THE CANCER THERAPY FACILITY

In recent decades, radiation therapy of cancer and the understanding of radiation effects at the molecular and cellular levels have progressed considerably. The qualitative differences in biological effects of radiation with low and high specific ionization are now fairly well understood.

Some types of tumors which have cells effectively insensitive to photons and electrons in tolerable therapeutic doses may be controlled by radiation with high specific ionization. In soft tissues, fast neutrons with energies of a few million electron volts produce such heavily ionizing charged particles. Hence, they could theoretically be effective where photons and electrons fail.

Fast neutrons have been under study for about five years at the Hammersmith Hospital in London, England, where 16-MeV deuterons bombard a beryllium target and produce a beam of neutrons of up to 8 MeV mean energy. The results concerning the local control of head and neck tumors are very encouraging compared with treatment by conventional means.

In 1946, R. R. Wilson suggested using fast protons in cancer therapy. A quarter of a century later, in 1971, Fermilab physicists interested in such possibilities organized a conference on this subject. The organizers had foreseen compatibility between the requirements of high energy physics and medical research in the use of the injector protons.

In the midst of the planning for a proton therapy facility by a group of local radiotherapists and physicists, Dr. David Hussey of the M. D. Anderson Hospital for Tumor Research (Houston) was invited to give a talk about his research program in cancer therapy using fast neutrons. He was very

convincing. By the end of his visit it was generally felt that neutron therapy would be the research choice of most local radiotherapists. Thereafter, the interest in using neutron beams in a medical facility at Fermilab grew.

Early plans for such a facility called for the transport of protons of any energy between 37 and 200 MeV from the linac to the proposed clinic. The planned facility would have been located some 800 feet southwest of the present linac building. The protons would have been used in medical research directly for either therapy or radiography and indirectly for neutron therapy.

This clinic would have had several treatment rooms for exposures to neutrons and protons. It was matched with equally ambitious plans. The estimated cost matched them in magnitude. Inevitably, the realities of practicality led us to suggest a more modestly priced facility located within the existing linac building. This facility is now under development.

Beam Requirements for Medical Research

Fermilab high energy research usually makes use of 400-GeV protons from the main accelerator. To fill the circumference of this accelerator with one turn of protons, the booster accelerator must inject 13 "pulses." This takes nearly one second. The acceleration and extraction of the 400-GeV proton beam plus the return of the accelerator's magnetic fields to injection values takes about 8 seconds. During 8 of these 9 seconds, the linac and booster are on standby conditions. This means the injector systems continue to operate while no protons are needed for the main accelerator. If a deflection mechanism existed ahead of the main accelerator, protons could be diverted for other research purposes. In the present cancer therapy research project, 66-MeV

protons are extracted from midway along the linac to produce a neutron beam. The proton energy was selected as a compromise between neutron flux, neutron energy spectrum, and the cost to build the extraction and transport system.

The final neutron-producing target has not been selected. Neutron beams having satisfactory physical characteristics have been obtained using protons bombarding thick beryllium targets. Beryllium targets are attractive because they may be operated at high temperatures, conduct heat adequately, and have low vapor pressures at high temperatures. However, lithium targets are being considered as well, because they may generate biologically more interesting neutron beams. Before a final selection of target configuration is made, neutron energy spectra, rates of energy loss by recoil particles, and dose per incident proton will be measured at the University of California, Davis.

The biological characterization of these beams has already commenced. Clinically speaking, "good physical characteristics" mean:

- Low entrance doses to avoid skin damage.
- Depth for a dose equal to half of the maximum dose greater than 10 to 12 cm.
- Low gamma-ray contamination.
- Dose rate large enough to permit treatment times shorter than 10 minutes.
- Uniform neutron dose over at the location of the tumor, an area of 30 by 30 cm^2 maximum.

At this time, preliminary values for these parameters have been measured for each of two beryllium target thicknesses.

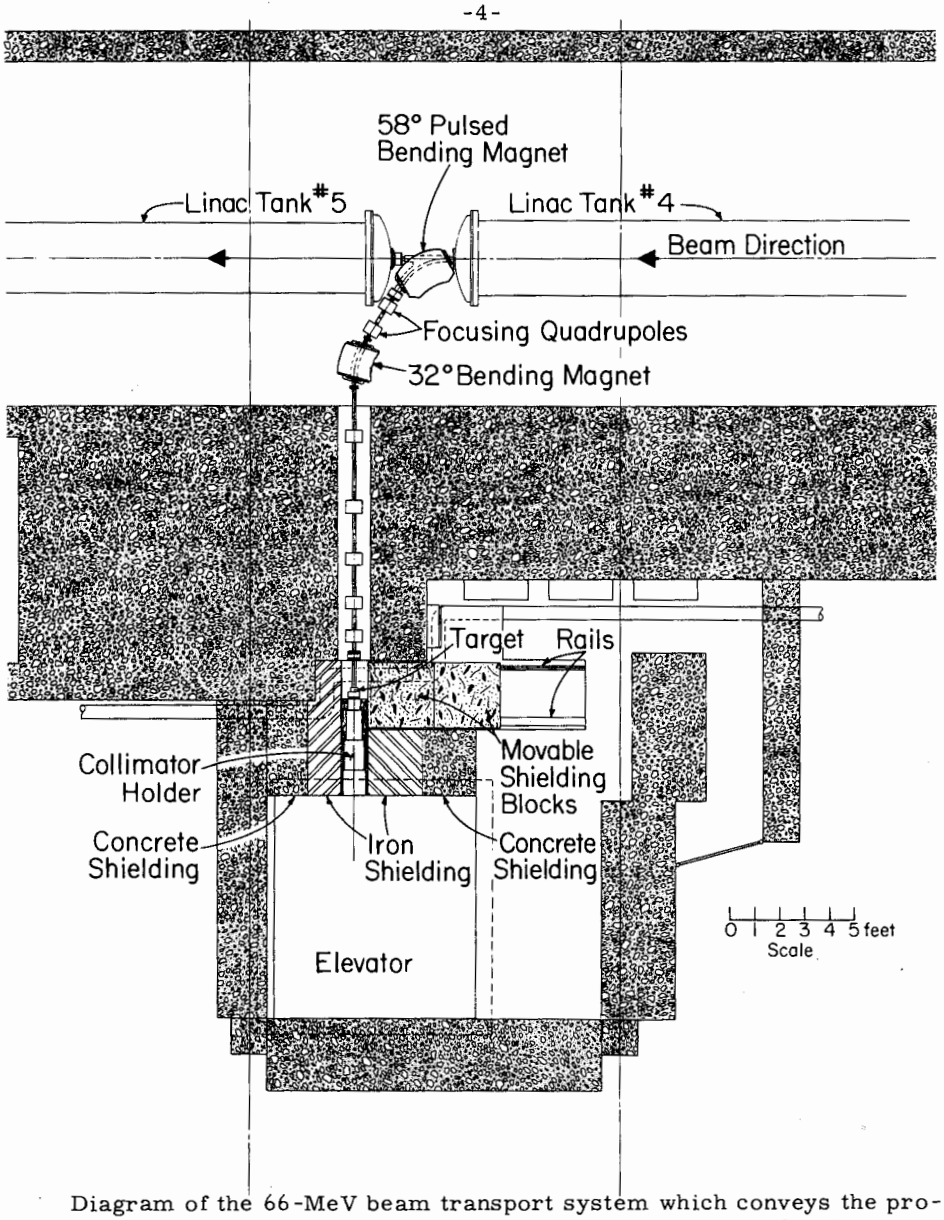


Diagram of the 66-MeV beam transport system which conveys the proton beam from the linac into a shielded enclosure on the lower level of the linac building. The first element in the transport line is a 58°-pulsed bending magnet, between linac tanks #4 and #5. Another bending magnet in the linac enclosure completes the 90° bend to direct the beam onto a beryllium target for the production of neutrons. The neutrons are aimed into a research area positioned on the elevator.

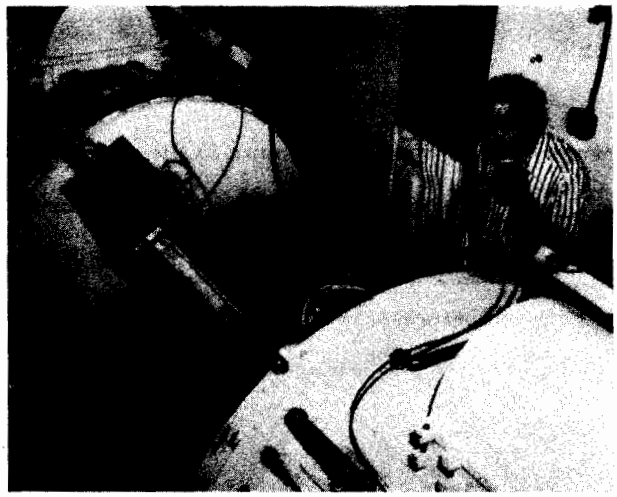
The Beam Line

The protons are extracted from the linac between tanks #4 and #5. The protons are bent by a pulsed magnet, shown in the photograph on page 6, through 58 degrees. After passing through a pair of quadrupole magnets, they are further deflected 32 degrees by a constant-field magnet. The protons then pass perpendicularly through a channel in a 10-foot concrete wall and are kept together with the aid of five additional quadrupoles, as shown in the diagram opposite.

The target is located 19 inches from the wall in the lower gallery of the linac building. The beam line is roughly centered within an area occupied by a hydraulic cargo lift measuring 8 by 9 square feet. Temporary shielding has been installed around and above this cargo lift to allow physical and biological measurements to be performed on the neutron beams. Small areas for radiobiology, reception, examination, and a control room have been planned for medical use on the first floor.

Funding

About $0.75 million of direct operating funds were obtained from the National Cancer Institute (U. S. Department of Health, Education, and Welfare) for an initial three-year period. Private funds are being sought from local foundations for plant modifications and some facility equipment. In addition to these two major sources of funds, two grants totaling slightly over $35,000 to purchase dosimetry equipment, beam time, and travel have been awarded by the American Cancer Society, Illinois Division.



D. Young checking the operation of the 58°-pulsed bending magnet between linac tanks #4 (upper) and #5, prior to the extraction of the first beam last July. Beam direction is left to right.

Status and Long-Term Schedule

The first neutron beam in the medical facility was obtained on July 17, 1975. Measurements of the neutron beam characteristics began this October. The work so far has consisted mainly of measurements to determine dose distributions. These will continue until early 1976, when the facility will be shut down to permit replacement of the temporary shielding with permanent shielding. Then measurements of the beam properties will be resumed.

The biological work has consisted of survival-versus-dose measurements for E. coli B/R bacilli under anoxic and oxic conditions, as well as hamster cell-tissue cultures. Some experiments with mice will also be carried out before the shutdown.

Should authorization and funds be secured, then research involving humans might begin in late spring 1976. It is expected that initially the

patients will come from the Chicago area; however, it is hoped that soon afterward patients will begin to come from throughout the United States.

The Fermilab Cancer Therapy Facility is planned for outpatients only. Other medical support will be provided from the patients' referring institutions, as well as from hospitals in Chicago and in the vicinity of Fermilab.

Most of the accomplishments thus far have been due to the efforts of enthusiastic volunteers, mostly from the Accelerator Division and the Chicago radiotherapy community. Since July 1975, Lionel Cohen of the Michael Reese Medical Center has assumed the position as Head of the Cancer Therapy Facility on a part-time basis. We thank everyone, and express the hope that their cooperation will continue in the future.

Reported by M. Awschalom