Beam Test of the Sc ECAL Engineering Prototype

CALICE@Annecy
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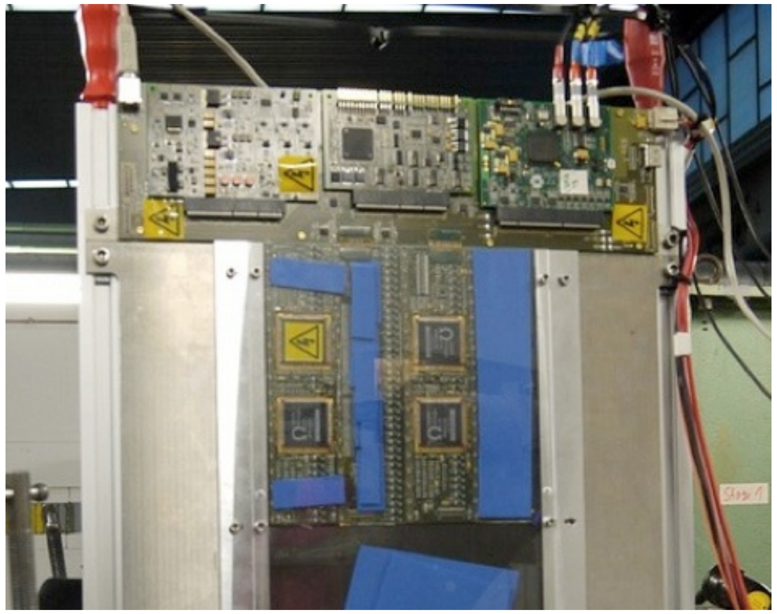
Introduction (2012 TestBeam)



- Shinshu-U with AHCAL group cooperation developed the EBU (ECAL Base Unit) for Sc ECAL .

- We carried out first Beam Test with this EBU on 2012.

  → We used only 1 EBU on 1 layer.

- Short summary.
  - LED gain monitoring

    Succeeded 53% out of 112ch.

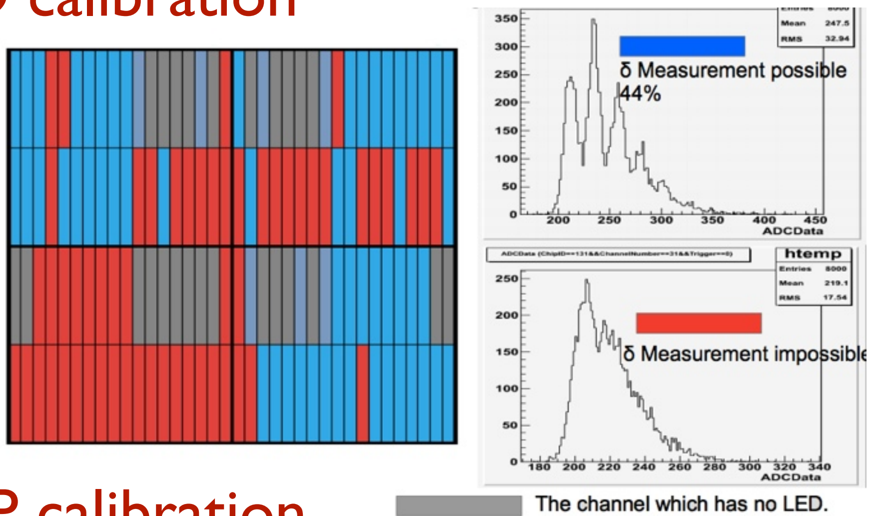
    Over 20% of channels had problems.

    → MPPC's bias voltage. LED system.
  - MIP calibration

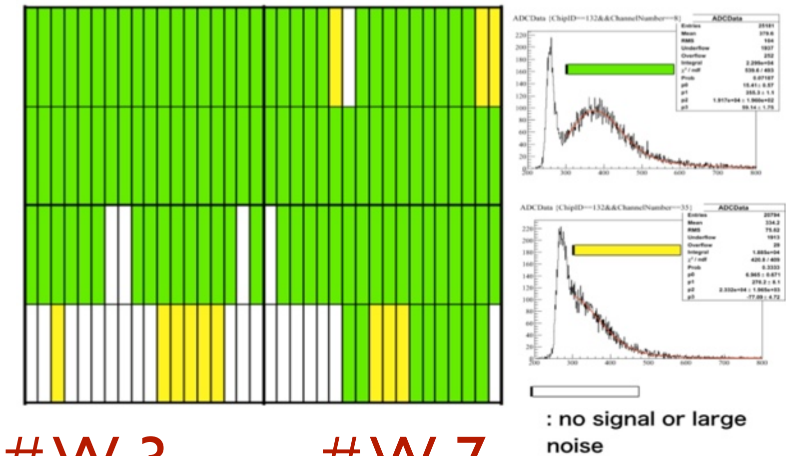
    108(75%) channels out of 144ch could have been measured MIPs.
  - Shower event

    Observe the spread of EM shower.

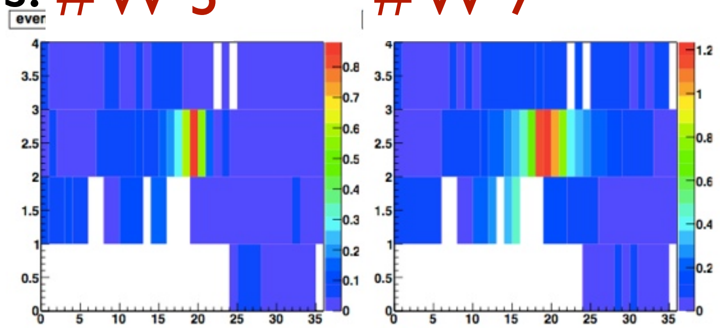
LED calibration



MIP calibration



#W 3 #W 7

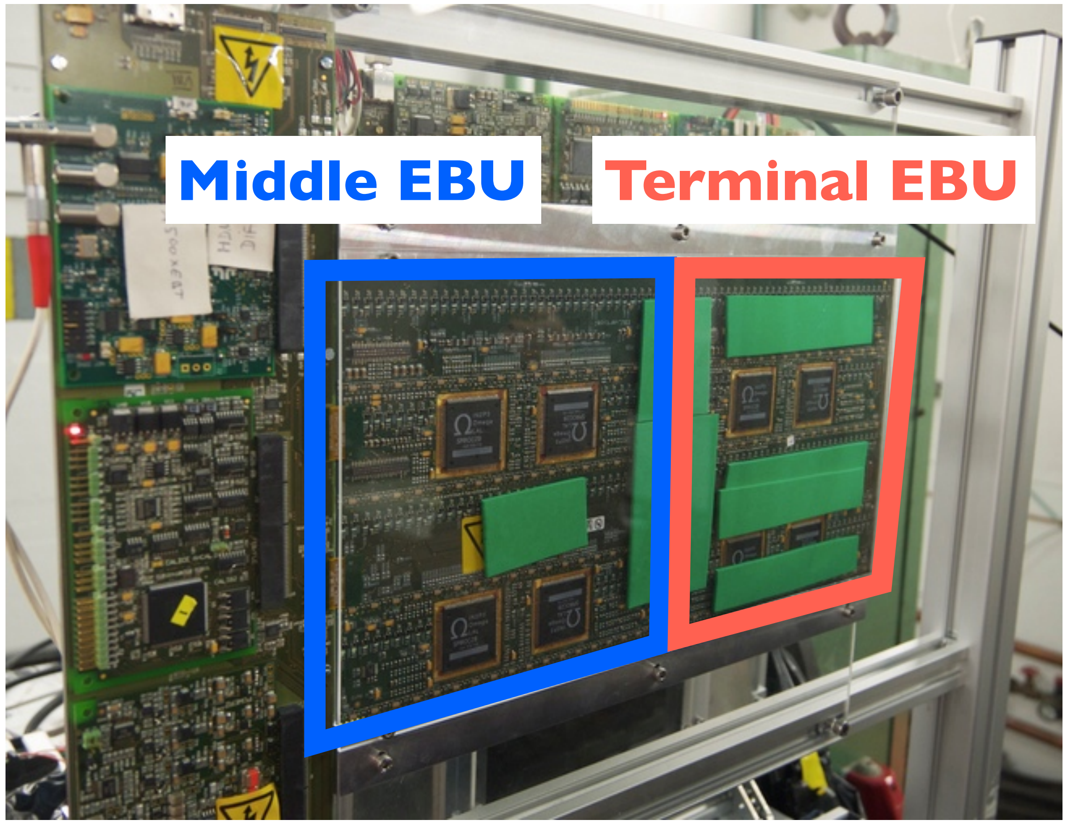


The Purpose of This TestBeam

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

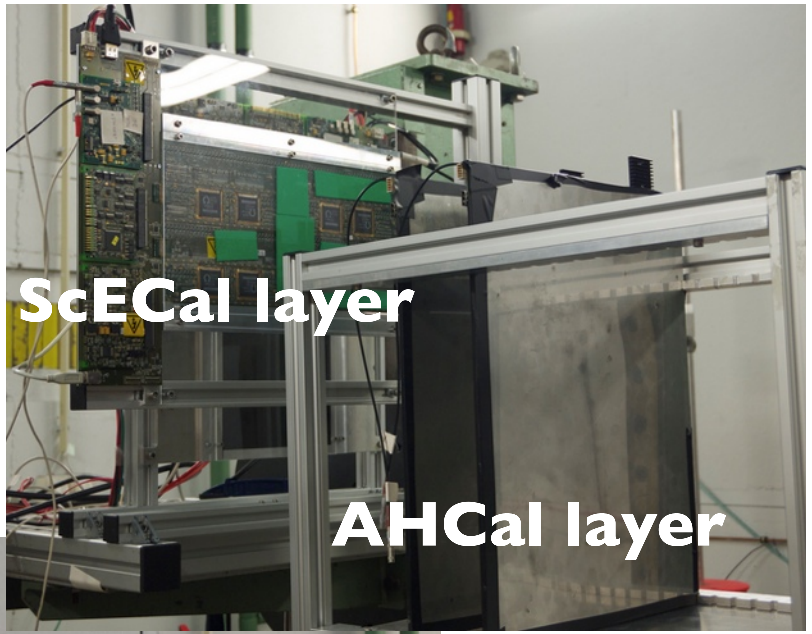
→ We need to confirm.

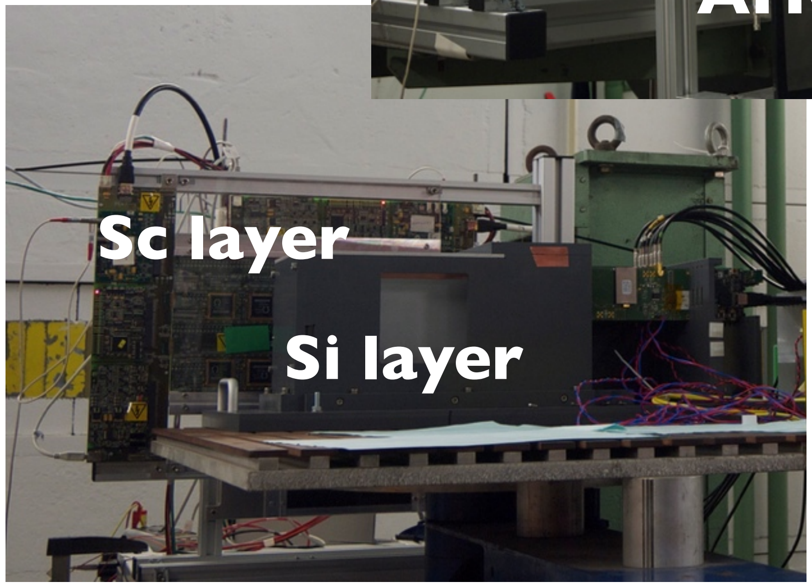
- Whether three EBUs work well.
- Whether a terminal EBU is connected through a middle EBU works well.
- Can we make two layers synchronize.



- What we couldn't deal with at previous TestBeam 2012.

- Study of TDC data.
- Precise position scan.
- Analysis shower events with SSA.





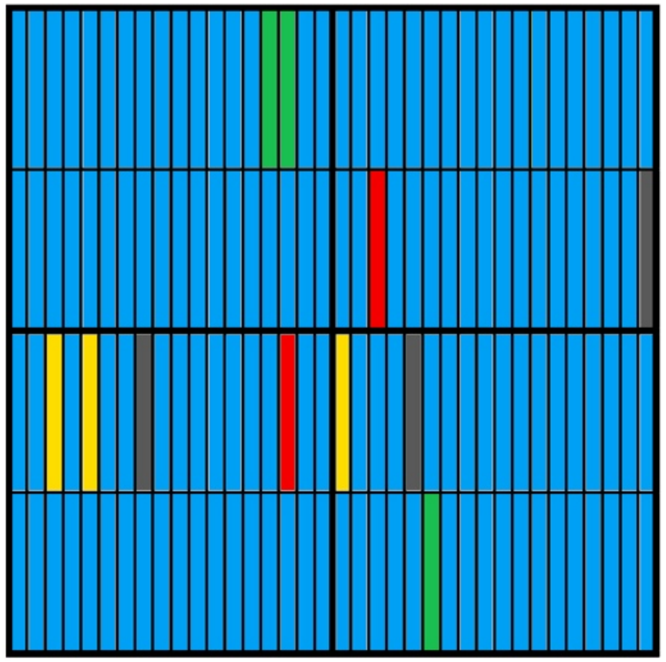
- We can make EBU synchronize with HBU?
- We can make EBU synchronize with SiECal?

LED Gain calibration

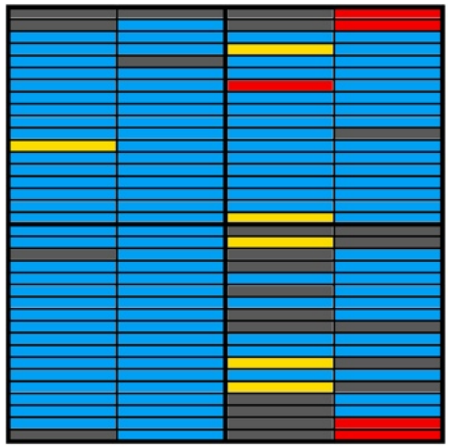
- Gain calibration result at DESY.

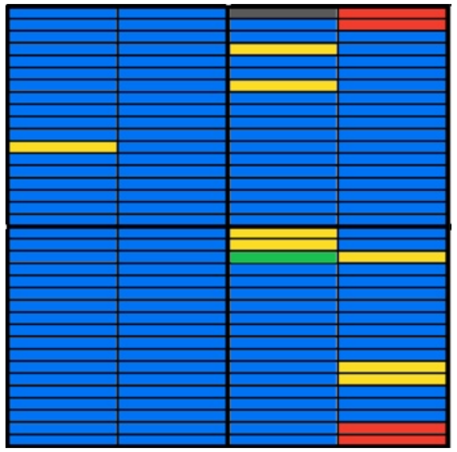
Blue	good p.e. separation
Green	is difficult to separate.
Yellow	strange signal (noisy)
Red	No signal
Dark grey	couldn't calibrate on time.

Forward layer result @DESY



Backward layer result @DESY





Backward layer result @Shinshu

On forward over 90%channels could be calibrated.

On backward near 90%channels could be calibrated.
(except problematic area.)

- ADC/p.e.

  ΔV = +3.0 from break down.
  Same settings on both layers.

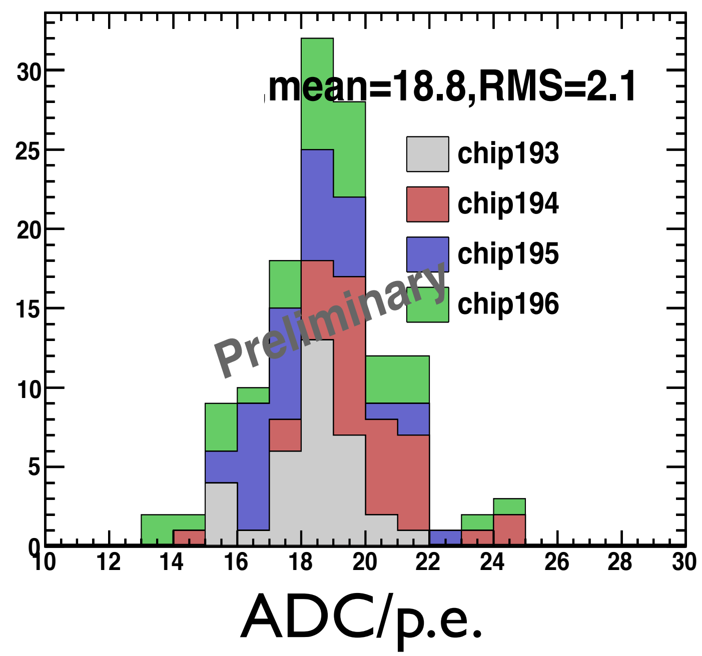
Gain (d-value).

Forward layer → mean: 18.8 RMS: 2.1

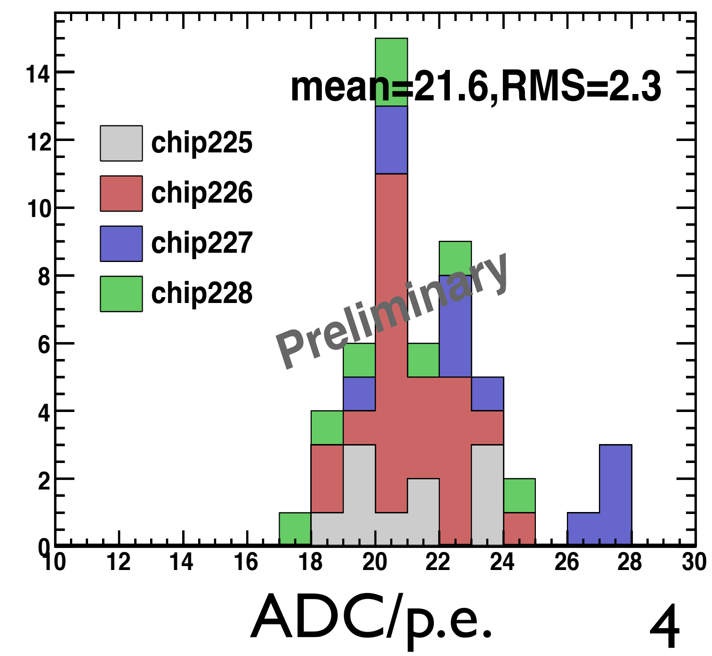
Backward layer → mean: 21.6 RMS: 2.3

* Although we set same bias voltage,
the gain seems to be little different

Forward layer d-value @DESY

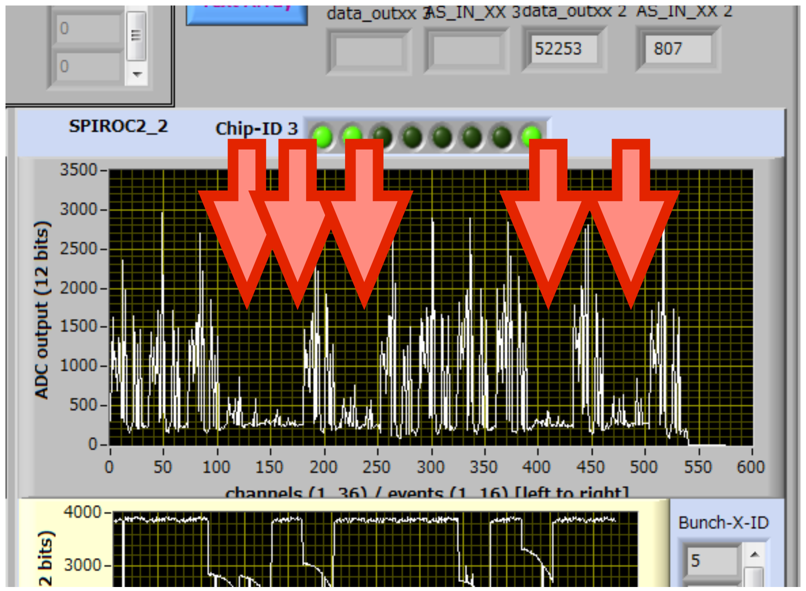


Backward layer d-value @DESY



LED System Problem (2012)

Backward layer
lower wright area.



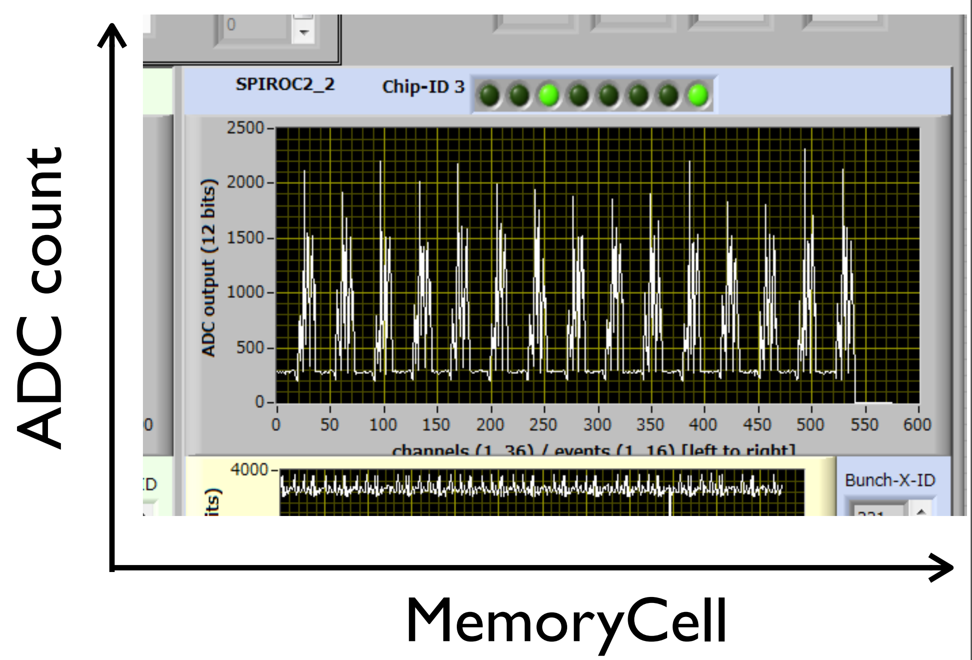
- A part of LED system does not work well.

  In case we control the EBU on LED mode for gain calibration.

  → Chip228 can not take LED signals at the middle of a event.

  → Setting trigger rate slow, we can take signal at every events.

Set trigger rate slow.



- The cause There are some possibilities...
  - The MPPC bias voltage might decrease at high rate.
  - The LED bias voltage might drop.

  We have not understood this cause so far.

- This TestBeam (2013)

  Brought the EBU from Shinshu to DESY.

  This signal lost occurred again, although LED system worked well at Shinshu.

  → Need to investigate this problem.

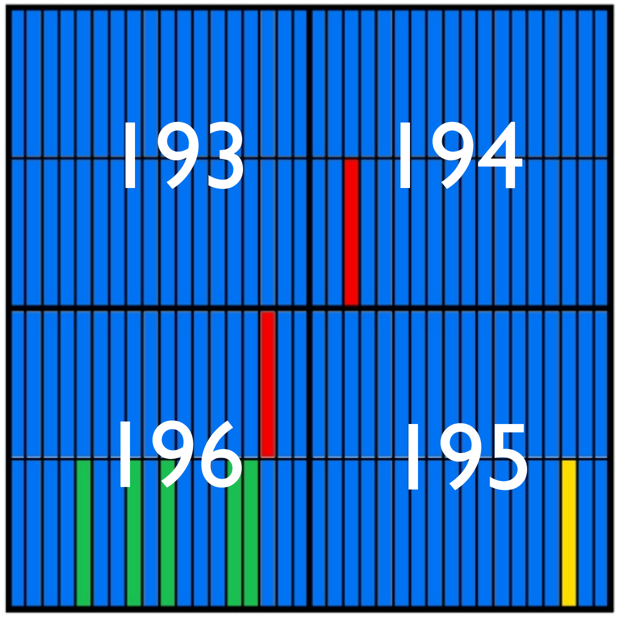
MIP Calibration

- Two EBUs on two layers were calibrated with 3GeV electron beam.
- Fully auto-triggered operation and externally validated trigger operation. → to suppress most noise.
- Fit with Landau-Gaussian convolution.   MPV → MIP position.

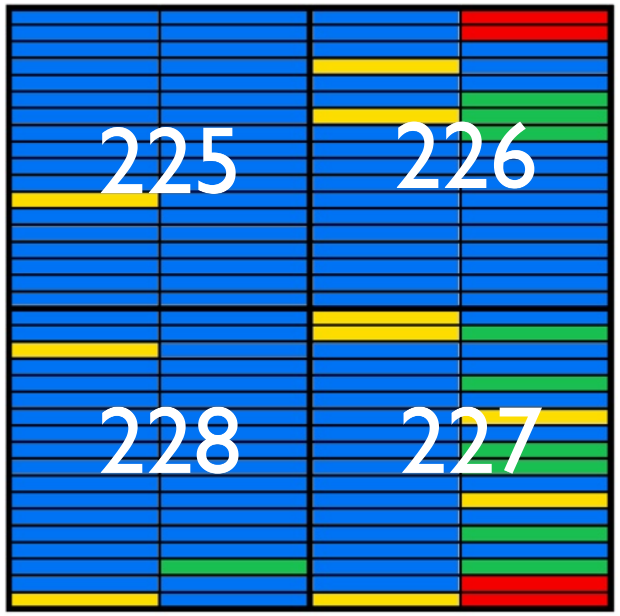
- MIP calibration result at DESY.

Blue	good MIP signal.
Green	is difficult to separate. But get the MPV.
Yellow	strange signal (noisy)
Red	No signal.

Forward layer result @DESY

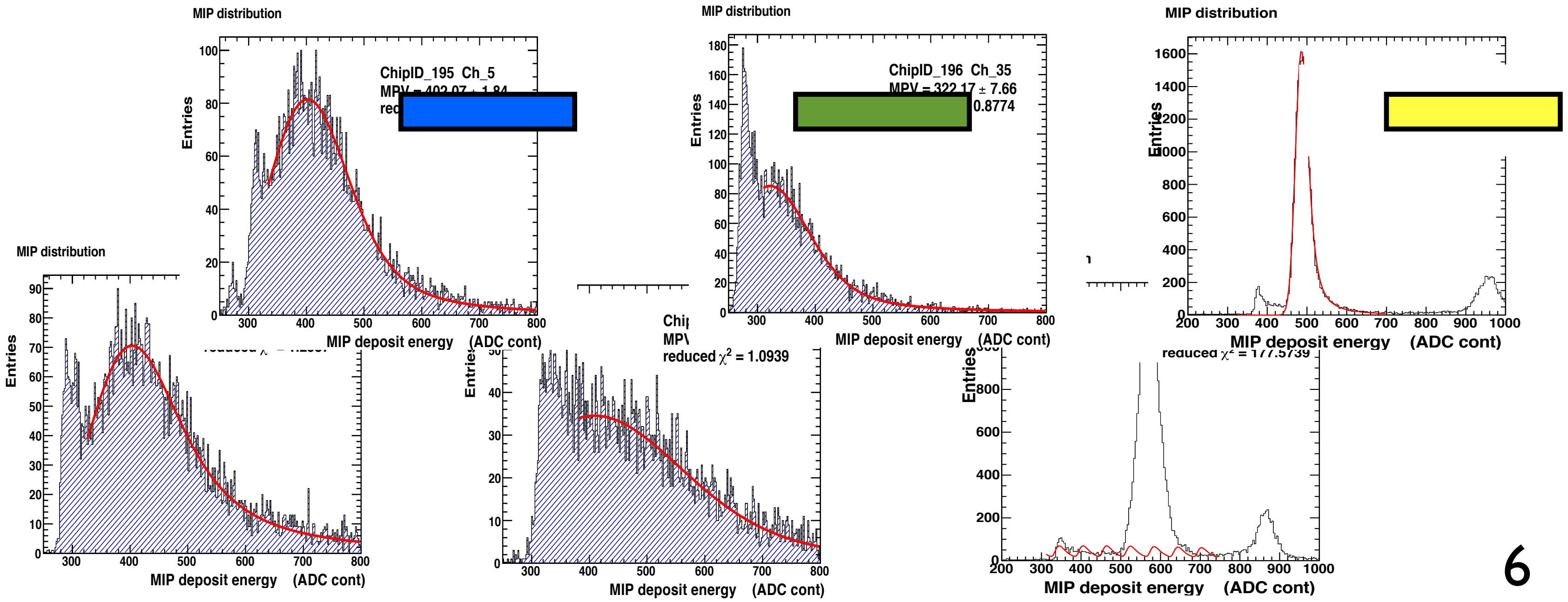


Backward layer result @DESY



On forward, over 90%channels could be calibrated.

On backward, over 80%channels could be calibrated.



MIP Calibration

- ADC/MIP conversion factor

Forward layer

avr.MIP constant = 116.4 ADC

RMS/MIP(MPV) = 23.1%

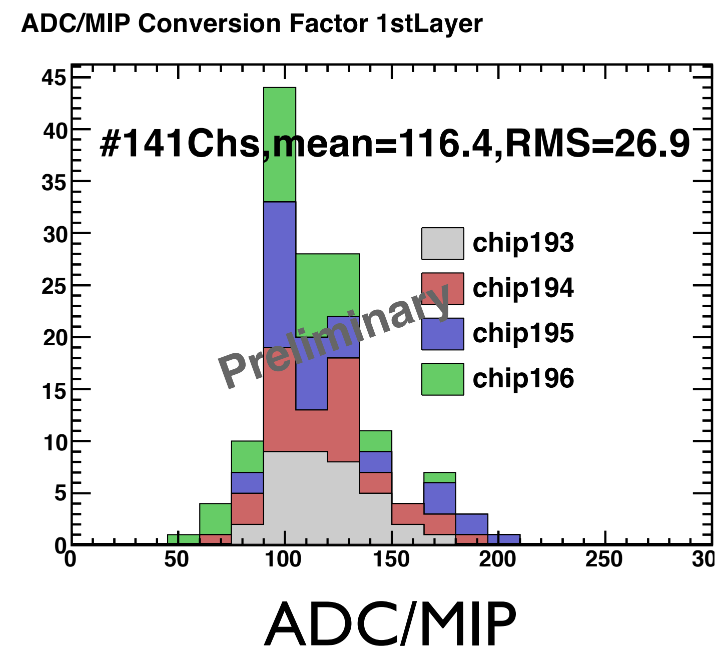
Backward layer

avr.MIP constant = 157.5 ADC

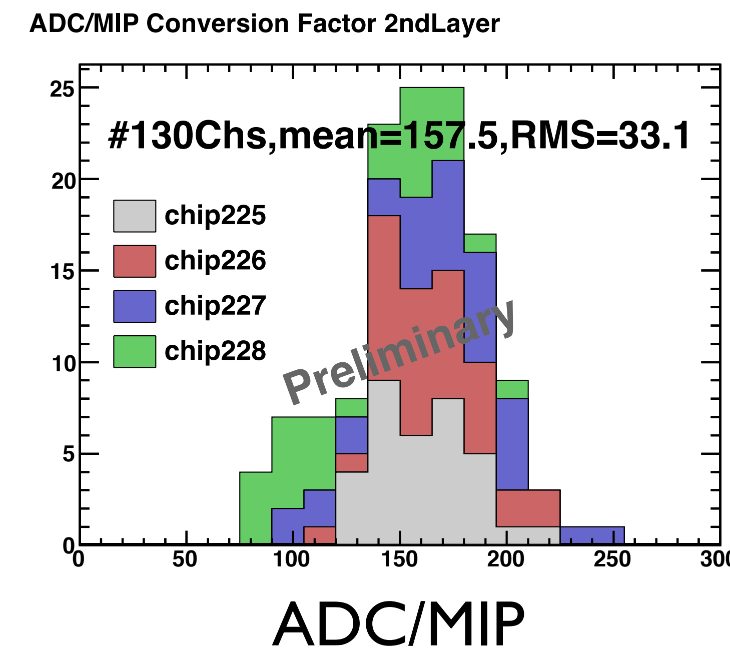
RMS/MIP(MPV) = 21.0%

Last TB (Backward layer → RMS/Means = 19.3%)

Forward layer ADC/MIP



Backward layer ADC/MIP



RMS/MPV of both layers are little bit higher than the result of last Test Beam.

※ Pedestal of TestBeam mode

- On forward layer, pedestal values are different in each chip.

  → What is the cause?

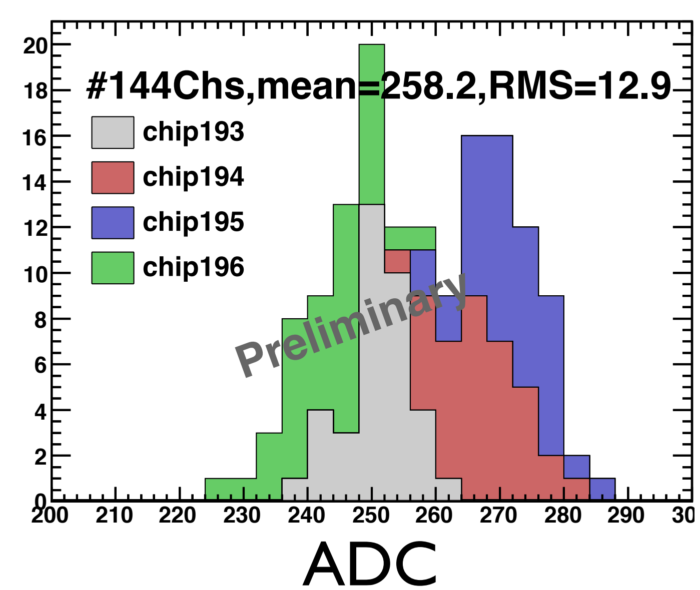
- Pedestal on some channels have problem.

  → Oblique, 2 or 3 peaks.

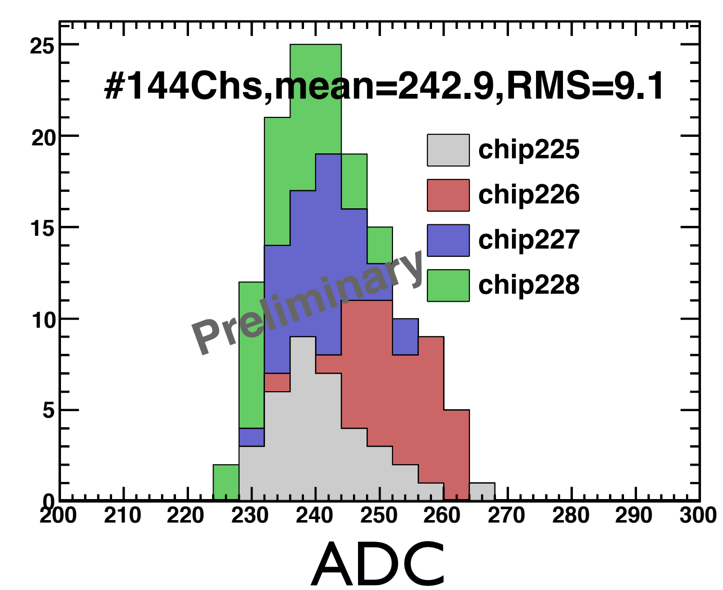
  → Instability of analog memory cells.

  → Under investigation.

Forward layer ADC/MIP



Backward layer ADC/MIP

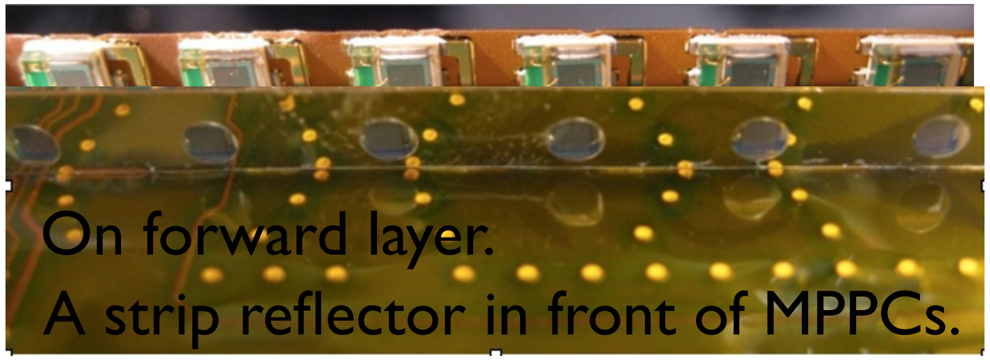


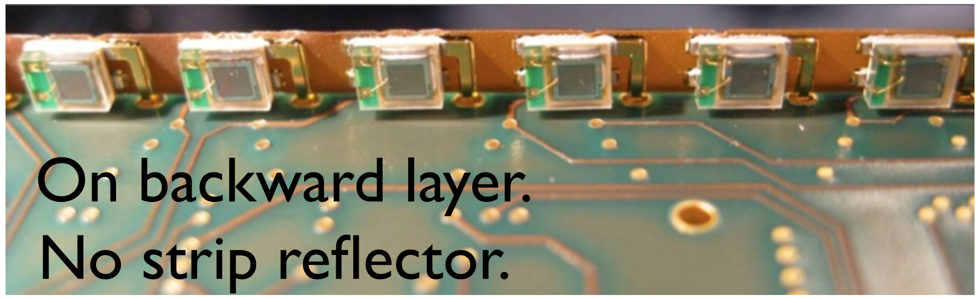
Photon detection

- About photon detection.

The forward layer has a strip reflector in front of MPPCs.
The backward layer does not have it.

→ We want to confirm whether
the difference of photon detection appear.





- Reflector in front of MPPC seems not to be better?
  Np.e. is smaller.

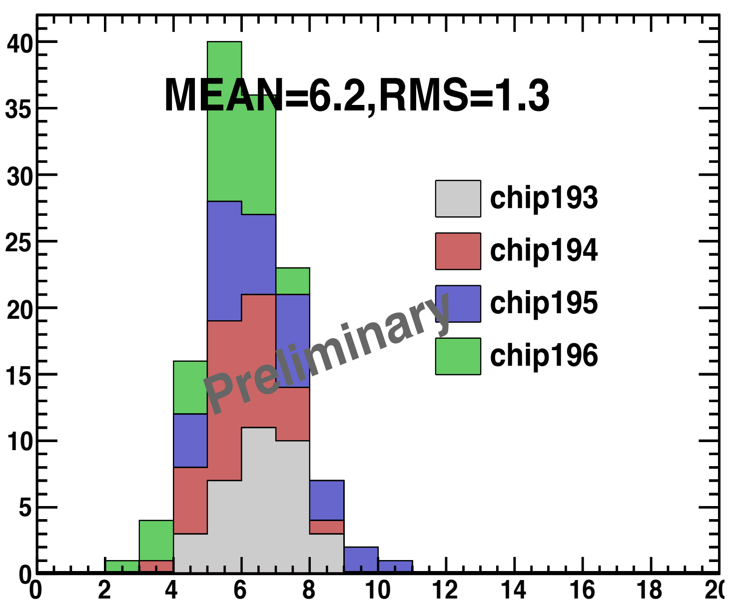
<u>Np.e.</u>

Forward layer → mean: 6.2

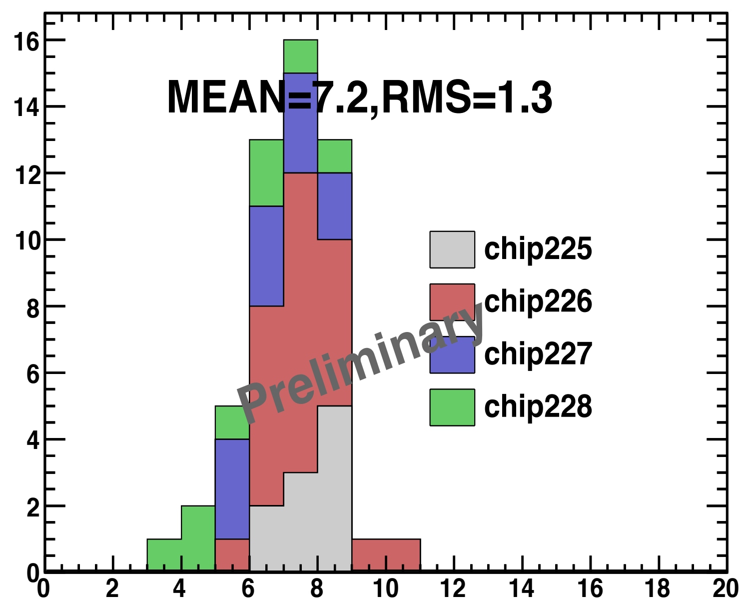
Backward layer → mean: 7.2

※we need 7p.e.
to remove thermal noise and keep response for Bhabha.

Forward layer Np.e.



Backward layer Np.e.



There is the possibility that the voltage on backward is a little bit higher than forward. (gain calibration)

→ Absorption efficiency of photon rises.

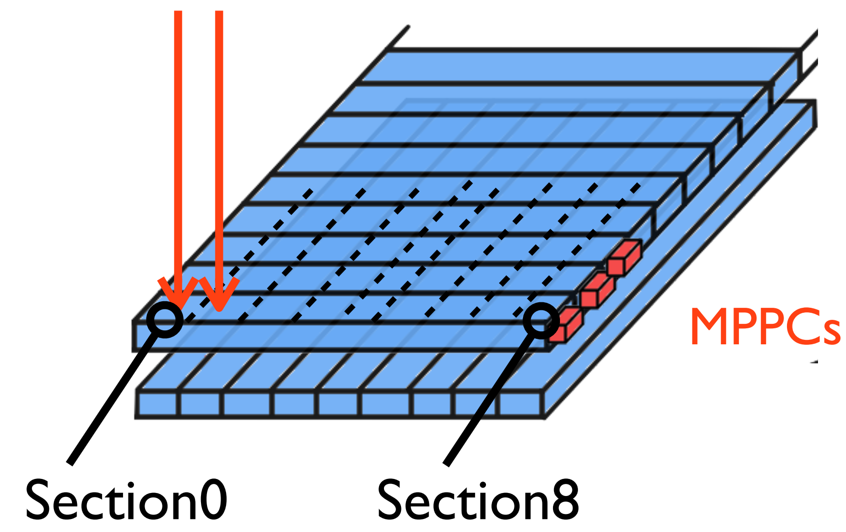
Uniformity

- About uniformity.

Changing the EBU position against beam,
we take a position scan with 5mm grid (divided 9 sections).

Confirm a uniformity of a scintillator
and in front of MPPCs.

→ Extract ADC count with 2 layer coincidence.

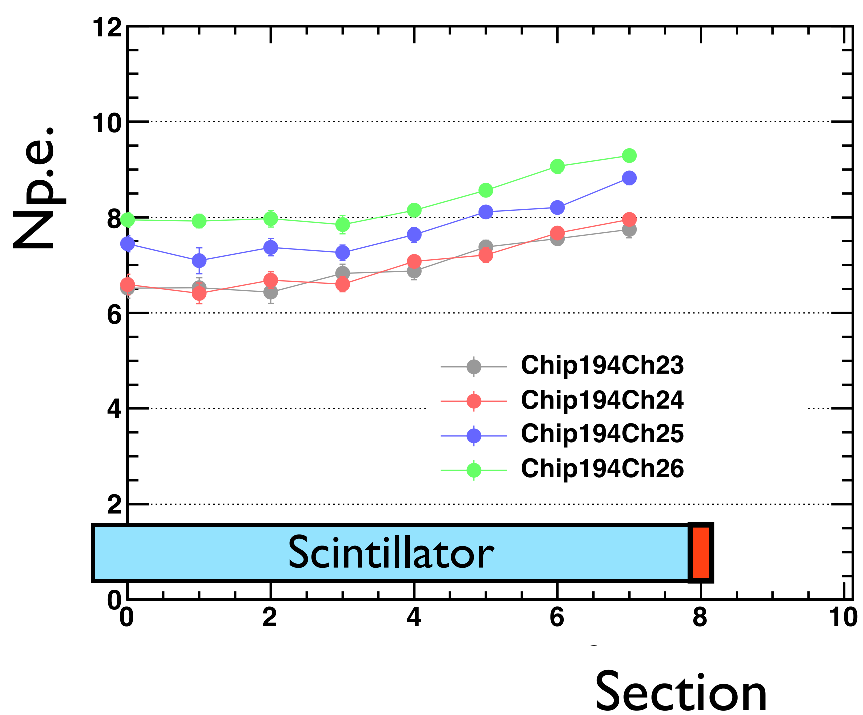


→ Photon yield is larger at in front of MPPCs.

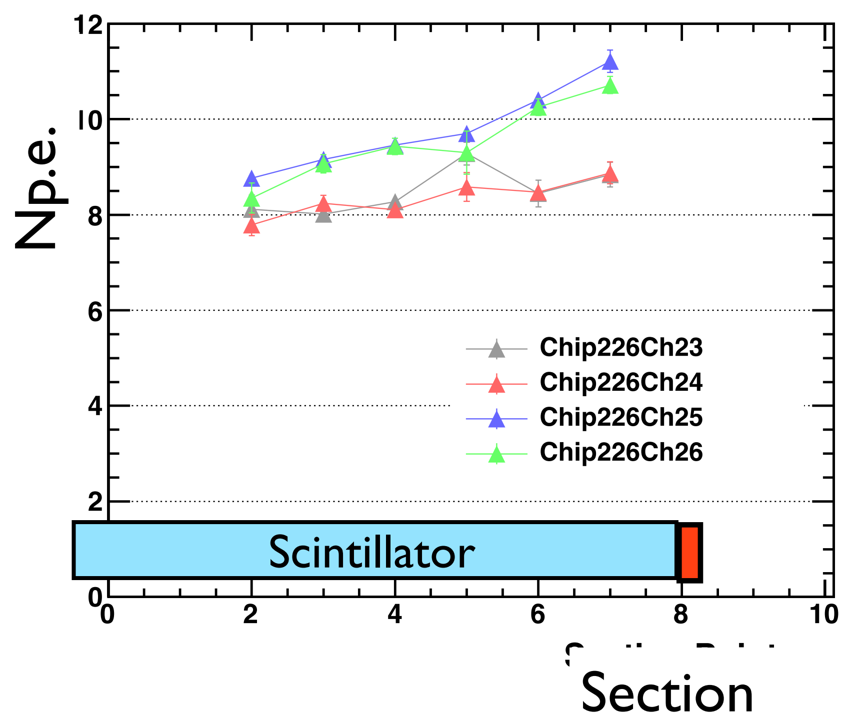
On forward layer,
the channel behind which is corresponding to the section 8 turns off.

On backward layer,
the data is only half of 1st layer.
There is no data on section 0 and section 1.

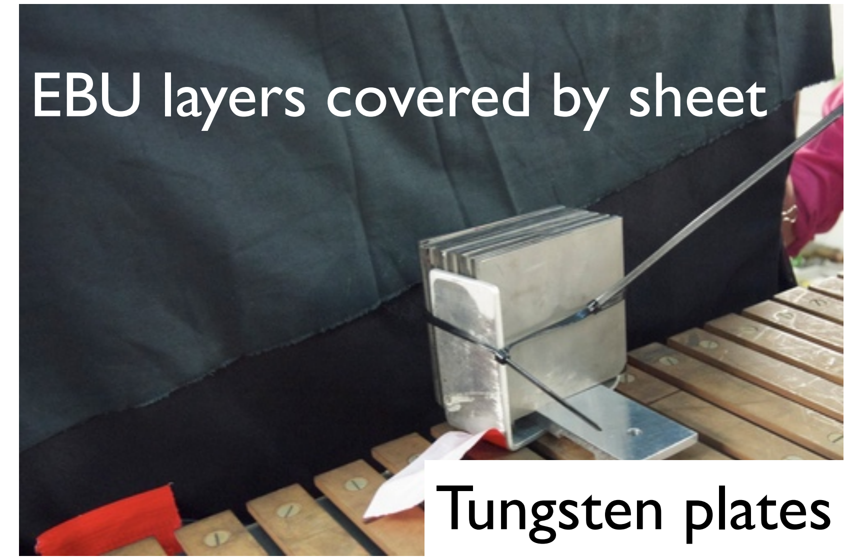
Forward layer Np.e.



Backward layer Np.e.



Energy Weight with Simple SSA

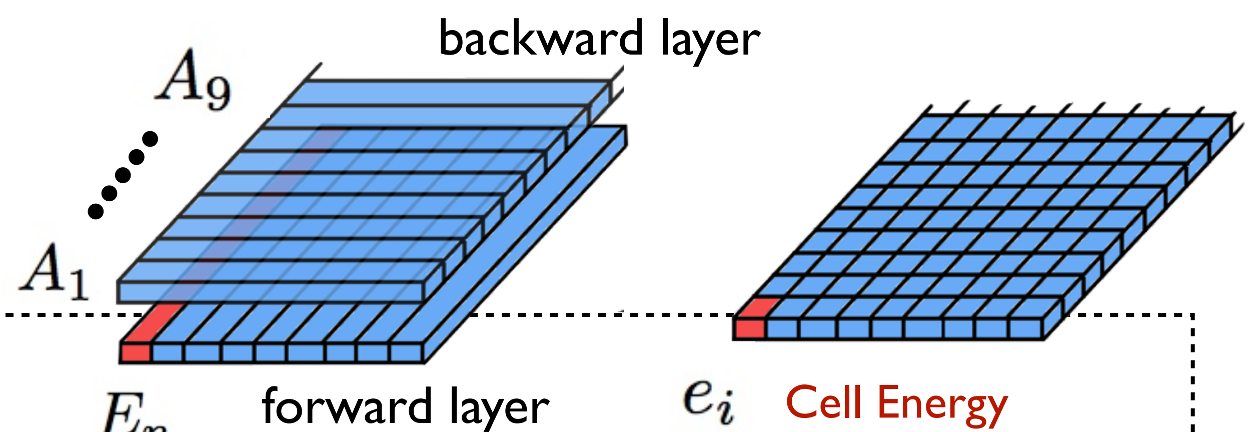


- We made shower events with Tungsten absorbers.

  Change the number of tungsten.

  → We want 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.)

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

Take an average

$$\sum_{i=1}^{9} A_i = \sum_{i=1}^{9} A_i \quad / \quad (\text{N of living Channels}) \quad \times \quad 9$$

Results of Energy Weight with simple SSA

- Spread of the EM shower. (Have not rejected noises completely yet.)

We could observe the spread of shower.

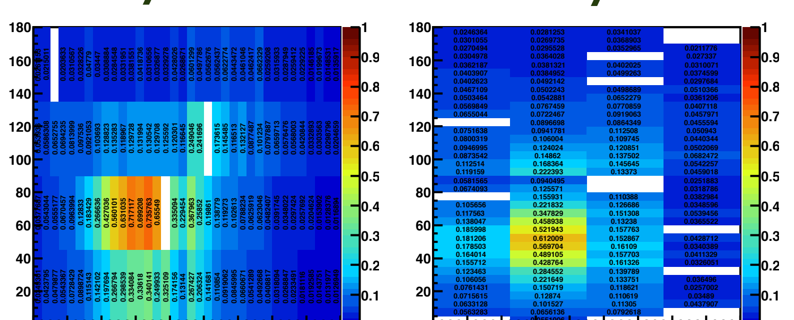
Strip Splitting Method is also working good.

※ Energy deposit on backward is smaller than on forward.

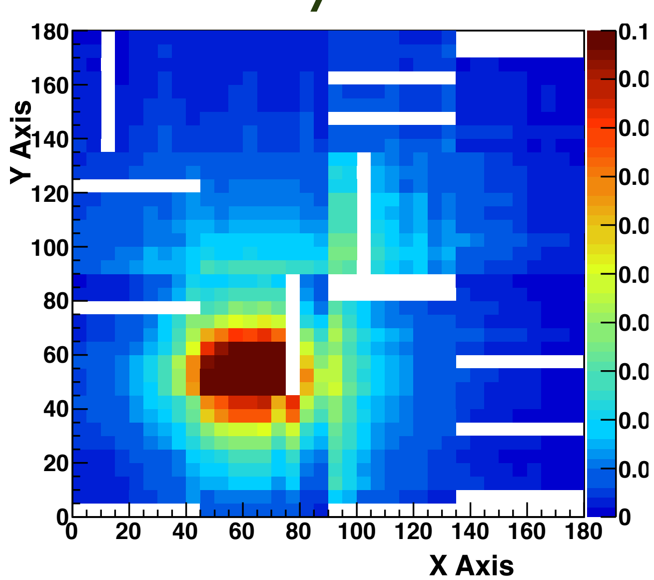
→ Small energy particles stop in forward layer and can't reach backward one.

Tungsten x 2

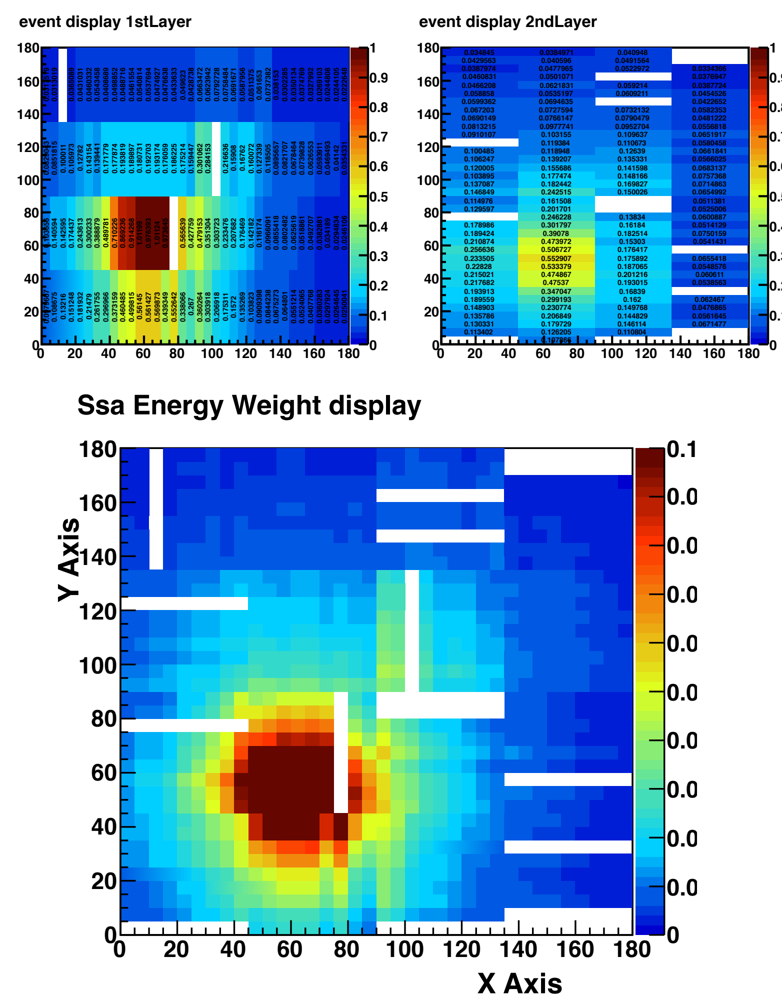
1st Layer Plot 2nd Layer Plot



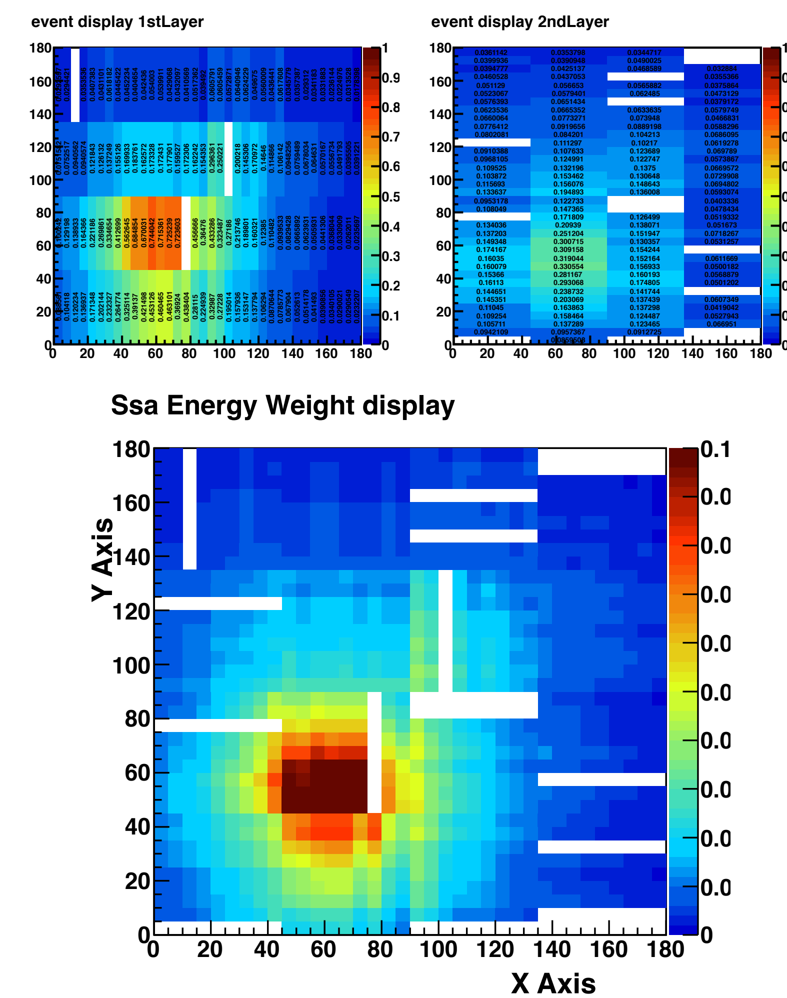
SSA on 2 layers Plot



Tungsten x 7



Tungsten x 11



Results of Energy Weight with simple SSA

- We compared the longitudinal shower shape.

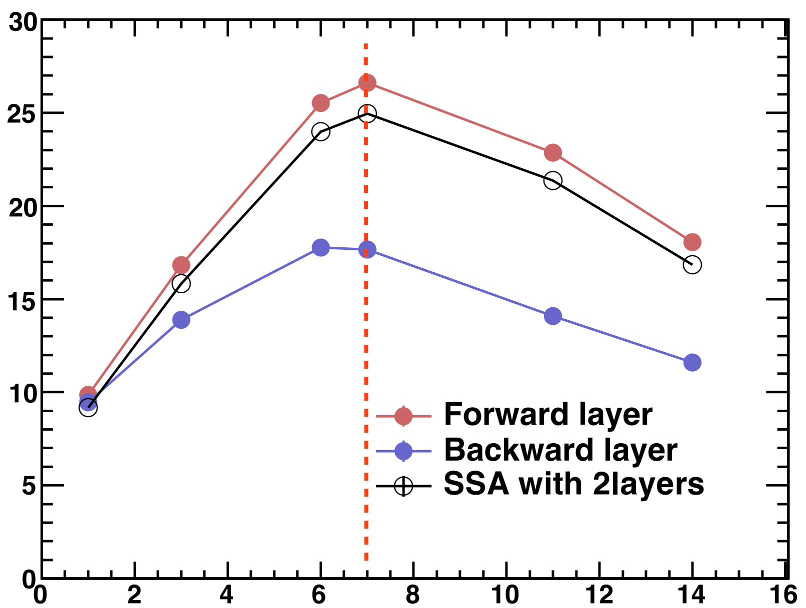
  → We used 3 GeV electron.

  On physics plot type, max deposit is 6 ~ 8 absorbers.

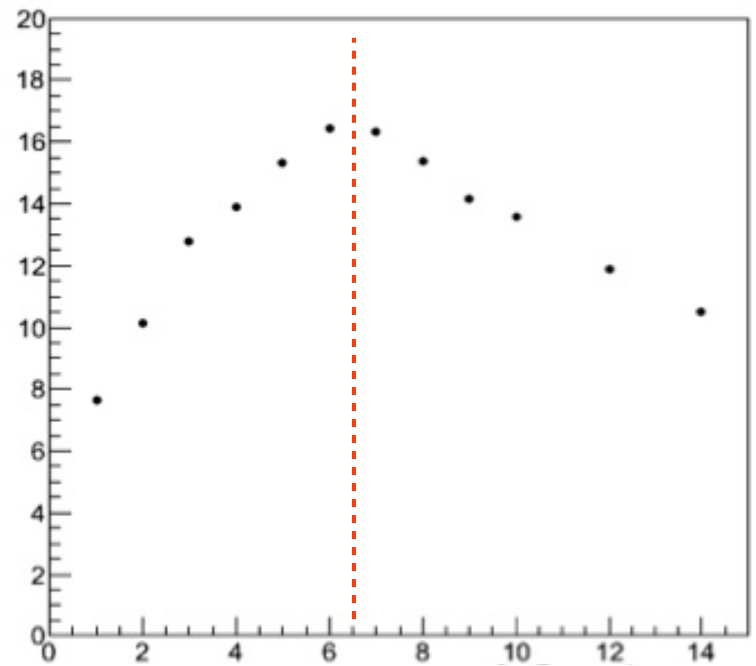
  On engineering plot type, max deposit is 6 or 7 absorbers.

Total MIP count

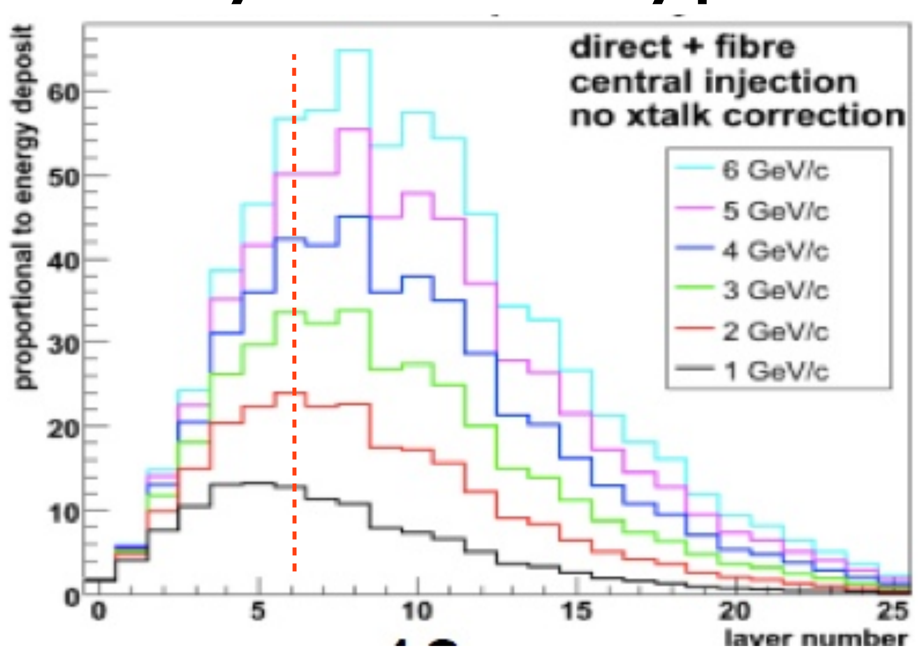
This Test Beam 2013



Previous TB 2012



Physics Plot Type



N of Tungsten Plates

Hit Map with EBU/HBU Synchronized Data

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

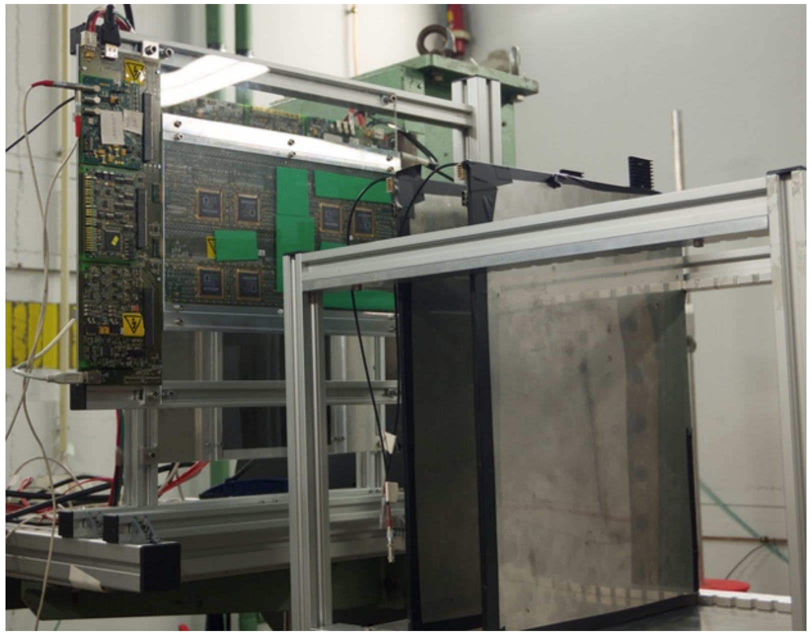
  In case of 4 layers coincidence. (4 auto trigger flag) → 1 hit.

  A diagonal area of HBU is high threshold

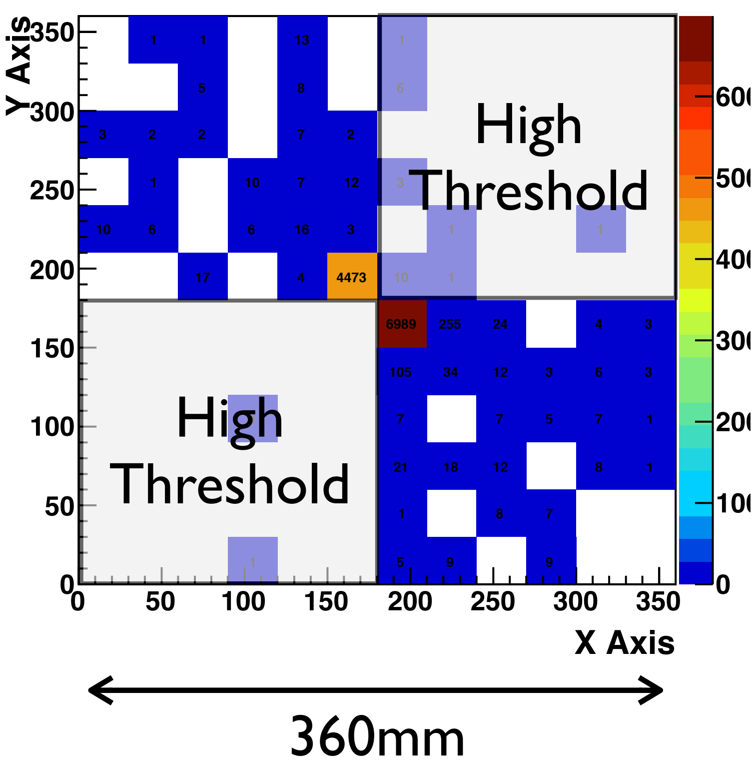
  → Hits are concentrated in opposite diagonal area.

  → On EBU, hits are concentrated in diagonal area.

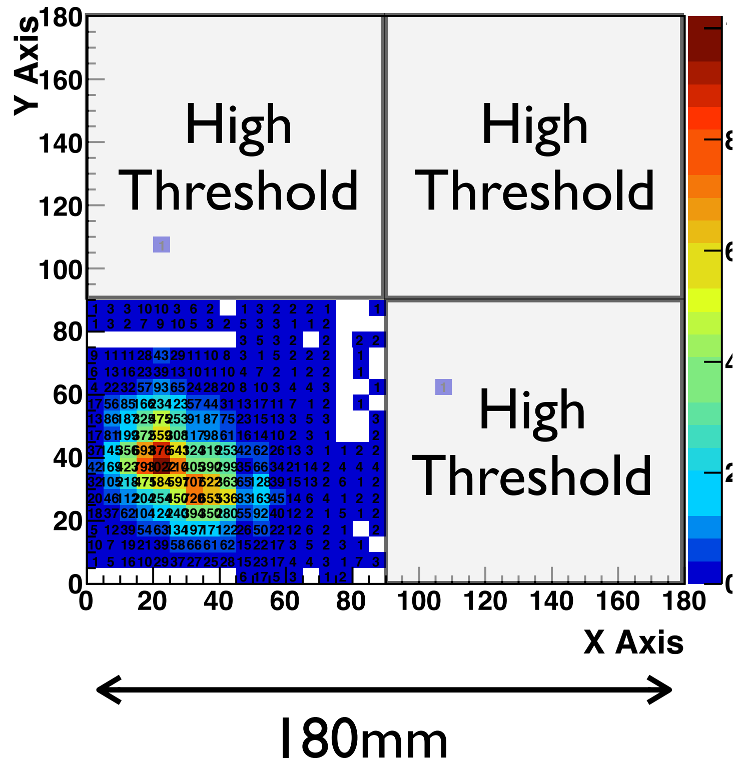
  Observed a correlation between EBU and HBU.

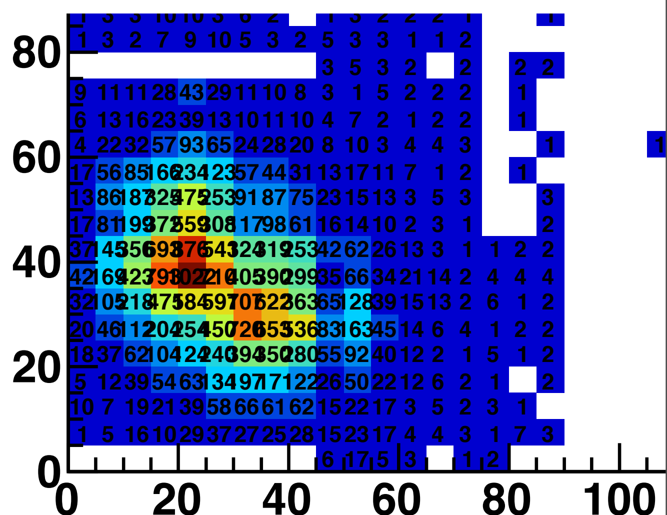


Hit Map of HBU



Hit Map of EBU





Summary

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

  On forward layer, we could be calibrated over 90% channels on both LED and MIP calibration.

  On backward layer, we could be calibrated over 80% channels on both LED and MIP calibration.
  (except problematic area on LED)

- Precision position scan and shower events.

  Number of photons detected by MIPs is little bit different between 1st layer and 2nd layer.

  By position scan, non uniformity appeared. We should be compared with bench test precisely.

  We confirmed the spread of shower.

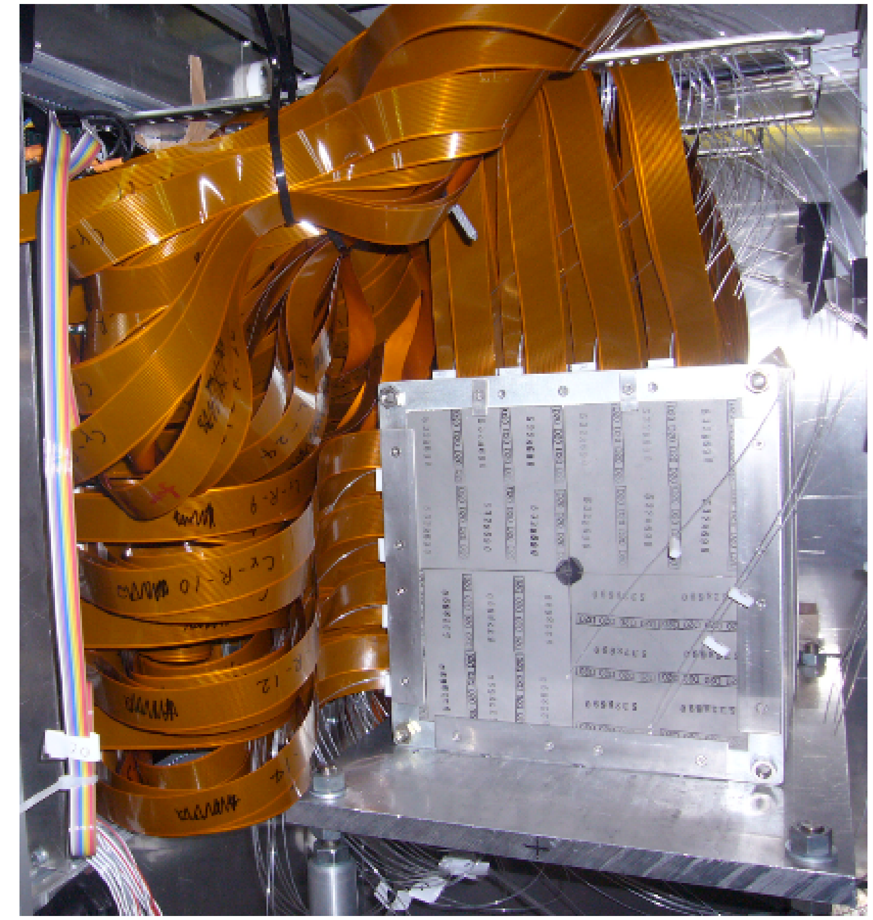
- Two layer ScECAL successfully worked with AHCAL in a good synchronization.

  We could observe the correlation between EBU and HBU.

All analysis is a first step.

Back Up

Introduction (Physics prototype)

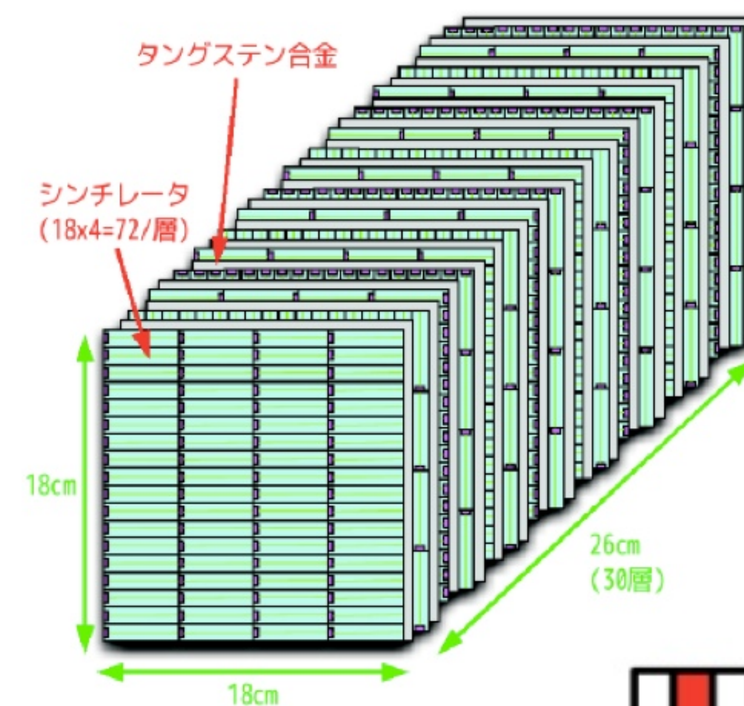


- We carried out a Beam test at 2008, 2009 with
  Sc ECal as a physics plot type.

- Having enough performance for the ILD ECAL,
  Sc ECal has been considered as one of the candidate.

ILD ECAL : $\frac{\sigma}{E} < \frac{15\%}{\sqrt{E}} \oplus 1\%$

Sc Physics plot type : Resolution:
Stochastic $12.9 \pm 0.4\%$
Constant $1.2^{+0.4}_{-1.2}\%$

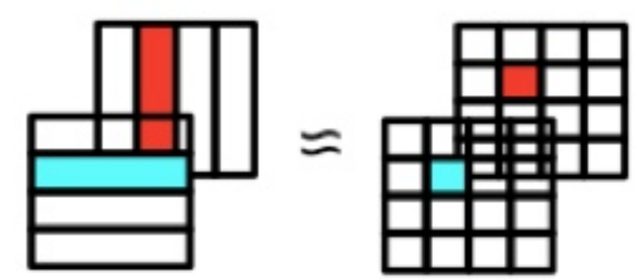


- The PFA is used as the way of analysis of ILC

- The ECal is needed to be separated very fine
  to distinguish particles precisely within itself.

Make scintillators intersect,
and achieve the high granularity (5x5mm grid)

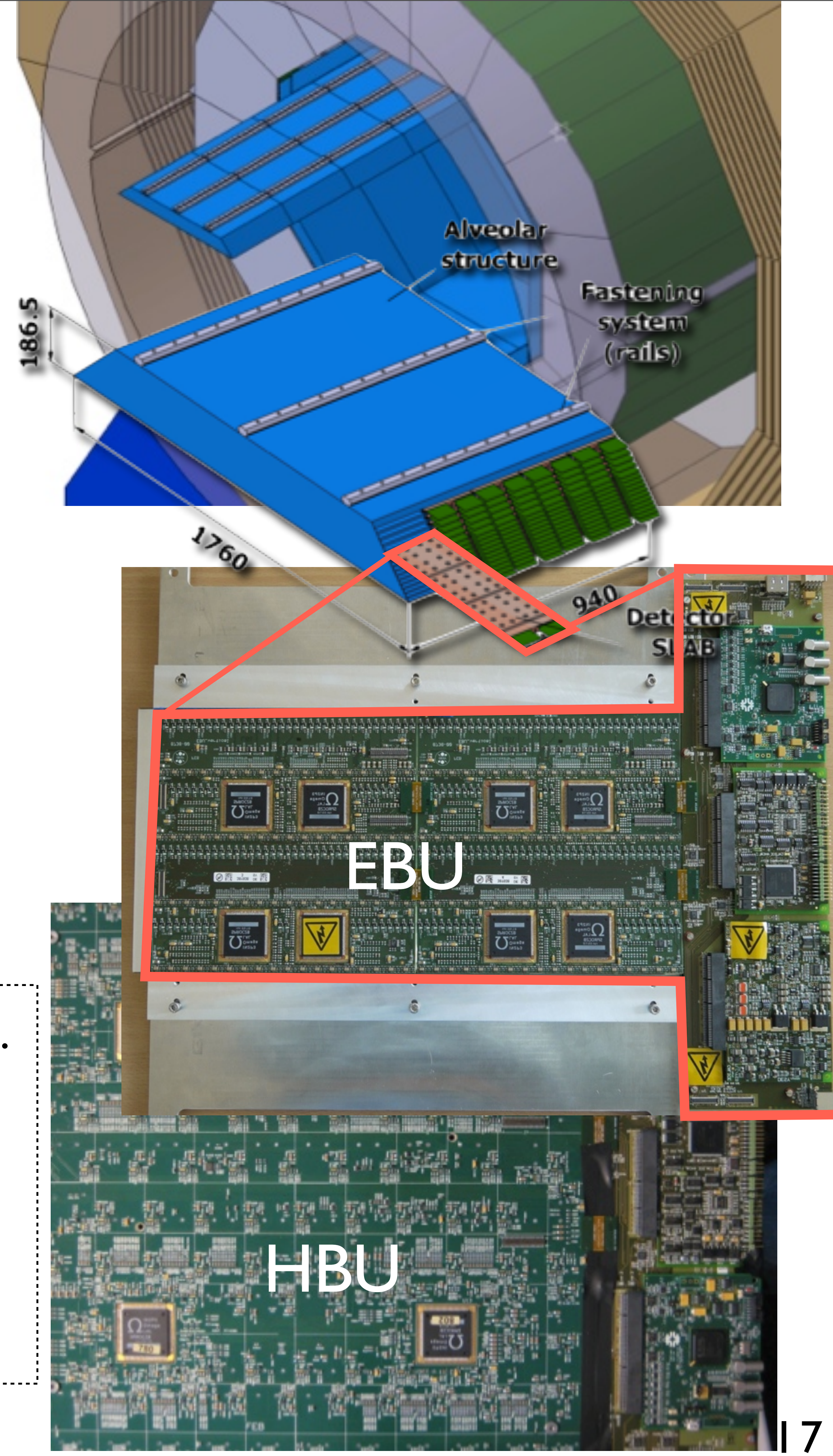
→ Strip Splitting Method (SSA)



Sc ECAL Base Unit (EBU)

- The physics plot type is different from an electronics that has been imagined at ILD ECal.

- We developed with DESY AHCal people the electronics (EBU) a readout chip is embedded at.



- About the EBU

This is a readout board for Sc ECal developed at DESY, and based on the technology of HBU for AHCal.

Both EBU and HBU have same number of channels 144.

Both have 4 PIROC2bs on board for readout.

Circuit of EBU is quadruple the density of HBU.
→ This is difficult technologically.

EBU has 112 LED for gain calibration.