2023 Beam Test of Sci-W ECAL and AHCAL Prototypes

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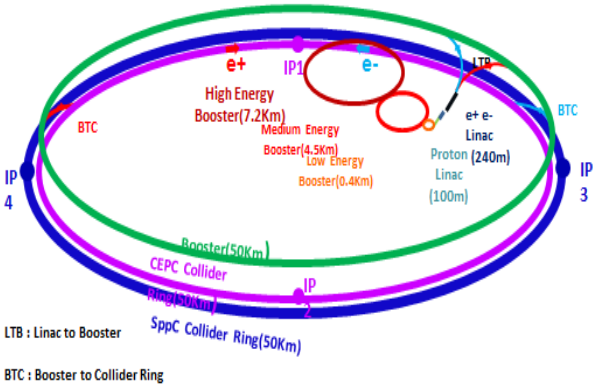
On behalf of CEPC Calorimeter working group

Outline

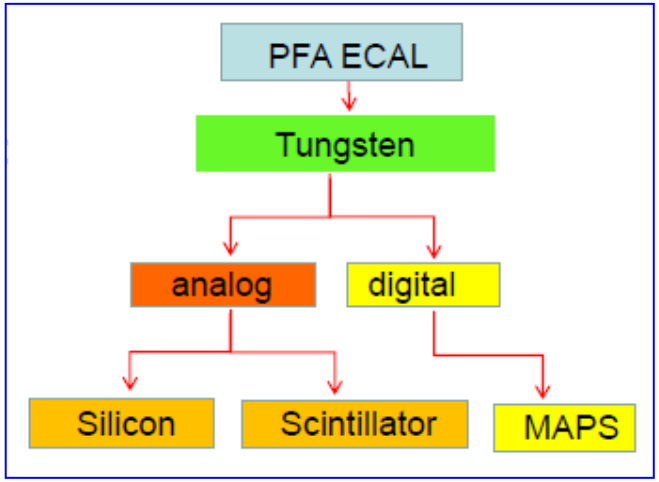
- Motivation
- Calorimeter prototypes introduction
- Beam test at CERN
  - SPS and PS
- Summary

Motivation

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



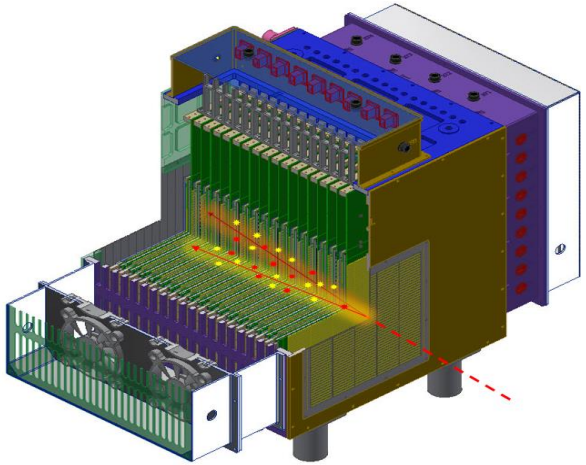
- The Particle Flow Algorithm (PFA) calorimeter concept was proposed
  - High granularity
  - Good track finding
  - Good energy resolution



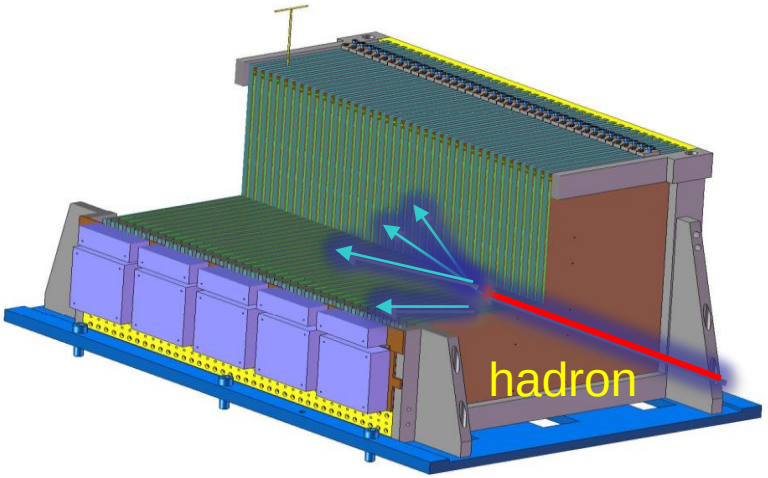
PFA Calorimeter prototype

Sampling Calorimeter

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



Sci-W ECAL



AHCAL

PFA Calorimeter prototype

Sci-W ECAL

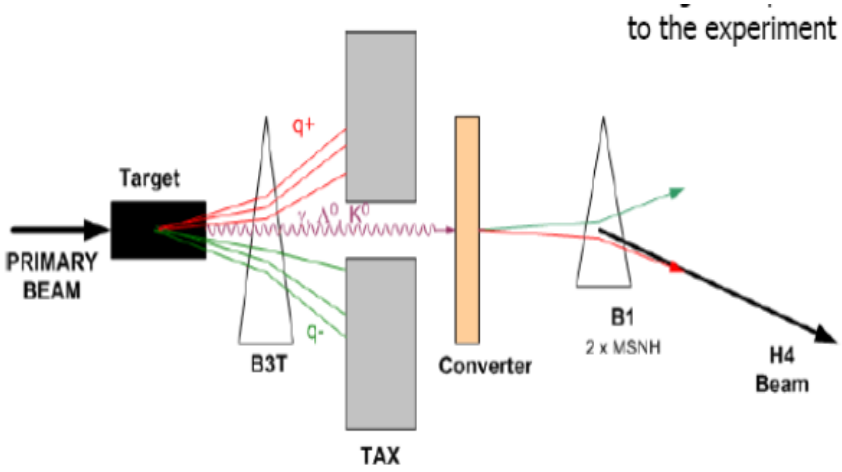
AHCAL

Beam Test in last autumn

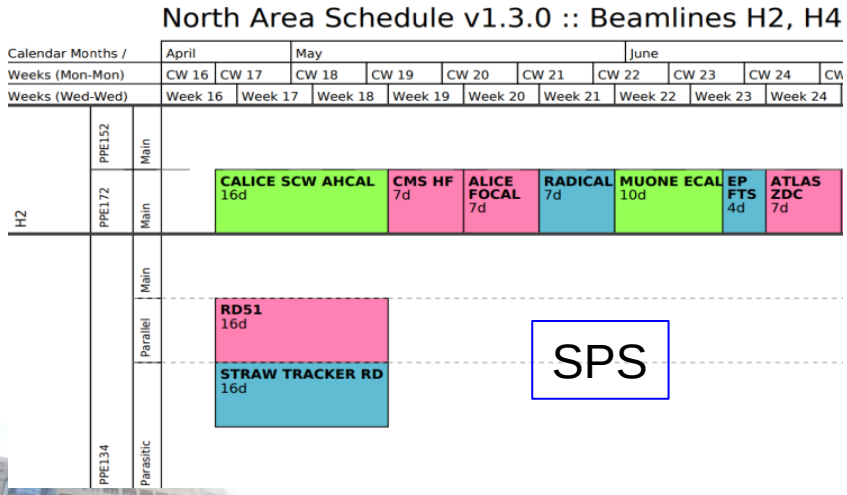
- In the autumn of 2022, we completed beam testing at H8 of SPS, and then stored the detectors in CERN, waiting for the next test

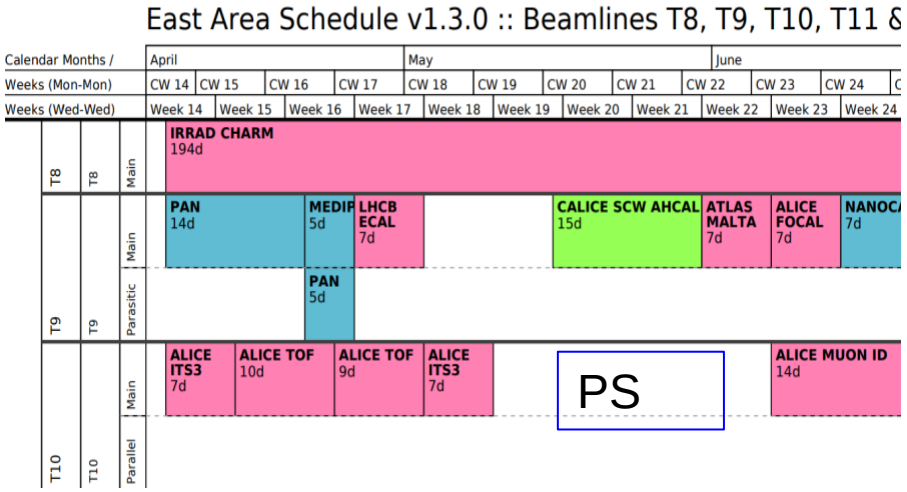
Beam Test in 2023

- Major motivations
  - Much Better beam purity at SPS-H2
  - Study low-energy in 1-15 GeV/c at PS
  - Update some problems of last year
- CERN PS/SPS schedule in 2023
  - SPS-H2: Apr. 24 – May 10 (16 days)
  - PS-T9: May 16 – 31 (15 days)

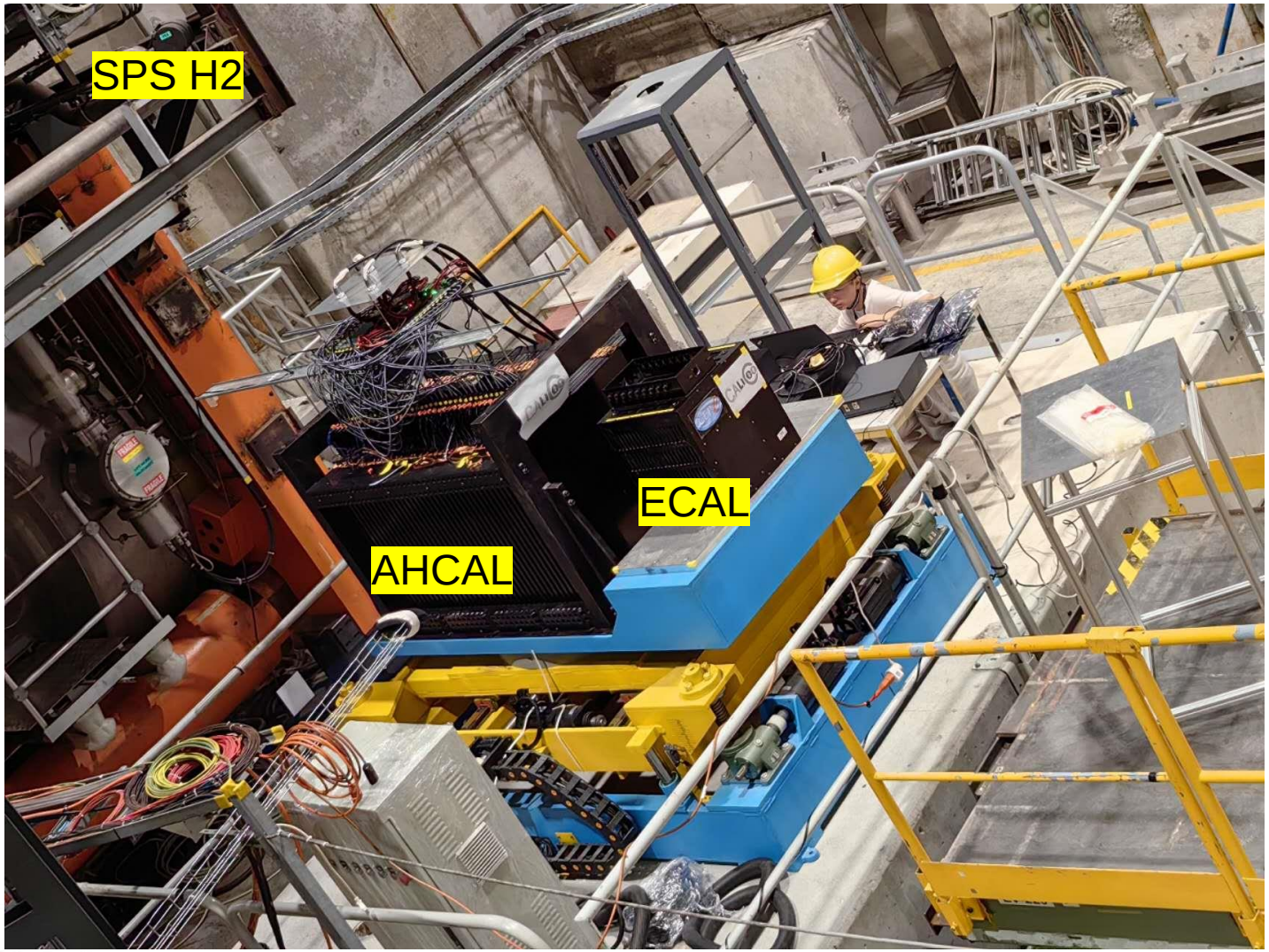


Similar to H2 and T9



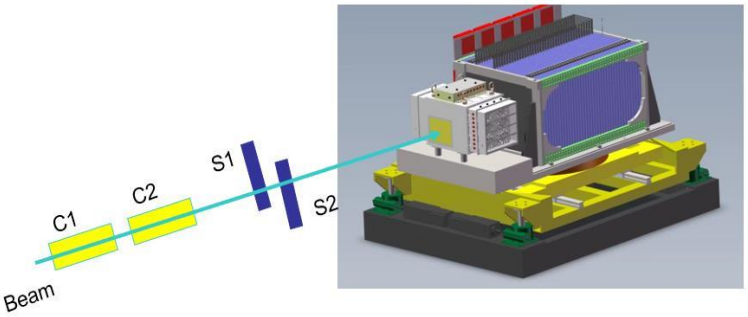


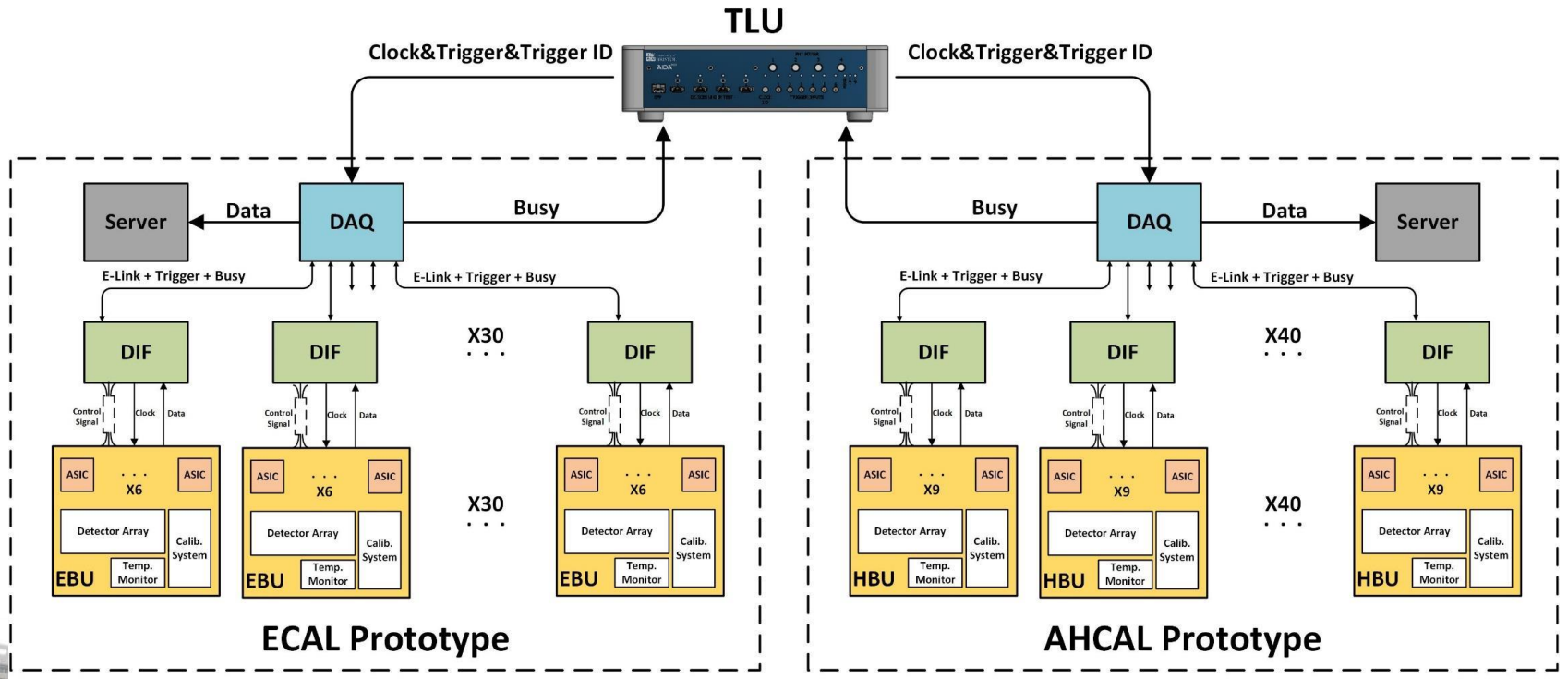
Calorimeter Test



Calorimeter Test

- **DAQ system for ECAL and AHCAL Prototypes**
  - **ECAL has 32 DIFs, AHCAL has 40 DIFs**
  - **Using TLU to synchronize two systems**





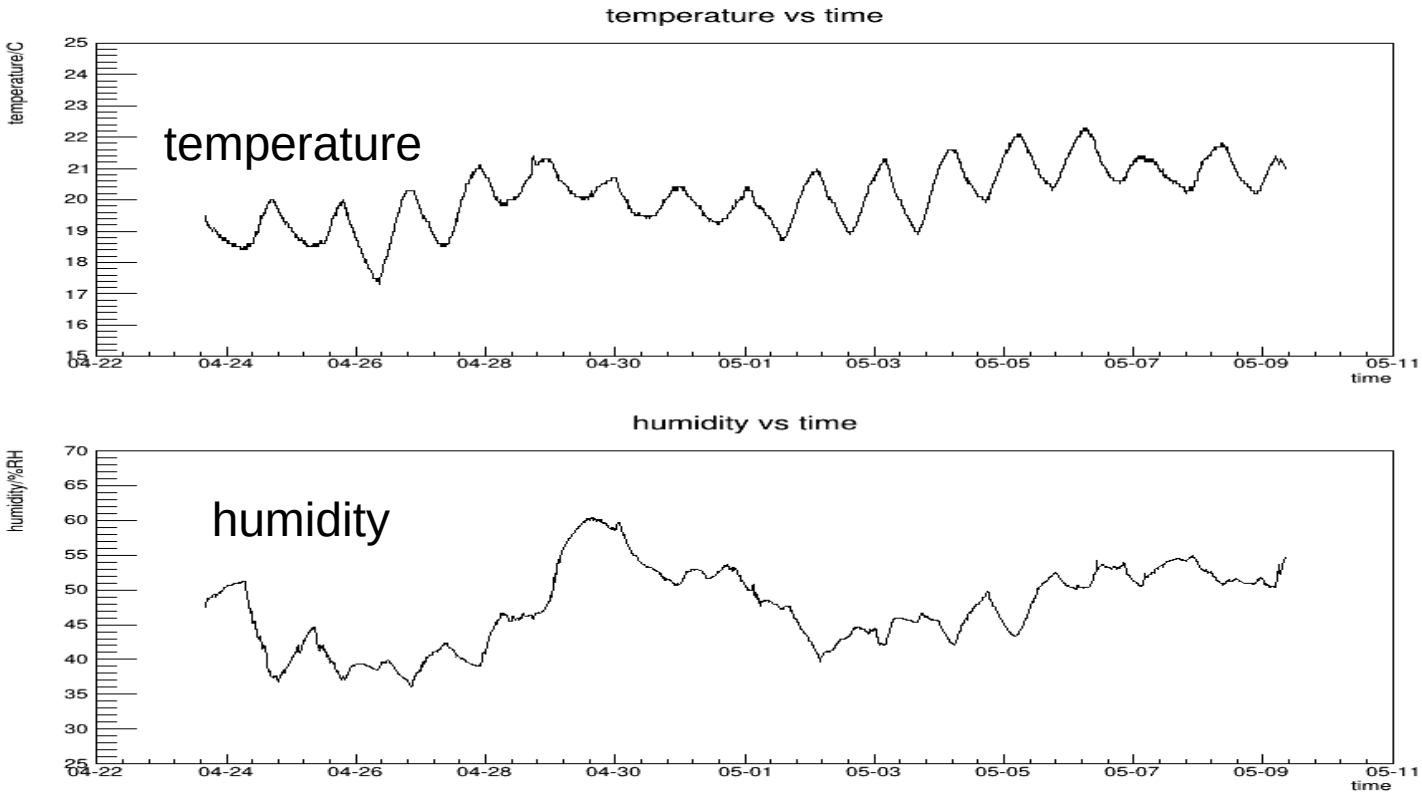
Beam in SPS H2

- 1 cycle: 34.8 s, 1 spill: 4.8 s
- About 2-3 k events per spill
- Beam size: ~4 cm (FWHM)

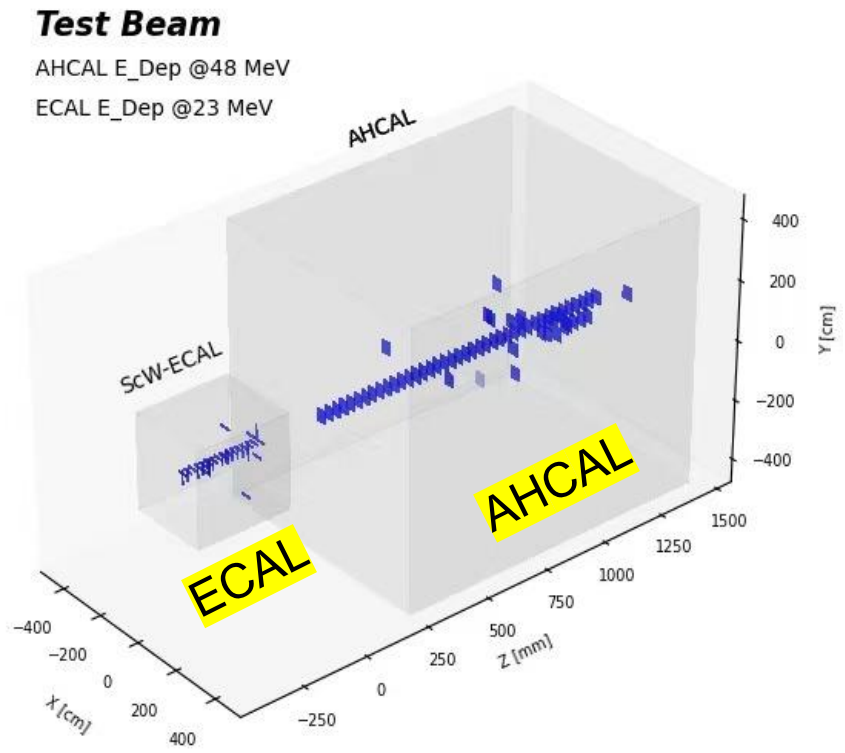
- Muon Test
  - Momentum：100 GeV/c
  - 6 million
- Pion- test
  - 10 – 120 GeV/c， 350 GeV/c
  - 20 million
- Electron Test
  - 10 – 250 GeV/c
  - 4.7 million
- Proton, 350 GeV/c
  - 1 million

Temperature and Humidity

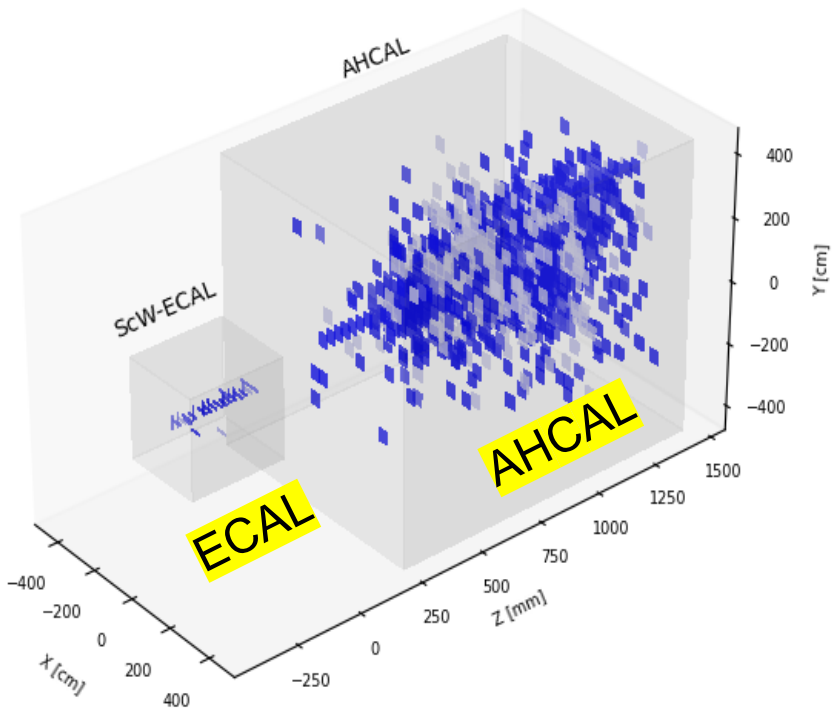
- The temperature changed from 17 degrees to 23 degrees, with a daily cycle
- The humidity varied from 35% to 65%,depended on the weather..



Event display



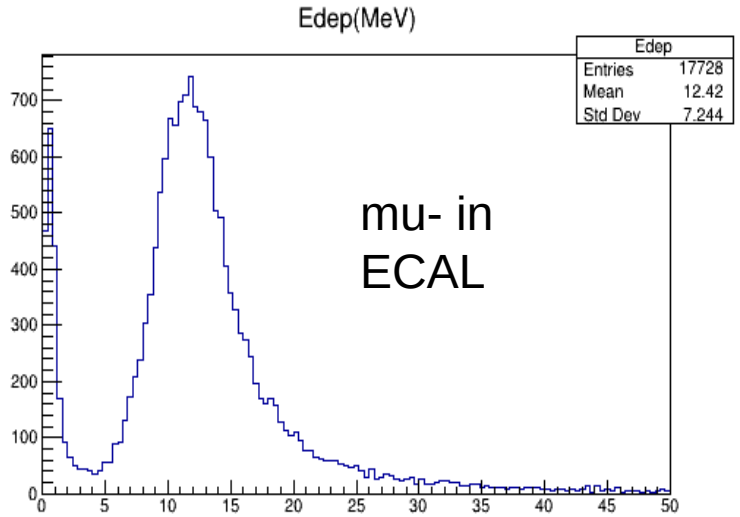
MIPs event

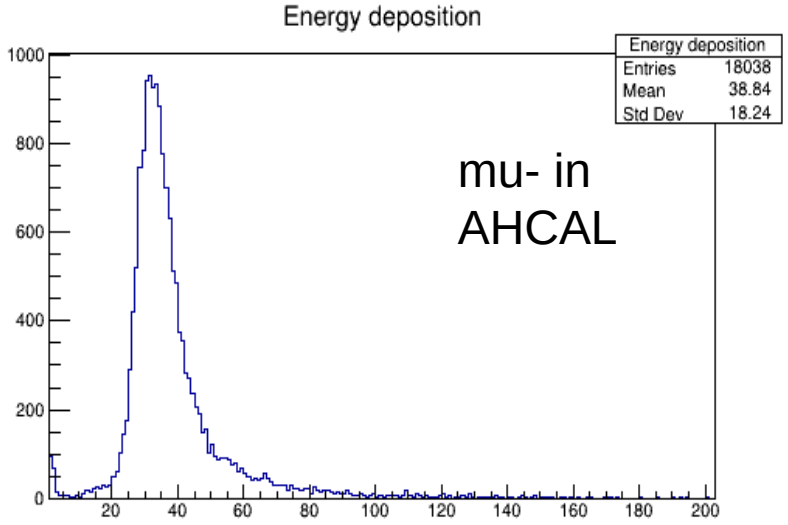


Pion event

Muon Test

- Muon testing can obtain the MIPs spectrum, which is a reference for us to reconstruct energy
- So it needs to be carried out channel by channel

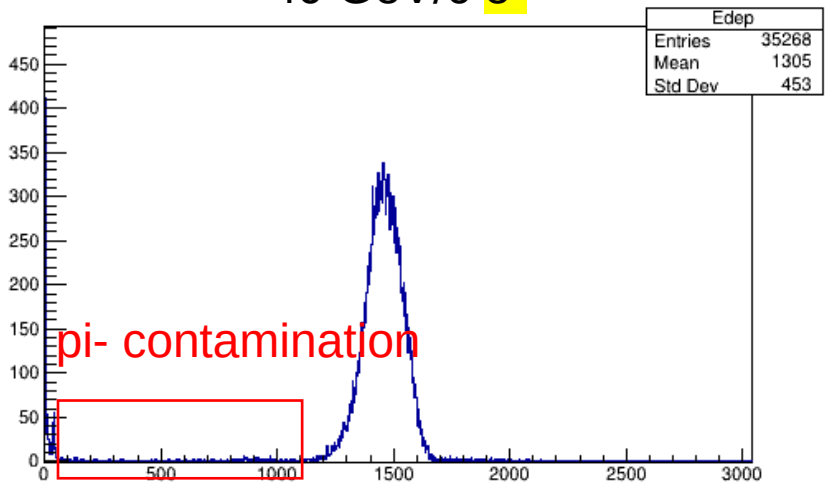




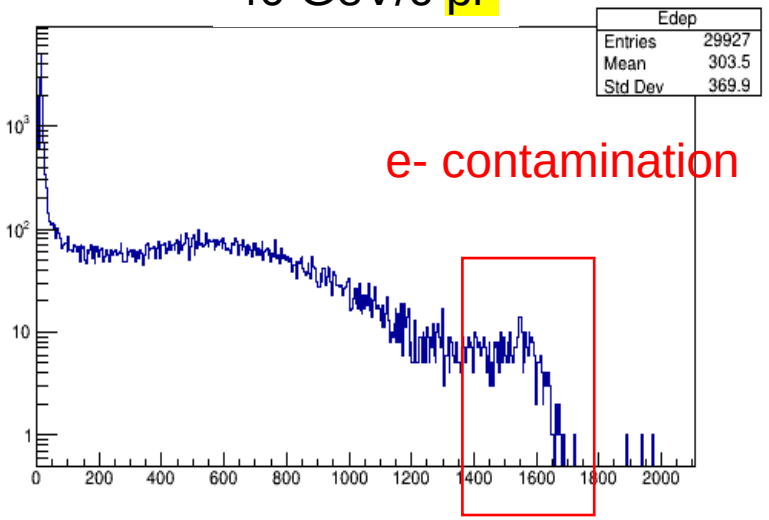
ECAL energy response to e- and pi-

- 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
  - About 3-4% energy deposited in ECAL
- In pi- beam, there is also a few e- contamination

40 GeV/c e-



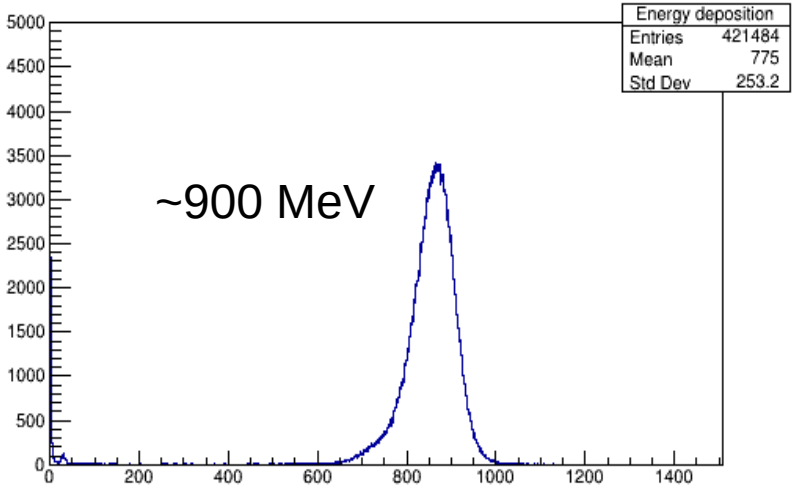
40 GeV/c pi-



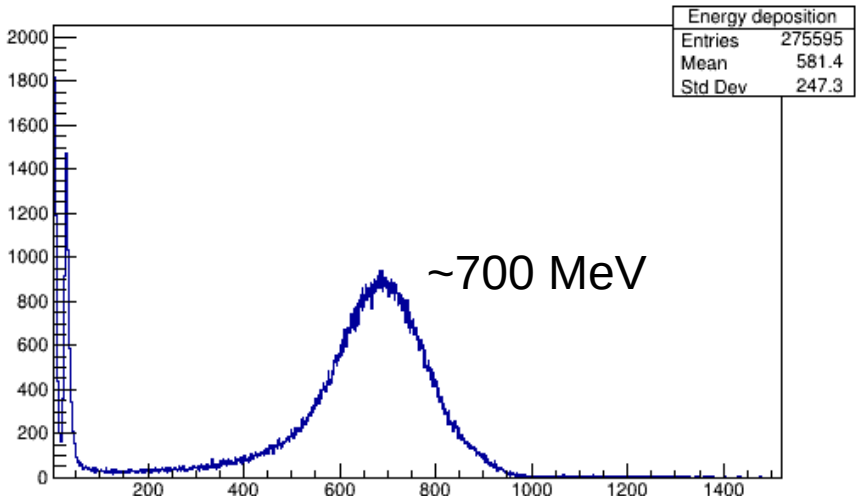
AHCAL energy response to e- and pi-

- In order to study the AHCAL response to EM composition, we also tested AHCAL alone with e- and pi- both
  - About 2% energy of electron deposited in AHCAL sensitive layers
  - For pion, the energy deposition in sensitive layers is a little less than electron

40 GeV/c e-



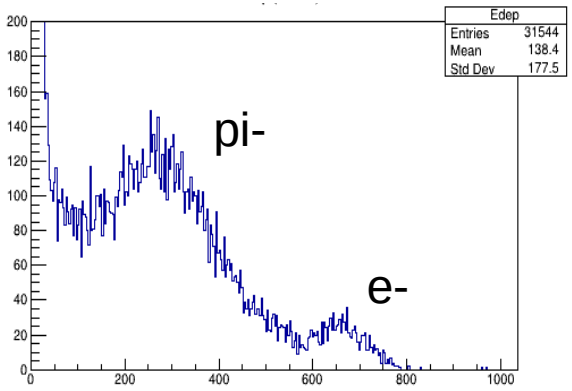
40 GeV/c pi-



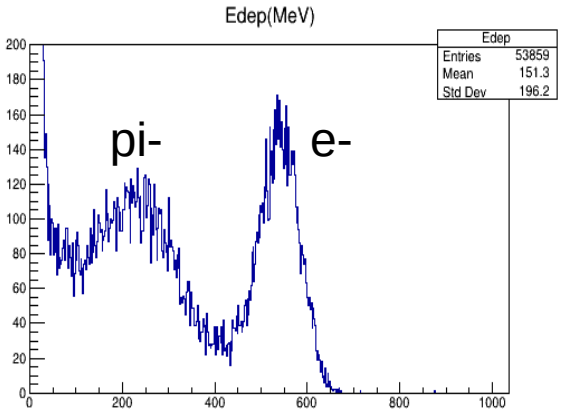
Low energy pi- in H2

- Low energy pi- are not pure
- 10 GeV/c，most of the events are e-

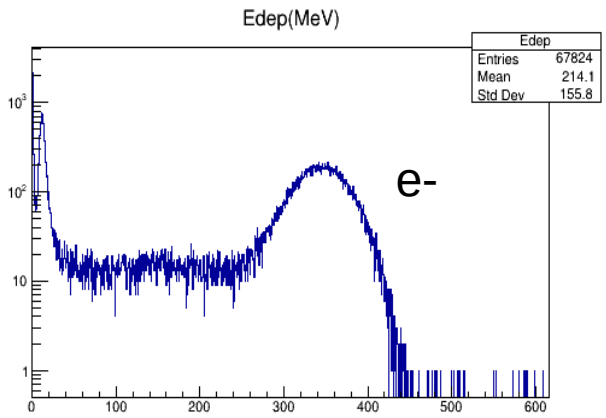
20 GeV/c



15 GeV/c



10 GeV/c



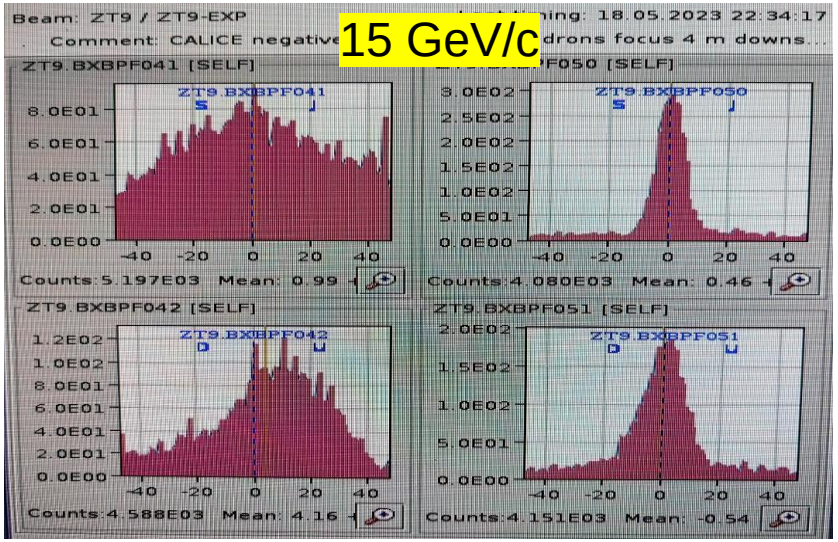
Energy deposition in ECAL (MeV)

Beam Test in PS T9

Beam in PS T9

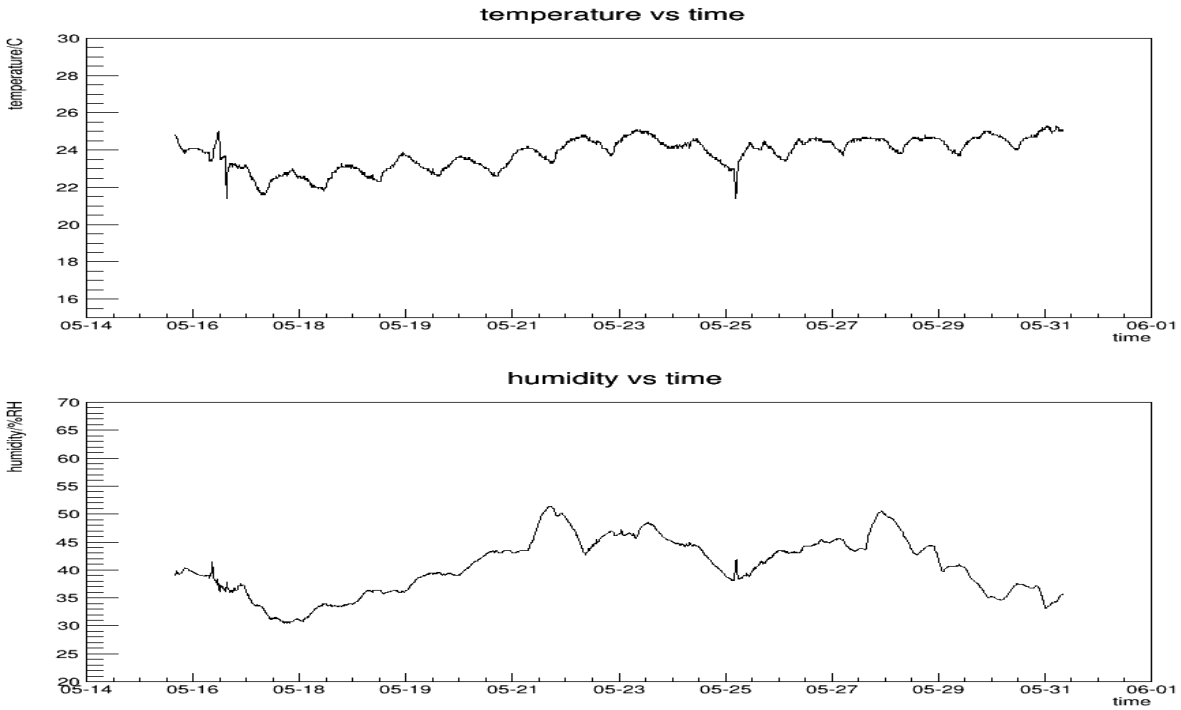
- Energy: 0.5 – 16 GeV/c
- Spill duration: ~ 2.4 sec with 0.4 sec flat-top, typically 1-2 spills / min
- About 2-3 k events per spill
- Typical beam size: ~1-2 cm

- Muon Test
  - Momentum： 10 GeV/c
- Pion- test
  - 1 – 15 GeV/c
  - 8 million
- Electron Test
  - 0.5 – 5 GeV/c
  - 2.6 million

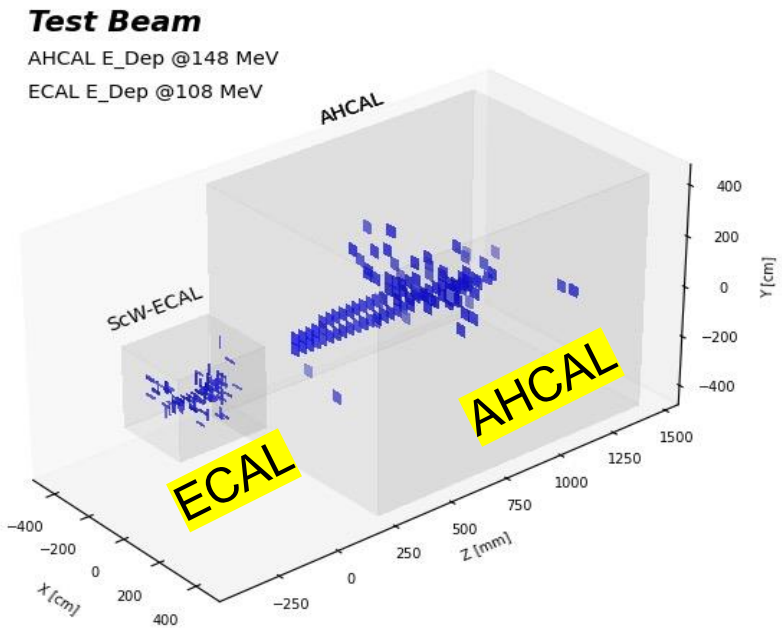


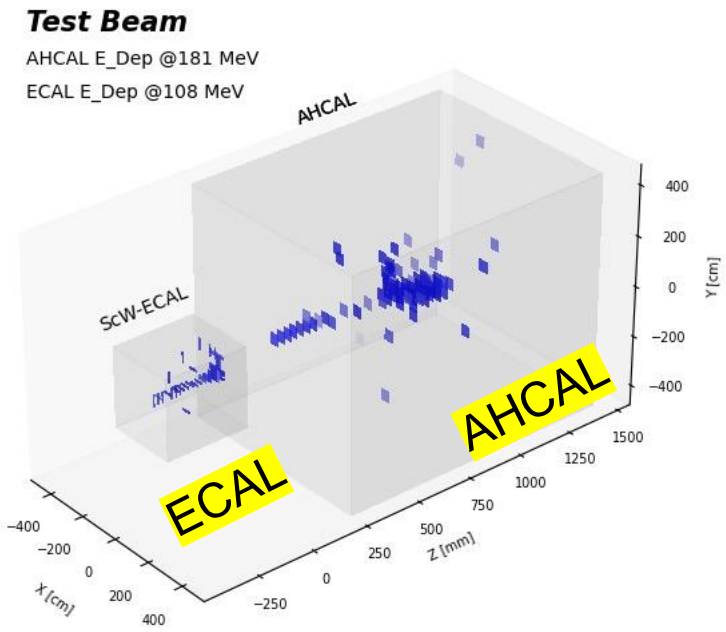
Temperature and Humidity

- The temperature changed from 21 degrees to 26 degrees
  - About 4 degree higher than SPS
- The humidity varied from 30% to 55%,depended on the weather..



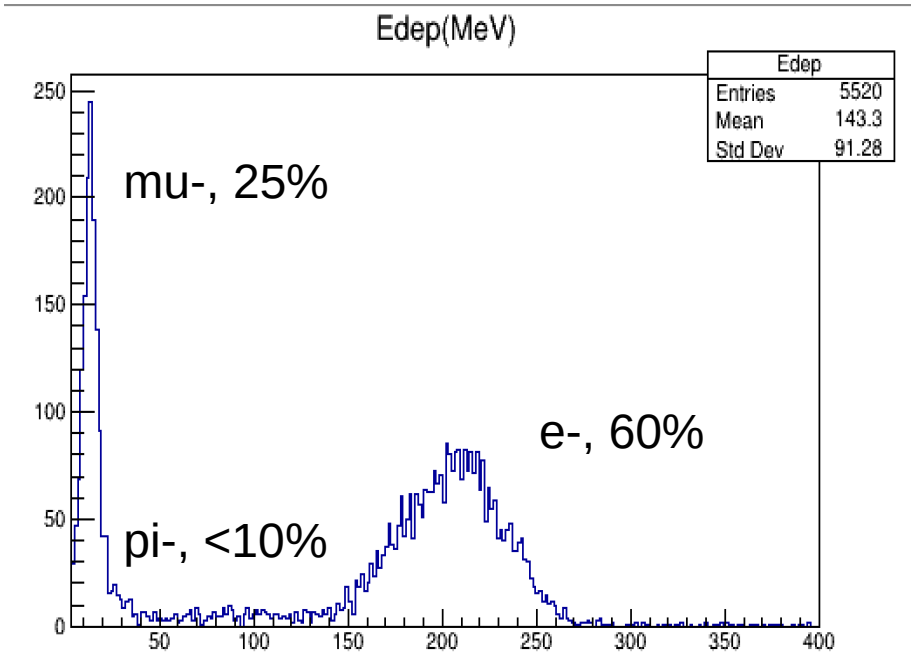
Event display





ECAL Energy Response to e-

- 5 GeV/c e- energy deposition in ECAL
- About 4% energy deposited in ECAL sensitive layers

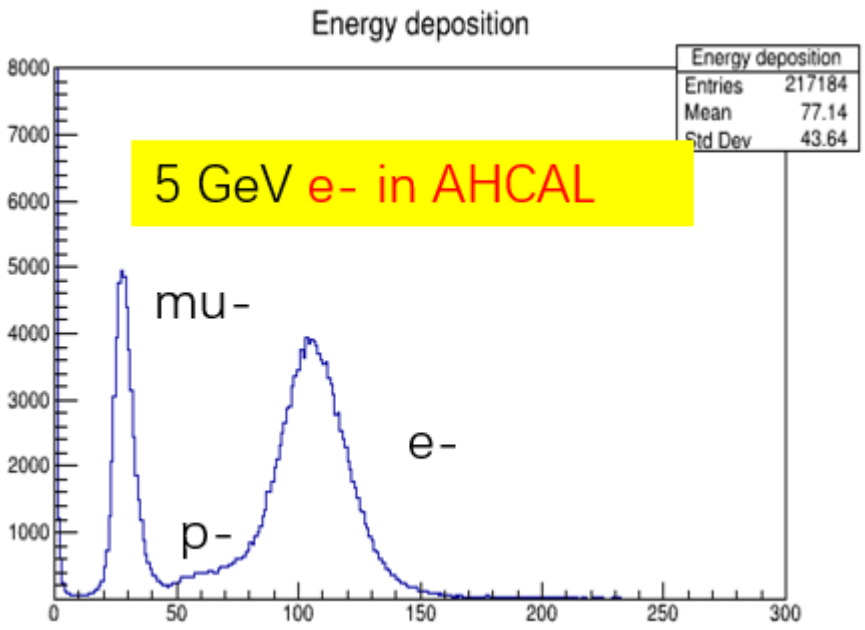


Energy deposition in ECAL (MeV)

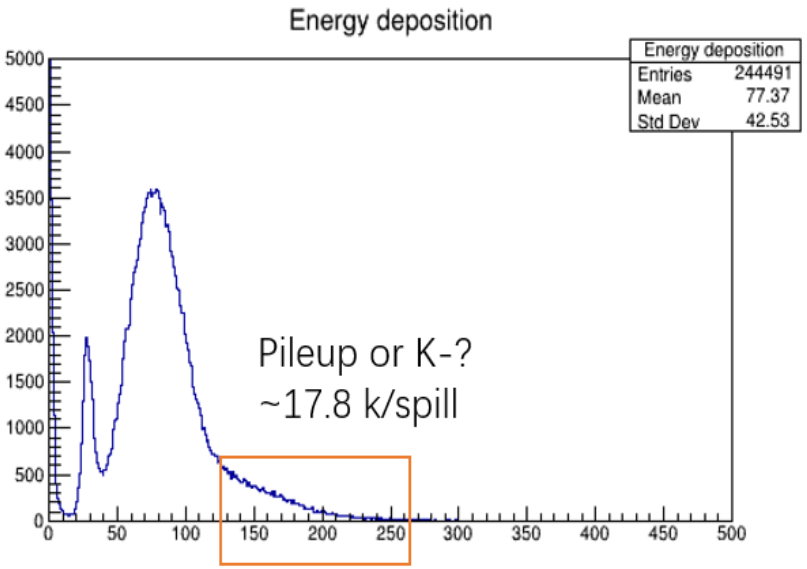
HCAL response to e-, pi-

- About 2% energy of electron deposited in AHCAL sensitive layers
- For pion, the energy deposition in sensitive layers is a little less than electron

5 GeV/c e- energy deposition in AHCAL

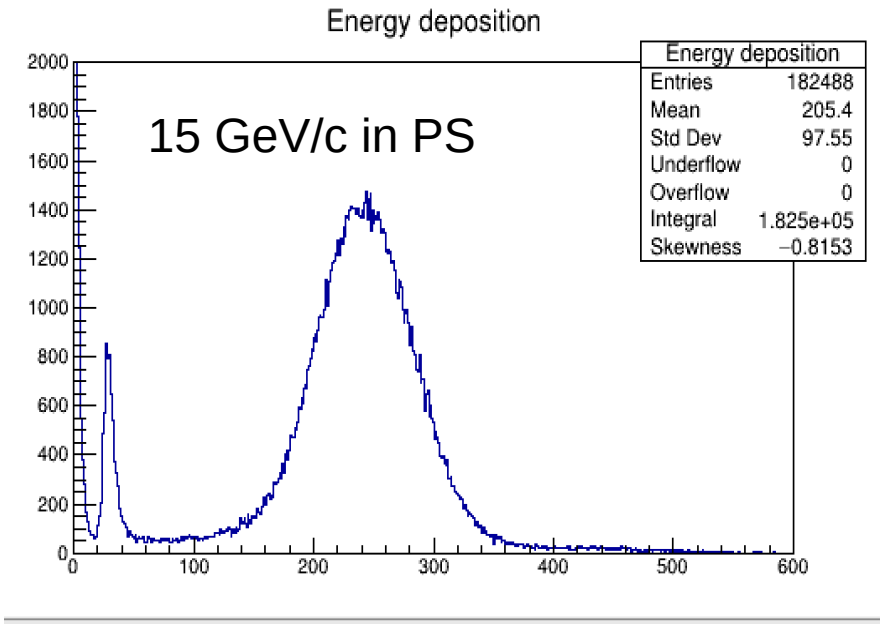


5 GeV/c pi- energy deposition in AHCAL

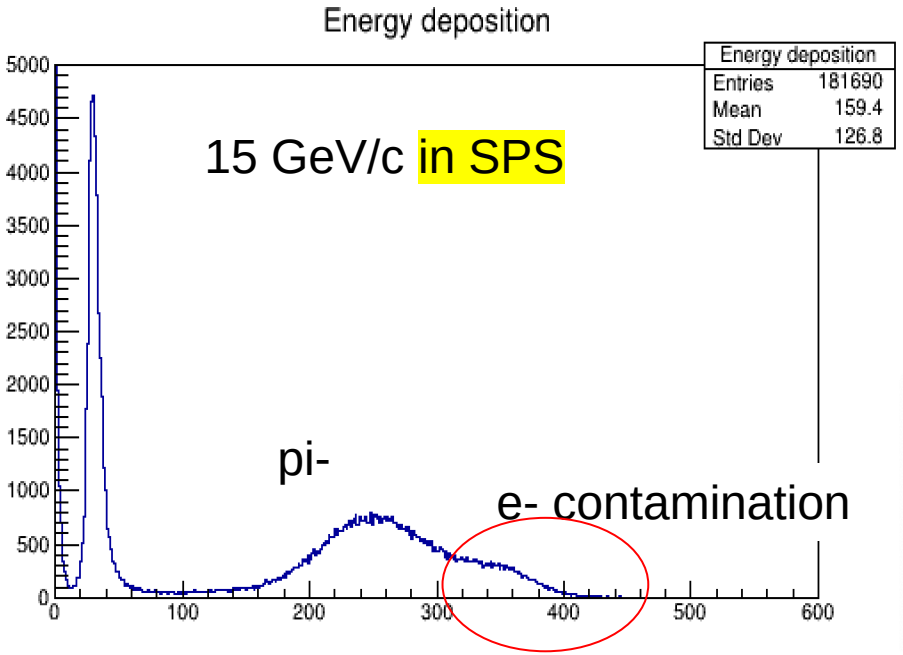


HCAL response： pi- Test

Compared with SPS low energy pion beam, the PS beam is much pure



Energy deposition in AHCAL (MeV)



Energy deposition in AHCAL (MeV)

Summary

- The two calorimeters has been taking beam test from April 24 to May. 31, the preliminary results show the calorimeters work very well
  - The Sci-W ECAL and AHCAL were tested with pions and electrons from 10 GeV/c to 120 GeV/c (SPS) and 0.5 GeV/c – 15 GeV/c (PS)
  - We collected about 40 million events in this beam test
- We will continue a detailed analysis of the data to further tap the potential of the data
- Thank the great support and help from CALICE and CERN for this beam test

Summary

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THANKS

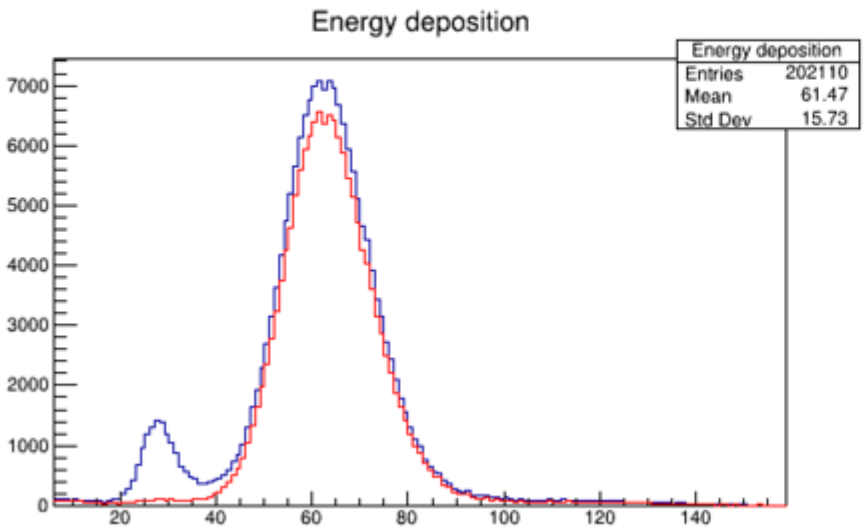
Cherenkov Detector

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

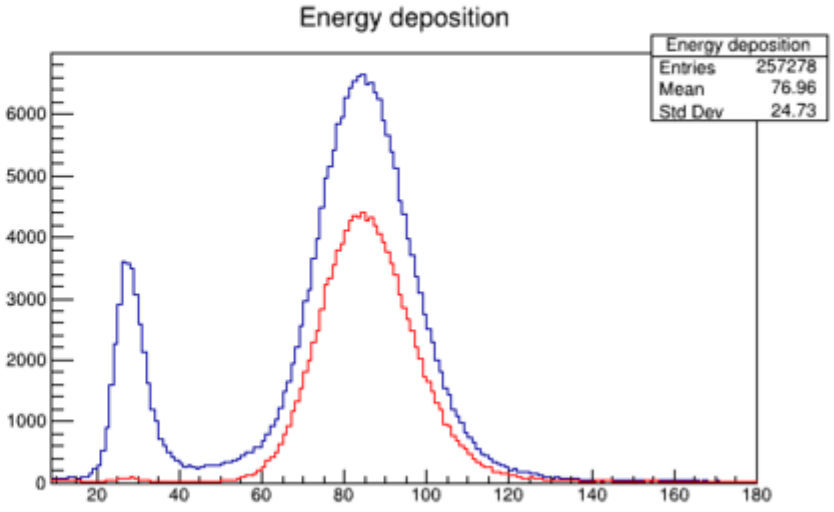
W/O Cherenkov

W/ Cherenkov

3 GeV/c e- in AHCAL



4 GeV/c e- in AHCAL



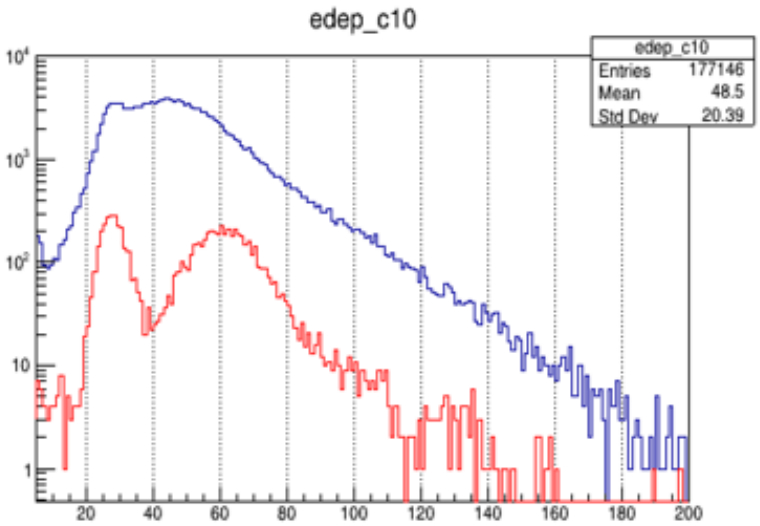
Cherenkov Detector

- We also could “see” the mu- and e- events in pi- data

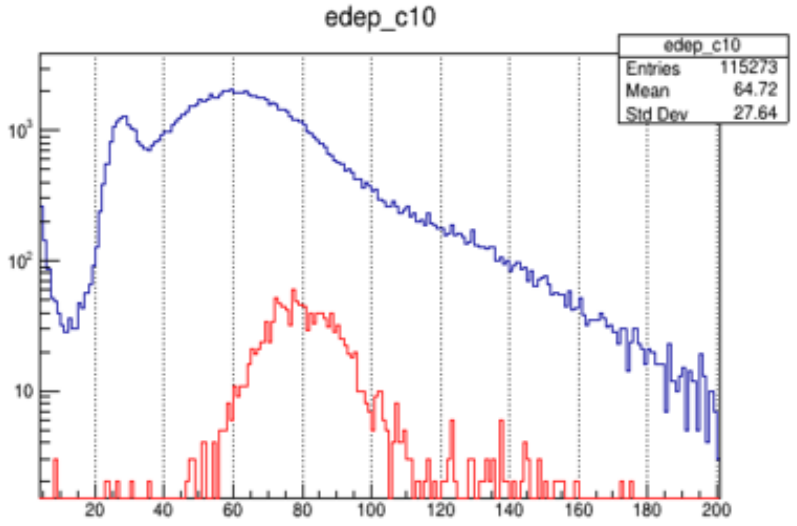
W/O Cherenkov

W/ Cherenkov， e-/mu- candidates

3 GeV/c pi- in AHCAL

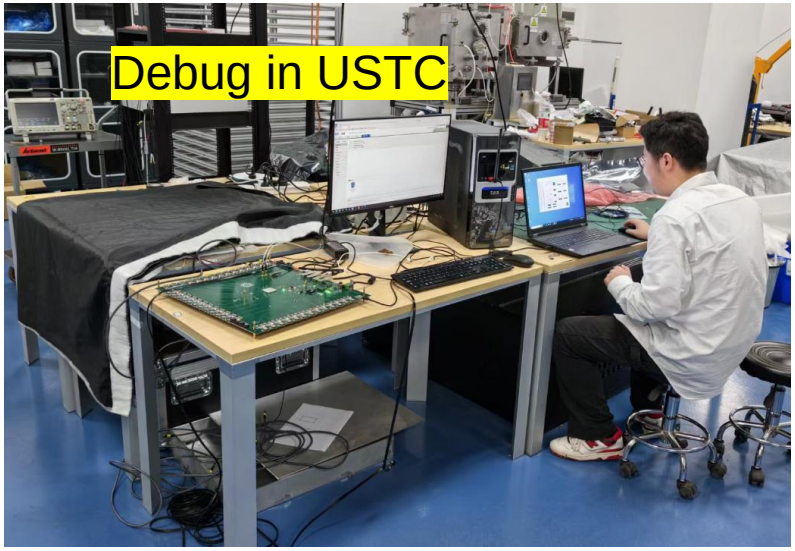


4 GeV/c pi- in AHCAL



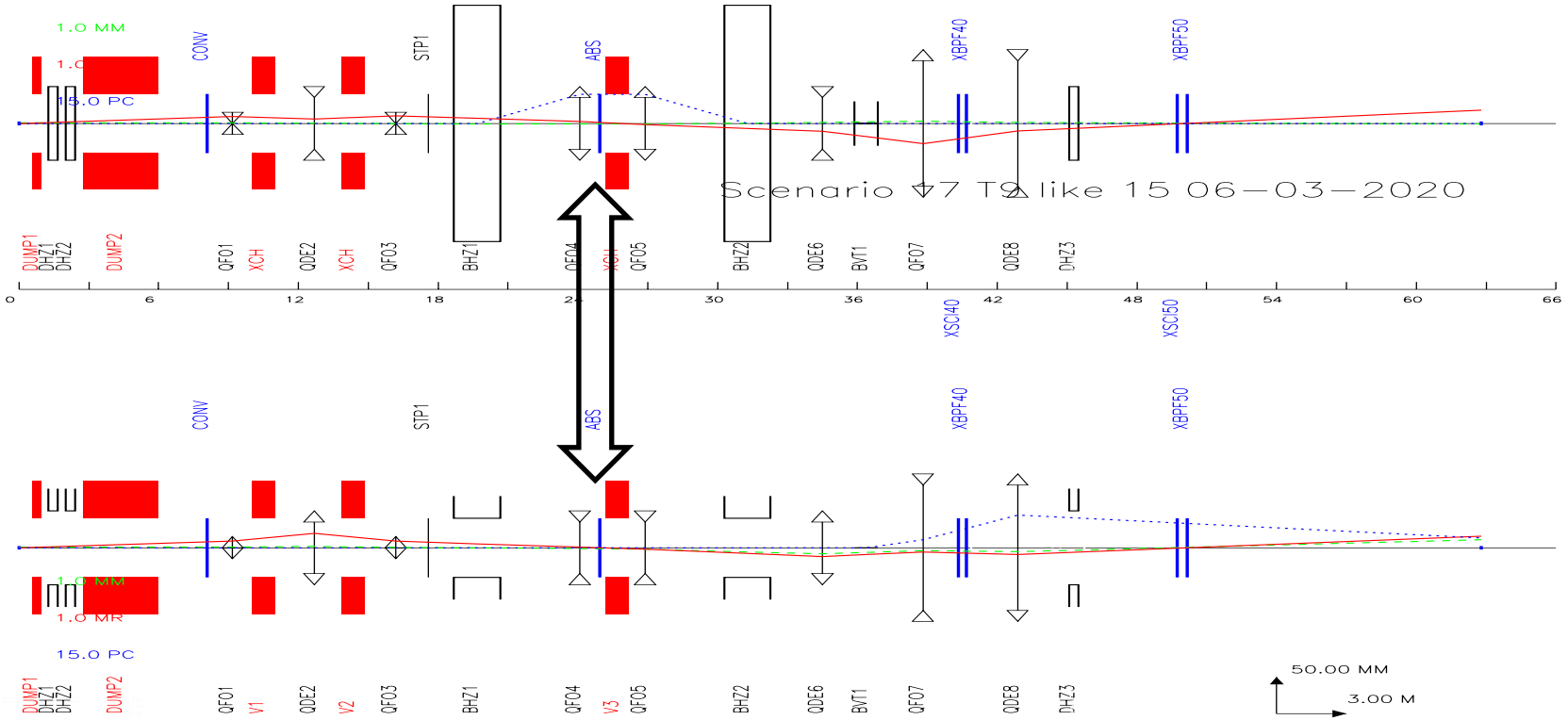
ECAL Update this year before beam test

- We have rebuilt two layers in the laboratory to study the problems discovered during last year's testing process
- The ECAL temperature
  - The temperature data in ECAL are disordered last year. This problem is fixed and tested.
- The autogain
  - We think the select thresholds used in 2022 are too low. We calibrate new thresholds for each chip
- ECAL stuck
  - In Beam test of 2022, the ECAL always got stuck and had no data for sometime. We modify a firmware bug and update the hardware.



Suppress e- yield using Absorber

- Take an obstacle in the beam to “absorb” the electrons
  - The secondary e+/- will be bended later



ECAL Energy Response to pi-

- Take an obstacle in the beam
  - XCON025, 4 mm lead
    - w/ obstacle
    - w/o obstacle