Using an iterative shielding approach for the first carbon ion therapy facility in the US by means of Geant4

D. Bolst[1] J. M. Dougherty[2], K. Furutani[2], S. Guatelli[1], A. B. Rosenfeld[1], C. J. Beltran[2]

[1]Centre for Medical Radiation Physics, University of Wollongong, Wollongong, Australia.
[2]Division of Medical Physics, Department of Radiation Oncology, Mayo Clinic, Jacksonville, Florida, USA

Background: This work presents shielding calculations for the first clinical carbon ion therapy (CIT) facility in the US, using Geant4. This project is being undertaken by the Mayo Clinic in Jacksonville, Florida, with Hitachi as the vendor. The typical process of obtaining approval for a radiation shielding facility includes providing a design to a shielding consultant who evaluates whether or not the proposed shielding design meets regulatory requirements. The evaluated design is based on a reference vendor design, which adopt conservative shielding designs and assumptions. This study presents an iterative design approach to shielding for a clinical CIT facility, where the facility's design is altered multiple times based on Geant4 calculations for each design iteration. This approach allows for both cost and floor space to be optimised.

Material and Methods: The shielding work presented here includes results relevant to stage 1 of construction, which consist of two proton gantry rooms and a fixed beam room for both proton and carbon ion beams. Planned maximum clinical beam energies are 230 MeV proton and 430 MeV/u carbon ion beams. Beam loss data provided by Hitachi assumes 16,000 patients are treated each year in each of the three treatment rooms. Computer aided design (CAD) files were provided by the architecture firm Perkins and Will, Fusion 360 was used to perform editing of the provided CAD files when needed and to export them as STL files. The STL files were imported into Geant4 (version 10.6, using the Bertini cascade model) using CADmesh. Over 100 different beam losses were simulated within Geant4. After a design iteration had been investigated within Geant4, information was then relayed back to the architects and the facility's design was updated, this process was repeated until a balance of cost/shielding was deemed achieved.

Preliminary results: Over 20 design iterations were evaluated, with the main areas of focus/concern for shielding being beam loss positions where high amounts of carbon ions were lost, namely the fixed beam room and the synchrotron. For the fixed beam room, a wall thickness of 4 m downstream of the beam's target was chosen to achieve an ambient dose equivalent below 20 uSv/hour (occupancy of 1). While external building walls, which includes the synchrotron, were chosen to be 1 m thick.