STATUS OF THE MIDWEST PROTON RADIOTHERAPY INSTITUTE

V. Anferov, J. Collins, D.L. Friesel, W. P. Jones, J. Katuin, S.B. Klein, & A.N. Schreuder
Indiana University Cyclotron Facility, Bloomington, IN 47408, USA

Abstract

Phase I construction of the Indiana University Midwest Proton Radiotherapy Institute (MPRI), including many reliability upgrades to the IUCF k220 cyclotron, construction of a variable energy proton Beam Delivery System (BDS), a horizontal beam Treatment Room with a Large Field Nozzle, and a Medical Clinic, is now complete. Commissioning of the BDS and the Large Field Nozzle is underway. Patient Treatment with this nozzle is scheduled to begin in late July 2003. This contribution discusses the unique features of the MPRI Cancer Treatment facility and the present Phase I commissioning results. In addition, two 360^0 rotating gantry systems were purchased from IBA in December 2002 for Phase II construction. The first gantry is scheduled for delivery in July 2003. The Phase II construction and installation schedule will also be briefly presented.

MPRI FACILITY DESCRIPTION

The MPRI Beam Production and Delivery Systems consist of the IUCF K220 separated sector cyclotrons [1], a 57m, 235 MeV proton beam “Trunk Line” to a Beam Dump, and three doubly achromatic Energy Selection beam lines (ES_n) to three Proton Beam Treatment Rooms (TR_n), as shown in Fig.1 [2][3]. A constant 206.5 MeV proton beam from the cyclotrons is delivered to the Beam Dump via the Trunk Line utilizing solid pole magnets. A Multi-Layer Faraday Cup (MLFC) in the Dump is used to monitor and maintain the beam energy and intensity from the cyclotron [4]. The proton energy in the Trunk Line is maintained at 206.5 ± 0.3 MeV as measured on the Dump MLFC, where the measured energy spread is ± 200 keV.

Fast ferrite magnets (3ms rise/fall time) in the Trunk Line are used to kick 206.5 MeV beam into the ES lines on demand. The ES line optics is designed as a double spectrometer to optimize momentum selection and beam transmission and to minimize neutron background in TR1 from the degrader. Proton beam energy, energy spread and intensity delivered to the Treatment Rooms are independently adjusted and verified in the ES lines using continuously variable double wedge Beryllium energy degraders, momentum band selection slits, MLFCs and non-destructive beam diagnostics. The ES line magnets are laminated to facilitate rapid beam energy changes. Figure 2 shows a detailed layout of the ES1 beam line.

The ES lines transmit 65 to 206.5 MeV protons (3.5 to 26 cm range in water) to the three Treatment Rooms. TR1 has two fixed horizontal treatment Nozzle systems, a Large Field Nozzle (up to 30 cm diameter, beam right) and an Eye Line Nozzle (beam Left). The nozzles are accessed by a $\pm 10^o$ switch magnet located at the end of ES1. The Large Field general purpose Nozzle is complete. An Eye Line Nozzle previously used at IUCF will be installed when patient needs require later in 2003 [5].

The ES2 and ES3 beam lines deliver similar beam to Treatment Rooms TR2 and TR3, each containing an IBA 360^o-rotating Gantry. All ES lines are identical in design, except that ES2 and ES3 do not require the switch magnet. The MPRI BDS is designed to deliver dedicated beam to one Treatment Room at a time for patient treatment. A fourth Ferrite magnet, located down stream of ES3, is used to deliver beam to two general-purpose research rooms (not show in Fig. 1) when beam is not needed for patient treatment.

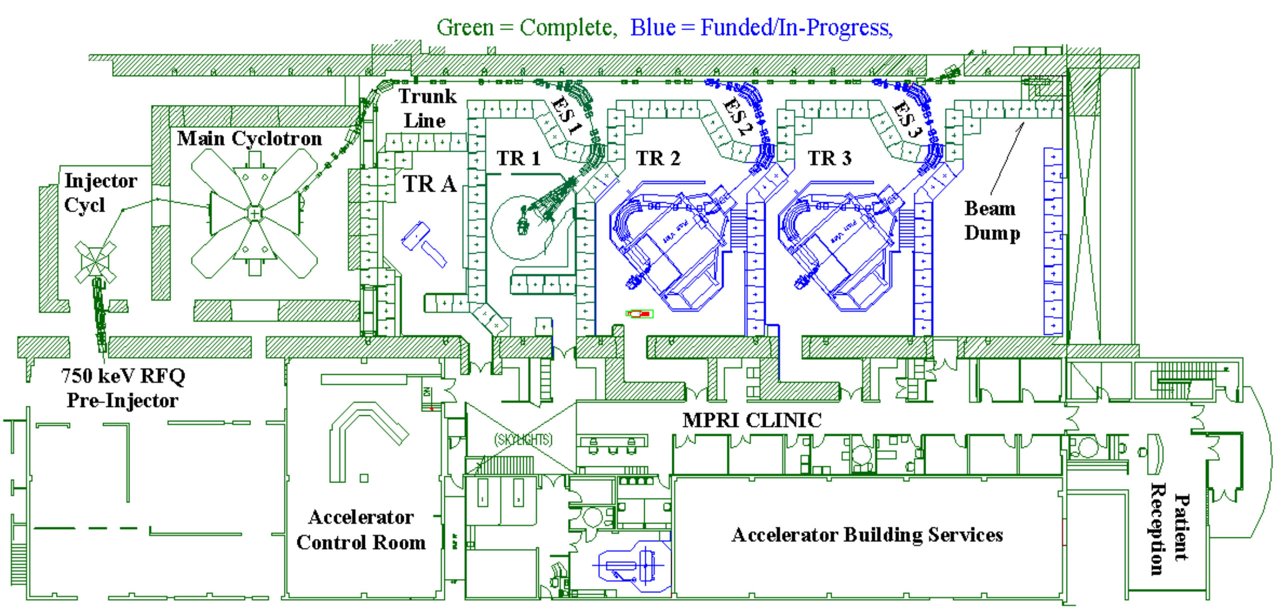

Figure 1. The MPRI Facility showing the IUCF cyclotrons, Trunk and ES lines, Treatment Rooms and Clinical Facilties.

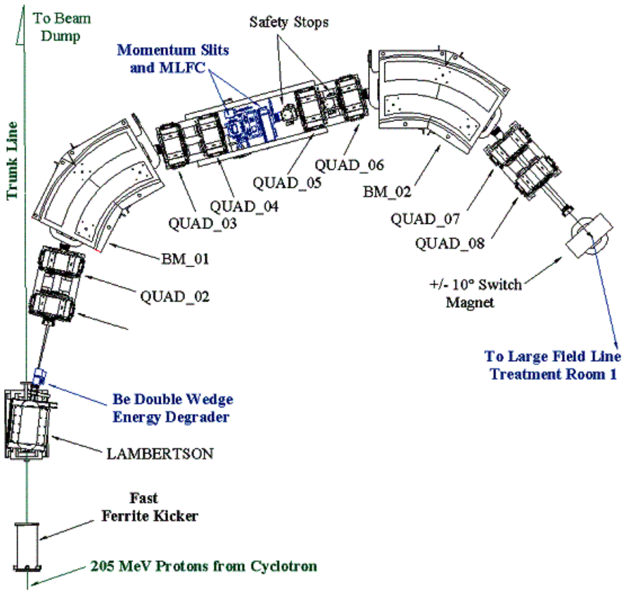

Figure 2. Layout of Energy Selection Beam line (ES1)

PHASE I CONSTRUCTION STATUS

Some MPRI Phase I beam commissioning and system validation results are described below.

Beam Production System Upgrades

Upgrades to the venerable IUCF cyclotrons (new water, vacuum, and computer control systems, ac and dc power upgrades, etc) needed to achieve the 95% operational reliability specified by MPRI [2] have been completed. A historically major source of breakdown, the 600 kV Cockroft-Walton pre-accelerator, is now being replaced by a 1 mA ECR proton ion source, a 750 keV RFQ pre-injector and a new cyclotron injection system designed to accept the higher injection energy [6]. The RFQ, built by AccSys Technology, Inc [7], and the in-house designed ECR source and 750 keV transport line were tested off-line at IUCF. Stable operation with 0.6 mA peak intensity proton beam at 750 keV was demonstrated, as reported elsewhere in these proceedings [8]. Installation of the pre-injector on the cyclotron began in April 2003 and final beam commissioning begins in May. Even without the upgrades, recent cyclotron operations at 206.5 MeV for ES1 and TR1 commissioning were reliable enough to meet MPRI performance requirements.

Trunk and ES Line Beam Commissioning

The doubly achromatic, focusing and transmission properties of the Trunk and ES1 lines are performing as designed [9]. Transmission through the ES1 line for ranges in water from 3.5 to 26 cm is shown in Fig 3. The transmission of protons degraded to 4 cm of range in water is 6.4%, as predicted, due in part to ES1's short length (11m), large acceptance (30π mm-mrad geom.), and the use of Beryllium as the degrader material. Calibration of the ES1 line tune, slits and MLFC using a water phantom at the isocenter of the Large Field Nozzle is complete and was used for Nozzle hardware, dose

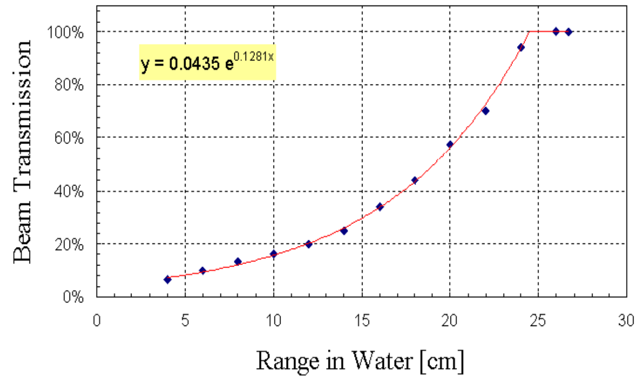

Figure 3. Transmission through ES1 vs. range in water.

delivery and treatment control system tests and validation. Water Phantom measurements of the momentum band slit effects on the width of pristine peaks for various proton energies are shown in Fig. 4.

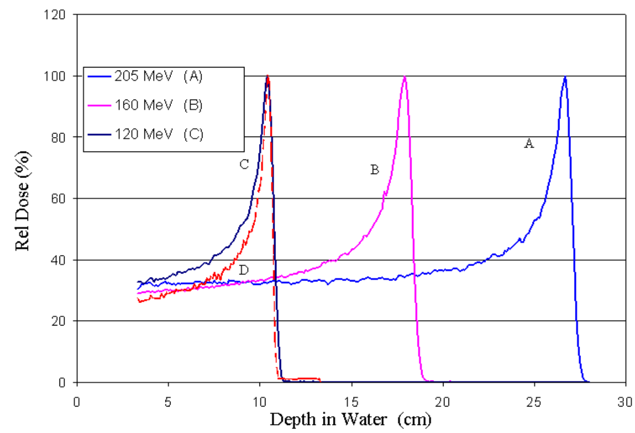

Figure 4. Pristine peak width vs. incident beam energy. Curve D shows the effect of the Momentum band slits.

Treatment Room 1 Commissioning

The MPRI fixed beam treatment room (TR1), shown in figure 5, contains two horizontal beam-line Nozzles: one for larger fields (2.5–30cm diameter) and high energy (Large Field Line) and another for small fields (1–3.5cm diameter) and lower energy treatments (Eye Line). Beam is delivered to only one Nozzle system at a time via the $\pm 10^{o}$ switch magnet. Active components of the Large Field Nozzle, shown in red, are both passive and active (wobbler magnet) beam spreading systems, collimators, four segmented and parallel plate ion chambers, and an IBA Snout system. Two industrial robots are used in TR1. A Motoman UP200 robot is used for precise patient positioning and a UP20 robot is use to position digital X-ray radiography panels for patient alignment [10].

Examples of proton beam Penumbra vs. energy and a full energy Spread Out Bragg Peak using the passive scattering system for a 12 cm field are shown in Fig. 6 and 7 respectively. Both measurements are well within the precision prescribed for the Large Field Nozzle in the MPRI Clinical Performance Requirements.

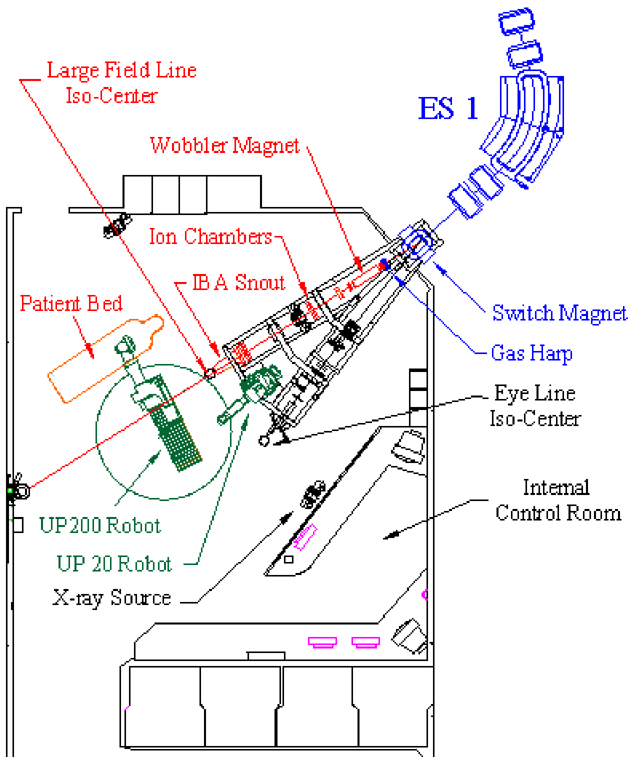

Figure 5. Layout of the fixed horizontal Treatment Room.

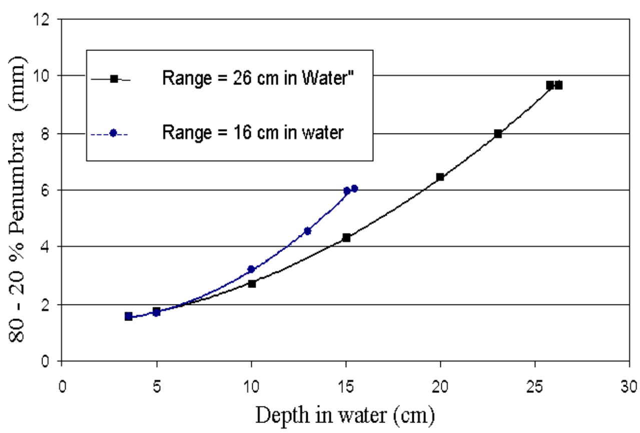

Figure 6, The effect of a lower incident beam energy on the proton beam penumbra.

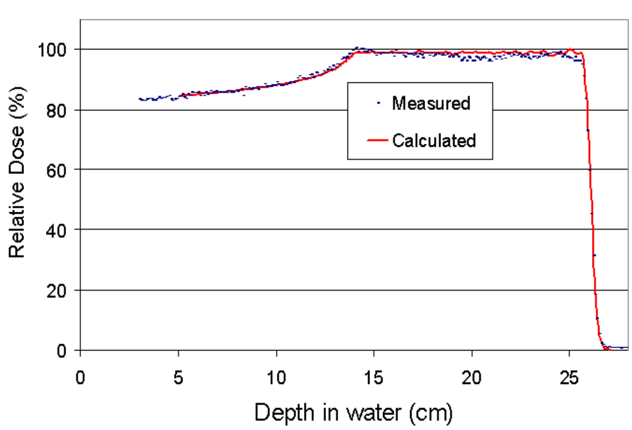

Figure 7, A typical Spread Out Bragg Peak (SOBP)

PHASE II CONSTRUCTION

MPRI Phase II construction, which includes installation of the ES2 and ES3 transport lines to Treatment Rooms TR2 and TR3 (Fig. 1), is underway. Two IBA gantries, purchased in December 2002, were selected for the Treatment Rooms on the combined basis of cost, operational efficiency and compatibility with the MPRI BDS. The ES lines were designed to provide a doubly achromatic round beam at the entrance of the gantry transport line that is well matched to the IBA gantry beam transport design. The gantries were purchased without the IBA nozzle or patient positioning and control systems. MPRI will use nozzle and patient positioning systems similar to those designed at IUCF and installed on the Large Field line in TR1. The IBA Gantry motion and beam transport elements will be interface to our in-house Treatment control system. Delivery of the TR2 and TR3 Gantries is scheduled for July 2003 and July 2004 respectively.

The 40’x29’x12’ deep gantry pits were completed in 2001. Detailed pit modifications specific to the IBA gantries are underway and installation of gantry utility systems (water, power, etc) for both TR2 and TR3 will begin in June. Installation of the TR2 gantry rotating structure by IUCF personnel will start in July with guidance from IBA consulting engineers. Patient treatment is scheduled to begin in TR2 and TR3 in July 2004 and September 2005 respectively.

CONCLUSIONS

MPRI Phase I and II construction are proceeding on a fast track nearly as scheduled. Final patient treatment beam delivery, nozzle, dose monitoring and treatment control system test and validation will commence in June. Request for FDA 510k approval of the MPRI clinical facilities is also being actively pursued. Support for this work is provided by the State of Indiana, Indiana University, Clarion Health, the DOE (Grant No. DE-FG-02000ER62966) and the NIH (Grant No. C06 RR17407-01)

REFERENCES

[1] R.E. Pollock, PAC’77, IEEE Trans. Nucl. Sci, Vol. NS-24, No.3, (1977) p. 1505
[2] D.L. Friesel *et al*, PAC’01, IEEE 01CH37268BC, (2001) p. 645.
[3] D.L. Friesel. AIP Conf. Proc 600, (2001) p. 27.
[4] A.N. Schreuder *et al*, PTCOG XXXII, Uppsala, SE, (2000) p 8.
[5] C. Block *et al*, PTCOG XXX, Capetown, SA, Particles 24 (1999).
[6] D.L. Friesel *et al*, AIP Conf. 576, (2000) p. 651
[7] AccSys Technology, Inc, Rhamm@Linacs.com
[8] V. Derenchuk *et al*, TPPE009, these proc, (2003)
[9] V. Anferov *et al*, PAC’01, IEEE 01CH37268BC, (2001) p.2488.
[10] J. Katuin & A.N. Schreuder, Proc. CAARI 2002, Denton, TX (2002) to be Published.