Status of the Proton Therapy Project at IUCF and the Midwest Proton Radiotherapy Institute

Susan B. Klein

Indiana University, Bloomington, IN

Abstract. The first proton therapy patient was successfully treated for astrocytoma using a modified nuclear experimentation beam line and in-house treatment planning in 1993. In 1998, IUCF constructed an eye treatment clinic, and conducted a phase III clinical trial investigating proton radiation treatment of AMD. Treatment was planned using Eyeplan modified to match the IUCF beam characteristics. MPRI was conceptualized in 1996 by a consortium of physicians and physicists. Reconfiguration began in 2000; construction of the achromatic trunk line began in 2001, followed by manufacture of 4 energy selection lines and two fixed horizontal beam treatment lines. Two isocentric, rotational gantries will be installed following completion of the horizontal beam lines. A fifth line will supply the full-time radiation effects research station. Standard proton delivery out of the main stage is specified at 500 nA of 205 MeV. Clinic construction began in April, 2002 and will be completed by mid-December. Design, construction and operation of these proton facilities have been accomplished by the proton therapy group at IUCF.

INTRODUCTION

The Midwest Proton Radiotherapy Institute (MPRI) at Indiana University will be the third full service proton therapy facility in the United States. The first continuously operating facility, constructed at the Harvard Cyclotron Laboratory, has recently relocated to the new Massachusetts General Hospital Northeast Proton Therapy Center (NPTC). The second facility, the first hospital based proton therapy facility, is located at Loma Linda University Hospital. Nearly 20 other facilities, full or partial service, exist outside of the United States in Europe, Russia, South Africa, China, Japan and Canada. A number of additional facilities are planned throughout the world, including Texas and Florida. This exciting application for particle accelerators will engage the activities of a number of accelerator and medical physicists for the next several years.

The Indiana University Cyclotron Facility (IUCF) will supply proton beam to MPRI utilizing the separated sector cyclotron accelerator system [1]. Conversion of the cyclotron system and construction of the medical facility are in process with a goal of treating the first patient in 2003. The main cyclotron extraction system and radio-frequency (rf) cavity structures have been modified to improve extraction efficiency and increase the routine operating energy to 205 MeV. A doubly achromatic extraction beam line has been installed and commissioning of the medical beam delivery system began in November of 2000.

HISTORY OF PROTON THERAPY AT IUCF

IUCF, in Bloomington, Indiana, began performing proton therapy in 1993 when Dr. Jim Morphis, oncologist at the Indiana University Department of Radiation Oncology, and collaborating medical physicist, Dr. George Sandison, requested proton therapy be made available for a patient suffering from a particularly challenging astrocytoma. Dr. Charles Bloch, accelerator and medical physicist at IUCF, designed the treatment beam line and wrote a simple planning program for the treatment. The treatment facility consisted of a chair designed to hold the patient's head rigid, a spinning propeller-style Lucite range

modulator, secondary electron emission monitoring and ion chamber dosimetry devices, beam spreading and collimating devices [2]. Orthogonal X-rays were taken to confirm correct tumor positioning at isocenter. The patient was successfully treated under the auspices of an emergency exemption from the Indiana State Department of Health and an Investigational Device Exemption (IDE) from the FDA.

In 1998, IUCF completed construction of a proton therapy eye treatment clinic. A phase III clinical trial investigating the potential for proton radiation treatment of choroidal neovascular membrane (CNVM) associated with age-related macular degeneration (AMD) commenced at that time and continued until December of 2001. The clinical trial was carried out in collaboration with Dr. Ron Danis and Dr. Tom Ciulla of the I.U. Ophthalmology Department, and two supervising oncologists: Dr. Newell Pugh and Dr. Jim Morphis. Treatment was planned using the Eyeplan proton treatment planning program written at Clatterbridge and modified to match the IUCF beam characteristics. The eye line was designed similar to the large field line used in 1993, modified to suit the small treatment field. It was not necessary to supply additional beam spreading over that induced by the beam intercepting diagnostic devices. A single, round, 1 cm diameter final collimator was used for all patients. Design of the line was relatively simple; all targets were treated as if identical, except for range and angle. The range modulator was a spiral Lexan wedge calibrated to depth in water. Patients were asked to focus on a green crosshair fixation target and eye movement was monitored with a video camera. A commercially available dentist's chair accommodated the patients comfortably in a seated position. The head fixation device was mounted independently to rigid horizontal rails and allowed adjustment in the x, y and z directions. The patient's head was firmly held by direct contact with the skull through a custom fitted bite block.

THE MIDWEST PROTON RADIOTHERAPY INSTITUTE

MPRI was conceptualized in 1996 by a consortium of physicians, physicists, researchers and entrepreneurs. Construction of the facility began in 2000, with the demolition, disassembly and reconfiguration of the research areas associated with the IUCF cyclotrons. Construction of the trunk line and cyclotron upgrades began in 2001, followed by manufacture and assembly of 2 of the eventual 4 energy selection (ES) lines and two fixed horizontal beam treatment lines. Two isocentric, 360 degree rotational proton gantries will be installed following completion of the fixed horizontal beam lines. A fifth ES line will supply the radiation effects research station (RERS), a radiation research facility available 24 hours a day, 7 days a week. The Cockcroft Walton pre-accelerator will be replaced at the end of this year with a CW RFQ injector that will significantly increase the reliability and stability of the medical beam delivery system [3]. Standard proton delivery is specified at 500 nA of 205 MeV beam out of the main stage cyclotron.

Treatment Facility Layout

IUCF will deliver proton beam to the MPRI medical facility by way of the doubly achromatic trunk line. The optics of this line form a waist at the entrance to each of the five ES lines. Beam will be delivered continuously during business hours to the dump, where the energy will be monitored using a multi-leaf Faraday cup. A kicker magnet is located at each waist, and switching technology developed at IUCF [4] will be used to transfer packets of proton beam into the selected ES line analogous to the way water may be acquired from a tap in a pipe. Each treatment room may thus operate independently of all the others. The kicker magnet is an audio frequency ferrite switching magnet that diverts the beam between high and low field regions of a vertical bending Lambertson septum magnet.

The ES lines are energy selection spectrometers composed of two 63 degree bending magnets, adjustable horizontal slits and an adjustable double wedge Beryllium energy degrader. The selected kicker will be energized upon demand from the clinic through the treatment control system. The treatment beam will enter the first treatment room at a switching magnet that selects whether the beam proceeds to the eye line or the large field line. The eye line is the same line used in the IUCF eye treatment facility, with the fixed 70 MeV Lucite degrader removed. The large field line is designed to accommodate either active or passive beam spreading and will use a library of static ridge filters to modulate the range of the beam. The treatment beam will enter the gantry at the rotational center of the gantry beam line.

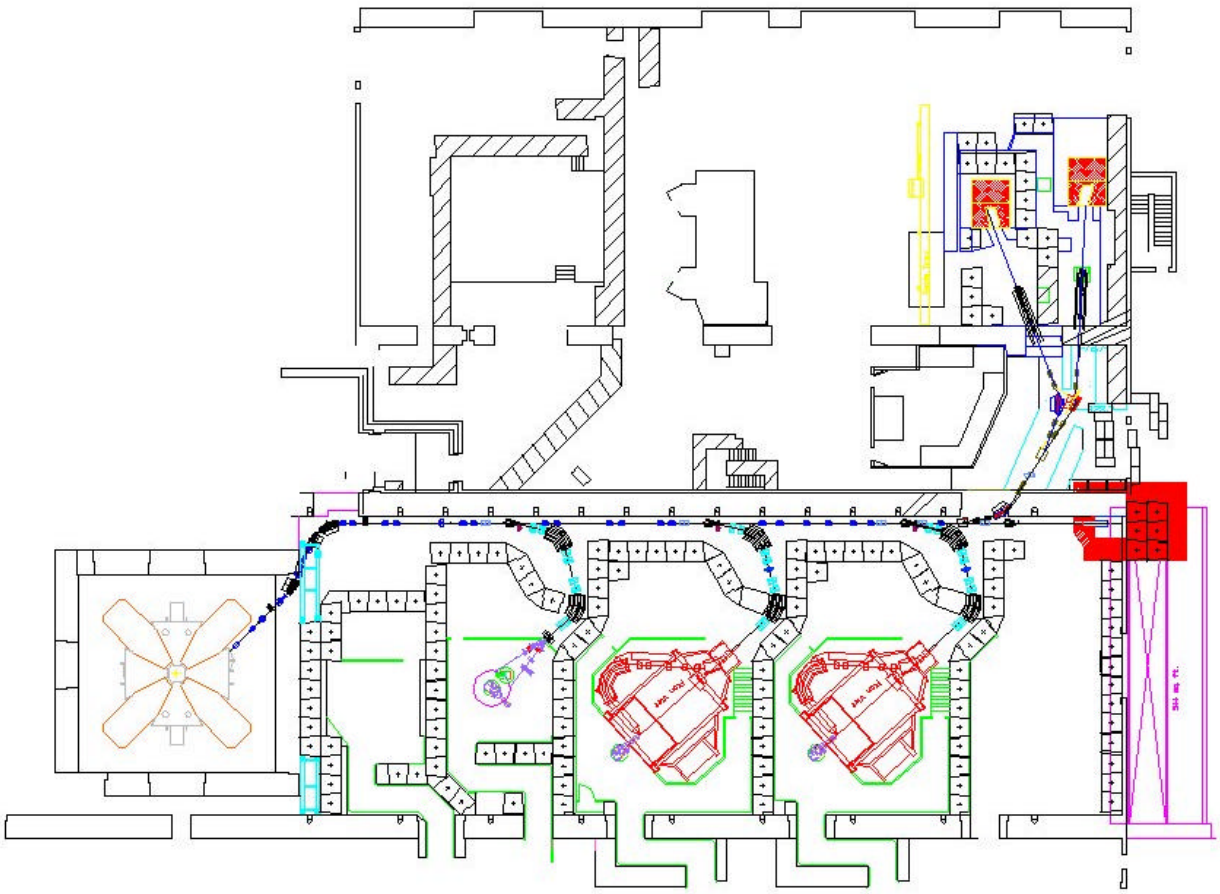

FIGURE 1. The proton beam delivery system. The beam exits the 205 MeV cyclotron and enters a doubly acromatic section of the trunk line. The double waist is translated to each of the ES lines entering the 3 treatment rooms and the RERS. The RERS houses two fixed horizontal lines, large and small field, that will be available for research 24 hours a day, 7 days a week. The treatment room closest to the cyclotron will house a commercially available high voltage photon linear accelerator. The first treatment room houses two fixed horizontal beam lines. Treatment rooms 3 and 4 house 360° isocentric rotating gantries.

Controls System

The computerized control system, the Proton Therapy System (PTS), is modular by design and is composed of 5 subsystems. The Radiation Therapy Technologist (RTT) communicates with the radiation machine from the Treatment Room Controller (TRC) graphical user interface (GUI). The TRC, in turn, sends information to or receives information from the Beam Delivery System (BDS) and the Dose Monitoring System (DMS). These systems communicate with the Kicker Enable System (KES), which controls the energizing of the kicker magnet. The MPRI Interlock and Radiation Safety (MIRS) system also communicates with the KES, preventing kicker operation whenever conditions are deemed unsafe. Patient positioning is accomplished by the Patient Handling System (PHS), which controls a commercially available industrial robot based patient positioner [5]. The gantry controls are being provided by IBA, the gantry manufacturer, and will be interfaced with the remainder of the PTS as required. Treatment planning will be accomplished using the CMS Focus proton package. Patient alignment will rely upon orthogonal, digital X-ray images from Varian flat panel imagers. X-ray sources are located in the beam line, under the floor (large field line only), and at 90 degrees horizontal to each of the two isocenters. A second industrial robot will position the Varian flat panel orthogonal to the selected X-ray source.

The MPRI Clinic Facility

Clinic construction began in April of 2002 and will be completed by mid-December. The clinic

facility will include 4 examination rooms, 2 offices, a physician conference area, reception area, nurses' station, CT/simulation suite, recovery area and a standard photon therapy linear accelerator room. The patient support facility has been constructed in the IUCF "low bay" area, which was divided into two floors of more than 15 vertical ft. each. The second floor will remain mostly unfinished until the first two treatment rooms are operating at full capacity. Only medical physics and physicians' offices will be located on the second floor until that time. The treatment facility is located within the IUCF "high bay" area. The floor was excavated to accommodate the two gantries, and the treatment rooms were constructed of moveable cement shielding blocks previously utilized for the nuclear physics experimental caves. The first room, closest to the cyclotron, was designed to house the photon linear accelerator for two reasons. This machine has unique shielding requirements and the cyclotron vault provided a permanent high radiation area on one side that required shielding for particle radiation only. In addition, the optics of the doubly achromatic trunk line prohibited delivering beam to this space. The second room houses the two fixed horizontal beam lines, the third and fourth room will house isocentric gantries. The fourth room treatment delivery system has not been determined and will be designed after a needs assessment has been completed.

The clinic is designed to be "totally digital," including all patient records, scheduling, radiology, treatment planning, patient alignment, treatment delivery, record and verify functionality and accounting. The complete interfacing of these systems is anticipated to be completed during the first year of operation.

FIGURE 2. Clinic layout. The patient support facility has been constructed in the "low bay" of the IUCF building. The reception area at the far right is new construction. The CT/simulation suite and recovery areas are located at the lower left. RTT control consoles are located to the right of each of the maze entrances to the treatment rooms at the upper edge of the layout.

ACKNOWLEDGMENTS

The eye treatment facility and MPRI have been designed and constructed by the Proton Therapy Group at IUCF. Included in this group during the past 6 years are: Chris Allgower, Vladimir Anferov, Mark Ball, George Berg, Chuck Bloch, Brian Broderick, John Cameron, John Collins, Vladimir Derenchuk, Gary East, Dennis Friesel, Chuck Hagen, Brett Hamilton, David Jenner, William Jones, Joe Katuin , Susan Klein, Don Rosselot, A. Niek Schreuder, Jeff Self, Bill Starks, Bill Vanderwerp, and Moira Wedekind.

REFERENCES

1. R.E. Pollock, PAC'89, *IEEE* **89,** CH2669-0, Chicago, 17 (1989).

2. Bloch, C., Derenchuk, V., Cameron, J., Fasano, M., Hashemian, R., Hornbeach, N., Low, D.A., Morphis, J., Peterson, C., Rosselot, D, Sandison, G., Shen, R-N., Shidnia, H., *NIMB* **B79**, 890-894 (1993).

3. Friesel, D.L., Anferov, V., Hamm, R.W., "A CW RFQ Injector for the IUCF Cyclotron," *Proc CAARI 2000*, Denton TX, Nov. (2000) pp. 651-654.

4. Friesel, D.L, Ellison, T.J.P., Sloan, T., Ball, M., *The 12th International Conference on Cyclotrons and their Applications*, edited by B. Martin and K. Zeigler, World Scientific Publishing Co., Berlin, (1989) pp. 380—384.

5. Katuin, J., Schreuder, N, "The Use of Industrial Robot Arms for High Precision patient Positioning," *Proc. CAARI 2002*, Denton TX, Nov. (2002), in press.