Development of a Geant4 simulation platform of the HollandPTC R&D proton beamline for radiobiological studies

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Background:
Radiobiological studies represent an important step in obtaining a greater fundamental understanding of the differences between photon and proton radiotherapy on the cellular level. The Holland Proton Therapy Centre (HollandPTC) in Delft facilitates the performance of radiobiological experiments, but to take full advantage of this opportunity, characterisation of the beamline is required. The aim of this work is to develop a Geant4 simulation platform of the HollandPTC R&D proton beamline to not only characterise the system, but also enable its optimisation for radiobiological studies.

Material and Methods:
The experimental setup at HollandPTC consists of a passive scattering system (Figure 1a) that is able to produce large fields of varying sizes. After the implementation of all beamline elements in Geant4 (Figure 1b), a full parameter sweep of the six beam parameters - lateral spread, angular divergence, both in x and y, initial energy and energy spread - was undertaken at multiple energies to find the optimal parameter values. A two-dimensional Gaussian function was fitted on the central x- and y-profile to assess the beam envelope (in terms of FWHM and FWTM) in both directions at different distances through air. This optimisation was performed at 70, 150 and 240 MeV, whereupon a surrogate proton beam model was created in order to predict beam parameter behaviour at intermediate energies. As a last step, the validity of the developed simulation platform was tested at 120 and 200 MeV by studying the beam envelope and depth dose distributions, and large field uniformity results at 150 MeV.

Preliminary results:
The comparison of Geant4 simulations with experimental data illustrated a high level of agreement for the beam envelope, depth dose distributions and large field uniformity with both a circular field (diameter of 10 cm) and squared field (10 by 10 cm). Figure 2 shows the result of the obtained circular large field at 150 MeV with a uniformity through the centre of the field of 97.7% in the experimental profile and 97.5% in the simulations. By testing the Geant4 simulation platform at intermediate energies, it will be shown that the developed simulation platform is able to reproduce the beam characteristics therefore allowing for the accomplishment and optimisation of radiobiological studies at HollandPTC.

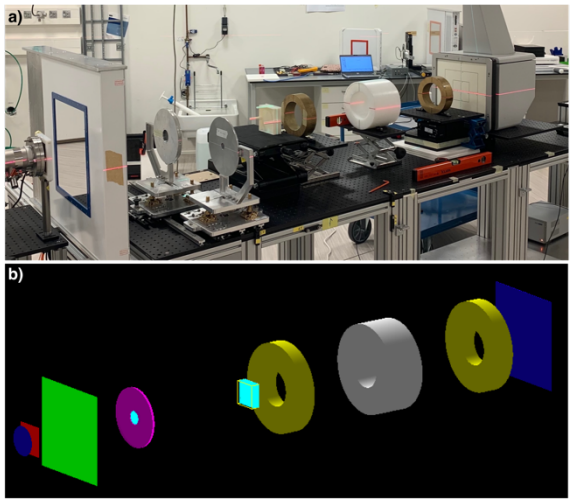

Figure 1: a) The experimental setup at the HollandPTC R&D proton beamline, and b) the implementation of all beamline elements in Geant4.

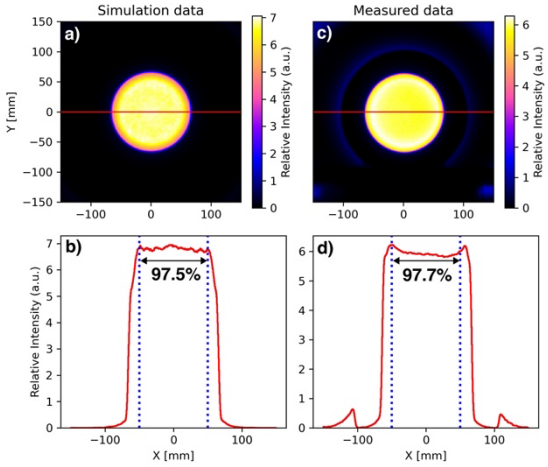

*Figure 2: Result of passive scattering simulations and experiments. **a)** Intensity plot of the beam cross-section of simulation data, with the red horizontal line showing: **b)** the line profile across the intensity plot of simulation data. **c)** Intensity plot of the beam cross-section of measured data, with the red horizontal line showing: **d)** the line profile across the intensity plot of measured data. The blue dotted lines confine the field of interest (radius = 5 cm).*