Status of Scintillator Strip ECAL Studies

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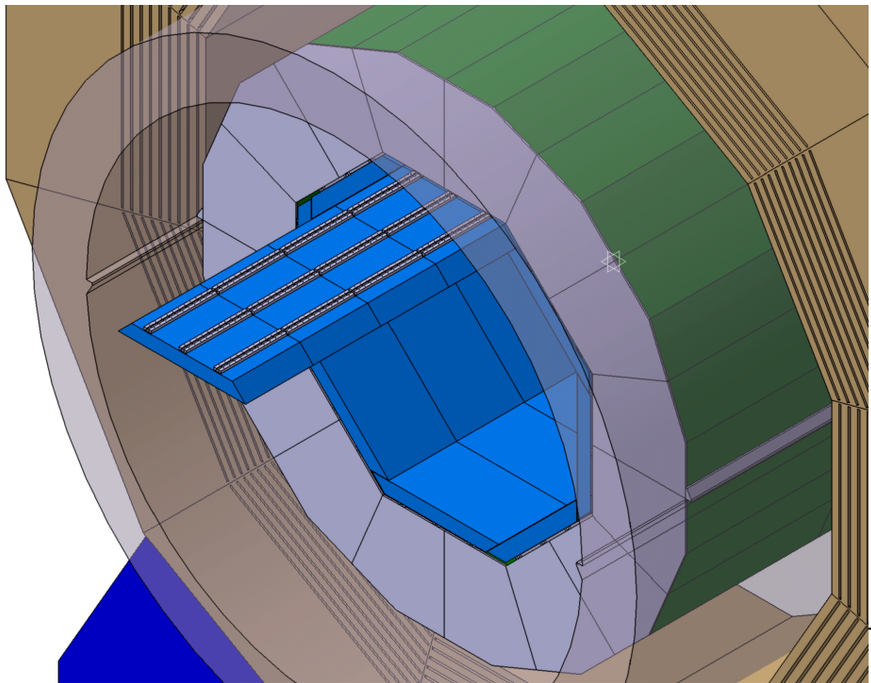
Fine tuning!

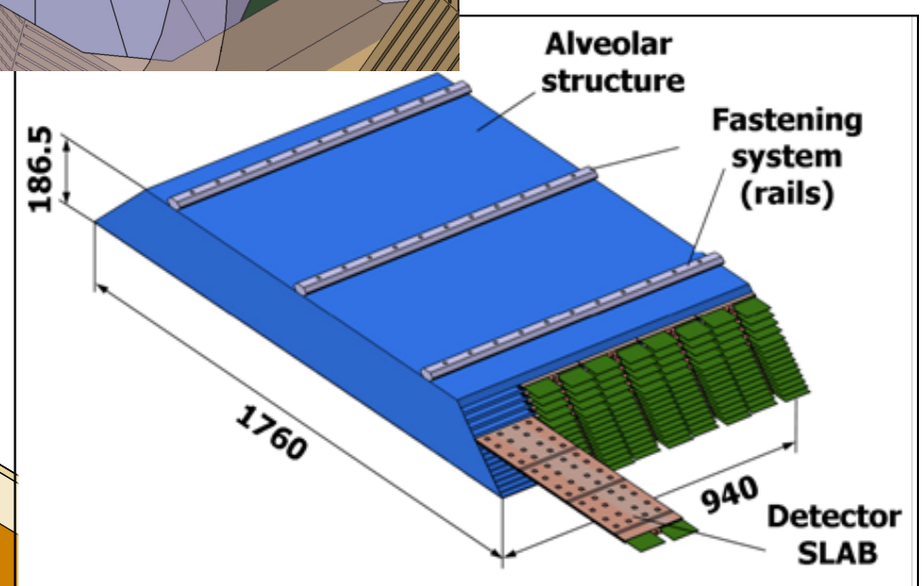
Contents

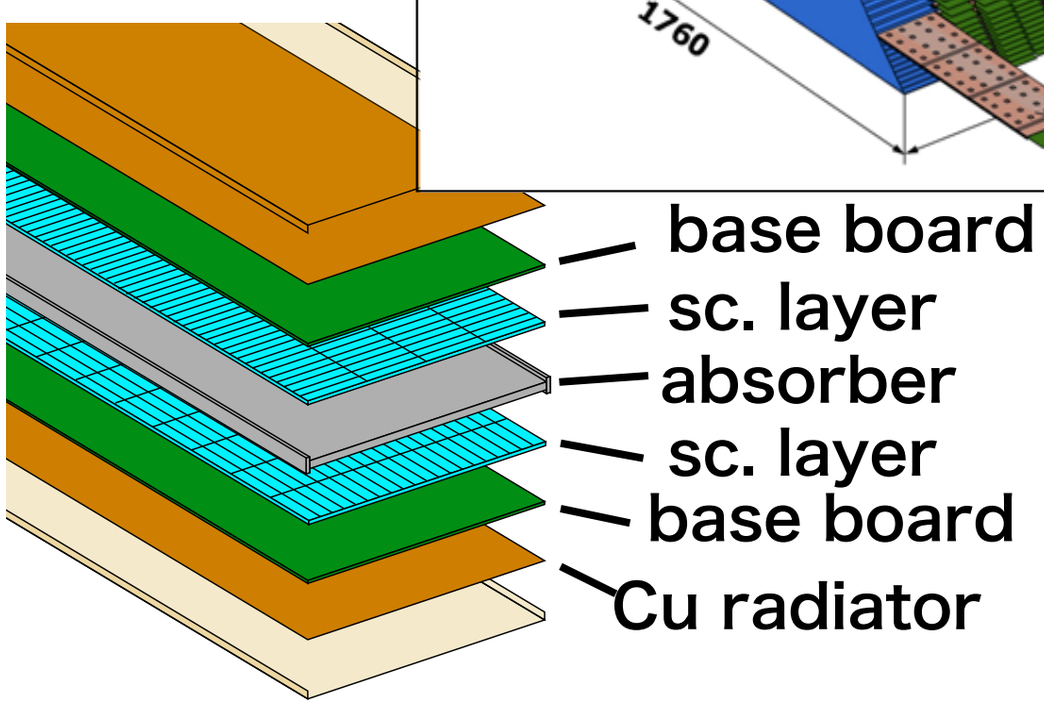
Why we study ScECAL

1. Requirements:
   1. 5 mm x 5 mm lateral segmentation
   - robustness for ~ 10^8 channels
   2. Low cost.
2. Drastic development of the PPD (SiPM, MPPC)
   1. high gain, small package,
3. Idea of strip segmentation, the strips in odd layers orthogonal to those in the even layers. $10^8 \rightarrow 10^7$
4. Especially for CLIC, scintillator can make timing measurement with resolution < 1 ns.

Strip ScECAL in ILD

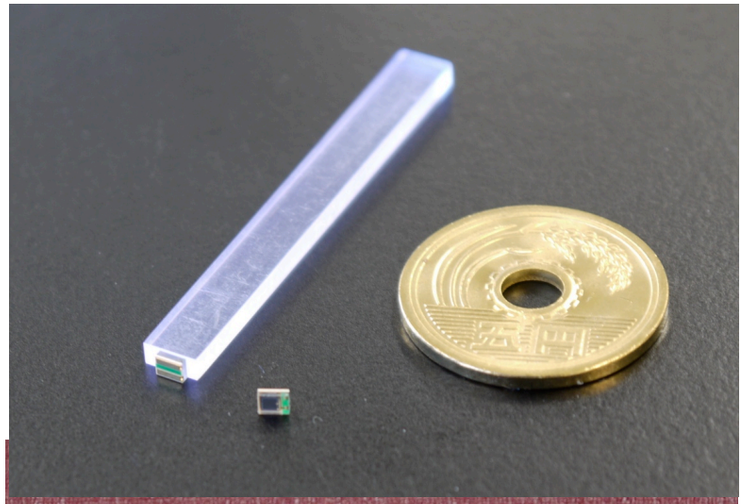


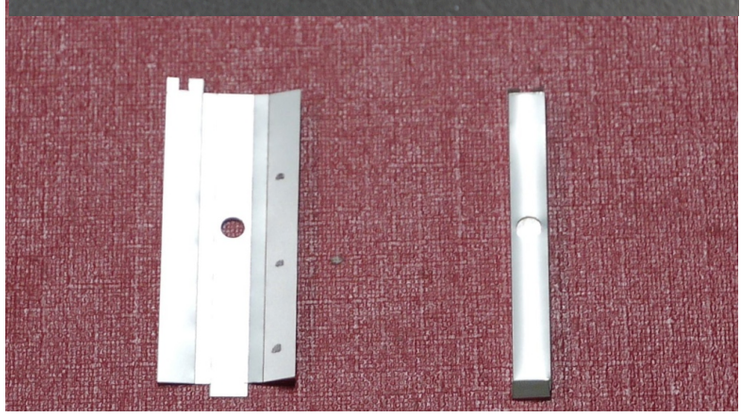




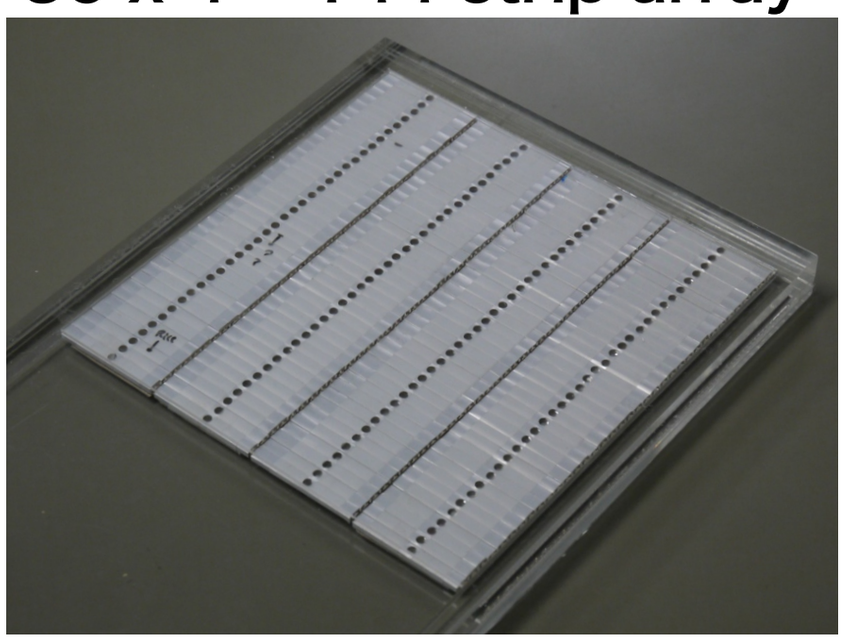
1. Mechanical design of the barrel and the endcaps is the same as SiECAL.
2. most of the alveolar structure is the same as that of SiECAL
3. alveolar structure itself made with W absorbers.
4. only layer structure is changed to suit to the scintillator sensors.
5. two scintillator layers in an alveolar make a sandwich structure with a tungsten absorber.
6. strip directions are orthogonal to each others.

Current design of scintillator and MPPC

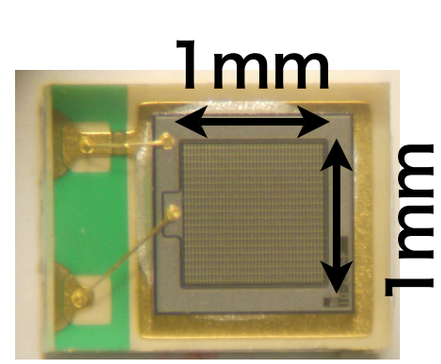


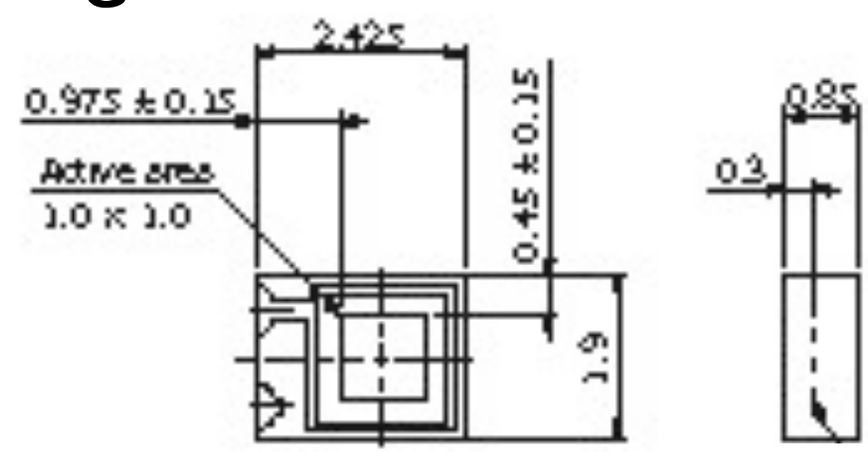


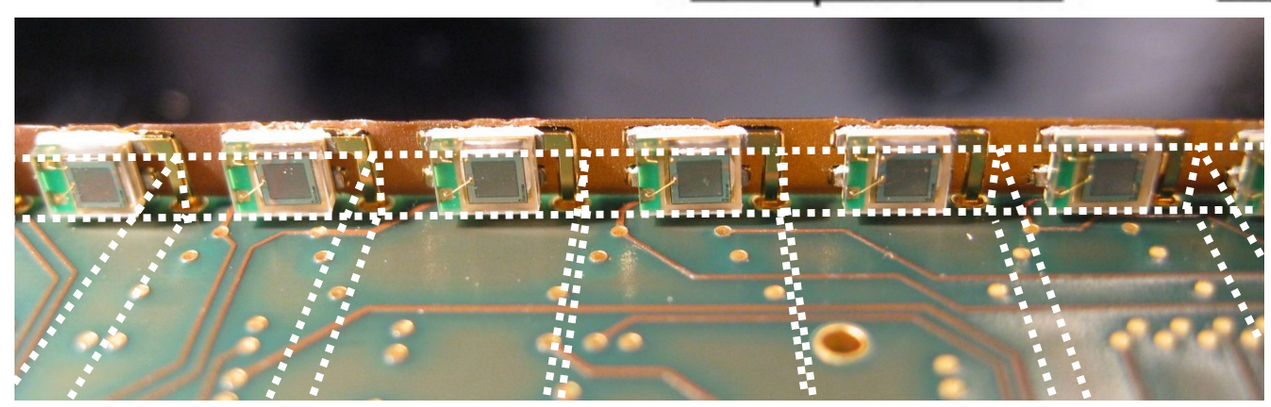
36 x 4 = 144 strip array



1. 45 mm x 5 mm x 2 mm plastic scintillator
2. with surface mounted MPPC
   1. > 1600 pixels in 1 mm x 1mm.
   2. Hamamatsu has developed 10k pixel MPPC recently --> We will test it.
   3. MPPC package: 2.4 x 1.9 x 0.85 mm^3





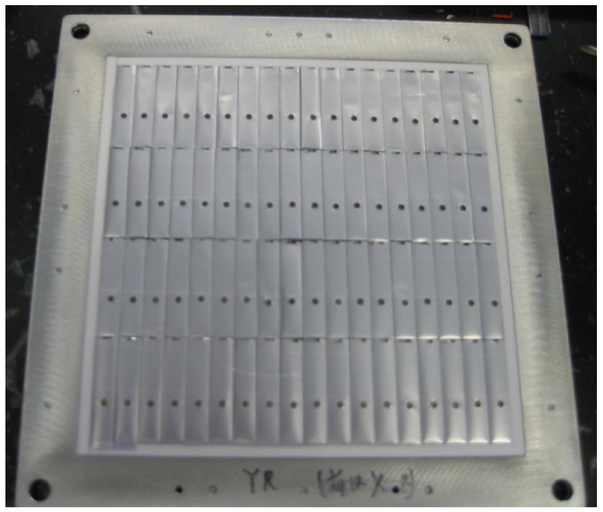


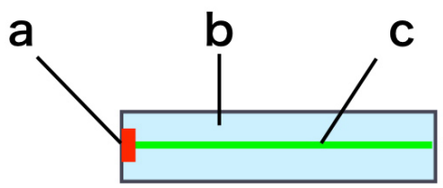
Each MPPC has electrodes connected to the baseboard directly.

Performance for the single particles

Results from physics prototype @ FNAL

One layer of the prototype



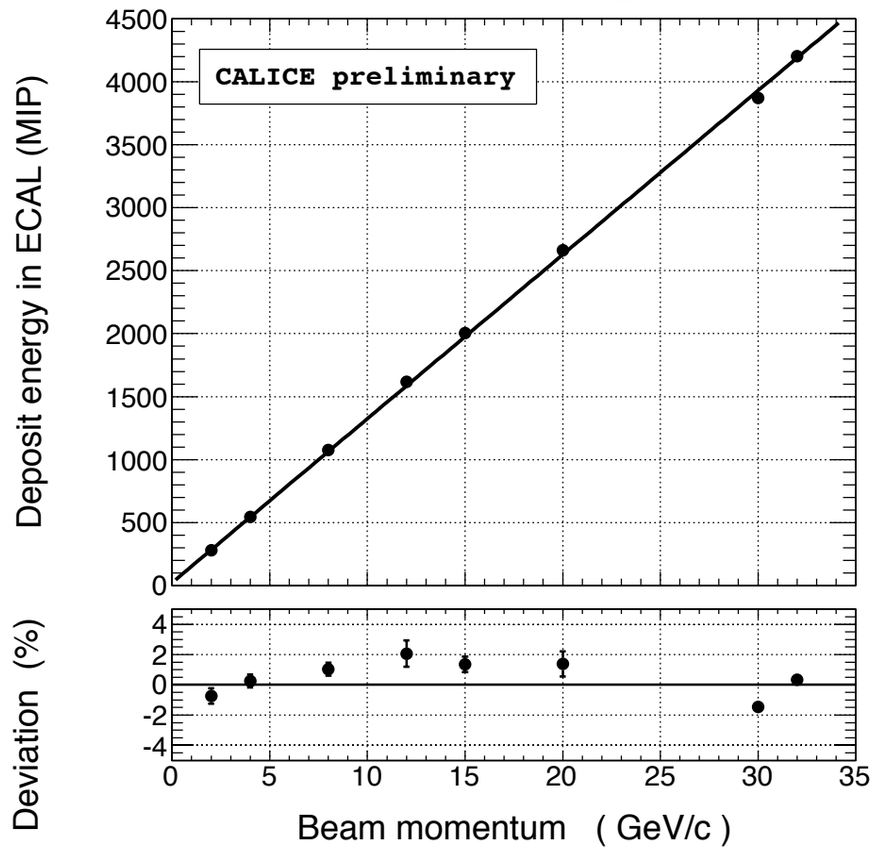


10 x 45 x 3 mm³ using WLS fiber

a. MPPC
b. scintillator strip
c. WLS fiber

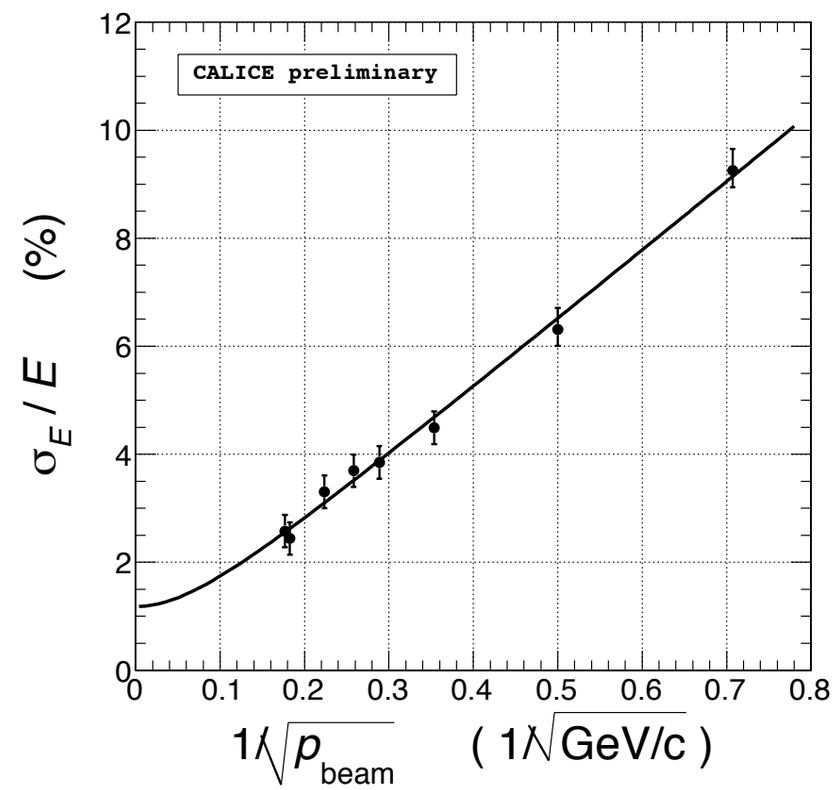
30 layers in the prototype

Linearity



Deviation from the linear fit is less than 2% for 2 - 32 GeV electron beams. MPPC saturation corre. and temperature corre. are implemented

Resolution

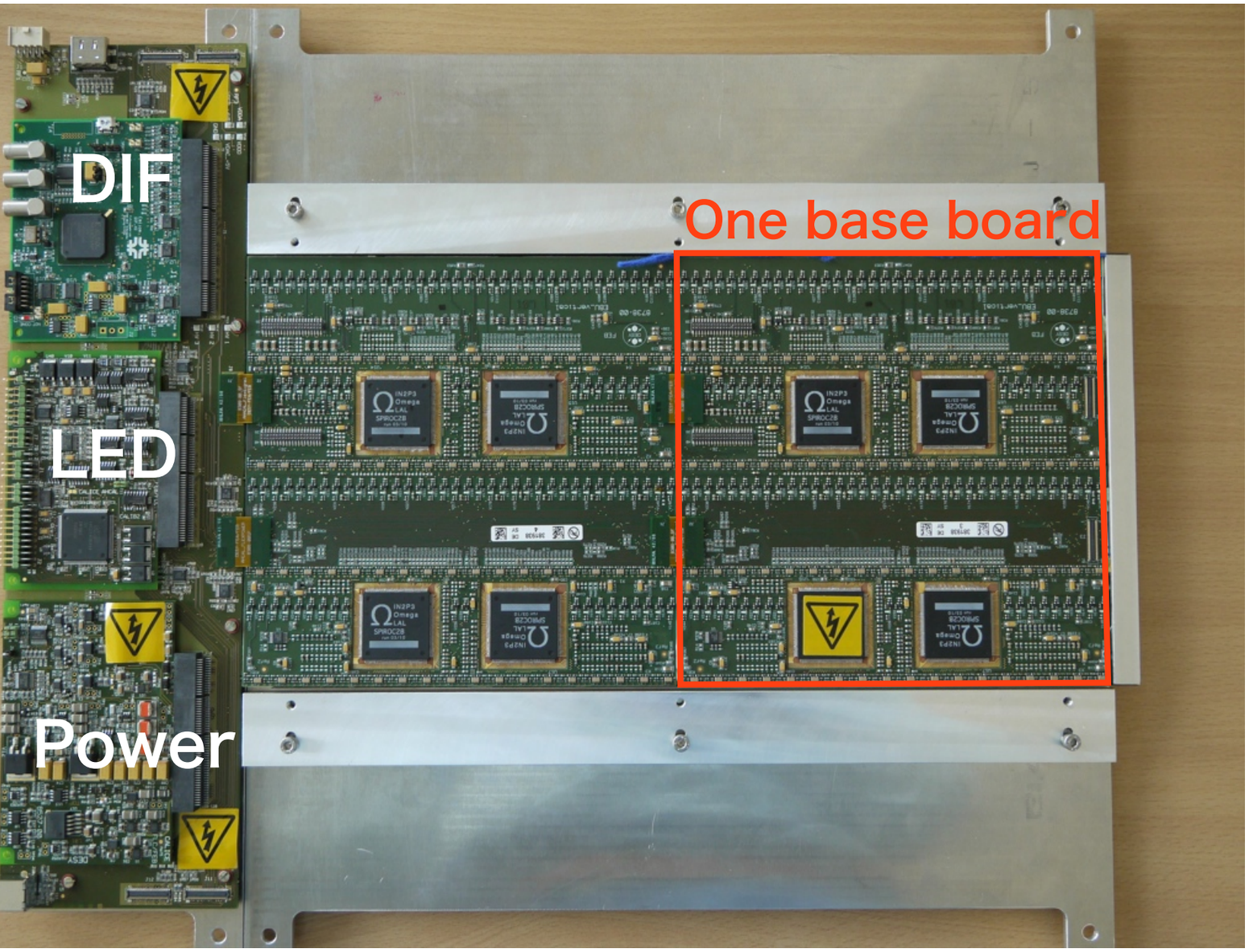


$\sigma_E/E = 1.2 \pm 0.1(\text{stat.})^{+0.4}_{-1.2}(\text{syst.})(\%)$

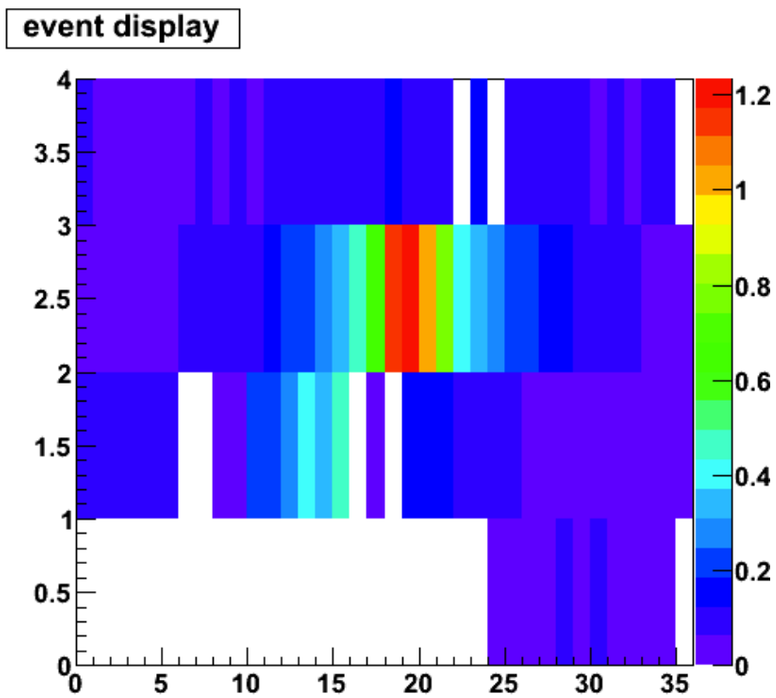
$\oplus 12.9 \pm 0.1(\text{stat.}) \pm 0.4(\text{syst.})(\%)/\sqrt{E}$

intrinsic beam momentum fluctuation was subtracted

Technological prototype module was tested with DESY electron beams



One base board has four chips which treat 36 channels respectively.



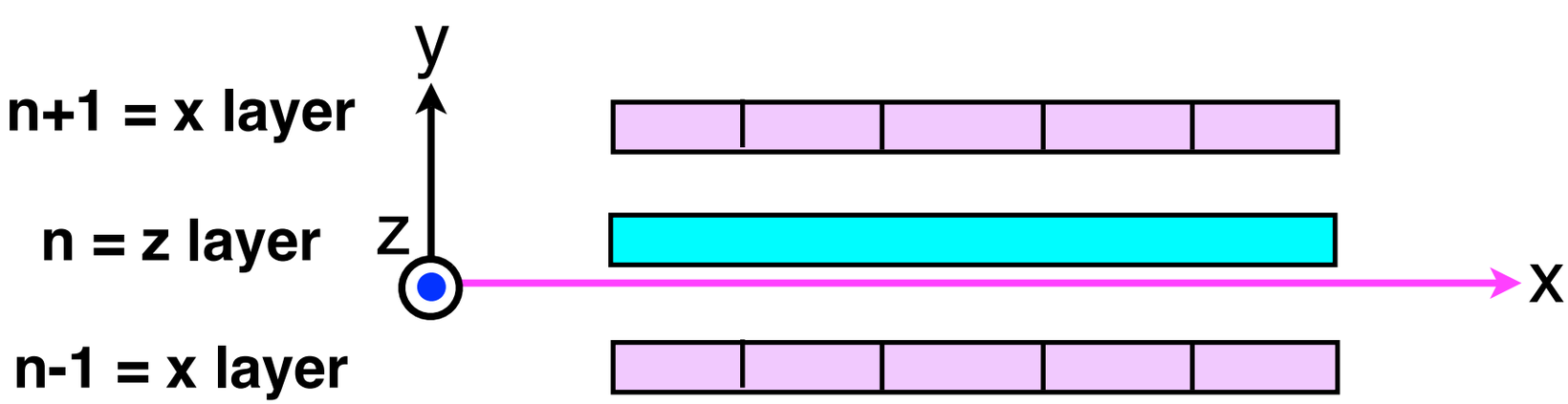
Shower event on a layer with 5 X_0 W absorber.

75% channels work at the first experiment

Strip Ecal reconstruction with the strip splitting algorithm

1. Assume that n-th is a z-layer (fine segmentation in z direction), while n±1 layers are x-layers (fine segmentation in x direction).
2. a shower comes from the bottom
3. split each strip in n-th layer into pseudo-square cells

Split method



4. energy deposit in n-th layer is distributed in pseudo cells referring adjacent n±1th layer strips.
5. The position and energy of pseudo square cells are fed into PandoraPFA.

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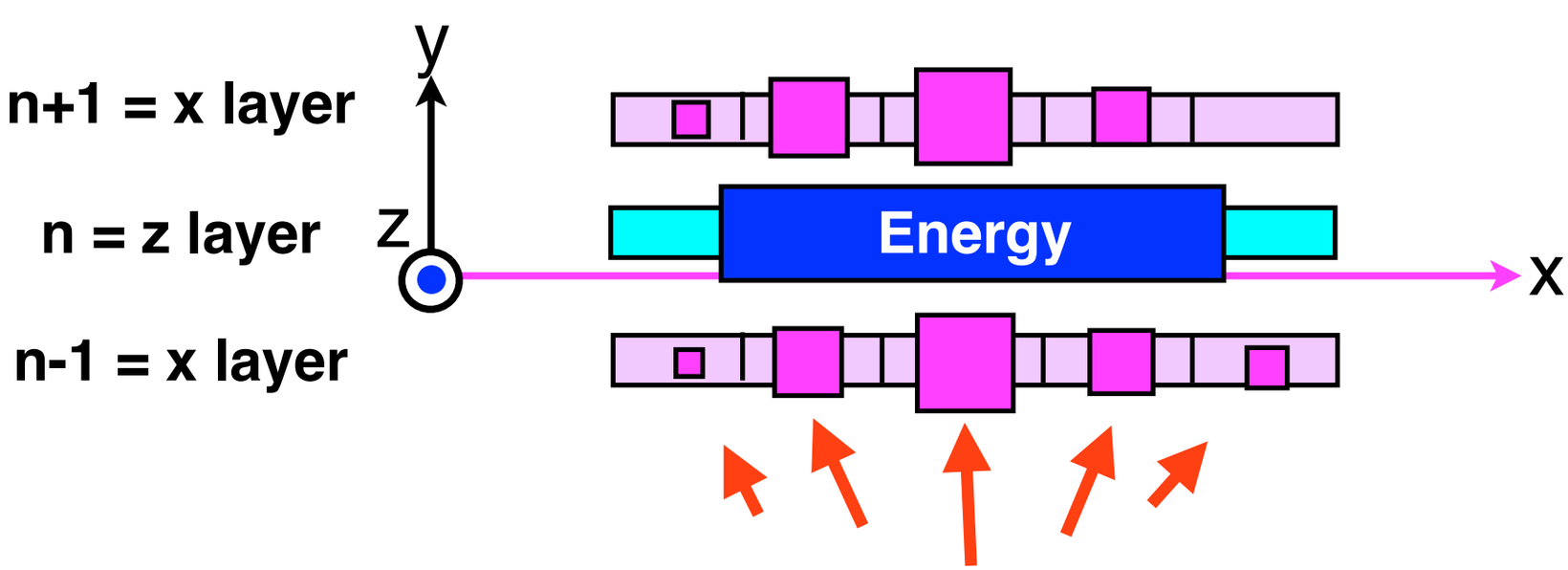

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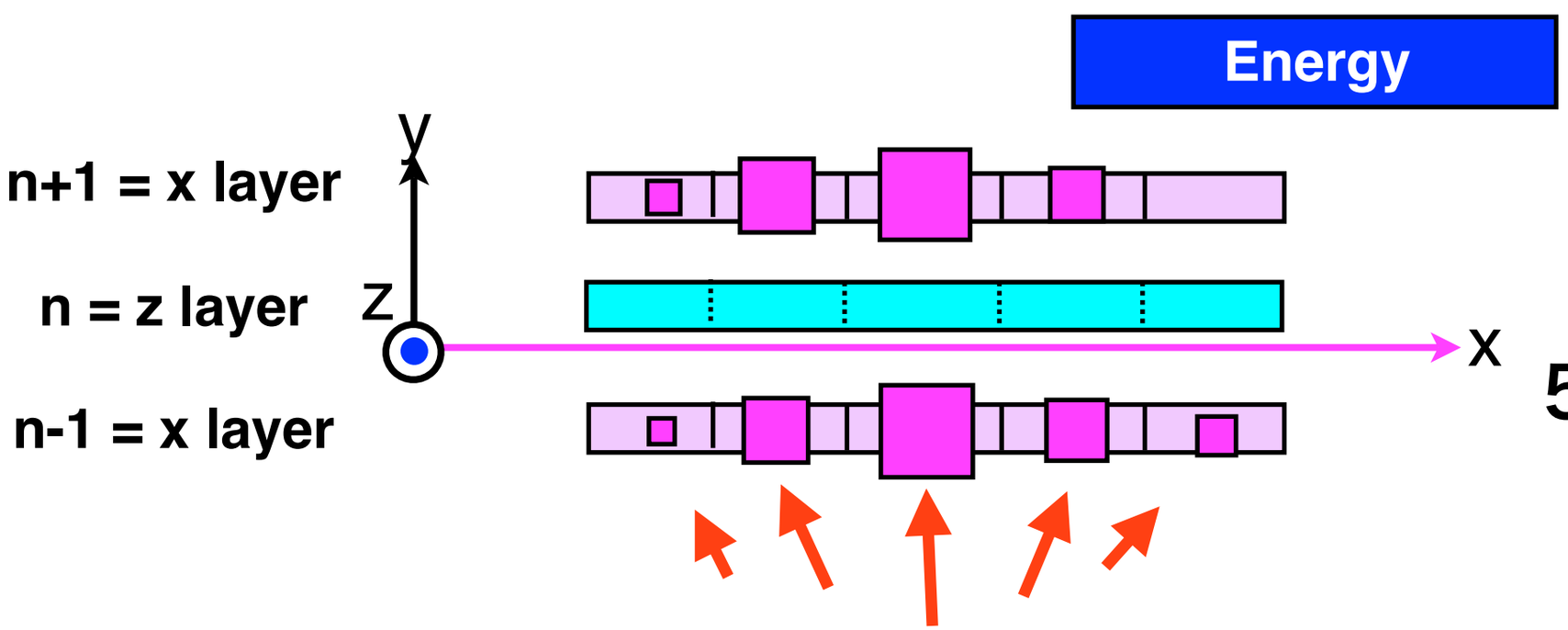

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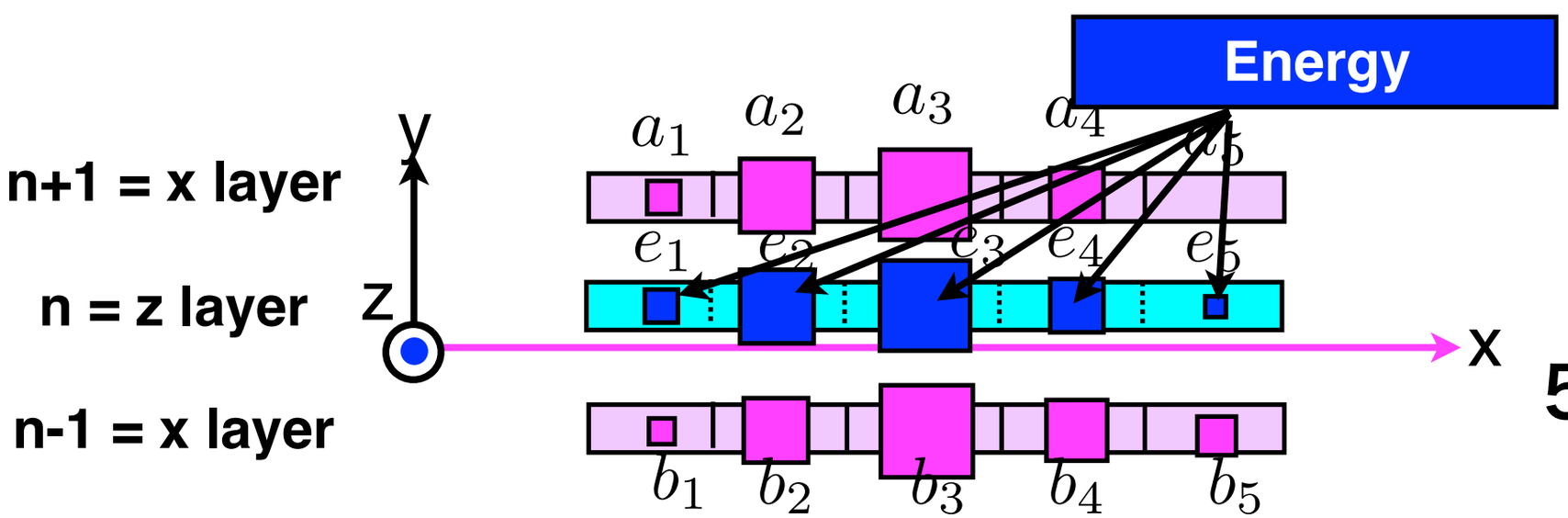

$$e_i = E_{\mathrm{n}} \cdot \frac{a_i + b_i}{\sum a_i + \sum b_i}$$

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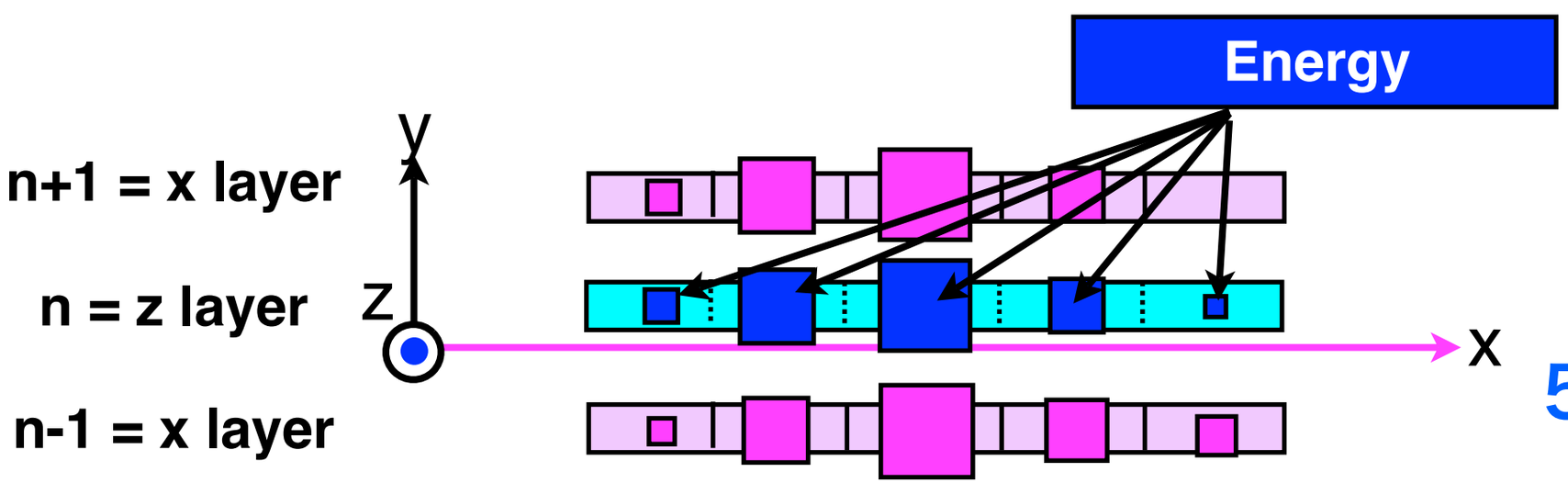
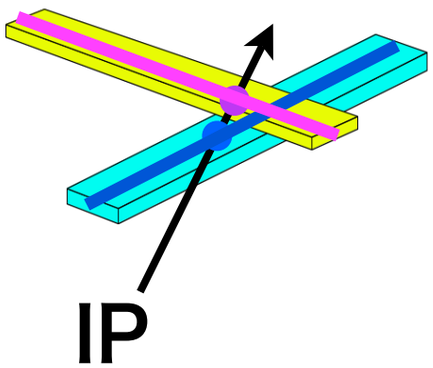


Strip Splitting Algorithm

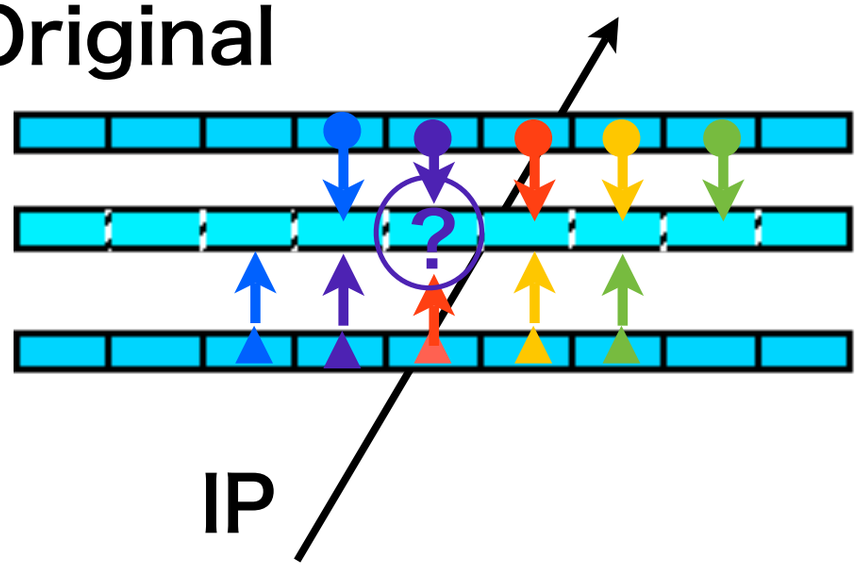
4. energy deposit in n-th layer is distributed in pseudo cells referring adjacent n±1th layer strips.
5. position and energy of pseudo square cells are fed into PandoraPFA.

Current version in MarlinReco takes more elegant way by Daniel Jeans

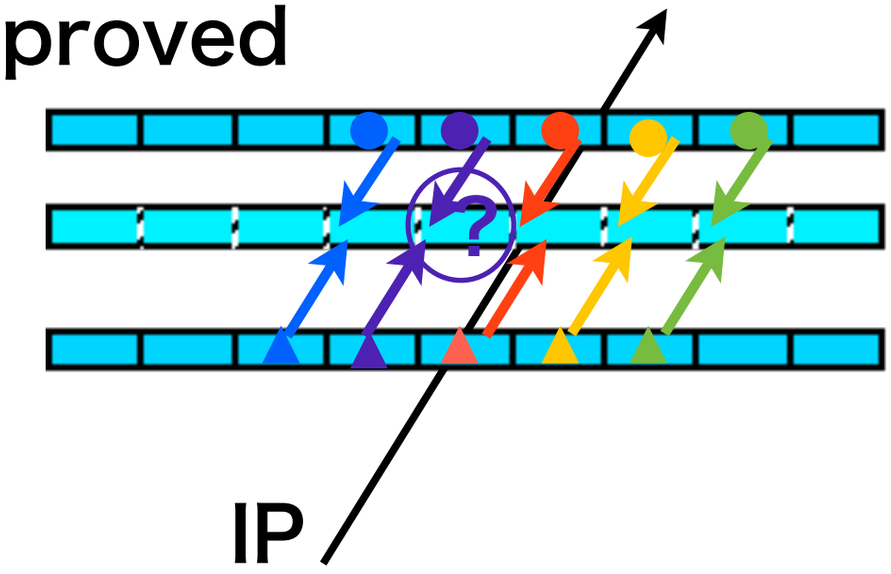


To refer the energy in the nearest neighbor layer, it scans intersection of center lines of respective scintillators toward the IP

Original



Improved

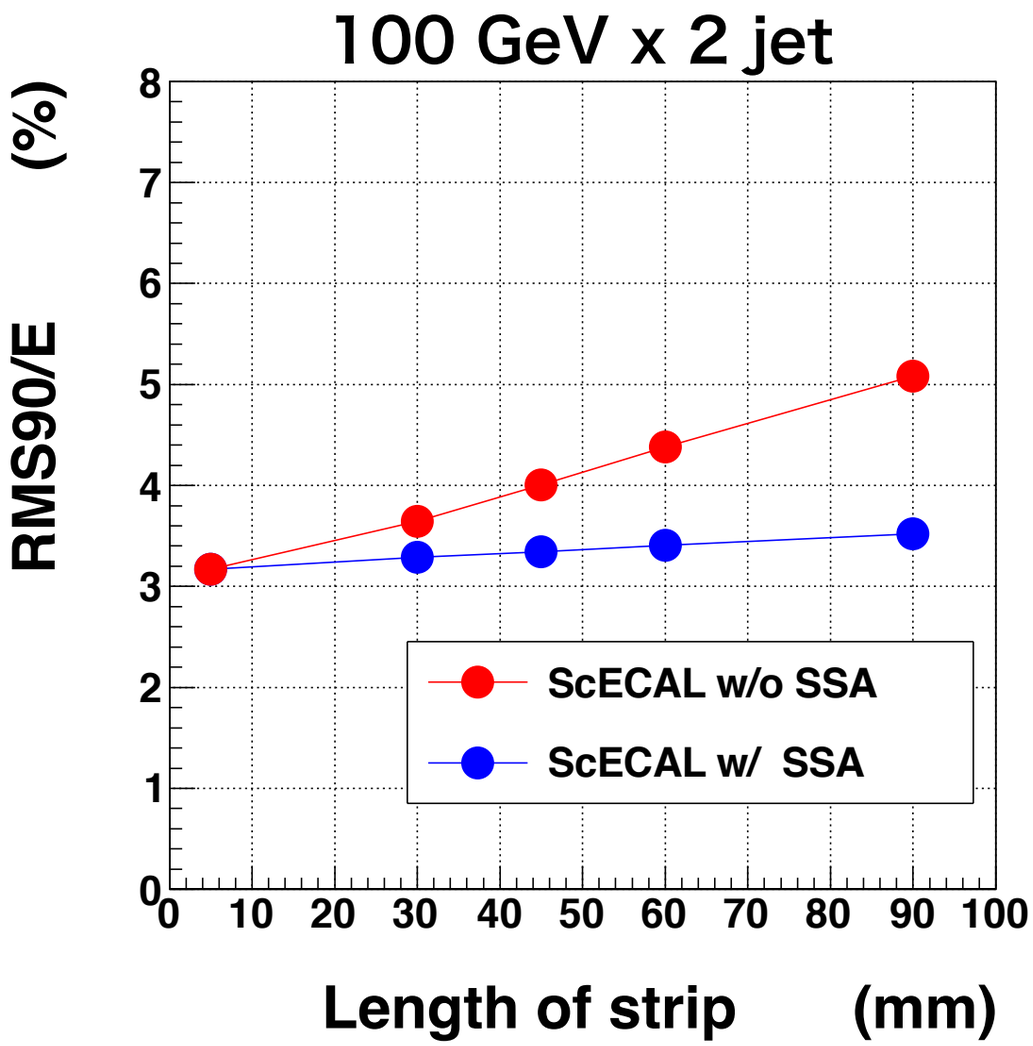


Energy in virtual cell (?) = Energy on this strip × $\frac{(\bullet + \blacktriangle)}{(\blacktriangle + \blacktriangle + \blacktriangle + \blacktriangle + \blacktriangle + \bullet + \bullet + \bullet + \bullet + \bullet)}$

Energy on this strip × $\frac{(\bullet + \blacktriangle)}{(\blacktriangle + \blacktriangle + \blacktriangle + \blacktriangle + \blacktriangle + \bullet + \bullet + \bullet + \bullet + \bullet)}$

uds two Jet Energy Resolution

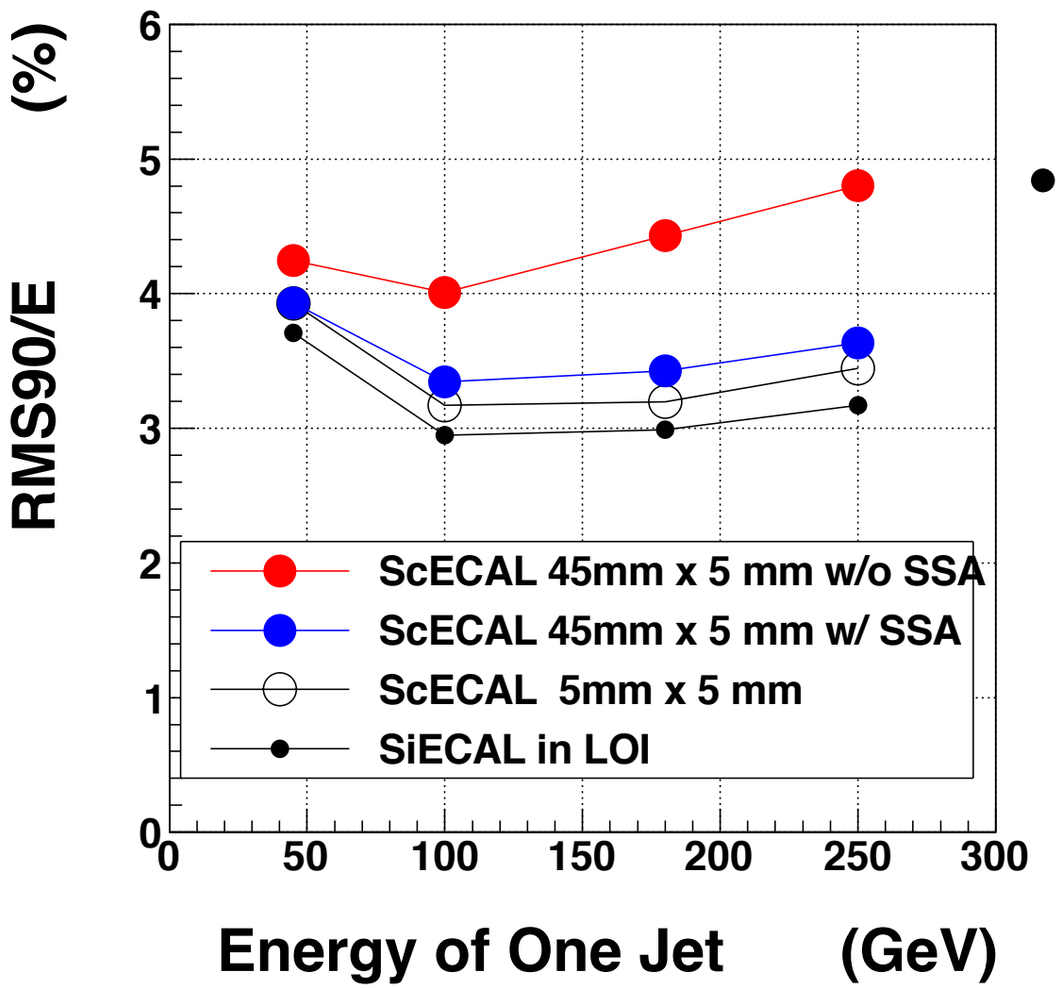
depending on the strip length



- No strong deterioration with increasing the strip length after applying SSA.
- Note that the SSA was tested by using 0.5 mm thick strip scintillators to focus on the performance of SSA. By this, we do not need to concern the tuning of parameters of PandoraPFA by using the same layer structure as SiECAL has.

uds two Jet Energy Resolution

depending on the jet energy



- JER is significantly improved by SSA (● → ●) especially for high energy.
- Comparison between 5 x 5 mm² and 45 x 5 mm² with SSA shows that SSA works well (○ → ●).

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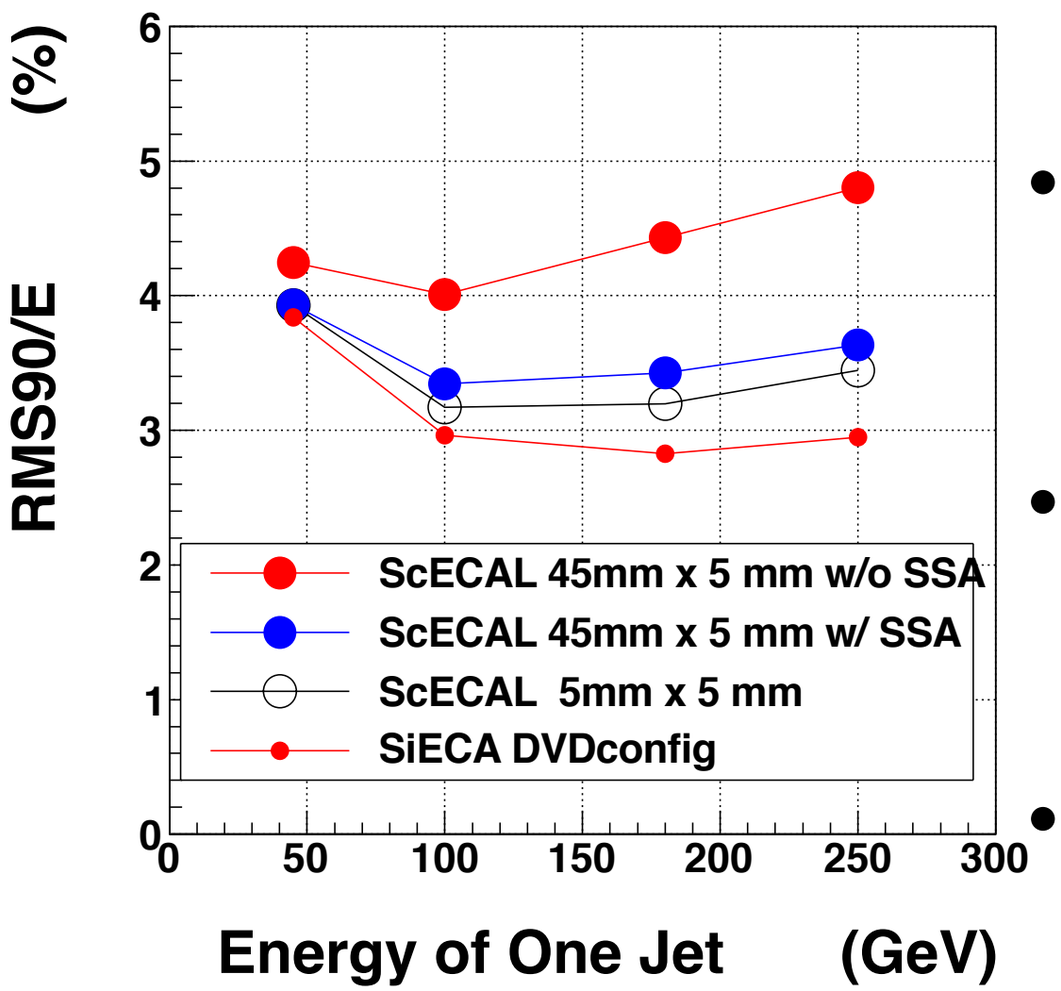
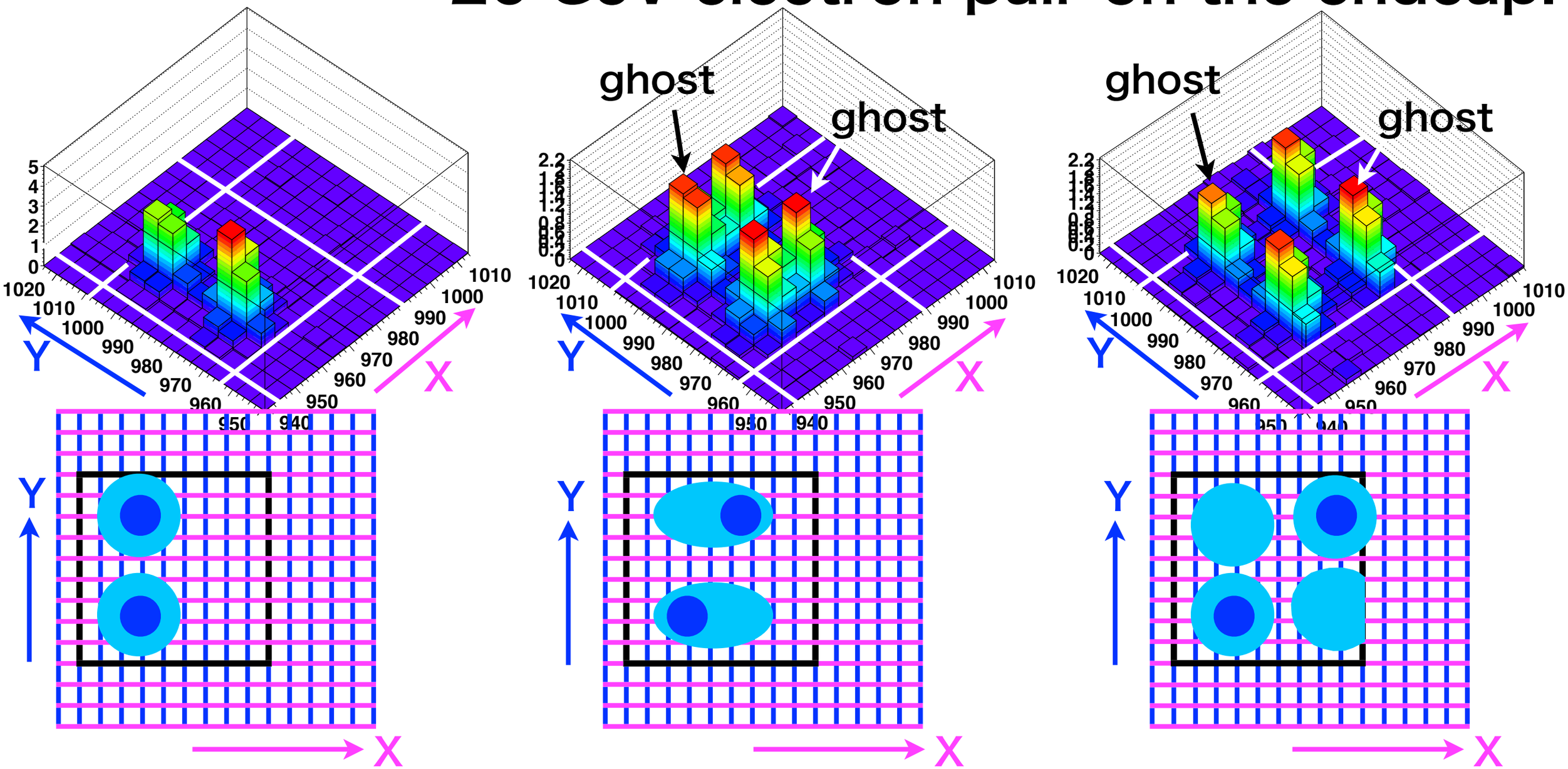
depending on the jet energy



- JER is significantly improved by SSA (● → ●) especially for high energy.
- Comparison between 5 x 5 mm² and 45 x 5 mm² with SSA shows that SSA works well (○ → ●).
- JER by SiECAL with the DBDconfig was improved for high energy Jet (by studying for CLIC?)
- There exist the discrepancy not only between SiECAL and strip ECAL but also between SiECAL and 5 x 5 mm² tile ScECAL (● → ○).➡We need special tune for Scintillator ECAL.

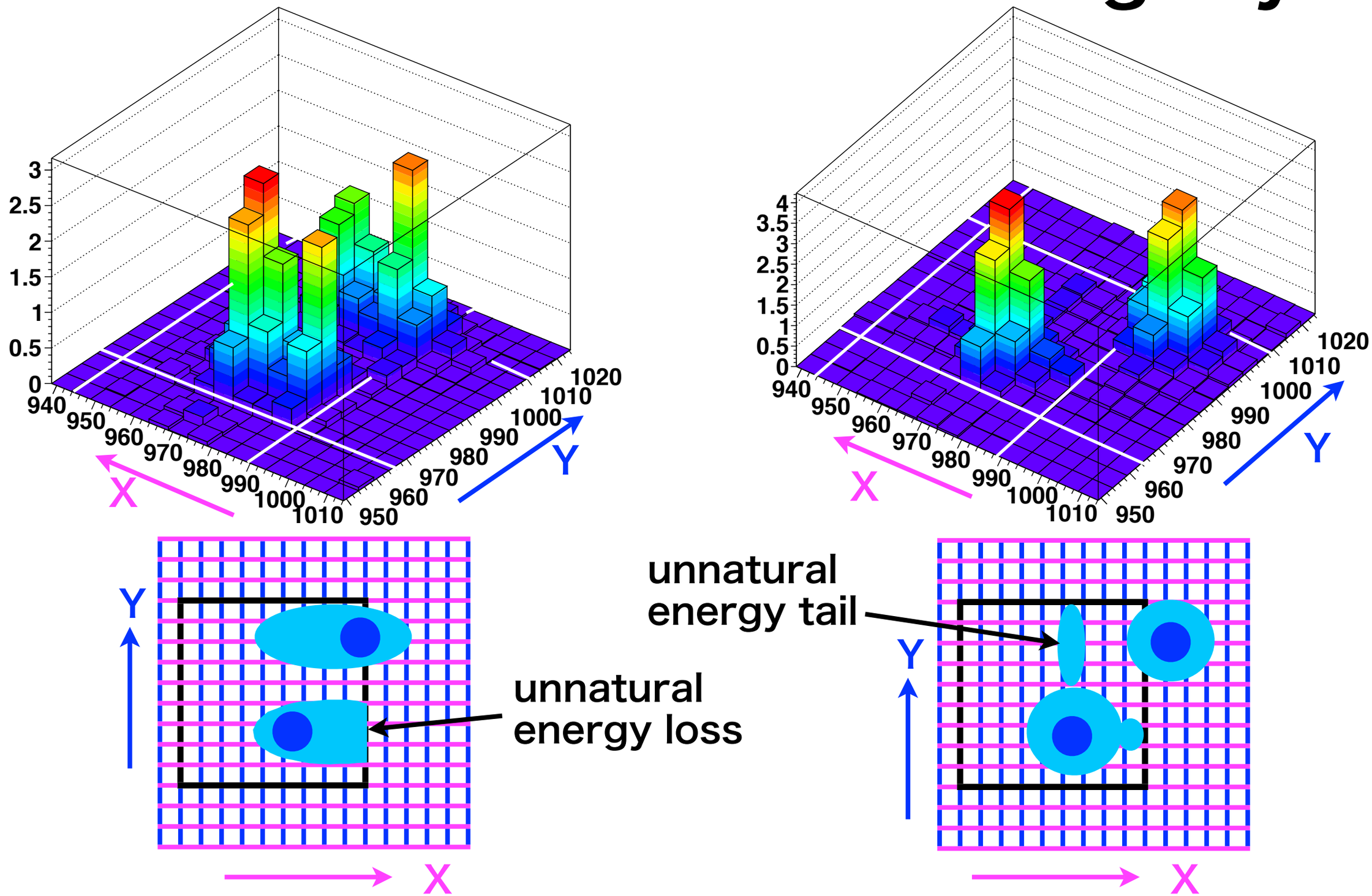
Separation of two electrons

20 GeV electron pair on the endcap.



1. Shapes of two clusters simultaneously exist in a 45 mm x 45 mm square area are always strained and typical case makes two ghost clusters.
2. For electrons we can use track info. to resolve this.

Pattern recognition might help us resolve the two-fold ambiguity



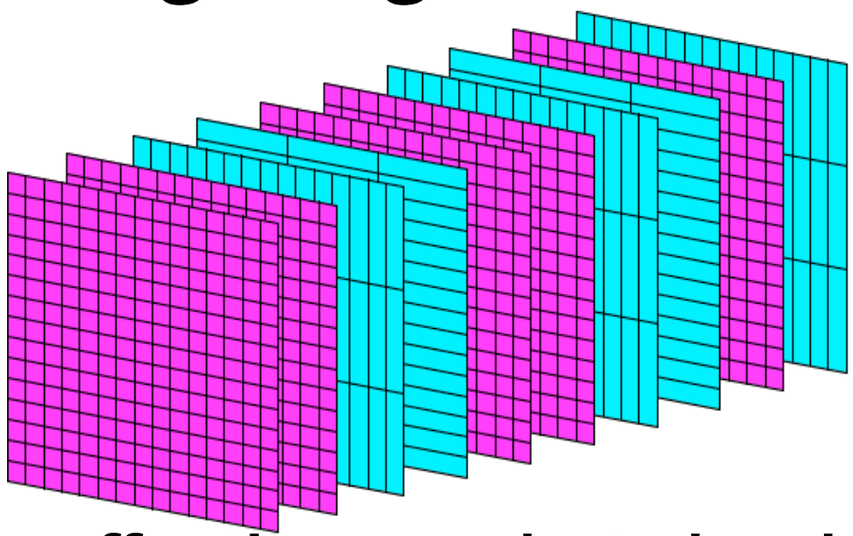
pattern analysis might improve to reduce ghosts.

ScECAL and SiECAL ... hybrid ECAL

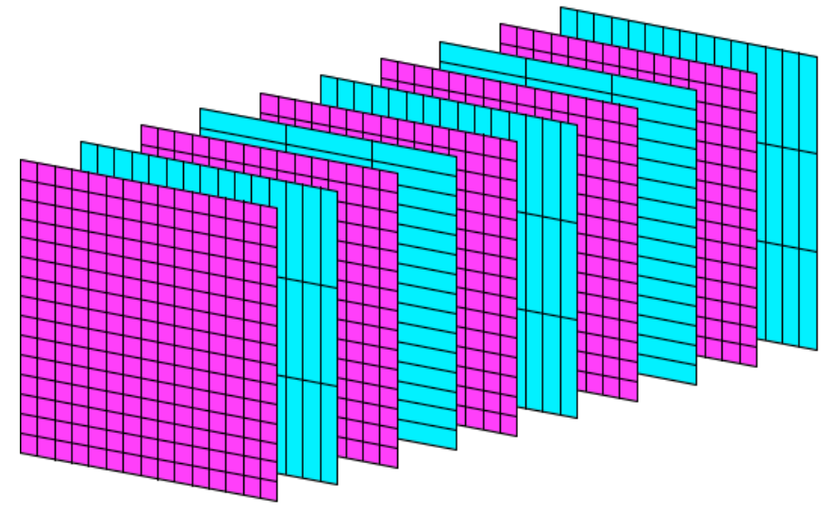
When ratio of Sc layer ↑, Cost ↓.

Type I :

giving weight to resolve the ghost (two hold ambiguity)



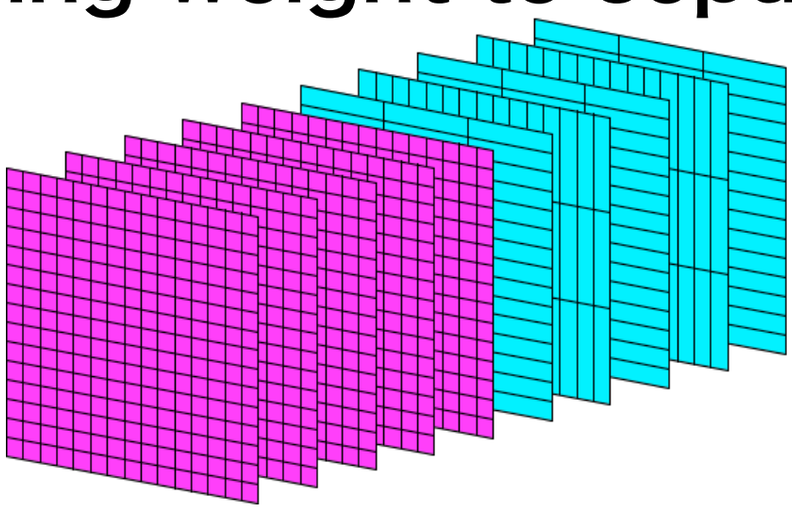
Not so effective way, but alveolar structure (pairs of Si or Sc) allows this way easily to implement into Mokka.



Recently, Daniel Jeans has implemented this type of hybrid in Mokka, and started to study on this.

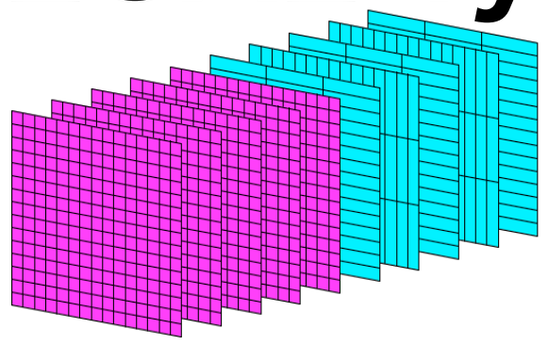
Type II :

giving weight to separation of clusters in inner layers

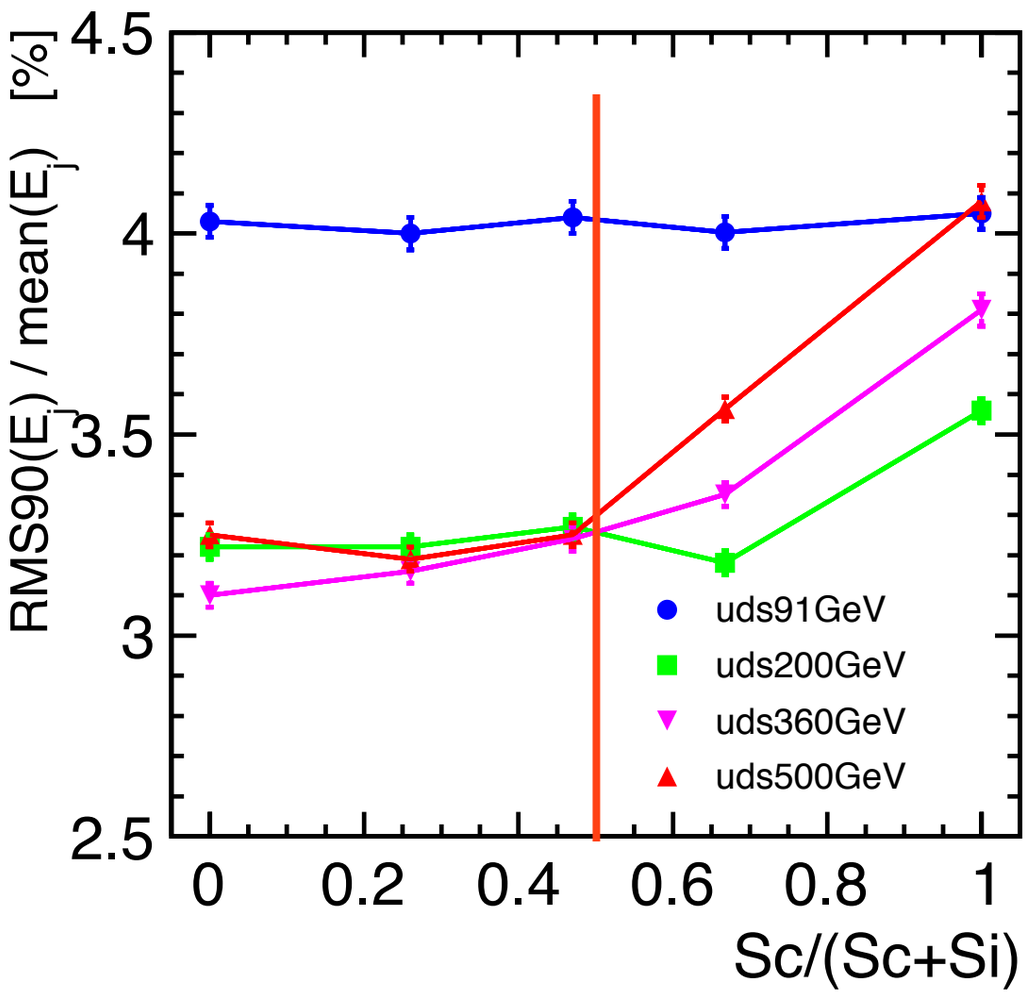


Hiraku Ueno studied on this type of hybrid ECAL varying the ratio of Si layers and Sc layers.

hybrid ECAL Type II



by Hiraku Ueno



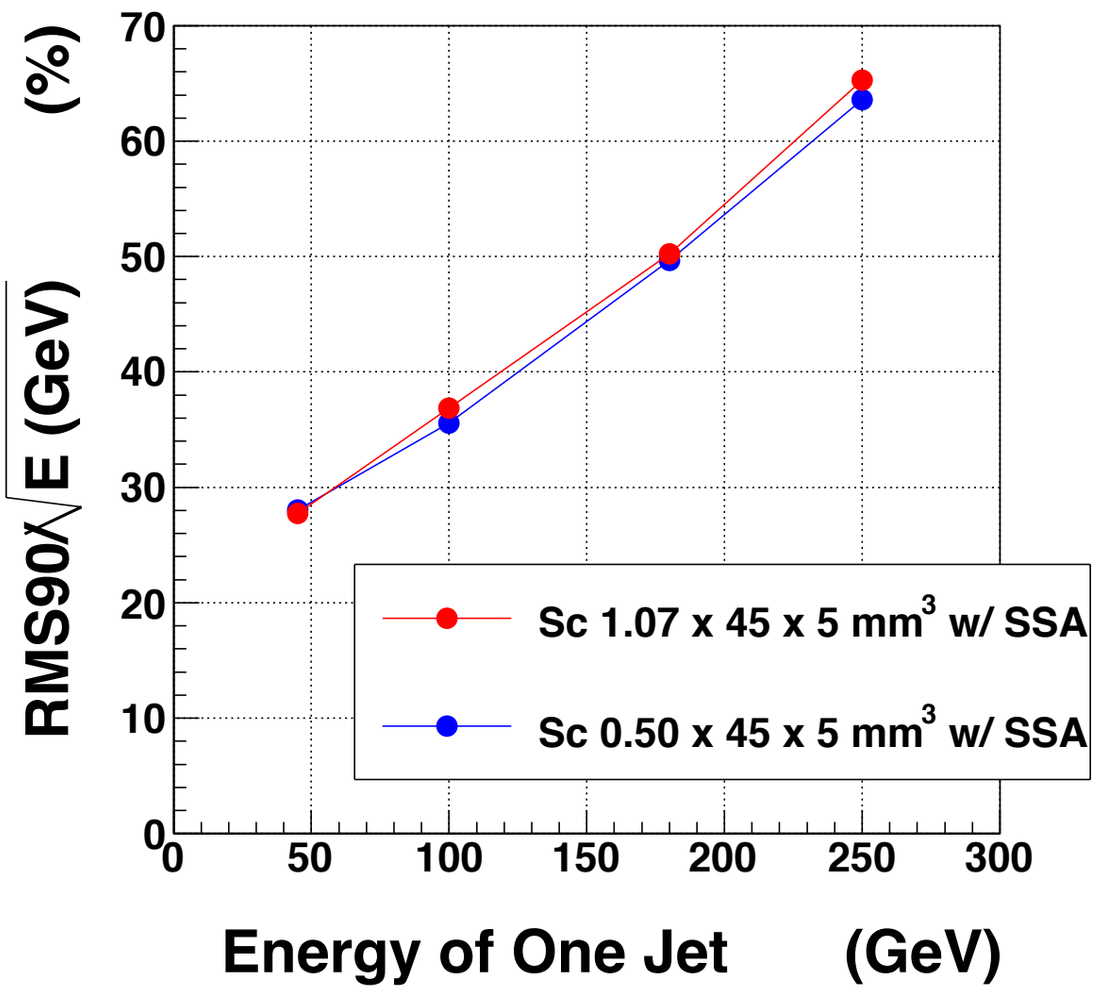
- Up to 50 % of Sc layer ratio, Hybrid ECAL has the same JER as the pure SiECAL has.
- Note that the total number of layers is always set to be 28 to avoid effect of difference of the total number of layers. Therefore, the resolution is not best case for each conditions of layer ratio.

Summary

1. We are developing a scintillator strip ECAL for future linear colliders with scintillator strips and PPD (MPPC).
2. Mechanical structure is almost the same as SiECAL.
3. Nice energy resolution for single particles is demonstrated with test beam experiments.
4. Special algorithm, Strip Splitting Algorithm to extract 5 x 5 mm^2 cell segmentation from 45 mm strip is established.
5. We need to tune PandoraPFA parameters to get good JER of high energy jets for the scintillator ECAL.
6. Multiple incident particles in 45 x 45 mm^2 area make strain of cluster shapes or ghost clusters.
7. We are trying to make pattern recognition analyses.
8. Hybrid ECAL with SiECAL is studied to get better energy resolution especially for high energy jet.
9. Up to 50% of Sc layer ratio does not degrade the JER.

Back up

1 mm thick scintillator



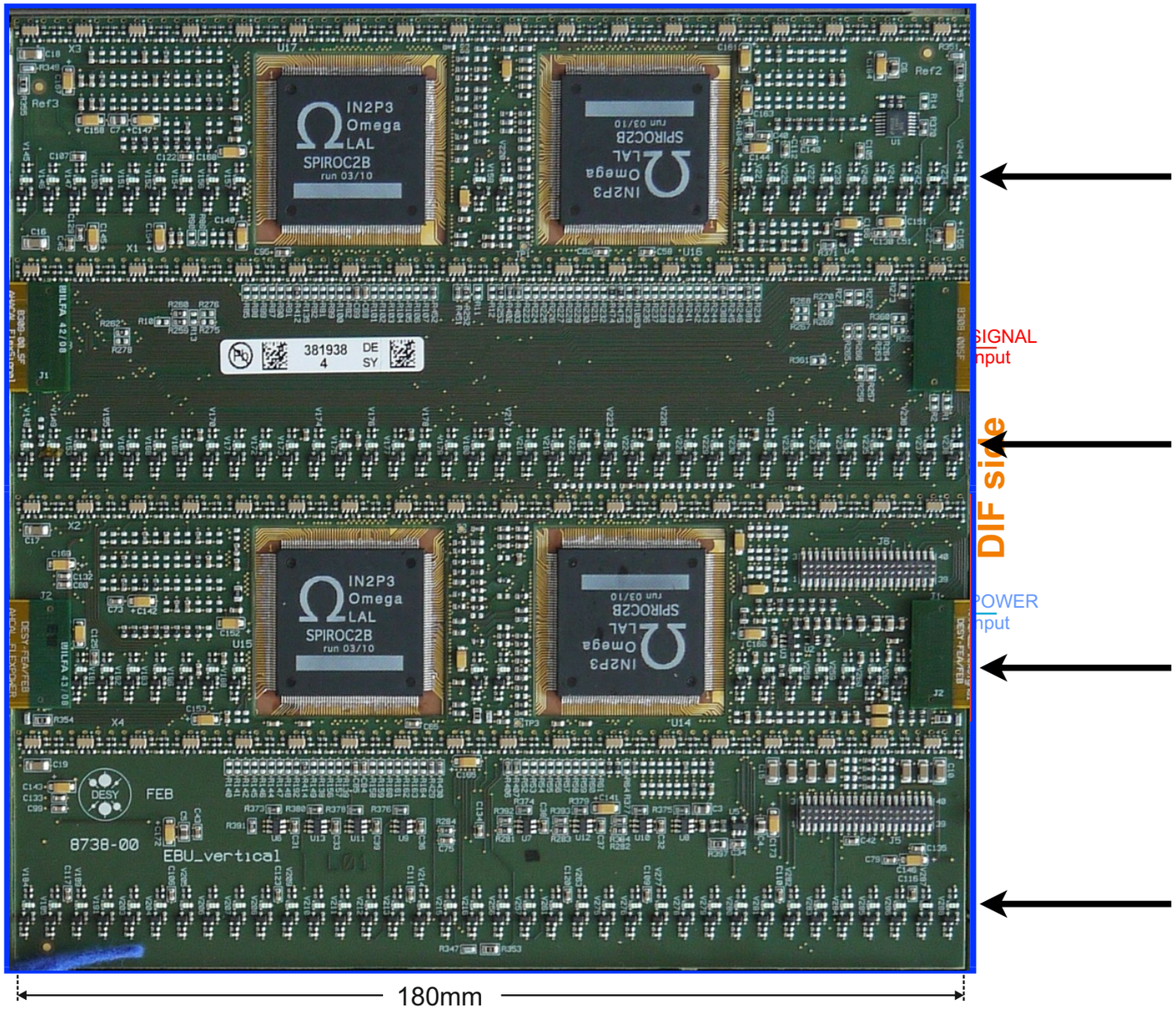
This study was done by using v0-09-02.

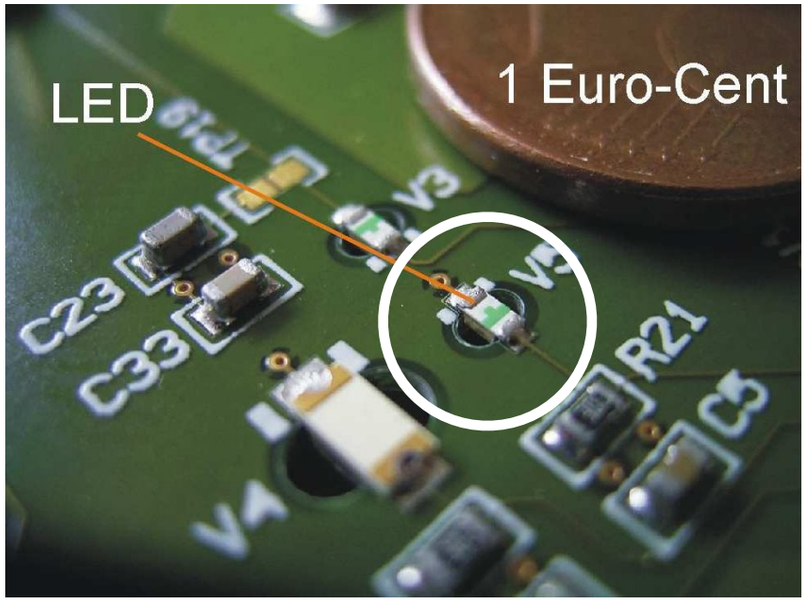
- To make 0.5 mm thick scintillator strip ECAL is difficult with current technology.

Therefore;

- 1(.07) mm thick scintillator has been tested in Mokka-Marlin.
- JER with 1 mm thick scintillator is comparable with 0.5 mm sc.
- Total module thickness of Ecal becomes only 1.5 cm greater than default Si ECAL of 18.5 cm.

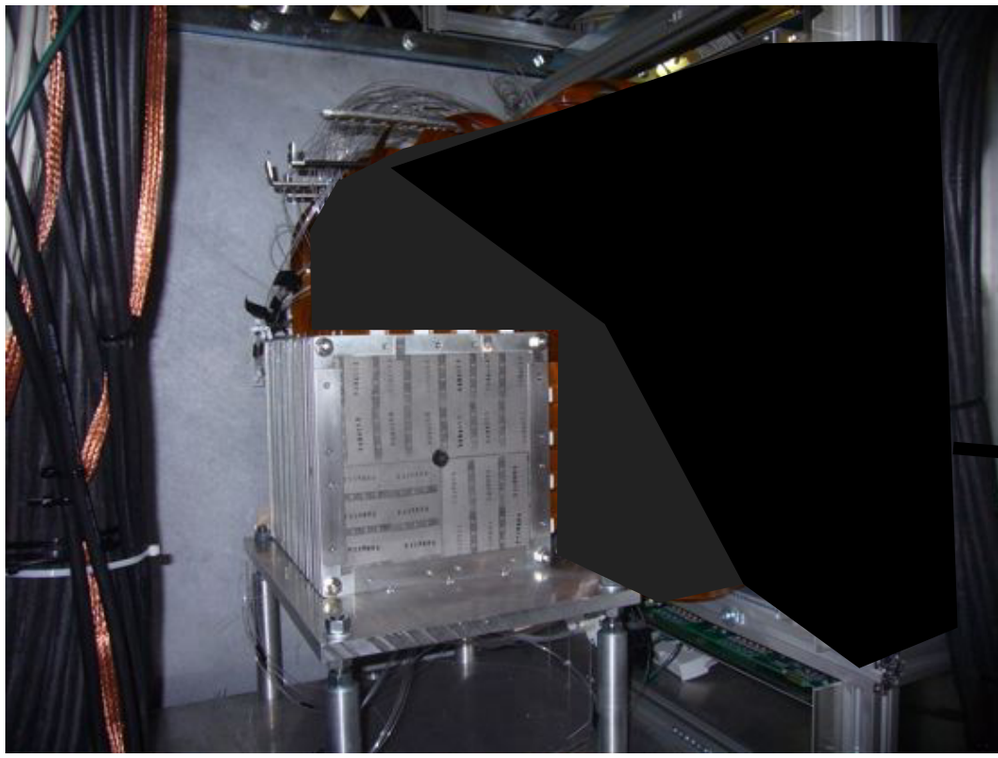
LED lights for gain monitoring



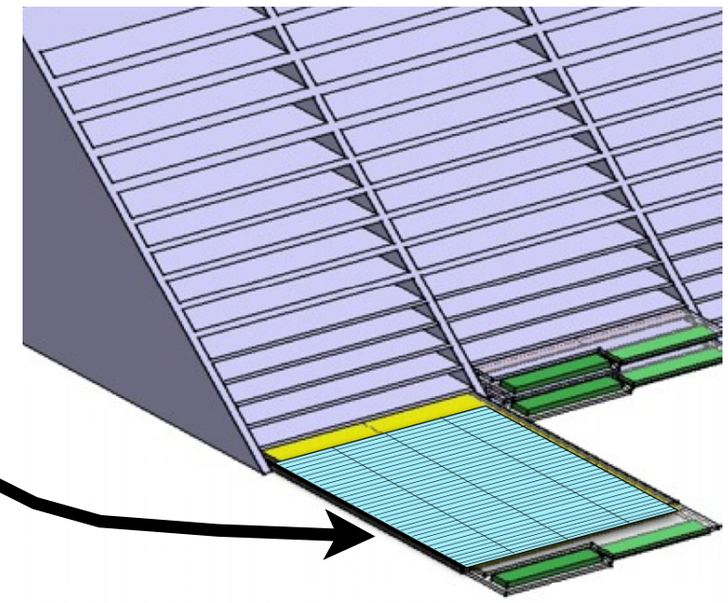


EBU has LEDs for each channel

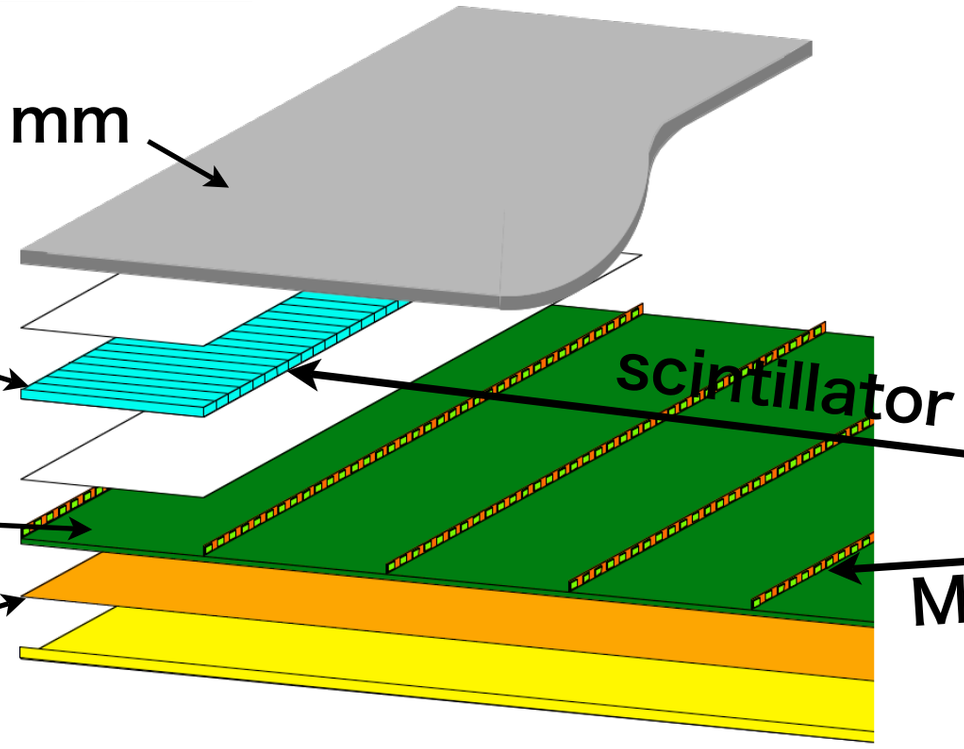
Purpose of technological ScECAL

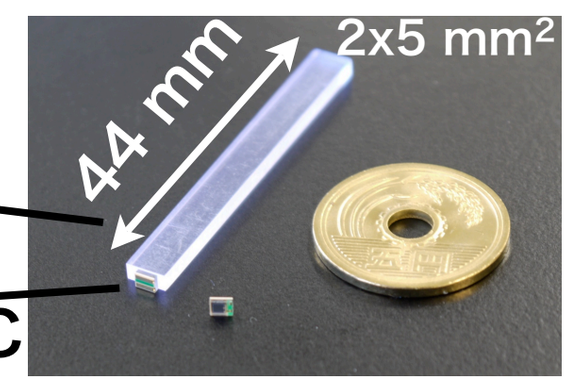


Electronics should be put in between sensor layers for ILD



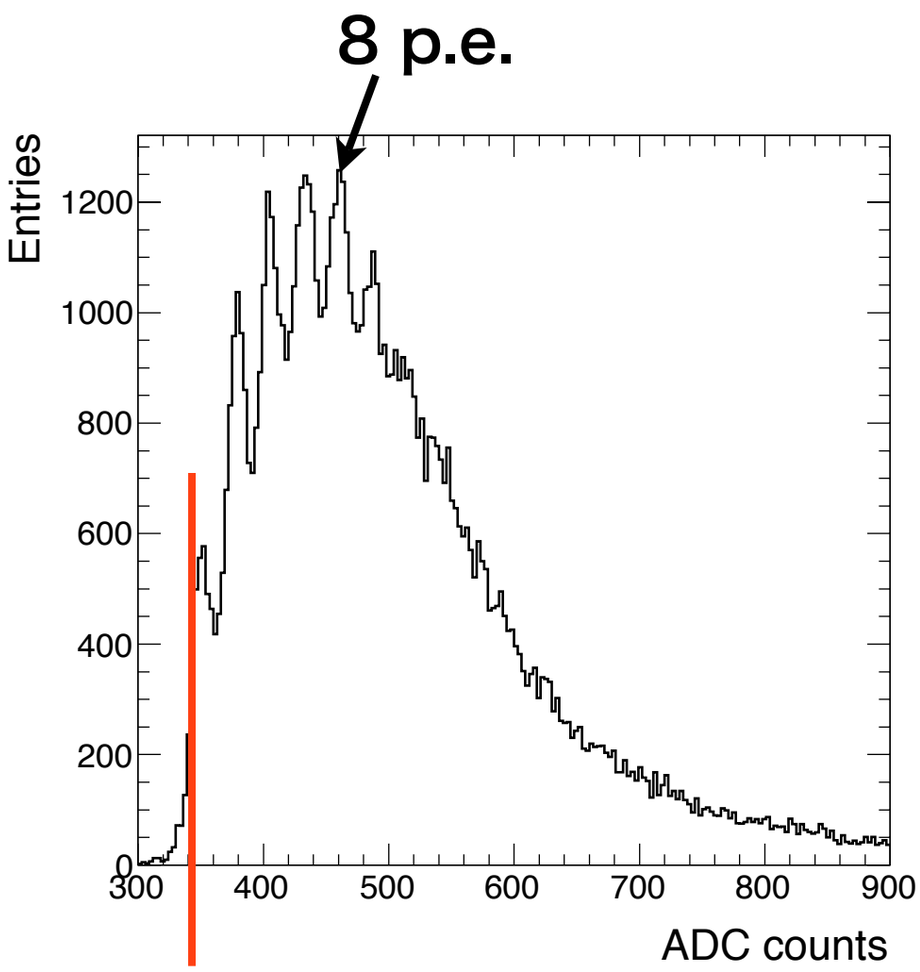
this carton is not true because electronics should cover the sensor





To Show how the technology works well

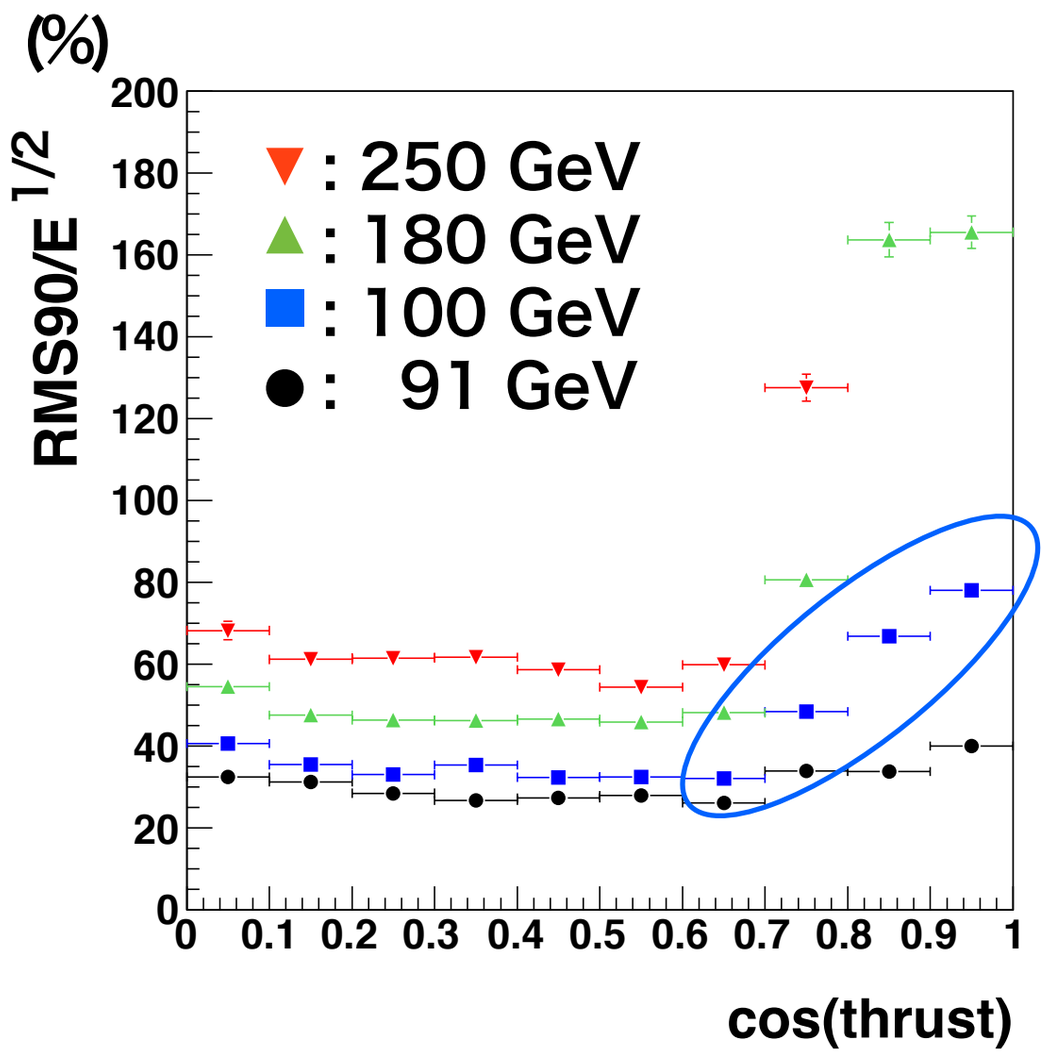
MIP energy deposit

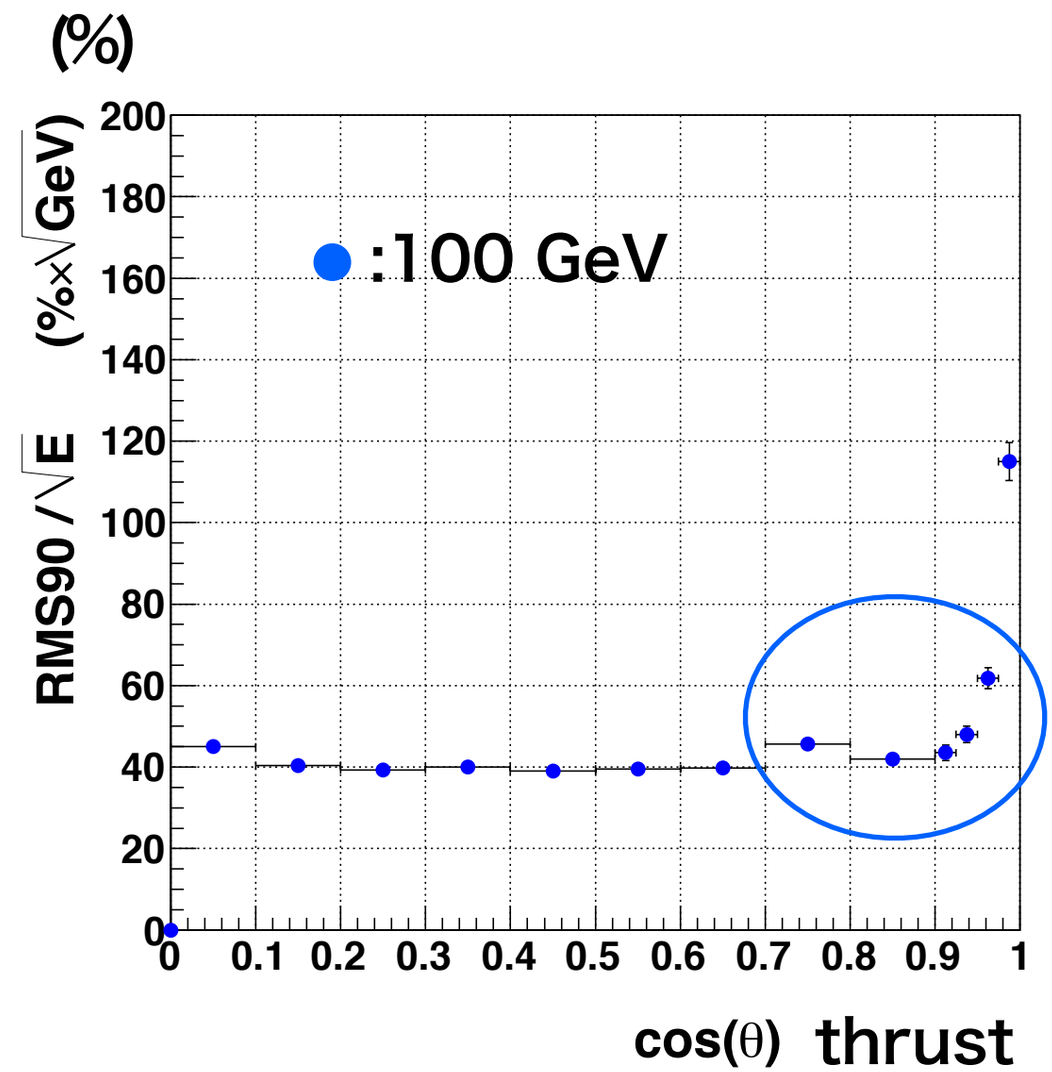


0.5 mip threshold

Energy deposit of mip events on a channel. Clear p.e. peaks can be seen

Endcap problem of strip ECAL (ILD meeting in Kyushu)

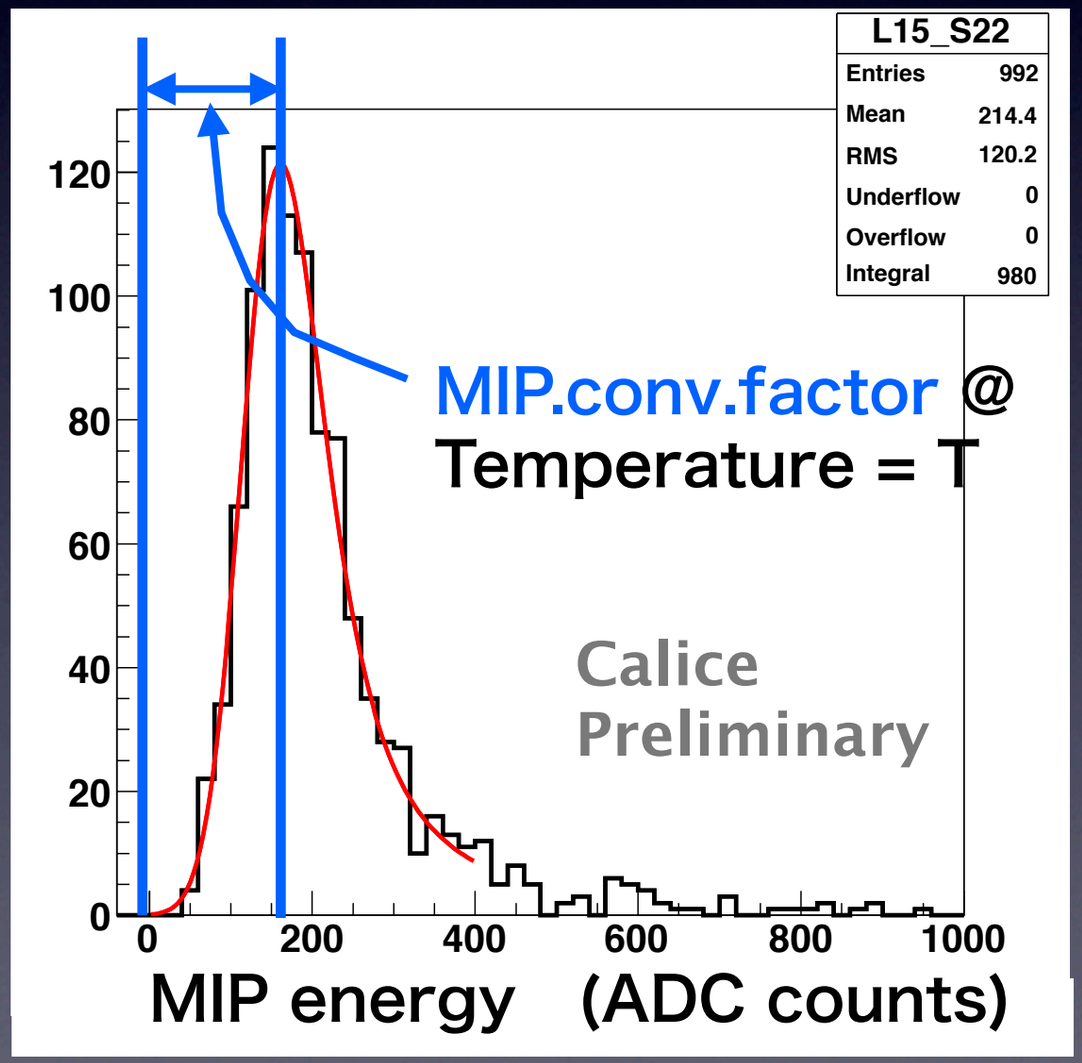


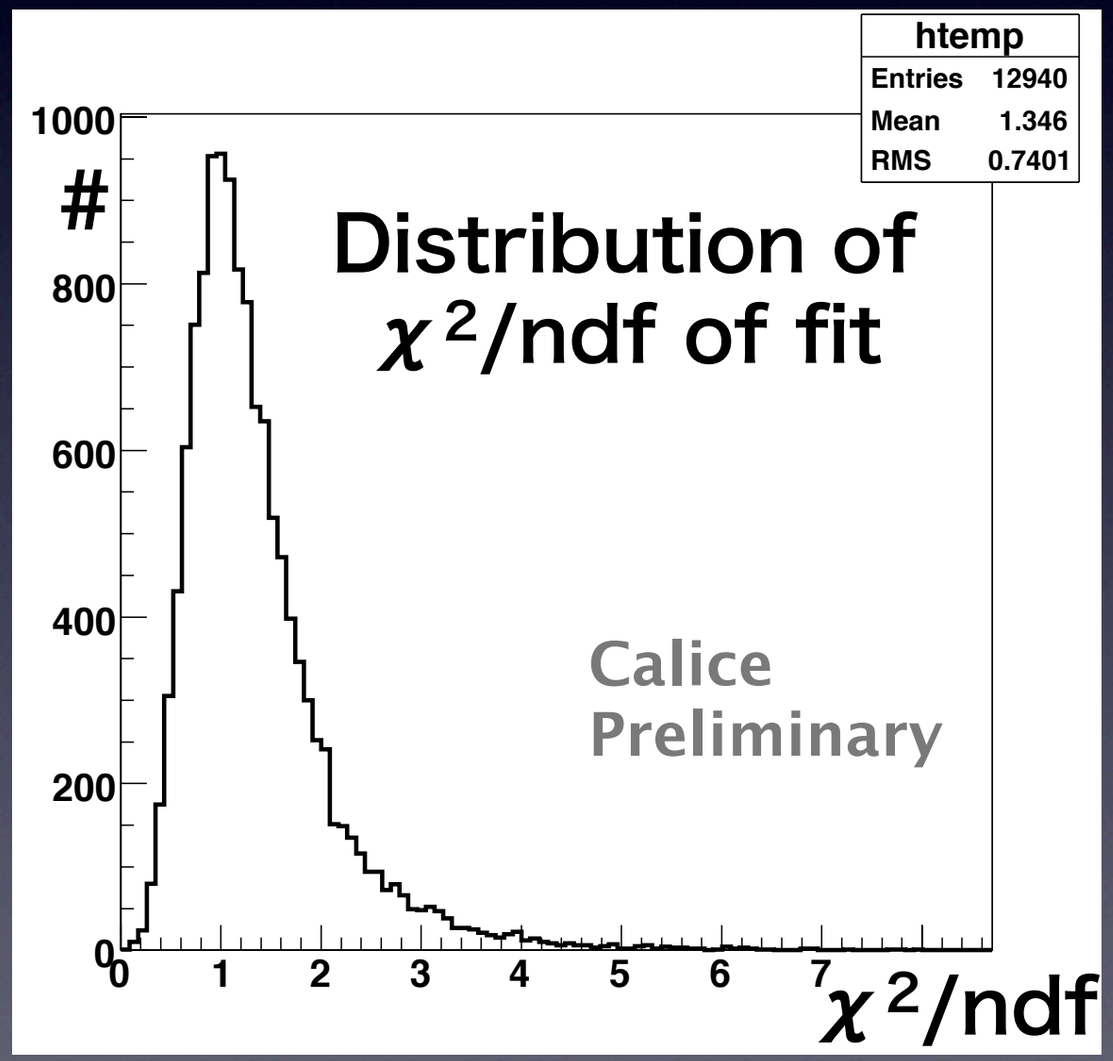


prevent the longitudinal gap correction

ADC/MIP.conv.factor

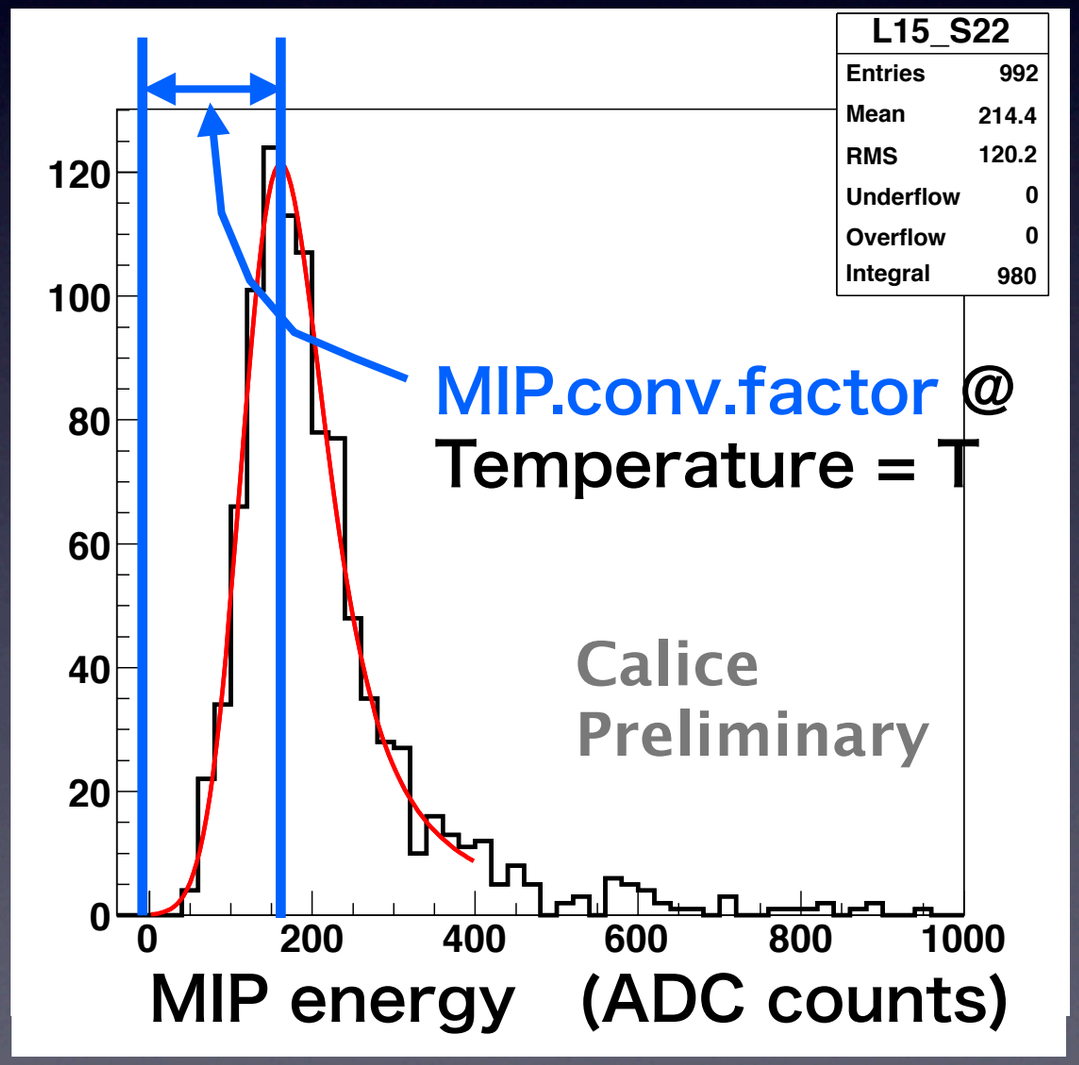
- To calibrate each channel, muon beams are used,
- ADC/MIP.conv.factor = “ADC counts”/“MIP”,

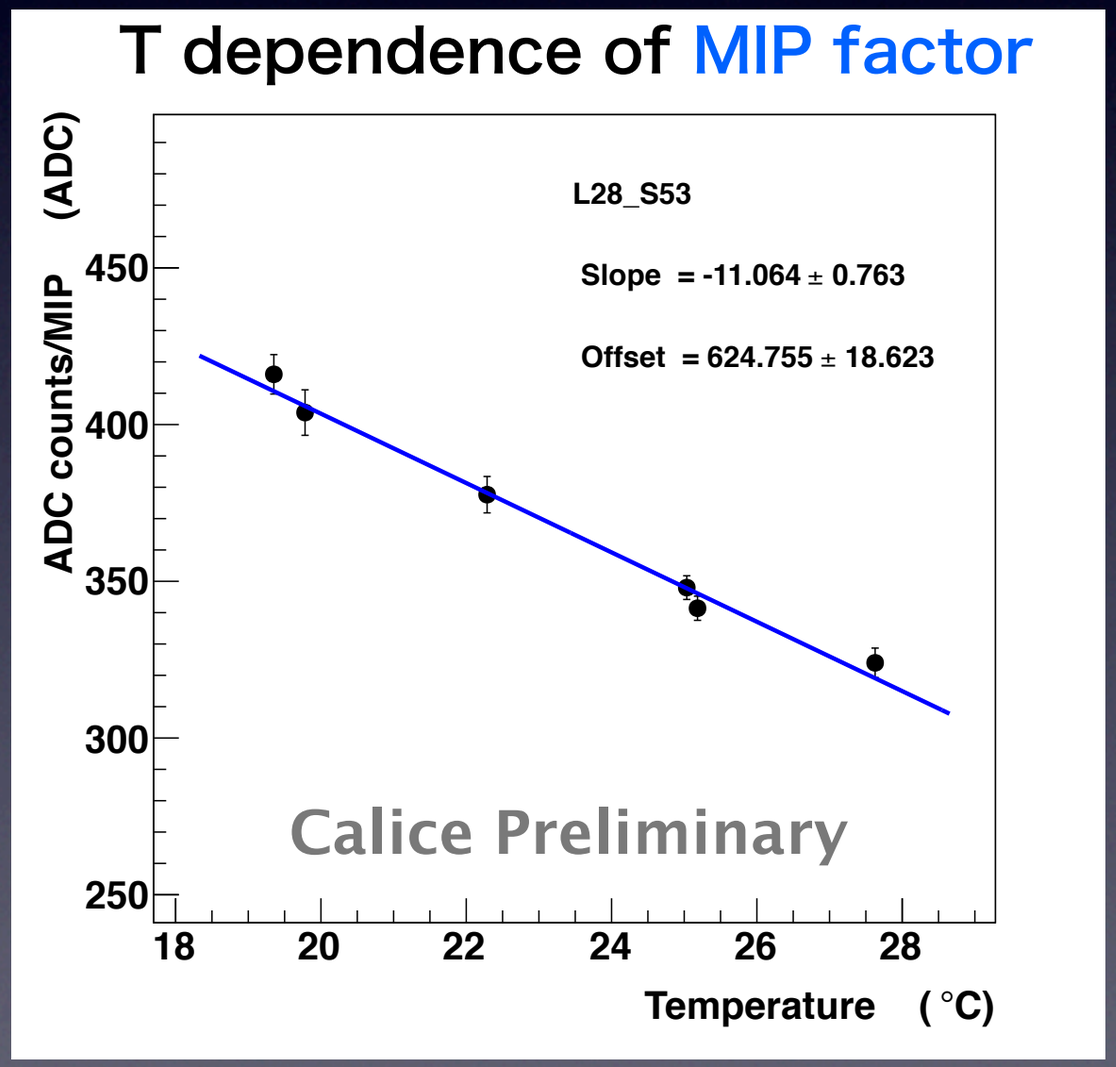




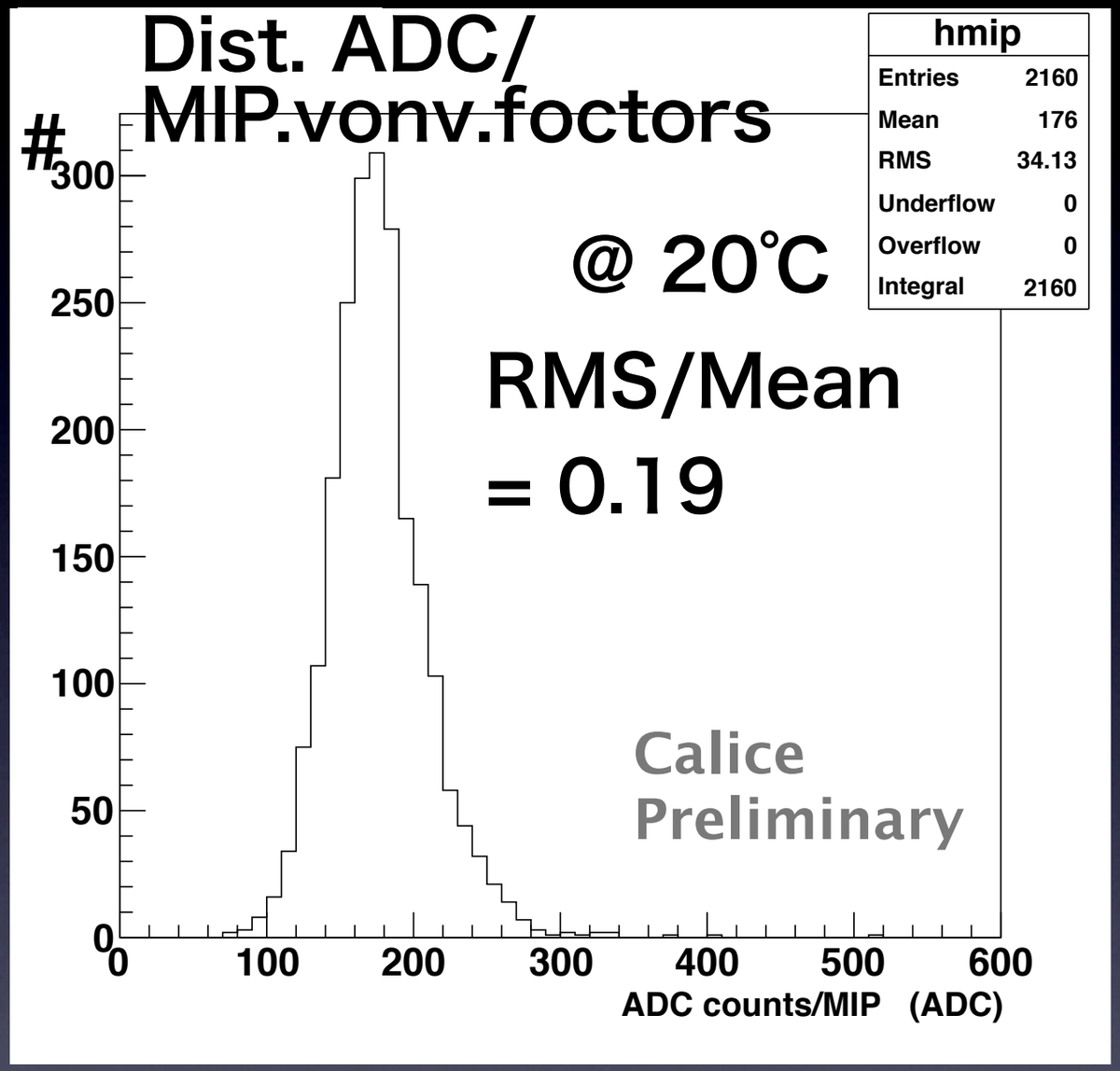
ADC/MIP.conv.factor

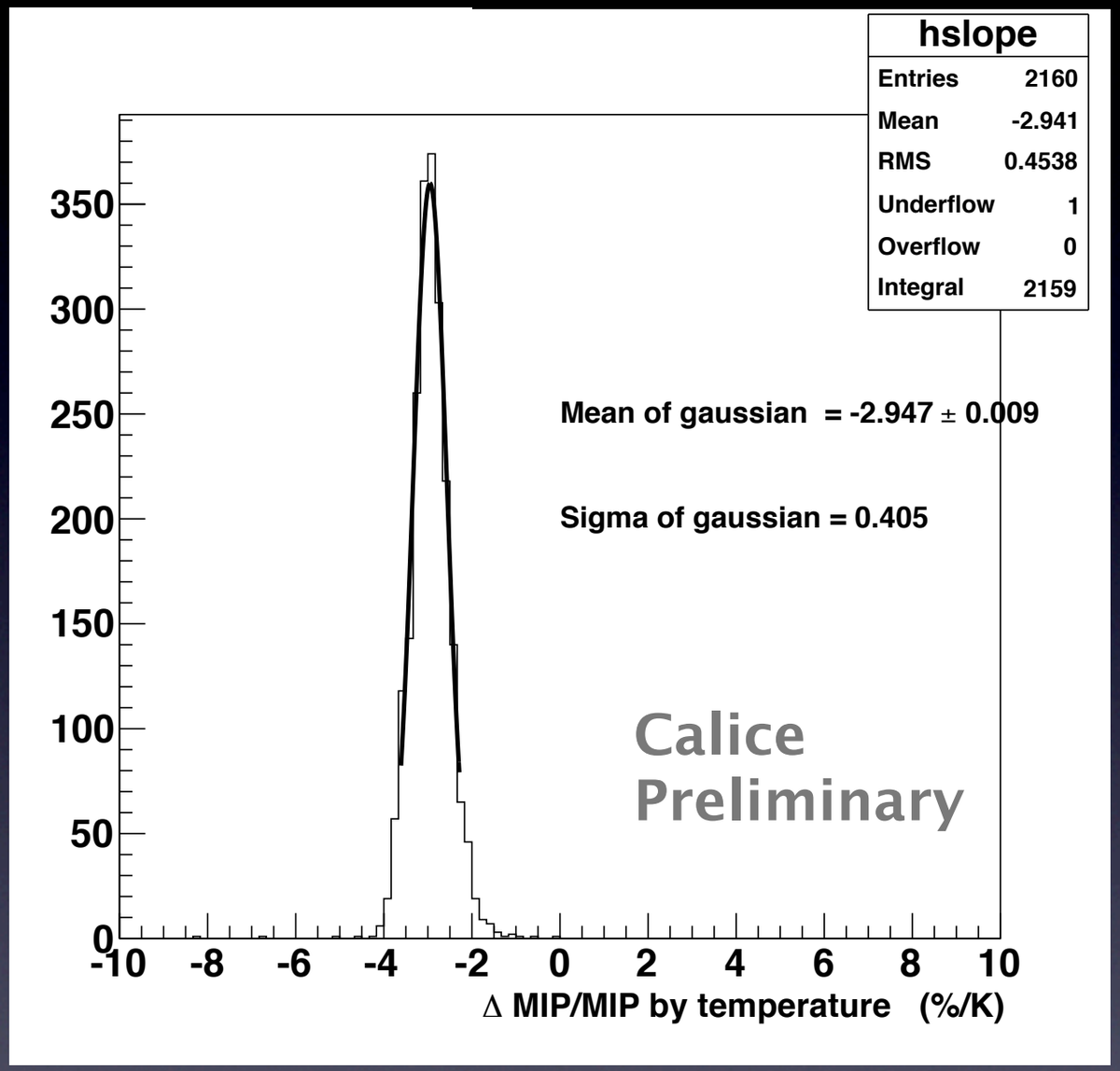
- To calibrate each channel, muon beams are used,
- ADC/MIP.conv.factor = “ADC counts”/“MIP”,
- Temperature dependence of ADC/MIP.conv.factor is the same as the energy deposition by other particles,





Distribution of ADC/MIP.conv.factors and slopes





- Variation of ADC/MIP.conv.factor is 19%, ▶ This comes from Scintillator WLS fiber system (variations of scintillator quality, MPPC fiber miss matching and so on.) ∵ Variation of MPPC gains is less than a few%
- except 3 channels(noisy), slopes of ADC/MIP conversion factor of 2157 channels are in this narrow distribution