Scintillator ECAL Technological Prototype: SPS Beam Test and Preliminary Results

Jiaxuan WANG

University of Science and Technology of China

On behalf of the sci-ECAL working group

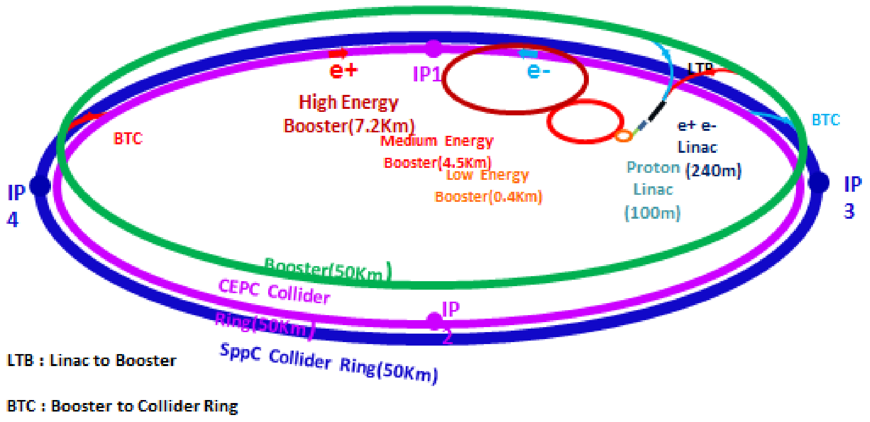
CALICE Collaboration meeting from March 29-31, 2023

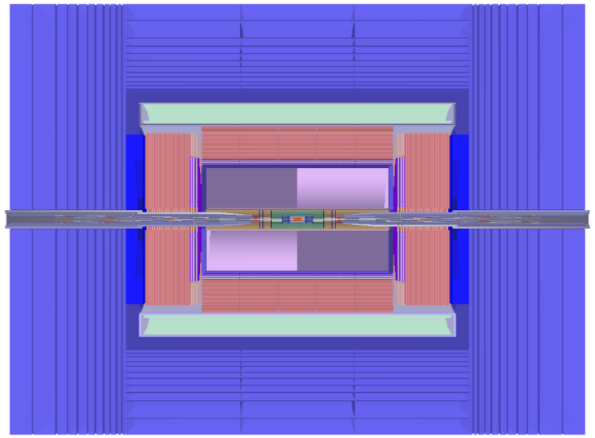
Outline

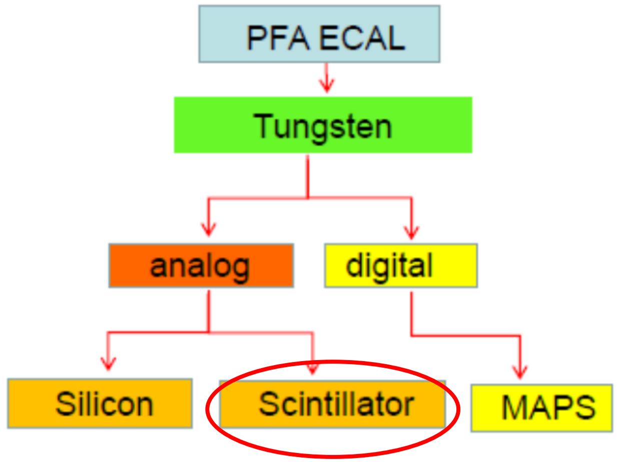
- Sci-ECAL and SPS beam test
- Preliminary test results
- Future plan

Motivation

- Circular Electron Positron Collider (CEPC)
  - $E_{cm} \approx$ 240GeV, luminosity ~ 2×10^{34} $cm^{-2}s^{-1}$
  - Precision measurement of the Higgs boson





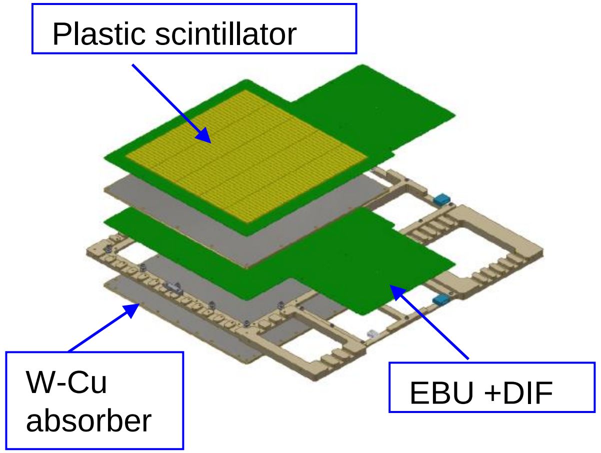


Sci-ECAL Prototype Overview

- Sampling calorimeter :
  - 32 layers, each has 210 sensitive cells
- Sandwich structure :
  - W-Cu alloy + scintillator strip + SPIROC2E chip
- Orthogonal placement ➔ 5mm Granularity
- Radiation length: 22 X_0

*Scintillator (5mm*45mm*2mm)*

*SiPM,
S12571 series, Hamamatsu*



Layer structure

Sci-ECAL structure

Sci-ECAL prototype

Timeline

Early Oct

Preparatory Stage

Arrived at CERN, waited for calorimeters' delivery and assembled the test system

Oct 16th

Parasitic Test

Beam test at downstream for Sci-ECAL and AHCAL

Oct 19th

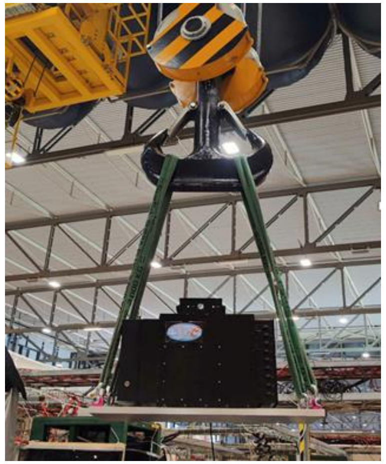
Beam Test Main User

AHCAL standalone Oct 19th- Oct 26th

Sci-ECAL and AHCAL combination Oct 26th- Nov 2nd

Nov 2nd

End of Beam Test



Hoist

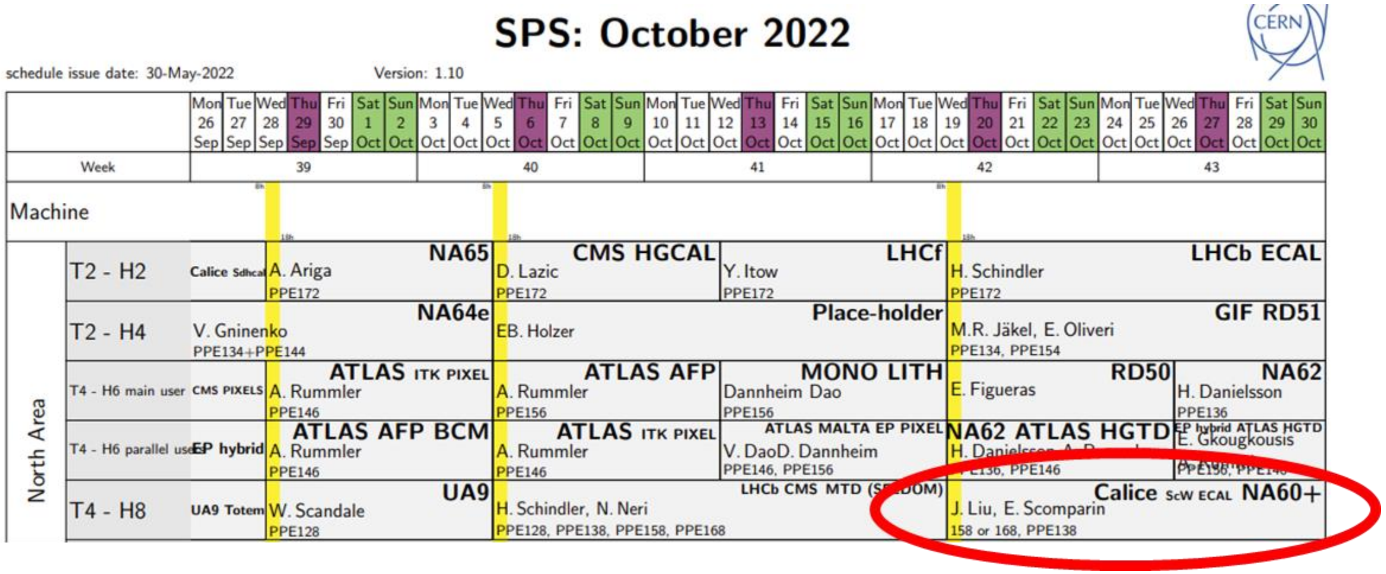
Assembling

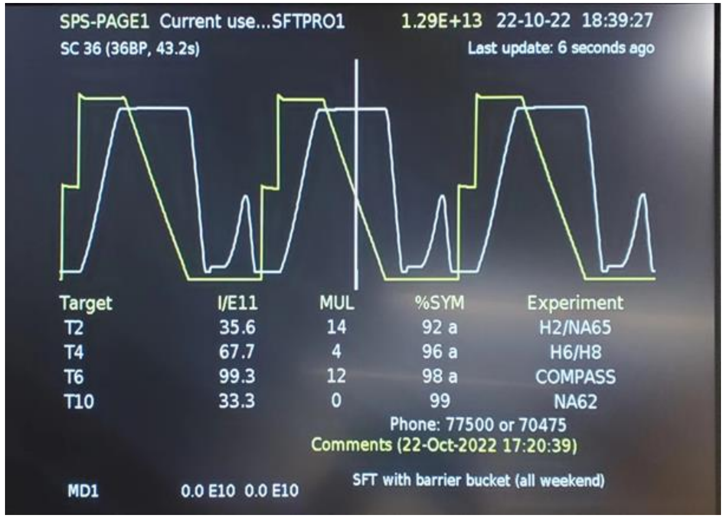
Sci-ECAL on platform

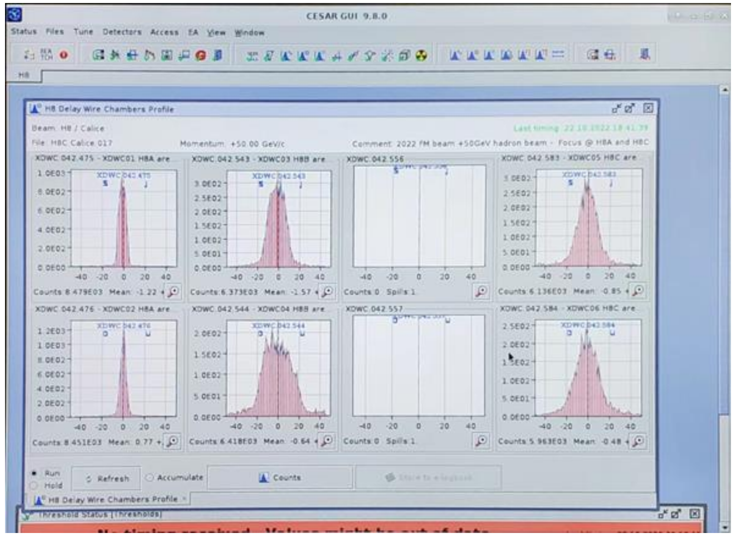
ECAL : One week beam test, Oct 26th- Nov 2nd at SPS H8, combined with AHCAL

SPS/H8

- The H8 beam line is a high-energy, high-resolution secondary beam line.
- Secondary mixed hadron beams within the range 10-360 GeV/c.
- the electron beams with variable purity (10 – 99 %) are also possible

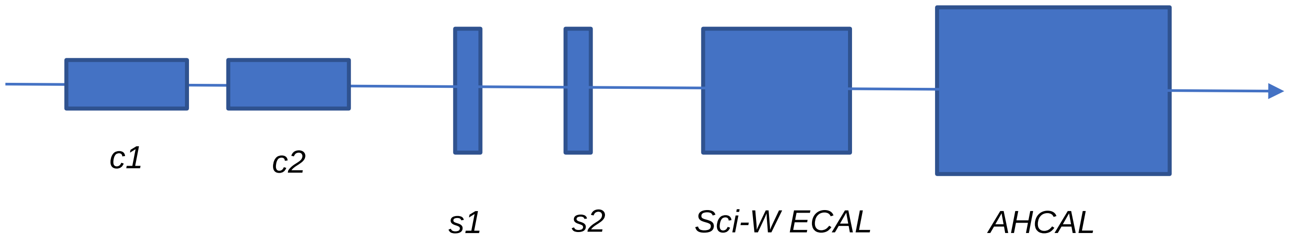


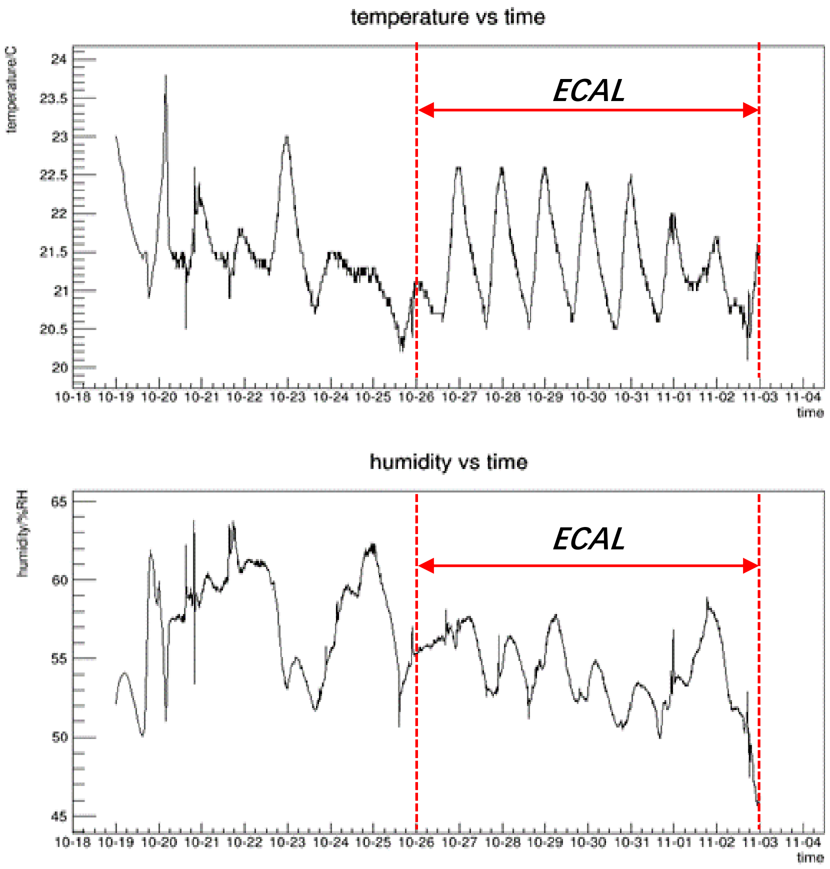




Data Acquisition

- Validation mode
  - $4\mu s$ slow clock period, time window
  - TLU coincide signal of telescope(two muon counters) which provides valid signal to DAQ module.
  - Use Cherenkov signal to improve the purity.





Temperature and humidity external monitor

Data Statistics

- Sci-ECAL was tested with e+, pi+, mu+
  - Positron (~1.5 million)
    - 10-100 GeV
  - Pi+ (~1.5 million)
    - 10-120 GeV
  - mu+
    - Threshold scanning
    - Position scanning(auto-gain mode)

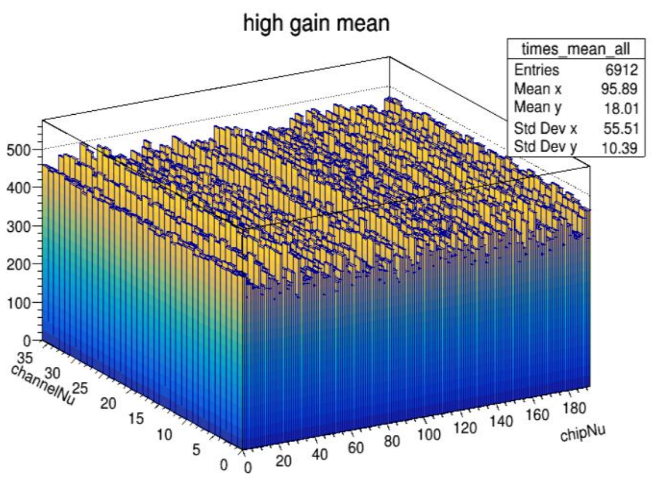
Energy Point	ECAL Entry No	
	e+	pi+
10GeV	217358	177087
20GeV	137191	189258
30GeV	172909	190373
40GeV	231526	185447
50GeV	310553	80447
60GeV	/	263427
80GeV	/	461108
100GeV	360840	264913
120GeV	/	328755

Outline

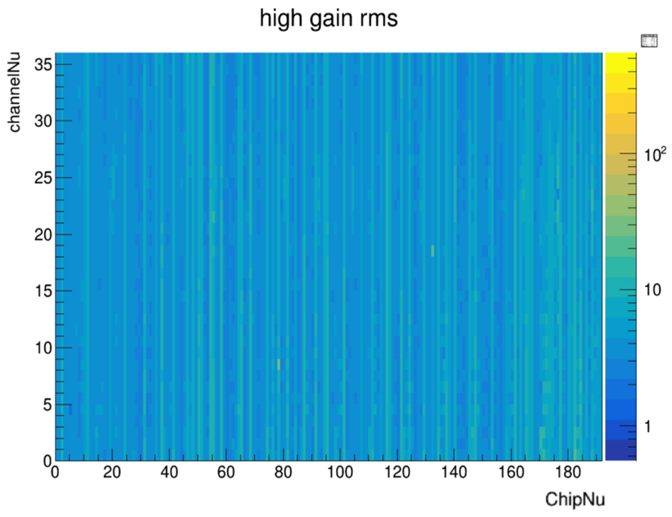
- ➢Sci-ECAL and SPS beam test
- ➢Preliminary test results
- ➢Future plan

Pedestal Calibration

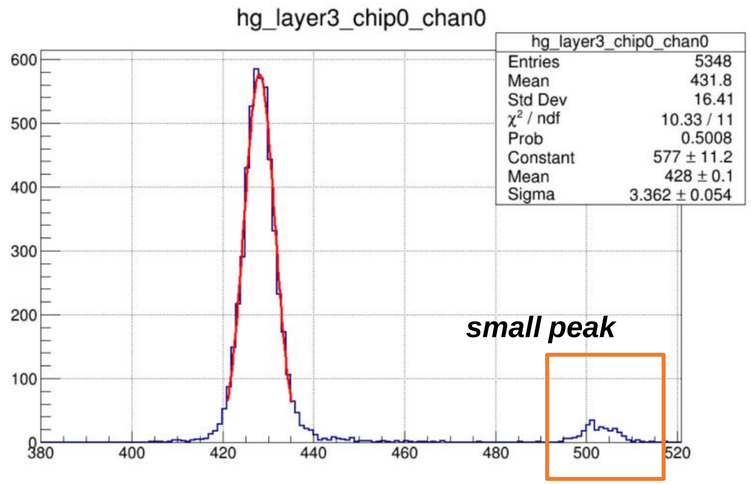
- ➢The pedestal distribution could be obtained from “HitTag=0” channel.
- ➢Gaussian mean of high gain ADC distribution : 350~500 ADC; rms: 2~6 ADC.
- ➢The small peak at the right of pedestal is observed.



High gain mean at channel level



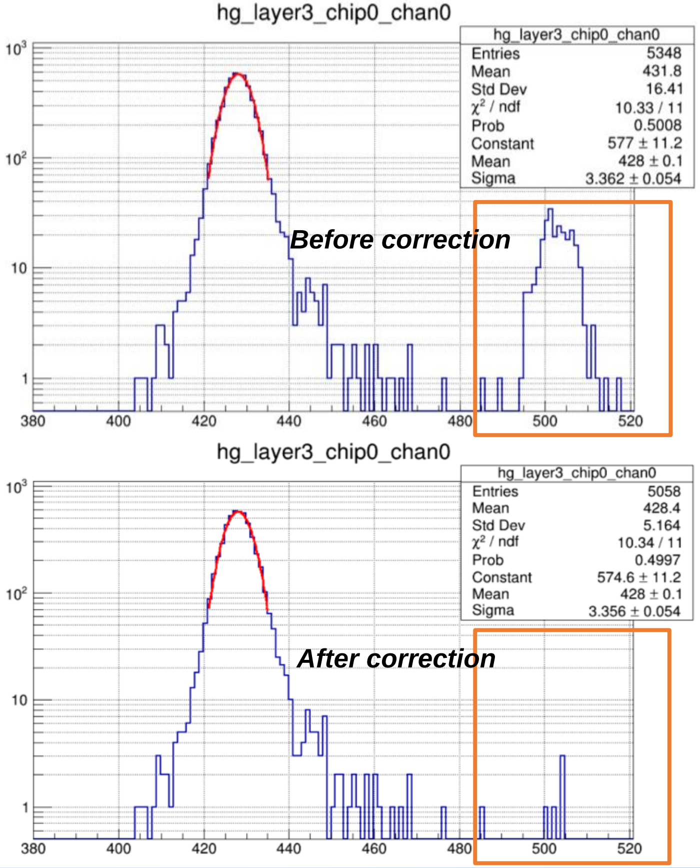
High gain rms at channel level



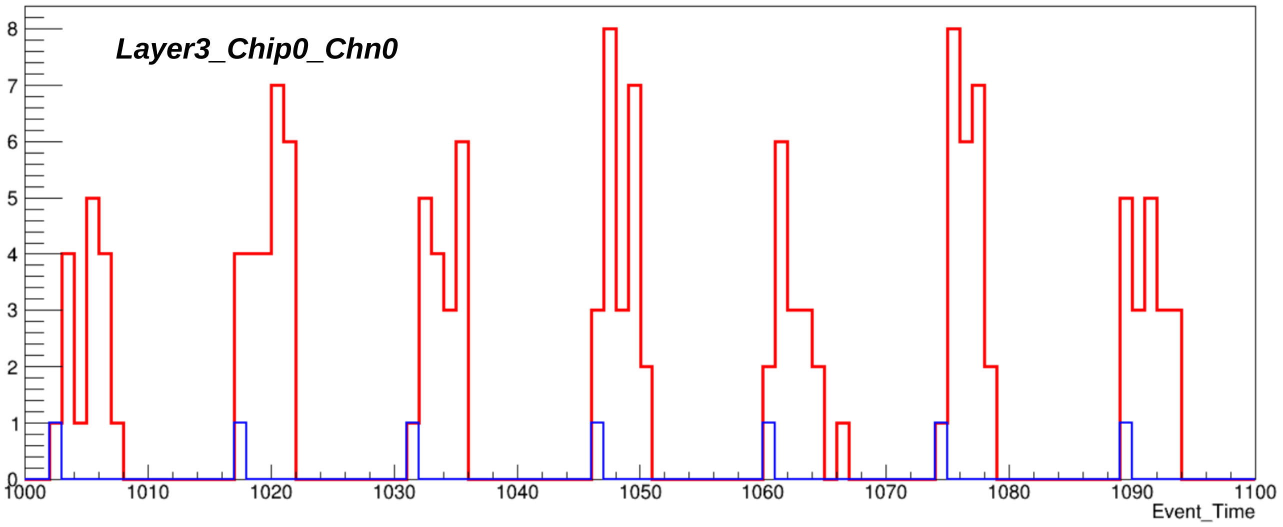
Pedestal distribution for layer3 chip0 channel0

Pedestal Correction

- Pedestal drifts when chip idles.
- Small peak could be removed by dropping the first event of each spill.



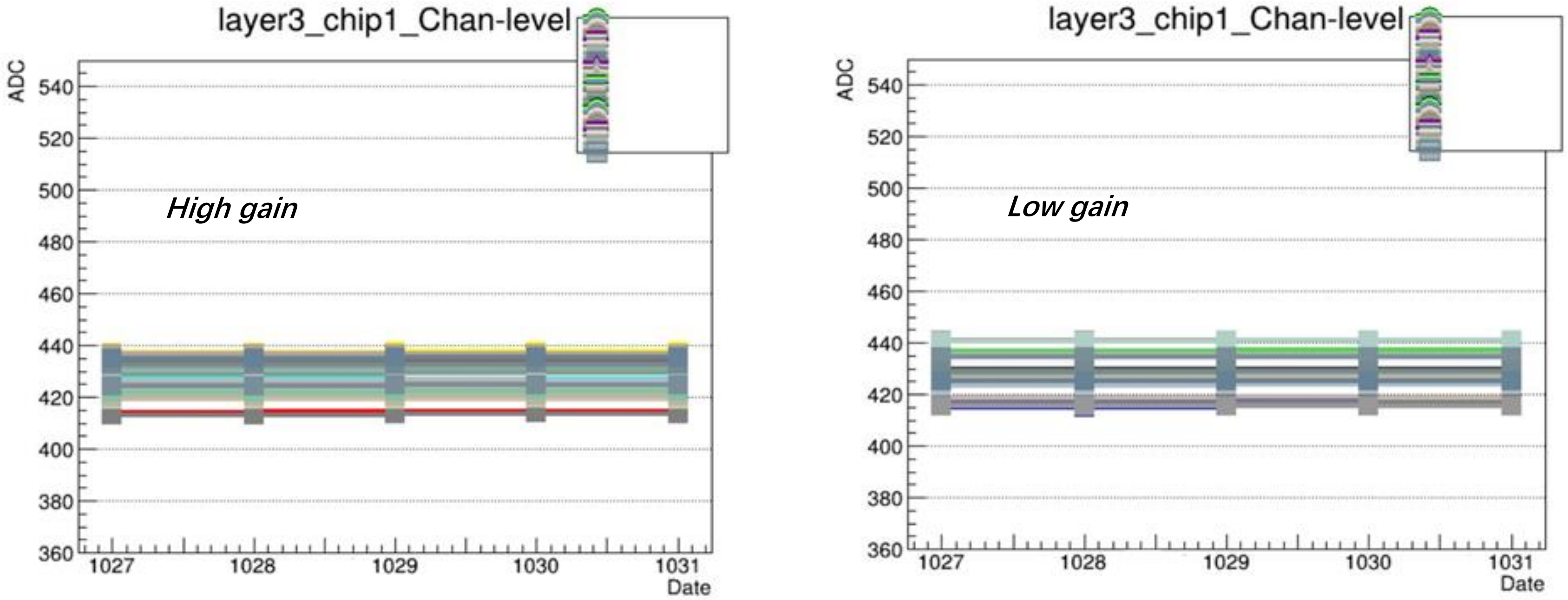
Spill structure



Red stands for main peak
Blue stands for small peak

Pedestal Stability

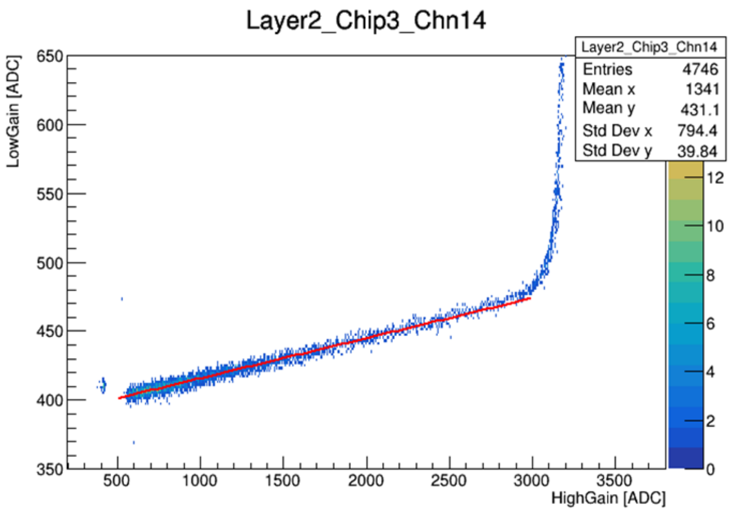
- Files were selected from every single day for time-stability study.
- Pedestal is stable during test period, mostly fluctuating within 2~3 ADC



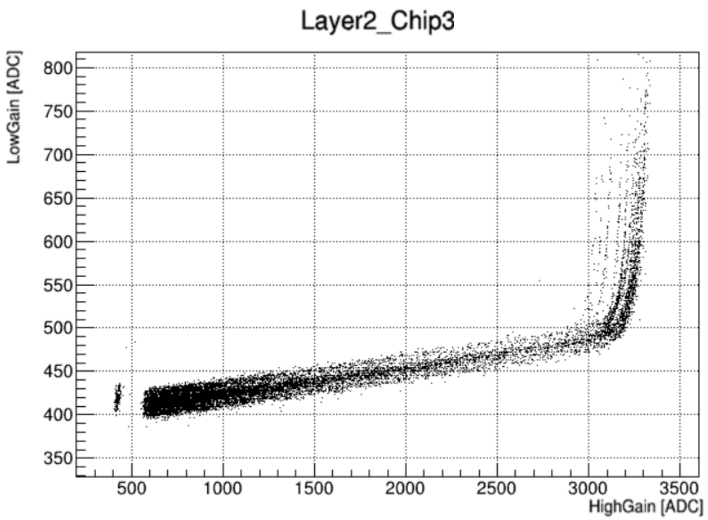
Time stability of 36 channels' pedestal in one chip

High-Low Gain Ratio Calibration

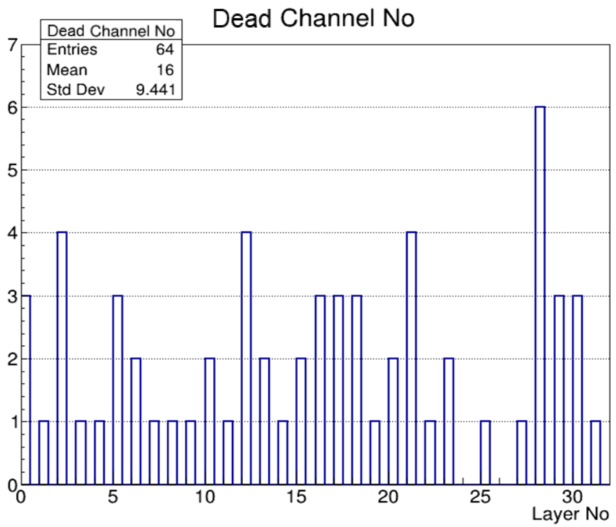
- SPIROC2E chip has two gain modes to get larger dynamic range
- High gain ADC saturates at different value
- About 0~6 dead channels in one layer(~210 channels), 0~2.8%



High-low gain ratio fit with e+ file



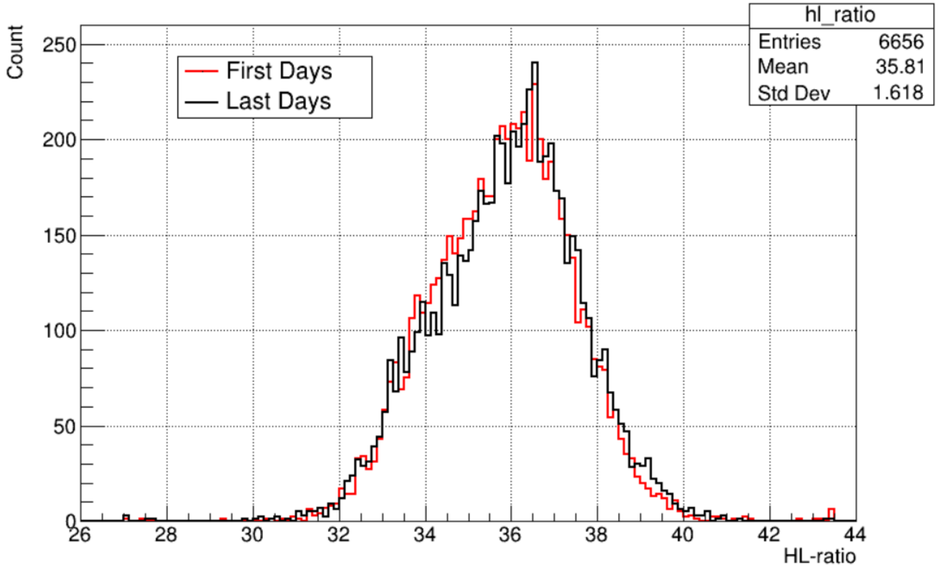
Different high gain value when saturation



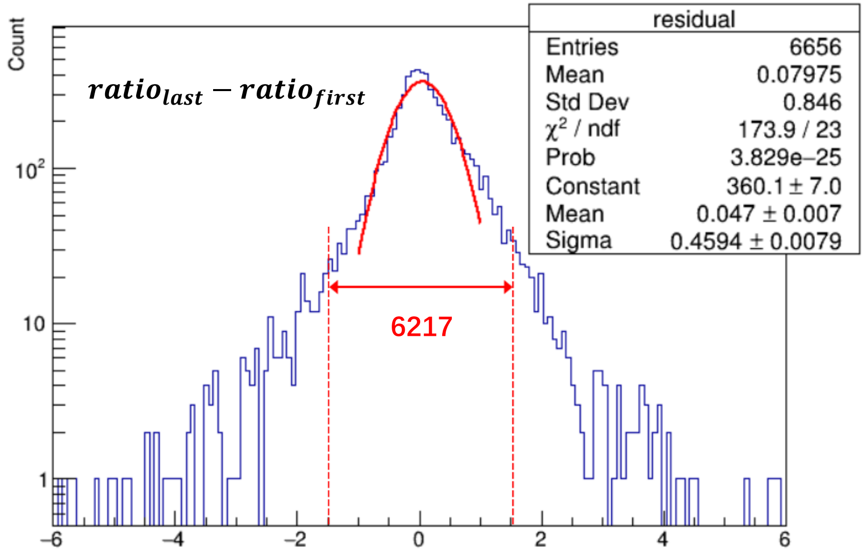
No statistics from these channels

High-Low Gain Ratio Stability

- High-Low gain ratio comparison
  - 93% channels’ ratio residual has ±1.5 fluctuation
  - Only few channels behave instable due to lack of statistics



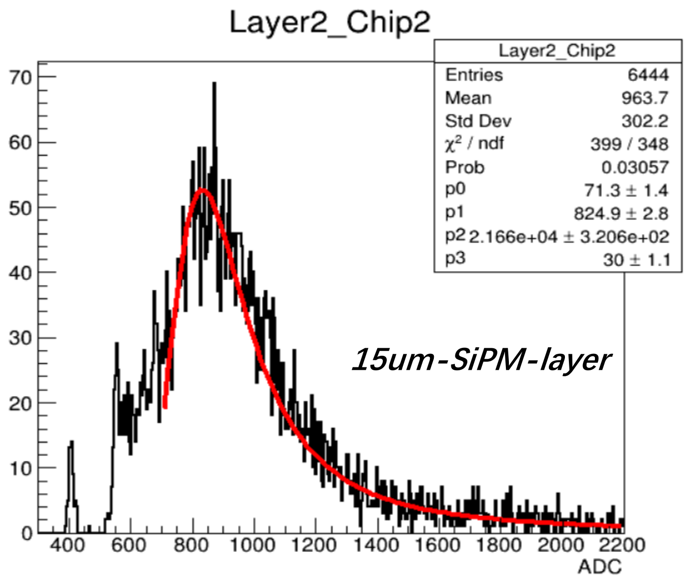
Ratio distribution of first day and last day

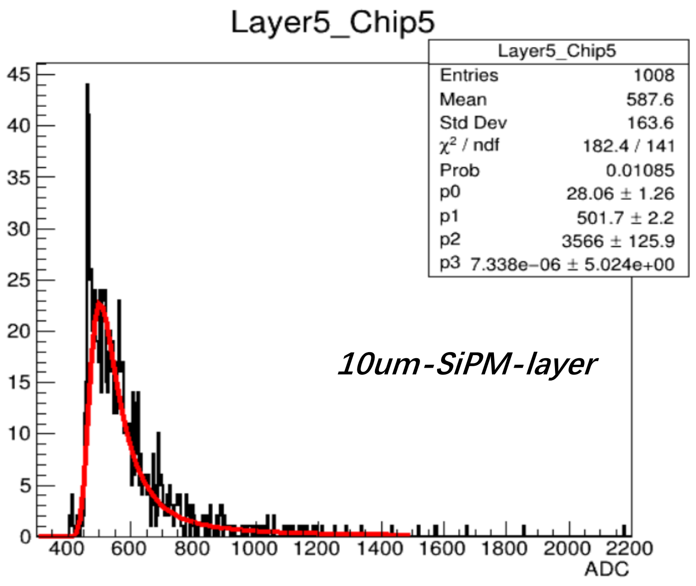


Residual distribution

MIP Spectra

- ECAL using mu+ with 108 GeV/c and different locations were scanned
- DAC threshold and SiPM voltage are optimized for better MIP spectra
- MIP spectra at chip level

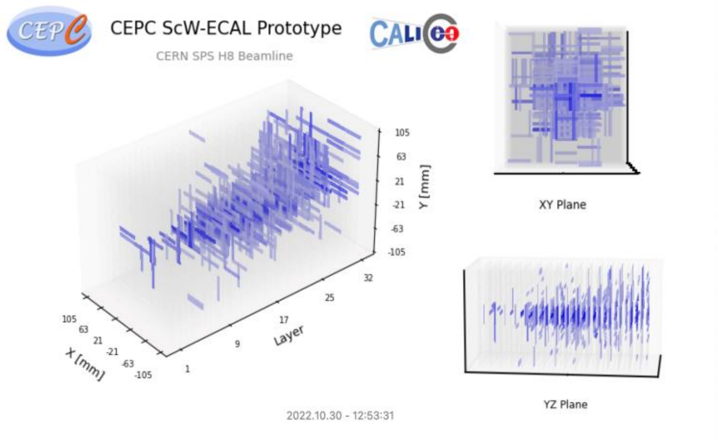




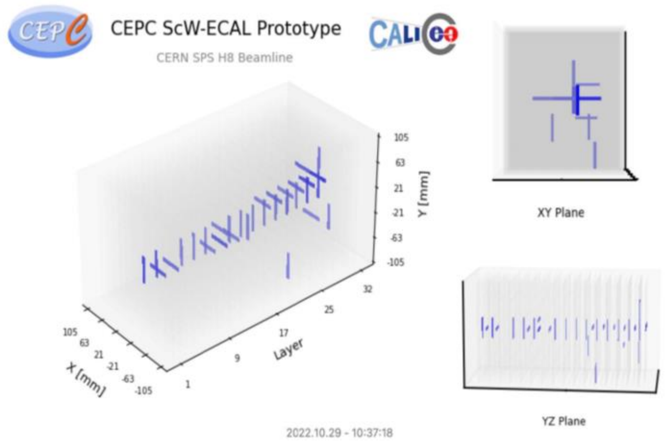
Landau convolution Gaussian function is used to fit

Event Display

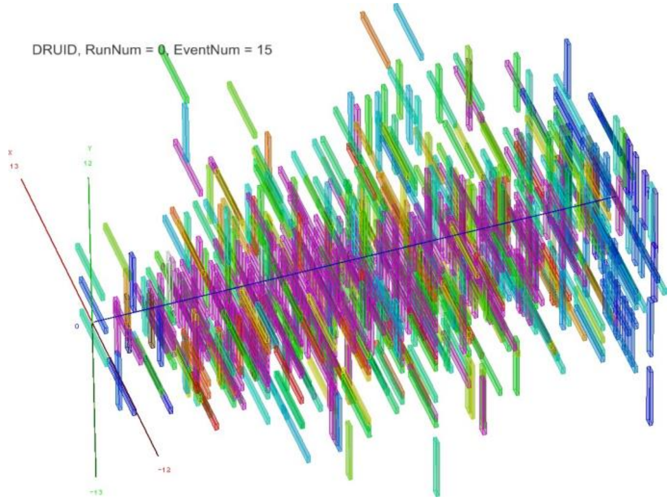
- ➢Offline display software could be used for data quality check or event alignment …
- ➢Python: one 3D figure and two 2D plane pictures.
- ➢Druid: CEPC software, available for slcio file



Hadron-like event



Muon-like event



Electron-like event

Outline

- Sci-ECAL and SPS beam test
- Preliminary test results
- Future plan

Summary

- Successful beam test
- Preliminary calibration
  - Pedestal analysis and correction
  - High-Low gain ratio calibration
  - MIP spectra analysis
- Further plan
  - ECAL performance study and algorithm development
  - Electronics update and the coming beam test

Schedule

- SPS
  - Apr 24 – May 10: 16 days at SPS H2
  - Similar test plan with last years but more high energy events

particle	momentum	position	test
Pion	10,20,30,40, 50,60,80 GeV/c	center	ECAL energy response
Electron	10,20,30,40, 50,60,80 GeV/c	center	ECAL energy response
Muon	108 GeV/c	Position scanning	ECAL MIPs response

- PS
  - May 14 – May 31: 2 weeks at PS T9
  - Study in detail low-energy particles
    - Muons : wide beam profiles needed
    - Electrons: energy scans for EM shower studies + calibrations
    - Hadrons: energy scans for hadronic shower studies

Schedule

- SPS
  - Apr 24 – May 10: 16 days at SPS H2
  - Similar test plan with last years but more high energy events

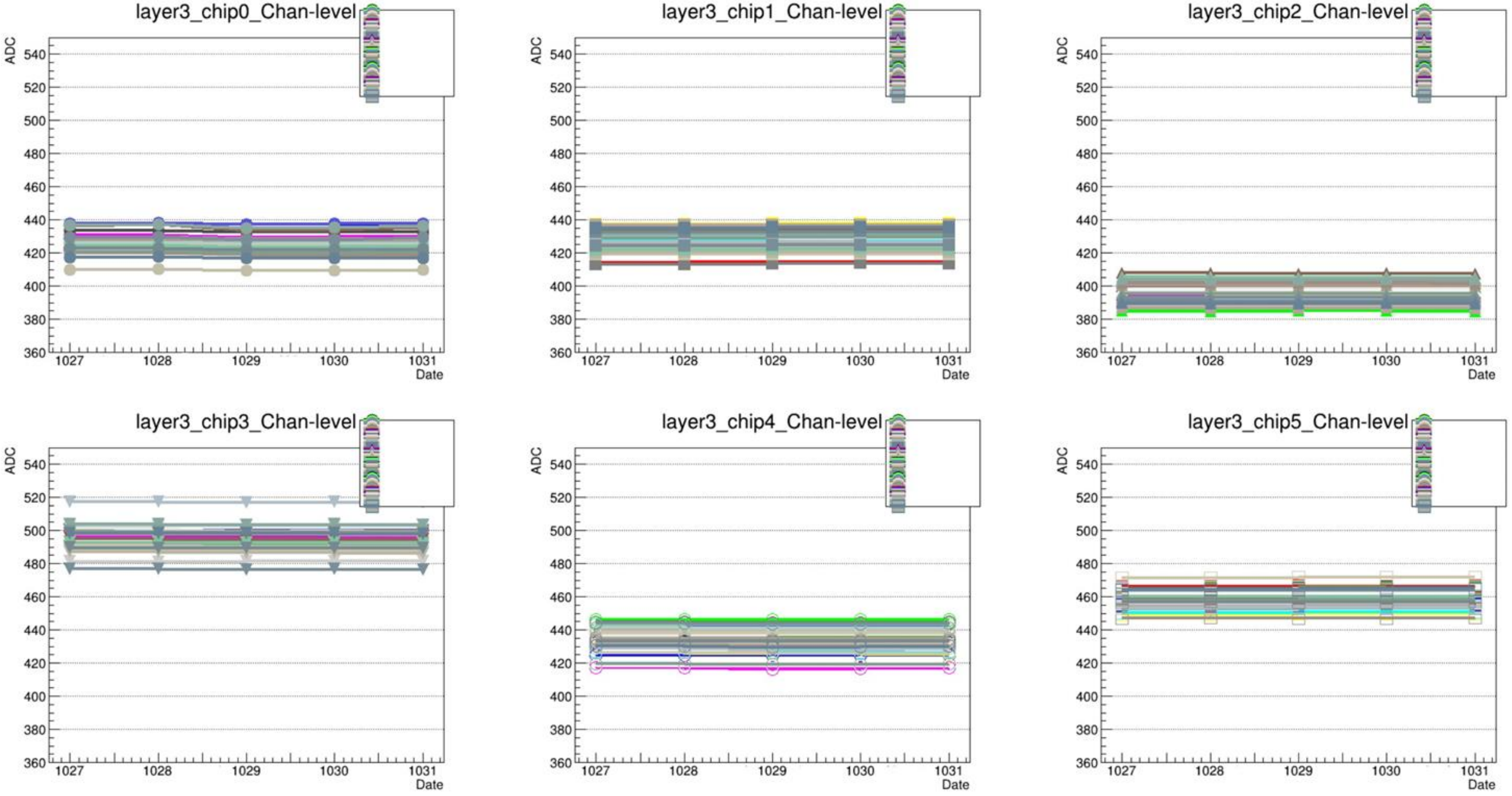
particle	momentum	position	test
Pion	10,20,30,40, 50,60,80 GeV/c	center	ECAL energy response
Electron	10,20,30,40, 50,60,80 GeV/c	center	ECAL energy response
Muon	108 GeV/c	Position scanning	ECAL MIPs response

- PS
  - May 14 – May 31: 2 weeks at PS T9
  - Study in detail low-energy particles
    - Muons : wide beam profiles needed
    - Electrons: energy scans for EM shower studies + calibrations
    - Hadrons: energy scans for hadronic shower studies

Thanks!

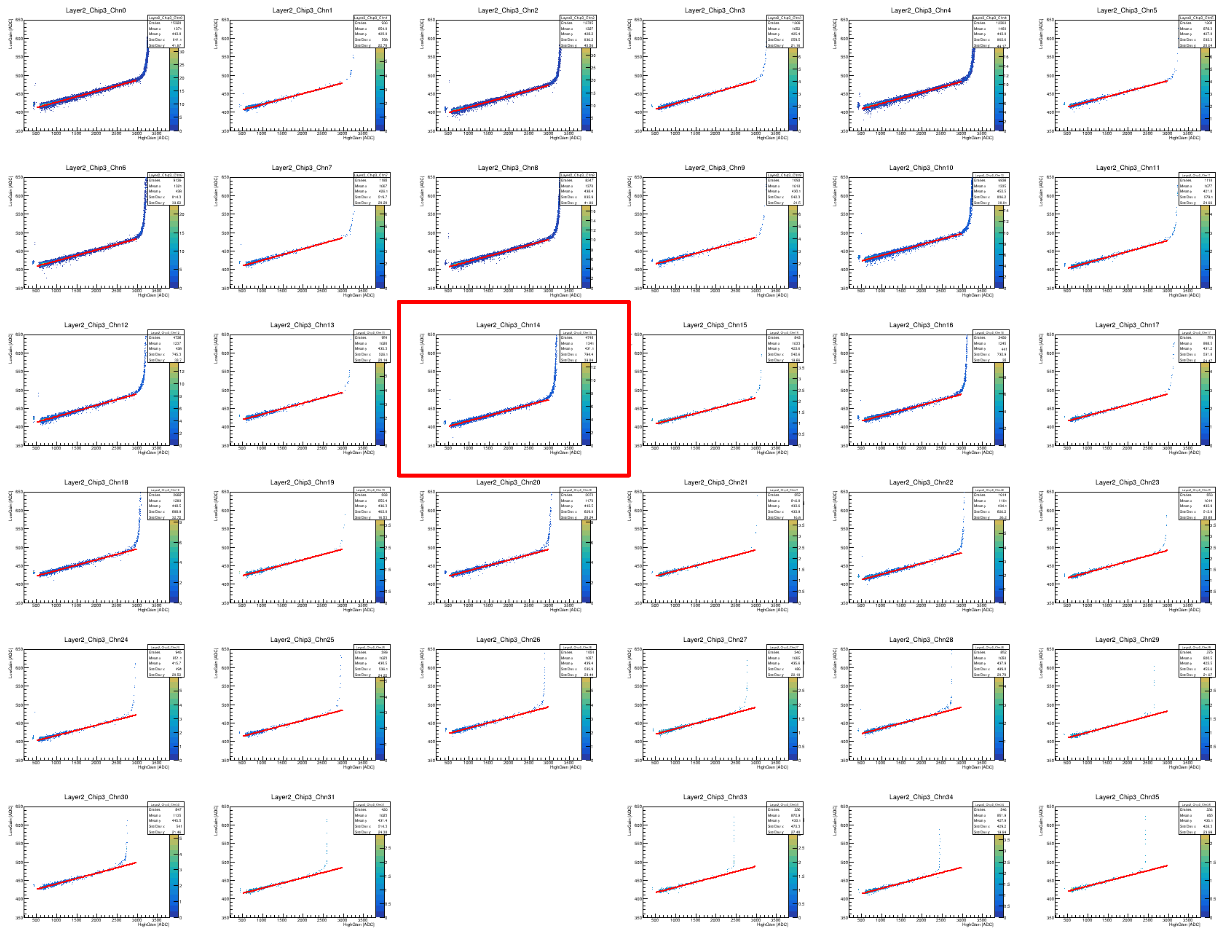
Backup

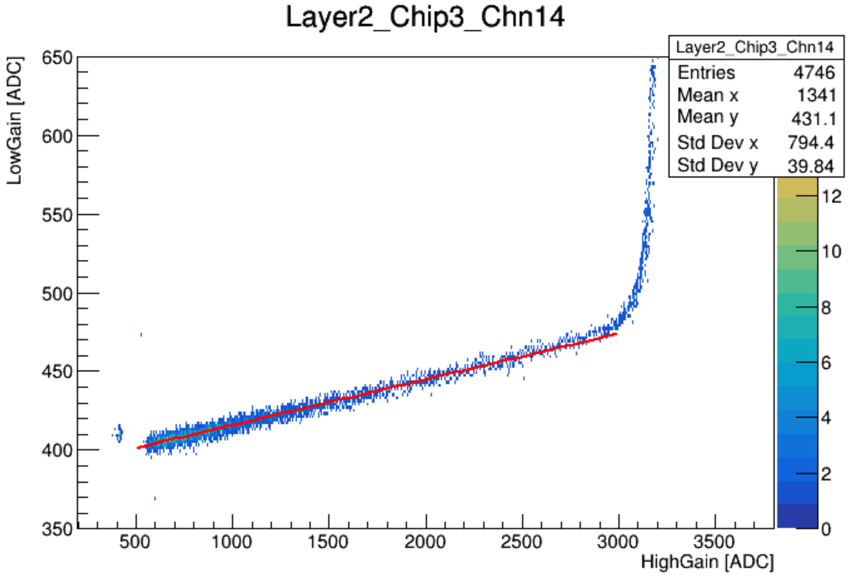
Pedestal Stability



All chips in layer 3,
each chip have 36 channels

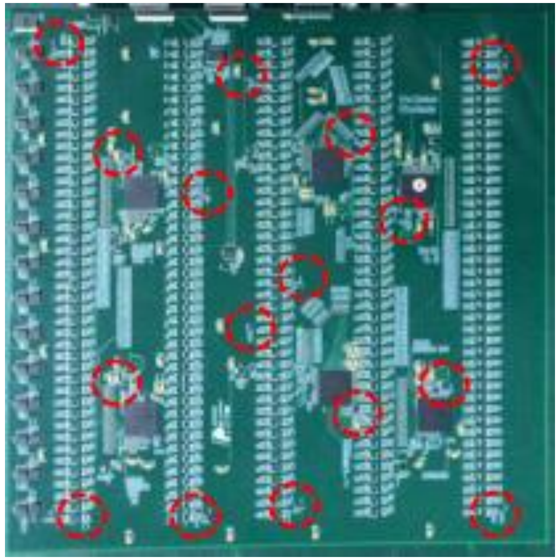
High-Low Gain Ratio

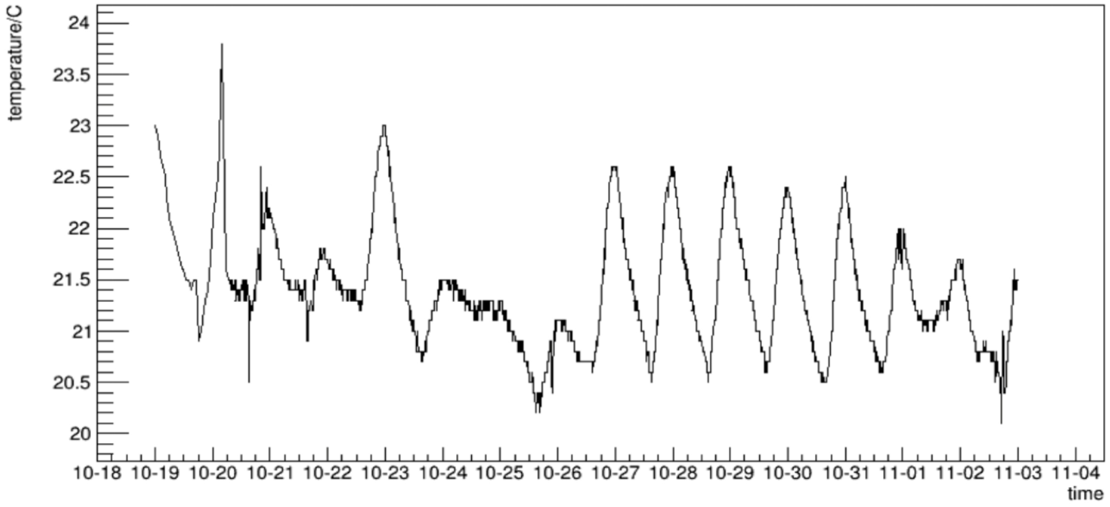




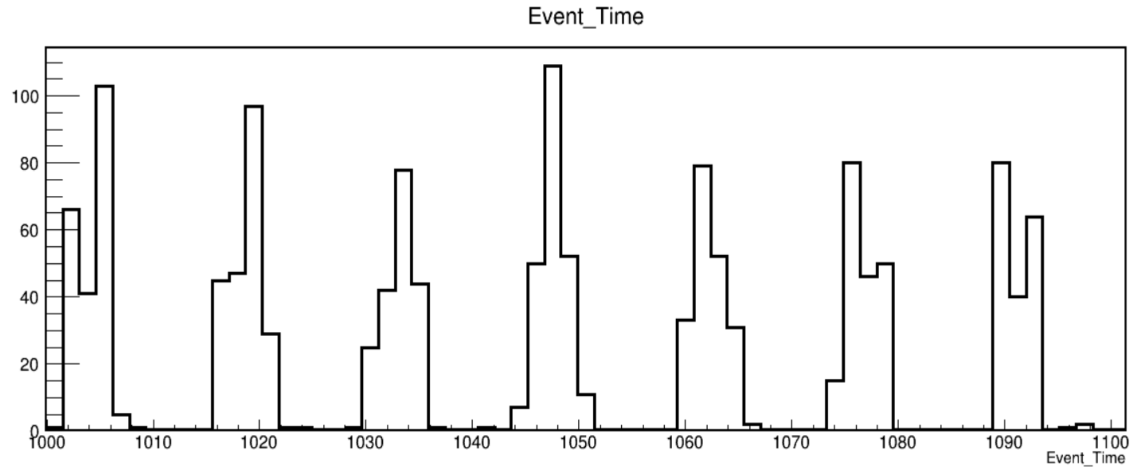
Temperature Monitor

- 16 temperature sensors on each PCB
- 2 external temperature and humiture monitor

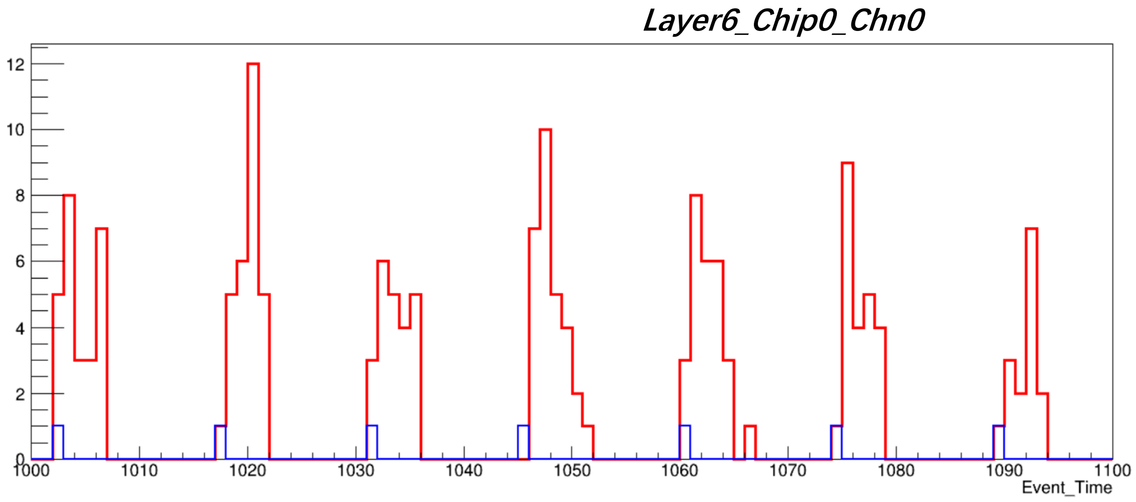


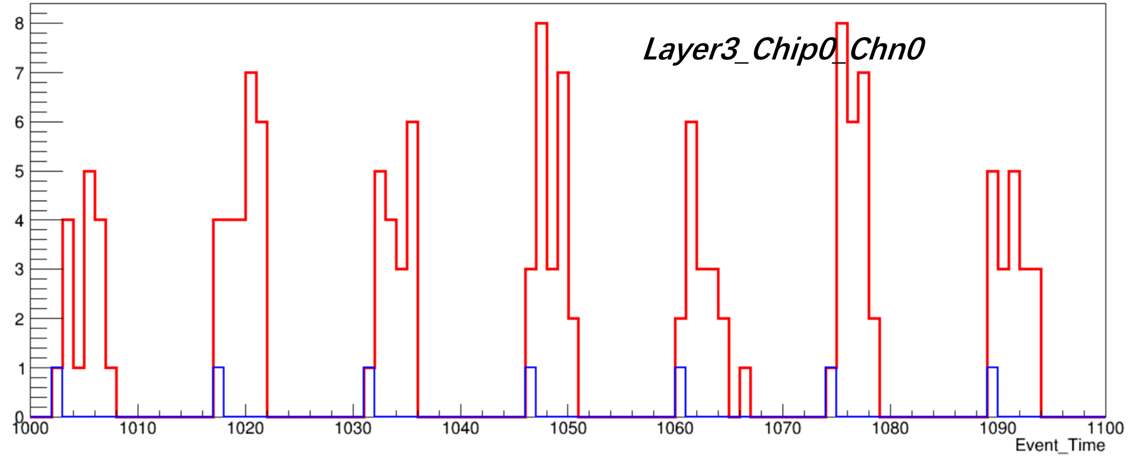


Pedestal Correction



- **For each chip, the total number of event whose hit tag equals 0 is different**
- **When doing correction, drop the event during which the chip is firstly hit in the spill**

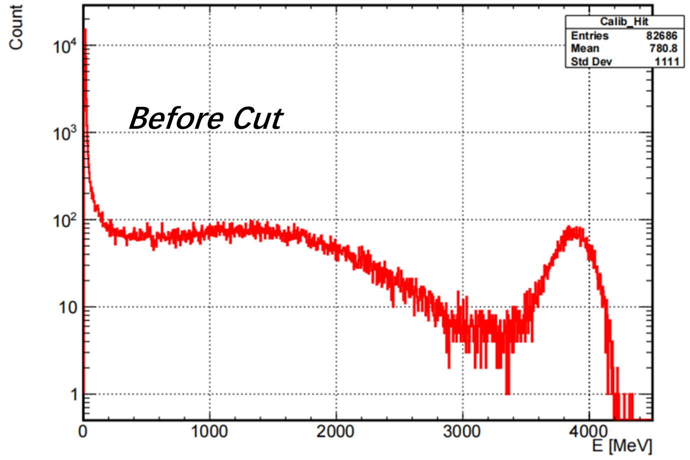


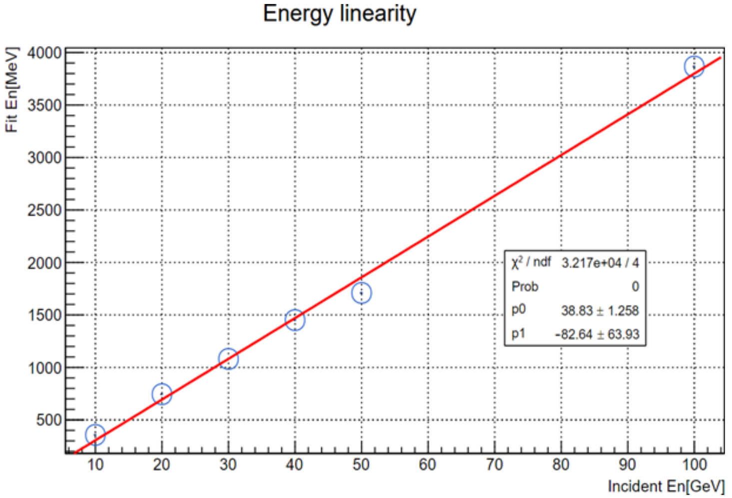


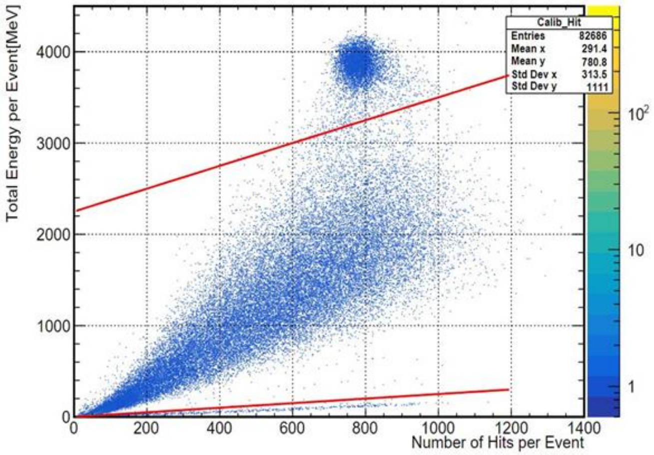
Red stands for first peak
Blue stands for small peak

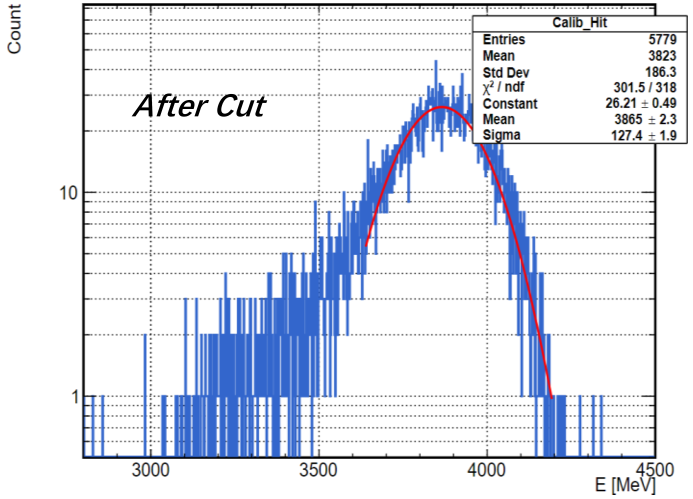
Energy Preliminary Results

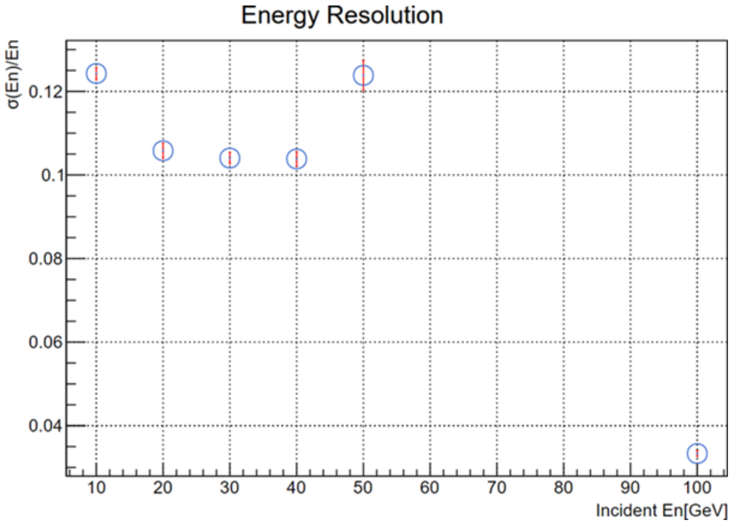
- Using cosmic ray data parameters before with test file, energy get reconstructed roughly











10.26，ECAL+HCAL combined test

- ECAL Threshold Scan：Muon test，108 GeV/c mu+
- HCAL has the muon data of the same run number as ECAL

No.	Time	ECAL filename	Threshold	Backup	Corresponding HCAL filename
1	10.26	ECAL_Run180_20221026_133431.dat	Baseline (Thr.)		
2	10.26	ECAL_Run181_20221026_145824.dat	Baseline		
3	10.26	ECAL_Run182_20221026_173912.dat	——	Bad run	
4	10.26	ECAL_Run184_20221026_211704.dat	——		
5	10.26	ECAL_Run186_20221026_215617.dat	——		
6	10.26	ECAL_Run187_20221026_222825.dat	——	Vop+0.5 V, bad	
7	10.26	ECAL_Run188 —— ECAL_Run207	——	Ignore them, bad	
8	10.27	ECAL_Run208_20221027_112551.dat	Layer0-3, 28-31, Thr. – 20; Layer4-27, Thr. + 20	All Layers, Vop+0.5;	
9	10.27	ECAL_Run209_20221027_121630.dat	Layer0-3, 28-31, Thr. – 20; Layer4-27, Thr. + 10	All Layers, Vop+0.5;	
10	10.27	ECAL_Run210_20221027_144642.dat	Layer0-3, 28-31, Thr. – 0; Layer4-27, Thr. - 0	All Layers, Vop+0.5;	
11	10.27	ECAL_Run211_20221027_152822.dat	Layer0-3, 28-31, Thr. – 0; Layer4-27, Thr. - 0	The same with 210	
12	10.27	ECAL_Run213_20221027_160053.dat	Layer0-3, 28-31, Thr. – 0; Layer4-27, Thr. - 10	All Layers, Vop+0.5;	
13	10.27	ECAL_Run214_20221027_164225.dat	Layer0-3, 28-29, Thr. – 0, Layer30-31, Thr-20; Layer4-27, Thr. - 20	All Layers, Vop+0.5;	
14	10.27	ECAL_Run215_20221027_171916.dat	Layer0-3, 28-29, Thr. – 0, Layer30-31, Thr.-20; Layer4-27, Thr. – 40;	All Layers, Vop+0.5;	
15	10.27	ECAL_Run216_20221027_174121.dat	Layer0-3, 28-29, Thr. – 0, Layer30-31, Thr.-20; Layer4-27, Thr. – 30;	All Layers, Vop+0.5;	
16	10.27	ECAL_Run217_20221027_184819.dat	Layer0-3, 28-29, Thr. – 20, Layer30-31, Thr.-40; Layer4-27, Thr. – 20;	All Layers, Vop+0.5;	The parameters that will be used in the following test.