Dose computation and validation for collimated small carbon ion fields

Background

There is a growing interest in computing accurate carbon ion dose for small field sizes. This would enable future animal experiments and treatments of small shallow targets such as ocular melanoma. The clinical RayStation version does not support collimators in carbon ion beams, and the dose computation is adapted for fields larger than a few centimeters. We have therefore developed a research prototype with improvements to the light ion dose engine in RayStation.

Methods

The prototype supports dose grid resolutions up to 0.2 mm, with added support for collimators. The collimator shape is projected along the beam and is used to mask the spot fluence, where the drop in fluence is modelled with a sigmoid function. The sigmoid parameters are determined by fits to single energy layers simulated in FLUKA [1,2].

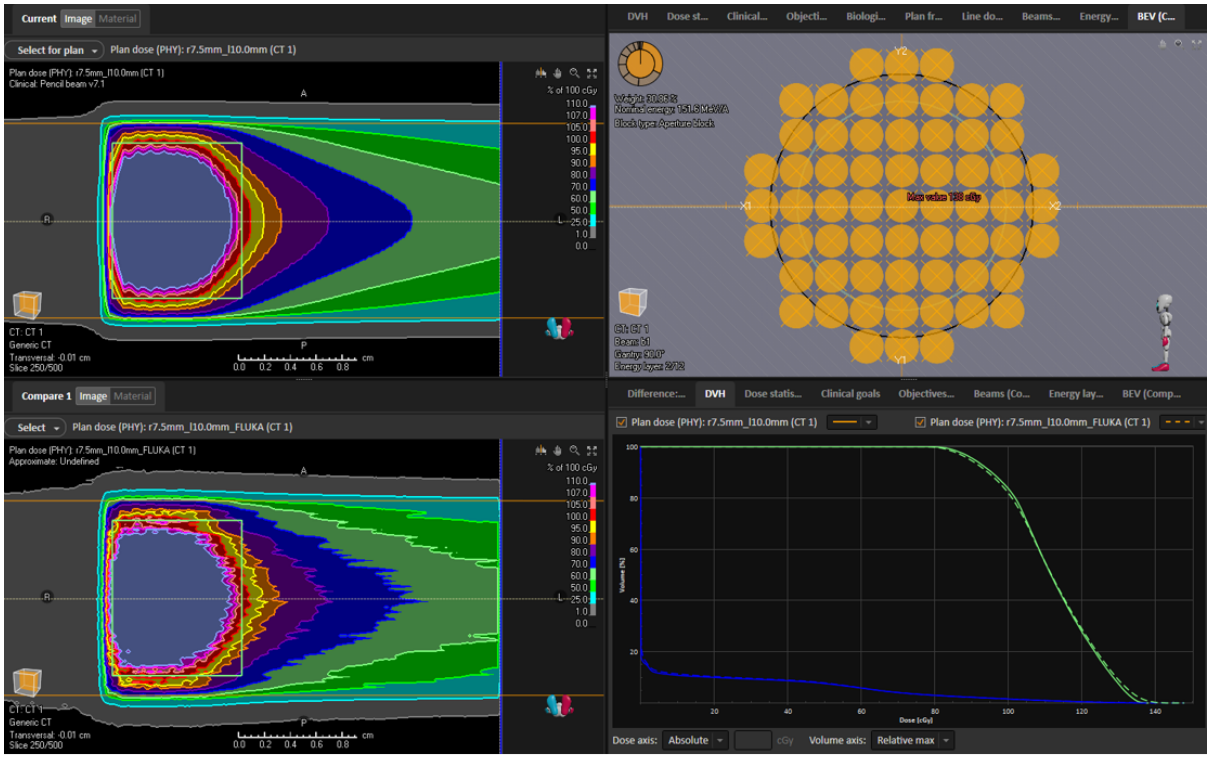
Validation of the dose calculation was done by comparison against reference simulations performed with FLUKA. Brass collimators with varying radius were placed 10 cm upstream of a water phantom and a 2 cm PMMA range shifter was placed 70 cm upstream of the collimator. The dose was optimized to achieve min DVH of 100 cGy to 80% volume in a cylindrical ROI with length 1.0 cm and radius 1.5 mm smaller than the collimator at 2.0 cm depth.

Results

Volume gamma analysis with criteria of 3%/1mm and 5%/1mm were performed to assess the RayStation calculation. The gamma results are shown in the table. The plan with 7.5 mm collimator is shown in the figure.

Collimator radius [mm]	Gamma > 1.0 (3%/1mm) [%]	Gamma > 1.0 (5%/1mm) [%]
10.0	8.8	2.2
7.5	4.9	1.5
5.0	5.0	1.6

Volume gamma analysis results. The gamma percentages indicate the ratio of voxels failing the gamma criteria. Only voxels with a dose level of at least 10% of the maximum dose are evaluated.



Comparison of RayStation and FLUKA dose calculation. **Top left:** RayStation dose distribution. **Bottom left:** FLUKA dose distribution. **Top right:** Beams-eye view of the delivered plan. Spots are placed with a constant spacing of 2 mm. The brass collimator with 7.5 mm radius is shown with a black circle. The target ROI with radius 6.0 mm is shown with the green circle. **Bottom right:** Dose-volume histogram of the target cylinder ROI and the whole water phantom. The solid line is RayStation calculation, and the dashed line is the FLUKA simulation.

Conclusions

Support for collimated dose calculation for small fields was implemented in a research version of RayStation. Validation against FLUKA showed good agreement and will be extended with validation against measurements performed at MedAustron. In addition to carbon ions, the prototype can be expanded to other ion species in the future.

References

[1] T.T. Böhlen, F. Cerutti, M.P.W. Chin, A. Fassò, A. Ferrari, P.G. Ortega, A. Mairani, P.R. Sala, G. Smirnov and V. Vlachoudis, Nuclear Data Sheets 120, 211-214 (2014)

[2] A. Ferrari, P.R. Sala, A. Fassò, and J. Ranft, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773