Validation of a GPU-Accelerated Monte Carlo Treatment Planning System for Proton Beam Therapy

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**Conclusions:** Proton beam model used clinically in Krakow PBT centre for patient treatment was implemented in the in-house developed, GPU-capable Fred MC code and validated against the measurements. Fred offers accuracy, flexibility, and high dose calculation speed impossible to achieve with the currently available commercial systems.

**Introduction**
A Monte Carlo (MC) code can support development of treatment planning procedures, treatment plan verification and Proton Beam Therapy (PBT) research.

A **GPU-accelerated MC** Treatment Planning System (TPS) **Fred** (Schiavi et al. 2017) developed at the University of Rome (Italy) has been commissioned against the physical beam model used for patient treatment in Krakow PBT centre (Poland) aiming to support in the near future physical dose verification, biological dose calculation with variable RBE and 4D dose verification of moving target treatments.

**Fast generation of proton beam model phase space library**
Time performance of GPU-accelerated Fred MC code enables fast proton beam model phase space characterisation based on the PBT facility commissioning and/or periodic QA data. The proton beam model library includes information on single pencil beam: energy, momentum spread, emittance parameters, dosimetric calibration.

**Simulations (Fred)**
- IDD of single pencil beams in WP
- \(10^8\) primary protons

**Validation: Fred simulations vs measurements**
- Five dose cubes of different range (10x10x5cm\(^3\))
- 160 QA verification plans of patients treated in Krakow PBT centre
- Evaluation: Dose profiles and gamma index in water

**Data (Krakow PBT centre)**
- DDD in Water Phantom (WP)
- lateral beam profiles in air & RW3

**Simulations (Fred)**
- Dose cubes and patient QA verification plans recalculated in water phantom

**Fred time performance** (@\(5\times10^5\) protons /spot)
- Total time: \(<10’\)
- Tracking rate: \(3.0-12.6\times10^6\) [protons/s]
- QA Verification plans
  - Total time: \(3’28s\pm1’41s\)
  - Tracking rate: \((8.5\pm1.6)\times10^6[\text{protons/s}]\)

**Data (Krakow PBT centre)**
- SOBP DDD (dose cubes) measured with Markus chamber in water phantom
- Patient QA verification measurements performed with an array of ionisation chambers (MatriXX)

**Krakow Proton Beam Therapy Centre (Poland)**
- Clinical operation from Oct 2016:
  - Head & neck, eye cancer patients
  - \(\approx100\) patients treated with Gantry

**Equipment**
- Proteus C-235 cyclotron (IBA)
- Pencil beam scanning
- Eclipse TPS
- Dedicated QA protocols
- old cyclotron: 62 MeV protons dedicated 24/7 for research

**Conclusion**
Proton beam model used clinically in Krakow PBT centre for patient treatment was implemented in the in-house developed, GPU-capable Fred MC code and validated against the measurements. Fred offers accuracy, flexibility, and high dose calculation speed impossible to achieve with the currently available commercial systems.