LASL # P-387

712706

PROPOSAL

for the

NEGATIVE PION THERAPY PROGRAM

for FY '76, Transition, and FY '77

To be performed by
The Los Alamos Scientific Laboratory (LASL)
under AEC Contract (W - 7405 - ENG - 36)
for the
American Cancer Society

Prepared by: Chaim Richman
Chaim Richman, Ph. D., LASL

Approved by: George L. Voelz, M.D.
George L. Voelz, M. D., LASL
Health Division Leader

A. D. McGuire
A. D. McGuire - LASL
Special Projects Office

November 1974

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APPLICATION FOR A RESEARCH OR CLINICAL INVESTIGATION GRANT

(Please read carefully the attached "Policies Governing Research and Clinical Investigation Grants" and the instructions on all pages of this form, before completing this application.)

TO: American Cancer Society, Inc.
219 East 42nd Street
New York, New York 10017

Date November 1, 1974

Application is hereby made for a grant* in the amount of $ 101,190
for the period from July 1, 1975 to June 30, 1977 inclusive.

Title Characteristics of the Pion Beam in Therapeutic Applications

FROM:

Dr. Chaim Richman — Chaim Richman
Name of Investigator — Signature

Staff Member — (505) 667 - 4915
Title — Telephone No.

Group H - 10, Health Division
Department — Division of Institution

Los Alamos Scientific Laboratory
P. O. Box 1663 Los Alamos, New Mexico 87544
Street and Number — City, State, Zip Code

U. S. Atomic Energy Commission
Official Name of Institution

Albuquerque Operations Office
Street and Number — City, State, Zip Code

Albuquerque, New Mexico 87115
Name of Official Authorized to Sign for Above Institution — Signature

Title

*It is understood that each applicant, by the act of applying for a grant, agrees, if the grant is made, to abide by the Society's POLICIES GOVERNING RESEARCH AND CLINICAL INVESTIGATION GRANTS.

Checks to be Made Payable to

Street and Number

City, State, Zip Code

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APPLICATION FOR A RESEARCH OR CLINICAL INVESTIGATION GRANT

I. BUDGET PROPOSED*

	1st Year	2nd Year
A) PERSONNEL *(Itemize all positions; indicate per cent of time on project and names of personnel, if selected)*		
C. Richman (100%)	-0-	-0-
Retirement or other security benefits (Total)		
CATEGORY TOTAL		
B) PERMANENT EQUIPMENT *(ITEMIZE)*		
See attached sheet 2A		
CATEGORY TOTAL	$11,385	$14,605
C) CONSUMABLE SUPPLIES *(GROUP IN MAJOR CATEGORIES)*		
Scintillation Detector Mounts	2,500	
Silicon Detector Mounts	5,500	4,000
Tissue Equivalent Solid Phantom	1,500	3,000
CATEGORY TOTAL	$ 9,500	$ 7,000
D) MISCELLANEOUS *(LIST SPECIFIC AMOUNT FOR EACH ITEM)*		
Visiting Staff Members	13,500	13,500
Consultants	7,300	5,300
Computer Analysis	8,700	10,000
Travel	200	200
CATEGORY TOTAL	$29,700	$29,000
SUBTOTAL		
E) INDIRECT COSTS	-0-	-0-
GRAND TOTAL	$50,585	$50,605

*See POLICES GOVERNING RESEARCH AND CLINICAL INVESTIGATIONS
If more space is needed prepare budget using above format.

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	1st Year		2nd Year	
B) PERMANENT EQUIPMENT (Itemize)				
	Unit		Unit	
Timer-Counter	1	845	3	2,535
Counter	2	1,190		
Constant Fraction Timing SCA	1	525		
Pile Up Gate	1	415		
Differential Discriminator	1	775	1	775
Linear Gate Stretcher	1	840		
Linear Gate	1	1,495	1	1,495
Fast Triple Trace Oscilloscope	1	4,500		
Digital Multimeter	1	800		
Multichannel Analyzer w/mag Tape Readout			1	9,800
CATEGORY TOTAL		$11,385		$14,605

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ESTIMATE OF BUDGET REQUIRED FOR:	3rd Year	4th Year	5th Year
A) PERSONNEL			
RETIREMENT (TOTAL)			
CATEGORY TOTAL			
B) PERMANENT EQUIPMENT			
CATEGORY TOTAL			
C) CONSUMABLE SUPPLIES			
CATEGORY TOTAL			
D) MISCELLANEOUS			
CATEGORY TOTAL			
SUBTOTAL			
E) INDIRECT COSTS			
GRAND TOTAL			

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APPLICATION FOR A RESEARCH OR CLINICAL INVESTIGATION GRANT

SUMMARY OF RESEARCH PROPOSED

Name and Official Title of Principal Investigator

Chaim Richman, Staff Member H-10

Name and Address of Applicant Organization

U. S. Atomic Energy Commission, Albuquerque Operations Office
Albuquerque, New Mexico 87115 Attn. Mr. J. Cotton
(for the Los Alamos Scientific Laboratory)

Title of Project

Characteristics of the Pion Beam in Therapeutic Applications

Use this space to summarize concisely your proposed research. Outline objectives and methods. Underscore the Key words (not to exceed 10) in your abstract.

Using the biomedical pion beam at the Clinton P. Anderson Meson Physics Facility (LAMPF), we will make further measurements of the dose distributions in phantoms as well as the low and high LET components of the dose. In collaboration with other LASL staff members, we will determine the optimum settings of magnet currents to produce dose distributions suitable for the treatment of tumor volumes at varying depths from the skin. Biological material will also be used to measure RBE and OER and thereby determine the therapeutic characteristics of the beam. We will advise as to specific dose distributions which can be achieved by the magnet settings and the collimator configurations when patients are brought to LAMPF for treatment.

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APPLICATION FOR A RESEARCH OR CLINICAL INVESTIGATION GRANT

BIOGRAPHICAL INFORMATION

(Give the following information for all professional personnel listed on page 3, beginning with the Principal Investigator. Use continuation pages and follow the same general format for each person.)

NAME	TITLE	BIRTHDATE (Mo., Day, Yr.)
Chaim Richman	Staff Member, H - 10	[redacted]
PLACE OF BIRTH (City, State, Country)	**PRESENT NATIONALITY (If non-U.S. citizen, indicate kind of visa and expiration date)**	**SEX**
[redacted]	U. S. A.	☒ Male ☐ Female

EDUCATION *(Begin with baccalaureate training and include postdoctoral)*

INSTITUTION AND LOCATION	DEGREE	YEAR CONFERRED	SCIENTIFIC FIELD
[redacted]	B.A. M.A. Ph.D.	[redacted]	Mathematics Mathematics and Physi Physics

HONORS [redacted] Sigma Xi; American Physical Society, Fellow
Ethel M. Rubelson Lecturer, Department of Radiology,
University of Minnesota Medical School
Chairman LAMPF Biomedical Users Steering Committee 1970-1972

MAJOR RESEARCH INTEREST	ROLE IN PROPOSED PROJECT
Pion Physics and Treatment Planning	Principal Investigator

RESEARCH SUPPORT *(See instructions)*
The Cancer Center of the University of New Mexico Medical School and the Los Alamos Scientific Laboratory Health Division and MP Division have a grant of about 1.2 million dollars per year for the overall investigation of pion treatment.

RESEARCH AND/OR PROFESSIONAL EXPERIENCE *(Starting with present position, list training and experience relevant to area of project, including teaching and clinical responsibilities. List all or most representative publications.*

Staff Research Scientist, Los Alamos Scientific Laboratory
Lecturer, Assistant Professor and Associate Professor, [redacted]
Staff Member, [redacted]
Director of Research, [redacted]
Professor of Physics, [redacted]
Professor of Physics, [redacted]

Dr. Richman started work on pions at the [redacted] 184-inch synchrocyclotron in 1949. From 1961-1971 he directed a program on radiotherapy with pions at [redacted] from the [redacted] This program involved various experiments on the dosimetry and radiobiology of negative pions. Since 1971 he has been at the Los Alamos Scientific Laboratory.

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PUBLICATIONS

Deuteron Disintegration by Electrons, with B. Peters, Physical Review, 59, 804 (1941)

Angular Distribution in Deuteron Disintegration by Electrons, (A), Physical Review, 61, 203 (1942)

The Production of Slow Neutrons in a Carbon Block, with T. Snyder and R.W. Williams, U. S. Atomic Energy Commission Report MDDC-302, Sept. (1946)

Drift Tubes for Linear Proton Accelerator, (A), with F. Oppenheimer and L. H. Johnston, Physical Review, 70, 447 (1946)

Initial Performance of a 32 MeV Proton Linear Accelerator, (A) with L. V. Alvarez, H. Bradner, H. Gordon, L. C. Marshall, F. Oppenheimer, W.K.H. Panofsky, R. Serber, C. Turner, and J. R. Woodyard, Science, 106, 506 (1947)

On the Neutron-Proton Scattering Cross Section, with D. Bohm, Physical Review, 71, 567 (1947)

Resonant Cavities, Electronic Lecture Series, BP-94, September 17 (1947)

Control of the Field Distribution in the Linear Accelerator Cavity, with W.K.H. Panofsky, Physical Review, 73, 535 (1948)

Apparatus for Measuring Proton-Proton Scattering at 32 MeV Using Proportional Counters, (A), with B. Cork and L. Johnston, Bulletin of the American Physical Society, 24, 214 (1949)

Berkeley Proton Linear Accelerator, with L. Alvarez and others, UCRL-236 (1949)

An Experiment for Measuring Heavy Meson Production by High Energy Particles, (A), with H. Wilcox, presented at the December 29-30, 1949 meeting of the American Physical Society at Stanford University, Physical Review, 78, 85 (1950)

Measurement of the Production of Positive and Negative Mesons by 345 MeV Protons on Carbon, (A), with H. A. Wilcox, presented at the December 20-30, 1949 meeting of the Americal Physical Society at Stanford University, Physical Review, 78, 85 (1950), also Classified Document No. LA-38, Lawrence Radiation Laboratory

Production Cross-Sections for π^+ and π^- Mesons by 345 MeV Protons on Carbon at 90° to the Beam, (L), with H. A. Wilcox, Physical Review, 78, 496 (1950)

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PUBLICATIONS (Continued)

The Production of π^+ Mesons by Protons on Protons in the Direction of the Beam, (L), with F. Cartwright, M. Whitehead, and H. A. Wilcox, Physical Review, 78, 823 (1950)

Proton-Proton Scattering at 31.8 MeV Proportional Counter Methods, with B. Cork and L. Johnston, Physical Review, 79, 71 (1950)

Production of a π^+ Meson Beam Using the Deflected Proton Beam of the 184-inch Synchrocyclotron, (L), with M. Skinner, J. Merritt, and B. Youtz, Physical Review, 80, 900 (1950)

Scattering of π^+ Mesons on Carbon, (A), with M. Skinner, Physical Review, 83, 217 (1951)

On the Angular Distribution of the π^+ Mesons from 341 MeV Protons on Protons, (L), with M. Whitehead, Physical Review, 83, 855 (1951)

On the Angular Distribution and the Polarization of the Deuteron in the Reaction $p + p - d + \pi^+$, with K. M. Watson, Physical Review, 83, 1256 (1951)

The Production of π^+ and π^- Mesons by 340 MeV Protons at 90° to the Beam from Carbon and Lead, with M. Weissbluth and H. A. Wilcox, Physical Review, 85, 161 (1952)

The Production of Positive Pions by 341 MeV Protons on Protons, with W. F. Cartwright, M. Whitehead, and H. A. Wilcox, Physical Review, 91, 677 (1953)

The Berkeley Proton Linear Accelerator, with L. W. Alvarez, H. Bradner, J. F. Finch, H. Gordon, J. Gow, L. C. Marshall, F. Oppenheimer, W. K. H. Panofsky, and J. R. Woodyard, Rev. Sci. Insti., 26, 2, 111 (1955)

On the Dosimetry of Negative Pions with a View Toward Their Use in Cancer Therapy, with H. Aceto, M. R. Raju, B. Schwartz, and M. Weissbluth, Spring 1964, Semiannual Report Biology and Medicine, 114, Donner Lab, University of California, Berkeley, California

The Therapeutic Possibilities of Negative Pions, Preliminary Physical Experiments, with H. Aceto, M. R. Raju, and B. Schwartz, American Journal of Roentgenology

Pion Studies with Silicon Detectors, with M. R. Raju and H. Aceto, Nuclear Instruments and Methods, 37, 152-158 (1965)

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PUBLICATIONS (Continued)

Lithium-Drifted Silicon Detector Used as a Pulse Dosimeter, with M. R. Raju, E. J. Lampo, S. B. Curtis, and J. M. Sperinde, UCRL-16924 (delivered at the 13th Nuclear Science Symposium on Instrumentation in Space and Laboratory, Boston, Massachusetts) (1966)

π^- Mesons, Radiobiology, and Cancer Therapy, C. Richman, Proceedings of the First International Symposium on the Biological Interpretation of Dose from Accelerator-Produced Radiation, 346-348 (1967)

A Review of the Physical Characteristics of Pions Beams, with M. R. Raju and S. B. Curtis, Proceeding of the First International Symposium on the Biological Interpretation of Dose from Accelerator-Produced Radiation, 349-367 (1967)

Studies of Vicia Root Meristems Irradiated with π^- Beam, with S. P. Richman, M. R. Raju, and B. Schwartz, Radiation Research, 7, 182-189 (1967)

Effect of Negative Pions on the Proliferative Capacity of Ascites Tumor Cells (lymphoma) in Vivo, with J. M. Feola, M. R. Raju, S. B. Curtis, and J. H. Lawrence, Radiation Research, 34, 70-78 (1968)

Physical and Radiobiological Aspects of Negative Pions with Reference to Radiotherapy, with M. R. Raju. Presented at the XII International Congress of Radiology, October 6-11, Tokyo, Japan. GANN Monograph on Radiology of Cancer, No. 9, 105 (1970)

The RBE of Negative Pions in 2-day-old Ascites Tumors, with J. M. Feola, M. R. Raju, and J. H. Lawrence, Radiation Research, 44, 637 (1970)

The Oxygen Effect of π^- Mesons in Vicia Faba, with M. R. Raju, N. Amer, and M. Gnanapurani, UCRL-18644, Radiation Research, 41, 135-144 (1970)

The Pion Radiobiology Program at Berkeley and the Biomedical Plans at the Los Alamos Proceedings of the Planning Meeting on Biomedical Applications of the Pion Beam from the 590 MeV Isochronous Syclotron Zurich, Switzerland, 1-17 (1971)

Negative Pion Radiotherapy: Physical and Radiobiological Aspects, with M. R. Raju, Currents Topics in Radiation Research Quarterly, 8, 159-233 (1972)

Recommendations for Implementing Radiotherapy with Negative Pions at LAMPF, LAMPF Biomedical Steering Committee, Chaim Richman, Los Alamos, LA Report (1973)

Characteristics of the Biomedical Pion Beam at LAMPF, Work in Progress. RSNA Meeting (1974)

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1. Aim and Method of Study

The first two patients have been treated at the C. P. Anderson Meson Physics Facility (LAMPF). In these first cases metastases from a breast tumor and gastro-intestinal cancer were exposed to negative pions for tumor regression studies. These irradiations initiate studies on a variety of tumors with this new modality in comparison to conventional irradiation controls.

For almost 15 years a background for pion radiotherapy has been built up. The accelerator for producing the beam has been under construction for about 10 years. We have finished the accelerator, the pion beam transport system, and the treatment facility. For the past six months the data needed for these human exposures has been assembled.

Of all the elementary particles in nature, the pion is best suited for therapy: First of all it is a penetrating and lightly ionizing particle whose range is clearly defined. This means that definite localized lesions can be irradiated with little entrance dose and practically no exit dose. Secondly, in the treatment volume the pion is captured by the oxygen, carbon and other nuclei to produce short range, medium and high LET fragments (called a star). These fragments give an increased RBE and a decreased OER. The combination of these features, we are becoming convinced from our data, is leading us to a possible unique and potent tool in the treatment of cancer.

The pion therapy program is a combined effort of the Cancer Center of the University of New Mexico Medical School and the U.S. Atomic Energy Commission at the Los Alamos Scientific Laboratory. Dr. Morton M. Kligerman is the principal investigator.

The aim of the total effort is to assemble the following data for pion radiotherapy.

a) Tuning of the magnets to produce various beams.

b) Studies of the contaminations, the total dose, and the different LET components for the treatment situations.

c) Radiobiology of pions for cell systems and for solid tumors in animals.

d) Response of selected tumors in patients.

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The Magnetic Tuning

The aim of all the studies is to combine and coordinate the work so that good therapy is carried out. This requires first of all good data from the transport system as to how the beam is coming down through the magnets. Figure 1 is a drawing of this system. At present the beam has an intensity of 5 rads/min. It is focused to a region just beyond the collimator. The tumors treated are close to the skin and the irradiation times are about 30 minutes. These beam studies are being made with large multiwire proportional chambers which by means of an on line PDP-11 computer give an instantaneous picture of the particle distributions.

The fashioning of a good therapeutic beam begins with the finding of suitable settings of the magnets that give a beam of the right energy, energy spread, and spatial distribution for the type of patient to be treated. These "tunes", as they are called, are then investigated dosimetrically and radiobiologically. (J. Helland, M. Paciotti).

The Electron and Muon Components

It is always true that in the actual therapeutic situation, the problems encountered are somewhat different than had been envisaged before the beam was available. It has turned out happily for example, that the electron and muon contaminations are only 14% of the particles in the beam. In treating small tumors under the skin with a narrow pion peak, these contaminations have only a small effect.

When treating large regions of say 10-15 cm. in depth, these contaminations have a significantly greater effect. This is true because the peak has to be spread out over large regions whereas the contaminations, having a long range, already exist over large regions. For any "tune", we will measure these contaminations with silicon detectors and scintillation detectors and determine their contribution to the dose.

The Three Dose Components

Tissue-equivalent ionization chambers are used to measure the total dose.

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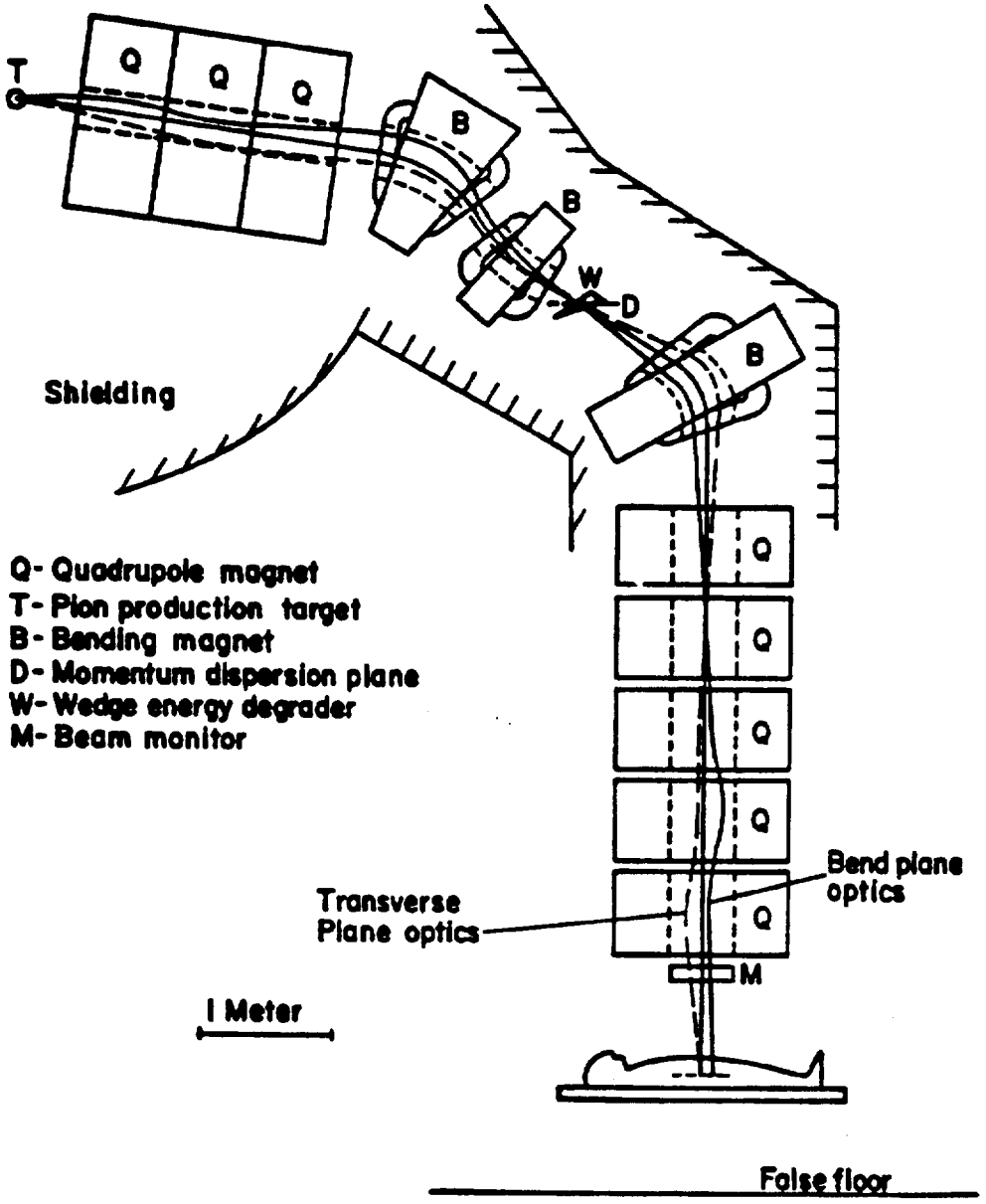

THE SYSTEM OF MAGNETS FOR TRANSPORTING THE PION BEAM

FROM THE TARGET TO THE PATIENT

Stubout floor

Figure 1.

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With pions the situation is more complex. Contained in the total dose are essentially three kinds of doses: a low, a medium, and a high LET dose. These will be measured by using silicon detectors of different thicknesses. The different particles give different size pulses in these detectors. These pulses are analyzed for their energy contributions and then integrated to obtain the different LET contributions to the dose. This entire process is done as a function of position of the detector. In this way we will arrive at isodose distributions for the different LET components in addition to the isodose curves for the entire dose. The therapist can be guided by the complete dosimetric picture as well as by the radiobiological data.

The dose measurements and dose characteristics surveys will take much of our time since they form the basis of the radiobiology and treatments. The low LET dose consists of the primary beam of passing electrons, muons, and pions. The disintegration products of protons, α-particles, and recoil particles produce the field of medium and high LET dose in the treatment volume.

The three components of dose have in general different distributions, and the placing of the tumor in the beam depends on which component dominates in its effect. If for example, the RBE for the high LET component is very high, it will dominate the therapy. We will measure these components and compare these with the radiobiological data.

Another question of importance is the following: In the present therapy collimators are used with circular openings of 5 cm., 4 cm., 3 cm., and 2 cm. in diameter. Much more detail is needed on how these collimators affect the beam. We will continue our studies of the beam under these collimators. (C. Richman, J. Dicello, T. Lane, H. Amols).

Scanning a Large Treatment Volume

With our system of magnets the pion beam produces a peak of dose at the end of its range which is shown in Figure 2. The peak covers a region of about 3-5 cm. To treat large regions, a variable absorber will be introduced into the

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beam to move the peak back and forth over the treatment volume. This variable absorber, in the form of a cylinder of light oil 10" in diameter, is now on the drawing boards. The system has many requirements to fulfill. First, it must be absolutely safe for the patient. Dosimetrically it must move the peak around in such a way that the total dose distribution is uniform. This means that the cylinder must be filled and emptied at a nonuniform rate. The rates of filling and emptying of the cylinder will be about 1.4 seconds per cycle. The resulting dose distributions, both total and in LET will be measured with our probes and the entire scheme will be studied experimentally. (D. Liska).

Another question arises in treating large regions. When the pion traverses healthy tissue on the way to the treatment volume, it produces by nuclear interaction a percentage of high LET component. This will also be measured for different therapeutic situations.

Tissue Inhomogeneities

We come now to more complex treatments where we have bone or lung or both present in the field. We have built a large water phantom with cooling coils. In this phantom we will mount various arrangements of lung and bone equivalent material in water and scan the distributions in and around these materials. The cooling keeps the noise level in the detectors down to a minimum. We have also finished a very accurate scanner for moving the probes around which is now in use and will be used in the future measurements.

The data is taken on a multichannel analyzer and then transferred to magnetic tape. This tape is then taken over to our large computer where the data is analyzed and the distributions are printed out.

Radiobiology and Therapy

The program in radiobiology is to use human kidney, T-1 cells, and CHO cells to ascertain the effective distributions of the beam and to measure RBE's and OER's. Mouse tumor cells will also be used to measure the effectiveness of pions. The distributions in depth under each collimator and laterally to the

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collimators will also be determined with T-1 cells. (M. Kligerman, D. Peterson, M.R. Raju).

The therapy program is now well underway. Carefully selected patients are being treated with both pions and conventional radiations to ascertain the advantages of pions. This program has just begun and will be expanded in the future. It is an encouraging fact that the machine is now running well enough so that patients can be treated almost every night during our running cycles.

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2. Work Accomplished

The accelerator is now fully operational and is producing a proton beam adequate for the biomedical program. A dose rate in the treatment room of 5 rads/min of pions in the peak is available. The beam transport system is fully operational and is computer controlled from the control room.

The treatment building is finished and patients are now being treated conveniently with excellent care for their comfort and safety. By means of closed circuit TV and audio hookups we are in full contact with the patient during treatment.

Carbon targets are used to produce the pion beam. In an effort to increase the dose rate, an Al_2O_3 target was tried but was less satisfactory because more contamination was produced and the proton beam underwent more multiple scattering and activated the detection equipment at the end of the accelerator. We have stayed therefore with carbon targets.

Total Dose Distributions, Contaminations, and Dose Components

The first measurement of therapy is the central axis depth dose. We have used standard tissue-equivalent ionization chambers and have determined this dose distribution in a water phantom and under the four collimators. The lateral distributions have also been determined. Figure 2 is a plot of the dose as a function of depth in a water phantom.

The narrowing of the peak to attain the higher dose rate is clear. All of our measurements give a full width at half maximum (FWHM) of about 2.8 cm. It means that the tumors must be placed carefully in the beam with due attention to any bolus being used. The peak is at a depth of 18.8 cm. of water or water equivalent.

Silicon detectors have been used to separate the different particles in the beam. Figure 3 is a spectrum of the pulses produced in a 5000 micron detector by the beam at a depth of 8 cm. in a water phantom. The electrons, muons and pions are distinguishable. The measurements give 4% electrons and 9% muon particles in the total beam at entrance.

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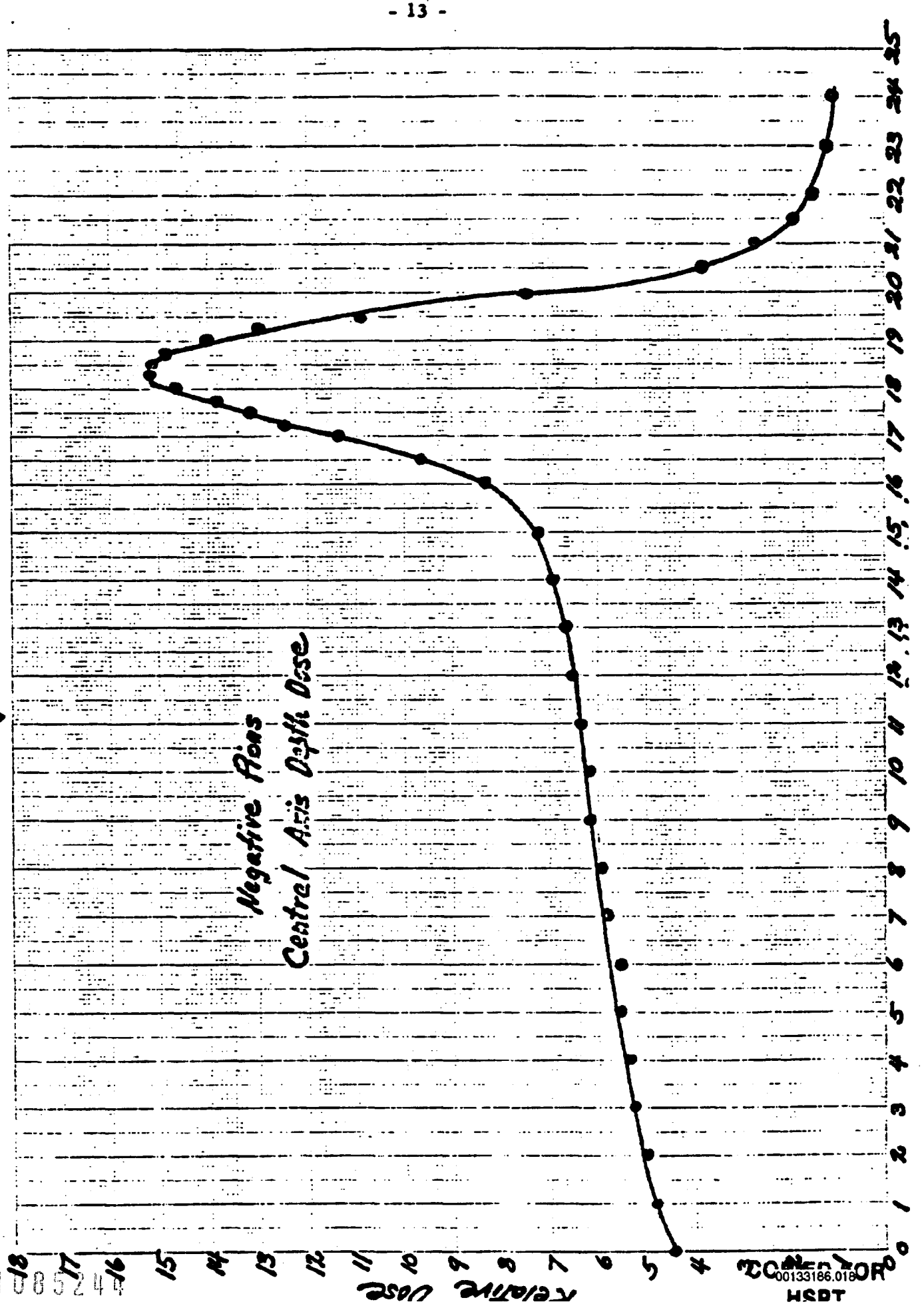

Figure 2.

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SEPARATION OF THE PRIMARY BEAM INT ELECTRONS, MUONS, AND PIONS

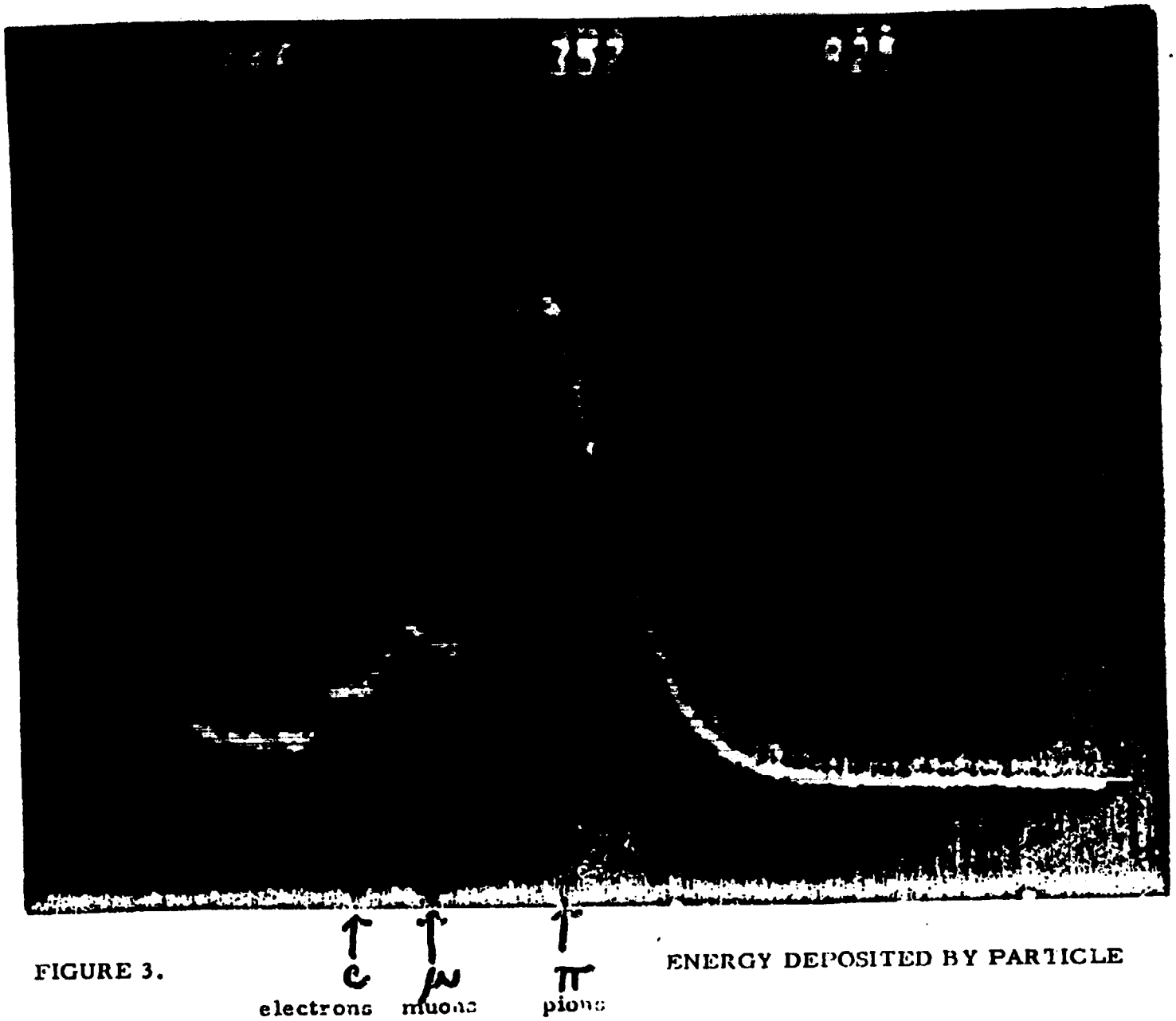

FIGURE 3.

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In the stopping region (star region) the detectors give the pulses produced by the primary particles (electrons, muons, pions) and the stars. The data for the 4 cm. collimator is shown in Figure 4. We conclude that under this collimator the proper place for the tumor is at the peak of the total dose, not displaced deeper into the phantom as had been thought earlier.

Radiobiology

The studies of RBE have begun with T-1 and CHO cells using standard tissue culture methods. We find some variation in the RBE and the results to date give an RBE between 1.2 and 2.0. More studies are needed at this point. The dose distribution studies with cells have so far shown a maximum effect about 0.5 cm. from the peak of the dose, in contradiction to the physical measurements. However, the data here is as yet incomplete and more experiments are in progress.

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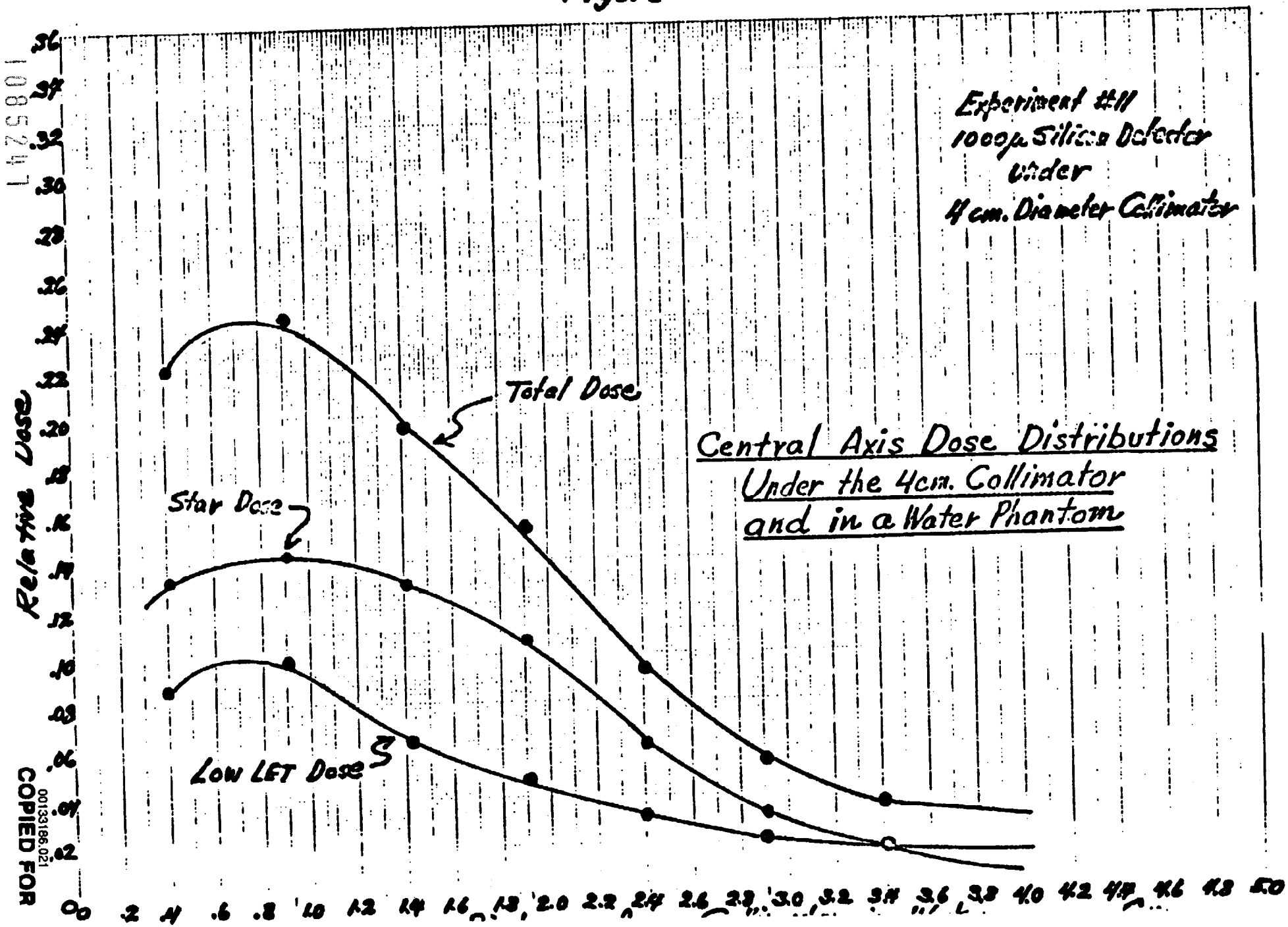
Figure 4



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3. Facilities Available

The accelerator is now operating well. A proton current of about 5-7 microamperes is reliably available and the pion dose rate is about 5 rads/min at the peak. The treatment facility is able to accommodate the patients very well. We have good electronics and shop facilities to support the experiments and the measurements. We also have elaborate tissue culture laboratories and animal holding facilities to do the radiobiology. Our computer facilities for analyzing data are extensive and we have good support from the people in the computer division.

4. Time to Accomplish the Work

The accelerator is virtually complete. During the next year it is planned to provide higher dose rates at the Biomedical Facility and also to provide improved shielding as required. I now believe that the role of pions in radiotherapy can be evaluated on the basis of a significant amount of data and experience within two to three years.

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COST ESTIMATE

Estimated Start Date: July 1, 1975

Duration : Two years

	FY (12 mo)	FY (3mo)	FY (9 mo)	Total
MAN-YEARS				
Scientific	-0-	-0-	-0-	-0-
Other	-0-	-0-	-0-	-0-
COSTS ($K)				
Direct Salaries	-0-	-0-	-0-	-0-
Materials & Services	9.7	2.4	4.8	16.9
Consultants	20.8	5.0	13.8	39.6
Computer	8.7	2.5	7.5	18.7
Labor Burden	-0-	-0-	-0-	-0-
Sub-Total	39.2	9.9	26.1	75.2
Major Equipment	11.4	7.6	7.0	26.0
TOTAL	50.6	17.5	33.1	101.2

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LOS ALAMOS SCIENTIFIC LABORATORY

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