Energy Loss of Muons in the CLIC ILD Detector

Sinan Kefeli

Supervisors:

Jacopo Nardulli & Erik van der Kraaij

Outline

- Aim of project: muon background
- Brief summaries of:

- Particle Detection
- Catastrophic muons
- ILD Detector Overview

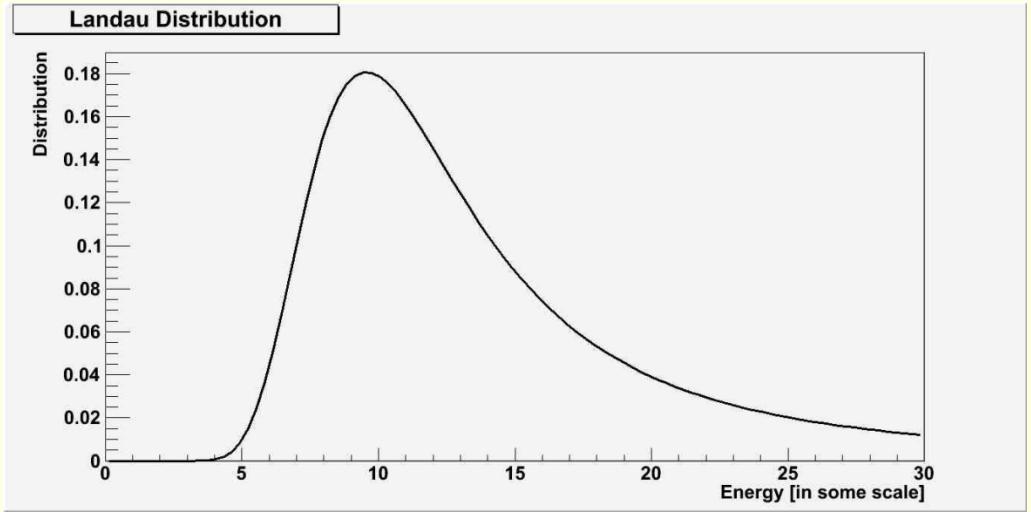
- Simulations
- My results

Aim of the Project

- Beam Halo Muons are pair production of muons from beam particles and beam gas
- These muons appear as background at the detectors in a physics event
- Would like to separate the background from the events
- My part: determining how often and how much energies are deposited from the muons

Particle Detection

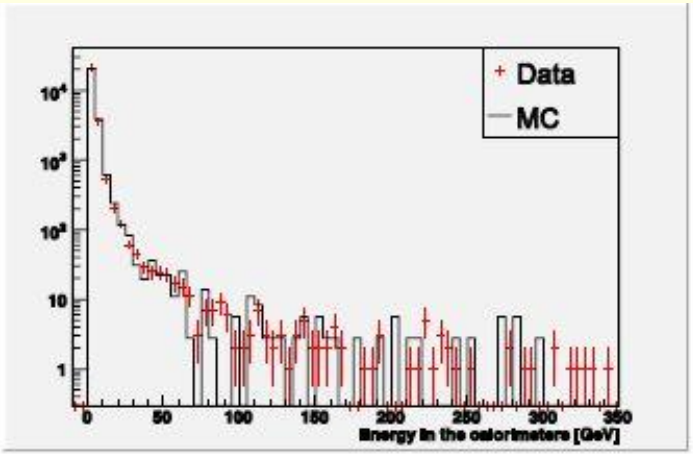
- Detect particles by interaction with materials
- Energy loss is statistical and fluctuates from event to event
- Particles lose energy inside matter, which is a Landau Distribution: Prob(energy loss E) inside matter of thickness h



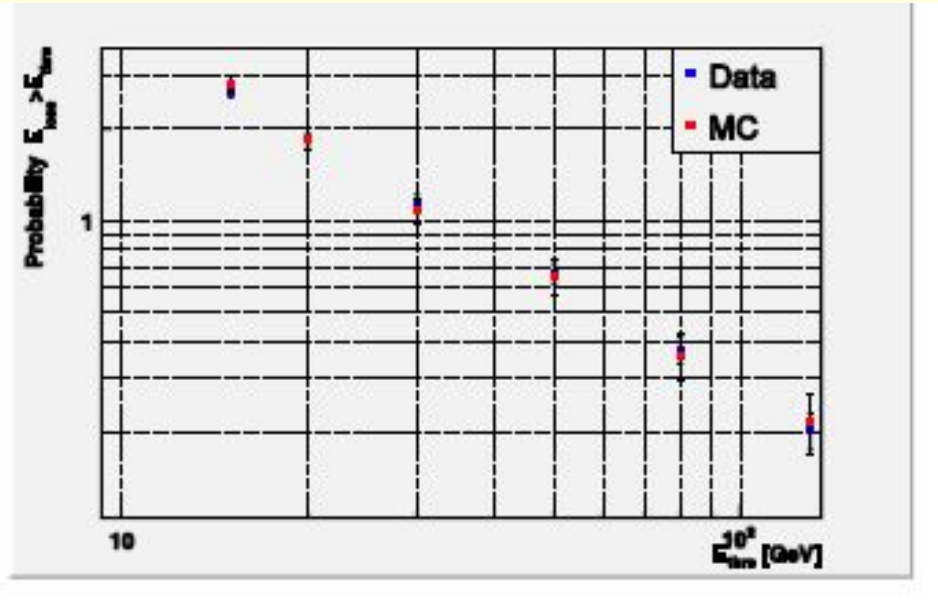
Catastrophic Muons (Atlas paper)

- Testbeam at CERN H8
- Muons traversing matter mainly lose energy by ionization
- Total energy loss increases with increasing momentum

(atlas paper: http://www.sciencedirect.com/science/article/pii/S0920563207009747)



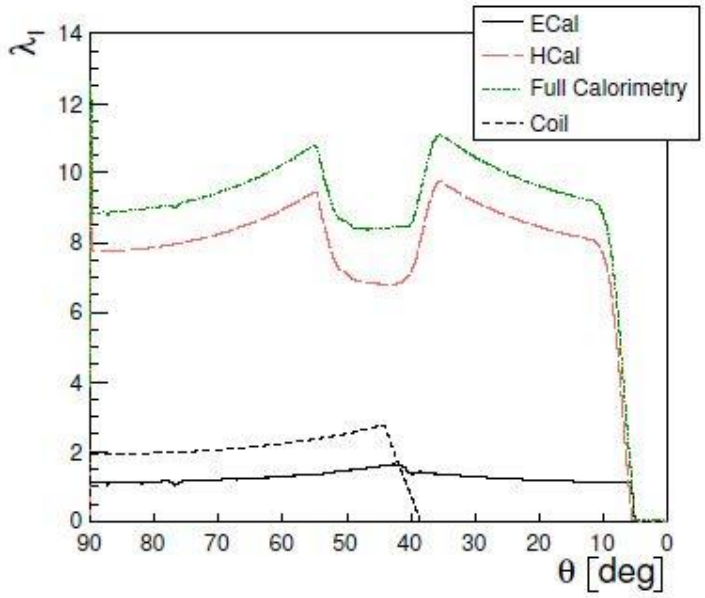
(a) Energy deposited in the calorimeters by particles tagged as muons.

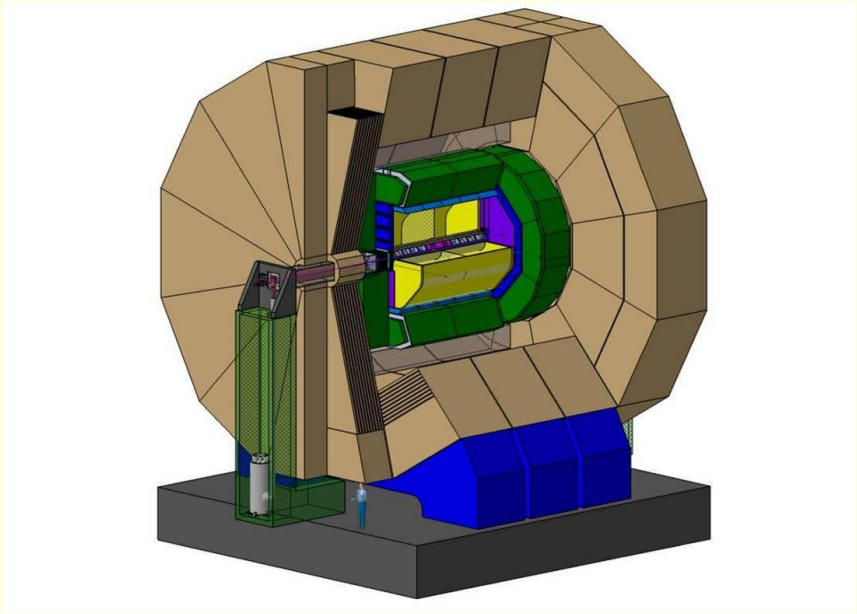


CLIC ILD Detector

Parameters for the calorimeter layers. The number of layers N_{Layers}, the thickness of one layer d_{Layer}, the absorber material, its thickness d_{Abs}, the active material and its thickness d_{Act} is given.

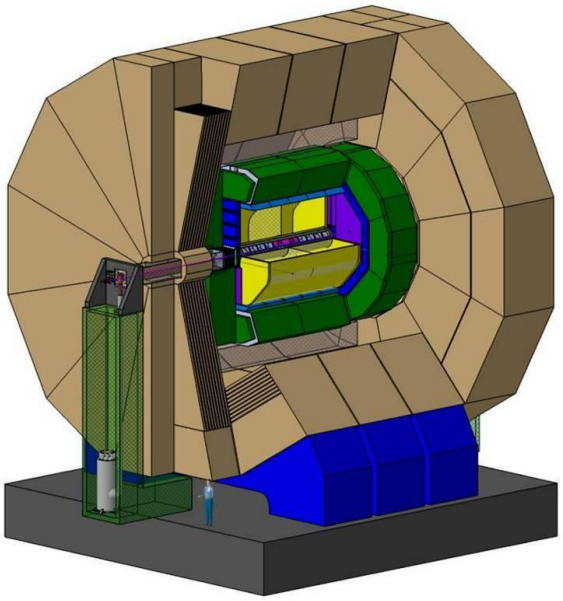
	N_{Layers}	d_{Layer} [mm]	Absorber	d_{Abs} [mm]	Active	d_{Act} [mm]
ECal 1	20	5.3	Tungsten	2.1	Silicon	0.50
ECal 2	9	7.3	Tungsten	4.1	Silicon	0.50
HCal Barrel	75	16.5	Tungsten	10.0	Scintillator	5.00
HCal Endcap	60	26.5	Iron	20.0	Scintillator	5.00





CLIC ILD Detector

My simulations were on the HCal only



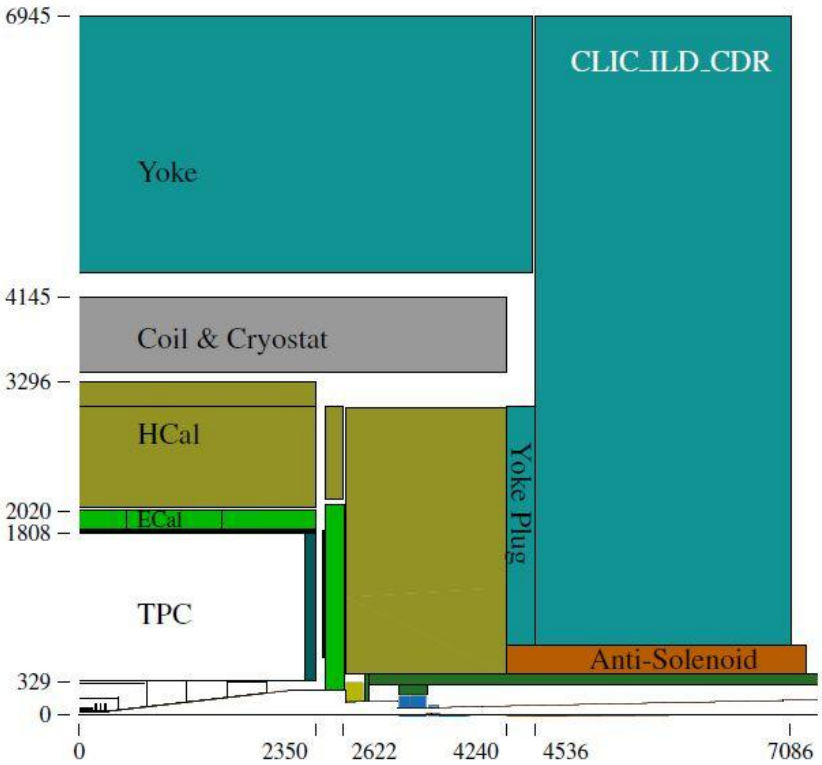
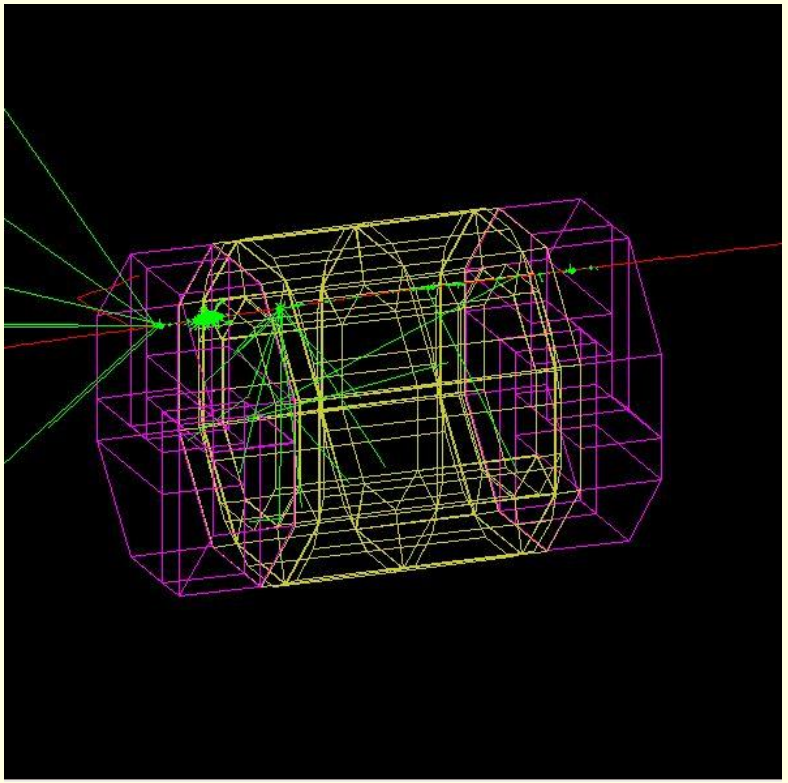


Figure 1: Dimensions of the CLIC_ILD_CDR model as implemented for the simulation. All values are given in millimetre and correspond to Table 1.

Simulations

Muons with momenta:

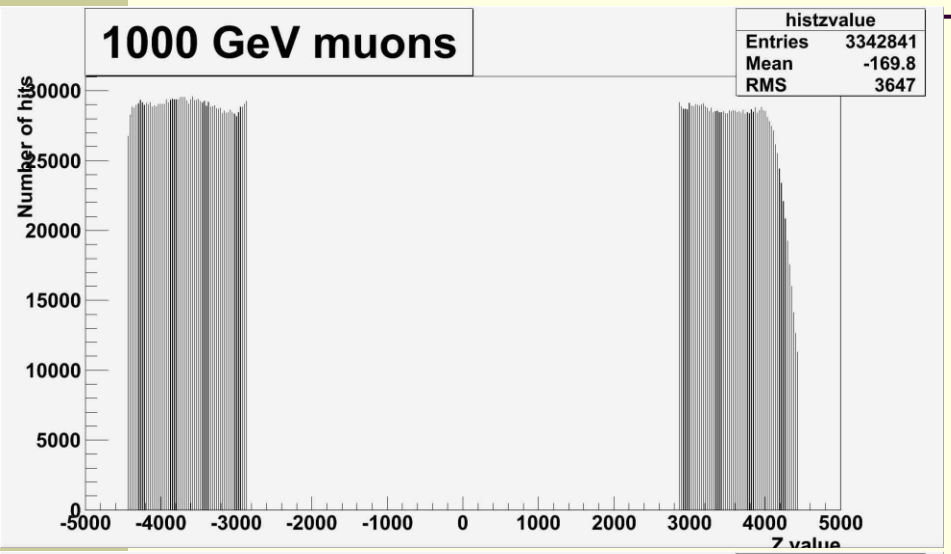
- 5 GeV
- 20 GeV
- 50 GeV
- 100 GeV
- 500 GeV
- 1000 GeV

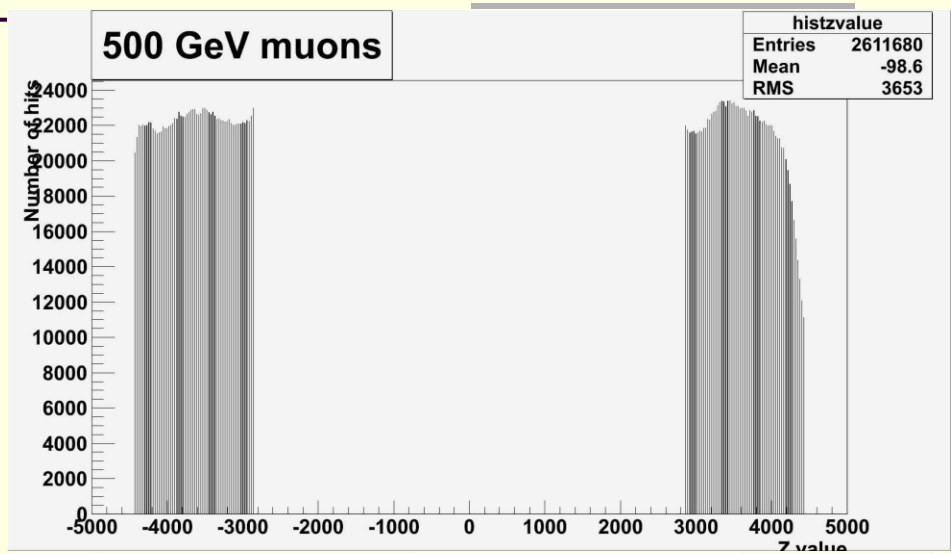


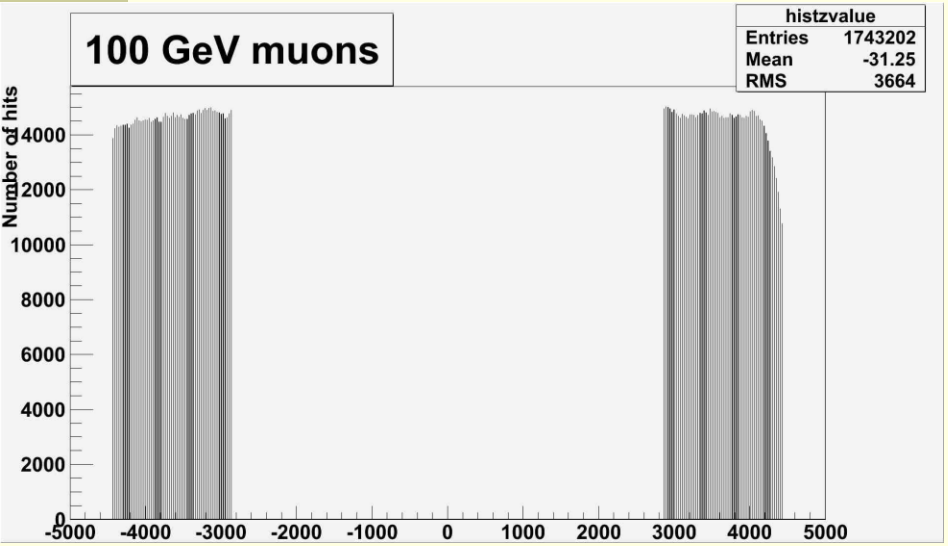
are simulated with Mokka

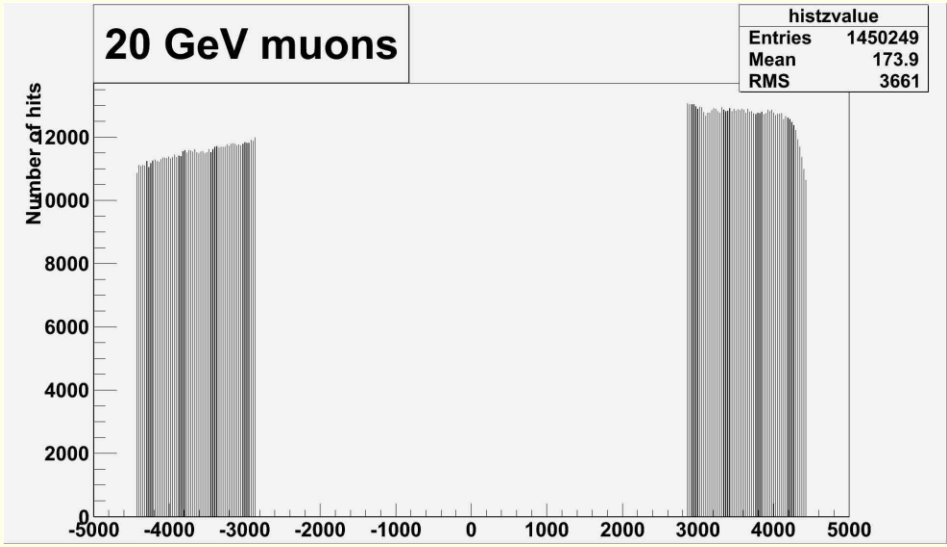
10,000 events for each momenta

Number of hits in layers

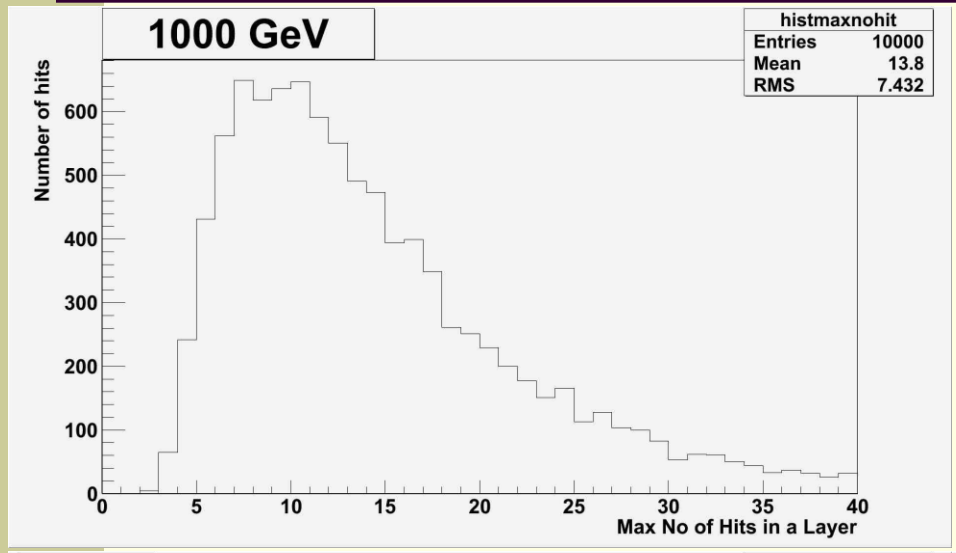


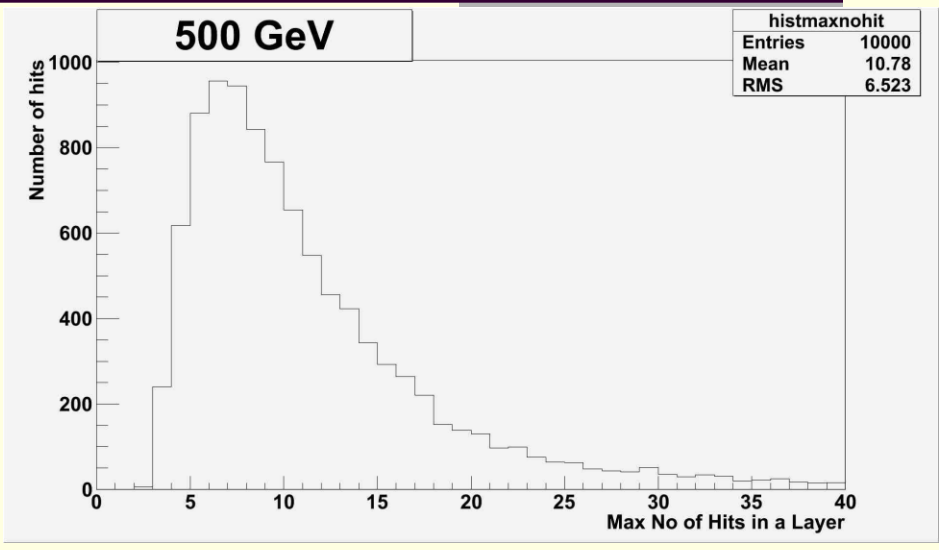


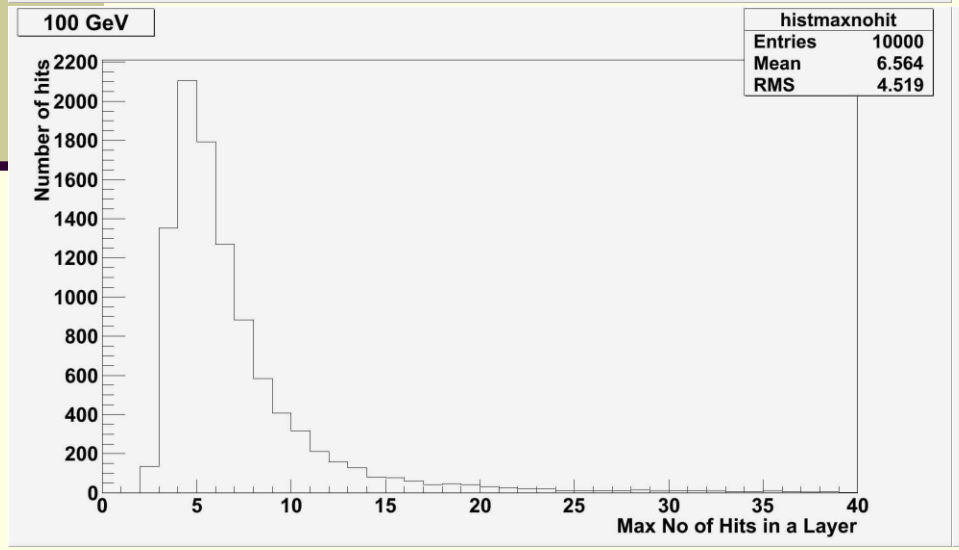


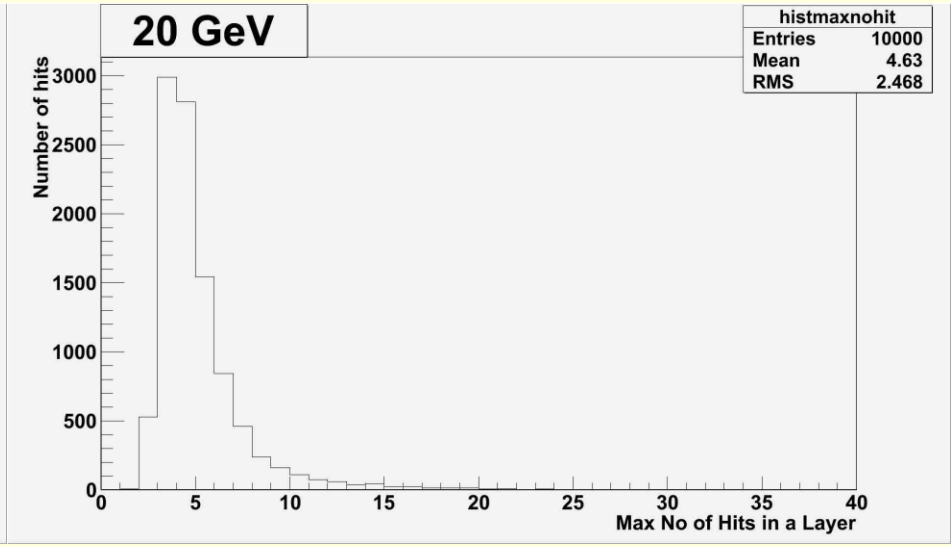


Clustering


1000 GeV
histmaxnohit
Entries 10000
Mean 13.8
RMS 7.432
Number of hits
Max No of Hits in a Layer

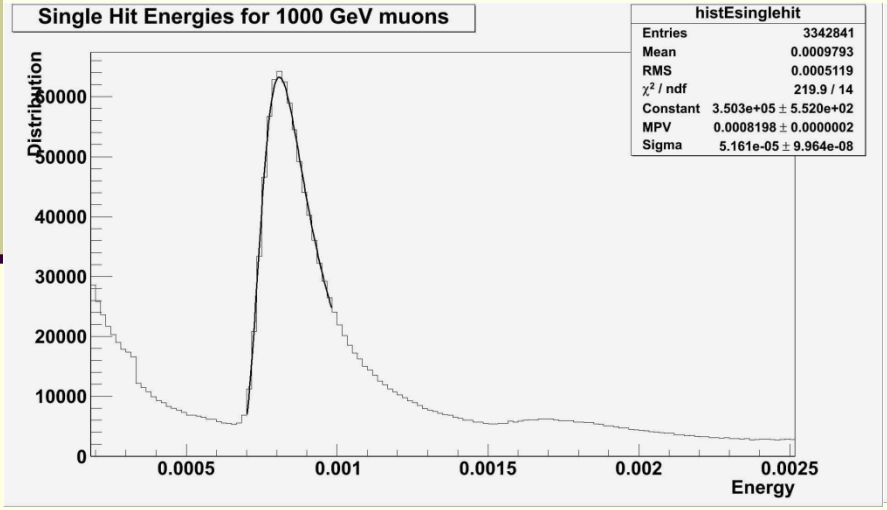

500 GeV
histmaxnohit
Entries 10000
Mean 10.78
RMS 6.523
Number of hits
Max No of Hits in a Layer

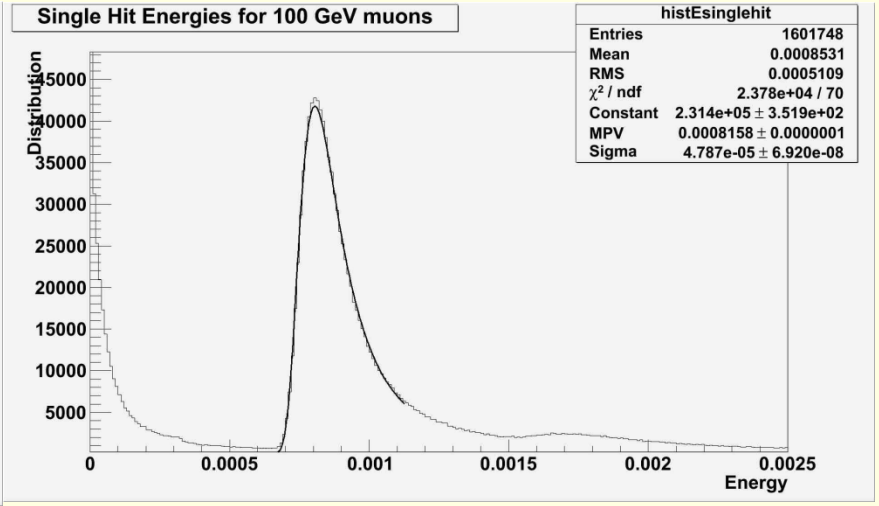

100 GeV
histmaxnohit
Entries 10000
Mean 6.564
RMS 4.519
Number of hits
Max No of Hits in a Layer


20 GeV
histmaxnohit
Entries 10000
Mean 4.63
RMS 2.468
Number of hits
Max No of Hits in a Layer

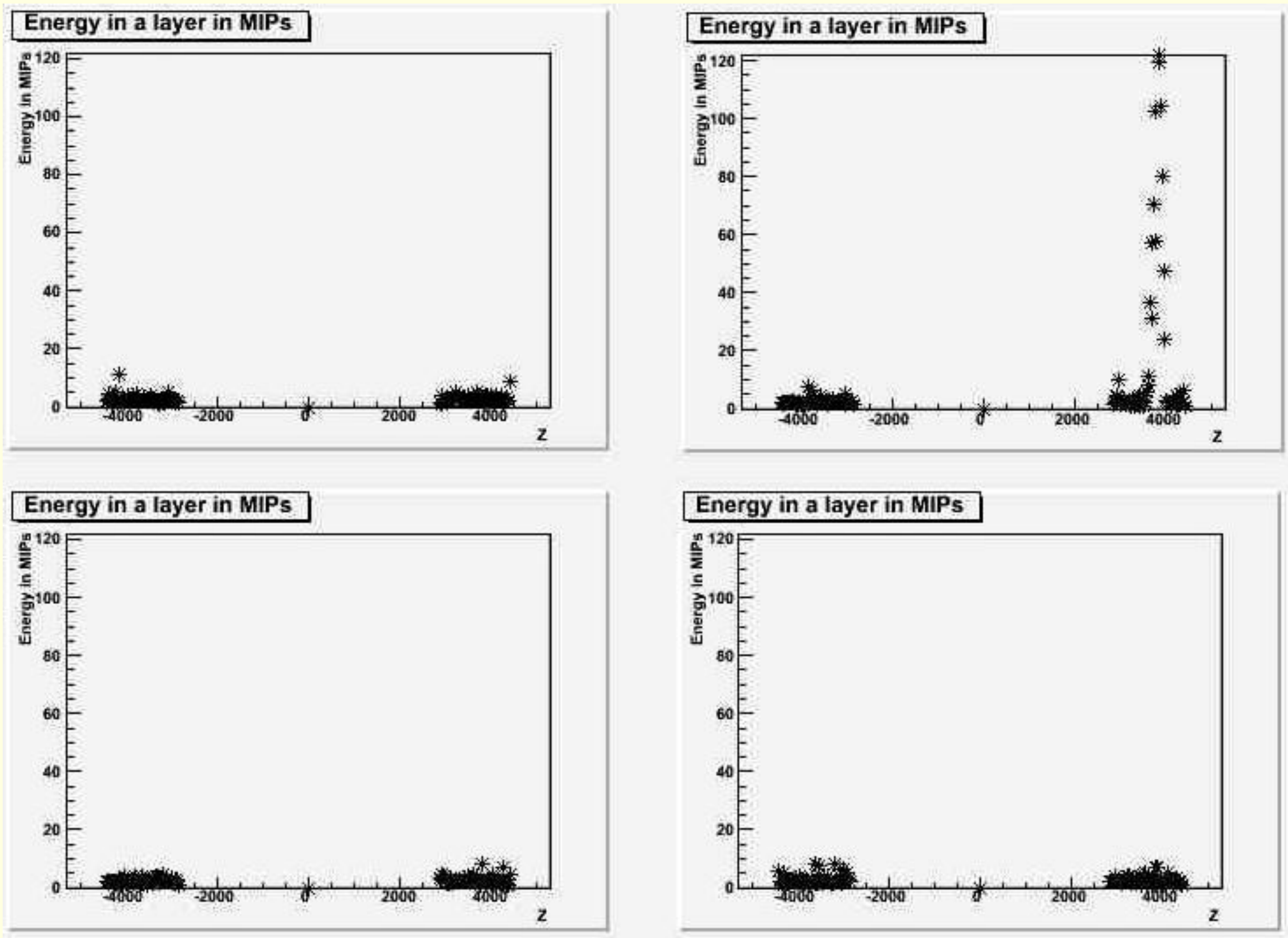
How Much Energy In Clusters

- 1MIP = 0.00082 GeV independent of momentum of the muon
- Measure the energy stored in the clusters in terms of MIPs





Energy stored in layers - Peaks



Cluster definition

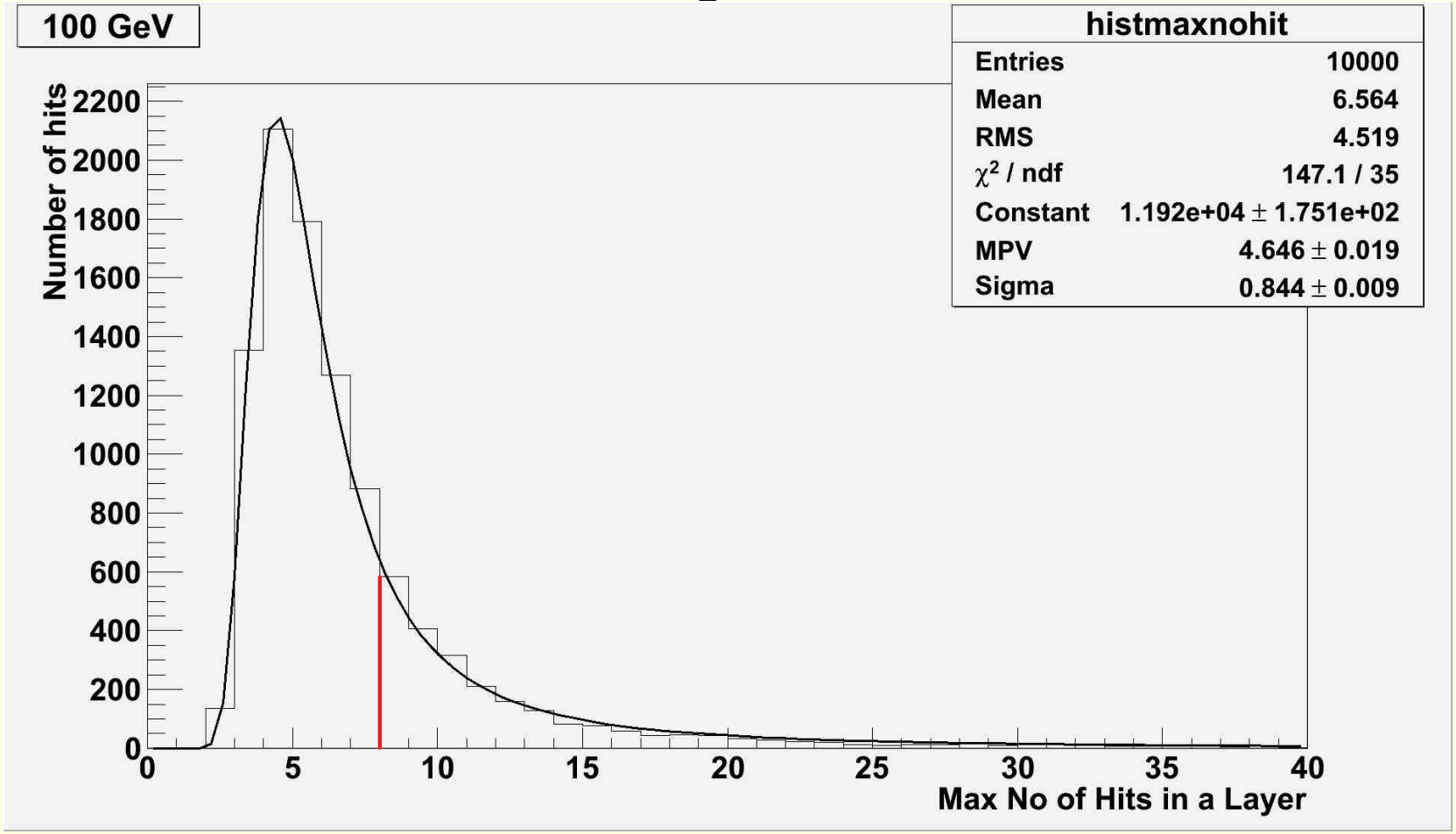
- Some events have higher energy depositions
- Determining cut values
- Clusters:

-Many particles in the layer

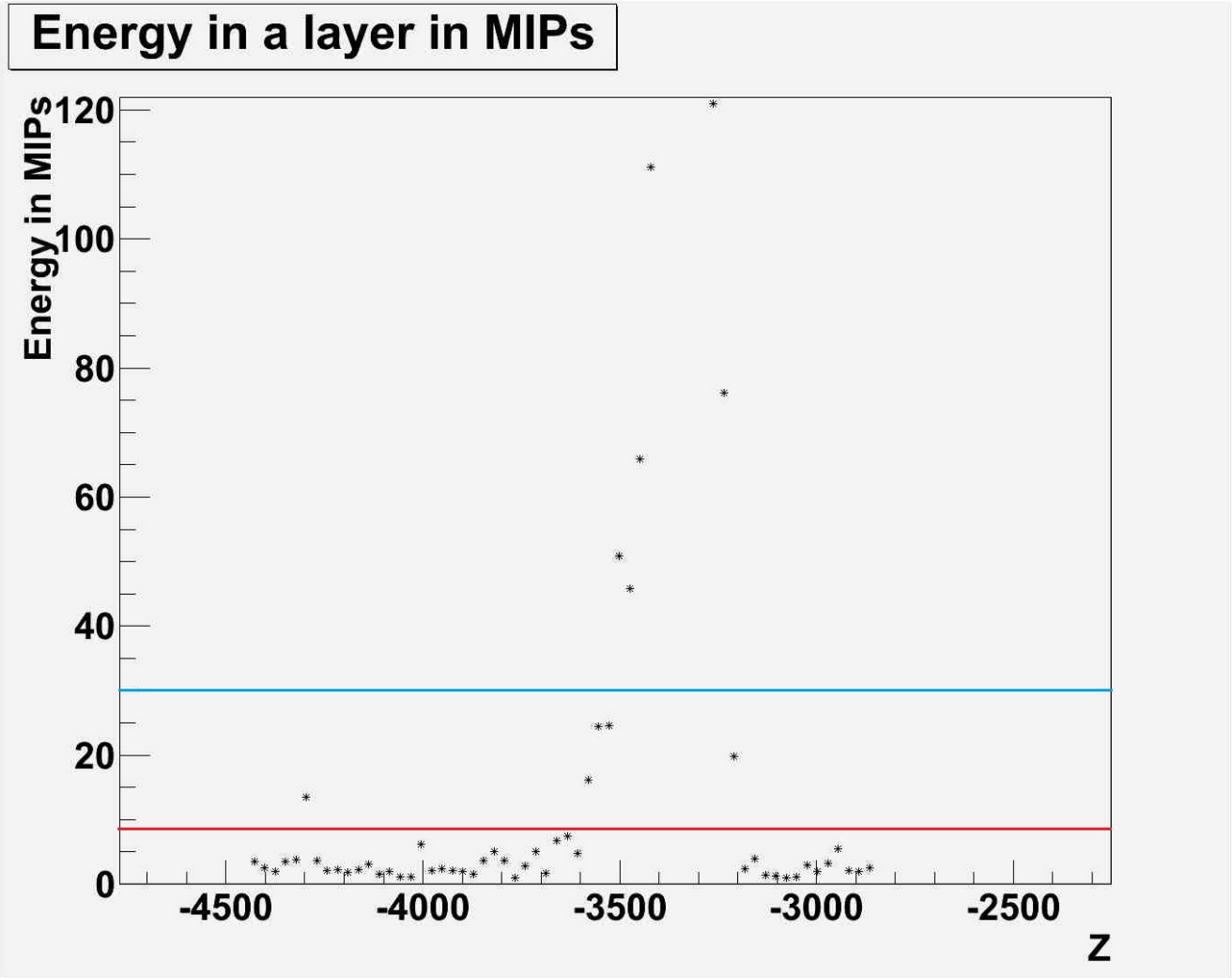
-More energy storage

Cluster Definition – Number Cut

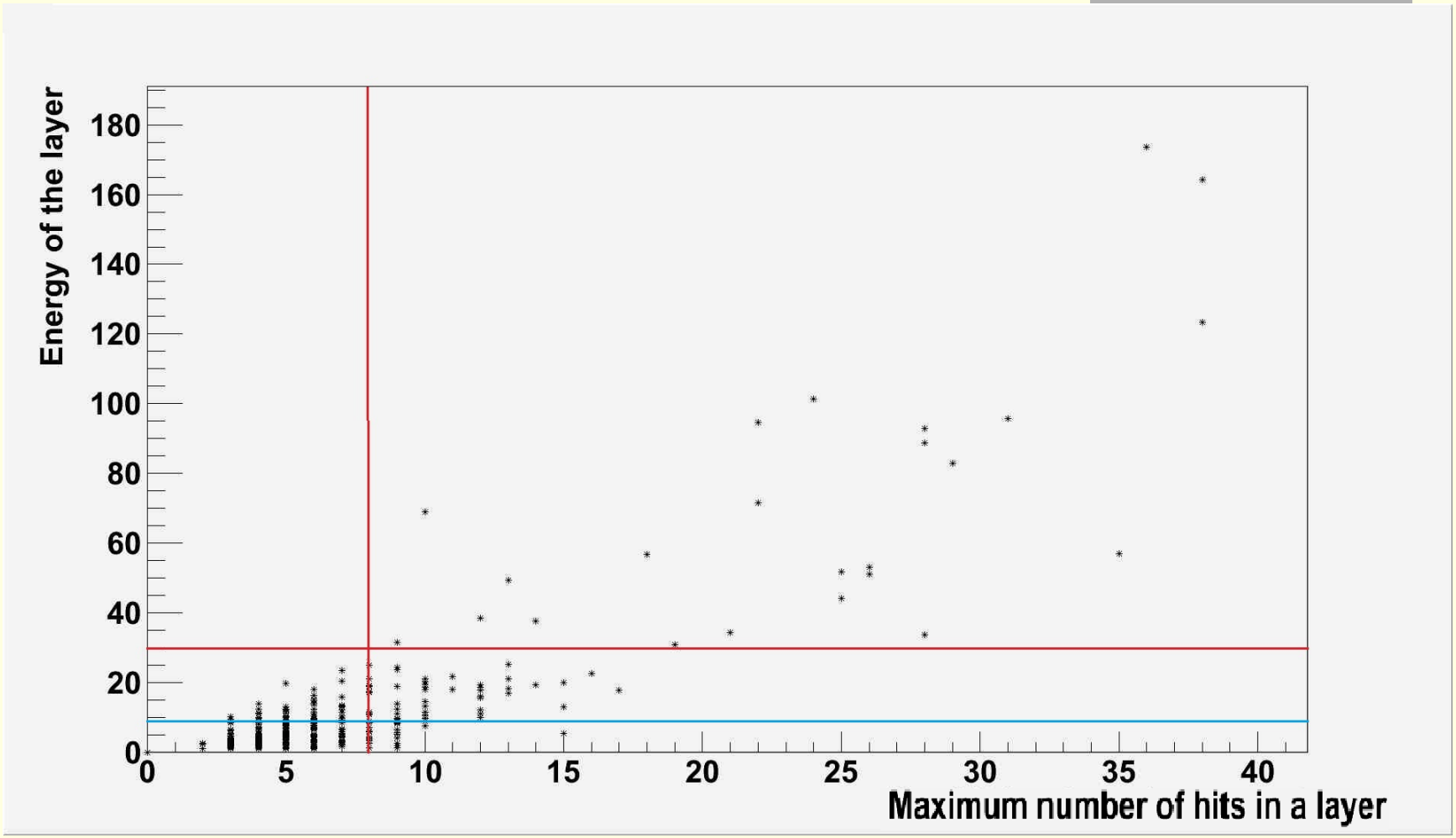
Hits Cut = MPV + 5*Sigma = 8



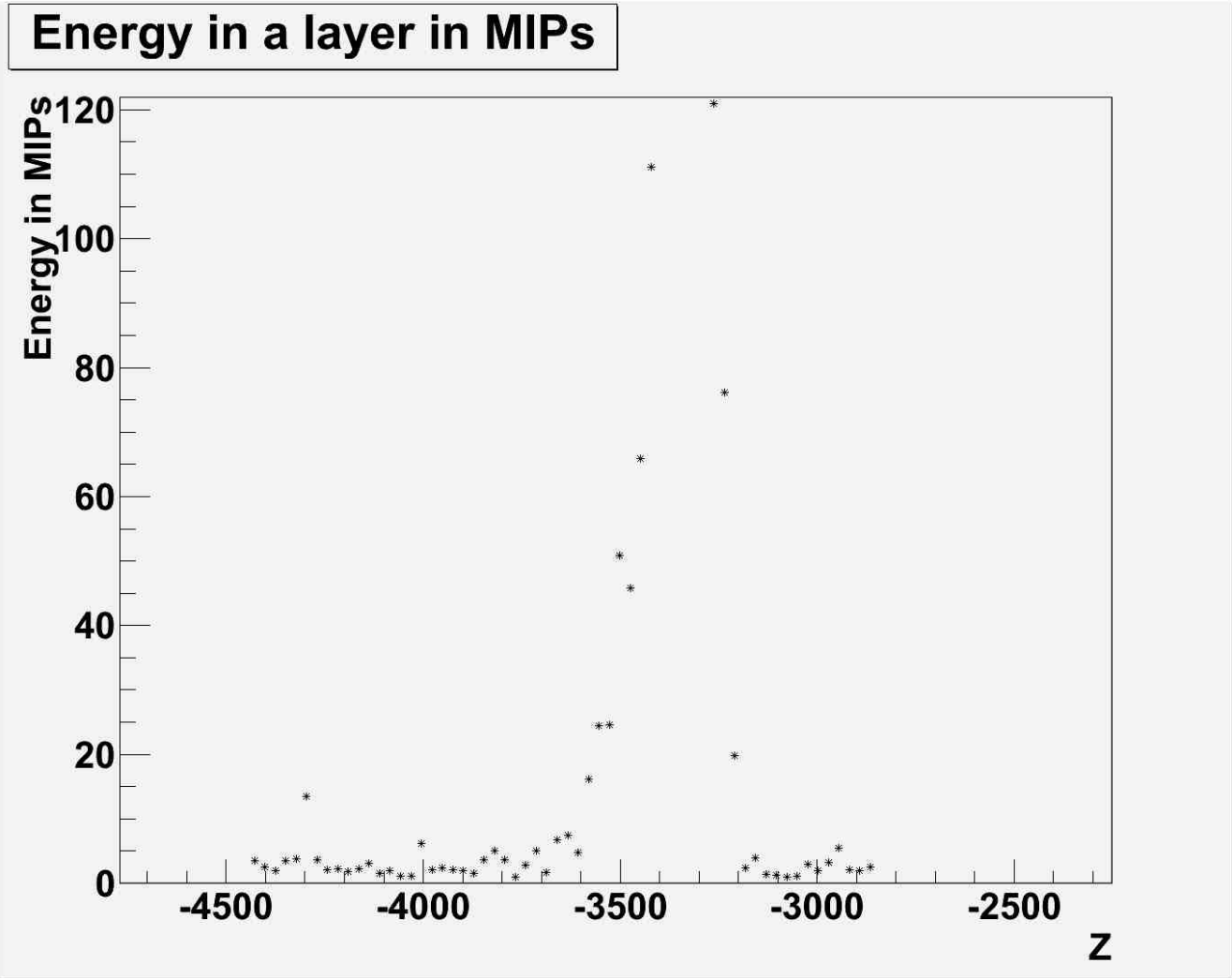
Cluster definition energy cut



Cluster Cut


Energy of the layer
180
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
Maximum number of hits in a layer

Cluster energy in 10 layers

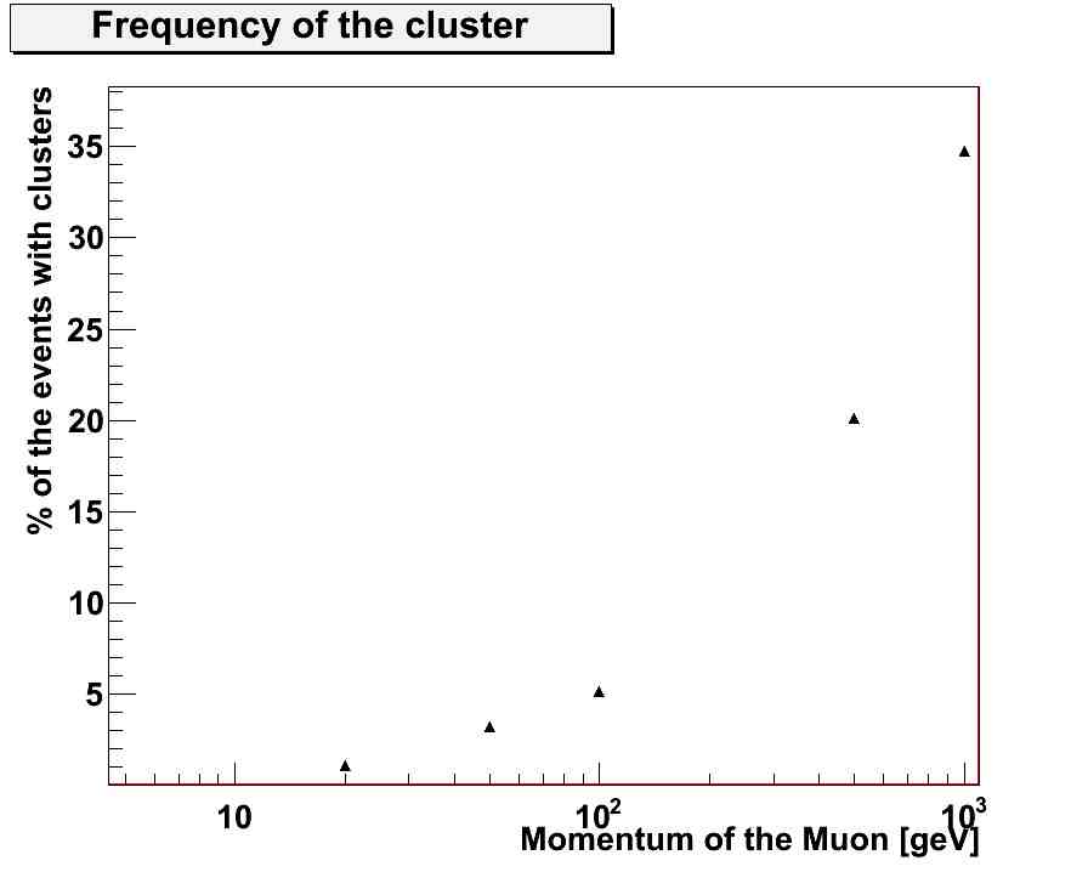


Results

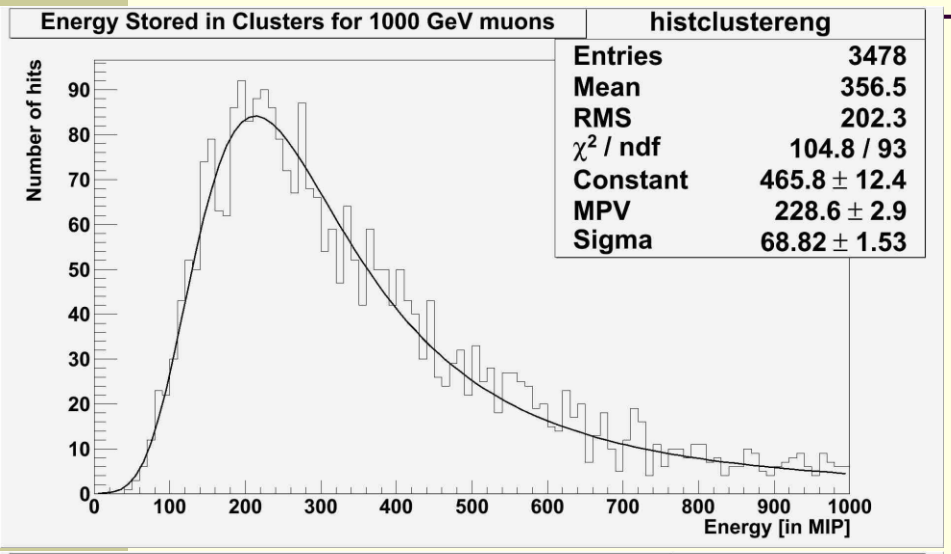
- How often do clusters occur?
- How much energy is stored in clusters?

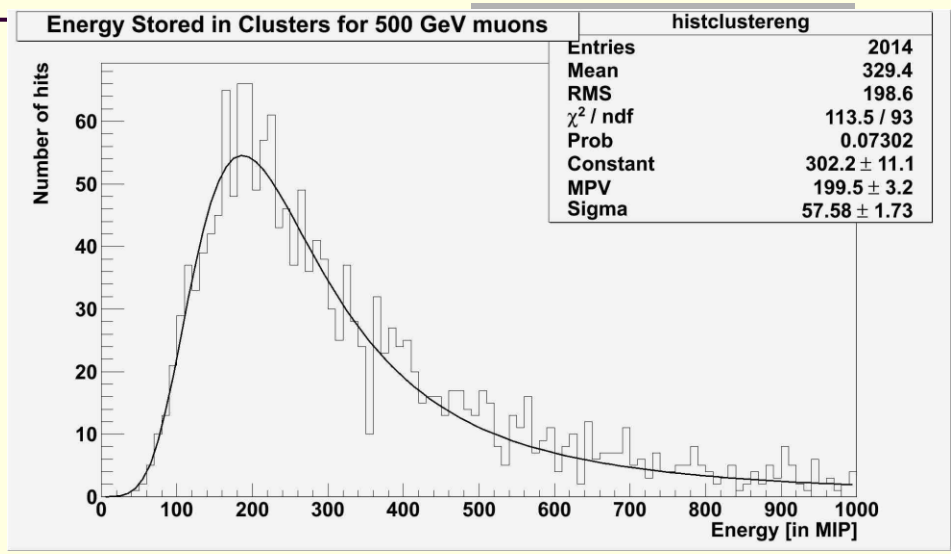
How Often Do Cluster Occur – 30MIP

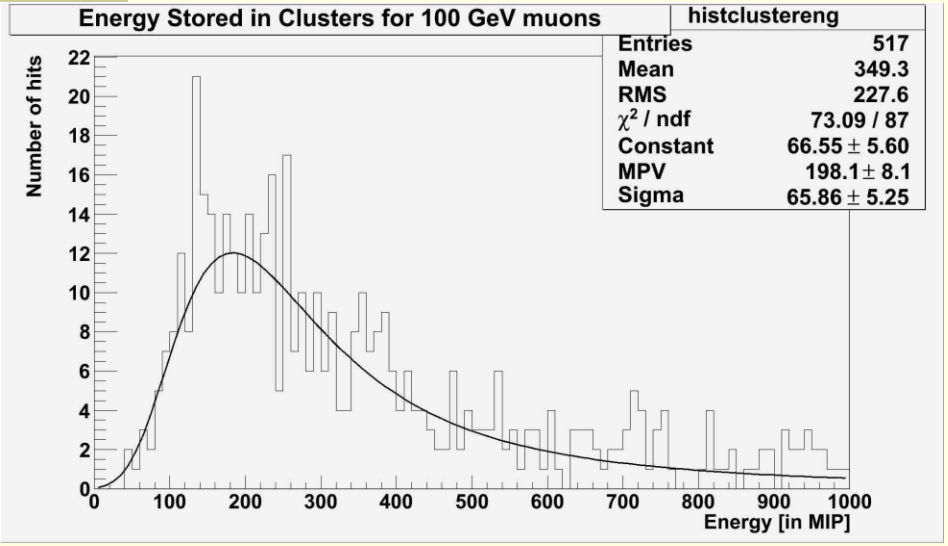
Muons with different momenta are simulated for 10,000 events

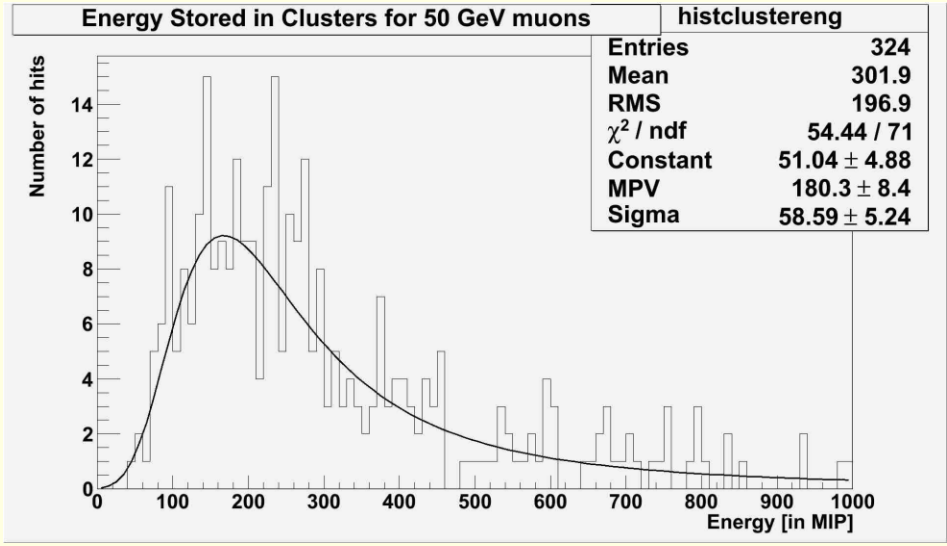


Energy stored in clusters in MIPs for 30 MIP cut

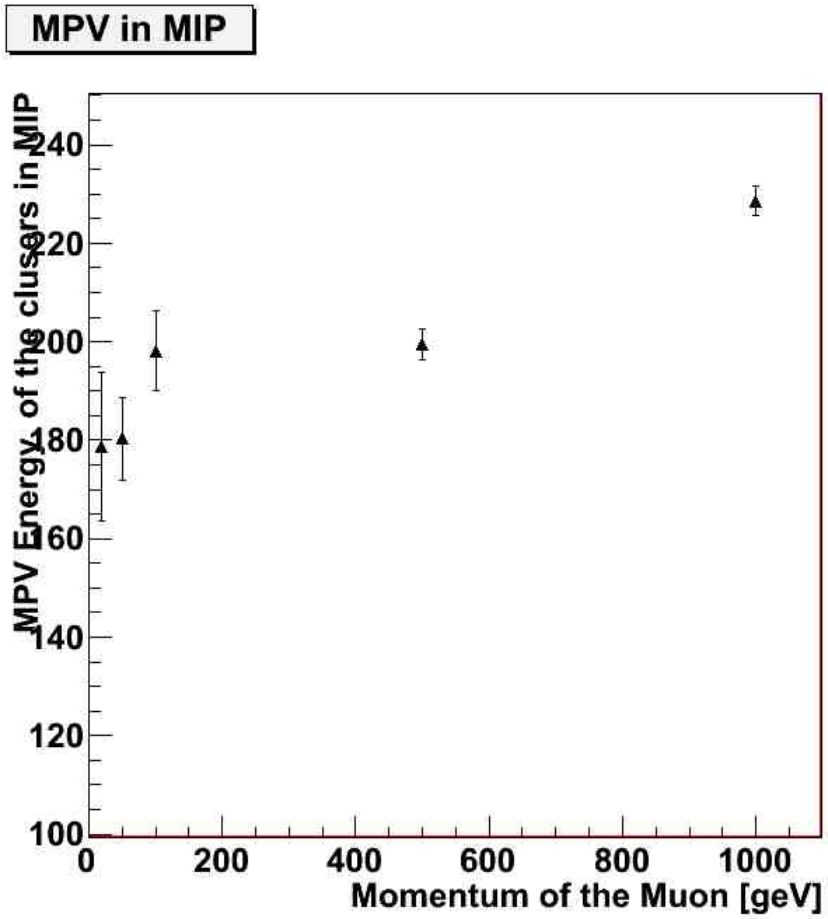


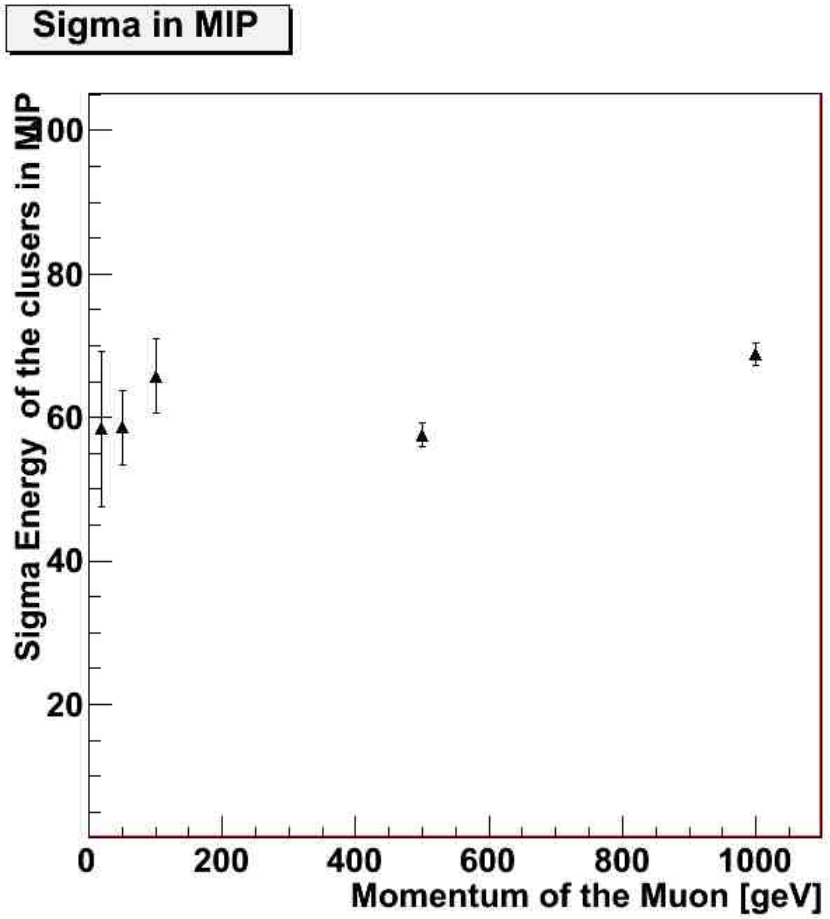






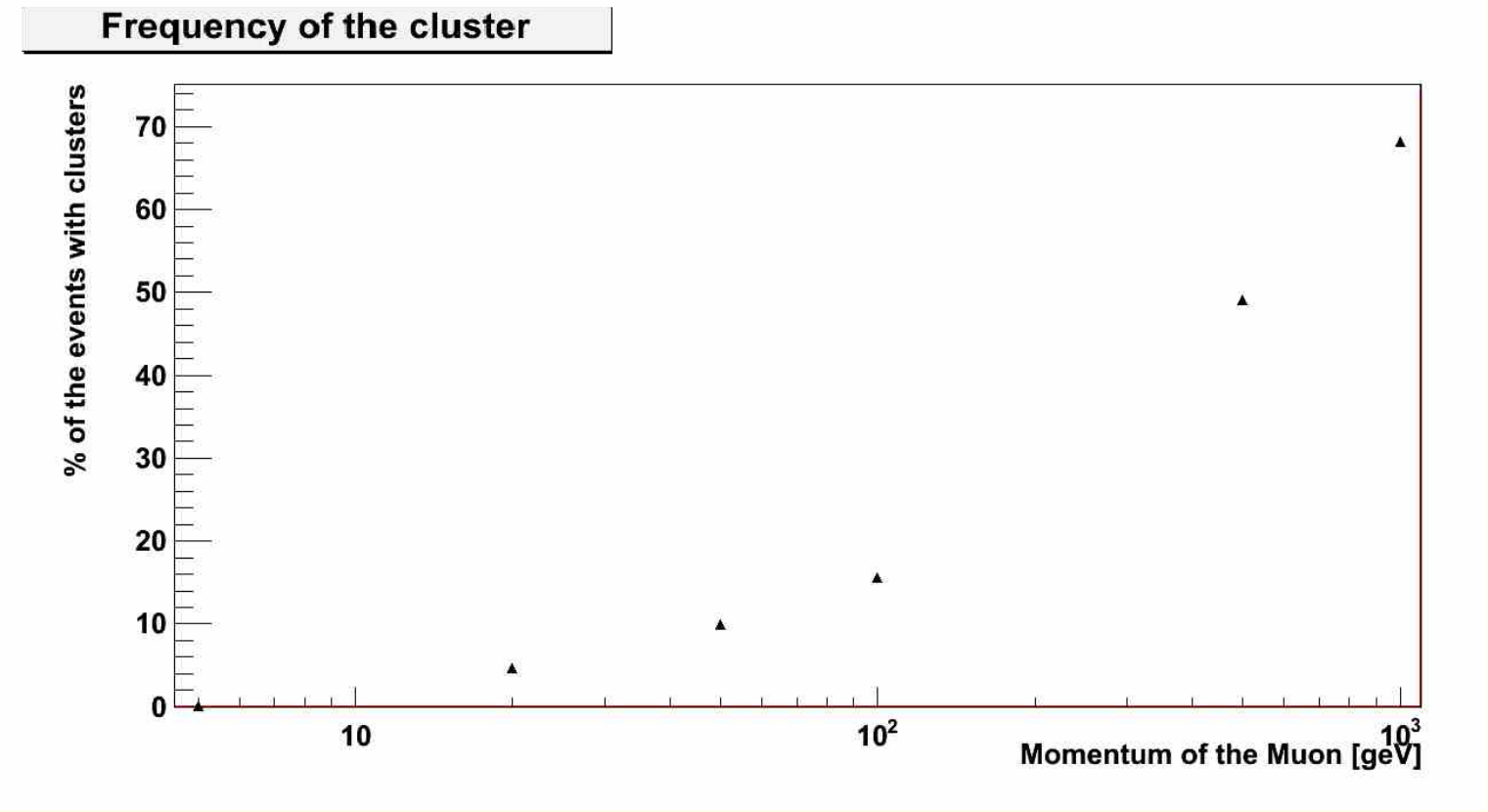
MPV and Sigma for 30 MIP cut



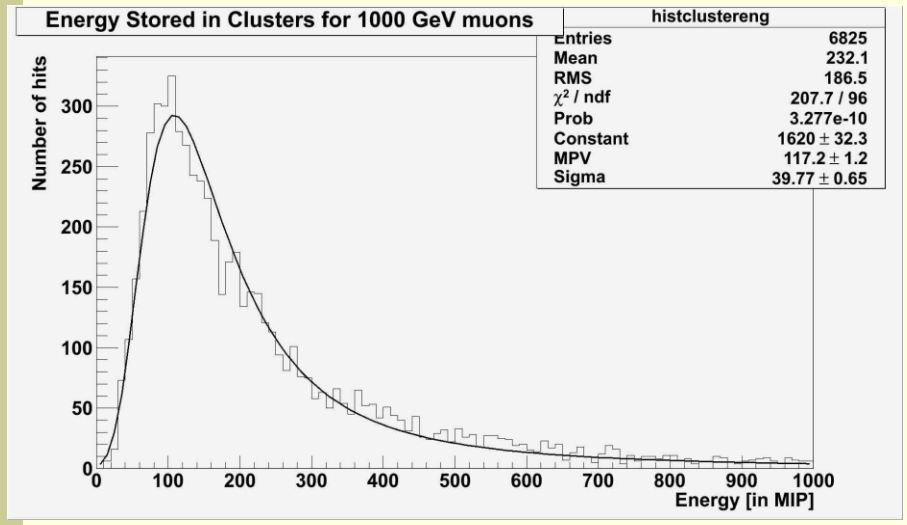


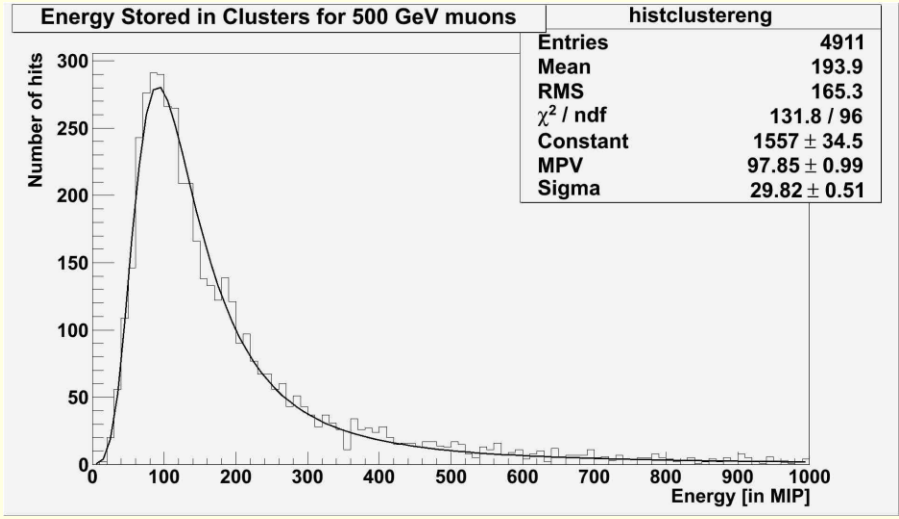
How Often Do Cluster Occur – 8MIP

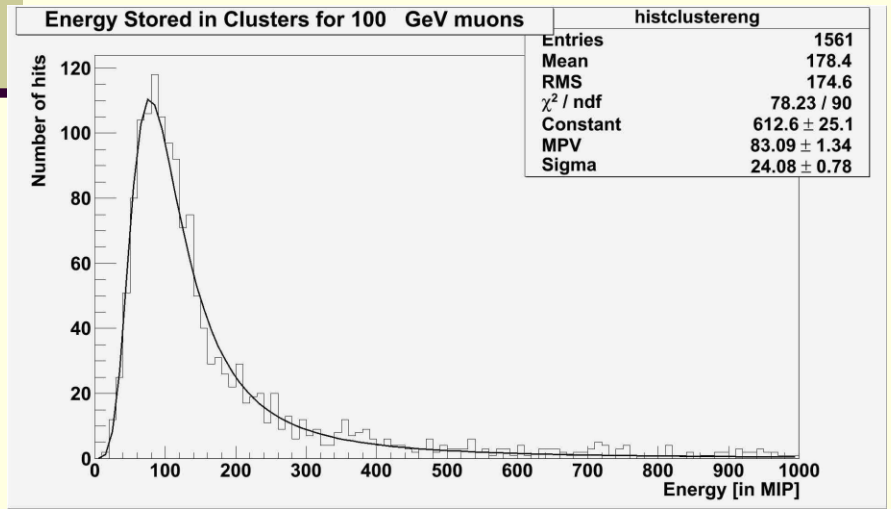
Muons with different momenta are simulated for 10,000 events

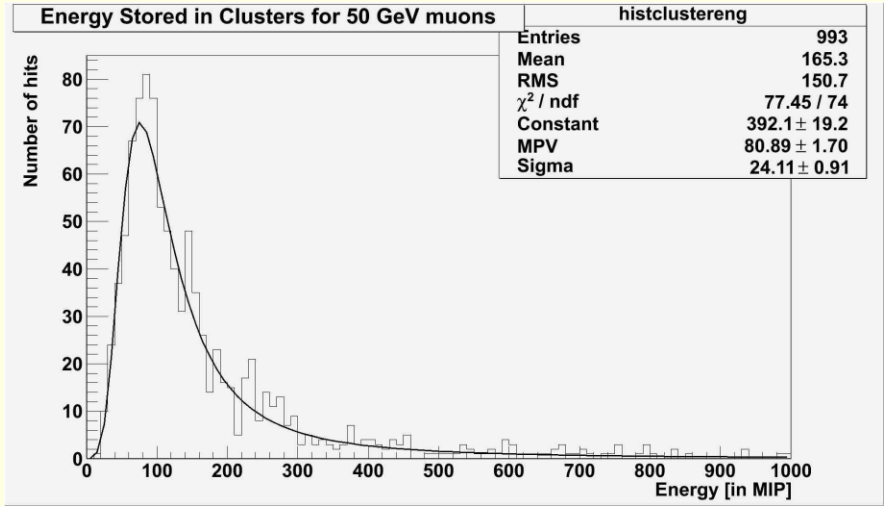


Energy stored in clusters in MIPs for 8 MIP cut

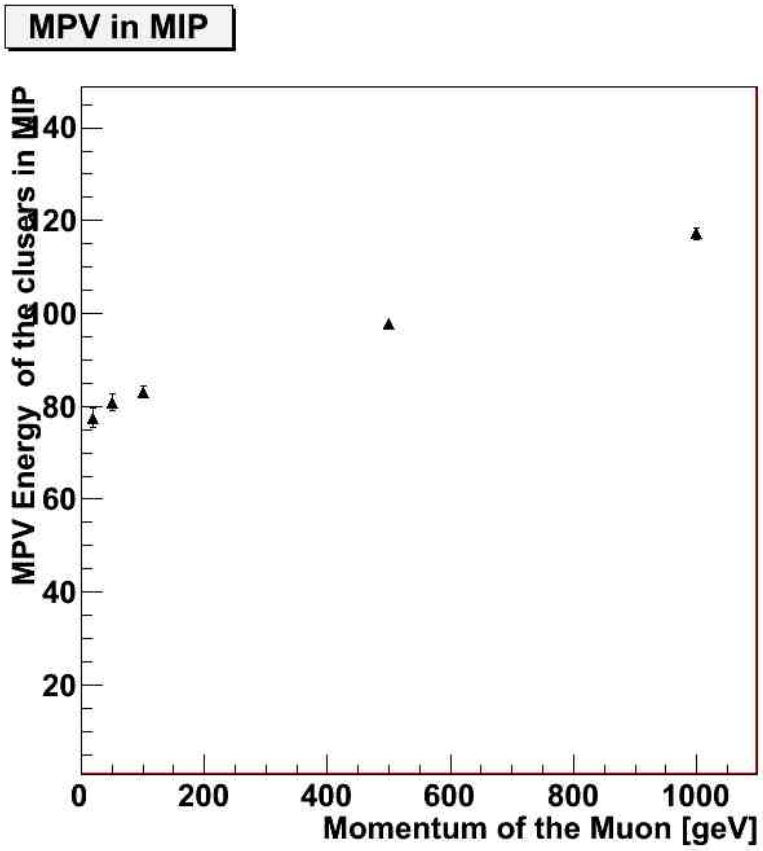


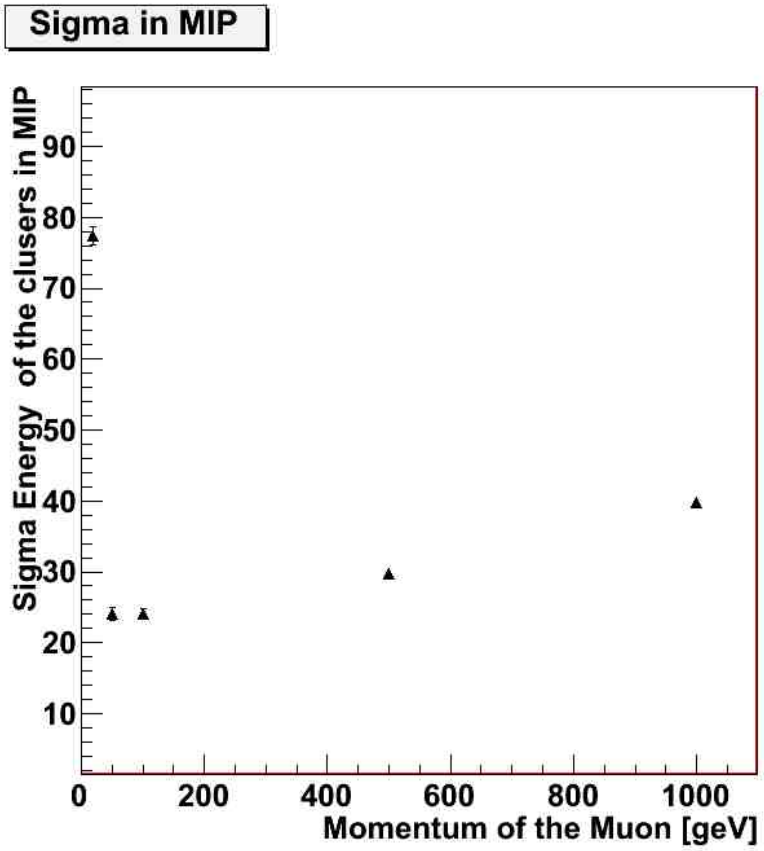






MPV and Sigma for 8 MIP cut





Conclusions

- Investigated the energy loss of muons by identifying clusters
- Looked at cluster frequency and the amount of energy lost by the clusters
- Comparison of different energy cut definition for the clusters
- Measured cluster energy that increases with increasing muon momentum

backup

Catastrophic Energy Loss

- Pair Production
- Bremsstrahrlung
- Nuclear Interactions
- Knock-on electrons

In this regime, these effects dominate over the energy lost due to ionization.

Landau Distribution – Energy loss for 100 GeV muons inside W