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High-fidelity Geant4 simulation of the Elekta Unity MR-LINAC for dose prediction

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The Elekta Unity is an MR-LINAC that integrates a 7 MV linear accelerator with a 1.5 T MRI in order to provide adaptive online radiotherapy. Using Geant4 version 11.1 and the EMStandard Option 4 Physics Constructor a highly accurate simulation of the Elekta Unity MR-LINAC was developed to produce patient specific dose maps. These dose maps are utilised for the training of a robust dose prediction machine-learning based model. The simulation contains a full model of the treatment head, including the MLC and jaws, as well as the MR cryostat, treatment couch and anterior coil. Simulation of the treatment head allows for positioning to any gantry angle, and individual leaf and jaw positioning allows for the generation of any beam profile, permitting complete control point replication. A uniform 1.5 T magnetic field is applied to the simulated MRI bore through Geant4's field manager with the Dormand-Prince 745 Runge-Kutta stepper so that the simulation is capable of accurately modelling the effects of the magnetic field on the dose profile. The X-ray beam was finely tuned by investigating the dose profiles for different electron beam configurations. Simulations of a water phantom and surrounding PMMA walls are used to validate the simulation to experimental measurements at gantry angles of 0 and 270 degrees, performed using different detector types. This paper will show that the simulated dose profiles have very strong agreement with the experimental results, with 100% 2%/2mm gamma pass rates for a variety of field sizes and detector depths, including in the crossplane direction, and mean and maximum relative error of less than 1% for the depth dose profiles.

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