Gate simulation of a complete proton treatment combined with prompt-gamma monitoring.

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Purpose.
Several systems are studied to monitor the deposited dose using prompt-gamma (PG) emitted during proton nuclear interactions. It was shown that ion and PG ranges are correlated. However, measuring spot-by-spot Bragg Peak positions in a scanned beam setup is still an open issue. We present a Monte-Carlo (MC) simulation of a treatment fraction combined with an innovative PG camera design. We used patient data imported from a clinical TPS (Xio, Elekta).

Methods.
We developed a spot scanning beam model based exclusively on calibration data required by the TPS. This model includes nozzle and beam line characteristics. We developed a DICOM plan to Gate macro conversion tool and a "dose to water" option to allow dose distribution comparison between TPS and MC. A collimated multi-slit PG detector, under development at IPNL-Lyon, was simulated. It is composed of tungsten collimators, BGO scintillators coupled with photo-multipliers. Each PG event is filtered (TOF and energy) to create a depth PG signal. Simulations were computed using the new Gate v6.2 release.

Results.
The beam model reproduced measured SOBP ranges within 0.7 mm [1]. The dose distributions obtained with Xio and Gate were in good overall agreement. Stopping power differences up to 3% were observed, due to the HU conversion procedure [2]. For a 2 Gy fraction, spot-by-spot PG monitoring estimates the Bragg peak position with a 0.6 mm standard deviation [3].

Conclusion.
A complete MC simulation of a clinical proton treatment plan, including the active scanning delivery system, patient data and PG camera is feasible with Gate. It represents an interesting tool to assess and optimize spot-by-spot PG-based dose monitoring for clinical treatment plans. This work is carried out within the framework of the ENVISION FP7 project.

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