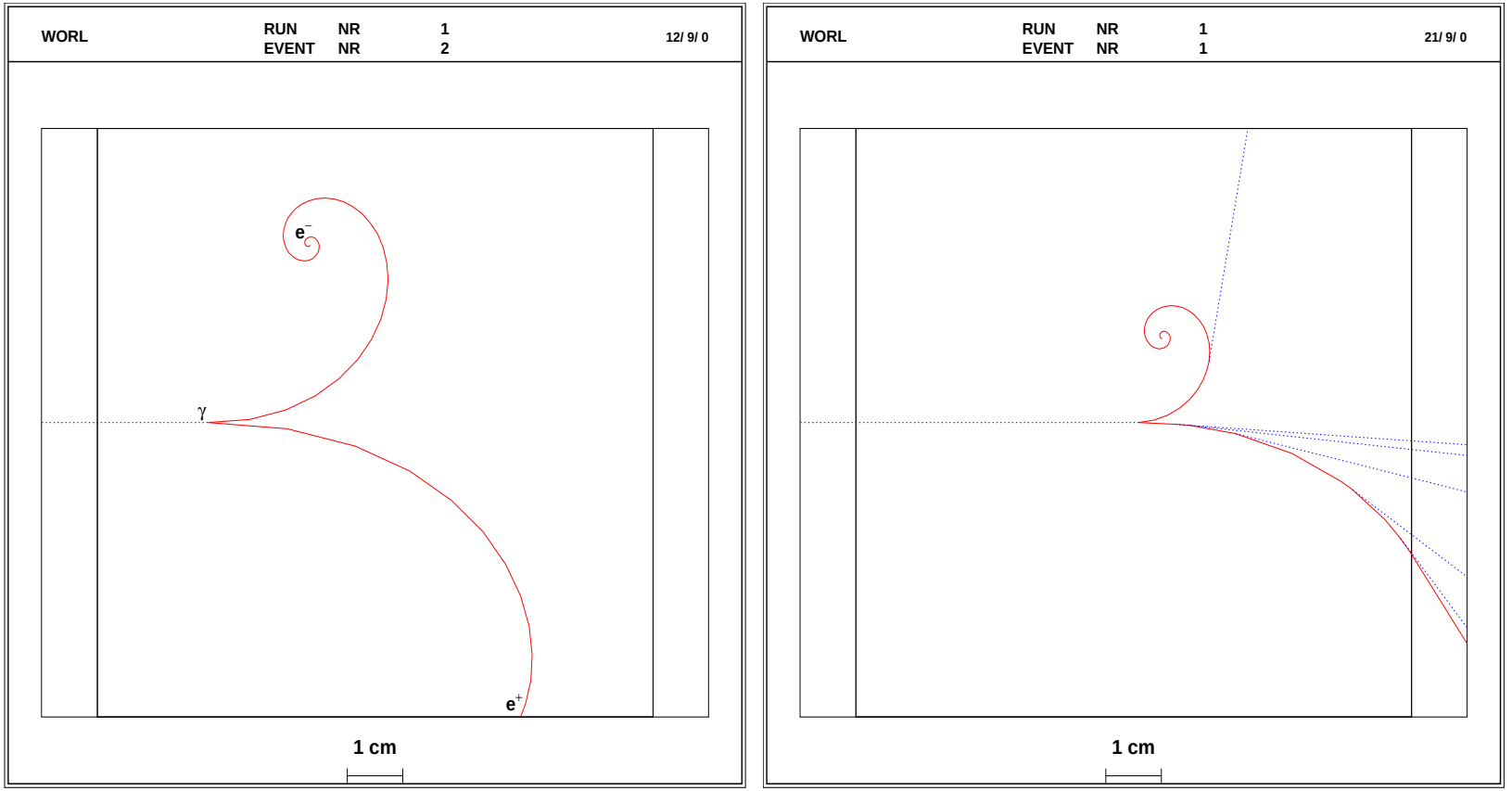
Electromagnetic cascades

Electromagnetic cascades

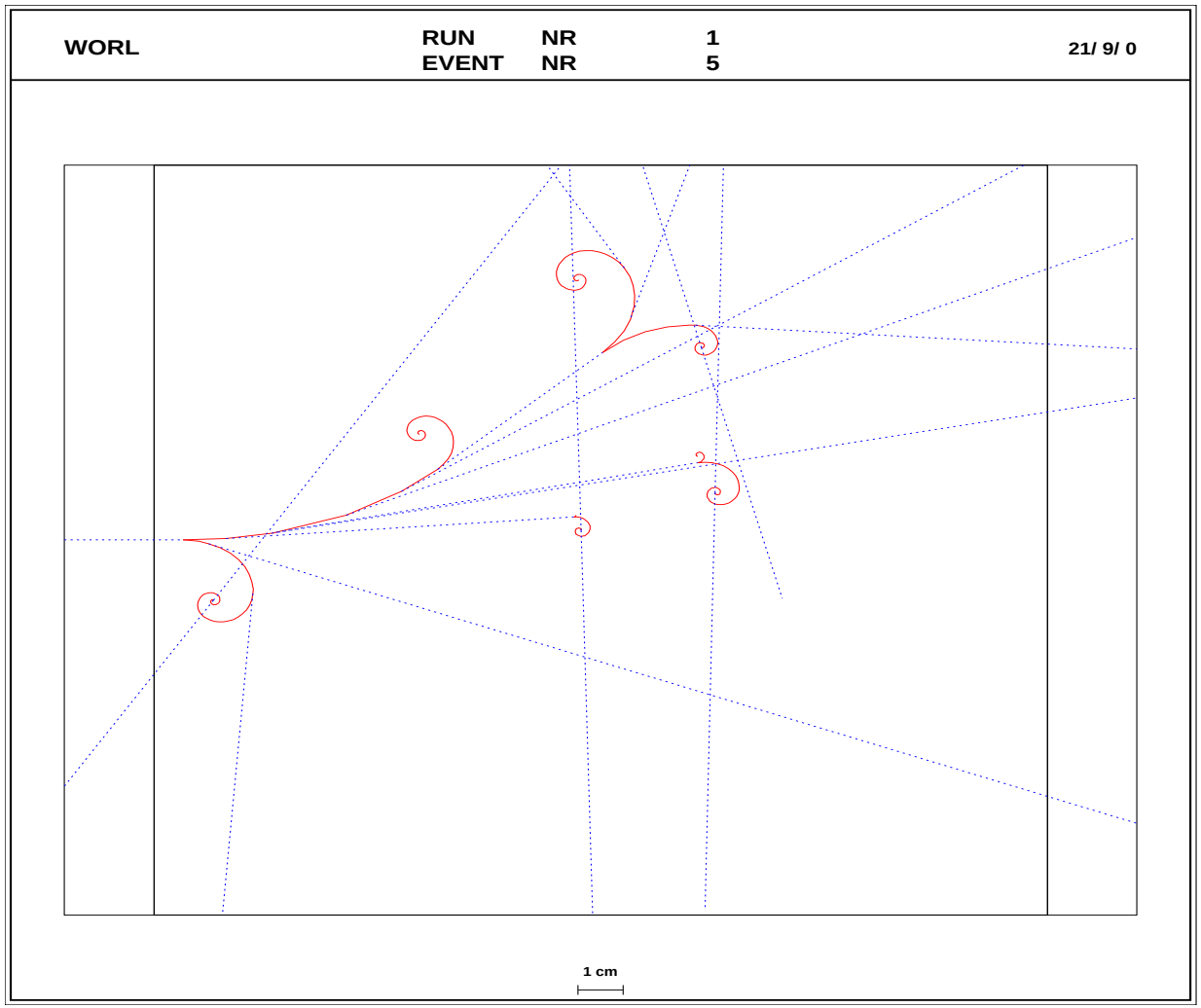
The development of cascades induced by electrons or photons is governed by bremsstrahlung of electrons/positrons and (e^+, e^-) pair creation by photons, until the energy of secondary electrons/positrons fall below the critical energy E_c.

Then the electrons and positrons lose their energy preferentially by ionization, halting the cascade.

γ 200 MeV in 1 X_0 Aluminium. left: pair only; right: pair + brem



γ 200 MeV in 2 X_0 Aluminium. Pair + brem



longitudinal profile in homogeneous material

Beyond the first radiation length, the mean longitudinal profile of the energy deposition is well described by a gamma function [Long75] :

$$\frac{dE}{dt} = E_0 \cdot \text{const} \cdot t^a \cdot \exp(-bt) \quad \text{with } t = x/X_0 \qquad (1)$$

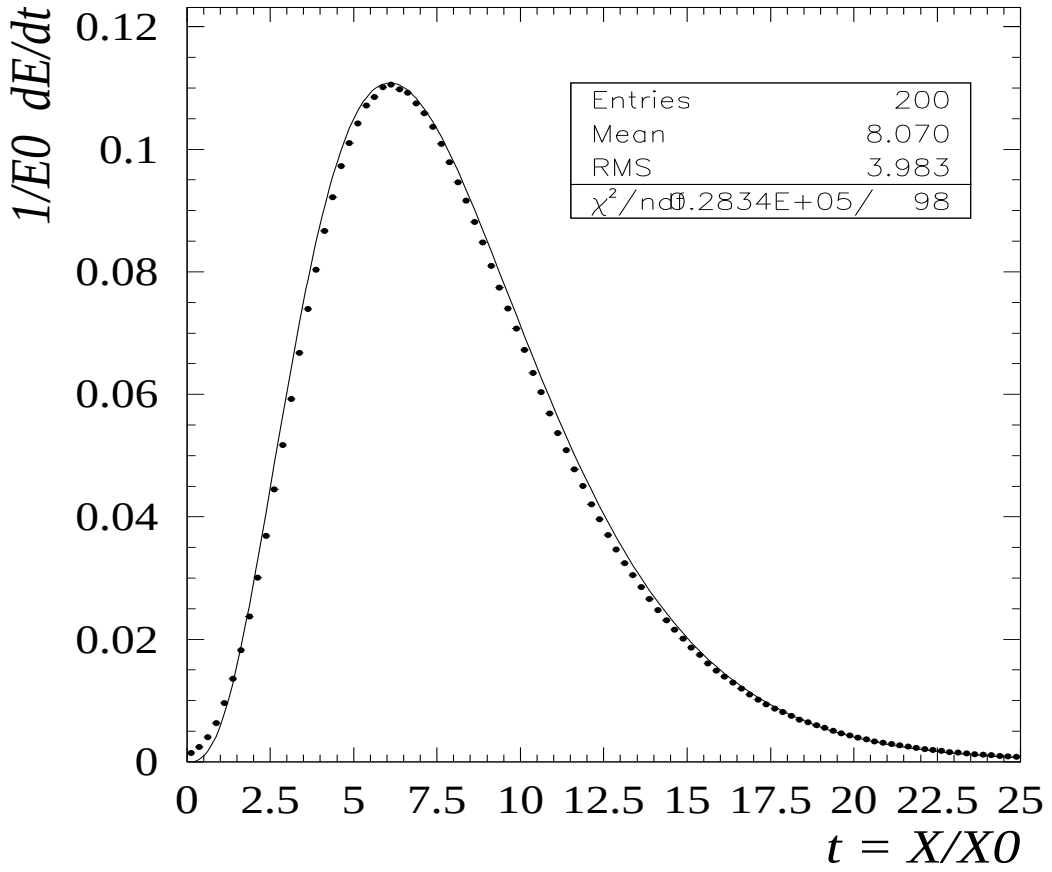
a and b are fit parameters dependent on the material.

On the other hand, a simple model of shower development ([Leo94]) can predict the maximum of the distribution :

$$t_{max} = \frac{a}{b} = k \ln\left(\frac{E_0}{E_c}\right)$$

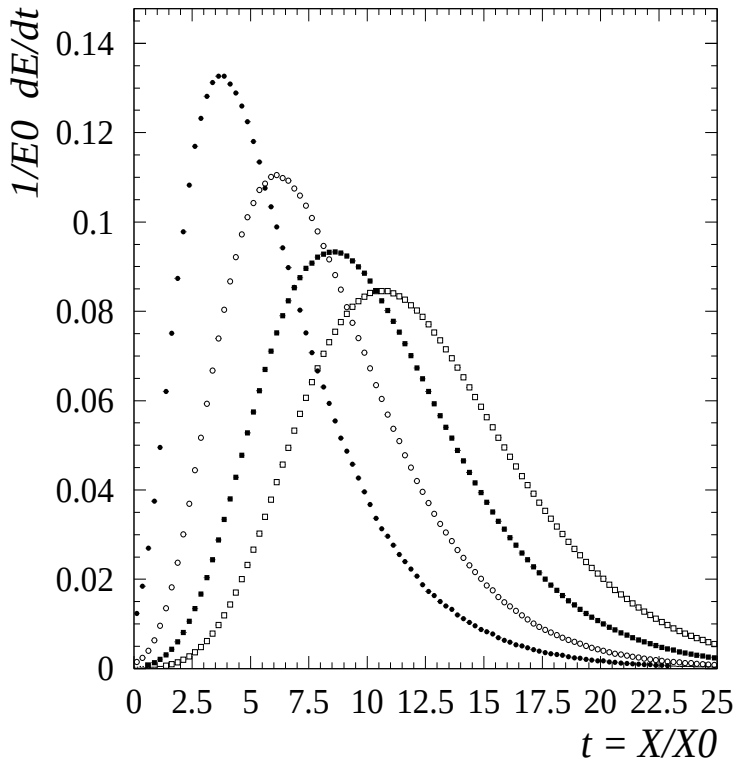
e^- 10 GeV in PbWO4

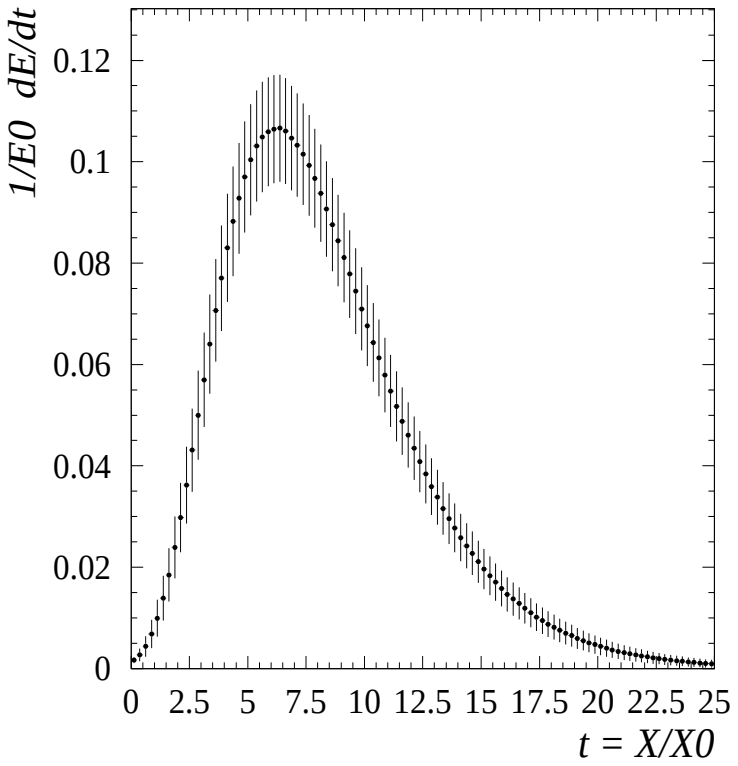
Simulation and gamma-fit of the longitudinal profile [Melo99]



left: e^- 1 GeV, 10 GeV, 100 GeV, 1 Tev in PbWO4

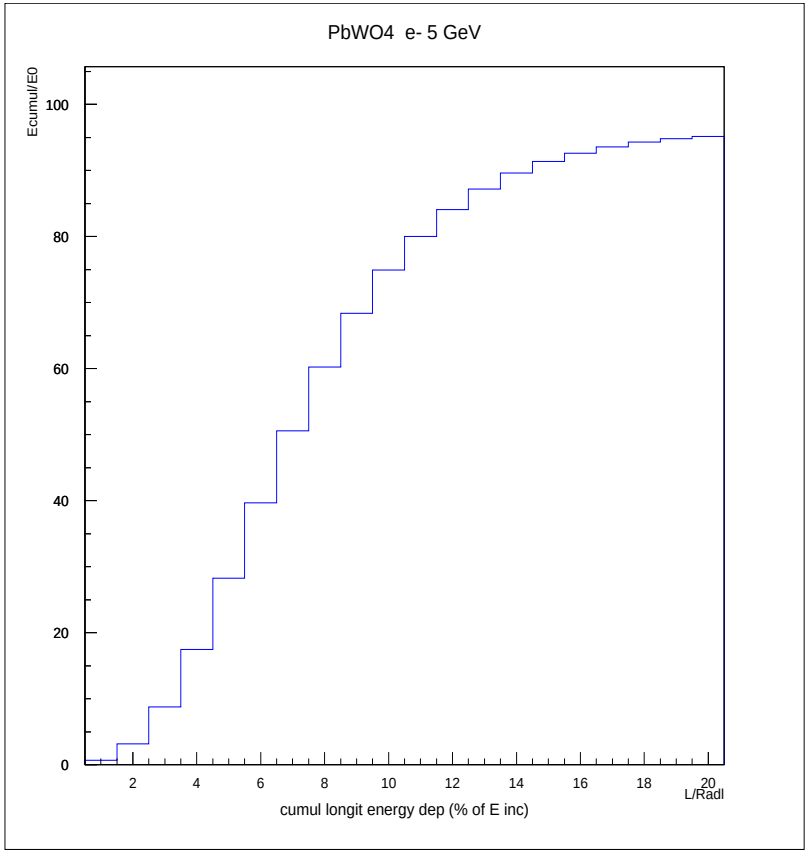
right: e^- 10 GeV; profile and its intrinsic fluctuations

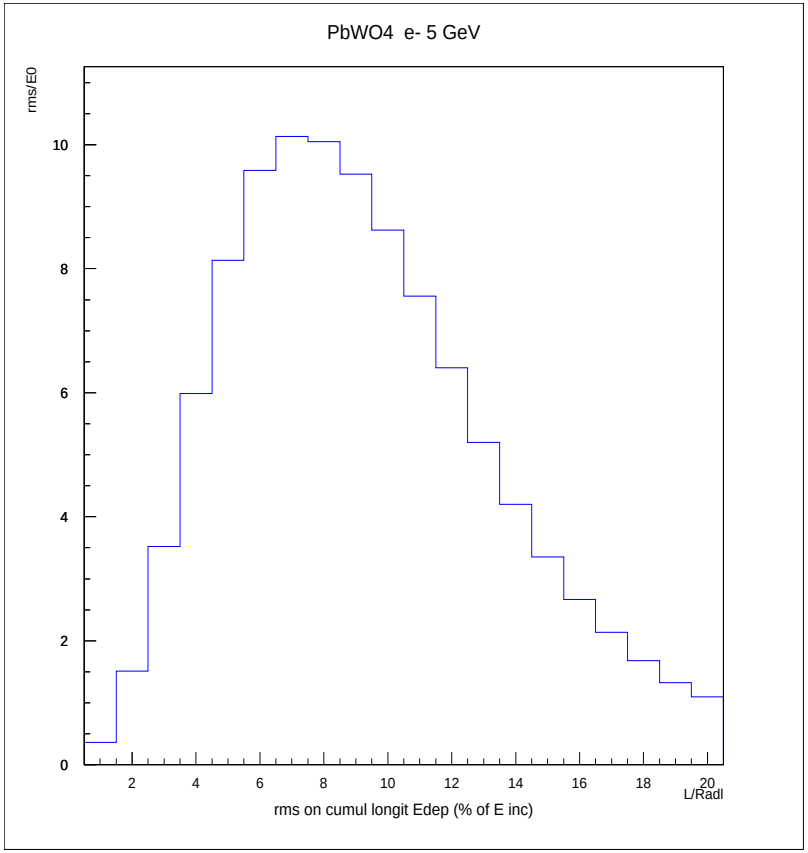




e^- 5 GeV in PbWO4

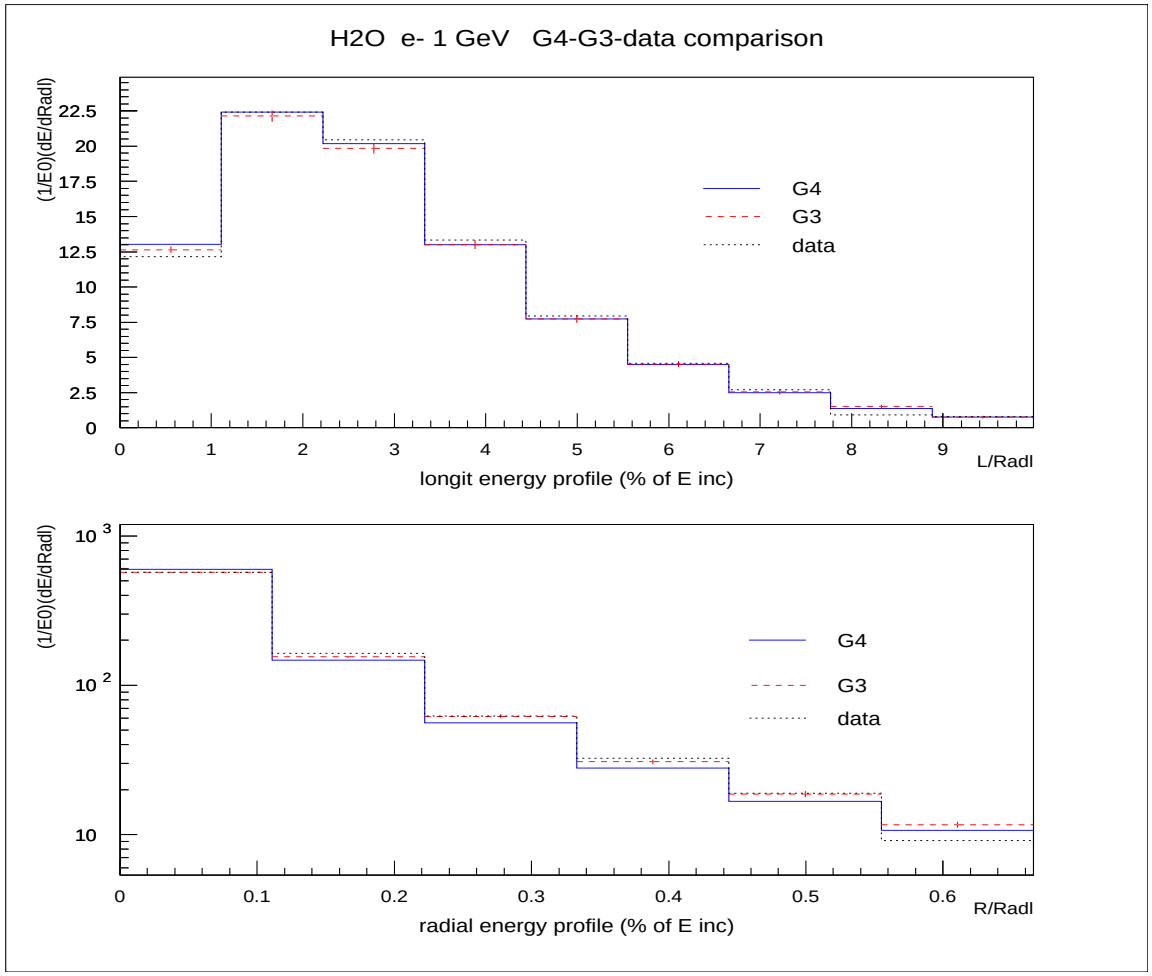
cumulative longitudinal profile and its intrinsic fluctuations ($\longrightarrow$ leakage)





e^- 1 GeV in Water

data [Cran69] and simulation of the longitudinal profile



radial profile in homogeneous material

The lateral spread of an electromagnetic shower is mainly caused by multiple scattering.

The Molière radius is defined :

$$R_m = \frac{21 \text{ MeV}}{E_c} X_0$$

On average, 90% of the shower energy is contained in a (semi infinite) cylinder of radius R_m, in any material.

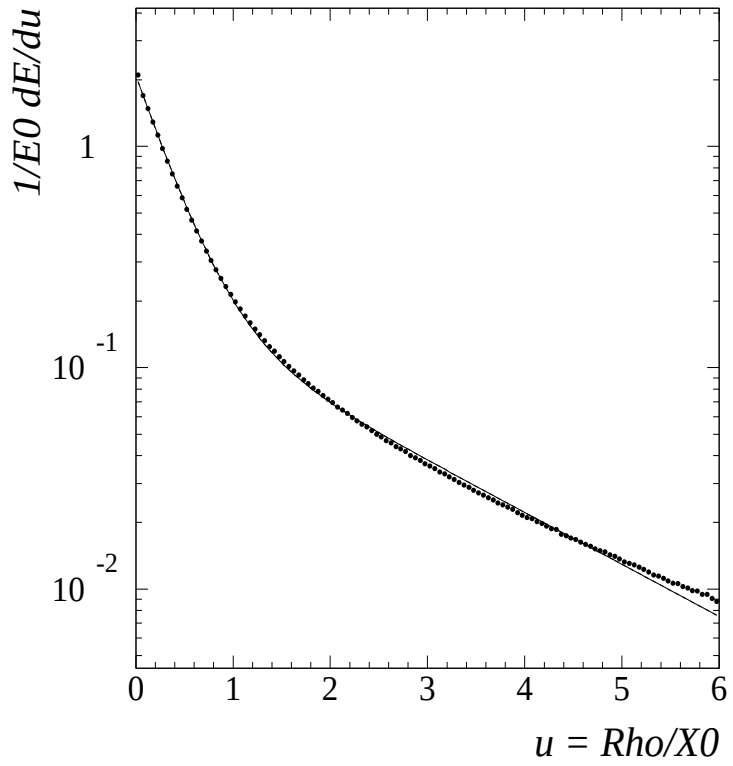
This radial distribution is well represented by the sum of two gaussian.

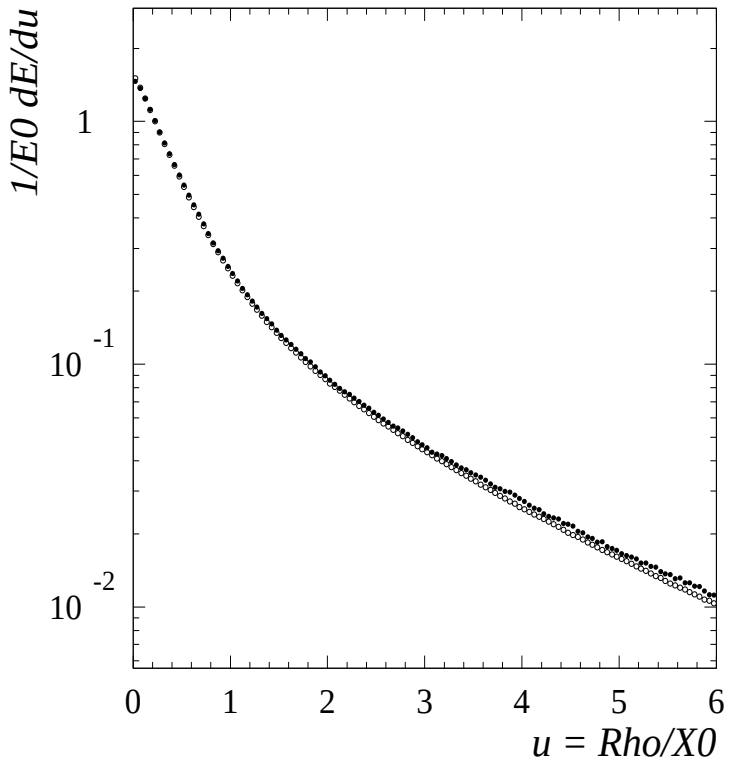
The distribution is nearly independent of the incident energy E_0

radial profile

left: e^- 10 GeV in PbWO4, simulation and two-gaussian fit.

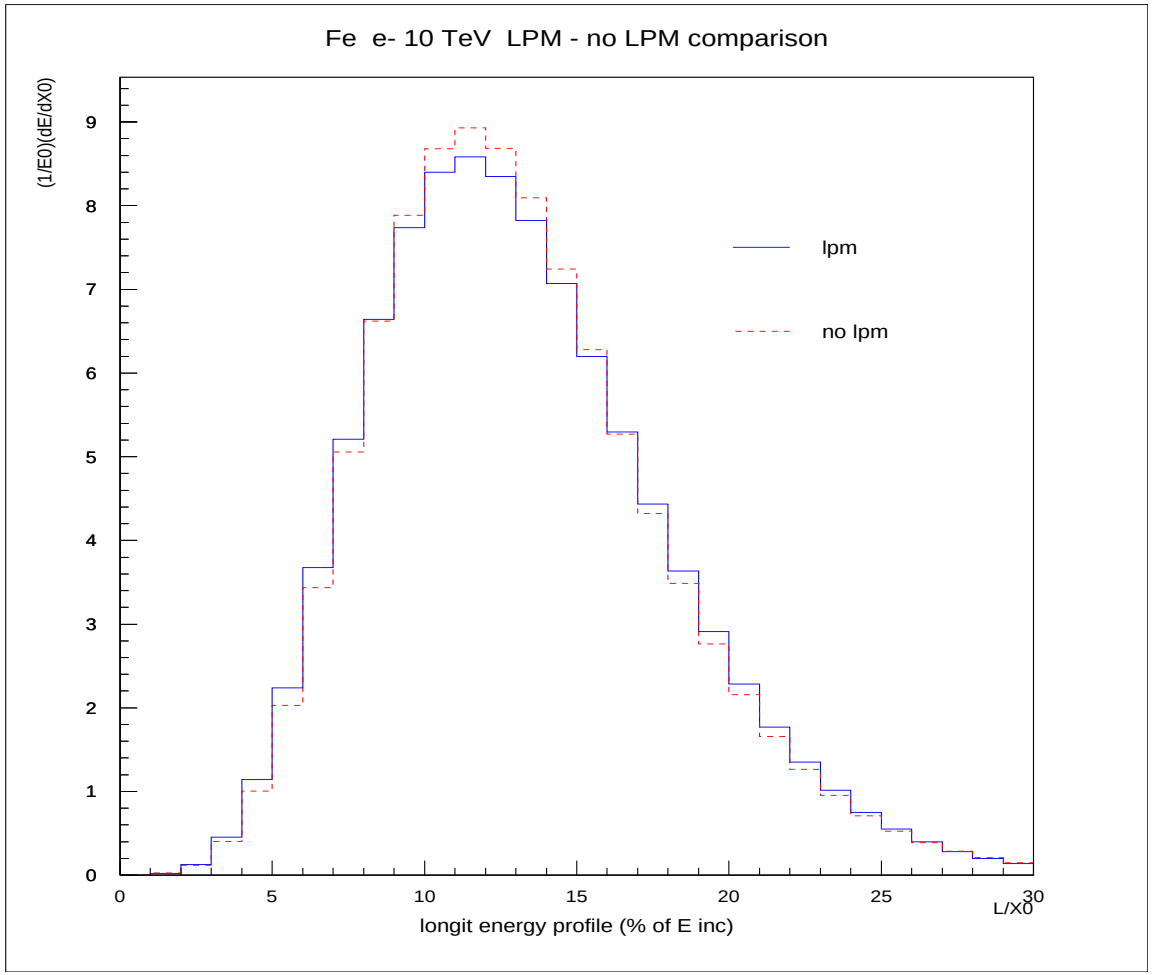
right: 1 GeV and 1 TeV profiles





At high enough energies, the LPM effect can cause signifiant elongation of electromagnetic cascades ...

apparently, not yet at 10 TeV ...



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