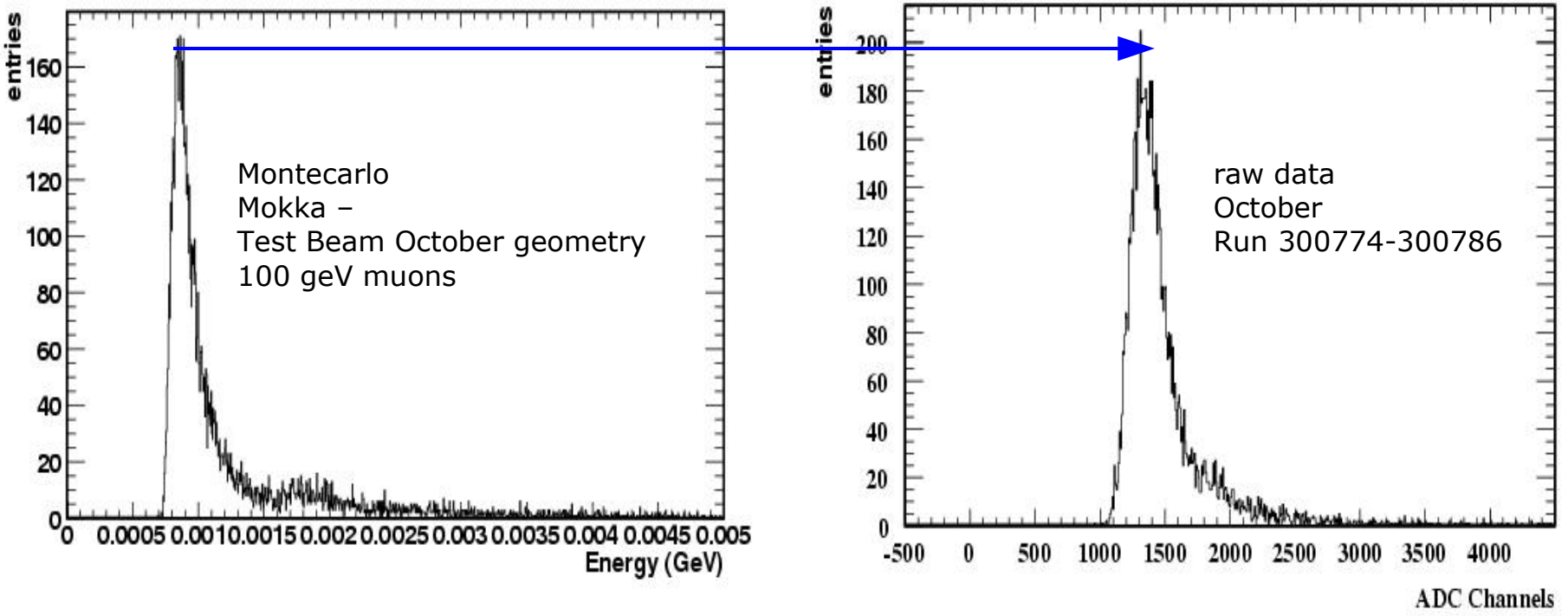
The response of the HCAL to muons: results from the test beam

Nicola D'Ascenzo
(DESY)

Hadron calorimeter and muons



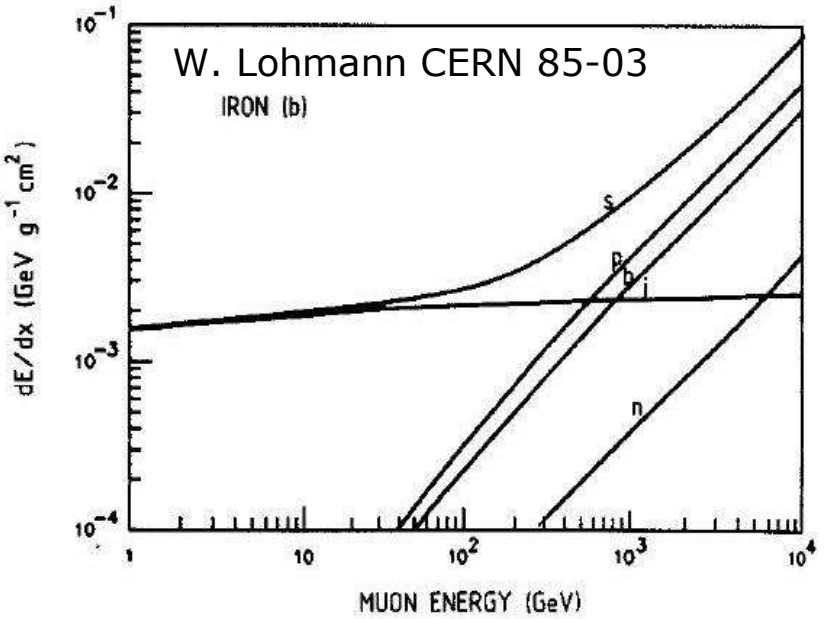
The main task of the hadron calorimeter is the measurement of the hadron part of a jet, but...

- The muon signal is used to fix a calibration "scale" to the raw data. This is the so called "MIP calibration". This scale is expected to be linear, at least for short signals.
- The muon signal is a good probe to check the basics propertied of the detector (noise...)
- Muon identification in the calorimeter can play an important role for the low energy muons, which can be stopped in the coil and are never detected in the muon chamber

The interaction of muons with the matter

- Ionization
- Delta rays
- Brehmstrahlung
- Direct electron-pair production
- Nuclear interactions

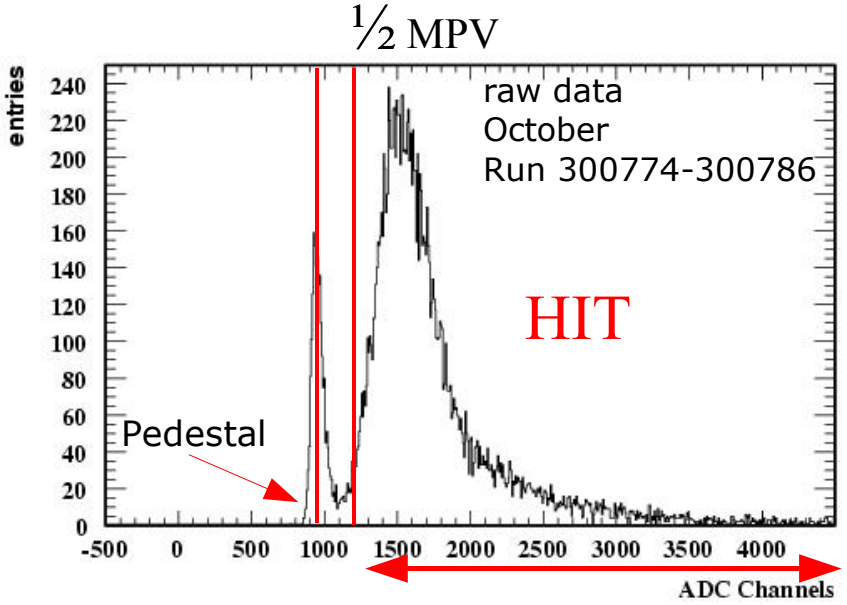
<u>The muon is not a mip!!!</u>



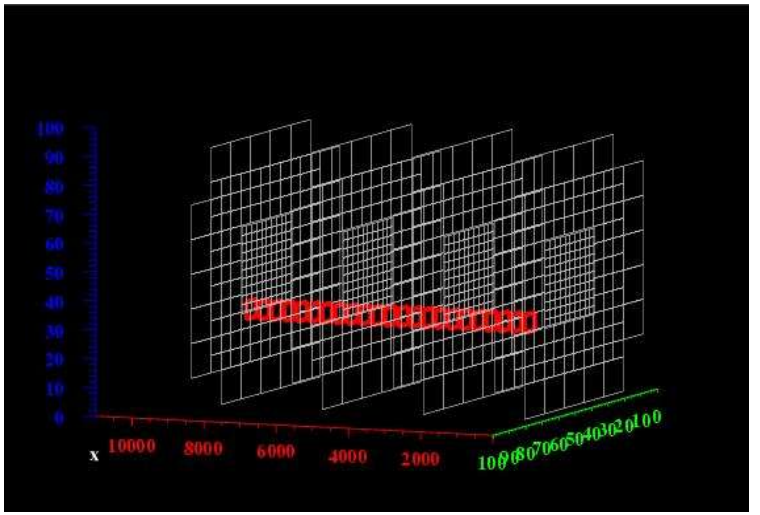
The MPV of the deposition of energy is extimated as 831 KeV for a 10 geV muon, and 8612 KeV for 100 geV muon

At high energies (>100 GeV) an high number of secondaries is expected

Analysis strategy



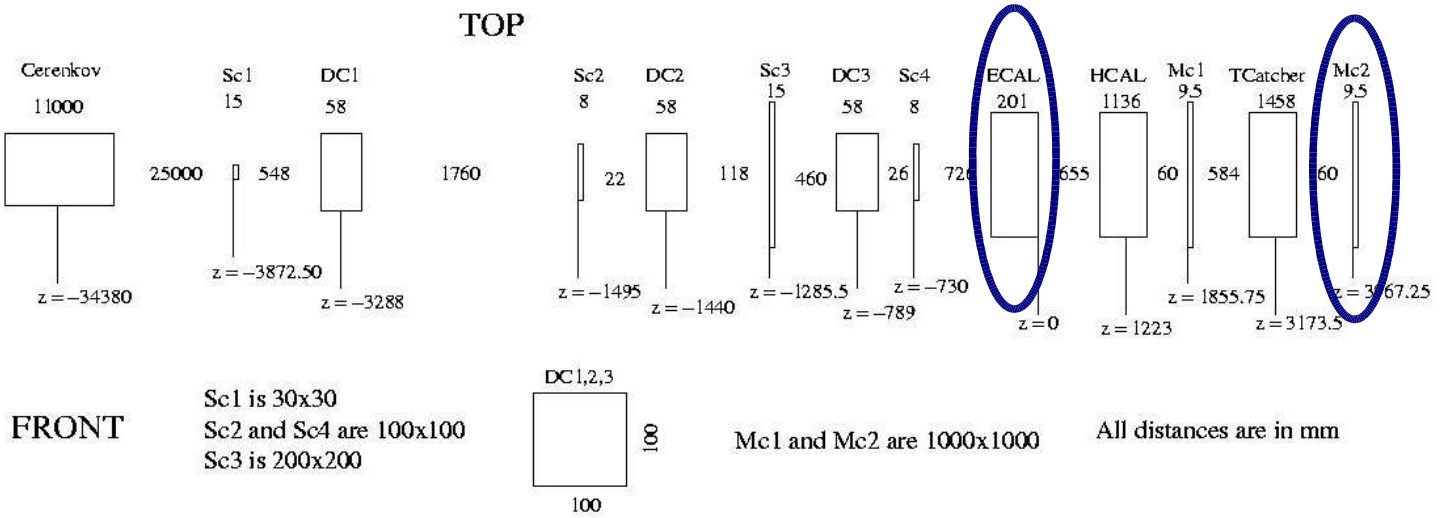
For every channel, the position of the Most Probable Value is identified. ½ MPV is the cut in amplitude which defines a physical **hit** in the calorimeter

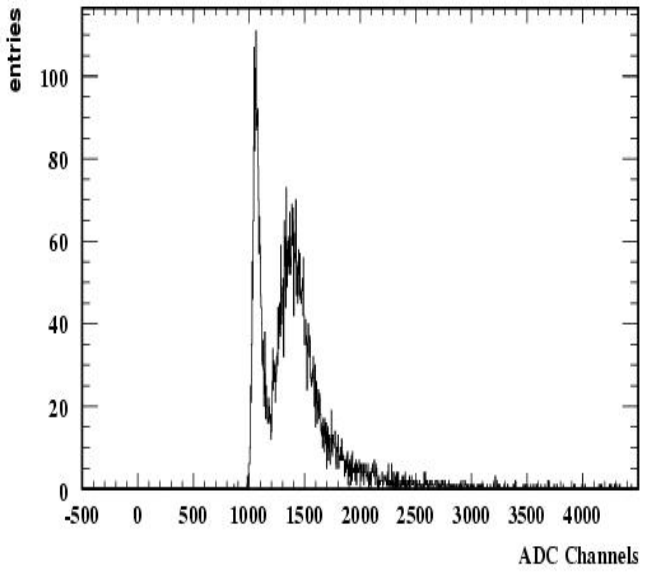


Each layer (23) of the calorimeter has 216 cells. They identify 216 **towers** (red)

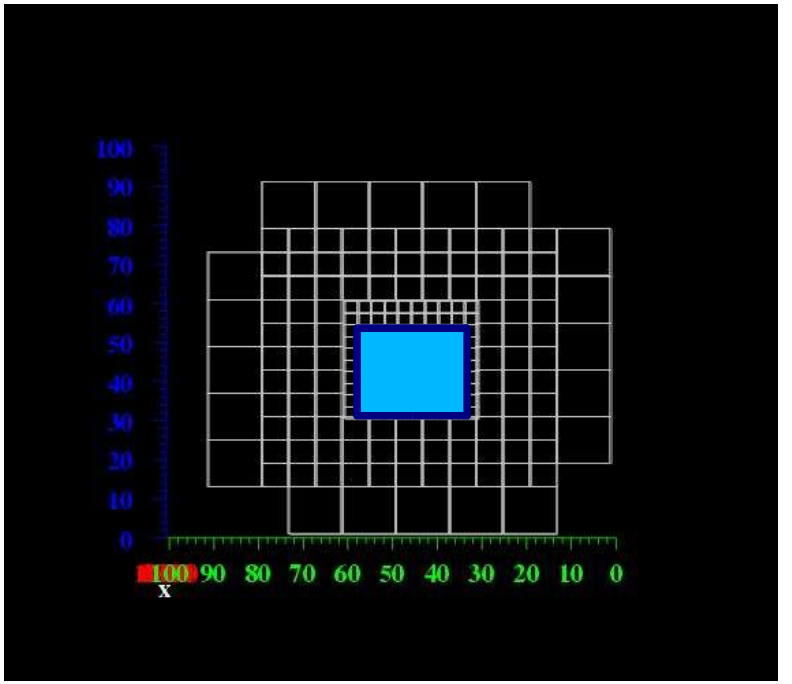
- Using the ECAL as "tracker", determination of a reference sample of muon for the core of the detector, independent on every cut in the HCAL
- Study of the high secondary production: influence on the collected signal.
- Definition and test of a simple tracking algorithm, using only HCAL, without any other tracker
- Analysis and modeling of the calorimeter signal for the muon: understanding of the detector properties.

The reference sample

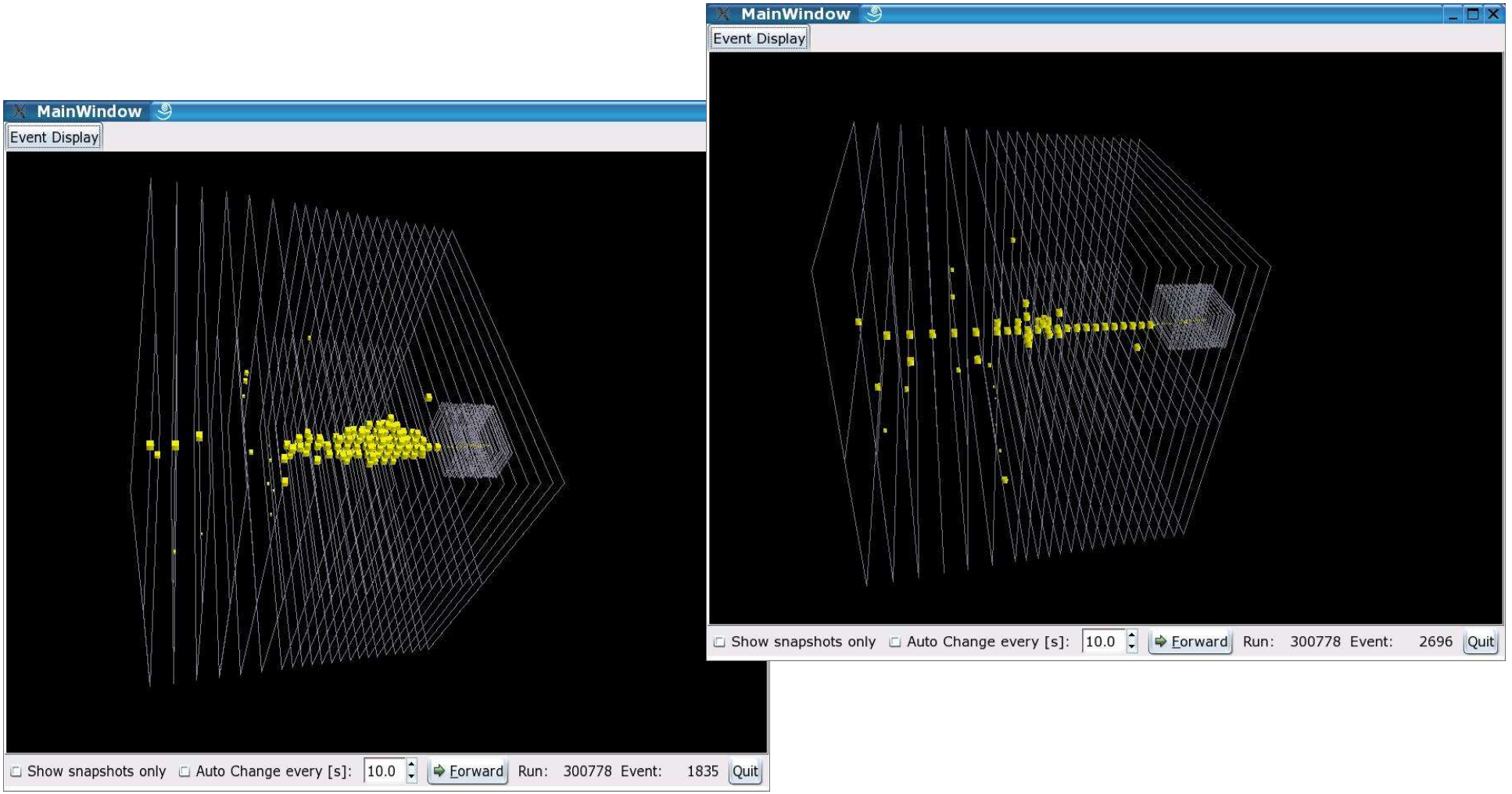




The statistical independent samples are obtained for 35 channels in the core of the detector.

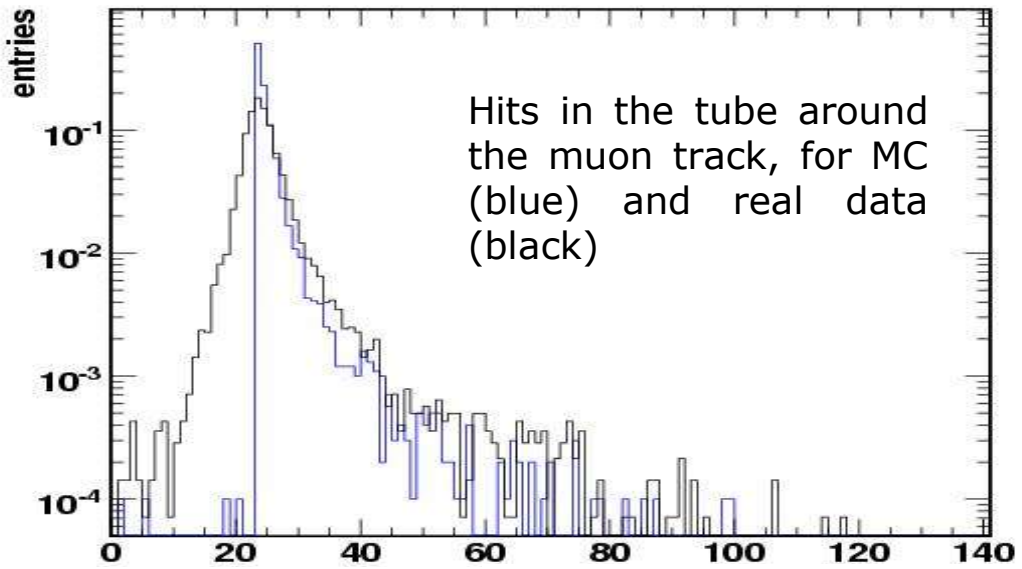


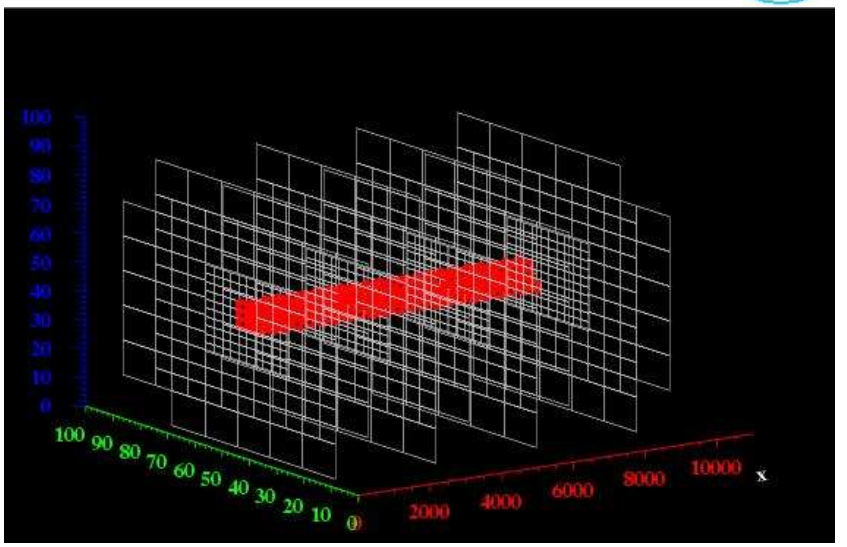
The topology of the muon events

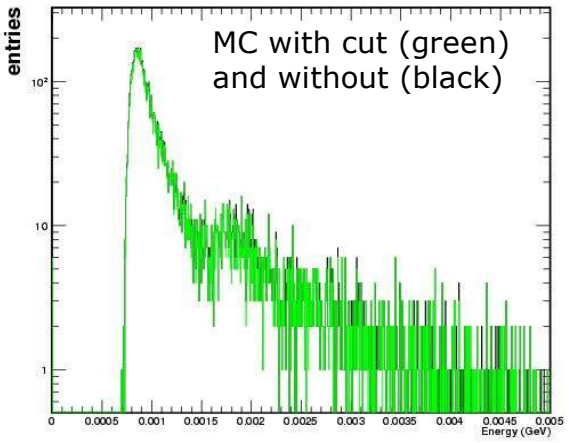


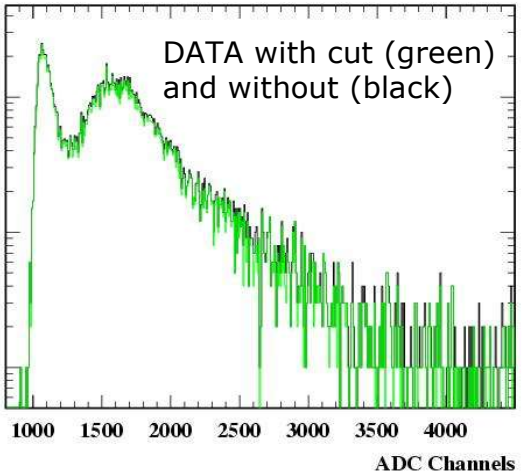
The high granularity makes it possible to see secondary particles: simple test of the imaging properties od the detector!

Secondary production investigation





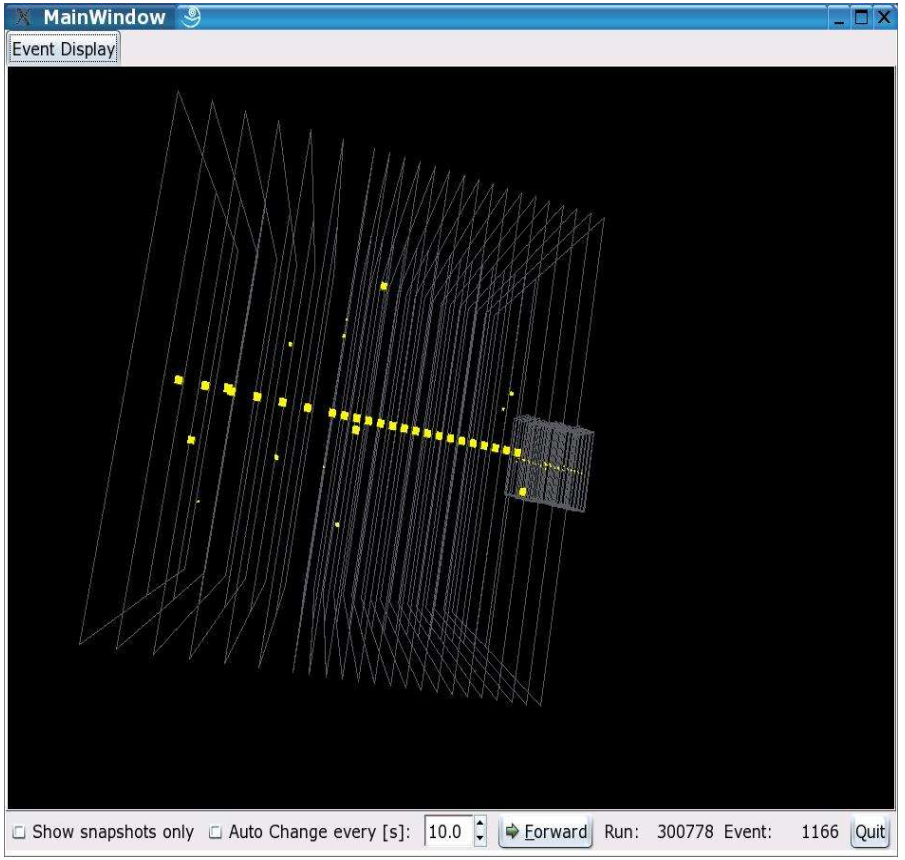




- A tube is selected around the muon track. The number of hits in the tube is counted
- A cut at 30 hits in the tower (excluding dead channels –see later) is chosen as definition of high secondary production
- The disagreement between data and montecarlo depends on the smearing effects due to the detector, which change the efficiency of the definition of the Hit.

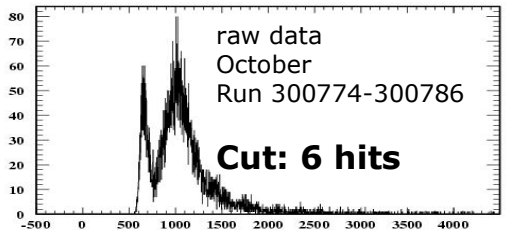
- The difference in the tails (>1.5 MPV) is less than 2%, in agreement with the montecarlo.
- The position of the MPV is invariant at 1% level.
- Because of the high granularity, the contribution of the secondaries is neglected just collecting the signal in the tower where a muon was identified.

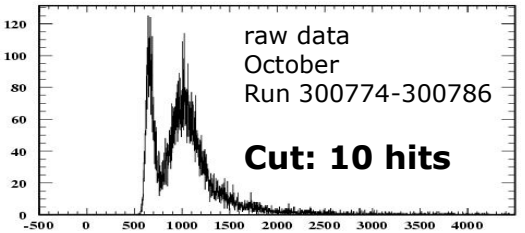
Muon track finder for the test beam

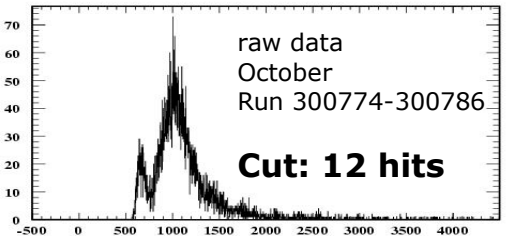


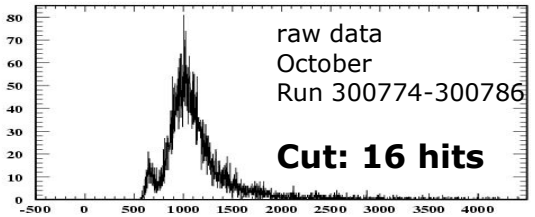
- A muon track in the test beam is expected to be straight.
- It is defined as a succession of hits.
- The easiest algorithm looks in all the towers of the calorimeter and find that one where the number of hits is more than a defined threshold

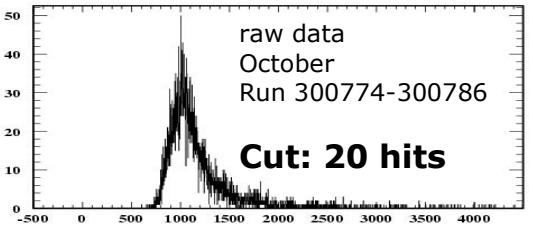
The best cut and the "MIP calibration"

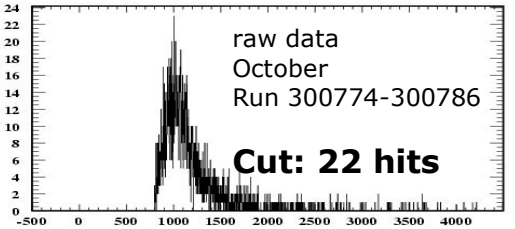


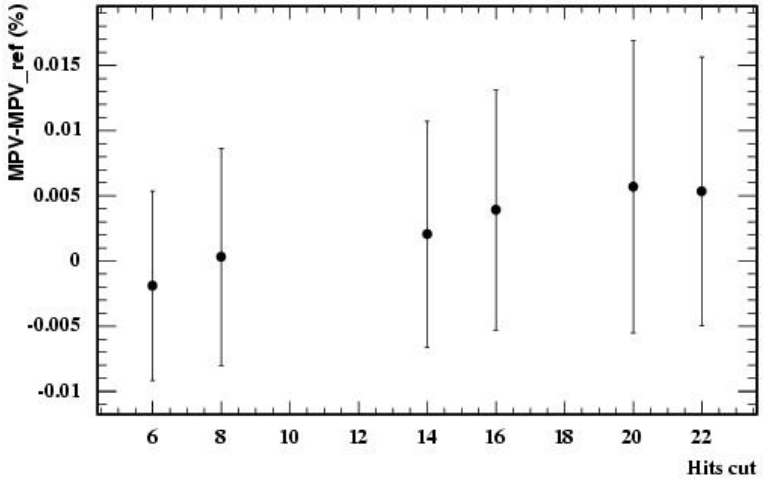


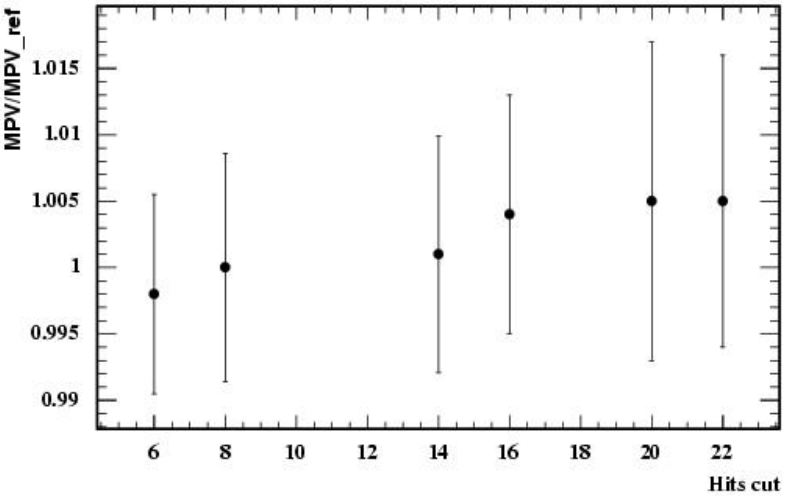






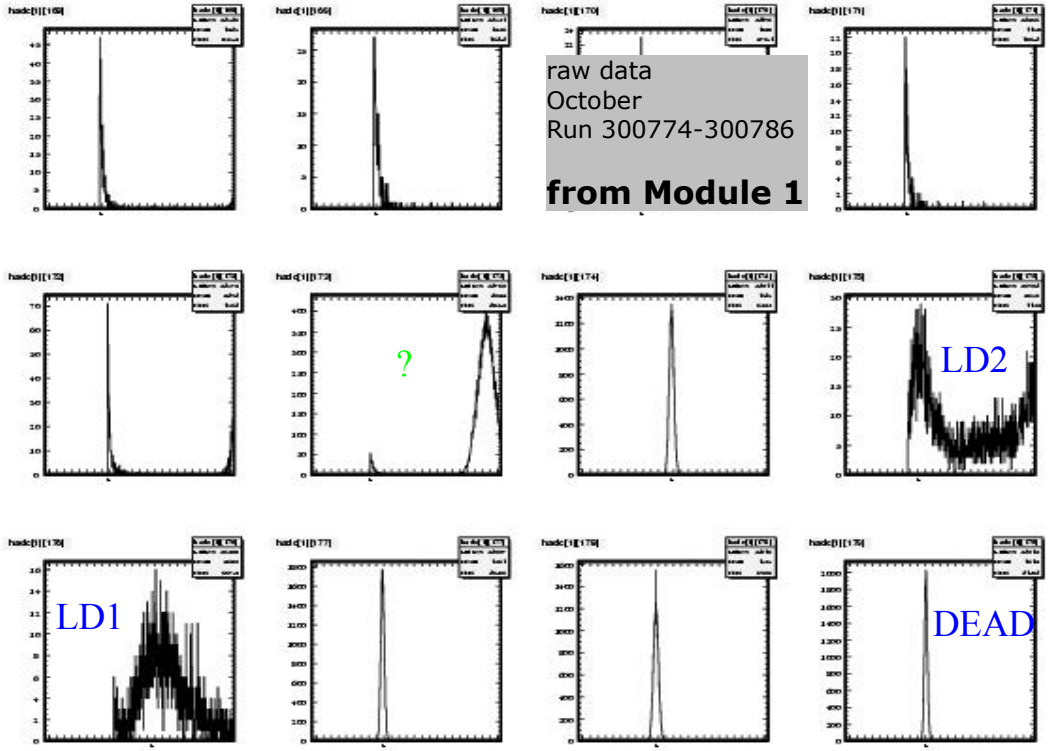


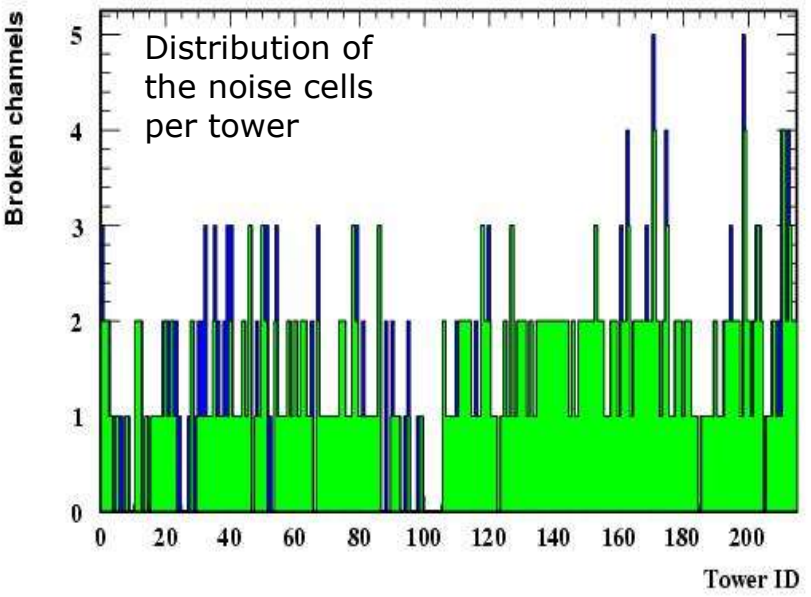


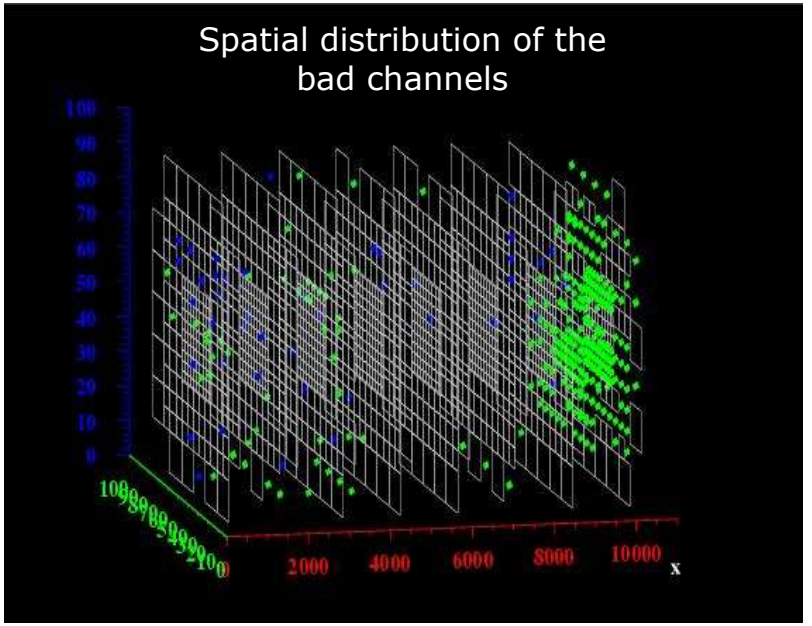


- The different cuts doesn't contribute to the determination of the MPV more than 1%. A cut of 16 hits was chosen for October (23 layers) and 10 hits for August (15 layers)
- A "MIP calibration" with a systematic error of 2% is obtained and it is currently used in the HCAL detector studies

The influence of the detector: bad channels,noise ...

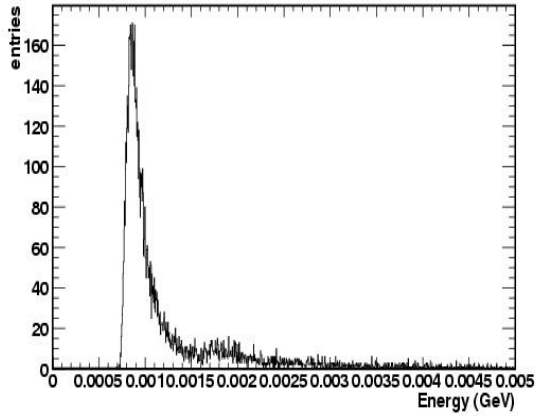




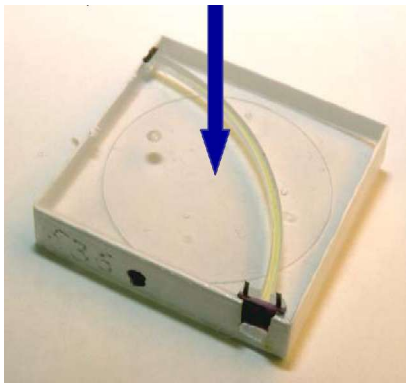


- 226/(23 modules) bad channels in total, in October most of them in module 1 and 2. Situation in August much better (only ~70/(15 modules)).
- The noise hits are poisson distributed, with a mean of ~7 (October 23 layers) and ~17 in August (15 layers)
- All the bad channels are "turned off" during the analysis of the muons and it is strongly suggested to not use them for any other analysis.

The influence of the detector: the photodetector...

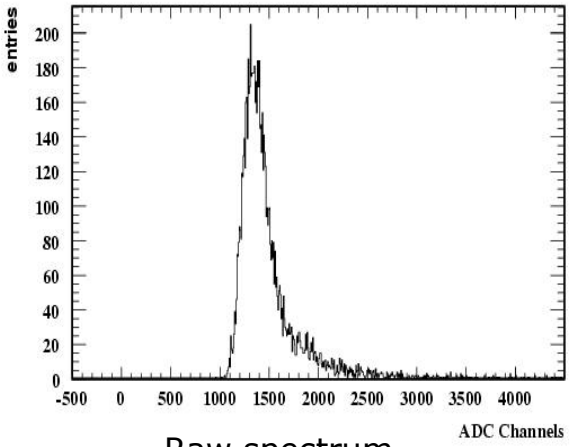


Energy deposited in the scintillator (landau)
MPV 861 KeV
Width 51 KeV
Width/MPV ~ 8%



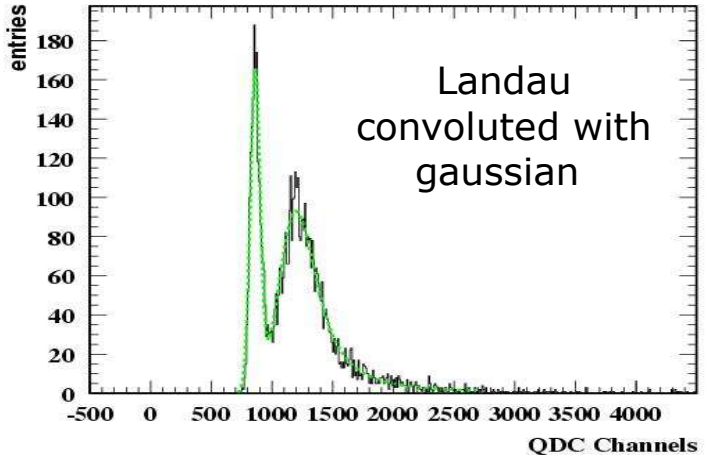
1) Scintillator photostatistics (Poisson)
2) Photodetection efficiency (Binomial)
The MPV ~ 15 photoelectrons

Electronic noise (Gaussian)



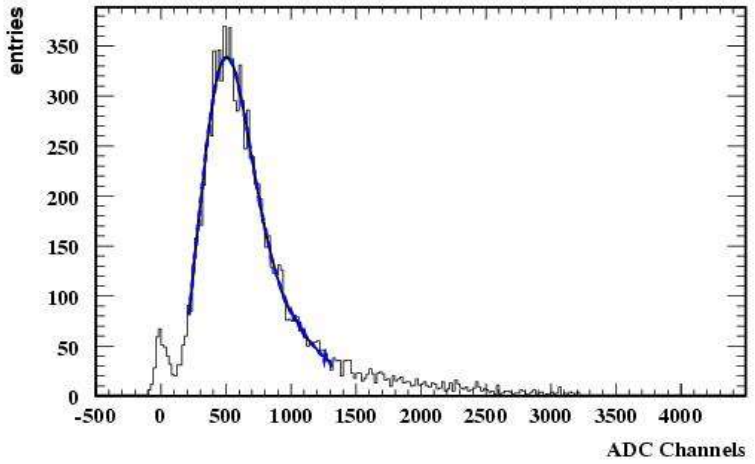
Raw spectrum
MPV~ 400 ADC Ch.
Width ~ 150 ADC Ch.

Width/MPV ~35%
signal/noise ~ 10



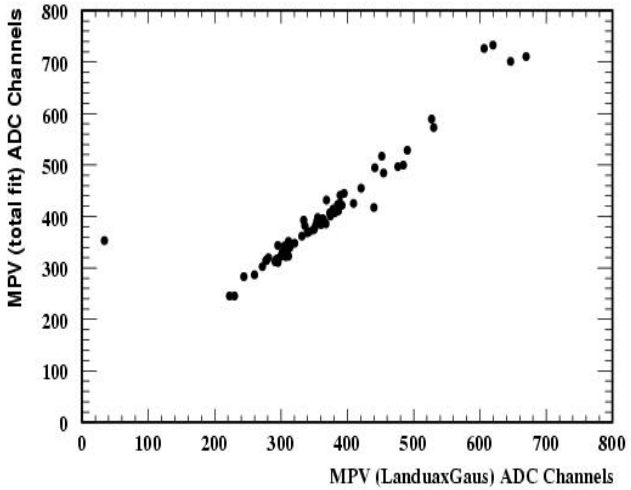
- The landau convoluted with gaussian fit is a good estimator of the MPV (at 95 % CL).
- The MPV of the extracted landau is ~400, while the width is ~70. width/MPV ~20%.
- This fit overestimates the sigma of the gaussian smearing... The poisson smearing can not be neglected at this level: 15 photoelectrons!!!

The influence of the detector: a new approach... first try!

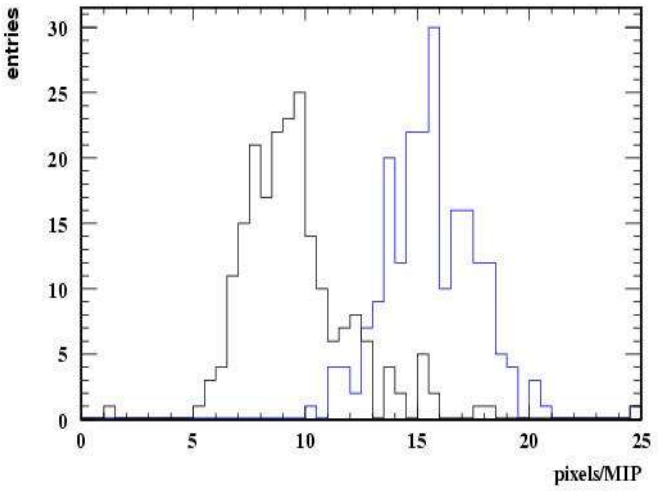


6 parameters:
MPV (GeV), Width (GeV) [MPV,w]
npixels/MPV(GeV)[a],
MPV(ADC)/npixels [b],
Noise (ADC) [s]
normalization coefficient [A]

$$D(x) = A \sum_{i=-\Delta}^{+\Delta} G(x+i|\beta l, \sigma) \sum_{j=-\Lambda}^{+\Lambda} P(l|(E_{dep}+j)\cdot\alpha)\, L(E_{dep}+j|MPV, w)$$



- The fitting function is compatible with a landau with MPV 861 KeV and width 51 KeV.
- Still some improvement needed to parametrize better the effects of the detector: the noise is still over esrtimated.



Conclusions

- A "MIP calibration" of the detector is avalaible, with a precision of 2%. The Muon Finder Processor will be avalaible soon in the main HCAL analysis framework.
- The study of the muons shows the possibility of using the HCAL as a tracking calorimeter: we observed even the secondary production!
- The noise of the detector is higher than requested: the technology needs still to be improved a bit more
- Future steps:
  - Better understanding of the model of the muon signal in the calorimeter
  - More realistic tracking algorithm
  - Likelyhood method implementation for the muon identification in the HCAL
  - Identification of the physics channels where the muon identification in the HCAL can play a significative contribute.