Preparation and operation of SiW-ECAL technological prototype for DESY test beam 2019

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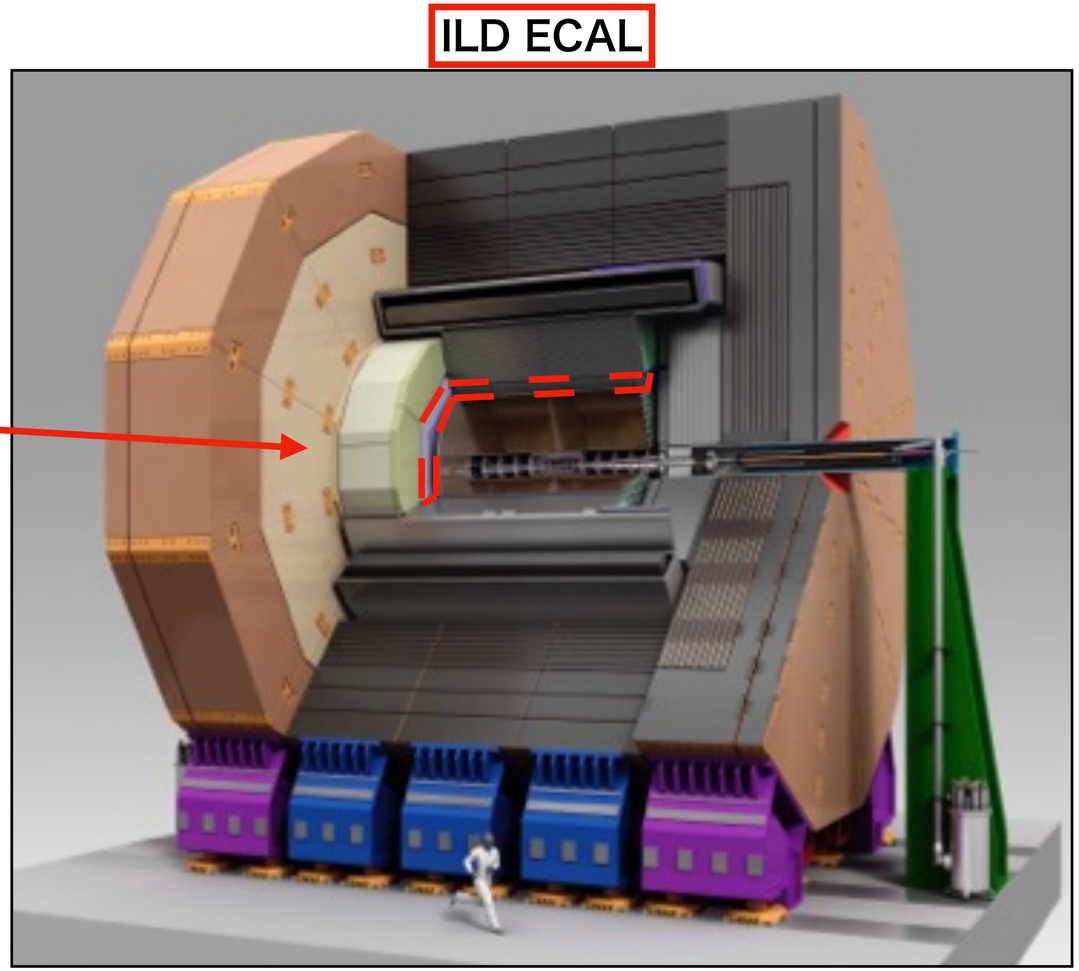
(A: Kyushu University, B: The University of Tokyo, C: LLR, D: LAL)

Contents

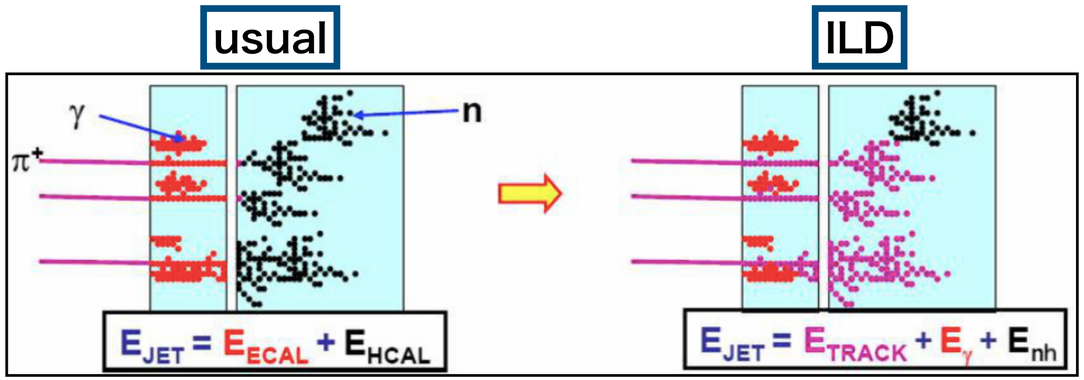
ILD (International Large Detector)

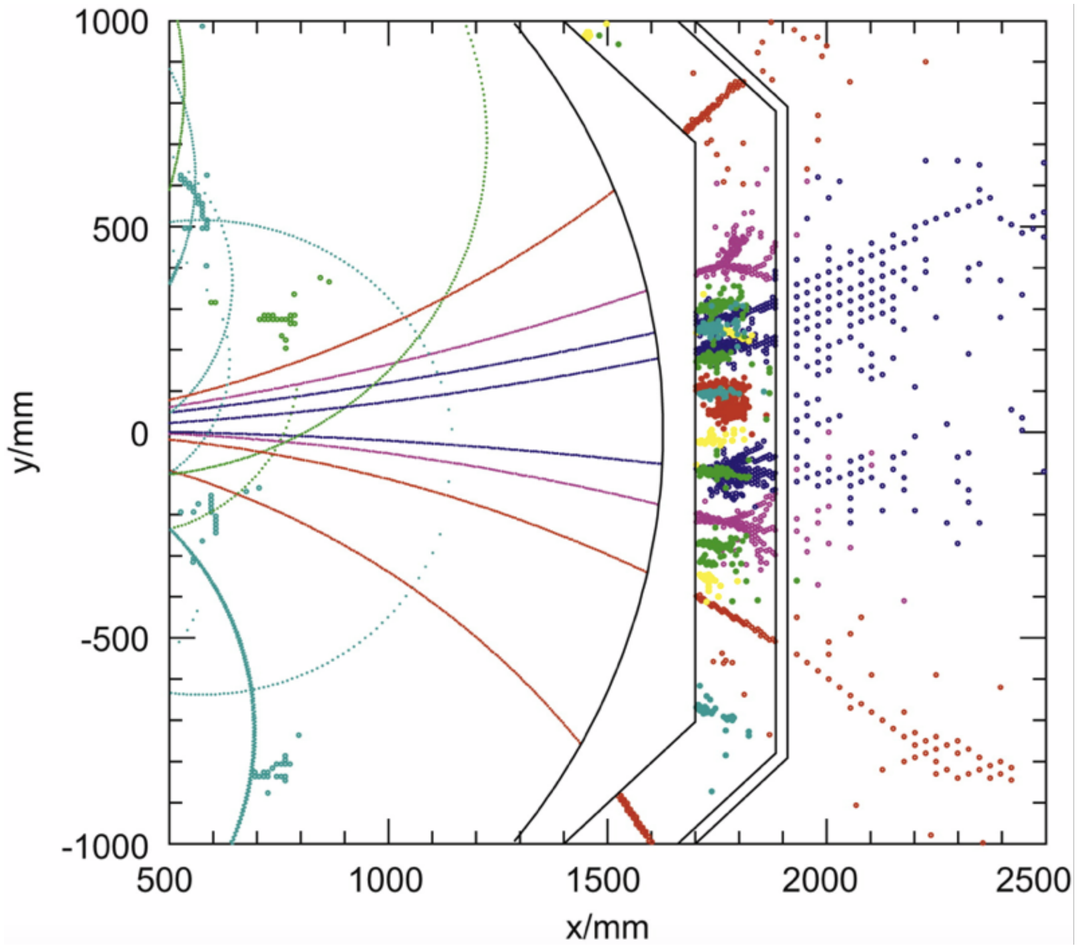
- ILD components
  - Vertex detector
  - Tracking detector
  - Electromagnetic calorimeter
    - ScW-ECAL : using scintillator
    - SiW-ECAL : using Si semiconductor
  - Hadron calorimeter
  - Muon detector



PFA (Particle Flow Algorithm)

- Separation of the particles in jets
- Reconstruction with appropriate detector
  - Charged particle : Tracking detector
  - Photon : Electromagnetic calorimeter
  - Neutral particle : Hadron calorimeter

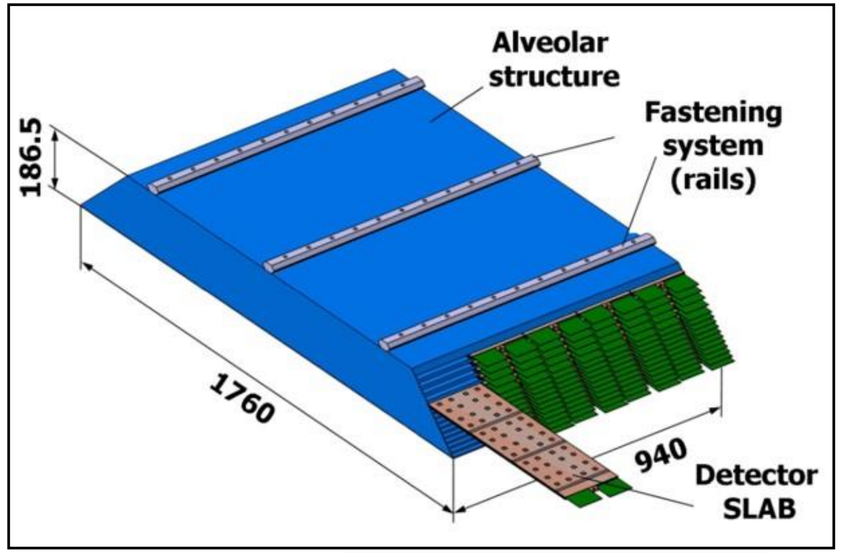


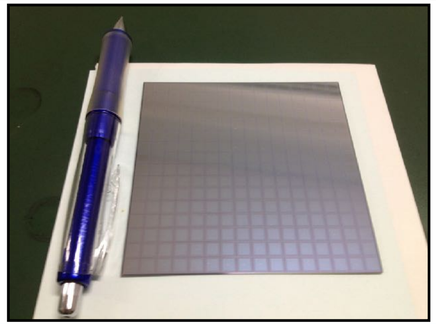


SiW-ECAL

- The electromagnetic calorimeter in ILD is a sampling calorimeter with 20-30 layers
- SiW-ECAL
  - Tungsten (absorber)
  - Silicon (detector)
    - Silicon pixel size : 5 mm × 5 mm
    - Silicon pad : 90 mm × 90 mm (256 pixels)
    - Silicon thickness : 320 μm, 650 μm

one component of ILD ECAL

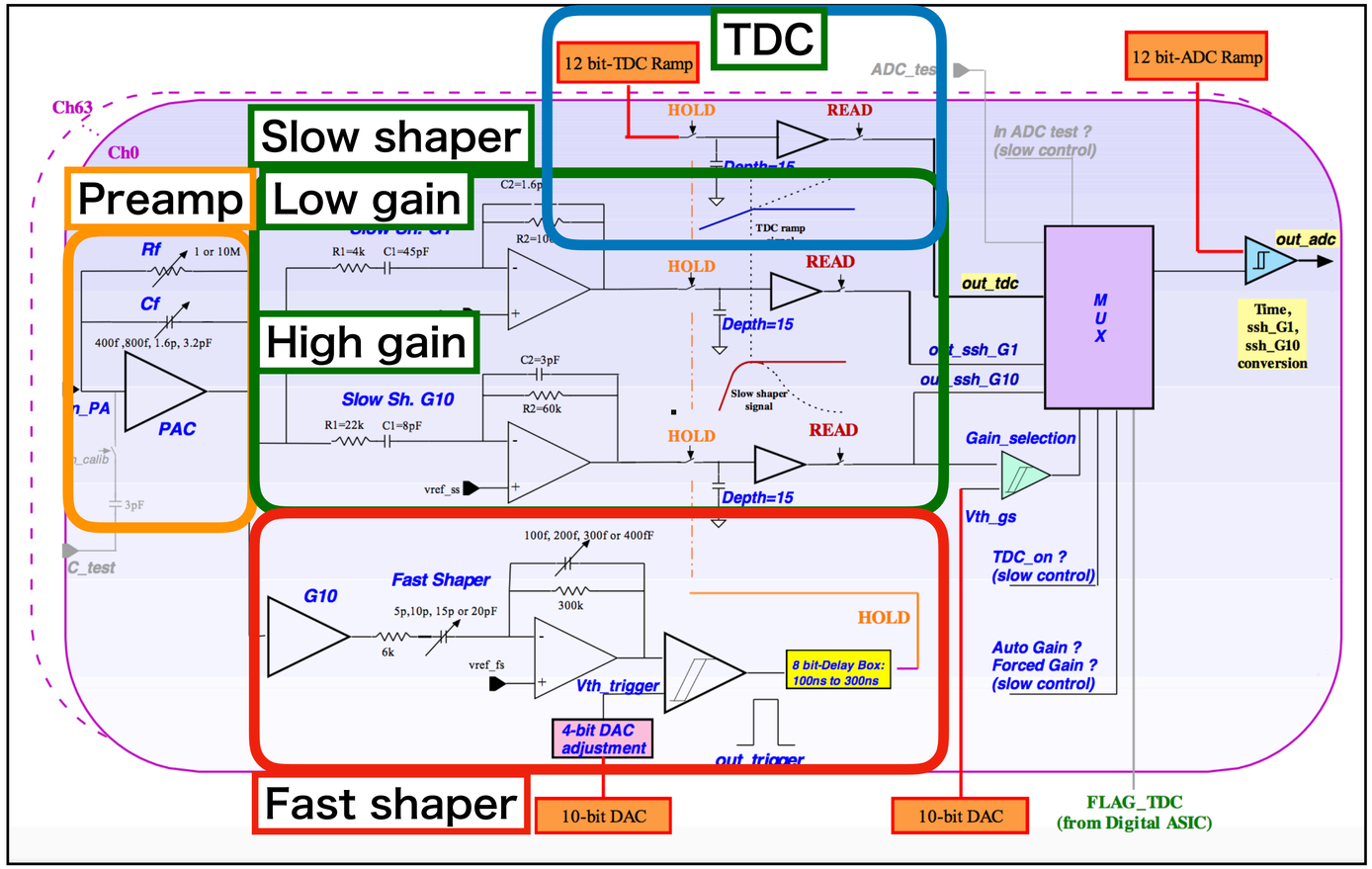




silicon pad

ASIC

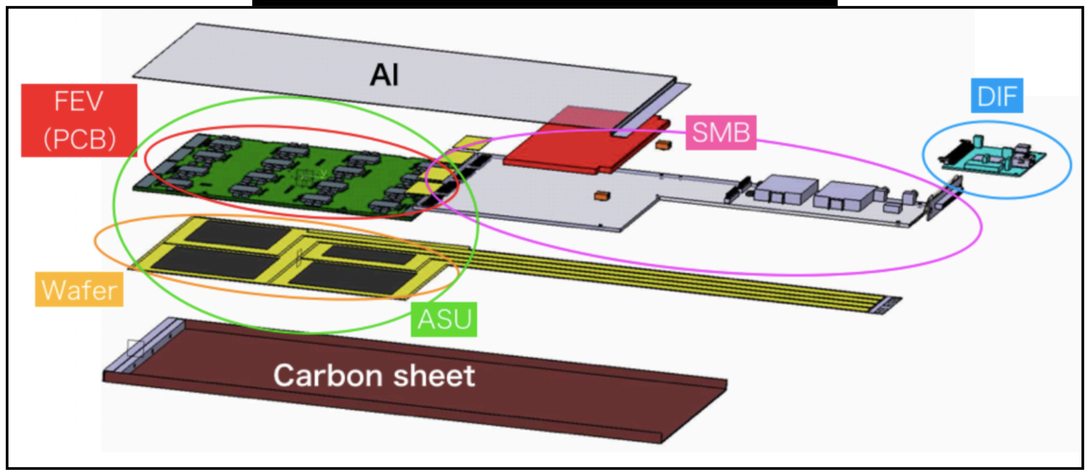
- ASICs (SKIROC2/2A) are used as the integrated circuit for data taking
- SKIROC2A
  - 64 channels
  - 15 memory cells
  - ADC mode
    - ADC high and low gain
  - TDC mode
    - TDC
    - ADC high or low gain



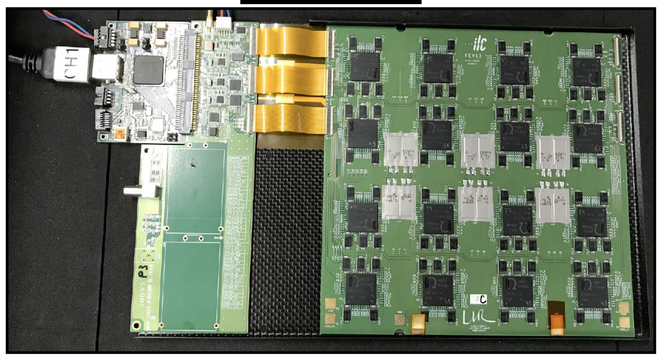
The technological prototype

- Slab : just one layer of the SiW-ECAL
  - One slab has 4 silicon pads (1024 pixels)
  - read by 16 ASICs (1 ASIC : 64 ch)
- Now we are studying FEV13
- FEV11 → FEV13
  - ASIC : SKIROC2 → SKIROC2A
    - improvements on TDC and individual threshold
  - FEV/SMB connection : kapton sheet → cable
    - avoiding to gluing trouble and easily detachable
  - Smaller SMB footprint

slab components (FEV11)



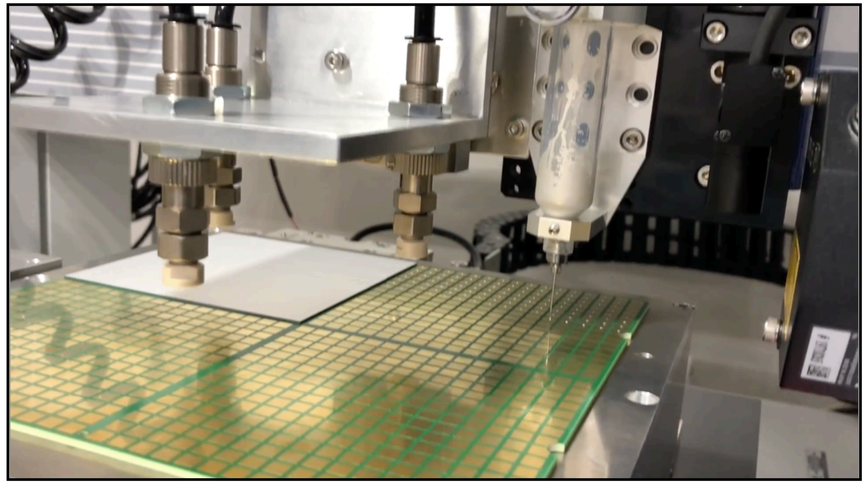
FEV 13

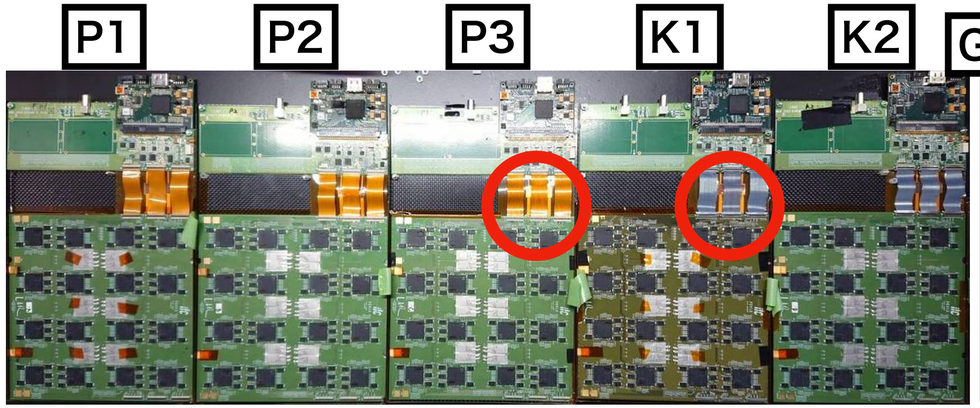


Assembly of the latest model (in Kyushu)

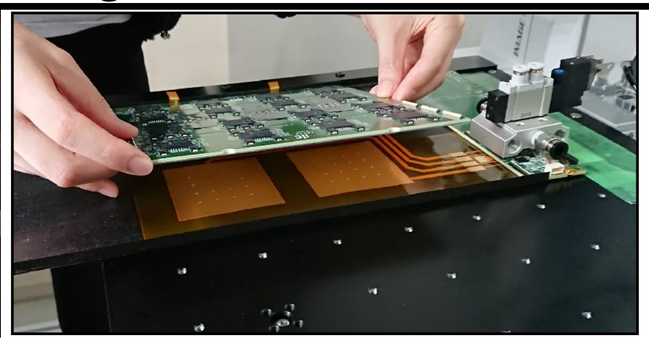
- 5 slabs were assembled in Kyushu University
- Gluing FEV and SMB to FPC
- Si thickness : 320 μm (P3/old), 650 μm (others/new)
  - for higher S/N ratio of charge and compared
- The difference of P and K
  - P : Flexible cable
  - K : Micro-coaxial cable

Gluing sensor to PCB in Kyushu





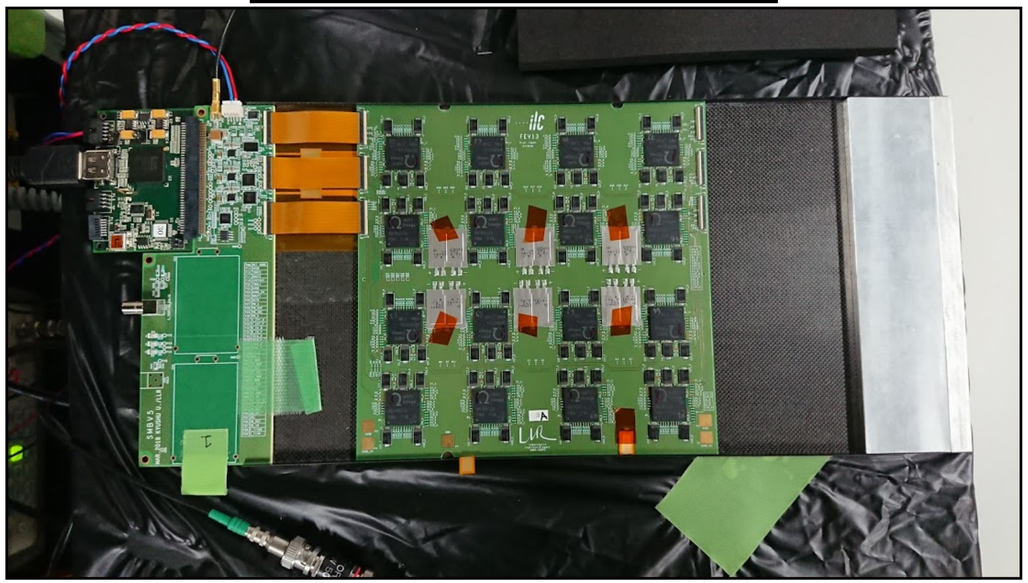
Gluing sensor to flexible circuit



Previous Test Beams

- 2018 (DESY)
  - Evaluation using the just one slab
  - Particle : electron (1 - 5 GeV)
  - We use the rigid PCB for HV connection

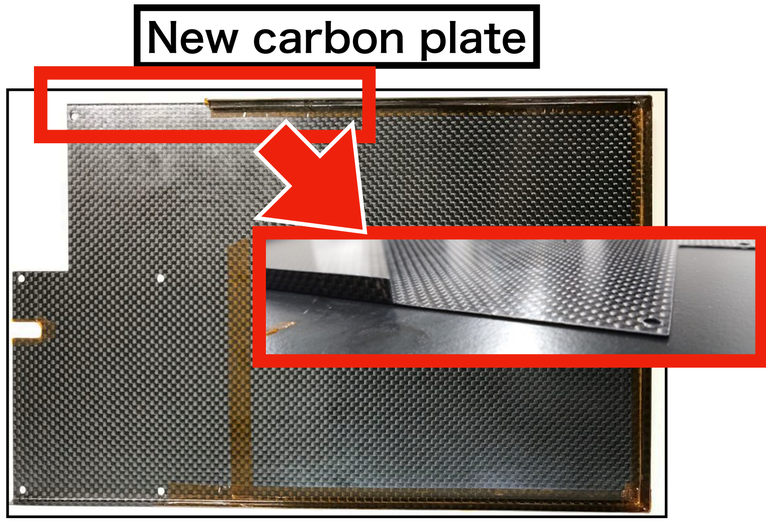
with older carbon plate

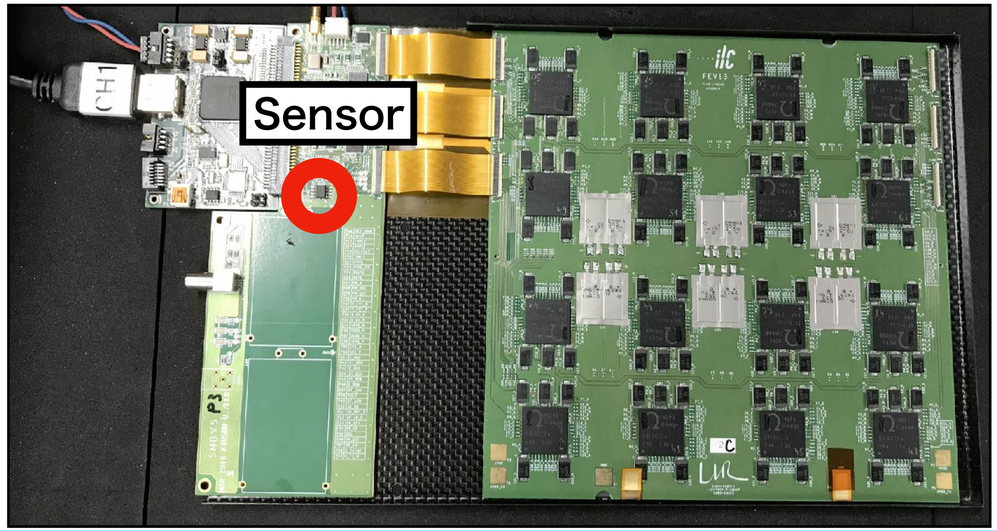


- 2018 (CERN/SPS)
  - Evaluation using the 5 slabs
  - Particle : muon, electron, pion (10 - 200 GeV)
  - HV connection was replaced to flex circuit
  - 4 slabs had the problem in HV → could take good data with only one slab because of the carbon plates of older model (FEV8)

Update from previous TB

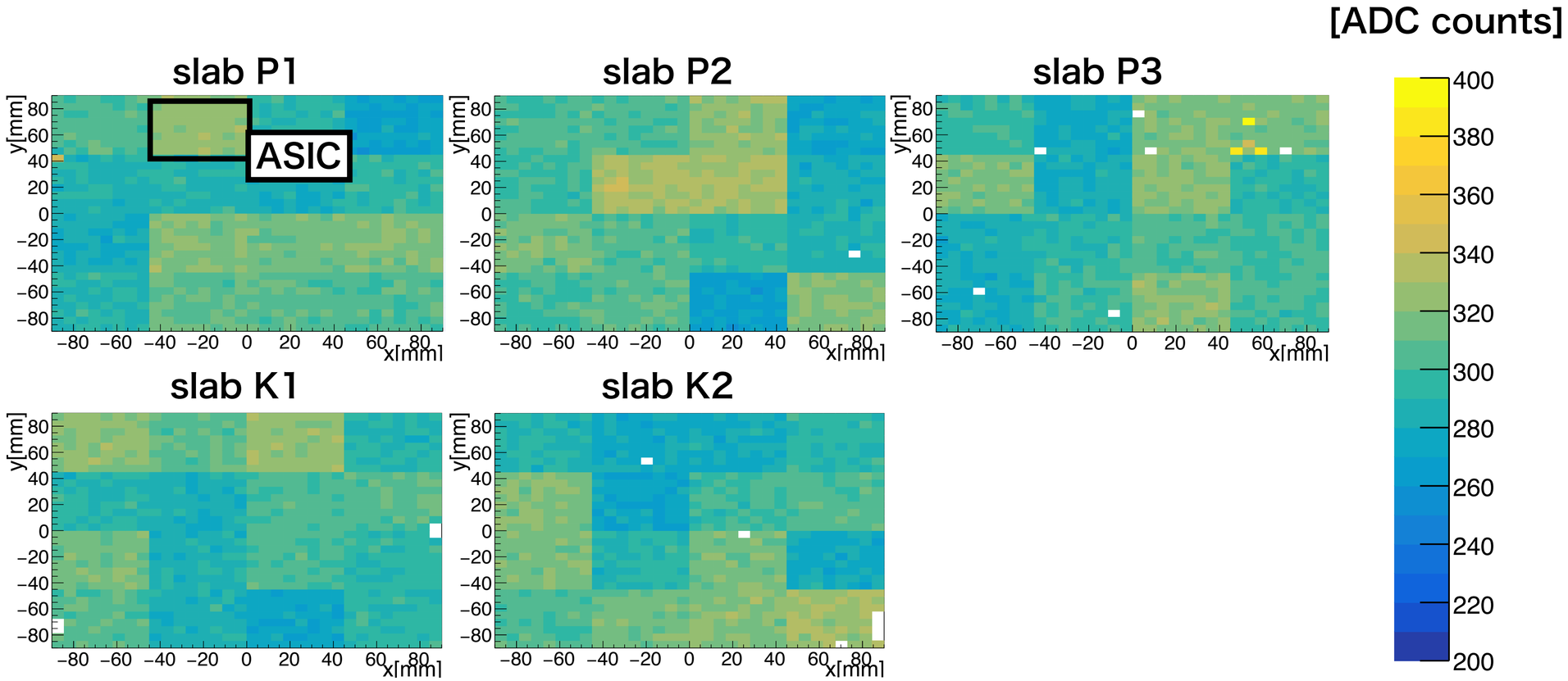
- Replace the carbon plate on the backside
- New carbon plate :
  - **improvement** cut the edge of the HV connector side
  - **improvement** pushing with screw
  - **problem** leakage current
- Temperature monitoring
  - Temperature monitoring by a chip on SMB prepared
  - Periodical temperature acquisition performed





Laboratory Test (1)

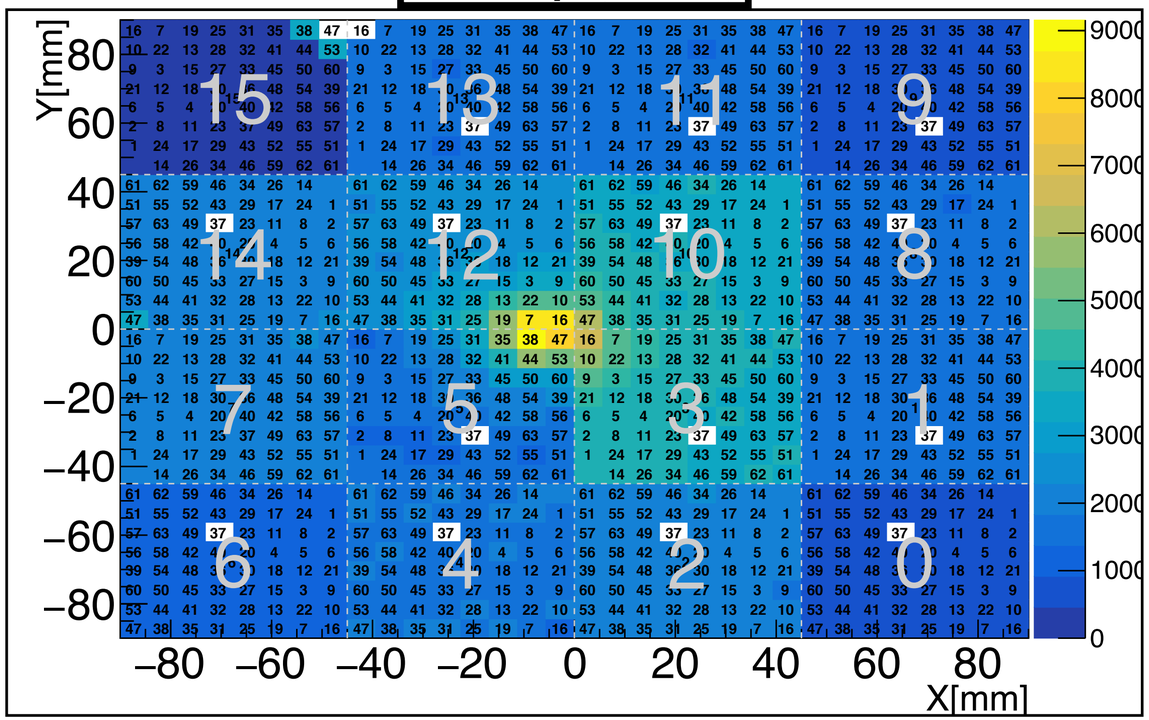
- Pedestal means for all channels are measured with thermal noise
- Pedestal means are almost same within each ASIC chip



Laboratory Test (2)

- Data acquisition test with radiation sources
- Data were measured using the ^{133}Ba and ^{57}Co as gamma radiation sources
  - ^{133}Ba :
    - 356 keV (62.1%)
      - Compton edge : 207 keV
    - 81.0 keV (34.1%)
  - ^{57}Co :
    - 122 keV (85.6%)
    - 136 keV (10.7%)

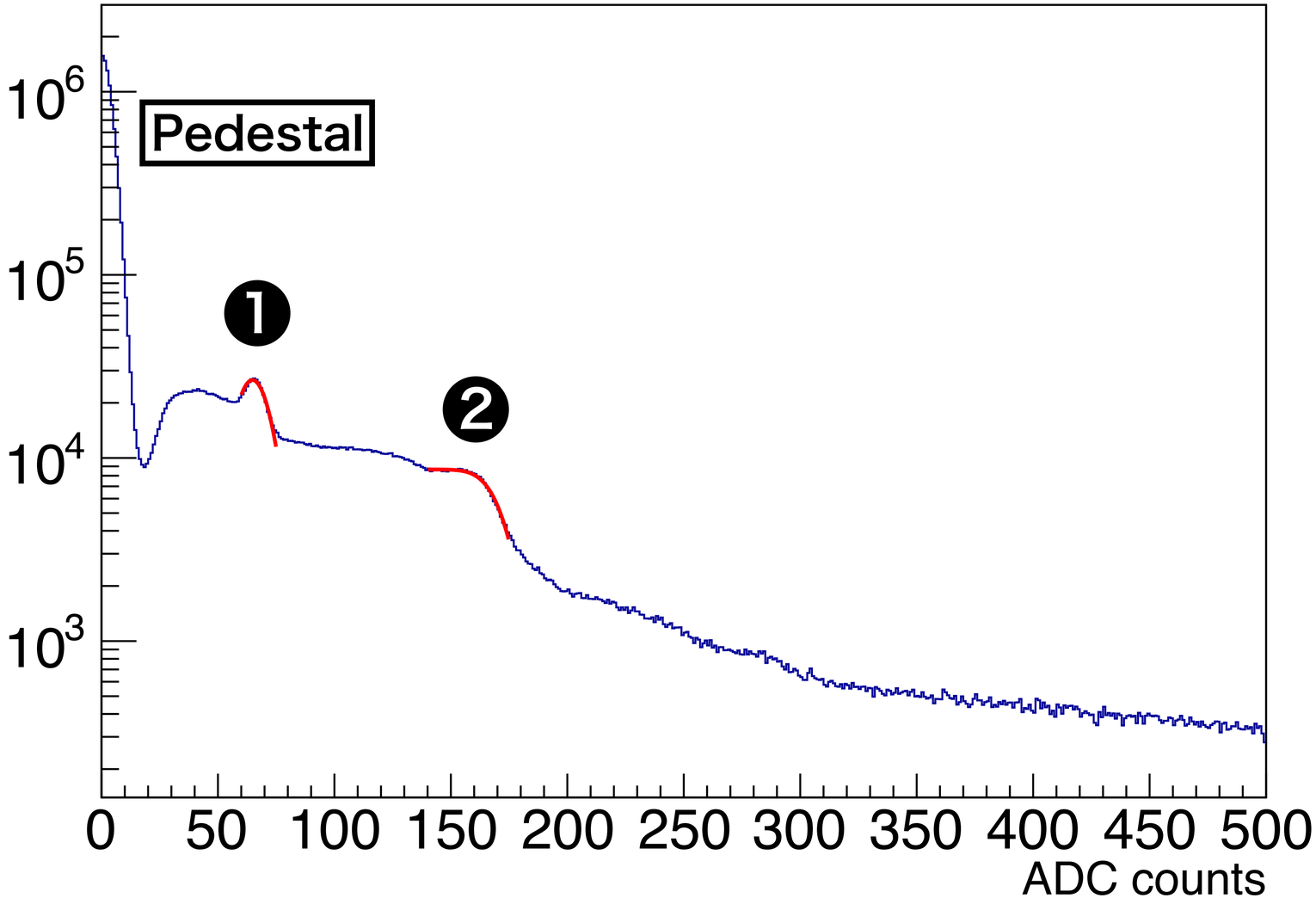
Hit map (^{133}Ba)



sources

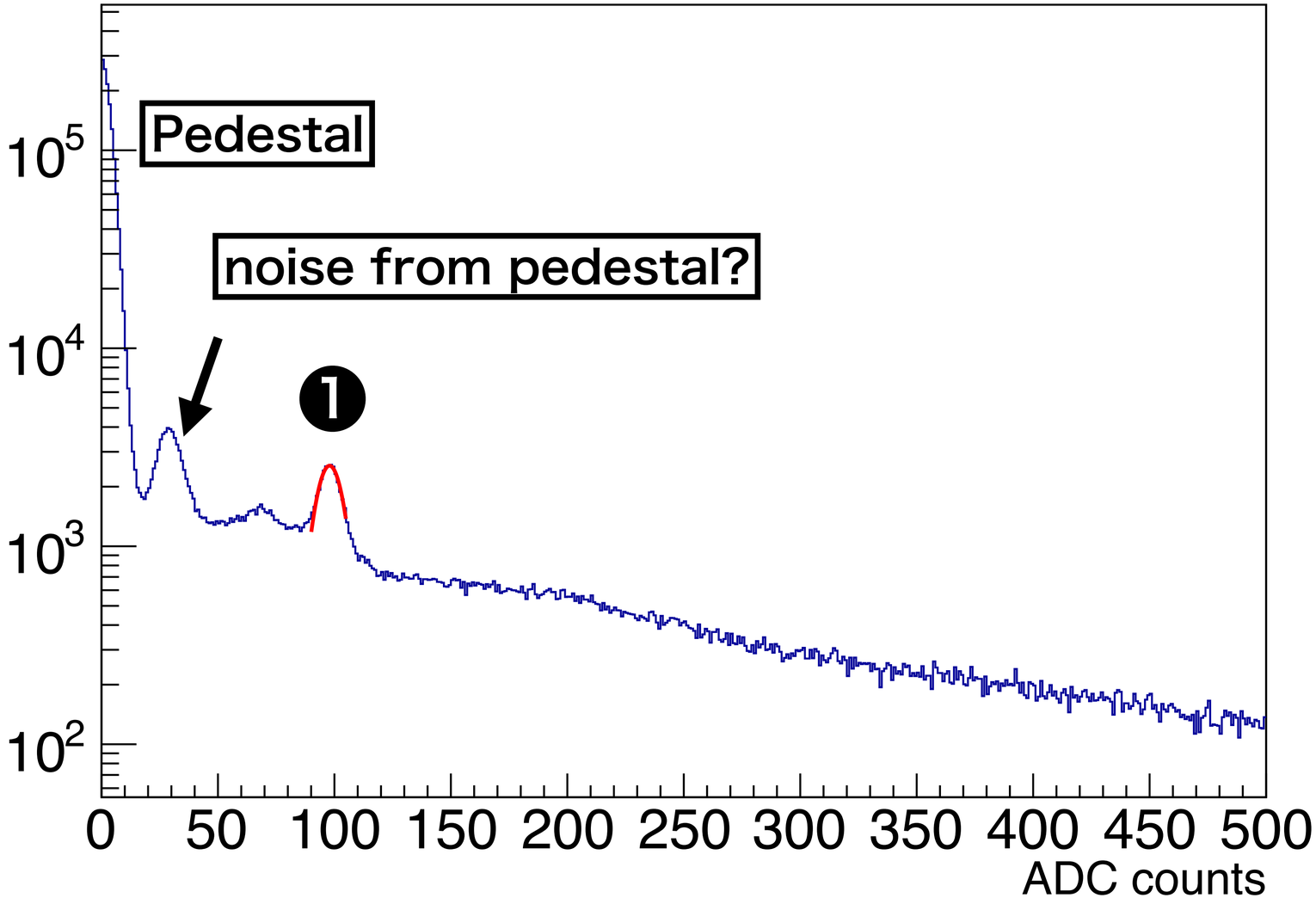
Laboratory Test (2)

- ^{133}Ba ADC Histogram
- ❶
  - Photoelectric peak
  - 81.0 keV
  - 64.8 ADC counts
- ❷
  - Compton edge
  - 207 keV
  - 173 ADC counts



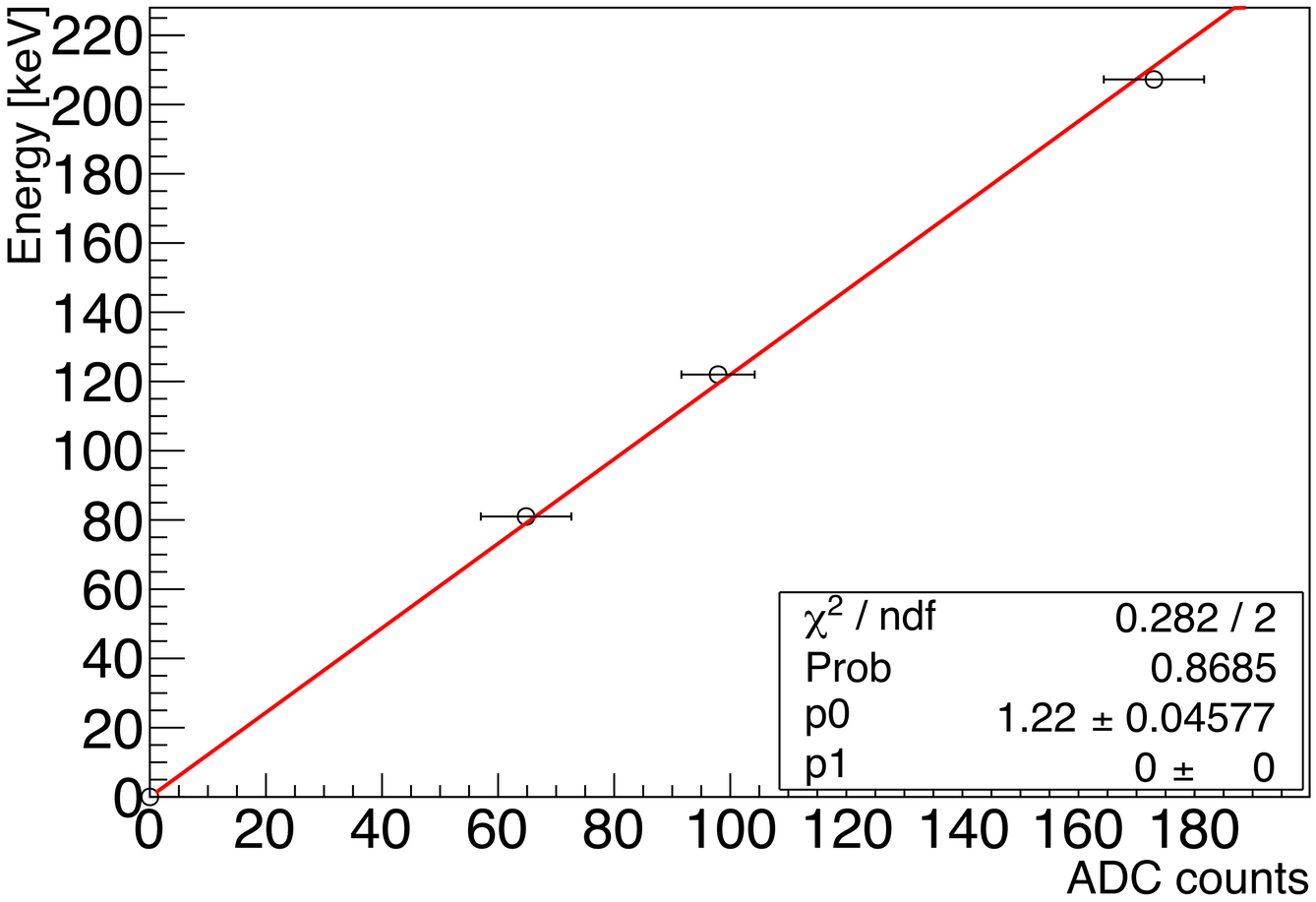
Laboratory Test (2)

- ^{57}Co ADC Histogram
- ❶
  - Photoelectric peak
  - 122 keV
  - 97.9 ADC counts



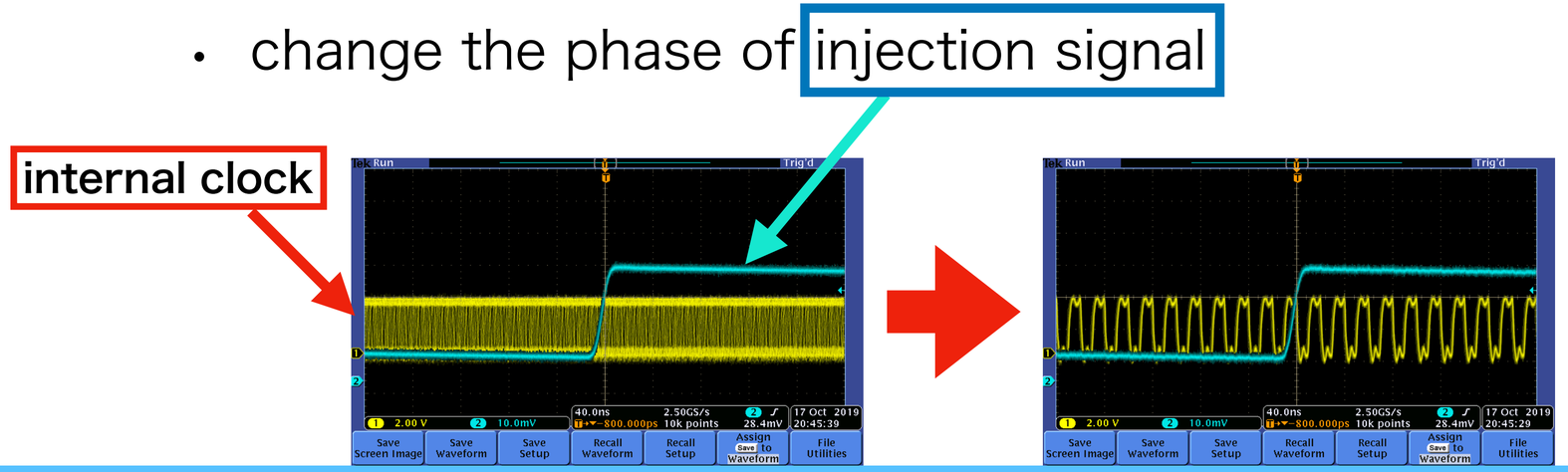
Laboratory Test (2)

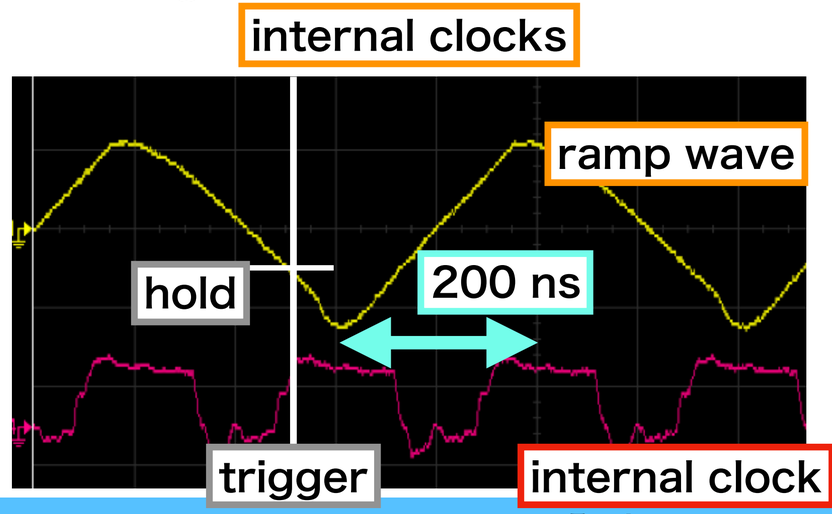
- Linearity of the ADC counts and Energy



Laboratory Test (3)

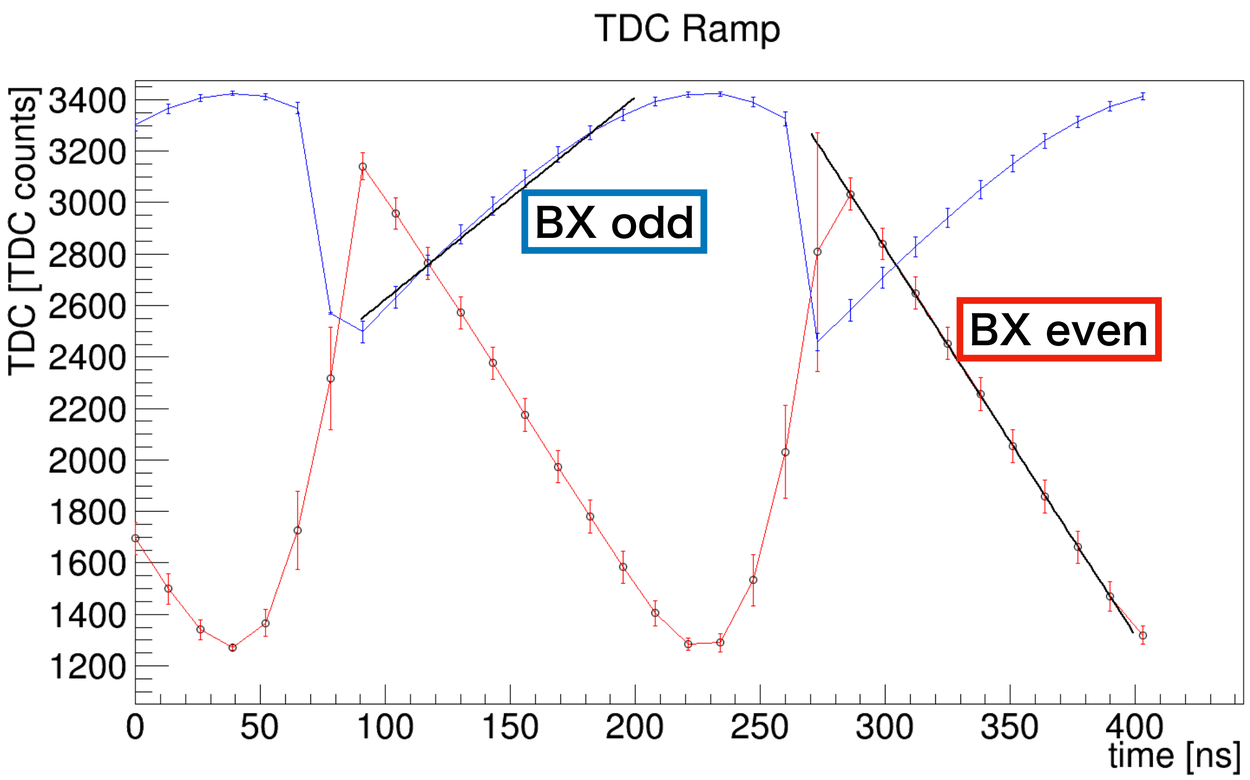
- TDC mode operation test
- SKIROC2/2A has the ramp wave as one of the internal clocks
  - I measured this ramp waveform for calculating from TDC to real time factor
- The ramp wave can be measured with
  - synchronization of internal and external clock (injection signal)
  - change the phase of injection signal





Laboratory Test (3)

- Using the following parameters
  - bunch crossing (BX) clock : 5 MHz
  - Injection frequency : 200 kHz
  - Injection voltage : 8.4 fC
    (~1 MIP with 650 μm Si)
  - Threshold (trigger) : 230



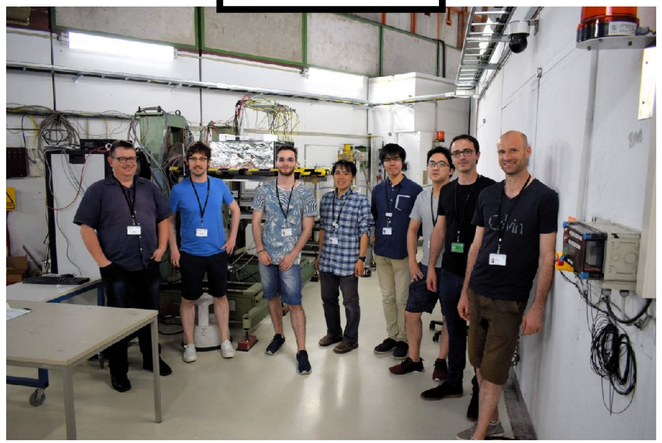
- TDC to real time calibration factors
  - 0.127 ns / TDC count (up)
  - 0.066 ns / TDC count (down)

the previous study using test board
0.094 ns / TDC count (up)
0.080 ns / TDC count (down)

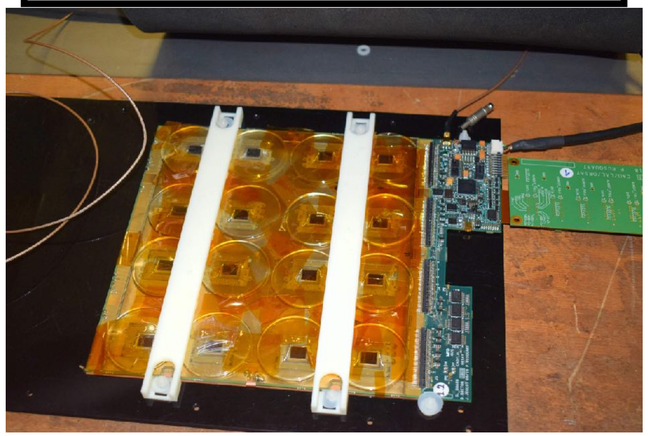
Test Beam 2019 (1)

- Purpose :
  - Data acquisition with electron beam (MIP, Shower)
  - Operation test (TDC, Auto Gain, etc.)
- 24th June 2019 - 7th July 2019 (DESY)
- Beam Status : electron, 1 - 5 GeV
- Setup : 5 slabs (Kyushu) and
  4 slabs including 2 Chip-In-Boards (France)
  - MIP (without tungsten)
  - Shower (with tungsten)

Members



Chip In Board using FEV12

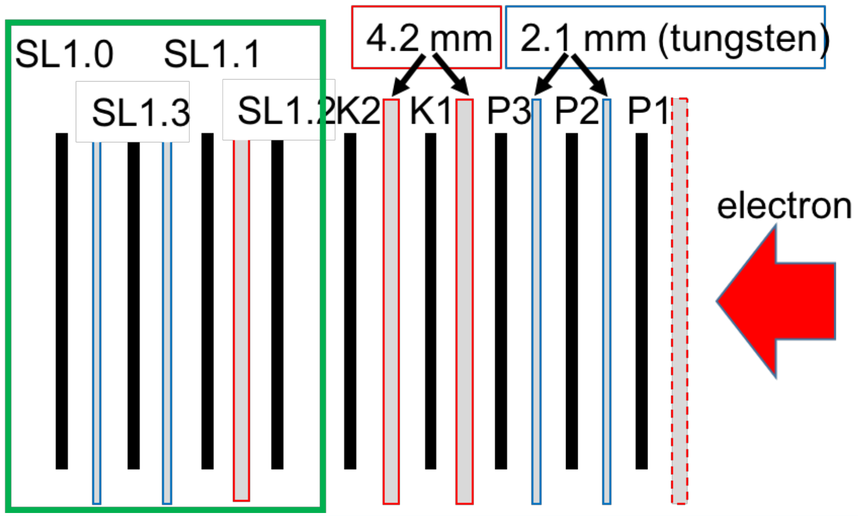


Test Beam 2019 (2)

- The box was used in TB2019
  - 5 slabs (Kyushu) were installed to this box
  - 4 slabs including CIBs (France group) were also installed
- The order of slabs is shown by the picture
- In shower setup,
  We use two patterns of tungsten thickness
  2.1 mm and 4.2 mm

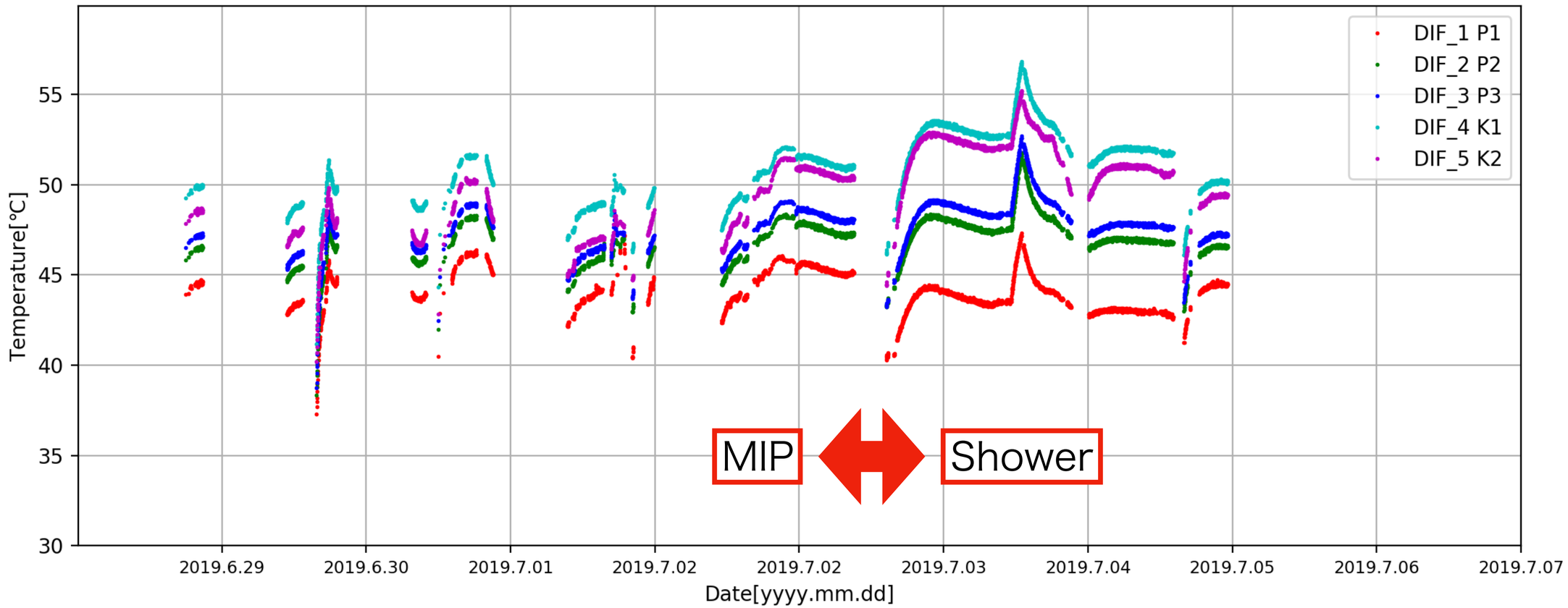
box used in TB2019

Shower setup



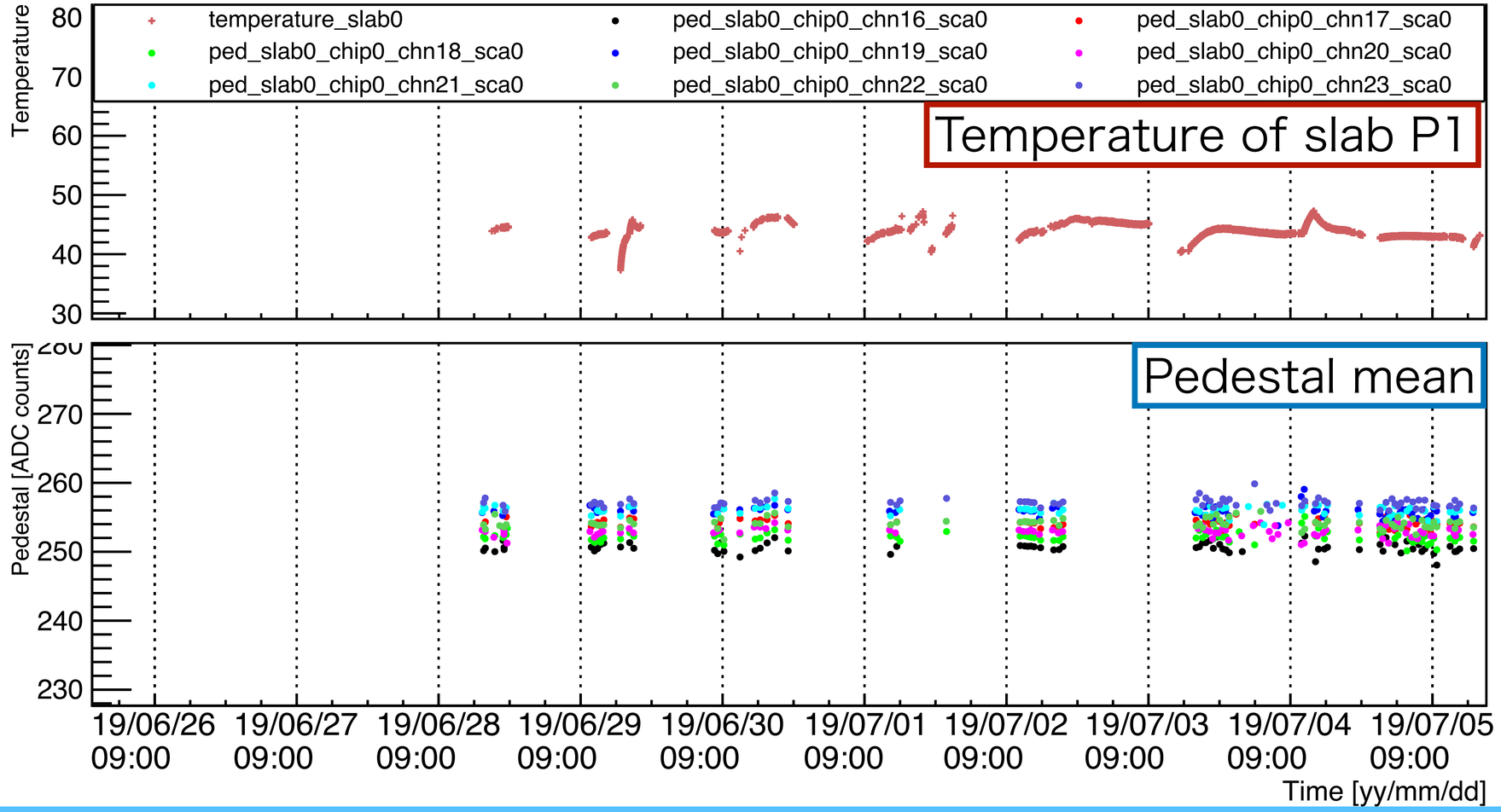
Temperature for all slabs

- Time variation of temperatures for all slabs



Temperature and Pedestal mean variation

- Time dependance of the temperature and pedestal mean

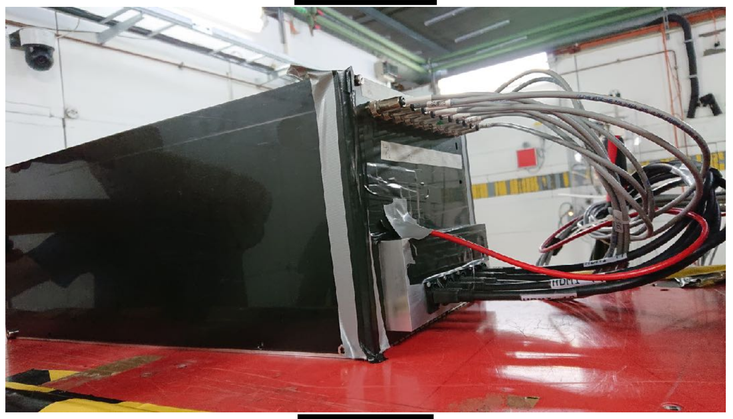


Connection issues

- We could take good data in this TB
- Some issues were happened for connections
- HDMI connection
  - HDMI connections are unstable and loose
- HV connector
  - HV connectors are too fragile
- Complicated cable connections
  - Three cables per a slab must be connected to outside of the box
- We should improve these issues

Complicated cable connection

outer



inner

Summary and next plan

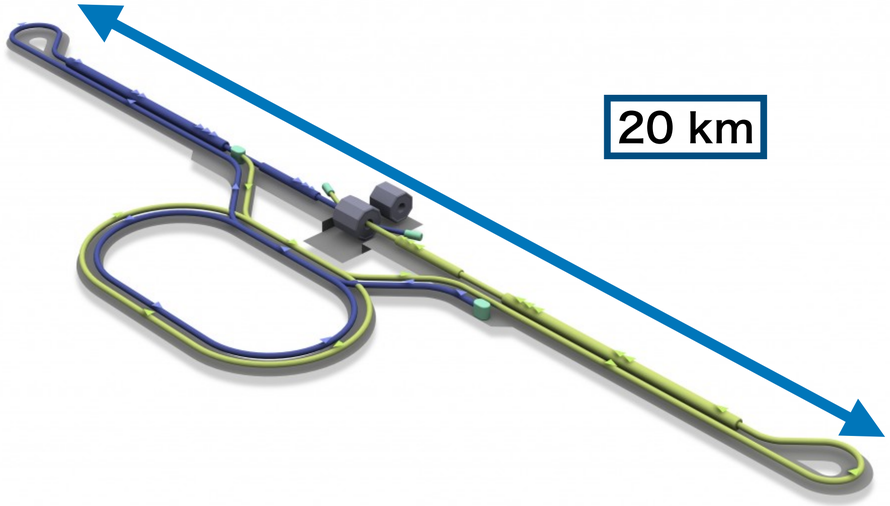
- Summary
  - Now, reading circuit for SiW-ECAL is optimized
  - We improved the slabs from previous TB
  - We measured ADC data using two gamma radiation sources
  - We calculated TDC calibration factors with charge injections
  - Detailed analysis results for this TB are shown in the next talk

- Next plan
  - measurement of TDC for all channels
  - solving these problem and making new version prototype

backup

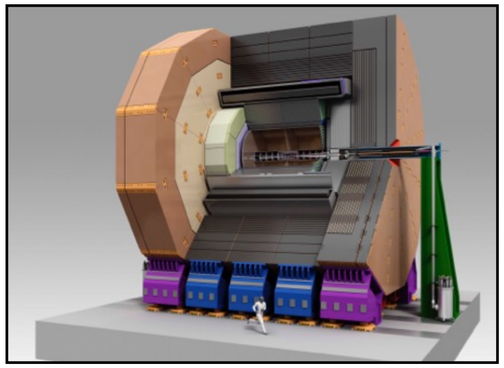
ILC (International Linear Collider)

- Collision of the electron and positron
- Center of mass energy : 250 GeV
- Exploring new physics by precise measurement of the SM particle, especially higgs

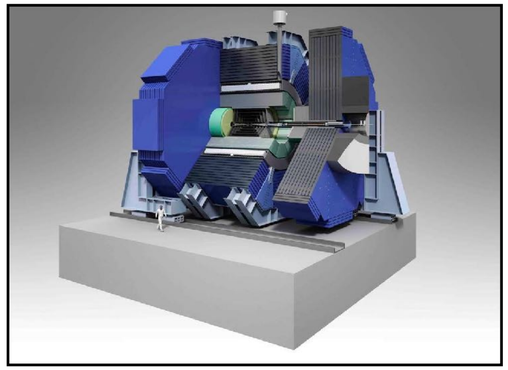


- Two candidates of the detector
  - ILD (International Large Detector)
  - SiD (Silicon Detector)

ILD

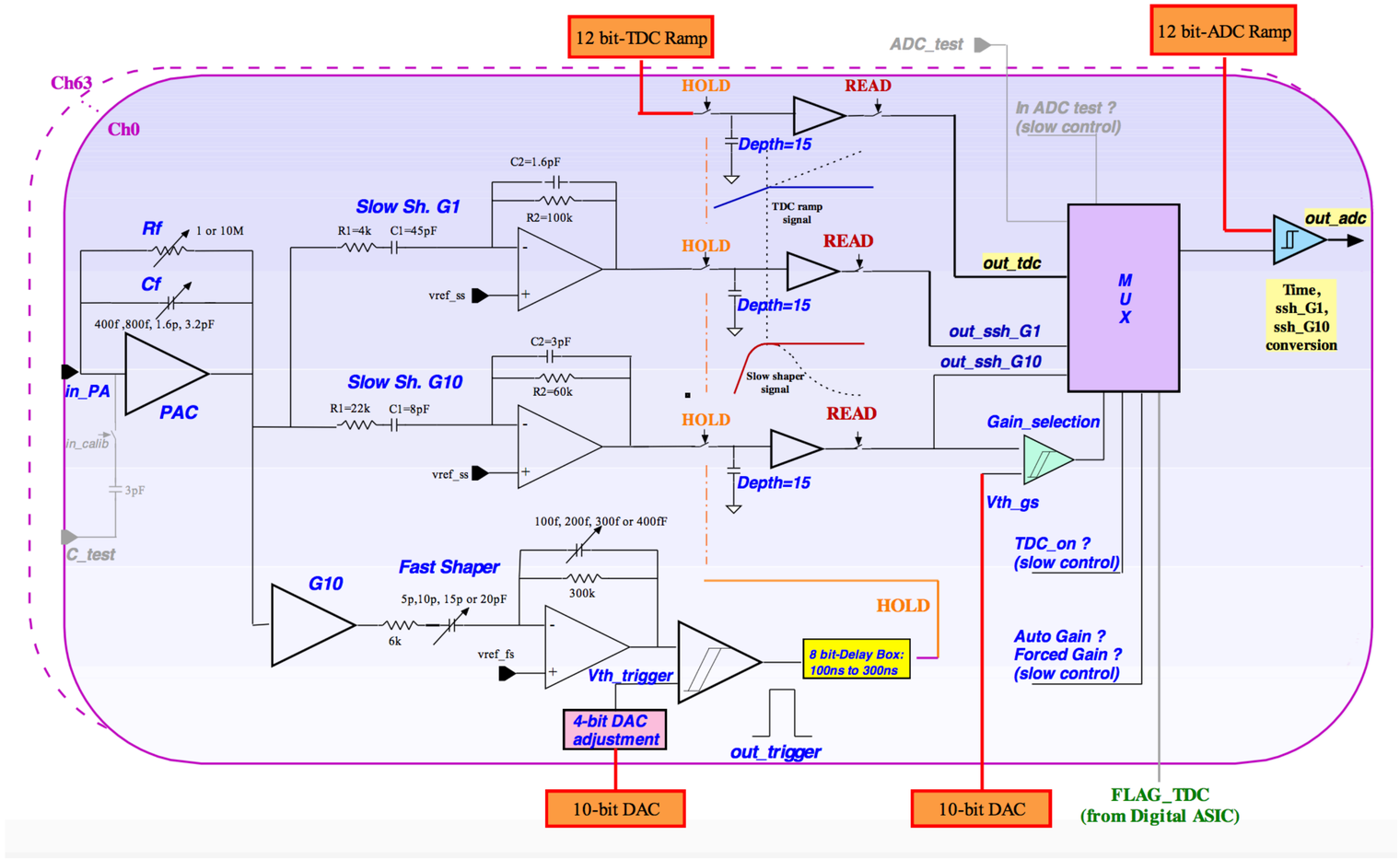


SiD



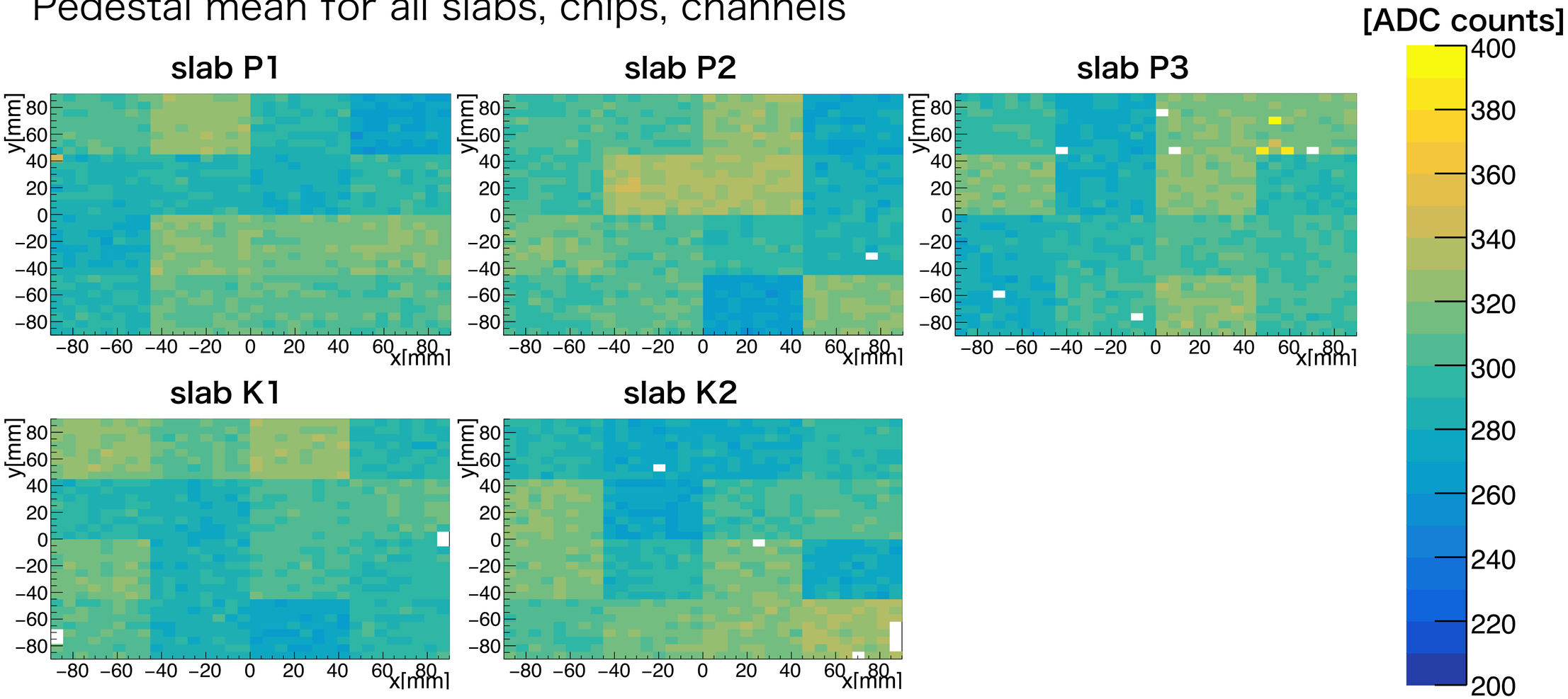
ASIC(SKIROC2/2A)

- 15 memory cells
- trigger : 0.5 MIP
- high gain : 0.5 - 150 MIP
- low gain : 150 - 2500 MIP
- to protect Re-trigger



Pedestal mean

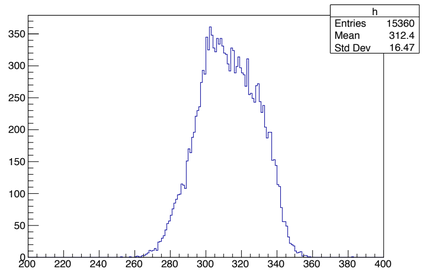
- Pedestal mean for all slabs, chips, channels



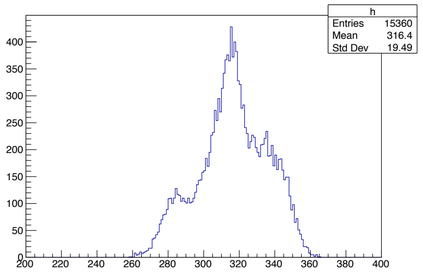
Pedestal distribution

- Pedestal mean distribution

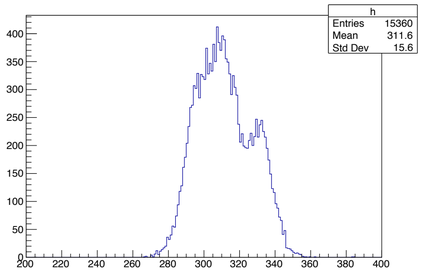
slab P1



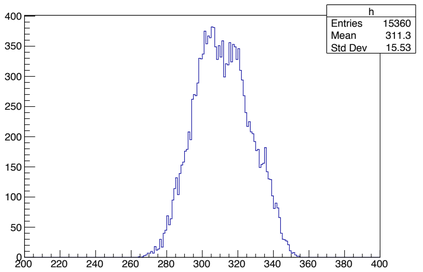
slab P2



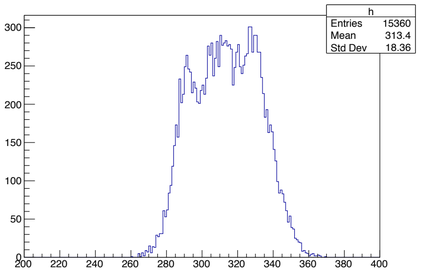
slab P3



slab K1

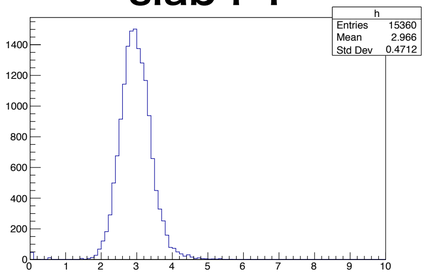


slab K2

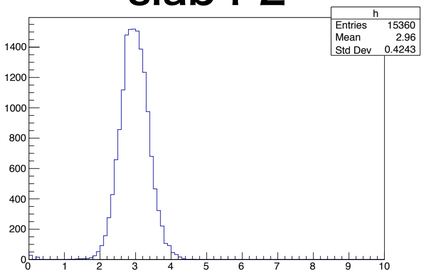


- Pedestal width distribution

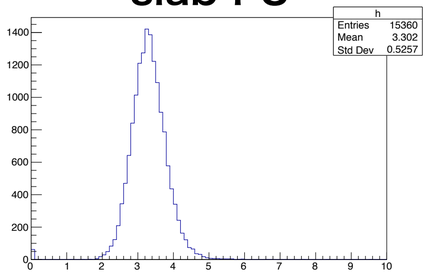
slab P1



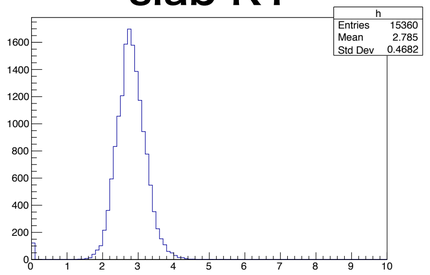
slab P2



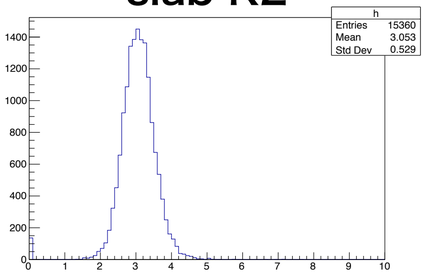
slab P3



slab K1

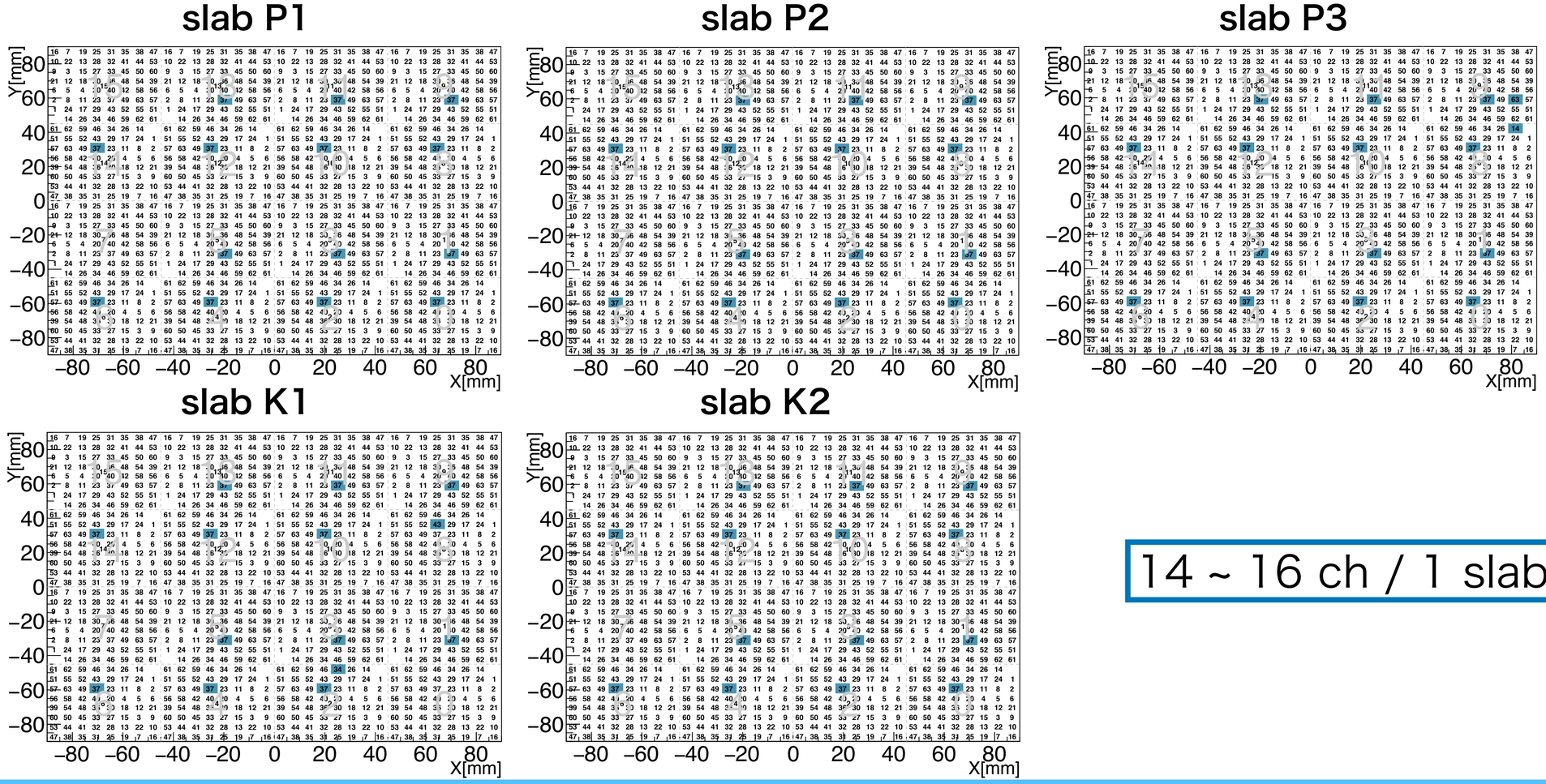


slab K2



Masked channels

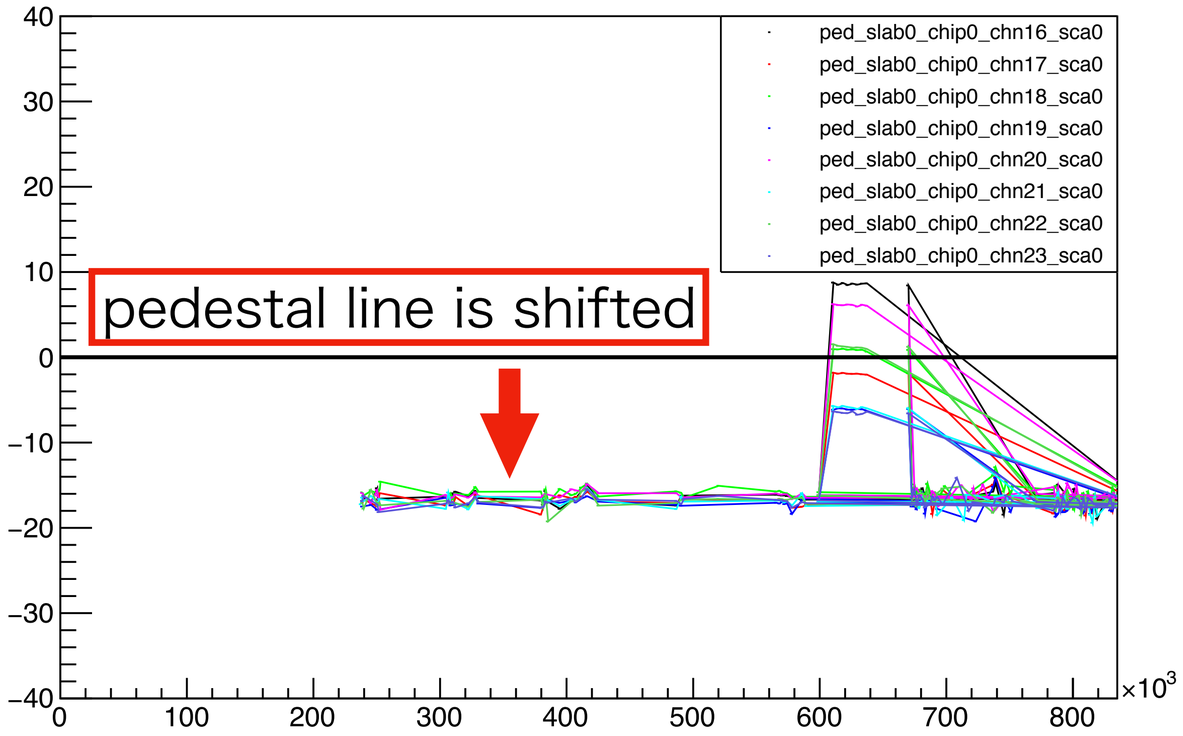
- the number of masked channels



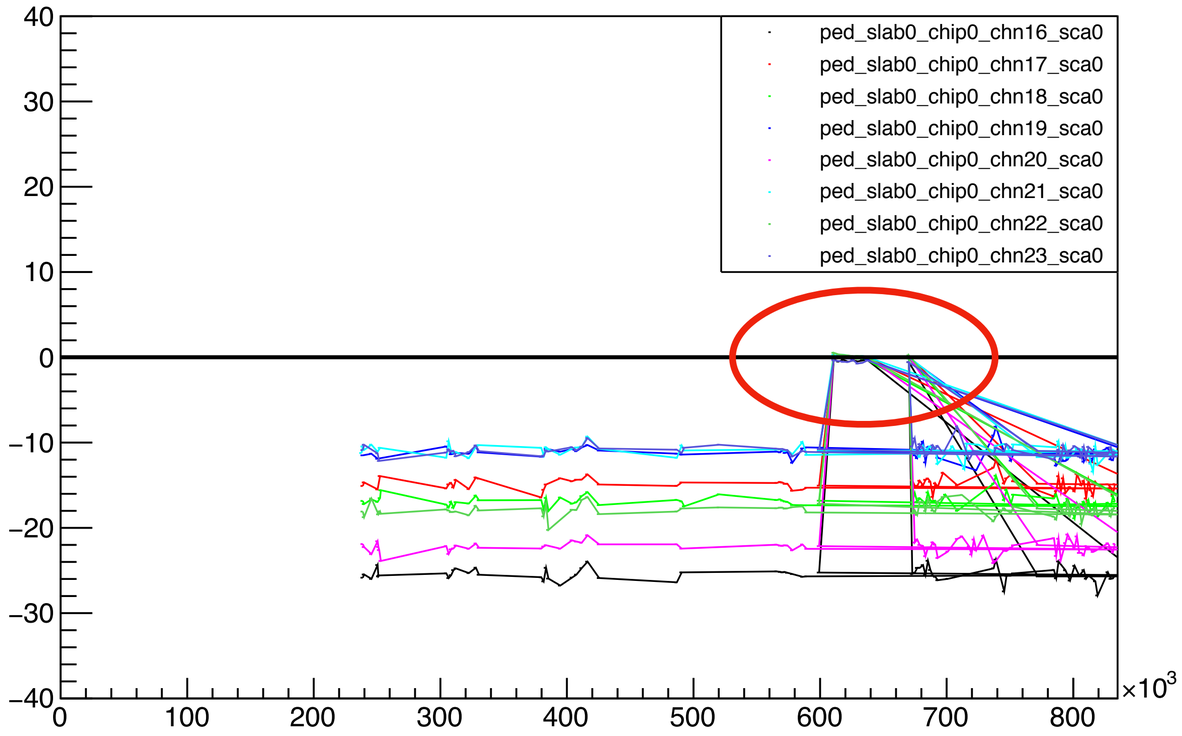
14 ~ 16 ch / 1 slab

Pedestal shift in TDC mode

ADC high gain (TDC mode)
ADC high gain (ADC mode)



ADC low gain (ADC mode)
ADC low gain (ADC mode)



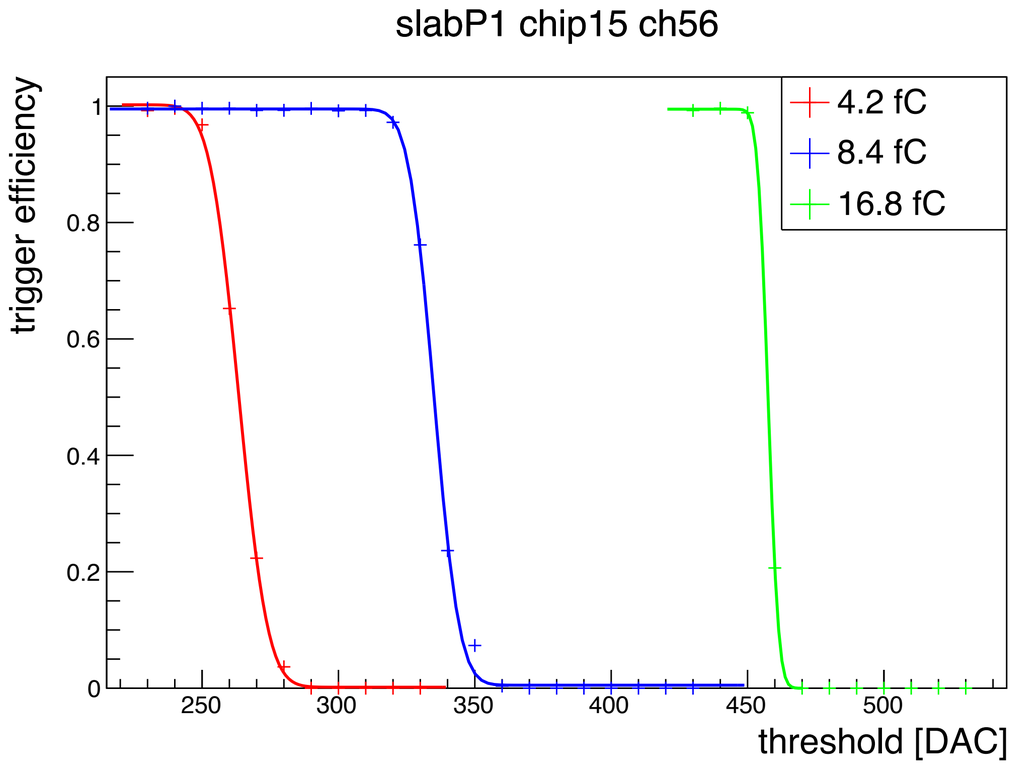
Measurement program

- MIP programs :
  - Position scan
  - Angle beam
  - TDC mode
  - Re-triggering / Double pedestal
- Shower programs :
  - TDC mode
  - Auto gain
  - Edge effect

Laboratory Test

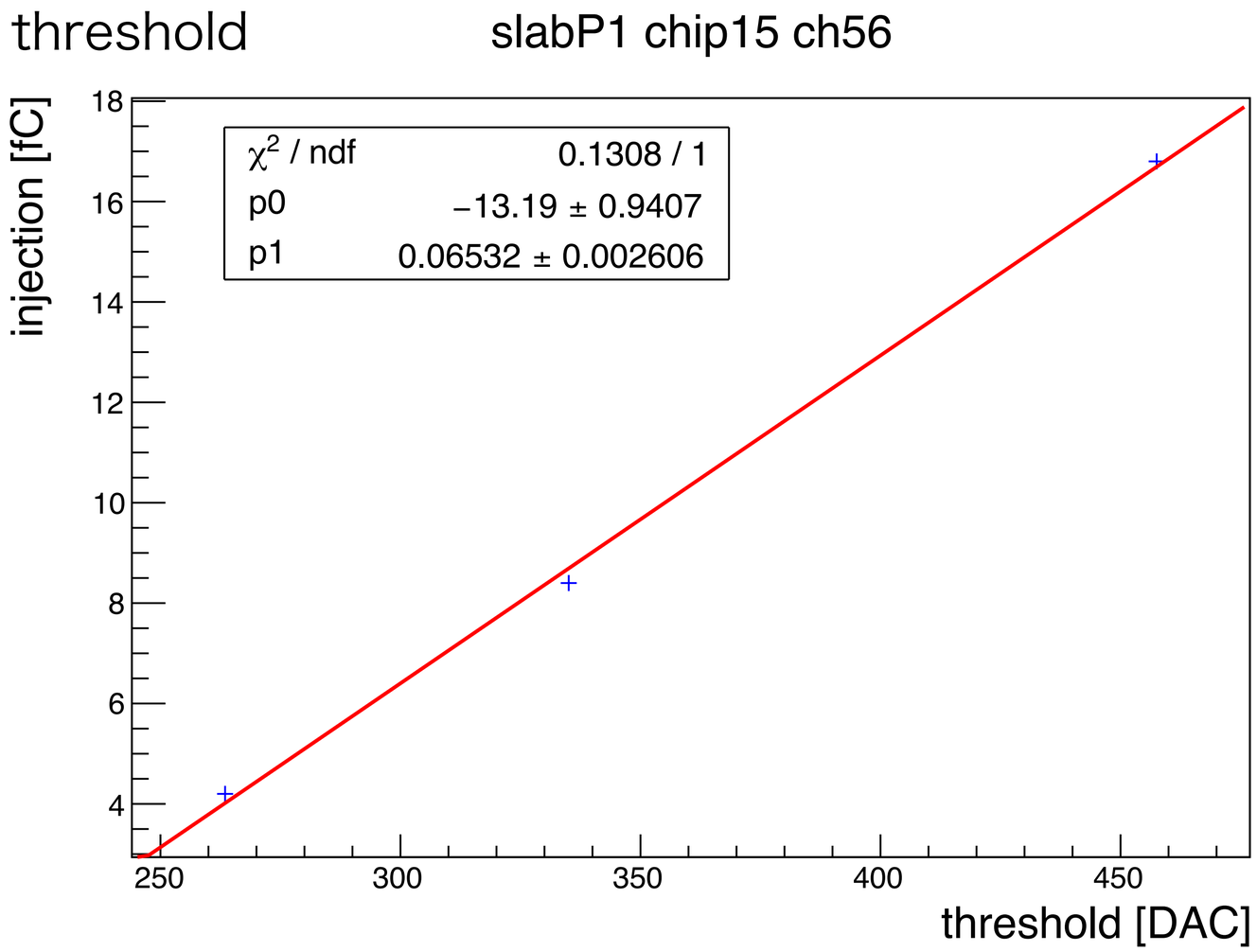
- S/N in the trigger line
  - defined by the study of the trigger line (fast shaper in SKIROC)
- threshold scans with charge injections
  - 1.4 mVpp : 1 MIP (4.2 fC)
  - 2.8 mVpp : 2 MIP (8.4 fC)
  - 5.6 mVpp : 4 MIP (16.8 fC)
- Finally S/N ratios for the threshold are

  8.4 fC - 4.2 fC : 6.03
  16.8 fC - 8.4 fC : 11.9

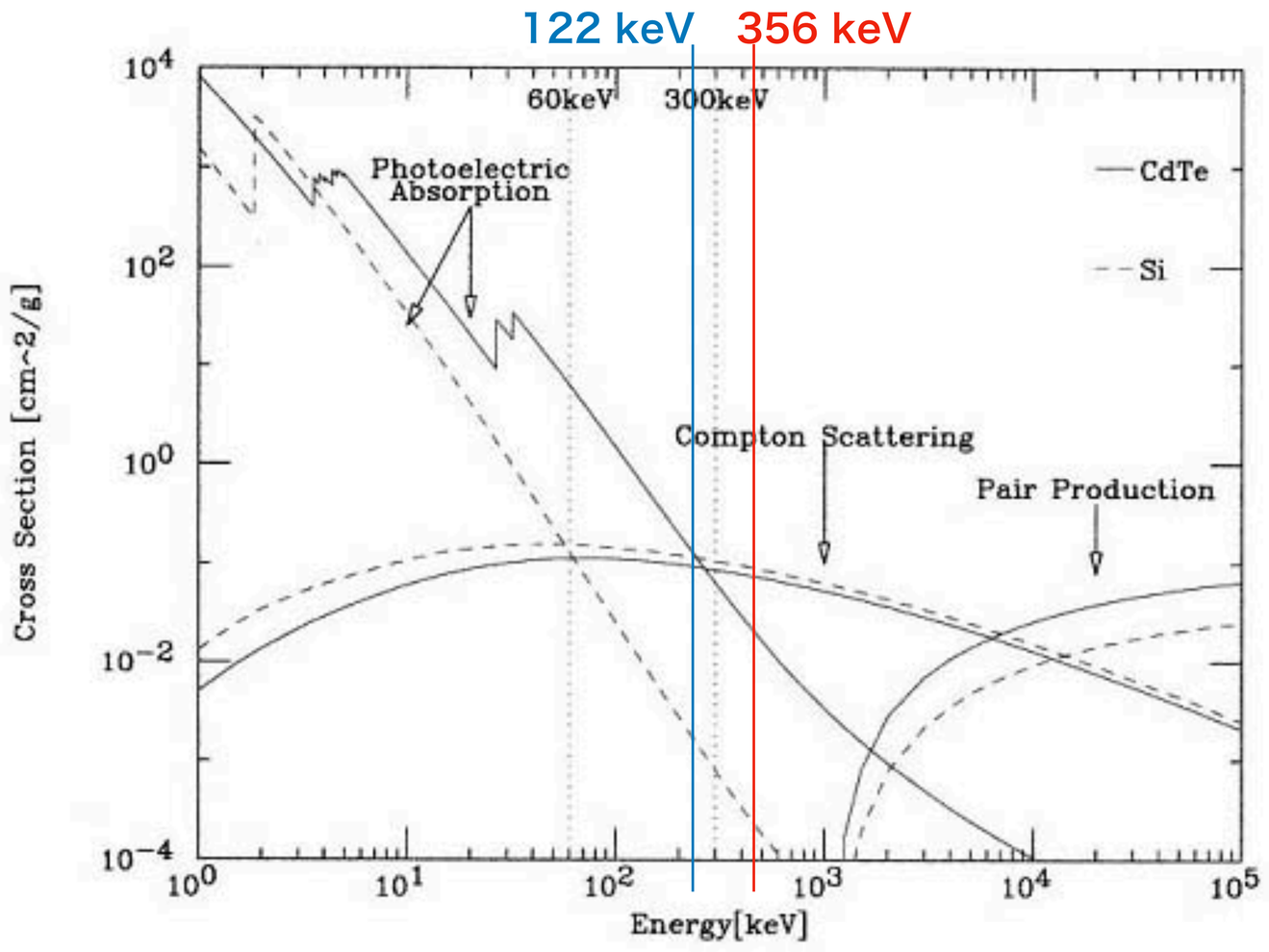


Laboratory Test

- Linearity of threshold

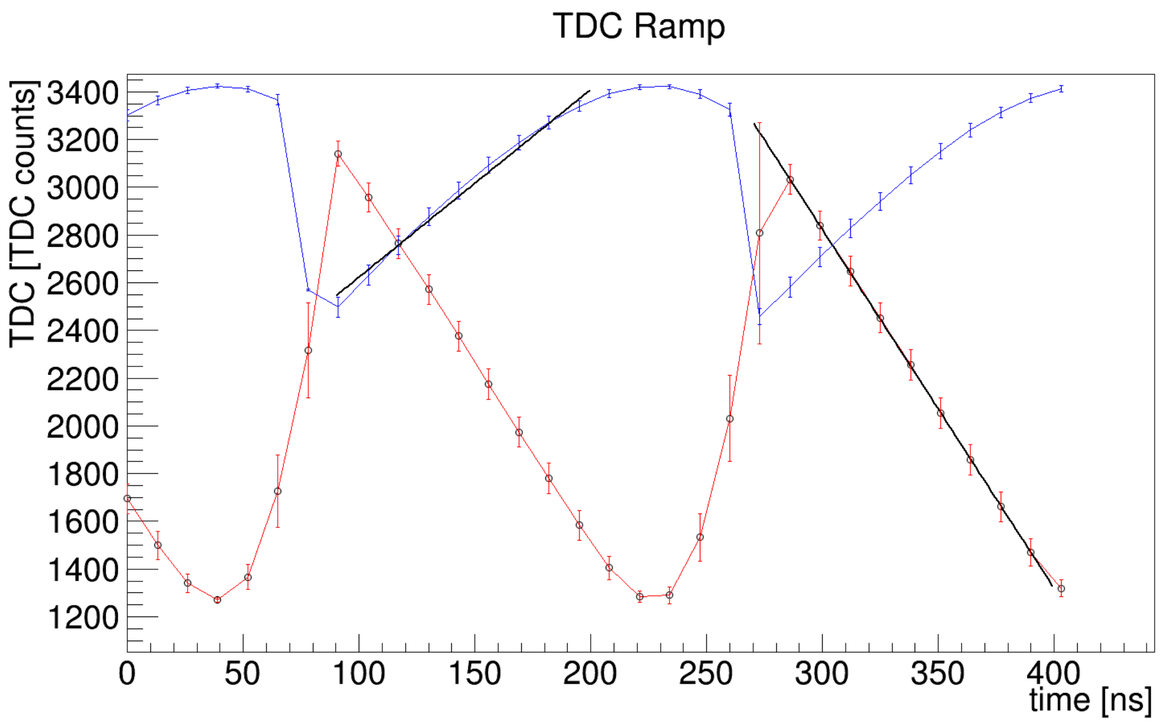


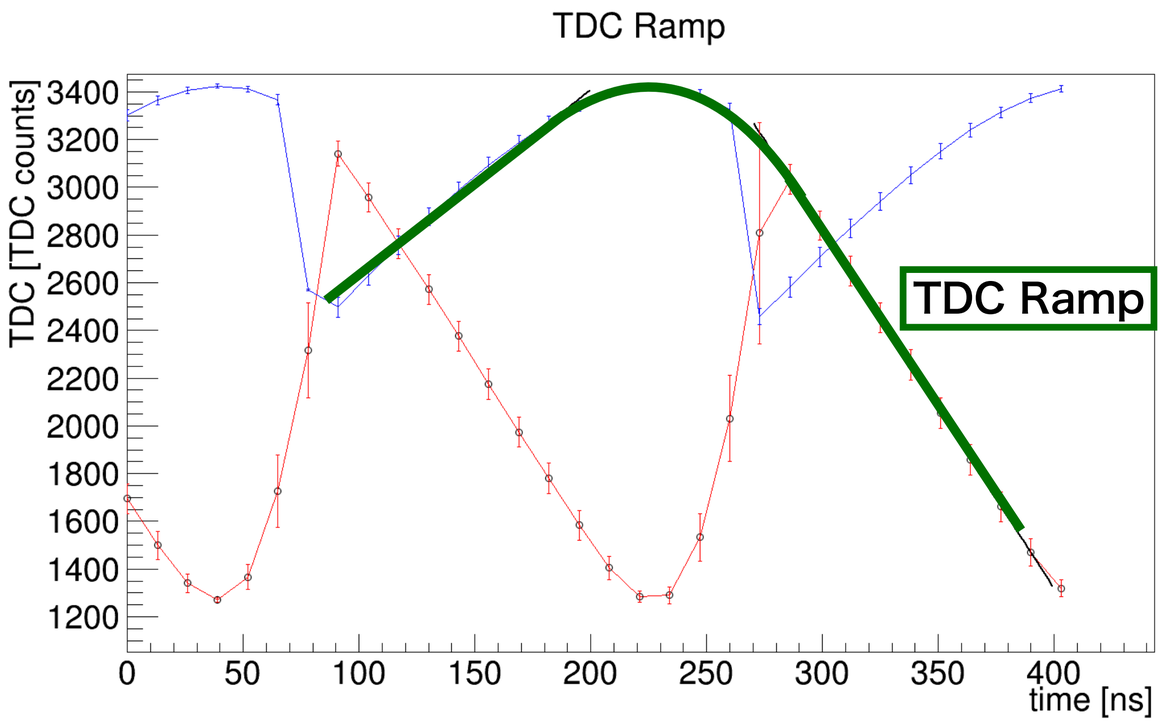
Laboratory Test (3)



<引用>
修士論文「テルル化カドミウム（CdTe）半導体を用いた硬X線・ガンマ線撮像用ピクセル検出器の開発」
東京大学大学院理学系研究科物理学専攻
宇宙科学研究所高橋研究室
渡辺伸
2001 年1 月

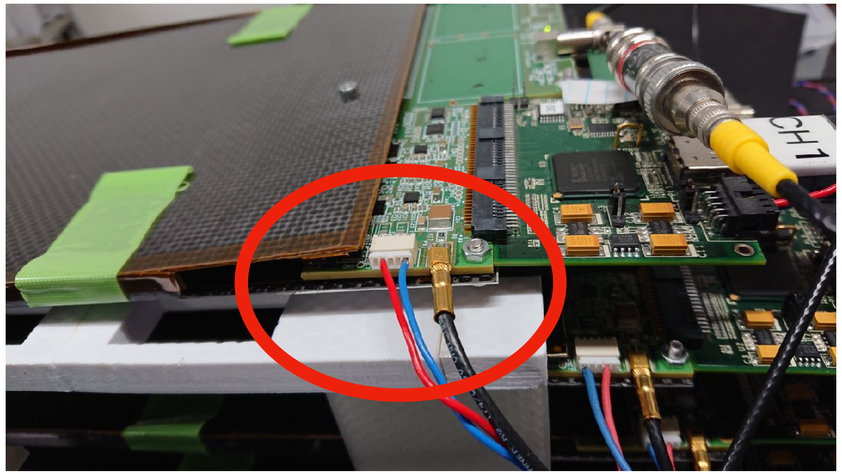
Laboratory Test (4)

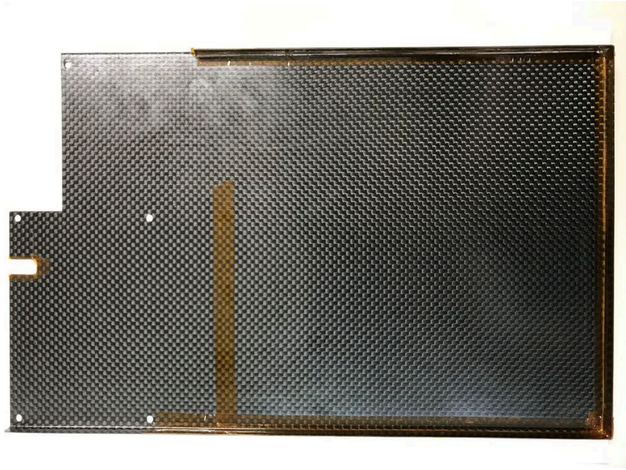


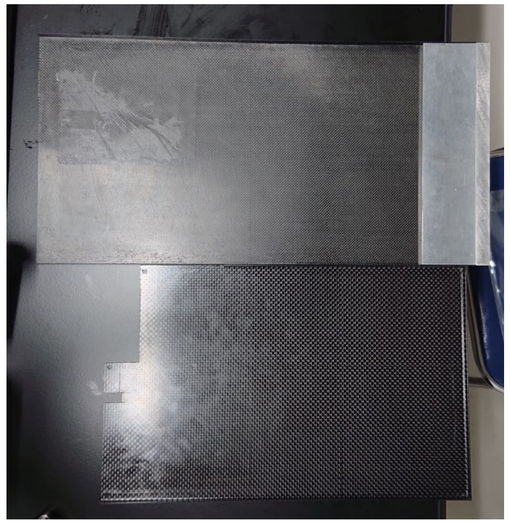


Update in this TB (1)

- Replace the carbon plate on the backside and cover
- New carbon plate :
  - cutting the edge of the HV connector side
  - pushing with screw
  - leakage current (imperfect insulation found)

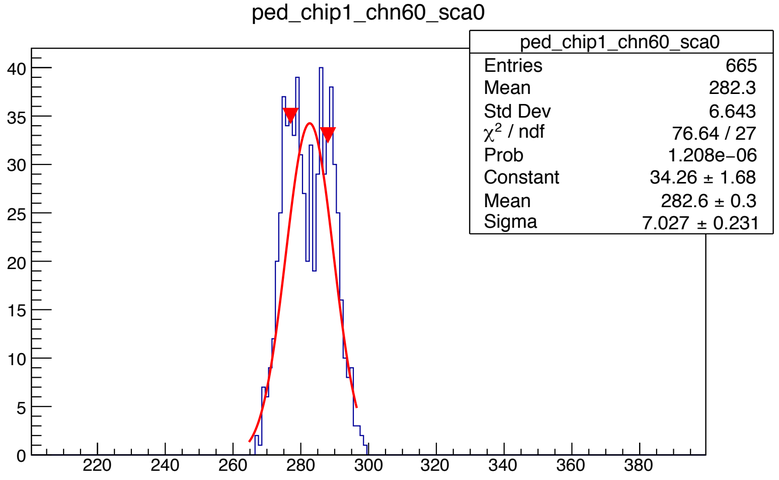


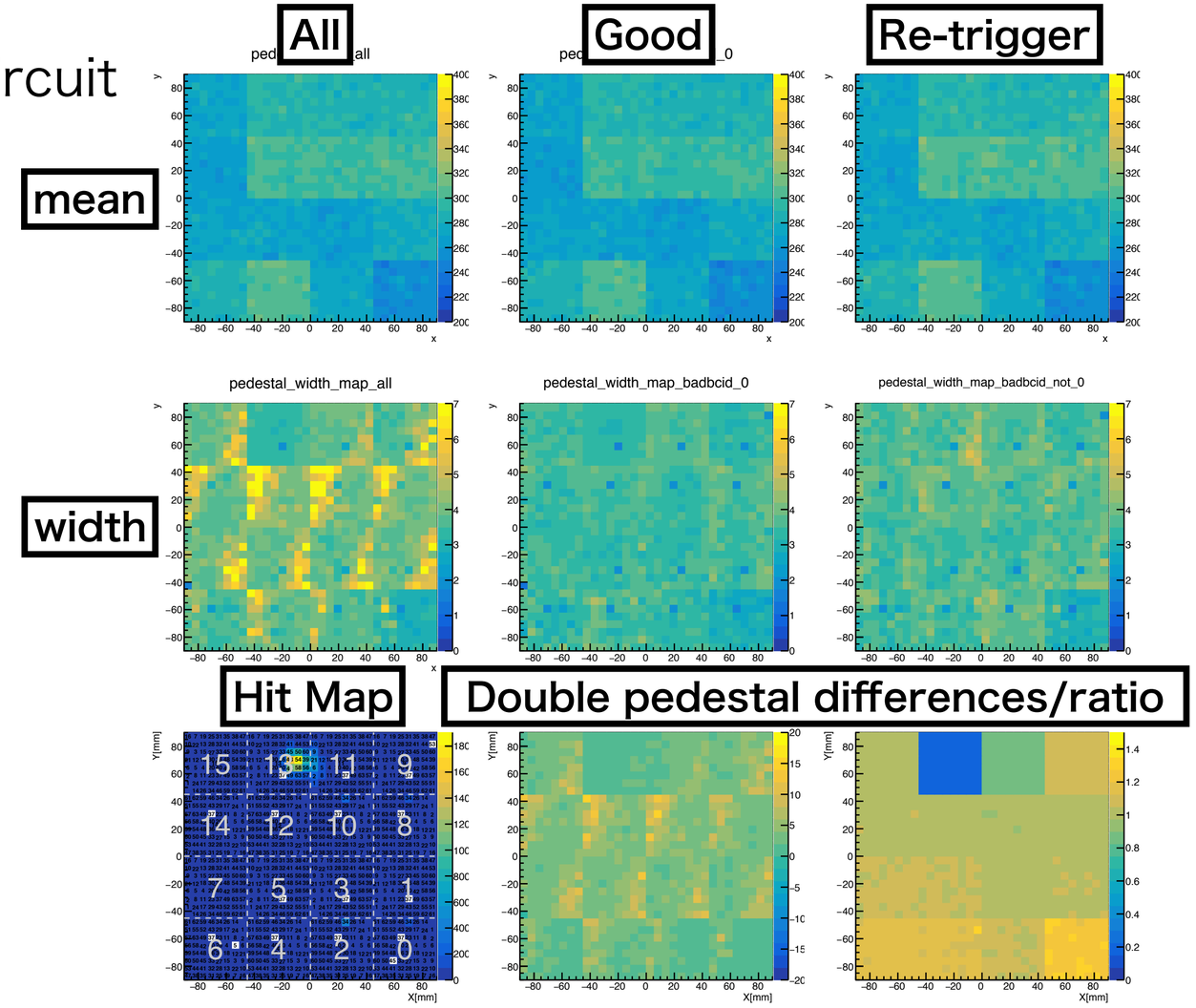




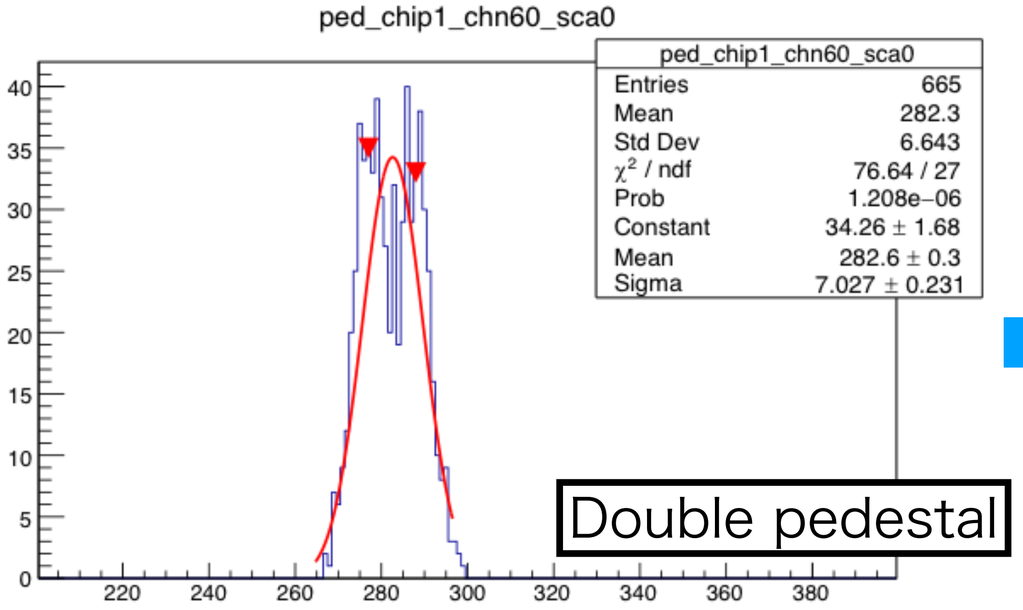
Some issues

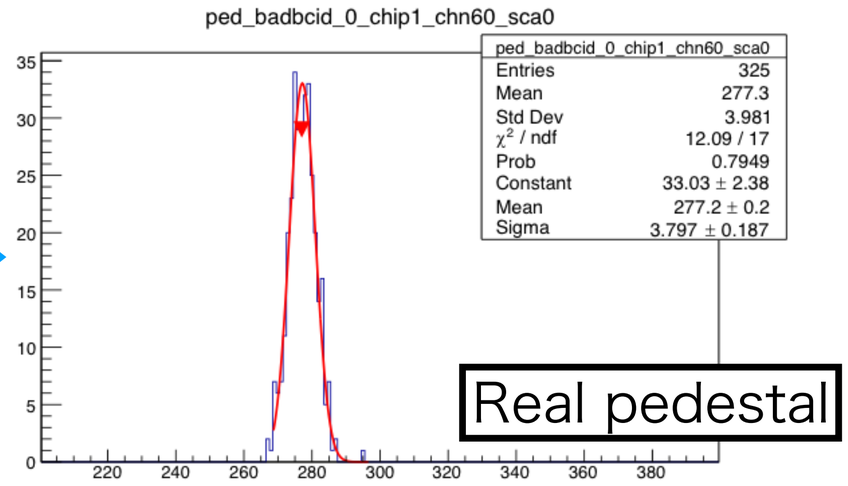
- Some issues were found for reading circuit
- Re-triggering :
  - dummy hits after the hit
- Double pedestal
  - now studying

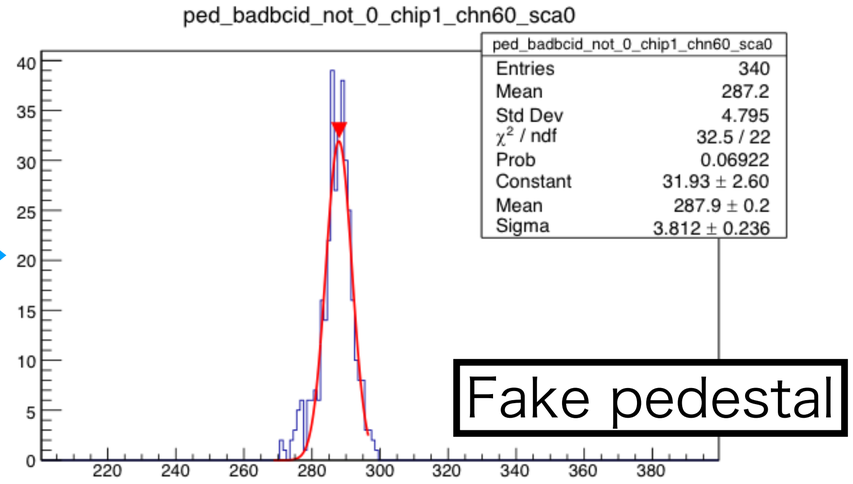




Double pedestal







Re-triggering

- the phenomenon filling the memory cells by some triggers after first hit in somewhere
- We don't know the detailing cause.
- Now we are trying to explore this problem.