14th Geant4 Users Workshop

Università di Torino

TPS-INFN project

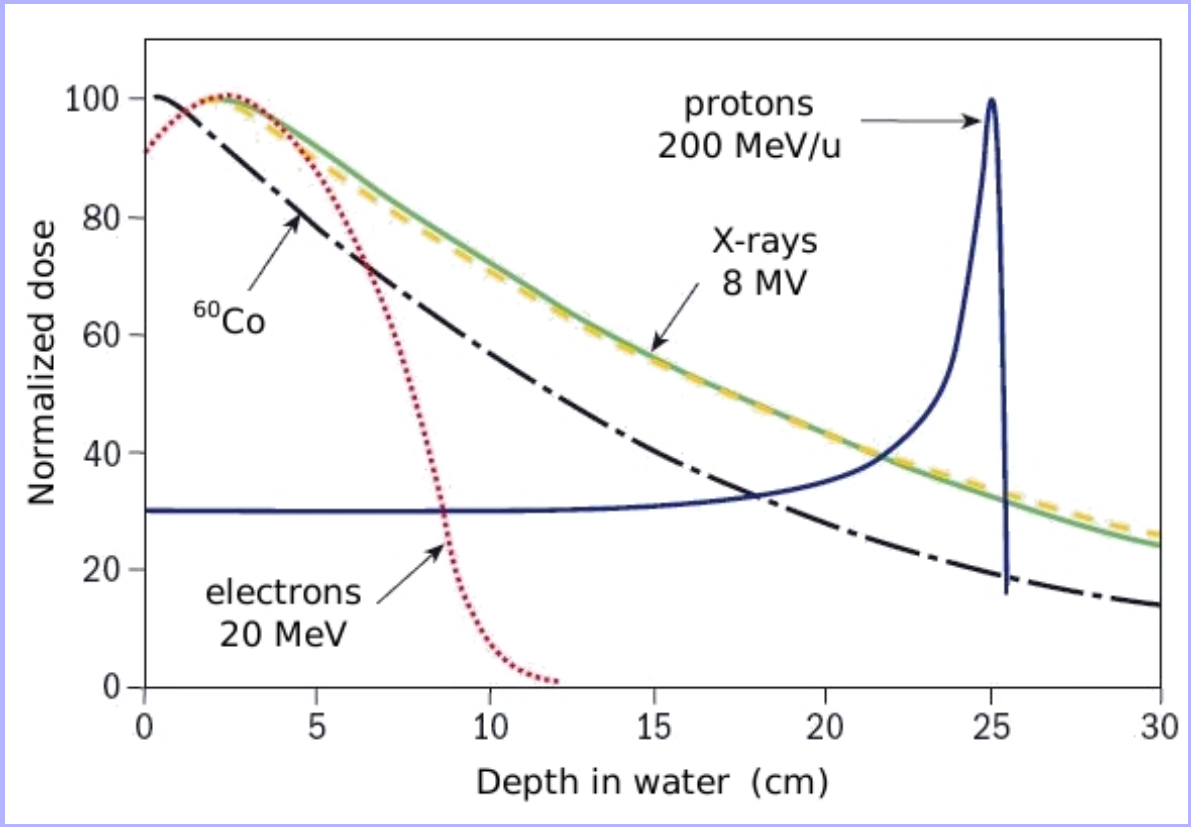
Parallel Session VIII - Medical

The role of Geant4 in the production of a database for an ion therapy Treatment Planning System

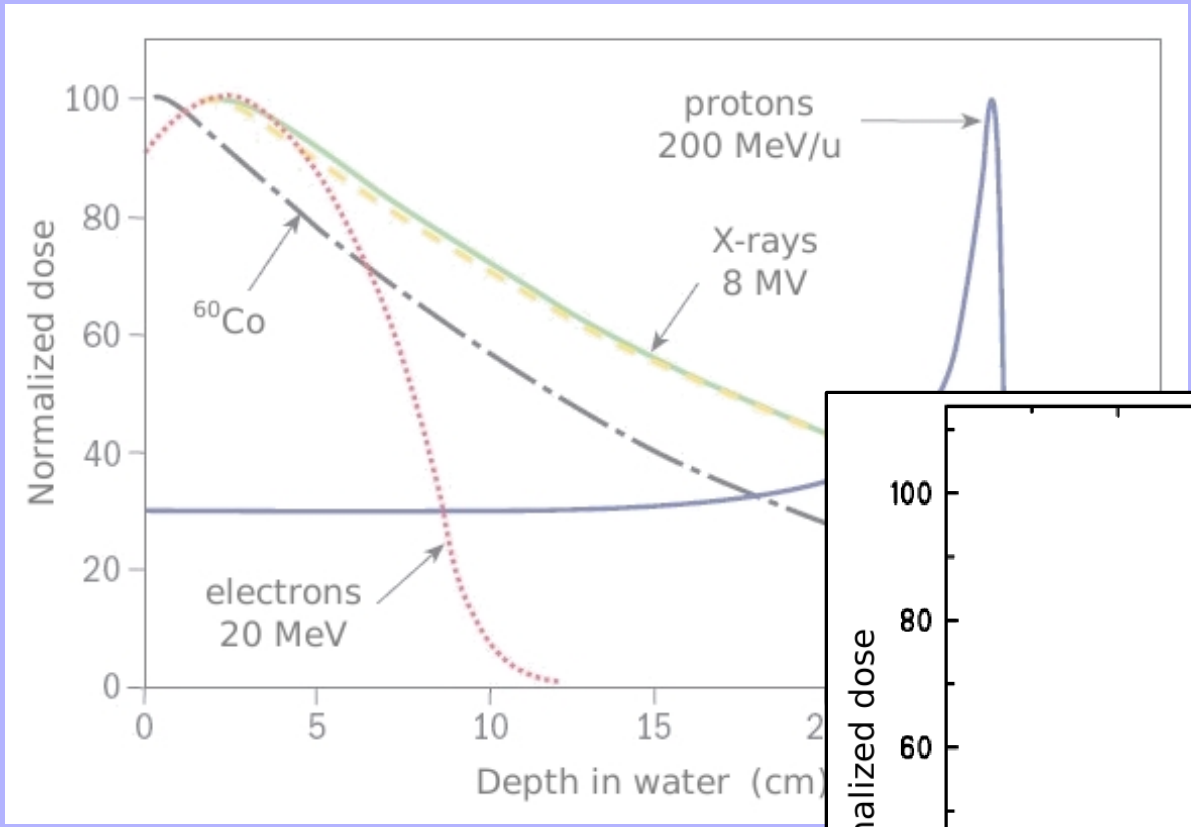
Russo G., Bourhaleb F., Solano A., Attili A., Marchetto F., Schmitt E., Ansarinejad A., Cirio R., Donetti M., Garella M.A., Giordanengo S., Monaco V., Peroni C., Sacchi R.

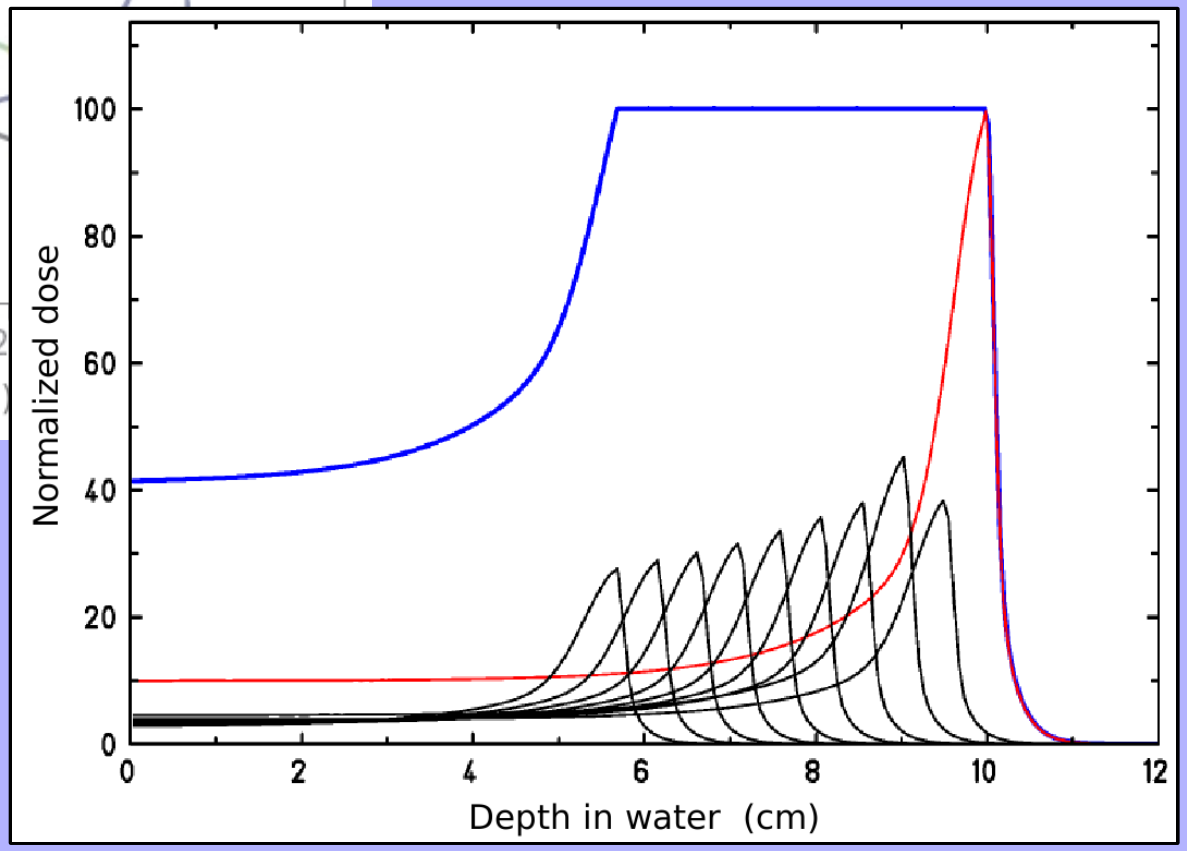
Catania, 15/10/2009

The principles of ion therapy | Bragg Peak

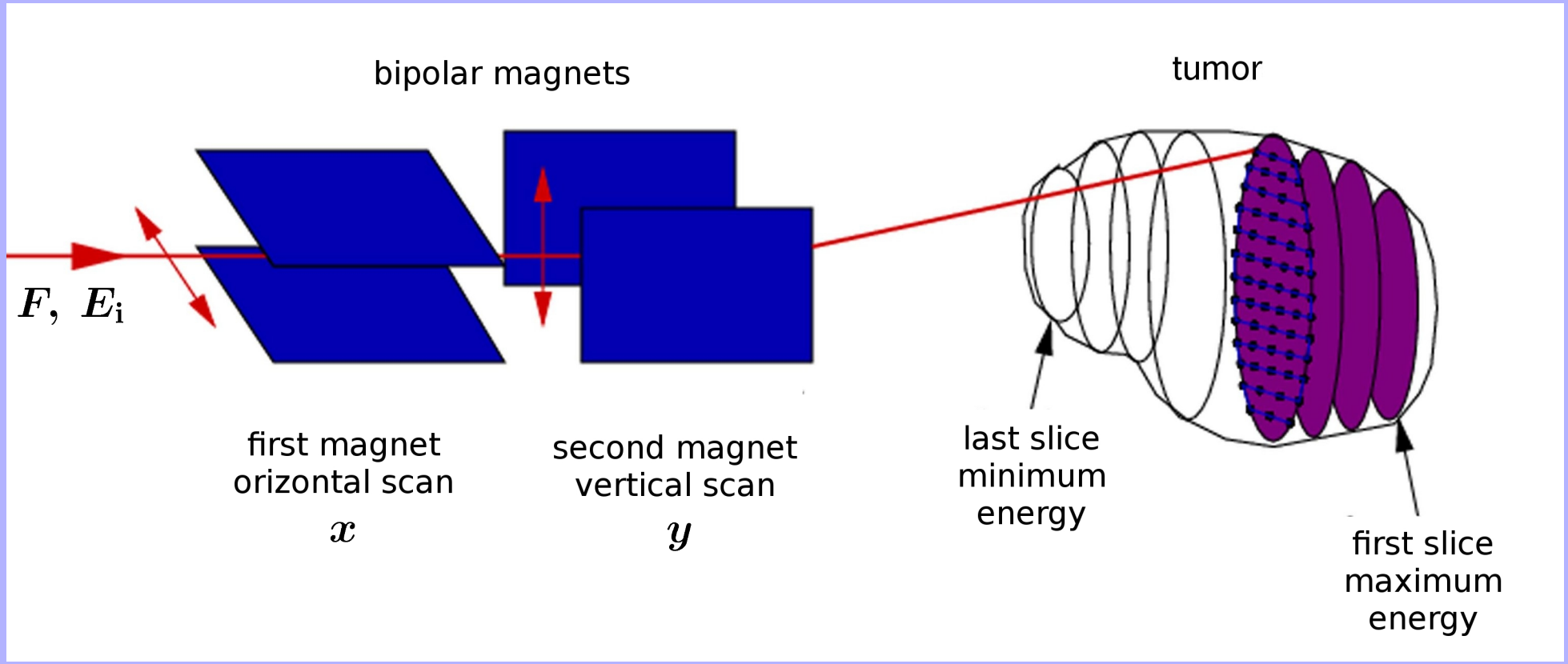


The principles of ion therapy | Spread Out Bragg Peak

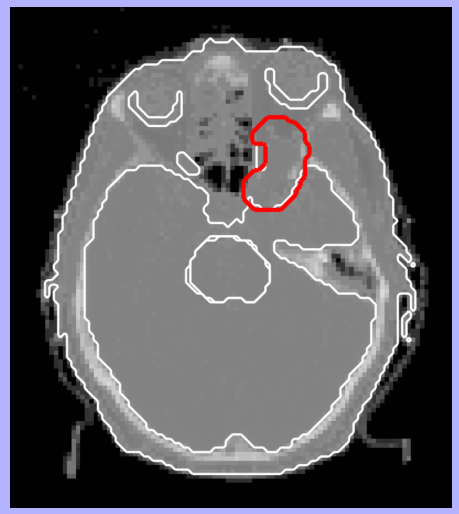




The principles of ion therapy | Active scan



The principles of ion therapy | TPS

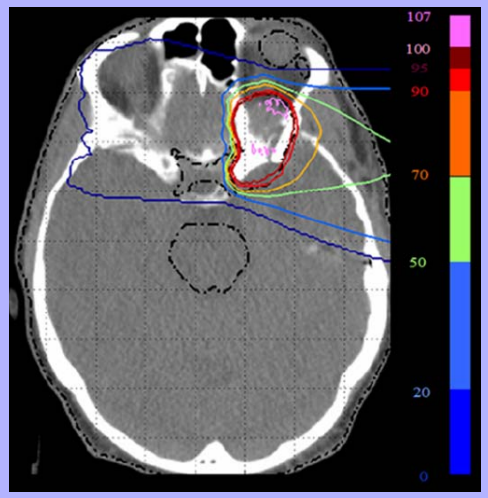


TPS

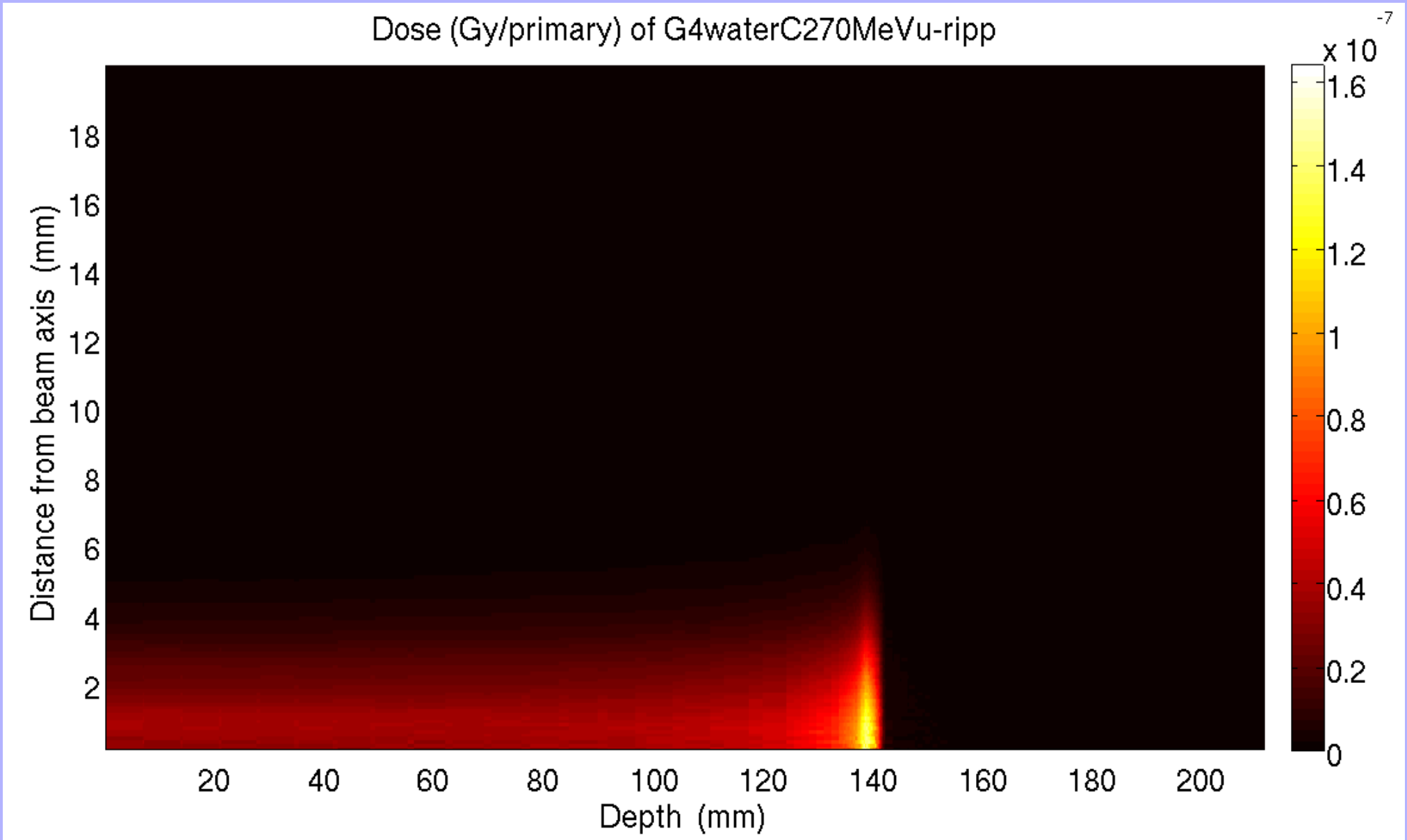
Physical Data
(Geant4, Fluka)

Biological Data
(LEM)

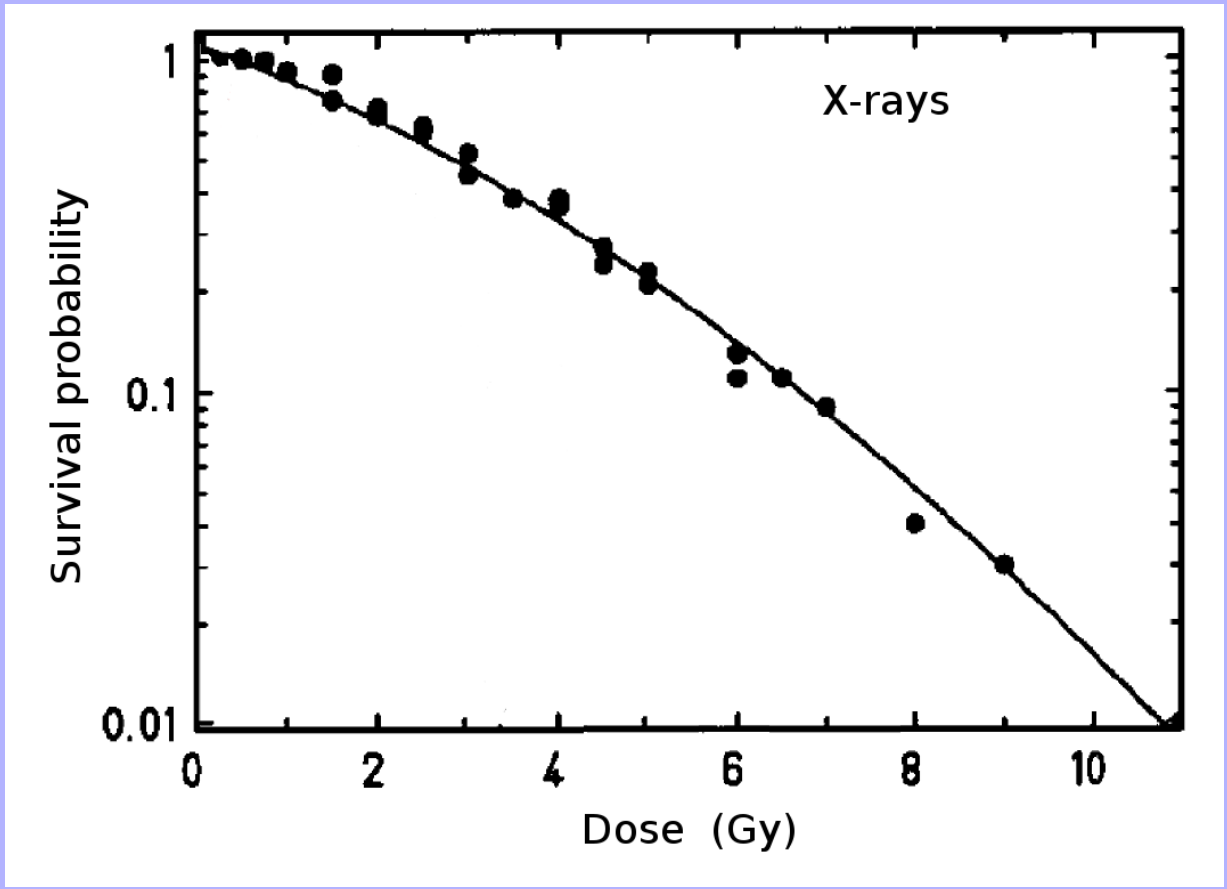
$$\{E_{\mathrm{i}}, F, x, y\}$$



TPS Physical Data



TPS Biological Data | Survival curves



$$S(D) = e^{-\alpha_x D - \beta_x D^2}$$

The biological effect depends on:

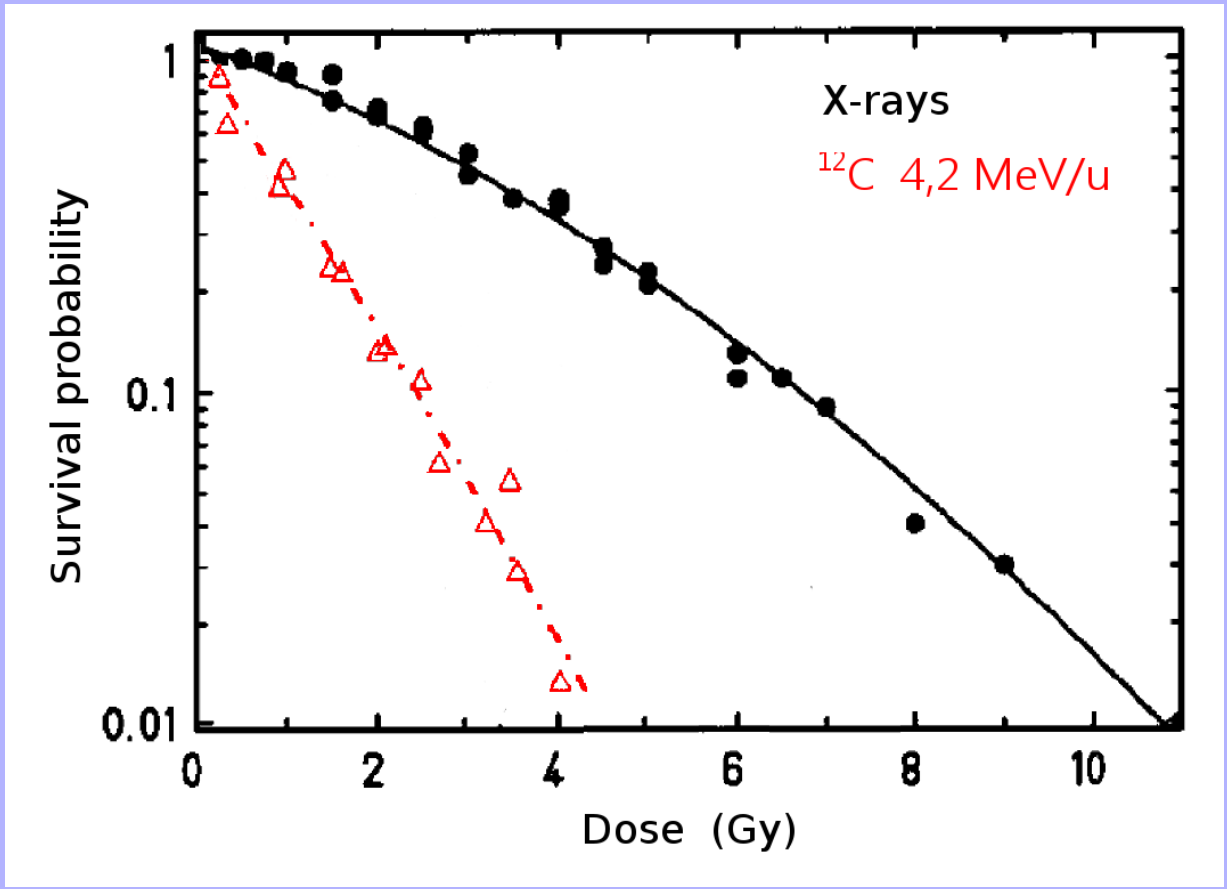
1) tissue type:

- cell line;
- oxygenation level;
- growing environment.

2) beam characteristics:

- dose released;
- radiation type.

TPS Biological Data | Survival curves



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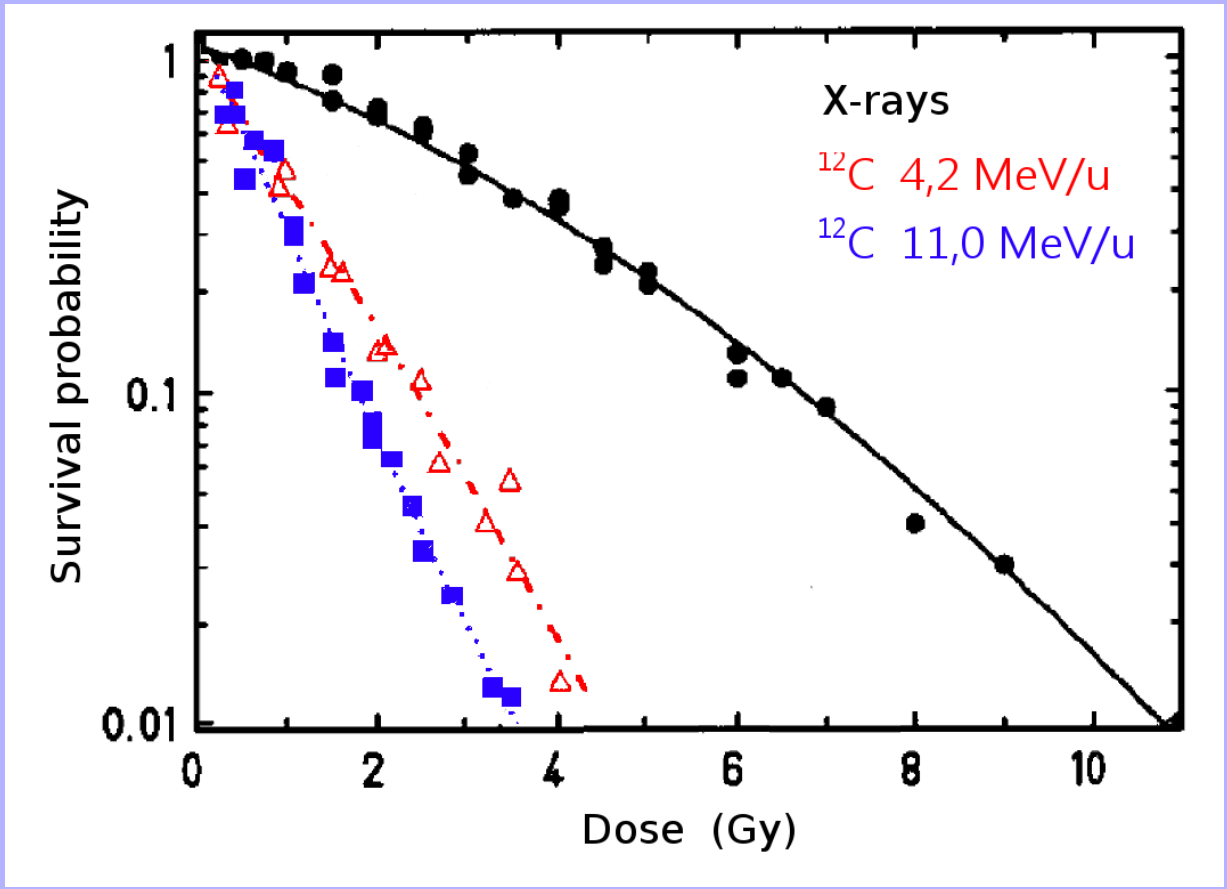

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2) beam characteristics:

- dose released;
- radiation type;
- p(e_c, LET).

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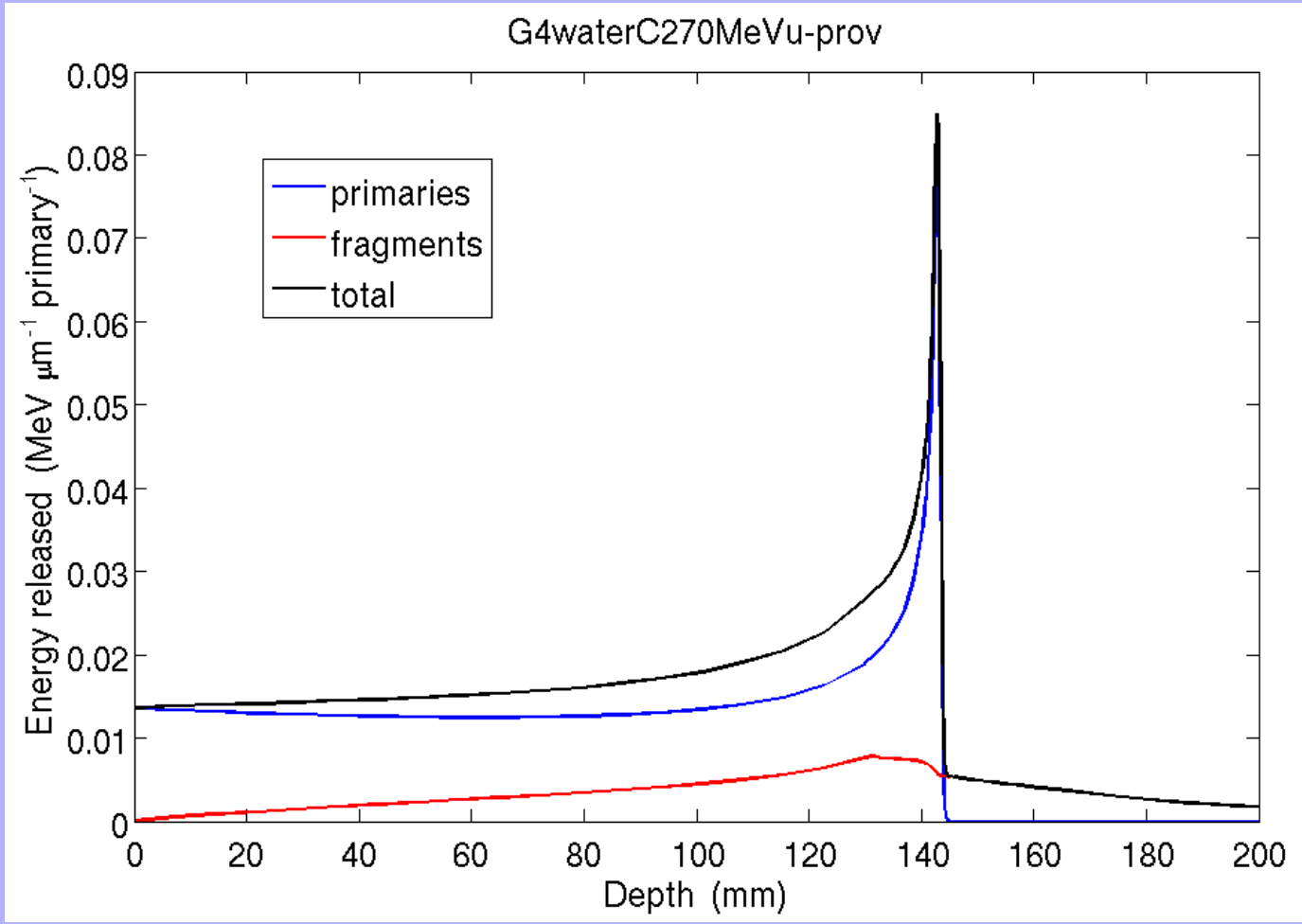
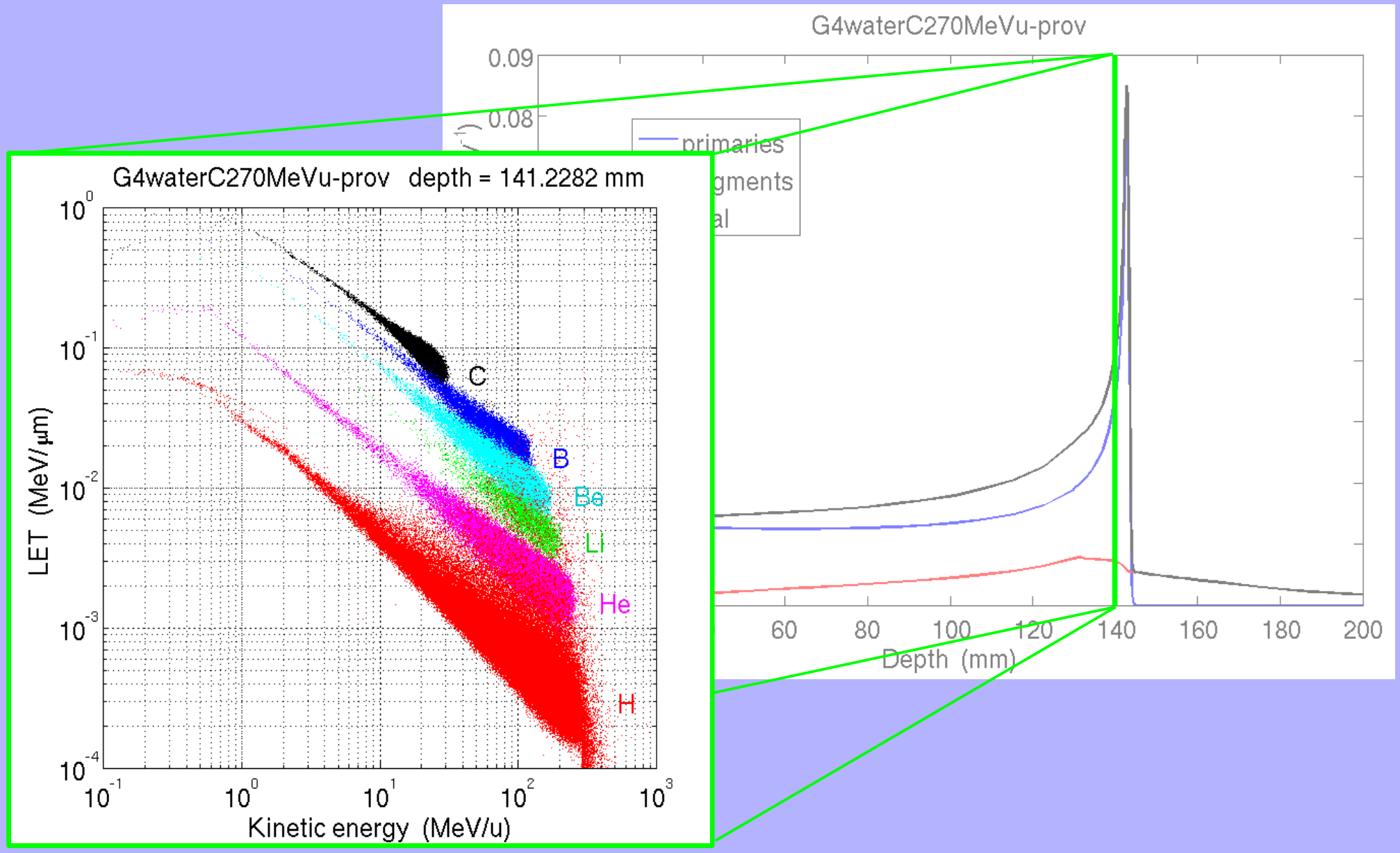
TPS Biological Data | Mixed fields



TPS Biological Data | Mixed fields



Geant4 simulation | PhysicsList

We have activated the following PhysicsLists (the nomenclature is that of the Hadrontherapy Advanced Example):

Decay

EM-Photon-Standard
EM-Electron-Standard
EM-Positron-Standard
EM-HadronIon-Standard (G4ionIonisation)
or as an alternative EM-HadronIon-LowE (G4hLowEnergyIonisation)
EM-Muon-Standard

HadronicEl-HadronIon-UElastic

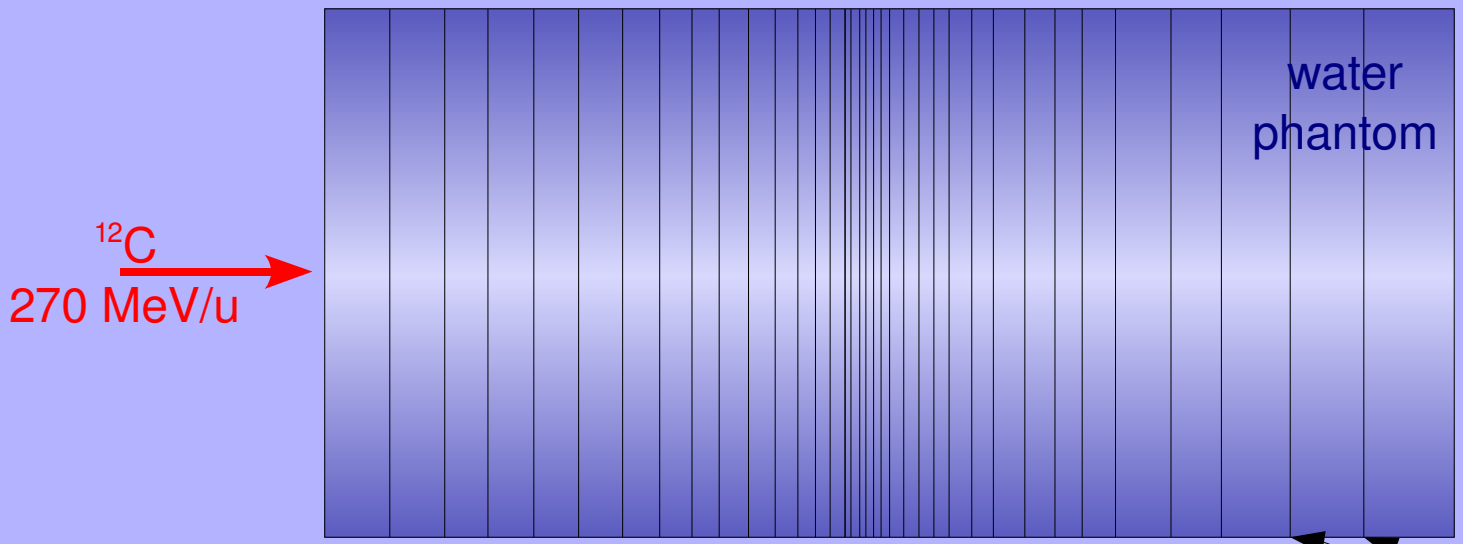
HadronicInel-ProtonNeutron-Bert

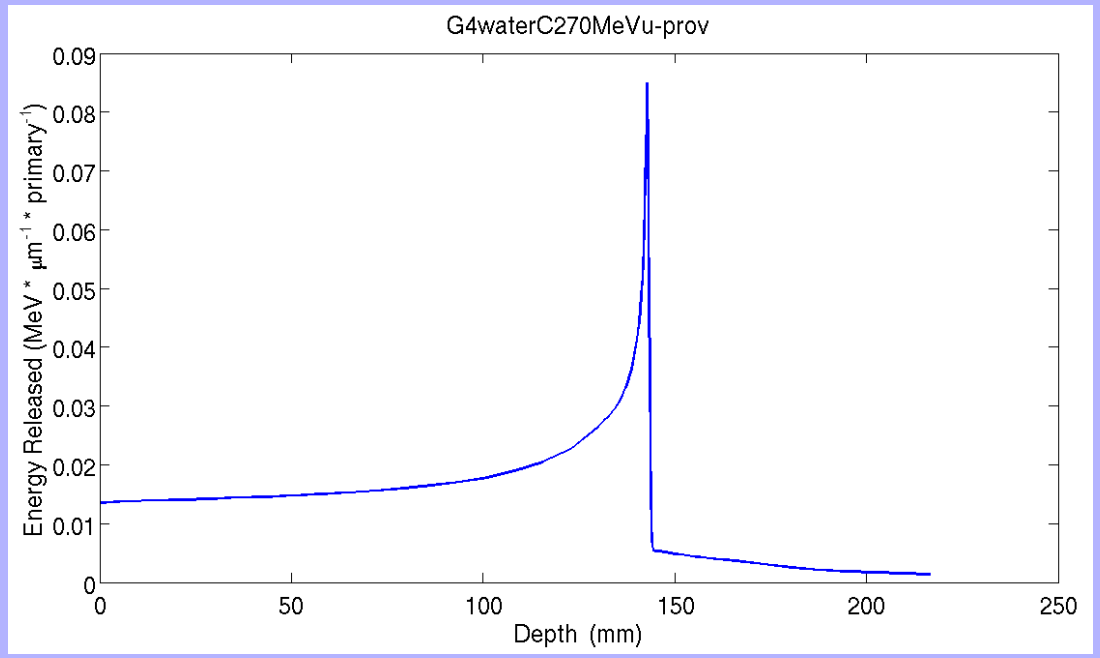
CarbonIon-physics (Ivantckenco implementation: G4HadronInelasticProcess with G4TripathiCrossSection and G4IonsShenCrossSection, G4BinaryLightIonReaction)

As an alternative, we use the QGSP_BIC package, as suggested in the Hadrontherapy Advanced Example (v. 9.2).

For biological modeling reason, we want to avoid completely the tracking of electrons. Then we set the defaultCutValue to 5 mm in the water phantom.

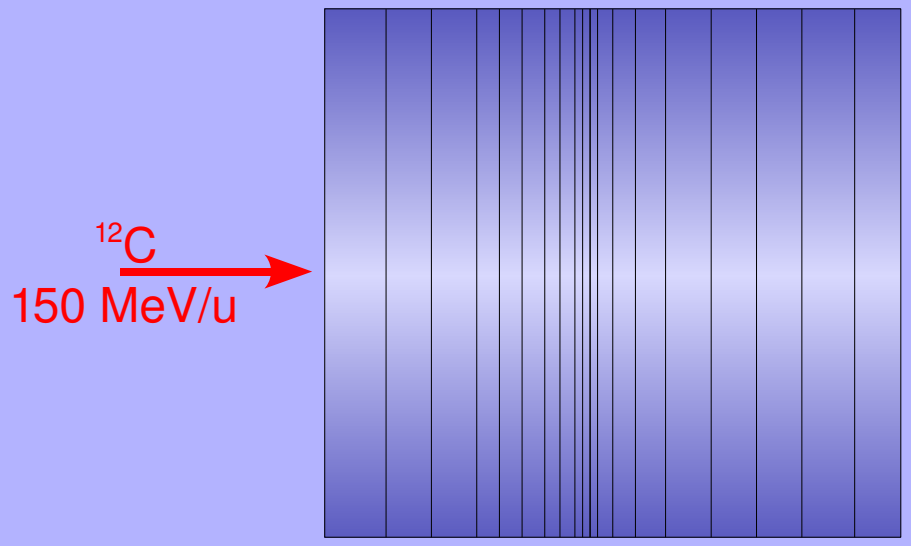
Geant4 simulation | DetectorConstruction





Slices as SensitiveDetectors (10 um wide to be comparable to cell dimensions)

Geant4 simulation | DetectorConstruction



Adaptive geometry

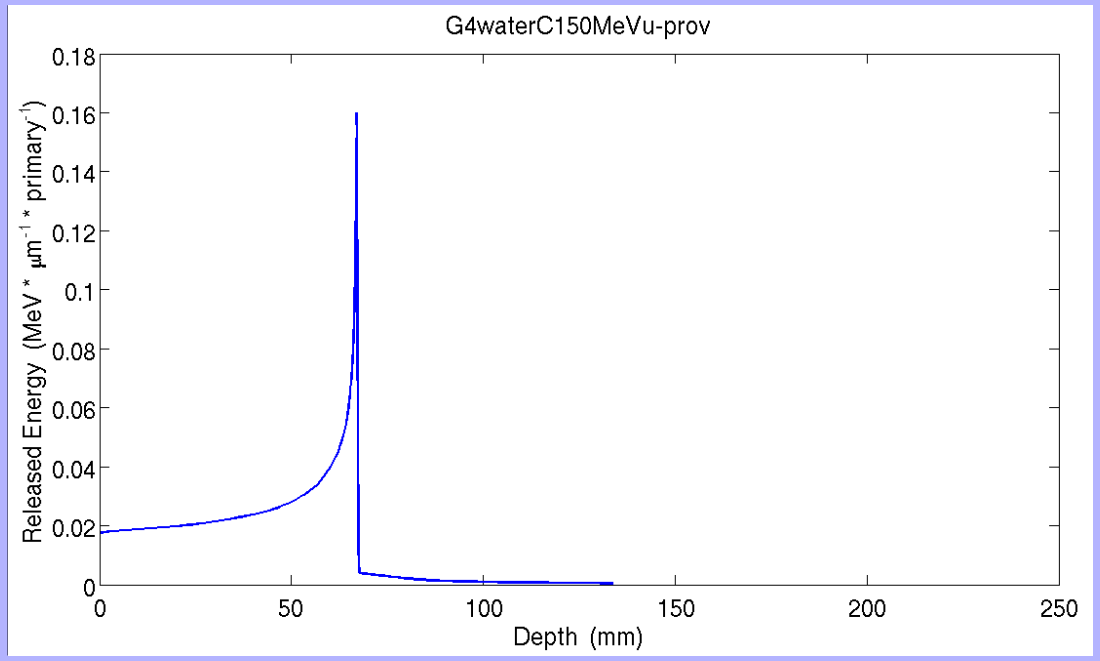
Fake run (0 events) for loading physics

↓

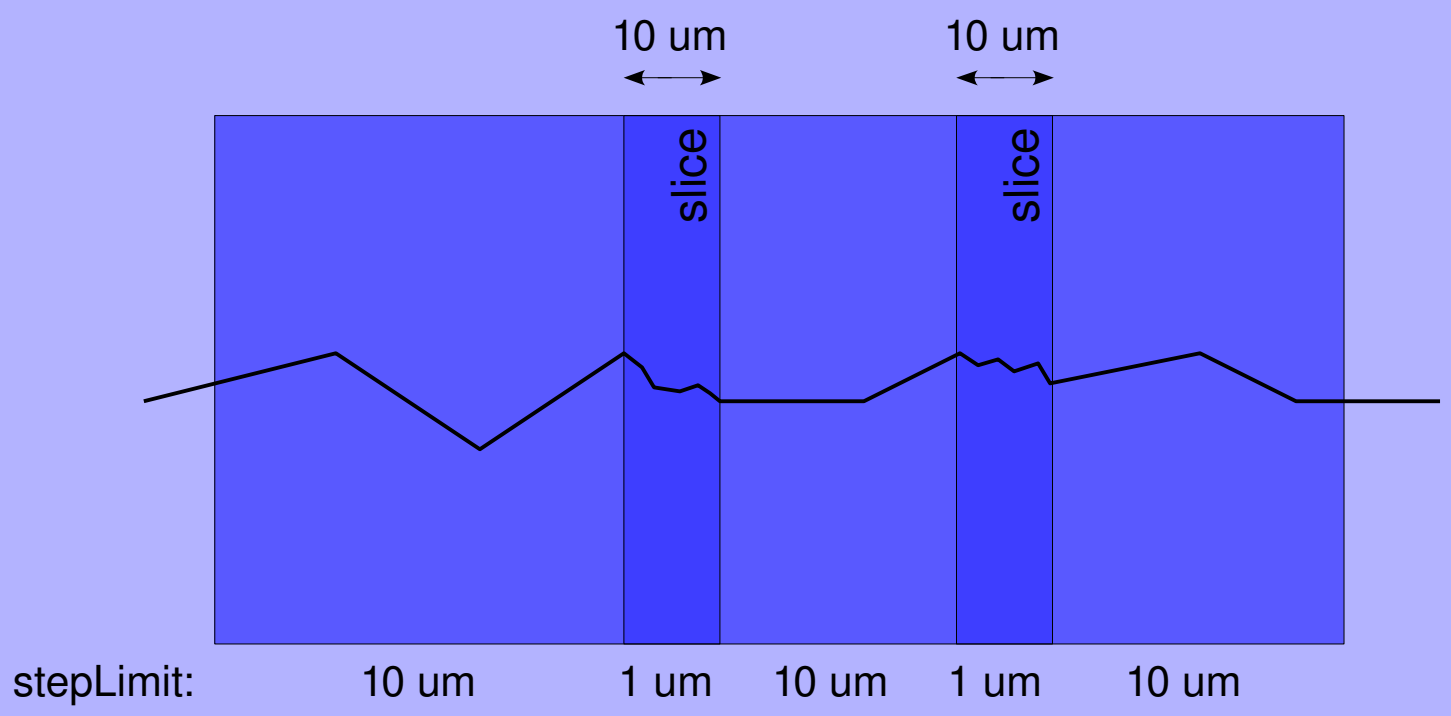
G4EmCalculator calc;
r = calc.GetRange();

↓

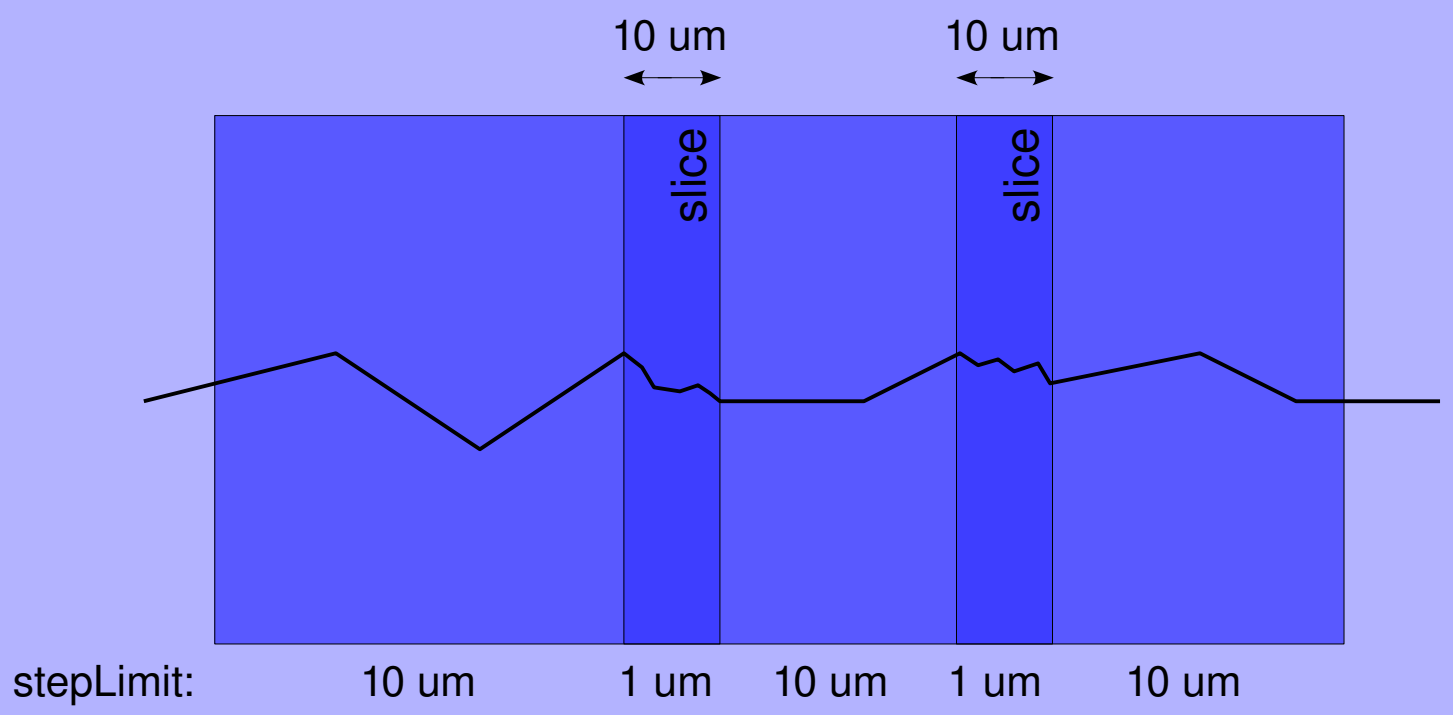
detector.SetSlices(r);



Geant4 simulation | Scoring



Geant4 simulation | Scoring

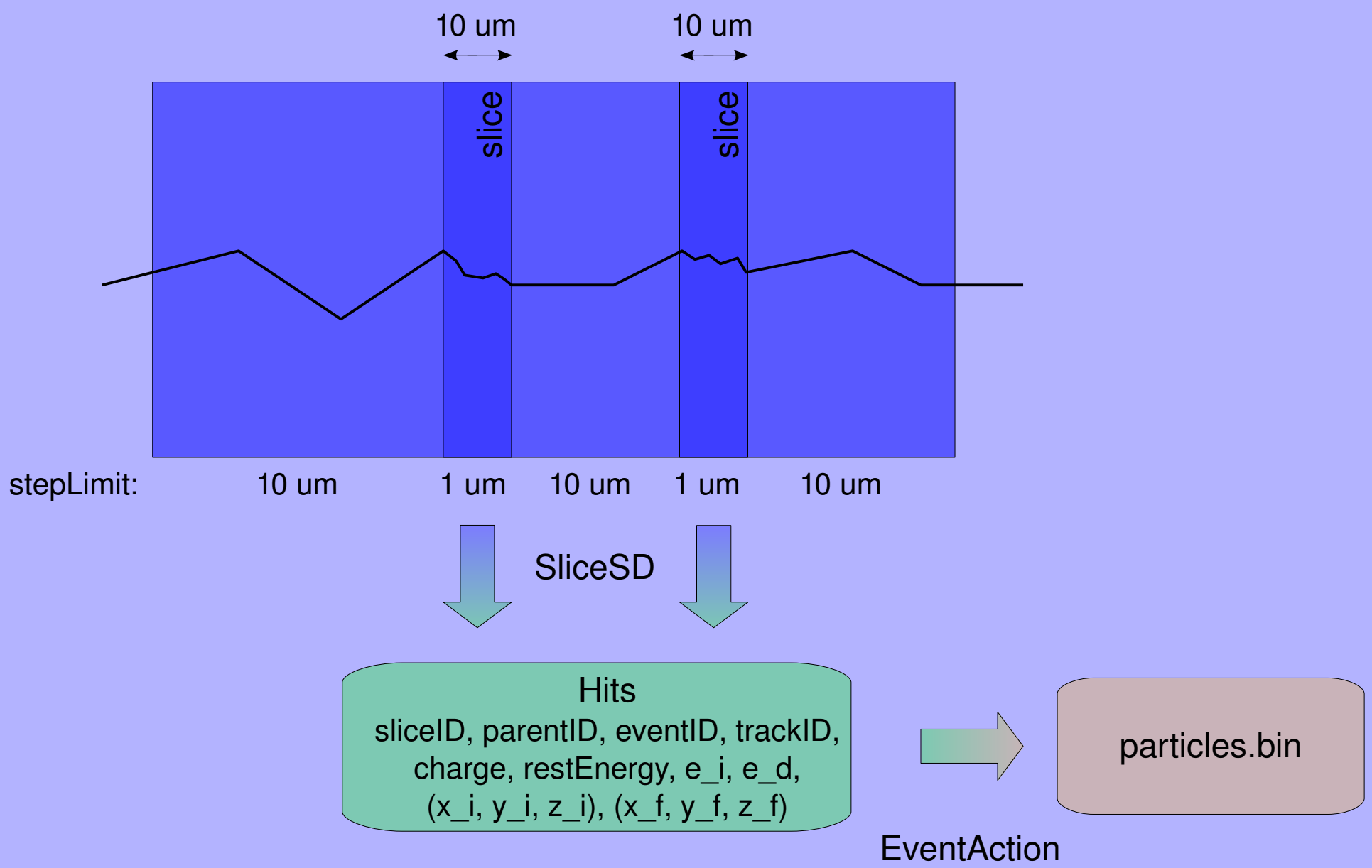


SliceSD

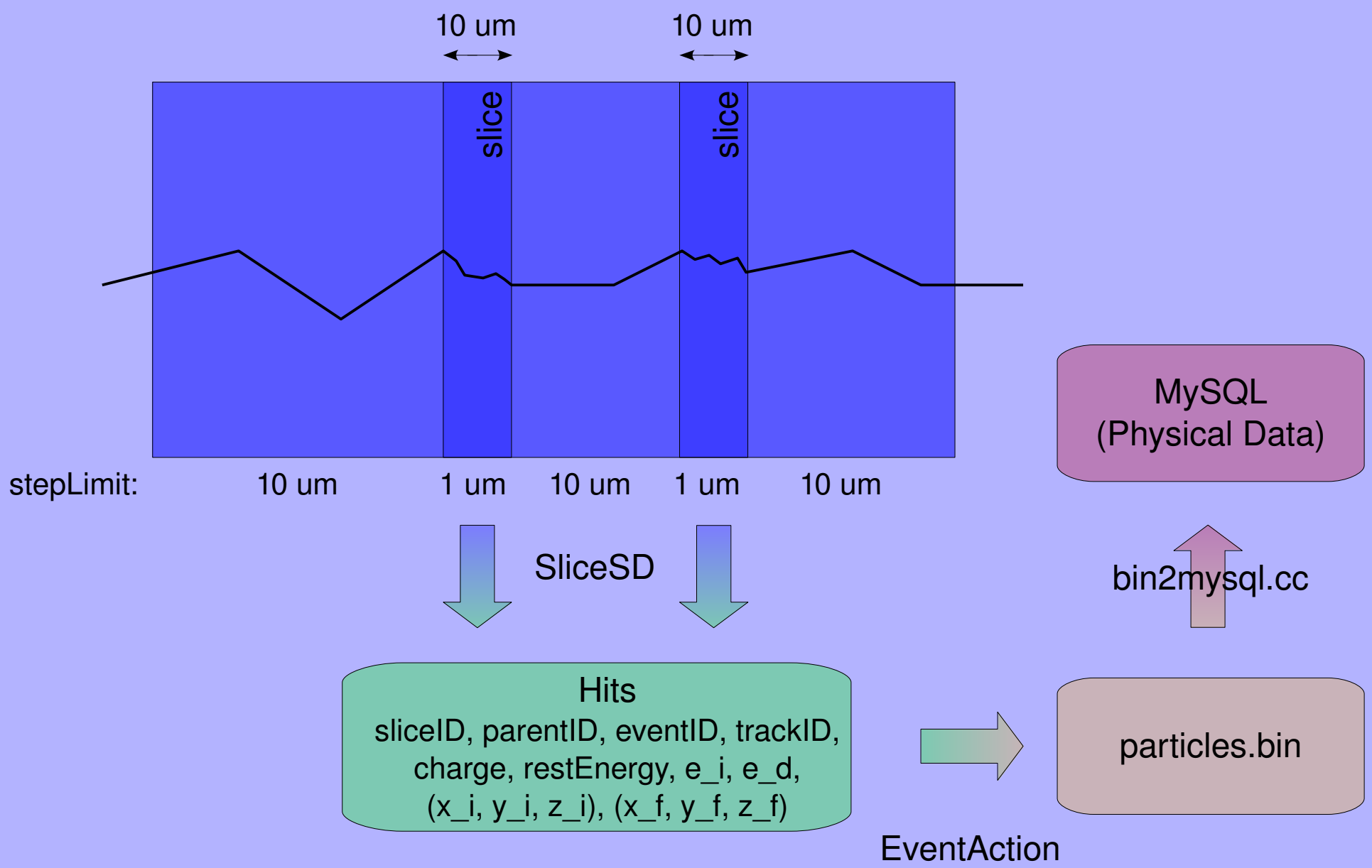
Hits

sliceID, parentID, eventID, trackID,
charge, restEnergy, e_i, e_d,
(x_i, y_i, z_i), (x_f, y_f, z_f)

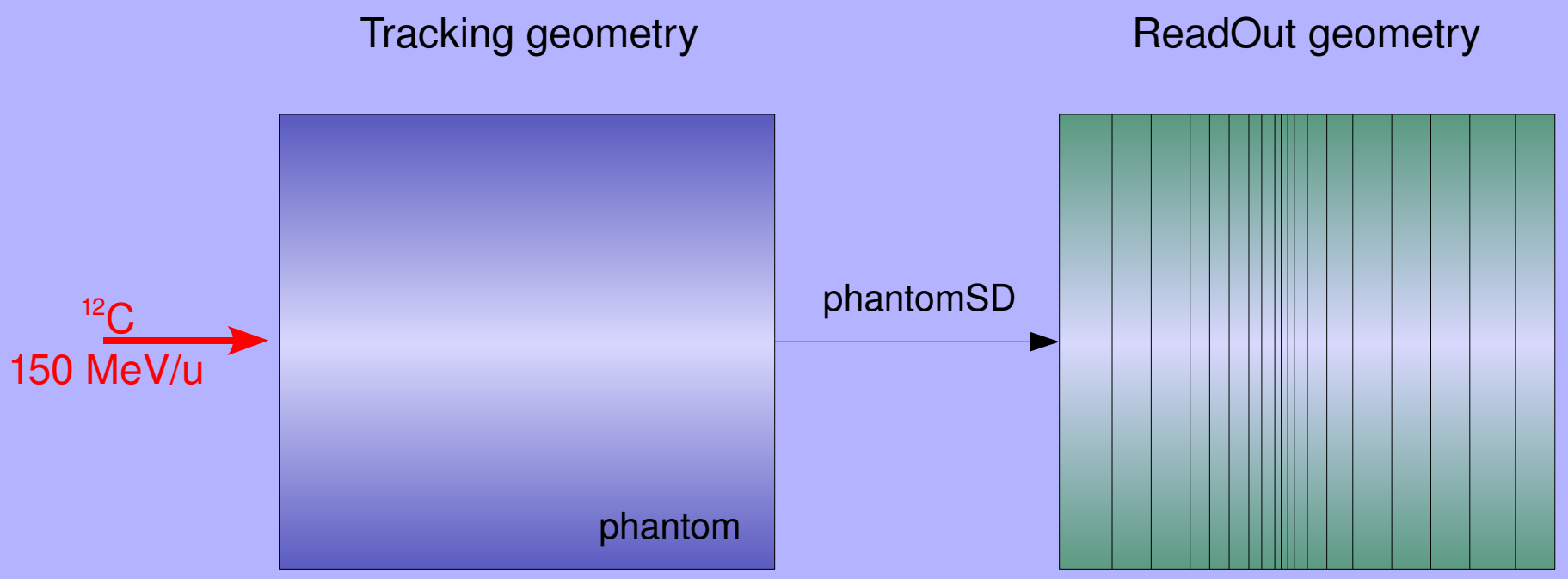
Geant4 simulation | Scoring



Geant4 simulation | Scoring

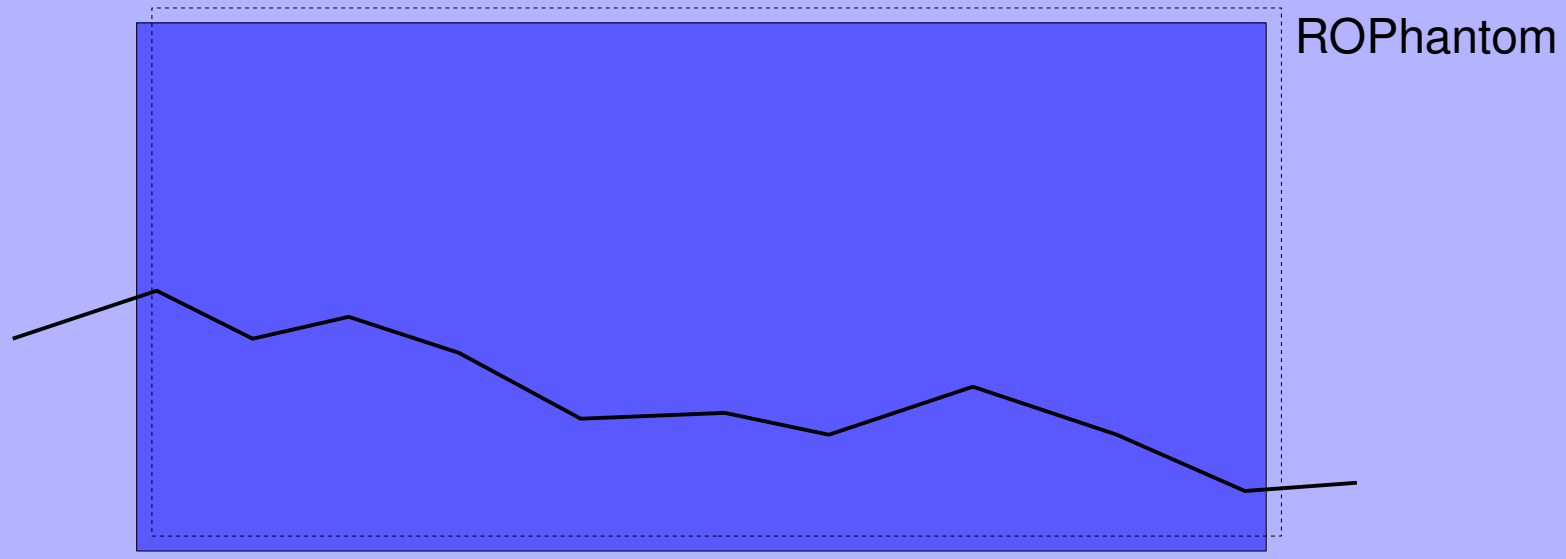


Geant4 simulation | ROGeometry



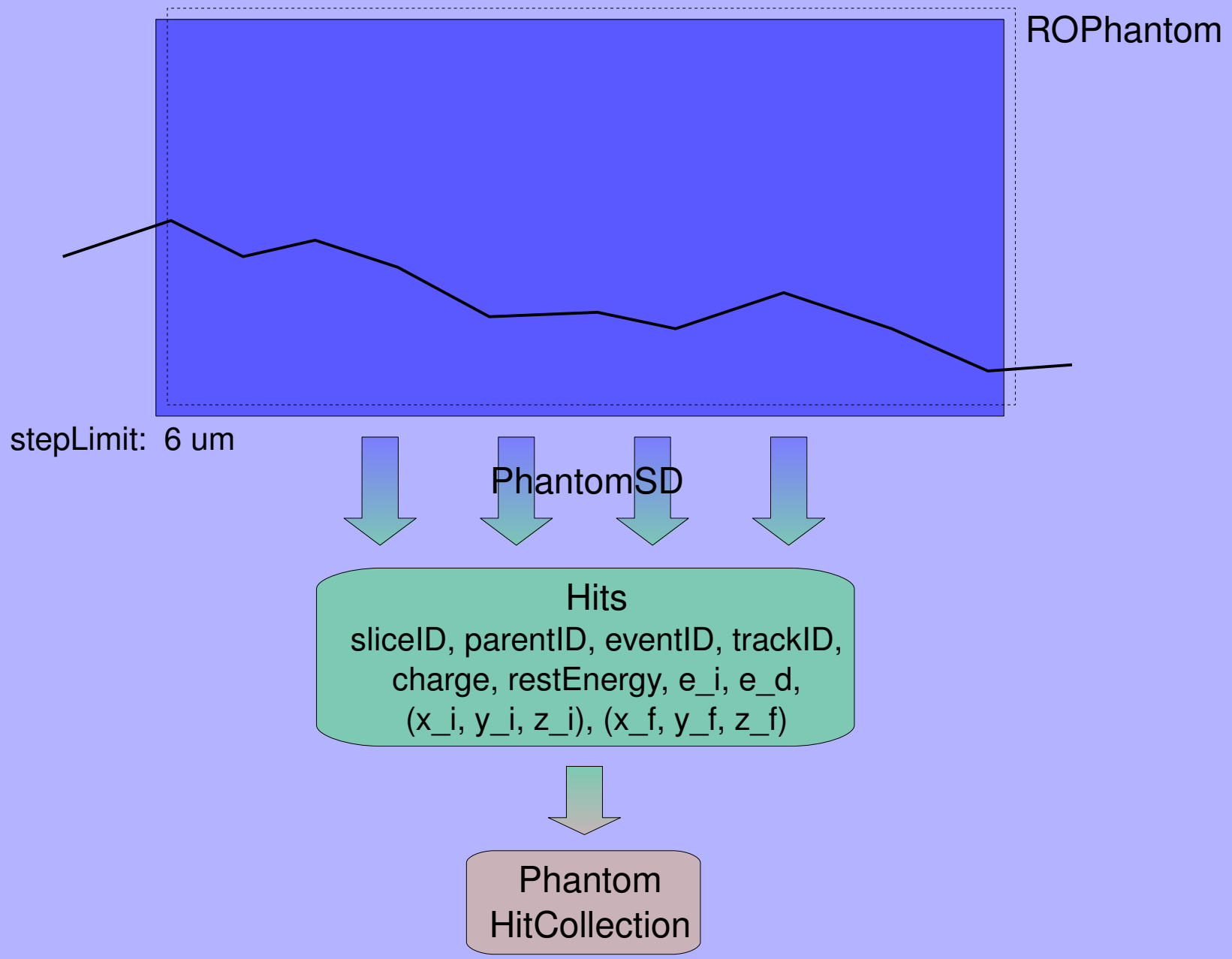
The use of a ReadOut geometry allows
to decouple the tracking from the scoring

Geant4 simulation | ROGeometry

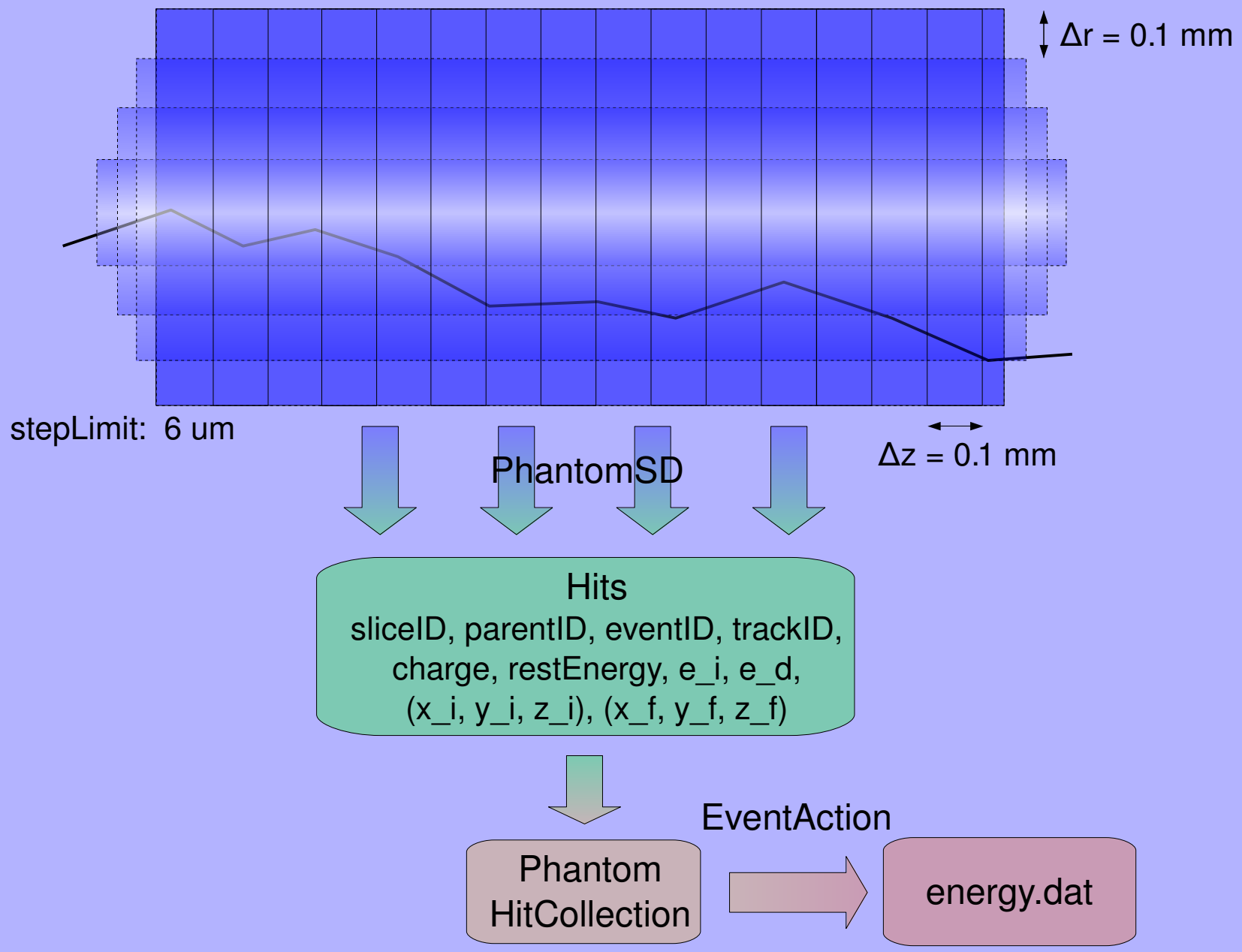


stepLimit: 6 um

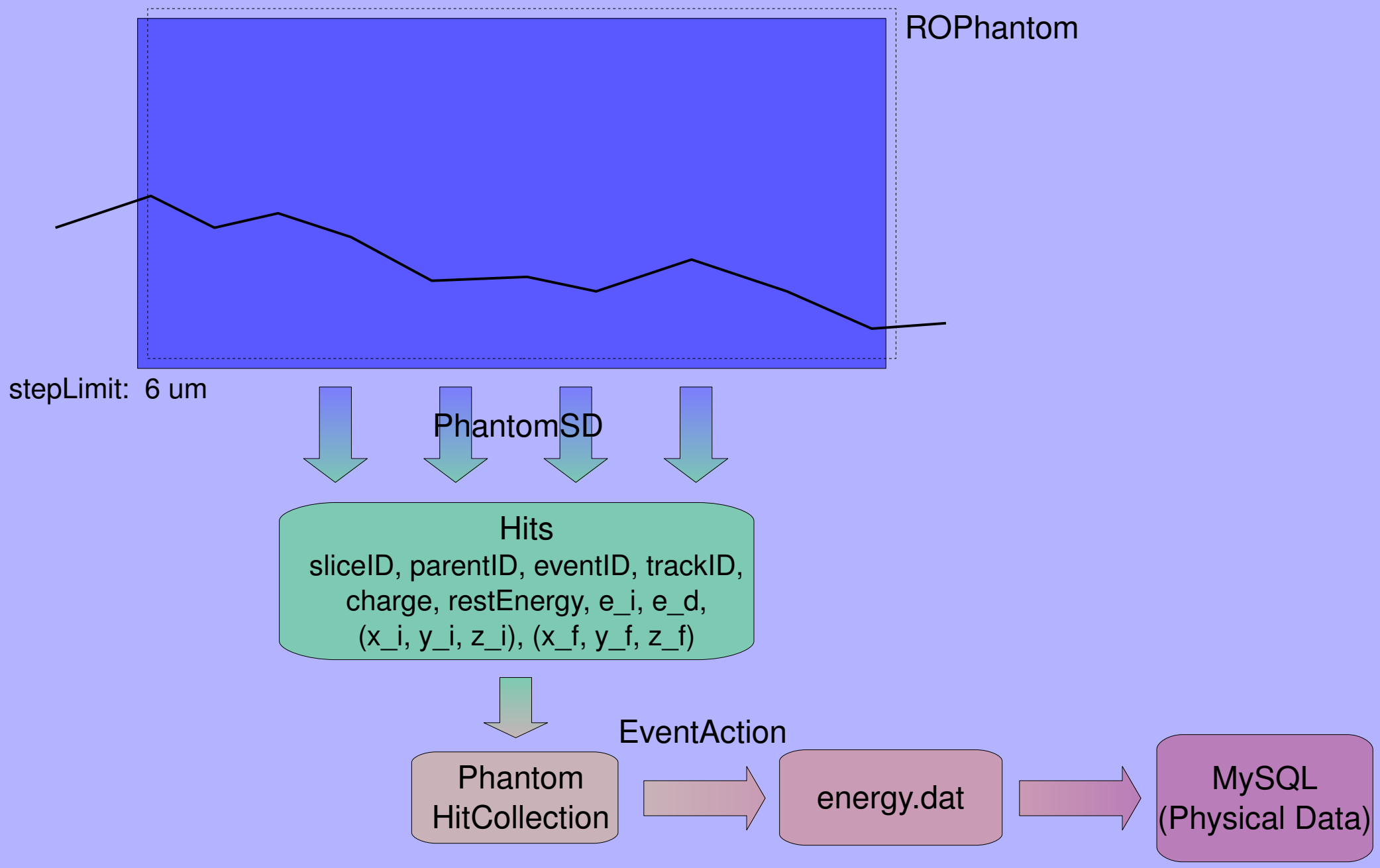
Geant4 simulation | ROGeometry



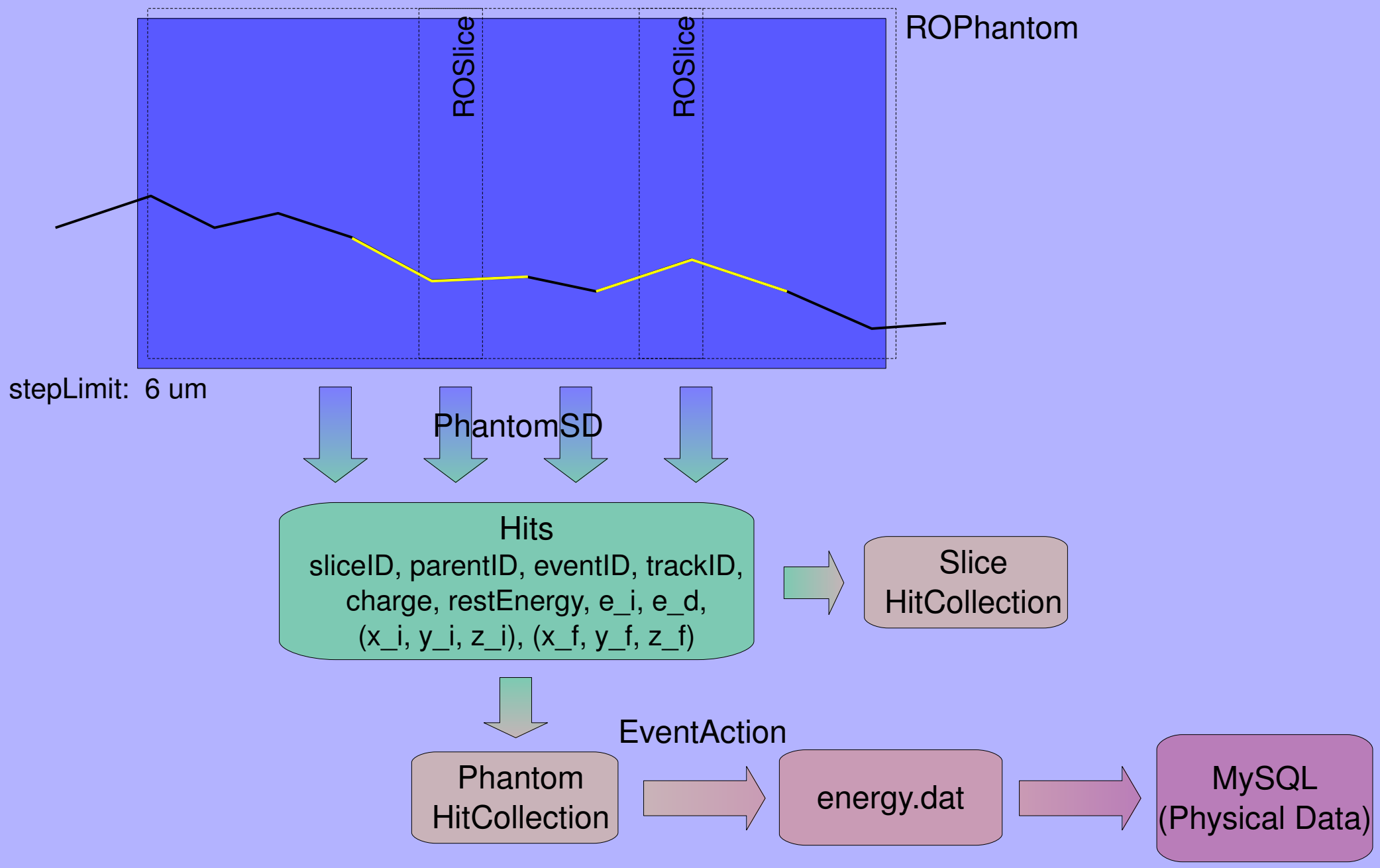
Geant4 simulation | ROGeometry



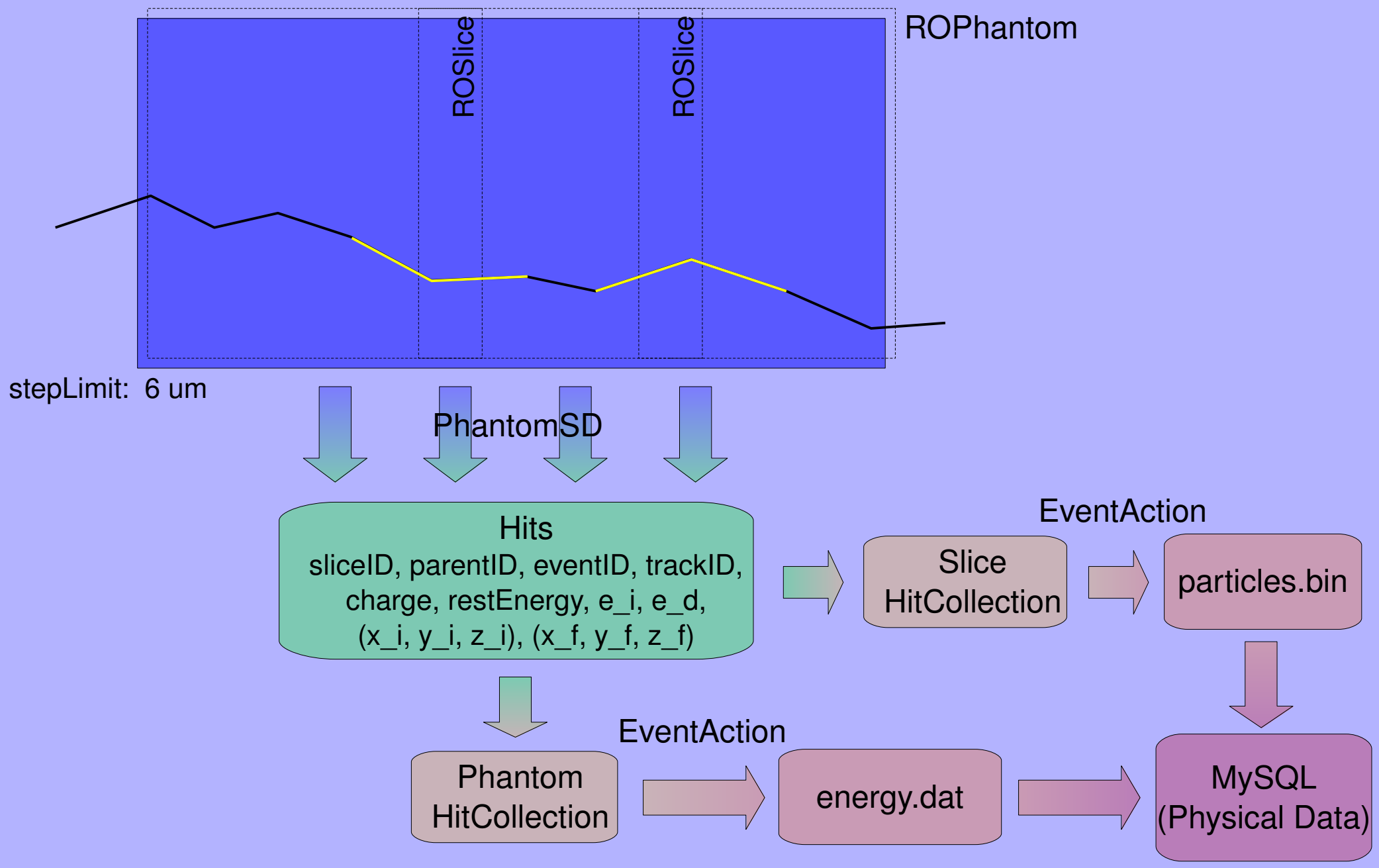
Geant4 simulation | ROGeometry



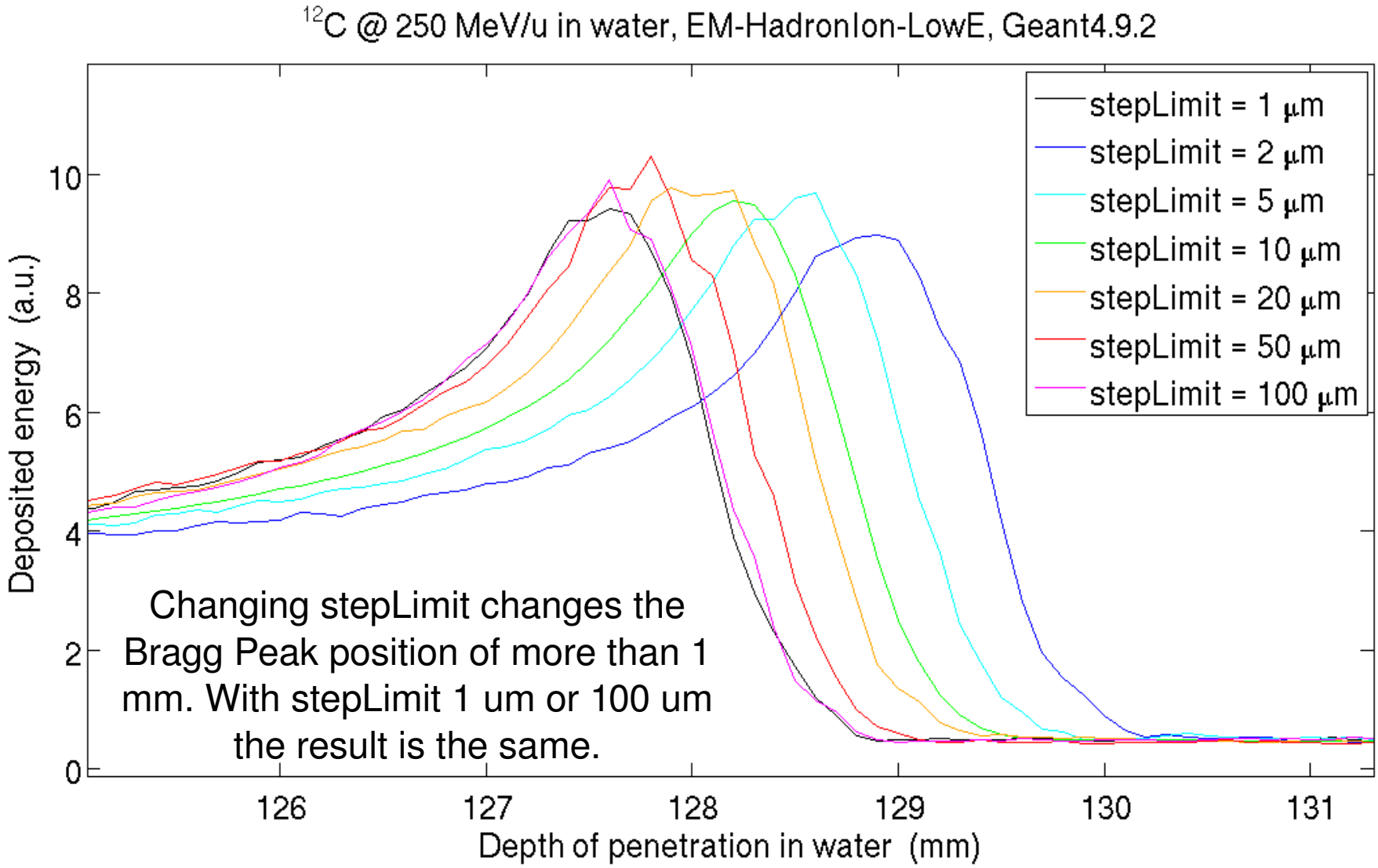
Geant4 simulation | ROGeometry



Geant4 simulation | ROGeometry

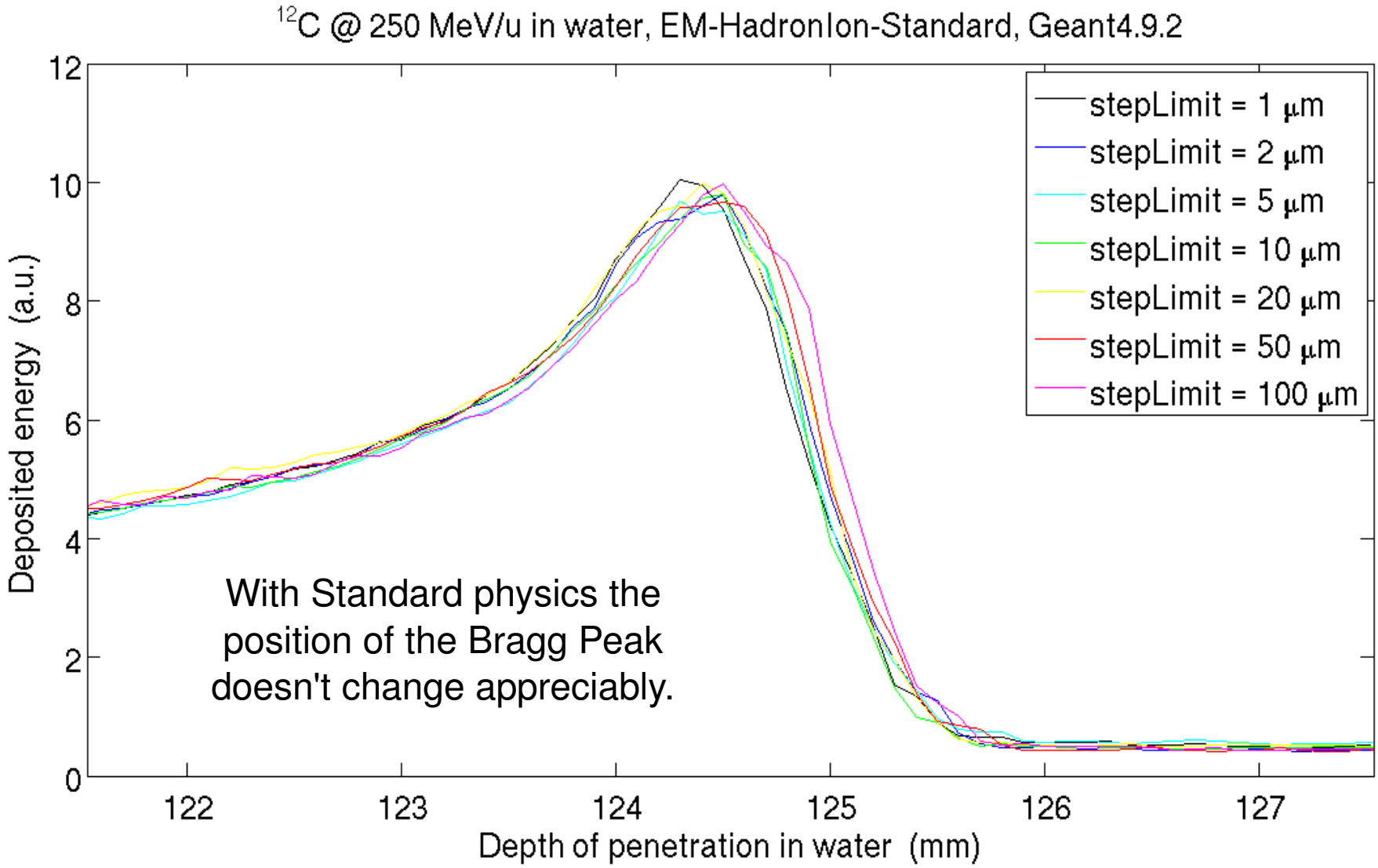


Geant4.9.2 apparent anomalies | BP position

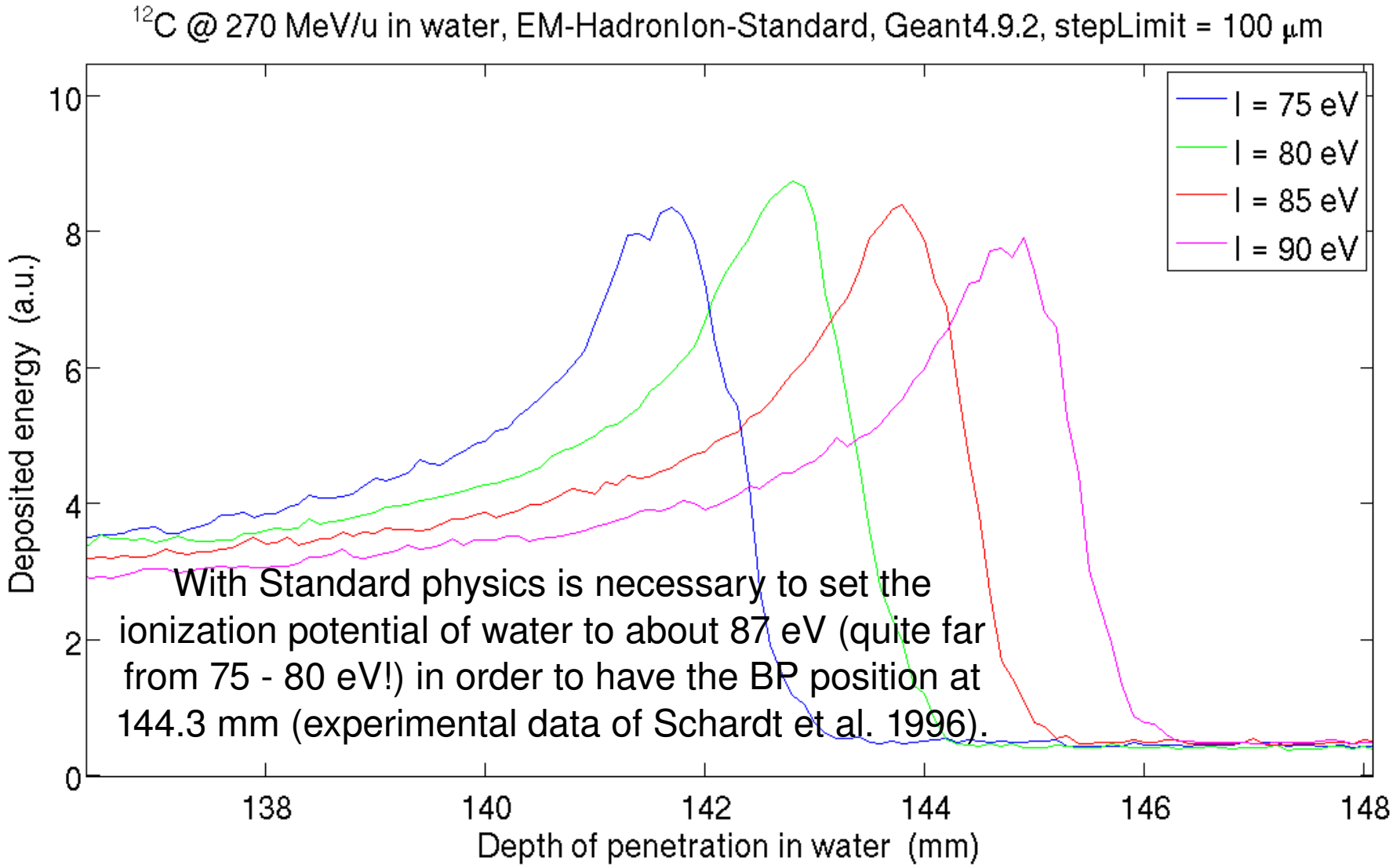


Changing stepLimit changes the Bragg Peak position of more than 1 mm. With stepLimit 1 um or 100 um the result is the same.

Geant4.9.2 apparent anomalies | BP position

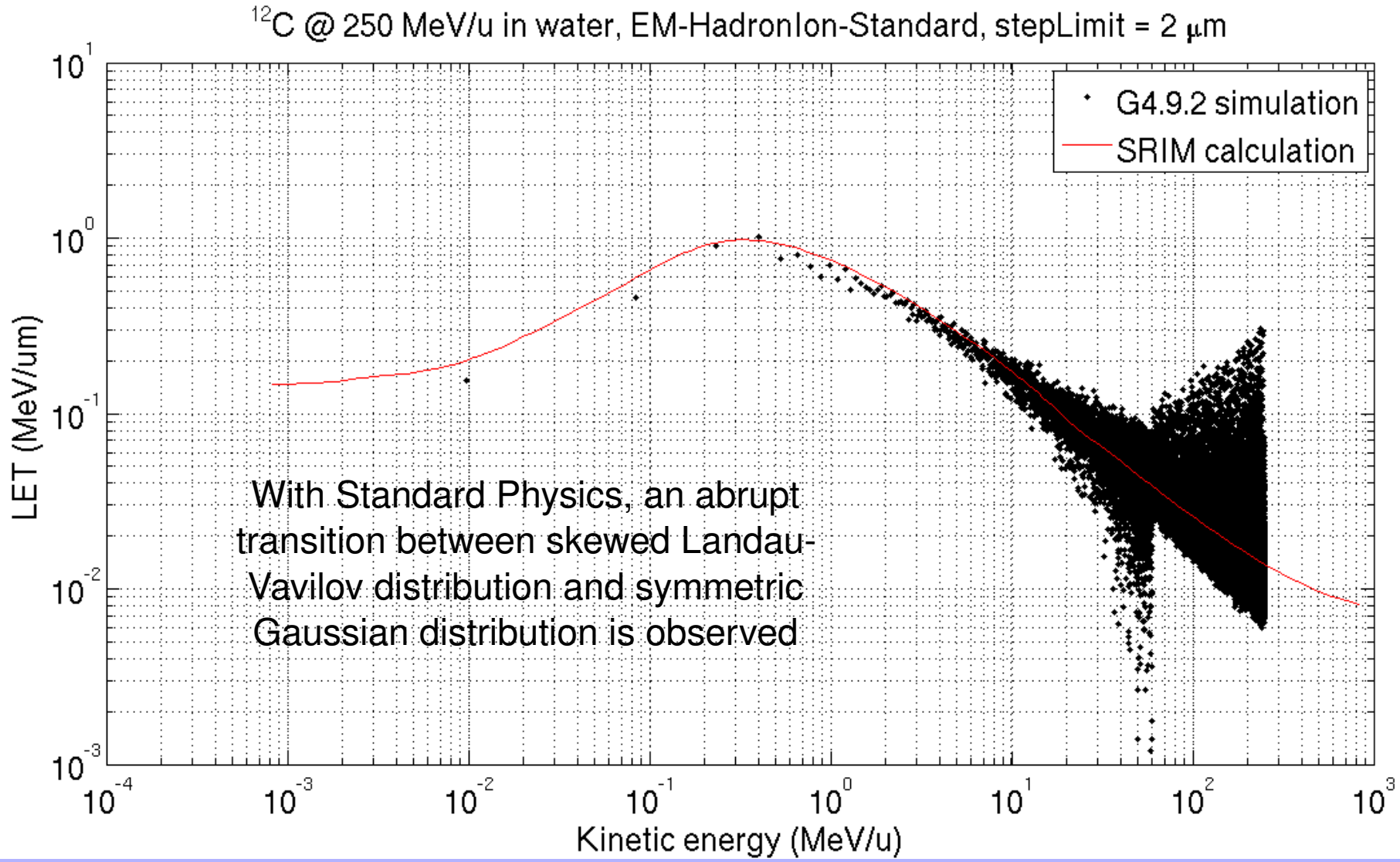


Geant4.9.2 apparent anomalies | BP position

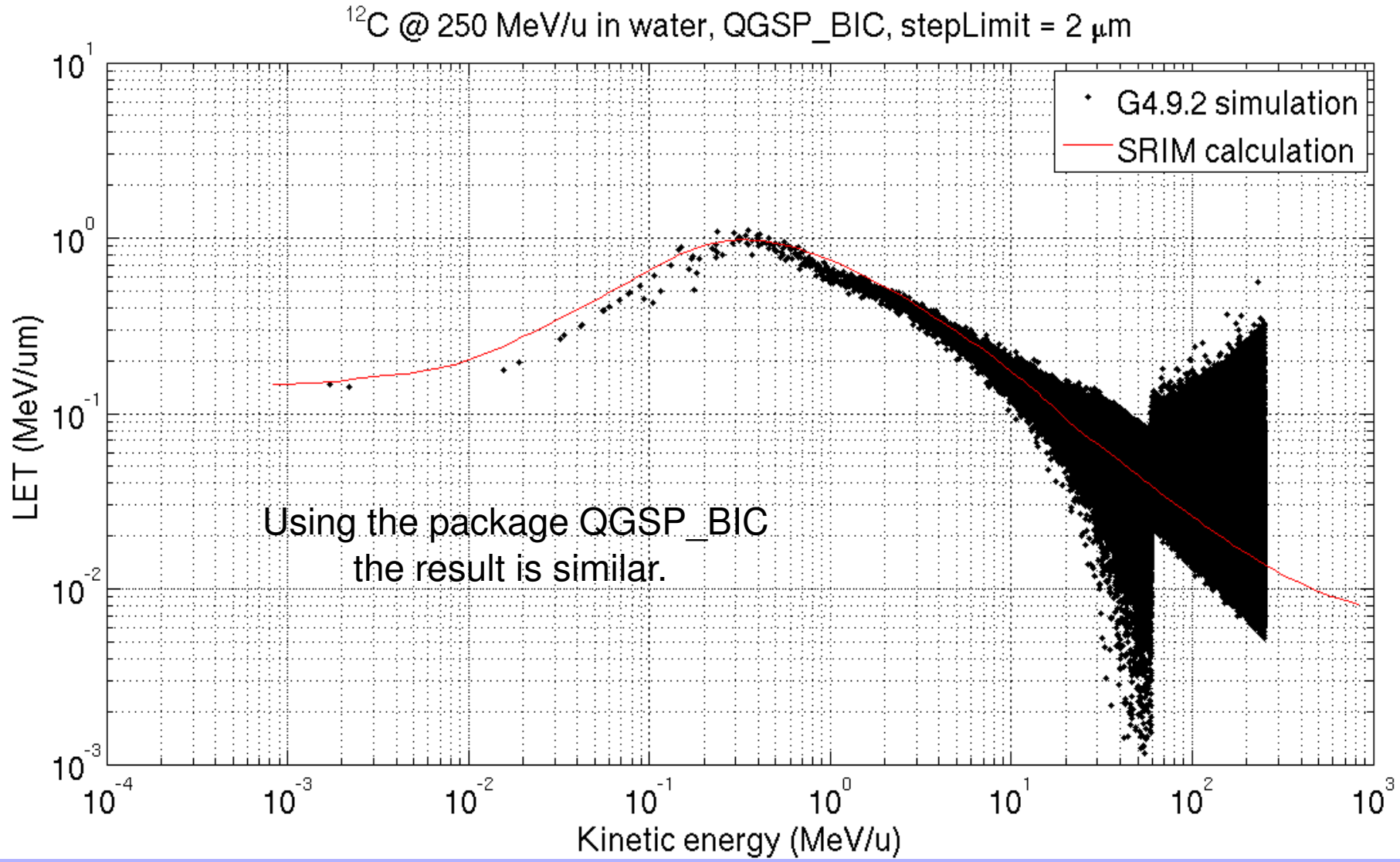


With Standard physics is necessary to set the ionization potential of water to about 87 eV (quite far from 75 - 80 eV!) in order to have the BP position at 144.3 mm (experimental data of Schardt et al. 1996).

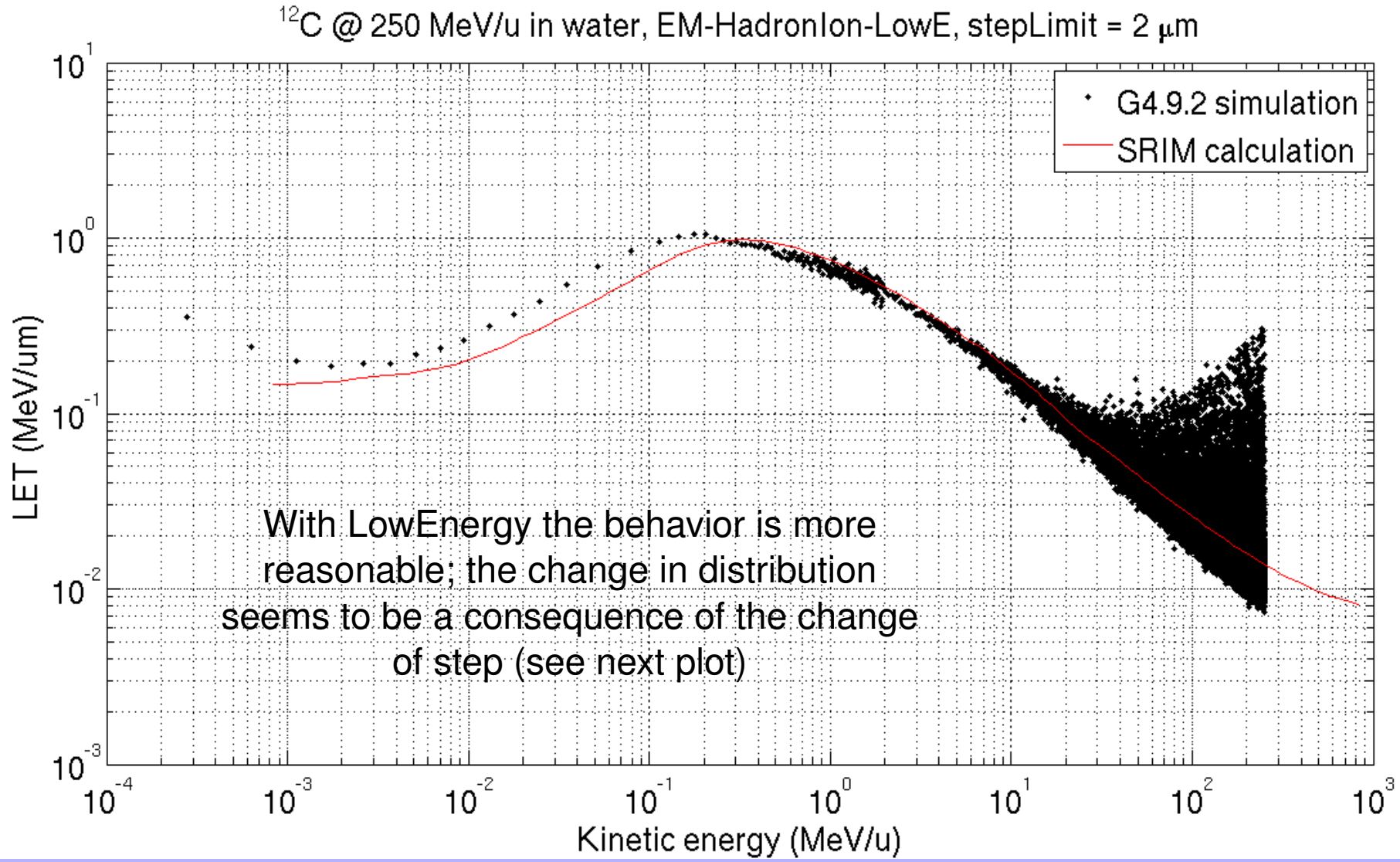
Geant4.9.2 apparent anomalies | Energy loss



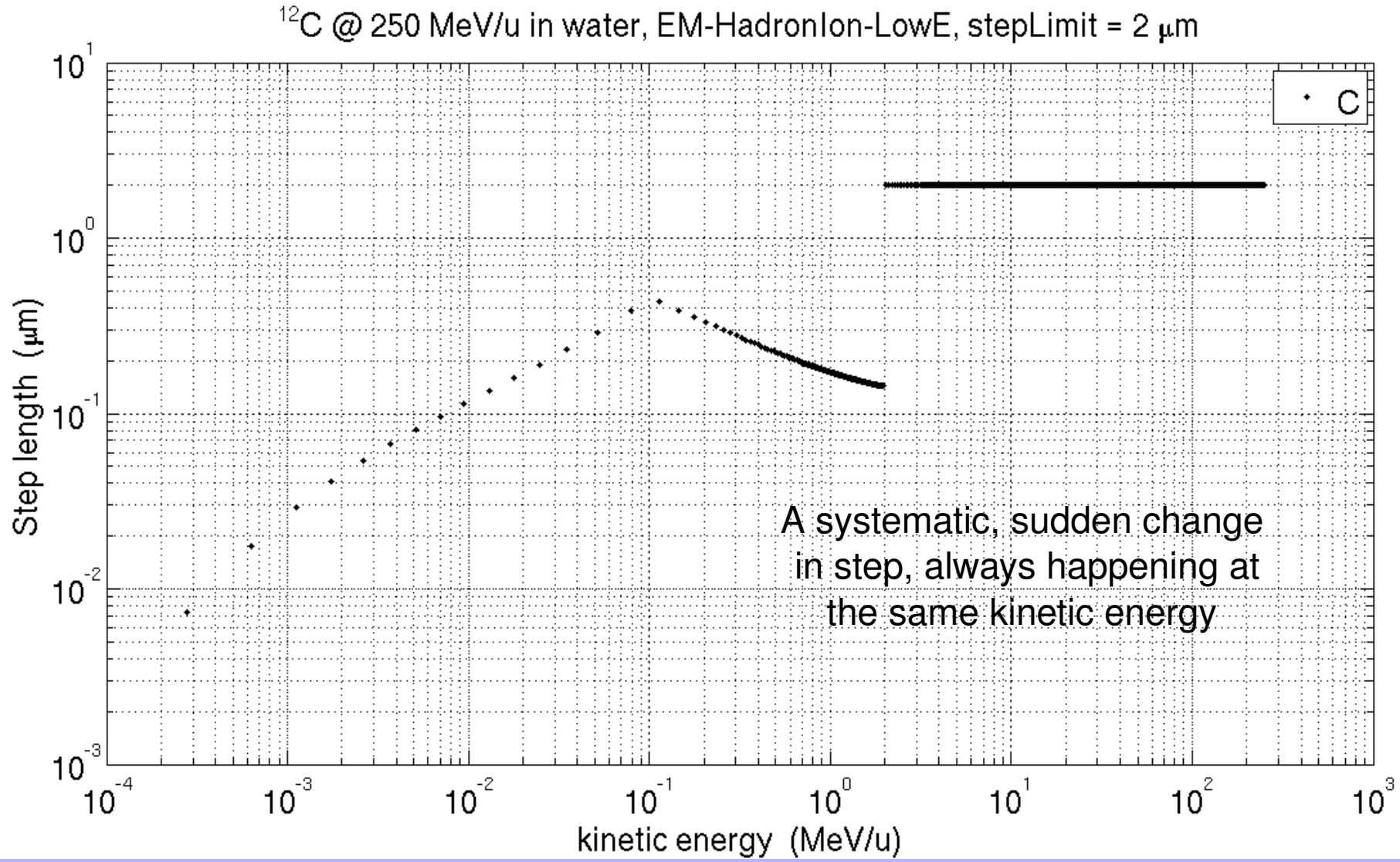
Geant4.9.2 apparent anomalies | Energy loss



Geant4.9.2 apparent anomalies | Energy loss



Geant4.9.2 apparent anomalies | stepLength



Geant4.9.2 apparent anomalies | stepLength