Purpose: To determine the accuracy of the GEANT4 Monte Carlo toolkit for ionization chamber calculations in radiotherapy photon beams.

Methods: First, we used the Fano cavity example included in the GEANT4 distribution to validate calculations under Fano conditions. We determined a combination of parameters and physics list that provided results consistent within +/- 0.5% with the Fano theorem. Next we performed simulations to investigate the accuracy of using GEANT4 for ionization chamber calculations. Eight ionization chambers were modeled using detailed manufacturer specifications including A1, A1SL, NE2571, PTW30010, PTW30012, PTW31010, PTW31014 and PTW31016. The absorbed dose to water for a cylindrical water cavity and the absorbed dose to air in the ionization chambers’ cavities were scored for 1.25 MeV photons. The ratio of these quantities was then compared to values from EGSnrc simulations.

Results: Simulations using the Fano cavity example yielded results within +/- 0.5% with the Fano theorem across 1.25, 3 and 4 MeV incident photon energies. The most accurate and consistent results were obtained using the G4eIonisation ionization model and G4GoudsmitSaundersonMscModel multiple scattering (MS) model with a maximum step size limitation of 0.001 mm, which yielded results accurate to +/- 0.3% for all energies. This set of parameters and physics processes as well as the G4UrbanMscModel93 MS model were used for the ionization chamber calculations. The calculated quantities were compared to those used in Muir and Rogers 2010 (Med. Phys. 37: 5939-5950) and agreed to within sub-percentage differences for most chambers.

Conclusions: The GEANT4 toolkit can achieve sub-percentage accuracy for ionization chamber calculations in radiotherapy photon beams. This is achieved by using either the G4GoudsmitSaundersonMscModel or G4UrbanMscModel93 MS models. Although less accurate (+/- 0.5%), simulations employing the G4UrbanMscModel93 MS model are on average two orders magnitude faster than that of the G4GoudsmitSaundersonMscModel MS model (+/- 0.3%).

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