Verification of a Monte Carlo-based source model for a Varian 10 MV photon beam

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Introduction

We are developing a flexible measurement-driven machine modeling process coupled to the Monte Carlo Dose Planning Method (DPM) dose calculation algorithm[1] to be used in the quality assurance of clinical trials. The multi-source model will be generic enough to include several photon energies (6 MV and 10 MV) from several linac manufacturers (Elekta, Siemens, and Varian). The work presented here details the development of the Varian 10 MV photon beam which is an extension of the original work based on the Varian 6 MV photon beam (See poster SU-GG-T-143).

Material & Methods

The three-source model (Figure 1) comprises of a primary photon isotropic point source, an extra-focal exponential disk source[2], and an electron contamination uniform disk source. The model accounts for fluence and off-axis energy[3] effects due to the flattening filter. The photon energy spectra for the primary and extra-focal sources are modeled by the statistical fatigue-failure function[4] combined with a Fermi-cutoff function. The energy spectrum of the electron contamination source is modeled by an exponential distribution.[5] The patient dependent aspect of the Monte Carlo dose calculation utilizes jaw positions and the multi-leaf collimator (MLC) leaf sequence file exported from the treatment planning system DICOM output.

Diagram	Source	Energy	Distribution
	Primary	Fatigue*Fermi (w/ off-axis softening[3])	Isotropic point, but w/ horn-effect
	Flattening filter (extra-focal)	Fatigue*Fermi, scaled down	Exponential, disk[2]
	e^- contamination	Exponential[5]	Uniform disk[5]

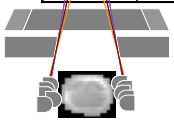

Figure 1: Table and figure describe the components of the three-source model including energy and distribution.

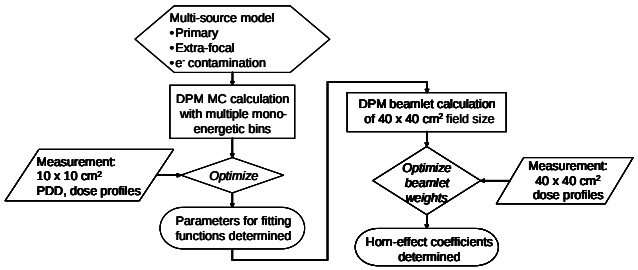

Figure 2: Commissioning process to determine the model parameters for energy spectrum (primary & extra focal), relative fluences for extra-focal and electron contamination sources, IC penumbra smearing, and horn-effect coefficients.

Model parameters are determined by an optimization process that minimizes the differences between measurement and calculation (Figure 2). To begin, doses are calculated for discrete energy bins having equal weight. Next, model parameters including those that define the energy spectrum, the relative fluences for the extra focal source and electron contamination source, and a smearing parameter to account for the volume effects of the ion chamber in the beam penumbra region are determined from percent depth dose (PDD) and dose profiles for the 10 x 10 cm² field size. With those parameters known, coefficients from a piecewise linear function that describe the increase in fluence as the off-axis axis increases (horn-effect) are determined from the optimization process using the dose profile at d_{max} for 40 x 40 cm² field size.

Results

To date, only the first step of the two step commissioning process has been completed. Results show the fatigue function combined with the Fermi cutoff function is able to reproduce an energy spectrum comparable to that computed in BEAM[6] (Fig. 3) for the Varian 10 MV photon beam. Comparisons between calculation and measurement for a 10 x 10 cm² field size show agreement within ±2%/2 mm except for the off-axis low-dose regions where DPM underestimates the dose up to 3% of dmax (Figures 4 and 5).

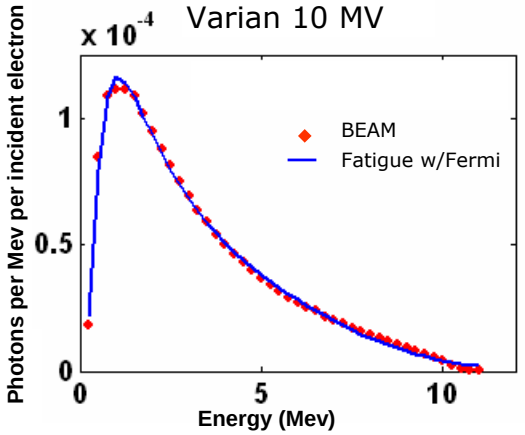

Figure 3: Energy spectrum comparison between Fatigue and combined Fermi function (blue) and the BEAM[6] (red) for Varian 10 MV photon beam

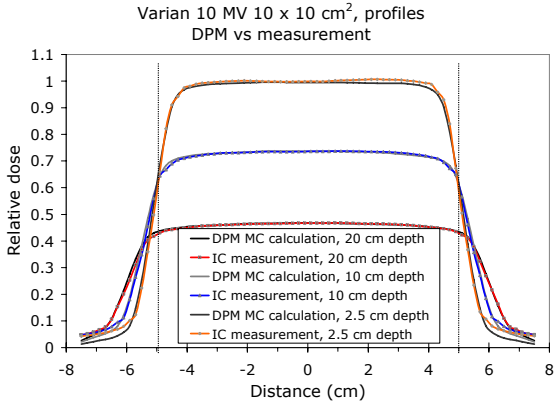

Figure 4: Comparison of the profiles at the depths of 2.5 cm, 10 cm, and 20 cm show good agreement at the ±2%/2 mm criteria level except for the low dose regions where the model tends to underestimate the dose.

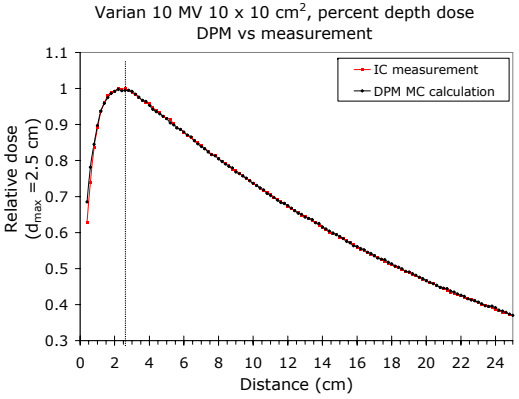

Figure 5: PDD comparison between the ion chamber measurement and the DPM Monte Carlo calculation shows agreement to ±2%/2 mm.

Conclusions

This work demonstrates the model can be extended to include the Varian 10 MV photon beam, although further development of the extra-focal model and/or jaw transmission is expected to improve agreement in the low dose regions. Commissioning the source model to include fluence changes due to the horn-effect is expected to be completed shortly enabling full validation of the Varian 10 MV photon beam. The model is also being extended to include Elekta and Siemens accelerators.

References

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