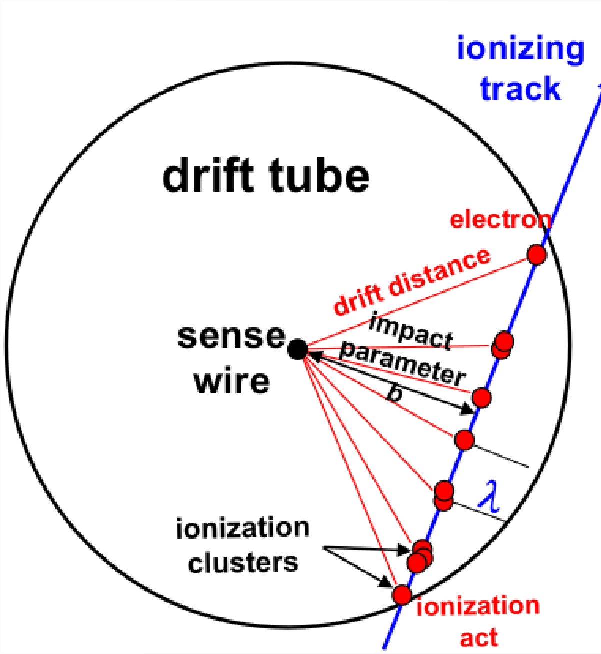
Ionization process simulation in gas

Goal : Simulation/parametrization of ionization cluster generation in Geant4

To investigate the potential of the Cluster Counting technique (for He based drift chamber) on physics events a reasonable simulation/parametrization of the ionization clusters generation in Geant4 is needed.



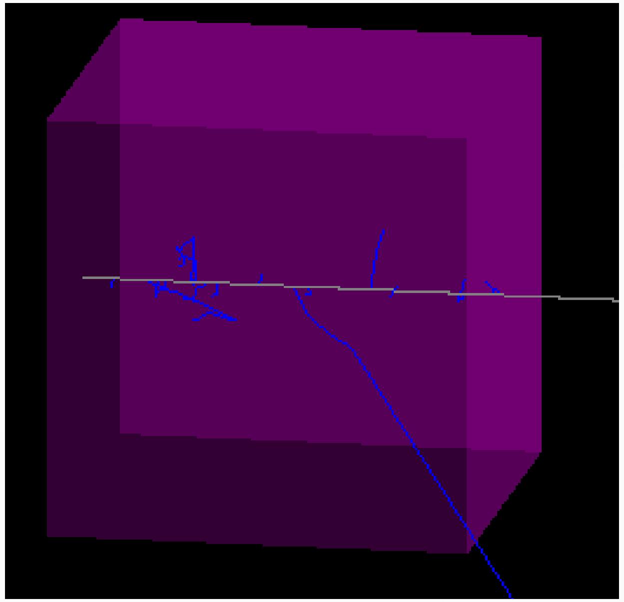
Garfield++ :

- **(Heed)** simulates the ionization process in the gasses (not only) in a detailed way.
- **(Magboltz)** computes the gas properties (drift and diffusion cœfficients as function of the fields value)
- solves the electrostatic planar configuration and simulates the free charges movements and collections on the electrodes.

So Garfield can study and characterize the properties and performance of single cell or drift chamber with simple geometry, but cannot simulate a full detector neither study collider events.

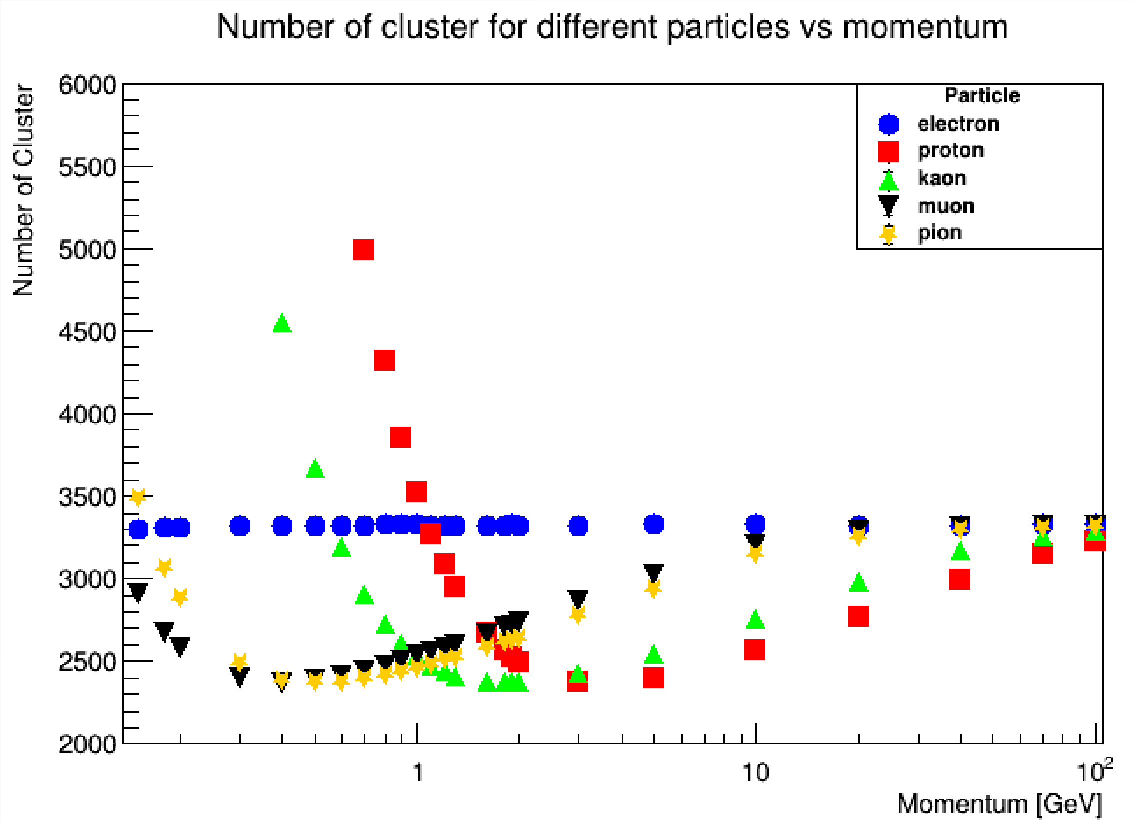
Geant4 :

- Simulates the elementary particle interaction with material of a full detector.
- Studies colliders events



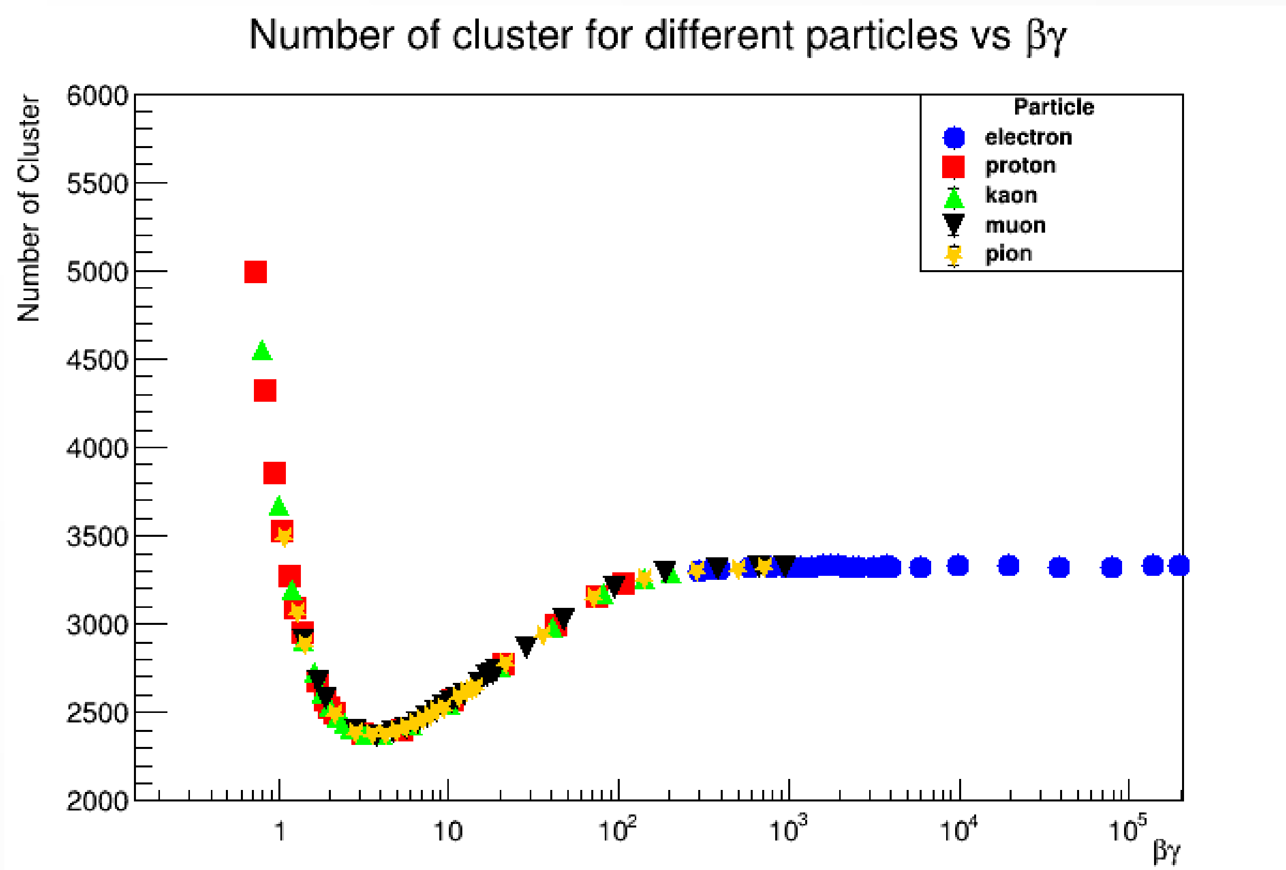
But...the fundamental properties and performance of the sensible elements (drift cells) have to be parameterized or ad-hoc physics models have to be defined.

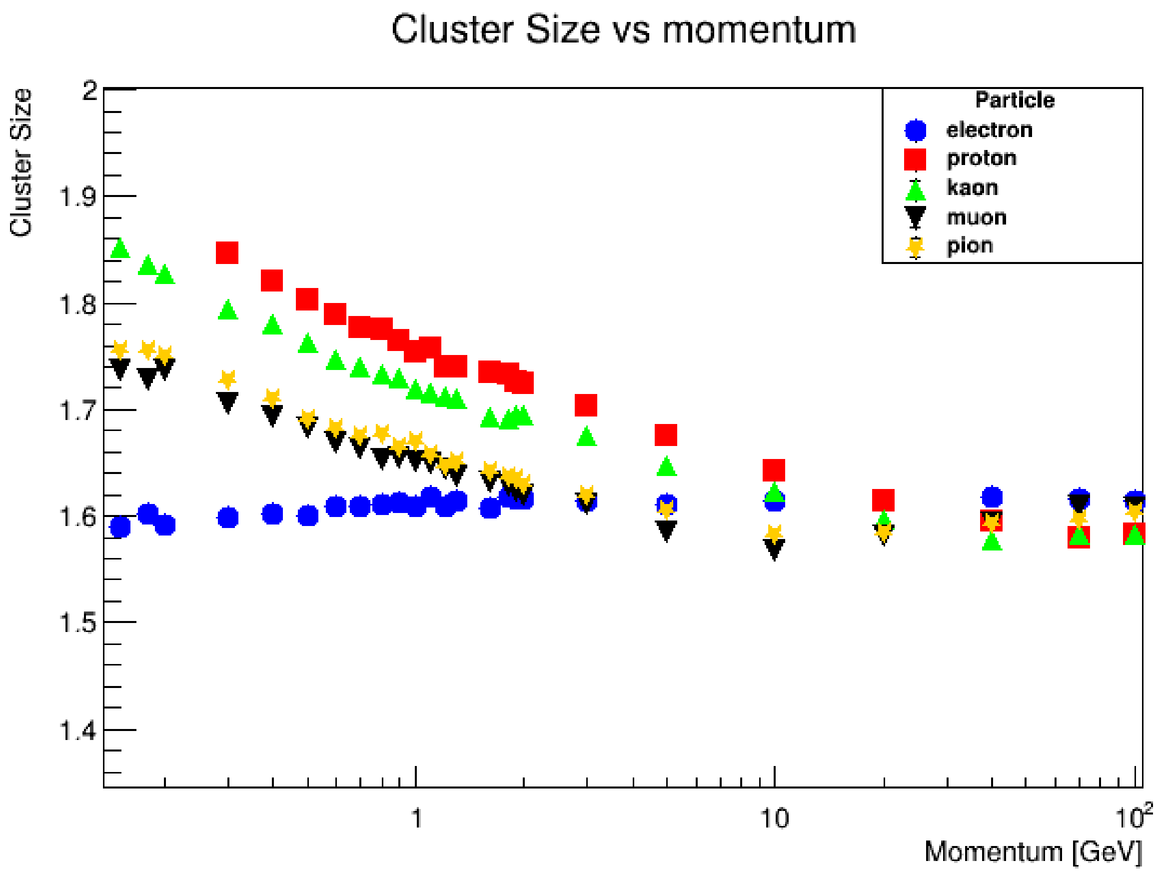
Actually we are simulating 2m long tracks which pass through a 1 cm long side box of 90% He and 10% iC_4H_{10}, with Garfield++ and Geant4 .



Number of cluster from Garfield++

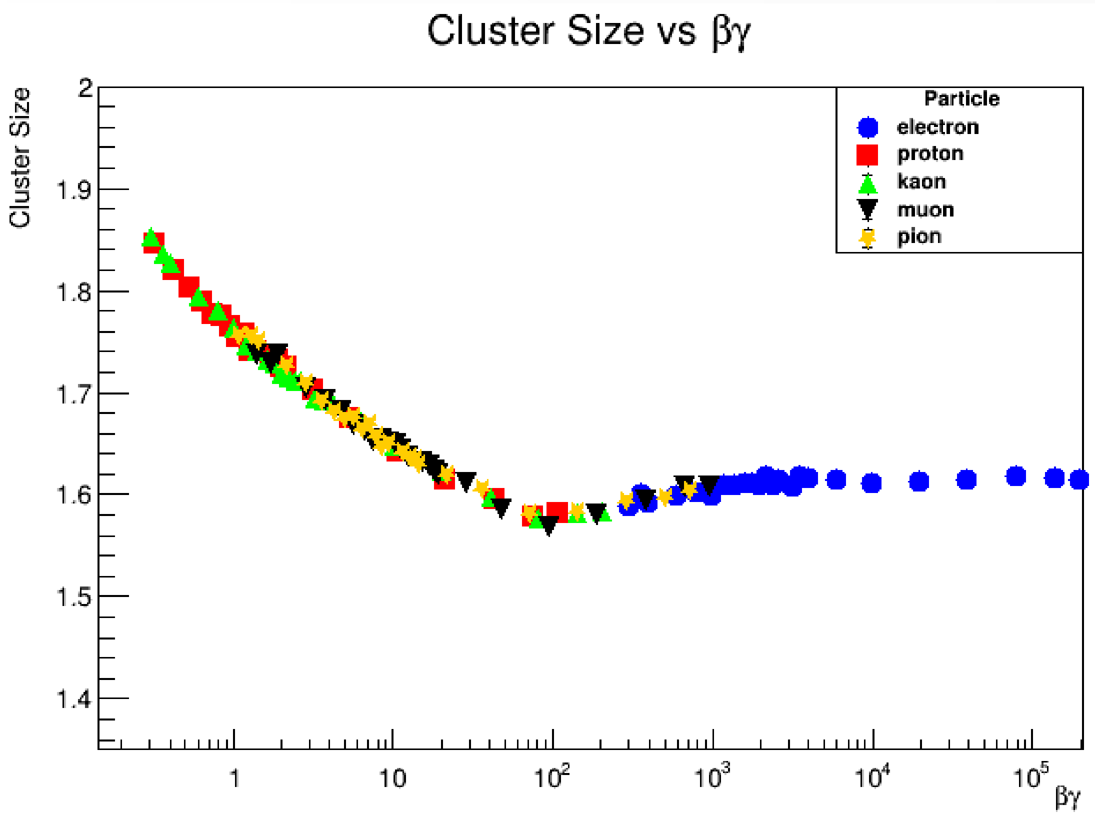
Here the distribution of number of cluster produced by different particle at different momenta, obtained with Garfield++

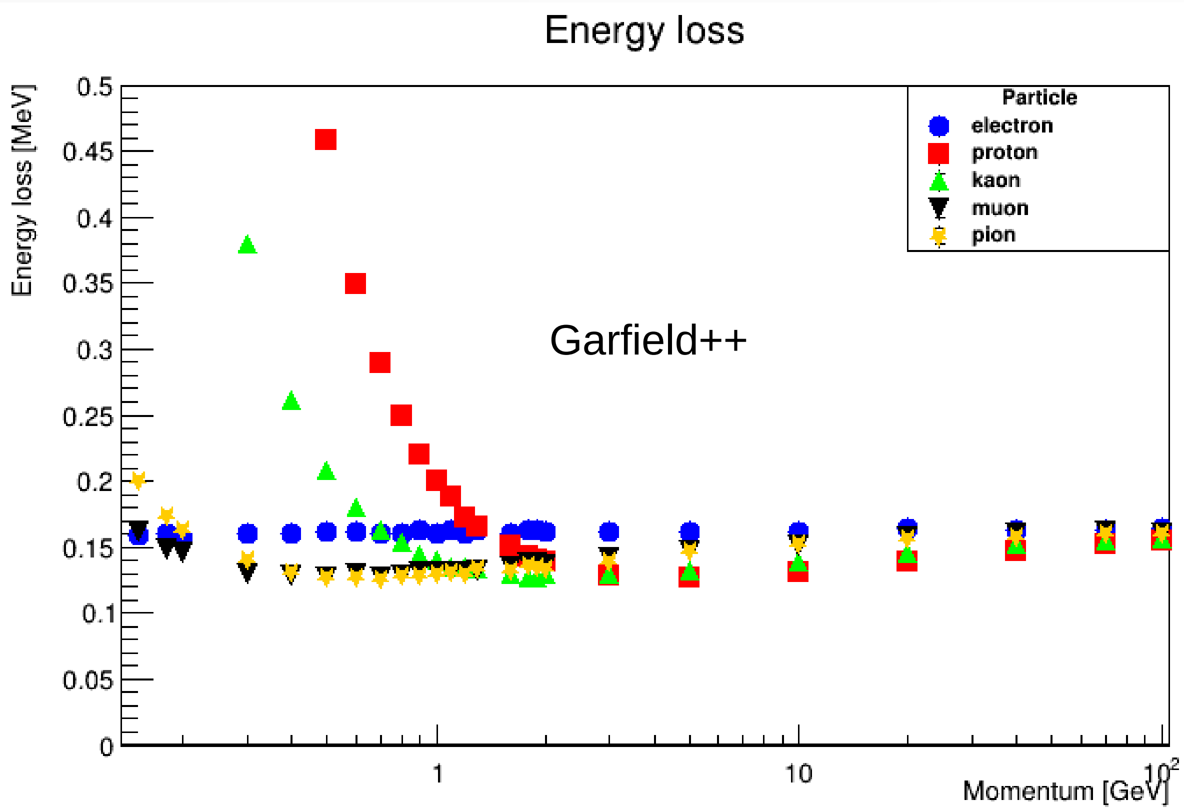




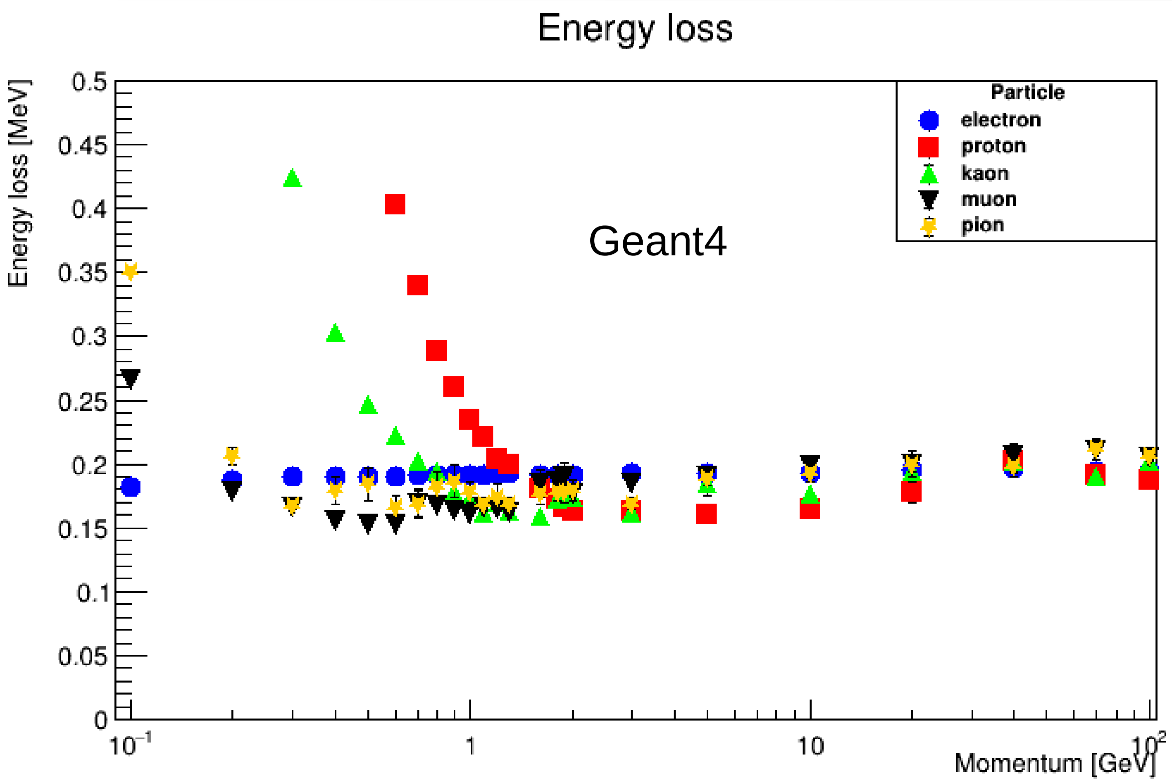
Cluster size from Garfield++

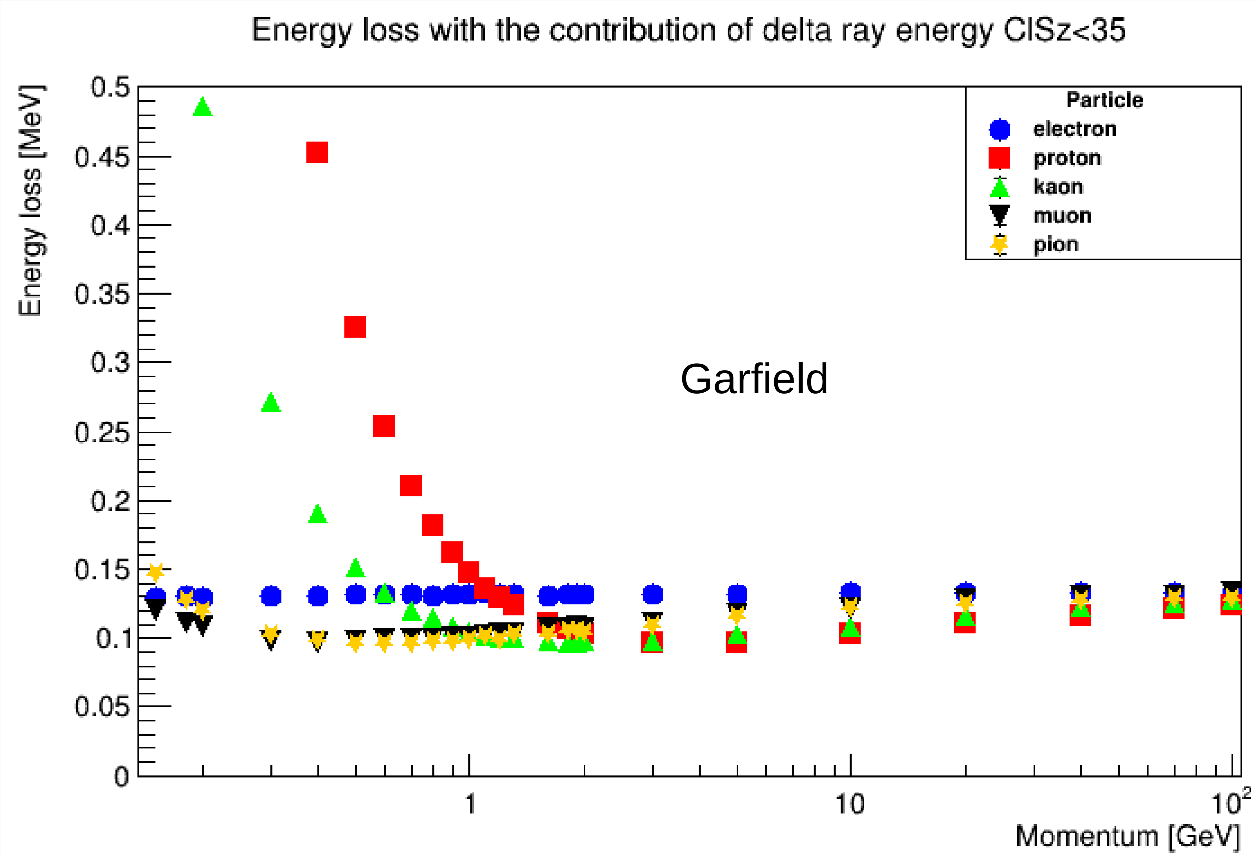
Here the distribution of cluster size produced by different particle with different momenta, obtained with Garfield++





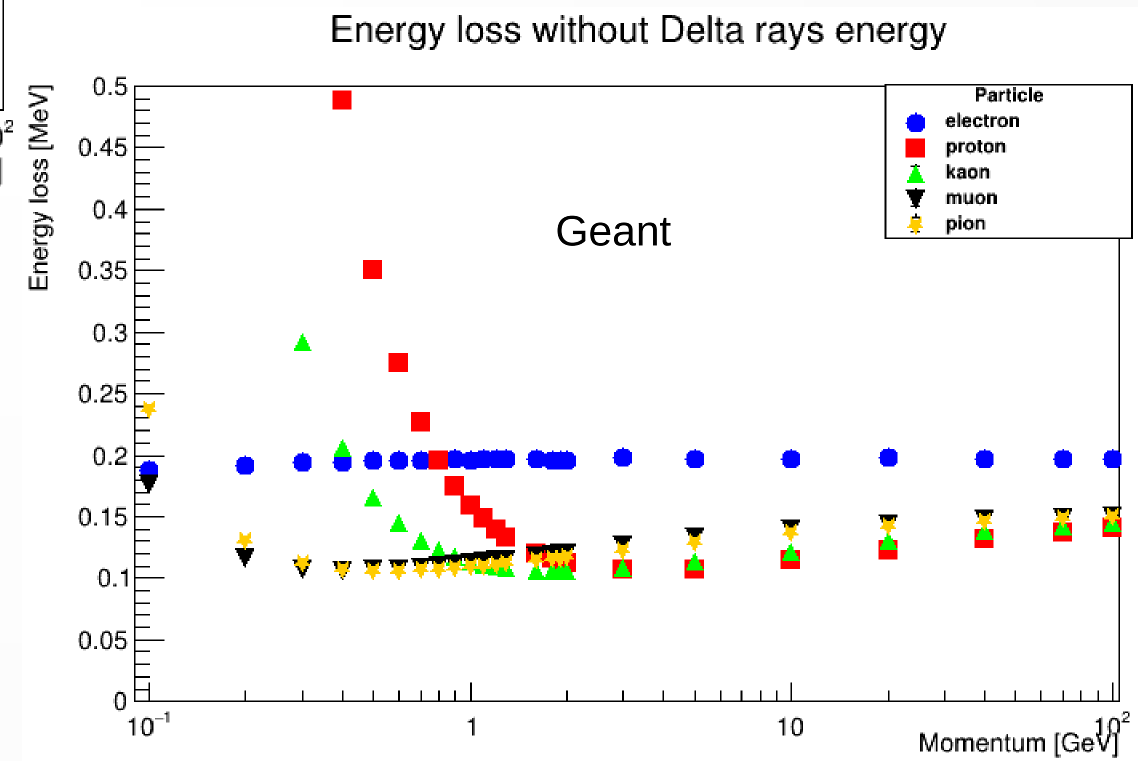
Here the distribution of energy loss for different particles simulated from Garfield++ (top left) and from Geant4 (bottom right).





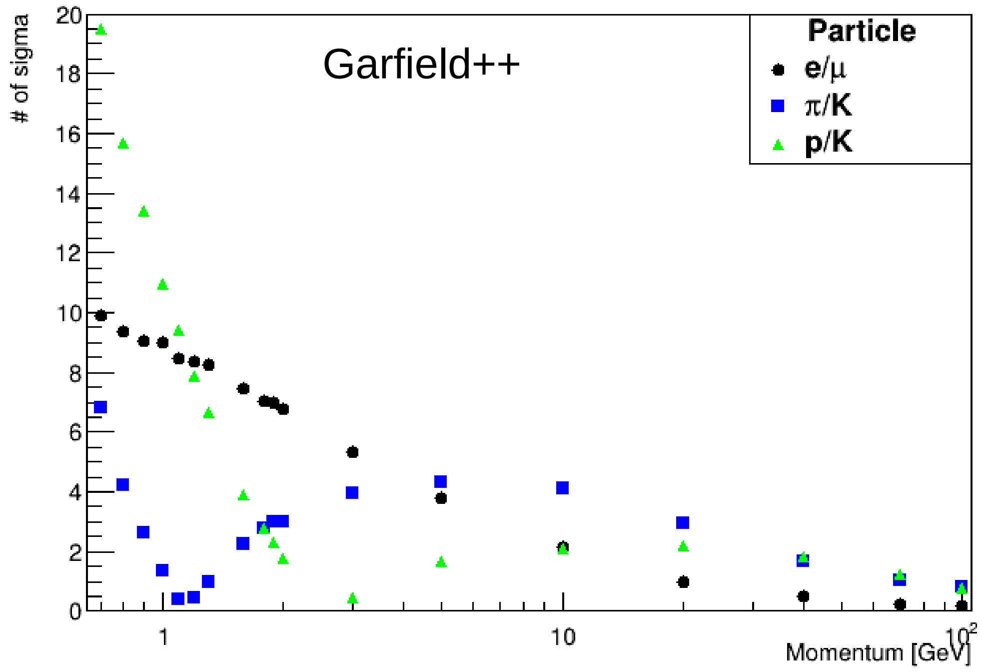
Here the distribution of energy loss without the contribution from delta rays energy for different particles simulated from Garfield++ (top left) and from Geant4 (bottom right).

In Garfield++, taking energy without delta rays contribution means considering the contribution of the delta electrons which produce cluster size less than 35 electrons.

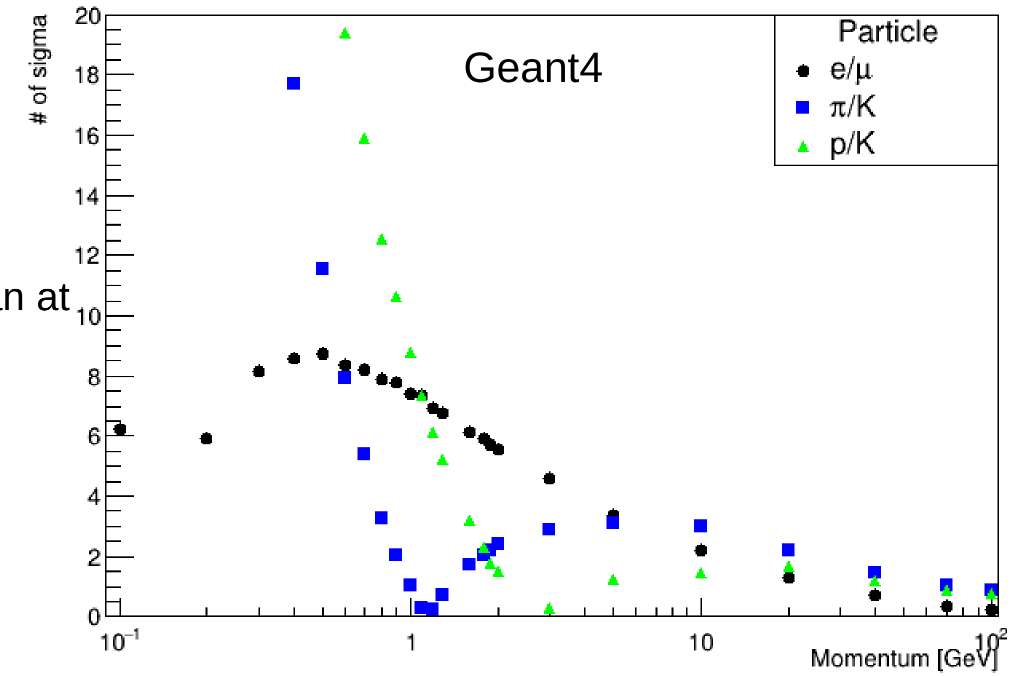


Particle separation with traditional dE/dx method and cluster counting

Particle separation from truncated mean dE/dx

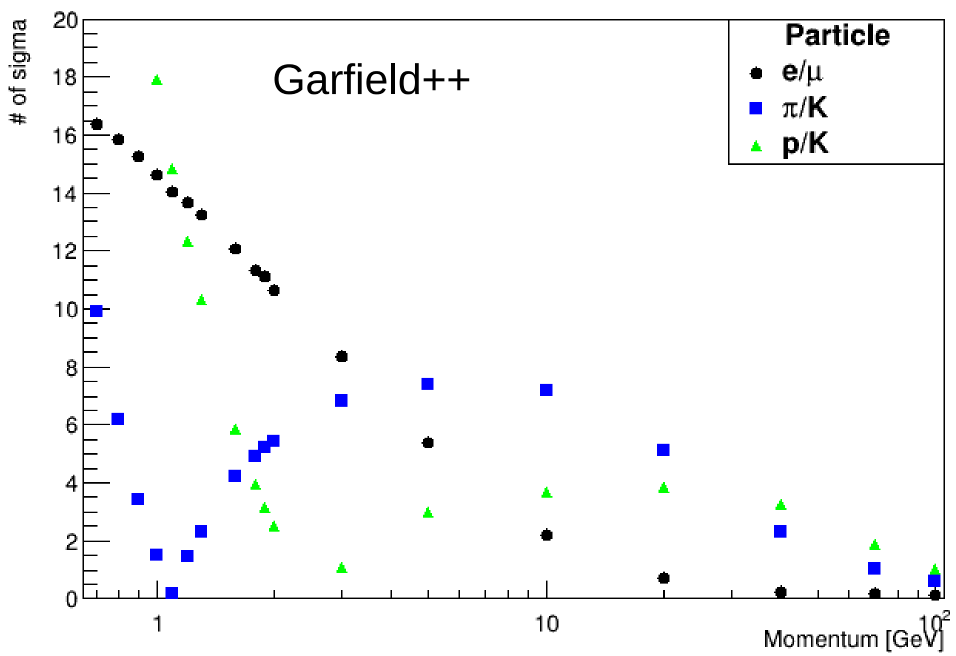


Particle separation from truncated mean dE/dx



Truncated mean at 70%

Particle separation dN/dx



$$n_\sigma = \frac{\Delta_A - \Delta_B}{\langle \sigma_{A,B} \rangle} .$$

σ is the average of the two resolutions.

We are simulating 2m long tracks which pass through a 1 cm long side box of 90% He and 10% iC_4H_{10} , with Garfield++ and Geant4

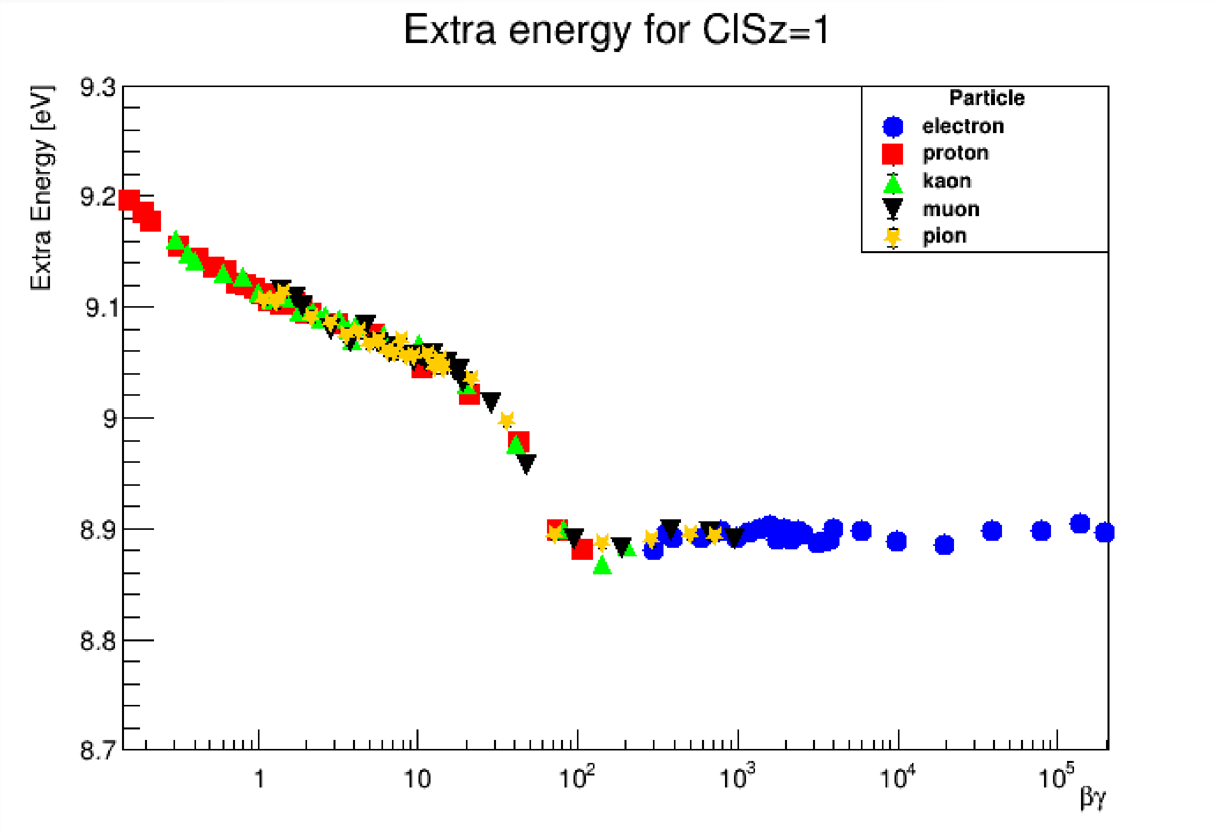
Strategy

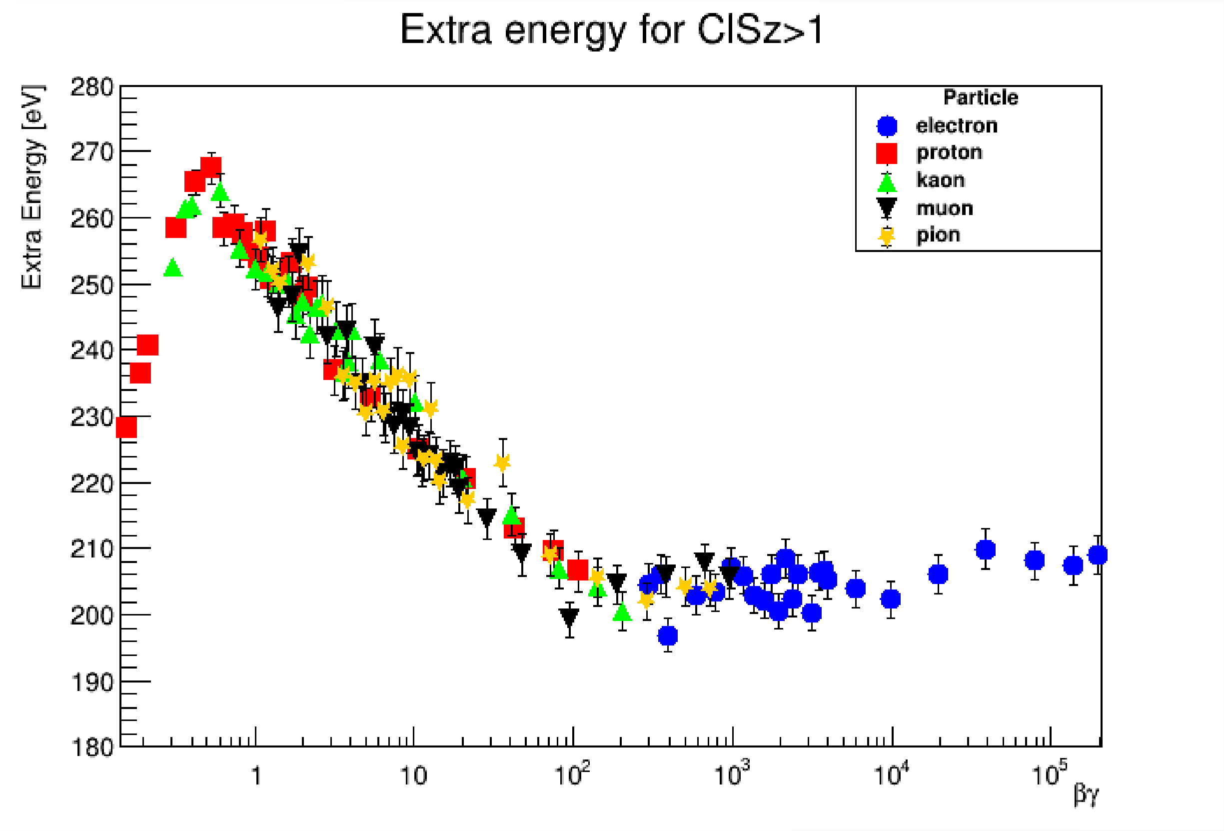
Studying the results from Garfield++ simulations, we can interpret correctly the results obtained from Geant4 simulations with the goal of reconstruct the number of cluster generated from different particles with different momenta passing through the tracker detector.

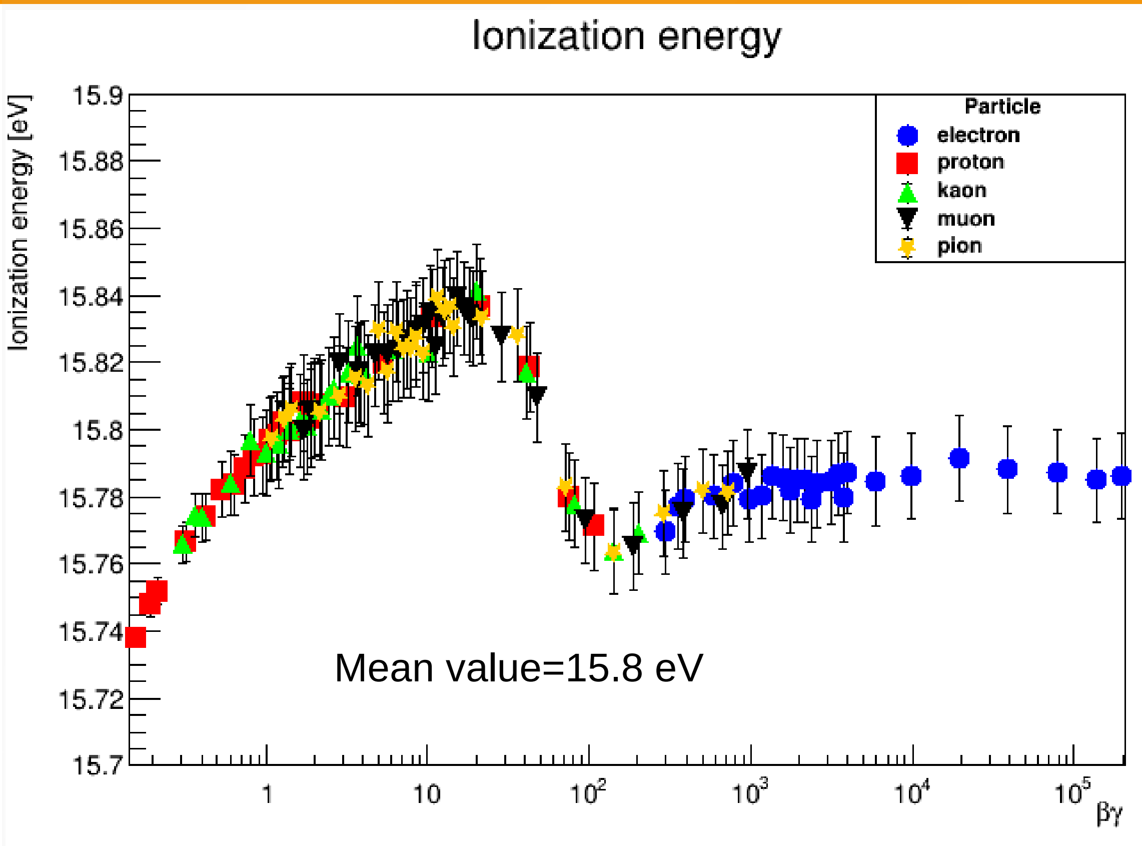
The strategy consist of :

- Constructing a model of primary and secondary ionization energy.
- Using the model to reconstruct the number of cluster from energy loss simulated by Geant4.

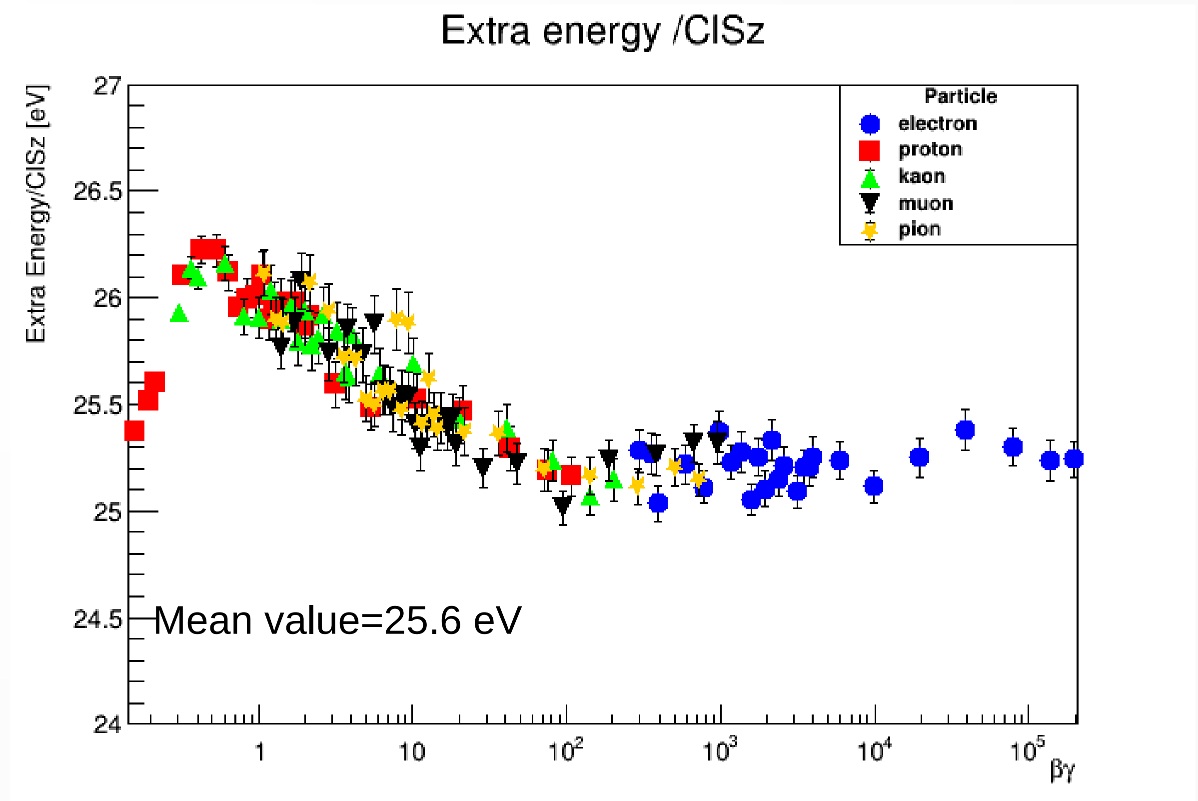
Here the mean value of Extra energy for cluster with cluser size higer equal to 1 and for cluster with cluster size higher than 1 for different particles at different momenta.



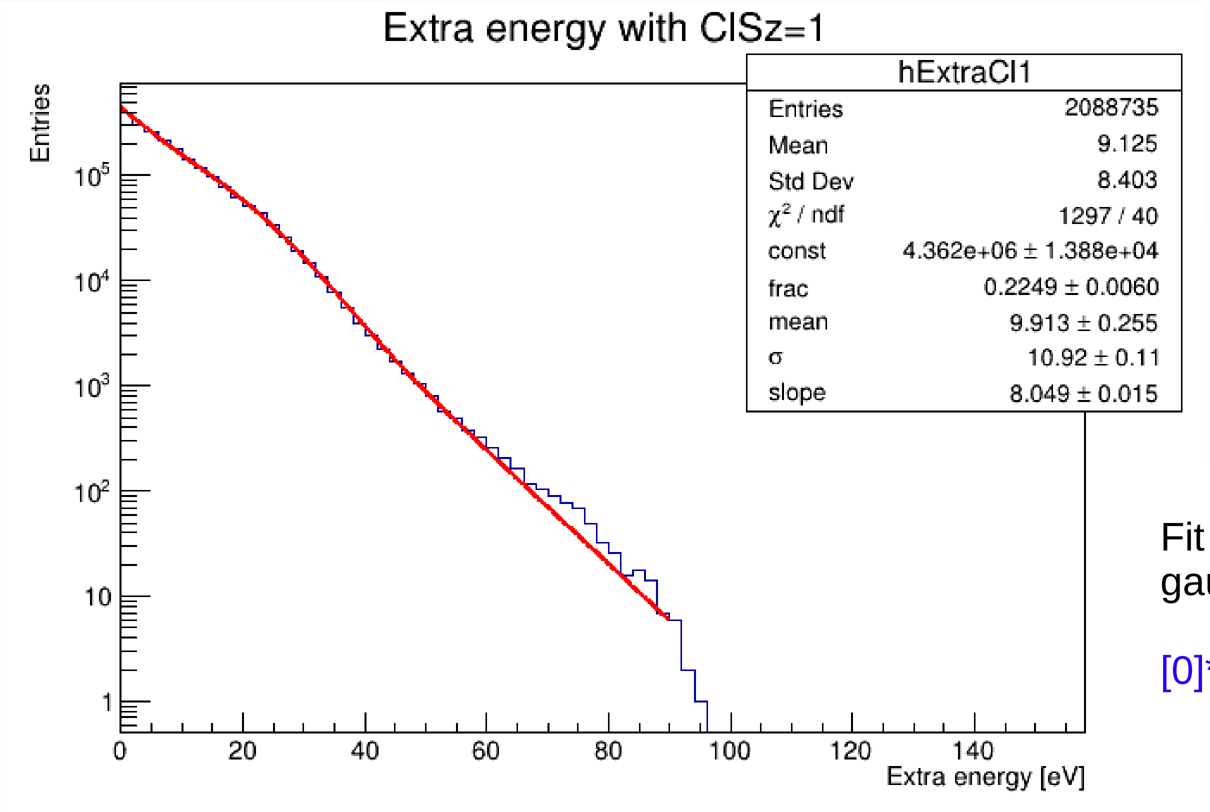




Ionization Energy is the ratio between the Energy loss without delta energy and the number of cluster.

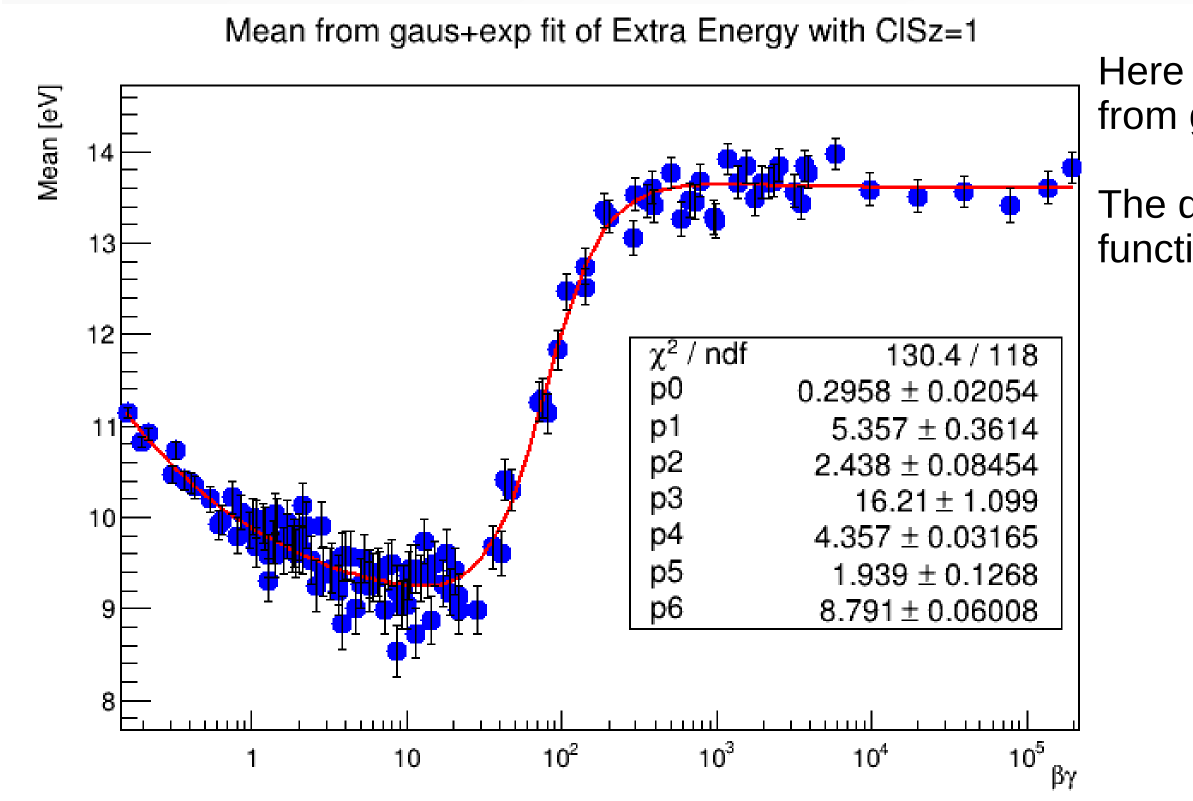


To construct the model we started with a fit of Extra energy distribution for cluster with cluster size equal to 1.
Here an example of muon with momentum of 300 MeV.



Fit function consists of:
gaussian function +exponential function

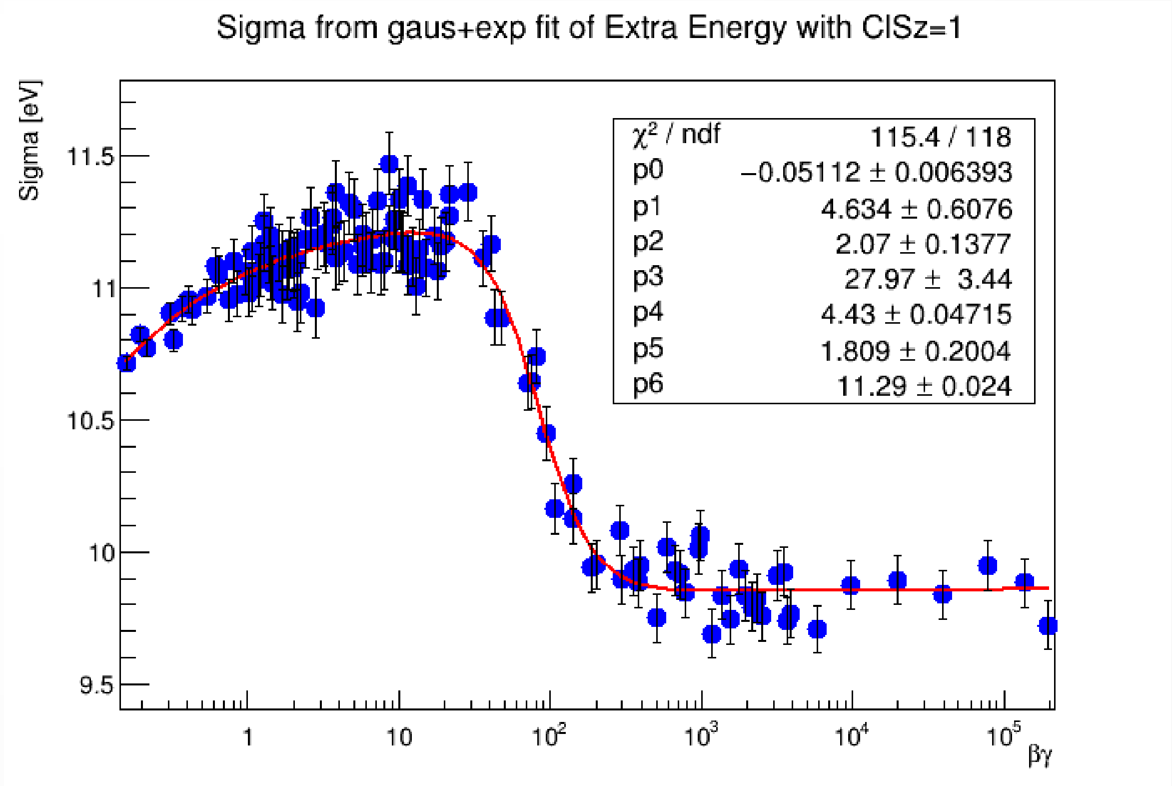
[0]*([1]*TMath::Gaus(x,[2],[3],true)+(1.0-[1])*TMath::Exp(-x/[4])/[4])

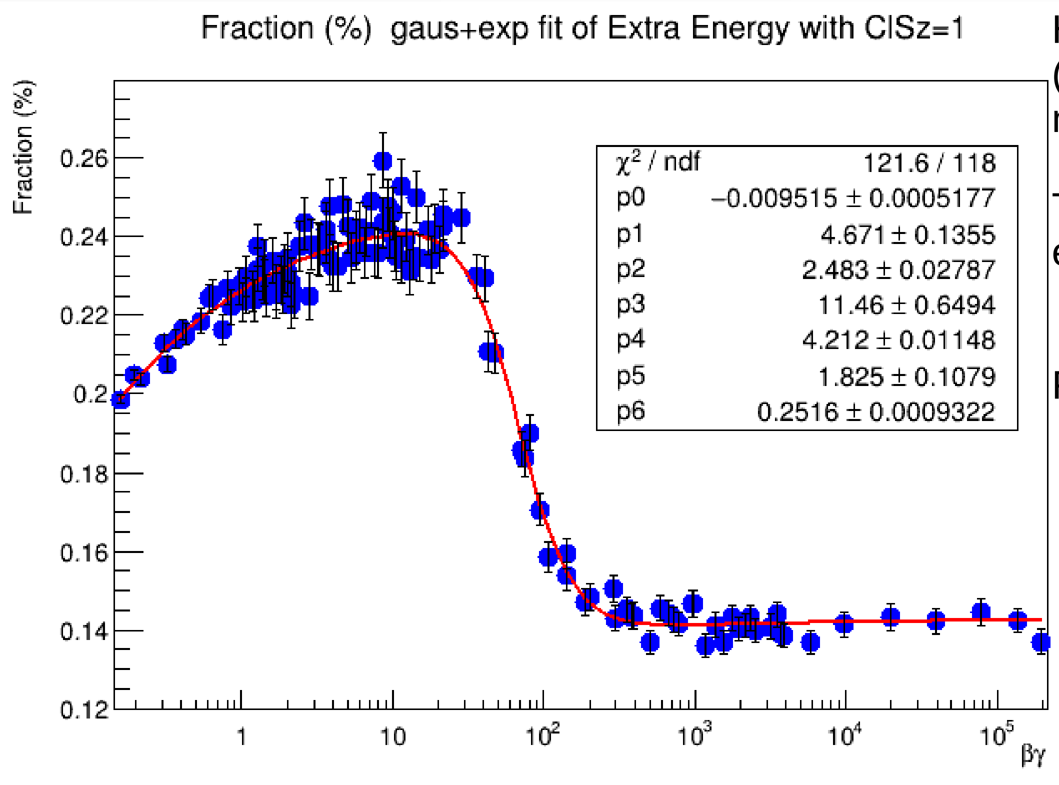


Here the distribution of mean value (top left) and sigma value (bottom right) from gaussian fit for different particles with different momenta.

The distributions are fitted with an exponential function plus an efficiency function.

$$Eff = \frac{Eff_{plateau}}{1 + 81^{\frac{V_{1/2} - V}{\Delta^{90\%}_{10\%}}}}$$

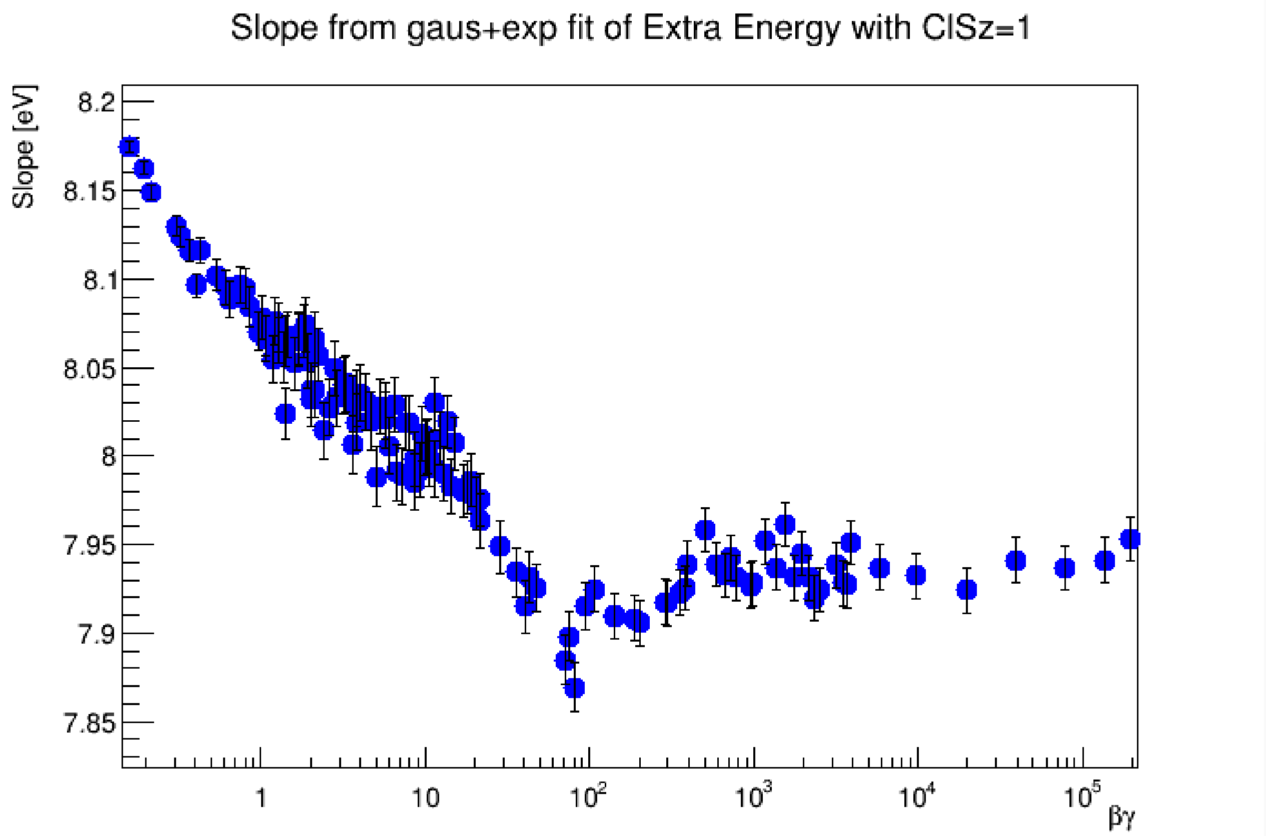




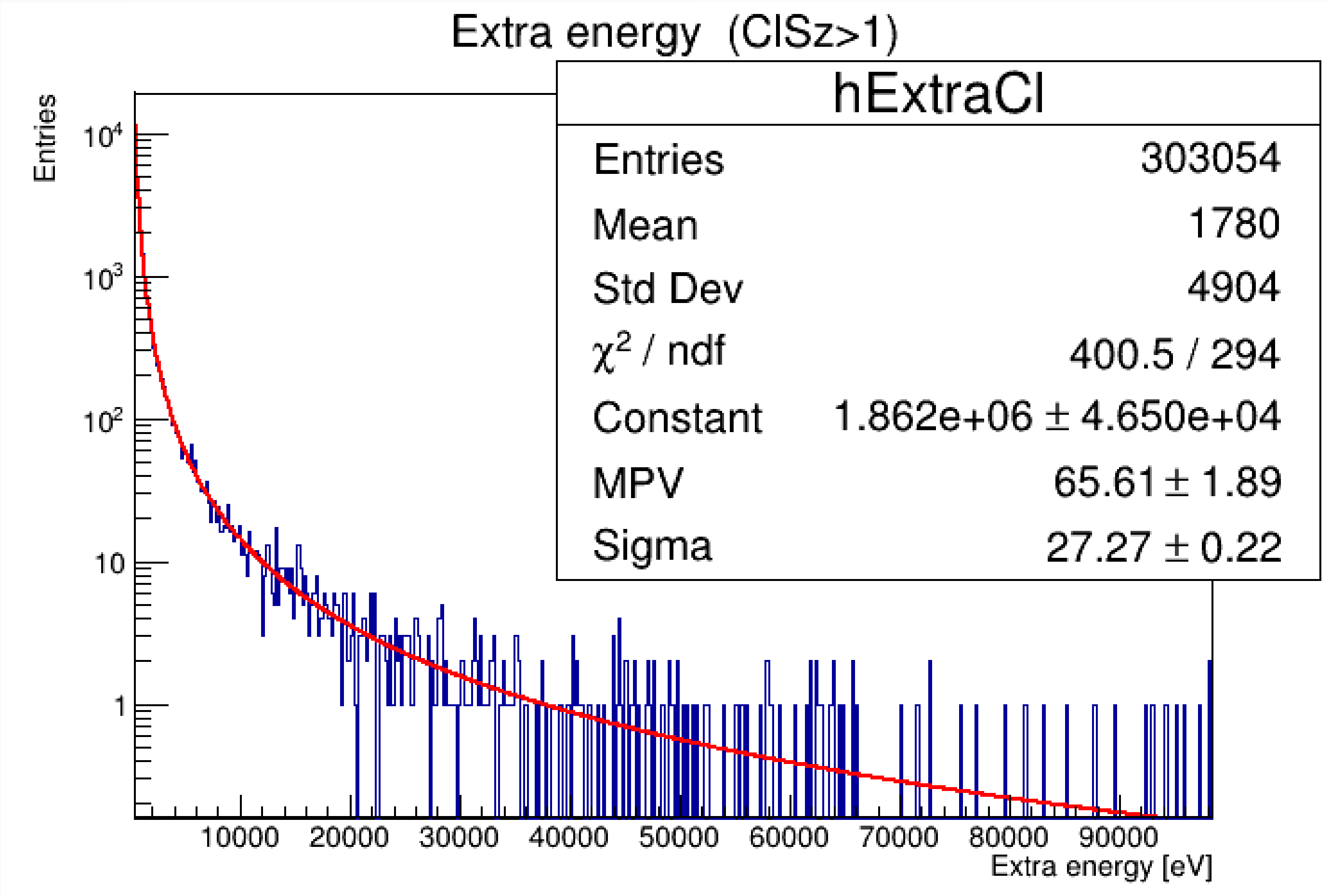
Here the distribution of the percentage fraction (top left) and slope value (bottom right) from gaussian fit for different particles with different momenta.

The fraction distribution is fitted with an exponential function plus an efficiency function.

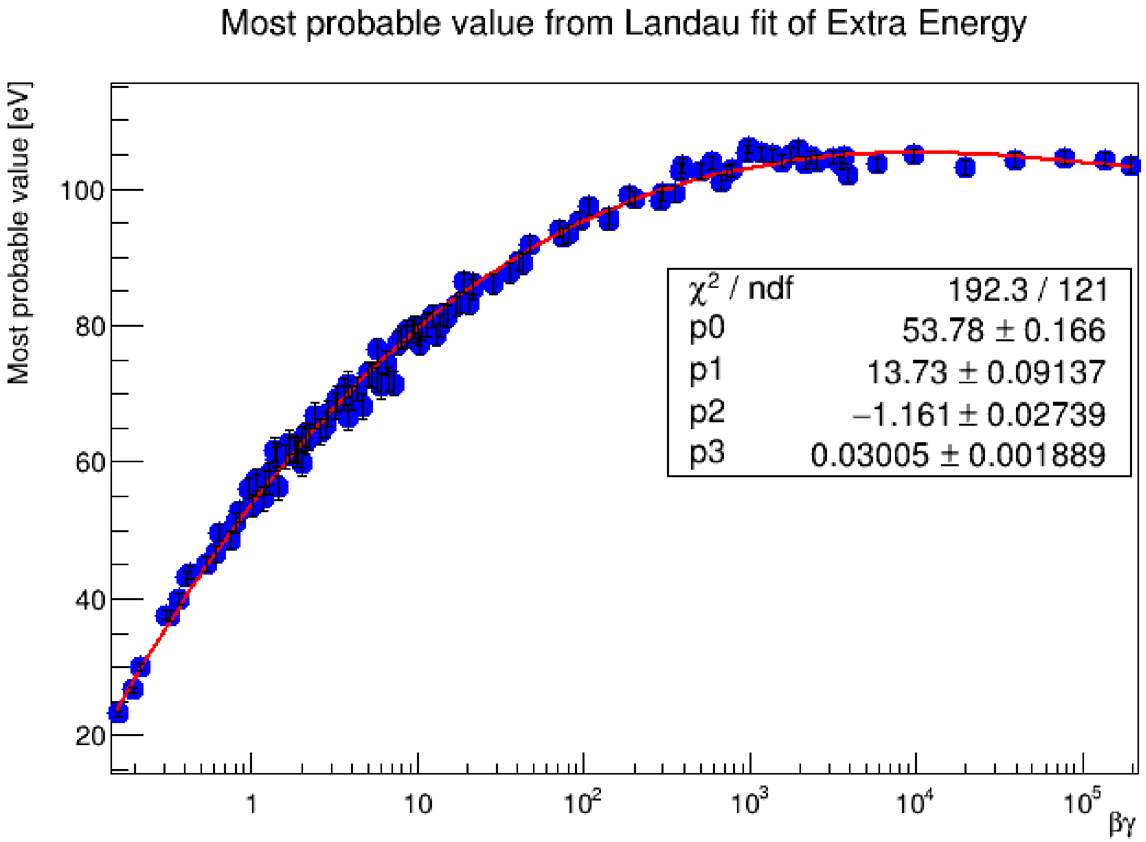
For the slope distribution...work in progress.



Here an example of Extra energy for Cluster size higher than 1 for muon with momentum of 300 MeV.

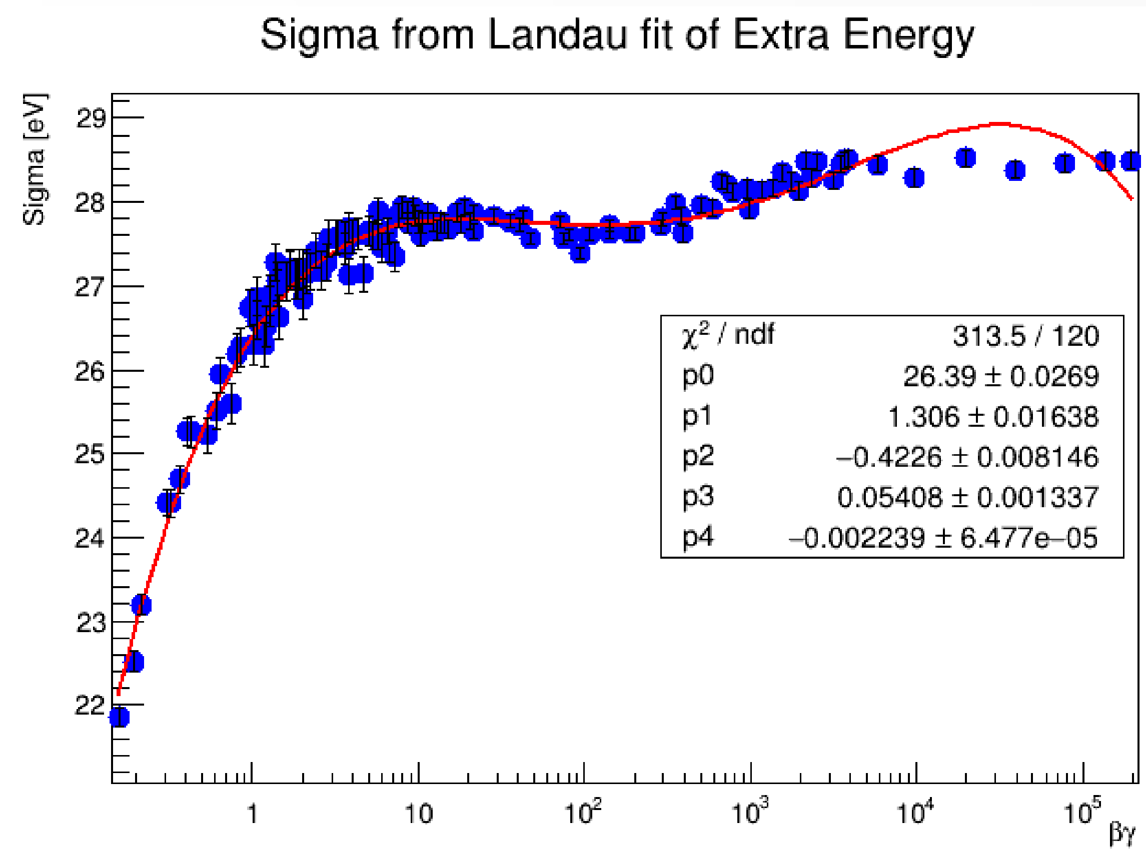


The distribution is fitted with a Landau function.



Here the distribution of the most probable value (top left) and sigma value (bottom right) from landau fit for different particles with different momenta.

Most probable value is fitted with a third degree polynomial and sigma with fourth degree polynomial.



Conclusion

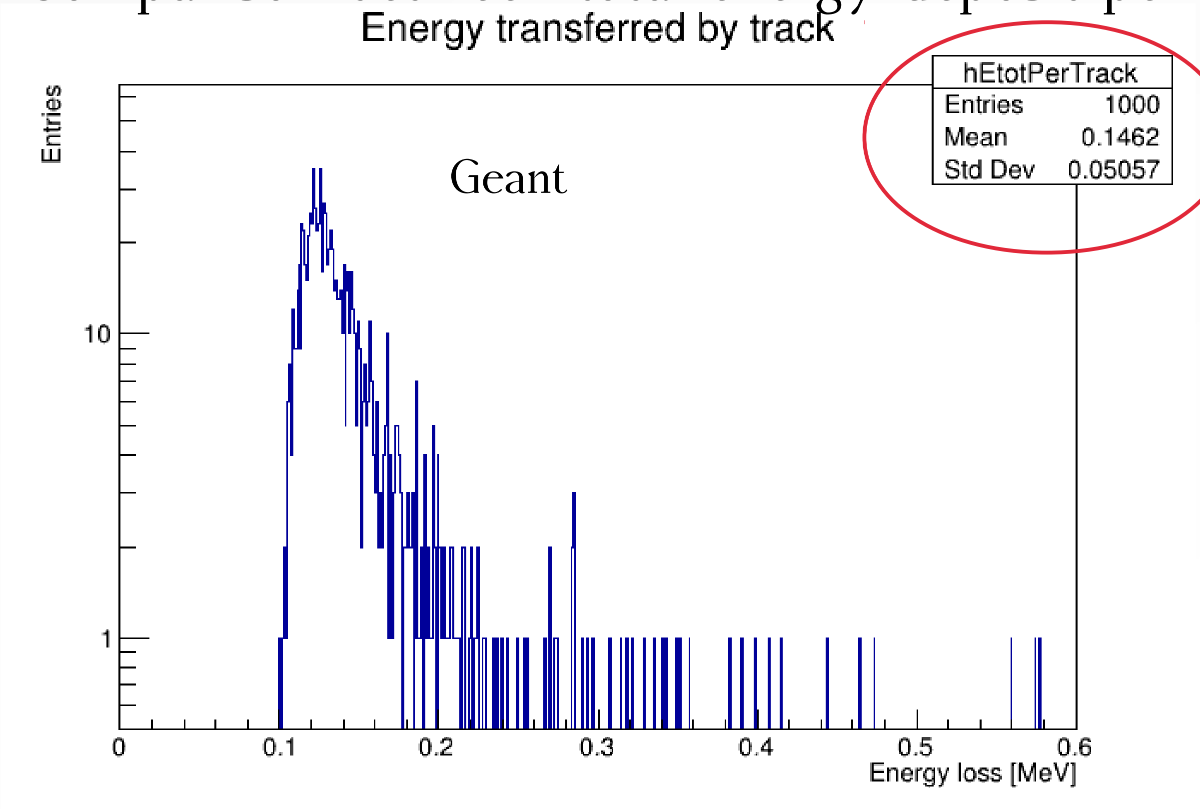
Obtained a suitable model, the next step is the reconstruction of the number of cluster produced by different particles in the same gas mixture, starting from the energy loss simulated by Geant4 .

Actually, we have a plan B.

We could use the cluster size distibution, neglecting the link with the energy.

BACK UP SLIDES

Comparison between total energy deposit per track



2m track μ- 300 MeV