GEM TN-92-55

GEM Collaboration Council Meeting SSCL

January 23, 1992

Abstract:

Transparencies and agenda of the GEM Collaboration Council Meeting held at the SSCL on January 23, 1992.

COLLABORATION COUNCIL MEETING
January 23, 1992
9:00

1.	Status of GEM	B. Barish
2.	First Internal Cost Review	G. Sanders
3.	PAC Review	B. Barish
4.	R&D/Engineering Plan	C. Baltay
5.	Report of BaF2 Panel	W. Willis
6.	Project Management (Plans for Technical Proposal)	M. Harris, M. Marx G. Sanders
7.	GEM Organization Discussion	B. Barish
8.	Creating Baseline Design General Issues Subsystems Plans	 M. Marx (Stroynowski;Taylor/Ahlen;Willis/ Kamyshkov;Baltay; Marlow/Shaevitz; McFarlane
9.	Other Business	

NEWS/STATUS

* CHINA/TAIWAN TRIP (Barish, Willis)

* FIRST COST REVIEW (SANDERS)
  $510M

* PAC Presentation + Report
  (APPROVED !!)

* PROJECT MANAGEMENT OFFICE
  (SANDERS/HARRIS/MARX)

* MAGNET DESIGN (STROYNOWSKI)
  (Forward Shaping)

* TECHNICAL DESIGN REPORT
  - Baseline Design (March/Tucson)
    (MARX)

* EXECUTIVE COMMITTEE MEETING
  + ROLE

DATES

FEB 21 HEPAP @ SSC
(Exec Comm - Feb 20)

MARCH 8-11 TUCSON - GENERAL MTG

APRIL 30 GEM CC Mtg (SSC)

JUNE 4 GEM CC Mtg (SSC)

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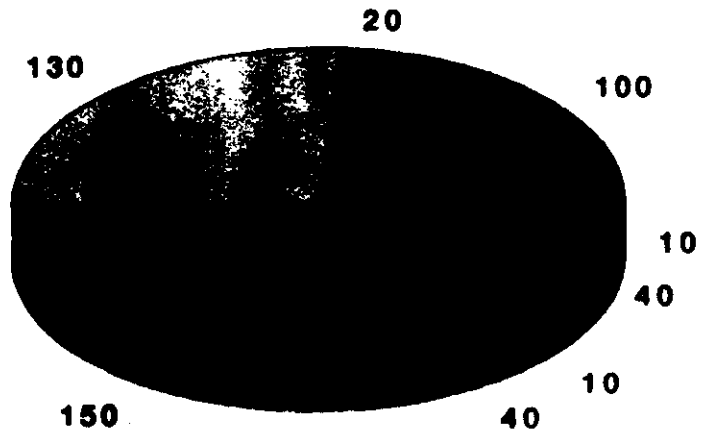
also April 13, 14 Wisconsin SSC Physics
March 4-6 IISSC - New Orleans

Initial Cost Targets ($Millions)



Total 500

- Magnet
- Structures
- Muon System
- Calorimeters (all)
- Tracker
- Computing
- R&D
- Trigger

GEM R&D PLANS

1. Nov 26, 1991 GEM R&D Plan submitted to SSC

   Total Plan 15 M$

2. R&D Funds expected

SSC Lab	10 M$
TNRLC	5 M$

3. Dec 20, 1991 TNRLC Funds do not materialize. Total funding expected from SSC Lab 12 M$

4. Jan 22, 1992

   We now expect that we can get ~ 2 M$ from the ongoing TNRLC R&D Program

   We thus are planning on

SSC Lab	12 M$
TNRLC R&D	2 M$
Total	14 M$

GEM R&D PLAN

SUBSYSTEM	Nov 26 Plan K$	Jan 22 Plan K$
1. Magnet	5000	5000
2. Calorimeter	4622	4260
3. Muons	2700	2430
4. Tracking	935	842
5. Electronics	975	878
6. Computing	100	0*
Reserve	668	590
Total	15 000	14 000

* Computing will be funded from other sources

Requests to TNRLC

Cal Tech	500 K$	Barium Floride
Boston Univ	365	Muon Chambers
MIT	500	Muon Chambers
Columbia	460	Electronics
Princeton	175	Electronics
	2000 K$	

Procedure

1. Subsystems to make detailed plans of how to subdivide Jan 22 Plan funds among projects and institution by morning of Jan 24

2. Proposals for SSC Lat funds to be submitted by Feb 1
   Instructions on format, who to send it to, etc will be sent out soon. } Bob Webb

   <u>Note</u>: think about division between "Operating" and "equipment" money.

3. Proposals to TNRLC due probably by April 1.

NORKING GROUP

KAMYSHKOV — COORDINATION

BRAU — SIMULATION

WILLIS — ACTING ....

TDR SCHEDULE

VIZ. PAC REPORT ...

KEEP NOVEMBER DATE!

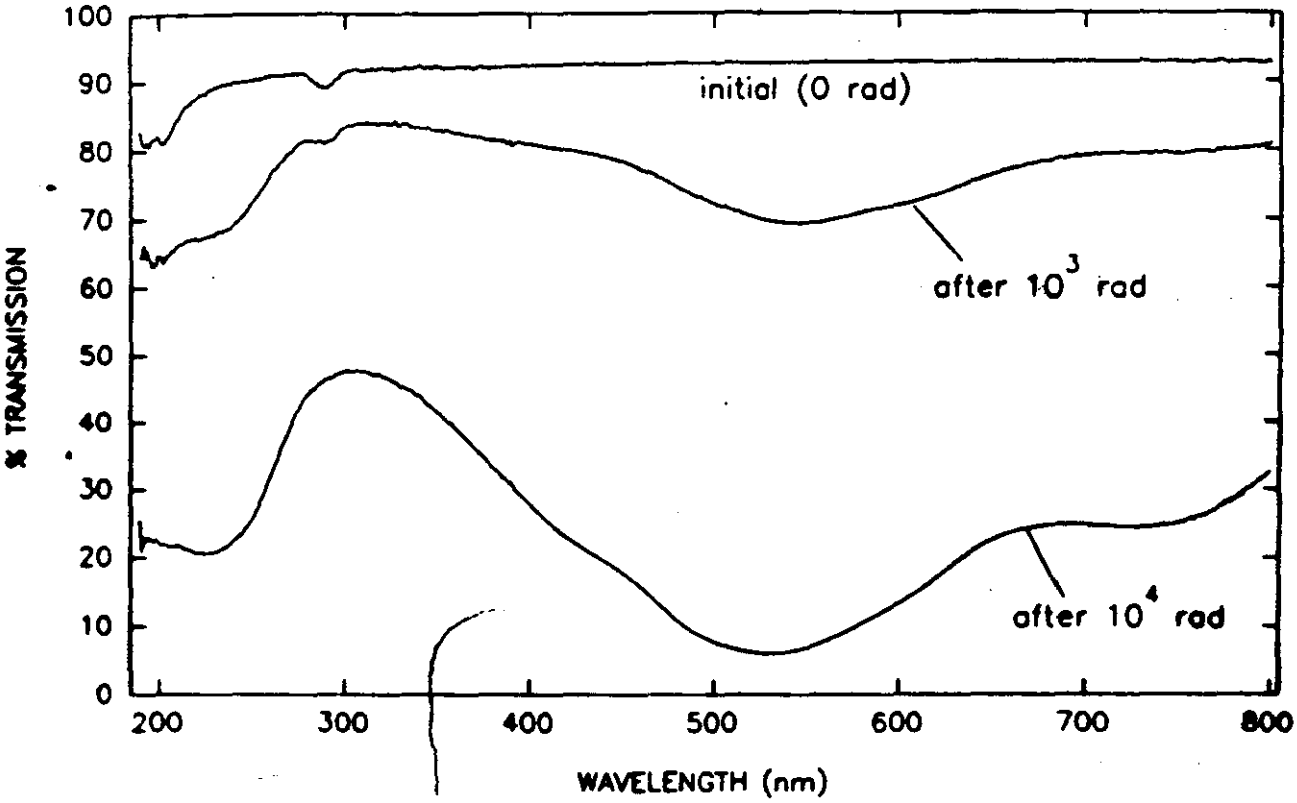
EXPERT PANEL on BaF_2

REPORT IN TWO WEEKS

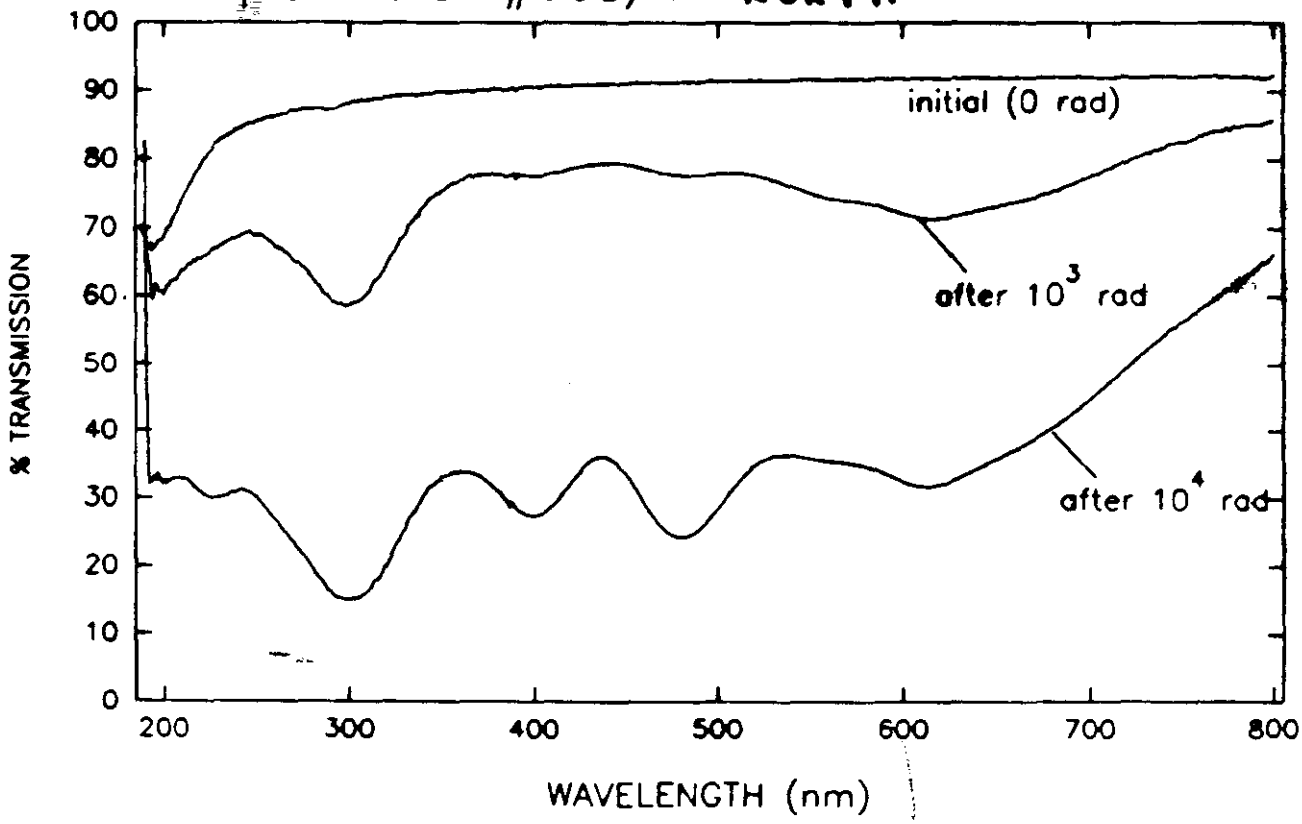
→ GEM RESPONSE

SUMMARY ⟹ C. WOODY

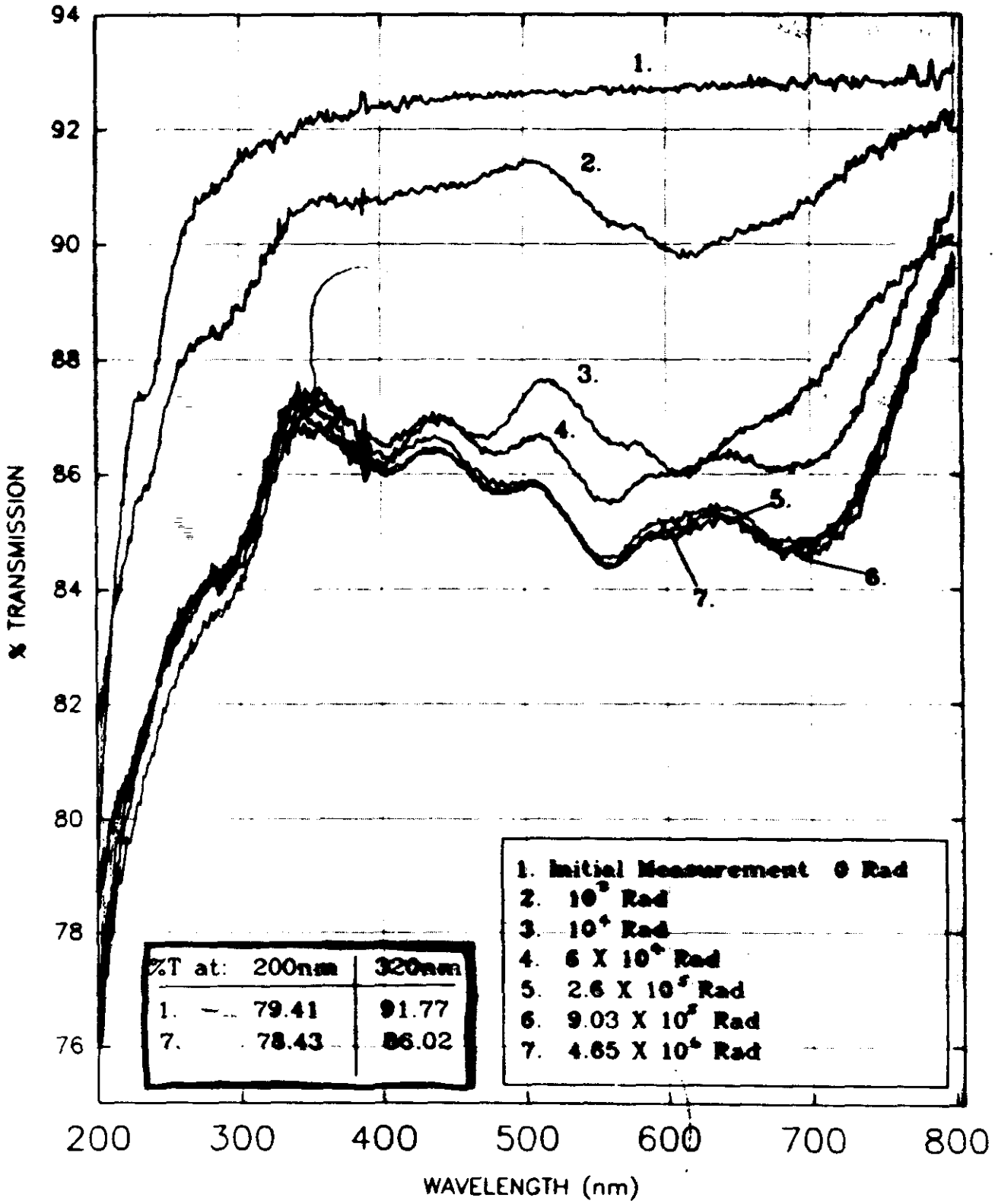
sample: #S1A011 SIC/BGRI 25cm



sample: Merck #668/1 KORTH 25 cm

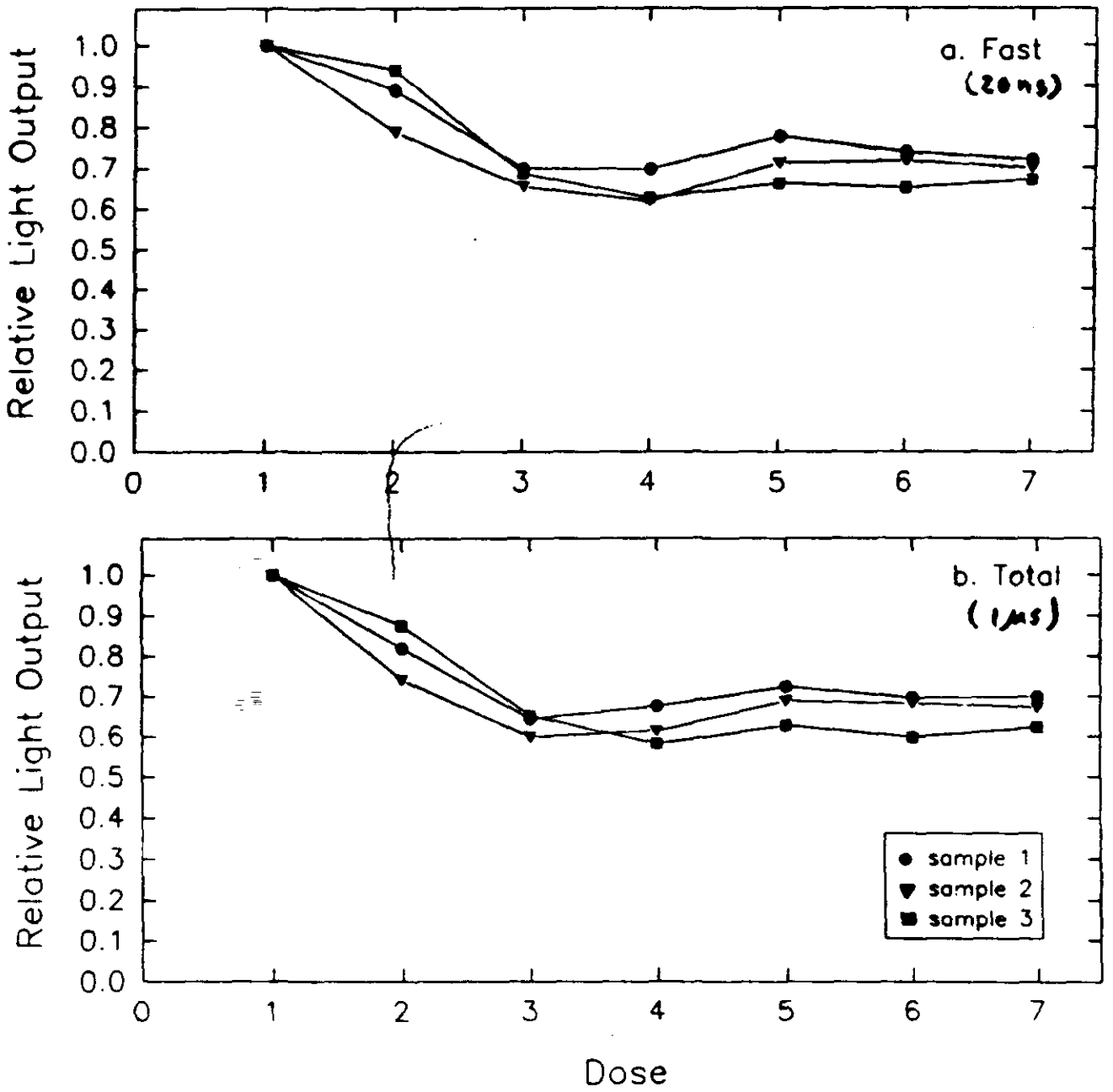


Hitachi Transmission Scans of BaF2 samples.
7/91 Radiation Damage Study
Sample: K458484B (samp1) 1 " CYLINDER



%T at:	200nm	320nm
1.	79.41	91.77
7.	78.43	86.02

fig 2

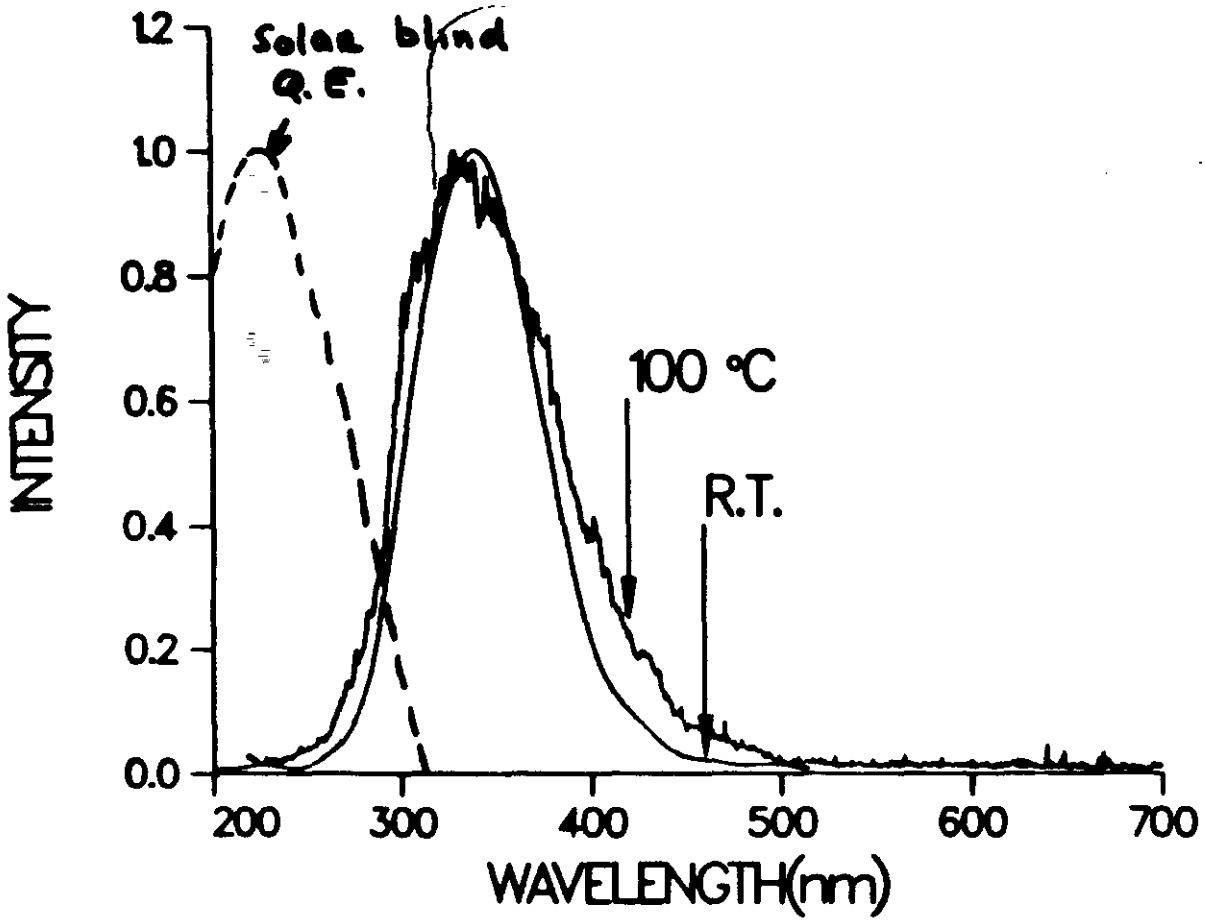


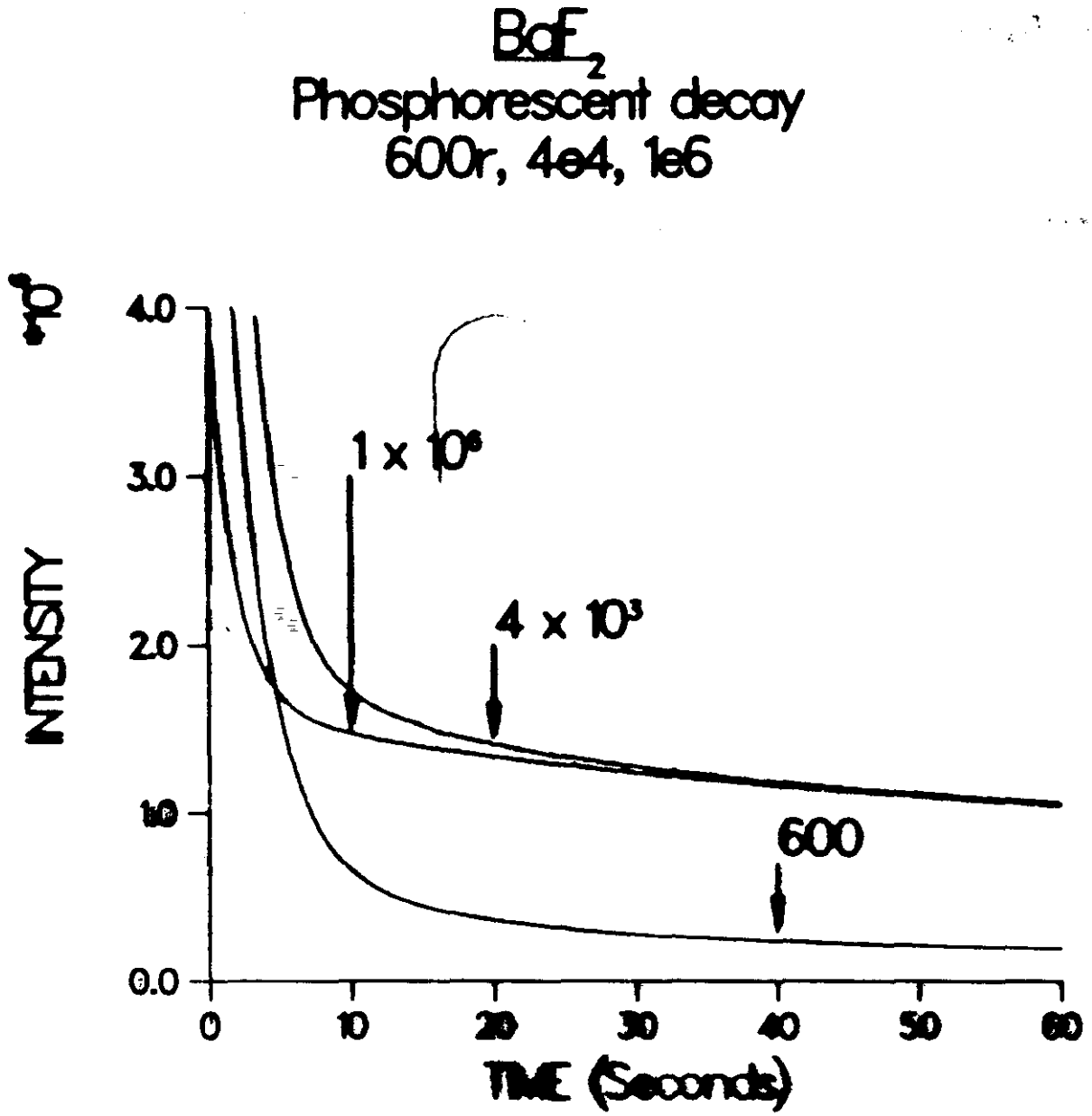
Dose

1. Initial Measurement
2. After 10^3 rad
3. After total of 10^4 rad
4. After total of 6×10^4 rad
5. After total of 2.7×10^5 rad.
6. After total of 9.0×10^5 rad
7. After total of 4.7×10^6 rad

c:\pdf\recover3.eps 11/1/91

Comparison
BaF2
Phosphorescence




BaF2
Phosphorescent decay
600r, 4e4, 1e6
INTENSITY
4.0
3.0
2.0
1.0
0.0
1 x 10⁶
4 x 10³
600
0
10
20
30
40
50
60
TIME (Seconds)

Cal Tech

(BaF_2 R+D Proposal
Sept 1991)

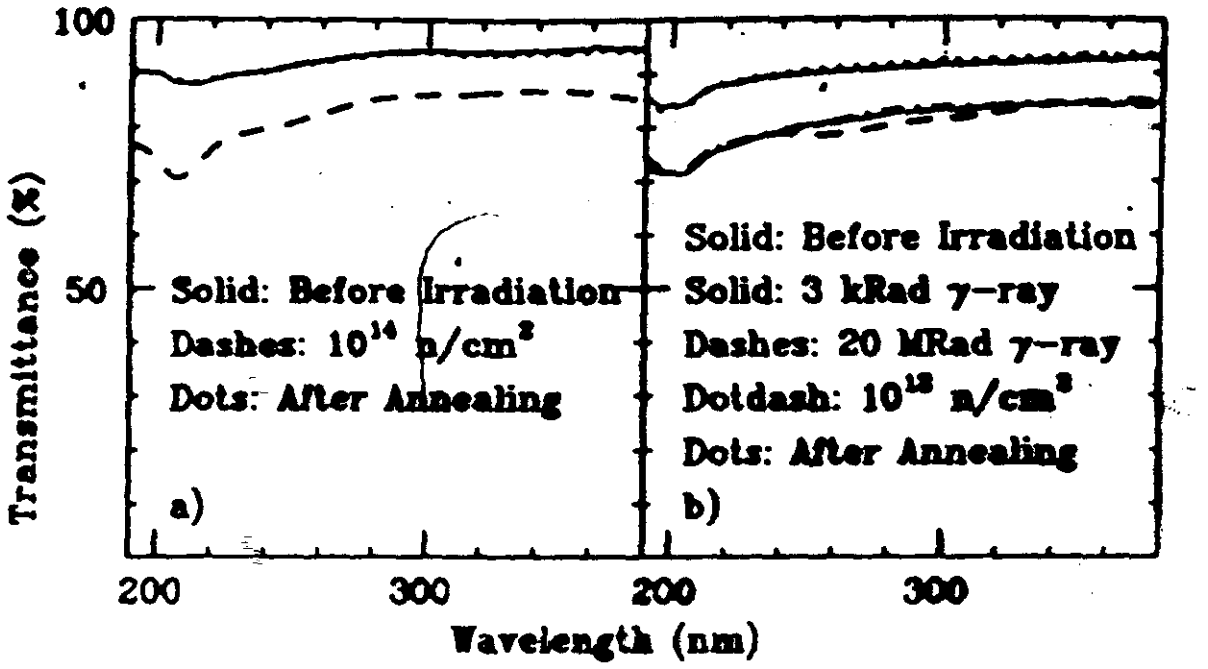


Figure 3.6: Transmittances before and after irradiation showing a) recovery from neutron damage; and b) typical saturation effect.

APPENDIX 1

I. SHORT TERM TESTS (by January 20, 1992)

1. Preliminary low dose rate study
   - small sample and possibly long sample
   - ~ 1 Mrad/yr for ~ 1 month
2. Trace analysis of already irradiated samples
3. Structural analysis of already irradiated samples
4. Look at VUV and IR spectra in existing samples
5. Possibly some thermoluminescene measurements of small samples
6. Further study of light loss vs transmission loss
   - measure even smaller samples
   - better Monte Carlo calculations (including surface effects, etc.)
7. Express results in consistent units (e.g., absorbance or abs. length)

II. INTERMEDIATE TERM TESTS (by ~ Aug 92)

1. Careful dose rate study
2. More irradiation studies with (fast) neutrons
3. Detailed trace element analysis using various techniques
4. Preparation of samples with traceable histories
5. Exchange material and grow samples at different facilities (SIC, Merck, STI)
6. Prepare samples with different types of annealing
7. Grow samples using sublimation preprocessing
8. Computation of spallation/transmutation processes

III. Long term studies (> 1 year)

1. Detailed plan not yet specified
2. Some possibilities
   - production of "ultra-pure samples"
   - extensive trace element analysis
   - irradiations to study spallation, neutron transmutation, etc.

APPENDIX 2.

Panel Questions for the GEM Collaboration.

1. Define by January 21, 1992, the radiation damage specifications including:

   a. Limits of degradation of the uniformity of light output
   b. Limits of degradation in total light output (absorbance)
   c. Acceptable rate of change as a function of time or dose
   d. Can specification vary for barrel and end-cap detectors?
   e. What is an acceptable potential failure rate (crystals per year) ?

2. Provide radiation damage dose broken down by particle type and energy.

3. Would the GEM collaboration consider UV annealing within the BaF_2 detector?

Summary from China trip

Recommendations

1. This first and foremost recommendation is to develop a strong coordination between the two institutes by the appointment of full time coordinators both in China and in the US during the next 8 months. A coordinated, comprehensive plan of research should be written to efficiently use all the talent that is available for solving the radiation damage problem.

2. Immediate efforts should be made to quantitatively correlate the degree of radiation damage with the levels of oxygen and other trace impurities in the existing crystals.

3. Investigate the use of CPAA for the measurement of the oxygen impurity.

4. Use high purity materials with the current processing techniques to grow crystals. Up-to-date analytical techniques should be used at each state to verify impurities. The results should be cross checked in other laboratories.

5. Investigate the accuracy and cross comparison of trace element analysis techniques.

6. Suspend the growing 35 cm crystals due to the cost, low yield and difficulty with impurities.

7. Concur with SIC decision to defer purchase of new furnaces until radiation damage issue is settled and the collaboration decides on the detector of choice.

8. Concur with the collaboration decision to limit the next purchase to 49 crystal pairs

9. Vacuum - It is our understanding this work is underway and will require three months to finish
   a. Determine if the fore-pump on the sintering ovens are adequate.
   b. Improve vacuum and vacuum monitoring on the growth furnaces to at least the 10^{-6} range. Use cold traps to improve the vacuum and decrease backstreaming. Add a second more up-to-date ion gauge closer to the chamber on the furnace to give better indication of vacuum problems. Helium leak detecting equipment is desirable to quickly locate problem areas.

10. Report the light transmission in absorption length to allow easier comparison of different length crystals.

11. Supply raw material, sintered material and final crystals from the new processing to US for radiation sensitivity evaluation.

12. Advice Rein-yuan Zhu supply crystals to SIC for impurity evaluation for comparison.

13. Demonstration of capacity and crystal quality of the new production furnaces should occur before the production cycle begins in 1993.

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.

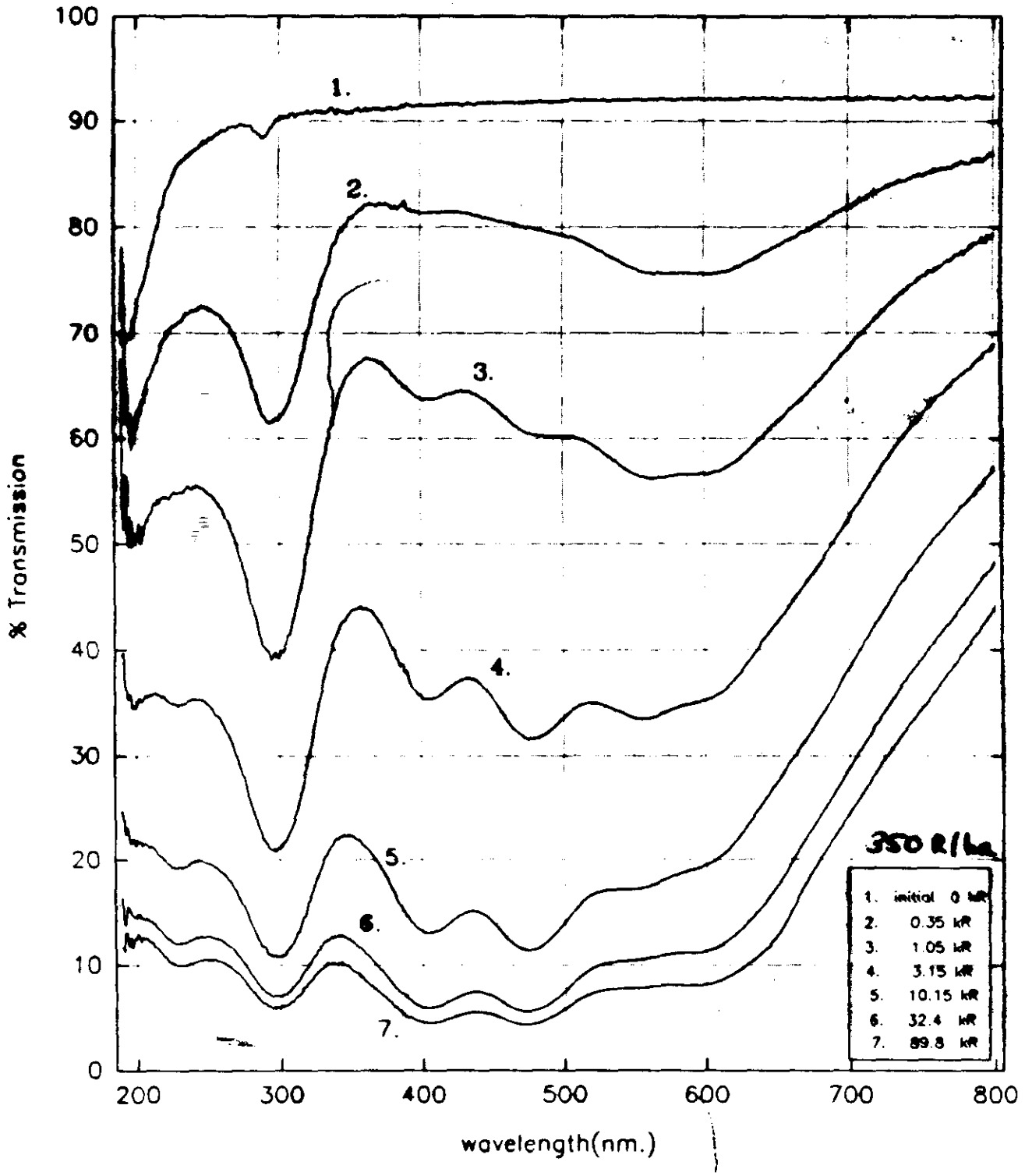
* GEM must define acceptable crystal characteristics for radiation environment.
  - Electron or Photon damage (ionization)
  - Hadron damage (spallation)
  - Variability of attenuation within crystal
  - Degree of saturation required (*i.e.* change of radiation damage over time)

* 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?

Radiation damage in large Merck BaF_2 sample #M652/1



Dose Rate Dependence Study

25 cm long BaF_2

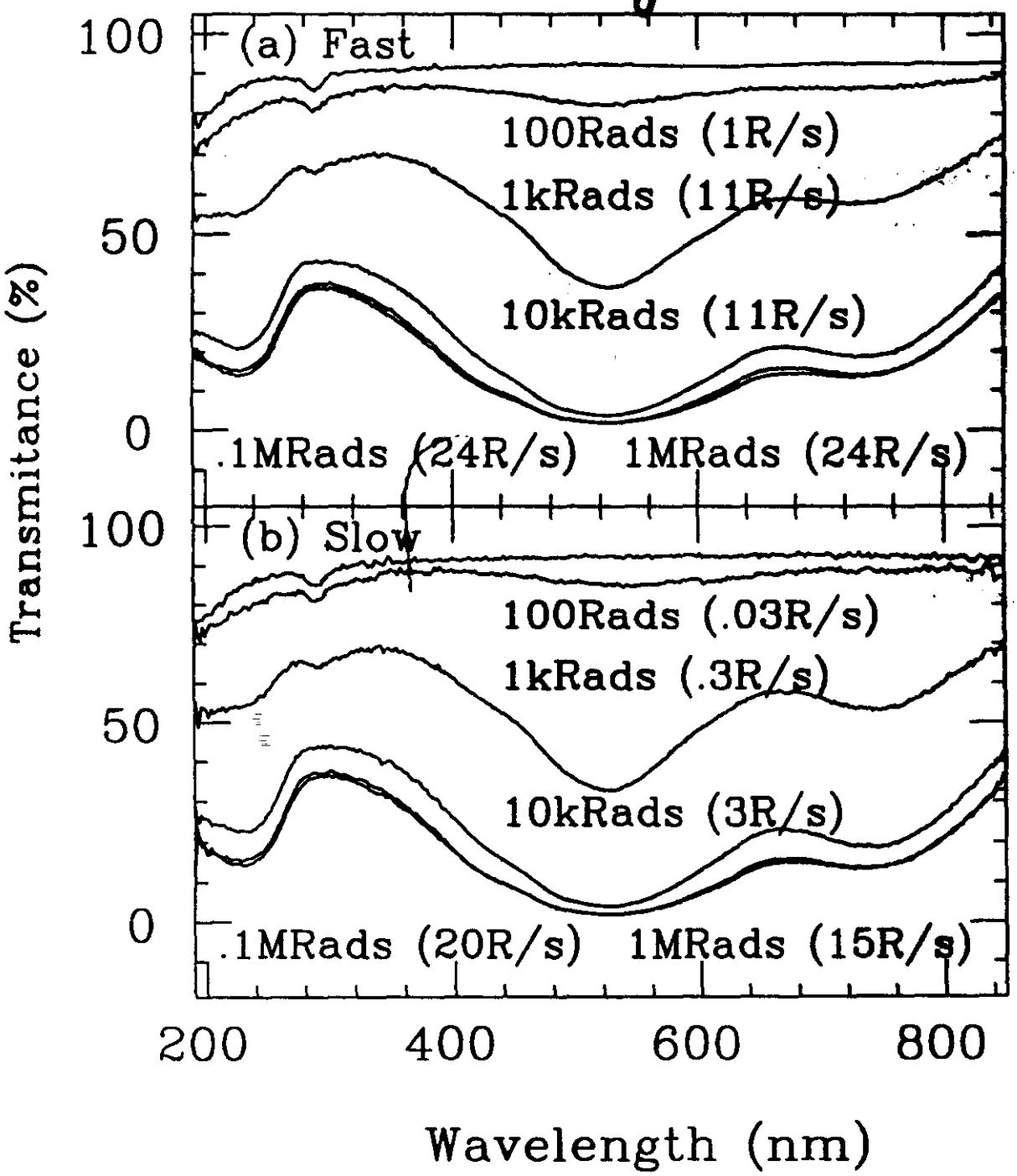


TABLE 1: ANALYTICAL METHODS AND MATERIAL PROPERTIES

METHOD	SENSITIVE TO/FOR:	INSTITUTIONAL AVAILABILITY	OBJECTIVE	CRYSTAL SAMPLE SIZE (inches)
FTIR	Impurities	PNL	Survey	1 x 1
VUV	Impurities	Acton Research	Band-end transmission	0.5 x 0.2, other
TLD/ Acoustic	Impurities/ Defects	CEA/ Other	Trap Depth	Chips, before & after irradiation
Ellipsometry	Surface quality	Woolam, Inc.	Contamination	1 x 1
ULRB	Impurities at low levels	USC/PNL	Actinides/ Lanthanides	1 x 1
GDMS	Survey	CEA	Traces	few grams
SIMS	C/N/O/H	CEA	Typical levels in crystals	few grams
EPR	H	MIT	H presence	0.2 x 0.2 x 0.3
EXAFS	O_2	NRL/NIST	Oxygen	Any
XRF	Survey	NRL	Species	Any
Channeling/ RBS	Interstitials & Stochiometry	CEA	Bulk Oxygen	2 x 2 x 0.1
TEM	Structure	CEA	Defects	
Etching	Defects		Defects	
ESCA	Impurities	CEA	Contamination	1 x 1

Glossary:

FTIR	Fourrier Transform Infrared transmission
VUV	Vacuum Utraviolet transmission
TLD/ Acoustic	Thermo-Luminescence
NMR	Nuclear Magnetic Resonance
ULRB	Ultra Low Radioactive Background
GDMS	Glow Discharge Mass Spectrometry
SIMS	Secondary Ion Mass Spectrometry
EPR	Electron Paramagnetic Resonance
ESR	
EXAFS	Extended X-ray Absorbed Fine Structure
XRF	X-ray Fluorescence
Channeling/ RBS	Rutherford Backscattering Spectroscopy
TEM	Transmission Electron Microscopy
STM	Scanning Tunneling Microscopy
ESCA/	Electron Spectrometry for Chemical Analysis
XPS	X-ray Photoelectron Spectroscopy

Preview
Composition Studies

Matrix Level Elements:

F - 66%

Ba - 30 to 33%

Sr - 15ppmw to 3%

Mid Level Impurities:

H - (No Calibration)

C - "

O - "

S - 100 to 1000 ppmw

Cl - 100 to 1000 ppmw

Trace Level Impurities:

B - 0.1 to 20ppmw

Na - 2ppmw

Mg - 1ppmw

Si - (No Calibration)

Al - (No Calibration)

Ca - 0.5 to 50 ppmw

Ag - (No Calibration)

Rare Earths (La/Sm) - 3 to 12 ppmw

Analyst: V.A. Vlach

TABLE 5

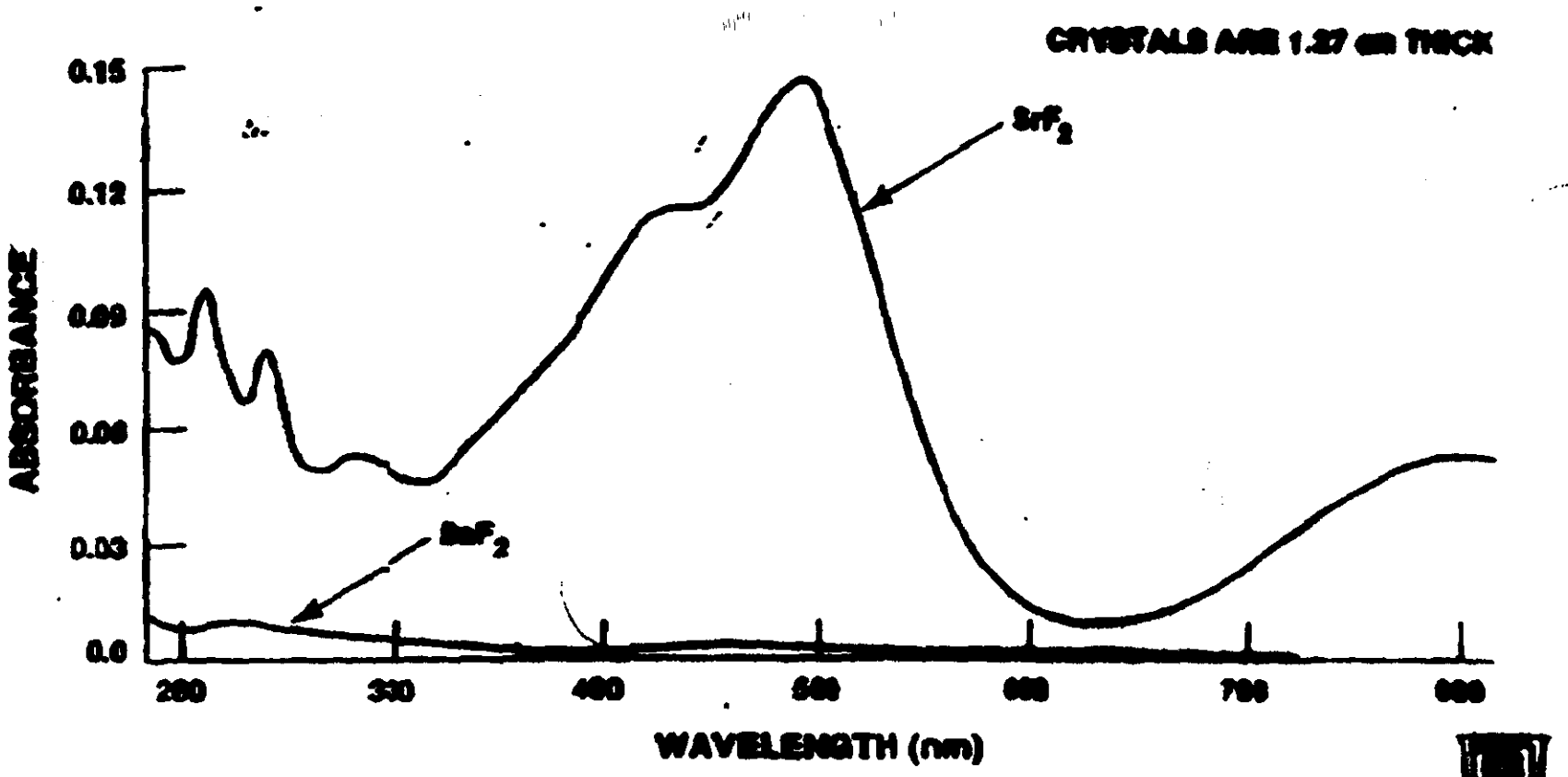
GDMS Analysis Results of One BaF_2 Glass Sample #SIC-XTL, Base Cleaved

Element	Concentration (ppmw)	Element	Concentration (ppmw)
Li	<0.003	Rh[1]	<120.
Be	<0.004	Pd[2]	<0.1%
B	0.3	Ag	BINDER
C	(<870.)	Cd	<1.
N	(≤1.7%)	In	0.04
O	(≤1.1%)	Sn	0.9
F	MATRIX	Sb[3]	<110.
Na	-4.	Te[4]	<280.
Mg	1.	I[5]	<130.
Al	12.	Cs[6]	<2.8
Si	10.-40.	Ba	MATRIX
P	0.6	La[6]	<33.
S[7]	-90.	Ce	0.07
Cl[7]	-210.	Pr[6]	0.2
K	<0.8	Nd[6]	1.6
Ca[9]	-70.	Sm[6]	<28.
Sc	<0.01	Eu[6]	<0.1%
Ti	<0.1	Gd[6]	1.3
V	<0.004	Tb[6]	0.3
Cr	<0.1	Dy[6]	≤3.4
Mn	<0.008	Ho[6]	0.1
Fe	<0.5	Er[6]	0.1
Co	<0.005	Tm[6]	0.2
Ni	<0.1	Yb[6]	2.
Cu	<0.2	Lu[6]	1.
Zn	<0.2	Hf	0.7
Ga	<0.04	Ta[10]	<25.
Ge	<0.1	W	<0.02
As	<1.	Re	<0.03
Se[11]	<0.7	Os	<0.03
Br	<0.6	Ir	<0.02
Rb[2]	<0.2	Pt	<0.04
Sr[2]	1.3%	Au	<0.2
Y[2]	<2.	Hg	≤0.5
Zr	<0.01	Tl	<0.04
Nb	<0.01	Pb	<0.1
Mo	<0.6	Bi	<0.01
Ru	<0.1	Th	<0.002
		U	<0.007

[1] BaH^+, BaO^+ interferences.
[2] $BaBr_2^+$ interferences.
[3] AgC^+, AgH^+, AgO^+ interferences.
[4] AgO^+, AgF^+, Ba^+ interferences.
[5] $AgFe^+$ interferences.
[6] BaH^+ interferences.
[7] Present in binder.
[8] BaC^+, BaH^+, BaO^+, BaF^+, $BaAr^+$, BaF_2^+, $AgAr^+$ interferences.
[9] Sr^{+2} interferences.
[10] Source material.
[11] Ar_2H^+ interferences.

... $_2$ AND SrF_2

(193 nm, 100 mJ cm^{-2}/Pulse, 2×10^6 Pulses)

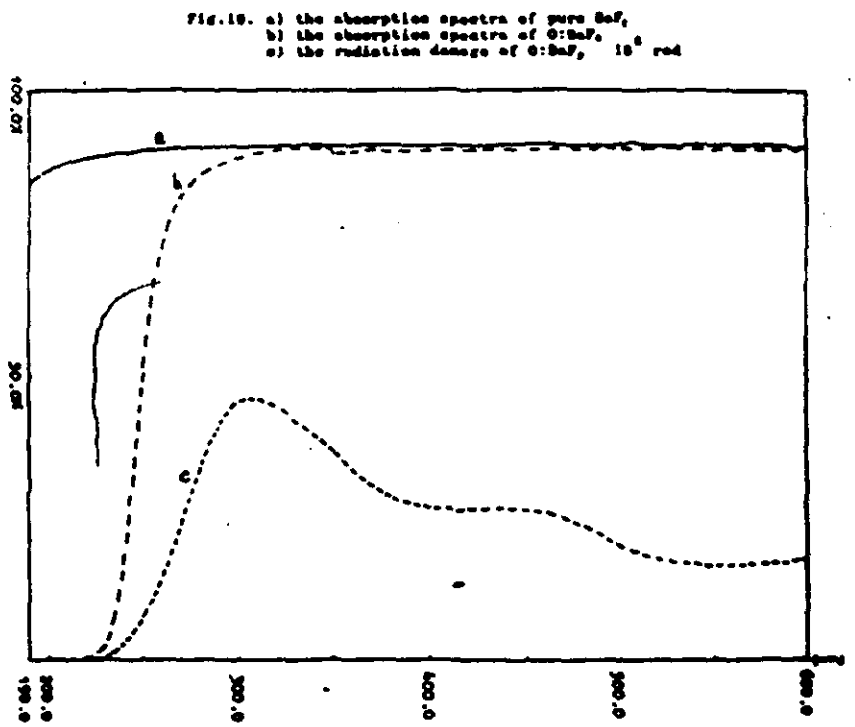


MIT/Optoran
Collaborator 1991

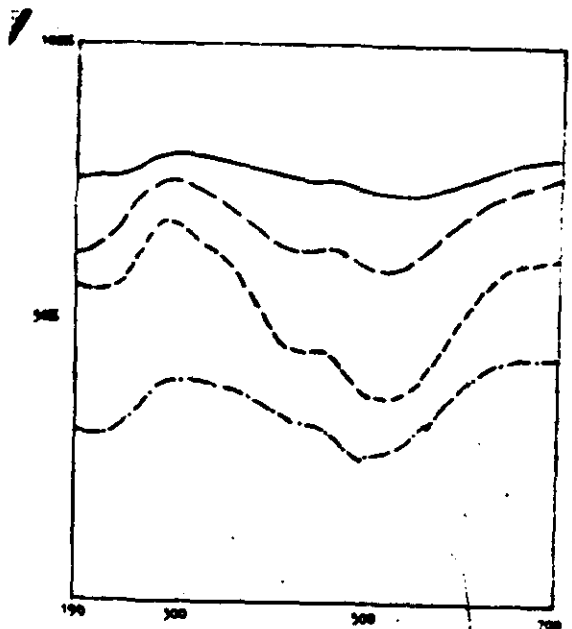
Fig. 1

FROM CALTECH HIGH ENERGY PHYS. TO 415 323 3909 P.02

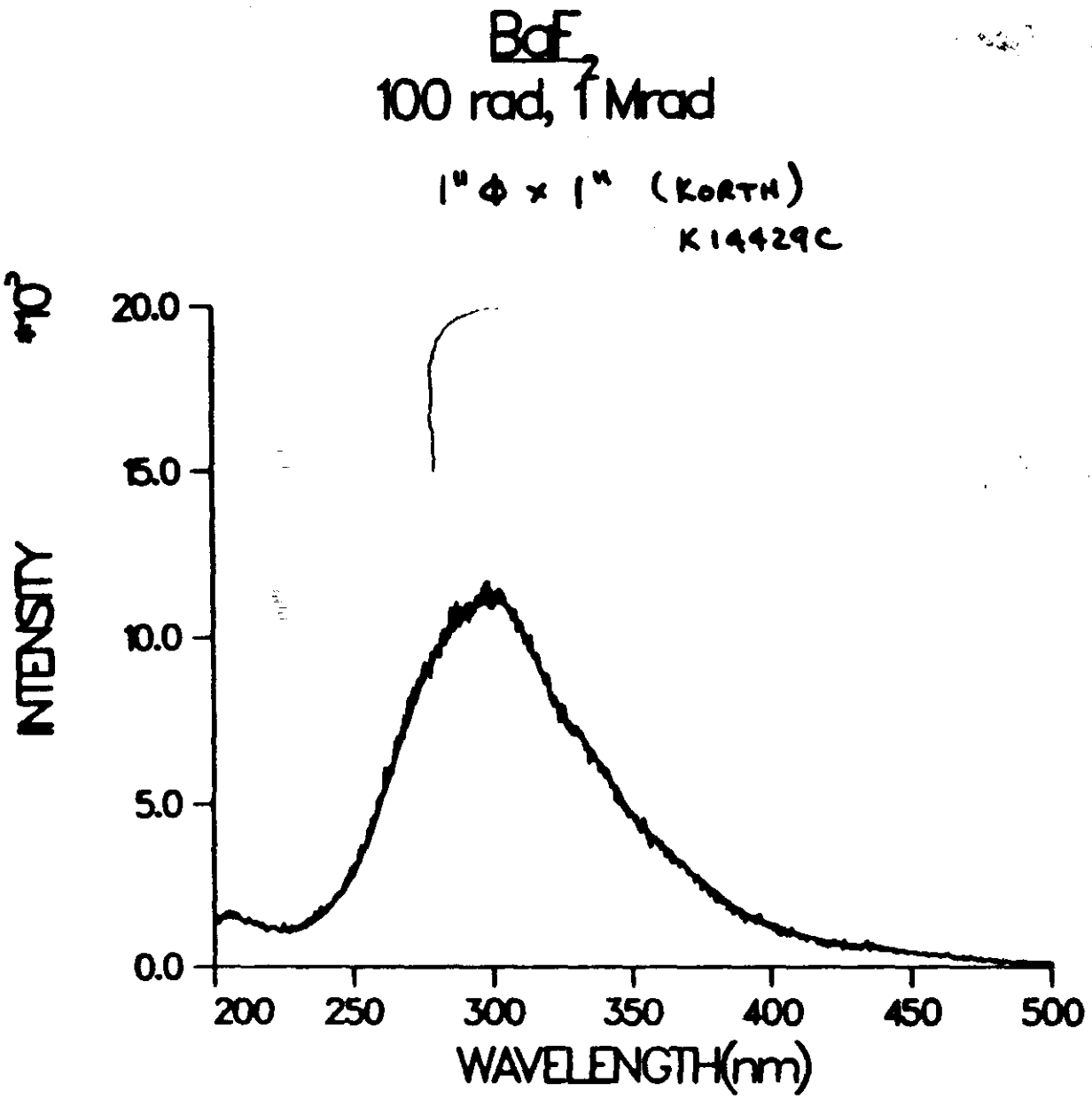
- <u>Less oxygen</u> in the crystals reduced the overall damage of the crystals (gradual slope off transm.) after irradiation.



oxygen in BaF_2
b unirad
c irrad.

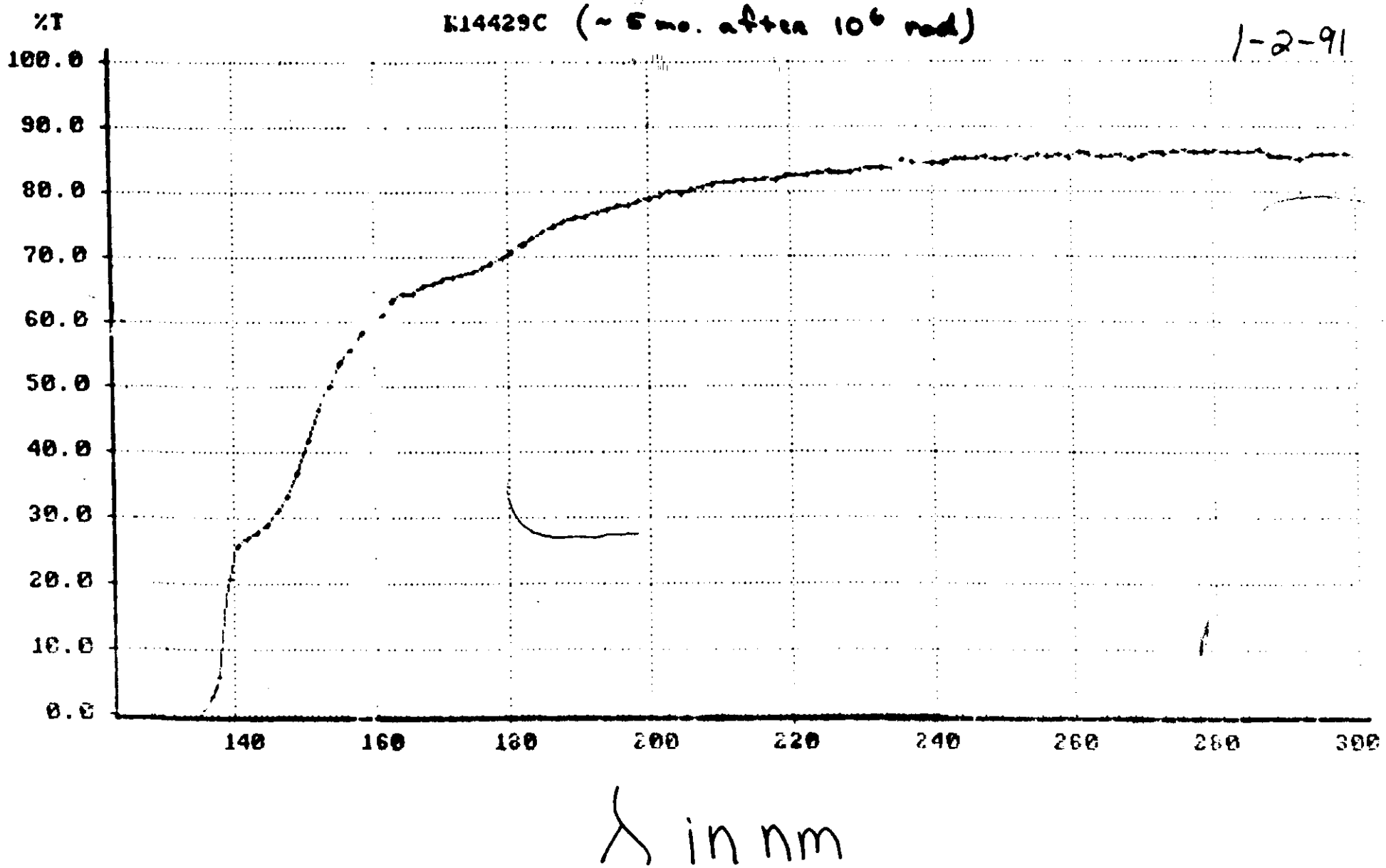


BGRI.


BaF2
100 rad, 1 Mrad
1" Φ x 1" (KORTH)
K14429C
*10^2
INTENSITY
20.0
15.0
10.0
5.0
0.0
200
250
300
350
400
450
500
WAVELENGTH(nm)

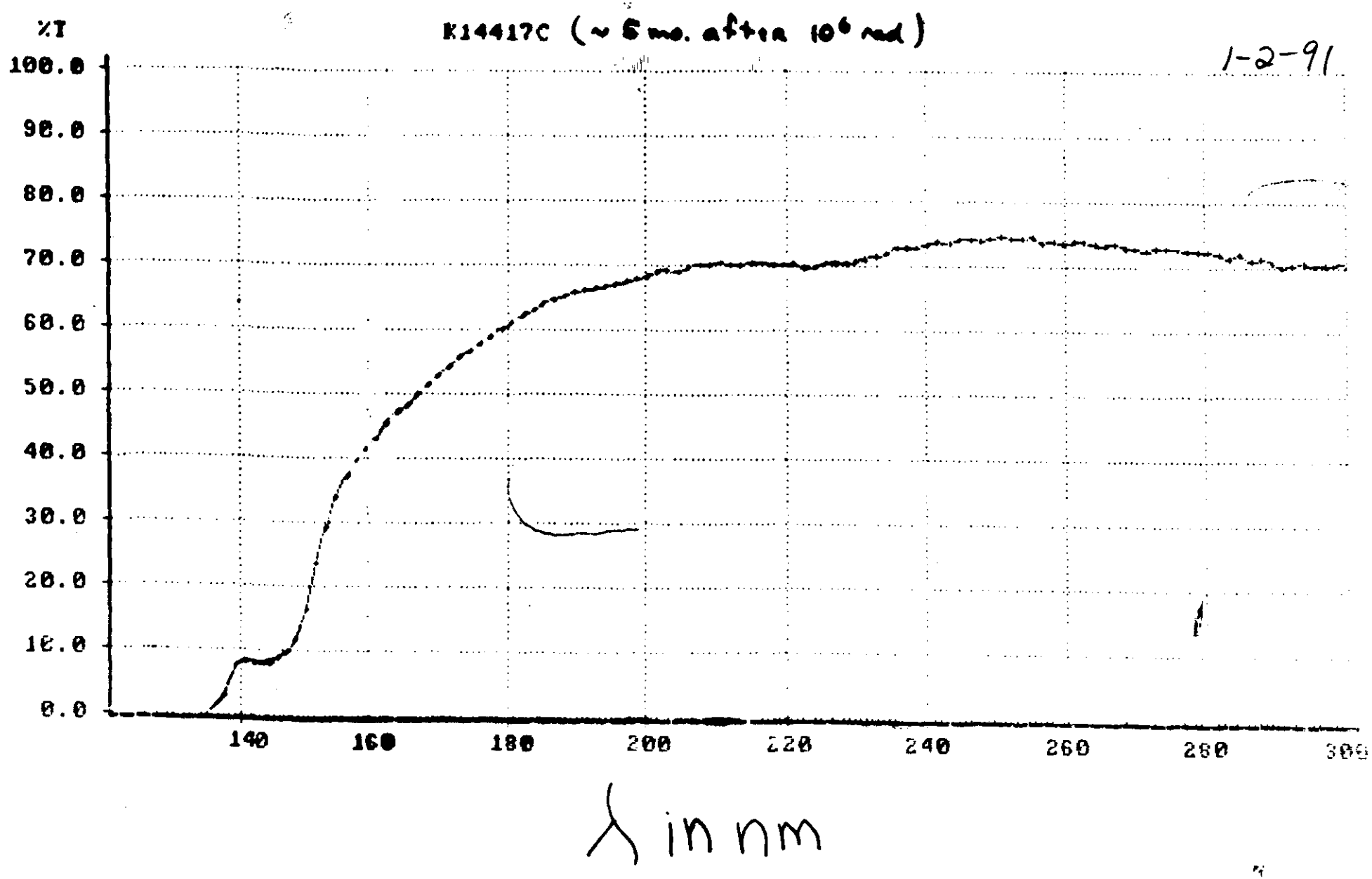
Acton Research Corporation
PO Box 2215 • 525 Main Street, Acton, MA 01720
Tel: (508) 263-3584 • Fax: (508) 263-5086

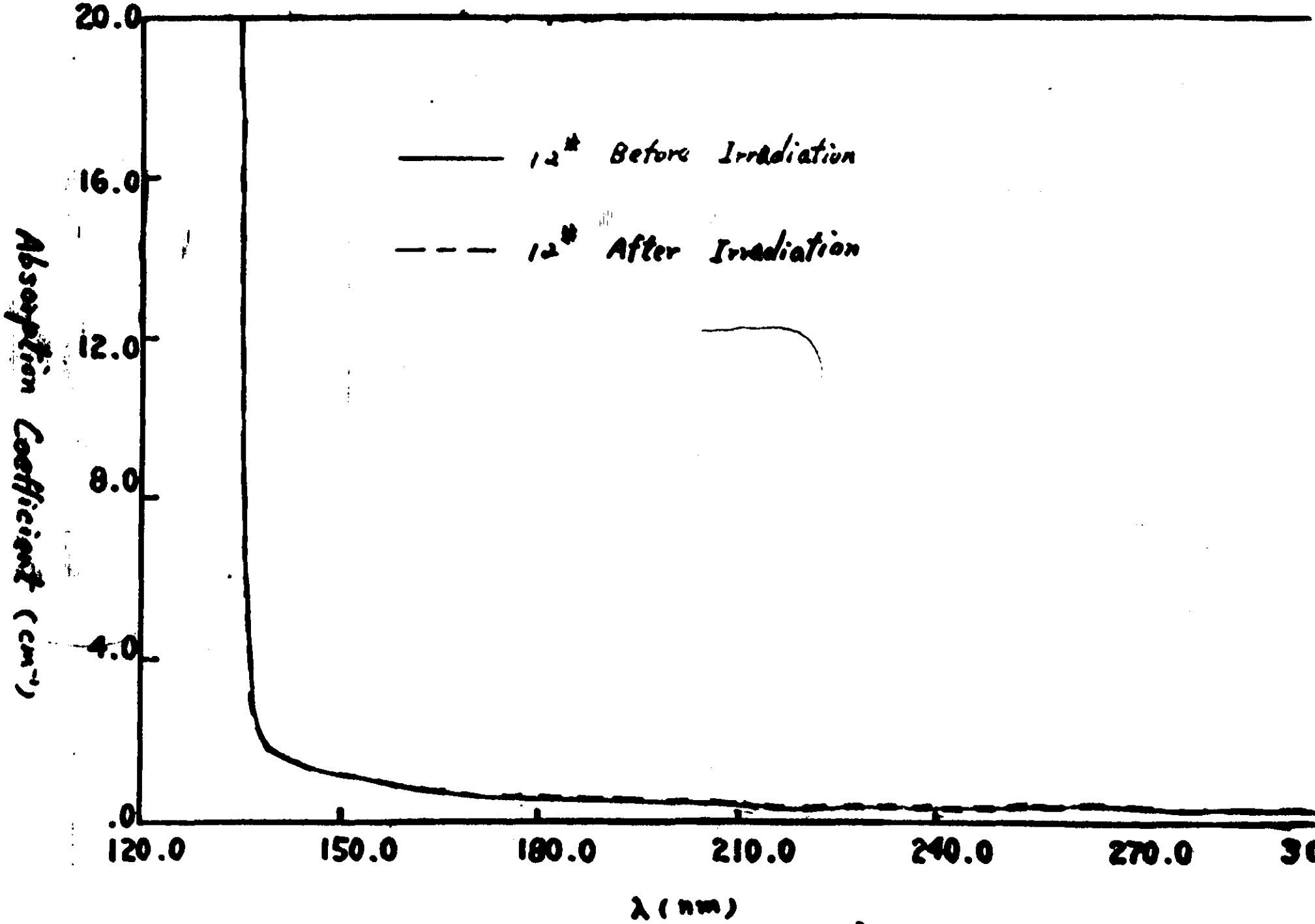
Calibration Curve

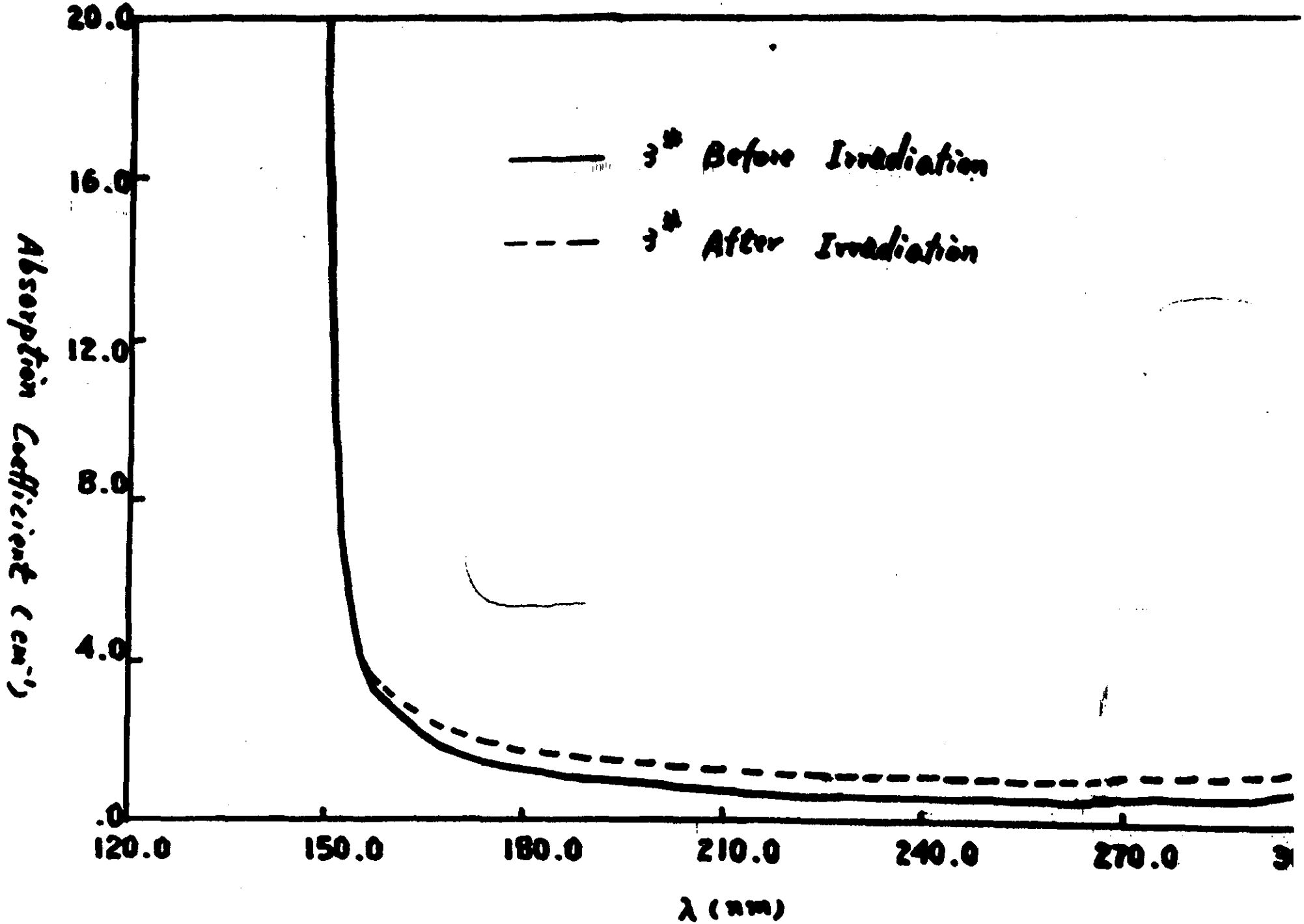


Acton Research Corporation
PO Box 2215 • [illegible] Main Street, Acton, MA [illegible]
Tel: ([illegible]) [illegible] • Fax: ([illegible]) [illegible]

Calibration Curve




20.0
16.0
12.0
8.0
4.0
.0
Absorption Coefficient (cm⁻¹)
12* Before Irradiation
12* After Irradiation
120.0
150.0
180.0
210.0
240.0
270.0
λ (nm)


3* Before Irradiation
3* After Irradiation
Absorption Coefficient (cm⁻¹)
20.0
16.0
12.0
8.0
4.0
.0
120.0
150.0
180.0
210.0
240.0
270.0
λ (nm)

SIMS Oxygen Bulk Analysis of BaF2

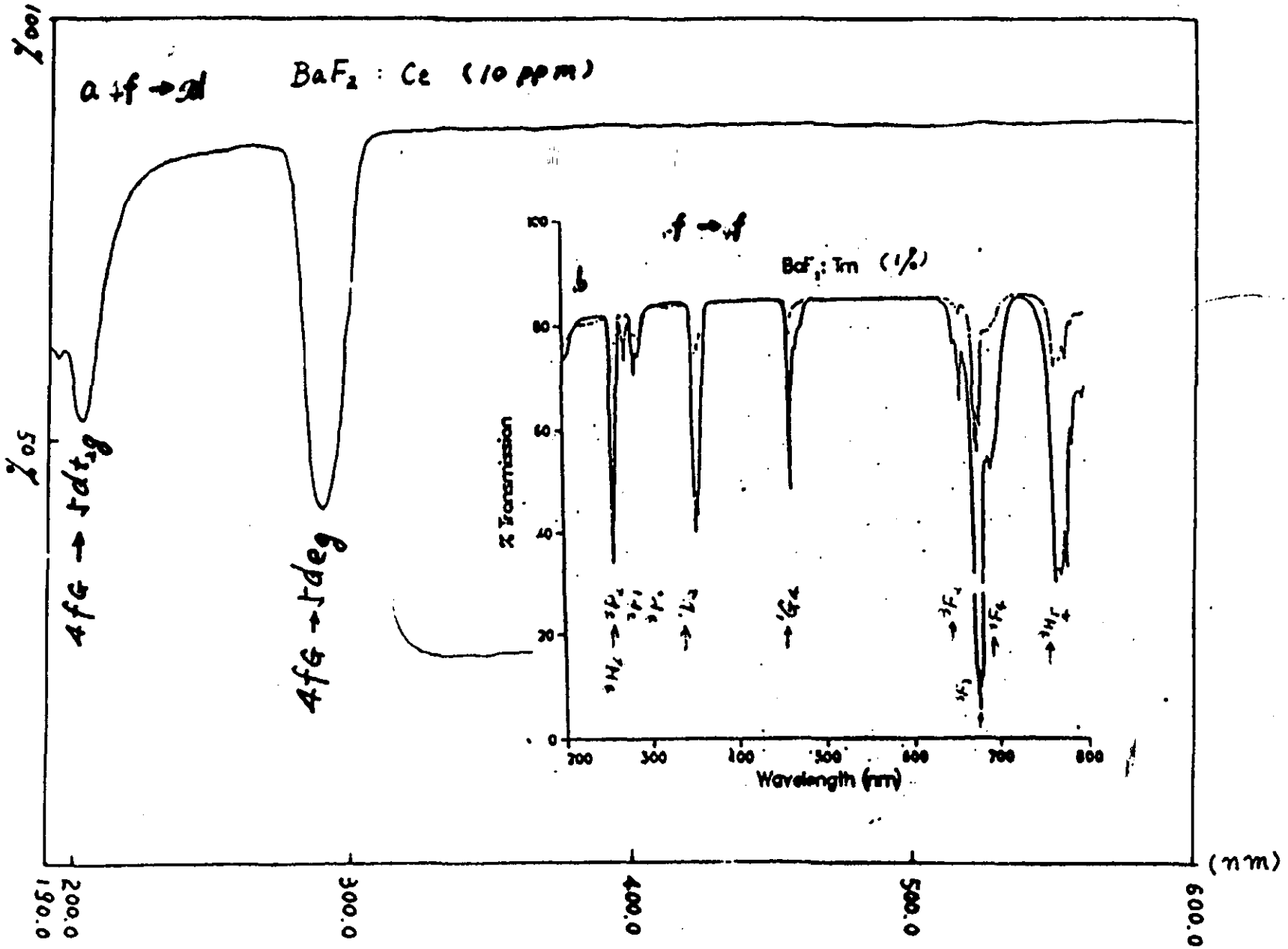
Sample	Relative Concentration
K14417D	3.2
K458484A	6.22
SICC2x2.5	3.1
SICCube	6.5
SICXTL Tip	1.9
SICXTL Base	3.4

Table. 2

The peak position of the color centers and oxygen impurity centers in BaF_2 crystals.

color centers	E(ev)	λ(nm)
F	2.03	611
M	1.72	720
V_k	3.69	336
	1.65	750
U	6.01	206
OH^-	6.5	191
O^-	7.2	175
	5.4	230
	3.0	413
$O^{=}$	9.5	130
	6.2	200
	4.25	292
$O^{=}V_a^+$	10.1	123
	9.8	127
	8.4	148
	6.6	188
$F_H(O^{=})$	10.0	124
	9.7	128
	8.1	153
	6.4	194
	3.2	394
	2.8	443
F_{aM}	2.3	539
	3.4	365

Fig.6. The absorption spectra of a) Ce:BaF_2 [from SIC]
b) Tm:BaF_2 [10]



He ion beam backscattering

[redacted]

Data Name = CRYSTAL SCAN: SSC MBS XTL TIP "Cleaved" <CE>

<110>

Y - TILT
X - TILT

Summary

of BaF2

Materials Characterization

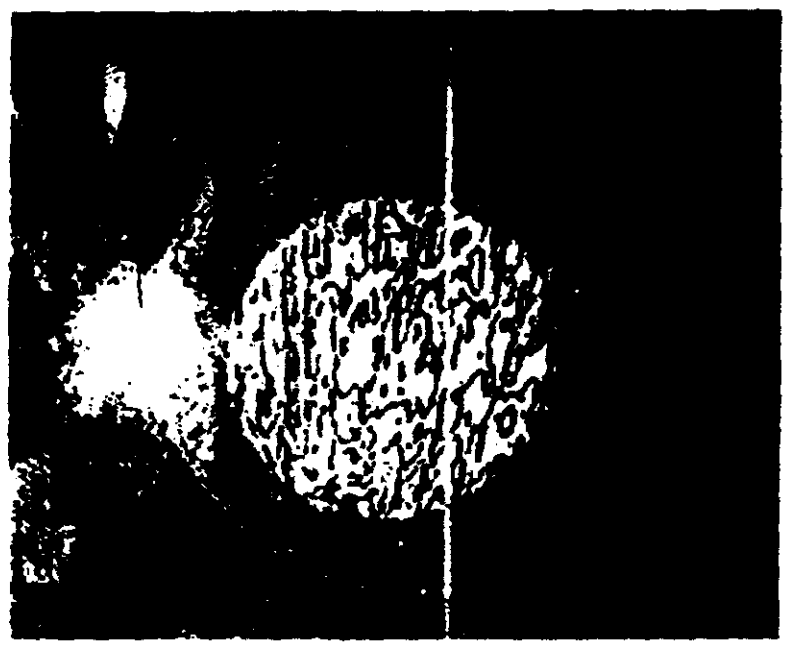
) The polished surface of BaF2 crystals is highly disorded.

.) There are several Mid Level impurites in both the K and SIC Series Crystals.

) Sr is present at Matrix concentrations in SIC crystals. There is optical data which suggest that SrF2 is not radiation hard.

R. Sparrow
Optovac

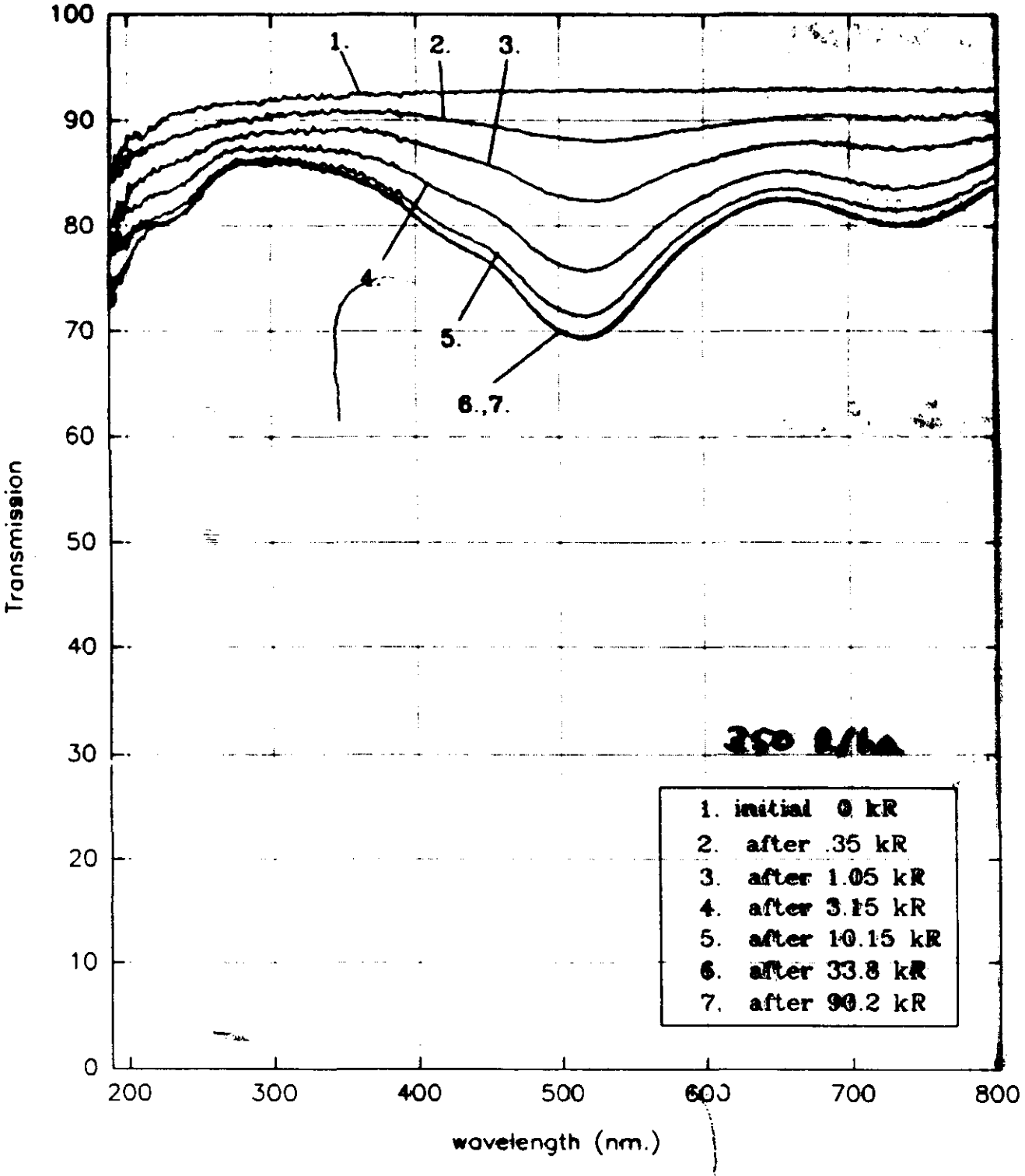
Refractive Index
Inhomogenities



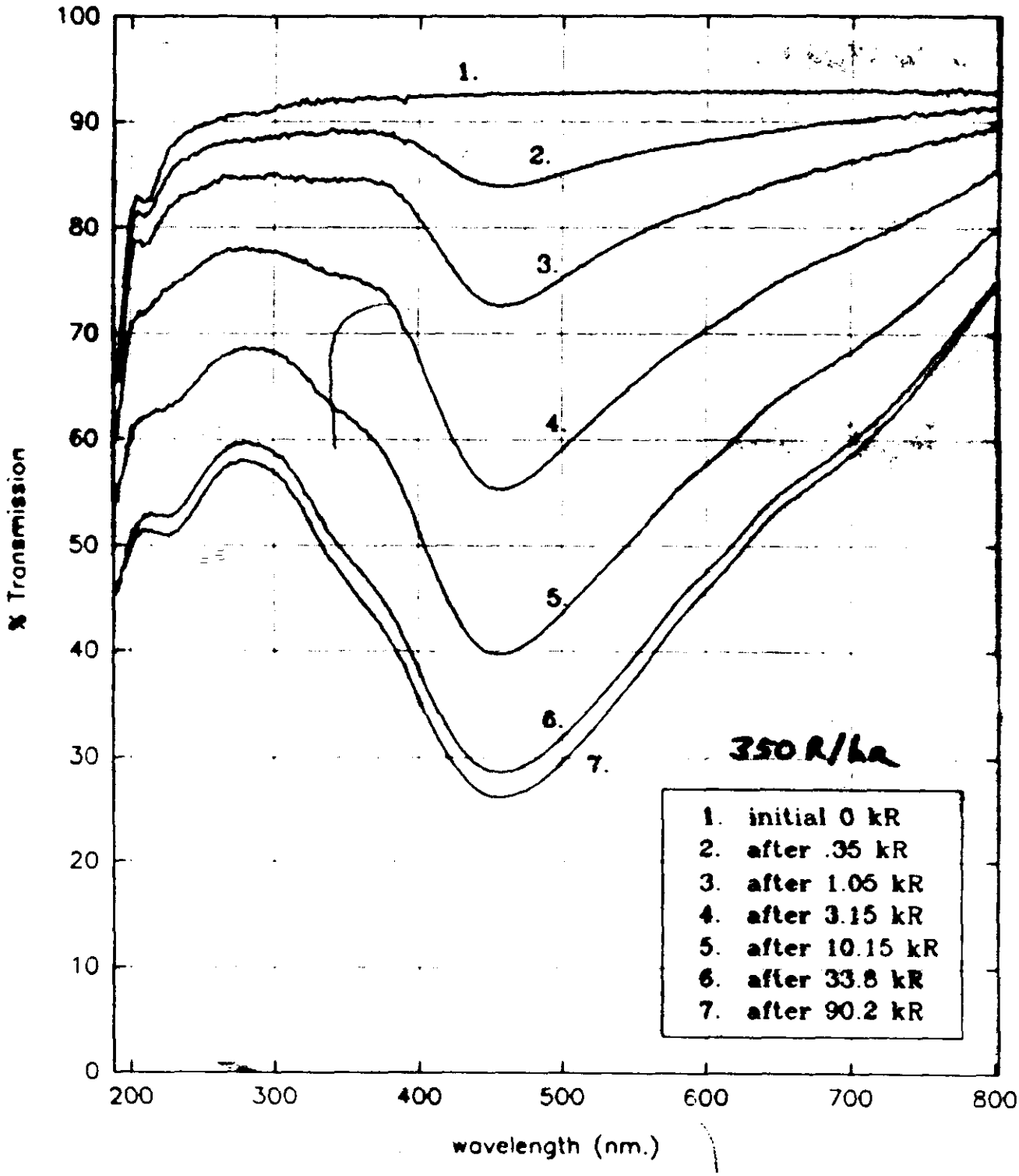
SiC Bat. 1"x1" Eaten from
Top of Trap.

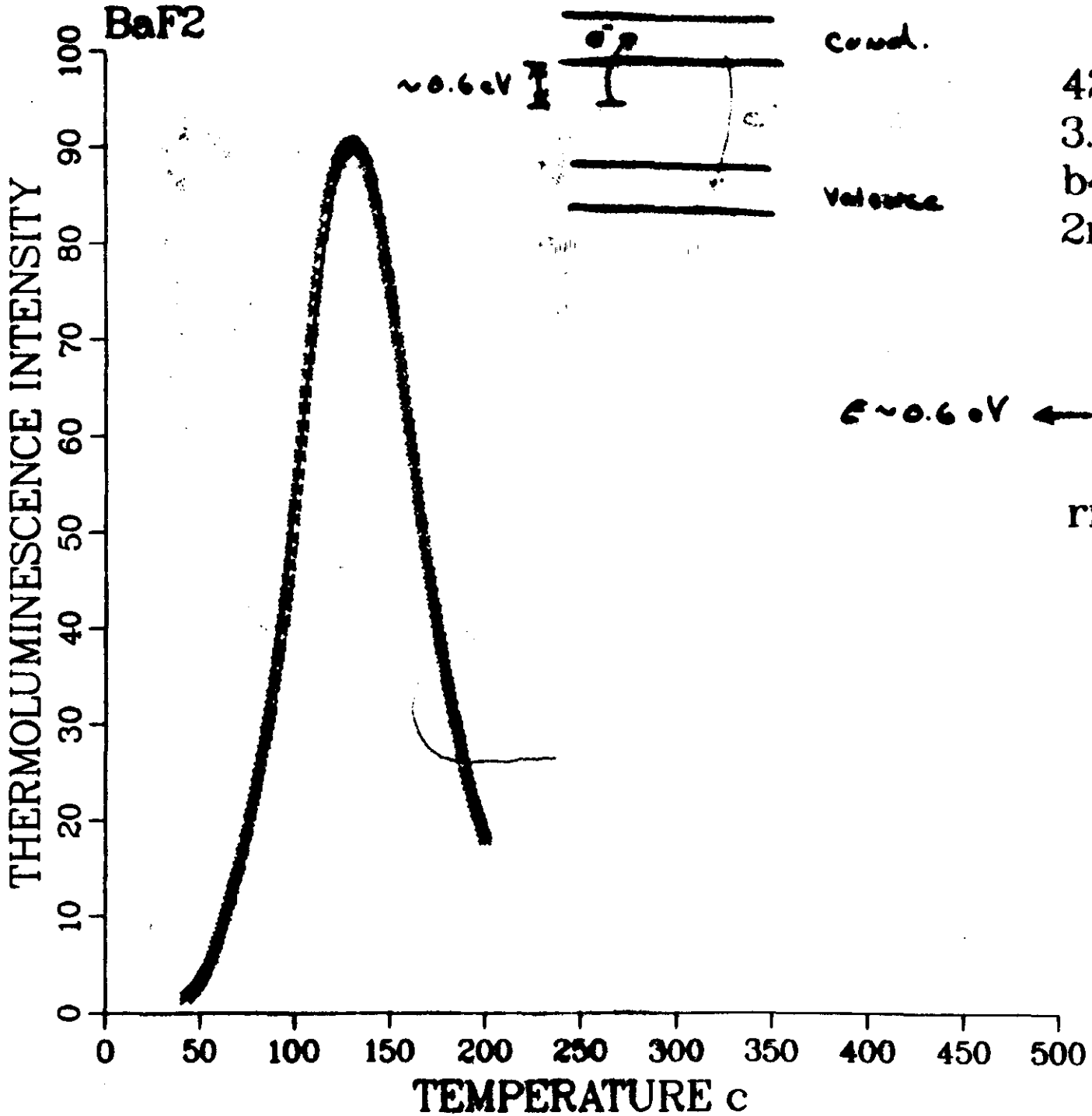
11/1/91

1" x 1"diam. BaF_2 SA91065 1/20/92



1" x 1"diam. BaF_2 # SA91060 1/20/92





42Ø Kurtz
3.e2 rad
b420m1.nor
2nd order

PARAMETERS

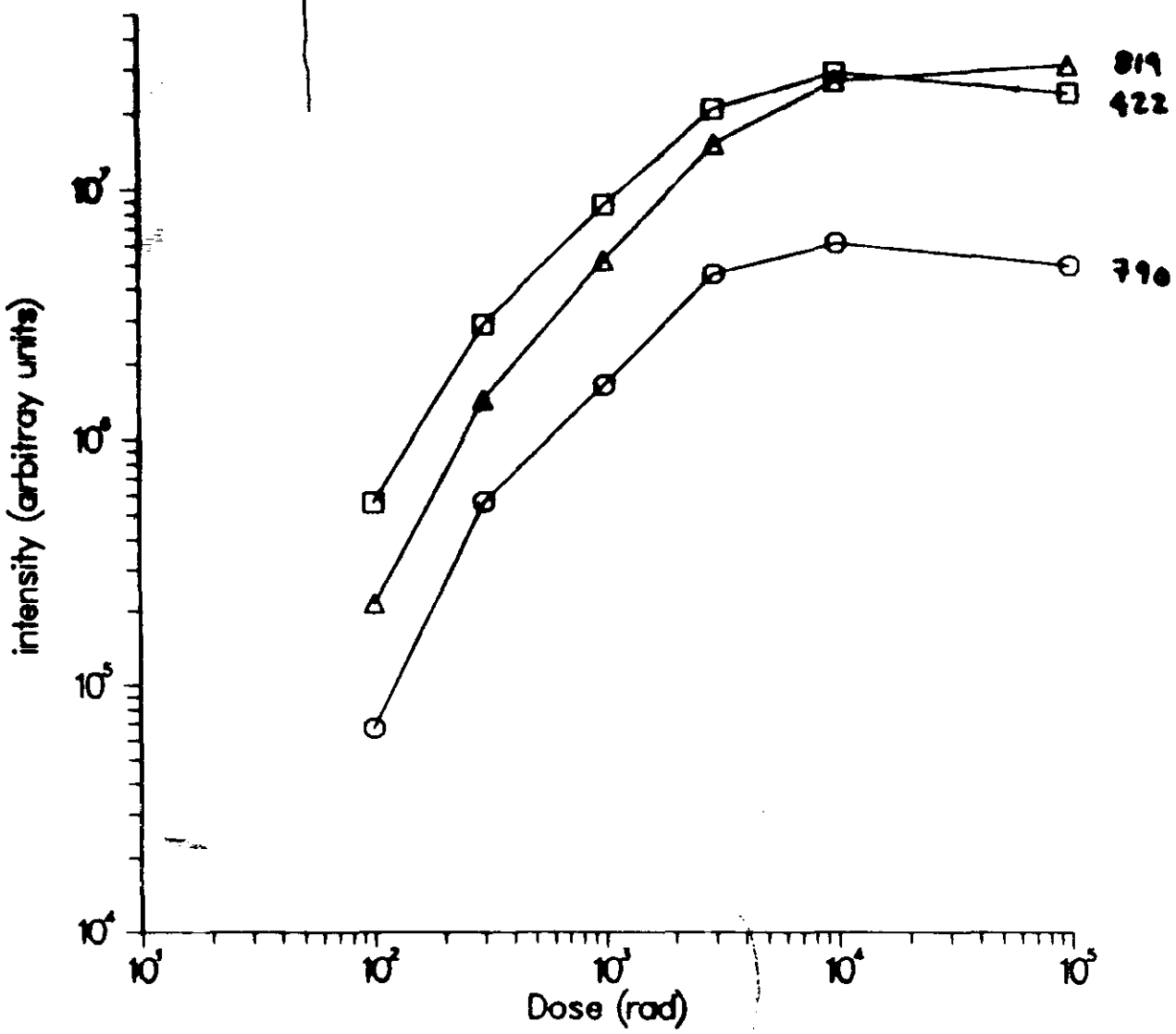
s' = 1.17 E6
E = 0.599 ← E ~0.6 eV
n_0 = 2.27 E6
rms = 2.56 E2

2

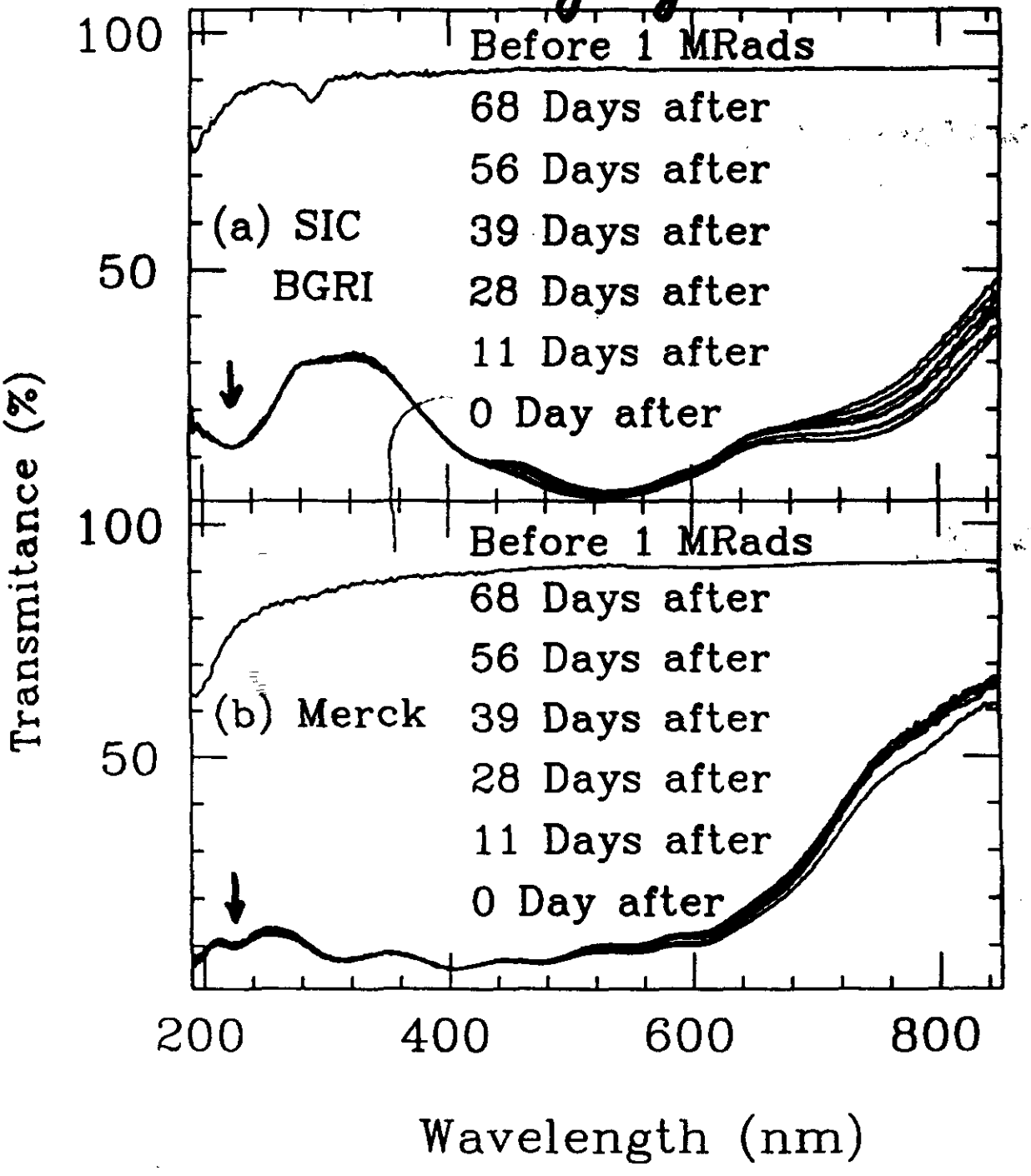
BaF2 (420,790,819)

Thermoluminescence

Integrated Intensity versus dose

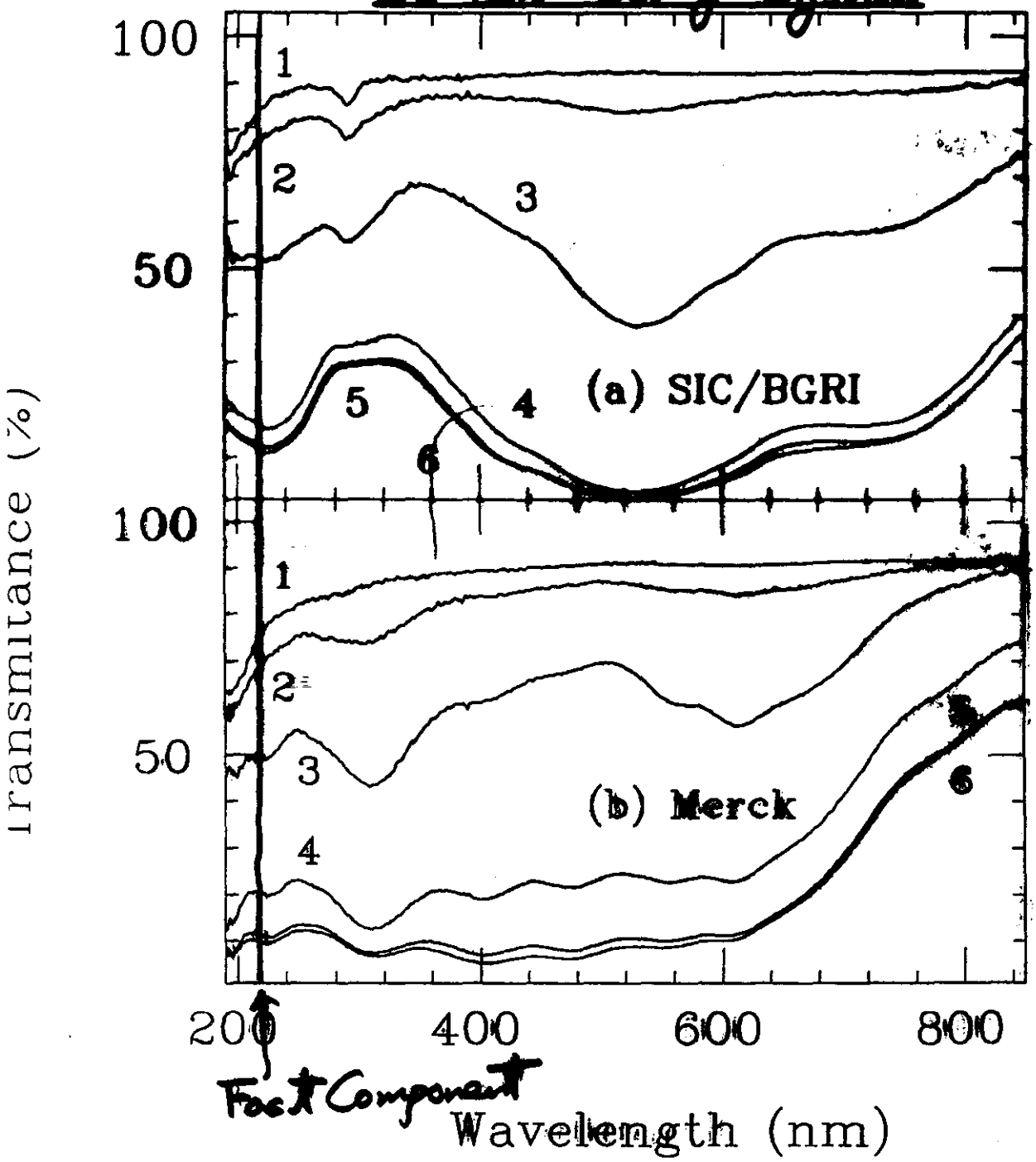


Recovery at room temperature
25 cm long crystal in dark



Radiation Damage of BaF_2 (I)

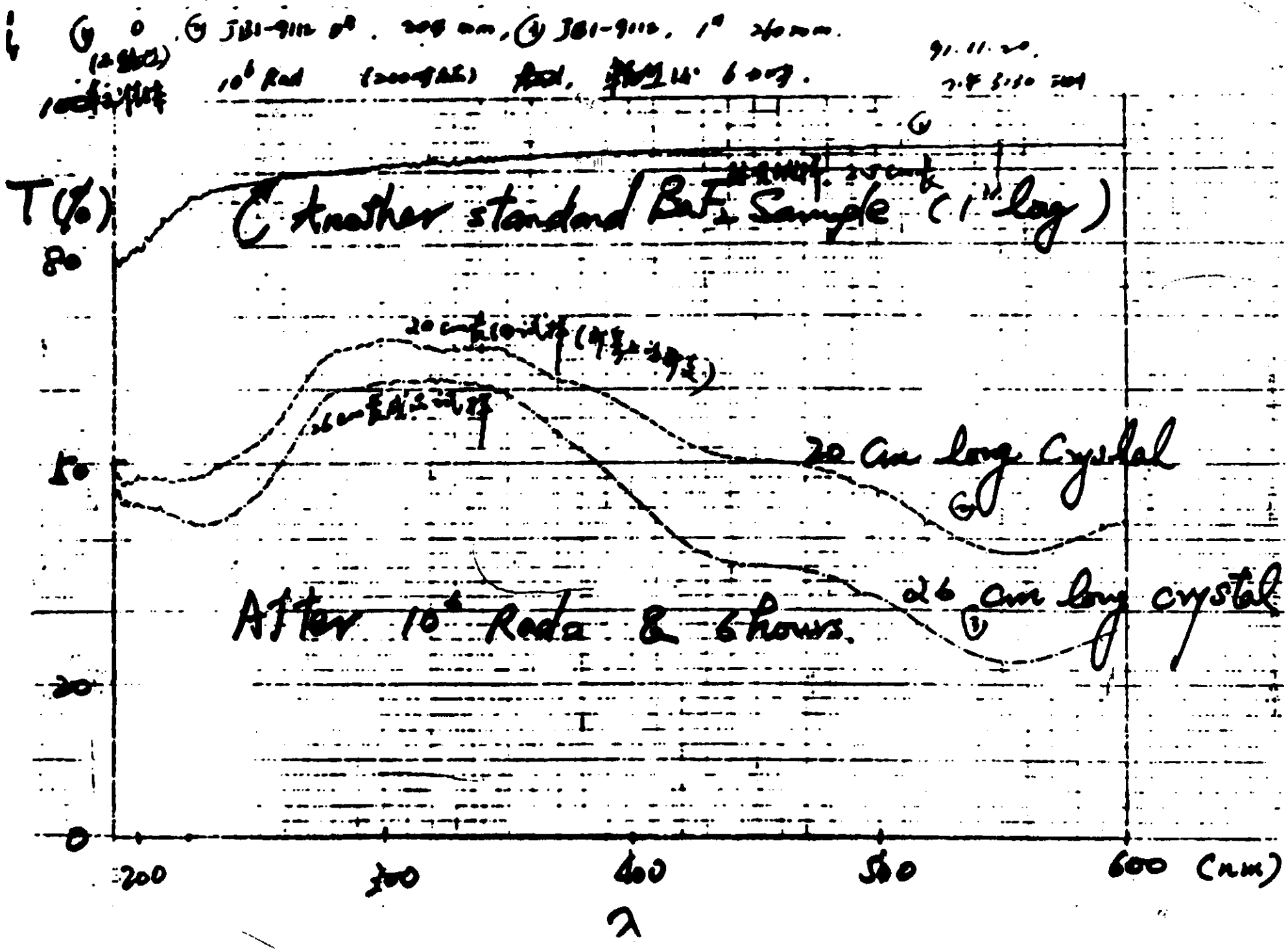
25 cm long Crystal



2: 100 Rads; 5. 100 kRads

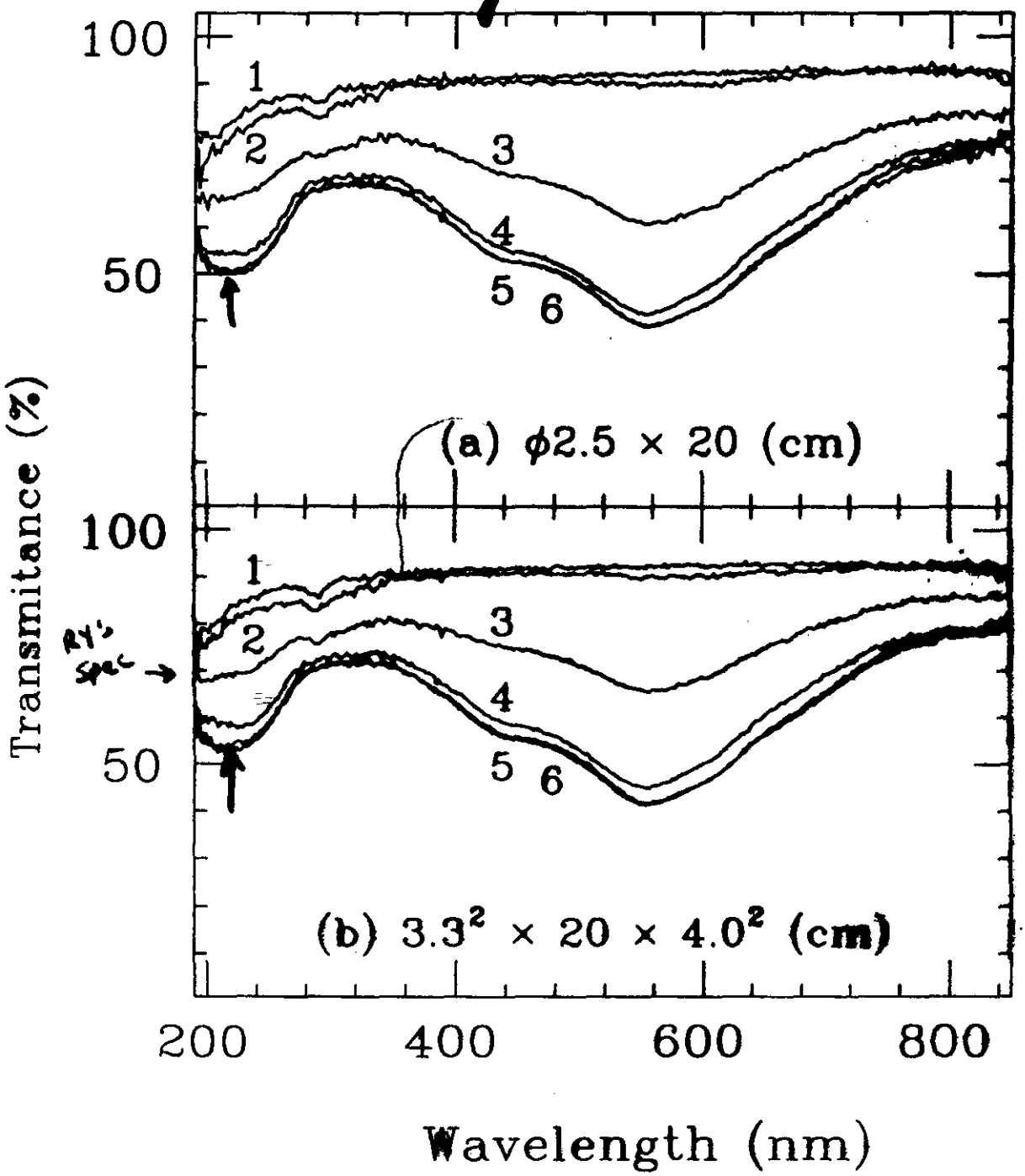
3: 1K Rads; 6. 1 MRads.

4: 10K Rads;


T(%)
80
60
40
20
0
200
300
400
500
600
(nm)
λ
Another standard BaF2 Sample (1st log)
20 cm long Crystal
26 cm long crystal
After 10^6 Rads & 6 hours.

Radiation Damage of BaF_2 (II)

New Crystals from SIC 20 cm long



1: before irradiation;
2: 100 Rads;
3. 1 kRads;
4. 10 kRads;
5. 100 kRads;
6. 1 MRads.

CONCLUSIONS

1. Assuming saturation with radiation and very slow self-recovery (response trimmed to uniform after preradiation) light absorbtion length at 220 nm should be > 53 cm (6 side polished crystal).

   Conservatively one can specify (as in R-Y Zhu specs) : T@

   Abs. length for irradiated crystals > 100 cm (> 200 cm fresh crystals)

   Response of the crystals with such absorbtion length can be trimmed to uniform by optical coating, wraping etc. Accuracy of such trimming should be at the level Delta < 3%.

2. Once crystals are coated and installed one can admit that global or local non-uniformity can be developed for 5 years of SSC operation at the level of no more than Delta=6% or change absorbtion length from > 100 cm to > 80 cm.

3. Change of global light yield of the crystal (with or without development of non-uniformity) should not exceed 1% per month of steady SSC operation (assume calibration once per month).

Conclusions from BaF_2 Panel

Jan 21-22, 1992

I. The panel endorses its previous findings in that it finds no evidence that BaF_2 cannot be made sufficiently Radiation hard for use in GEM at the SSC

II. Although no crystals produced so far in China or the west would meet the Rad. requirements for GEM, the Chinese have demonstrated significant progress in recent months in understanding and solving the radiation damage problem in BaF_2

III. The panel endorses a vigorous R&D program, which will be specified in the final report, to determine if sufficiently radiation hard crystals can be produced to meet the GEM requirements. The time for final evaluation of this effort would

GEM BaF_2 Panel report
after the first meeting at the SSCL, Dec 4-5

"The charge to the Panel is to review the current level of understanding of radiation damage in Barium Fluoride crystals and the progress in producing appropriately radiation hard crystals in China. If the prospect of producing radiation hard crystals and their cost is judged to be of sufficient promise, the Panel is requested to help define a systematic program of research and development that will lead to identification and elimination of the principal causes of damage. This program should be on a time scale that will show sufficient progress during 1992, so as to permit a final GEM decision on calorimeter technology and then completion at a time so as to permit full scale mass production of crystals to proceed before the end of 1993." (from the letter to the Panel members by Fred Gilman, Associate Director of the SSCL, dated November 11, 1991).

During its first meeting on December 4-5 the Panel has heard and considered the issues related to the radiation hardness of BaF_2 for GEM detector. The agenda of the meeting is attached.

1). The Panel finds that at this time there are no obvious fundamental reasons why BaF_2 could not be made sufficiently radiation-hard to meet the perceived GEM radiation-hardness criteria within a time schedule sufficient to enable full-scale production of radiation-hard crystals before the end of 1993.

2). However, at the present time, the data base is insufficient for the Panel to recommend BaF_2 as a radiation-hard crystal scintillator suitable for a precision electromagnetic calorimeter for the GEM detector.

3). Therefore, the Panel is recommending several steps that are meant to clarify outstanding issues and provide the basis for such an assessment by August, 1992. These studies should start without delay and some of the results can be expected even before the next Panel meeting, on January 21-22 at the SSC Laboratory.

4). This plan of action is divided into short and long term plans. The objectives of the plan of action are:

A. By January 21, 1991 to broaden our knowledge base so as to be in a better position to recommend a scope of work that will have a reasonable probability of successfully making progress with respect to resolving the questions associated with radiation damage.

B. In the event that R&D funding is provided, it was felt that manufacture of a few improved samples would be necessary but not sufficient for a sensible decision to be made as to proceeding to large scale production. It was agreed that an understanding of the mechanisms of damage would also be necessary. A range of tests for achieving a better understanding of mechanisms would be needed to be completed by August, 1992.

A list of analytical techniques felt to be relevant was prepared (Table 1). These were cross-referenced with the types of impurity and defects thought to be of concern (Table 2). A list of tests that could be completed by January 21 was made that corresponds to an estimated budget of $30K (Table 3). The remainder of the material tests, to be completed by August, 1992, were budgeted at approximately $150K.

14 members.

Barium Flouride Mtg. List

Name	Institution	Address	Country	Phone	FAX	Bitnet
Charles Dozier	Naval Research Lab	Code 4682 4555 Overlook Ave S.W. Washington, DC 20375	USA	202-767-2154 202-767-2993	202-767-4868	
Richard A. Craig	Battelle Memorial Inst. Pacific Northwest Lab.	K5-25 P.O. Box 999 Richland, WA. 99352	USA	509-375-6907	509-375-3614	D37813@PNL6.PNL.GOV (Internet)
Yok Chen	Oak Ridge National Lab USDOE	P.O. Box 2008 Bldg. 3025, MS 6024 Oak Ridge, TN 37831	USA	615-574-6284 301-903-3428	615-574-4143 301-903-6594	
Marvin Abraham	Oak Ridge National Lab	P.O. Box 2008 Bldg. 2000, MS 6056 Oak Ridge, TN 37831	USA	615-574-6282 615-574-5491 (sec)	615-574-4143	
* Majewski, Stanley	Continuous Electron Beam Accelerator Fac	12000 Jefferson Avenue Newport News, VA 23606	USA	804-249-7448 249-7235	804-249-7363	majewski@cebaf
• Steve King	Naval Research Lab	Code 4616 4555 Overlook Avenue S.W Washington, D.C. 20375	USA	202-767-5692	202-767-6908	KING1@CCF.NAVY.MIL (Internet)
Craig Woody	Brookhaven National Lab	Physics Dept. 510A 20 Pennsylvania Street Upton, NY 11973	USA	516-282-2752	516-282-5568	woody@bnldag
Mordechai Rothschild	MIT Lincoln Laboratory	244 Wood St. Lexington, MA 02173-9108	USA	617-981-7816	617-981-4983	
• Rob Sparrow	Optovac	North Brookfield, MA. 01535	USA	508-867-6444	508-867-8349	
• Paul Schotanus		G Gezellelaan 72 2624 KZ DELFT	The Netherlands	31-3406-69229 31-15-562860	31-3406-61471	schotanus@hutruu51
Andrew Drukier		7986 Lakecrest Drive Greenbelt, MD 20770	USA	301-864-0816 301-982-9808	301-864-0816	drukier@umdhcp
Michael Strathman	Charles Evans and Associates	301 Chesapeake Dr. Redwood City, CA 94063	USA	415-369-4567	415-369-7921	
Harvey Lynch	SLAC	2575 Sandhill Rd. Menlo Park, CA. 94025	USA	415-926-3671	415-926-2923	hll@slacvm

* Chairman + P. Lecoq, CERN

• → China
Dec 11-15, 1991

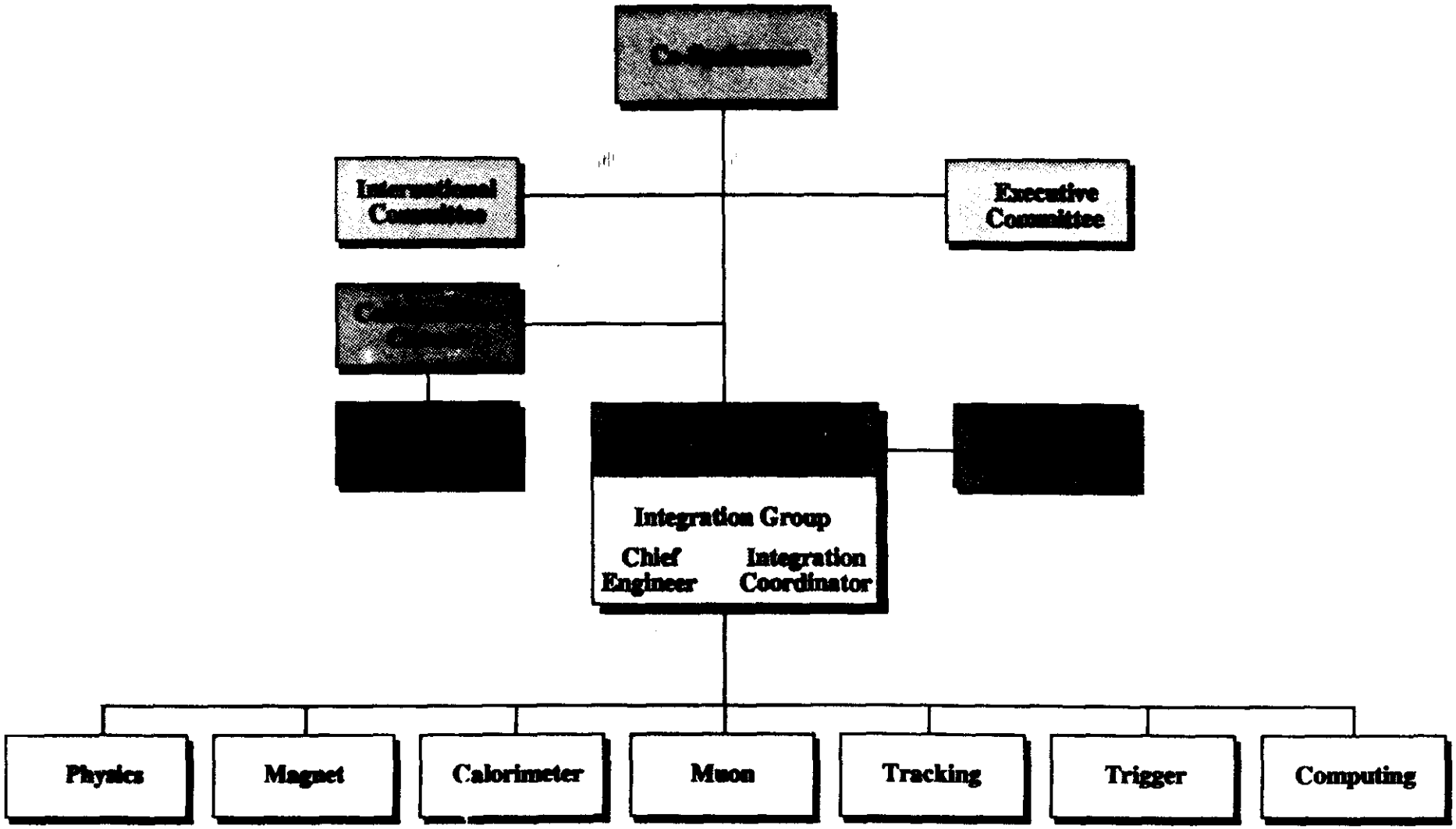
1/23/93

Computing 'Subsystem' Plans for TDR

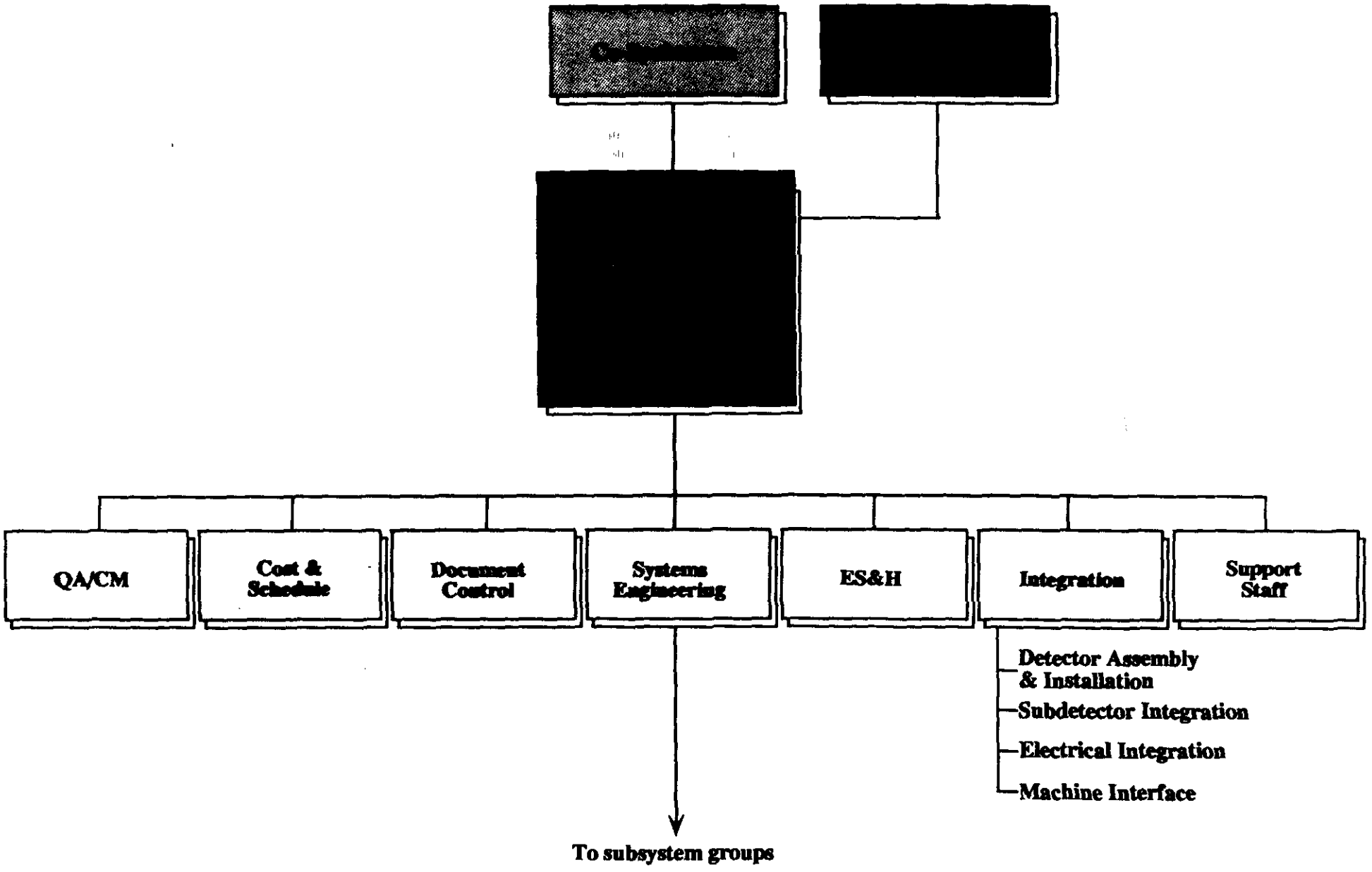
- Slow Control — SSCL (Accel. Div.)
- On Line (level 3) — E-Systems
- Offline
  - Physics simulations for TDR
    - Physics menu, subsystem parameterizations
    - GEMLIB
  - Software development — UTA
  - System architecture, costs — E-Systems, SSCL
- Storage
  - Architecture, costs — E-Systems, SSCL
- Communications — SSCL
- Software

NEED HELP ON TDR preparation

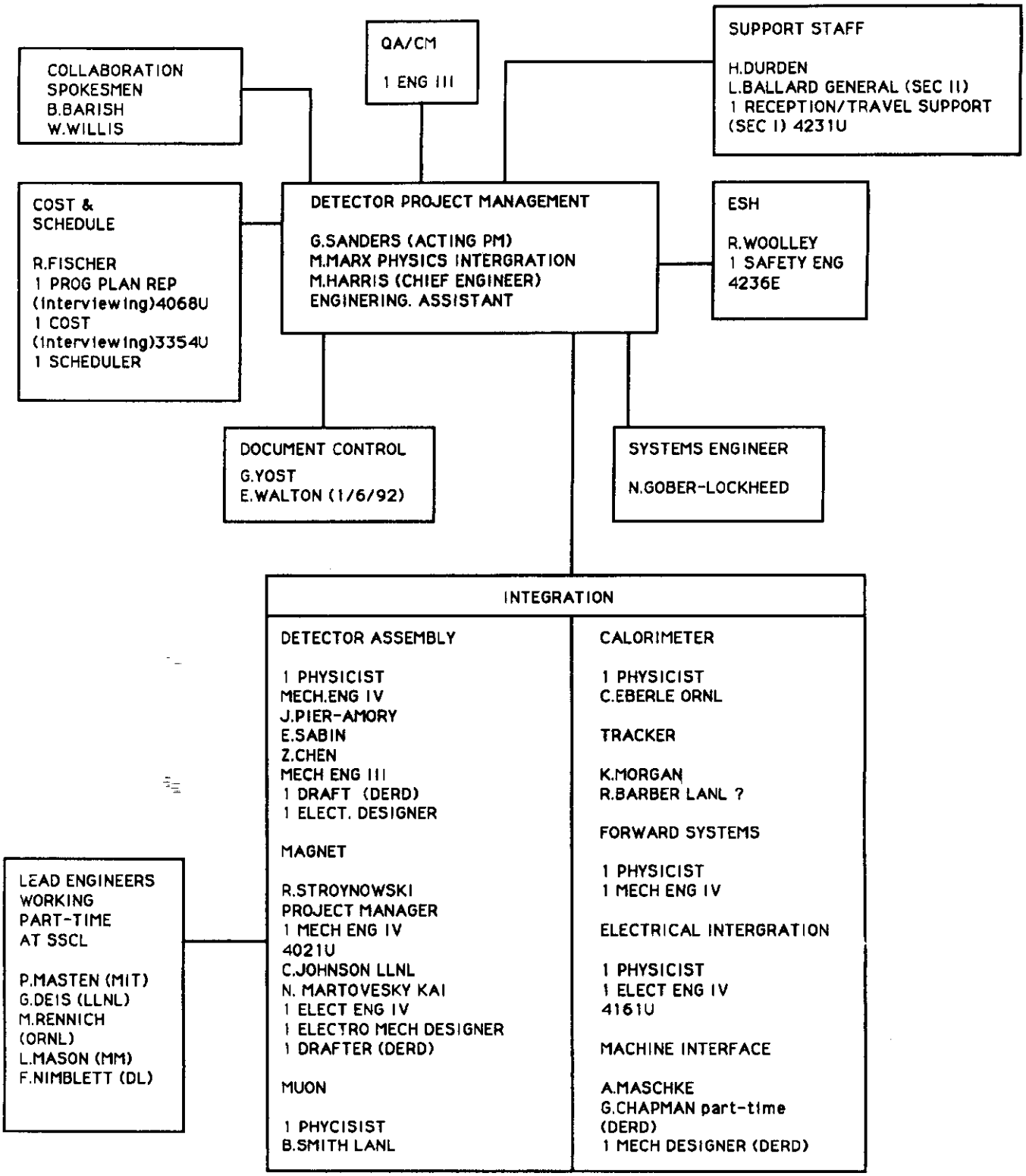
Steering committee ?


Executive Committee
Integration Group
Chief Engineer
Integration Coordinator
Physics
Magnet
Calorimeter
Muon
Tracking
Trigger
Computing

GEM Project Management



hd/1-8-92



PROPOSED GEM PROJECT MANAGEMENT FY 92

RECRUITMENT STATUS 1/21/92

M.H.

STAFFING

COST/SCHEDULE

Program Planning Manager Richard Fisher
Cost Analysts (x2) - offer out on 1, interviewing
Scheduler - interviewing
others...

DOCUMENT CONTROL

Ed Walton (G. Yost physicist guidance)

SYSTEMS ENGINEERING

Norm Gober

ES&H

R. Woolley
Safety Engineer - interviewing

SUPPORT STAFF

Admin. Assistant to PM - H. Durden
Secretary II - L. Ballard
Secretary I (travel/reception) - requisition
others...

STAFFING (continued)

INTEGRATION

Detector Assembly/Installation - Sabin, Chen
Subsystems
Electrical Integration - N. Lau (LLNL)
Machine Interface

TASK FORCES

MUON SUBSYSTEM REVIEW

TRACKER SUBSYSTEM REVIEW

R&D TASK FORCE

TEST & CALIBRATION BEAMS

MUON SUBSYSTEM REVIEW

FORMAL CHARGE

WRITTEN REPORT TO SPOKESMEN, PM, SUBGROUP LEADERSHIP

PANEL Branson - chair
Webb
Rennich

ATTENDED BY WILLIS, SANDERS

SCHEDULED FEBRUARY 5 IN BOSTON

TRACKER SUBSYSTEM REVIEW - Feb. 25

SAME FORMAL CHARGE

WRITTEN REPORT TO SPOKESMEN, PM, SUBGROUP LEADERSHIP

PANEL Rutherfoord - chair
R. Morrison (non-GEM)
A. Weinstein (non-GEM)
Nimblett
Mitselmakher

ATTENDED BY BARISH, WILLIS, SANDERS

R&D TASK FORCE

Reports to PM
Long-term planning
Receive internal proposals, review proposals
Monitor Statements of Work/Monthly Progress Reports
Communicate with subgroups
Prepare unified GEM proposal for GEM review

R. Webb - chair
+ 2 physicists
+ 1 SSCL-located engineer
+ SSCL Program Planner

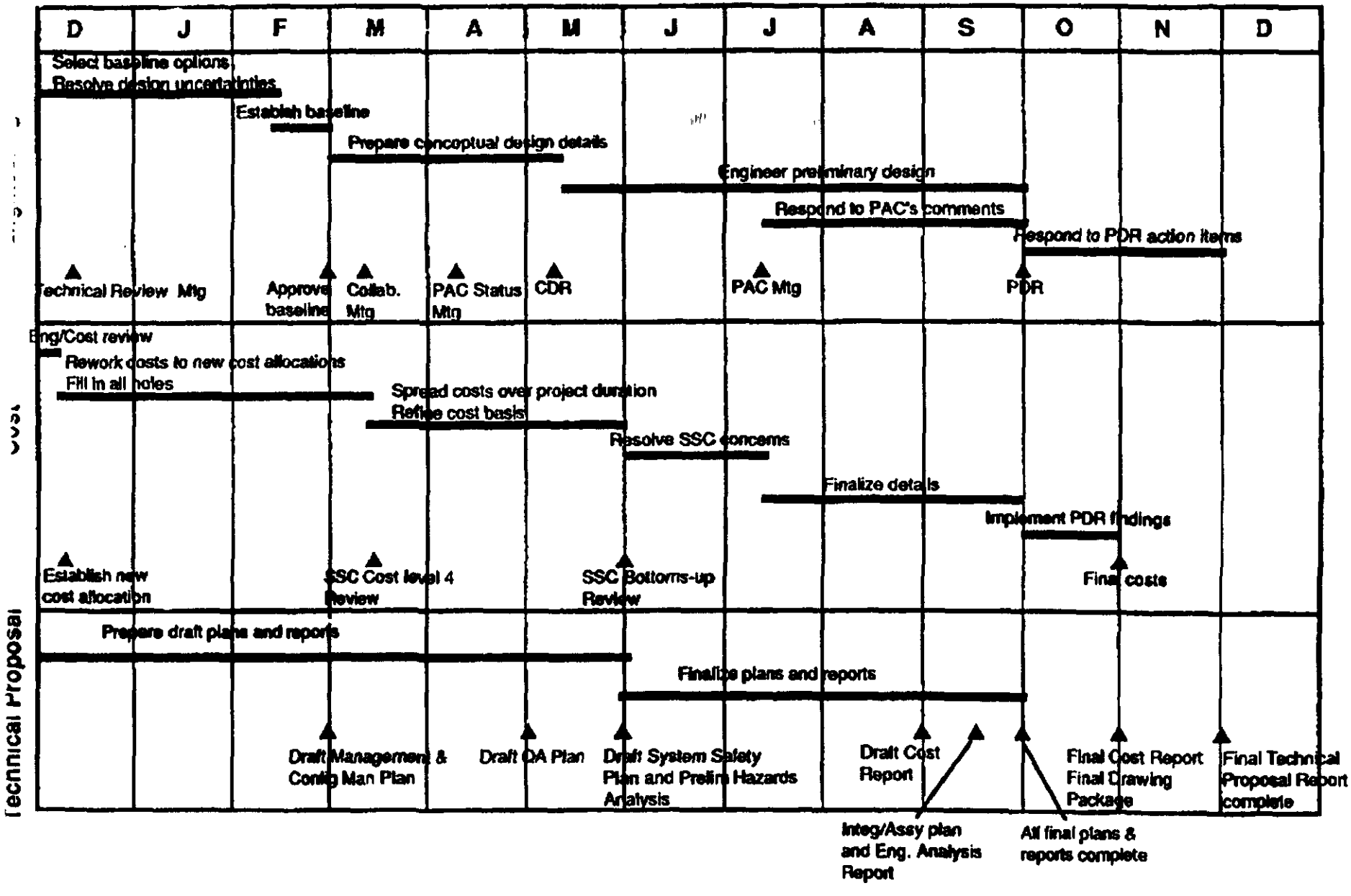
TEST AND CALIBRATION BEAM TASK FORCE

Report to PM
Near-term Test Beam plan due Tucson for FY92-94
Longer-term receipt/review of internal GEM proposals
Provide control/uniform communication to other labs
The "face" of GEM to base HEP researchers

G. Yost - chair

P. Denes, CERN
, BNL
H. Kobrak, FNAL

Proposed GEM CY 92 Engineering/cost schedule



TECHNICAL PROPOSAL ORGANIZATION

VOLUME	CONTENTS	PAGES
1	Executive Summary, overview, physics goals, specifications	50
2	Magnet Preliminary. Design Report	50
3	Muon System Conceptual Design Report	50
4	Calorimeters Conc. Design Report	50
5	Tracker Conceptual Design Report	50
6	Data Acquisition/Trigger CDR	50
7	Computing/Analysis/Simulation/ Control/Communication CDR	25
8	Physics Performance/Simulations	50
9	Integration/Assembly/Installation Plan	50
10	Cost Estimate/Responsibility Matrix/ Funding Plan	100
11	GEM Project Management Plan	25

TECHNICAL PROPOSAL ORGANIZATION
(continued)

VOLUME	CONTENTS	PAGES
1 2	Preliminary Safety Analysis Report/ES&H	2 5
1 3	Draft GEM Acquisition and Assistance Plan	2 5
1 4	Operational Plan/Upgrades	2 5
1 5	R&D/Engineering Plan	5 0
1 6	GEM Experimental Facilities User Requirements (GEFUR)	1 0 0
	TOTAL PAGES	7 7 5

1992 MILESTONES FOR TECHNICAL PROPOSAL

JANUARY	Establish TP requirements, organization Organize GEM project
FEBRUARY	Draft GEM baseline Magnet procurement plan
MARCH	Establish GEM baseline definition Draft GEM baseline CDR Draft test/calibration beam report Establish magnet baseline
APRIL	GEM Cost Estimate Report for review
MAY	Cost Review
JUNE	GEM report to PAC
JULY	PAC review of GEM Technical review of magnet by PAC
AUGUST	
SEPTEMBER	DOE review of magnet Draft Technical Proposal

OCTOBER

NOVEMBER Technical Proposal

SubSystem Issues

1) Fix boundaries

- LAr Cal depth vs $\frac{dp_\nu}{p_\nu}$, Punchthru

  Im Forward?

  $\eta = 0$

- Pre Radiator?

2) Muon/Magnet Parameters

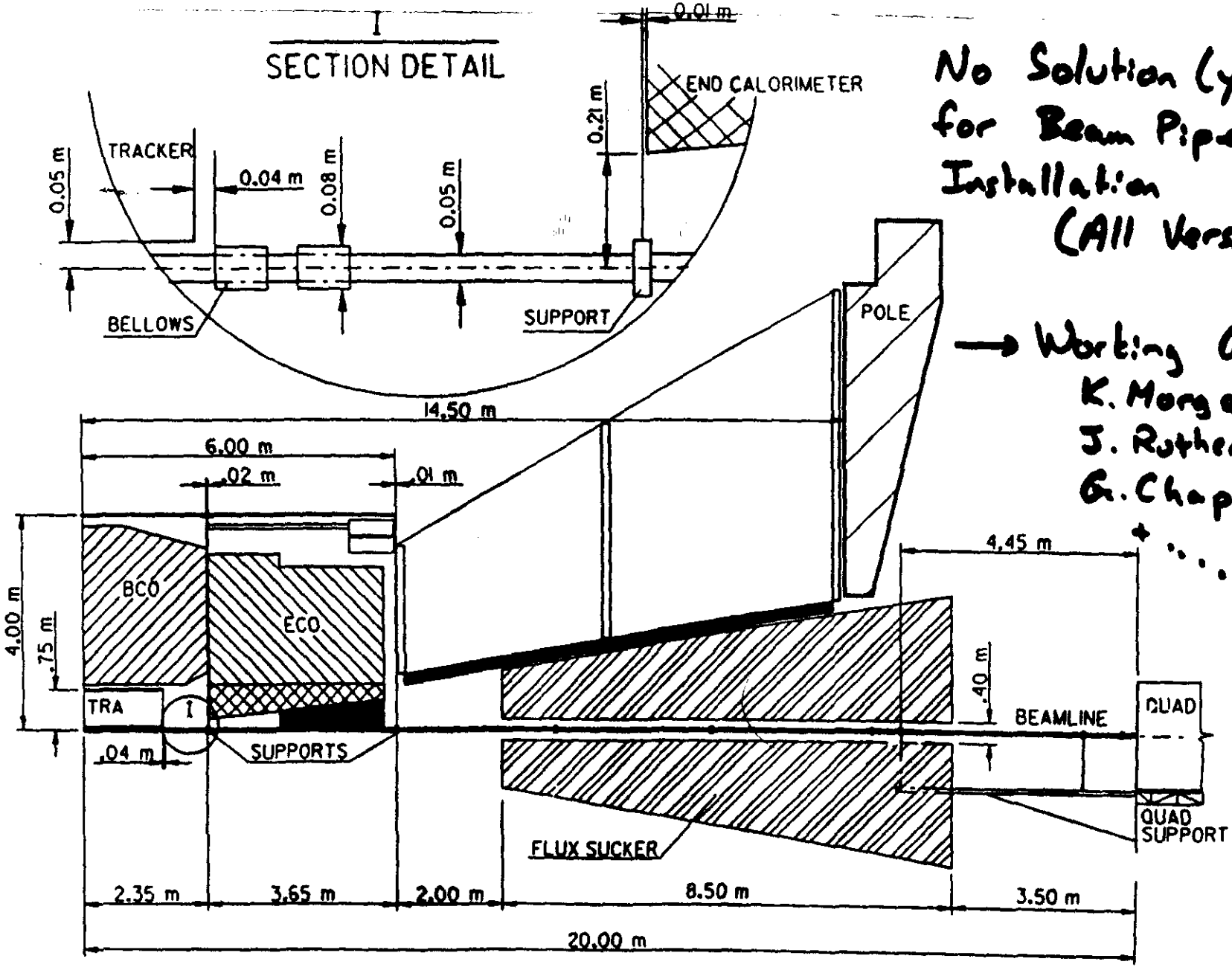
   B, L, R

   Fine Tune Flux Sucker/Coils

3) Sign off on limited access

4) Forward Calorimeter
   - Beam Pipe
   - Alignment

5) Define all Utilities + Services



No Solution (yet) for Beam Pipe Installation (All Versions)

→ Working Group
K. Morgan
J. Rutherfoord
G. Chapman
+ ...

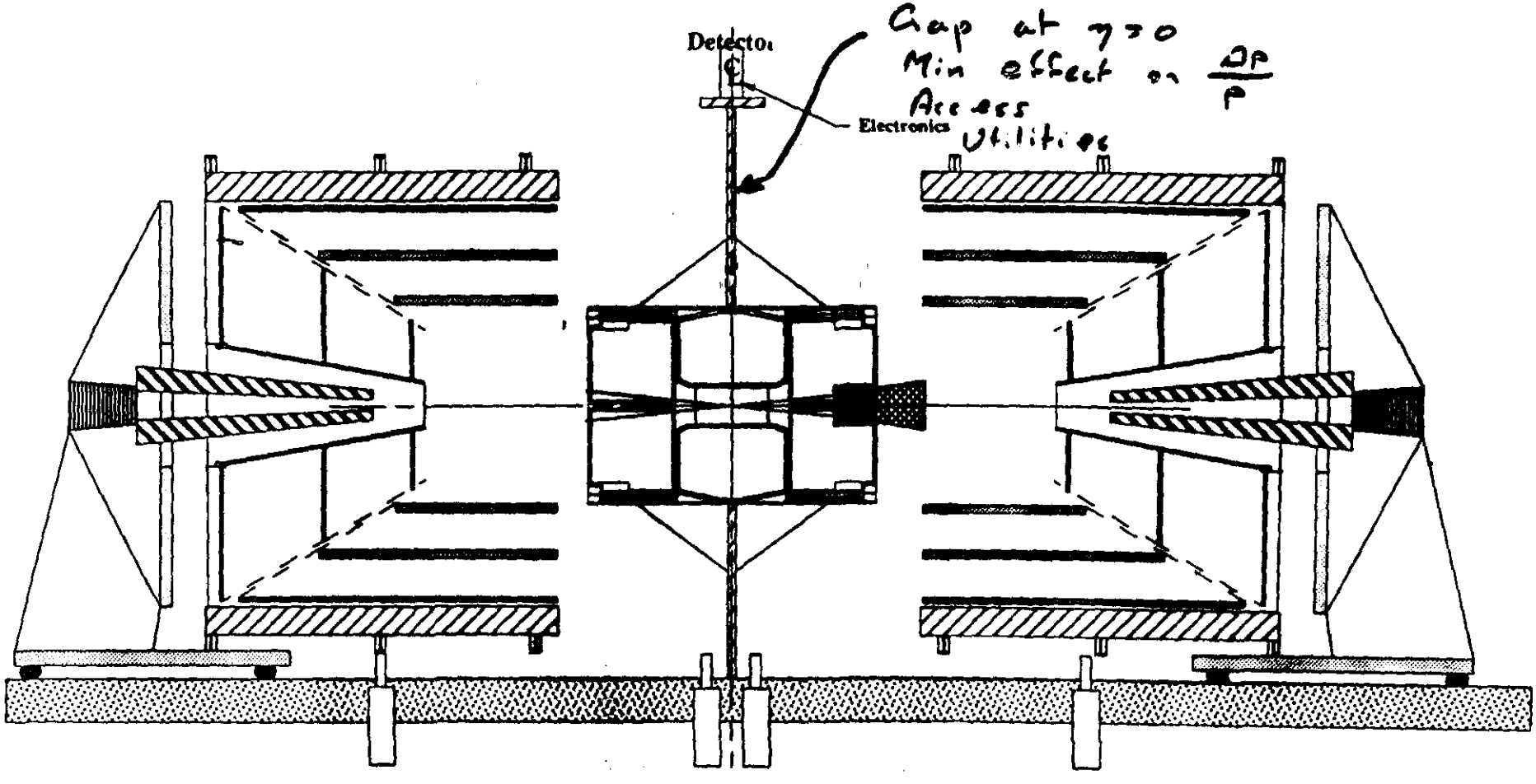
GEM DETECTOR
BEAMLINE AND SUPPORT

IR Workshop 2/17

GEM Installation Schedule Considerations

	Calorimeter Configuration														
Hall Configuration	**Integrated**			**Split**			**Half Coil**			**Fixed Coils**			**Cones**		
Long Hall/One Shaft	*			*			*			*			*		
Long Hall/Two Shaft		*			*			*			*			*	
Short Hall/Two Shaft			*			*			*			*			*
Installation Scenario															
Tracker Accessibility	X	X	X	X	X	X	X	X	X	O	O	O	X	X	X
Late Calorimeter Installation	X	X	X	X	X	X	O	O	O	O	O	O	O	O	O
Late Muon Installation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Late Magnet Installation	O	X	X	O	O	O	O	O	O	O	O	O	O	O	O
Muon/Calorimeter Together	X	X	O	O	O	O	O	O	O	O	O	O	O	O	O
Simulaneous Shake-Down	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O

Note: Short hall assumes the Flux Sucker will be removable
Note: Short hall assumes Muon End Caps supported inside Magnet volume

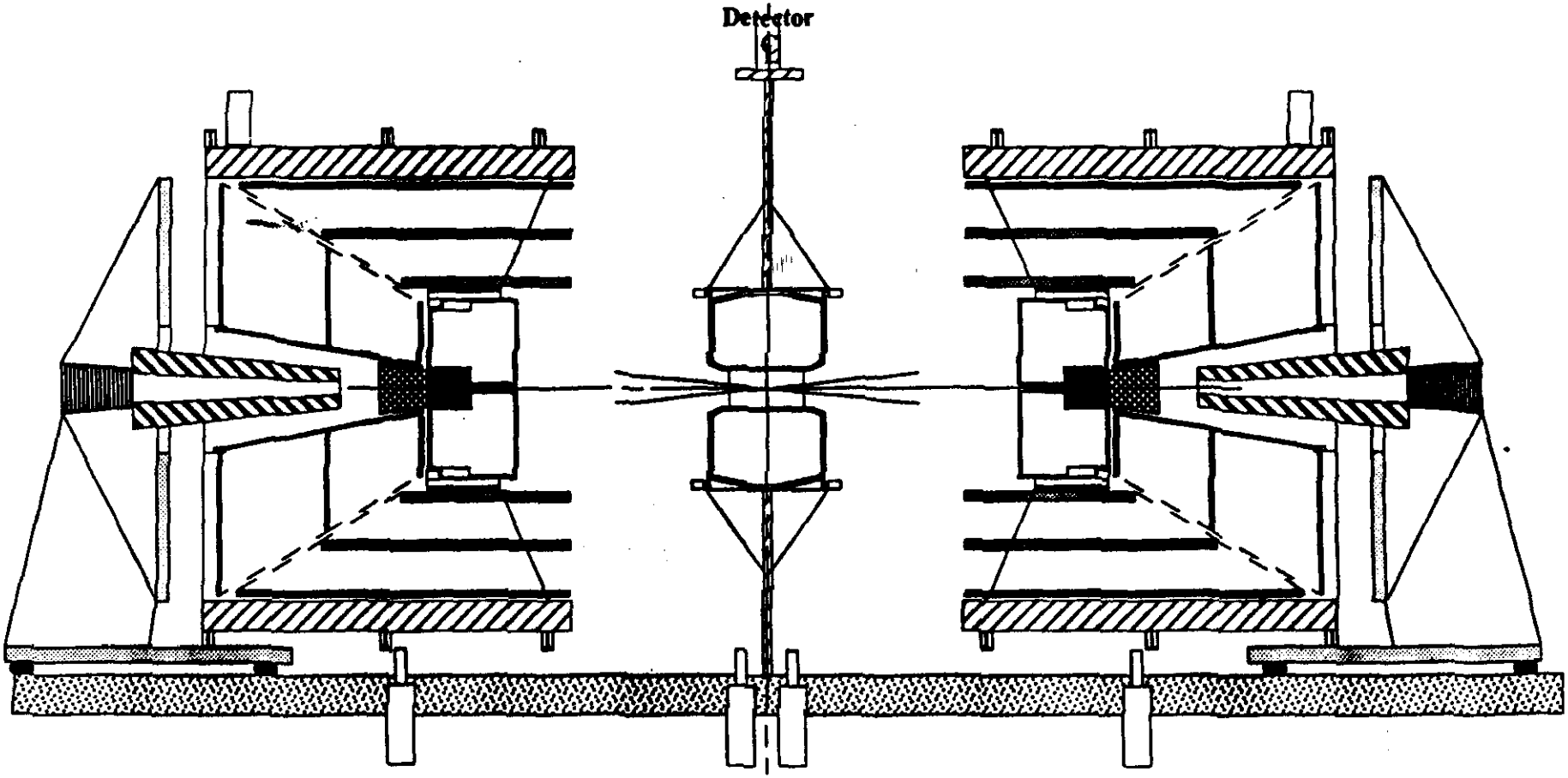


Decouples Cal + Tracker
Simplify Muon/Magnet
Cal Utilities } Access
Supports

GEM Configuration Option Study
Liquid Argon Calorimeter
Integral Calorimeter Version

G.03.AS.0003

LE/BENNICH

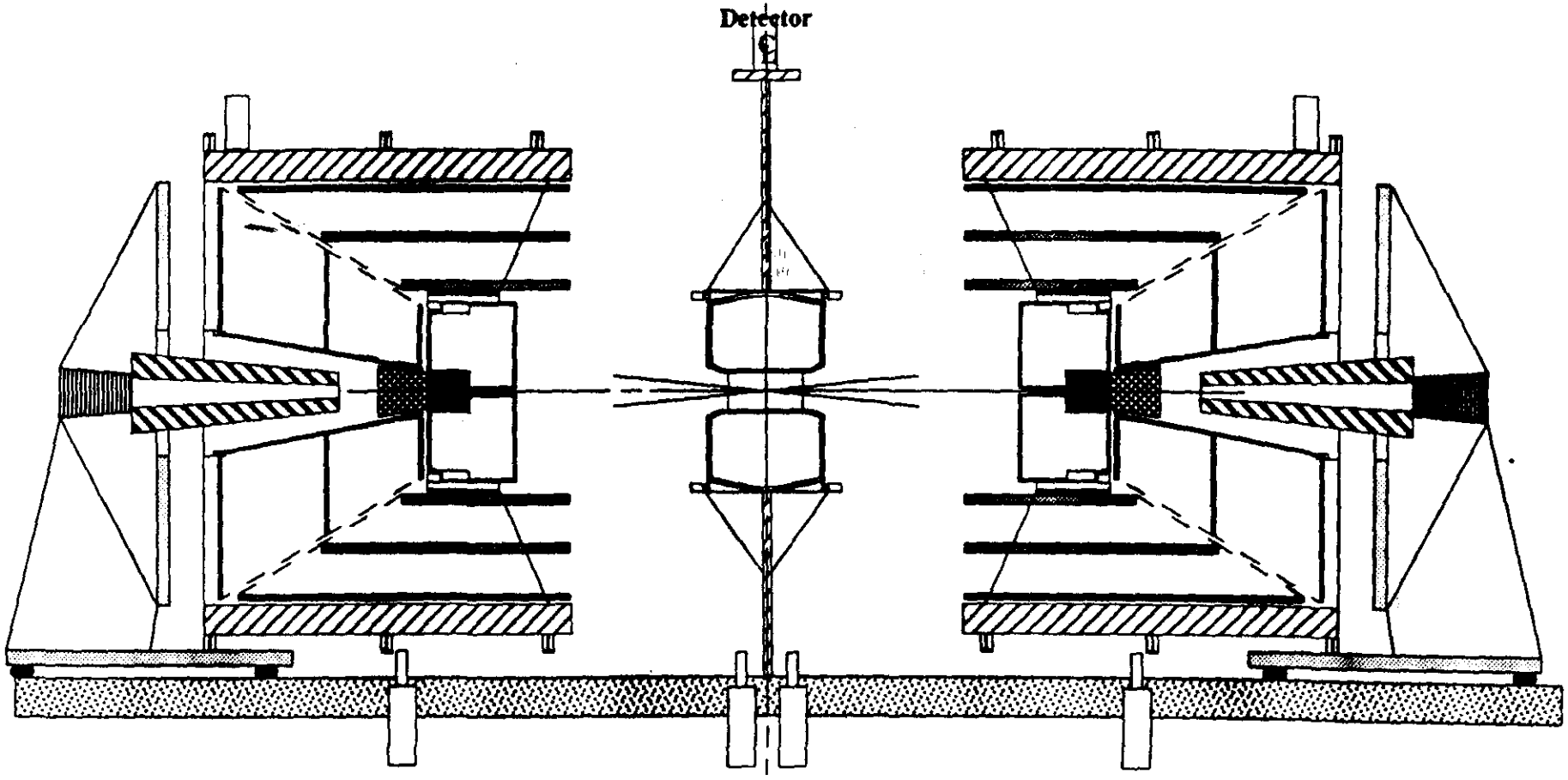


Simplify Cal Utilities
Simplify Cal/Track Access
Complicate Magnet
Muon

GEM Configuration Option Study
Liquid Argon Calorimeter
Split Calorimeter Version

G.03.AS.0005

EBERLE/RENNICH

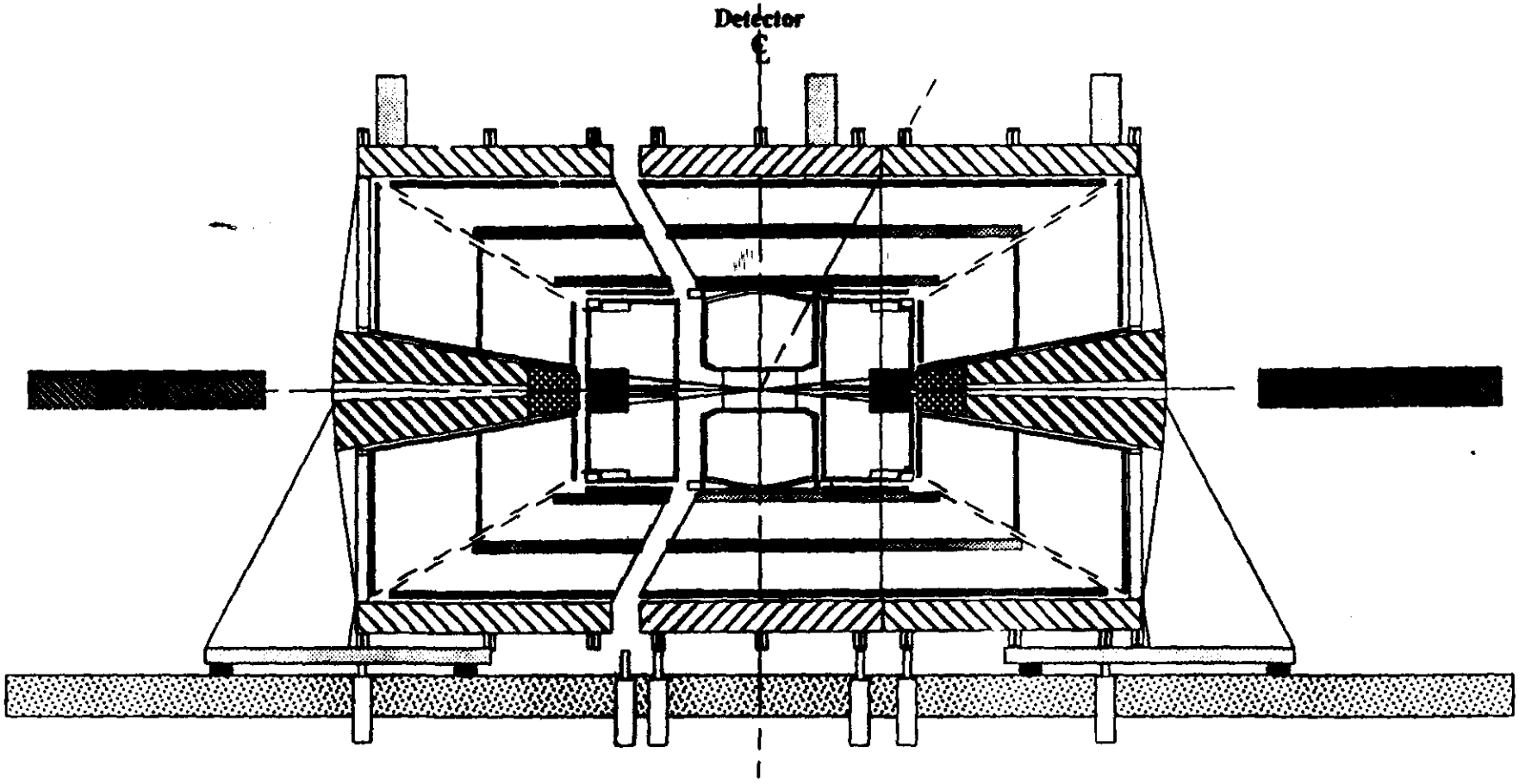


Simplify Cal Utilities
Simplify Cal/Track Access
Complicate Magnet
Muon

GEM Configuration Option Study
Liquid Argon Calorimeter
Split Calorimeter Version

G.03.AS.0005

EBERLE/RENNICH



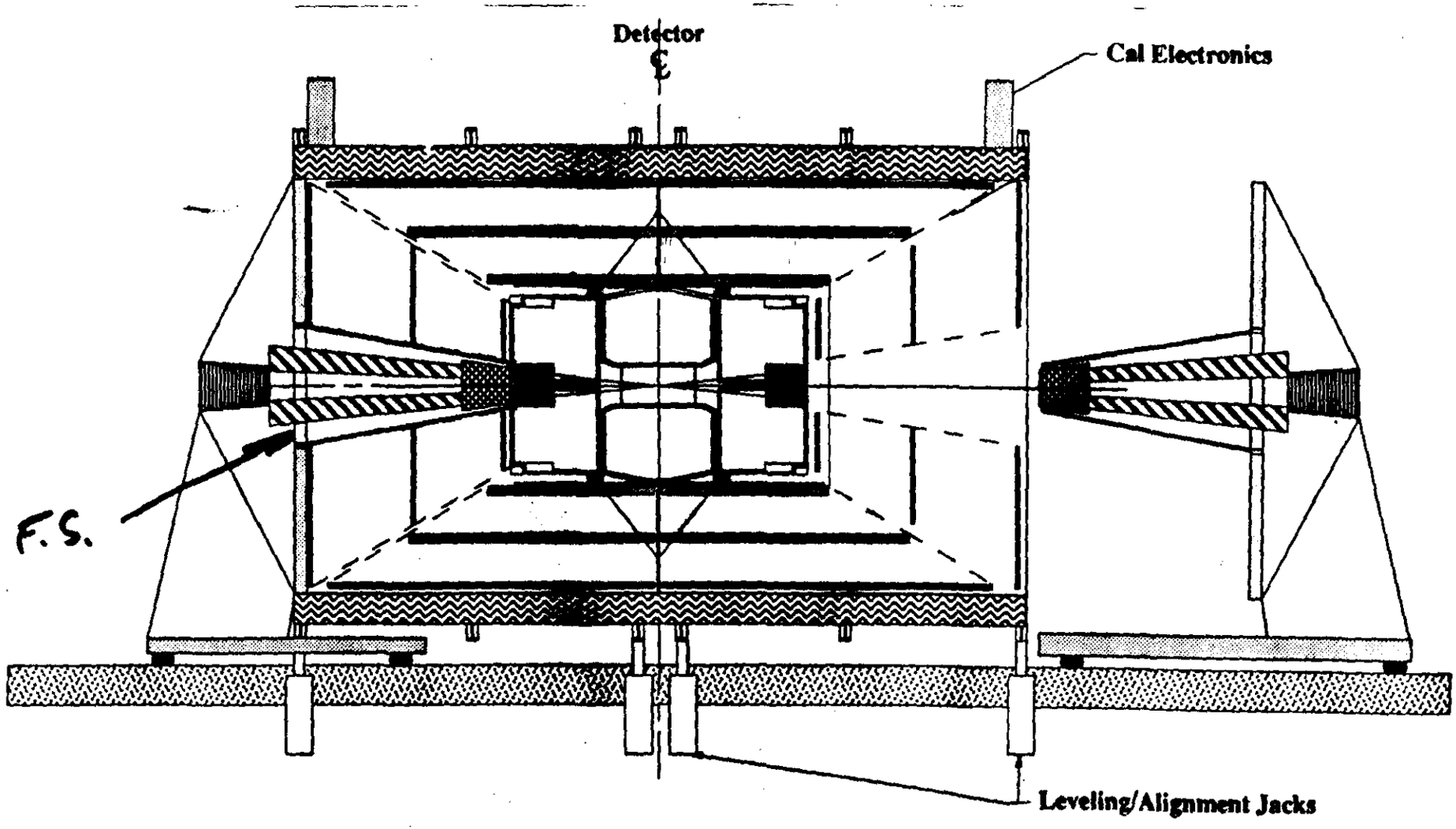
"Fast" Access 1m

GEM Configuration Option Study
Liquid Argon Calorimeter
Three Coil Version

3 Coils
4 Muon Modules /Barrel

G.03.AS.0006

EBERLE/RENNICH



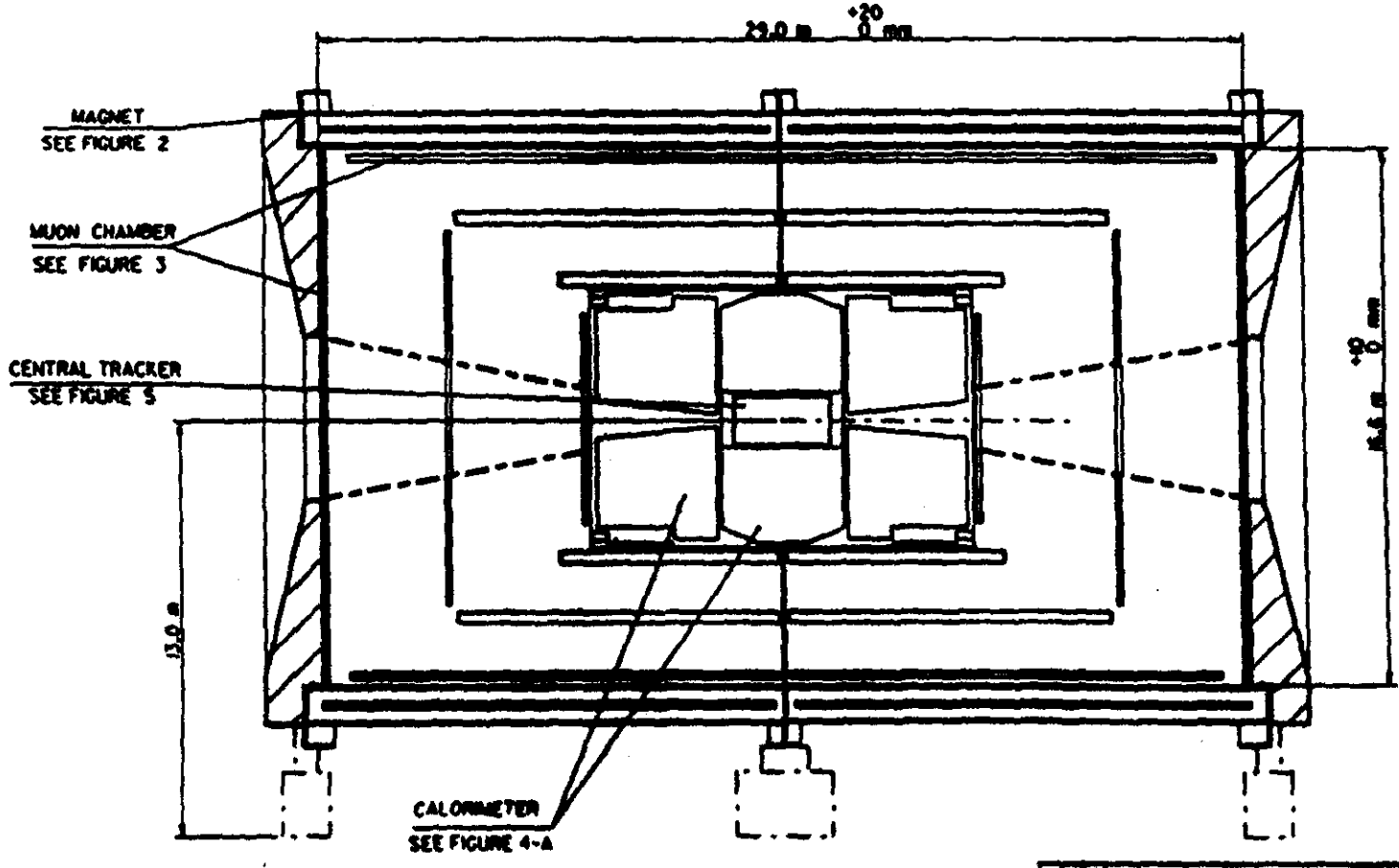
GEM Configuration Option Study
Liquid Argon Calorimeter
Fixed Coil Version

Requires RR to install Cal/Track

G.03.AS.00014

EBERLE/RENNICH

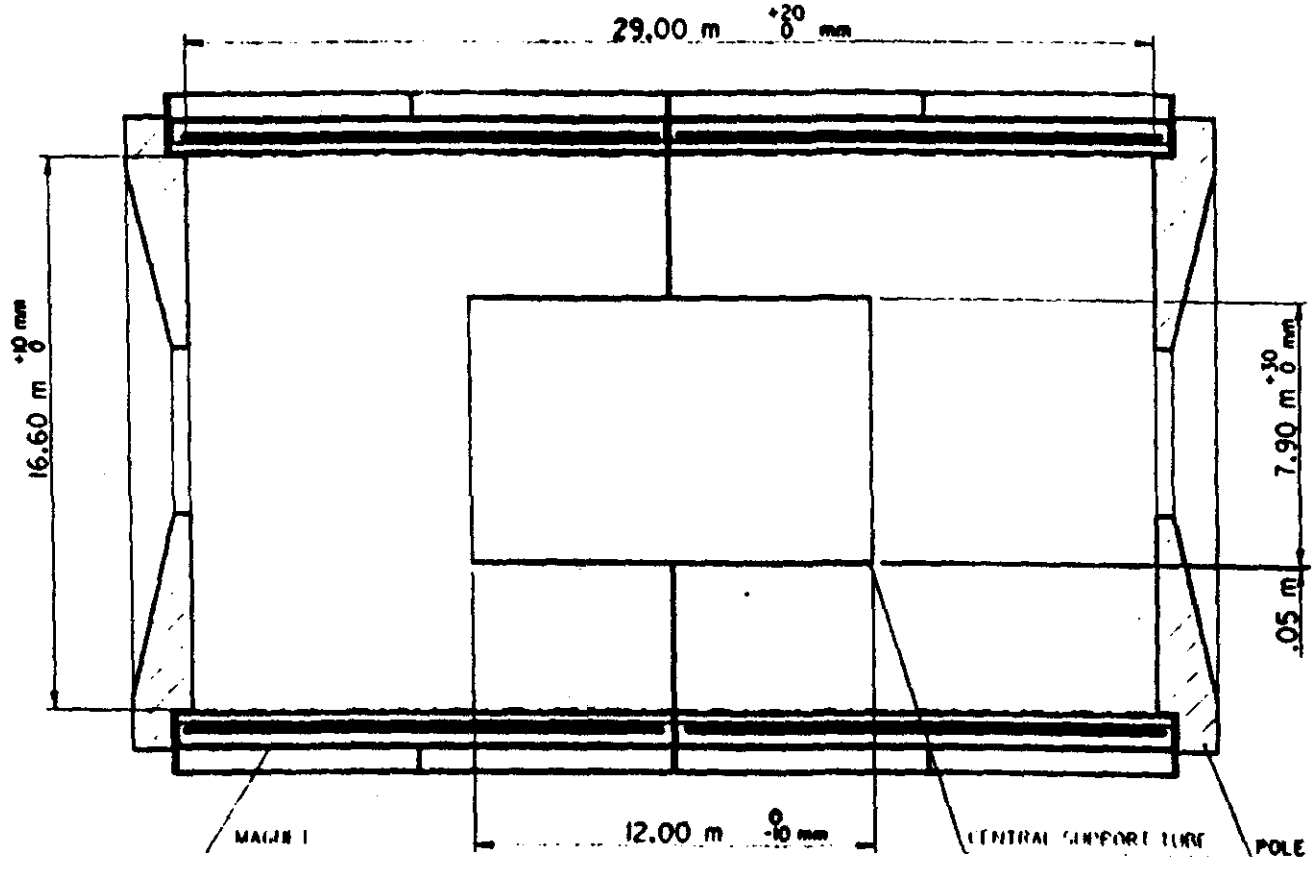
FIGURE 1



SSC

GEM DETECTOR
LAYOUT PARAMETERS

FIGURE 2



SSC
GEM DETECTOR
MAGNET INSIDE VOLUME
PARAMETERS

FIGURE 3

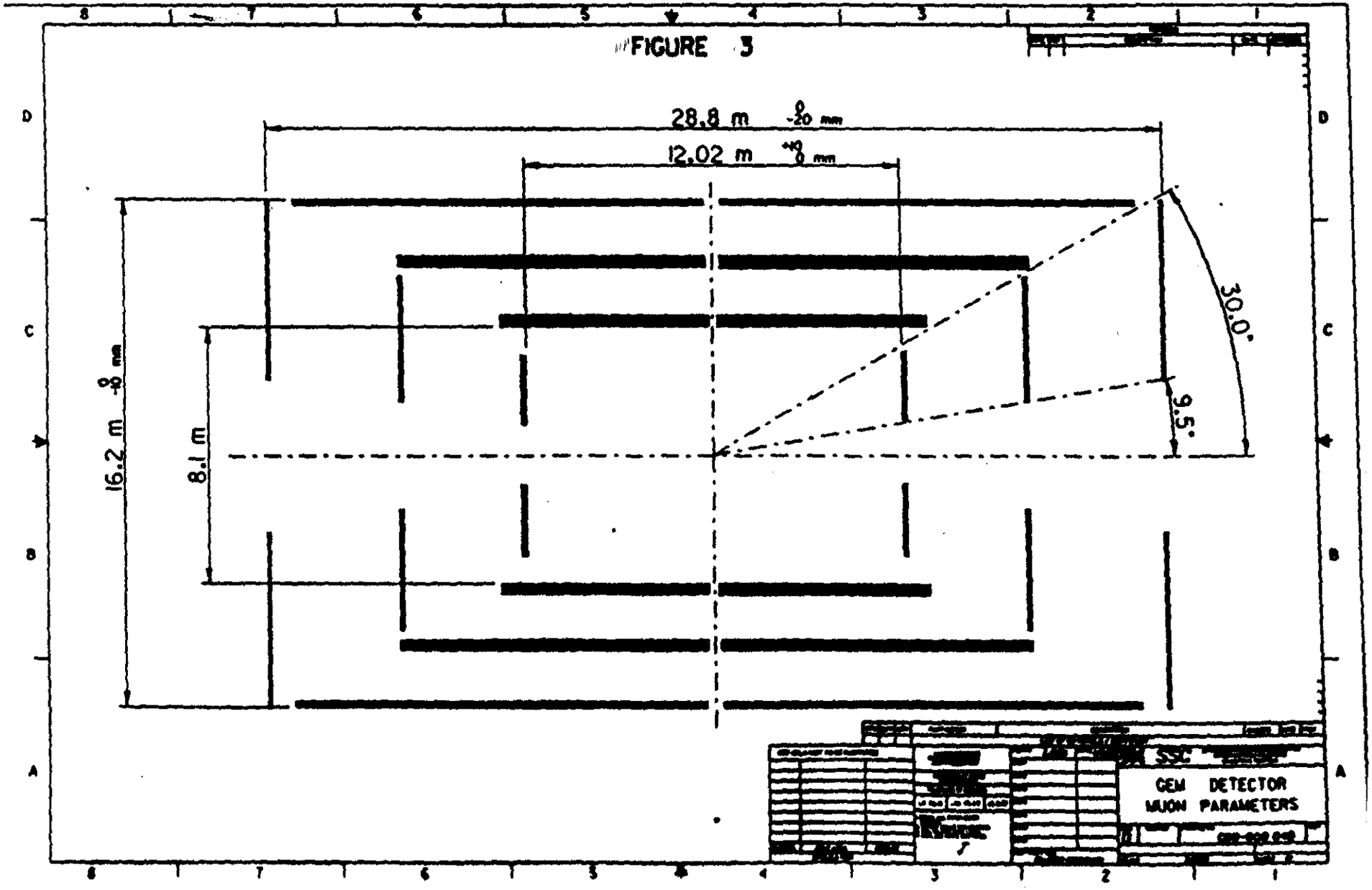


FIGURE 4 - A

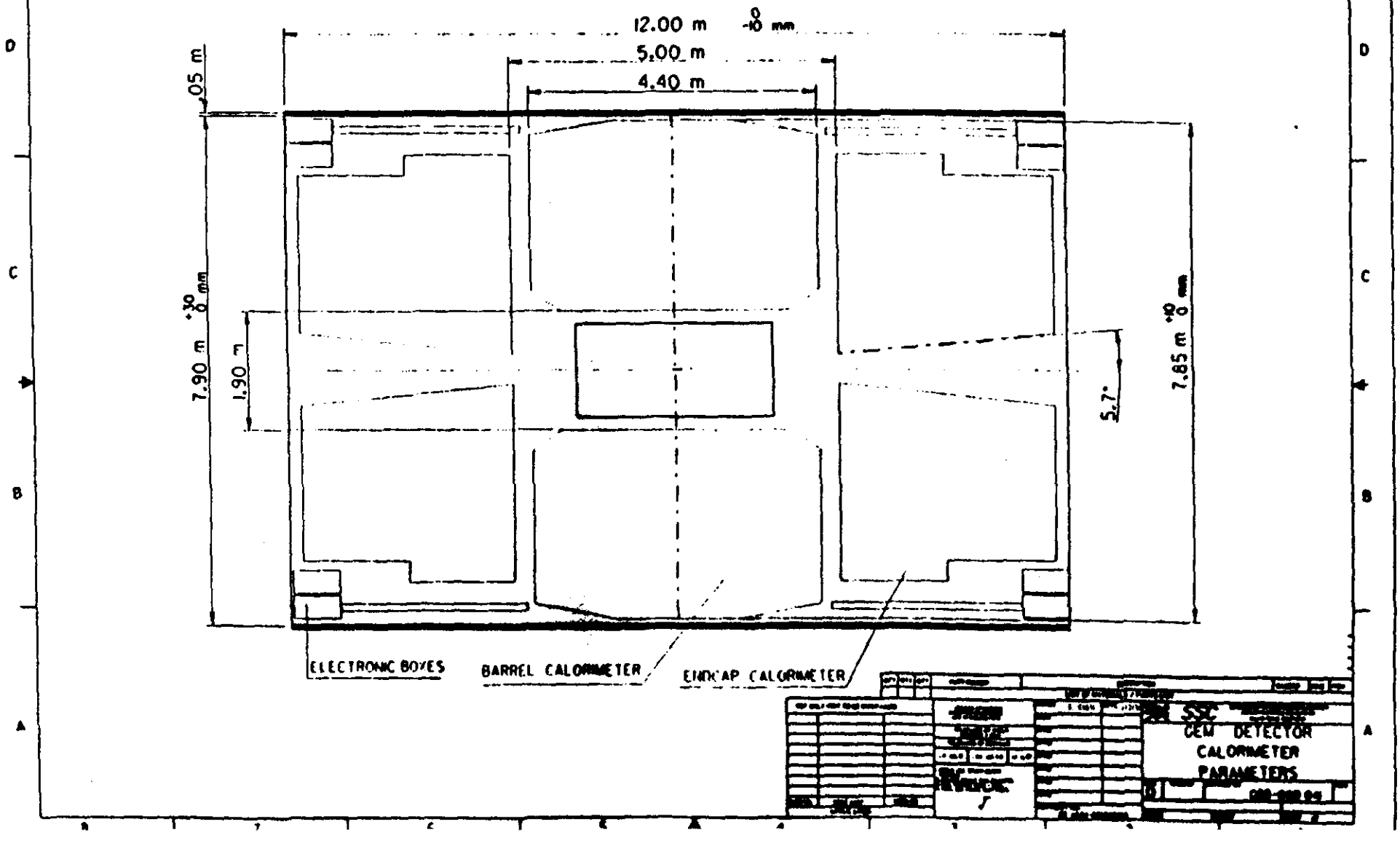
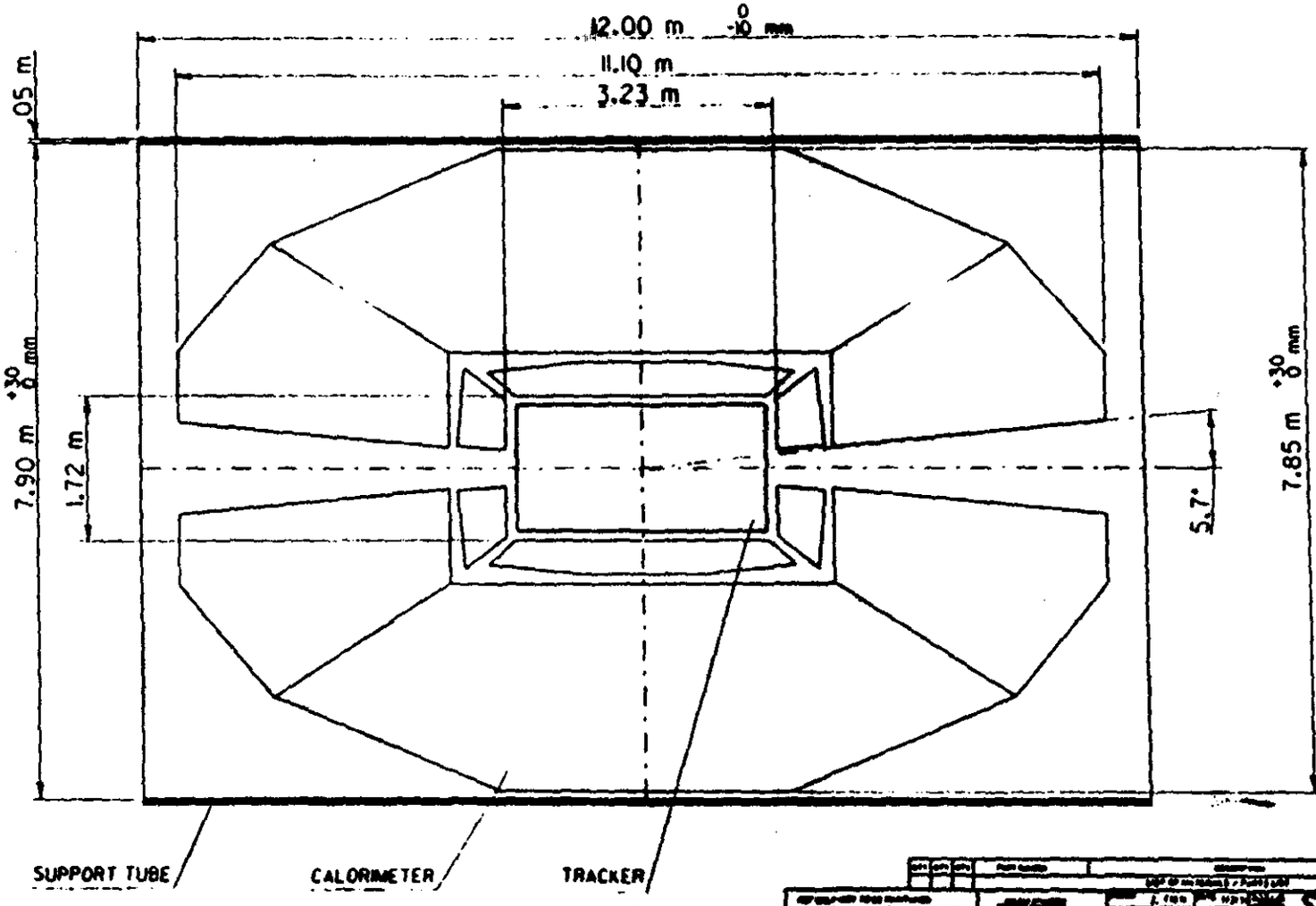

12.00 m
5.00 m
4.40 m
.05 m
7.90 m
1.90 m
5.7°
7.85 m
ELECTRONIC BOXES
BARREL CALORIMETER
ENDCAP CALORIMETER
SSC
GEM DETECTOR
CALORIMETER
PARAMETERS

FIGURE 4 - B

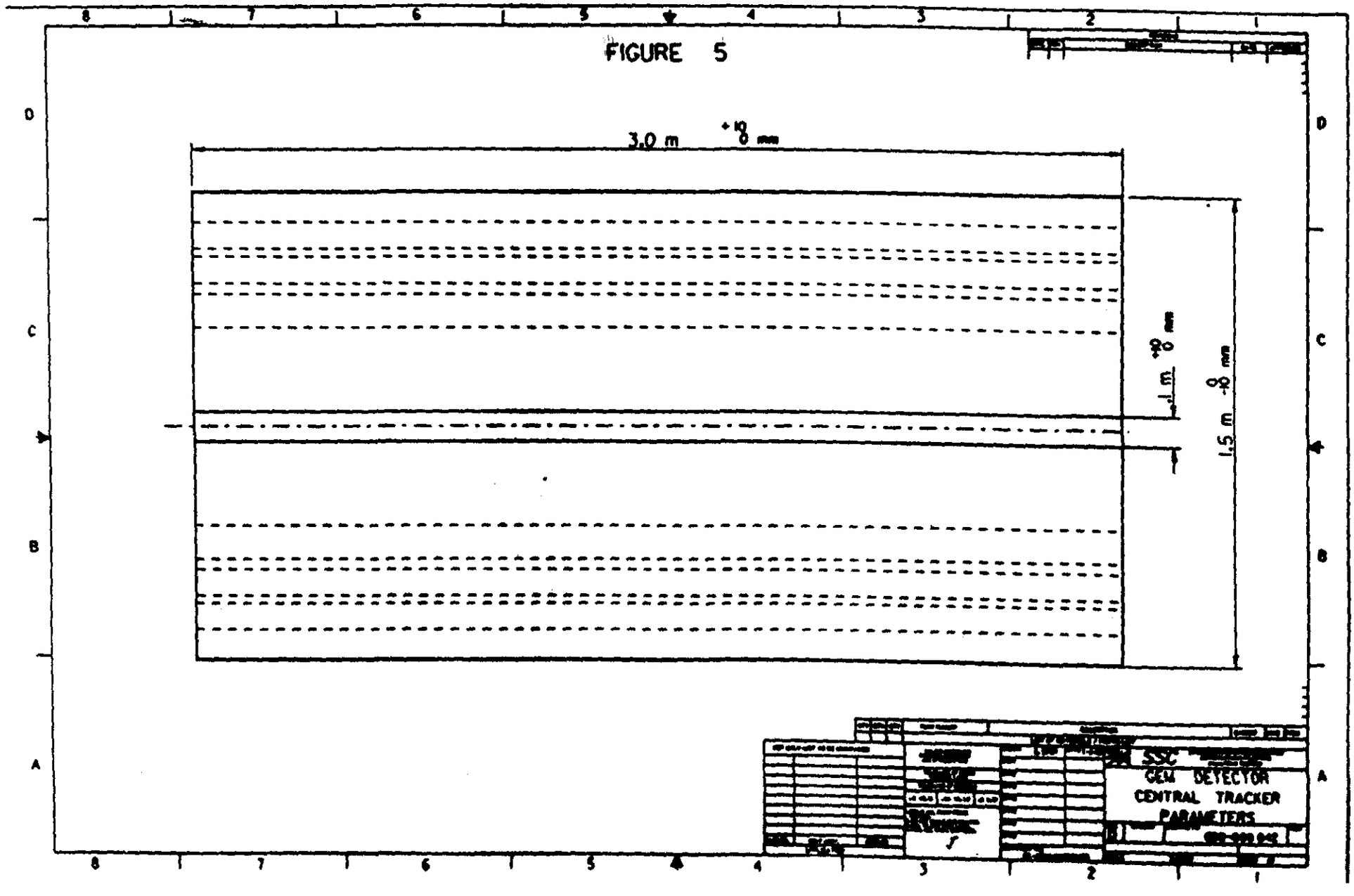


SSC

GEM DETECTOR
CALORIMETER
PARAMETERS

600-000 04

FIGURE 5


3.0 m +10 0 mm
1 m +10 0 mm
1.5 m -0 0 mm
SSC
GEM DETECTOR
CENTRAL TRACKER
PARAMETERS

1/23/92
M. MARX

DETECTOR INTEGRATION

GOAL -

SET DETECTOR BASELINE IN TUCSON TO DEVELOP NOV TDR

1) SET SUBSYSTEM BOUNDARIES

2) SET ASSEMBLY SEQUENCE
   - HALL PARAMETERS
   - ACCESS

3) RESOLVE OPEN ISSUES
   - FORWARD B SHAPE
   - FORWARD CALORIMETRY
   - BEAM PIPE

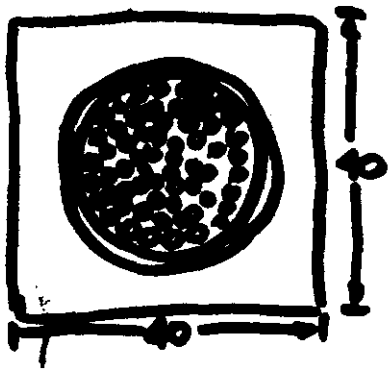
R. STROYNOWSKI
SMU

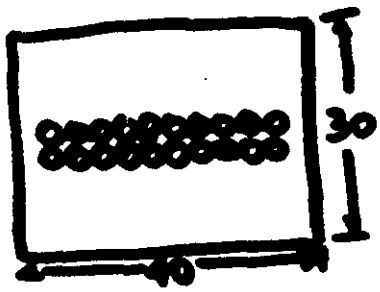
MAGNET - Progress Report

WORK CONCENTRATED ON

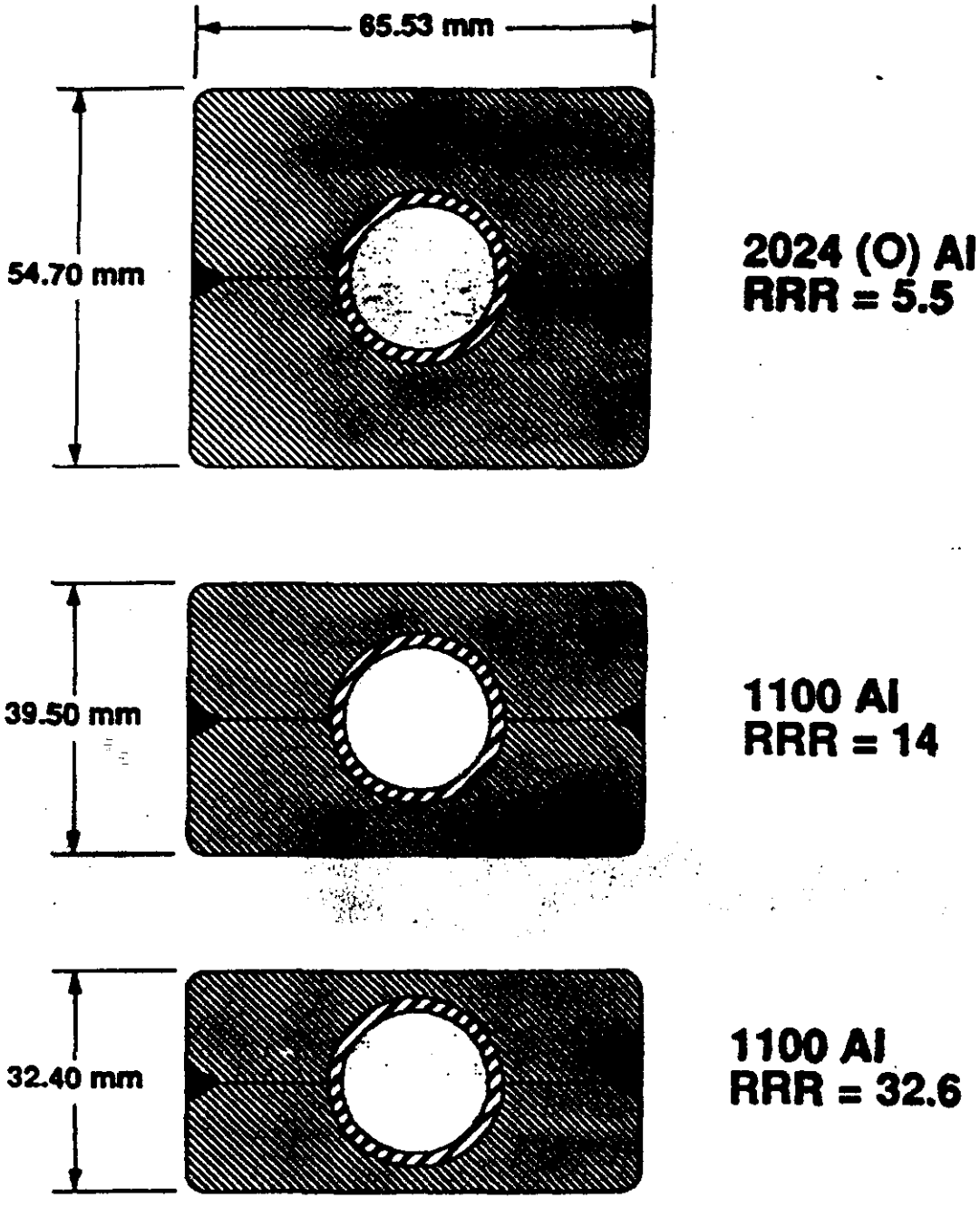
CONDUCTOR DEVELOPMENT
OPTIMIZATION + INTEGRATION

- CONDUCTOR DEVELOPMENT
  WORKSHOP: December 4-5, January 14-15, March 23-24
  TWO MAIN OPTIONS SELECTED:
  DIRECT COOLED CABLE-IN-CONDUIT (MIT
  INDIRECTLY COOLED (RUTHERFORD LAB + FNM





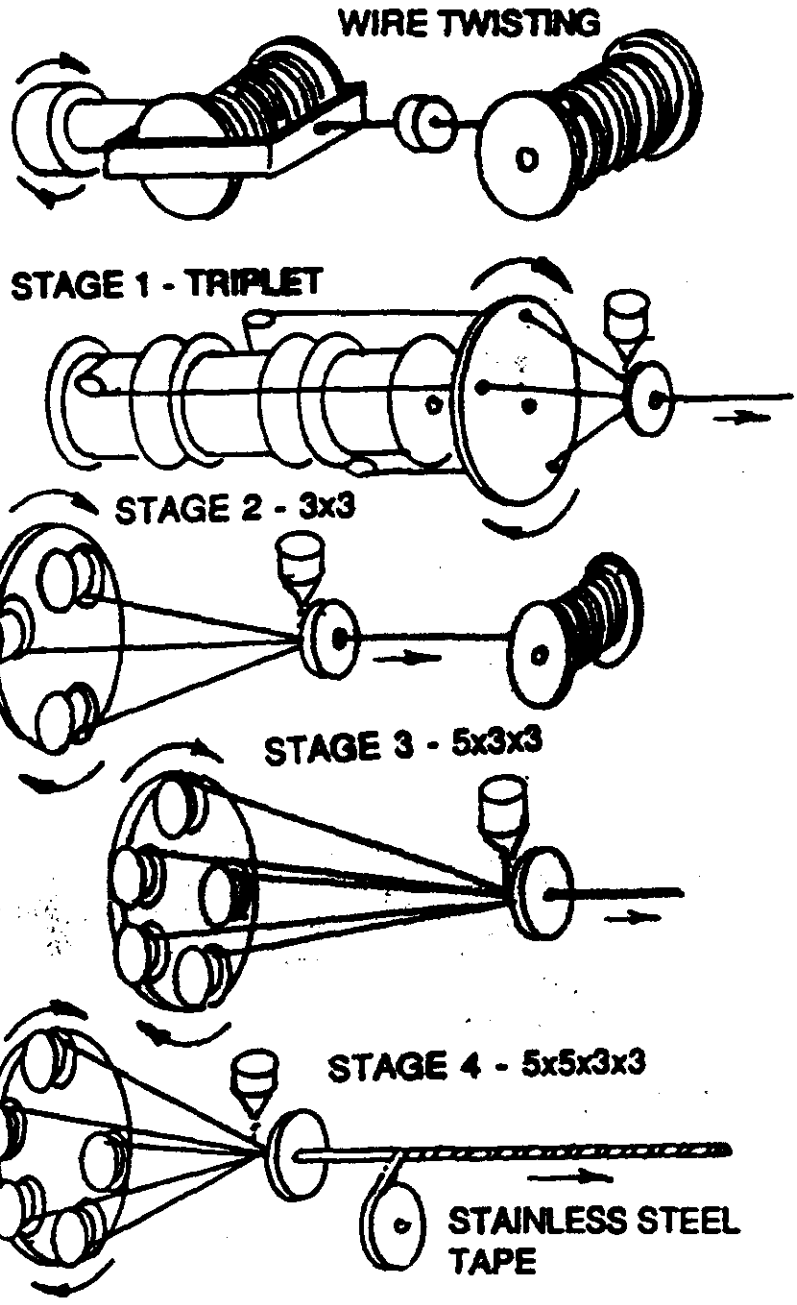
STUDIES INCLUDE: STABILITY, PERFORMANCE, COST
DEPENDENCE ON MATERIALS etc.
MANUFACTURING PROCESS


65.53 mm
54.70 mm
2024 (O) Al
RRR = 5.5
39.50 mm
1100 Al
RRR = 14
32.40 mm
1100 Al
RRR = 32.6

CABLE-IN-CONDUIT : CABLE MANUFACTURING

SEM

US-DPC example



3 $\xrightarrow{1st}$

X

5 $\xrightarrow{2nd}$

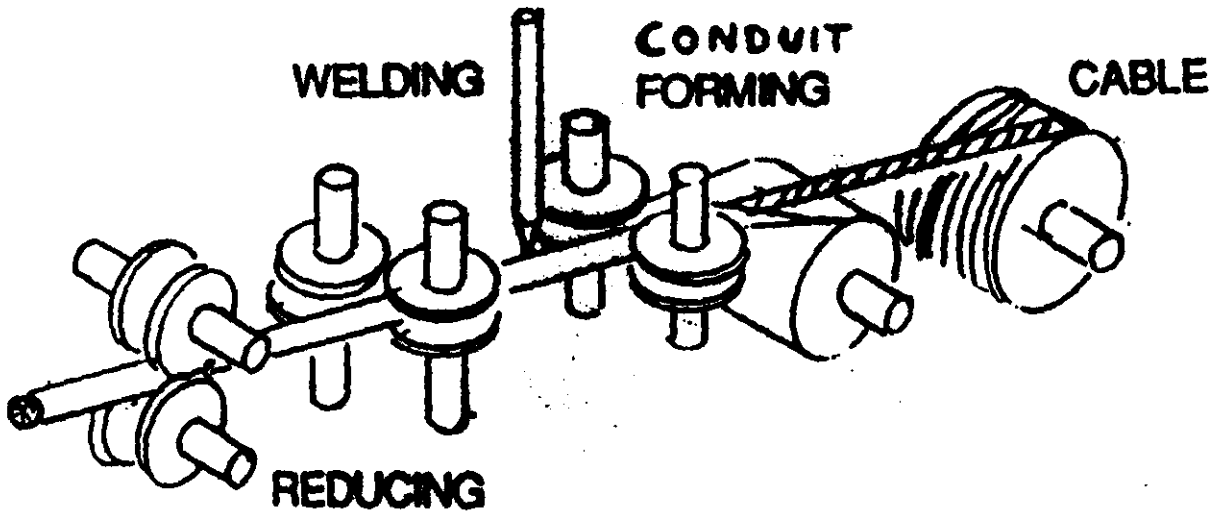
X

5 $\xrightarrow{3rd}$

X

6 $\xrightarrow{4th}$

CABLE-IN-CONDUIT



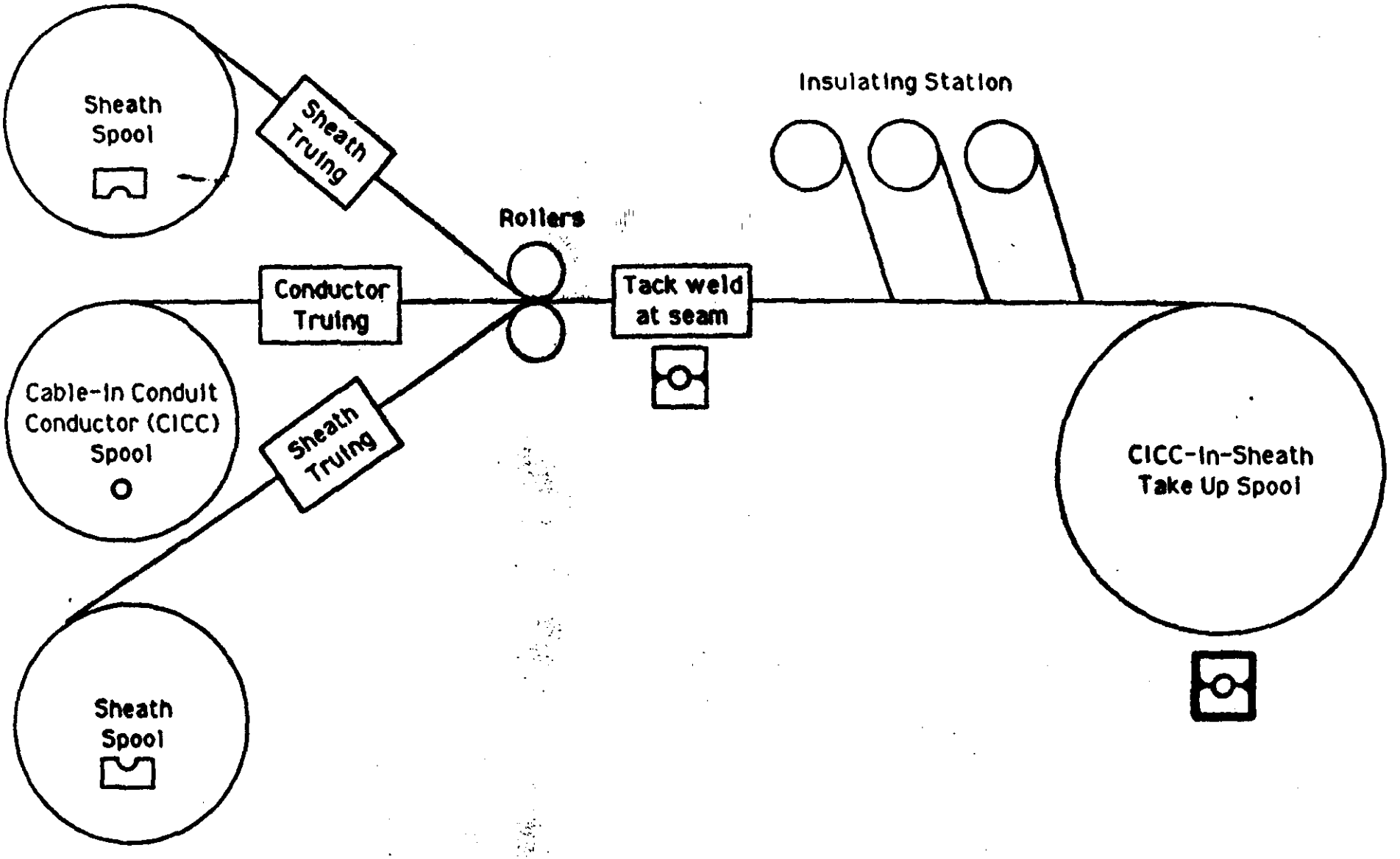
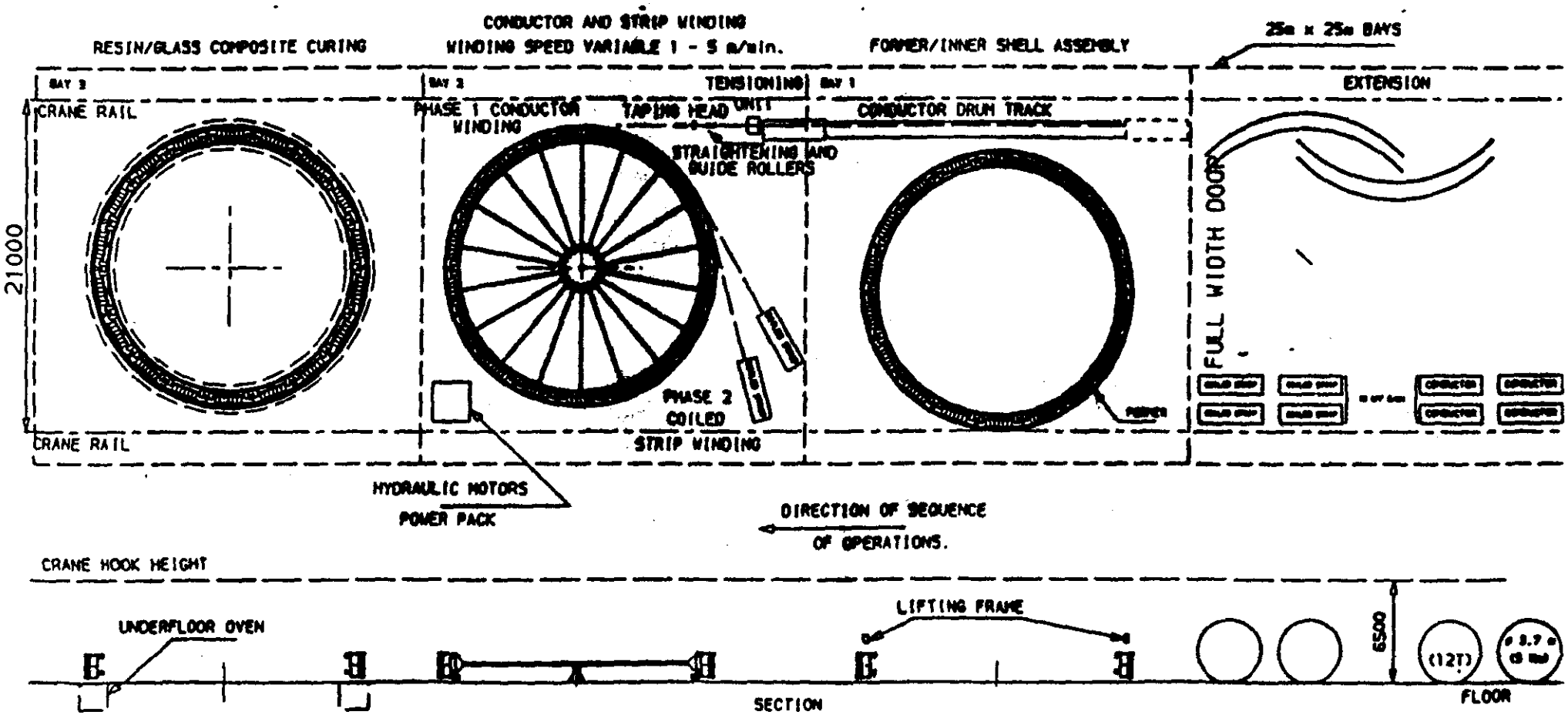


Figure 3 Schematic of Spooling and Insulating of CICC-in-Sheath (Factory Pre-assembled)

Cond-in-StabRev 1

Fig. 4.5 GEM MAGNET WINDING PROCEDURE



- CONDUCTOR SELECTION WILL BE COUPLED TO CABLE PRODUCTION AND WINDING SCHEME

- CABLE-IN-CONDUIT
  - VERY STABLE CONDUCTOR
  - POTENTIAL PROBLEMS IN MANUFACTURING
  - SERIOUS QUESTIONS OF STABILITY OF CABLE JOINTS

- INDIRECTLY COOLED
  - SAFETY MARGIN SUFFICIENT BUT LOW
  - EASY TO MANUFACTURE
  - REQUIRE GOOD BONDING TO BOBBIN OVER ENTIRE AREA (~ 1/2 FOOTBALL FIELD)

- MODIFIED WINDING SCHEME PROPOSED FOR BOTH CONDUCTORS

Magnet size and field cost derivatives (materials only)

Additional	1 m of length	~\$1M
Additional	1 m of radius	~\$10M
Additional	0.2T field	~\$8M

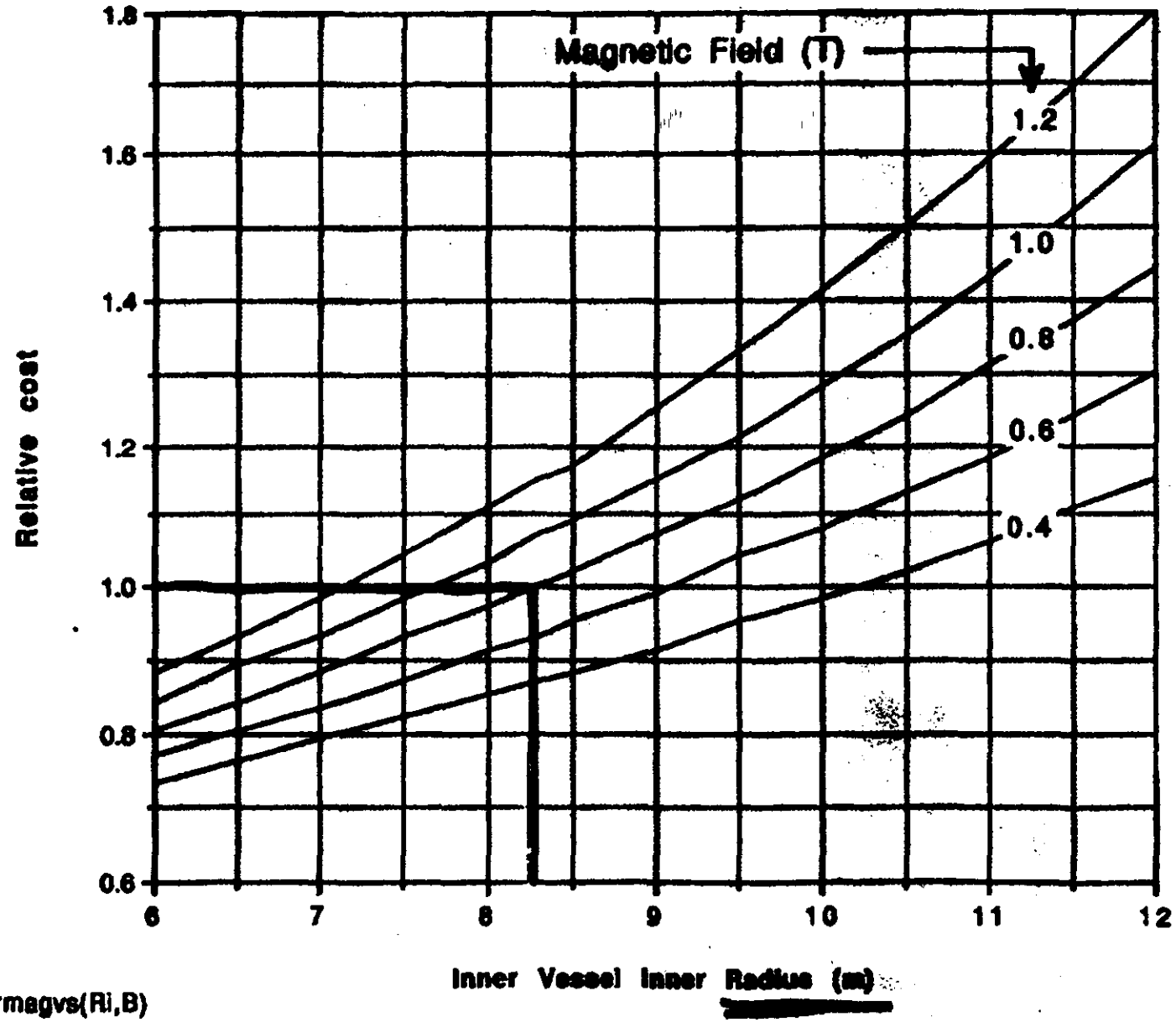
Not included:

size
- Incremental costs of experimental hall, access shafts, fabrication buildings
- Incremental cost of muon system

field
- Incremental cost of engineering and changes of mechanical supports due to increased weight and magnetic forces
- May need changes in conductor design

Figure 1 - GEM Single-Coil Magnet Cost vs Radius and Field

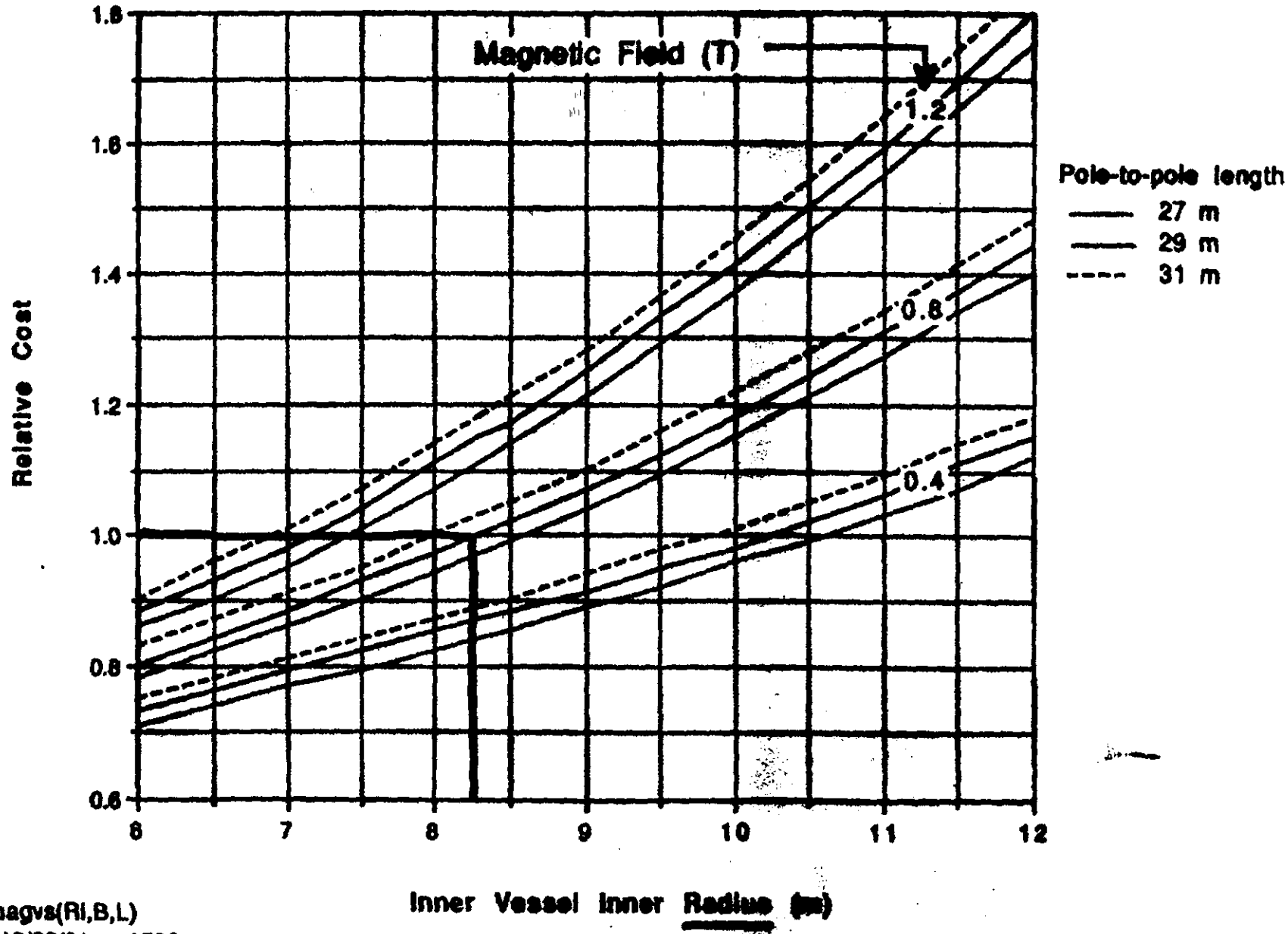
PRELIMINARY



:Cbarmagvs(Ri,B)
·gd - 12/20/91 - 1449

Figure 2 - GEM Single-coil Magnet Cost vs Radius, Field, and Length

PRELIMINARY



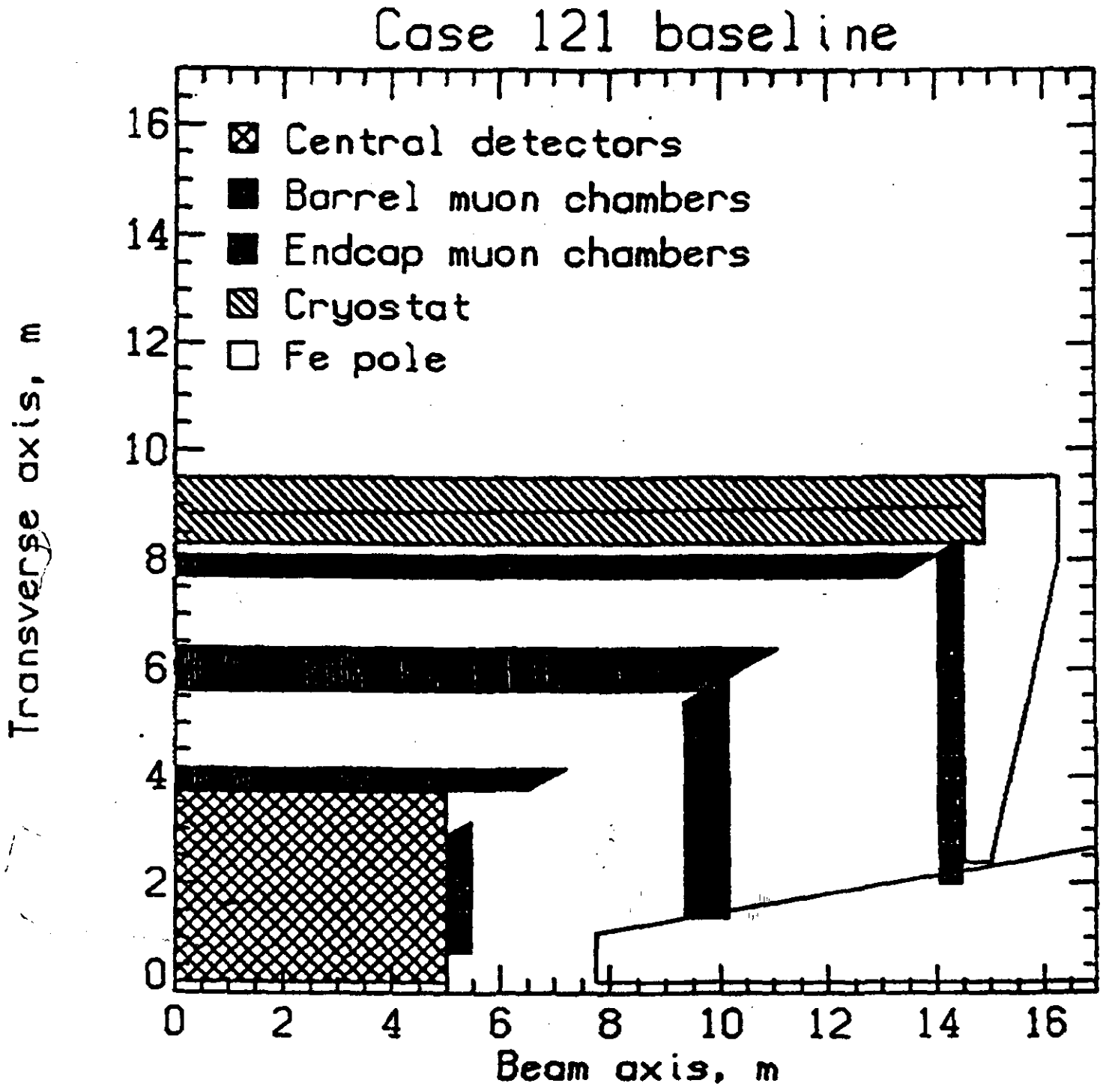
Cbarmagvs(Ri,B,L)
gd - 12/20/91 - 1506

FORWARD DIRECTION

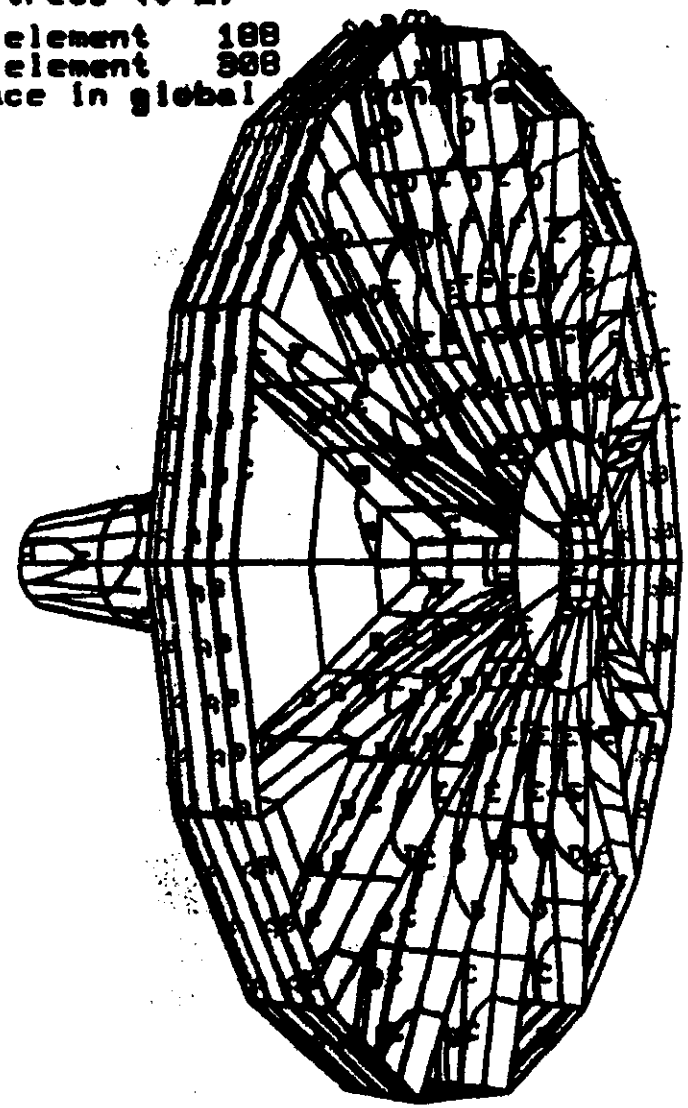
NEED FLUX CONCENTRATOR

- CAN IMPROVE MUON RESOLUTION BY FACTOR OF 3+5
- NEED TO EXTEND BEYOND THE REGION OF THE POLE
- WILL BE HEAVY (~1000 TONS) AND WILL NEED SUBSTANTIAL SUPPORT

CENTRAL REGION


Case 121 baseline
Central detectors
Barrel muon chambers
Endcap muon chambers
Cryostat
Fe pole
Transverse axis, m
Beam axis, m
0
2
4
6
8
10
12
14
16

2 in thick plate spider
time = 0.10000E+02
contours of eff. stress (v-m)
min= 5.058E+06 in element 108
max= 1.423E+08 in element 308
shell middle surface in global



contour values
A= 1.66E+07
B= 3.08E+07
C= 4.51E+07
D= 5.94E+07
E= 7.37E+07 ← 70 MPa : 10 ksi
F= 8.79E+07
G= 1.02E+08 ← ≈ 15 ksi
H= 1.16E+08
I= 1.31E+08 ← ≈ 20 ksi

disp. scale factor = 0.100E+01 (default)

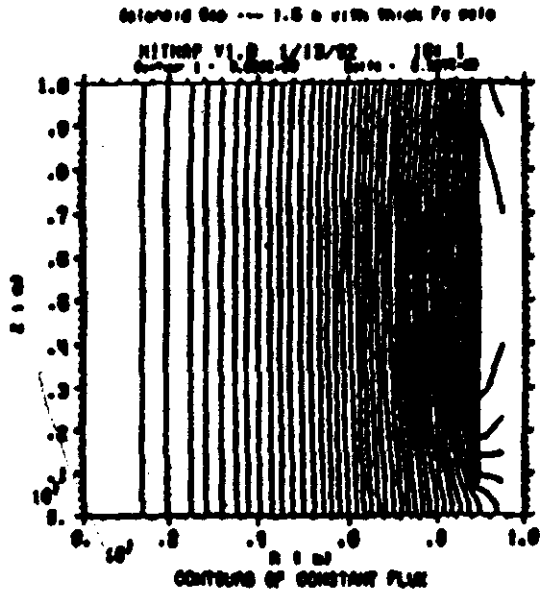
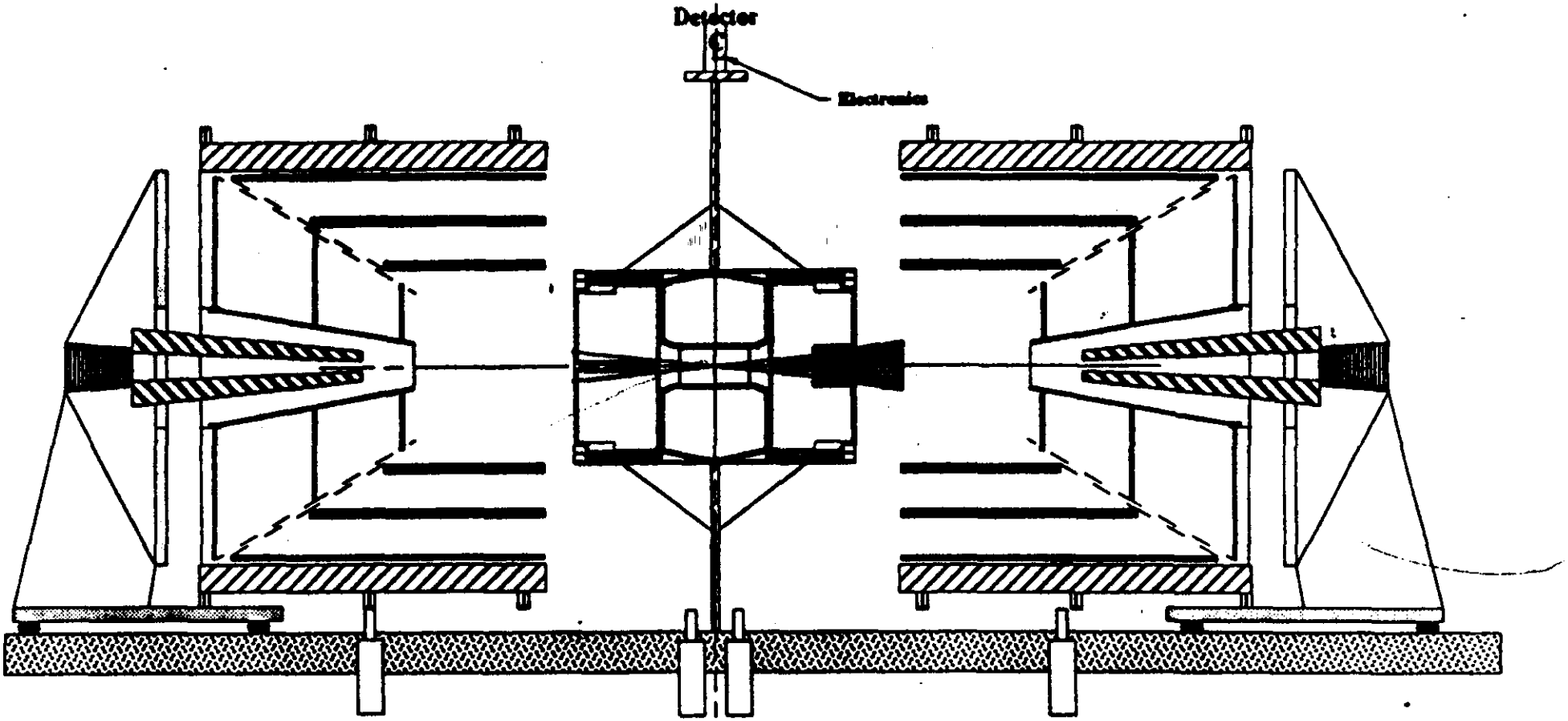


Figure 5: Flux isopleths for 1.5 m coil-to-coil gap with iron poles



GEM Configuration Option Study
Liquid Argon Calorimeter
Integral Calorimeter Version

G.03.AS.0003

EBERLE/RENNICH

Case	Resolution, %								
	$\eta = 0.04$	0.5	1.0	1.25	1.35	1.5	2.0	2.45	2.5
	87.7°	62.5	40.4	32.0	29.0	25.2	15.4	9.9	9.4°
200	8.6	8.4	8.8	10.4	7.2	9.0	16.0	19.9	19.7
201	8.6	8.4	8.8	10.4	7.2	9.0	15.8	19.5	19.4
202	8.6	8.4	8.8	10.4	7.2	9.0	15.7	19.4	19.3
203	8.4	8.3	8.9	10.6	7.4	9.7	21.6	35.3	36.5
205	8.5	8.3	8.9	10.6	7.4	9.6	21.1	33.3	34.4
210	8.5	8.3	8.8	10.2	7.1	8.9	15.9	20.1	20.3
220	8.5	8.3	8.7	10.1	7.0	8.9	16.5	20.7	21.4
222	8.5	8.3	8.7	10.1	7.0	8.9	16.3	20.1	20.8
230	8.6	8.4	8.8	10.3	7.1	8.9	15.2	18.0	17.8
232	8.6	8.4	8.8	10.3	7.1	8.8	14.9	17.4	17.2
250	8.5	8.3	8.7	10.0	7.0	8.8	15.7	18.7	19.2
252	8.5	8.3	8.7	10.0	7.0	8.7	15.4	18.0	18.4
300	8.5	8.3	9.1	11.6	9.2	11.7	20.5	22.9	22.3
301	8.5	8.3	9.1	11.6	9.2	11.7	20.2	22.5	21.9
302	8.5	8.3	9.1	11.6	9.2	11.7	20.1	22.4	21.8
303	8.4	8.3	9.2	11.9	9.5	12.9	30.2	47.2	48.3
310	8.5	8.3	9.0	11.3	9.0	11.6	20.5	23.3	23.1
320	8.4	8.3	9.0	11.3	9.0	11.6	21.4	24.0	24.6
330	8.6	8.4	9.0	11.4	8.9	11.3	18.3	19.7	19.4
390	8.5	8.4	9.0	11.5	9.0	11.3	18.1	19.2	18.5
LoI	8.4	8.2	8.7	9.7	6.8	9.4	27.9	93.9	105
200	8.6	8.4	8.8	10.4	7.7	9.8	17.1	20.2	20.0

2 sectors

Table 6: The muon detector resolution at $P_t = 500$ GeV is tabulated against selected values of η for the various magnet field shaping options. Note that for the last two comparisons (LoI and 200) the outer end-cap chamber has been moved in 0.5 m in order to accomodate the thick iron pole in the LoI case and permit direct comparison.

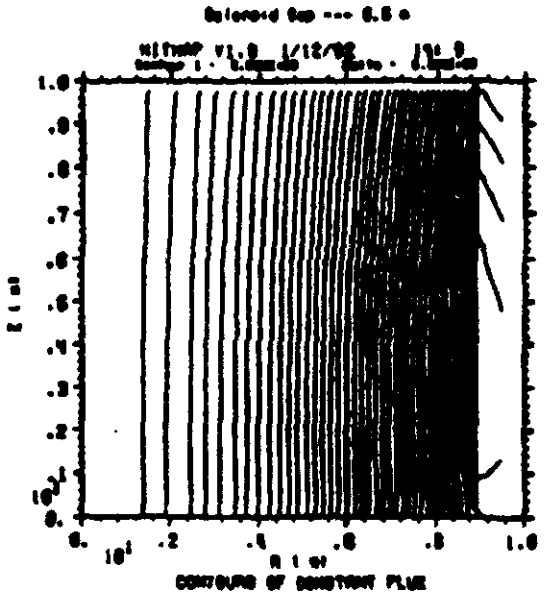


Figure 1: Flux isopleths for 0.5 m coil-to-coil gap

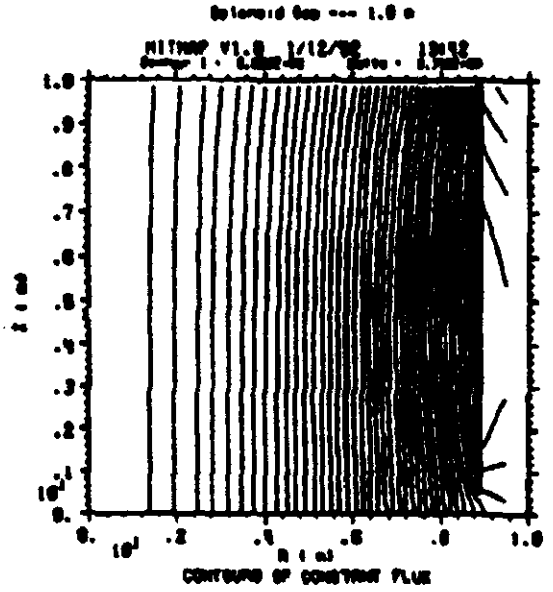
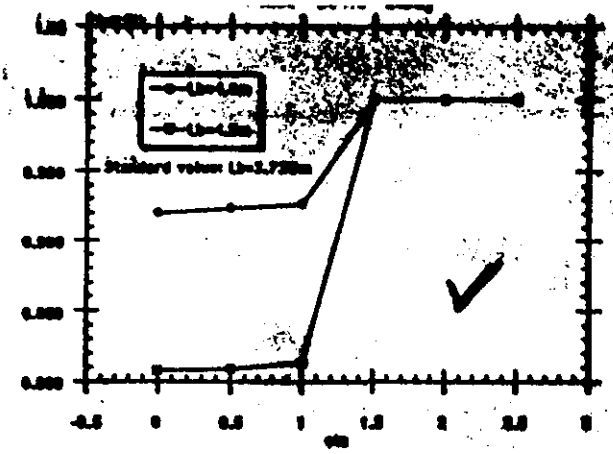
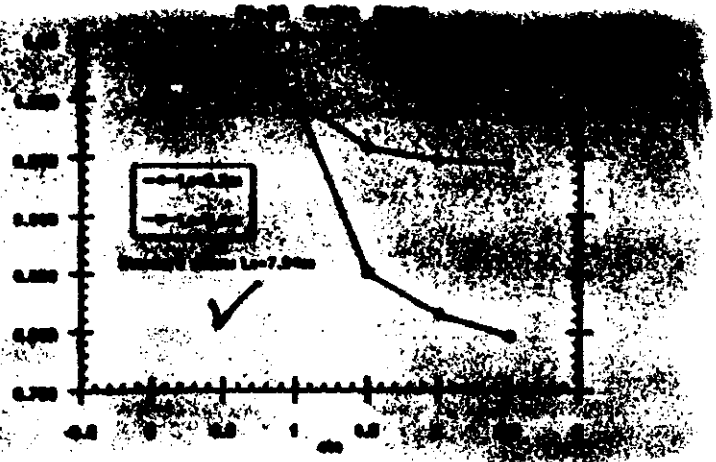
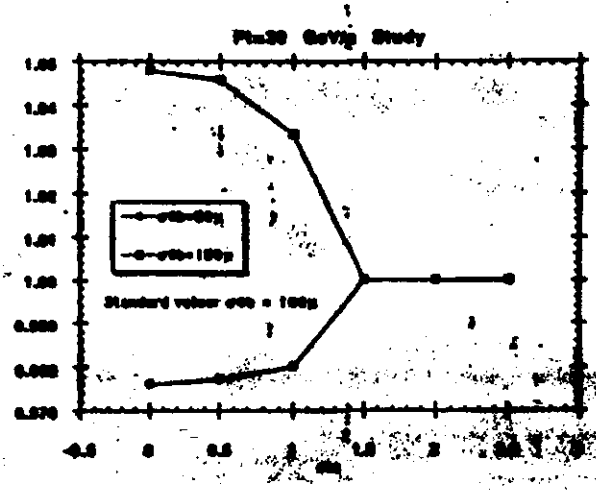
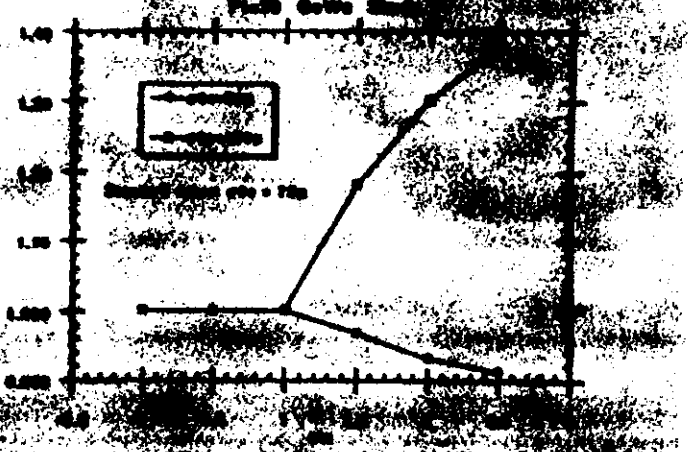


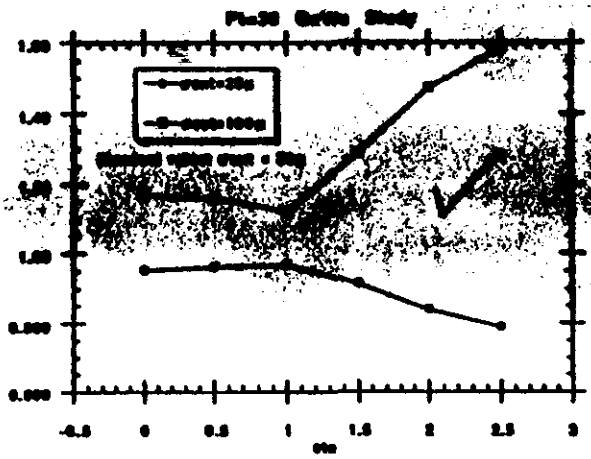
Figure 2: Flux isopleths for 1.0 m coil-to-coil gap

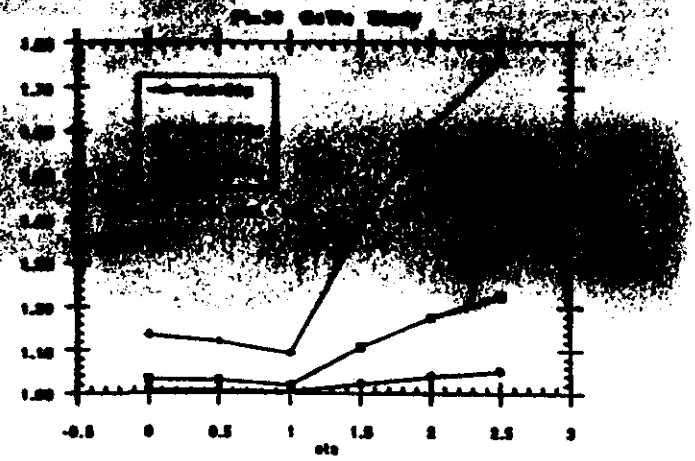


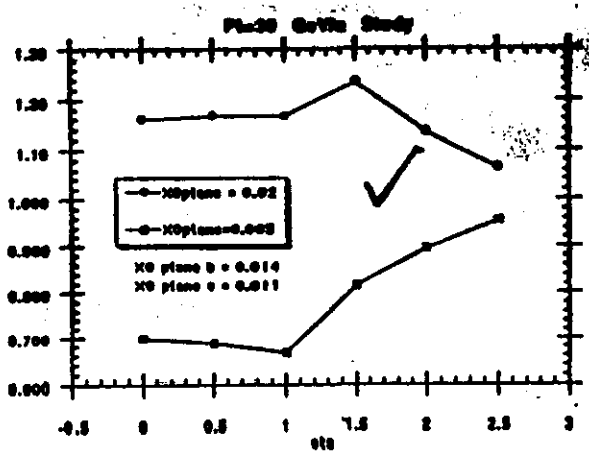


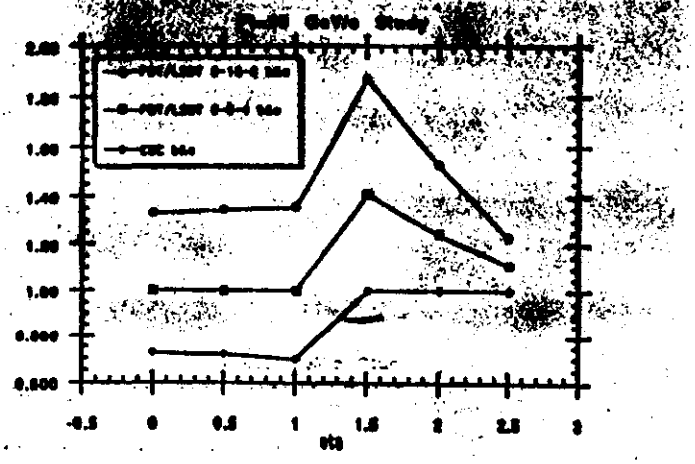


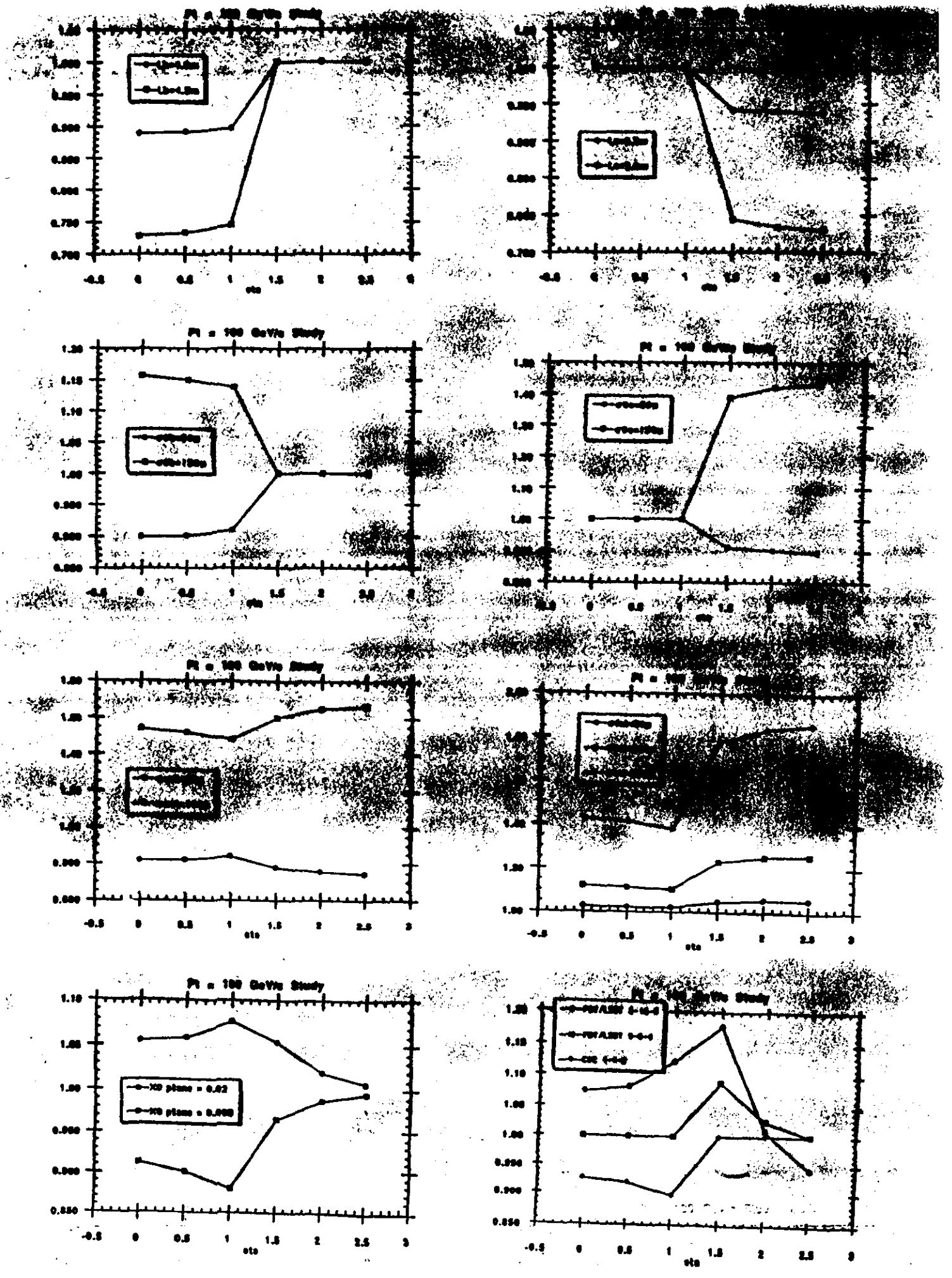


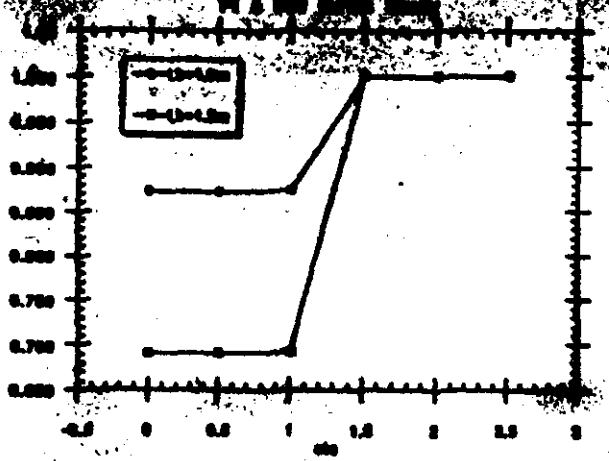


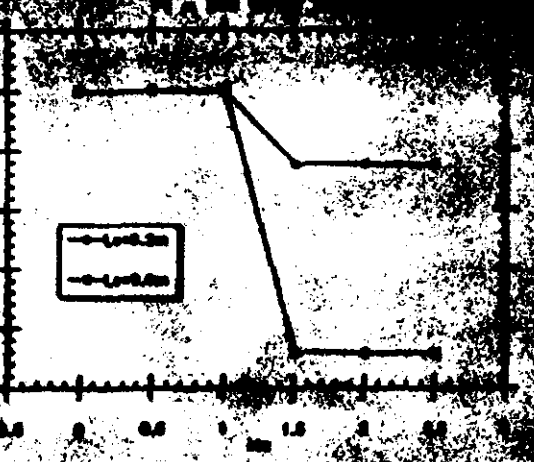


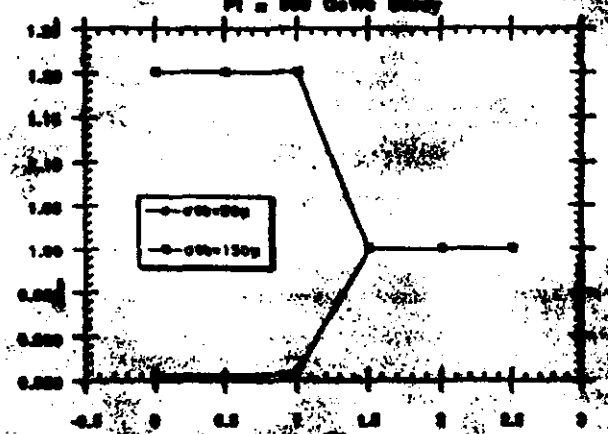


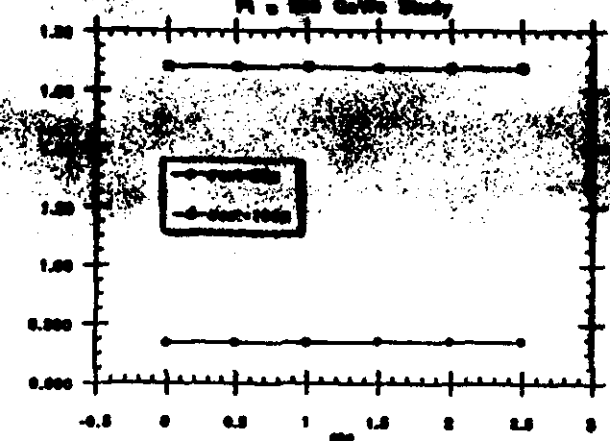


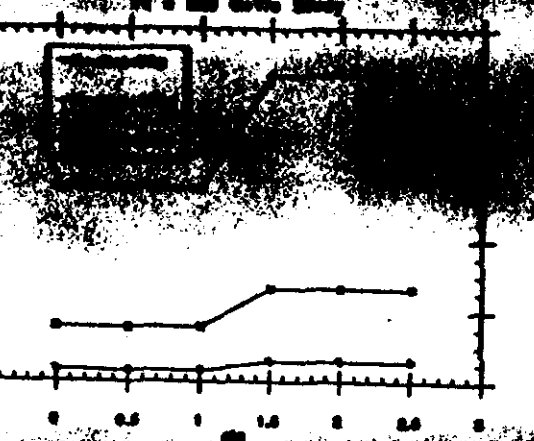

Pt = 100 GeV/c Study
eta

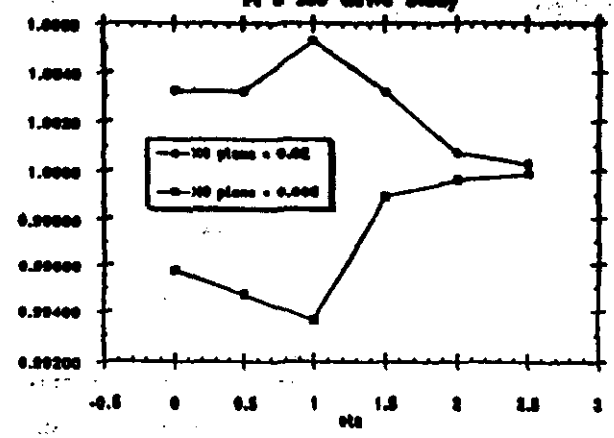


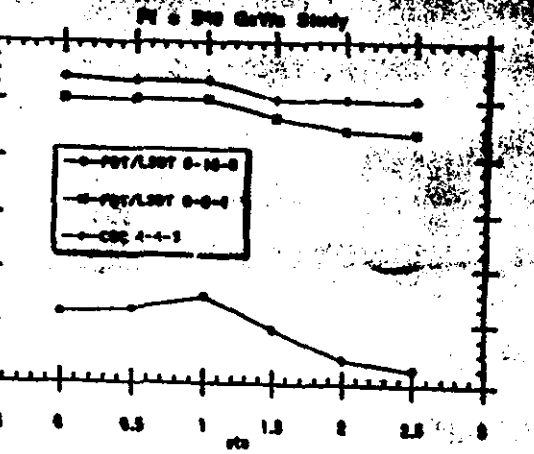


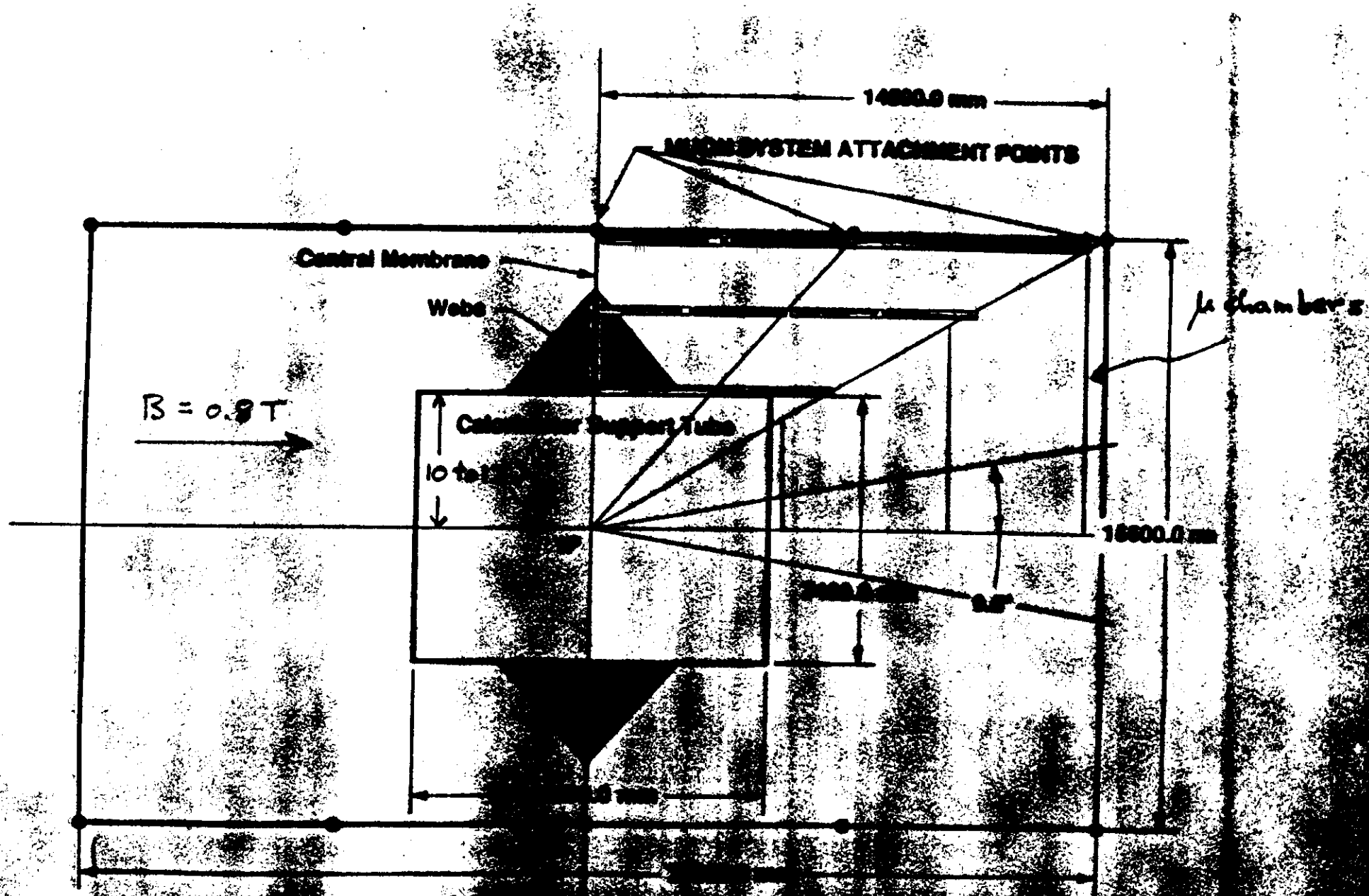






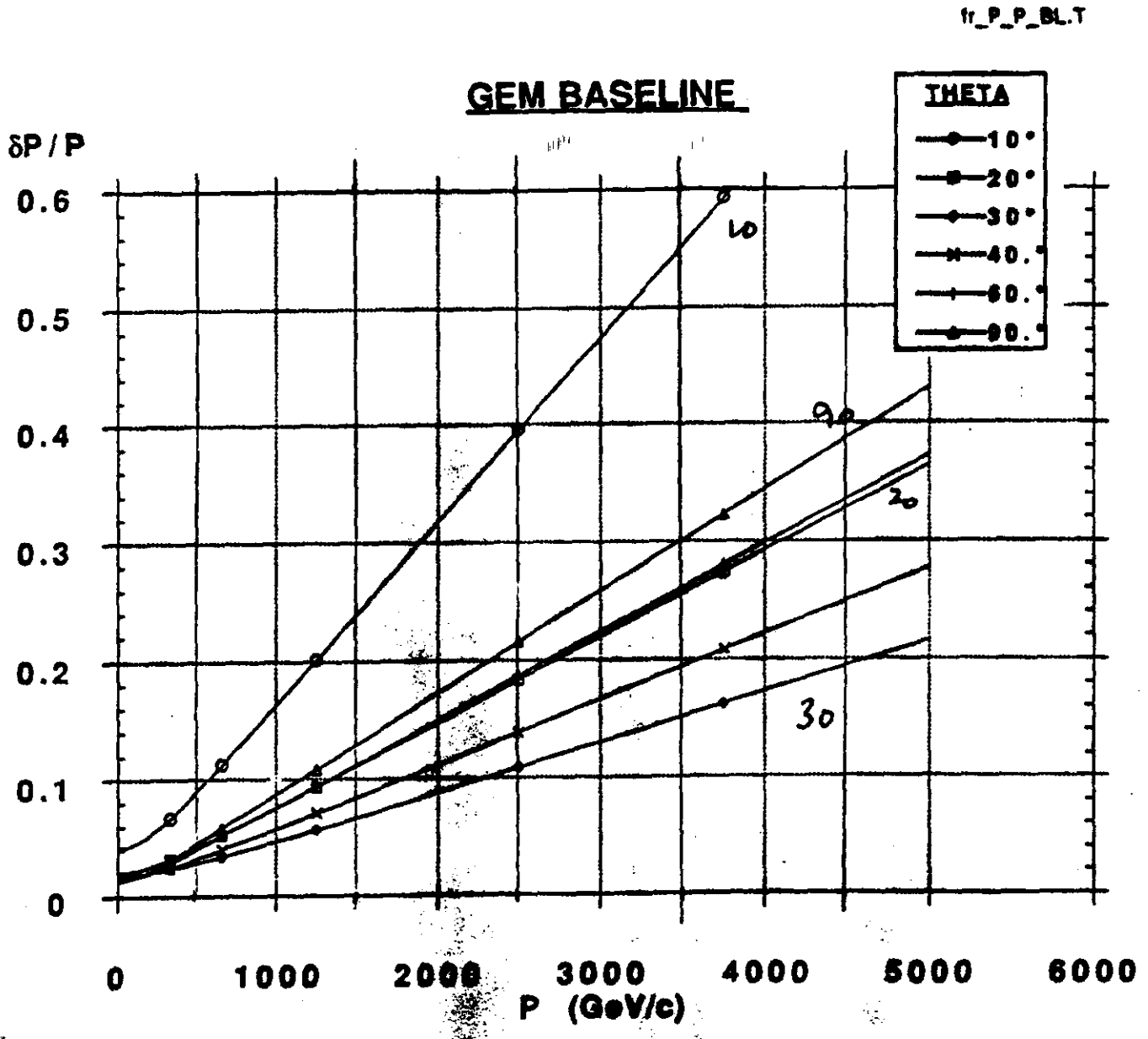




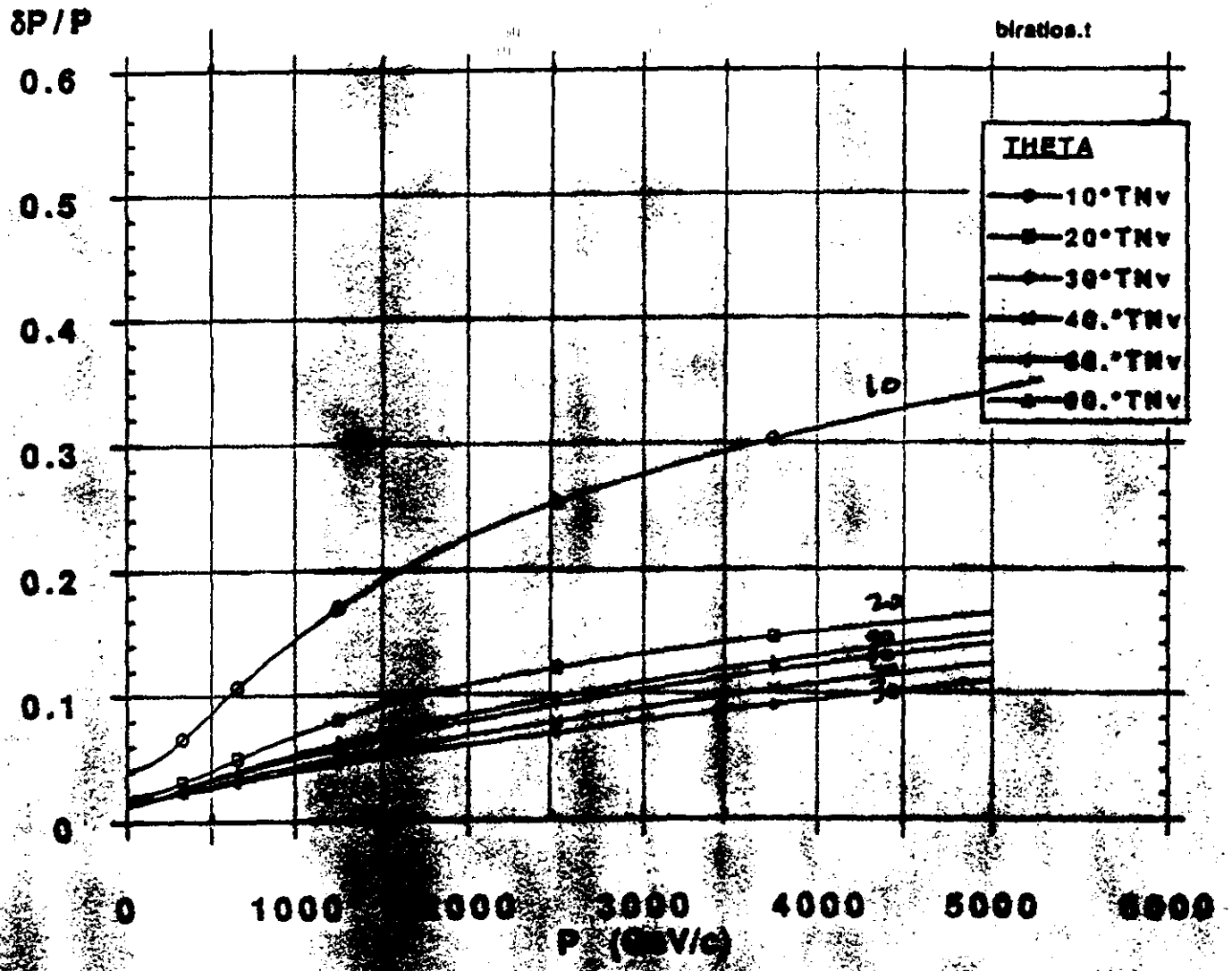


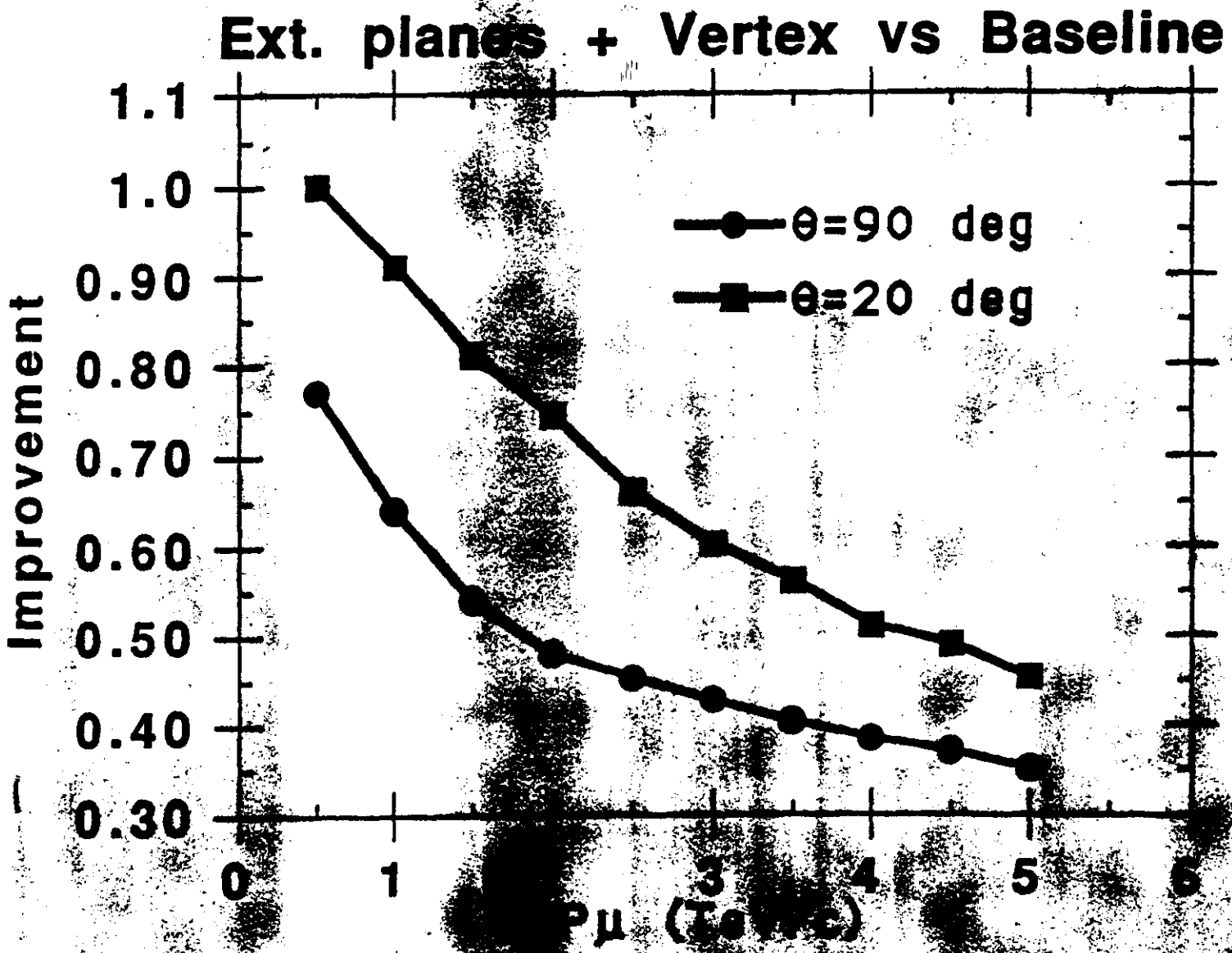
Elevation of

L. Rosenson


tr_P_P_BL.T
GEM BASELINE
δP / P
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1000
2000
3000
4000
5000
6000
P (GeV/c)
THETA
10°
20°
30°
40.°
60.°
90.°
10
90
20
30

GEM BASELINE +THIN POLE+VERT +3 EXTERNAL PLANES




Ext. planes + Vertex vs Baseline
Improvement
1.1
1.0
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0
1
3
4
5
6
θ=90 deg
θ=20 deg

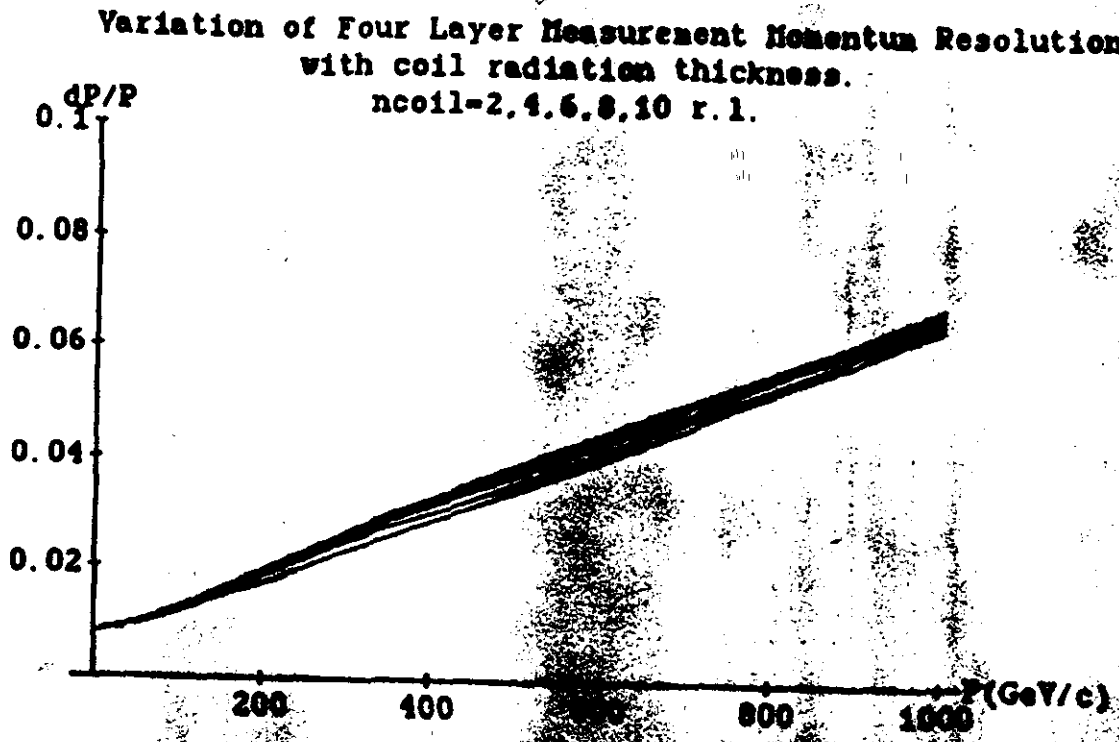


Figure 4

Variation of Four Layer Measurement Momentum Resolution with coil radiation thickness ,n_{coil} . The lowest curve corresponds to n_{coil} = 2 radiation lengths. The curves successively correspond to increments of n_{coil} = 2 radiation lengths.

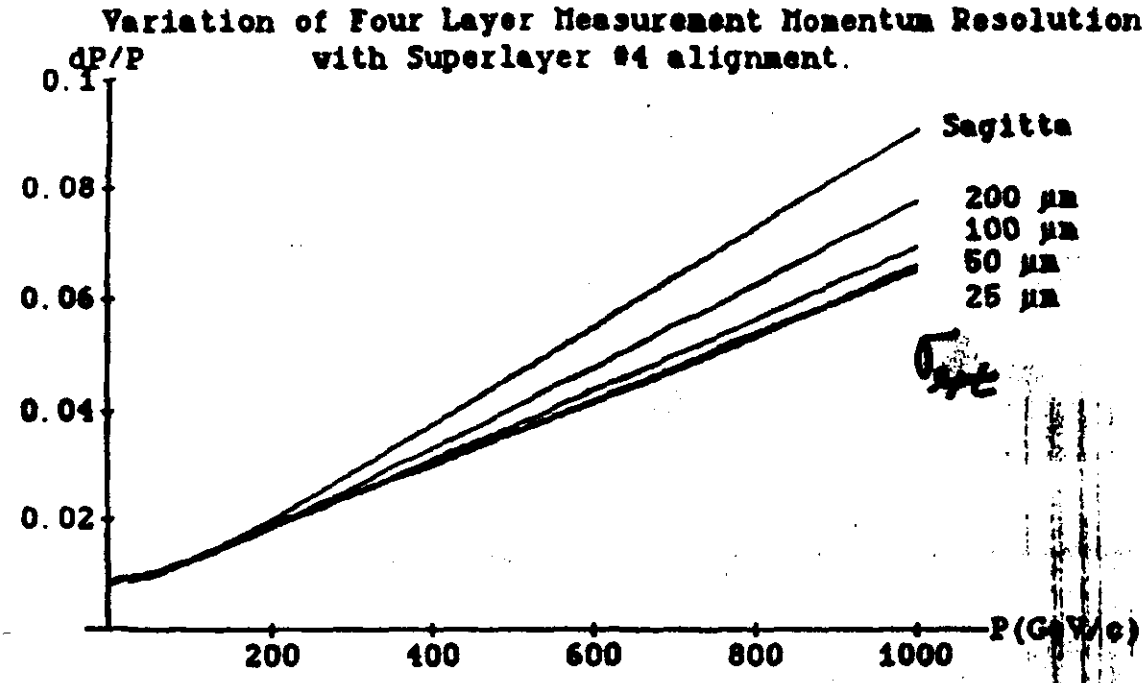
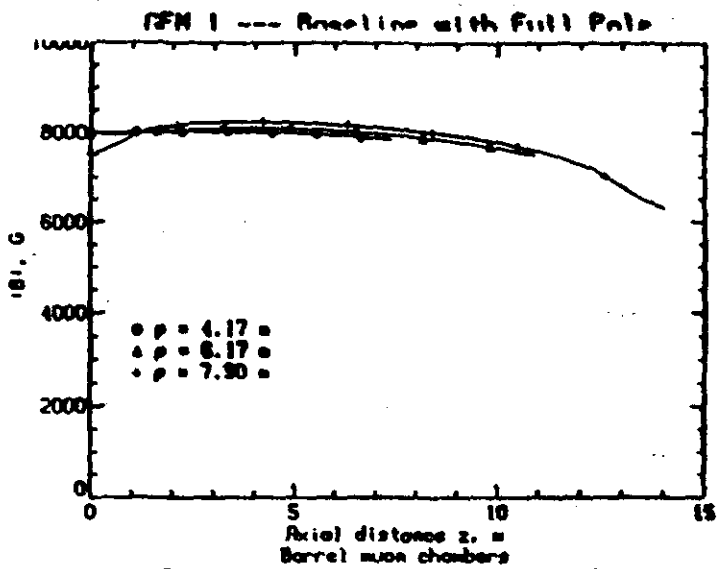
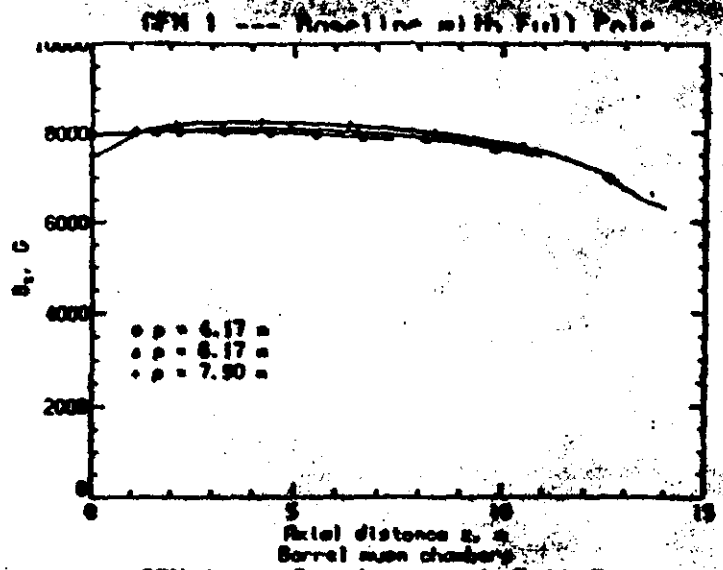


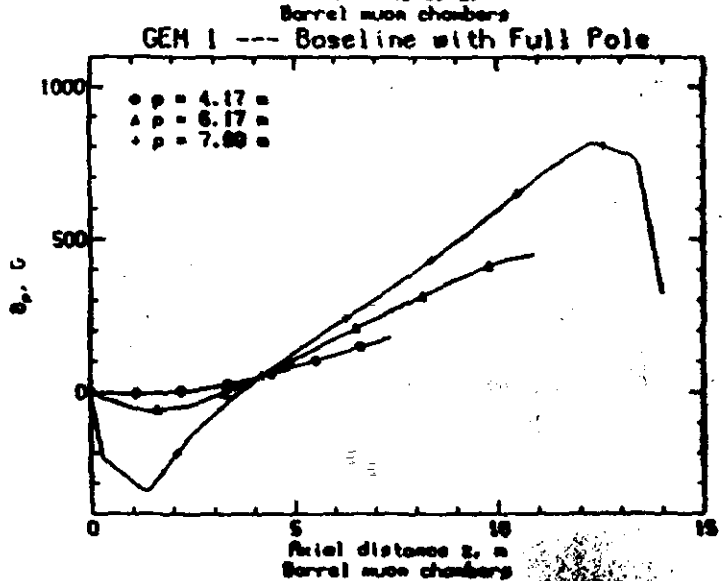
Figure 7

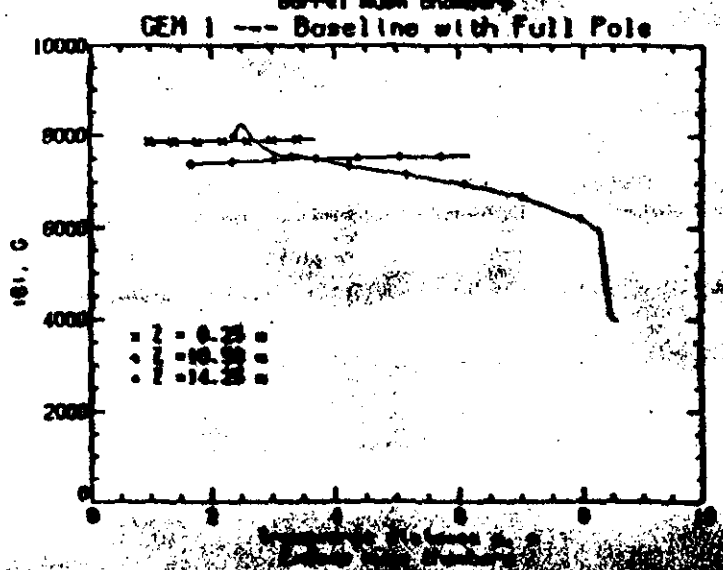
Variation of Four Layer Measurement Momentum Resolution with Superlayer #4 Alignment. The four lowest curves correspond to $\sigma_{ext\text{-}Superlayer\ \#4}$ ranging from 25 µm. to 200 µm. The highest curve, labeled 'Sagitta', is a reproduction of Figure 2 curve a) for comparison. It is close to the limiting resolution from the Four Point Measurement for a completely useless coordinate measurement by Superlayer.#4 and gives a scale for the degradation arising from misalignment of this Superlayer.

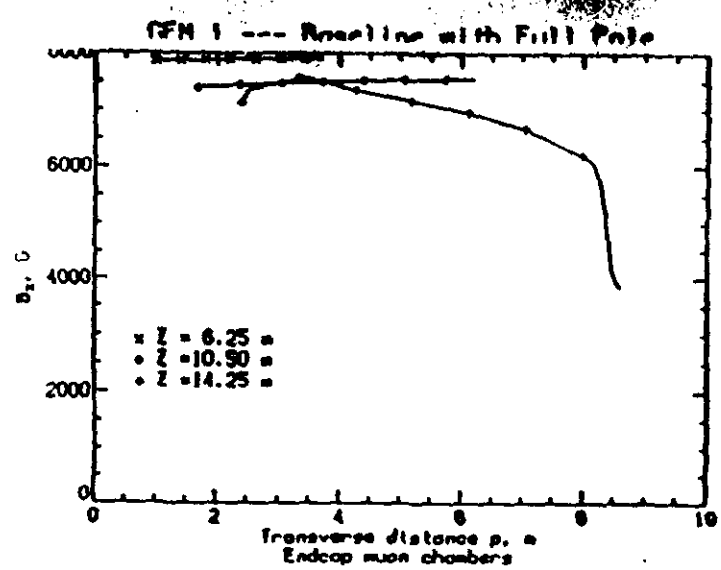
Field Shaping 1/20/92 From Jim [illegible]

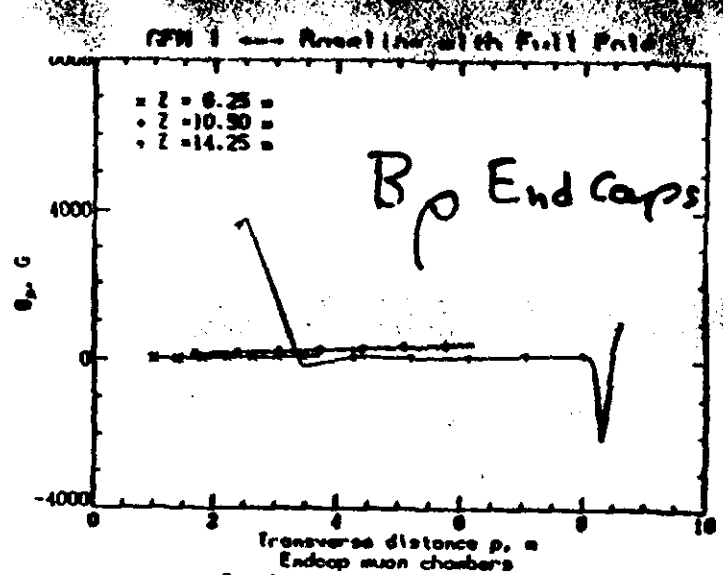




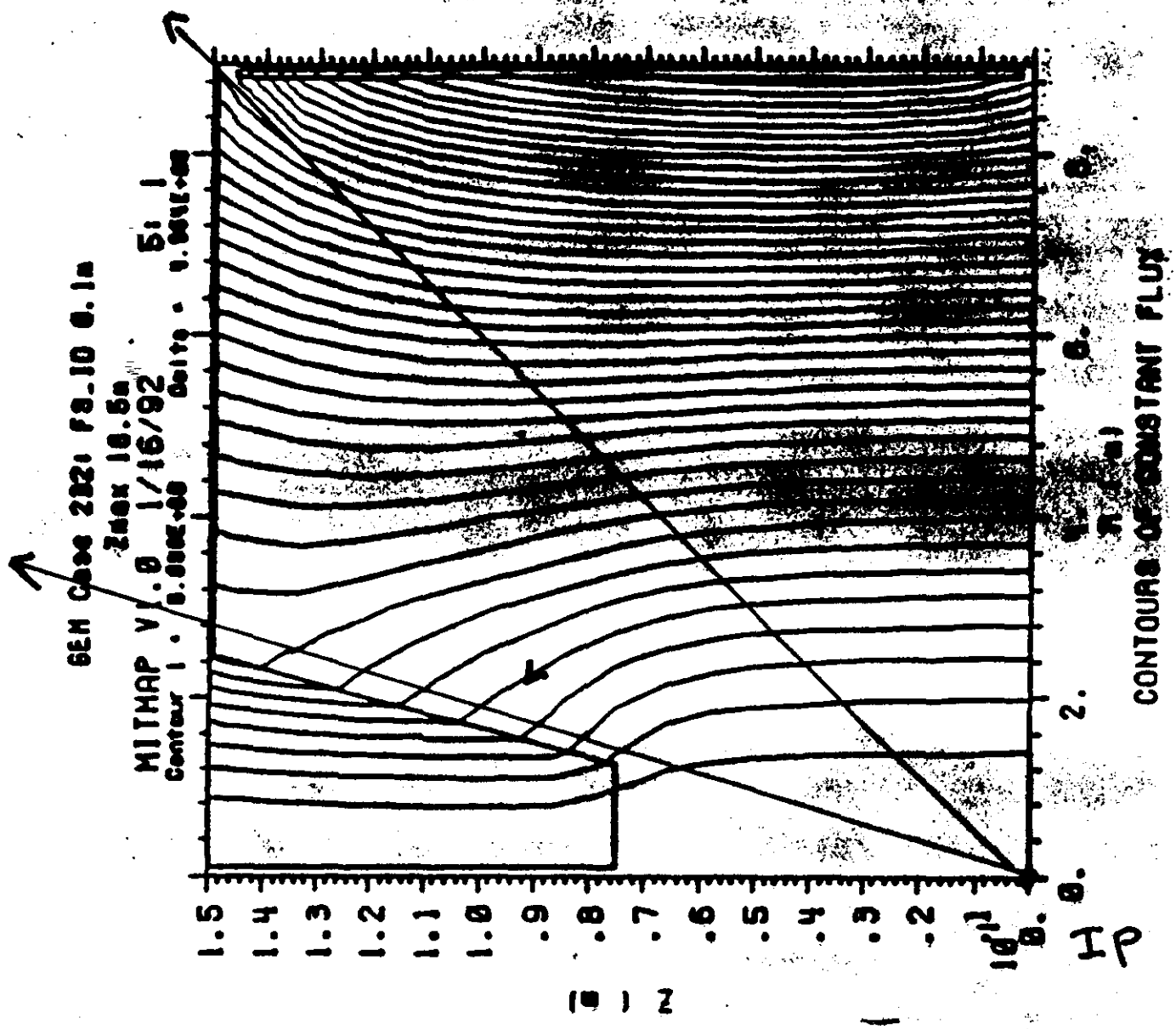




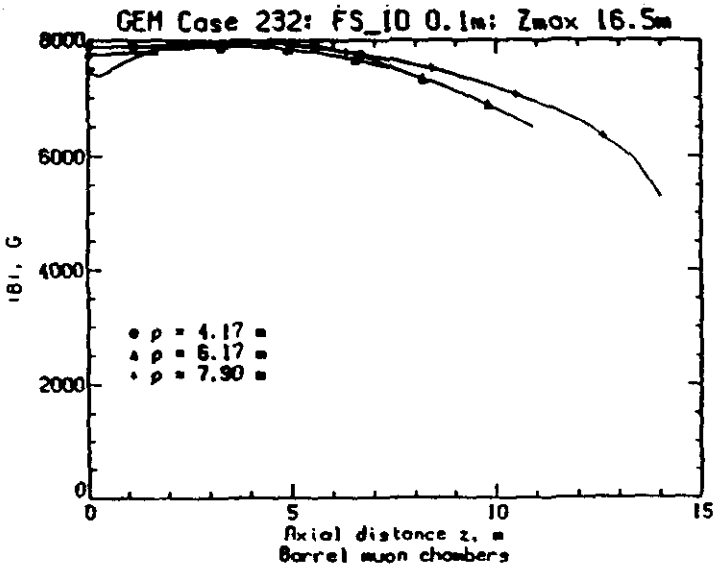


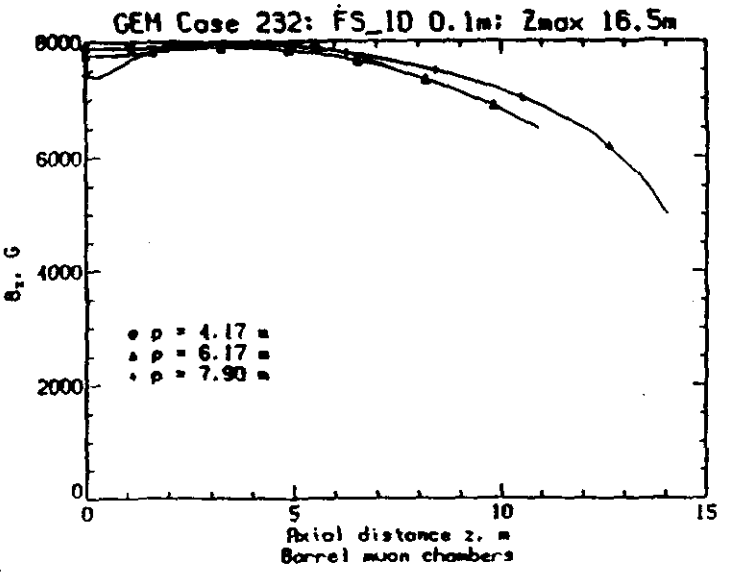


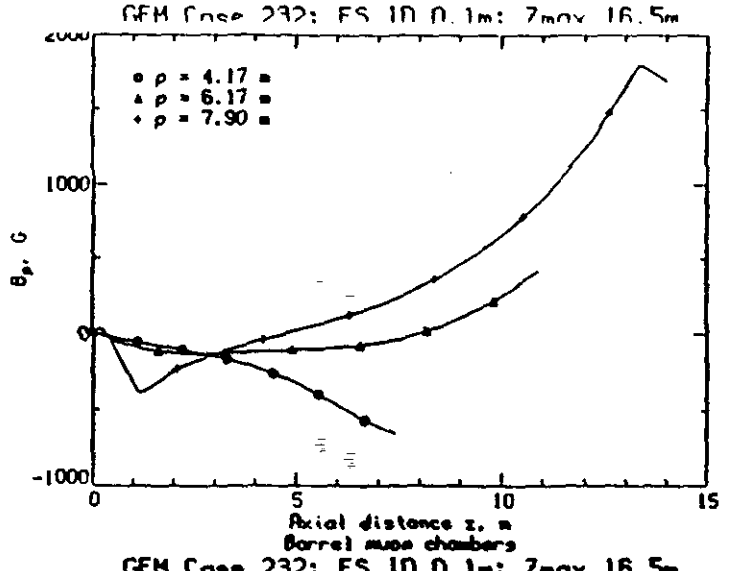
Flux Concentrator

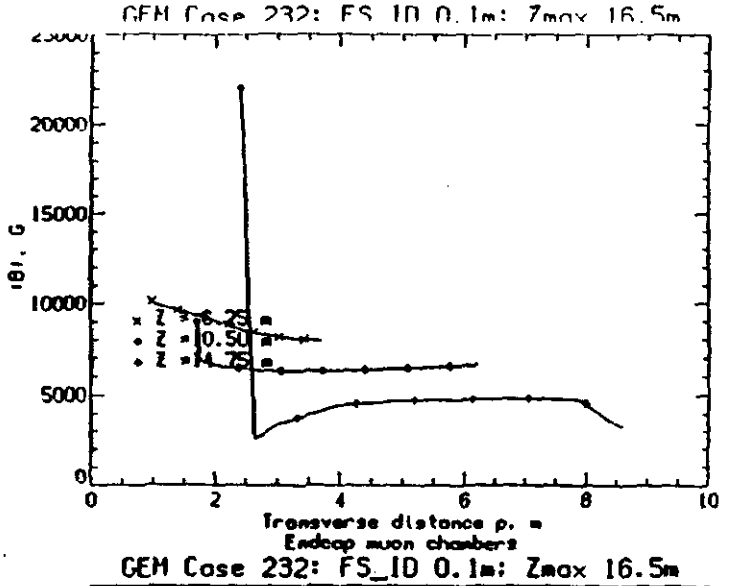


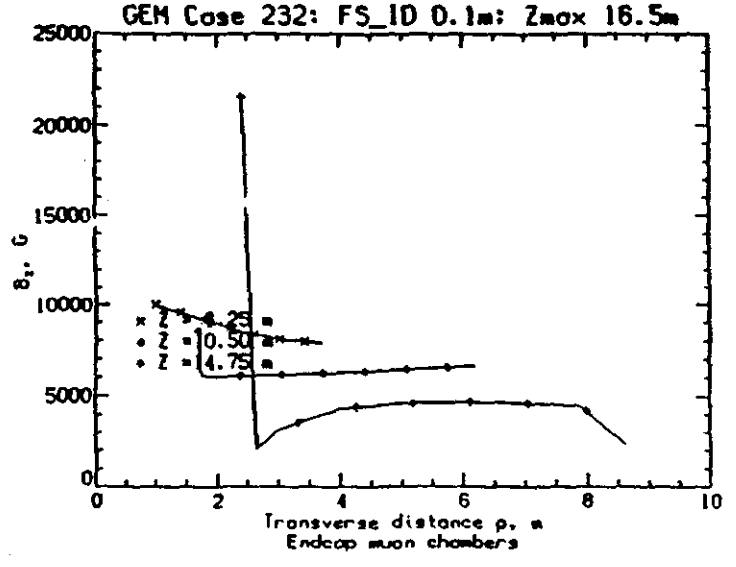
HP

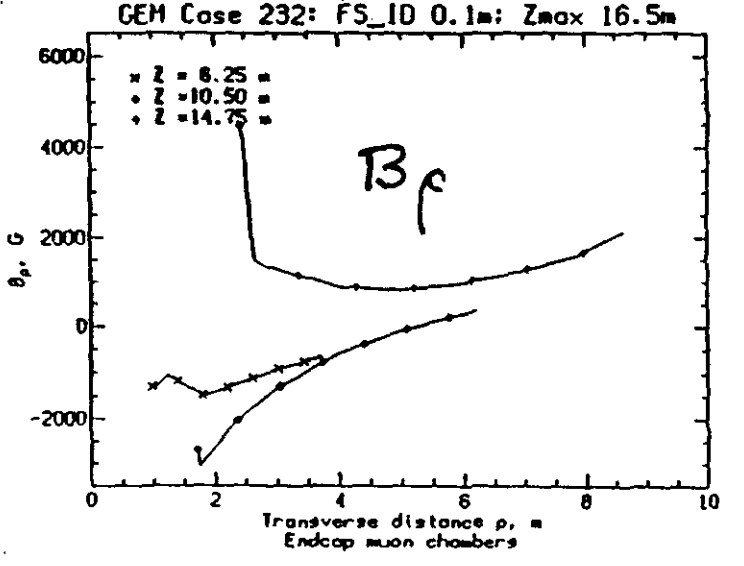

GEM Case 232: FS_ID 0.1m: Zmax 16.5m
|B|, G
• ρ = 4.17 m
▲ ρ = 6.17 m
+ ρ = 7.90 m
Axial distance z, m
Barrel muon chambers

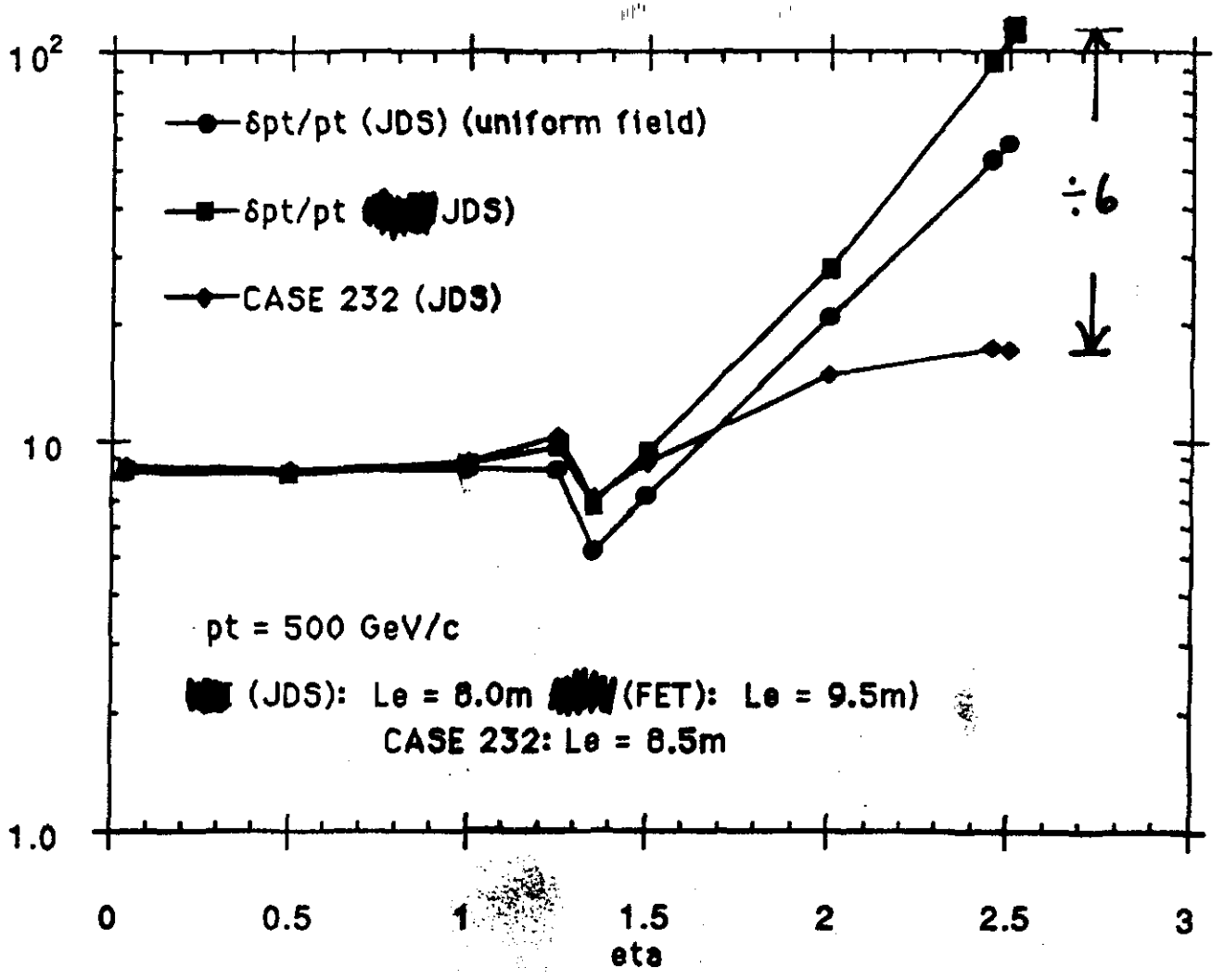

GEM Case 232: FS_ID 0.1m: Zmax 16.5m
B_z, G
• ρ = 4.17 m
▲ ρ = 6.17 m
+ ρ = 7.90 m
Axial distance z, m
Barrel muon chambers


GEM Case 232: FS_ID 0.1m: Zmax 16.5m
B_ρ, G
• ρ = 4.17 m
▲ ρ = 6.17 m
+ ρ = 7.90 m
Axial distance z, m
Barrel muon chambers


GEM Case 232: FS_ID 0.1m: Zmax 16.5m
|B|, G
× Z = 6.25 m
• Z = 10.50 m
+ Z = 14.75 m
Transverse distance ρ, m
Endcap muon chambers


GEM Case 232: FS_ID 0.1m: Zmax 16.5m
B_z, G
× Z = 6.25 m
• Z = 10.50 m
+ Z = 14.75 m
Transverse distance ρ, m
Endcap muon chambers


GEM Case 232: FS_ID 0.1m: Zmax 16.5m
× Z = 6.25 m
• Z = 10.50 m
+ Z = 14.75 m
B_ρ, G
Transverse distance ρ, m
Endcap muon chambers



Resolution at $\eta = 2.5$ improved by factor of 6

Further improvements possible with coil around Flux Concentrator

For a "robust" design which achieves $\frac{\delta p_\perp}{p_\perp} \leq 5\%$

at 500 GeV/c $= p_\perp$ at $\eta = 0$:

Robust • increase L_b and B (expensive!)

Robust • increase L_b slightly (radius calorimeter smaller?
(gain as $1/L_b^2$)
demand more perfect alignment : $\sigma_{x\perp} \lesssim 25\mu m$

• external planes (cost effective? more detailed analysis needed.) Helps in TeV/c range.

Things to be gained in many parameters.

But:

What are the Constraints? How large B & L?

Note:

Have not included $\delta B/B$, $\delta \Delta E_\mu$, Lorentz angle compensation, δ-rays, pattern recognition, non-bend plane segmentation (for $p_\parallel$).

R & D Program:

- need budget settled

- Texas test rig

  designed, parts being ordered

- Pressurized drift tubes

  HRS array in Boston, Tests at LNP/Dubna

  pressure seals being designed at MSU

- LSDTubes

  0.5 m × 6 m chamber designed and under construction

  Lorentz angle being measured

  thinner cathodes R & D

- R P Counters

  36 cm × 137 cm operational at MIT

  30 cm × 30 cm under const. at LLNL

  trigger schemes under study

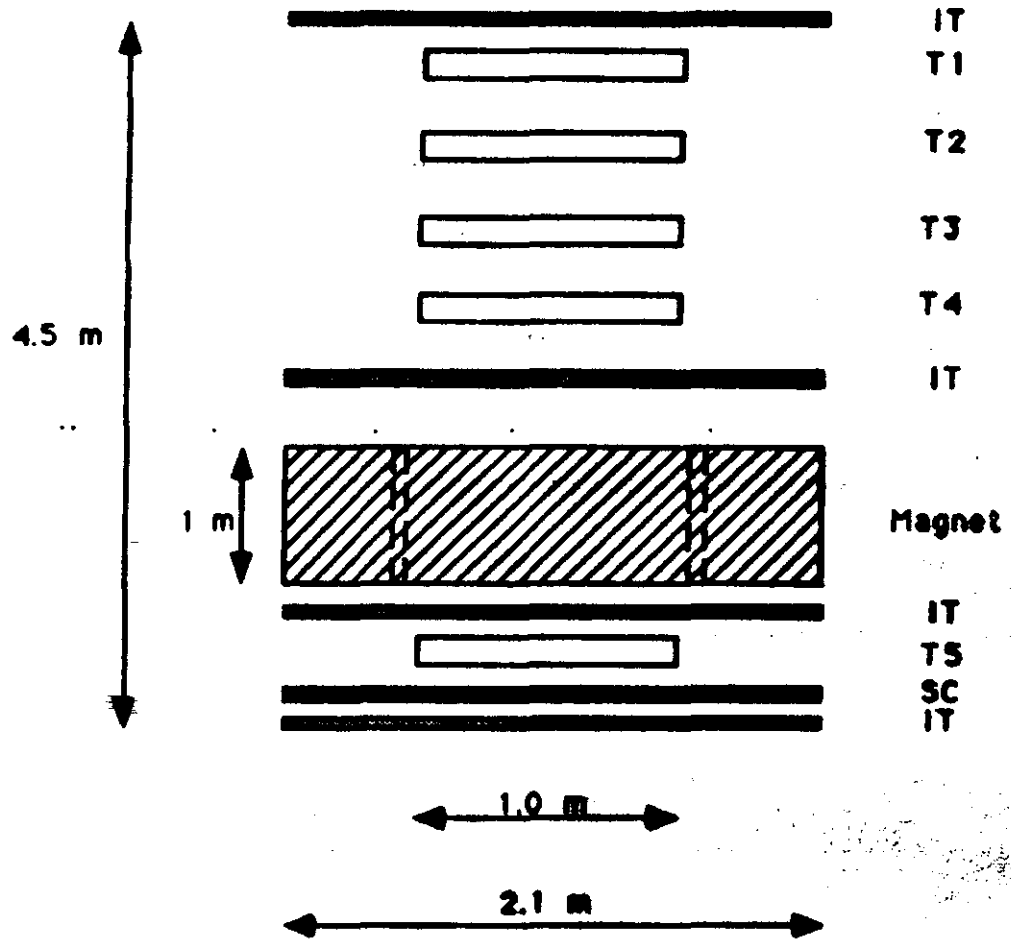
- C S Chambers

  1 m × 1 m prototype

  electronics and triggering under study

TTR TEXAS TEST RIG

GEM MUON CHAMBERS EVALUATION TEST STAND



Legend:

T1-T5 Technologies to be Evaluated
- T1 Pressurized Drift Tubes
- T2 Limitied Streamer Drift Tubes
- T3 Cathode Strip Chambers, Multiwire Geometry
- T4 Cathode Strip Chambers, Open Profile
- T5 Resistive Plate Chambers

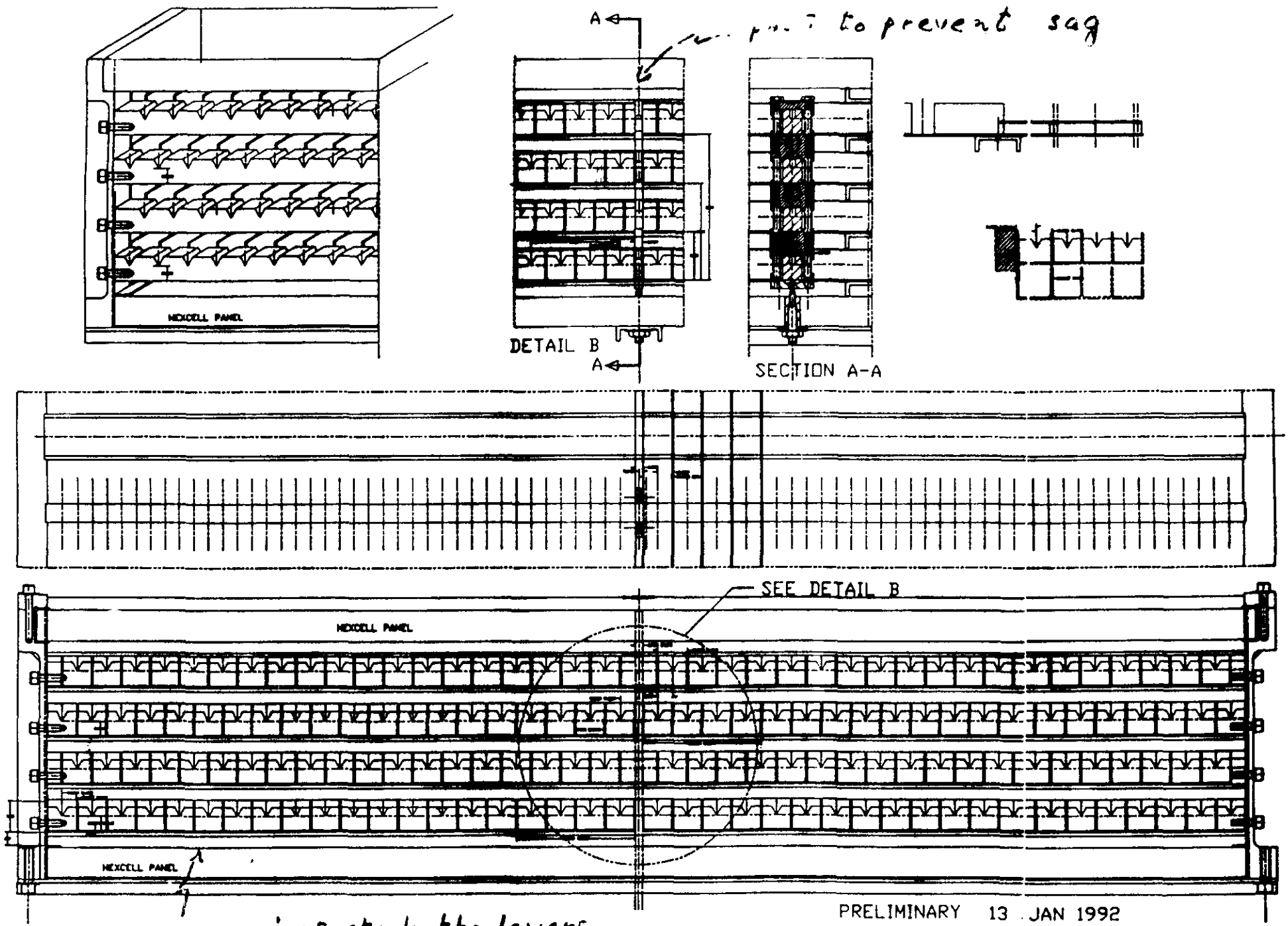
SC Scintillator Counters

IT Iarocci-Tube Chambers for Trigger

LSDT R&D Work

Milestones(all in '92): (from proposal to TNRLC)

Delivery of LeCroy electronics for 0.5 m. chm	Jan. 1 ready
Design of thin cathodes	Jan. We are hoping "Solar kinetics" succeeds
Design of 1.0 m. chamber	Jan. So far on schedule
Assembly of 0.5 m. chambers	Feb. Parts are in
Assembly of 1.0 m. chambers	March
Delivery of 1.0 m. chamber to SSCL	May
Set final specs. on chambers	Aug.
Assemble cost figures for CDR	Sept.


to prevent sag
A
DETAIL B
A
SECTION A-A
HEXCELL PANEL
SEE DETAIL B
HEXCELL PANEL
HEXCELL PANEL
we may just stack the layers
PRELIMINARY 13 JAN 1992

GEM MUON DETECTOR R&D PROGRAM ON 1992 at LNP JINR DUBNA

DETECTOR STUDIES

- DRIFT TUBE CHAMBER

  * design and tests of the small prototypes based on high pressure drift tubes
  * intrinsic resolution vs pressure (up to 10 atm)
  * drift tube parameters optimization (gaz mixture, wire, tube diameters, ...)

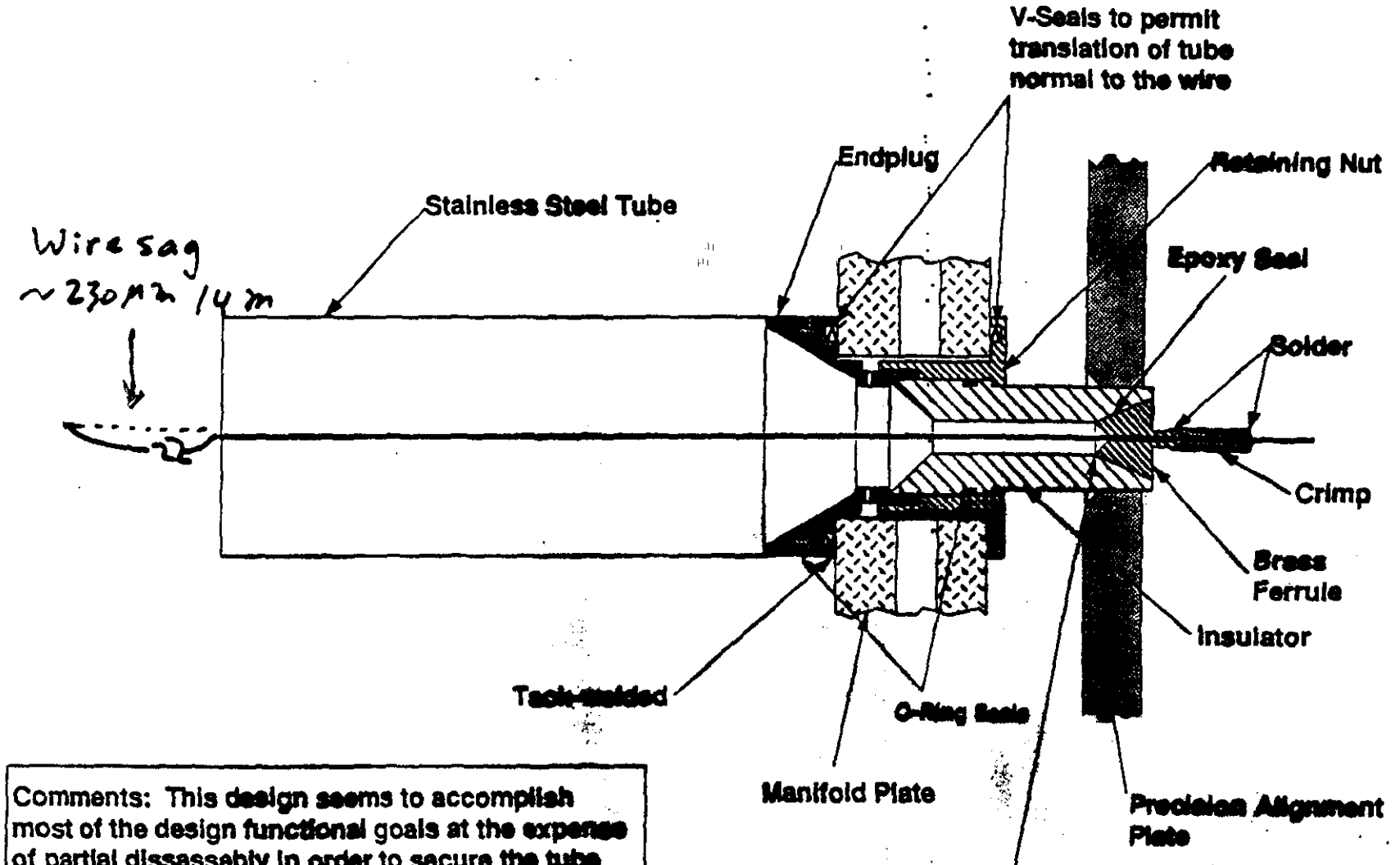
- PROFILED CATHODE DETECTORS

  * gas mixture (fast for trigger)
  * design and tests of the prototypes
  * drift and strip read-out resolution

- MODULE DESIGN AND ALIGNMENT STUDIES

- FRONT-END ELECTRONICS STUDY

MC SIMULATION OF A MUON SYSTEM PERFORMANCE



Comments: This design seems to accomplish most of the design functional goals at the expense of partial dissassebly in order to secure the tube to the Manifold plate. It should only serve as a indication of the desired functions rather than a final solution !!

Accuracy Achieved with precise alignment plate, an accurate (size and concentricity) ferrule and similar concentricity for the insulator section between the ferrule and the Precision hole in the Alignment Plate.

Pressurized Drift Tube End Plug Assembly Concept (Reduction in complication HIGHLY DESIREABLE!!)

F. Nimblett 10 Sept 91
Draper Laboratory

Resistive Plate Counter
Basic R&D Program

1. Measure the properties of 1 m x 2 m Italian RPC.
2. Develop new materials and construction techniques.
3. Build a 1 m x 2 m RPC with new materials.
4. Measure the properties of the new RPC.

Brown, Indiana, MIT, and Tennessee will construct a muon tel[illegible] using drift chambers and scintillator hodoscopes, which will be [illegible] to measure the properties of the various RPCs.

LLNL will develop new materials and construction techniques. Us[illegible] the new materials, LLNL will construct a 1 m x 2 m RPC.

R&D Work to Date:

1. Two glass RPCs (36 cm x 137 cm) have been [illegible]
   Rise time < 5 ns; Width < 50 ns; Height ~ 600 mV into 50 [illegible]
2. 30 cm x 30 cm RPC Test Stand constructed at LLNL. Chrome and Cermet electrodes deposited on resistive gl[illegible]

GEM RPC

Each muon sector will have three RPC layers. One layer will be attached to each of the three muon tracking super-modules.

For each sector, the RPC strip count is:

Non-bend plane:	1,127
Bend plane:	552
TOTAL:	1,679

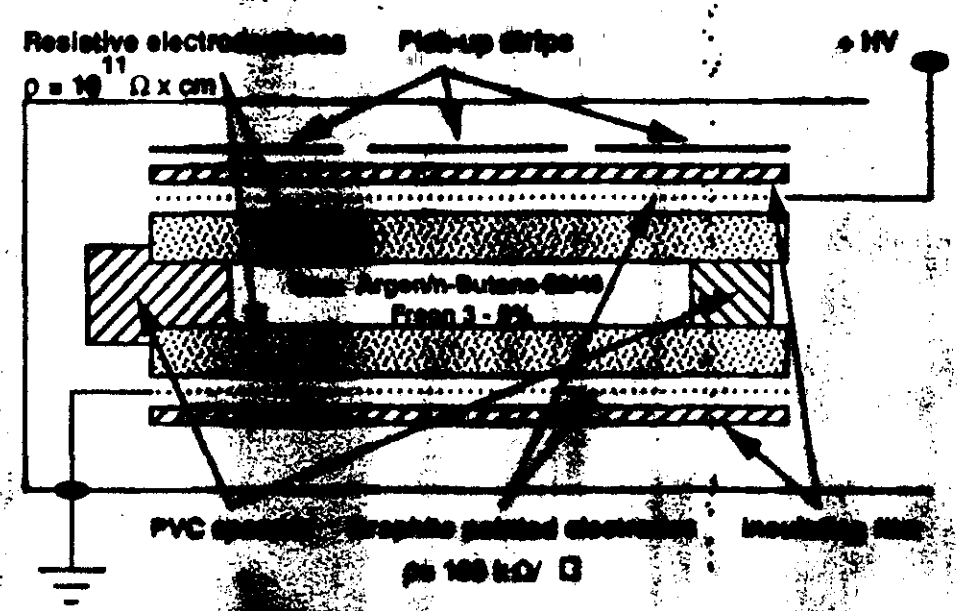
Total channel count for GEM RPC subsystem is:

32 x 1,679 = 53,728

Resistive Plate Counter (RPC) Program

Brown, Indiana, LLNL, MIT, Tennessee

Sketch of a Resistive Plate Chamber



[illegible]nel RPC functions:

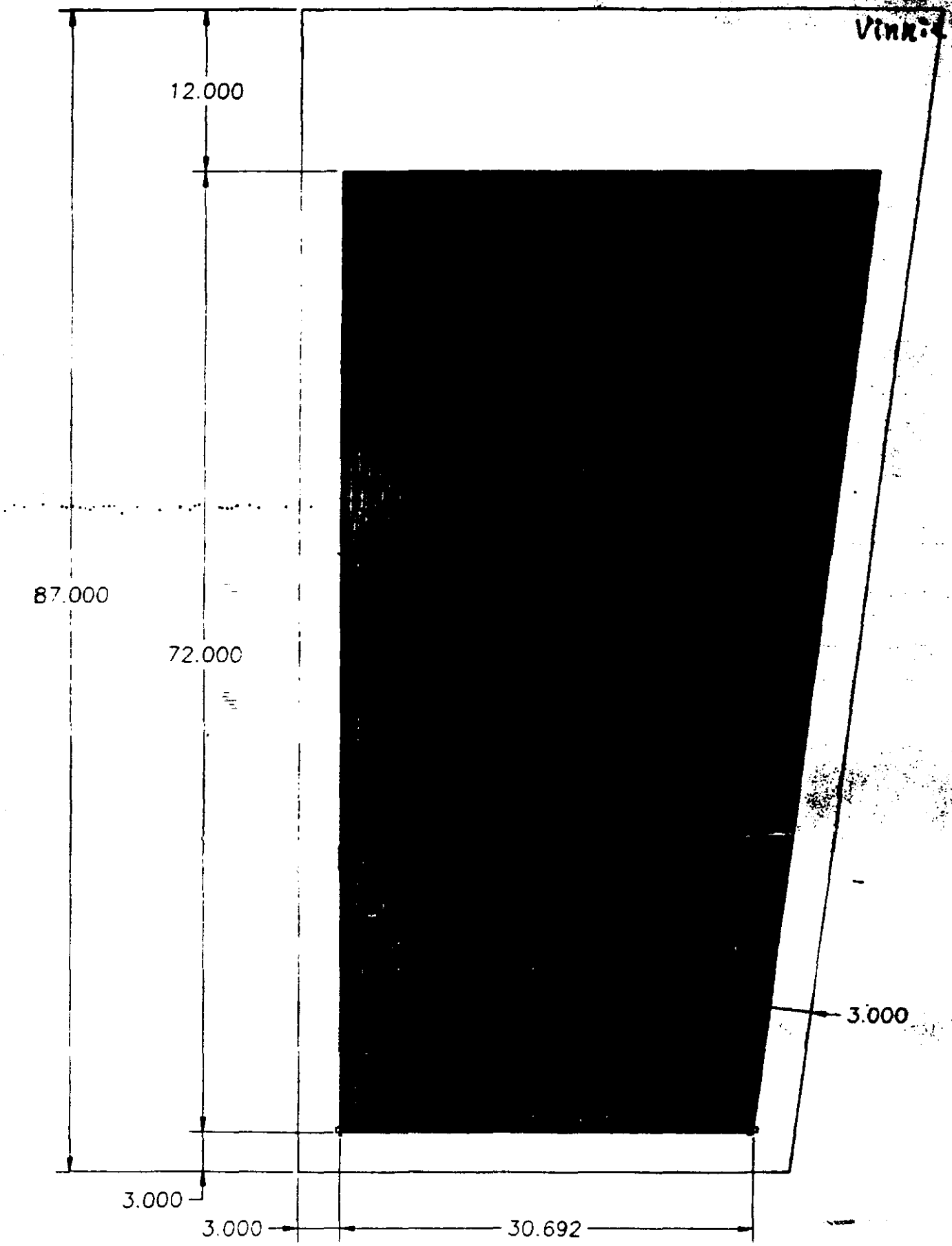
1. Beam cro[illegible]
2. Muon trig[illegible]
3. Z coordinate of [illegible]
4. Pattern recognit[illegible]

Amo[illegible]D [illegible] of:

1. Rise time [illegible]
2. Efficiency [illegible]
3. Gas (non-[illegible]le)
4. Noise an[illegible]
5. [illegible]
6. [illegible]
7. [illegible]

Cathode Strip chamber for TT

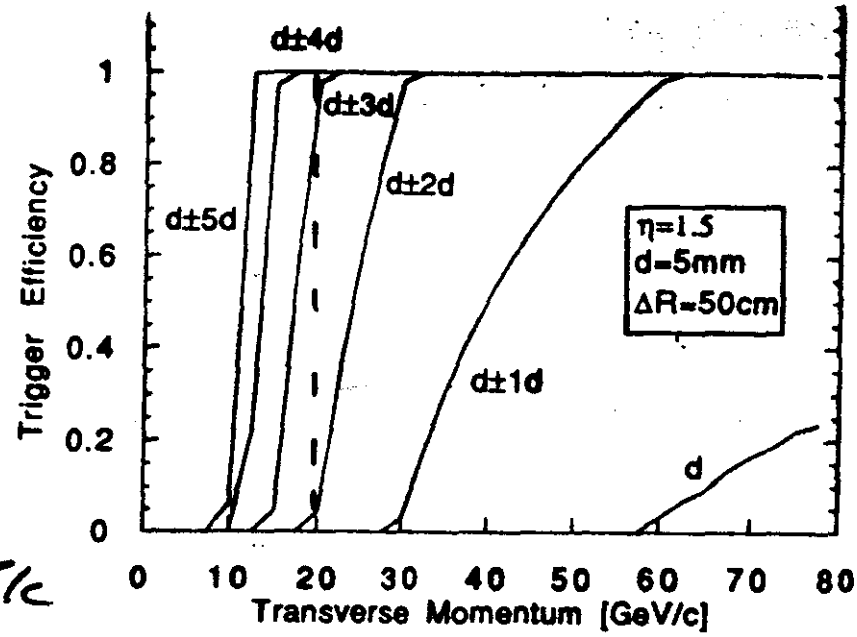
Vinkit Poly.



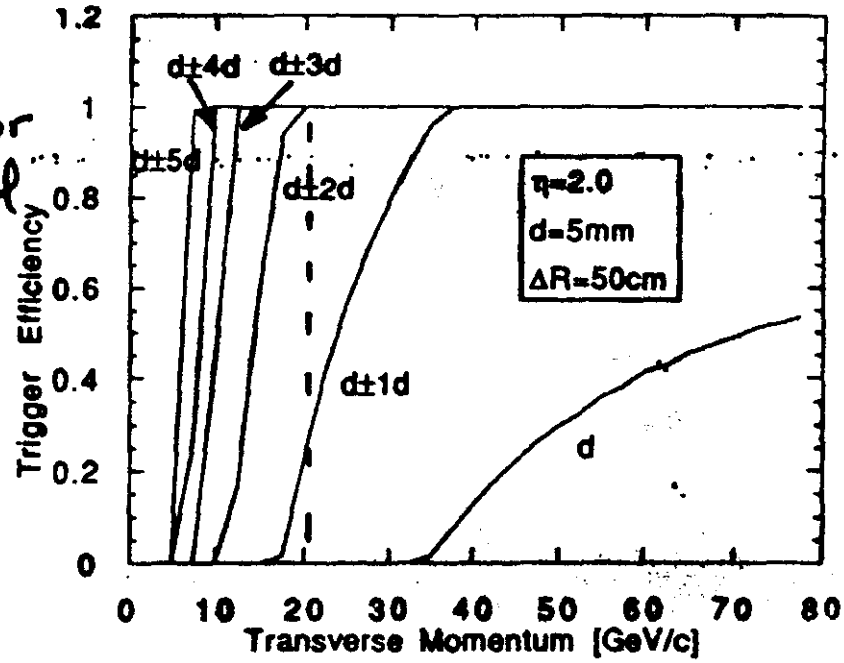
$P_\perp$ trigger in endcaps

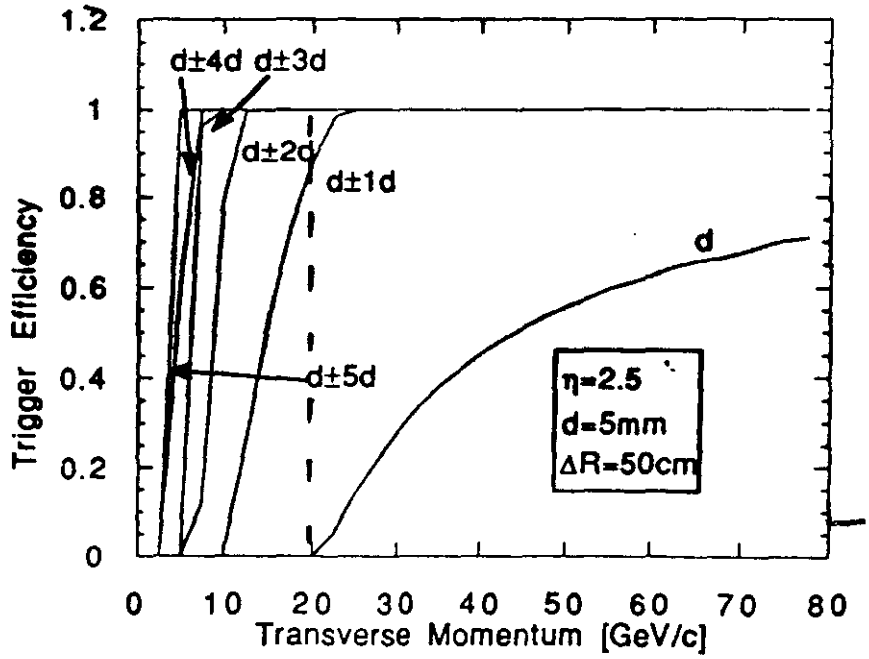
$\varepsilon \sim 100\%$

$P_\perp \geq 20$ GeV/c



Same studies under way for RPCs in barrel





Simulations of Trigger & Performance $\frac{\delta p_\perp}{p_\perp}$

- Active group formed
- Simulating various trigger options
  - segmentation of channels
  - what $p_\perp$ cuts are practical
- Simulation of hadron punch through
  - how thick for Calorimeter?
  - neutrons from GEANT
- Full field integrals for more realistic $\delta p_\perp / p_\perp$ studies
- Hit level simulation (δ-rays, etc.)

High Priority! Need guidance for design.

4:35 Bill Willis - Calorimeter

1. There are 3 pre-radiator configurations
   1) Silicon a la Brau
   2) Parallel plate LAR
   3) Accordion LAR

2. Forward calorimeter is more complex and needs much study

3. Assurance - the calorimeter group is sensitive to the hassle that changing the calorimeter configuration causes the muon group.

Trigger / Electronics Meeting

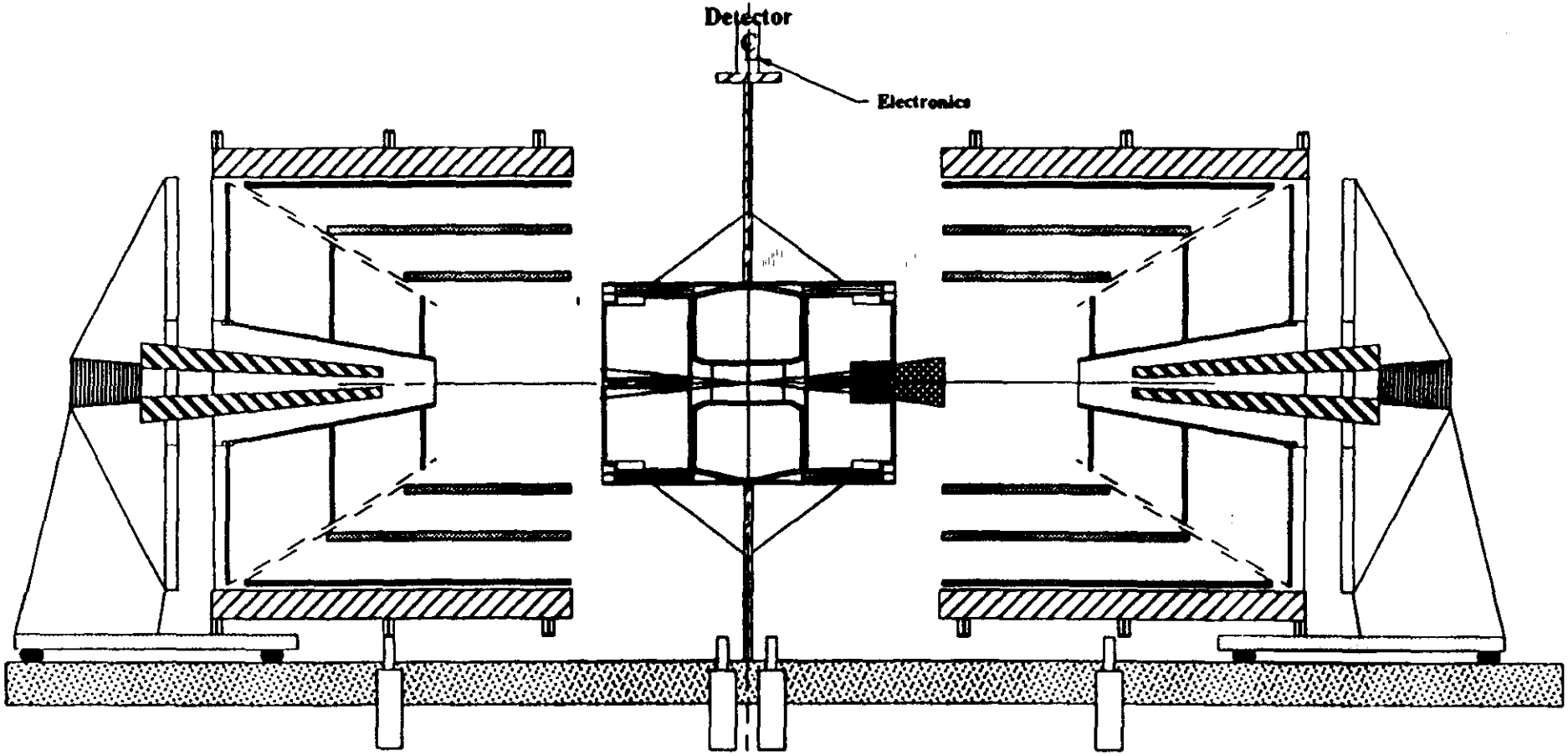
Fri. JAN. 24

- Review of Muon PAD Readout System
- Discussion of Silicon Tracker readout and possible use in trigger.
- Discussion of "DATAWAVE" array processor for Level 1 trigger.
- Reports of progress/plans for subgroups:
  - Tracker
  - Calorimeter
  - Muons
  - Trigger

1/22/92
JST

Status of GEM Muon System

- Integration with rest of GEM
- Specify new baseline design by 3/8/92
- Evaluation of Performance: $\delta P_\perp / P_\perp$
- Improvements of resolution
- R & D Efforts
- Simulations



GEM Configuration Option Study
Liquid Argon Calorimeter
Integral Calorimeter Version

G.03.AS.0003

EBERLE/RENNICH

Features:

- integral muon chamber support structure
- gap at $\eta \approx 0$
  acceptance loss?
  resolution loss?
- flux concentrator

Muon System

Baseline performance:

Sagitta measurement:

Barrel region ($\theta > 30^0$):

$$S = 0.3\ B\ \Delta R^2\ /\ 8P\mu\ \sin\theta$$

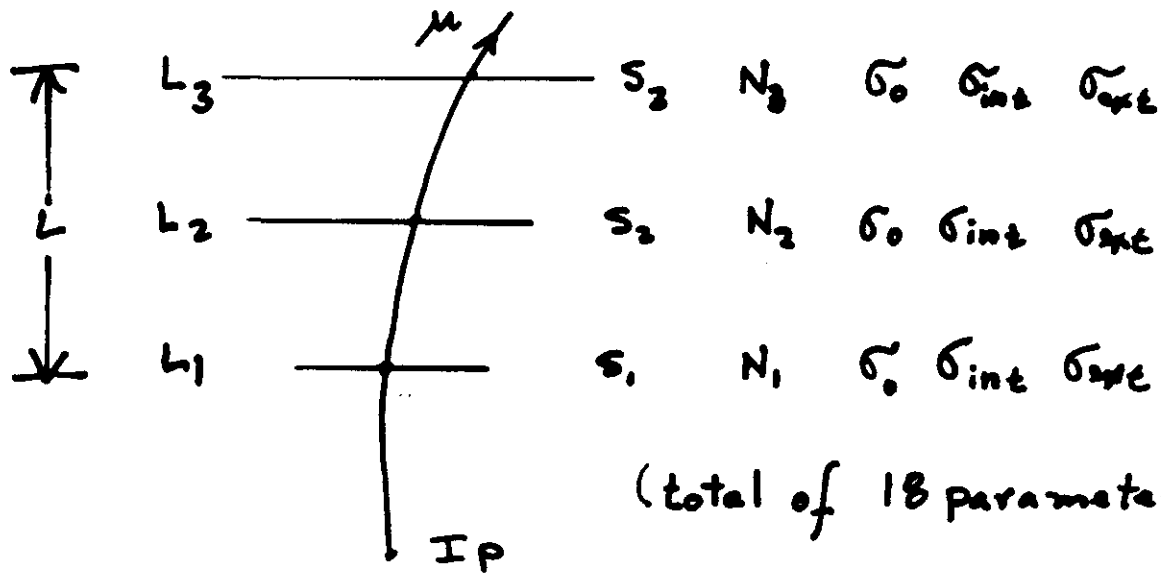
Endcap region ($30^0 > \theta > 9.5^0$):

$$S = 0.3\ B\ \Delta Z^2\ \tan\theta /\ 8P\mu\ \cos\theta$$

Momentum resolution depends on:

$P\mu$, $\theta\mu$	$\longrightarrow$	given
$B\Delta R^2$	$\longrightarrow$	wants to be large
ΔS	$\longrightarrow$	hit resolution alignment errors multiple scattering $\delta(\Delta E\mu)$ calorimeter

ΔS(errors):



(total of 18 parameters)

<u>barrel case</u>:

<u>Spatial errors</u>:

$$\sigma_{S_1}^2 = \sigma_{ext}^2 + (\sigma_{int}^2 + \sigma_0^2)/N_1$$

$$\sigma_{S_3}^2 = \sigma_{ext}^2 + (\sigma_{int}^2 + \sigma_0^2)/N_3$$

<u>m.s. error in lager 2</u>:

$$\sigma_{ms}^2 = (0.015\, L/\sin\theta_\mu)^2 X_{0plane} N_2/16\, \gamma_\mu^2 \sin\theta_\mu$$

<u>total error in lager 2</u>:

$$\sigma_{S_2}^2 = \sigma_{ext}^2 + (\sigma_{int}^2 + \sigma_0^2)/N_2 + \sigma_{ms}^2$$

<u>total sagitta error</u>:

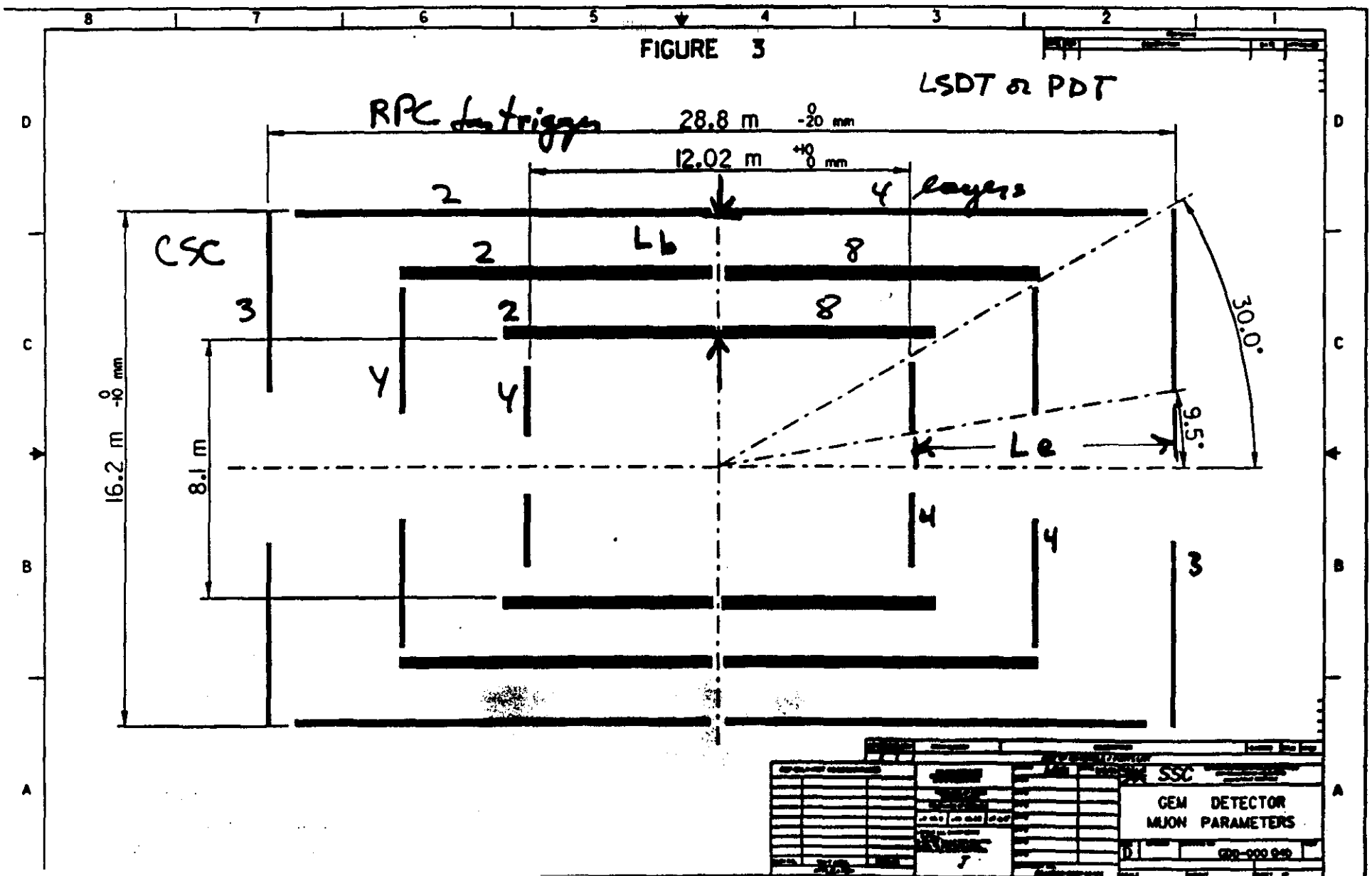
$$\sigma_s^2 = \sigma_{S_2}^2 + (\sigma_{S_1}^2 + \sigma_{S_3}^2)/4$$

Sagitta lever arms μ-chamber locations/configuration 1/8/92

Δ radius = 3.735 m

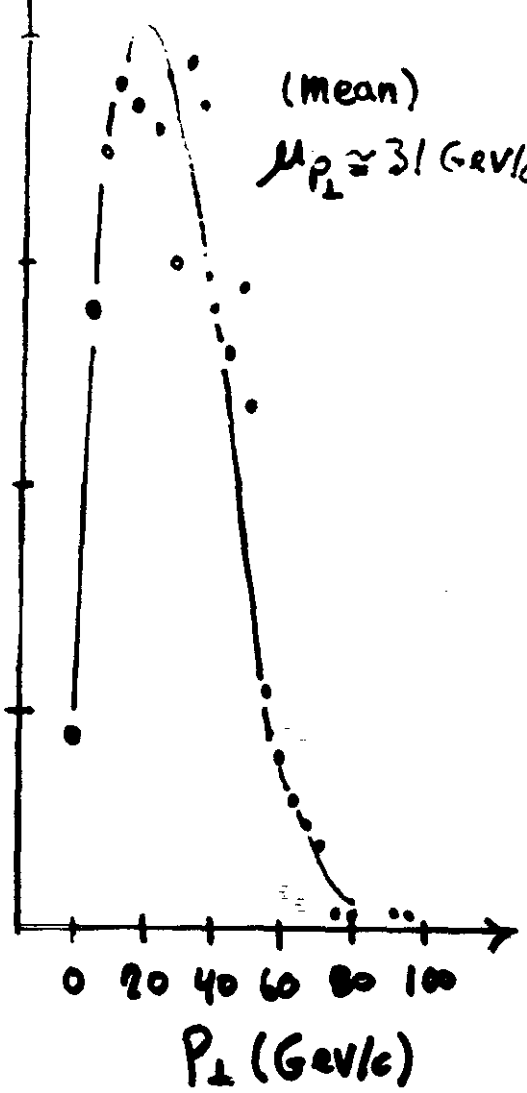
Z length = 7.94 m

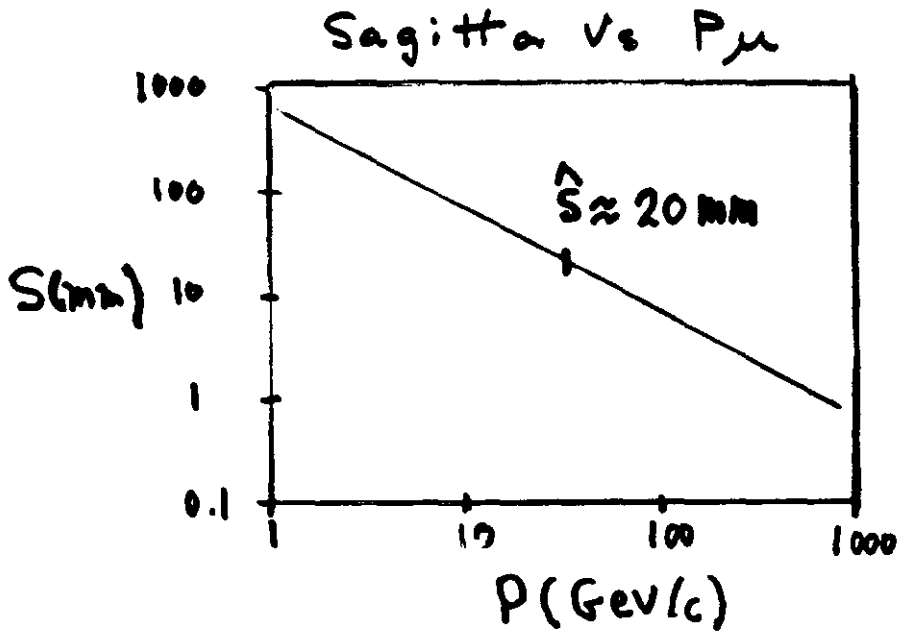
FIGURE 3



Typical Measurement Problem

- $H_0(140\ \mathrm{GeV}/c^2) \to \mu^+\mu^-\mu^+\mu^-$ ($\theta_\mu > 10°$, no P_{cuts})/Isajet





30 GeV/c $s = 20$ mm

100 GeV/c $s \cong 6$ mm

500 GeV/c $s \cong 1$ mm

LOI

Table 2.3-1 Configuration of GEM Muon System

Dimensions of system:		Sagitta lever arms
Length of magnet		29 m
Inside diameter of magnet	length	16.6 m
Uniform magnetic field		0.8 T
Calorimeter length	9.5 m	10 m
Calorimeter diameter		8 m
Calorimeter thickness at 90 degrees		12 λ
General characteristics of muon chambers:		
Intrinsic single layer resolution		100 μm
Layer-to-layer within a superlayer		25 μm
Superlayer-to-superlayer		50 μm
Global alignment systematics		200 μm
An 8 layer superlayer is <10% X_o		
Barrel region:		
Angle region: 30° to 90° ($1.32>\eta>0$)		
For momentum reconstruction and Level. 2 trigger:		
Three superlayers:	Bend plane	8-8-4 layers
	Nonbend plane	2-4-4 layers
Channel segmentation		3 cm
Channel count:	Bend plane	133 k
	Nonbend plane	25 k
For Level 1 trigger:		
Three superlayers:	Bend plane	2-2-2 layers
	Nonbend plane	2-2-2 layers
Channel count:	Bend plane	18 k
	Nonbend plane	21 k
Endcaps:		
Angle region: 10° to 30° ($2.44>\eta>1.32$)		
For momentum reconstruction and Level 1 & 2 trigger:		
Three superlayers:	Bend plane	4-4-3 layers
	Nonbend plane	2-2-2 layers
Channel segmentation		5 mm
Channel count:	Bend plane	231 k
	Nonbend plane	21 k

radius 4.3m

1/20/92

Summary of versions of GEM μ-System

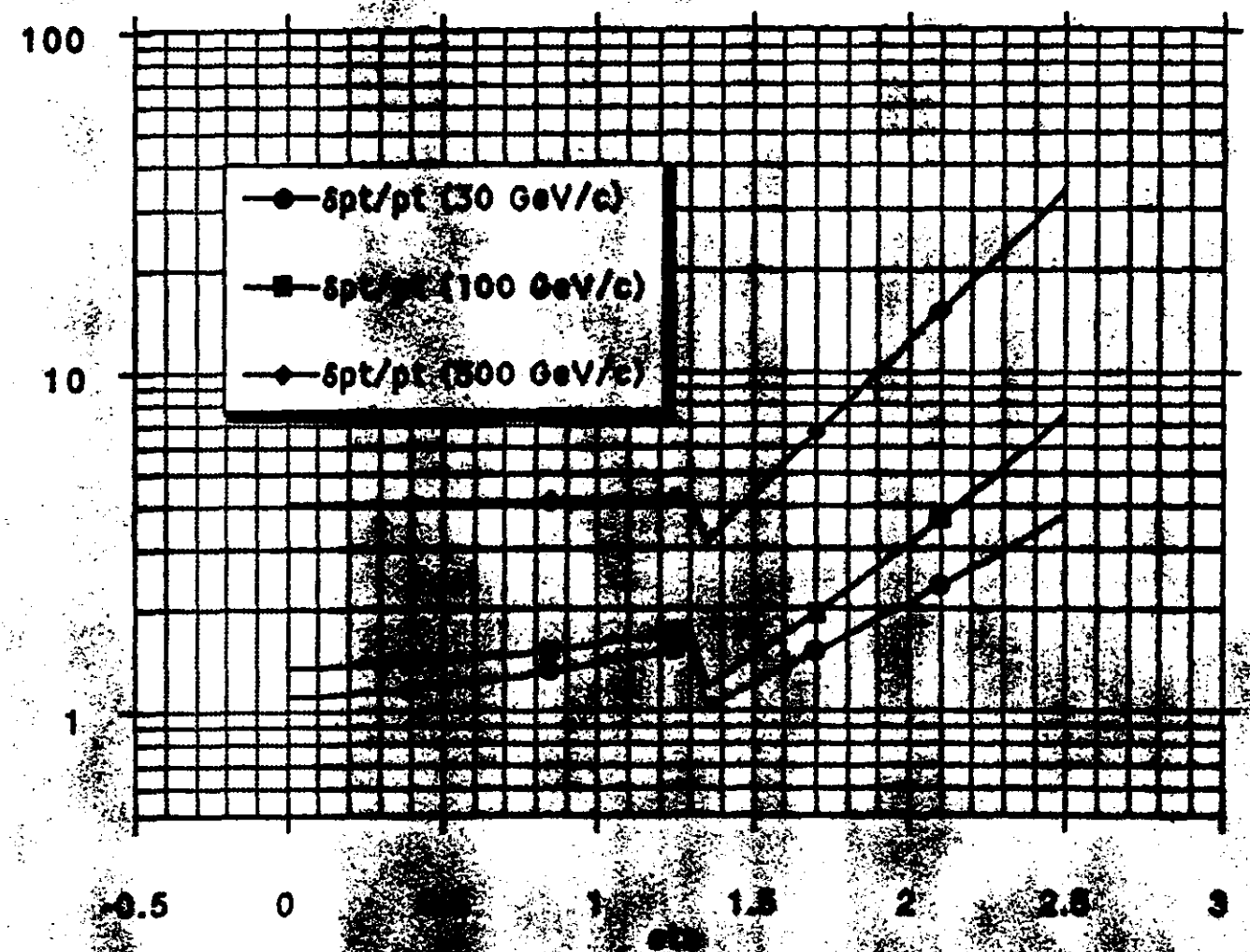
B=0.8 T Uniform

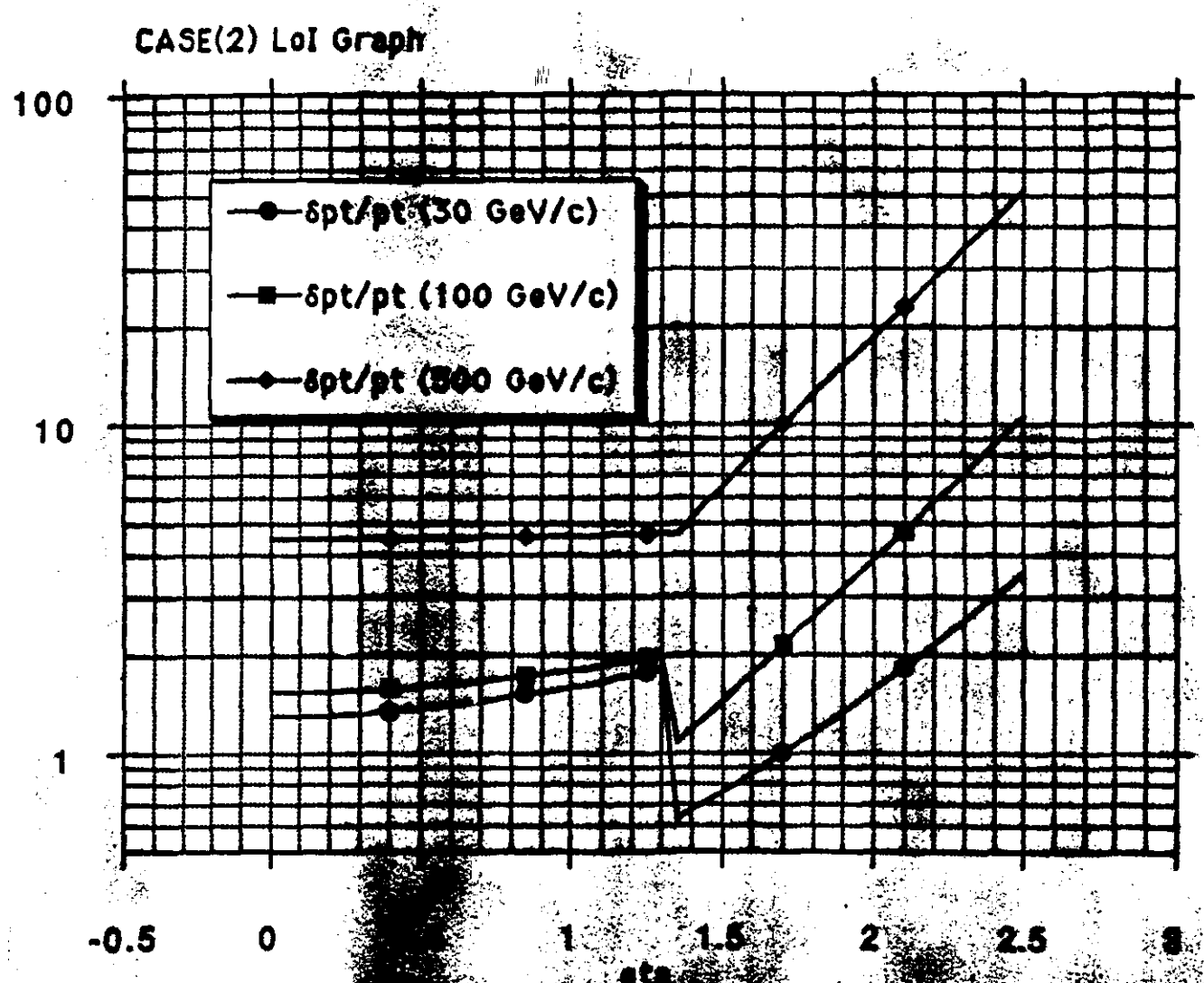
Chambers	L	σ0	σext	σint	X0/plane
(1) August 1991 Baseline:					
8-16-8	4.6 m	100μm	25μm	50μm	0.01
8-16-8	9.5 m	100μm	25μm	50μm	0.01
(2) Parameters for graph of LoI:					
8-16-8	4.4 m	100μm	25μm	50μm	0.0125
4-4-3	9.5 m	100μm	25μm	50μm	0.0125
(3) Parameters in Table of LoI:					
8-8-4	4.3 m	100μm	50μm	25μm	0.0125
4-4-3	9.5 m	100μm	50μm	25μm	0.0125
(4) Parameters used in Higgs resolution study 1/15/92:					
8-8-4	4.0 m	100μm	25μm	50μm	[illegible]
4-4-3	8.0 m	75μm	25μm	50μm	0.01
(5) New Baseline 1/28/92 per GDD-000-040 drawing:					
8-8-4	3.735 m	100μm	50μm	25μm	0.014
4-4-3	7.94 m	75μm	50μm	25μm	0.011
(6) Recoup of LoI 1/20/92:					
8-16-8	4.2 m	100μm	25μm	50μm	0.014
4-4-3	9.0 m	50μm	25μm	50μm	0.011

Resolutions (dpt/pt in %)

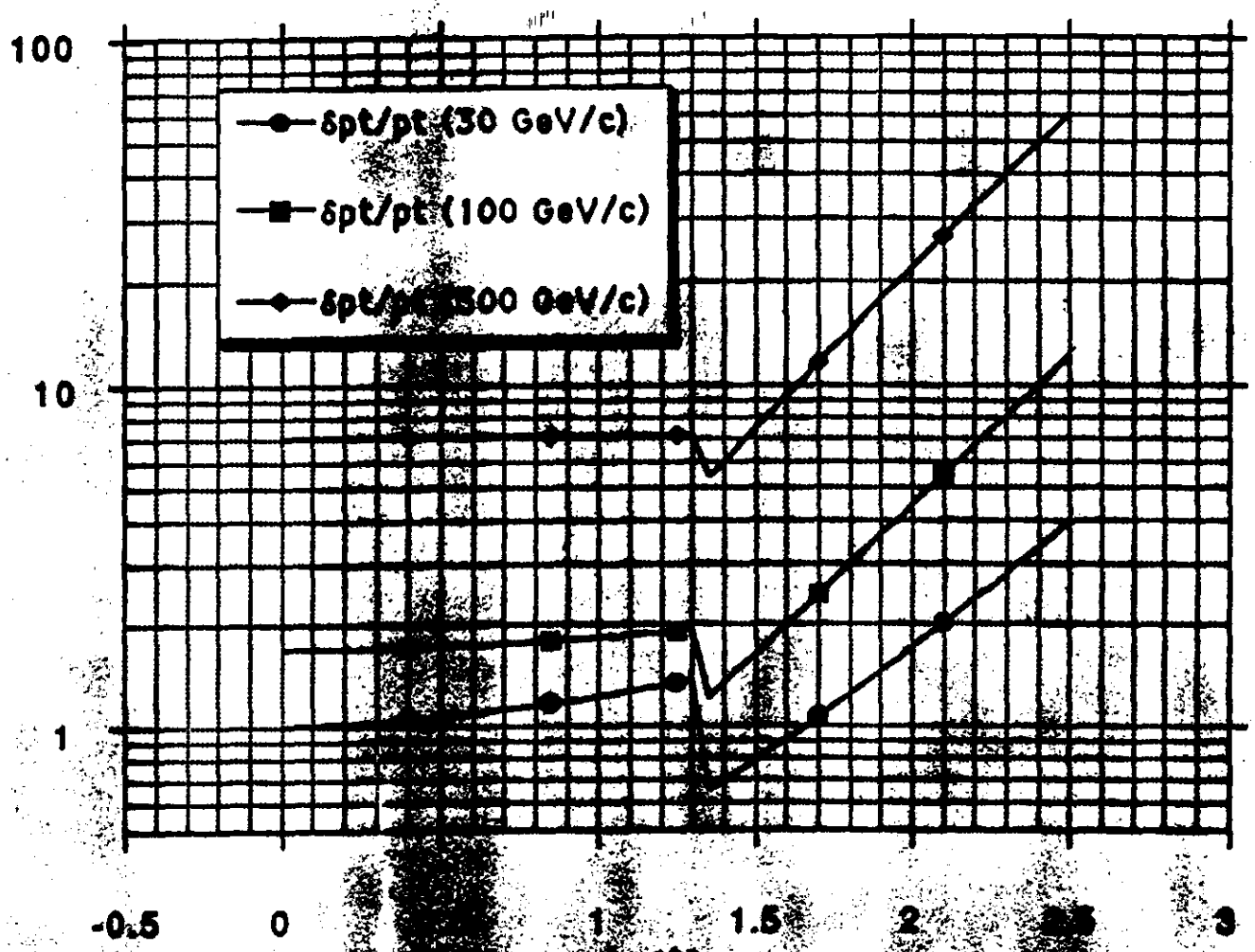
Pt (GeV/c)	eta values 0	1.32	2.5
(1) August 1991 Baseline:			
30	1.11	0.99	3.79
100	1.34	1.13	7.48
500	4.09	2.94	33.95
(2) LoI Graph parameters:			
30	1.30	0.86	3.59
100	1.53	1.01	10.53
500	4.49	4.29	51.89
(3) Parameters in Table of LoI:			
30	1.01	0.82	4.04
100	1.68	1.13	12.19
500	7.09	4.07	60.32
500 (JDS LoI B-field shape)	8.3	6.8	105
(4) Parameters used in Higgs 1/15/92 Study:			
30	0.96	0.86	4.15
100	1.64	1.17	12.43
500	6.37	5.16	61.47
(5) New Baseline 1/28/92:			
30	1.24	0.74	5.00
100	2.17	1.54	15.40
500	9.38	7.10	76.37
(6) Recoup of LoI 1/20/92:			
30	1.44	0.58	3.02
100	1.70	0.86	8.33
500	4.93	3.40	40.72

CASE (1) August 1991 Baseline

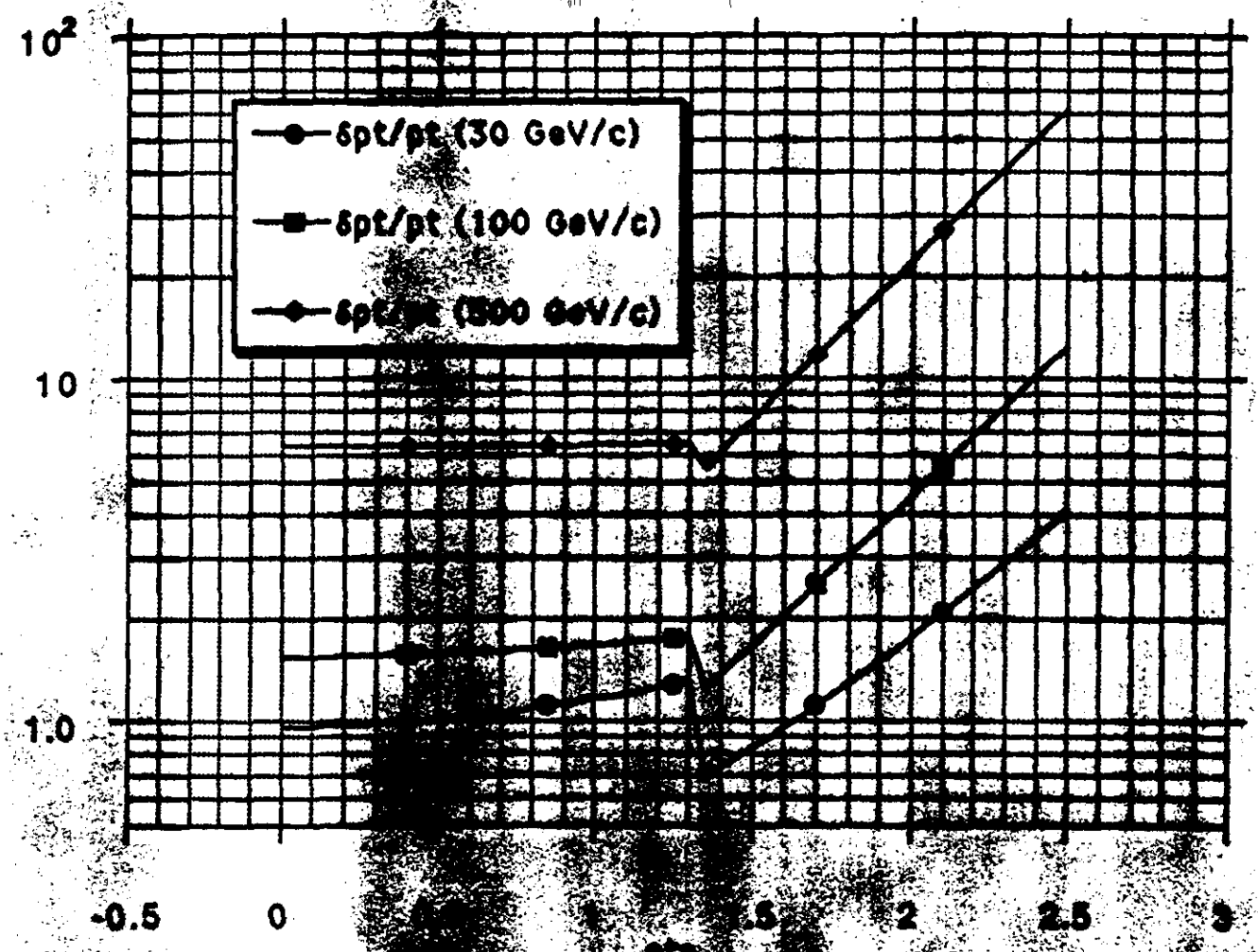



CASE(2) LoI Graph
100
10
1
δpt/pt (30 GeV/c)
δpt/pt (100 GeV/c)
δpt/pt (300 GeV/c)
-0.5
0
1
1.5
2
2.5
3
eta

CASE(3) Parameters for LoI Table



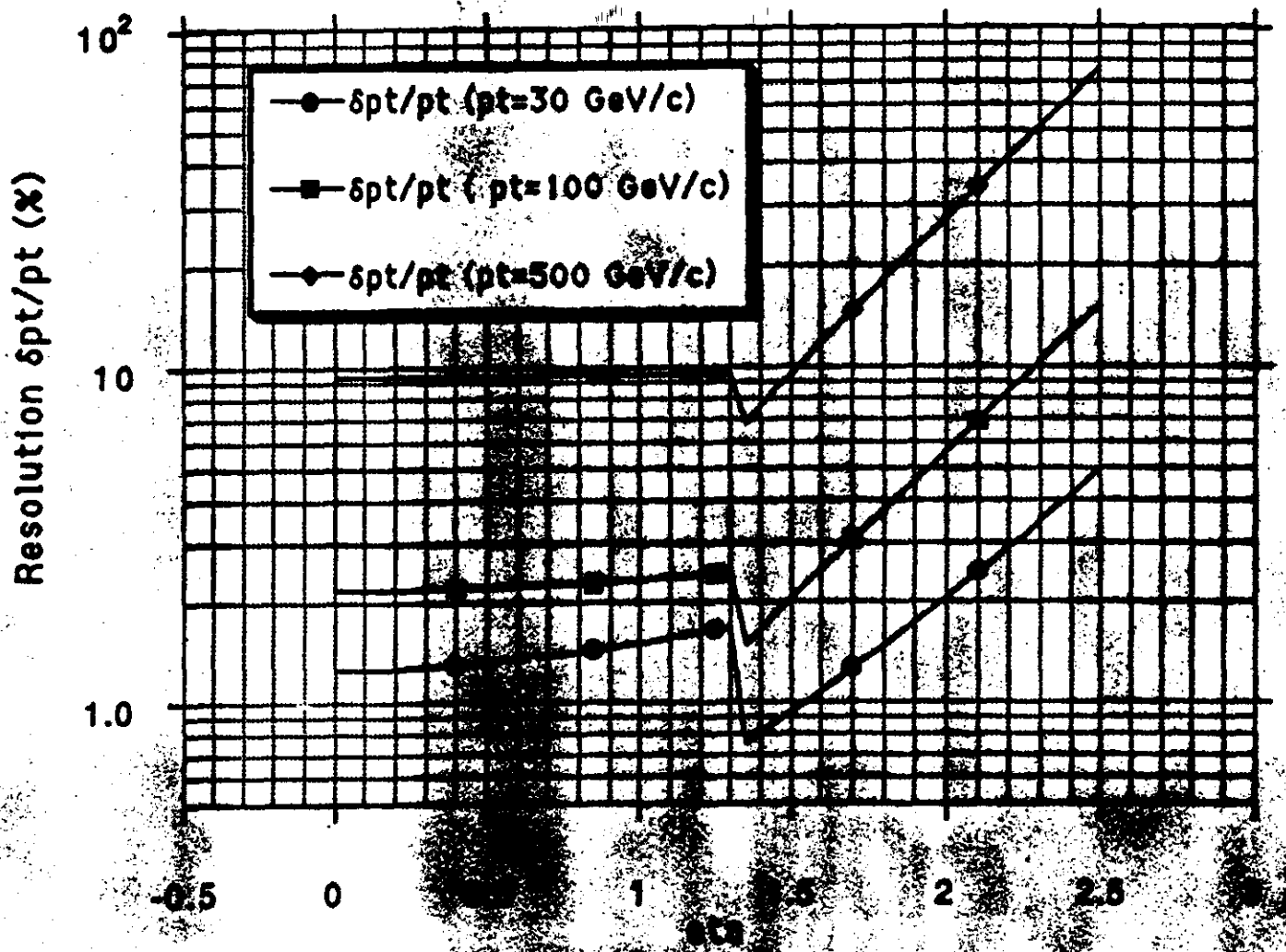
Case (4) Higgs Resolution Study



From 1/8/92 Eng./Coord. meeting

Case (5)

1/18/92



What is important?

- Explore parameter space around CASE (5)

B: 8-8-4 $L_b = 3.735\,m$ $\sigma_0 = 100\,\mu m$ $\sigma_{xb} = 50\,\mu$ $\sigma_{zb} = [illegible]$

EC: 4-4-3 $L_c = 7.94\,m$ $\sigma_0 = 75\,\mu m$ "

- Perform calculation for $\gamma\beta_\perp = 30, 100, 500$ Gauss

- Plot ratio $(\delta P_\perp / P_\perp)_{New} / (\ldots)_{old}$ vs η

Trigger / Electronics R&D WORK

- Analog Fiber Optics (Electro-optics Modulators)
  - Temp. stability (Probably ok)
  - Studying radiation effects
  - R&D Efforts
    - Light Source + Distribution ⇒ Fiber Amp.
    - Fiber Connections + handling
    - Modulator fab. with trimming

- ~~CCD Analog Memory System~~
  ~~(Backup to Switched Cap. Array)~~
  - R&D to be funded through ⇐ [illegible] Inc.
    SBIR grant from DOE

- BNL working on current source calibration system for calorimeter electronics
  - Question on clock + current distr. system

- Columbia developing new SCA design for GEM
  ⇒ Studying Berkeley chip
  Design and capabilities

- Working on Level 1, 1.5 Calorimeter trigger algorithm to reduce rate.
  ⇒ Bring in some isolation info. early

Trigger / Electronics Meeting

Fri. Jan. 24

- Review of Muon PAD Readout System
- Discussion of Silicon Tracker readout and possible use in trigger.
- Discussion of "DATAWAVE" array processor for Level 1 trigger.
- Reports of progress/plans for subgroups:
  - Tracker
  - Calorimeter
  - Muons
  - Trigger

Trigger / Electronics R&D Work

- Analog Fiber Optics (Electro-optics Modulators)
  - Temp. stability (Probably ok)
  - Studying radiation effects
  - R&D Efforts
    - Light Source + Distribution ⇒ Fiber Amp.
    - Fiber Connections + handling
    - Modulator fab. with trimming

- C.C.D. Analog Memory System
  (Backup to Switched Cap. Array)
  - R&D to be funded through ⇐ Q-Dot, Inc.
    SBIR grant from DOE

Small Business

- BNL working on current source calibration system for calorimeter electronics
  - Questions on clock + current distr. system

- Columbia developing new SCA design for GEM
  ⇒ Studying Berkeley chip
  Design and capabilities

- Working on Level 1, 1.5 Calorimeter trigger algorithm to reduce rate.
  ⇒ Bring in some isolation info. early

The detector and physics simulations should done in two stages: (1) full detector simulations and (2) physics simulations with parameterized detector responses.

I. Full Detector Simulations

Full simulations of each subsystem, or groups of subsystems, should be carried out to determine responses to the relevant individual "particle" stimuli (with the underlying event included). These simulations should cover the full rapidity range of the subsystem and the expected dynamic range for new physics and their backgrounds. As a *tentative* example, I offer the following table (subsystems are denoted by: TR (trigger/DAQ), CT (central tracker), ECAL (EM calorimeter), HCAL (hadron calorimeter), MUON, and F/B (forward / backward calorimetry)).

particle/jet	η_{max}	E_T range	Subsystem
γ	2.5	10 GeV – 1 TeV	CT, ECAL, HCAL, TR
e	2.5	10 GeV – 5 TeV	CT, ECAL, HCAL, TR
μ	2.5	10 GeV – 5 TeV	CT, MUON, HCAL, TR
jet	3.0	50 GeV – 6 TeV	ECAL, HCAL, TR
$b \to \mu$	2.5	50 – 500 GeV	CT, E/HCAL, MUON
$\tau \to \nu\pi$'s	2.5	50 – 500 GeV	CT, E/HCAL
$\not{E}_T$ (jets, $\ell\nu$)	5.0	50 GeV – 1 TeV	E/HCAL, F/B

One of our tasks right now is to prepare a COMPLETE table along these (or better) lines.

Then, we have to do the following:

A. First Priority Processes to Determine GEM Capabilities

1. $H^0 \to \gamma\gamma$ ($M_H \simeq 100\,\mathrm{GeV}$)
   — tests CT, ECAL, (HCAL), TR.

2. $H^0 \to e^+e^-e^+e^-$ ($M_H \simeq 150 - 400\,\mathrm{GeV}$)
   — tests CT, ECAL, (HCAL), TR.

3. $H^0 \to \mu^+\mu^-\mu^+\mu^-$ ($M_H \simeq 150 - 400\,\mathrm{GeV}$)
   — tests CT, MUON, TR.

4. $H^0 \to \ell^+\ell^-$ jet jet, $\ell^\pm = e^\pm$ or $\mu^\pm$ ($M_H = 800\,\mathrm{GeV}$)
   — tests CT, ECAL/MUON, HCAL, TR.

5. $H^0 \to \ell^+\ell^-\nu\bar{\nu}$, $\ell^\pm = e^\pm$ or $\mu^\pm$ ($M_H = 800\,\mathrm{GeV}$)
   — tests CT, ECAL/MUON, F/B, TR.

6. Leptoquark pair-production and decay, $\mathcal{G}\mathcal{G} \to \pi_{LQ}\pi_{\bar{Q}L} \to b\tau^+\bar{b}\tau^-$
   — tests CT, MUON, HCAL, F/B, TR.

7. Quark substructure in high-p_T and invariant mass jet production (deviation from QCD cross sections at $p_T \gtrsim 4\,\mathrm{TeV}$)
   — tests ECAL, HCAL, TR.

8. Quark/lepton substructure in $\bar{q}q \to \mu^+\mu^-$ at high invariant mass (a deviation from the Drell-Yan cross section at $\mathcal{M} \gtrsim 2\,\mathrm{TeV}$) and ultrahigh luminosity, $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. Determination of the chiral structure of the contact interactions and the reach in the substructure scale, Λ
   — tests CT, MUON, (ECAL, HCAL), TR.

9. $Z'^0 \to \ell^+\ell^-$, with $\ell^\pm = e^\pm, \mu^\pm$. Precision measurements of mass, width (via e^+e^-) and asymmetries (via $\mu^+\mu^-$); determination of the reach in $M_{Z'}$. Detector performance at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
   — tests CT, ECAL, HCAL, MUON.

10. Gluino pair production via the $\not{E}_T$ and and likesign-dilepton signatures
    — tests F/B, E/HCAL, CT, MUON.

Superconducting Super Collider Laboratory

Physics Research Division
2550 Beckleymeade Avenue
Mail Stop 2001
Dallas, TX 75237-3946
(214) 708-6113• FAX (214) 708-0006

January 17, 1992

Professor James Reidy
University of Mississippi
Department of Physics & Astronomy
University, MS 38677

Dear Professor Reidy,

Thank you for your progress report on your FY1991 effort under SSC Detector Subsystem R&D proposal number 247 and your new proposal for FY1992 on "Liquid Scintillator Calorimetry," to which we have assigned the number 30400.

The SSC Detector Subsystem R&D Committee met on October 18 - 19 and December 3 - 4, 1991 in Dallas and reviewed your proposal along with a number of others. This year the great majority of detector R&D support will be allocated within the overall engineering and R&D plans of the GEM and SDC detectors. Very limited funding is available for a number of interesting proposals that fall outside the plans of the major detectors. The Committee was directed to set priorities, and the Laboratory is able to fund only the highest priority projects. In your case, this means funding only to complete the tests you have planned.

We would like to pass on a summary of the Committee's comments, as being possibly helpful to your future work. The Committee felt that the potentially superior radiation hardness of liquid as compared to plastic scintillator calorimetry depended on demonstrating a readout method. It is encouraging that you have identified compatible liquid scintillator-wavelength shifting fiber combinations. However the data presented on radiation tests of WLS fiber was disappointing, and the cell uniformity appeared poor.

Please submit a budget for completion of existing tasks (beam tests at ITEP and possibly radiation damage tests) in which funds are divided into operating and equipment categories for each task at each institution. The budget should be sent to Ken McFarlane, and will be the first step in preparing a Memorandum of Understanding. We encourage you also to find other sources of funds to support your effort.

Regards,

Fred Gilman

FG:ct

cc: Roy Schwitters
K.McFarlane
H. H. Williams, Univ. of Penn.
N. Lockyer, Univ. of Penn.
G. Haas, DOE
R. Diebold, DOE
Central Files

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