GEM TN-92-94

Calorimeter Meeting
SSCL

May 1, 1992

Abstract:

Agenda, presentation, and attenders of the GEM Calorimeter Meeting held at the SSC Laboratory on May 1, 1992. Agenda items were: Baseline Status; Forward Activities; Discussion on April 21/22 Cost Review and International Contributions; BaF2 Activities; SSCintCal Activities; LAr Activities; Quartz Fiber Calorimeter; SSCL Test Beam Facilities; and Simulations and Test Beam Data.

A G E N D A

of GEM Calorimeter group meeting on Friday May 1-st at SSCL

9 am H.Gordon - Presentation of base line design status (60')

Forward activities (15') Dave Winn

Discussion on April 21/22 cost review and intnl. contributions (30')

Engineering for alternative opt. Mark Rennich

BaF2 activities (30') H.Newman

SSCintCal activities (15') L.Sulak

LAr activities (15') H.Gordon

noon Lunch break (60')

1 pm Philippe Gorodetzky (CERN) - quartz fiber calorimeter (45')

G.Yost - SSCL test beam facilities (20')

Simulations and test beam data (H.Ma, J.Brau ...) (35')

Next meeting, plans, AOB (5')

3:00 pm Adjourn

ORNL>

		Bitnet
Yuri Kamychkov	ORNL	KAMYSHKOV@ORPHØ1
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William (Bill) Brower	UCSD	27833:: WSB
Cliff Eberle	ORNL@SSC	SSCVX1:: EBERLE
Mark Rennich	ORNL	REN@ORNLSTC
Hans Cohn	ORNL	COHN@UTKVX
Ren-yuan Zhu	Caltech	ZHU@CITHEX
Jim Reidy	U. Miss.	REIDY@UMSPHY
David Winn	Fairfield	WINN@FAIR1
Howard Gordon	BNL	BNLCL6:: GORDONH
Frank Plasil	ORNL	FRANK@ORPHØ1 46681::FRN
Karl van Bibber	LLNL	PEGASYS@SLACESA
Bennie Ward	Univ. of Tenn	BFLW at SLACVM

Presentation by:

Yuri Kamyshkov

Cost Review of Calorimetry Options

(SSCL April 21-22)

Preliminary

1.	BaF2	$ 80.3 M	China $15 M ?
2.	Sci. Fibers	$ 55.7 M	Albania Belorus $ 11 M ?
3.	Forw. Liq. Sci.	$ 16.4 M	China ?
4.	Sci. Tiles	$ 51.8 M	
5.	LAr e-m + hadr	$ 136.7 M	(+ 4-5% 91→92 $) China e-m ? Russia hadr. mo. Korea cryostat ?
5.1	LAr separate e-m	$ ~ 60.0 M	
5.2	LAr e-m + hadr. forw	$ ~ 84.0 M	
5.3	add accordion prerad	$ > 5.0 M ?	
6.	Forward LAr	$ 15.3 M	
7.	LKr parall. plates + π^0	$ > 37.8 M ?	(cryostat, install. etc. not included)
8.	Si prerad	$ 16.0 M	

Comments

- ✓ Baseline LAr (em + hadr + forw) — $ 152 M
- ✓ Alternative (BaF2 + SciFi + forw) — $ 152 M

- ✓ LAr hadronic @ R = 360 cm and Z = 550 cm doesn't satisfy baseline parameters :
  only 10.2 λ at $\eta = 0.$ and
  11.5 λ at $\eta = 3.$

  The problem is being fixed.

- ✓ Alternative option @ R = 330 cm and Z = 470 cm provides 12 λ at $\eta = 0.$ and
  14 λ at $\eta = 3.$

- ✓ SciFi engineering progress was demonstrated

- ✓ Cost of BaF2 can potentially go up if individual crtystal treatment will be required

- ✓ LAr e-m accordion end cap design - no progress

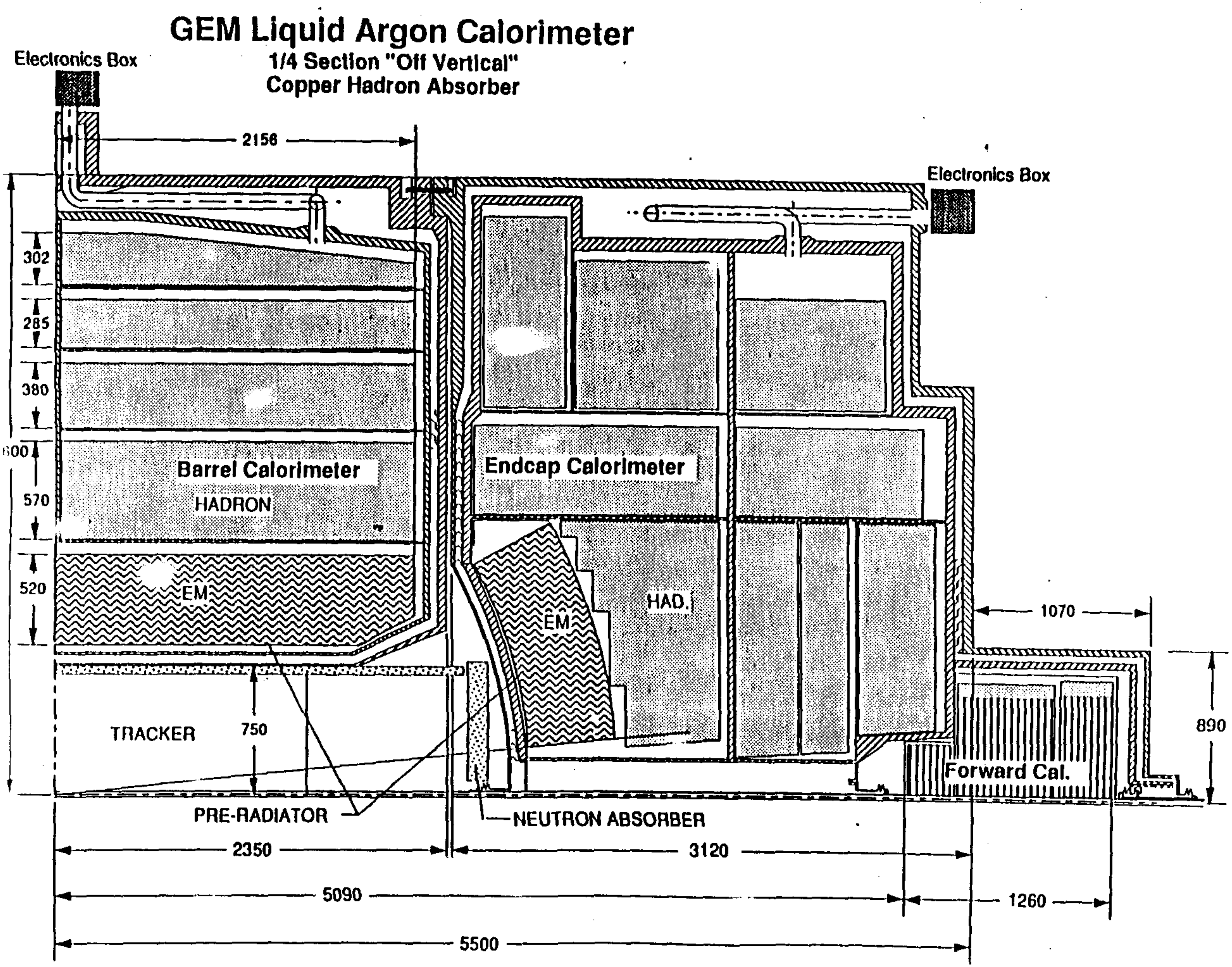
Procedure

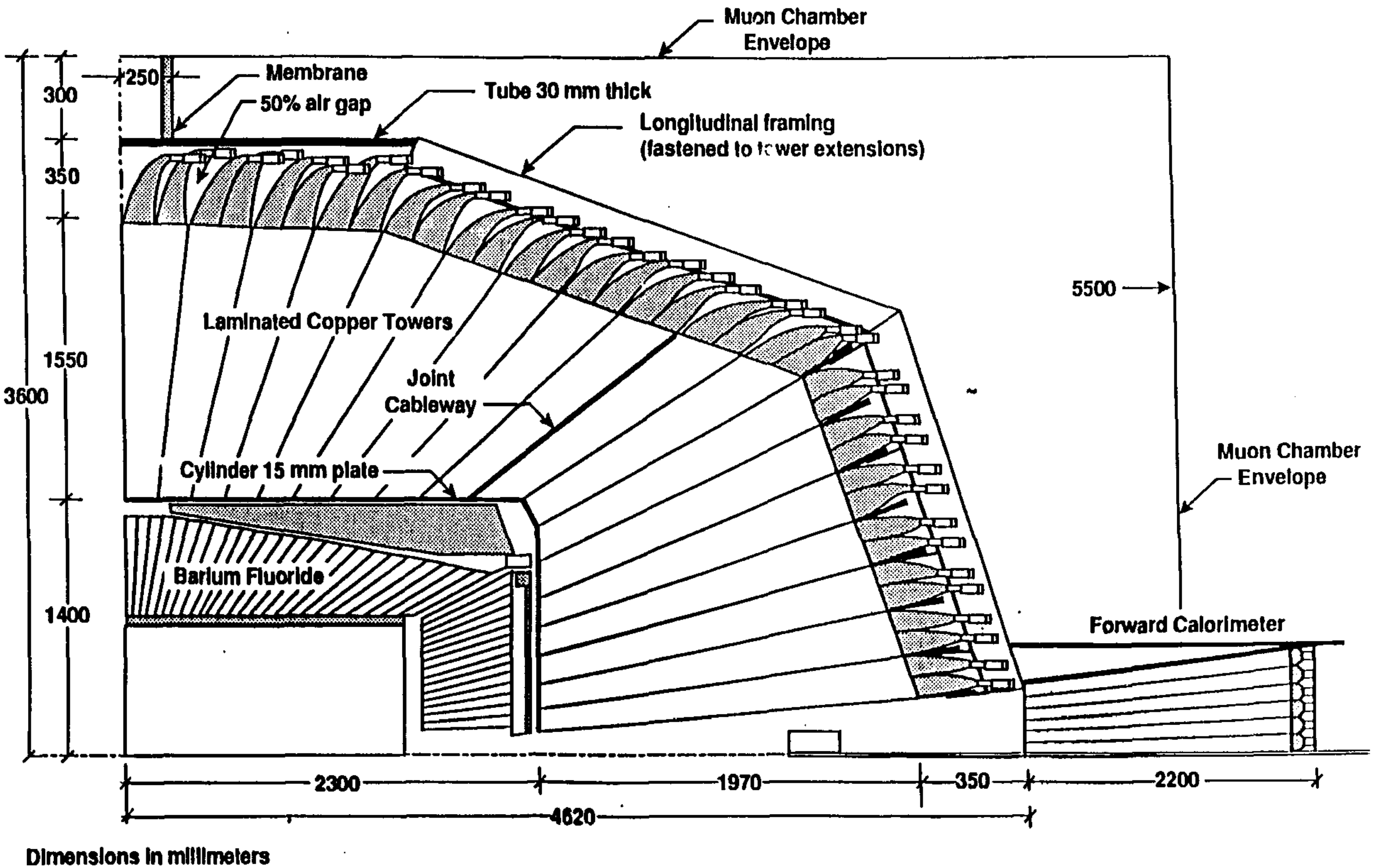
Charge from collaboration management to develop the decision process which should include considerations how different cal. options impact the cost of overall detector (via magnet, muon system, assembly etc.)

Engineering aspects of saving :

1. Direct cost
2. Detector size
3. Utilities
4. Engineering resources

- ✓ We have set the requirements for two e-m options to be resolved before the decision in August
- ✓ Do we have any new information in hadron calorimetry before August ?
- ✓ Are the decisions on e-m and hadron calorimetry are tightly coupled together? Why ? *Mixed options.*
  └ physics, eng., cost, or others ?
- ✓ Do we want NOT to make any decisions between now and August?


GEM Liquid Argon Calorimeter
1/4 Section "Off Vertical"
Copper Hadron Absorber
Electronics Box
2156
Electronics Box
302
285
380
600
570
520
Barrel Calorimeter
HADRON
EM
Endcap Calorimeter
HAD.
EM
1070
890
Forward Cal.
TRACKER
750
PRE-RADIATOR
NEUTRON ABSORBER
2350
3120
5090
1260
5500



GEM Scintillator Calorimeter System

F. Ayer 9203D270

E – m

- More engineering efforts (+? money) are needed for LAr e-m accordeon option

- Engineering aspects of the separate e-m LAr calorimeter option should be studied (M. Rennich, L. Mason)

A. Requirements for BaF2 technology :

1. Demonstrate substantial improvement in radiation resistance of large BaF2 crystals (20-25 cm long) towards the GEM specifications - reach absorbtion length of at least >60 cm at 220 nm after 1MRad irradiation with photons, and if possible high energy hadrons. Present a detailed plan to obtain final GEM quality crystals, along with evidence of manufacturability and cost, including work required to prepare crystals after delivery.

by August 1, 1992

2. As proposed by the expert panel, produce small radiation-hard crystals to demonstrate there are no fundamental limitations in making rad hard BaF2 crystals. (eg. absorbtion length >= 95 cm at 220 nm after 1 MRad)

by August 1, 1992

3. Address in detail questions of preradiation, wrapping, residual non-uniformity, etc in crystals we can practicably expect to manufacture. Cosmic ray transverse measurements in produced crystals could provide useful data. Provide detailed practical plan for calibration of BaF2 system in-situ :describe calibration strategy, RFQ layout, required calibration time for each proposed technique to achieve necessary accuracy.

by July 1, 1992

4. Show by MC and by lab.tests that the following effects do not dest y the resolution of the BaF2 system (maximum tolerable constant term is 0.6%) :

- residual non-uniformity (as installed);
- non-uniformity developed by possible further radiation damage of "saturated" crystals and/or by possible annealing; (note - the expert panel and executive committee are not convinced of the proposal to preradiate the crystals)
- accuracy of intercalibration (see point 3);
- short term instabilities of readout system;
- linearity, linearity calibration and dynamic range of readout system.

by July 1,1992

B. Requirements for LAr-Kr technology :

1. Demonstrate by beam tests stochastic term in resolution for non-projective geometry <= 7%/sqrt(E). Determine angular dependence of this resolution.
by August 1,1992

2. Produce detailed mechanical design/analysis of e-m barrel and end caps with optimization of gap between barrel and end cap, wall thicknesses, etc.
by July 1,1992

3. Demonstrate by MC simulations for realistic projective geometry and full angular range (between 90 and 5.7 degrees) the resolution
<= 7%/sqrt(E) + 0.4%
and physics consequences of the gap between barrel and end cap, wall thicknesses, etc.
by July 1, 1992

Hadronic section

- Hadronic LAr cost:

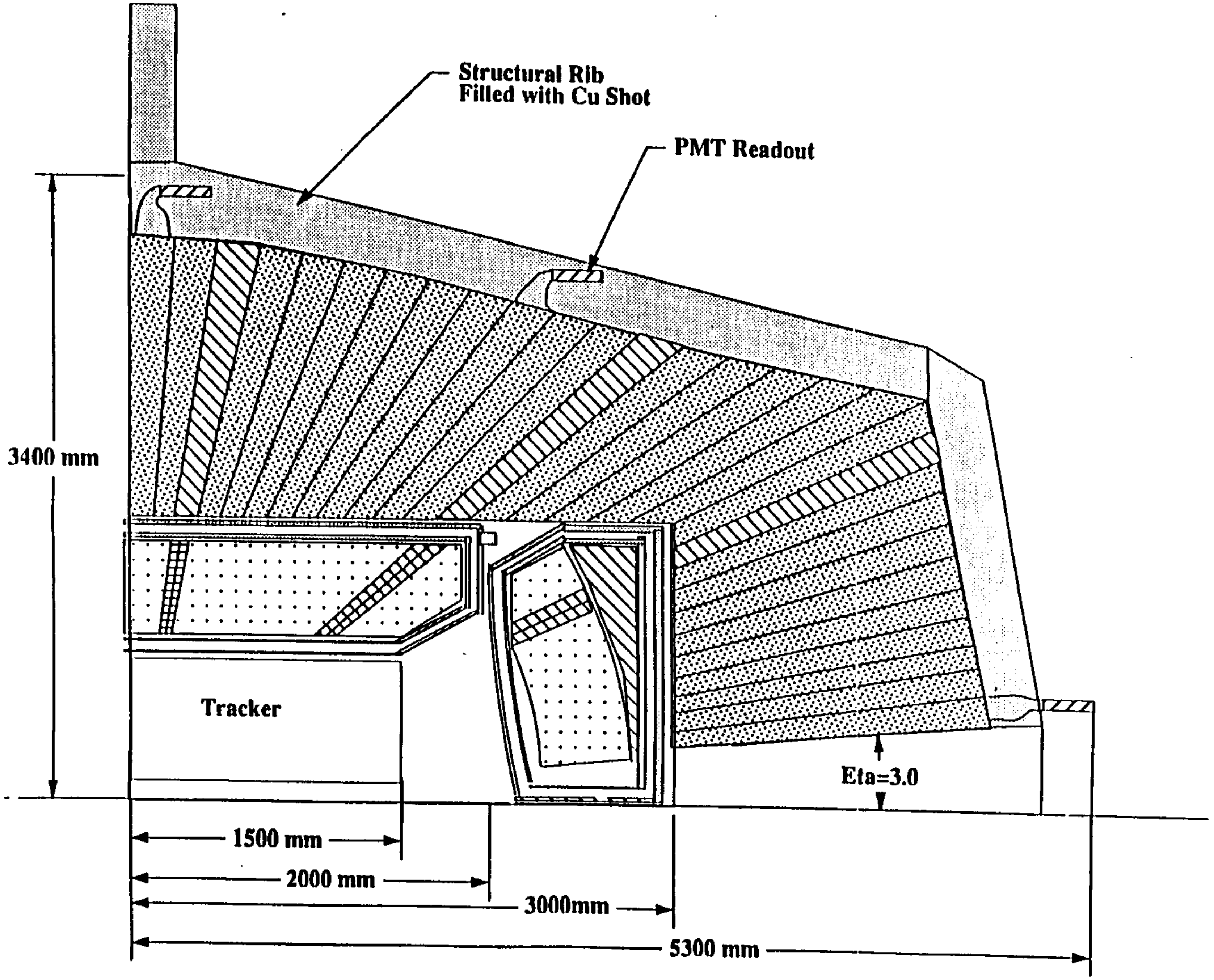
  $\$ (136.7 - 60) \cdot 1.04 \simeq 80$ M

  If lambda shortage will be fixed

  cost most likely will go up

- Hadronic scint. cost:

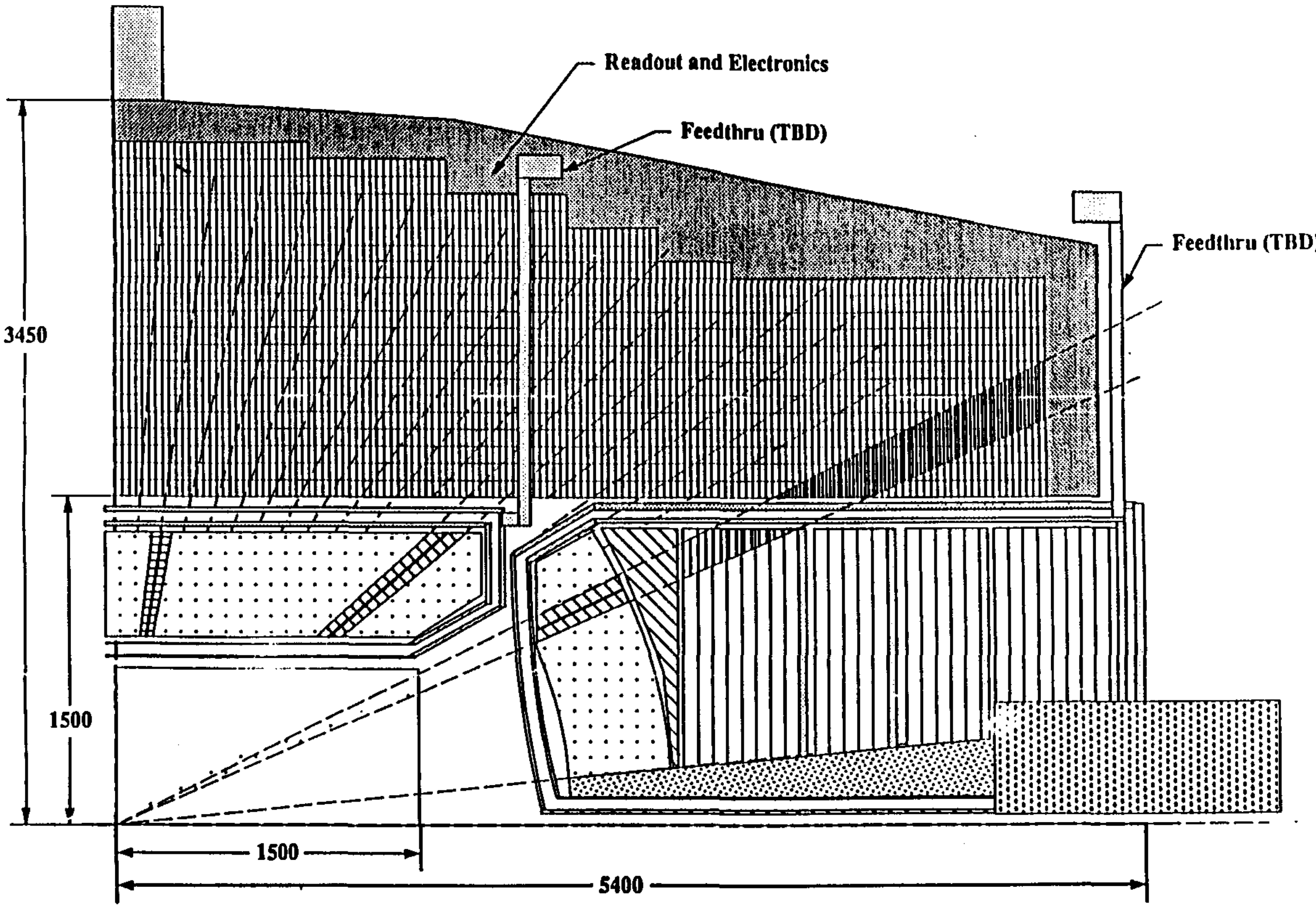
  $ 52 - 56 M



Spaghetti Hadron Calorimeter
Copper Fill/0.12 Segmentation
Liquid Argon EM Calorimeter

G.03.SC.00080

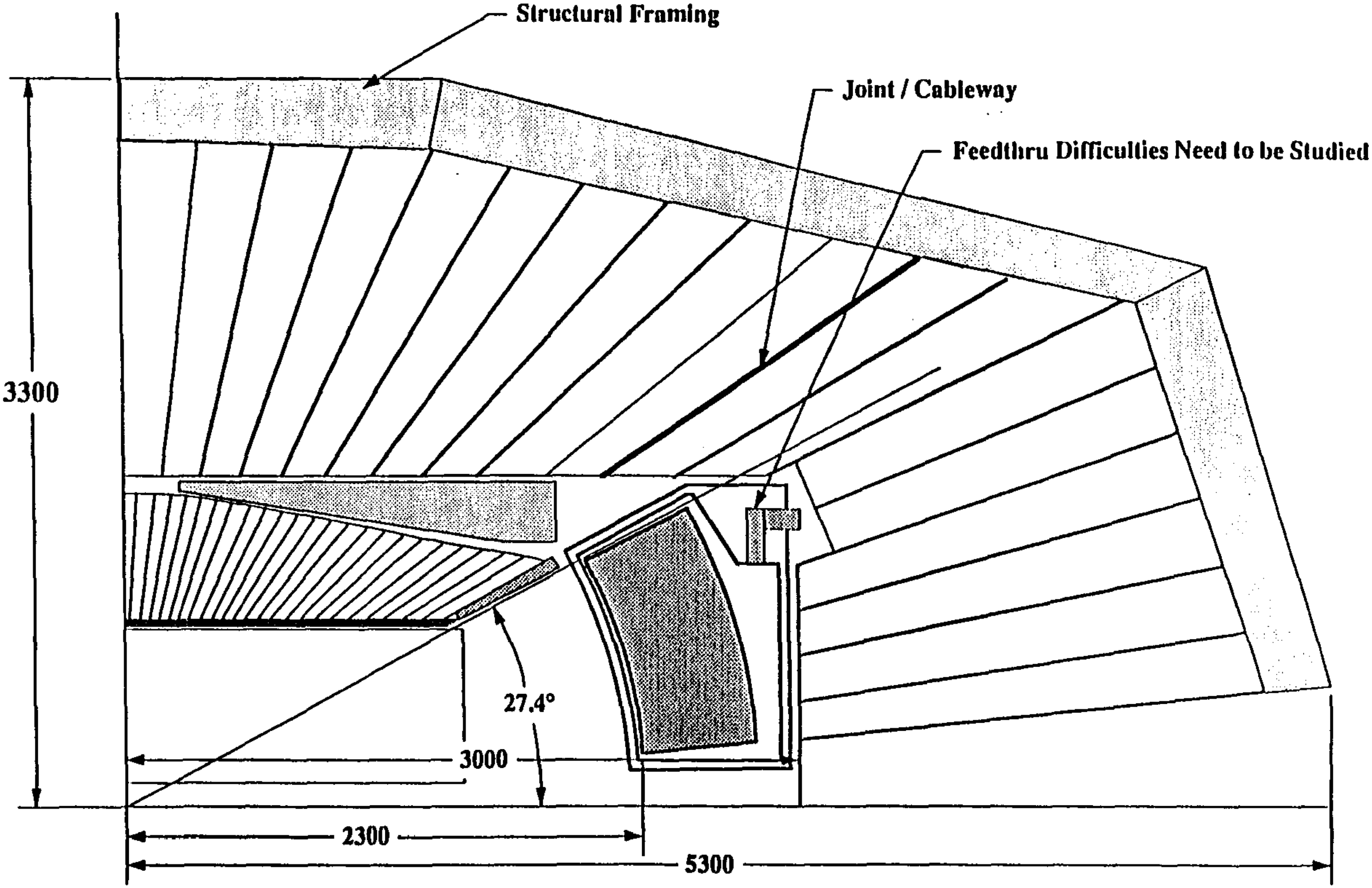
Rennich



GEM Detector
Plastic Tile/Copper
Hadron Barrel Calorimeter,
LAr EM - Hadron End Cap and
LKr EM Barrel Calorimeter

G.03.T.018

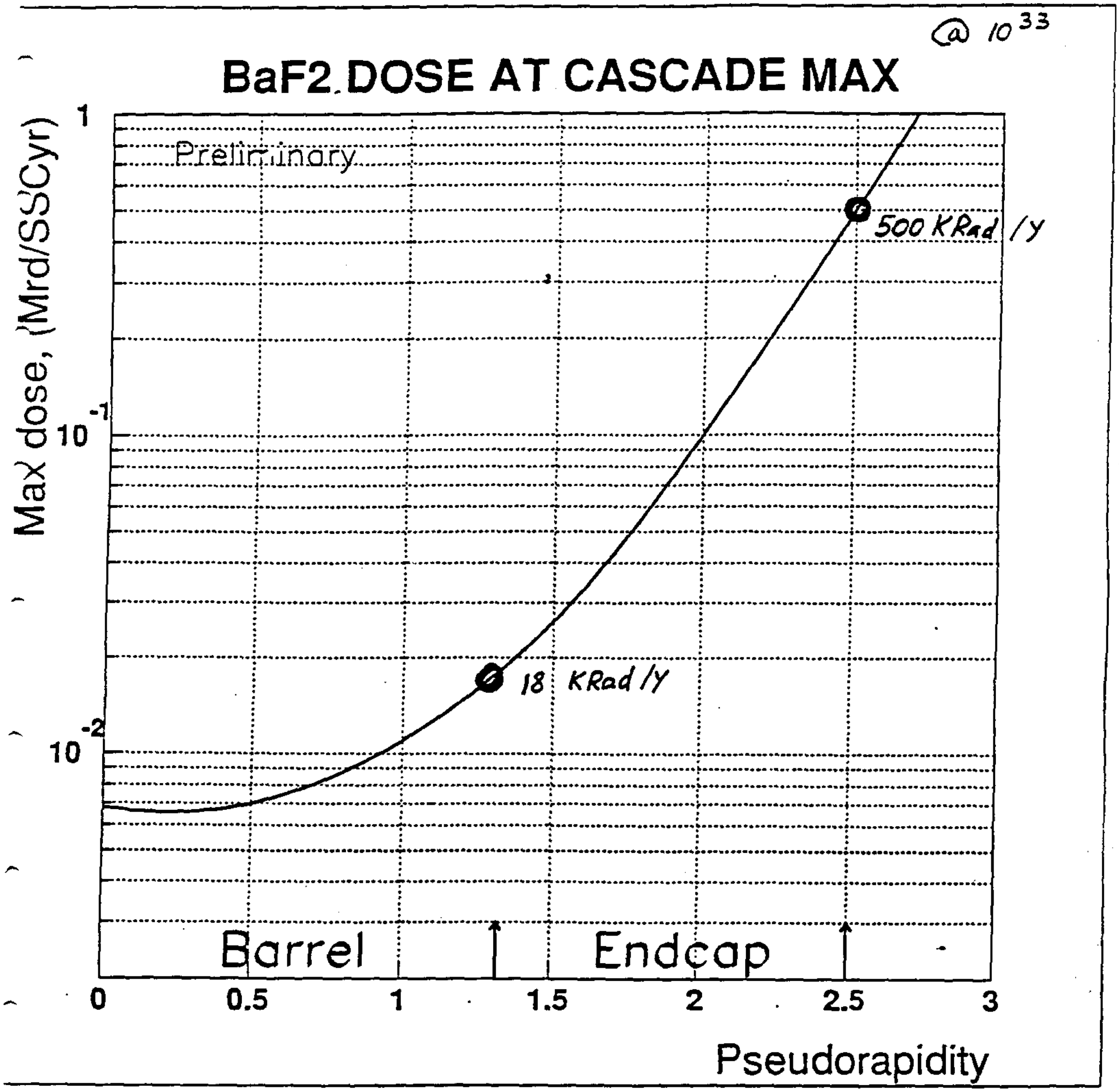
Rennich



GEM Detector
BaFFiLAr Calorimeter

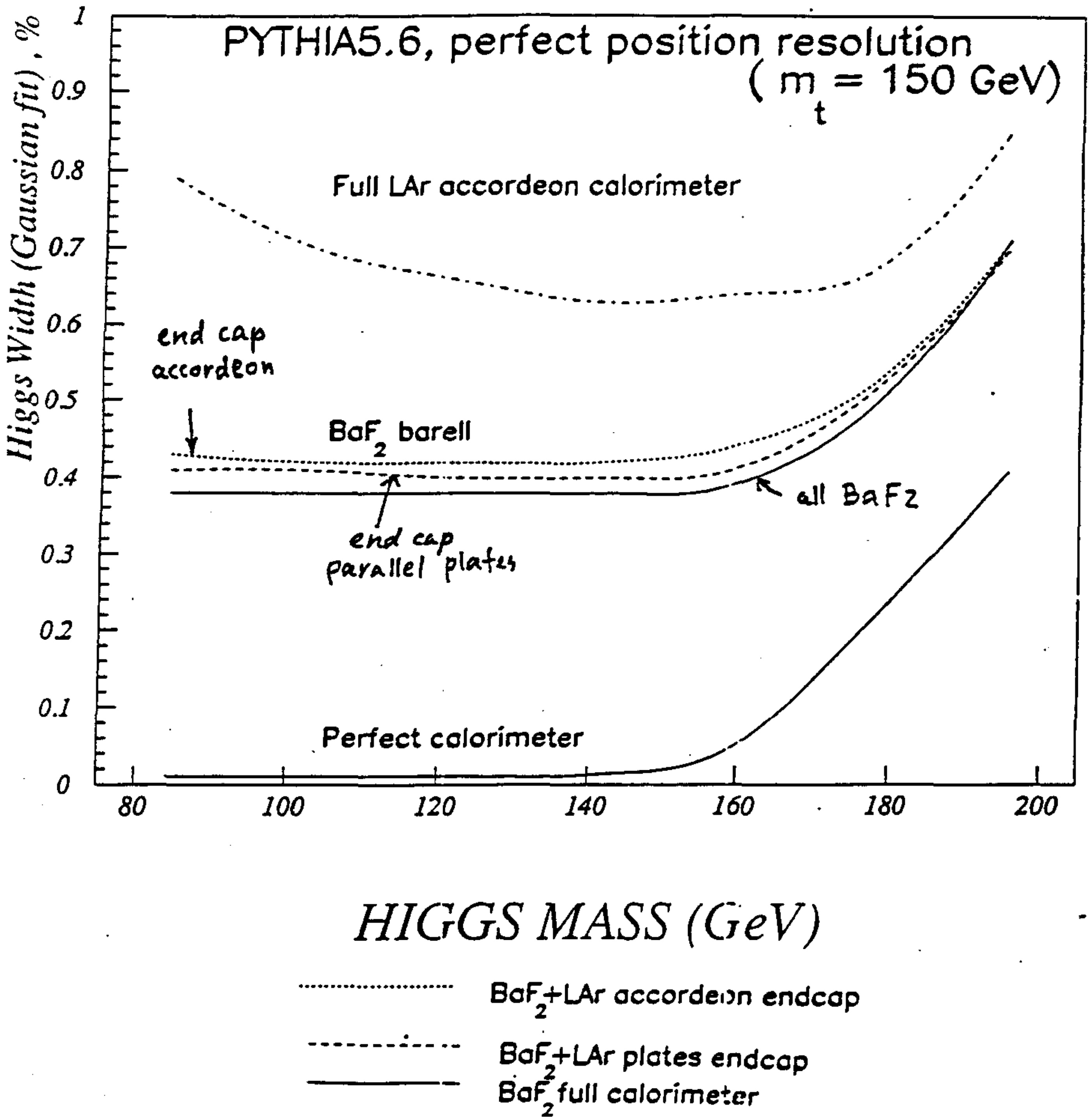
G.03.CU.017

Rennich



@ 10 33
BaF2.DOSE AT CASCADE MAX
Preliminary
Max dose, (Mrd/SSCyr)
1
10 -1
10 -2
500 KRad /Y
18 KRad /Y
Barrel
Endcap
0
0.5
1
1.5
2
2.5
3
Pseudorapidity

HIGGS MASS RECONSTRUCTION



HIGGS MASS (GeV)

Engineering meetings

~ May 12 - 14 at MMA Denver

May 19 at Boston CDL

~ May 27 - 28 at SSCL

gem

γeμ

Presentation by:

Dave Winn

Dave Winn

SCCintCAL Forward Calorimetry

STRATEGY:

[1] **Fiber Geometry:**

No Active Elements, No HV in high radiation environment

Fast - Scintillator,Cerenkov+no WLS+optics -> 40 ns Eh,15 ns em

PMT survives > 100's MRad, also shielded by calorimeter

Replacement possible: fibers exit back of calorimeter

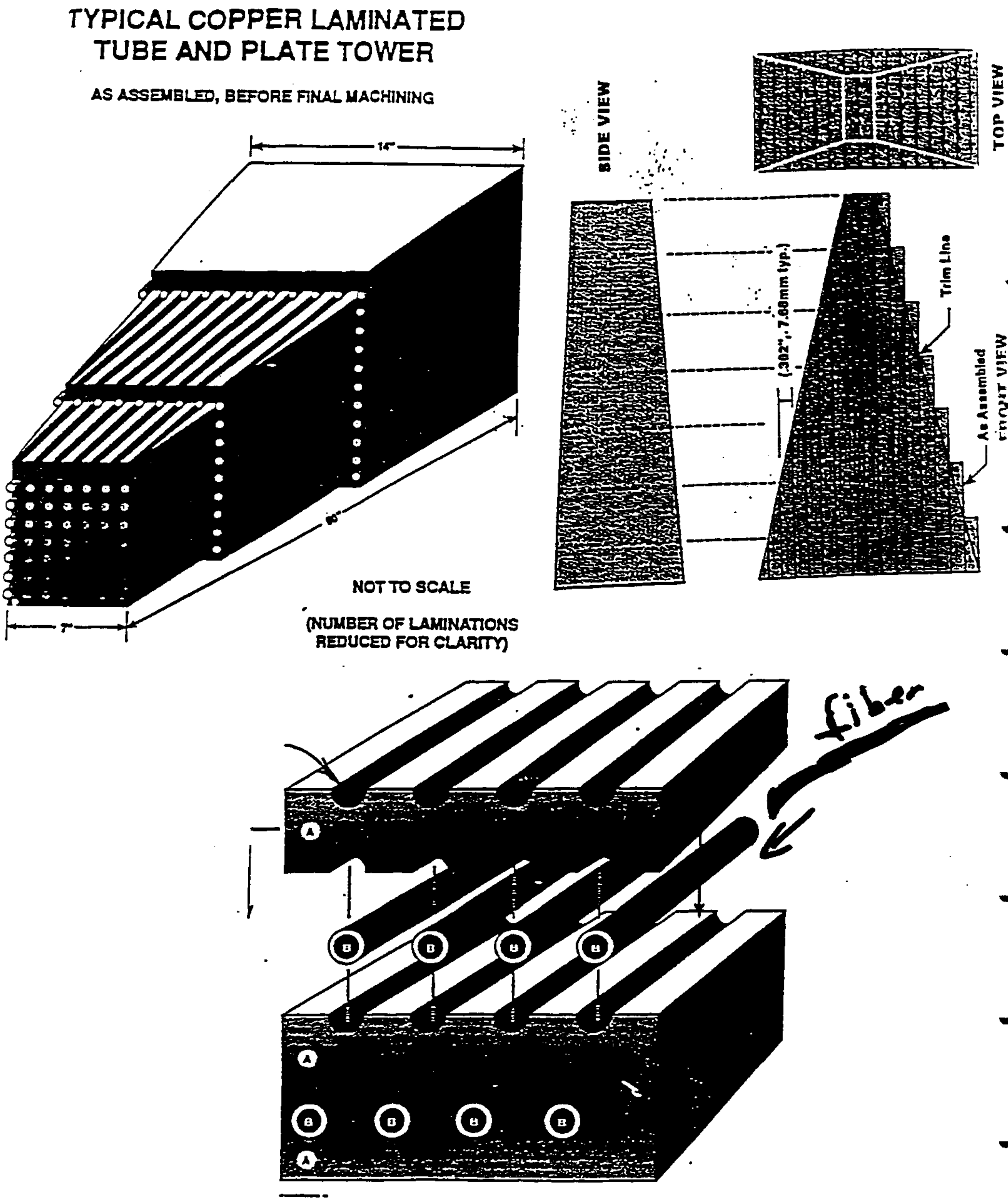
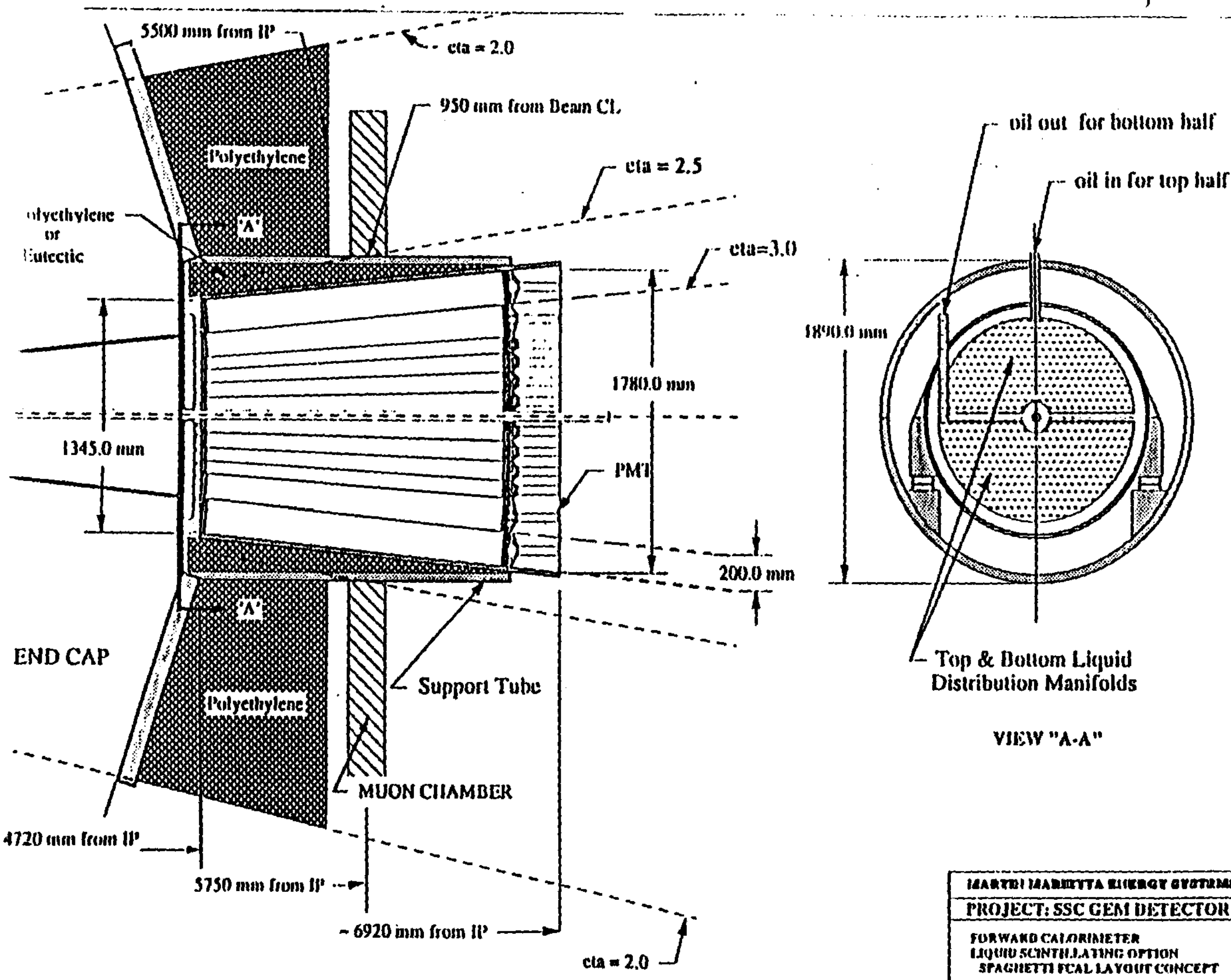


Figure 15a,b: Schematics of SSCintCAL Cu hadron towers - example only for use of the fibers.



NOTE:
1. OIL PIPING SYSTEM IS NOT SHOWN.

MARTIN MARIETTA ENERGY SYSTEMS

PROJECT: SSC GEM DETECTOR

FORWARD CALORIMETER
LIQUID SCINTILLATING OPTION
SPAGHETTI FCAL LAYOUT CONCEPT

PRINT NO: D-FCLS-MD001 | REV 3

DRAWN BY: S. M. CHAE

CHECKED & APPROVED BY:

[2] Two General Rad-Hard Alternatives to Plastic Fibers

•Liquid Core Scintillator Fibers

Liquids:
- Existing liquid scintillators rad-hard to >200 MRad
- pumpable/replacable
- Isopropyl biphenyl: reactor coolant, no plating, n=1.58
- methyl naphthalene, n=1.62; benzyl alcohol, n=1.55

Claddings:

-radiation damage -> Labs, not to refractive index

- PEEK ~ 0.5-1 GRad, n~1.5
- Kapton ~ 0.5-1 GRad, n~1.55
- Halar ~ 200 Mrad, n~1.43
- PUR ~ 200 Mrad, n~1.5
- Quartz or glass tubing, n~1.5
- Viton, Polysiloxanes, n~1.4-1.5

Commercial Technology - Oriel Inc.

N.A.=0.47, Labs=5m, 3 mm fiber polymer spaghetti
Sealed optical end plugs
Flexible (can be bundled)
Rugged
Replace Claddings & Liquids as above
Optical surface obtained by standard die extrusions

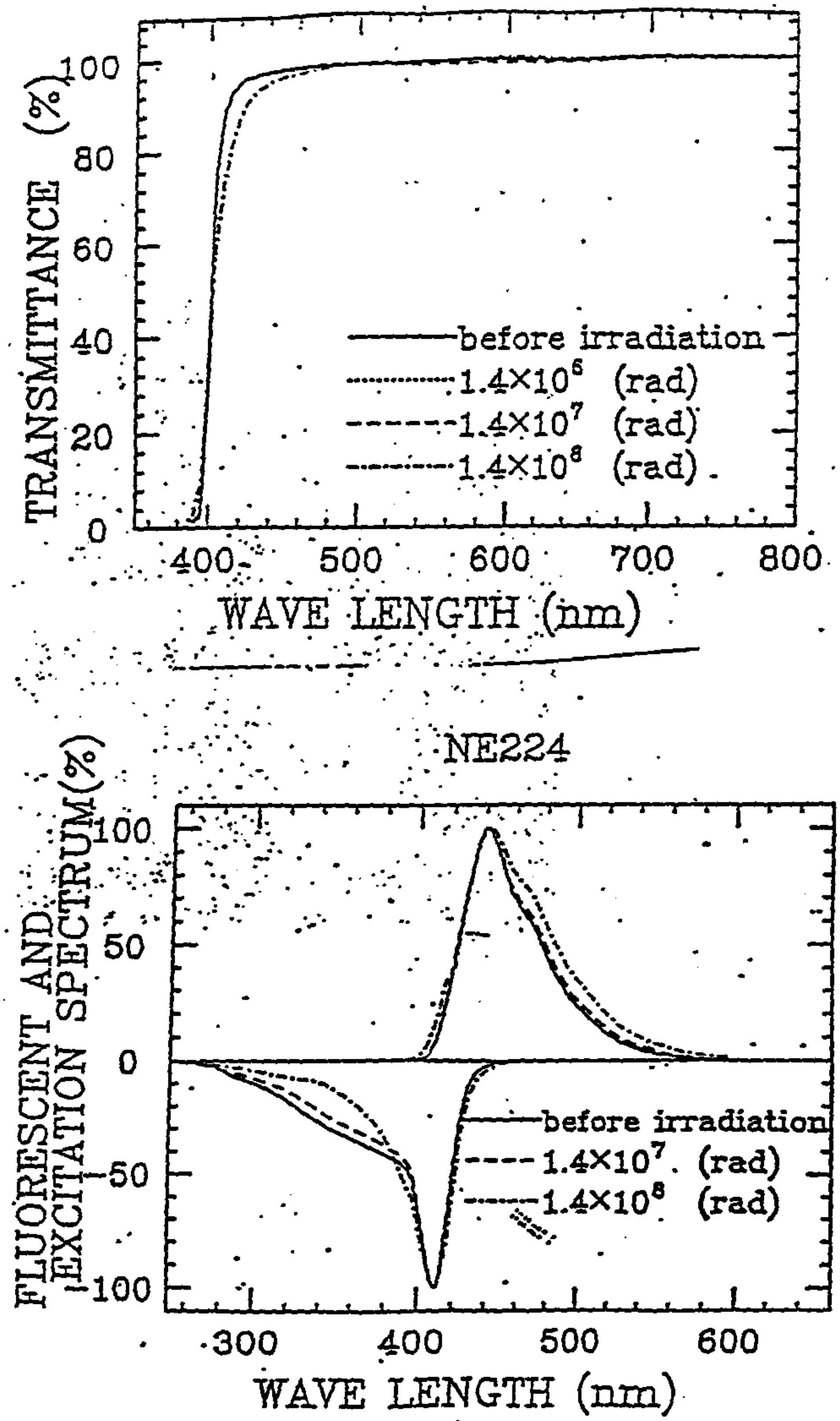


Figure 1:Typical toluene based liquid scintillator's (NE224) properties before and after 140 MRad [Chiba et al p 381, CDF Conference at Tsukuba, April, 1990, KEK publ.]

HALAR® ECTFE FLUOROPOLYMER

HALAR® ECTFE is a melt processable fluoropolymer from Ausimont, Inc. It possesses a unique combination of properties as a result of its chemical structure - a 1:1 alternating copolymer of ethylene and chlorotrifluoroethylene.

HALAR fluoropolymer offers excellent chemical resistance, good electrical properties, broad use temperature range - from cryogenic to 300°F(150°C), and meets the requirements of the UL-94 V-O vertical flame test in thicknesses as low as 7 mils. It is a tough material with excellent impact strength over its broad use temperature range. HALAR ECTFE also maintains useful properties on exposure to cobalt - 60 radiation at dosages of 200 megarads. It is one of the best fluoropolymers for abrasion resistance.

HALAR fluoropolymer is a thermoplastic which can be processed by virtually any technique applicable with polyethylene. It can be extruded, injection molded, blow molded, rotomolded, and applied by ordinary fluidized bed or electrostatic coating techniques. It is available in a range of viscosity grades for extrusion and molding applications. HALAR ECTFE powders are available in three different particle sizes optimized for specific coating processes.

For The Designer and Processor

Processability - HALAR fluoropolymer can easily be processed by injection molding, compression molding, blow molding, extrusion, rotomolding, and electrostatic spray and fluidized bed coating techniques.

Thermal Properties - The continuous thermal rating for HALAR flouropolymer is 300°F (150°C) depending on resin grade.

Chemical Resistance - HALAR fluoropolymer is resistant to a wide variety of corrosive chemical and organic solvents, including strong acids, chlorine and aqueous caustic. No Known solvent dissolves or stress cracks the polymer at temperatures up to 250°F (120°C).

Electrical Properties -The dielectric constant of HALAR fluoropolymer is low (2.6 for solid insulation to 1.5 for foamed insulation) and stable across a broad temperature and frequency range. The dielectric strength is 2000 volts/mil in 1 mil thickness.

Toughness and Strength - HALAR fluoropolymer possesses excellent mechanical properties over a wide range of temperature from cryogenic temperatures to 300°F (150°C). It has nylon-like durability and provides excellent impact resistance at ambient and subambient temperatures.

Weldability - HALAR fluoropolymer is weldable with ordinary thermoplastic welding equipment at 480-500°F (249-260°C).

Barrier Properties - Barrier properties of HALAR fluoropolymer are excellent - 10 to 100 times better than those of PFTE or FEP to oxygen, carbon dioxide, chlorine gas or hydrochloric acid.

Radiation Resistance - HALAR fluoropolymer maintains useful properties on exposure to cobalt 60 radiation of 200 megarads.

Flammability - HALAR fluoropolymer, in thicknesses as low as 7 mil, has received a UL 94 V-O rating. The oxygen index (ASTM-D-2863) of HALAR fluoropolymer is 60 on a 1/16" thick specimen and 48 for .0005 inch diameter filament yarn.

Flame Spread and Smoke Generation - HALAR fluoropolymer, because of its low flame spread and low smoke generation characteristics, has received UL 910 (NFPA 262) listing up to 200 pair communication plenum cable.

Weatherability - No change after 3000+ hours exposure in a Xenon arc weather-ometer.

Machinability - Similar to nylon 6.

Water Absorption - Less than 0.1%.

n = 1.42

Figure 6: Properties of Halar from the manufacturer; Note Radiation Resistance of 200 MRads.

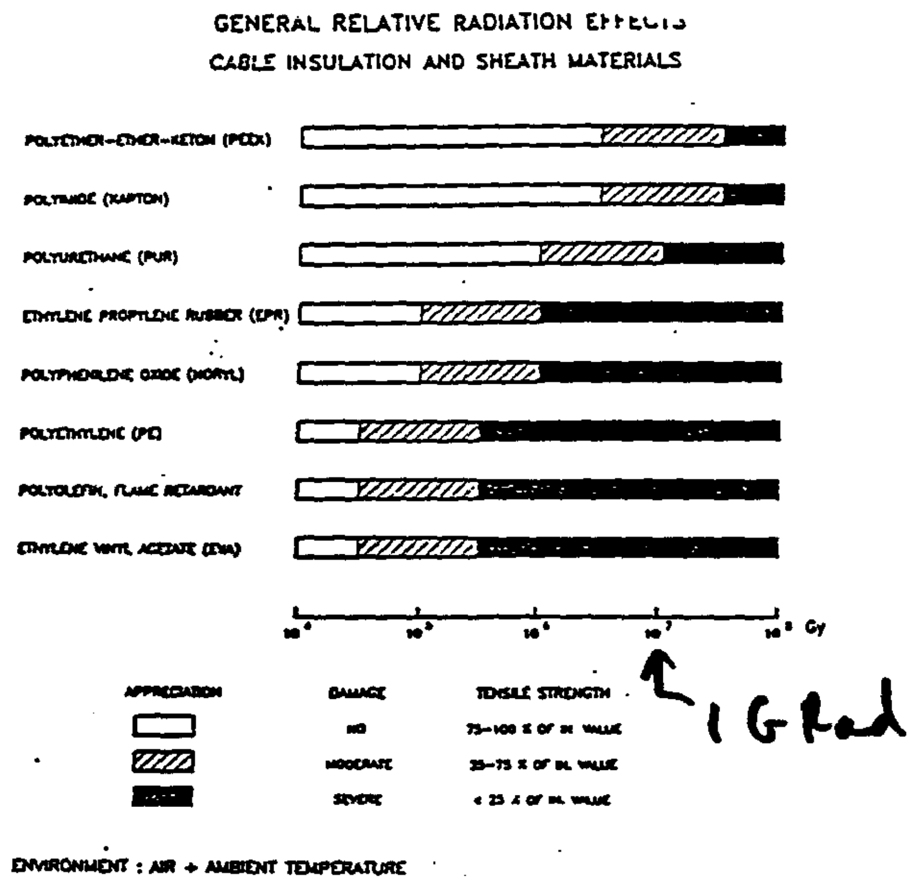
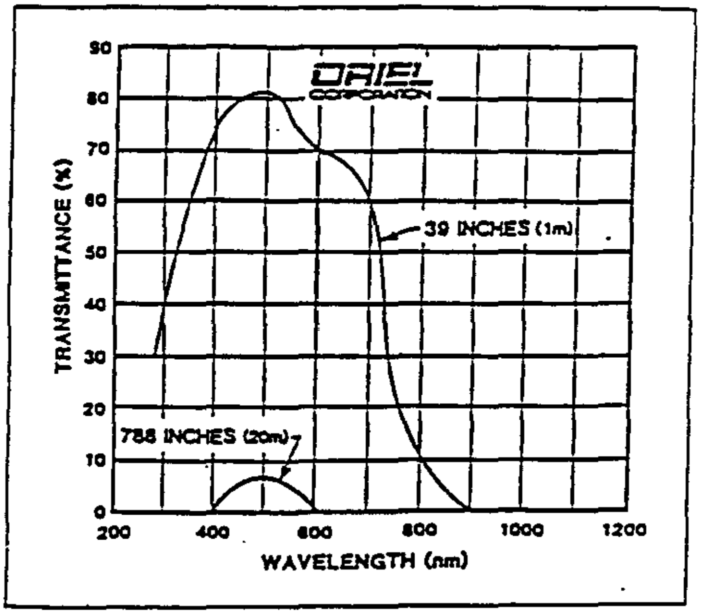
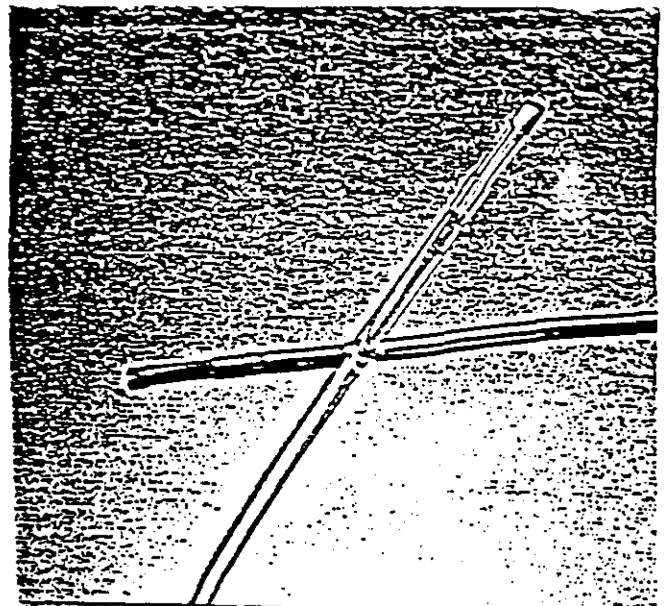
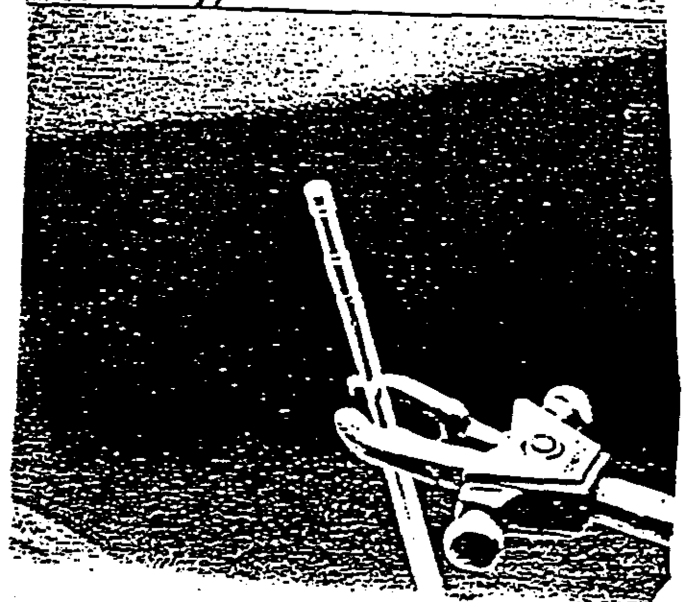
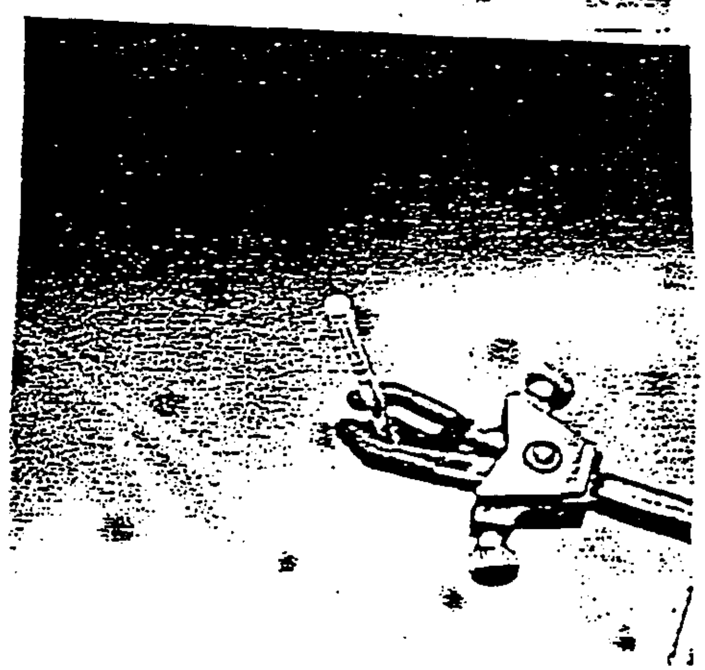


Figure 7: Radiation resistance of some polymers from a CERN report. Note the highest 3 will be investigated as claddings using commercial tubing manufacturers as the tubing sources.


ORIEL CORPORATION
TRANSMITTANCE (%)
WAVELENGTH (nm)
39 INCHES (1m)
788 INCHES (20m)
0 10 20 30 40 50 60 70 80 90
200 400 600 800 1000 1200







ORIEL LIQUID LIGHT GUIDES

- Excellent light gathering - large cores, no packing losses, high N.A.
- High UV transmittance - from 270 nm
- Flexible tubing

Liquid Light Guides transfer ultraviolet and visible radiation very efficiently. These light guides function in a similar manner to fiber optic bundles, using internal reflection to guide energy along their length, but they have higher transmittance than fused silica bundles of equivalent core size and are more flexible. (See Fig. 1 for a transmittance curve.) Liquid light guides are usable from 270 to 720 nm.

CONSTRUCTION

Liquid Light Guides consist of a plastic tube covered by a protective aluminum spiral and covered by a PVC jacket. The inner tube is filled with a proprietary, transparent, anaerobic non-toxic fluid. The tube is sealed at both ends with polished fused silica windows and protected by an interlocking stainless steel sheathing.

Like our fiber bundles, these guides have 11 mm ferrule adapters that mount to any Oriel Fiber Optic Cable Accessory found on pages 8-20 to 8-23.

Our liquid light guides are robust and long lived in normal use. To ensure long life the temperature at the input face should not exceed 60 °C.

LARGE CORE DIAMETERS

We offer liquid light guides in larger core diameters than our fiber bundles. The guides use the full input aperture and have no packing fraction losses. The large core diameters, and the high numerical aperture allow efficient coupling to large light sources. Core diameters of 3 and 5 mm are standard; 8 mm core diameters are available on special order.

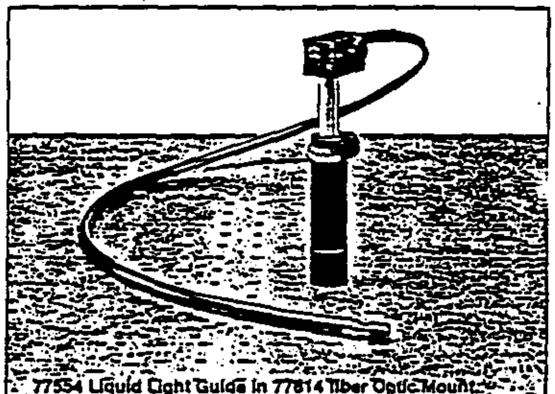
LIGHT ACCEPTANCE

The acceptance angle a for these guides is 28 degrees, with corresponding NA of 0.47. The acceptance cone angle 2a is 56 degrees. The geometrical extent, a measure of fiber optic light gathering capability, is 14.4 mm^2 sr for the 5 mm guides. This compares with 3 for the 3.2 mm diameter fused silica bundles and 7 for the 3.2 mm diameter glass bundles.

BEND RADIUS

The minimum bend radius for the 3 mm core guides is 3 inches (76.2 mm), and 4.8 inches (122 mm) for the 5 mm core guides.

Changing the position of the guide will change the output beam distribution and power. Care should be taken to avoid appreciable movement of the guide during a measurement.



77554 Liquid Light Guide in 77614 Fiber Optic Mount

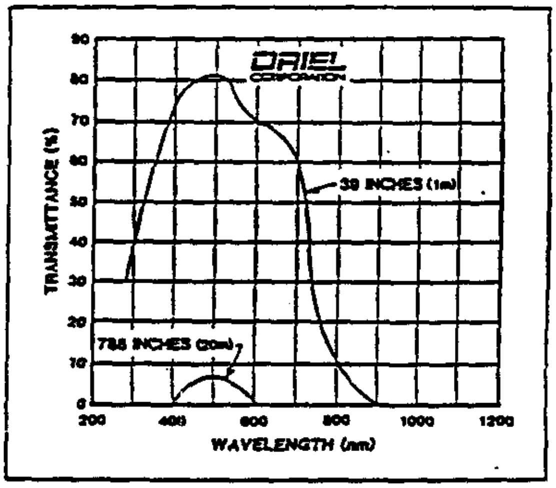
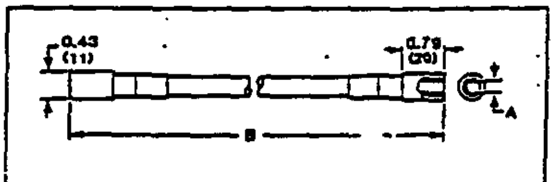


Fig. 1 Transmittance of Oriel Liquid Light Guides.



Dimensions in inches (mm).

Fig. 2 Oriel Liquid Light Guides.

Figure 8: Oriel spec sheet for liquid optical light guide. Note sample in photograph is armored.

ORIEL
CORPORATION

April 1, 1992

Dr. David Winn
Fairfield University
Physics Department
Fairfield, Connecticut 06430

via fax: 254-4126

Dear Dr. Winn:

We are looking forward to our participation with your team in the development effort for the SSC forward calorimeter based on liquid light guide scintillator concept.

The time scales listed in your proposal, even though somewhat ambitious, appear to be feasible and we would exert every e ort to help you meet them. The total budget for our part of the effort, with some ext a contributions of our engineering team time, appear to be appropriate for the scope of the project. We would like to offer to contribute extra effort as needed, up to 20% of that planned below, to help achieve the goals of this work.

The project will be charged at cost for materials, components, and consultant time. Engineering and assembly time will be charged with 35% corporate overhead rate added. We are projecting that materials and fixtures will consume $29,200. Use of the equipment located in Oriel's test laboratories, such as the light sources and detector systems, is included in the overhead rate. We plan to utilize the consulting services of Mr. Clyde Hinman for 120 hrs, at an hourly rate of $40.00, for a total expenditure of $4,800. A total of 400 hrs of labor is planned for the assembly and testing of the 800 fibers for the Calorimeter Tower. 600 hour effort is planned for adapting our light guide technology to this ne application and assistance in materials testir and optical properties determination.

250 LONG BEACH BLVD., P.O. BOX 872, STRATFORD, CT U.S.A. 06497 ■ TEL (203) 377-8282 ■ TWX 710-453-8719 ■ FAX 203 378-2457

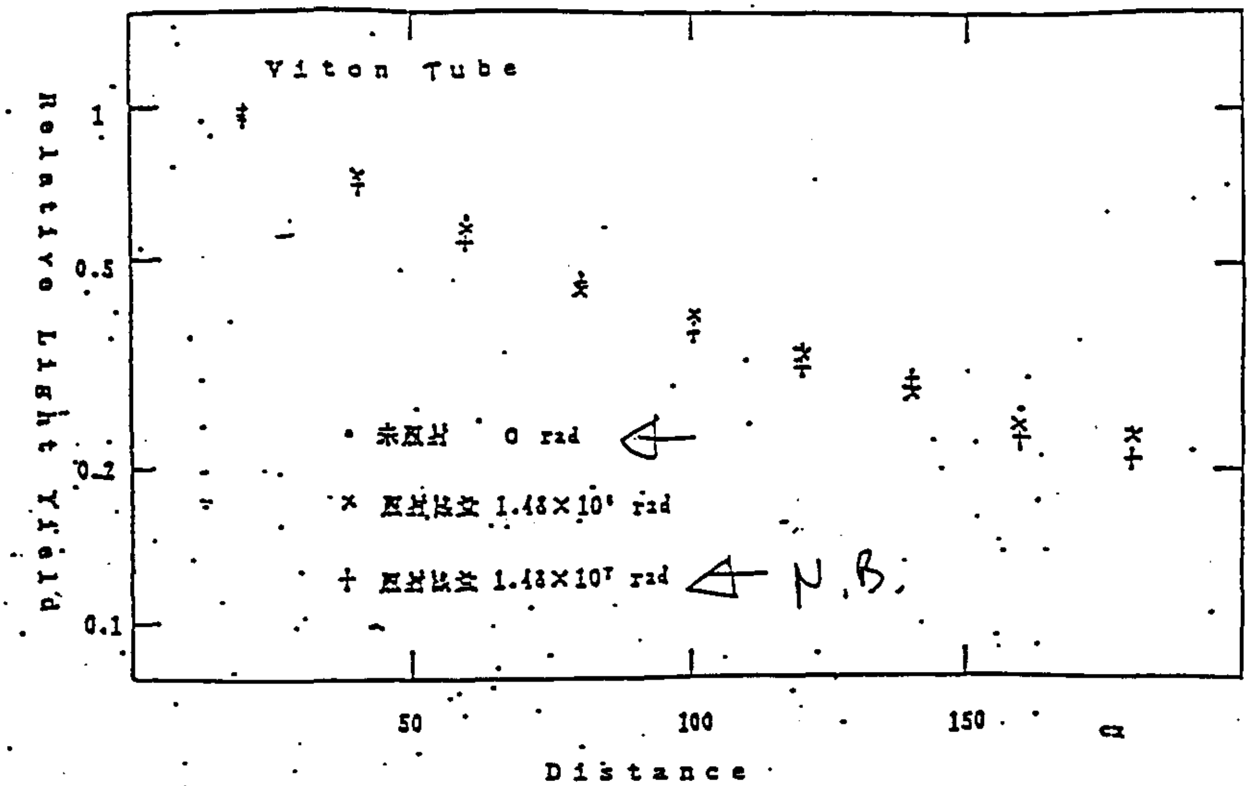


Figure 3a: Light yield as a function of distance, before and after 15 MRads: NE224 in a Viton Tube Chiba et al p 381, CDF Conference at Tsukuba, April, 1990, KEK publ.]

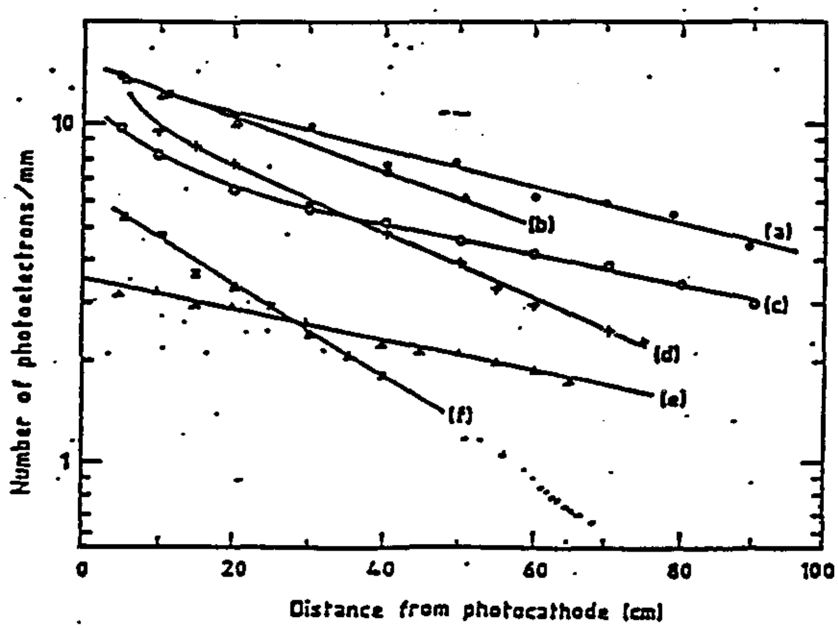
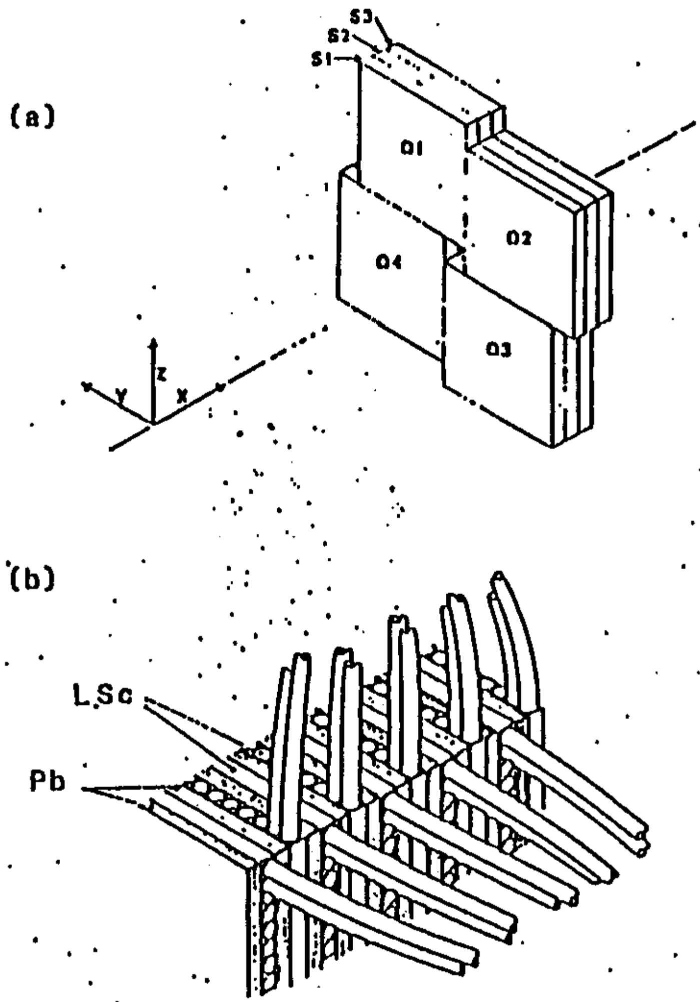
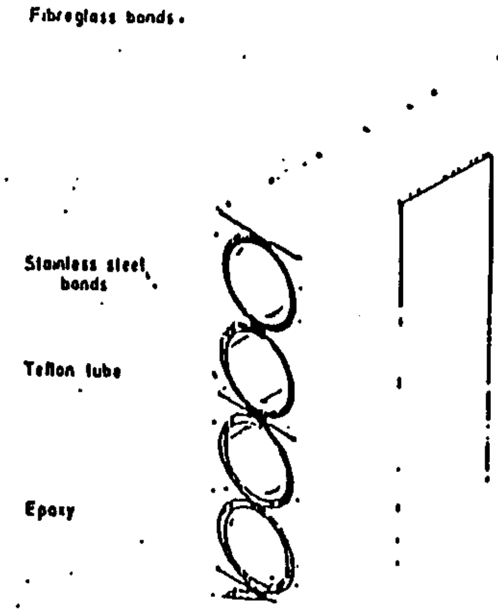


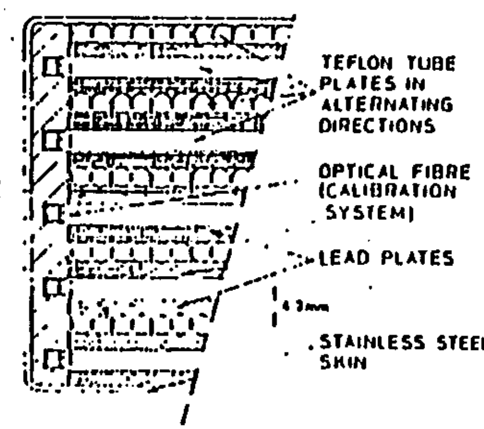
Figure 3b: Light yield as a function of distance in glass capillaries for various high index liquids produced by Bicron, Inc. [J. Bahr, et al., NIM A306 169 (1991)]



(a) The geometry of the calorimeter, showing the four quadrants (Q) and the three segments (S). (b) The structure of the outer corner of one segment showing the lead (Pb) and the tubes of scintillator (Sc). Light from groups of tubes in the five layers in a given direction was mixed and fed to one photomultiplier. Groups of two tubes gave a granularity of 1.07 cm.



Teflon tube plate.



Calorimeter construction: detail of one segment.

Figure. 5: Plate calorimeter using plates of liquid scintillator in teflon tubes, used at CERN [M. Bonesini et al NIM A270 32 (1988) & NIM A263 325 (1988)]

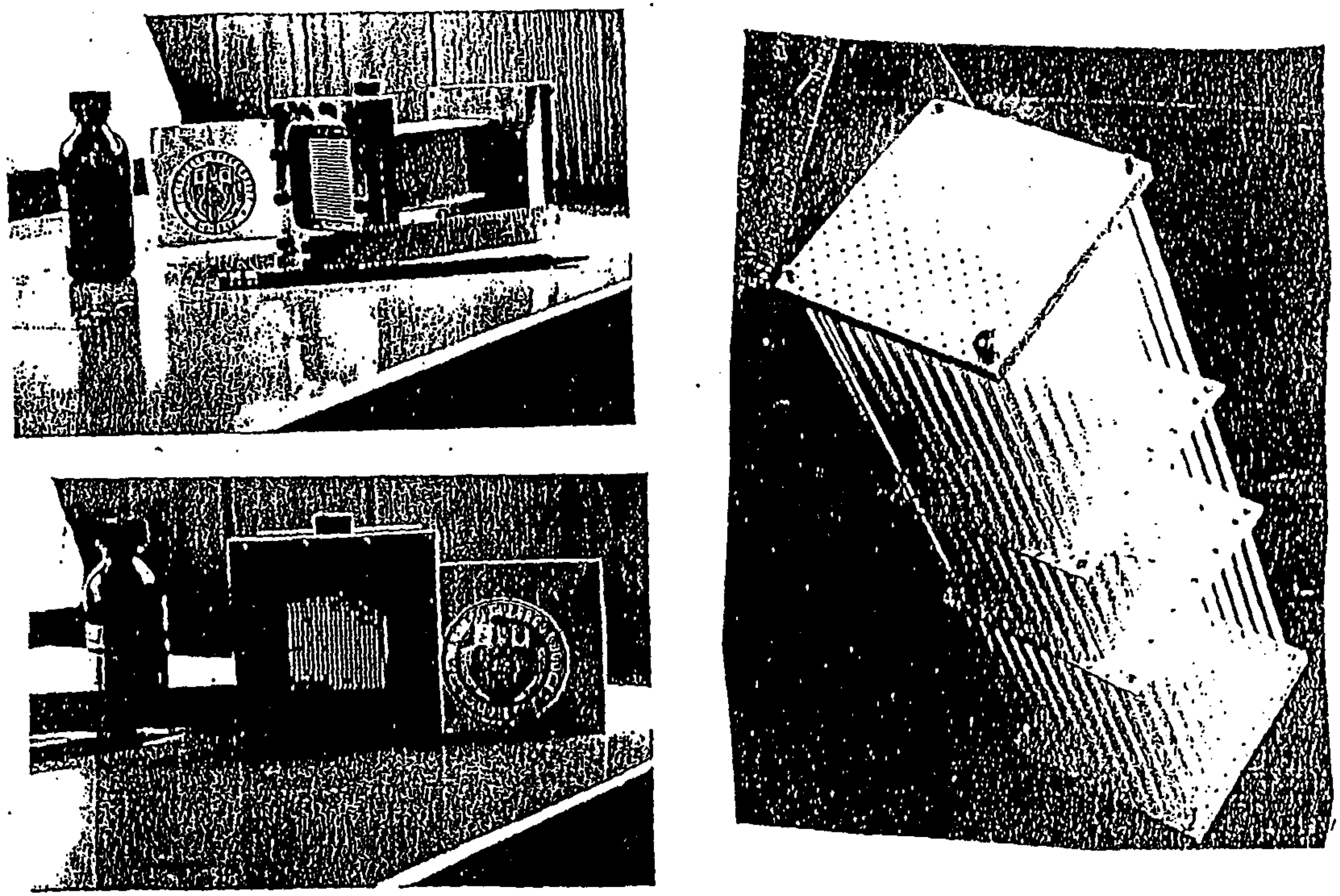
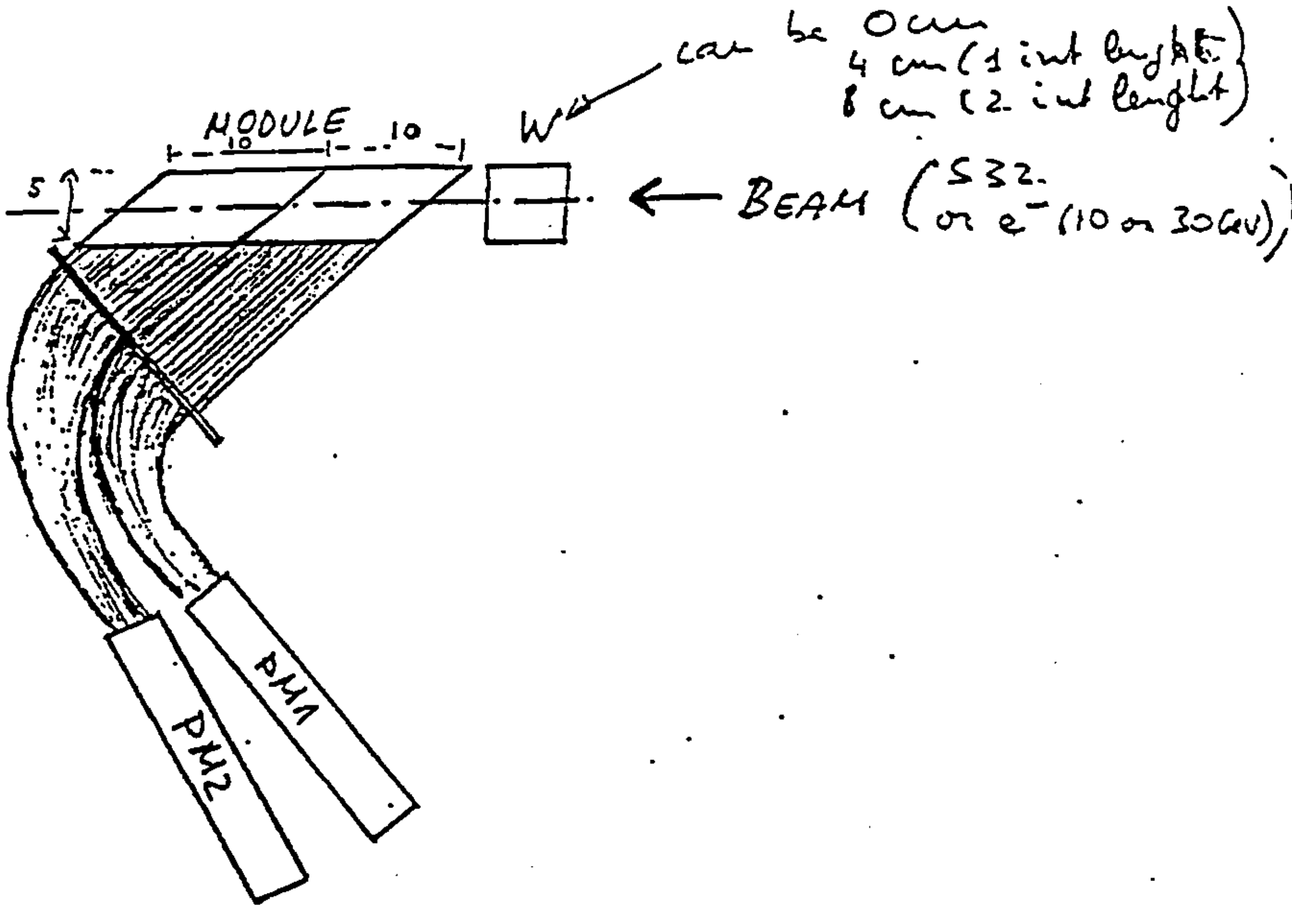


Figure 4: Liquid spaghetti E-M calorimeter using teflon tubes filled with liquid scintillator, constructed and tested at BNL by the authors [IEEE TNS]. (a): Teflon spaghetti armature; (b) Cast Pb block encased in SS containment vessel with glass windows for PMT. The resolution was about 17%/E**0.5 at low energy (1-3 GeV).

- **Quartz Fiber Cerenkov Sampling**

  -[Developed for NA38 - Ph. Gorodetzky]

  - Potentially hard to 10's GRads
  - 1 mm Quartz fibers w/ PEEK cladding: \$5/m
  - 3 mm Quartz tubes: \$9/m
  - Energy: 3-4 p.e./GeV hadrons; 35-40%/$\sqrt{E}$ em
  - Resolution: ~8-10% constant term hadrons
  - Exceptional Speed



DIMENSIONS OF THE MODULE : 5 x 5 x 20 cm

THICKNESS OF TUNGSTEN BLOCK : 0, 4, 8 cm

1474 FIBERS 50 cm LONG.

DISTANCE BETWEEN FIBERS 2.22, $V_{Pb} : V_{Fib.} = 4:1$

INTERACTION LENGTHS FOR S^{32}:

- IN W $\lambda_{int} = 4$ cm

- IN MODULE $\lambda_{int} = 9.1$ cm (including quarz fibers)

Figure 10: Schematic of the the 5x5x20 cm quartz fiber Cerenkov sampling calorimeter module read out by 2 PMT, tested at CERN in an Sulphur-32 (160 GeV/nucleon) or e- (10-30 GeV) beam. Note that the 1mm quartz fibers (20% p.fraction) are arranged to maximize at least some of the Cerenkov emission along the fiber meridional ray. The tungsten is to partially develop the hadron shower before the calorimeter. [Courtesy of P. Gorodetzky].

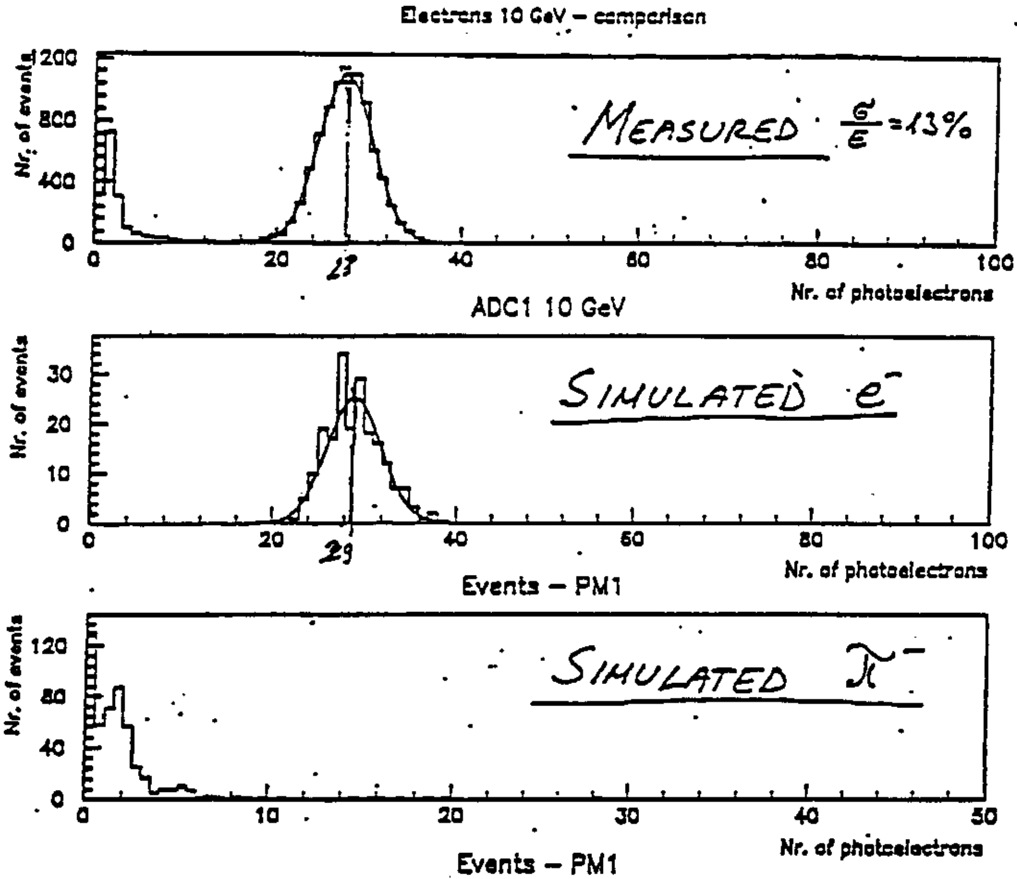


Figure 11: The measured & simulated ADC spectra (resolution) for electrons at 10 GeV in the quartz fiber Cerenkov calorimeter of Fig. 10. Note the simulated 10 GeV pions reproduce the low energy peak in the data. The resolution is roughly 37%/√E. [Courtesy of P. Gorodetzky].

PMT Specifications

DRW - 5/1/92

Photocathode:

- Photocurrent: 2% linearity for 10^7 p.e. in 10 ns
- Lifetime: 1 mC for 50% gain loss
- Uniformity: ±10% over 25 mm circle

Multiplier:

- Gain: ~6,000-10,000
- Pulsed Current: 25 mA in 10 ns with <0.5% non-linearity
  200 mA in 10 ns <2% non-linearity
- Risetime (delta f^n pulse, 20%-80%, 10ma in 50 Ω) : < 4ns
- Falltime (delta f^n pulse, 80%-20%, 10ma in 50 Ω) : < 6ns
- Width at Baseline (5%): < 12 ns
- Pulse Shape Change: < 20% for pulses between 0.1 -100 mA
- Average Anode Current: 1 μA
- Lifetime: 2 C w/ 50% loss
- Anode Capacitance: < 10 pF to all other electrodes combined
- Anode Inductance: < 45 nH

Noise:

- Single p.e.: <100 kHz at 0.5 pe peak
- Afterpulsing: < 0.1%/p.e for afterpulses > 10 p.e.
- Pre Pulsing: Arrival < 5 ns early
  amplitude< 0.5% of signal

Stability:

- Long Term: < 1%/month
- Hysteresis: <1% gain shift within 100 ns after pulse of 10 ma x 10 ns

Magnetic field: Operates parallel to 0.7 T

Full Scale: 5 TeV jet
Min Scale: 0.1 min ionizing ~ 50 MeV
Gain: Max Charge = 200 mA x 10 ns=2 nC, 100 p.e./GeV-> Gain = 12,000

SSCintCAL CALIBRATION DRW- 5/1/92

1. Absolute:

- Radiosources, cross calibrated with beam tests
  - Cs or Co source capsules on wires in tubes (like CDF)
- Landau Distributions
  - See SPACAL reports; detailed difference $50<E\mu<200$ GeV
- Pion Punch-thru
  - Tracker + min. ionize in BaF2 + isolation -> E pion known.
- Neutron Generator Activation, cross calibrated
  - 14 MeV D-T neutron generators (10**9/s) (like UA-1)
  - Generator: 6 terminal metal-ceramic 5 cm dia x 25 cm long
  - 1 μsec pulses, 1% D.F.

2. Relative:

- Light Injection on Fibers
  - Achieved <0.5% in CLEO, Bugey Neutrino Expt., etc.
  - Long term: several months
  - Cross-calibrate in lab, on bench, & w/ radiosource
  - CDF, UA-1, UA-2: ~1% long term
  - lasers, plasma pinches, LED's, stable arcs, laser diodes, etc
  - [- Tunable ring laser, phase locked machine RF
    -> sub ns pulse, stability: 10^{-4}]
  - [- Inject front/rear at several wavelengths
    -> rad damage, separate fibers from PMT stability]
- Symmetries of Energy Deposition
  - Towers of constant $\pm\eta$ (a ring of towers): same Energy.
  - Sets of towers of constant ϕ: same $\delta E/\delta\eta$ (Energy profile)
  - Compute Entropy; anneal
  - Use tracker to correlate with absolute $d^3E/dt d\phi d\eta$.

Nuclear Instruments and Methods 206 (1983) 177–181
North-Holland Publishing Company

A SIMPLE METHOD FOR THE STABILIZATION OF SCINTILLATION DETECTORS

M. BÖTTCHER, W.D. BREWER, and E. KLEIN
Fachbereich Physik, Freie Universität Berlin, W. Germany

Received 10 May 1982

We report on the design and operation of a gain-stabilized NaI(Tl) scintillation spectrometer for use in stray magnetic fields utilizing a blue light-emitting diode as reference source. The spectrometer is simple, compact, and robust and the stabilization can be constructed at modest additional cost. It is easy to operate, and yields long-term gain stability of better than ±0.2%, as well as greatly improved operation in stray magnetic fields.

(~ 300 P.M.T.)

Nuclear Instruments and Methods in Physics Research A279 (1989) 73–76
North-Holland, Amsterdam

PERFORMANCE OF A LIGHT FLASHER SYSTEM FOR A PROTOTYPE CsI CALORIMETER AND THE DESIGN FOR CLEO II

Yuichi KUBOTA and Chris O'GRADY *
Cornell University, Ithaca, New York 14853, USA

→ Have now reported long term ±0.5 %

A study of the light calibration system installed in a prototype CsI shower counter is reported. The system is able to observe a change of less than 0.5% in the sensitivity of the detector.

Nuclear Instruments and Methods in Physics Research A234 (1985) 517–520
North-Holland, Amsterdam

GAIN STABILIZATION OF PHOTOTUBES USING A LED DIODE SCHEME *

L. HOLM, H.W. FIELDING and G.C. NEILSON
Nuclear Research Centre, Physics Department, University of Alberta, Edmonton, Canada, T6G 2N5

Received 13 July 1984

The performance of LED diode gain stabilization schemes for RCA 4522 phototubes is evaluated. Under normal experimental conditions the use of a green Litronix GL56 LED and an ORTEC surface barrier detector provide the best results. An overall gain stabilization of ±0.5% over several months has been achieved.

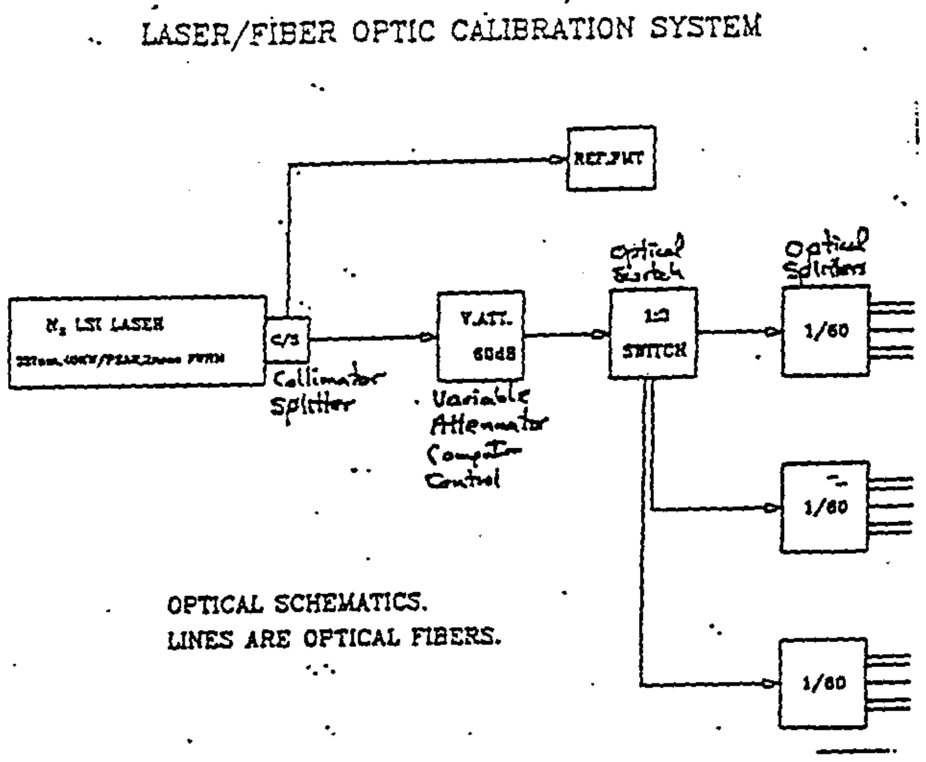


Fig. 2a: Schematic of full optical pulser system for a large scale calorimeter system.

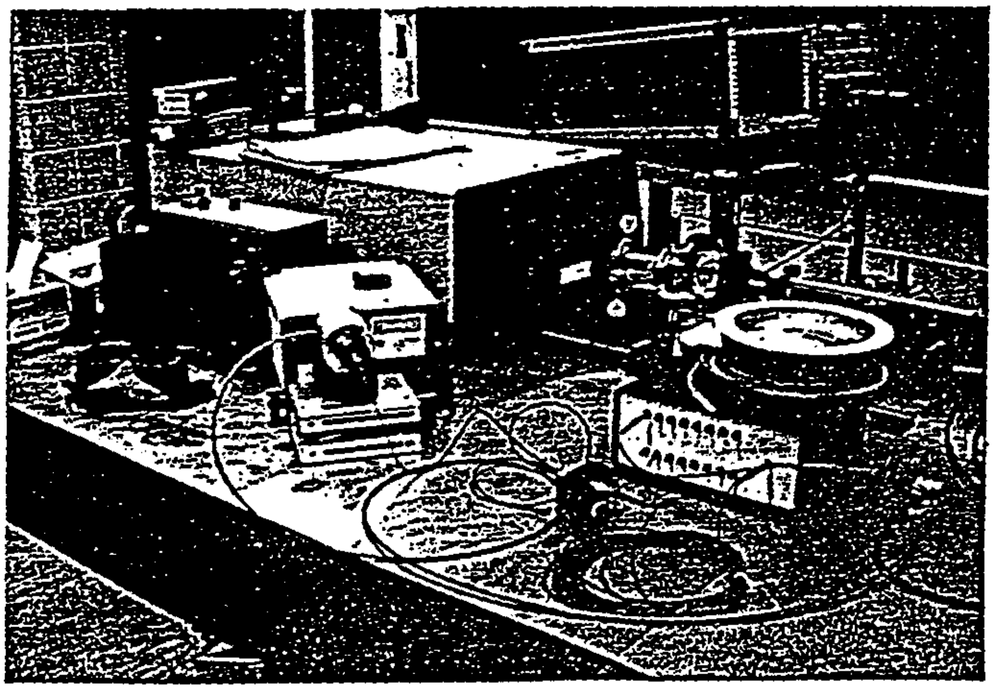
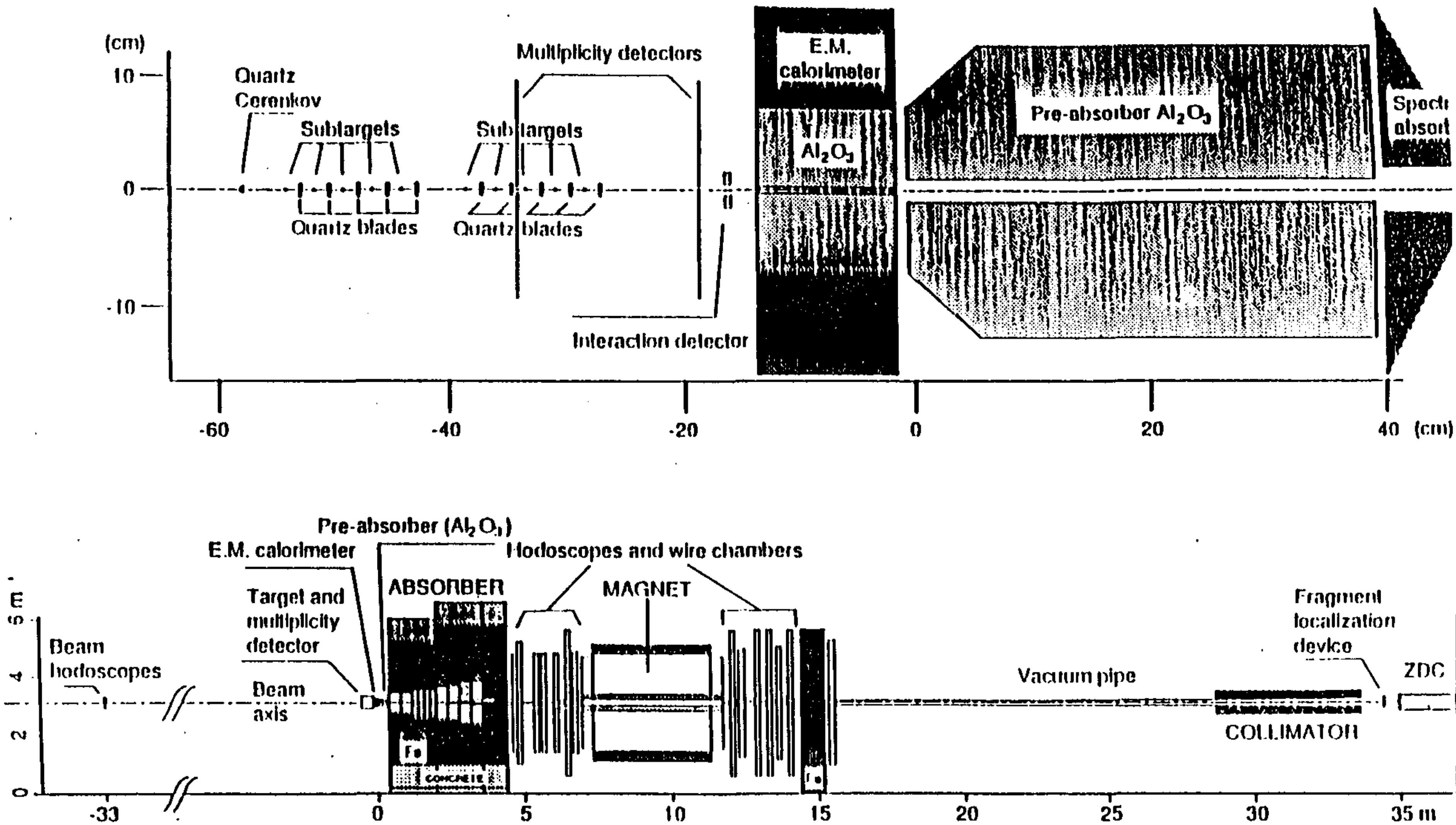


Fig. 2b: Photograph of early test assembly of the 16 channel light pulser calibration system.

Presentation by:

Philippe Gorodetzky



III.5: *Vue générale de la nouvelle expérience.*

REQUIREMENTS FOR NA38 with Pb Beam

1) Fast response

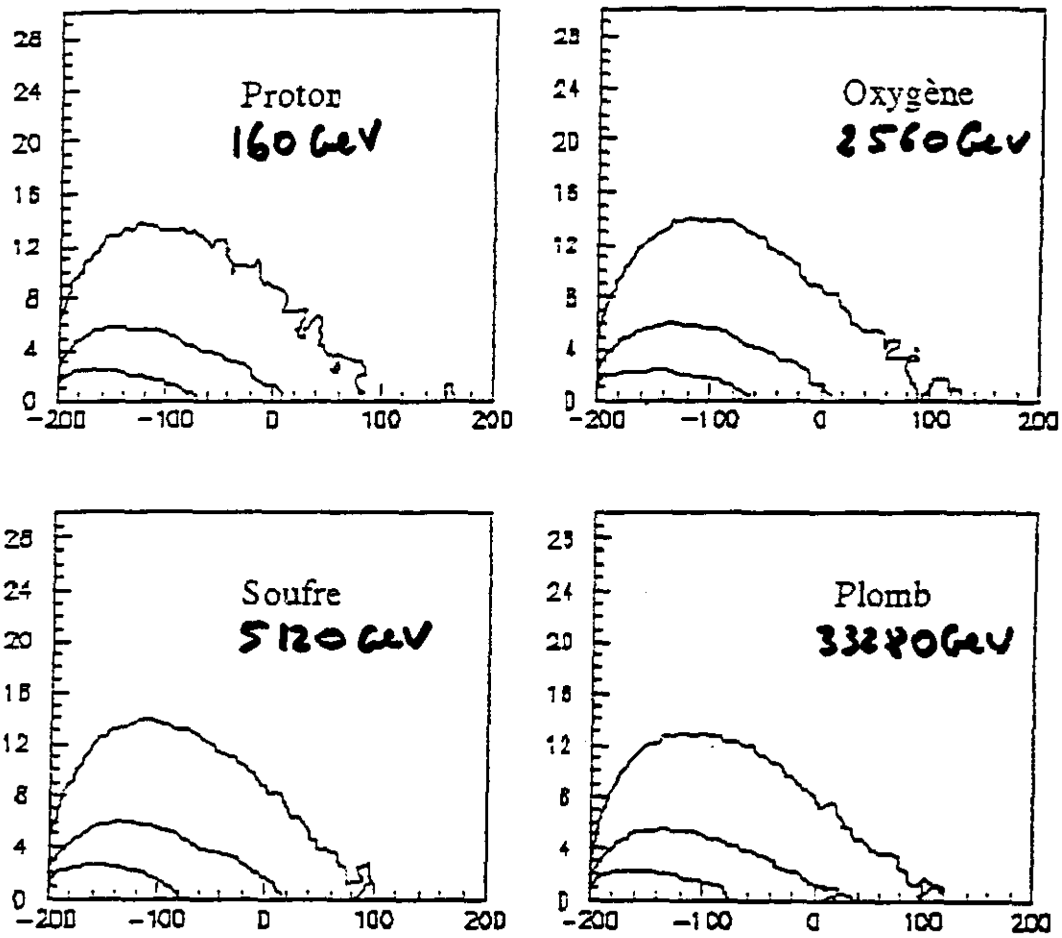
Itensity is $1.0 \cdot 10^7$ ions/sec
⇒ pulse should be back to zero before 20 us

2) Radiations

Shall suffer 2-5 Grads (10^7 Gy)

3) Resolution in hadronic mode better than 10%

4) Ease of construction


Proton
160 GeV
Oxygène
2560 GeV
Soufre
5120 GeV
Plomb
33280 GeV

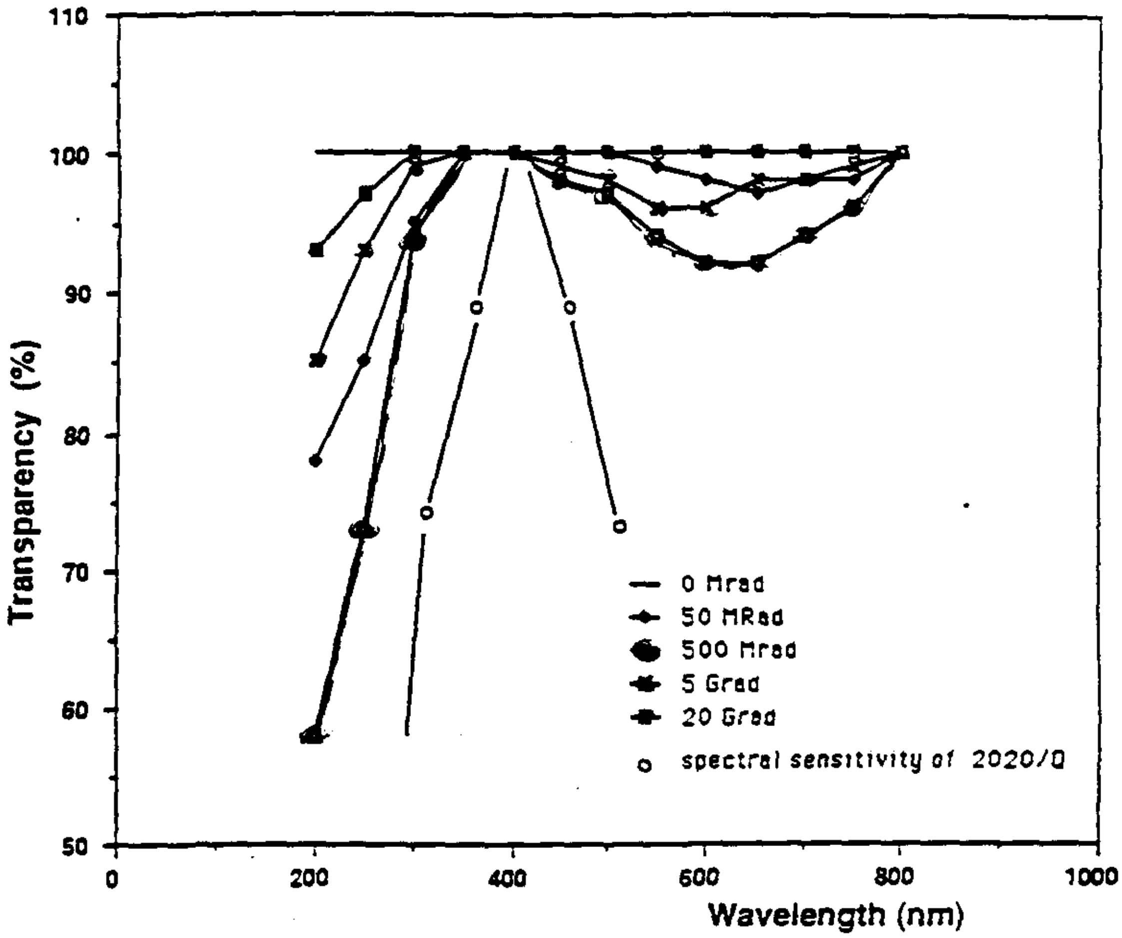
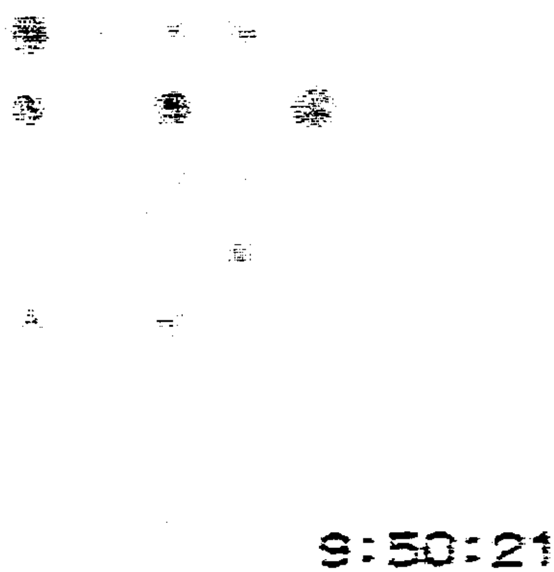
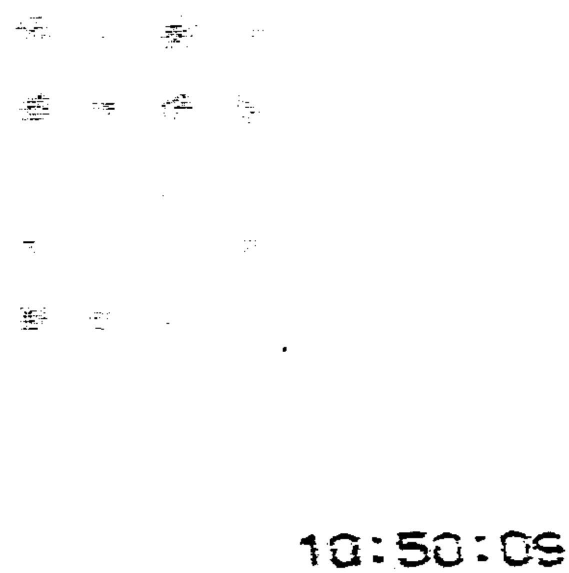


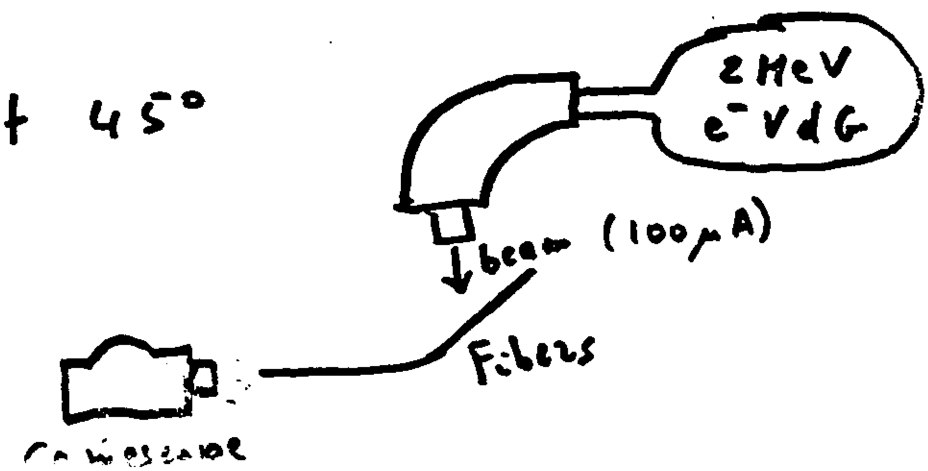
Figure 6 : Transparency of a 2 mm thick Suprasil quartz disc after different doses of irradiation. The spectral sensitivity of the 2020 Q photomultiplier shows the interesting fact that this wavelength range is the most insensitive to radiation.

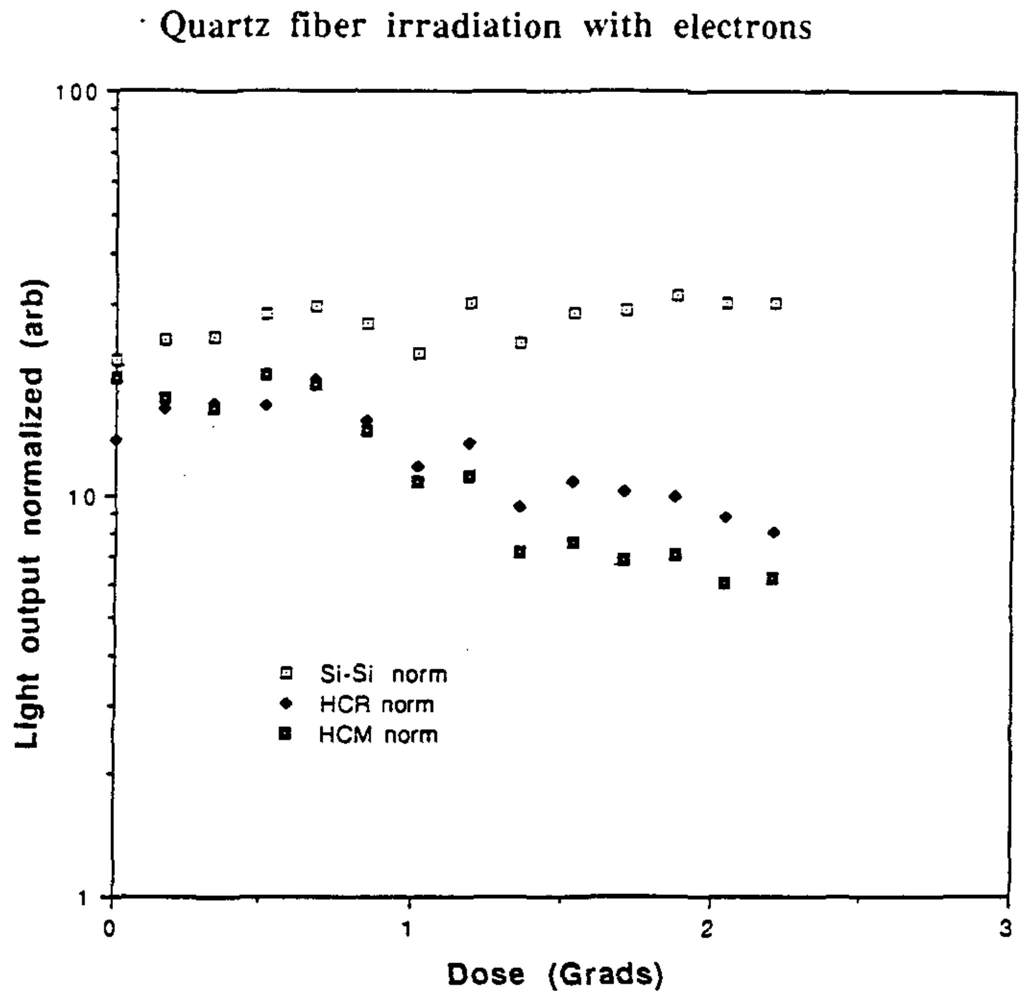
Duke's transparent





Fibers at 45°




Quartz fiber irradiation with electrons
100
10
1
0
1
2
3
Light output normalized (arb)
Dose (Grads)
Si-Si norm
HCR norm
HCM norm

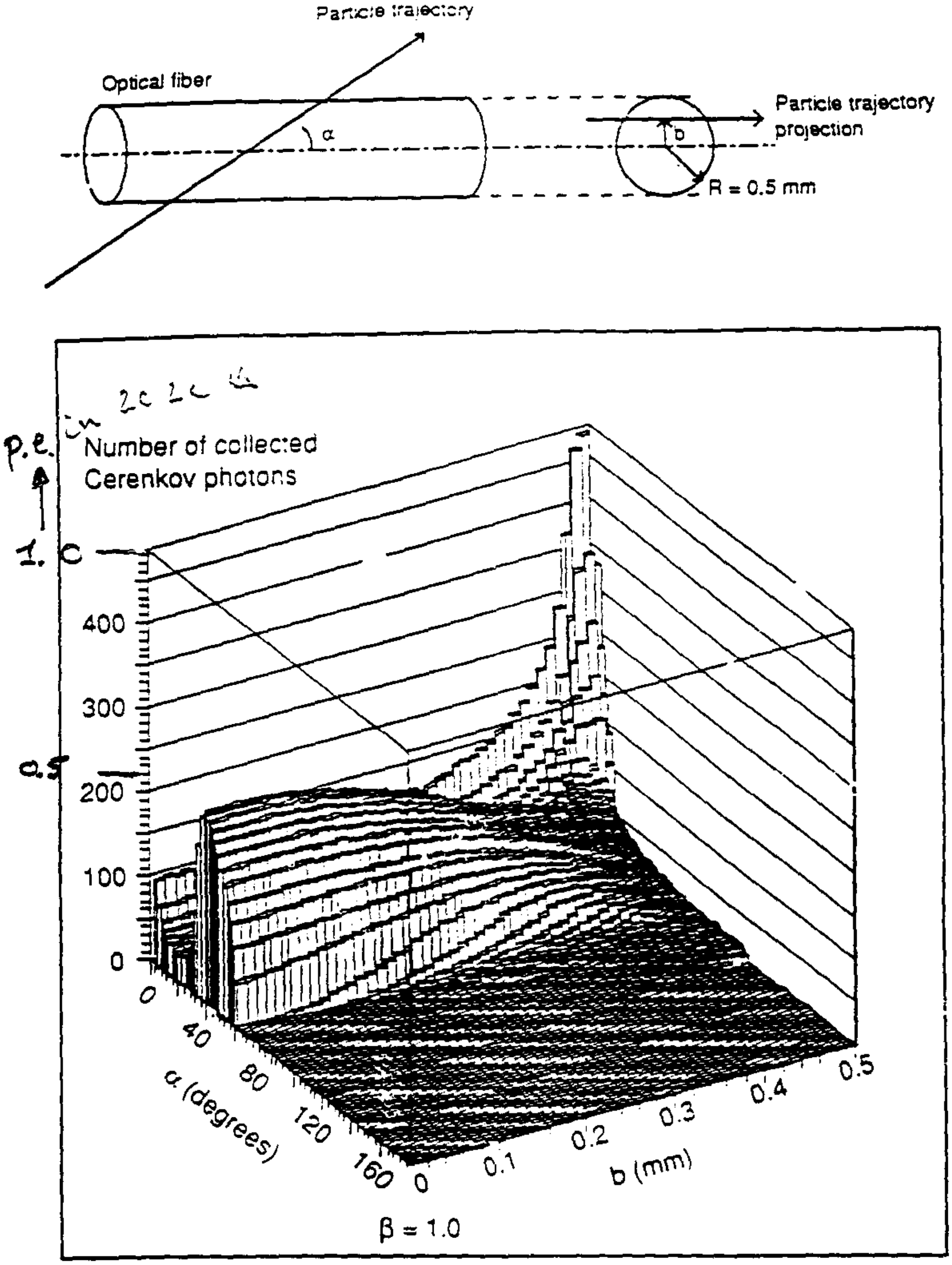
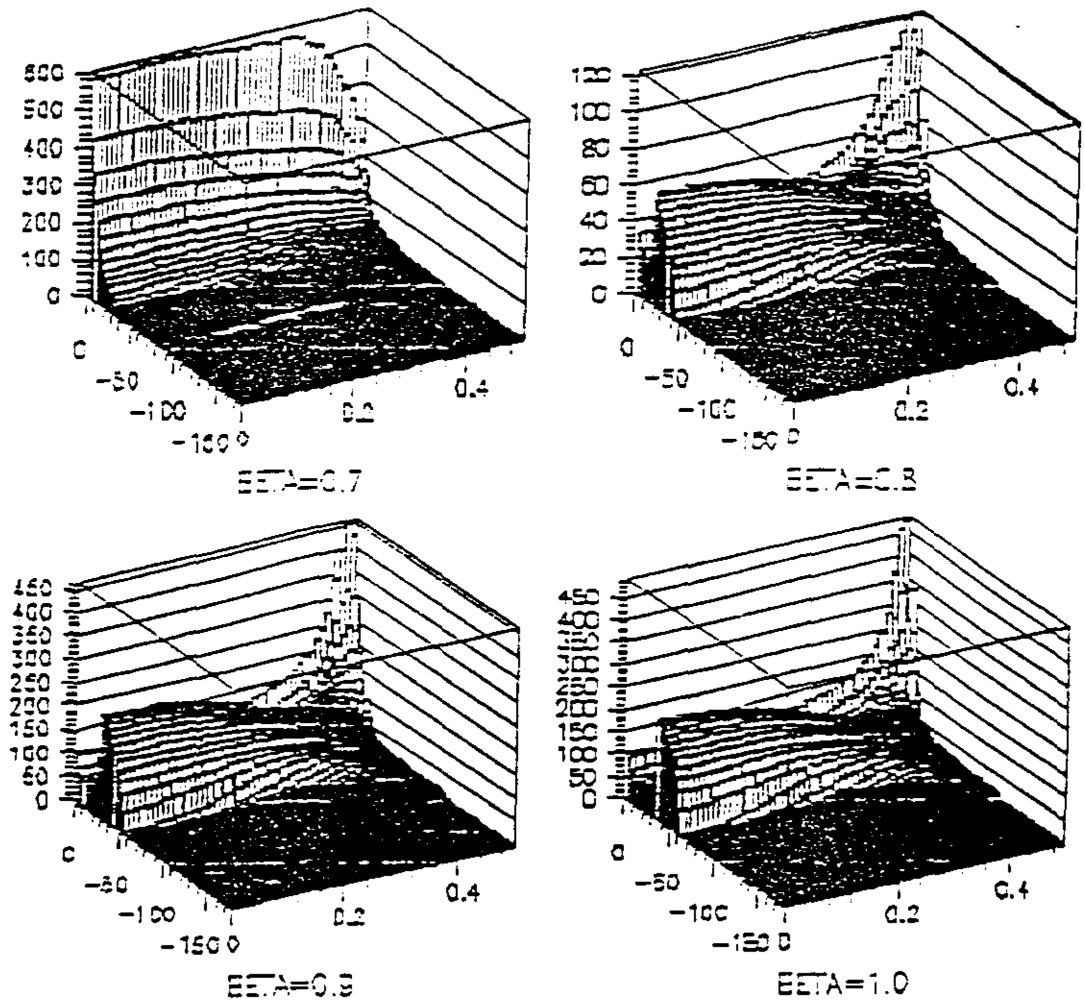


Figure 2 : Top) Geometrical parameters of an optical fiber - particle trajectory system. Bottom) Number of photons produced by Čerenkov effect and collected at the extremity of a fiber (1 mm diameter and numerical aperture of 0.37) intercepted by a charged particle (Z=1, $\beta = 1$).

$\beta = 1$, $Z = 1$ at 45° through the center of a fiber 1 mm thick gives 0.44 p.e.



<u>Fig V.22:</u> Nombres de photons (quelle que soit leur longueur d'onde) arrivant en bout de fibre en fonction de l'angle et du "paramètre b" exprimés en mm pour les 4 intervalles de β.

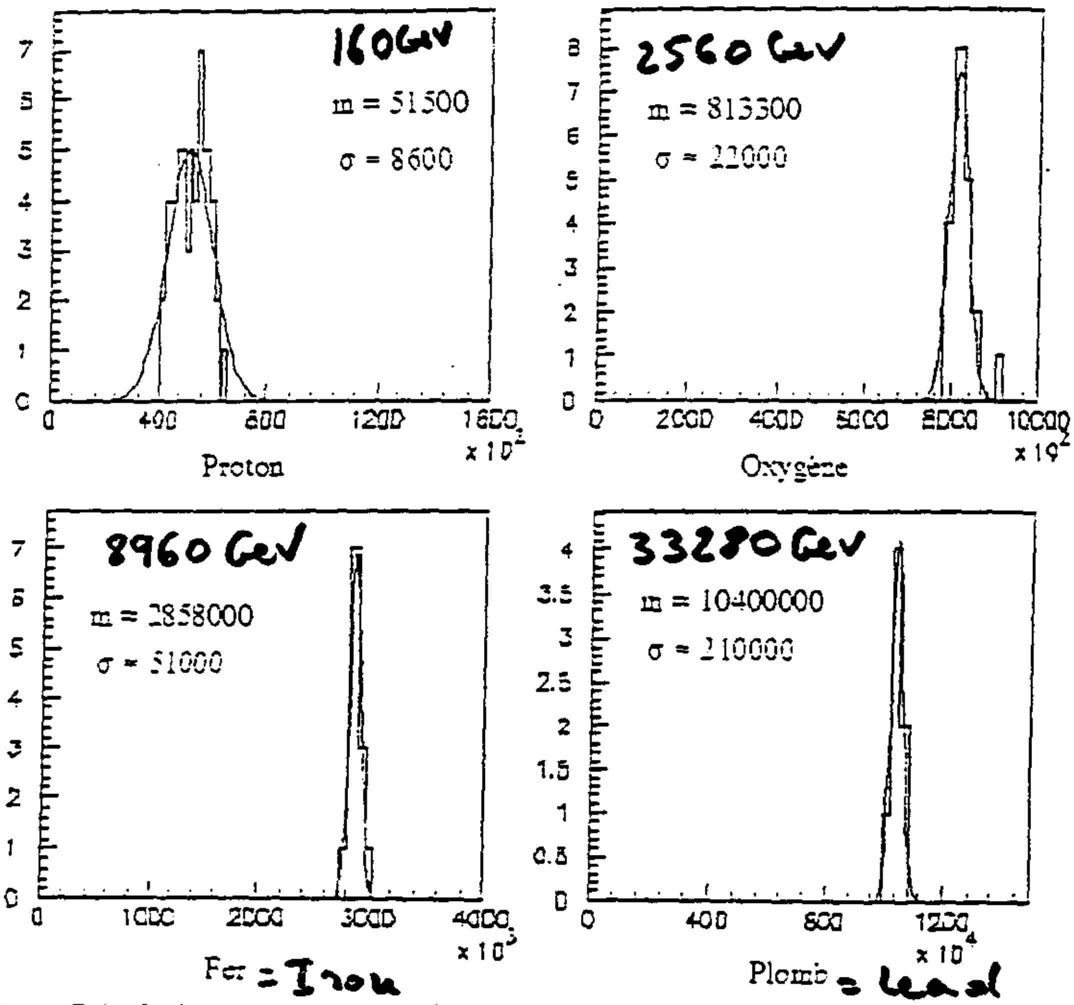
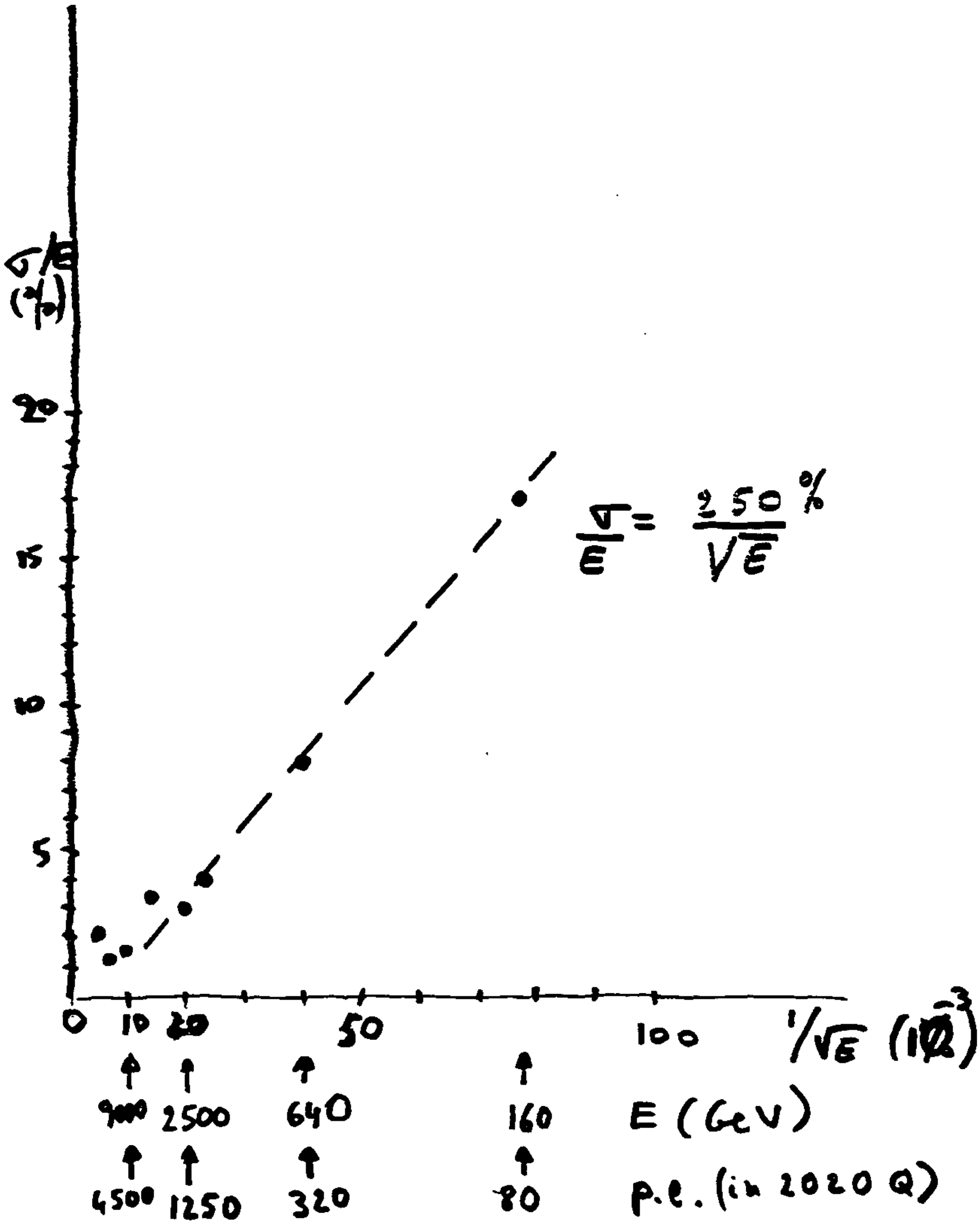


Fig V.29.a: *Résolution en proton, oxygène, fer et plomb.*



σ/E (%)
20
15
10
5
$\frac{\sigma}{E} = \frac{250}{\sqrt{E}}$ %
0
10
20
50
100
$1/\sqrt{E}$ (10^{-3})
9000
2500
640
160
E (GeV)
4500
1250
320
80
p.e. (in 2020 Q)

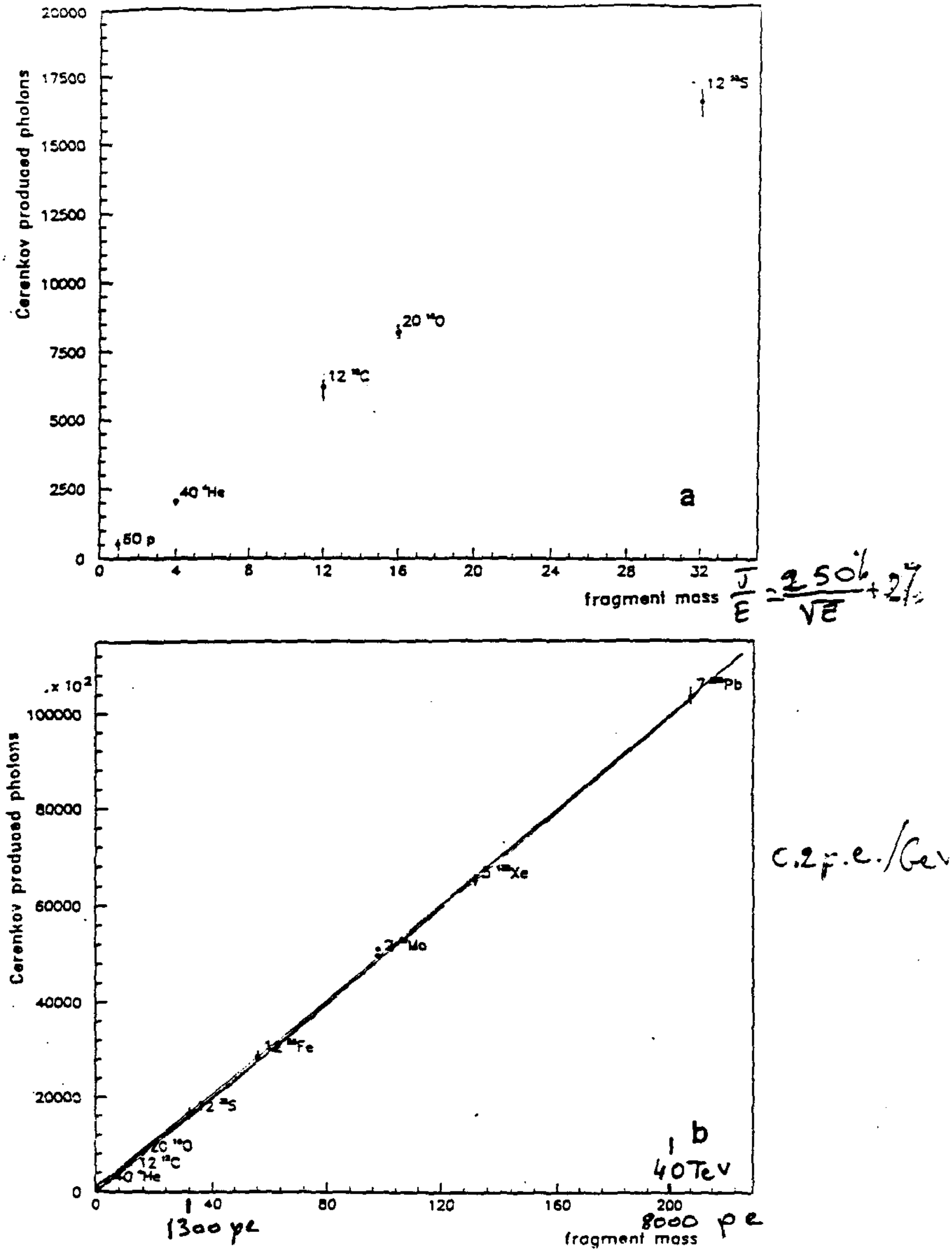
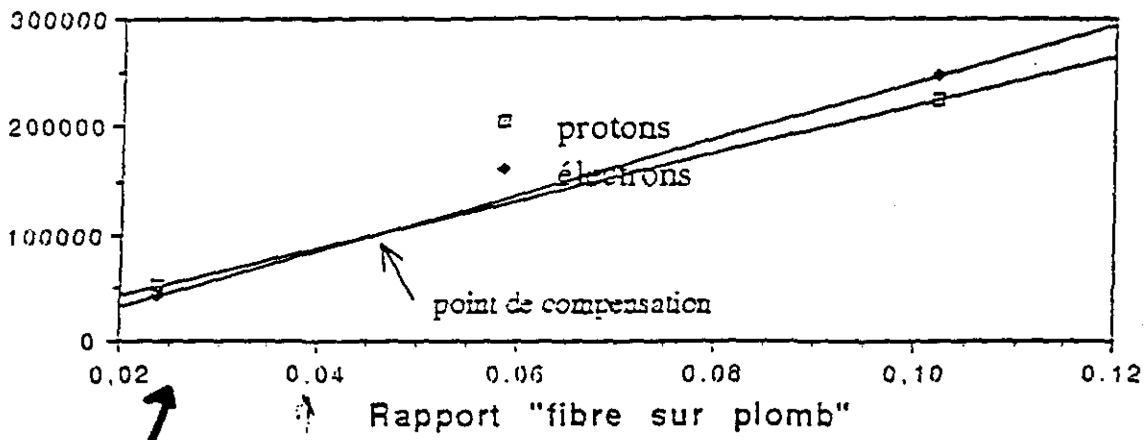
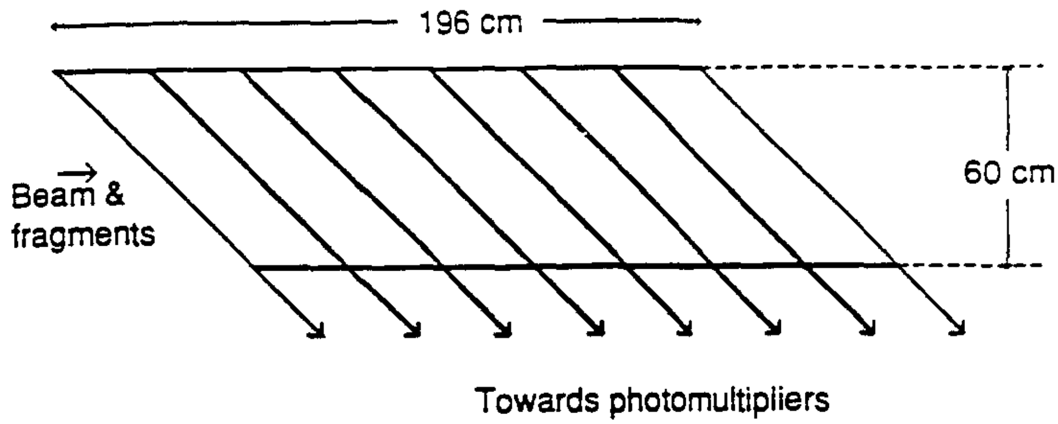


Figure 4 : Linearity of the ZDC. Figure on the top is a magnification of the low mass region. Near each point is indicated the number of events calculated by the simulation program. The error bars correspond to the FWHM energy resolution as deduced from a least squares fit. See text for more details.



"our" rat:

$E_{e^-} = E_p = 160$ GeV



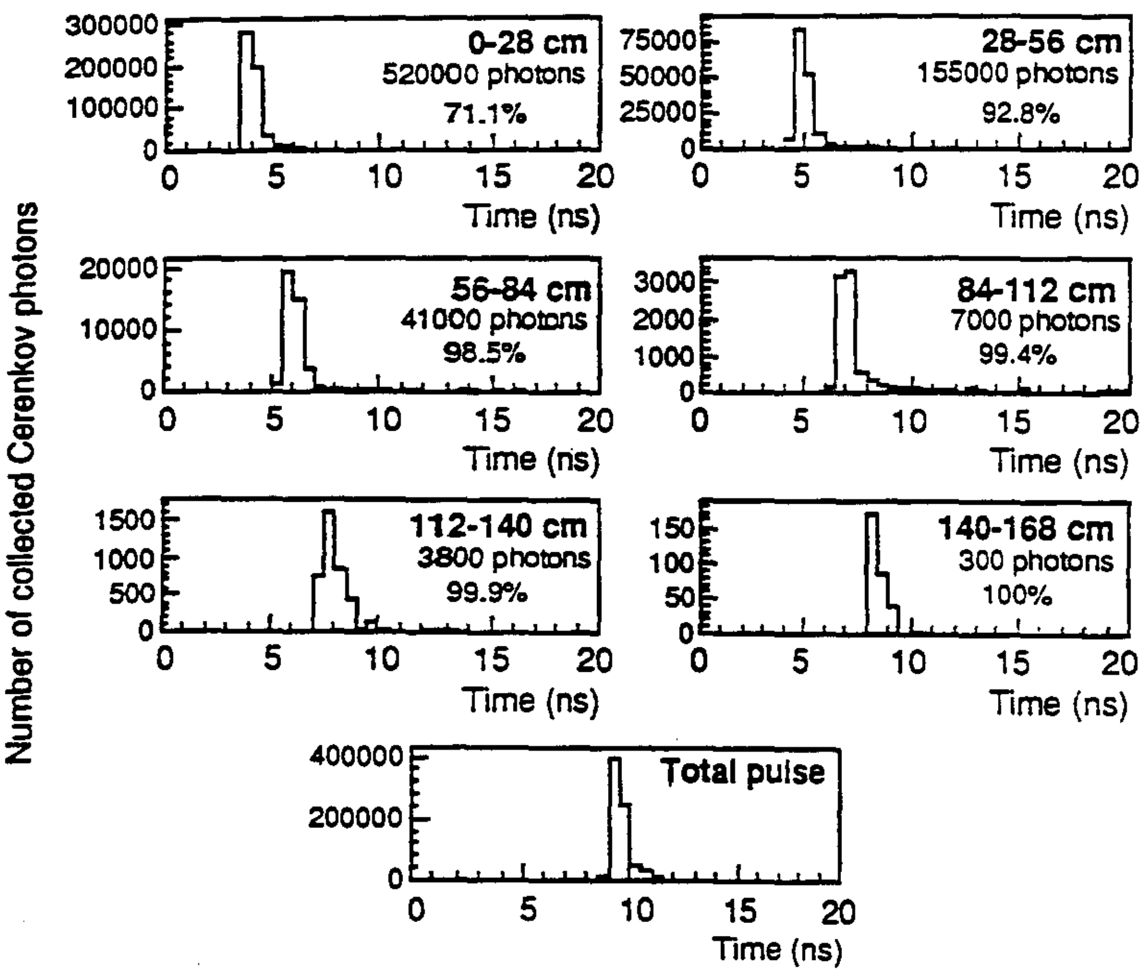


Figure 5 : Top) Schematic view showing the seven 28 cm thick slices along the Z-axis. Bottom) The anode pulses from the Čerenkov light from the different slices collected by the different photomultipliers as a function of time for an Oxygen ion of 160 GeV/nucleon. Pulses of adjacent slices are shifted by one nanosecond due to the shower developement along the z-axis with a value of β close to 1. The full shower for this event is contained inside 6 slices. The last pulse is the sum of the six pulses, each of them being delayed by one nanosecond relative to the next one. It is the useful pulse for the experiment.

P. GORODETZKY
D. LAZIC

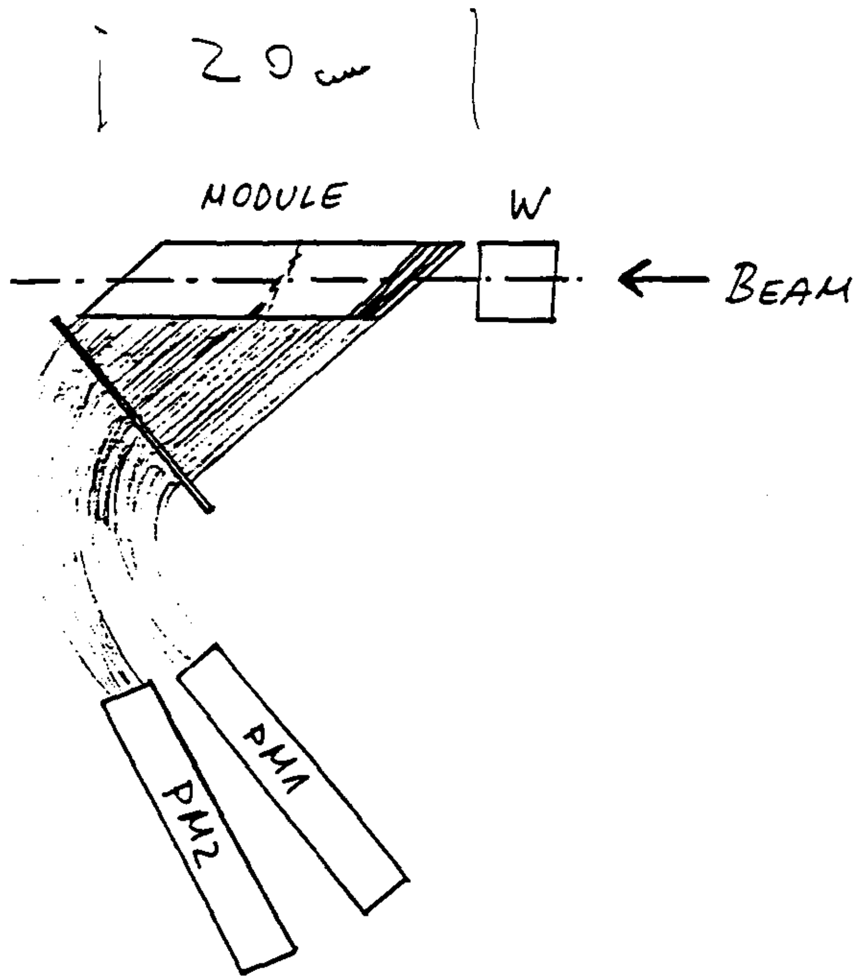
SILICAL

CALORIMETRY WITH SILI(CA) FIBERS

Tests performed at CERN on the small prototype with S^{32} at 200 GeV/n and electrons at 10 and 30 Gev

– PRELIMINARY RESULTS –

October 1991



DIMENSIONS OF THE MODULE : 5 x 5 x 20 cm

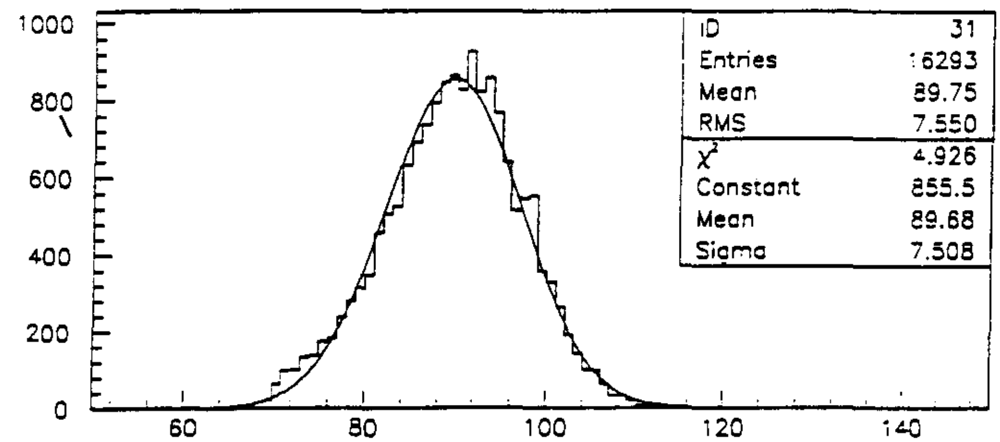
THICKNESS OF TUNGSTEN BLOCK : 0, 4, 8 cm

1474 FIBERS 50 cm LONG

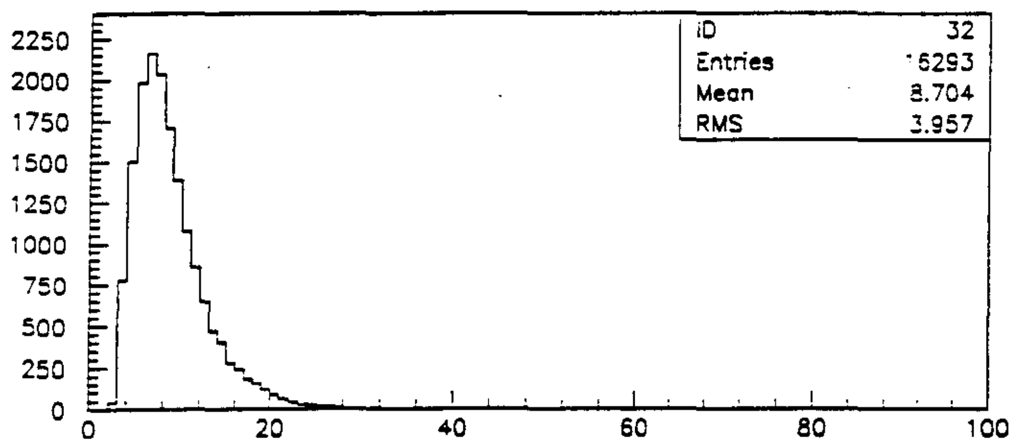
DISTANCE BETWEEN FIBERS 2.22, $V_{Pb} : V_{Fib.} = 4:1$

INTERACTION LENGTHS FOR S^{32}:

- IN W $\lambda_{int} = 4$ cm
- IN MODULE $\lambda_{int} = 9.1$ cm (including quartz fibers)



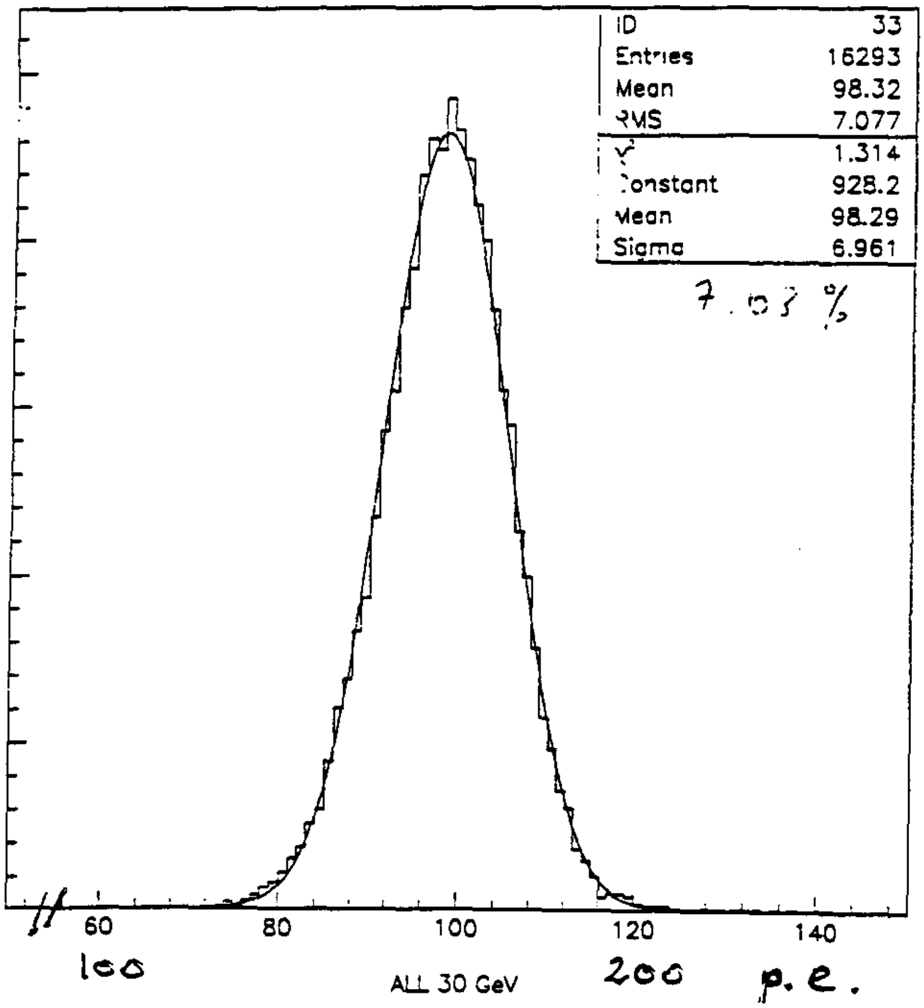
ADC1 30 GeV



ADC2 30 GeV

G221 17/12/91

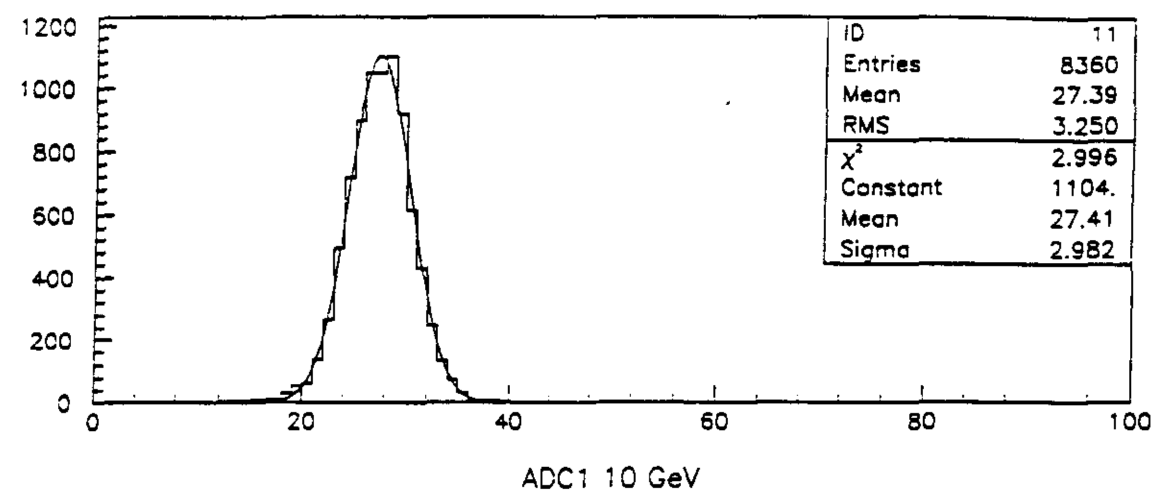
e^-

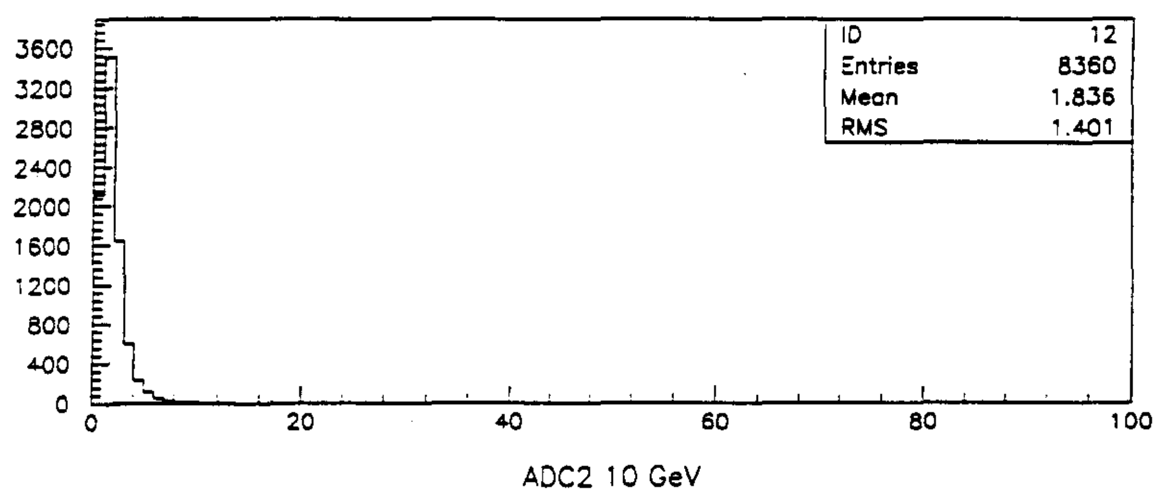


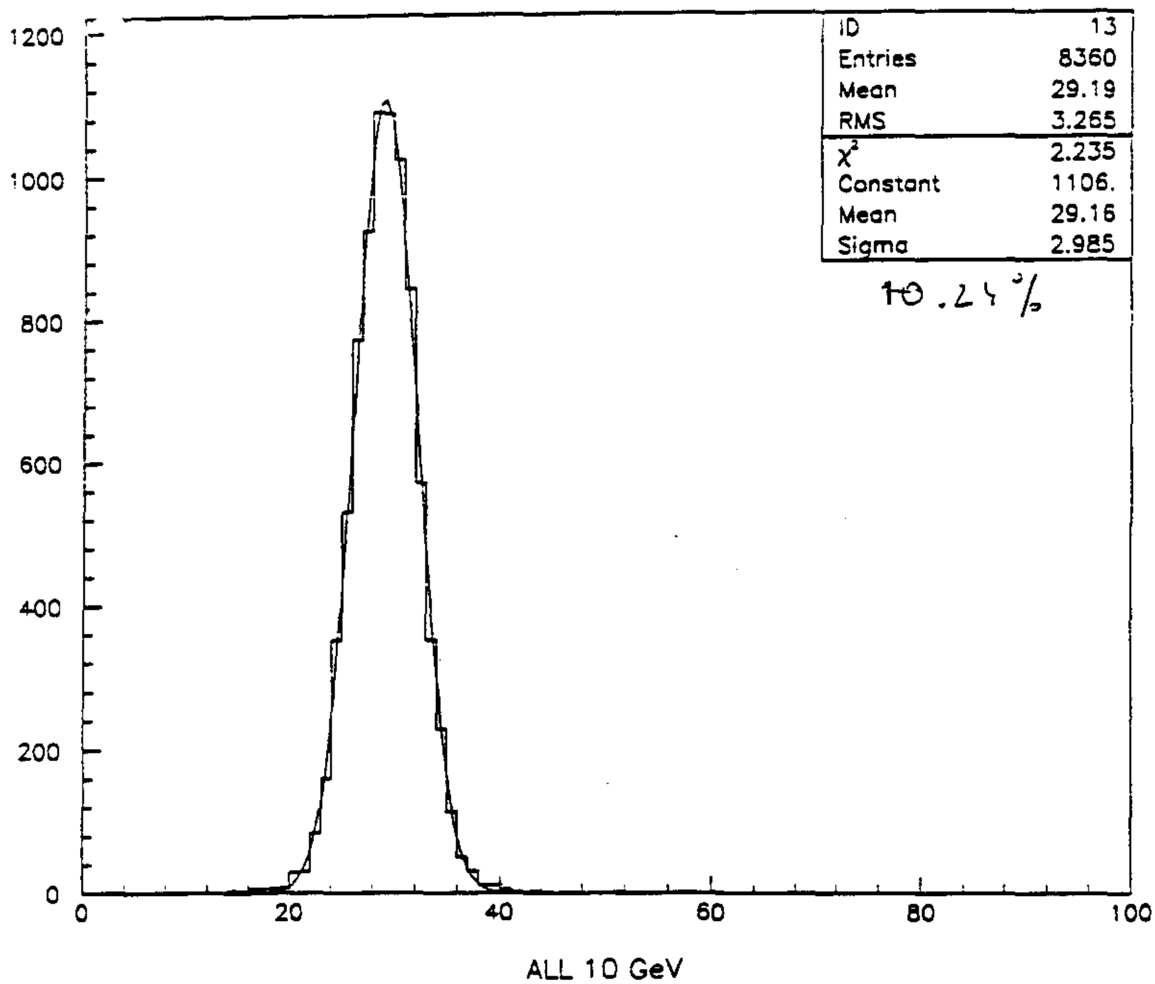
$$\Rightarrow \frac{\sigma}{E} = \frac{23.6\%}{\sqrt{E}} + 2.77\,\%$$

$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} + b$$

6 p.e. / GeV

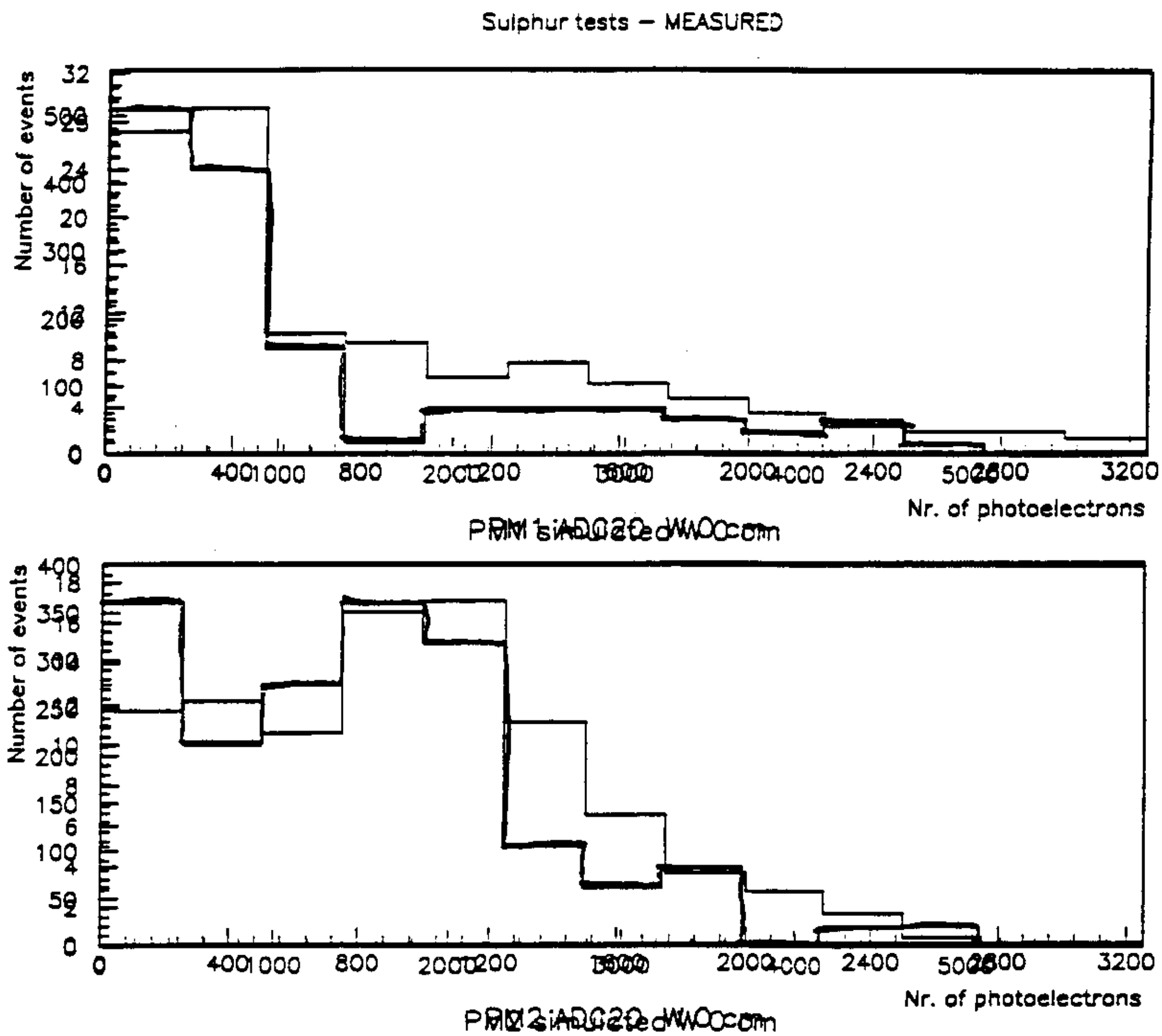

1200
1000
800
600
400
200
0
0
20
40
60
80
100
ID 11
Entries 8360
Mean 27.39
RMS 3.250
χ^2 2.996
Constant 1104.
Mean 27.41
Sigma 2.982
ADC1 10 GeV


3600
3200
2800
2400
2000
1600
1200
800
400
0
0
20
40
60
80
100
ID 12
Entries 8360
Mean 1.836
RMS 1.401
ADC2 10 GeV



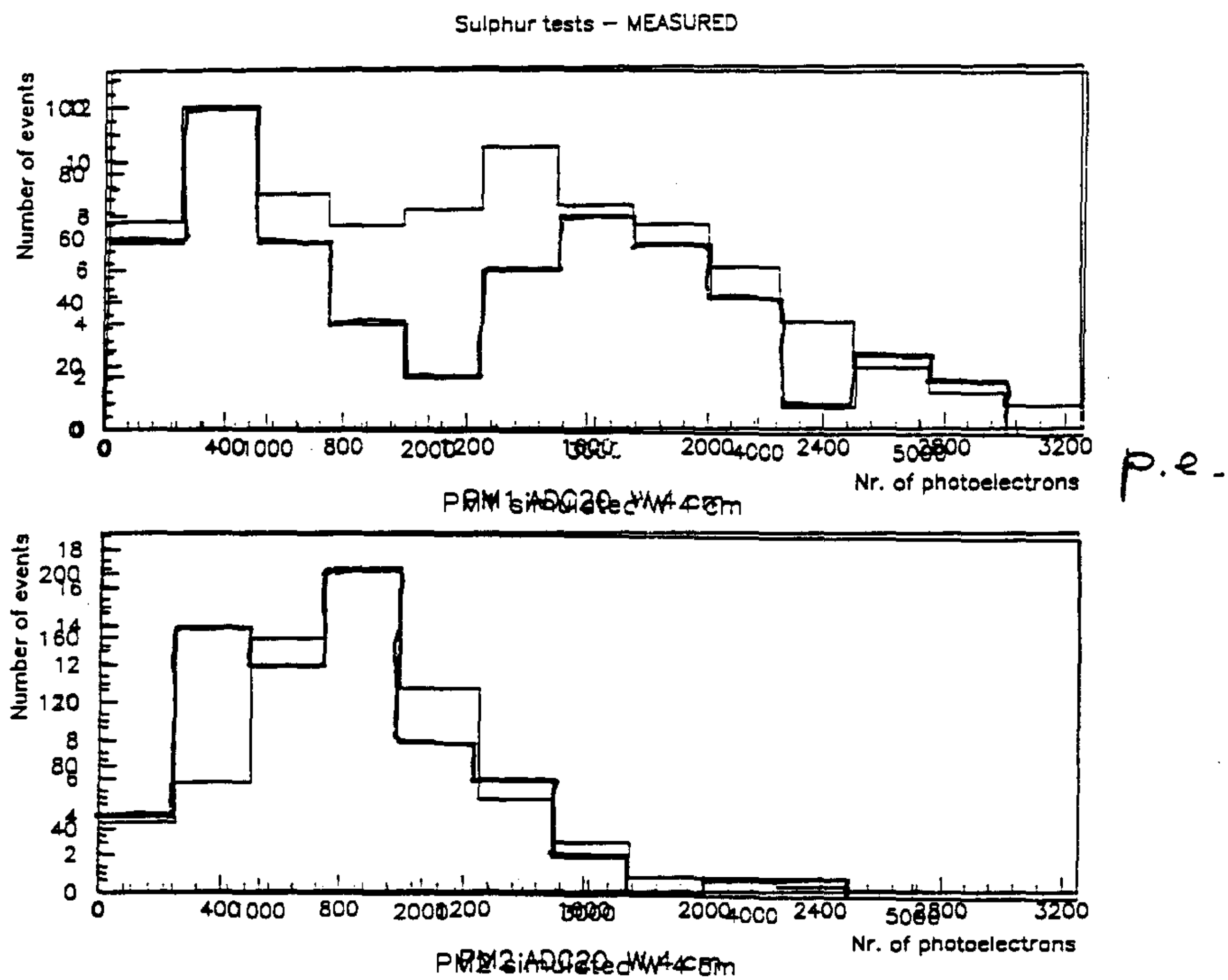
1200
1000
800
600
400
200
0
0
20
40
60
80
100
ID 13
Entries 8360
Mean 29.19
RMS 3.265
χ^2 2.235
Constant 1106.
Mean 29.16
Sigma 2.985
10.24%
ALL 10 GeV

SIMULATED

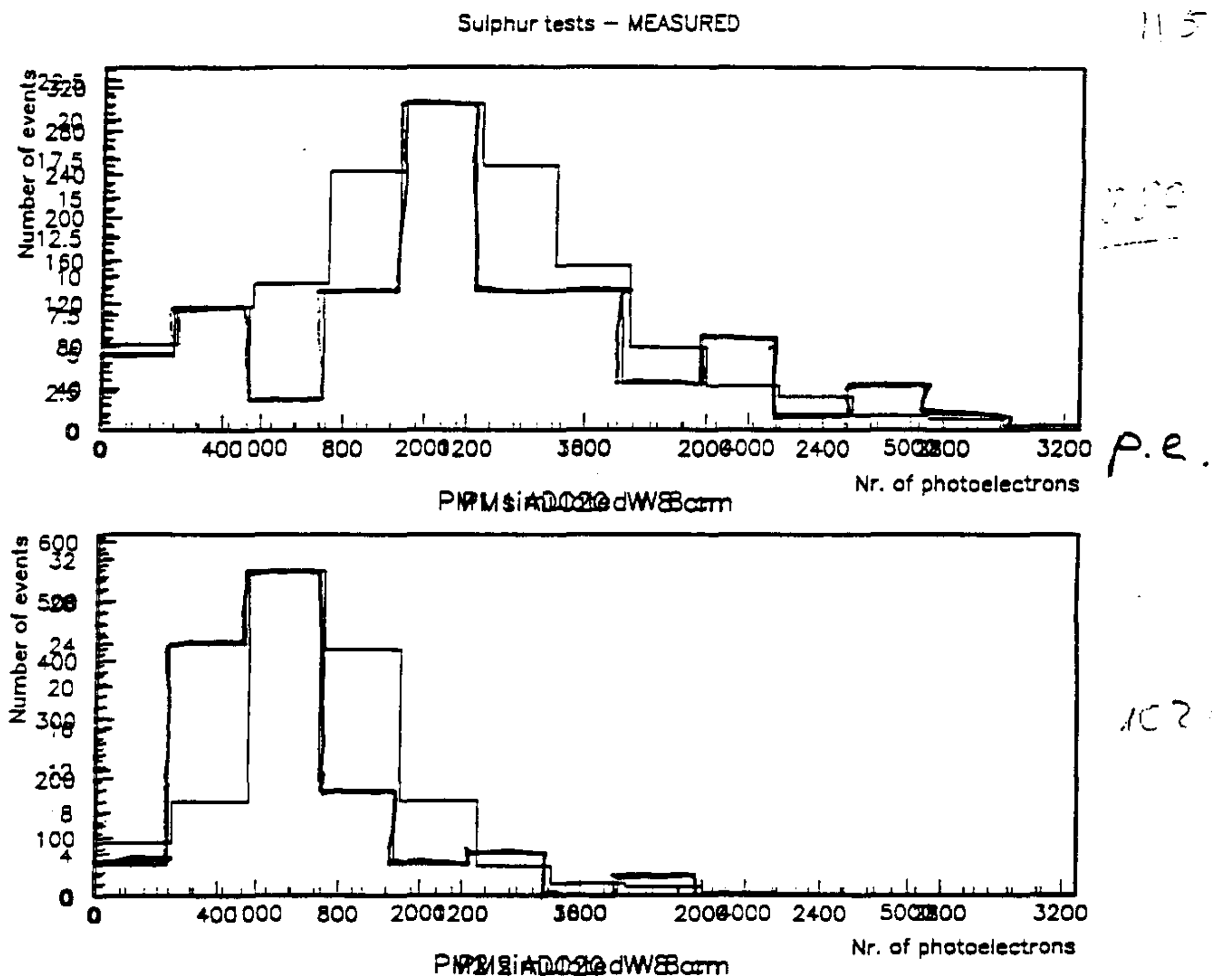


pe

SIMULATION

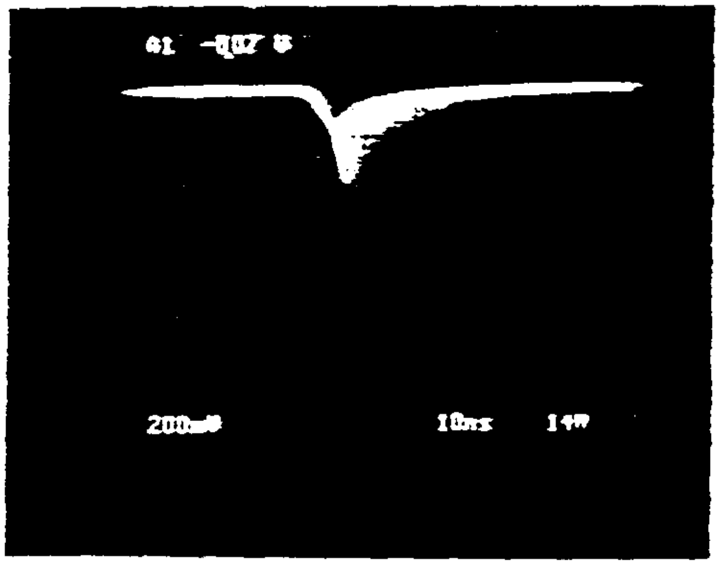

Sulphur tests – MEASURED
Number of events
Nr. of photoelectrons
PM1:ADC20, W4cm
PM1 simulated W 4 cm
p.e.
Number of events
Nr. of photoelectrons
PM2:ADC20, W4cm
PM2 simulated W 4 cm

SIMULATED

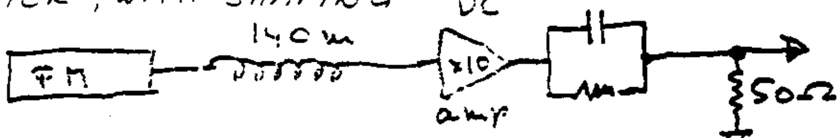

Sulphur tests — MEASURED
Number of events
Nr. of photoelectrons
p.e.
Number of events
Nr. of photoelectrons

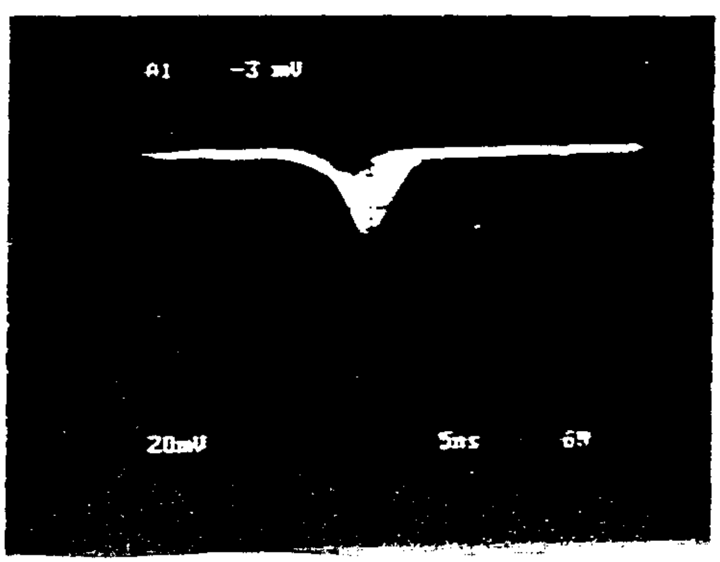
T32 TEST 8cm W PULSE SHAPES

PM1, TWO AMPLIFIERS, NO SHAPING (140 m CABLE)

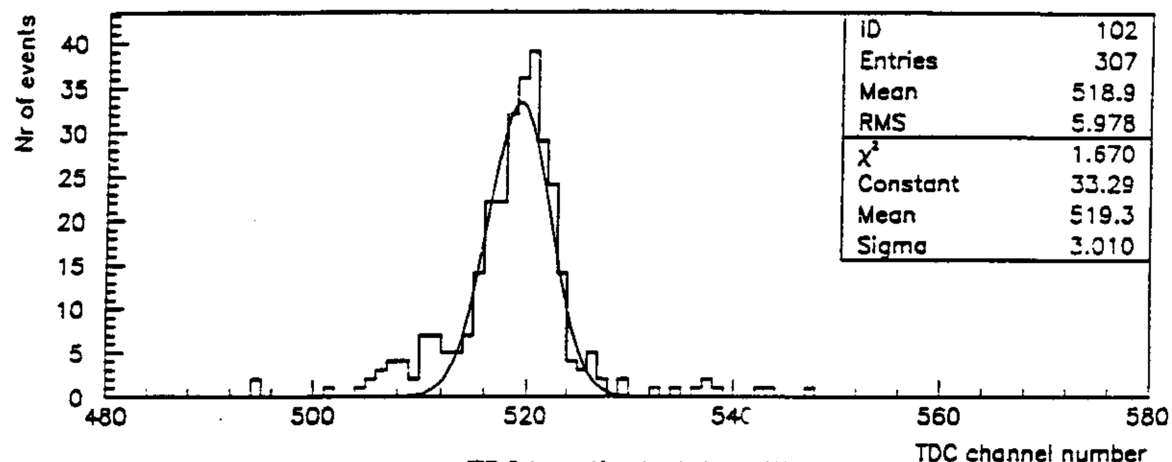


PM1, ONE AMPLIFIER, WITH SHAPING

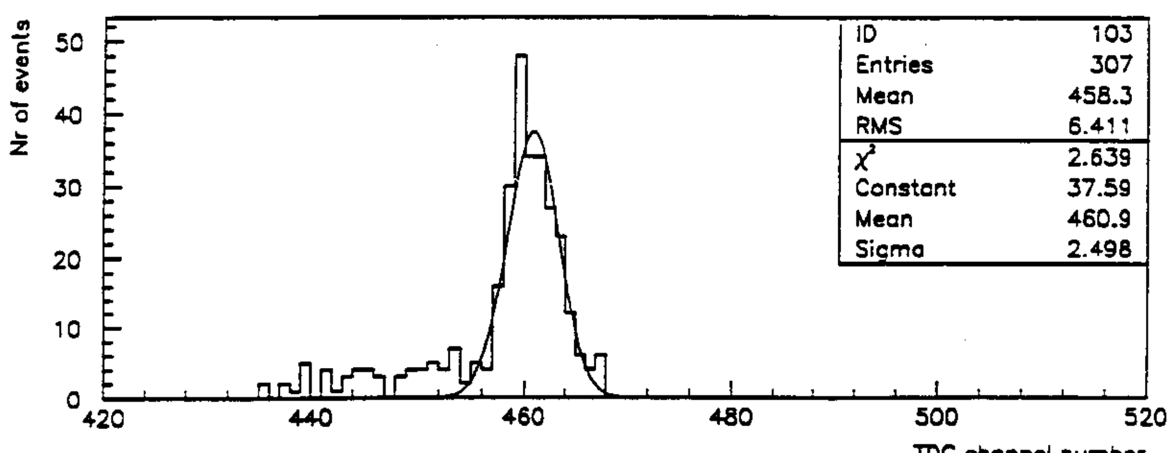




TIME RESOLUTION AFTER THE TRANSFORMATION:



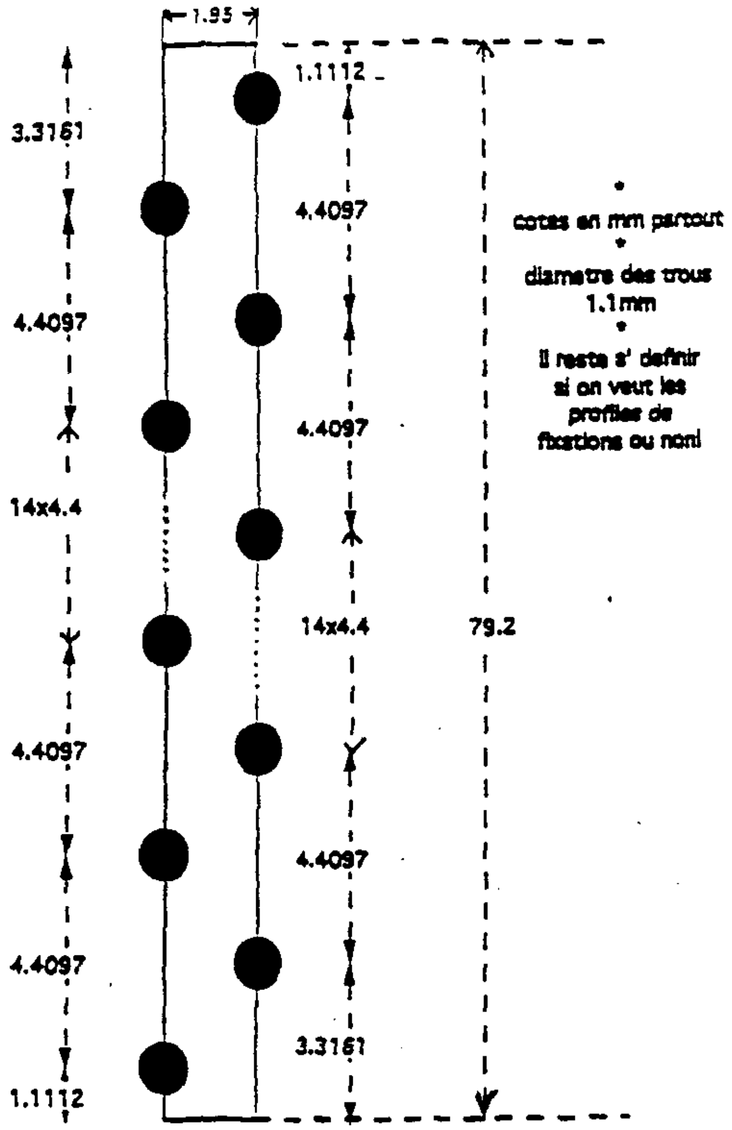
TDC1−adjusted 4cm W



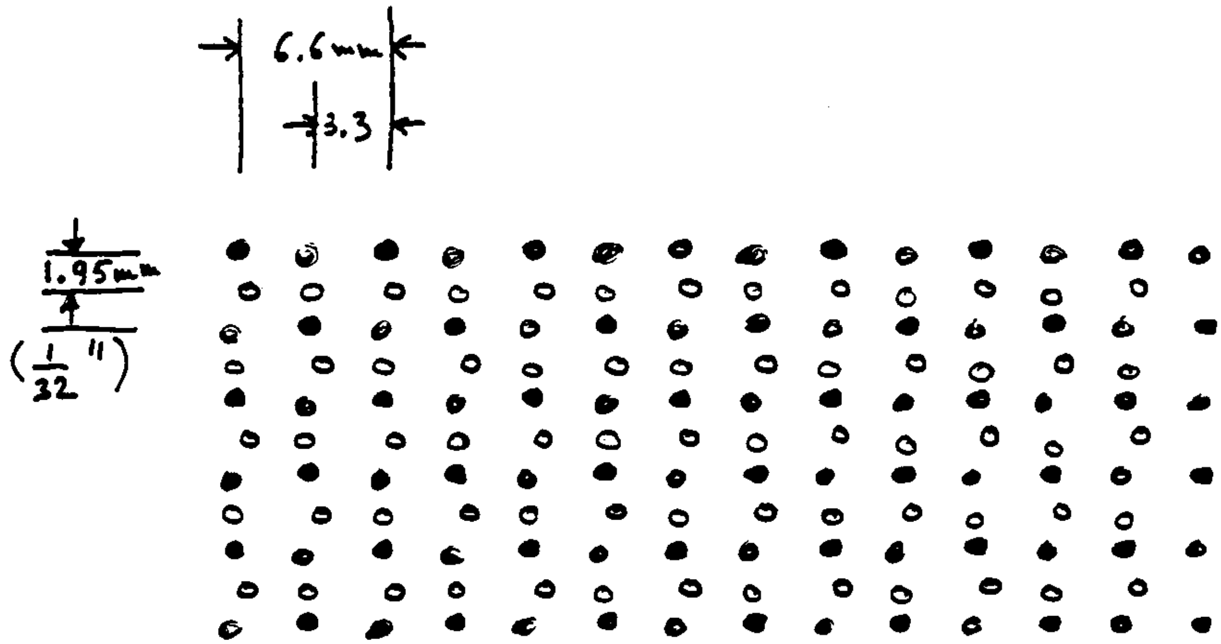
TDC2−adjusted 4cm W

$$\sigma = 250 - 300 \text{ ps}$$

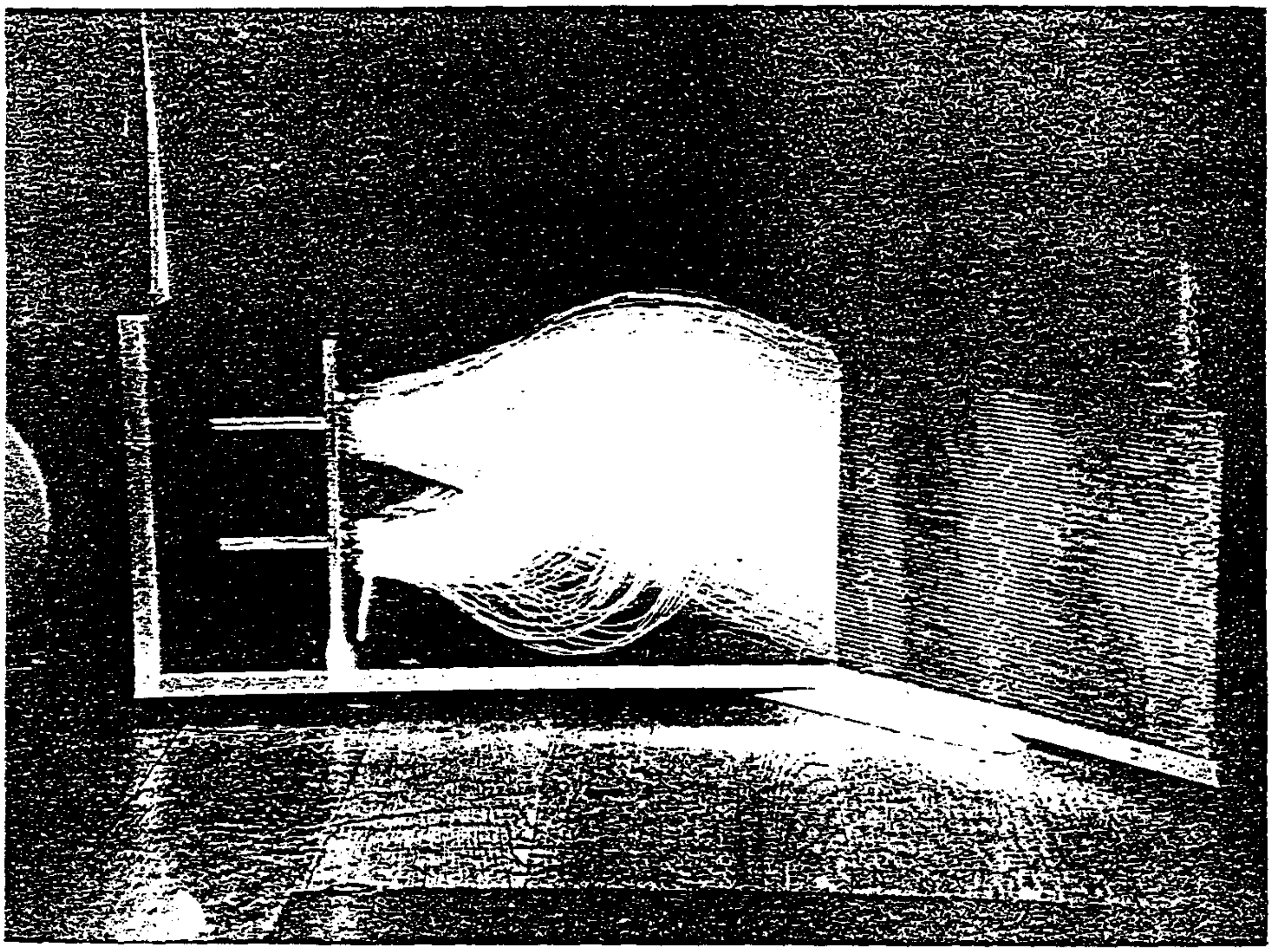
LEAD PLATES (ORDERED):

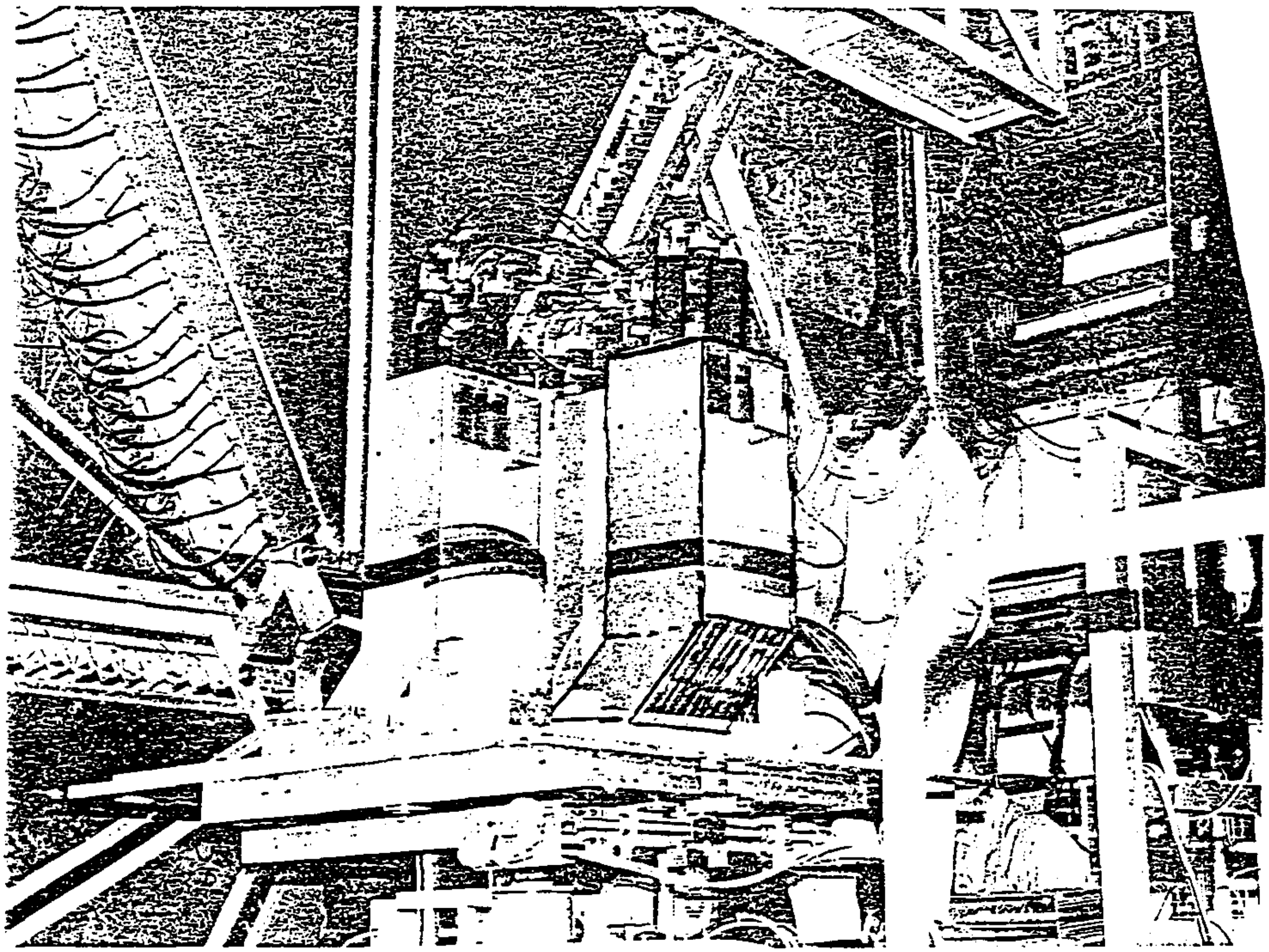


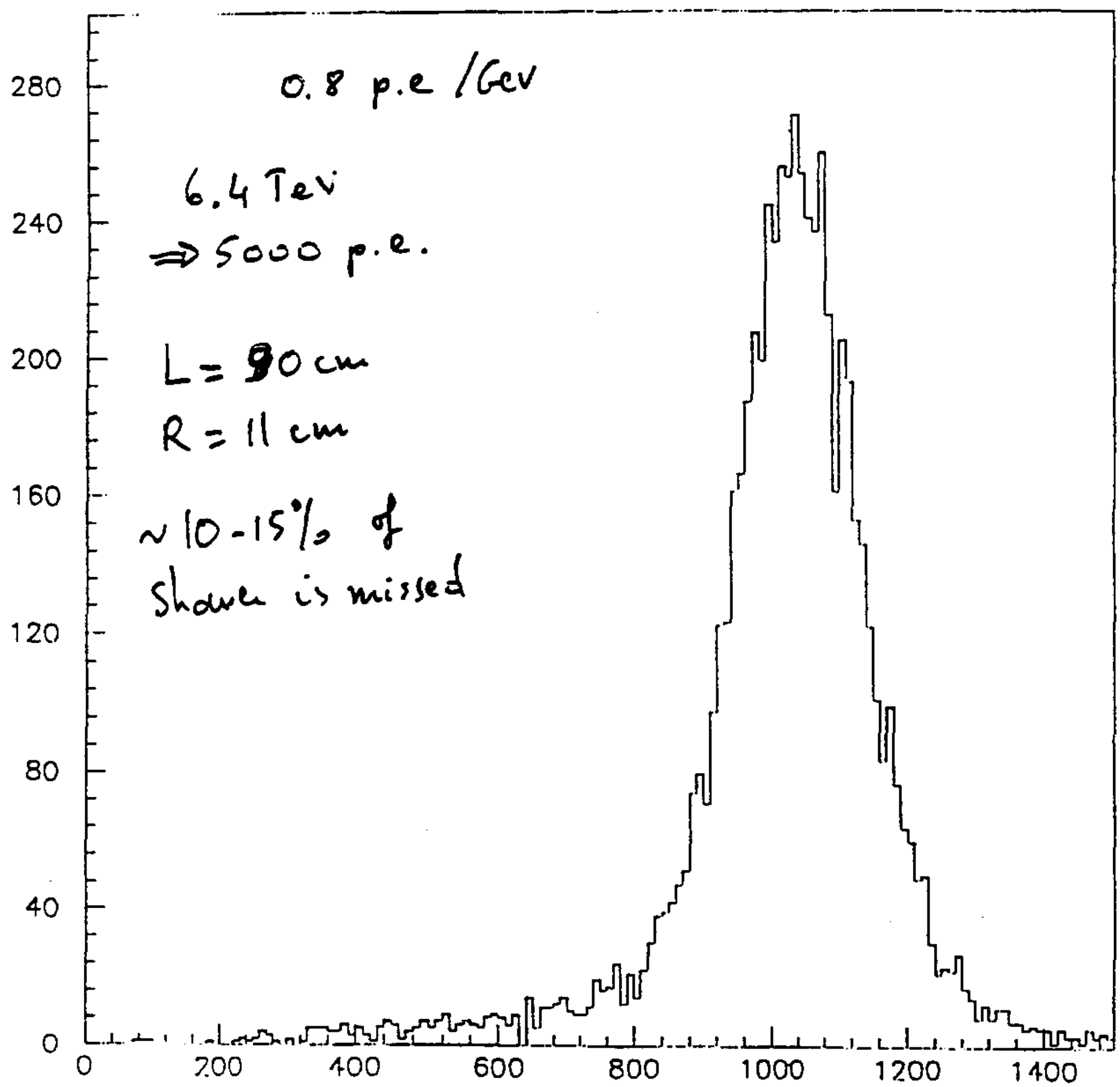
. fibers and
l fiber is
hree triangles)
ws side and



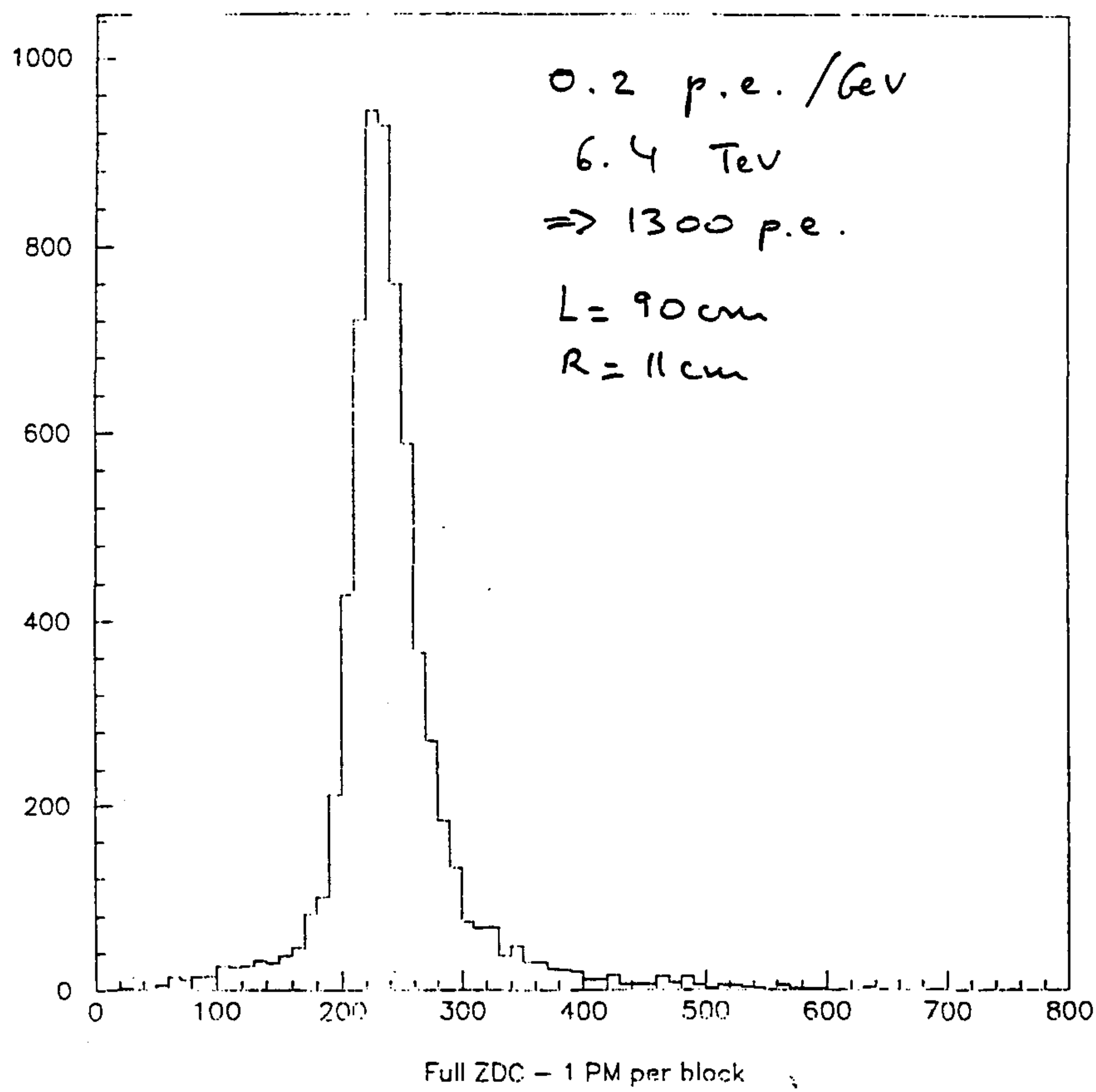
6.6 mm
3.3
1.95 mm
(1/32 ")





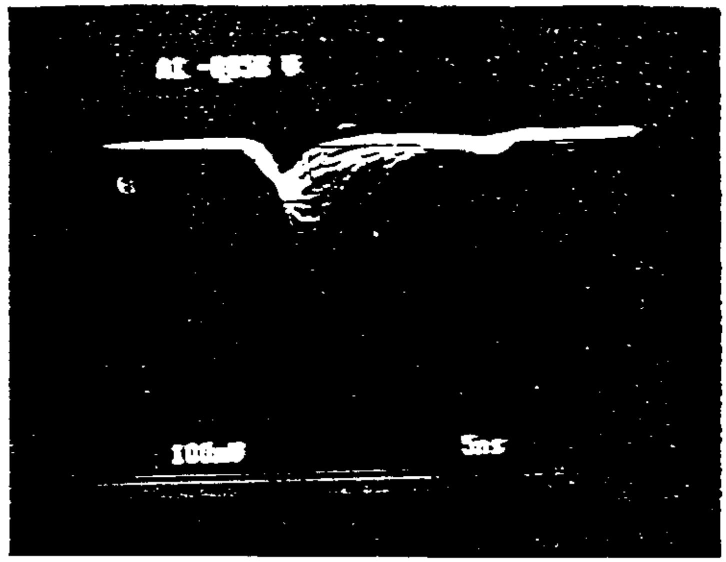


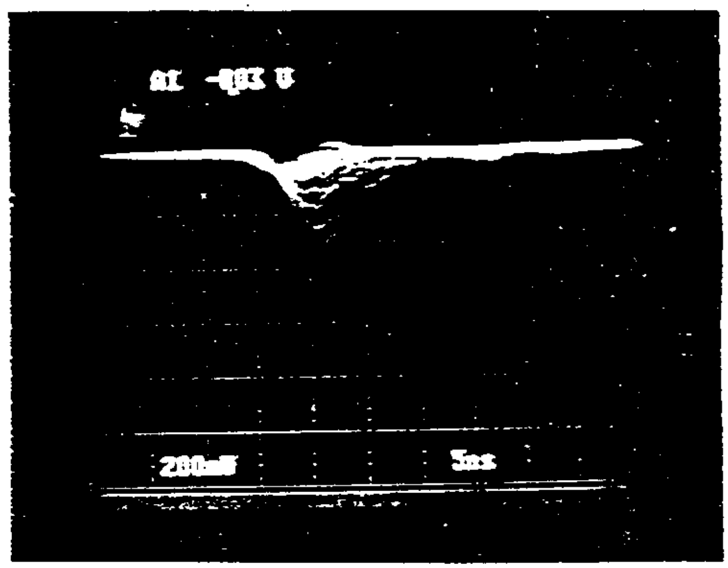
Full ZDC — 4 PMs per block

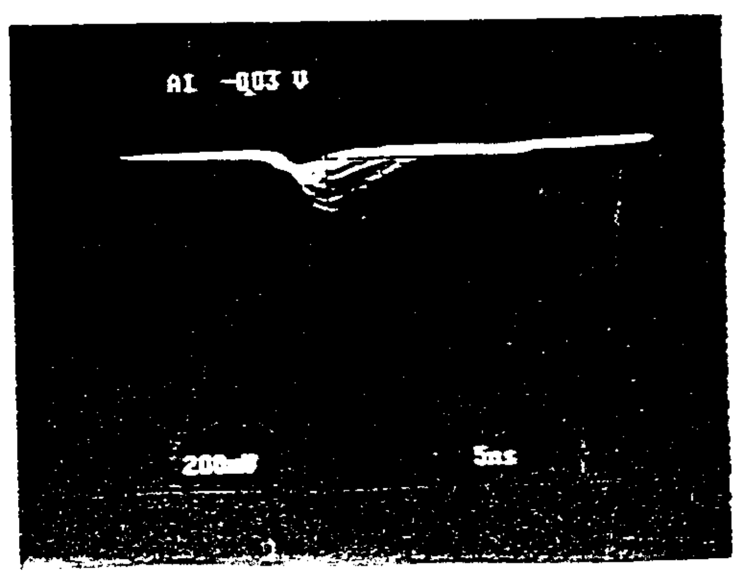

0.2 p.e./GeV
6.4 TeV
=> 1300 p.e.
L = 90 cm
R = 11 cm
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
Full ZDC – 1 PM per block

104/'92.

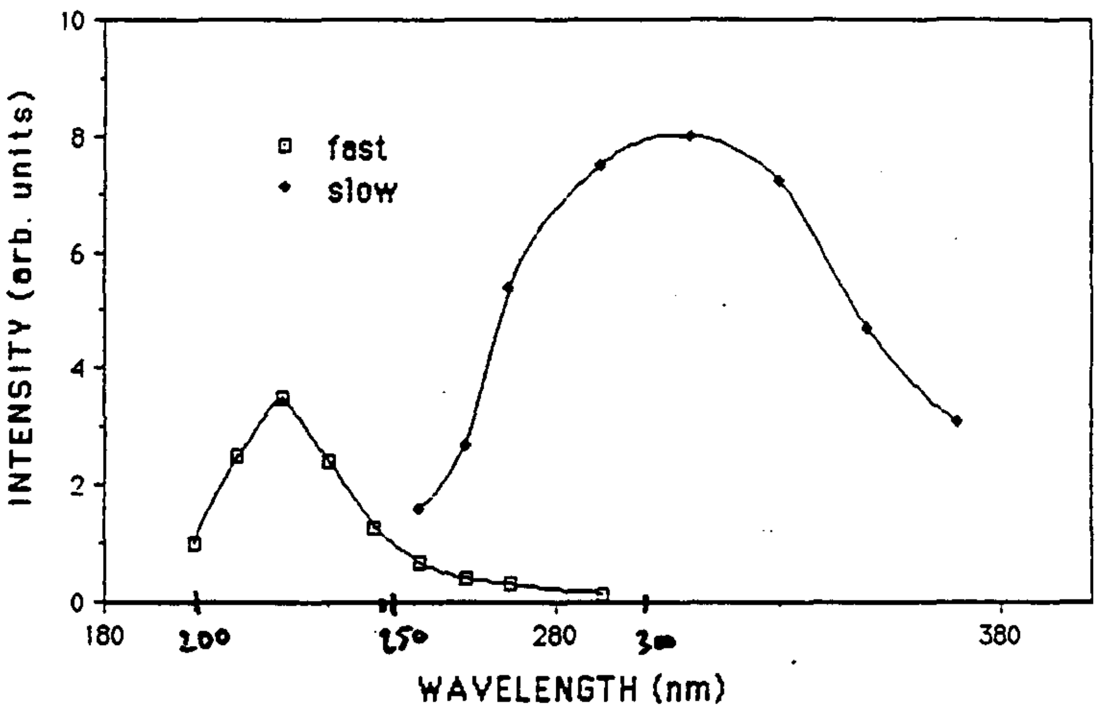
ing
from
35V
)

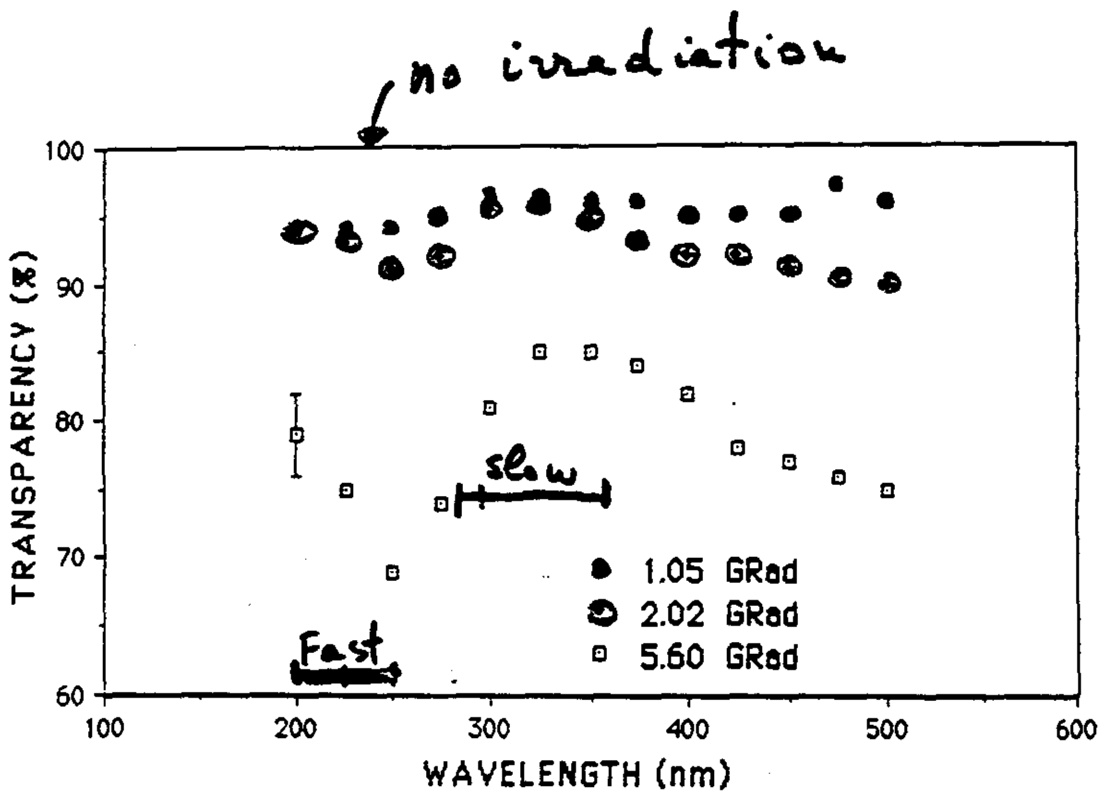




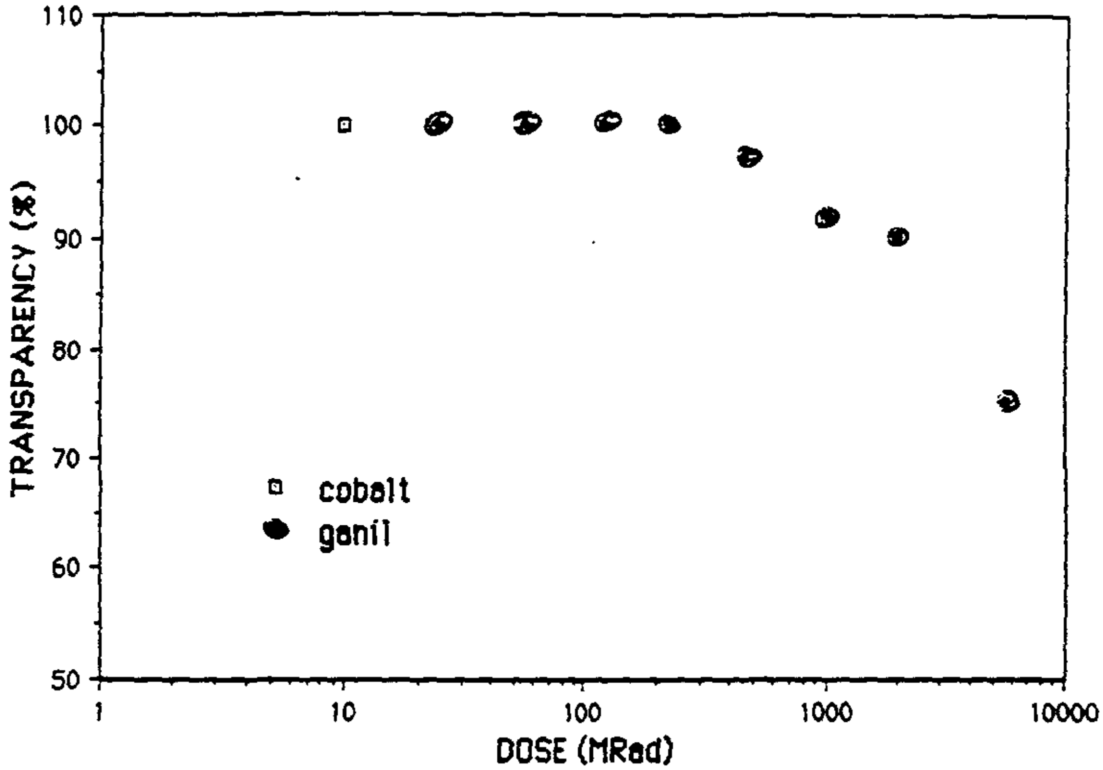


The 2 components of BaF_2



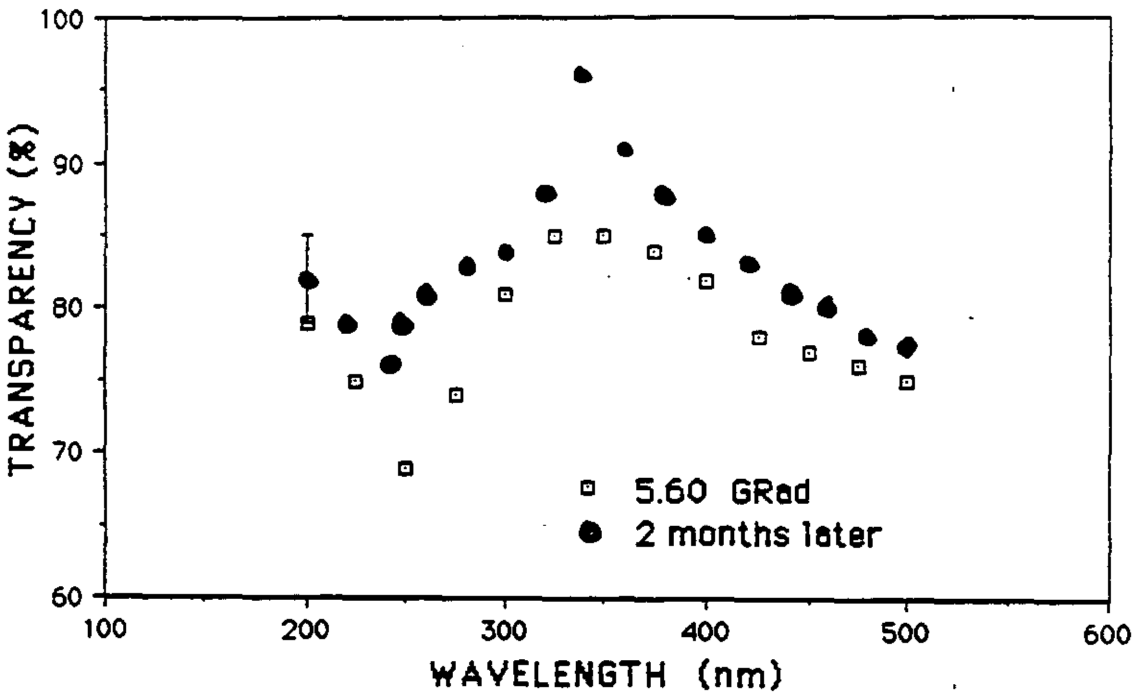


1 mm thick BaF_2



1 mm thick BaF_2

Fast component



1 mm thick BaF_2 .

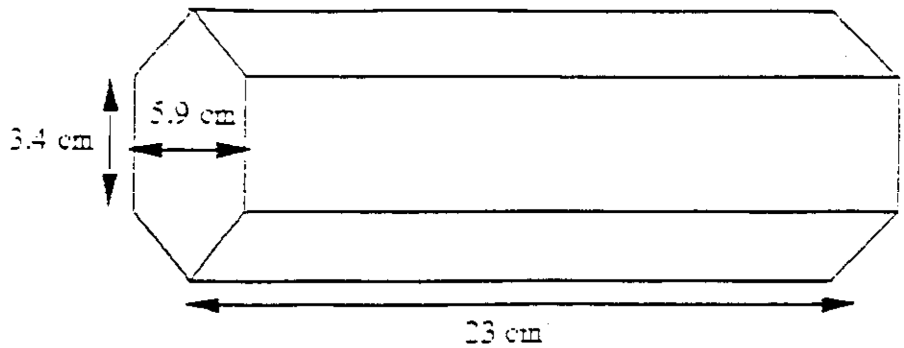


Fig V.7: *Caractéristiques d'un module TAPS.*

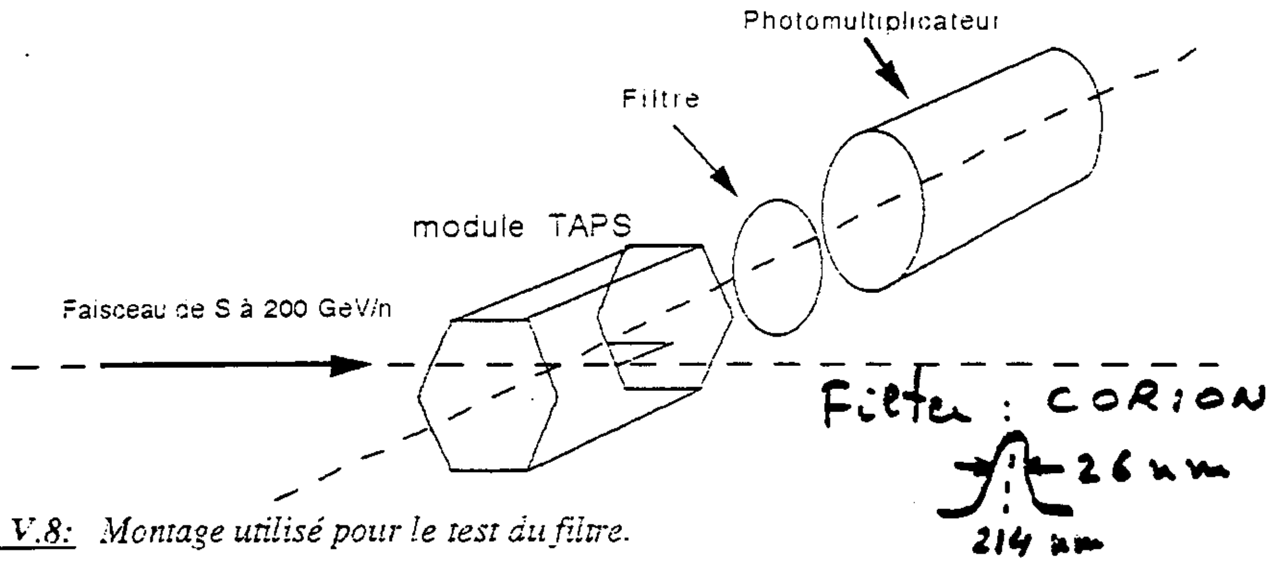


Fig V.8: *Montage utilisé pour le test du filtre.*

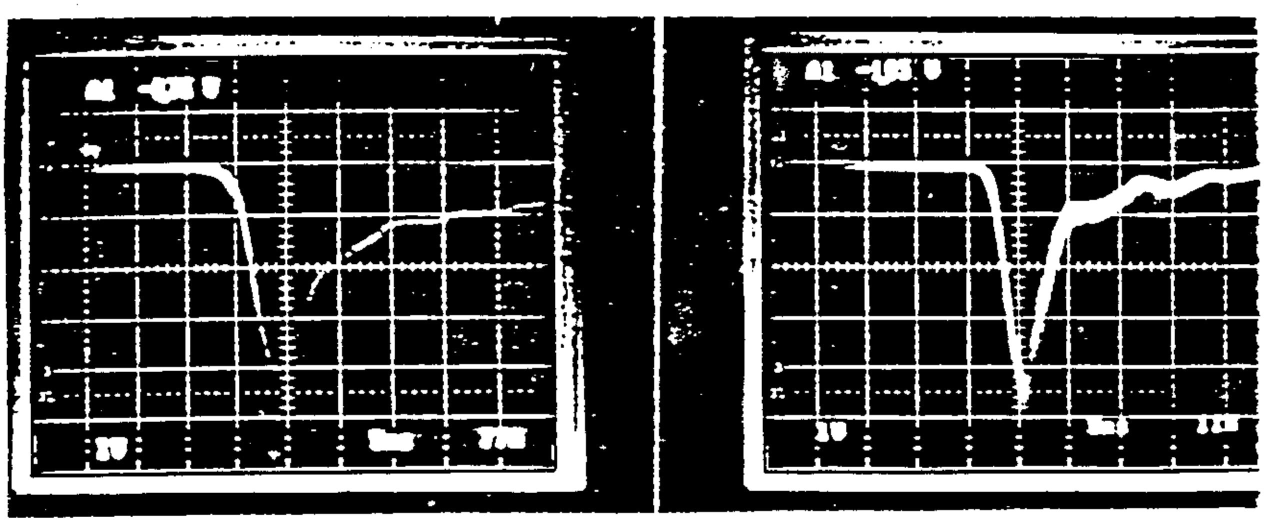
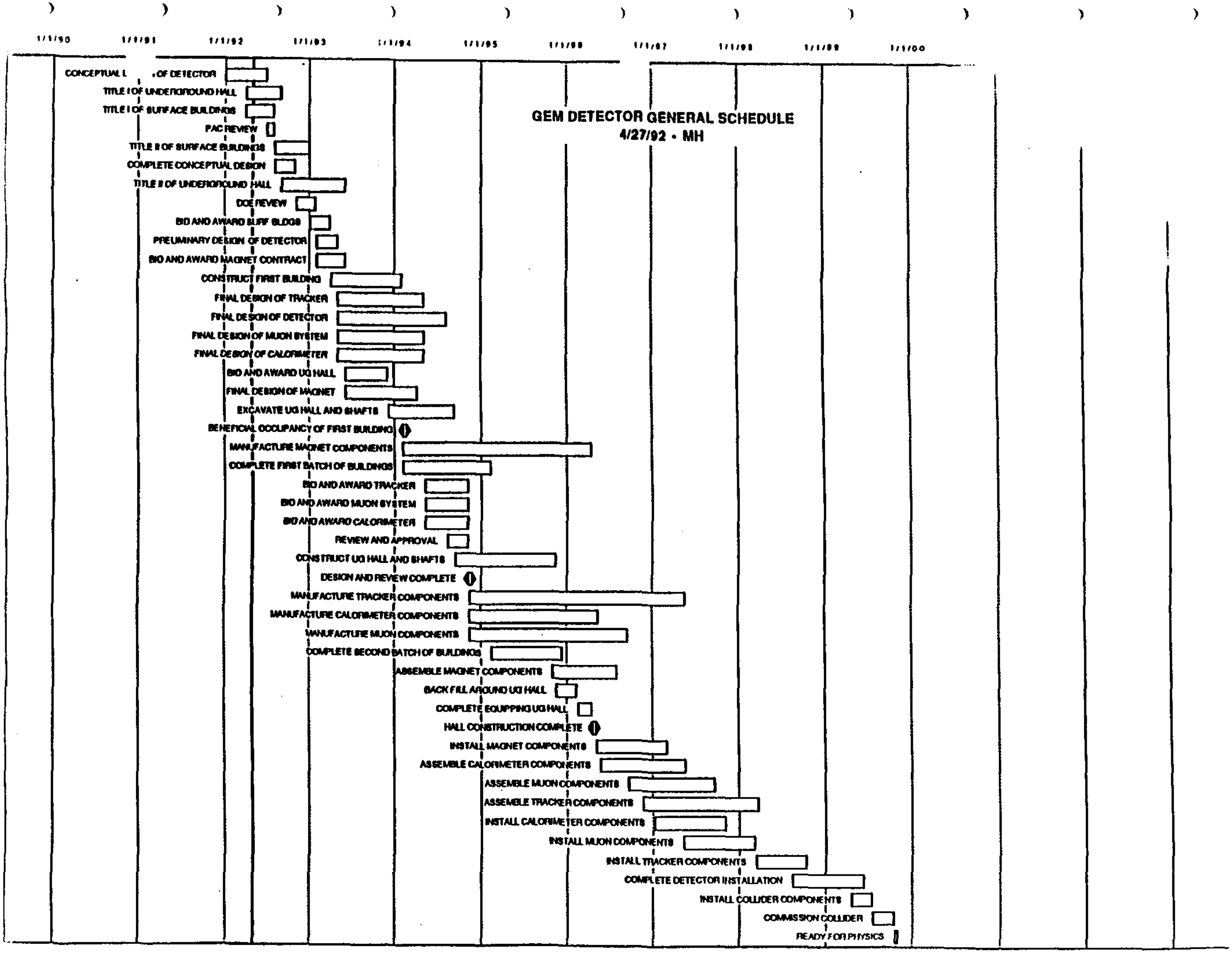


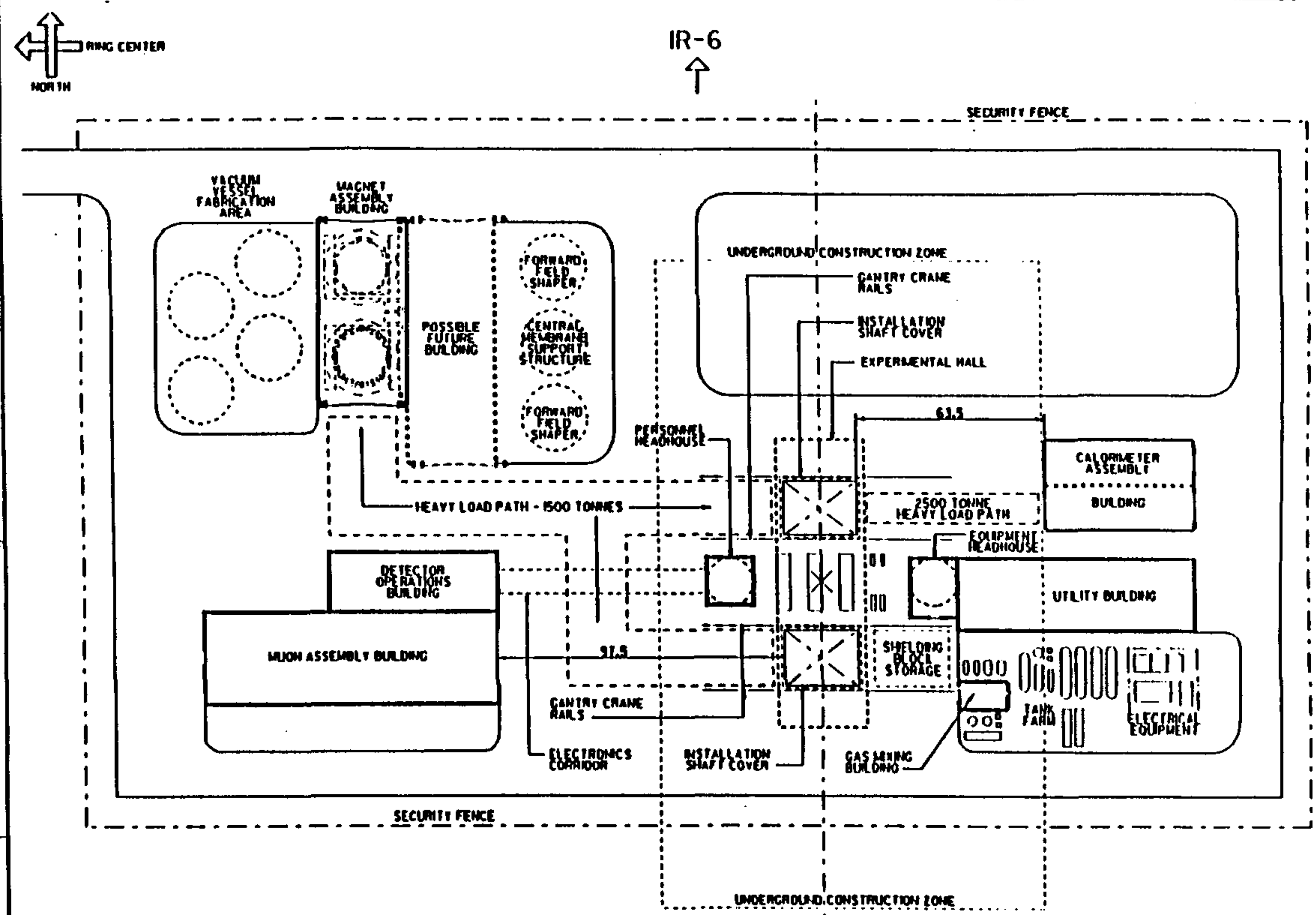
Fig V.9: *Courbe de l'oscilloscope sans le filtre (à gauche) n°1 avec le filtre (à droite) n°2. Les échelles horizontale et verticale sont respectivement égales à 5ns par division et 1 V par division.*

La composante lente apparait sur la photographie n°1 à gauche du pic. le signal ne revient pas à 0 mais reste constamment à -1 V. Sur la photographie n°2. le signal revient à 0. Nous constatons bien l'effet du filtre. Cette atténuation du signal d'un gem γeμ

Presentation by:

Mark Rennich


GEM DETECTOR GENERAL SCHEDULE
4/27/92 - MH
1/1/90
1/1/91
1/1/92
1/1/93
1/1/94
1/1/95
1/1/96
1/1/97
1/1/98
1/1/99
1/1/00
CONCEPTUAL [illegible] OF DETECTOR
TITLE I OF UNDERGROUND HALL
TITLE I OF SURFACE BUILDINGS
PAC REVIEW
TITLE II OF SURFACE BUILDINGS
COMPLETE CONCEPTUAL DESIGN
TITLE II OF UNDERGROUND HALL
DOE REVIEW
BID AND AWARD SURF BLDGS
PRELIMINARY DESIGN OF DETECTOR
BID AND AWARD MAGNET CONTRACT
CONSTRUCT FIRST BUILDING
FINAL DESIGN OF TRACKER
FINAL DESIGN OF DETECTOR
FINAL DESIGN OF MUON SYSTEM
FINAL DESIGN OF CALORIMETER
BID AND AWARD UG HALL
FINAL DESIGN OF MAGNET
EXCAVATE UG HALL AND SHAFTS
BENEFICIAL OCCUPANCY OF FIRST BUILDING
MANUFACTURE MAGNET COMPONENTS
COMPLETE FIRST BATCH OF BUILDINGS
BID AND AWARD TRACKER
BID AND AWARD MUON SYSTEM
BID AND AWARD CALORIMETER
REVIEW AND APPROVAL
CONSTRUCT UG HALL AND SHAFTS
DESIGN AND REVIEW COMPLETE
MANUFACTURE TRACKER COMPONENTS
MANUFACTURE CALORIMETER COMPONENTS
MANUFACTURE MUON COMPONENTS
COMPLETE SECOND BATCH OF BUILDINGS
ASSEMBLE MAGNET COMPONENTS
BACK FILL AROUND UG HALL
COMPLETE EQUIPPING UG HALL
HALL CONSTRUCTION COMPLETE
INSTALL MAGNET COMPONENTS
ASSEMBLE CALORIMETER COMPONENTS
ASSEMBLE MUON COMPONENTS
ASSEMBLE TRACKER COMPONENTS
INSTALL CALORIMETER COMPONENTS
INSTALL MUON COMPONENTS
INSTALL TRACKER COMPONENTS
COMPLETE DETECTOR INSTALLATION
INSTALL COLLIDER COMPONENTS
COMMISSION COLLIDER
READY FOR PHYSICS



SITE PLAN

DIMENSIONS ARE SHOWN IN METERS UNLESS NOTED OTHERWISE.

THIS IS A CAD GENERATED DRAWING. DO NOT MAKE MANUAL REVISIONS OR ALTERATIONS.

E. HAWLES

T. PROSAPIO

PHYSICS RESEARCH DIVISION

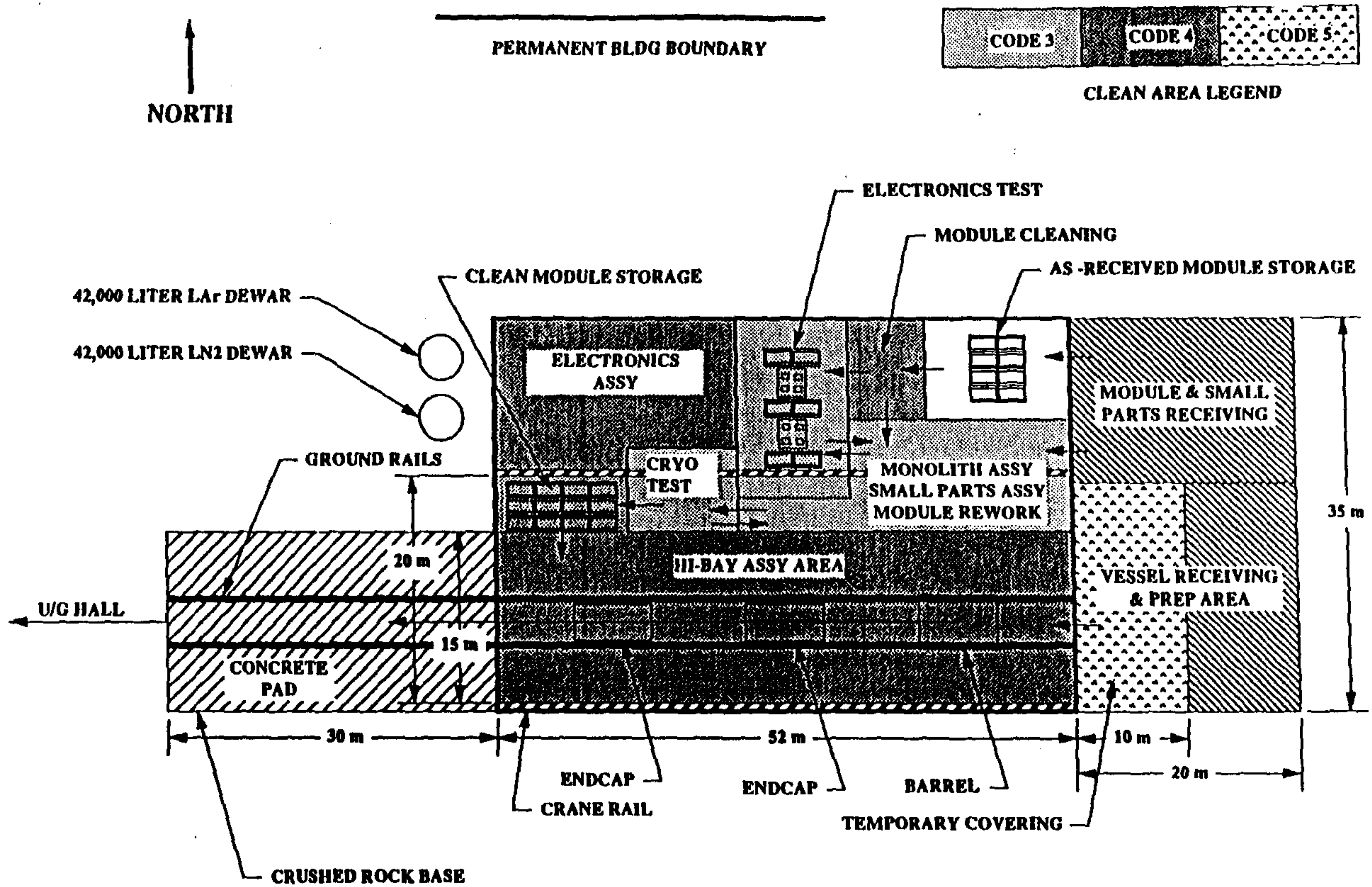
SSC

GEM EXPERIMENTAL FACILITIES

IR-5

SITE PLAN

GCD-000113 | 001



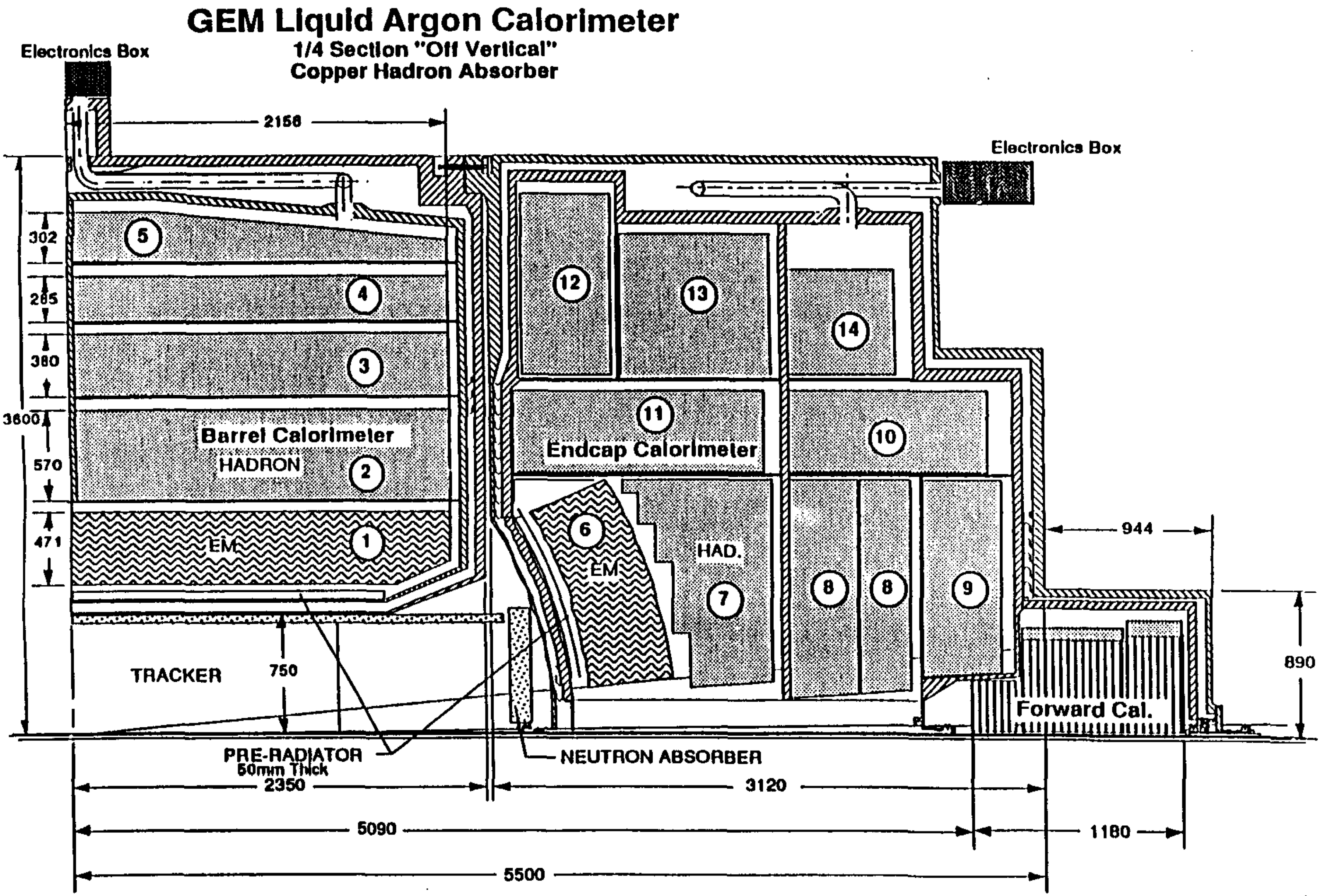
DRAFT
SCALE 500:1
Eberle 03/02/92

CRANE REQUIREMENTS

HI-BAY: 50/10 TONNE BRIDGE CRANE
VESSEL RECEIVING/PREP: 50 TONNE BOOM CRANE

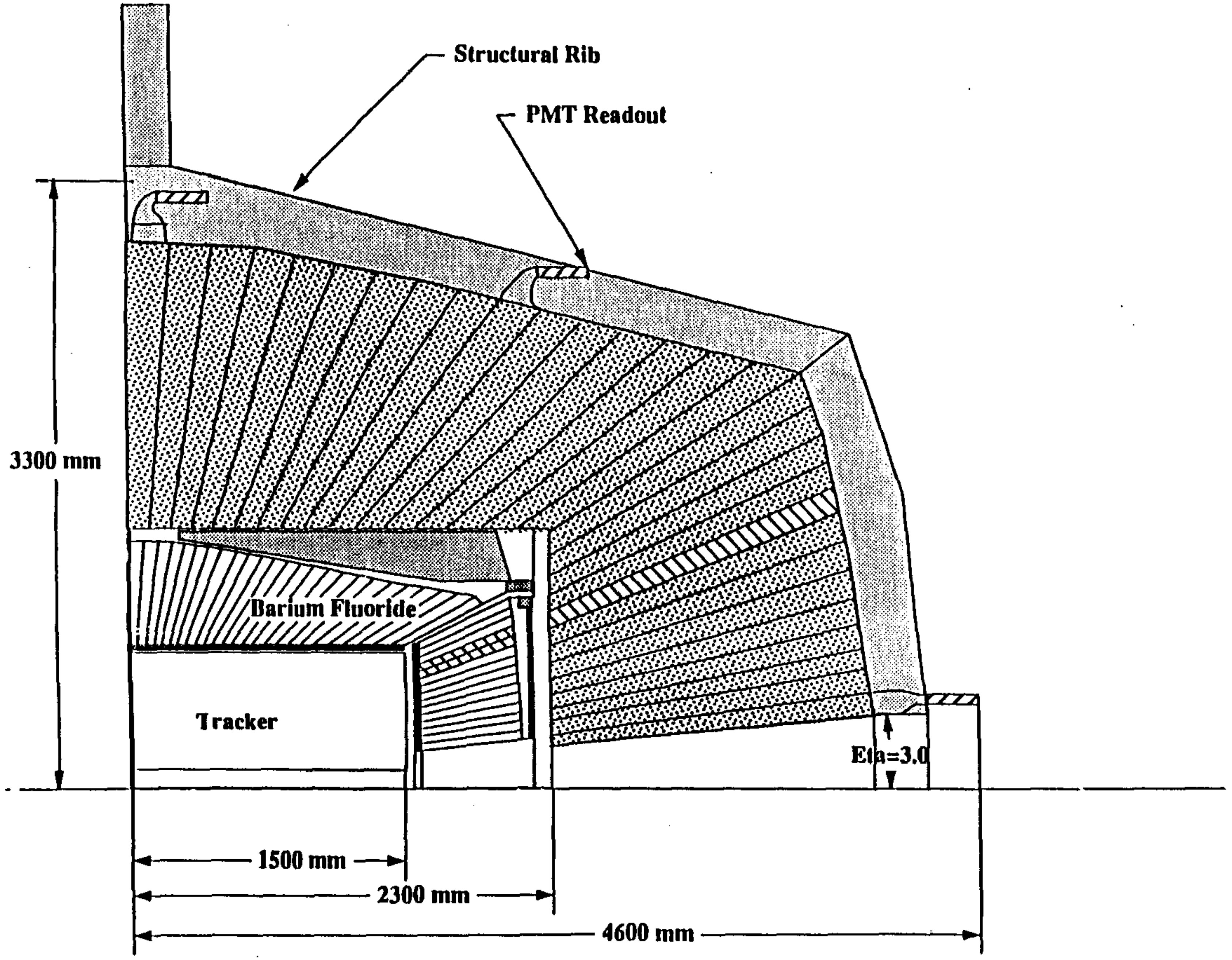
GEM CALORIMETER ASSY BLDG PLAN VIEW

Co..figuration



LLMason GEMLAC.4/10/92

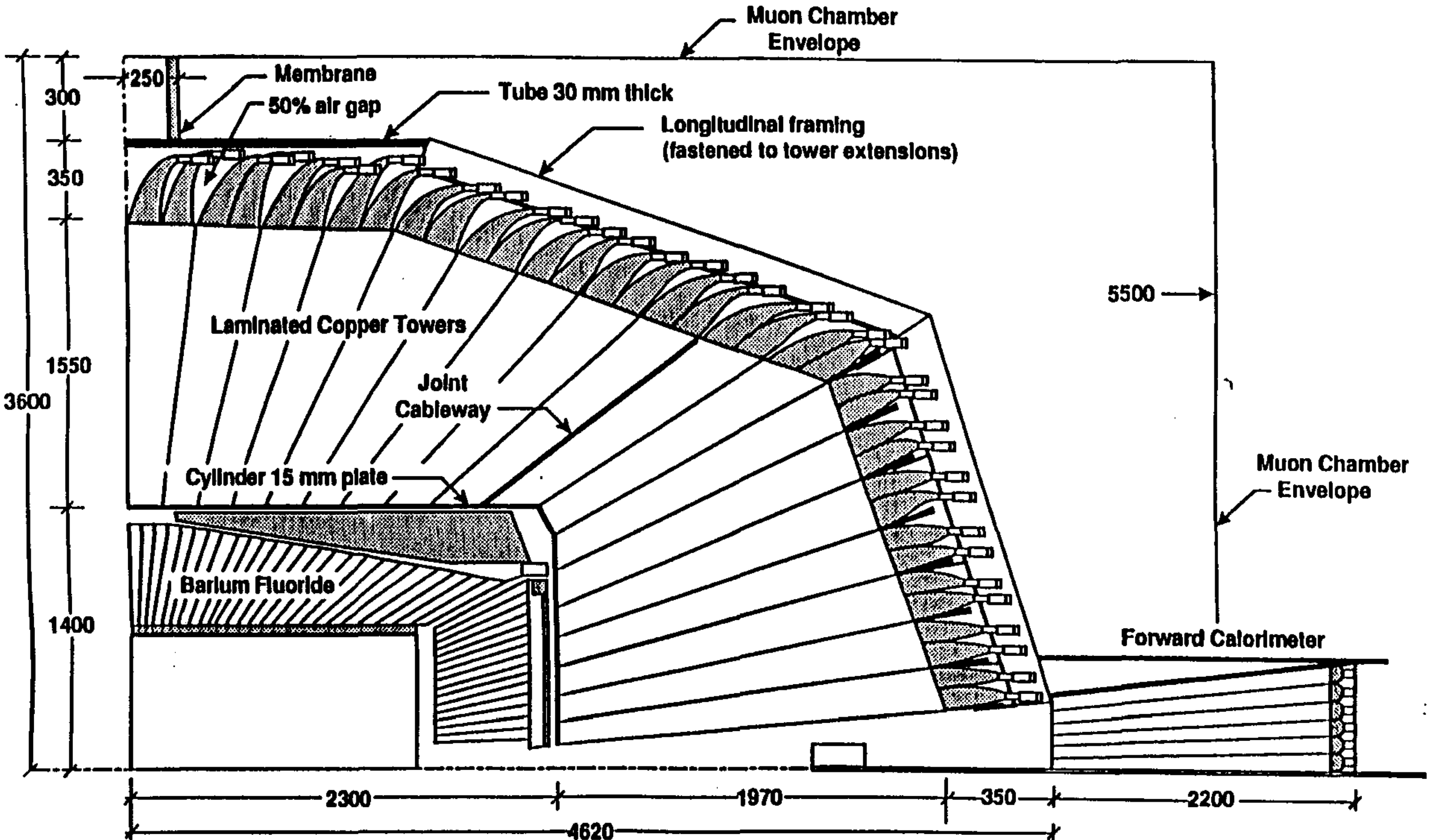
4/21/92



Spaghetti Hadron Calorimeter
Copper Fill/0.12 Segmentation
Barium Fluoride EM Calorimeter

G.03.SC.00079

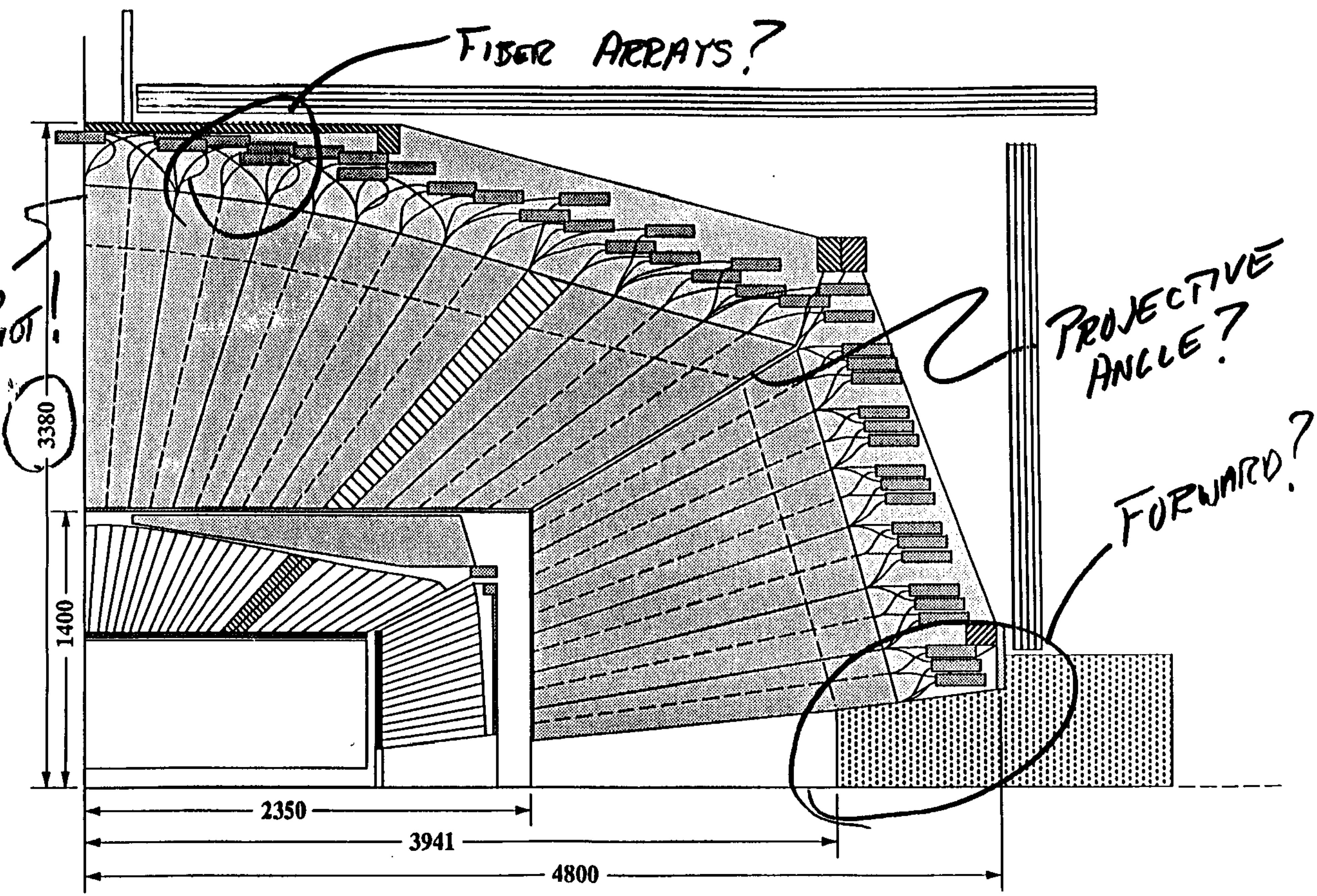
Rennich



Dimensions in millimeters

GEM Scintillator Calorimeter System

F. Ayer 9203D270

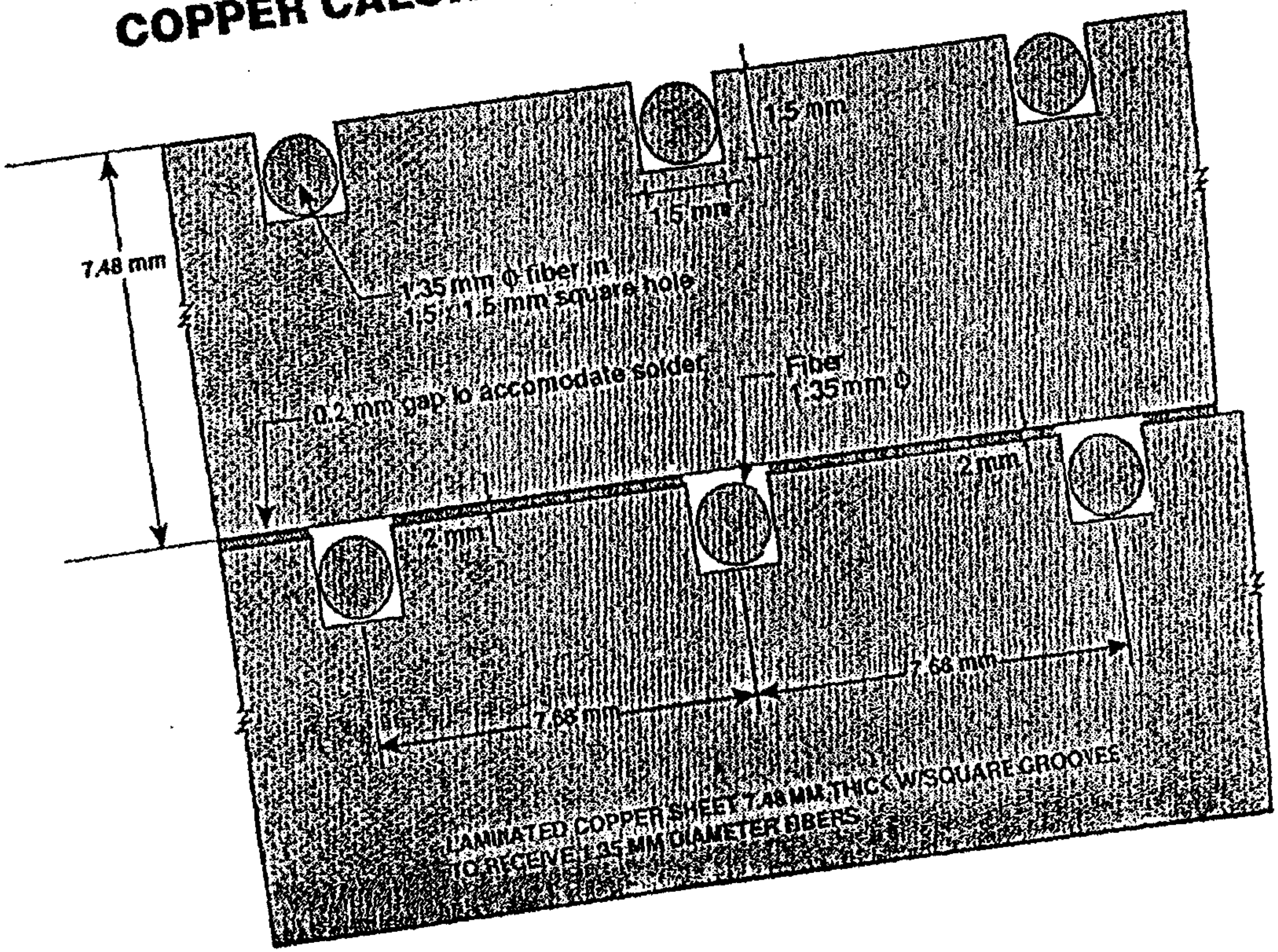


GEM Detector
Fiber Hadron Calorimeter

G.03.CU.020

Rennich

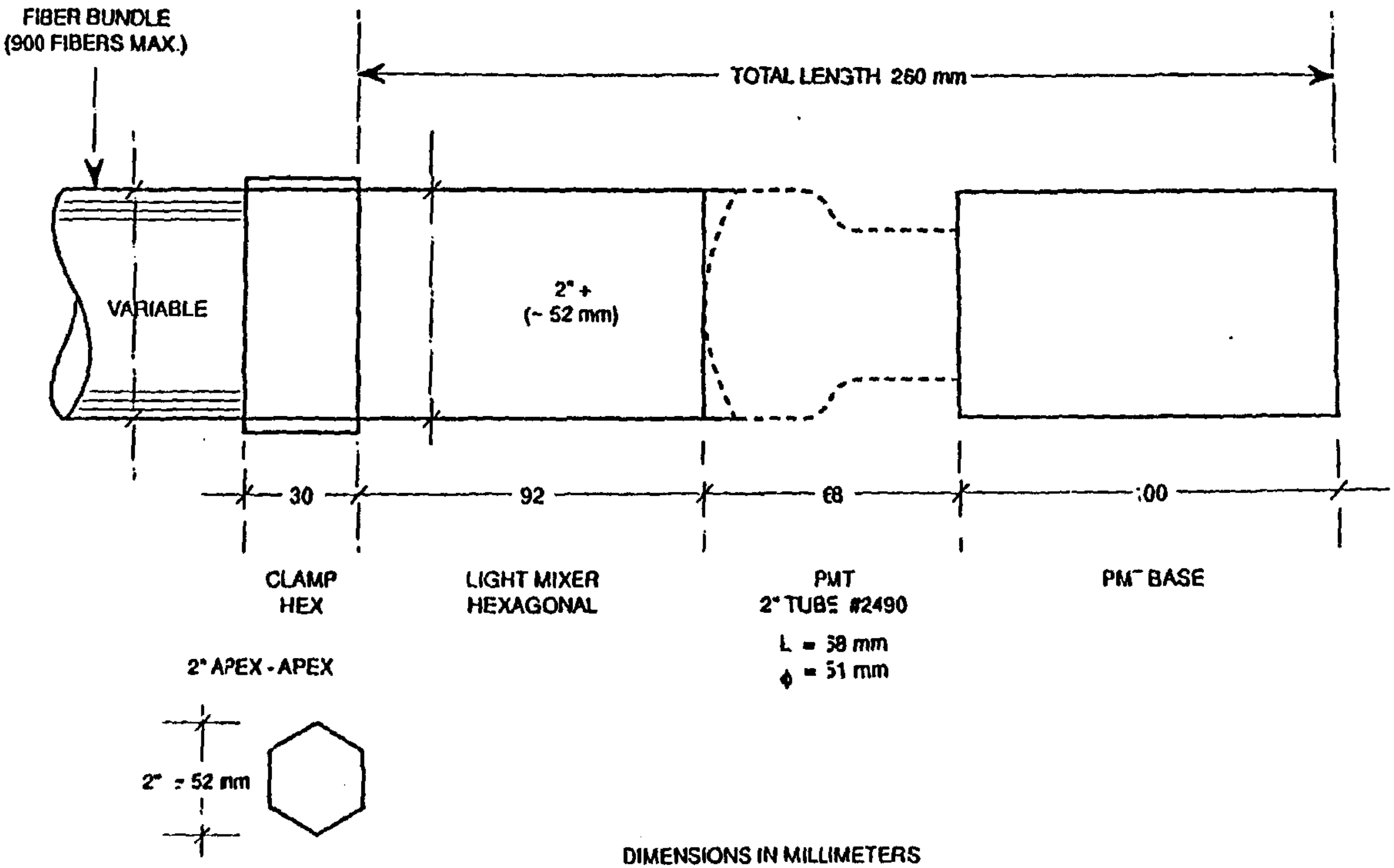
COPPER CALORIMETER TOWER GEOMETRY

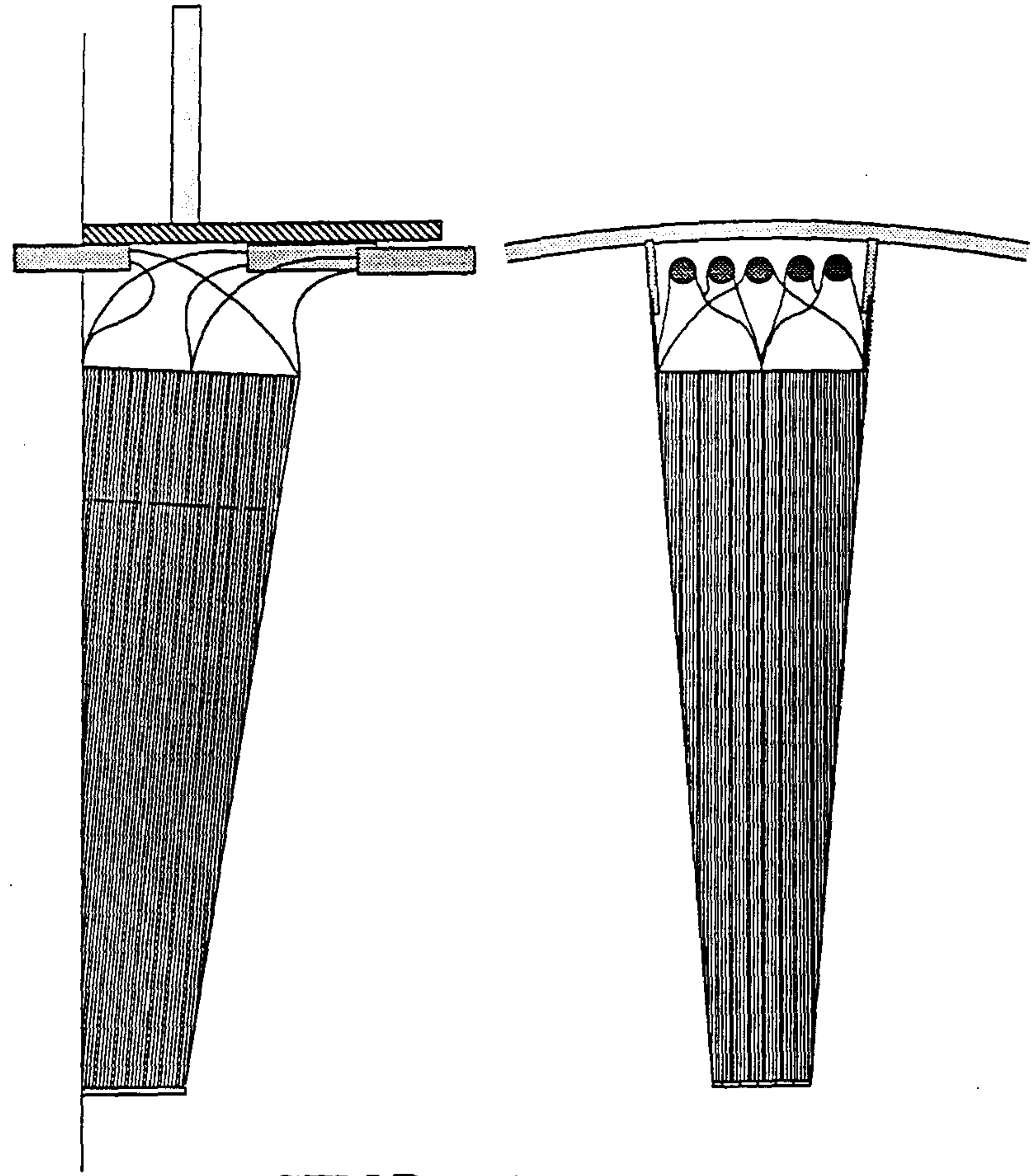


Ayer/4/9/92

LIGHT GUIDE / PMT / BASE ASSEMBLY

SCHEMATIC VIEW

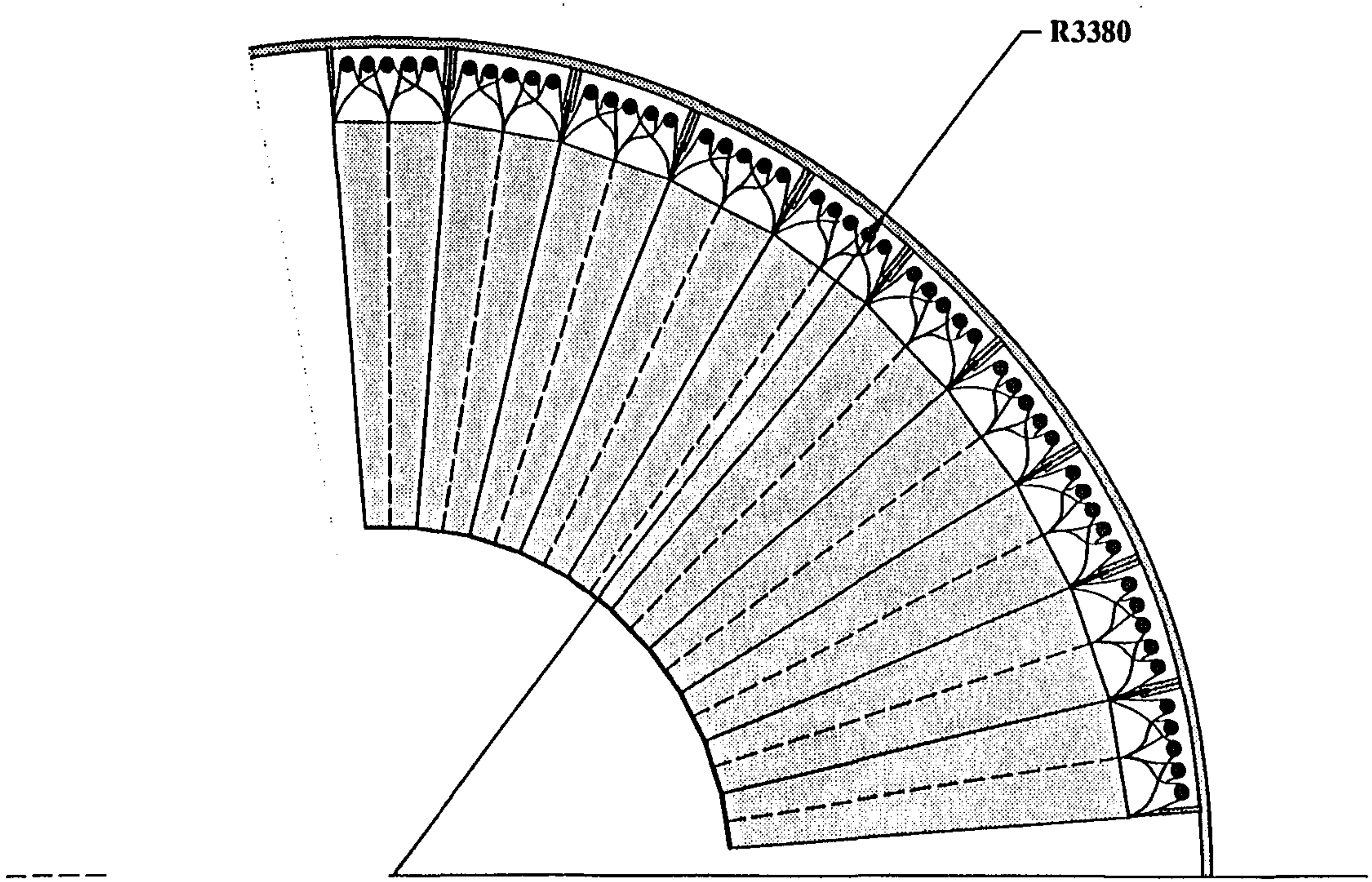




GEM Detector
Fiber Hadron Calorimeter
Eta=0 Tower

G.03.CU.021

Rennich



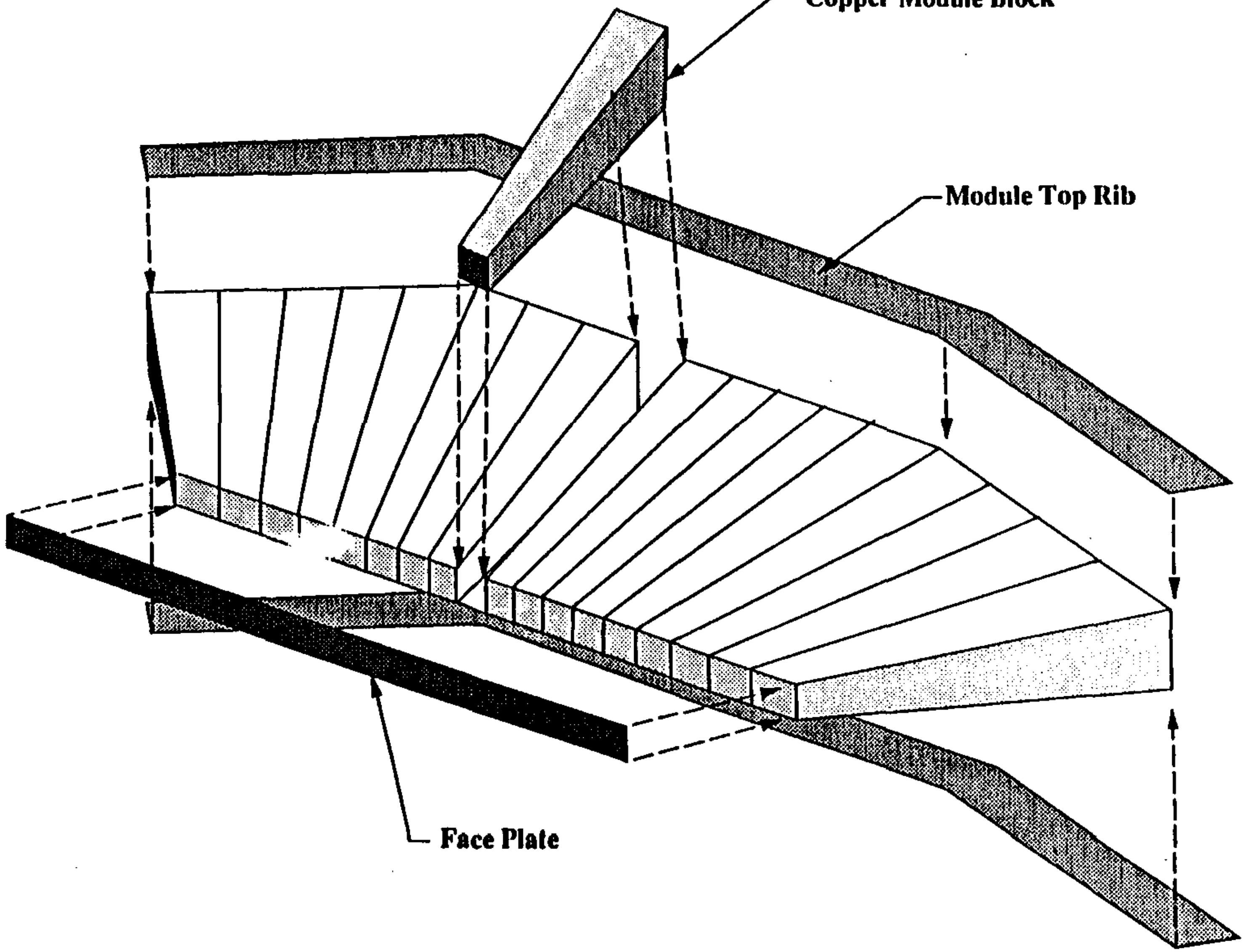
GEM Detector
Fiber Hadron Calorimeter

G.03.CU.020

Rennich

Computed Parameters for Complete Fiber Calorimeter

	Total	
Number of Mech.Theta Rows	28	Each
Number of Mech. Towers	940	Each
Absorber Volume	169.88	M^3
Fiber Lenght	3,749,264	M
Cu Tube Length	2,884,050	M
Cu Tube Volume	131.00	M^3
Number of Cu Plates	48,668	each
Copper Plate Weight	1292.47	Mt
Number of Fibers	2,510,848	each
Total Weight	1434.99	MT



GEM Detector
Fiber Calorimeter
Central Barrel Module
Assembly-Station One

G.03.CU.006

Rennich

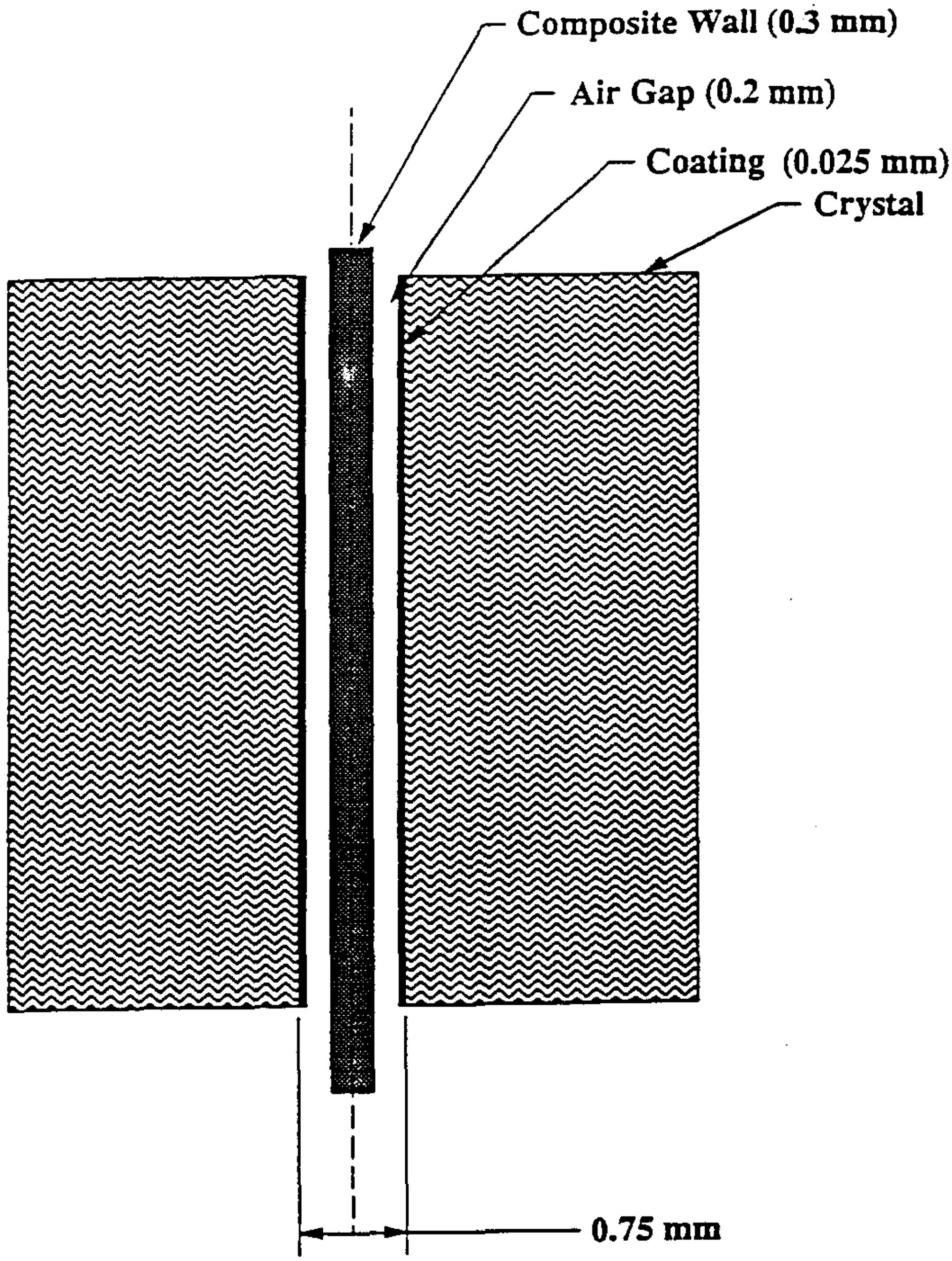
Scintillating Fiber Calorimeter
Catagory Distribution

Catagory	Estimate	Fraction
Research & Devel.	$3,445K	11.3%
EDIA	$9,419K	30.9%
Construction	$30,492K	
Contingency	$12,375K	31.0%
Total	$55,730K	

GEM Barium Fluoride EM Calorimeter

Potential Improvements

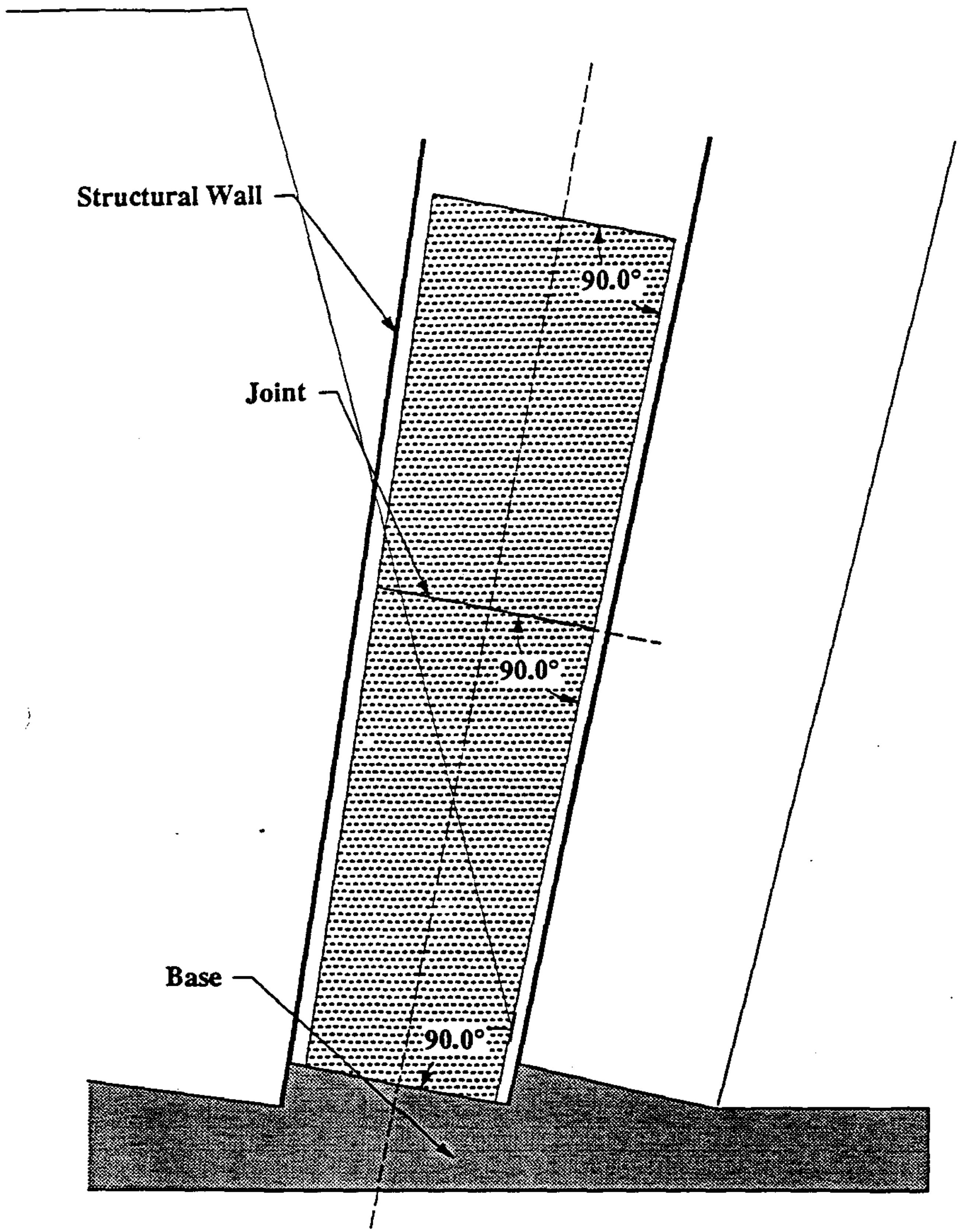
	Current	Potential
Structure	Fiber Composite	Titanium/Aluminide
Tolerancing	Centerline Reference	Face Reference
Inspection	Mechanical Gages	Coordinate Measuring Machine
Readout	Phototriode	Solid State Diode
Joint Matching	Lapping	Diamond Cutting



Barium Fluoride
Detail of Gap Between Crystals

G.03.BF.012

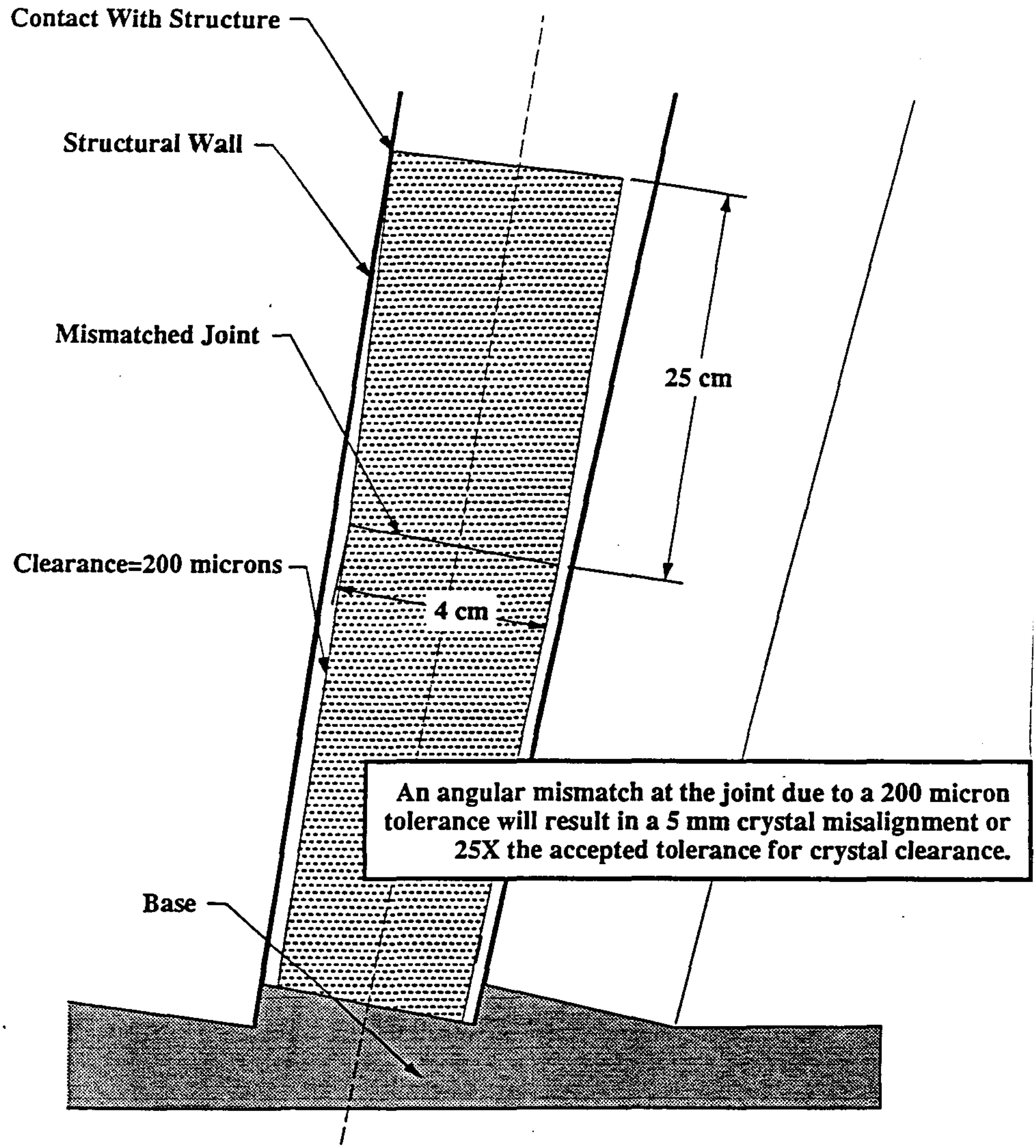
Rennich



Barium Fluoride
Preferred Crystal Tolerancing

G.03.BF.010

Rennich



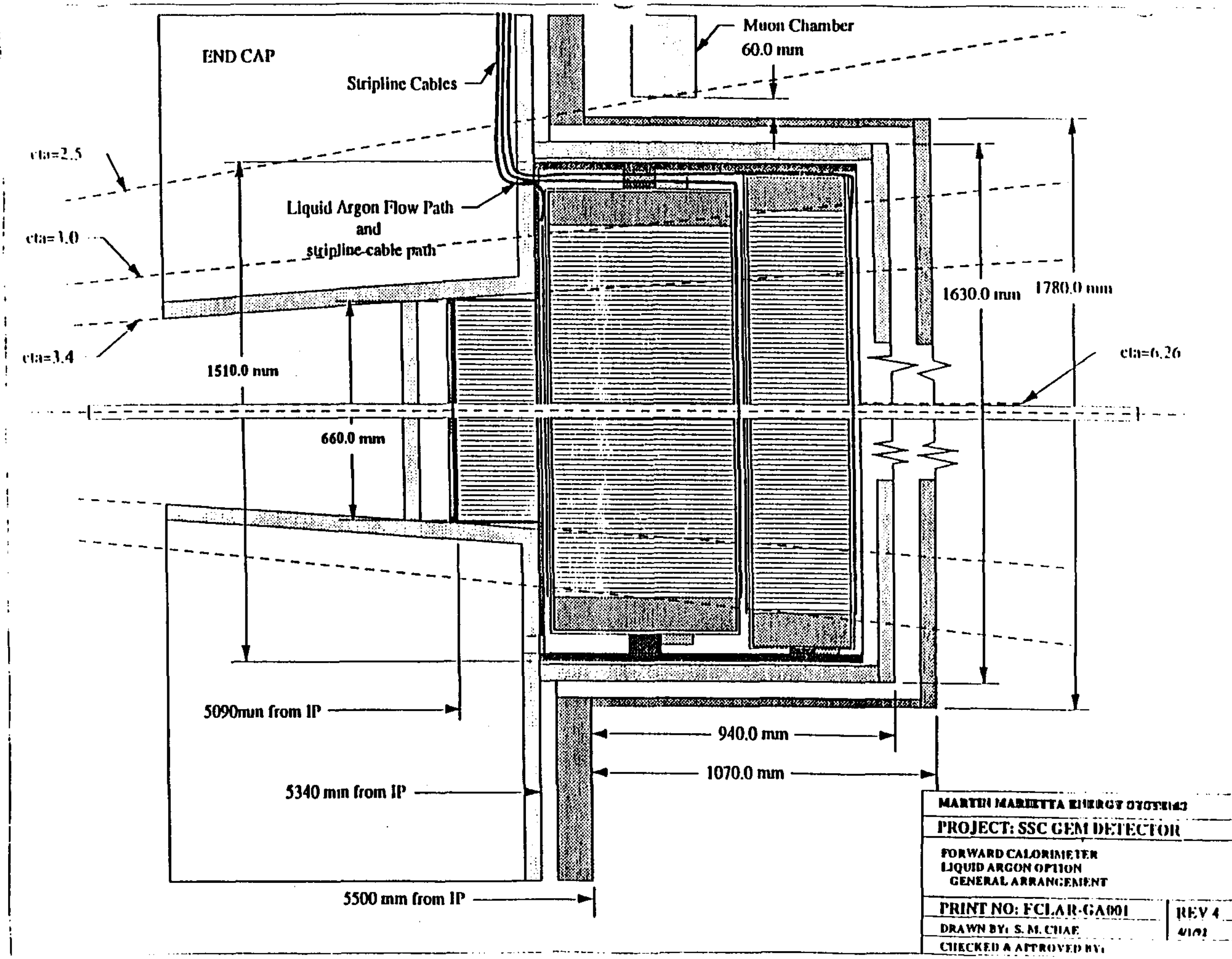
Barium Fluoride
Crystal Tolerancing
Joint Error

G.03.BF.011

Rennich

Barium Fluoride Calorimeter
Catagory Distribution

Catagory	Estimate	Fraction
Research & Devel.	$4,093K	7.2%
EDIA	$8,271K	14.6%
Construction	$56,509K	
Contingency	$11,417K	17.6%
Total	$80,290K	



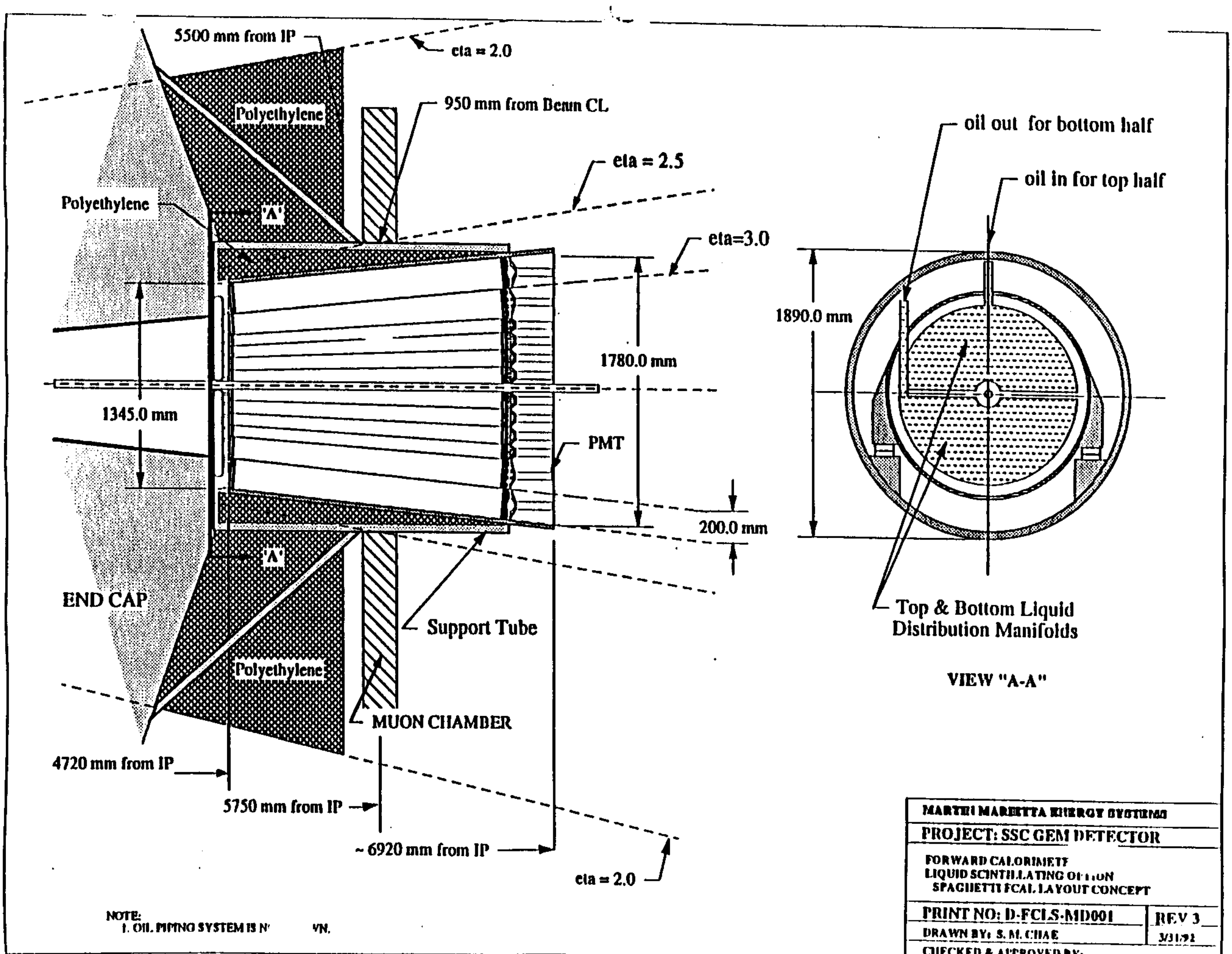
END CAP
Stripline Cables
Muon Chamber
60.0 mm
eta=2.5
eta=3.0
eta=3.4
eta=6.26
Liquid Argon Flow Path
and
stripline cable path
1510.0 mm
660.0 mm
1630.0 mm
1780.0 mm
5090mm from IP
5340 mm from IP
5500 mm from IP
940.0 mm
1070.0 mm
PROJECT: SSC GEM DETECTOR
FORWARD CALORIMETER
LIQUID ARGON OPTION
GENERAL ARRANGEMENT
PRINT NO: FCLAR-GA001
REV 4
DRAWN BY: S. M. CHAE
CHECKED & APPROVED BY:

LIQUID ARGON OPTION FORWARD CALORIMETER

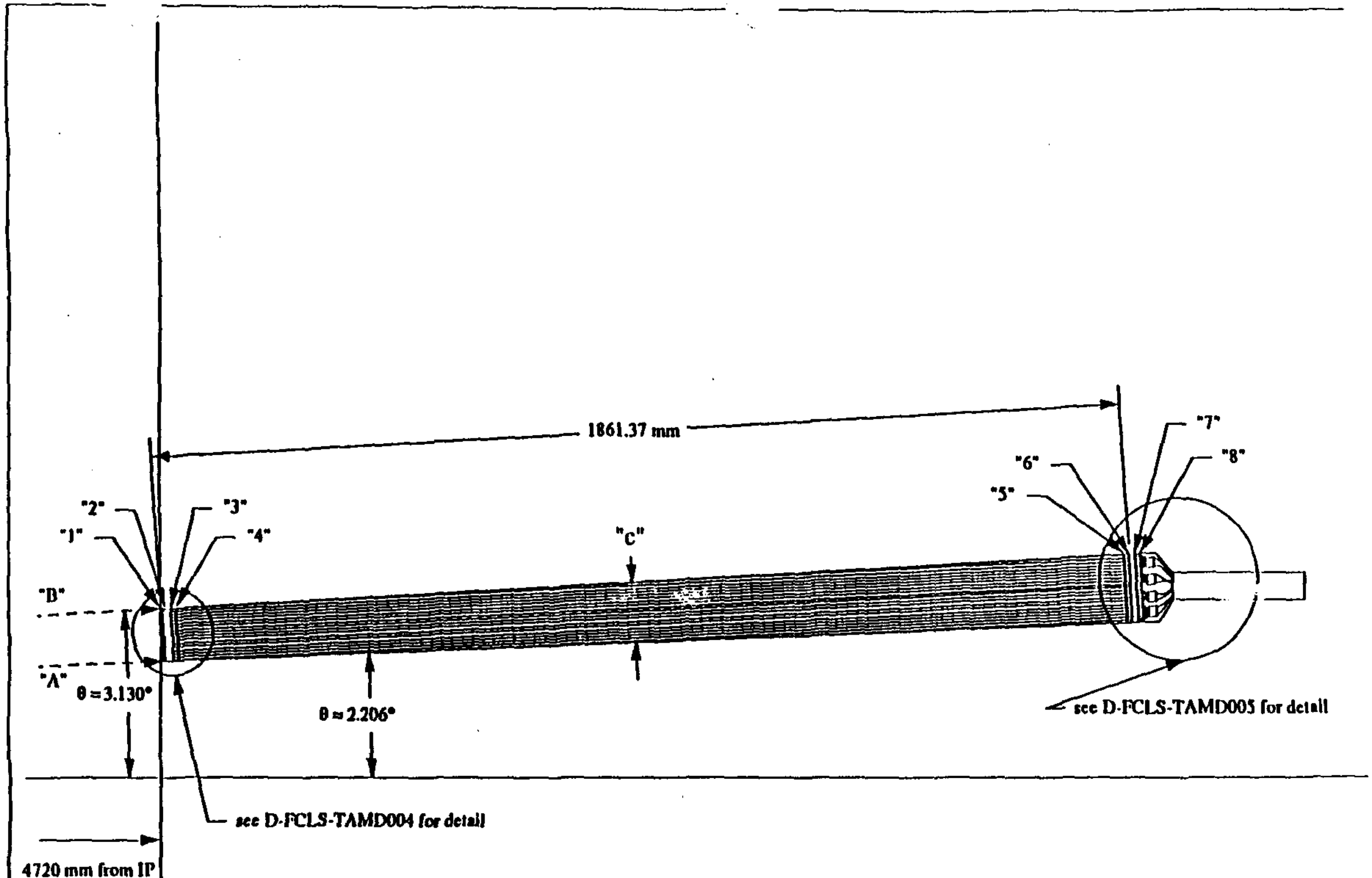
COST ESTIMATE SUMMARY

	ENGR/DESIGN M&S and INSPECTION	PROC/FAB MATERIAL	LABOR ASSEMBLY	LABOR INSTALLATION	SUBTOTAL
CONSTRUCTION	$2,332K	$7,103K	$883K	$20K	$10,338K
R&D	$708K	$165K	$37K	$0K	$910K
ENGINEERING	$282K	$0K	$0K	$0K	$282K
SUBTOTAL	$3,323K	$7,268K	$920K	$20K	$11,530K

	COST	PERCENTAGE
R&D	$910K	11.37%
EDIA	$2,614K	32.66%
CONSTRUCTION	$8,006K	
CONTINGENCY	$3,756K	35.37%
TOTAL	$15,286K	



5500 mm from IP
eta = 2.0
950 mm from Beam CL
Polyethylene
eta = 2.5
oil out for bottom half
oil in for top half
Polyethylene
'A'
eta=3.0
1890.0 mm
1780.0 mm
1345.0 mm
PMT
200.0 mm
'A'
END CAP
Support Tube
Top & Bottom Liquid
Distribution Manifolds
Polyethylene
VIEW "A-A"
MUON CHAMBER
4720 mm from IP
5750 mm from IP
~ 6920 mm from IP
eta = 2.0
MARTIN MARIETTA ENERGY SYSTEMS
PROJECT: SSC GEM DETECTOR
FORWARD CALORIMETE
LIQUID SCINTILLATING OI ·,ON
SPAGHETTI FCAL LAYOUT CONCEPT
PRINT NO: D-FCLS-MD001
REV 3
DRAWN BY: S. M. CHAE
3/31/92
CHECKED & APPROVED BY:
NOTE:
1. OIL PIPING SYSTEM IS N VN.



	1	2	3	4	5	6	7	8
RA	181.90	182.09	182.67	183.06	253.17	253.55	253.59	253.98
RB	258.03	258.30	259.12	259.67	359.13	359.67	359.73	360.28
**Length A	4725.28	4730.28	4745.28	4755.28	6576.65	6586.65	6587.65	6597.65
**Length B	4725.28	4730.28	4745.28	4755.28	6576.65	6586.65	6587.65	6597.65
Length C	74.75	74.83	75.07	75.22	104.04	104.19	104.21	104.37

** The lengths in the table indicate the distance from the interaction point.

MARTIN MARIETTA ENERGY SYSTEMS

PROJECT: SSC GEM DETECTOR

FORWARD CALORIMETER
LIQUID SCINTILLATING OPTION
SPAGHETTI TOWER & MODULE DESIGN
SUPER TOWER OF MODULE 4

PRINT NO: D-FCLS-TAMD003 | REV 2

DRAWN BY: S. M. CHAE | 3/24/92

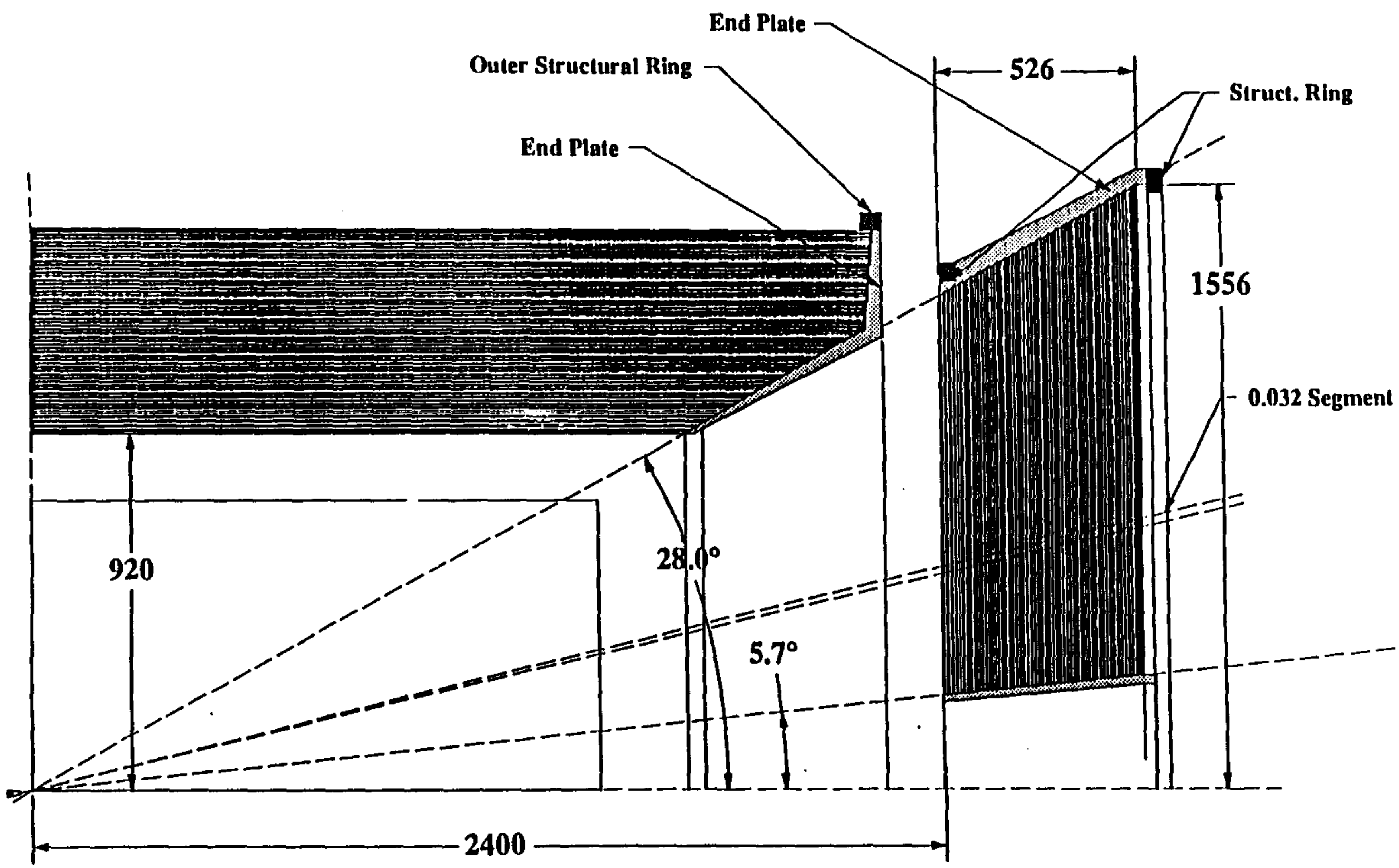
CHECKED & APPROVED BY:

SCINTILLATING LIQUID OPTION FORWARD CALORIMETER

COST ESTIMATE SUMMARY

	ENGR/DESIGN M&S and INSPECTION	PROC/FAB MATERIAL	LABOR ASSEMBLY	LABOR INSTALLATION	SUBTOTAL
CONSTRUCTION	$2,481K	$6,726K	$1,179K	$252K	$10,638K
R&D	$484K	$582K	$294K	$0K	$1,360K
ENGINEERING	$271K	$0K	$0K	$0K	$271K
SUBTOTAL	$3,236K	$7,307K	$1,474K	$252K	$12,269K

	COST	PERCENTAGE
R&D	$1,360K	16.76%
EDIA	$2,753K	30.59%
CONSTRUCTION	$8,111K	
CONTINGENCY	$4,139K	38.11%
TOTAL	$16,362K	



GEM Detector
Liquid Argon
EM Calorimeter
Parallel Plate

G.03.PP.001

Rennich

Computed Paramters for Complete Detector

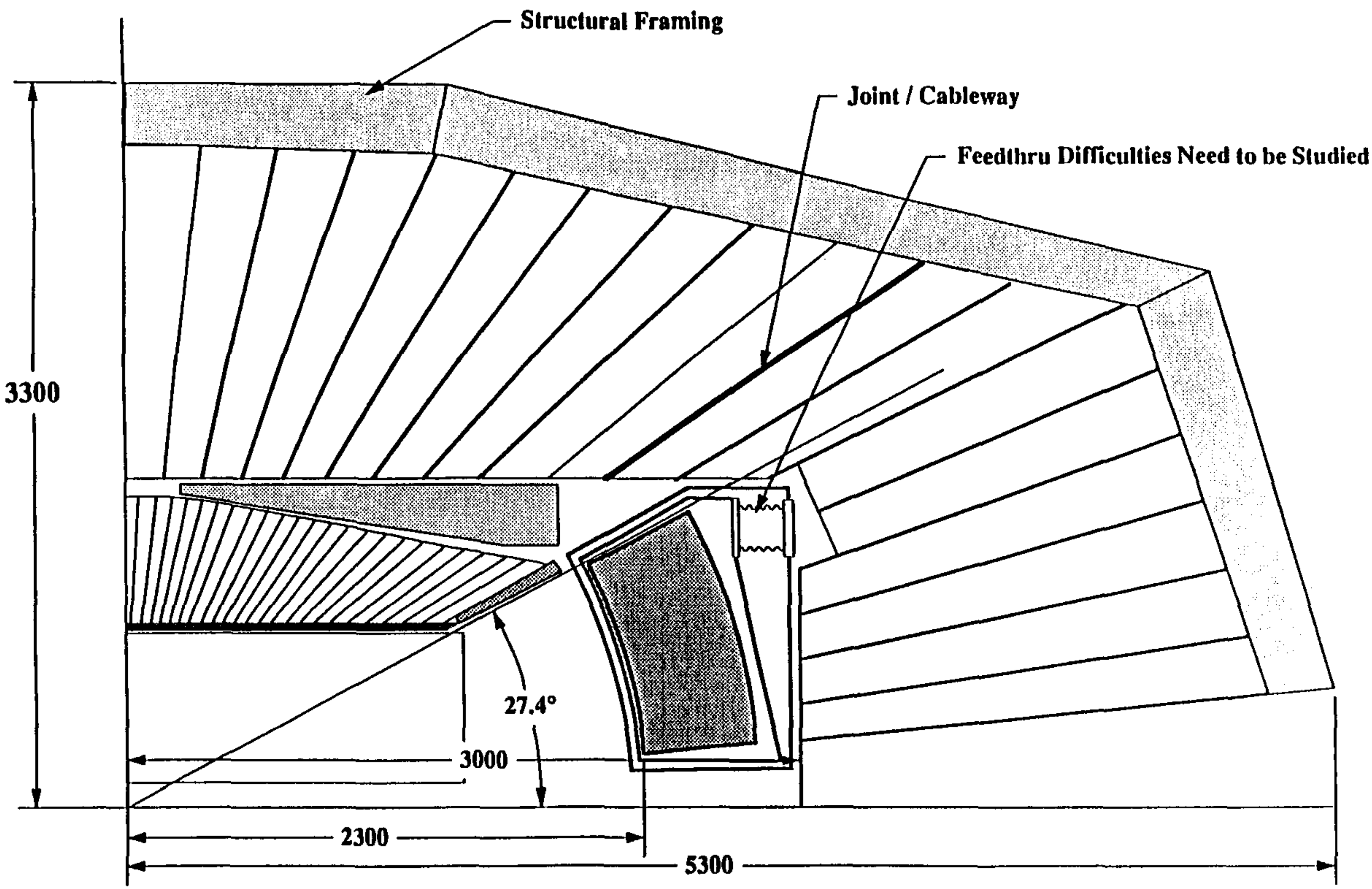
Totals	PreRadiator	EM Cal	Detector	
Segments	85,624	3,051,328	3,136,952	each
Channels	31,136	31,136	62,272	each
Striplines	1,948	7,784	9,732	each
Types of Stripline	42	42	84	each
Lenght of Stripline			5,357	M
Connections	281,697	3,814,160	4,095,857	Each
PreRadiator Plate Area	408	4244	4,652	M^2
Volume of Lead	0.61	6.37	6.98	M^3
Weight of Lead	6.95	72.25	79.20	Mt
Area of Copper	816	8,488	9,304	M^2
Weight of Copper	0.18	1.92	2.10	Mt
Area of PrePreg	816	8,488	9,304	M^2
Weight of PrePreg	0.42	4.33	4.74	Mt
Area of electrodes	408	4,244	4,652	M^2
Weight of Electrodes	0.14	1.49	1.63	Mt
Volume of LKr	0.73	7.64	8	M^3
Weight of LKr	1.25	12.99	14.23	Mt
Area of Amplifier	31.14	48.51	79.65	M^2
Active Material Weight	8.94	92.97	101.91	Mt

Parallel Plate LKr Calorimeter
Catagory Distribution

Catagory	Estimate	Fraction
Research & Devel.	$2,005K	10.3%
EDIA	$6,517K	23.9%
Construction	$19,461K	
Contingency	$9,766K	38.2%
Total	$37,750K	

GEM Detector Silicon Pre-Radiator

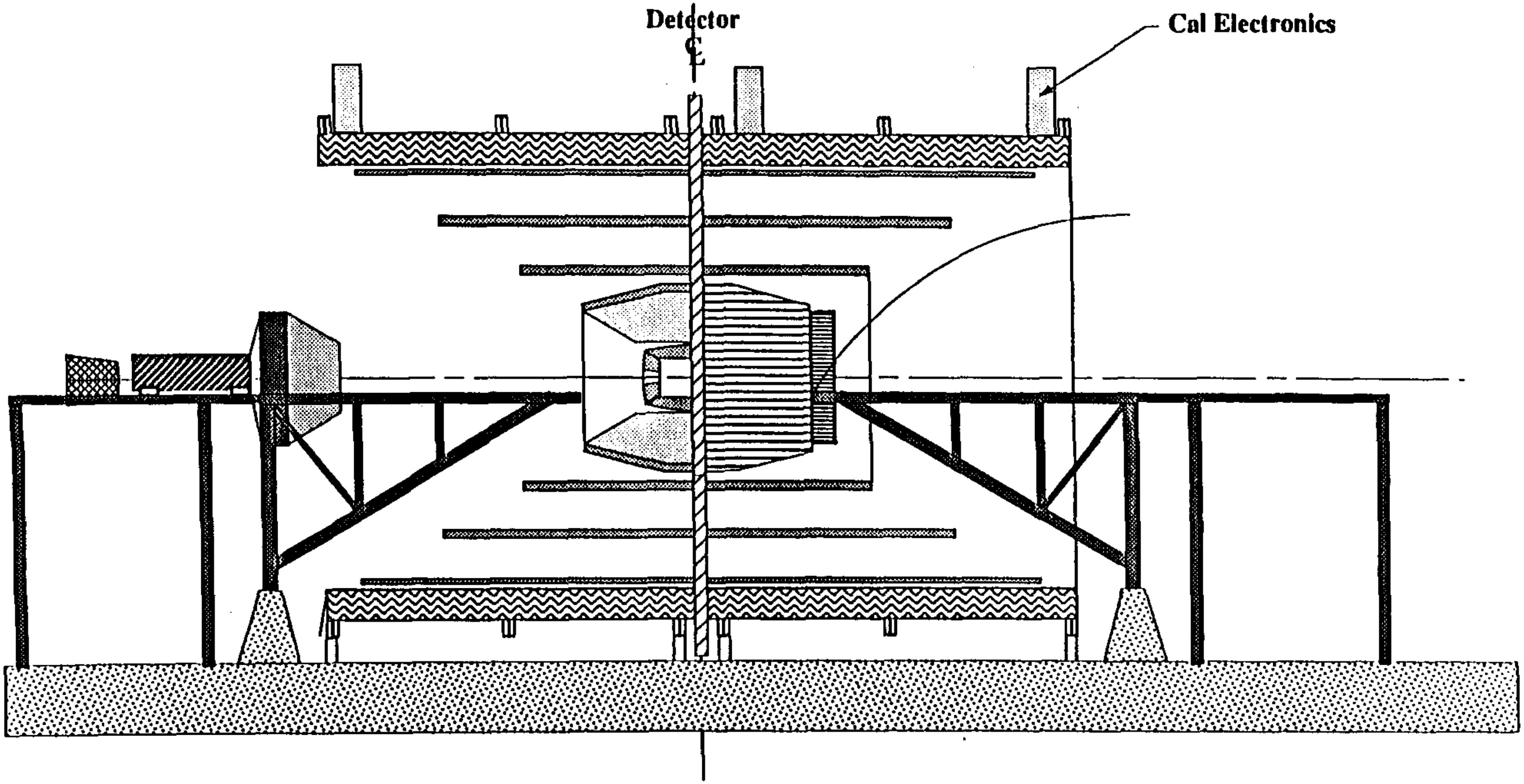
	Catagory	Tot Uts	$K/UNIT	Units	Cost
1.00	Material				
1.10	Skis				$90K
1.20	Silicon				$400K
1.30	MultiLayer Cards				$338K
2.00	Readout				
2.10	Electronics				$1,100K
3.00	Structure				
3.10	Cylinders	2	300.00	Each	$600K
3.30	End Plates	4	100.00	Each	$400K
4.00	Thermal Cont				$980K
5.00	Assembly				
5.10	Ass & Test	4	0.045	MH/chip	$2,761K
5.20	Tooling				$500K
6.00	Testing				
6.10	Test Beam Labor				$500K
6.20	Test Equip				$250K
7.00	Transport.				$100K
8.00	Installation				
8.10	Install. Labor	5550	0.045	MH	$250K
8.20	Install. Equip				$100K
	Direct Cost				**$8,369K**
	EDIA	25%			$2,092K
	Base Cost				**$10,461K**
	Contingency	40%			$4,184K
	Subtotal				**$14,646K**
	R&D	11%			$1,611K
	TOTAL				**$16,257K**



GEM Detector
BaFFiLAr Calorimeter

G.03.CU.017

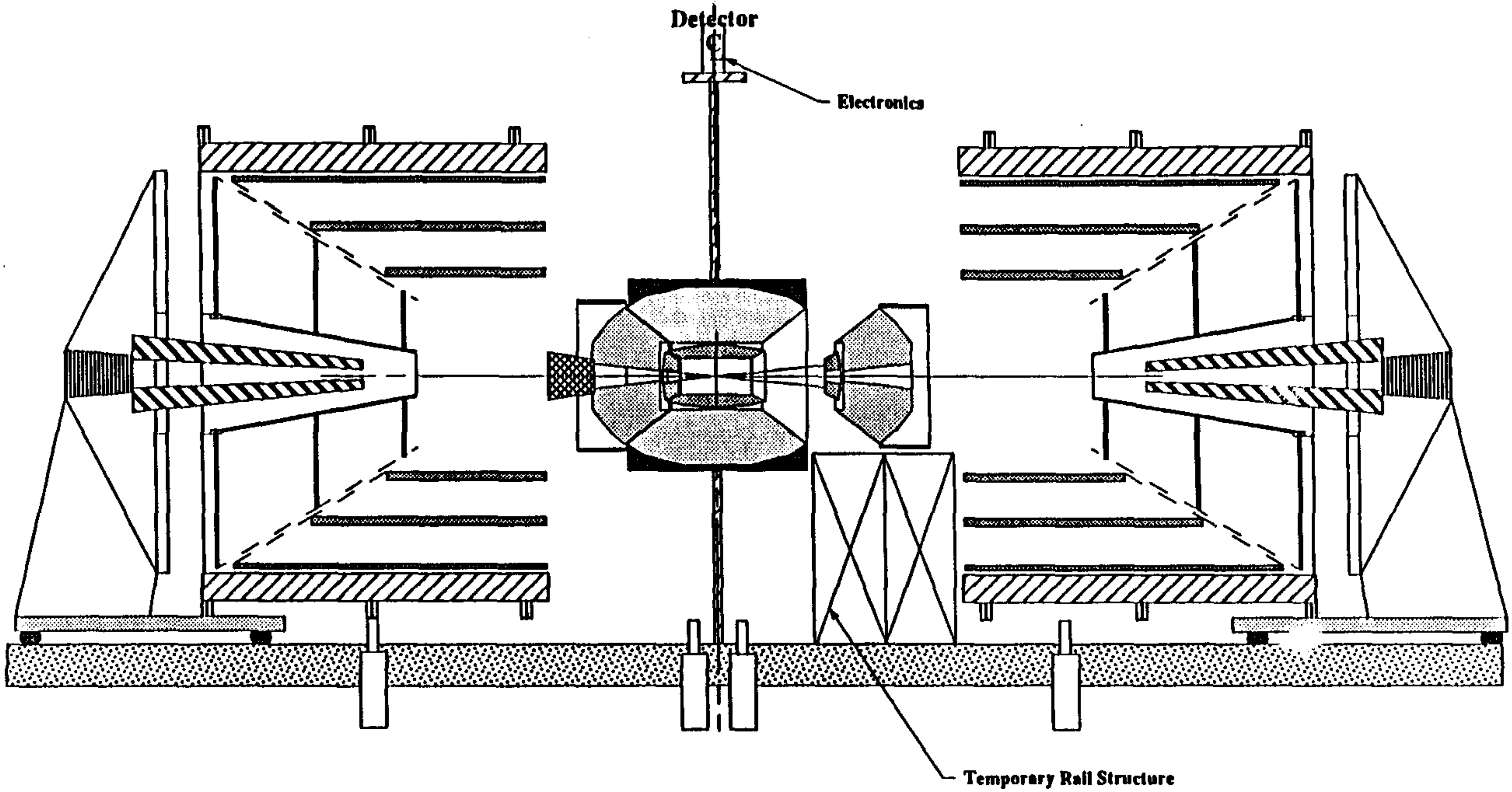
Rennich



GEM Configuration Option Study
Scintillating Calorimeter
Fixed Coil Version
ELEVATION VIEW

G.03.AS.015

EBERLE/RENNICH

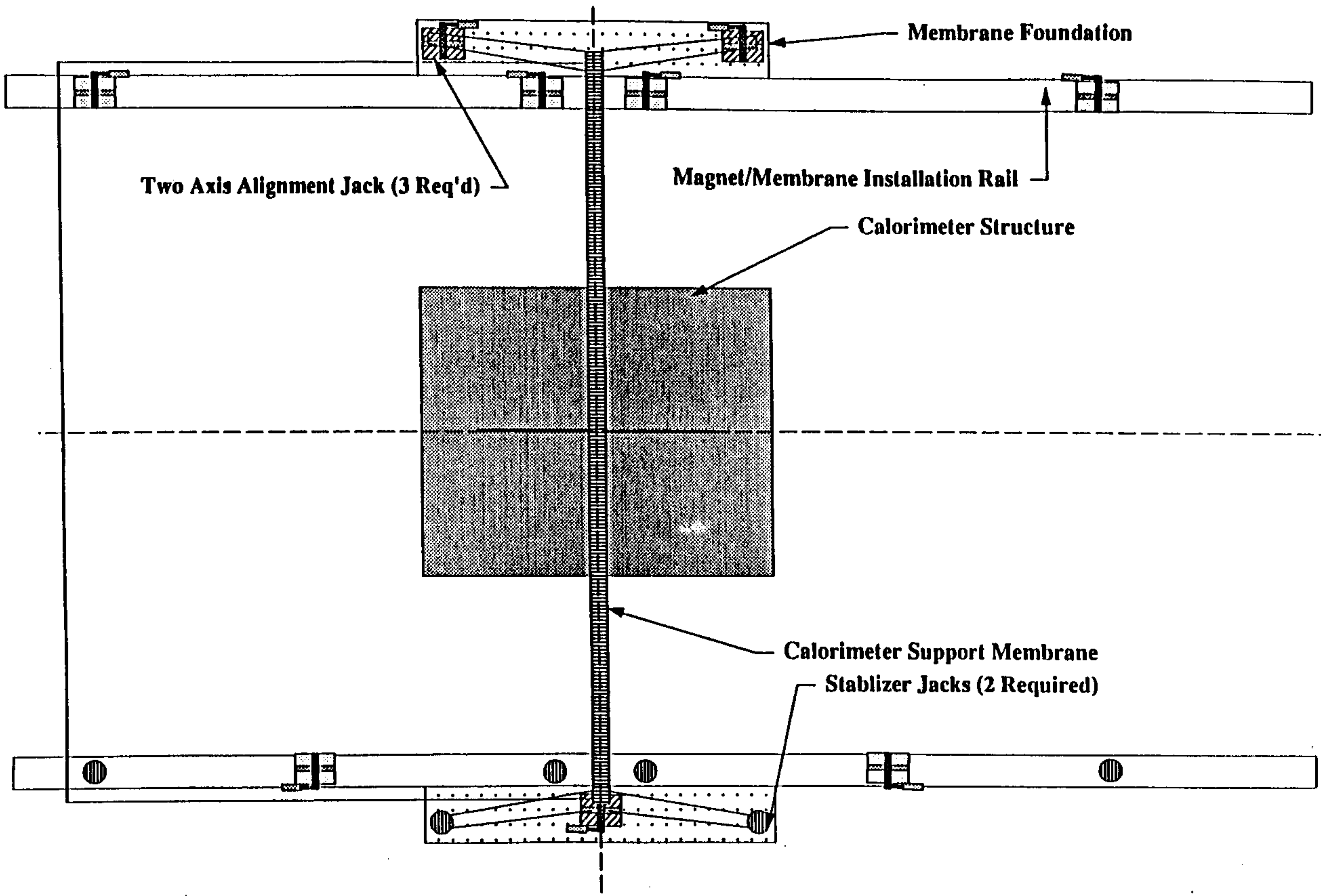


GEM Configuration Option Study
Scintillating Calorimeter
Integral Calorimeter Version

G.03.AS.00010

EBERLE/RENNICH

Note: One Side Access Possible with Revised Structural Arrangement



GEM Detector
Membrane Support System

G.03.M.005

Rennich

gem

γeμ

Presentation by:

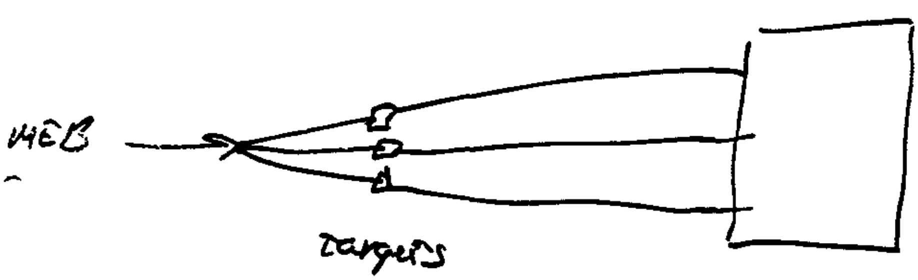
George Yost

[YOST]

SSCL TEST & CALIBRATION BEAMS & HALL

3 BEAMS FROM MEB.

200 GeV primaries - we will get secondaries.



calibration hall

Beam structure 16 ns bunch separation

~ 800 bunches

10^{10} p/bunch for main ring operation

5×10^{10} p/bunch for test beams operation

8 sec refill time

≤ 1 sec spill time

ping ~ few ms possible - Need requirements

max flux ~10^7 π's /pulse

anything less is easy

Serious radiation safety questions @

max intensity: 6' concrete shielding

(Stefanski memo)

We need input on:

space req's (anything that will influence conventional construction)

Safety concerns (")

Utilities - power, gas, cooling, LCW, ...

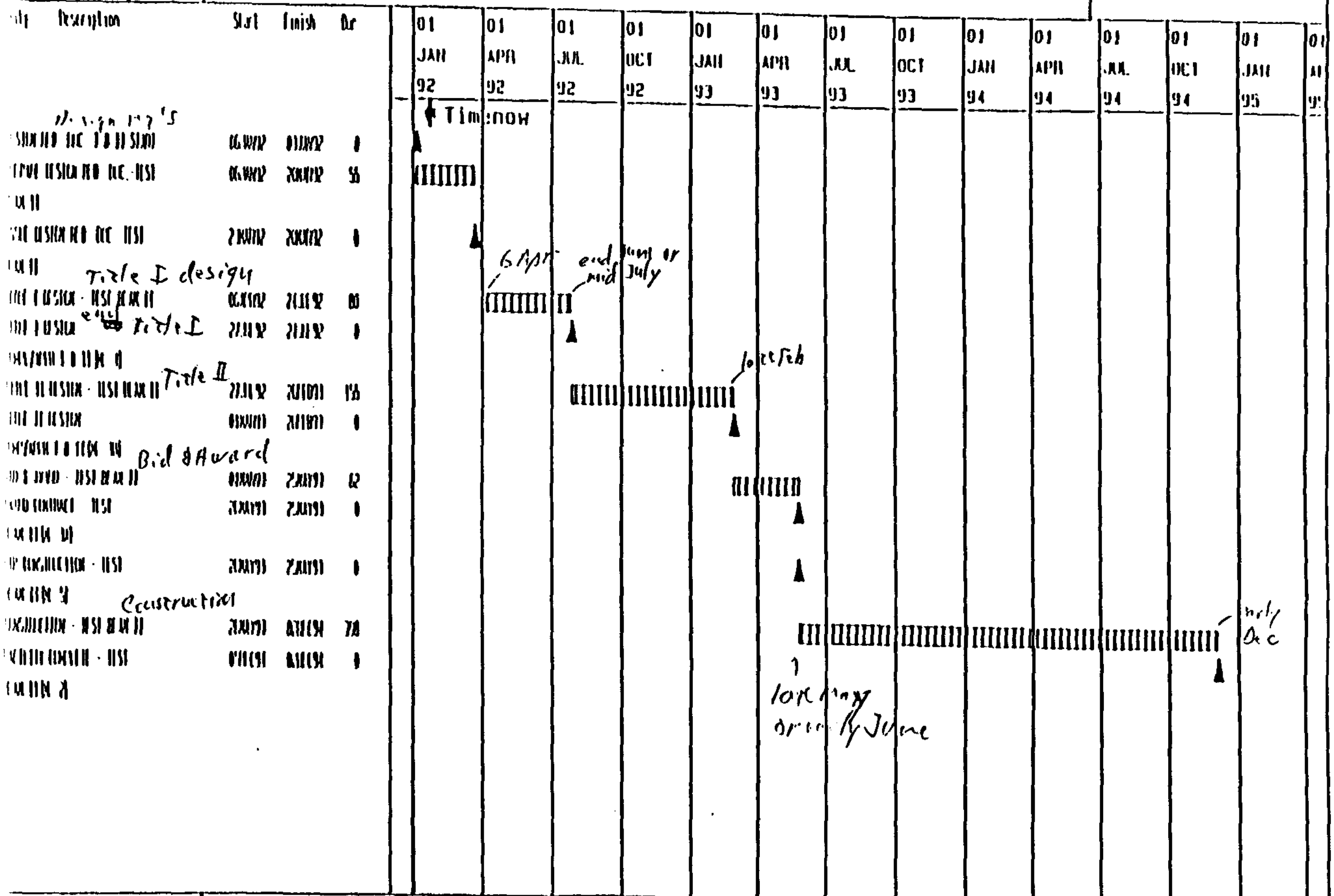
Beam flux needs

Also urgent: Needs for '92, 93, 94, ...

We must present a plan to SSCL management in ~1 month.

SSC LAB

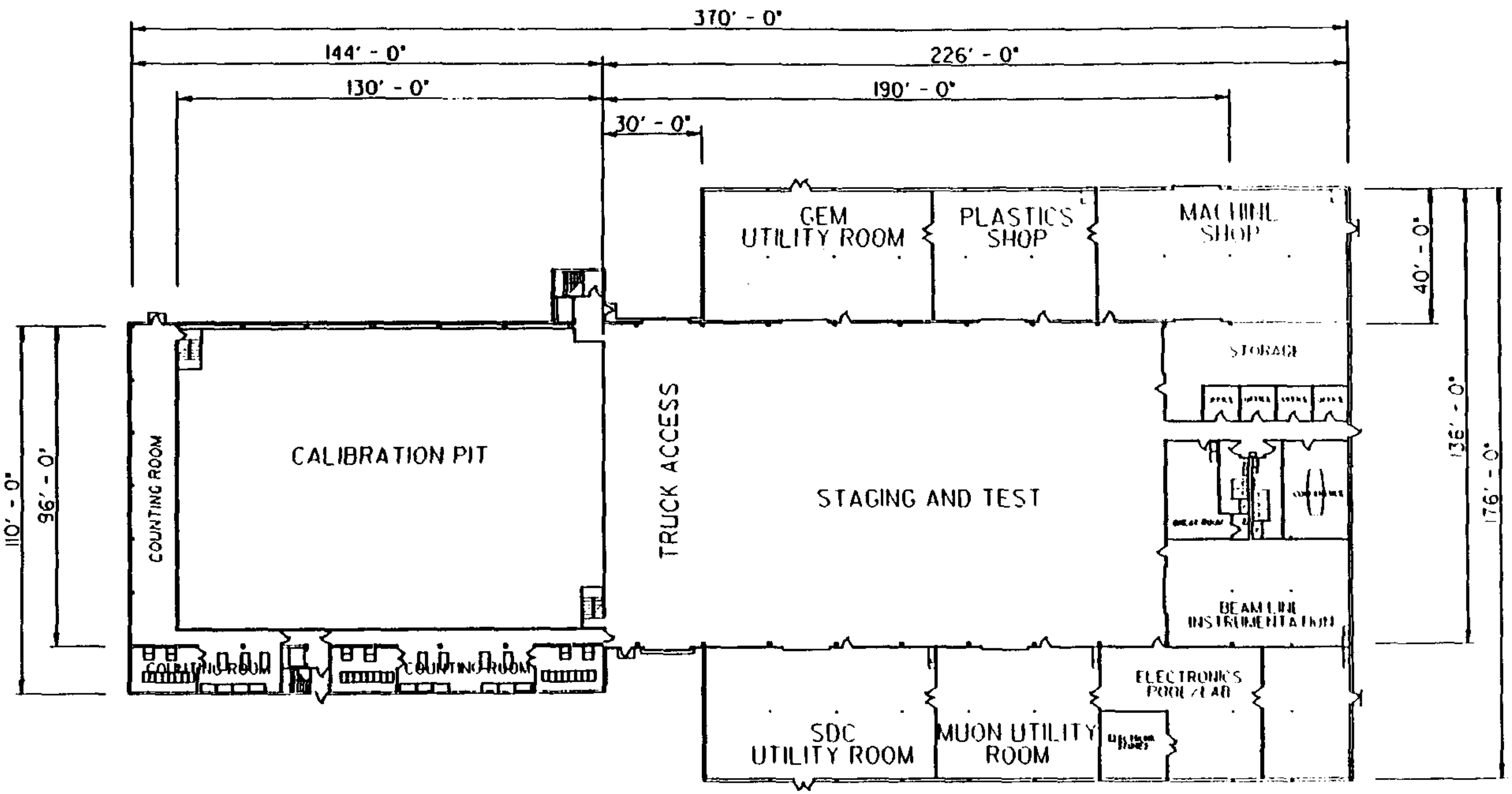
TEST BEAM PART-II, WP8 (, .II) -WP12 (CALIBRAT)



Bar Chart Key: Early Dates

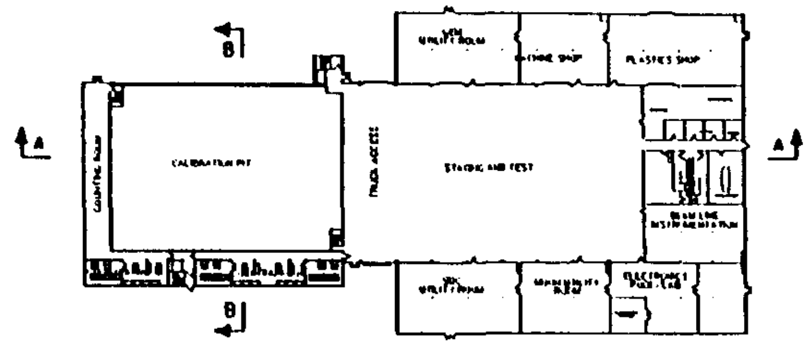
Legend
In progress
Planned
Critical

Signatures
Prep:

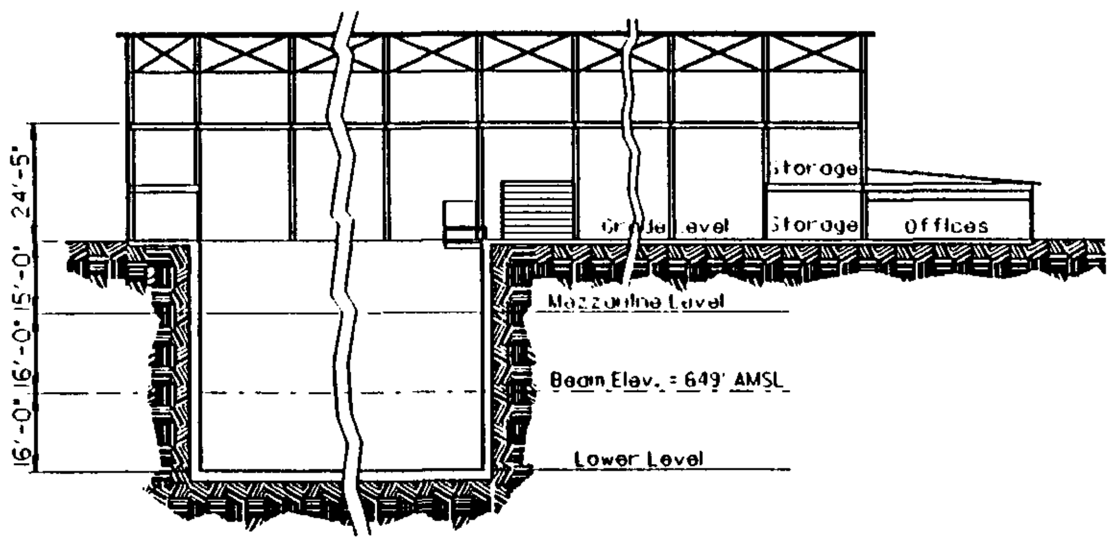


370' - 0"
144' - 0"
226' - 0"
130' - 0"
190' - 0"
30' - 0"
40' - 0"
136' - 0"
176' - 0"
110' - 0"
96' - 0"
GEM UTILITY ROOM
PLASTICS SHOP
MACHINE SHOP
STORAGE
COUNTING ROOM
CALIBRATION PIT
TRUCK ACCESS
STAGING AND TEST
BEAM LINE INSTRUMENTATION
COUNTING ROOM
COUNTING ROOM
ELECTRONICS POOL/LAB
SDC UTILITY ROOM
MUON UTILITY ROOM

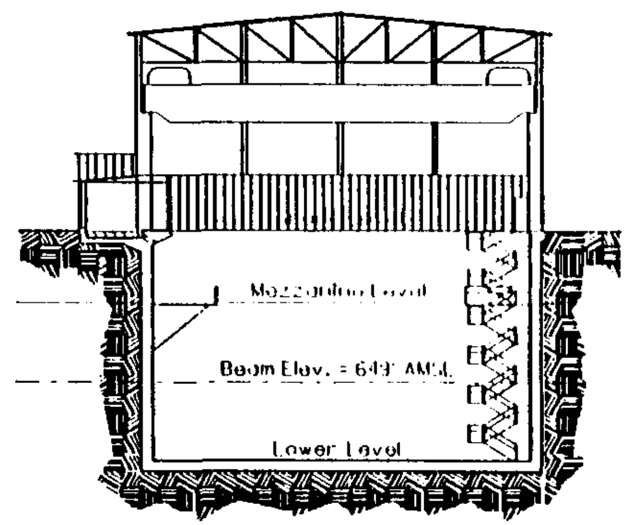
PLAN VIEW



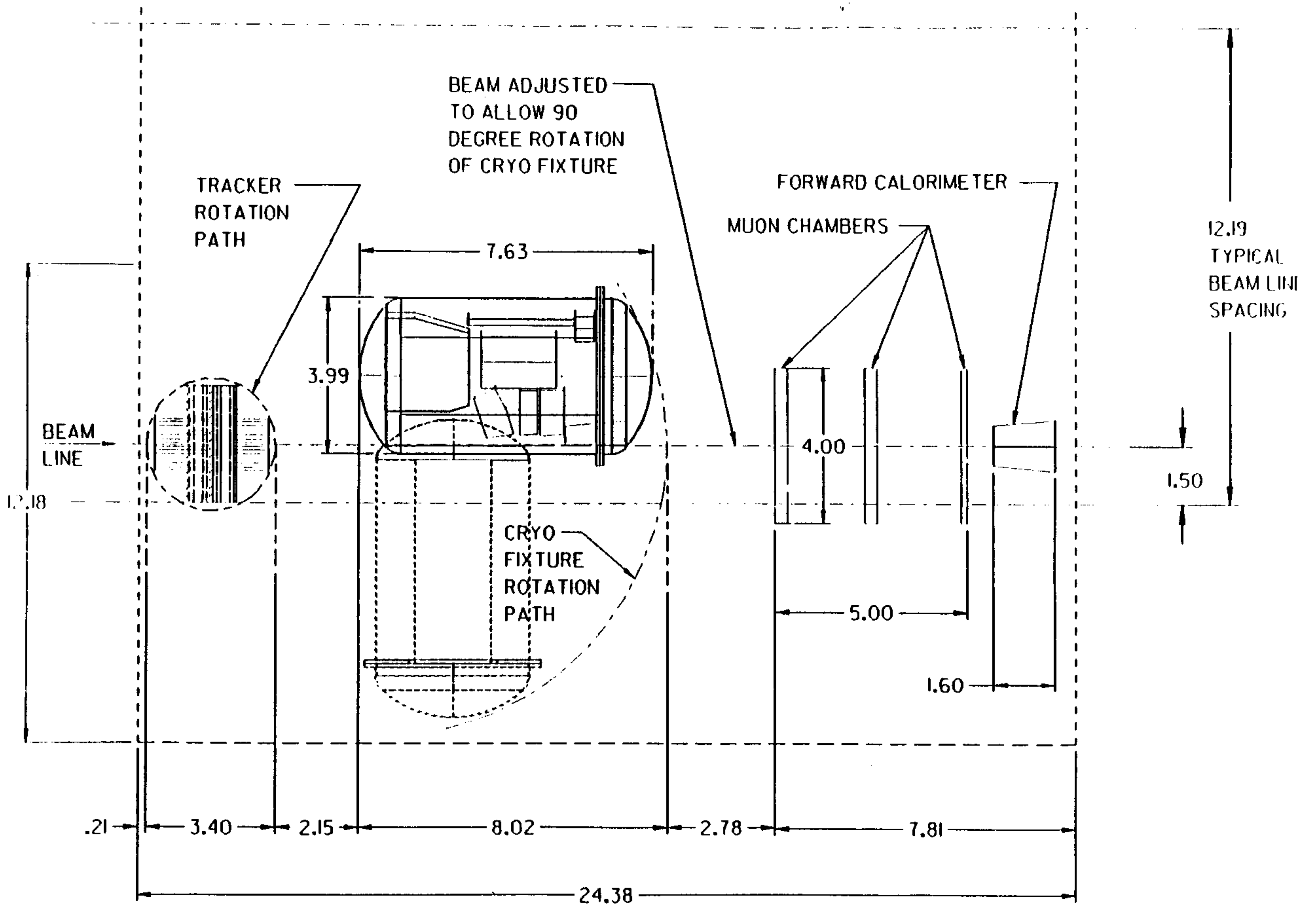
PLAN VIEW



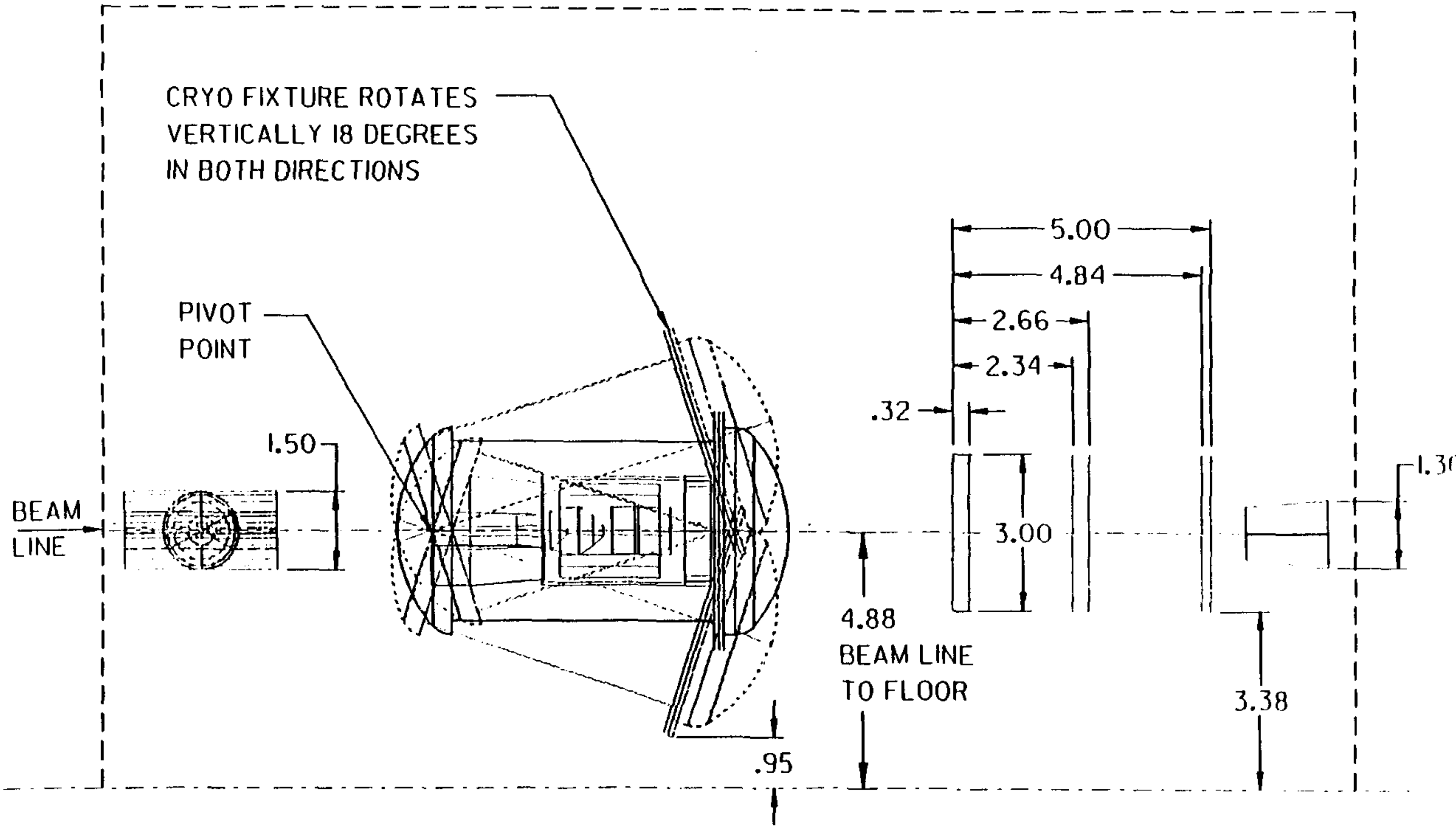
SECTION A-A



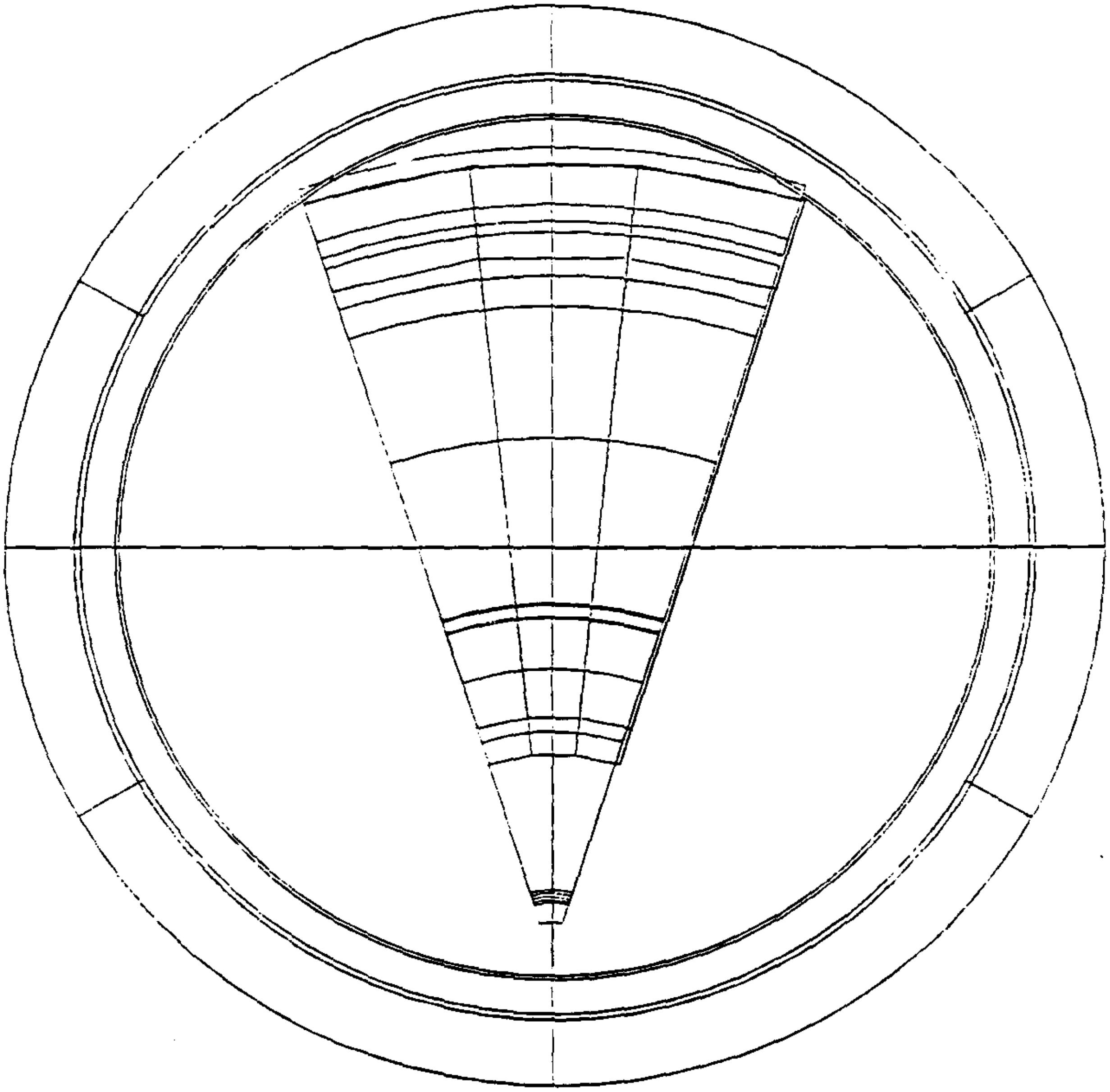
SECTION B-B

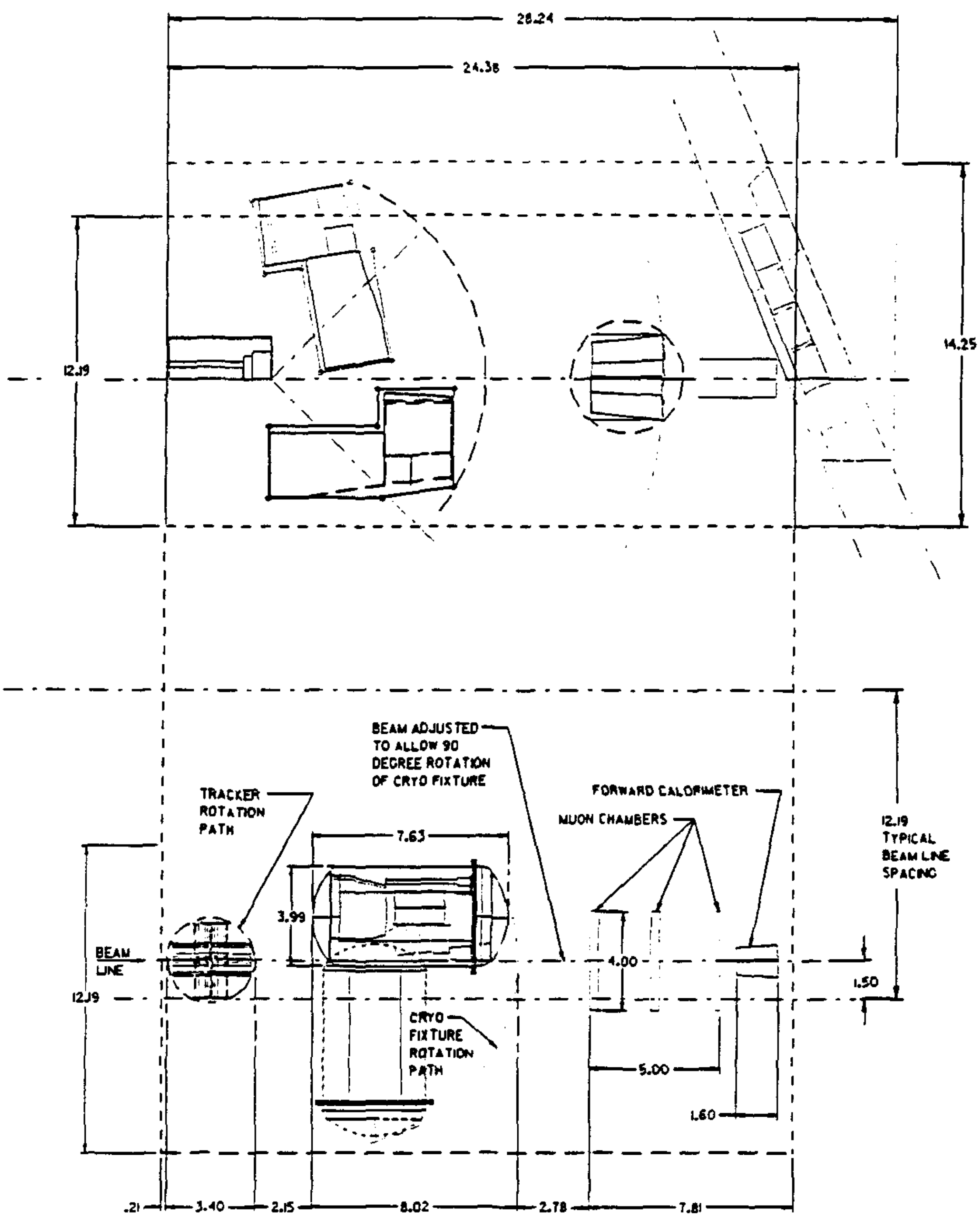

BEAM ADJUSTED TO ALLOW 90 DEGREE ROTATION OF CRYO FIXTURE
TRACKER ROTATION PATH
FORWARD CALORIMETER
MUON CHAMBERS
12.19 TYPICAL BEAM LINE SPACING
7.63
3.99
BEAM LINE
4.00
1.50
12.18
CRYO FIXTURE ROTATION PATH
5.00
1.60
.21
3.40
2.15
8.02
2.78
7.81
24.38

PLAN VIEW


CRYO FIXTURE ROTATES
VERTICALLY 18 DEGREES
IN BOTH DIRECTIONS
PIVOT
POINT
5.00
4.84
2.66
2.34
.32
1.50
1.30
BEAM
LINE
3.00
4.88
BEAM LINE
TO FLOOR
3.38
.95

ELEVATION




28.24
24.38
12.19
14.25
BEAM ADJUSTED TO ALLOW 90 DEGREE ROTATION OF CRYO FIXTURE
TRACKER ROTATION PATH
FORWARD CALORIMETER
MUON CHAMBERS
7.63
3.99
BEAM LINE
4.00
12.19 TYPICAL BEAM LINE SPACING
1.50
12.19
CRYO FIXTURE ROTATION PATH
5.00
1.60
.21
3.40
2.15
8.02
2.78
7.81

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Memorandum

To: File
From: Ray Stefanski Ray
Subject: Shielding Requirements for Calibration Hall
Date: Wed, Apr 29, 1992 (revised) sorry for the error!

After our meeting on test beams held in Fred's office on April 28, I consulted with Steve Butalla (at Fermilab RSO) on their general shielding requirements for test beams. We recall that the D0 and CDF test beam facilities at Fermilab have no concrete shielding associated with them. Areas that require control for radiation safety are fenced, with access through interlocked gates. This is the model that we used in establishing parameters for the Calibration Hall at SSC, namely we did not account for the possible use of shielding block in these beams.

Apparently, acceptable guidelines for radiation shielding have changed dramatically in the last two years. Steve sited an incident where a long thin detector was inserted in a test beam, without going through formal preparation, and raised radiation levels in the surrounding area by more that an order of magnitude. It's this kind of experience which has lead to a policy at Fermilab to provide shielding to account for the worst event that could possibly occur in the area. Administrative or barrier controls are no longer acceptable.

Steve did a back of the envelope estimate of shielding requirements for operation in a hadron beam at 10^7 particles per second and a flat-top of one second in an eight second cycle time. He sited FNAL-TM 1140 as a reference for shielding guidelines. (I've asked the Fermilab library to send me a copy.) The assumption is that one must provide shielding for a thin target, three interaction lengths in length (one assumes that we achieve shower maximum in the target), and that the occupied area is about six meters from beam center. The occupied area must be kept below 0.1 mrem/hr, which is conservatively set below the guideline of 0.25 mrem/hr established by DOE for such areas. The result is:

> Two meters of concrete for 10^7 particles per second,
> One meter of concrete for 10^6 particles per second,
> and 2.5×10^4 particles per second for no shielding.

One can assume that radiation levels fall as the inverse of the square of the distance for distances beyond six meters.

These requirements would apply to areas where people are expected to work for extended periods. This would not apply to catwalks, for example, since occupancy would be for very short duration. Shielding for the roof of the building would also probably not be required.

xc:

Jim Siegrist	George Yost	Harvey Lynch
John McGill	Ron Hoffmann	Bob Richardson
Tom Prosapio	Fred Gilman	Ed Verminski
Ronn Woolley	Bob Lavelle	Tom Murphy
Howard Fenker	Frank Stocker	Steve Butalla(FNAL)

Presentation by:

Craig Wuest

Barium Fluoride Surface Preparation and UV Coating R&D at LLNL - A Progress Report

Craig R. Wuest
Lawrence Livermore National Laboratory

April 23, 1992

1. Introduction

Lawrence Livermore National Laboratory (LLNL) has been asked to provide R&D on new methods of barium fluoride (BaF_2) crystal surface preparation, as well as optical coating methods to improve the efficiency of transport of scintillation light through the crystal to the photodetector. The goal of the R&D is to identify a method (or methods) for preparing the surface to eliminate the amorphous layer that has been found to be a product of the surface preparation techniques used when the crystals are manufactured in China and provide a crystalline surface free from oxygen and other contamination, with suitable flatness for optical coating. UV reflective coatings have been identified that are suitable for the wavelengths of the scintillation light (220 nm peak). The coating consists of a layer of aluminum with a magnesium fluoride over-layer. This coating can be applied in a uniform layer or in a graded layer, with reflectance varying as a function of position. It is ultimately desired that the UV coating be applied with graded reflectance to linearize the response of the crystal along it length.

2. BaF_2 Surface preparation R&D at LLNL

A number of surface preparation techniques have been identified as potentially capable of removing the amorphous layer and providing a clean crystalline layer for coating. The R&D program, which began in early March, 1992 has explored the following surface preparation techniques:

A. Polishing with diamond grits

BaF_2 crystals have been polished at LLNL using this standard technique for use as laser windows. Up to this point it has not been known how the crystal structure is affected. Comparison of this polishing technique with diamond turning has shown that diamond turned laser windows are less susceptible to damage in high intensity laser beams. The process uses diamond impregnated pads and a BaF_2 sample was polished to 20 angstrom RMS surface finish for study. This technique is probably not suitable for large area polishing because edges tend to be rounded off and flatness over large areas is not easily achieved

B. Ductile grinding

The process known as ductile grinding uses a specially prepared wheel coated with diamond. The wheel is prepared so that it is flat to within 0.25 - 0.5 microns and the part to be polished is translated across the surface of the rotating wheel. In effect, this is using many diamond turning bits instead of one. The advantage of this process is that it is very suitable for mass production polishing of large numbers of crystal surfaces. LLNL's ductile grinding system was dismantled last year and I have requested that it be rebuilt. We do not have results from this process yet.

C. Diamond pitch lapping

This process uses specially prepared wheels coated with a synthetic pitch and impregnated with diamond powder. The prepared wheel is rotated and the sample to be polished is translated back and forth across the wheel as the wheel rotates. The sample is usually immersed or heavily washed with a low viscosity silicon oil. We have prepared a small sample using this technique and have measured a surface finish of about 10 angstroms RMS. This technique has the advantage of being simple to implement and can provide large area and large quantity polishing capability.

D. Diamond turning of the crystal surface

Diamond turning of crystal surfaces are routinely done at LLNL in support of the Laser Program and other programs requiring precision optical surfaces. LLNL's Large Optics Diamond Turning Facility (LODTM) is capable of turning surfaces with radii as large as 1.65 meters with a precision at the few angstrom level. Other smaller diamond turning machines are available for preparing surfaces with similar precisions.

We opted to perform "wet" diamond turning using a highly purified water-free lubricating fluid (Drakeol 7, a low viscosity poly-alpha olefin oil). Alternative cutting fluids include low viscosity silicone oil or a pure hydrocarbon such as hexanes. Drakeol 7 is routinely used for diamond turning potassium di-hydrogen phosphate crystals (KDP) for use as frequency doubling and tripling crystals for the Nova laser at LLNL. The crystals are turned and then cleaned using a pure toluene soak for 24 hours. A similar cleaning method was used on BaF_2 crystals.

We achieved very successful results using small samples of BaF_2 crystals. In one sample we were able to achieve a 6 angstrom RMS surface finish measured over a 600 micron area of the crystal. We also observed that the surface finish depended on the crystal lattice orientation. In one sample we observed markedly different surface finish quality when machining across a crystal grain boundary. The surface finish on one side of the boundary was found to be 80 angstroms RMS compared with 6 angstroms RMS immediately on the other side of the grain boundary.

In summary BaF_2 appears to be a good material for diamond turning and other diamond cutting processes, such as ductile grinding and diamond pellet lapping.

E. Argon Ion Beam Milling

Argon ion beams are also available for removing material from the crystal surface. In this technique a beam of argon ions is directed onto the surface to be milled, with the rate of material removal determined by the orientation of the crystal surface with respect to the beam. For our studies the crystal was oriented at 45 degrees. Removal rates vary depending on the material but typically are a few microns per minute to a few microns per hour. For our study a carbon mask about 2 cm x 1 cm was prepared to allow the crystal to be milled in a controlled manner. Carbon is a good material for the mask because of its extremely low sputtering rate compared to most materials.

We prepared three samples with measured removal depths of about 0.5, 1.0 and 2.0 microns. The samples took about 1/2 hour to remove 1 micron of material. Surface quality was observed to be poor (compared to previously described surfaces finishes) and in general followed the original surface quality.

2. X-ray diffraction analysis and energy dispersive spectroscopy

Crystals were analyzed, before and after preparation using x-ray diffraction analysis, and electron beam microprobe methods for the determination of structural and chemical properties of the surface, respectively. We noticed that x-ray diffraction measurements would show the BaF_2 lines slightly shifted and additional unidentified lines would also be present. Unfortunately, we were unable to precisely identify the nature of these spurious lines. Also, x-ray diffraction was unable to qualitatively distinguish between crystalline and amorphous surfaces. We did closely examine the sample crystal that exhibited the two different surface finishes on diamond turning. We cleaved small samples from the two regions and crushed them into a powder. There was no noticeable difference in the two materials.

We also performed energy dispersive spectroscopy (EDS) on a sample and found the strongest signals due to strontium and iodine.

3. Rutherford Backscattering Analysis at Charles Evans & Associates

Three BaF_2 samples were brought to Charles Evans and Associates for Rutherford Backscattering (RBS) analysis. The samples were: 1) the diamond turned piece with the two different surface finishes, 2) the diamond pad polished piece with the 20 angstrom surface finish, and 3) the ion beam milled sample with the three different depths of cut.

Measurements were first made on sample 1) for the two different finish regions. No channeling was observed on either area for this sample, leading us to believe that the crystal surface on the sample is amorphous

The second sample measured was the ion milled sample 3) which had to be broken down to a smaller size to fit in the RBS machine. We opted to look at the 2 micron depth milled portion. In this measurement, strong channeling was observed, indicating a crystalline layer had been exposed. In addition RBS was performed across the sample on a portion of original Chinese surface finish that was masked off. In this region no channeling was observed.

The third sample measured was the standard polished sample 2). Measurements are still in progress on this sample.

A fourth sample, prepared using the diamond pitch polishing method is being measured at this time.

4. UV Reflective Coatings

LLNL regularly coats optics with both reflective and anti-reflective coatings. Magnesium fluoride is typically used for anti-reflective coatings. The reflective coating to be applied to the BaF_2 crystals consists of a thin layer of aluminum (about 500 angstroms) with a MgF_2 over-layer. Reflective coatings of this type exhibit high reflectance, typically 75%-85% down to about 180 nm. In addition the coatings are robust. We utilize an electron beam evaporative coating system specifically designed for the purpose of laying down MgF_2 and aluminum.

We have prepared two different samples for the purpose of characterizing the quality of the reflecting coatings. One sample was a large piece of BaF_2, left with the original Chinese surface finish, about 6 inches long cut from a larger prepared crystal pair. The other sample was a small BaF_2 sample with a high quality surface finish for use a witness sample. This witness sample was used to quantitatively characterize the quality of of the reflective coating.

Measurements were made on the witness sample for both front surface reflectivity and back surface (through the BaF_2) reflectivity. The front surface reflectivity was measured to establish that the coating was of the proper quality. Results of the front surface measurement confirmed that the coating was high quality, with a reflectivity of about 90% from 300 nm to about 220 nm followed by a gradual drop to about 86% at 190 nm. Back surface reflectivity showed that the reflectance was about 87% at 300 nm falling gradually to about 85% at 240 nm with a steeper fall to 74% at 190 nm. At 220 nm the reflectivity is about 81%.

A qualitative look at the large BaF_2 sample shows that surface finish plays an important role in the uniformity of the coating. Pin hole sized areas were observed that were not coated, presumably due to the observed scoring of the crystal surface during the Chinese surface preparation.

These initial samples were coated with uniform reflectance coatings. Gradient coatings will also be studied. Two alternative ways of performing gradient coatings exist. One involves translating the sample past the source at a varying rate. The other involves placing the sample at an angle with respect to an isotropic coating source. It is likely that the translation method will be adopted because it is suitable for long crystals and translation stages are easily programmed for variable motion to allow the deposition of coatings with complex reflection gradients.

The Monte Carlo program LTRANS[3], developed at the Institute for Theoretical and Experimental Physics (ITEP), Moscow is being adapted to model the BaF_2 crystal properties. This Monte Carlo code combines scintillation light emission, crystal transmission, absorption, wall effects and geometric ray tracing to allow an evaluation of the uniformity of light transport to the end of the crystal as a function of position on scintillation light emission. This code can be used to estimate the correct gradient for the surface reflective coating to provide the optimum uniformity along the crystal length.

4. Conclusions

We have performed R&D on four different BaF_2 surface preparation techniques. All the techniques have demonstrated surface finishes better than 20 angstroms RMS. Three techniques: diamond turning, ductile grinding, and diamond pellet lapping hold promise for mass production of large area high quality surface finishes on BaF_2 crystals. Unfortunately, RBS studies show that diamond turning and standard diamond polishing does not provide a crystalline surface.

It is unknown at this time if the surface finish starts out crystalline and then becomes amorphous over time. It has been suggested that Charles Evans & Associates perform an RBS on a freshly cleaved BaF_2 sample and then follow up a few days later to see if a change in the surface is evident.

Ion beam milling is effective for removing BaF_2 surfaces down to a depth of a few microns/hour. In addition, there is an indication that ion milling provides a somewhat crystalline surface. Adapting this technique to mass production is feasible, but the quality of the surface is only as good as the surface one starts with and, in general, is worse than surfaces prepared using various grinding or machining techniques.

Optical coatings for high reflectance in the UV (> 80% at 220 nm) appear to be achievable using standard E-beam evaporative coaters. We also intend to study the effect of applying a hard silicon dioxide overcoat to protect the coatings from damage.

Finally, it is worth reiterating the previously mentioned work comparing laser damage to optical windows prepared using standard polishing techniques and diamond turning. It is likely that this is a surface or near-surface phenomena and is related to stress build-up in the crystal during the polishing technique. Acid etching of surfaces reveal these stresses as micro-cracks, or pits, and acid etching is commonly used as an analytical tool in characterizing laser glass surfaces.

We are currently studying the character of BaF_2 surfaces using acid etching. For example, a sample of BaF_2 was pitch polished to 10 angstroms RMS surface finish and then one half was dipped into an acid solution consisting of 10% hydrofluoric acid, 5% hydrochloric acid and the remainder, water. After 5 minutes the sample was removed and the surface was studied under an optical microscope and a profilometer. The optical observations show small linear scratches indicative of shear stress on the crystal, however the size of the scratches indicates that the stress is small. Also, no pits are observable. The etched surface shows a 35 angstrom RMS finish and appears identical to the adjacent un-etched surface to the naked eye. We have sent this sample to Charles Evans and Associates for RBS analysis of the two surface treatments.

Despite the lack of channeling observed in RBS measurements of some of the samples we have prepared we feel that it is probably worthwhile to explore the radiation hardness of BaF_2 crystals prepared using the various techniques described in this paper.