OPTIMISATION OF GEANT4 MONTE CARLO SIMULATIONS FOR SYNCHROTRON-BASED MICROBEAM RADIATION THERAPY

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Introduction: Microbeam Radiation Therapy (MRT) is a promising new treatment for cancer that uses many spatially fractionated micrometre-sized fields to irradiate tumours [1]. A typical MRT radiation field consists of multiple high dose 'peaks' separated by low dose 'valleys' (peak width 25-50 µm; pitch 200-400 µm) with treatment dose, delivered at dose rates of up to 20 kGy/s. The minute microbeam dimensions and high dose rate of MRT requires a high level of precision for quality assurance. Dose Verification and Treatment Planning Systems (TPS) are crucial aspects of quality assurance, allowing for independent prediction and verification of dose distributions delivered to patients. The most accurate form of TPS is Monte Carlo computer simulations.

Materials and methods: The Centre for Medical Radiation Physics (CMRP) has developed a Geant4 toolkit-based [2] synchrotron beamline model for dose verification at the Australian Synchrotron Imaging and Medical Beamline (IMBL). This model, denoted G4IMBL [3], operates on Geant4 version 9.6 and uses a multi-stage procedure to generate and transport synchrotron light through the beamline model (Stage I), and calculate dose deposition in a parameterised moving phantom (Stage II). G4IMBL models the production of x-ray photons entirely using Geant4 by transporting electrons through the sinusoidal magnetic field of a 'wiggler'. This allows for optimisation of multiple operation modes via tuning of wiggler magnetic field strength and electron steering angle (IMBL standard: 3T; optional: 1.4 T, 2 T). Scaling of energy deposition to total primary electrons allows for dose calculation within a user-defined phantom.

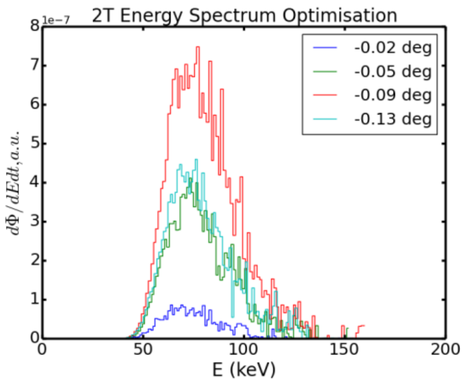

Figure 1. Optimisation of electron beam steering angle in simulated 2T wiggler

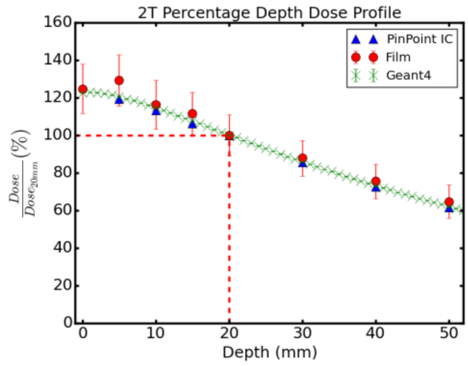

Figure 2. Simulated depth dose profile (broad beam) in phantom, normalised at 20 mm (dotted line) compared against experimental results.

Results: Electron beam steering angle was optimised for 2T field wiggler magnetic field strength (Fig. 1) and optimised energy spectrum agreed well with theoretical estimate [4]. Simulated Stage II normalised depth dose profile (broad beam field) agreed with experimental Ion Chamber and Radiographic film measurements within error (Fig. 2)

Conclusions: Optimisation of G4IMBL for 2T wiggler field, produced energy spectra and normalised depth dose profiles that showed good agreement with theoretical and experimental broad beam results. Optimisation for 1.4 T and 3 T wiggler fields for a variety of beamline conditions is ongoing. Validation of microbeam radiation field simulation against experimental results is ongoing.

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