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Validation of GPU-accelerated Fred Monte Carlo code for proton dose recalculation

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In modern radiotherapy of cancer using charged particles, the Monte Carlo (MC) methods are exploited for reliable dose recalculation. Unlike analytical dose calculation methods employed in commercially available Treatment Planning Systems (TPS), the MC tools explicitly take into account many details of particle interactions with target athoms, such as multiple coulomb scattering or nuclear inelastic interactions. Nevertheless, application of general purpose, CPU-based MC tools is limited by the long computational time, thus MC engines based on graphic cards (GPU) calculations are investigated. A GPU-accelerated proton transport code FRED (Fast paRticle thErapy Dose evaluator) was developed at the University of Rome (Italy) for clinical research at proton beam facilities. Application of MC tools in proton therapy can improve accuracy of dose calculations performed with TPS and support Quality Assurance (QA) procedures.
A physical beam model used for patient treatment in Krakow Cyclotron Centre Bronowice (CCB) has been implemented in FRED based on measurements performed during facility TPS commissioning. Furthermore, a stoichiometric calibration of CT scanner, taking into account the Hounsfield Unit to the relative proton stopping power relation, as well as material nuclear composition has been implemented. The dose recalculation accuracy was validated experimentally in homogeneous and heterogeneous media. Patient QA treatment plans measurements in water performed with MatriXX array of ionisation chambers and spread-out bragg peaks (SOBP) dose profile measurements with a Markus chamber were used for validation in homogeneous water phantom. Validation in heterogeneous media was performed measuring 3D dose distribution behind a CIRS head phantom.
The maximum difference of the dose measured in SOBPs and calculated in FRED MC is up to 2%. Percentage gamma index passing rate (%GP) with 2mm/3% criteria, obtained comparing 182 simulated and measured layers of patient QA plans was 96.28(3.3)%. Dose distributions measured behind the CIRS head phantom are in agreement with FRED MC simulations showing 3D %GP (2mm/2%) over 99%.

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