Energy-Range relation

Energy-Range relation

Mean total pathlength of a charged particle of kinetic energy E :

$$R(E) = \int_{\epsilon=0}^{\epsilon=E} \left[\frac{d\epsilon}{dx}\right]^{-1} d\epsilon$$

In GEANT4 the energy-range relation is extensively used :

- to control the stepping of charged particles

- to compute the energy loss of charged particles

- to control the production of secondaries (cut in range)

control the stepping of charged particles

The continuous energy loss imposes a limit on the stepsize.

The cross sections depend of the energy. The step size must be small enough so that the energy difference along the step is a small fraction of the particle energy.

This constraint must be relaxed when $E \to 0$: the allowed step smoothly approaches the stopping range of the particle.
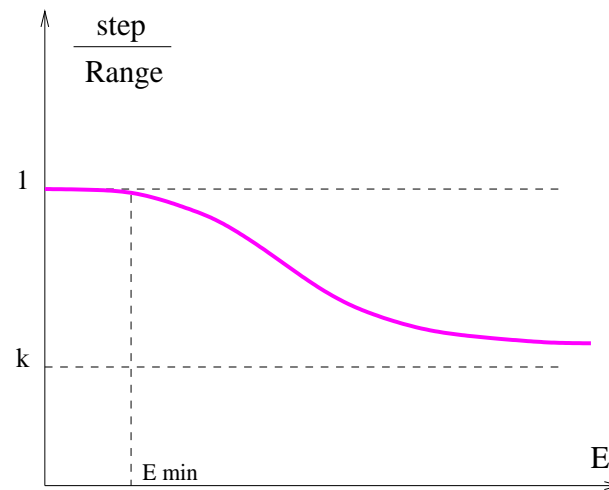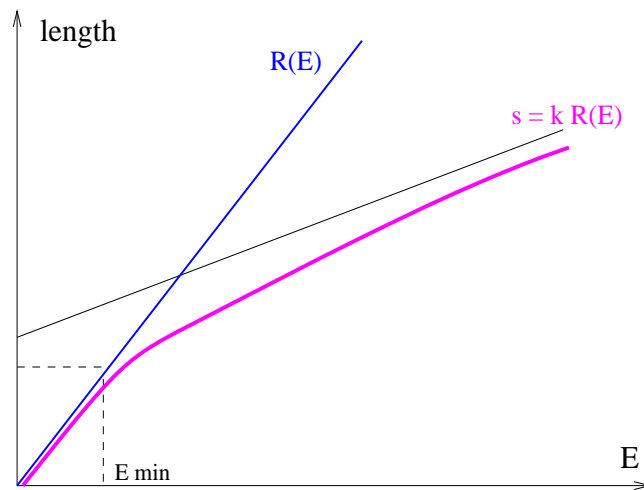
compute the mean energy loss of charged particles

The computation of the mean energy loss on a given step is done from the Range and inverse Range tables.
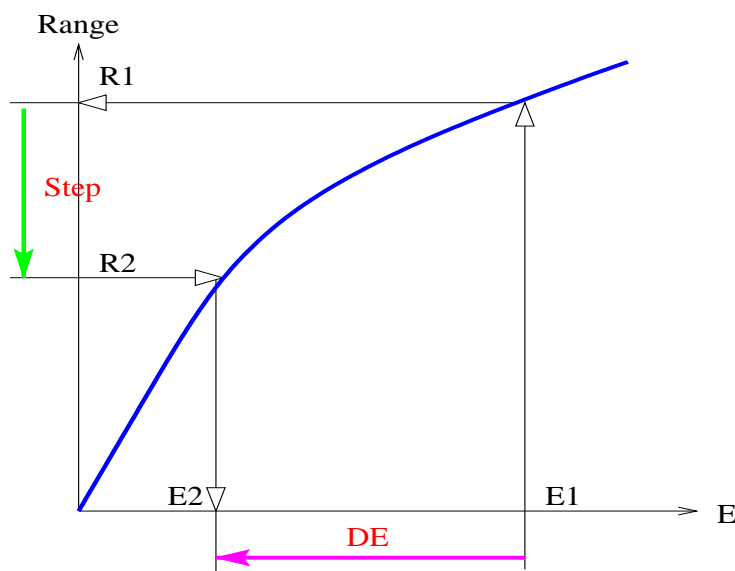
This is more accurate than $\Delta E = (dE/dx) * \text{stepLength}$.

On the same spirit, the time of life of the particle is updated from tables, automatically taking account that the particle velocity is slowing down along the step.

production thresholds (cuts) of secondaries

Production thresholds are expressed in range (instead in energy) for charged particles and photons (photon 'range' = abs.length)

No difference in a homogenous material, but GEANT4 choice is better in general, e.g. sampling calorimeter.

**example :** Pb + liquidArgon + Pb + liquid Argon each layer is few mm thick → cut/threshold can be 1(0.1) mm, cuts in energy $E_{lAr}^{cut} < E_{Pb}^{cut}$ give 'coherent' physics while using the same energy cut in both material gives 'not so good' physics in the case of high cut or degrades the efficiency (speed) for small cut value.
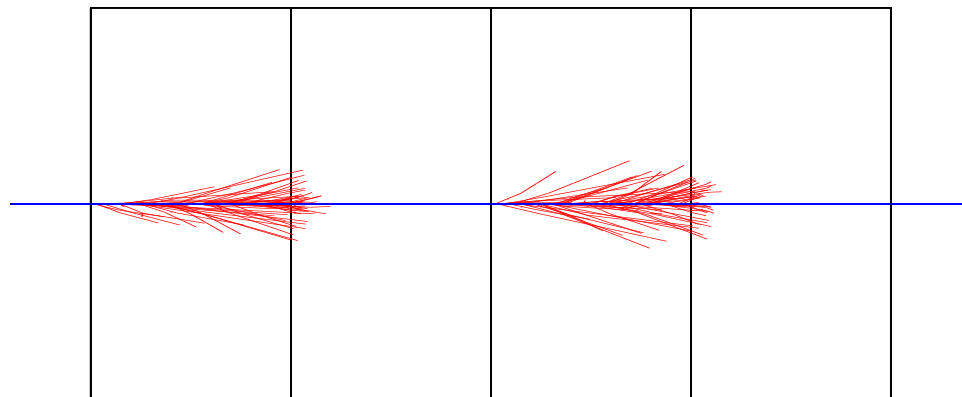
sampling: LAr(4mm) Pb(4mm). Protons 500 MeV. GEANT3

left: cut = 2MeV; right: cut = 450keV
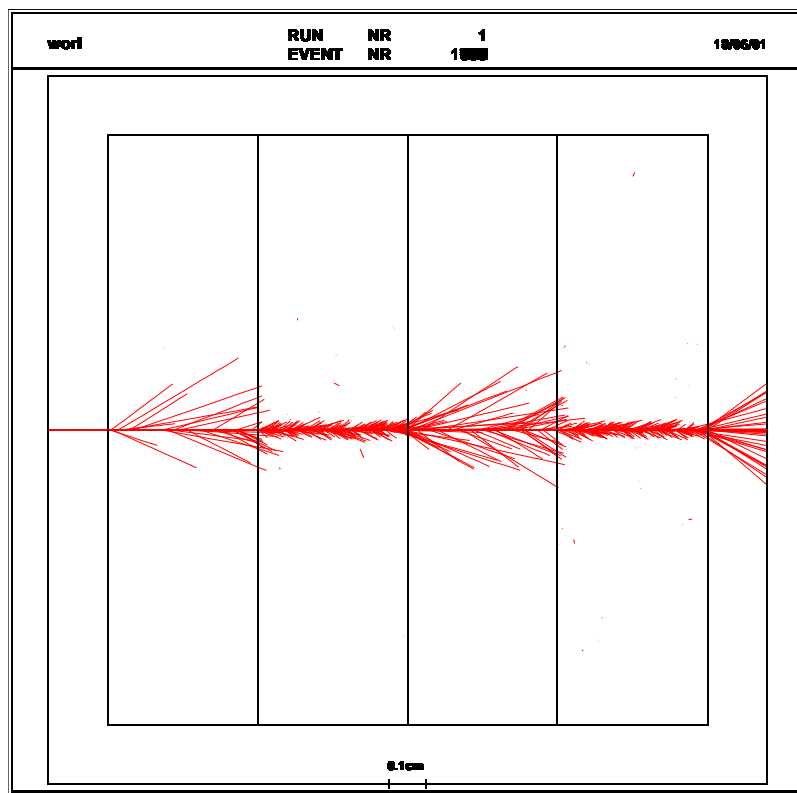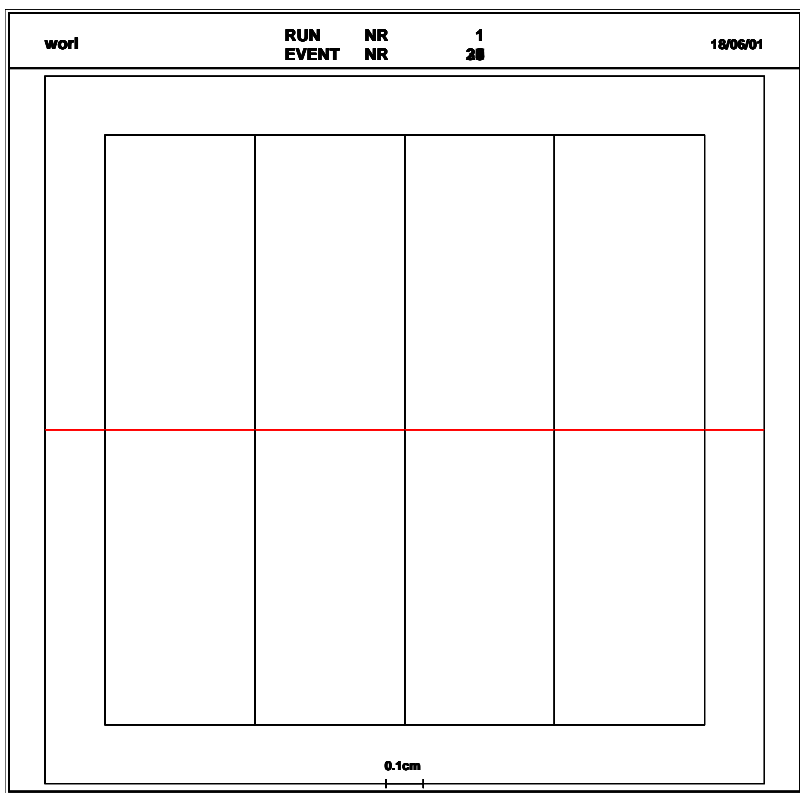
Cut in range: sampling: LAr(4mm) Pb(4mm). Protons 500 MeV.
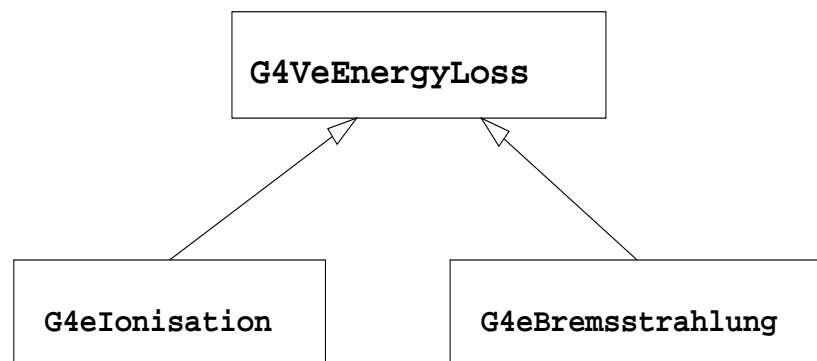
GEANT4 cut: 1.5mm =(450keV, 2MeV)

design details

Ionization and Bremsstrahlung cannot be independent :

$$\left[\frac{dE}{dx}\right]_{tot} = \left[\frac{dE}{dx}\right]_{ioni} + \left[\frac{dE}{dx}\right]_{brem}$$

$$R(E) = \int_{\epsilon=0}^{\epsilon=E} \left[\frac{d\epsilon}{dx}\right]_{tot}^{-1} d\epsilon$$

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                    G4VeEnergyLoss
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    G4eIonisation          G4eBremsstrahlung
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The processes compute the individual contributions.

The base class computes the sum and the range.

The base class is pure virtual : it cannot be directly instantiated.