Low energy electron beam dose calculation using eMC

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Introduction

In Eclipse (Varian Medical Systems) the electron Monte Carlo (eMC) dose calculation algorithm is based on the macro MC method [1, 2] and is able to accurately predict dose distributions for high energy electron beams. However, there are some limitations for low energy electron beams such as 4 and 6 MeV. The aim of this work is to improve the accuracy of the dose calculation for 4 and 6 MeV electron beams of Varian linear accelerators using eMC.

Material and Methods

The eMC algorithm implemented in Eclipse uses the initial phase space multiple source model (IPS) as particle generator [3] and the macro MC method for the dose calculation [1, 2]. The IPS consists of 4 sub-sources: a *main diverging source* representing electrons and photons coming from the scattering foil; an *edge source of electrons* which accounts for electrons produced at the edges of the applicator or insert; a *source of transmitted photons* through the applicator or insert and a *second diverging source* which takes into account all the photons and electrons not included in the aforementioned sources. Figure 1 shows a schematic view of the 4 sub-sources.

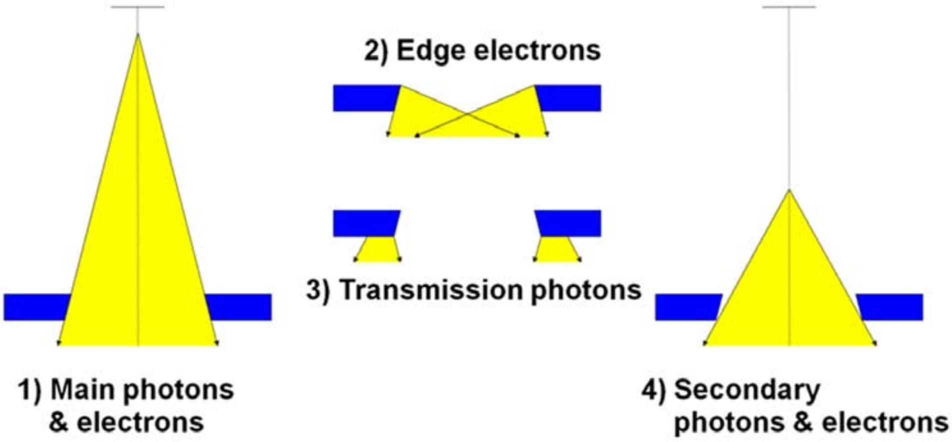

Figure 1: *Schematic representation of the four sub-sources used by the IPS model [3]: 1) main diverging sub-source of electrons and photons, 2) sub-source of edge electrons, 3) sub-source of transmitted photons and 4) second diverging sub-source of electrons and photons.*

In order to improve the accuracy of the dose calculations for low electron beams, the original eMC implementation has been modified with respect to both the beam model and the transport code for the dose calculation. In this improved version of the beam model all three scrapers of the applicator are taken into account. Based on the geometric information of the scraper positions it is determined for each sampled electron from the main diverging source whether or not it intersects within a scraper. If there is an intersection, the electron is rejected otherwise the particle is transported downstream for the dose calculation. In order to improve the accuracy of the energy spectrum for the electrons of the main diverging source, the resolution of the mono-energetic depth dose curves used during beam configuration has been increased.

The modification of the transport code for the dose calculation has been performed by reducing the maximum allowed size of the sphere used for the electron transport according to the energy of the initial electron. Overall, spheres between 1 mm and 5 mm are available. Thresholds between 4 and

7.5 MeV have been introduced so that if the energy of the incident electron is below such a threshold the maximum size of the possible sphere is reduced. This scheme is illustrated in figure 2.

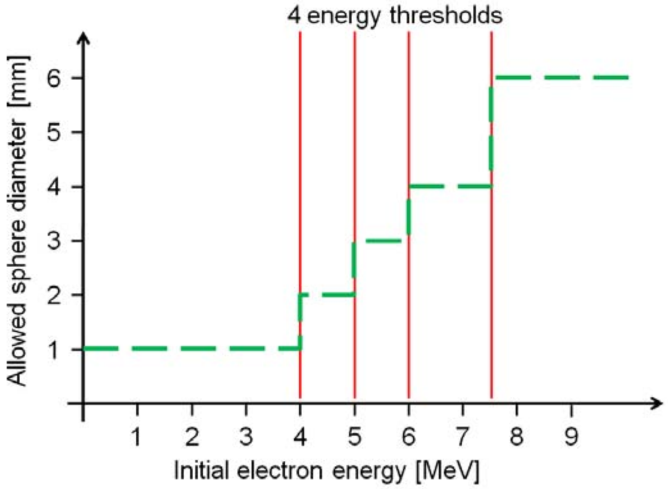

Figure 2: *The maximal allowed sphere sizes used in the dose calculation as a function of the initial energy of the electron. The energy thresholds are shown as red lines. The maximum allowed sphere size is gradually reduced with reduced initial energy illustrated as broken green line.*

The impact of these changes in eMC is investigated by comparing calculated dose distributions for 4 and 6 MeV electron beams with applicators ranging from 6x6 to 25x25 cm^2 of a Varian Clinac 2300C/D with the corresponding measurements.

Results

In figure 3 calculated absolute depth dose curves together with the corresponding measurements are shown for the 4 MeV beam and a 10x10 cm^2 applicator. On the left the results are depicted using the original implementation of the eMC and on the right the improved version of eMC is used. The agreement with the improved eMC is within 1.5%, whereas the original eMC leads to dose differences of up to 6%.

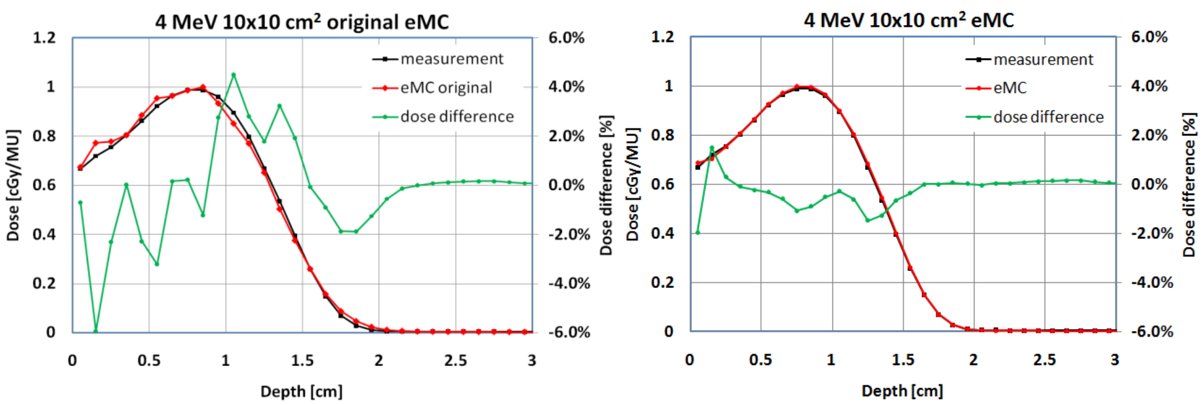

Figure 3: *Calculated and measured absolute depth dose curves in water comparison for a 4 MeV electron beam with a 10 x 10 cm^2 applicator together with the corresponding dose differences using the original (left) and improved (right) eMC.*

The analogous data for the 4 MeV beam and a 25 x 25 cm^2 applicator is shown in figure 4 demonstrating the increased accuracy when using the improved version of eMC. Overall, the agreement between measured and calculated absolute depth dose curves using the improved eMC is within 1.5% for 4 and 6 MeV energies and all applicators considered, whereas the original eMC leads to dose differences of up to 6%.

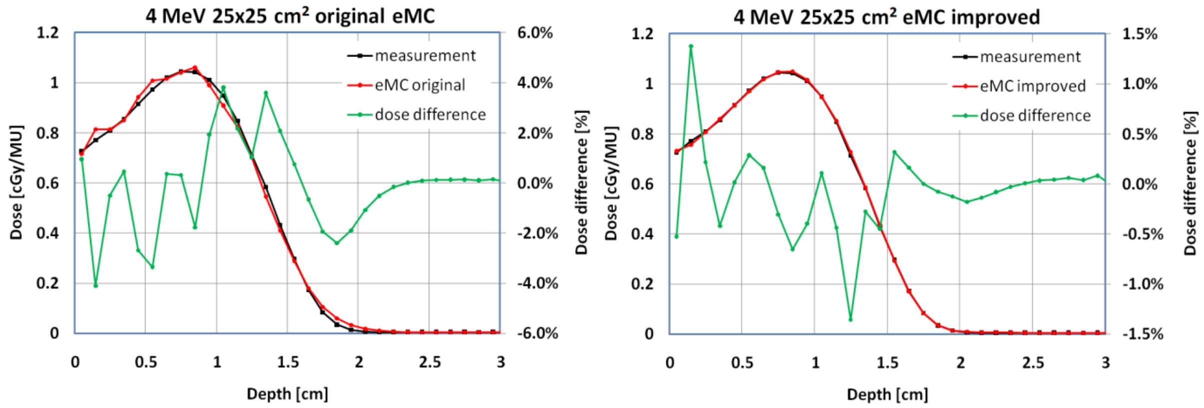

Figure 4: *Calculated and measured absolute depth dose curves in water comparison for a 4 MeV electron beam with a 10 x 10 cm2 applicator together with the corresponding dose differences using the original (left) and improved (right) eMC.*

Figure 5 depicts examples for calculated and measured absolute dose profiles at several depths in water. The original eMc version leads to dose differences of up to 8% for low electron beams and applicators larger than 15x15 cm^2. Those differences are reduced to about 2% for all dose profiles investigated when the improved version of eMC is used.

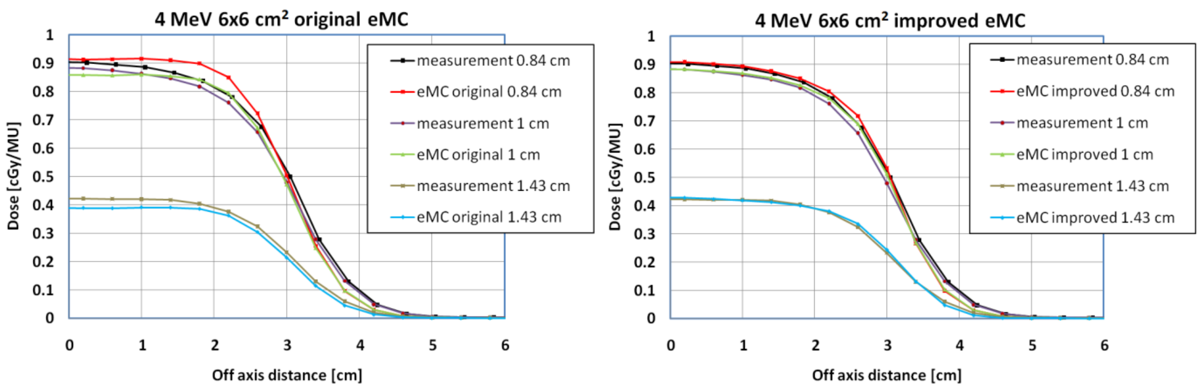

Figure 5: *Calculated and measured absolute dose profiles at several depths in water comparison for a 4 MeV electron beam with a 6 x 6 cm2 applicator using the original (left) and improved (right) eMC.*

Discussion

In this work several enhancements were made in the original eMC beam model and dose calculation algorithm. It has been shown that these modifications lead to significant improvements in the accuracy of the dose calculation for 4 and 6 MeV electron beams of Varian linear accelerators. This work was supported by Varian Medical Systems.

References

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