# PS and SPS beam test analysis

International Workshop

Yoko Minato

Nara Women's University

## ✓ Outline

# 1. Test beam experiment in 2018

# 2. Test Beam at PS with 9 GeV Hadron Beam

- Setup
- Measurement of Minimum Ionization Particles

# 3. Test Beam at PS with 3 GeV Electron Beam

- Setup
- Detect the electromagnetic shower

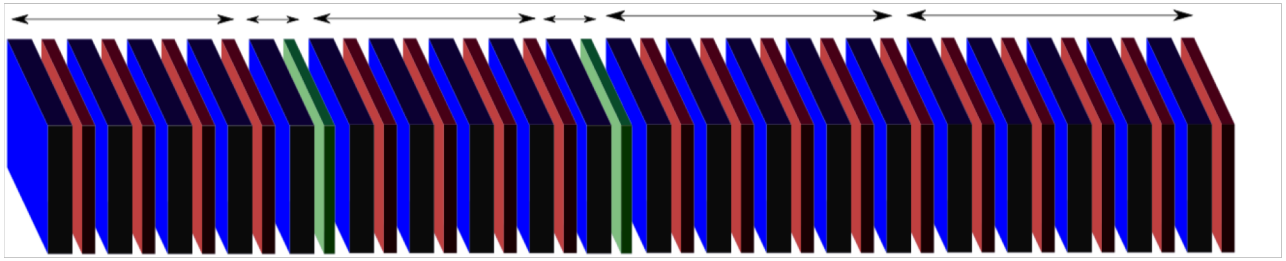
# 4. Test Beam at SPS with 150 GeV positron Beam

- Setup
- Observed the electromagnetic shower

# 5.Summary and Outlook

## Summary of beam test setup

| | layer | Beam | Aim to |
|---|---|---|---|
| **Experiment. 1 at PS** | **Only 8×8 Si-layer** | **9 GeV hadron beam** | **to study the detector response for MIPs** |
| **Experiment. 2 at PS** | **1 - 3 W plates + 8×8 Si-layer** | **1 - 5 GeV Electron Beam** | **Detect electromagnetic shower** |
| **Experiment. 3 at SPS** | **The full FoCal prototype (20 layers)** | **110 to 250 GeV positron and hadron beam** | **Detect development of electromagnetic shower at each Si-layer** |

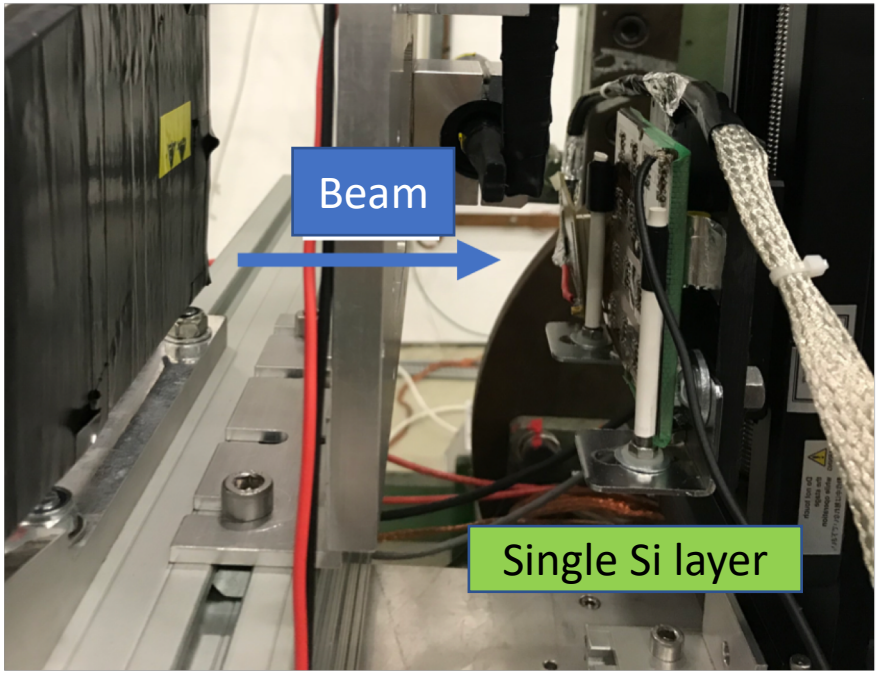


FoCal (20 W+Si-layers)

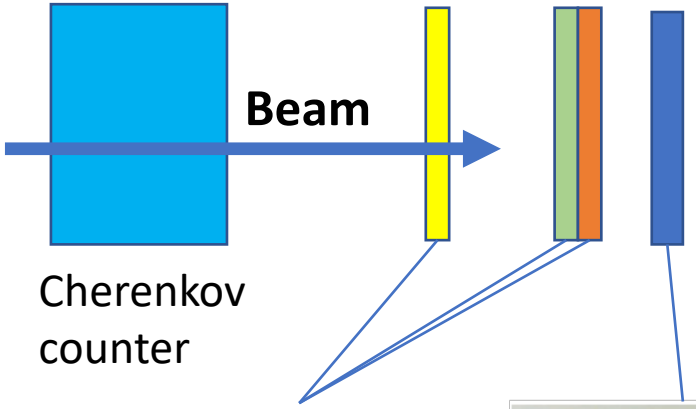
FoCal prototype

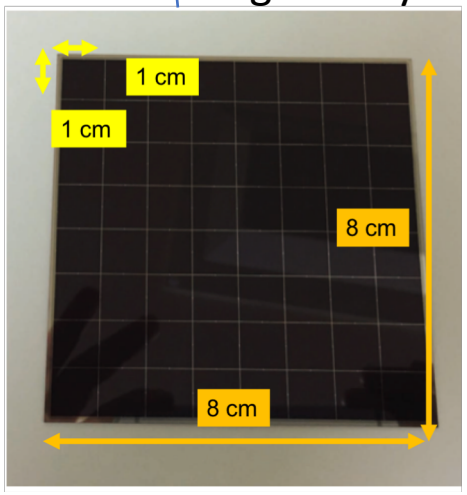
**Test beam experiment at PS to study the detector response for the Minimum Ionizing Particle (MIP)**

**with the single Si layers. Observe hadron E=9 GeV/c**

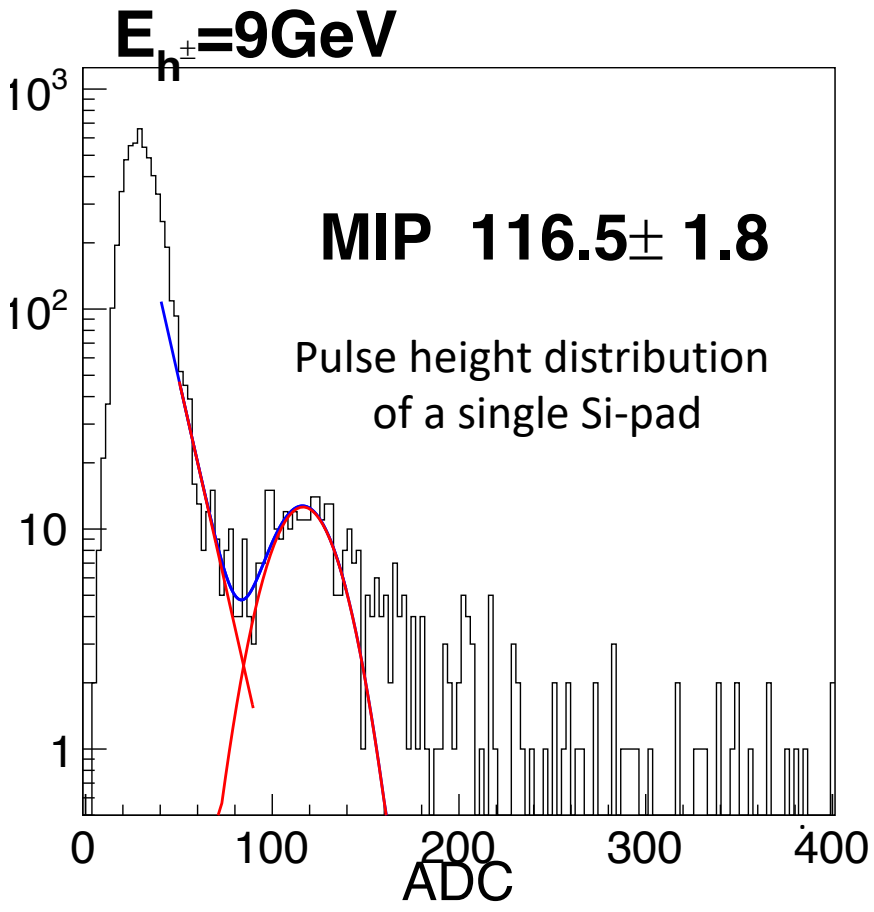



Setup of FoCal prototype



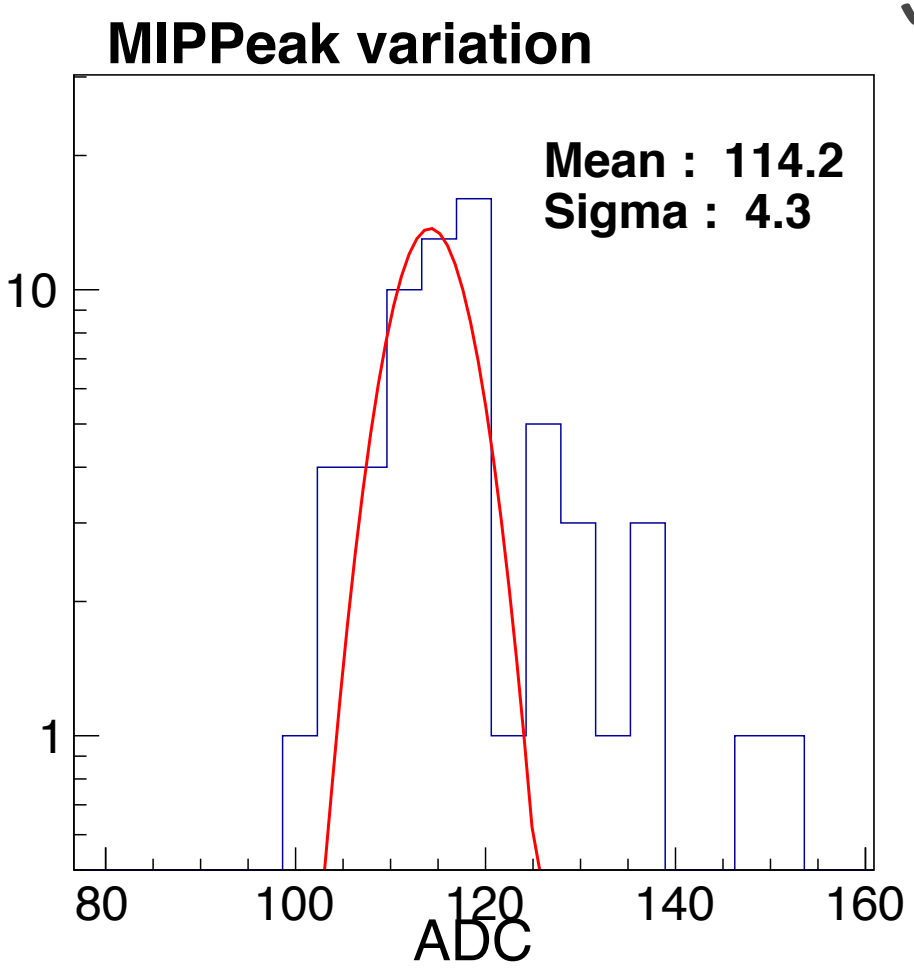



# Measurement of ADC count corresponding to MIP energy with FoCal prototype (single Si-pad)



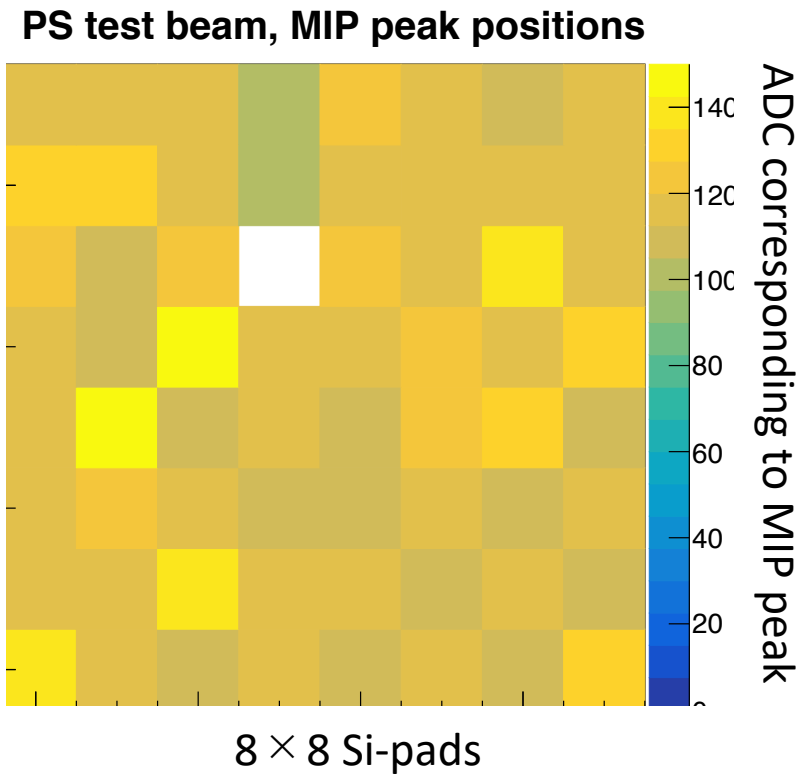

- ✓ Subtraction of pedestal signal in each individual Si pad
- ✓ Subtraction of time-dependent common noise in each time bin
- ✓ Observation of clear MIP peak signal separated from electronics noise
  - MIP peak ≒ 116 ADC counts
- ✓ Extraction of signal in ADC distribution
  - Gaussian function → signal
  - Exponential function → background.

# Evaluate variation of MIP peak position for 8×8 Si-pads




✓ Variation of MIP peak position = ~5 %

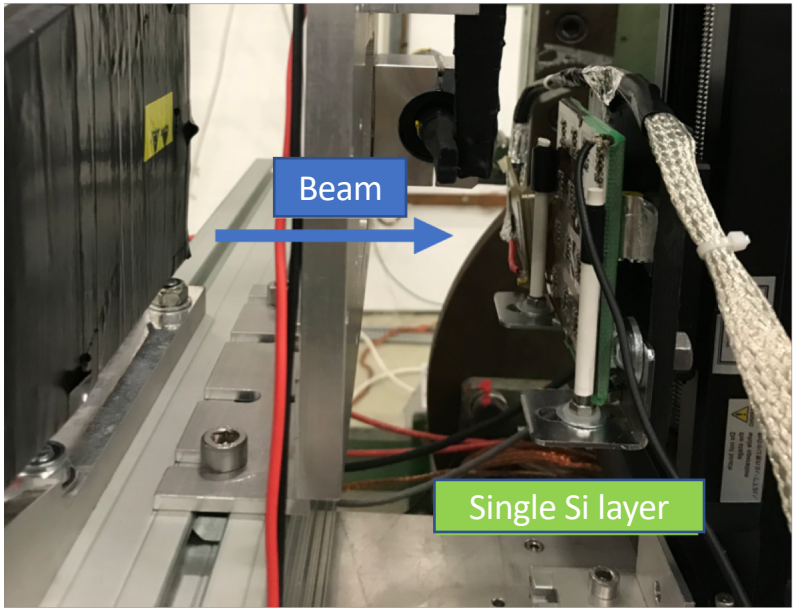
→ reasonable stability of Si-pads

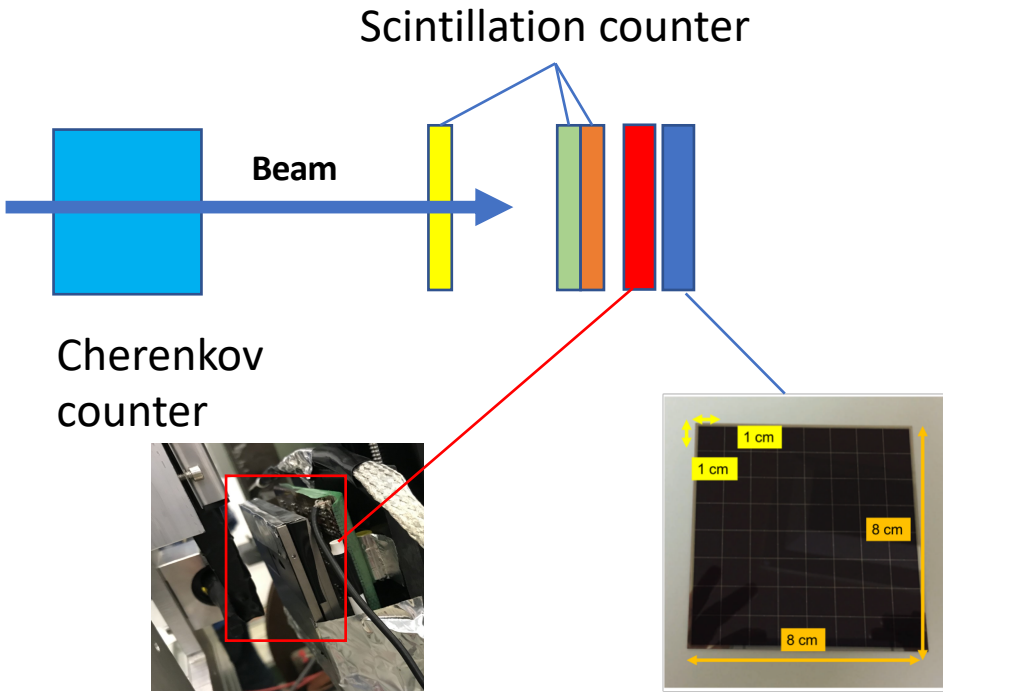


**Test beam experiment at PS to detect the electromagnetic shower.**

**(2) Electron beam with energy from 1 ~ 5 GeV**

**- 1 ~ 3 W plates (= 1 ~ 3 $X_0$) are placed before the single Si layer.**



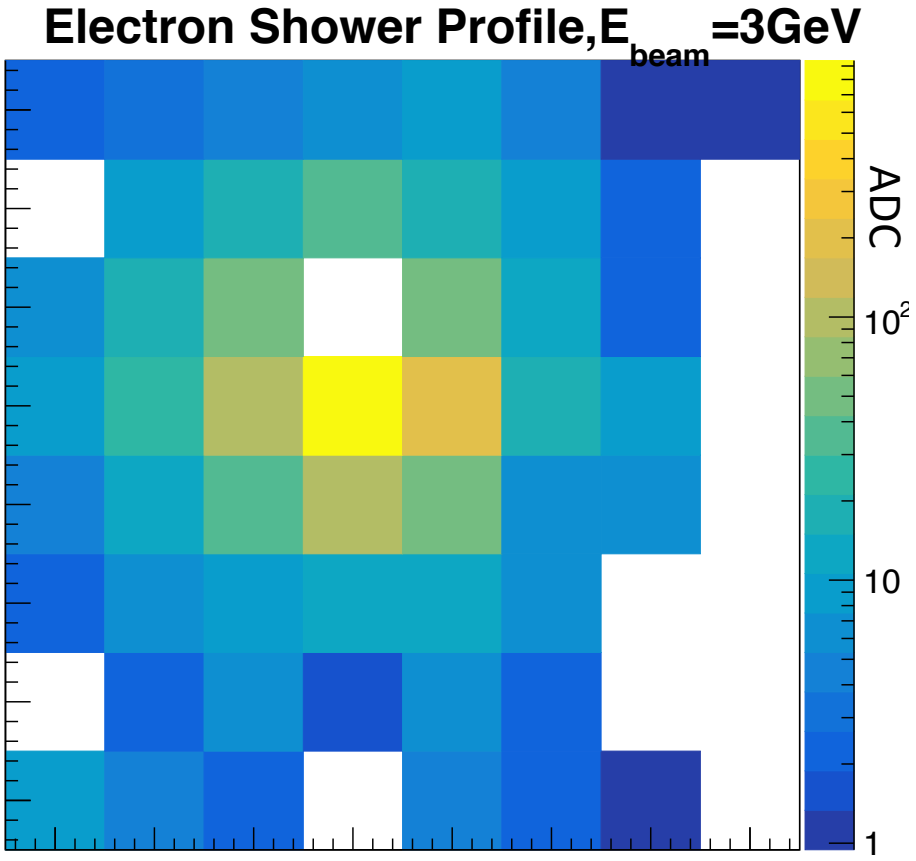

Tungsten plates

The single Si layer

thickness : 3.5 mm (=1 $X_0$)

Moliere radius : 9.3 mm

## Detects the spread of electromagnetic shower in 3 GeV electron beam with 3 $X_0$ W plates

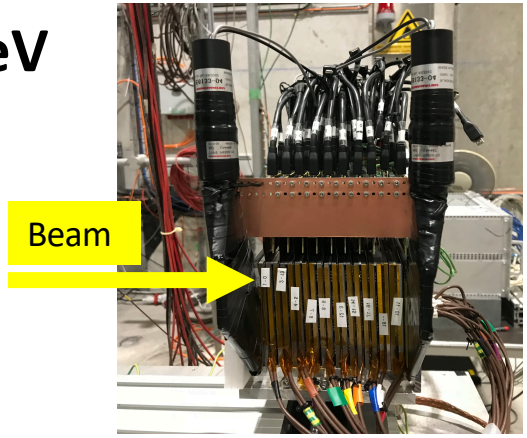


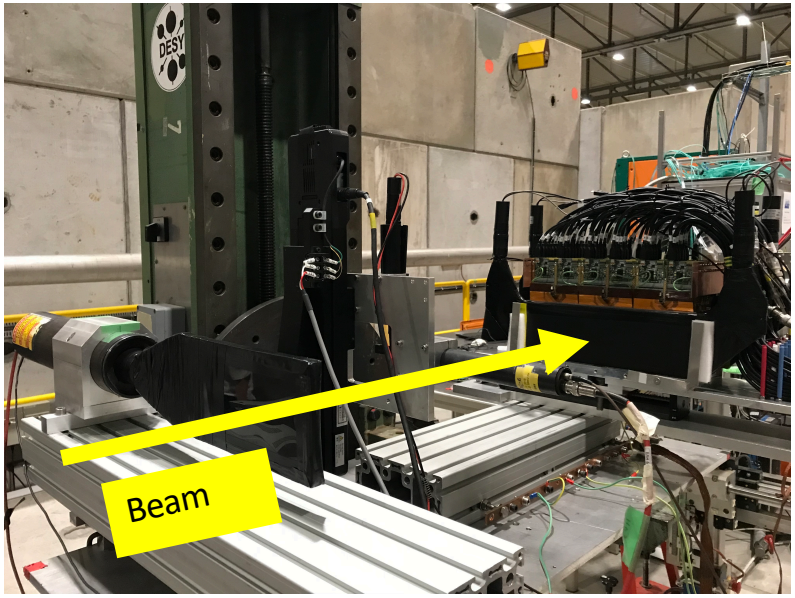

- ✓ **To inject 3 GeV electron beam at center of FoCal prototype**
  - W absorber = 3 $X_0$
- ✓ **Observation of pre EM shower**
  - almost energy deposits within Si-pad size (1cm).
- ✓ **Demonstration of detecting EM shower**
  - next detects full EM shower with full-FoCal

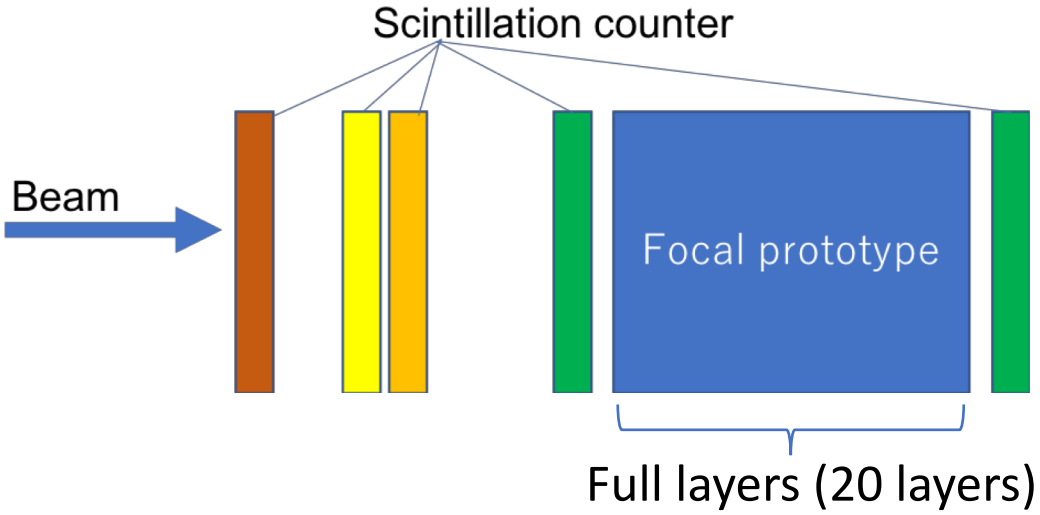
## Test beam experiment at SPS

### (3) Positron beam with energy from 110 ~ 250 GeV

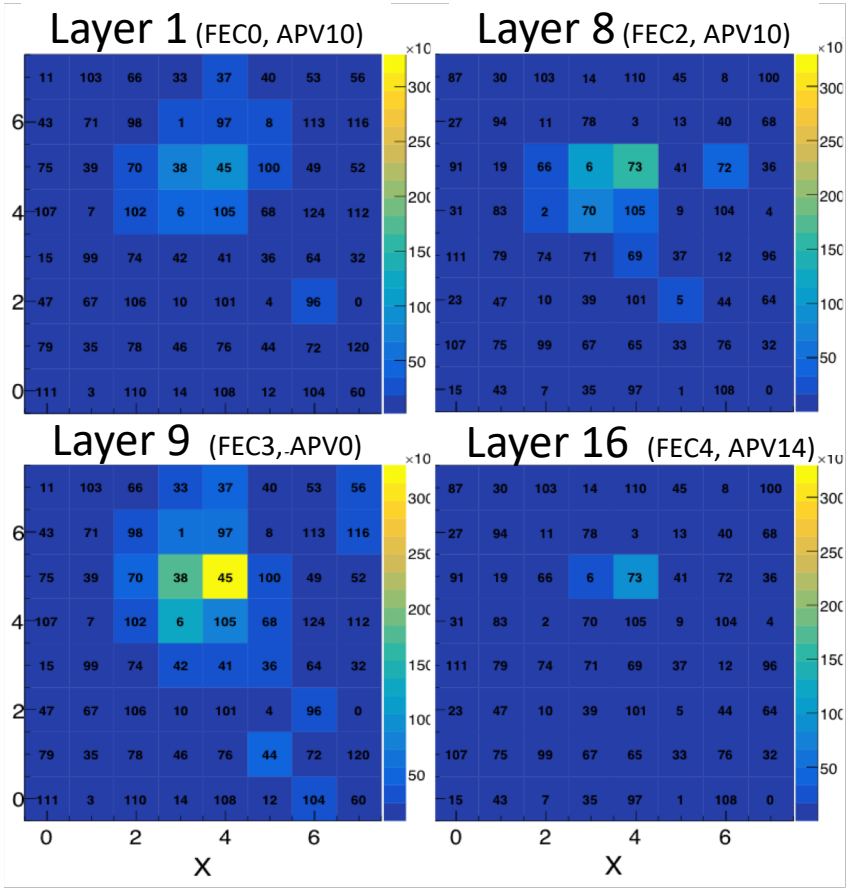
- composed of full 20 W+Si layers
- detects full evolution of EM shower



**The 9th detection layer detects highest energy deposit.**
**It is consistent with the expectation in the GEANT-4 based detector simulation.**




✓ **Detection of EM shower evolution at each detection layer**
- using 150 GeV positron beam

✓ **Highest energy deposit at 9th layer**
- EM shower maximize at 9 $X_0$
- consistent with GEANT4 simulation

✓ **Installation of high-granularity Si-pad**
→ Pre-shower detector at 5 $X_0$
→ Shower-max detector at 10 $X_0$

## ✓ Summary & Outlook

★ Three beam tests with PS and SPS at CERN were carried out to evaluate the FoCal performance in summer 2018.

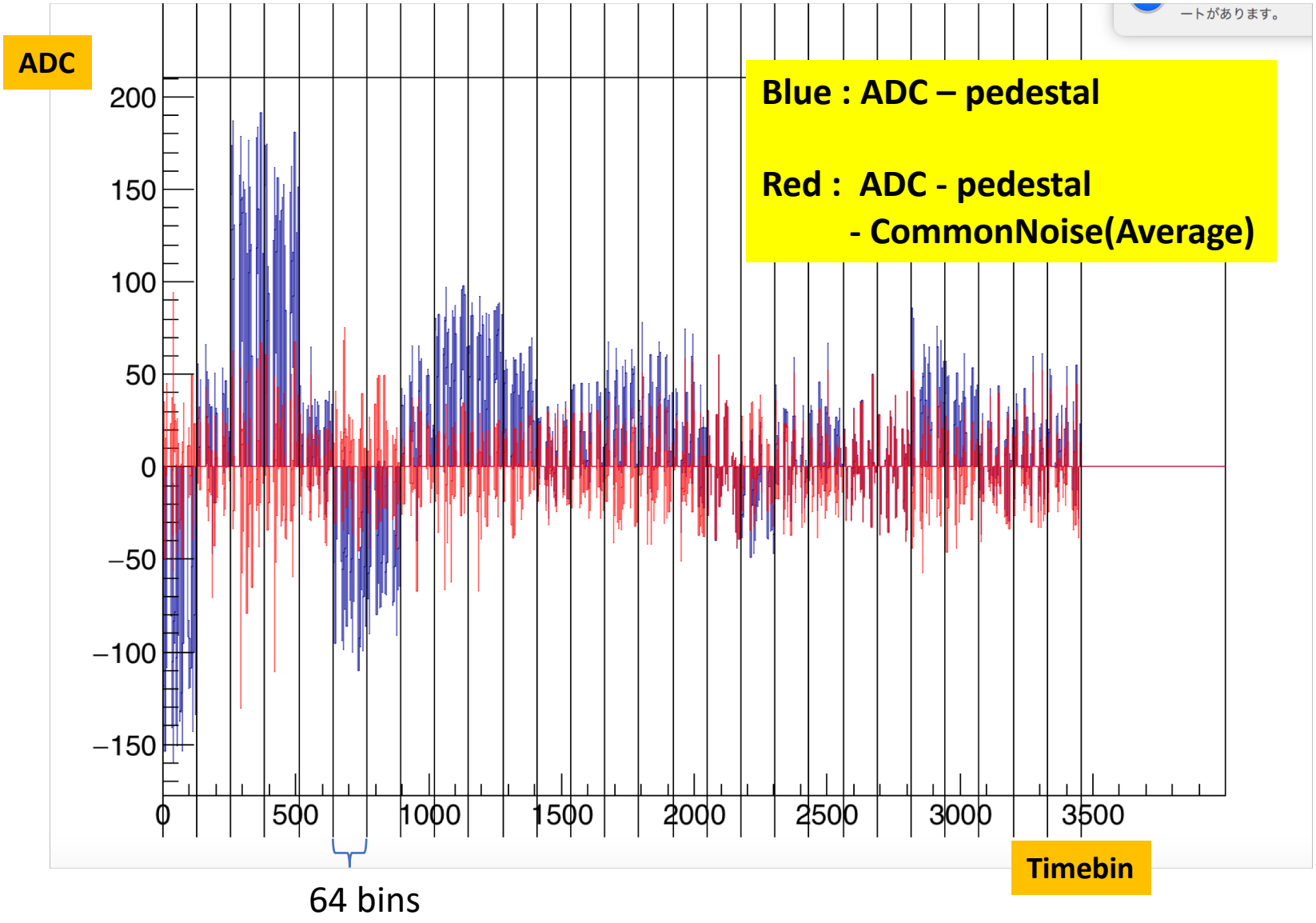
* **Test beam with 1-9 GeV hadron beam at PS**
  - ADC counts corresponding to MIP energy are measured for 8 × 8 Si-pads.
  - MIP peak ≒ 116 ADC counts
  - Variation of Si-detector gain channel by channel is about 15 %.

* **Test beam with 1-5 GeV electron beam at PS**
  - FoCal prototype (1 Si-pad + 3 $X_0$ W) detects pre- EM shower.

* **Test beam with 100-250 GeV positron beam at SPS**
  - Full-evolution of EM shower is observed with full FoCal prototype (20 layers).
  - EM shower maximizes at the 9th layer (= 9 $X_0$)
    → consistent with GEANT4 simulation

★ The analysis of the PS and SPS test beam data is in progress to evaluate the energy resolution and its energy dependence.

# Back up

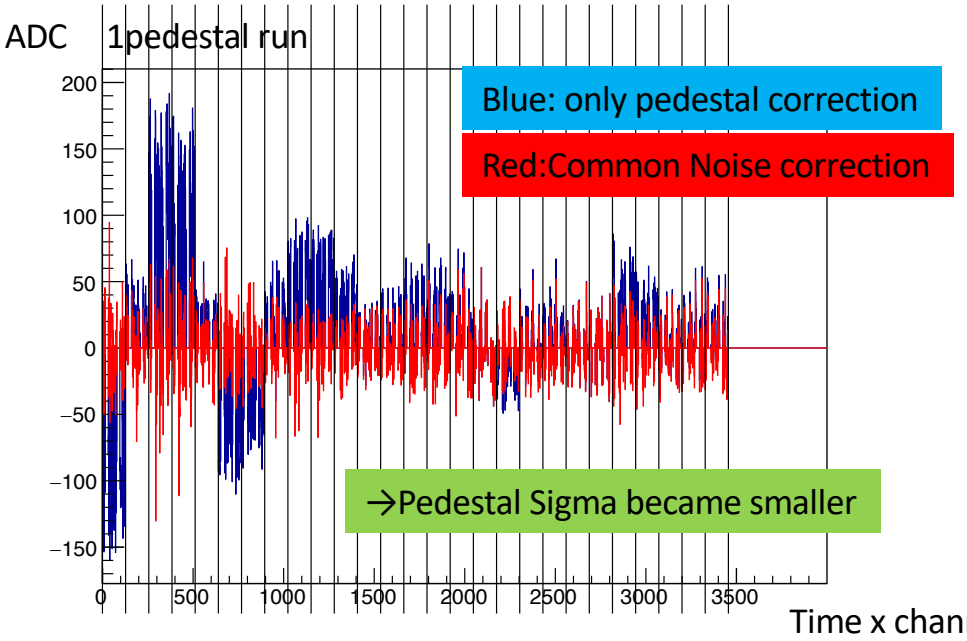

ADC
Blue : ADC – pedestal
Red : ADC - pedestal
- CommonNoise(Average)
200
150
100
50
0
−50
−100
−150
0
500
1000
1500
2000
2500
3000
3500
64 bins
Timebin

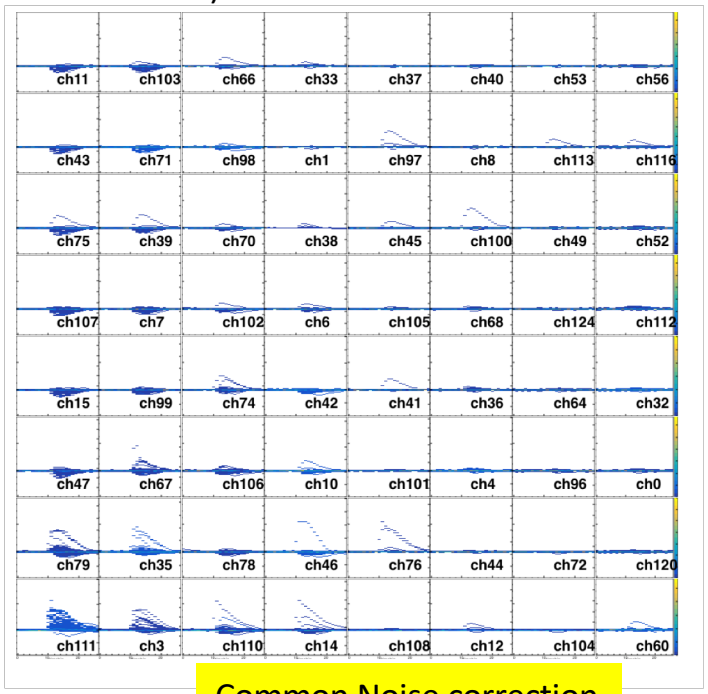
# Noise Cut

Common Noise :

Noise of each time bin
I cut Common Noise each time bin.

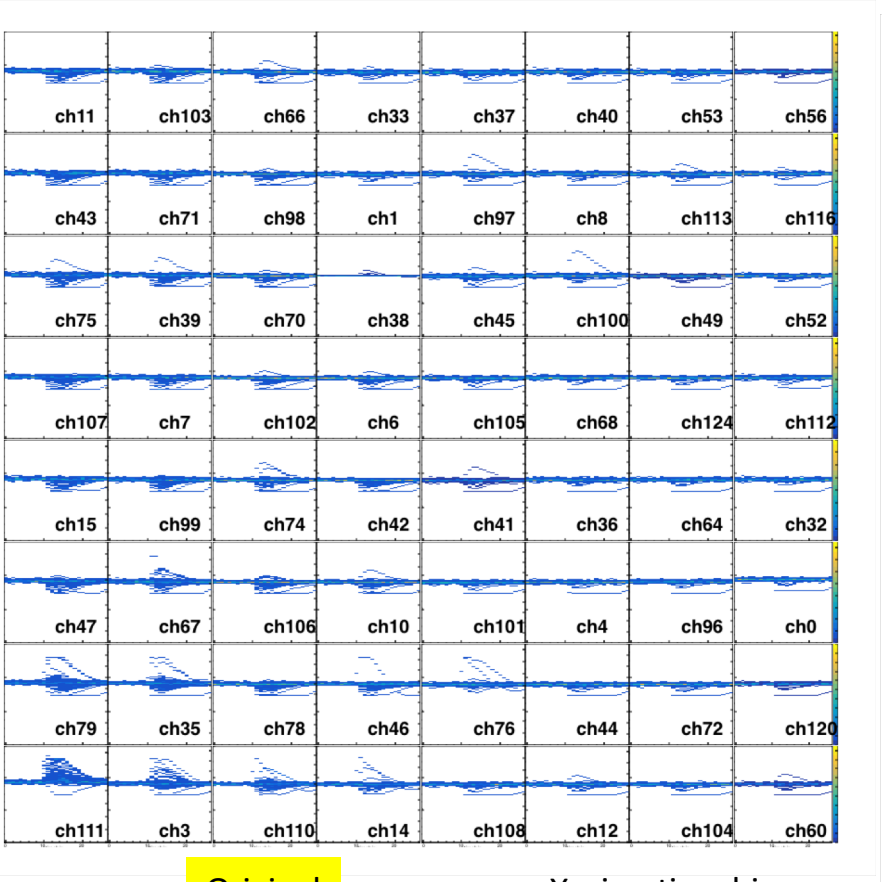
CN=(signal – pedestal) × 63/63 (without dead channel)
→I got this every time bin,
and subtract from signal.

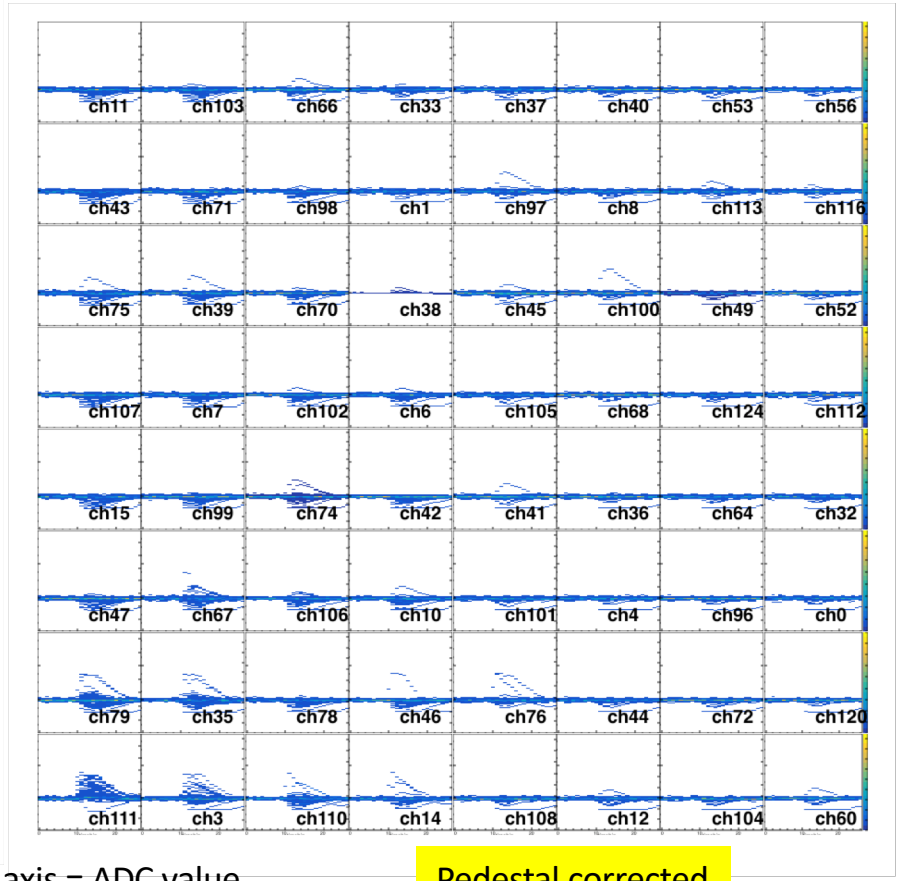



Common Noise correction

# Pedestal Corrected



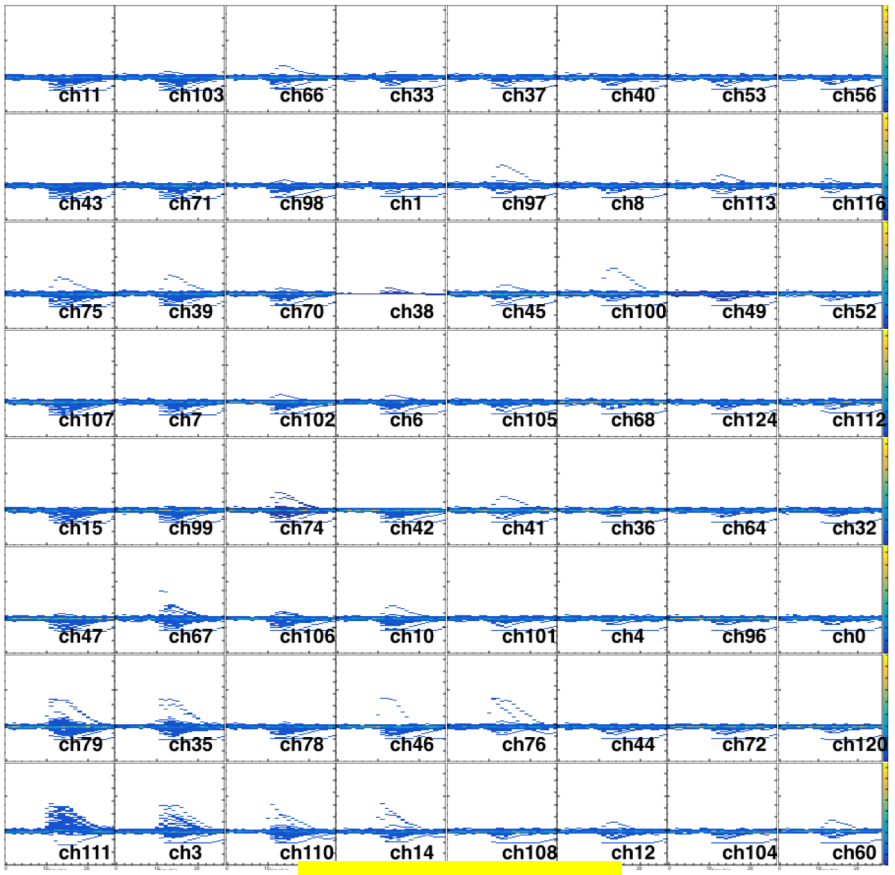




Original

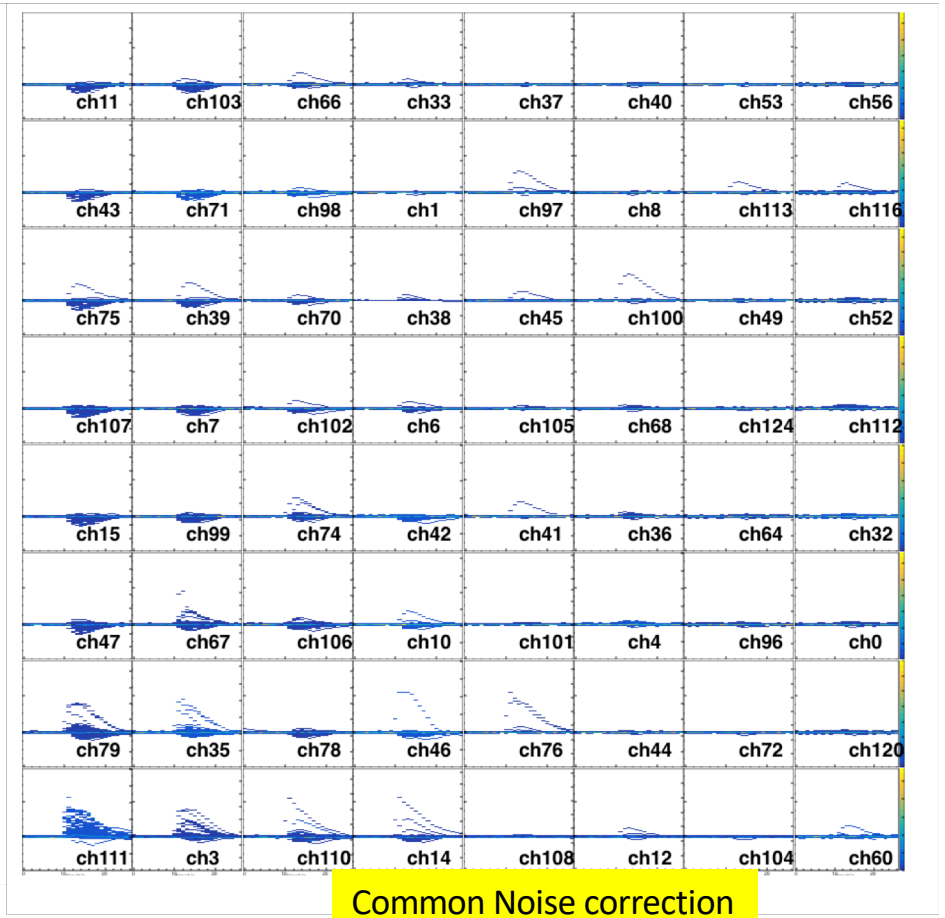
Xaxis = time bin  y axis = ADC value

Pedestal corrected

# Noise Correction

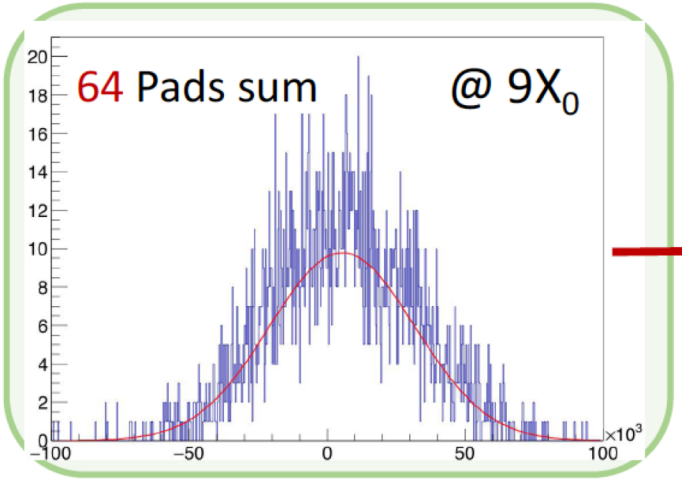


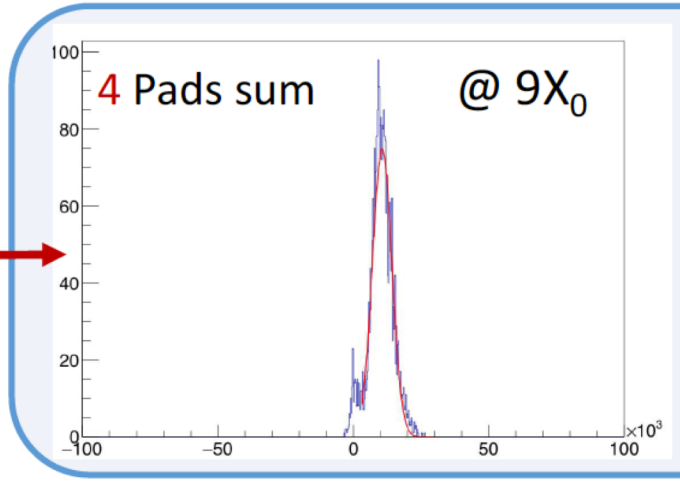

Pedestal correction

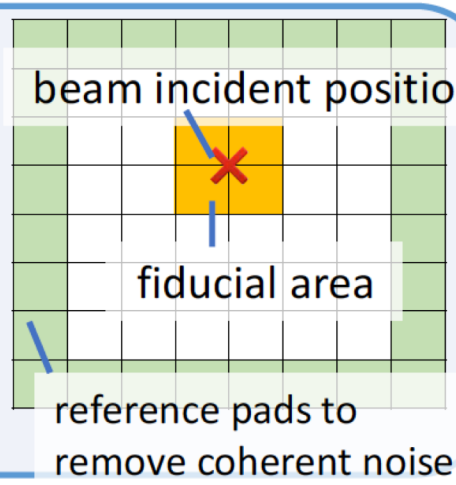


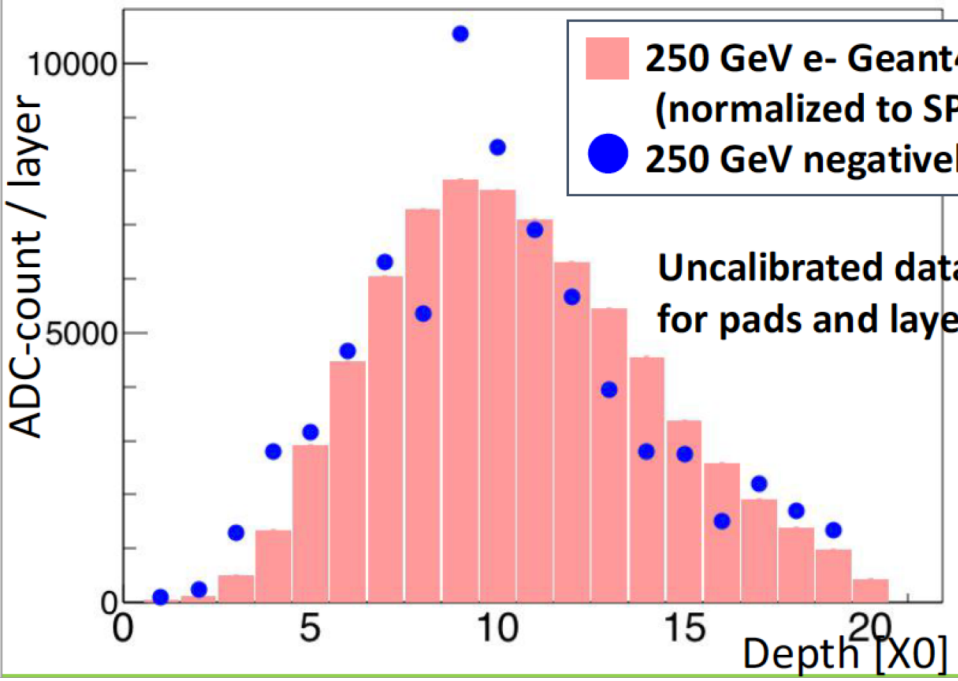

Common Noise correction

# Shower development and convergence



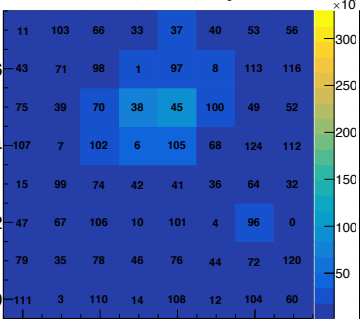



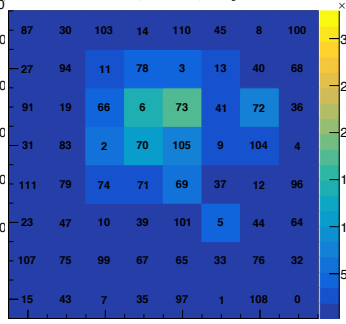




* 4 pads sum and reference pads reduce coherent noise.
* The shower max depth found at $9X_0$ as expected by Geant4 simulation.
* The layer dependence is observed.

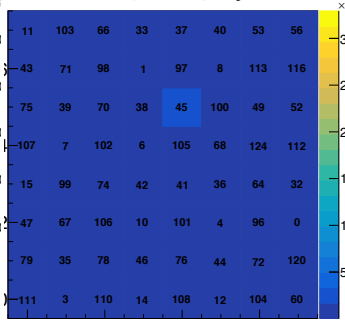
FEC0, APV0, Layer 1



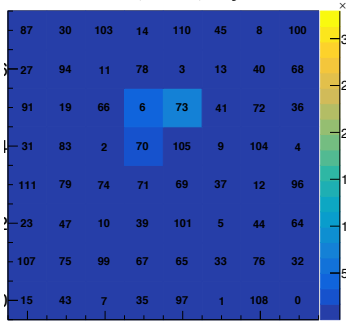
FEC0, APV6, Layer 2



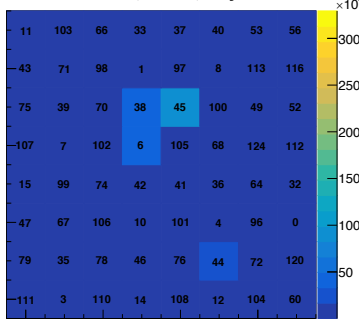
FEC0, APV12, Layer 3



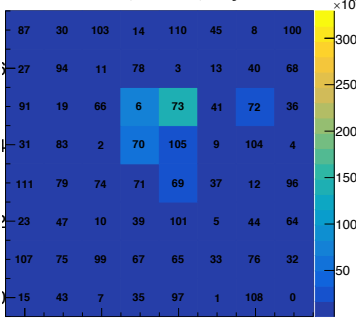
FEC1, APV2, Layer 4



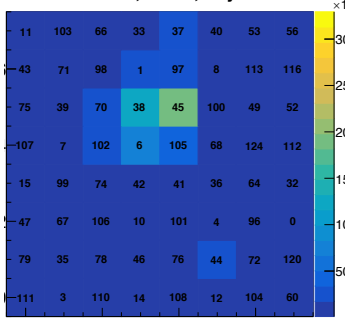
FEC1, APV8, Layer 5



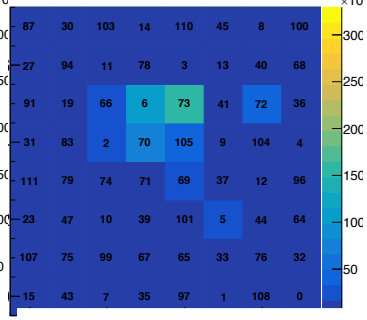
FEC1, APV14, Layer 6



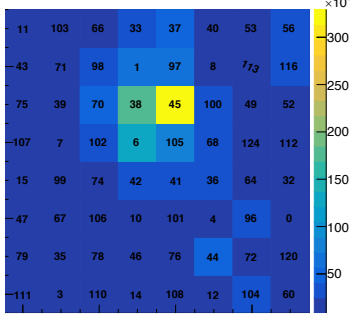
FEC2, APV4, Layer 7



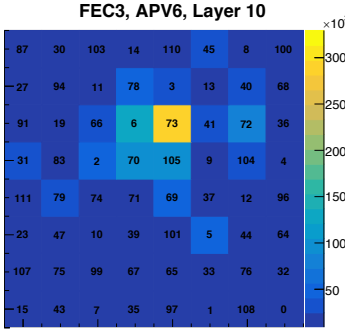
FEC2, APV10, Layer 8



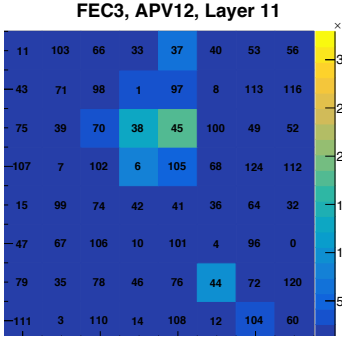
FEC3, APV0, Layer 9



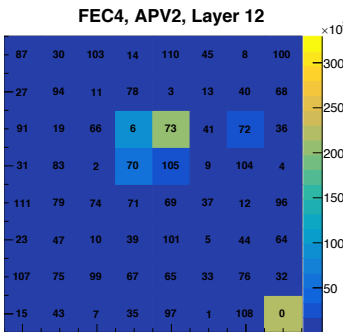
FEC3, APV6, Layer 10



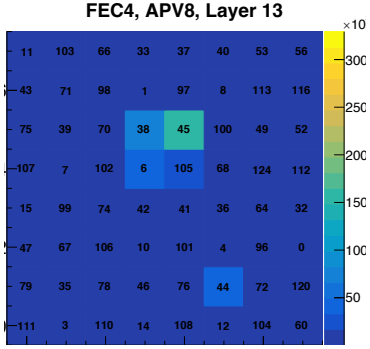
FEC3, APV12, Layer 11



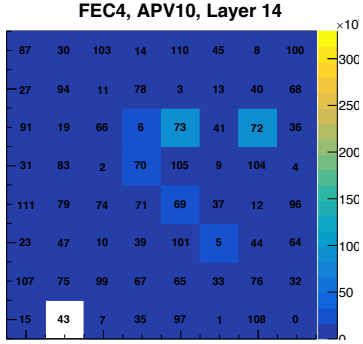
FEC4, APV2, Layer 12



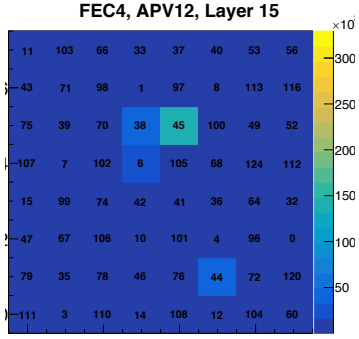
FEC4, APV8, Layer 13



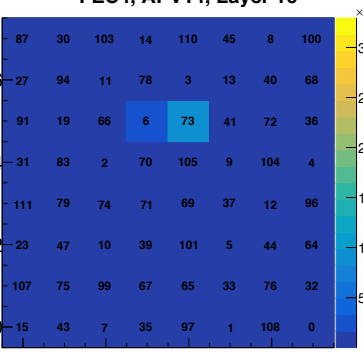
FEC4, APV10, Layer 14



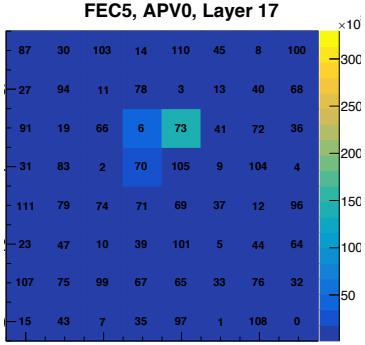
FEC4, APV12, Layer 15



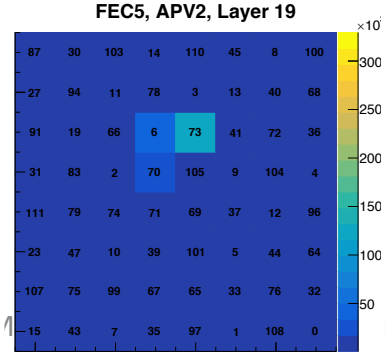
FEC4, APV14, Layer 16



FEC5, APV0, Layer 17



FEC5, APV2, Layer 19



FEC5, APV8, Layer 20