# Preliminary Study on PID for CEPC AHCAL

--Zhen Wang

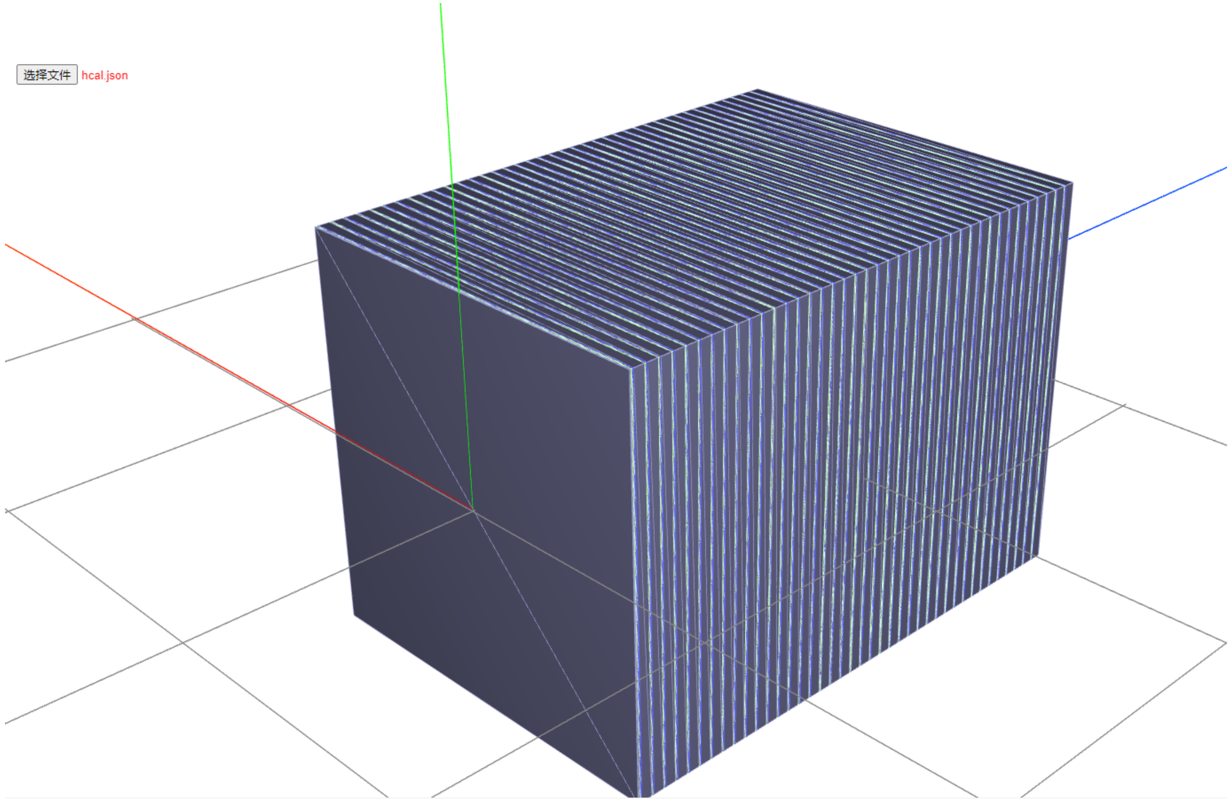
# Contents

- Motivation:
  - Check beam line purity, help distinguish particles.

- How:
  - Basic: Different particles generate different shower shapes in calorimeters.
  - Sample: Simulation with Geant4
  - Method: ROOT::TMVA BDT for training and tagging.
  - Variables:
    - Xwidth, ywidth, zwidth, edep,
    - Shower_start_layer, shower_layer_ratio, shower_density
    - Shower_length, track-multiplicity

- Performance check
- Summary & Plans

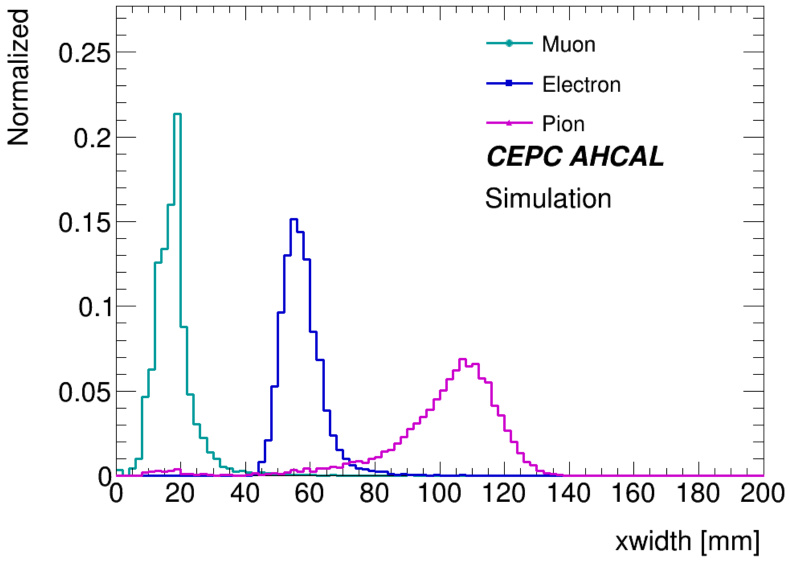
# Simulation

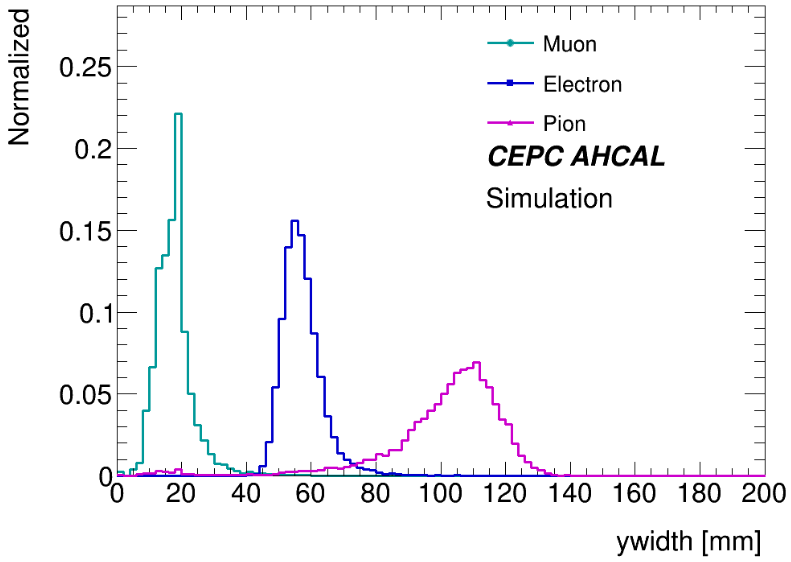


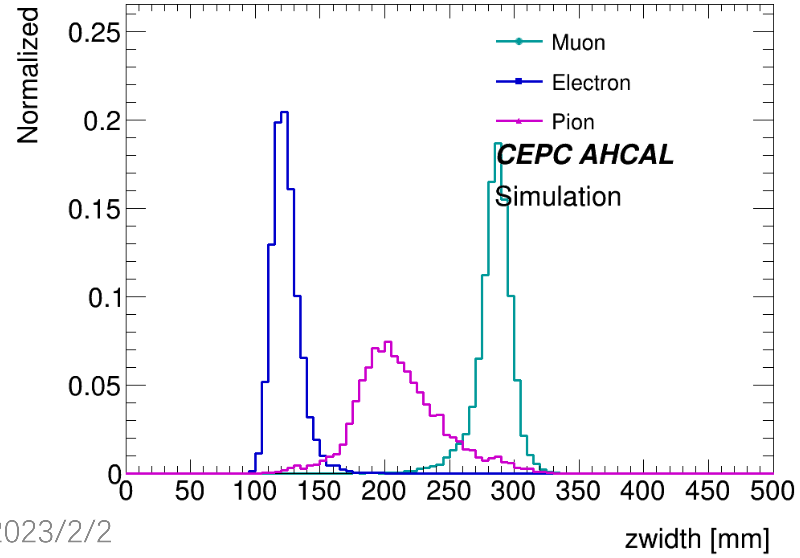

- Geometry:
  - AHCAL alone
- Incident Particle:
  - Electron 50 GeV
  - Pion 50 GeV
  - Muon 100 GeV
- Source shape: Point
- Incident direction: 0 0 1
- Incident position: 0 0 -100

Simulation code: https://github.com/wangz1996/cepc-calo

# Shower width [mm]



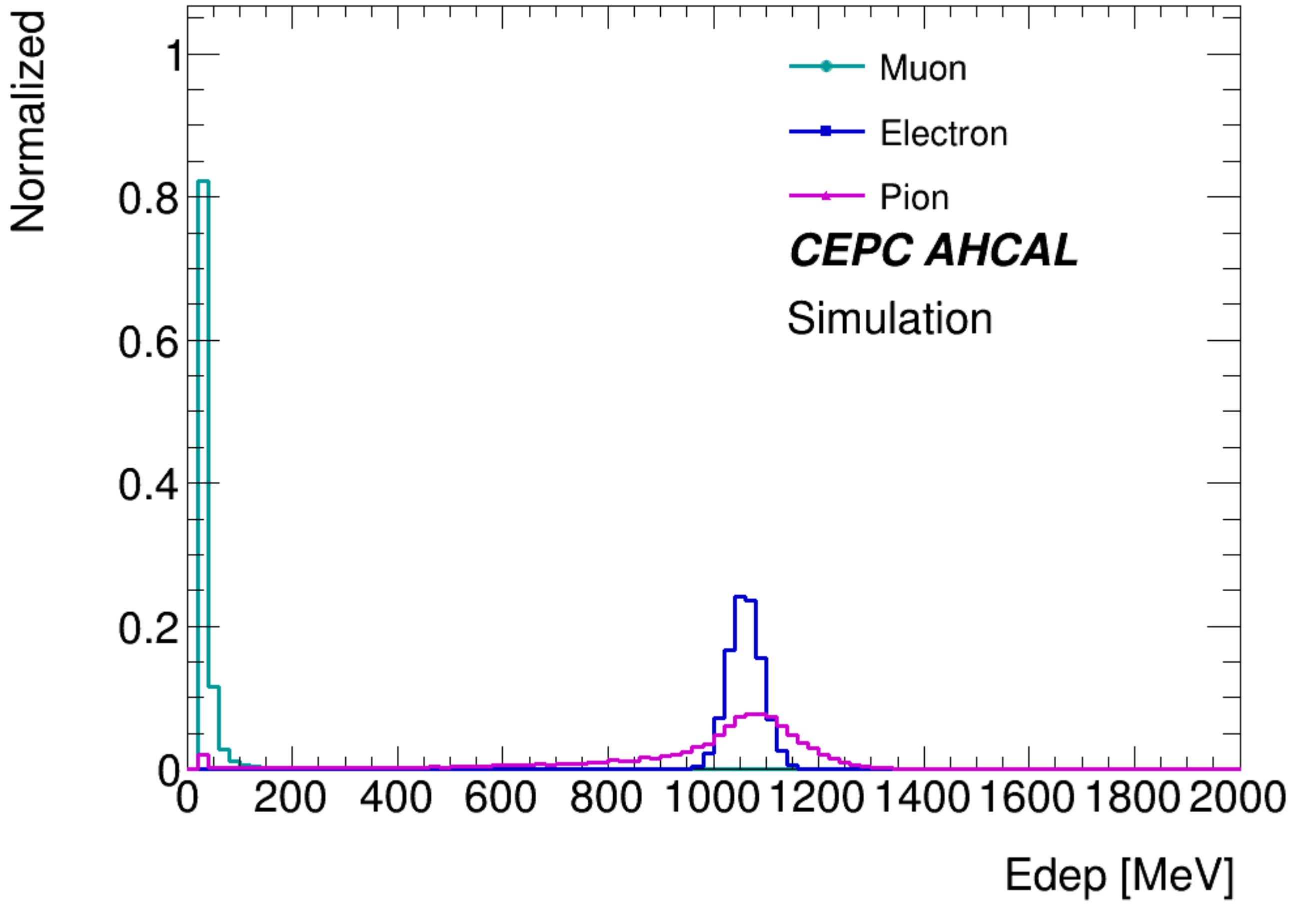

**Width** : RMS of shower projection in certain axis

**Muon** : Small width along x&y, large width along z

**Electron** : Middle width along x&y, quick truncation along z

**Pion** : Large width along x&y, middle width along z

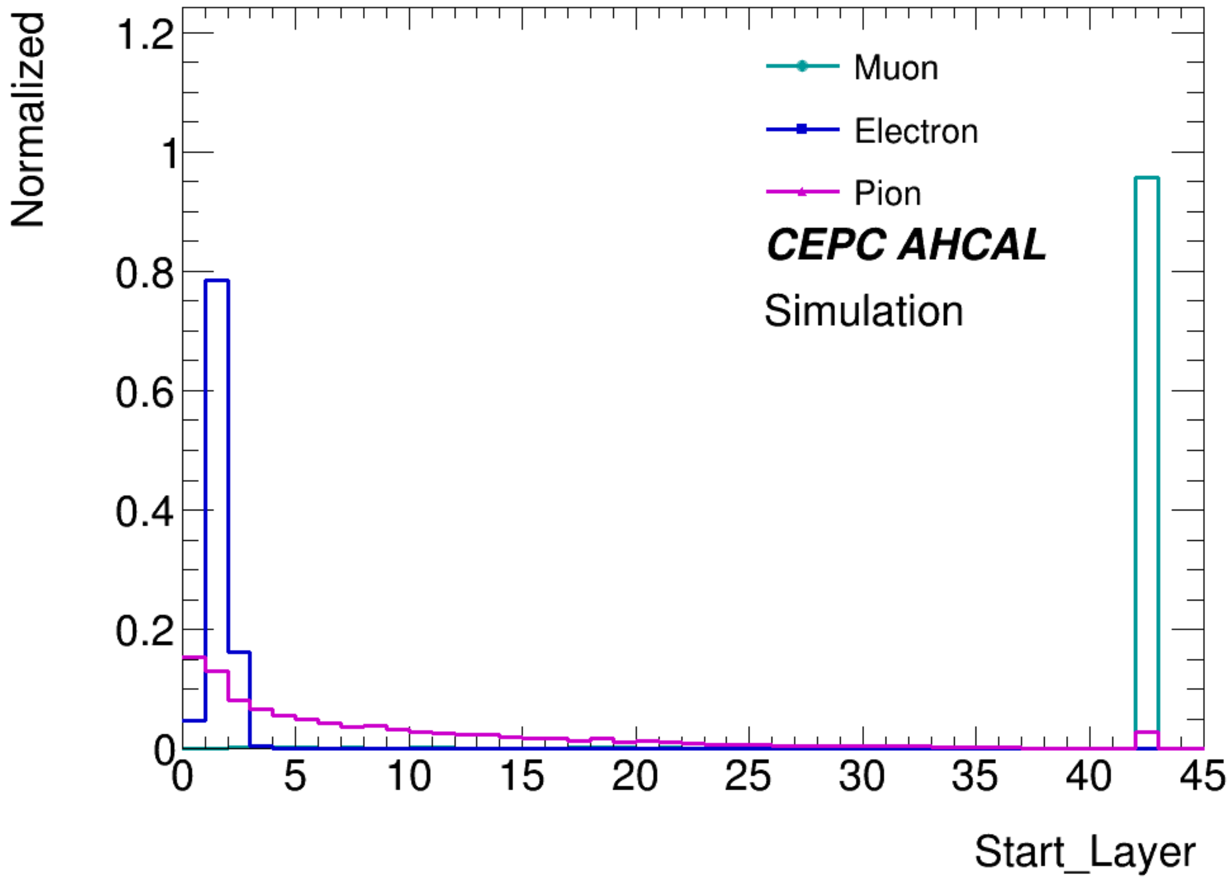
# Edeps




Muons deposit small fraction of energies as expected.

Electrons and pions deposit part of the particle's energy into the calorimeter but with different width.

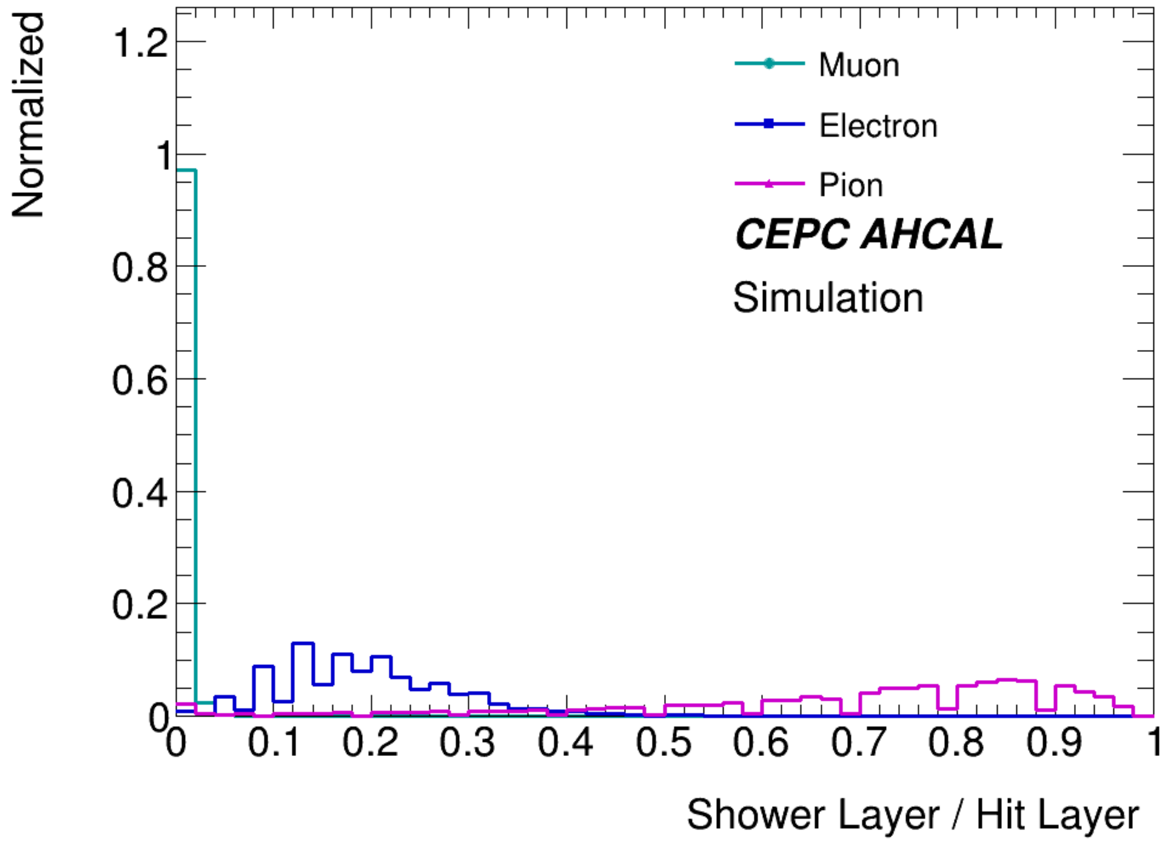
# Shower start layers




Start layer is selected only if the layer and the following 3 layers each has at least 4 hit cells

If no such layers are found, start layer would be set to 42.

# Shower layer ratio

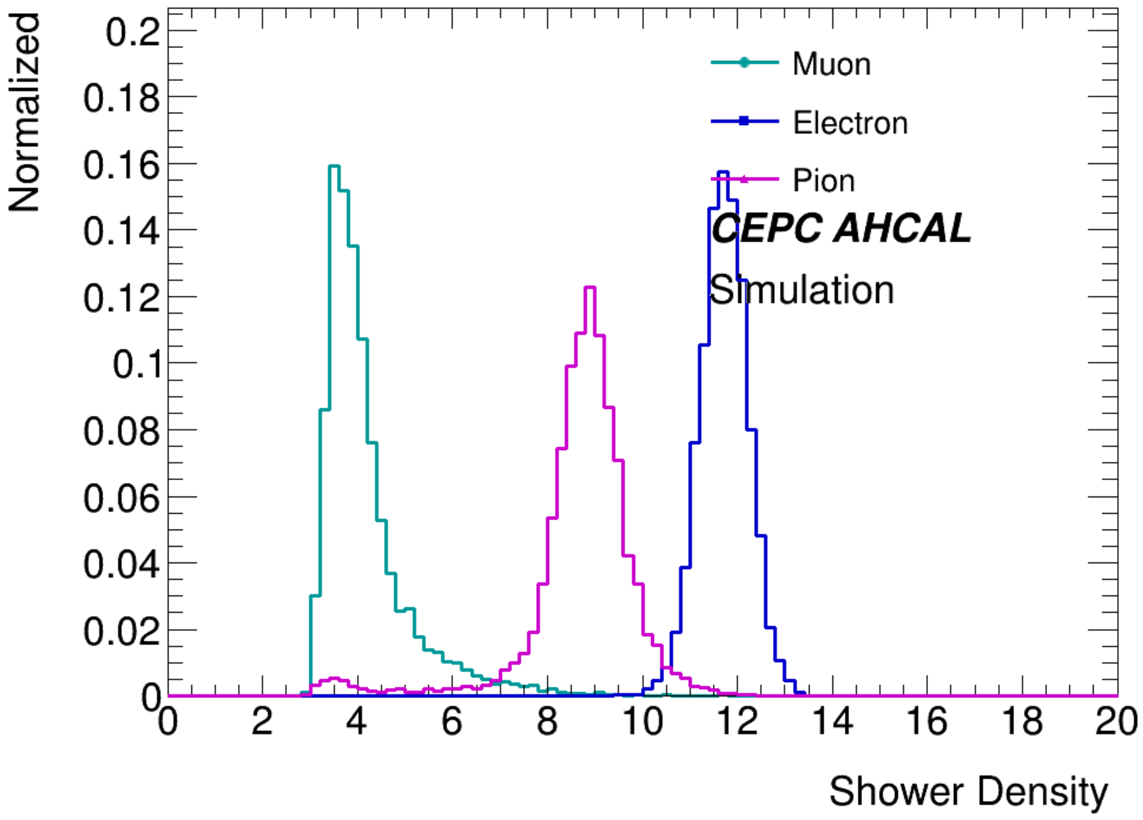



Shower layer: Layers with RMS of x and y larger than 50 mm.

Hit layer: Layers with at least one cell hit.

The ratio could be used to distinguish muons

# Shower density

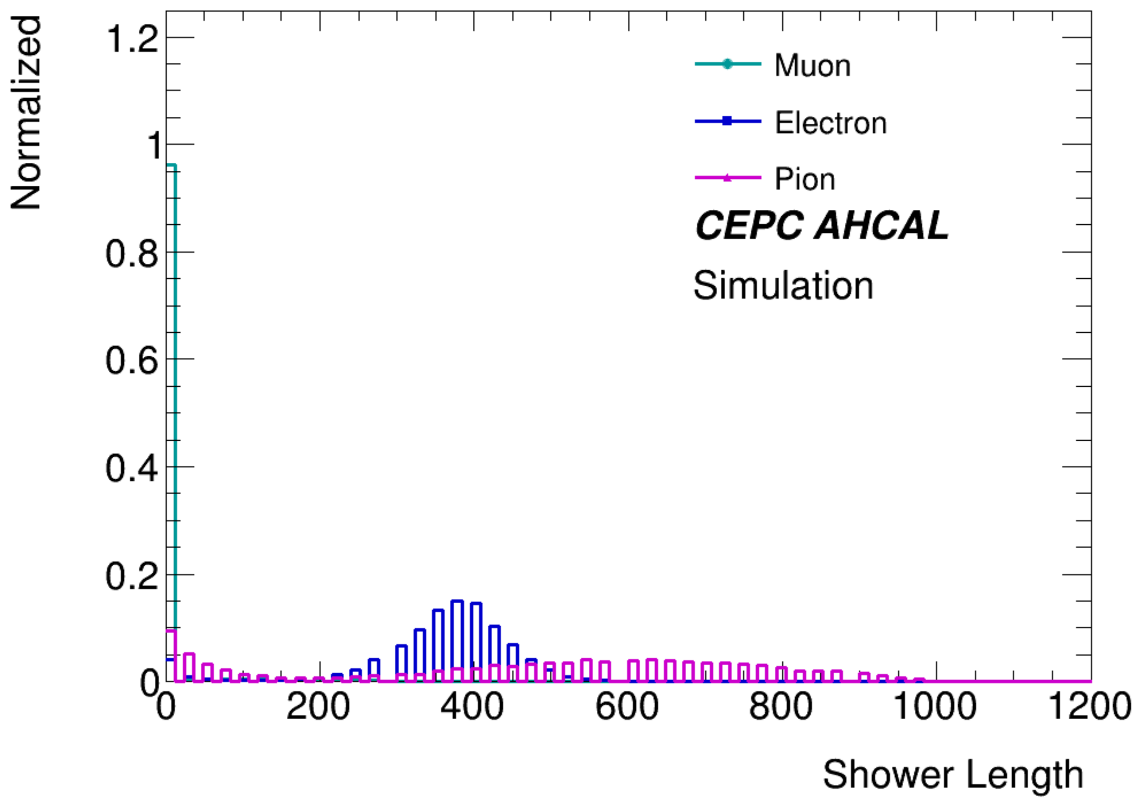



Density is calculated by counting the number of hit cells within the 3x3 range of each hit.

$$Density = \frac{\sum_{i=1}^{i=N_{hit}} N_i}{N_{hit}}$$

As expected, muons have smallest density.
EM shower density is the largest.

# Shower Length



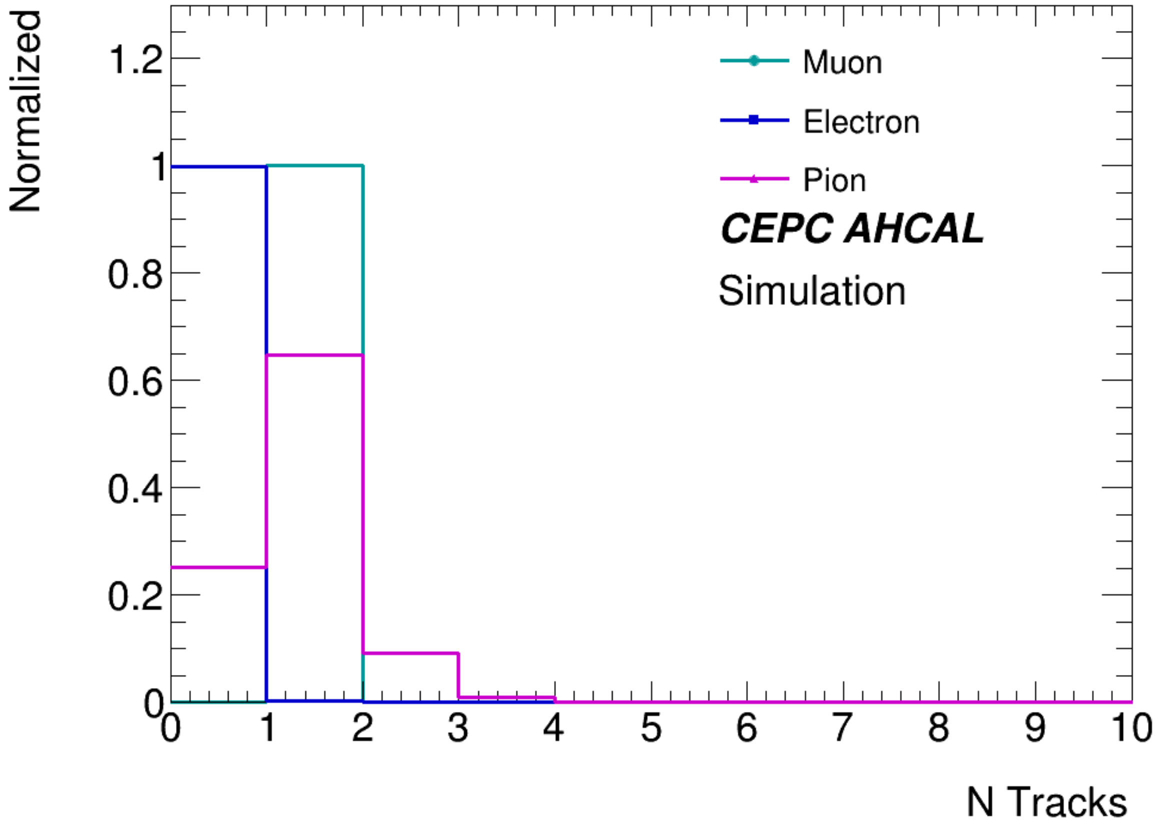

Length is defined as the distance between the start layer and the maximum RMS layer of the shower

Muons have no shower for most of the events

Electrons have certain peaks around 400 mm

Pions have no certain peaks

# Track-Multiplicity




Hough Transformation is applied to pick out single tracks inside the shower.

HT technique here follows:
1.Merge adjacent hit cells in one layer
2.Do hough transformation from x-z plane to ρ-θ plane
3.Count number of tracks based on 2D ρ-θ histogram

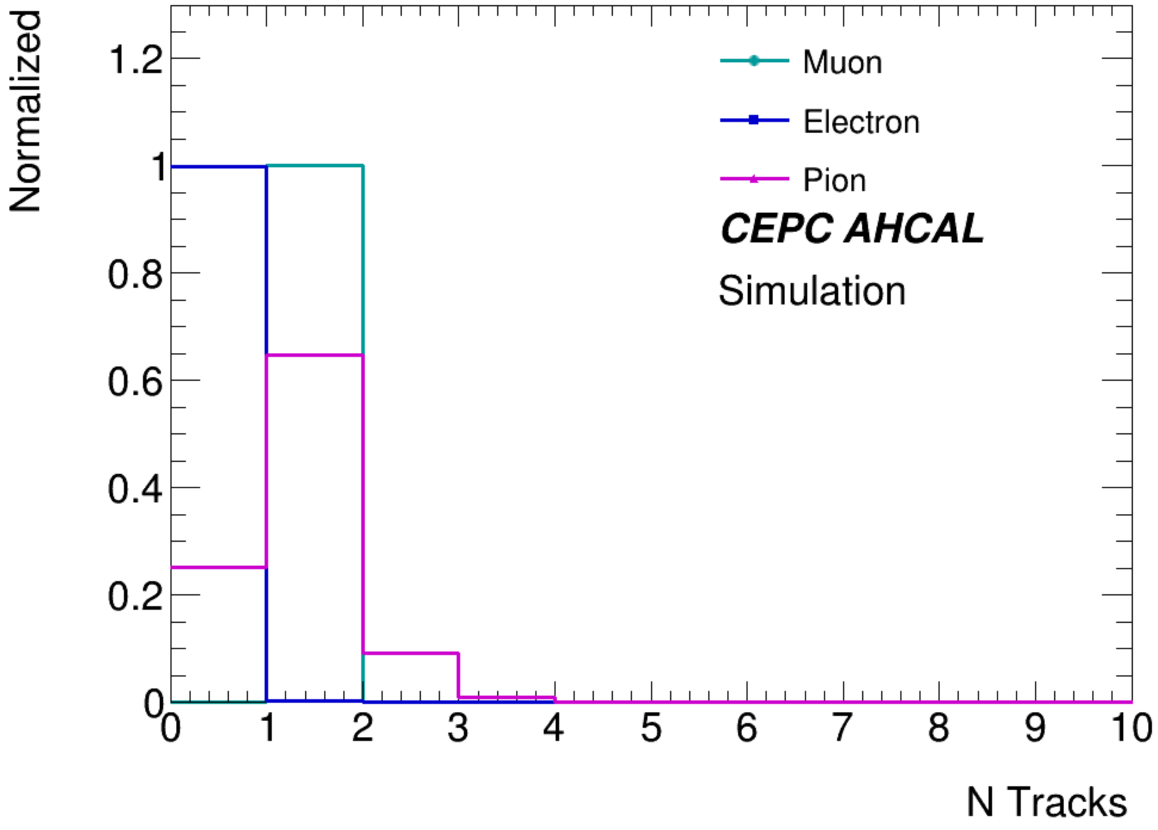
$$\rho = zcos\theta + xsin\theta$$

Preliminary implementation of HT technique, need to be refined.



Ref: https://iopscience.iop.org/article/10.1088/1748-0221/12/05/P05009

# Track-Multiplicity

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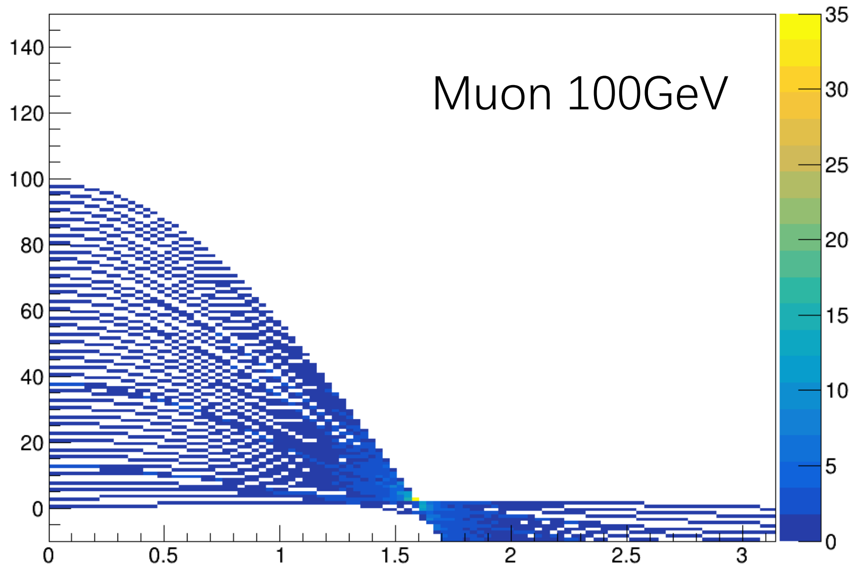


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# MVA Method for PID

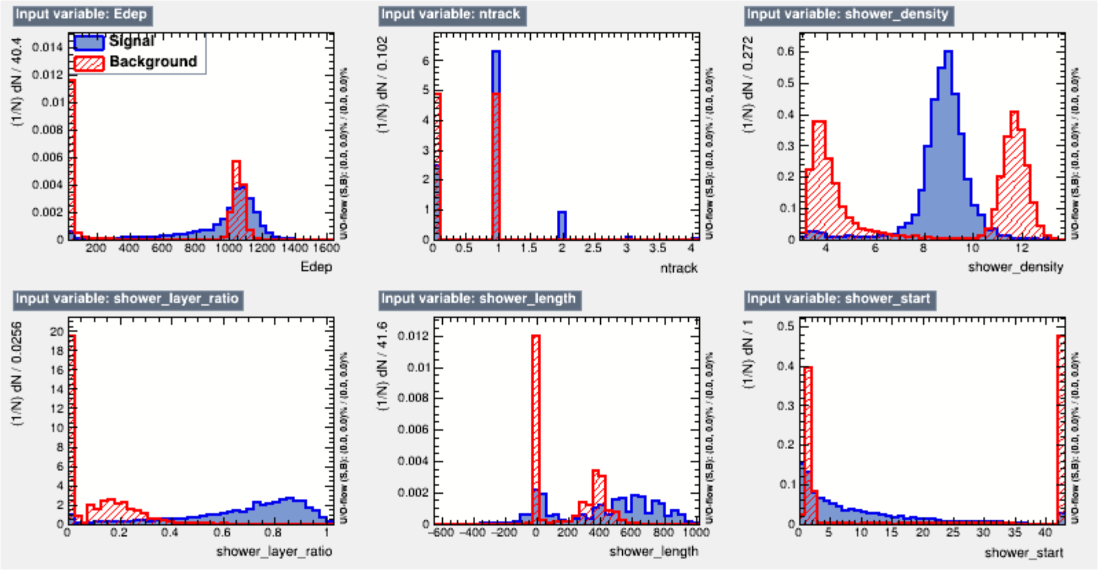
- Sample preparation:
  - E+: 1e4 events at 50 GeV
  - Pi+: 1e4 events at 50 GeV
  - Muon+: 1e4 events at 100GeV
- Input variables:
  - X,Y,Zwidth
  - Edep
  - StartLayer
  - LayerRatio
  - Density
  - Length
  - nTrack

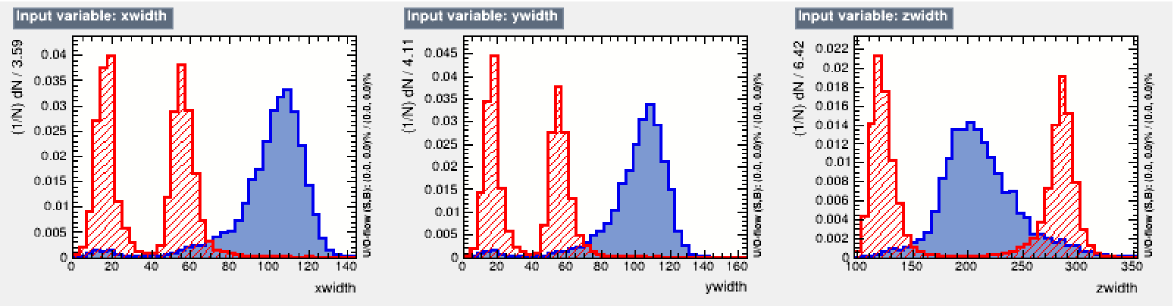
```
Number of training and testing events
---------------------------------------------------
Signal     -- training events             : 7000
Signal     -- testing events              : 3000
Signal     -- training and testing events: 10000
Background -- training events             : 14000
Background -- testing events              : 6000
Background -- training and testing events: 20000
```

Signal: Pion simulation samples

Bkg: Electron and muon simulation samples

# Signal vs Bkg



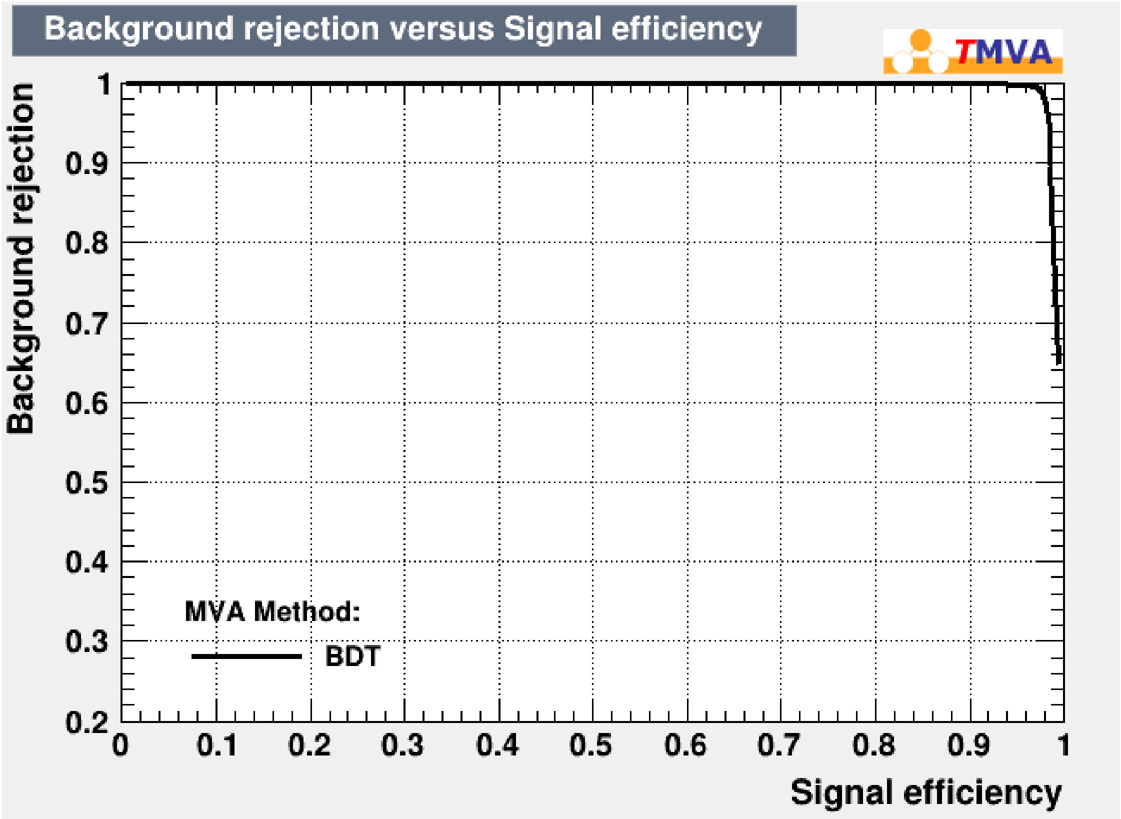

Shower width along different axis could be powerful.

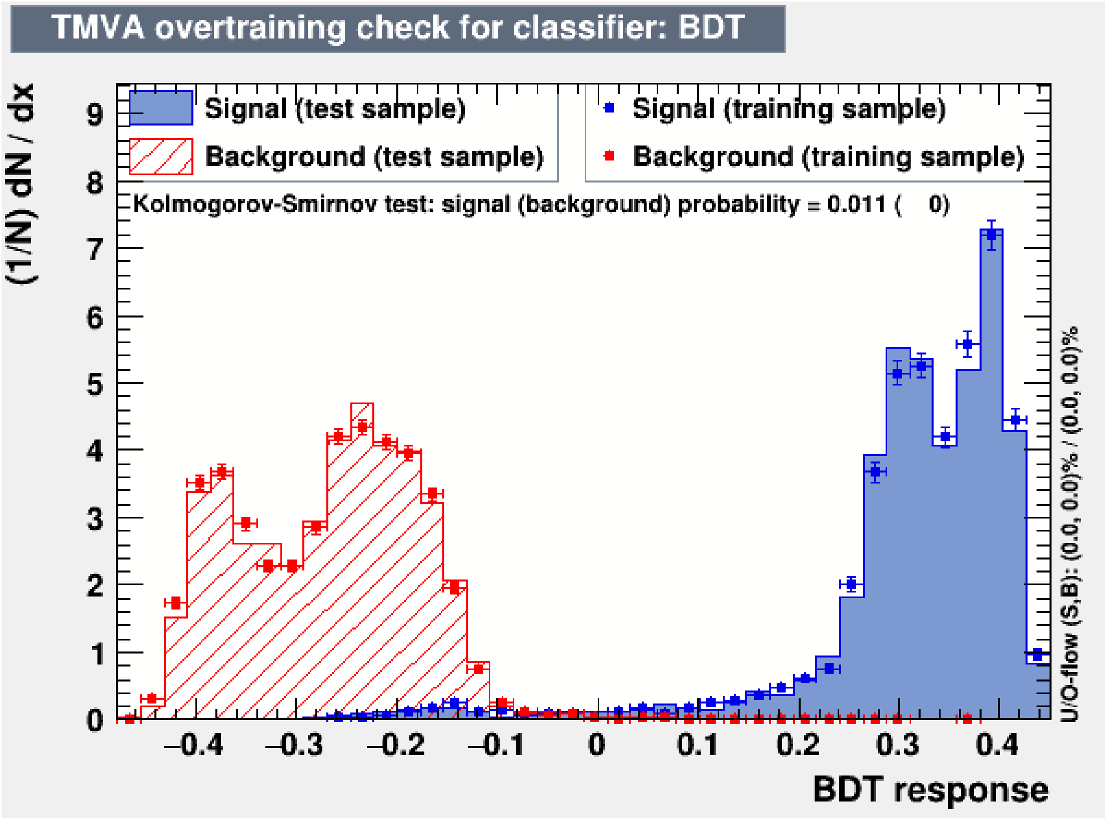
Track-Multiplicity needs to be further optimized.

Energy deposition should be calibrated before put into BDT training

| Rank | Variable | Variable Importance |
|---|---|---|
| 1 | xwidth | 1.629e-01 |
| 2 | zwidth | 1.618e-01 |
| 3 | ywidth | 1.585e-01 |
| 4 | shower_density | 1.451e-01 |
| 5 | Edep | 9.852e-02 |
| 6 | shower_layer_ratio | 8.991e-02 |
| 7 | shower_start | 8.894e-02 |
| 8 | shower_length | 6.744e-02 |
| 9 | ntrack | 2.688e-02 |

# ROC && Separation



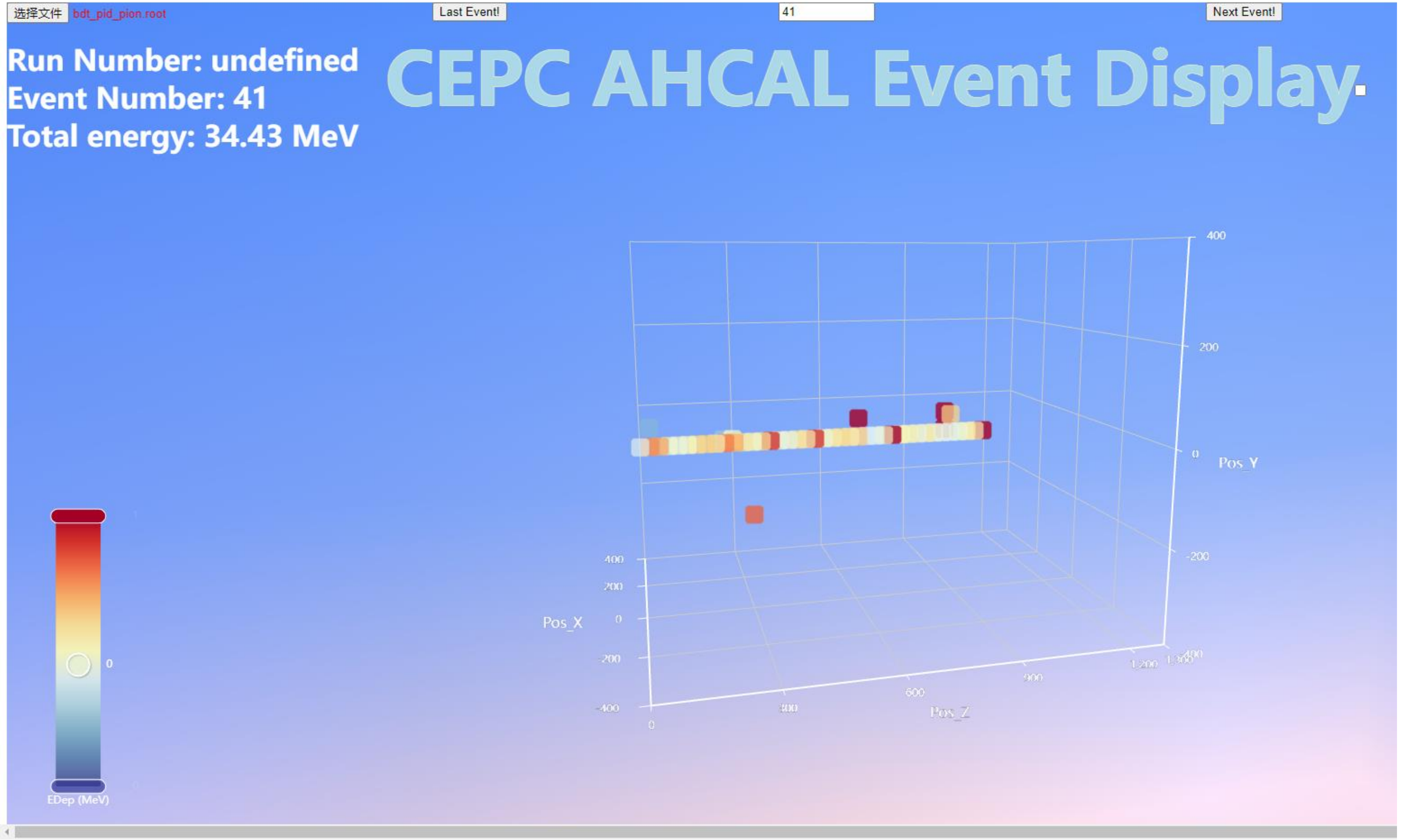






Analysis code: https://github.com/wangz1996/cepc_hbuana

# Detector Limits

- 40 layers * 20 mm/layer = 800 mm ≈4.8 Radiation Length




Simulated Pion events

# Todos

- Shower radius is being studied and will be added to the tool(Jiyuan Chen).
- Future data tagging with trained BDTs and help check purity.
- Training of ECAL+AHCAL combined showers for PID
- Documentation….