# LGAD/PSD development

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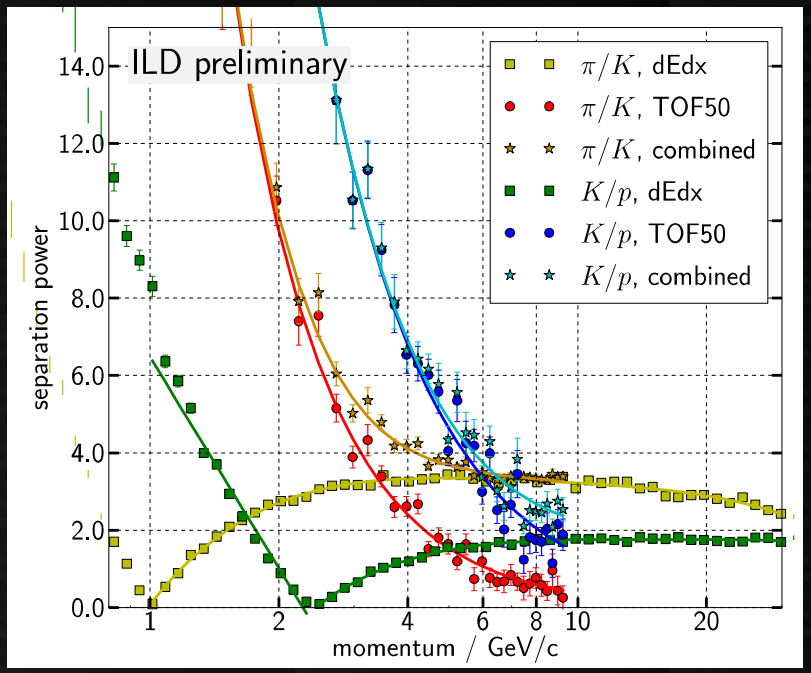
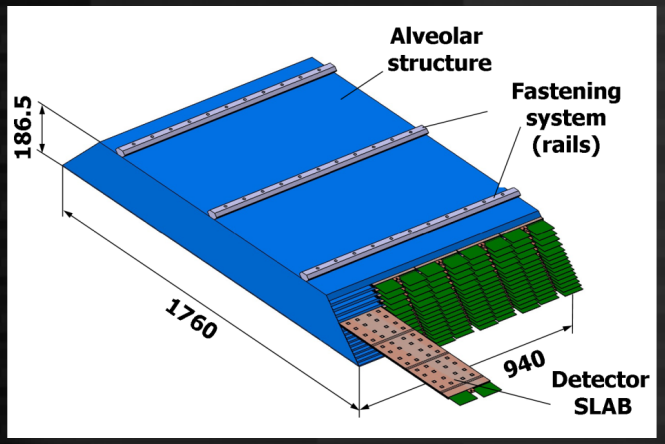
Apologies for the previous meeting I could not attend.
This talk also covers what has been uploaded on the slides of previous meeting.

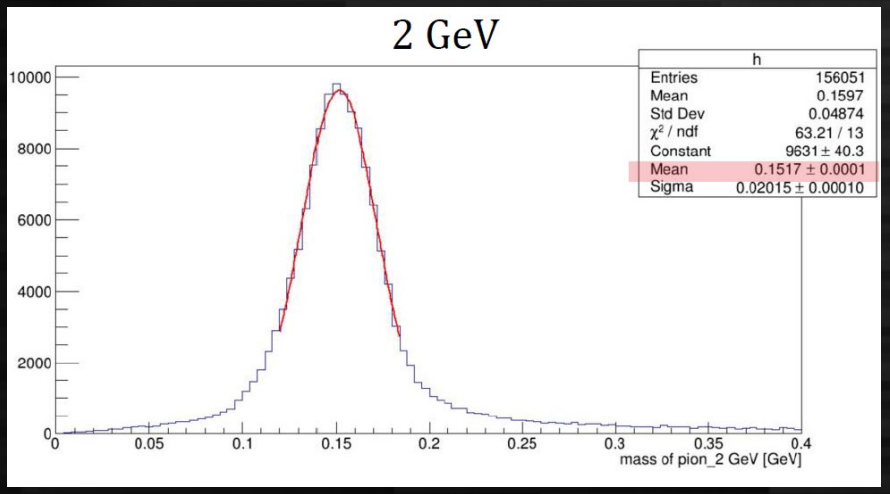
# LGAD

# Timing measurement and PID




Possible to separate π/K/p up to 3-5 GeV by 50 psec ToF with dE/dx at TPC



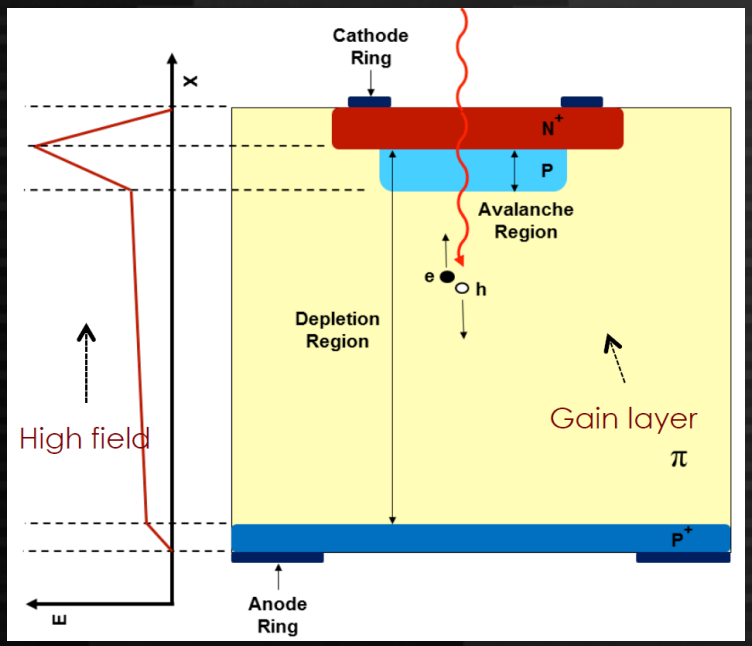

Pion mass from ToF (MC truth time)

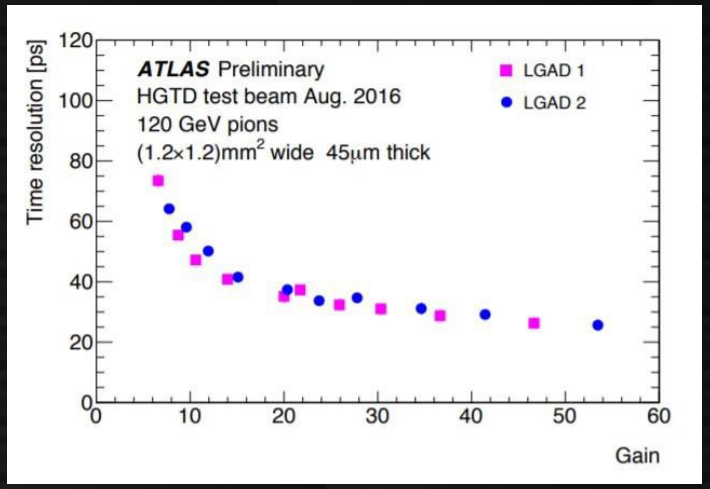
How timing resolution affects PID?
Which layers should be replaced?

Simulation study ongoing…

# Low Gain Avalanche Detector (LGAD)

- Silicon sensor with avalanche region (same as APD)
  - Good timing resolution because of
    - Thinner sensor possible
      → shorter drifting time
    - Larger signal height
      → steeper rise of the signal current
  - 20-30 psec demonstrated for LHC pileup rejection



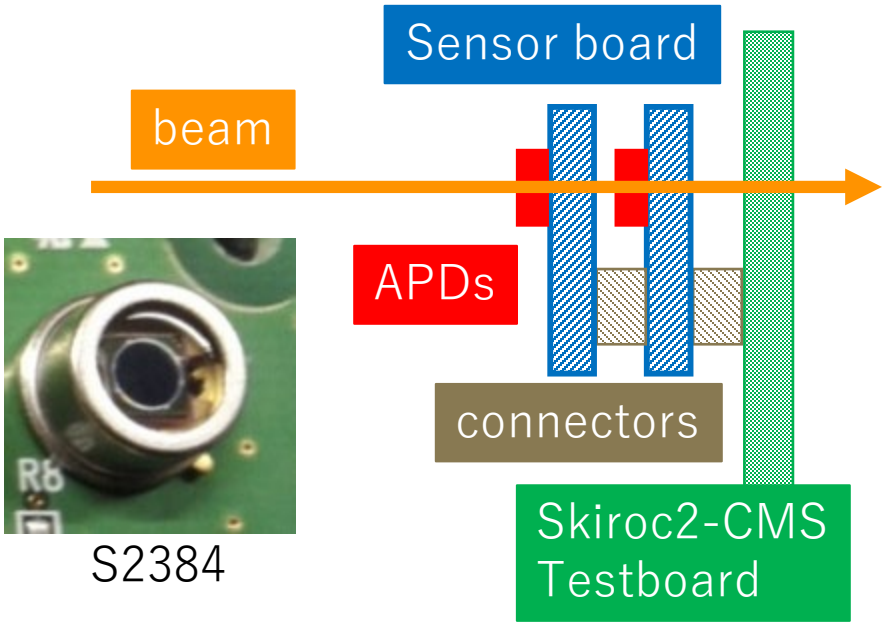




Issues to investigate
- Timing resolution with realistic electronics
- Gain variation, position dep., stability etc.

# Positron beam irradiation (Nov. 2019)

- Test Beam @ELPH(Tohoku)
  Positron beam, 500 MeV

Measurements of timing resolution



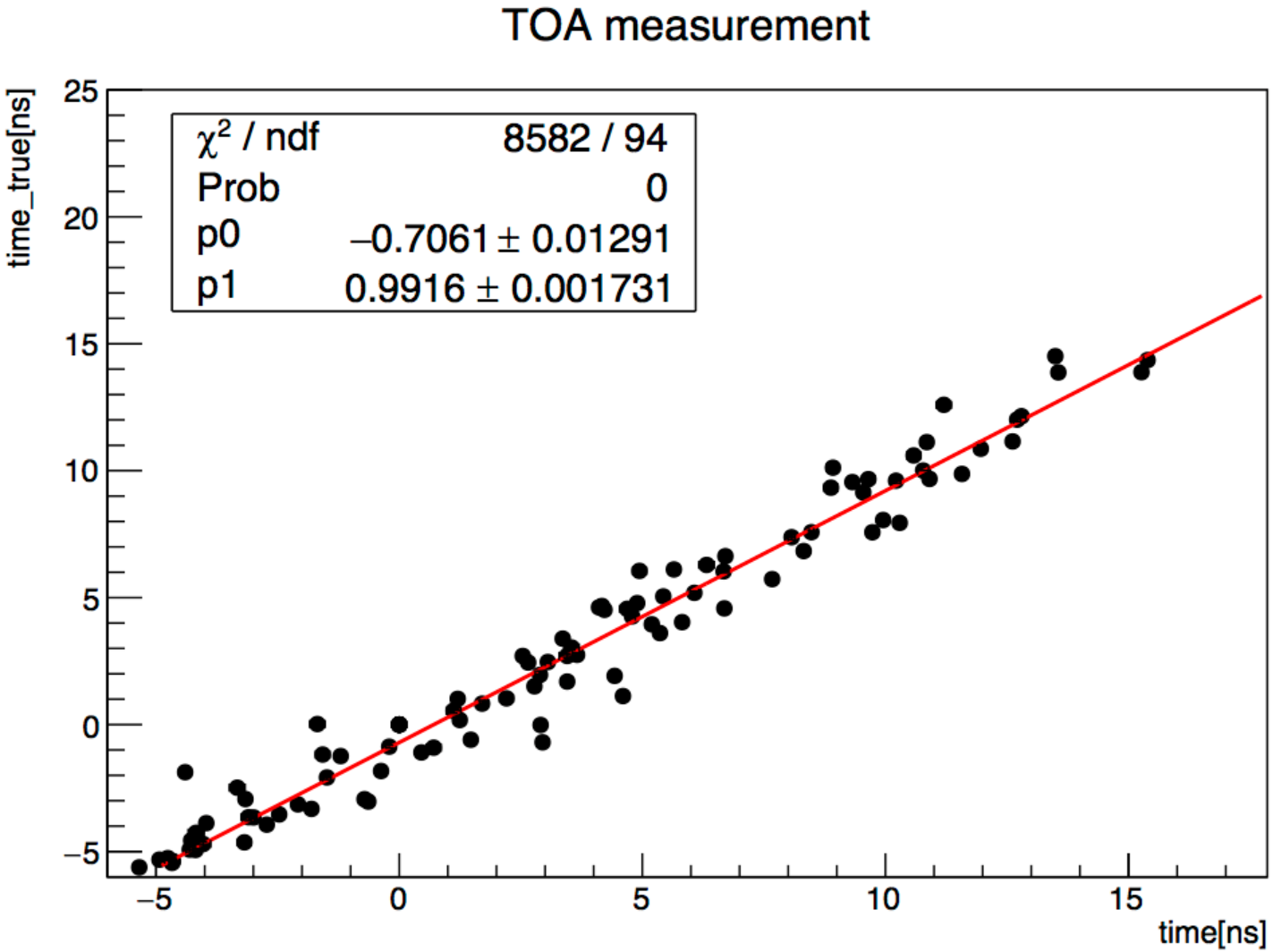



S2384

Penetrating events with identical APDs

Timing resolution from timing correlation

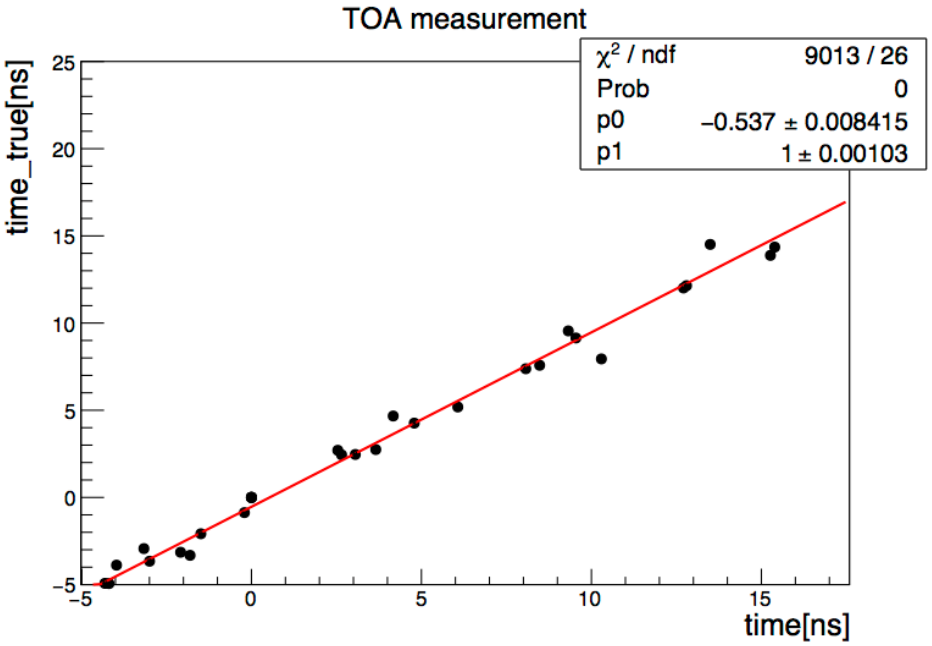
# Measurement result

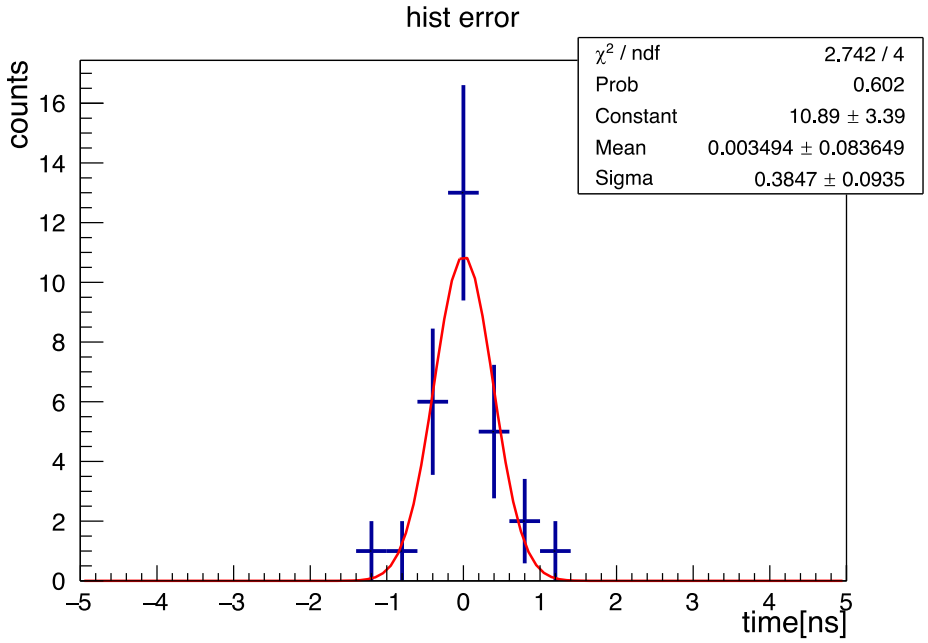



※Timewalk corrected

# Measurement result

- Only with > 100 fC
  - Smaller timewalk effect
  - Smaller jitter
  - Should have better resolution because of steeper voltage-rise




Timing resolution (> 100 fC) : 385 ± 94 ps

With Jitter of 50 ps at 100 fC… $\sqrt{385^2 - 50^2} \cong 382$ ps

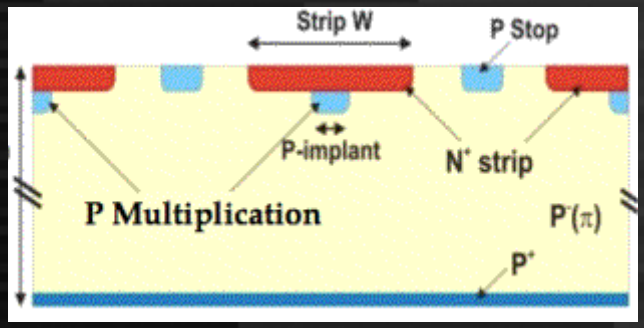
# Issues at last year

| APD serial No. | # hits @ APD-1 | # hits @ APD-2 | # coin. | Eff. |
|---|---|---|---|---|
| S12023-10A | 1002 | 965 | 147 | 14.9 % |
| S8664-10K | 613 | 298 | 4 | 0.9 % |
| S2384 | 4355 | 5796 | 1136 | 22.4 % |
| S8664-20K | 368 | 185 | 2 | 0.7 % |
| S8664-55 | 3060 | 2327 | 96 | 3.6 % |

- Lower double-hit rate
  - Esp. with inverse type
  - Low efficiency?
  - Different gain by position?
    → Tracking detector at front and back side should help
  - Measurement of 3 sensors (2 in previous due to tech. reason)
- Lower statistics
  - Using bigger sensors, short distance, better DAQ etc.
- Bad timing resoultion
  - Correction (timewalk, ch-dep of TDC) is not working?
  - More statistics and 3-sensor measurement should help to investigate more

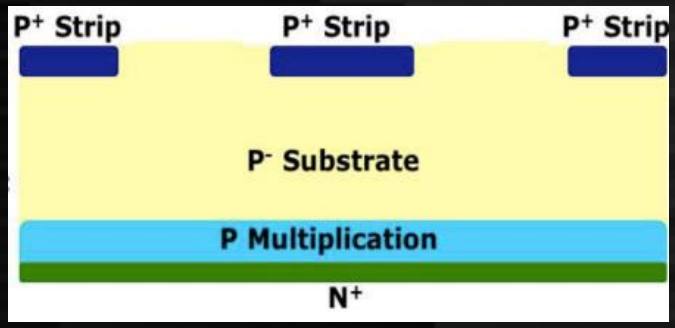
# APD sensors to test in 2020/21

Bigger sensors will be tested this year because we got difficulty on efficiency and position dependence as well as timing resolution mainly because of lower rates

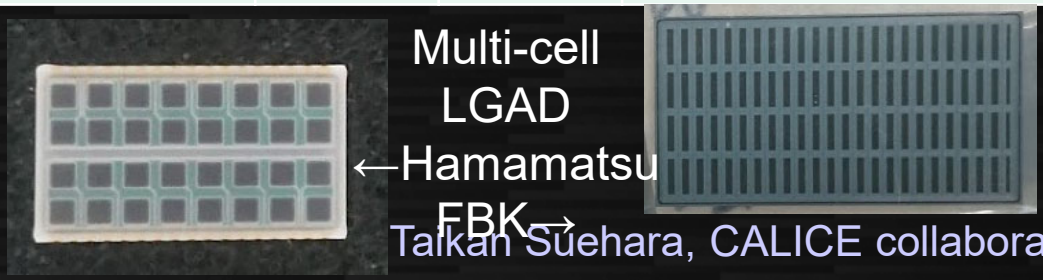



Reach-through: performance demonstrated but multiplication only at the P-implant

| Spec no | type | VBR[V] | size [mm] |
|---|---|---|---|
| S8664 | Inverse | 400 | 3ϕ, 5ϕ, 5 x 5 mm |
| S5344/5345 | Inverse | 150 | 3ϕ, 5ϕ |
| S2384/2385 | RS | 150 | 3ϕ, 5ϕ |
| S6045 | RS | 200 | 3ϕ, 5ϕ |
| S8550-02 | Inverse | 400 | Array (32ch, 1.6 mm sq) |
| FBK sensor | RS | ? | Array (92ch, 1 x 3 mm) |



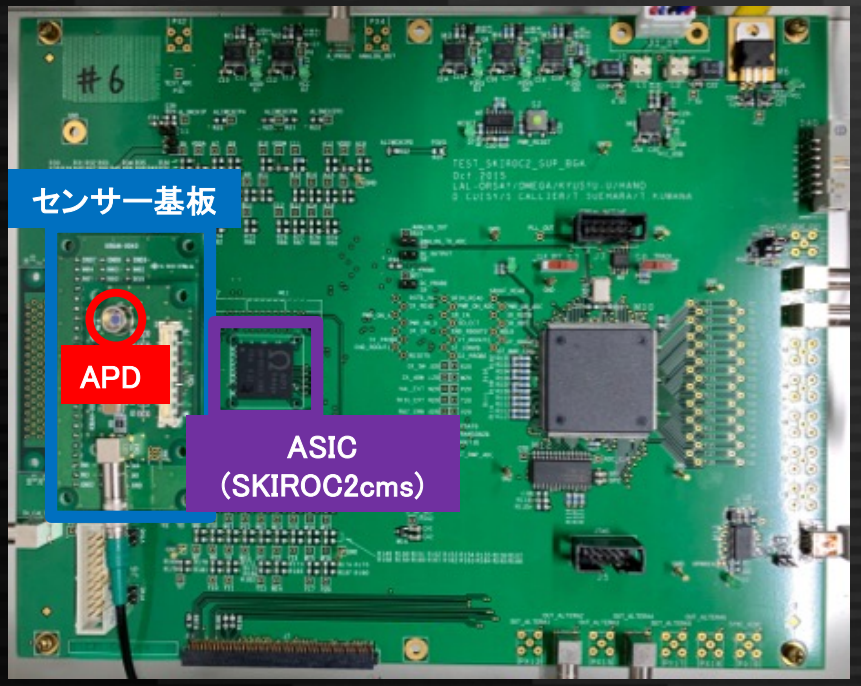

Inverse: Good for calorimeter because of better gain flatness but need to investigate



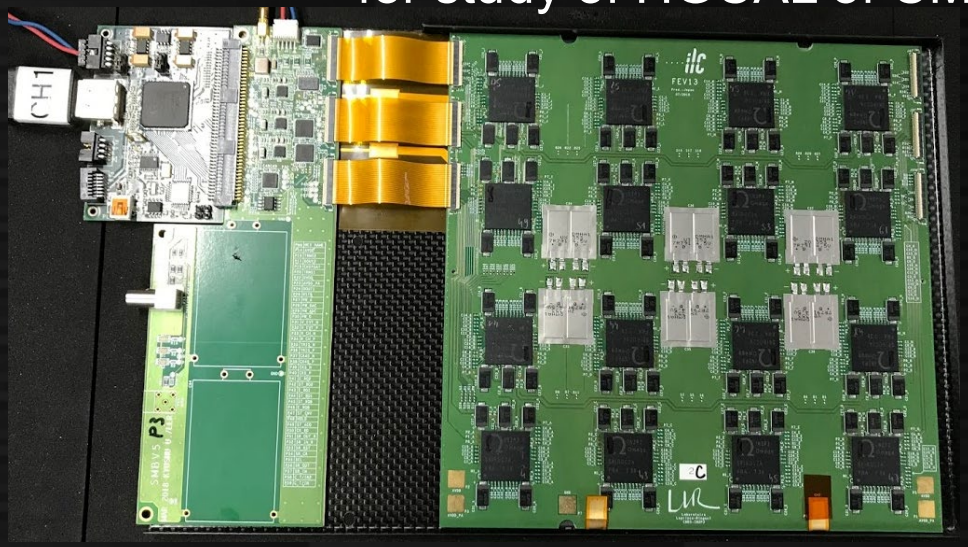
Multi-cell LGAD
←Hamamatsu
FBK→

# Readout ASIC and PCBs

SKIROC (2A/CMS)
by OMEGA
64 ch readout
Preamp + 2 gain (1/10)
slow shaper + fast
shaper for triggering
SKIROC2CMS: good TDC
+ 13 cell 40 MHz digitizer
for study of HGCAL of CMS



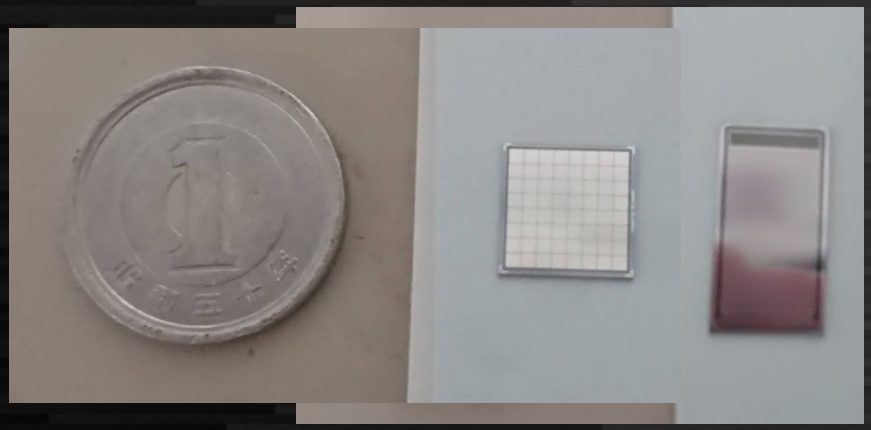

↑ SKIROC2 evaluation board
A daughter board is connected with a PCB connector to use this board for readout of various sensors



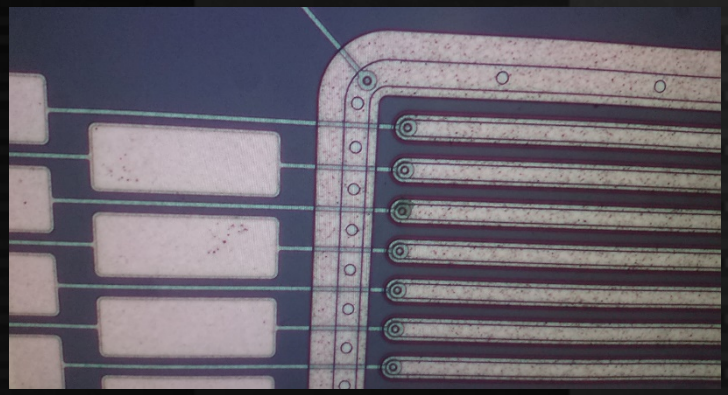
← FEV13
Developed as a technological proto-type for SiW-ECAL: usable for sensor studies with pads at the back side

# Tracking sensors

- Silicon pad with 1 mm cells
  - 8 x 8 mm (16 x 16 mm covered with 4 sensors)
  - Measuring beam profile
  - Used for trigger
- Silicon-strip sensors
  - 50 μm pitch, 128 ch (256ch with 2 direction)
  - Precise measurement of position dependence
- 256ch readout with FEV13
  - Using an adapter board (wire bonding for strips)



1mm-cell sensor (left)
strip sensor (right)



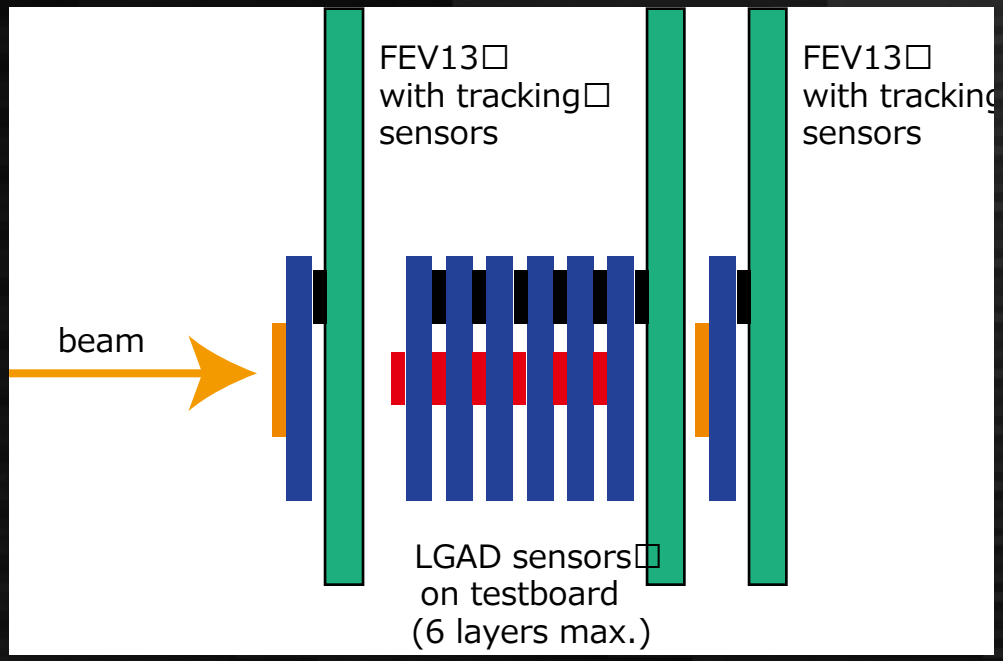
Edge of strip sensor

# Plan for next TB at ELPH (Feb. 2021)

Beam time: 17-18 Feb, 2021 at ELPH, Tohoku University

- ~500 MeV electrons, ~kHz quasi-DC, a few cm spot size

1. Timing resolution and efficiency of LGADs
   - 3/5 mm sensors with several production configuration (several types of reach-through and inverse each)
   - With tracking detectors to ensure center hits
   - Dependence on bias voltage (optional)
2. Position dependence with multi-cell LGADs

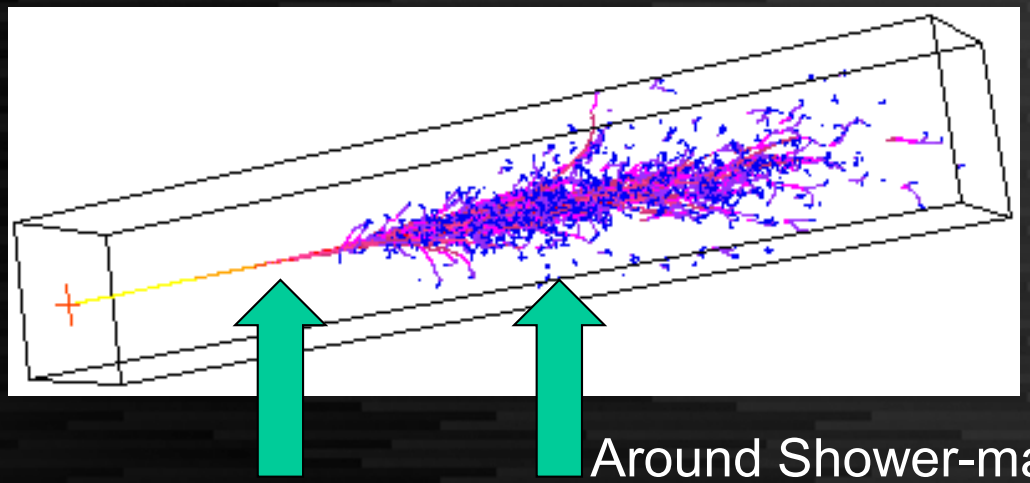


# PSD

# PSD and position of photons

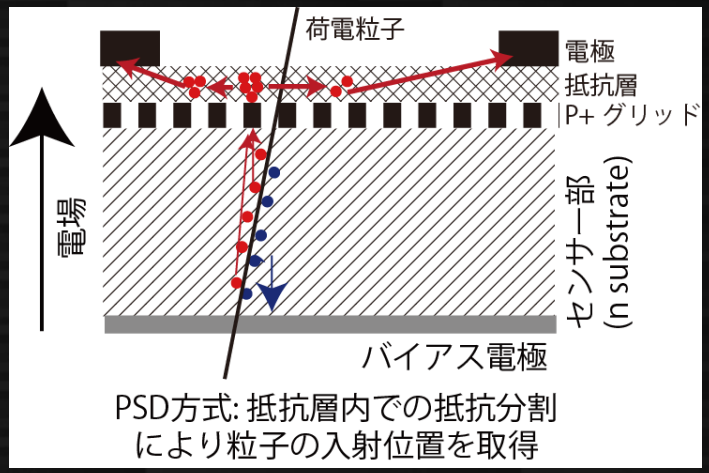
Better position (direction) resolution of photons can be used for $\pi^0$ reconstruction and photon-related BSM search

Simulation study will be done (after LGAD study)



Position resolution is important at beginning of showers ~2 mm with standard pads

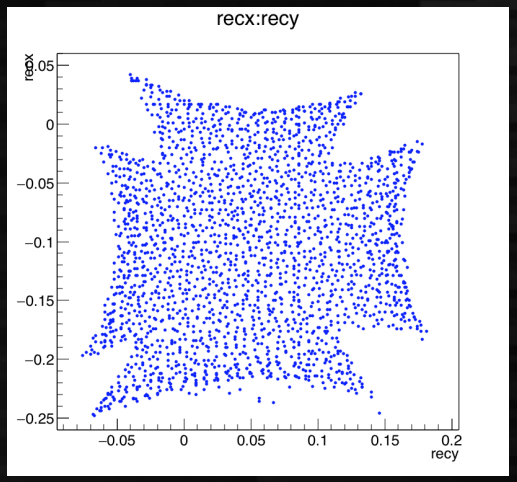
Around Shower-max it is determined with Moriere radius and number of hits ~0.3 mm in ILD




PSD uses resistive division to identify gravity center with multiple electrodes without significantly changing number of readout channels

# PSD sensors

## 1st gen (2016)

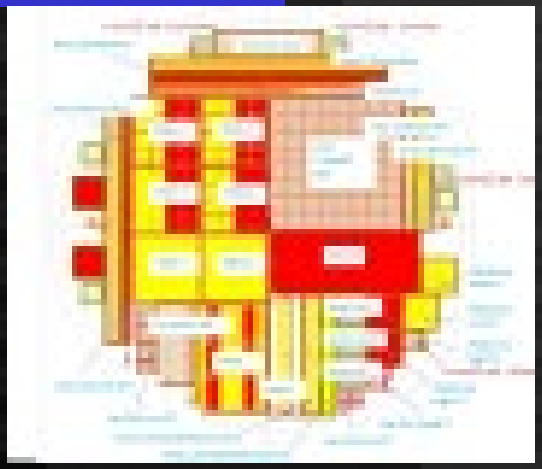



Result of laser scan

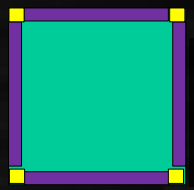
Parasitic production with g-2 sensors
7 mm cell, single, 320 μm thickness
Position reconstruction with laser

Low dynamic range of ~20%
→ need improvements

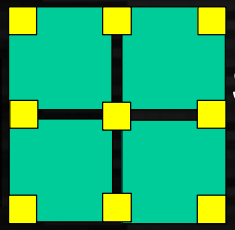
## 2nd gen (2018)



Dedicated for PSD
4 x 4 cells, 5.5 mm cell size,
650 μm thick, resistive split
with two methods of
P+ mesh and dedicated
resistive layers tried



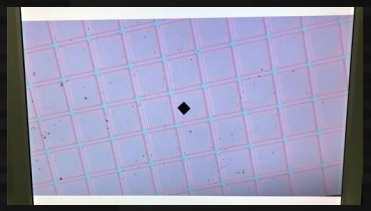
Low-R edge

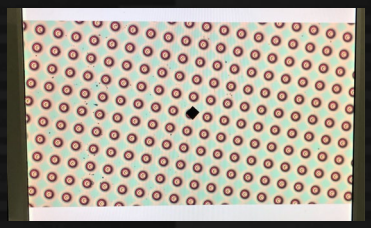


Sharing pads

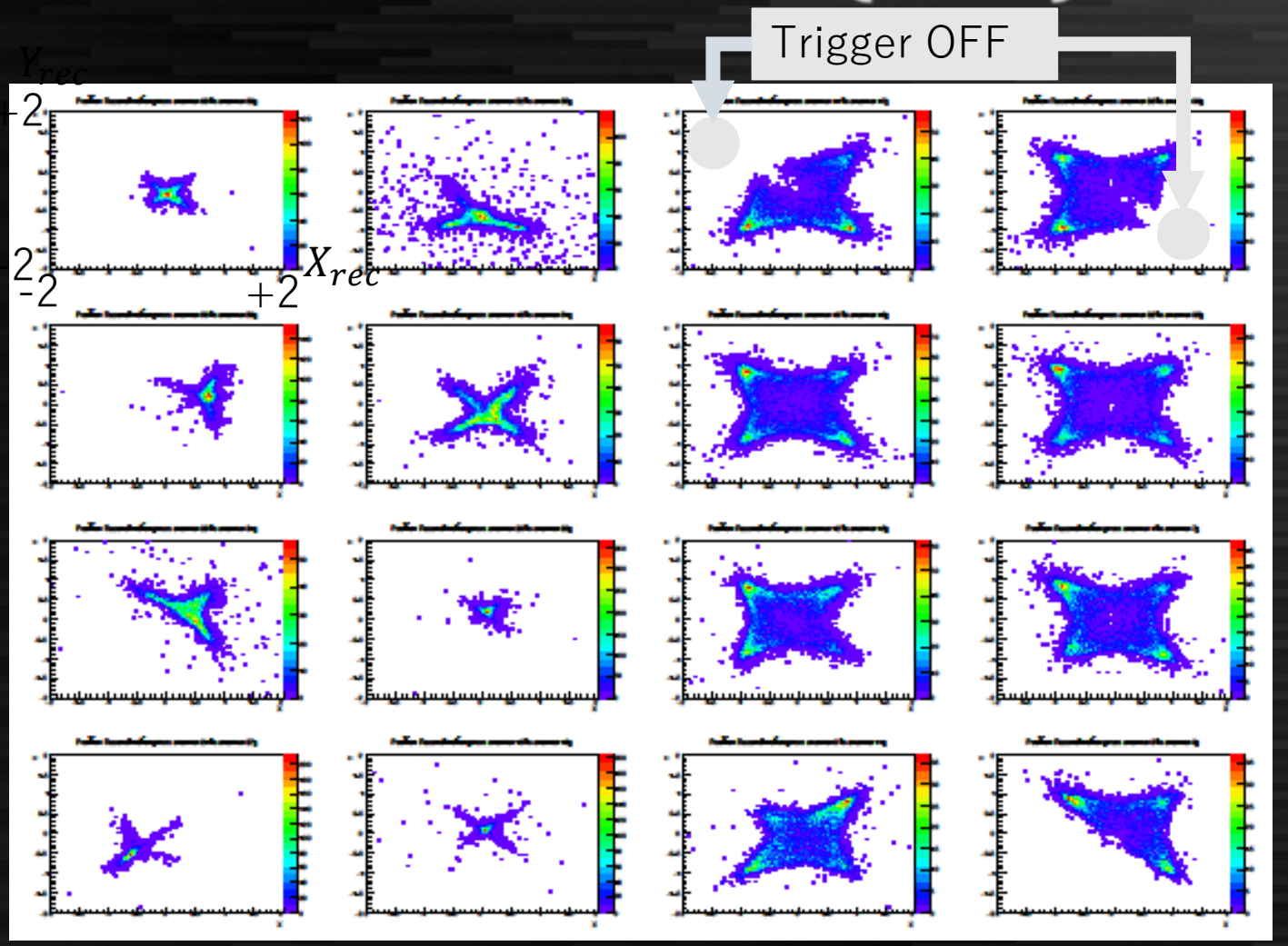
# Measurements in 2019 ($^{90}$Sr)

PSD (normal)
P+ mesh (left)
R layer (right)





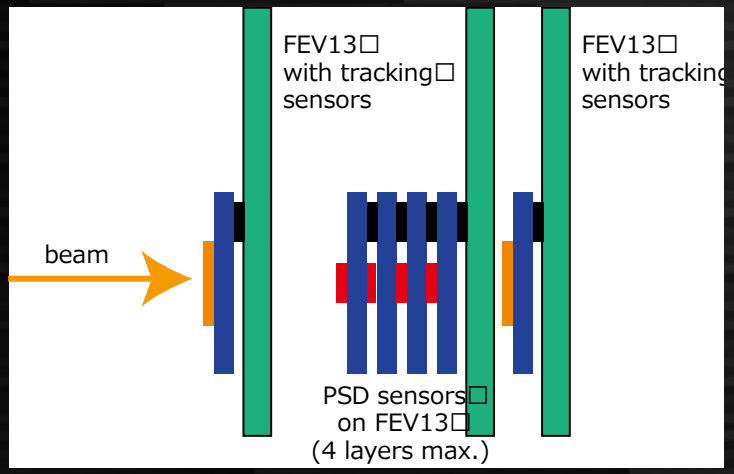
R layer has 10x resistivity to P+ mesh




Good dynamic range confirmed with R layer

# Plan for Next TB (for PSD)

- Tried to collect beam data in the previous TB (2019)
  - Noise was too high to check position reconstruction (due to the test beam environment)
- Retry with improved setup in the next TB (Feb. 2021)
  - Along with LGAD (sharing beam time)
  - Readout with FEV13 instead of testboard (issues exist with testboard on sensor connection)
  - Better shielding (casing, grounding)
  - Concentrate on the basic property (position reconstruction, distortion, resolution, efficiency)



# Things to do before TB

- Preparing FEV13 for sensor connection
  - First assembly with 1 ASIC done, not tested yet
- Preparing adapter PCBs
  - Design ongoing
- Assembly, wire-bonding for strips (Oct. – Nov.)
  - Mainly plan to use anisotropic conductor sheets
  - Wire bonding at Kyushu
- Test with RI and laser (Nov. – Dec.)
- Mechanical structure (Oct.-Dec.)
- Preparation for beam test analysis (Dec.-Feb.)
  - Have to be prepared for instant analysis in short beam time

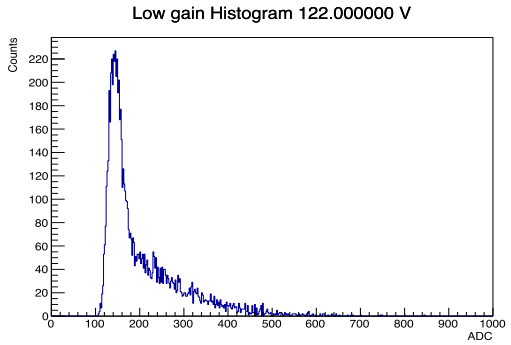
# Summary

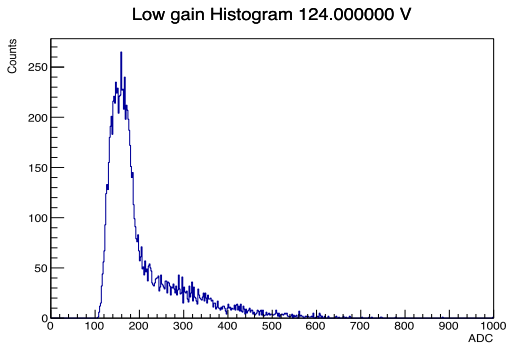
- We are developing LGAD and APD for application on some layers in SiW-ECAL
- Timing correlation of a few 100 psec seen in the previous test beam with APDs
  - Target: < 50 psec
  - Efficiency on inverse time especially low
- Detailed study will be done with next TB on Feb. 2021 with bigger/multi-cell APDs
- Position reconstruction of PSD will be tested as well in the TB

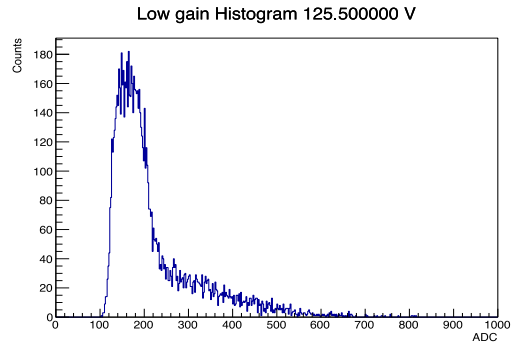
# Backup

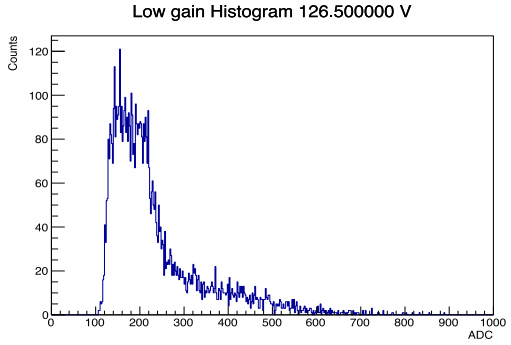
# 放射線源を用いた測定

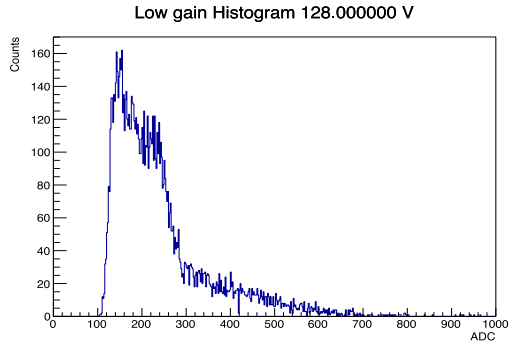
- ガンマ線でのGain測定

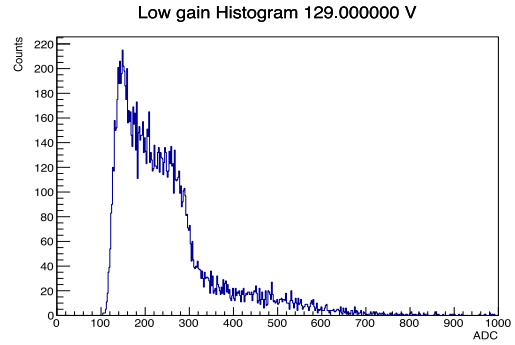


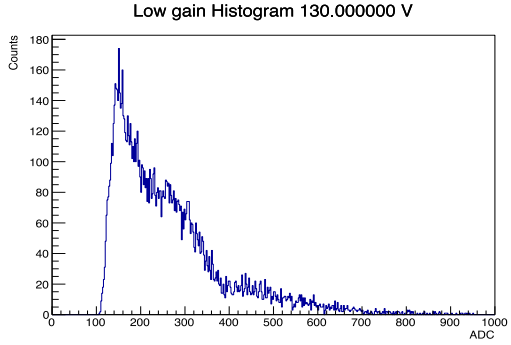



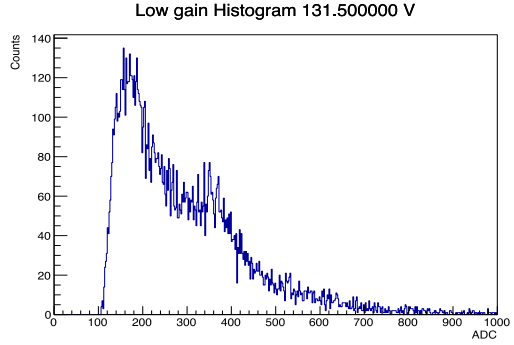



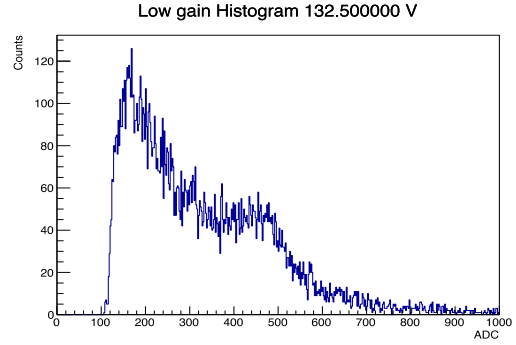



# 放射線源を用いた測定

- 各APDのADC分布 (Low gain)