



Status of high granular Sci-ECAL for future electron positron colliders

Tatsuki Murata

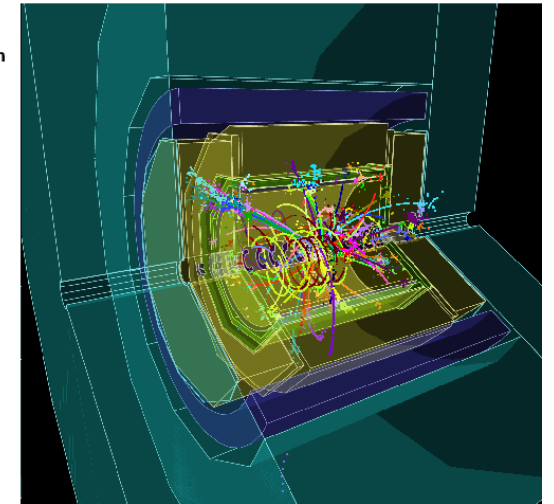
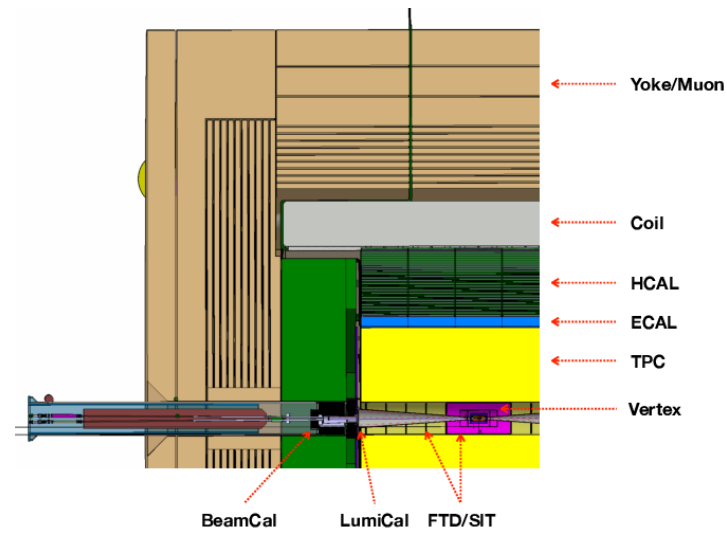
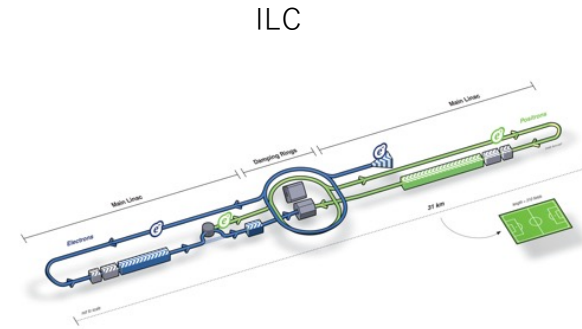
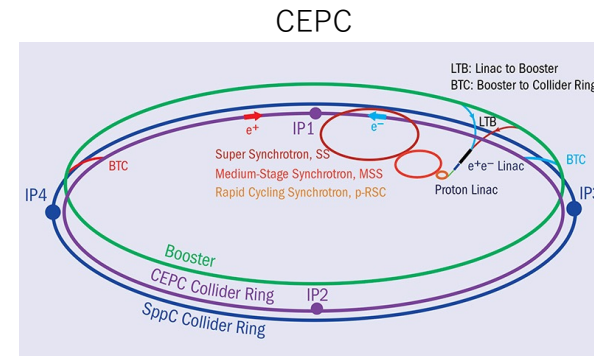
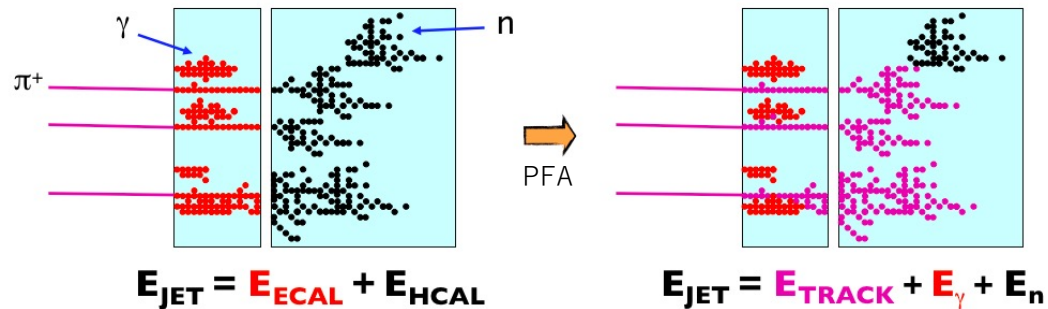
On behalf of the Sci-ECAL working group

October 26th, 2023

The 2023 International Workshop on CEPC

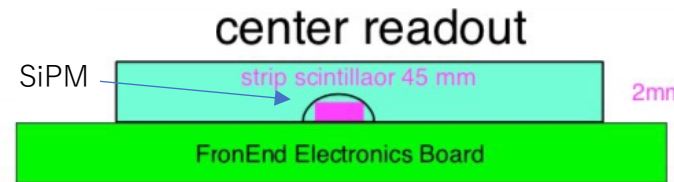
Introduction

- Future electron positron collider
 - Precision measurements of the Higgs/EW/QCD
 - Calorimeter system requirement
 - High granularity for both ECAL and HCAL
 - 5 mm for ECAL, few cm for HCAL
 - Jet resolution $\sim 30\%/E$
- Particle Flow Algorithm (PFA) oriented Detector
 - SiWECAL, Sci-ECAL, DECAL, etc...



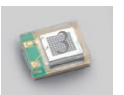
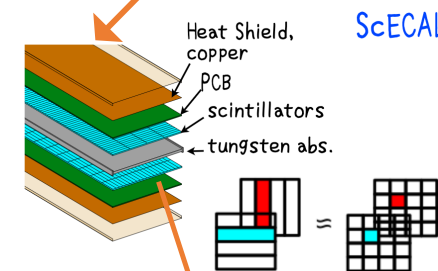
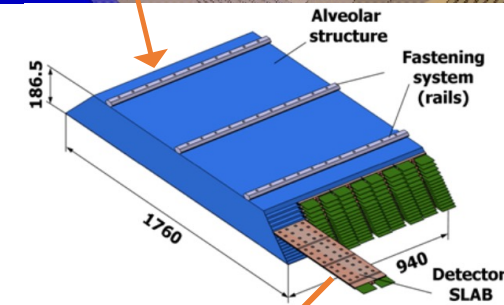
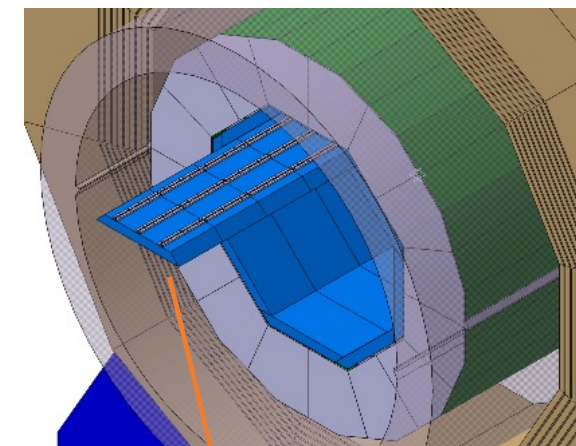
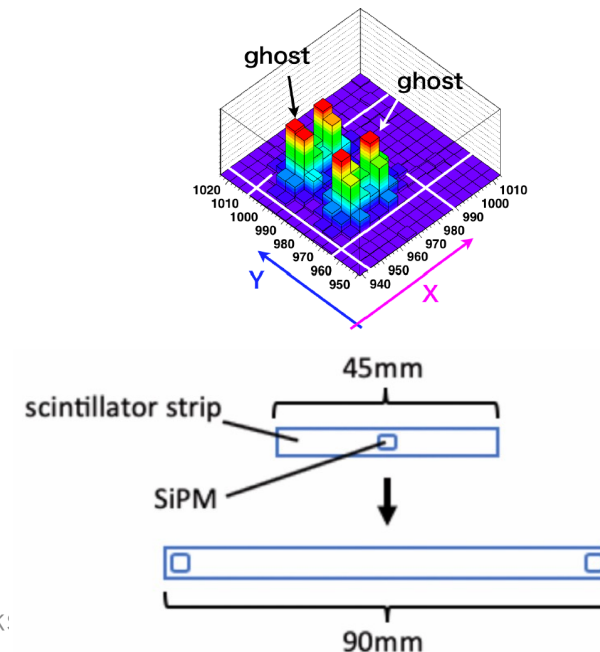
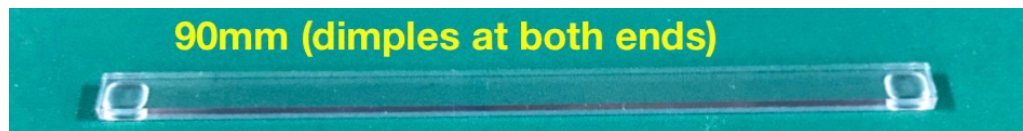
Sci-ECAL

- Scintillator-based Electromagnetic Calorimeter (Sc-ECAL)
 - ECAL concept based on strip-shaped plastic scintillator readout by SiPM
 - Center dimpled readout based on $5 \times 45 \times 2 \text{ mm}^3$ scintillator strip



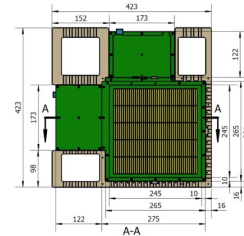
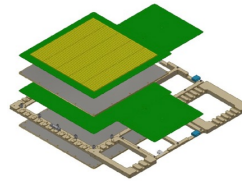
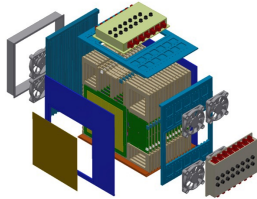
- Virtual segmentation of $5 \times 5 \text{ mm}^2$ cell can be achieved by x-y configuration of strips with strip splitting algorithm (SSA)

- Ghost hit problem
 - False signal from simultaneous hits
 - Expected to be eliminated by double SiPM readout
- Double SiPM readout
 - readout by two SiPMs at strip ends

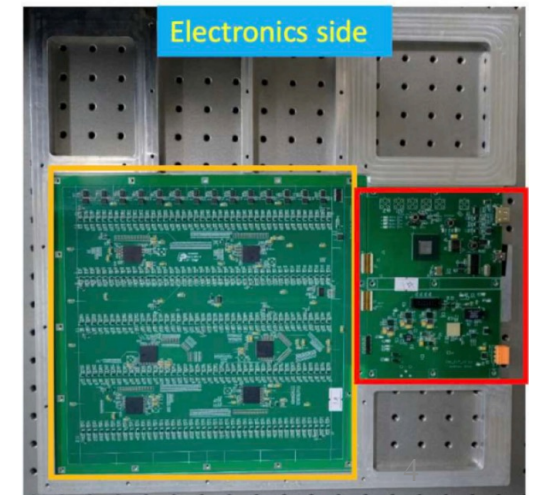
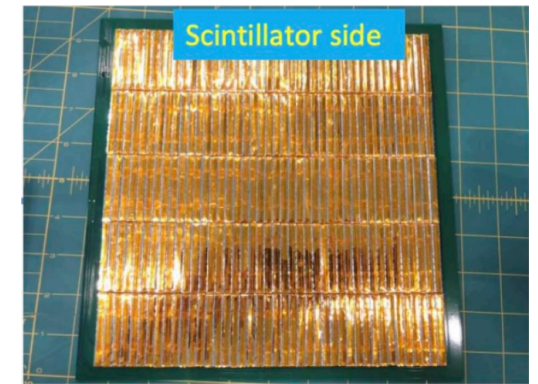
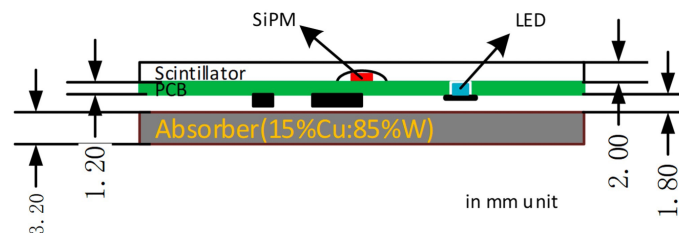
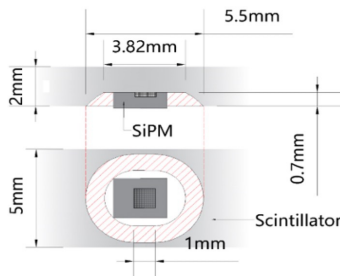


Sci-ECAL large technological prototype

- The prototype consists of 32 absorber(W) and detection layer (EBU)
 - Total absorption layer thickness : $32 \times 3.2 \text{ mm}$ ($\sim 23.3 X_0$)
 - Two absorber layers and two detection layers are integrated on a braced frame (super layer)
 - 16 super layers are mounted on the prototype

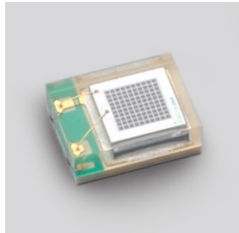
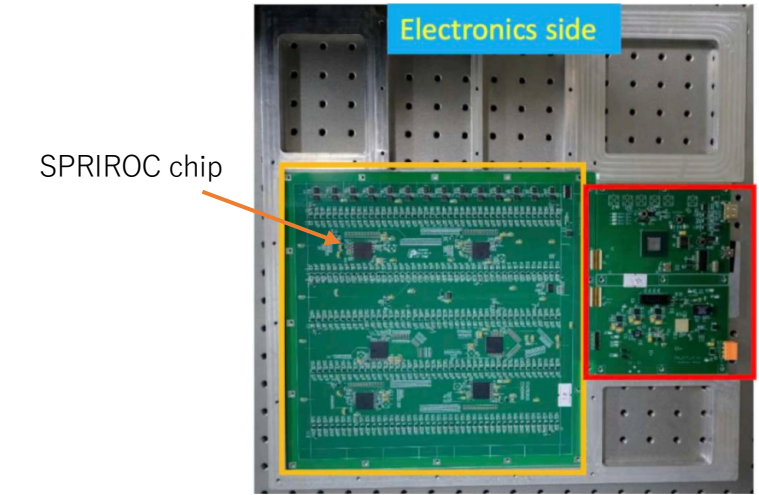
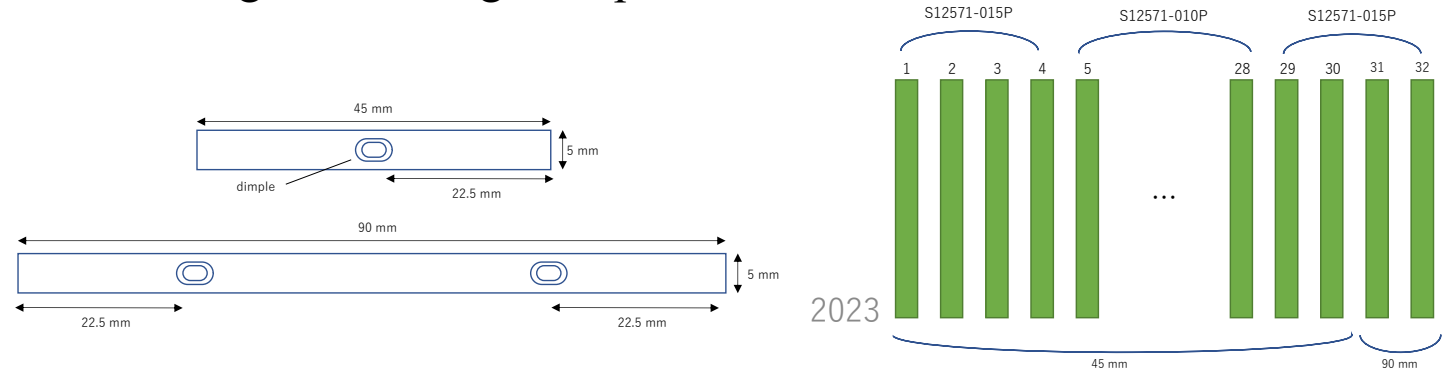


- ECAL Base unit (EBU) and scintillator strips + SiPM readout unit for detection layer
 - 42 (columns) \times 5 (rows) strip readouts per EBU
 - Each channel have LED for calibration of SiPM gain

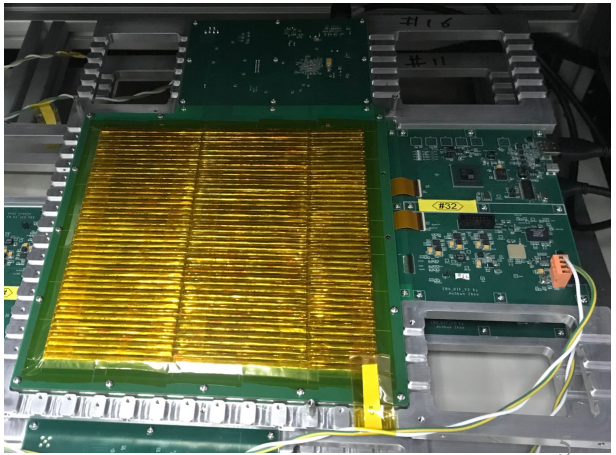


Sci-ECAL large technological prototype

- All channels on each EBU can be individually readout by 6 SPIROC2E chips developed by OMEGA lab and CALICE collab
 - High and low gain mode for wide dynamic range
 - 16 temperature sensors are implemented
- Two types of MPPC are used for SiPM on detection layer (manufactured by Hamamatsu K. K.)
 - S12571-010P, -015P
- Last 2 layers have double SiPM readout part
 - Using 90 mm length strip instead of standard 45 mm strip

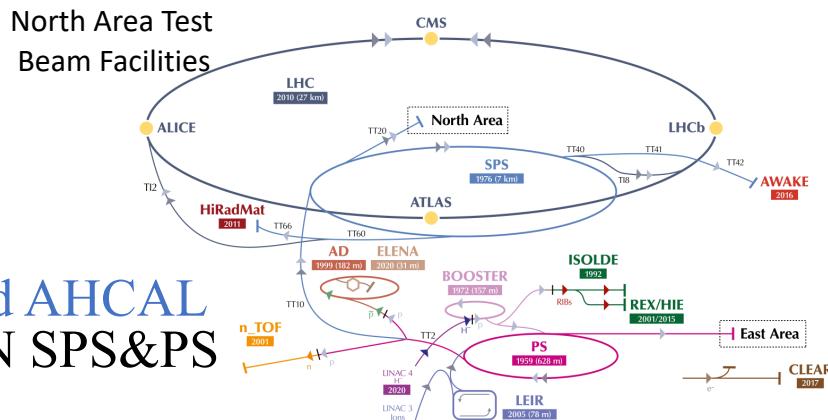


	Pixel size	# of pixel
S12571-010P	10 um	10,000
S12571-015P	15 um	4,489



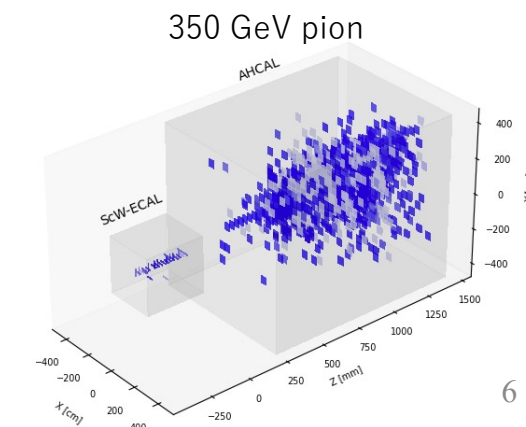
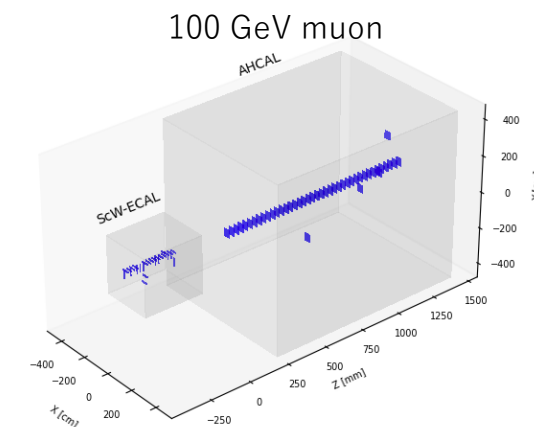
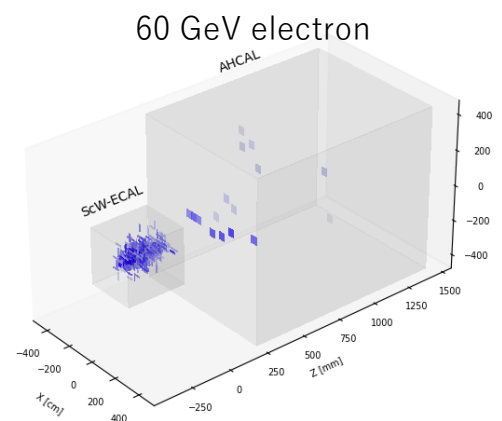
Test beam experiment

- Test beam experiment for **Sci-ECAL and AHCAL combined system** is conducted at CERN SPS&PS
 - SPS : site 887, H8 beamline
 - October 19th to November 2nd, 2022
 - High energy beam (10-160 GeV)
 - μ^- , π^- , e^-
 - SPS : Site 887, H2 beamline
 - April 26th to May 10th, 2023
 - High energy beam (10-350 GeV)
 - **Higher energy and purity beam than last year's H8 beamline**
 - μ^- , π^- , e^- , p^-
 - PS : Site 157, T9 beamline
 - May 17th to 31st, 2023
 - Low energy beam (1-15 GeV)
 - μ^- , π^- , e^-
- Collaborators
 - CALICE, UTokyo, Shinshu university, USTC, IHEP, SJTU



Sci-ECAL

AHCAL

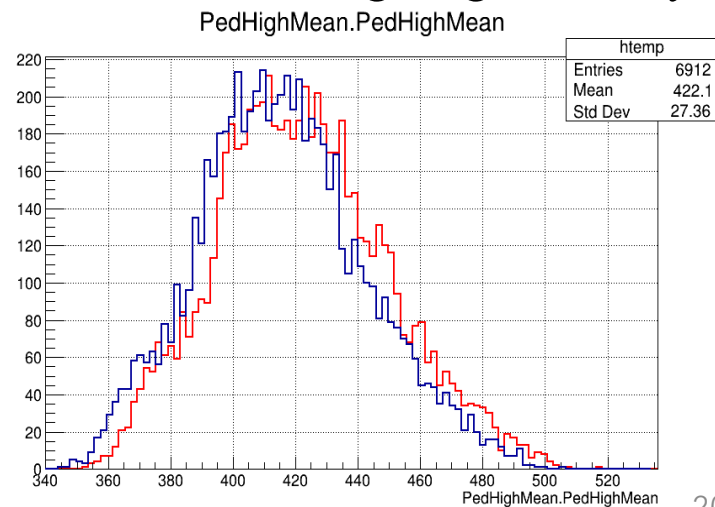


Preliminary results

- Pedestal
- Gain calibration
- MIP calibration
- High gain and low gain intercalibration
- Simulation and validation

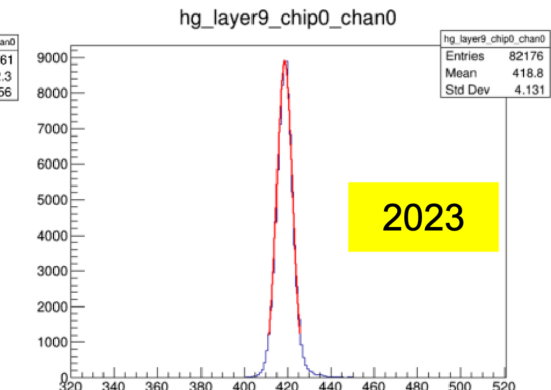
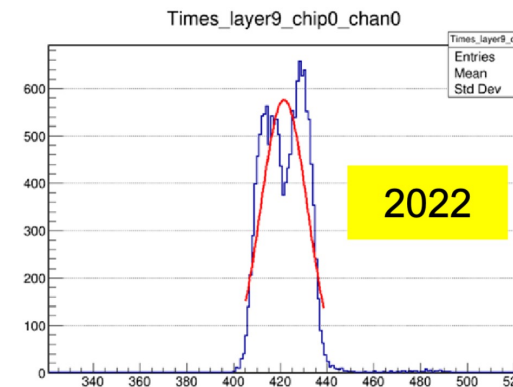
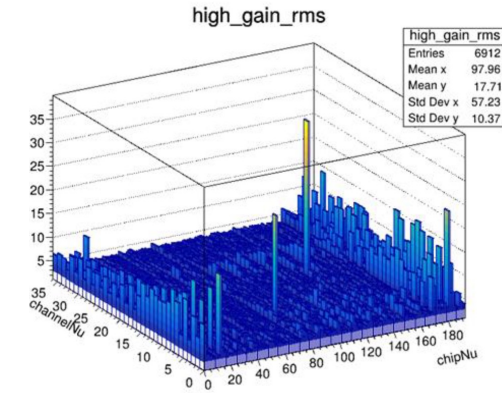
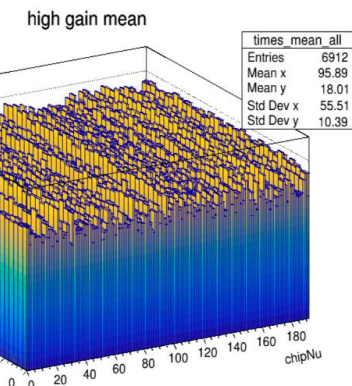
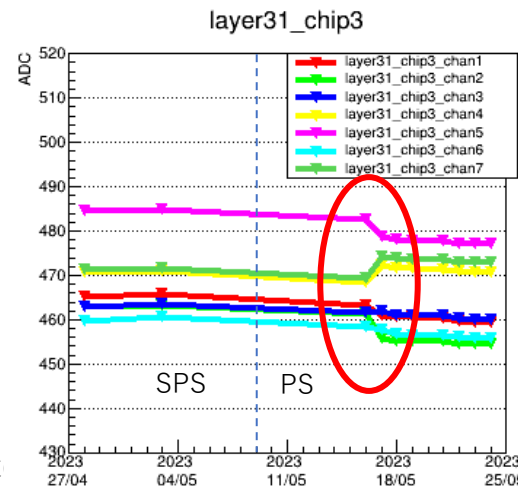
Pedestal calibration

- Pedestals were originally obtained from events that did not exceed threshold
 - Some channels had multi-peaks due to electronics problem at last years data
- Pedestals are obtained from force-trigger-mode to prevent the problem in 2023
- Pedestals were stable during the beam test in SPS or PS respectively within a 2~3 ADC fluctuation when temperature did not change significantly



Blue histogram stands for pedestal from force-trigger-mode file
Red histogram stands for pedestal from beam data file

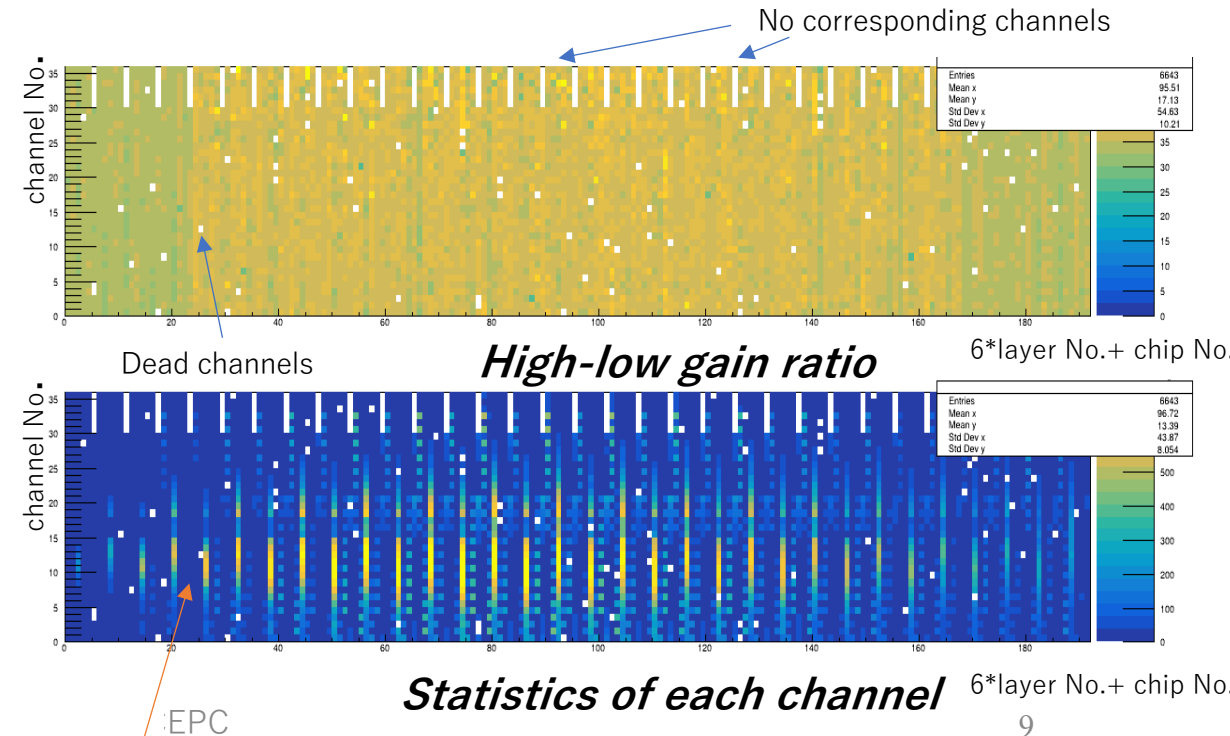
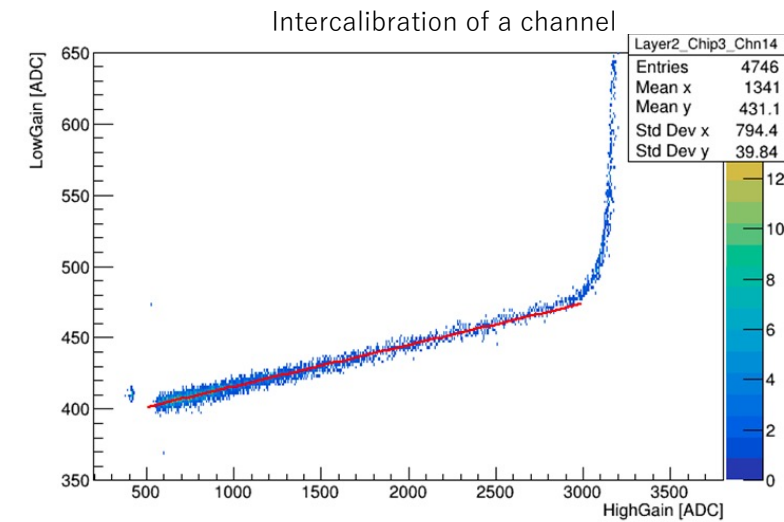
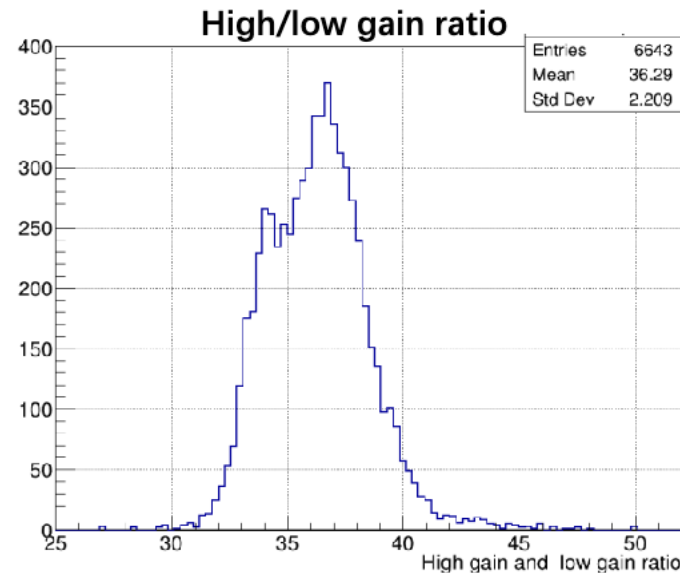
2023 Int



High gain and low gain intercalibration

- SPIROC2E chip records both two gains (high gain and low gain) to cover a large dynamic range
 - Ratio of high and low gain is calculated using electron beam data
 - Many statistics at the center region of the calorimeter
- High gain ADC saturates at different value among channels
- The result is consistent with the gain difference

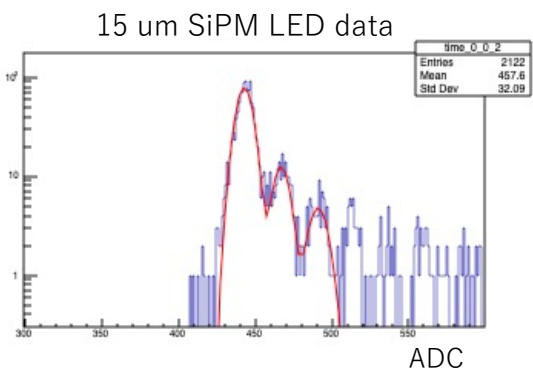
- White bins
 - Dead channels
 - No corresponding channels



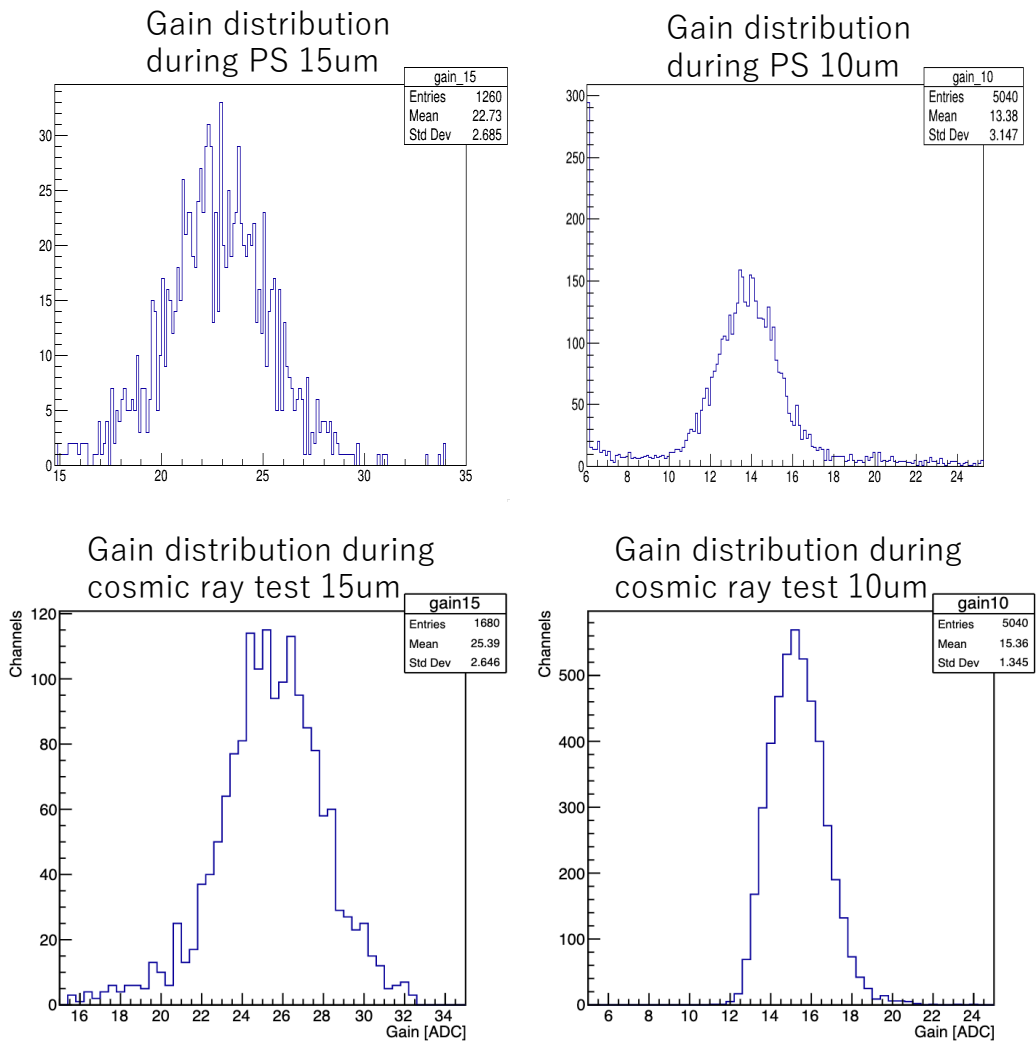
Center region of the calorimeter

LED calibration

- LED data are taken during the 2023 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



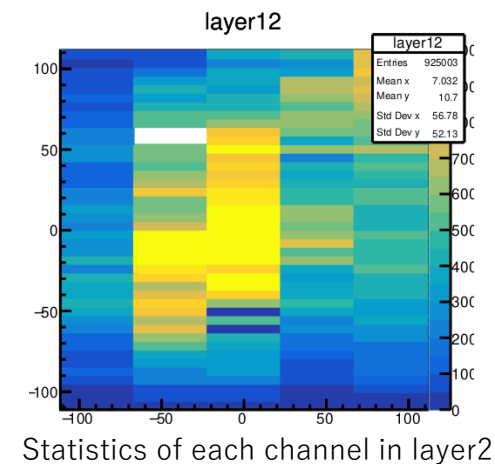
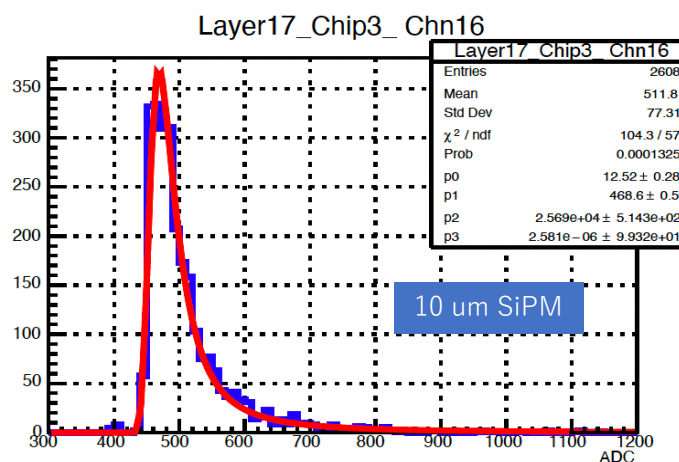
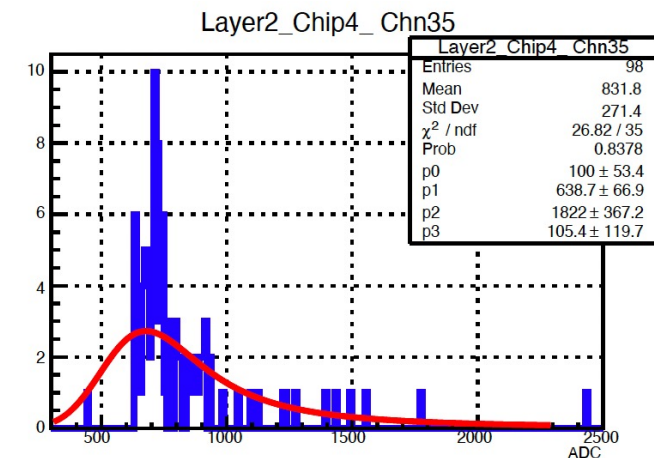
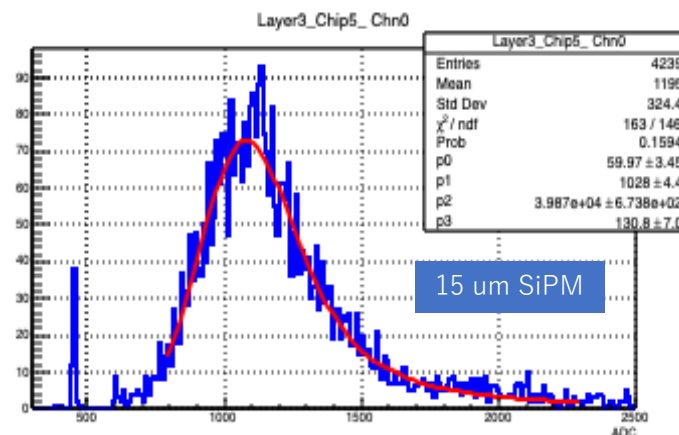
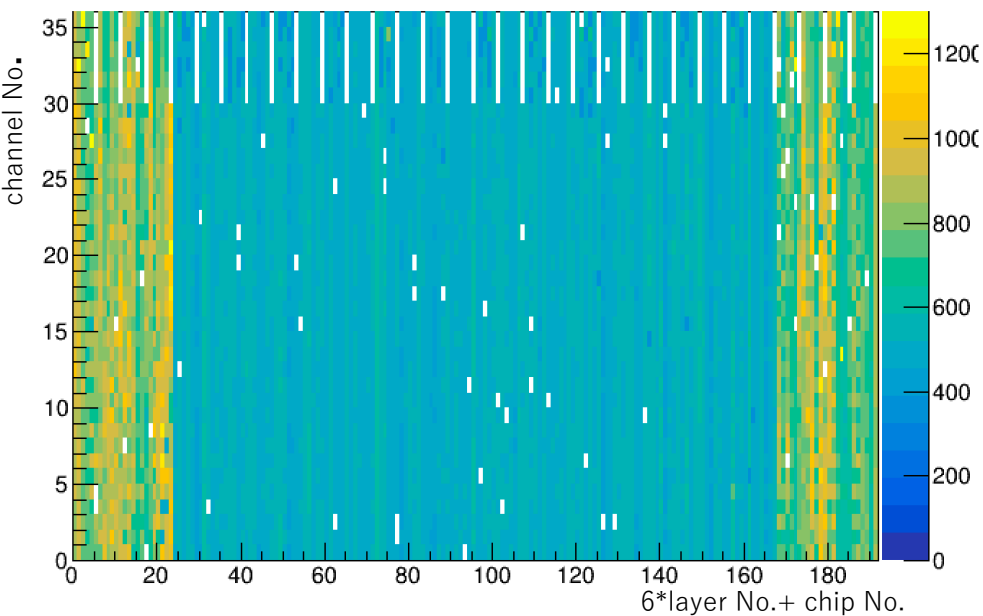
ECAL	CR	Beam test
temperature	~20 C	25~29 C
Bias voltage	-	+0.5 V



MIP calibration

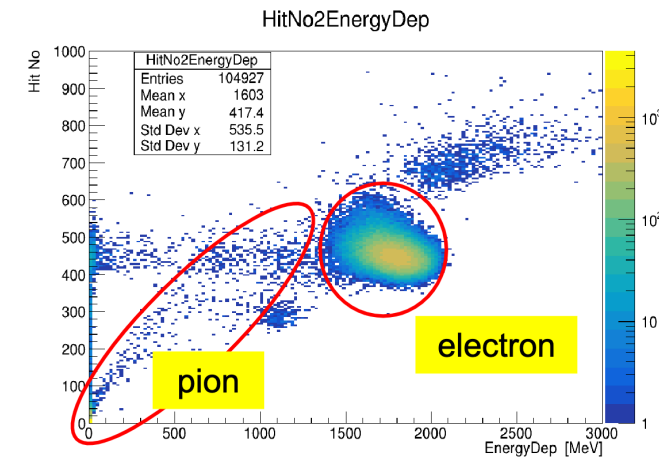
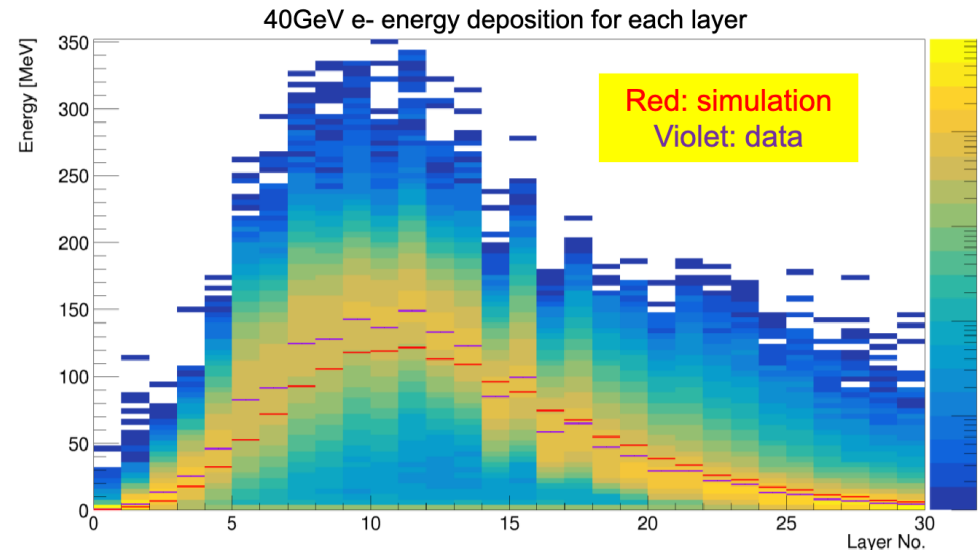
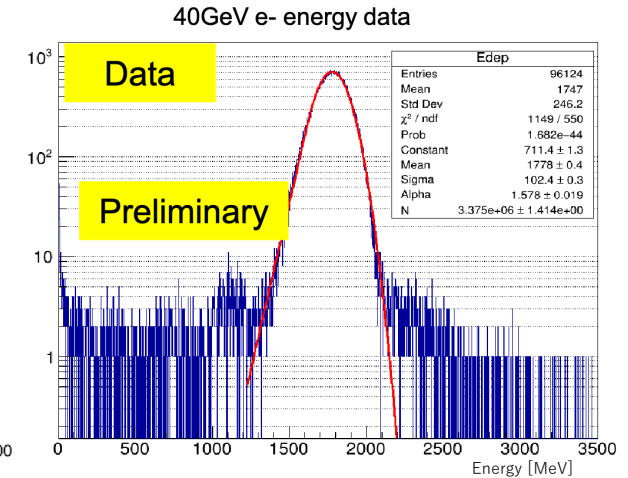
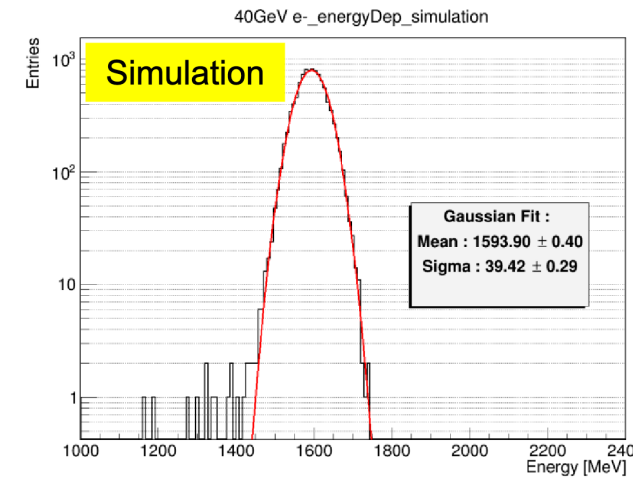
- MIP peak value is obtained from fitting 100 GeV/c muon events' ADC distribution by Langaus function
- Threshold and SiPM voltage are optimized
- Track restriction s are used to improve fit result
- A small part of channels are not well fitted due to lack of statistics

ECAL MPV



Simulation and validation

- Geant4 full simulation is established
 - Geometry : for both Sc-ECAL and AHCAL prototype
 - Scintillation : quenching effect (Birks' law) is implemented
 - Assuming perfect response uniformity for each channel
 - MIP calibration of each channel: done in data
 - Digitization
 - Photon statistics, SiPM saturation, ASIC saturation
- 40 GeV/c electron data from SPS H2
 - Calibrated with 100 GeV muon data
 - Threshold: 0.5 MIP
 - No obvious energy leakage
 - Contamination is not yet eliminated
- More effort to match data and simulation



Summary and prospect

- Sci-ECAL and AHCAL combined test beam experiments are conducted at CERN
 - SPS H8 beamline in last October
 - SPS H2 beamline in this April to May
 - PS T9 beamline in this May
- Collected data in wide energy range for electrons, pions, and muons
- Analyses of the combined beam test is ongoing
 - Preliminary calibrations are ongoing
- Some detailed analyses are also ongoing
 - shower analysis,
 - PID
 - Test beam simulation
 - etc...
- Plan
 - SiPM saturation, temperature correction
 - Geant4 MC validation
 - Sci-ECAL and AHCAL combined analysis

Thanks for CERN, CERN staff,
and CALICE collaboration colleagues