FoCal Project in ALICE

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TCHoU workshop

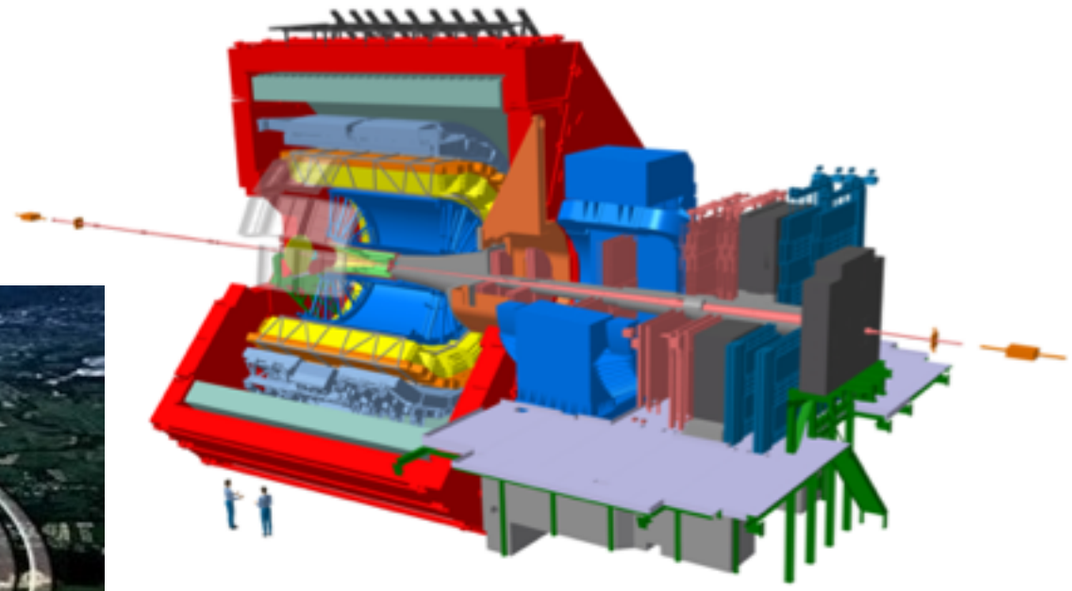
2018/3/15

Outline

- ✦ Introduction of FoCal Project
  - ✦ Motivation
  - ✦ Detector design
- ✦ The result of past test beam (2014~2016)
- ✦ Activity in 2017
  - ✦ Production of new Si detector
  - ✦ Test beam at ELPH
- ✦ Summary

FoCal project

LHC



ALICE detector

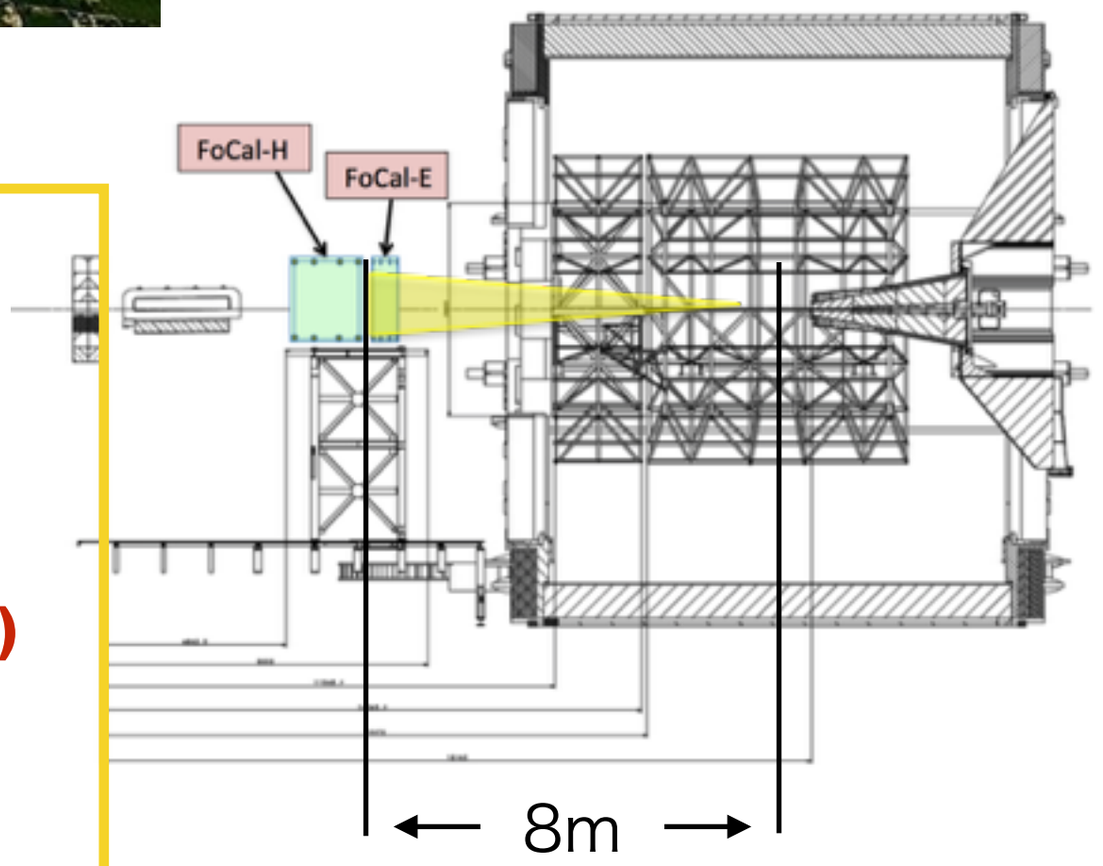
✦FoCal：Forward Calorimeter

.. Electromagnetic calorimeter installed in the forward direction (3.3 <η <5.3)

✦ALICE upgrade plan

ー>Install finished machine in 2024 (LS3)

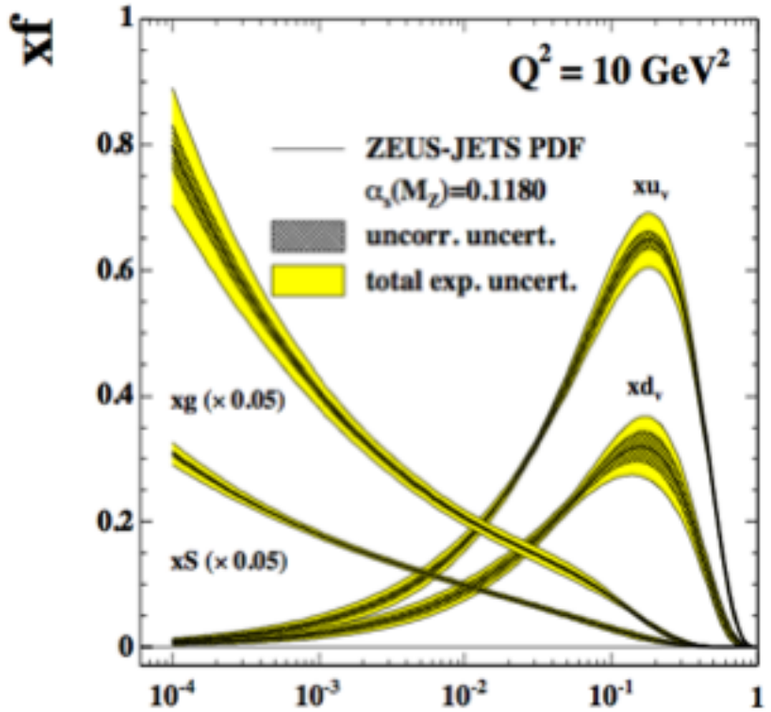
✦Experimental verification of CGC by direct photon measurement



FoCal in ALICE detector

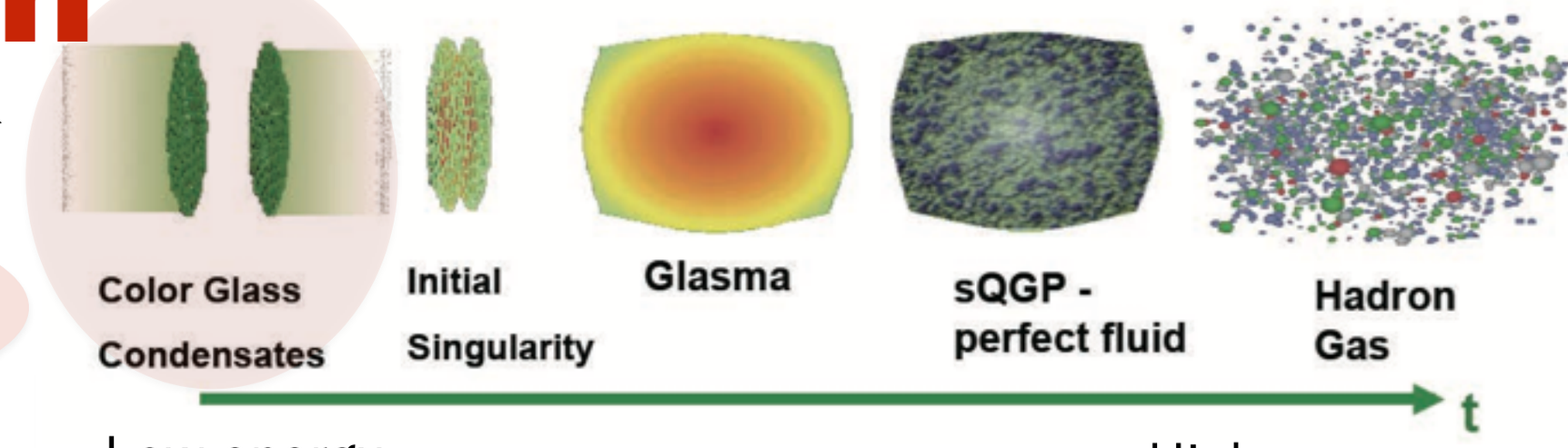
Motivation

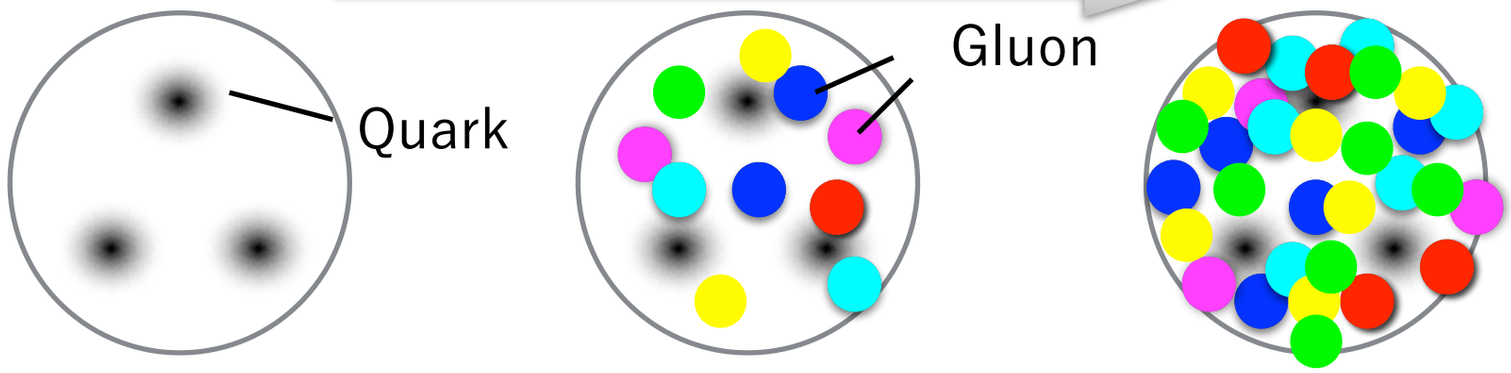
What is the nucleon before the collision ?



Parton distribution as a function of Bjorken-x at Q^2 = 10 GeV^2

The time scale of collision





Bjorken-x

$$x = \frac{2p_T}{\sqrt{s}} e^{-y}$$

Small-x

$x \leq 10^{-4}$..**CGC occures?**

Nuclear form before nuclear collision ..

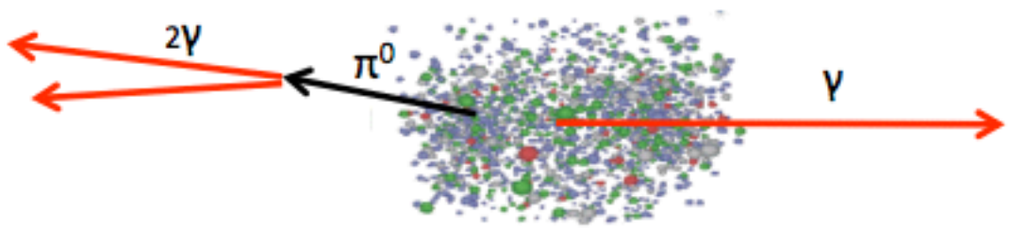
- **Model "Color Glass Condensate(CGC)" ..the saturation of gluon**
- **Access to information in the initial stage of collision**

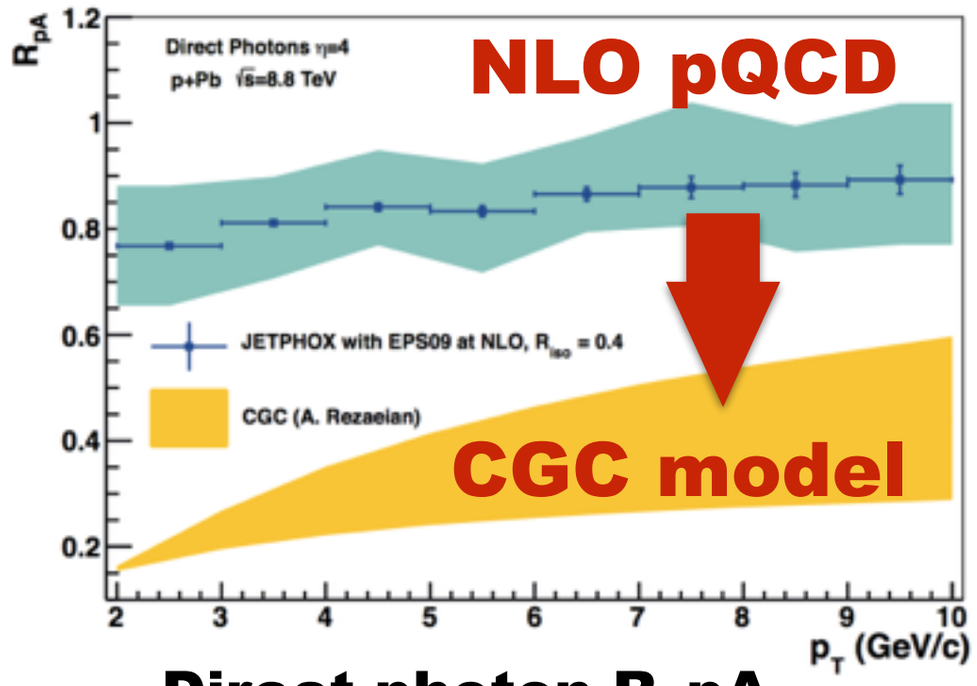
  ..Low x , that is at high energy and forward region

Direct Photon measurement

Experimental validation Probe ..

Direct (isolated) photon



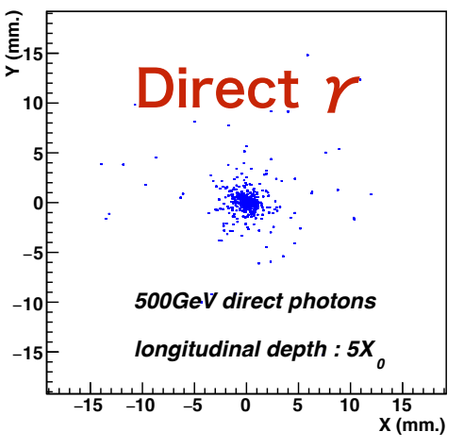


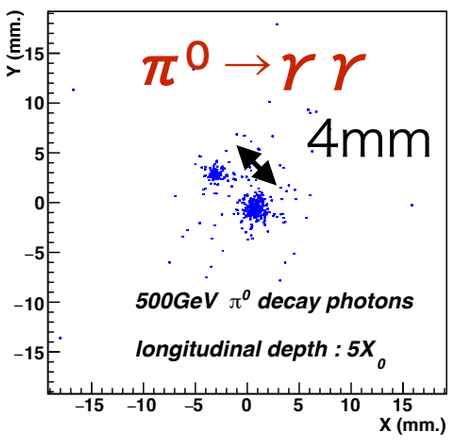
Direct photon R_pA

η = 4, p+Pb,√s = 8.8 TeV

Required performance → **1, high position resolution enough to separation γ/π0**

2, energy measurement with wider dynamic range





simulation by GEANT4

1, HGL(high Granularity Layer)

..High position resolution (MAPS detector)

2, LGL(Low Granularity Layer)

..Energy measurement (PAD detector)

FoCal design

Si/W sandwich constructer

W: Absorber

$1X_0 = 3.5\ \mathrm{mm}(1\mathrm{layer})$

$R_\mathrm{M} = 9.3\ \mathrm{mm}$

2 types of Si sensor

1. LGL(Low Granularity Layer)
   Si Pad

   $1\mathrm{Pad} = 1 \times 1\ \mathrm{cm}^2$

   $1\mathrm{layer} = 64\ \mathrm{Pads}(8 \times 8)$

   Energy measurement

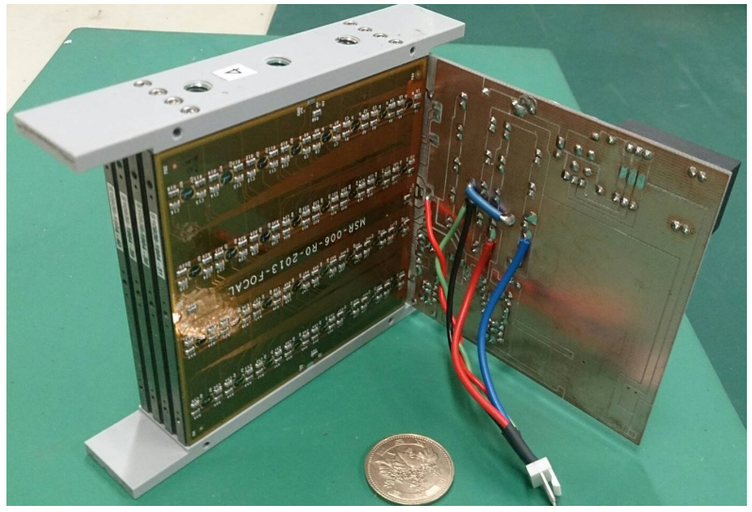
2. HGL(High Granularity Layer)
   Monolithic Active Pixel Sensors
   (MAPS)

   $1\mathrm{pixel} = 30\ \times 30\ \mu\mathrm{m}^2$

   digital readout

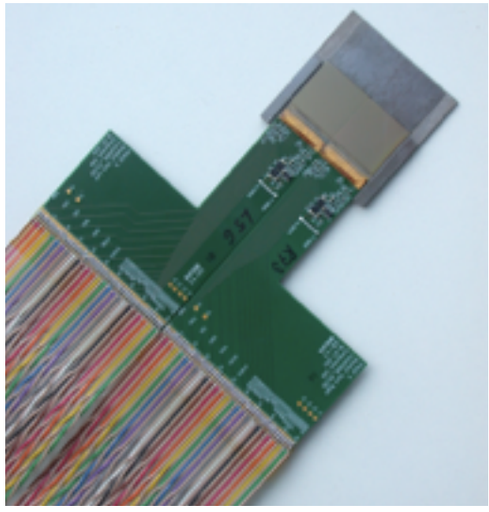
   High position resolution

LGL

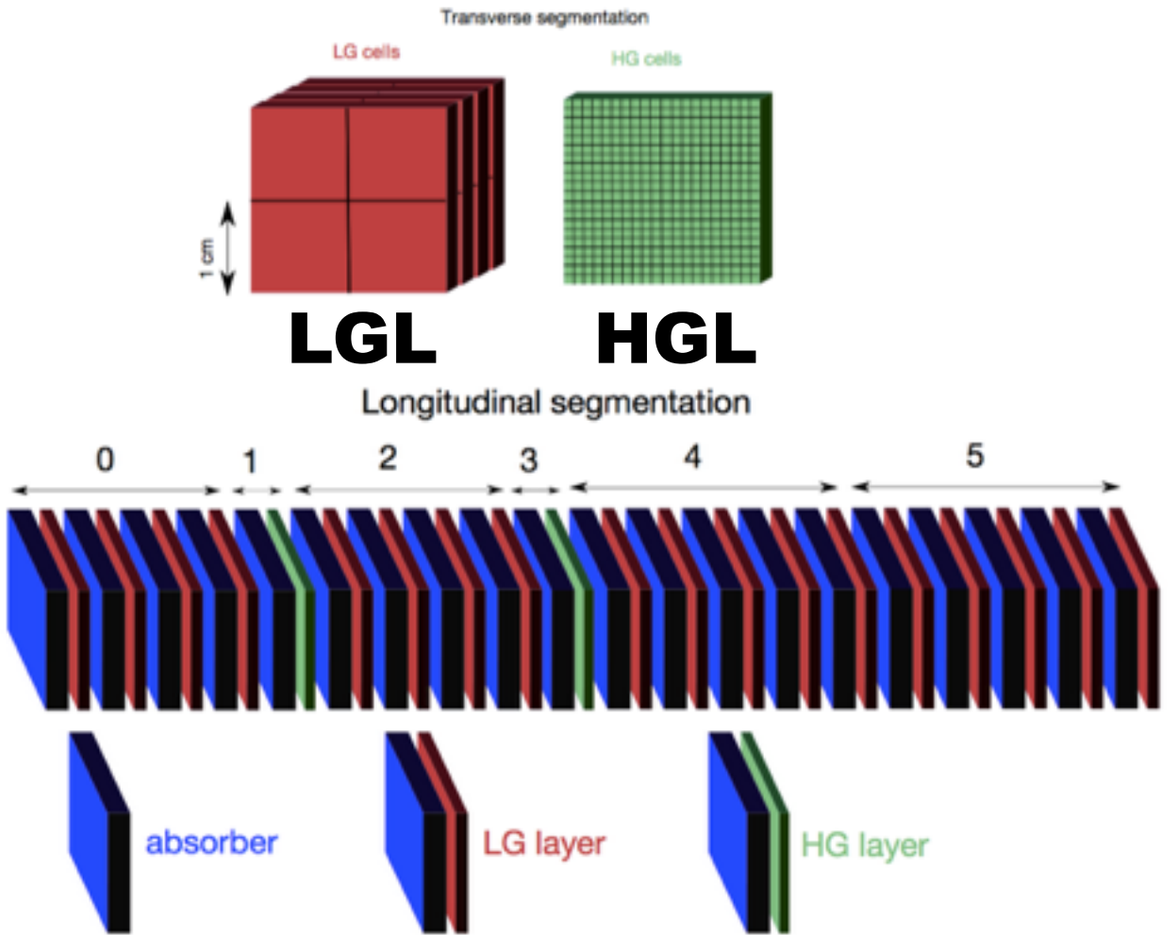


University of Tsukuba

HGL

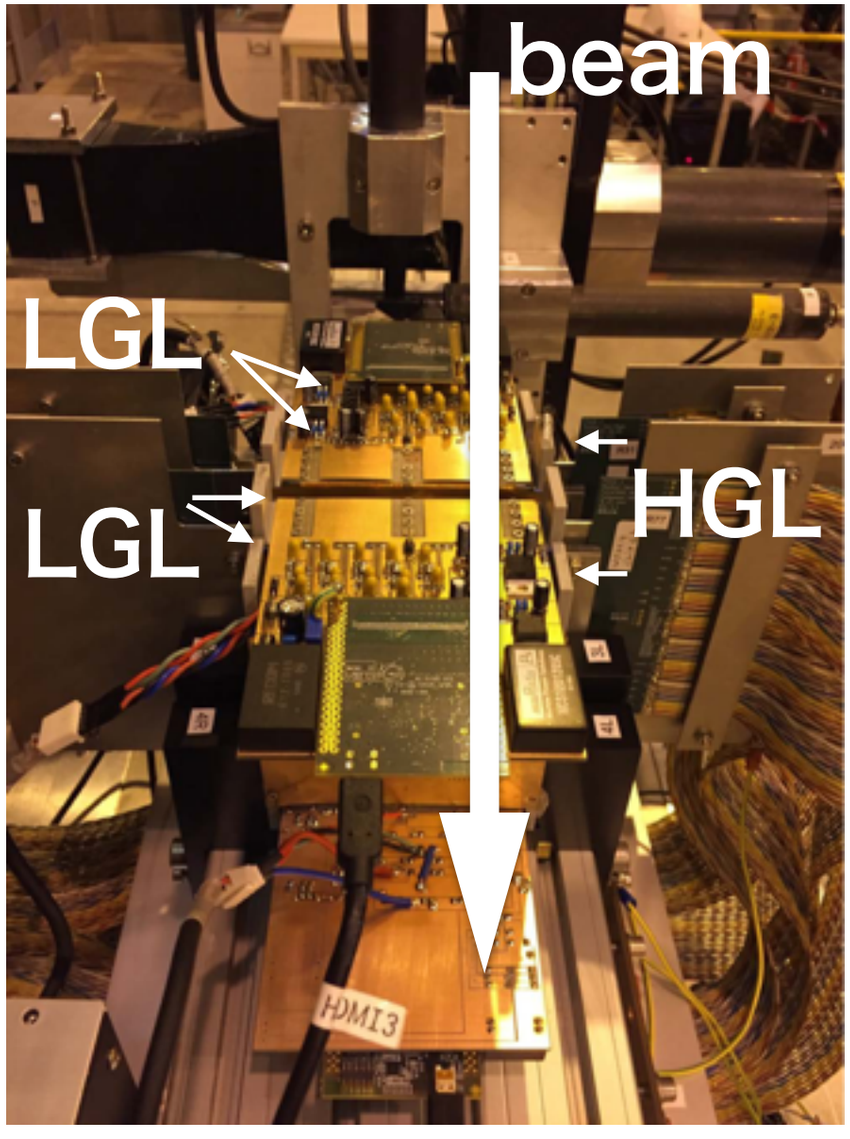


Utrecht Univ.

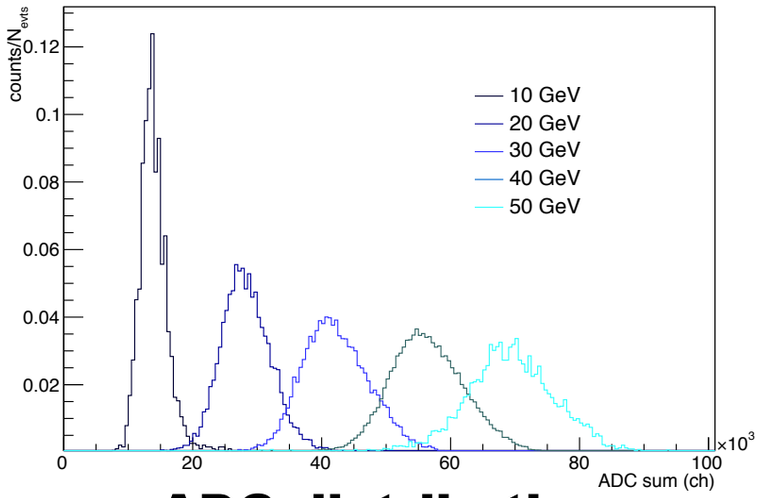


Straw man design

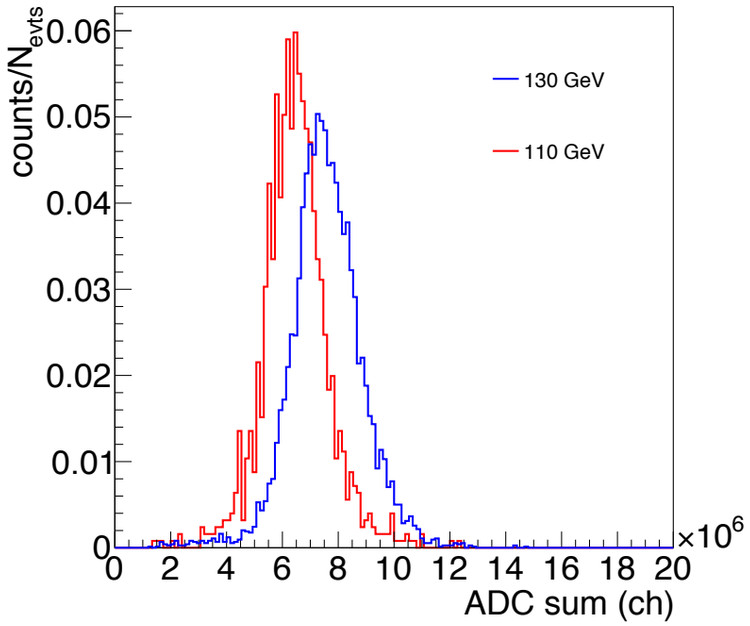
Performance evaluation of the prototype

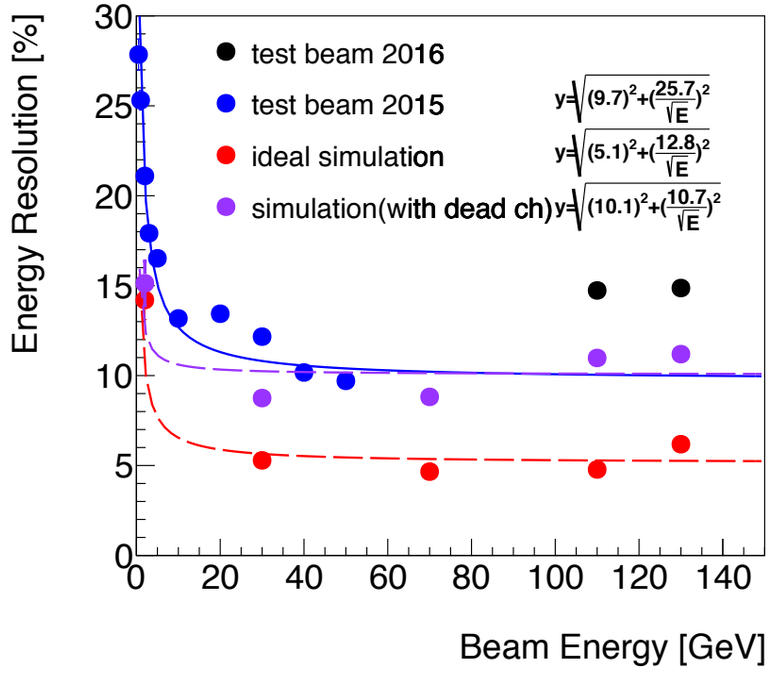


Test beam at CERN SPS in 2016



ADC distribution





✓Take data up to 130GeV

✓Energy resolution 15%

✦Test beam ORNL (Oak Ridge National Laboratory)
prototype until 2014～2016

next.. MIP measurement and more wider dynamic range
Improve energy resolution

Activity in 2017

✦Trial in this year..

Production new prototype

(The first attempt of Japan FoCal group)

Ongoing

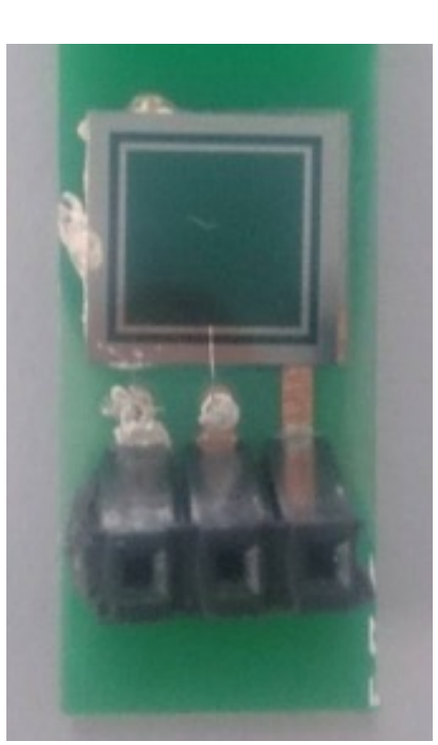
✦Evaluation of basic characteristics

✦Si-Pad Design optimization

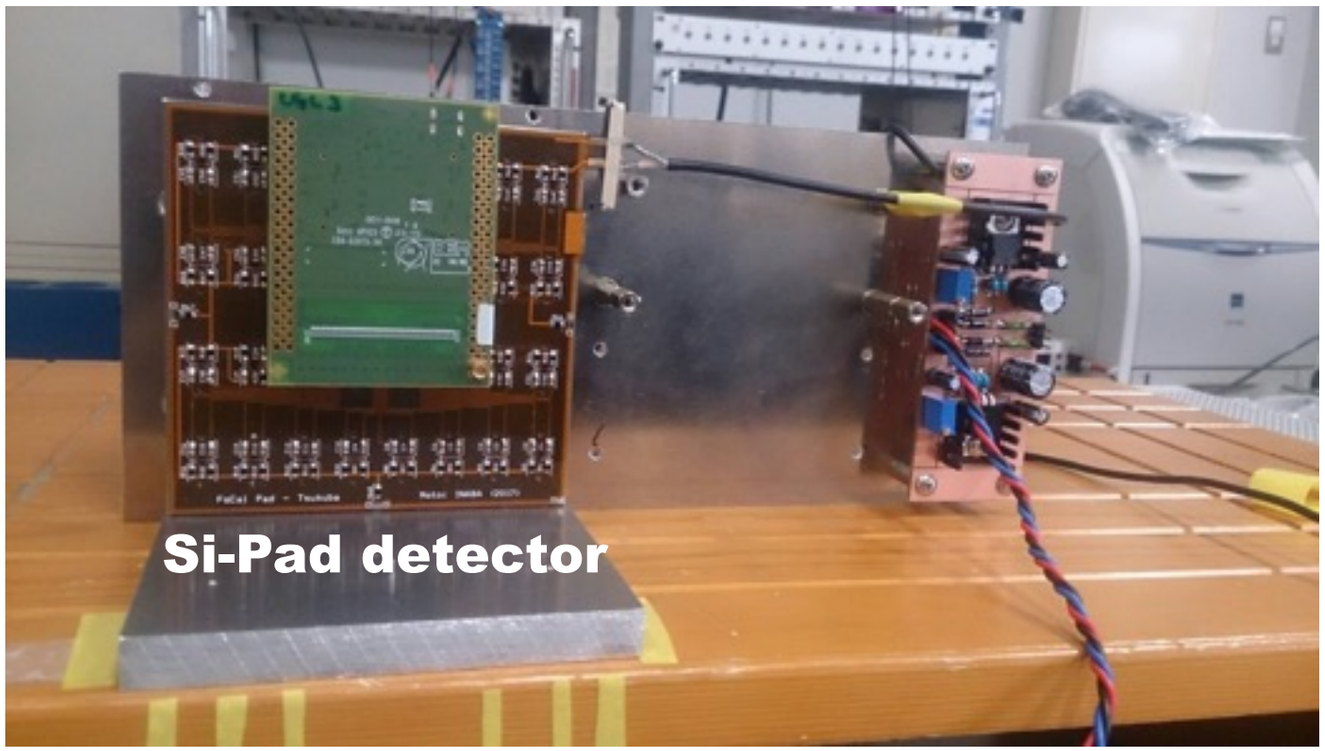
✦Si detector production

✦Test beam (at Tohoku univ. ELPH)

MIP ~ Low Energy measurement

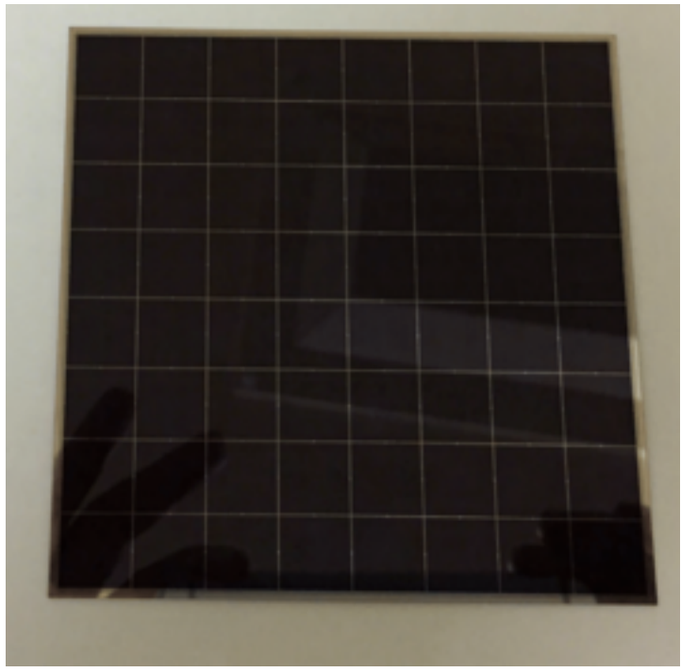


1ch monitor PD for basic characteristics test



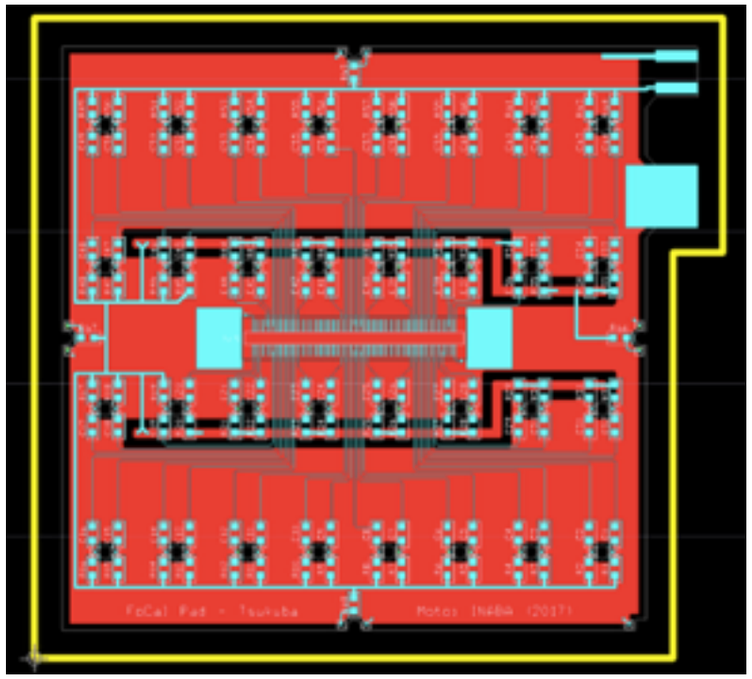
Si detector (8×8 ch)

Production

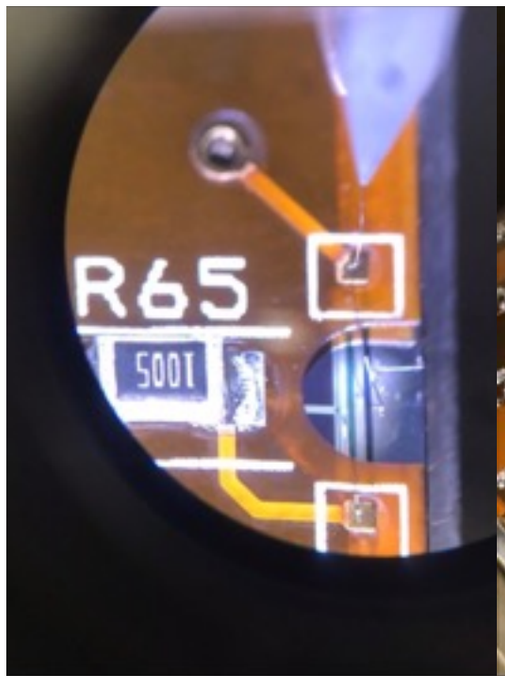


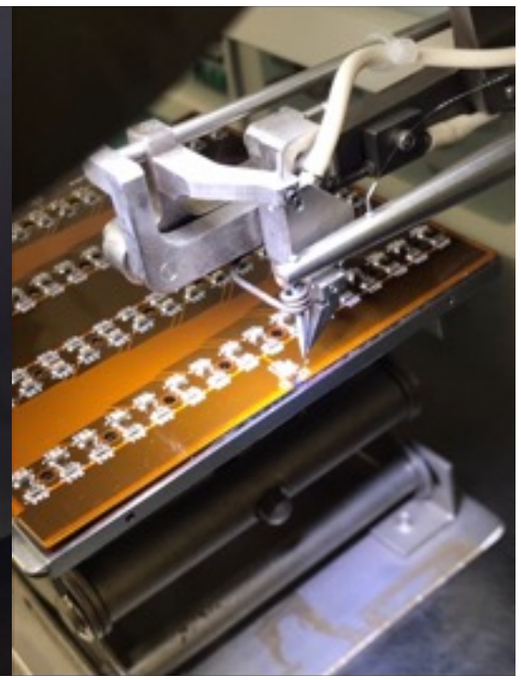
Si PAD made by Hamamatsu
1cm^2 Pad size 8×8 cell

Double-sided
adhesive tape

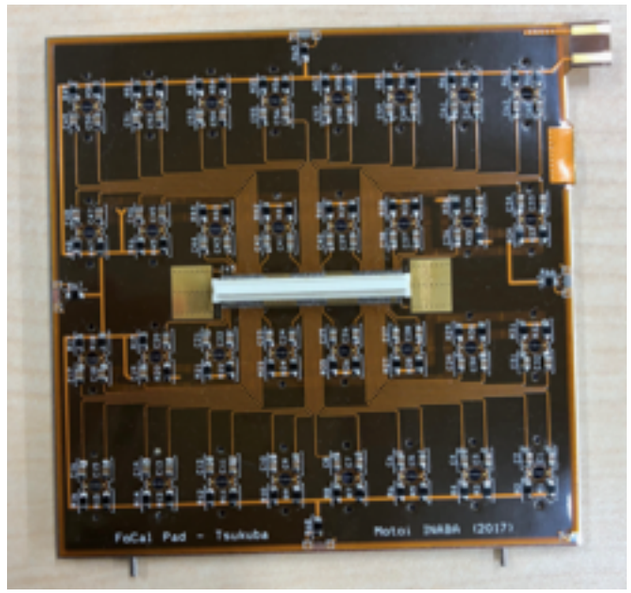


Flexible printed circuits

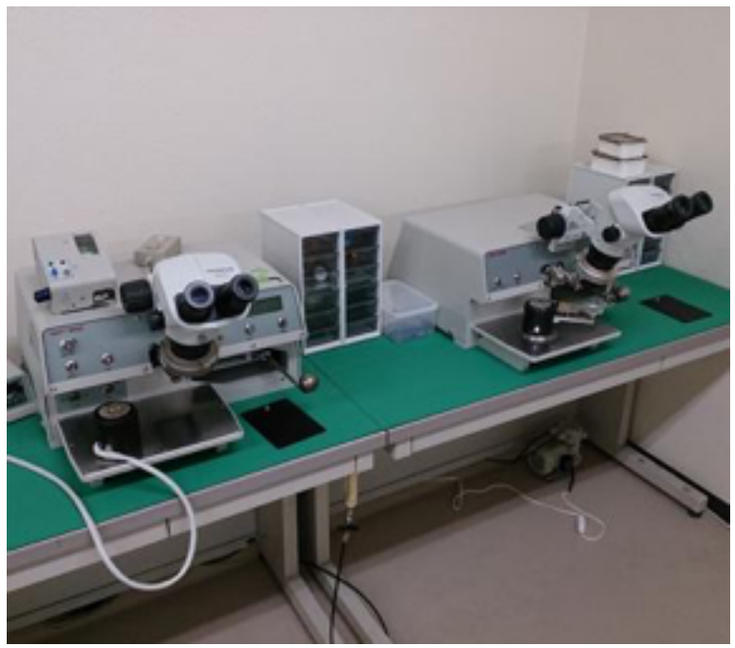




Picture when boning



Comple !



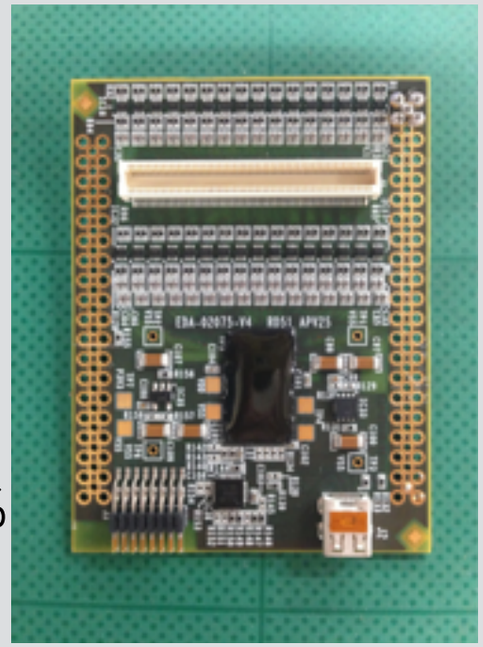
Bonding machine

Bias circuit and read line to each cell,
GND connect with silicon
with wire of several 10 μm thickness

Readout System

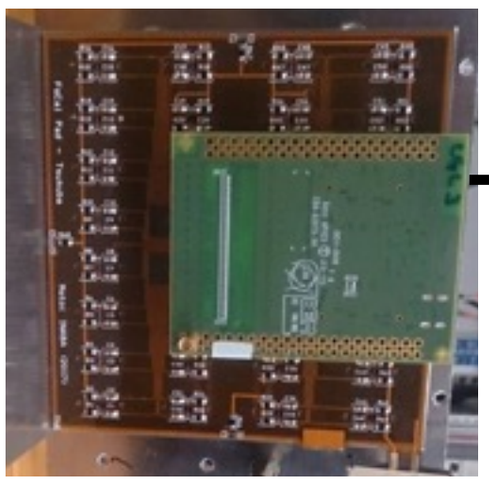
APV25(CERN RD51)

readout chip
preamp, shaper
128 ch : output
Sampling frequency:40MHz
5Gains: 80,90,100,110,120%

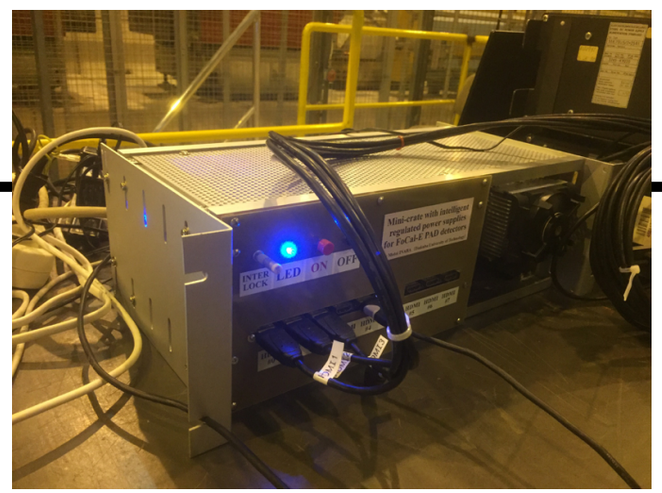


SRS(Scalable Readout System) (CERN RD51)

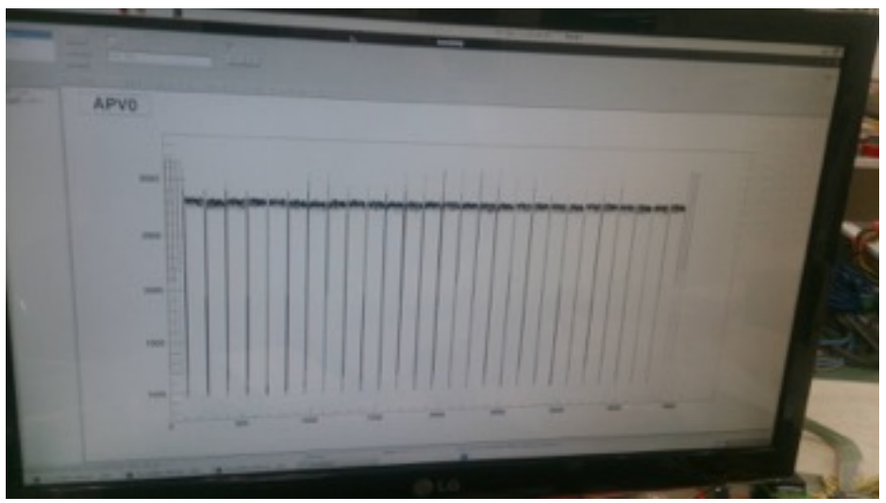
ADC Board:12bit 16ch ADC
128×16 = 2048ch
FEC Board: front-end
Control of digital information by FPGA on FEC
UDP communication by GbE



HDMI



GbE

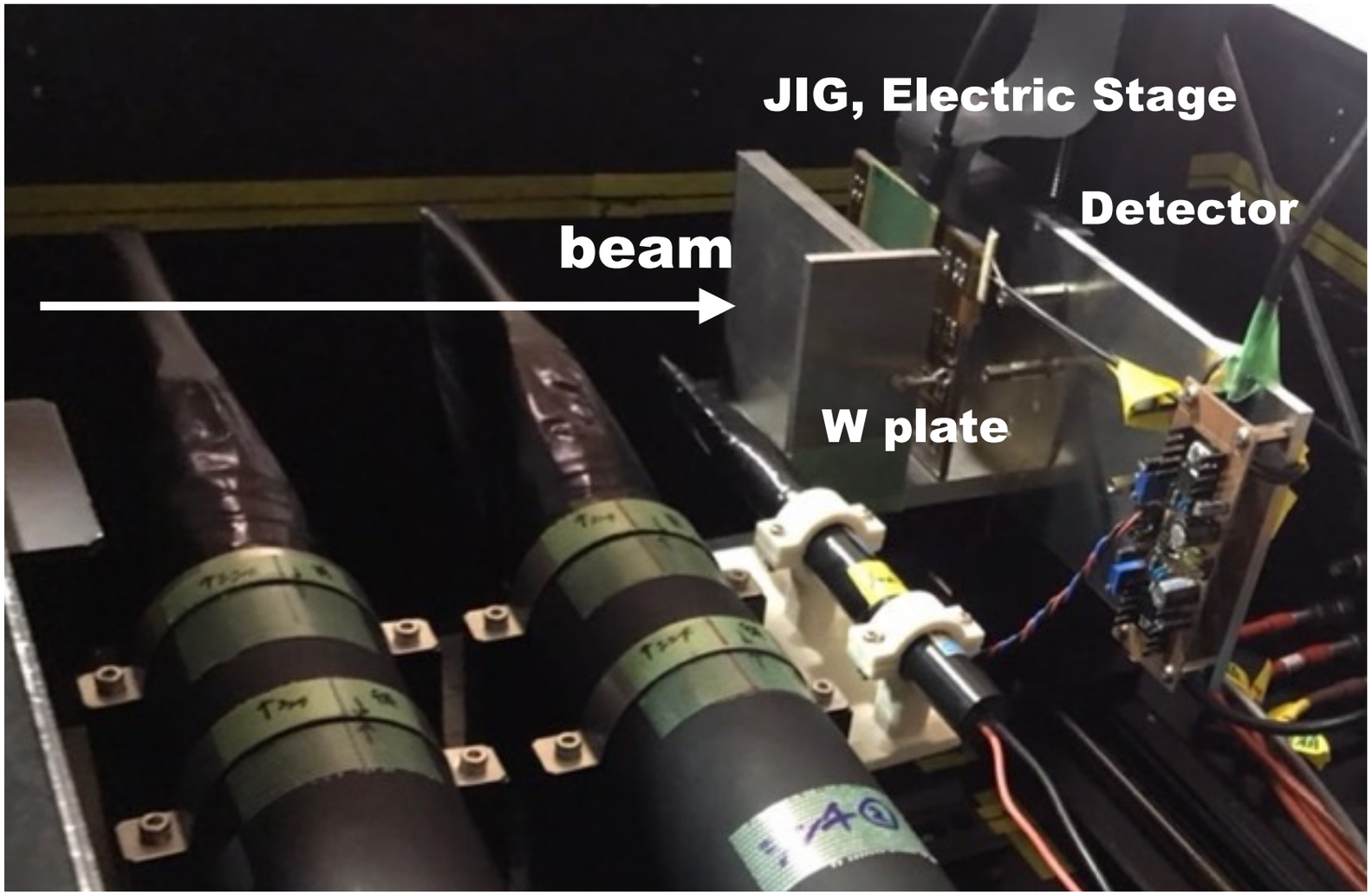


Detector

SRS
- **AD conversion**
- **Front end**

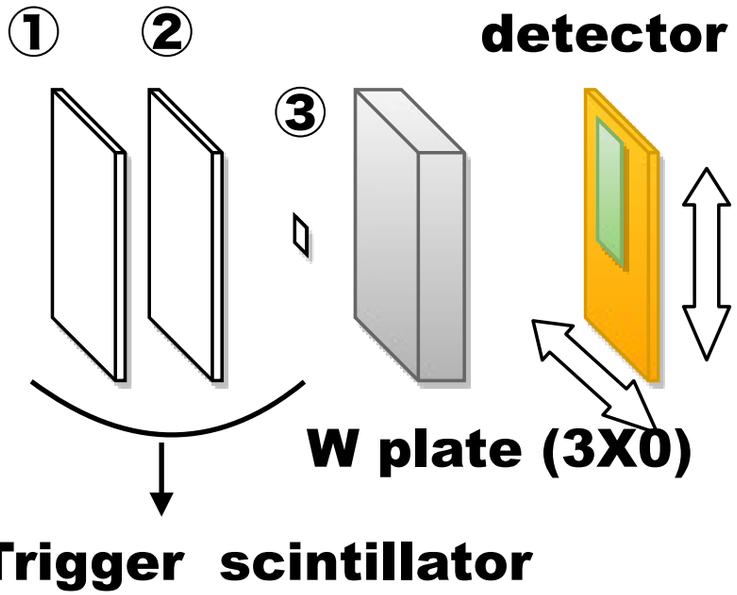
mmDAQ(PC)
- **Online monitor**
- **Data taking**

Set up



①②: 10×10 cm

③: 4×4 mm



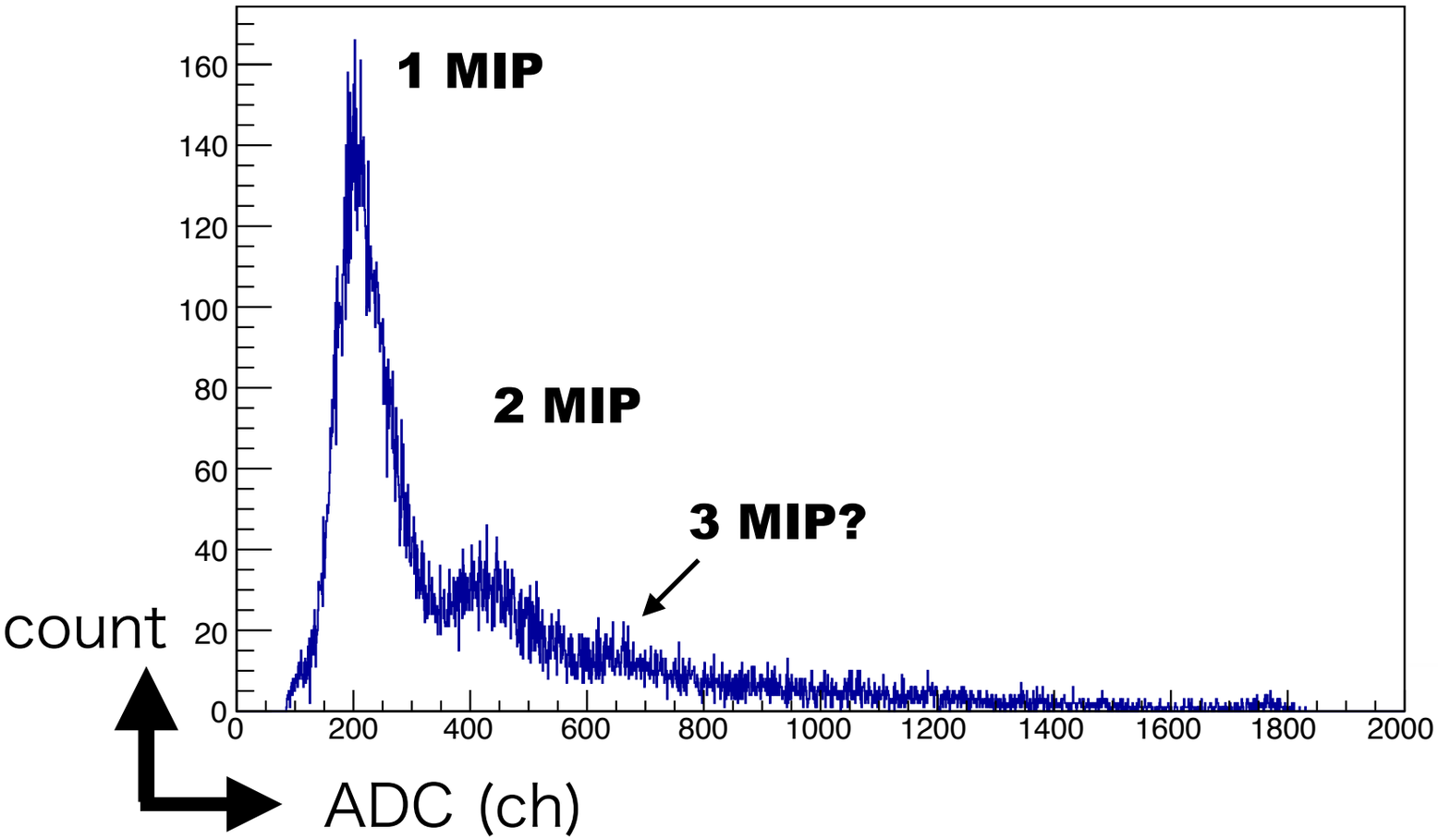
✦Date: December 15 - 22 at ELPH in Tohoku University

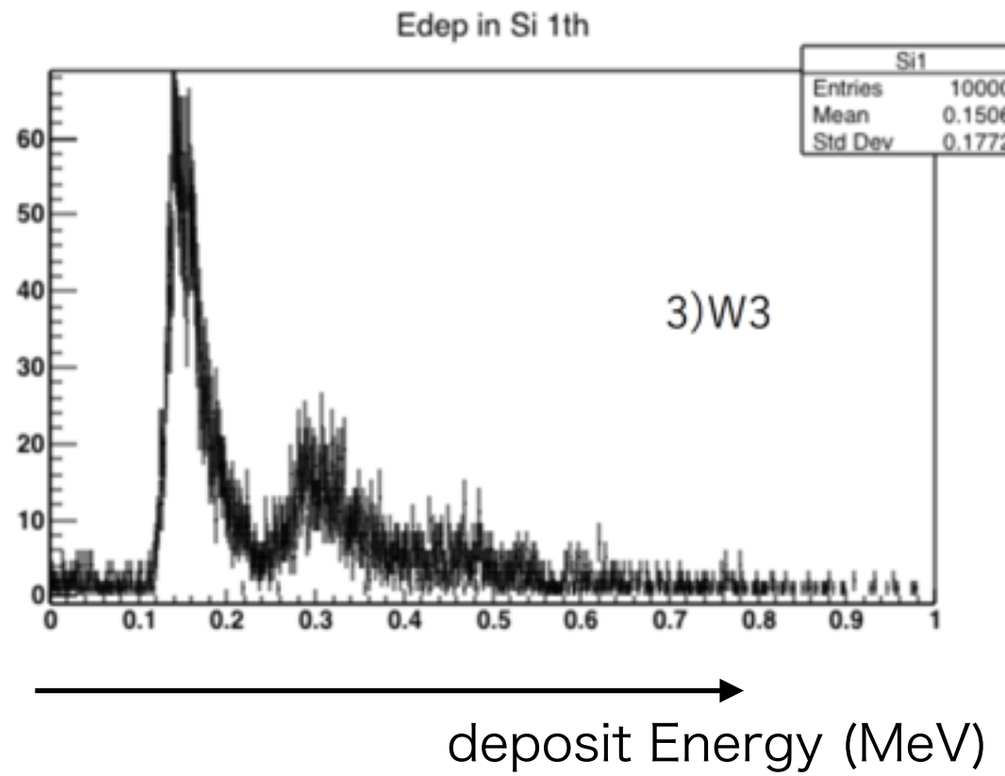
✦800 MeV/c e^+ beam

✦Generate beam trigger with coincidence of three scintillator

✦Place $3X_0$ tungsten plates in front of the detector to raise a shower (take data with W on and off)

Result MIP response

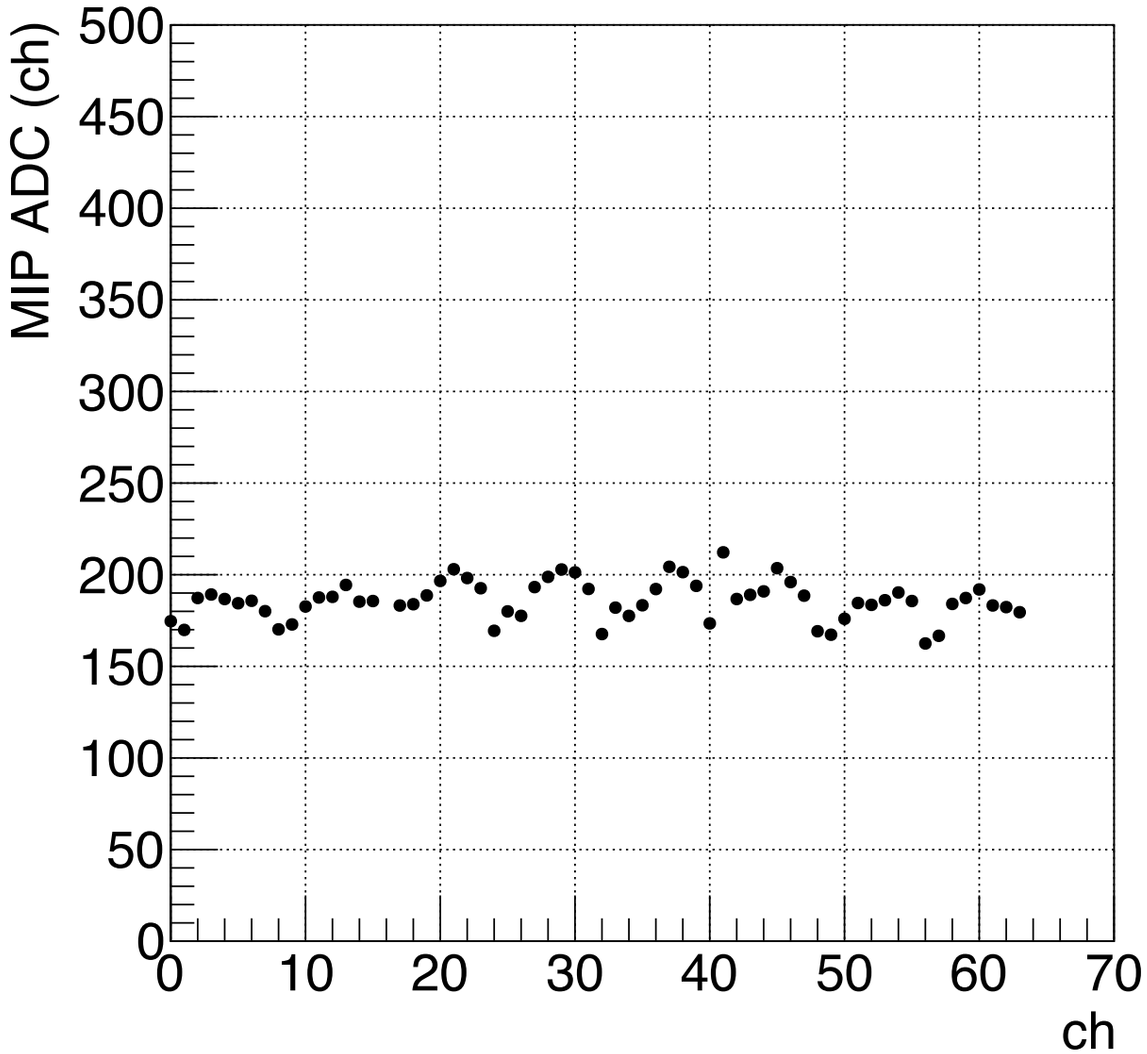




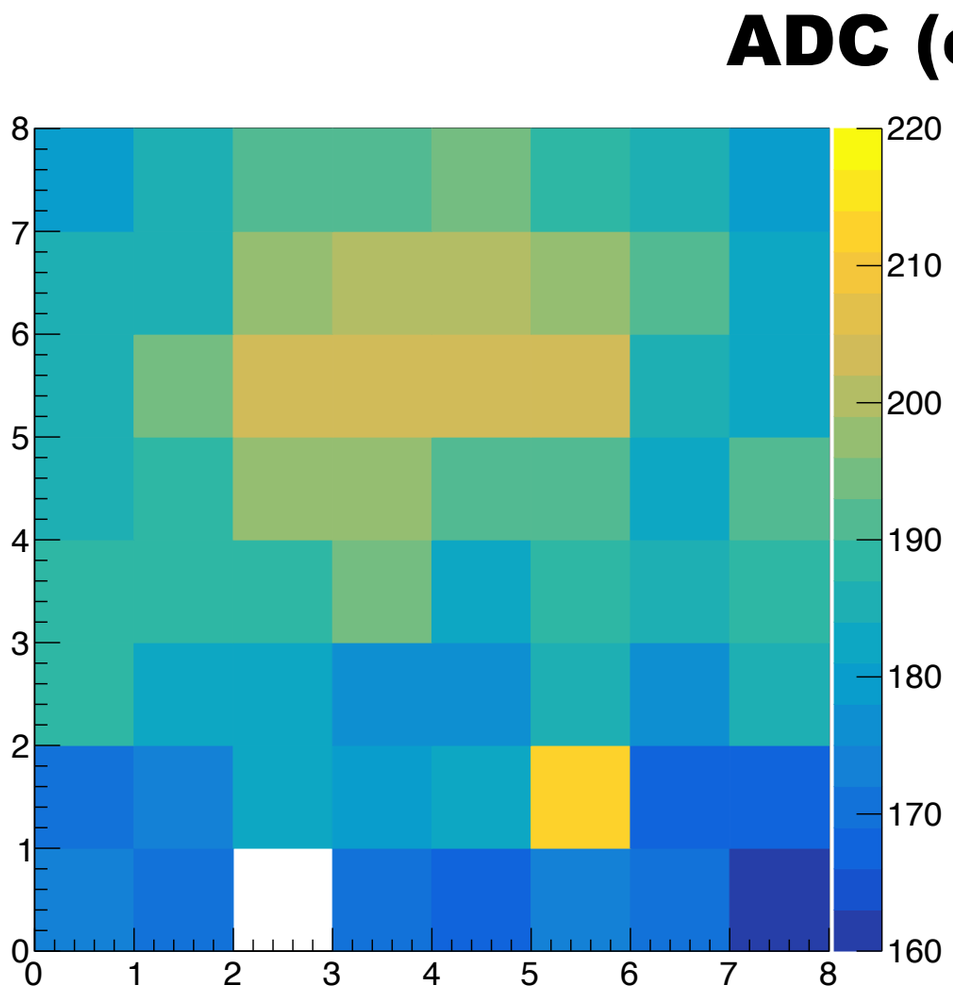
GEANT4 simulation

- **1 Pad ADC distribution**
- **1 Events that two electrons, three entered in Pad, can also be observed (peak is proportional to number of electron)**
- **Consistent with GEANT4**

Characteristics of each channel



MIP ADC channel as a function of ch



8×8 hit map

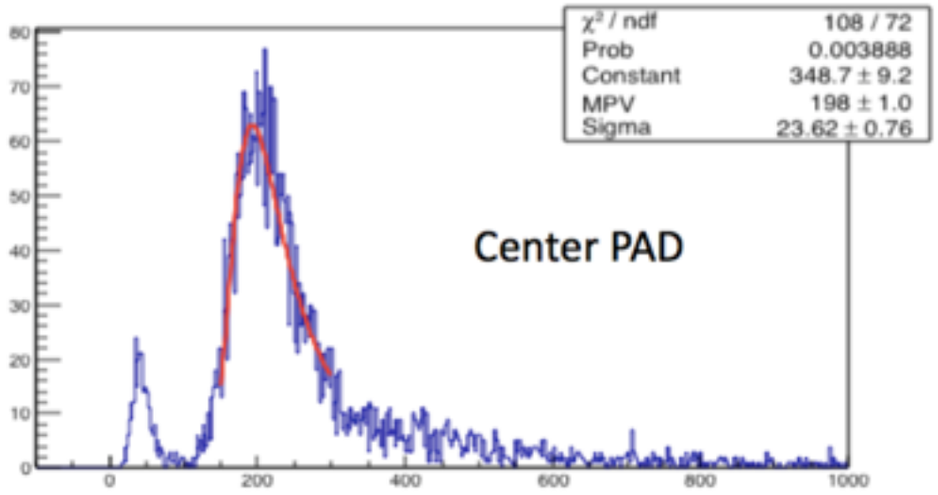
- ✦Without tungsten : beam behave as MIP
- ✦Variation < 10 %
  - (Pad and electronics characteristics ?)
- ✦Signal is smaller at the edge
  - -> Because of dark current ?
  - or signal attenuation due to wiring length ?

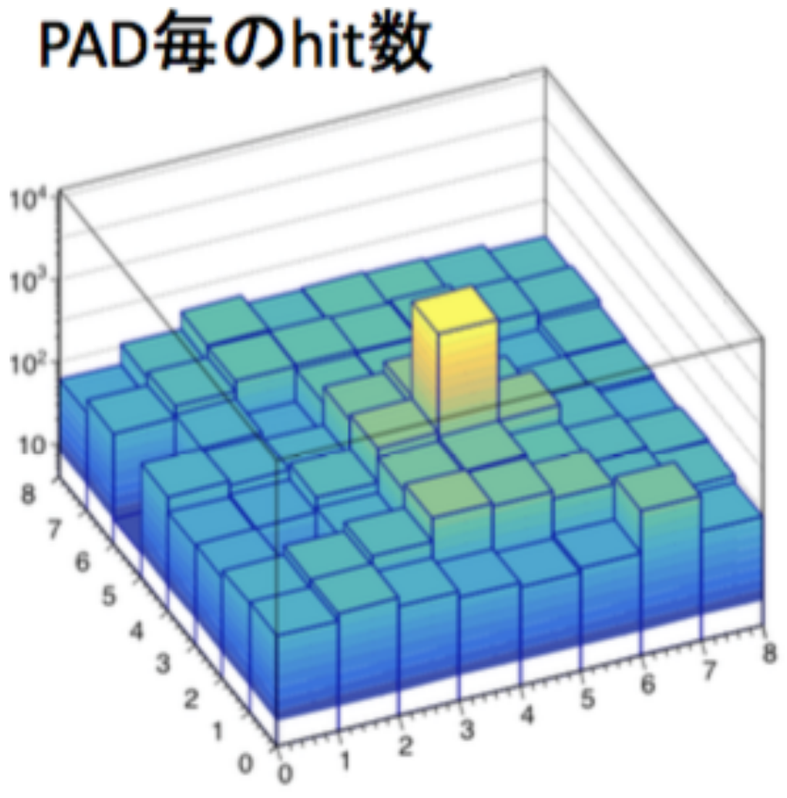
Efficiency

- **Efficiency = hits / entries**

hit .. Number detected by pad

entries .. Number detected by the trigger





number of hits

- efficiency(=hits/entries)
  - Ch72 only->89 %
  - 9PADs-> 94 %
  - 25PADs->96 %
  - 49PADs -> 97 %
  - 64(all)PADs -> 97%

✦Total efficiency is about 97%

..The beam is not narrowed down to 1 channel

Summary

- ✦ **FoCal project**

  ..Electromagnetic calorimeter scheduled to be installed in front of ALICE detector

- ✦**Silicon Detector production for the first time**
- ✦**ELPH test**
  - **Successful observation of MIP signal**
  - **the variation of PAD < 10 %**
  - **efficiency 97 %**

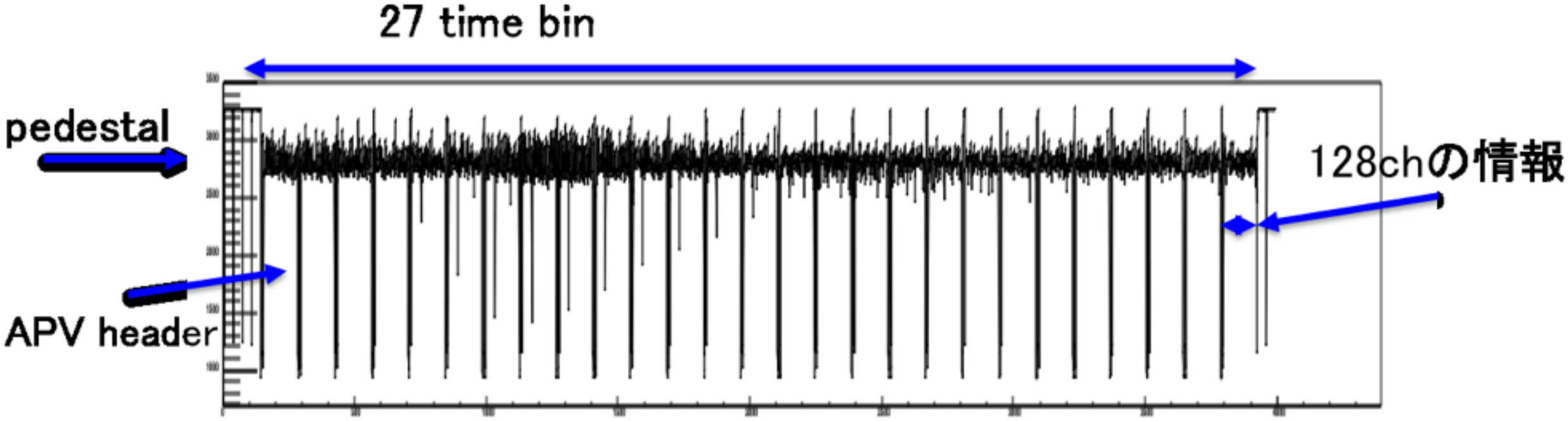
Next..

- ✦**Production of prototype for real machine by increasing the layer of silicon as a calorimeter**
- ✦**Dynamic range expansion to enable observation of high particle energy in the forward direction**

Thank you very much for your attention !

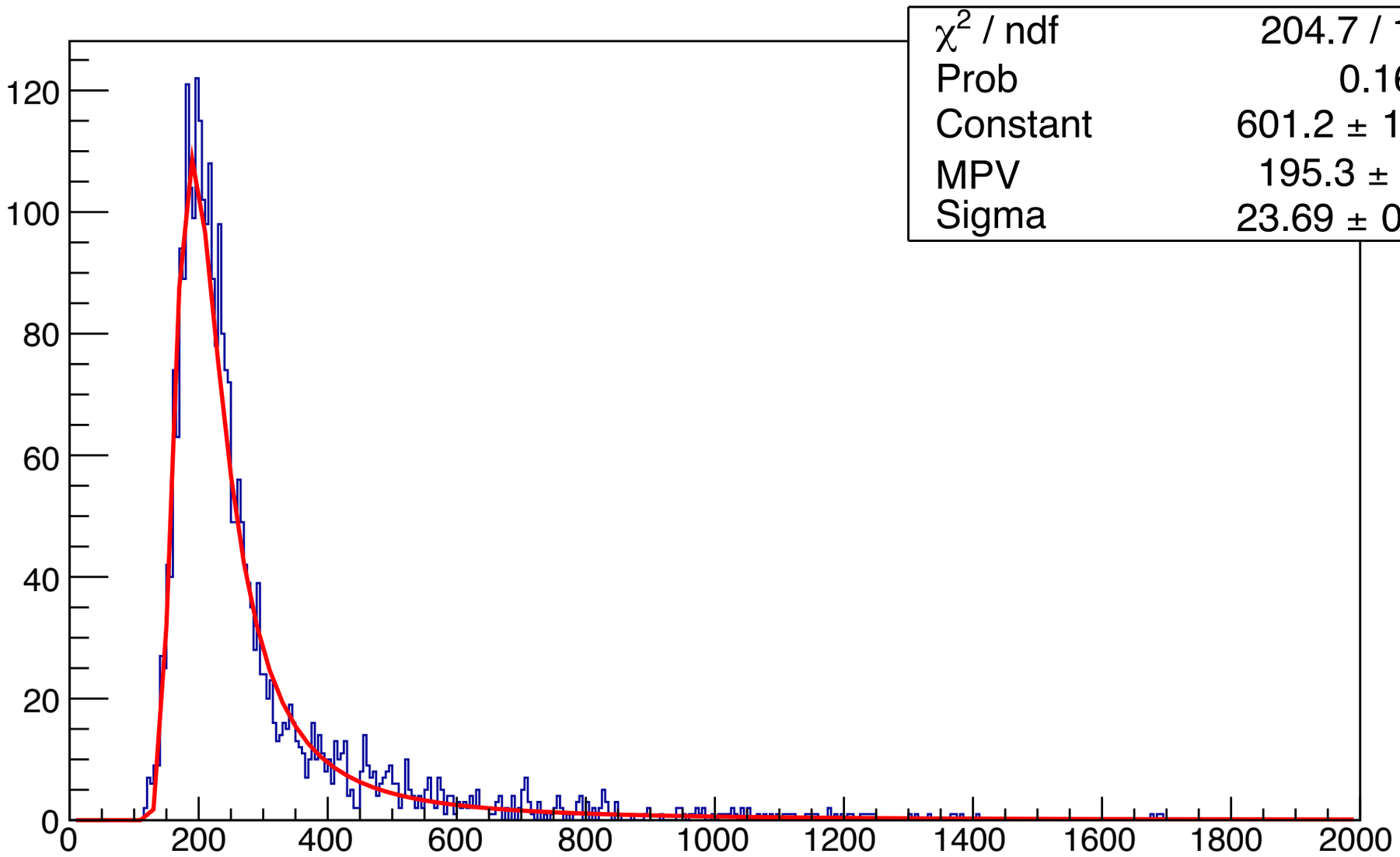
back up

データ構造



✦APVのサンプリング周波数40MHz（25nsec）ごとにAPV128 ch分の波高をADCにして読み出す

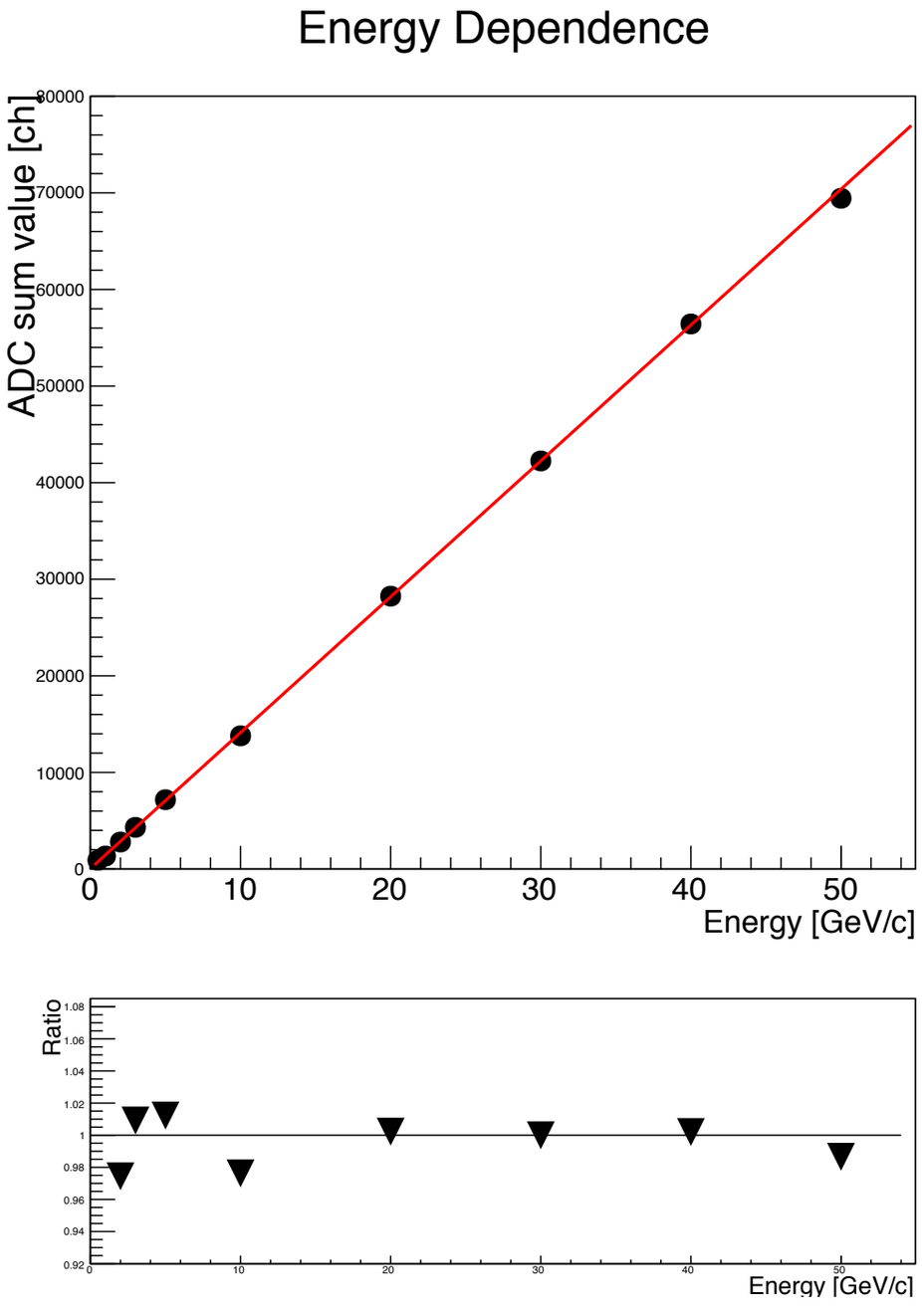
MIP

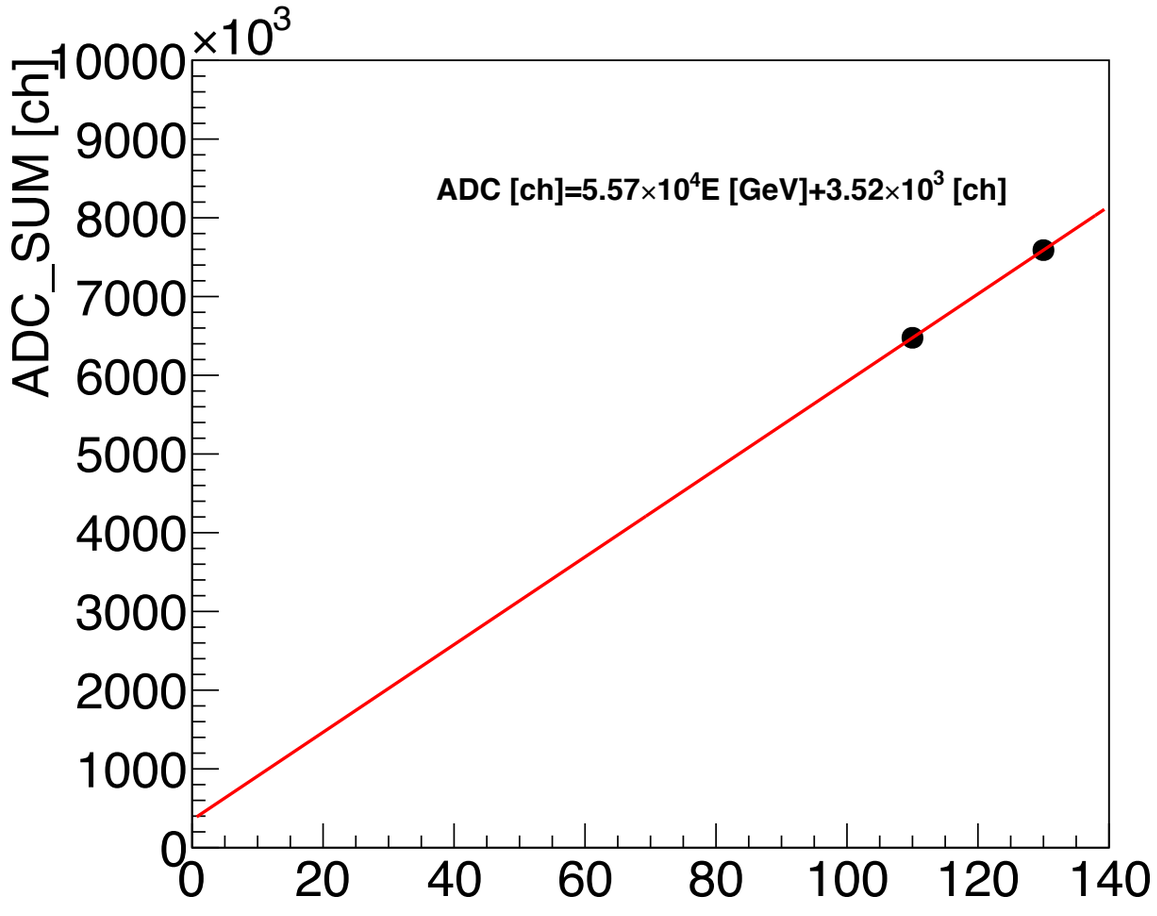


1MIPの分布

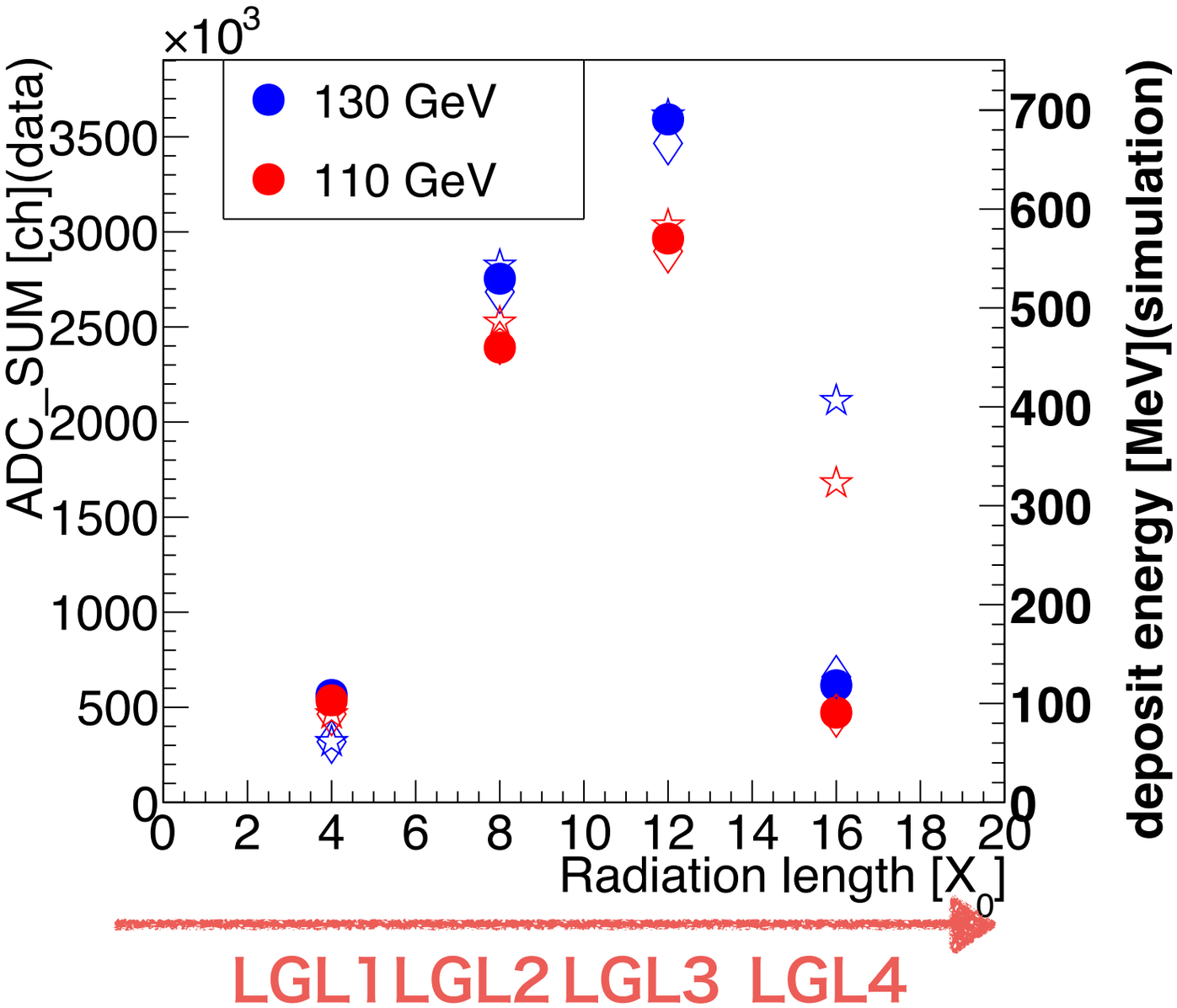
（Wを置かない場合のデータ）

Linearity


Energy Dependence
ADC sum value [ch]
Energy [GeV/c]
Ratio
Energy [GeV/c]


ADC_SUM [ch]
×10^3
ADC [ch]=5.57×10^4E [GeV]+3.52×10^3 [ch]
Beam Energy [GeV]

Longitudinal shower growth



beam test result

simulation (with dead ch)

ideal simulation