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GEM TN-92-110

Barium Fluoride Calorimeter Meeting - SSCL

June 5, 1992

Abstract:

Agenda, attendees, and transparencies of the GEM Barium Fluoride Calorimeter Meeting held at the SSC Laboratory on June 5, 1992. Agenda items included: Introduction; Calorimeter System Engineering Overview; GEM Engineering Integration Issues and Schedules; BaF2 Progress in China; LLNL R&D Progress; Discussion of BaF2 Detector Production Scenario; Scintillating Fiber HCAL Design and Test Status; Discussion of BaF2 and SSCintCal Engineering and GEM Detector Issues; BaF2 R&D and Options for Crystal Production and Test in Russia; BaF2 Radiation Damage Studies (U.S.); Discussion: Work Plan and Milestones for the GEM Decision, and TDR; Preliminary Discussion of R&D Needs for FY93, and Test Beam; Test with Hadron and the AGS and LAMPF in June; Cosmic Ray and UV Monitor Test Setups at UCSD and CMU; and Progress and Plans on BaF2 Simulation: Fast Simulation, Detector Calibration.

BARIUM FLUORIDE CALORIMETER MEETING

Agenda -- June 5, 1992

8:30	Introduction	H. Newman
8:45	Calorimeter System Engineering Overview	M. Rennich, J. Heck
9:15	GEM Engineering Integration Issues and Schedules	M. Harris
9:30	BaF2 Progress In China:	
	(a) Crystal R&D at SIC, BGRI, Tongji	R. Zhu
	(b) Prototype (25 Crystal Pair) Design and Manufacture	J. Heck
	(c) Schedule and Plans for Prototype Crystal Deliveries (25 + 5 Pairs)	R. Zhu
	(d) BaF2 Detector Production	R. Zhu J. Heck
10:30	BREAK	
10:45	LLNL R&D Progress	C. Wuest
	(a) Crystal Cutting, Polishing, Coating; Manufacturing Process Design	
	(b) June China Trip (Fuchs, Wuest)	
	(c) High Purity Crystal Growth at LLNL	

BARIUM FLUORIDE

June 5 Meeting

Agenda -- II

11:10	Discussion of BaF2 Detector Production Scenario (China and U.S.)	R. Zhu
11:25	Scintillating Fiber HCAL Design and Test Status	L. Sulak (TBC)
11:45	Discussion of BaF2 and SSCintCal Engineering and GEM Detector Issues	M. Harris M. Rennich
12:15	LUNCH	
13:00	Discussion of Engineering and General GEM Detector Issues (Cont'd)	M. Harris M. Rennich
14:00	BaF2 R&D and Options for Crystal Production and Test in Russia	Y. Kamyshkov
14:15	BaF2 Radiation Damage Studies (U.S.): (a) Fast Neutron Tests at Univ. Lowell (b) Materials Studies at Charles Evans	 H. Newman
14:30	Discussion: Work Plan and Milestones for the GEM Decision, and TDR	H. Newman, Y. Kamyshkov
15:30	BREAK	

BARIUM FLUORIDE

June 5 Meeting

Agenda -- III

15:45	Preliminary Discussion of R&D Needs for FY93, and Test Beam	H. Newman, H. Kobrak
16:10	Tests With Hadrons at the AGS and LAMPF in June	X. Shi
16:20	Cosmic Ray and UV Monitor Test Setups at UCSD and CMU	H. Kobrak, H. Vogel
16:40	Progress and Plans on BaF2 Simulation: Fast Simulation, Detector Calibration	X. Shi
17:00	ADJOURN	

B&F2 MEETING JUNE 5/92

H. NEWMAN	CAL TECH
R. ZHU	" "
H. KOBRAK	UC SAN DIEGO
X. SHI	CAL TECH
R. REID	BOSTON U.
L. SULAK	" "
H. COHN	ORNL
R. WEBB	TEXAS A&M
Y. EFREMENKO	ORNL/UT/ITEP
M. HARRIS	SSC
Y. KAMYSHKOV	ORNL/UT/ITEP
K. SHMAKOV	ORNL/UT/ITEP
K. YOUNG	ORNL
C. EBERLE	ORNL/SSC
M. RENNICH	ORNL
C. WUEST	LLNL
M. JAHAN	Memphis State
N. GOBER	SSCL
A. GOBER	SSCL (SUMMER)
H. VOGEL	CMU

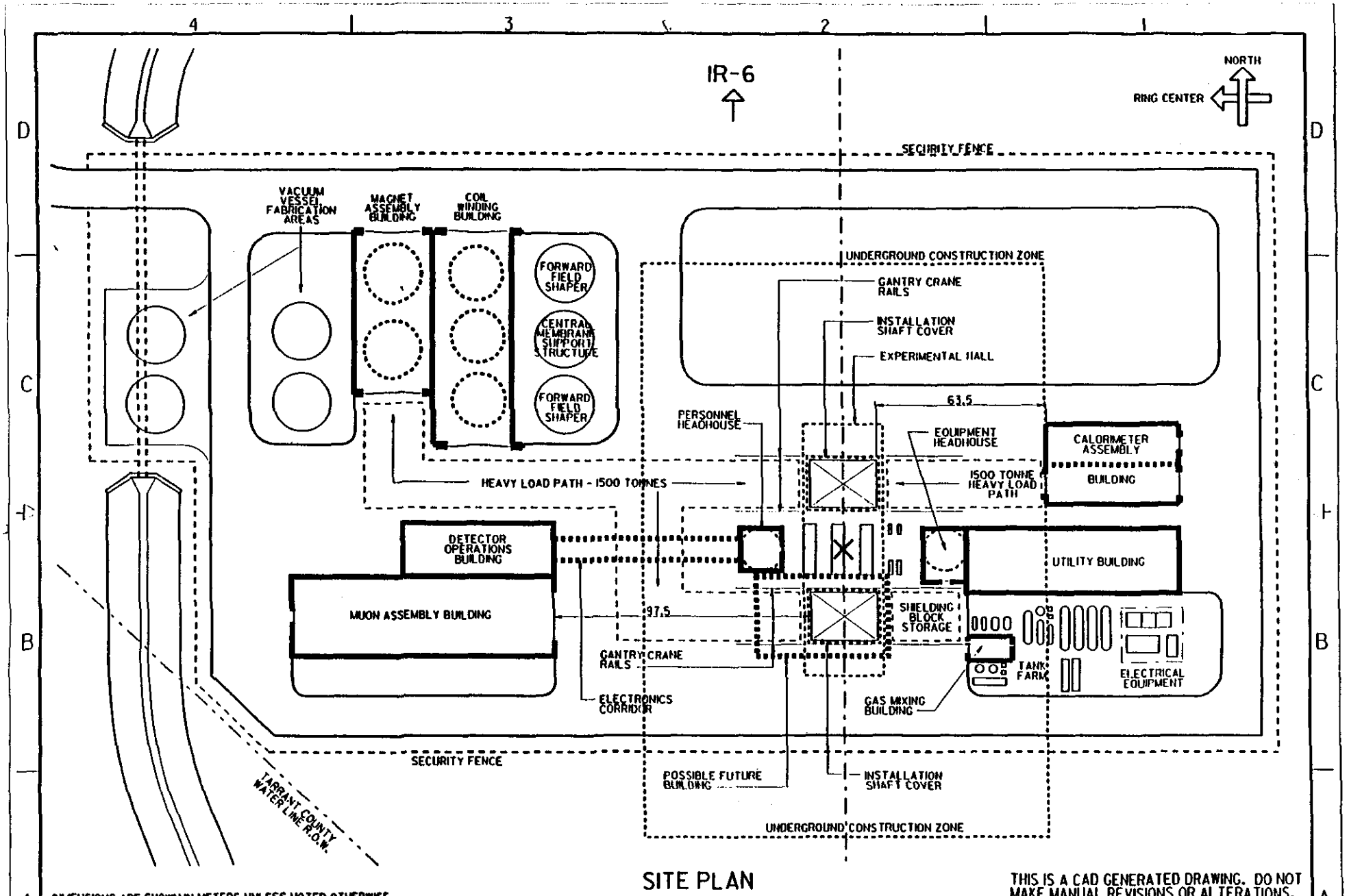
Presented by:

Mike Harris

Schedule Milestones

1	PAC 10/11	July, 1992
2.	Calorimeter choice	August, 1992
3.	Title 1 of Facilities Starts	September, 1992
4.	TDR	October, 1992
5	DOE Review	November, 1992
6	Facility Available	September, 1995
7.	Installation	October, 1997

MH 6/5/92



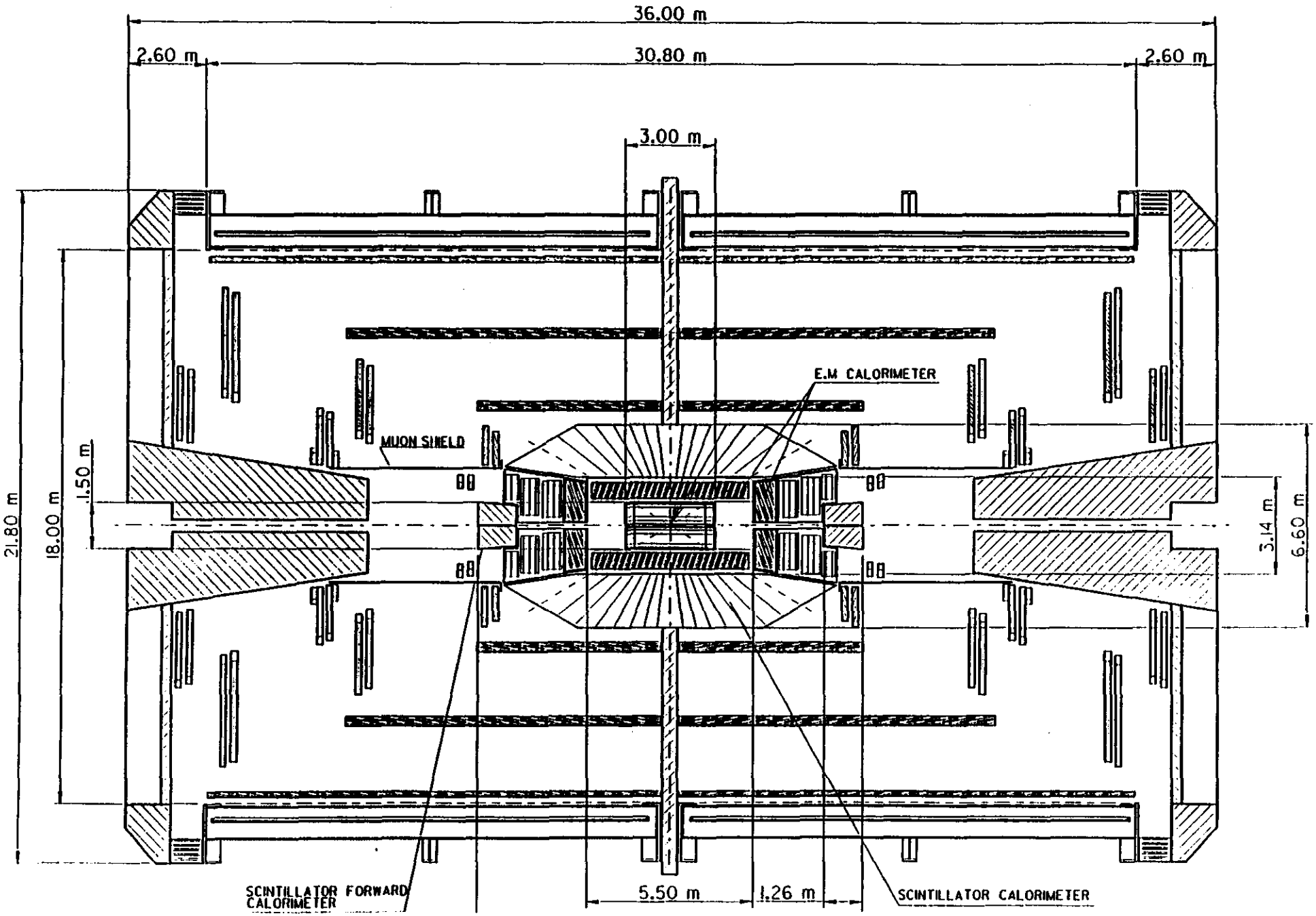
SITE PLAN

DIMENSIONS ARE SHOWN IN METERS UNLESS NOTED OTHERWISE.

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

R. HAWKES	T. PROSAPIO	PHYSICS RESEARCH DIVISION	SSC
CONTRACT NUMBER DE-AC35-89ER40486	GEM EXPERIMENTAL FACILITIES	IR-5 SITE PLAN	SCALE NONE · DATE 5-5-92 · SIZE C · PROJECT NUMBER · DRAWING NUMBER GCD-000143 · REVISION A02 · SHEET 1 OF 1

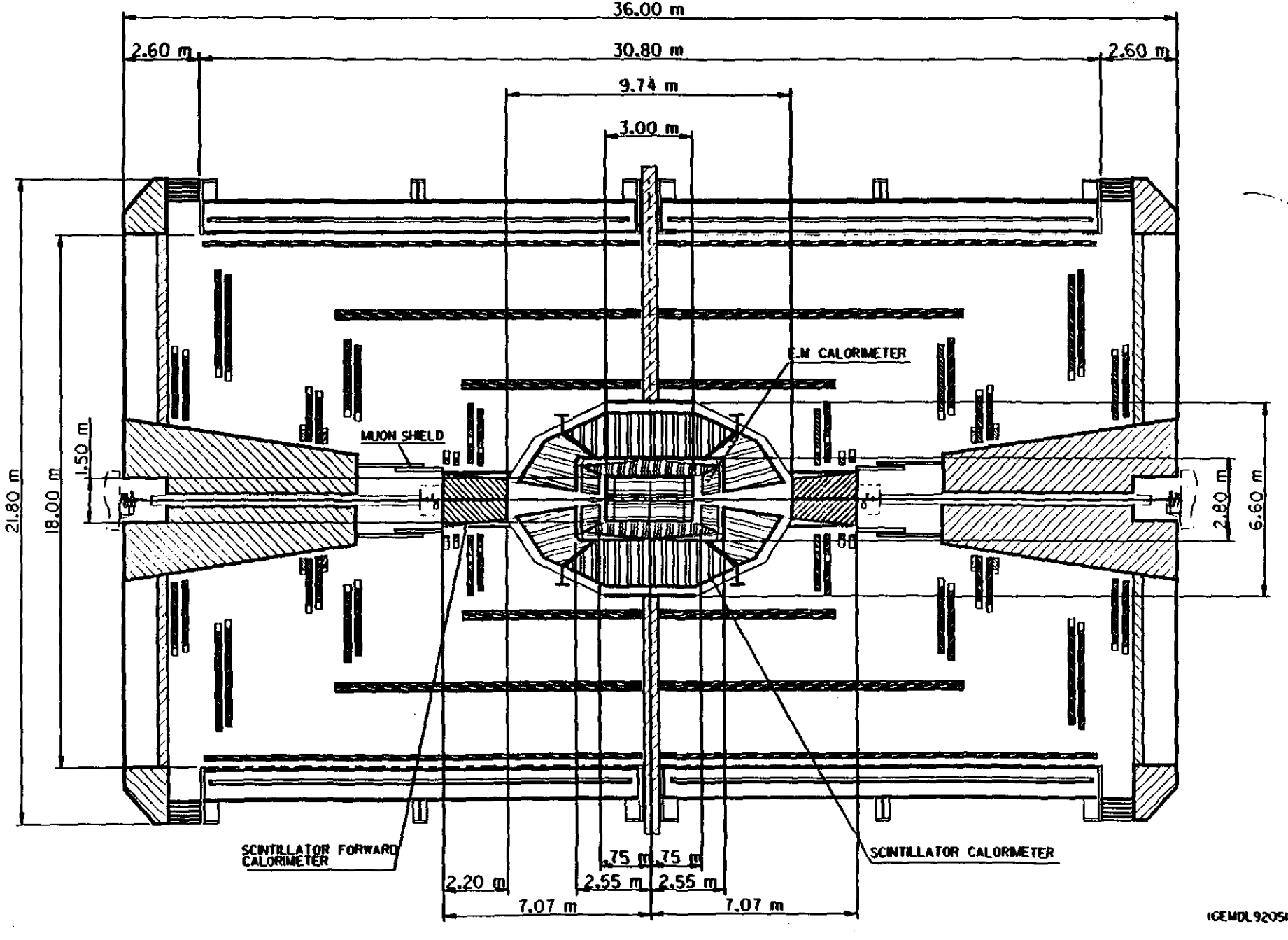
GEM DETECTOR LAYOUT
WITH SCINTILLATOR CALORIMETER



Presented by:

Mark Rennich

GEM DETECTOR LAYOUT
WITH SCINTILLATOR CALORIMETER
OPTION I



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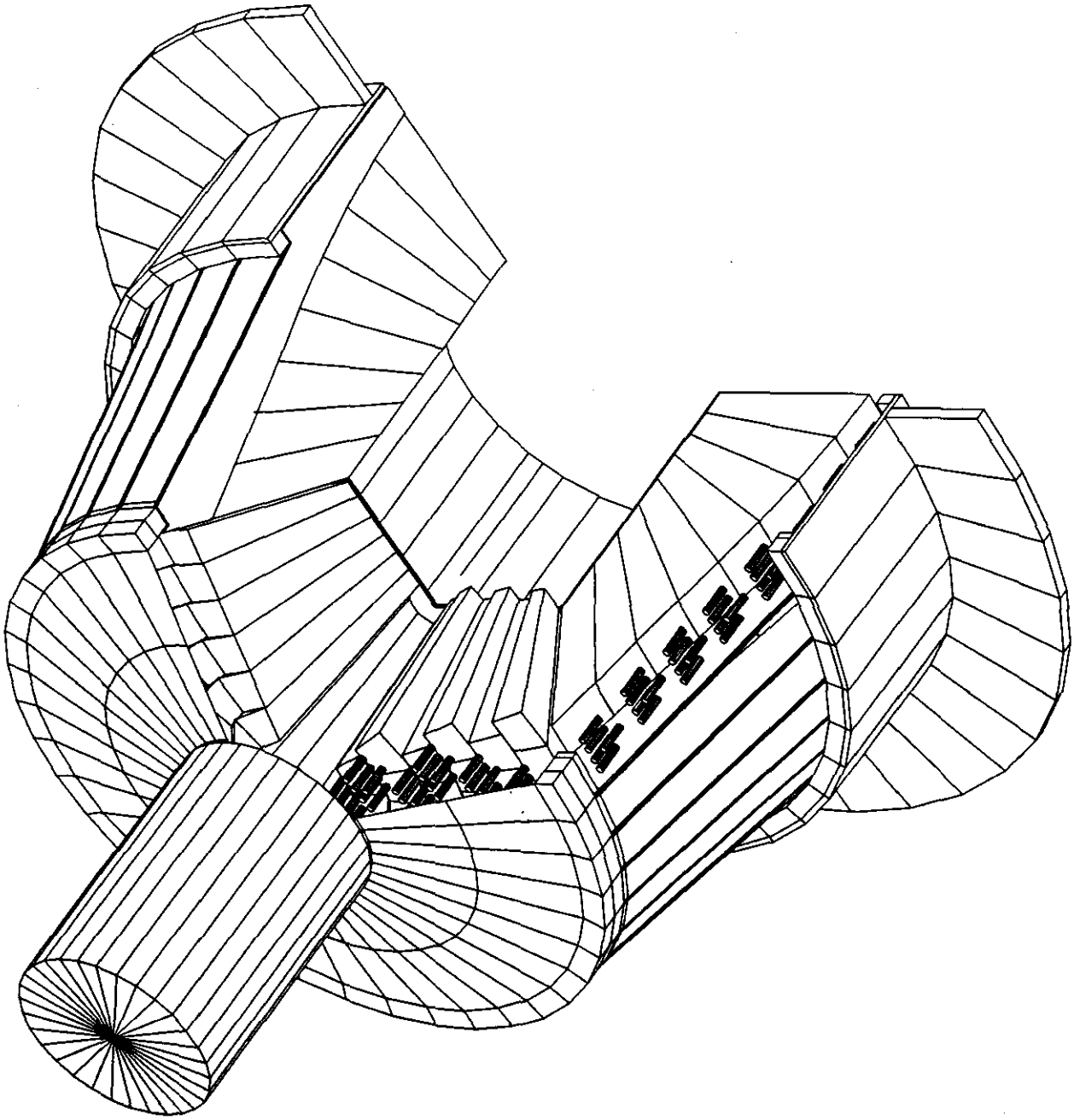

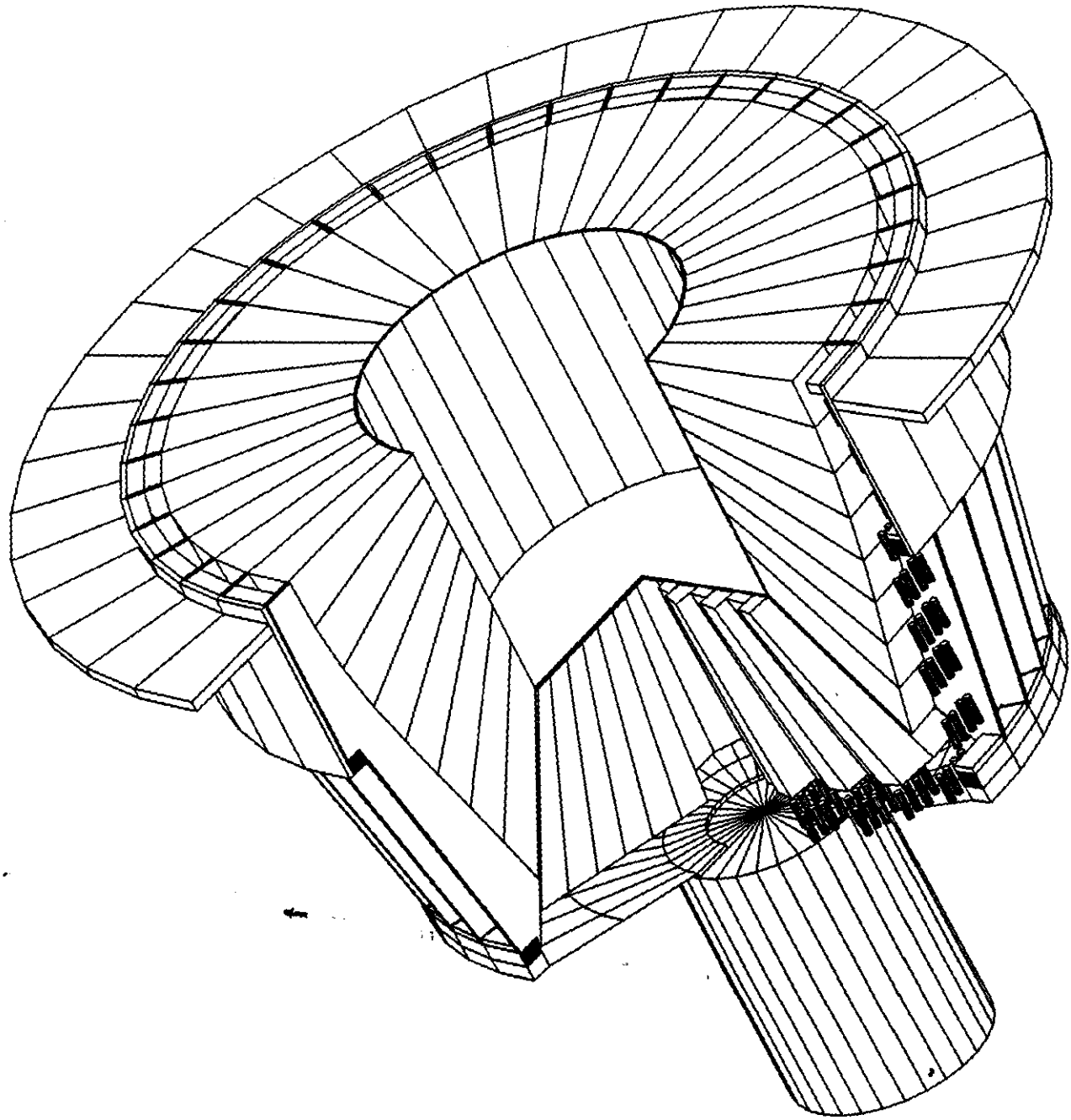

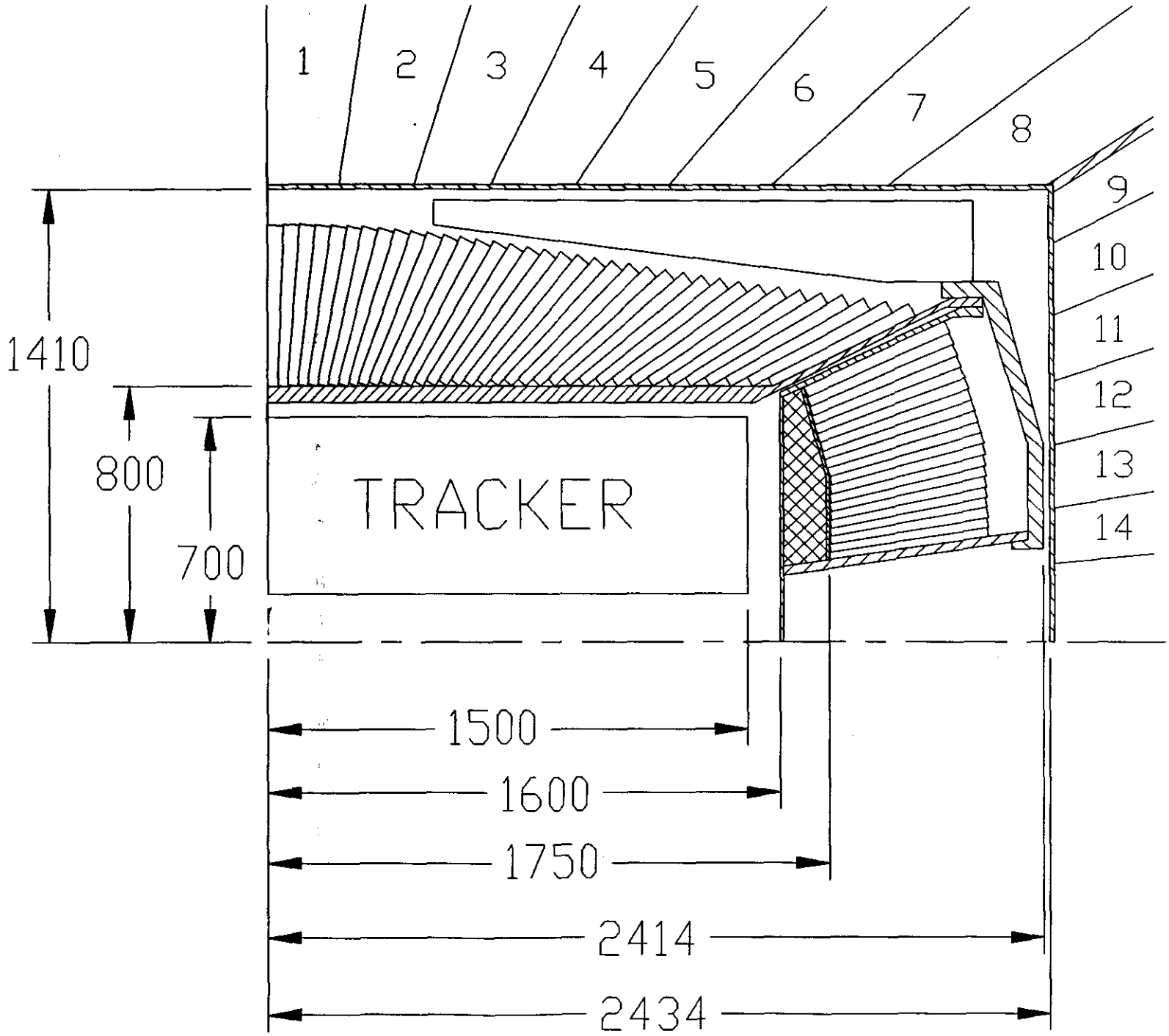
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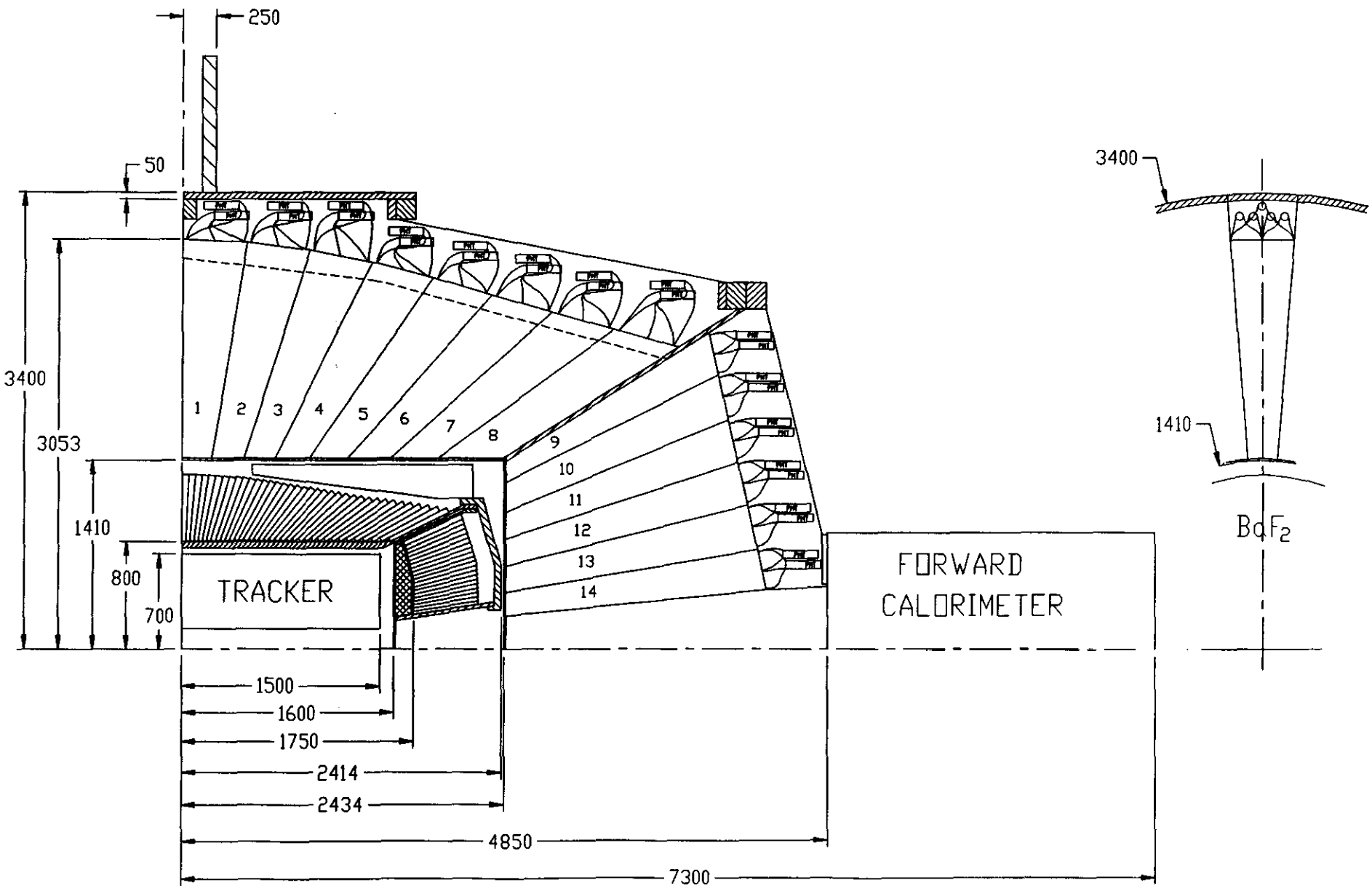
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BaF2

Presented by:

C. Wuest

BaF2 Crystal Growing

- Small (cm) samples of ultra-pure BaF2 will be grown using zone refining in reactive gas atmosphere and inert gas atmosphere.
- Dr. W. Kway maintains a number of zone-refining and Tzochowski process crystal growing systems. Experienced with growing fluorides of all kinds.
- Ultra-dry/pure BaF2 powders ordered from Fluortran and Johnson-Massey.

Schedule:

- Week 1 (June1): initial pre-treat of BaF2 in HF atmosphere at high temp.
- Week 2: zone refine first sample and evaluate for impurity and quality.
- Weeks 3-8: Parallel effort to grow BaF2 using different sources and different growth methods - all crystals to be chemically analyzed at LLNL and Charles Evans and Associates.
- As crystals are made available, B. Fuchs will polish and samples will be analyzed for optical properties and radiation hardness.

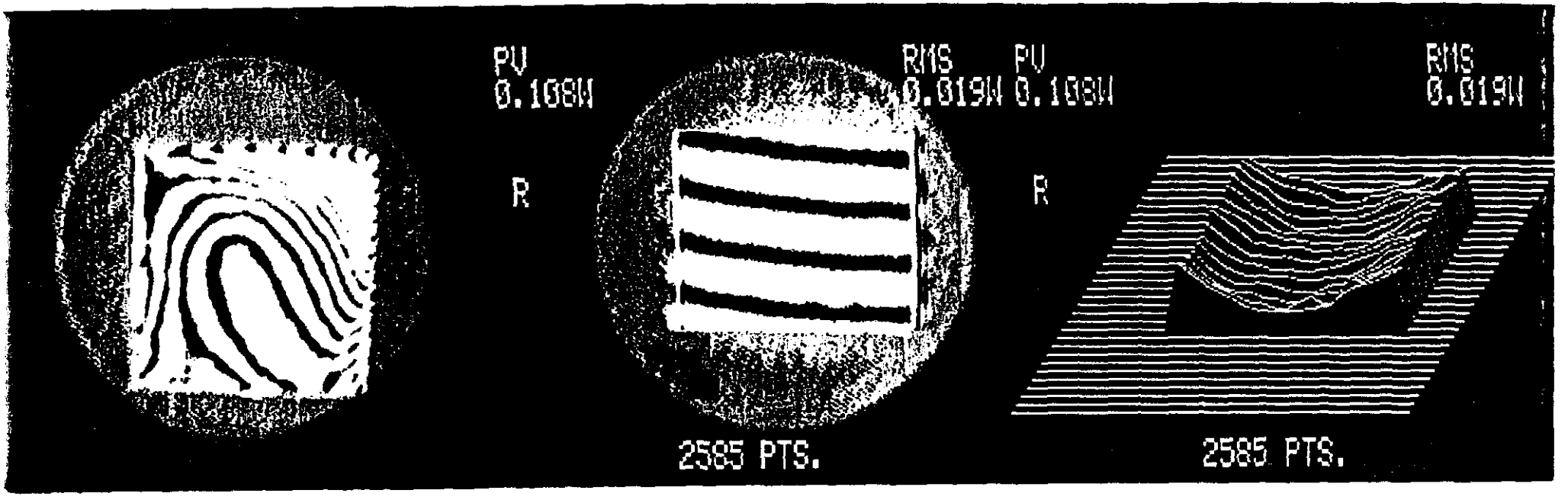
BaF2 UV Reflective Coatings

- Aluminum/MgF2 coatings applied and analyzed at LLNL - 90% @ 220 nm.
- Scatterometry and Reflectometry measurements on new samples in progress.
- Cost estimates have been made for coating 15,000 crystals: $1M - $1.5M
- LLNL owns and operates a number of large (3m x 3m x 3m) evaporative coaters at Spectra-Physics and Optical Coatings Laboratory, Inc. (OCLI).
- Discussions will be held with BGRI to transfer coatings technology (coating composition, masks for graded coatings) to their large evaporative coating system.
- Discussions with coatings experts at LLNLto evaluate long term integrity of coatings - accelerated aging tests, etc.
- Summer student at LLNL to evaluate 50 cm BaF2 for linearity with various coatings using HTV R-431S PMT (CsTe photocathode) and Co-60, SR-90 sources.

BaF2 Surface Preparation and Analysis

- Diamond Pitch Wheel Polishing method chosen for surface preparation.
- Interactions with J. Heck - ORNL to develop the necessary polishing procedures to satisfy mechanical specifications.
- Design and fabrication of polishing blocks and fixtures is proceeding at LLNL.
- Trips to Shanghai and Beijing planned - early June, mid-summer.
  - B. Fuchs and C. Wuest to meet with SIC, BGRI, Wuhan Defense.
  - Evaluate Chinese technology and equipment.
  - Suggest LLNL-developed polishing methods and begin discussions on adapting existing polishing machines to new methods.
- Visits to LLNL by Michel Lebeau and others during the summer.

BaF2 Surface Preparation and Polishing



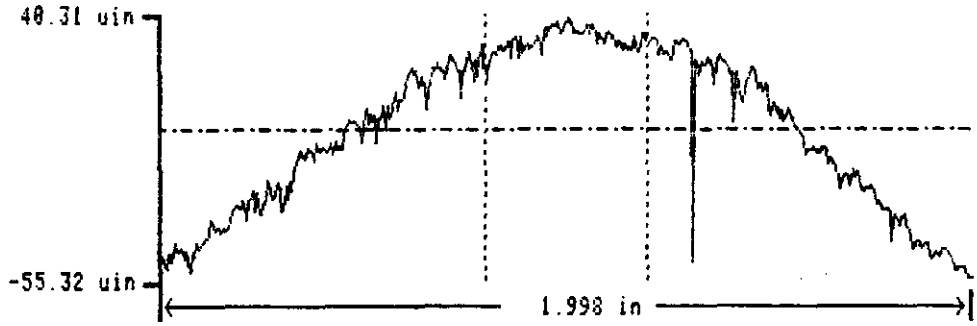
Chinese-finish on 4 cm x 4 cm crystal end face

LLNL-finish on 4 cm x 3 cm cut BaF2 sample

Surface scan of LLNL-finished sample: 0.108 λ P-V @ 633 nm

F1 - Analysis
F2 - Graph
F3 - Dump
F4 - Expand
F5 - Exclude

Mode	Traverse Length	Reference	Ignore
UNFILTERED	2.00 in	STRAIGHT	0 %
TAPERED GLASS ROD - JOE ~~MONTANO~~ VARGAS			



Peak To Valley = 95.63 uin

TIME: 18:11
DATE: 1-JUN-92

-1-

Taylor-Hobson

F1 - Analysis
F2 - Graph
F3 - Dump
F4 - Expand
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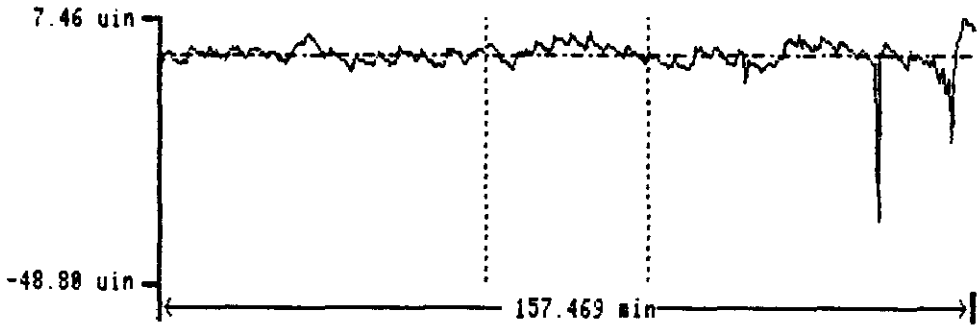
ROUGHNESS	.030 in	ISO	STRAIGHT	0 %
TAPERED GLASS ROD - JOE ~~MONTANO~~ VARGAS				



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DATE: 1-JUN-92

-1-

Taylor-Hobson

F1 - Analysis

Mode	Cut Off	Filter	Reference	Ignore
ROUGHNESS	.030 in	ISO	STRAIGHT	0 %

TAPERED GLASS ROD - JOE ~~MONTANO~~ VARGAS

Rta	=	17.85 uin	SLOPE	=	.17 Deg	Ra	=	1.71 uin
Rpm	=	4.53 uin				Rq	=	3.20 uin
Ry	=	56.27 uin	Lo	=	157.469 mm	Rsk	=	-7.6
Rt1	=	6.23 uin	Rp	=	7.46 uin	Rku	=	104.9
Rt2	=	4.89 uin	Rv	=	48.80 uin	Delq	=	.79 Deg
Rt3	=	7.77 uin	Rt	=	56.27 uin	Lamq	=	1.462 mm
Rt4	=	10.10 uin				S	=	2.710 mm
Rt5	=	56.27 uin				Sm	=	5.797 mm

TIME: 18:14
DATE: 1-JUN-92

-2-

Taylor-Hobson

F1 - Analysis
F2 - Graph
F3 - Dump
F4 - Expand
F5 - Exclude

Mode	Traverse Length	Reference	Ignore
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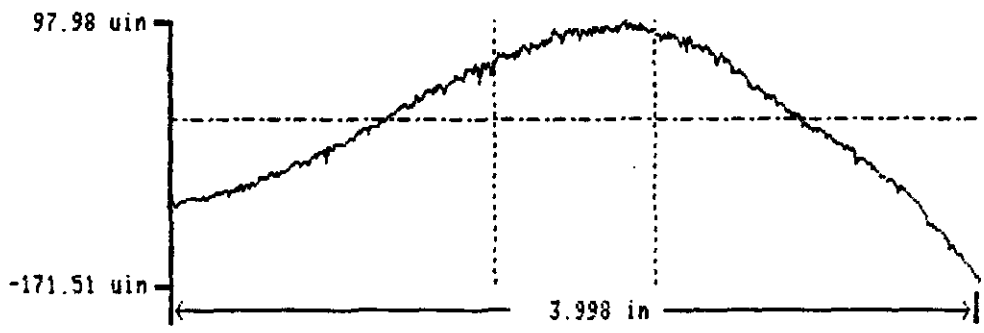
TAPERED GLASS ROD - JOE ~~MONTANO~~ VARGAS



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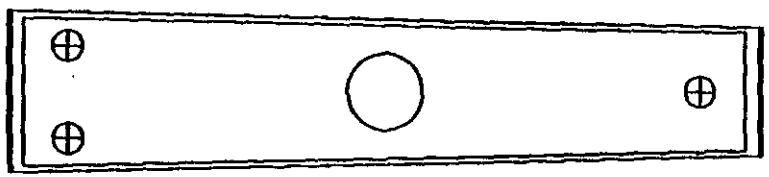
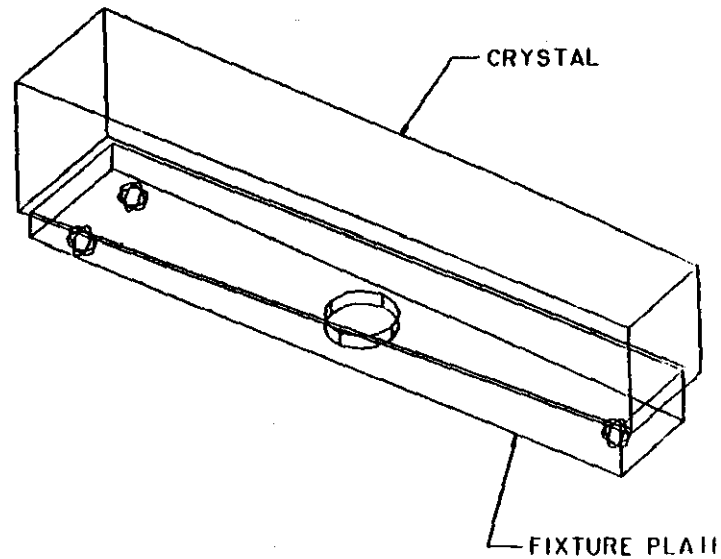
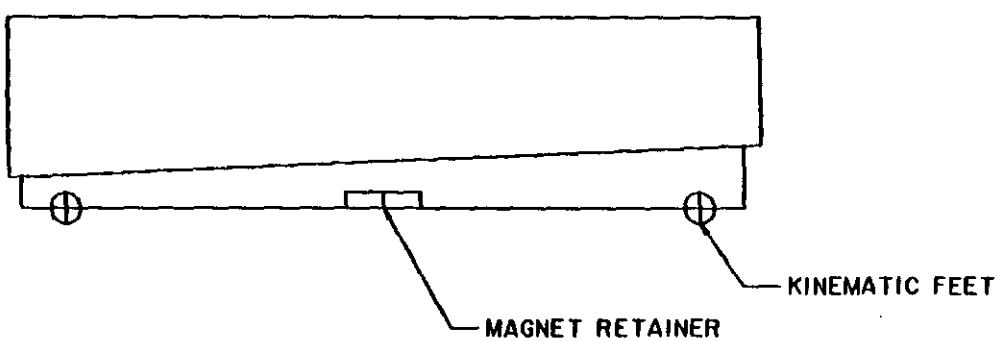
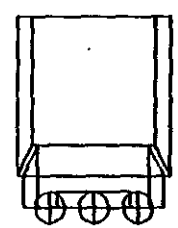
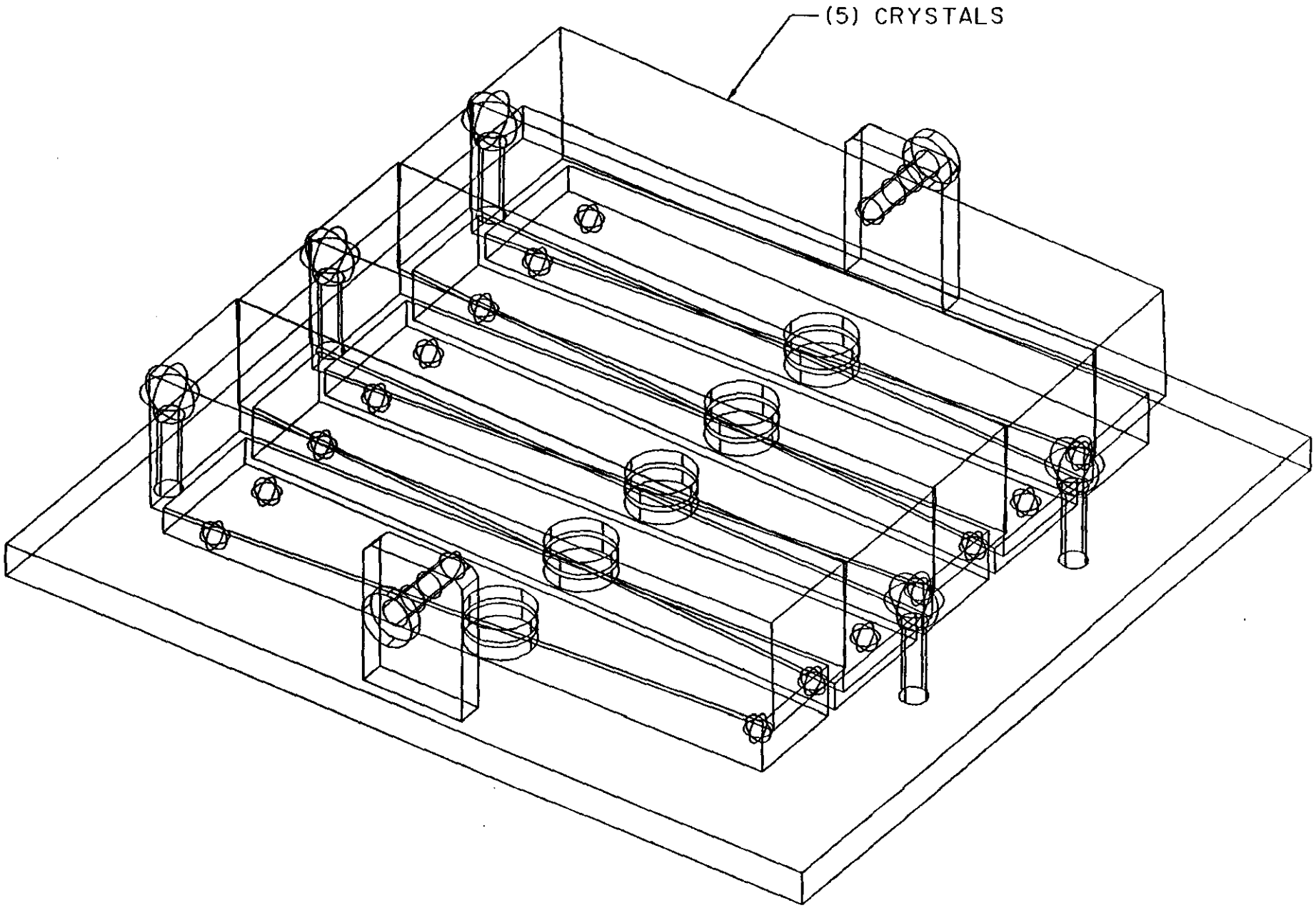
Taylor-Hobson




CRYSTAL
FIXTURE PLATE


KINEMATIC FEET
MAGNET RETAINER

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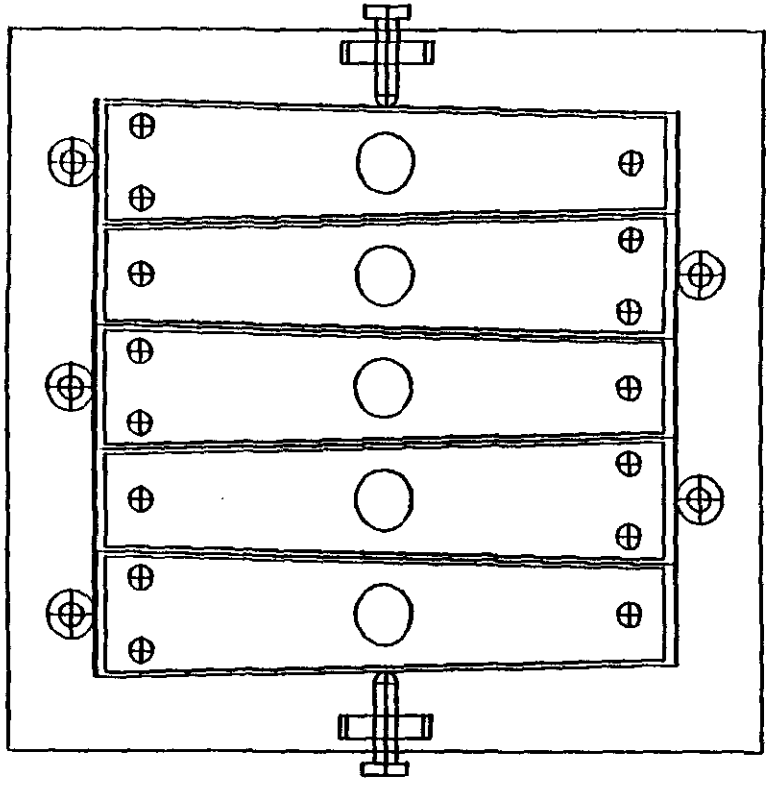
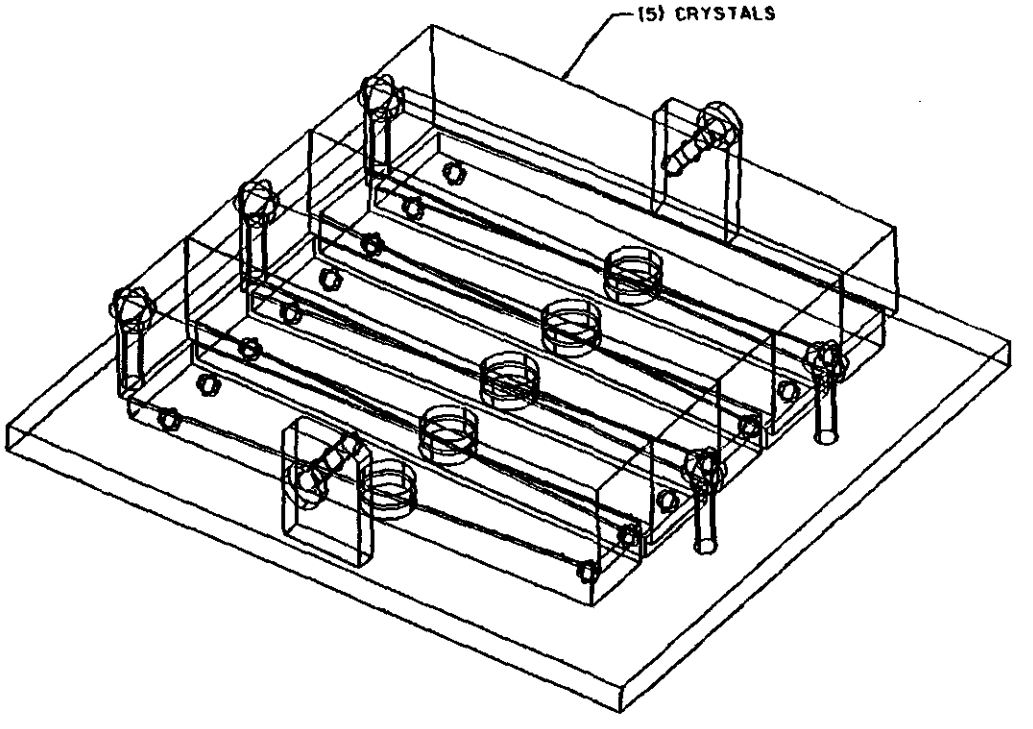
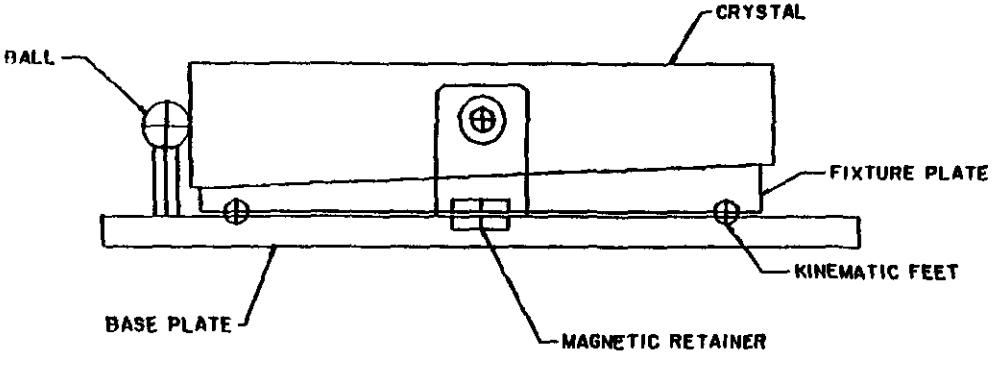
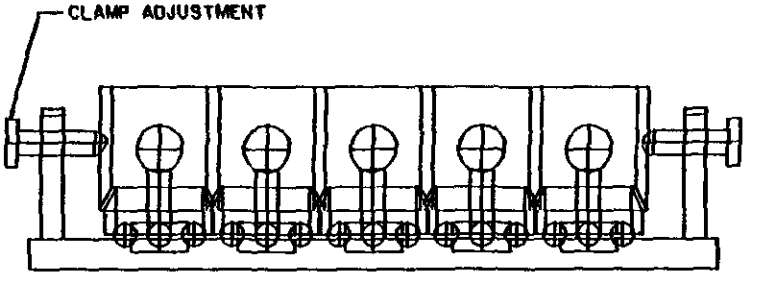



(5) CRYSTALS


CRYSTAL
BALL
FIXTURE PLATE
KINEMATIC FEET
BASE PLATE
MAGNETIC RETAINER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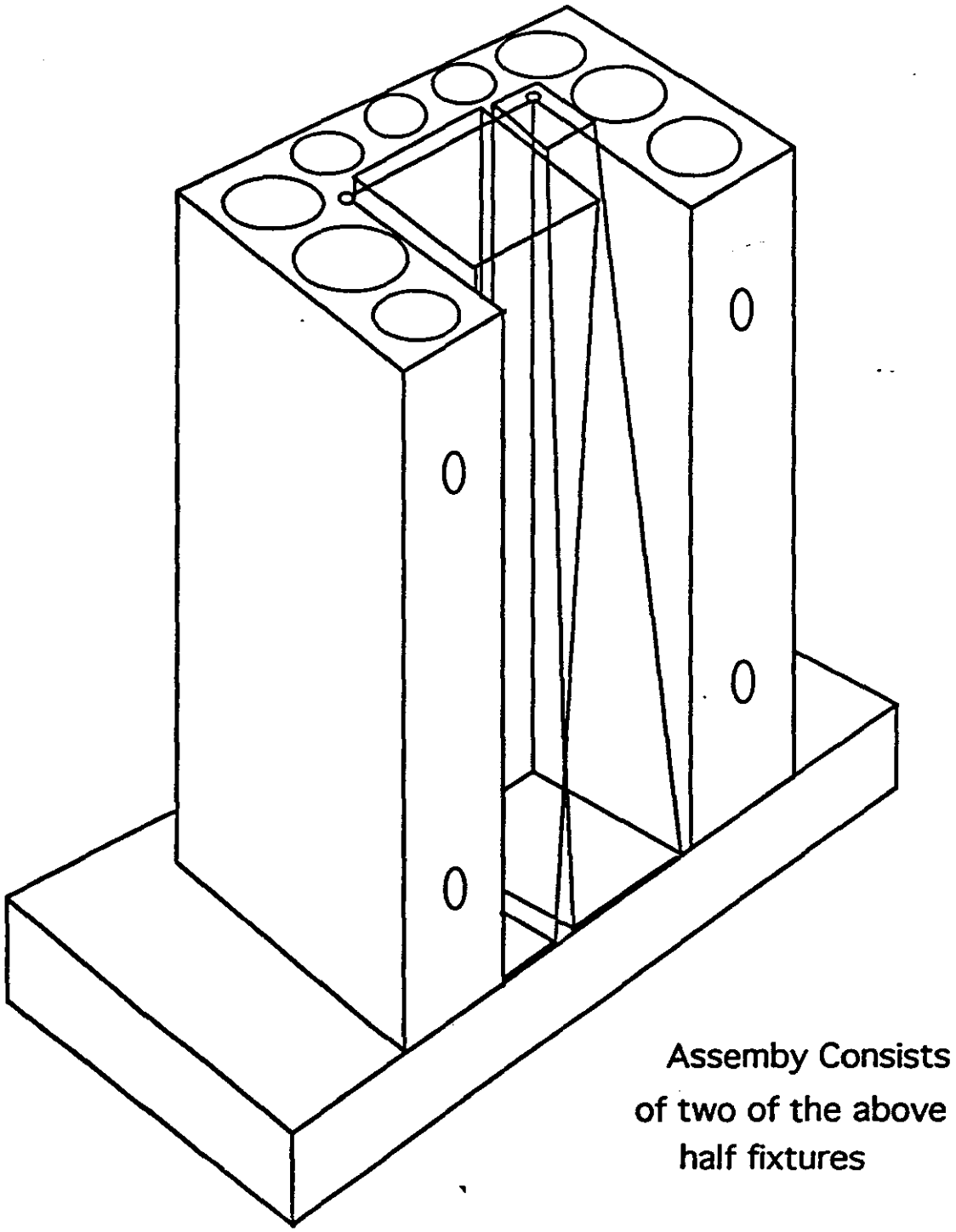


Figure 5. Crystal End Mount

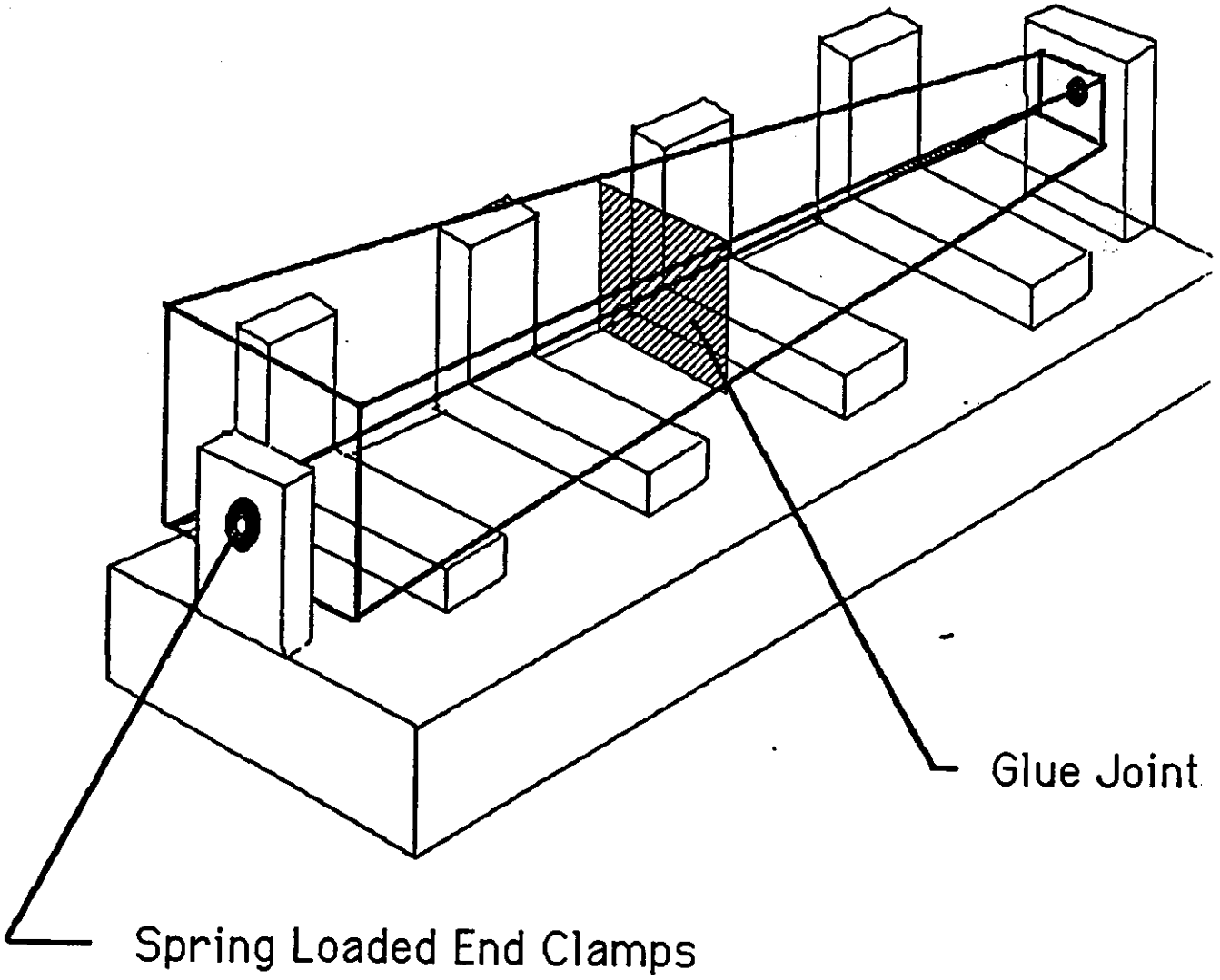
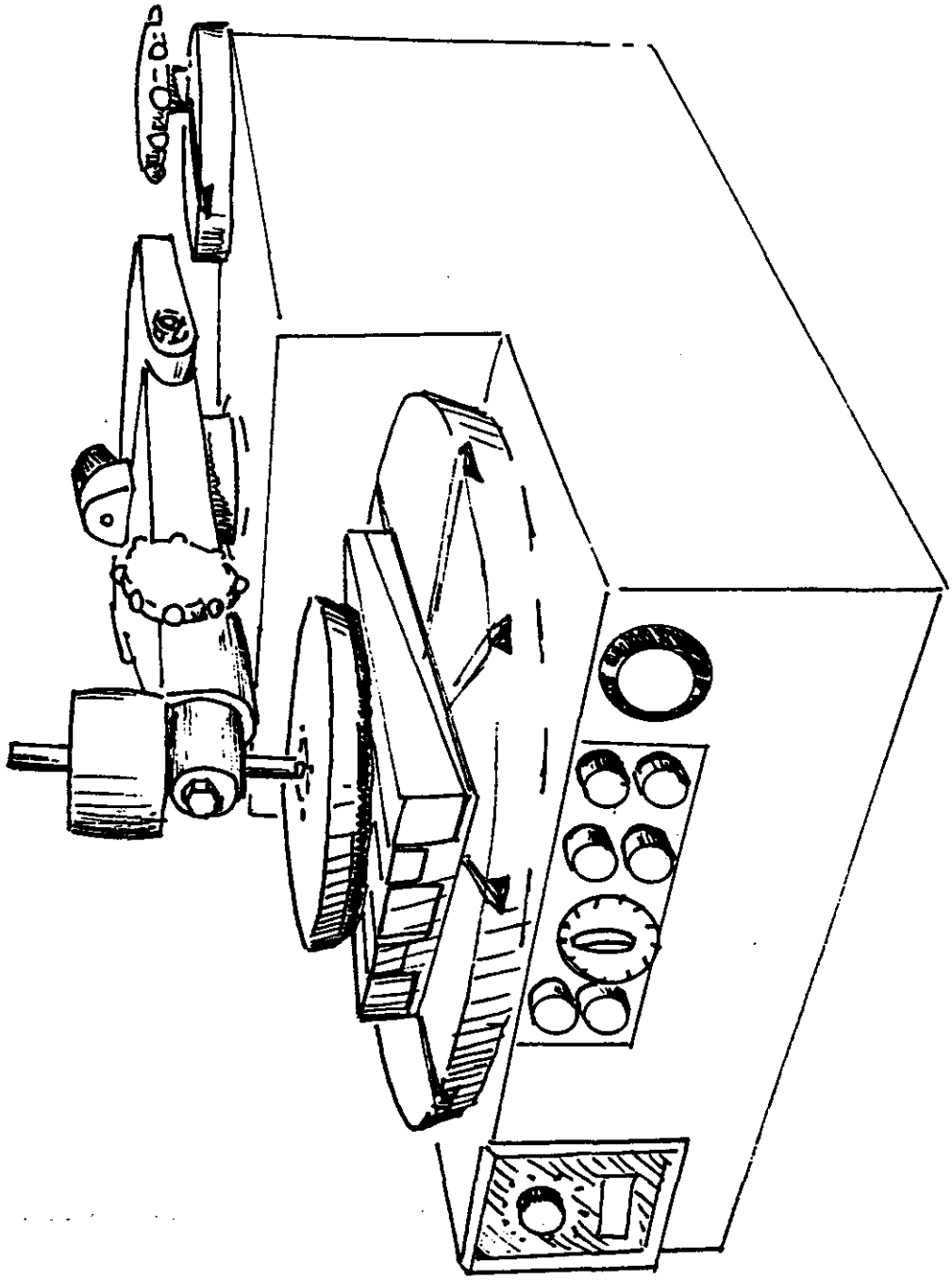


Figure 6. Crystal Gluing Fixture



Presented by:

Yuri Kamyshkov

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Subj: minutes of Russian-GEM meeting at ITEP Moscow May 14

Here are the minutes of the Russian-GEM meeting hold at ITEP on May 14. It is still PRELIMINARY, because several people would like to read it and possibly correct their statements. With my best regards, Yuri

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Minutes of the meeting of the representatives of the
Russian Physics Institutes in GEM

May 14, 1992 at ITEP Moscow

The representatives (list of participants is enclosed) of Russian Physics Institutes participating in GEM collaboration met at ITEP on May 14, 1992 to discuss the Institute involvements in GEM project. Present GEM activities of the Institutes are mainly the R@D programs performed in Russia.

Yu.Kamyshkov presented current status of GEM detector design, various detector options and encouraged Institutes to express their intentions in the construction of GEM Detector (particulary in the Calorimetry subdetectors). These intentions should become more definite commitments by the fall this year when TDR is due.

M.Danilov explained possible sources of financial support of Russian Institutes participating in GEM experiment from all-Russian High Energy Physics State program.

Present state of R&D developments and possible contribution intentions were reviewed.

1. Budker Institute of Nuclear Physics, Novosibirsk (Onuchin)
- plans to produce field shapers. The engineering department (10-20 people) is working on drawings and contacts with industry.
- The question of possible membrane production can be studied when a)cost figures and b)mechanical details information will be provided.
- group of 10 physicists and engineers is participating now in R&D for LKr calorimetery. If LKr option is choosen for GEM e-m calorimeter, Novosibirsk is going to supply LKr for the whole e-m detector and continue to collaborate in that field. Current price for Kr gas is 30 Rubles/liter. It is unlikely that Novosibirsk can take responsibility for the construction of e-m calorimeter proper because of large commitments to KEDR detector.
- No interest in BaF2 technique.

2. St-Petersburg Nuclear Physics Institute, Gatchina (Seliverstov)
- Presently SPNPI participating in R&D for BaF2 calorimeter (radiation hardness and uniformity tests). There are approx. 5 people in this group. It may be increased in the future up to 10-15 people. Russian industry produces long crystals up to 25 cm long which can withstand radiation doses up to 1 MRad. This radiation hardness is considered to be adequate for the BaF2 barrel calorimeter where radiation doses are significantly lower than in end caps. The production capacity is 2 t/year and may be increased up to 6 t/year. With this additional effort Russia may produce a half of total amount of crystals. The price

is expected not to exceed $2/cc. There is an intention to participate in prototype tests and calibration.

- As to production of CeF3 crystals is concerned the cost of raw materials is 1.5-2 times higher and the production technology presently is not sufficiently developed.
- The intention of the Institute is to produce the end-cap muon chambers for GEM detector. This is supposed to include the chamber supporting structure, alignment system and may be (?) front end electronics. There is an intention to reach 30 u space resolution with prototypes under construction. X-ray source and test beam set-up are being prepared. There are 10 scientists and 20 engineers in this group. For mass production group of 50 people will be required.

3. Institute of Nuclear Research, Moscow (Bolotov)

- This group has experience in nonorganic scintillating crystals. There are about 20 people in this group + contractors from other institutes. They studied ittrium orthoaluminate activated by Tl (40*40 mm, density 5.32g/cc, 30 ns decay time,12KRubles/kg).
- beam test with a sample of hafnium glass activated by Ce (10*10*20 cm) was performed. After 5 MRad irradiation crystal became slightly yellowish, but after 1 day fully recovered.
- E-m Pb/Scintillator prototype detector exists with WLS fibers readout (run perpendicular to scint. plates). Size 10x10 cm2, length 40 cm = 14 X0. Energy resolution of 6%/sqrt(E) + 1.5% was obtained.
- POLYCHROM small enterprise created within INR can produce scintillating and WLS fibers with PS core and florinated PMMA cladding. Samples exist at ORNL. WLS fibers are being used in E765 and at BNL. With equipment being installed by winter this year production capability will be few tons/year.
- The group participates in the development of AsGa photodetectors sensitive in 500 nm range and as large as 6*6 mm**2
- The group studies AsGa strip detectors which can withstand 10 MRad irradiation dose. The 4 channel amplifier with NEC=3000e mounted in 4 mm chip is used with this detector. The detector is radiation hard up to 10 MRad. Present price 15 KRuble for the pad 32x32 mm2 (connections included). These detectors can be produced for GEM end-cap tracker. Institute is interested in the construction of tracker end-caps.

4. Institute for Theoretical and Experimental Physics, Moscow and Joint Institute for Nuclear Research, Dubna (Danilov)

- ITEP group is working in tight contact with the JINR group on muon chambers R&D. The ITEP/JINR group has 20/30 people working on barrel muon chambers development. The possibility of production of chambers in Russia for GEM barrel muon detector (may be for end caps as well) is being studied. Front end electronics can be produced at Belorussia State University. Study of chamber mass production technique was initiated. There are no plans to participate in the construction of structural support or alignment equipment for muon chamber system.
- ITEP/ORNL group (8 researchers) is working on tests, design, integration and simulation in GEM calorimeter project.
- ITEP would like to participate in one large GEM detector subsystem. Presently emphasis is being made on muon chambers. The participation in calorimeter construction is not excluded.

5. Kurchatov Center - Institute of Atomic Energy (Selivanov)

- The group of 6-7 people is studying the alternative to BaF2

scintillating crystals. They are participating in R&D on pure CsI crystals. Samples were given to R-Y Zhu whose results on radiation damage of CsI are not convincing. Results of R&D program on rad. hardness of CsI are due by fall this year. The production capacity of CsI available now is about 5 t/year. It can be essentially increased by using Kharkov plant facilities. Expected price is $2/cc but CsI is more dense than BaF2.

- NaBi(WO4)2 crystals are being studied with X0 about 1 cm and Moliere radius 1.6 cm. Time constant is 3 ns. This crystals may be used as Cherenkov radiators. Light output is 1% of NaI. Radiation hardness is very high. Price 12 KRubles/kg. Cutting/polishing may be expensive. Raw materials exist.

6. Moscow State University (Ermolov)
- Group of 20-30 people is collaborating in GEM R&D.
- participating in development of u-strips for tracker. By autumn of 1992 set of prototypes will be produced. This work is being made in collaboration with Oregon.
- Si-preshower (without electronics) has been developed previously. Mechanical design for the Si-preshower has been developed too.
- The development of muon tubes is continuing. Prototype "matrass" is being sent to SSCL.
- Group is interested in general electronics (non rad.hard), possibly can participate in electronics production.

7. Lebedev Physics Institute (Shmeleva)
- Group of 7 people is working on TRD for EAGLE. In future can probably join LAr GEM collaboration.
- Big workshop facility (in Pakhra) exists (presently available but may become independent) - possible to participate in mass production of mechanical parts for GEM detector.

8. Moscow Engineering Physical Institute (Dolgoshein,Grigoriev)
- The group has 5-6 physicists and has many contacts with industry. Group is working on Si R&D and now ready to produce 10 sq.m of u-strips for 50% world price.
- Other group (approx. 10 people) has expertise in nonorganic scintillators, namely: radiation hardness, variation of scintillator transmission and kinetics under irradiation. Some results of rad.hard crystals R&D are due in summer this year. The group would like to join the detector construction in order to take part in production,acceptance tests, calibration, measurements.

Conclusion.

It is important to coordinate Russian R&D efforts in GEM particulary in the field of crystal study and u-strips. Consensus of the meeting was that the efforts of Russian Institutes in GEM should be coordinated.

Though main activity of Institutes has to be done through bilateral contacts between members of collaboration. the common opinion was expressed to organize the Russian collaboration within GEM. As the first step it was proposed to keep M.Danilov informed about GEM activities in all Russian Physics Institutes.

List of participants of the meeting.

Danilov Mikhail Vladimirovich	ITEP	F15DAN@DHHDESY3.BITNET 123-31-95
Onuchin Alexey Pavlovich	BINP	ONUCHIN@VXINPB.INP.NSK.SU (3832)-35-97-03 off 35-39-49 hom
Ruzin Sergey Mironovich	MSU	
Suvorov Vsevolod Mikhailovich	PNFI	8-812-71-32046, 2979150
Seliverstov Dmitry Mikhailovich	PNFI	8-812-71-31837, 2979132
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Kuleshov Sergey Vasilievich	ITEP	KULESHOV@ITEP.MSK.SU
Vasiliev Maxim Atlantovich	KIAE	VAS@SLV.KIAE.SU 196-97-49
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Golutvin Andrey Igorevich	ITEP	GOLUTVIN@SSCVX1
Ermolov Pavel Fedorovich	MSU	
Grigoriev Vladislav Anatoljevich	MEPI	
Grigoriev Evgueny Anatoljevich	ITEP	GRIGORIE@ITEP.MSK.SU
Morgunov Vassily Lvovich	ITEP	VXDESY::MORGUNOV
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Shevchenko Sergey Valerianovich	ITEP/ CALTECH	SHEVCHEN@VXCERN
Kamyshkov Yuri Alexeevich	ITEP/ ORNL	KAMYSHKOV@VXCERN (615)-576-6914

*) was not present at the meeting.

Suggestions for IMprovement of Baseline 1
M. Marx
June 2, 1992

We intend to upgrade and improve the baseline 1 document for the dual purposes of providing more coherent information to the collaboration and to use as a major part of our submission to the PAC in July. For the former we request help from the subsystems in updating the information, improving the format, adding material where needed, and weeding out extraneous material. For the latter, we intend to beef up the textual material as a guide for the PAC to our current design status. It is worthwhile to recall that the last submission to the PAC was our LOI in December - this had no FFS, a completely different tracker, no mobile magnet, etc...

We list below requested changes in the baseline. First general changes and additions are listed, and then subsystem specific comments are indicated. Further improvements suggested by each susbsystem are welcomed, and suggestions of others will be forwarded. You are urged to look critically at all subsystems - this volume is intended to be read and used by non-experts as well as afficionados!

General Comments:

1 We will add 2 new sections on Radiation Levels/Activation and on SSC Test Beam Facilities and Plans.

2 All technical drawings should conform to standard engineering practices.

3. All drawings, plots, and illustrations should be provided with clear captions, if at all possible, directly on the figure.

4. All subsystems should revisit the introductory texts from the point of view of explanation to the PAC of changes from the LOI (and rationale), and the current staus of the design and the outstanding issues. **These should be submitted within 1 week (due June 12).**

5 All subsystems should re-examine the statements of physics and engineering specifications which preface the sections. These should provide a clear statement of the highest level specifications, goals, purposes and constraints within which the design is proceeding.

6. All plots of performance calculations should reference existing or future GEM notes to provide the basis of the calculations. This includes resolutions, acceptance, efficiencies, etc.

7. All drawings showing more than one subsystem should show baseline versions of each system for consistency.
8. All systems should provide abbreviated lists of key milestones to augment the general GEM and facility milestones. **These are due by June 12.**
9. All submissions to the new baseline should be complete by June 25.

Specific System Comments:

Magnet and Field

Check that Baseline is coinsistent with TDR

Tracker

Fix consistency of calorimeter drawings
Wire readout to stereo pads
Material budgets for silicon and IPC - plots for all eta
Drop cabling requirements

Calorimeter

Legitimize new baseline
Show module details - EM and Hadron
Show plots of X0 and lambda vs eta,phi
Resolution vs eta
Acceptance for e,gamma

Muon

Show technical details of technologies
Show truss details for barrel and ends
Fix table p 11-17
Captions and Figures in Sec 4 don't match
DEpth doesn't match calorimeter baseline
Does energy loss include calorimeter measurements??
Trigger plots hand drawn!!! General quality poor

Alignment

Needs beef

Presented by:

Harvey Newman

TEM study

TEM observation and electron diffraction

Experiment condition: 200KV, 20-30 μA

Vacuum: 10^{-7} torr.

An electron beam of diameter of 1000Å focused on crystal.

Every 2 minutes tooK a picture.

Samples: No.1, 3 and 4. oxygen content: about 1000 ppm No3 > No.4 > No.1

No.4 is a fast cooling sample

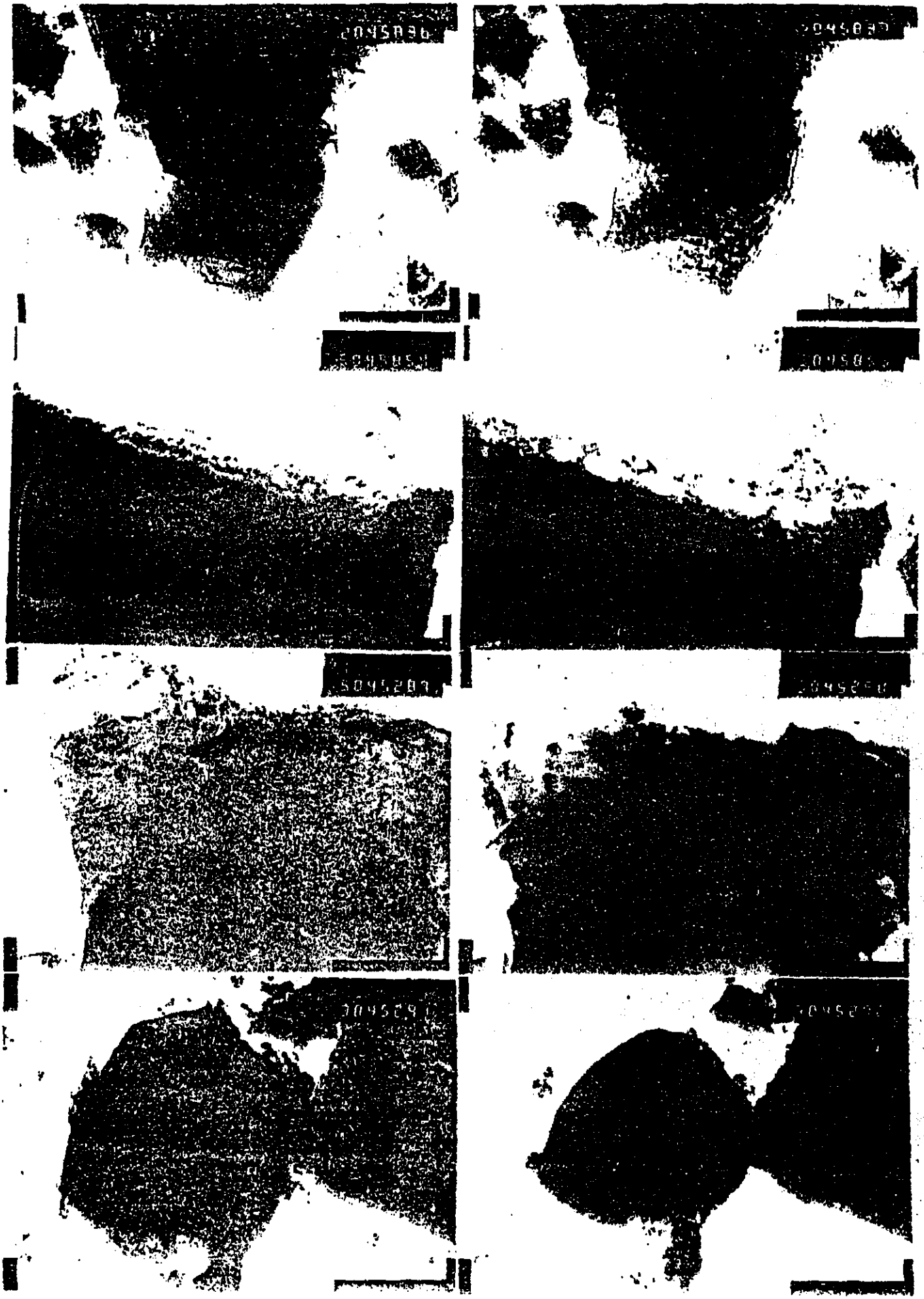
In powder form: ϕ 0.1 - 1 μm

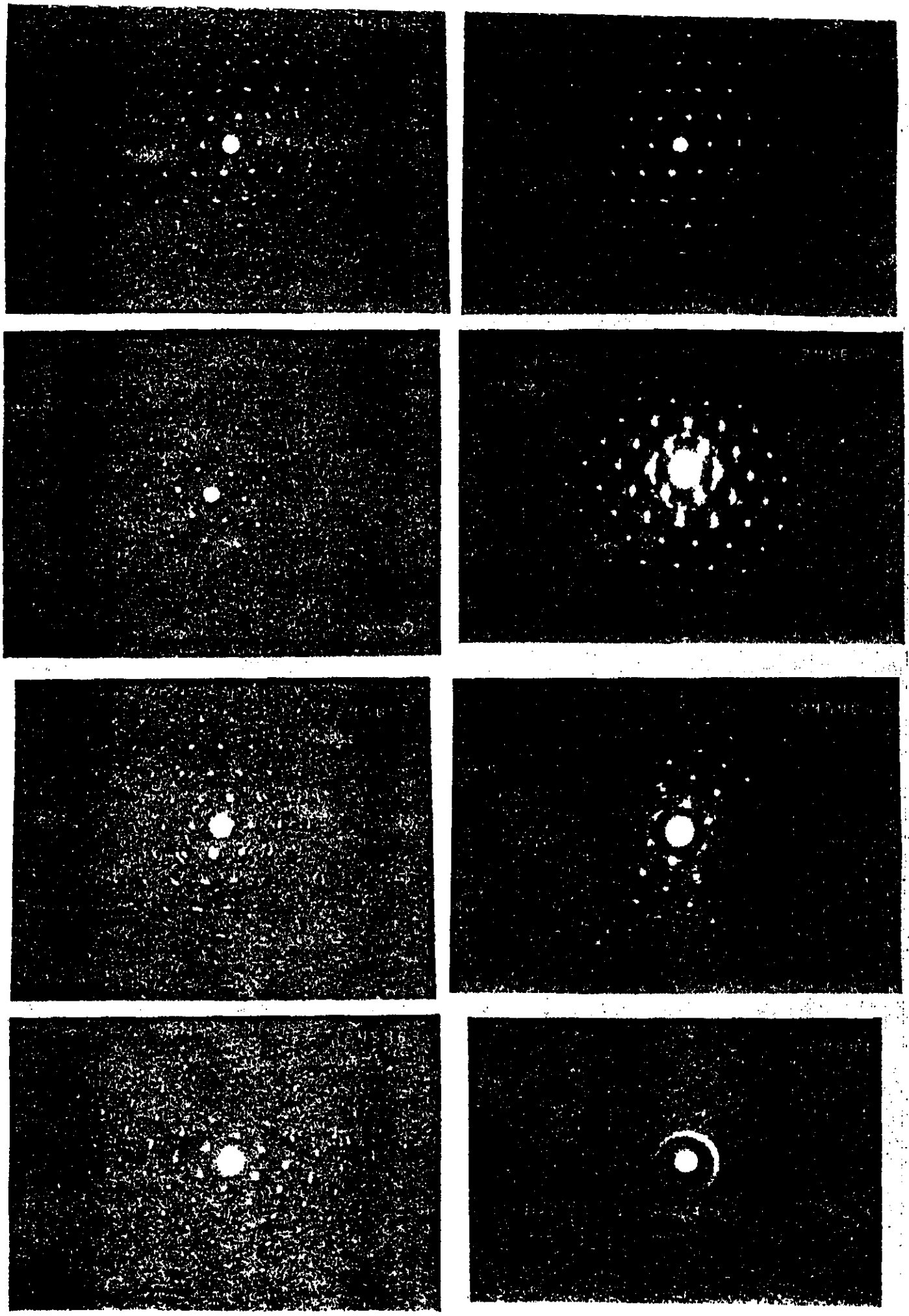
1. Observation of morphology change (Fig.9)

2. electron diffraction patterns (Fig.10)

Transmission of samples after 10^6 rad irradiation (at 220 nm):

No.1: 50%, (25 cm long) No. 3: 25% No. 4: <5%





Effect of OH^- on radiation damage in BaF_2

Pohl Institute of Solid State Physics, Tongji University

Sample: From Shanghai Institute of Ceramics

Heated in air (70% R.H) at 900°C

Hydrolysis Process:

$$BaF_2 + 2H_2O \longrightarrow Ba(OH)_2 + 2HF$$

OH^-: 192 nm

Radiolysis Process:

$$OH^- \longrightarrow \begin{cases} H_i^0 + O_s^- & \text{or} \\ H_s^- + O_i^0 \end{cases}$$

U: 204 nm ($U = H_s^-$)

793.75 cm^{-1}

O_s^-: ~ 240 nm

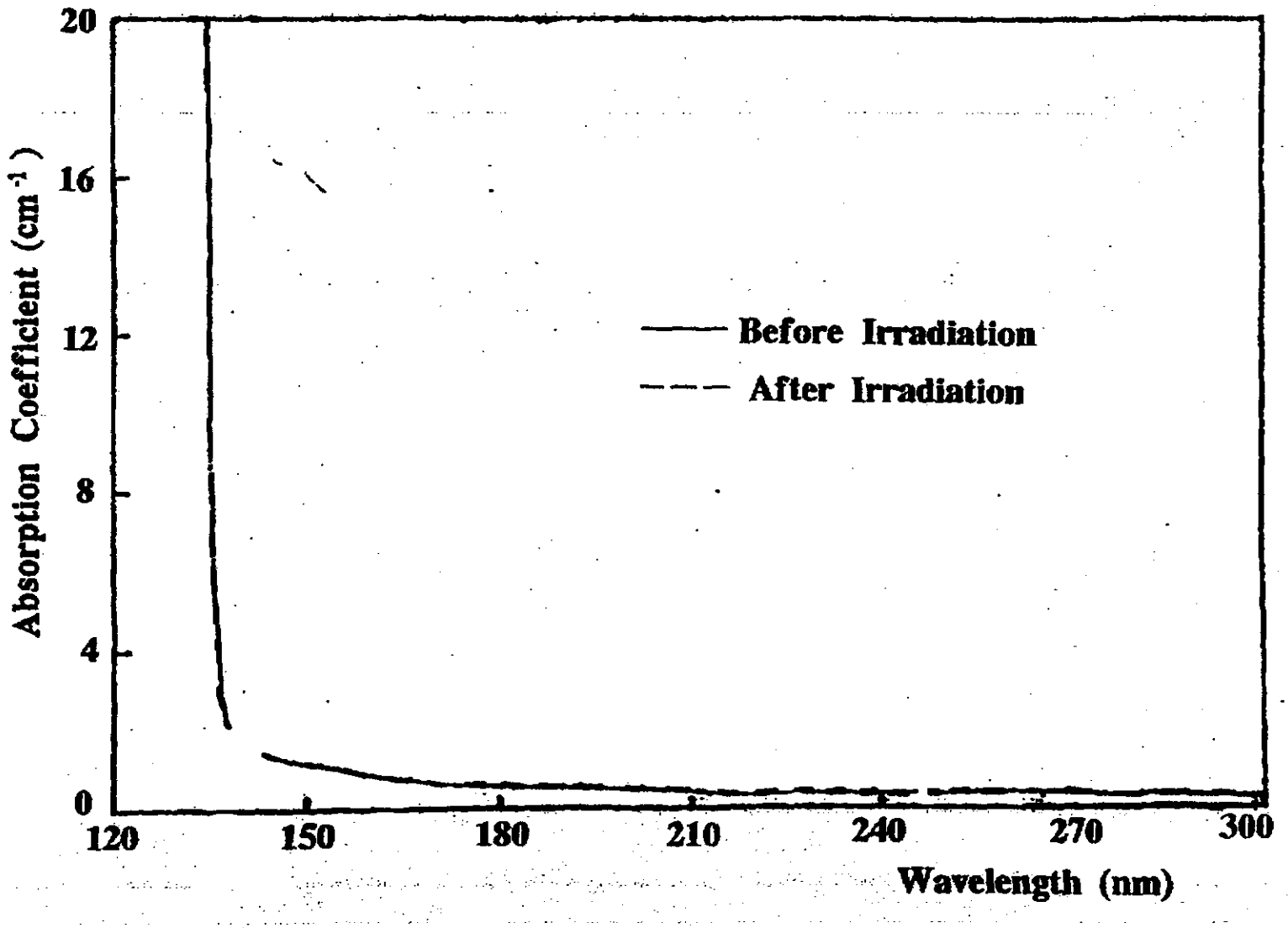


Figure 10 The UV absorption of undoped BaF_2 crystal

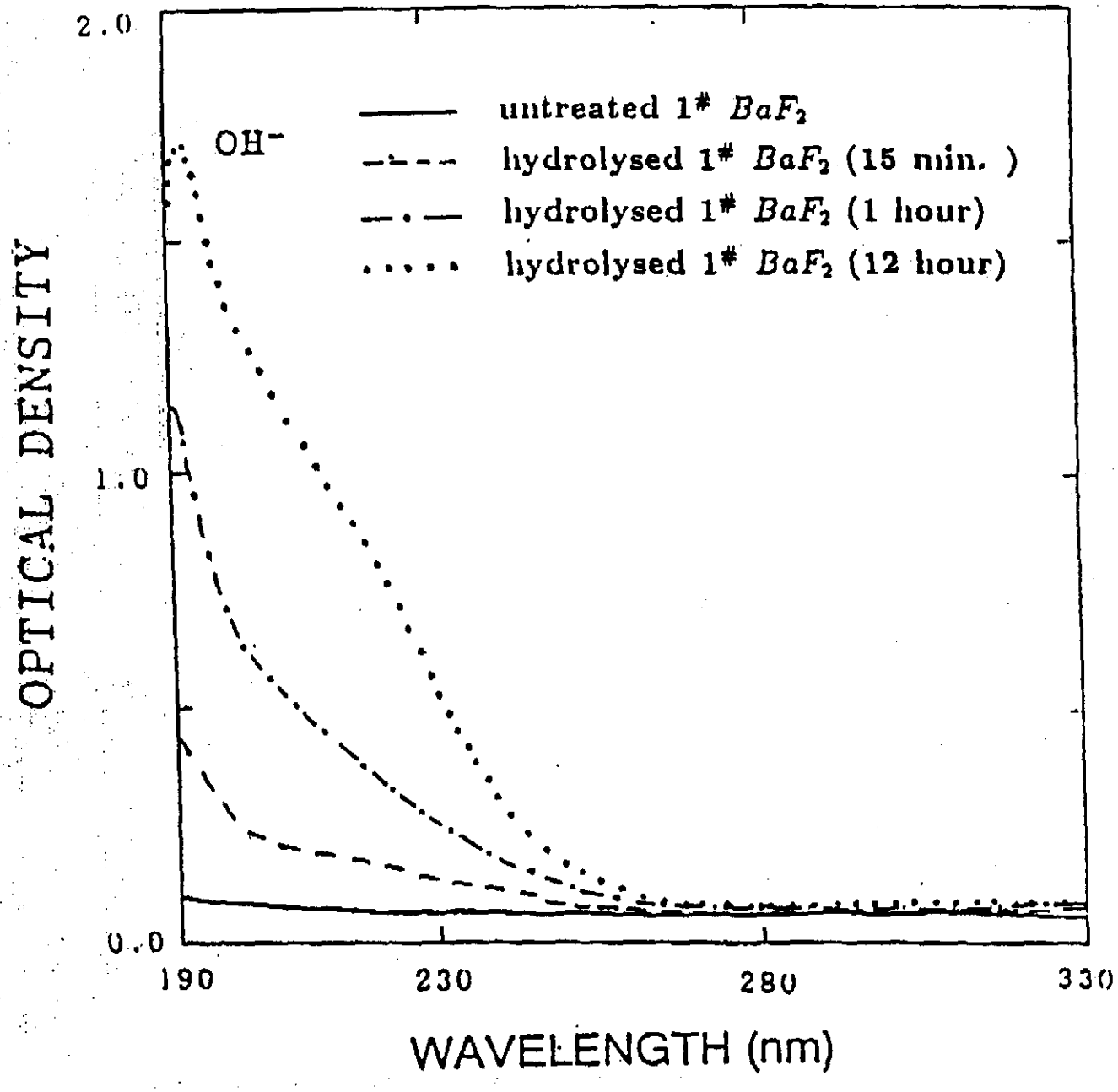


Fig. 1. Absorption spectra for different hydrolysed 1# BaF_2

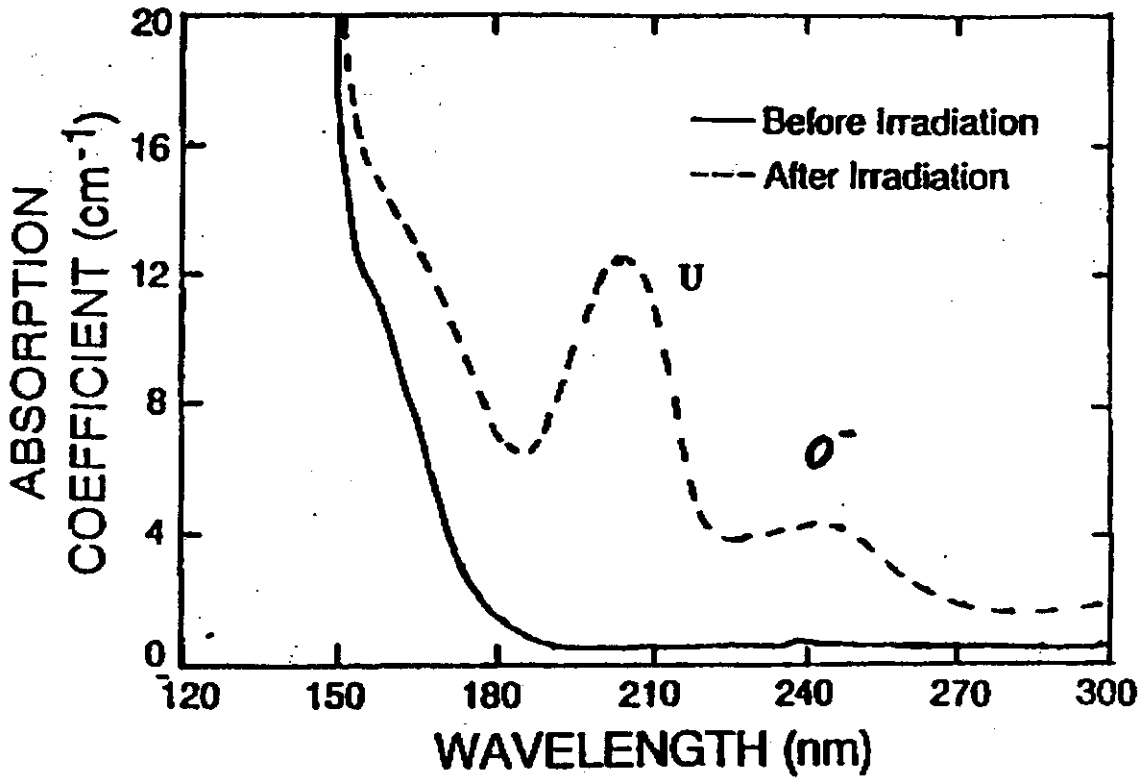


Fig. 5. Absorption spectra of hydrolysed 1# BaF_2 before and after irradiation

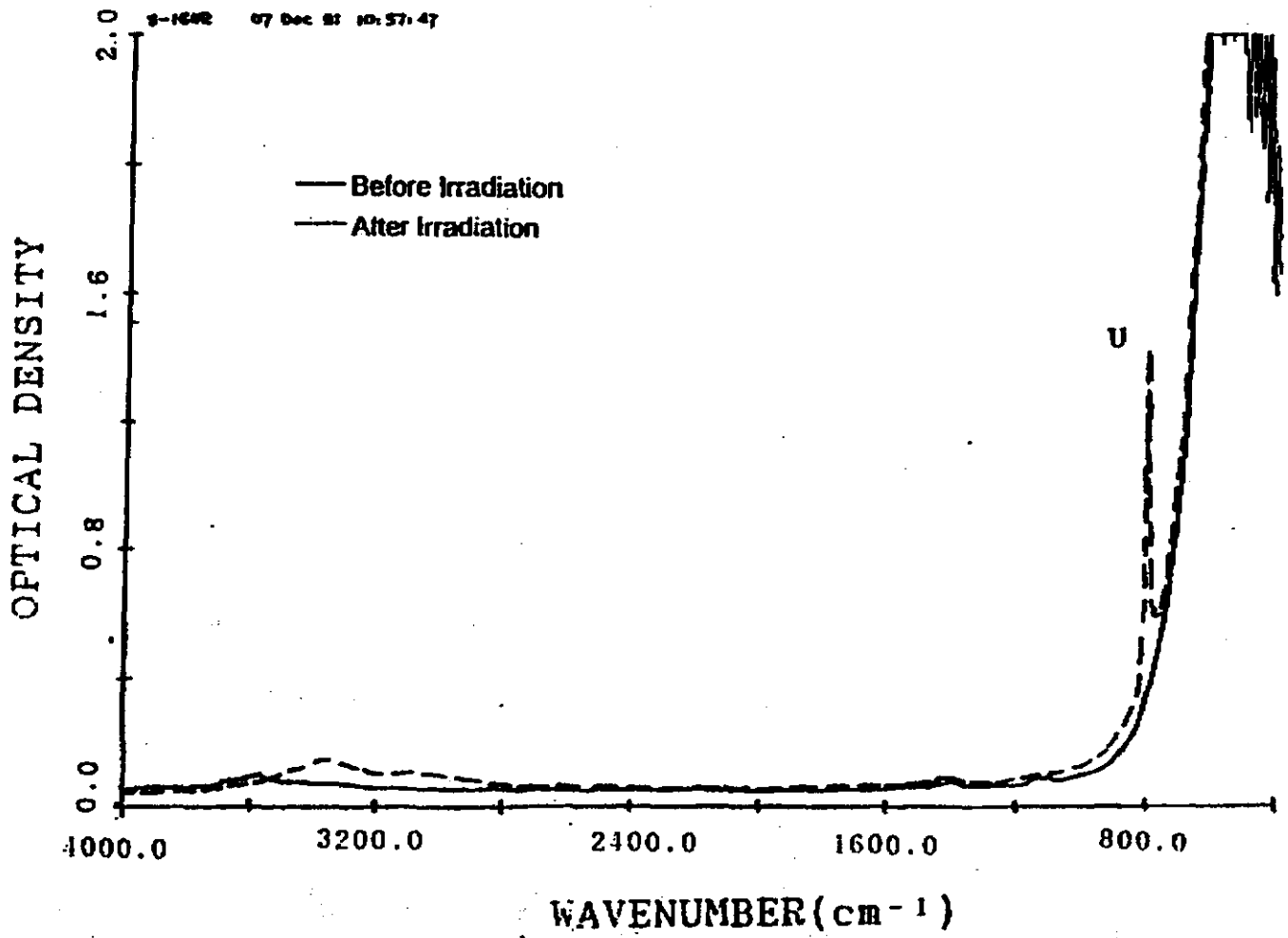


Fig. 6. IR Absorption spectra for hydrolysed 1# BaF_2 before and after irradiation

CALIFORNIA INSTITUTE OF TECHNOLOGY

CHARLES C. LAURITSEN LABORATORY OF HIGH ENERGY PHYSICS 256–48

Mr. M. Harris
Physics Research
SSC Laboratory
2550 Beckleymeade Ave.
Dallas, TX 75273

May 10, 1992

Dear Mike:

Per our conversation on May 1st, I have since contacted Dr. R. Hamm, the president of AccSys Technology which provided L3 calibration RFQ, and asked him to look into the problem of RFQ installation in GEM.

After a study on GEM detector layout, we propose to install RFQ beam pipe through central membrane. Dr. Ken Crandall of AccSys has performed a preliminary beam transport calculation, and concluded that it is feasible to have an H^0 beam through 12 m long beam pipe and hit a target which is located as close as possible to the IP, provided the target diameter is $\sim$5 cm.

Enclosed please find a fax from Dr. Hamm and corresponding figures of a 3.85 MeV H^- RFQ Linac, layout of RFQ calibration system and result of the beam transport calculation. If you have any problem please do not hesitate to let me know. I will be at Caltech on Monday, May 11, and will be in a China trip starting from May 12.

Sincerely yours,

Ren-Yuan Zhu

cc: H. Newman
M. Rennich
J. Heck

PASADENA, CALIFORNIA 91125 TELEX 675425 CALTECH PSD

TELEPHONE: (818) 356–6661 TELEFAX (818)-795-3951

ACCSYS TECHNOLOGY, INC.

1177 Quarry Lane
Pleasanton, CA 94566
(510) 462-6949
FAX: (510) 462-6993

FACSIMILE TRANSMITTAL SHEET

DATE: 10 May 1992 TIME: 11:00 a.m.

NO. OF PAGES: 4 (INCLUDING THIS PAGE)

TO: Dr. Ren-Yuan Zhu, HEP
Caltech

FAX NO: (818) 795-3951

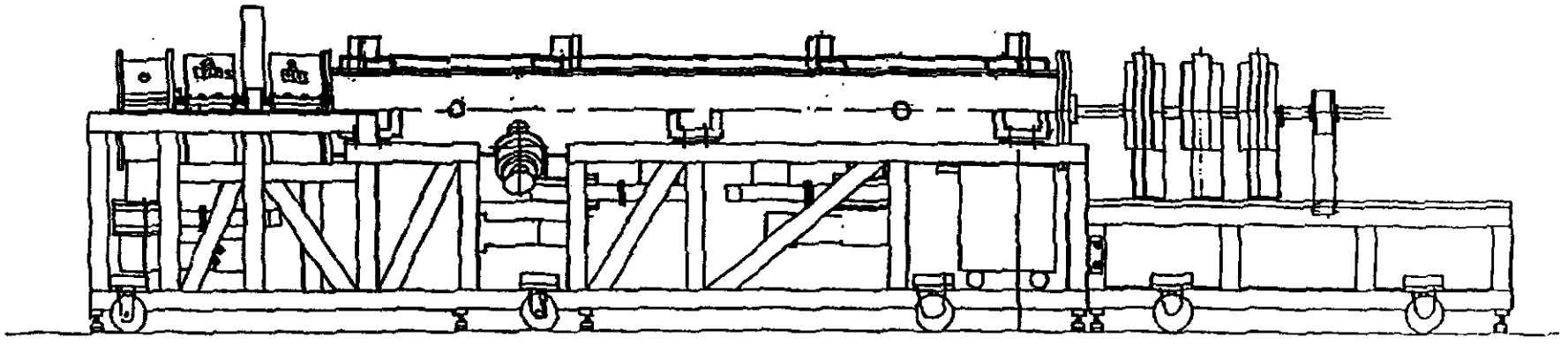
FROM: Robert W. Hamm

SUBJ: GEM Calibration RFQ

MESSAGE:

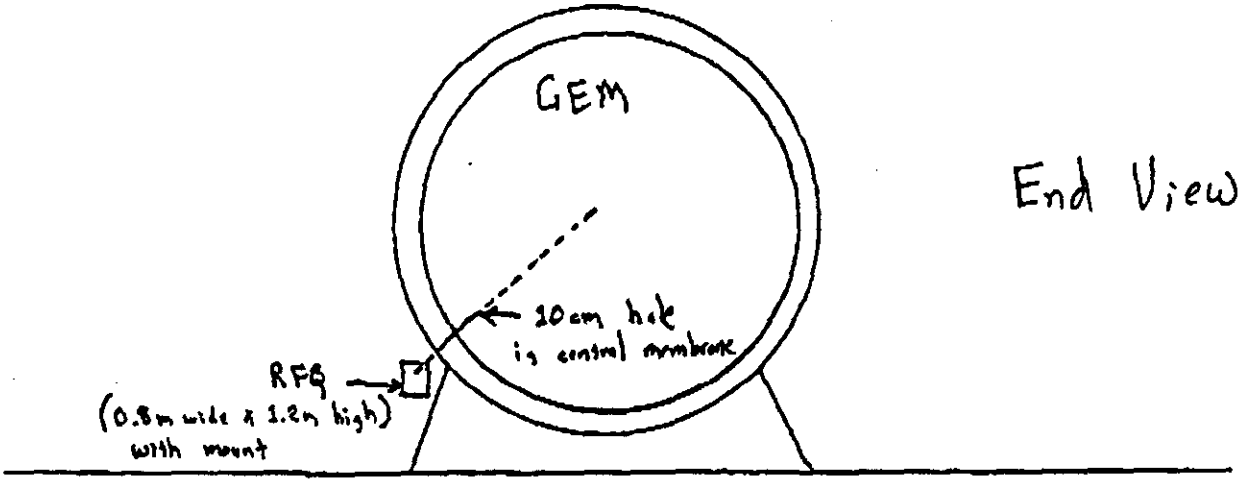
Ken Crandall has looked at the beam optics that would be necessary to inject an H^0 beam through the central membrane in the GEM detector and it appears to be feasible if the target spot is ~5cm. I would recommend that the RFQ be put on the floor under the Detector (as shown on the next sheet) with the beamline going into the center of the detector at an angle to the floor. Also attached is the beam optics calculation, assuming an H^- beam current of 40 mA (peak during 1-3 μsec pulse), that would result from using the machine we're now completing for the Navy. I've attached a preliminary drawing of this RFQ and output optics before the bend

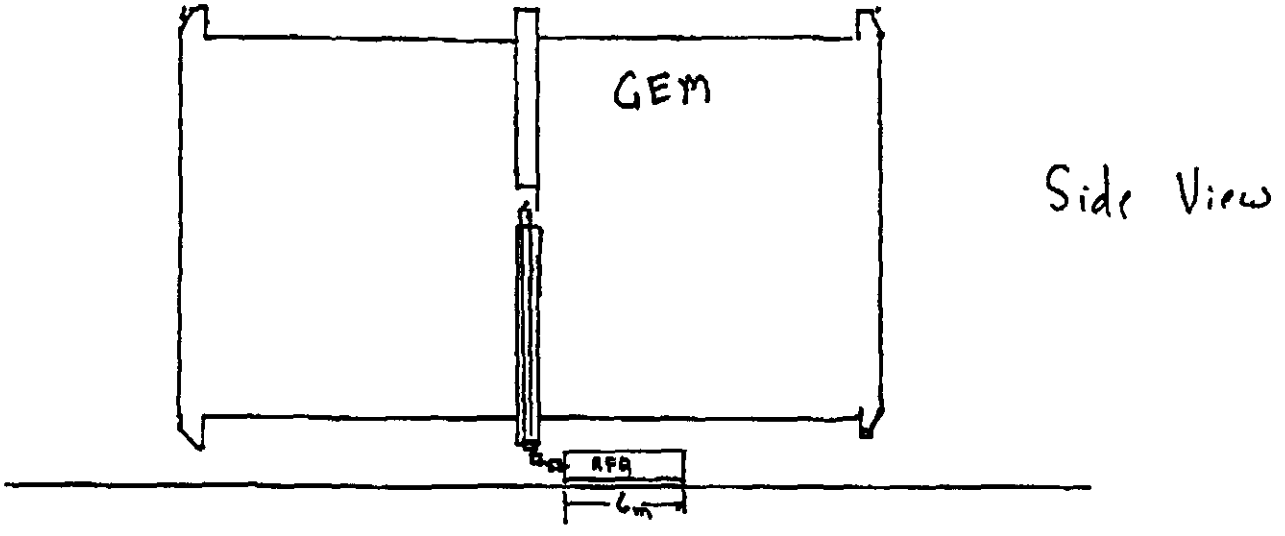
WE ARE TRANSMITTING FROM AN OMNIFAX G38. PLEASE CALL IF YOU HAVE ANY QUESTIONS.

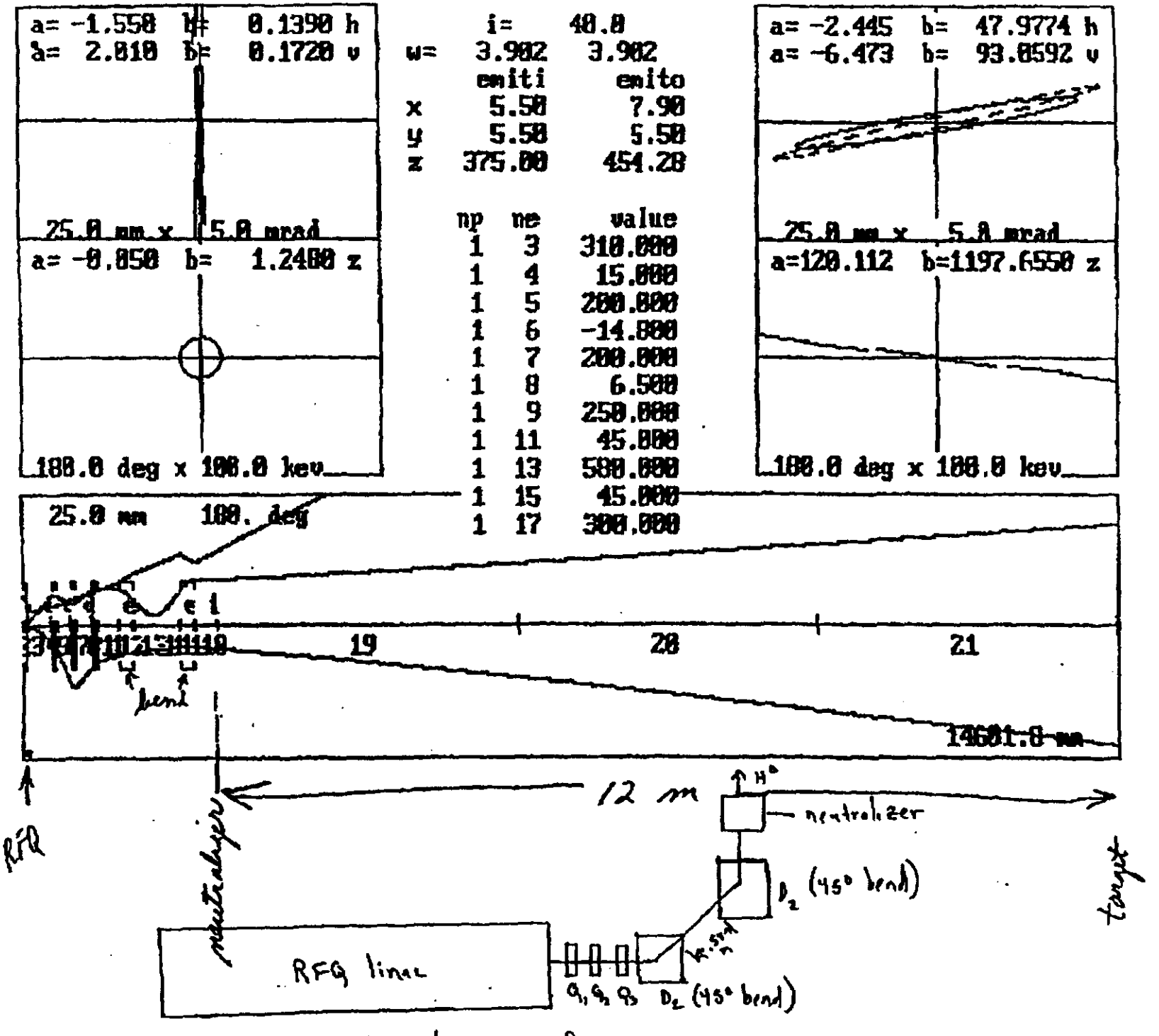


RFQ Linac (3.85 MeV H^-)

Layout of GEM calibration RFQ 5/10/92







H⁻ beamline configuration

Radiation Laboratory, University of Mass. Lowell
Irradiation Report for Brookhaven National Laboratory
April 29, 1992

1. Summary

Two barium fluoride scintillators were irradiated with fast neutrons on April 29, 1992 at the University of Massachusetts Lowell Van-de-Graaff Accelerator, in one eight-hour exposure. Neutron and gamma fluences and gamma dose estimates at five locations are shown in Table 1.

Table 1. Neutron and Gamma Fluences

Location	Axial Distance, z [cm]	Radial Distance, a [cm]	Fast Neutron Fluence [n/cm^2]	Gamma Fluence (429.2keV) [γ/cm^2]	Estimated Gamma Upper Limit [rad]	Surface Dose Lower Limit [rad]
1	1.019	1.785	7.30×10^{13}	4.56×10^{12}	1970	924
2	0.318	2.269	6.52×10^{13}	3.67×10^{12}	1580	740
3	0.797	1.785	8.27×10^{13}	5.04×10^{12}	2180	1022
4	1.477	1.751	5.44×10^{13}	3.67×10^{12}	1580	741
5	1.019	1.785	7.30×10^{13}	4.56×10^{12}	1970	923

Notes to Table 1:

(1) The irradiation geometry is shown in Figure 1 and 2. Fig. 1 also shows the coordinates z (axial) and a (radial). Together with an angle variable (not used) z and a form a cylindrical coordinate system. The two figures are not shown to scale; coordinates of the locations are given in Table 1.

(2) Fluences in Table 1 have not been corrected for neutron out- or in-scattering in the target cooling sleeve, nor for neutron absorption. It is estimated that these effects may lead to a fluence attenuation between 5% and 10%.

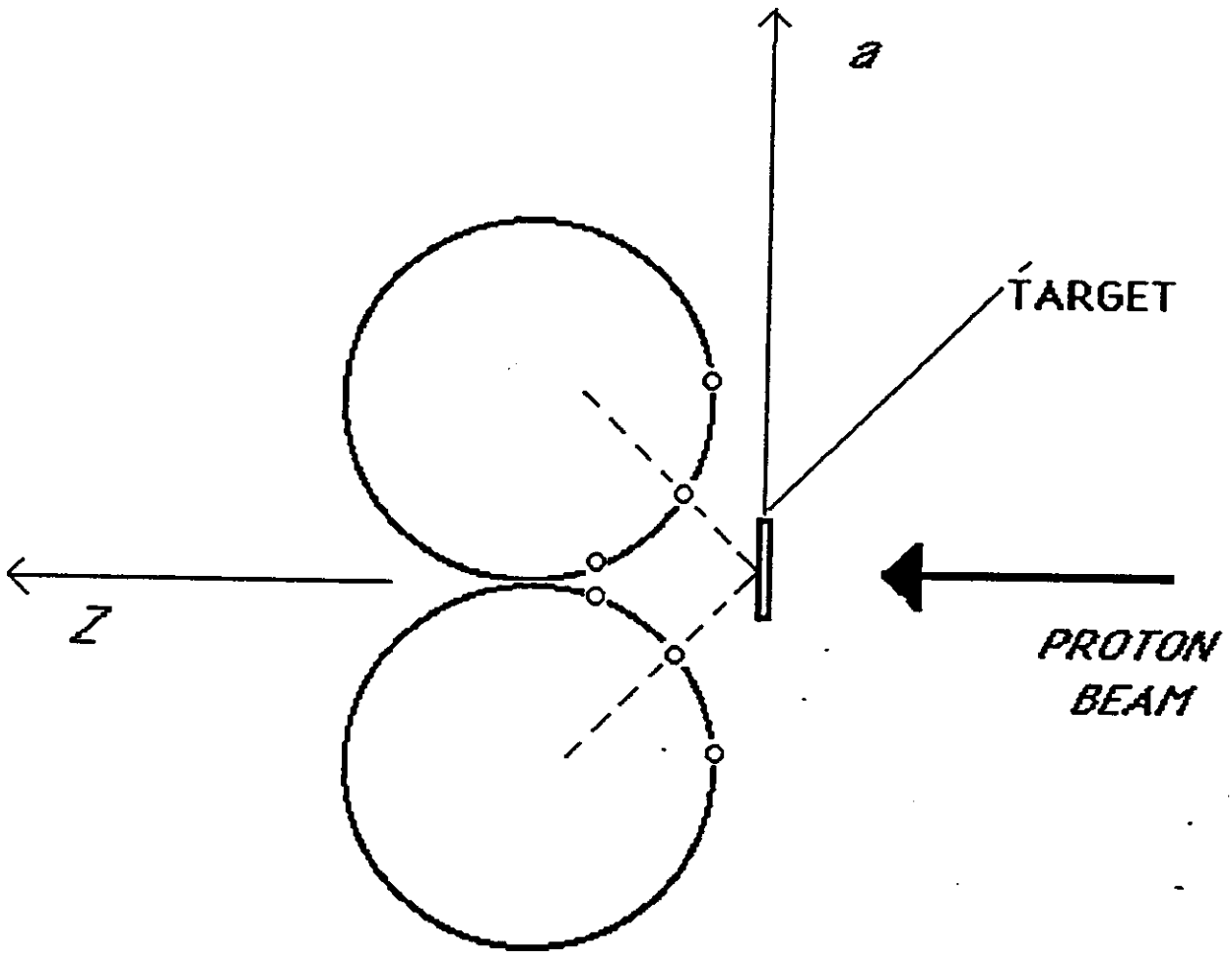


Fig. 1 Irradiation Geometry

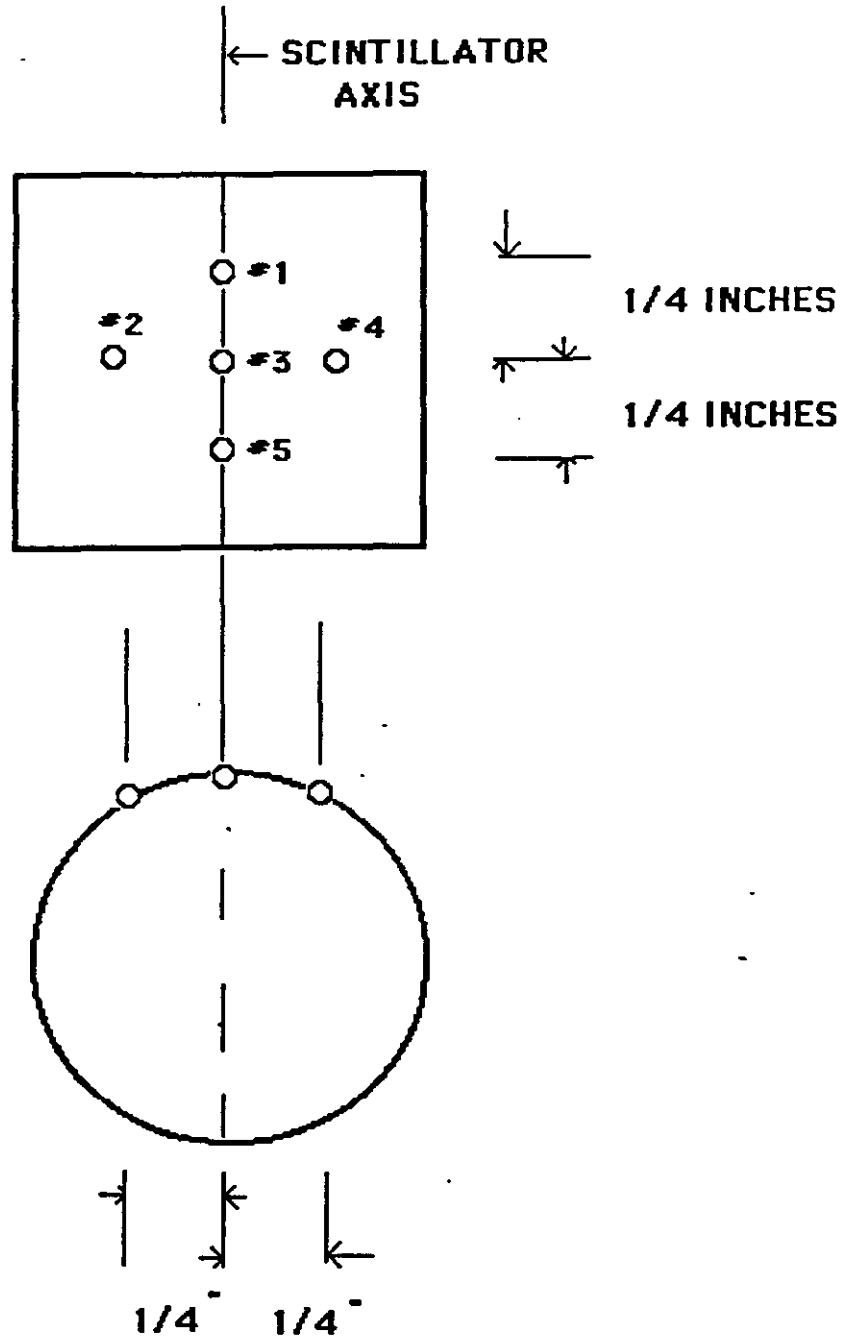


Fig. 2 Irradiation Geometry

2. Irradiation Parameters

Proton energy: 4 MeV

Proton current: Approx. 20 μA

Run Duration: from 11:00 AM, to 7:00 PM, April 29, 1992

Measured total neutron production, based on the ^{7}Be-activity determination (See sections 3, 4): 1.936×10^{15}.

3. Neutron Dosimetry

The neutron fluences in column 4 of Table 1 were obtained in the following way: (i) The total number of neutrons generated was determined (see section 5). (ii) Computer code MURI was run for each location in Table 1; MURI input parameters were selected to yield a total number of neutrons generated (counting both, first and second neutron groups) equal to that obtained from the activity determination. Copies of the MURI output are attached for locations 1 through 4. (Locations 5 and 1 have the same coordinates a and z).

4. Gamma Dosimetry

There are two neutron generating reactions; the second, weaker reaction leaves the daughter nucleus, ^{7}Be, in an excited state from which it de-excites emitting a 429.2 keV gamma ray. The present section covers this gamma transition only.

Output data of code MURI show that 12.5% of all neutrons generated originate in the weak second reaction; this leads to a figure of 2.42×10^{14} gammas emitted during the irradiation. The gamma radiation involves a spin 1/2 state, hence it is isotopic. Thus we obtain the gamma fluence (column 5 of Table 1) by dividing the gamma emission by $4\pi r^2$ where $r^2=a^2+z^2$.

To estimate gamma doses we use interpolated data for neighboring nuclei (iodine and oxygen) as given by C.M. Davisson (Chapter 2 and Appendix I, "Beta and Gamma Spectroscopy", K. Siegbahn, ed., North Holand, 1955). We obtain for one BaF_2 group and for 429.2 keV gamma rays:

Scattering cross section (coh. + incoh.): 20.0b

Photoelectric cross section (K+L+M shells): 6.3b

With a BaF_2 density of 1.67×10^{22} cm^{-3} we obtain a gamma attenuation factor of 2.08 cm^{-1} and a surface energy deposition of 0.0211 J/cm^3 for

10^{12} gamma rays. With a density, for BaF_2, of 4.88 g/cm^3 this is equivalent to 4.32 J/kg or 432 rad. This figure has been used to compute the doses listed in column 6 of Table 1. It is based on the assumption that the entire gamma energy is retained in the absorbing volume.

Alternatively we can assume that the Compton scattered gamma radiation leaves the absorber completely. This is equivalent to using the Compton absorption cross section in the place of the Compton attenuation cross section. According to Davisson (loc. cit) the ratio of these cross sections a 429.2 keV is .319, leading to a total absorption cross section (including the photoelectric absorption) of 12.68 barns. This datum has been used to obtain the entries of the last column of Table 1.

5. Be Activity Determination

The target planchet was placed at fixed distance D from a calibrated Ge(Li) detector and the ^{7}Be spectrum was measured for a time interval t. The results obtained are shown in Table 2.

Table 2. Be Activity

Irradiation date	April 29, 1992
Measurement date	May 1, 1992
Delay	2 days
Data file	UT320
Measurement distance, D, [cm]	221.4
Measurement time, t, [min]	14.08
477 keV peak area [counts]	112087
Gamma detection rate [gamma/sec]	132.68
Efficiency at 477 keV and at D, (1)	4.493×10^{-6}
^{7}Be gamma emission rate, [sec^{-1}]	2.953×10^7
Branching ratio for 477 keV level (2)	.104
Decay correction	.9743
^{7}Be decay rate, [sec^{-1}]	2.914×10^8
^{7}Be mean life, [sec]	6.644×10^6
Number of ^{7}Be atoms (3)	1.936×10^{15}

Notes to Table 2.

(1) See section 6.

(2) From Lederer and Shirley, "Table of Isotopes", Wiley, 1978.

(3) The number of ^{7}Be atom is equal to the number of neutrons generated.

6. Detector Efficiency

The Ge(Li) detector efficiency at 477 keV was obtained using a NBS Mixed Radioactivity Standard (SRM 4275-174) to determine the detector efficiency for five gamma lines (427.95, 463.51, 591.75, 600.77, and 635.89 keV, ^{125}Sb and ^{154}Eu). Logarithmic interpolation provided the efficiency at 477 keV.

7. MURI Output

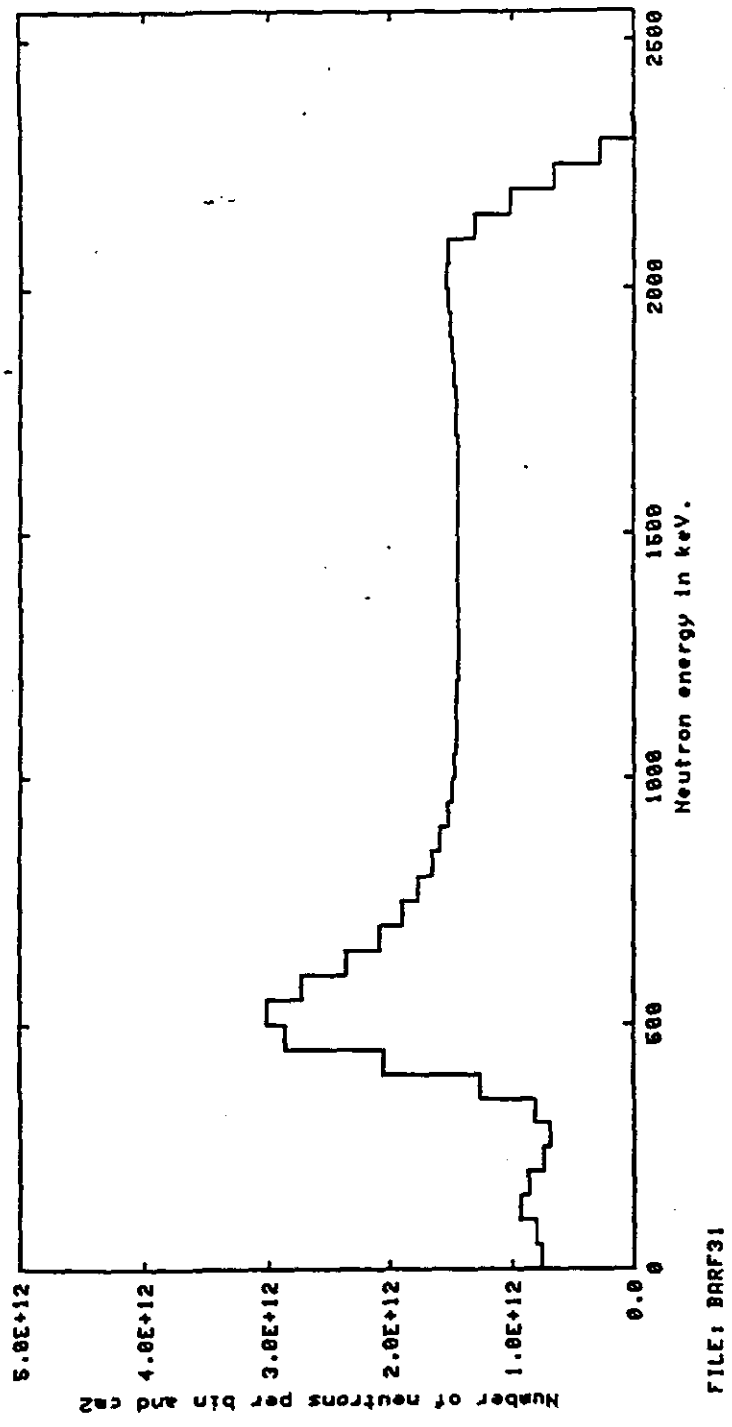
The attached output data of code MURI are ordered by the location. Two printouts are provided for each of locations 1 through 4. No separate printouts for location 5 are provided since it is identical to that of location 1. The two printouts at a location cover the first and the second neutron groups. Each printout is followed by the respective neutron energy spectrum.

NEUTRON ENERGY SPECTRUM.
University of Lowell. 3:48 AM TUE., 12 MAY , 1992

The following table gives the neutron fluence in neutrons per cm2, for an irraddiation of a thick lithium target with a 4000 keV proton beam.
The total charge delivered to the target is
578.2 mC.
The parameters are:
a= 1.019 cm.
z= 1.785 cm.
R= .8000 cm.
Kappa= 20.00
Slow neutrons (En < 10 keV) per cm2: .5222E+11
Fast neutrons (En > 10 keV) per cm2: .6758E+14
Equivalent number of 1MeV-neutrons per cm2: .6488E+14
The total number (angle and energy integrated) of neutrons generated is: .1694E+16
The output file name is BARF31

Bin number	Bin energy [keV]	Number of neutrons per cm2	ASTM KERMA (E722-85) divided by 95.0MeVmb	1Mev equivalent number of neutrons per cm2
1	30	.749E+12	.233E-01	.175E+11
2	75	.812E+12	.626E-01	.508E+11
3	125	.940E+12	.425E-01	.400E+11
4	175	.871E+12	.425	.370E+12
5	225	.744E+12	.824	.613E+12
6	275	.689E+12	.587	.404E+12
7	325	.823E+12	.548	.451E+12
8	375	.126E+13	.546	.688E+12
9	425	.206E+13	.565	.116E+13
10	475	.286E+13	.594	.170E+13
11	525	.302E+13	.966	.291E+13
12	575	.272E+13	1.14	.312E+13
13	625	.236E+13	.600	.142E+13
14	675	.209E+13	.612	.128E+13
15	725	.190E+13	.669	.127E+13
16	775	.177E+13	.886	.157E+13
17	825	.166E+13	1.02	.169E+13
18	875	.159E+13	.899	.143E+13
19	925	.153E+13	1.03	.158E+13
20	975	.150E+13	.967	.145E+13
21	1025	.148E+13	.763	.113E+13
22	1075	.147E+13	.659	.969E+12
23	1125	.146E+13	.659	.963E+12
24	1175	.146E+13	.463	.674E+12
25	1225	.145E+13	.463	.672E+12
26	1275	.145E+13	.736	.107E+13
27	1325	.145E+13	.736	.106E+13
28	1375	.144E+13	.975	.141E+13
29	1425	.144E+13	.975	.141E+13
30	1475	.144E+13	1.04	.150E+13
31	1525	.144E+13	1.04	.150E+13
32	1575	.145E+13	1.07	.155E+13
33	1625	.145E+13	1.07	.155E+13
34	1675	.145E+13	1.27	.184E+13
35	1725	.146E+13	1.27	.185E+13
36	1775	.147E+13	1.02	.149E+13
37	1825	.148E+13	1.02	.151E+13

38	1875	.150E+13	1.78	.266E+13
39	1925	.151E+13	1.78	.269E+13
40	1975	.153E+13	1.86	.285E+13
41	2025	.154E+13	1.86	.288E+13
42	2075	.152E+13	1.95	.296E+13
43	2125	.132E+13	1.95	.257E+13
44	2175	.101E+13	1.50	.152E+13
45	2225	.655E+12	1.50	.983E+12
46	2275	.277E+12	1.40	.388E+12
47	2325	.145E+11	1.40	.203E+11

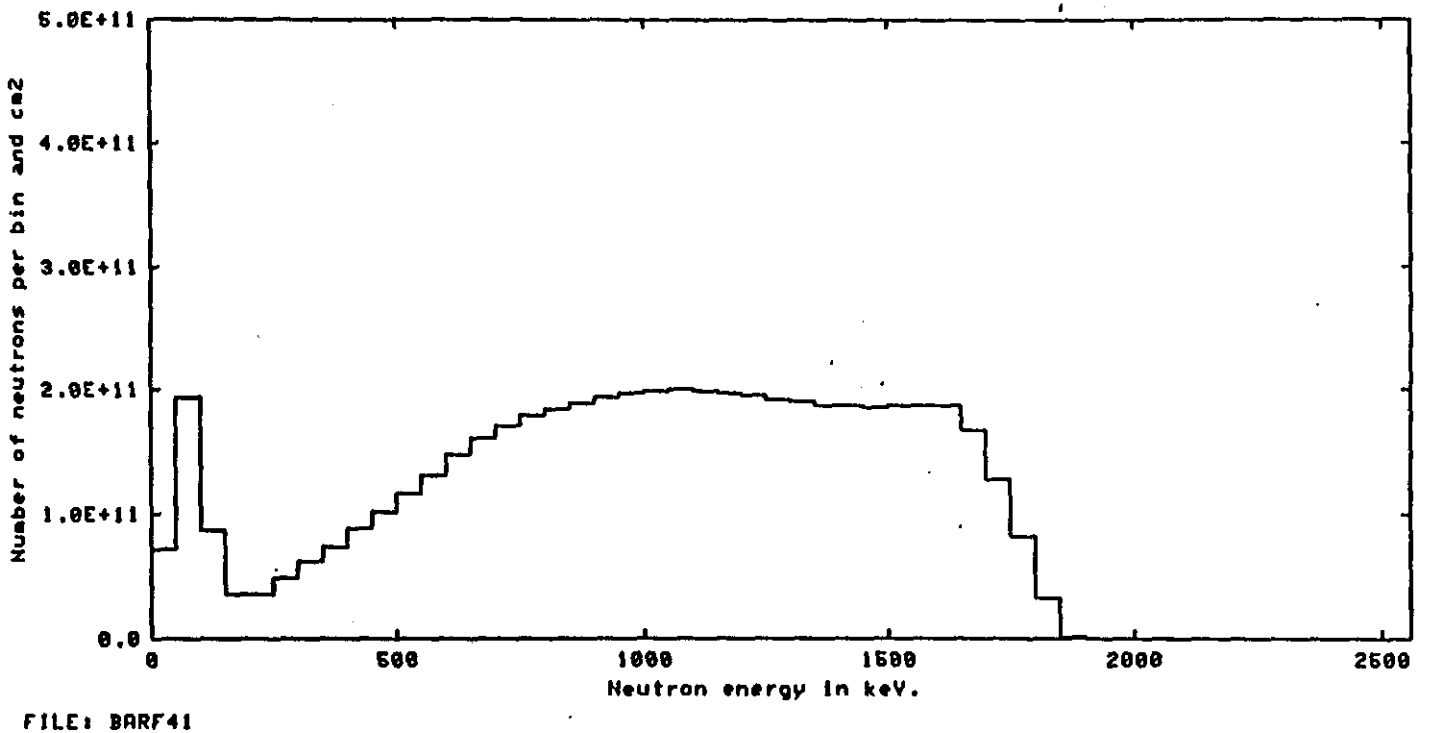

5.0E+12
4.0E+12
3.0E+12
2.0E+12
1.0E+12
0.0
Number of neutrons per bin and cm2
0
500
1000
1500
2000
2500
Neutron energy in keV.
FILE: BARF31

NEUTRON ENERGY SPECTRUM.
University of Lowell. 3:49 AM TUE., 12 MAY , 1992

The following table gives the neutron fluence in neutrons per cm2, for an irraddiation of a thick lithium target with a 4000 keV proton beam.
The total charge delivered to the target is
578.2 mC.
The parameters are:
a= 1.019 cm.
z= 1.785 cm.
R= .8000 cm.
Kappa= 20.00
Slow neutrons (En < 10 keV) per cm2: .6234E+10
Fast neutrons (En > 10 keV) per cm2: .5389E+13
Equivalent number of 1MeV-neutrons per cm2: .4282E+13
The total number (angle and energy integrated) of neutrons generated is: .2422E+15
The output file name is BARF41

Bin number	Bin energy [keV]	Number of neutrons per cm2	ASTM KERMA (E722-85) divided by 95.0MeVmb	1Mev equivalent number of neutrons per cm2
1	30	.716E+11	.233E-01	.167E+10
2	75	.195E+12	.626E-01	.122E+11
3	125	.874E+11	.425E-01	.371E+10
4	175	.360E+11	.425	.153E+11
5	225	.366E+11	.824	.302E+11
6	275	.486E+11	.587	.285E+11
7	325	.629E+11	.548	.345E+11
8	375	.740E+11	.546	.404E+11
9	425	.891E+11	.565	.503E+11
10	475	.102E+12	.594	.605E+11
11	525	.117E+12	.966	.113E+12
12	575	.132E+12	1.14	.151E+12
13	625	.147E+12	.600	.884E+11
14	675	.161E+12	.612	.987E+11
15	725	.171E+12	.669	.115E+12
16	775	.180E+12	.886	.159E+12
17	825	.184E+12	1.02	.187E+12
18	875	.190E+12	.899	.170E+12
19	925	.194E+12	1.03	.200E+12
20	975	.198E+12	.967	.192E+12
21	1025	.199E+12	.763	.152E+12
22	1075	.200E+12	.659	.132E+12
23	1125	.200E+12	.659	.131E+12
24	1175	.198E+12	.463	.916E+11
25	1225	.196E+12	.463	.907E+11
26	1275	.193E+12	.736	.142E+12
27	1325	.191E+12	.736	.140E+12
28	1375	.188E+12	.975	.183E+12
29	1425	.187E+12	.975	.182E+12
30	1475	.187E+12	1.04	.194E+12
31	1525	.187E+12	1.04	.194E+12
32	1575	.187E+12	1.07	.201E+12
33	1625	.187E+12	1.07	.201E+12
34	1675	.168E+12	1.27	.213E+12
35	1725	.129E+12	1.27	.163E+12
36	1775	.819E+11	1.02	.833E+11
37	1825	.329E+11	1.02	.334E+11

38	1875	.113E+10	1.78	.201E+10


5.0E+11
4.0E+11
3.0E+11
2.0E+11
1.0E+11
0.0
Number of neutrons per bin and cm2
0
500
1000
1500
2000
2500
Neutron energy in keV.

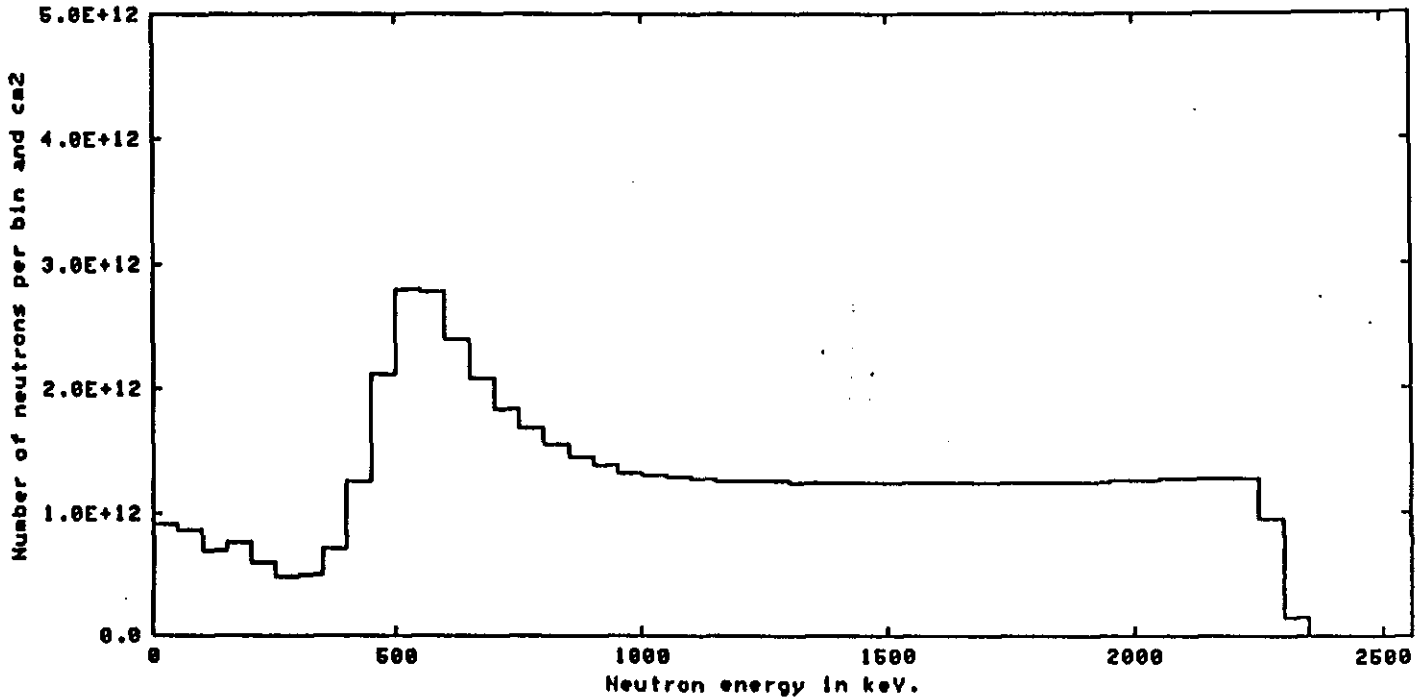
FILE: BARF41

NEUTRON ENERGY SPECTRUM.
University of Lowell. 3:49 AM TUE., 12 MAY , 1992

The following table gives the neutron fluence in neutrons per cm2, for an irraddiation of a thick lithium target with a 4000 keV proton beam.
The total charge delivered to the target is
578.2 mC.
The parameters are:
a= .3180 cm.
z= 2.269 cm.
R= .8000 cm.
Kappa= 20.00
Slow neutrons (En < 10 keV) per cm2: .4094E+11
Fast neutrons (En > 10 keV) per cm2: .6110E+14
Equivalent number of 1MeV-neutrons per cm2: .5956E+14
The total number (angle and energy integrated) of neutrons generated is: .1694E+16
The output file name is BARF32

Bin number	Bin energy [keV]	Number of neutrons per cm2	ASTM KERMA (E722-85) divided by 95.0MeVmb	1Mev equivalent number of neutrons per cm2
1	30	.926E+12	.233E-01	.216E+11
2	75	.879E+12	.626E-01	.550E+11
3	125	.704E+12	.425E-01	.299E+11
4	175	.767E+12	.425	.326E+12
5	225	.603E+12	.824	.497E+12
6	275	.493E+12	.587	.289E+12
7	325	.503E+12	.548	.276E+12
8	375	.722E+12	.546	.394E+12
9	425	.127E+13	.565	.716E+12
10	475	.213E+13	.594	.126E+13
11	525	.280E+13	.966	.271E+13
12	575	.278E+13	1.14	.318E+13
13	625	.241E+13	.600	.144E+13
14	675	.209E+13	.612	.128E+13
15	725	.184E+13	.669	.123E+13
16	775	.169E+13	.886	.150E+13
17	825	.157E+13	1.02	.160E+13
18	875	.147E+13	.899	.132E+13
19	925	.141E+13	1.03	.145E+13
20	975	.133E+13	.967	.129E+13
21	1025	.132E+13	.763	.101E+13
22	1075	.129E+13	.659	.852E+12
23	1125	.129E+13	.659	.848E+12
24	1175	.127E+13	.463	.590E+12
25	1225	.127E+13	.463	.588E+12
26	1275	.126E+13	.736	.927E+12
27	1325	.126E+13	.736	.926E+12
28	1375	.125E+13	.975	.122E+13
29	1425	.125E+13	.975	.122E+13
30	1475	.125E+13	1.04	.130E+13
31	1525	.125E+13	1.04	.130E+13
32	1575	.125E+13	1.07	.134E+13
33	1625	.125E+13	1.07	.134E+13
34	1675	.125E+13	1.27	.158E+13
35	1725	.125E+13	1.27	.158E+13
36	1775	.125E+13	1.02	.127E+13
37	1825	.125E+13	1.02	.127E+13

38	1875	.125E+13	1.78	.223E+13
39	1925	.126E+13	1.78	.223E+13
40	1975	.126E+13	1.86	.236E+13
41	2025	.127E+13	1.86	.237E+13
42	2075	.128E+13	1.95	.248E+13
43	2125	.128E+13	1.95	.249E+13
44	2175	.129E+13	1.50	.193E+13
45	2225	.128E+13	1.50	.192E+13
46	2275	.948E+12	1.40	.133E+13
47	2325	.147E+12	1.40	.205E+12


5.0E+12
4.0E+12
3.0E+12
2.0E+12
1.0E+12
0.0
Number of neutrons per bin and cm2
0
500
1000
1500
2000
2500
Neutron energy in keV.

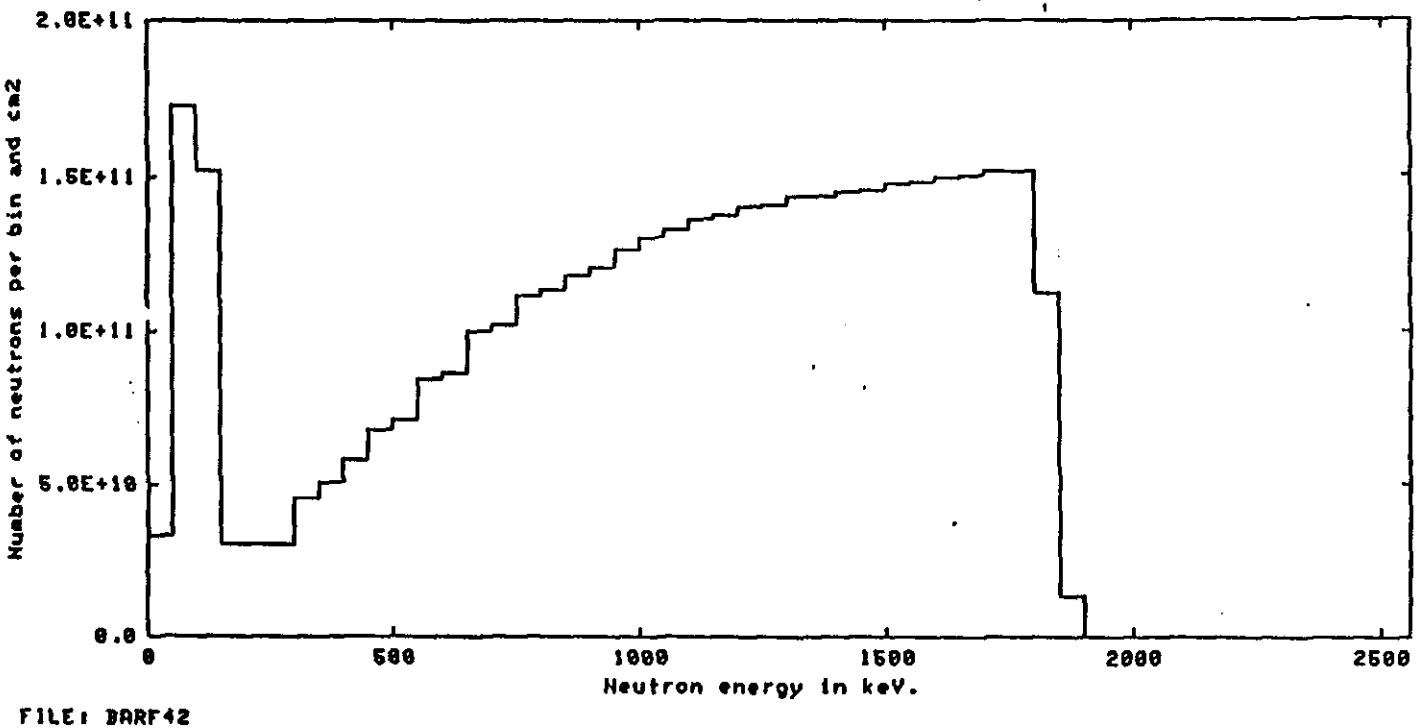
FILE: BARF32

NEUTRON ENERGY SPECTRUM.
University of Lowell. 3:50 AM TUE., 12 MAY , 1992

The following table gives the neutron fluence in neutrons per cm2, for an irraddiation of a thick lithium target with a 4000 keV proton beam.
The total charge delivered to the target is
578.2 mC.
The parameters are:
a= .3180 cm.
z= 2.269 cm.
R= .8000 cm.
Kappa= 20.00
Slow neutrons (En < 10 keV) per cm2: .3602E+10
Fast neutrons (En > 10 keV) per cm2: .4119E+13
Equivalent number of 1MeV-neutrons per cm2: .3302E+13
The total number (angle and energy integrated) of neutrons generated is: .2422E+15
The output file name is BARF42

Bin number	Bin energy [keV]	Number of neutrons per cm2	ASTM KERMA (E722-85) divided by 95.0MeVmb	1Mev equivalent number of neutrons per cm2
1	30	.329E+11	.233E-01	.767E+09
2	75	.173E+12	.626E-01	.108E+11
3	125	.152E+12	.425E-01	.646E+10
4	175	.300E+11	.425	.128E+11
5	225	.302E+11	.824	.249E+11
6	275	.304E+11	.587	.178E+11
7	325	.453E+11	.548	.248E+11
8	375	.506E+11	.546	.276E+11
9	425	.580E+11	.565	.327E+11
10	475	.679E+11	.594	.403E+11
11	525	.714E+11	.966	.689E+11
12	575	.840E+11	1.14	.962E+11
13	625	.862E+11	.600	.517E+11
14	675	.997E+11	.612	.610E+11
15	725	.102E+12	.669	.683E+11
16	775	.111E+12	.886	.983E+11
17	825	.113E+12	1.02	.115E+12
18	875	.118E+12	.899	.106E+12
19	925	.121E+12	1.03	.124E+12
20	975	.126E+12	.967	.122E+12
21	1025	.130E+12	.763	.992E+11
22	1075	.133E+12	.659	.876E+11
23	1125	.136E+12	.659	.898E+11
24	1175	.138E+12	.463	.637E+11
25	1225	.140E+12	.463	.649E+11
26	1275	.141E+12	.736	.104E+12
27	1325	.143E+12	.736	.106E+12
28	1375	.143E+12	.975	.140E+12
29	1425	.145E+12	.975	.141E+12
30	1475	.145E+12	1.04	.151E+12
31	1525	.148E+12	1.04	.153E+12
32	1575	.148E+12	1.07	.159E+12
33	1625	.149E+12	1.07	.160E+12
34	1675	.150E+12	1.27	.190E+12
35	1725	.151E+12	1.27	.192E+12
36	1775	.151E+12	1.02	.154E+12
37	1825	.112E+12	1.02	.113E+12

38	1875	.130E+11	1.78	.231E+11


2.0E+11
1.5E+11
1.0E+11
5.0E+10
0.0
Number of neutrons per bin and cm2
0
500
1000
1500
2000
2500
Neutron energy in keV.

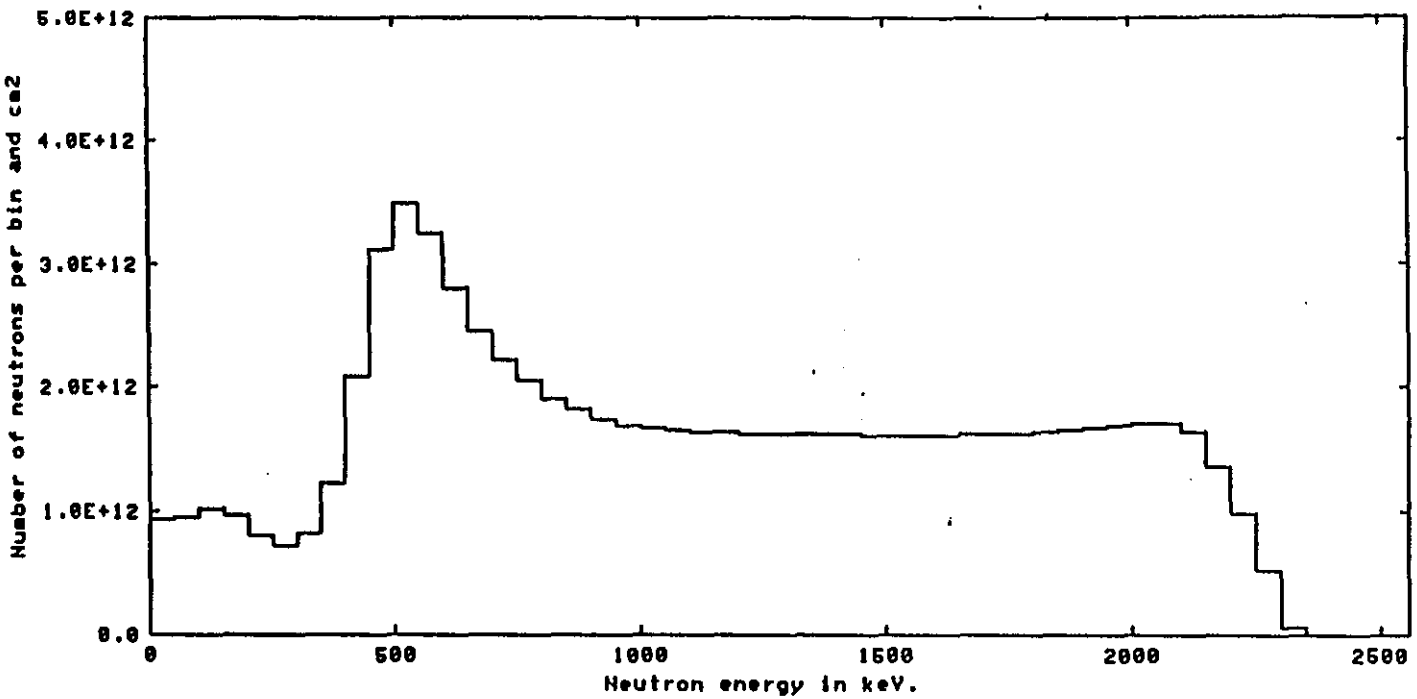
FILE: BARF42

NEUTRON ENERGY SPECTRUM.
University of Lowell. 3:50 AM TUE., 12 MAY , 1992

The following table gives the neutron fluence in neutrons per cm2, for an irraddiation of a thick lithium target with a 4000 keV proton beam.
The total charge delivered to the target is
578.2 mC.
The parameters are:
a= .7970 cm.
z= 1.785 cm.
R= .8000 cm.
Kappa= 20.00
Slow neutrons (En < 10 keV) per cm2: .5685E+11
Fast neutrons (En > 10 keV) per cm2: .7689E+14
Equivalent number of 1MeV-neutrons per cm2: .7432E+14
The total number (angle and energy integrated) of neutrons generated is: .1694E+16
The output file name is BARF33

Bin number	Bin energy [keV]	Number of neutrons per cm2	ASTM KERMA (E722-85) divided by 95.0MeVmb	1Mev equivalent number of neutrons per cm2
1	30	.939E+12	.233E-01	.219E+11
2	75	.960E+12	.626E-01	.601E+11
3	125	.102E+13	.425E-01	.434E+11
4	175	.977E+12	.425	.415E+12
5	225	.813E+12	.824	.671E+12
6	275	.724E+12	.587	.425E+12
7	325	.822E+12	.548	.450E+12
8	375	.124E+13	.546	.677E+12
9	425	.209E+13	.565	.118E+13
10	475	.311E+13	.594	.184E+13
11	525	.349E+13	.966	.337E+13
12	575	.323E+13	1.14	.370E+13
13	625	.280E+13	.600	.168E+13
14	675	.245E+13	.612	.150E+13
15	725	.221E+13	.669	.148E+13
16	775	.205E+13	.886	.182E+13
17	825	.191E+13	1.02	.195E+13
18	875	.182E+13	.899	.164E+13
19	925	.175E+13	1.03	.180E+13
20	975	.170E+13	.967	.164E+13
21	1025	.168E+13	.763	.128E+13
22	1075	.166E+13	.659	.109E+13
23	1125	.165E+13	.659	.109E+13
24	1175	.164E+13	.463	.759E+12
25	1225	.163E+13	.463	.756E+12
26	1275	.163E+13	.736	.120E+13
27	1325	.162E+13	.736	.119E+13
28	1375	.162E+13	.975	.158E+13
29	1425	.162E+13	.975	.158E+13
30	1475	.162E+13	1.04	.168E+13
31	1525	.162E+13	1.04	.168E+13
32	1575	.162E+13	1.07	.174E+13
33	1625	.162E+13	1.07	.174E+13
34	1675	.162E+13	1.27	.206E+13
35	1725	.163E+13	1.27	.206E+13
36	1775	.163E+13	1.02	.166E+13
37	1825	.164E+13	1.02	.167E+13

38	1875	.166E+13	1.78	.294E+13
39	1925	.167E+13	1.78	.297E+13
40	1975	.169E+13	1.86	.315E+13
41	2025	.170E+13	1.86	.317E+13
42	2075	.172E+13	1.95	.334E+13
43	2125	.165E+13	1.95	.320E+13
44	2175	.137E+13	1.50	.206E+13
45	2225	.987E+12	1.50	.148E+13
46	2275	.527E+12	1.40	.738E+12
47	2325	.680E+11	1.40	.952E+11


5.0E+12
4.0E+12
3.0E+12
2.0E+12
1.0E+12
0.0
Number of neutrons per bin and cm2
0
500
1000
1500
2000
2500
Neutron energy in keV.

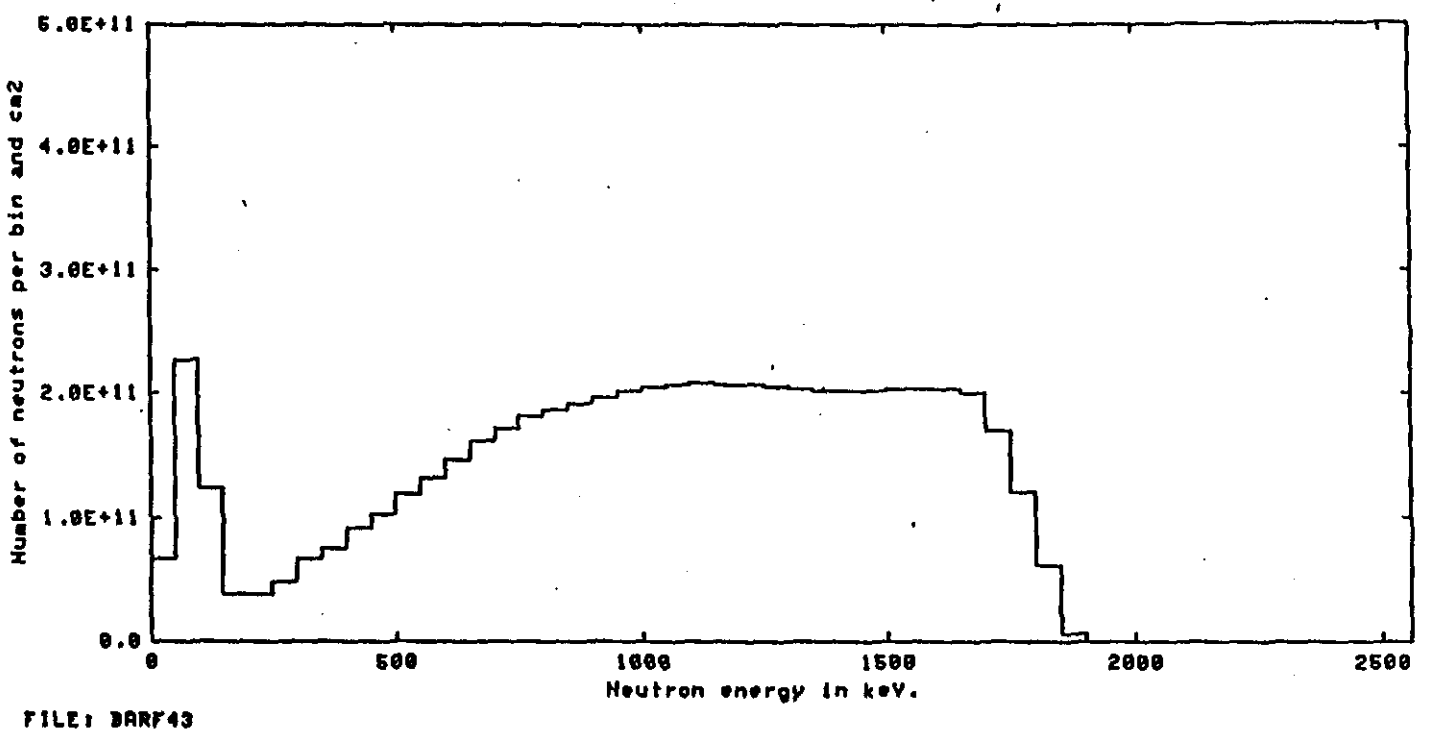
FILE: BARF33

NEUTRON ENERGY SPECTRUM.
University of Lowell. 3:51 AM TUE., 12 MAY , 1992

The following table gives the neutron fluence in neutrons per cm2, for an irraddiation of a thick lithium target with a 4000 keV proton beam.
The total charge delivered to the target is
578.2 mC.
The parameters are:
a= .7970 cm.
z= 1.785 cm.
R= .8000 cm.
Kappa= 20.00
Slow neutrons (En < 10 keV) per cm2: .6197E+10
Fast neutrons (En > 10 keV) per cm2: .5812E+13
Equivalent number of 1MeV-neutrons per cm2: .4635E+13
The total number (angle and energy integrated) of neutrons generated is: .2422E+15
The output file name is BARF43

Bin number	Bin energy [keV]	Number of neutrons per cm2	ASTM KERMA (E722-85) divided by 95.0MeVmb	1Mev equivalent number of neutrons per cm2
1	30	.676E+11	.233E-01	.158E+10
2	75	.226E+12	.626E-01	.142E+11
3	125	.125E+12	.425E-01	.533E+10
4	175	.399E+11	.425	.170E+11
5	225	.400E+11	.824	.330E+11
6	275	.490E+11	.587	.287E+11
7	325	.670E+11	.548	.367E+11
8	375	.757E+11	.546	.413E+11
9	425	.925E+11	.565	.523E+11
10	475	.104E+12	.594	.615E+11
11	525	.119E+12	.966	.115E+12
12	575	.133E+12	1.14	.152E+12
13	625	.148E+12	.600	.890E+11
14	675	.162E+12	.612	.992E+11
15	725	.173E+12	.669	.116E+12
16	775	.182E+12	.886	.161E+12
17	825	.187E+12	1.02	.190E+12
18	875	.192E+12	.899	.173E+12
19	925	.197E+12	1.03	.203E+12
20	975	.203E+12	.967	.196E+12
21	1025	.205E+12	.763	.157E+12
22	1075	.207E+12	.659	.137E+12
23	1125	.208E+12	.659	.137E+12
24	1175	.208E+12	.463	.963E+11
25	1225	.207E+12	.463	.960E+11
26	1275	.206E+12	.736	.151E+12
27	1325	.205E+12	.736	.151E+12
28	1375	.203E+12	.975	.198E+12
29	1425	.202E+12	.975	.197E+12
30	1475	.202E+12	1.04	.210E+12
31	1525	.203E+12	1.04	.211E+12
32	1575	.204E+12	1.07	.218E+12
33	1625	.205E+12	1.07	.220E+12
34	1675	.201E+12	1.27	.255E+12
35	1725	.171E+12	1.27	.216E+12
36	1775	.122E+12	1.02	.124E+12
37	1825	.623E+11	1.02	.634E+11

38	1875	.604E+10	1.78	.107E+11


5.0E+11
4.0E+11
3.0E+11
2.0E+11
1.0E+11
0.0
Number of neutrons per bin and cm2
0
500
1000
1500
2000
2500
Neutron energy in keV.

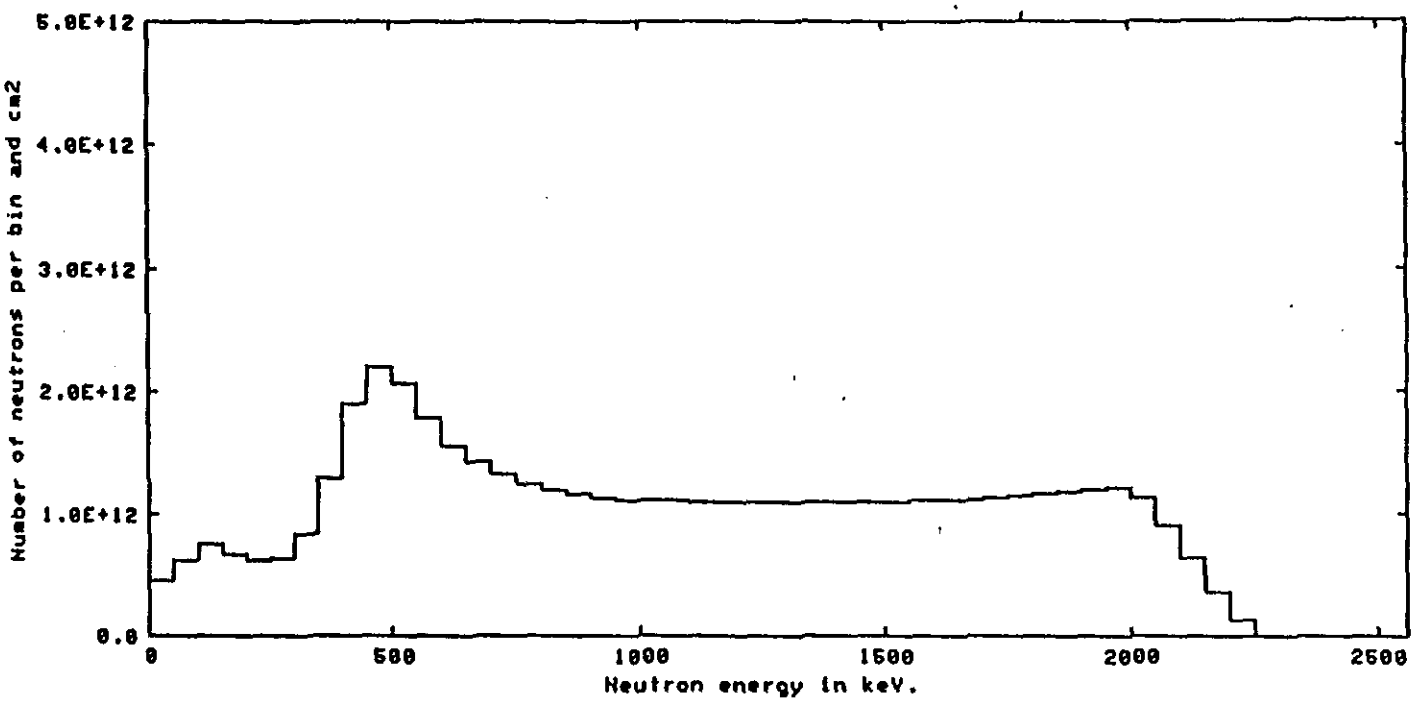
FILE: BARF43

NEUTRON ENERGY SPECTRUM.
University of Lowell. 3:51 AM TUE., 12 MAY , 1992

The following table gives the neutron fluence in neutrons per cm2, for an irraddiation of a thick lithium target with a 4000 keV proton beam.
The total charge delivered to the target is
578.2 mC.
The parameters are:
a= 1.477 cm.
z= 1.751 cm.
R= .8000 cm.
Kappa= 20.00
Slow neutrons (En < 10 keV) per cm2: .4325E+11
Fast neutrons (En > 10 keV) per cm2: .4988E+14
Equivalent number of 1MeV-neutrons per cm2: .4664E+14
The total number (angle and energy integrated) of neutrons generated is: .1694E+16
The output file name is BARF34

Bin number	Bin energy [keV]	Number of neutrons per cm2	ASTM KERMA (E722-85) divided by 95.0MeVmb	1Mev equivalent number of neutrons per cm2
1	30	.461E+12	.233E-01	.107E+11
2	75	.624E+12	.626E-01	.391E+11
3	125	.760E+12	.425E-01	.323E+11
4	175	.682E+12	.425	.290E+12
5	225	.618E+12	.824	.510E+12
6	275	.639E+12	.587	.375E+12
7	325	.847E+12	.548	.464E+12
8	375	.129E+13	.546	.705E+12
9	425	.190E+13	.565	.107E+13
10	475	.221E+13	.594	.131E+13
11	525	.207E+13	.966	.200E+13
12	575	.179E+13	1.14	.205E+13
13	625	.157E+13	.600	.942E+12
14	675	.142E+13	.612	.871E+12
15	725	.133E+13	.669	.888E+12
16	775	.125E+13	.886	.111E+13
17	825	.120E+13	1.02	.122E+13
18	875	.116E+13	.899	.104E+13
19	925	.113E+13	1.03	.117E+13
20	975	.112E+13	.967	.109E+13
21	1025	.112E+13	.763	.852E+12
22	1075	.111E+13	.659	.732E+12
23	1125	.111E+13	.659	.730E+12
24	1175	.111E+13	.463	.512E+12
25	1225	.110E+13	.463	.511E+12
26	1275	.110E+13	.736	.812E+12
27	1325	.110E+13	.736	.813E+12
28	1375	.110E+13	.975	.108E+13
29	1425	.111E+13	.975	.108E+13
30	1475	.111E+13	1.04	.115E+13
31	1525	.111E+13	1.04	.115E+13
32	1575	.111E+13	1.07	.119E+13
33	1625	.112E+13	1.07	.120E+13
34	1675	.112E+13	1.27	.143E+13
35	1725	.114E+13	1.27	.144E+13
36	1775	.115E+13	1.02	.117E+13
37	1825	.117E+13	1.02	.119E+13

38	1875	.119E+13	1.78	.211E+13
39	1925	.121E+13	1.78	.214E+13
40	1975	.122E+13	1.86	.227E+13
41	2025	.114E+13	1.86	.212E+13
42	2075	.912E+12	1.95	.177E+13
43	2125	.644E+12	1.95	.125E+13
44	2175	.369E+12	1.50	.553E+12
45	2225	.124E+12	1.50	.186E+12
46	2275	.350E+10	1.40	.489E+10


5.0E+12
4.0E+12
3.0E+12
2.0E+12
1.0E+12
0.0
Number of neutrons per bin and cm2
0
500
1000
1500
2000
2500
Neutron energy in keV.

FILE: BARF34

NEUTRON ENERGY SPECTRUM.
University of Lowell. 3:52 AM TUE., 12 MAY , 1992

The following table gives the neutron fluence in neutrons per cm2, for an irraddiation of a thick lithium target with a 4000 keV proton beam.
The total charge delivered to the target is
578.2 mC.
The parameters are:
a= 1.477 cm.
z= 1.751 cm.
R= .8000 cm.
Kappa= 20.00
Slow neutrons (En < 10 keV) per cm2: .6276E+10
Fast neutrons (En > 10 keV) per cm2: .4519E+13
Equivalent number of 1MeV-neutrons per cm2: .3550E+13
The total number (angle and energy integrated) of neutrons generated is: .2422E+15
The output file name is BARF44

Bin number	Bin energy [keV]	Number of neutrons per cm2	ASTM KERMA (E722-85) divided by 95.0MeVmb	1Mev equivalent number of neutrons per cm2
1	30	.779E+11	.233E-01	.182E+10
2	75	.123E+12	.626E-01	.768E+10
3	125	.375E+11	.425E-01	.159E+10
4	175	.282E+11	.425	.120E+11
5	225	.324E+11	.824	.267E+11
6	275	.467E+11	.587	.274E+11
7	325	.559E+11	.548	.306E+11
8	375	.701E+11	.546	.383E+11
9	425	.827E+11	.565	.467E+11
10	475	.982E+11	.594	.583E+11
11	525	.113E+12	.966	.109E+12
12	575	.129E+12	1.14	.148E+12
13	625	.144E+12	.600	.866E+11
14	675	.156E+12	.612	.955E+11
15	725	.166E+12	.669	.111E+12
16	775	.171E+12	.886	.151E+12
17	825	.176E+12	1.02	.179E+12
18	875	.180E+12	.899	.162E+12
19	925	.183E+12	1.03	.188E+12
20	975	.184E+12	.967	.178E+12
21	1025	.183E+12	.763	.139E+12
22	1075	.181E+12	.659	.119E+12
23	1125	.178E+12	.659	.117E+12
24	1175	.174E+12	.463	.806E+11
25	1225	.169E+12	.463	.784E+11
26	1275	.165E+12	.736	.121E+12
27	1325	.161E+12	.736	.118E+12
28	1375	.158E+12	.975	.154E+12
29	1425	.156E+12	.975	.152E+12
30	1475	.155E+12	1.04	.161E+12
31	1525	.154E+12	1.04	.160E+12
32	1575	.150E+12	1.07	.161E+12
33	1625	.124E+12	1.07	.133E+12
34	1675	.880E+11	1.27	.112E+12
35	1725	.506E+11	1.27	.642E+11
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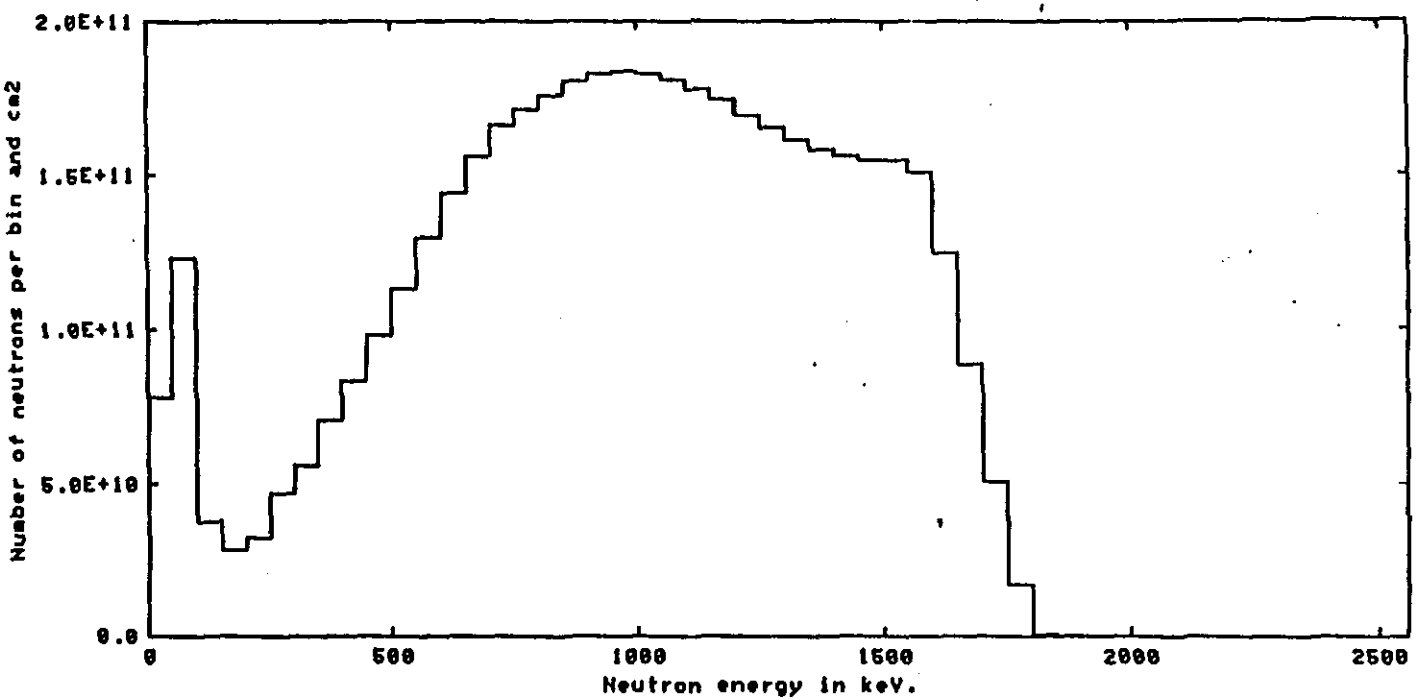
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1.5E+11
1.0E+11
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0.0
Number of neutrons per bin and cm2
0
500
1000
1500
2000
2500
Neutron energy in keV.

FILE: BARF44

Radiation Effect In Hydrolysed Barium Floride Crystal

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May 15, 1992

Radiation Effect In Hydrolysed Barium Floride Crystal

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1 Introduction

BaF_2 is the fastest scintillator known with its fast decay time of 0.6 ns at 220 nm wavelength, and could be used as electromagnetic colorimeter for high counting rates mesurement.

As we know most BaF_2 crystals generally available exist a serious radiation damage where the radiation dosage is high. The damage results in the reduction of both its optical transmission and scintillation light output, and become an extremely important issue for its application such as at the SSC. There are indications that the radiation damage in BaF_2 crystal relates to oxygen[1-3]. We believe that the hydrolysis process is a possible way for oxygen incorporated into the BaF_2. The purpose of the present work is to investigate the radiation effect in hydrolysed BaF_2. We hope it would be helpful to understand the mechanism of the radiation damage in BaF_2.

2 Theoretical Research

The Localized Spin-State Density (LSD) theory was employed to calculate the electronic structure of impurities in BaF_2. Since it is known that hydroxyl and oxygen impurities could be incorporated into the bulk by means of hydrolysis process, particular attention has been paid to them. The absorption bands of color centres, hydroxyl and oxygen impurity centres are summarized in Tab. 1.

Tab. 1 The absorption peaks of the color centres, hydroxyl and oxygen impurty centres

Color centres	λ (nm)	Color centres	λ (nm)	
F	611	O^{2-}	130	
			200	
M	720		290	
V_K	336	O^{2-}-V_a	123	148
	750		127	188
U	206	$F_H(O^{2-})$	394	
OH^-	191		443	
O^-	175	$F_{2H}(O^{2-})$	365	
	230		539	
	413			

From the above results we know the U,OH^-, O^- and O^{2-} centres would be all the possible sources for the damage in BaF_2, since they have the absorption bands near 220 nm. But we need to make it clear what would be the main one that results in the radiation damage in actual process.

3 Experimental Results and Discussion

3.1 Experimental Procedure

The BaF_2 crystals used in our experiment were provided by Shanghai Institute of Ceramics. One is 1# BaF_2 grown in recent experiment, and the other is 2# BaF_2 grown at low vacuum. All the samples were processed to the thickness of 2 mm. Some were treated in air above 900 °C. The characteristic of optical absorption curves of samples before and after γ -irradiation were obtained in the regions of VUV, UV and IR with Acton VM 505, Graphicord UV-204 and Nicolet DX-V 5.07 Spectrophotometres. The radiation test was performed with the dose of 1×10^6 rad.

3.2 Optical Absorption Spectra of Hydrolysed BaF_2

The UV absorption curves of 1# sample which had been treated in air with different time were shown in Fig. 1. From these spectra we can see that the absorptions at low wavelength are much strong. These phenomena are quite similar to the absorption in large BaF_2 generally available. When we prolonged the heating time, an absorption peak at 192 nm appeared. The position was just situated at OH^- absorption band obtained by our theoretical study. We proposed that OH^- can incorporated into BaF_2 by means of hydrolysis process.

The absorption band in IR region between 3100 ~ 3700 cm^{-1} obtained in our experiment also shown the present of OH^- in hydrolysed BaF_2 (see Fig. 2). It is known that OH^- occupying a fluoride site in BaF_2 has an absorption band at 3630 cm^{-1} corresponding its stretching mode. While the OH^- act as an interstitial traps to form OH^--interstitial centre, the O-H valence bond is elongated and shifts the corresponding absorption band towards low energy.

For the hydrolysed BaF_2 crystals, their VUV absorption edges shift towards lower energies from 134 nm to 150 nm (see Fig. 3). the edge of 2# sample grown at low vacuum is situated at 148 nm near to the hydrolyzed BaF_2. It seems to be reasonable to consider that the 2# sample is contaminated by hydroxyl or oxygen impurities.

From the above results we get an impression that OH^- are very easy to enter into BaF_2 crystals by means of hydrolysed process,and oxygen probably can also get into the bulk through this process to form $O^{2-}V_a$ centre.

3.3 Radiation Effect In Hydrolysed BaF_2

The absorption spectra from VUV to UV between hydrolysed and as grown BaF_2 before and after irradiation were shown in Fig. 4 and Fig. 5. From the spectra we can see that the hydrolysed one exists a serious radiation damage, although no obvious absorption at 192 nm was found before irradiation. The results indicate that only a small amount of hydroxyl or oxygen impurities can lead to a serious radiation damage in BaF_2. Concerning our theoretical analysis, we proposed that after irradiation the absorption bands of hydrolysed BaF_2 situated at 204 nm and ~ 240 nm corresponded to U and O^- centres respectively, which might be produced by the following radiolysis processes.

(1) The OH^- was decomposed through radiolysis to form U and O^- centres

$$OH^- \longrightarrow \begin{cases} H_i + O_s^- & \text{or} \\ H_s^- + O_i^0 \end{cases}$$

This hypothesis was further confirmed by the the absorption at 793.75 cm^{-1} in IR spectra (see Fig. 6) originated from the U centre.

(2) The $O^{2-}V_a$ was decomposed through radiolysis to form O^- and F-related centres:

$$O^{2-} + V_a \longrightarrow O^- + F$$

The absorption spectra of hydrolysed BaF_2 before and after irradiation are shown in Fig. 7. The spectra demonstrate that after irradiation three absorption bands appeared. The absorption at ~ 240 nm and ~ 670 nm can explained by O^- and F-related centres.

4 Conclusion

From above discussion, it is emerged a clear picture that hydroxyl and oxygen-contained impurities are very easy to enter into BaF_2 by means of hydrolysis process. The mechanism of radiation damage in hydrolysed BaF_2 can be explained in Tab. 2.

Tab. 2 The mechanism of radiation damage in hydrolysed BaF_2

Before Irradiation		After Irradiation
OH^- : 192 nm	$\longrightarrow$	U : 204 nm
		O^- : ~240 nm
$O^{2-}V_a$: 148 nm	$\longrightarrow$	O^- : ~240 nm
		F-related centre : ~670 nm

If we can find a way that can destroy the above radiolysed processes. The radiation damage results from hydroxyl and oxygen impurities can be controled.

Acknowledgements

The authors would like to acknowledge Prof. Z. W. Yin, Prof. P. J. Li for providing BaF_2 and their stimulating discussions. This work was supported by the National Science Foundation of China and the contract **191-750-31**.

References

1. L.M.Wang *et. al.*, *Paper presented in GEM BaF_2 Panel Meeting, Shanghai, May 24, 1991.*

2. Z.W.Yin *et. al.*, *Paper presented in GEM BaF_2 Panel Meeting, Shanghai, May 24, 1991.*

3. G.Chen *et. al.*, *Paper presented in GEM BaF_2 Panel Meeting, Shanghai, Dec 12, 1991.*

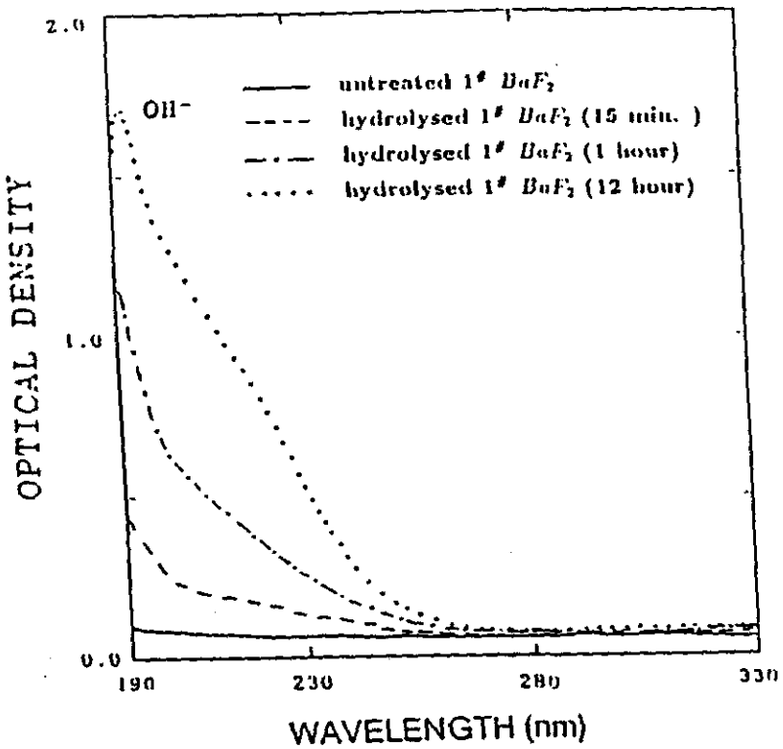

Fig. 1. Absorption spectra for different hydrolysed 1# BaF_2

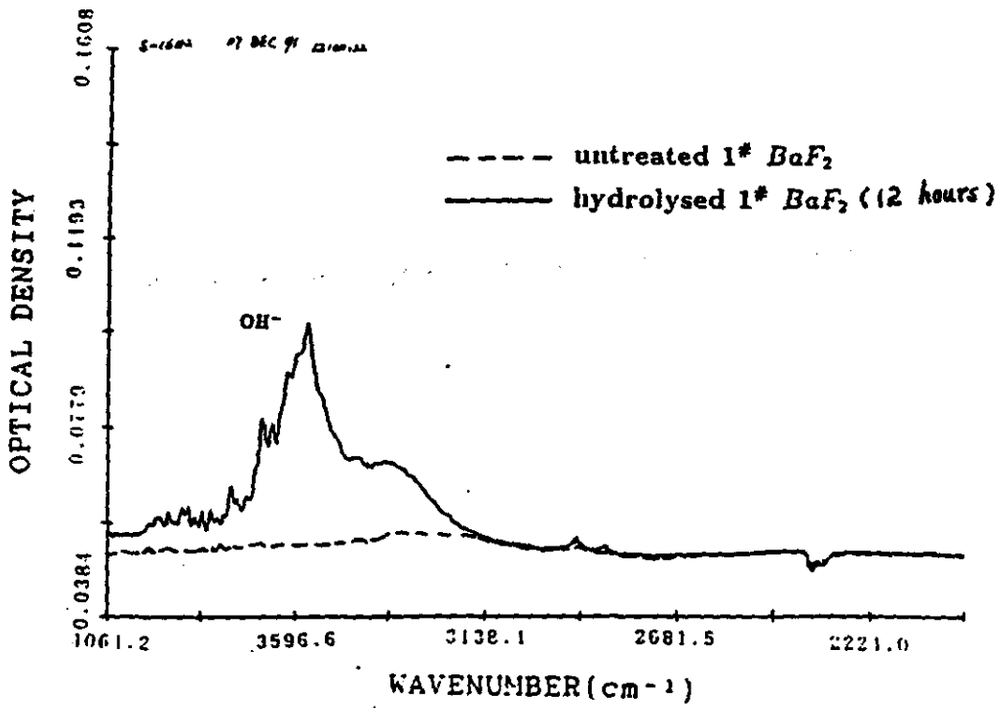

Fig. 2. Infrered spectra for hydrolysed and untreated 1# BaF_2

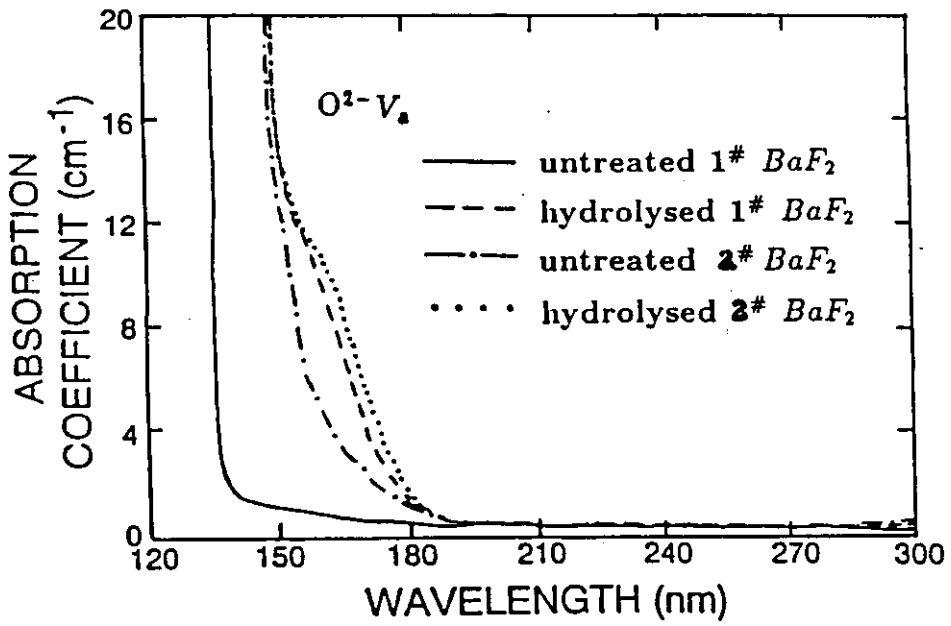

Fig. 3. VUV absorption for hydrolysed and untreated BaF_2

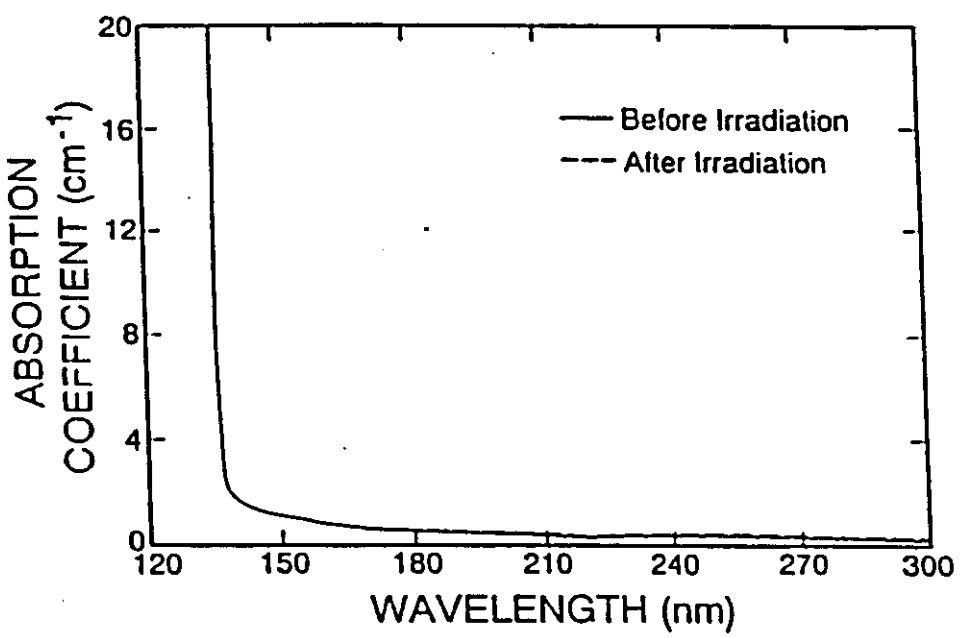

Fig. 4. Absorption spectra of 1# BaF_2 before and after irradiation

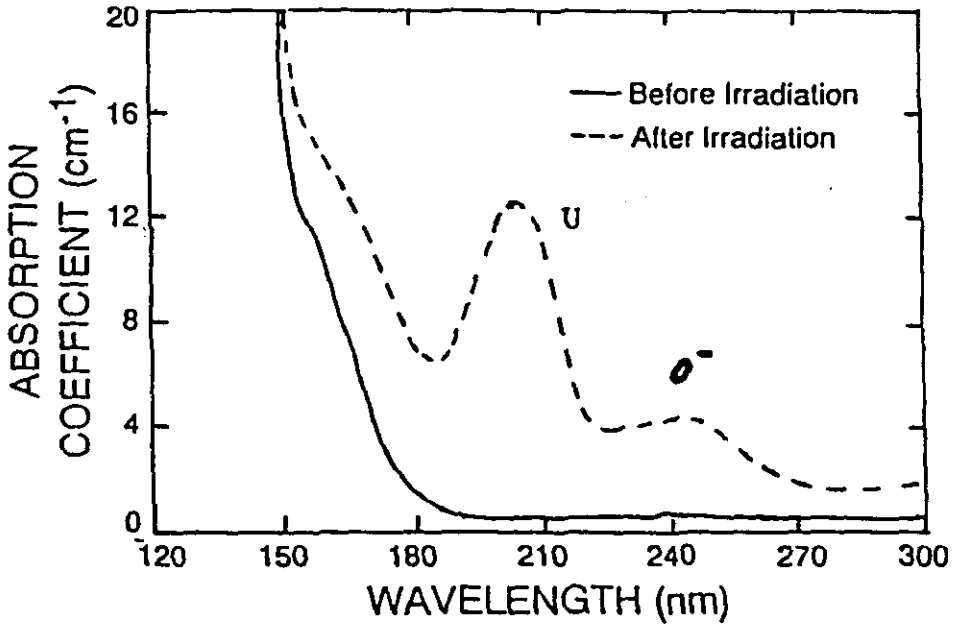

Fig. 5. Absorption spectra of hydrolysed 1# BaF_2 before and after irradiation

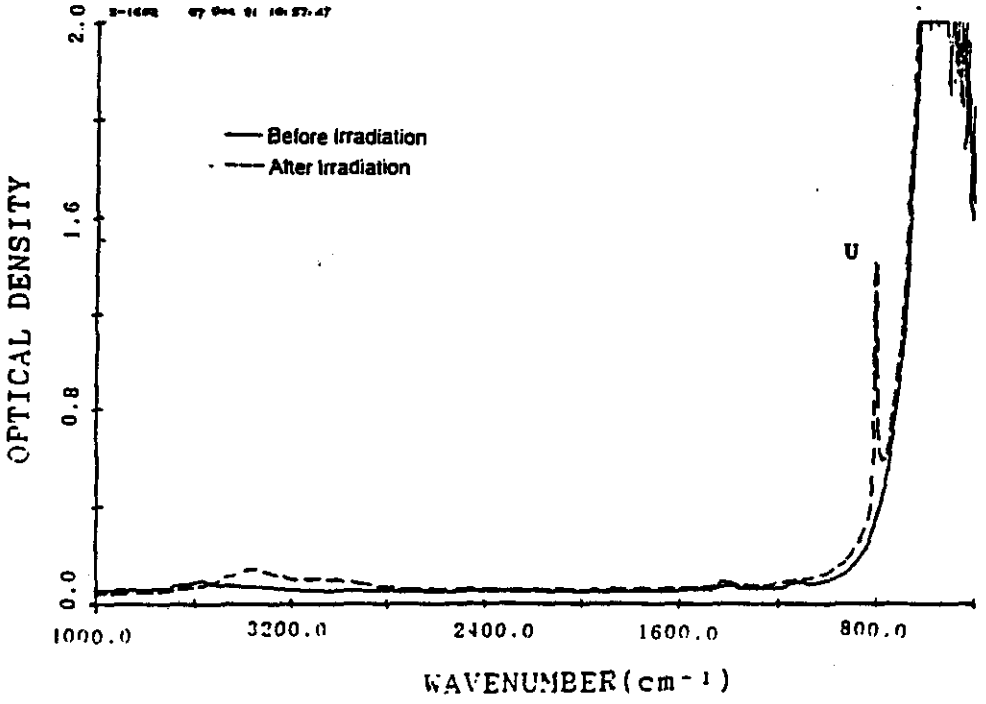

Fig. 6. IR Absorption spectra for hydrolysed 1# BaF_2 before and after irradiation

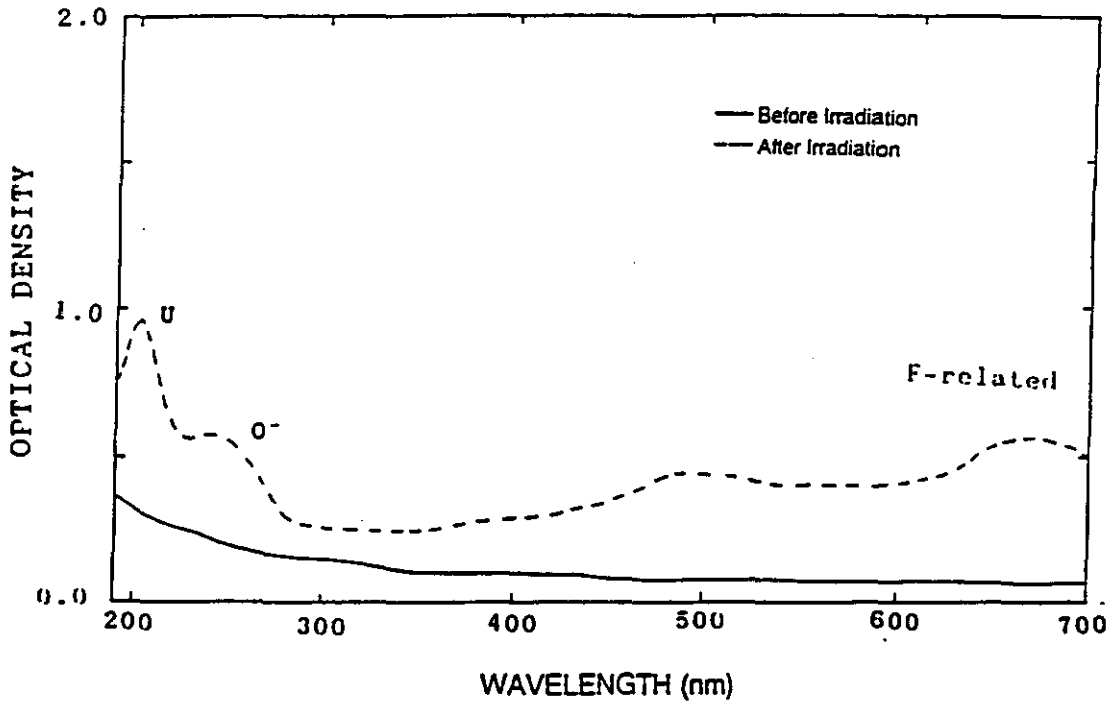

Fig. 7. Absorption spectra for hydrolysed 1# BaF_2 before and after irradiation

CHARLES EVANS & ASSOCIATES
SPECIALISTS IN MATERIALS CHARACTERIZATION

May 13, 1992

TO: Harvey Newman
Lauritsen Laboratory
California Institute of Technology
391 S. Holliston
Pasadena, CA 91125

FM: Michael D. Strathman

RE: SIMS Report for work performed April 1 and 9, 1992.

Previously reported results:
The results of the oxygen bulk measurements and the deep depth profiles have been faxed or attached to previous reports. Confirming copies of this data are included in this report. The oxygen data is presented in table #1. The deep depth profiles are presented in figures #0 through #4. Figures #0 and 1 are color plots of profiles in which inclusions were not found. Figures #3, 4 and 5 show evidence of inclusions.

SIMS Elemental Imaging:
Three sequences of SIMS elemental images were acquired from sample T27 cut from the 1 of 19 prototype crystal. These data are presented in figures #5 through #14. All images were taken with a 150um x 150um image area at a depth of less than twenty microns from the surface of the cleave. Figure #5 is a background check of the RAE detector. This image shows the residual noise on the image detector when no signal is present.

Figures #6, 7, and 8 are elemental images taken from area A. Figure #6 presents the images of barium and fluorine. Notice that the high intensity barium signal in the lower left hand corner of the image is not duplicated in the fluorine image. Of special note is that the fluorine secondary ion intensity was large enough that electron ablation (rather than ion sputtering) was used to acquire the fluorine image. Figure #7 shows good correlation between the oxygen and hydrogen signals and an anticorrelation with the carbon signal. Figure #8 presents the images of the sulfur and chlorine. Note that the chlorine signal has a hot spot on the left edge of the image that is not correlated with the hot spots in the other elemental images. This sequence of images tends to support the theory that much of the oxygen may be present with hydrogen, possibly as OH. Most important, these images show that there are lateral variations in all of the elements imaged. The difference in the barium and fluorine images suggests that the crystal may not all be BaF_2.

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Figures #9, 10, and 11 are images taken from area B. This sequence captures a carbon - oxygen precipitate. Figure #9 shows the barium and fluorine data. Note the hot spot near the center of the fluorine image. This area is to the right of the carbon - oxygen hot spot presented in figure #10. Figure #11 shows that there may be an enhancement of the chlorine and sulfur in the precipitate found in region B.

Figures #12, 13, and 14 are the images acquired from region C. Area C is below Area B. The images for area C were acquired just after the images for Area B, in the same SIMS crater. This area was fairly elementally uniform. The only hot spot is a small area in the fluorine data shown on figure #12. The rest of the images are devoid of features, although there may be a slight increase in the carbon and oxygen on the right had side of their respective images.

<u>Summary:</u>
The SIMS images suggest that there are microscopic variations in the lateral chemical composition of the BaF2 crystals. The variation of oxygen is sometimes correlated with carbon and at other times correlated with hydrogen. Thus measurement of the total oxygen concentration may not give a clear picture of the oxygen which is optically active in the crystal. Processing parameters may effect the chemical state of the oxygen in the crystal and thus change the optical response of the material.

All of these images were acquired from the near surface of the cleave. It may be useful to sputter into a crystal cleaved face for several microns in the depth profiling mode (as in figure #3) until a precipitate is found. Then the SIMS instrument could be used to image the precipitate at depth in the crystal.

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9 Apr 92 Cs

CHARLES EVANS AND ASSOCIATES
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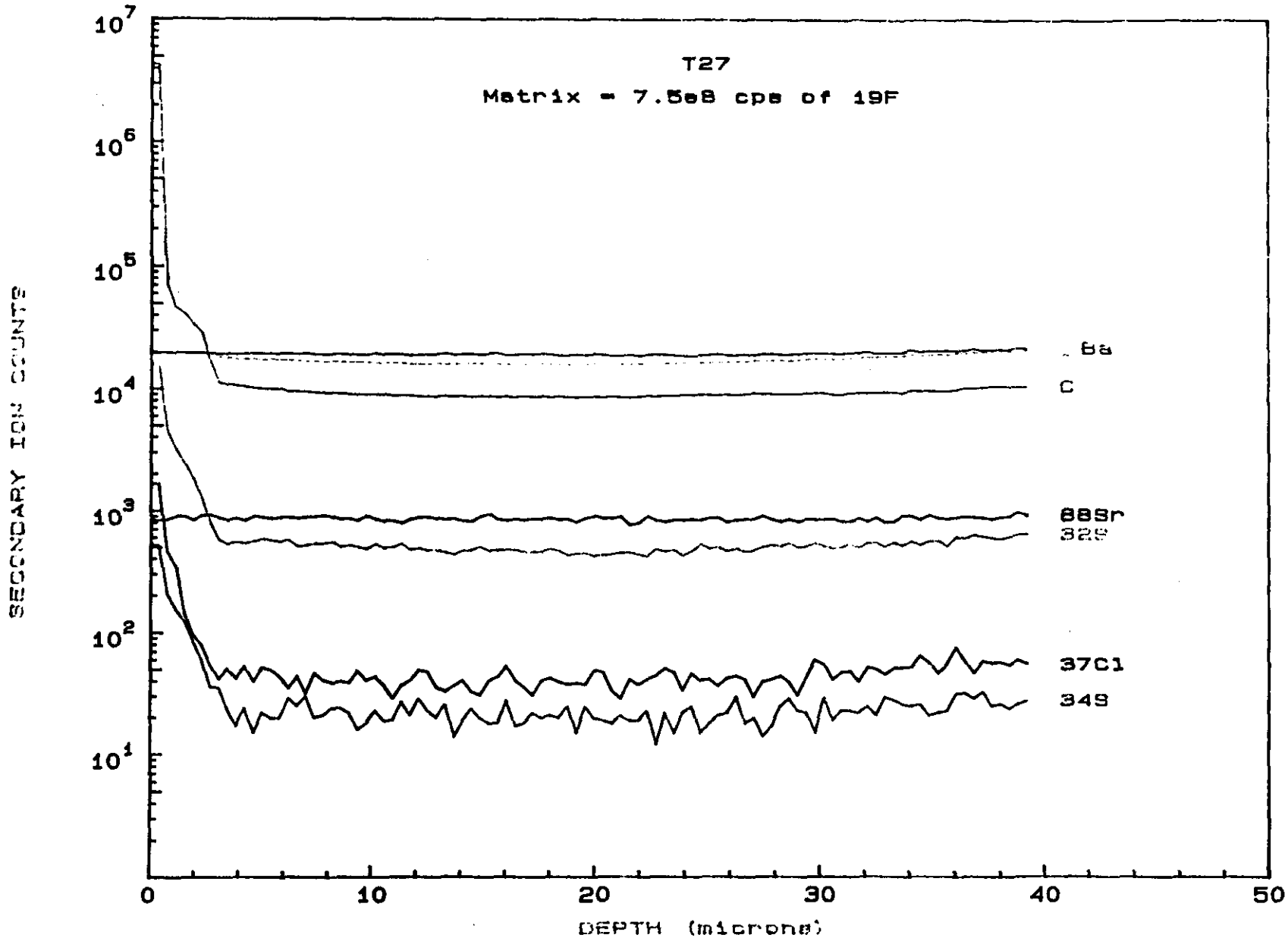

Fig. 6

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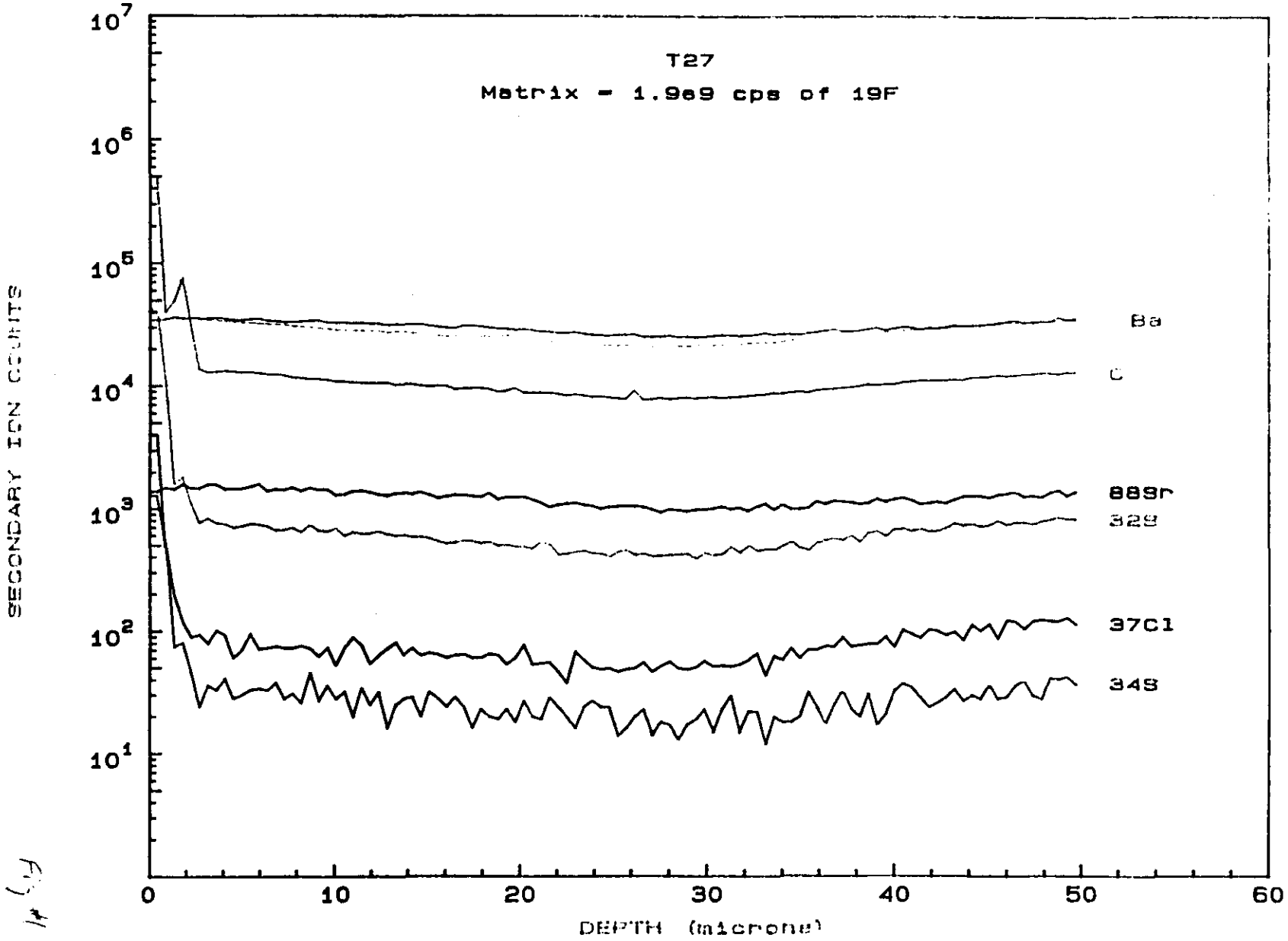

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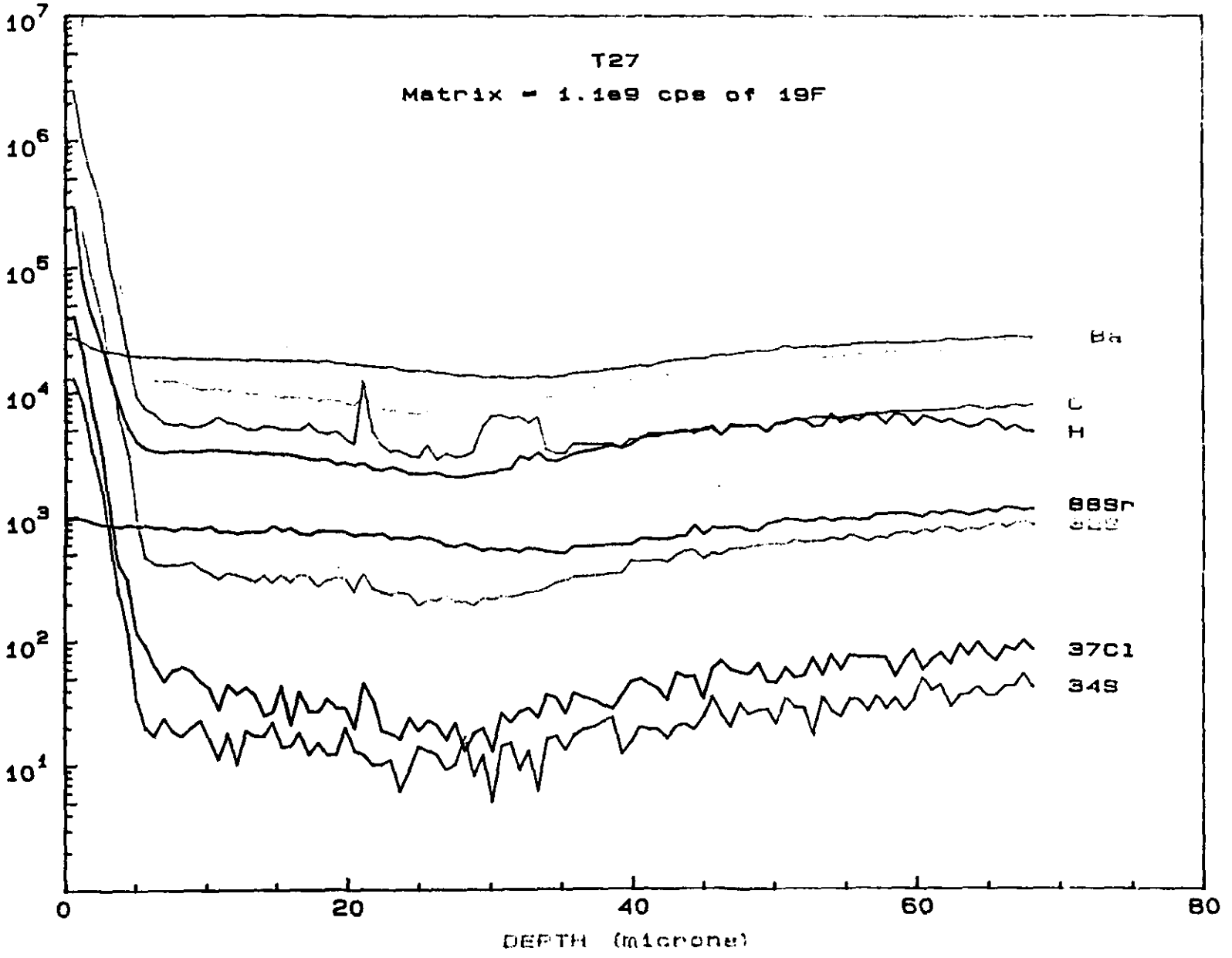

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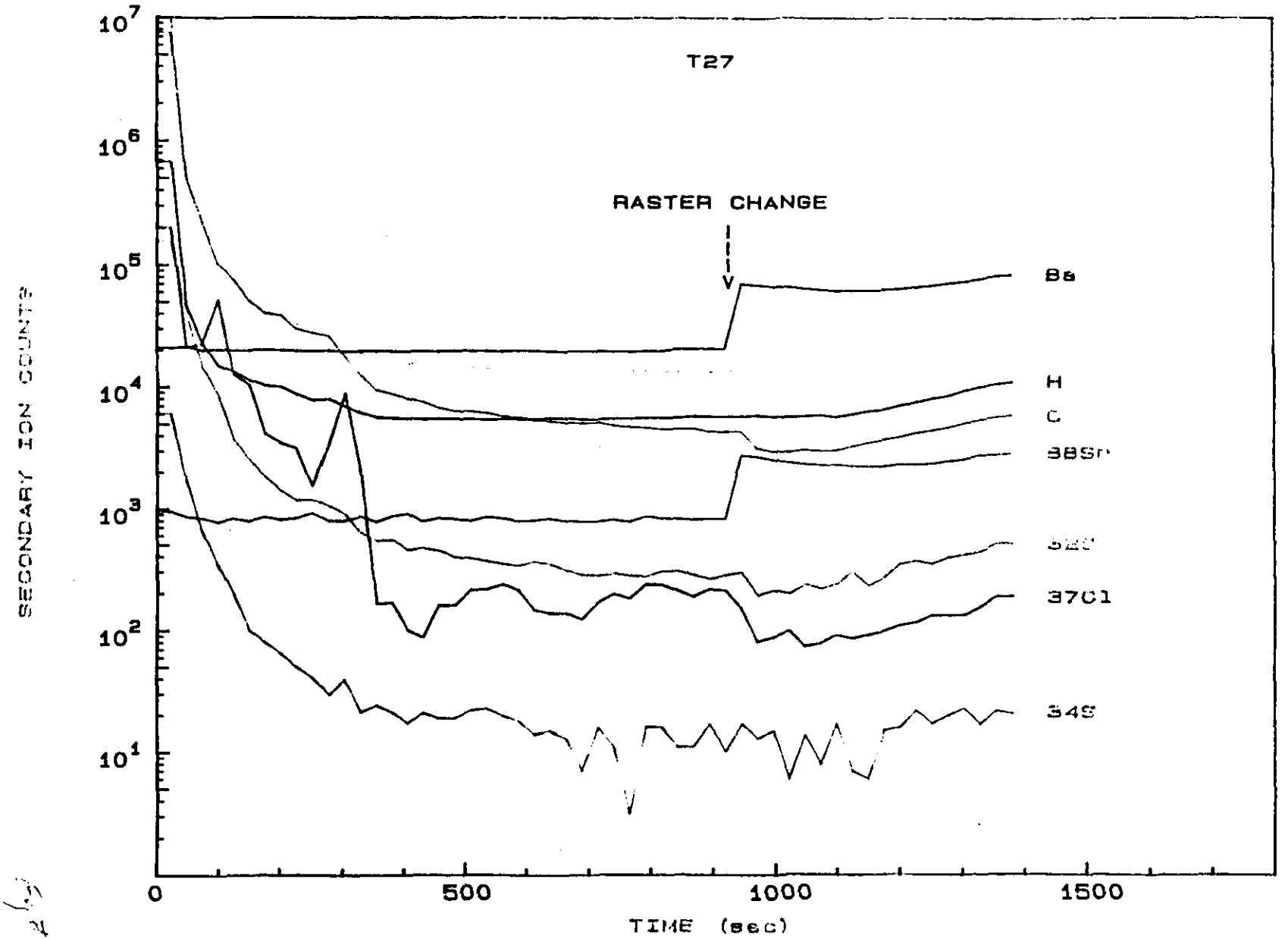

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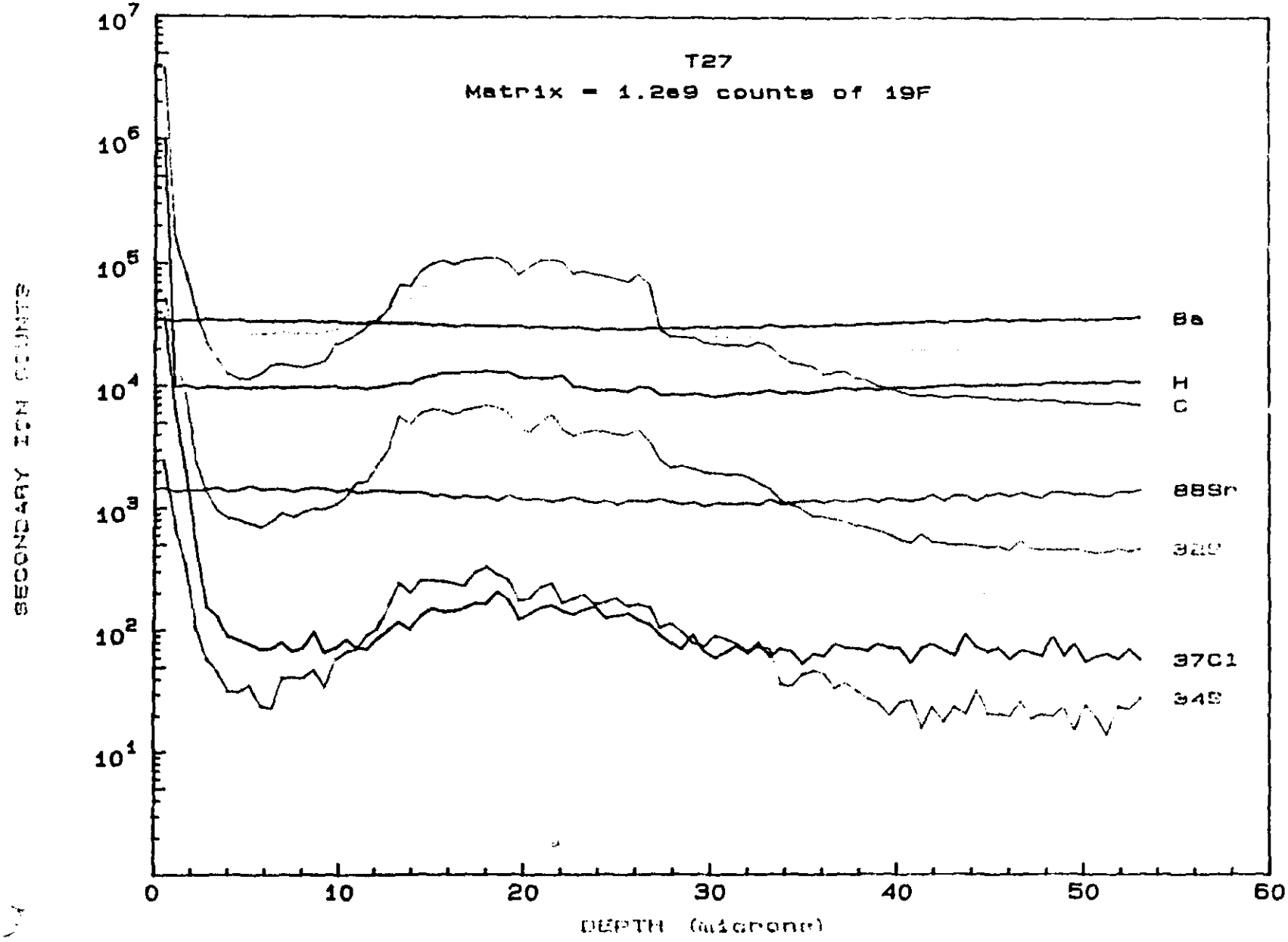

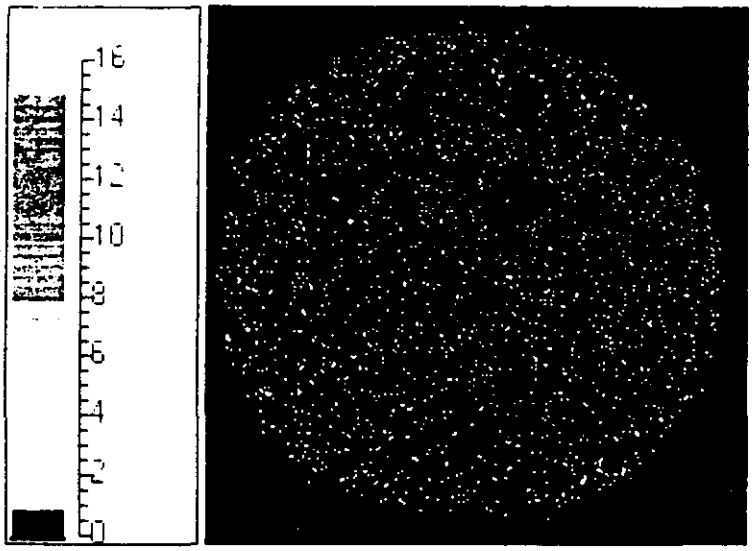

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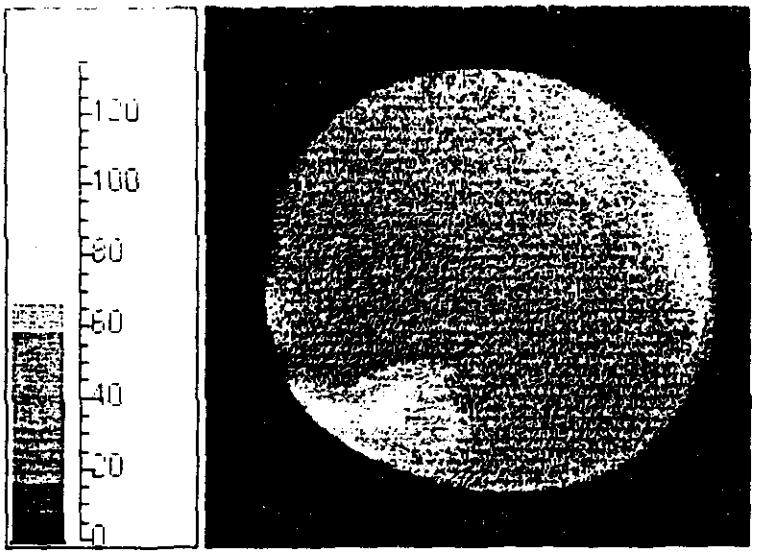

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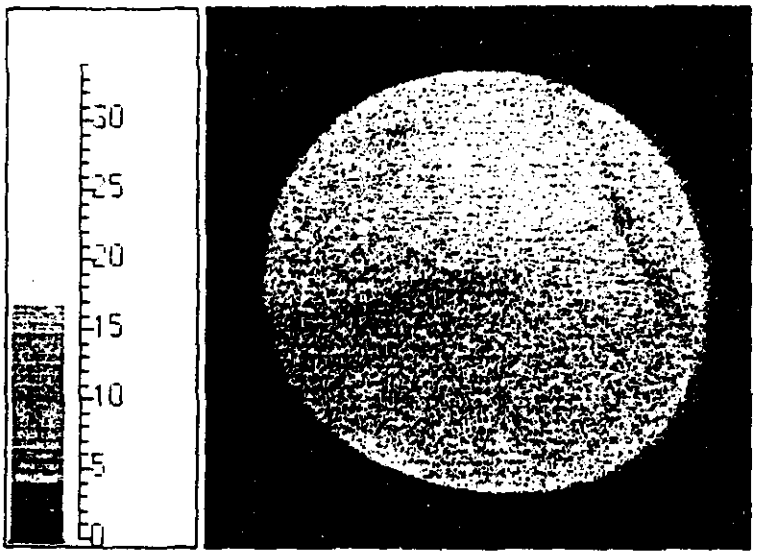

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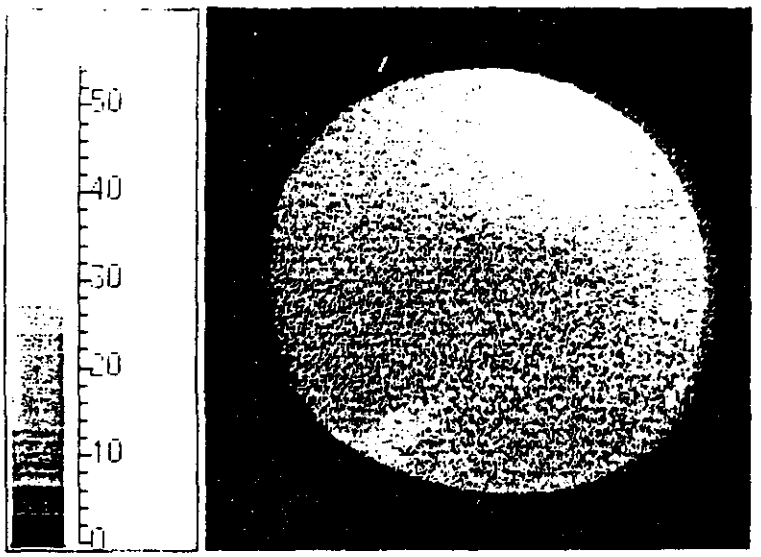

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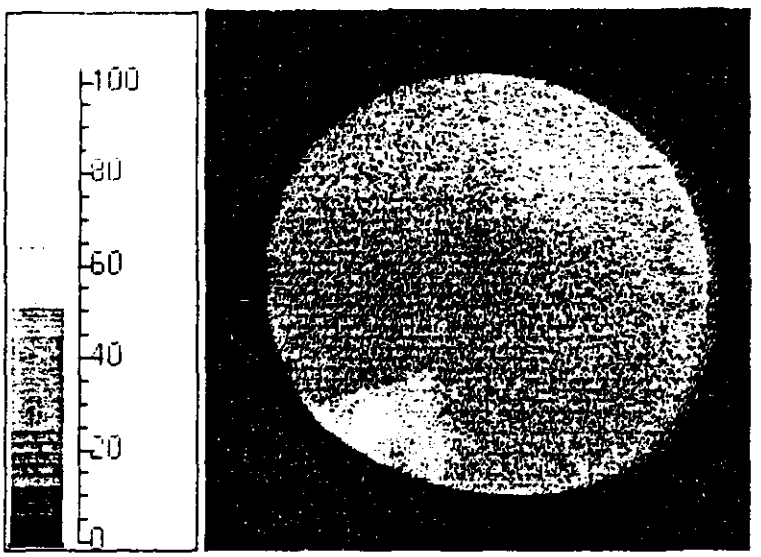

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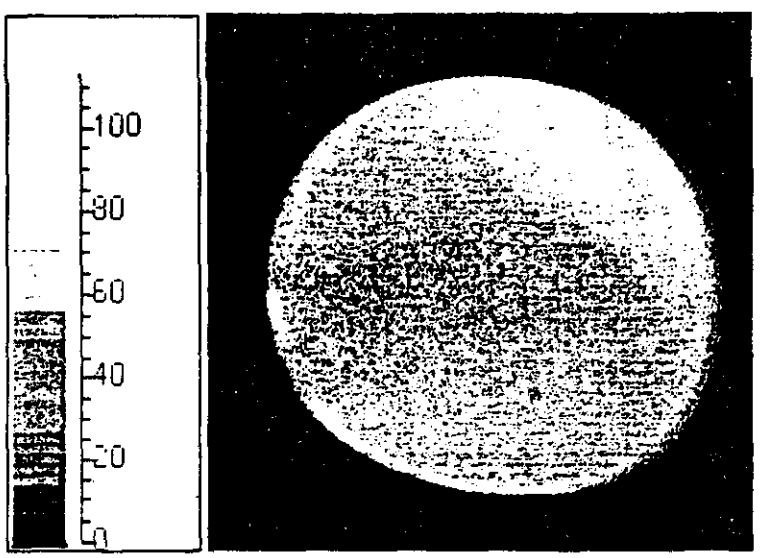

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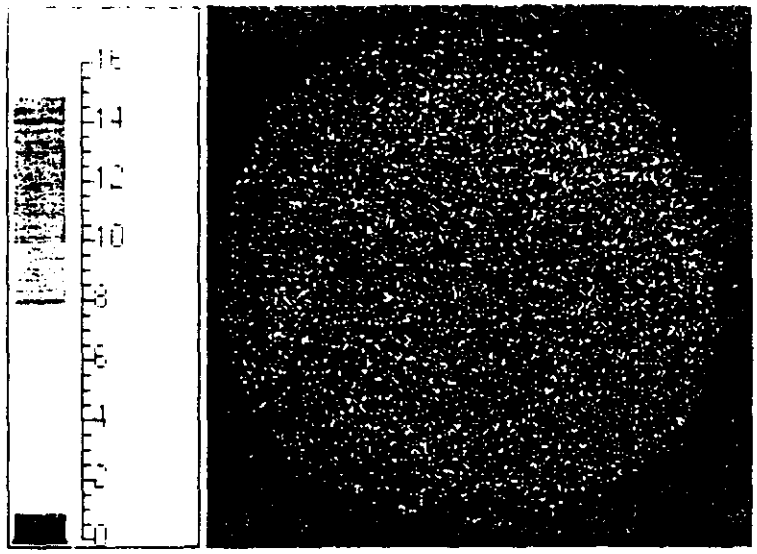

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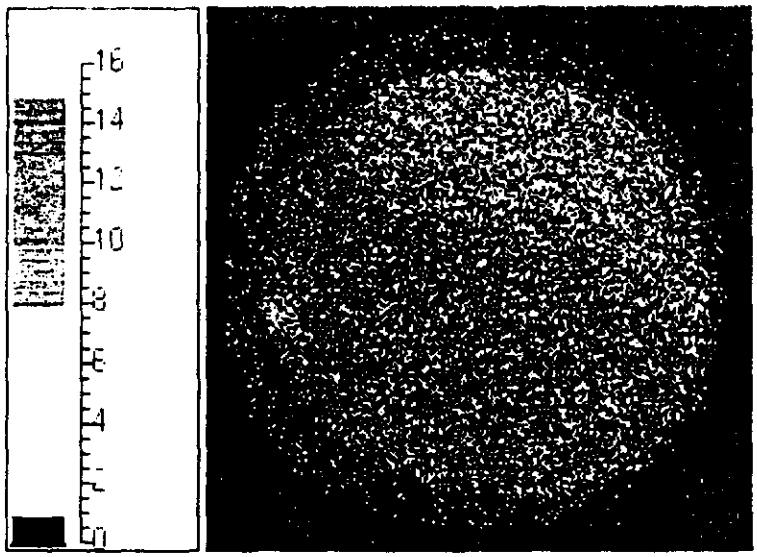

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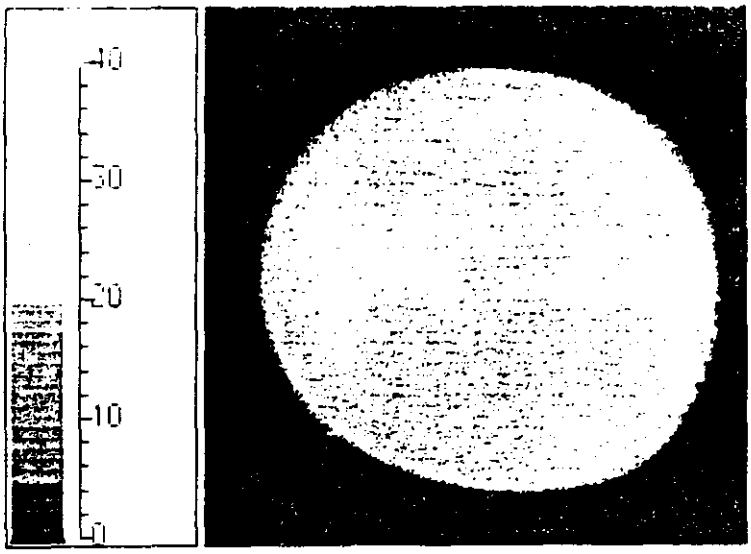

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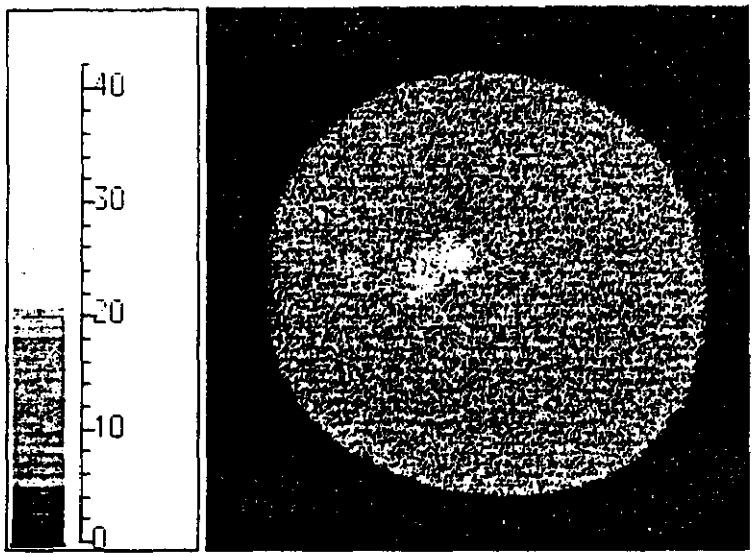

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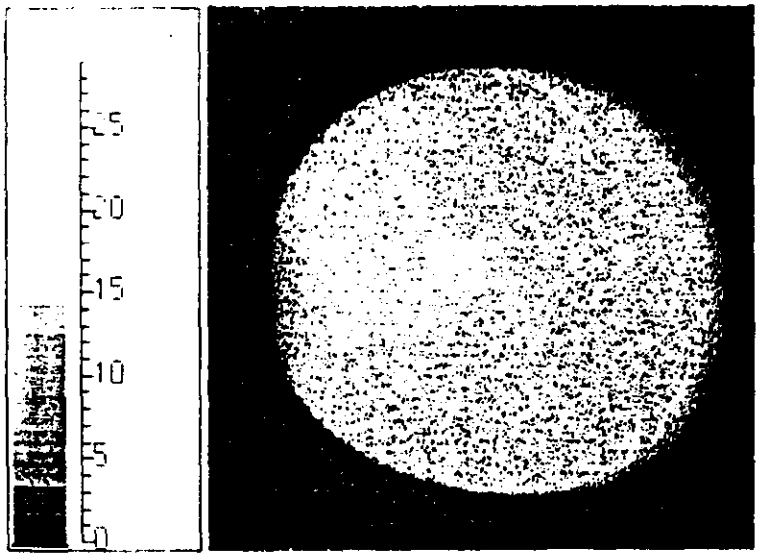

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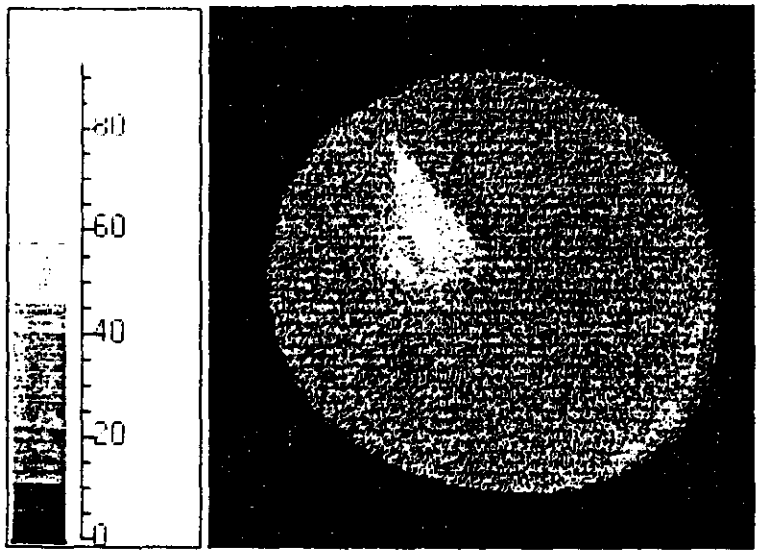

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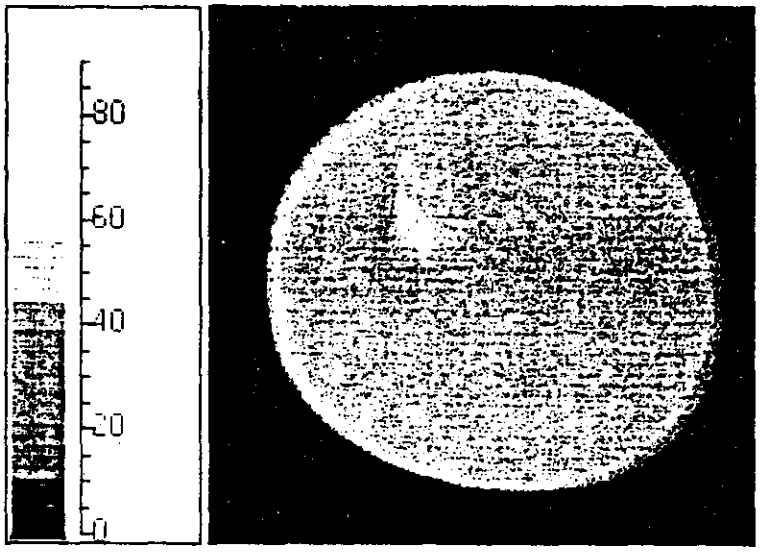

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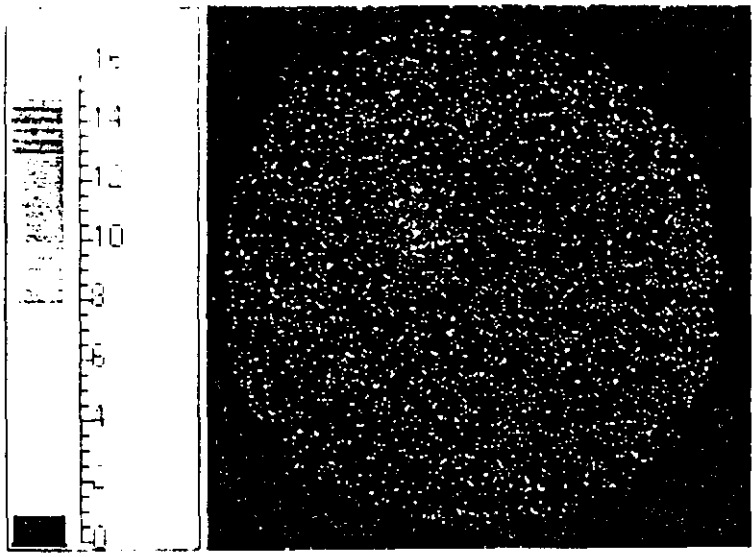

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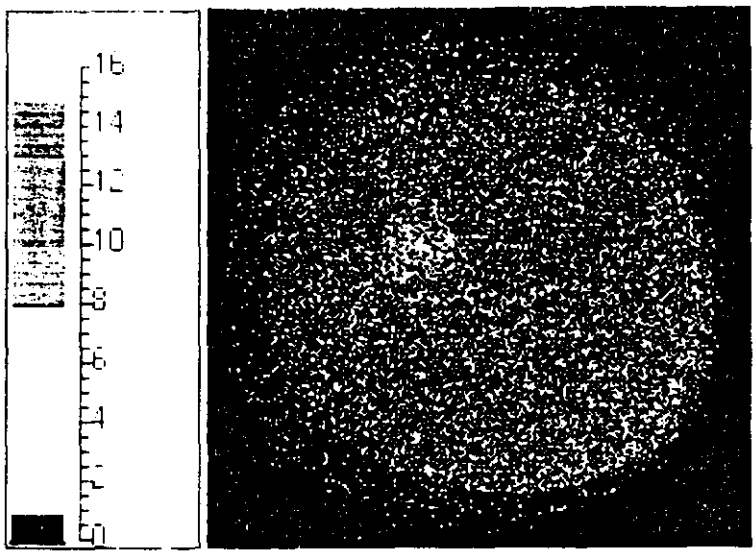

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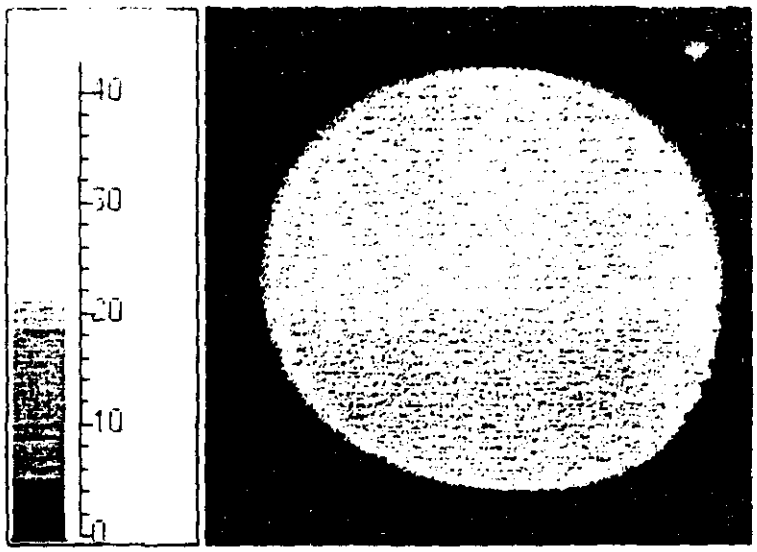

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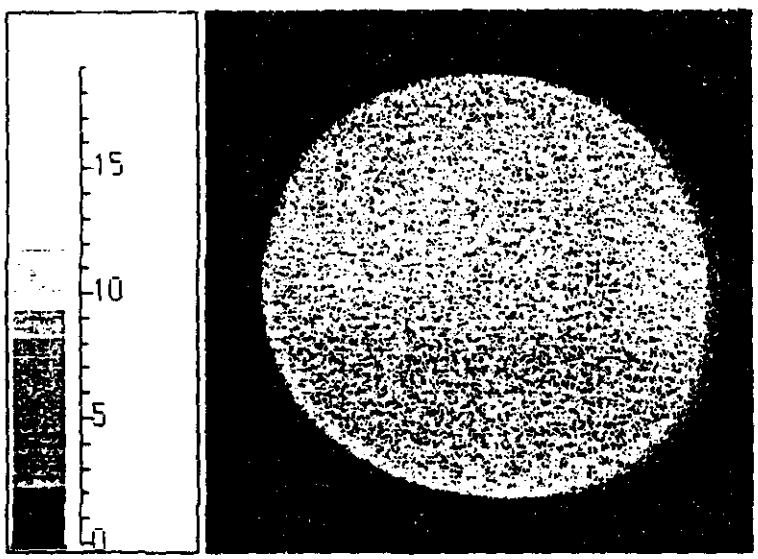

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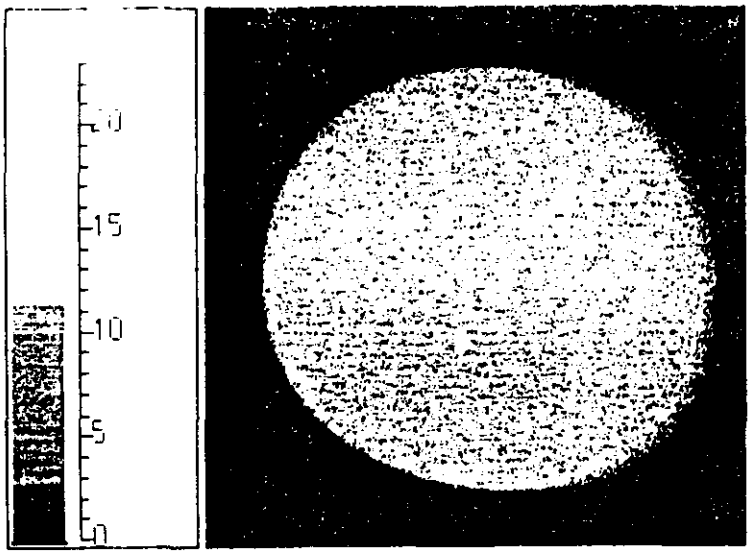

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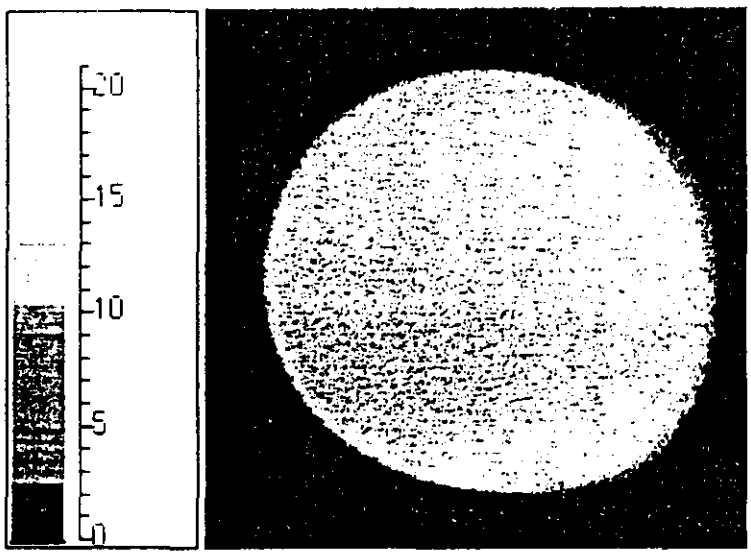

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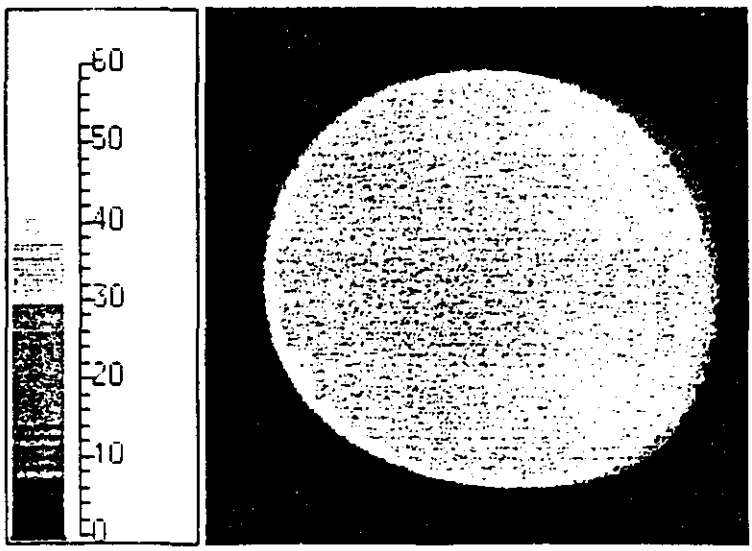

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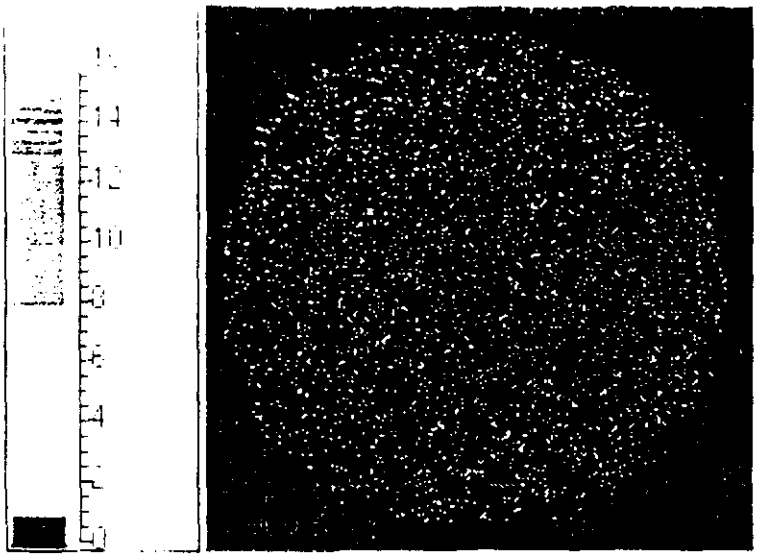

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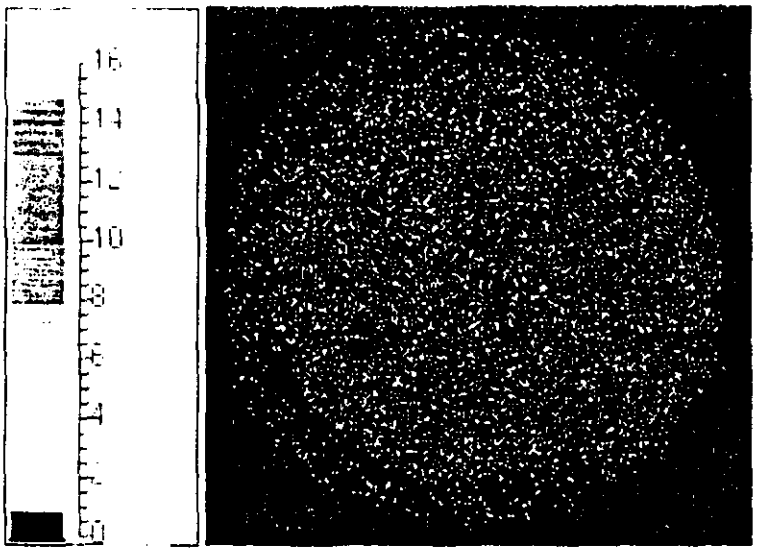

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A. Requirements for BaF2 technology :

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 destroy 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

gem

γeμ

Presentation by:

J. Heck

J. Hecr
ORNL

China has the Necessary Tools and Skills to Produce a BaF2 Detector

However

Additional Process Development and Control will be required for Large Volume Production

Vacuum Furnace Issues

1. Leak Up Rate Of Furnaces Is High, Outgassing And/Or Real Leaks, The Chinese Have Been Asked To Measure And Evaluate Results

2. Better Vacuum Instrumentation And Contol Of Process, Location Of Vacuum Gauges, Leak Test Port, RGA, Etc.

3. Better Vacuum Seals

   - Metal Seals Wherever Practical, Viton O-rings

   - Metal Bellows Or Differentially Pumped Dynamic Seal

   - Current Dynamic Seal Is A Molded Lip Seal

4. **Control Water Vapor In Vacuum Furnace**

   - **Eliminate As Much Graphite As Possible.**

   - **Remove Graphite Heats Shields.**

   - **Bake Water Cooled Metal Surfaces During Pumpdown.**

   - **Check Leak Up Rate Prior To Charging Crucible, Must Not Exceed A Specified Value.**

5. **A Vacuum System For A High Purity Product Is Seldom Too Good.**

6. **<u>Need to Develop a Vacuum System Process Control Procedure</u>**

Mechanical Processing Of Crystals

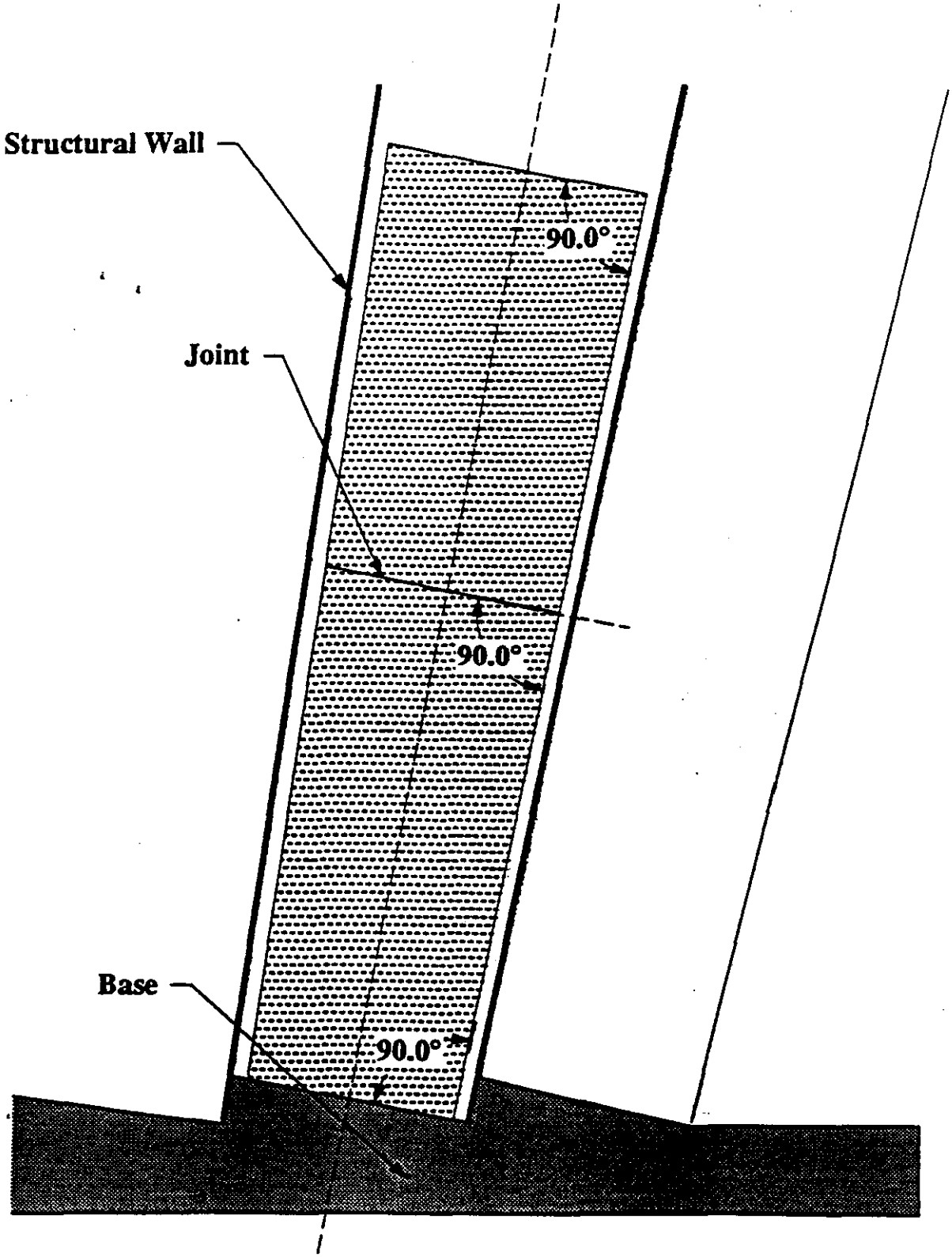
1. Front And Back Crystals Will Be Rough Cut And Chamfered To Minimize Damage During Handling. Chamfering operation Requires Careful Control.

2. Joint Faces Will Be Finished And Crystal Halves Glued Together (Without Chamfers).

3. Assembled Pair Will Be Finished Together. An Important Departure From Current Practice.

- By Finishing The Glued Crystal The Chamfer At The Joint Faces Can Be Eliminated.

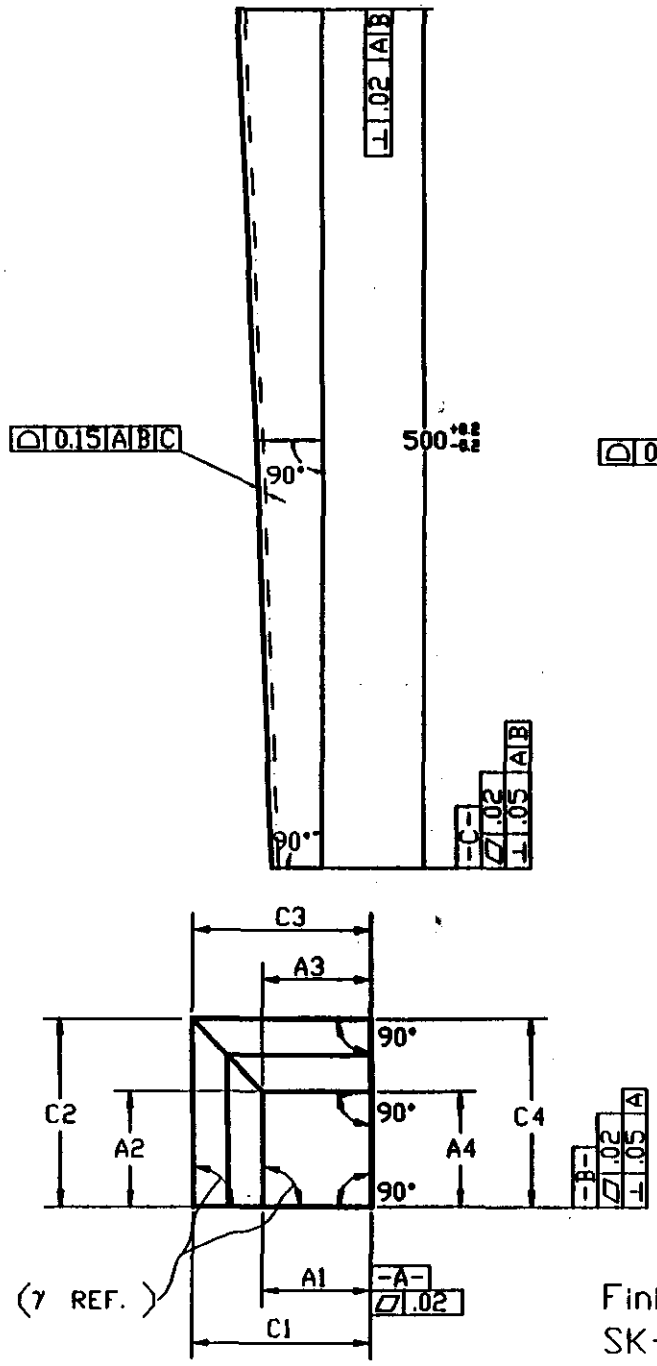
- Tolerance On Cross Section Dimensions Is 200 Microns From Maximum Material To Minimum Material Conditions.

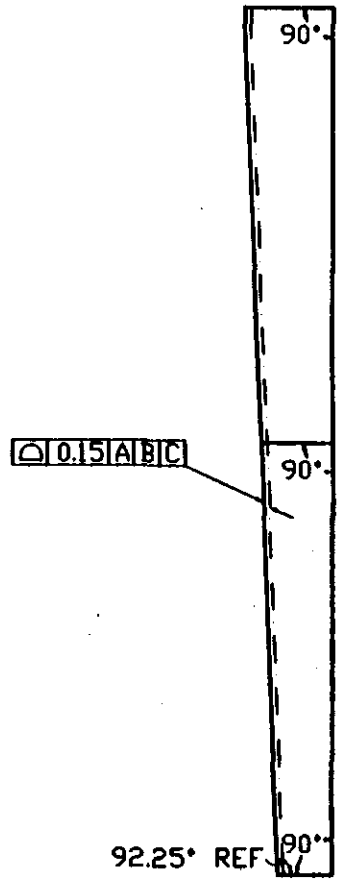


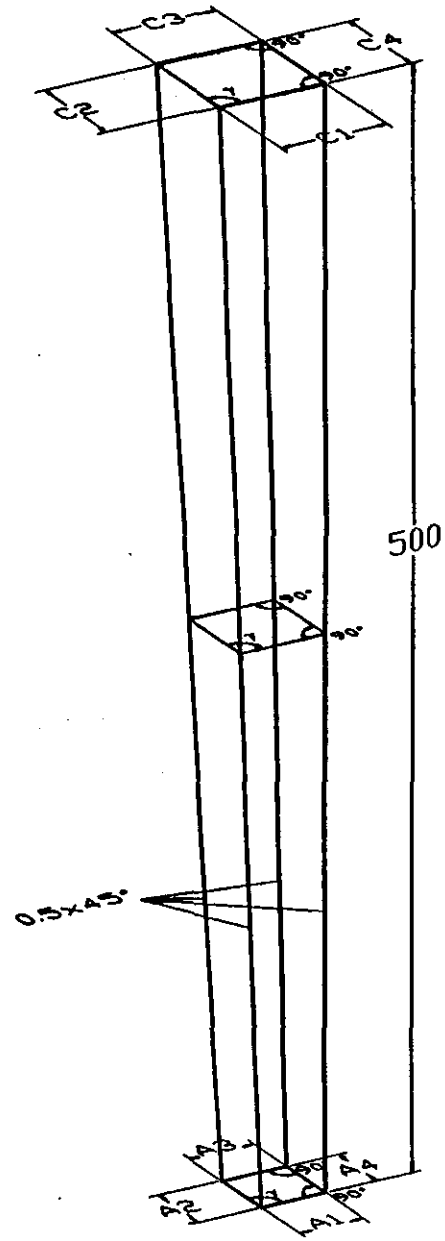
Barium Fluoride
Preferred Crystal Tolerancing

G.03.BF.010

Rennich

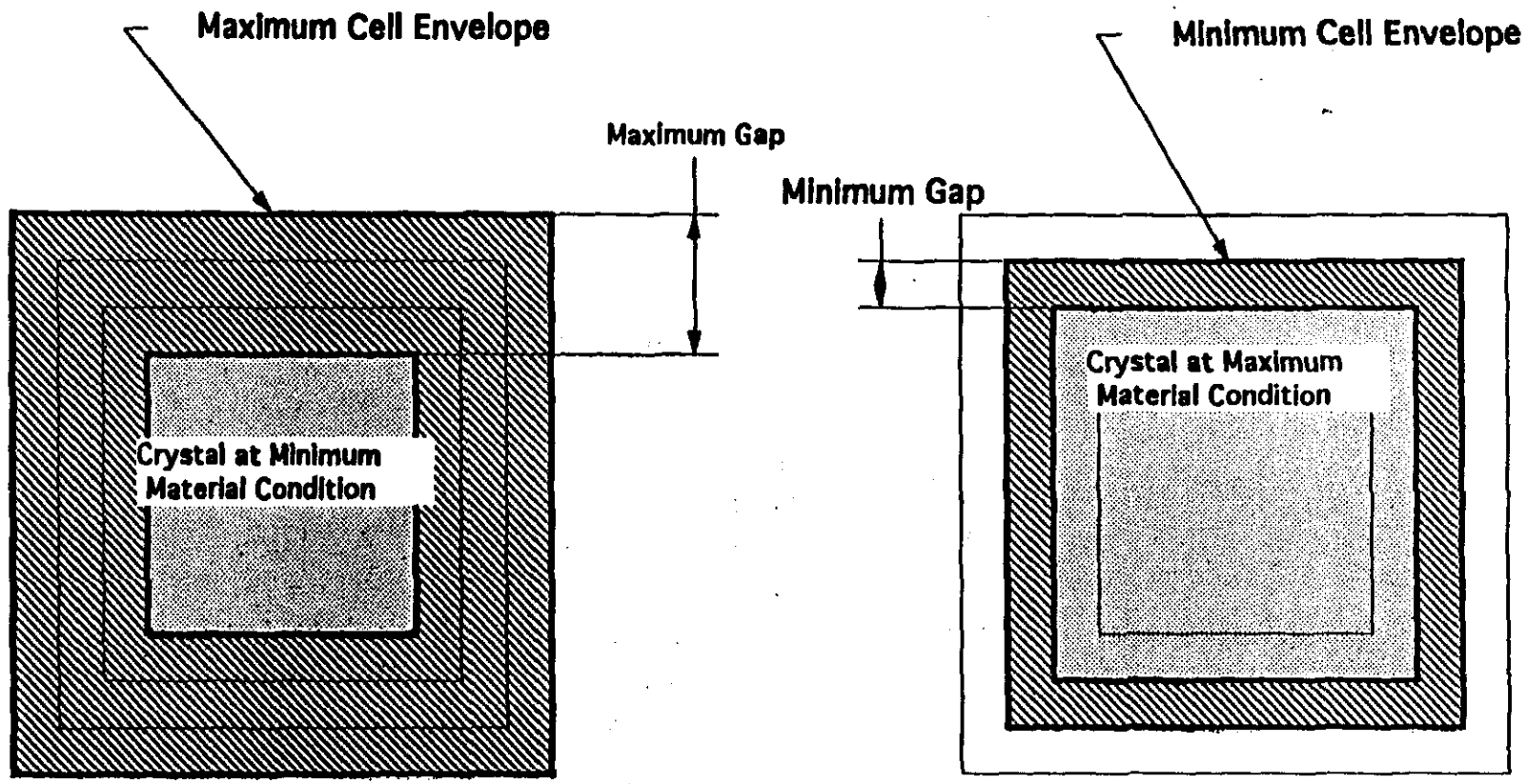






Left Hand (LH)
Finished matched pair
SK-TS-A6292-02-01

SURFACE FINISH NOTE:
MAXIMUM ROUGHNESS ON ANY
SURFACE SHALL NOT EXCEED
0.01 μm RA



WORST CASE FOR MAXIMUM CELL GAP

BEST CASE FOR MINIMUM CELL GAP

EFFECTS OF CRYSTAL TOLERANCES & CELL TOLERANCES ON TOTAL GAP IN CALORIMETER

Mechanical Processing Of Crystals

4. Final Dimensional Inspection Of Crystal Pairs.

- Crystals Are Dimensioned With Reference To Maximum Material Condition With Tolerances Based On Flatness, Perpendicularity, And Profile Of A Surface To Better Control The Gap Tolerance In The Calorimeter.

5. LLNL Will Recomment Improvements in the Mechanical Process ing of Crystals.

6. Machining And Inspection Procedures Should Be Developed And Documented By the Chinese.

Radiation Hardness Of Crystals

1. Quality Of Feed Material To Minimize Impurities

   - Specification Of Maximum Allowable Levels Of Various Contam(eg Strontium)

   - Inspection Of Feed Material As Received

2. Chemical Processing And Drying Of Feed Material

   - Establish Procedures For Chemical Processing Of Feed Material, Reacting With HF, Drying, Etc.

3. Procedures And Equipment To Control Water Vapor And Oxygen During Sintering And Crystal Growing

4. Need To Develop And Document A Production Plan And Quality Control System

Crystal Cell Structure

1. Laser Welded Titanium Alloy Foil Structure Is Being Considered:

   - Nomimal Foil Thickness Is 100 Microns, Single Layer In Wall.

   - Fabricated By Welding "As You Go".

2. Tsinghua University, In Beijing Is Looking At The Feasibility Of Fabricating The Structure.

   -Laser Welder Available.

   -Some Robotic Capability Available.

   - Develope Weld Parameters To Minimize Distortion.

   - Will Practice On A 7 X 7 Grid To Determine Tolerances On Cells.
   (Not for Prototype)

Crystal Cell Structure cont'd

3. Key Design Issues:

- Titanium Alloy Selection And Availability.

- Assembly Of Structure To The Calorimeter Barrel And End Cap.

- Means To Retain Crystal And Photodetector.

- Structural Strength And Rigidity.

- Tolerances In Fabricating Each Crystal Cell, The Maximum Gap Between Crystals In The Calorimeter Will Be Determined By The Tolerances Of The Crystal Plus The Tolerances In The Cell Structure.

4. Work Is In Very Early Stages and Estimted by ORNL to Require Up To 12 Months of Effort.

BaF2 Near-Term Engineering and Manufacturing Goals

1. Finalize Crystal Mechanical Processing Requirements (LLNL, ORNL,LAPP)

2. Finish The Design Of The Beam Test Box (ORNL)

3. Determine The Crystal And Cell Structure Dimensions For The End Cap Based On New Configuration Requirements (ORNL funding to be requested)

4. Evaluate Feasibility Of The Welded Titanium Alloy Cell Structure, And Determine What Tolerances Can Be Held On The Interior Cell Dimensions (ORNL funding to be requested, LAPP)

5. Assist In The Specification Of Production Vacuum Ovens For Sintering And Crystal Growing. (ORNL and LAPP)

6. Assist in Developing Process Control And Quality Control Documentation (ORNL, LLNL, LAPP)

7. Design Of The Barrel And End Cap Support Structures And Interface With Hadron Calorimeter (ORNL funding to be requested)

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

Craig R. Wuest
Lawrence Livermore National Laboratory

May 28, 1992

1. Surface Preparation R&D

In our last progress report, dated April 23, 1992, we reported on a number of different polishing techniques that give excellent surface finishes on barium fluoride. These include ion beam milling, diamond machining, diamond pad polishing and diamond pitch wheel polishing. These samples have been analyzed using RBS at Charles Evans and Associates and the results are that ion beam milling gives the best crystalline surface, followed by diamond pitch wheel polishing. The diamond turning method does not appear to give a crystalline surface.

We have continued this work by focusing on the diamond pitch wheel method as the best method in terms of ease of implementation and cost. In addition it is felt that this technology is most easily transferred to our Chinese collaborators. In anticipation of this we have begun a program to fully final-finish the 25 crystal pairs that will be produced in China for the prototype Calorimeter section. This program has involved the interaction of Jack Heck from Oak Ridge National Laboratory with our optics specialist, Ben Fuchs and a designer/draftsman at LLNL to design polishing fixtures to achieve the special shapes that are required in the prototype and at the proper tolerances. Appendix I is a memo from Ben Fuchs and the Designer, Fred Holdener, describing this concept and a plan of work to polish the crystals.

We are preparing to go to the Shanghai Institute of Ceramics as well as other institutions that are deemed necessary by our colleagues in China. Ben Fuchs is now scheduled to leave for Beijing on June 4, arriving on the 5th and I will meet him in Shanghai on June 11. We will both return to the US together on the 13th. It is our desire to educate ourselves as much as possible on the capabilities of the Chinese and to educate the Chinese as much as possible on our polishing process. We expect that this will take more than one trip to accomplish and we are prepared to travel as necessary, given the constraints imposed upon us by the DOE and by LLNL.

2. UV Coating R&D

We have coated a sample of Chinese-finish barium fluoride with aluminum and magnesium fluoride and have determined that the coating is a good reflector of light down to about 180 nm with a reflectance of 81% measured through two air/BaF_2 interfaces at 220

nm. It is clear that surface finish can effect the quality of the coating. The Chinese-finished crystal exhibited pin-holes and a rough texture upon coating due to the poor quality polish. We are currently coating BaF_2 samples that have been prepared using diamond pitch polishing and we will be evaluating the reflectance and scattering behavior of the coating for the purpose of incorporating these parameters into Monte Carlo light transport calculations. Another area of concern is the long term viability of the coating to changes in temperature, humidity, etc. We have begun discussions with coatings experts here at LLNL to understand methods of accelerated aging of coatings to assess the long term integrity.

We have also performed a cost estimate for coating 15,000 crystal pairs. LLNL maintains a number of large (3m x 3m x 3m) evaporative coating systems and we have initiated a study to determine the processing time and procedures required for mass production of coatings.

3. BaF_2 Crystal Growing at LLNL

At the request of Professor Harvey Newman and Dr. Yuri Kamyshkov we are beginning a program to grow small samples of high quality BaF_2 for evaluation and comparison with existing crystals produced in China and elsewhere. We have initiated a program with Dr. W. Kway at LLNL to grow cm sized samples of BaF_2 and have asked Dr. Kway to apply his best effort to growing very pure samples with the goal of demonstrating low impurity contamination and good radiation resistance. Dr. Kway has extensive experience in growing fluorides of various types with and without dopants for laser applications. He has grown BaF_2 in the past and is quite familiar the processing and handling of BaF_2. He has identified a number of sources of high quality BaF_2 powders (Fluortran and Johnson-Massey) and will work with two or three vendors to asses their relative purities. Initial samples will be pre-treated with a reactive gas such as hydrogen fluoride to remove residual moisture and then the material will be zone-refined in a pyrolytically coated vitreous carbon crucible about 2.5 cm wide and 20 cm long. Zone refining is performed in a reactive atmosphere or an inert atmosphere and is a multi-pass process in which impurities migrate to the ends of the crystal melt over time as the melt is passed through an RF heated region at a rate of 1 - 10 mm/hour. Typically these ends are discarded and the good quality crystal from the central region is used.

Tzochowski processing is also available for growing single crystal BaF_2 and can be studied as well. This process is used normally to accurately control the introduction impurity dopants or to keep impurities out during the process. Large single crystals of Gadolinium Germanium Garnet (GGG) with diameters of 4 inches and lengths of about 10 inches have been grown at LLNL in this process.

We anticipate that small samples of high quality BaF_2 will be available by the end of June or early July. We will perform in-house, measurements on impurity levels and also provide samples to Charles Evans and Associates for analysis.

Interdepartmental letterhead
Mail Code L-490
Tel. Ext. 2-7003

May 26, 1992

To: Craig R. Wuest

From: Ben Fuchs/Fred R. Holdener

Subject: Crystal manufacturing procedures for Barium Fluoride Crystals

---

The following is a proposed procedure for manufacturing crystals for the Electromagnetic Calorimeter to be used by the Superconducting Super Collider Laboratory in Dallas, Texas.

Proposed Manufacturing Steps:

(1) - Choose best surface (i.e. flatest) as Surface Datum #1 (SD#1) for a set of four crystals.

(2) - Use standard oven procedure to hot wax SD#1 to Wedge Crystal Mount and repeat for the additional three similar crystals as shown in Figure 1.

(3) - Assemble four crystals into Closed Pack Assembly (CPA-4). This step is performed on a cleaned, stable (e.g. granite) flat surface as shown in Figure 2.

(4) - Blanchard and loose abrasive grind (see Appendix) top surfaces to establish Surface Datum #2 (SD#2) for the set of four crystals of CPA-4.

(5) - Use standard oven procedure to remove four Crystals to deblock from their wedge mounts.

Note: If the chosen best surface of Step (1) is not flat to less than 0.025 mm (0.001 inch) then steps 2 through 5 need to be repeated with SD#2 down to allow a Blachard and loose abrasive grind of SD#1.

(6) - Block set of four crystals to their 90 Degree Side Mount Guides using oven hot wax procedure with Wedge Crystal Mount laying on its side as shown in Figure 3. Shim as necessary to Wedge Crystal Mount to accept loads during grinding procedure to follow.

(7) - Assemble crystals into CPA-4-90 with side blocks for Blanchard grind/polish to establish Surface Datum #3 (See Figure 4.) Note: This will establish the three plains at 90 degrees to one another common to all crystals.

(8) - Deblock crystals and reblock with newly established Surface Datum #3 down and Side Mount Blocks removed. Assemble into CPA-4 and Blanchard and loose abrasive grind top to establish Surface Datum #4.

Note: All four Datums are now established with four 90 degree surfaces.

(9) - Use oven Procedure to Mount four similar Crystals within Crystal End Mount as shown in Figure 5. Note: Two crystals mount in each half assembly.

(10) - Blanchard and loose abrasive grind Crystal Ends and perform final polish.

(11) - Flip fixture and Blanchard and loose abrasive grind to desired height (150 mm) (i.e. establishing crystal length) and perform final polish. Use Oven procedure to remove crystals mounting blocks.

(12) - Clean crystals and assemble using glue mating fixture (See Figure 6) to maintain alignment during gluing procedure. The two glued crystals are now 500 mm in overall length (250 mm per individual crystal).

(13) - Remount long (500 mm) crystals onto Long Mating Crystal Mounts with SD#1 down using Oven Wax Procedure and reassemble into Long Crystal Closed Pack Assembly with eight crystals as shown in Figure 7.

(14) - Final Grind and Polish SD#2.

(15) - Remove crystals and remount with SD#2 down and perform final grinding and polishing procedure to complete SD#1.

(16) - Remove crystals and remount with SD#3 down and perform final grind and polish procedure to complete SD#4.
(Note: Now the three 90 degree sides are complete)

(17) - Remove crystals and remount with SD#4 down and mounted with tabbed shim stock of specified dimension along entire edge of SD#4. Edge will be left or right depending on the orientation of the crystal specification. (Tabbed and individually matched for each specific size matching to the specification table angle with SD#4 laquer protected).

(18) - Perform final Blanchard and loose abrasive grinding and polishing procedure to finish last angled surface on long crystal. (Polishing complete).

Note: Chamfering edges (0.5 mm x 45 deg.) will occur between above steps as required.

(19) - Clean, Inspect, Protect, Package & Ship.....

APPENDIX

Notes regarding specifics on grinding and polishing steps.....

1. GRINDING (Bound)

(1a) Initial grinding will use a Blanchard bound abrasive grinding machine.

(1b) Lubrication will consist of white mineral oil.

2. GRINDING (Loose)/POLISHING

(2a) Loose abrasive grinding and polishing will be performed on a 31" diameter conventional polishing machine.

(2b) 30 micron aluminum oxide loose abrasive will be used to remove surface and sub-surface damage from bound abrasive surface generator.

(2c) 9 micron aluminum oxide loose abrasive will be used to remove surface damage from previous operation.

(2d) Lubrication will consist of either silicon fluid or ethylene glycol.

3. POLISHING

(3a) Polishing will use Gugolz pitch (Hardness 64 to 73)

(3b) Fine graded 1/4 micron diamond powder will be loose abrasive for polishing

(3d) lubrication will be either silicon fluid of ethylene glycol.

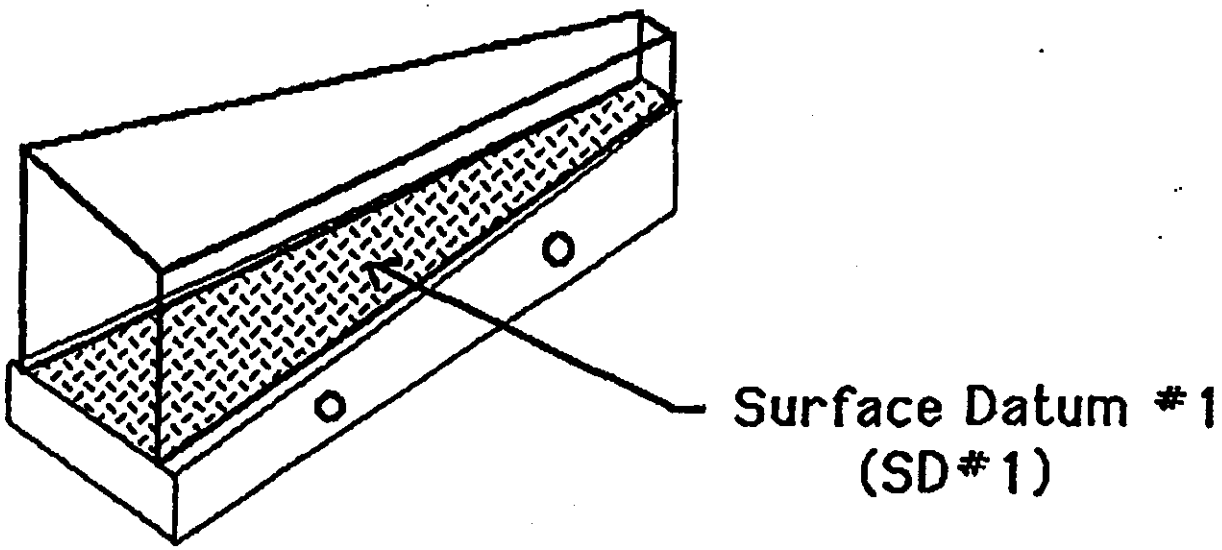
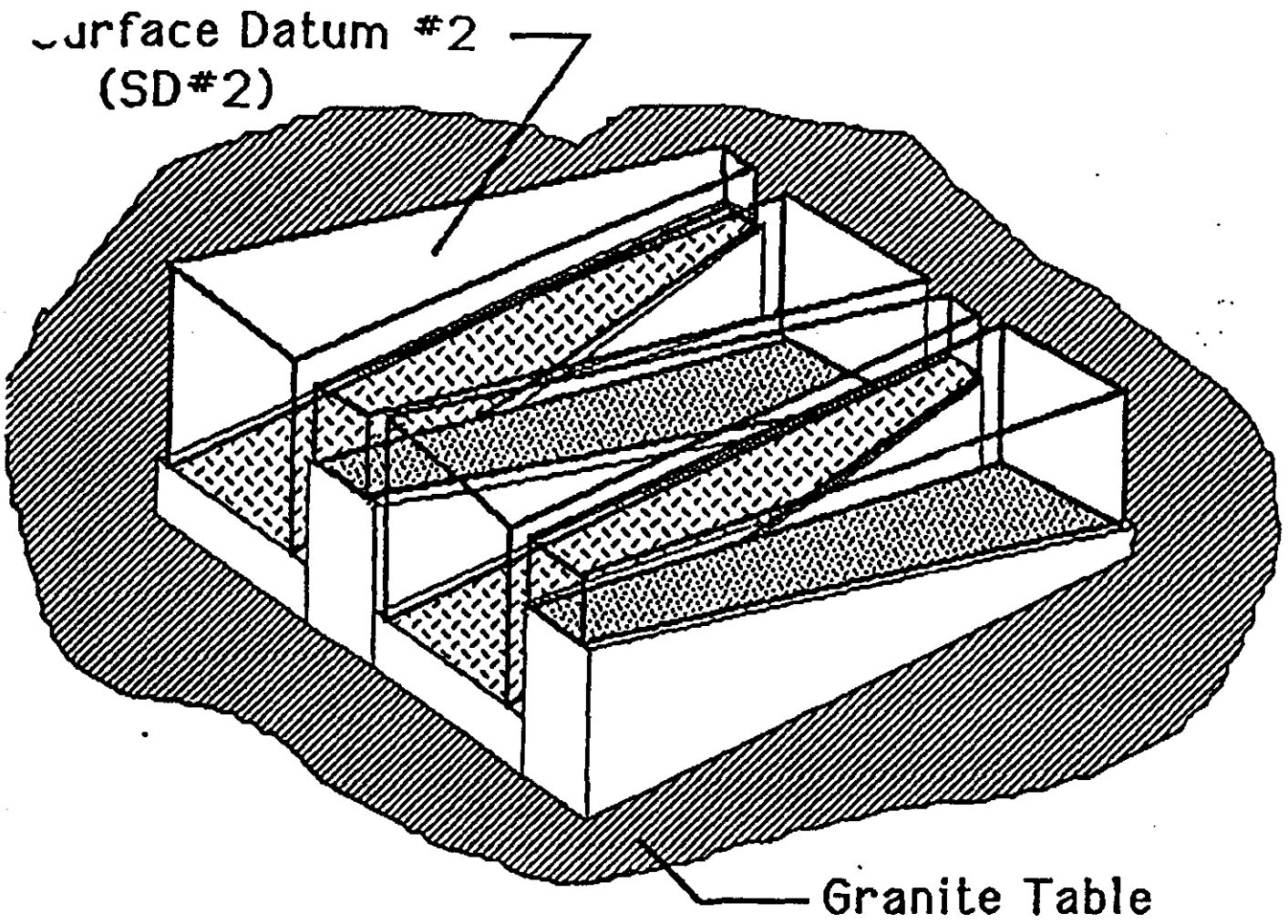
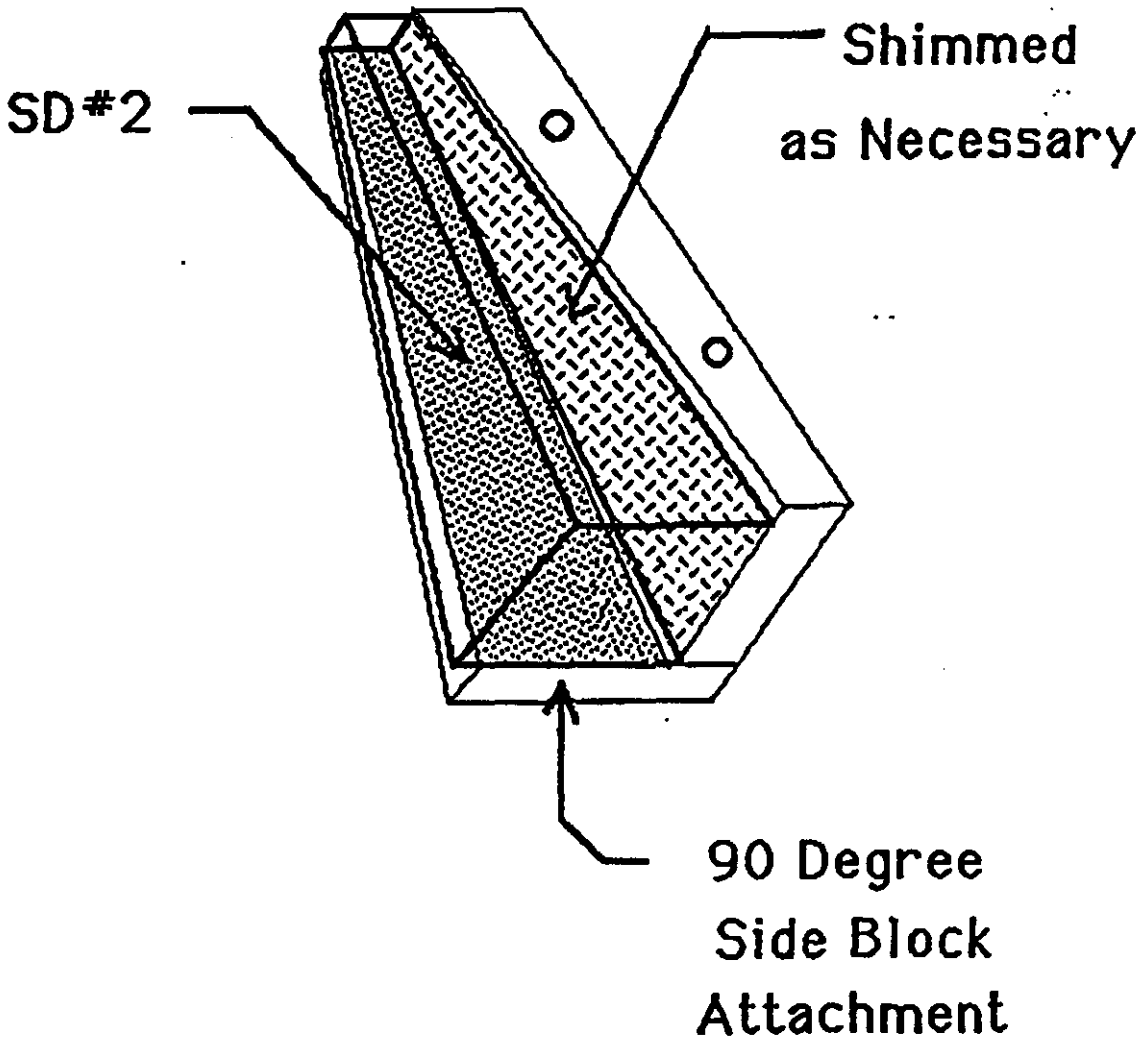


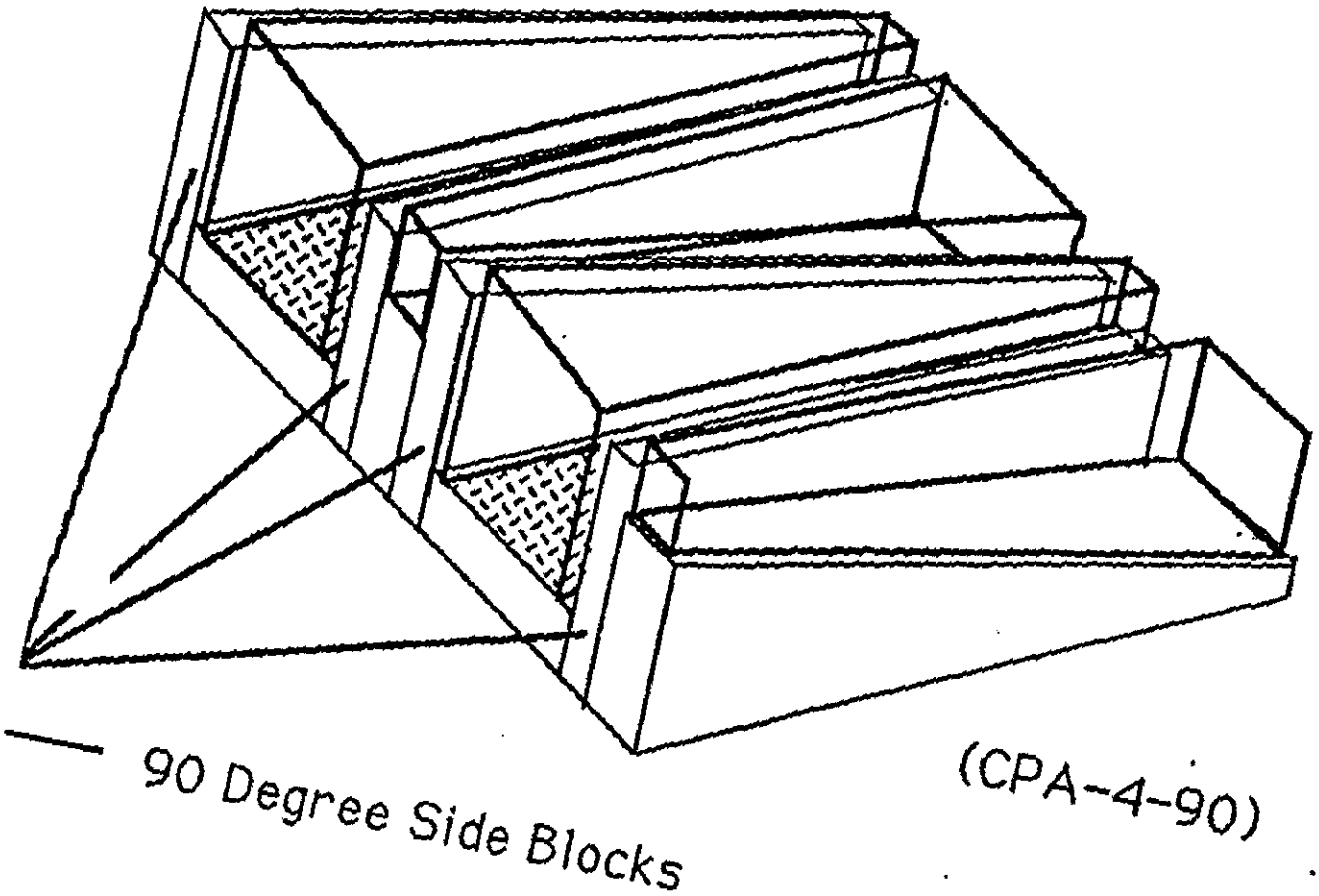
Figure 1. Wedge Crystal Mount



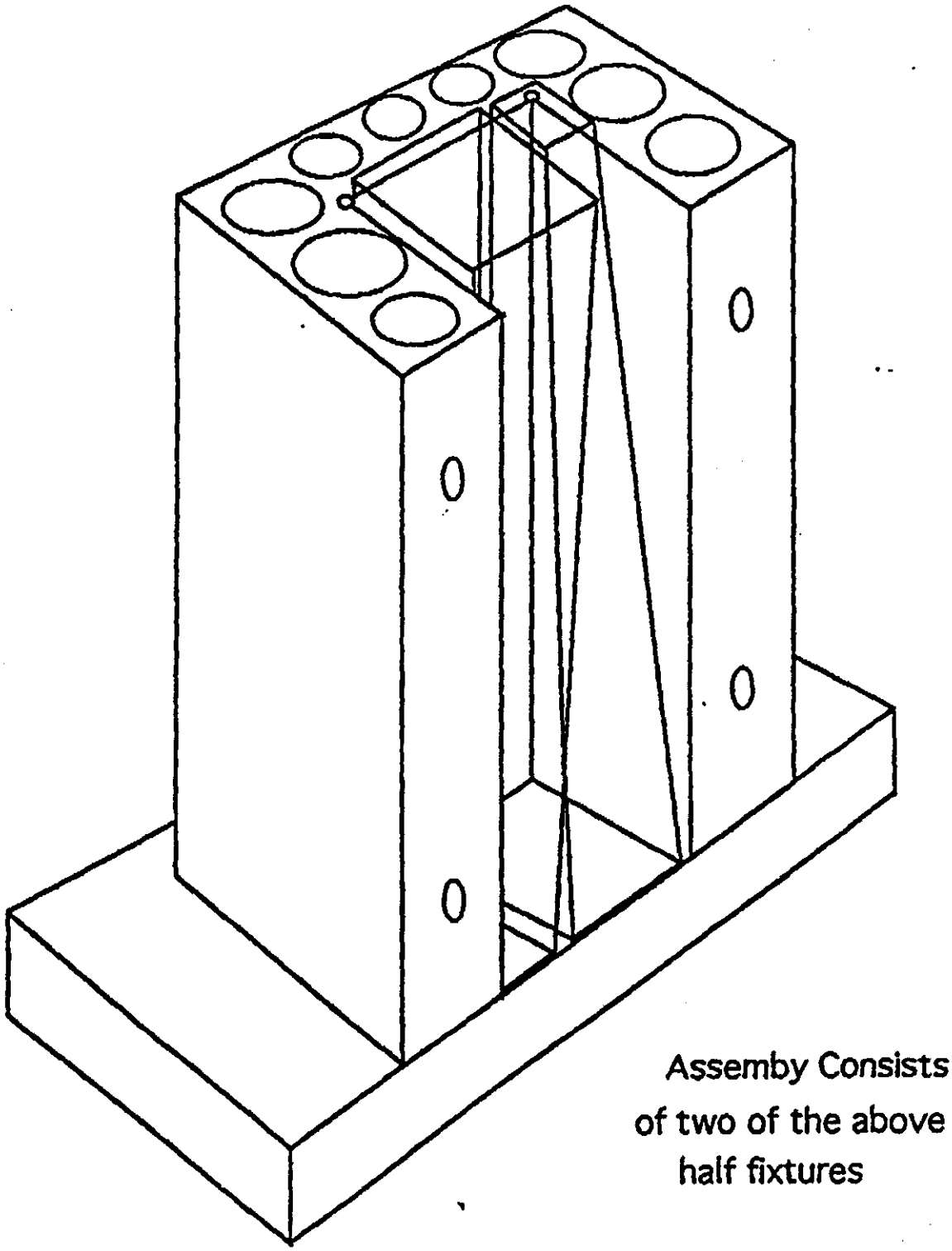
igure 2. Closed Pack Assembly (CPA-4)



gure 3. 90 Degree Side Mount



ure 4. Closed Pack Assembly with 90 Degree Side Mount Blocks



ıure 5. Crystal End Mount

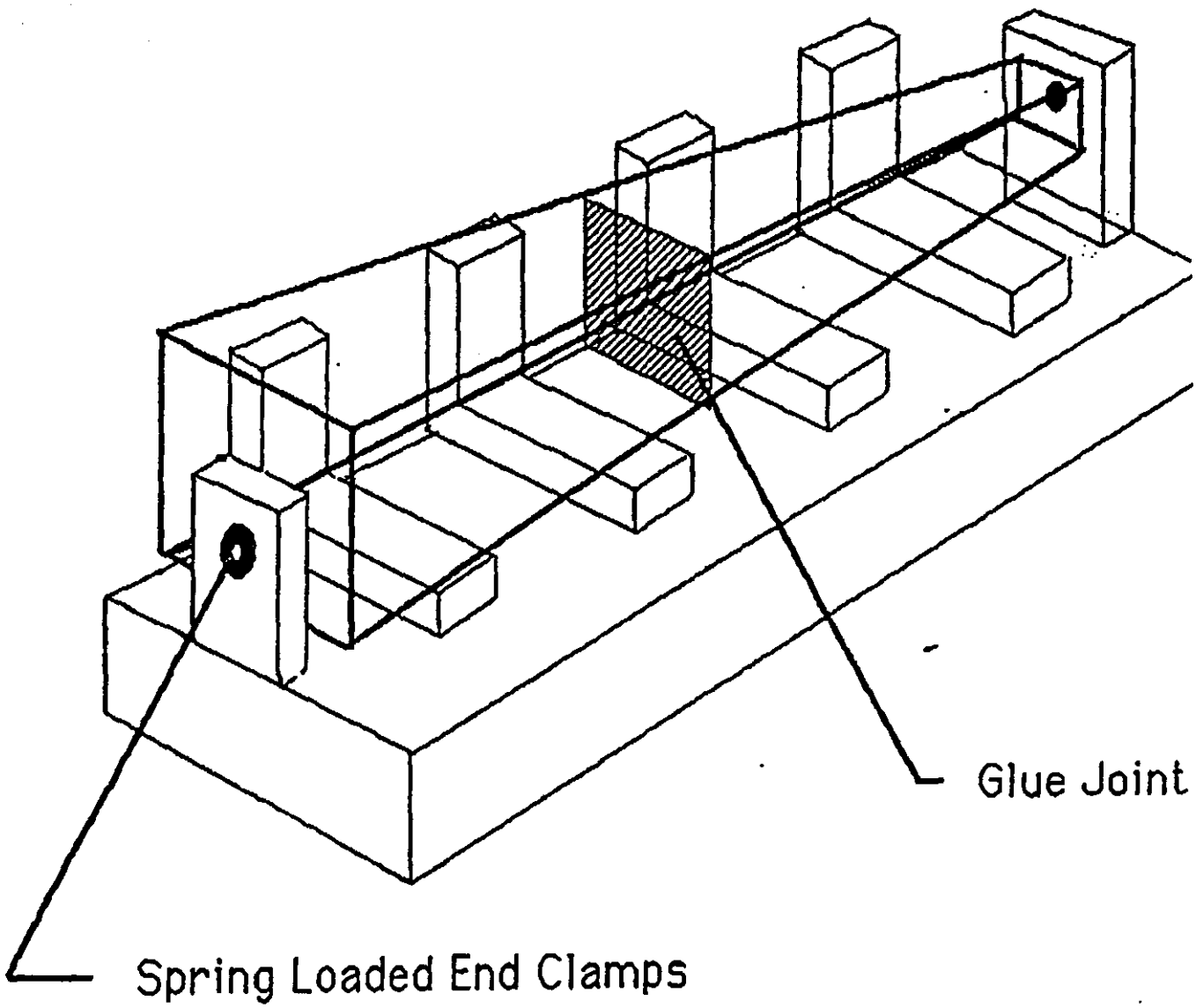


Figure 6. Crystal Gluing Fixture

Closed Pack Assembly
CPA-8

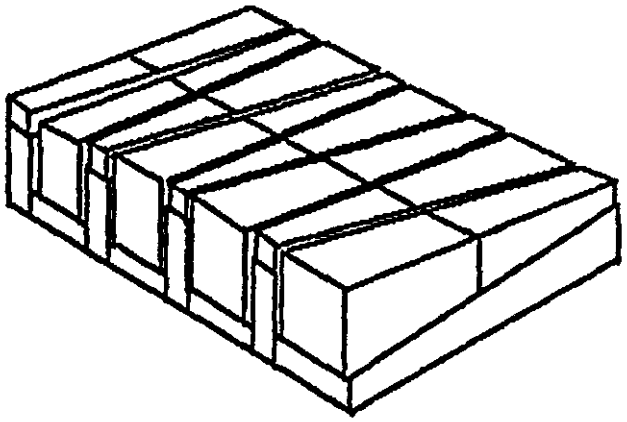
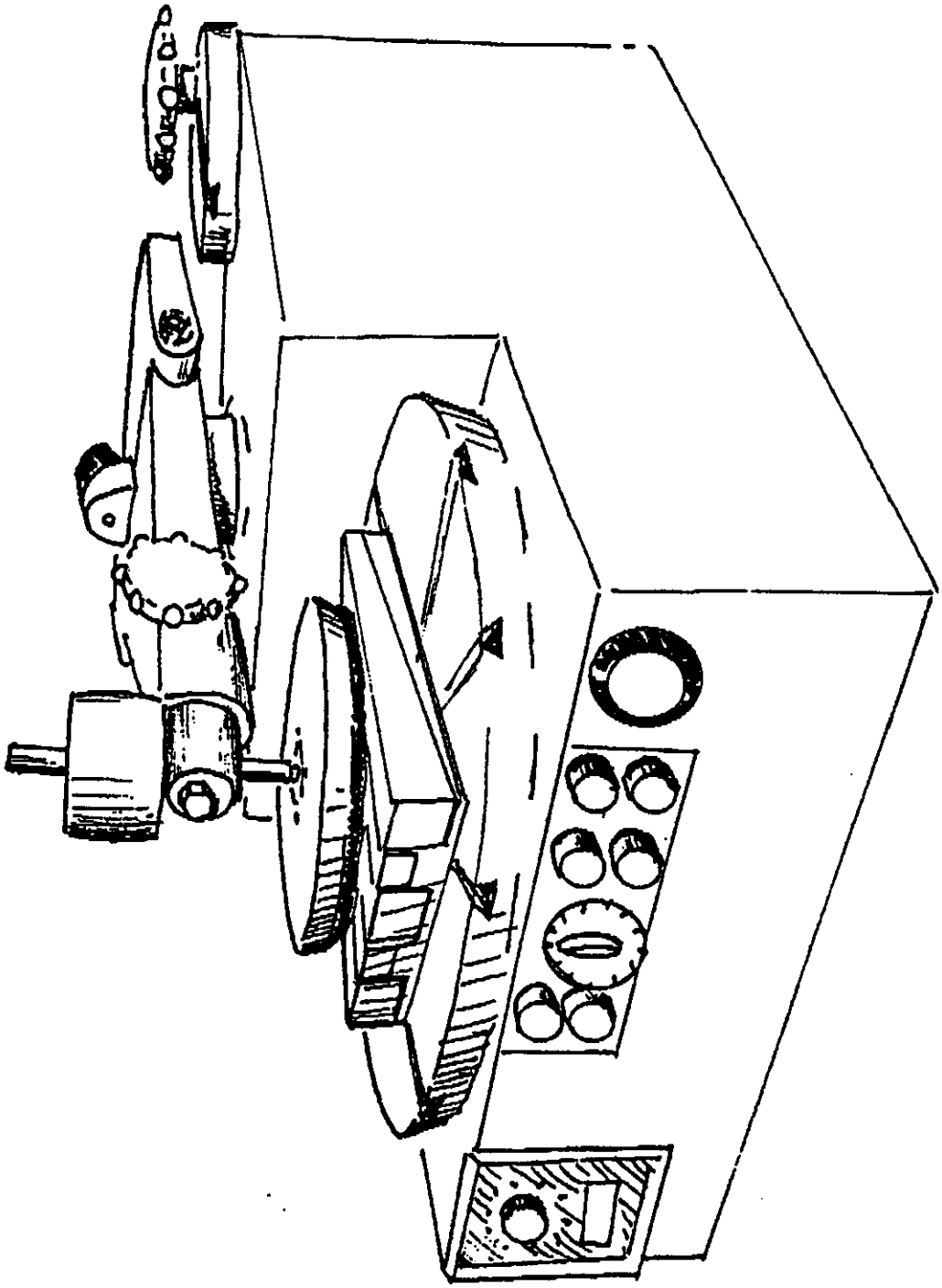
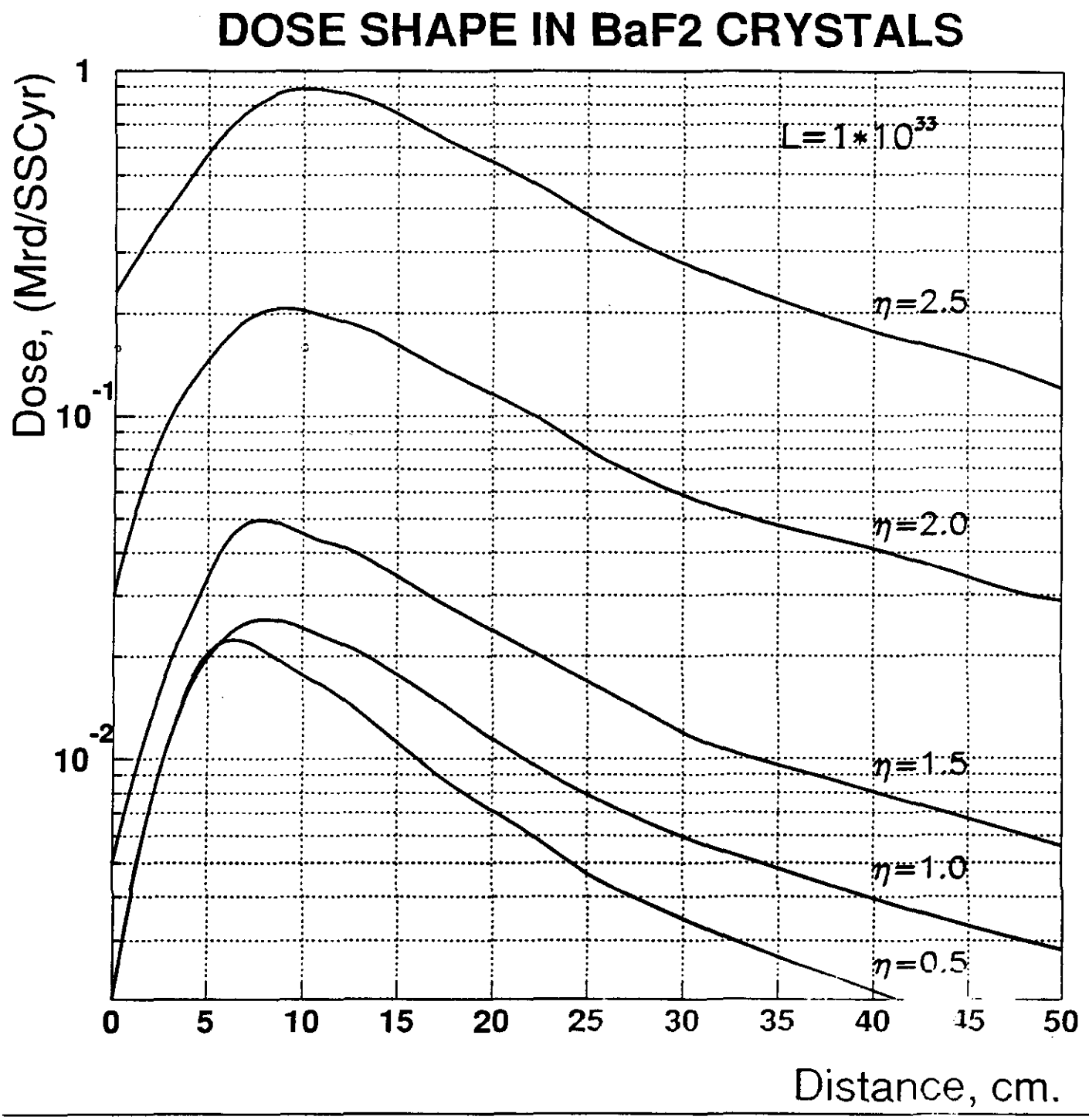


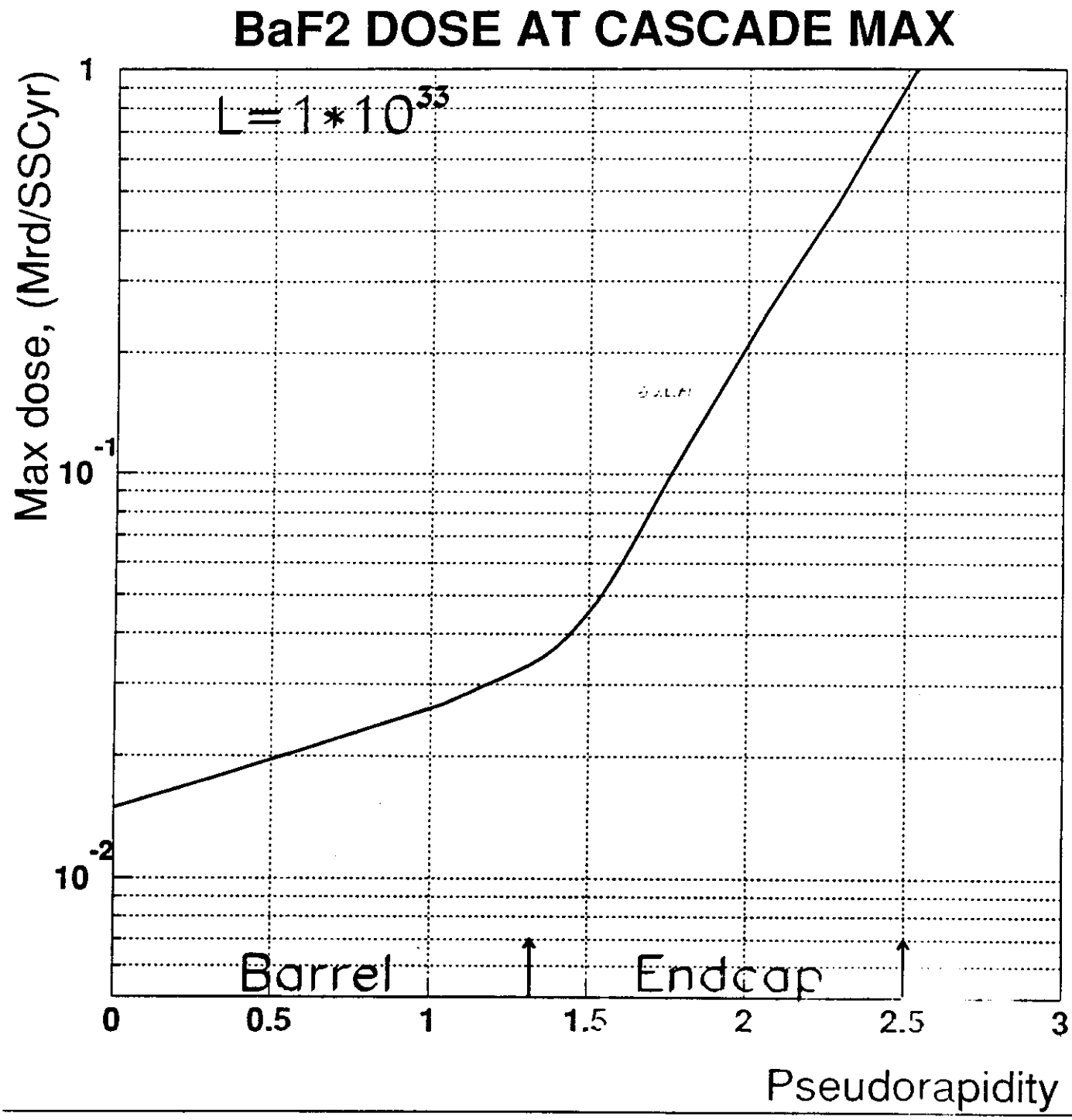
Figure 7. Long Crystal Closed Pack Assembly



Presented by:

Y. Efremenko


DOSE SHAPE IN BaF2 CRYSTALS
Dose, (Mrd/SSCyr)
1
10^-1
10^-2
L=1*10^33
η=2.5
η=2.0
η=1.5
η=1.0
η=0.5
0
5
10
15
20
25
30
35
40
45
50
Distance, cm.



Yu. Efremenko
5 June 92