POTENTIAL ALTERNATE BEAM SOURCE FOR PROTON THERAPY

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Abstract

Studies have been carried out to determine the suitability of the IUCF Cooler Injector Synchrotron (CIS) as a potential replacement or supplement to the Indiana University Cyclotron as a source of proton beams for the Midwest Proton Radiotherapy Institute (MPRI). The primary modification to the synchrotron would be the development of a slow extraction system. An achromatic beam line connecting CIS and the MPRI beam trunk line has been designed and could use magnets from the recently decommissioned Cooler ring at IUCF. In addition to providing redundancy, this project would increase the proton energy to 240 MeV and could provide higher resolution beams to the radiation effects target stations.

MPRI FACILITY DESCRIPTION

A complete description of the present status of the MPRI project will be given later this week by D.L. Friesel [1]. 206.5 MeV proton beams for the treatment facility will be accelerated by the Indiana University Cyclotron. The first treatments will be carried out using a fixed horizontal beam line. Over the course of the next two years, two additional treatment rooms will be commissioned and brought into operation. Each of these treatment rooms will contain an IBA 360^{o} - rotating gantry. This paper will consider the possibility of using the IUCF Cooler Injector Synchrotron (CIS) [2] as a source of protons for the MPRI treatment rooms.

DESCRIPTION OF CIS

A complete description of CIS has been published by D.L. Friesel et al. [2]. Figure 1 shows the configuration of CIS, which has four superperiods. Each superperiod is composed of a drift space, a dipole magnet with 90^{o} bending angle and 12^{o} edge angle at both ends. Four trim quadrupoles are used in order to have flexibility in adjusting betatron tunes. Including the injection chicane dipoles the horizontal betatron tune is 1.48 In its current configuration CIS has accelerated protons to 240 MeV and extraction is accomplished via a fast rise time horizontal kicker which jumps the beam across the septum of a vertical extraction Lambertson magnet in the following straight section.

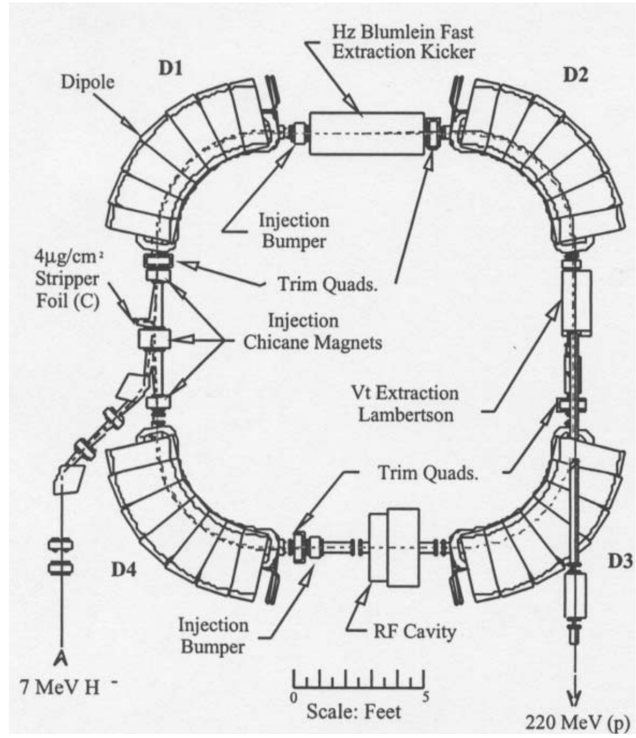

Figure 1. Current Layout of Cooler Injector Synchrotron (CIS)

DEVELOPMENT OF A SLOW EXTRACTION SYSTEM

In order to use CIS as a source of proton beam for a proton radiotherapy facility it will be necessary to develop a slow extraction system. Kang et al. [3] have studied slow extraction using the half integer resonance. The half integer resonance extraction method was chosen because the horizontal tune 1.48 of CIS is close to 1.50. The quadrupole magnets can be used to drive the half integer resonance. The fast extraction kicker magnet would be removed from CIS and in its place an electrostatic deflection system with a thin wire septum would be installed. Extraction efficiency can be increased by optimizing the location of the trim quadrupoles and by locating the wire septum as close to the dipole magnet as possible. This system could be implemented fairly quickly because it does not involve rearrangement of the basic CIS ring. There are concerns about the overall extraction efficiency that can be achieved with this method because of the relatively low value of horizontal beta in the straight sections (~1m).

A second method would involve modification of the CIS ring elongating two of the straight sections is based on a study by Al Harbi and Lee[4]. The stretched CIS would have a horizontal betatron tune near 1.70 at its operating point. This is close to the third order integer resonance and the trim quadrupoles can be used to adjust the tune to allow the use of third order resonance to move the beam across the deflection system's thin wire septum. Because of the additional length in two of the straight sections, it would be possible to keep the fast kicker magnet and maintain the flexibility of having both fast extraction and slow extraction systems available. Because of the necessity of significant modifications to CIS for this system, the time scale for this would be considerably longer.

DESIGN OF THE CIS – MPRI TRANSFER BEAM LINE

A beam transfer line has been designed using magnets which can be recycled from the recently decommissioned IUCF Cooler. This design, which would use 12 of the Cooler quadrupoles and 3 of the Cooler 30^{o} dipole magnets, had as its goals matching the beam phase shape at the entrance to the Kicker-Lambertson system for Treatment Room 2, having high transmission from CIS to the MPRI Trunk Line, and being achromatic in the Trunk Line. Fig. 2 shows the horizontal and vertical beam envelops along with the quadrupole apertures at their locations along the length of the transfer line. The transfer beam line is achromatic after the third dipole magnet.

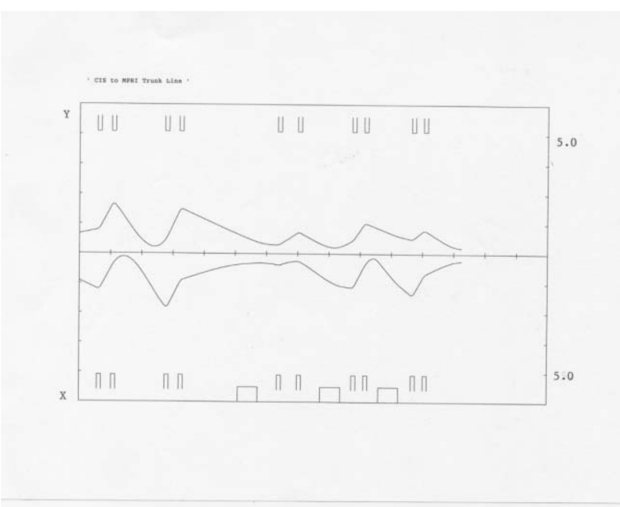

Figure 2. Vertical and Horizontal Beam Envelopes in CIS to MPRI Transfer Line

The dipole and quadrupole magnets which would be used in the transfer line are all laminated magnets and would be able to be reset very quickly as new energies are requested by the Treatment Room. While the rest of the magnets in the MPRI Beam Trunk Line are solid core magnets, they are either relatively small quadrupole or steerer magnets and can their strengths can be varied fairly rapidly. If the speed of their variation became an issue, the quadrupole magnets in the Trunk Line could be replaced by additional laminated magnets from the Cooler. Figure 3 shows the proposed layout of the Beam Transfer Line connecting CIS with the MPRI Trunk Line.

ADVANTAGES AND DISADVANTAGES OF USING CIS FOR MPRI

A major advantage of CIS relative to the IUCF cyclotron for MPRI is the higher energy of the proton beam (240 MeV rather than 206.5 MeV). Another advantage would occur when a beam scanning system is implemented in the Treatment Rooms in that it would be simpler to control the dose delivered at each treatment depth with a active system controlling the energy for each layer of dose rather than using a passive range shifting system such as a propeller or ridge filter.

Disadvantages to using CIS rather than the cyclotron include the fact that beam from CIS cannot be brought to Treatment Room 1 with the system currently under consideration and a much more complex system would be required to reach Treatment Room 1. With the current design, the cyclotron could still be used to provide beam to Treatment Room 1.

The beam delivered to the Radiation Effects Research Program (RERP) target stations (at the exit from the MPRI Trunk Line) would be improved in that the range of energies available would be increased and the beam quality at low energies would be better because they would not be degraded from a high fixed energy but rather extracted from CIS at the energy desired by the experiment.

REFERENCES

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[2] D.L. Friesel and S.Y. Lee, "CIS, A Low Energy Accelerator for the IUCF Cooler, IEEE95CH35843, 336 (1995).

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[4] Nader Al Harbi and S.Y. Lee, Design of a compact medical synchrotron, Review of Scientific Instruments **74**, 2540 (2003).

Figure 3. Layout of CIS to MPRI Beam Delivery System Transfer Lines.