DOSE CALCULATION FOR ORTHOVOLTAGE RADIOTHERAPY USING SWISS MONTE CARLO PLAN

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Introduction

Dose calculation for low energy (kV) treatments are mainly based upon measured depth dose curves and output factors in water for the used energies and add-ons. Therefore, treatment planning is limited and interpretation of clinical outcome of the treated patients becomes very difficult because of not knowing the delivered 3D dose distributions. Due to difficulties in low energy dose calculations using analytical models, Monte Carlo dose calculations are preferred in this situation. The goal of this work is to enable dose calculations of an orthovoltage beam within the Swiss Monte Carlo Plan (SMCP)[1].

Material and Methods

To implement the geometry of the PANTAK DXT300 equipped with a COMET MXR-321 x-ray tube, the dimensions of all beam defining components were measured. The parts within the vacuum tube could not be measured and therefore the dimensions supplied by the manufacturer were used. The thickness of the Beryllium window and the anode angle were assumed to be 3 mm and 30°, respectively, as provided by the manufacturer. X-ray tube voltages were measured with the Keithley Triad System 35080B non invasive divider and the Mobile Filter Pack 50-135kV. Measured x-ray tube voltages were about 5% higher than the nominal voltages. The geometry was implemented in BEAMnrc[2] using the provided user interface. Geometry modules XTUBE, SLABS, CONS3R, CONESTAK and CHAMBER were used to define the X-ray tube with the energy depending filter.
A first phase space was generated after the exit window of the PANTAK machine for each of the available 8 energies (50 kV, 75 kV, 100 kV, 125 kV, 150 kV, 200 kV, 250 kV, 300kV). A second phase space was created after an add-on using the previous generated phase space data from the Pantak machine head as input (see figure 1). Having 8 energies and 7 add-ons meant to produce 43 phase spaces, 8 for each energy and 35 for each add-on at each energy. Using particles from the phase space below the add-on, dose calculations in a 30x30x30 cm^3 water tank were performed with the DOSXYZnrc code within SMCP. Simulation results were compared with measurements made with an ionization chamber (PTW 31010 0.125 ccm) as well as with a Diode (PFD Scanditronix) to obtain measurements near the surface for energies lower than 100 kV. Having checked the plausibility, the phase spaces were taken as input for the SMCP calculations on CT data.

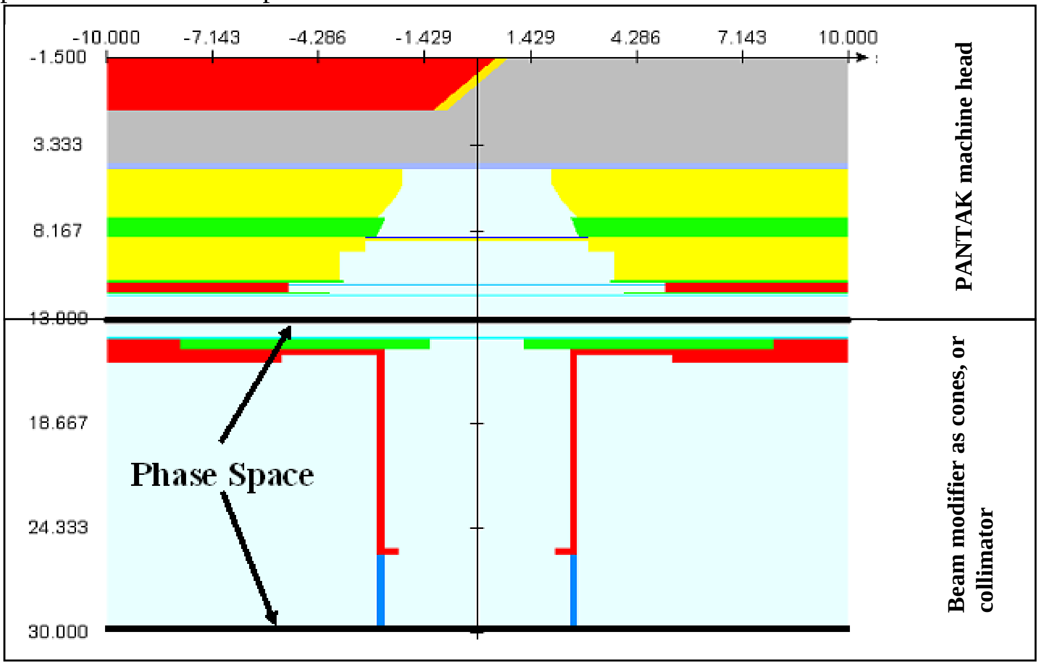

Figure 1: Scheme of the PANTAK DXT 300 implementation in BEAMnrc with the 5 cm cone

Results

Calculated and measured depth doses and profiles for all add-ons agree within the 3% (2σ) uncertainty. As an example the percentage depth dose (PDD) curve of the 300kV beam with the 2.5cm cone is shown in figure 2 and the corresponding PDD for the 5cm cone at 100kV is represented in figure 3. In figure 4 the PDD is calculated for the 2.5 cm cone at 100 kV within the SMCP framework and in figure 5 a crossplane-profile at 20 mm depth in water for the 5 cm cone at 50 kV is shown. Dose calculation grid size was 2x2x2 mm^3 for all presented calculations. Dots represent MC calculations and the dashed line the measurement in figures 2 to 5.

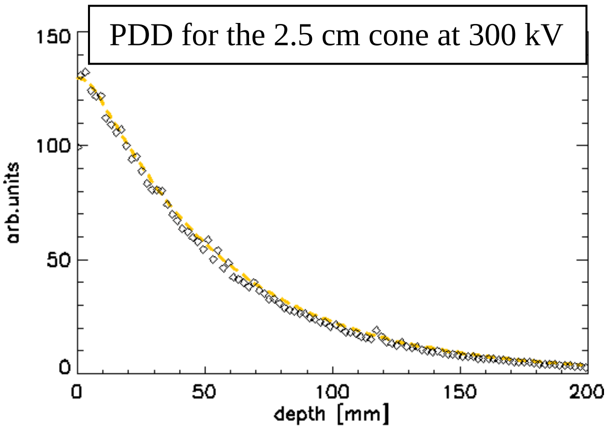

Figure 2: PDD for 2.5 cm cone at 300kV

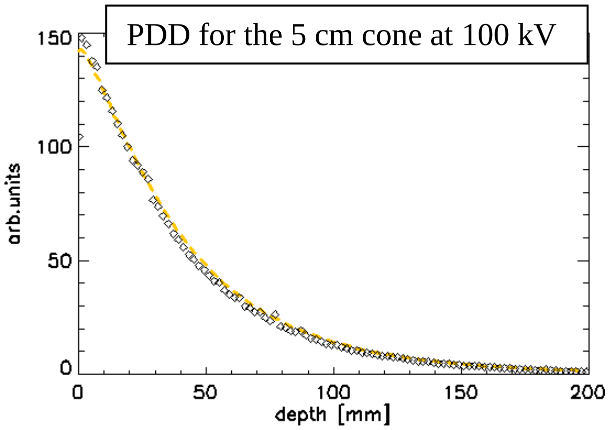

Figure 3: PDD for 5 cm cone at 100kV

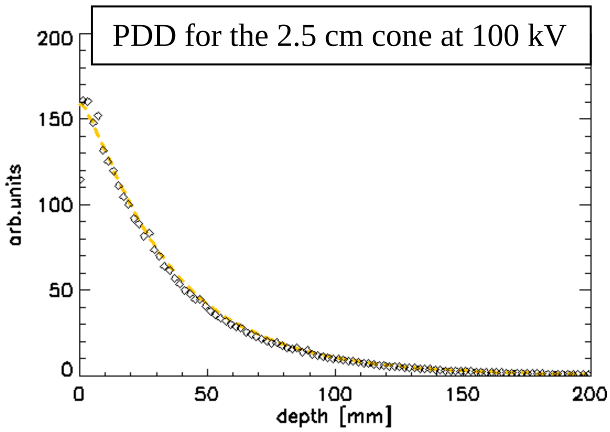

Figure 4: PDD for 2.5 cm cone at 100 kV

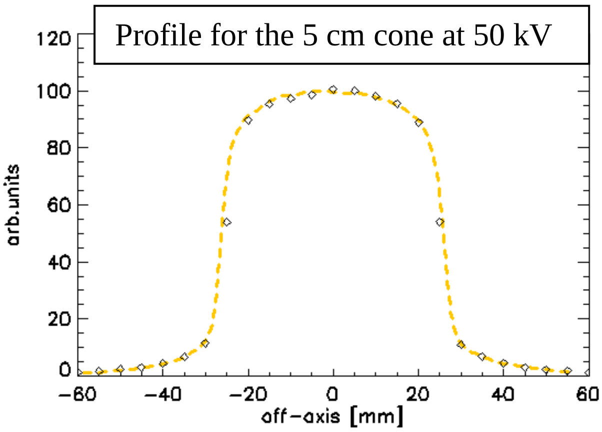

Figure 5: crossplane-profile in water for 5 cm cone at 50 kV in a depth of 2 cm

Figure 6 represents the resulting 3D dose distribution of a typical nose treatment using one field with a 5 cm cone at an energy of 100 kV calculated using SMCP. Due to calculating dose to medium bony structures absorbed about 4 times more energy than water equivalent tissue at this energy. This is also visible in the related dose volume histogram (DVH) shown in figure 7.

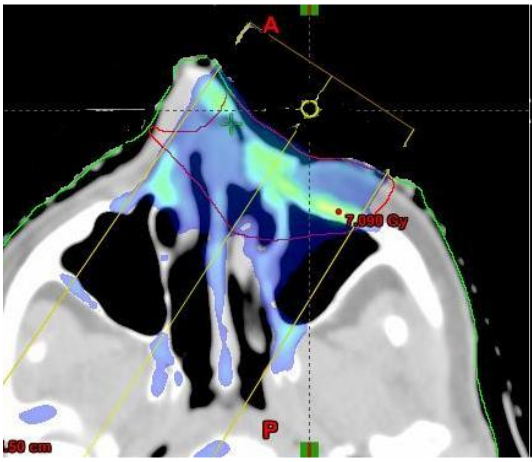

Figure 6: 3D dose distribution of a nose treatment

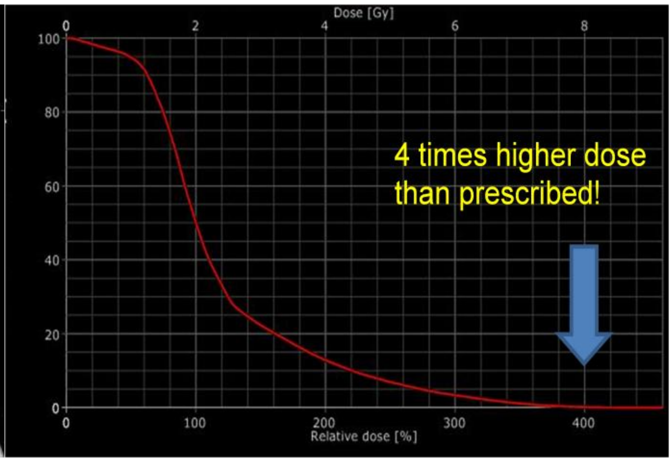

Figure 7: DVH of the dose distribution shown in figure 6

Figure 8 represents the resulting 3D dose distribution of an academic skull treatment using 5 fields with an energy of 100 kV each defined with an adjustable collimator calculated using SMCP. The surface of the skull receives a mean dose of 2 Gy, whereas bony structures receive again up to 5 times more dose due to dose to medium calculation and overlapping of the treatment fields.

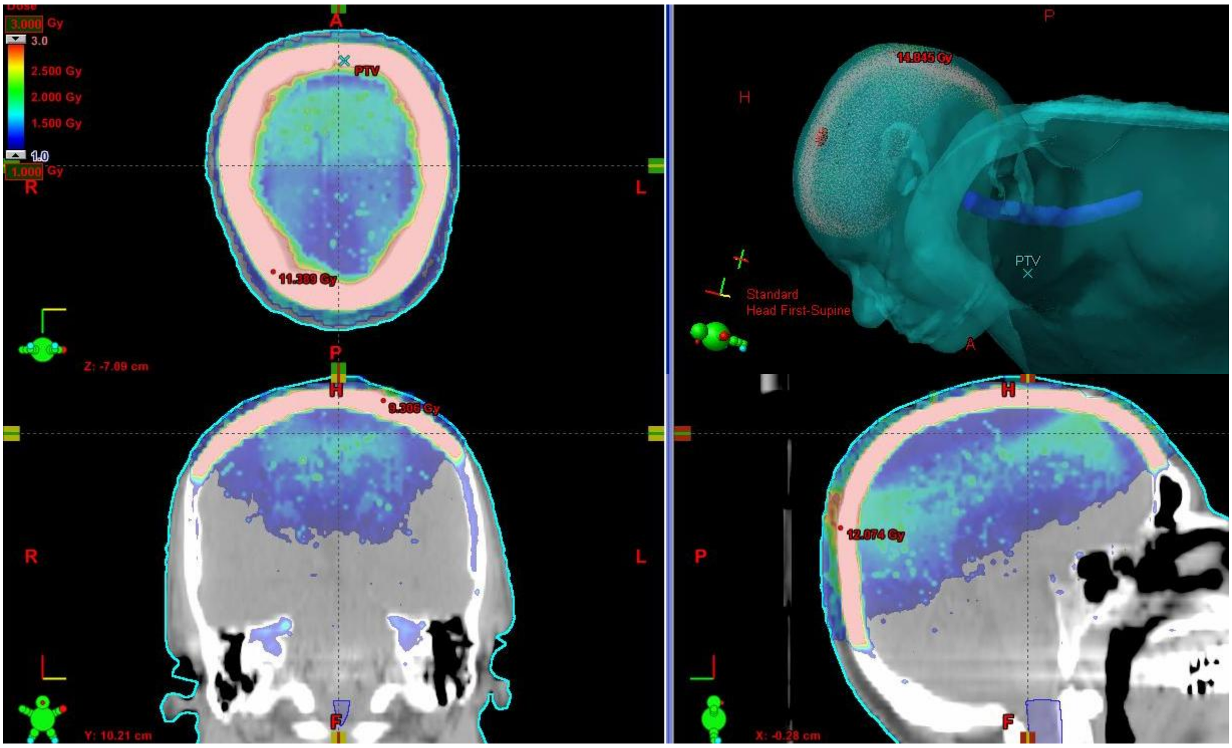

Figure 8: 3D dose calculation of an academic 5 field skull treatment using an adjustable collimator at 100 kV

Discussion

3D dose calculations of an orthovoltage treatment have been performed using SMCP with phase space data derived using the BEAMnrc user code. To improve accuracy of simulations an optimization of the geometries is work in progress. To obtain better statistics, that means lowering the simulation uncertainties, the number of simulated particles have to be increased. Enabling the calculation of dose to water within SMCP will be considered if necessary. The interpretation of such dose calculations as shown is beyond the goal of this work but have to be discussed elsewhere.

References

[1] Fix M K et al, An efficient framework for photon Monte Carlo treatment planning, Phys. Med. Biol. 52, N425-N437, 2007

[2] Kawrakow I, Rogers DWO, The EGSnrc Code System: Monte Carlo Simulation of Electron and Photon Transport, NRCC Report PIRS-701, 2003