The particle identification using BDT in the Semi-Digital Hadronic calorimeter

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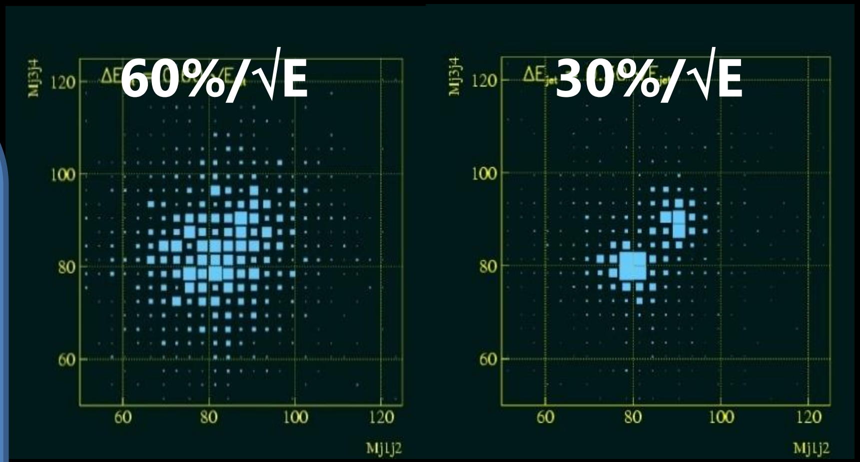
Outline

- Semi-Digital Hadronic calorimeter (SDHCAL)
- Particle identification using Boosted decision tree (BDT)
- Conclusions

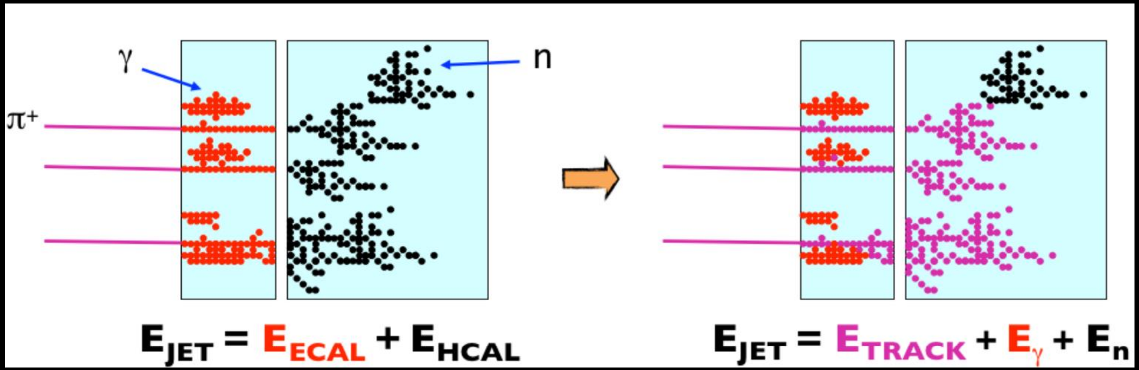
Particle Flow Algorithm (PFA) oriented Calorimeter

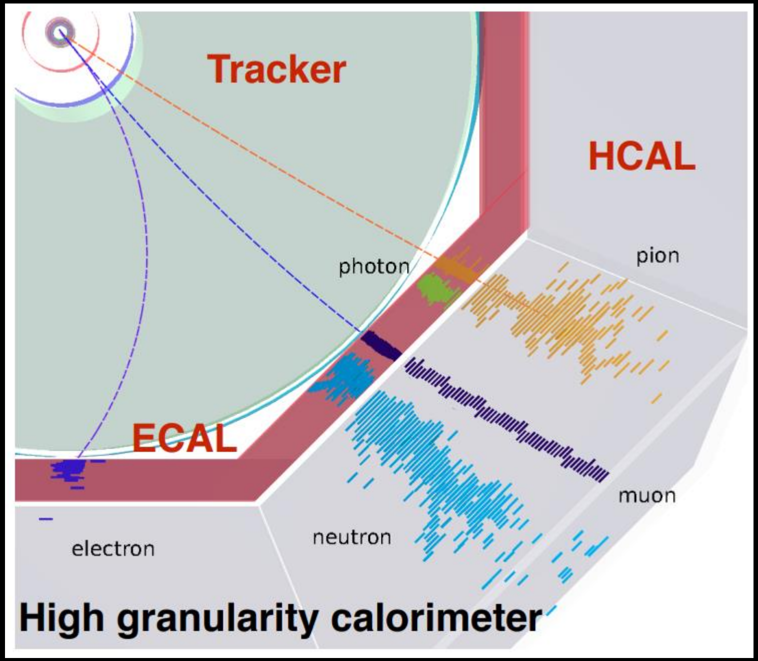
Particle Flow Algorithm : an algorithm that tries to reconstruct individual final state particle from the information recorded in detector.

- It can lead to measure jet energy accurately, and consequently improve the energy reconstruction and event identification
- High granularity needed



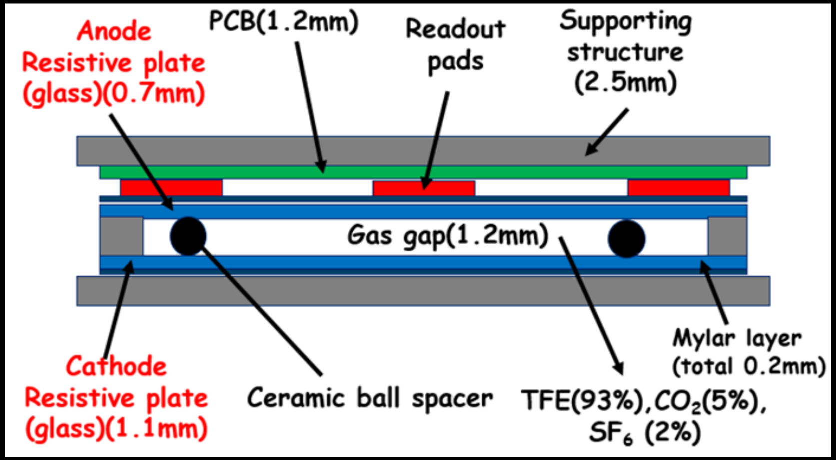
Simulation of W, Z reconstructed masses in hadronic mode.





SDHCAL prototype — Main features

Detector: GRPC (glass resistive plate chamber, 1 X 1 m^2) operating in avalanche mode



1×1 cm^2 pads.

Semi-Digital readout, 2bits — 3 thresholds

→ Counts how many and which pads have a signal larger than one of three thresholds

Advantages of Resistive Plate Chambers:

- High efficiency
- Good Homogeneity
- Well contained avalanches
- Not expensive, robust, …

→ **Energy resolution**

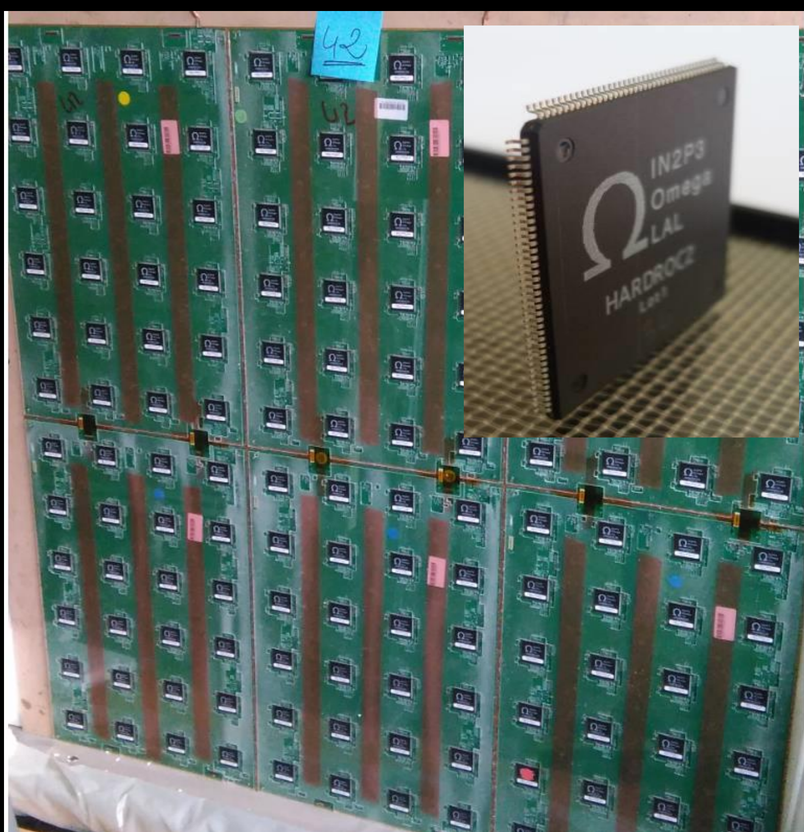
SDHCAL prototype — Main features

Embedded electronics:

PCB separated from the GRPC by a mylar layer (50 μm)

→**Bottom** : 1 × 1 cm^2 pads, one layer 9216 pads.

→**Top**:144 HARDROC2 (HAdronic Rpc Detector ReadOut Chip)



Absorber:

Stainless steel (20mm)

Surface planarity < 1mm

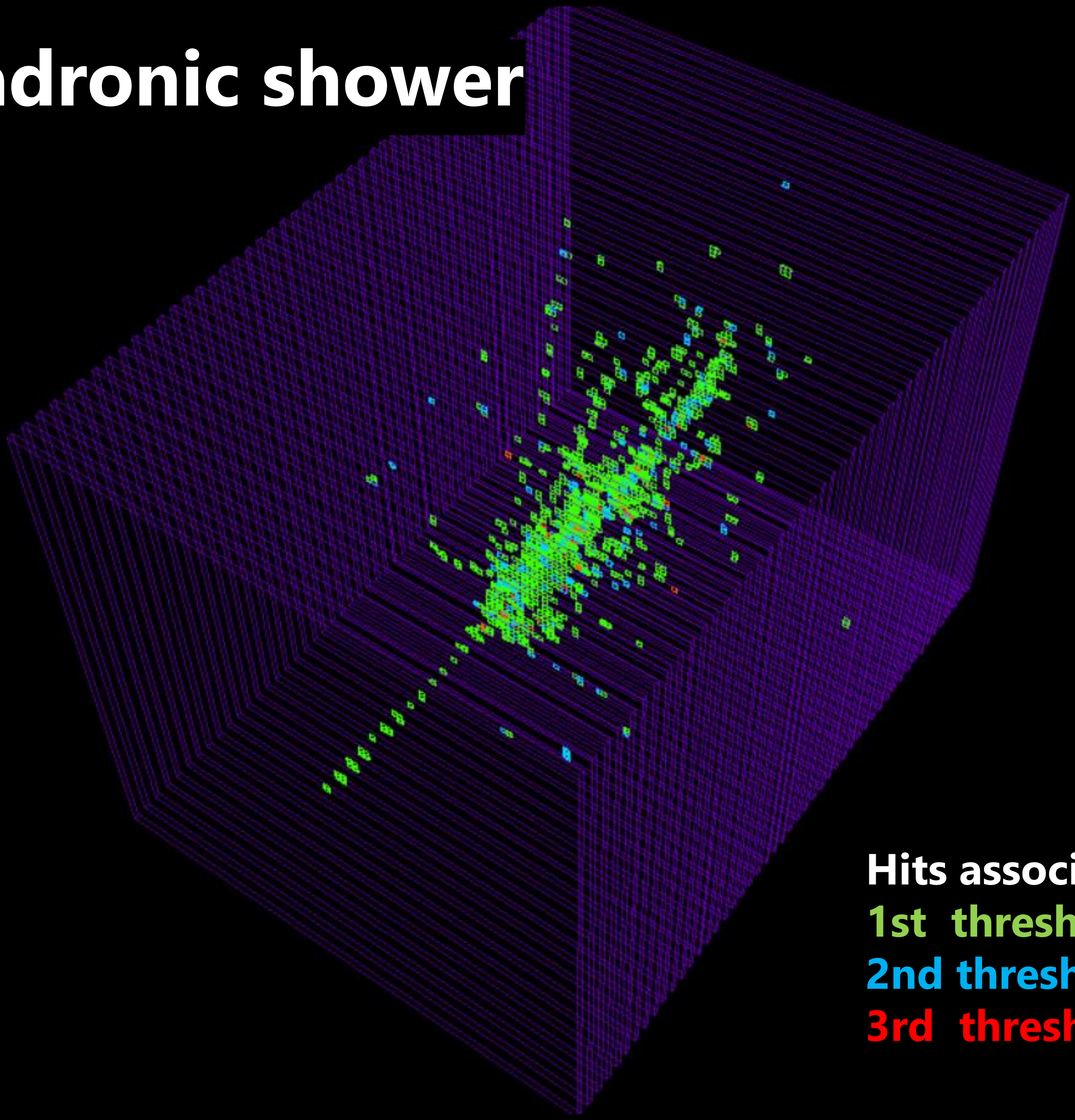
Thickness tolerance 50 μm

SDHCAL
Since 2011

SDHCAL prototype
Size: 1m x 1m x 1.4m
No. of layers: 48
Cell size: 1cm x 1cm
No. of channels: ≈440K

TB: 2012,2015, 2016, 2017 and 2018 with ECAL

Hadronic shower



Hits associated to:
1st threshold (110 fC)
2nd threshold (5pC)
3rd threshold (15pC)

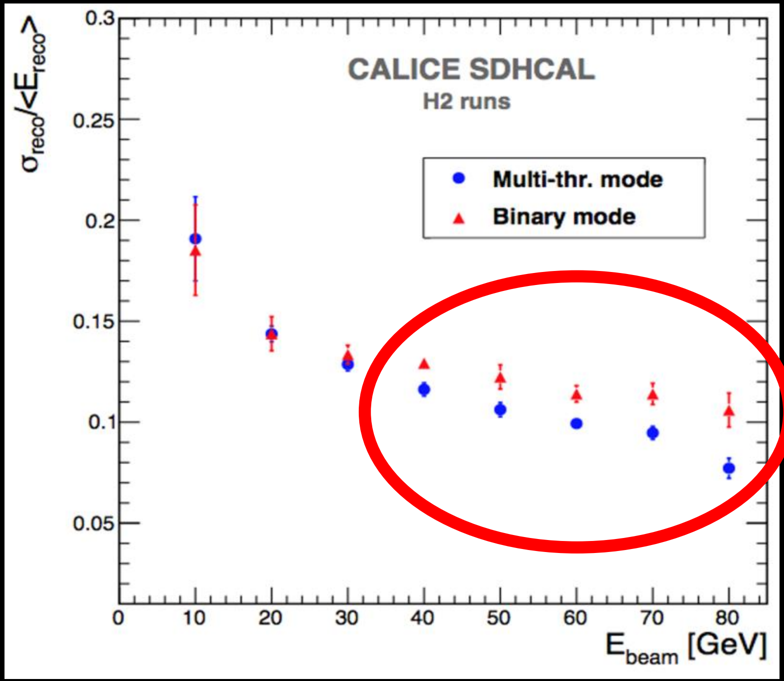
SDHCAL prototype — Performance

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

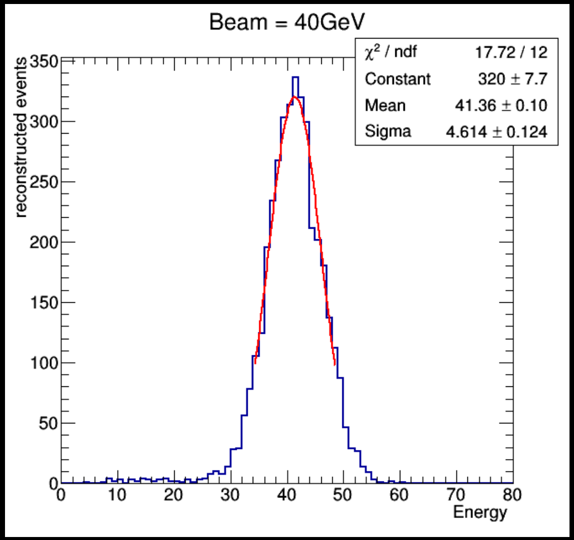
→N_1 = Nb. of hits with 1st threshold < signal < 2nd threshold
→N_2 = Nb. of hits with 2st threshold < signal < 3nd threshold
→N_3 = Nb. of hits with signal > 3rd threshold
→$N_{tot} = N_1 + N_2 + N_3$

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



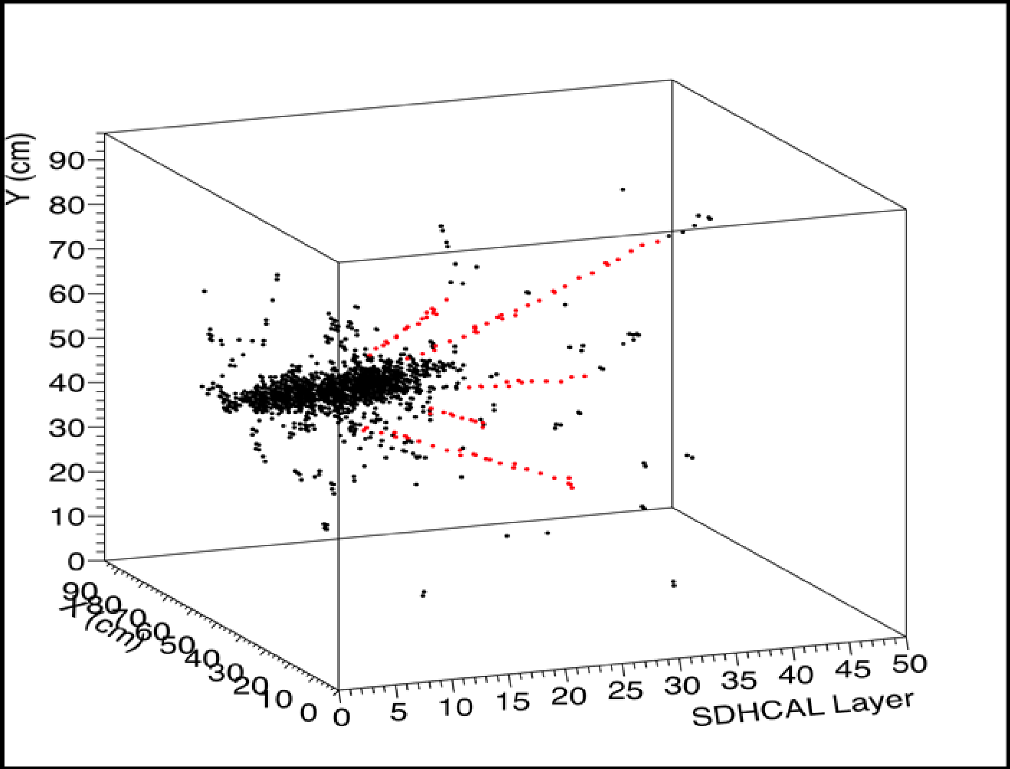
PID with BDT

◆ Tool: Standard cuts, BDT
Standard cut: shower begins after 5 layer

◆ TMVA package

◆ BDT 6 var Input:

1. First layer of the shower (Begin)
2. Number of tracks in the shower (TrackMultiplicity)
3. Ratio of shower layers over total fired layers (NInteractinglayer/Nlayers)
4. Shower density (Density)
5. Shower radius (Radius)
6. Maximum shower position (Length)

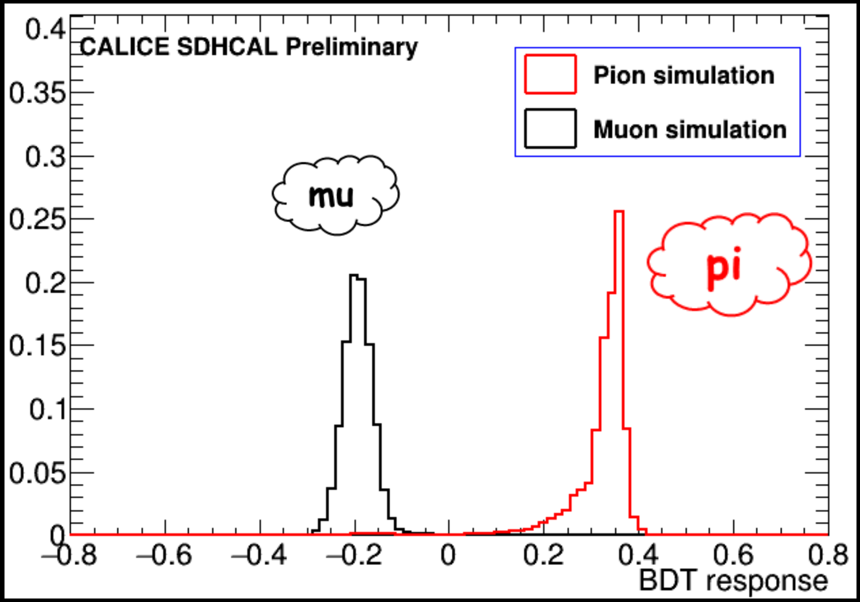


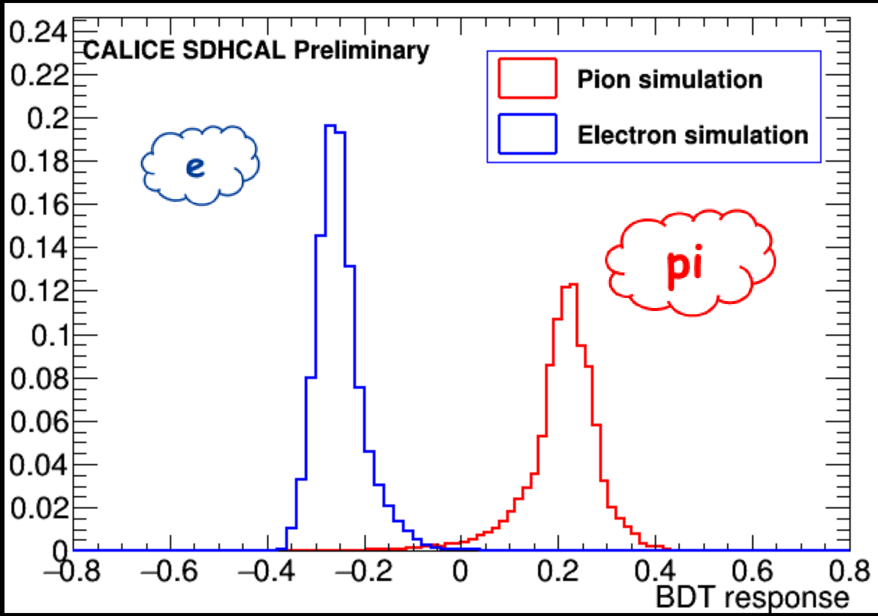
Strategy I: with MC samples training

Training phase

- **Signal:** 10000 simulated **pion** events for per energy point (10,20,30,40,50,60,70 and 80GeV)
- **Background1:** 10000 simulated **electron** events for per energy pont (10,20,30,40,50,60,70 and 80GeV)
- **Background2:** ≈7500 simulated **muon** events for per energy point (10,20,30,40,50,60,70 and 80GeV)

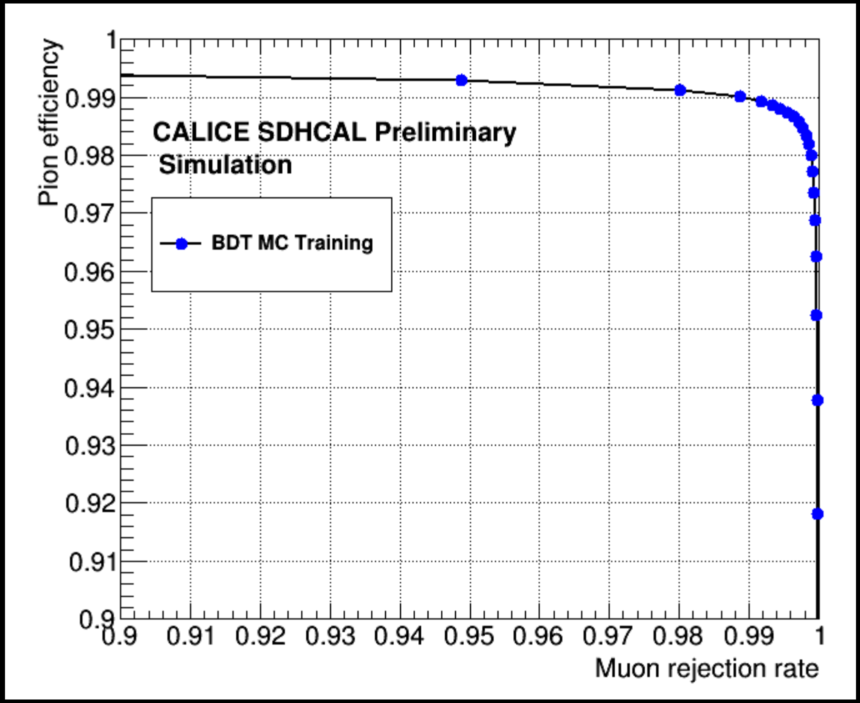
Test phase: the same as training phase but with independent samples

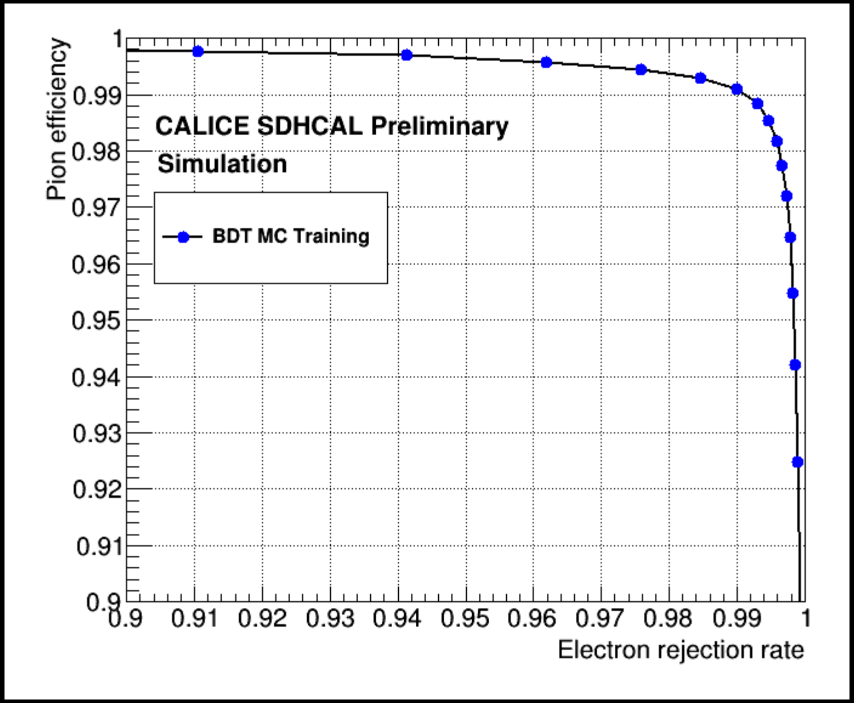




PID: Performance

- **Good pi/e and pi/muon separation**
- High **pion efficiency** exceeding **99%** with electron and muon **rejection rate** of the same level **(>99%)**

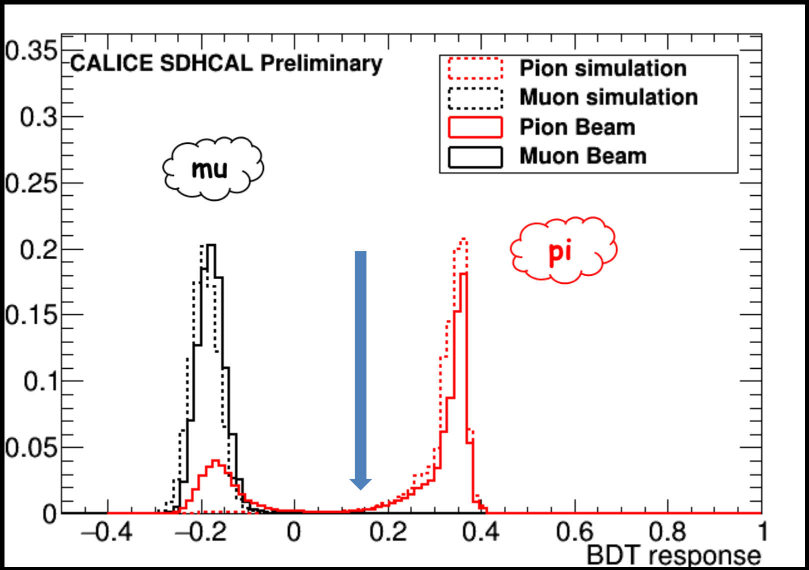


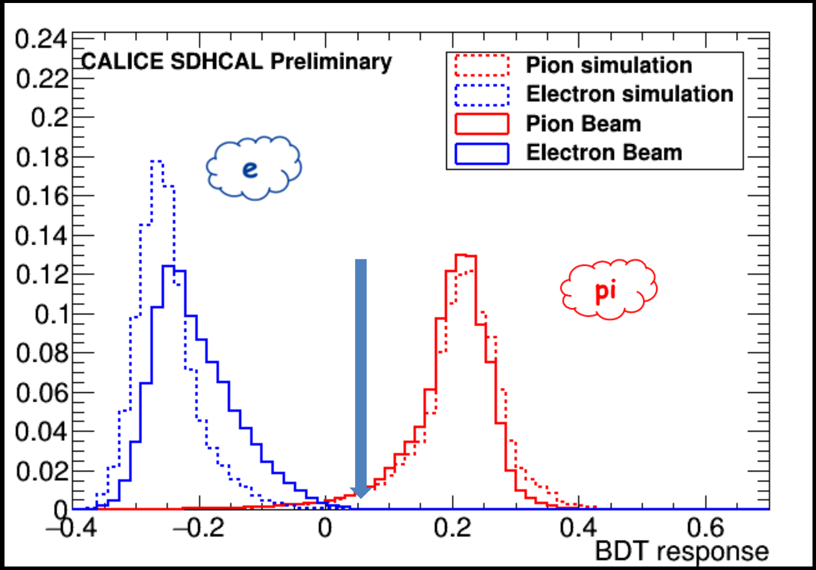


PID: beam data validation

SPS 2015

- electron 10,20,30,40 and 50 GeV
- Pion 10,20,30,40,50,60,70,80GeV
- Muon 110 GeV

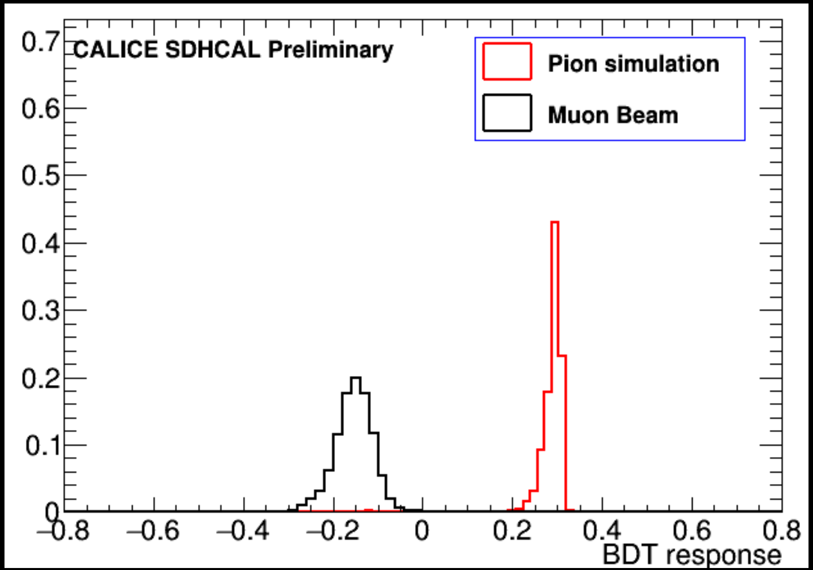


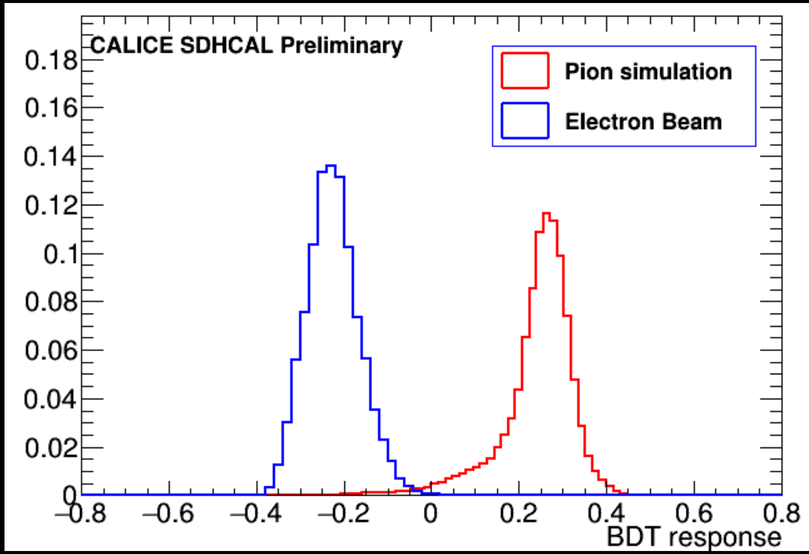


Strategy II: with data samples training

Training phase

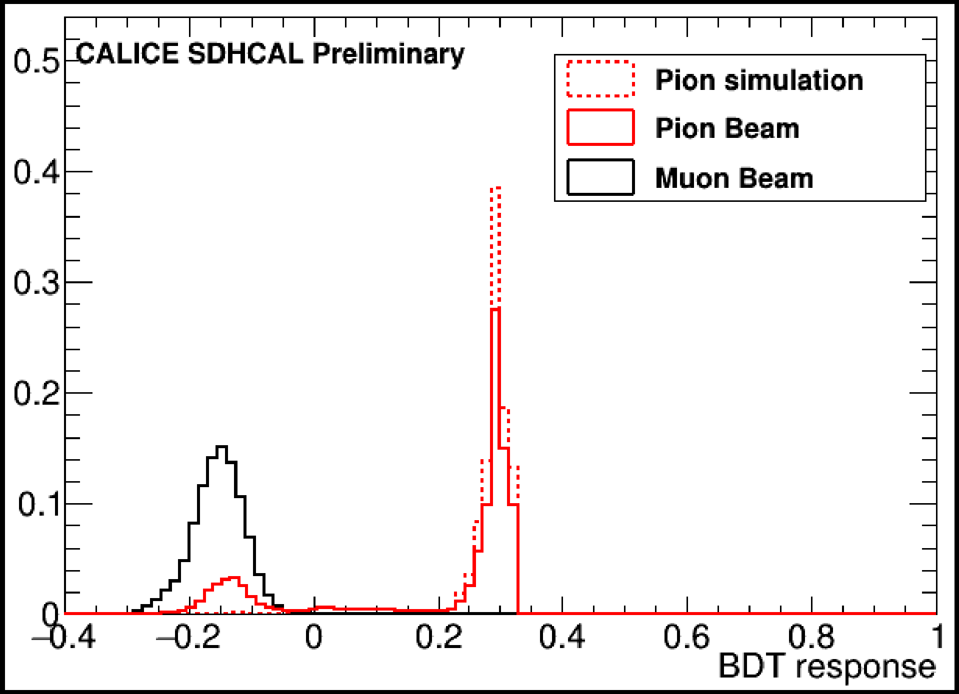
- **Signal:** 10000 simulated pion events for per energy point (10,20,30,40,50,60,70 and 80GeV)
- **Background1:**25000 beam electron events for energy 10,20,30,40,50 GeV
- **Background2:** ≈25000 beam muon events for energy 110GeV

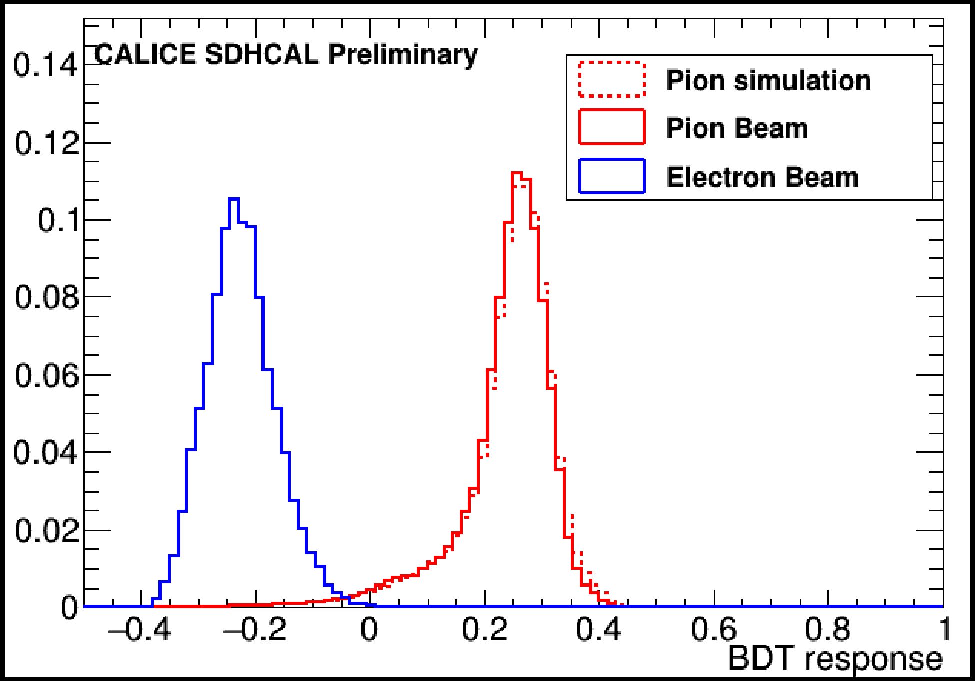




Test phase: the same as training phase but with independent samples

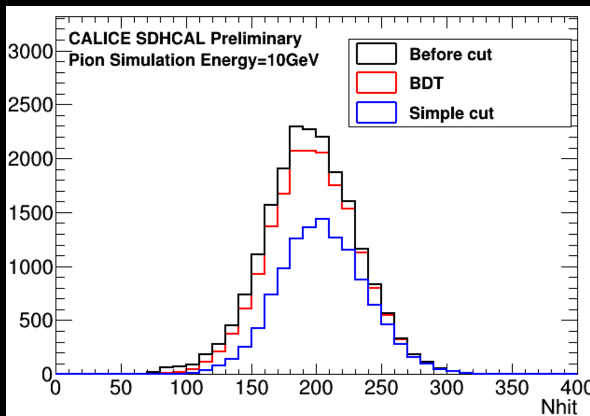
PID: beam data validation

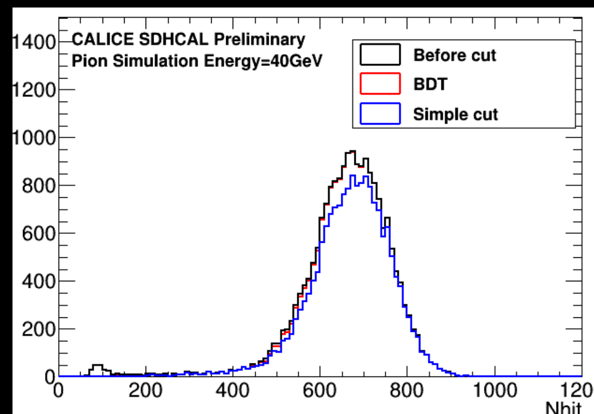


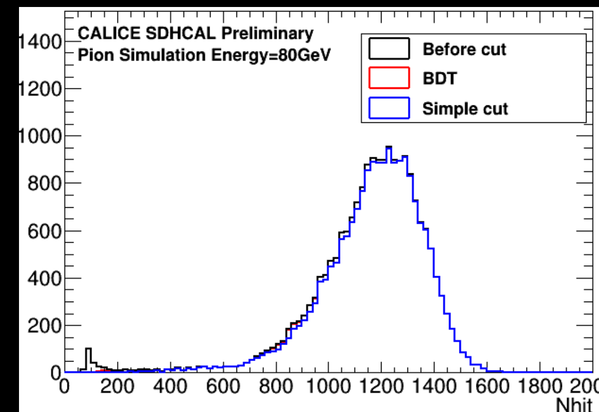


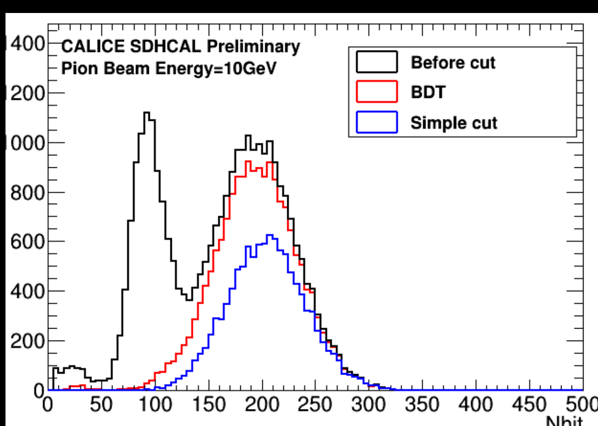
Good separation power and in agreement with strategy I

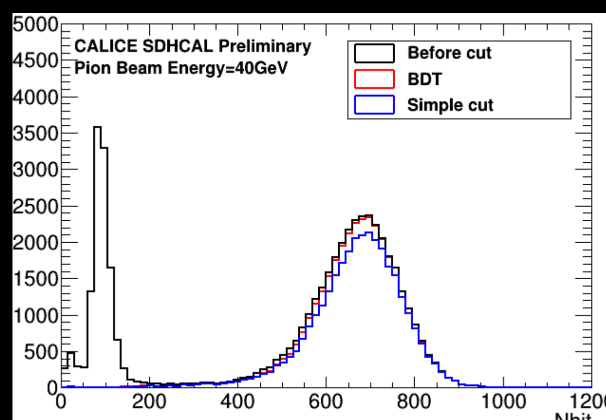
Nhit: standard method & BDT

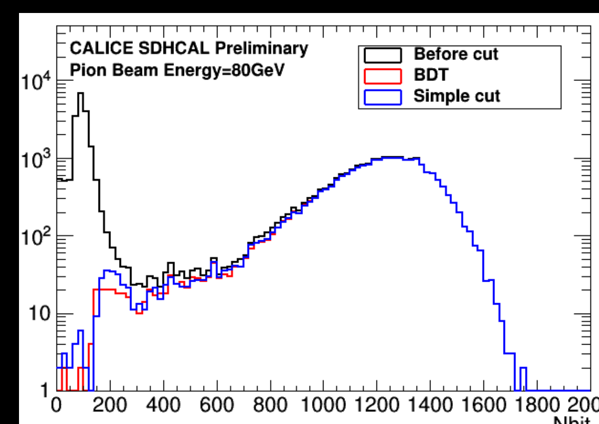






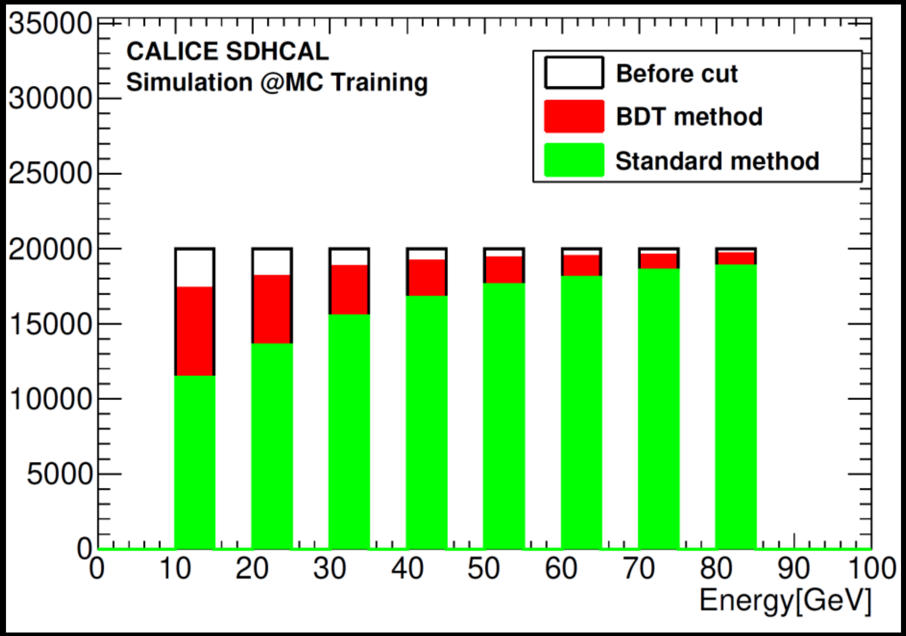




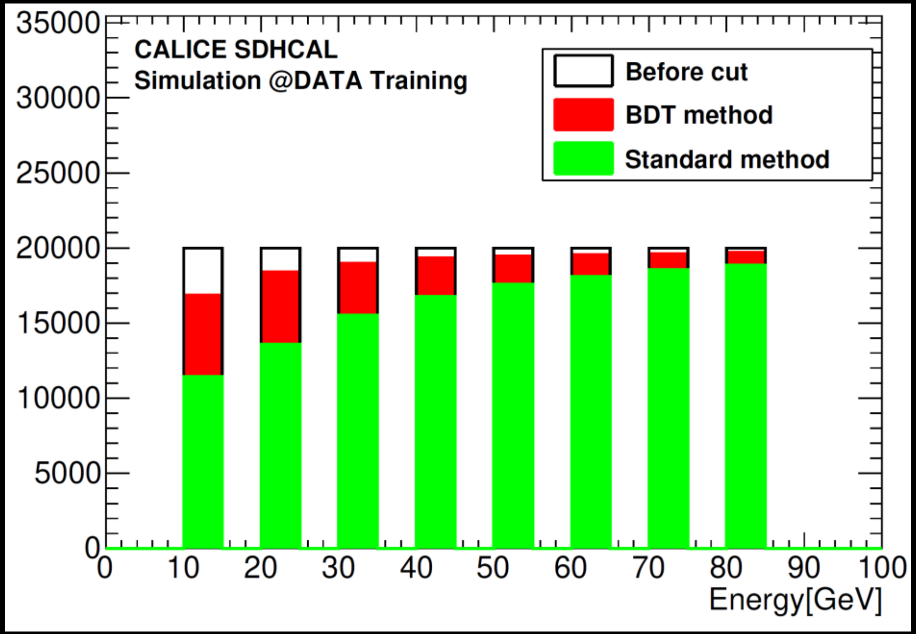


→In the low energy, BDT saves many events

The improvements on statistics



BDT with MC Training



BDT with DATA Training

Summary

- Technological protoype running successfully since 2012
- Many results validate the potential of the concept
- PID with BDT is reliable: Good pion efficiency with high electron and muon rejection rate
- Good improvement on statistics comparing with standard method

Thanks for your attention !