IDEAL/GATE-RTion for independent dose calculation in carbon ion beam therapy

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Background: The IDEAL v1 software was released in March 2021 enabling independent dose calculation (IDC) of light ion beam treatment plans with GATE-RTion/Geant4 [1]. The aim of IDEAL is to replace time consuming and little specific patient specific quality assurance (PSQA) measurements with IDC for carbon ions. IDEAL v1 offers physical dose computation in phantom and voxelized geometries, while v2.0 will also offer RBE weighted dose computation, since RBE varies by up to a factor 3 over the clinically relevant beam ranges and doses.

In this study we extended on the one hand the dose benchmark for carbon ions compared to an earlier study [1], and, on the other hand we investigated LEMI-RBE computation with Geant4 against FLUKA where most experience is based.

Material and Methods: The beam model was validated from 120.0 to 402.8 MeV/u against 1D/2D and 3D beam line and TPS commissioning measurements in water and air [1].

The TPS uses pre-generated energy fluence look-up tables to calculate the RBE. By default, they are generated by the vendor using FLUKA, where the influence of the nozzle elements is approximated. To evaluate both, the influence of the nozzle and difference between FLUKA2011 and GATE-RTion, two additional fluence tables were generated with those two applications using a detailed geometry and compared for 3 water and 10 patient cases.

While IDEAL v1 is using GATE-RTion v1, which is based on GATE 8.1/Geant4 10.3, GATE-RTion v2 will be based on GATE 10, which will replace the macro file with a python interface. This will drastically simplify the IDEAL v2 (mostly python 3.6) interface and facilitate implementing new features as well as data pre- and post-processing.

Preliminary results: Beam ranges and peak widths in water, as well as lateral beam widths in air, agreed within 0.3 mm with measurements, thus verifying the accuracy of the beam model. Point doses in the cuboidal targets agreed in average better than 3%. Currently more complex geometries are investigated.

RBE weighted doses differed in average by less than 1% in the water as well as in the patient cases.

Thus, we conclude that IDEAL v1 can be used to replace PSQA measurements, but RBE computation needs to be implemented and commissioned in v2 to provide a more clinically relevant IDC.

[1] Grevillot *et al.*, Front. Phys. V9, pp. 1-14, 2021
[2] Resch *et al*., Med. Phys. V49/6, pp.4092-8, 2022