Progress on Proton Therapy Facility Project in National Cancer Center, Korea

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ABSTRACT

A Proton Therapy Center was established this year in National Cancer Center, Korea. We chose IBA of Belgium as the vendor of the equipment package. A 230 MeV fixed-energy cyclotron will deliver proton beams into two gantry rooms, one horizontal beam room, and one experimental station. The building for the equipment is currently under design with a special emphasis on radiation shielding. Installation of equipments is expected to begin in September next year starting with the first gantry, and the acceptance test will be performed about a year later. To generate therapeutic radiation fields the wobbling method will be a main treatment mode for the first gantry. A pencil beam scanning system on the other hand will be equipped for the second gantry relying on the availability at the time of installation. The beam scanning with intensity modulation adapted will be a most advanced form in radiation therapy known as IMPT. Some details on the project progress, scope of the system, and design of building are described.
Keywords: Proton therapy, gantry, IMPT, nozzle, radiation shielding

1. INTRODUCTION

National Cancer Center, Korea (NCC) was established in 2001 to carry out frontier cancer researches and to care cancer patients. The Proton Therapy Center opened this year at NCC will employ state-of-art proton therapy equipment as a major cancer treatment tool. IBA of Belgium was chosen as equipment vendor partly considering their extensive experiences accumulated with installation of a similar system at Northeast Proton Therapy Center (NPTC) in Massachusetts General Hospital [1]. The facility will have two gantries along with one horizontal fixed beam room and one experimental station. A 3-D view of major equipments is given in Fig. 1. The parts of gantry and cyclotron will be rigged into the building from September next year, and the completion of installation is expected to be in the middle of 2004. Commissioning will then follow to treat patients in 2005. An experimental station, located in the end of beamline in the beam transport room can be used for researches in various disciplines such as nuclear and material sciences, and biology.

One gantry will be equipped with a standard nozzle of IBA, which is capable of performing both scattering and wobbling, while the other gantry is expected to be equipped with Pencil Beam Scanning (PBS) system. The intensity modulated proton therapy (IMPT) can be carried out using this PBS system together with intensity modulation of ion source current. The bolus or block will become obsolete with the PBS.

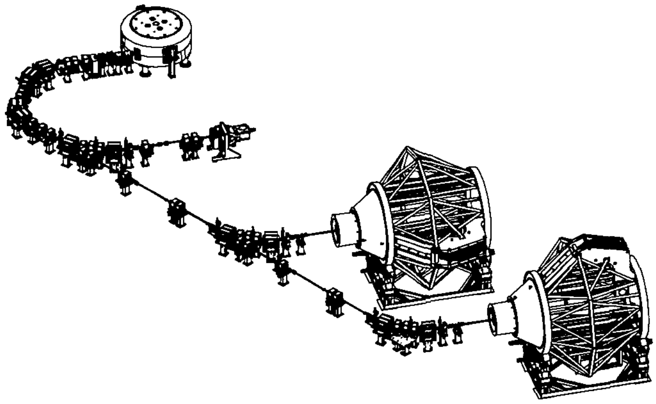

Figure 1: 3-D view of proton therapy equipment.

A next major milestone in the project is to complete the building design by the end of October. The radiation shielding, which is one of major issues in the facility design, is being analyzed based on computational and experimental works performed at the NPTC [2,3].

2. MAJOR COMPONENTS AND CLINICAL REQUIREMENTS

The major components of the system are: cyclotron, beam transport line, two gantries, one horizontal beamline, and ancillary system like patient positioning and treatment planning. First, the cyclotron is 230 MeV fixed energy machine, and the beam energy is varied using the energy degrader made of graphite to the range of 70-230 MeV. The momentum and beam emittance selections are made in the beamline called Energy Selection System (ESS). The maximum beam current is 300 nA for therapy, while the cyclotron can produce up to 1 μA. Figure 2 shows the cyclotron beam current as a function of range in the patient. To reach the range below 5 cm, the initial beam current required is around 300 nA. The beamline is achromatic to reduce the beam size inside the magnets of gantry. The gantry is structurally designed to maintain the isocenter within a sphere of confusion of radius 1 mm under all operating conditions.

The clinical parameters of the IBA system predominantly achievable with a wobbling method are listed in Table 1. Those are the values that will be used for the acceptance test when installation is complete.

3. GENERATION OF PROTON RADIATION FIELD

The first gantry will be equipped with an IBA standard nozzle that can be used to perform single- and double scattering as well as wobbling method. Currently double scattering is the main mode of operation

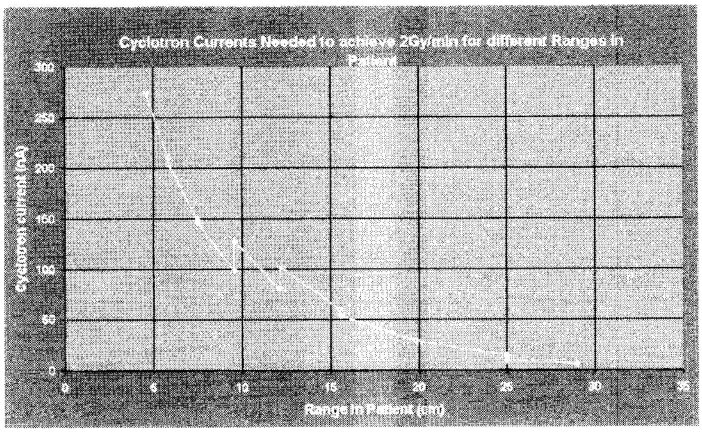

Figure 2: Cyclotron beam current as a function of range in patient to achieve the dose rate of 2 Gy/min.

Table 1: Clinical parameters of the IBA proton therapy system.

Range in patient	3.5—30 g/cm^2
Range modulation	< 0.5 g/cm^2
Average dose rate	> 1 Gy/min for 25 × 20 cm
Max. field size	40 × 30 cm
Dose uniformity	± 4%
SAD (source to axis distance)	> 2 m
Distal dose falloff (80-20 %)	0.25 g/cm^2
Lateral penumbra (80-20 %)	< 2.5 mm
Delivered dose accuracy	±2%

as FDA has approved it. We expect wobbling will be the main mode of operation by the time of equipment installation at NCC. For the second gantry the Pencil Beam Scanning (PBS) nozzle is expected to be installed depending upon the approval by FDA. The PBS nozzle is specifically designed to raster scan the beam for each slice in tumor as schematically shown in Fig. 3 [4]. The nozzle contains two more quadrupole magnets than in standard nozzle to change the beam size, and the beam intensity is varied with filament current of ion source using a fast digital loop. The IBA system controls both the scan speed and the beam current to perform IMPT. The settling time of source current is about 150 μs so as to limit very fast change of beam current.

4. DESIGN OF RADIAITON SHEIDLING

The building design is ongoing for completion by the end of October this year. One of major issues in the design is associated with effective radiation shielding for the facility. This issue is in fact delicate in Korea as the highest energy proton machine that has been installed is only 50 MeV, no comparable hadron facility being existent. Thus we have tried to evaluate the shield design of similar proton facilities overseas, mainly NPTC, to adapt the design concept to our building.

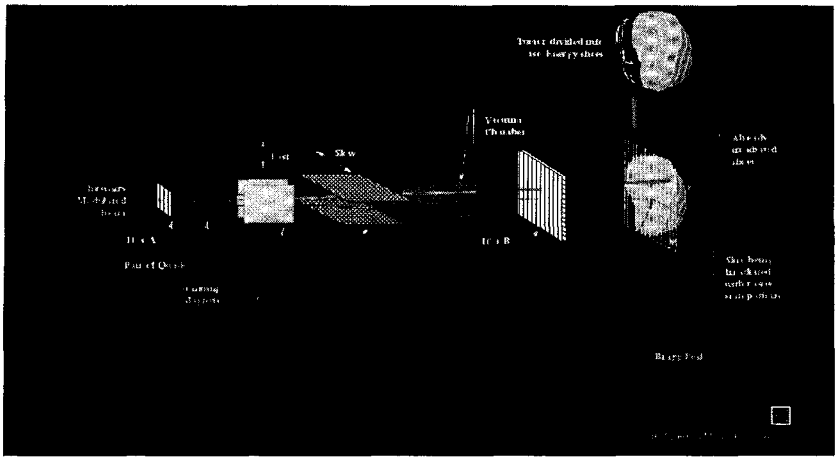

Figure 3: A schematic view of pencil beam scanning system of the IBA proton therapy system.

The analytic formula for the dose estimate comes from the NPTC design works of MGH. As recently reported in [2,3], we assume the analytic estimates tend to overestimate the dose for given shielding walls, which was shown by comparison with measurement. Major beam losses occur in the ESS, and the radiation field from treatment rooms depends on the treatment type and gantry orientation. The radiation at each receptor is computed by summing the doses from all the major losses. The Monte Carlo simulation e.g. using MCNPX [5] will also be carried out involving realistic geometry, which should allow more reliable evaluation especially on the radiation outside of the maze,

5. PRESENT STATUS

The next major milestone is to design the building by the end of October. The radiation shielding design attained a great deal of helps from experimental and computational works on the shield design done for NPTC. Similar radiation criteria and shielding formulae are applied to the building design at NCC. We plan to perform Monte Carlo simulations for realistic geometry along with more detailed analytic calculations.

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