BEAM QUALITY ENSURING INSTRUMENTS AT THE GUNMA UNIVERSITY HEAVY-ION MEDICAL CENTER

E. Takeshita#, T. Kanai, S. Yamada, K. Yusa, M. Tashiro, H. Shimada,
K. Torikai, A. Saito, Y. Kubota, A. Matsumura, M. Kawashima,
Gunma University Heavy-Ion Medical Research Center
3-39-22, Showa, Maebashi, Gunma 371-8511 JAPAN

Abstract

Since carbon beam based cancer therapy started at the Gunma University Heavy-ion Medical Center in the year 2010, the total number of treated patients increased to 306 by the end of 2011. This fiscal year, already 164 patients have been treated. In order to control the medical beam qualities, i.e., position, size and intensity of the beam, monitoring devices were mounted on the high-energy beam transport line. The beam position and size can be measured and tuned with a screen monitor, which consists of a fluorescent screen and a CCD camera. Just before starting the treatment, the operators check for a proper beam position by strip-line monitor measurements placed close to the isocenter. The irradiation dose is controlled using two secondary electron emission monitors placed before wobbling magnets. This dose monitor is helpful as for high beam intensities it's less affected by the recombination effect. The technical layout of all beam monitors are described.

INTRODUCTION OF GHMC

The Gunma University Heavy Ion Medical Center (GHMC) [1] is located at the Gunma University Hospital. Basic and accelerator building designs started in April and July 2006, respectively. The construction works started in February 2007 and were completed in October 2008. The facility's dimension is about 65 m × 45 m, approximately 1/3 of the Heavy Ion Medical Accelerator in Chiba (HIMAC) [2]. The layout of the bottom floor is shown in Figure 1. The facility contains three treatment rooms with four irradiation ports (horizontal; Room A, horizontal + vertical; Room B, and vertical; Room C) and a room with a vertical port intended for R&D of beam delivery system and biology experiments.

Accelerator Complex

The injection part consists of a compact ECR ion source and two linear accelerators, which are the radio frequency quadrupole linac (RFQ linac) and the alternating phase focusing linac (APF linac) [3]. The RFQ linac accelerates the carbon ion beam up to 600 keV/u

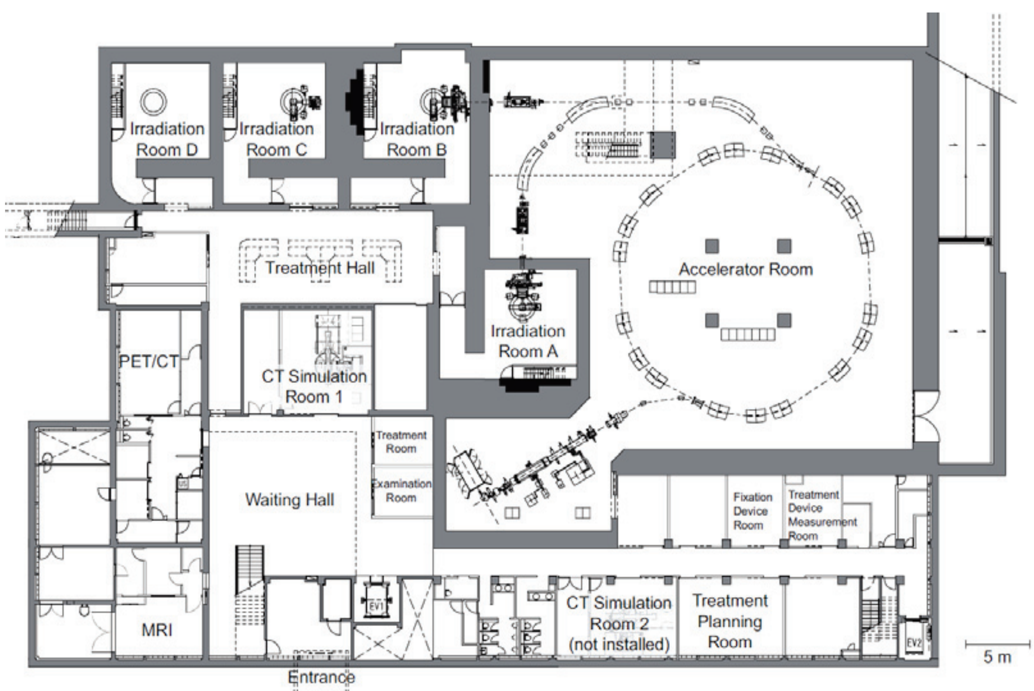

Figure 1: Layout of B1 floor in GHMC.

#eriuli@gunma-u.ac.jp

ISBN 978-3-95450-119-9

and the APF linac accelerates the carbon beam up to 4 MeV/u.

The maximum carbon beam energy achieved by the synchrotron [4] is 400 MeV/u, and the extracted beam is delivered through a high energy beam transfer line (HEBT) to the isocenter. The excitation pattern cycle of the synchrotron is normally 2.7 seconds: Injection time is 0.1 seconds, acceleration and deceleration are 0.7 seconds, respectively, and 1.2 seconds are needed for the extraction. The maximum beam intensity is 1×10^9 particles/seconds, which is equivalent to 5 GyE/min.

Beam Delivery System

The beam delivery system guides the high-energy carbon beams generated by the accelerator complex to the therapeutic usage and delivers them to the patient lying in the treatment room. A beam delivery system comprises of several devices, i.e., dose monitors, wobbler magnets, a scatterer, a ridge filter, a range shifter set, a multi-leaf collimator, a compensator and a patient positioner system, for precise aiming of the therapeutic beams on the planned target volume by adopting a beam wobbling method.

CHECK BEAM POSITION AND SIZE

Screen Monitors for HEBT Tuning

The HEBT section includes 19 screen monitors (SC) and 4 strip line monitors (SLM) beam profile measurements. A screen monitor consists of a fluorescent screen (Al_2O_3) and a CCD camera. The beam profile is observed as motion picture with 30 frame/sec. After taking profile data, the position and size are manually calculated during measurement time. To tune the beam position, the beam profile is measured using the screen monitor and the position of the beam manually modified using steering magnets in order to decrease beam axis misalignments. Figure 2 shows a result obtained by the screen monitor data. The position was calculated applying the center of gravity method. It can be seen that the beam positions have a few millimetres time dependence during extraction. However, in a broad beam irradiation technique, position time dependence is not a serious problem for the treatment. As the beam's shape is very narrow and the beam size is about >10 mm on the isocenter, the irradiation field is not sensitive due to the beam motion. Every morning, the beam profile on the isocenter is inspected and adjusted to the center within 2 mm.

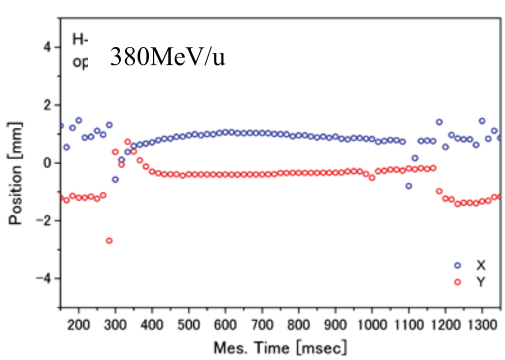

Figure 2: Position of the extracted beam at the isocenter measured by SC as a function of time.

Verification beam before and during treatment

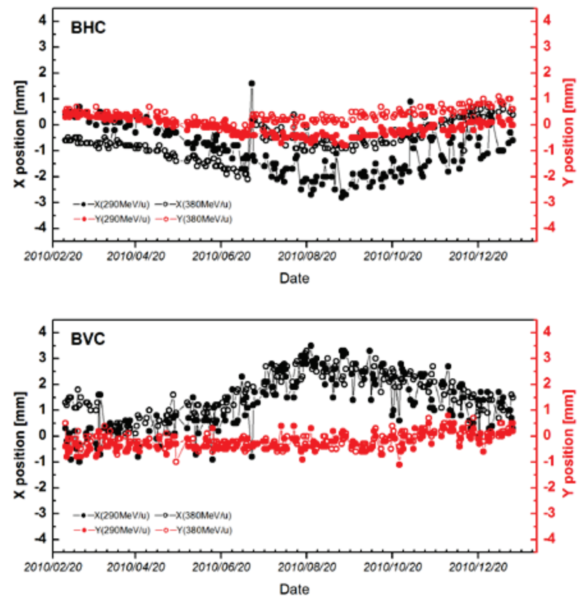

Figure 3: Season variation of the beam position measured by the SLM in room B (BHC and BVC).

The SLM is mounted on every irradiation port close to the isocenter in order to verify the position and size of the beam just before treatment begins. Each of the horizontal and vertical planes is covered by 30 strips with 1.5 mm spacing and the effective area is 45 mm × 45 mm. The beam position variation depends on the season as shown in Figure 3. The maximum difference for the position in each port, measured at several beam energies, stay within ~4 mm in a year.

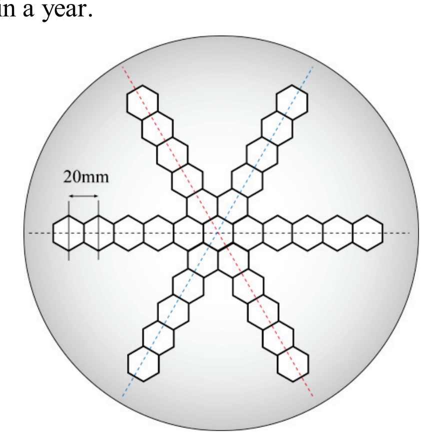

Figure 4: Schematic view of “flatness monitor”.

ISBN 978-3-95450-119-9

Also during treatment beam position and size are controlled using the SLM and the flatness of the irradiation field is verified by a parallel plate type ionization chamber called "flatness monitor". Figure 4 shows the schematic view of the flatness monitor. The effective area is ϕ 220 mm and the electrode gap is 9 mm.

CONTROL INTENSITY

Spill Profile

Every morning, the extracted beam intensity is counted using a FC placed on the entrance of the HEBT. The efficiencies of the injection, acceleration, capture and extraction of the beam are measured by the DCCT inside the synchrotron. Figure 4 shows the spill structure (green line) and the beam current (blue line) at an energy of 380 MeV/u. The average intensity of the extracted beam is almost 1.0×10^9 particles/seconds, which satisfies the initial design criterion.

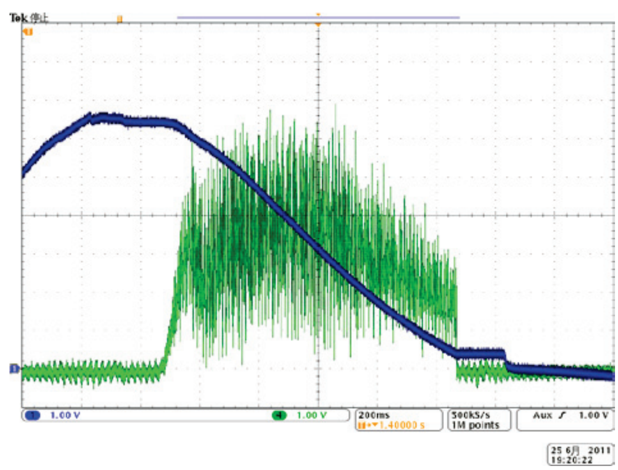

Figure 5: Spill structure of the extracted carbon beam on 380MeV/u.

Dose monitors

Two secondary emission monitors (SEM) are set up upstream of the wobbler magnets to control the irradiation dose for the treatment. The detection efficiency of the dose monitor for the treatment should not change due to the irradiation condition of the beam wobbling method. In order to measure the dose of the pencil beam before wobbling, the SEM as the dose control monitor is employed. The SEM is very helpful for high beam intensities, as it's less affected by the recombination effect. Main monitor is used for the dose control mainly and the leak current of the beam continue to measure using sub monitor during the treatment. If the leak current surpasses a threshold value (~1% of preset count), the beam is stopped immediately by an interlock system using a fast quadrupole magnet set up within the synchrotron. Figure 5 shows the linearity of the dose response on the SEM depending on the irradiation preset count. From 1 to 5×10^4 counts, which was used for the treatment, the linearity of the response is acceptable within 0.3 %.

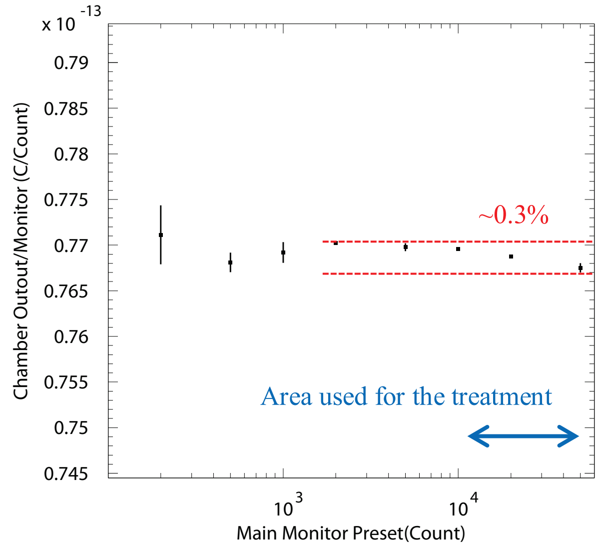

Figure 6: Linearity of the dose response by the SEM as a function of number of the irradiation preset counts.

CONCLUSIONS

The presented data show that the beam diagnostics of the GHMC facility provide all necessary equipment for commissioning and machine operation, especially for beam quality verification during medical treatment. The HEBT devices deliver high resolution data and allow fine-tuning of synchrotron extraction and HEBT lines. Any device, most importantly the isocenter diagnostics, can be integrated into therapy protocols.

ACKNOWLEDGMENT

The authors would like express their thanks to the Mitsubishi Electric Corporation staff members for their dedicated operation and support of our facility. We also would like to thank all members of medical doctors, clinical nurses and medical radiology technicians at the GHMC for their valuable advices and encouragement.

REFERENCES

[1] T. Ohno et al., "Carbon Ion Radiotherapy at the Gunma University Heavy Ion Medical Center: New Facility Set-up", Cancers 2011, 3, 4046-4060.

[2] K. Noda et al., "HIMAC and new facility design for wide spread use of carbon cancer therapy", APAC'04, Korea, March 2004, p. 552-556.

[3] Y. Iwata et al., "THE COMPACT INJECTOR AS THE SECOND INJECTOR OF THE HIMAC", LINAC2010, Japan, 2010, p. 190-192.

[4] T. Furukawa et al., "Design of synchrotron and transport line for carbon therapy facility and related machine study at HIMAC", Nucl. Instr. and Meth. A 542 (2006) 1050-1053.

ISBN 978-3-95450-119-9