

# Beam Test of Sci-W ECAL and AHCAL Prototypes

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On behalf of CEPC Calorimeter working group



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Institute of High Energy Physics  
Chinese Academy of Sciences

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# Outline

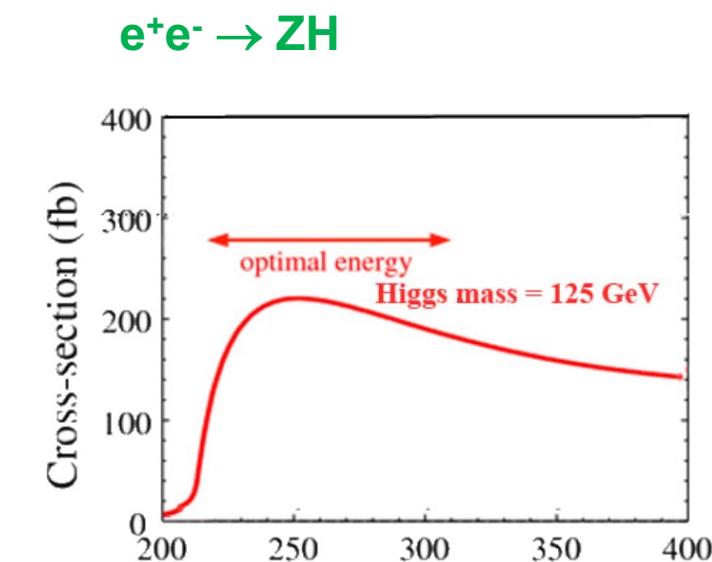
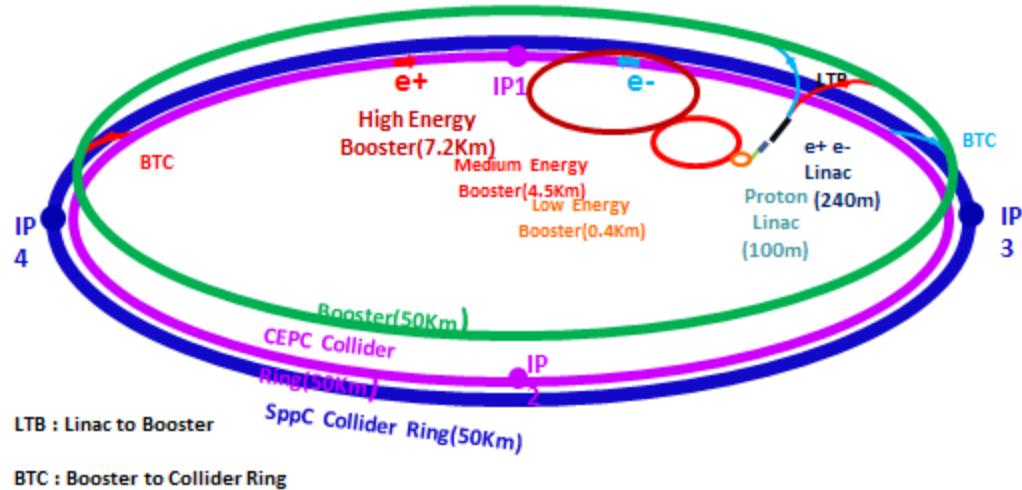
- Motivation
- Calorimeter prototypes introduction
- Beam test at CERN
- Summary



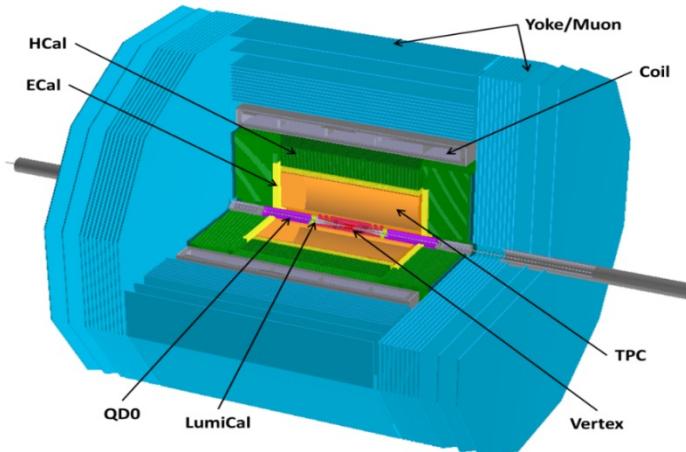
# Motivation

## Circular Electron Positron Collider (CEPC)

$E_{cm} \approx 240\text{GeV}$ , luminosity  $\sim 2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$  can also run at the Z-pole  
Precision measurement of the Higgs boson (and the Z boson)



# Requirements of CEPC Calorimeter

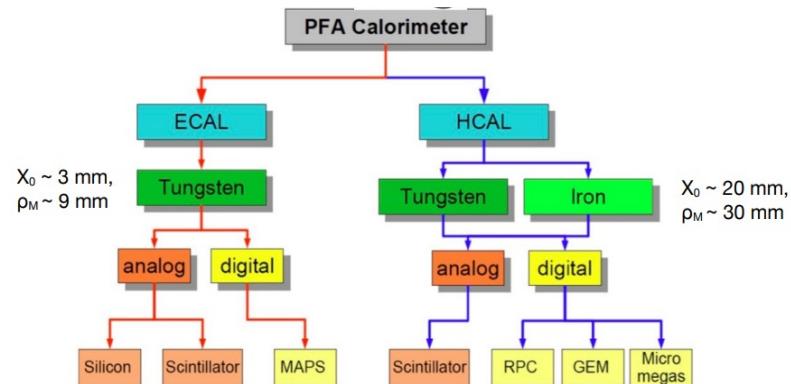


- **ILD-like detector with additional considerations.**

## Challenges:

- **Momentum:**  $\sigma_{1/p} < 5 \times 10^{-5} \text{ GeV}^{-1}$
- **Impact parameter:**  $\sigma_{r\phi} = 5 \oplus 10 / (p \cdot \sin^{\frac{3}{2}}\theta) \mu\text{m}$
- **Jet energy:** 
$$\frac{\sigma_E}{E} \approx 3 - 4\%$$

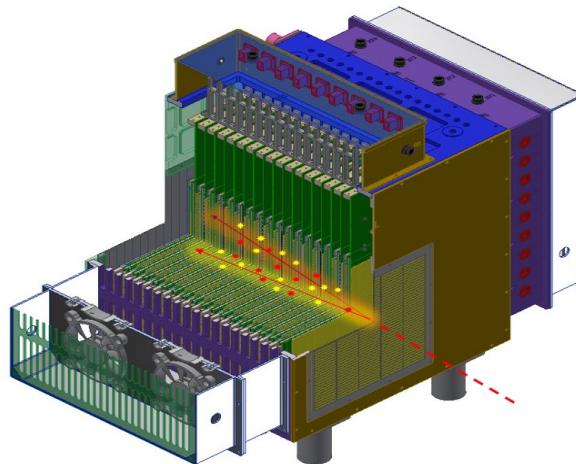
- The Particle Flow Algorithm (PFA) calorimeter concept was proposed
  - High granularity
  - Good track finding
  - Good energy resolution



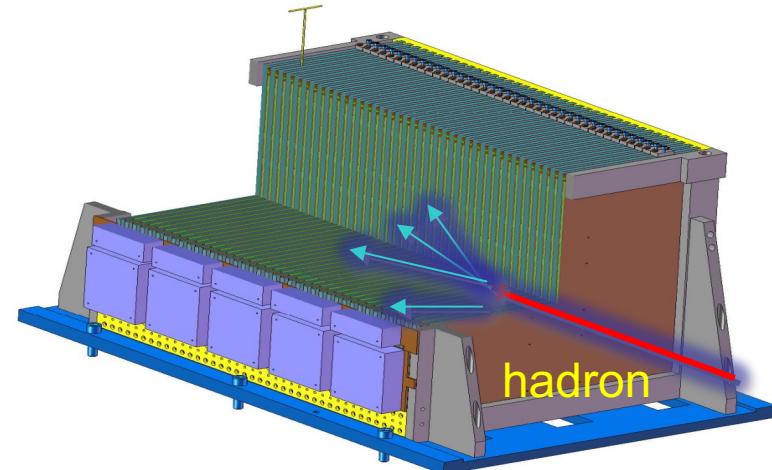
# PFA Calorimeter prototype

## Sampling Calorimeter

Calo	Sampling No.	Sensitive detector	Absorber	Granularity	Electronics	Absorb length	Energy Resolution	weight
Sci-W ECAL	32	PSD+SiPM	W-Cu	5mm×5 mm	SP-2E	22 $X_0$	16%@ 1 GeV	0.3 T
AHCAL	40	PSD+SiPM	Fe	40mm×4 0mm	SP-2E	4.7 NIL	60%@ 1 GeV	5.0 T



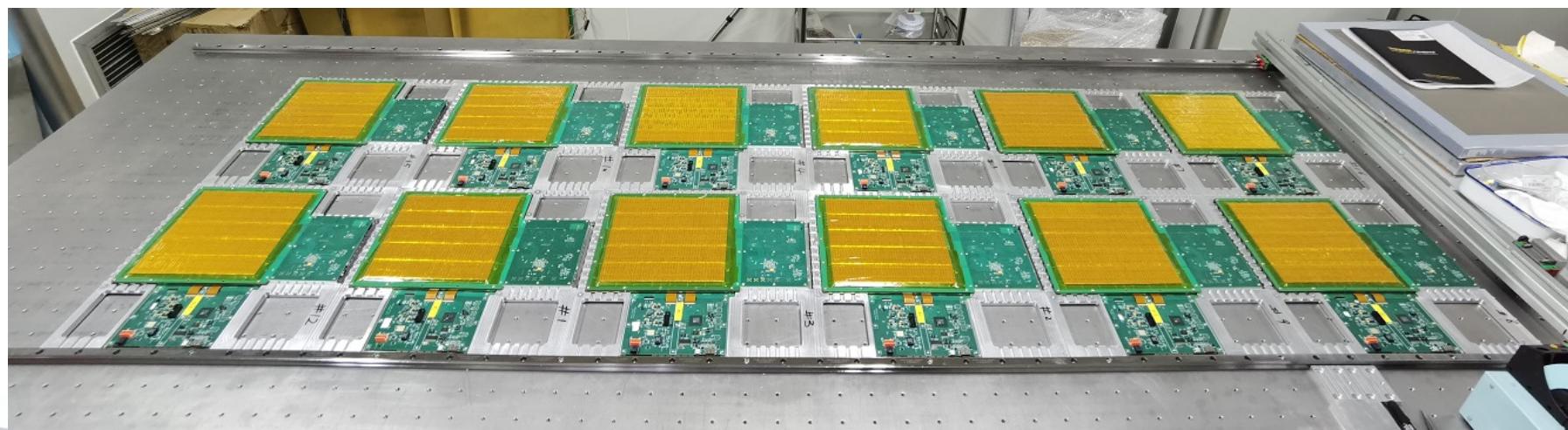
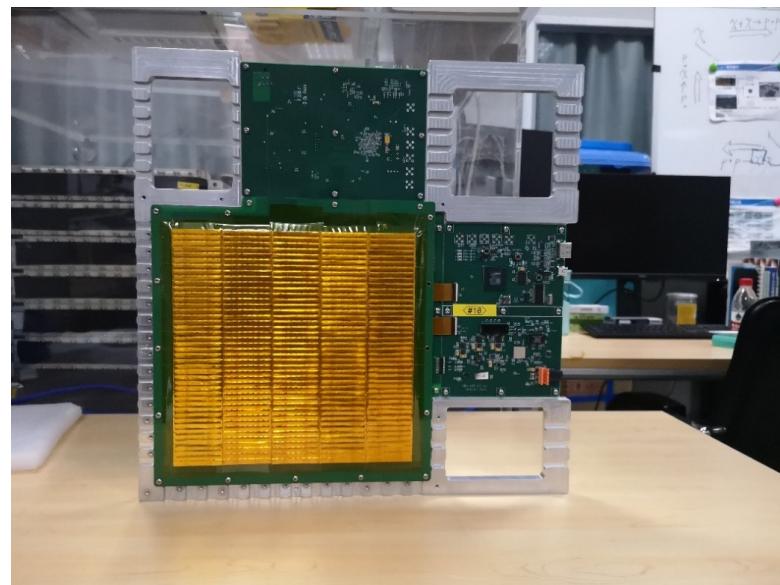
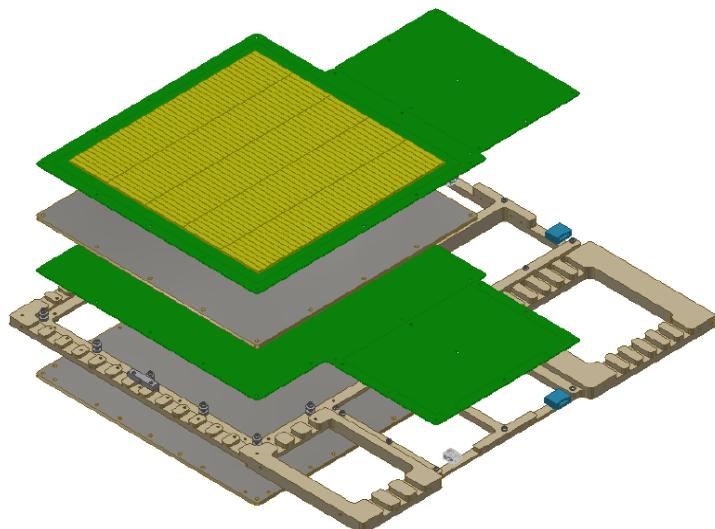
Sci-W ECAL



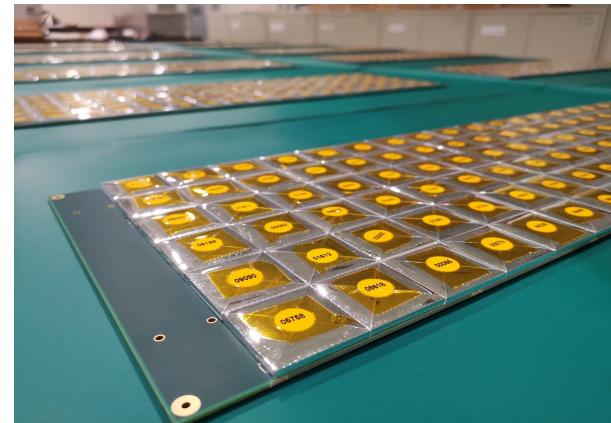
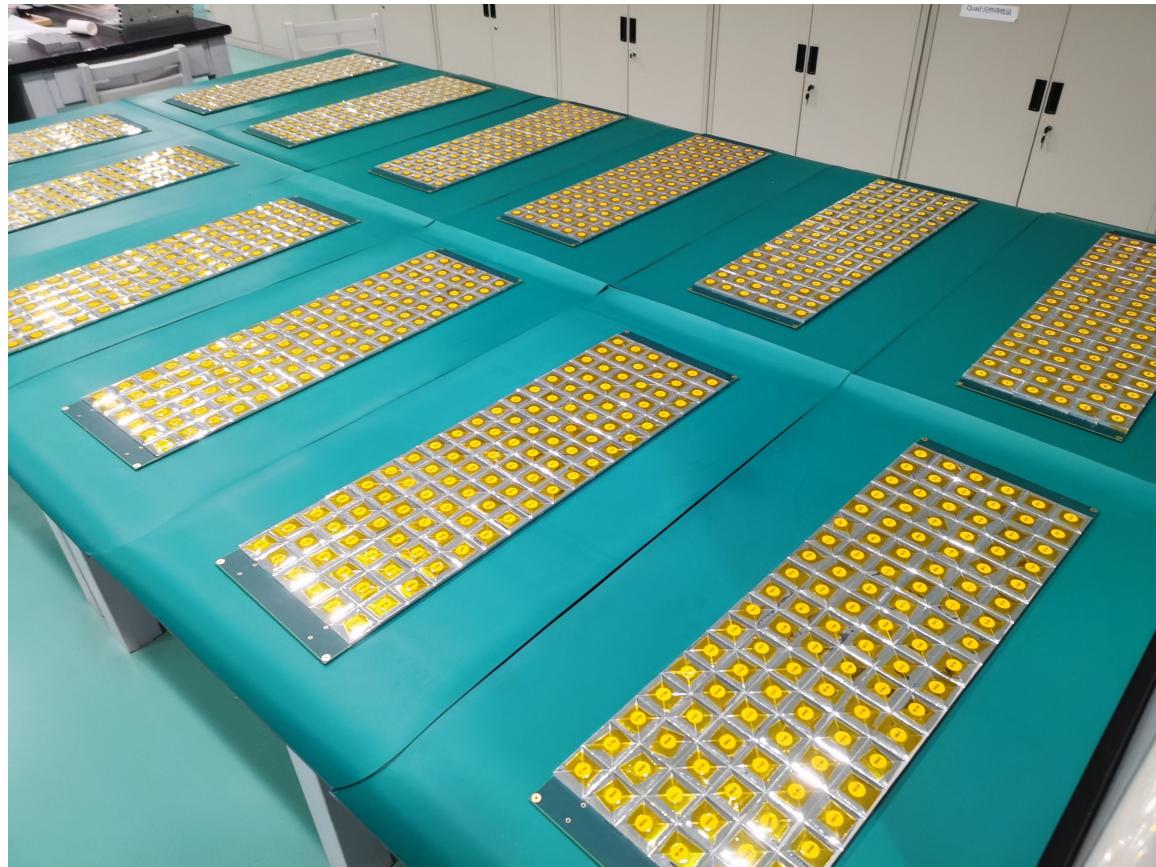
AHCAL



# Super-layer assembly



# HBU assembly



2023/8/9

# PFA Calorimeter prototypes



Sci-W ECAL



AHCAL



# Shipping to CERN for Beam Test

- ◆ In the middle of Sep. 2022, the detectors were sent to CERN from Hefei. The total weight is 10.6 tons.
- ◆ On Oct. 14, the detectors were arrived at CERN.



Hefei, 15/9



CERN, 14/10

# Beam test in CERN

- In Oct. 2022, There was a two weeks beam test at H8 of SPS
- In April, May, There was a two weeks test at H2 and T9 respectively.
- $\pi^+/-$ ,  $e^+/-$  were tested.  $e$ : 0.5 - 250 GeV/c,  
Pion: 1 - 120 GeV/c
- In 2022, about **25 million** events were collected
- In 2023, about **40 million** events



# Install the detectors in beam area

Supporting Table



ECAL



AHCAL

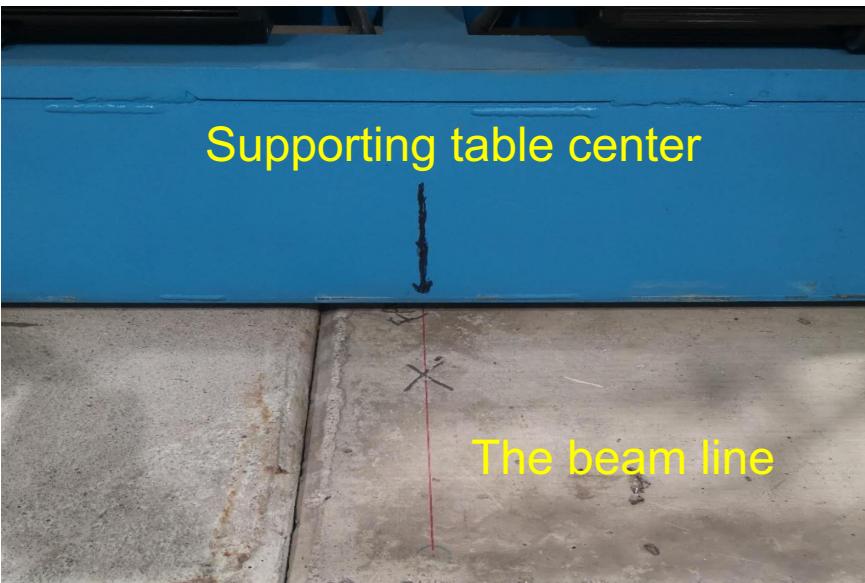


Table

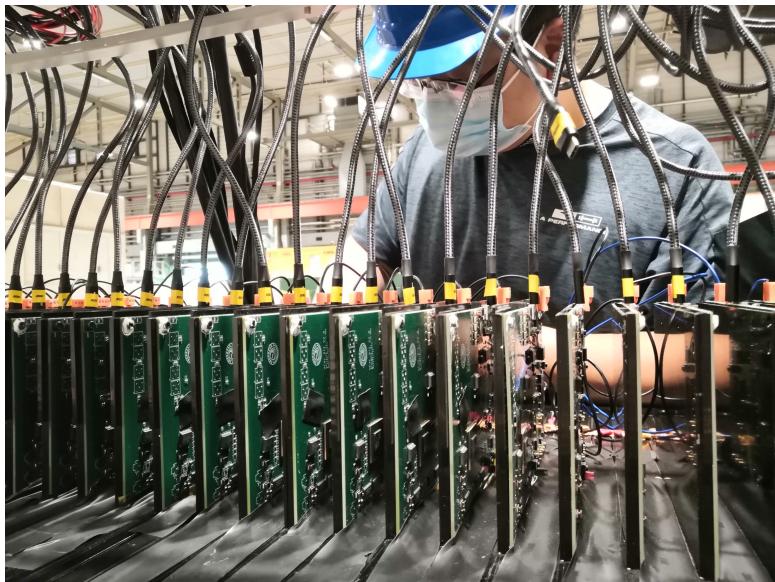


Supporting table center

The beam line

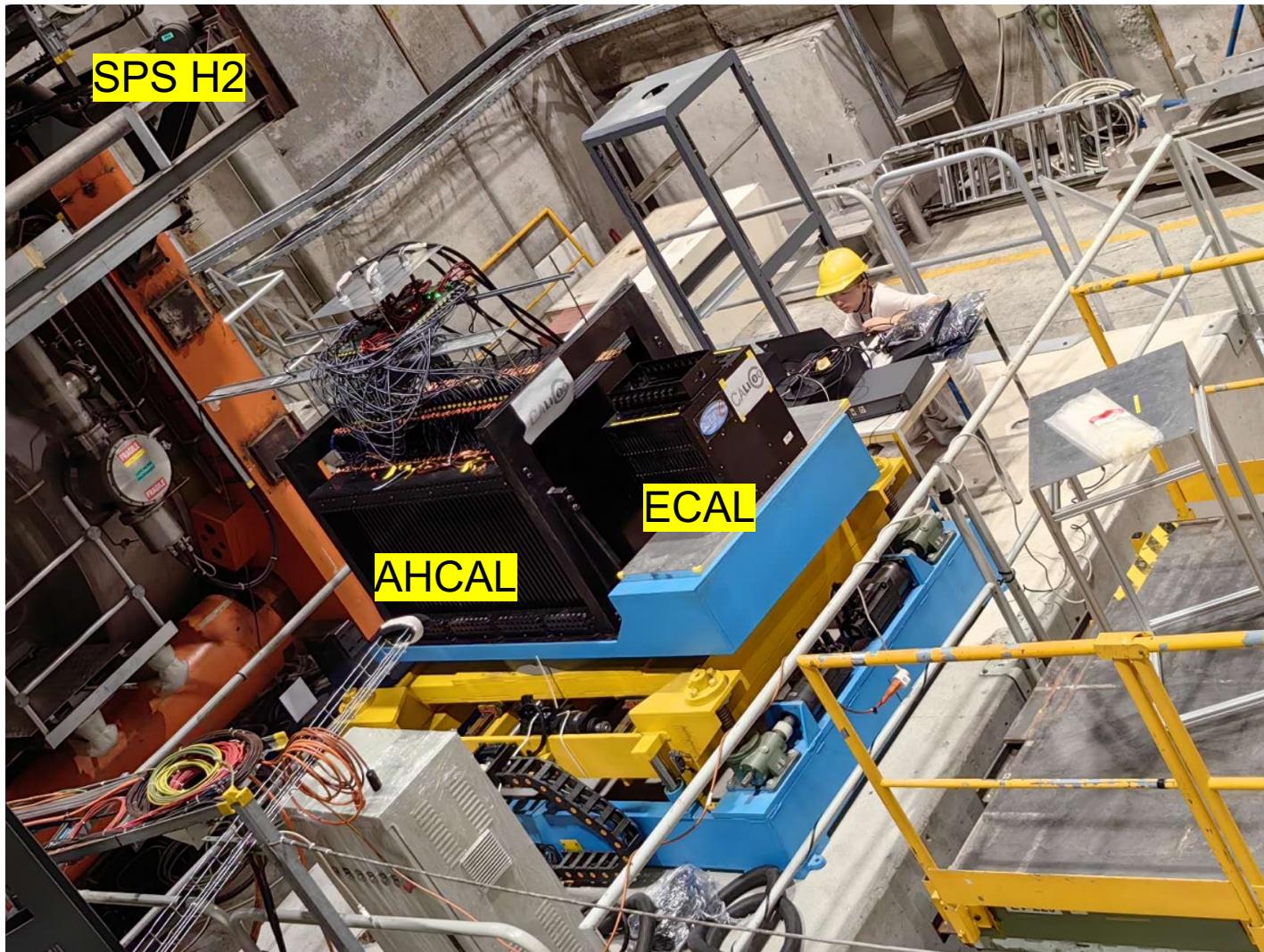


# Install the detectors in beam area

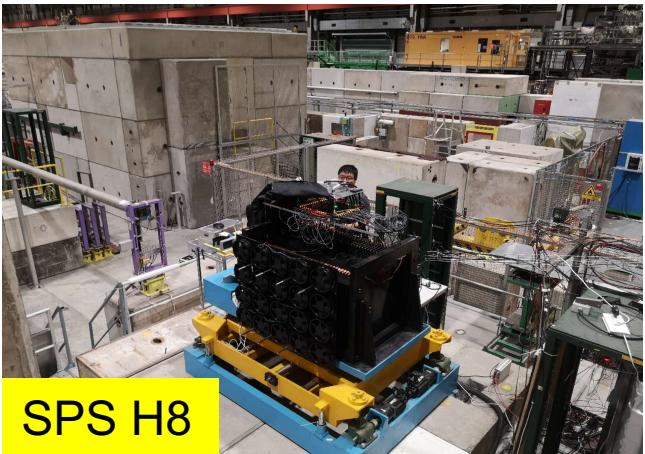


2023/8/9

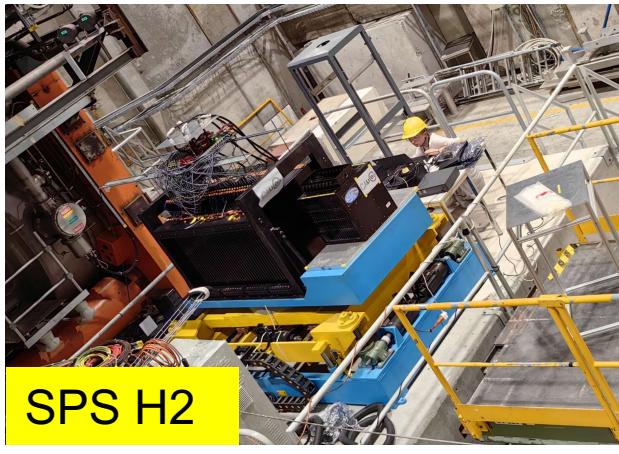
# Calorimeter Test



# Data Taking



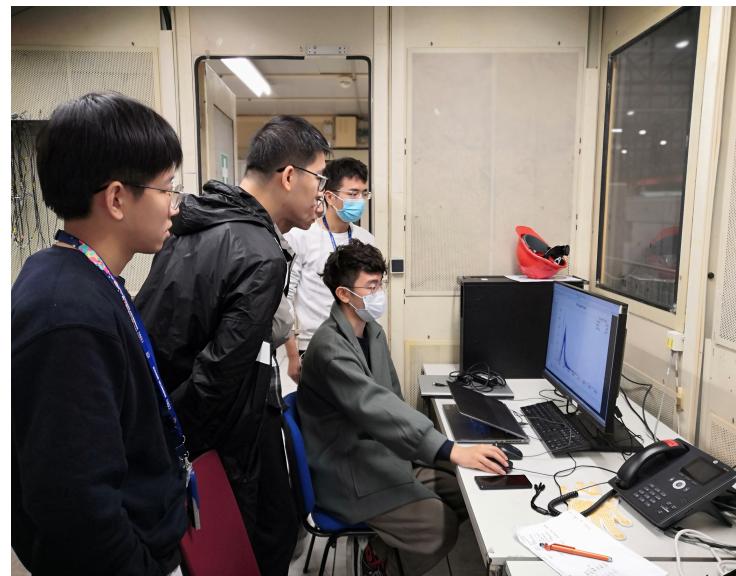
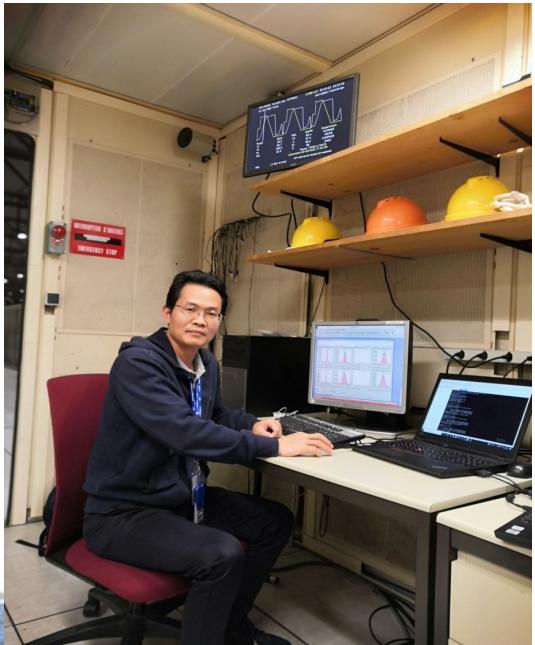
SPS H8



SPS H2



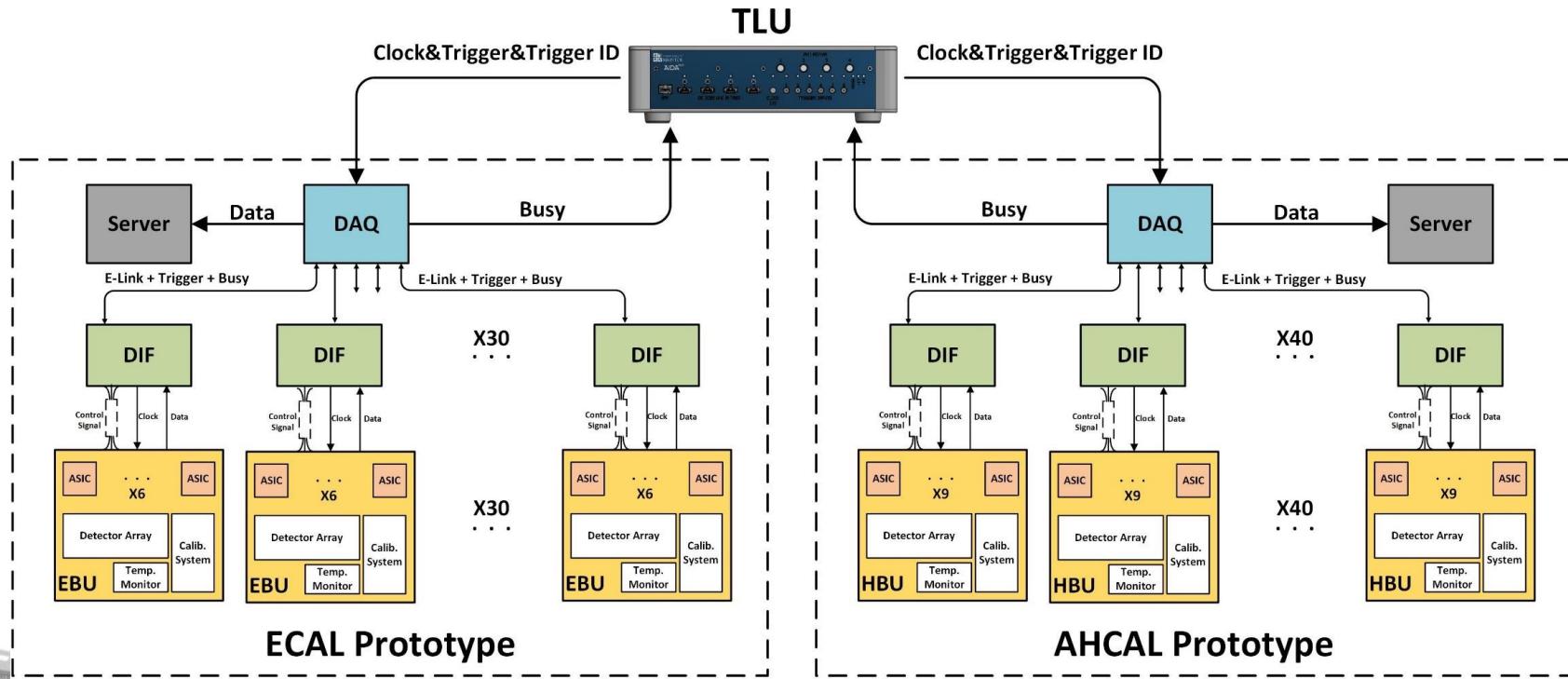
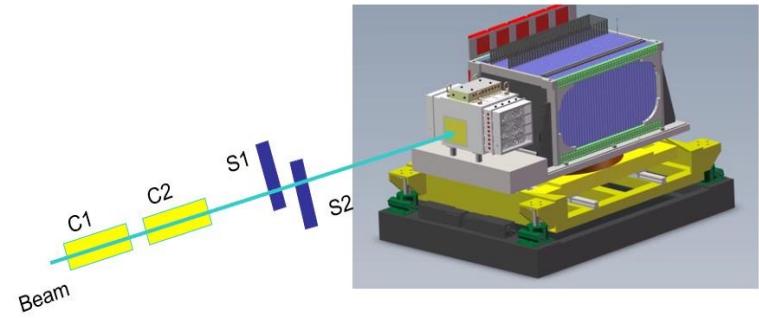
PS T9



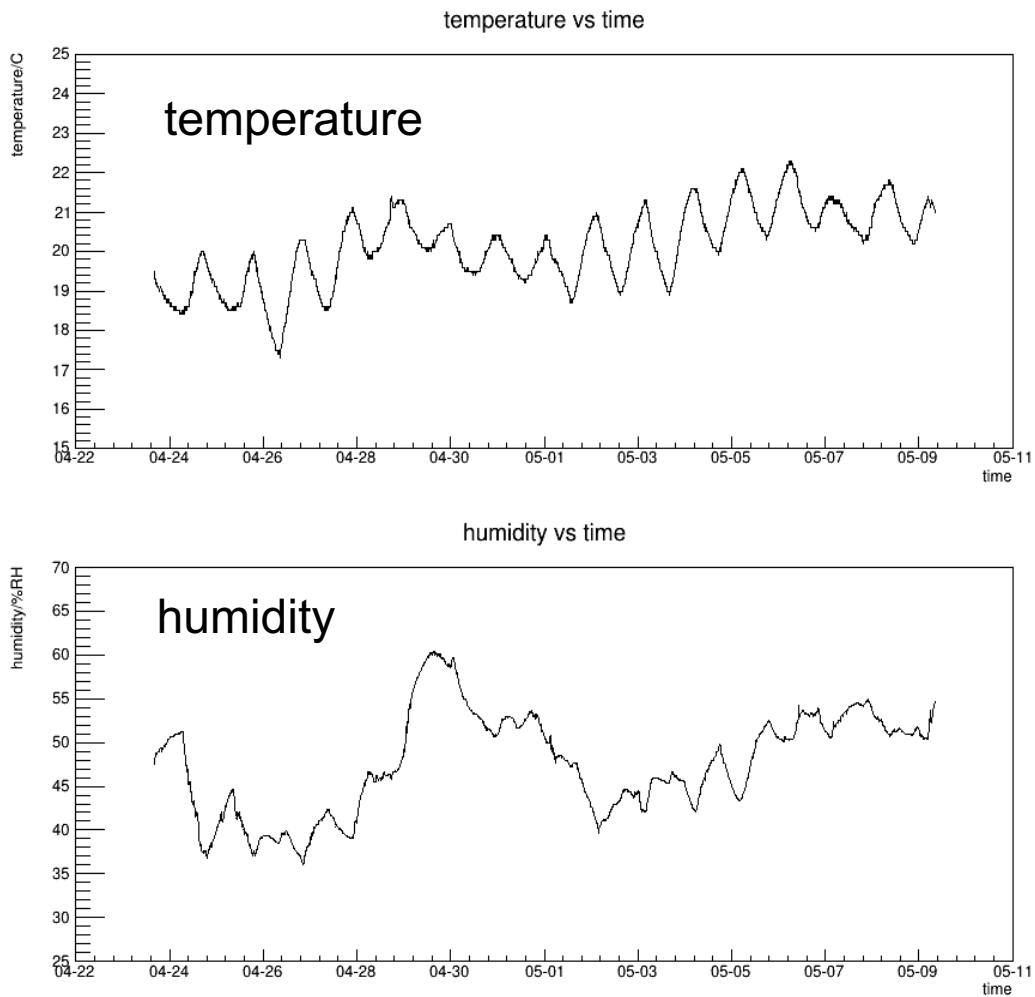
2023/8/9

# Calorimeter Test

- DAQ system for ECAL and AHCAL Prototypes
  - ECAL has 30 DIFs, AHCAL has 40 DIFs
  - Using TLU to synchronize two systems

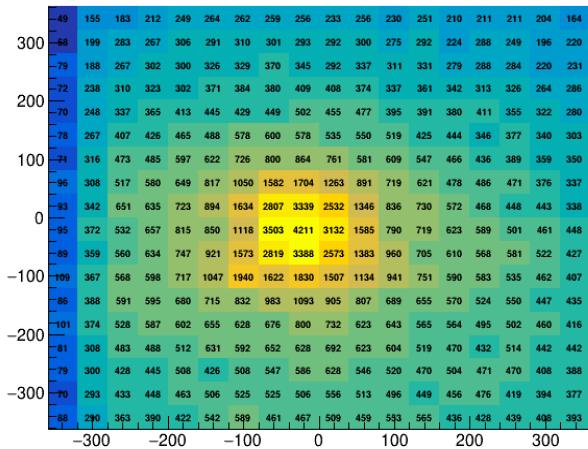
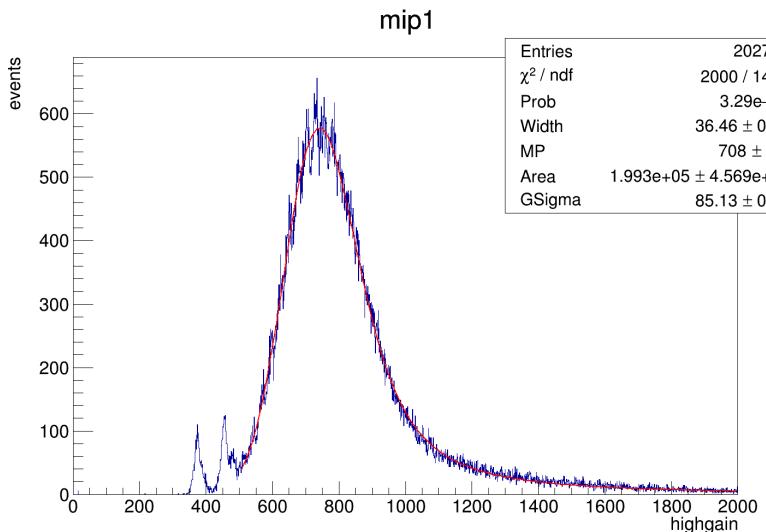


# Temperature and Humidity

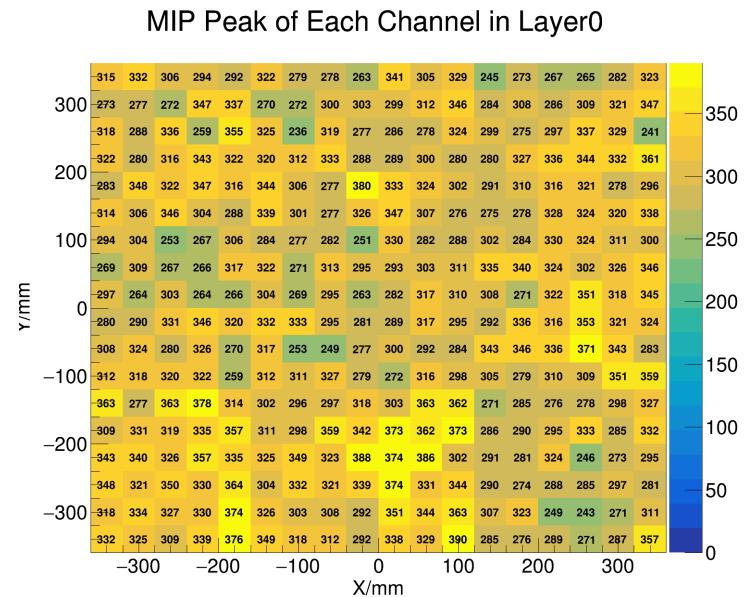


# Test with Muon

- The energy reference should be taken from MIPs which could be calibrated using high energy muons
- The halo size is about 20 cm x20 cm, and we changed the supporting table to test different area



Hitting map

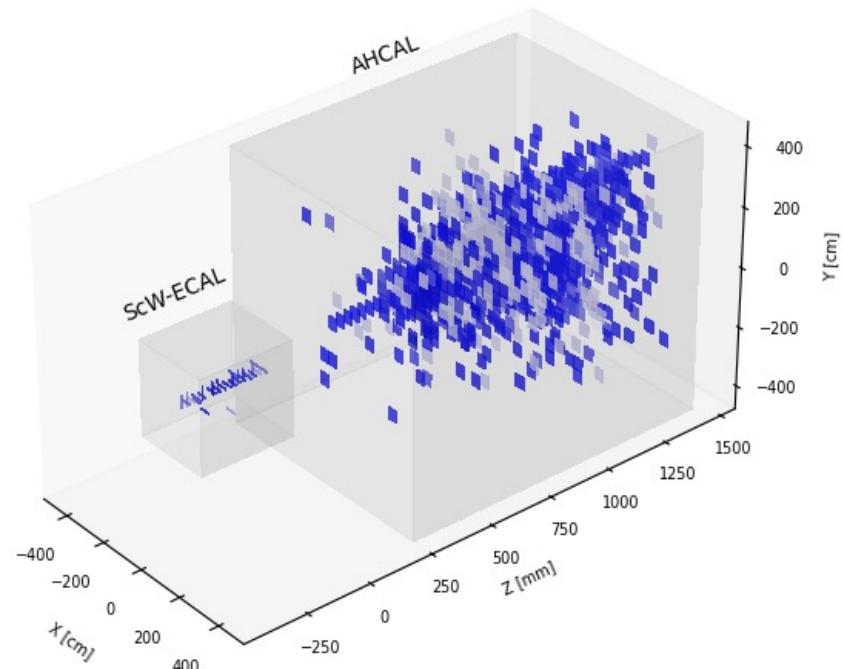
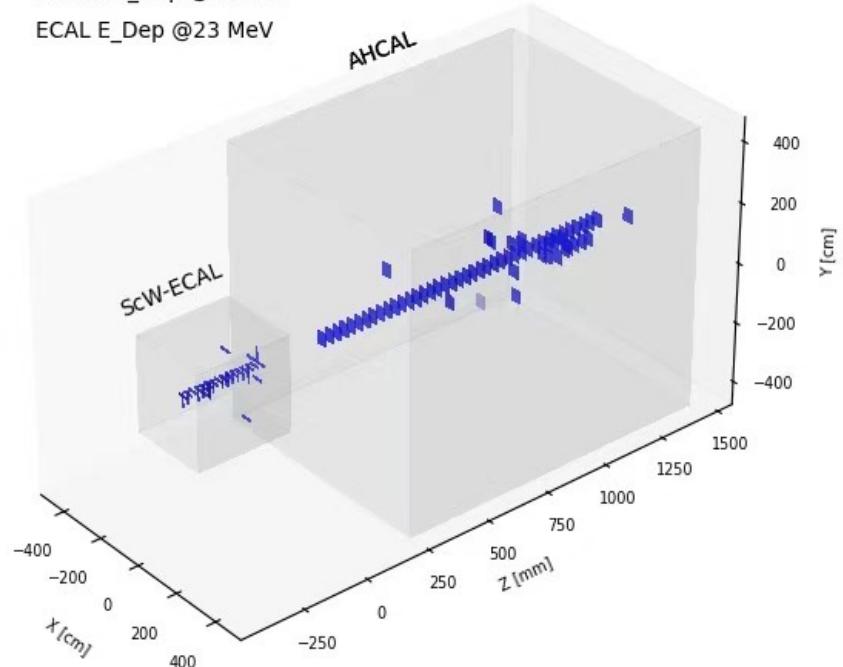


# Event display

## Test Beam

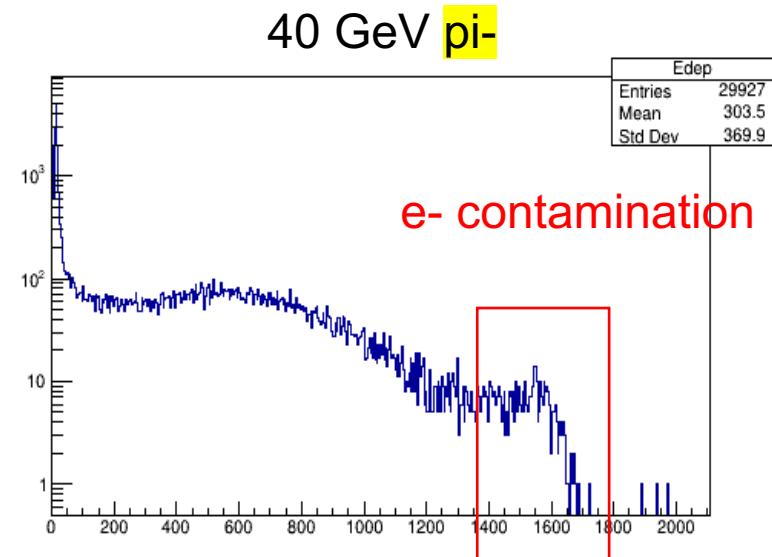
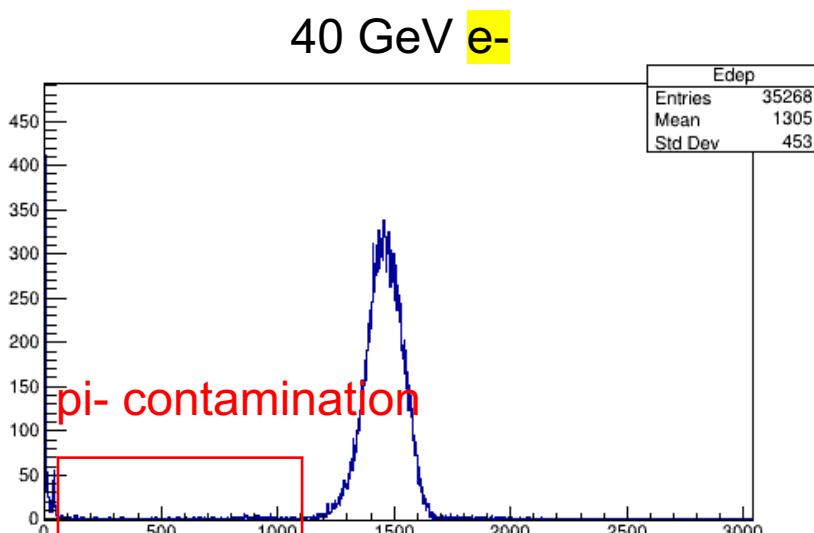
AHCAL E\_Dep @48 MeV

ECAL E\_Dep @23 MeV



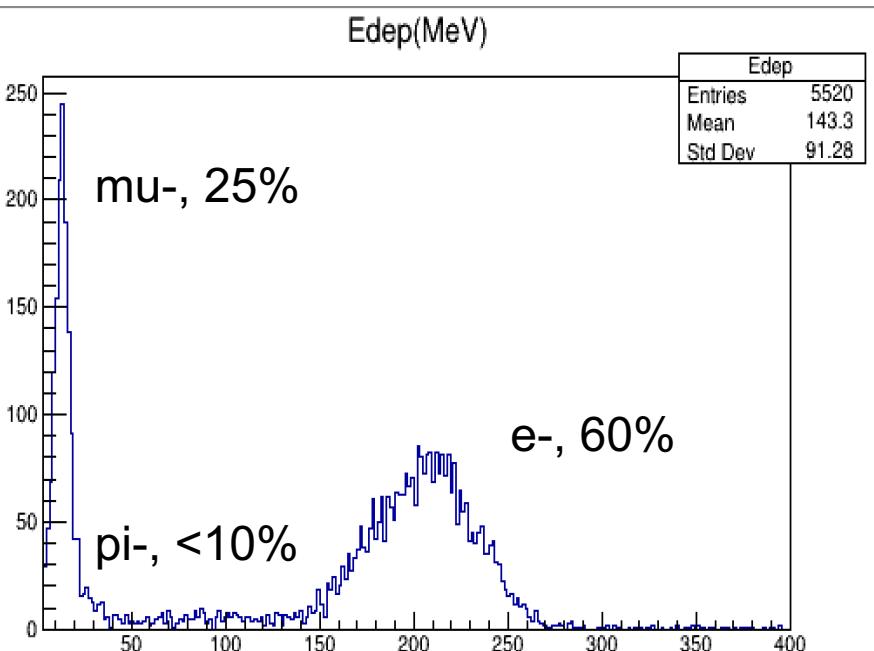
# ECAL energy response to e- and pi-

- In H2, the beam purity is very good
  - electron, 10 GeV/c – 250 GeV/c
  - Pi-, 40 GeV/c – 350 GeV/c
- In e- beam, only a few pi- contamination
- In pi- beam, there is also a few e- contamination



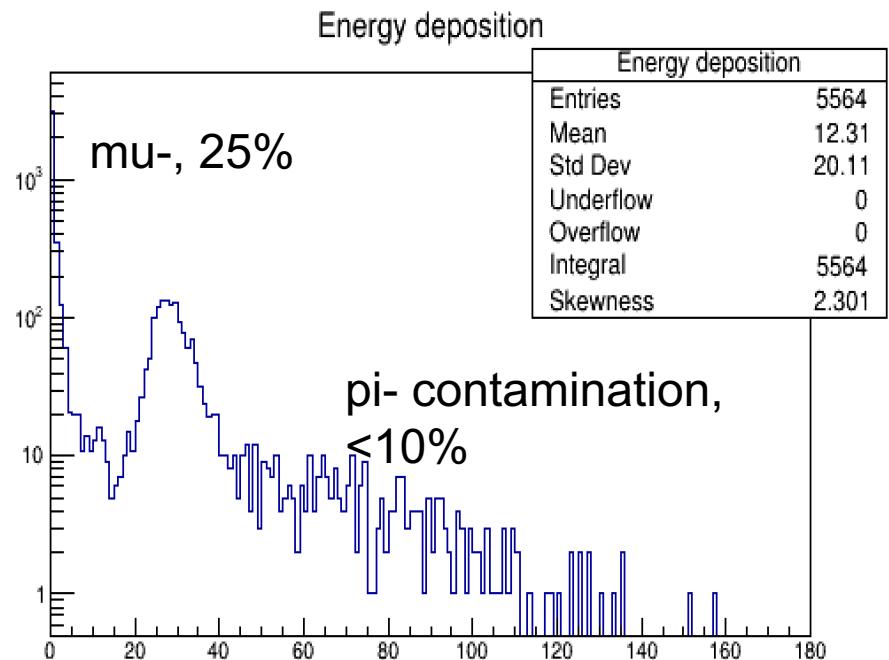
# ECAL Energy Response to e-

5 GeV/c e- energy deposition in ECAL



ECAL

5 GeV/c e- energy deposition in AHCAL

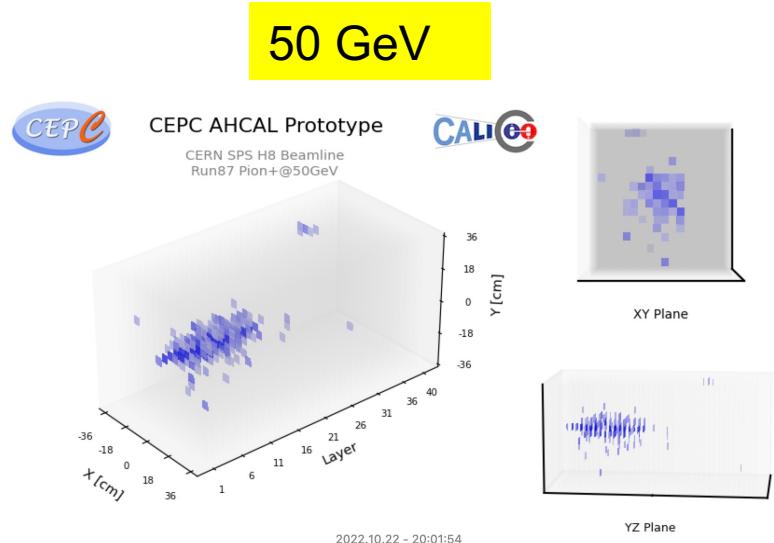


AHCAL

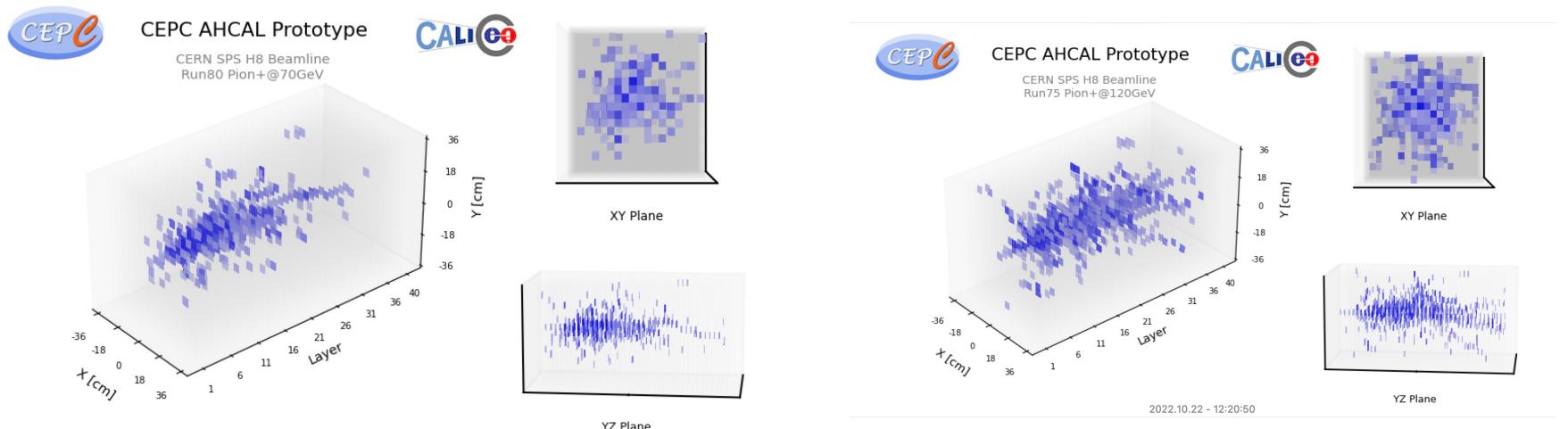
# AHCAL单独测试

- The energy response of AHCAL was studied by pions
- The calorimeter could cover the whole shower

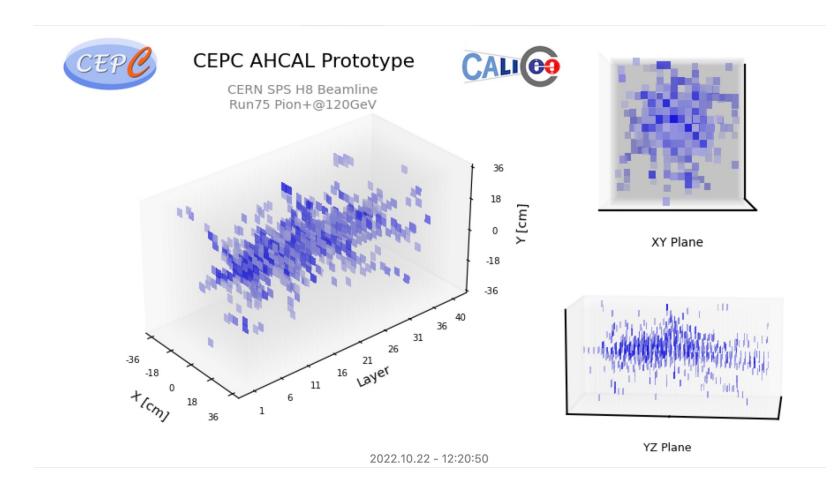
50 GeV



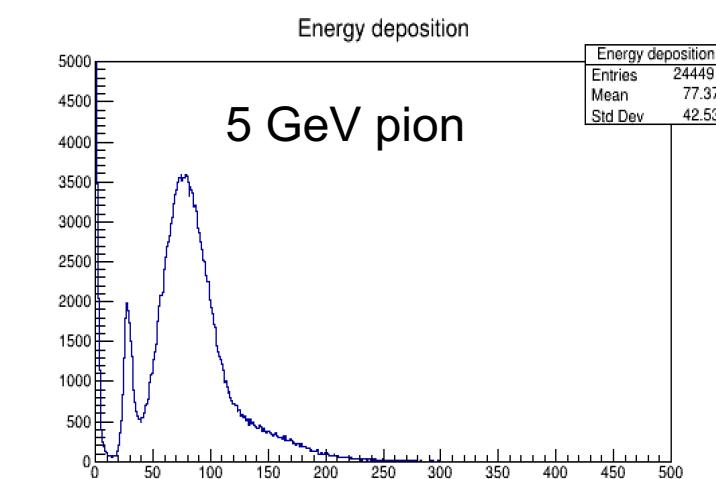
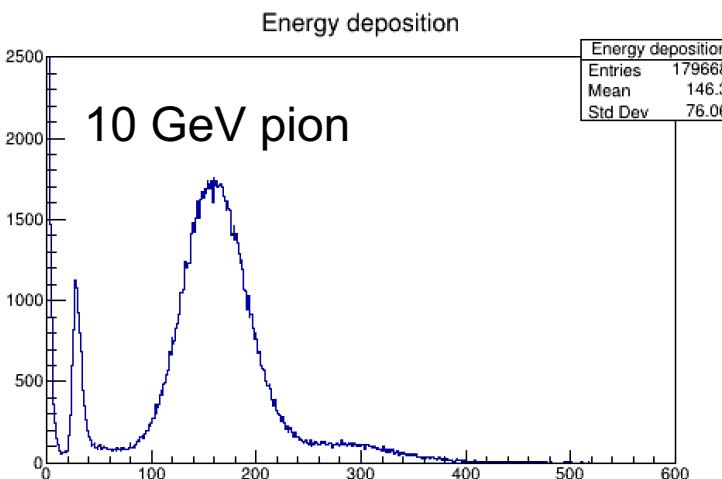
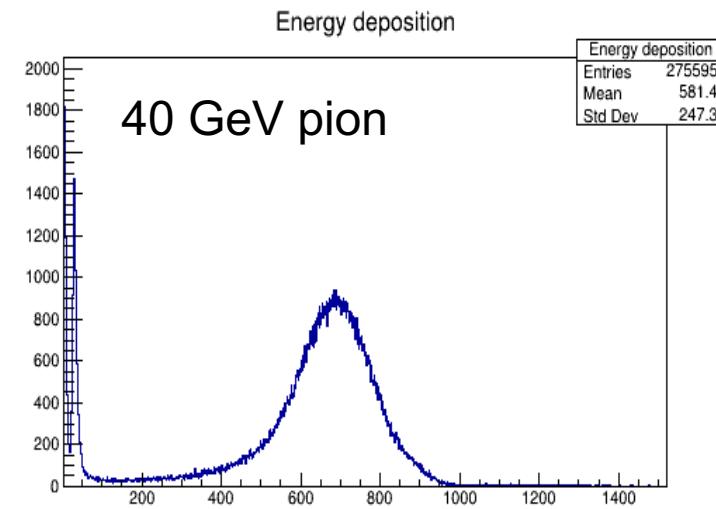
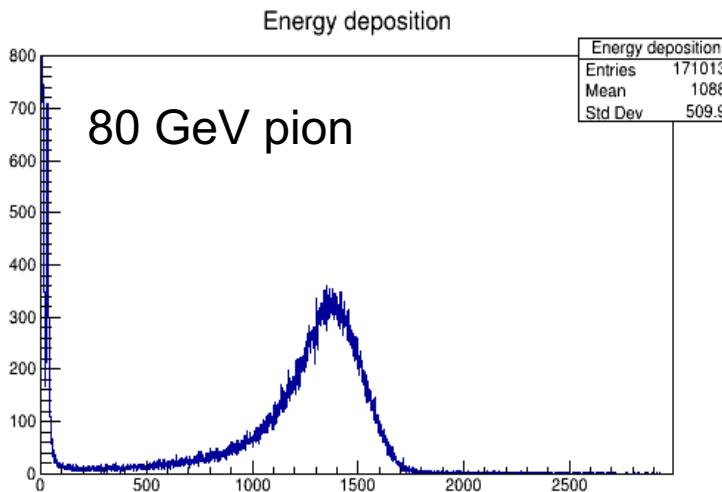
70 GeV



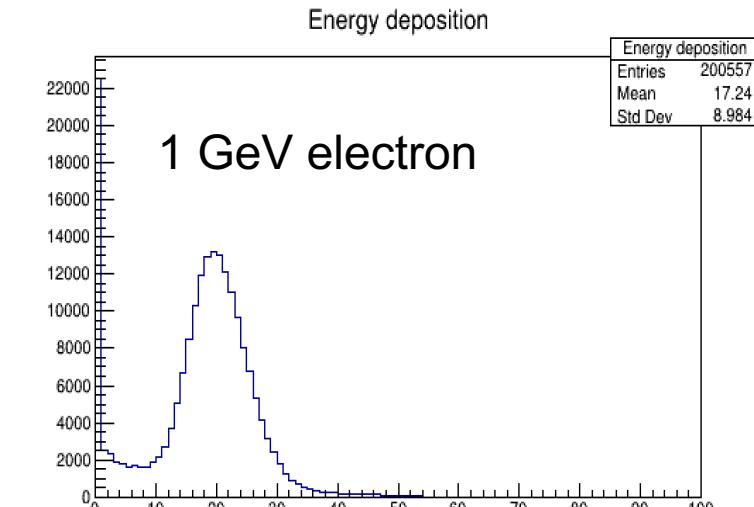
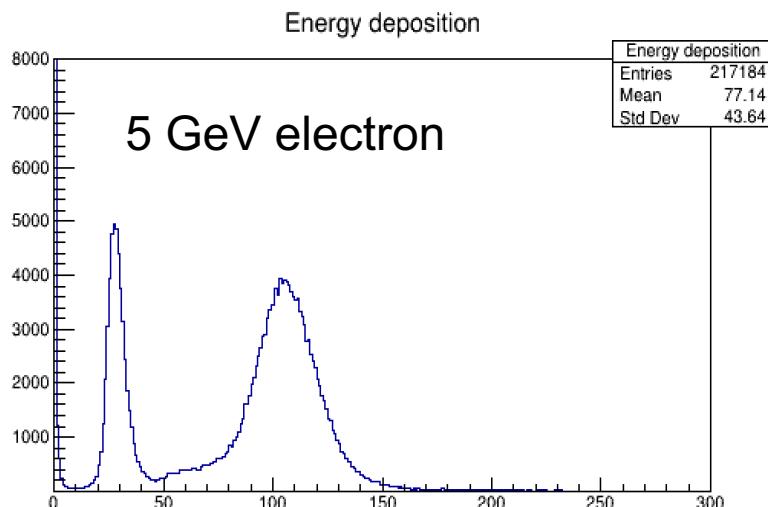
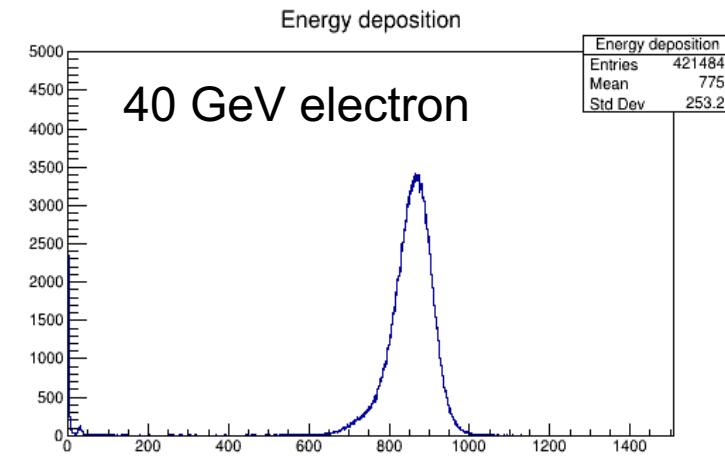
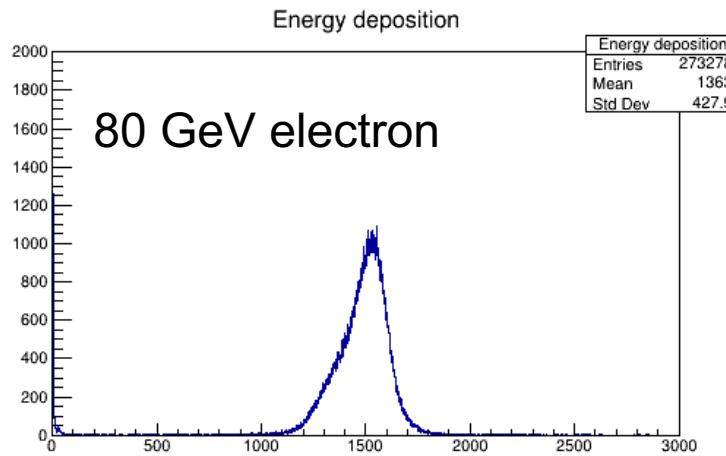
120 GeV



# AHCAL Test with pion

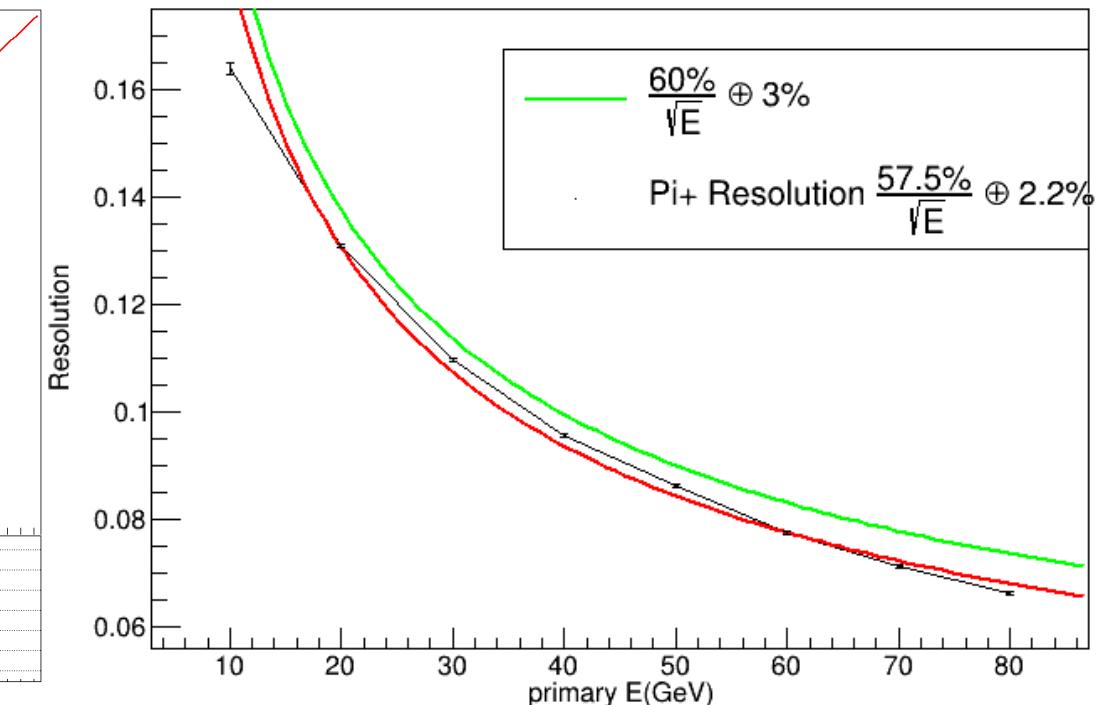
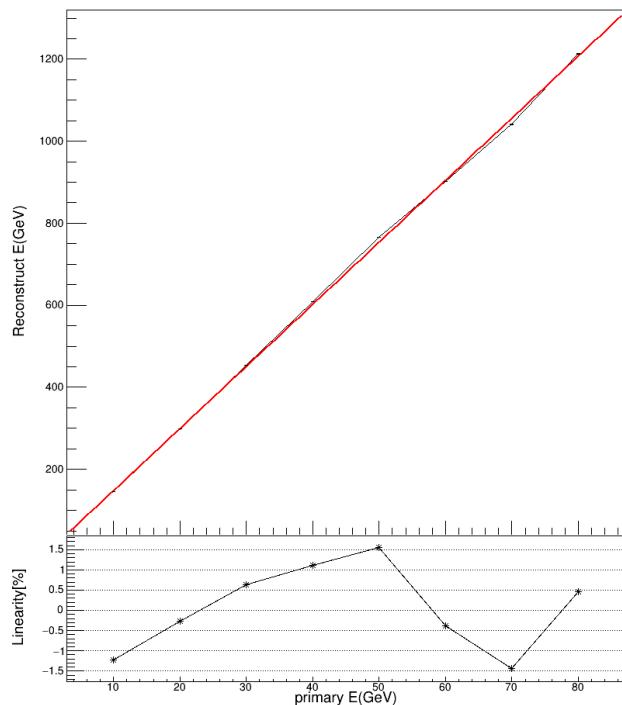


# AHCAL Test with electron



# AHCAL Linearity and Resolution

- The energy linearity is within  $\pm 1.5\%$
- The energy resolution is  $\frac{57.5\%}{\sqrt{E}} \oplus 2.2\%$



Energy linearity and resolution



# 总结

- CEPC谱仪基准设计采用基于粒子流算法的方案
- 完成了电磁量能器和强子量能器两个高颗粒度样机的研制
  - 电磁量能器颗粒度为 $5 \text{ mm} * 5 \text{ mm}$ , 强子量能器为 $40 \text{ mm} * 40 \text{ mm}$
- 在CERN开展了2次高能粒子束测试
  - 利用高能电子、pion (10 GeV/c to 120 GeV/c (SPS) and 0.5 GeV/c – 15 GeV/c (PS)) 开展了标定
  - 我们收集了约6500万高能粒子, 为开展高颗粒度量能器的性能研究提供了基础数据, 详细的分析还在进行中
- 样机的研制及测试, 为CEPC量能器的研制积累了宝贵经验



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THANKS





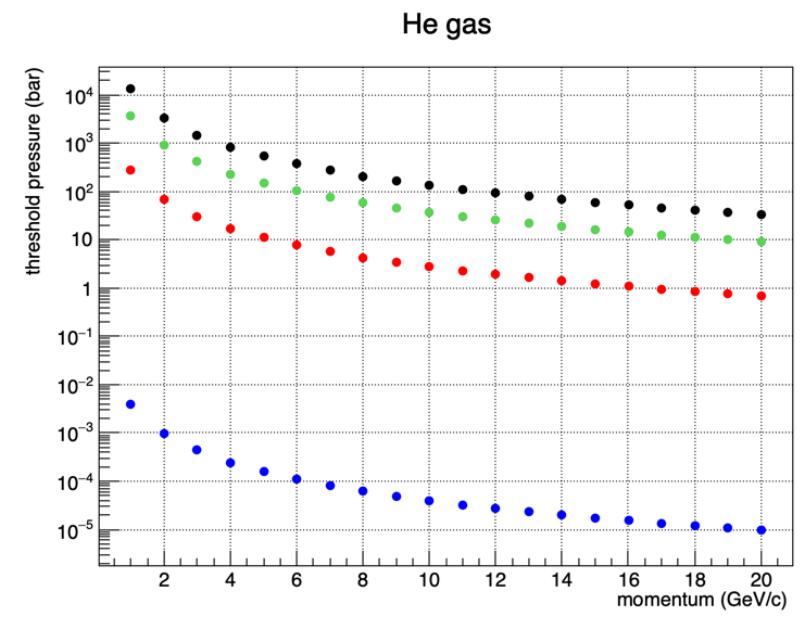
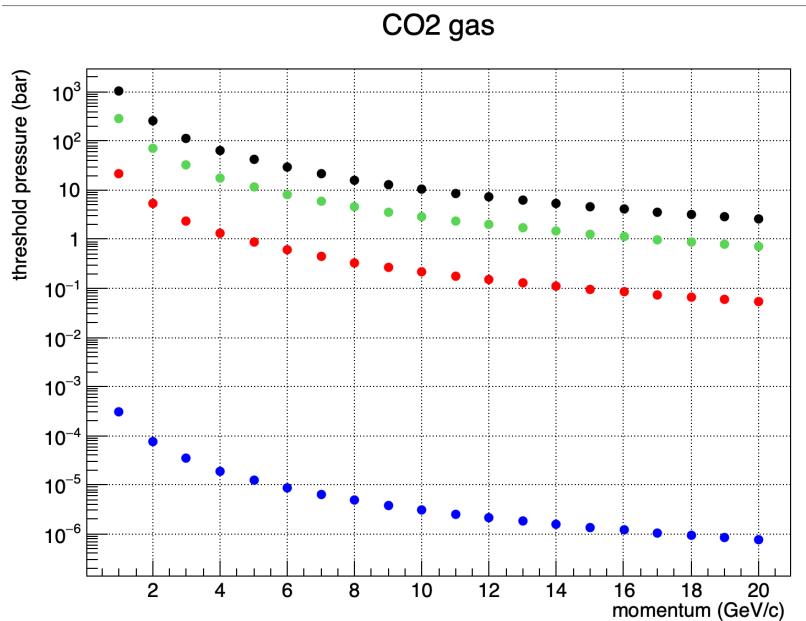
# Final transportation back to China

17/6, arrived in Hefei



# Cherenkov Detector Threshold

by Takeshita-san)

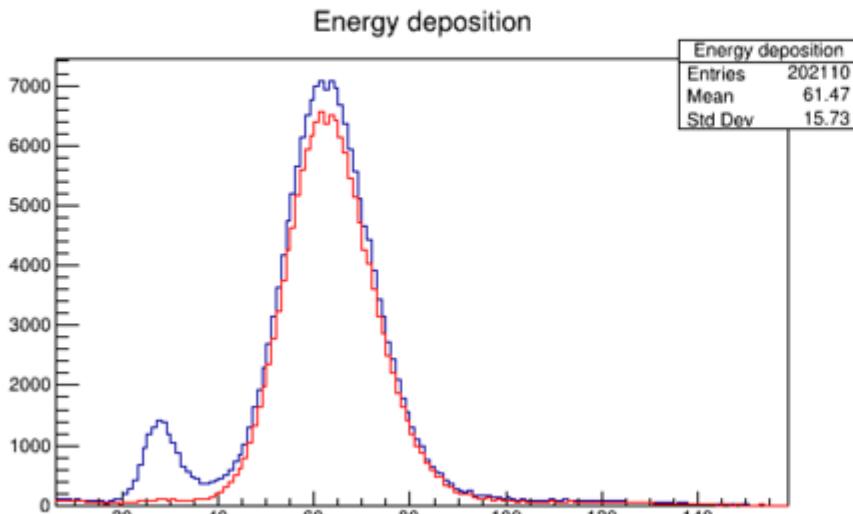


# Cherenkov Detector

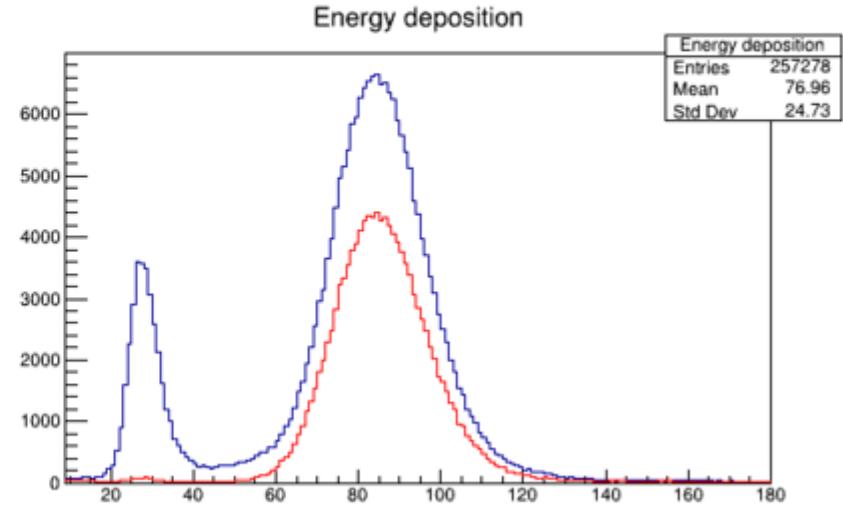
- The Cherenkov detectors were used to identify e-, mu-, pi-
- The muon peak disappear after we used the C signals

— W/O Cherenkov  
— W/ Cherenkov

3 GeV/c e- in AHCAL

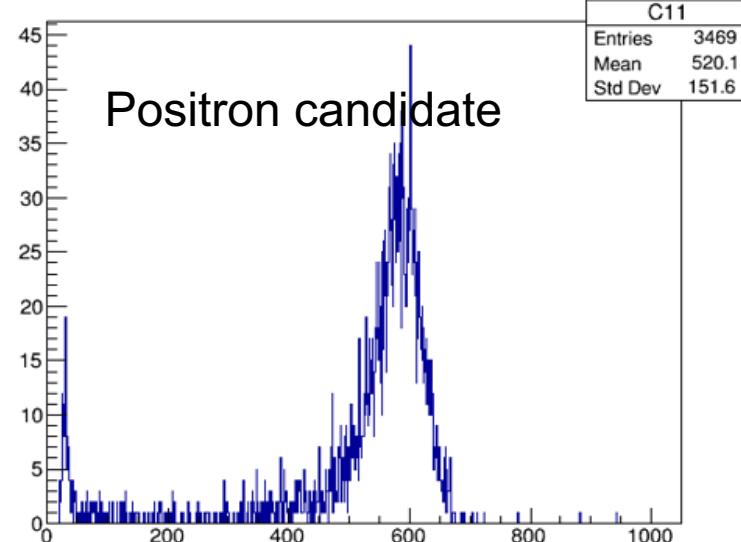
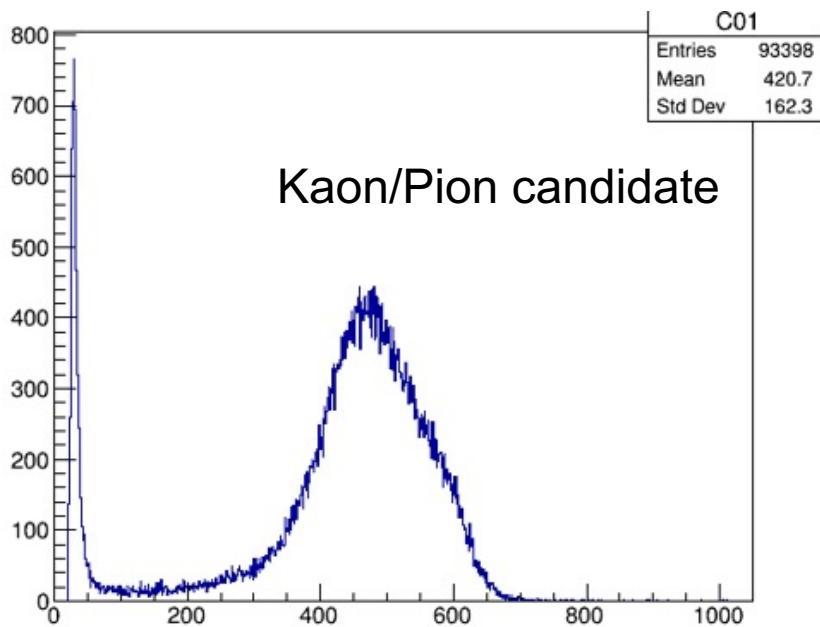
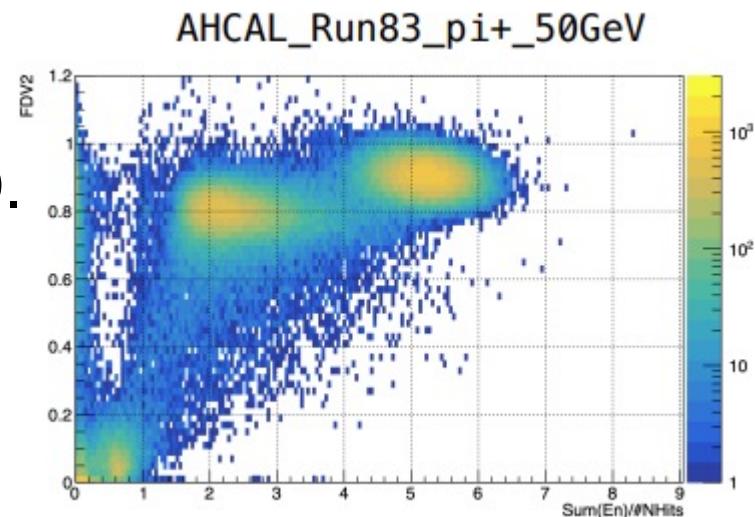


4 GeV/c e- in AHCAL



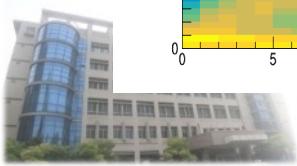
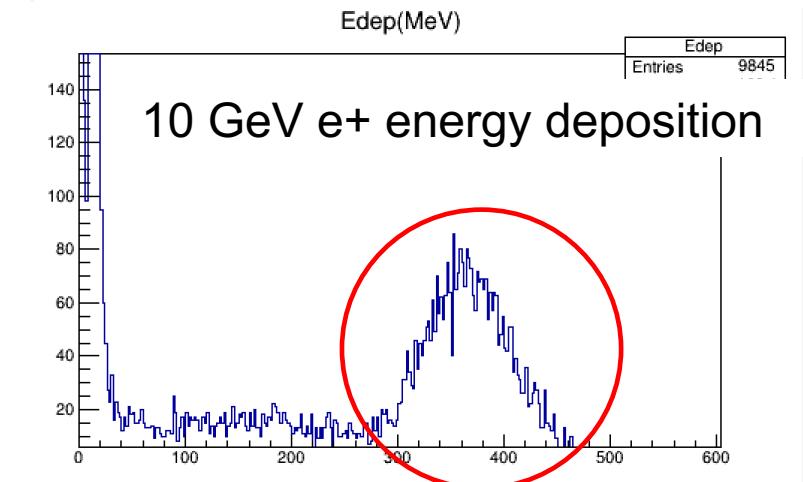
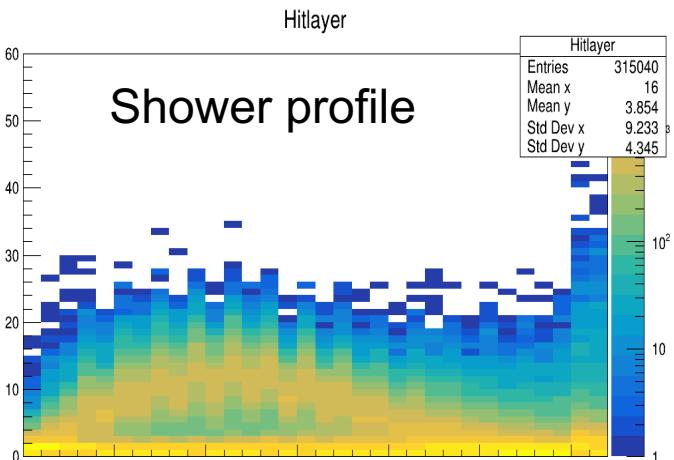
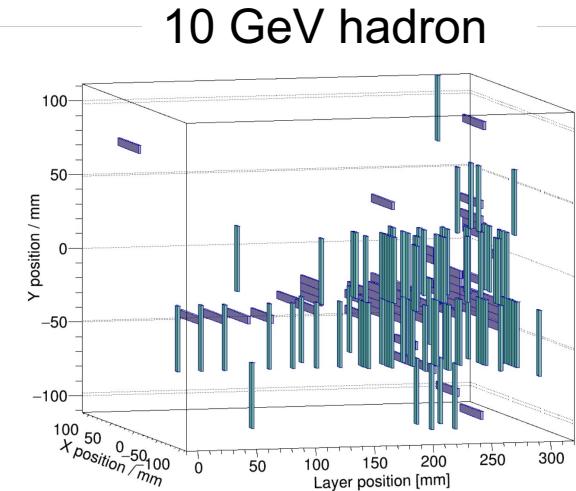
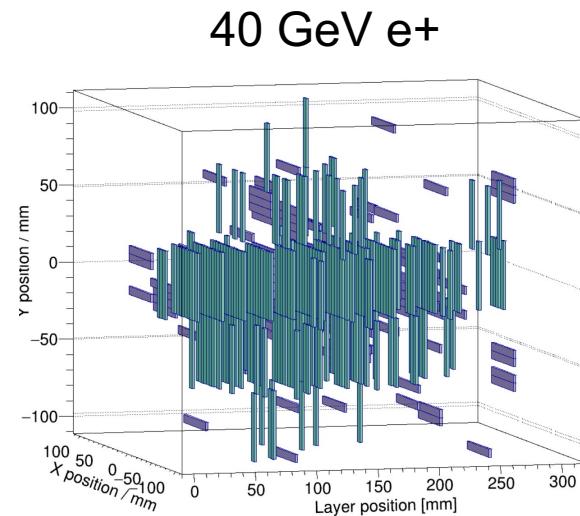
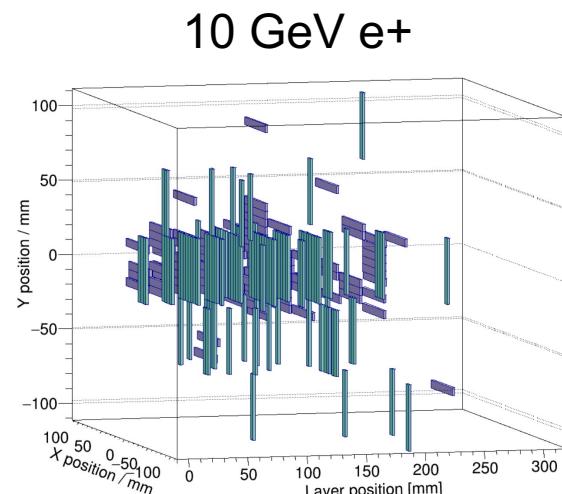
# AHCAL Test with pion+

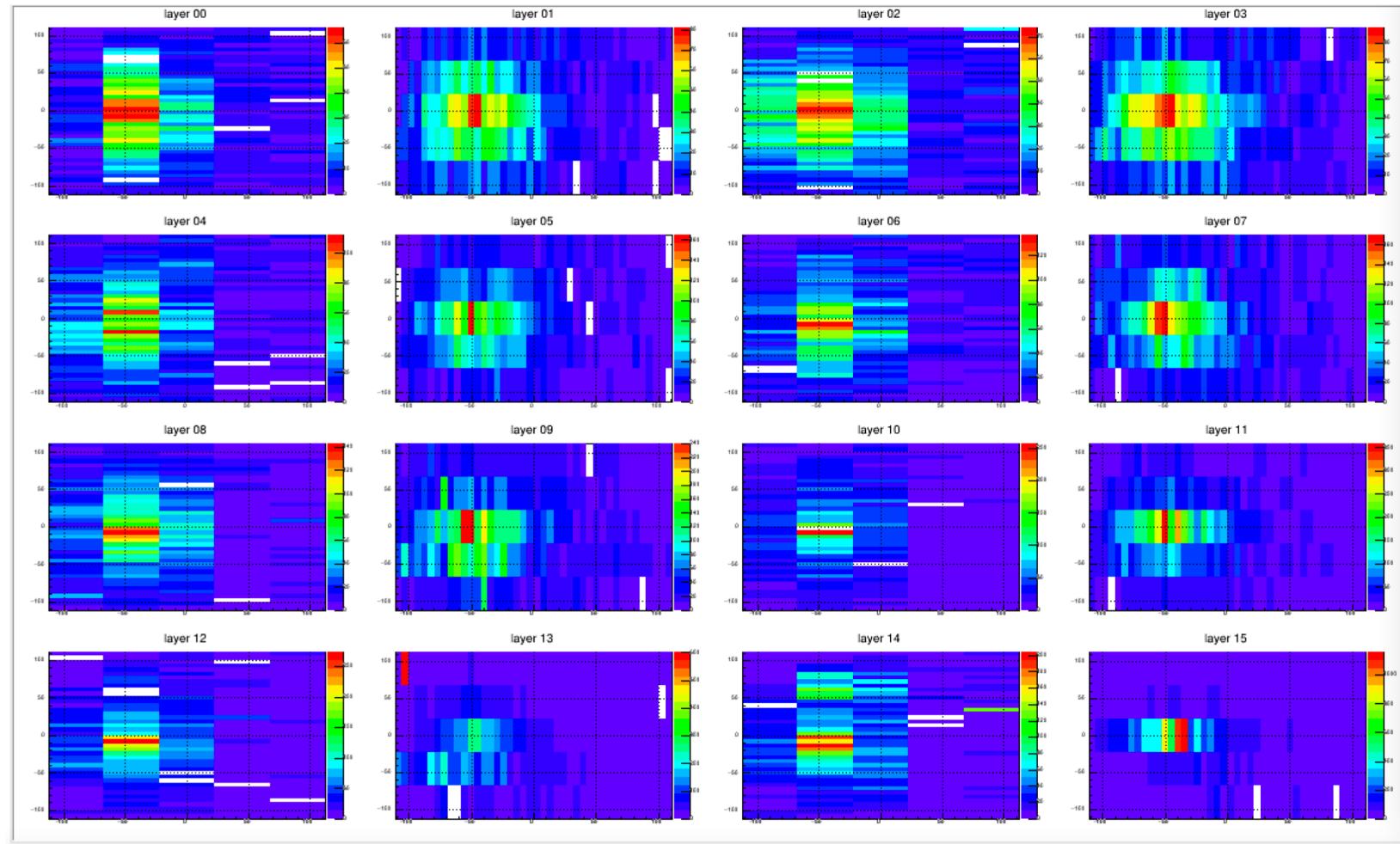
- The Cherenkov detectors in the beam were also used to do the PID.
  - One is low pressure
  - The other is high pressure



# Sci-W ECAL Test with Positron

- The e+ test, also the beam has hadrons.





# AHCAL Test with Mu+

- The thresholds were calibrated using muon beam

