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The Neutron Therapy Facility at the Institute of High Energy Physics, Academia Sinica

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Introduction

The 10 MeV proton linac which was designed as preinjector for the Beijing 50 GeV Proton Synchrotron (BPS) was completed by the end of 1982. Because of the economic readjustment in the People's Republic of China the BPS project was cancelled. Then, the Institute of High Energy Physics decided to increase the energy of the linac from 10 MeV to 35.5 MeV. This increase will take place using the primary five megawatts RF system of the 10 MeV linac.

This 35.5 MeV proton linac will be used for research in radiomedicine and radiobiology in general and in particular for research in fast neutron therapy and radiopharmaceutical production. This project has been approved by the Academia Sinica.

General Parameters of 35.5 MeV Linac

The proton linac consists of the following systems: (a) a preinjector which generates 750 KeV beam, (b) a 750 KeV beam transport system, and (c) a six tank linac. The general parameters are shown in Table 1. The 35.5 MeV proton beam transport system is composed of one main line and two brach lines. The layout of the transport system and the arrangement of the assemblies are shown in Figure 1. The distance from the last linac quadrupole magnet to the neutron producing target is 51 m. This transport system will be built inside a tunnel.

Neutron Source and Characteristics of the Clinical Neutron Beam

The clinical neutron beam will be produced bombarding a semi-thick Be-target with 35.5 MeV protons. The proton beam current will have an intensity of 100 μA. The neutron producing target will be 1.16 cm thick beryllium. It will be directly cooled with low conductivity water.

Dose Rate

The average dose, as measured in air at a source-to-skin distance of 150 cm and at 0 degrees direction, will be about 60 rad/min. See Table II.

Neutron Energy Spectrum

The fast neutron spectrum is shown in Figure 2.[2]

Angular Distribution of the Fast Neutrons

The neutrons are produced by the bombardment of beryllium target with 35 MeV protons. The angular distribution of the fast neutrons is shown in Figure 3.[3]

Skin Sparing

The skin sparing properties of the neutrons from 35 MeV p on Be is illustrated in Figure 4.[4] The dose buildup at an air tissue interface of the neutrons is comparable to that of ^{60}Co γ-rays.[5]

Depth Dose

Central axis depth dose curves from neutron beam (35 MeV p+Be) is shown in Figure 5.[4] The 35 MeV p+Be neutrons have comparable depth dose characteristics of ^{60}Co γ-rays. The γ-ray contamination in the neutron beam is about 2%.

Neutron Therapy Facility

For patient treatment, an isocentric system using a fixed horizontal neutron beam will be utilized. The designs of the target assembly, the transmission ion chamber and electronics, the interchangeable collimator system, the treatment chair, the laser system to define the isocenter, the dosimetry equipment to measure dose distributions, the neutron treatment planning and control system will be designed based on the experience gained in neutron therapy at the Fermilab Neutron Therapy Facility. It will be completed in 1983.

Treatment Room

The treatment room will be 5 m long and 5 m wide. The target will be mounted outside 1 m from the entrance shielding wall and it will have a moveable shield on one side to allow maintenance. The level of the proton beam is 1.5 m above the ground. The SAD will be 150 cm. The treatment chair will be suitably installed at the isocenter with a mechanism to change at will the elevation of the patient (Figure 6).

In the future a vertical neutron beam will be added to the facility.

The radiation shielding at 0 degrees direction is 2 m thick and the side walls are 2 m ($\rho = 3.5\ g/cm^3$). Heavy concrete will be used in the shielding. Precautions will be taken to minimize the sodium content of the walls.

There will be a diagnostic x-ray machine in the room for treatment simulation (patient positioning).

In addition, the facility will have a control room, examination rooms, and the waiting room next to the treatment room. A redundant interlock system will be installed in the treatment room. It will have two safety loops, a simple hard wired one and another one with solid state logic that will have the ability to turn-off the beam and indicate where the unsafe condition took place.

The patient treatment room will be in voice contact with the therapy control room by intercom and under constant surveillance via closed circuit television.

Acknowledgement

From December 1982 through March 1983, Fermilab Neutron Therapy Facility personnel gave us a lot of help. We would like to thank them very much for it. Special thanks are given to Drs. M. Awschalom and R. Ten Haken as well as Miss. M. Gleason and Mrs. L. Hanabarger for typing this report.

References

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TABLE I. 35.5 MeV Linac design performance parameters

Output energy	35.51 MeV
Cavity length	21.828 m
Cavity diameter	94.9 cm
Total power for 60 mA beam current	3.97 MW
Total power for 80 mA beam current	4.66 MW
Output momentum spread	± 0.15% ∿ ± 0.30%
Normalized emittance	6 ∿ 8 π mm · mrad
Pulse repetition rate	12.5 HZ
Beam pulse length	50 ∿ 150 μs
Average beam current	100 μA*

*According to calculate by pulse beam current 60 mA beam pulse length 150 μs and pulse repetition rate 12.5 HZ

TABLE II. Comparison of some parameters of accelerator produced neutron beams

Parameter \ Institute	Fermi-lab	Hammer-smith[1]	Univ. of W.[2]	NRL[3]	M.D.A. T.A. & MU.[4]	cp-42[5]	cp-30	HEPI BPL
Particle	p	d	d	d	d	p	p	p
Target	Be	Be	Be	Be	Be	Be	Be	Be
Incident energy MeV	66	16	21.5	35	50	42	30	35.5
Beam power (Kw)	1.32	1.3	0.86	0.35	0.35	2.0	2.0	3.5
Mean neutron energy (MeV)	26±2	7.6	8	15	21	20	15	18
TSD (cm)	190	116	150	125	140	125	125	150
Depth of Dmax[6] (g/cm^2)	1.7	0.23	0.3	0.55	1.07			
Depth of 50% Dmax[6] (g/cm^2)	16	8.8	10.2	12.8	13.8	14.7	12.4	
Tissue Dose Rate Dmax at stated TSD (rad/min)	30	43	40	66	60	47	21	60

1. Hammersmith Hospital MRC, London, England.
2. University of Washington.
3. Naval Research Laboratory Washington, D.C.
4. M. D. Anderson Hospital & Texas A & M University, Houston, Texas.
5. Cyclotron company U.S.A.
6. 10-x 10-cm field at stated TSD.

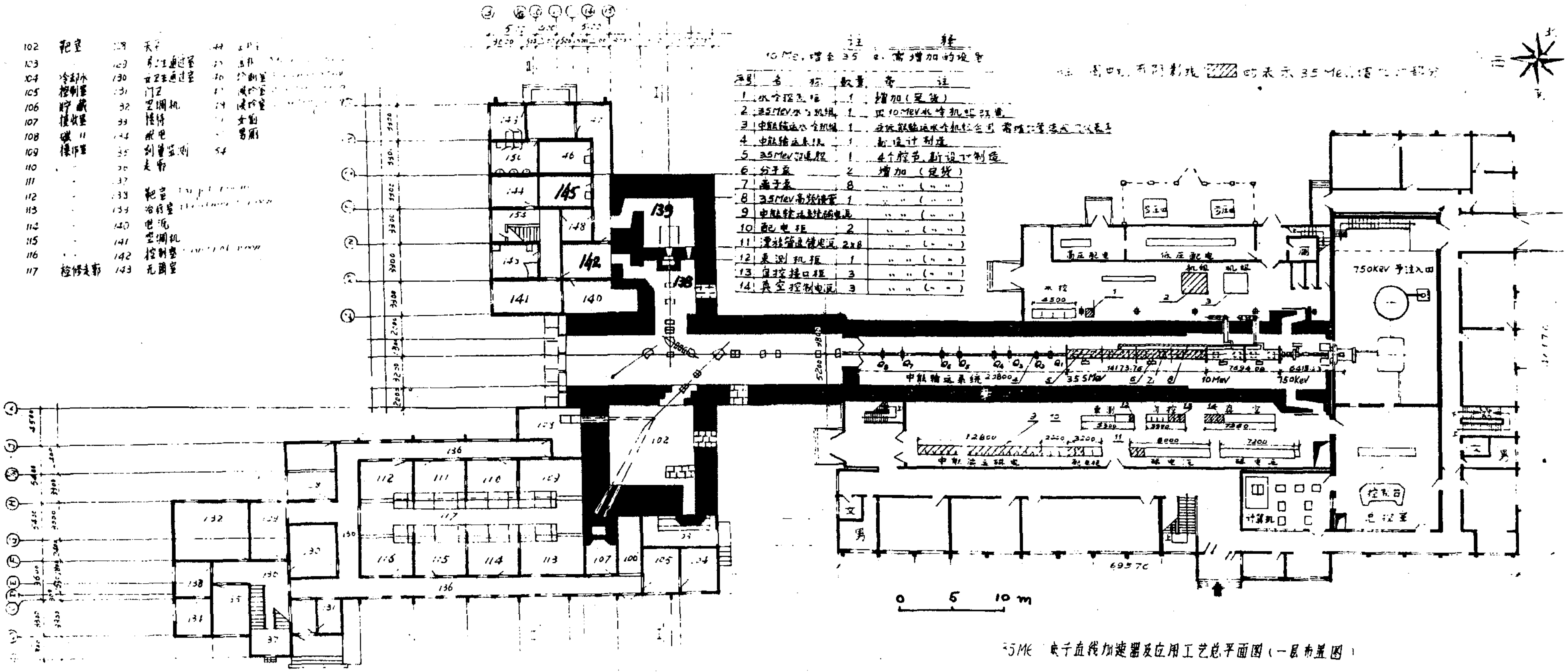

Fig. 1

General Layout of 35 MeV Proton Linac

138 - Target area
139 - Treatment room
142 - Control room
145 - Medical office
148 - Waiting room

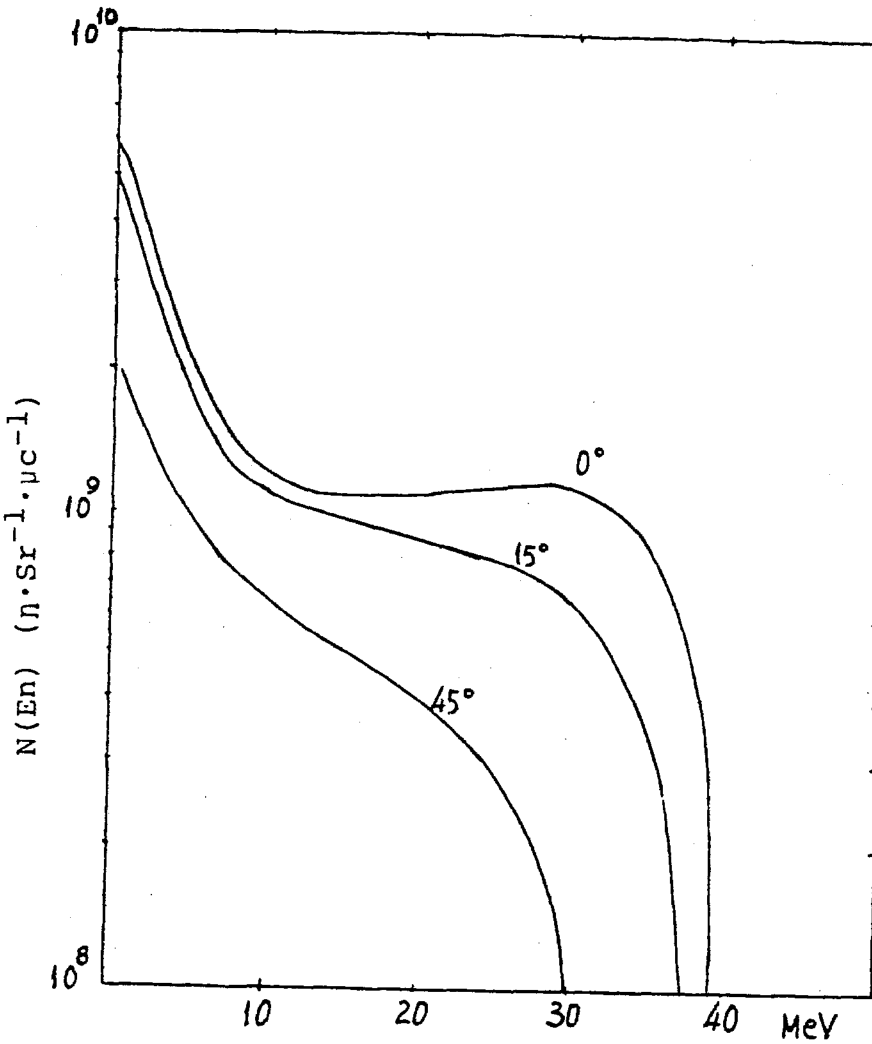

Figure 2   Neutron Energy

Spectra of neutrons produced at 0°, 15° and 45° by bombarding a thick beryllium target with 35 MeV protons.

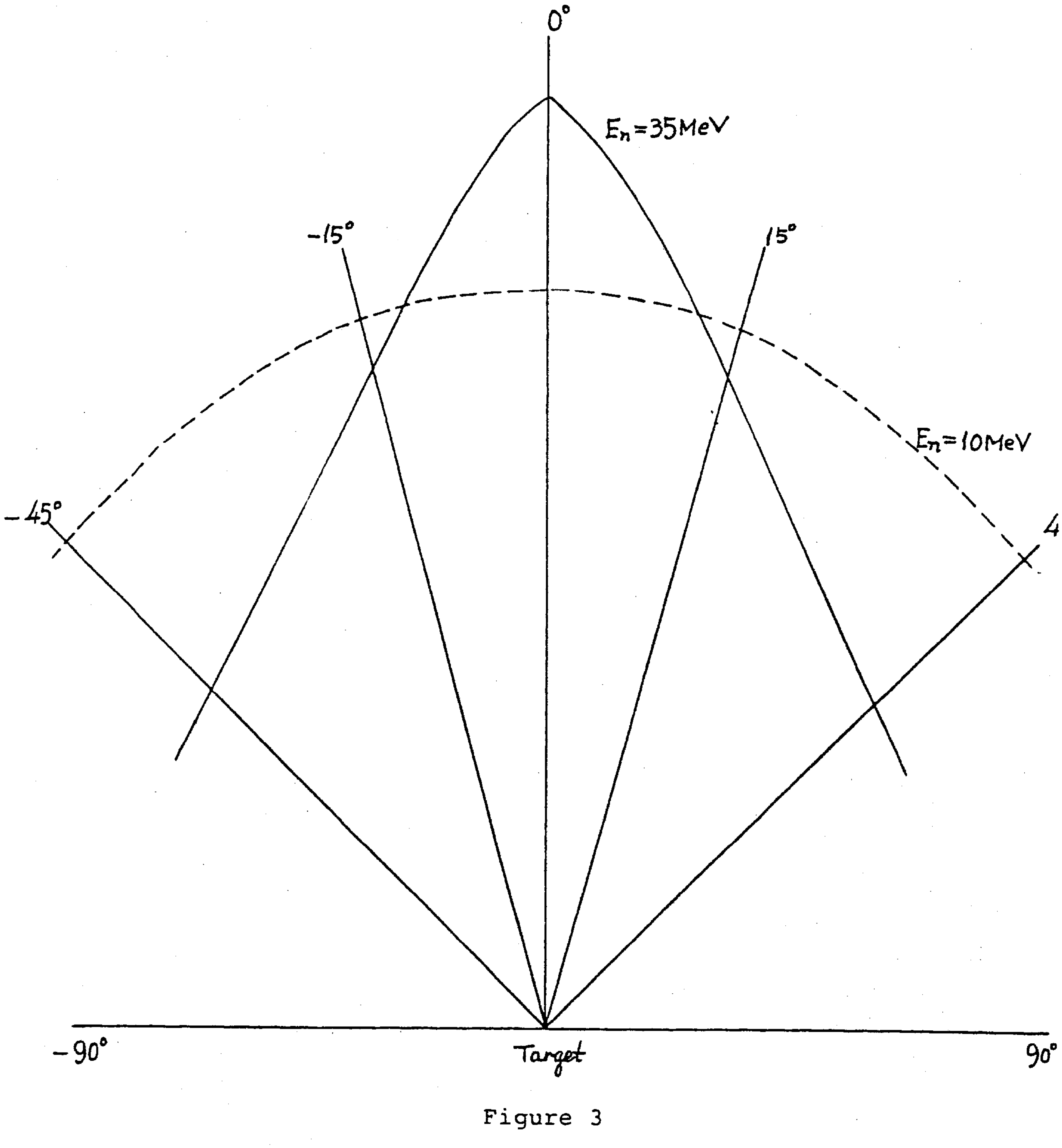

Figure 3

Angle distribution of 10 and 35 MeV neutrons.

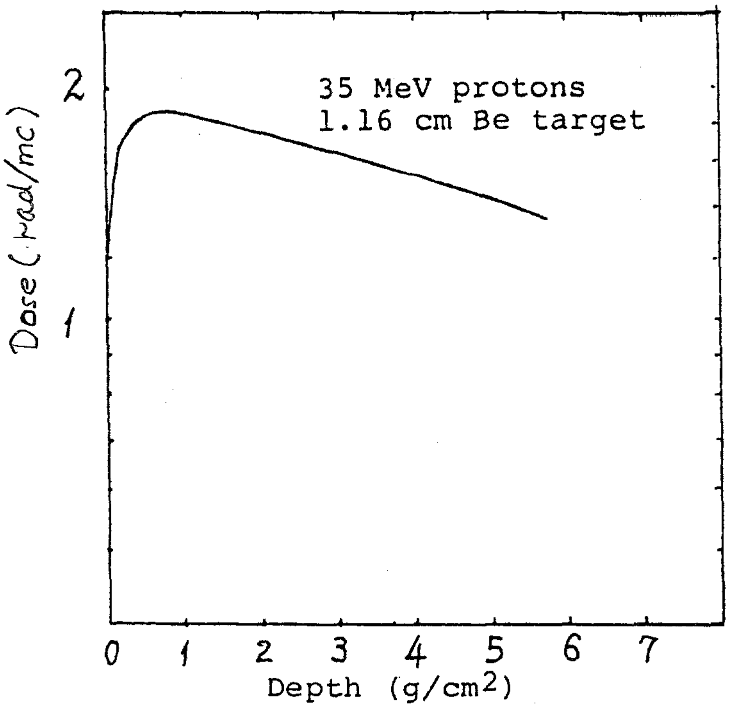

Figure 4

Dose buildup in tissue equivalent plastic. 35 MeV protons are incident on a thick beryllium target.

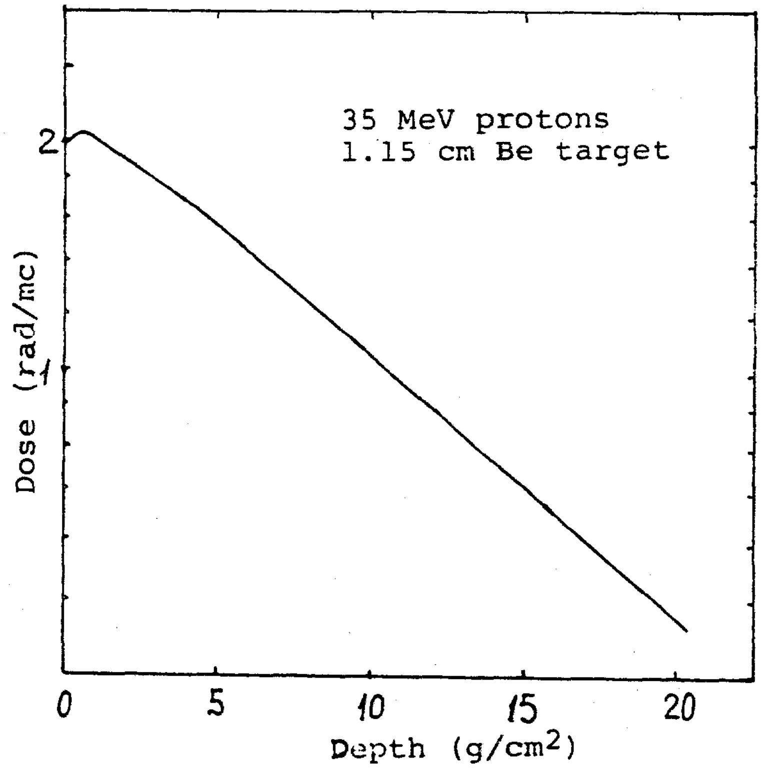

Figure 5

Central axis depth-dose measurements in a water phantom at 125 cm TSD. 35 MeV protons are incident on a thick beryllium target.

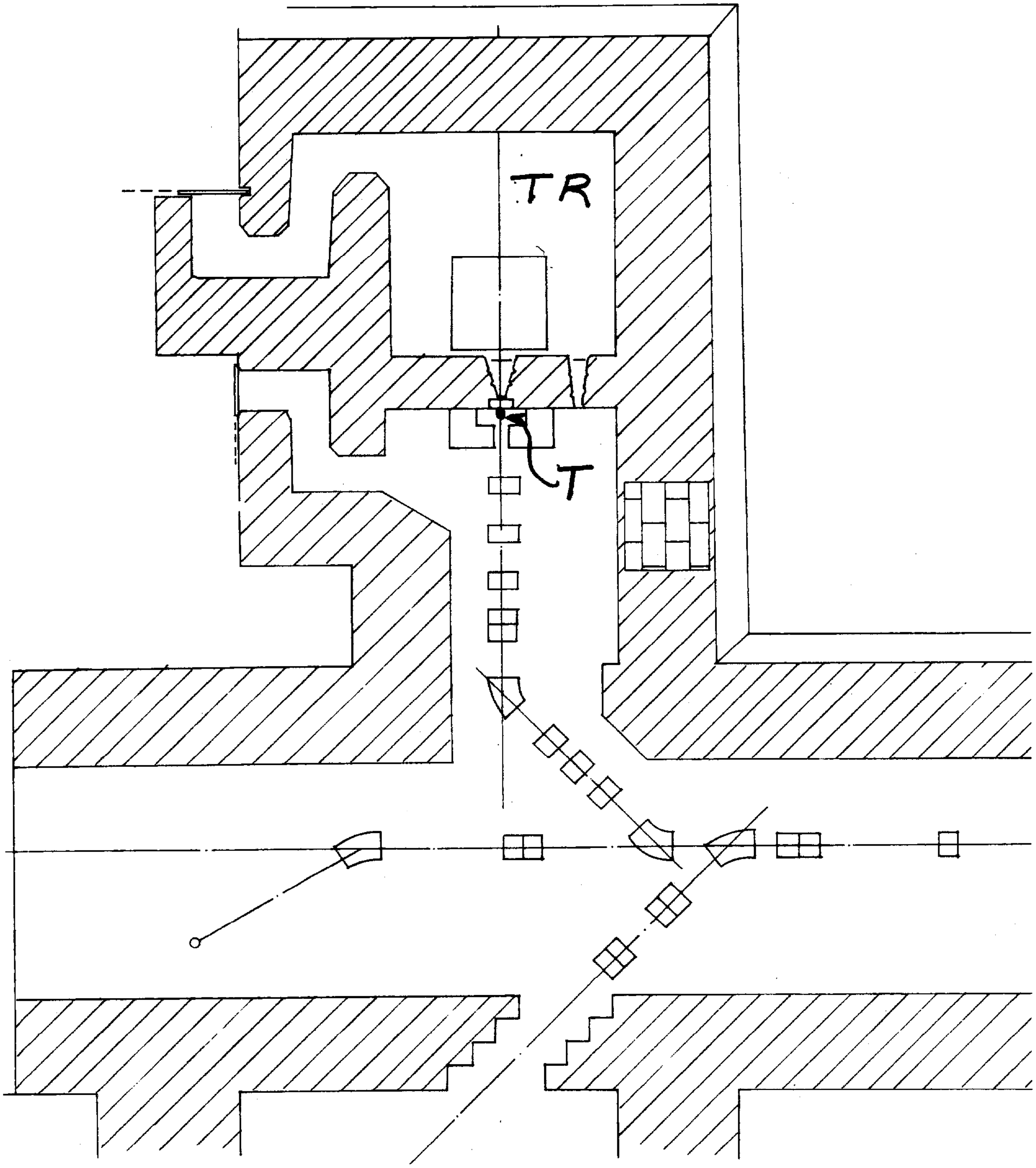

Fig. 6

Details of proton beam transport, target area and treatment room. TR = treatment room, T = target location.