Beam Characteristics of the IUCF Proton Therapy Beam Line

The Indiana University Cyclotron Facility (IUCF) and the Department of Radiation Oncology at Indiana University at Indianapolis have been collaborating to develop a proton radiation therapy capability. Intense proton beams with energies from 185 to 200 MeV are frequently delivered to nuclear physics researchers. During about 50% of scheduled operation, a beam splitting system is used to deliver beam to two different users. Nuclear physics research can therefore continue even when the beam is required for the proton therapy beam line.

A method of splitting a beam from the cyclotron to two different beam lines using a fast switching magnet and Lambertson septum magnets has been in use at IUCF since 1986[1]. The peak beam intensity delivered to either user can be individually adjusted using a beam intensity modulation system timed to the period of the switching magnet. For proton therapy, initial characterization and set up of the beam before patient treatment can be completed as a secondary user, with little affect on the primary user. During the actual treatment, 100% of the beam would be used for less than 2 minutes, causing minimal impact on the nuclear physics research program. Proton beams can be delivered in the range from 5 nA to 500 nA or more within a phase space area of about 2.5(π)mm-mrad horizontal by 2.0(π)mm-mrad vertical, with energies from 185 to 200 MeV.

Layout of the proton therapy beam line with the beam spreading system, the range modulator and

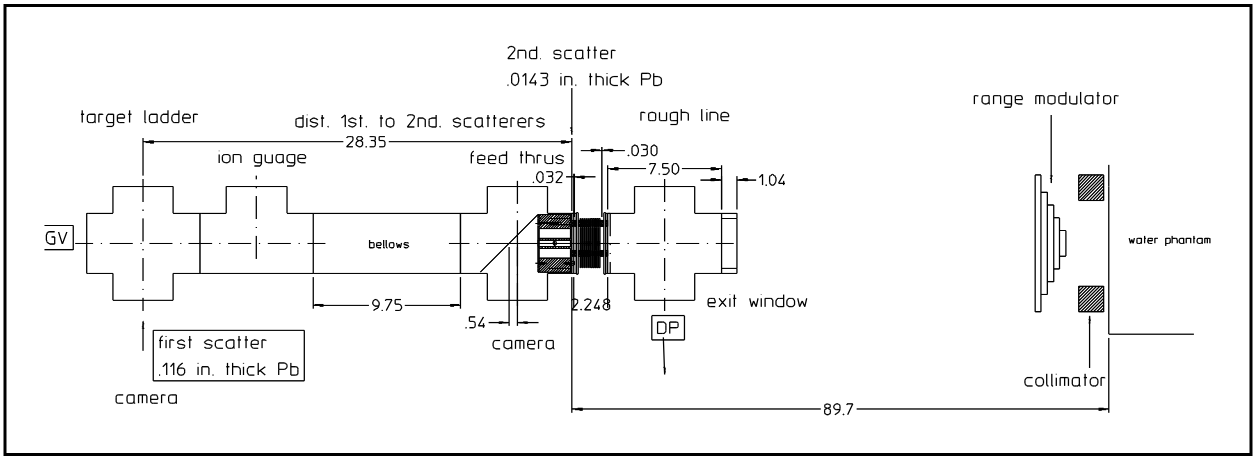

Figure 1 IUCF proton therapy beam line layout.

the beam and dose monitoring diagnostics are shown in Figure 1. Beam position at the beam spreading system is monitored using 1 mm thick plastic scintillator material viewed with a television camera. A secondary electron monitor is located at the exit of the beam spreading system to monitor beam flux. Dose profiles are measured in a water phantom with a reference ion chamber at its proximal surface and a signal ion chamber attached to a robot arm controlled by a Multidata computer dosimetry system. Data files from the Multidata can be graphically displayed and can be sent to the local Vax cluster over a serial link using Kermit.

Lateral beam spreading is accomplished with two scattering foils and an occluding-ring assembly[2]. Systems were designed with the Harvard beam spreading program, NEU[3], which for three field sizes: 10, 15, and 20 cm. The range of the Bragg peak is modulated using a propeller type range modulator[4]. Typical measurements are shown in Figure 2: an 8 cm 200 MeV SOBP and a 15 cm horizontal profile (taken at the Bragg peak).

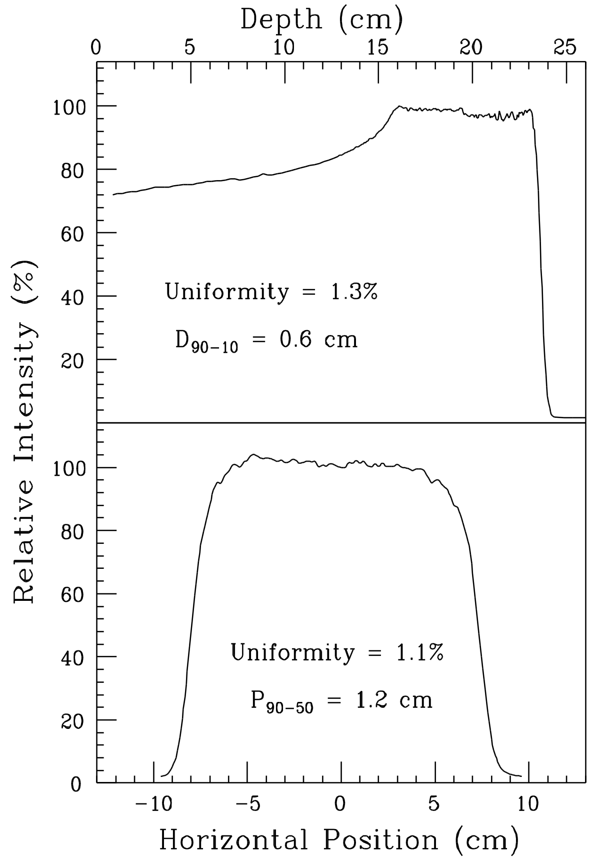

Figure 2 8 cm SOBP and 15 cm horizontal profile measured for 200 MeV protons.

A secondary electron monitor (SEM) is used to measure total beam current as well as dose delivered. Initially the SEM is cross calibrated with a Faraday cup for absolute flux measurement. For dose delivery, the SEM is calibrated against a Markus ion chamber, which is cross calibrated against a Farmer type cylindrical ion chamber that has been calibrated by an accredited dosimetry laboratory. There is no measurable difference in dose delivered between continuous 100% duty cycle beam and beam from the beam splitter at 10% duty cycle. Presently, a conventional beam-stop is used to start and stop the delivery of beam based on a visual reading of integrated charge on a current integrator.

Beam position upstream of the beam spreading system is ascertained with a segmented collimator. This collimator consists of four wedge shaped brass segments oriented to read horizontal and vertical beam position errors. A 1.0 cm aperture in the center of the collimator is sufficient to allow 100% beam transmission. Current on each of the segments is read out by the IUCF cyclotron control computer. In addition, there are two thin mylar foils, coated with a fluorescent paint, mounted on the upstream side of the beam spreading system and the SEM. The beam spot on the foils is viewed at the accelerator control console on television monitors hooked up to cameras in the proton therapy area. Split ion chambers will be used to monitor field uniformity.

The basic devices for a proton therapy system are in place and functioning. The next task is to create an integrated computer control/monitor system suitable for patient treatments. Beam diagnostics will be added to beam lines upstream of the proton therapy area so that beam can be monitored and tuned for best field uniformity without using the scintillators in the patient treatment area. This will allow reliable delivery of beam to the beam spreading system with the correct position and trajectory necessary to produce a uniform field. Much work is yet to be done before patient treatments, but we are optimistic and are making good progress towards this goal.

References

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3 B. Gottschalk, "Proton Nozzle Design Program NEU", Harvard Cyclotron Lab internal note.

4 A.M. Koehler, R.J. Schneider, and J.M. Sisterson, "Range modulators for protons and heavy ions", Nucl. Instrum. Meth. **131**, 437-440 (1975).