Comparison of beam model implementation methods for commissioning of Monte Carlo code in proton beam therapy centre

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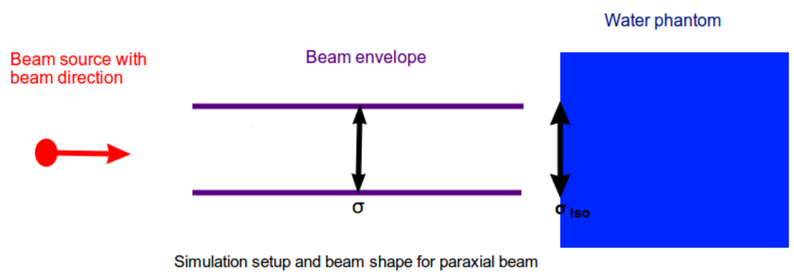
Objectives

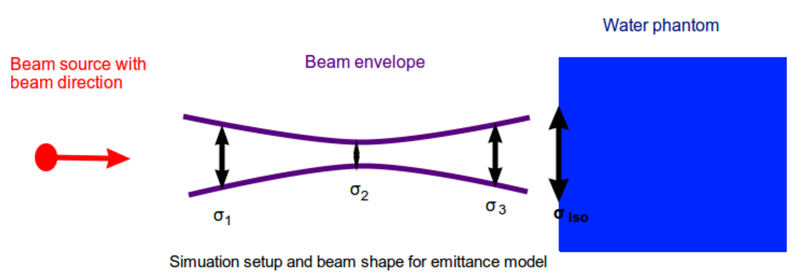
- Implementation of the clinical beam model used in Krakow proton beam therapy (PBT) center for patient treatment into Fred MC-based treatment planning system (TPS).
- Introduction of the beam model implementation methods: (i) TPS emittance model, (ii) Fred emittance model, (iii) Fred paraxial beam source.
- Validation of the Fred MC calculation against the clinical quality assurance (QA) treatment plans and measurements.

Methods: Fred MC code

- **Fred** (*Schiavi et al. 2017 PMB*) **the GPU-accelerated MC-TPS**.
- Simulations of pencil beams and QA dose cubes placed at varying depths in a water phantom.
- The simulation setup mimics the PBT center experimental conditions (distance between beam source and isocenter, magnets position).
- MC beam models consist of paraxial beam parameters (energy, energy spread, beam size) and emittance model (energy, energy spread, Twiss parameters).



Simulation setup and beam shape for paraxial beam



Simuation setup and beam shape for emittance model

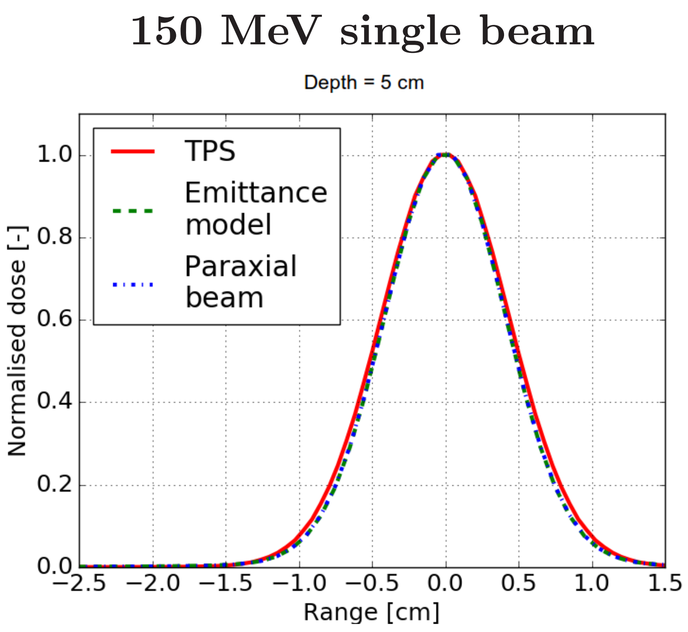
Results: A comparison of the paraxial source and beam emittance model

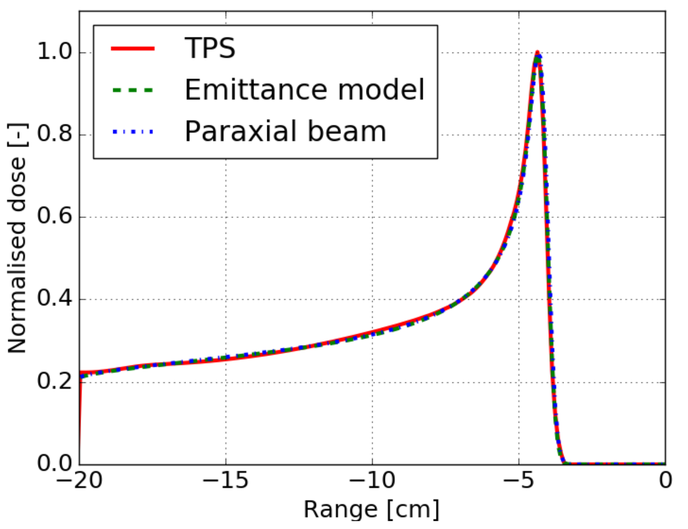
The standard deviation (σ) of **lateral dose profiles** in plateau region (top) and range of **depth dose profiles** (bottom) comparing Eclipse™ TPS (solid line) and Fred MC calculations (dashed lines) for single beams agree within 0.1 mm both for paraxial beam and emittance model approach.

The comparison of lateral and depth dose profiles obtained from TPS (solid line) and Fred MC dose computations (dashed lines) performed for a QA dose cube of 25 cm range and 5 cm modulation are presented below. The results are compared with measurements performed with ionisation chamber in water (bottom, dotted line).

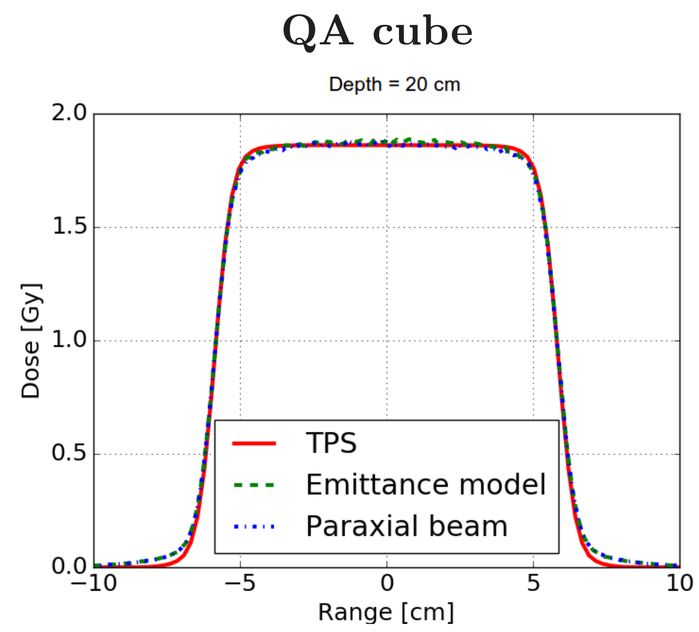
The GI passing rate in 3D **GI analysis**, for passing criteria 3%/2mm used in PBT center in Krakow, between TPS and Fred MC dose computation was better than 95% (top). The 3D GI analysis between paraxial beam and emittance model obtained using Fred MC for 1%/1mm passing criteria gave a passing rate over 99% (bottom).

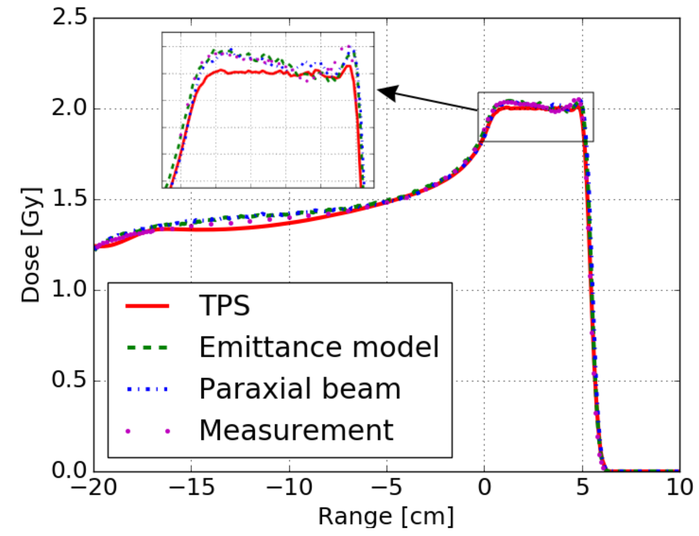
150 MeV single beam

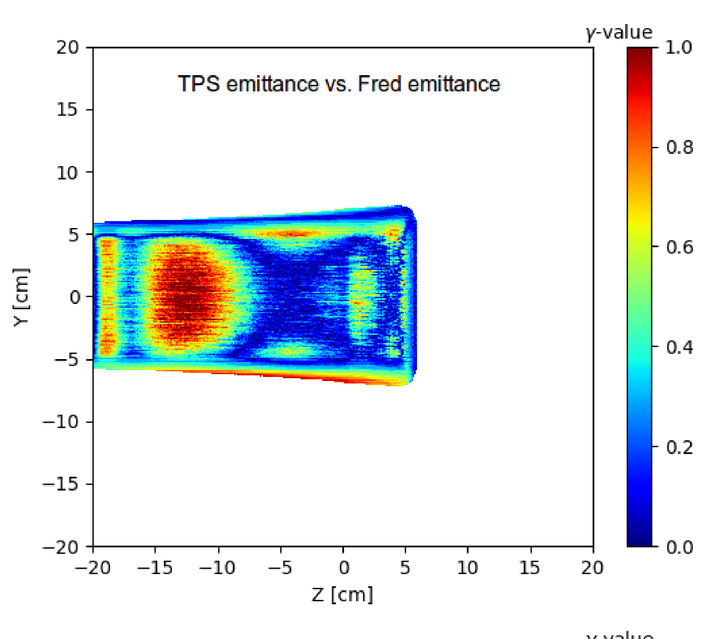


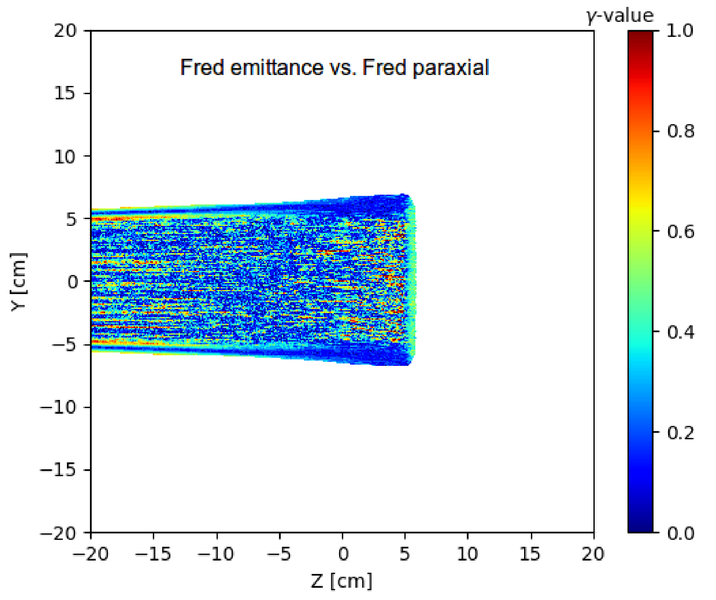


QA cube









Conclusions

The results showed that the distribution profiles of QA dose cubes in water calculated using Fred MC (emittance and paraxial model) agree with TPS calculation and with measurements within 2% (GI pass rate of 95%) and 1% dose value, respectively. Fred MC calculations show that dose distributions obtained with emittance and paraxial beam source implementation methods do not differ substantially (GI passing rate 99.7%) suggesting that both approaches can be used for dose calculations in the PBT center.

Acknowledgments

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