Experimental study for the absorbed-dose to water of heavy ion beam by an ionization method

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INTRODUCTION

The heavy ions interact with the matters and transfer most of the energy around the terminals of their paths. The mechanism for the interaction between heavy ions and matters is more complicated than that of photons, the parameters such as stopping power ratio for heavy ions are simplified in theoretical calculation due to the above reason[1-4]. From the experimental perspective, absolute measurement for reproducing the absorbed-dose to water of heavy ion beam has not been widely carried out, compared to the research activities for photon beams[5,6]. In the present work, the experimental study for the absorbed-dose to water of heavy ion beam was performed by a conventional ionization method. The calorimetric research for the absorbed-dose to water of heavy ion is being prepared in National Institute of Metrology of China, by considering the dosimetry properties of the heavy ion therapy facility based on the current study.

AIM

The preliminary dosimetry study concerning the heavy ion therapy facility is necessary to the following absolute measurement with a water calorimeter. The present work aims to clarify the relevant characteristics of the heavy ion therapy facility, through the commonly used ionization method in both dosimetry and clinical cases.

METHOD

The experiment was carried out at Wuwei heavy ion hospital, where the heavy ion beams can be delivered to terminals either in vertical or horizontal direction. A 400 MeV/u ^{12}C ion beam, with the spread-out Bragg peak(SOBP) of 6 cm by quickly scanning , impinged on the water phantom with a field size of 10 cm x 10 cm. The experimental layout is shown in Fig. 1. Thimble chambers and parallel-plate chambers were applied to measure the absorbed-dose to water of the incident heavy ion beam at the equivalent depth of 3 cm in water, where the dose gradient was small and thus suitable to perform the preliminary dosimetry study. A monitor chamber was installed somewhere behind the measurement chambers to supervise the beam intensity in order to normalize the experimental data. During the beam time, the polarization and ion recombination effected were evaluated.

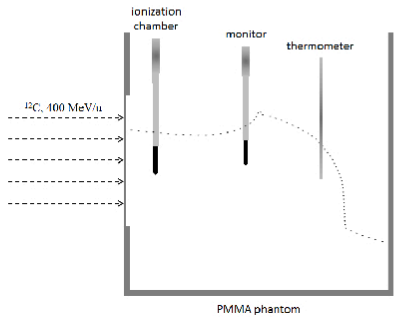

Fig. 1 Schematic layout for the experimental setup

RESULTS

The absorbed-dose to water, D_w, of a 400 MeV/u ^{12}C ion beam with SOBP of 6 cm is calculated by

$$D_w = M \cdot k_{TP} \cdot k_{elec} \cdot k_{pol} \cdot k_s \cdot k_s^{ini} \cdot N_{D,w} \cdot k_Q, \quad (1)$$

where M is the charge reading from the chamber, k_{TP} corrects the air density in the chamber with the reference condition, the polarization effect and ion recombination effect for the chamber have been measured on-site and given the correction factors k_{pol} and $k_s \cdot k_s^{ini}$, respectively, $N_{D,w}$ is the calibration coefficient of the chamber from the reference beam quality of ^{60}Co, k_Q is the beam quality correction factor for heavy ion beam. In this work, the k_Q is adopted from two approaches, in which the k_Q value is deduced from the recent absolute measurement [7]or recommended for nearly two decades[8]. The comparison for the absorbed-dose to water of heavy ion beam is illustrated in Fig. 2, the main contributor for the uncertainty is k_Q, for instance, the k_Q uncertainly for the thimble chamber is 0.8% from the absolute measurement, 2.8% from the recommended value in IAEA TRS-398. The uncertainty is 1.2% through the quadratic combination of the items except k_Q in formula (1). The values aforementioned are relative standard uncertainties. The uncertainties from the polarization and ion recombination are more significant in the ionization measurement for heavy ion beam, compared with the situation in photon beam.

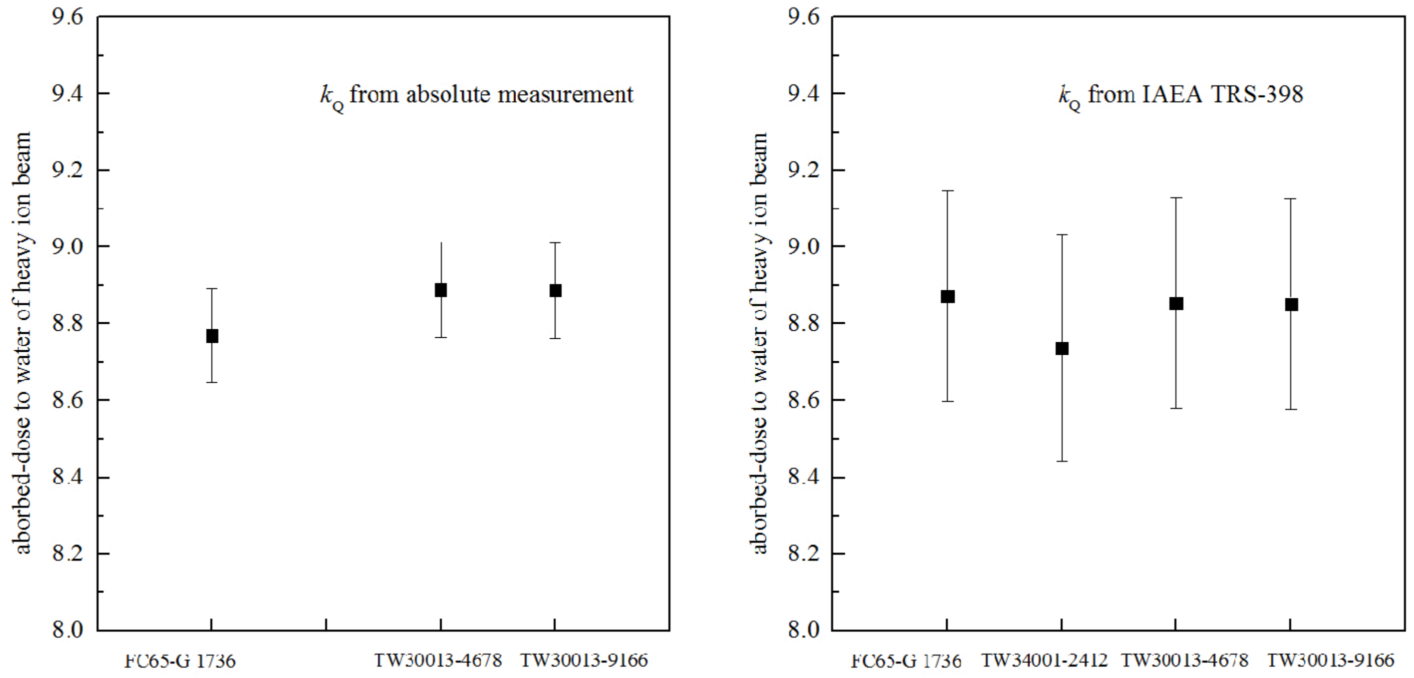

Fig. 2 The absorbed-dose to water of a 400 MeV/u ^{12}C ion beam with SOBP of 6 cm measured by ionization chambers

CONCLUSIONS

The absorbed-dose to water of heavy ion beam deduced from different ionization are consistent within the acceptance of uncertainty. Based on the measurement with ionization chambers, it is crucial to conduct more intensive research activities of radiation dosimetry including the absolute measurement with calorimetric facility, with the purpose of further optimizing the uncertainty in the measurement for the absorbed-dose to water of heavy ion beam.

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