e/pi separation in SDHCAL based in their different shapes

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Outline

- Introduction
- Removing cosmic and beam muons
- Longitudinal discrimination optimization
- Transversal discrimination optimization
- Combined Longitudinal & Transversal discrimination optimization (effects in the linearity & resolution)

General description

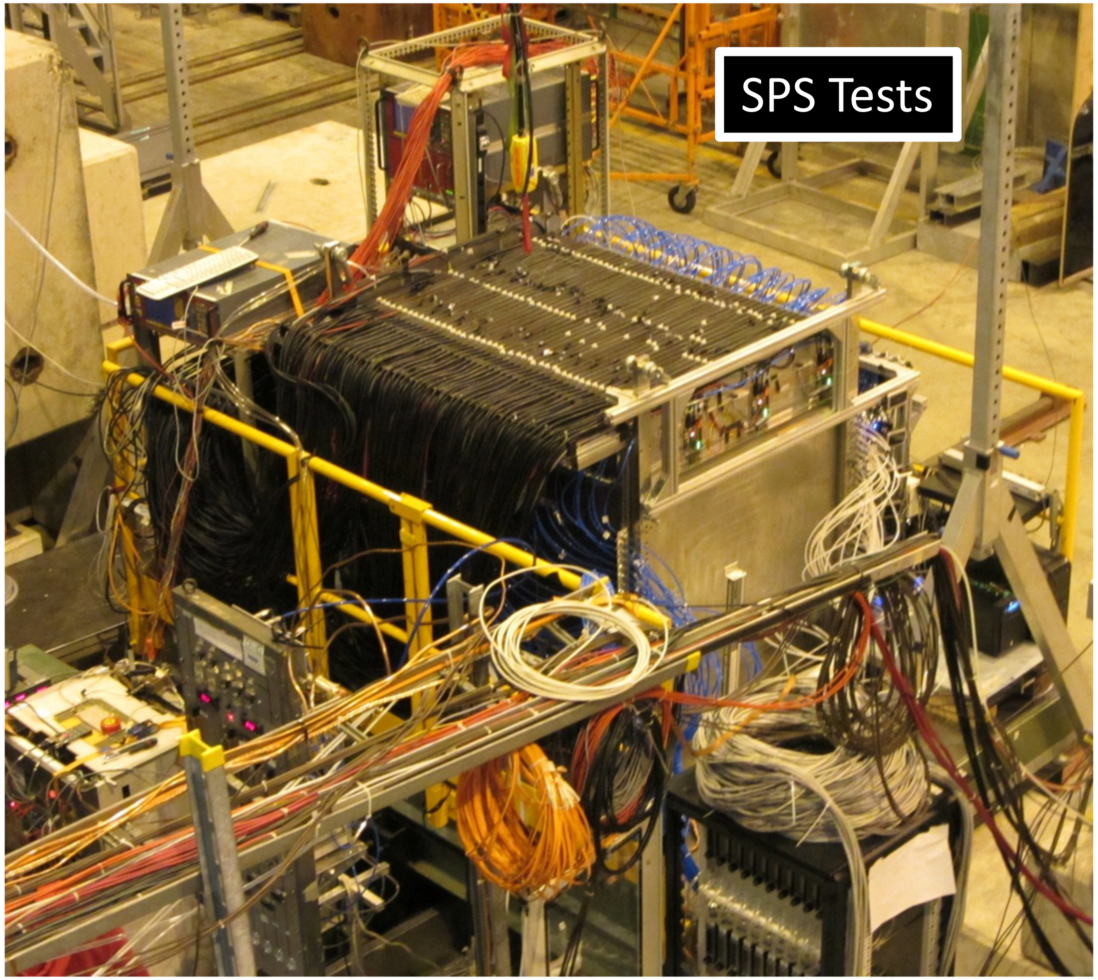
The SDHCAL consists of 48 GRPC + 2MICROMEGAS detectors embedded in a stainless steel absorber structure.

The total absorber width in between plates is 20 mm.

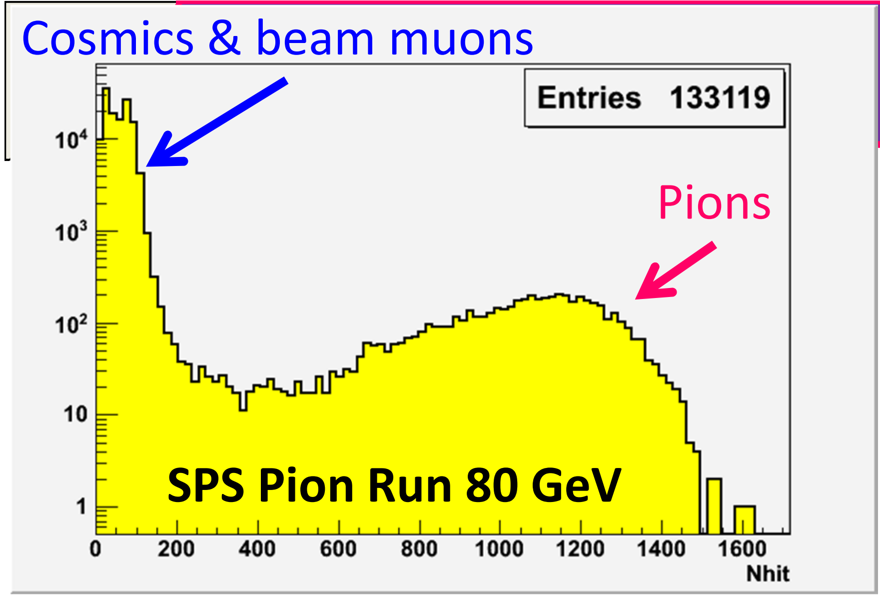
Each detector plate consists of ~10.000 cells with a section of 1x1 cm^2.

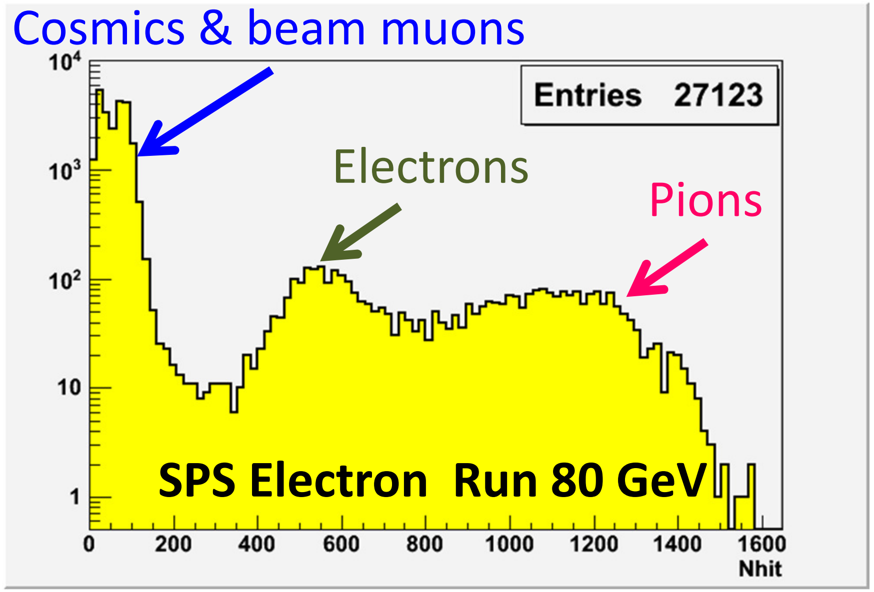
The readout is done in semidigital mode using 3 thresholds.

For the present studies the information of the different thresholds has not been used, it´s equivalent to a pure digital device.



Introduction





The data were taking in power pulsing mode
The acquisition is enable during the SPS cycle.
All hits are recorded continuously without trigger, the events are built using the time information of hits.

Four different types of events are recorded in the same run:

- Cosmics
- Muons coming from beam
- Pions
- Electrons

The runs configured as electrons have a very large contamination of pions.
The pion runs don´t have electrons.
In both cases de muon contamination is very huge

Before performing any study on the response of the calorimeter it´s mandatory to separate the different types of particles.
For the moment we don't pretend a perfect separation between particles but a separation good enough to reduce the contamination to a level that doesn't affect to the performance studies (linearity and resolution mainly). The study was done only for the SPS energies, where a large contamination of pions is present in the electron runs

Removing muons

1. Muons don't use to produce showers. The number of hits per plane should be small. (except in case of very noisy events).

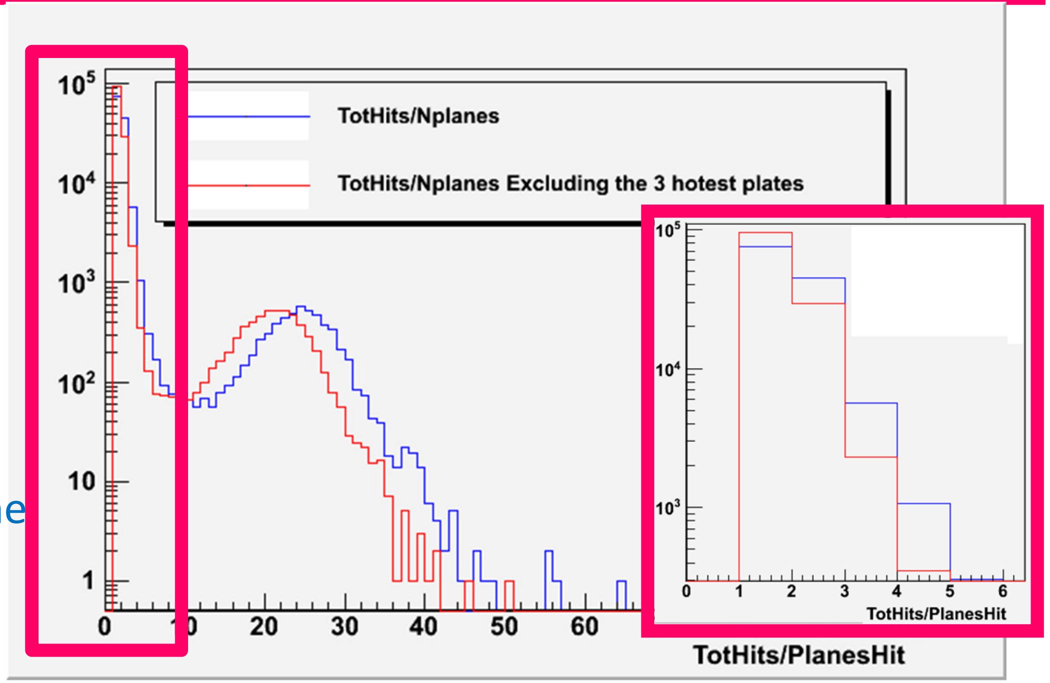
   We compute the variable:

   MuonCut = #Total hits/#Total Plates with hits

To avoid eventual noisy planes in some cell the same variable (MuonCutb) is computed by removing from the counting of hits and plates the "hottest" three plates

.

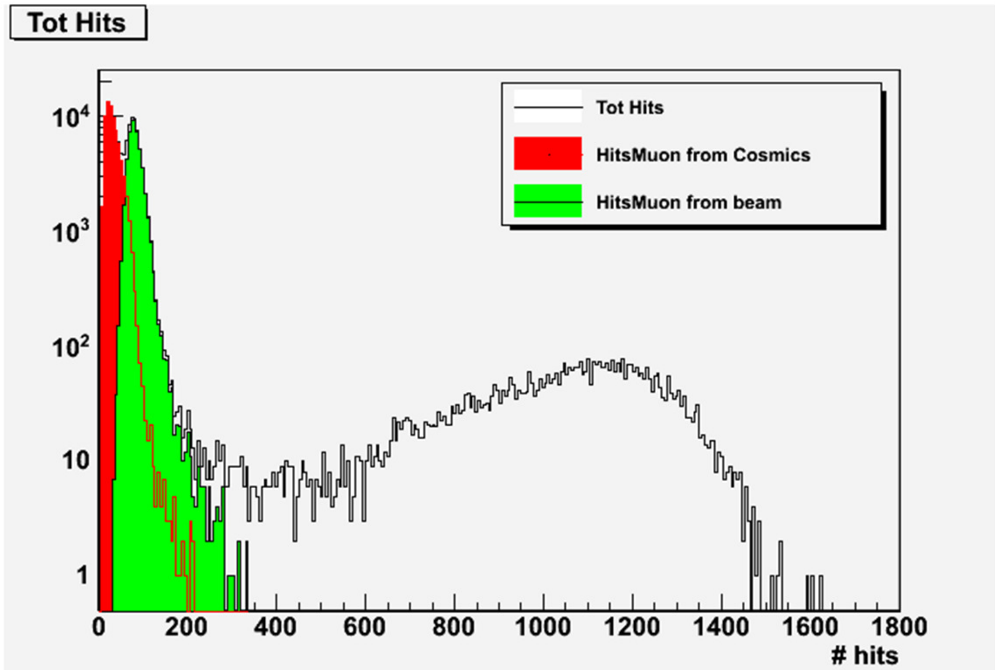
The distributions of both variables are very similar, and there is not significant differences between using one or the other.



MuonCutb < 6 → Muon

2. Muons coming from the beam should go through all the detector, cosmics not. To select muons from beam without bias efficiency:

   Plates 1-10. At least 5 plates with signal
   Plates 11-20. At least 5 plates with signal
   Plates 21-40. At least 9 plates with signal
   Plates 41-50. At least 4 plates with signal



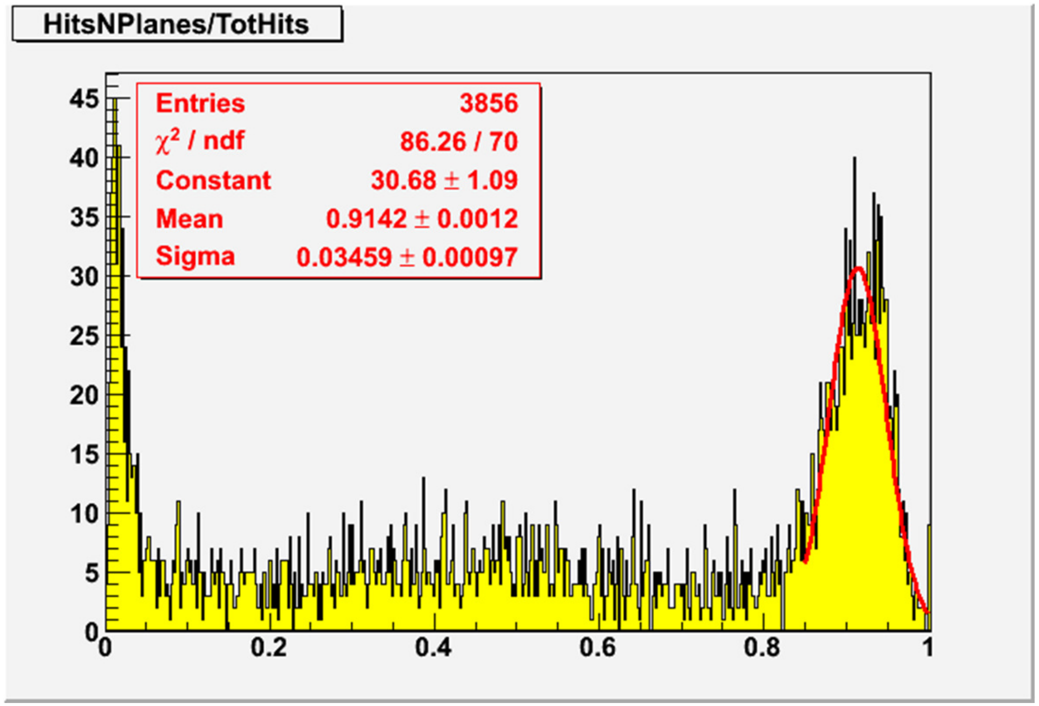
Differences on longitudinal development (I)

The electrons should be contained mostly in the first part of the calorimeter, the hadronic shower will extend much more.

We can compute:

LongitudinalCut = Hits in the first N Plates / Total Number of hits

Using **N=14** the following distributions are obtained for a **electron – pion run of 80 GeV**
The peak on the right corresponds to electrons (as we'll see in next slide).



But... ¿which is the optimum value of N?

It could be estimated using the pion runs where the contamination of electrons seems negligible.

For each value of N the distribution is computed and the peak fitted. Then 3 different cuts are applied on the data from the pion run to select electrons:

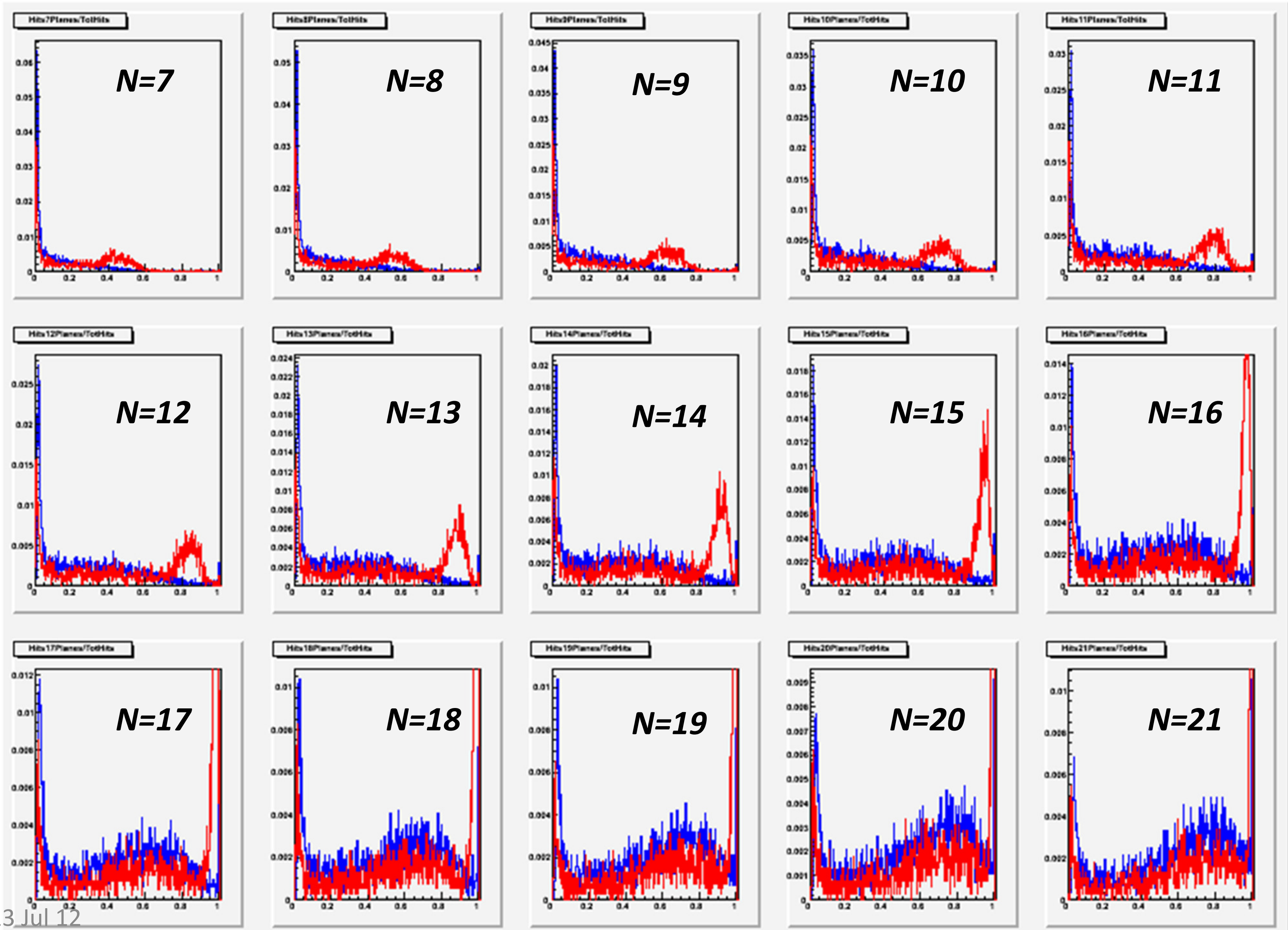
a) > Mean – 2 Sigma
b) > Mean – 2.5 sigma
c) > Mean – 3 Sigma

The percentage of entries assigned as electrons are counted.

The absolute values are not very important, the intention is to compare the relative values

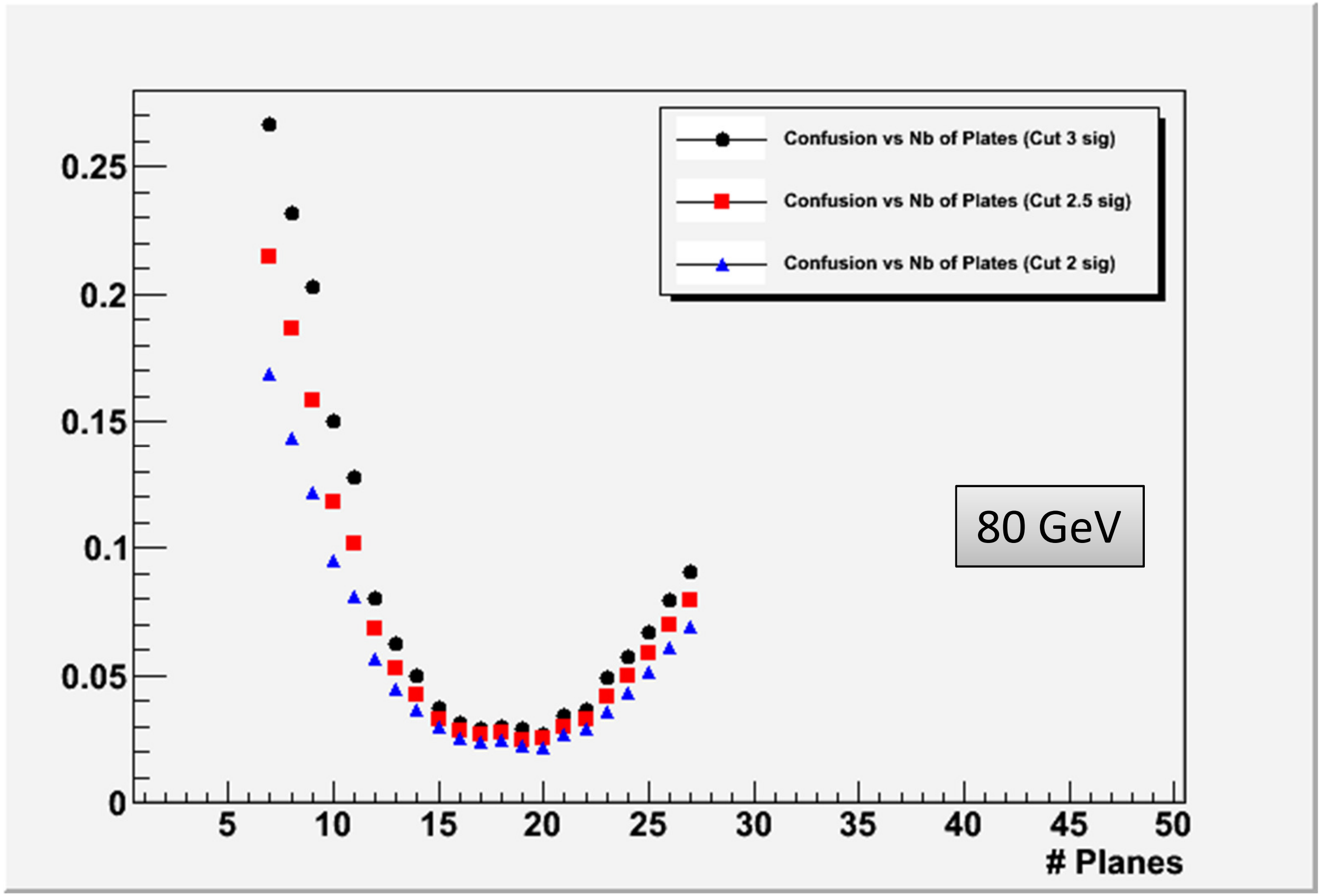
Differences on longitudinal development (II)

The plots show the variable LongitudinalCut = Hits in the first N Plates / Total Number of hits
For **Pion Runs (80 GeV)** (blue) and **Electron Runs (80 GeV)** (red).



Differences on longitudinal development (III)

The percentage of entries assigned as electrons in pion runs of 80 GeV for the different cuts and number of planes are show in this figure

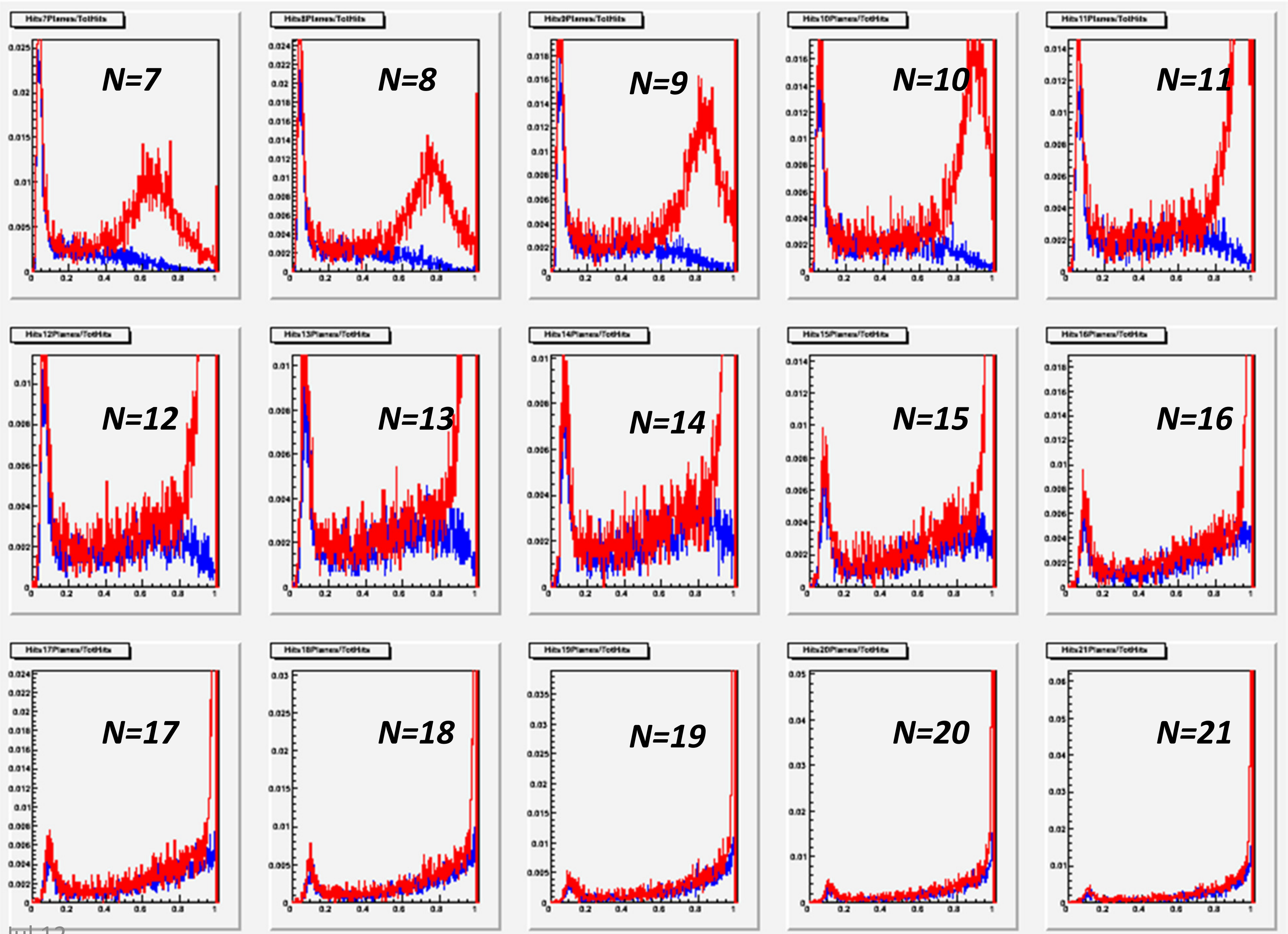


There are several values that provides a minimum in the distribution

BUT the development of the shower depends on the energy,
What happens for other energy values?

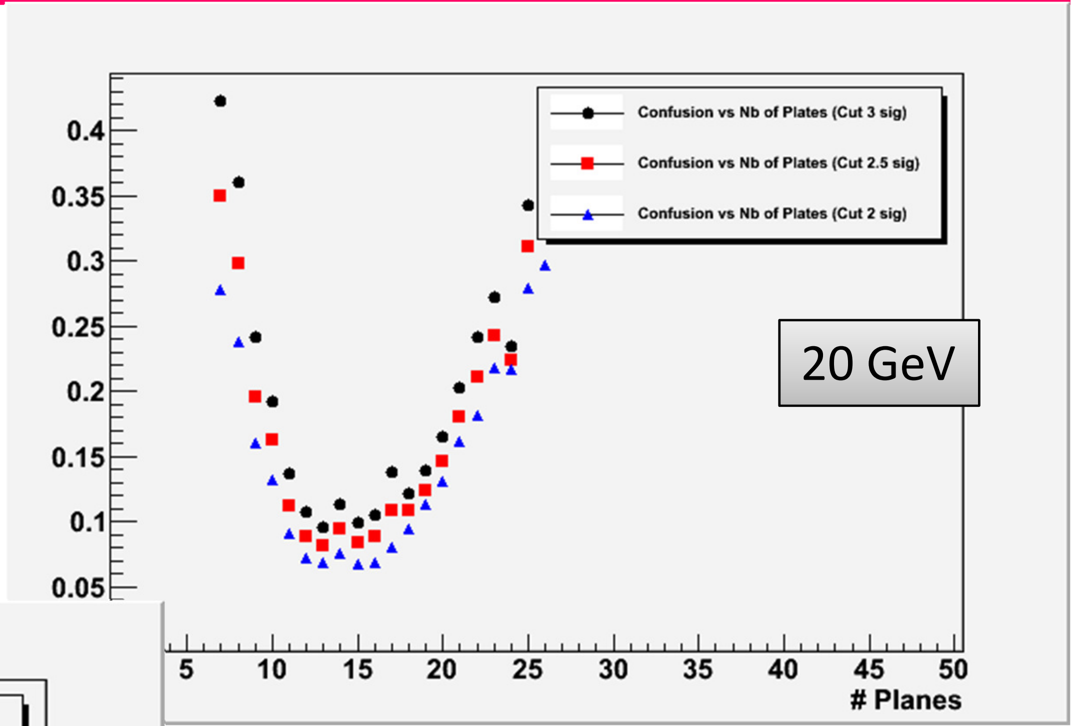
Differences on longitudinal development (IV)

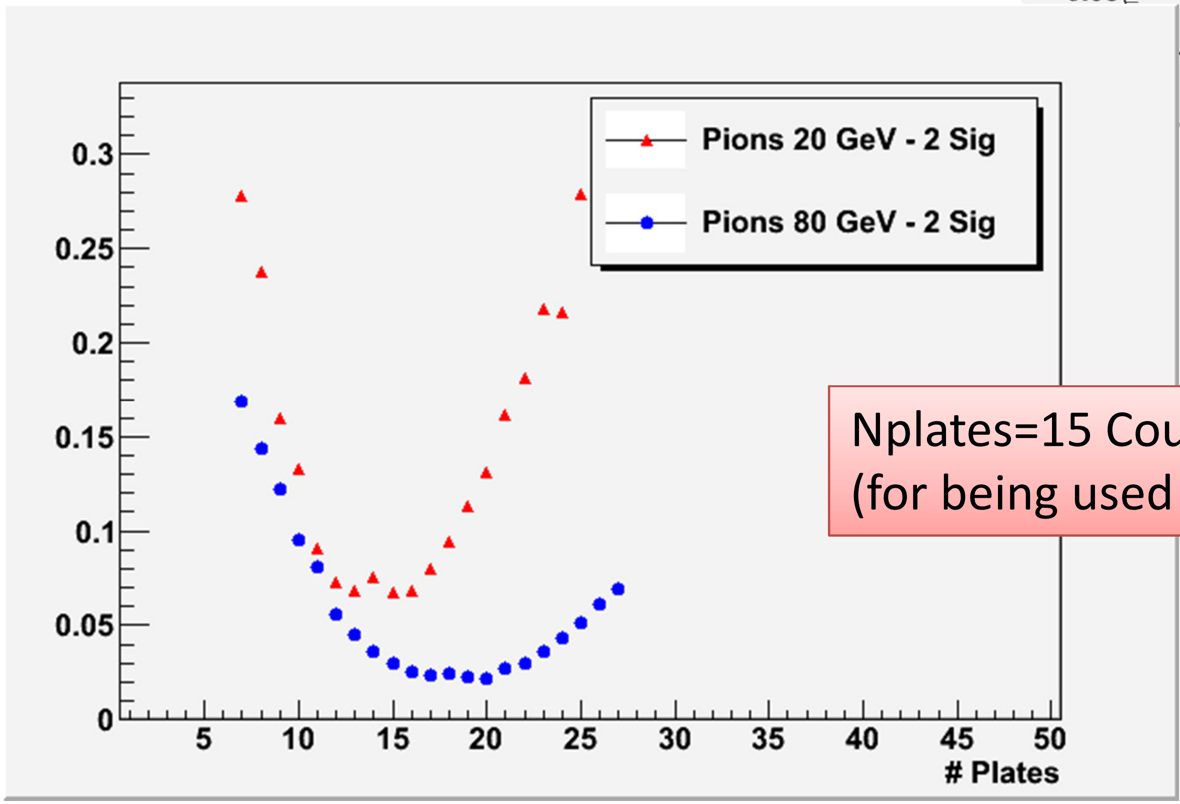
The plots show the variable LongitudinalCut = Hits in the first N Plates / Total Number of hits
For **Pion Runs (20 GeV)** (blue) and **Electron Runs (20 GeV)** (red).



Differences on longitudinal development (V)

The percentage of entries assigned as electrons in pion runs of 20 GeV for the different cuts and number of planes are different from the values obtained for 80 GeV





Nplates=15 Could be a reasonable value (for being used for ALL energies)

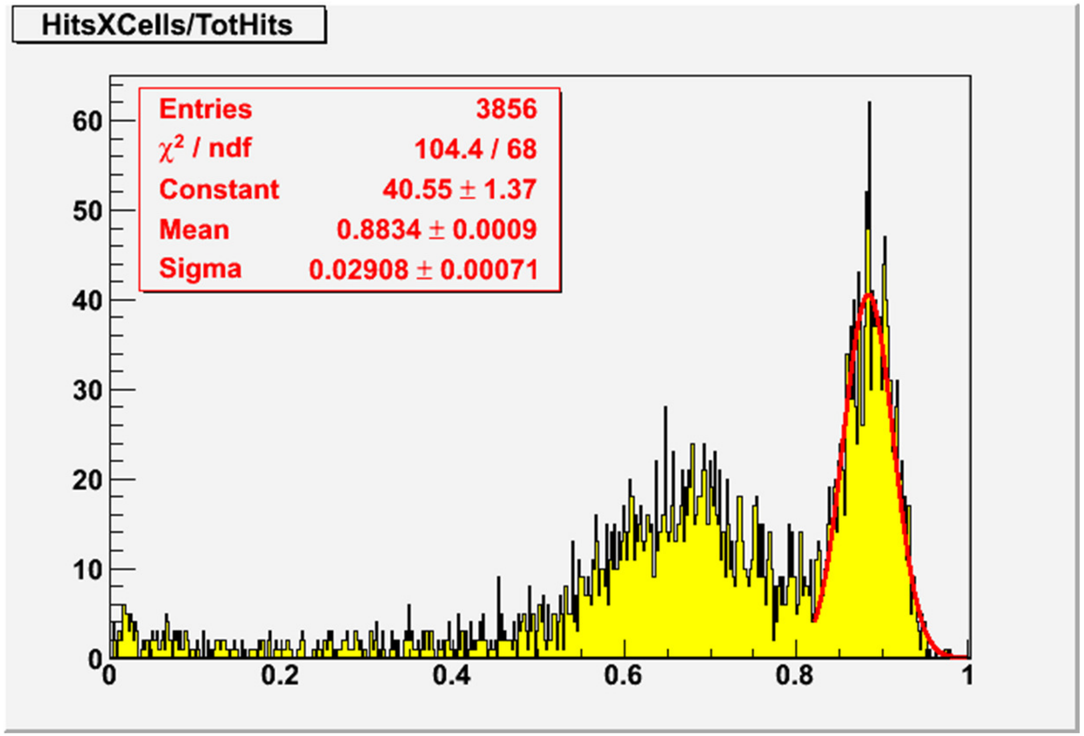
Differences on transversal development (I)

The electromagnetic showers are narrower compared to the hadronic ones.
We can compute:

TransversalCut = Hits in the X central Cells / Total Number of hits

In order to determine the "center" of the shower a naïve computation has been done, taken all the hits in the first 4 plates and computing the mean X & Y values of their positions (the electrons could have developed a shower in the first plates but probably the measurement is not very much affected)

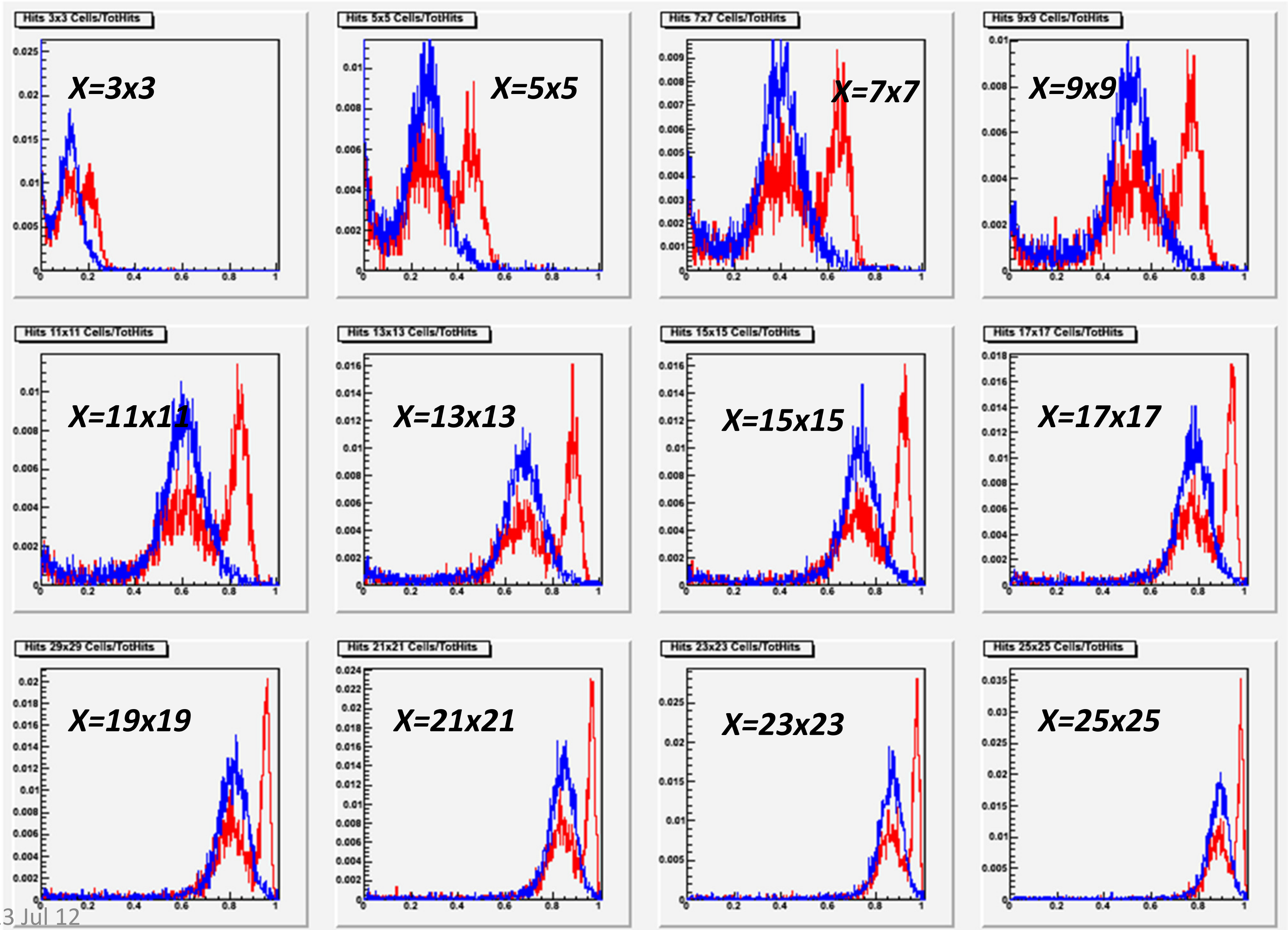
Using **X=13x13 cells** the following distributions are obtained for a **electron – pion run of 80 GeV**
The peak on the right corresponds to electrons (as we'll see in next slide).



The "optimal" X value is computed as before, fitting the electron peak, putting cuts and seeing with is the value for which there is the minimal electron assignation in the pion runs

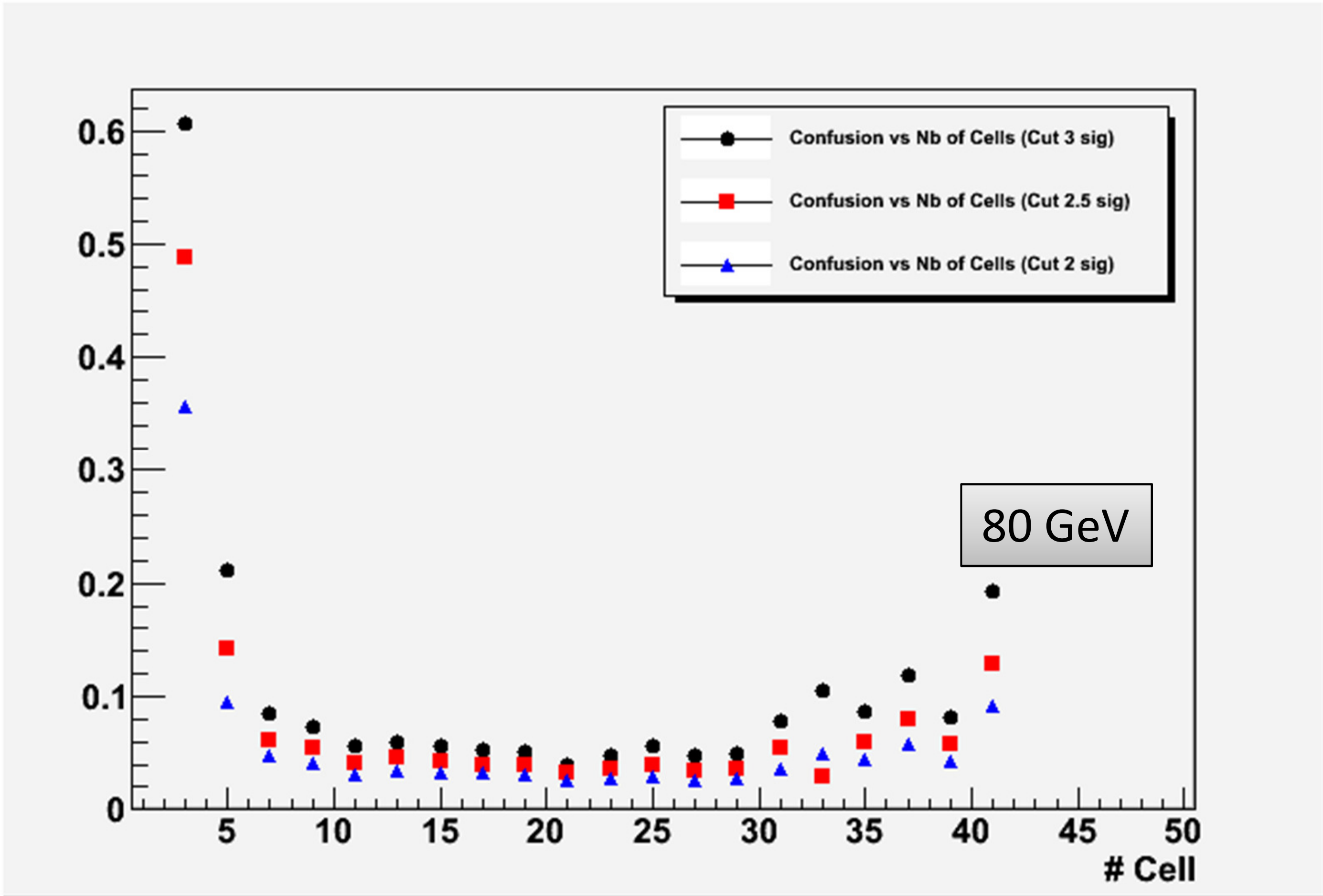
Differences on transversal development (II)

The plots show the variable TransversalCut = Hits in the X CentralCells / Total Number of hits
For **Pion Runs (80 GeV)** (blue) and **Electron Runs (80 GeV)** (red).



Differences on transversal development (III)

The percentage of entries assigned as electrons in pion runs of 80 GeV for the different cuts and number of cells (cell =11 means 11x11 cells) are shown

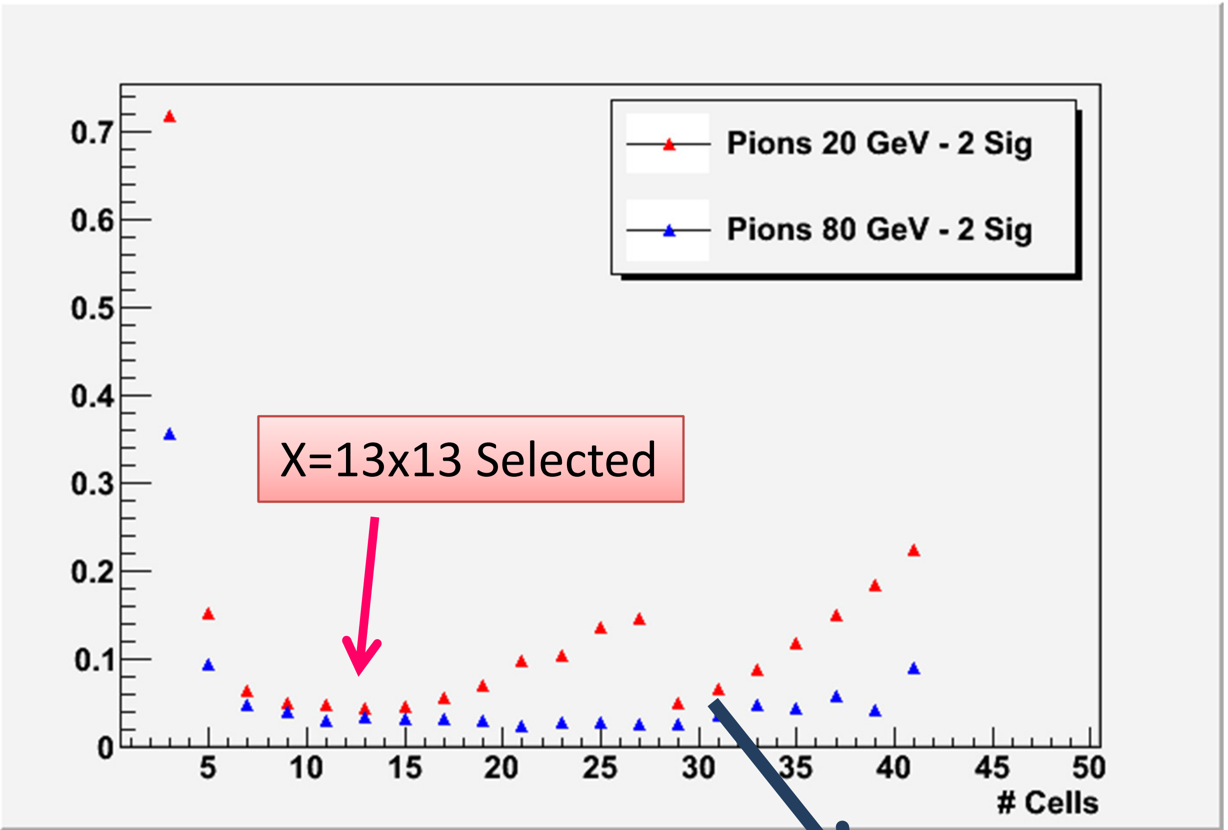


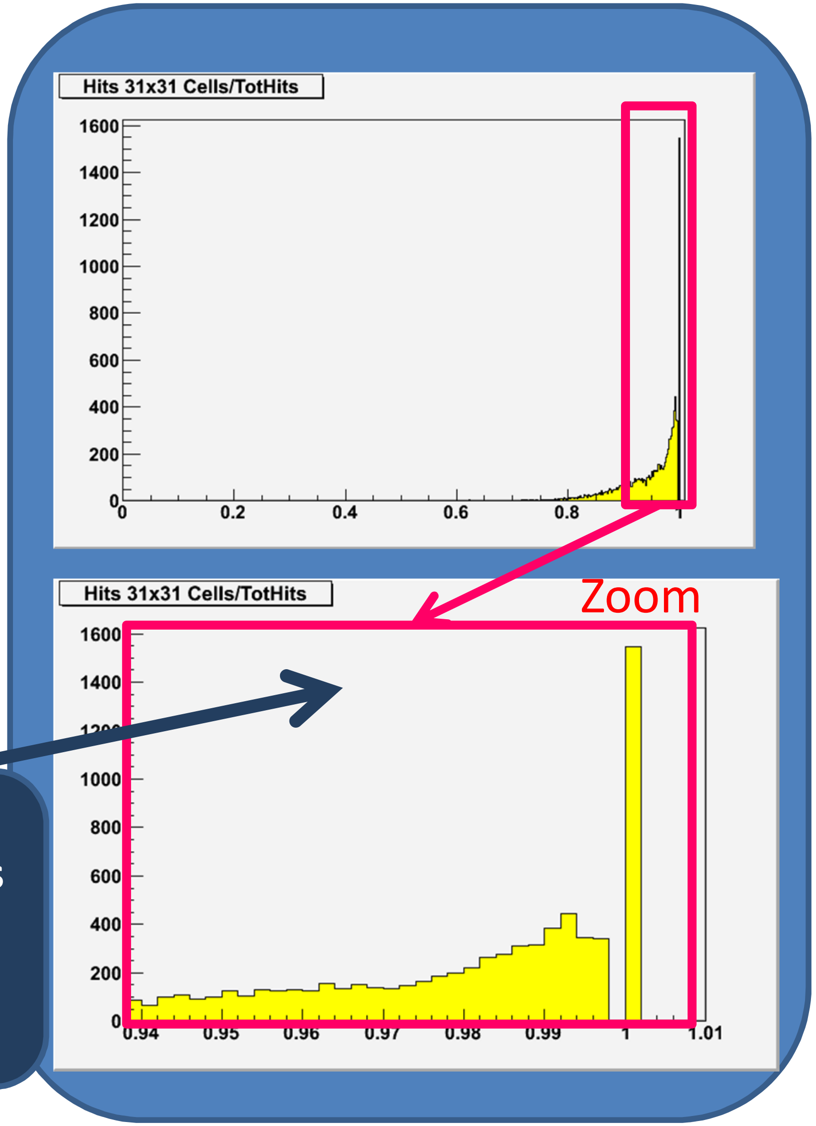
BUT again the development of the shower depends on the energy,

What happens for other energy values

Differences on transversal development (IV)

Comparing the previous distribution of 80 GeV and 20 GeV

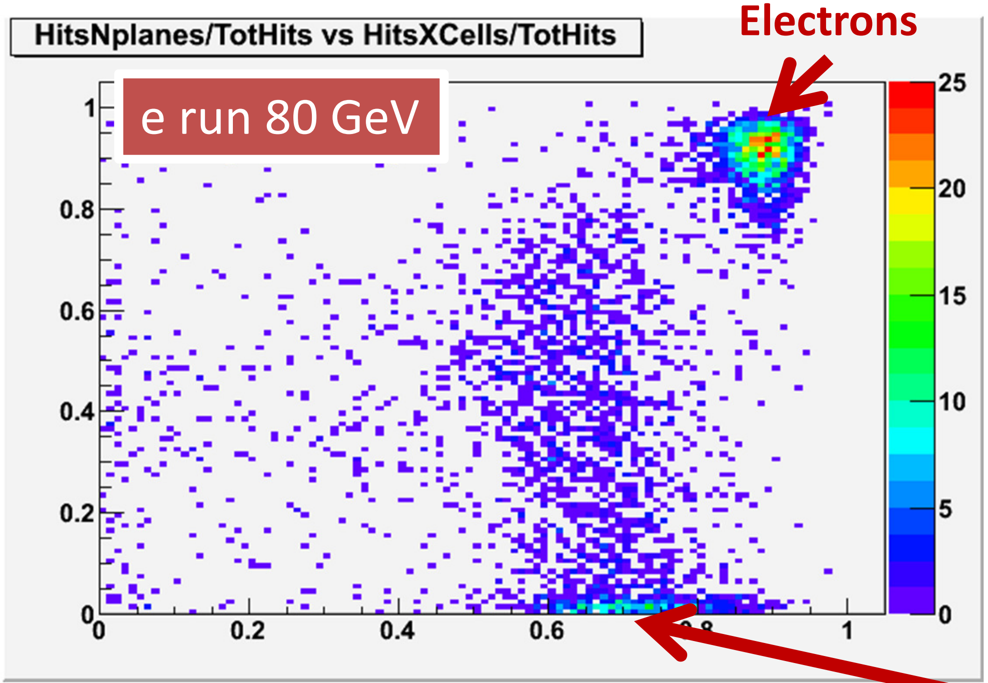




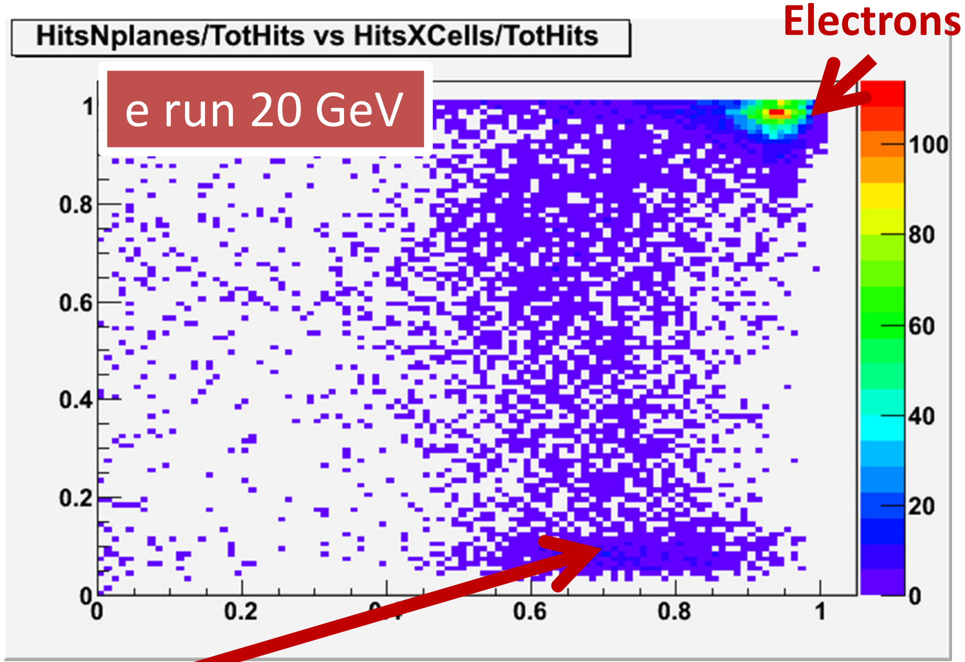
This effect is due to the problems when fitting the distribution. At 20 Gev the electromagnetic shower is narrow and most of it will be contained when increassing the transversal size. The pions are also narrower than for 80 GeV

Transversal & Longitudinal profile correlations (I)

Electrons



Electrons



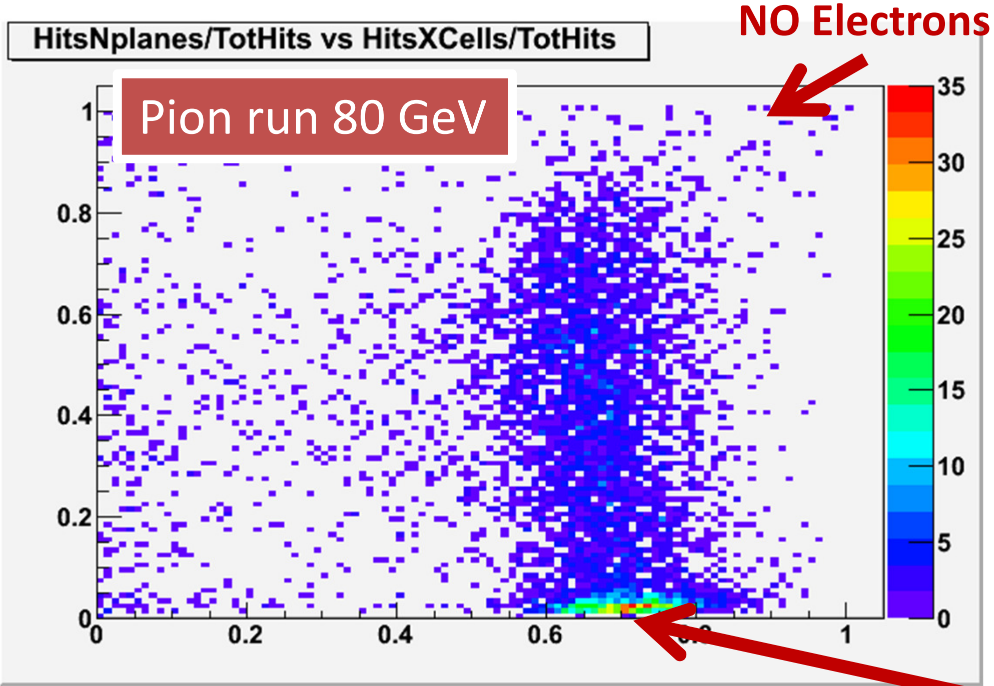
Pions interacting "later"

These pions deposit behave as MIPs in the first part of the calorimeter and their lateral distribution is compatible with a muon

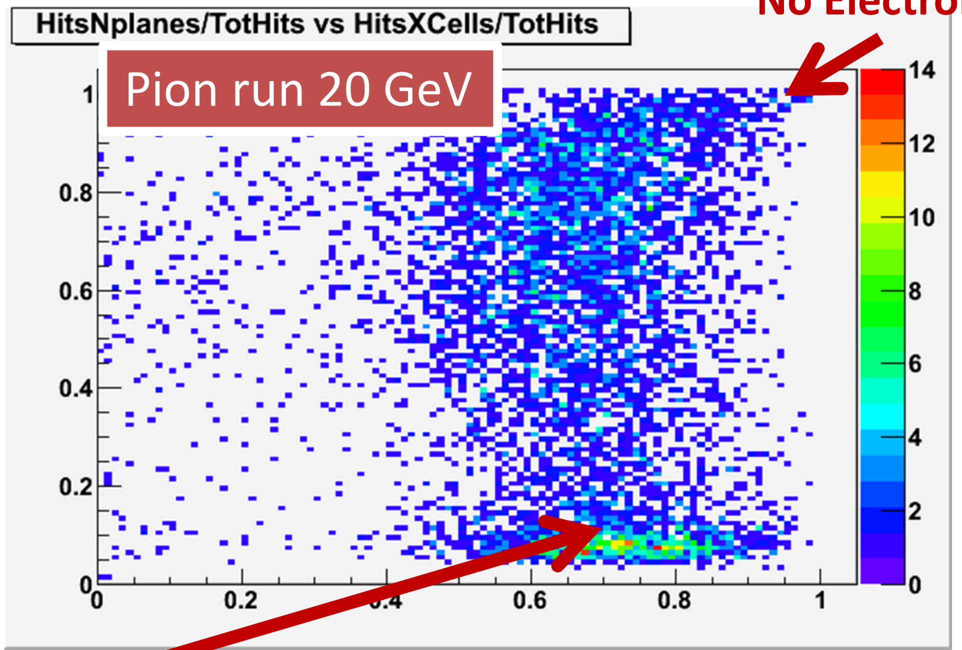
See in couple of slides

Transversal & Longitudinal profile correlations (II)

NO Electrons



No Electrons



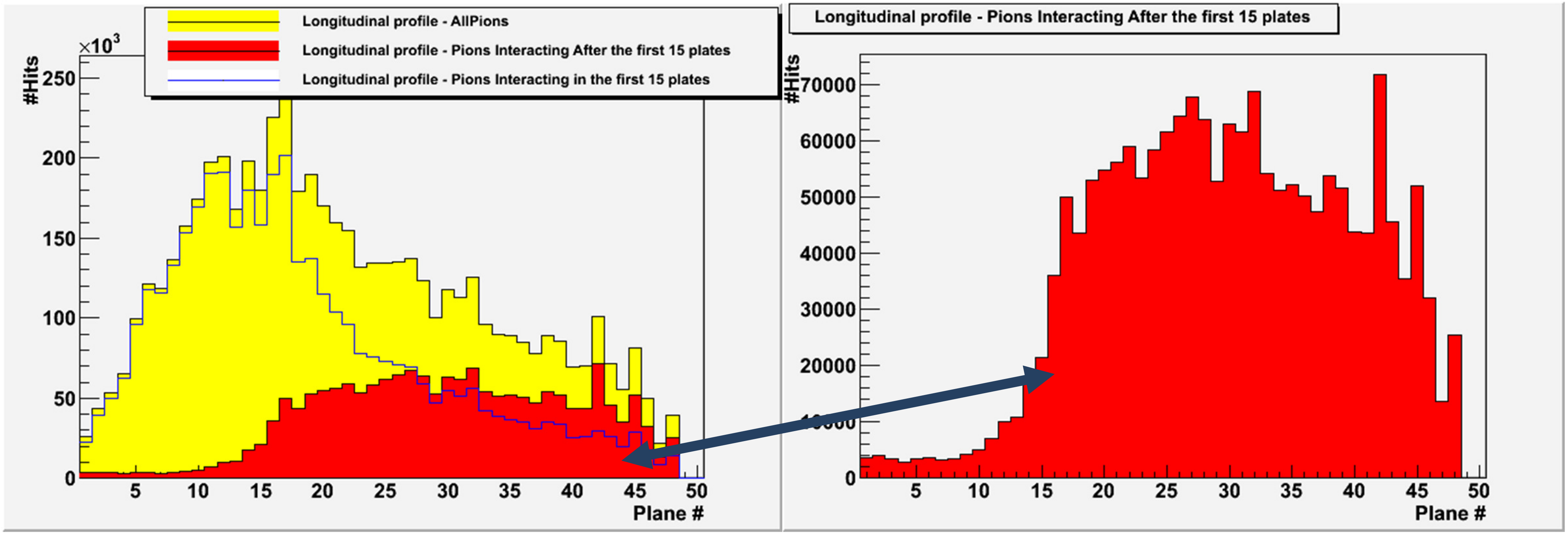
Pions interacting "later"

These pions deposit behave as MIPs in the first part of the calorimeter and their lateral distribution is compatible with a muon

See next slide

Pions not interacting in the first part of SDHCAL

In a 80 GeV Pion run we can separate the events marked as "interacting later" in previous slides by cutting on the previous variables and plot the longitudinal profile for all muons and both groups.



Transversal & Longitudinal profile correlations (III)

With the previous two variables we can obtain a new one:

$$\text{CombinedCut(E)} = \sqrt{(\text{LongitudinalCut} - \text{MeanLC(E)})^2 + (\text{TransversalCut} - \text{MeanTC (E)})^2}$$

Where

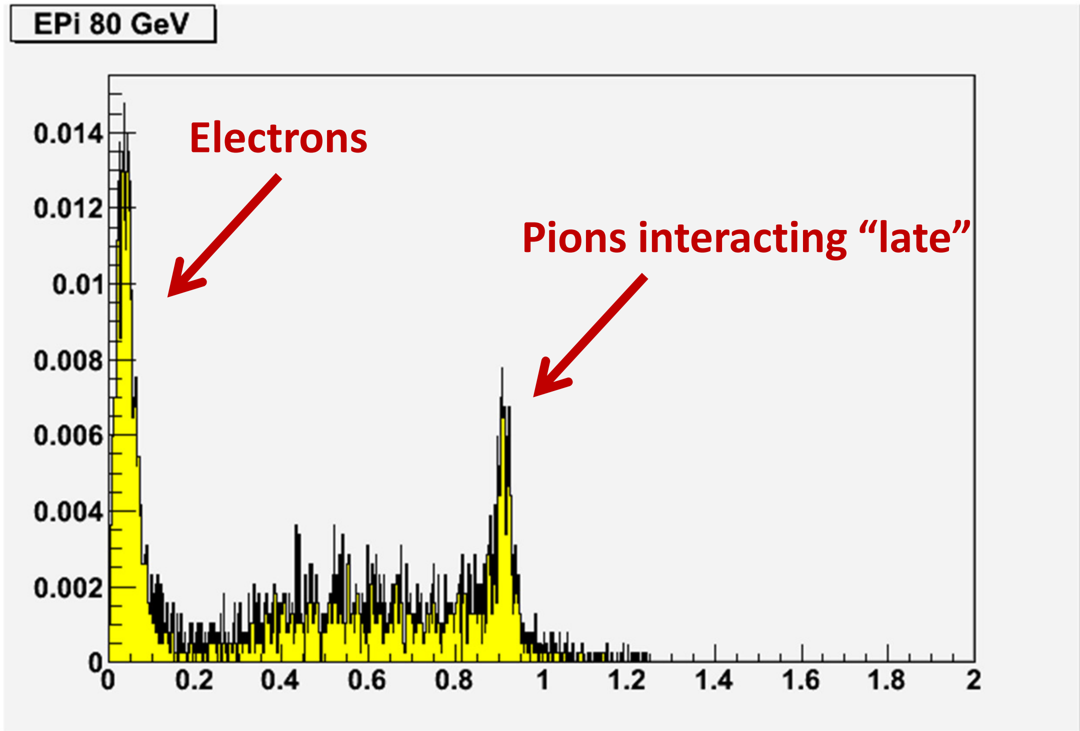
E= Energy

MeanLC(E) ➔ Expected mean value for the LongitudinalCut Variable for Electrons of energy E

MeanTC (E) ➔ Expected mean value for the TransversalCut Variable for Electrons of Energy E

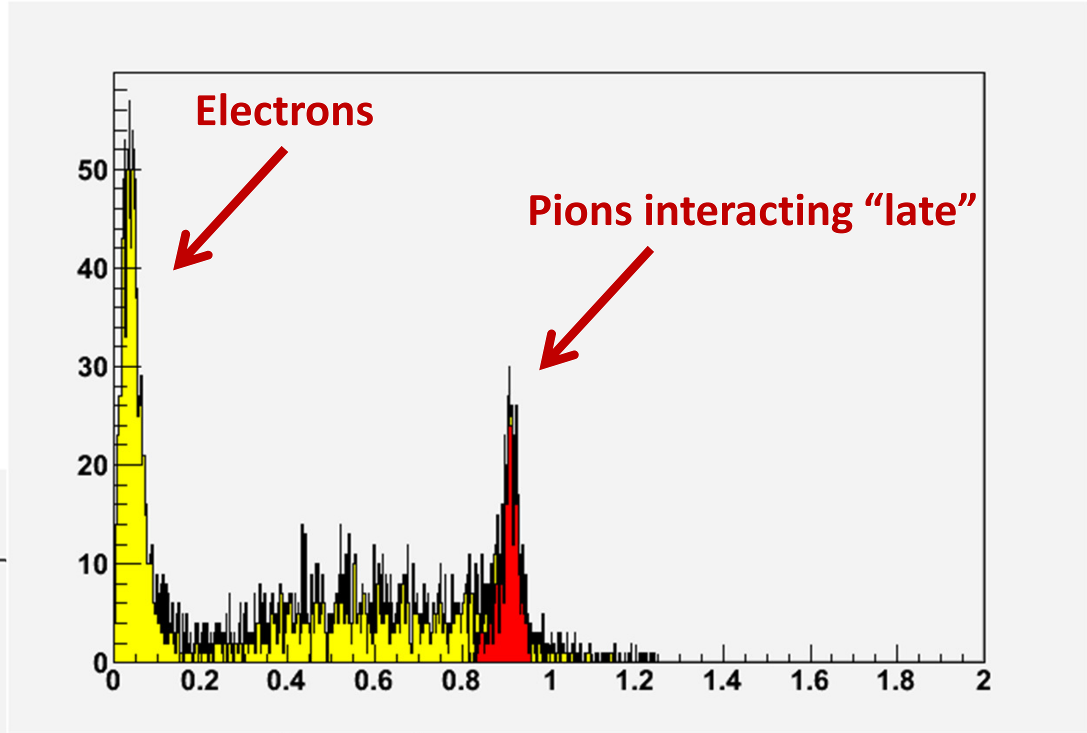
"Expected" as computed from data (they could have some bias taking into account there is contamination and there aren't pure electron runs. It could be worth perform some study using MC)

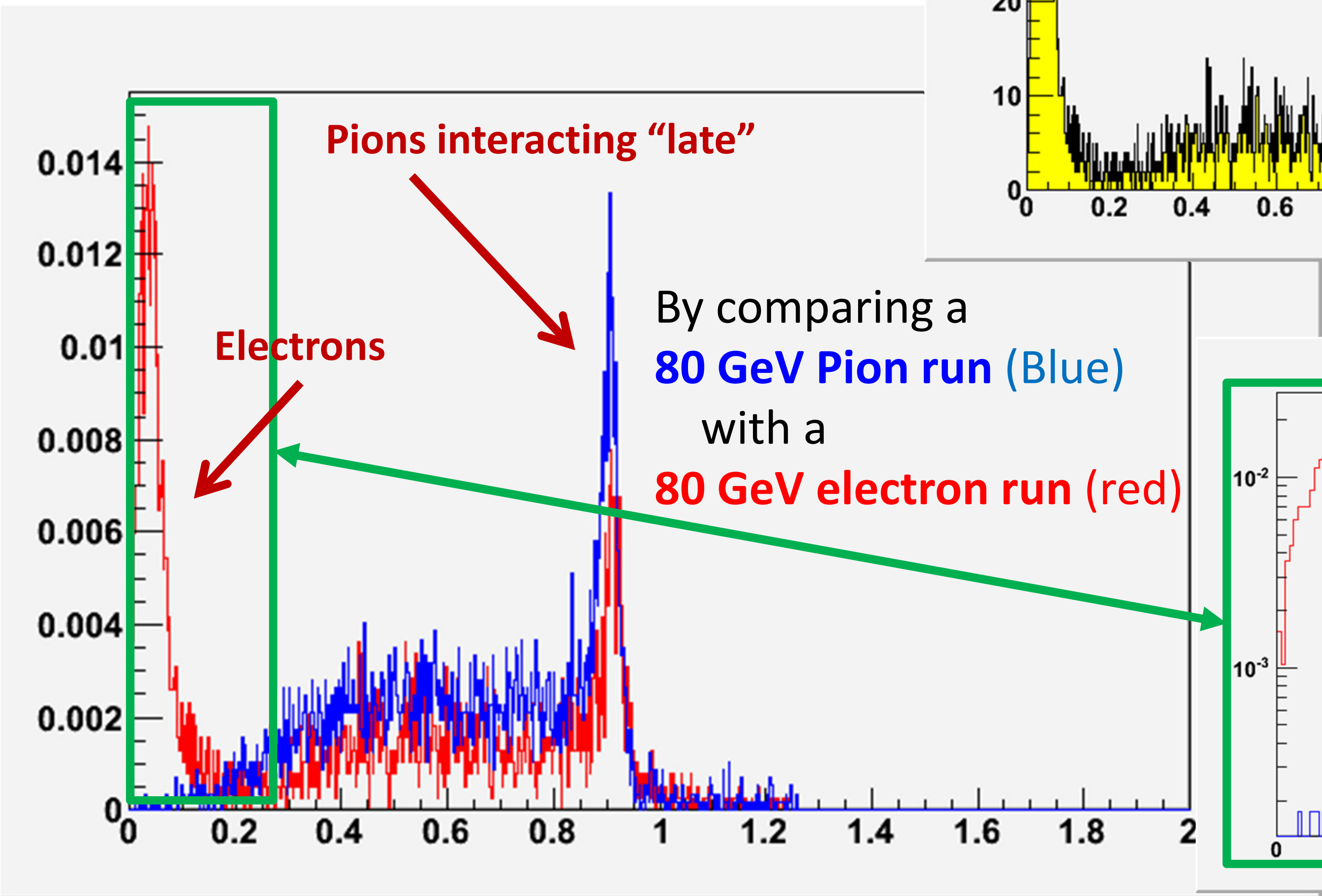
The distribution obtained for the 80 GeV electron Run



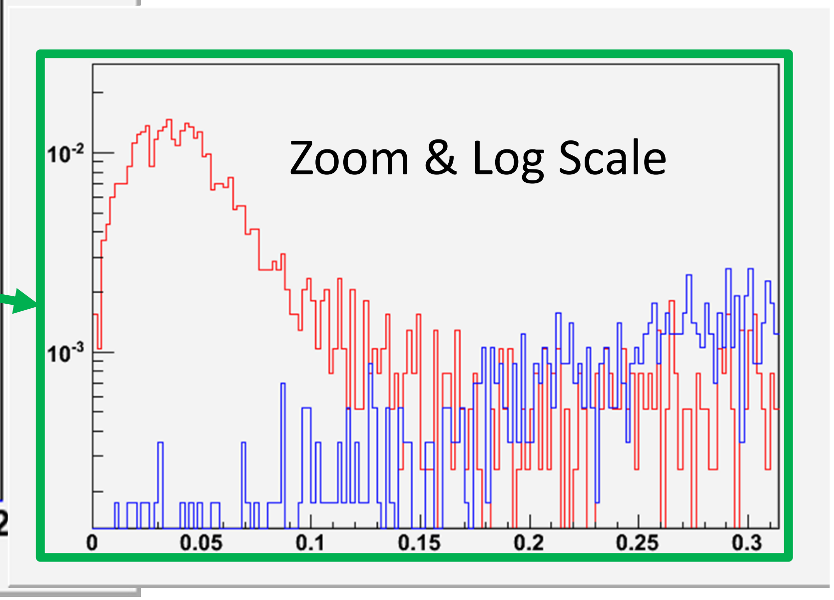
Transversal & Longitudinal profile correlations (IV)

If we imposed the cuts for the pions that "interacts later" the red distribution is obtained





By comparing a
80 GeV Pion run (Blue)
with a
80 GeV electron run (red)

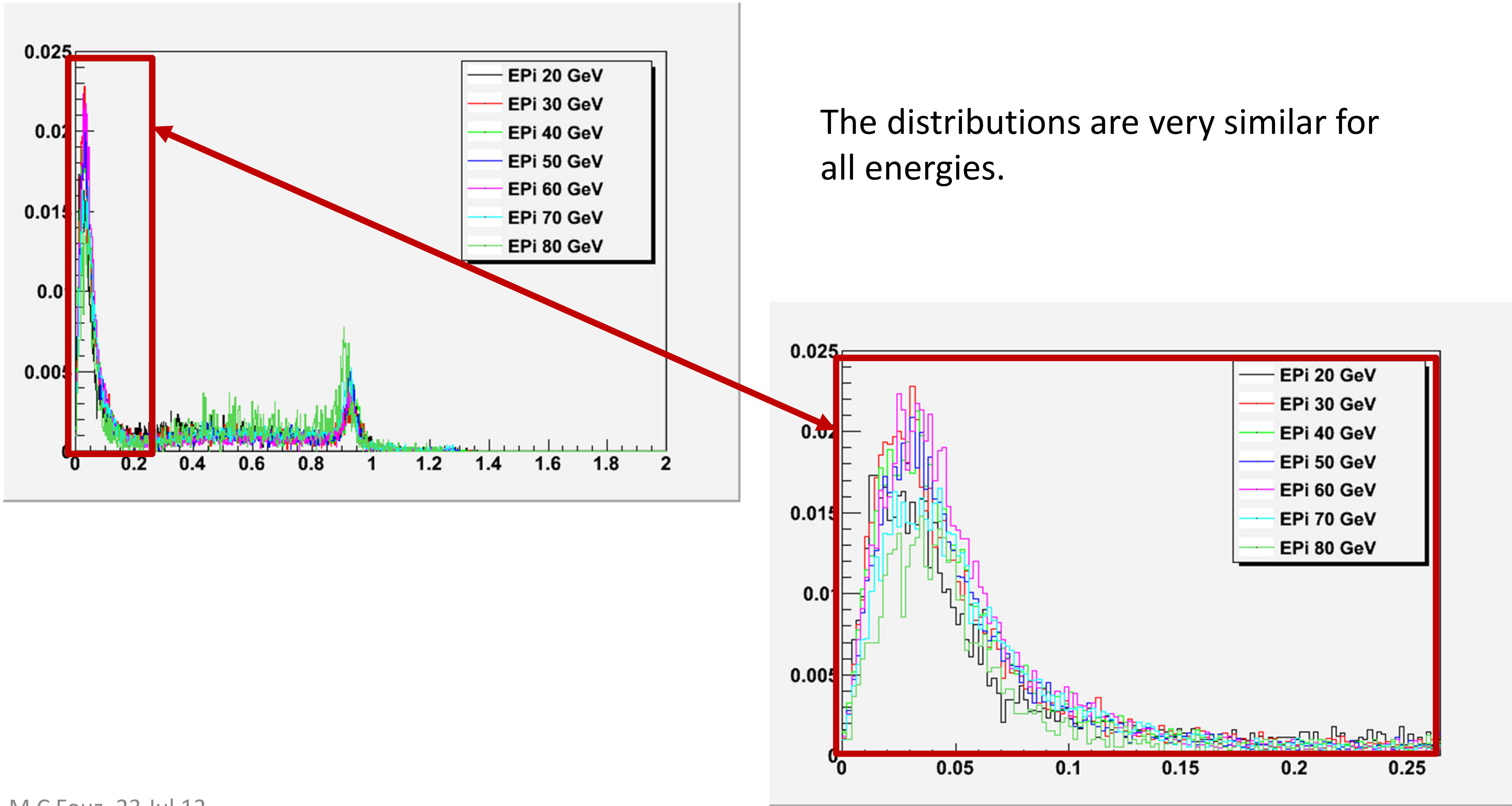


Transversal & Longitudinal profile correlations (V)

Computing

$$\text{CombinedCut(E)} = \sqrt{(\text{LongitudinalCut-MeanLC(E)})^2 + (\text{TransversalCut} - \text{MeanTC (E)})^2}$$

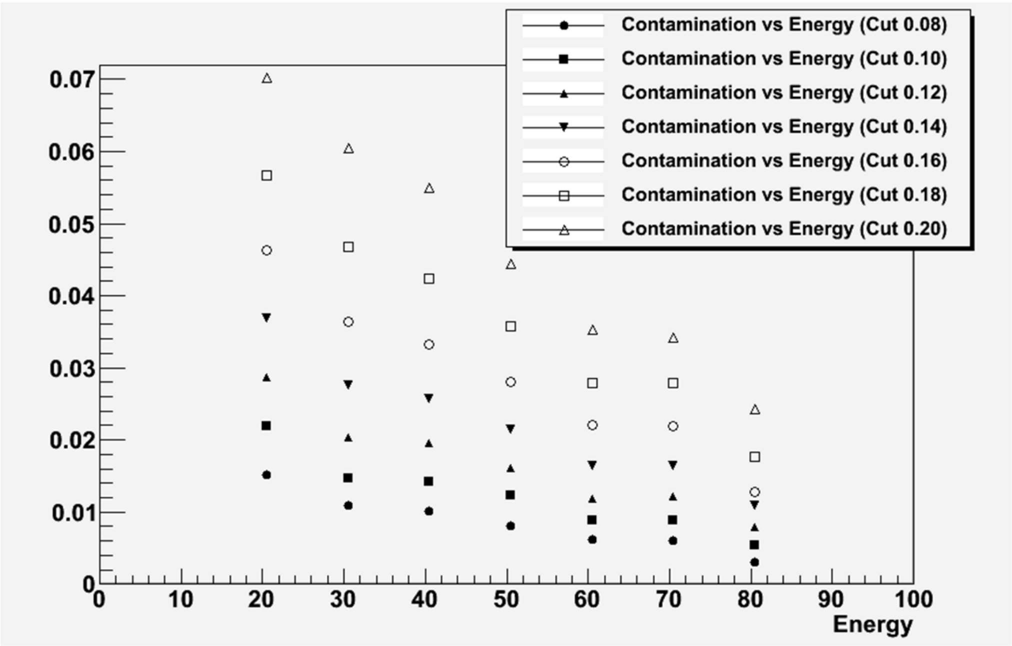
For all the available electron energies

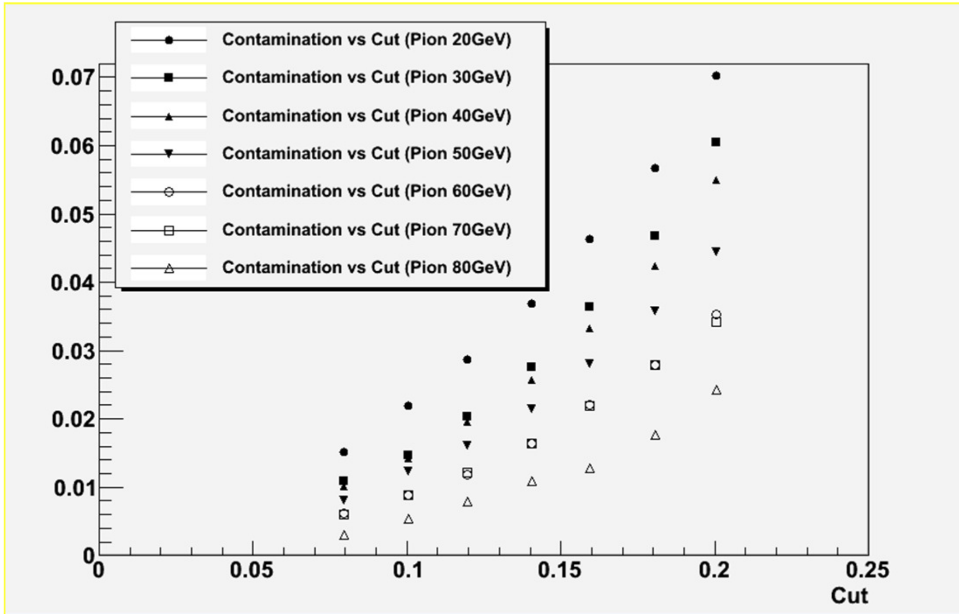


The distributions are very similar for all energies.

Transversal & Longitudinal profile correlations (VI)

Using the pion runs the percentage of events assigned as electrons are computed for different cuts.
Next plots contains exactly the same information plotted in two different ways

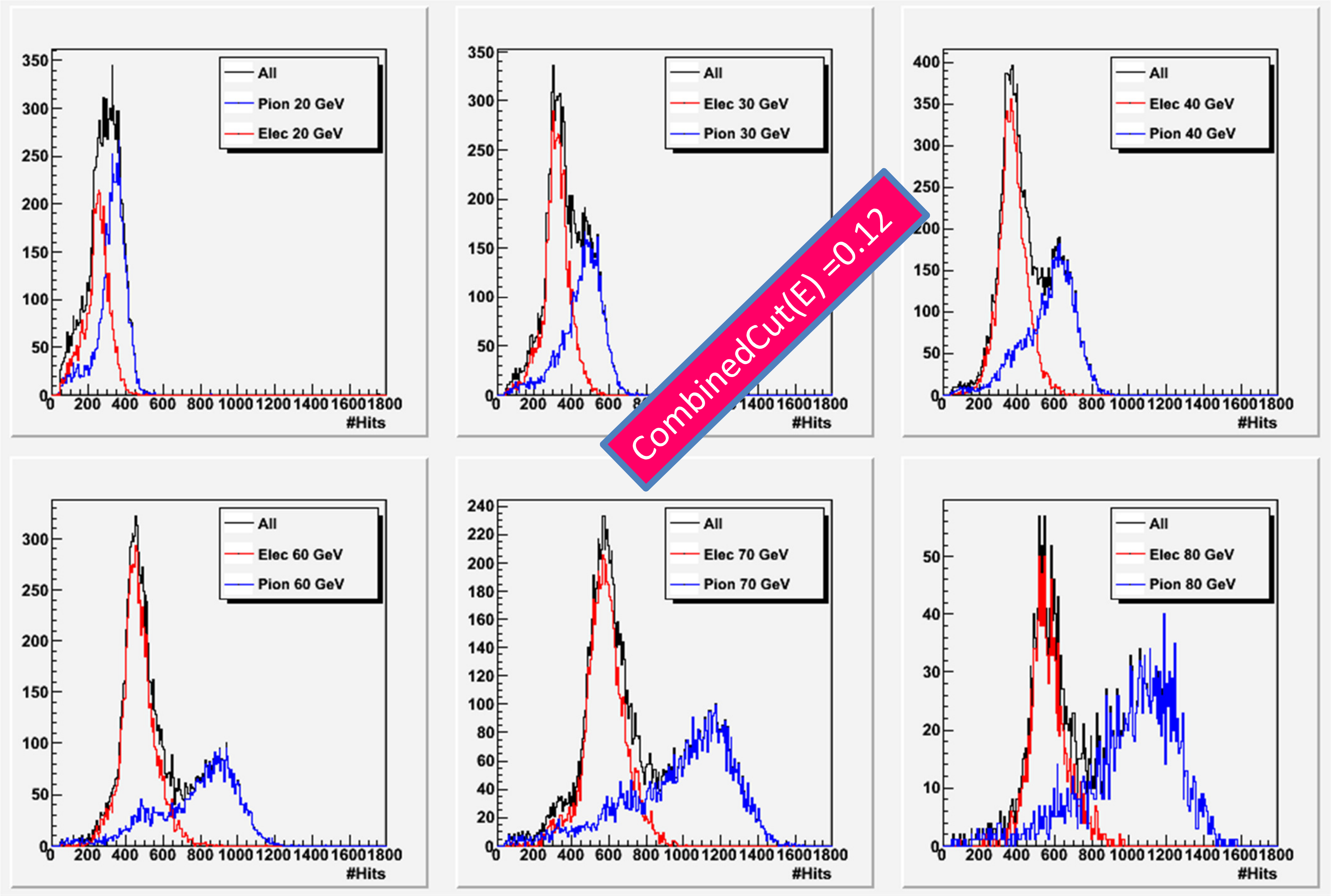




Depending on the cut and on the energy
the missassignment goes from few per mill till close to 7%

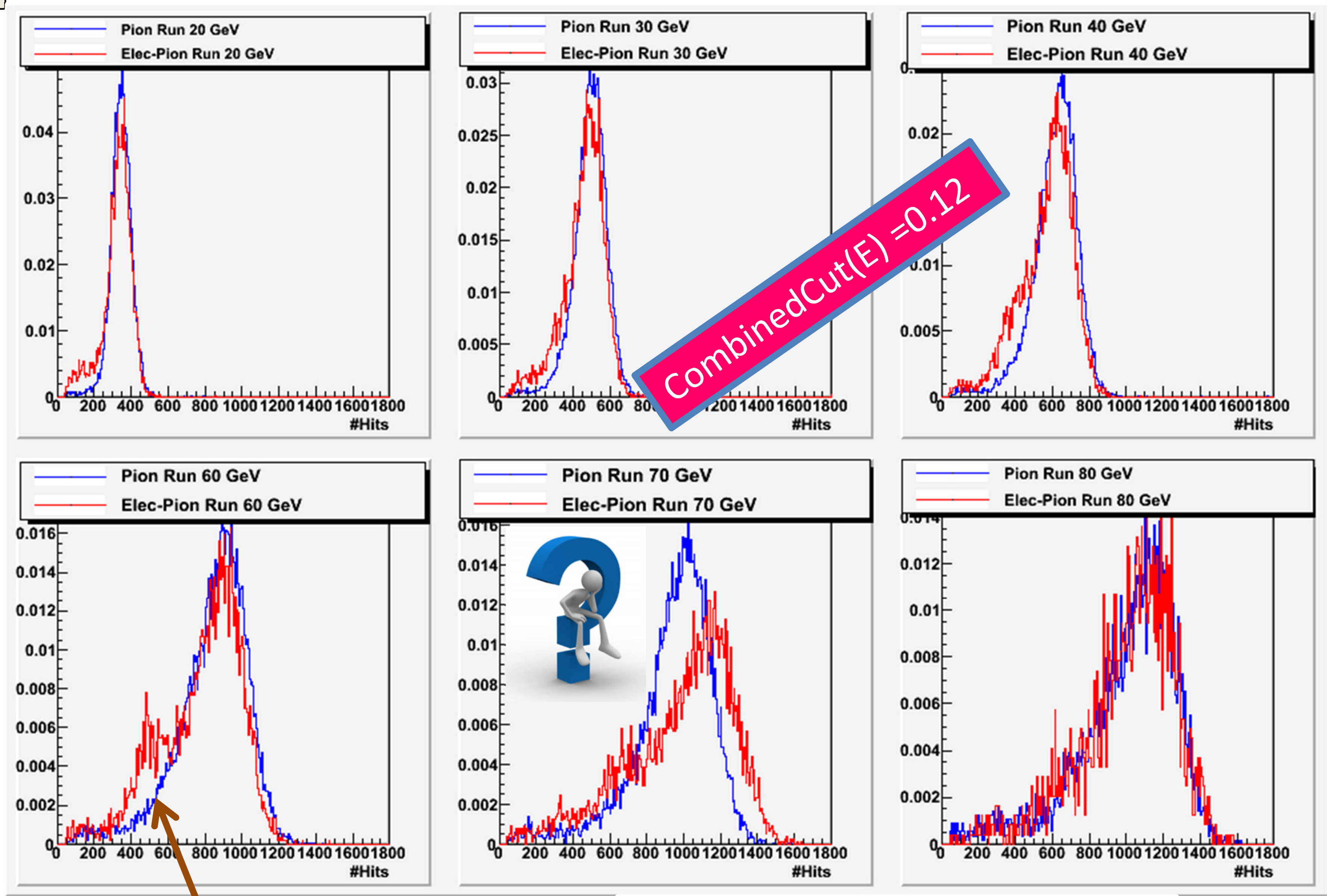
In the next three slides a cut of 0.12 has been used as a first attempt of separating the showers

Electron Runs – Separation of em and had showers



There is still contamination of electrons in the pion distributions

Pions: Pion Runs & Electron runs



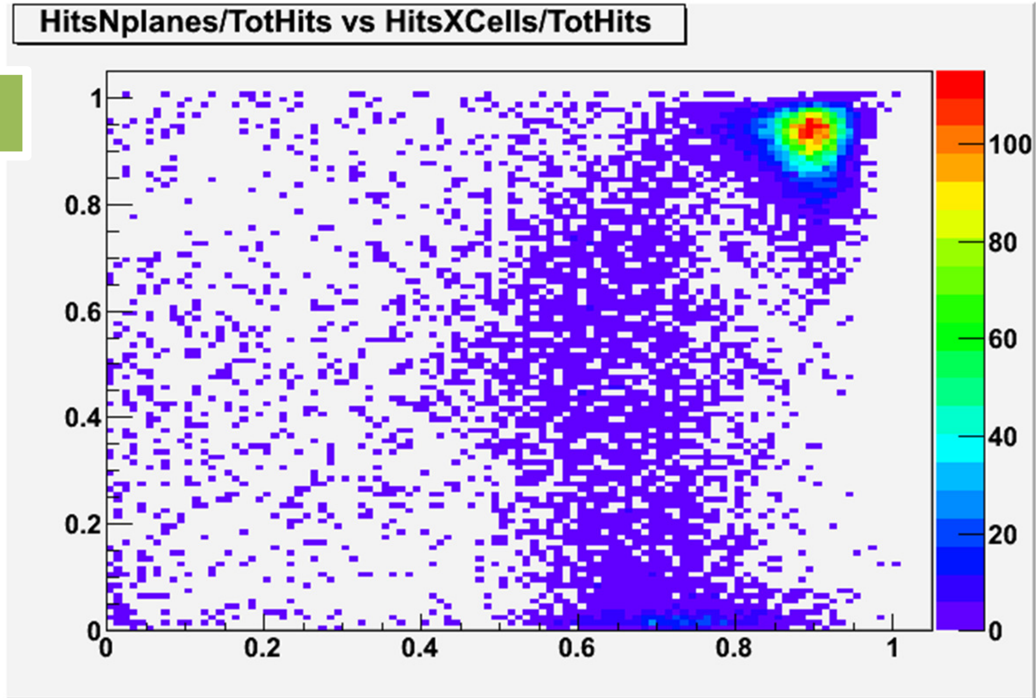
What happen with the 70GeV Runs?

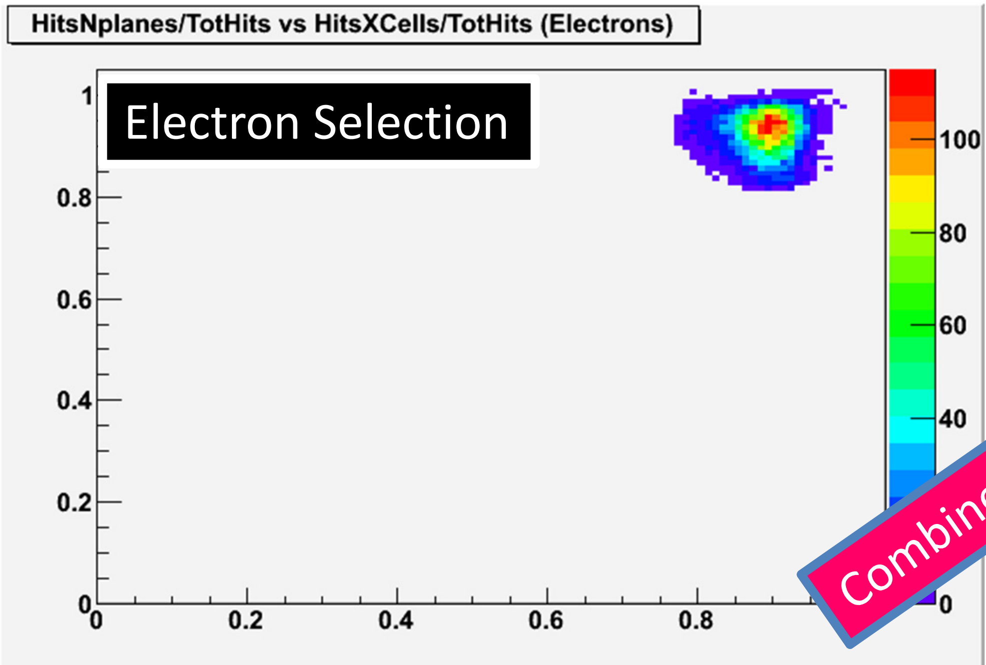
There is still contamination of electrons in the pion distributions

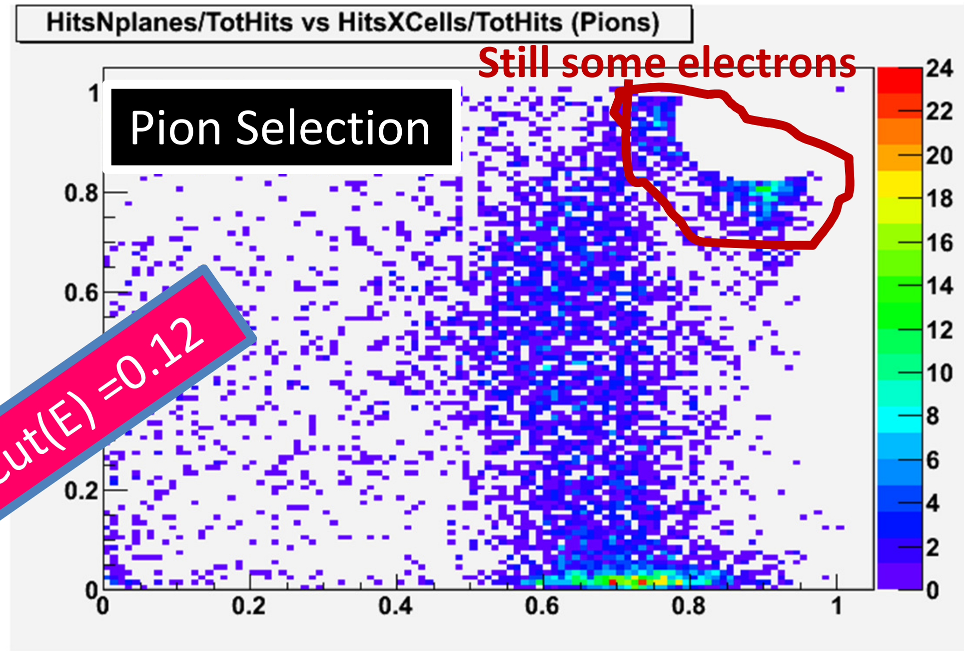
➔ Selection must be improved

Transversal & Longitudinal profile correlations (VI)

Electron Run 60 GeV







Effects of the cut value in the distributions - Aim

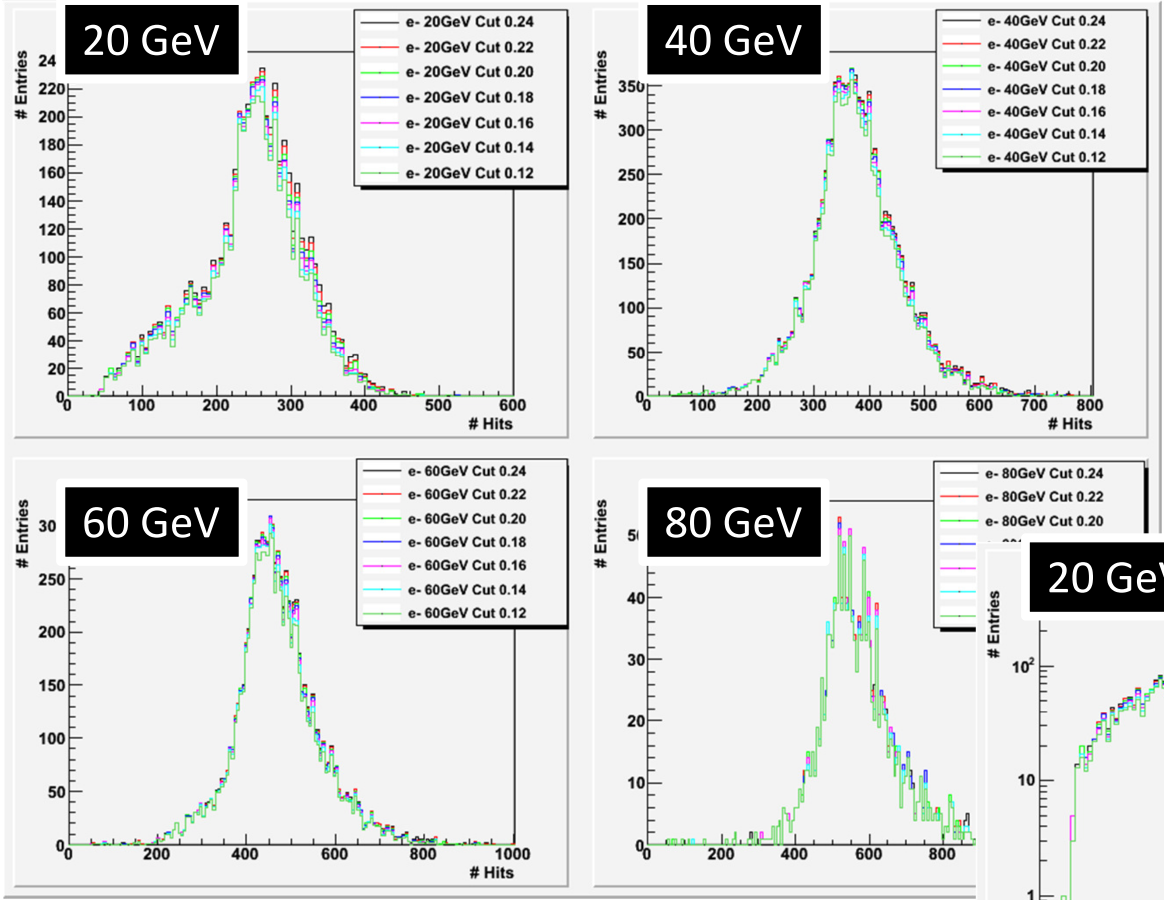
At the moment the **main aim for separating pions from electrons** is to be able **to study the performance of the calorimeter for pions and electrons.**

We need to separate both distributions as better as possible but at this moment we only need to avoid the contamination that change the distributions shapes/values.

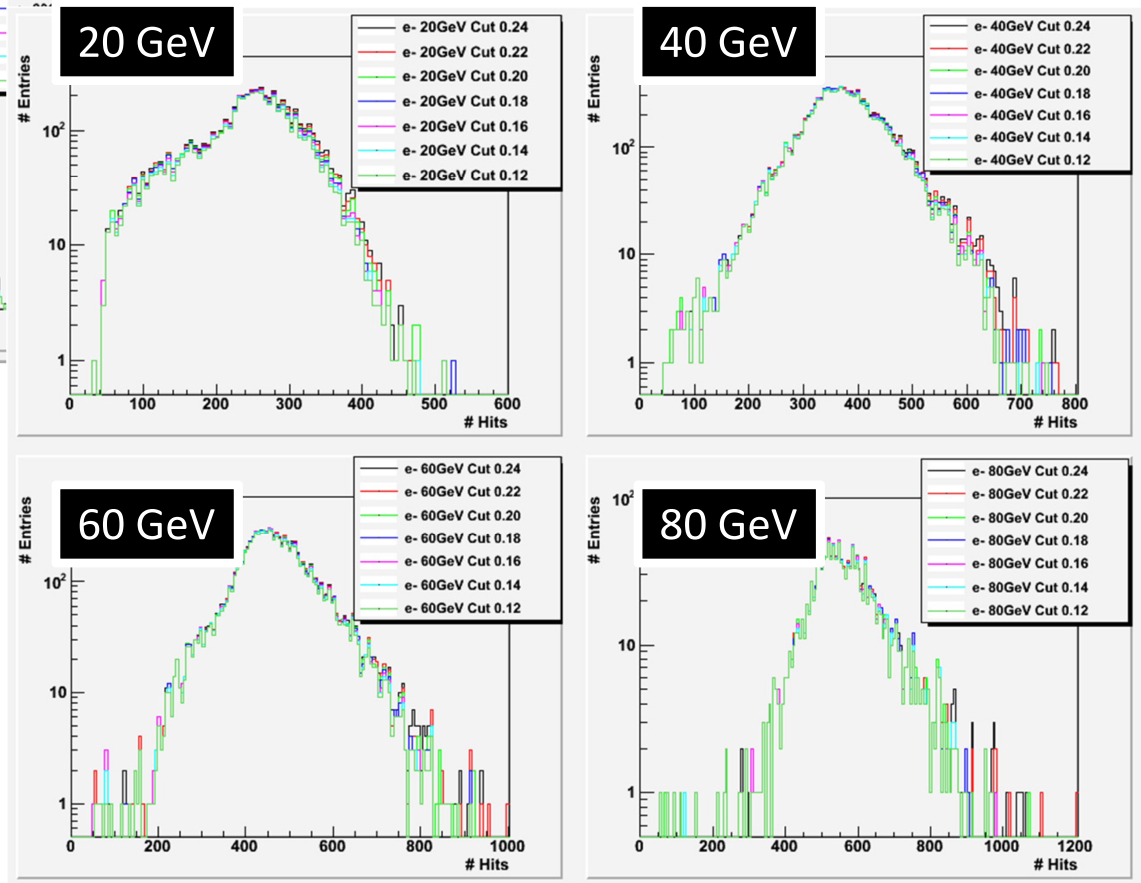
If some pions looks like and electrons and are tagged as them perhaps it is not going to change too much the distributions. It will depend on how much particles are misidentified.

We are going to perform some studies using different cut values in order to see which are the effects and look for the optimal values.

Nhits distributions for different CombinedCut(E) values
Electrons

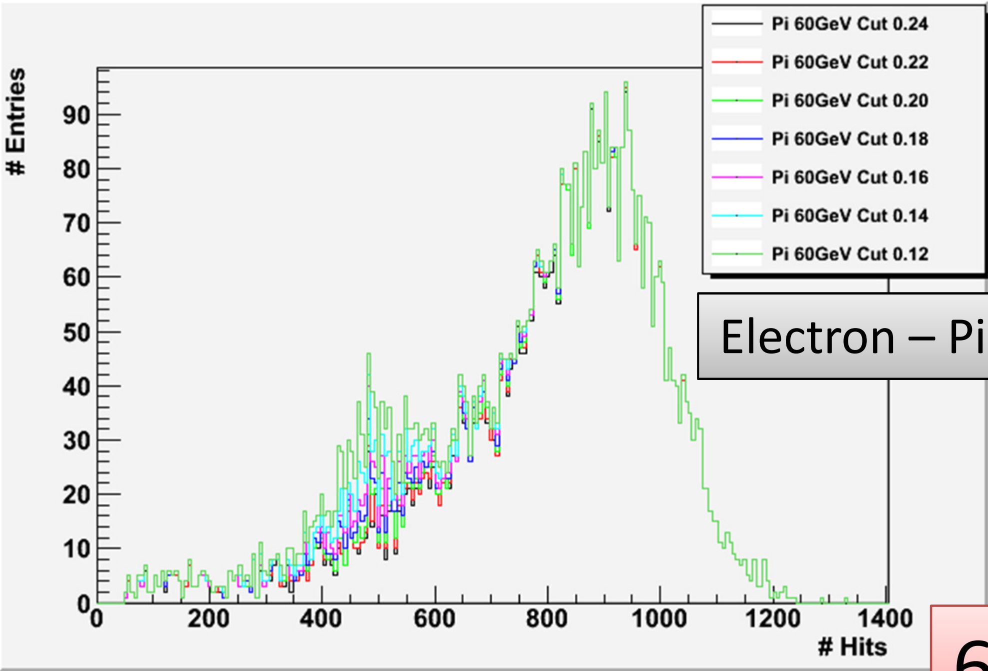


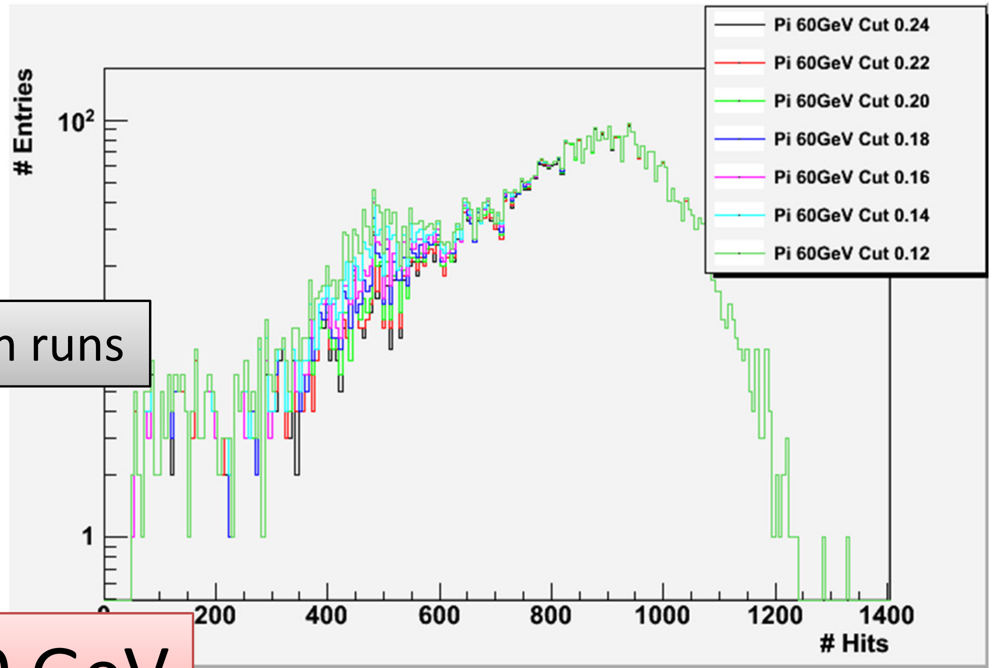
Nhits distributions for electrons of several energies and different CombinedCut(E) values (from 0.12 to 0.24)



The distribution looks similar for different energies

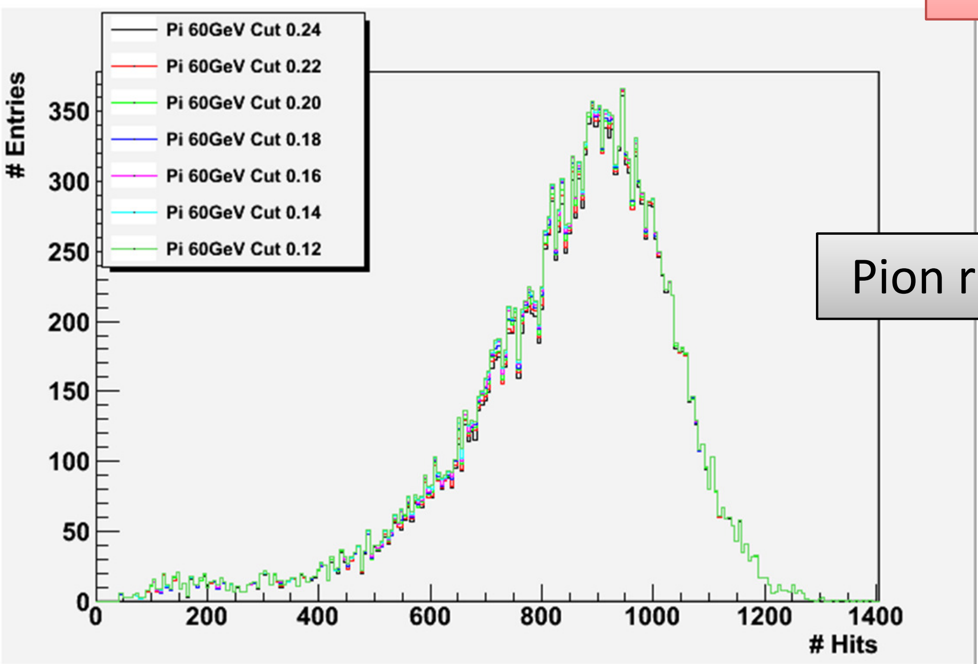
Nhits distributions for different CombinedCut(E) values
Pions

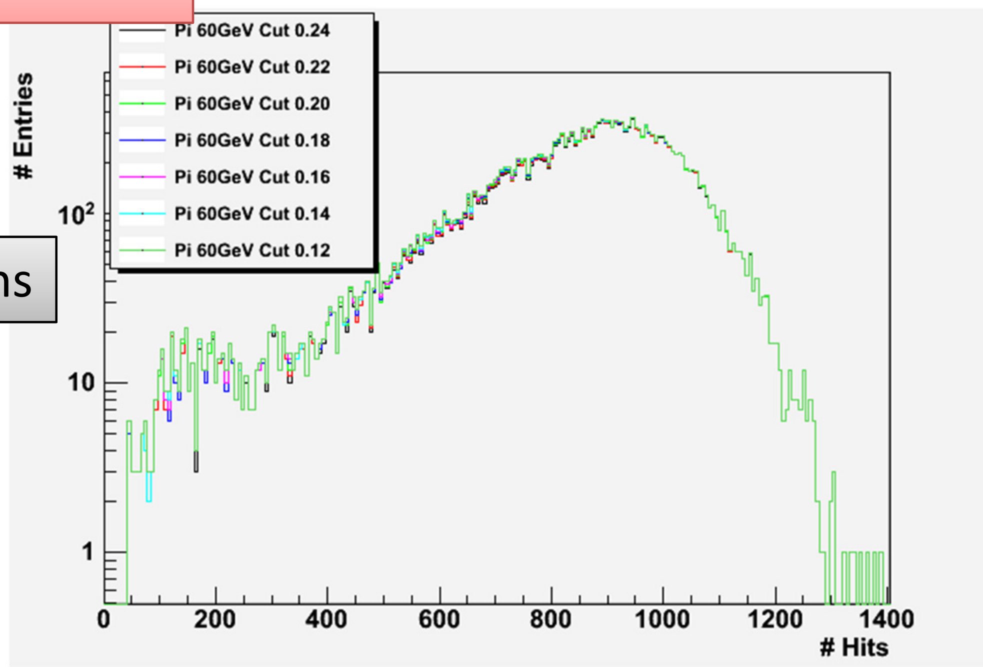




Electron – Pion runs

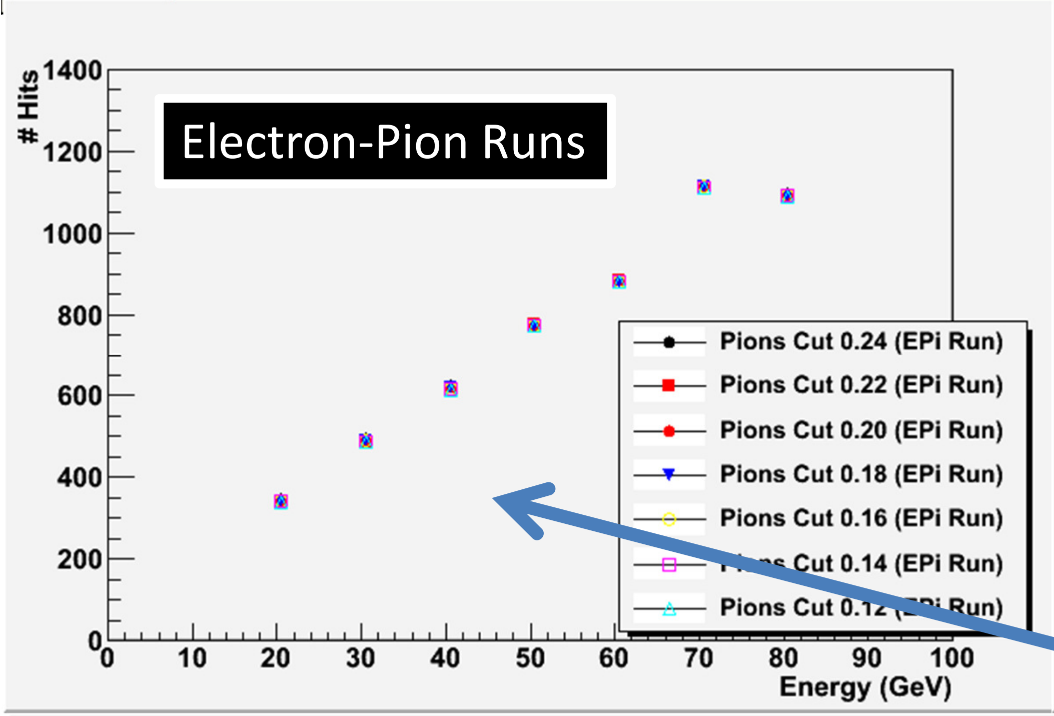
60 GeV

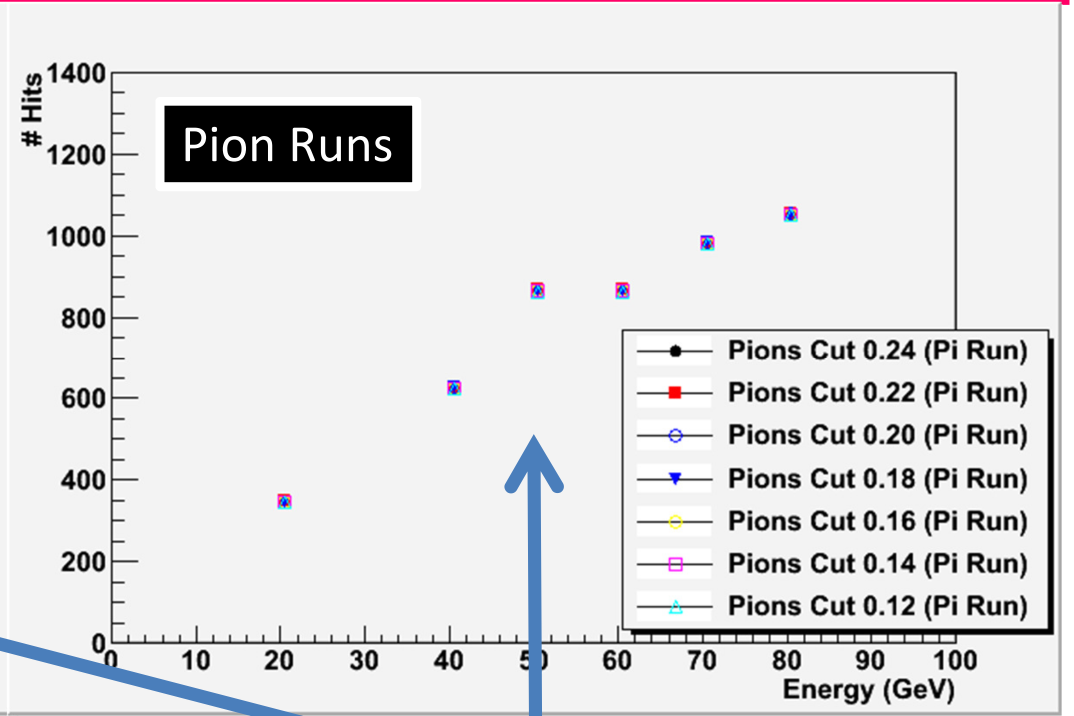




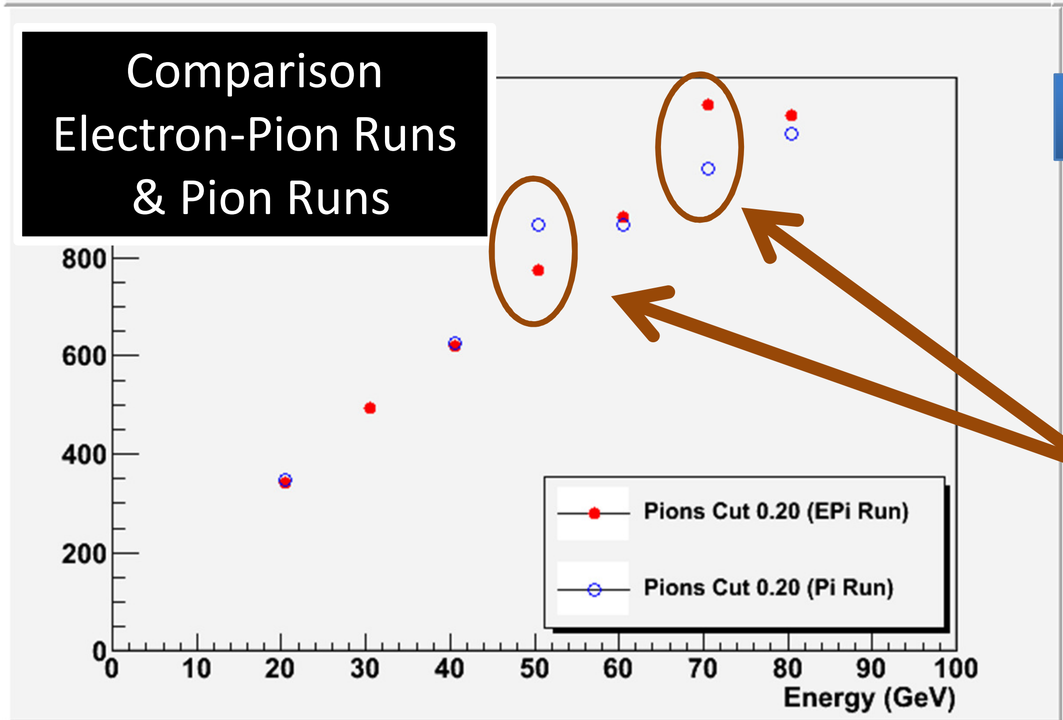
Pion runs

#Hits vs Energy for Pions for different Cuts



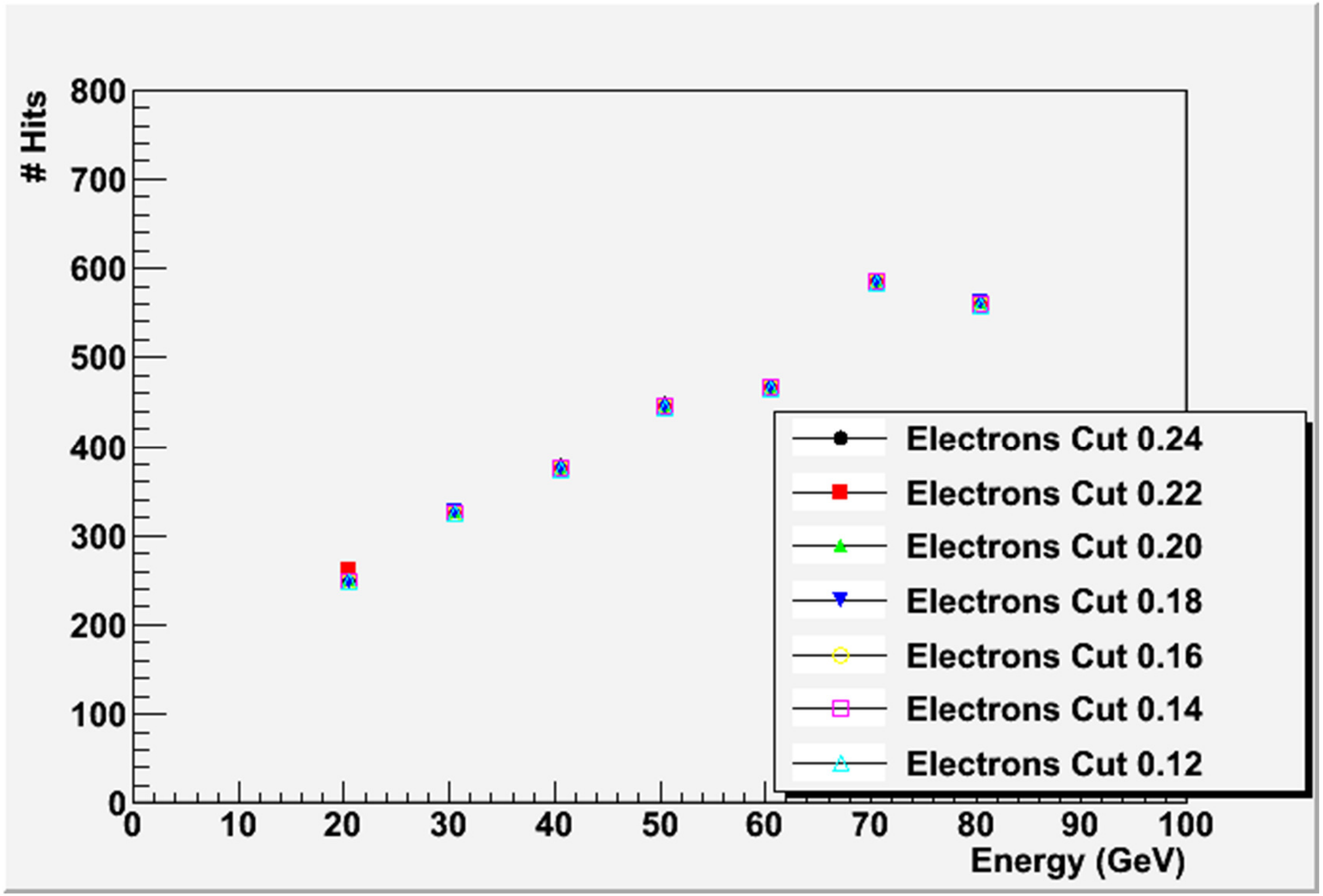


No significant differences for the different cuts



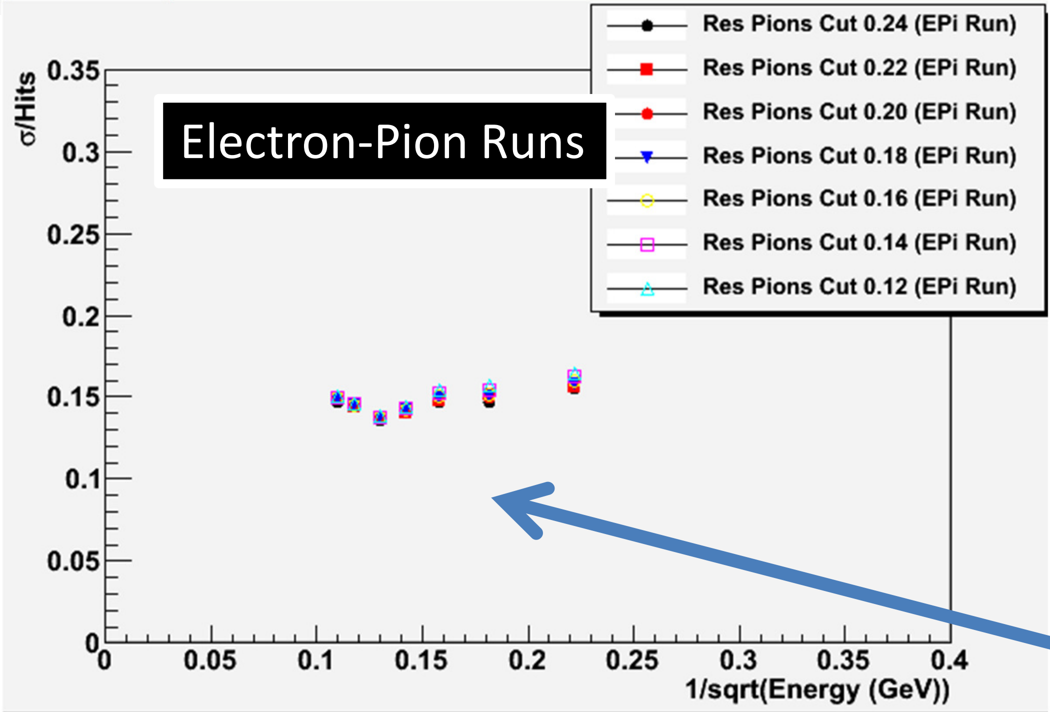
No differences between Electron-Pion runs and Pion runs except for a couple of points (Probably due to different or wrong data taken conditions)

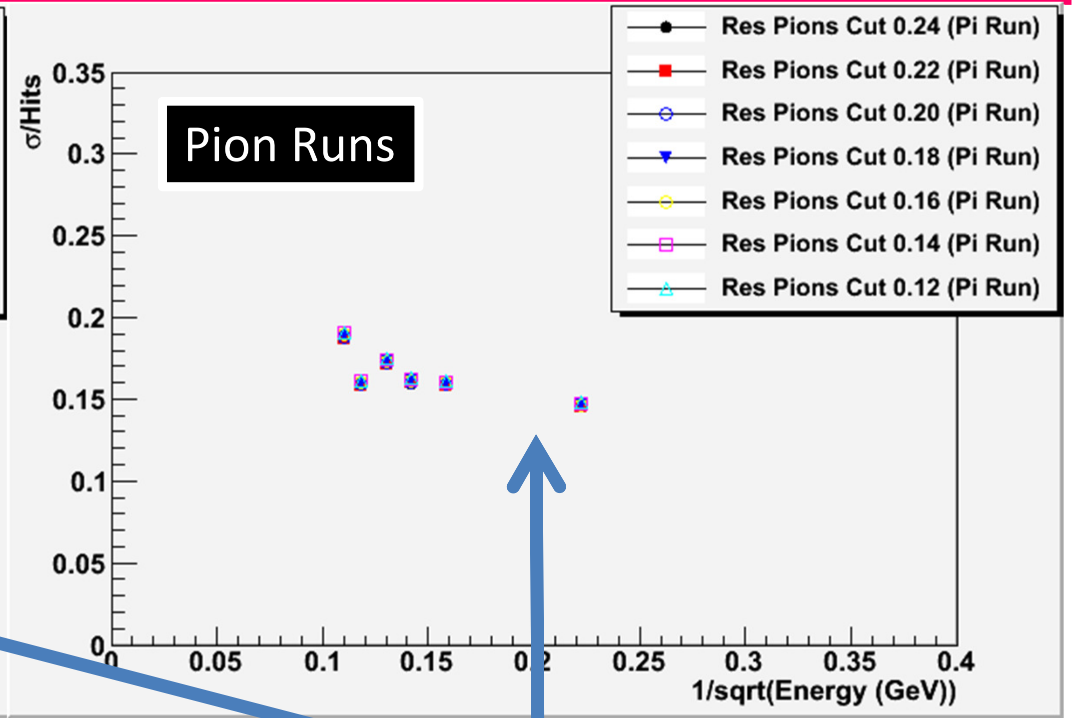
#Hits vs Energy for Electrons for different Cuts



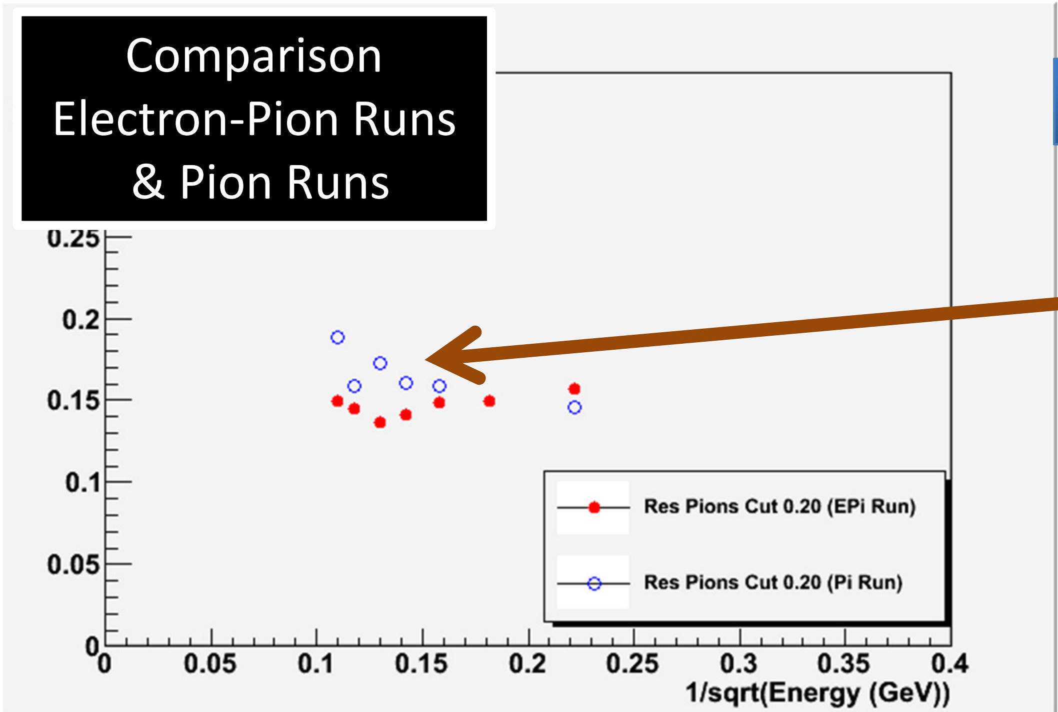
No significant differences for the different cuts

Resolution vs 1/√E for Pions for different Cuts





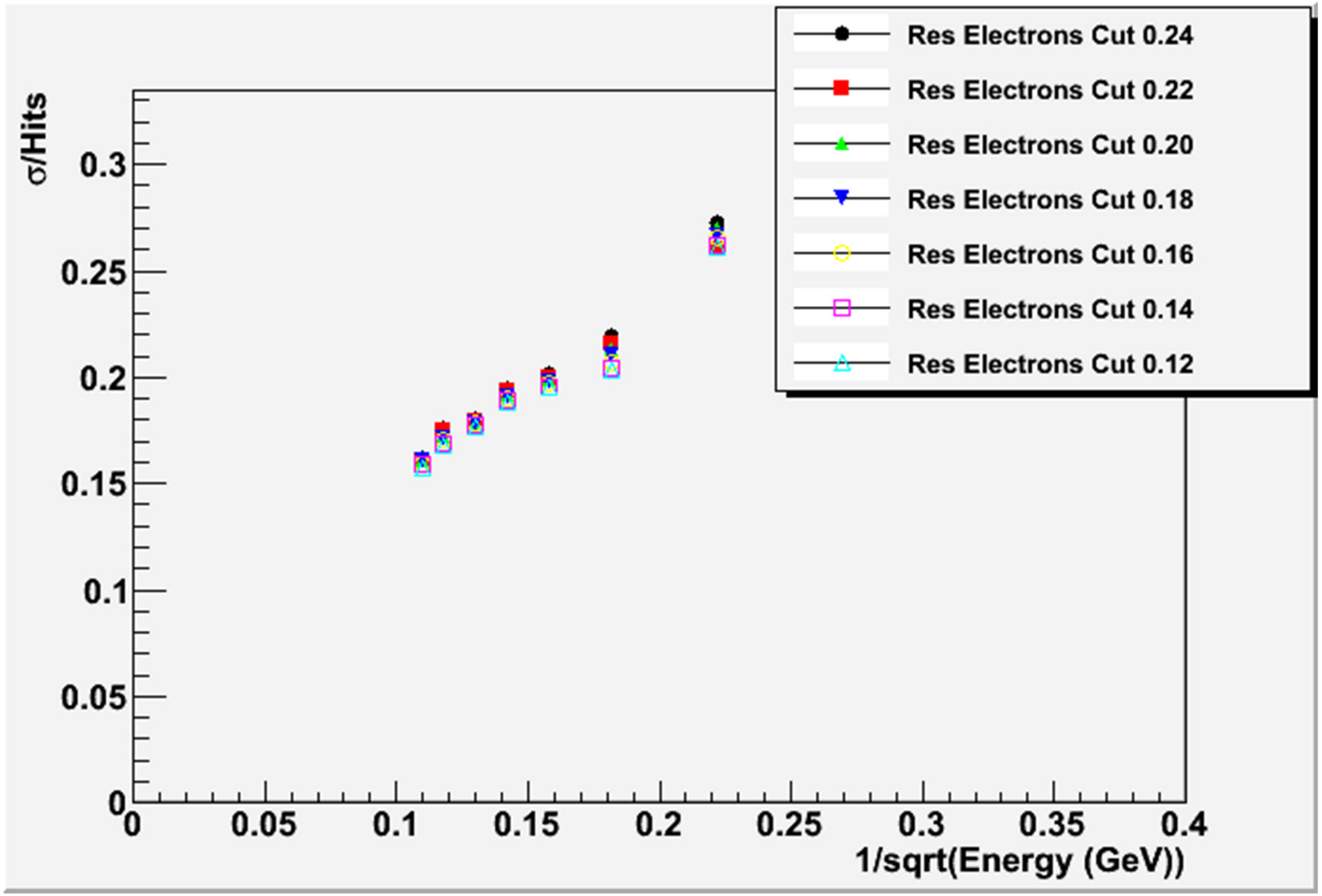
No significant differences for the different cuts



Some Differences for highest Energy values

The electron-Pion runs have probably still some electron contamination

Resolution vs 1/√E for Electrons for different Cuts



No big differences for the different cuts. Mainly for highest energies

Summary

A method to separate electromagnetic and hadronic showers has been presented.

➔ **Parameter selections and cut values have been optimized for the SPS energy range**

➔ **The mean values and resolutions are very similar when changing the cut values**

➔ **The pion resolution for electron-pion runs and pion runs are slightly different**
   ➔ **It should be still understood**

➔ **There are several energy points with values different to the expected ones when looking to the dependency of the number of hits with the energy or when comparing electron-pion runs with pion runs**
   ➔ **Differences on gains, SPS beam settings ???**

➔ **To be done: Study the possibility of using also the information of different thresholds to optimize the e/pi discrimination**