3 - 70 Correction of Calibration Factors for Online Beam Monitor in Heavy Ion Spot Scanning at IMP

Dai Zhongying and Li Qiang

Active beam delivery such as spot scanning in combination with energy variation by the CSR synchrotron itself has been realized recently in the therapy terminal at HIRFL-CSR. Also a monitor calibration procedure in terms of particle number for dynamic particle beam delivery system was developed according to the protocol recommended by the International Atomic Energy Agency (IAEA). The calibration is performed in a homogeneous calibration field generated by the dynamic beam delivery system using a Gaussian shaped monoenergetic beam in accordance with a predefined grid of scan points. In this procedure, the energy of the beam, the sizes of the beam spot and the calibration field, the scan point spacing and the calibration depth will definitely produce effects on the calibration factor (CF). For pencil heavy-ion beams with large spots, the spot-scanning online beam monitor calibration will be very sensitive to the size of the calibration field.

According to the CF formula in terms of the accumulative central absorbed dose, the larger the calibration field is, the bigger the dose that accumulated in the center of the field is, therefore the larger the CF is. On the other hand, the calibration field influences the value of CF indirectly through the accumulative central absorbed dose. As shown in Fig. 1, for the ϕ80 mm field, the measured CFs increased with the beam energy varying from 165 to 400 MeV/u. While for the ϕ30 mm field, the distribution tendency of the CFs measured with the beams of 172 to 193 MeV/u with an small interval of 7 MeV/u was consistent with that measured in the ϕ80 mm field, although the absolute values between the two groups were significantly large. During the measurements, the scan step for both the calibration fields was 3 mm and the carbon ion beams maintained a lateral profile with σ of 9.55 mm at the effective depth of 6.8 mm in water.

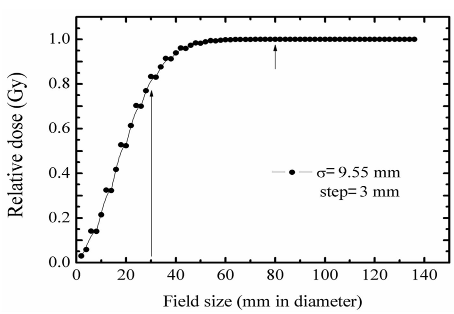

Fig. 1 The CF data for carbon ion beams of different energies.

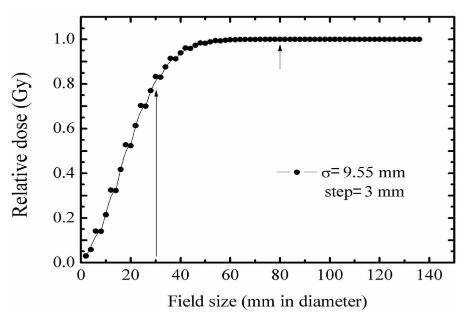

Fig. 2 The dependence of central dose on calibration field size.

Our calculation also shows that the relative central dose at the calibration field was on the rise till a saturation took place when the size of the field increased gradually, as shown in Fig. 2. Notice that the difference of the CFs between the ϕ80 mm and ϕ30 mm fields could be determined technically. We developed a correction method for the CFs measured in small calibration fields. A parameter "field size factor" (FSF) was introduced into this correction method, defined as the ratio between the central doses (D_{d1} and D_{d2}) of the saturation field (or big calibration field) and the small field. The FSF is given as follows:

$$\mathrm{FSF}(\mathrm{d1},\mathrm{d2}) = \frac{D_{\mathrm{d1}}}{D_{\mathrm{d2}}} \quad (1)$$

Corrected CF is computed by multiplying the FSF and the measured CF.

In this work, the CFs obtained in the ϕ30 mm field were corrected on the basis of FSF(80, 30). Then a comparison was made between these two kinds of CFs, which is displayed in Fig. 1. The results show that the measured CFs for 172, 179, 186 and 193 MeV/u carbon ions in the small calibration field were corrected to be 428.34, 466.31, 488.77 and 513.34 by, respectively, using the calculated FSF curve shown in Fig. 2. The tendency of the corrected CFs with the data in the ϕ30 mm field was almost the same as that measured in the ϕ80 mm field with an average deviation of 5.25%.

In sum, the correction method of calibration factors of online beam monitor was developed for heavy ion spot scanning at IMP. Its feasibility was priliminarily verified although there is still room to improve our work.

3 - 71 Indirect Cross Calibration for Particle Spot Scanning at HIRFL-CSR

Dai Zhongying, Li Qiang, Liu Xinguo, He Pengbo and Xiao Guoqing

Recently a monitor calibration procedure in terms of particle number for dynamic particle beam delivery system was developed according the protocol recommended by the International Atomic Energy Agency (IAEA), although the measurement method of the calibration factor (CF) was time-consuming and indirect. As a consequence, an indirect cross calibration method was tested for particle spot scanning in the therapy terminal at HIRFL-CSR in order to predict the CF of the monitors in a short time.

Cross calibration for particle spot scanning was based on the linear regression analysis between the dose measured in a field of 80 mm in diameter with a Markus 23343 detector and that measured for a single beam spot with a Bragg peak chamber 34070 (BPC). The measured dose with the Markus 23343 detector in the 80 mm diameter field used to calculate the CF can be predicted using the measured dose of the single beam spot with the BPC when the linear relationship was determined already. The cross calibration was performed with 200 MeV/u pencil-like carbon ion beams while the 80 mm diameter calibration field was generated by magnetically deflected pencil beam in accordance with 3mm spaced grid of scan spots.

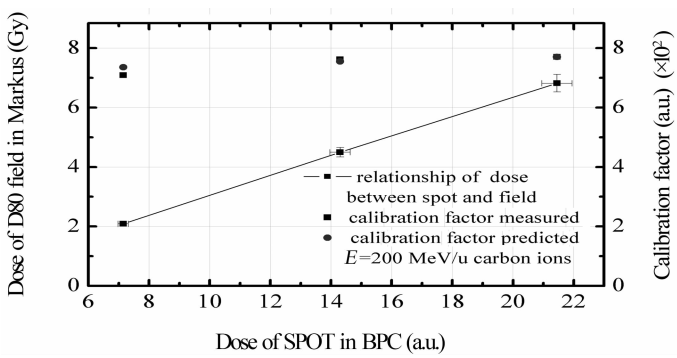

Fig. 1 Cross calibration for particle spot scanning.

The result shows that a good linear response was achieved between the dose in the 80mm diameter field measured with the Markus 23343 and that measured with the BPC for the single beam spot. So the perdicted dose is 2.17 Gy based on the linear relationship when the measured dose of the beam spot with the BPC is 7.15 Gy. The corresponding predicted CF is 735.32 with less than 3.7% deviation compared to the measured CF of 708.55, which were shown in Fig. 1.

In conclusion, the cross calibration procedure shows its feasibility and the experience acquired in this study will be very useful for improving the spot scanning technique in the project of heavy ion therapy at HIRFL-CSR.