Update on the common SiWECal – SDHCal TB data analysis

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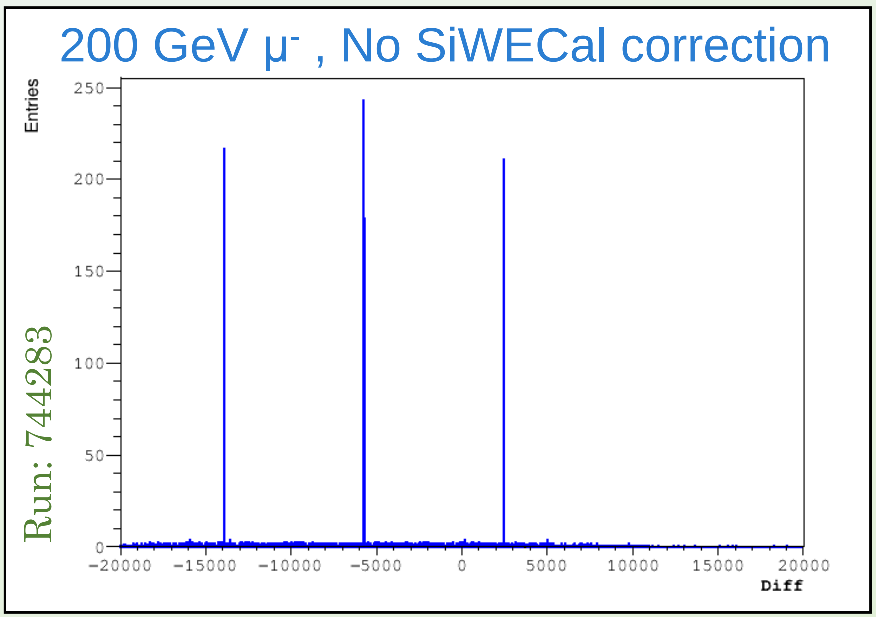
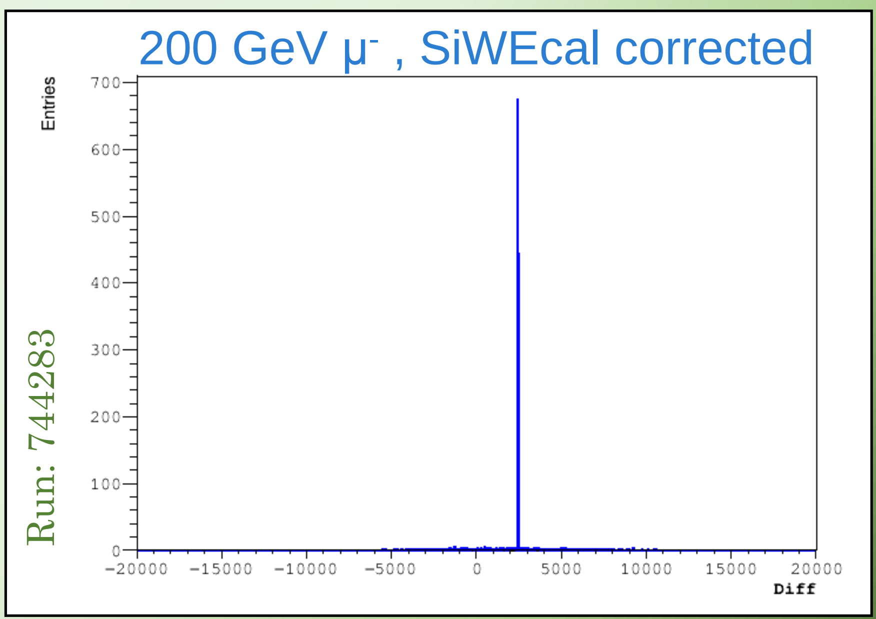
SiWECal – SDHCal synchronization

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

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

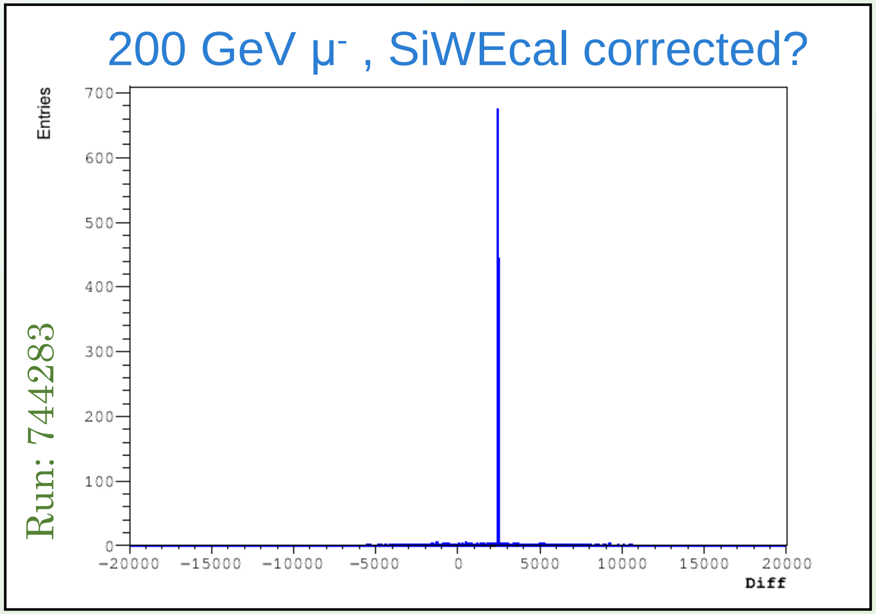
- The two tracks with the closest set of parameters are selected as a match.

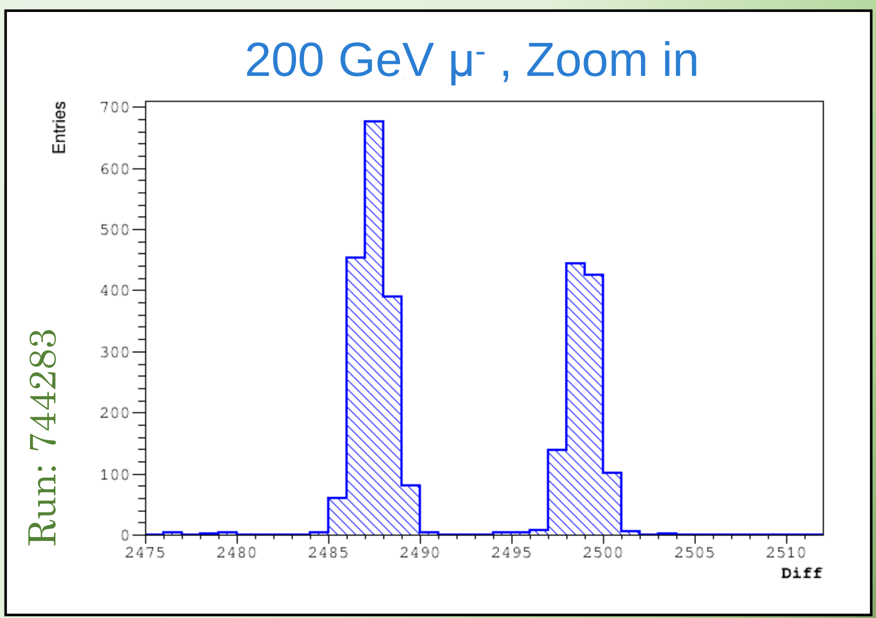




SiWECal – SDHCal synchronization

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



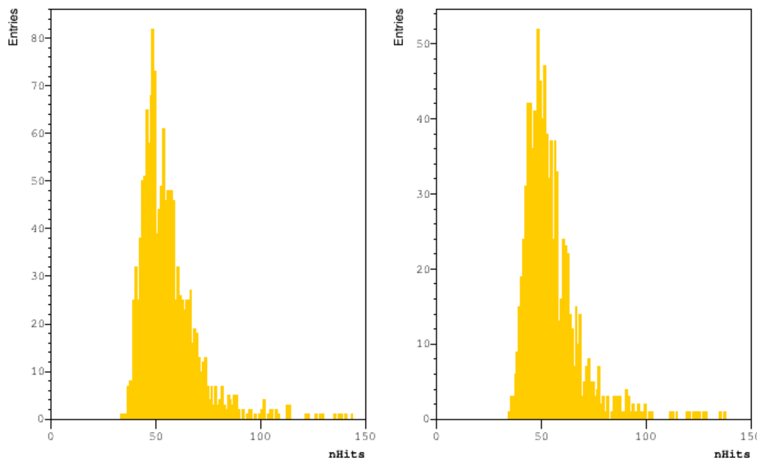


SiWECal – SDHCal peaks validation.

SDHCal NHit

Peak BCID [2485, 2489] Peak BCID [2496,2500]

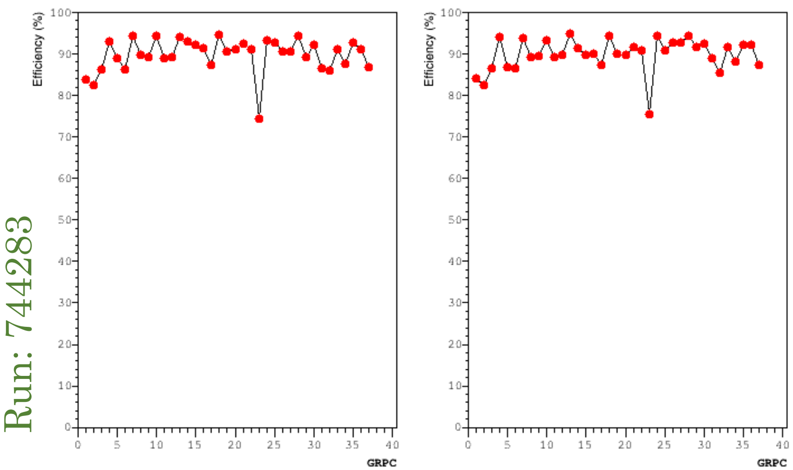
Run: 744283



SDHCal Efficiency

Peak BCID [2485, 2489] Peak BCID [2496,2500]

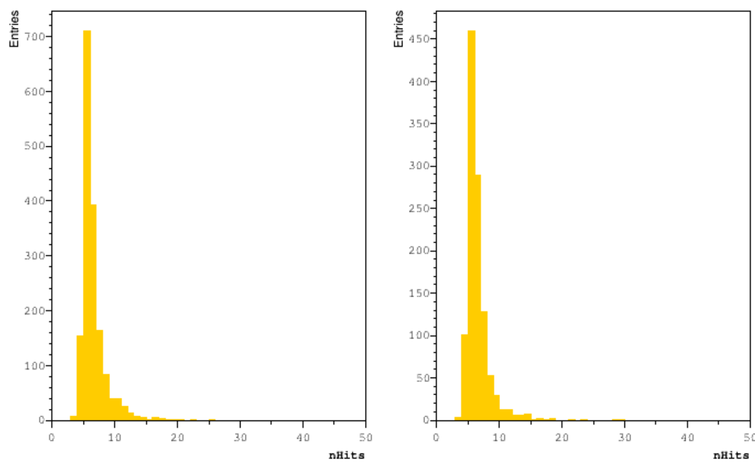
Run: 744283



SiWECal NHit

Peak BCID [2485, 2489] Peak BCID [2496,2500]

Run: 744283



SiWECal Efficiency

Peak BCID [2485, 2489] Peak BCID [2496,2500]

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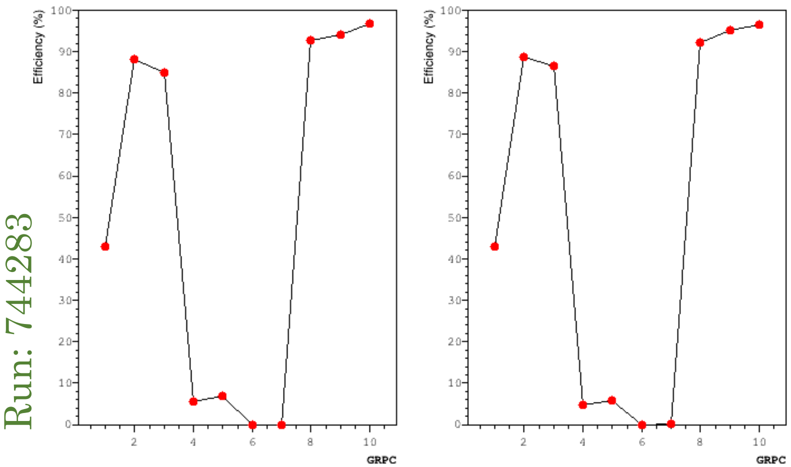
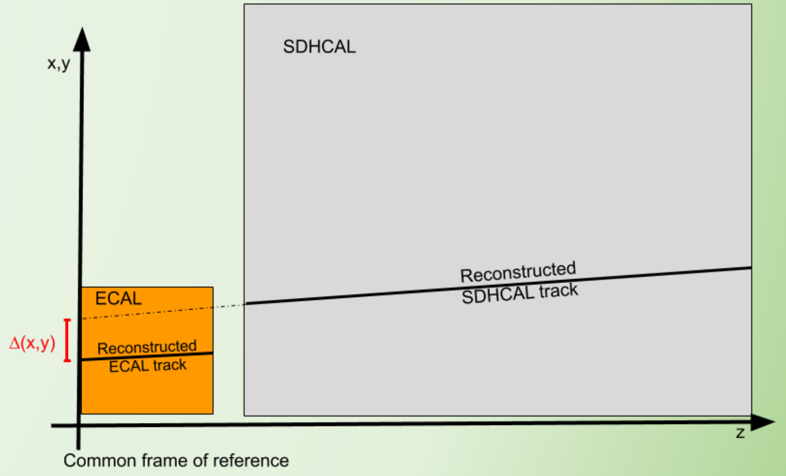
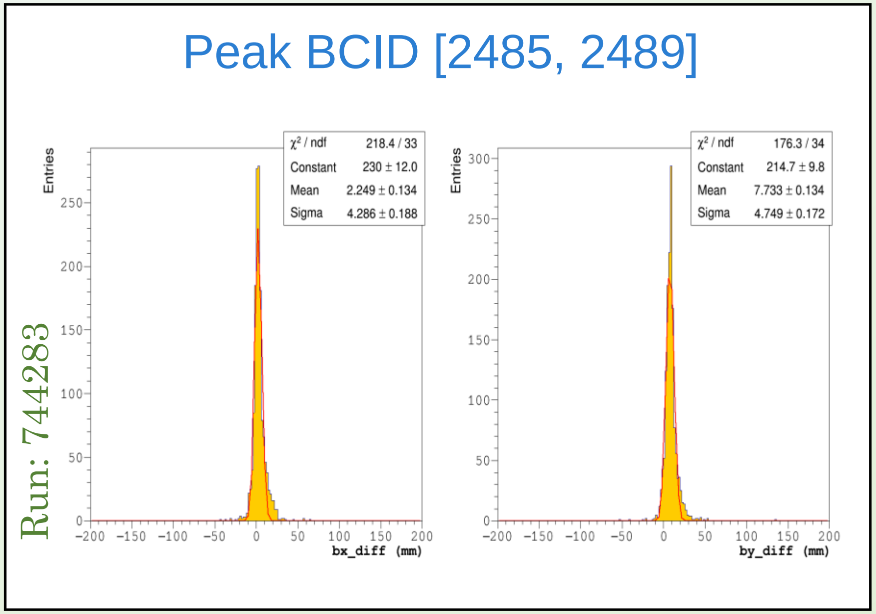
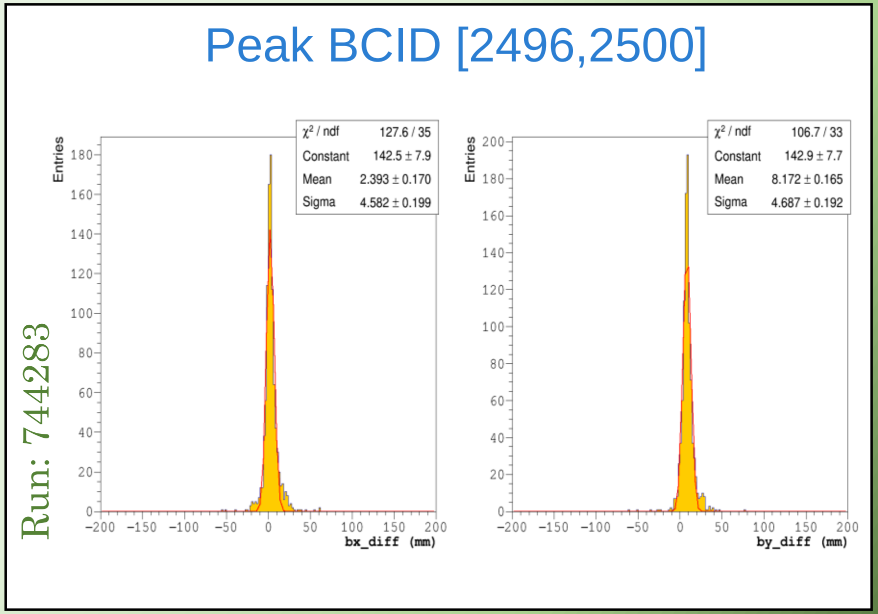


SiWECal-SDHCal BCID peaks – track differences

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







Common events statistics

All the macros for analysis can be found in:

CERN: **/afs/cern.ch/user/h/hegarcia/public/TB_StandarAnalysis/**

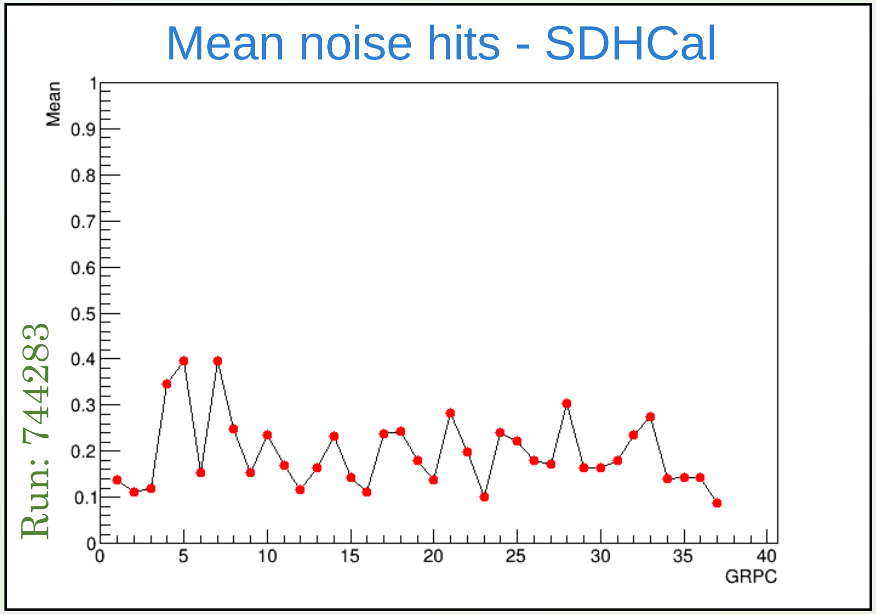
Look for the *README.txt* for information in how to run the BCID matching.

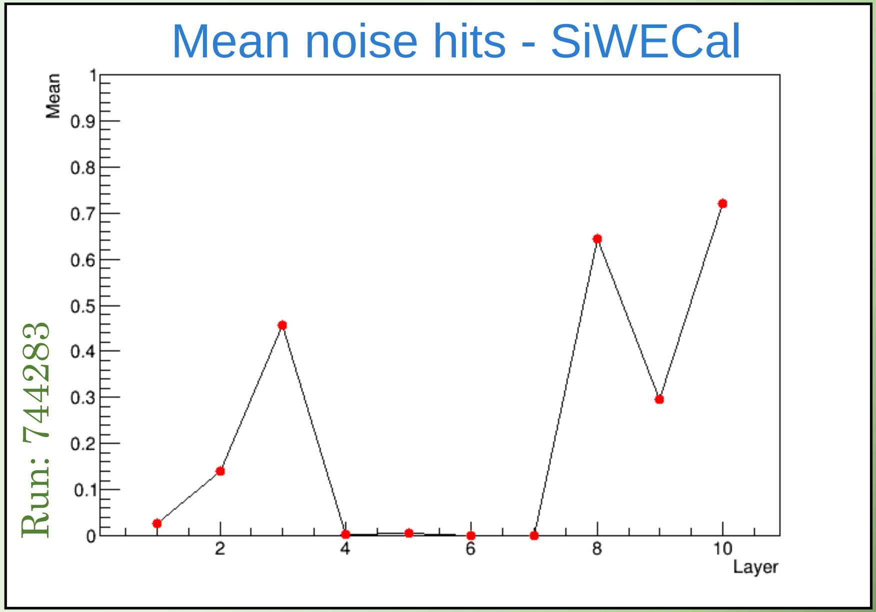
Using the synchronization macros we can compute the amount of common events falling in both *BCID Diff* peaks:

Run type	Nº Matched Events	Nº runs analyzed
200 GeV Muons	37900	18
40 GeV Pions	4385	4
50 GeV Pions	2043	4
60 GeV Pions	6969	5
70 GeV Pions	6553	4
80 GeV Pions	1396	2

Mean noise hits

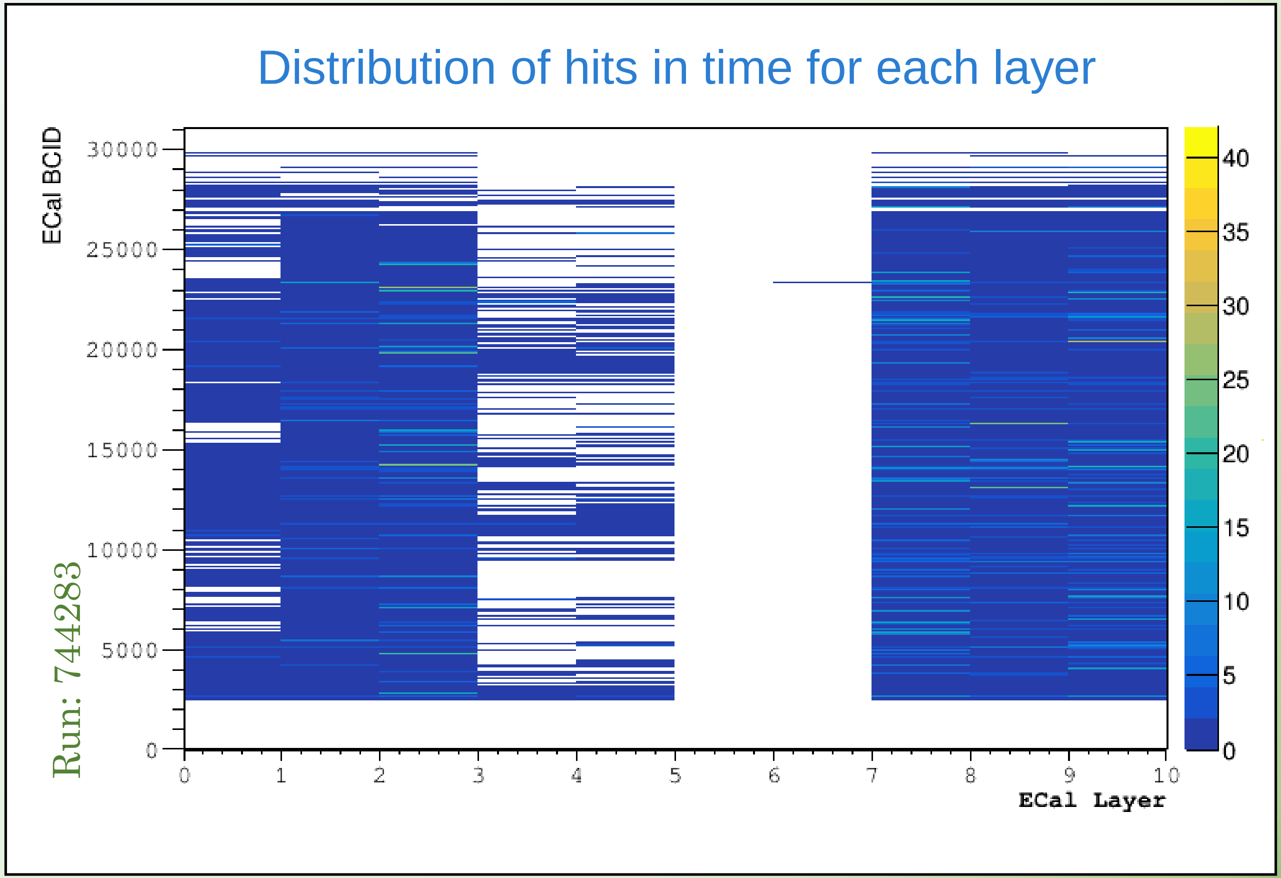
Noise hit: Defined as a hit which is not associated to a muon track.





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.

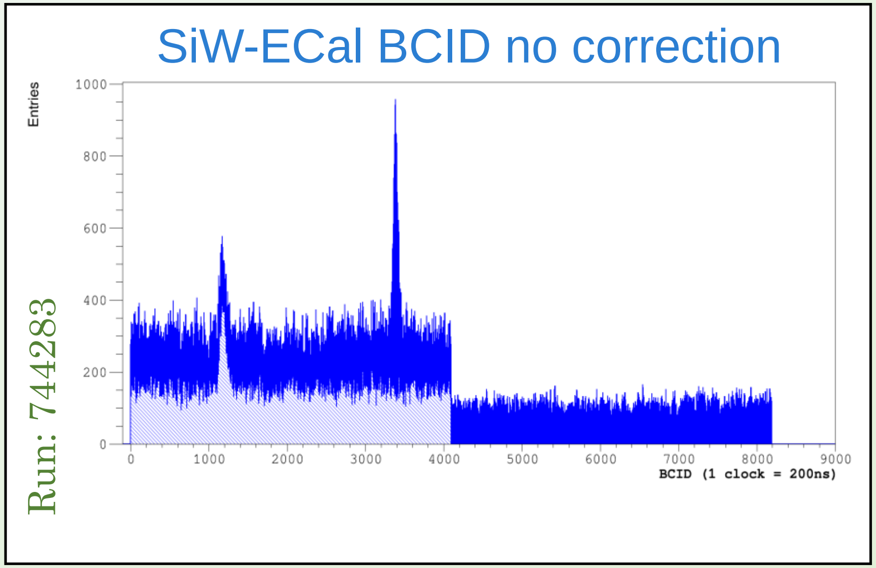


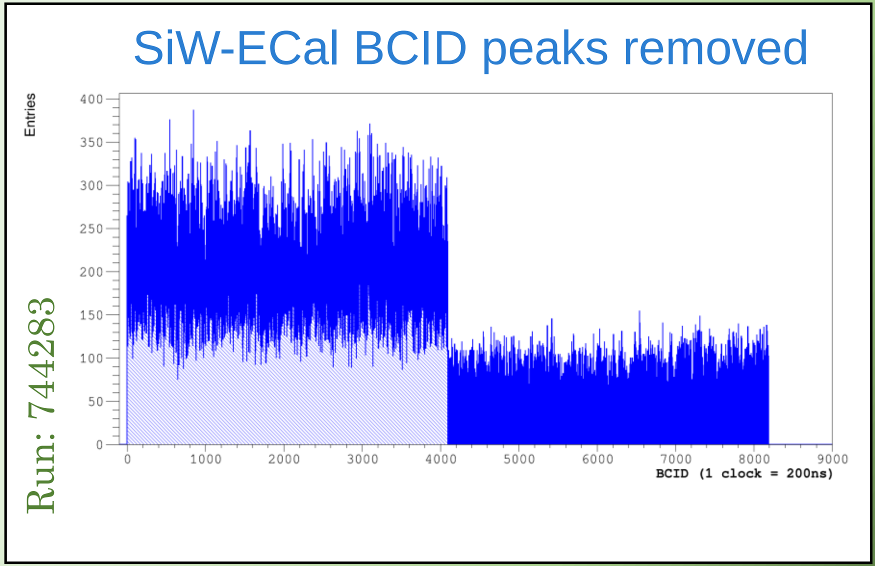
SiW-Ecal BCID preliminary correction

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.





Back-up

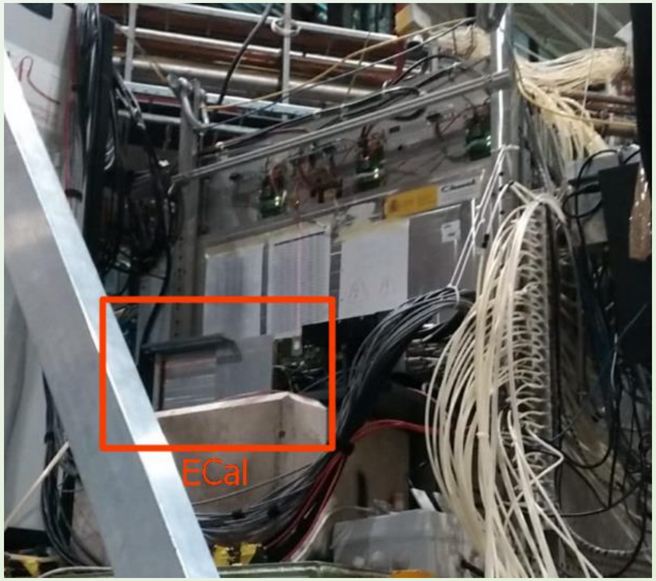
Test Beam setup

CERN H4 SPS. October 2018

- Muon (200 GeV), Π^{+} (40 – 80 GeV) and electron (40 GeV) runs.
- 3 main positions for the support table (center (ECal), top and top-right)

SiWECAL:

- 9 working layers (layer 5 was malfunctioning)



SDHCAL:

- 37 layers present in the prototype
- SiWECal placed in front of the SDHCal:

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

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

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

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.

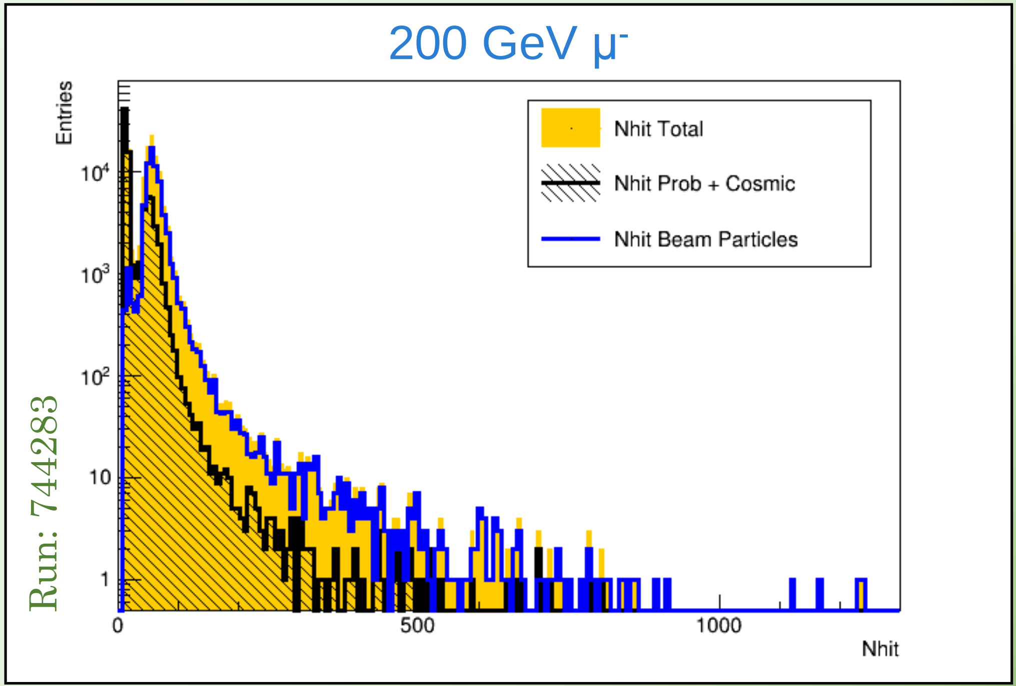
ROOT File names: **run_** + run number + **_TriventSplit.root**

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*

Particles selection. SDHCal beam cuts

Cuts adjusted from the TB of 2012 to account the presence of less layers (48 -> 37)

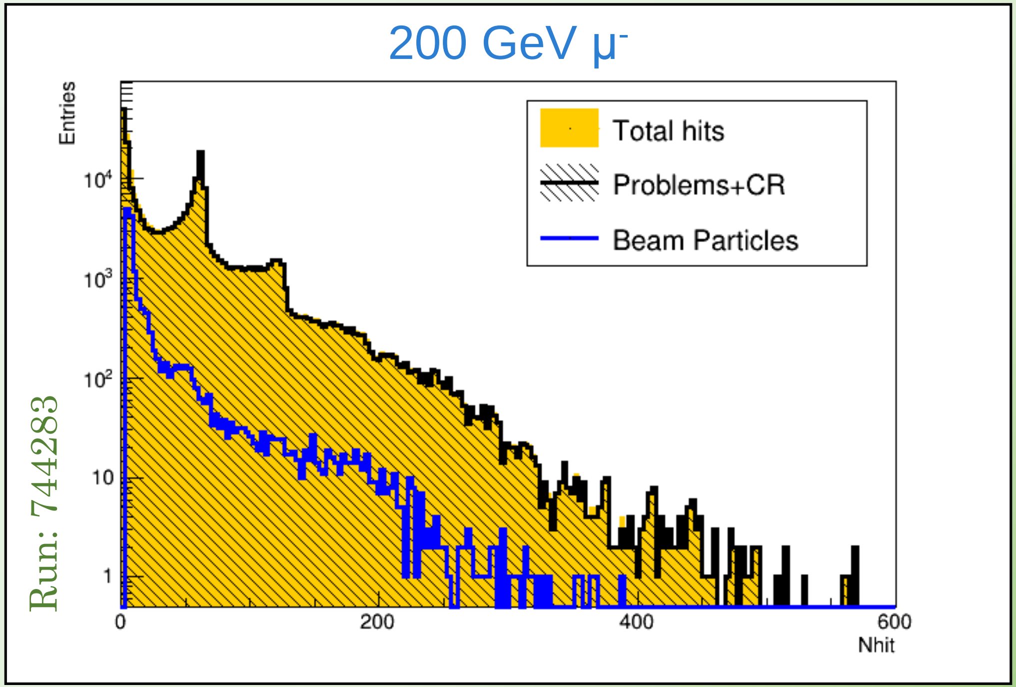
- To reconstruct a physical process: $Nhits > 7$.
- We assume that there is signal in the first 2 layers.
- It is required 4 layers with signal between the first 10 and 3 among the first 6.
- To reconstruct the trace we require at least 5 close (less than 3 layers without signal in between) GRPCs with 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

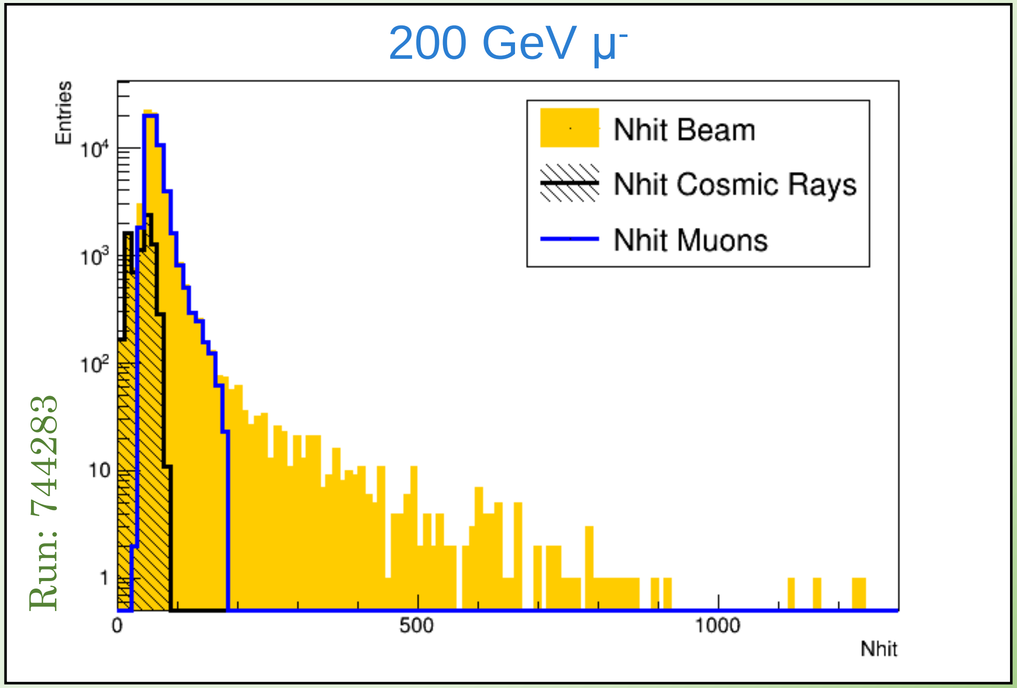
- Signal in the first half. Layers 01- 05
- Signal in the second half. Layers 06 – 10

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 → $\rho < 5 + P.C.$

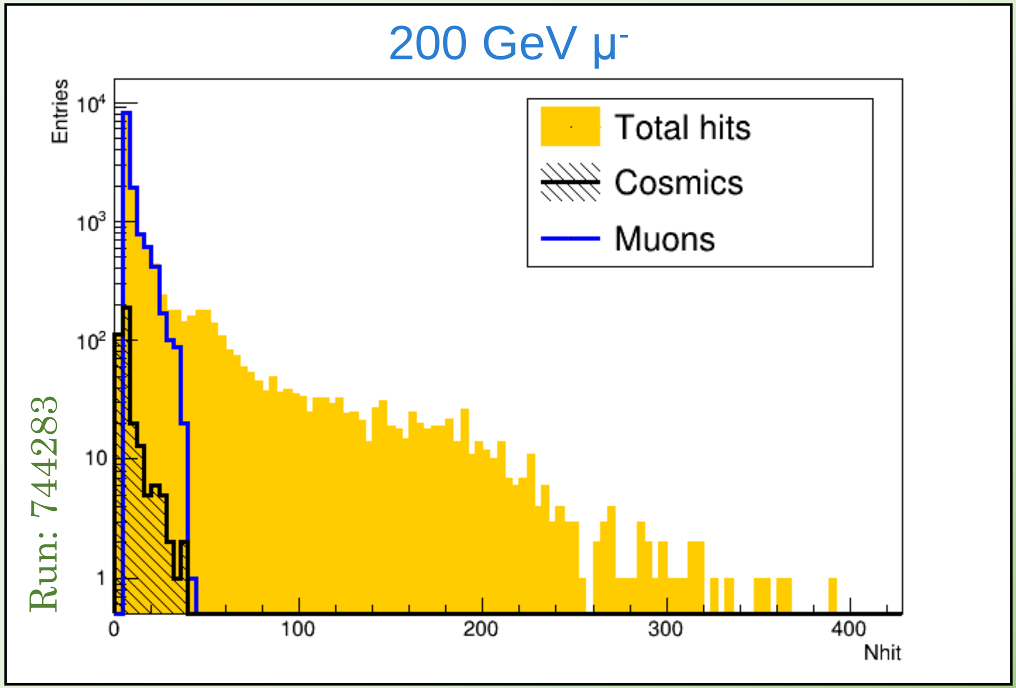


Particles selection. SiWECal muon cuts

Density: **ρ**
nHit maximum in a single layer: $\boldsymbol{Hit_{Max}}$
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:

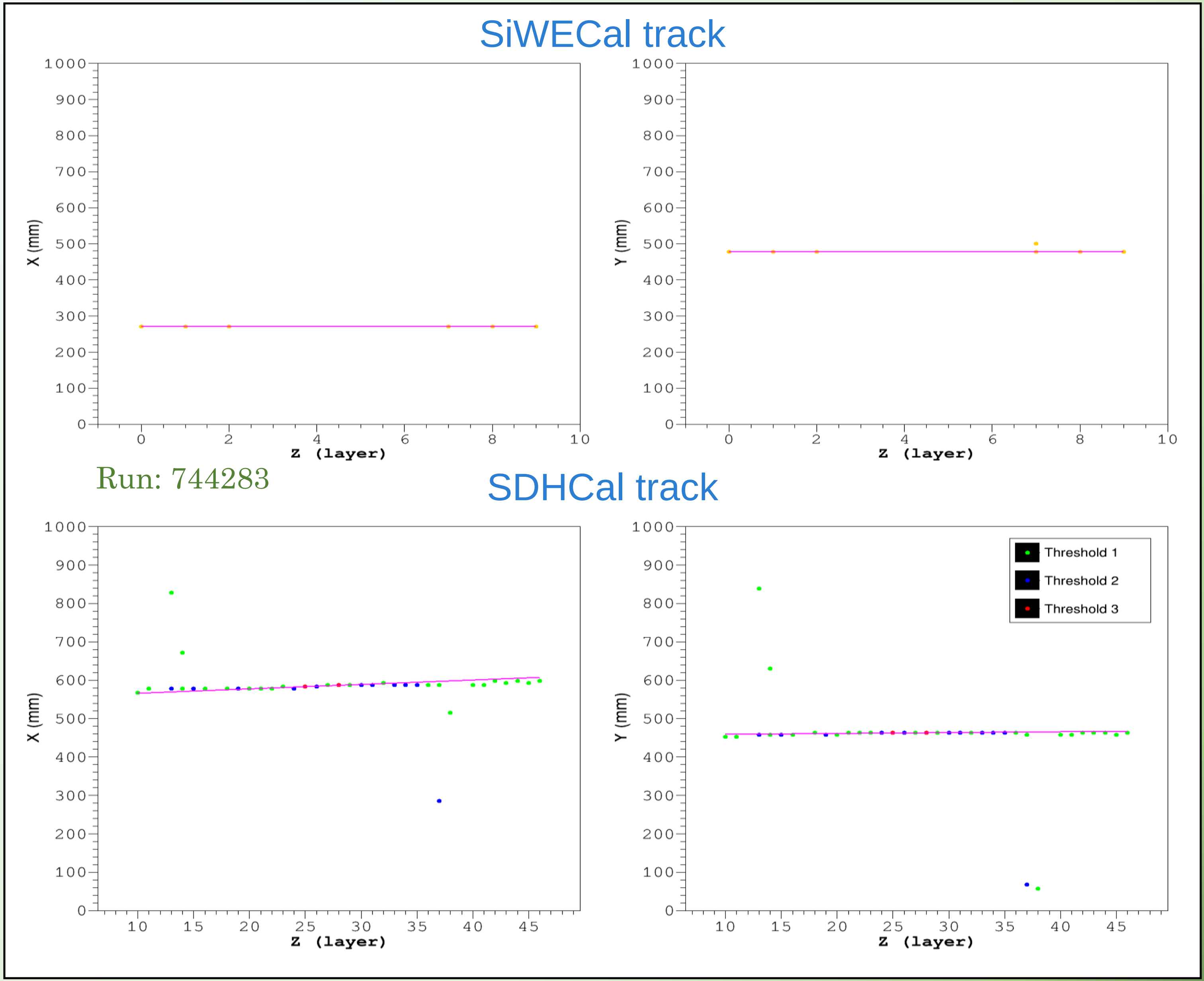
- A first approximation by taking the mean value of all clusters in each layer
- This approximation is fitted to a straight line.
- Then the closest cluster with a distance less than 20.8 mm in X and Y to the previous approximation is selected for each layer. *(It is possible that a layer has no cluster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

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

No less than 5 layers with clusters selected

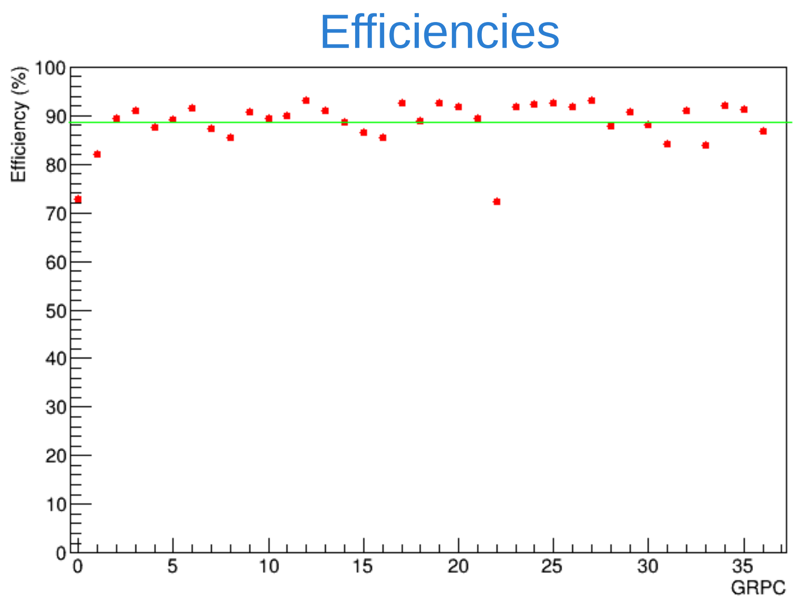
Tracks reconstruction. Examples

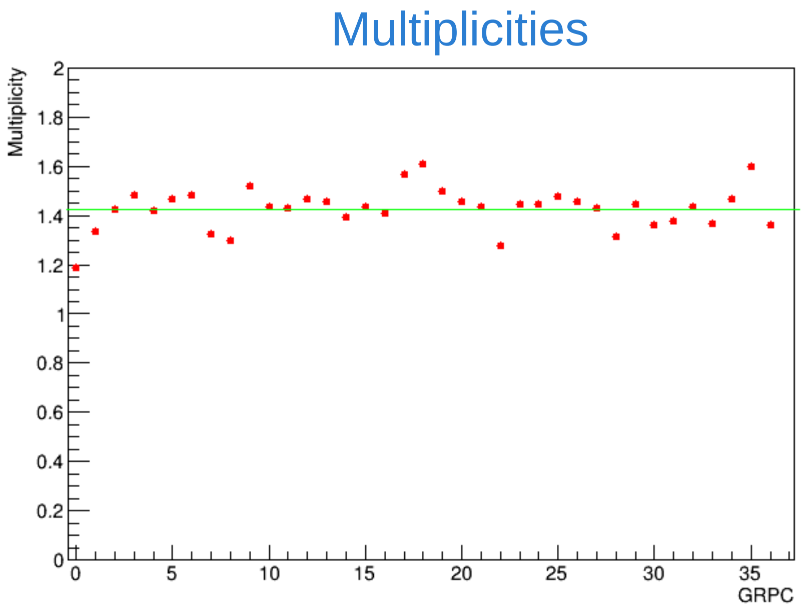


Efficiencies and multiplicities

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 pad) of the cluster associated to that layer.





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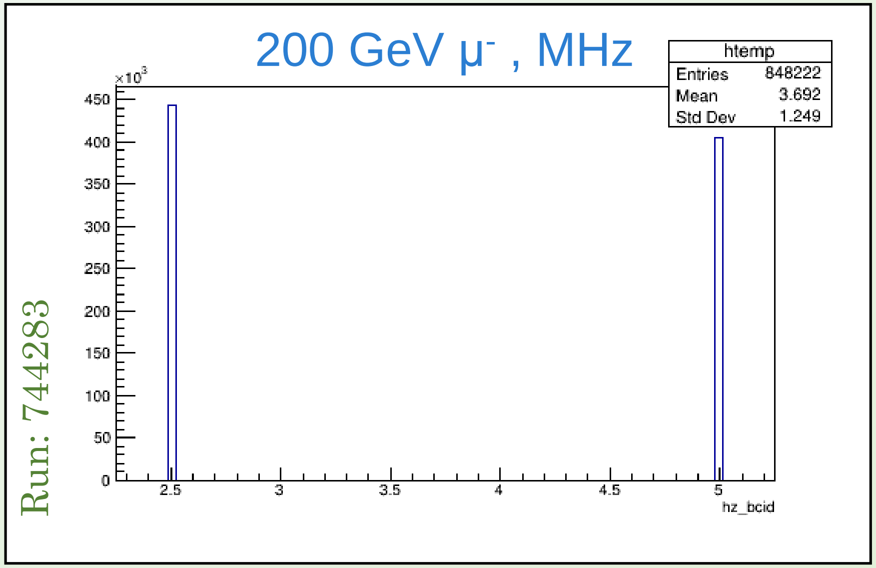
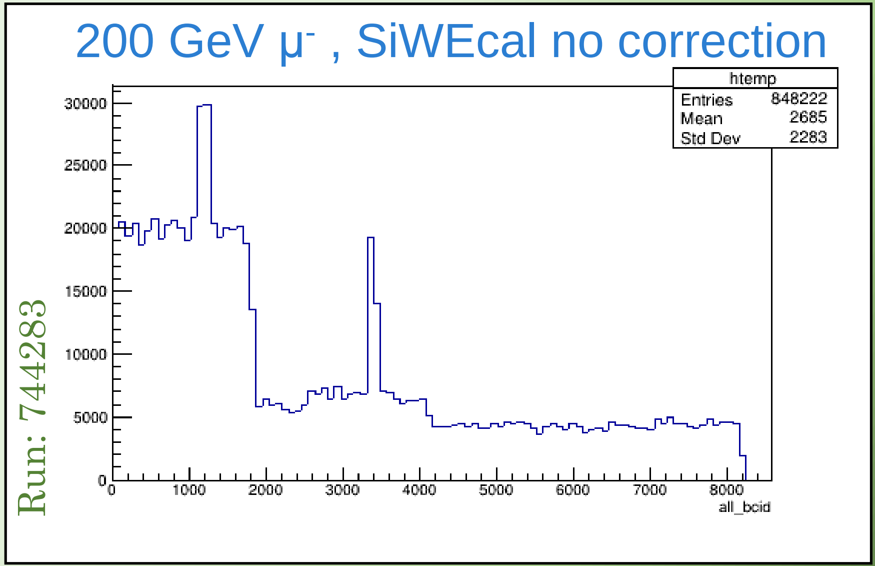
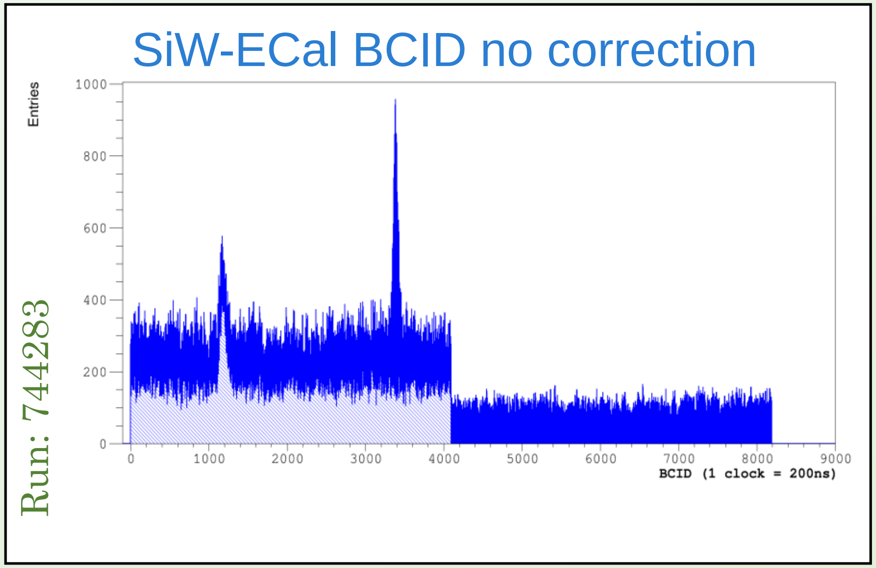


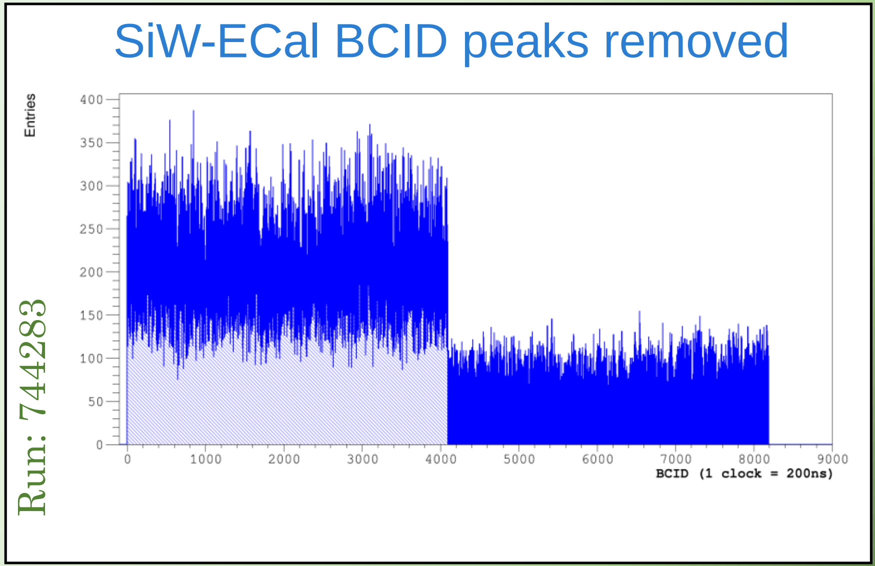


SiW-Ecal BCID distribution

The shape of the BCID distributions without corrections, only changing the frequency from 2.5 to 5 MHz for layers 1, 2, 7, 8 and 9, displays two unexpected peaks.

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.





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:

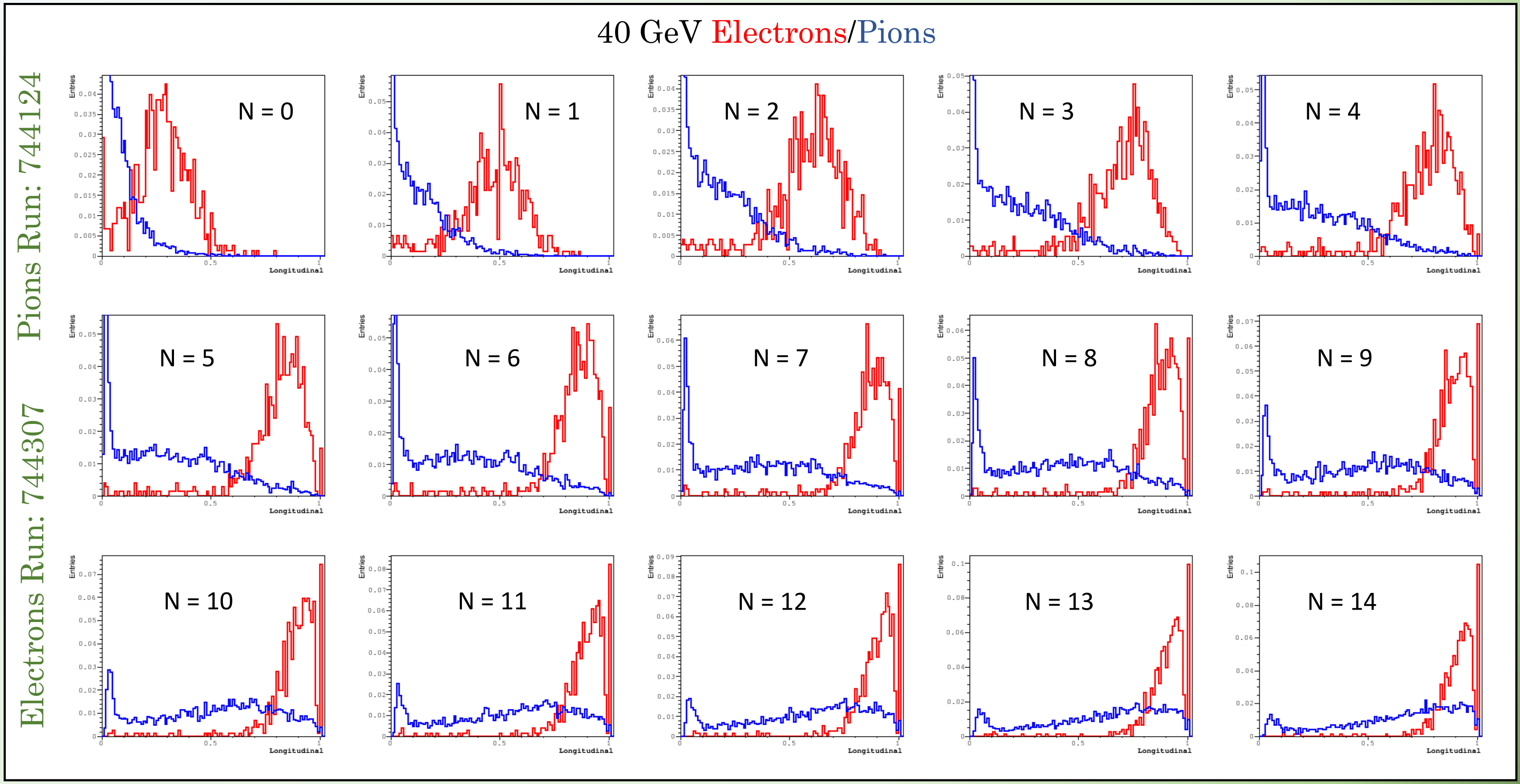
$$\mathrm{L}ongitudinal(N) = \frac{nHit(N)}{nHit}$$

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



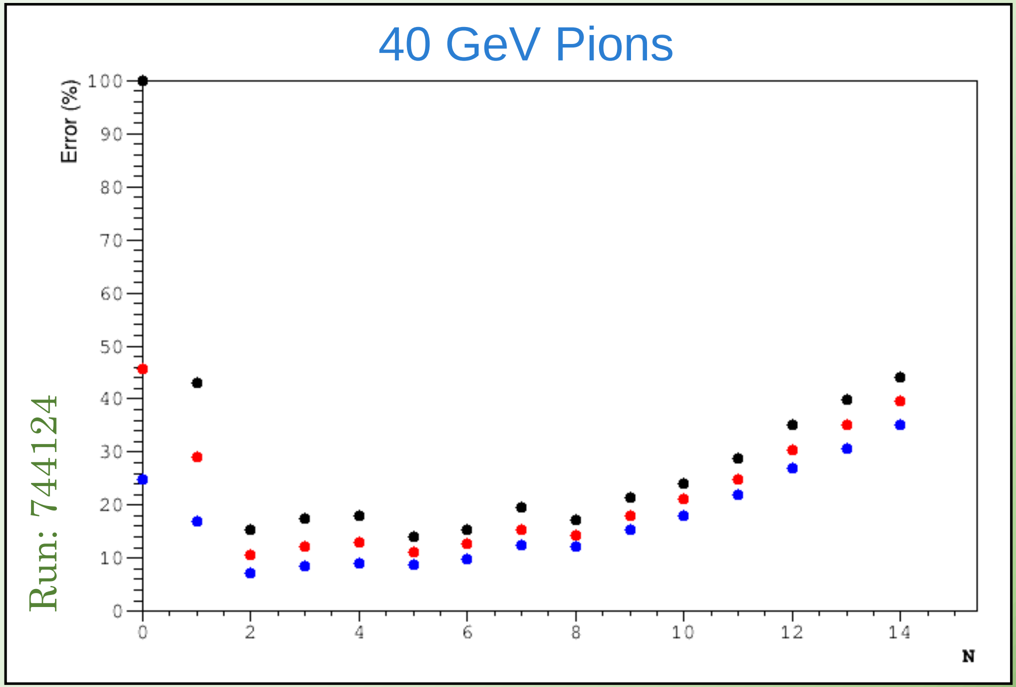
Longitudinal analysis of showers

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

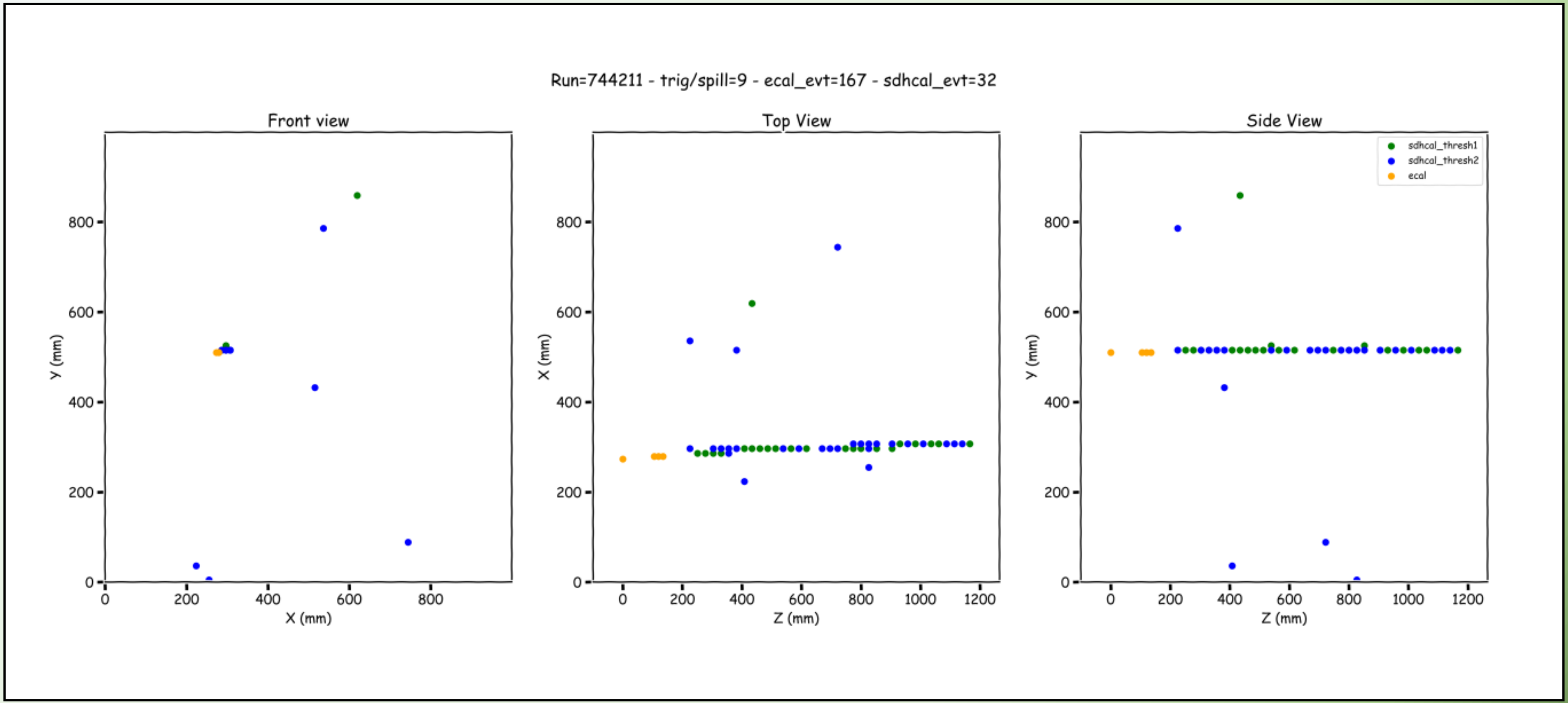
$$Cut(N) = < \mathrm{L}ongitudinal(N) > -\, n\sigma$$

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.

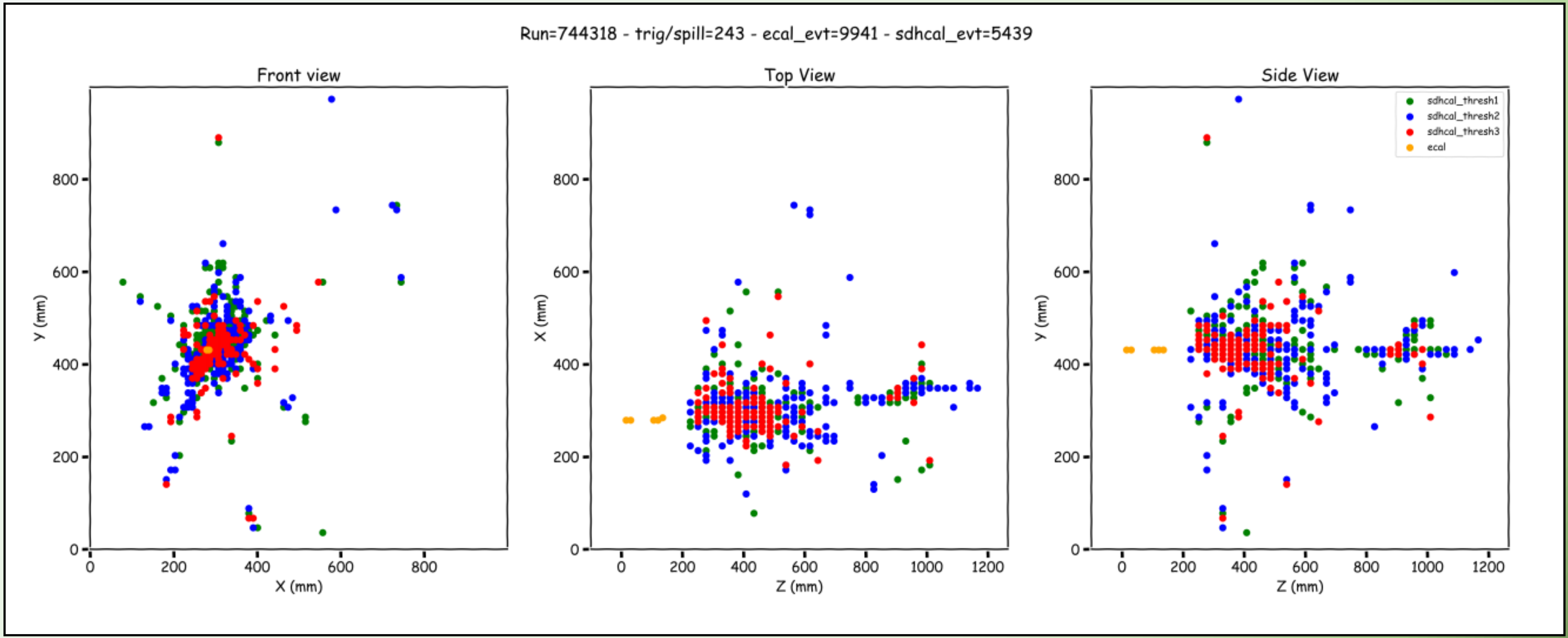
If $\mathrm{L}ongitudinal(N) \geq Cut(N)$ then the event is assigned as an electron. Using the Pion run we can compute the percentage of wrongly assigned events and find the optimal value of N minimizing the error.



Common events visualizer. 200 GeV Muon



Common events visualizer. 70 GeV Pion



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.

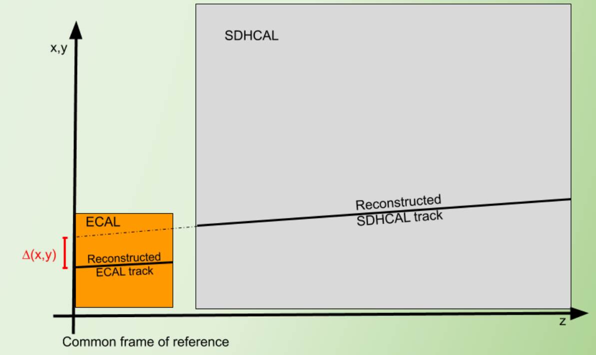
Single Gaussian fit:

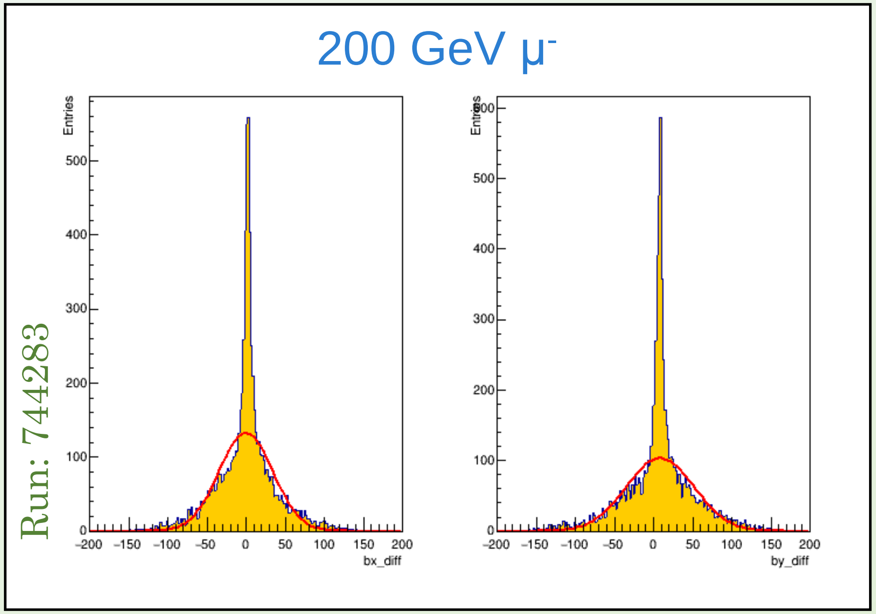
$$X'_{HCal} = X_{HCal} - \mu_X$$

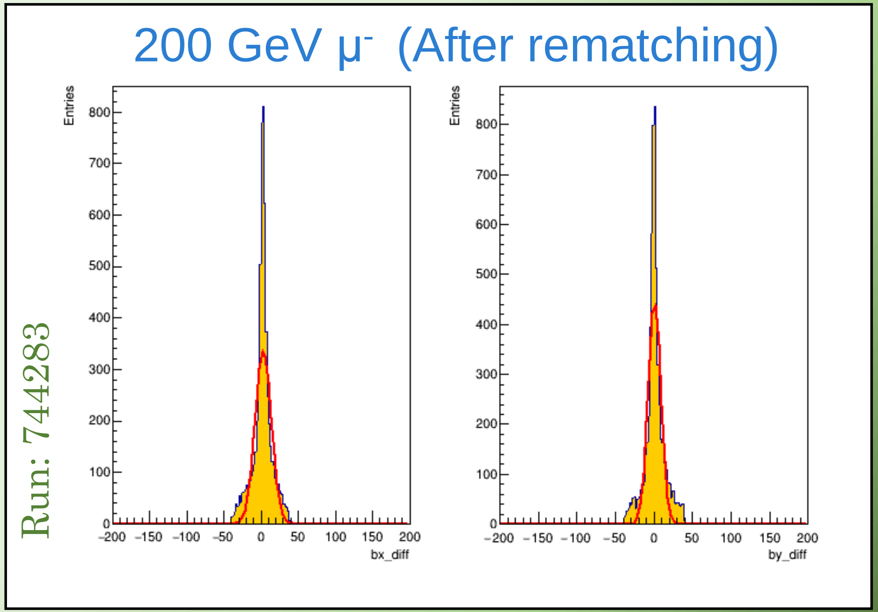
$$Y'_{HCal} = Y_{HCal} - \mu_Y$$

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

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







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 sum of Gaussians the differences of the tracks from both detectors.

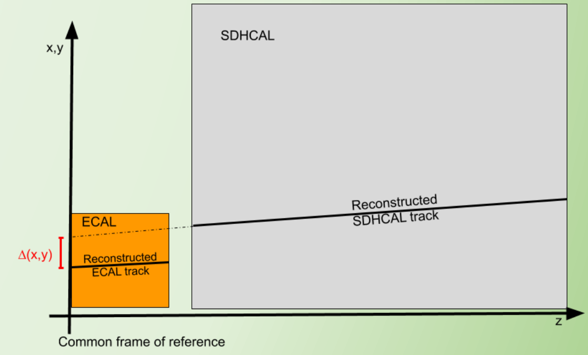
Single Gaussian fit:

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

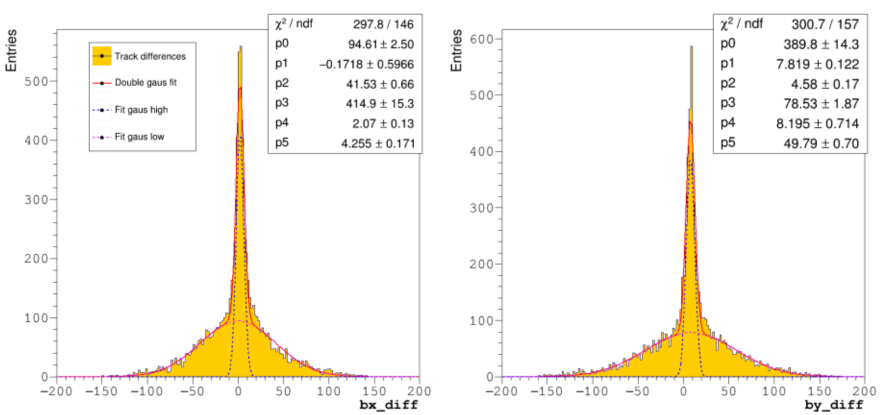
$$Y'_{HCal} = Y^{H}_{HCal} - \mu_Y$$

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

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

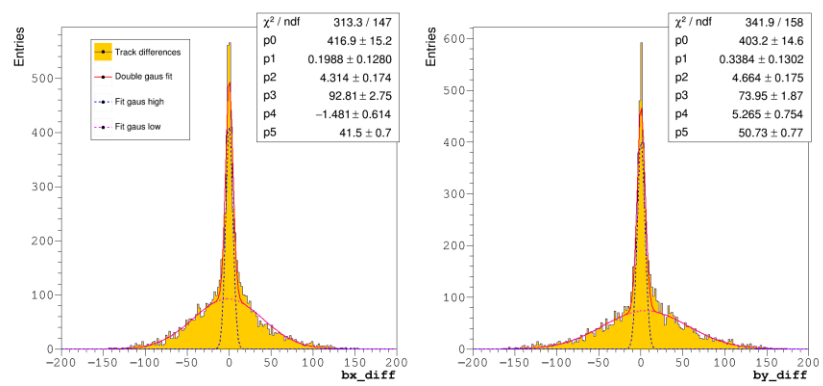


200 GeV μ⁻



Run: 744283

200 GeV μ⁻ (After rematching)



Run: 744283

SiWECal-SDHCal pion-electron selection

Following the process made for the system of scintillator calorimeters in:

Scintillator Calorimeters for a Future Linear Collider Experiment (http://inspirehep.net/record/1482313/files/main_print.pdf?version=1)

Define the layer of *First Hadronic Interaction (FHI)* as the layer in which the first hard interaction between the primary hadron and a nucleus takes places in the detector.

Its reconstruction needs to be adapted from the *moving average of visible energy* M_i to number of threshold crossed N_{thri}. Values for the cuts were optimized with simulations.

Scintillators:

$$(M_i + M_{i+1}) > M_{cut} \; \& \; (N_i + N_{i+1}) > N_{cut}$$

Silicon + GRPCs:

$$(N_{thri} + N_{thri+1}) > N_{thr\_cut} \; \& \; (N_i + N_{i+1}) > N_{cut}$$

$$N_{thri} = (a\, N_{thri}^{1} + b\, N_{thri}^{2} + \mathrm{c}\, N_{thri}^{3})/3$$

$$a = \frac{1}{\widehat{N}^{1}{}_{thr}}$$

$$b = \frac{1}{\widehat{N}^{2}{}_{thr}}$$

$$c = \frac{1}{\widehat{N}^{3}{}_{thr}}$$