Sci-ECAL Technological Prototype: Beam Test@CERN and Status of ECAL Data Analysis

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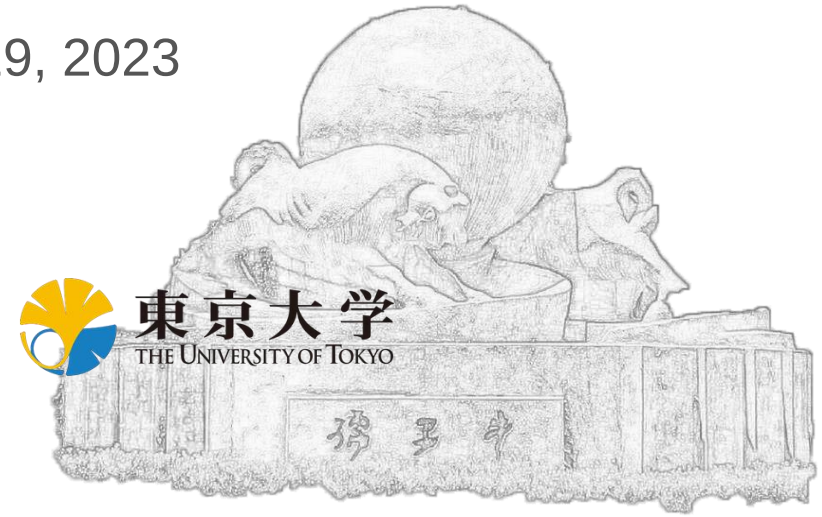
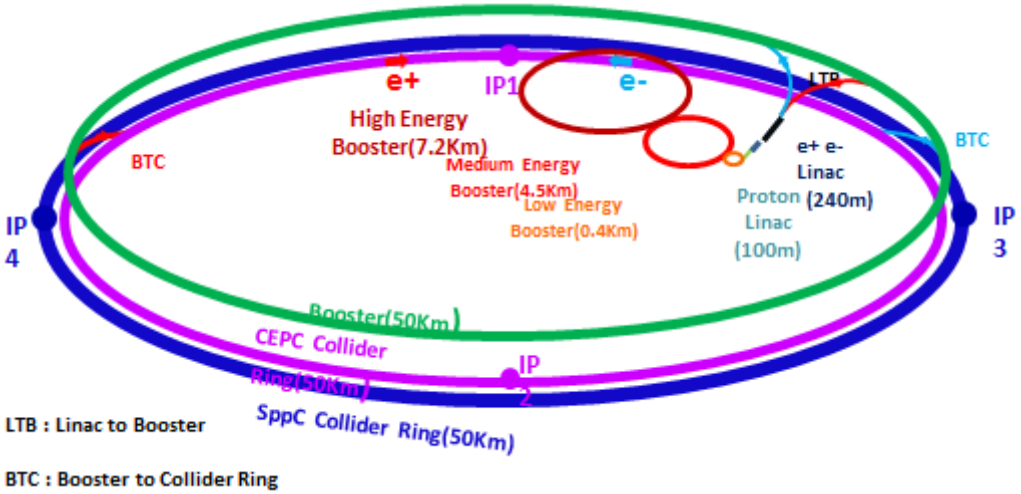
On behalf of the Sci-ECAL working group

CALICE Collaboration meeting from Sept 27-29, 2023

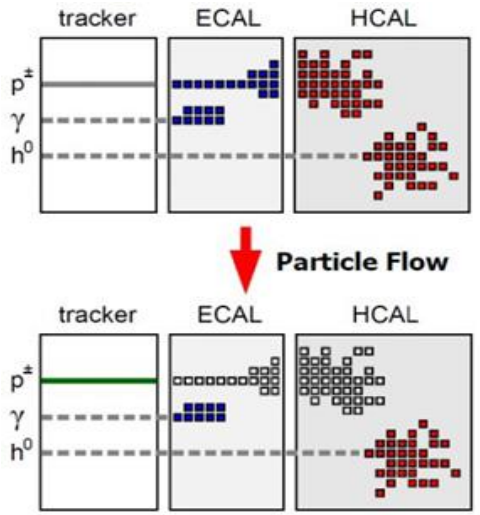


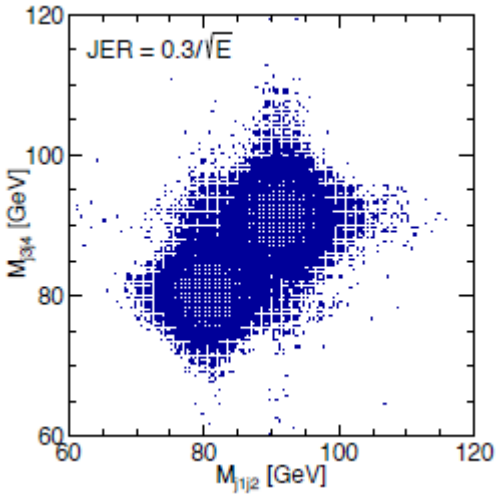
Introduction

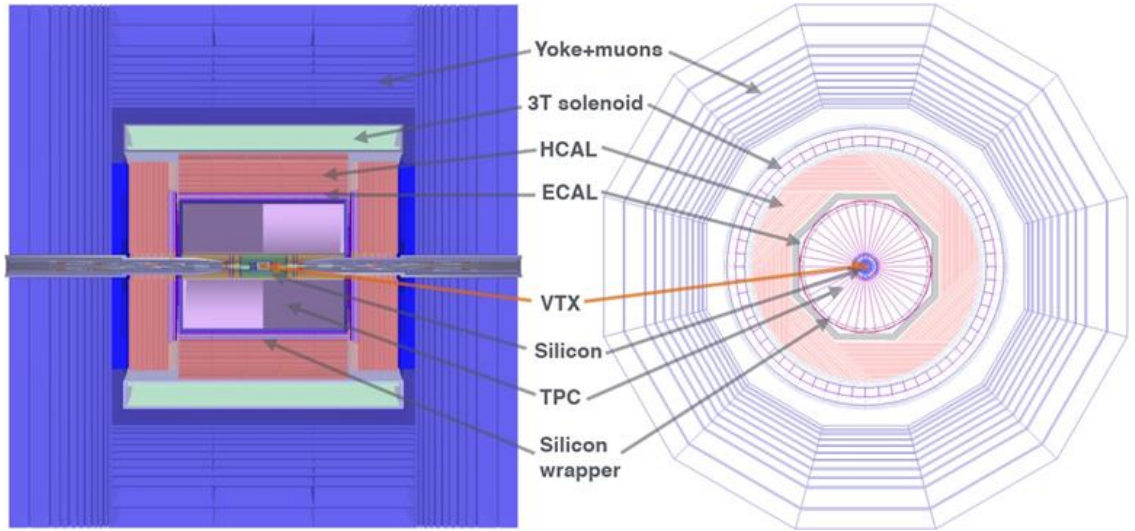
- CEPC: future lepton collider experiment
  - Precision measurements of the Higgs/EW/QCD
  - Calorimeter system requirement
    - 3-4% invariant mass resolution for two-jets system
    - Jet resolution ~ 30%/√E



- PFA-oriented detector
  - SiWECAL, **Sci-ECAL**, DECAL…







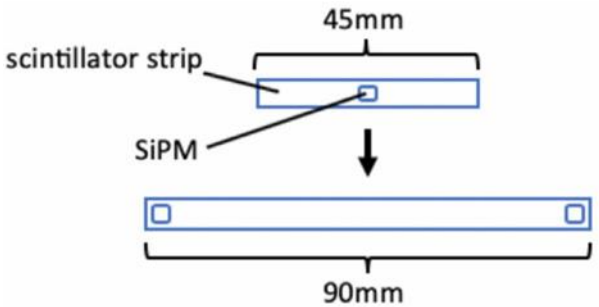
(CEPC,CDR)

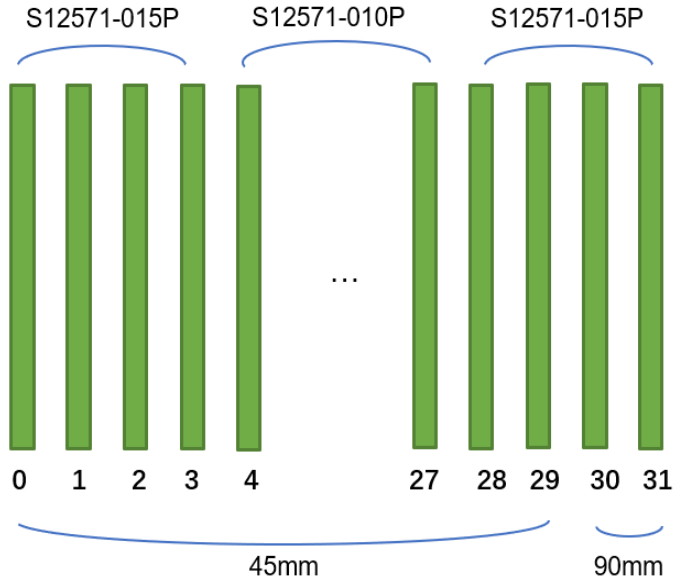
Sci-ECAL technological prototype

- Scintillator-based electromagnetic calorimeter(Sci-ECAL)
  - Sampling calorimeter with sandwich structure
  - ECAL basic unit(EBU)
    - scintillator strips + Hamamatsu SiPMs + SPIROC2E chips
    - tungsten-copper alloy (mass fraction: 85:15) board
  - 32 EBU layers, total radiation length ~ 23 X_0

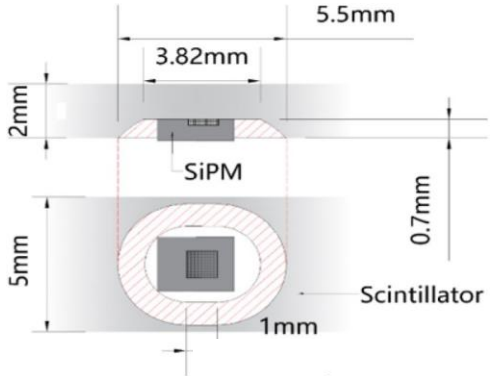
*Scintillator (5mm*45mm*2mm)*

St Gobain. BC408

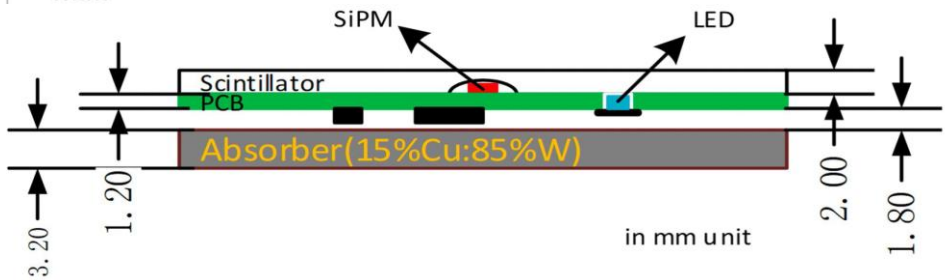




SiPM,
S12571 series, Hamamatsu

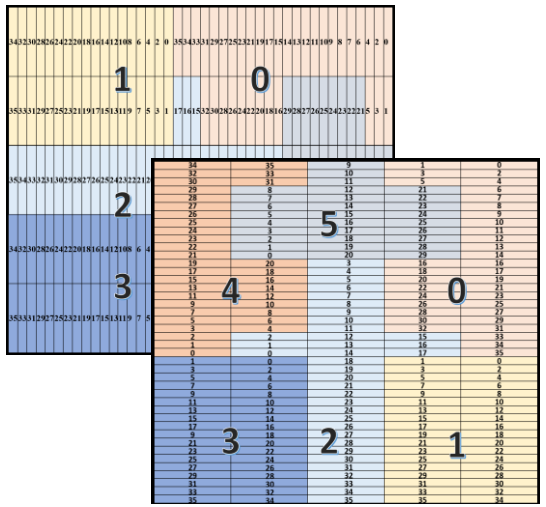


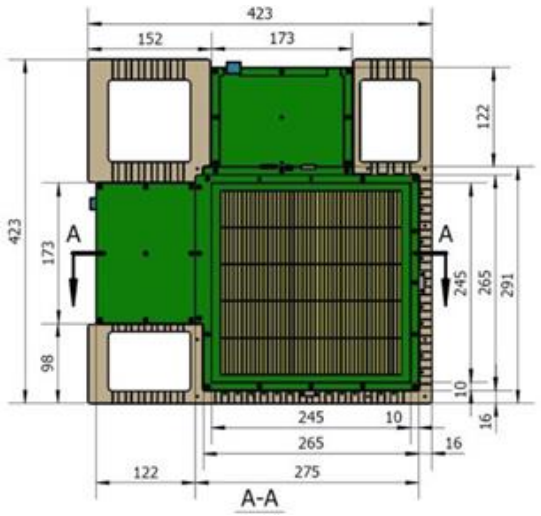
	Pixel size	Pixel No
S12571-010P	10 um	10,000
S12571-015P	15 um	4,489

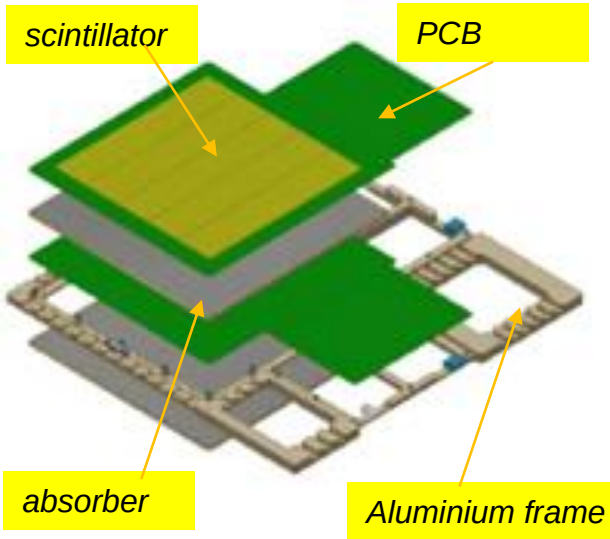


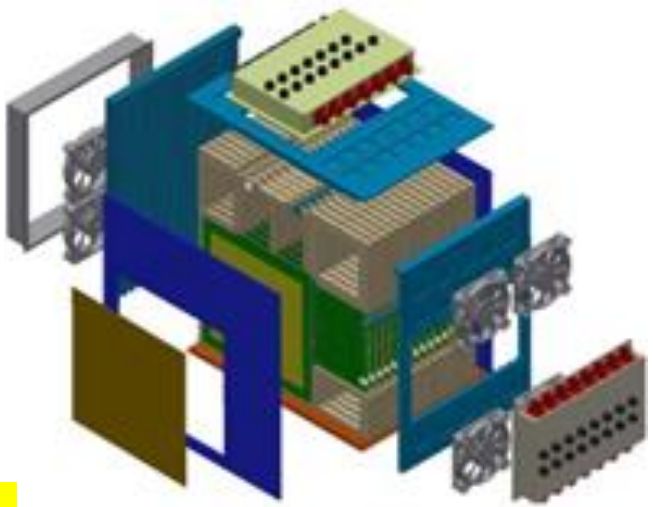
Sci-ECAL technological prototype

- High granularity calorimeter
  - Adjacent layers are of orthogonal placement ➔ 5mm*5mm virtual cell
  - Two layers get integrated into one superlayer
  - 16 superlayers are assembled in ECAL Aluminium frame
- All channels' signal could be readout individually at the same time
  - 6720 electronics channels









Beam test timeline

Oct 19 – Nov 2, 2022 — SPS H8 beamline

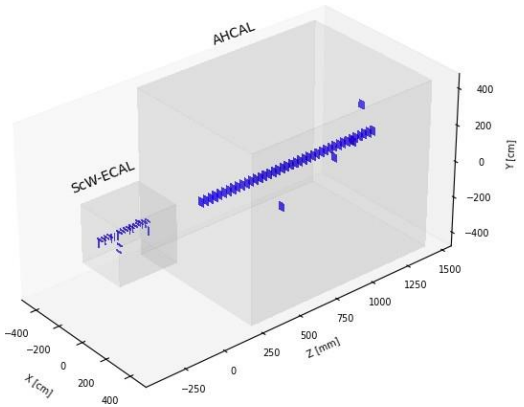
Apr 26 – May 10, 2023 — SPS H2 beamline

May 17 – 31, 2023 — PS T9 beamline

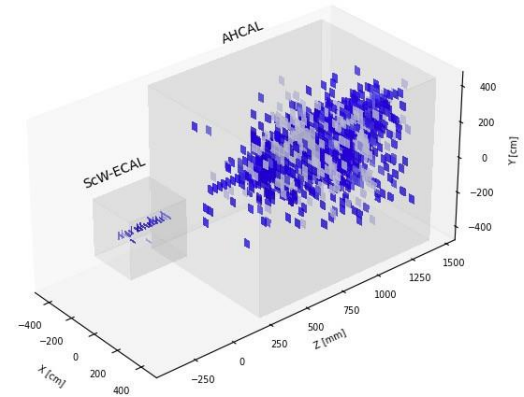
- Collaborators
  - CALICE
  - China
    - USTC
    - IHEP
    - SJTU
  - Japan
    - UTkoyo
    - Shinshu university

Beam test @CERN

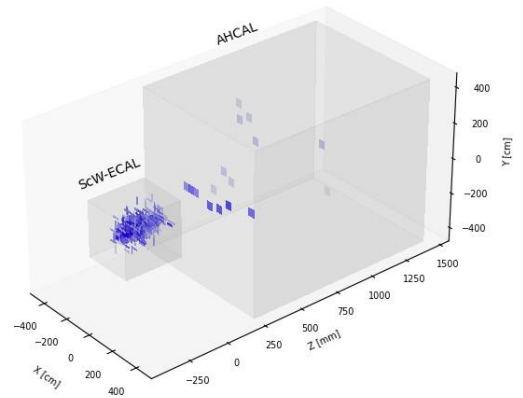
- ECAL Beam test : Sci-ECAL + AHCAL
  - SPS : H8 beamline, Oct 19 – Nov 2, 2022
    - mu+ : 108GeV/c(inadequate)
    - pi+ : 10, 15, 20, 30, 40, 50, 60,80, 100, 120GeV/c (~150K events each point)
    - e+ : 10, 20, 30, 40, 50, 100GeV/c (~150K events each point)
  - SPS : H2 beamline, Apr 26 – May 10, 2023
    - mu- : 100GeV, 120GeV (>3M events)
    - pi- : 10, 15, 20, 30, 40, 50, 60, 70, 80, 100, 120GeV/c (>100K events each point)
      350GeV/c
    - e- : 10, 20, 30, 40, 50, 60, 70, 80, 100, 120GeV/c (>100K events each point)
      150, 200, 250GeV/c
  - PS : T9 beamline, May 17 – 31, 2023
    - mu- : 10GeV/c
    - pi- : 1, 3, 5, 8, 10, 12, 15GeV/c
    - e- : 0.5, 1, 2, 3, 4, 5GeV/c



100GeV muon



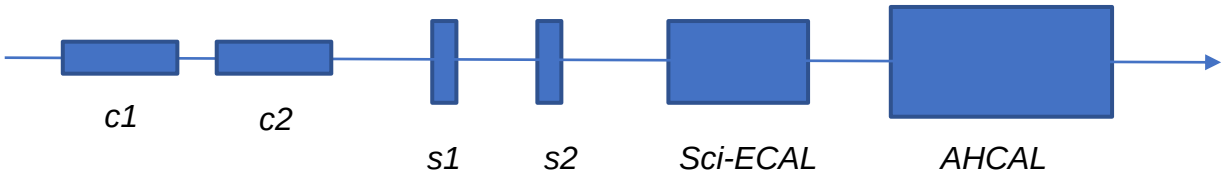
350GeV pion

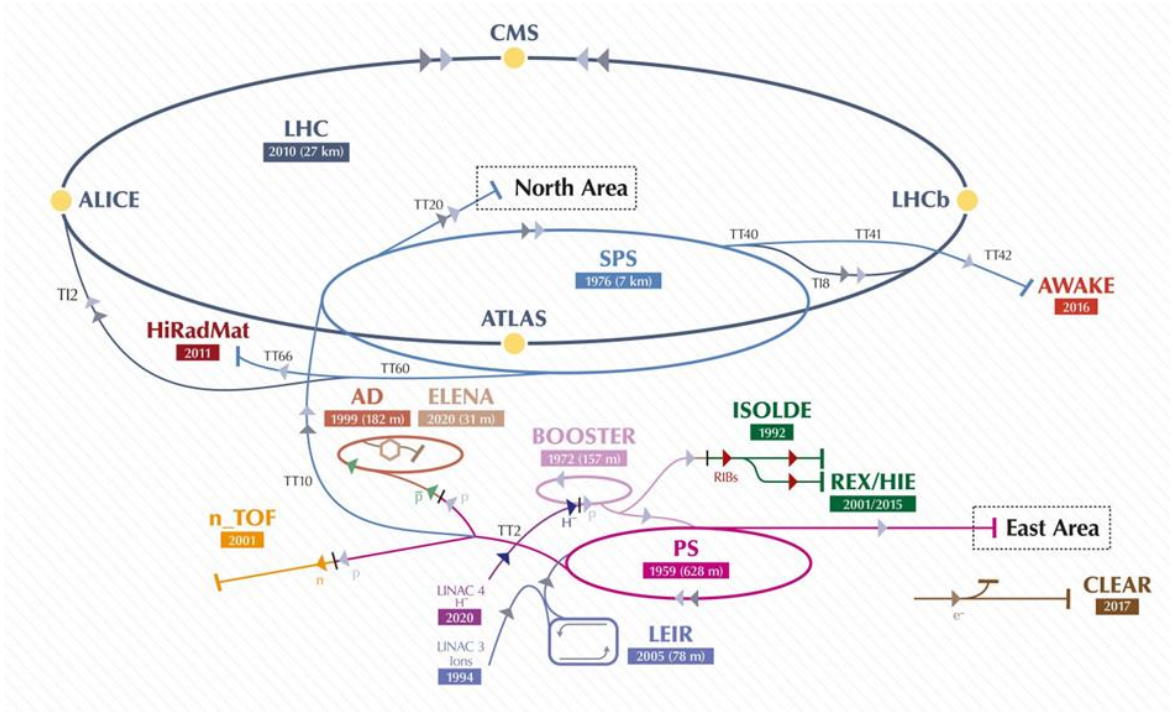


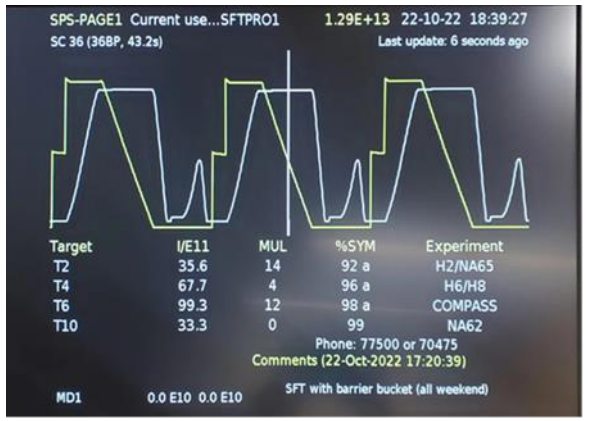
60GeV electron

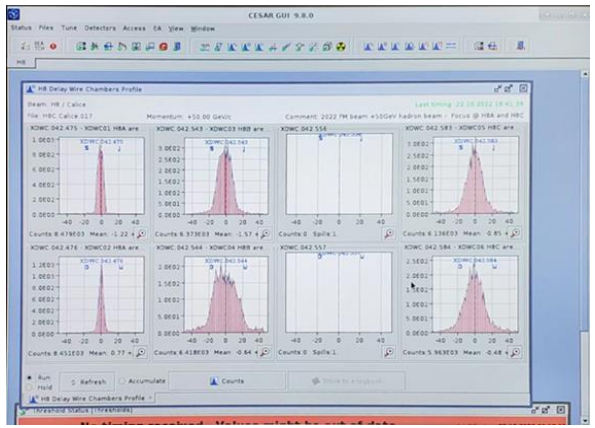
Beam test @CERN

- Cherenkov detector is used to improve particle purity.
- Validation mode
  - $4\mu s$ slow clock period as time window
  - TLU coincide signal of telescope system which provides valid signal to DAQ module.







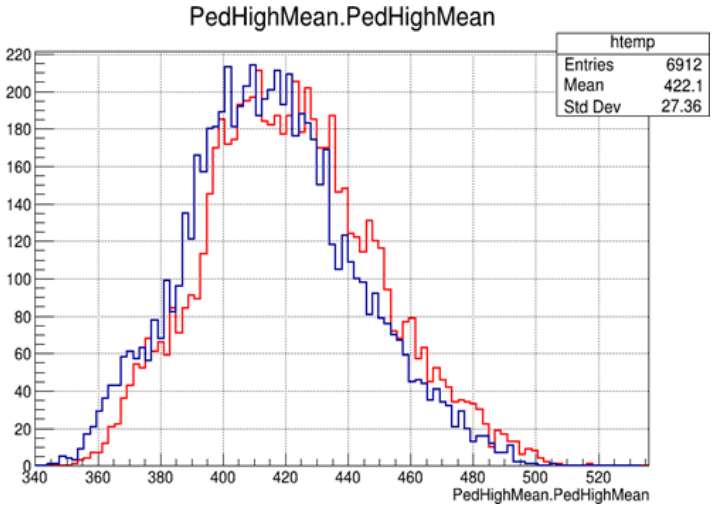


Preliminary results

- Pedestal calibration
- High gain and low gain intercalibration
- SiPM calibration
- MIP calibration
- Energy response

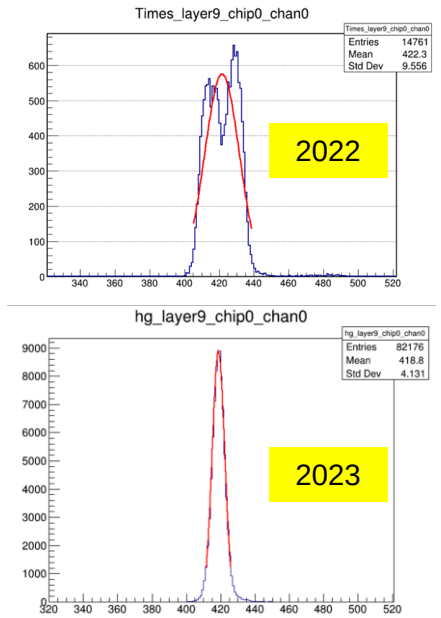
Pedestal calibration

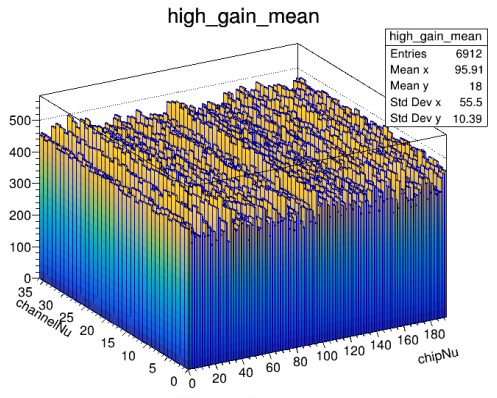
- Pedestal used to be obtained from signal whose hit tag = 0
  - Some channels have multi-peaks pedestal distribution from beam test files in last year
- Pedestal is obtained from force-trigger-mode file to prevent potential problems.
- Pedestal is stable during beam test in SPS or PS respectively with a 2~3 ADC fluctuation when temperature no longer changes significantly.

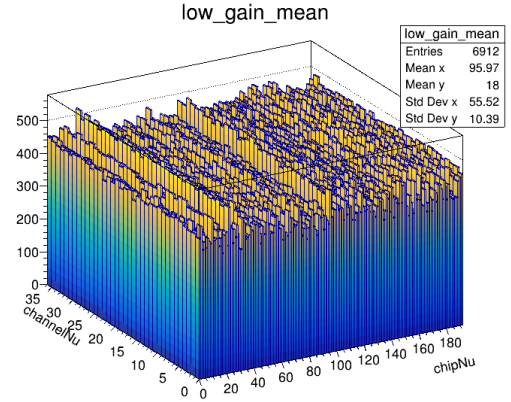


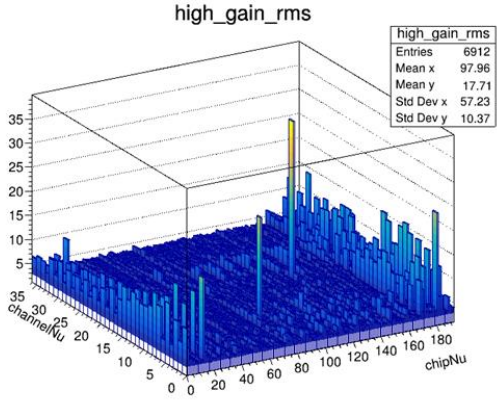
Blue stands for pedestal from force-trigger-mode file

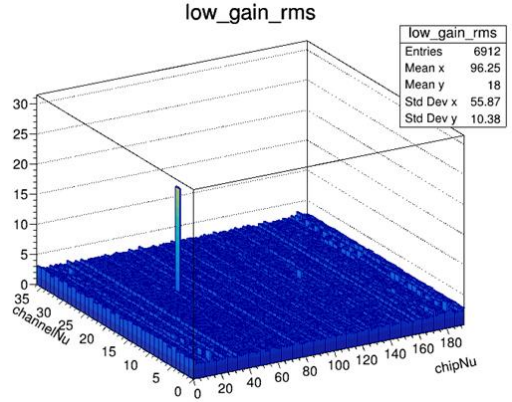
Red stands for pedestal from beam data file

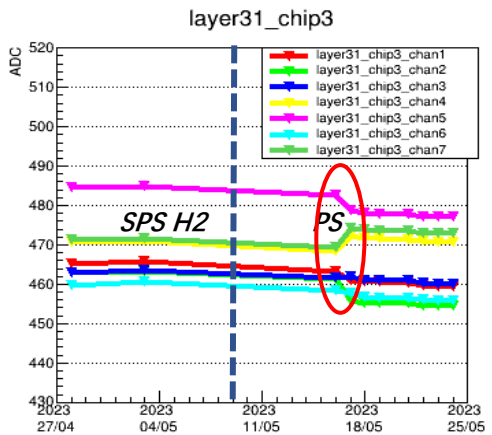


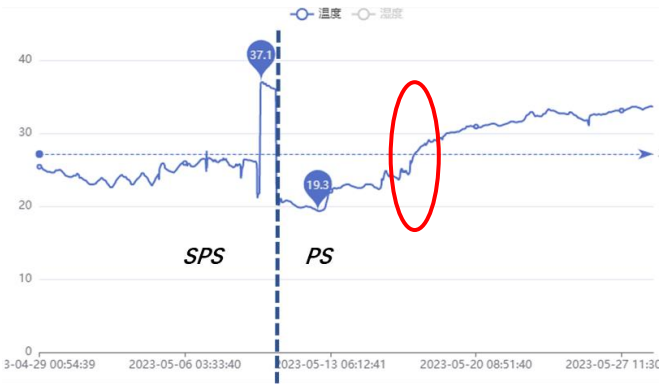






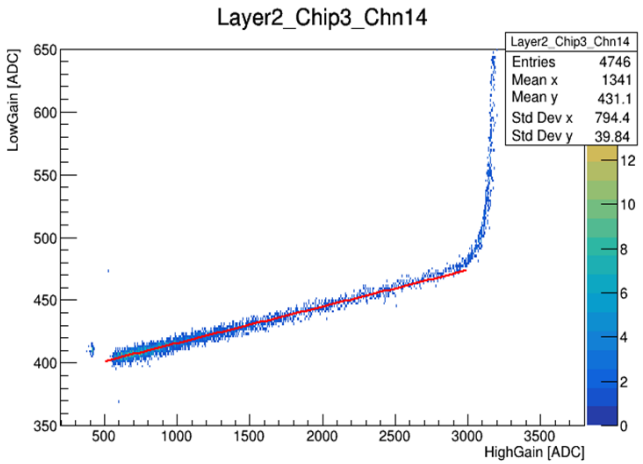


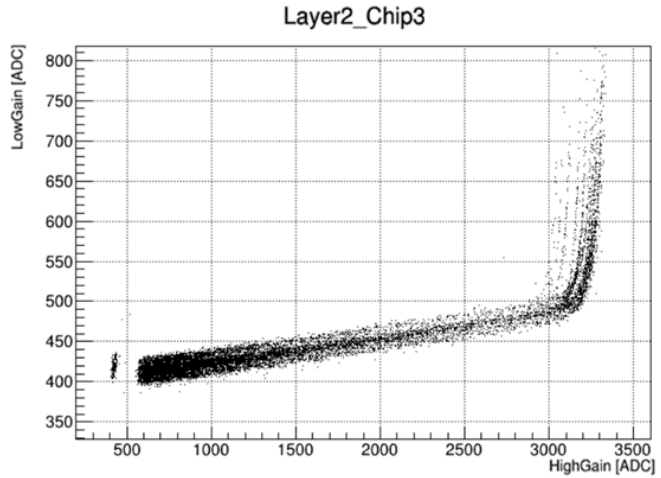


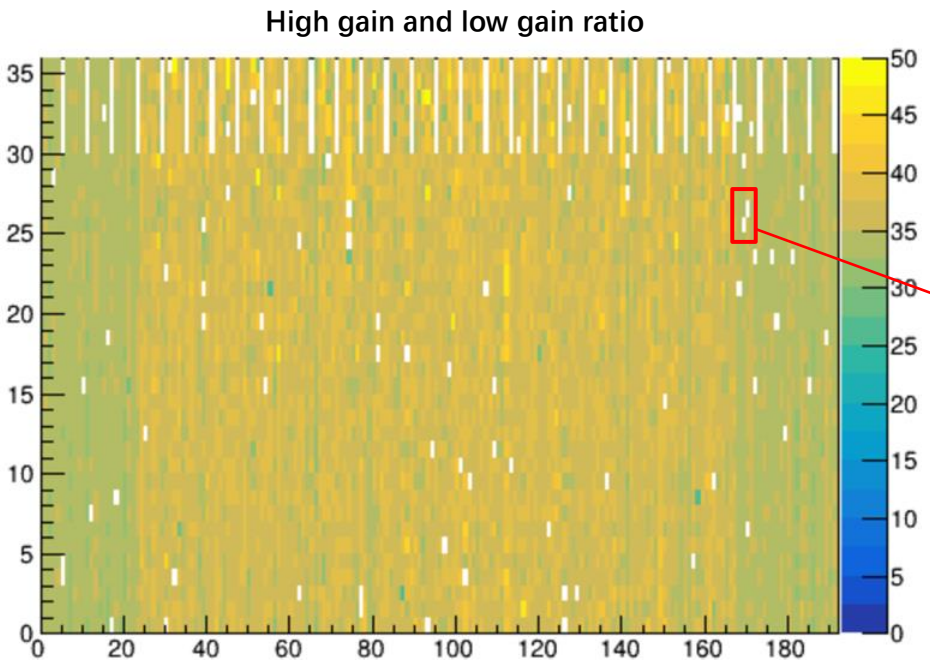


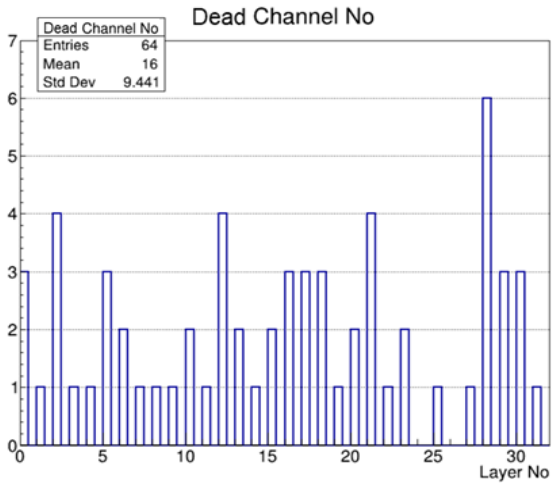
High gain and low gain intercalibration

- SPIROC2E chip has two gain modes to cover larger dynamic range
- High gain ADC saturates at different value in the same chip
- About 0~6 dead channels in one layer(~210 channels), less than 3%

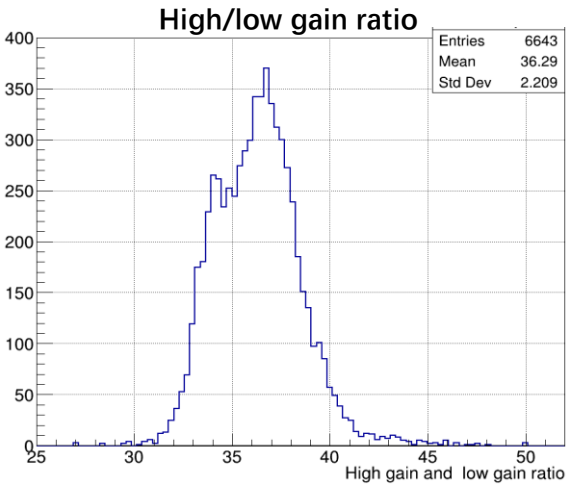






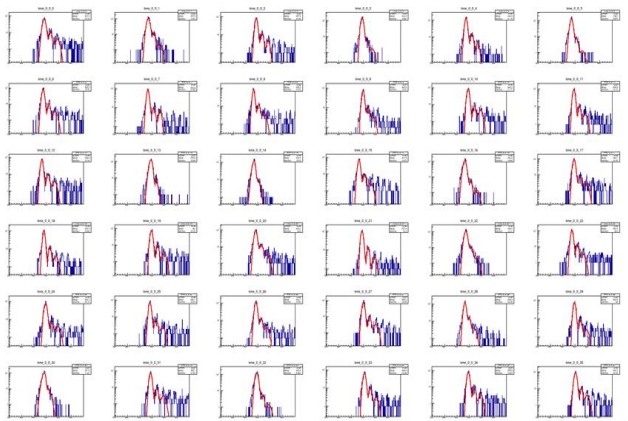


No statistics from dead channels



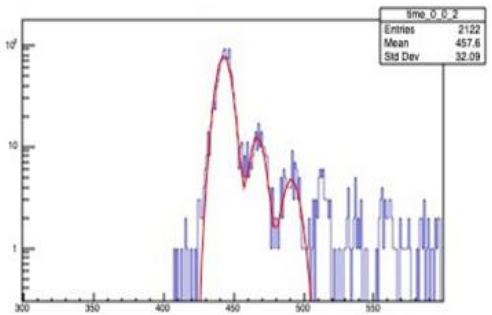
LED calibration

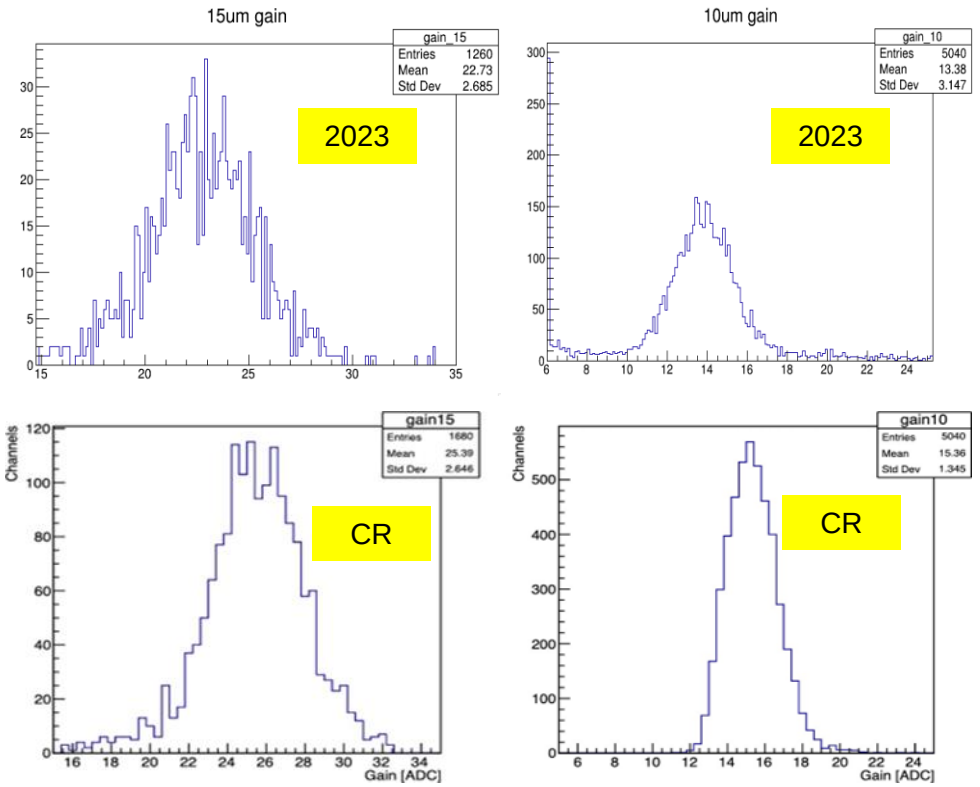
- LED data are taken during the beam test
  - SPS : 3 times (at the beginning and the middle of the beam test)
  - PS : every day
- LED data are fitted with multi-gaussians to calculate gain for each channel
- Increased the bias voltage of all channels at the beam test to compensate temperature difference from the CR test
  - The gains still decreased compared to the cosmic ray test



LED calibration at channel level

15 um single photon spectrum



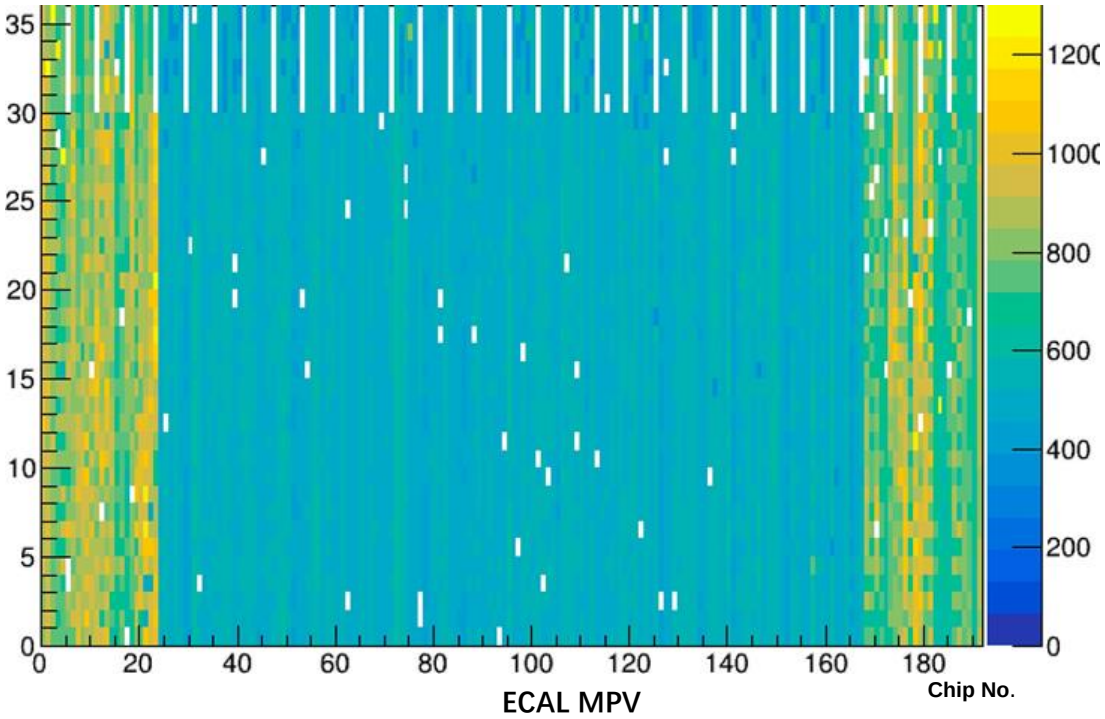


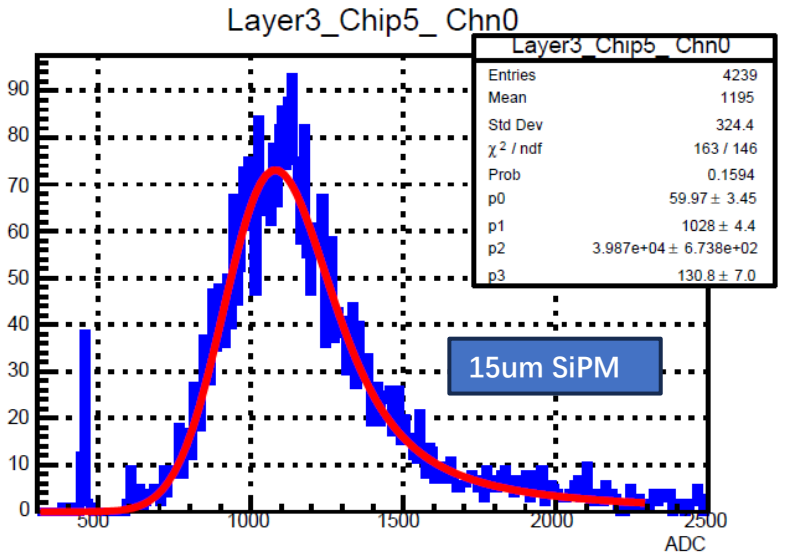
ECAL	CR	Beam test
temperature	~20 C	25~29 C
Bias voltage	-	+0.5 V

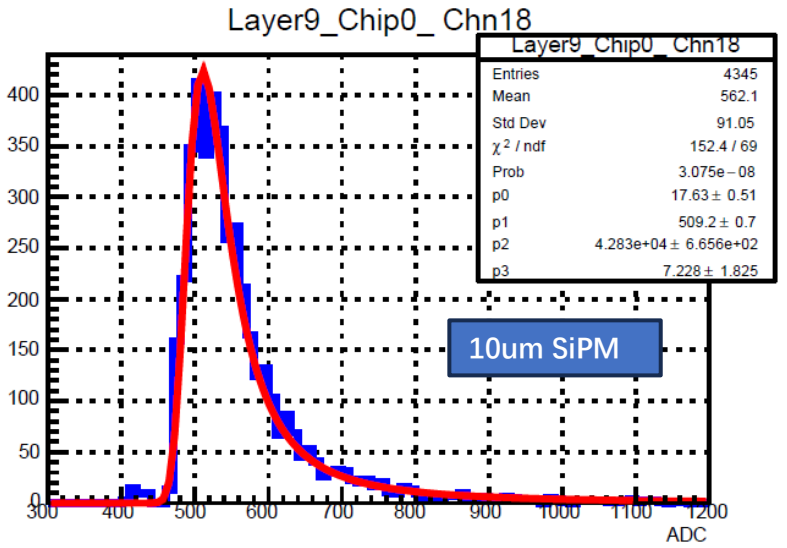
(Tatsuki, UTkoyo)

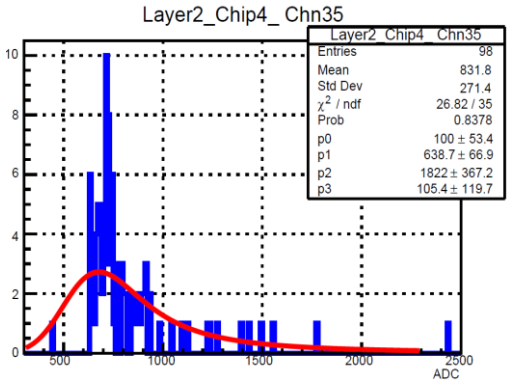
MIP calibration

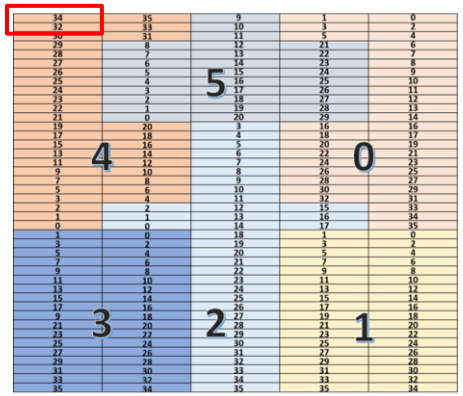
- MIP peak value is obtained by fitting 100GeV/c muon-events with Landau Convolutional Gaussian function
- DAC threshold and SiPM voltage are optimized
- Track restrictions are used to improve fit result
- A small part of channels are not well fitted due to lack of statistics



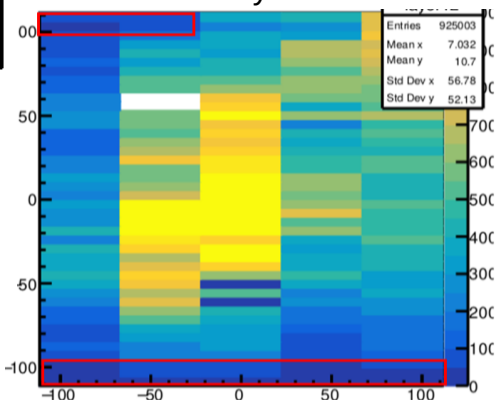






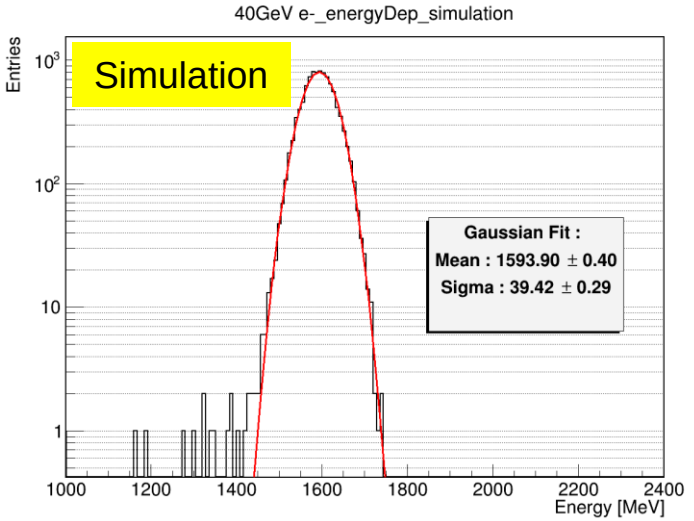


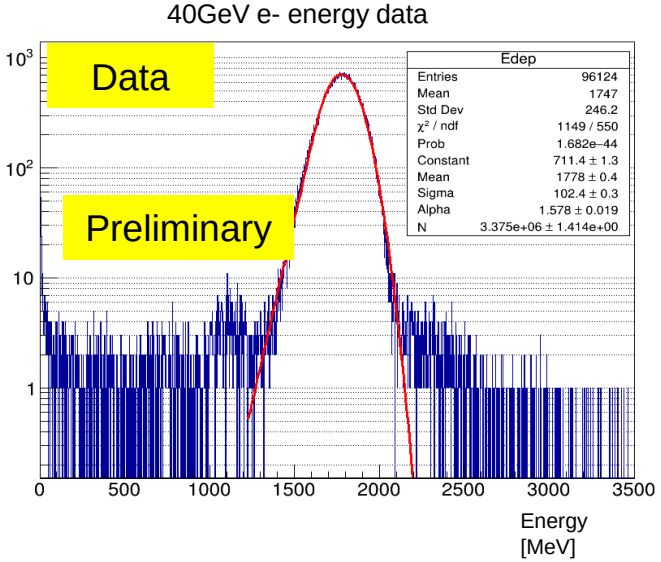
Layer 2

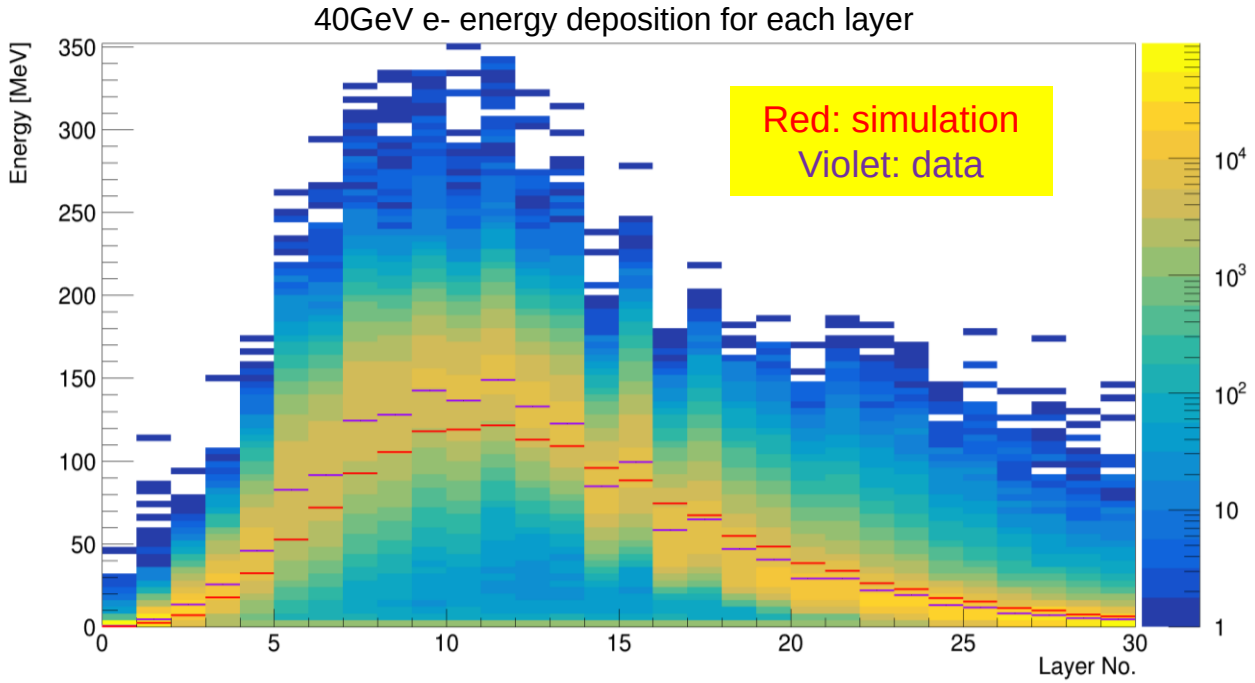


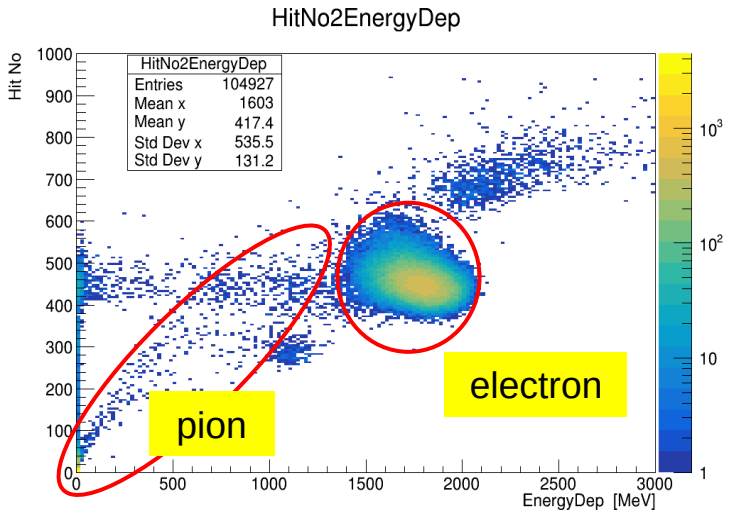
Energy response

- 40GeV/c electron data from SPS H2
  - Calibrated with 100GeV muon data
  - Threshold: 0.5 MIP
  - No obvious energy leakage
  - Still contamination
- More effort to match data and simulation …









Summary and plan

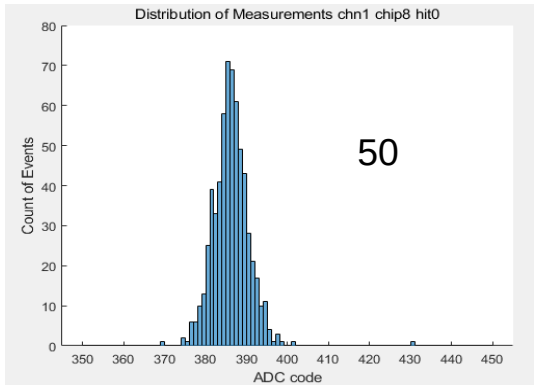
- Sci-ECAL and AHCAL combined test beam @CERN
  - SPS H8 beamline in last October
  - SPS H2 beamline in this April to May
  - PS T9 beamline in this May
- Beam test data covers wide energy range for electrons, pions, and muons
- Preliminary results about fatal parameters' calibration and energy response
- Ongoing activities
  - Data purity and selection
  - Energy linearity and energy resolution
  - Geant4 simulation and digitization
  - Double check for the calibrated parameter
- Plan
  - SiPM saturation, temperature correction …
  - Geant4 MC validation
  - Sci-ECAL and AHCAL combined analysis
  - EM shower performance, Clustering/PFA performance

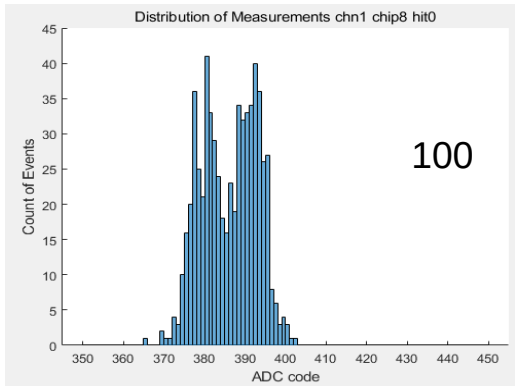
Thanks for CERN and CERN staff!
Thanks for all CALICE Collaboration colleagues!

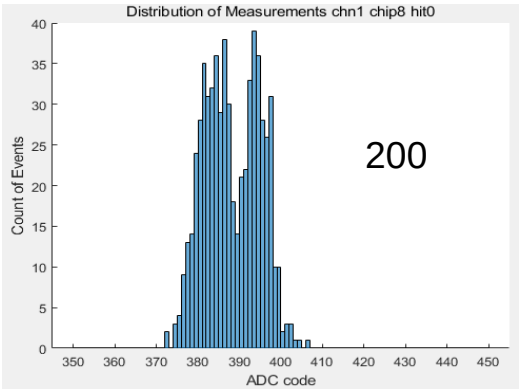
Backup

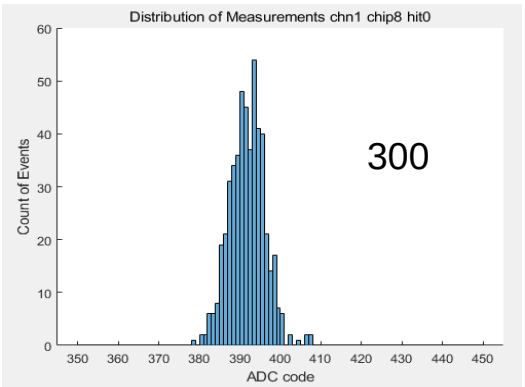
Pedestal multi-peaks

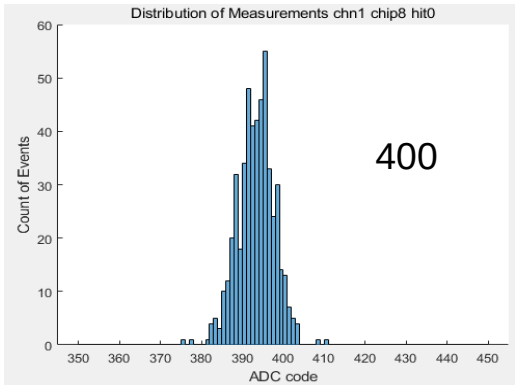
- Self-trigger mode, DAC calibration
- Inject DAC(50, 100, 200, 300, 400) into channel 0, and observe the signal in channel 1







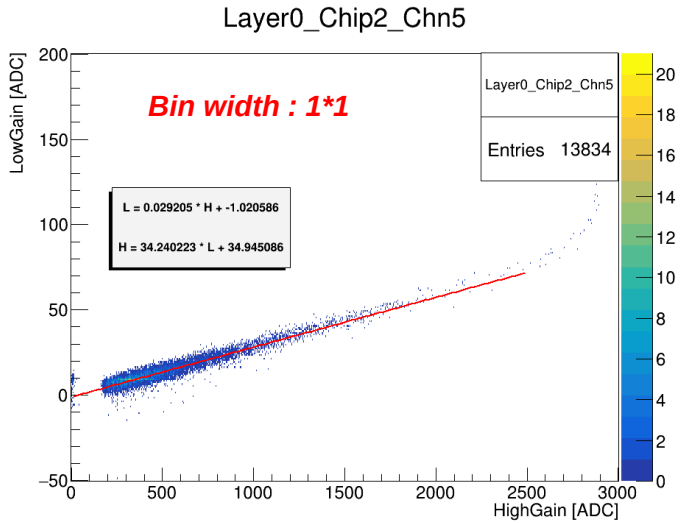


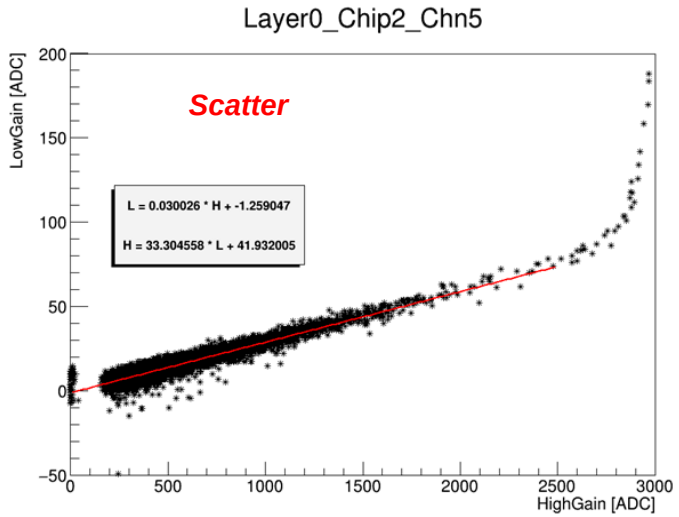


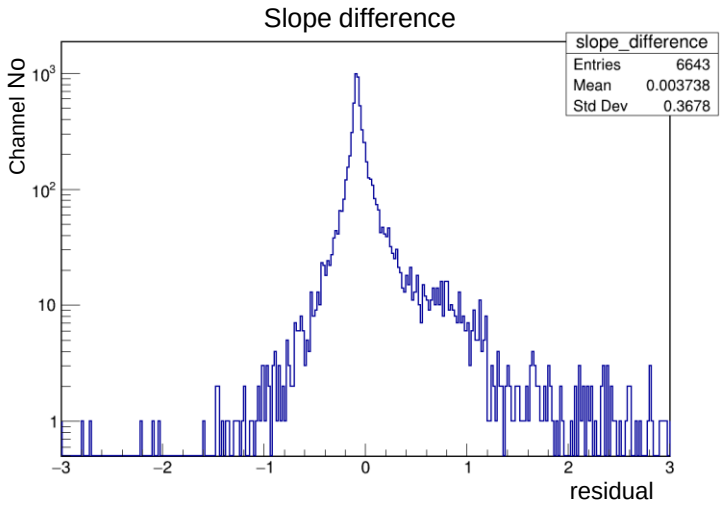
- guess : crosstalk may exist in some chips and crosstalk will change

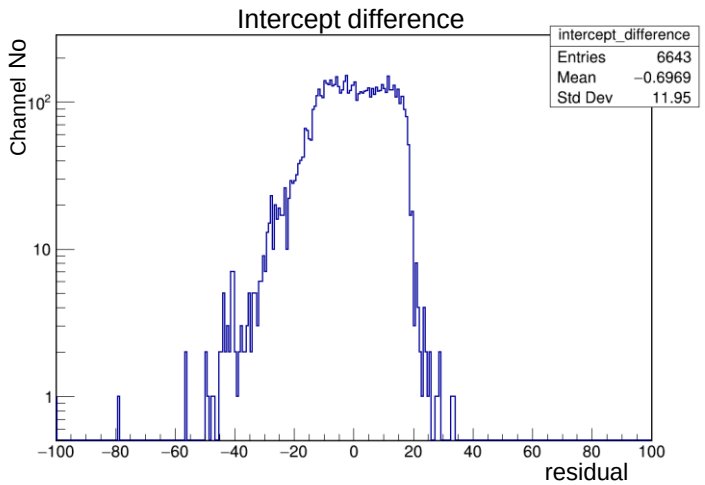
H-L gain ratio – Fit method comparison

- Bin and unbin fit









- Linear fit
- Fit range: (300,x_max-600)