Performance of Geant4 for modelling silicon microdosimeters in heavy ion therapy

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Heavy ion therapy (HIT) refers to the treatment of cancer with ions larger than protons. HIT offers many advantages over conventional photon radiotherapy including a more conformal treatment due to its well defined range and reduced scattering as well as a higher linear energy transfer (LET) which allow for better treatment of radio-resistant tumours. A large complication with HIT is that the relative biological effectiveness (RBE) of the beam changes drastically with energy, with a value changing from ~1 to ~3 at the Bragg Peak (BP). RBE is a measure of how effective a radiation type is at producing a biological effect and is vital to take into account its changing value when treating patients. An additional difficulty in HIT is the fragmentation of the primary beam with target nuclei, producing lighter fragments. These fragments have ranges which extend beyond the BP and laterally from the primary beam, transporting energy away from the treatment field to surrounding healthy tissue. It is critical to consider the effects of RBE and fragmentation and to confirm the delivered radiation field matches the planned treatment through quality assurance measurements.

Microdosimetry involves measuring the energy deposition spectrum in micron sized volumes and allows an estimation of the biological effect for any mixed radiation field. Conventional microdosimetry measurements are performed using tissue equivalent proportional counters (TEPC), traditional TEPCs suffer from a bulky size and complicated operation, these make them not well suited for routine quality assurance measurements. The Centre for Medical Radiation (CMRP) adopts solid state silicon-on-insulator (SOI) designs which address the shortcomings of traditional TEPCs.

In this study experimental measurements performed at the Heavy Ion Medical Accelerator in Chiba (HIMAC, Japan), using CMRP devices, are presented and compared to Geant4 (version 10.2p2). The microdosimeters were irradiated in ^{12}C, ^{14}N and ^{16}O beams with primary energies of 290 MeV/u, 180 MeV/u and 400 MeV/u, respectively. Comparisons between experiment and simulation yielded reasonable agreement between the two, demonstrating the favourable performance of the device. Downstream of the BP the energy peaks of fragments gave good agreement between experiment and simulation. However, in terms of the contribution of fragments it was observed that Geant4 produced an overabundance of lighter fragments compared to larger fragments.