

AbstractID: 13384 Title: Evaluation of Performance of a Conceptual Time-Resolved Proton Range Telescope for In-Room Respiration Monitoring Using Monte Carlo Simulations and 4DCT Patient Data

Purpose: To demonstrate the feasibility to perform and optimize a time-resolved proton range telescope (TRRT) in localization of moving lung tumors and quantification of proton range variations.

Method: A TRRT is designed to detect transmission protons and provide a fluoroscopic image showing tumor location and range perturbations prior to or during treatment. MCNPX code with a particle-tracking feature was used to simulate and evaluate the TRRT performance, especially in visualizing and quantifying the proton range variations during respiration. Monoenergetic protons, 235 MeV in a 15cm x 15cm field, were tracked one by one as they pass through position detectors, 4DCT phantom, and finally scintillators that measured position and residual energies. Mass density and elemental composition of tissues were defined from a set of 4DCT of a lung patient. Radiological pathlength in the patient was determined by an energy-range algorithm. Effects of multiple Coulomb scattering on image quality were determined by comparison with a pure ray-tracing algorithm in Aqualyzer.

Results: Interesting water equivalent length (WEL) maps for 10 respiratory phases were obtained to form fluoroscopic sequences. Appropriate color-map windowing was used to visualize and measure tumor trajectories. The tumor trajectory extracted from the proton fluoroscopic simulation agreed with ground-truth established by 4DCT to about 1mm. WEL difference maps were reconstructed to quantify respiration-induced range changes. The maximum proton range pullback for the tumor target was measured to be 2.29 cm. Rejection of wide angle scatter events was found to effectively sharpen the image. Clinical applications to track the tumor during proton therapy using the range telescope are discussed.

Conclusion: The performance of a TRRT is systematically studied and demonstrated by Monte Carlo simulations. When parameters are optimized, localization of a 2cm tumor is possible with an accuracy of about 1mm. Technical requirements for an operational device are discussed, including GPU acceleration.