TestBeam of Scintillator ECAL Engineering Prototype

LCWS13
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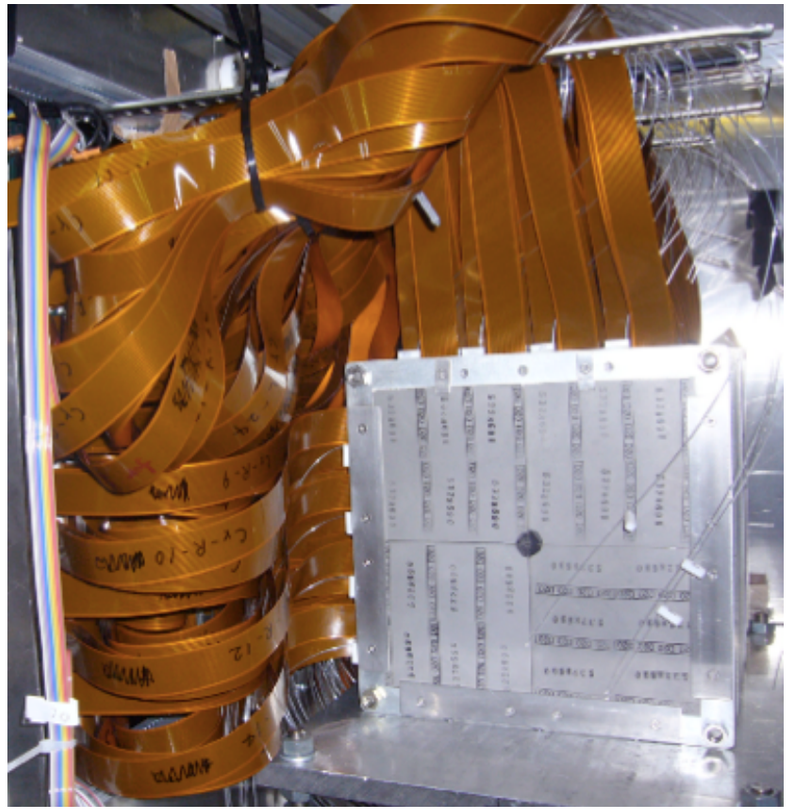
Introduction (ScECAL Physics prototype)

- CALICE group had made the scintillator ECAL physics prototype and tested them at FNAL in 2008, 2009.

- the scintillator ECAL showed having enough performance for the demands of ILD ECAL
  and it is now one of the candidates of ILD ECAL.



Demands of ECAL

Granularity : less than 1cm^2

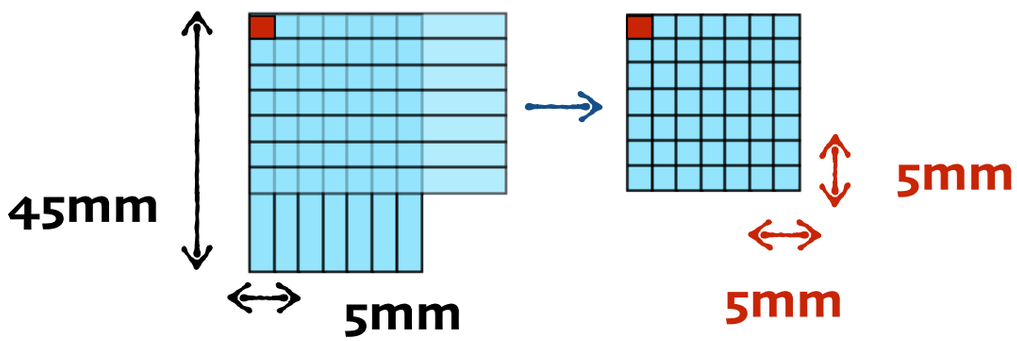
Energy Resolution : $15\% / \sqrt{E_{jet}}$ (for jet)

In order to achieve jet energy resolution of $30\%/\sqrt{E_{jet}}$ with PFA

- Granularity :

  Intersect 45x5mm scintillators and achieve 5x5mm granularity.

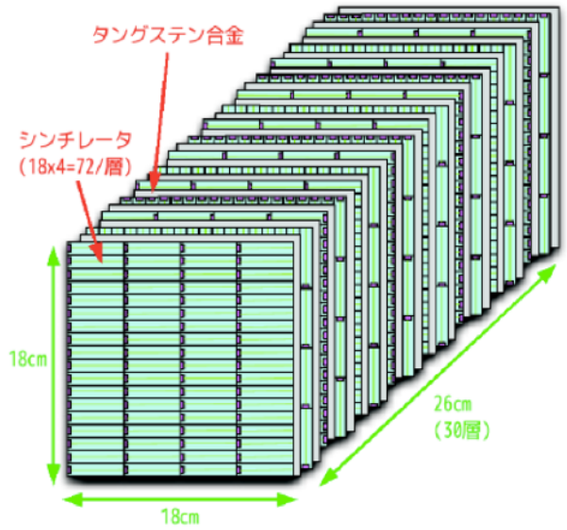
Strip Spriting Algorithm



- Energy Resolution :

  $12.9 \pm 0.4\% / \sqrt{E}$ (for single particle)

  ※ At this time we used 45x10mm scintillators



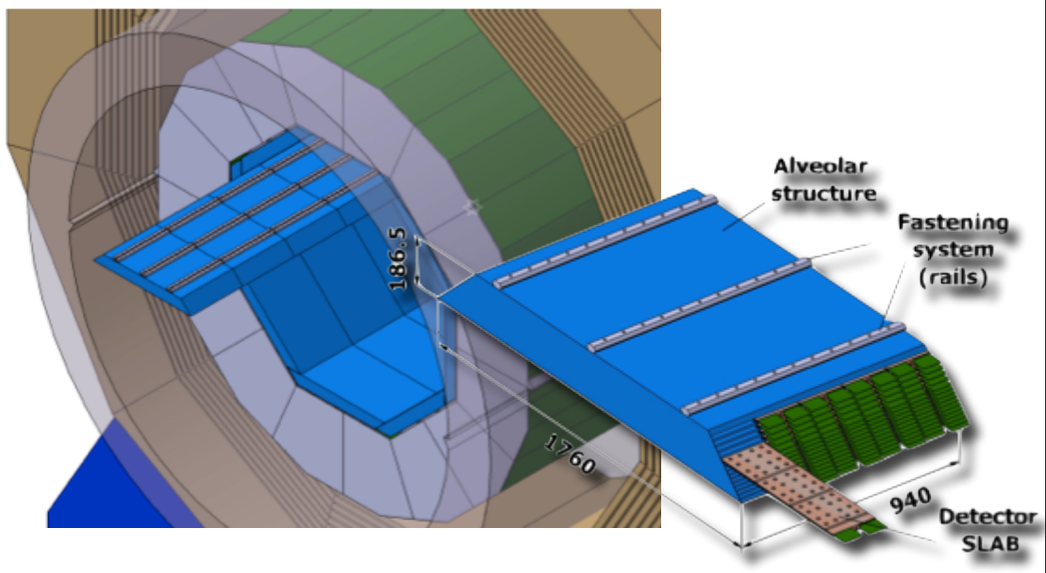
Scintillator ECAL Base Unit (EBU)

- Currently at stage of development of engineering prototype.

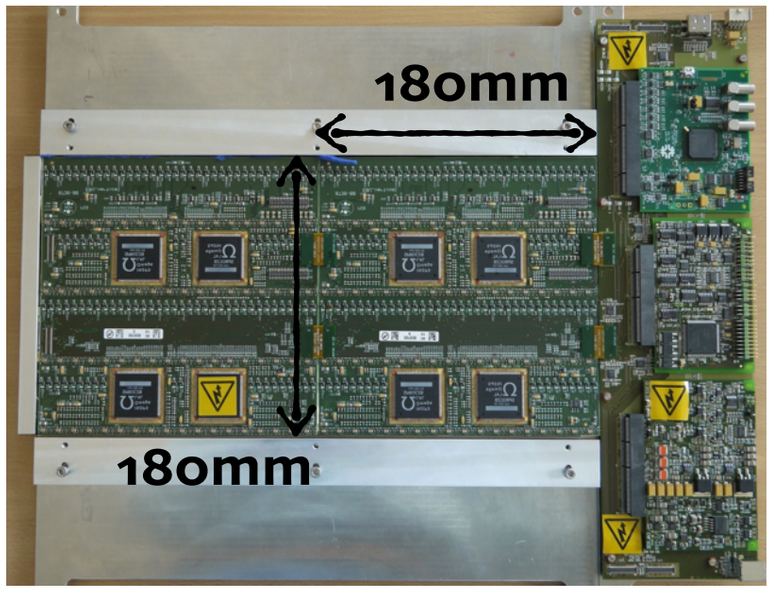
- CALICE group has developed the electronics "EBU" (scintillator ECAL Base Unit) which a readout chip is embedded at, based on analog HCAL electronics "HBU".

- The electronics "EBU",
  - Four readout chips are embedded at one EBU.
  - Can readout for 144 channels at one EBU.
  - Is quipped LEDs for each channel to gain calibration.
  - Is quarter the size of HBU.

- The readout chip "SPIROC",
  - to readout the silicon photomultipliers, SiPM.
  - Can set voltage for each channel individually.
  - Each channel has 16 memory cells to store data.
  - Has 12-bit ADC and 12-bit TDC.

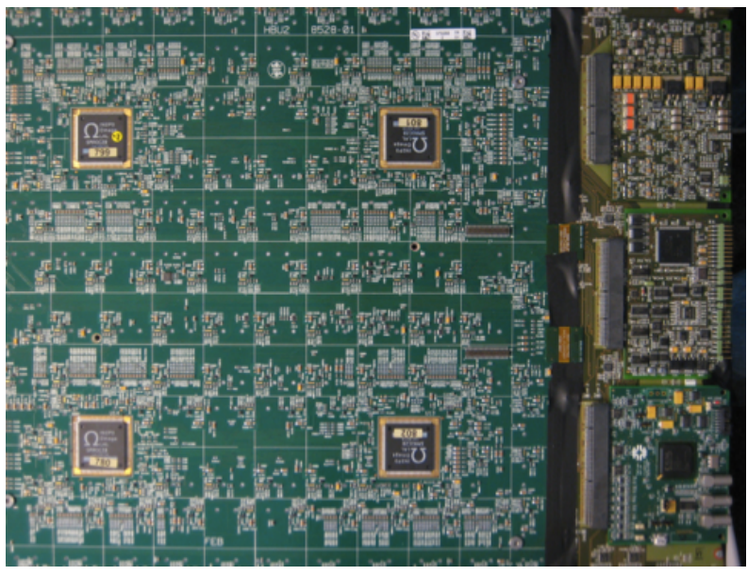


EBU

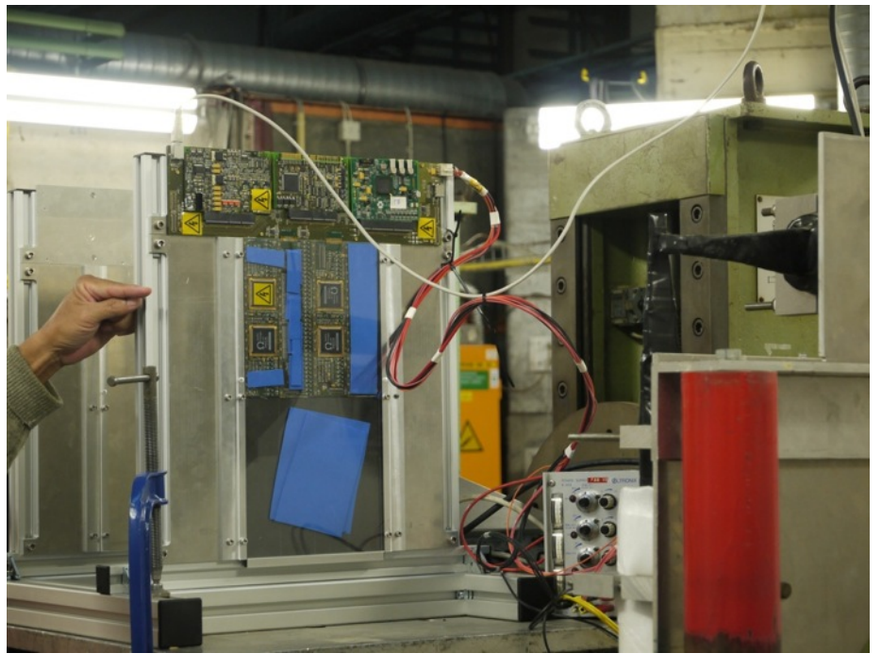


HBU 360mm

360mm



First TestBeam 2012 Oct.



- We had first Test Beam with this EBU on 2012 Oct.

  → Used only 1 EBU on 1 layer.

- Short summary.

LED gain monitoring

Succeeded 53% out of 112ch.

Over 20% of channels had problems.

→ MPPC's bias voltages. LED system.

MIP calibration

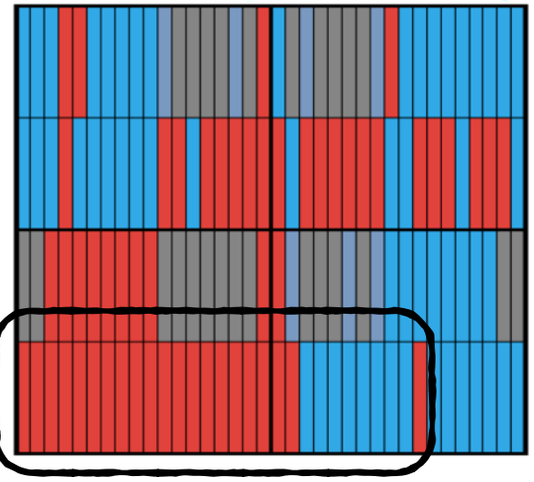
108(75%) channels out of 144ch could measure MIPs.

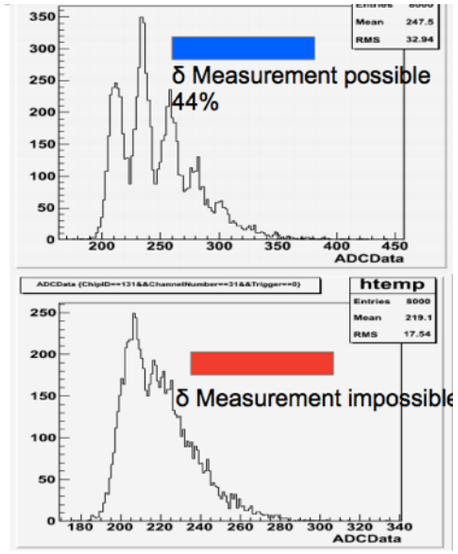
Problems

Settings of MPPCs bias voltage is too small.

Reflector film in front of MPPCs probably made problem on a ASIC

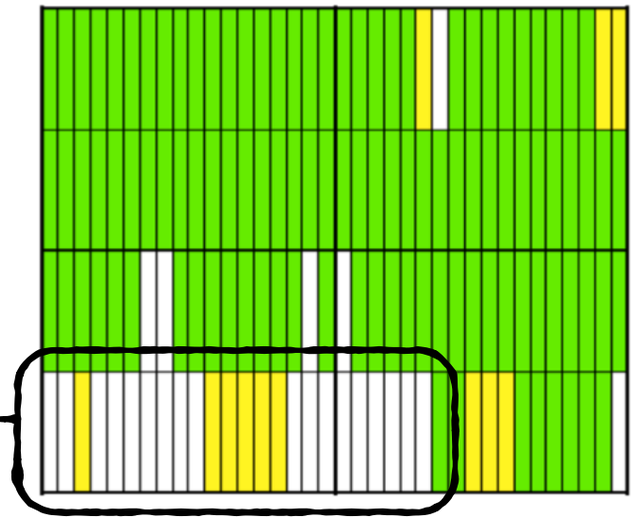
LED calibration

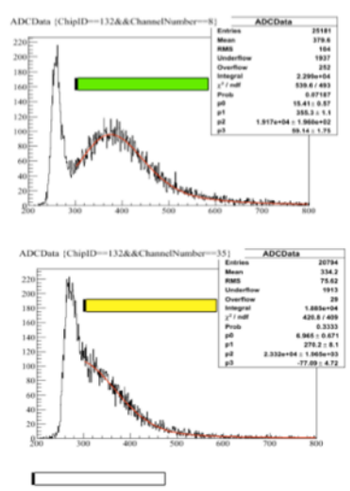




The channel which has no LED.

MIP calibration





: no signal or large noise

The Purpose of TestBeam 2013 July.

- We prepared two layers (Forward and Backward) consist of two EBUs (middle and terminal) and one EBU.

→ There are somethings to need to confirm.

Whether three EBUs work well.

Whether a terminal EBU is connected through a middle EBU works well.

Can we make two layers synchronize?

- What we missed at previous TestBeam 2012.

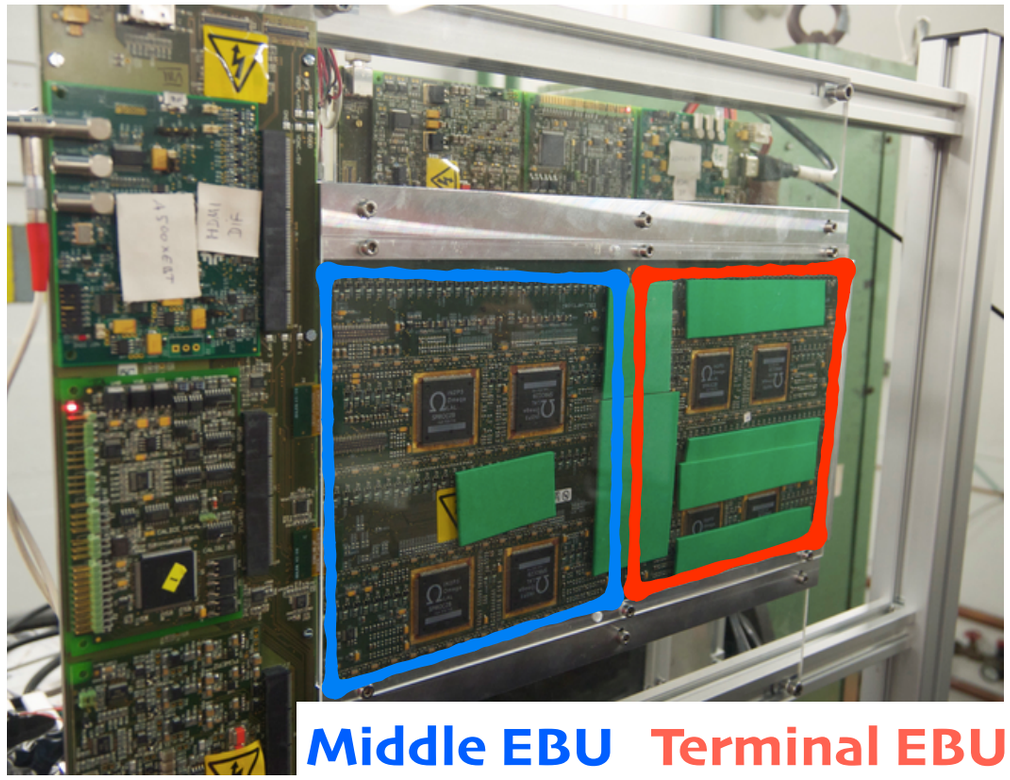
Study of TDC data.

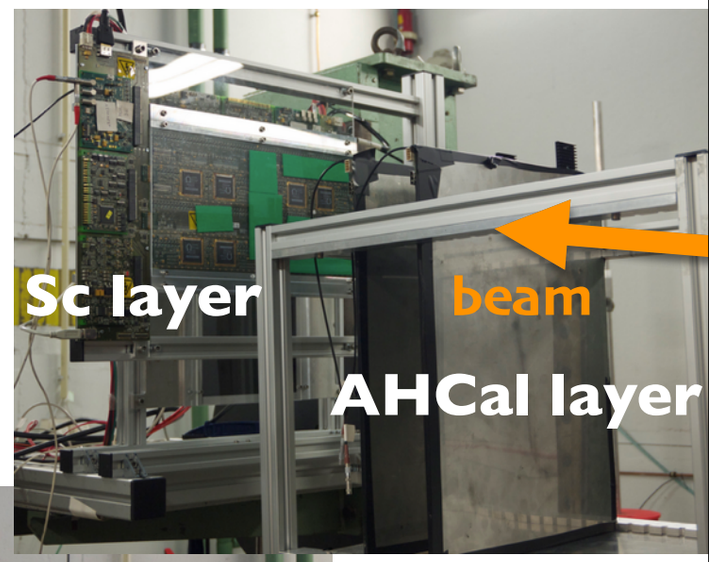
Precise position scan

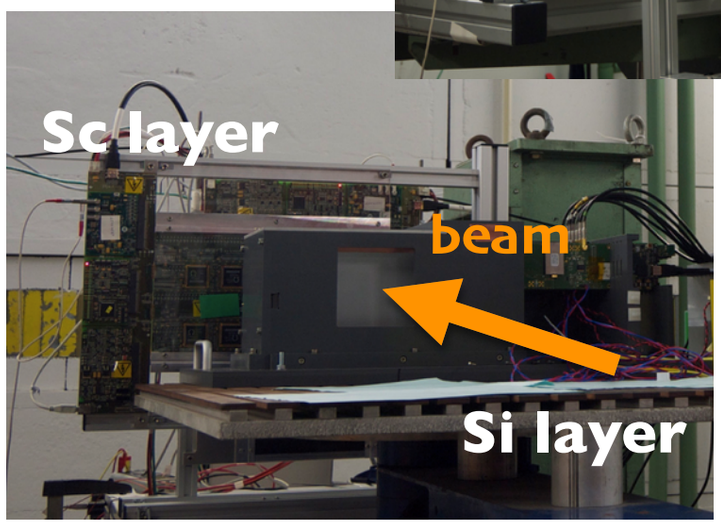
Analyze shower events with SSA.

Additionally

- We can make EBU synchronize with HBU?
- We can make EBU synchronize with SiECal?







Problem of Analog Memory Cells

- Each channel has 16 memory cells.

- Pedestals of each memory cell are quite different.

→ Need to analysis cell by cell
or correct pedestal for each memory cell.

- Cell by cell analysis.

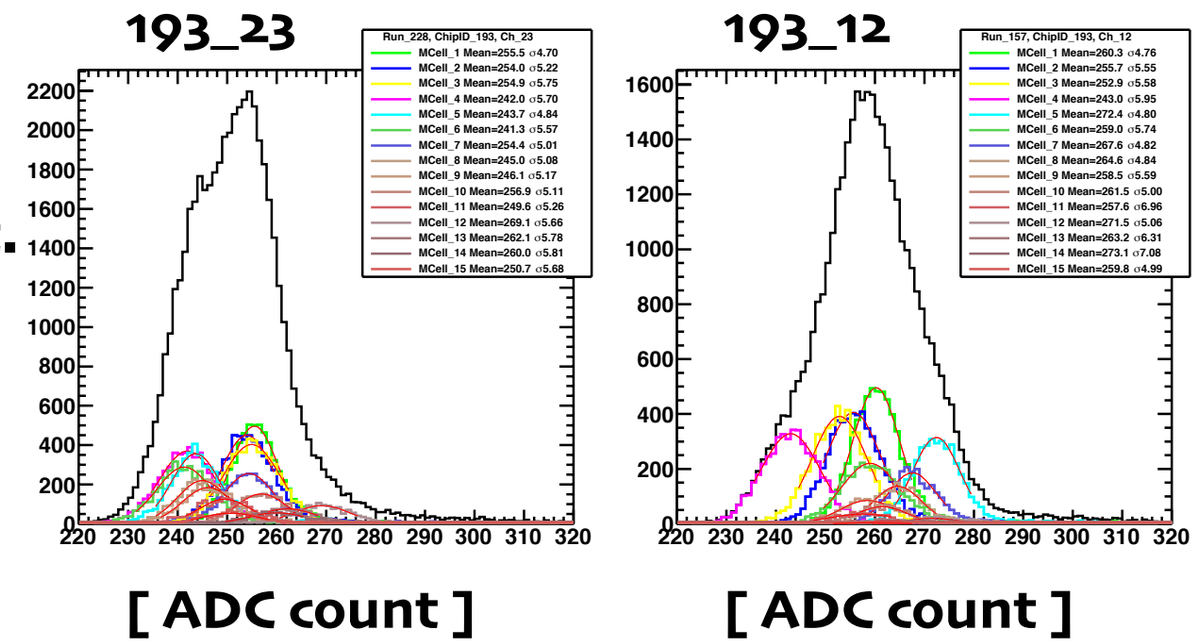
This means memory cells need to have
ADC/MIP conversion factor individually.

In case we analysis cell by cell,
the statistics decreases to less
than about 1/15.

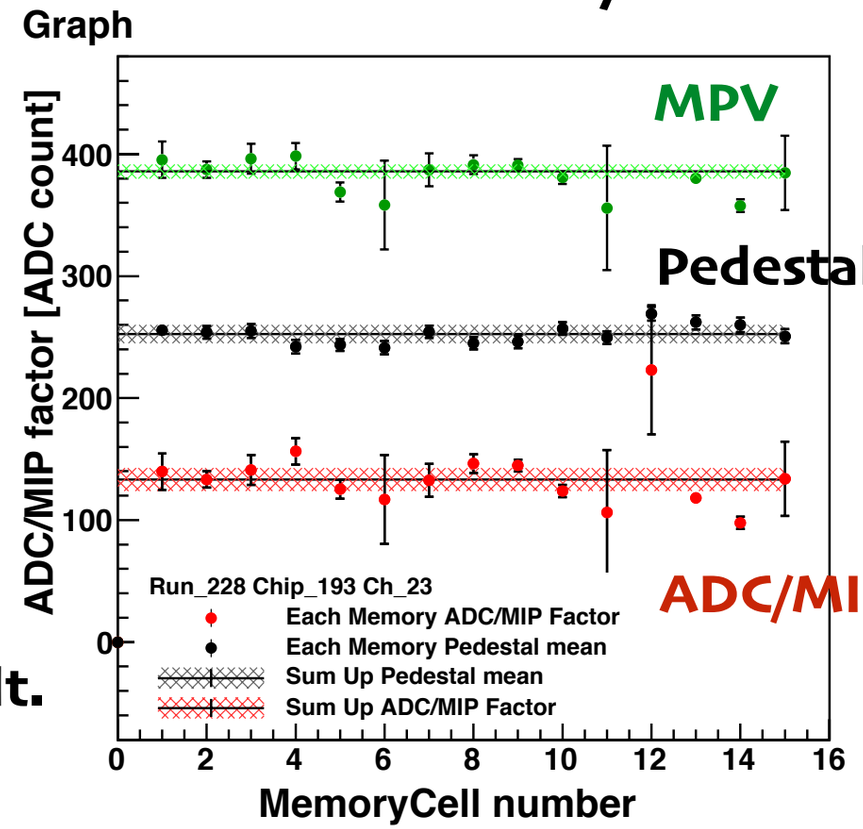
On latter half memory cell,
It becomes more difficult
to fit with langau and estimate MPV.

→ Cell by cell analysis seems to be difficult.

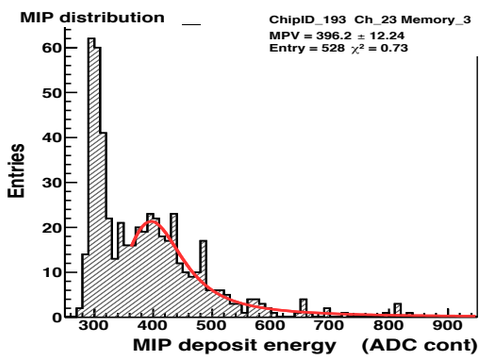
Pedestal of each memory cells



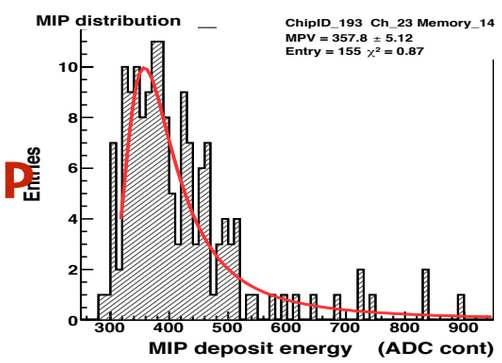
for each memory cells



Memory_3



Memory_14

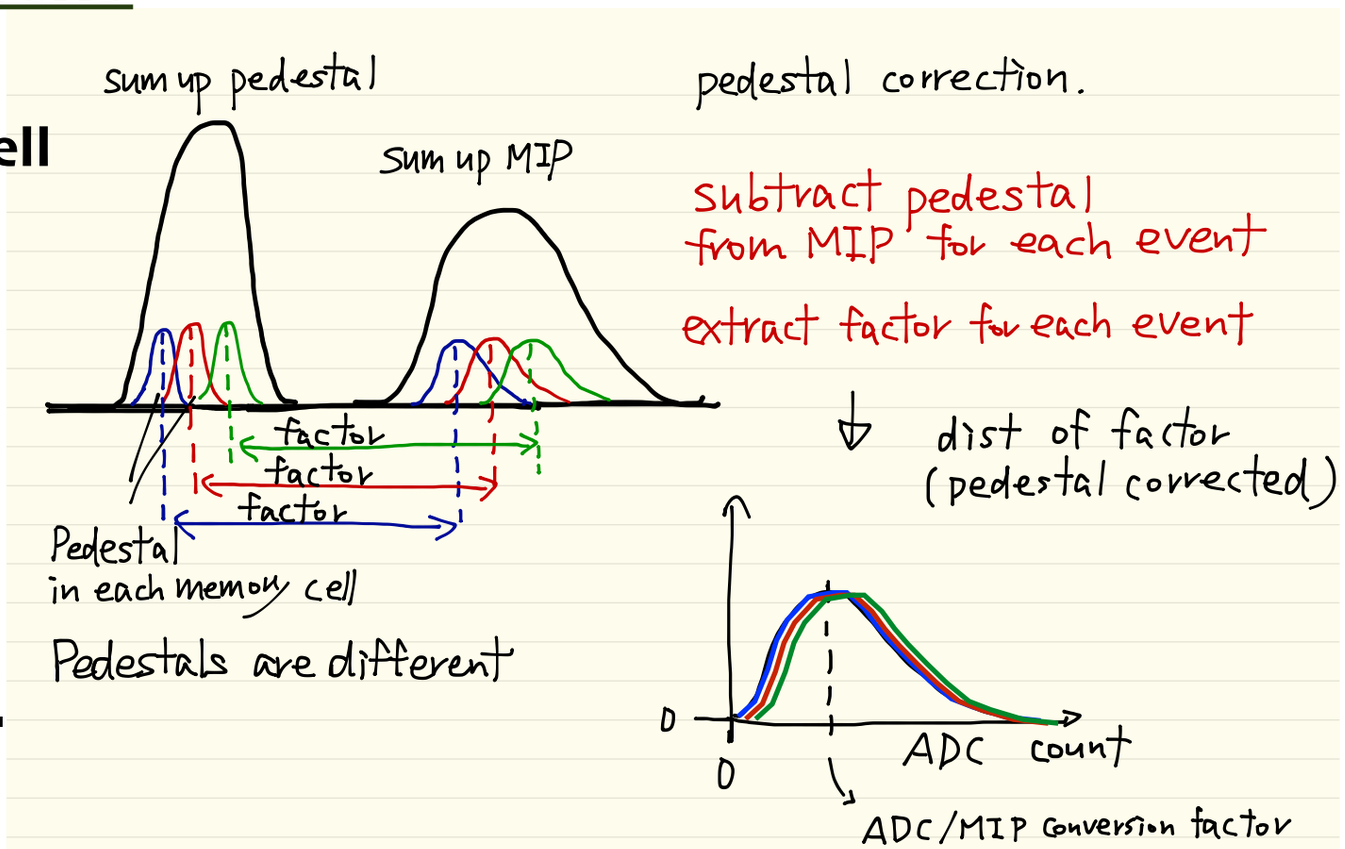


Problem of Analog Memory Cells

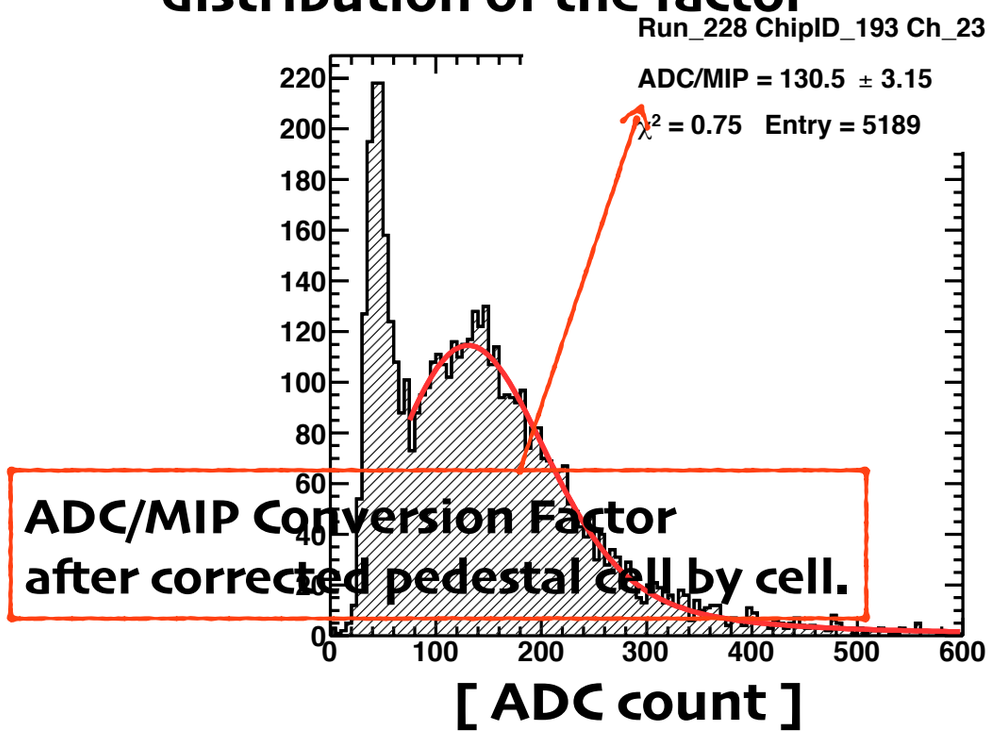
- We apply pedestal subtraction on cell by cell instead of cell by cell analysis.

  - Subtract pedestal from MIP for each event (for each memory cell), and extract factor.

  - From these factor we estimate ADC/MIP conversion factor.



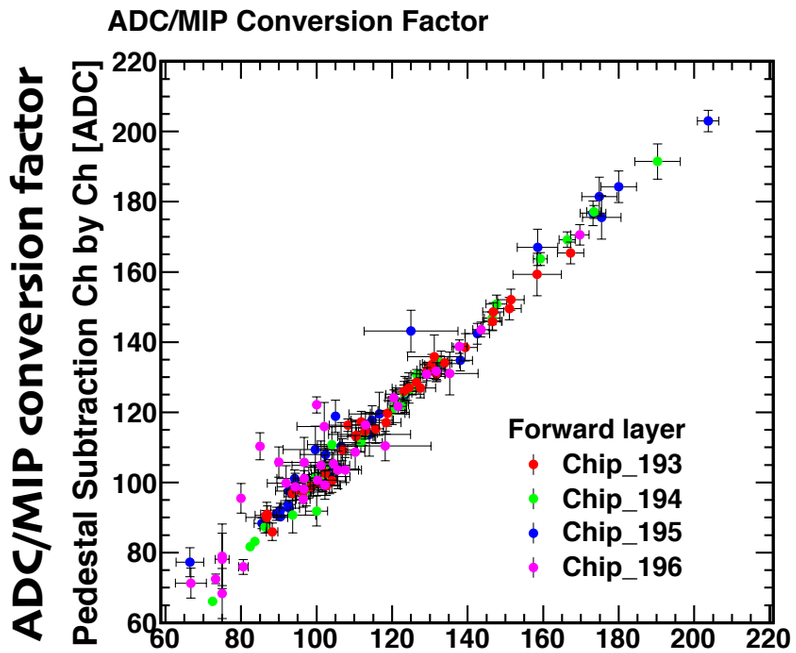
distribution of the factor



ADC/MIP Conversion Factor after corrected pedestal cell by cell.

subtraction ch by ch and subtraction cell by cell match on around ± 20%

effect of pedestal subtraction



MIP Calibration

- **Two EBUs on two layers were calibrated with 3GeV electron beam.**

- **Fully auto-triggered operation and externally validated trigger operation.**

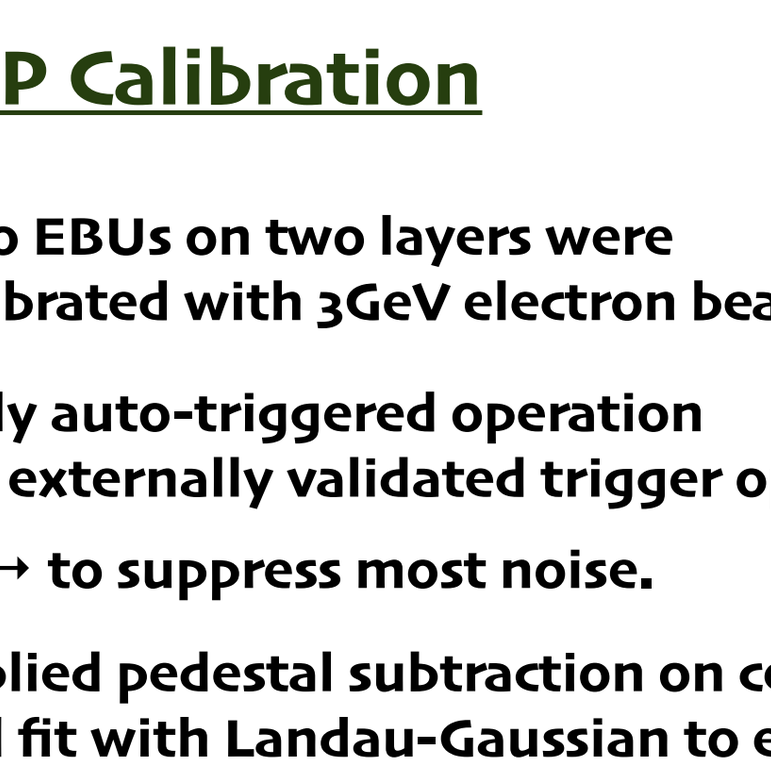
  → **to suppress most noise.**

- **Applied pedestal subtraction on cell by cell and fit with Landau-Gaussian to estimate ADC/MIP factor.**

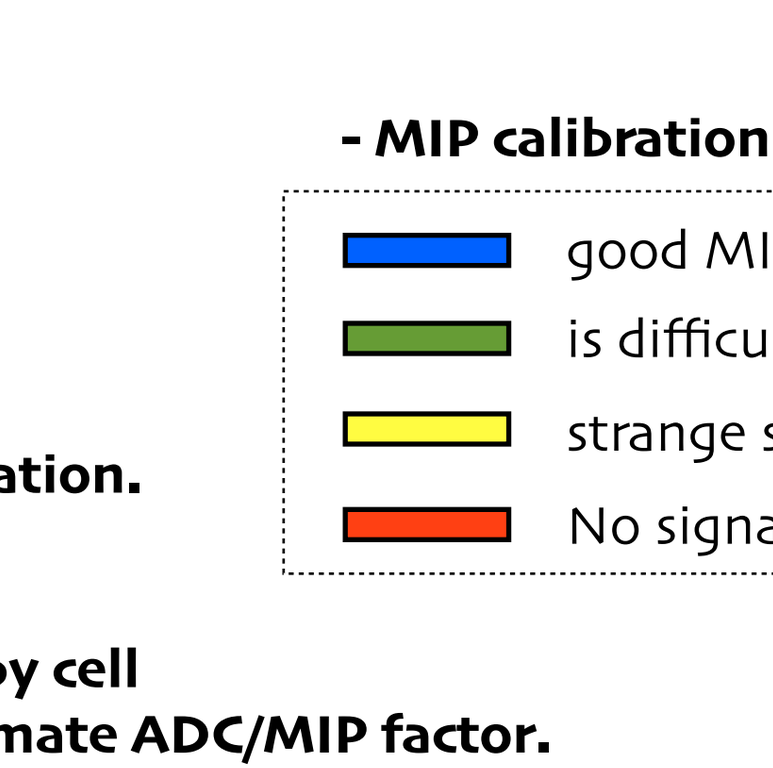
- MIP calibration result at DESY.

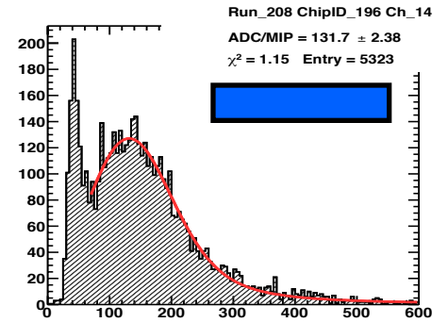
- good MIP separation.
- is difficult to separate MIP.
- strange signal (noisy)
- No signal

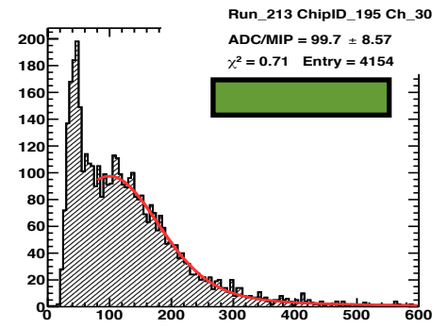
Forward layer result

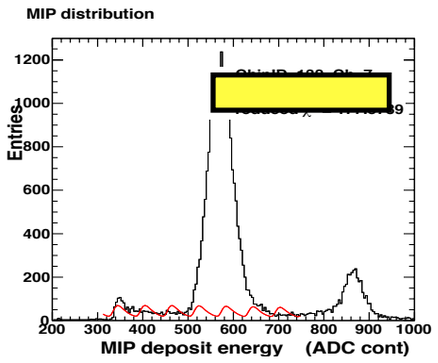


Backward layer result









- **On forward layer, over 90% channels could calibrate.**
- **On backward layer, over 80% channels could calibrate.**

MIP Calibration

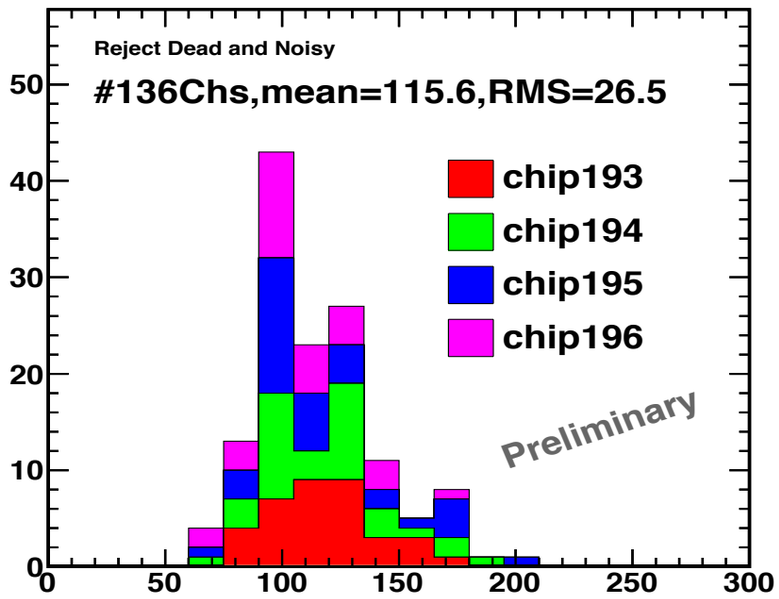
- **ADC/MIP conversion factor** ※ Include only blue channels.

On forward layer

average of ADC/MIP factor = 115.6 ADC

RMS/Mean = 22.9%

Forward layer ADC/MIP



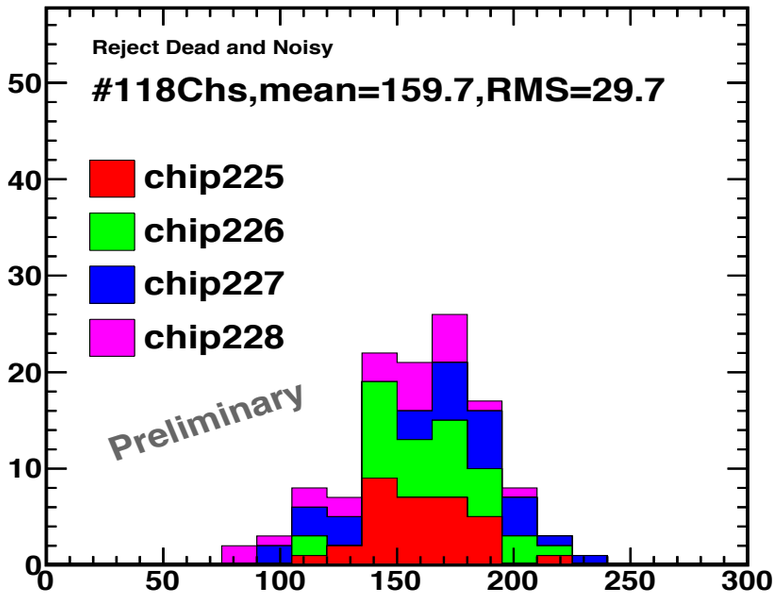
[ADC/MIP conversion factor]

On backward layer

average of ADC/MIP factor = 159.7 ADC

RMS/Mean = 18.6%

Backward layer ADC/MIP



[ADC/MIP conversion factor]

- **Average values are little bit different between both layer despite we intended to set the same bias voltage for each channel.**

(set voltage ΔV = +3.0 from break down for all channels)

→ Need to clear the reason of this difference.

Applying Simple SSA

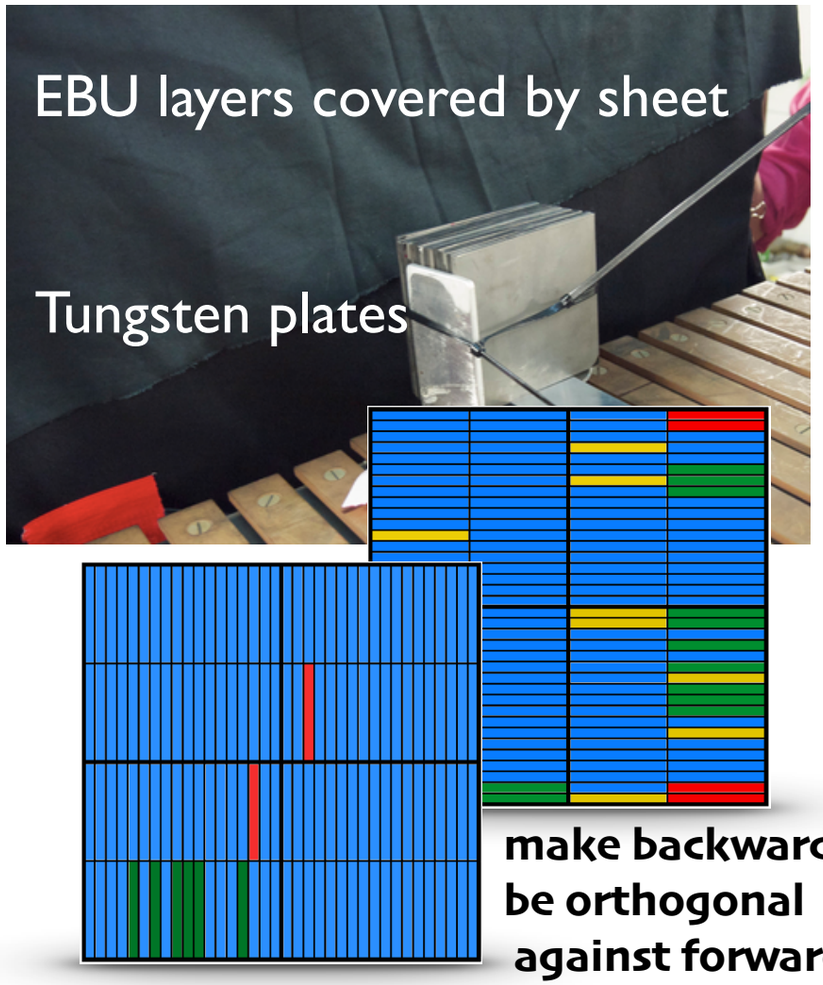
strip scintillator ECAL requires a sophisticated algorithm
named SSA (Strip Splitting Algorithm)
to produce square cells and achieve high granularity 5x5mm.

- We made shower events with Tungsten absorbers.

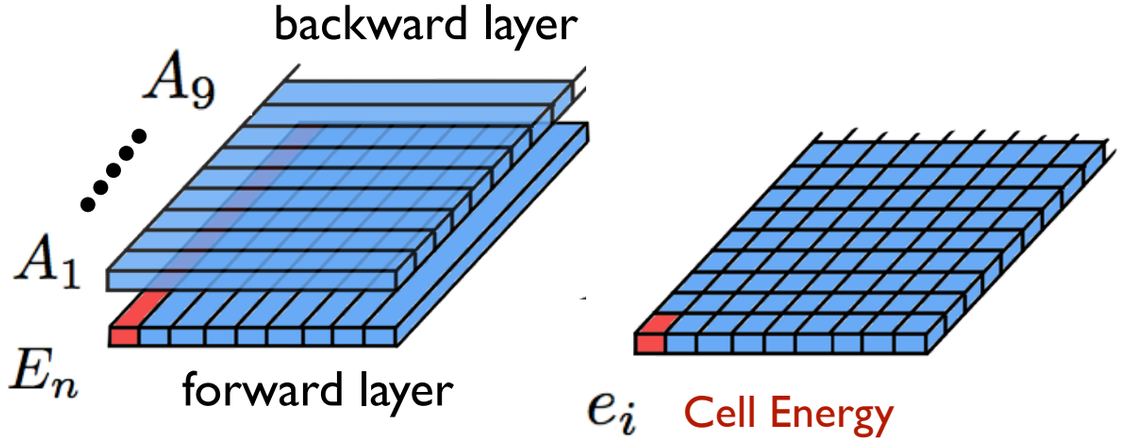
Changing the number of tungsten absorbers.

→ We try to measure the spread of EM shower like a pseudo multi layer.

- Try to calculate Cell Energy by using simple SSA.



$$e_i = E_n \cdot \frac{A_i}{\sum_{i=1}^{9} A_i}$$



Cell energy with SSA = N of MIPs of one strip on the forward layer × (N of MIPs of one strip on the backward layer which is corresponding to the strip on forward layer. / Sum of MIPs of nine strips on backward layer which is corresponding to forward layer.)

Deposit Energy on 5x5mm cells estimated by simple SSA

- lateral EM shower shape.

  - We could observe the spread of shower according to the thickness of the absorbers.

  - Strip splitting algorithm also works well.

※ Energy deposit on backward is smaller than on forward.

→ Small energy particles stop in forward layer and can't reach backward one.

- We compared the longitudinal shower shape.

→ We used 3 GeV electron.

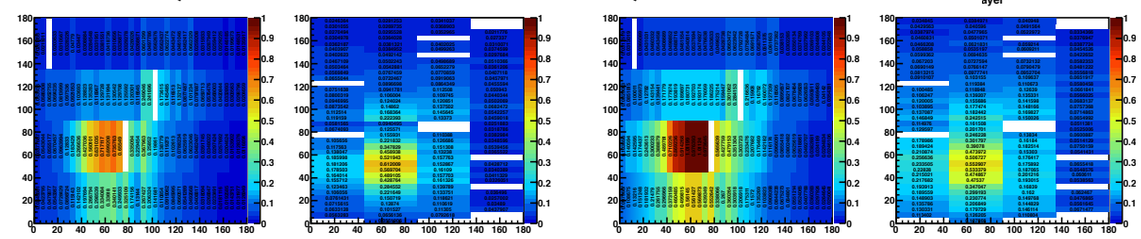
- On physics prototype, max deposit occurred at 7 or 8 absorbers.

- On engineering prototype, max deposit occurred 6 or 7 absorbers.

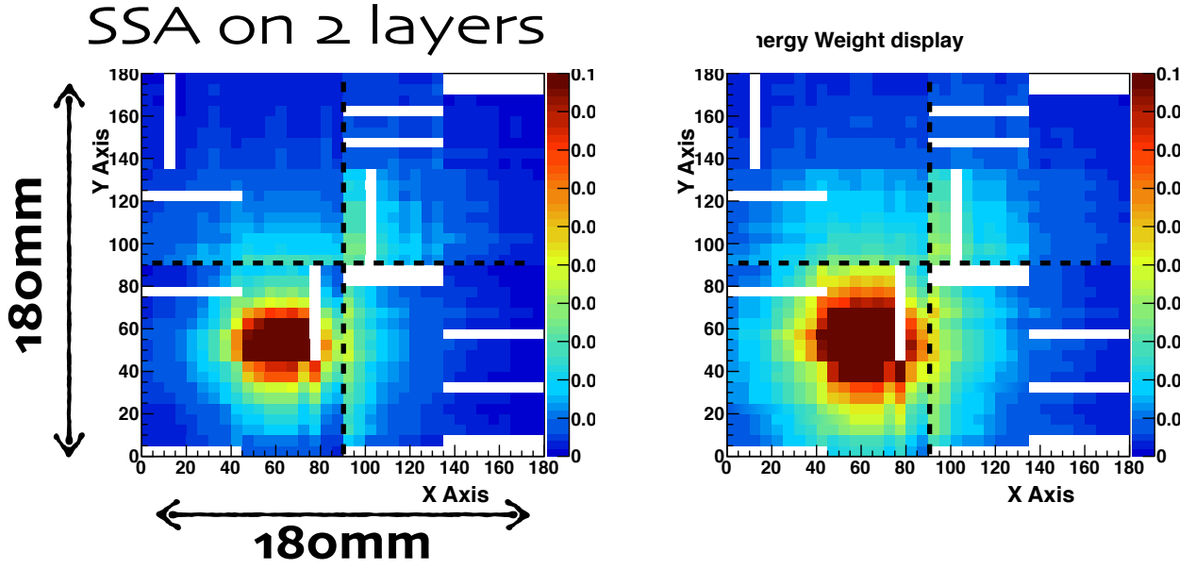
(Have not rejected noises completely yet.)

Tungsten x 2 Tungsten x 7

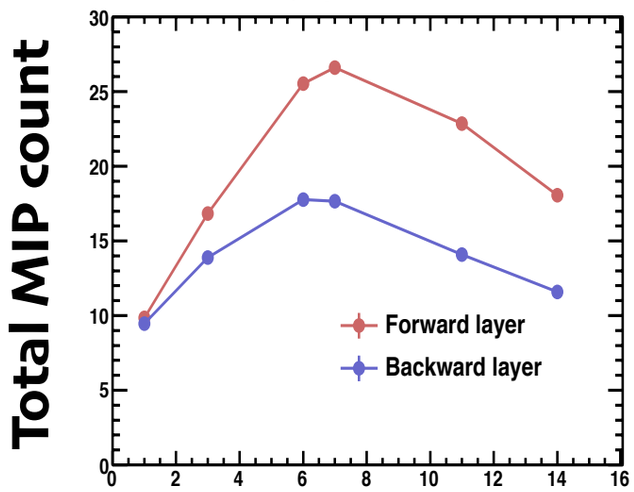
Forward layer & Backward layer



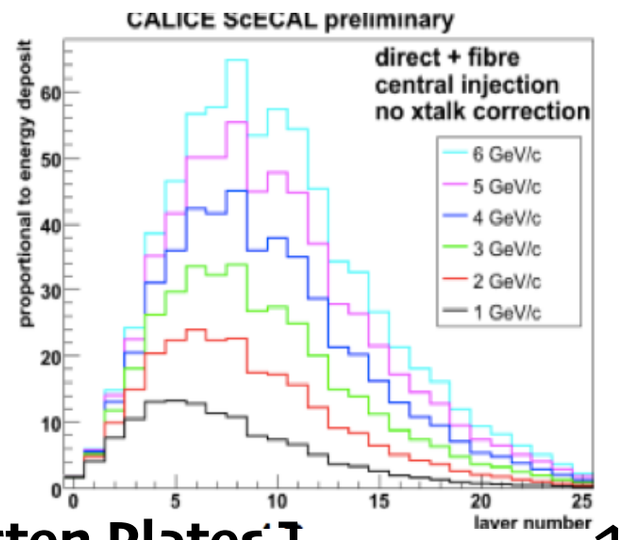
SSA on 2 layers



Engineering Prototype



Physics Prototype



[N of Tungsten Plates]

Hit Map with EBU/HBU Synchronized Data

- Made EBU and HBU synchronize and plot the hit map.

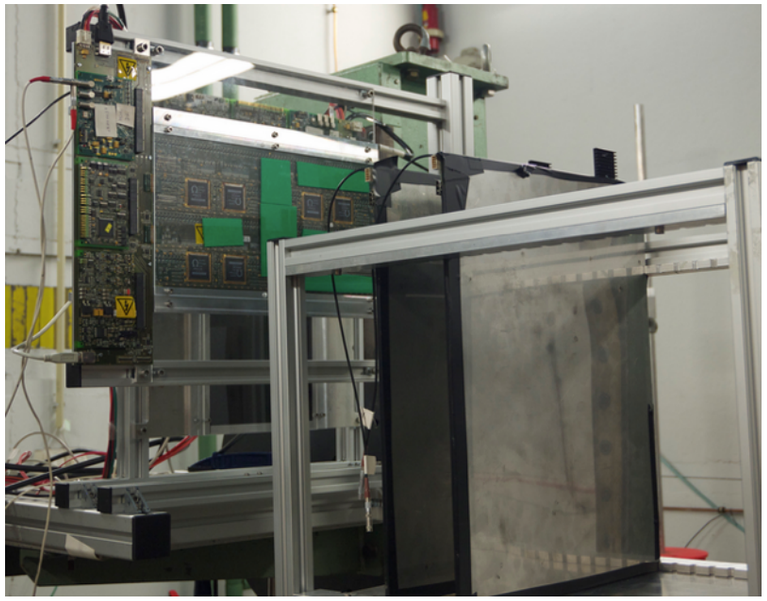
  In case of 4 layers coincidence, (4 auto trigger flag)
  we consider as being hit. → 1Hit.

  - A diagonal area of HBU were set at high threshold

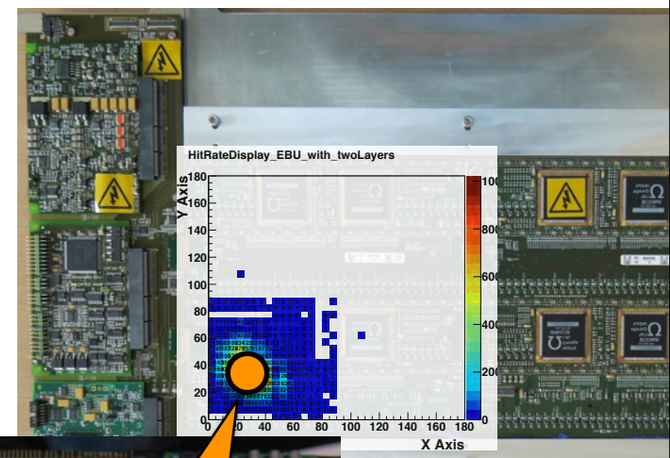
    → Hits are concentrated in opposite diagonal area.

    → On EBU, hits are concentrated in diagonal area
    with fine resolution.

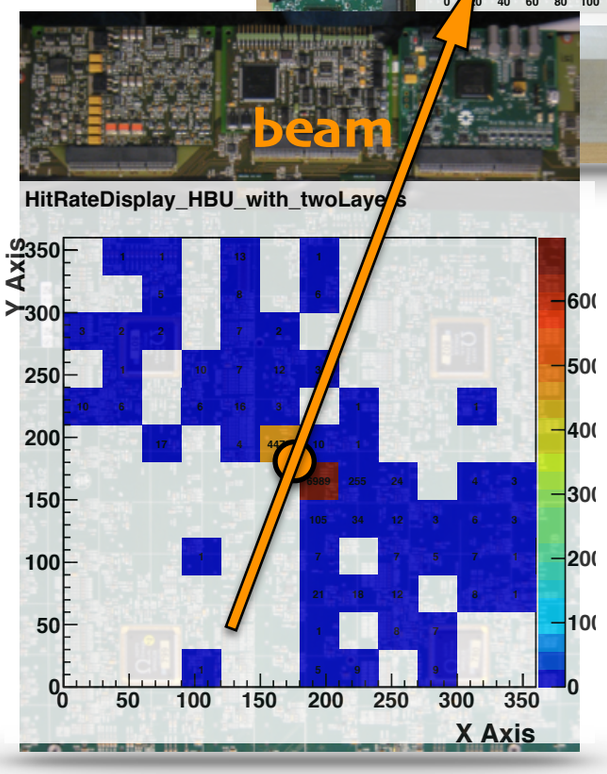
- Observed correlation between EBU and HBU.



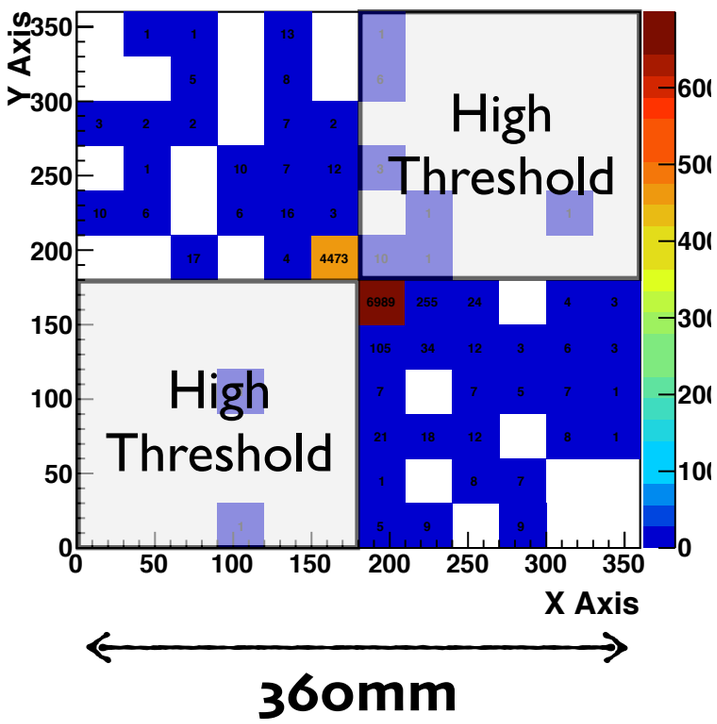
EBU



HBU

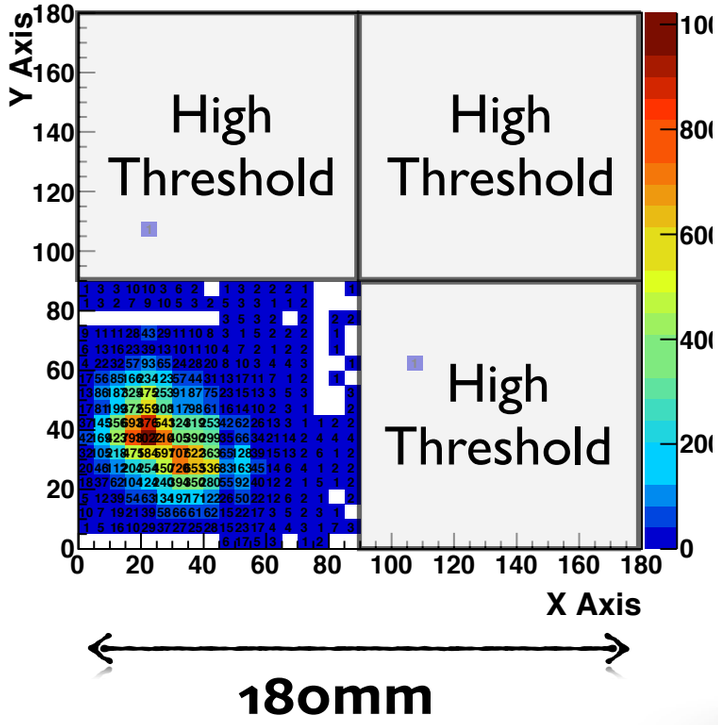


Hit Map of HBU



360mm

Hit Map of EBU



180mm

Summary & Outlook

- ScECAL two layer engineering prototype was tested at DESY with 2 - 4 GeV electrons.

  We found out pedestals of each memory cell are quite different.

  We applied pedestal subtraction on cell by cell instead of cell by cell analysis
  and estimated one ADC/MIP factor for one channel.

  ADC/MIP factor by the method of pedestal subtraction on cell by cell
  matched with the sum-up simple estimation on about ±20%.

  On forward layer, we could calibrated more than 90% channels on MIP calibration.

  On backward layer, we could calibrated more than 80% channels.

  Average of ADC/MIP factor is different between 2 layers → Need to clear.

- SSA works well.

  We could confirm SSA works well for the lateral shower shape,
  but need to reject noise more.

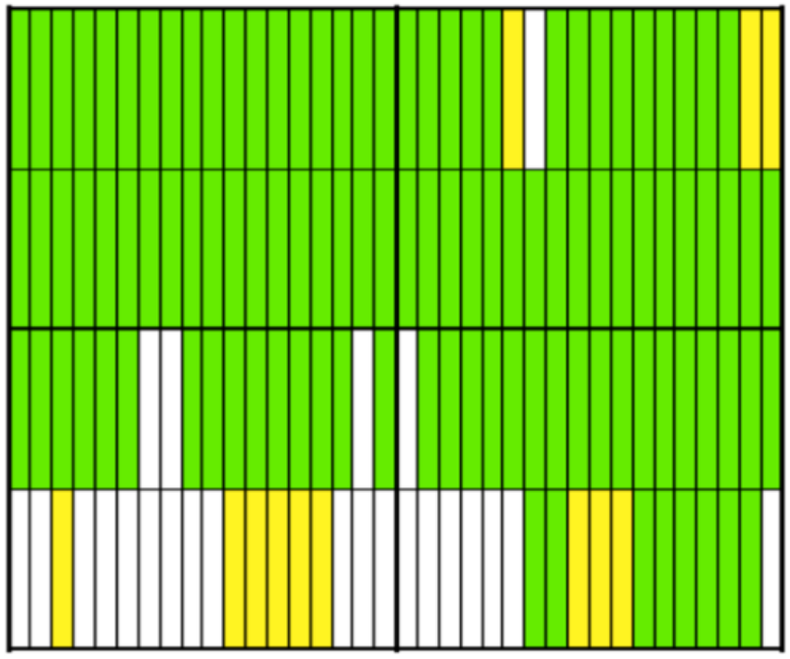
- Two layer ScECAL successfully worked with AHCAL layers in a good synchronization.

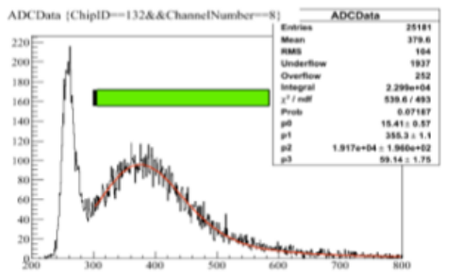
  We could observe the correlation between EBU and HBU.

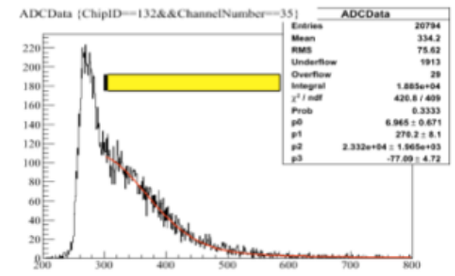
  Next, We need to confirm the correlation between EBU and Si layers.

Back Up

Color Map

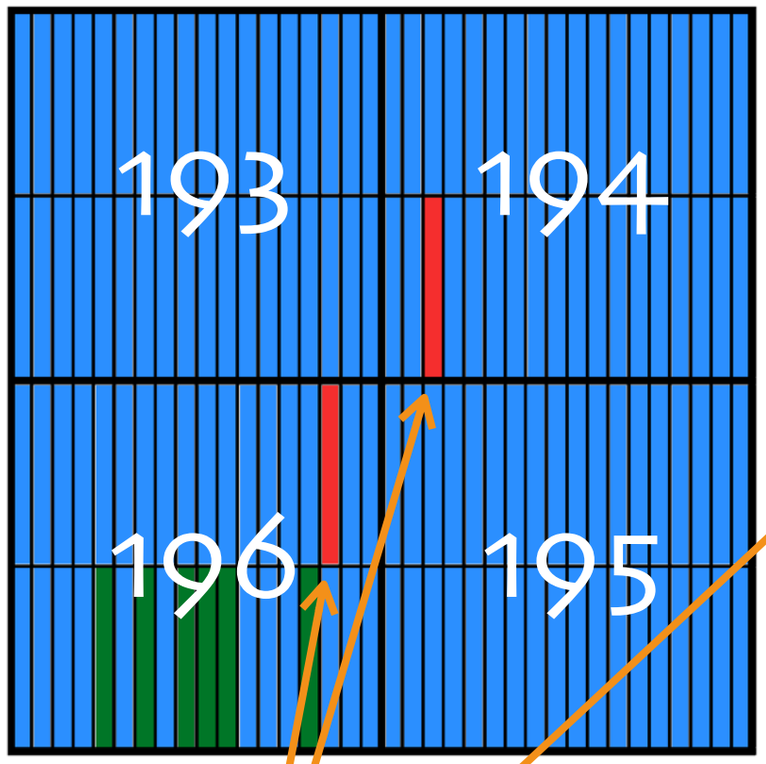




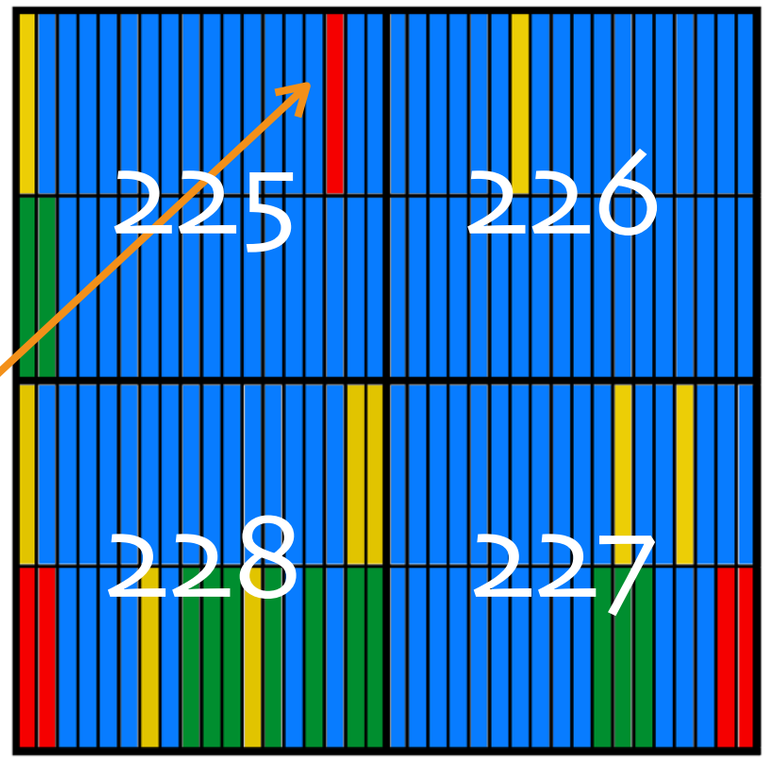


: no signal or large noise

Forward layer result

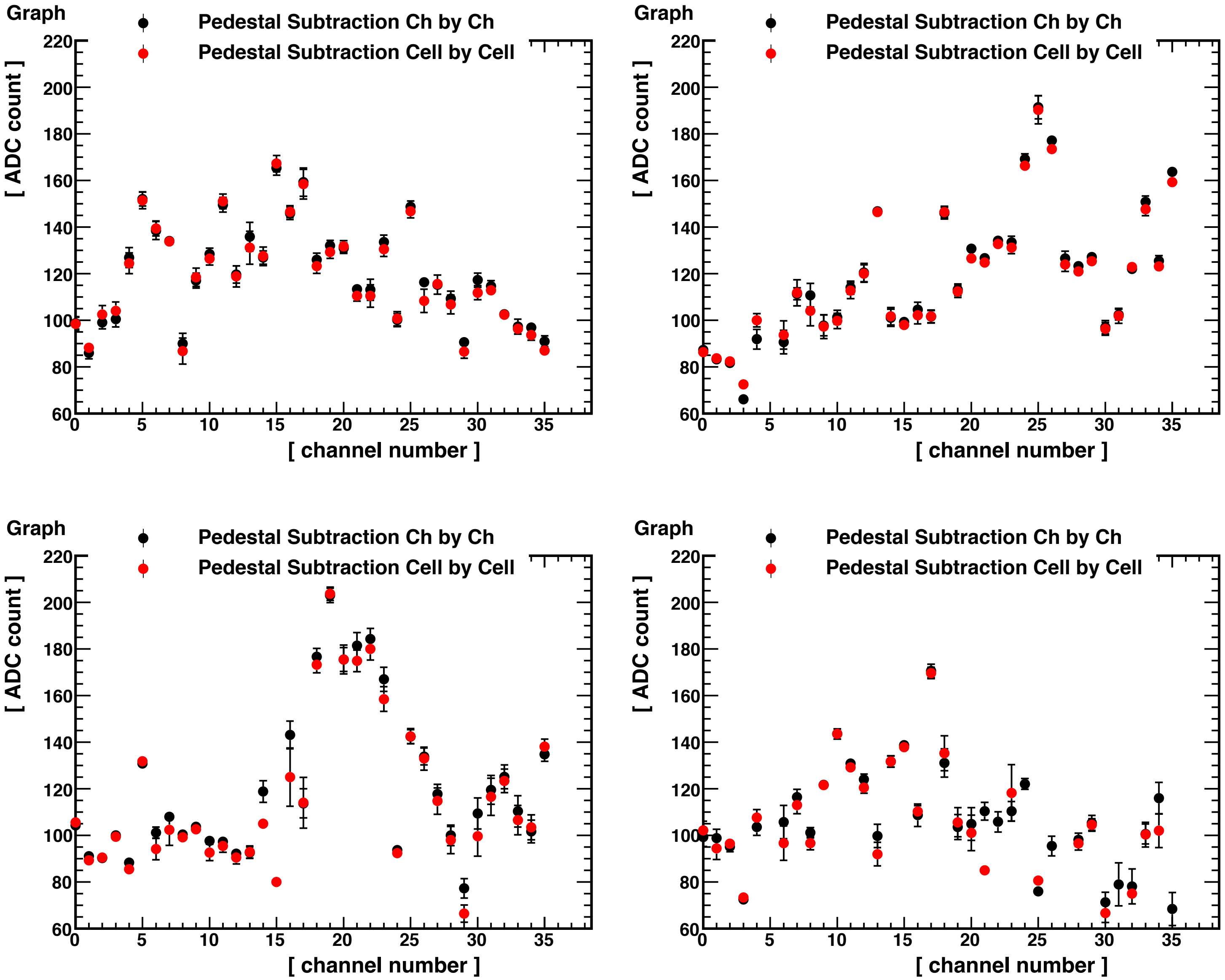


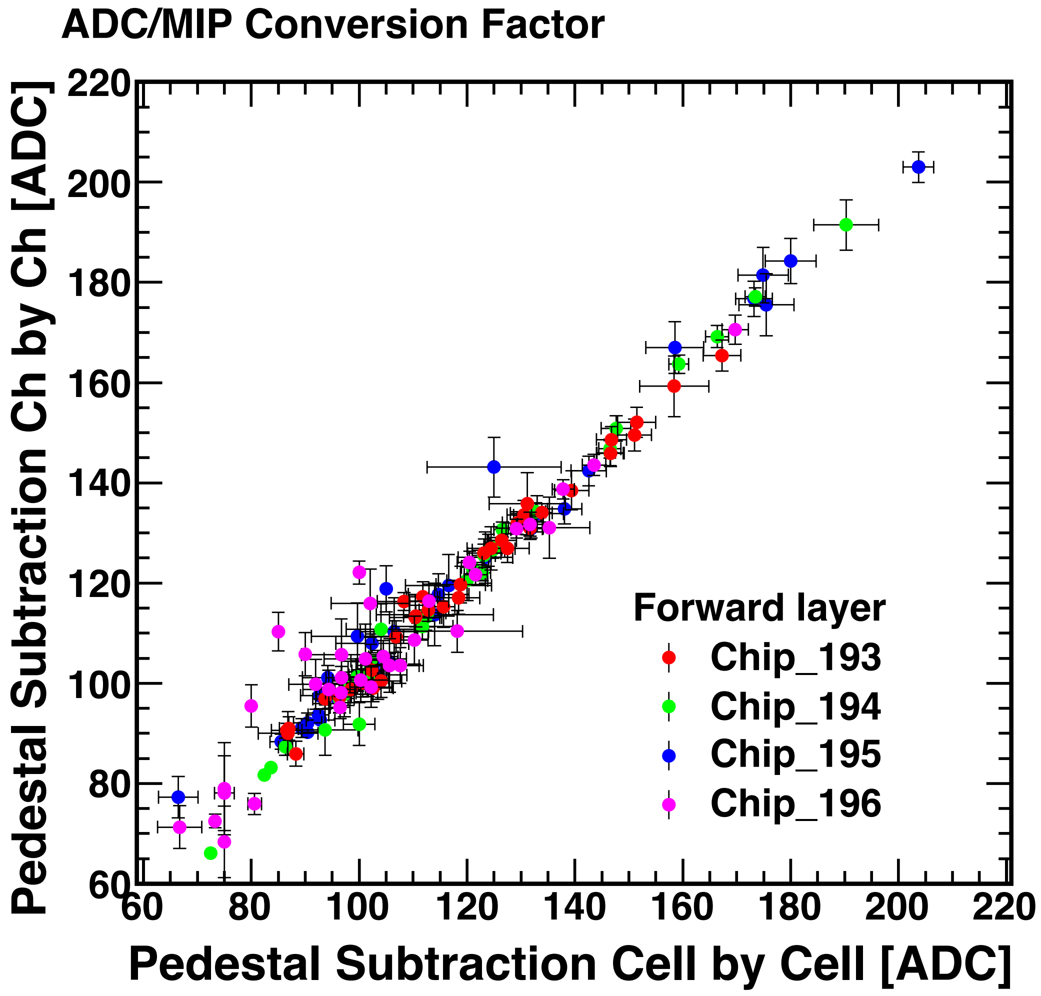
Backward layer result



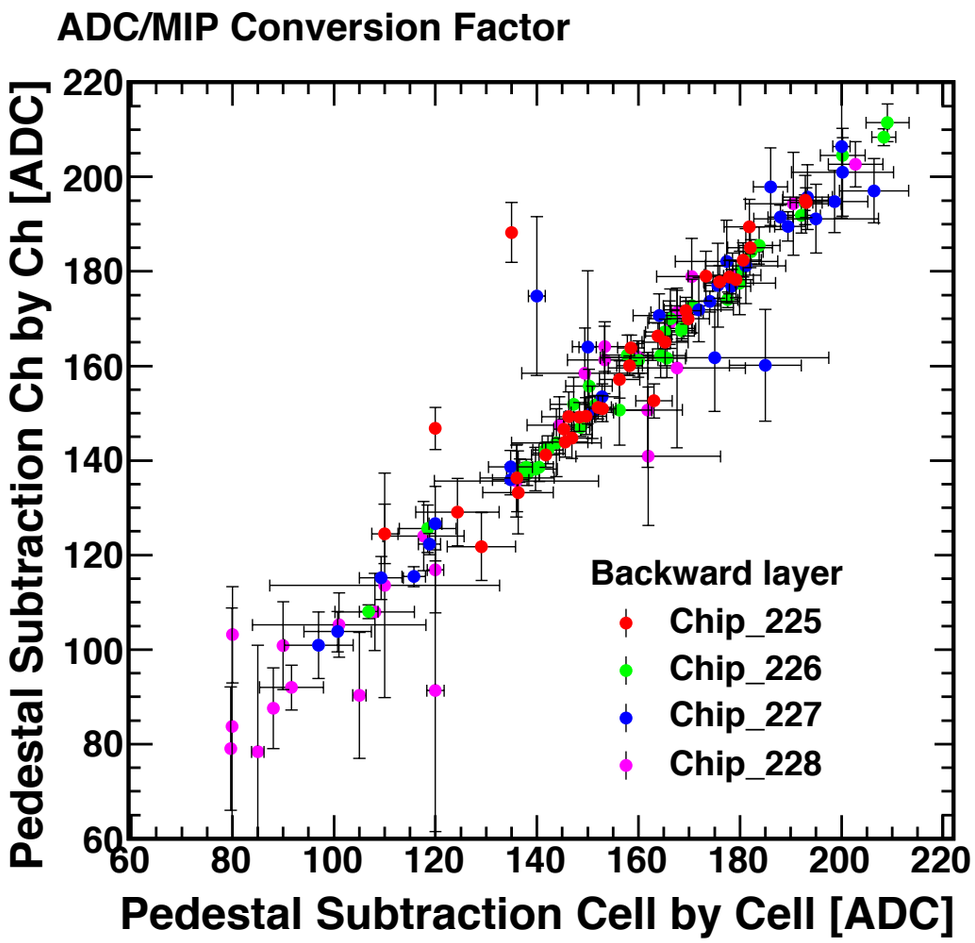
Channel_5

Pedestal Subtraction forward layer

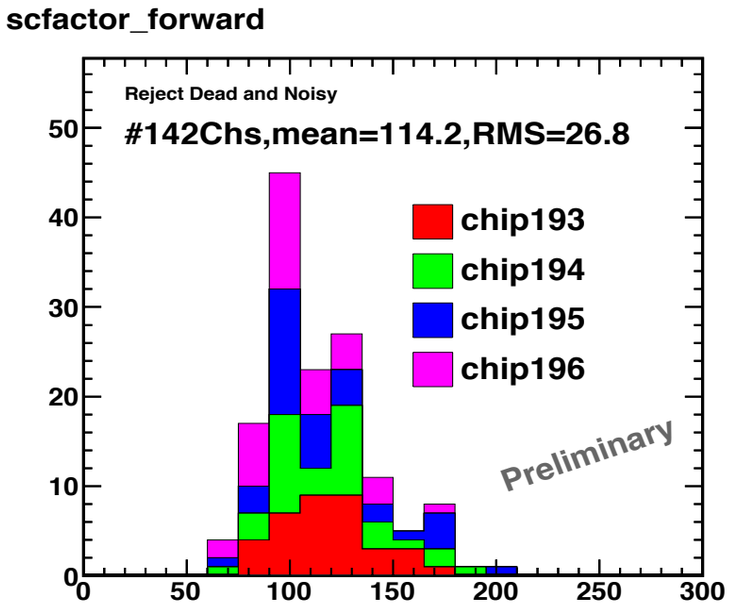


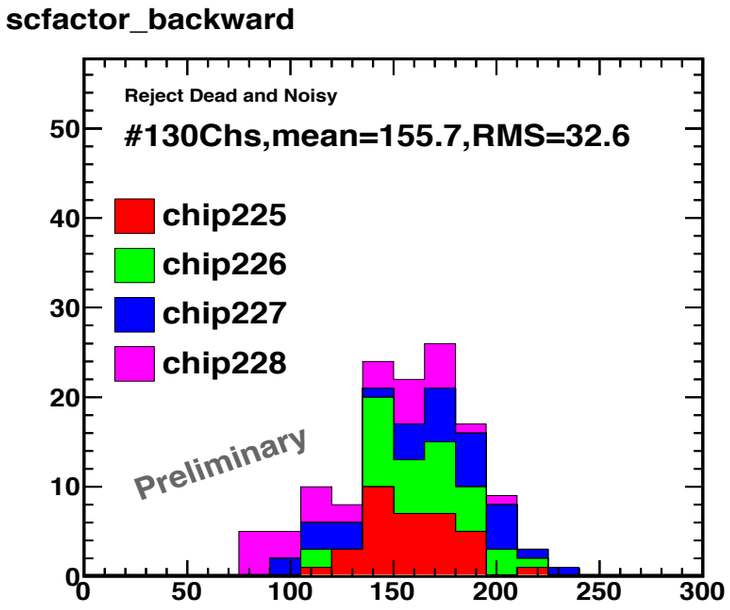


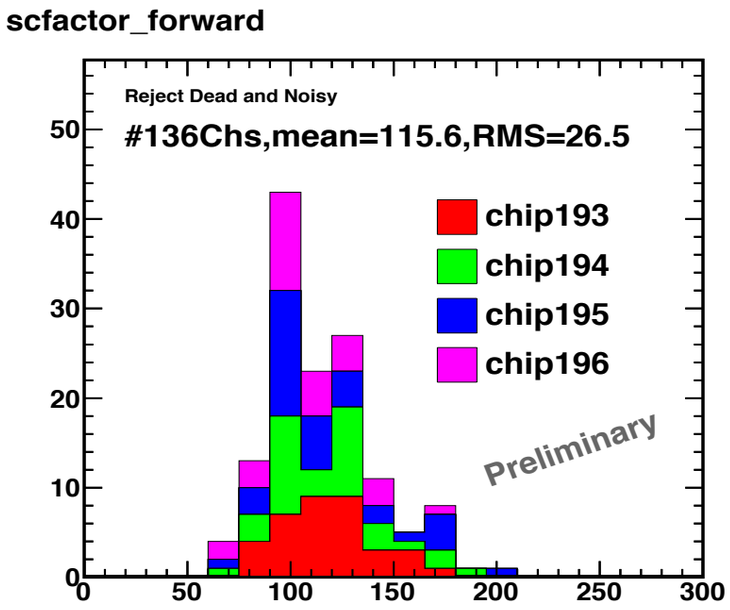
Pedestal Subtraction backward layer

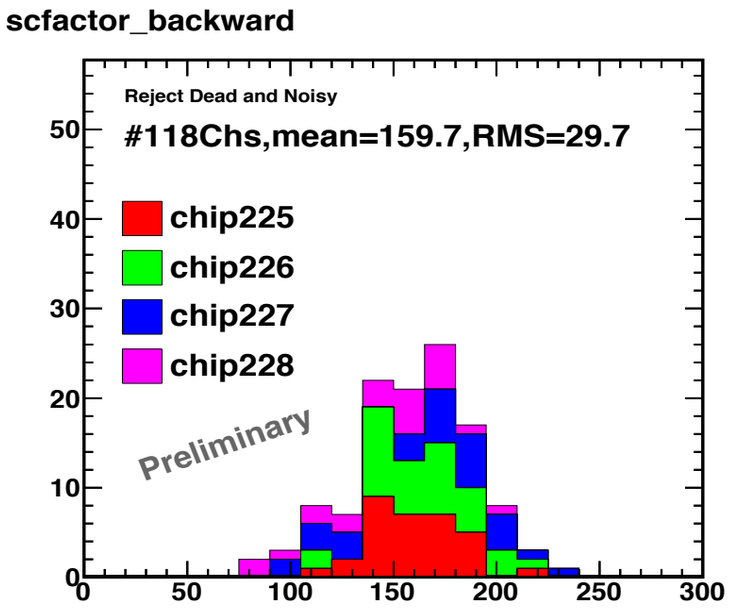


ADC/MIP factor









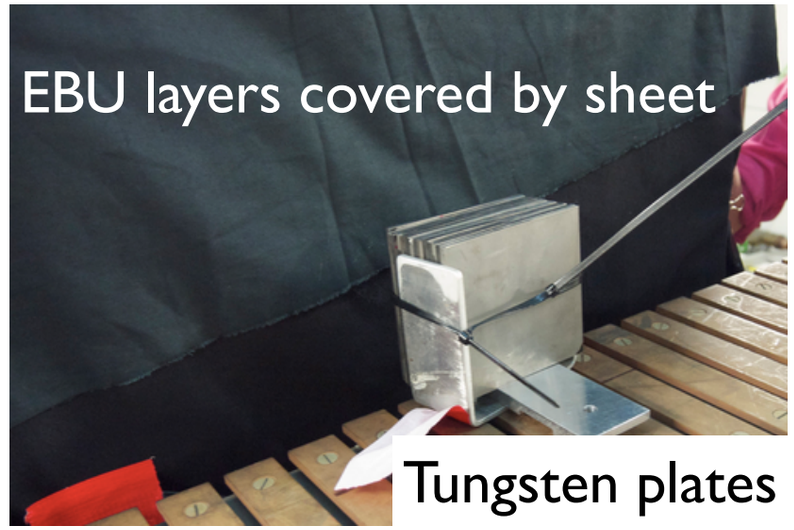
Applying Simple SSA

- We made shower events with Tungsten absorbers.

  Change the number of tungsten.

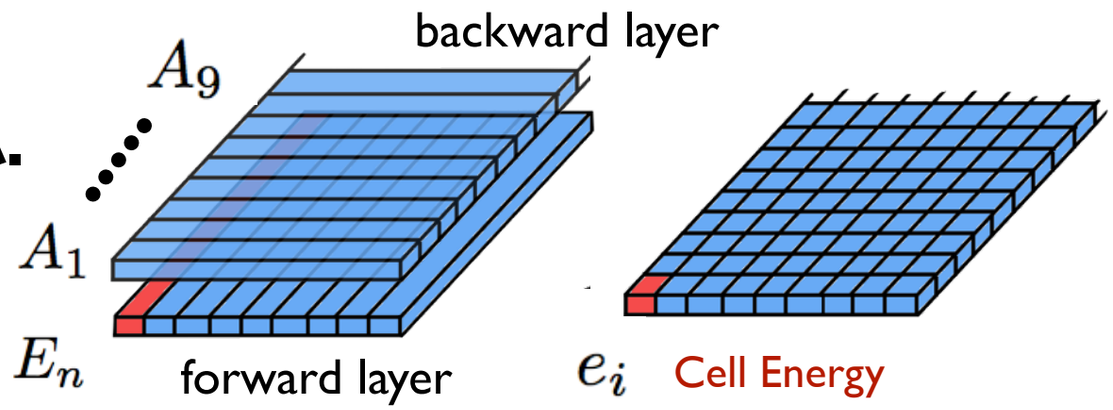
  → We try to measure the spread of EM shower like a pseudo multi layer.

- Try to calculate Cell Energy by using simple SSA.



Tungsten plates

$$e_i = E_n \cdot \frac{A_i}{\sum_{i=1}^{9} A_i}$$



Cell energy with SSA = N of MIPs of one strip on the forward layer × (N of MIPs of one strip on the backward layer which is corresponding to the strip on forward layer. / Sum of MIPs of nine strips on backward layer which is corresponding to forward layer.)

※ In case there is some dead channels, need to correct.

Take an average $\sum_{i=1}^{9} A_i$ = $\sum_{i=1}^{9} A_i$ / (N of living Channels) x 9

Beam Test of Scintillator ECAL Engineering Prototype

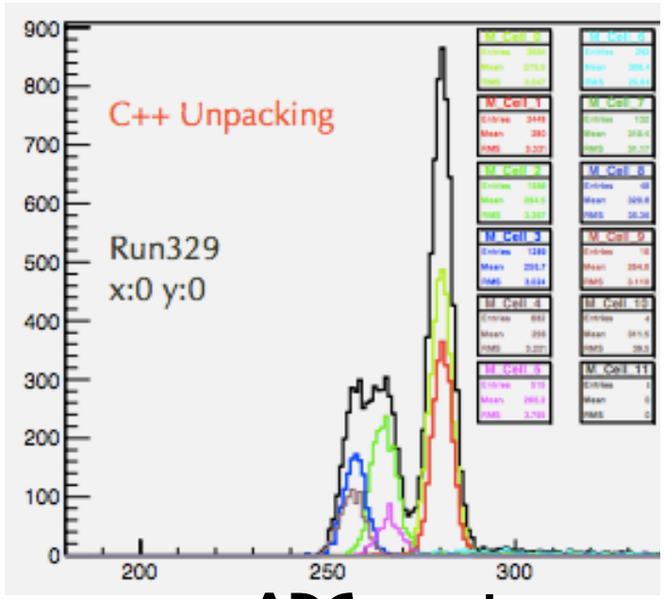
- CALICE group has developed the electronics "EBU"(scintillator ECAL Base Unit) which a readout chip is embedded at, based on analog HCAL electronics "HBU".

- SPIROC ASIC is used for readout and it has 16 memory cells at each channels to store data.

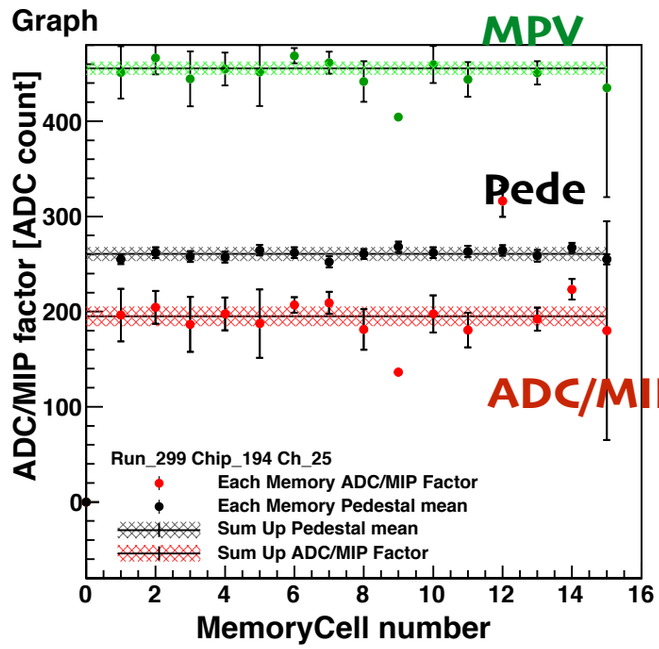
- We CALICE group tested this EBU engineering prototype and found out these memory sells are not stable (and bug of program).

Pedestal distribution →
at each memory cells
on one channel.
(analysis by Lloyd)

memory number
0,1,2….15



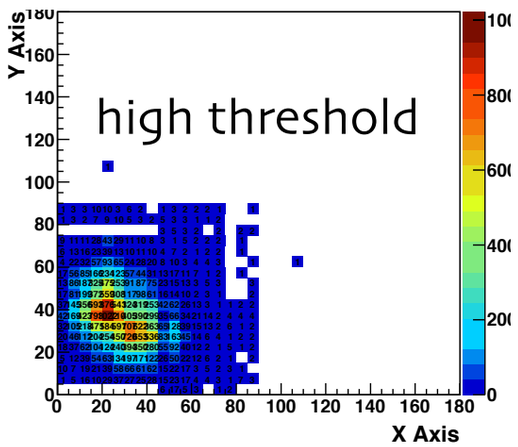
- Actually we need to analysis cell by cell. but because statistical reduce, we use a sum-up value.



- Also we tried testing synchronization with analog HCAL layer for next step.

Hit rate →
Hit concentrate on diagonal area.
(In case there is 4layers coincidence)

EBU



HBU