Istituto Nazionale di Fisica Nucleare

Radiobiology

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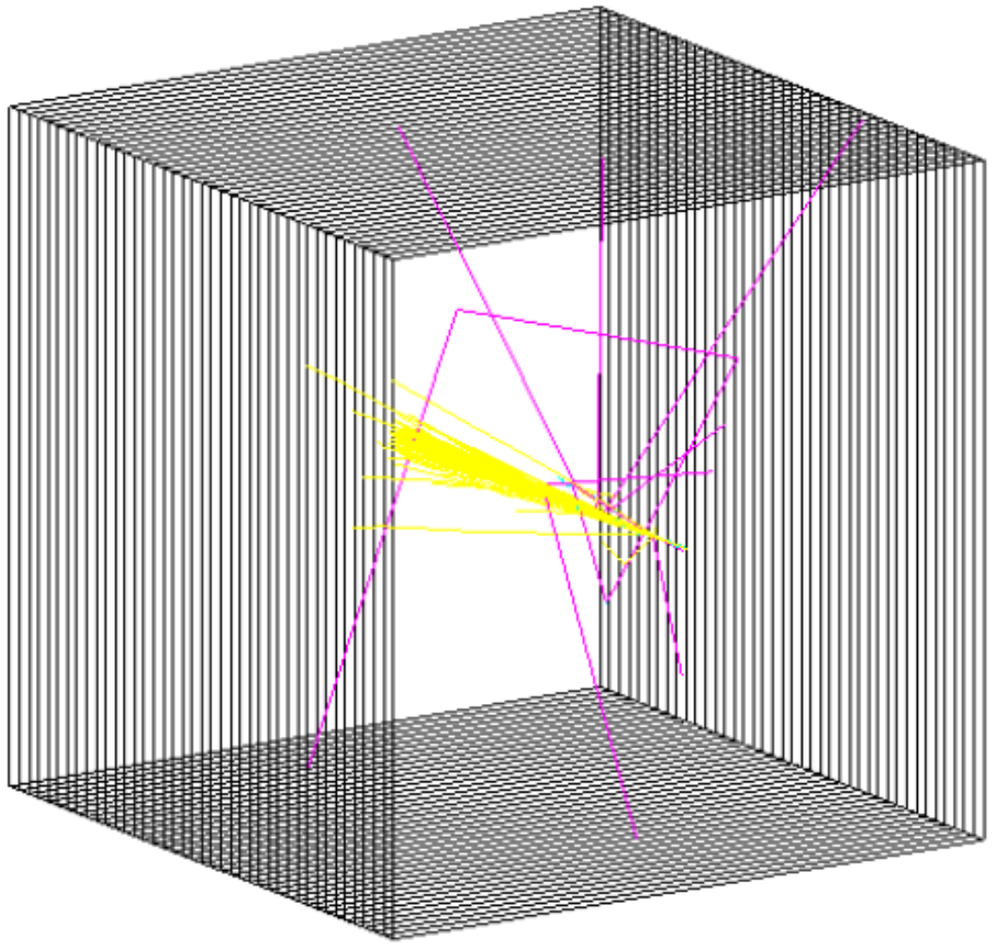
Geometry

Customisable water tank used as a phantom in clinical hadrontherapy.

default tank dimensions of 4x4x4 cm, sliced into 0.2x40x40 mm.

Voxel dimensions customisable by the user



Physics Models

Predefined physics list targeting medical applications:

Electromagnetic: G4EmStandardPhysics_option4 for accurate electron, hadron, and ion tracking.

Hadronic: QGSP BIC and QGSP BIC HP constructors, incorporating Geant4's native models.

Output

Depth dose distributions

LET data collected in real-time, processed at the end of each simulation run.

Algorithms derived from the “hadrontherapy” example, validated many times with experimental data from proton and ion beams experiments:

Petringa, G., et al. "Monte Carlo Implementation of New Algorithms for the Evaluation of Averaged-Dose and -Track Linear Energy Transfers in 62 MeV Clinical Proton Beams." Physics in Medicine & Biology, vol. 65, no. 23, 2020, 235043.

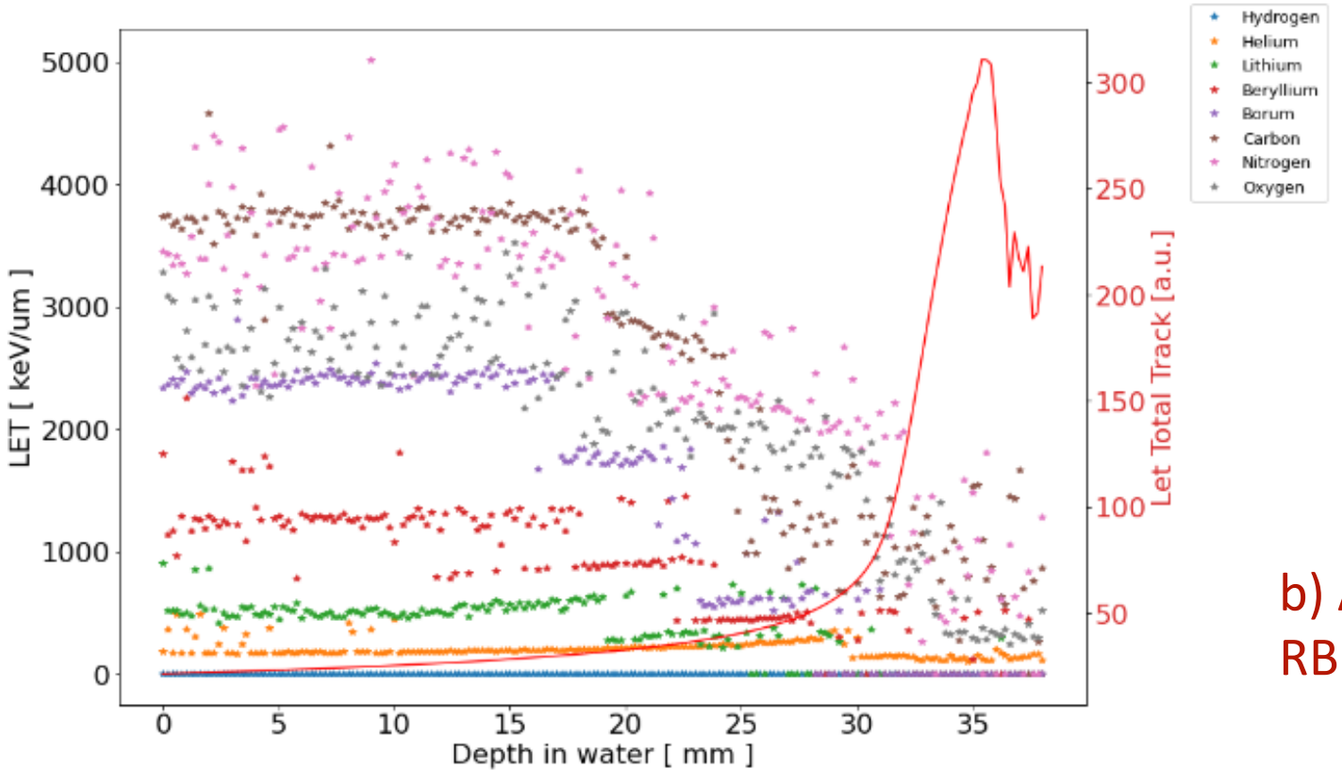
Fattori, S., et al. "4He Dose- and Track-Averaged Linear Energy Transfer: Monte Carlo Algorithms and Experimental Verification." Physics in Medicine & Biology, vol. 67, no. 16, 2022, 165003.

The **Look-Up Table (LUT)** based on LEM (I, II and III) and MKM method for calculating **Relative Biological Effectiveness (RBE)** involves pre-computed tables of RBE values based on specific parameters (namely alpha and beta)

Output files: Dose.out Let.out for LET values, AlphaAndBeta.out for alpha and beta parameters, and RBE.out for RBE.

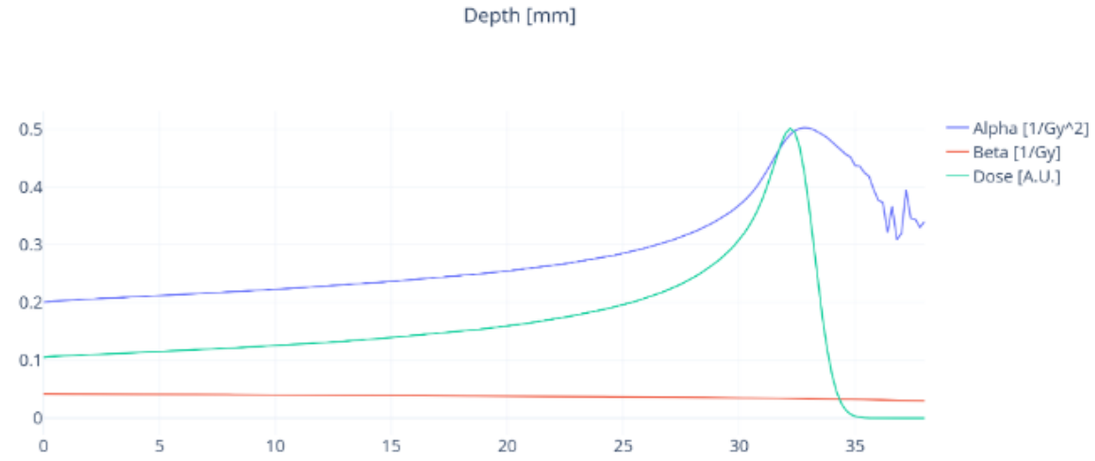
Example (clinical-like protontherapy beam)

The beam modelled after the protontherapy facility at INFN-LNS consists of **10M protons** simulated using a **Gaussian** energy distribution with a mean of **62 MeV** and a standard deviation of 0.65 MeV, the water phantom has a dimension of 4x4x4 cm and was divided in 0,2x4x4mm voxels



LET Total Track of secondaries (markers)

LET Total Track of primaries (red line)



b) Alpha (Blue line) and Beta (Red line) parameters for RBE calculation plotted together with the physical dose

Conclusions & Future Perspectives

Hadrontherapy is constantly maintained and developed

Upgrade for the laser-driven section is ongoing

16O validation is ongoing vs experimental microdosimetric data

Radiobiology example offers customisable geometry, advanced physics lists, and comprehensive outputs for dosimetric and biological evaluations.

Radiobiology **future direction**: **Sandbox usage** for testing Machine Learning (ML) post-processing models.

Aim: Improve the accuracy and efficiency of dosimetric and biological predictions.

Integration: Facilitate the implementation of ML algorithms into Geant4's workflow.

In system testing, pubblicazioni in December 2023, a paper is in progress.

Thanks for Listening

Left to right:
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