Inter-comparison of electron Monte Carlo dose calculations for EGSnrc, GEANT and Penelope

Joao Seco[1], Alex Howard[2] and Frank Verhaegen[3]
[1]*Physics Department, Royal Marsden Department, Fulham Road, London UK*
[2]*Blackett Laboratory, High Energy Physics Imperial College, London SW7 2BW*
[3]*Medical Physics Unit, McGill University, Montreal Canada*

ABSTRACT

Introduction: Electron beams with a nominal energy of 4–20 MeV are frequently used in radiotherapy for superficial or deep-seated tumours. Electron therapy is usually performed in regions with heterogeneities such as bone, air cavities, lung and soft tissue, etc. Since electron transport and scatter in matter is strongly influenced by density and material composition, dose calculation in heterogeneous media is extremely challenging. In the present study 3 Monte Carlo electron dose calculation codes: EGSnrc, GEANT and Penelope are inter-compared in water, bone and lung tissue. The study was performed for mono-energetic electron pencil-beams incident on cylindrical slabs, where the following parameters were evaluated:

- dose deposited as function of depth;
- energy spectrum at two (2) fixed depths, situated either side of the maximum dose;
- angular distribution of electrons as a function of the cylinder radius at two (2) fixed depths, situated either side of the maximum dose;
- electron particle fluence at two (2) fixed depths, situated either side of the maximum dose.

By evaluating these parameters for each Monte Carlo code and inter-comparing them, it is possible to assess how each transport algorithm, scattering algorithms (elastic and inelastic) and cross section data are performing.

Methods: Mono-energetic electron pencil-beams, with nominal energy from 100keV - 20MeV, were modelled perpendicularly incident on a sequence 200 cylindrical scoring slabs, all with identical thickness and radius of 100 cm. The slab thickness varied with the energy of the incident electron beam and was obtained from:

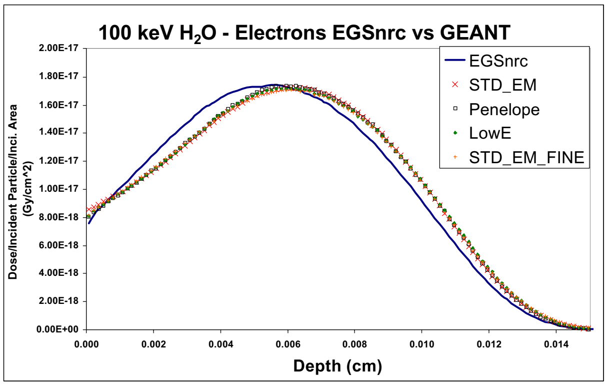
$$SLAB\_THICKNESS = \frac{CSD}{100 * \rho},$$

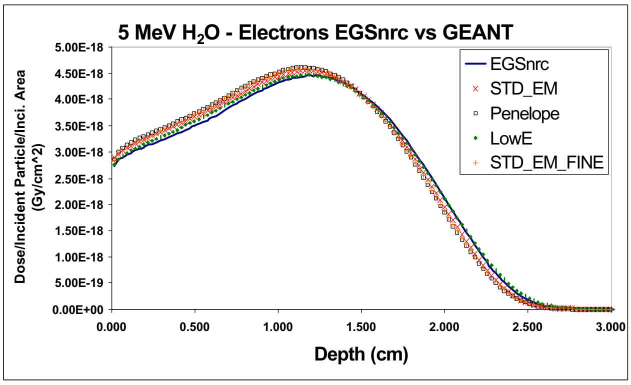
where CSDA is the continuous slowing down approximation range in g/cm^2 obtained from NIST database and ñ is the density of the slab material in g/cm^3. A phase space file was also generated at depths of 30% and 50% of the CSDA range, where the particle energy, position (x and y co-ordinates) and cosine directors "u,v,w" were kept. The two (2) selected depths correspond to depths before and after the depth at which maximum dose occurs.

In the case of the GEANT Monte Carlo code several electron models and cross section data are available and were assessed. They are (i) standard electromagnetic model (referred to as STD_EM) with 1mm cut-off range, (ii) standard electromagnetic model with 0.001mm cut-off range (referred to as STD_EM_FINE) (iii) Penelope model and (iv) low energy model (referred to LowE).

Results: Preliminary results obtained for the deposited dose as a function of depth for water, bone and lung tissue materials show significant differences between the EGSnrc results and the GEANT (STD_EM, STD_EM_FINE and LowE models) and Penelope values for electron energies below and above 1 MeV (c.f.figure for H_2O dose results obtained for 100keV and 5MeV). However, in the case of 1MeV incident electron energy all Monte Carlo dose prediction are in very good agreement (c.f. following figure for H_2O and BONE dose results).

(continued overleaf)





The EGSnrc, GEANT and Penelope Monte Carlo codes use different cross section for electron dose calculation. While EGSnrc use ICRU 37 (1984) restricted collision and radiative stopping powers, GEANT and Penelope use Seltzer and Berger (1985) cross section data. Differences observed in deposited dose for energies below and above 1 MeV, are possibly due to differences in the cross section data and in the scattering (elastic and inelastic) algorithms used. These differences will be assessed by comparing the energy spectrum, angular distribution and particle fluence obtained for various electron energies at two (2) fixed depths, situated either side of the maximum dose.

Conclusions: Preliminary results obtained in water, bone and lung tissue indicate that differences in the cross section data used Monte Carlo code lead to large differences in the deposited dose for electron energies below and above 1MeV.