A simulation framework of the preclinical proton irradiation workflow

Justin Malimban[1], Felix Ludwig[1], Danny Lathouwers[2], Marius Staring[3], Frank Verhaegen[4] and Sytze Brandenburg[1]

[1]Department of Radiation Oncology and Particle Therapy Research Center, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands
[2]Department of Radiation Science & Technology, Delft University of Technology, Delft, the Netherlands
[3]Department of Radiology, Leiden University Medical Center, Leiden, the Netherlands
[4]Department of Radiation Oncology (MAASTRO), GROW School for Oncology and Developmental Biology, Maastricht Medical Center, Maastricht, the Netherlands

The size of orthotopic tumors in small animals (typically a few mm) presents some challenges in preclinical proton dose delivery. For tumors situated deeper in the animal close to critical organs, determination of the actual dose distribution and conformity is challenging especially for Bragg peak irradiations. Therefore, it is important to optimize beam properties, verify CT HU-RSP calibration, and ensure the quality of dose distributions.

In this work, we present a simulation framework that (1) allows generation of realistic X-ray μ-CBCT images, (2) facilitates CT HU calibration, and (3) performs proton dose calculations.

A μ-CBCT model was developed using the fastCAT toolkit. Monte Carlo simulations were performed to generate the primary and scatter kernels and imaging dose calibration appropriate for μ-CBCT scans. CTs were then generated for a mini Gammex phantom and the MOBY/ROBY digital rodent phantoms. The HU – SPR conversion is performed with the mini Gammex phantom. The resulting calibration parameters are then used to convert the CTs of the MOBY/ROBY phantoms to SPR maps. These are then used to calculate dose distributions in TOPAS for treatment plans created in matRad using realistic beams based on measured emittances and simulations of the beam transport with BDSIM. Since the composition of the MOBY/ROBY phantoms is known, a ground truth exists against which the accuracy of the calibration and dose distributions can be verified.

This framework is used to optimize the irradiation setup and assess the quality of small animal irradiations.