Consideration of the Bragg peak detector size in the modeling of proton PBS machines in the treatment planning system RayStation

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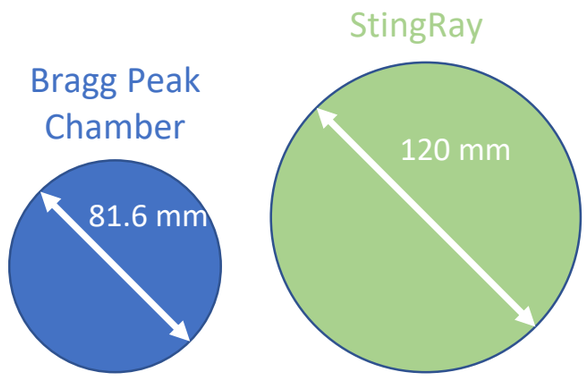
Introduction

Measured single spot integrated depth doses (IDDs) are regularly used in treatment planning system (TPS) beam modeling of proton therapy (PT) systems. The limited lateral extension of detectors used to capture the IDDs has been a concern and several methods of adjusting the measured IDDs used for the TPS beam modeling have been employed [1, 2]. In the commercial Treatment Planning System RayStation, PT beam modeling is performed using uncorrected, as-measured IDDs taking the lateral size of the detector as explicit input in the modeling.

In this work we perform an experimental validation of the Bragg peak detector size algorithm in RayStation. Two sets of single spot IDDs are measured using two IDD detectors of different lateral extension. The two sets are used to create two beam models in RayStation, which are validated against measured depth doses curves (DDCs) of scanned single energy layers.

Experimental

- IBA dedicated nozzle of Gantry 4 at the West German Proton Therapy centre
- IDDs of single spots measured using
  - Bragg Peak Chamber (BPC) from PTW (Φ=81.6 mm)
  - StingRay detector from IBA Dosimetry (Φ=120 mm)
- DDCs of 10x10 cm^2 scanned single energy layers using a PPC05 ion chamber
- See Ref. [3] for more details



Analysis

- IDDs and DDCs are shifted up to 1.5 mm in depth so that the distal ranges match exactly
- All IDDs and DDCs are normalized at a depth of 2 cm
- The measured IDDs using the two different detectors are mutually compared
- Two beam models based on the two sets of measured IDDs are created in RayStation 8A, where the size of the detectors is input in the modeling
- DDCs of the scanned fields are computed by the Monte Carlo dose engine in RayStation 8A using the two beam models and are compared to the measured DDCs

Results

- Excluding the high gradient parts around the Bragg peak, the relative difference between the measured IDDs of the two detectors is found to be up to 3%, with the largest differences at intermediate depths for the highest energies (Figure 2)
- The relative difference between calculated and measured DDCs are for the most part within 1% and is dominated by random noise from the measurements, without any clear systematic dependence in depth or energy (Figure 3)
- No systematic difference between the beam models based on the BPC or StingRay detectors is found (Figure 3)

Summary

- The relative difference between IDDs, delivered by an IBA PBS dedicated PT delivery system, as measured with the 81.6 mm BPC and 120 mm StingRay detectors are found to be up to 3%
- The IDD detector size algorithm implemented in the beam modeling algorithm of RayStation eliminates this difference, and calculated DDCs of 10x10 cm^2 scanned fields using models based on both sets of IDDs are mutually close to identical and exhibit excellent agreement to the measured DDCs

References

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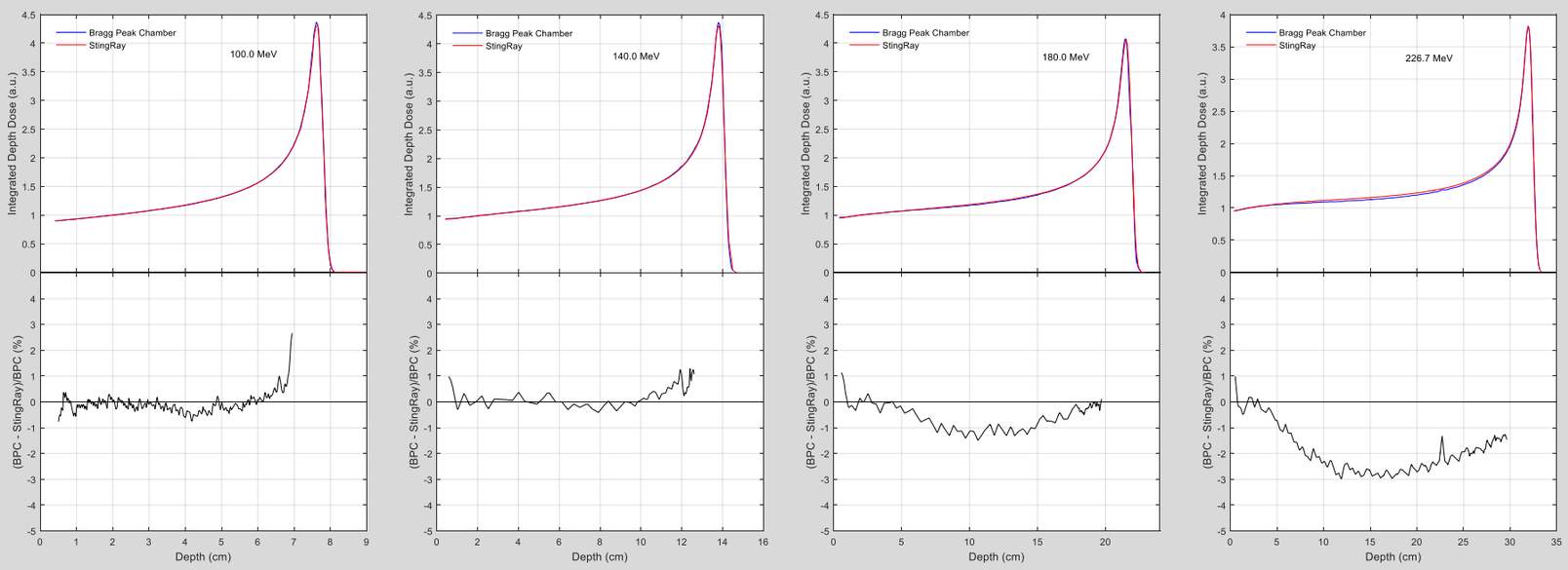

Figure 2 (Top panels) Measured integrated depth doses (IDDs) of single spots at nominal beam energies of 100, 140, 180, and 226.7 MeV using, respectively, a Bragg Peak Chamber (Φ=81.6 mm) (blue curves) and StingRay (Φ=120 mm) detector (red). The relative difference between the IDDs of the two detectors are shown below.

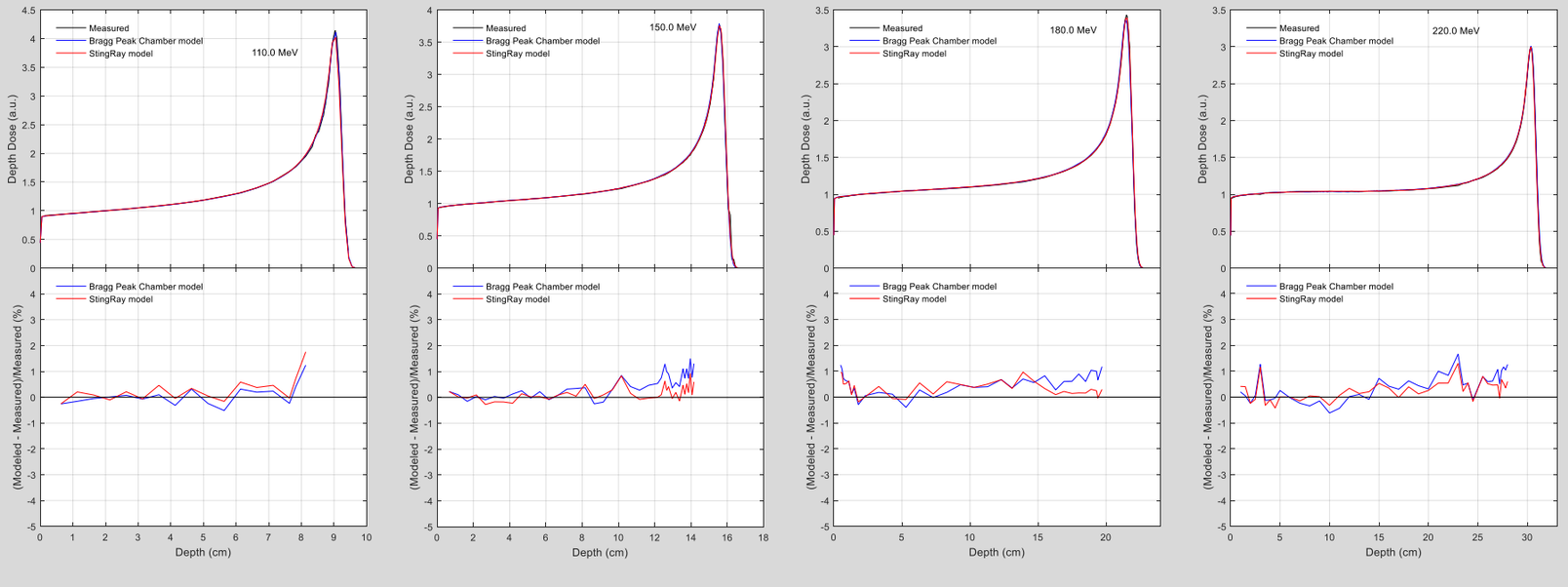

Figure 3. (Top panels) Measured central depth dose curves (DDCs) of 10x10 cm^2 scanned single energy layers at 110, 150, 180, and 220 MeV (black curves). Corresponding calculated DDCs using RayStation 8A with beam models based on the Bragg Peak Chamber (blue) and StingRay IDDs (red) are also included. The relative difference between measured and calculated IDDs are shown below.