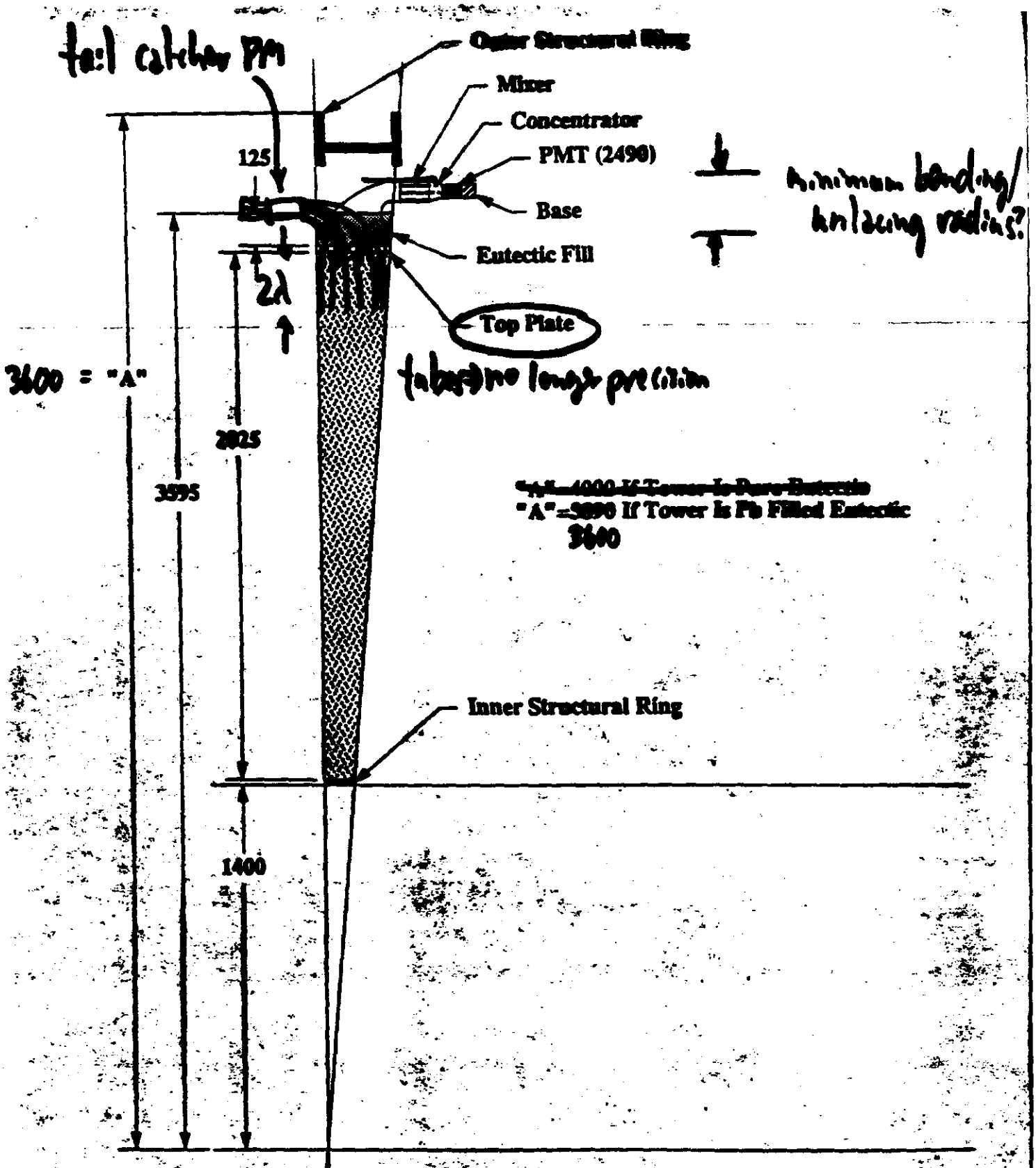
1) Eliminate crucial interface {from massive tower to precision optics}
   .. no splice plate
2) Separate optical/fiber package from casting industry
   .. minimize handling of fibers in "dirty" environment
3) Buffer fibers .. mechanically from growth of eutectic
   chemically " eutectic
   radiation .. can be replaced
4) Less expensive construction; cheaper since 1/10 the expensive fiber
5) Longitudinal sampling has enormous freedom

Physics Compromised?

Wigmans [illegible] } independently
Pauc [illegible] @ [illegible]

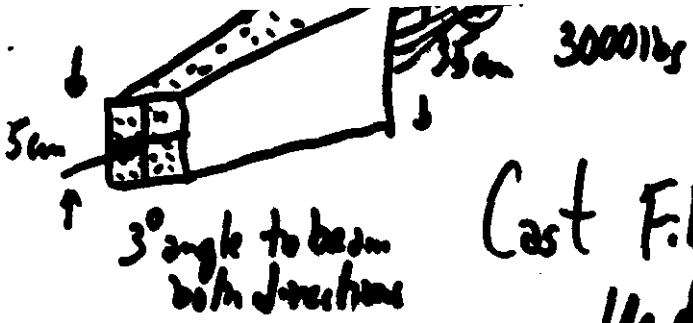
1) scaling from SPACAL, other detectors
   $e/h \sim 1.05$ to 1.07 ± 0.04
2) sufficient p.e. if 1.5 mm fiber

.. need test beam results!



Spaghetti Tower Height

G.03.SC.00063



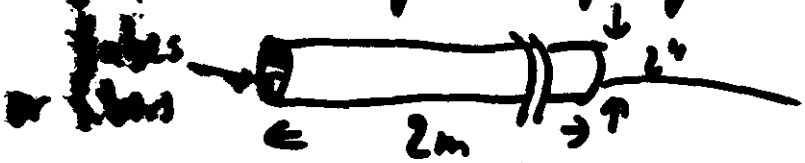
Cast Fiber Diagnostics

Under way

1) Analysis of FNAL test module #2 - 26 hr of test beam (out of 2 weeks of work there)
   e & π, 30-50-100 GeV, on tape, being analysed
   front face scan, 10x10 cm + up slope
   crude air coupling from scintillating fibers to 4 PM's
   preliminary: 10 pe's/GeV, due to fiber & coupling
   ← RH1, DS, 3HF

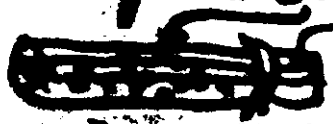
2) Meltdown of 1st module to evaluate fiber strain, position

3) Fiber Casting - Integrity after heating, stressing { mechanical / chemical



test with ring ^{60}Co source @ VSD

4) Fiber Casting with lead shot, including tubes



percolation ok through 0.5mm shot
can thread through butyl tube after pressure head
now testing lead dust percolation ⇒ better to use [illegible]

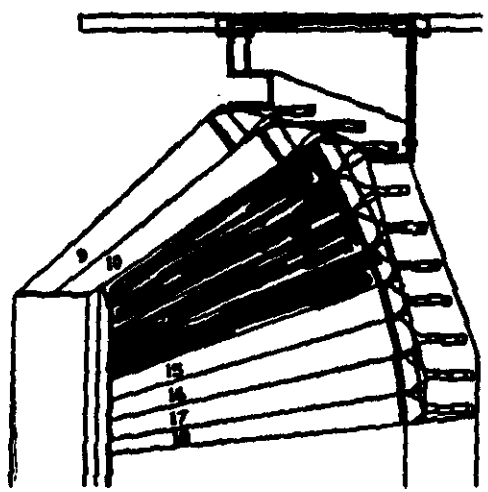
5) Casting a tower with lead shot & tubes

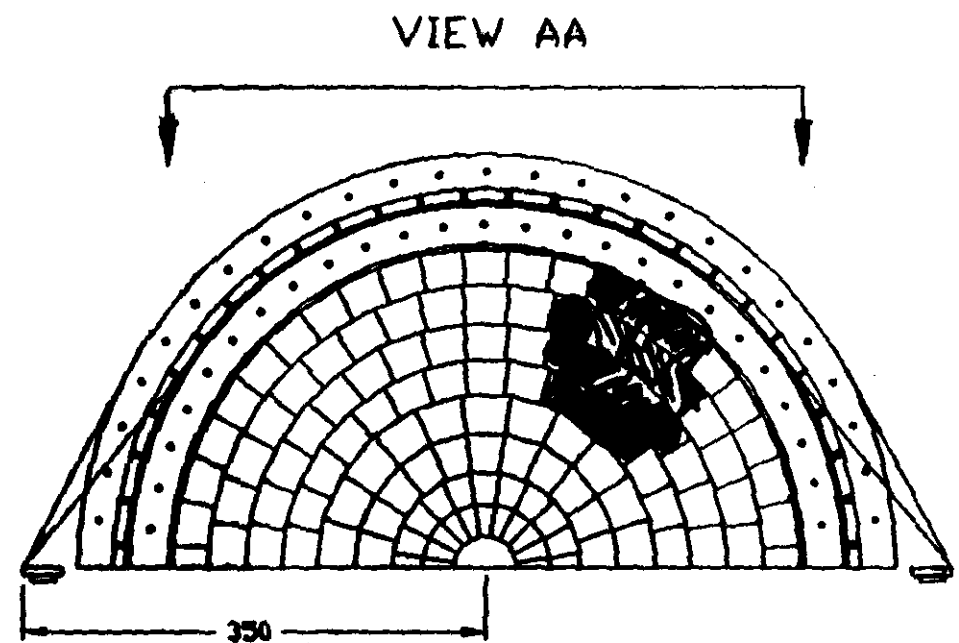
7 module prototype ... approximates a segment of endcap

a.) Stacked overlapping

b.) ~ straight "light pipes"

14 for ≳ July CERN Test





... with longitudinal segmentation

... on FNAL table at BNL behind Light em Prototype

1 of 4 pages ... ready to go into production

PRELIMINARY SPECIFICATIONS
PROTOTYPE SPACAL TOWER FOR GEM (11.3%)

Casting Size

- Length after clean-up of both ends: 2m (78.74in)
- Size of small end:
  - a. After casting: 149mm (5.866in) square mold size
  - b. After clean-up removal of 40.83mm (1.601in) from small end: 153.1mm (6.027in) square
- Size of big end:
  - a. After casting: as required to adequately cover the top plate
  - b. After clean-up removal of 3.18mm (1/8 inch) from the top plate: 350.56mm (13.8in) square
- Casting taper angle: 5.73° included

Functional Make-up of Casting

- Scintillating fiber size: 3mm
- Volume % scintillating fiber: 11.3%
- Fiber configuration:
  - a. Place on 7.9mm (.311in) center
  - b. 1849 Fibers through top plate (43 x 43 array)
    361 fibers through bottom plate (19 x 19 array)
- Volume ratio of lead to eutectic: 60% fine dust lead to 40% 158 eutectic
- Densities:

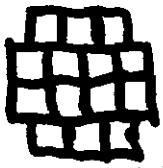
  Lead (fine dust): 6.9gm/cc (430 #/ft^3)
  158 Eutectic: 9.4 gm/cc (.339 #/in^3)

Status of SSC int CAL Beam tests Program

Goal: Fully-tested, hadron containing, fast prototype

Deadline: August decision - Scintillator vs liquid argon

Minimum Project:

ne	prototype	beam	possible em detector in front	e/h (E) goals
15-'30	7 modules / 10T longitudinally segmented	A3* @ BNL e/π to 20GeV with 0.1% $\frac{\Delta p}{p}$	Liq Ar / BaF_2	"Effective Compensation" (pe yield/resolution) is no meaningful at low energy: π° fluctuation (E)
	(~5% loss ∴ insufficient for CERN "forward" cal geometry)			
1/2	14 modules / 20T - outer 7 segmented	X5 @ CERN π's of 110GeV with 0.8%	BaF_2	constant term Effective compensation longitudinal freq of H.E. showers
				

(fall back: put BaF_2 in front of SPACAL?)

Other Priority:

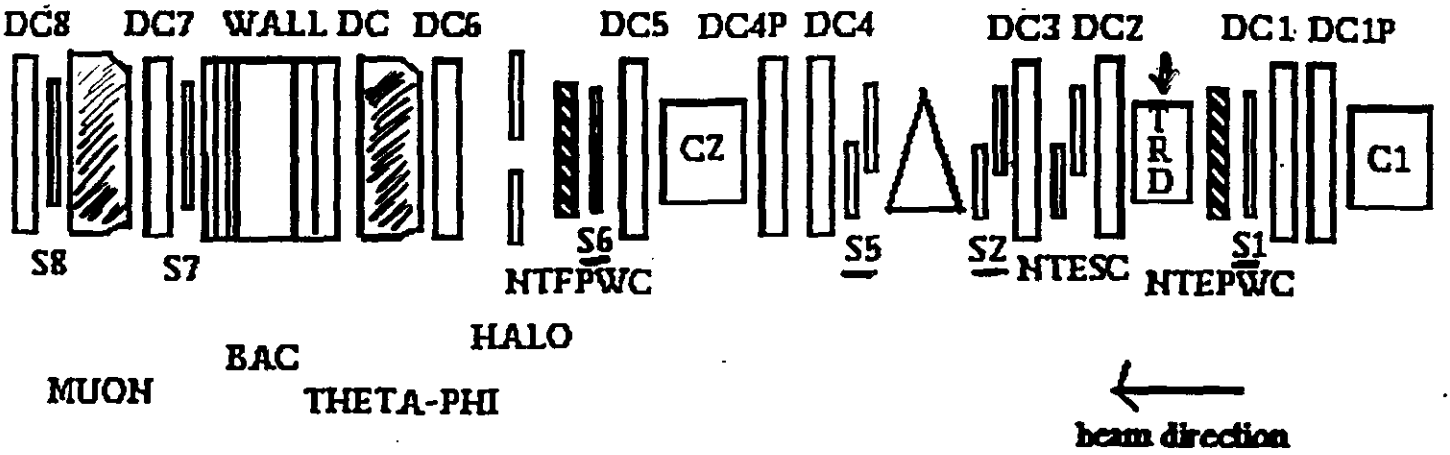
Issues long term stability

* 856 ½ time Pb glass
878

FERMILAB TEST BEAM

12/13/91 - 1/8/92 e,π,μ Runs

- CALTECH: Shi*, Shevchenko, Lu, Nolty, Zhu, Matzner, Newman; Wei*
- UCSD: Kobrak*, Branson, Swanson, McKigney
- ORNL: Read, Bauer, Kamyshkov
- CMU: Vogel
- BEIJING: Sun, Zhu
- PRINCETON: Marlow
- BOMBAY: Gupta
- OREGON: Funuro, Hwang



DC configuration

DC1P : 3X	DC1 : 2X2Y	DC2 : 2X2Y	DC3 : 3X	DC4 : 2X2Y
DC4P : 3X	DC5 : 2X2Y	DC6 : 2X2Y	DC7 : 4X4Y	DC8 : 4X4Y

Beamline device

SWIC : NTEPWC , NTFPWC

S : NTESC

Triggers in EPICURE system

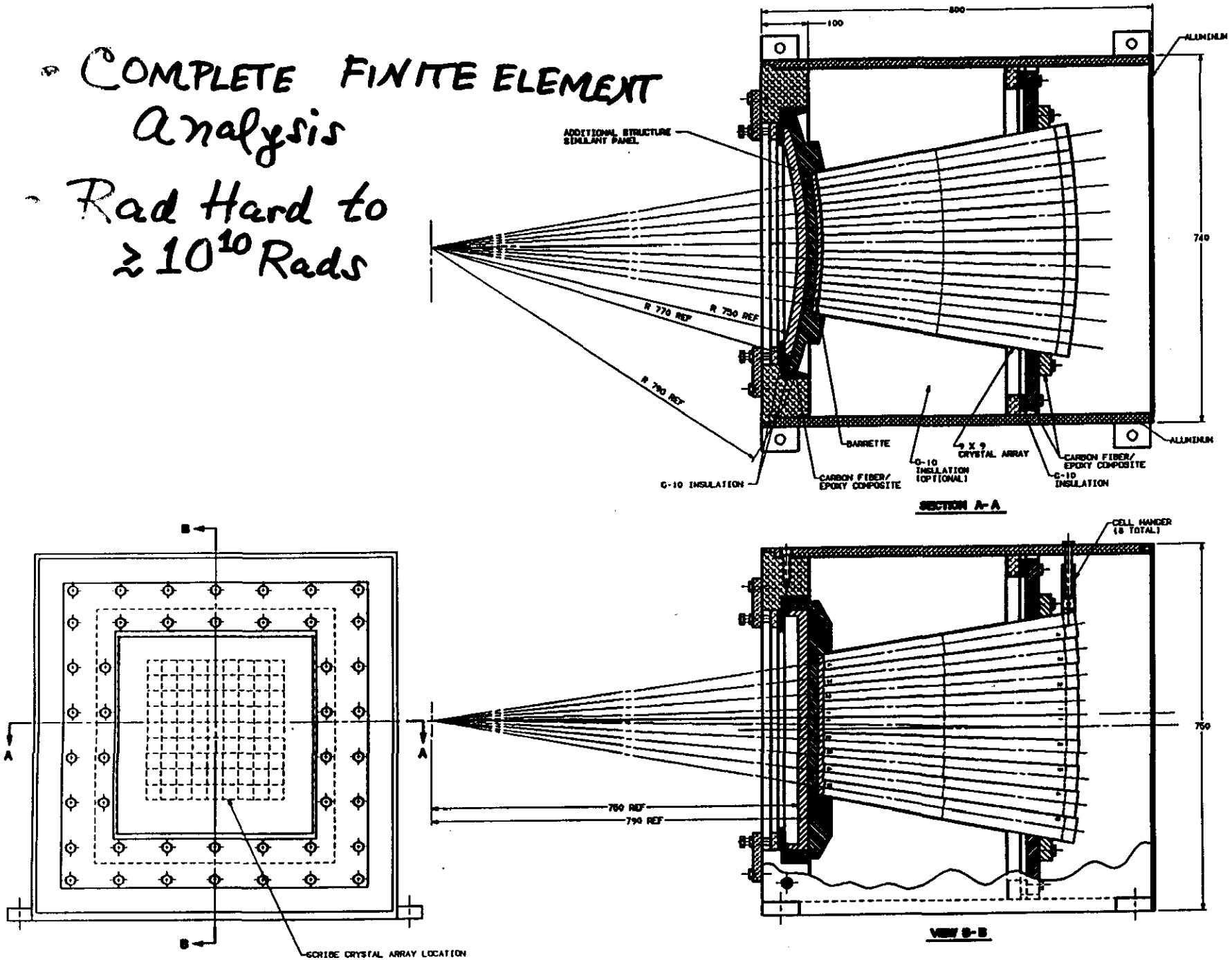
NTESSC1 : S1
NTESSC2 : S1 * S2A * S2B
NTEESC3 : S2 * S5
NTEESC4 : S1 * S2 * S5 = R5
NTEESC5 : S1 * S2 * S5 * S6 = R6
NTEESC6 : S1 * S2 * S5 * S6 * $\overline{\text{VETO}}$ = GOOD BEAM
NTEESC7 : VETO
NTEESC8 : S1 * S2 * S5 * S6 * $\overline{\text{VETO}}$ * S7 * S8

BARIUM FLUORIDE CALORIMETER TEST DATA

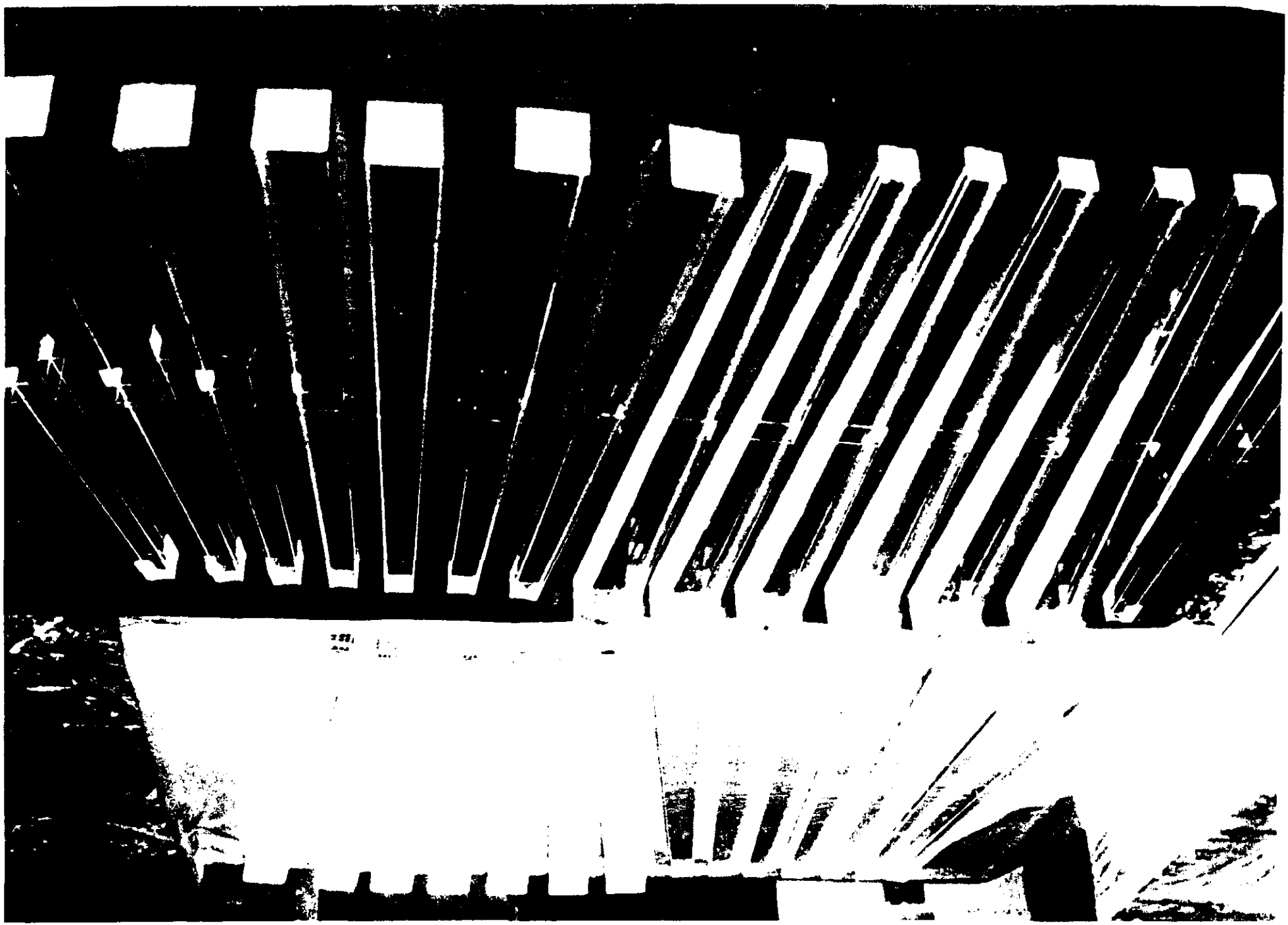
Photomultiplier Readout
Fermilab T-849 – 12/91

Date (December 1991)	Activity
3 - 6	Install Prototype Matrix in NT beam
9 - 12	Alignment and trigger studies
13	Muon Calibration, central 9 crystals
14 - 16	15,000 triggers 46 GeV electrons 10,000 triggers 115 GeV electrons 25,000 triggers 68 GeV electrons
17 - 18	Muon Calibration, full matrix (49 crystals)
18 - 21	250,000 triggers 68 GeV electrons
21 - 22	Muon Calibration, full matrix (49 crystals)
22	60,000 triggers 68 GeV electrons
23	Change ADC
23 - 26	300,000 triggers 68 GeV electrons
27	60,000 triggers 16 GeV electrons

- COMPLETE FINITE ELEMENT analysis
- Rad Hard to $\gtrsim 10^{10}$ Rads

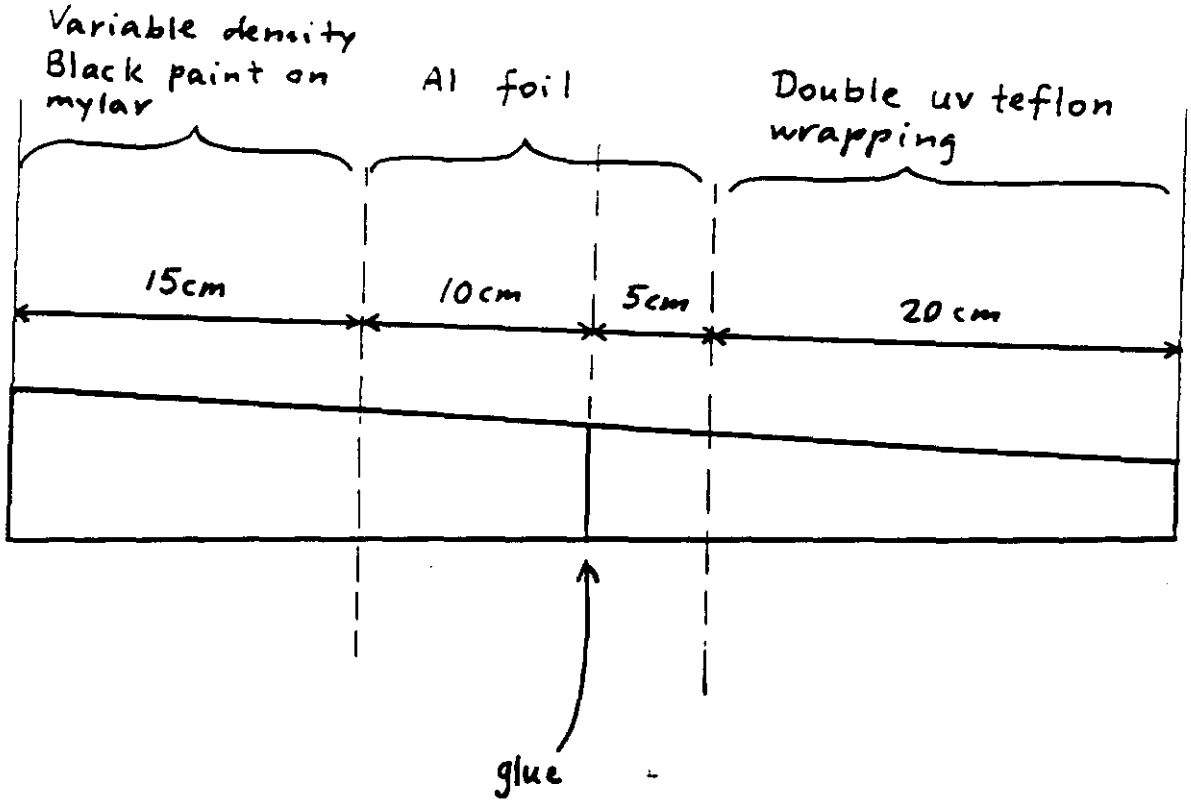


BaF2 EMC PROTOTYPE - 9 X 9 ASSEMBLY



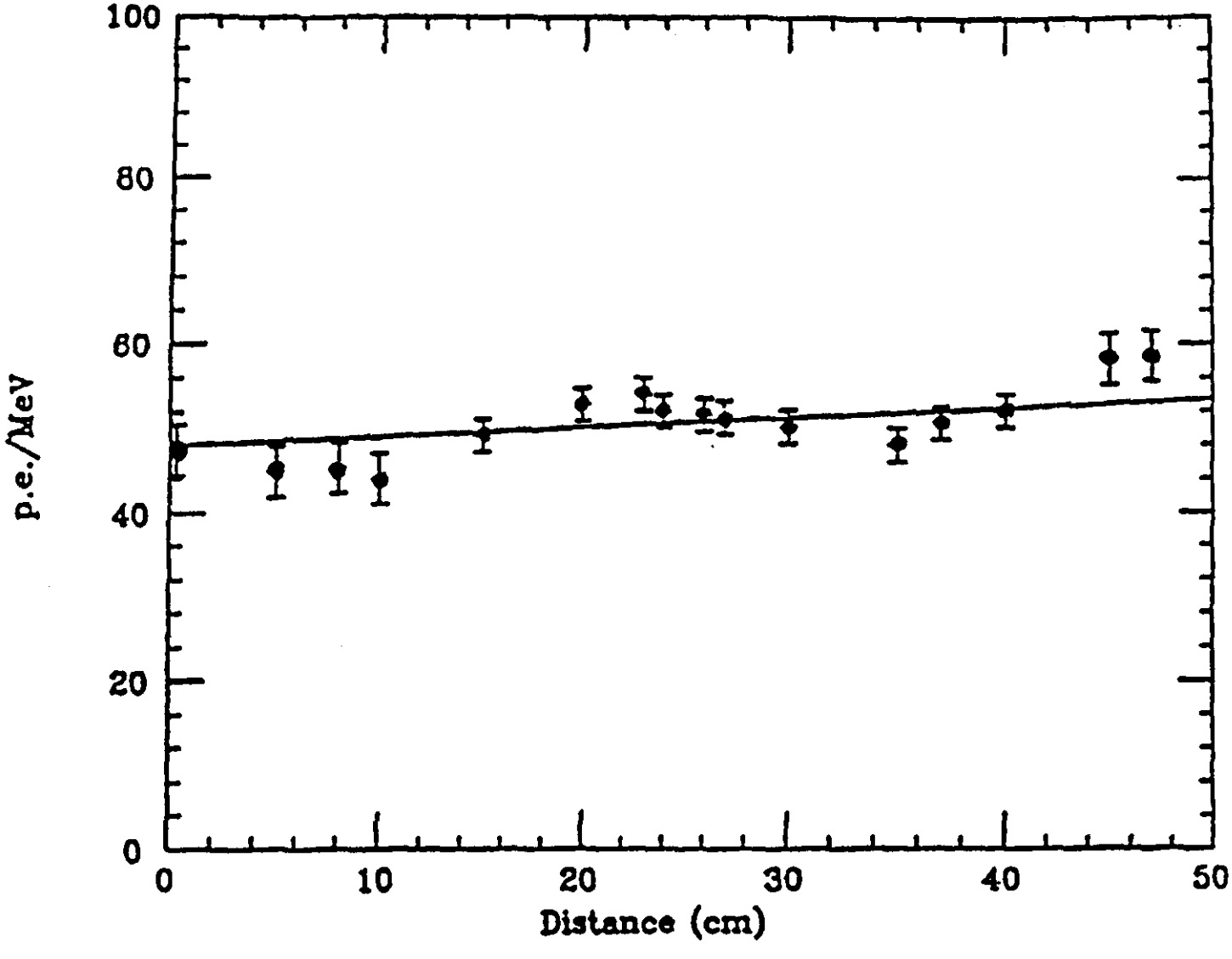
```
*********************************************
*                                           *
*         Light yield test report           *
*(The crystals were wrapped with Aluminum foil*
* and tested  with H4652 PMT(K-Cs-Te).)     *
*                                           *
*                                May 23, 1991*
*********************************************
```

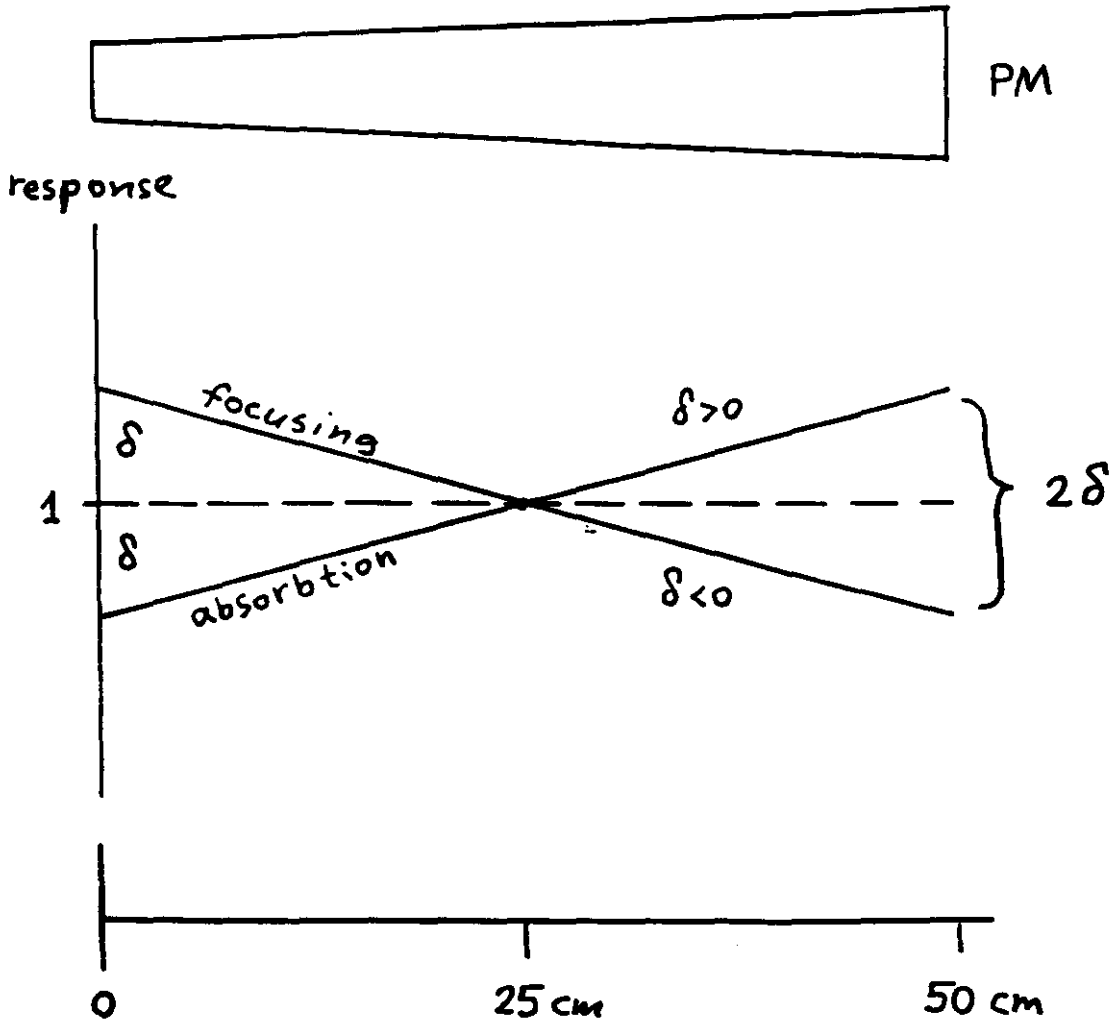
Crystal	Demension	Light Output (p.e./MeV) 55 nsec.	2000 nsec.	S.G./L.G (%)
● S1B008	2*25*3	47+-2	77+-3	61
S1B009	=	59+-2	89+-3	66
S1B010	=	63+-2	95+-3	66
● S1B011	=	61+-2	88+-3	69
S1A008	3*25*4	75+-3	110+-4	68
S1A009	=	74+-3	108+-4	69
S1A010	=	78+-3	108+-4	72
S1A011	=	78+-3	109+-4	72
S3B003	2*25*3	63+-2	96+-3	66
S3B004	=	52+-2	88+-3	59
S3B005	=	61+-2	90+-3	68
S3B006	=	43+-2	77+-3	56
S3B007	=	65+-2	98+-3	66
S3A003	3*25*4	77+-2	105+-4	73
S3A004	=	71+-2	98+-3	72
● S3A005	=	65+-2	95+-3	68
S3A006	=	78+-2	114+-4	68
● S3A007	=	82+-3	111+-4	74
S2B010	2*25*3	43+-2	76+-3	53
S2A010	3*25*4	68+-2	93+-3	73
S2B012	2*25*3	61+-2	88+-3	69
S2B013	=	60+-2	90+-3	67
S2B014	=	69+-2	100+-3	69
S1A012	3*25*4	69+-2	98+-3	70
S1A013	=	75+-2	104+-4	72
S1A014	=	66+-2	95+-3	69
S2A004	=	61+-2	88+-3	69
S3A009	=	79+-2	110+-4	72
S3A010	=	80+-2	112+-4	71
S3A011	=	81+-3	112+-4	72
S3A012	=	79+-2	110+-4	72
S3A013	=	77+-2	108+-4	71
S3A014	=	81+-3	111+-4	73



BaF_2 crystal coating for FNAL tests

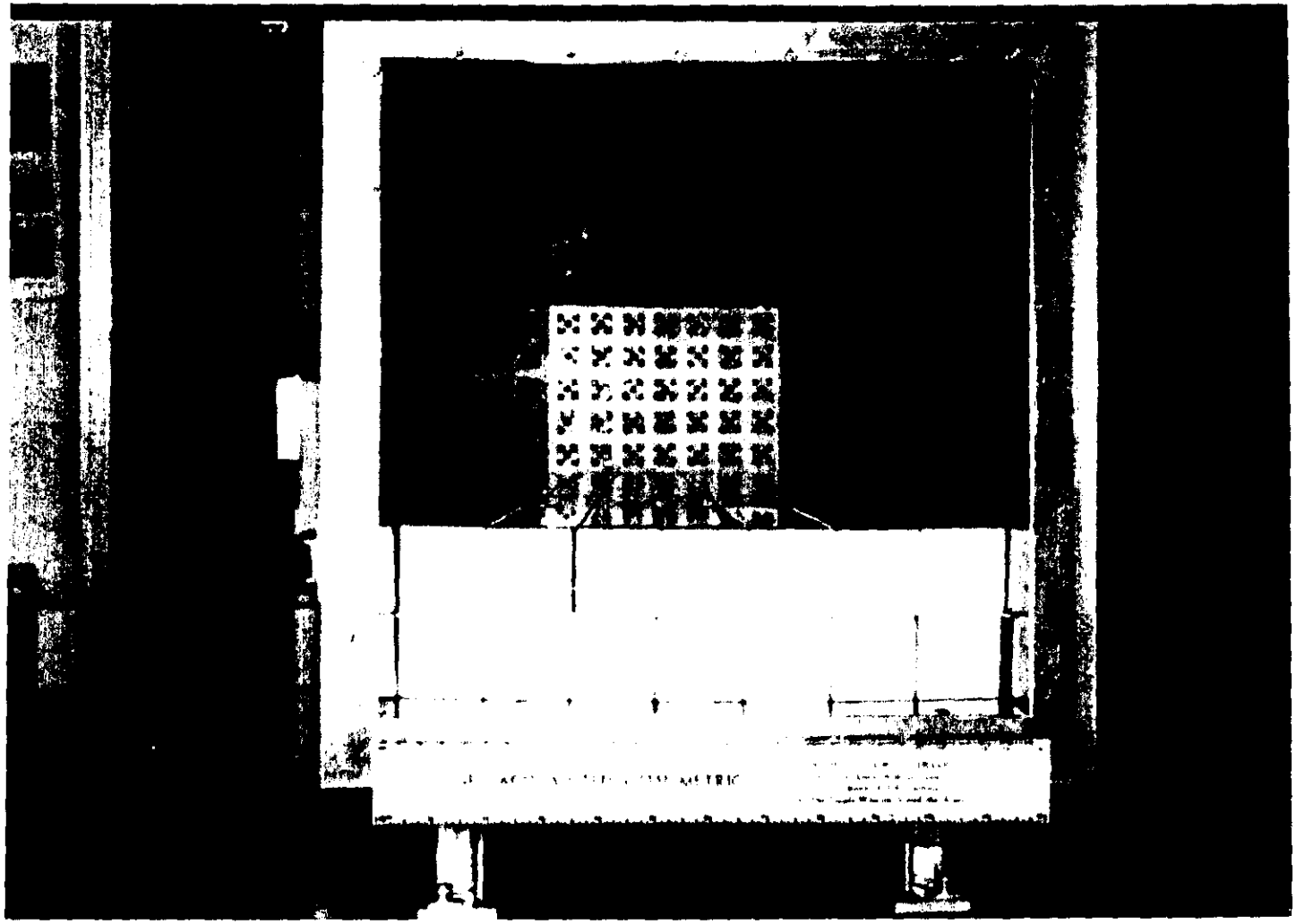
Photoelectrons/MeV For 50 cm BaF_2 Crystal-Pair Measured With Cs^{137} Source: $\delta = 6.8\%$.

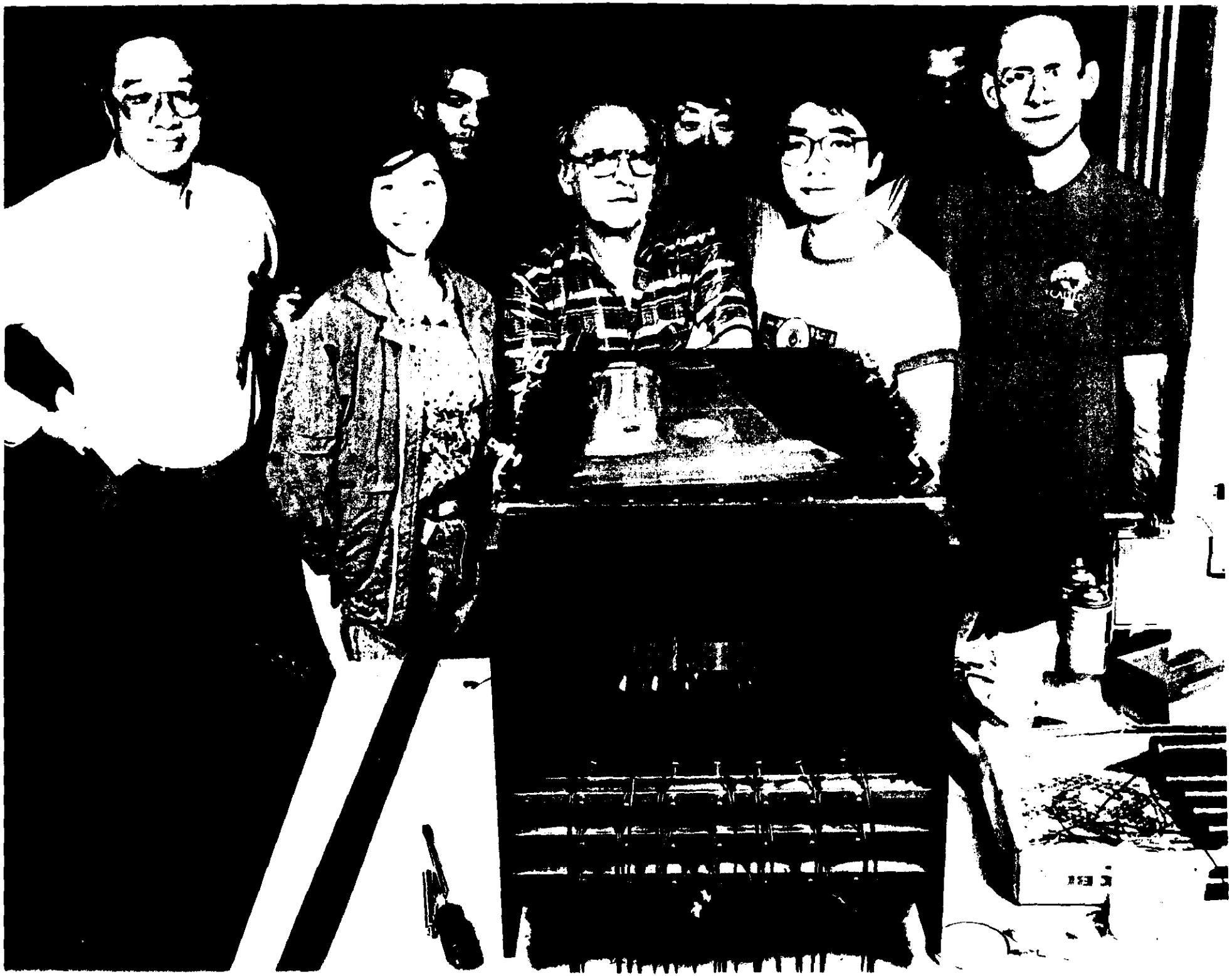




Linear parametrization of non-uniformity
(definition of δ)

- $\delta_{TYPICAL}$ (FNAL) : 10-15%
  → USE „MUON UNIFORMITY „MAPS"





Latest Update: 25 November 1991

No./Old No.	Cable No.
Glue Step High Voltage	
Downstream Piece	Upstream Piece

PH(225mm)
PH(275mm)

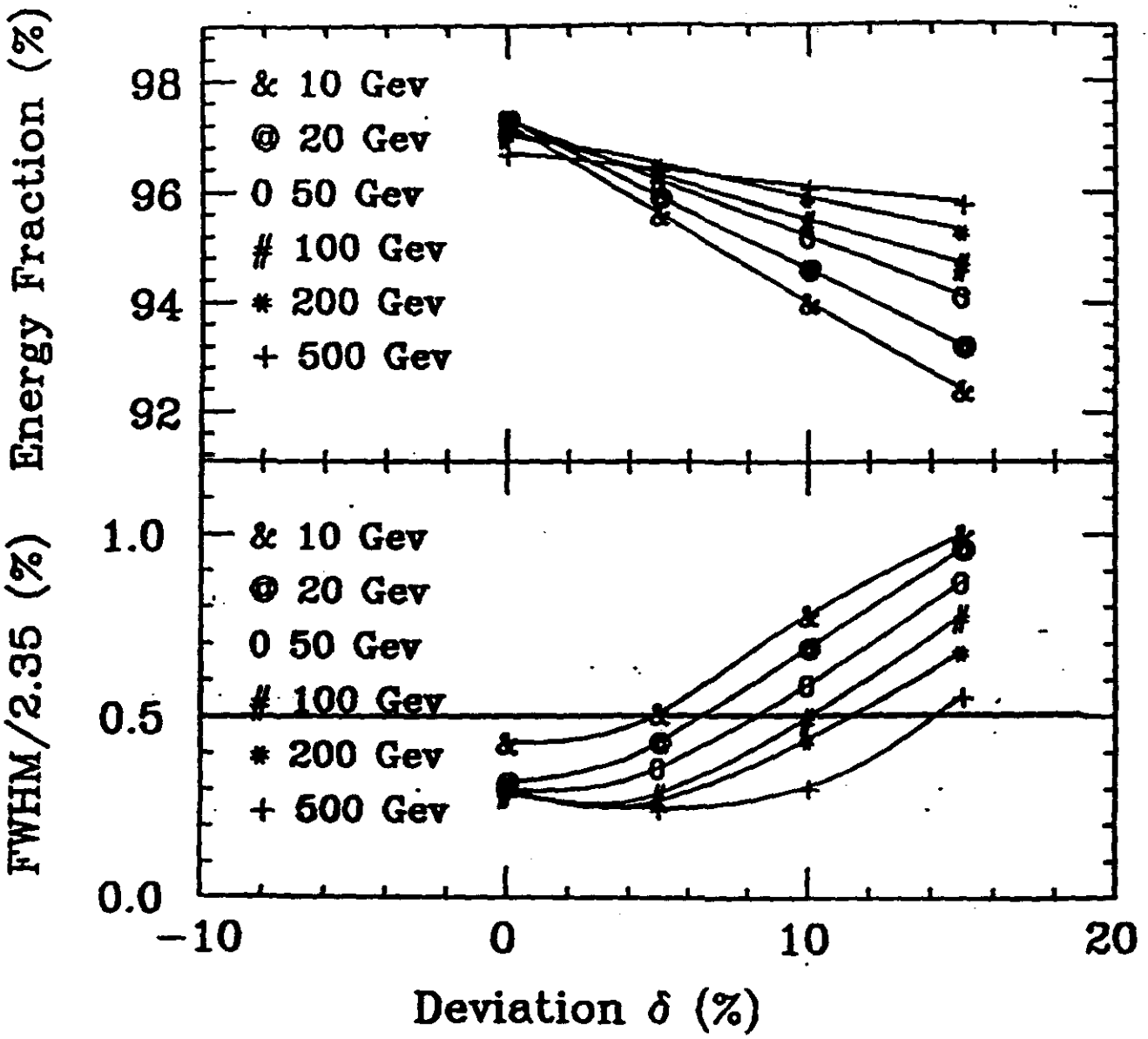
As seen when looking into the upstream end

Top

71/11 3	72/12 5	73/13 6	74/53 7	75/25 32	76/31 33	77/67 34
1.00	0.91	0.89	0.97	0.93	0.95	0.90
1259	1407	1439	1312	1429	1812	1549
3A2 3B14	2A7 2B10	1A2 1B5	1A10 1B12	2A2 2B11	3A1 3B4	4A1 4B4
61/51 8	62/75 9	63/73 10	64/54 35	65/45 36	66/76 37	67/77 38
0.91	1.08	1.19	1.01	1.04	1.03	1.10
1705	1500	1547	1657	1747	1593	1473
3A11 3B7	2A3 2B6	1A6 1B7	1A17 1B17	2A12 2B4	3A7 3B8	4A6 4B2
51/61 11	52/52 12	53/14 13	54/74 14	55/65 39	56/71 40	57/47 41
0.92	1.05	1.02	1.09	0.98	1.07	1.01
1355	1475	1669	1692	1439	1396	1729
3A4 3B9	2A11 2B8	1A5 1B2	1A4 1B4	2A4 2B5	3A8 3B13	4A7 4B3
41/21 15	42/42 16	43/43 17	44/44 42	45/55 43	46/46 44	47/17 45
1.10	0.94	1.73	0.98	0.96	1.03	1.07
1439	1424	1392	1648	1181	1489	1355
3A13 3B6	2A15 2B13	1A16 1B16	1A12 1B10	2A9 2B12	3A9 3B1	4A5 4B1
31/36 18	32/22 19	33/33 20	34/34 21	35/35 46	36/41 47	37/37 48
1.13	1.11	0.95	1.00	0.96	2.05	1.05
1803	1749	1590	1460	1269	1819	1579
3A13 3B2	2A8 2B2	1A9 1B13	1A7 1B9	2A1 2B14	3A10 3B12	4A2 4B6
21/56 22	22/32 23	23/23 24	24/24 49	25/15 50	26/26 51	27/27 52
0.76	1.00	1.02	1.07	1.09	1.03	1.06
1759	1409	1499	1334	1599	1325	1716
3A14 3B3	2A5 2B3	1A14 1B8	1A8 1B14	2A14 2B7	3A6 3B10	4A4 4B5
11/66 25	12/72 26	13/63 27	14/64 28	15/62 53	16/16 54	17/57 55
1.02	1.29	0.99	1.67	0.93	1.04	1.03
1356	1426	1439	1424	1397	1299	1544
3A3 3B11	2A10 2B9	1A15 1B15	1A13 1B11	2A13 2B1	3A12 3B5	4A3 4B7

Bottom

Effect of Light Uniformity (5 x 5)



$\delta_{TYPICAL}$: 10 - 15%

SECOND BaF_2 MATRIX CONSTRUCTION: (UCSD, CALTECH)

Experience from the First Matrix:

PROTOTYPE ENGINEERING REQUIRED

- Oven Improvements in China: Cold Trap, Western Diffusion Pump, Vacuum Gauges and Readout
- Crystal Dimensional Tolerances: Small Bevels
- Mounting Without Carbon Fiber Structure: (ORNL)
  - Crystals Mounted In Compression; Longitudinal Loading Only
  - Bonded Surfaces Flat and Parallel to 10μm
  - Reliable THIN Grease Joints to Photodevice: OR AIR GAP.
- Develop $MgF_2 - Al_2O_3$ (Multilayer) Reflector: (LIVERMORE)
  - Improved Control of Uniformity
  - Sealant Against Adsorbed H_20
- Control Electronic Noise Pickup: Higher S/N; Dynamic Range (PRINCETON)
  - Improved Front End, Shielding, Grounding Cable Layout, Power Distribution
  - Tested Prior to CERN Beam Test, At UCSD Test-Bed (First Matrix)

DD
CERN LIBRARIES, GENEVA
90.4337.3

SLAC-PUB-5199
April 1990
(E)

PRODUCTION OF 400 MIRRORS WITH HIGH VUV REFLECTIVITY FOR USE IN THE SLD ČERENKOV RING IMAGING DETECTOR*

K. Abe,[1] P. Antilogus,[2] D. Aston,[2] A. Bean,[3] T. Bienz,[2] F. Bird,[2(a)] D. Caldwell,[3] P. Coyle,[4] D. Coyne,[4] P. Datte,[3(b)] J. Duboscq,[3] W. Dunwoodie,[2] P. Gagnon,[4] D. Hale,[3] G. Hallewell,[2] K. Hasegawa,[1] M. Hilton,[3(c)] J. Huber,[3] P. Jacques[5] R. A. Johnson,[6] H. Kawahara,[2] Y. Kwon,[2] D. W. G. S. Leith,[2] A. Lu,[3] J. Martinez,[6] L. Mathys,[3] S. McHugh,[3] R. Morrison,[3] D. Muller,[2] T. Nagamine,[2] M. Nussbaum,[6] T. Pavel,[2] R. Plano,[5] B. Ratcliff,[2] P. Rensing,[7] A. K. S. Santha,[6] D. Schultz,[2] S. Shapiro,[2] A. Shoup,[6] C. Simopoulos,[2] E. Solodov,[2(d)] P. Stamer,[5] I. Stockdale,[6] F. Suekane,[1] N. Toge,[2] J. Va'vra,[2] J. S. Whitaker,[7] D. A. Williams,[4] S. H. Williams,[2] M. Witherell,[3] R. J. Wilson,[7] S. Yellin,[3] and H. Yuta[1]

THE SLD CRID COLLABORATION

[1] *Department of Physics, Tohoku University, Aramaki, Sendai 980, Japan*
[2] *Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309, USA*
[3] *Department of Physics, University of California, Santa Barbara, CA 93106, USA*
[4] *Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA 95064, USA*
[5] *Serin Physics Laboratory, Rutgers University, PO Box 849, Piscataway, NJ 08855, USA*
[6] *Department of Physics, University of Cincinnati, Cincinnati, OH 45221, USA*
[7] *Department of Physics, Boston University, Boston, MA 02215, USA*

Submitted to *Nuclear Instruments and Methods B.*

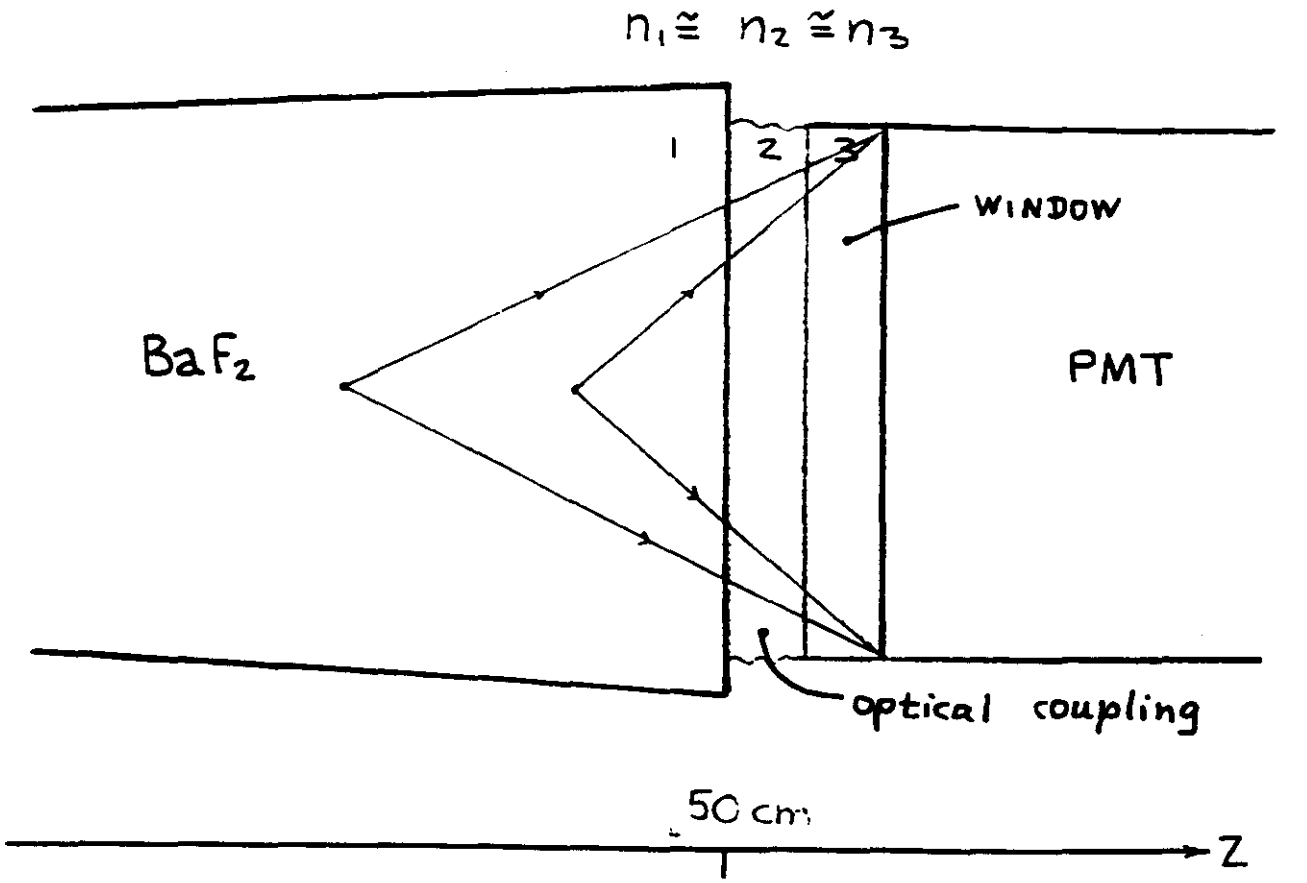
* Work supported by Department of Energy contract DE-AC03-76SF00515; and National Science Foundation grants PHY88-13669 and PHY88-13018.

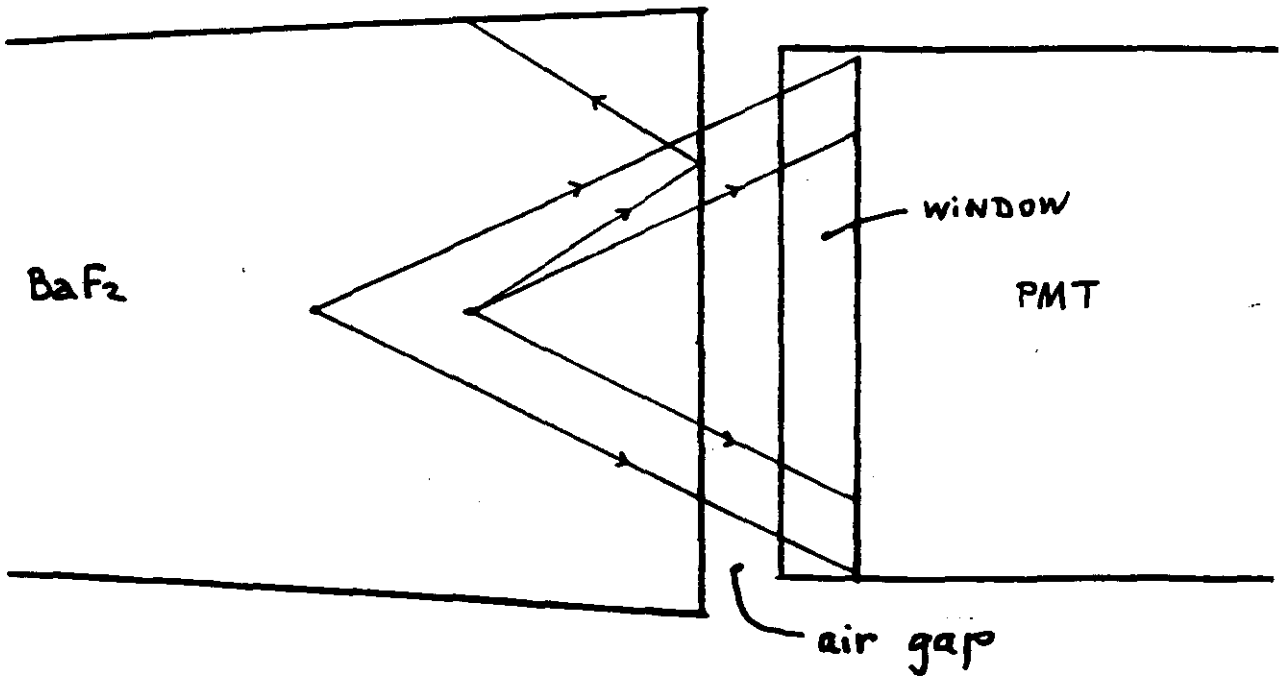
(a) Present address: EP Division, CERN, CH1211, Geneva 23, Switzerland.
(b) Present address: Texas Accelerator Center, 2319 Timberloch Drive, The Woodlands, TX 77380, USA.
(c) Permanent address: Applied Magnetics Company, Goleta, CA 93117.
(d) Permanent address: Institute of Nuclear Physics, Novosibirsk, 630090, USSR.

SLAC-PUB 5199
C1

ABSTRACT

The Stanford Large Detector for experimental particle physics detection at the SLAC Linear Collider contains a Čerenkov Ring Imaging Detector (CRID). The barrel CRID mirrors have been successfully produced and installed. The industrial mirror production process, the quality control of the mirrors produced, and the results of the vacuum ultraviolet (VUV) reflectivity and mirror-shape accuracy are described. An average reflectivity of at least 80% for light at 160 nm and 85% for light in the 180–230 nm wavelength range has been achieved in the production of over 400 mirrors of a typical size of 30 by 30 cm. The surface roughness and optical distortion measurements imply that the light loss due to scattering is a few percent of the incident light and the angular error due to shape distortion is less than 1 mrad.



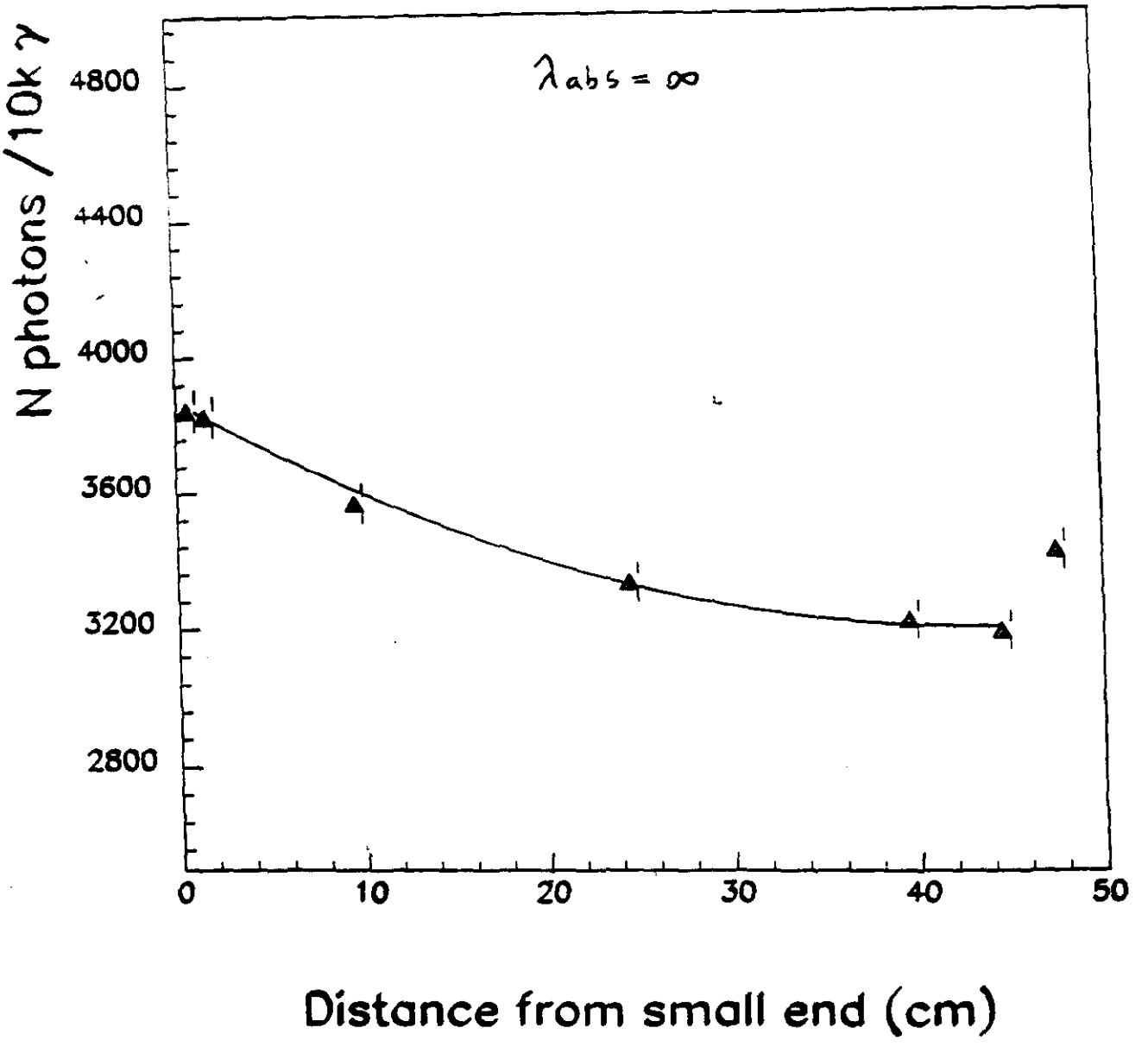


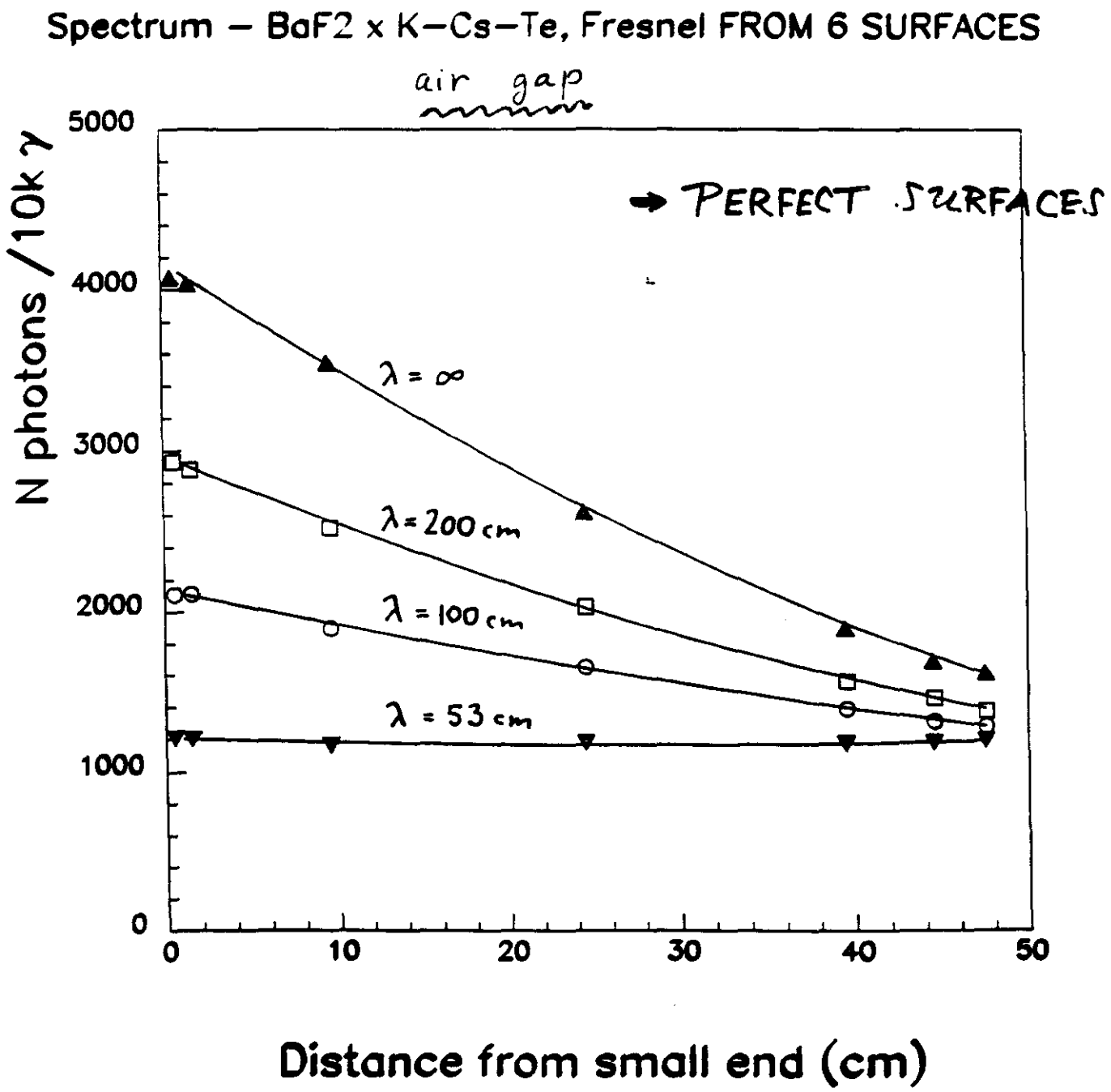
Region of BaF_2 close to photocathode

Global nonuniformity simulations

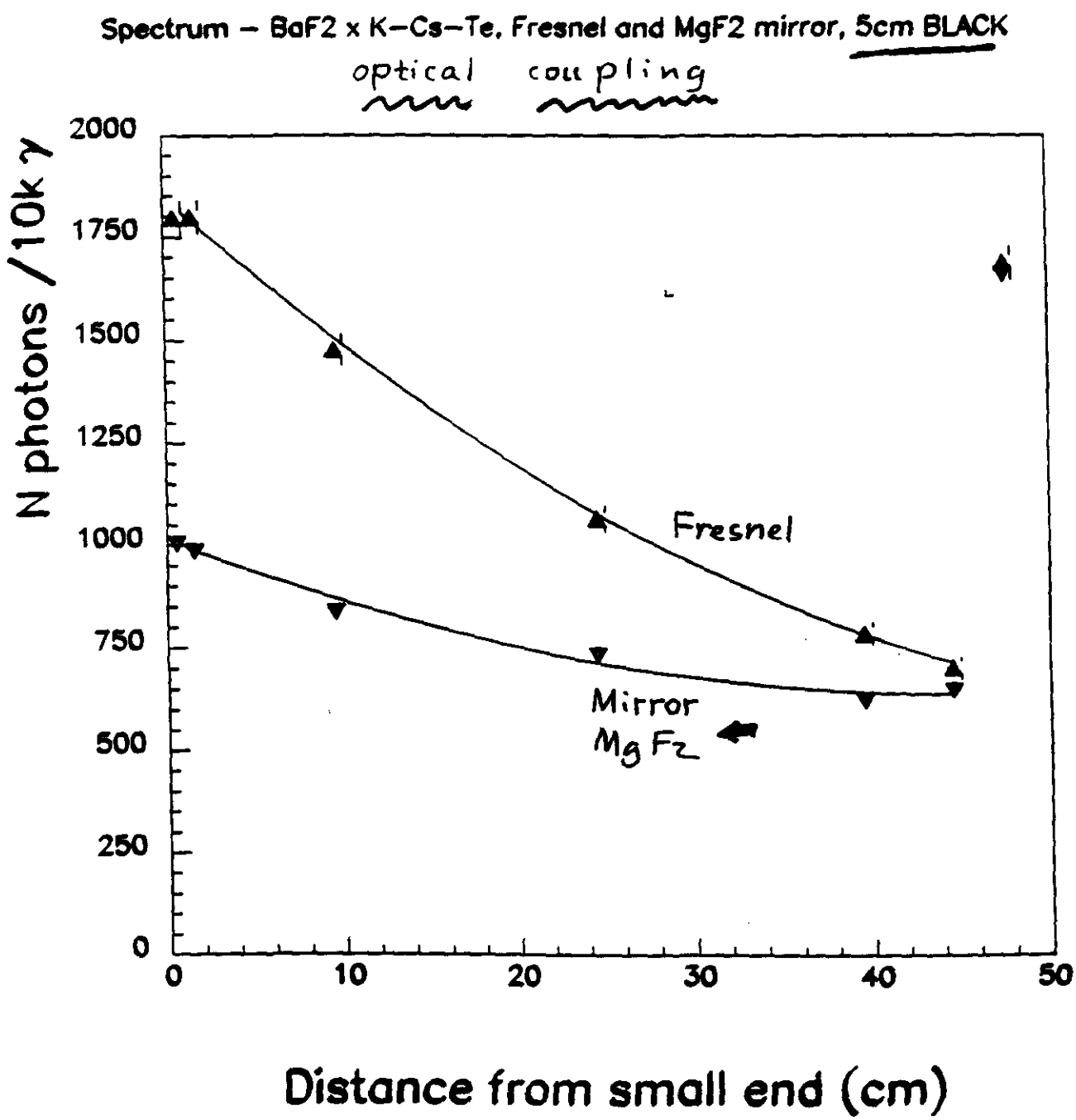
by K. Shmakov ORNL

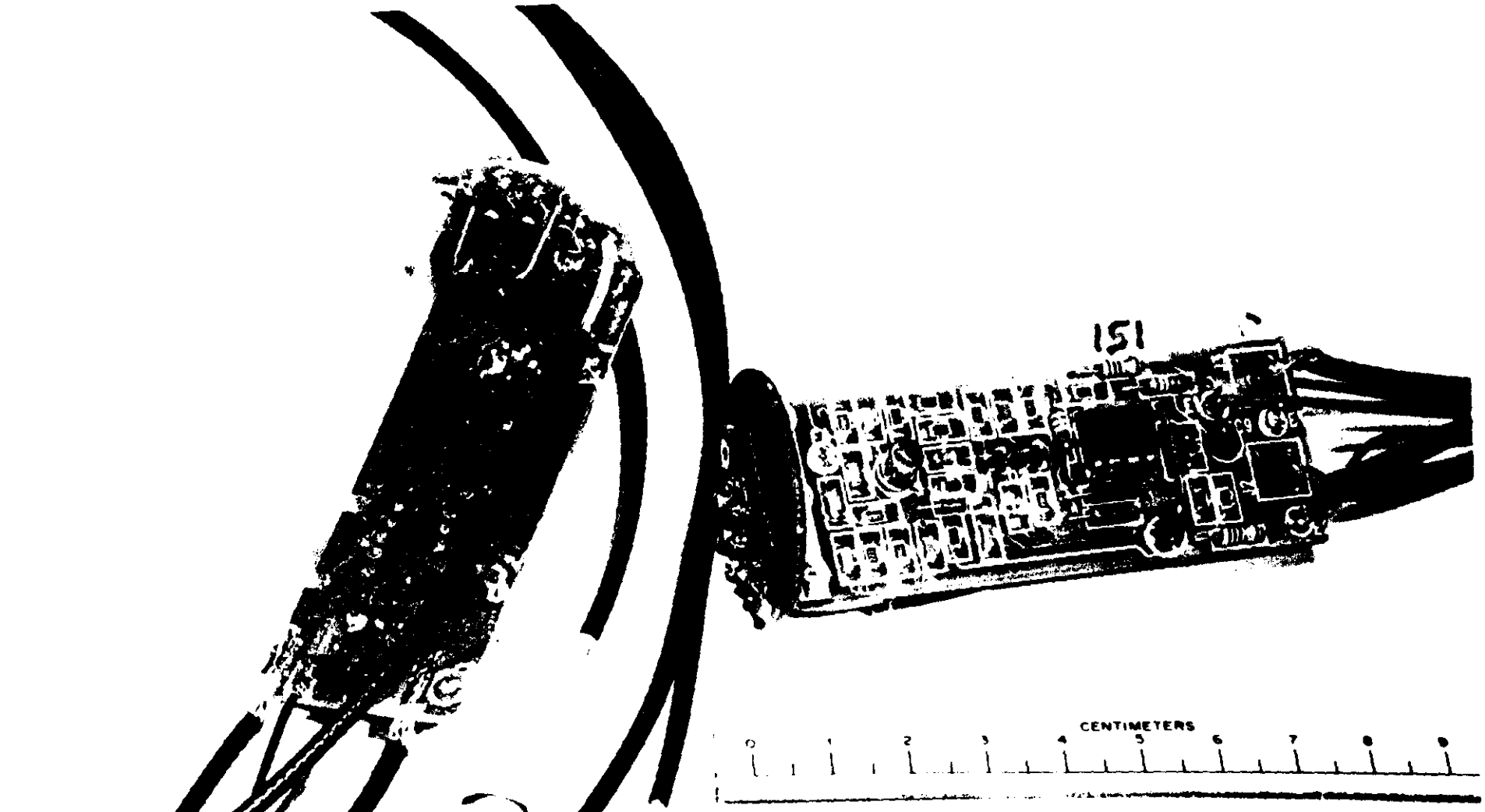
Natural BaF2 spectrum, Fresnel, optical coupling




Spectrum – BaF2 x K–Cs–Te, Fresnel FROM 6 SURFACES
air gap
→ PERFECT SURFACES
N photons /10k γ
5000
4000
3000
2000
1000
0
λ = ∞
λ = 200 cm
λ = 100 cm
λ = 53 cm
0
10
20
30
40
50
Distance from small end (cm)

- $K_{refl}(MgF_2) = 0.88$





- DYNAMIC RANGE
- NOISE REJECTION
- SPEED + OCCUPANCY
- MATCHING TO ADC
- GAIN of PHOTO DEVICE

• BaF_2 + SCINTILLATOR
HCAL SYSTEM BEAM TEST
By END 1992 (8/92 - 10/92)

- EFFECTIVE COMPENSATION:
  Weighting Methods for Best Resolution
- ENERGY RESOLUTION:
  Systematics (Constant Term)
- e/π SEPARATION:
  Shower Shape, HCAL Veto, E-p Matching
- MIP CALIBRATION TEST

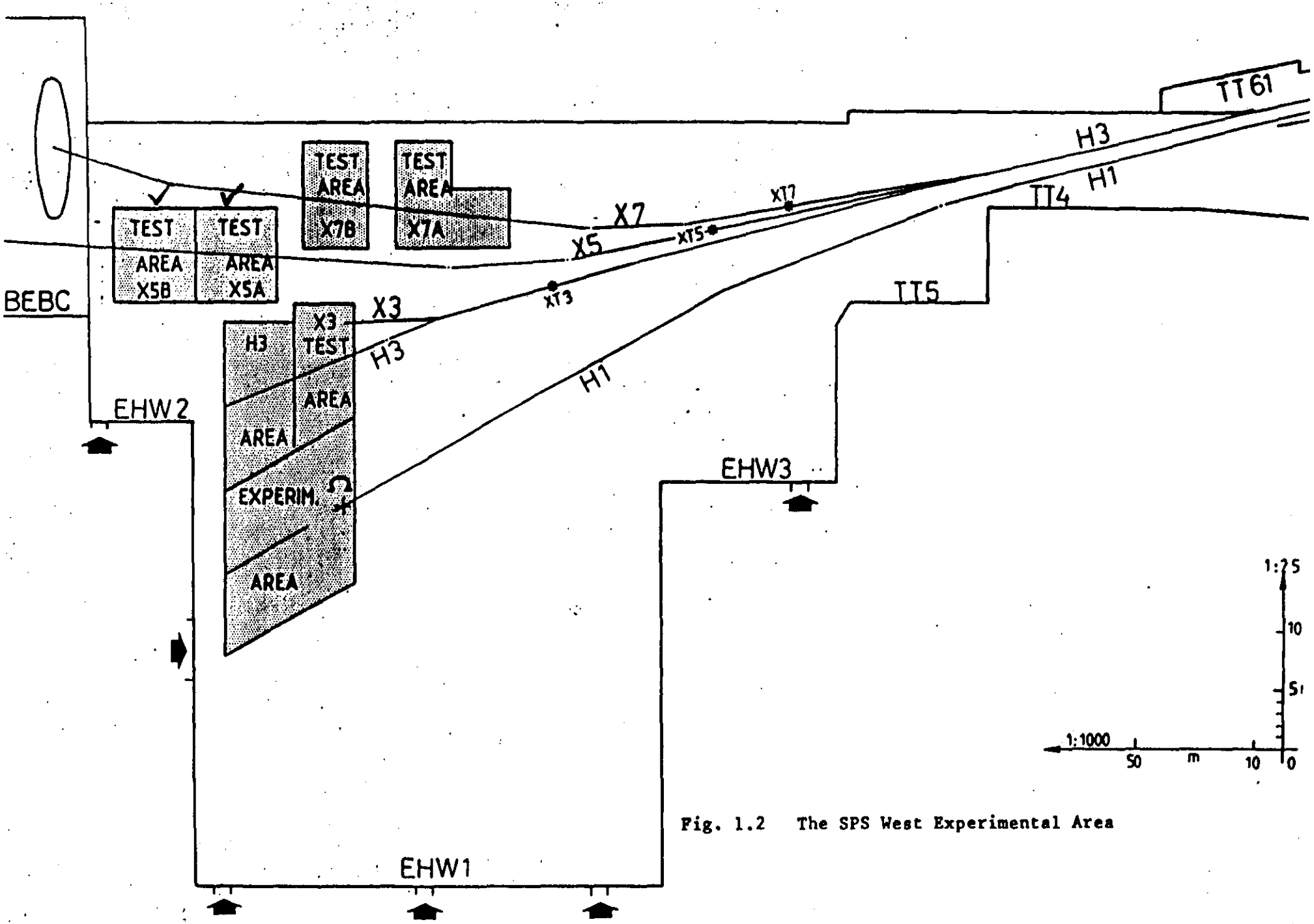


Fig. 1.2 The SPS West Experimental Area

TABLE 3.1

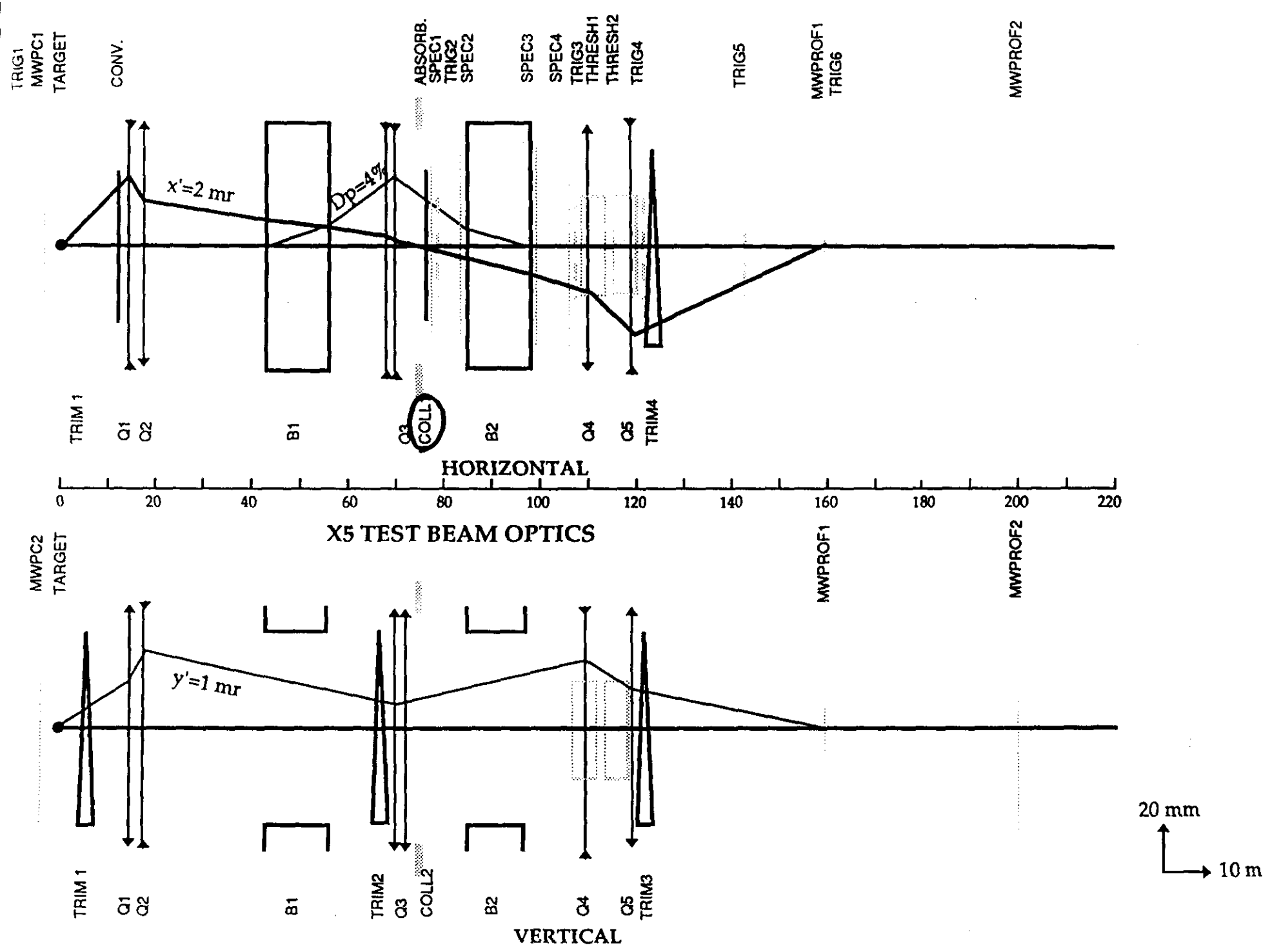
Test Beam Characteristics

Requested

	X3	X5	X7
Maximum Momentum (GeV/c)	50	100	100
Horizontal angular acceptance (mrad)	2.0	3.9	3.7
Vertical angular acceptance (mrad)	5.0	1.4	0.9
Solid angle acceptance μsr	31	17	10
RMS Momentum bite (%)	± 3.5	± 3.5	± 4.5
Intrinsic (i.e. slit) momentum	± .4	± .6	± .75
Spectrometer resolution (%)	≥ 0.2	.3-.6	.3-.8
Length of Test Area A (m)	15	25	38
Length of Test Area B (m)		27	24
Area of Test Area A (m^2)	~ 80	200	210
Area of Test Area B (m^2)		250	190
Distance Target - middle Area A (m)	63	160	116
Distance Target - middle Area B (m)		192	155
Beam Height above floor level (m)	3.66	3.64	**

*) X5 can be run exceptionally at 300 GeV/c for calibration of the neutrino detectors - X7 can be run exceptionally at 150 GeV/c to BEBC. Extra power supplies and magnets would be taken from other beams.

**) X7 descends at 6 mrad towards BEBC (see Section 3.7).


TRIG1
MWPC1
TARGET
CONV.
ABSORB.
SPEC1
TRIG2
SPEC2
SPEC3
SPEC4
TRIG3
THRESH1
THRESH2
TRIG4
TRIG5
MWPROF1
TRIG6
MWPROF2
x'=2 mr
Dp=4%
TRIM 1
Q1
Q2
B1
Q3
COLL
B2
Q4
Q5
TRIM4
HORIZONTAL
0
20
40
60
80
100
120
140
160
180
200
220
X5 TEST BEAM OPTICS
MWPC2
TARGET
MWPROF1
MWPROF2
y'=1 mr
TRIM 1
Q1
Q2
B1
TRIM2
Q3
COLL2
B2
Q4
Q5
TRIM3
VERTICAL
20 mm
10 m

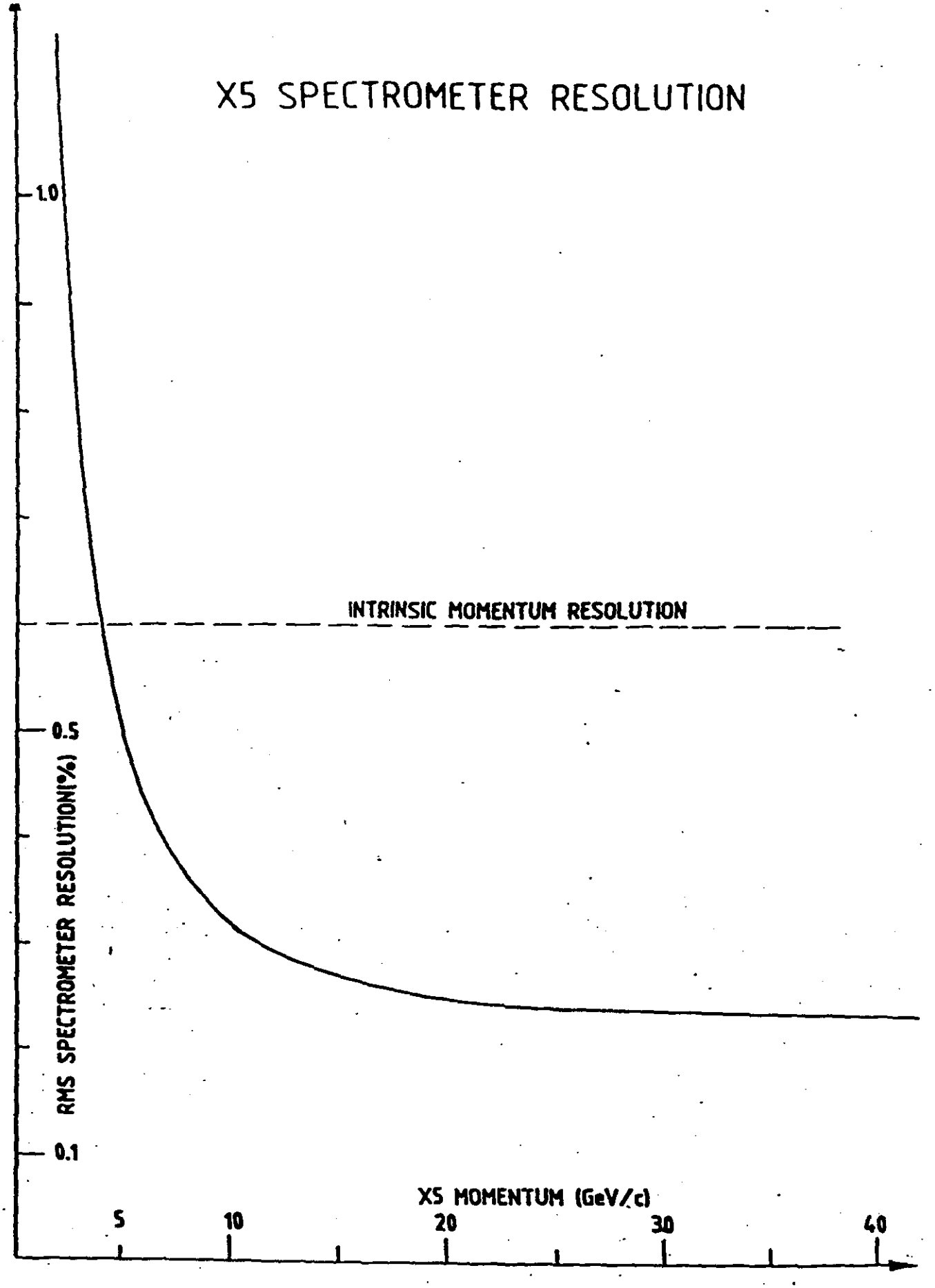


Fig. 3.4 The X5 Beam Spectrometer Resolution. 4 Planes of MWPC. 1.6 % Radiation Length/Plane.

TABLE 3.2

X5 Beam

RMS spot sizes without Coulomb Scattering

Position	Q4, Q5 Polarity	σ_x (mm)	σ_y (mm)
X5A	FD	18.4	3.2
X5B	FD	23.6	4.4
X5B	DF	4.6	11.0

TWO USER AREAS

MAINLY BaF_2

MAINLY HCAL

TABLE 3.3

X5 Beam

Effect of Multiple Coulomb Scattering

Position	Q4,Q5 Polarity	Effect of in Beam	scattering Spectrometer*	Effect of scattering in 2 Cerenkov's**
		σ_x(mm)	σ_y(mm)	σ_x (= σ_y) (mm)
X5A	FD	96/P	32/P	75/P
X5B	FD	114/P	45/P	126/P
X5B	DF	33/P	148/P	126/P

*) Spectrometer = 4 MWPC : 0.0016 radiation lengths/detector.

**) 1 % radiation length/detector.

From: DXMINT::FROID@CERNVM.CERN.CH
To: vxcern::newman
CC:
Subj: Re: Test Beam Request -- Please acknowledge to Branson and to newman@cithex

As we discussed a week ago, there are no real problems with your request on my side ... However, I have been told very firmly by W. Hoogland tht you will get this test beam time only if the SSC management comes clearly with a statement that they will pay for this test beam following the lines which they have discussed (Gilman and Stefanski) with W. Hoogland ... My feeling is that you should make them feel the urgency of satisfying the CERN management if you want to run next year for an extensive period ...

If anything happens before Christmas please inform me ... After Christmas you should deal with J. Shukraft the new SPS coordinator ...

Daniel Froidevaux

CERN TEST BEAM Meeting 1/23/92

- G. Yost, J. Schukraft, P. Grafstrom, P. Denes
- [Official Minutes Next Week]

→ 1992: Use existing Beam Lines; Pay Operating Cost

→ Future: Move Towards Dedicated Beam Line(s) for SSC; "Pay Per Proton"?

- One Contact Person Per Experiment
  Use of Line INTERNALLY Decided

1992 Plan: GEM → X5 Beam (West Area)
SDC → H6 Beam (NORTH Area).

- X5: WEST AREA BEAM (Choice So Far)
  - TERTIARY Beam; X5 & X7 Good Optics
  - 100 - 10^4 PPP; FEW to 110 GeV
  - BEAM SPECTROMETER: 0.3% RESOLUTION
  - Upgrade to 200 GeV in 1993 Planned

- X5 Requests: BaF_2; BaF_2 + SciFi; "LXe Accordion" (?)

→ WILL Beam Be Instrumented?
- If Not; 2-3 MONTHS FULL TIME for SETUP

CERN NORTH AREA TEST BEAMS

$\Delta p/p \rightarrow 0.7\%$; for electrons ?

NO SPECTROMETERS

- H2 : TO 450 GeV ; HIGH INTENSITY e/pi ; ALSO A HEAVY ION BEAM
- H4 : NOW LIKE H2
- H6 : 200 GEV PIONS

→ " NORTH AREA BEAMS ARE HEAVILY IN DEMAND"

" THEY ARE UNLIKEY TO BE AVAILABLE"

November 26, 1991

Daniel Froideveaux
SPS Coordinator
CERN

Dear Daniel,

I would like to make the following preliminary test beam request for use of the CERN X5 Test Beam next year, on behalf the BaF2 crystal calorimeter project in GEM for the SSC, together with the Scintillating Fiber (SF) hadron calorimeter project. This initial request is for your first planning purposes. I expect to be discussing this further within the GEM Collaboration starting with the next meeting at the SSC Dec. 4-5.

After this note, Jim Branson will serve as the onsite contact person until mid-December. Starting next year, we will designate a contact person for GEM who is based at CERN, to begin the actual planning of the beam area and to handle other issues which may arise during 1992.

It is my fervent hope that matters concerning the "special status" of SSC-related test beam work may be handled directly between the administrations of CERN and the SSC laboratories.

Following my discussions with you and with M. Gatignon, it is clear that the X5 beam is very well suited to our needs. I cite as examples the high electron resolution (0.25%) and purity, energy range for electrons and pions (to 110 GeV), and the good state of the barrack and areas available for putting equipment in the beam.

Request

(1) 4 weeks from August 1 onward, for BaF2 in the forward area.

Preparations of the SF HCAL in the rear area can proceed in parallel with the BaF2 running, with the movable beam dump in place.

(2) Startup of the SF hadron calorimeter for the remainder of the first period, through September 14, and at the beginning of the second period, from September 24 - 30.

(3) 3 weeks of joint running of the BaF2 and the SF calorimeters during the second period, starting approximately October 1.

Sincerely,
Harvey Newman
CALTECH

A PRECISION BaF_2 CRYSTAL CALORIMETER FOR THE SSC

R&D PLAN FOR FY 1992

Submitted by

California Institute of Technology
University of California, San Diego
Princeton University
Carnegie Mellon University
Brookhaven National Laboratory
Oak Ridge National Laboratory
Los Alamos National Laboratory
LIVERMORE NATIONAL LABORATORY

November 15, 1991

BaF_2 R&D FY 1992 (11/15 Version)

- (1) RADIATION DAMAGE STUDY $310K
- (2) CRYSTALS + MATRIX ASS'LY + PHOTODEVICES $414K
- (3) BEAM TEST at CERN (+C.R.) $241K
- (4) ELECTRONICS READOUT for MATRIX $167 K
- (5) UV Performance MONITOR $47 K
- (6) Rad Hard Electronics $30 K

$1209 K

→ NO CARBON FIBER STRUCTURE

- There ARE CHANGES ...

BaF_2 R&D PROGRAM

CHANGES SINCE 11/15/91 NET

- BaF_2 PANEL: \$180K + \$30 (EST.)
  − \$150K Budgeted +\$60K

- R&D IN CHINA:

  + \$120K (SIC)
  + \$ 50K (BGRI)
  − \$100K (81 → 49 CRYSTALS) +\$70K
  (PAIRS)

- R&D Radiation Damage
  Coordination WITH CHINA +\$40K

- UV Surface Coating +
  Measurements,
  COMPUTATIONS
  → UNIFORMITY (LLNL) —

+ \$170K

BaF_2 R&D PROGRAM

1. REDUCTIONS

	NOV. '91	NOW
→ UV MONITORING (CMU)	$47K	$15K
→ MATRIX ELECTRONICS (ORNL) DEVELOP + BUILD	$117K	$60K
→ RAD HARD ELECTRONICS (LANL)	$30K	—
NET REDUCTION		$119K

2. BUDGET SUMMARY

→ NOVEMBER, 1991	$1209 K
→ ADDITIONAL EXPENSES	+ $170 K
→ REDUCTIONS	− $119 K
● FINAL PROPOSED BUDGET	$1260K

BaF_2 R&D BUDGET

BY INSTITUTION

	OPER.	EQUIP	TOTAL
• CMU	$15K		$15K
• PRINCETON	$30K	$20K	$50K
• BNL	$50K	$20K	$70K
• ORNL	$12K	$48K	$60K
• UCSD	$15K	$129K	$144K
• CALTECH	$712K	$209K	$921K *
	$834K	$426K	$1260K

* INCLUDES RADIATION DAMAGE STUDY IN U.S. & CHINA

BaF_2 PROTOTYPE ENGINEERING TASKS (ORNL)

I. • REDIMENSION: CRITICAL SURFACES ⊥ to REFERENCE FACES ($24K)

- Flat & Parallel to 10μm
- ESTABLISH PROCESS & CHECK

• MOUNTING CRYSTALS IN SECOND MATRIX: DEVELOP STRUCTURE ($74K)

- LONGITUDINAL COMPRESSION SYSTEM
- NO CARBON FIBER STRUCTURE

• IMPROVE CHINESE OVEN: ($12K)
$10^{-5} \rightarrow (10^{-6}$ to $10^{-7})$ Torr

- WESTERN DIFFUSION PUMP
- COLD TRAP
- GAUGES
- INSTALL & TEST

II. PROJECT ENGINEERING ($70K)

- STANDARD OPERATING PROCEDURES
- MECHANICAL PROCESSING; SPECS.
- TRACKING + QUALITY CONTROL PROCEDURES; HANDLING STEPS
- PROJECT PLAN By 8/92

• TOTAL BaF_2 ENGINEERING IN 1992 **$180K**