On behalf of CALICE

Fine Segmented Scintillator ECAL

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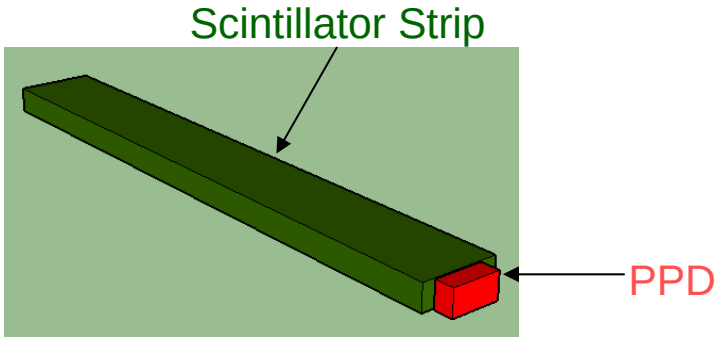
Introduction

- Fine Segmented Scintillator ECAL: Plastic scintillator strips and pixelated photon detector (PPD).
- Layers of scintillator strips are arranged orthogonally, and by using the Strip Split Algorithm (SSA), ScECAL can achieve a granularity that is equal to the width of the strip.
- Currently, the Fine Segmented Scintillator ECAL is being developed for the ILD by CALICE activity (Detector for ILC).
- Event construction at the ILD uses the Particle Flow Algorithm (PFA) requires the ECAL to have 5mm x 5mm lateral granularity.
- Normal method, total of $\sim 10^8$ channels are required for 5mm x 5mm granularity. By applying the strip method, we can reduce the number of channels to $\sim 10^7$ channels
- We need a very simple and robust design.

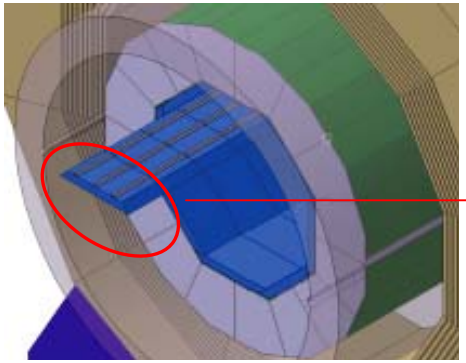
ScECAL

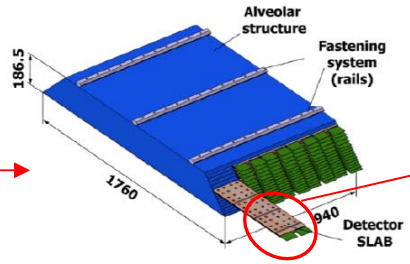
- Particles passing through the scintillator strips produce scintillation light, which are picked up by the PPD.
- Plastic scintillator strips: Simple, robust and low cost, and can be made into various shape easily.
- PPD: Currently using Multi-Pixel Photon Counter (MPPC), which is developed by Shinshu University and Hamamatsu Photonics.
- MPPC Pros: Small package, high gain($10^{5\sim7}$),stable in magnetic field, low operating voltage etc.
- A lot of improvements in MPPC in the past few years. The latest MPPC design features 10,000pixels in an area of 1mm x 1mm.



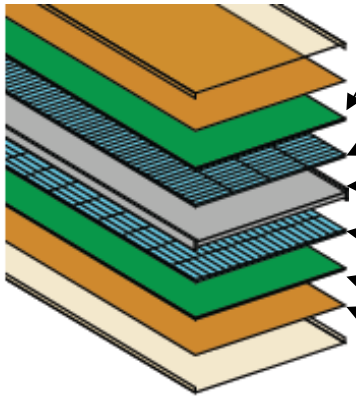
ScECAL in the ILD

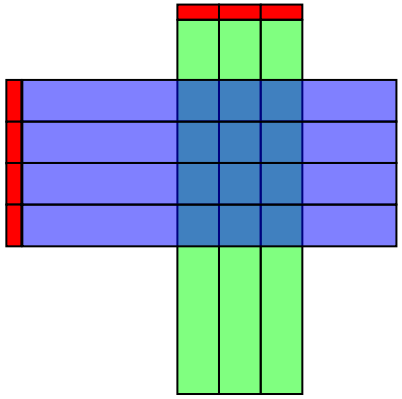
- Mechanical design of the ECALmodule has equally distanced space for the insertion of the detector system (Alveolar structure).
- The Alveolar structure, which is developed for silicon-ECAL(LLR&Orsay), has tungsten plate absorbers.
- Readout electronics are integrated into the detector slab.
- For ScECAL, scintillator layers are placed orthogonally into the alveolar structure together with another tungsten absorber layer.
- By applying the Strip Split Algorithm (SSA), an effective granularity very near to the required 5mm x 5mm can be achieved.





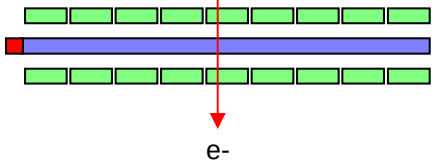
Alveolar Structure





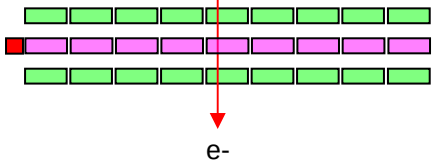
Top View

Blue: 45mm strip



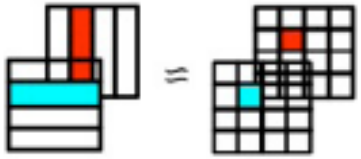
+ SSA =

Purple: 5mm x 9 virtual cell

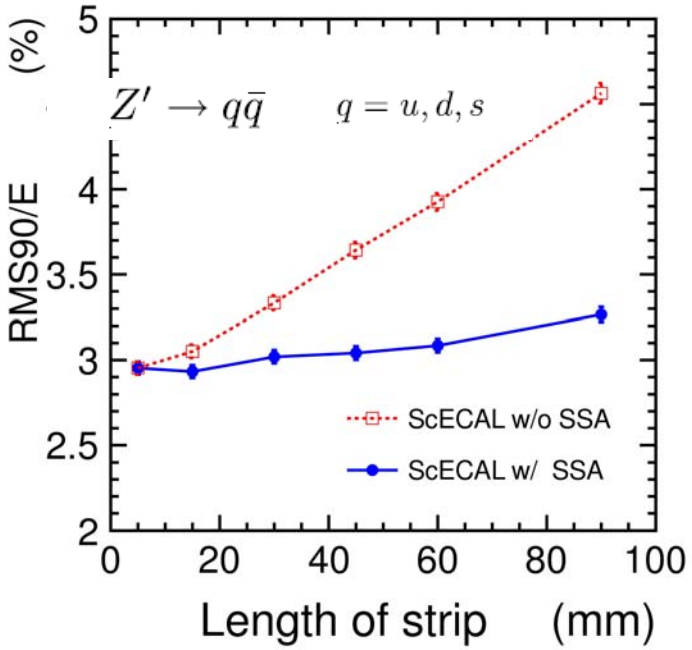


Side View

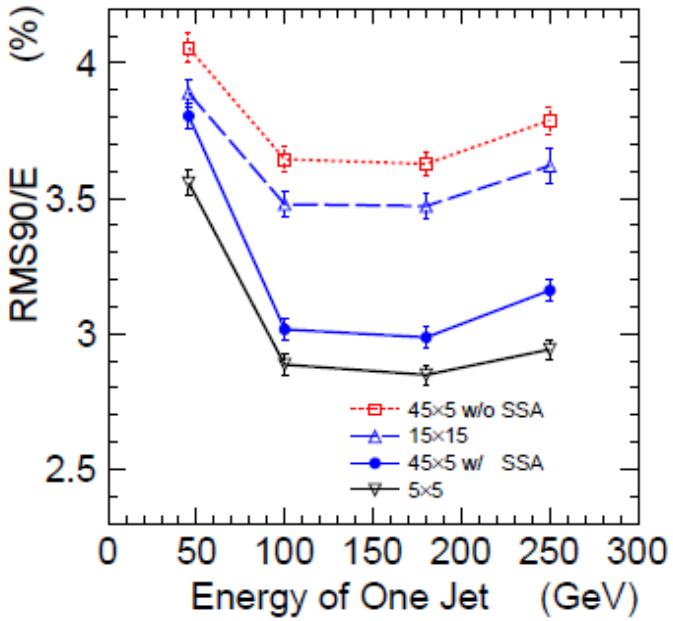
Strip Split Algorithm



- Virtual cells are created and the energy deposit in these cells are reconstructed from hits in nearest layers.
- No strong deterioration along the length of the strip using SSA.
- JER of strip ECAL reconstructed using SSA is very near to that of 5mmx5mm tile ECAL. (Difference of 0.2-0.25%)



Energy of One Jet = 100GeV, strip thickness is set to 1.0mm

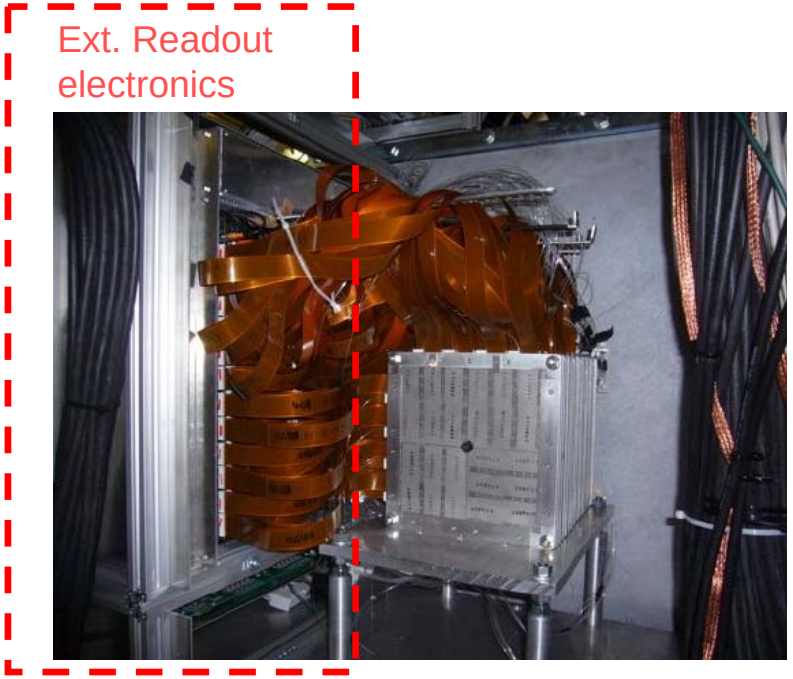


JER for 45GeV to 250GeV

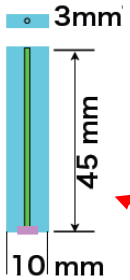
*please refer to arXiv: 1405.4456v2 for more information on these two plots

ScECAL for ILD: 2009 Prototype

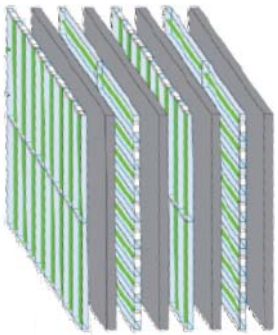
- The 2009 ScECAL prototype (or Physics Prototype) consists of 2160 channels in 30 active scintillator layers, sandwiched with tungsten absorber plates.
- For gain monitoring purpose, fibers are used to supply the LED light to each channels.
- 45mm x 10mm x 3mm scintillator strips are used.
- Wavelength shifting fibers are inserted into center of the plastic scintillator to collect light transport it to the MPPC.
- 1600pixel MPPC (old type) are used.
- MPPC are connected externally to the read out electronics which are fabricated by AHCAL(DESY)-CALICE.



2009 prototype at Fermilab

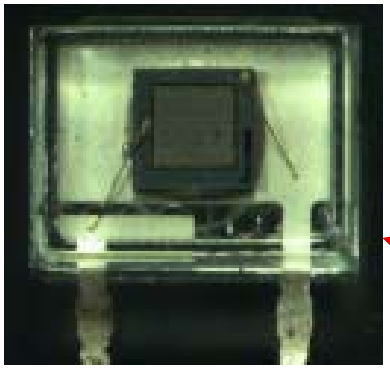


Sc. strip

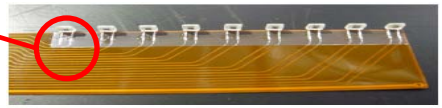


Sc. & W layers

Optic fibers



MPPC

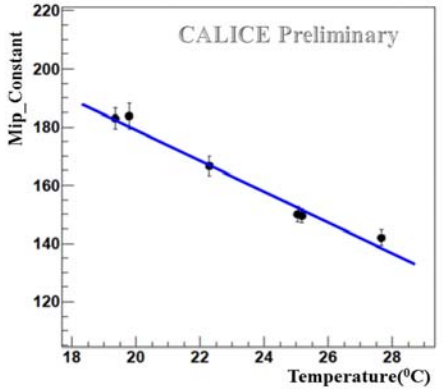


MPPCs in strip

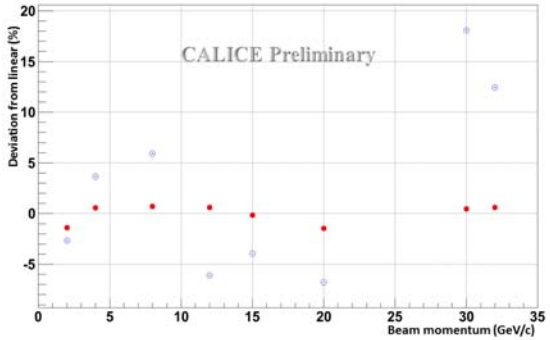
ScECAL for ILD: 2009 Prototype Performance

- Tested at Fermilab using beam momenta of 2-32 Gev (using muons, electrons and pions).
- Energy is reconstructed after temperature correlation.
- Electron energy was measured to be linear to within 2% in the given energy range.

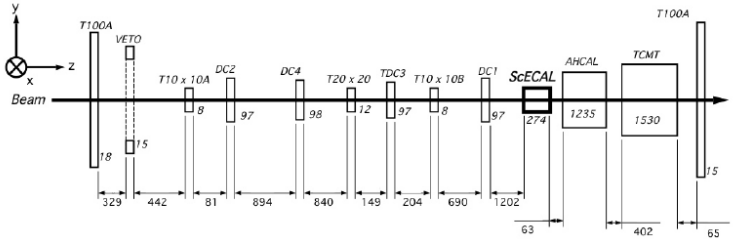
$\sigma_E/E = 12.9 \pm 0.4/\sqrt{E} + 1.2^{+0.4}_{-1.2})\%$



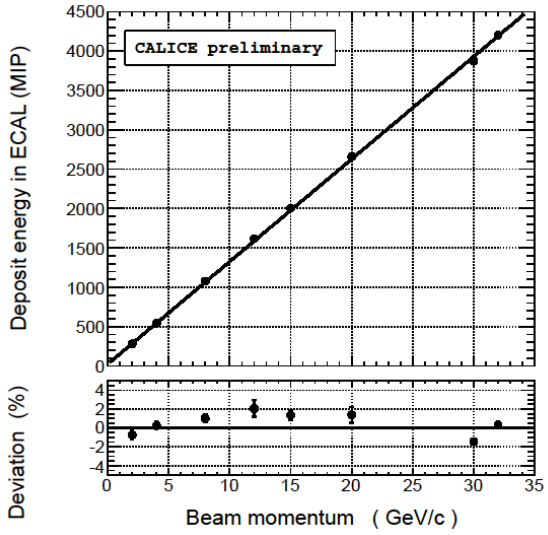
ADC/MIP as a function of temp.

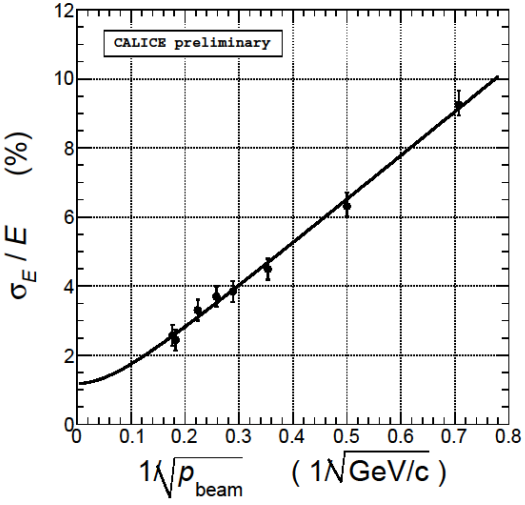


Deviation from linear fit before(grey dot) and after temp. correlation (red dot)



Testbeam setup

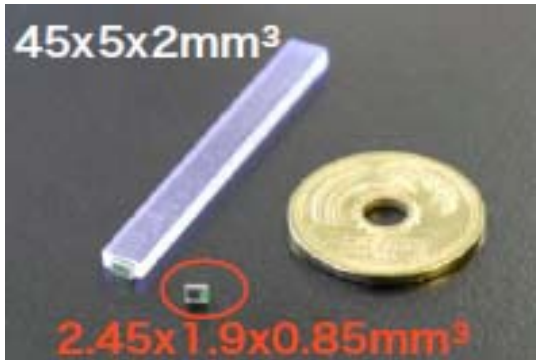




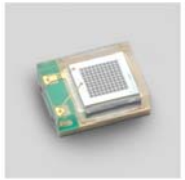
Linearity and energy resolution as a function of beam momentum

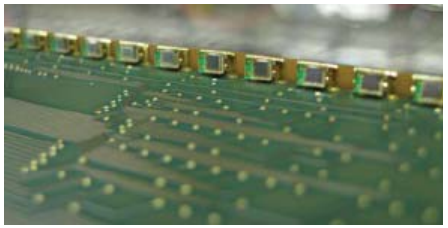
ScECAL for ILD: Tech. Prototype

- Readout electronics are integrated into the active layers, which is called the ECAL Base Unit(EBU), developed from the collaboration between ScECAL and AHCAL group at DESY.
- It has the same read-out electronics and DAQ as the AHCAL.
- EBU:
  - The EBU has 4 ASIC (SPIROC2b developed by IN2P3-OMEGA group) which can accommodate 36 channels. Each EBU has 144 channels.
  - Individual bias voltage can be set for each channels.
  - Individual threshold can be set for each ASIC
  - Each channel is equiped with LED for calibration.
  - Other features: TDC, power pulsing
- Individual scintillator strips of 45mm x 5mm x 2mm are used.
- The WLSF was removed.
- Using the SMD 1600pixel MPPC.

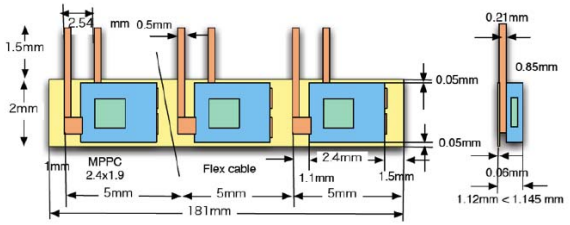


The scintillator strip and MPPC size

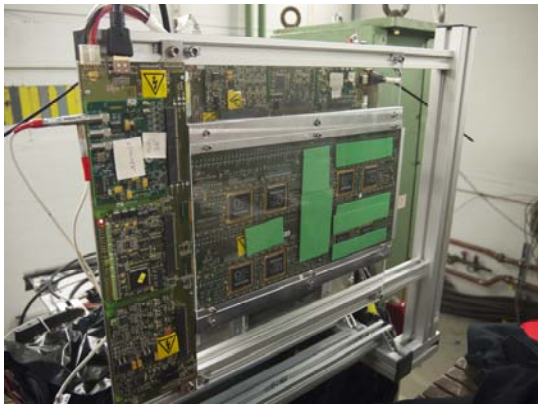




MPPC strips soldered onto the EBU



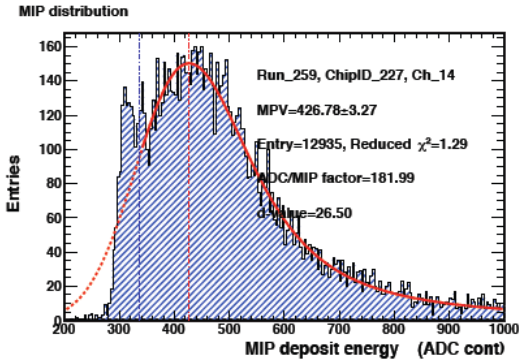
MPPC in a strip



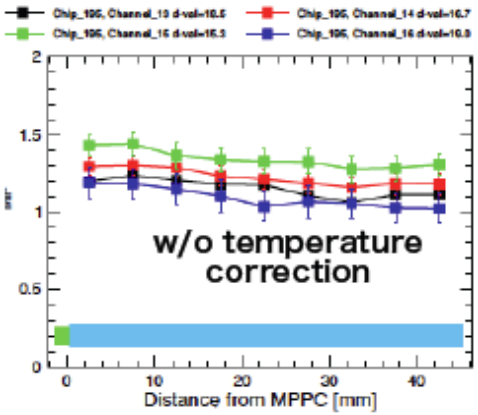
Tech. Prototype for TestBeam at DESY

ScECAL for ILD: Tech. Prototype Performance

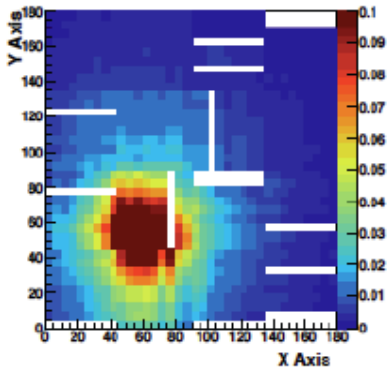
- Uniform along the length of the strip, with a slight peak near the MPPC.
- Multilayer synchronization operated smoothly, we could synchronize 3 layers of EBU using the Clock and Control Card (CCC).
- We could apply a 2 layer SSA to get the hit map.
- In addition, since the ScECAL share similar readout electronics with the AHCAL, we can also synchronize 2 ScECAL with 2 layers of the AHCAL.



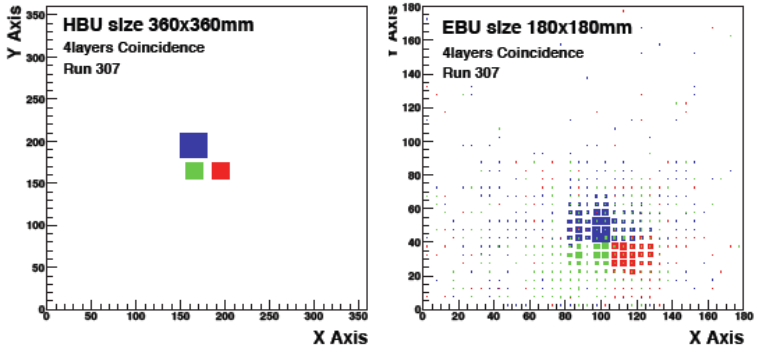
MIP plot of a typical channel



MIP as a function of distance from MPPC



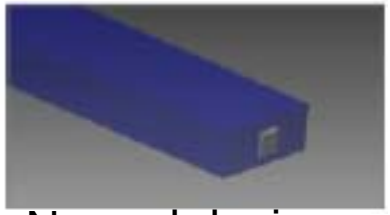
Hit Map of the 2 layers



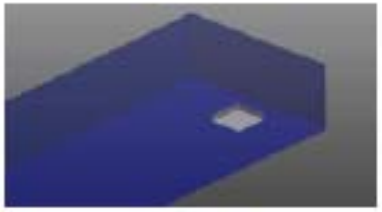
HBU hits (left) and it's corresponding hit the EBU(right). Granularity for AHCAL is 30x30mm^2 while for ScECAL is 5x5mm^2

Next: Scintillator and MPPC Improvements

- ScECAL design problem:
  - 2% dead volume due to the MPPC.
  - Light yield is slightly higher near the MPPC.
- Placing the MPPC right below the scintillator strip
  - Pros:
    - Remove dead space
  - Cons:
    - Light yield (Npe) reduced
    - Uniformity reduces
- Changing the shape of the scintillator strip to guide the light to the MPPC.
  - Pros:
    - Increase light yield
    - Increase uniformity
  - Cons:
    - Light yield is still lower then the normal design.



Normal design



Normal bottom

Normal design

Wedge design

Tapered wedge

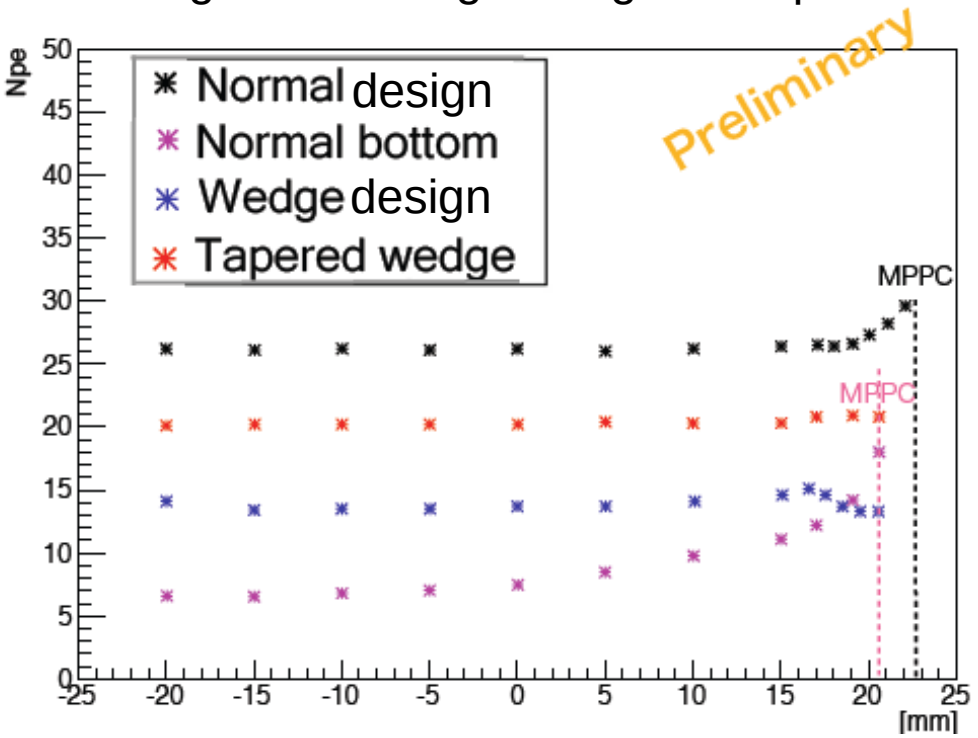
Next: Scintillator and MPPC improvements

- Tapered wedge photon collection is 70%~80% of the normal design.
- No increase in photon yield near the MPPC
- Promising results, but the EBU design will be more complex.

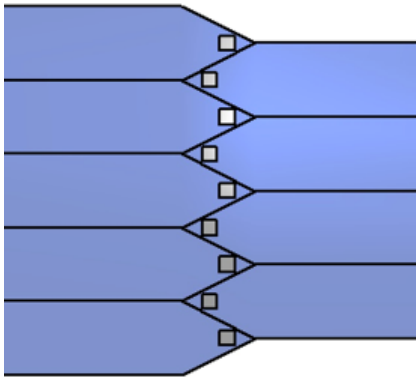
Normal design

Wedge design

Tapered wedge



Photon yield for various scintillator configuration

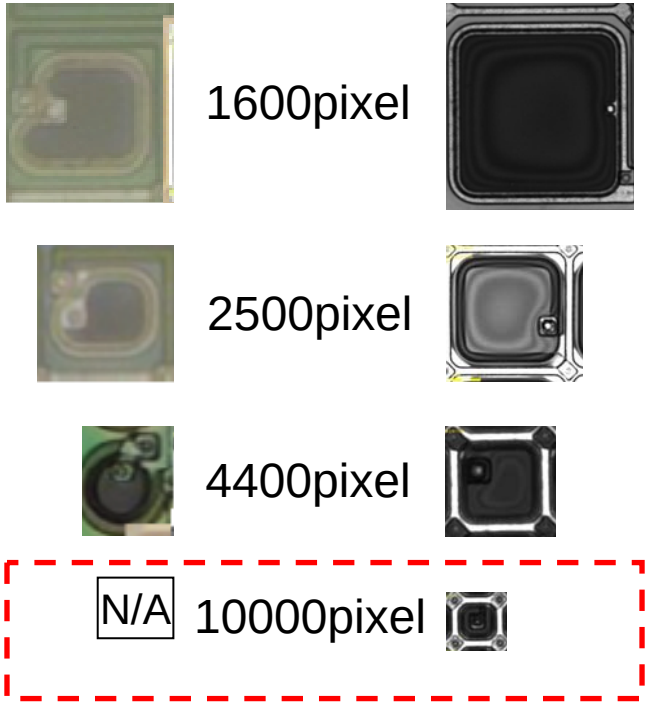


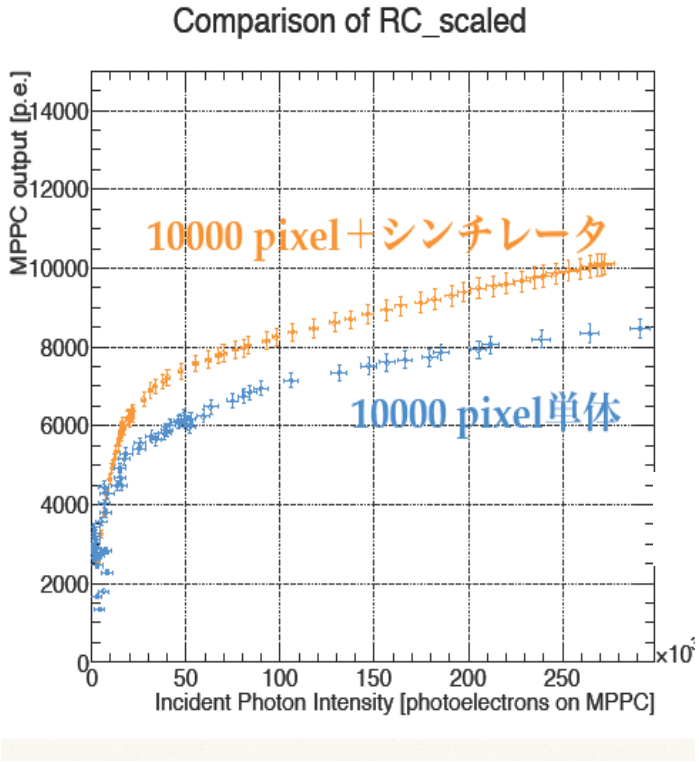
Tapered wedge on EBU

Next:MPPC Improvements

- New MPPC has larger sensitive area.
- Higher dynamic range gives better energy resolution
- We need ~10,000 pixels for MPPC
- By changing polysilicon to metal quenching resistor→10,000pixel MPPC is made possible

Previous Improved





Saturation of MPPC for MPPC & Scin. (orange) and MPPC only (blue)

Next: Test beam at Cern 2014

- The next testbeam will be carried out by CALICE AHCAL effort, and we will join it.
- 4 layers of the second prototype will be tested.
- The 3 layer SSA can be tested.
- Current plan:
  - Layer 1 & 2:
    - layers used previously
  - Layer 3 & 4:
    - new 10000 pixel MPPC
    - Plastic scintillator with 1 mm thickness
    - Bottom MPPC readout, with tapered wedge configuration

Conclusion

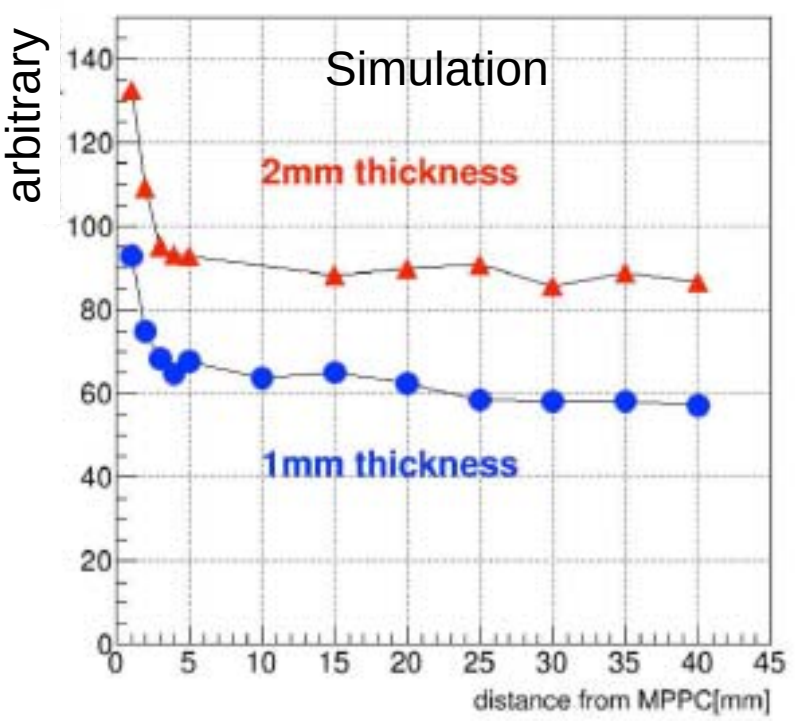
- Fine Segmented Scintillator ECAL (ScECAL) has been developed and results from simulation and testbeam suggest that it can achieve the high requirements of ILD.
- It is still undergoing many improvements, such as the strip design and MPPC development.
- The next testbeam is schedule in 2014 by CALICE.
- After successful Testbeam, the final design for ScECAL in ILD will be decided.

Thank you!

Backup

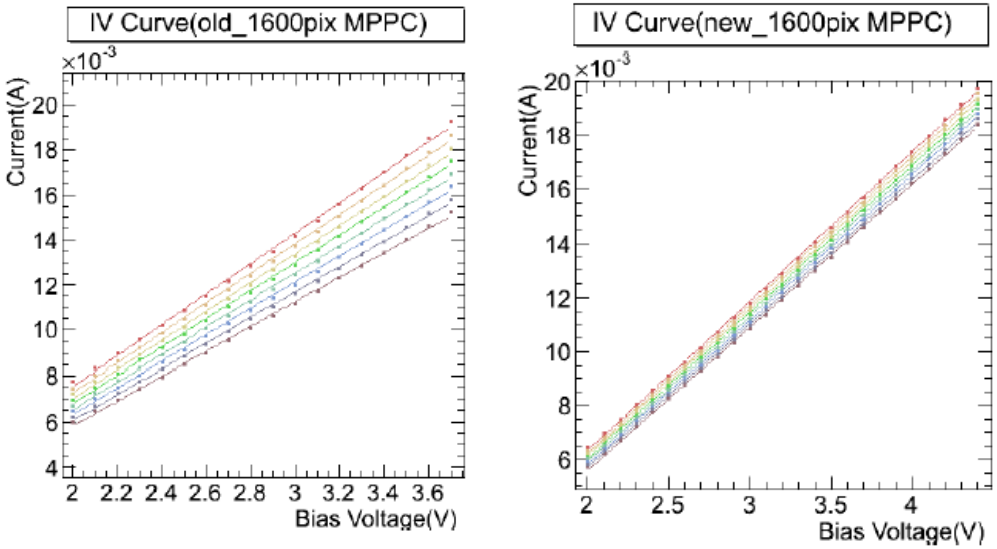
Next: Scintillator thickness

- Reduce thickness from 2mm to 1mm
  - Pros:
    - Reduction in ECAL thickness will helps reduce the overall size of the ILD, especially the coil. This will reduce the cost for ILD.
  - Cons:
    - Npe yield reduces compare to the normal 2mm thickness. The right plot shows results from a lab measurement.
- We need more data on 1mm thickness, especially from beam test.

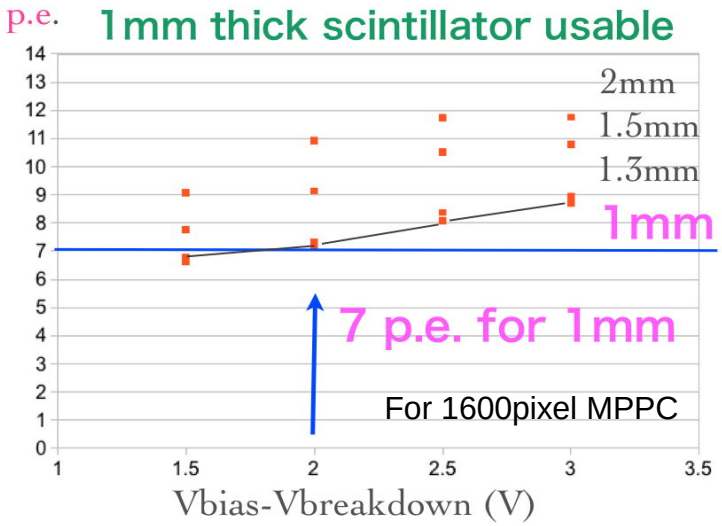


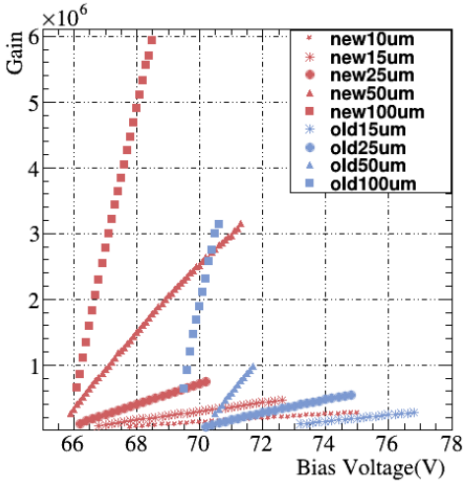
Photon output for 1mm and 2mm scintillator

The MPPC

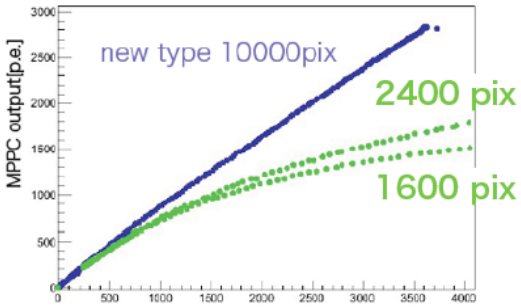


IV curve for various temperatures(old vs new MPPC)

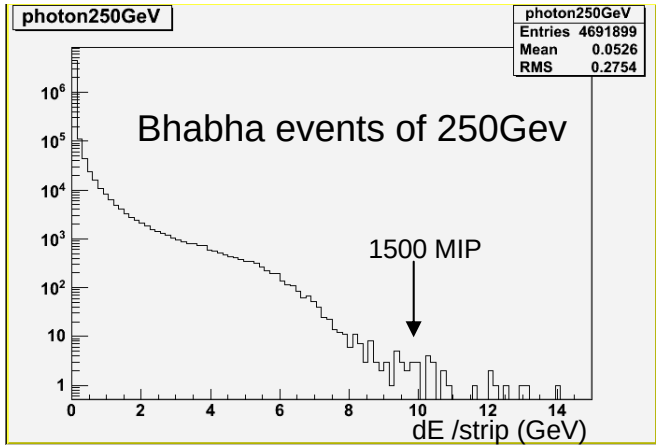




Gain vs bias voltage for old(blue) and new(red) MPPCs

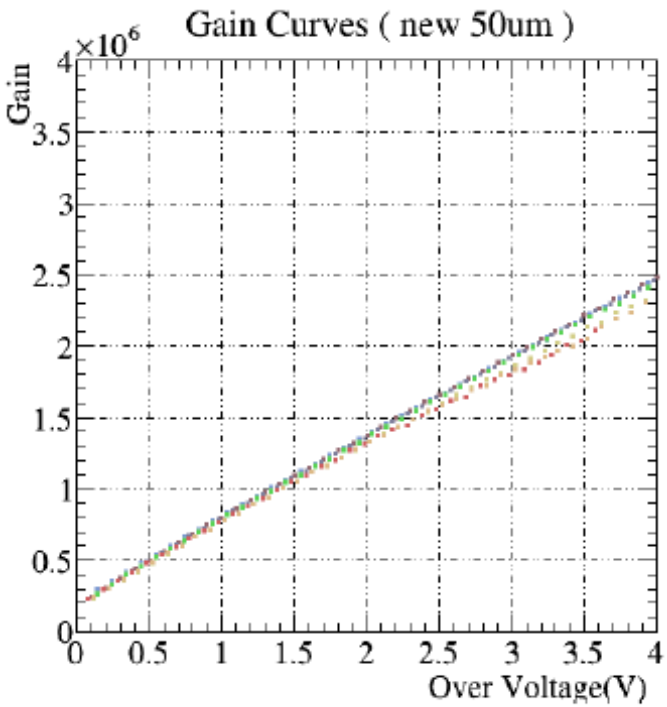


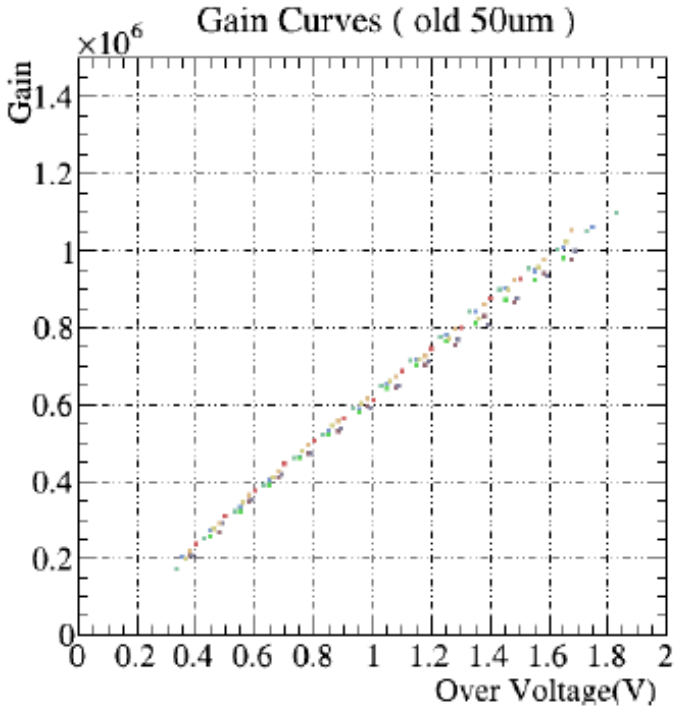
MPPC photon output against incident photons for 10000pixel, 2400pixel and 1600 pixel MPPC



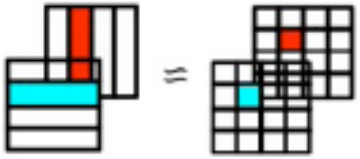
1500mip x 7p.e./mip = 10500p.e.

Gain curves vs over voltage applied

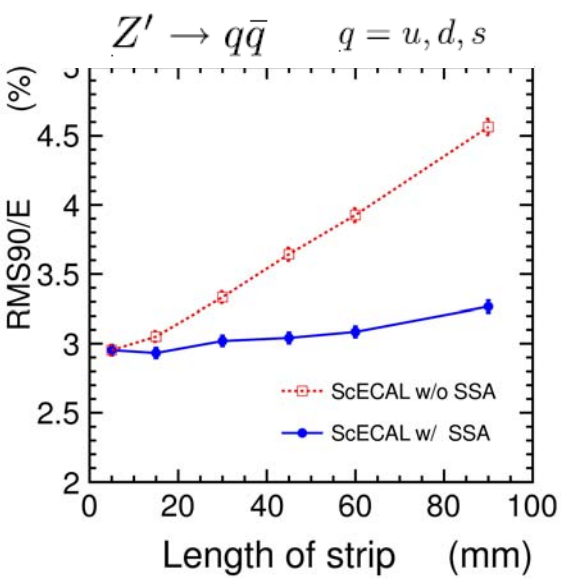




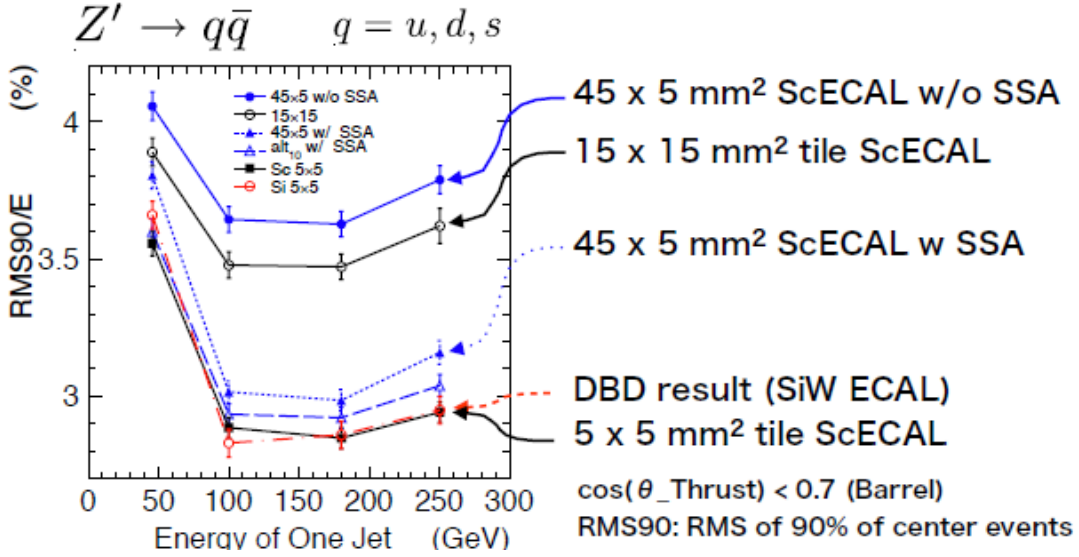
Strip Split Algorithm



- Virtual cells are created and the energy deposit in these cells are reconstructed from hits in nearest layers.
- No strong deterioration along the length of the strip using SSA.
- JER of strip ECAL reconstructed using SSA is very near to that of 5mmx5mm tile ECAL. (Difference of 0.2-0.25%)
- By using strip scintillator and SSA, we can reduce the number of channels by an order of magnitude.



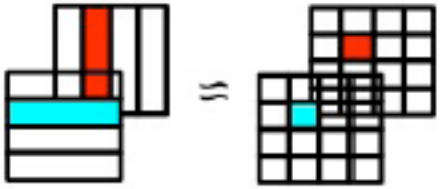
Energy of One Jet = 100GeV, strip thickness is set to 1.0mm



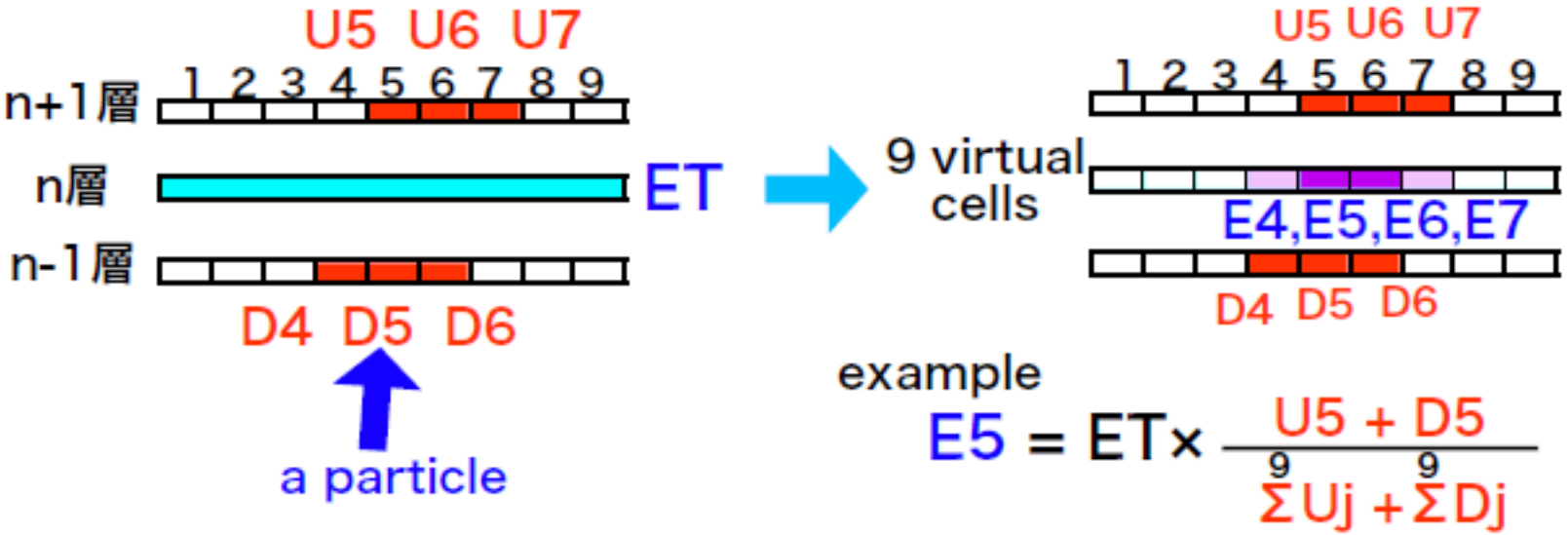
JER for 50GeV to 250GeV

*arXiv: 1405.4456v2

Strip Ecal reconstruction with the strip splitting algorithm



deposited energy on a strip
delivered into virtual square cells

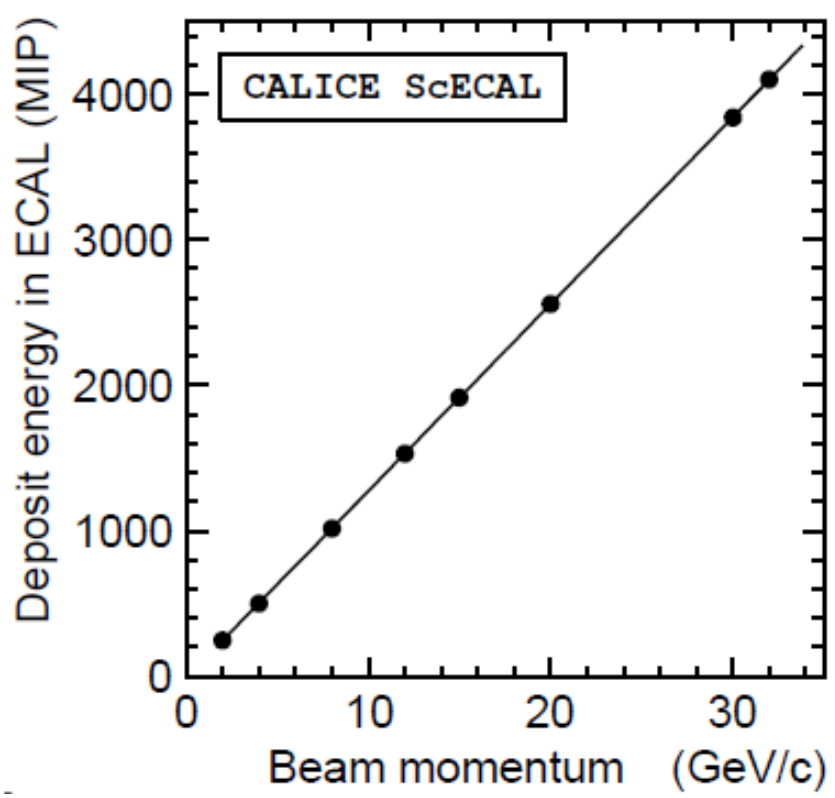


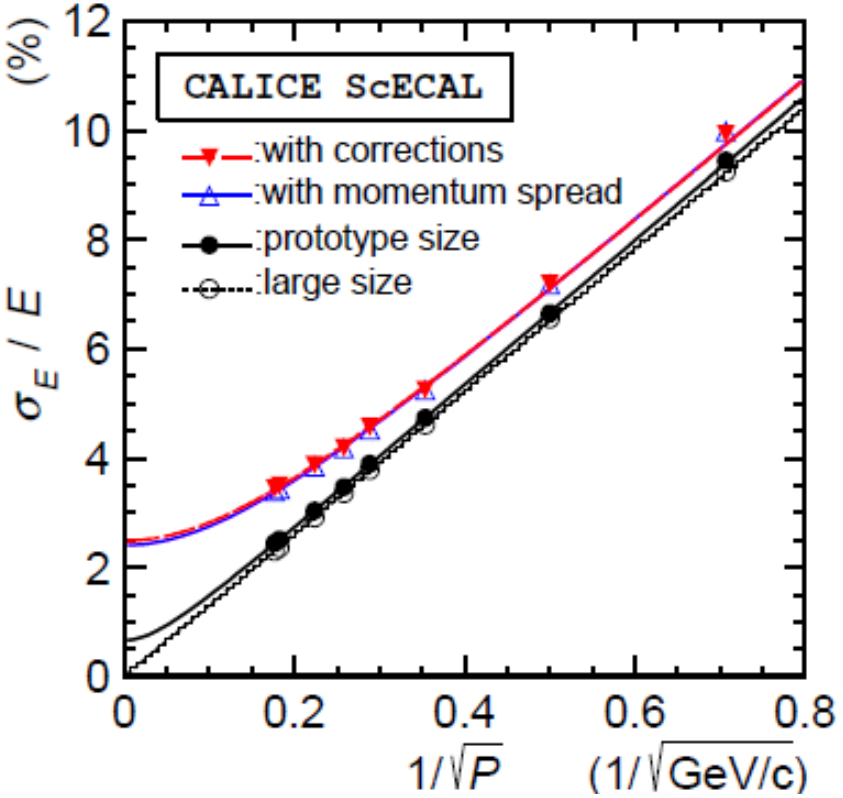
example

$$E5 = ET \times \frac{U5 + D5}{\sum_{9} Uj + \sum_{9} Dj}$$

positions and energies of all virtual cells are fed into the PandoraPFA program

JER (Simulation results)

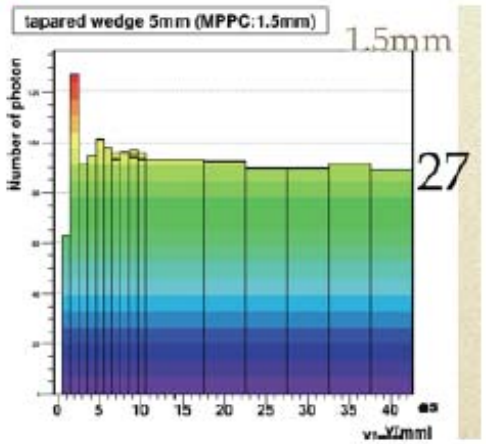


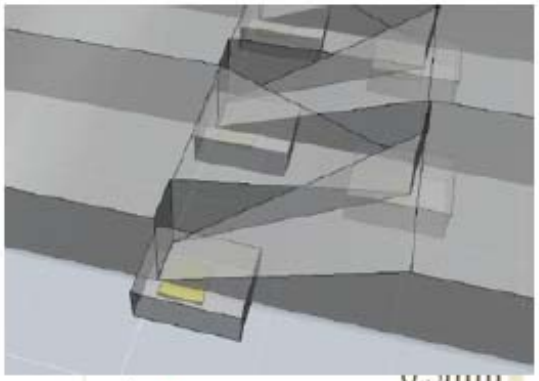


MC Simulation

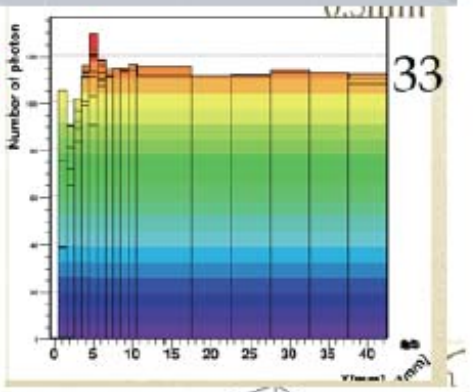
Possible scintillator configurations and its light output

MC

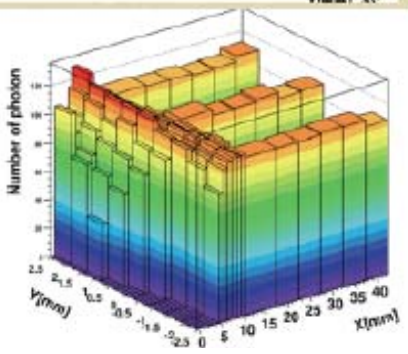


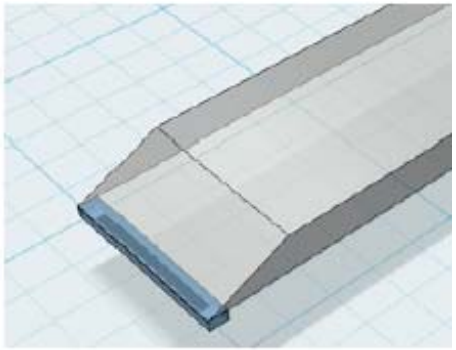


MC



MC

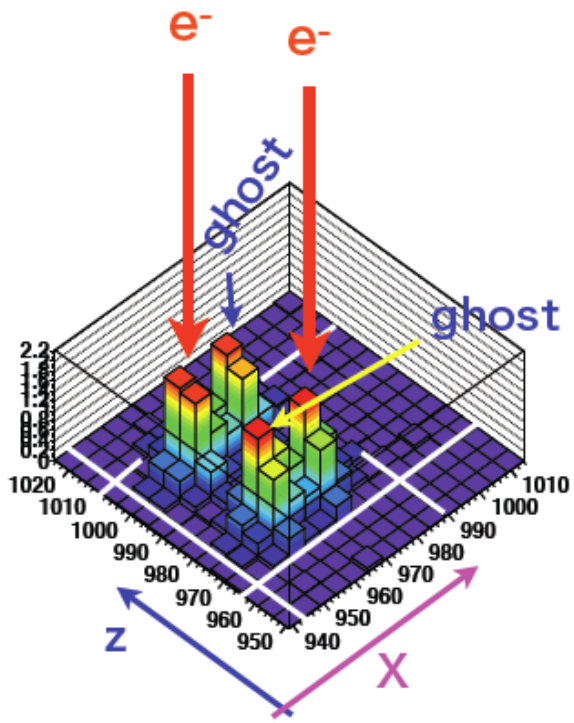




4 x 0.25 mm² MPPC

no difficulty to make it for Hamamatsu

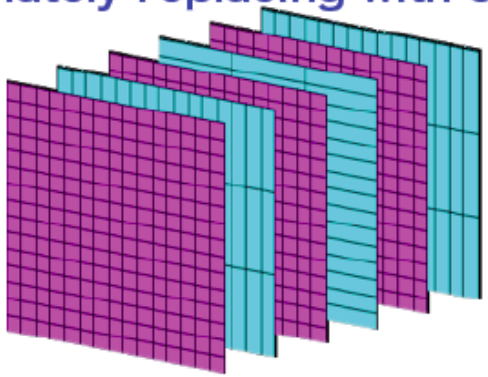
Alt. tiles layer to solve ghost event



We call those;

alternative { 5x5, 10x10, 15x15

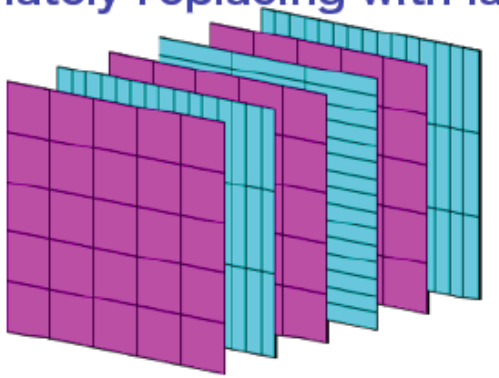
Alternately replacing with 5x5mm² tile layers.



note:
merit of orthogonal setting of strip layers is not used.

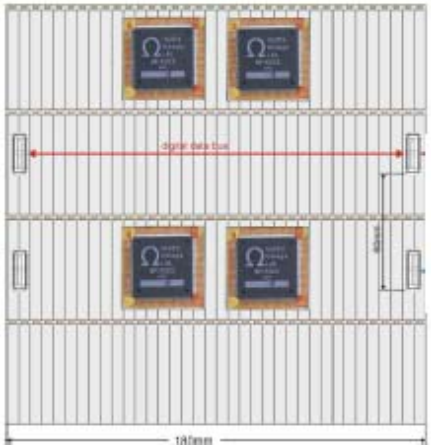
5x5mm² tile Si layer is one of option ▶ hybrid ECAL

Alternately replacing with large tile layers.

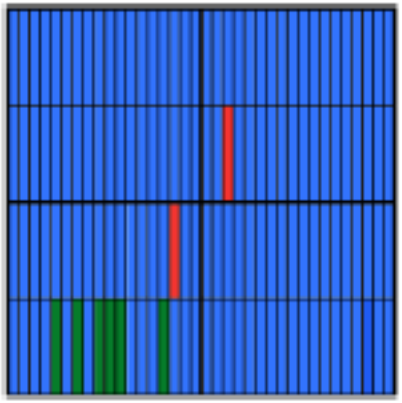


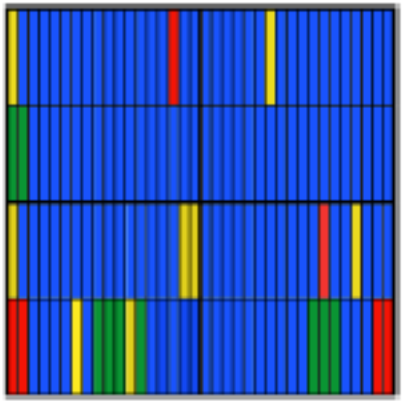
10x10 or 15x15mm² is reasonable to make pure scintillator ECAL

EBU



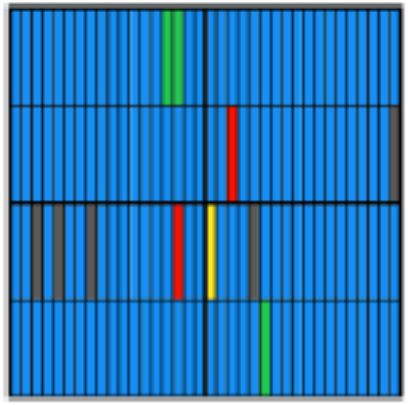
Placement of scintillator strips onto the EBU

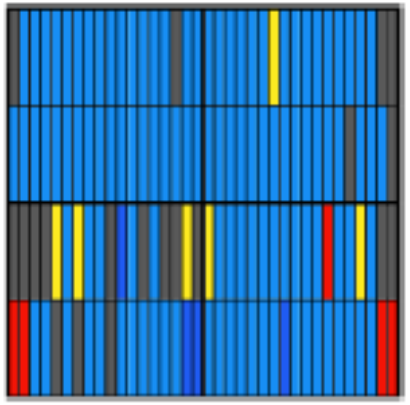




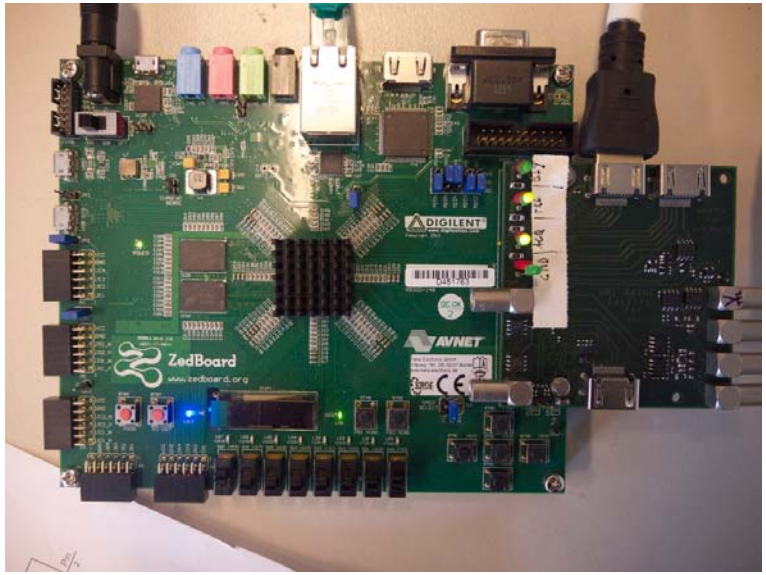
Some bad channels in the tech. prototype(TB mode)

Red: Couldn’t get signal
Green: Signal peak is not distingusable from pedestal
Yellow: Strange signal

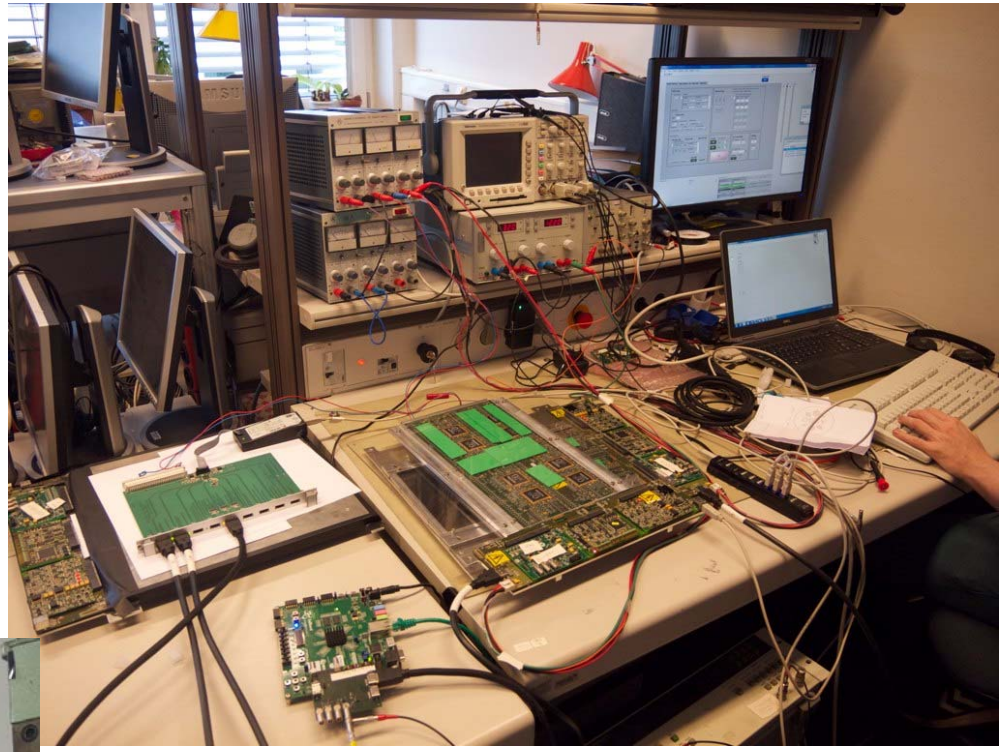




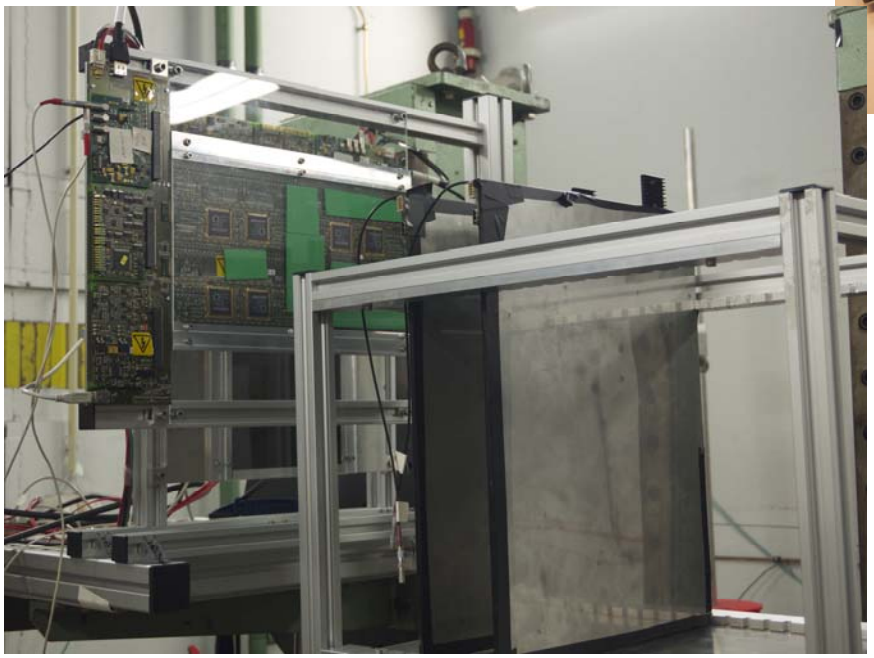
Some bad channels in the tech. prototype(LED calib mode)



↑ The Clock and Control Card



↑ Multiple layer synchronization setup



↑ ScECAL + AHCAL TB setup

←XY scintillator counter for validation signal