Status report on the proton therapy facility at National Cancer Center

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1. Introduction

The proton beam is a modality of radiation therapy for cancer treatment. Compared to conventional radiation therapy using photons or electrons, the proton beam has the advantage of concentrating the major portion of the dose in the tumor region due to the presence of Bragg peak, which helps in sparing normal tissues.
The proton therapy facilities, which are based in hospitals, have been successfully operated at several locations in the US, Japan, and new centers are recently under construction [1]. A proton therapy facility has been constructed at the National Cancer Center (NCC) near Seoul to provide high quality radiation therapy for cancer patients [2]. The therapy system is a product of a Belgian company IBA contracted in July 2002. The building to house the equipments is nearly complete, and the major parts of the equipments are currently being installed. Installation and validation for the first treatment room will take more than a year, and patient treatment is expected to begin around the mid 2006.

2. Status of facility construction

The building to accommodate the proton therapy equipments has been constructed from June 2003, and it is near completion. The major therapy equipments such as the beam line magnets, gantries, cyclotron, have been installed from Feb. 2005, and the installation will continue for more than a half year. The next step is to precisely align the components and validate each sub-system to ensure the performances required. The layout of the facility is shown in Fig. 1.

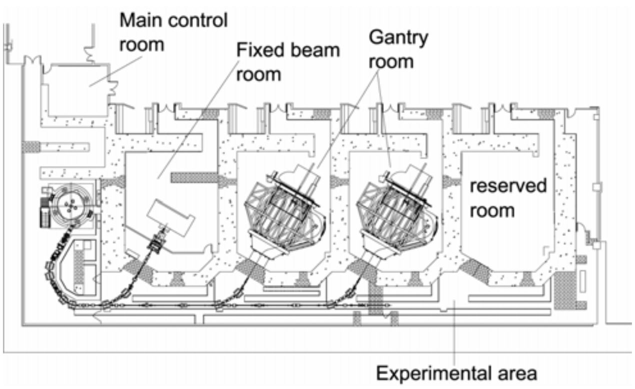

Figure 1. Layout of the proton therapy facility.

2.1 Radiation Shielding

The building was designed considering the aspects of radiation shielding. The design is based on that of the Northeast Proton Therapy Center (NPTC) in the US [3], which has been in operation from Nov. 2001. The site specific aspects were considered such that the treatment floors are located in B2 at the NCC rather in B1 at the NPTC, and the nearby location of parking lots was another different factor. In some area the shielding design is reinforced according to the experiences at the NPTC. The analytic evaluation was first performed using the expressions devised by Tesch [4], and Monte Carlo simulations using NCNPX [5] were followed involving more realistic geometry. The criteria of ICRP Report 60 is applied i.e. 1 mSv/yr for the public area considering the proper occupancy factors. We expect to attain the site license to operate the radiation equipments soon from the Korea Institute of Nuclear Safety (KINS).
The patient specific elements such as bolus or aperture become activated during irradiation for treatments. The bolus is made of Lucite, and the aperture of brass. The plastic can be disposed in a few hours after irradiation, while the brass apertures need storage for a couple of months to allow the decay of isotopes such as $^{58,56}Co$, which has the half life of about two months.
One of the most activated areas is the inside of the cyclotron. When the cyclotron needs to be opened to repair the parts, the beam should be off at least overnight to reduce radio-activities. Other major activated parts include degrader, slits, and beam stopper, but they are not usual items for maintenance.

2.1 Main equipments

The cyclotron has the fixed beam energy of 230 MeV, and the energy for therapy is varied with a graphite degrader followed by the slit system. The major parameters of the cyclotron are given in Table 1. The degrader has more than 200 steps for energy variation from 230 MeV to 70 MeV, and precise selection of the energy is made by the slit system.

Table 1: Major parameter of the cyclotron

Energy	230 MeV
Current	1-300 nA
Size (diameter)	4.34 m
Weight	220 tons
Power loss	446 kW (full beam)
Frequency	106.1 MHz
Harmonic mode	4

The rotating gantry is isocentric to deliver the beam to the same point regardless of its angular orientation. The isocentricity is within ±0.5 mm. It has two dipole magnets for 45^o and 135^o bending in the vertical plane as shown in the sectional view of Fig. 2. The maximum diameter is about 11 m, and the weight is over 100 tons. The end of the therapeutic beam line is a device called nozzle [6], which forms therapeutic proton beams. We will use single and double scattering system as well as wobbling in the beginning. The plan was to use the pencil beam scanning system (PBS) for the second gantry, but the development of the system has been delayed. The PBS will be equipped for the second gantry in the future when it is approved for the medical use.

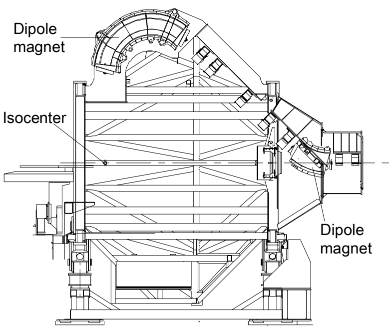

Figure 2. Sectional view of the gantry.

In addition to the gantry there is a treatment room equipped with a fixed horizontal beam line. The patient can be positioned either on the chair or on the couch. The beam line is designed mainly for the eye or head and neck therapy. The nozzle is the same kind as in the gantry, but is tuned for smaller field sizes.

The control software is also a major part of the system. The therapy control system is operated by therapist, while the beam production is controlled by the operator in the main control room. To ensure the safety of the system, the safety interlocks are redundantly composed of hardwire components and also PLC.

2.2 Experimental area

The facility has the area for experiments with proton beams at the end of beam line as indicated in Fig. 1. The beam time requested is 5,000 nA·hr, although the shielding was designed to sustain higher beam losses.
The experiments expected using the beam energy in the range of 70-230 MeV include radiation damage measurements to simulate the space environment, radiation biology, and nuclear physics. The final beam line is not configured yet for the area.

23 Commissioning

The control of the proton therapy equipments will be officially transferred to the NCC in steps when each treatment room is accepted with demonstration by the vendor of the clinical performances as listed in Table 2. To actually treat the patients additional commissioning is needed to collect all the information e.g. for treatment planning program. Each room will take more than a month for the clinical commissioning.

Table 2. Clinical parameters of the therapeutic proton beams.

Items	Parameter
Range in patient	3.5– 30 g/cm2
Range modulation step	< 0.5 g/cm2
Average dose rate	>1 Gy/min for 25x20 cm at 30 g/cm2
Max. field size	40 x 30 cm
Source to Axis Distance	> 2 m
Lateral penumbra (80-20%)	< 2.5 mm
Distal dose falloff (80-20%)	< 0.25 g/cm2

Since the proton therapy system is introduced for the first time in Korea, it is considered to be a new medicine so that the Korea Food and Drug Administration requires a permission to use for therapy. Two major considerations are safety and effectiveness, in which the safety is the main concern. On the other hand the KINS require the facility to be safe in the aspects of radiation protection and handling of radioactive materials from the proton irradiation. Extensive measurements on the radiation doses will be carried out when the cyclotron is in operation to check the soundness of the shielding, and to compare with the simulations.

3. Conclusion

Installation of the proton therapy equipments is ongoing, and the effort for precise alignment of the system and its validation process will be followed. The facility is planned to be complete in the mid 2006, and the first patient could possibly be treated in the same year.

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