Common SiWECal – SDHCal TB data analysis

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GOBIERNO DE ESPAÑA

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cfp CIEMAT física de partículas

Contents

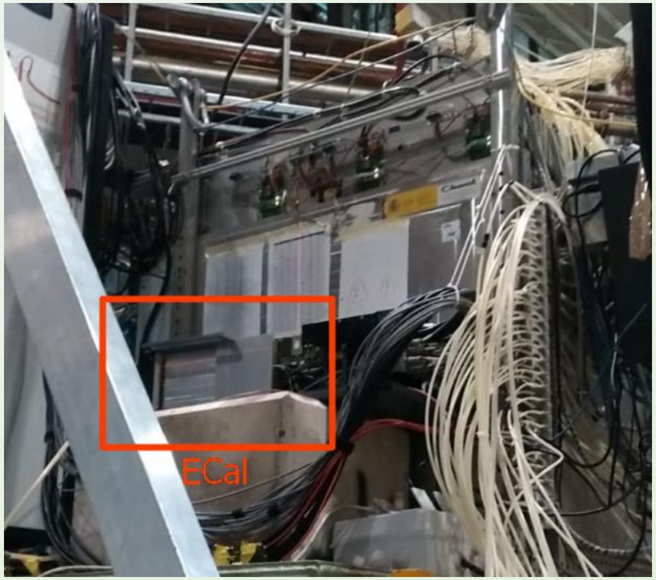
Test Beam setup

CERN H4 SPS. October 2018

- Muon (200 GeV), Π^{+} (40 – 80 GeV) and electron (40 GeV) runs.

SiWECAL:

- 9 working layers, 10 installed.



SDHCAL:

- 37 out of 48 layers present in the prototype. There may be leakage at high energies.
- SiWECal placed in front of the SDHCal:

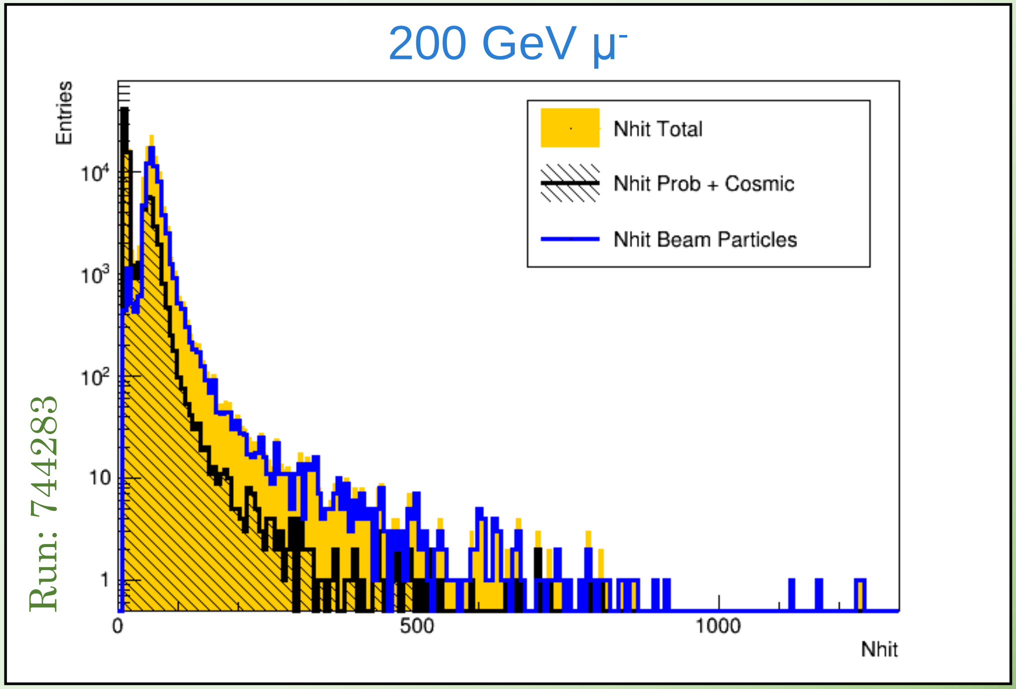
$\{0\ ,0\} \equiv$ SDHCal's bottom left corner

$$X^{0}_{ECal} = 225\ mm$$

$$Y^{0}_{ECal} = 377\ mm$$

Particles selection. SDHCal beam cuts

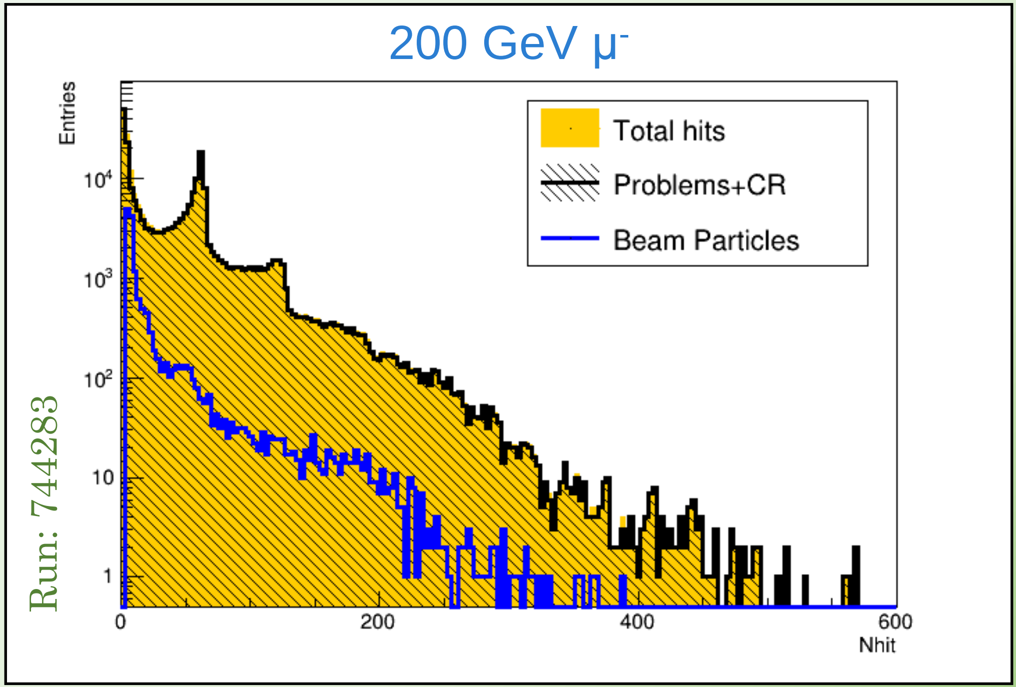
- To separate a physical process from electronic noise: $Nhits > 7$.
- We require that there is signal in the first 2 layers.
- It is required 4 layers with signal between the first 10 and 3 among the first 6.
- To reconstruct the trace we require at least 5 close (less than 3 layers without signal in between) GRPCs with signal.
- Only one set of close RPCs with signal in the whole prototype.



Particles selection. SiWECal beam cuts

Following a similar procedure than the SDHCal:

- Signal in the first 2 layers required.
- At least 3 close layers with signal.



Particles selection. Muon selection variables

Density: $\rho = \frac{nHit}{nLayers}$

$\boldsymbol{nHit} \rightarrow$ total number of hits in the detector.

$\boldsymbol{nLayers} \rightarrow$ number of layers with signal.

Second maximum of hits in a single layer: Hit_{Max2}

Penetrability Condition (P.C.):

SDHCal

- Layers 01-08: at least 6 with signal.
- Layers 09-16: at least 6 with signal.
- Layers 17-28: at least 7 with signal.
- Layers 29-37: at least 6 with signal.

ECal

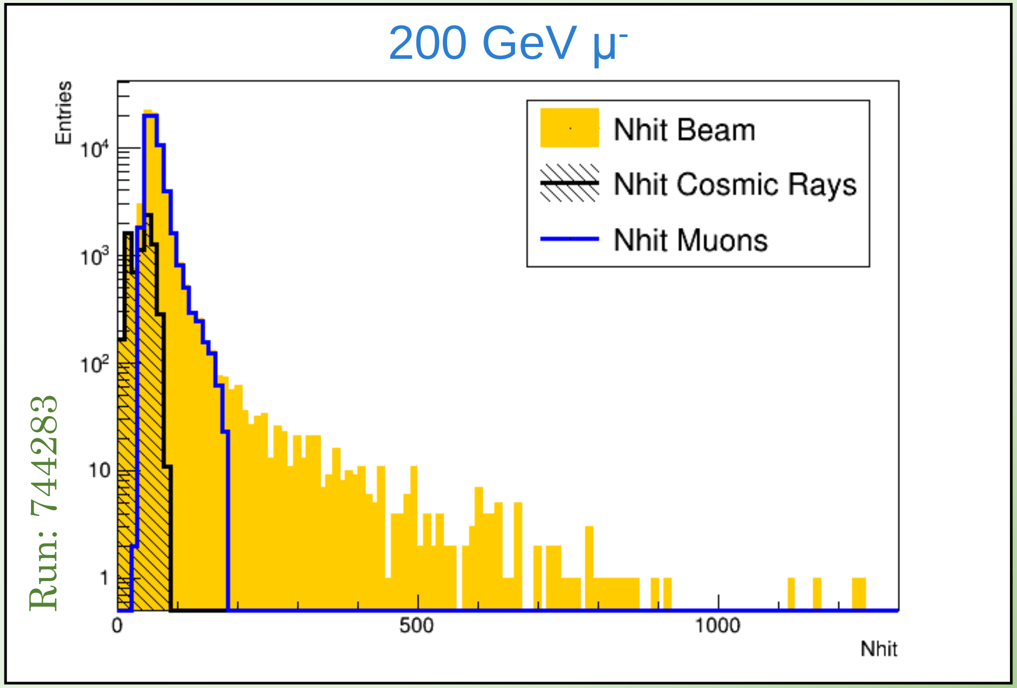
- Signal in the first half. Layers 01- 05
- Signal in the second half. Layers 06 – 10

Particles selection. SDHCal muon cuts

Density: **ρ**
Second nHit maximum in a single layer: $\boldsymbol{Hit_{Max2}}$
Penetrability condition: ***P.C.***

Muons → $(\rho < 2.2 \ or \ Hit_{Max2} < 5) + P.C.$

Muons with shower → $\rho < 5 + P.C.$

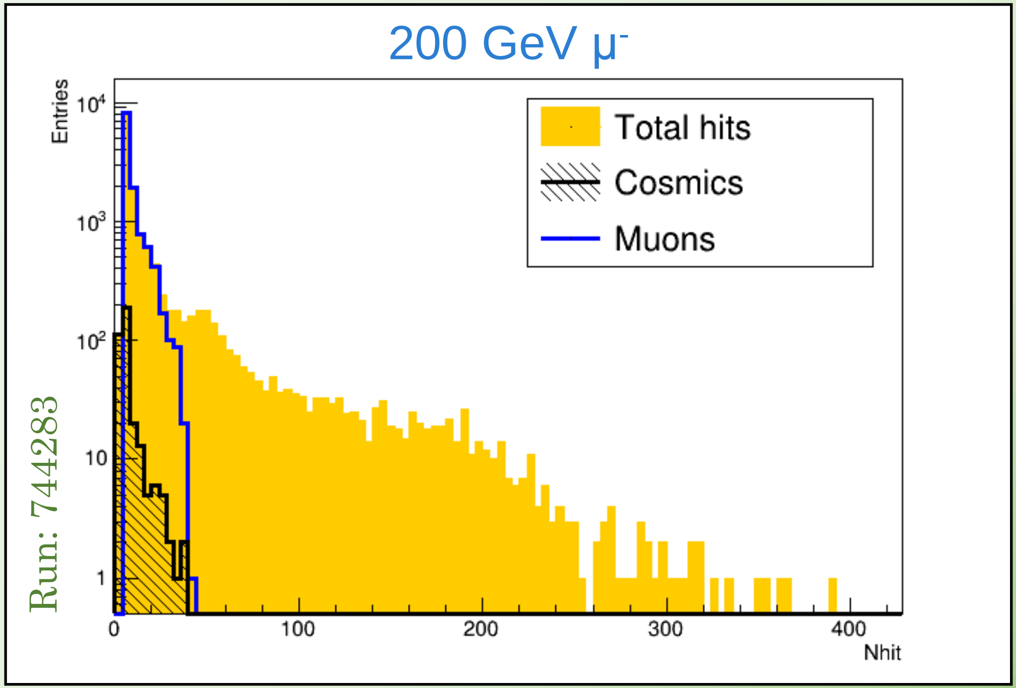


Particles selection. SiWECal muon cuts

Density: **ρ**
nHit maximum in a single layer (To remove noisy channels): $\boldsymbol{Hit_{Max}}$
Second nHit maximum in a single layer: $\boldsymbol{Hit_{Max2}}$
Penetrability condition: ***P.C.***

Muons → $(\rho < 2.5 \text{ or } (Hit_{Max2} < 5 \ \& \ Hit_{Max} < 32)) + P.C.$

Muons with shower → $\rho < 5 + P.C.$



Tracks reconstruction

The process of track reconstruction is made in a few steps:

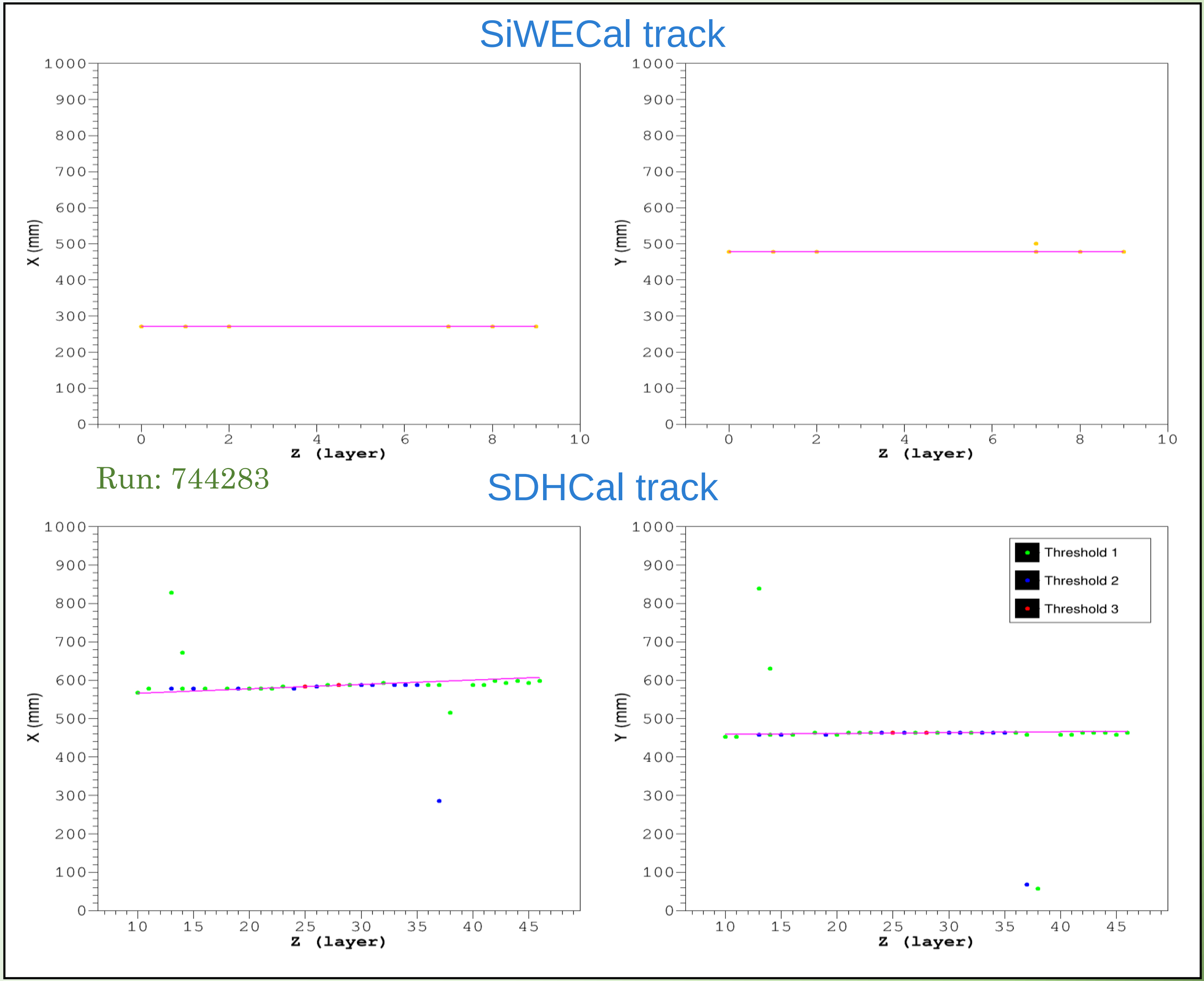
- A first approximation by taking the mean value of all clusters in each layer
- This approximation is fitted to a straight line.
- Then the closest cluster with a distance less than 20.8 mm in X and Y to the previous approximation is selected for each layer. *(It is possible that a layer has no cluster selected)*
- The final track is the set of selected clusters fitted to a straight line.

Finally the following cuts are applied to select the tracks:

$$|\alpha_X| < 0.2 \;\;\&\;\; |\alpha_Y| < 0.2$$

Where α_X and α_Y are the slopes of the tracks
No less than 5 layers with clusters selected

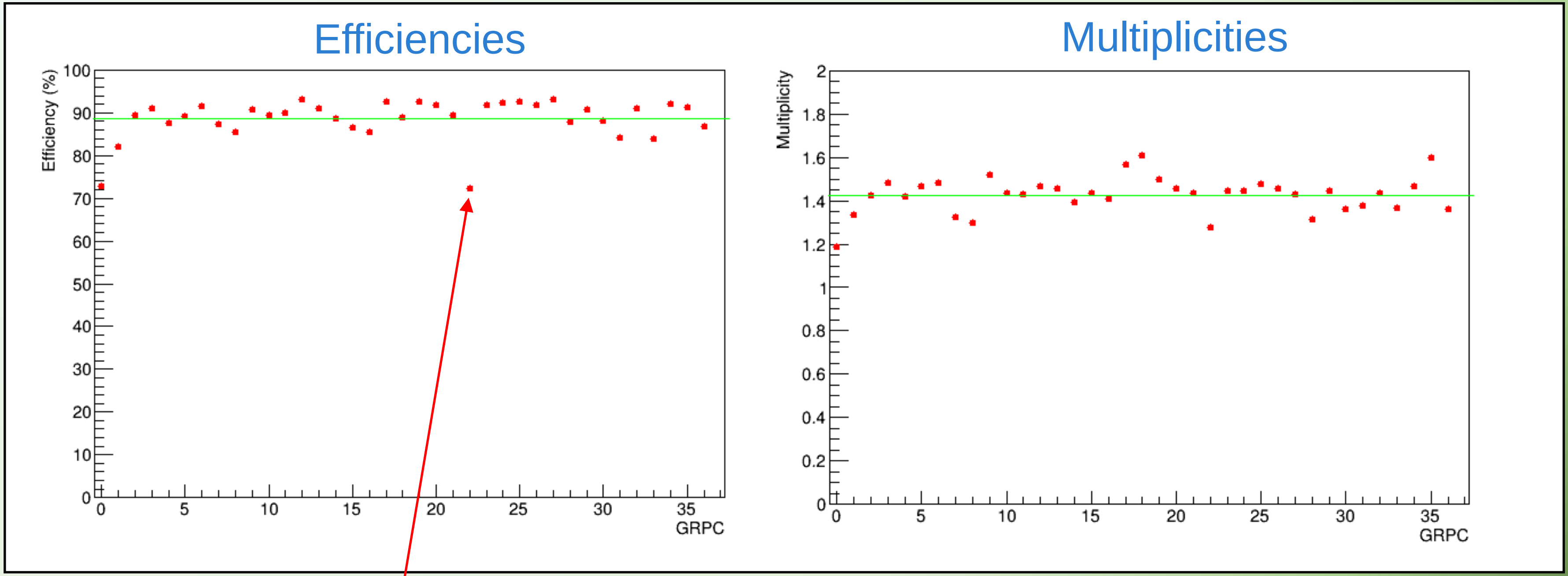
Tracks reconstruction. Muon example



Efficiencies and multiplicities. SDHCal

Efficiencies: A layer is said to be efficient if there is a cluster in the track of a reconstructed muon in such layer.

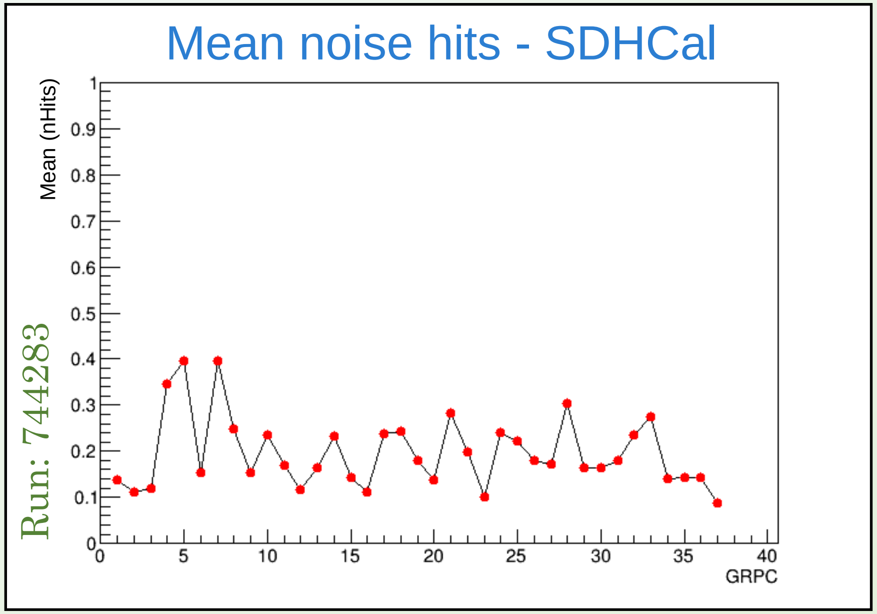
Multiplicities: If a layer is efficient the multiplicity is defined as the size (in number of pads) of the cluster associated to that layer.

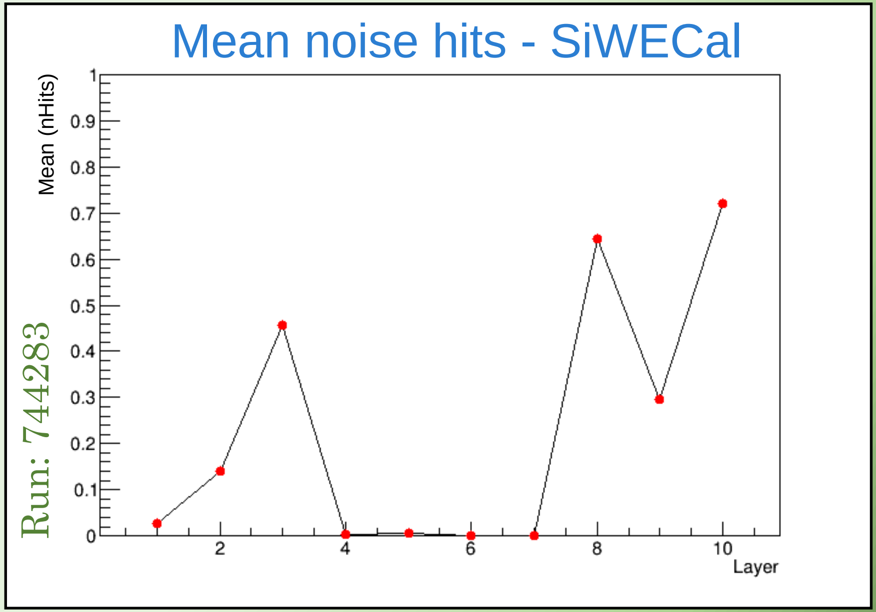


A third of the electronics was out of order

Mean noise hits

Noise hit: Defined as a hit which is not associated to a muon track.



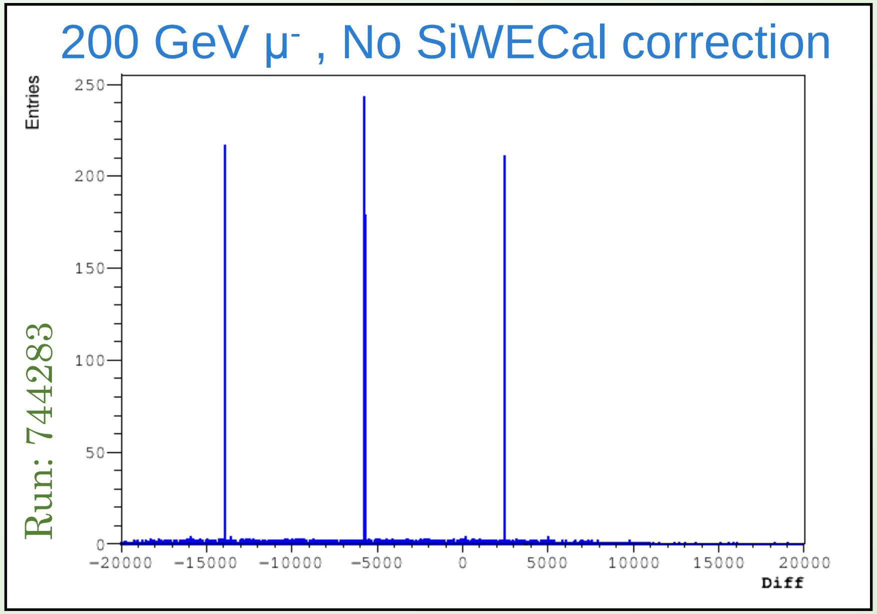


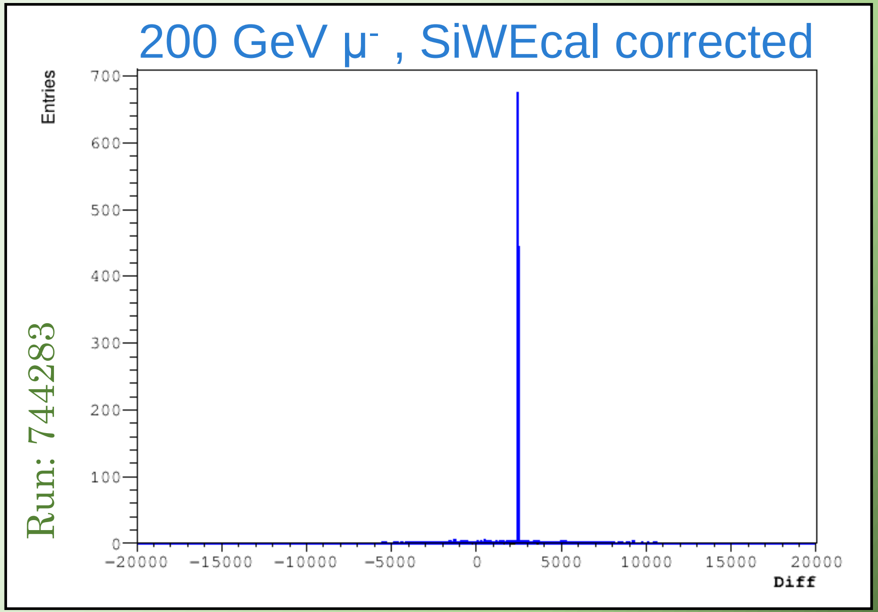
SiWECal – SDHCal synchronization

- Events must share the same run and spill.
- SDHCal tracks must go through the SiWECal boundaries:

$$227.75\,mm < x < 397.75\,mm$$
$$379.75\,mm < y < 550.25\,mm$$

- The two tracks with the closest set of parameters are selected as a match.





SiWECal – SDHCal geometrical alignment

Using muon tracks it is possible to try to find a correction to the SDHCal position by fitting to a sum of Gaussians the differences of the tracks from both detectors.

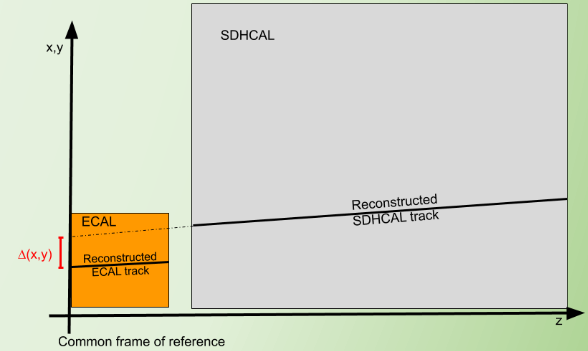
Single Gaussian fit:

$$X'_{HCal} = X^{H}_{HCal} - \mu_X$$

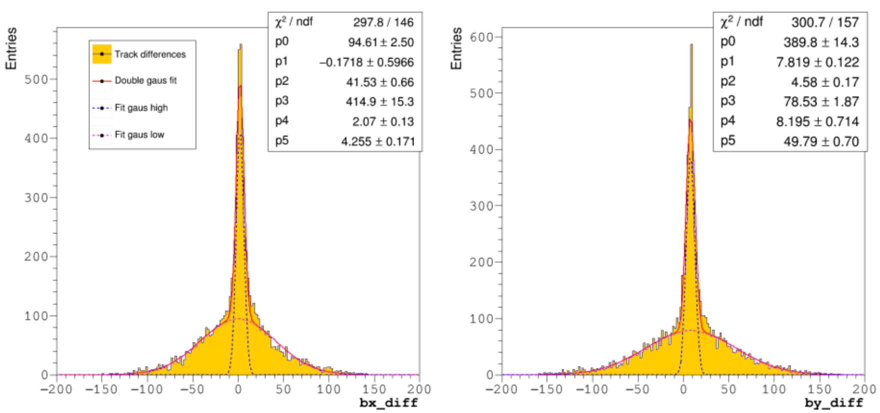
$$Y'_{HCal} = Y^{H}_{HCal} - \mu_Y$$

X: $\mu^{H}_{X} = 2.07 \pm 0.13$; $\sigma_X = 4.255 \pm 0.171$

Y: $\mu^{H}_{Y} = 7.819 \pm 0.122$; $\sigma_Y = 4.58 \pm 0.17$

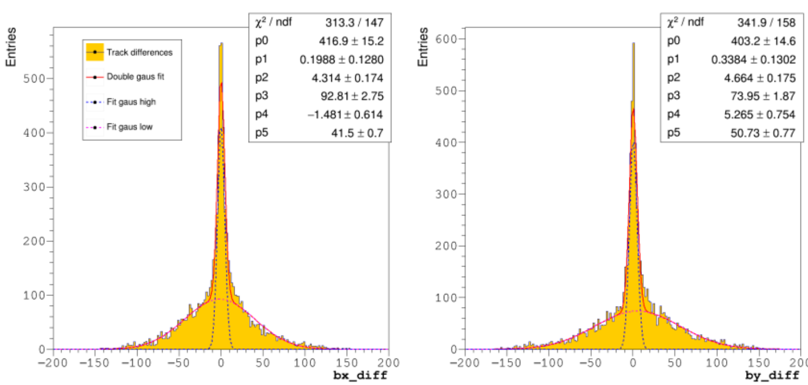


200 GeV μ⁻



Run: 744283

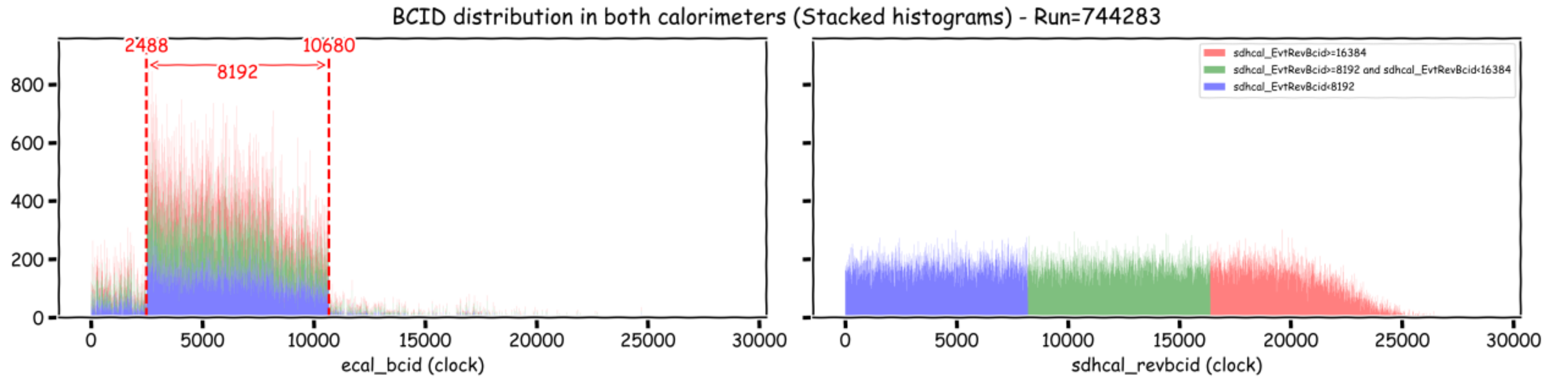
200 GeV μ⁻ (After rematching)



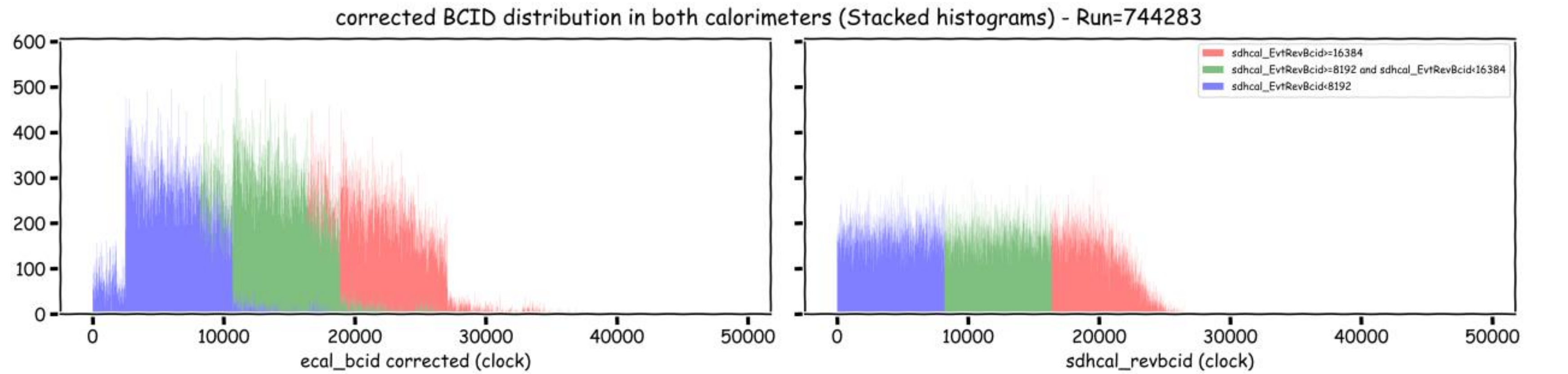
Run: 744283

SiWECal – SDHCal synchronization. $SiWECal_{BCID}$ *correction*

The BCID of the SiWECal gets overrun due to large acquisition times and requires correction.

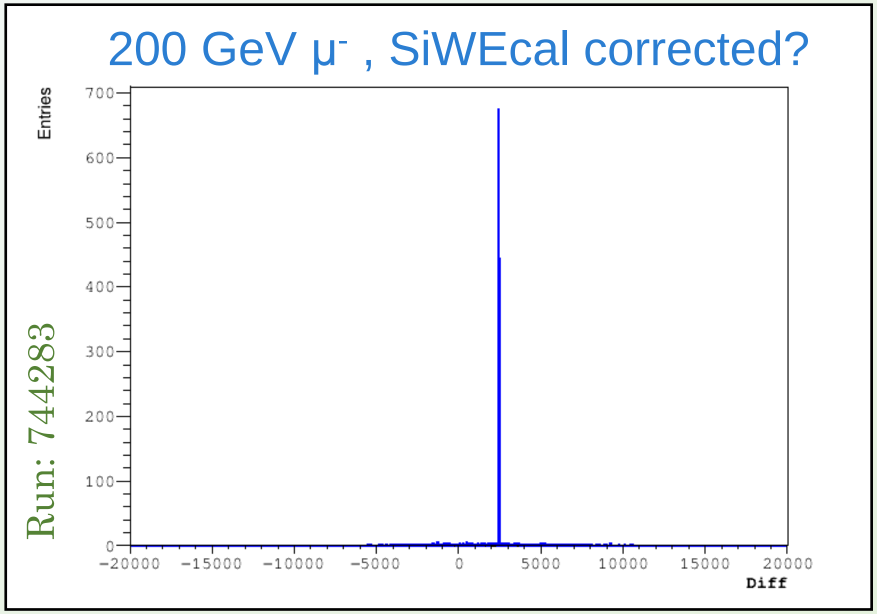


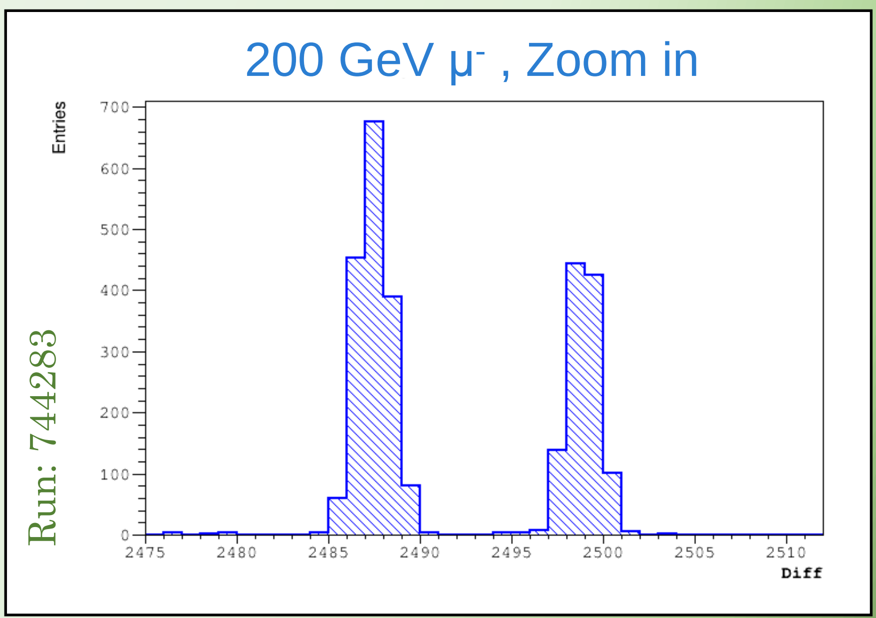
If $hcal_{BCID} > n * 8192 \rightarrow ecal_{BCID} = ecal_{BCID} + n * 8192$



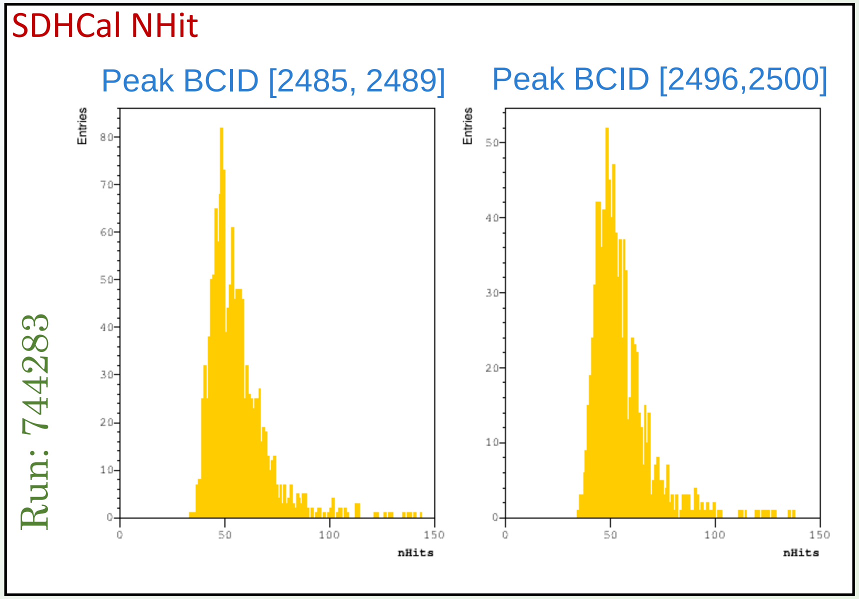
SiWECal – SDHCal synchronization

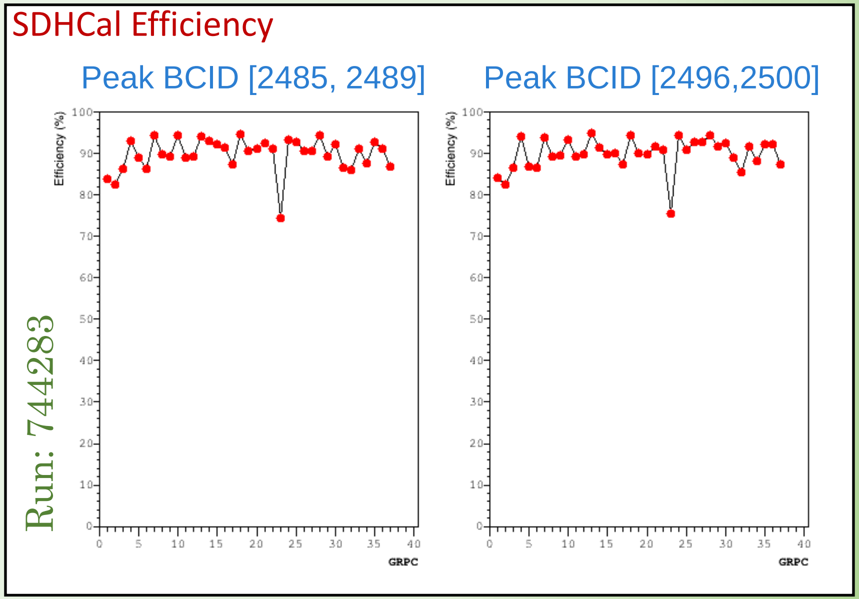
Once the BCID is *"corrected"* if we take a look with more precision we find two peaks:

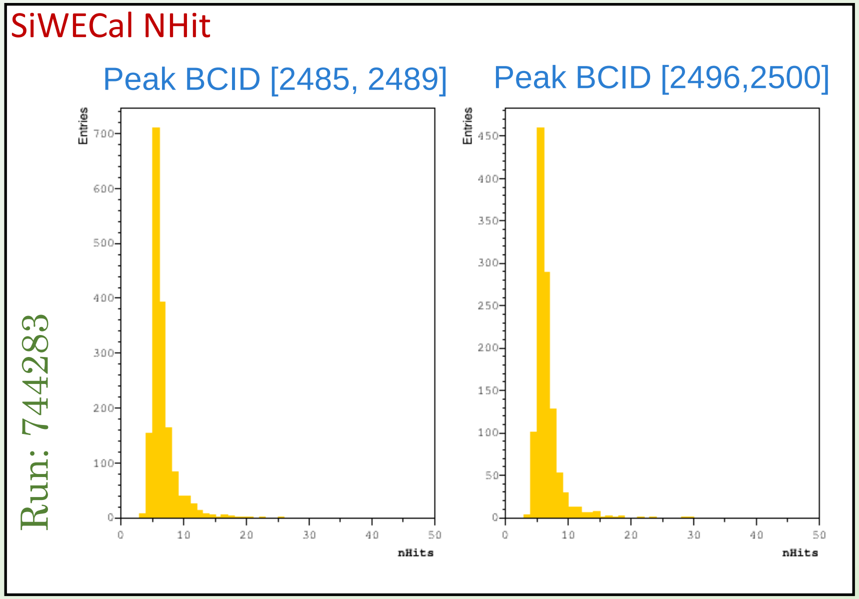


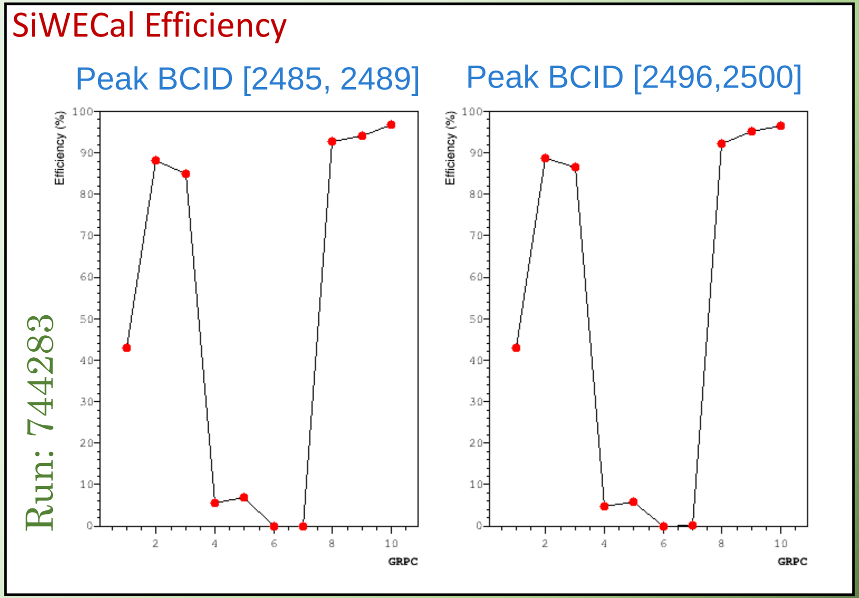


SiWECal – SDHCal synchronization. Peaks validation



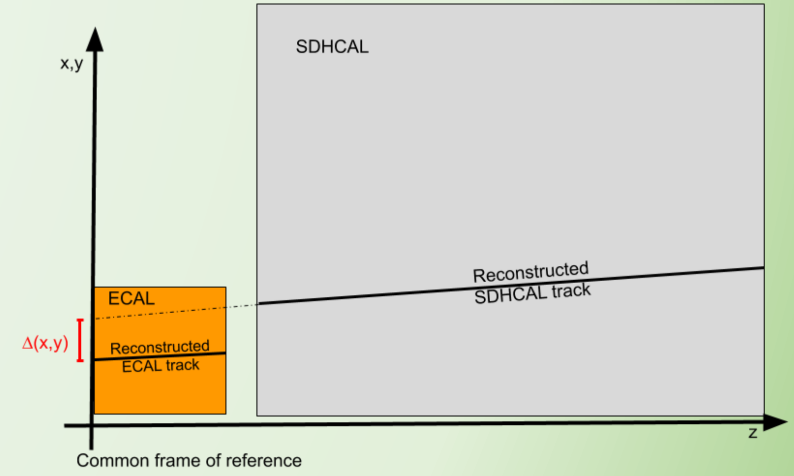




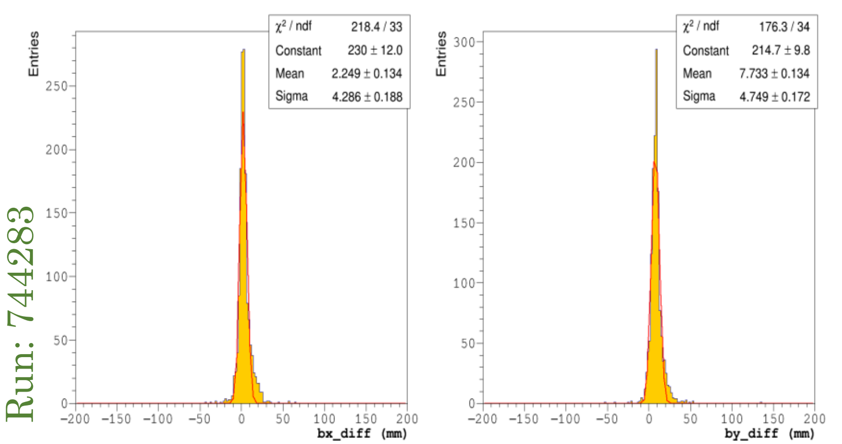


SiWECal – SDHCal synchronization. Peaks track differences

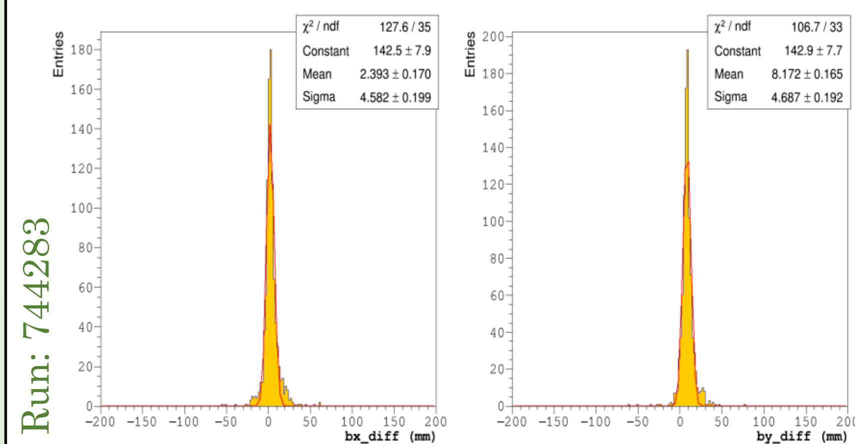
Trying to find a correlation between the track differences and any of the two synchronization peaks have been unfruitful.



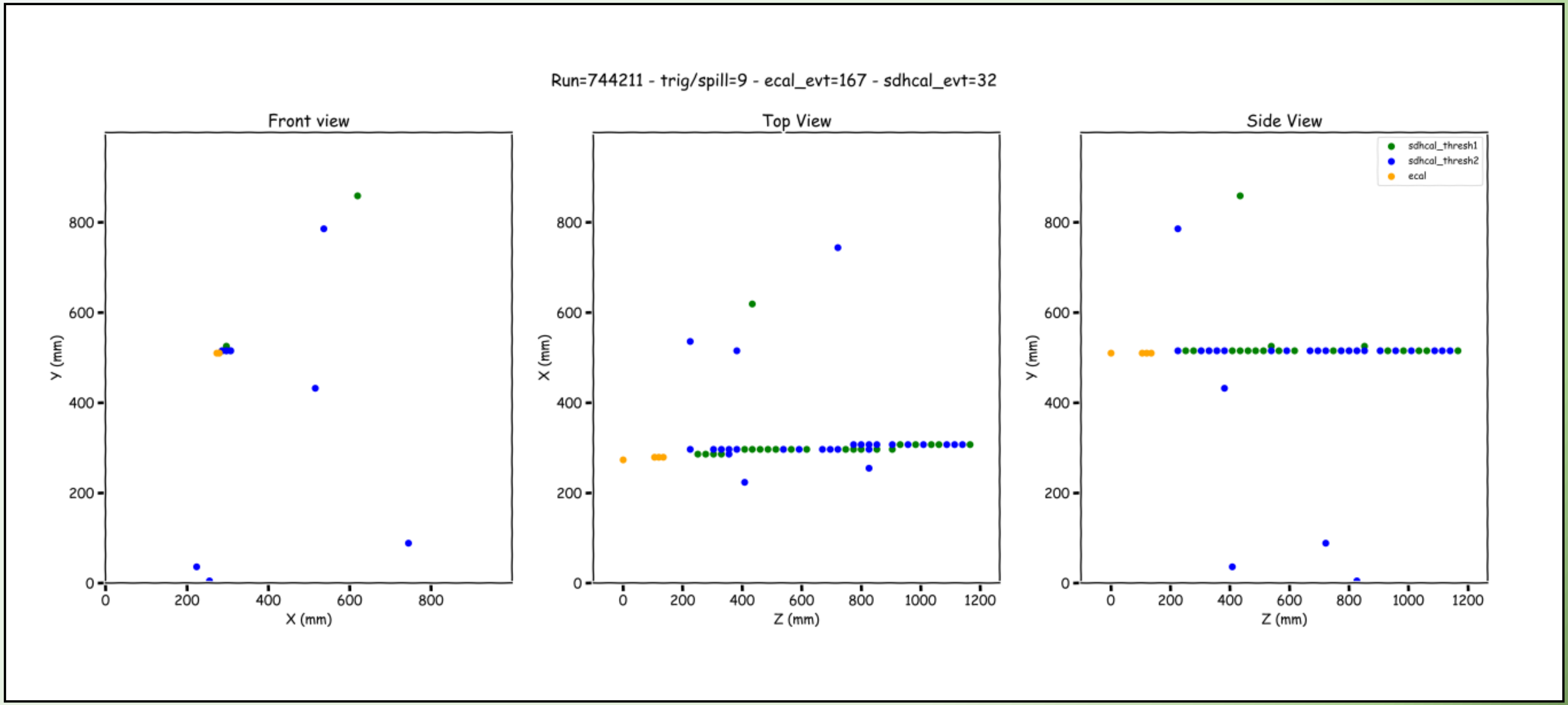
Peak BCID [2485, 2489]



Peak BCID [2496,2500]



Common events visualizer. 200 GeV Muon



Contained Pions selection

Selection for the set of Pions:

- No real e^- contamination observed in the data so we will assume it to be negligible.
- Events inside the SiW-ECal must behave like a MIP.
- Compute the layer in which the shower starts *ipStart* in the SDHCal:

  - First consider a region $X_{10} = 10x10\ pads$ around the axis of the shower (approximated as the mean value of al hits in the detector).

  - Then count the hits inside X_{10} for each layer.

  - Finally *ipStart* will be the first layer in a set of 3 layers with more than 4 hits in X_{10}.

  - In the case that the start of the shower is not found $ipStart = -1$

Contained Pions selection

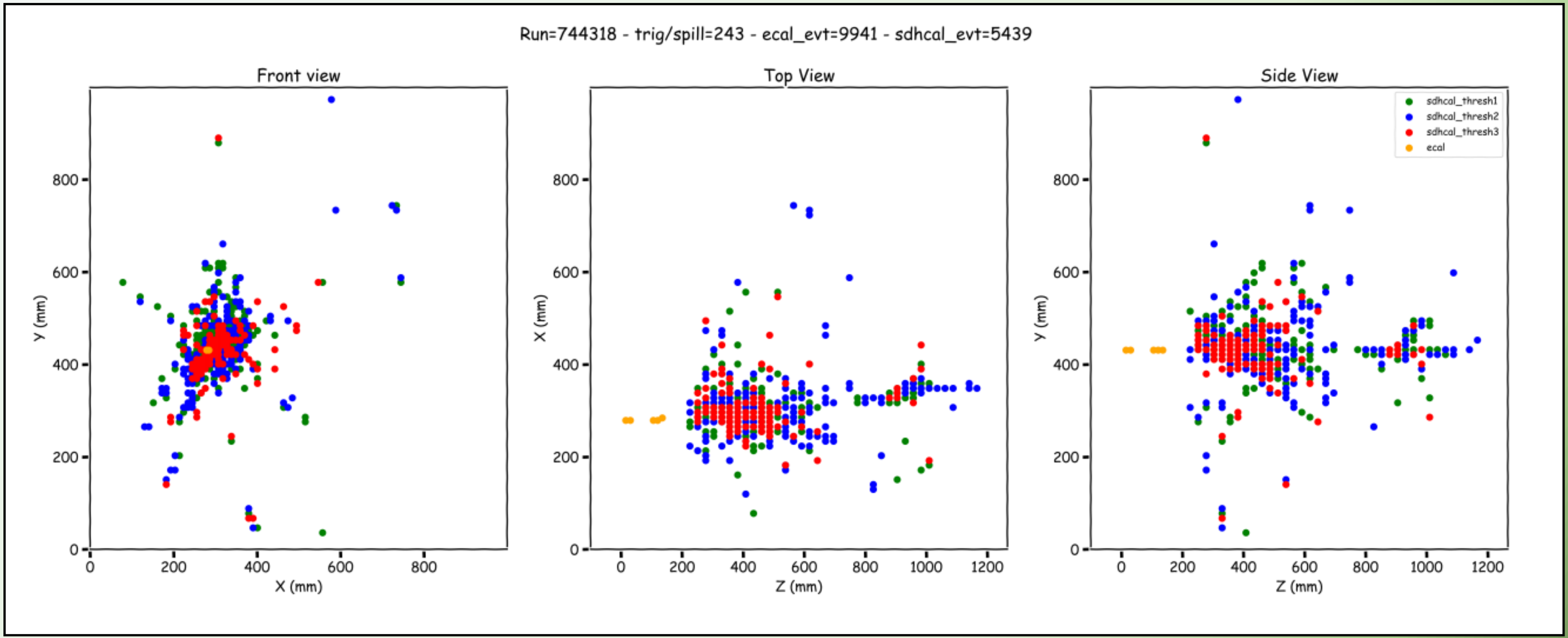
We want showers that are contained inside the SDHCal then adapting the cuts from 2012 taking into account the presence of the SiW-ECal we make the selection:

$$ipStart < 10 \quad \& \quad \mathrm{ipStart} > 0$$

We end with the final selection of Pions with the following statistics:

Run type	Nº Matched Events	Nº runs analyzed
200 GeV Muons	37900	18
40 GeV Pions	1110	4
50 GeV Pions	490	4
60 GeV Pions	1561	5
70 GeV Pions	1549	4
80 GeV Pions	282	2

Common events visualizer. 70 GeV Pion



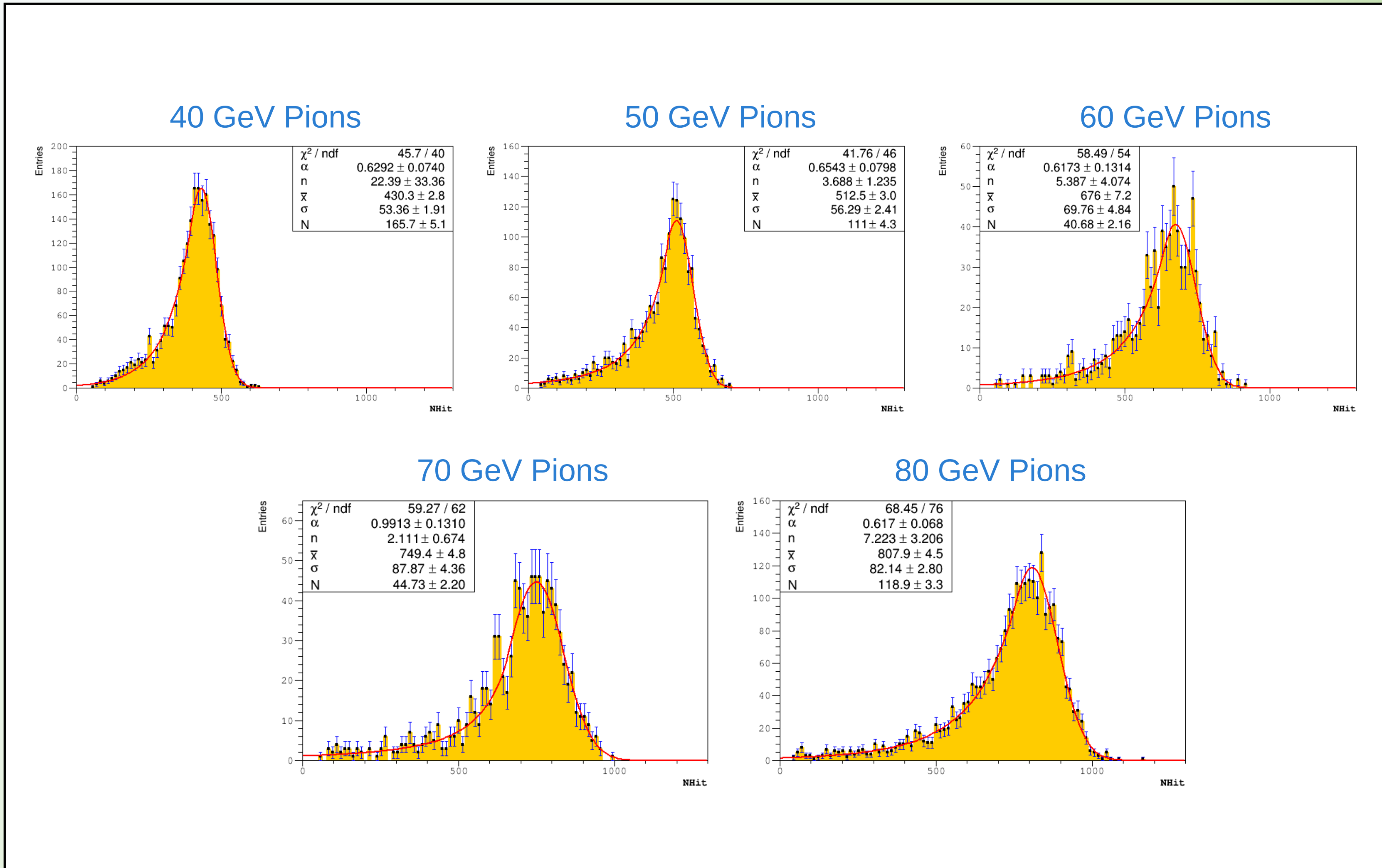
Crystal-Ball function

The distribution of nHit are fitted using the Crystal-Ball function defined as:

$$f(x;\alpha,n,\bar{x},\sigma) = N \cdot \begin{cases} \exp\left(-\frac{(x-\bar{x})^2}{2\sigma^2}\right) & if \quad \frac{x-\bar{x}}{\sigma} > -\alpha \\ A \cdot \left(B - \frac{x-\bar{x}}{\sigma}\right)^{-n} & if \quad \frac{x-\bar{x}}{\sigma} \leq -\alpha \end{cases}$$

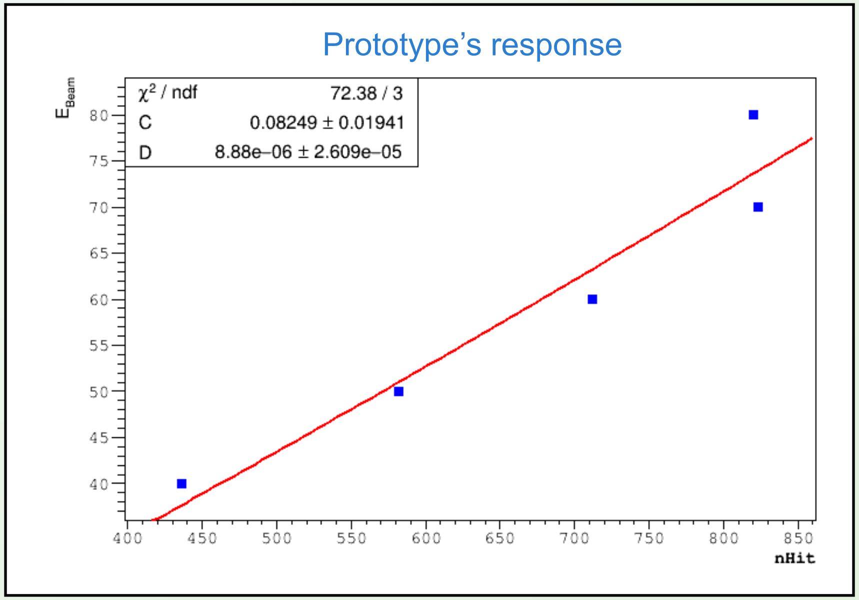
$$A = \left(\frac{n}{|\alpha|}\right)^n \cdot exp\left(-\frac{|\alpha|^2}{2}\right) \qquad \text{and} \qquad B = \frac{n}{|\alpha|} - |\alpha|$$

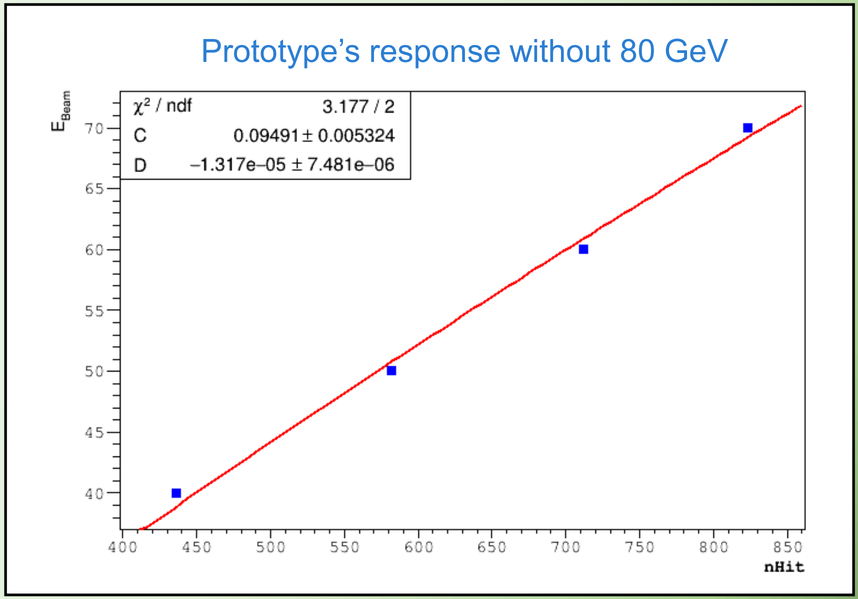
EReco. Digital mode. nHit distributions



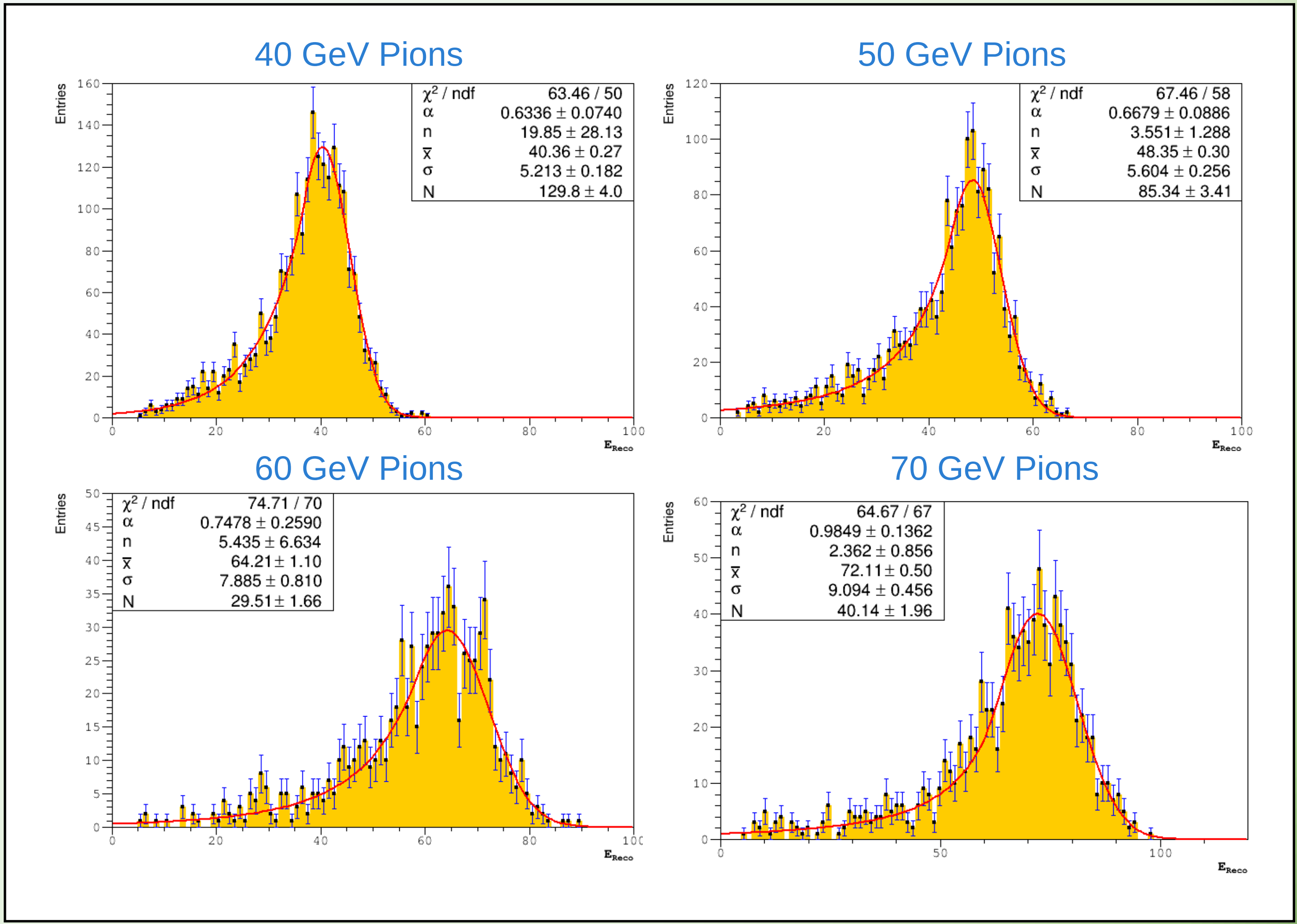
EReco. Digital mode. SDHCal response for pions

With the mean values from the previous fits we have the response of the protype for pions and we fit it to: $E_{reco} = (C + D \cdot N_{hit}) \cdot N_{hit}$

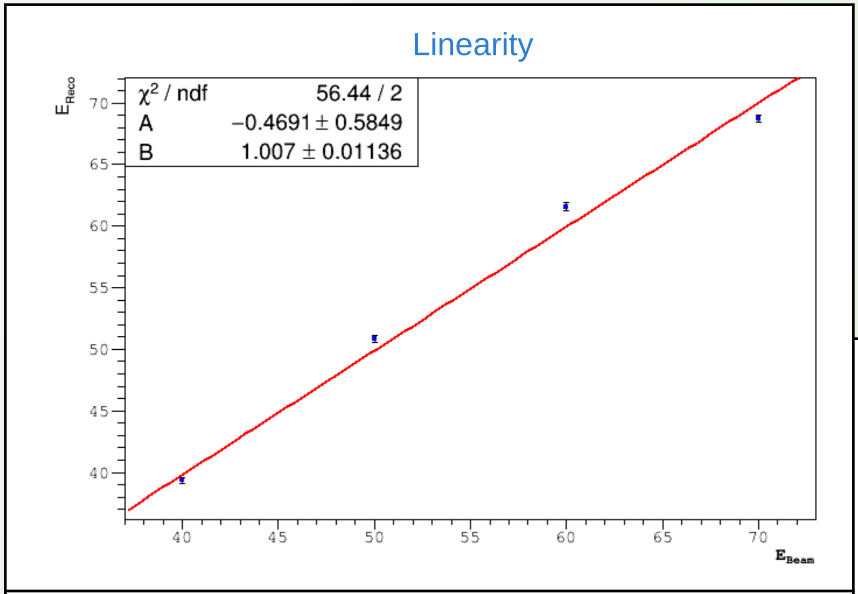


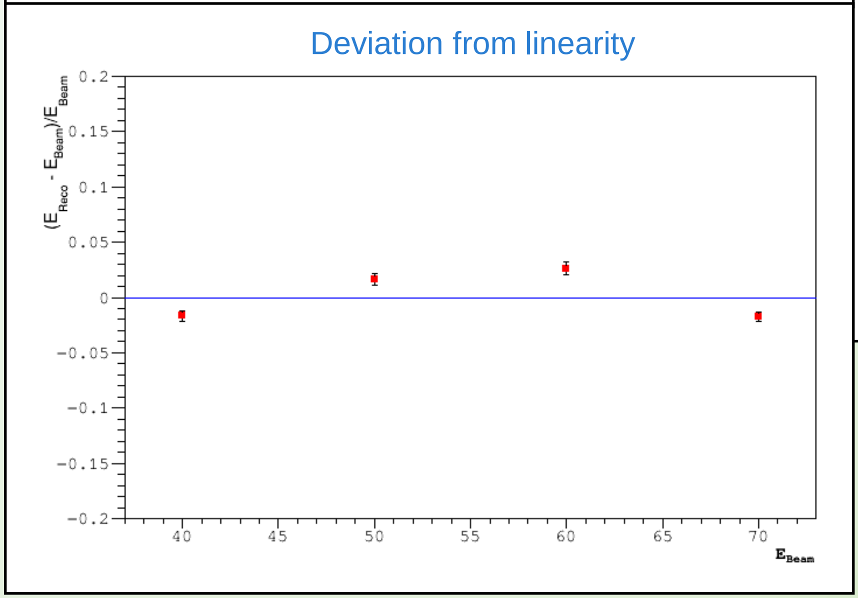


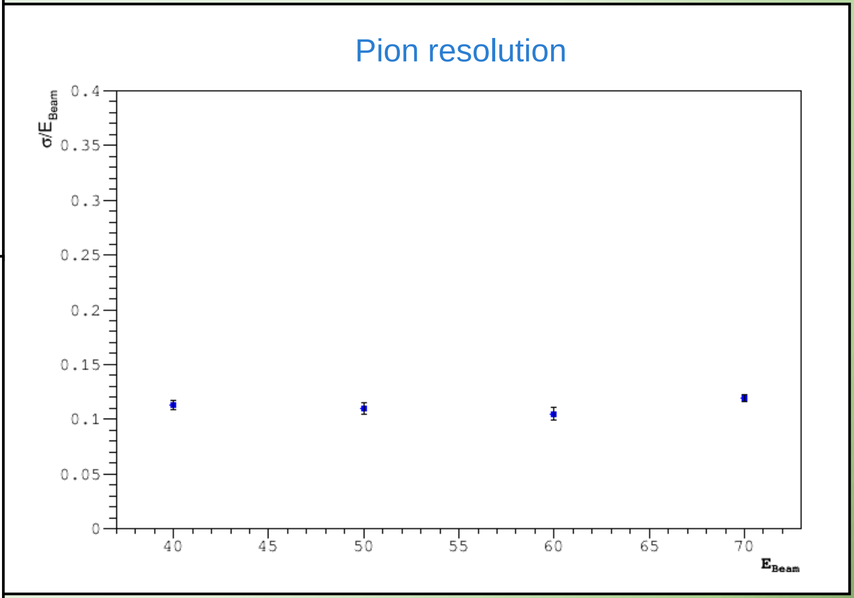
EReco. Digital mode. Reconstructed energy



EReco. Digital mode. Linearity and resolution







Summary

- The analysis for 2018 data was based on the ones performed with the 2012 data, finding similar results for efficiencies and multiplicities.
- Synchronized events between the ECal and SDHCal have been found. Common muon tracks allowed for geometrical alignment corrections.
- It was possible to reconstruct the energy of common pion showers contained inside the SDHCal in the digital mode of operation, despite the low statistics.

Back-up

ROOT Files production

Raw data as produced by the DAQ can be found locally in:

eos: **/eos/project/s/sdhcal/data/SPS_09_2018/Raw/**
gaeuicali1 (Ciemat): **/pool/calice/carrillo/TB2018/**

ROOT Files produced with Gerald's code are stored in:

eos: **/eos/project/s/sdhcal/ROOT/**
gaeuicali1 (Ciemat): **/pool/calice/hectorgc/Data/**

In both folders there is a **RunsList.txt** with comments about the runs processed, bad data, etc.

ROOT File names: **run_** + run number + **_TriventSplit.root**

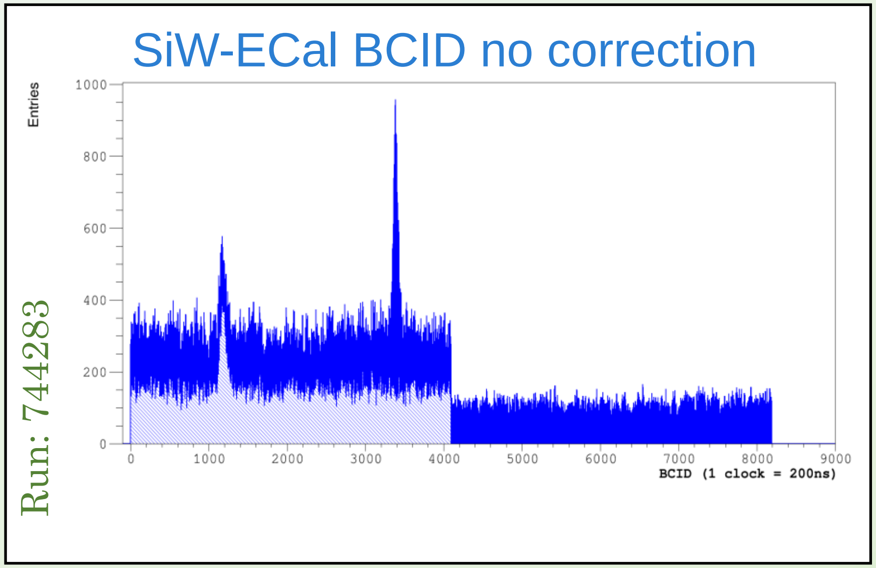
Each ROOT File has a *README* object that explains the variables in the TTree.
Additional information can be found in: *gitlab.cern.ch/carrillo/calice*

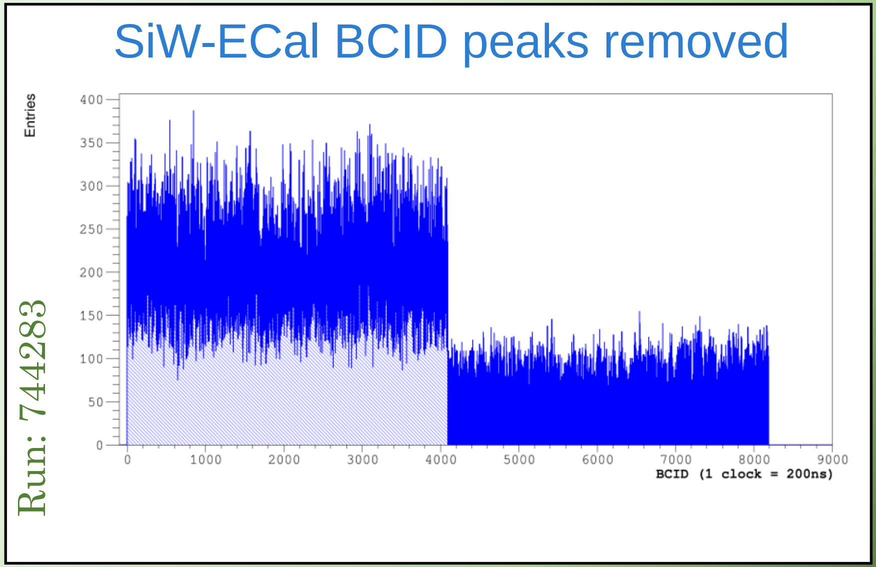
SiW-Ecal BCID distribution

Scripts for production of ROOT files in the SiW-ECal can be found in:
https://github.com/SiWECAL-TestBeam/SiWECAL-TB-analysis/tree/TB201809_10slabs

The BCID overrun correction is made without an external clock before time clustering in *mergeRootFiles.py.* However, layers with different frequency of operation could lead to mismatched hits.

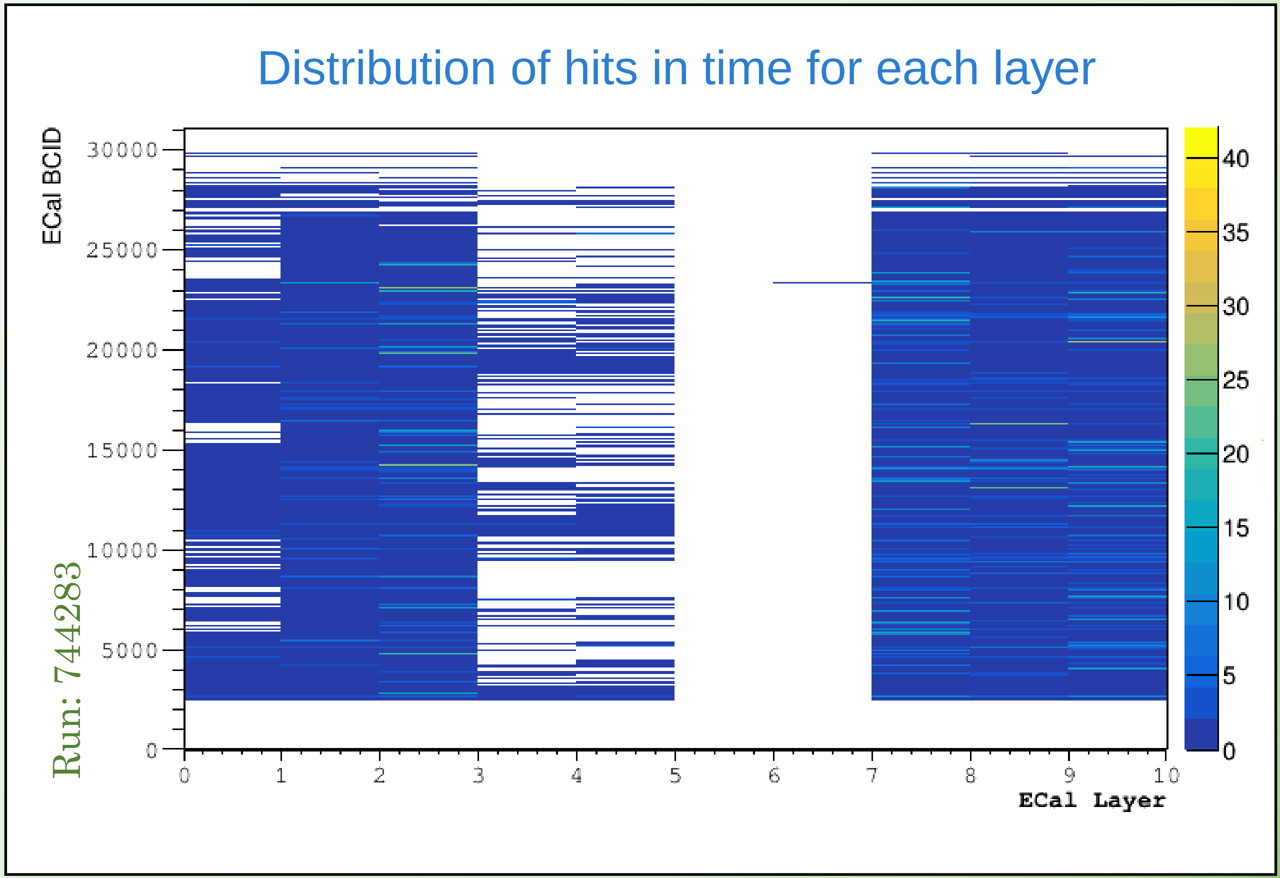
Seems to be two different channels producing retriggers and multiple consecutive events with a single hit in layers 0 and 1, each with a different faulty channel.





SiW-ECal BCID

Taking a look to the distribution of the hits in time for each layer shows that maybe the events are not properly reconstructed between slabs.



Longitudinal analysis of showers

We identify as a selection of particles showering in the detector the events that remain from the muon selection cuts. We now can make a longitudinal analysis of the showers by defining the following variable:

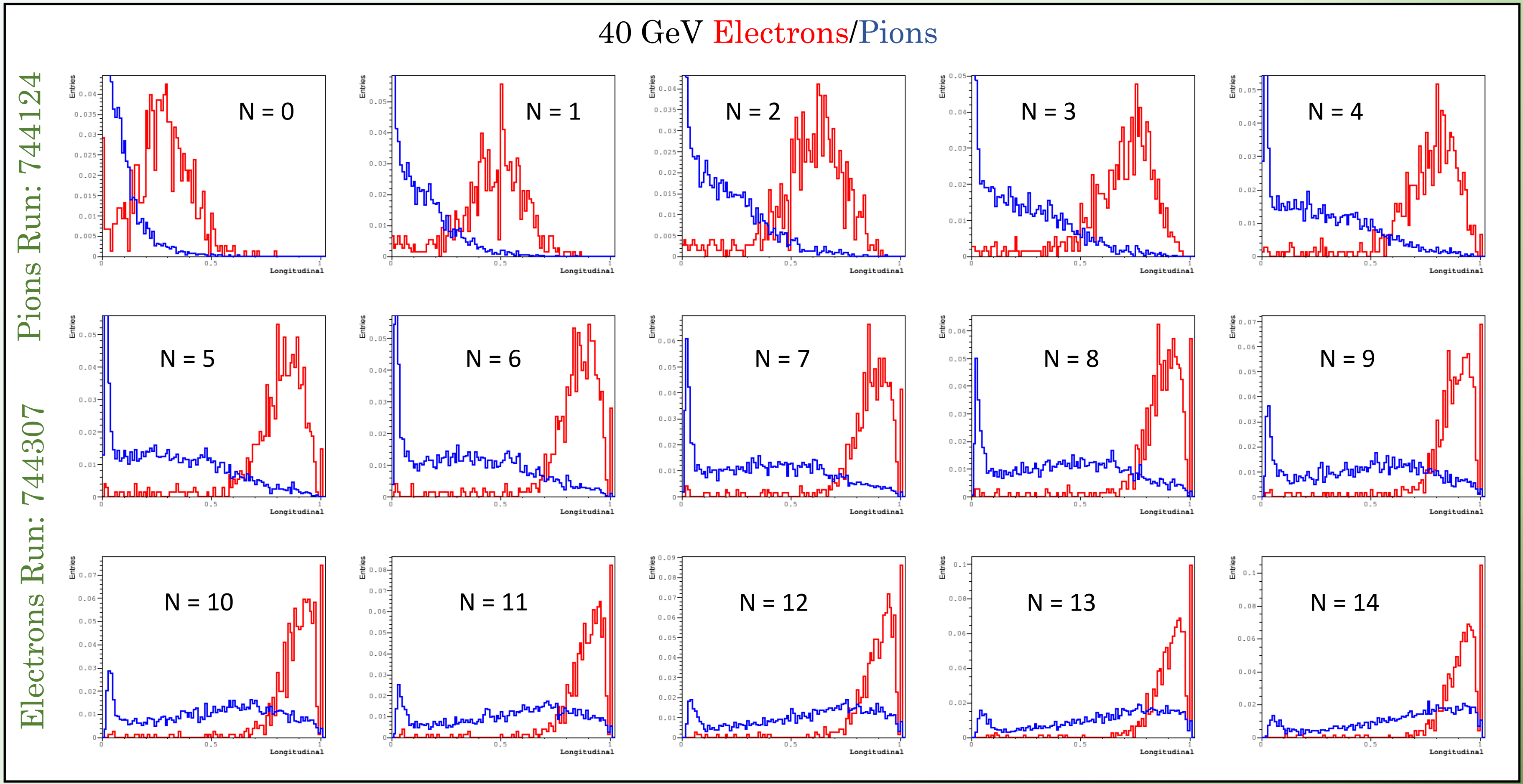
$$\mathrm{L}ongitudinal(N) = \frac{nHit(N)}{nHit}$$

Where $nHit(N)$ is the number of hits up to the layer N, included.

Then we can compute the value of *Longitudinal(N)* for different values of N using Pion and electron runs and compare the distributions.

Longitudinal analysis of showers

N = 0 is the first layer



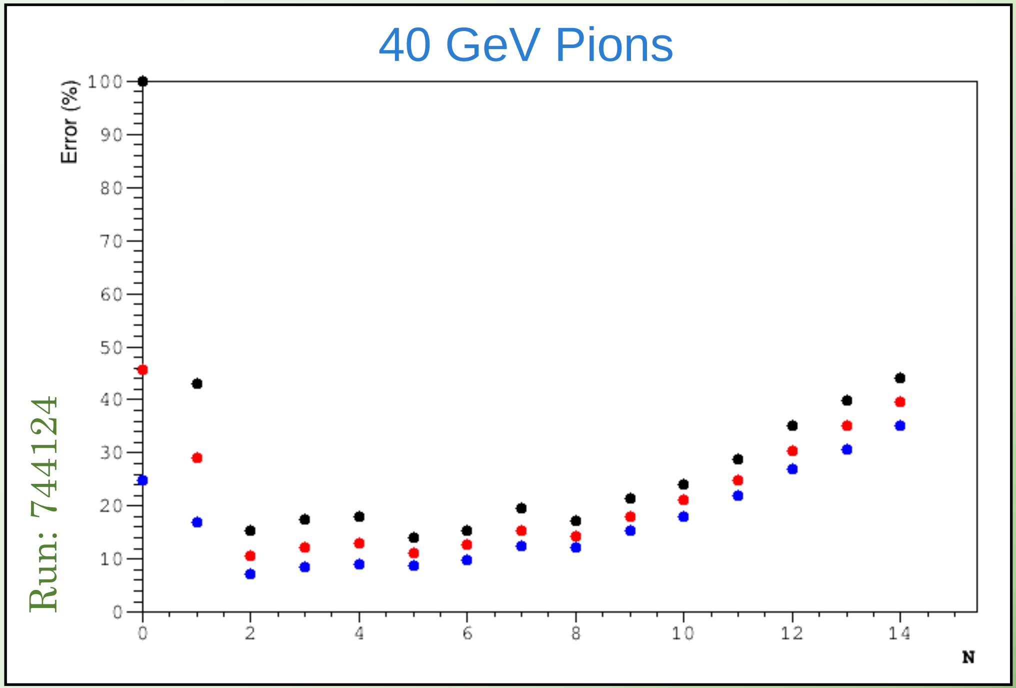
Longitudinal analysis of showers

Fitting to a Gaussian the Electrons distribution we can compute for each value of N the following variable:

$$Cut(N) = < \mathrm{L}ongitudinal(N) > - n\sigma$$

Where $< \mathrm{L}ongitudinal(N) >$ and σ are the mean and width of the fit and n is a testing value with three possibilities: 2, 2.5 and 3.

If $\mathrm{L}ongitudinal(N) \geq Cut(N)$ then the event is assigned as an electron. Using the Pion run we can compute the percentage of wrongly assigned events and find the optimal value of N minimizing the error.



SiWECal-SDHCal geometrical alignment

Using the matched tracks it is possible to try to find a correction to the SDHCal position by fitting to a Gaussian the differences of the tracks from both detectors.

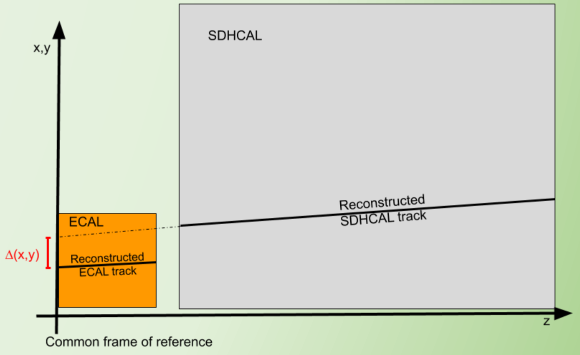
Single Gaussian fit:

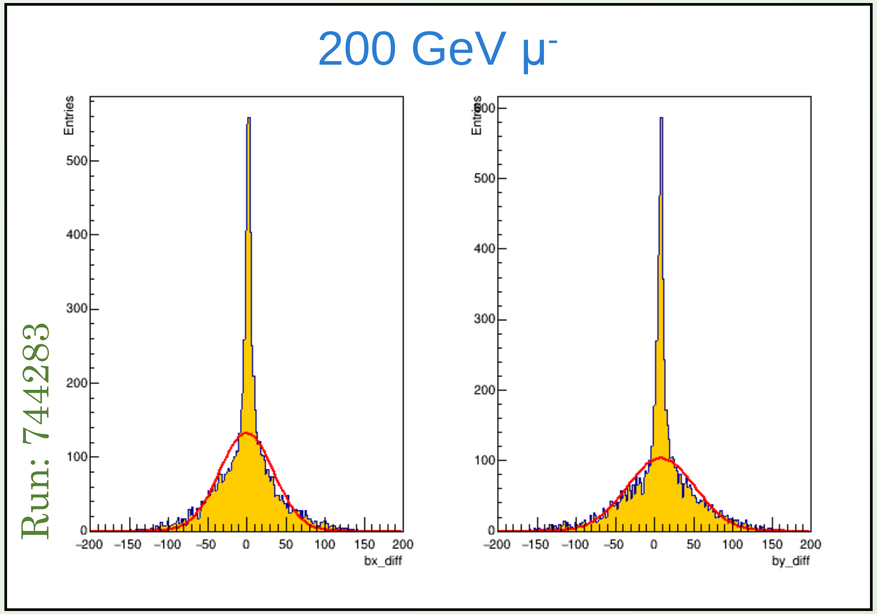
$$X'_{HCal} = X_{HCal} - \mu_X$$

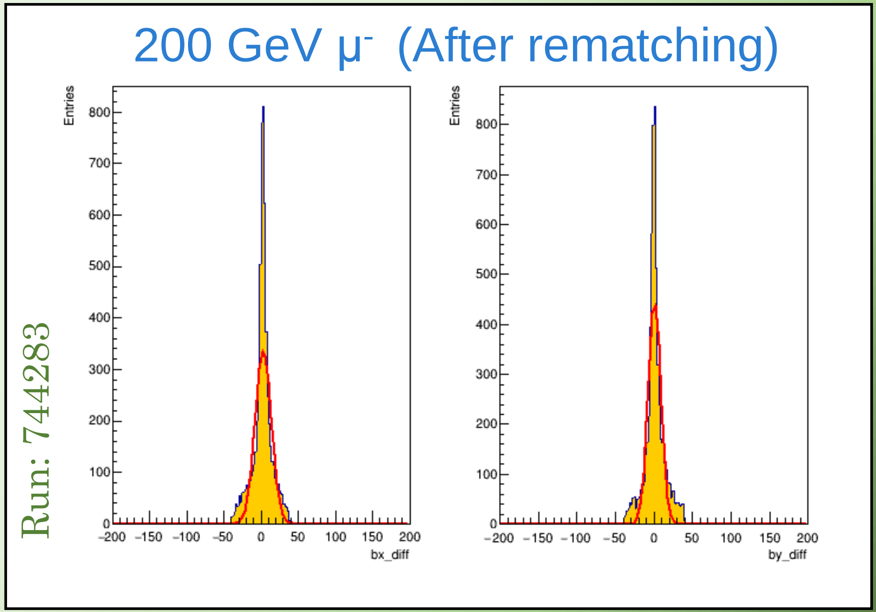
$$Y'_{HCal} = Y_{HCal} - \mu_Y$$

X: $\mu_X = -0.305 \pm 0.467$; $\sigma_X = 35.67 \pm 0.61$

Y: $\mu_Y = 8.104 \pm 0.508$; $\sigma_Y = 44.0 \pm 0.7$







EReco. Semi-digital mode. Preliminary

In this mode of operation we now know for each hit the value of the threshold crossed. In this case the energy is reconstructed with the following function:

$$E_{reco} = \alpha N_1 + \beta N_2 + \gamma N_3$$

$$N_{hit} = N_1 + N_2 + N_3$$

$$\alpha(N_{hit}) = \alpha_0 + \alpha_1 N_{hit} + \alpha_2 N_{hit}^2$$

$$\beta(N_{hit}) = \beta_0 + \beta_1 N_{hit} + \beta_2 N_{hit}^2$$

$$\gamma(N_{hit}) = \gamma_0 + \gamma_1 N_{hit} + \gamma_2 N_{hit}^2$$

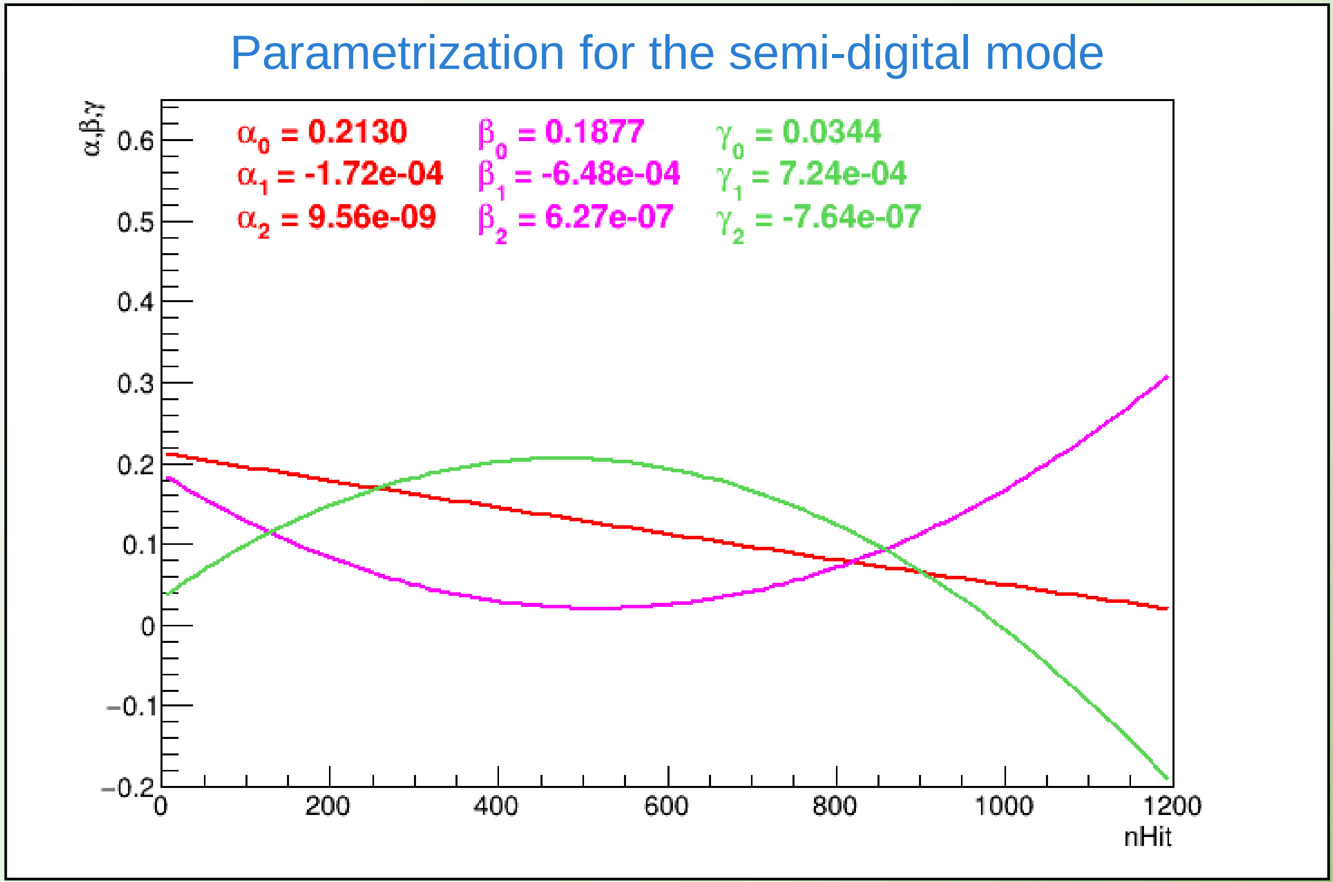
N_a is the number of hit that crossed the threshold *a.*

The optimal values of the parameters is found using the whole data set (*N events*) through the minimization of the following χ^2:

$$\chi^2 = \frac{1}{N} \sum_{i=0}^{N} \frac{\left(E_{beam} - E_{rec}^{i}\right)^2}{E_{beam}}$$

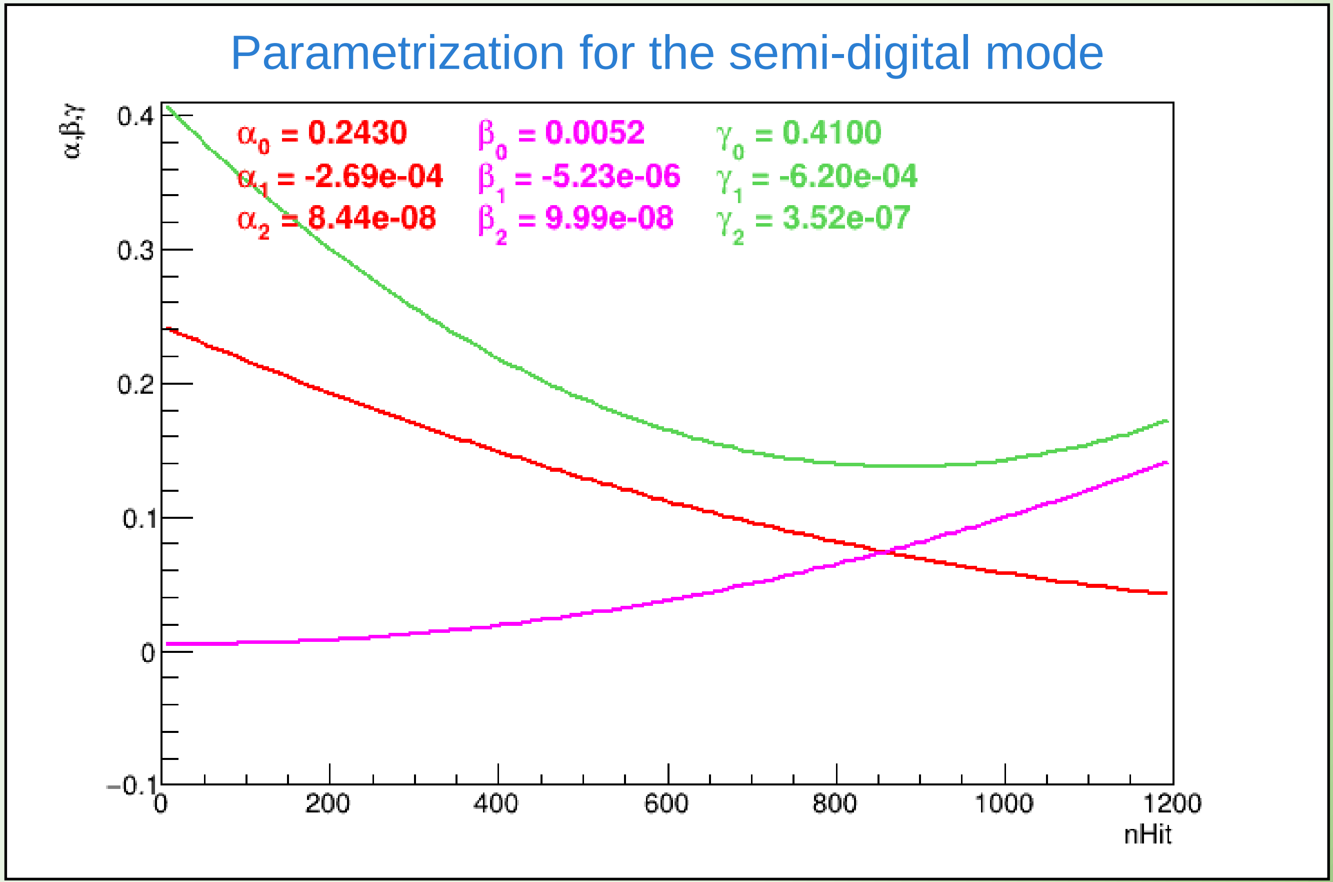
EReco. Semi-Digital mode. χ^2 minimization. Preliminary

Using the sets of data form the common events we obtain the following parameters:

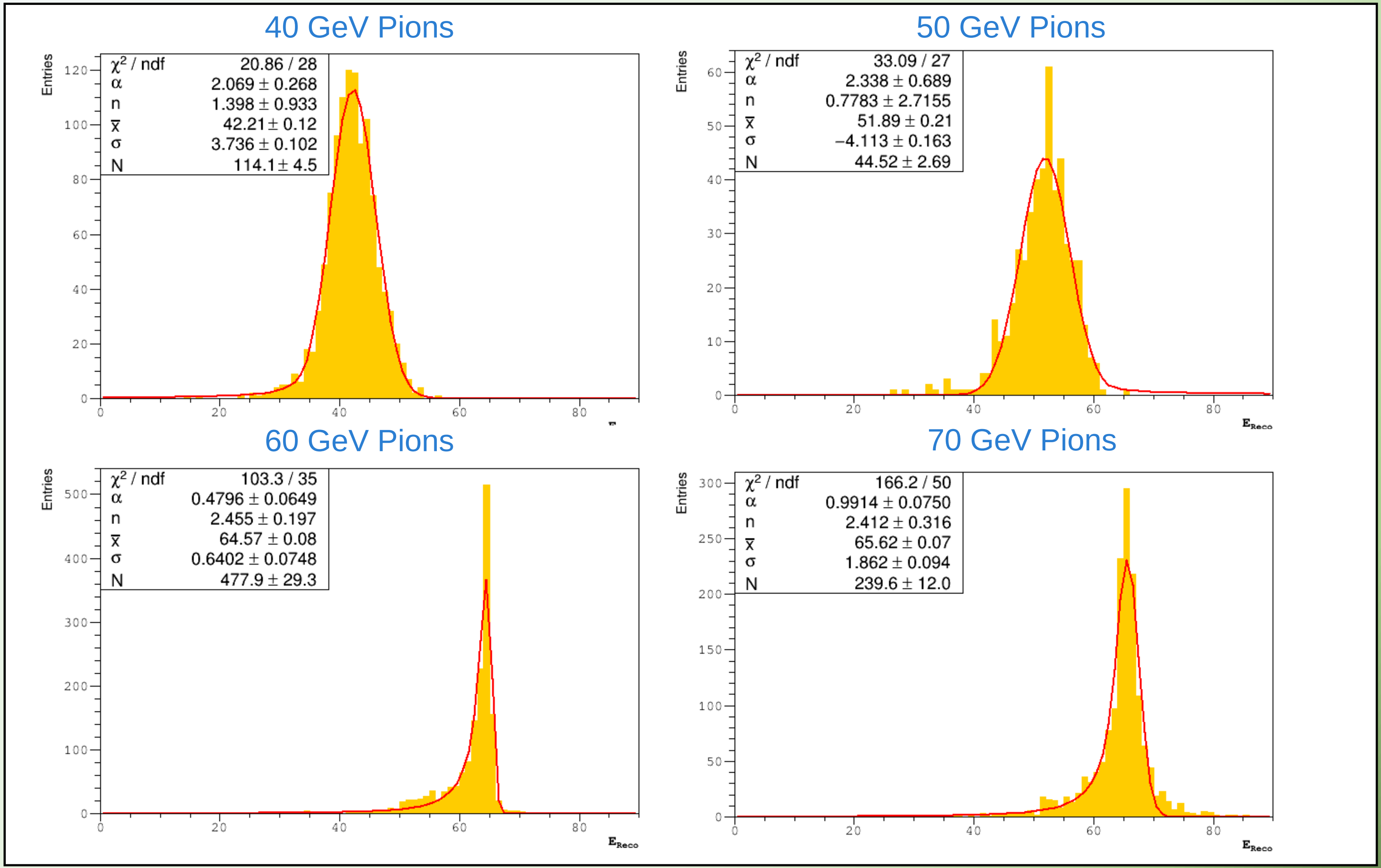


EReco. Semi-Digital mode. Constrained χ^2 minimization. Preliminary

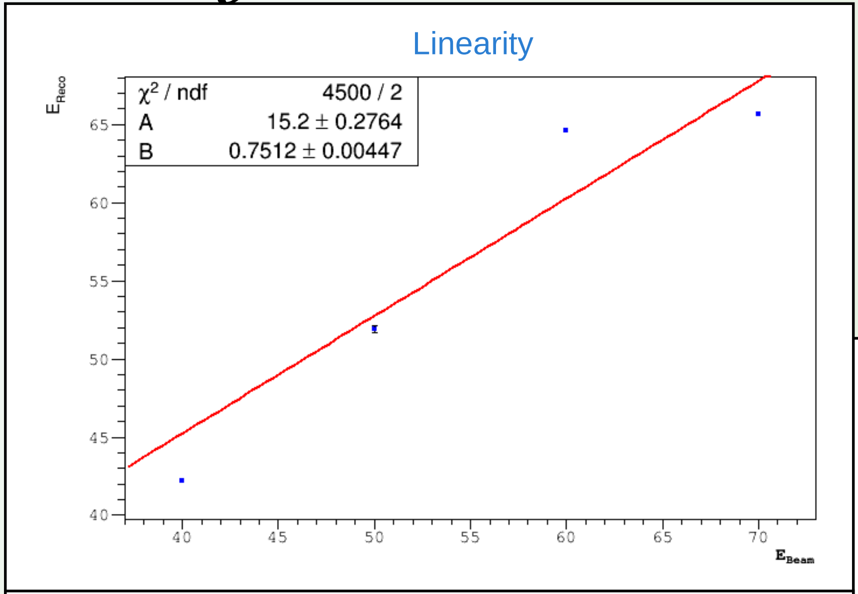
Now we apply constraints to the parameters to avoid unphysical results:

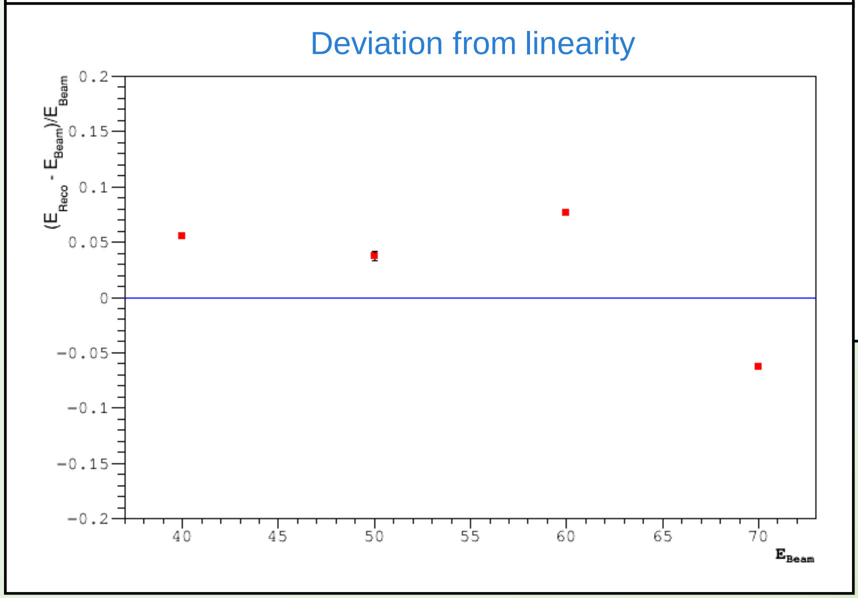


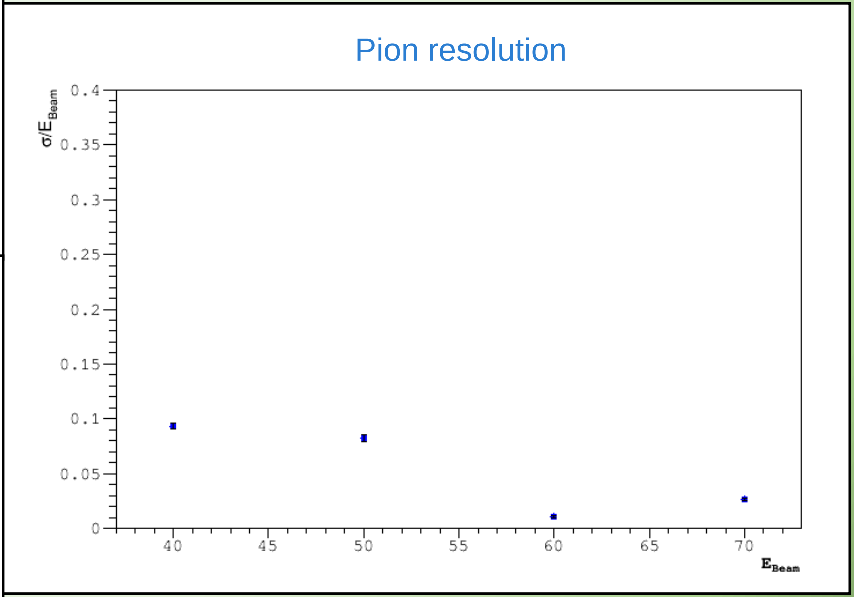
EReco. Semi-Digital mode. Reconstructed energy. Preliminary



EReco. Semi-Digital mode. Linearity and resolution. Preliminary

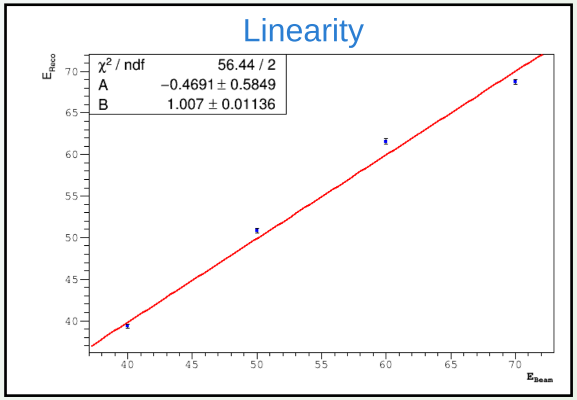


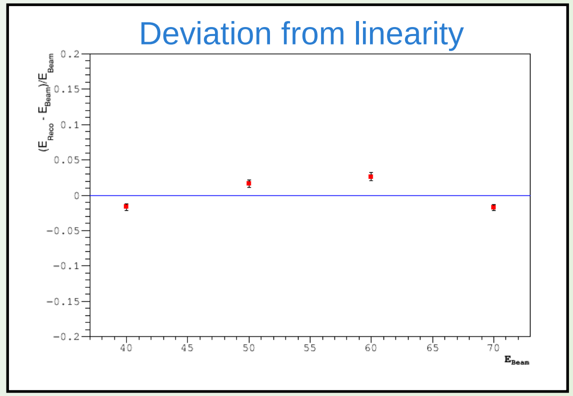


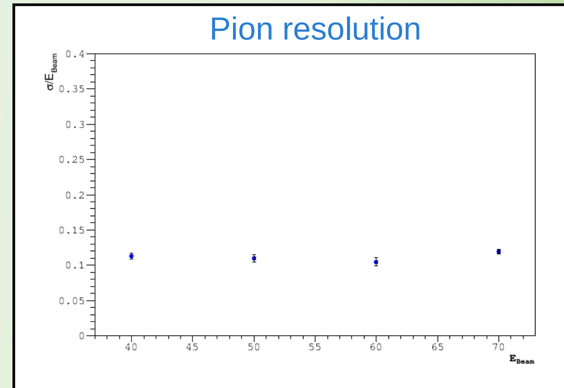


Comparison of modes. Preliminary

Digital mode:







Semi-Digital mode: