SDHCAL data analysis

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LAPP

The SDHCAL

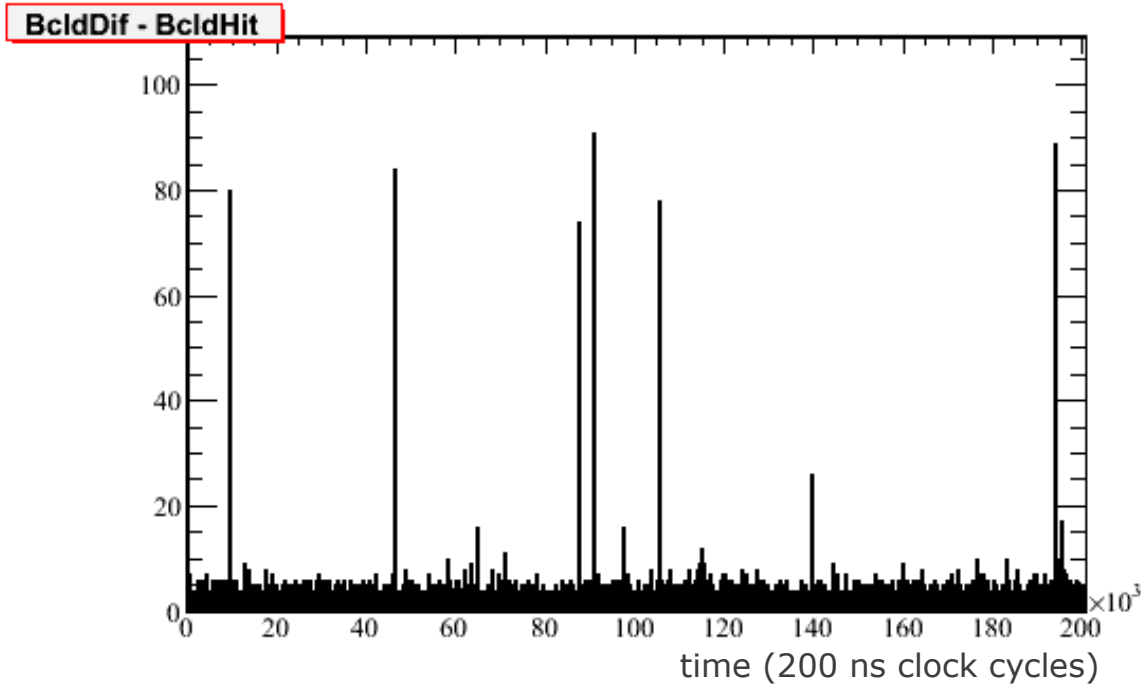
- Measures the number of hits above a threshold not the deposited energy
- Three thresholds to sample the signal versus one for the DHCAL
- Work plan
  - ➢ Obtain results using the lowest threshold and compare with DHCAL
  - ➢ Validate the simulation
  - – Measure the added value of having a semi-digital detector

    → see G. Grenier talk in DHCAL session tomorrow

Outlook

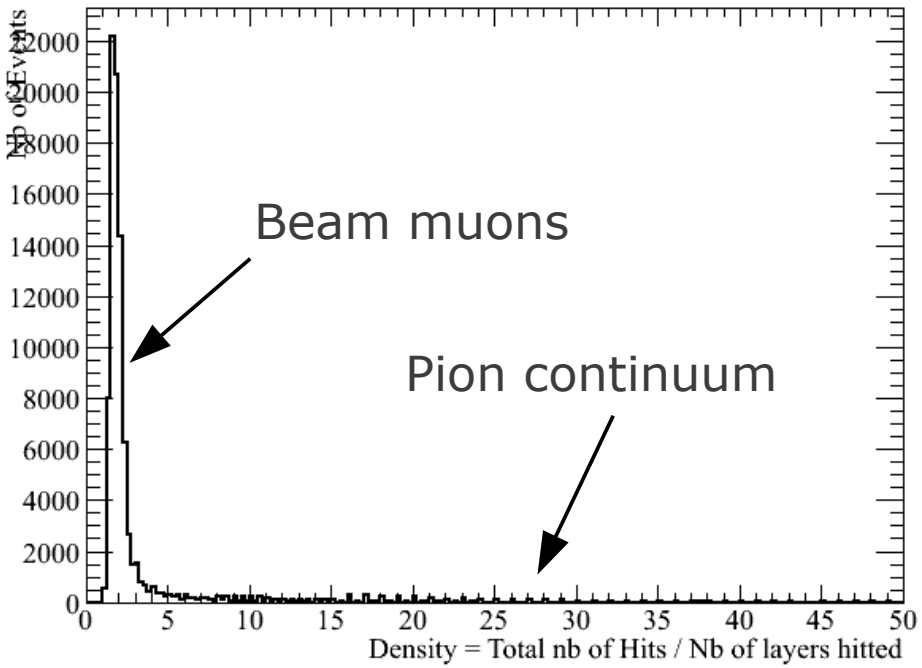
- Event building
- Event selection
  - Pions versus muons and electrons
  - Fiducial cuts
- Simulation versus data at each step
- Fitting the total number of hits
- Resolution and linearity
- Systematic studies
- Conclusions

Event building



- Time order hits
- Count the number of hits in the same time slot t
- If count > threshold then an event is all hits in the time slots between $t-\delta t \leq t \leq t+\delta t$, $\delta t=2$ counts

Event selection π versus μ

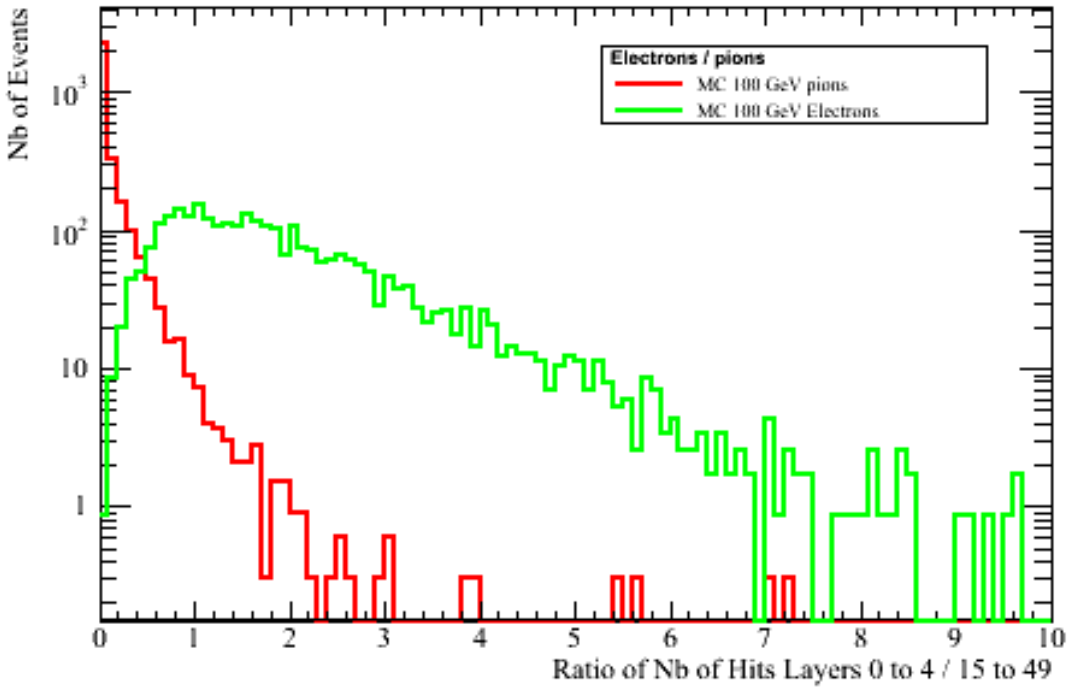


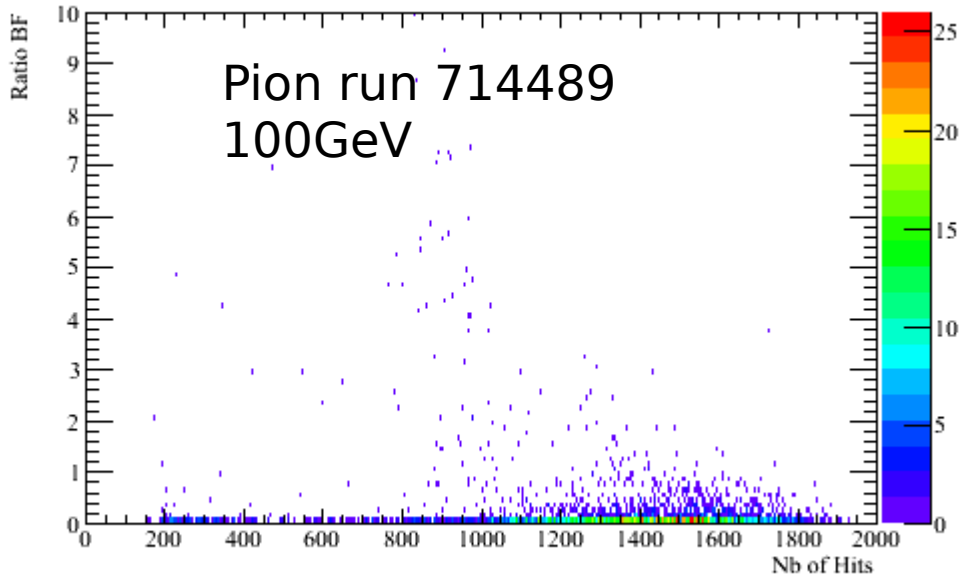
- Lot of beam muons
- Density = Number of hits / Number of layers hit D>4
- Total number of hits > 150

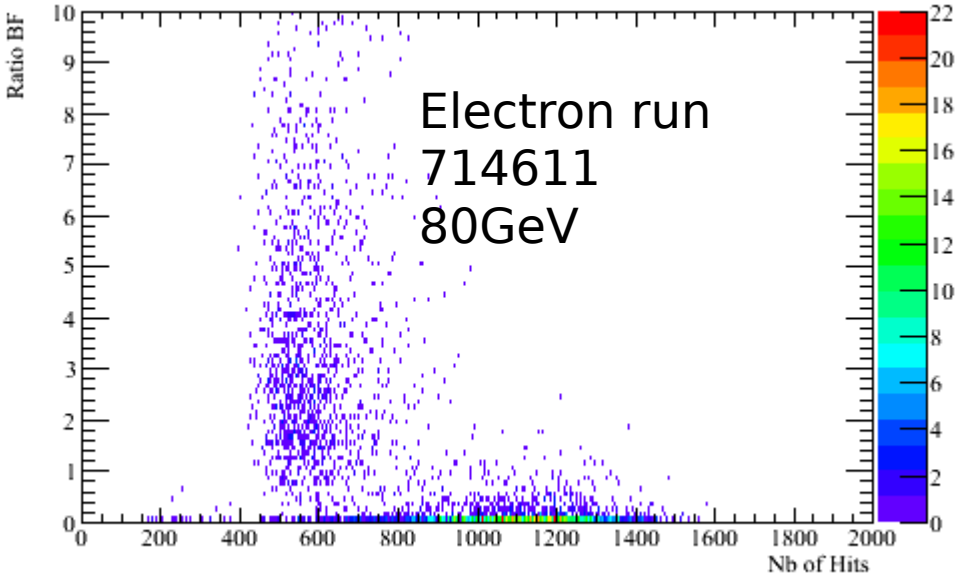
Event selection π versus e

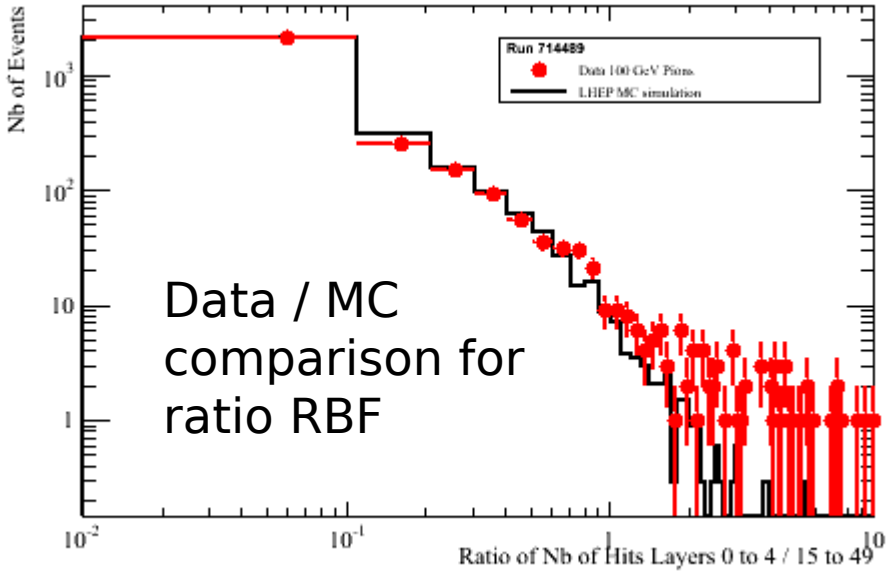
Use longitudinal shower distribution to select electrons and pions

$$\mathrm{RBF} = \frac{\sum_{l=0}^{4} Nb\ of\ Hits\ of\ layer\ l}{\sum_{n=15}^{49} Nb\ of\ Hits\ of\ layer\ n}$$

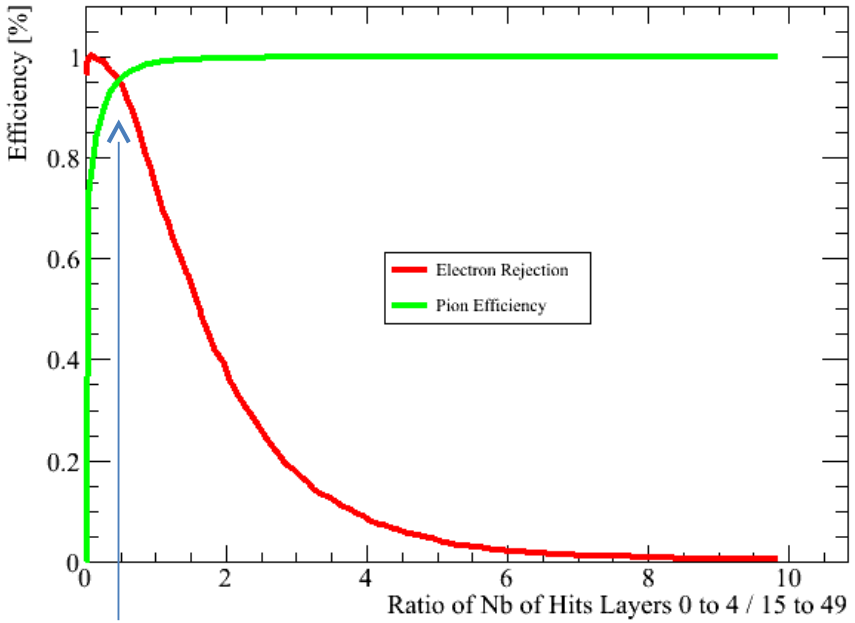



Pion run 714489
100GeV
Ratio BF
Nb of Hits


Electron run
714611
80GeV
Ratio BF
Nb of Hits



With cut R<0.5
Electron rejection and pion selection efficiency > 95%

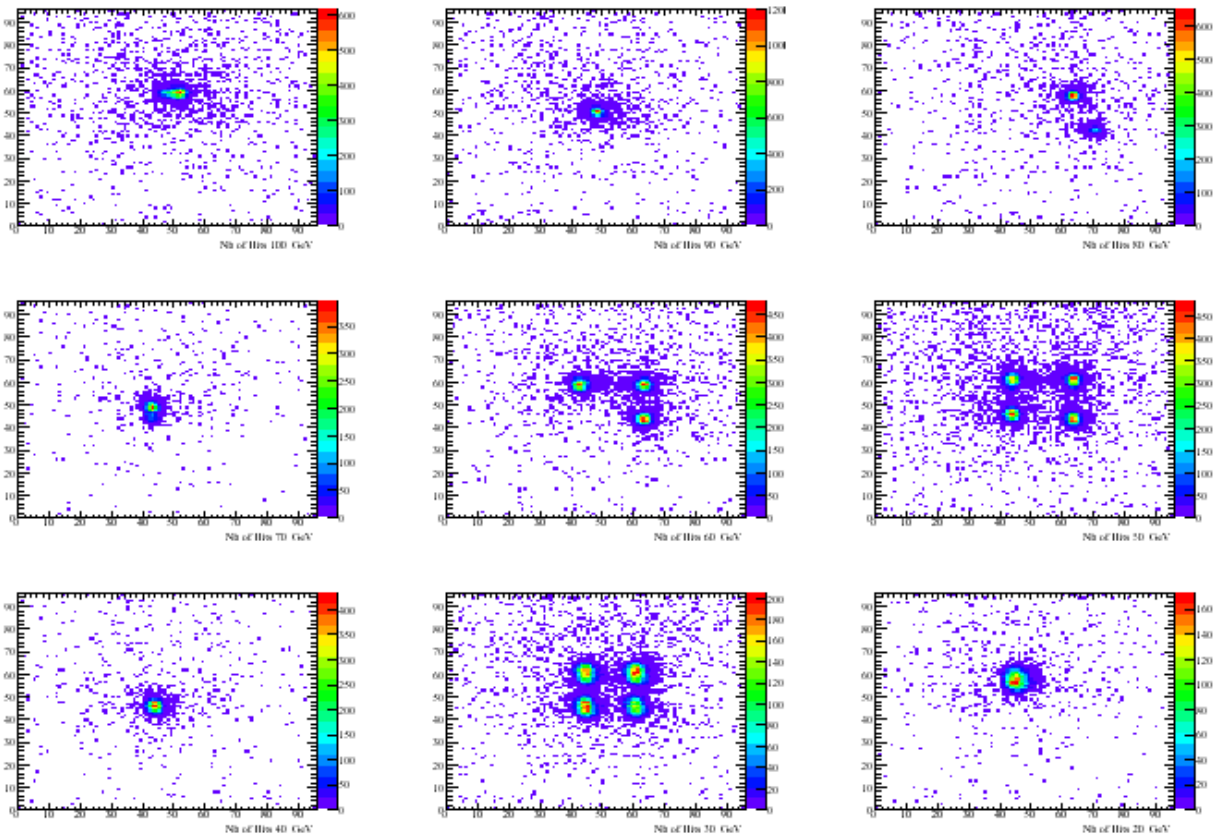


Select π in the center of the SDHCAL

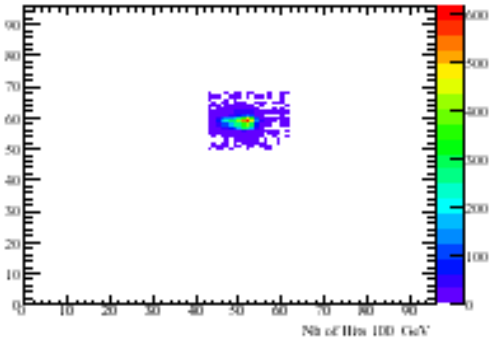
- Ensure full lateral containment of the shower
- Beam has moved during the same run → fiducial cuts

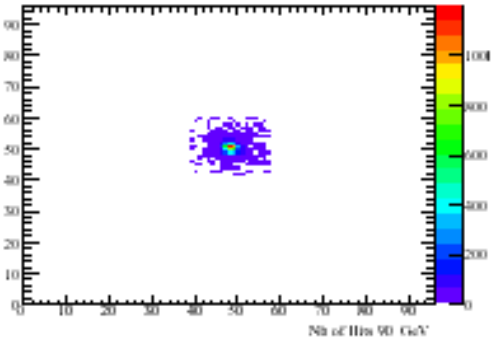
Hit maps for Pion candidates for each run (Pad nb X vs Y)

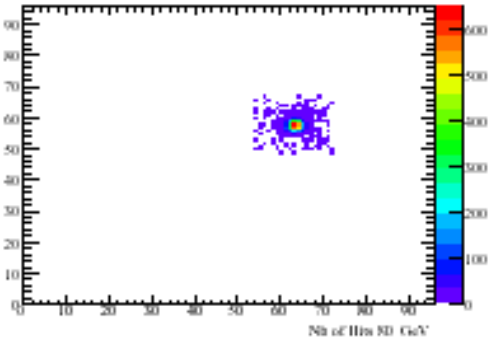
Beam energy in GeV:
100 90 80
70 60 50
40 30 20

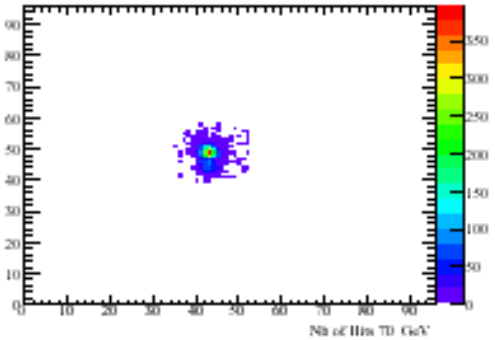


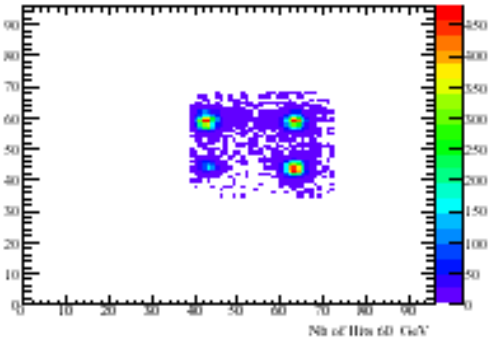
Selected regions

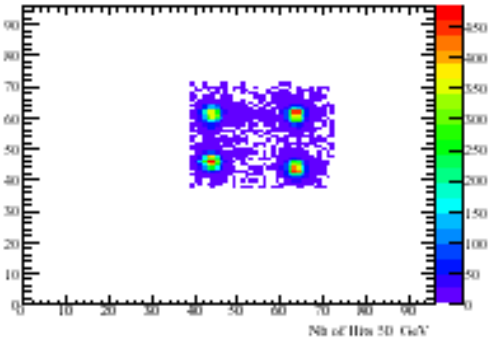


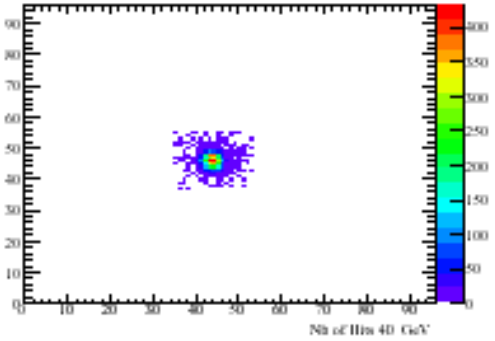


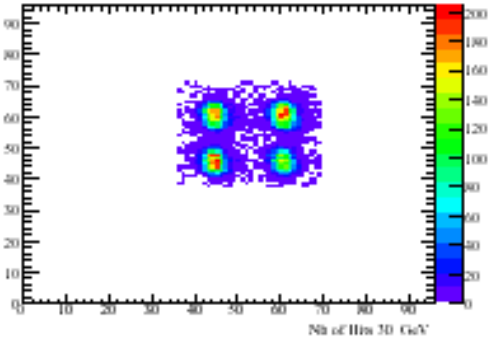


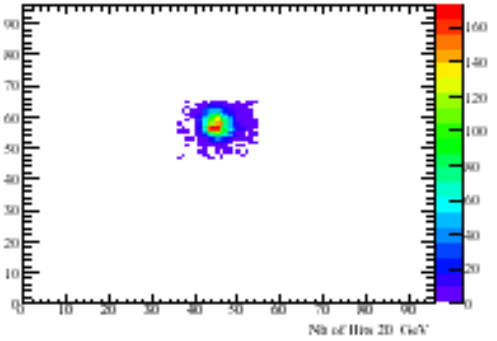










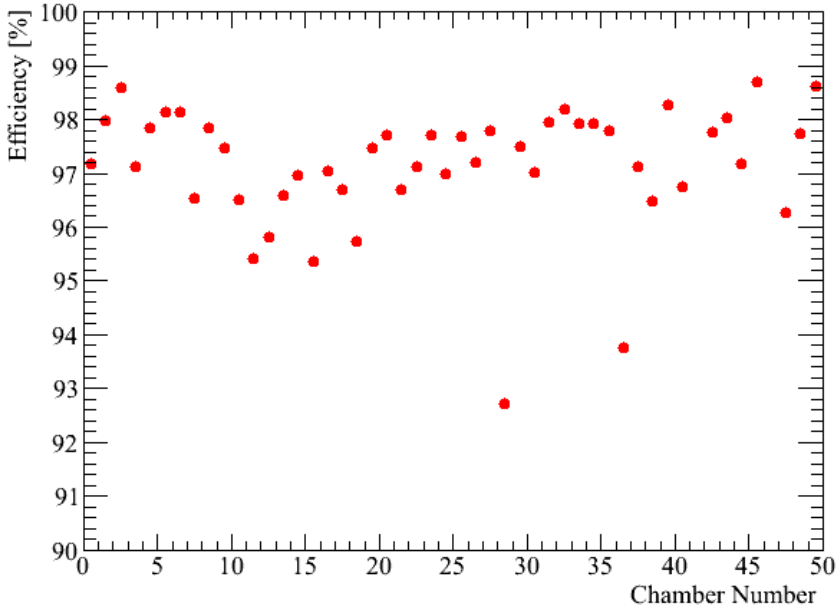


Pion event selection

- Total number of hits > 150
- Density > 4
- RBF < 0.5
- Fiducial cuts depending on each run

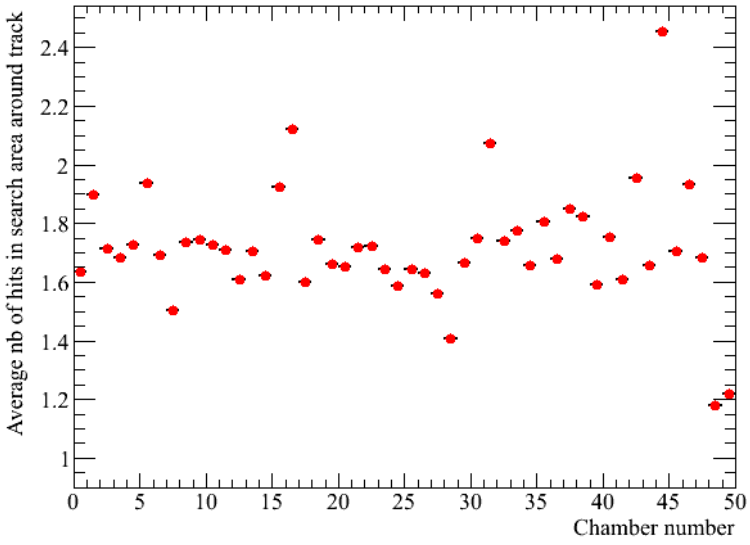
Linearity and resolution studies

- Using low intensity runs
- For each run :
  - Compute efficiency and multiplicity for each layer using plenty of penetrating muons taken at the same run
  - Correct the nb of hits per layer by its efficiency
  - Correct the nb of hits per layer by its multiplicity
  - Sum up the number of hits
  - Fit the total number of hits
  - From fit get average nb of hits and resolution



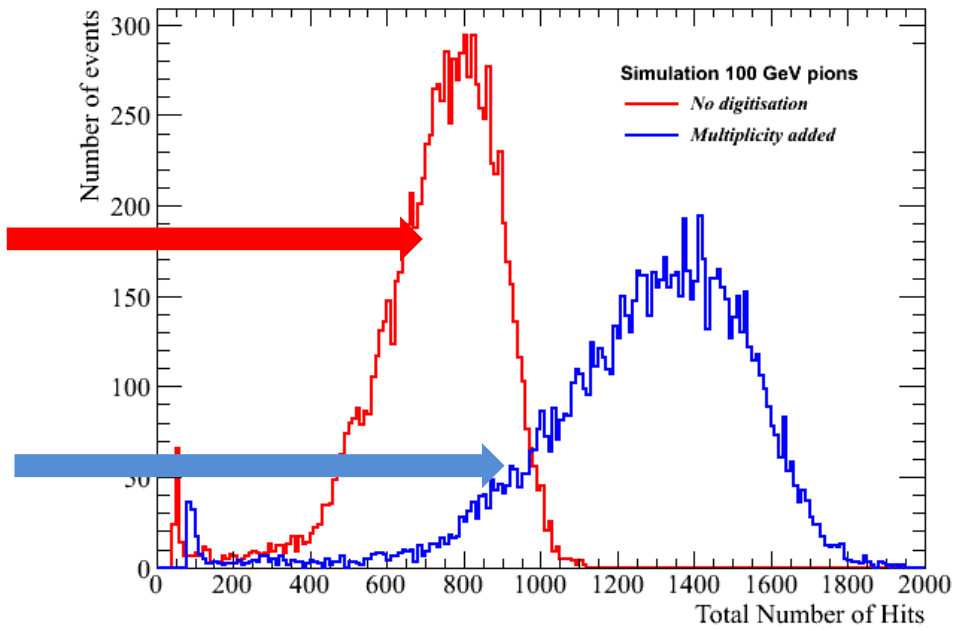
Efficiencies and multiplicities ex: Run 714489

An overall 5% correction to the number of hits almost independent for the runs considered in this analysis

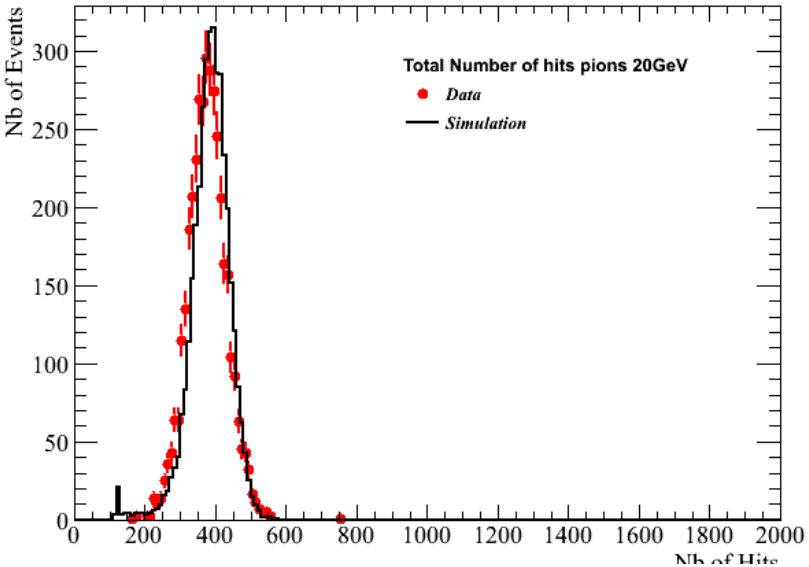


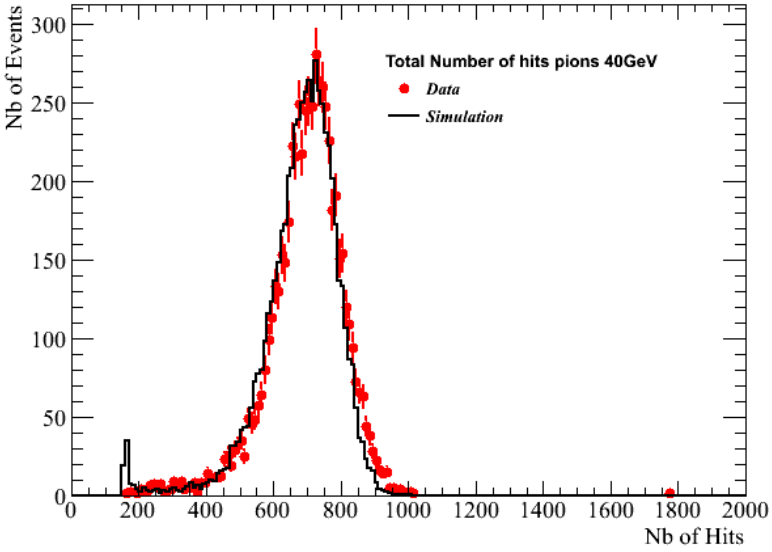
The total number of hits

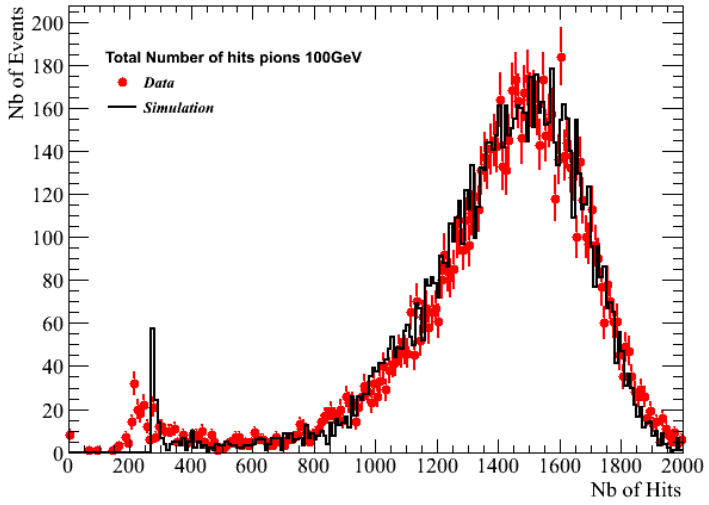
- The distribution of the total number of hits is not Gaussian.
- There is a left tail probably due to rear leakage & saturation
- From simulated 100 GeV events we weight each hit by the layer's multiplicity and efficiency as measured in the data.



Comparison Data / MC Total Nb of Hits







Total Nb of simulated hits =
(Nb of hits from MC)*Multiplicity
*Efficiency +
48*4*E/100 !

- **The simulation fits very well the resolution**
- **Misses the average nb of hits by 48*4*E/100 !**

Fit total number of Hits

1. Crystal Ball Function
   - Fits left tail much better than a gaussian

$$f(x;\alpha,n,\bar{x},\sigma) = N \cdot \begin{cases} \exp(-\frac{(x-\bar{x})^2}{2\sigma^2}), & \text{for } \frac{x-\bar{x}}{\sigma} > -\alpha \\ A \cdot (B - \frac{x-\bar{x}}{\sigma})^{-n}, & \text{for } \frac{x-\bar{x}}{\sigma} \leqslant -\alpha \end{cases}$$

$$A = \left(\frac{n}{|\alpha|}\right)^n \cdot \exp\left(-\frac{|\alpha|^2}{2}\right)$$

$$B = \frac{n}{|\alpha|} - |\alpha|$$

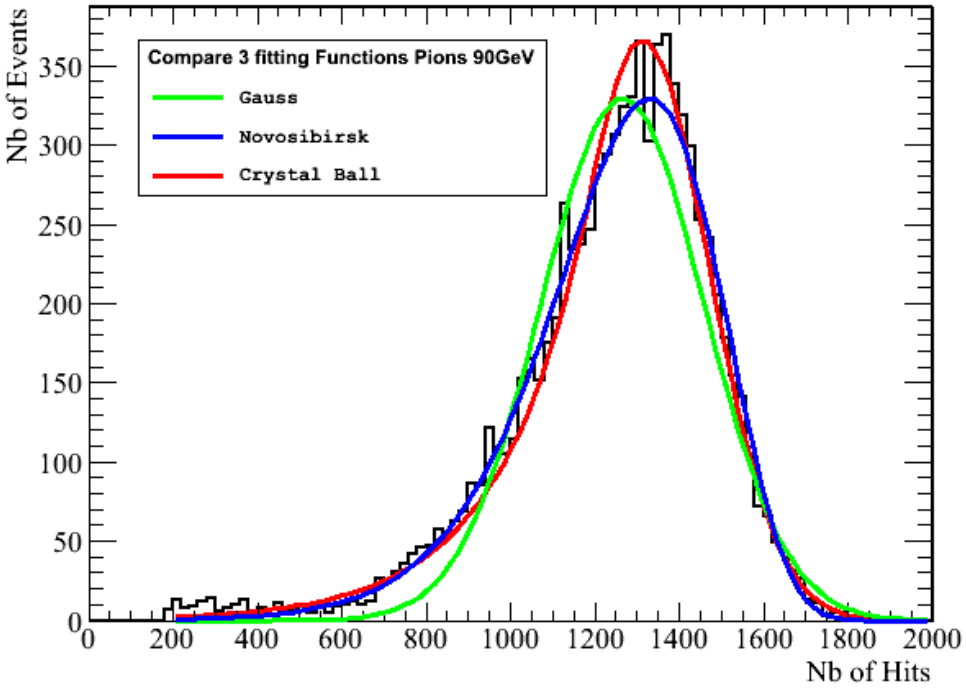
2. Novosibirk
   - Fits left tail much better
   - More stable than CB
   - One parameter less

The Novosibirsk function is given by

$$\mathcal{P}_{\mathrm{h}}(x; m_{\mathrm{h}}, \sigma_{\mathrm{h}}, t_{\mathrm{h}}) = \exp\left[\frac{-\ln^2\left(1 + t_{\mathrm{h}}\Lambda\frac{x-m_{\mathrm{h}}}{\sigma_{\mathrm{h}}}\right)}{2t_{\mathrm{h}}^2} - \frac{t_{\mathrm{h}}^2}{2}\right], \quad \text{(A2)}$$

where $\Lambda = \sinh(t_{\mathrm{h}}\sqrt{\ln 4})/(t_{\mathrm{h}}\sqrt{\ln 4})$. This function approaches a Gaussian function when the parameter t_{h} vanishes.

Comparing Fitting Functions



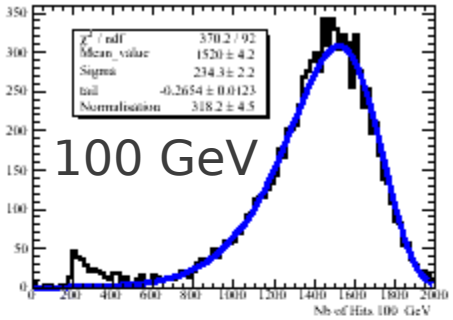
The Novosibirsk function is more stable and is used as the reference later

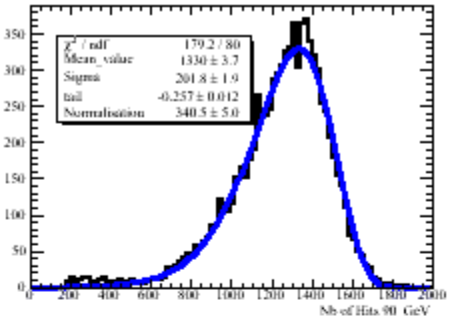
Gauss underestimates the average number of hits.

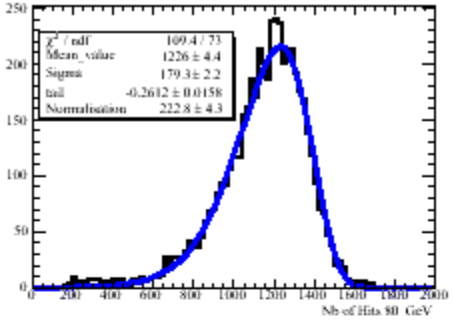
Results on the 90 GeV run:

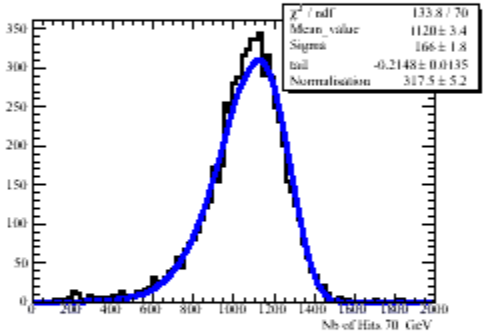
Function	Average	Sigma
Gauss	1265	15.29%
Crystal Ball	1313	12.15%
Novosibirsk	1329	15.17%

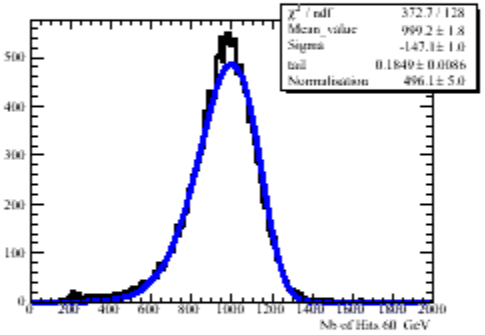
Fitting the number of hits for 9 energies

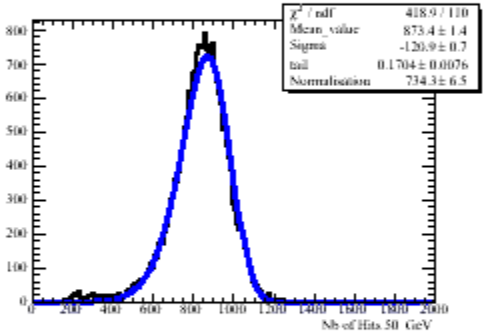


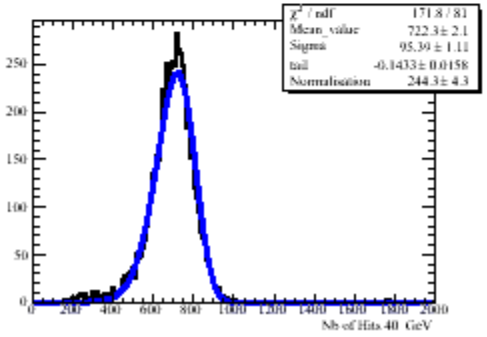


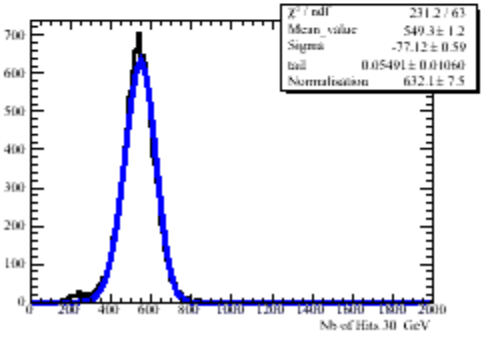


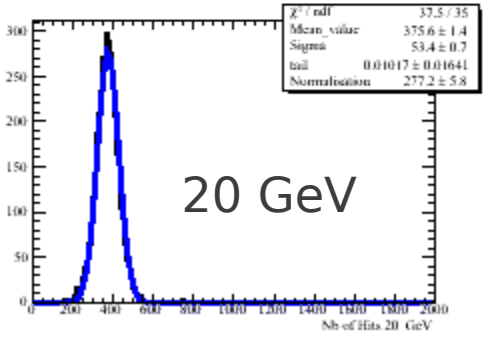




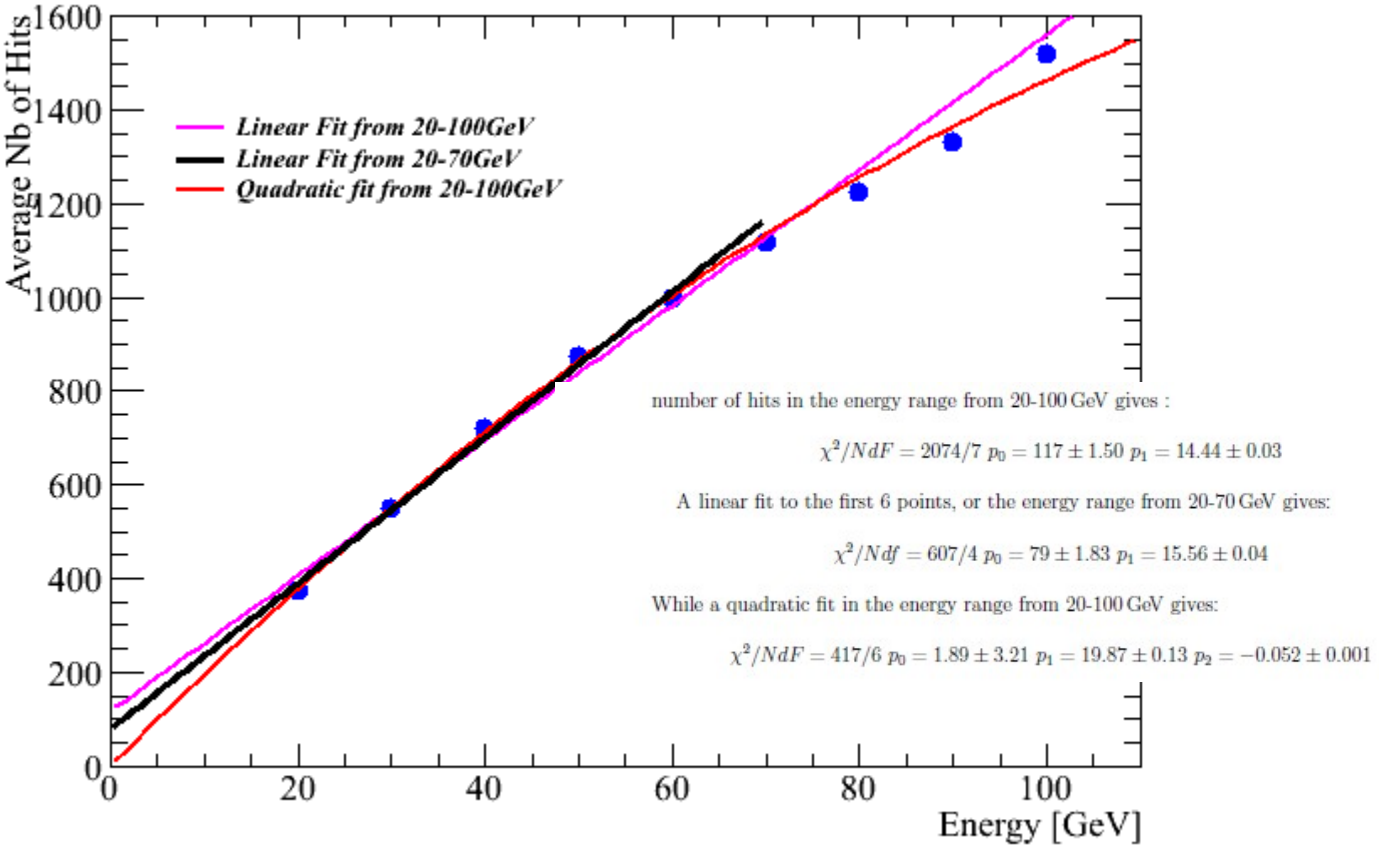






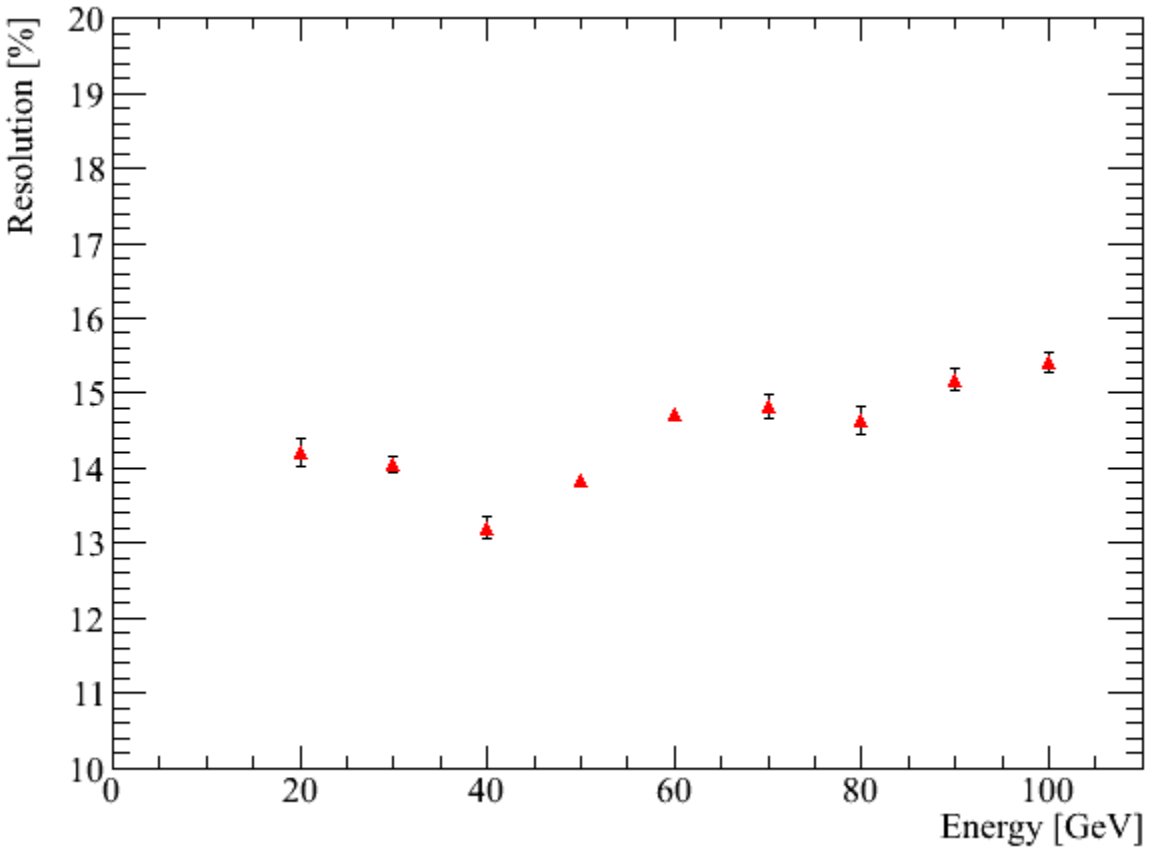


Linearity and Resolution



The linear fits give a very bad $\chi 2$

Resolution



Flat versus energy : Dominated by the rear leakage

Systematic studies

- Hits selection
  - Hits are selected using a δt <= 2 cycles

Energy(GeV)	$< Hits > \delta t = \pm 2$	$< Hits > \delta t = \pm 1$	$< Hits > \delta t = \pm 5$
100	1520	1509	1534
90	1329	1323	1340
80	1225	1218	1234
70	1119	1114	1127
60	999	995	1007
50	873	868	880
40	722	719	728
30	549	546	554
20	375	373	380

TABLE VI: Variation of the average number of hits with the time window

The <Nb of Hits> varies very little (Novosibirsk fit). The resolution is 1% better at δt<=1 cycle.

Systematic studies (2)

- Fitting with a Crystal Ball function

- If no efficiency and multiplicity corrections are applied the variation is ~5%.

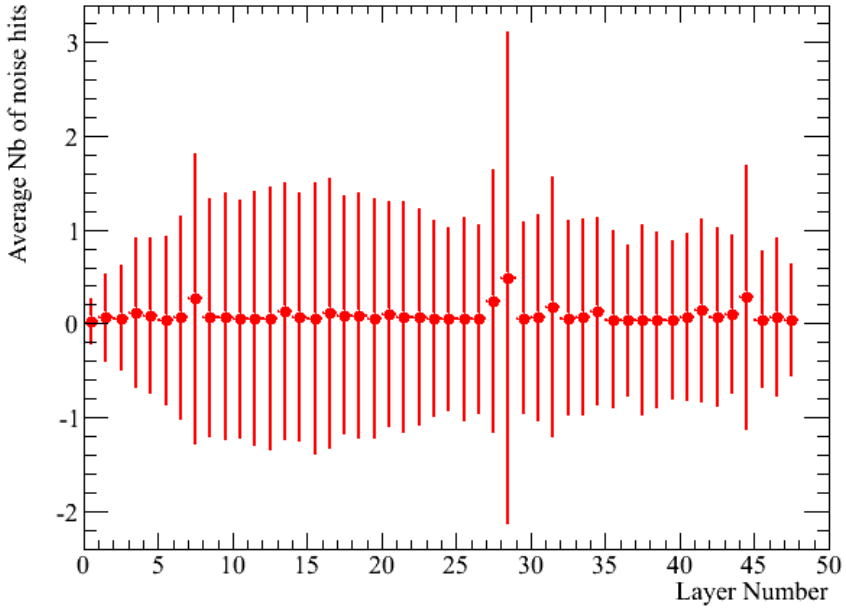
Energy(GeV)	$\Delta Average$ Crystal Ball
100	-2.1%
90	-1.2%
80	-1.6%
70	-1.6%
60	-1.4%
50	-1.4%
40	-1.3%
30	0.6%
20	-0.2%

Noise estimation

- We estimate noise by

a) Counting the number of hits outside the dt selected window

b) Using penetrating μ events we count the number of hits outside an area of 7x7 pads around the μ track

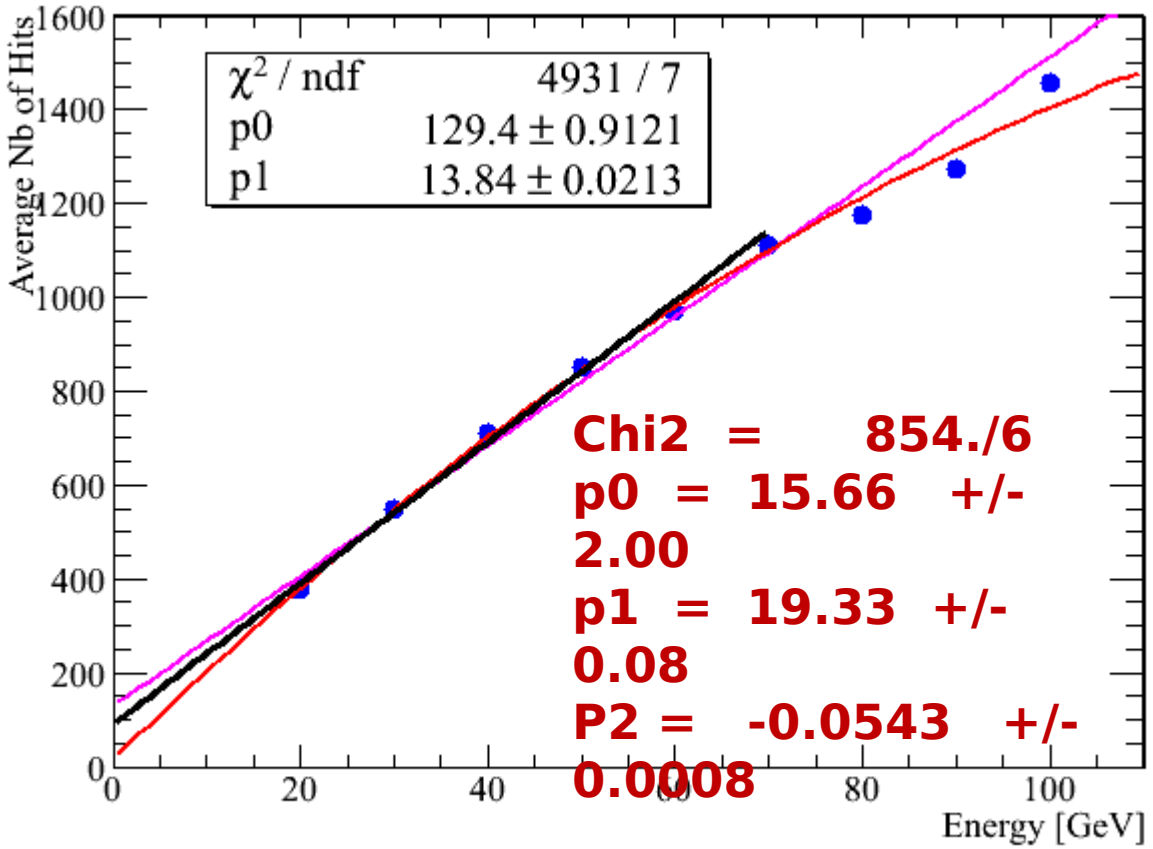


We find on average less than 1 noise hit per event, noise conditions are good

Conclusions

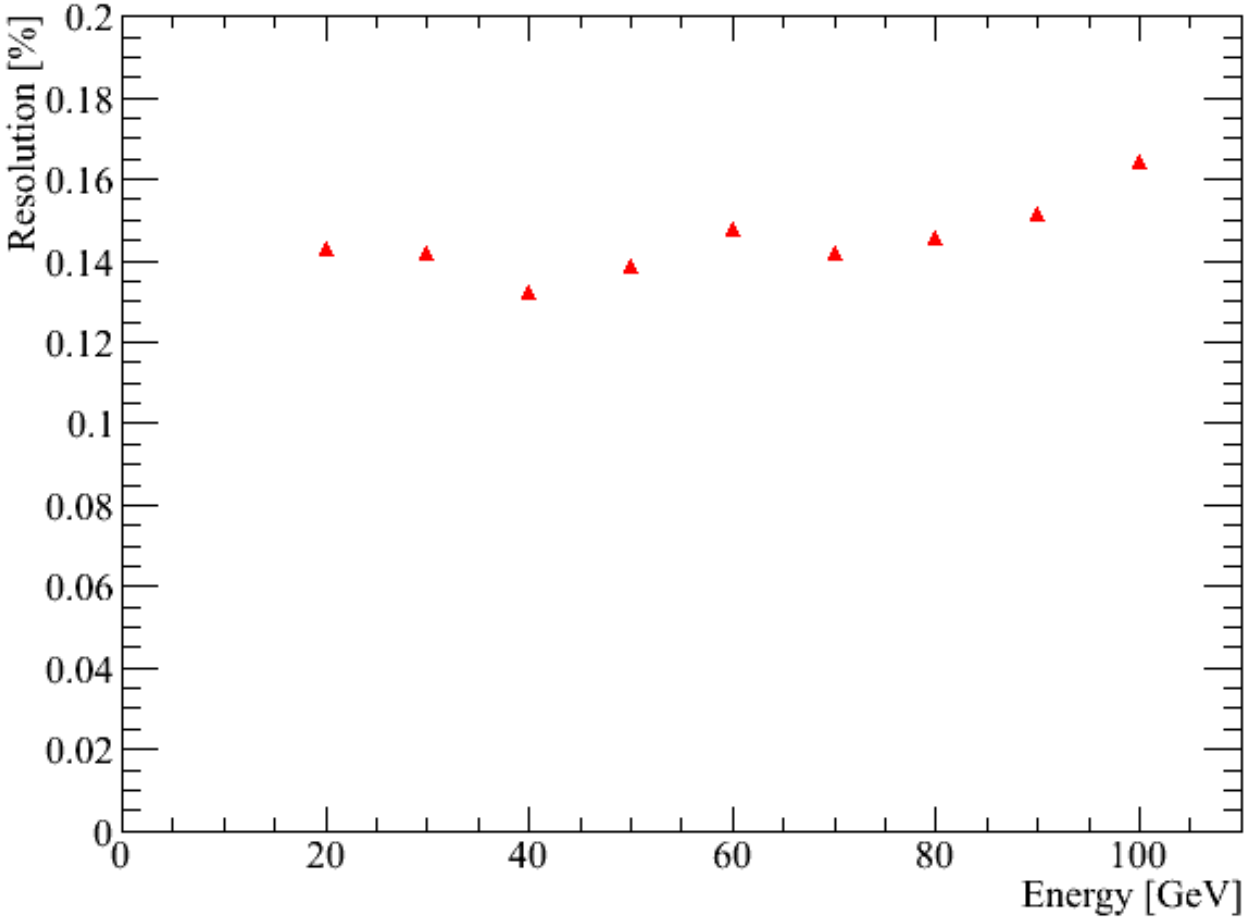
- Efficient pion, electron and muon event selection
- Reliable simulation based on SLIC and the test beam geometry description
- First results on resolution and linearity using only the 1st threshold.
- For the future : Include higher thresholds information to quantify the gain of a semi-digital device

Linearity Gauss Fit
Efficiency Multiplicity corrections applied

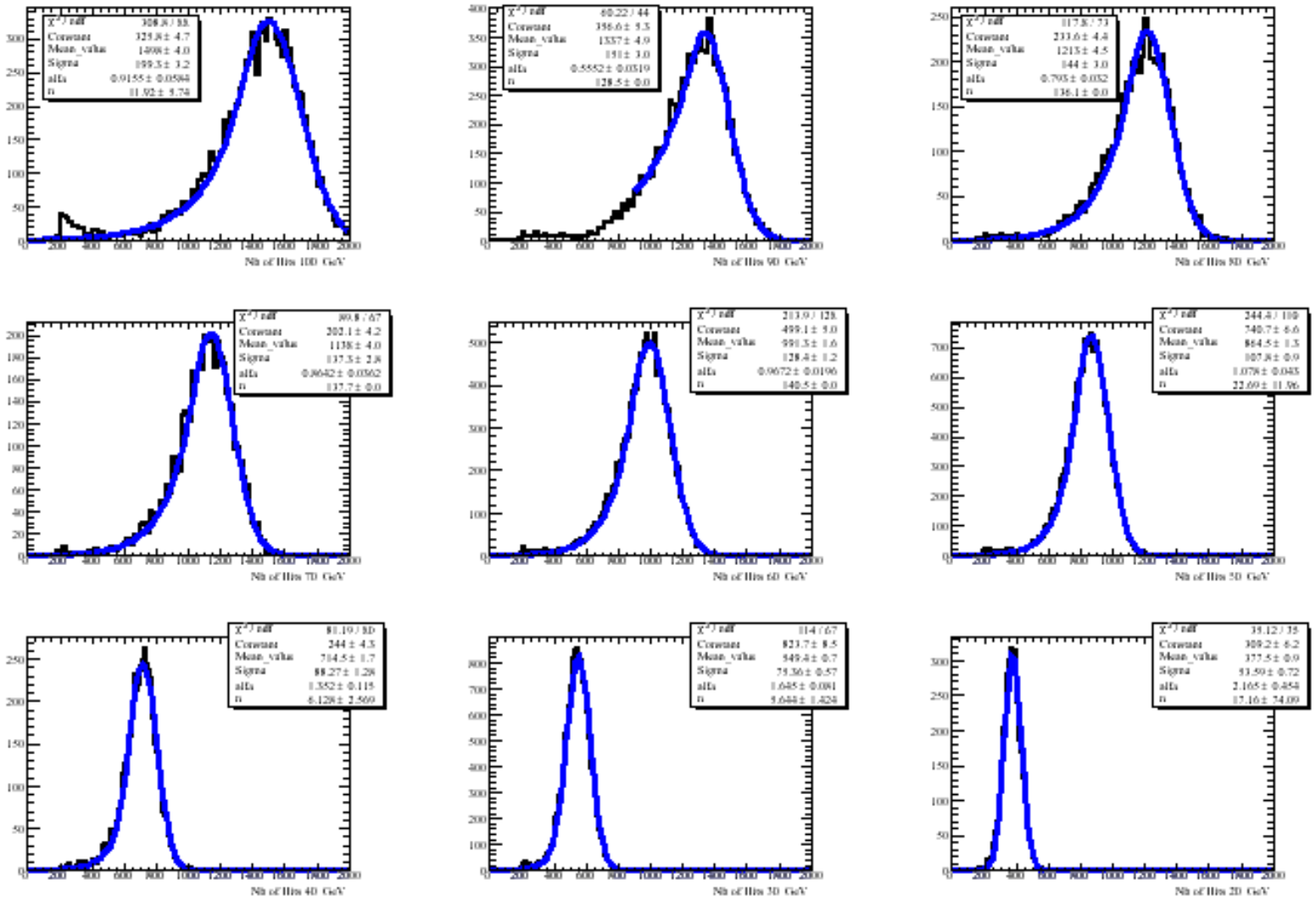


Black line fits from 0-70 GeV Gives a better fit than the magenta over the full range

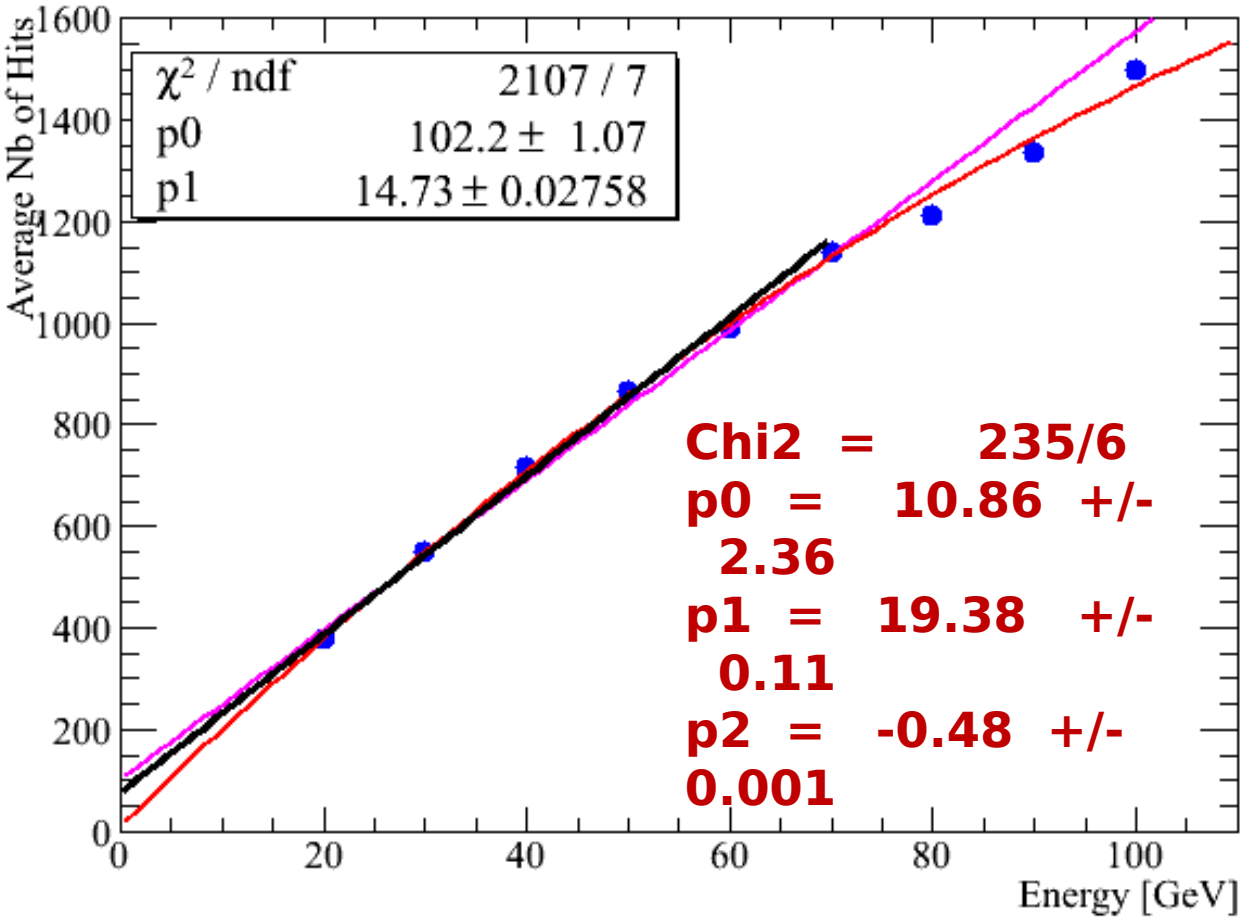
and Resolution Gauss Fit



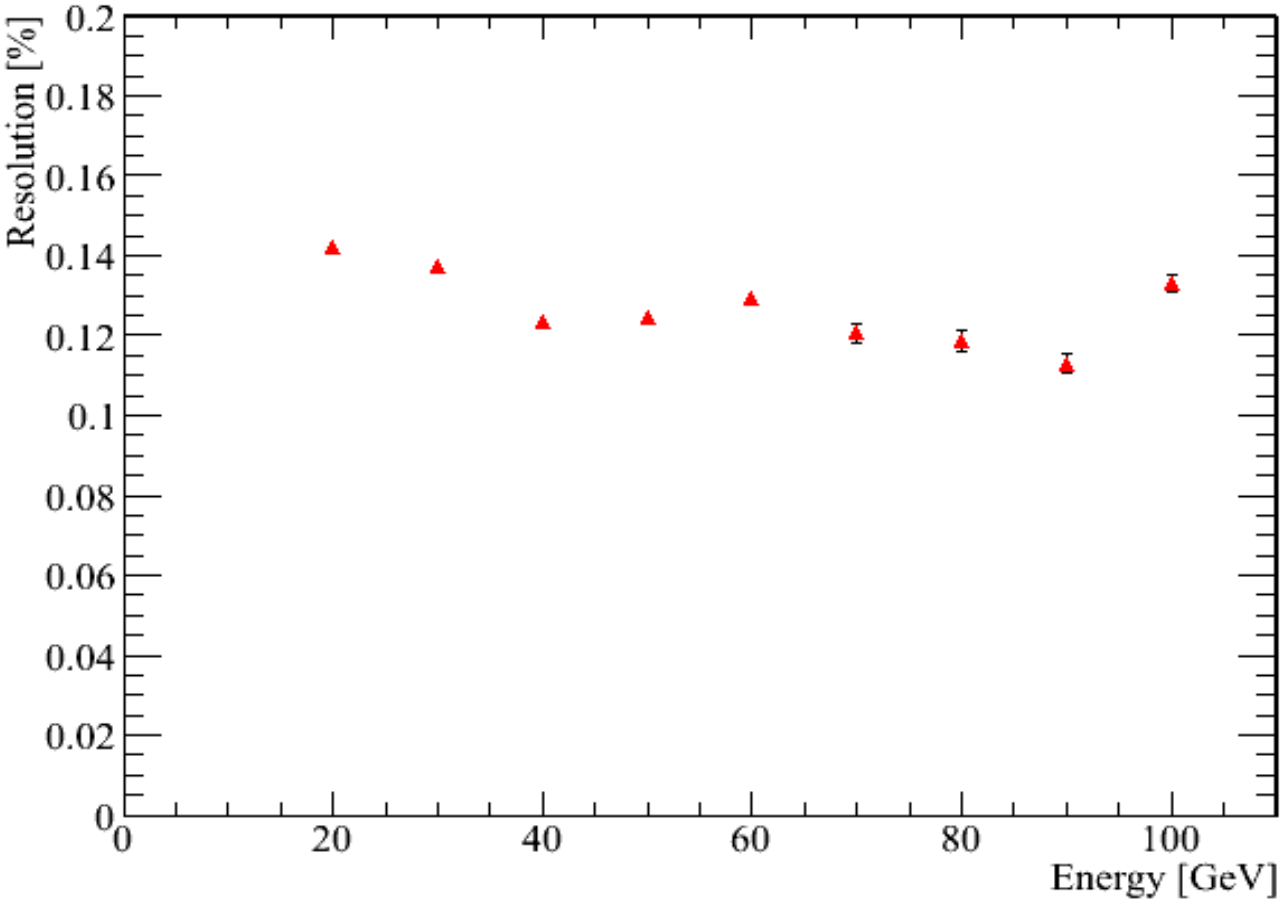
Fitting with a Crystal Ball function



Linearity CB Fit

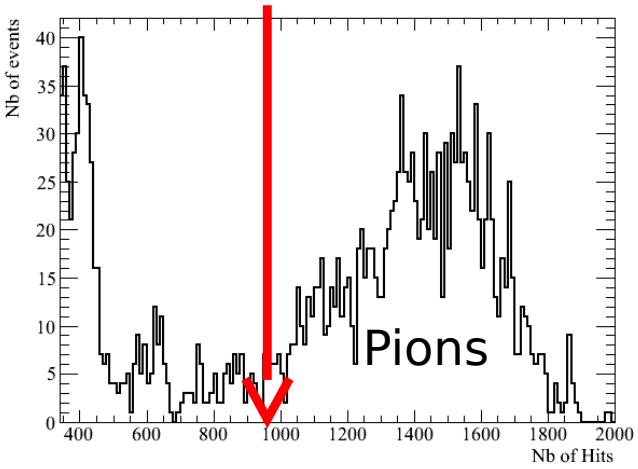


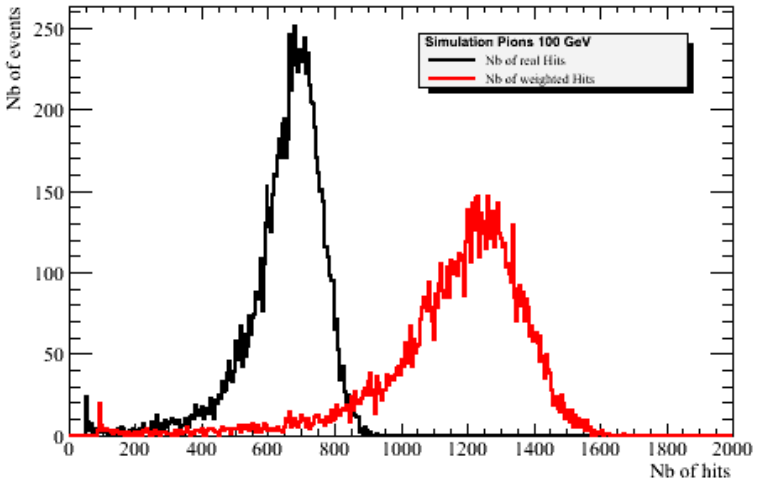
Resolution CB Fit

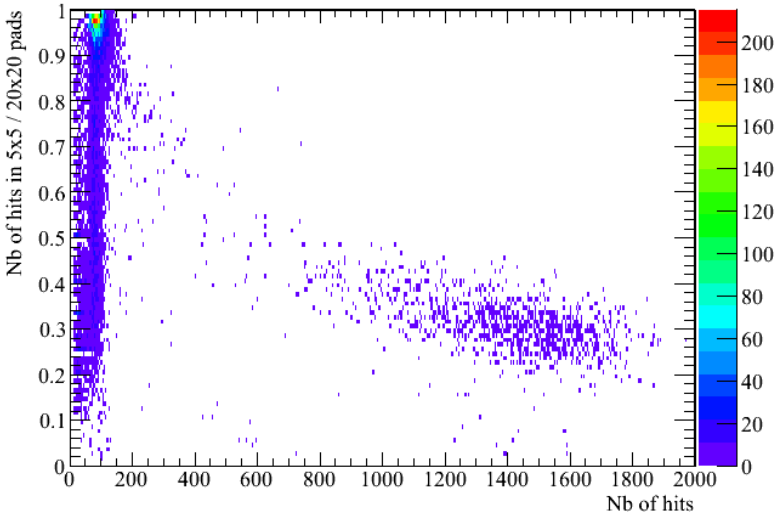


Similar Results but still investigating fits

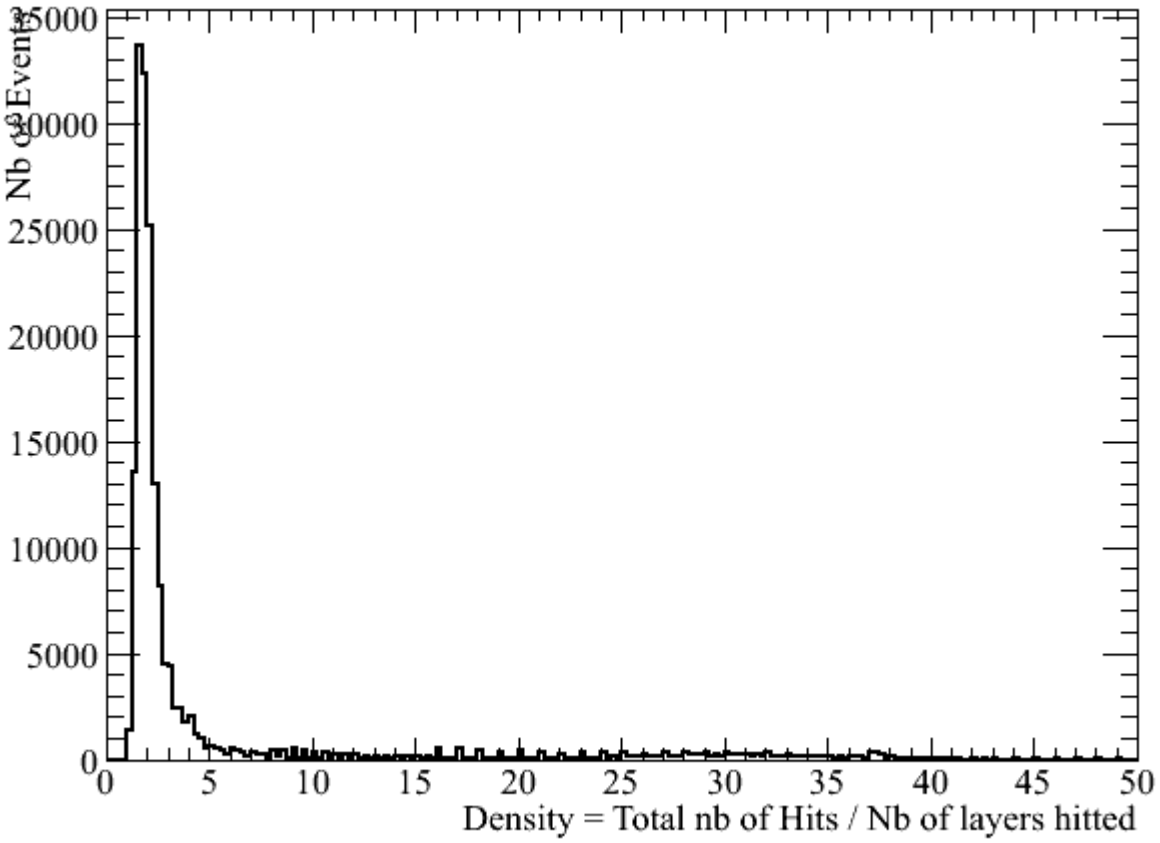
Select Pions



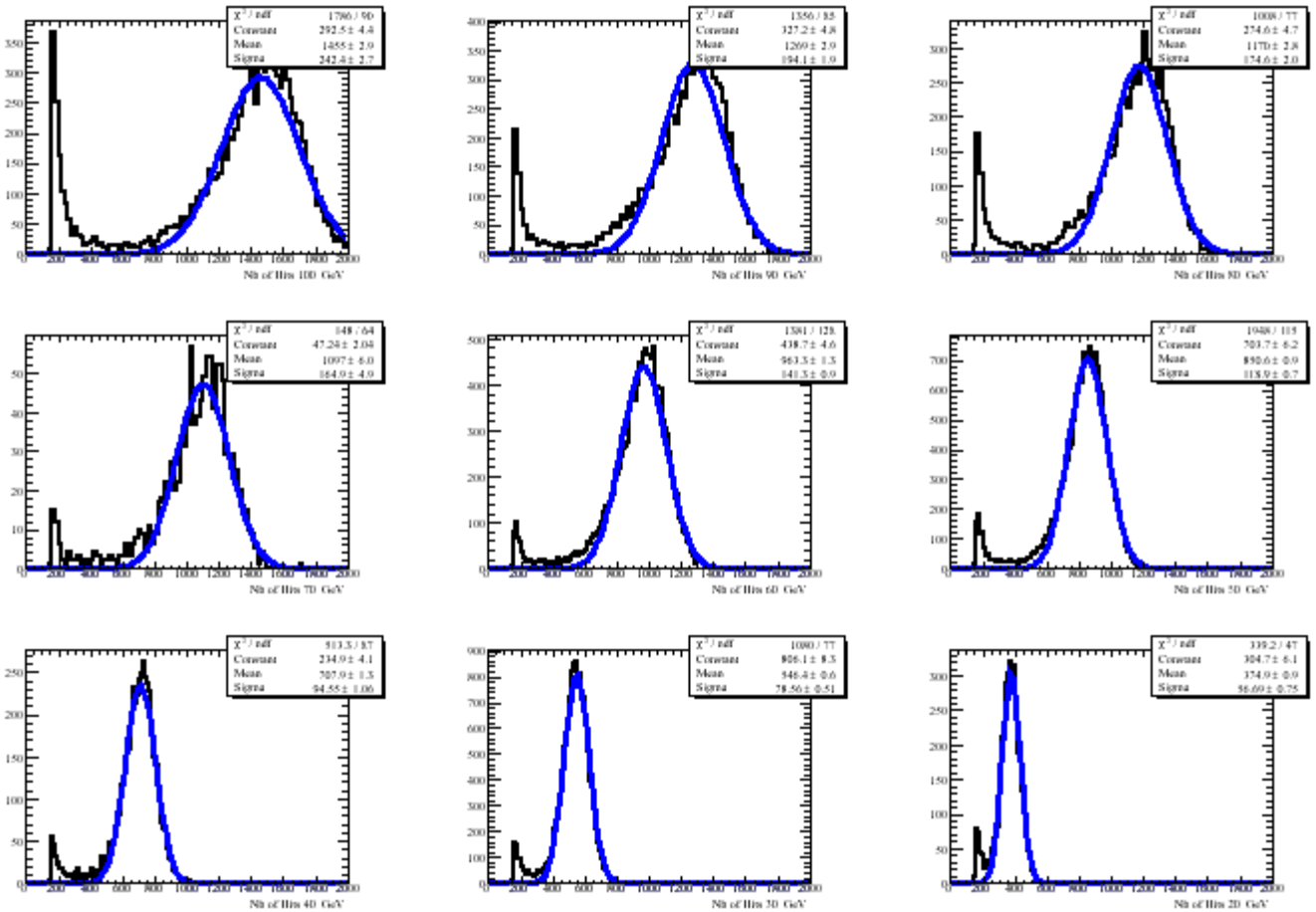




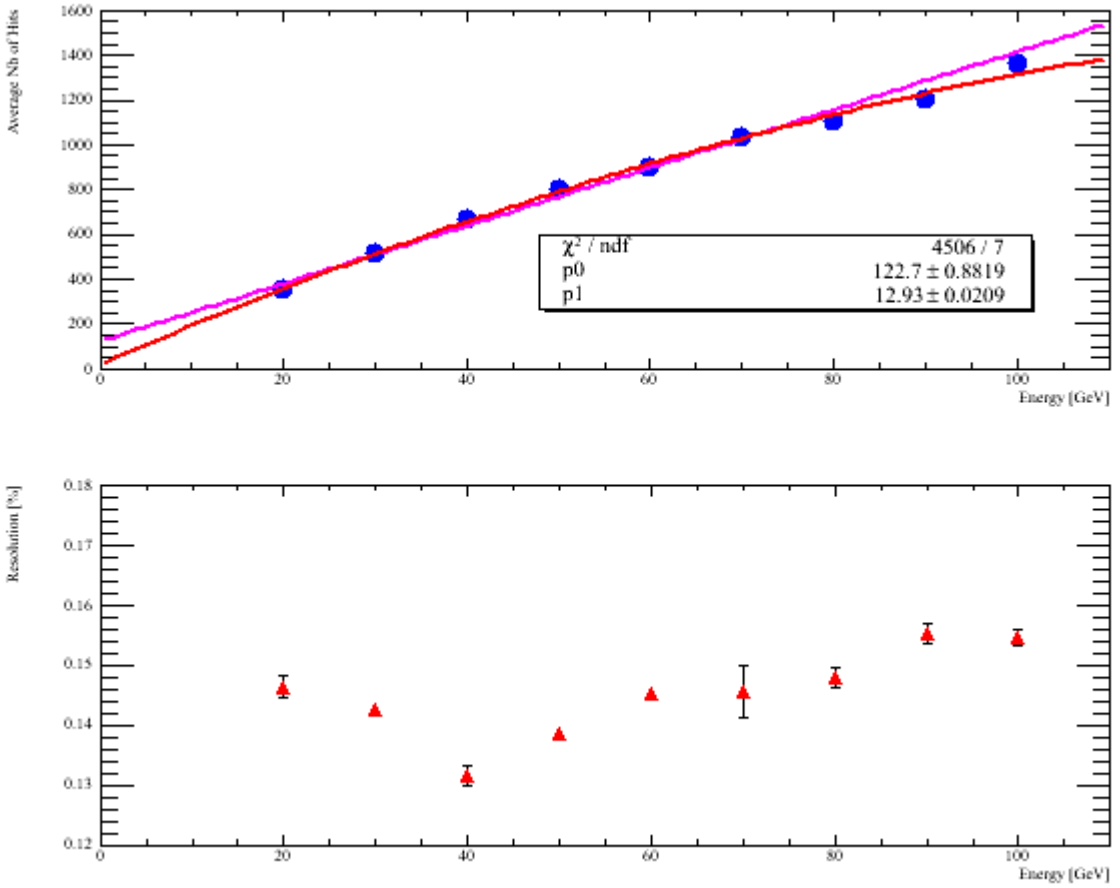
The number of hits in a small core of 5x5 cells compared to a larger core 20x20, must be closer to 1 for μ and e and smaller values for π


Nb of Events
35000
30000
25000
20000
15000
10000
5000
0
0
5
10
15
20
25
30
35
40
45
50
Density = Total nb of Hits / Nb of layers hitted

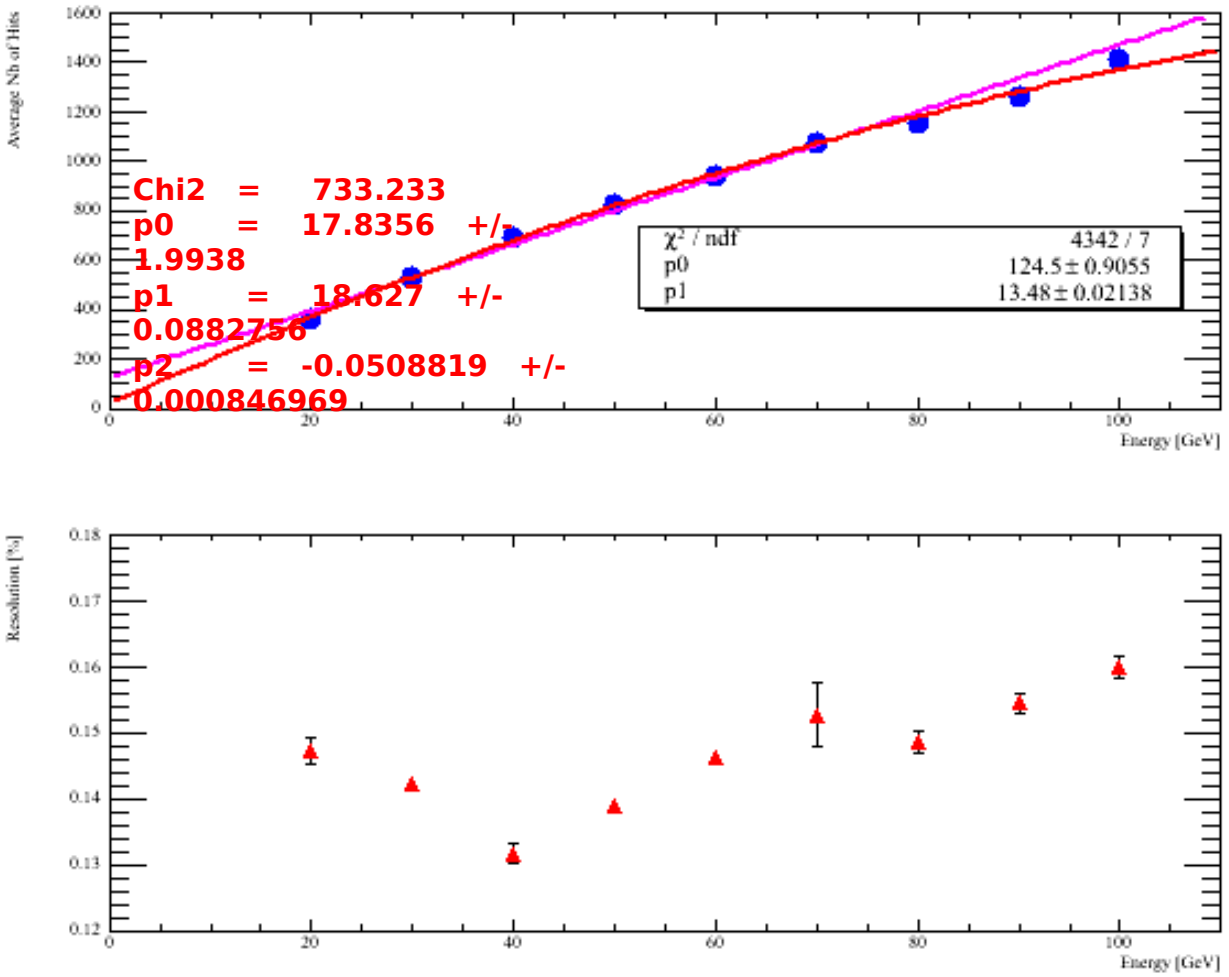
Hit distribution
Density < 3 & No cut on Hits Map



No Chamber efficiency correction applied



Resolution and Linearity
Efficiency correction applied



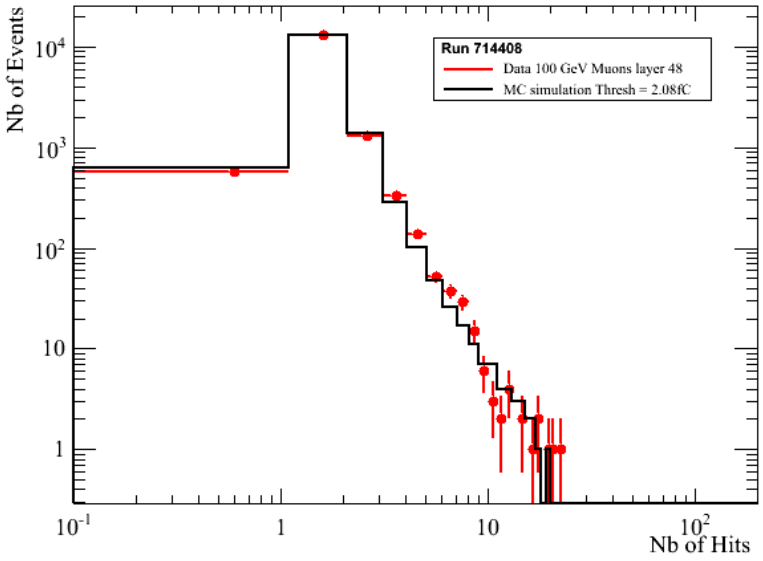
Fitting Linearity with

- A straight line (Magenta)
- A 2nd order polynomial Better fit (Red)

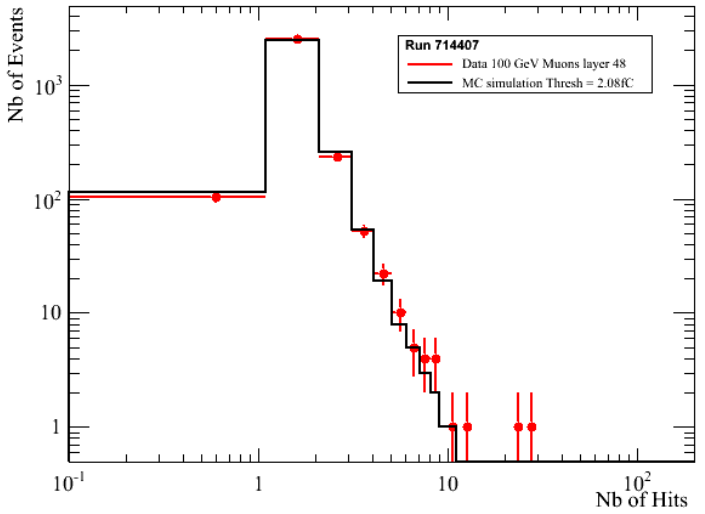
Aim to compare the nb of hits layer by layer Strategy

- Select penetrating MIPS (cf previous presentations)
  - 1< Nb of hits / Nb of layers < 3
  - 6/10 of the forward layers and 6/10 of the backward layers
- Fix threshold 1 to reproduce inneficiency
- Compare MIPs
- Use the same digitization and thresholds and look for pions in the same run

Compare Data / MC for MIPS



QGSP_BERT library



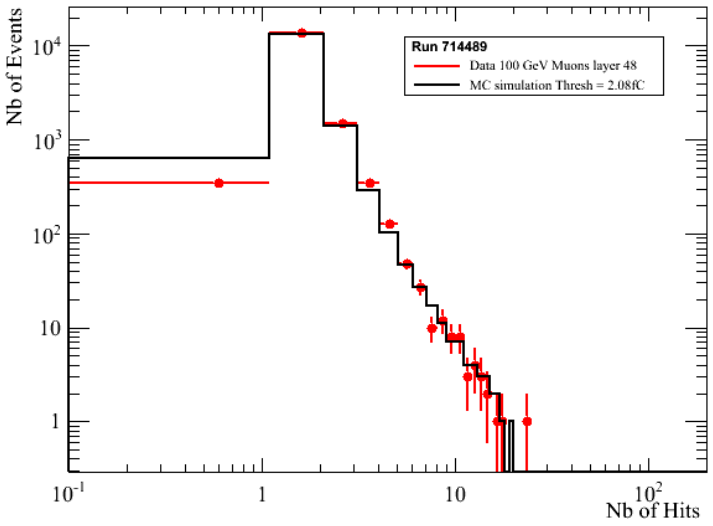
Run 714408 our famous μ Run

Run 714407 High intensity π run but mostly μ's

Very good agreement between data and Monte Carlo.
Strategy :

- Keep the same digitization and thresholds and look for the same distributions for pions.

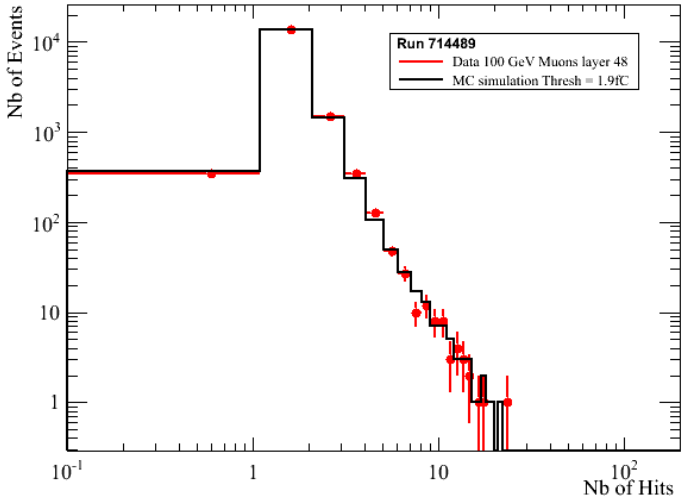
Compare Data / MC for MIPS (2)



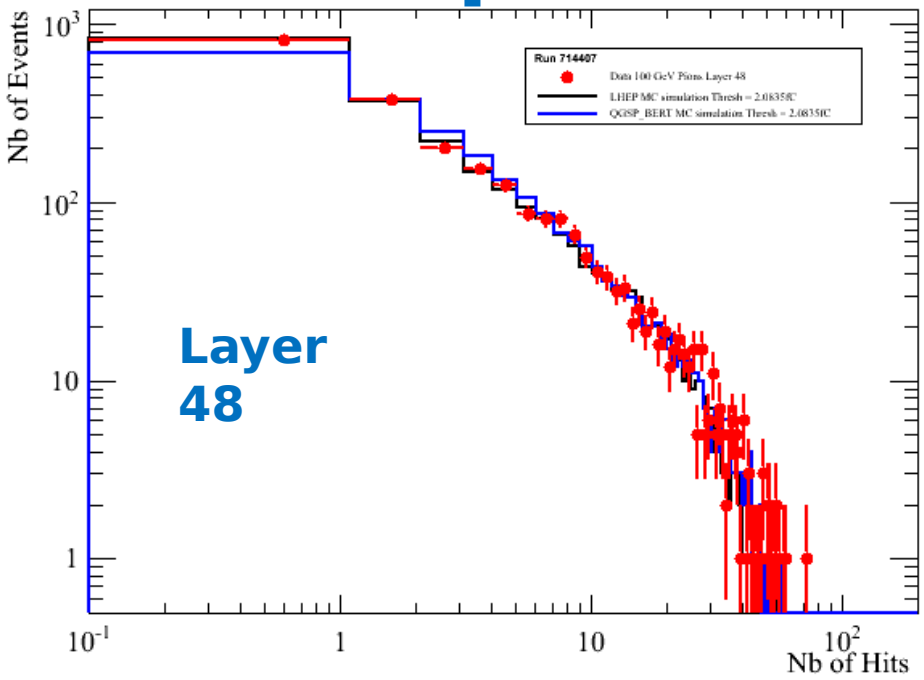
New Run 714489 low intensity, few days later. Keep same MC threshold

Run 714489

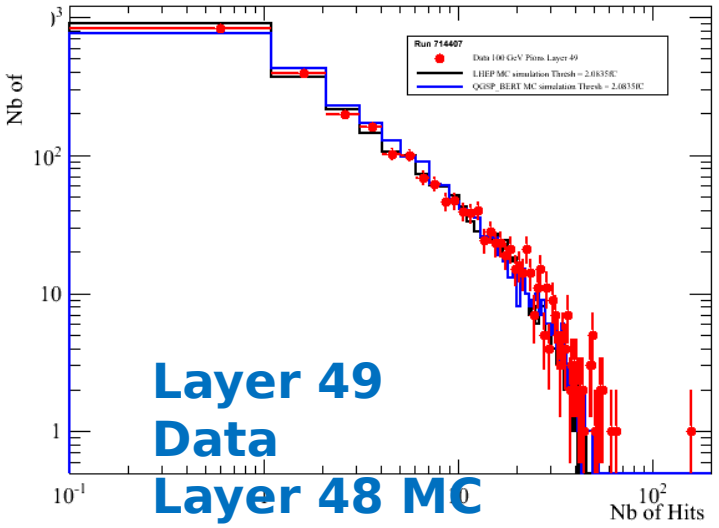
Change Threshold from 2.083fC



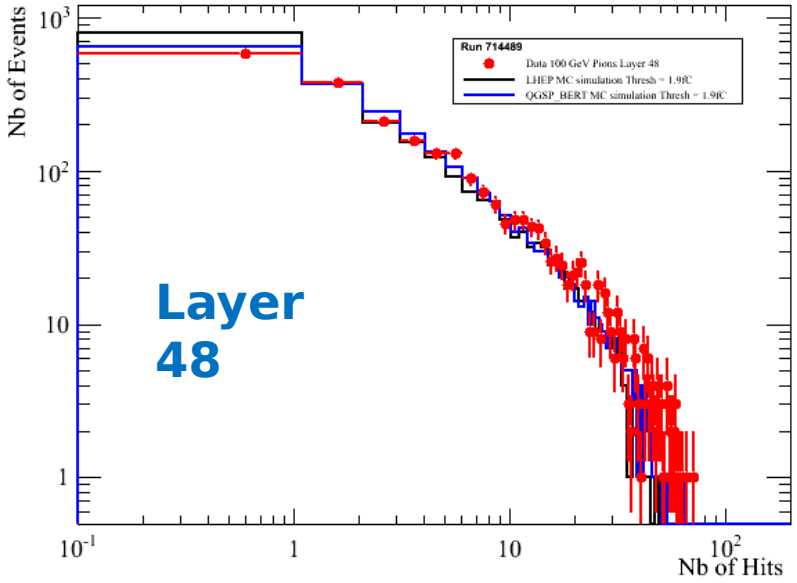
Compare Data / MC for Pions



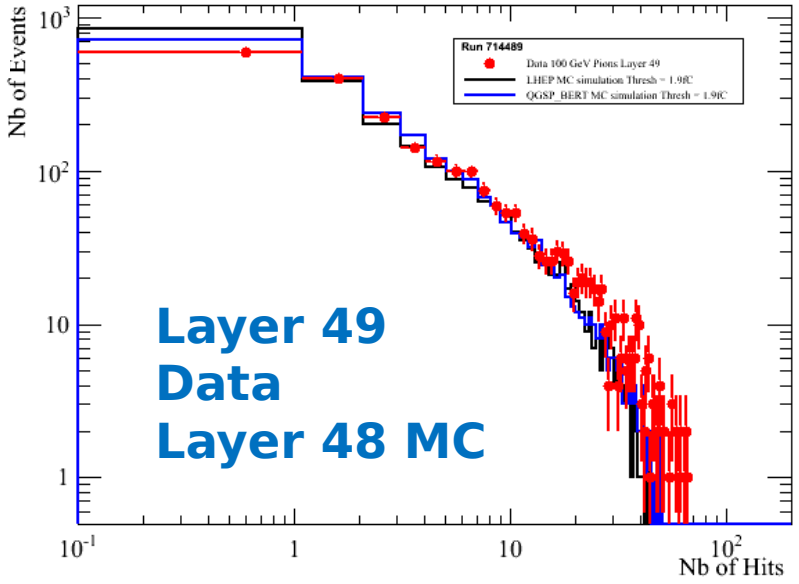
Run 714407 High Intensity



Compare Data / MC for Pions



Run 714489 Low intensity pions



Pions selection

- To compare different energies the showers must be fully contained
- It is better to take data at all energies with the beam crossing at the center of the calorimeter especially when the statistics is limited
- Selecting pions in the center avoids tails in the distribution of the number of hits.
- I consider only pions crossing inside the zones shown next !