Optimisation of 12 MeV Electron Beam Simulation Using Variance Reduction Technique

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ABSTRACT

Full Monte Carlo (MC) method is the most accurate and reliable computational method in determining the dose distribution of electron beam in radiotherapy [1]. However, electron beam requires a longer simulation time compared to photon beam. Algorithmic technique which called variance reduction techniques (VRT) were introduced to speed up the simulation time [2]. The goal of VRT is to minimize the simulation time by modifying the algorithm and simultaneously maintain an unbiased estimation of variance. In this condition unbiased means the result of VRT must not deviate compared to without VRT results with a realistic history number [3]. By using optimised variance reduction parameters total simulation time can be reduced remarkably [2-5]. The EGSnrc MC source code was used to determine percentage of depth dose (PDD) of 12 MeV electron beam for SIEMENS PRIMUS linear accelerator and validated by using 3D water phantom. The MC simulation was validated by comparing the simulation results with the experimental results. Various PDD of 12 MeV electron beam were obtained from different global electron cut-off energy of electrons (1-5 MeV) using 20 x 10^7 particle history in MC simulation. Further the result from electron cut off-energy, simulation with fastest calculation was evaluated with 7.5 x 10^7 to 20 x 10^7 particle histories. Using 5 MeV electron cut-off shorter total calculation time demonstrated with 50% of reduction of calculation time from initial simulation. With proper knowledge on VRT, calculation time of MC can be reduced significantly and the accuracy of calculations is conserved. In this study a total calculation time was reduced from 27.6 hours to 7.3 hours and demonstrate that less than 1% deviation from the non-VRT calculation.

Keywords: Electron beam, Monte Carlo, Variance reduction technique

OBJECTIVE

- To simulate and validate 12 MeV electron beam on 3D water phantom by using EGSnrc MC code
- To optimise VRT to reduce the total simulation time, but at the same time to maintain the accuracy of dose calculation

METHODS

1) Monte Carlo (MC) Simulation and Validation

- BEAMnrc - simulate SIEMENS PRIMUS linear accelerator's head.
- DOSXYZnrc - determine percentage of depth dose (PDD) of 12 MeV electron beam and validated by using 3D water phantom
- Total calculation time = BEAMnrc simulation time + DOSXYZnrc simulation time

2) Variance Reduction Technique (VRT)

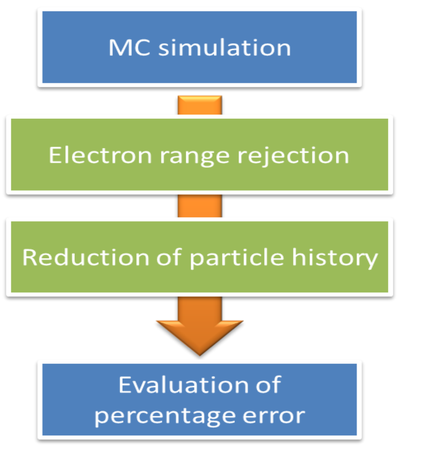

Figure 1: Flow chart of VRT optimization strategy

VRT	Range	VRT Value
Electron Range Rejection	1 MeV 2 MeV 5 MeV	Particle History: 20.0 x 10^7
Particle History	20.0 x 10^7 17.5 x 10^7 15.0 x 10^7 12.5 x 10^7 10.0 x 10^7 7.5 x 10^7	Electron Range Rejection: 5 MeV

Figure 2: VRT parameters used in this study

RESULTS AND DISCUSSIONS

1. Monte Carlo Validation for 12MeV beam for 10 x 10cm^2 field size

i) Result shows peak of the spectrum obtained at 11.5 MeV and validated for 12 MeV beam

ii) Phase space file generated from BEAMnrc validated by using 3D water phantom

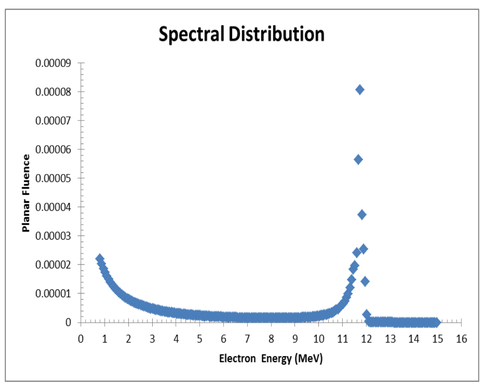

Figure 3: Spectral distribution of 12 MeV electron beam

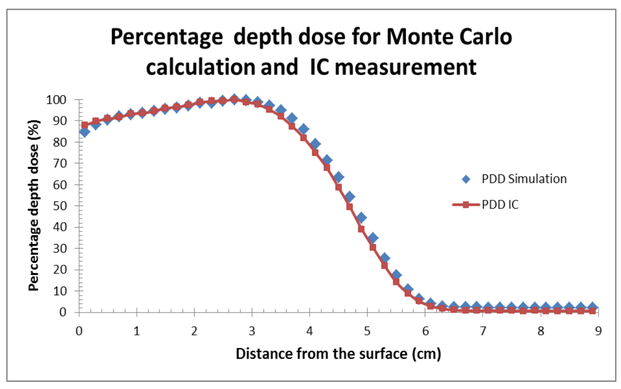

Figure 4: Validation of 12 MeV MC calculation. Less than 2% error was observed

2. Variance Reduction Technique

i) **Electron Range Rejection**: Global electron cut-off of 5 MeV shows shorter calculation time, 13.7 hours compared to 27.6 without range rejection for 20 x 10^7 particle history.

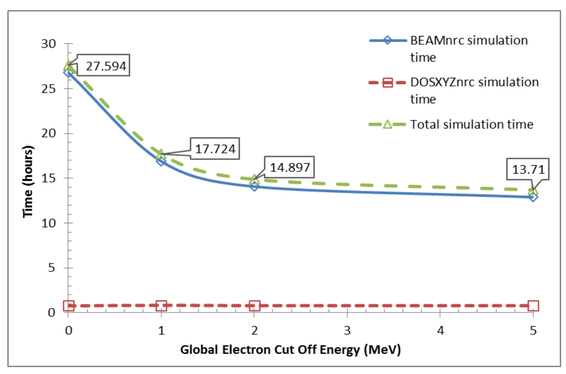

Figure 5: Simulation time using different electron cut off energy. 5 MeV reduce simulation time to 13.7 hours.

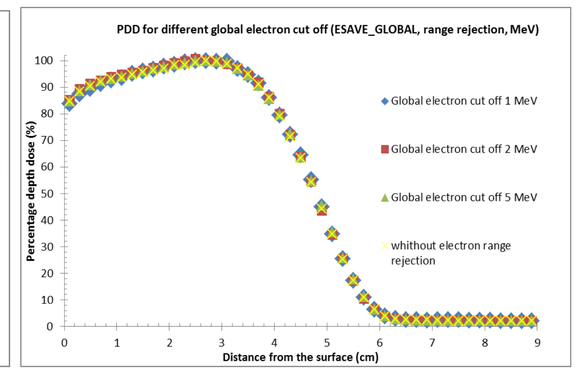

Figure 6: PDD of simulation using different electron cut off energy. Less than 1% errors was observed.

ii. **Particle History:** Particle history 7.5 x 10^7 shows the shorter calculation time, 5.8 hours compared to 13.7 hours for 20 x 10^7 particle history with electron range rejection of 5 MeV

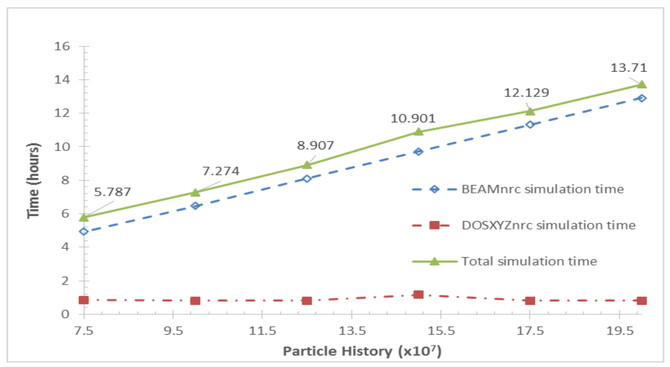

Figure 7: Simulation time using different particle history. 7.5 x 10^7 reduce simulation time to 5.8 hours.

iii. **Percentage Error of PDD:** Particle history of 7.5 x 10^7 simulation results unacceptable dose discrepancy (7.4%). 10 x 10^7 particle history results less than 1% dose errors.

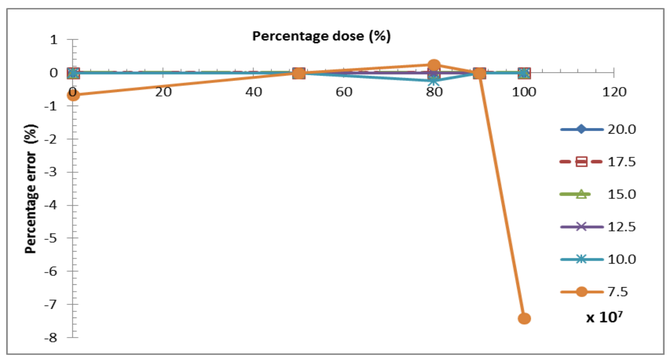

Figure 8: Percentage errors of simulation using different particle history. 7.5 x 10^7 particle history result high percentage error at D_{max}.

CONCLUSIONS

- The optimise VRT for 12 MeV electron beam is 5 MeV global electron cut-off energy and 10 x 10^7 particle histories.
- These parameters reduce total calculation time from 27.6 hours to 7.3 hours and demonstrated less than 1% deviation from the non-VRT calculation.
- 5 MeV global electron cut-off energy and 7.5 x 10^7 particles history result unacceptable dose discrepancy for MC calculation.

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