Energy reconstruction of hadronic showers in SDHCAL for 2015 TB data taken at CERN PS and SPS

Bing Liu, Imad Laktineh, Haijun Yang

July 30, 2020

Outline

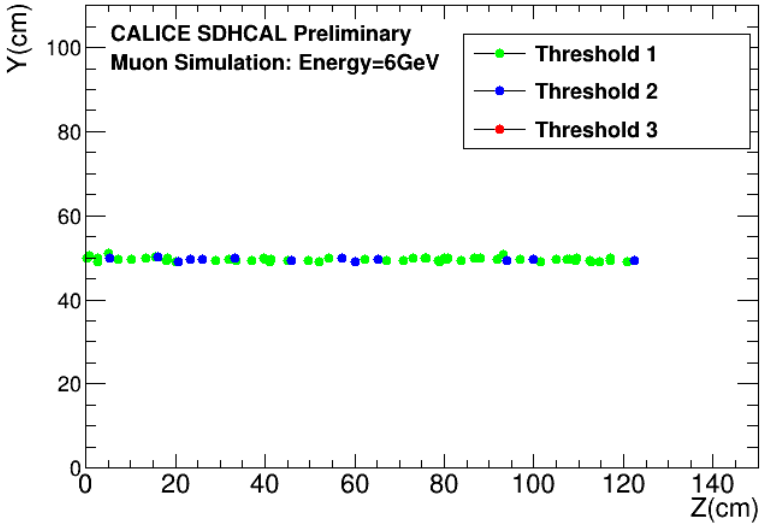
- Introduction for energy beam data
- Event selection
  - Muon rejection
  - Electron background check & rejection
- resolution
- Conclusion

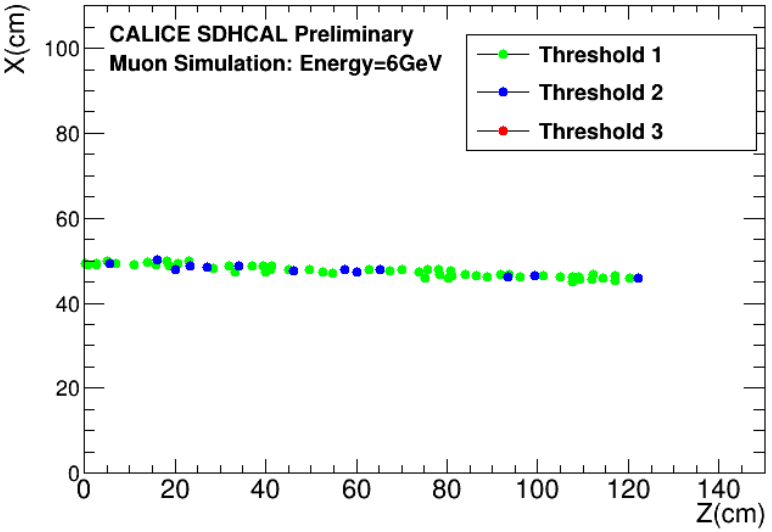
Low energy beam data analysis

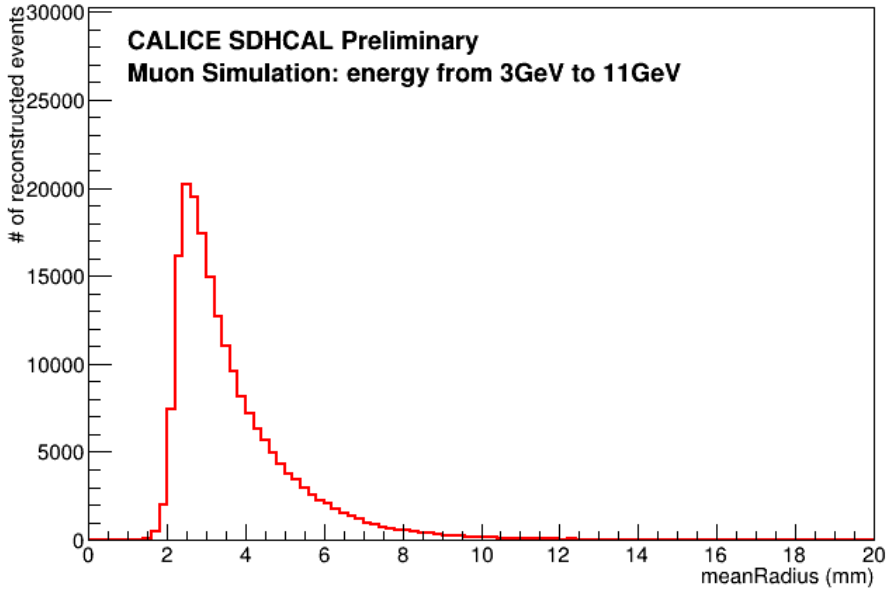
- Data samples were taken at PS, May 2015
  SPS data (10-80GeV)already analyzed can be found in CALICE-CAN-2019-001
- Energy : 3, 4, 5, 6, 7, 8, 9, 10, 11GeV
- Contamination : muons , electrons(since using electron eliminator in test beam period, the electron contamination is negligible except 3-5GeV samples)
- Simulation: FTF_BIC , geant4.9.6

Muon background rejection

MeanRadius of muon track

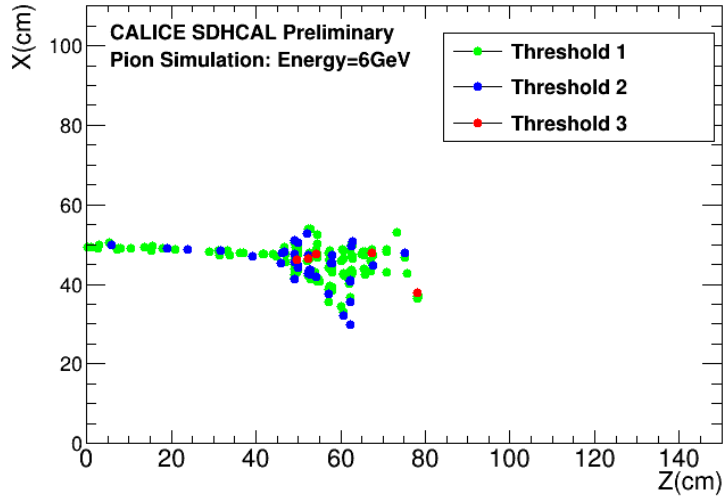


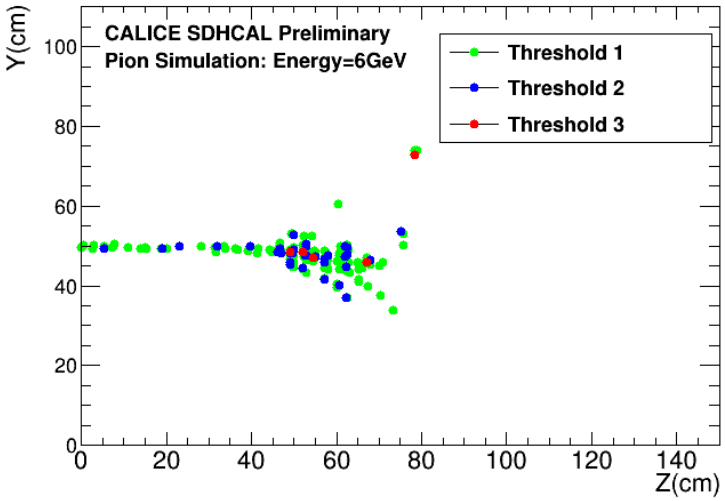


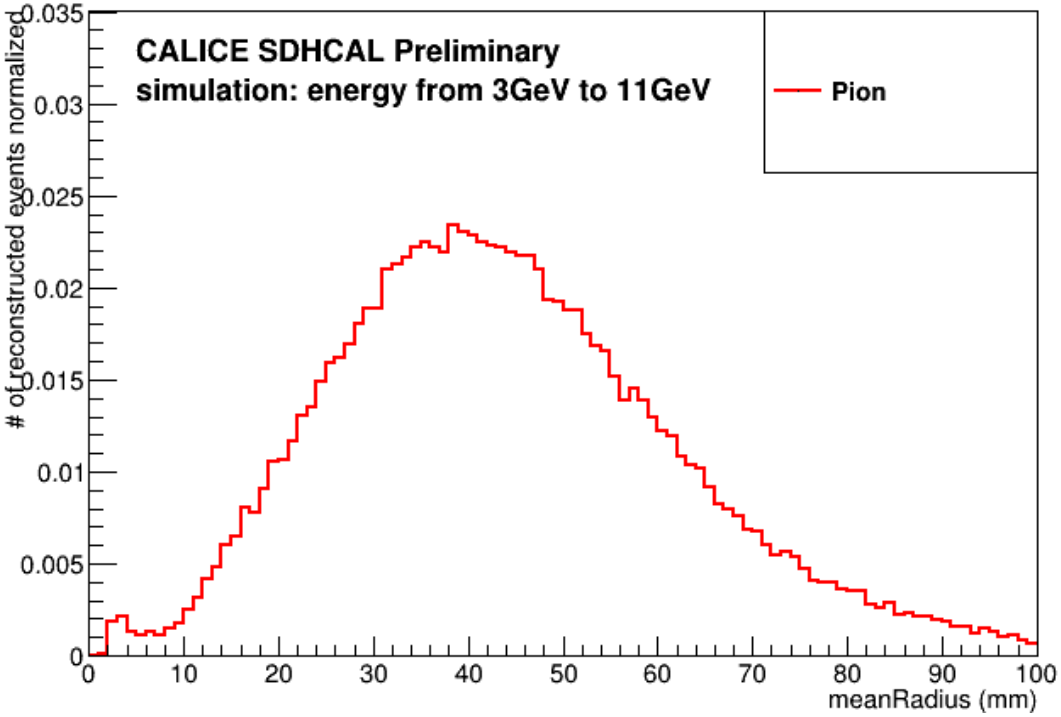


The shower radius is very small < 15mm(≈1.5pad size)

MeanRadius of pion shower

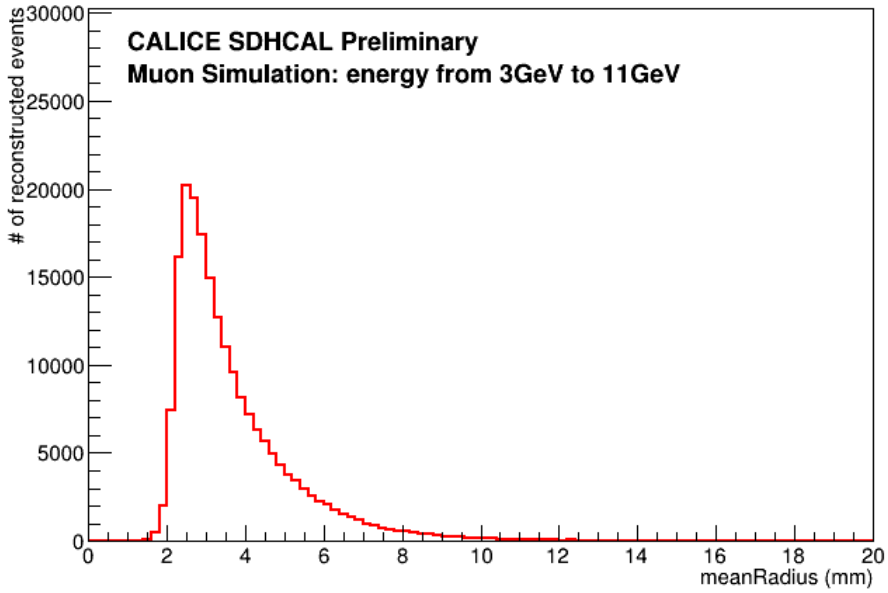




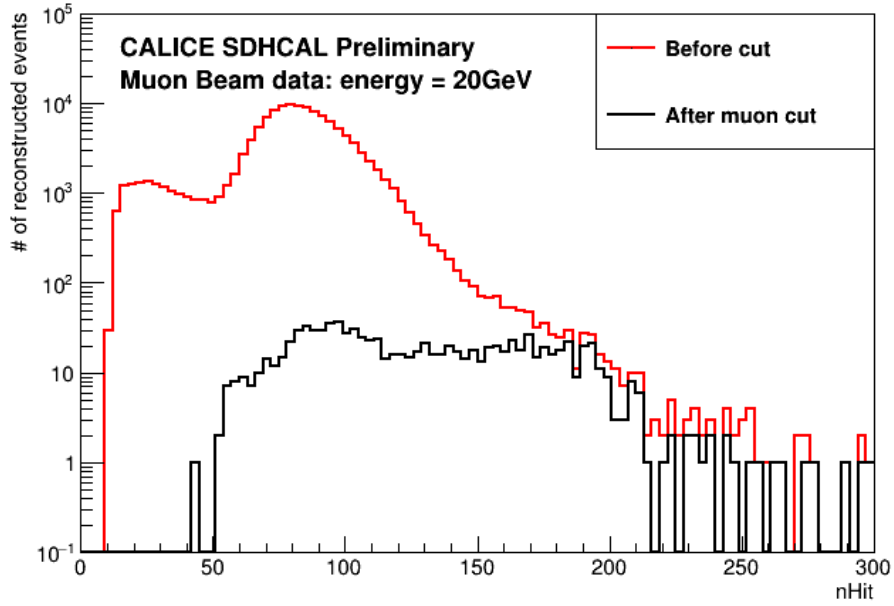


Larger shower radius than muon

Event selection: muon rejection



MeanRadius > 15mm



Muon beam data validation
99% background rejection rate achieved

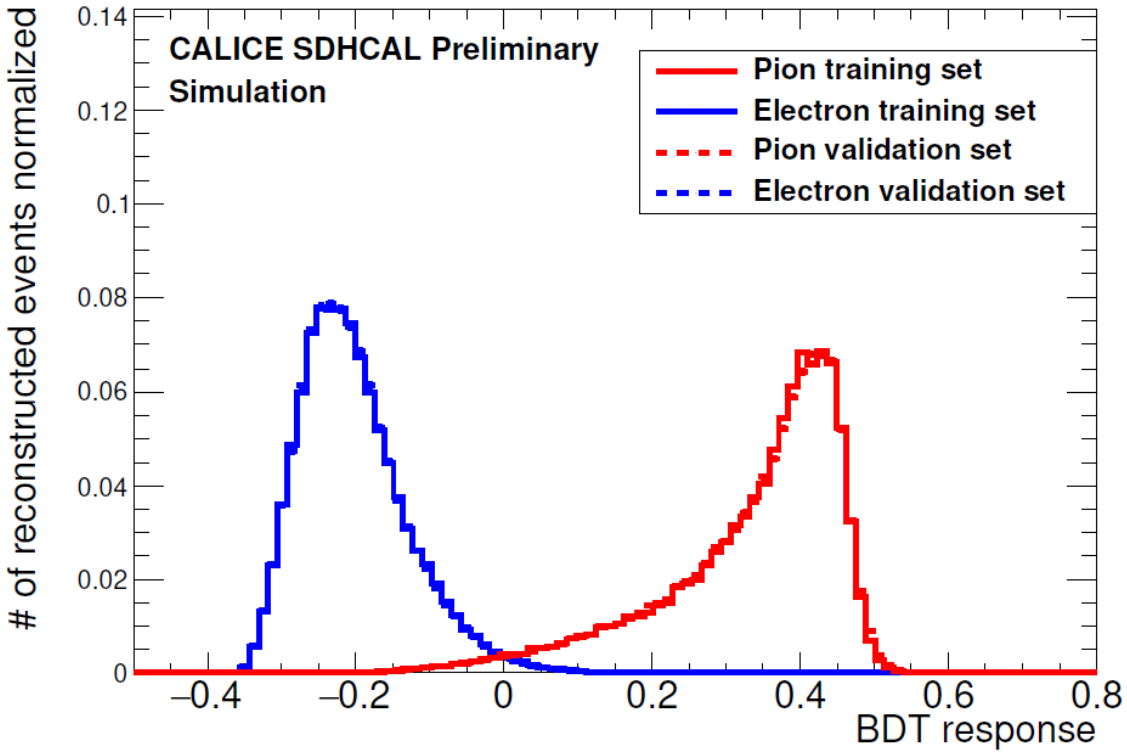
Electron background

- Method: Boosted decision tree (BDT)

- Training set:
  - Electron 1-12GeV, 10000 events per GeV
  - Pion 1-12GeV, 10000 events per GeV
- Test set: the same size

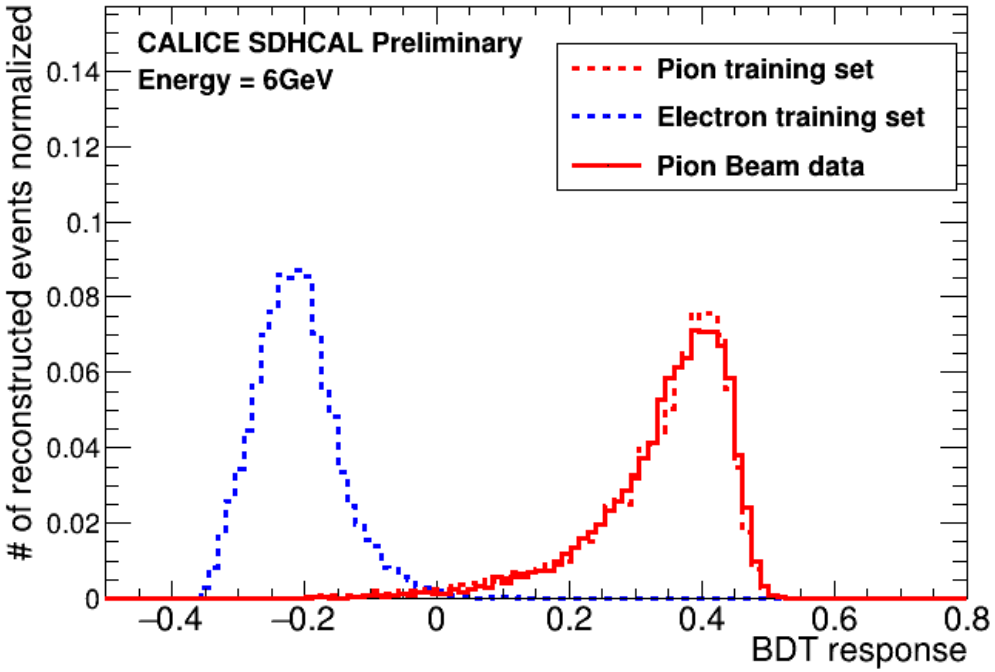
- Input variables: Begin, nTrack, nCluster, radius, nHit/nLayer, density, nHit1/nHit, nHit3/nHit, nShowerlayer/nLayer

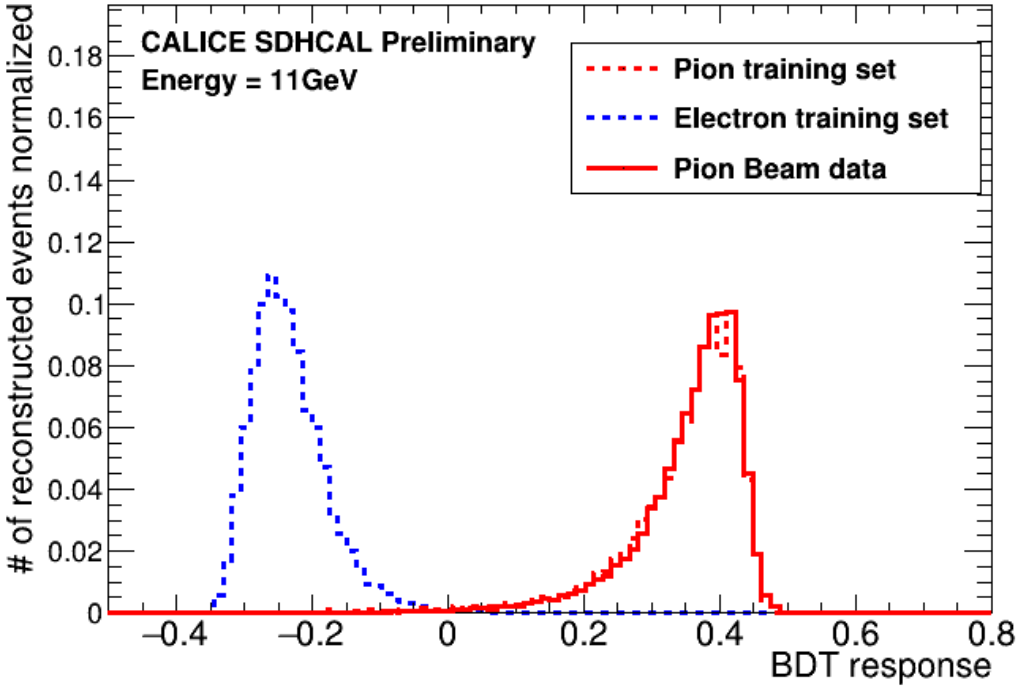
Model Performance



A good agreement between training and validation sets. The model is reliable

Pion beam validation for 6-11GeV

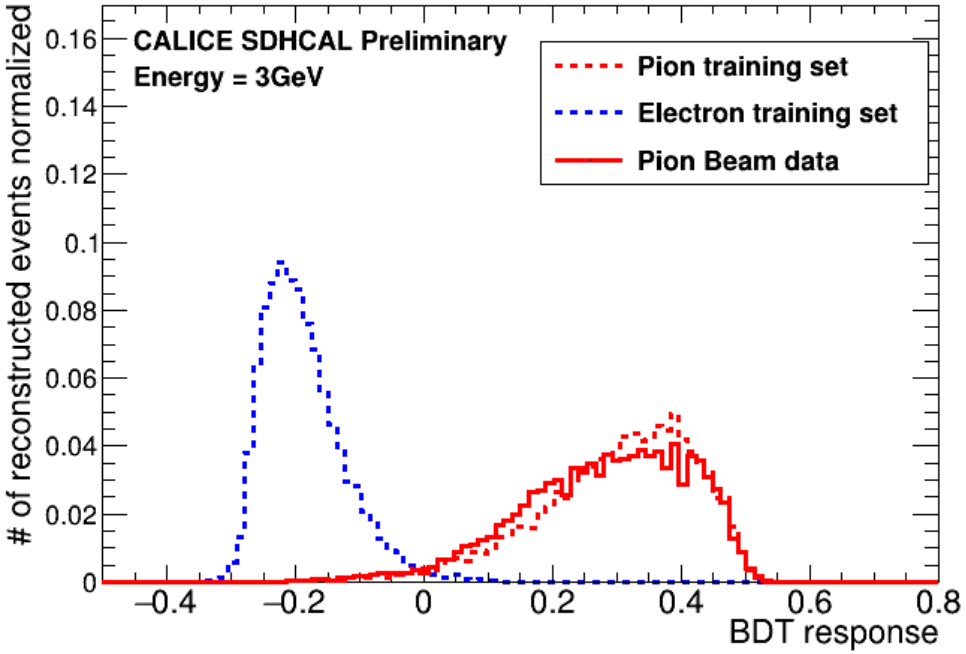


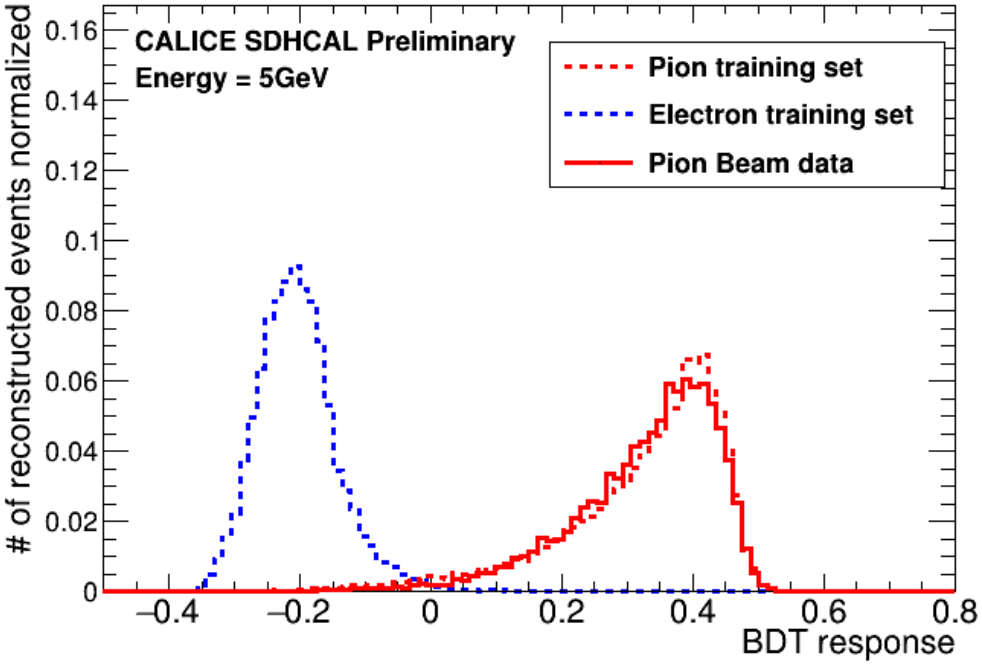


We know there is no electron for 6-11GeV pion beam. These two results confirm it.

The model reliable.

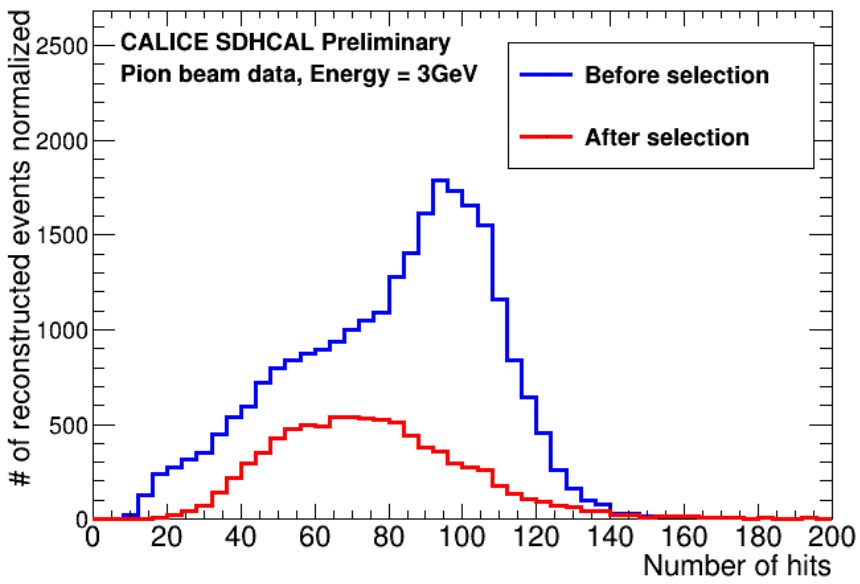
Electron check for pion beam 3-5GeV

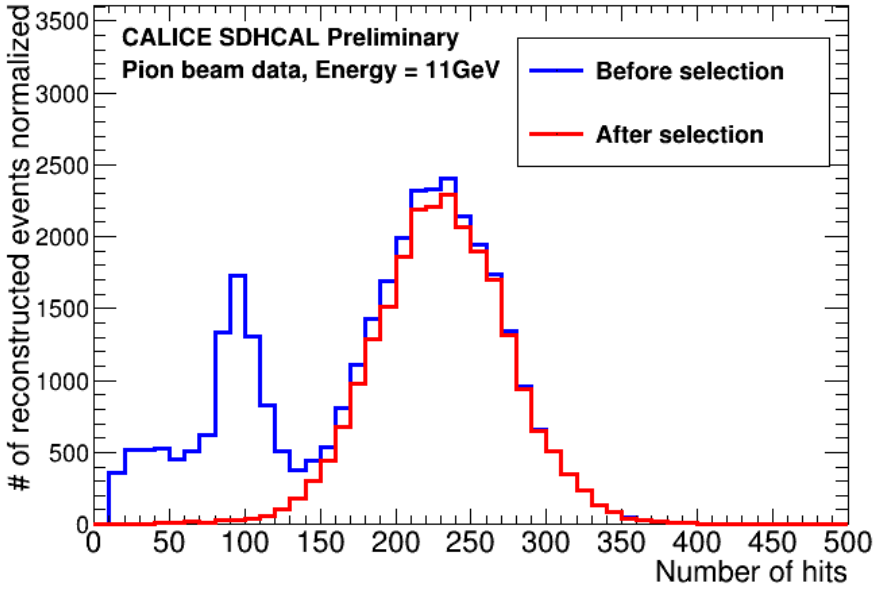




The electron contamination is almostly negligible. Applying BDT value cut > 0.0 is enough to reject electron-like events

Apply the muon rejection and electron rejection





The number of hits before and after selection

Energy reconstruction

- Only feeding SPS (10-80GeV) data to energy reconstruction algorithm.
- Feeding combined data, PS (3-11GeV) + SPS (20-80GeV).

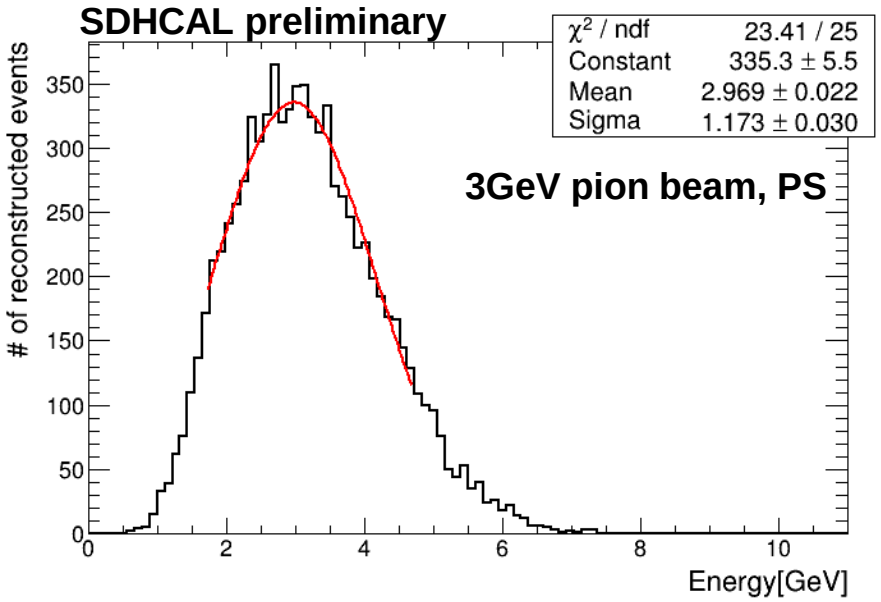
$$E_{reco} = \alpha N_1 + \beta N_2 + \gamma N_3$$

→N_1 = Nb. of hits with 1st threshold < signal < 2nd threshold
→N_2 = Nb. of hits with 2st threshold < signal < 3nd threshold
→N_3 = Nb. of hits with signal > 3rd threshold
N_{tot} = N_1 + N_2 + N_3

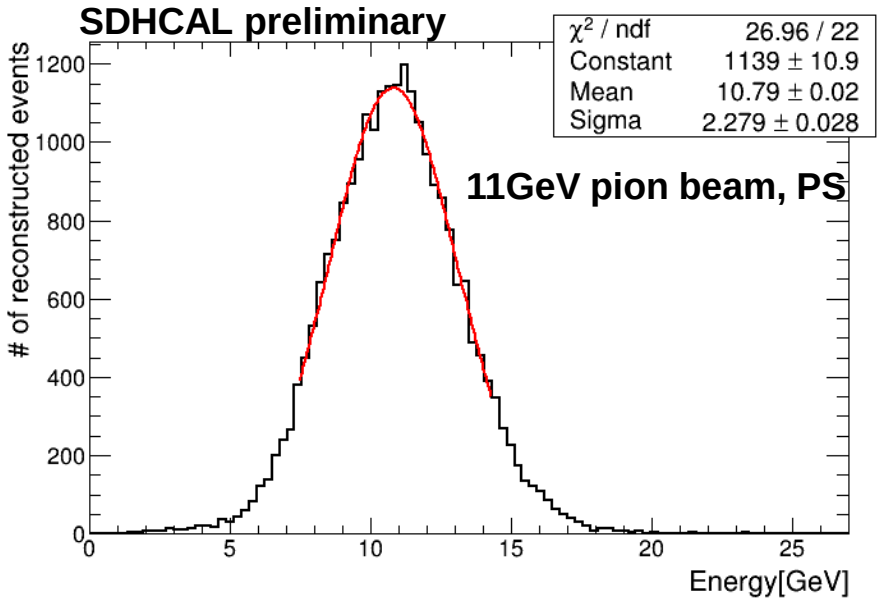
α, β, γ are parameterized as quadratic functions of N_{tot}
→They can be determined by minimizing a χ^2

$$\chi^2 = \sum_{i=1}^{N} \frac{(E^i_{beam} - E^i_{reco})^2}{\sigma_i^2} \qquad \sigma_i = \sqrt{E^i_{beam}}$$

Energy reconstruction



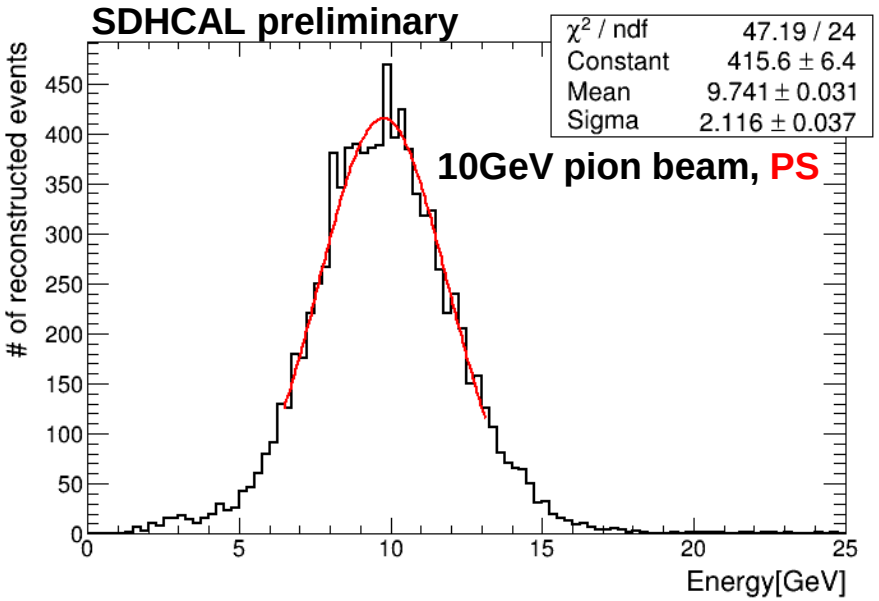
Fitting range 1.5σ

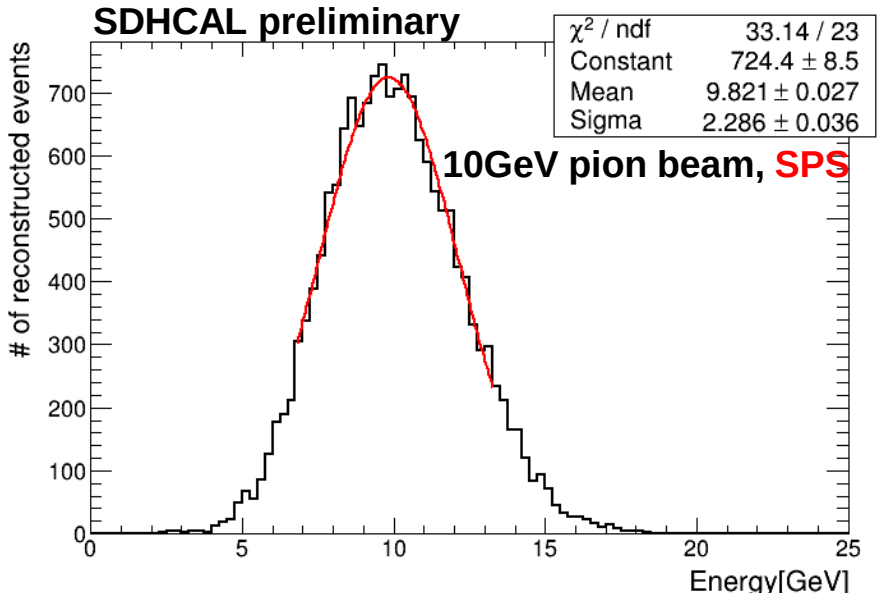


Fitting range 1.5σ

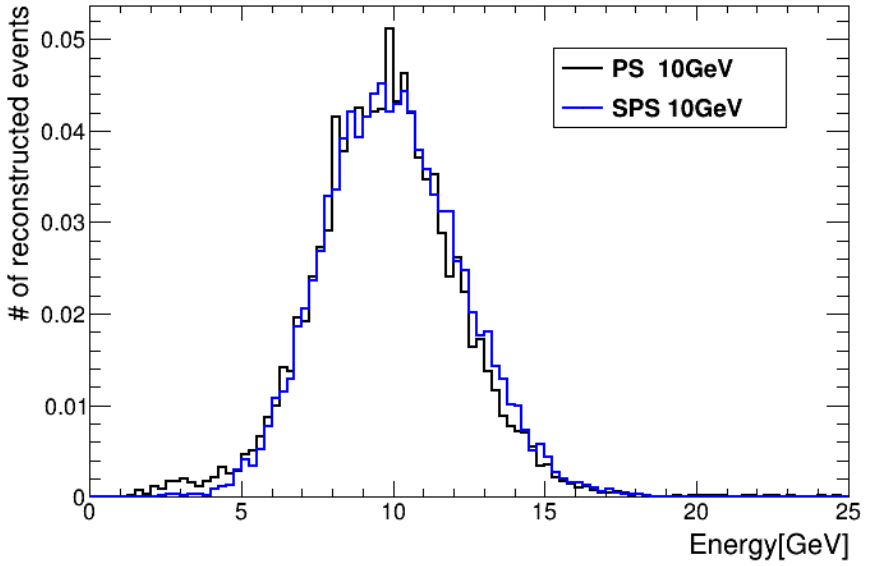
The two-step Gaussian fits are applied.

Energy reconstruction

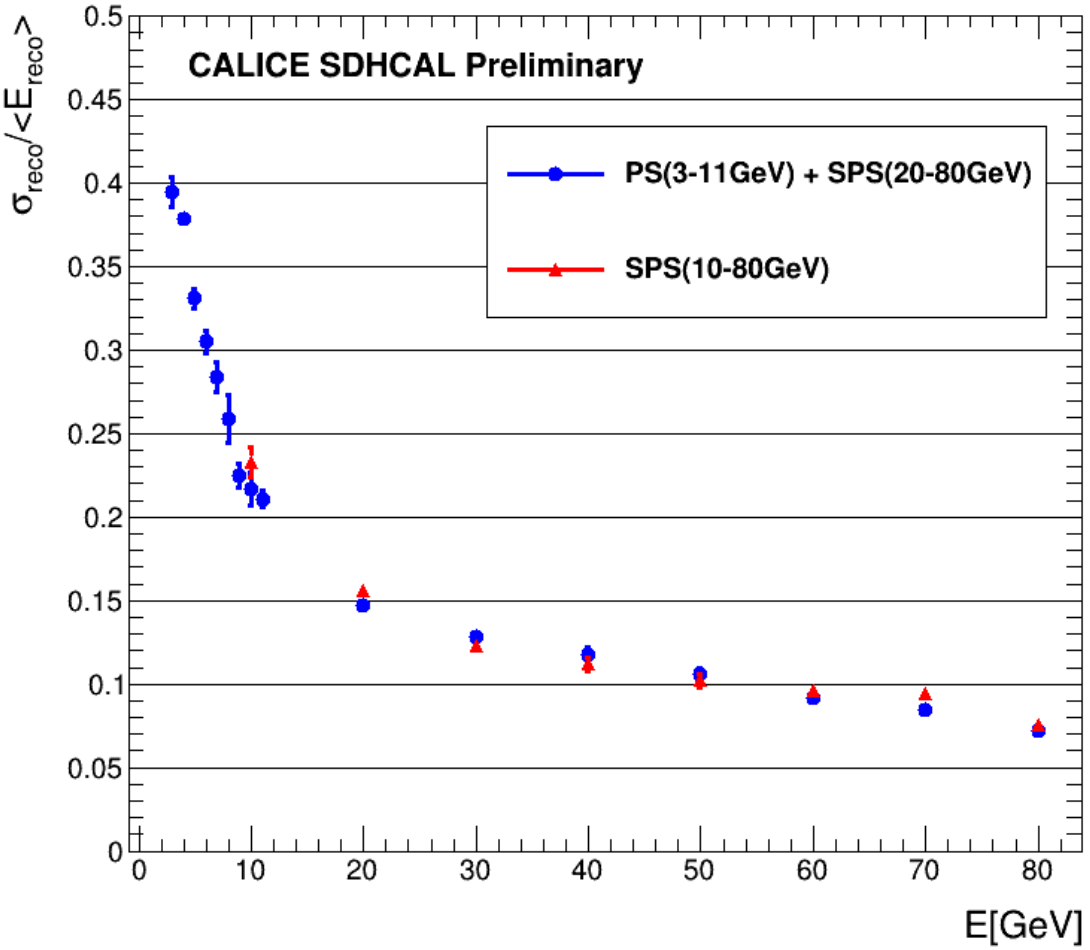




The common energy point 10GeV, for both PS and SPS.



resolution

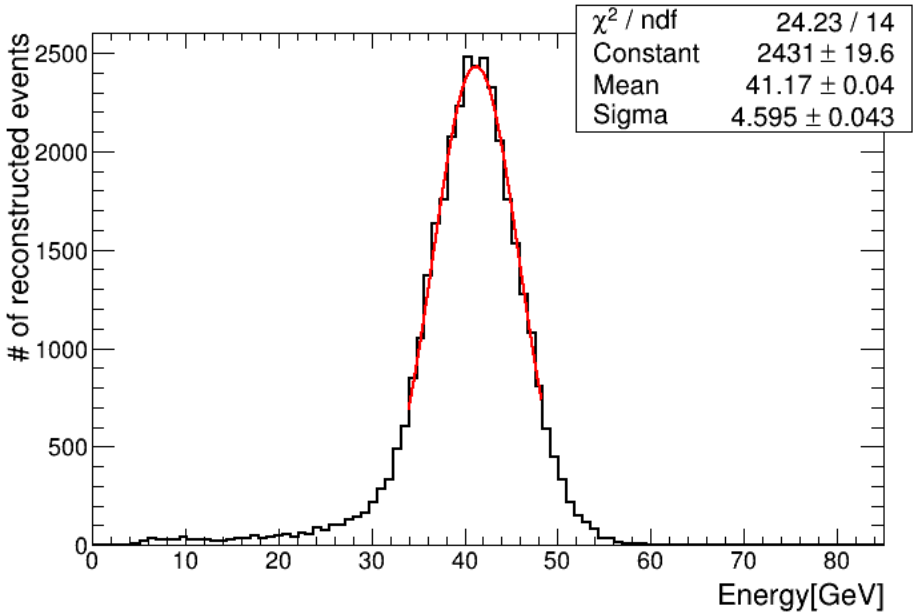


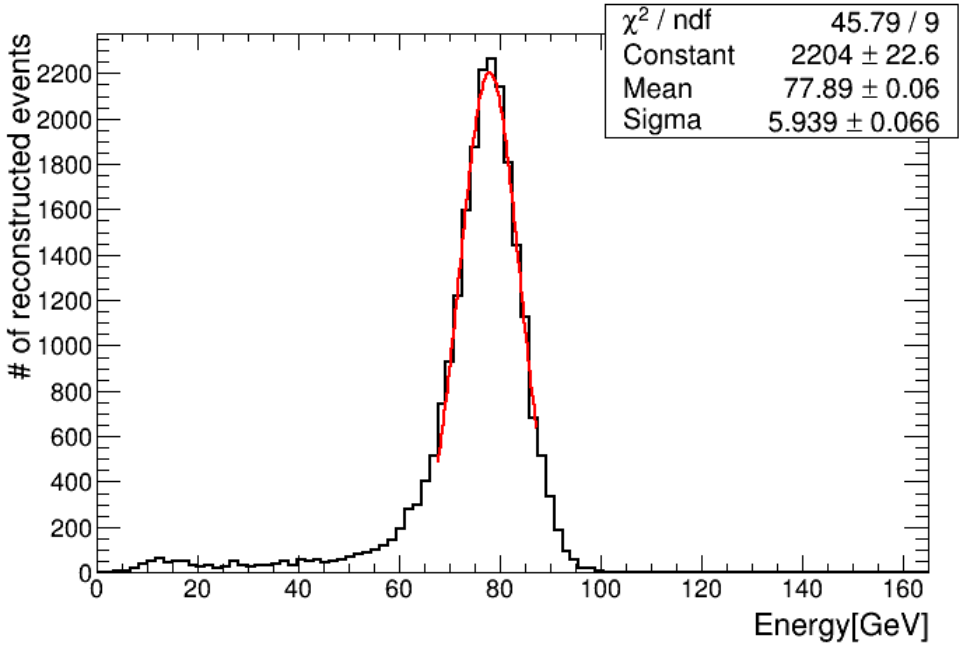
Good agreement with SPS data taken at 2015 October

Conclusions & Next

- The cut based on MeanRadius can easily remove the muon background
- The BDT model is robust and it can separate electron and pion of low energy beam data
- The resolution of low energy beam data has a good agreement with SPS data.
- To do systematic uncertainty study

Backup


χ^2 / ndf 24.23 / 14
Constant 2431 ± 19.6
Mean 41.17 ± 0.04
Sigma 4.595 ± 0.043
# of reconstructed events
Energy[GeV]

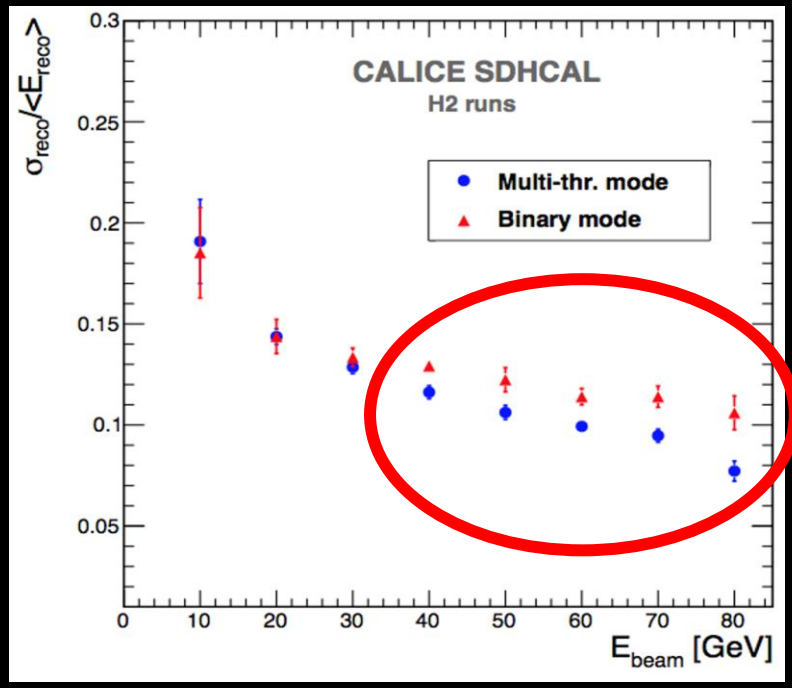

χ^2 / ndf 45.79 / 9
Constant 2204 ± 22.6
Mean 77.89 ± 0.06
Sigma 5.939 ± 0.066
# of reconstructed events
Energy[GeV]

SDHCAL prototype — Performance

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

→N_1 = Nb. of hits with 1st threshold < signal < 2nd threshold
→N_2 = Nb. of hits with 2st threshold < signal < 3nd threshold
→N_3 = Nb. of hits with signal > 3rd threshold
→$N_{tot} = N_1 + N_2 + N_3$

α, β, γ are parameterized as quadratic functions of N_{tot}
→They can be computed by minimizing a χ^2



$$\chi^2 = \sum_{i=1}^{N} \frac{(E^i_{beam} - E^i_{reco})^2}{\sigma_i^2} \qquad \sigma_i = \sqrt{E^i_{beam}}$$

SDHCAL with 3-threshold results in better energy resolution than binary mode for E_{beam} > 30 GeV