Monte Carlo Phase Space Production to Model Magnetically Scanned Proton Beams for IMPT

Introduction: Efforts are made to create a novel numerical dose computation engine based on Monte Carlo data. This study reports on our activity of a Monte Carlo model of the scanned proton beam deliver system employed at the proton therapy center of the M.D. Anderson Cancer Center. Lateral dose profiles of 90 proton beams with energies from 76.1 MeV to 221.8 MeV were measured, simulated and compared at various depths in a water phantom. The results of the comparison are presented in the following.

Methods and Materials: A more detailed description of the measurement technique can be found in (Sawakuchi et al., 2010).

Simulations: The Monte Carlo system used for this study was MCNPX version 2.7d. A water phantom was located such that the upstream surface was at a distance of 324.5 cm from the source particle plane. A more detailed description of the nozzle geometry can be found in (Sawakuchi et al., 2008). Because the SDEF card, did not allow the flexibility to selectively modify the energy distributions and directional as well as spatial distributions of the source particles, the surface source (phase space) capability was utilized. In house software was developed, to create this phase space file with the possibility to provide several energy distributions, spatial and directional distributions defining the particle source. Iteratively the sigma of the Gaussian functions describing the spatial distributions of the source particles on the source location plane was modified to achieve agreement of 0.5 mm or smaller of the full widths at half maximum (FWHM) of normalized simulated and measured lateral profiles, at a depth of 20 mm in the phantom.

Results: Typical examples of measured and simulated lateral energy deposition profiles at a depth of 20 mm in the water phantom are shown in Figures 1a and 1b. In Figures 1c and 1d, the profiles at a depth of 70 mm, and finally in Figures 1e and 1f the profiles at a depth of 146 mm in the phantom are presented. The initial energy of the protons was 151.0 MeV, corresponding to a range of 15.6 cm in water. The distributions of the differences are given in Figure 3.

Figure 1: Lateral measured and simulated profiles at various depths in a water phantom. The profiles at deeper depths showed excellent agreement without further need of source parameter variations.

Figure 2: Differences in FWHM between the simulated and the measured lateral energy deposition profiles at a depth of 20 mm in water.

Figure 3: Statistical distribution of the differences in FWHM between the simulated and the measured lateral energy deposition profiles at a depth of 20 mm in water.

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