Pattern recognition at CEPC AHCAL prototype using beam test data at CERN

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Introduction

An analog hadronic calorimeter (AHCAL) prototype developed for the CEPC

- Absorber: stainless steel; sensitive material: plastic scintillator
- Transverse: $72 \times 72\ cm^2$; granularity: $4 \times 4\ cm^2$; 40 sampling layers
- 12960 channels; 5 tons; developed in 2018-2022

Successful beam test campaigns and decent statistics of beam test data samples collection

- Conducted at CERN (SPS-H2, SPS-H8, PS-T9) during 2022-2023
- muons: 10/120 GeV; electrons/positrons: 0.5 - 5 GeV, 10 - 250 GeV; pions: 1 - 350 GeV

Beam purity issue: observed beam contamination

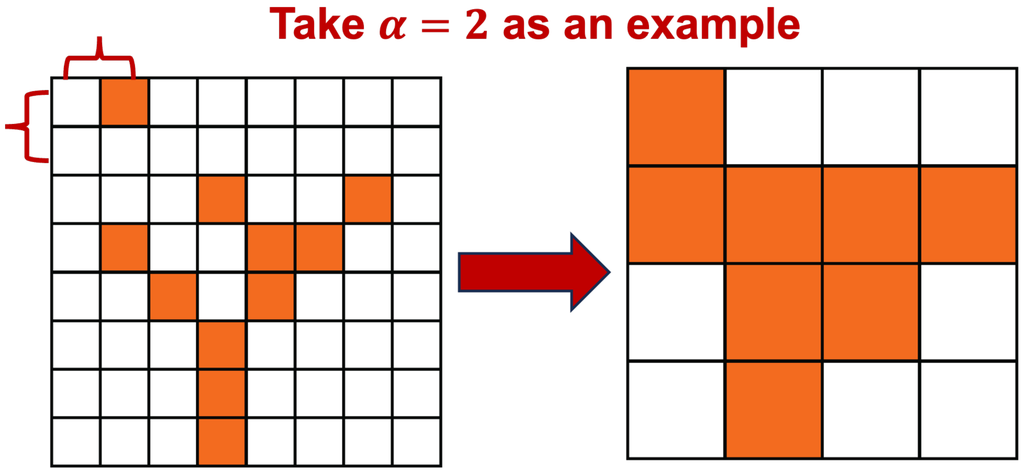
- Particle identification technique developed: to select high-purity data sample

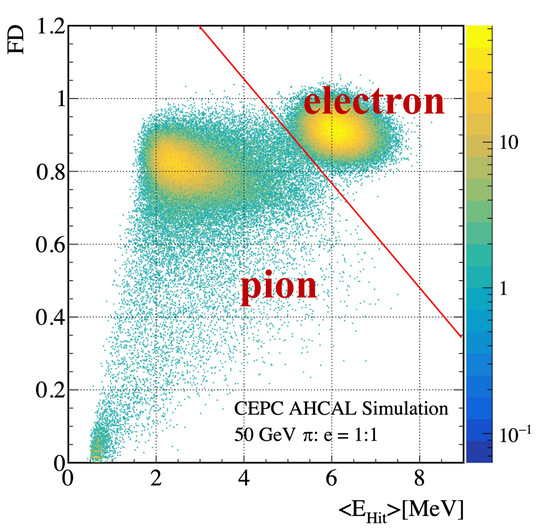
PID technique based on Fractal Dimension

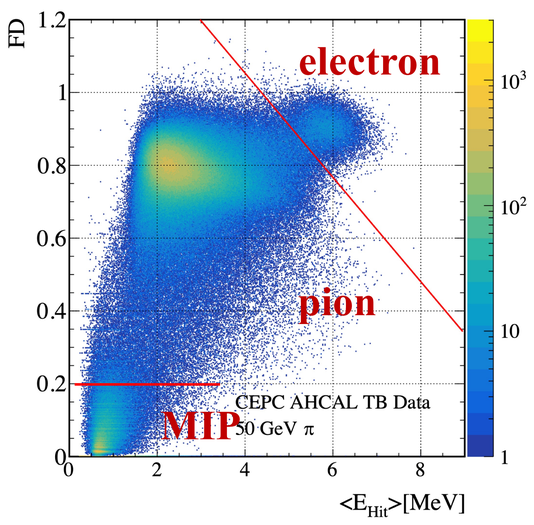
Particle Identification (PID) method:

- Fractal Dimension (FD):
  - $FD = \left\langle \frac{log(R_{\alpha,1})}{log(\alpha)} \right\rangle + 1$, where $R_{\alpha,1} = \frac{N_1}{N_\alpha}$ and N_α is number of hits scaled by the factor α
  - Self-similarity in patterns of showers in transverse plane
  - Utilize the high granularity characteristic of calorimeter and sensitive to the nature of particle and the type of interaction
- Average Hit Energy: $\langle E_{Hit} \rangle = E_{\mathrm{sum}} / \mathrm{N}_{\mathrm{Hits}}$

Take $\alpha = 2$ as an example

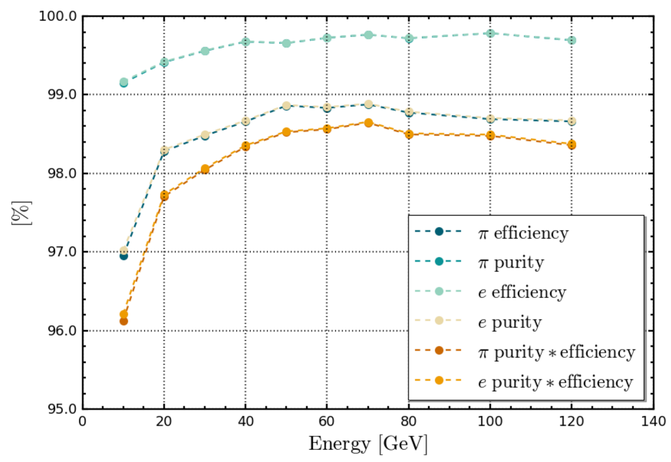






PID performance:

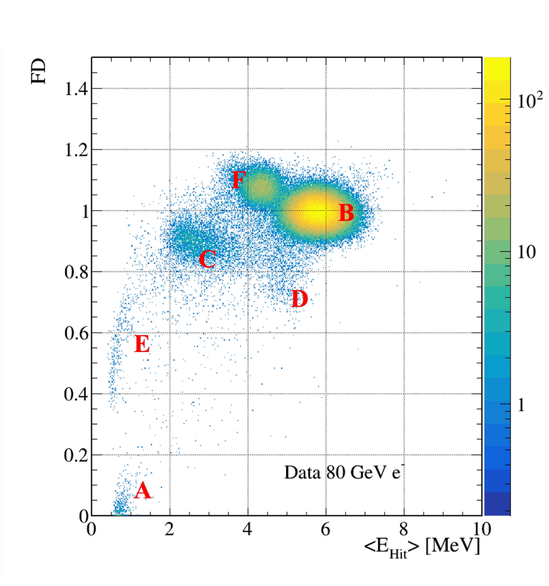
- Efficiency and purity better than **97%** and can achieve 99.7%
- Improve with larger energy and enter in plateau from 30 GeV

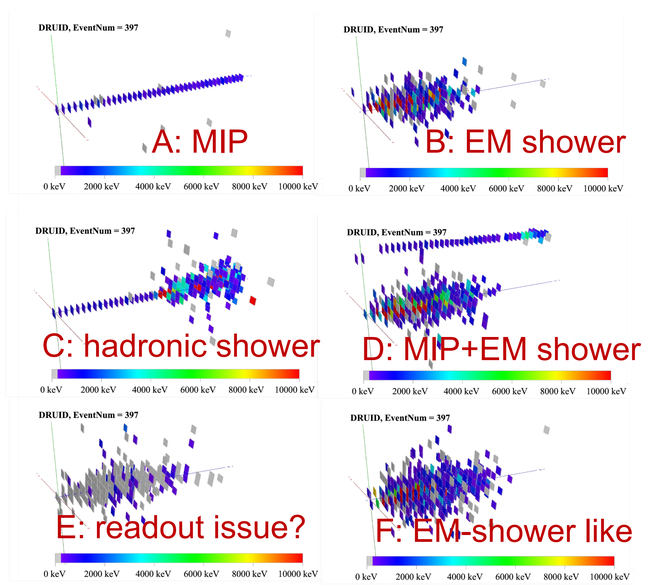


PID studies with beam test data

Characteristics of different beam particles

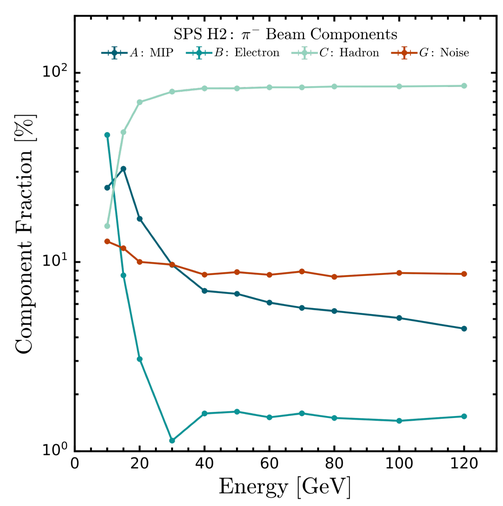
- Imaging capability of high granularity calorimeter

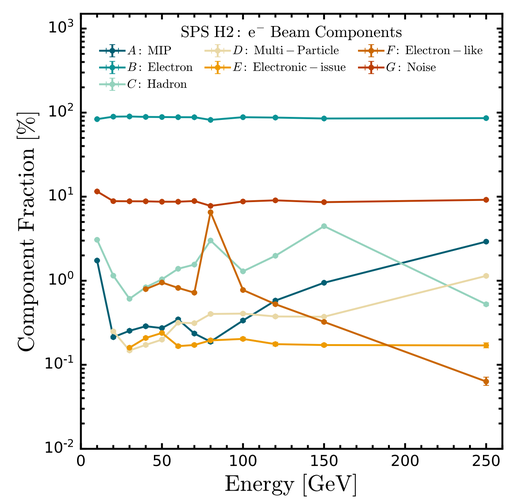




SPS-H2 Beam purity analysis

- Electron beam: purity > 80%
- Pion beam: purity improves with energy
  - When energy > 30 GeV, purity > 80%
- Noise events become a dominating factor





Conclusions

- An AHCAL prototype developed and successful beam test at CERN
- Develop a new PID technique based on fractal dimension, efficiency and purity are better than 97%
- Comprehensive beam purity analysis, SPS-H2 beam purity > 80% for electron and pion beams > 30 GeV

Acknowledgement

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