Extended example: medical/dna/jetcounter

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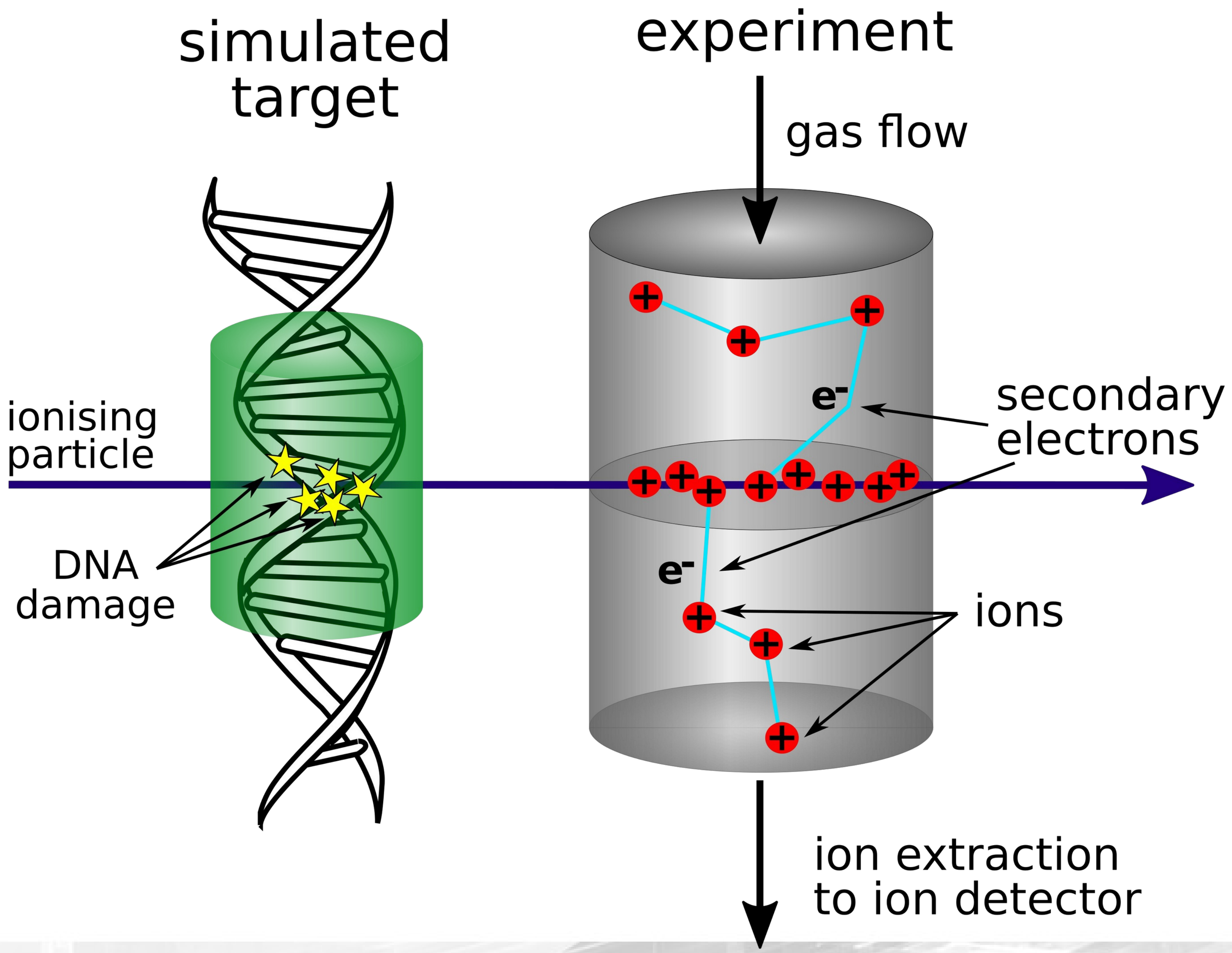
Jet Counter nanodosemeter

The **extended/medical/dna/jetcounter** example is meant to represent the Jet Counter nanodosimetric setup for measurements with alpha particles.

The Jet Counter device is an experimental model for a nanometric biological target comparable in size to a short segment of a DNA.



Geometry

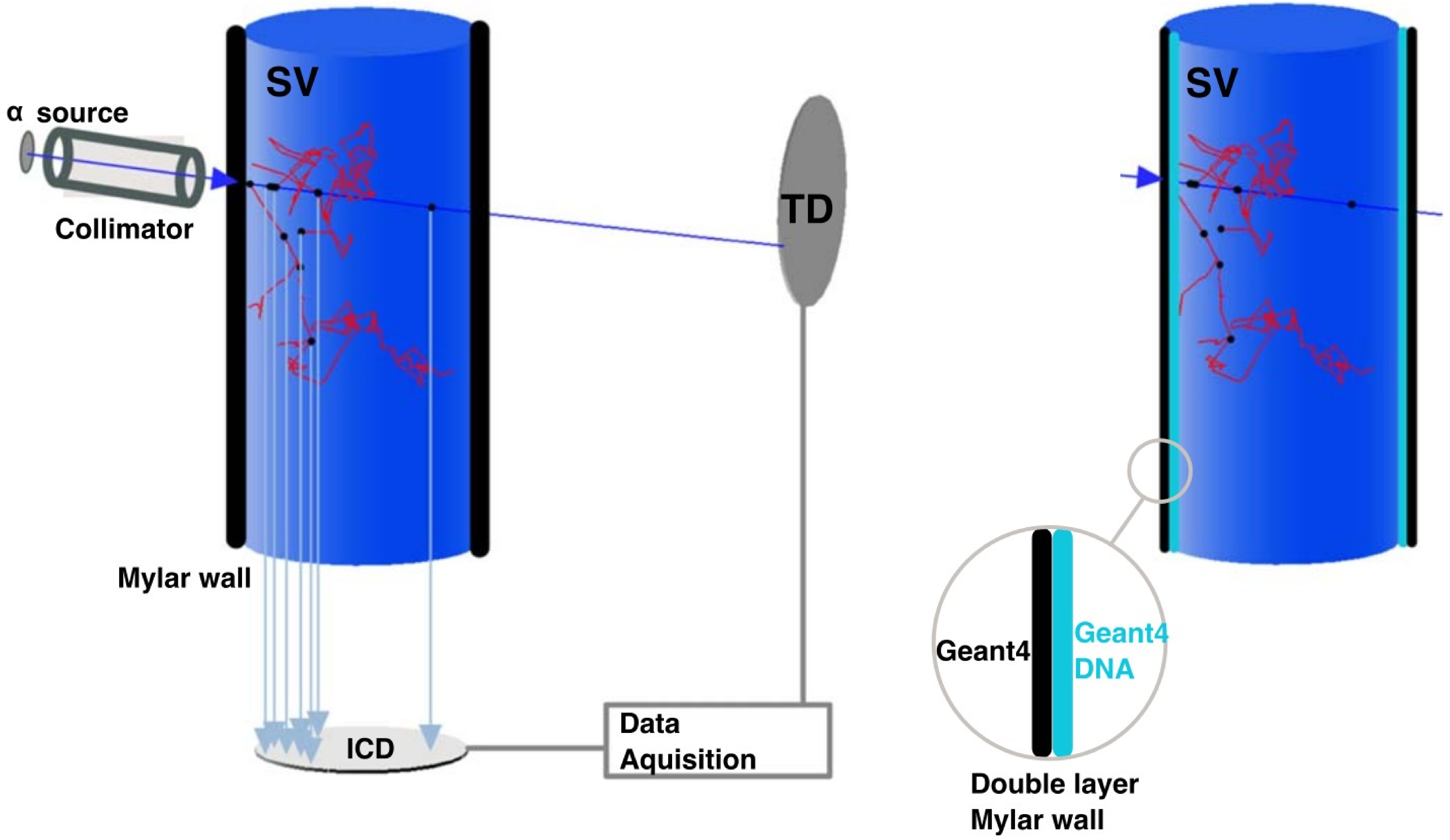
Schematic illustration of the
Jet Counter nanodosemeter setup
represented in the **jetcounter** example.

Cubic world (8×8×8 cm³) is filled with
0.15 mg/m³ G4_WATER.

Sensitive Volume (SV)
(2 cm in height, 1 cm in diameter)
is filled with 0.45 µg/cm³ G4_WATER.
Water is used instead of nitrogen, which
is used in the experiment.

Double layer wall 7 µm in total:
- outer: 6.86 µm of G4_MYLAR
- inner: 0.14 µm of G4_WATER (density of G4_MYLAR)

Trigger detector (TD) and collimator are
also represented in the simulation.
The trigger registers the energy
deposited in each event.



Physics

Two physics regions:

- World – G4EmLivermorePhysics
- Target – G4EmDNAPhysicsActivator – must be activated in the macro file "init_phys.in" by adding the target region with an option name, by default: `/process/em/AddDNARegion Target DNA_Opt4`

The boundary of the Target region is inside the wall.

Particle source

Custom made particle source based on G4ParticleGun that represents the properties of the experimental source (spectrum, intensity).

In the experiment, the source is Am-241 that emits alpha particles of energy equal to 5.5 MeV (degraded to 4.6 MeV due to losses in the gold covering layer).

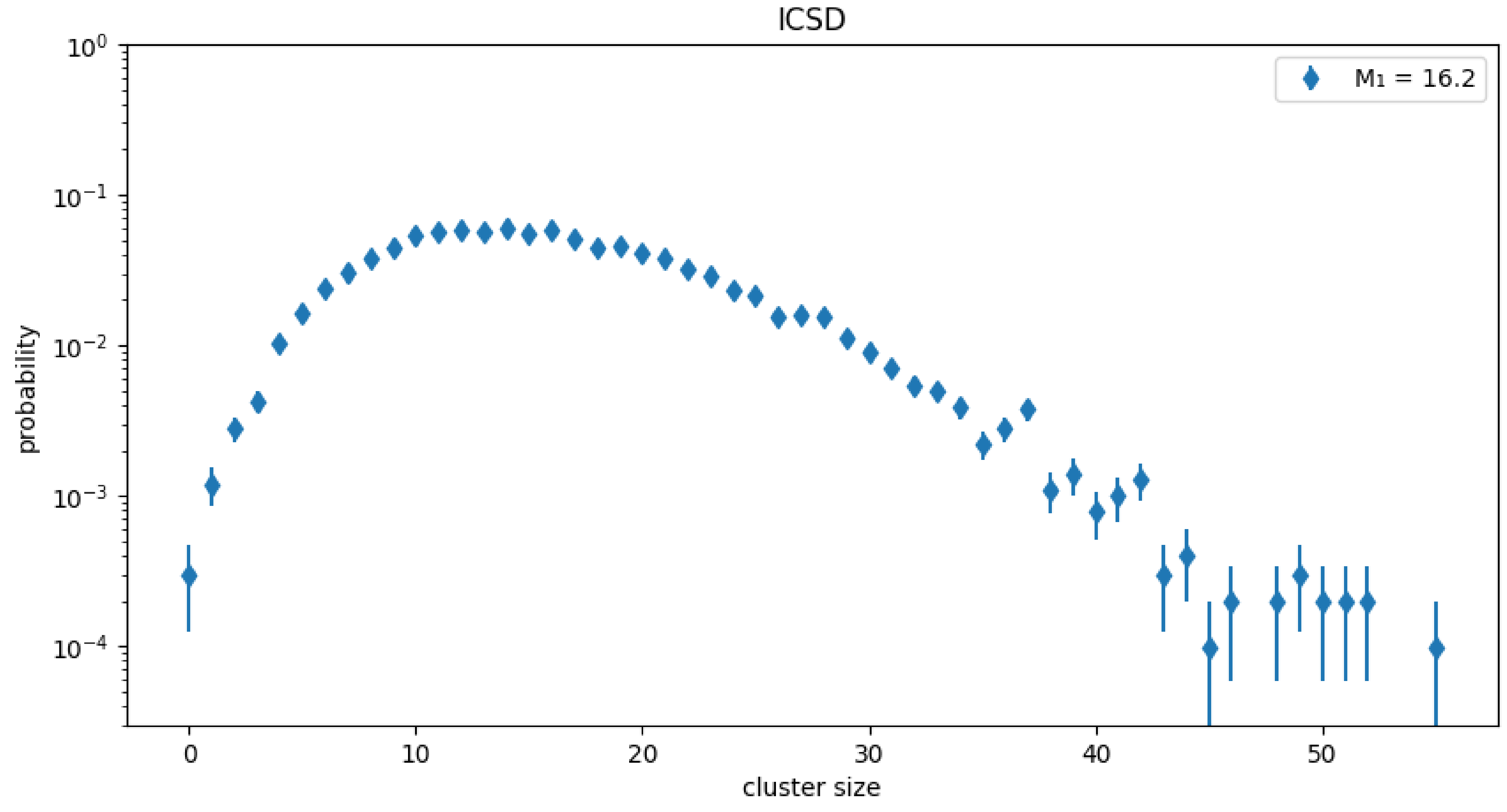
Output

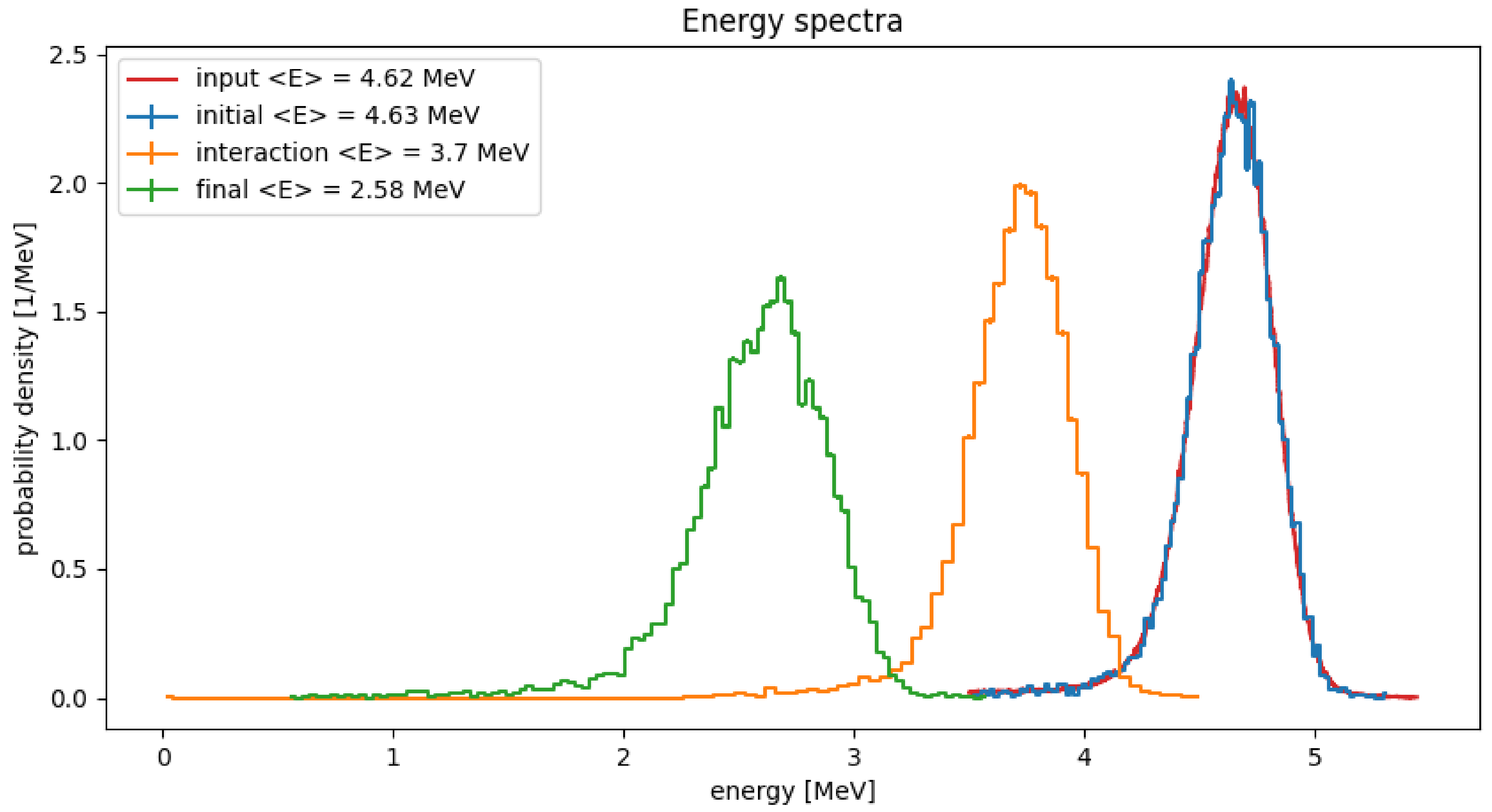
The simulation geometry can be visualised.
The output is in the form of two columns text file.

The first column contains the ionisation cluster size (number of ionisations) counted in the given event.

The second column contains the energy of the alpha particle responsible for creating the ionisation cluster.

A Python script is provided to read and plot Ionisation Cluster Size Distribution based on the simulation output, as well as three energy spectra (the input/initial energy of alpha particle, the energy inside Sensitive Volume (SV) and the final energy deposited in the trigger detector).





Paper

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PAPER

Geant4-DNA modeling of nanodosimetric quantities in the Jet Counter for alpha particles

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Supplementary material for this article is available online

Abstract

The purpose of this work was to validate the calculation accuracy of nanodosimetric quantities in Geant4-DNA track structure simulation code. We implemented the Jet Counter (JC) nanodosimeter geometry in the simulation platform and quantified the impact of the Geant4-DNA physics models and JC detector performance on the ionization cluster size distributions (ICSD). ICSD parameters characterize the quality of radiation field and are supposed to be correlated to the complexity of the initial DNA damage in nanoscale and eventually the response of biological systems to radiation. We compared Monte Carlo simulations of ICSD in JC geometry performed using Geant4-DNA and PTra codes with experimental data collected for alpha particles at 3.8 MeV. We investigated the impact of simulation and experimental settings, i.e., three Geant4-DNA physics models, three sizes of a nanometer sensitive volume, gas to water density scaling procedure, JC ion extraction efficiency and the presence of passive components of the detector on the ICSD and their parameters. We found that ICSD in JC geometry obtained from Geant4-DNA simulations in water correspond well to ICSD measurements in nitrogen gas for all investigated settings, while the best agreement is for Geant4-DNA physics option 4. This work also discusses the accuracy and robustness of ICSD parameters in the context of the application of track structure simulation methods for treatment planning in particle therapy.

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