CERN beamtests with CALICE scintillator-based ECAL + HCAL prototype

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On behalf of the CERN beam test team

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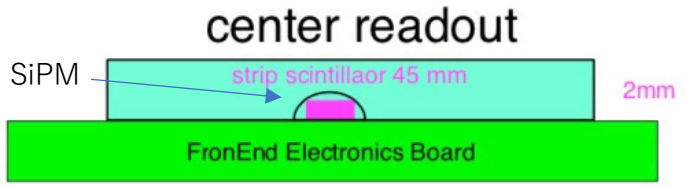
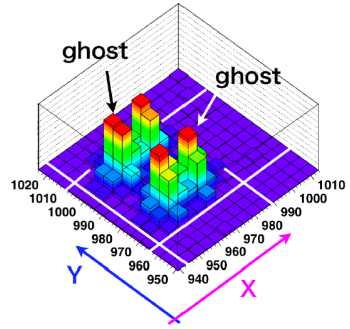
The 2023 International Workshop on CEPC (European edition)

Sc-ECAL

- Scintillator-based Electromagnetic Calorimeter (Sc-ECAL)
  - ECAL concept based on strip-shaped plastic scintillator readout by SiPM
  - Center dimpled readout based on $5\times45\times2$ mm^3 scintillator strip



  - Virtual segmentation of 5×5 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

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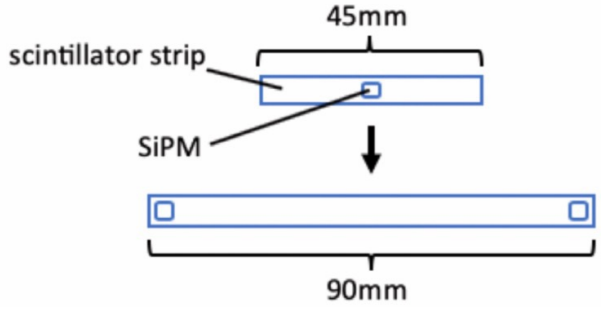
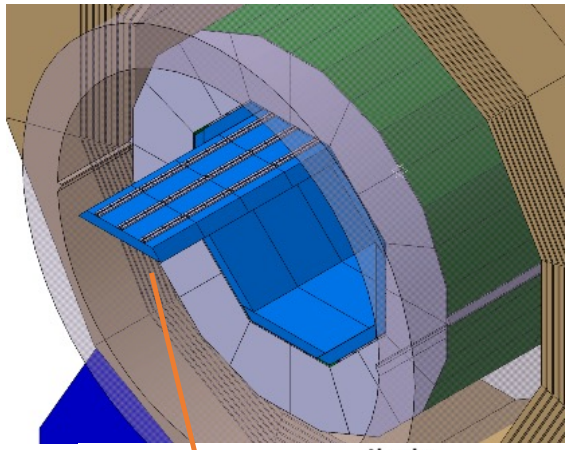
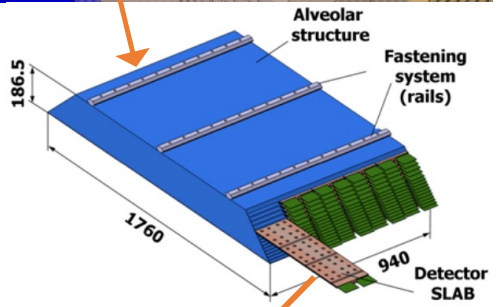
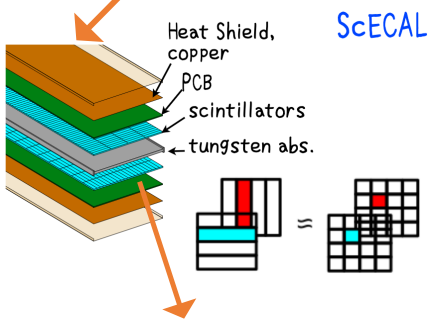
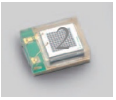




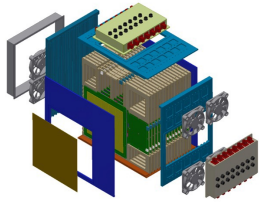


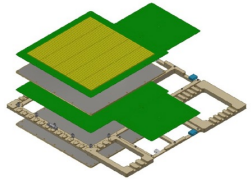


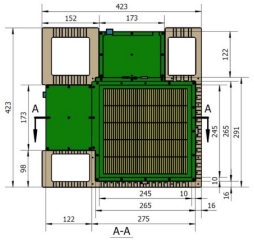


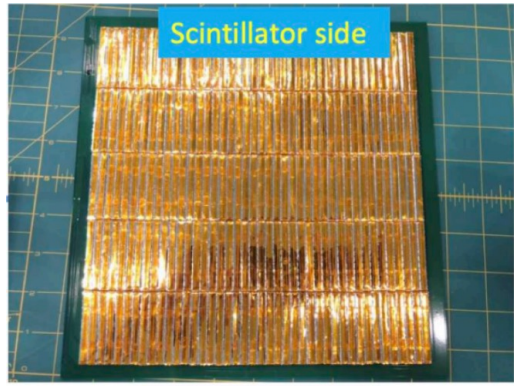
Sc-ECAL large technological prototype

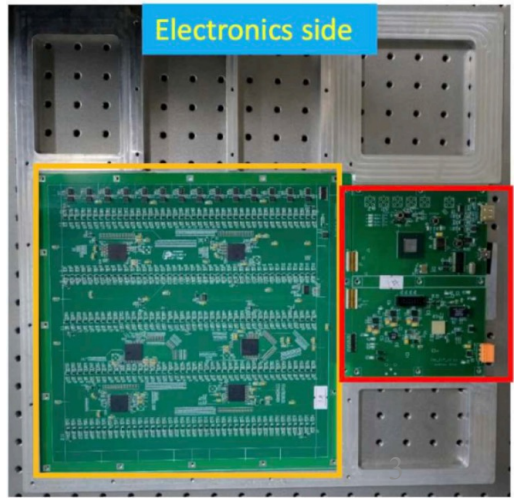
- The prototype consists of 32 absorber(W) and detection layer (EBU)
  - Total absorption layer thickness : 32×3.2 mm (~23.3 X_0)
  - Two absorber layers and two detection layers are integrated on a braced frame (super layer)
  - 16 super layers are mounted on the prototype



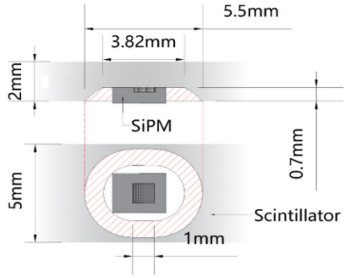


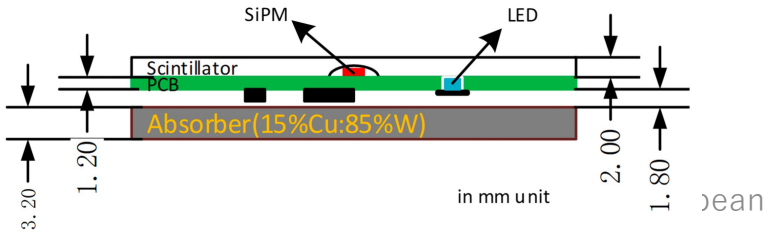






- ECAL Base unit (EBU) and scintillator strips + SiPM readout unit for detection layer
  - 42 (columns) × 5 (rows) strip readouts per EBU
  - Each channel have LED for calibration of SiPM gain





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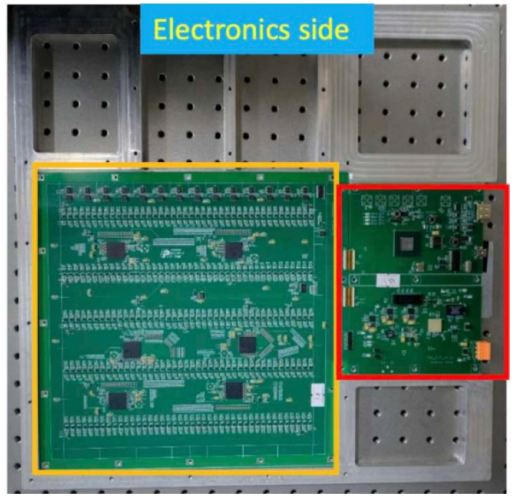
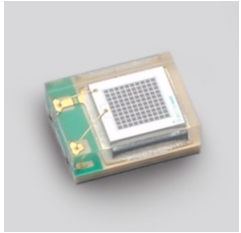
Sc-ECAL large technological prototype



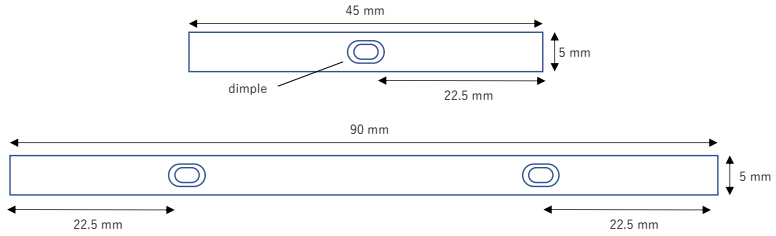
- All channels on each EBU can be individually readout by 6 SPIROC2E chips developed by OMEGA lab and CALICE collab
  - High and low gain mode for wide dynamic range
  - 16 temperature sensors are implemented

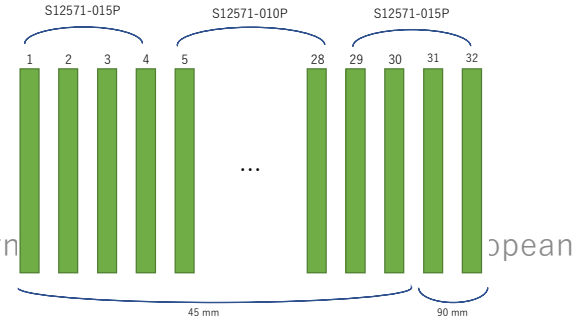
- Two types of MPPC are used for SiPM on detection layer (manufactured by Hamamatsu K. K.)
  - S12571-010P, -015P

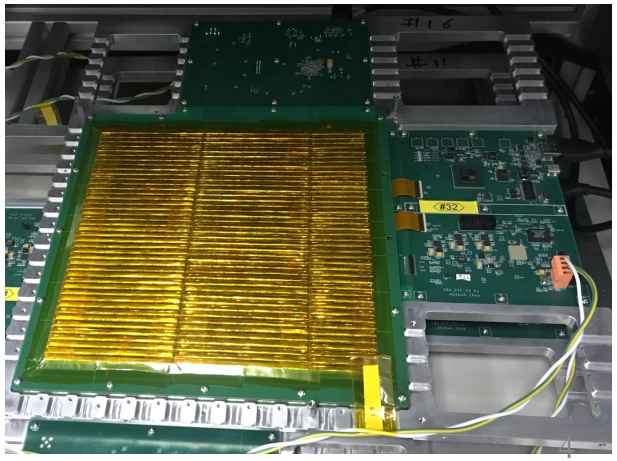


	Pixel size	# of pixel
S12571-010P	10 um	10,000
S12571-015P	15 um	4,489

- Last 2 layers have double SiPM readout part
  - Using 90 mm length strip instead of standard 45 mm strip

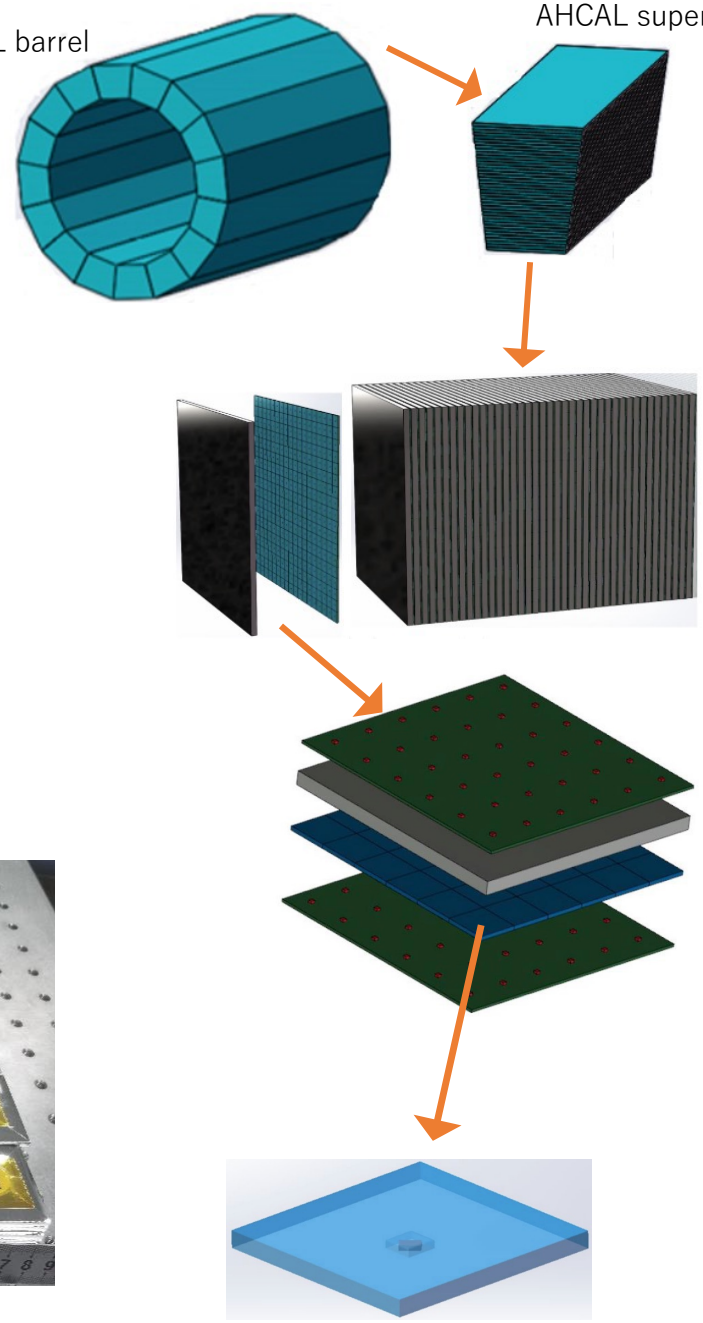


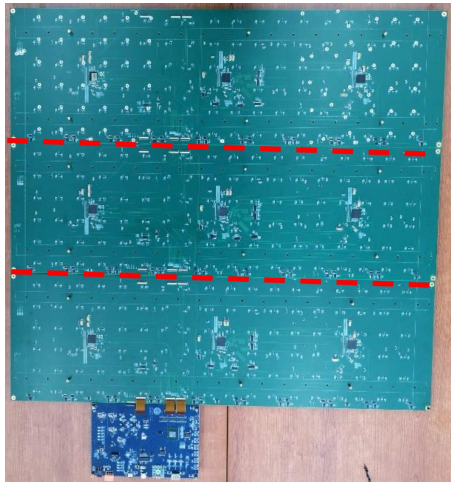




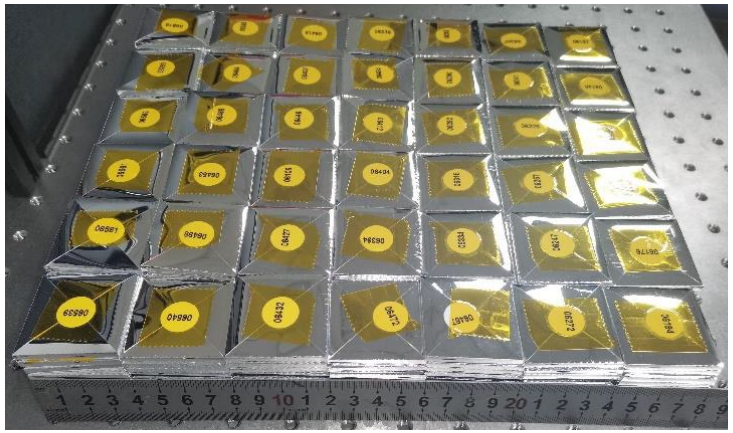
AHCAL

- Analog Hadron Calorimeter (AHCAL)
  - HCAL concept based on scintillator cell readout by SiPM with center dimple
  - AHCAL barrel consists of 32 super modules, a super module has 40 sampling layers
  - tile size : 40×40×3 mm^3
  - PFA oriented design





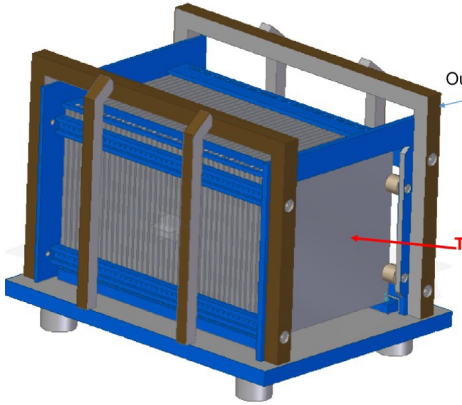
1 full layer : 3 HBU + cassette

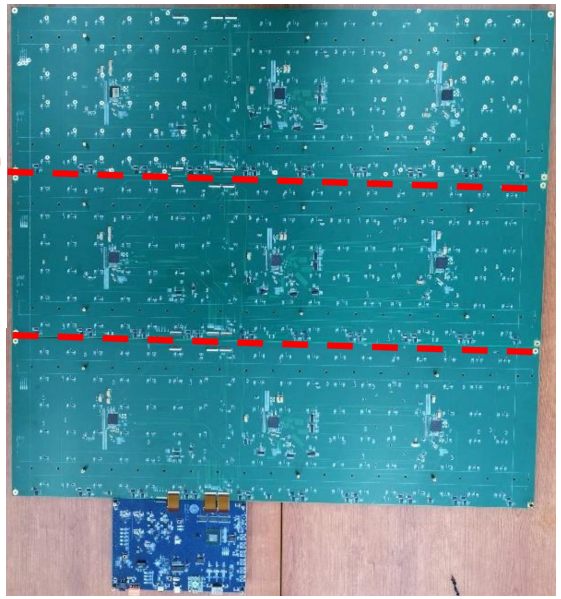


Scintillator tile with ESR

AHCAL large technological prototype

- AHCAL consists of consists of 40 absorber (Fe) + detection layer (HBU)
  - Total absorption layer thickness :
    40×20 mm (steel) ~4.7 λ_n, ~3.9 λ_π

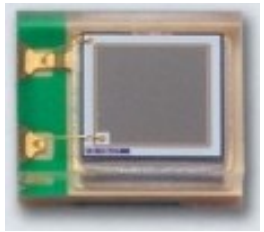




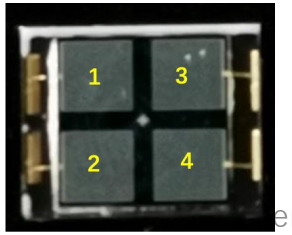
- All readout channels are readout by 9 SPIROC2E chips on a layer
  - 72×72 cm^2 detection layer, 324 channels per layer

- 2 types of SiPM are implemented
  - MPPC S14160-1315PS and NDL 22-1313-15-S
  - NDL SiPMs are implemented at the last two layers

MPPC



NDL



	Pixel size	Sensor area	# of pixels
S14160-1315PS	15 um	1.3×1.3 mm^2	7,284
22-1313-15-S	15 um	4.45×3.65 mm^2	7,396 × 4

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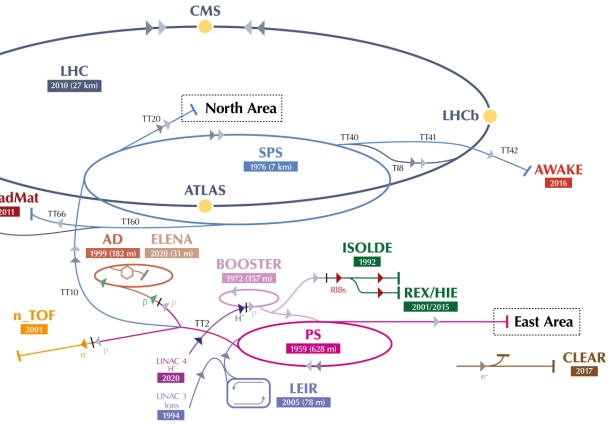
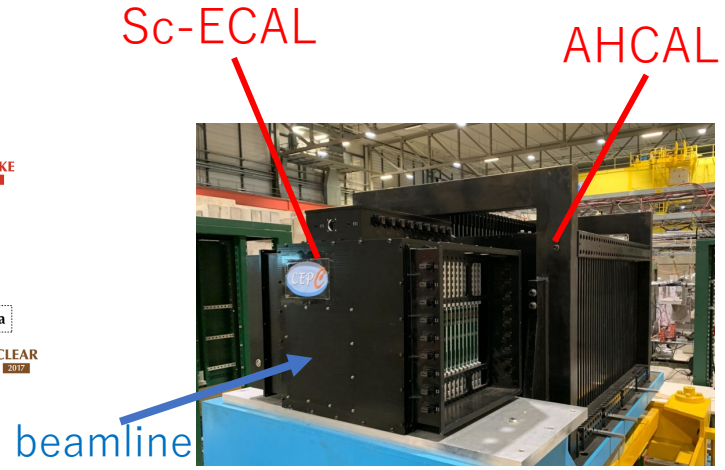
Test beam experiment

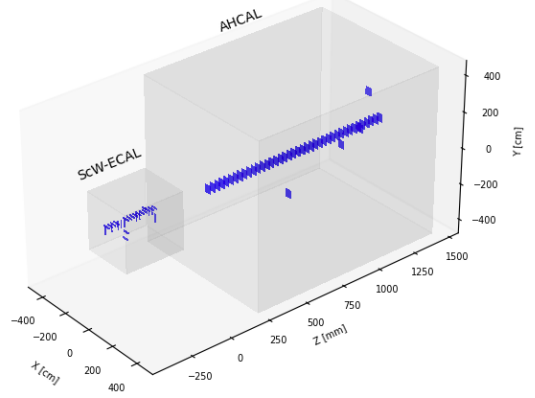
North Area Test Beam Facilities



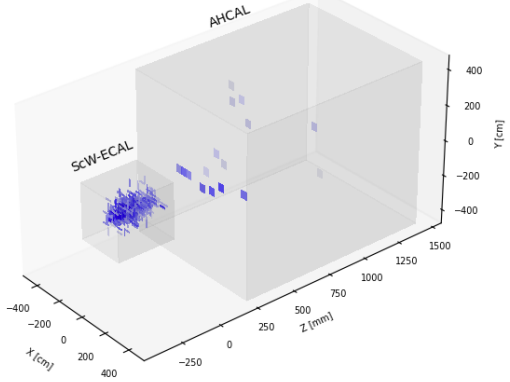


- Test beam experiment for Sc-ECAL and AHCAL combined system is conducted at CERN SPS&PS
  - SPS : site 887, H8 beamline
    - October 19th to November 2nd
    - High energy beam (10-160 GeV)
    - μ^-, π^-, e^-
  - SPS : Site 887, H2 beamline
    - April 26th to May 10th
    - High energy beam (10-350 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
    - Low energy beam (1-15 GeV)
    - μ^-, π^-, e^-
- Collaborators
  - CALICE, UTokyo, Shinshu university, USTC, IHEP, SJTU

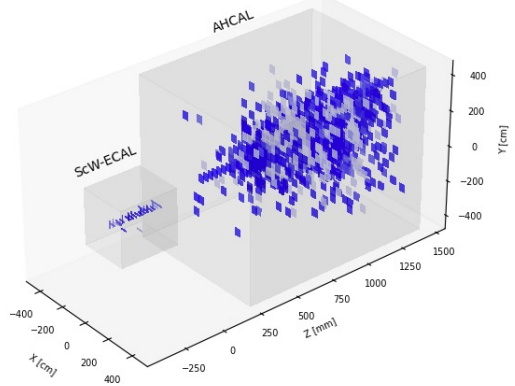
100 GeV muon



60 GeV electron



350 GeV pion

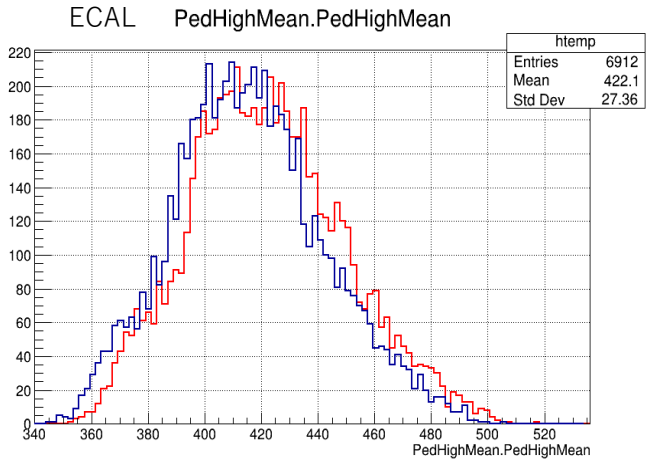


Preliminary results

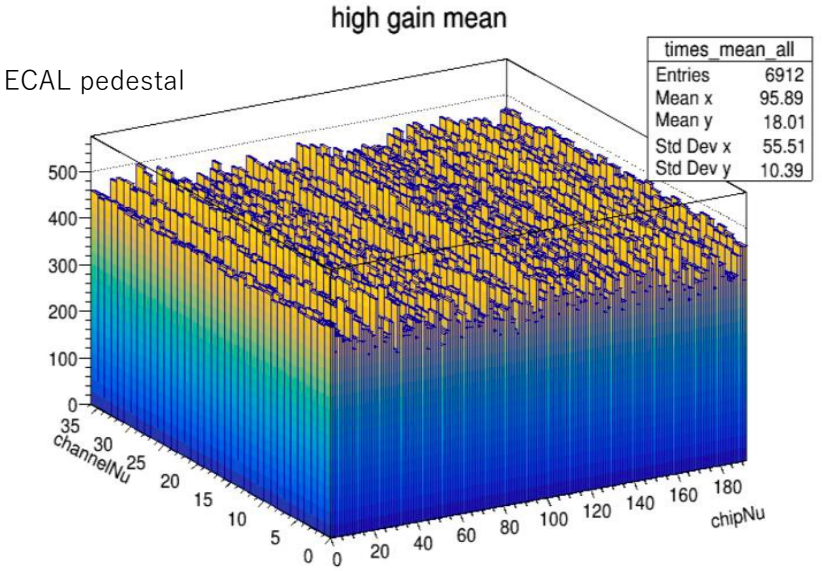
- Pedestal
- Gain calibration
- MIP calibration
- High gain and low gain intercalibration
- Simulation and validation

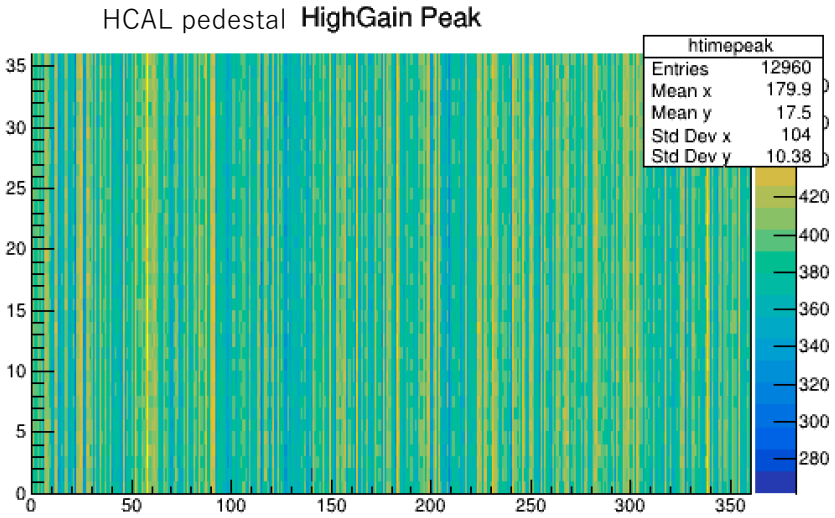
Pedestal calibration

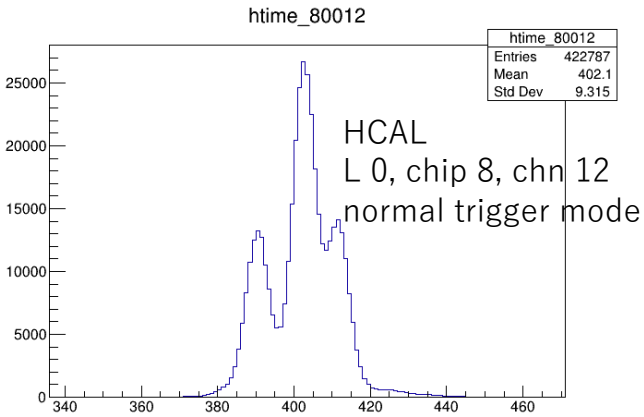
- Pedestal was obtained from events that did not exceed threshold
  - Some channels had multi-peaks due to electronics problem at last years data
- Pedestal is obtained from forced trigger mode

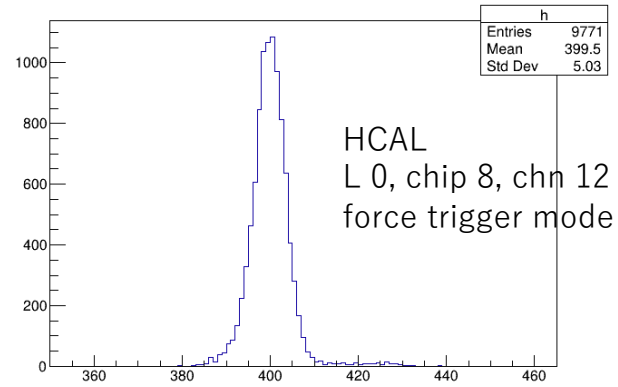


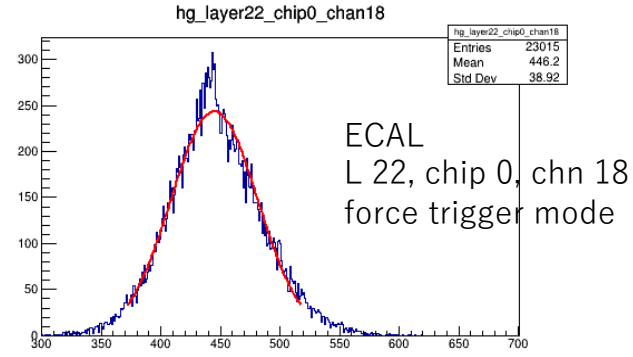
Blue histogram stands for pedestal from force-trigger-mode file
Red stands for pedestal from beam data file









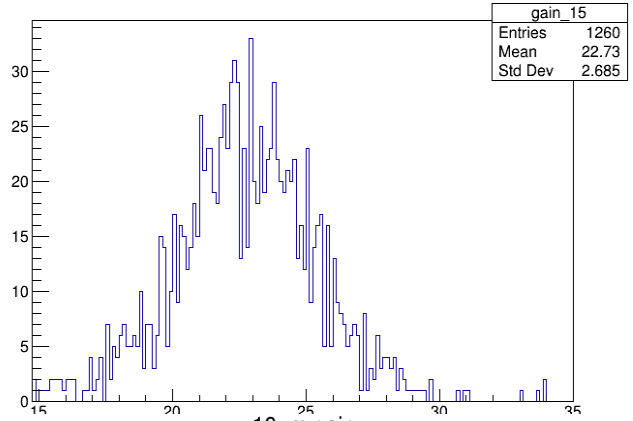


Gain calibration

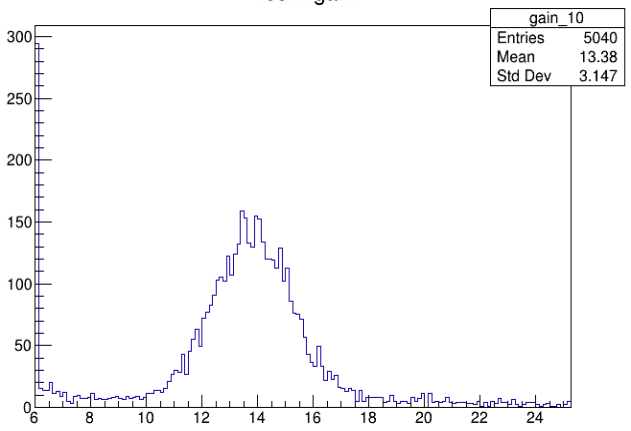
- LED is mounted in EBU and HBU to measure gain for each channel
  - LED data are fitted with triple gaussian to find gain
  - Fitting is not good for some channels

ECAL gain

15um gain

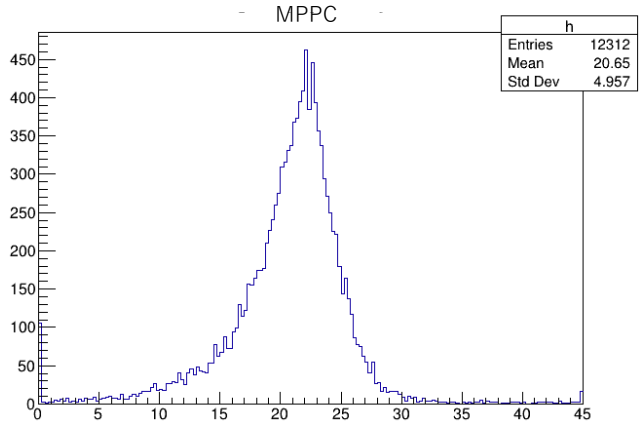


10um gain

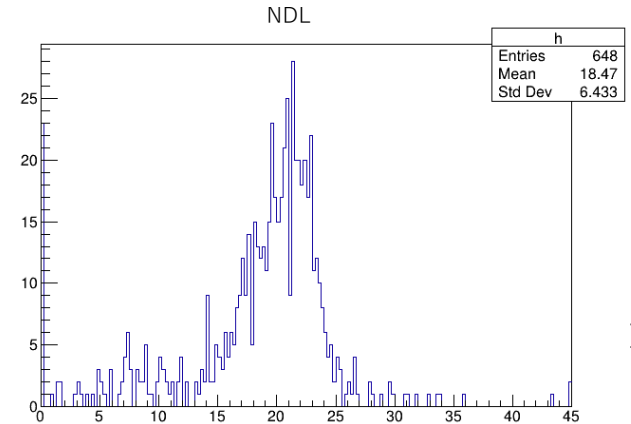


HCAL gain

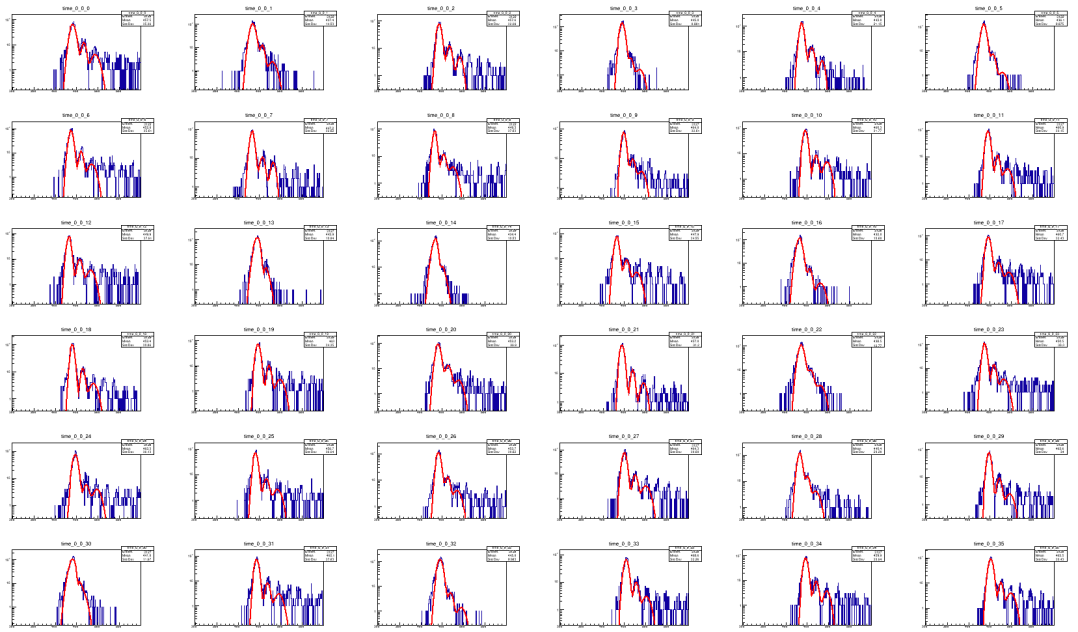
MPPC



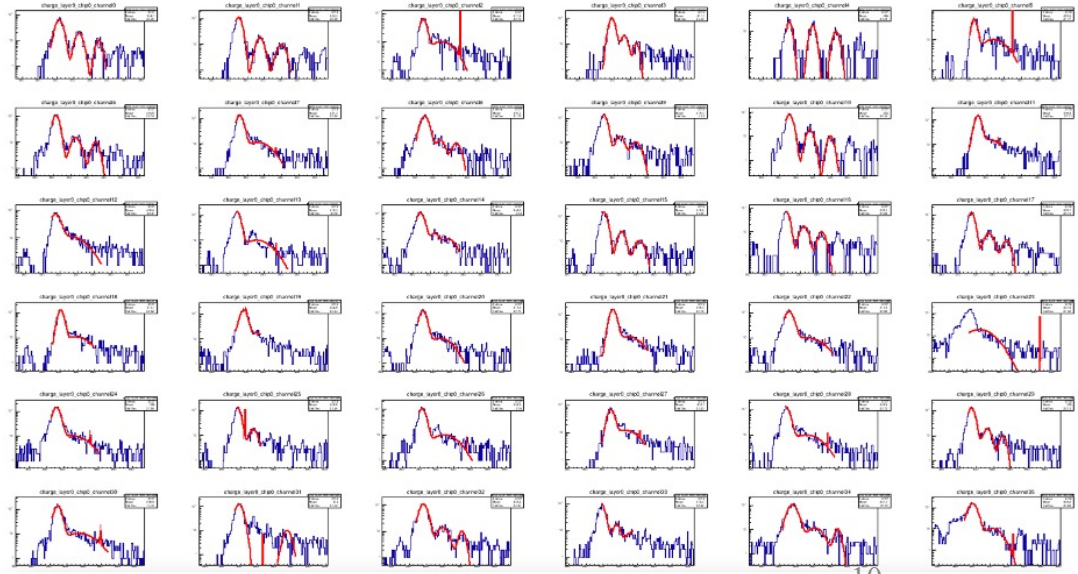
NDL



ECAL

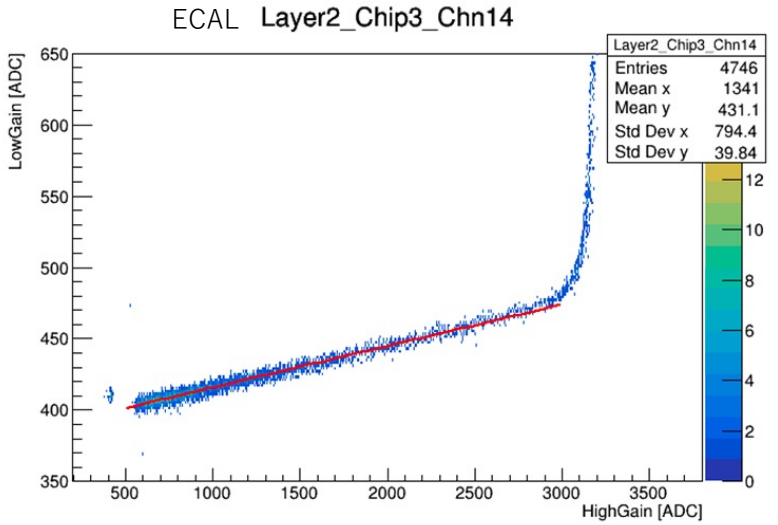


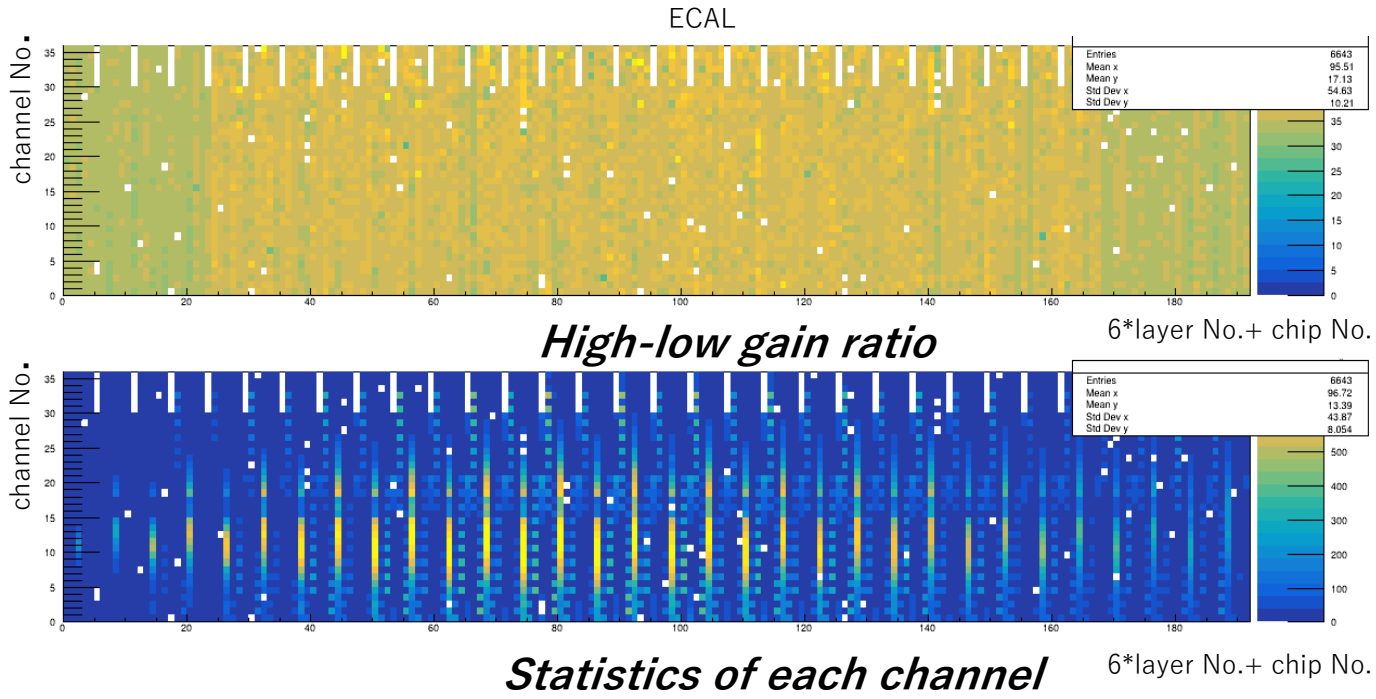
HCAL

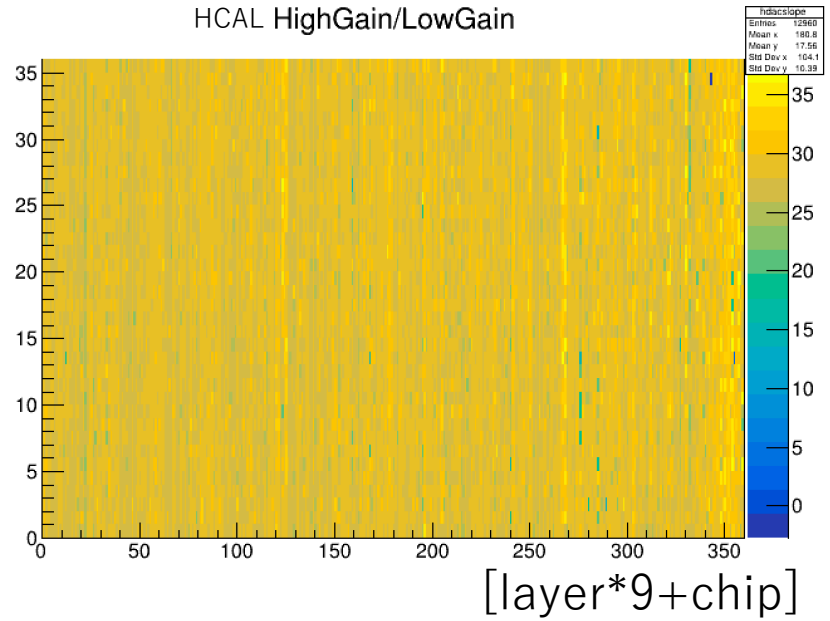


High gain and low gain intercalibration

- SPIROC2E chip has two gains (high gain and low gain) to cover a large dynamic range
- High gain ADC saturates at different value among channels
- The result is consistent with the gain difference



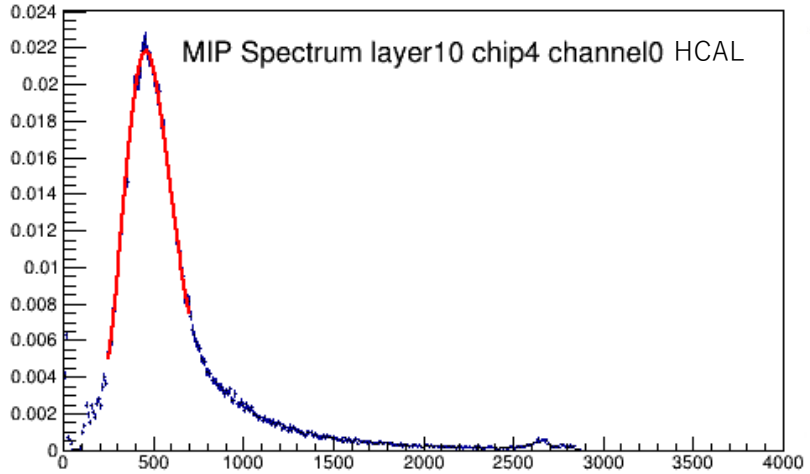


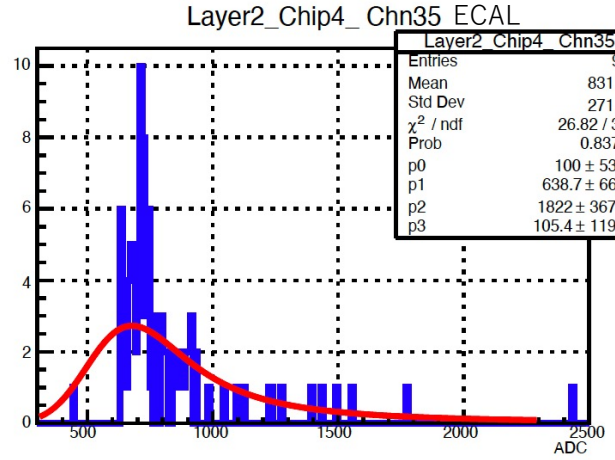


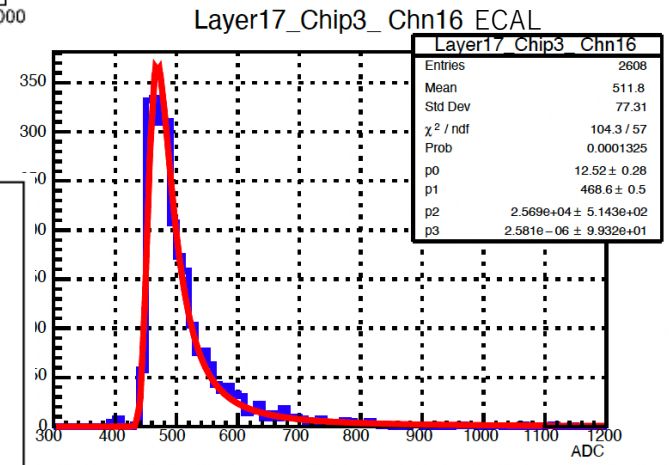
European

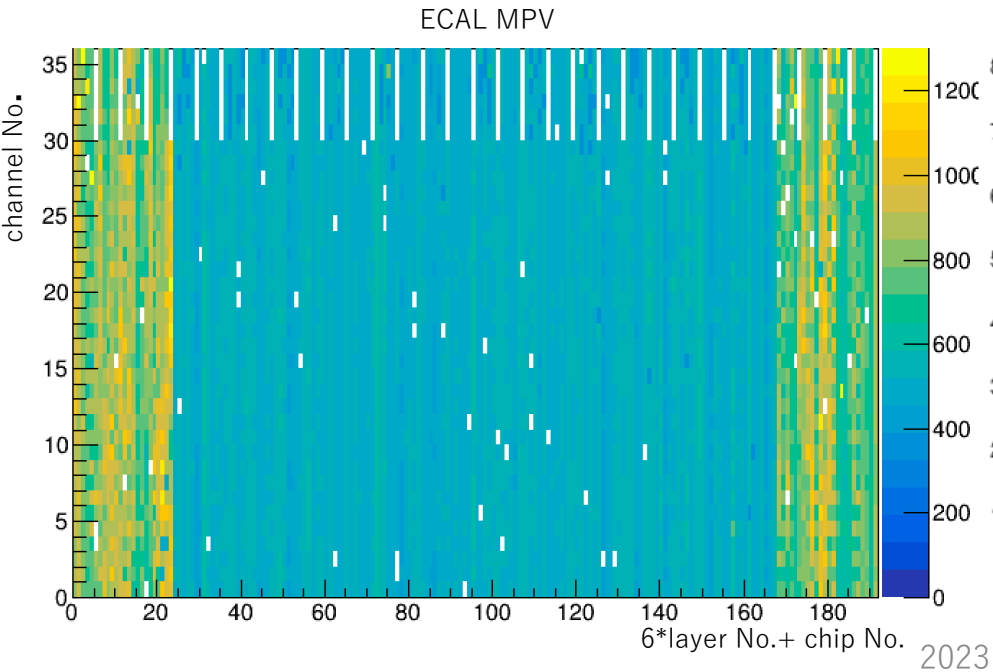
MIP calibration

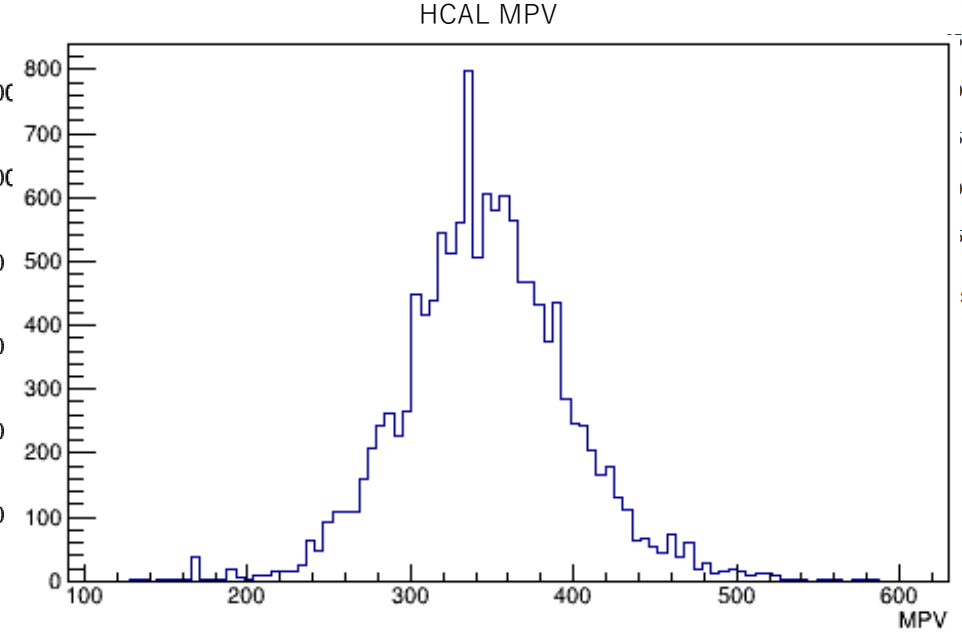
- MIP peak value is calculated from fitting muon events' ADC distribution by Langaus function
- Some channels are not well fitted due to lack of statistics and bad SN ratio







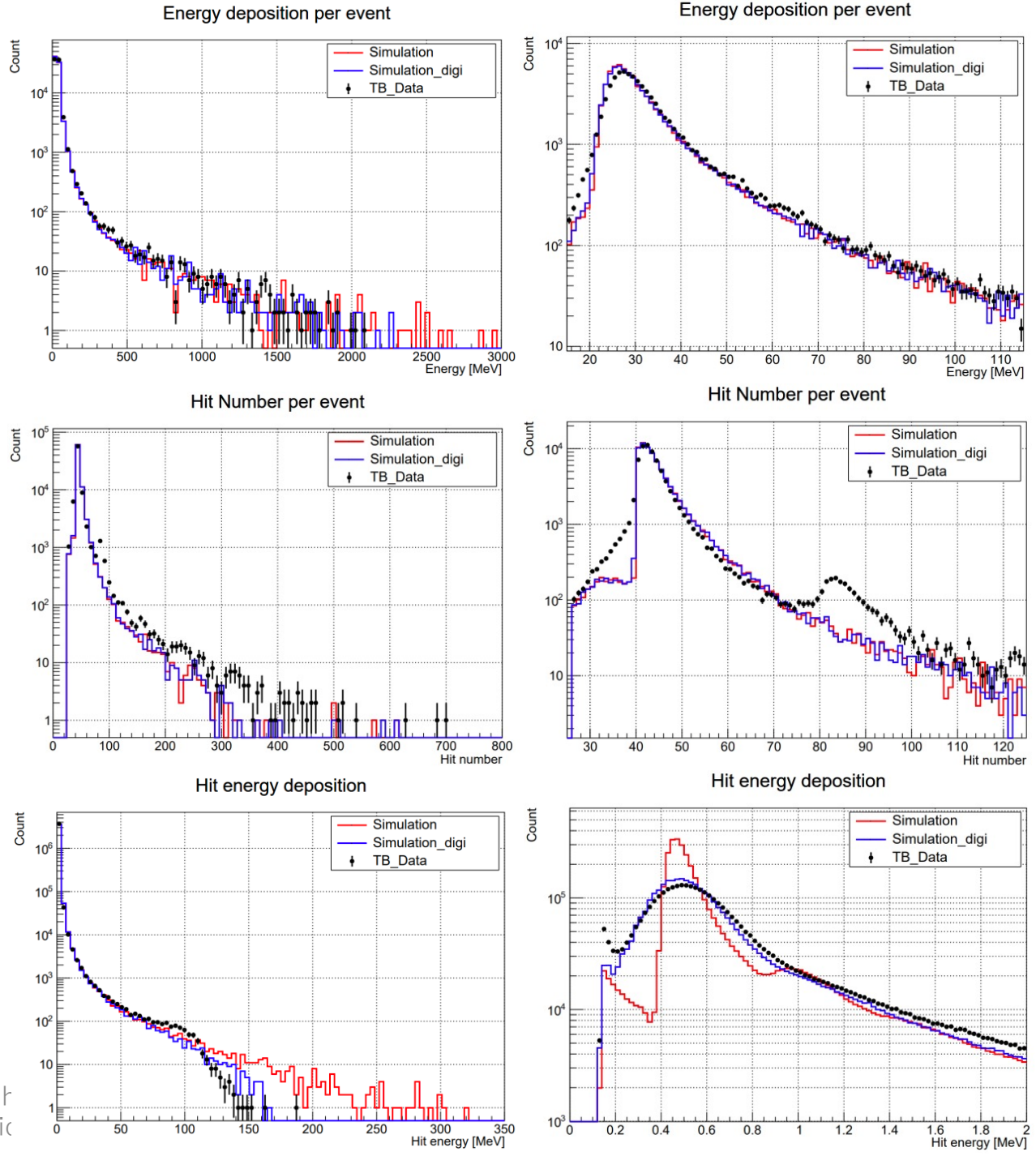




Simulation and validation

- 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

- AHCAL : comparison of data vs MC
  - Muons : noises, channel-wise uniformity, etc…
  - Positron and hadrons : work in progress
    - Beam contaminations, SiPM and ASIC saturation effects, etc…



Summary and prospect

- Sc-ECAL and AHCAL combined test beam experiment is 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 samples in wide energy range for electrons, pions, and muons

- Analysis of the combined beam test is ongoing
  - Preliminary calibrations is ongoing
- Some detailed analysis is also ongoing
  - shower analysis,
  - PID
  - Test beam simulation
  - etc…