Strip Scintillator CAL in PFA

3rd November 2015(13:30)

K. Kotera Shinshu University

at LCWS2015 in Whistler BC CANADA

What are important for PFA Calorimetry?

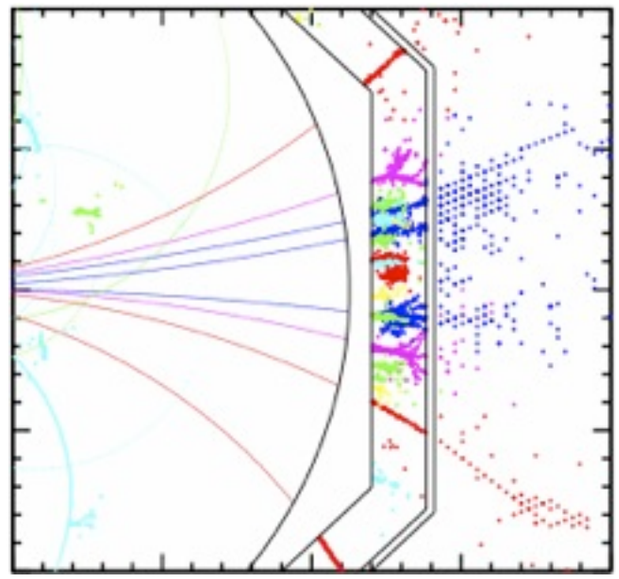
Separation ability of particles in jets

↓

Imaging calorimeter

↓

Fine granularity for ECAL and HCAL



Still

Energy resolution of single particles

↓

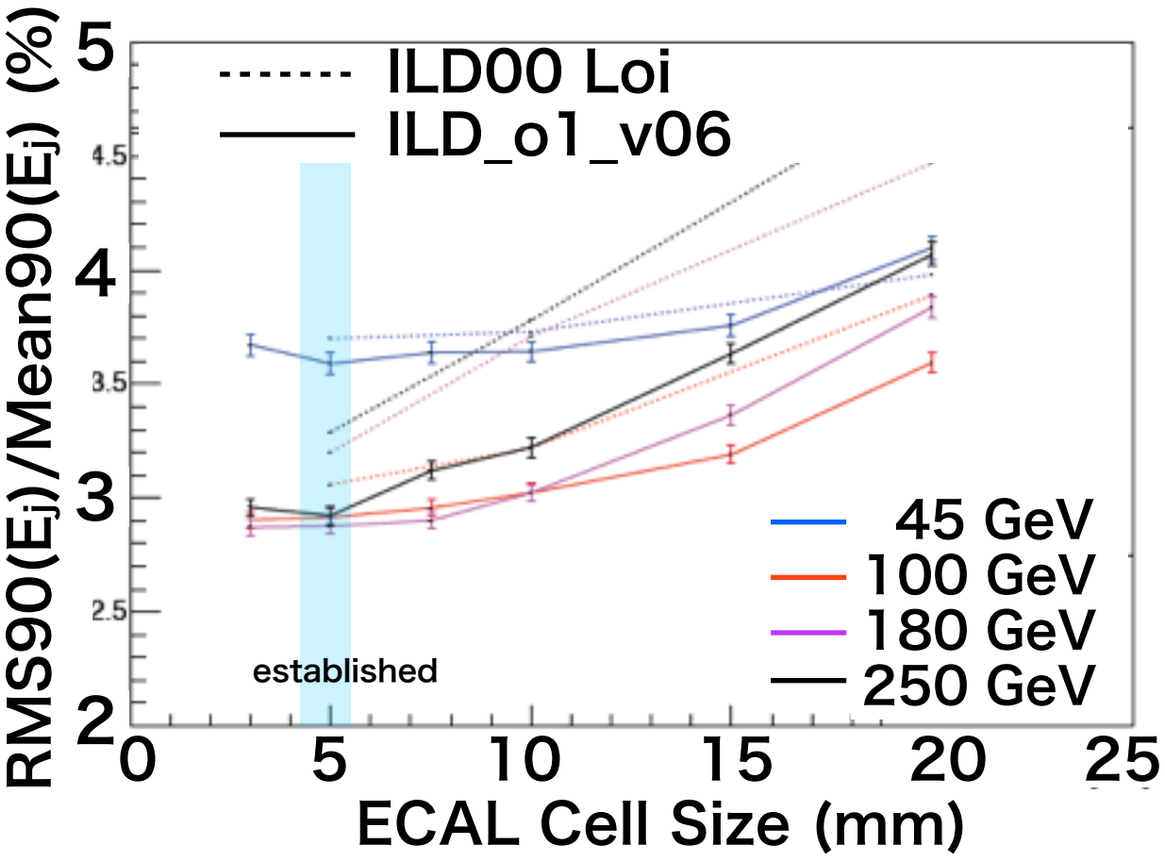
Energy measurement performance

Some times those are conflict with each other.

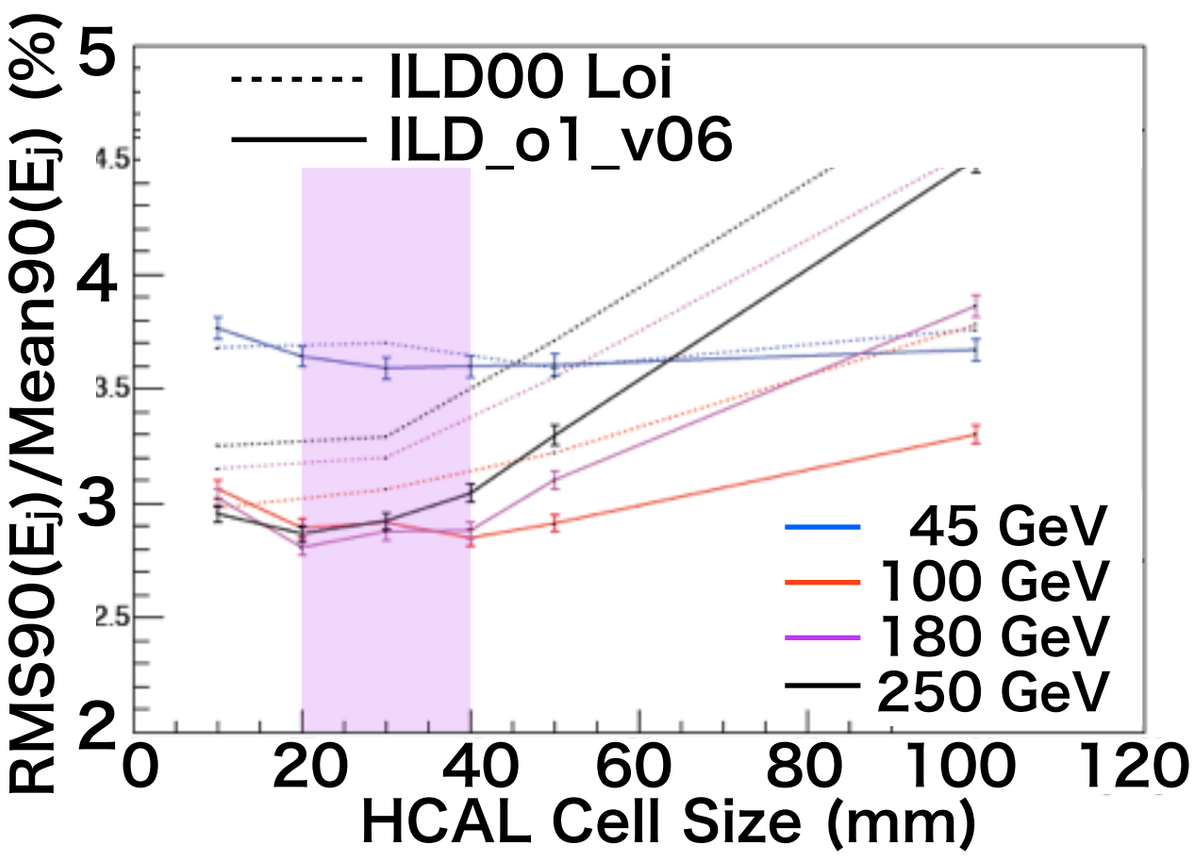
We suggest a way to avoid this conflict.

Granularity for ECAL, HCAL

ECAL:



HCAL:



using PandoraPFA in ILD_o1_v06 by Steven Green

Best granularity. ECAL: 5×5mm², HCAL: (20~40)²mm²

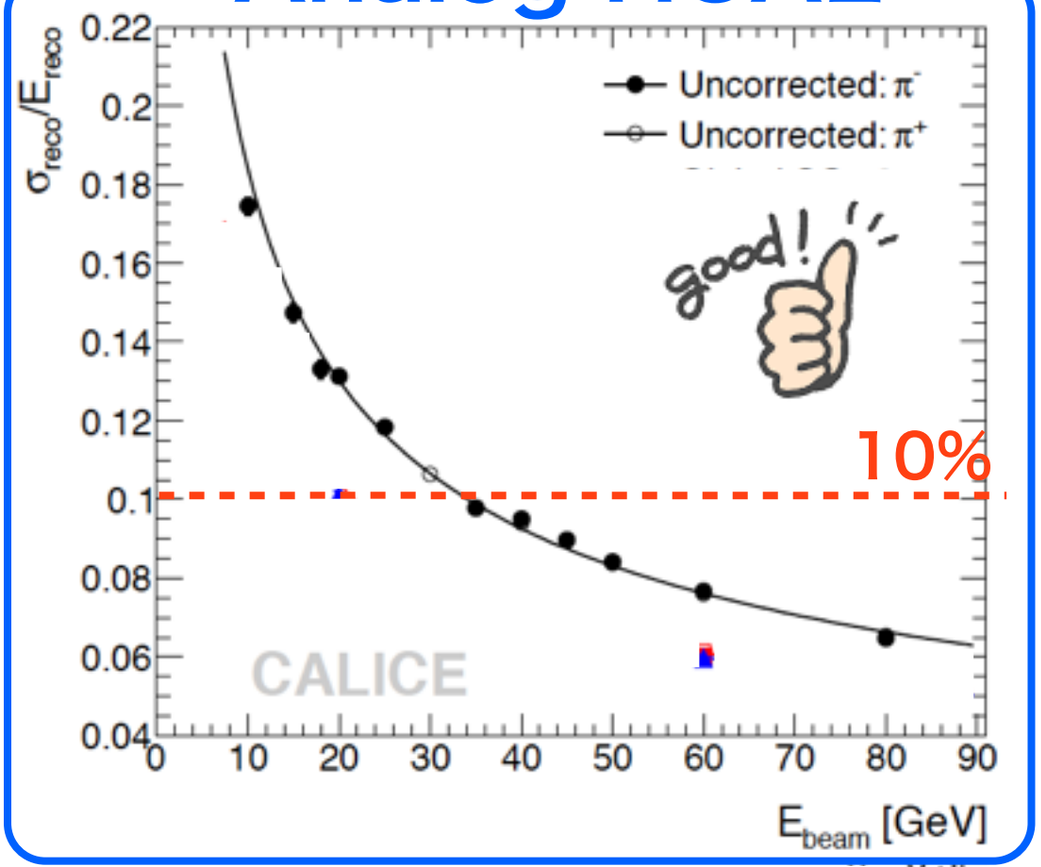
HCAL result is applicable to only Analog HCAL.

10×10mm² is required for Digi and SemiDigi HCAL.

→ things are not so simple on HCAL.

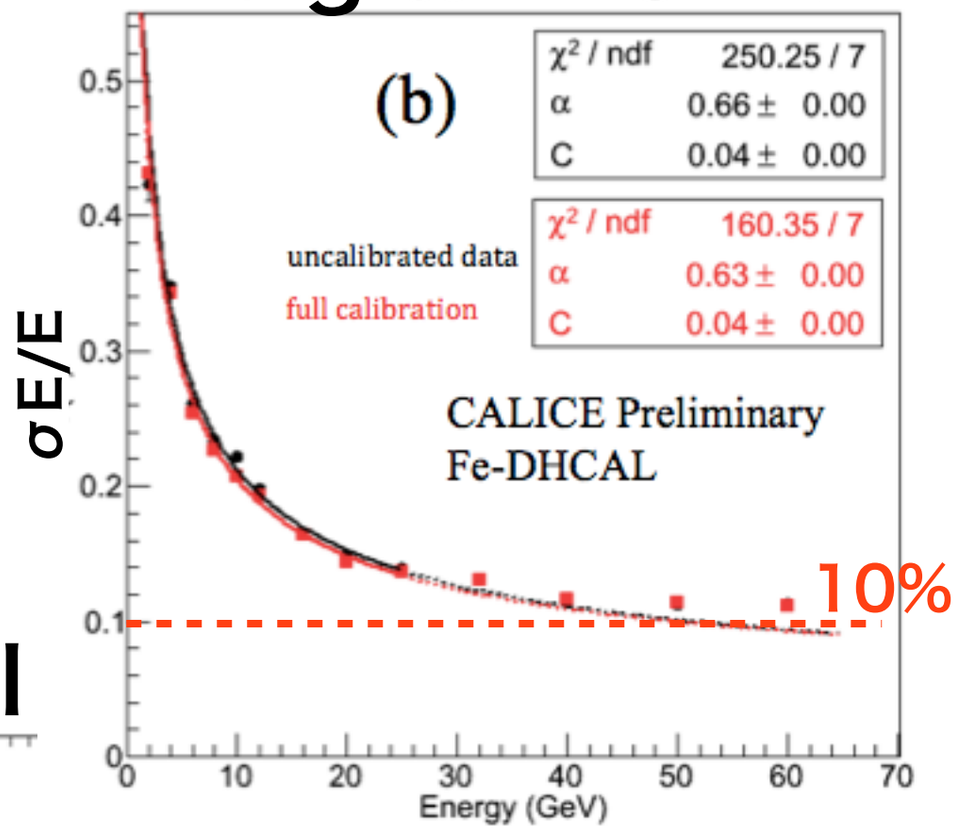
Single particle($\pi^{\pm}$)

Analog HCAL

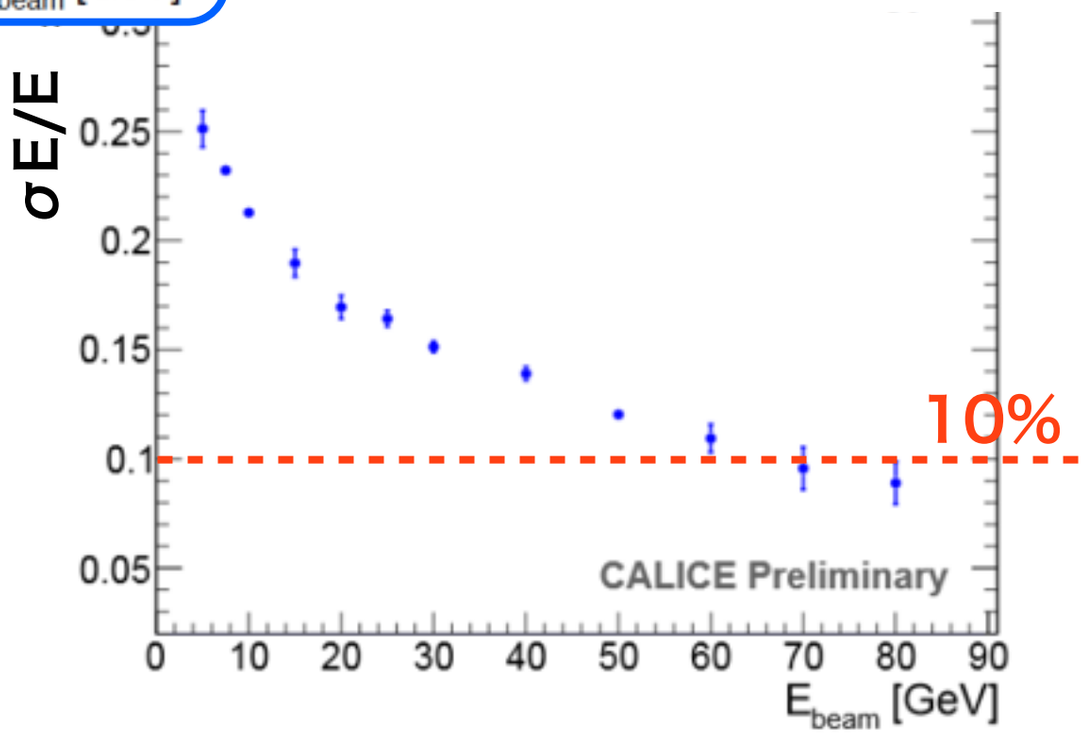


AHCAL takes more advantage of energy info.

Digital HCAL

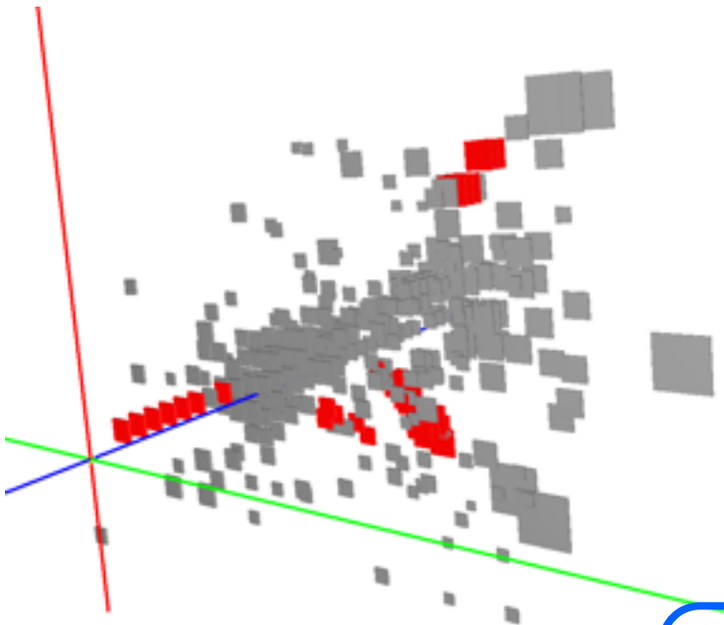


Semi Digital



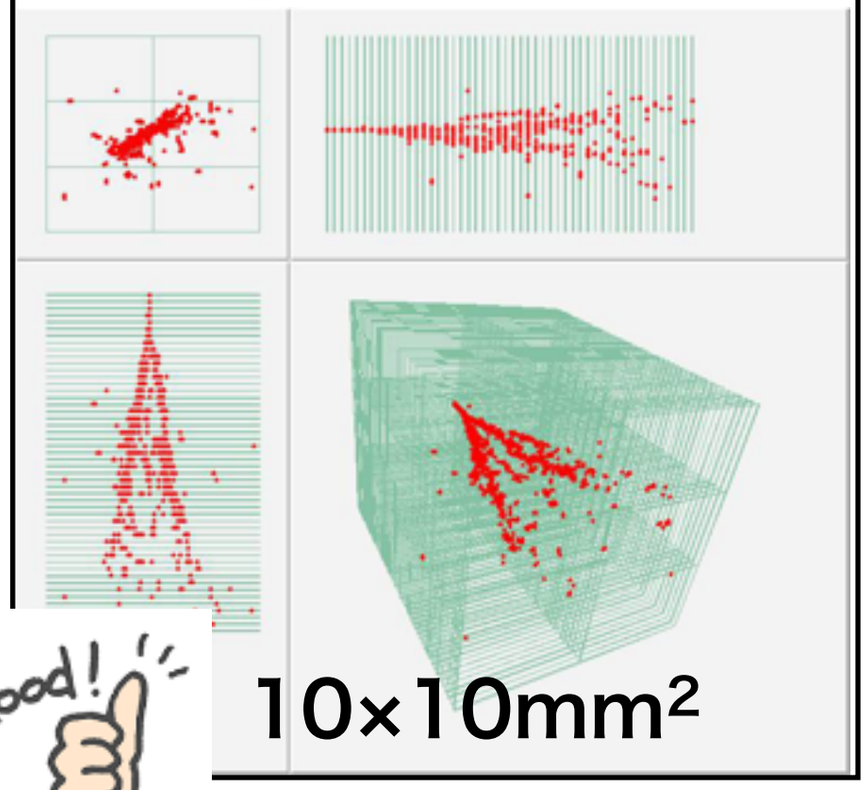
Clear track shape of SD,Dhcal

Analog HCAL



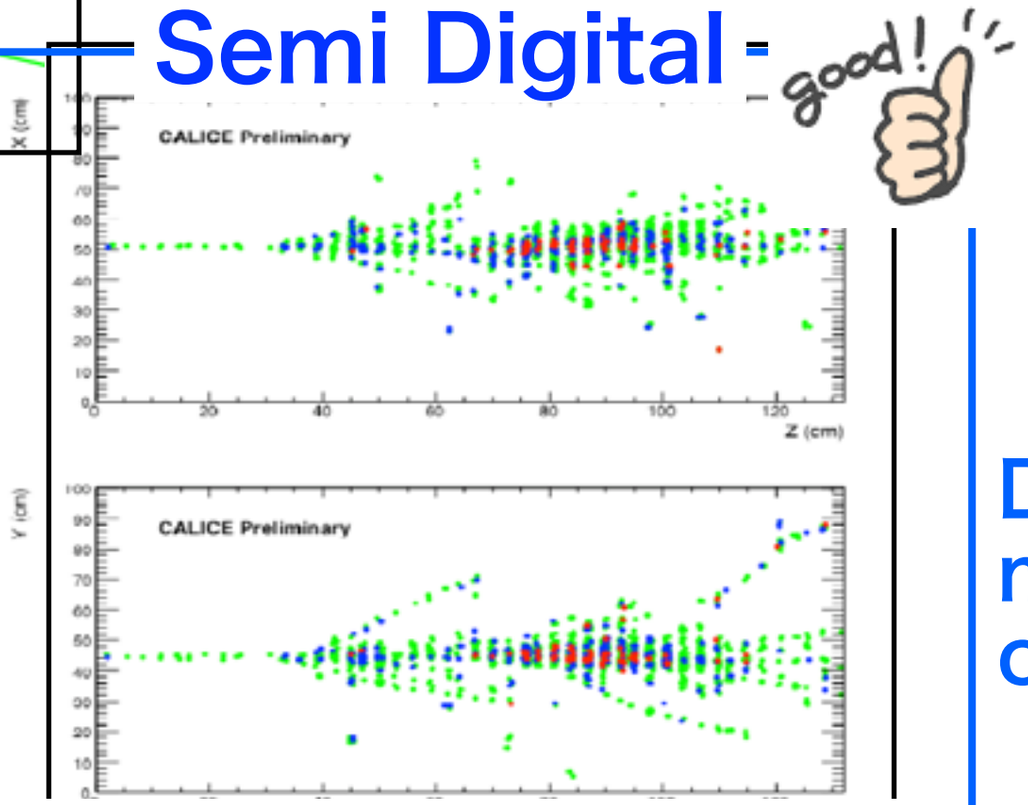
30×30mm²

Digital HCAL



10×10mm²

Semi Digital



(Three colors come from different energy threshold)

good!

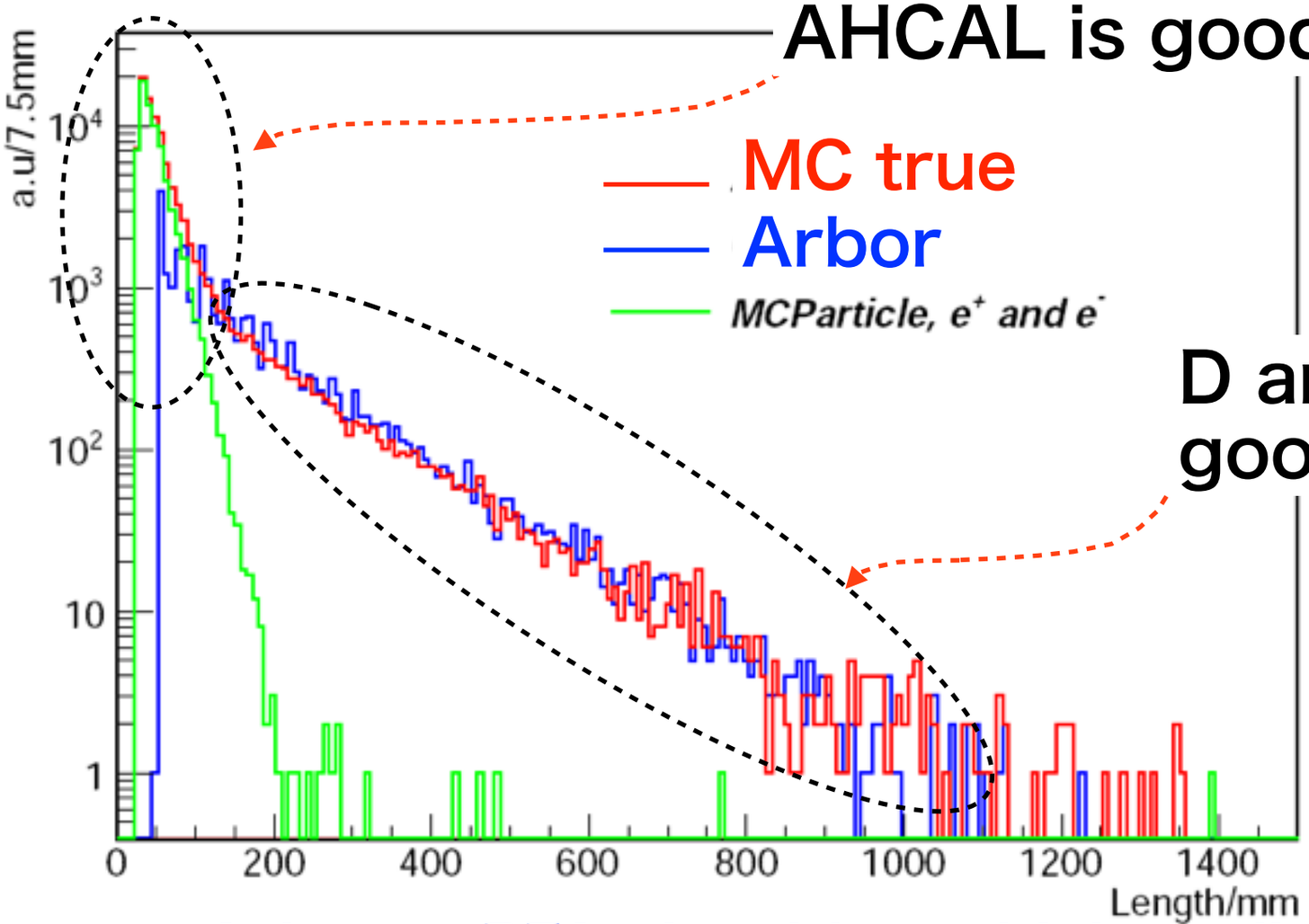
D,SDHCAL take more advantage of fine granularity.

Advantages of A_{Hcal} and D_{Hcal}

Distribution of cal track length in HCAL

by Manqi Ruan

AHCAL is good for this region



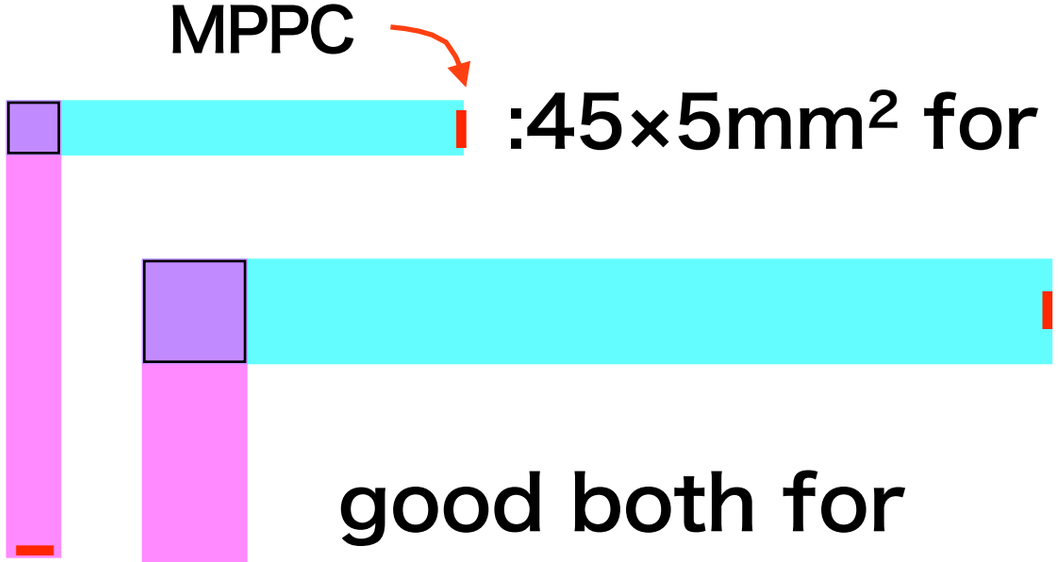
D and SD HCAL are good for this region

Arbor: a PFA algorithm which dedicates to Cal.Track analysis for D, SDHCAL

If we have - 10×10mm² AHCAL and
- algorithm which can show merit of 10×10mm²,
we can take advantage of both cases→Strip CAL

Our suggestion:

Strip ScCAL can take both



:45×5mm² for ECAL

:90×10mm² for HCAL

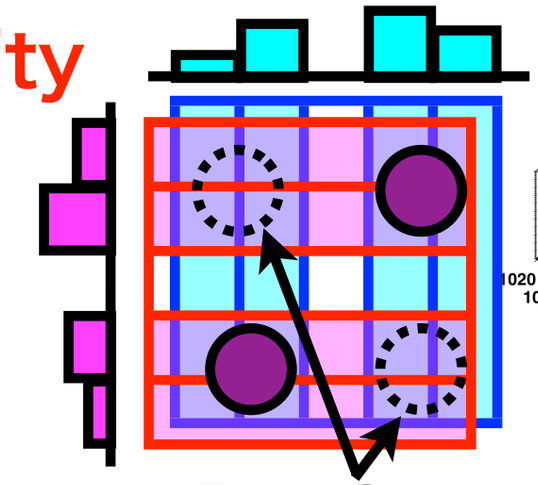
Same area/SiMP as 30×30mm²

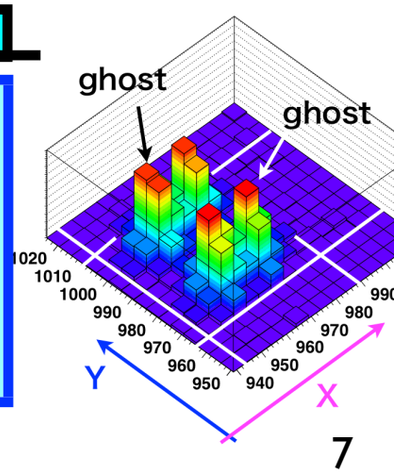
good both for

- Energy measurement with scintillator.
- fine segmentation by strip crossing

however

- An issue: twofold ambiguity

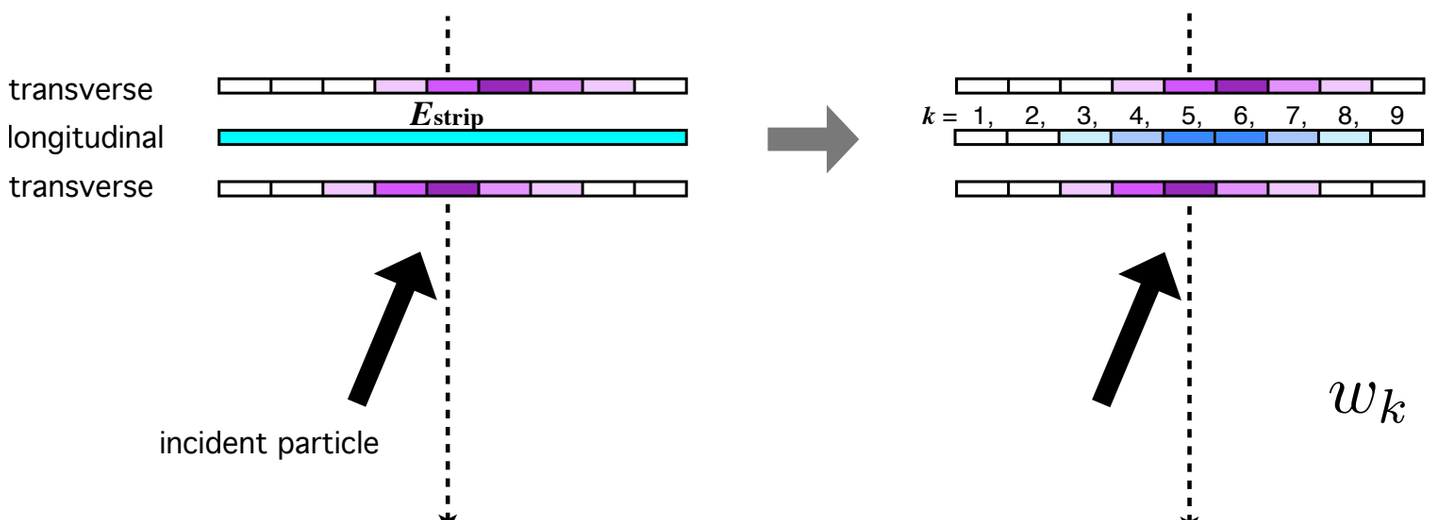




We discuss Strip ScCAL.

Strip energy Splitting Algorithm

for ECAL (KK, A. Miyamoto, D. Jeans, T. Takeshita, NIM **A789**(2015) pp.158-164)

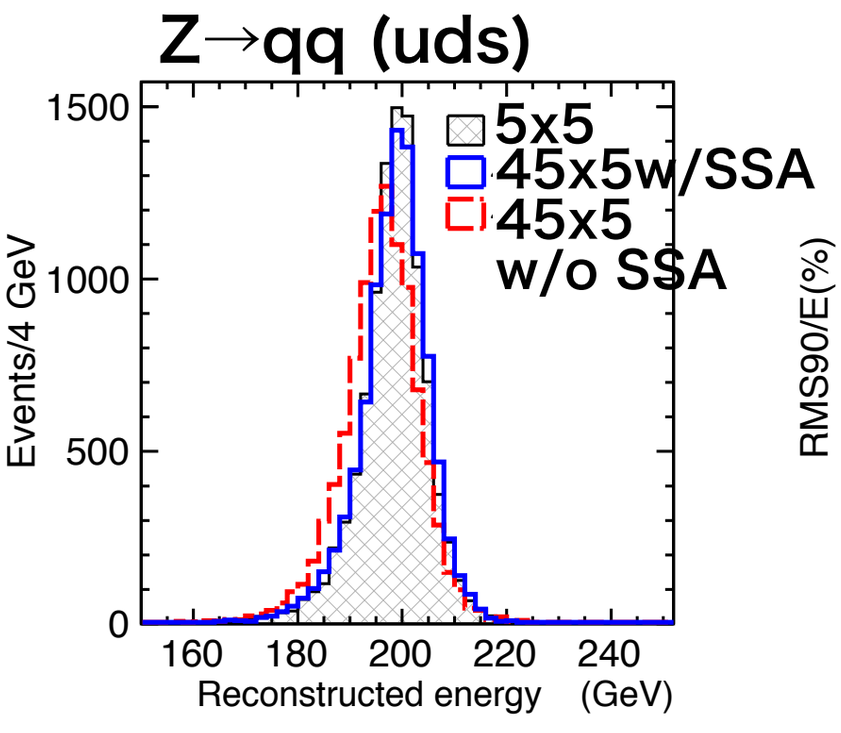


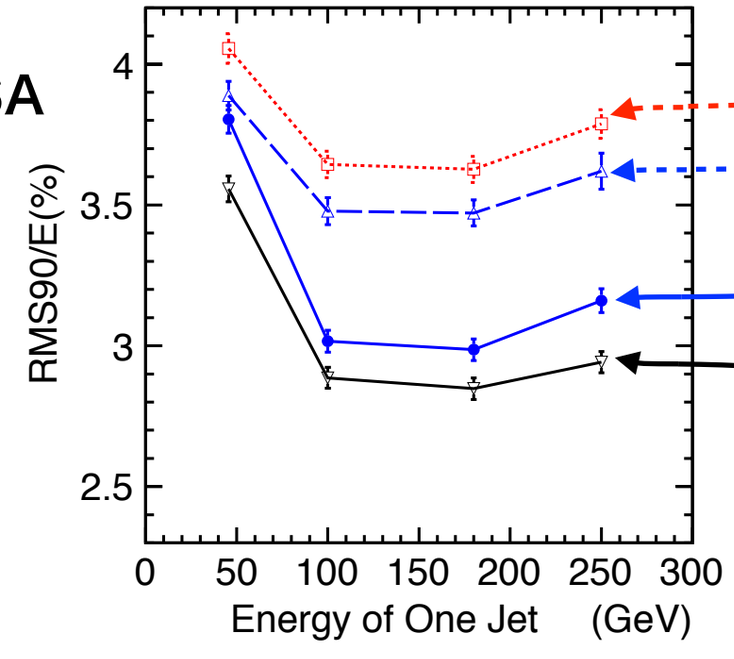
The energy in the center strip (left) is split among nine virtual cells (right), considering weights referring energy in orthogonally aligned strips in neighboring layers.

$$w_k = \frac{E_{\mathrm{transverse,inner,k}} + E_{\mathrm{transverse,Outer,k}}}{\sum E_{\mathrm{transverse,k}}}$$

(not rigorous def.)

Simulation shows good JER of strip ECAL w/ SSA





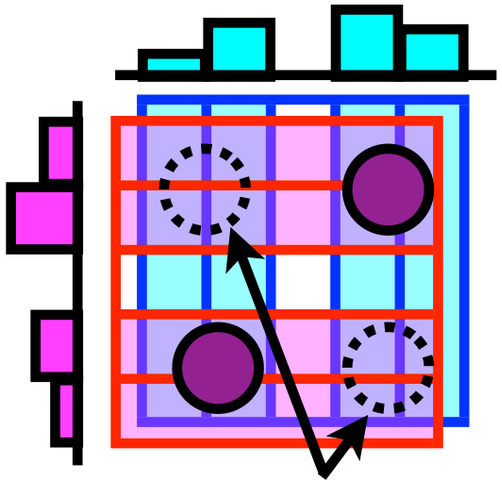
45x5mm² strip ECAL w/o SSA

15x15mm² tile ECAL

45x5mm² strip ECAL w/ SSA

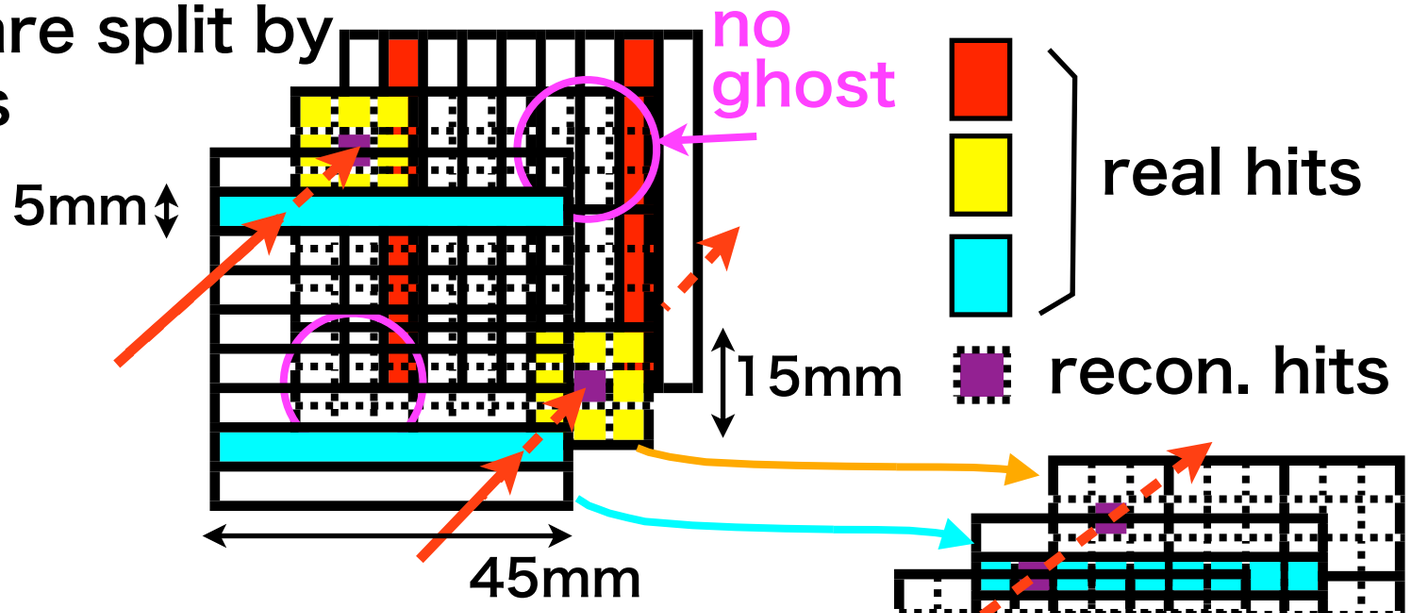
5x5mm² tile ECAL

To resolve ghost problem



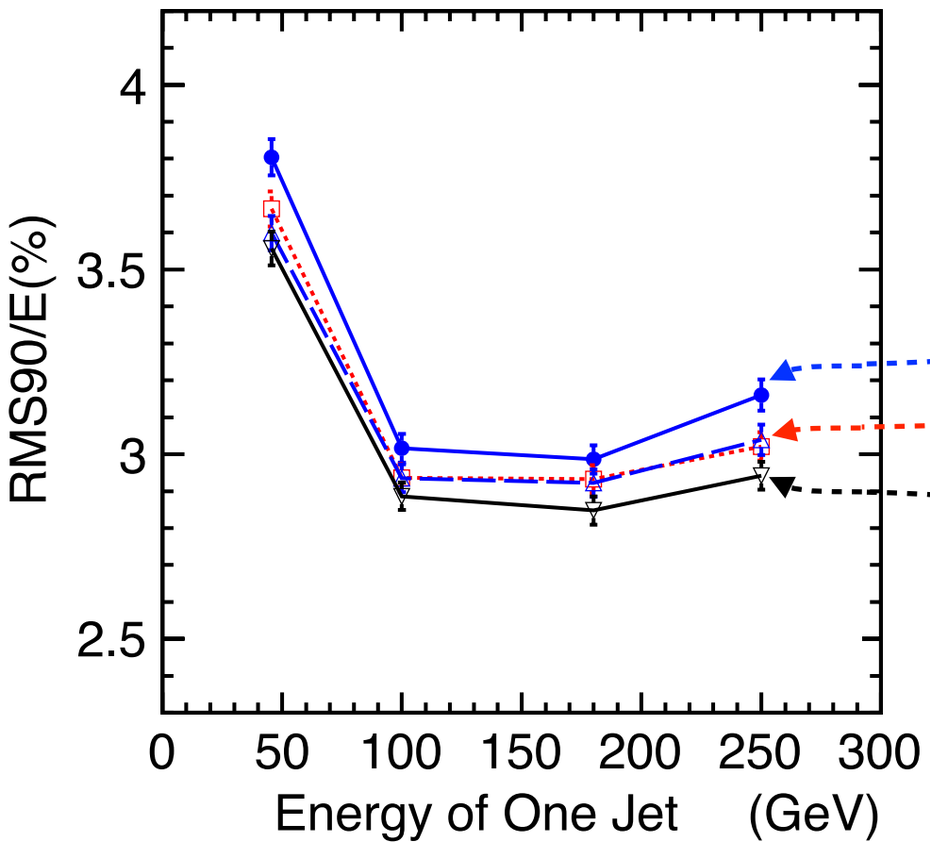
1st step: tile hits are split by referring strip hits

degradation
comes from twofold ambiguities



2nd step: strip hits are split by referring virtual cells on square tiles.

ECAL case



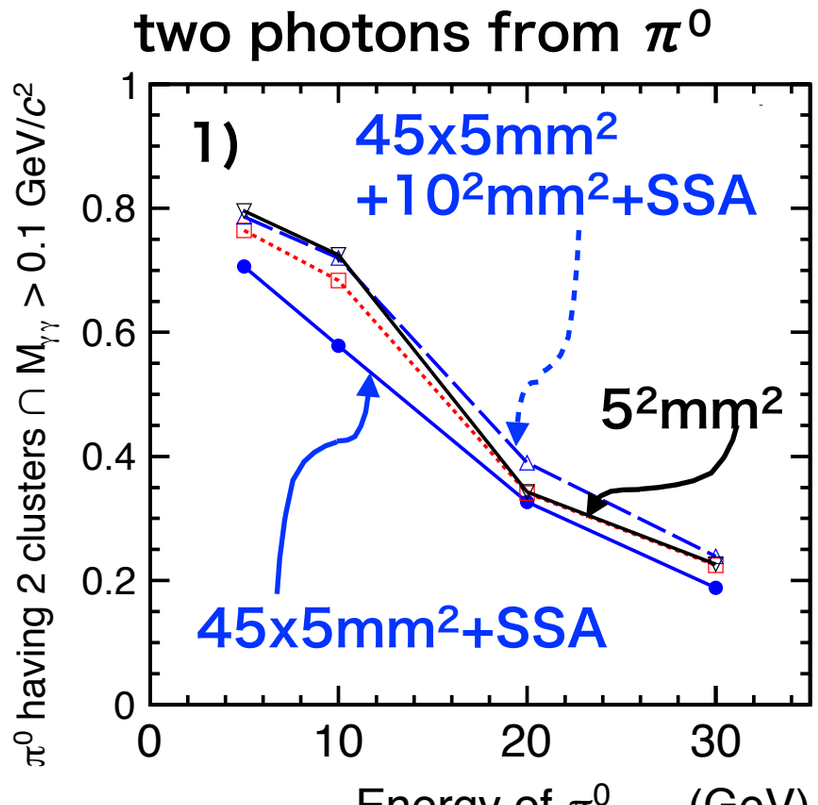
Strip only (45x5mm²)trip w/ SSA

Strip + tile(5×5mm² or 10×10mm²)

Tile only (5x5mm²)

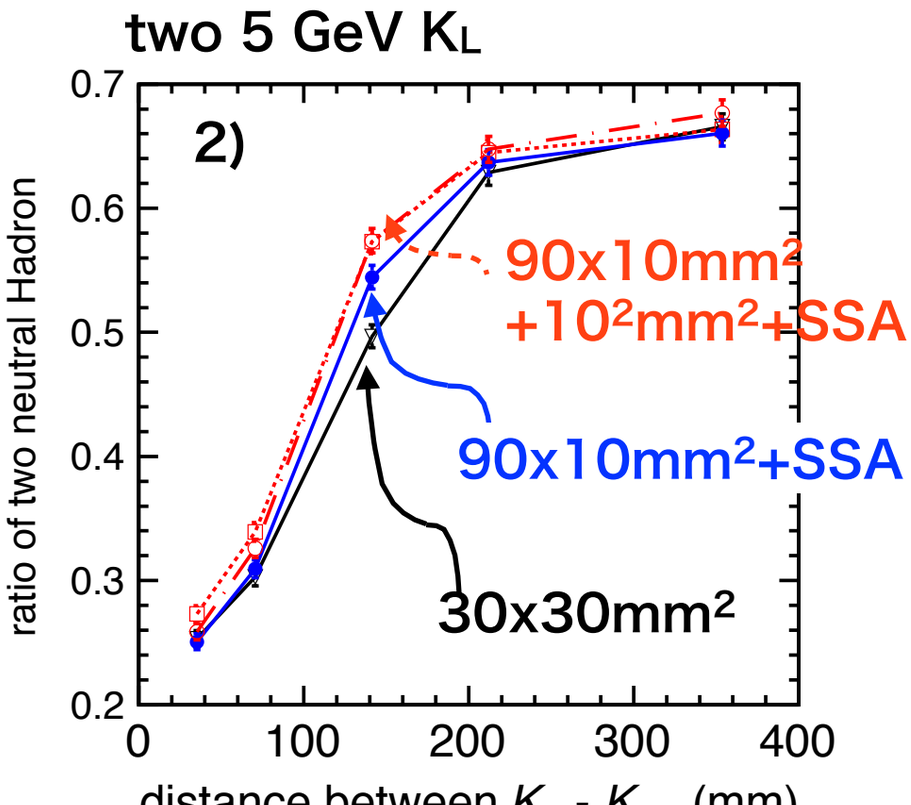
We will confirm with HCAL.

Particle separation



PandoraPFA with SSA

1) two photon separation in ECAL, degradation from 5^2mm^2 tile to 45x5mm² strip/SSA is recovered by alternately replaced 10^2mm^2 tiles.



PandoraPFA with SSA
for HCAL

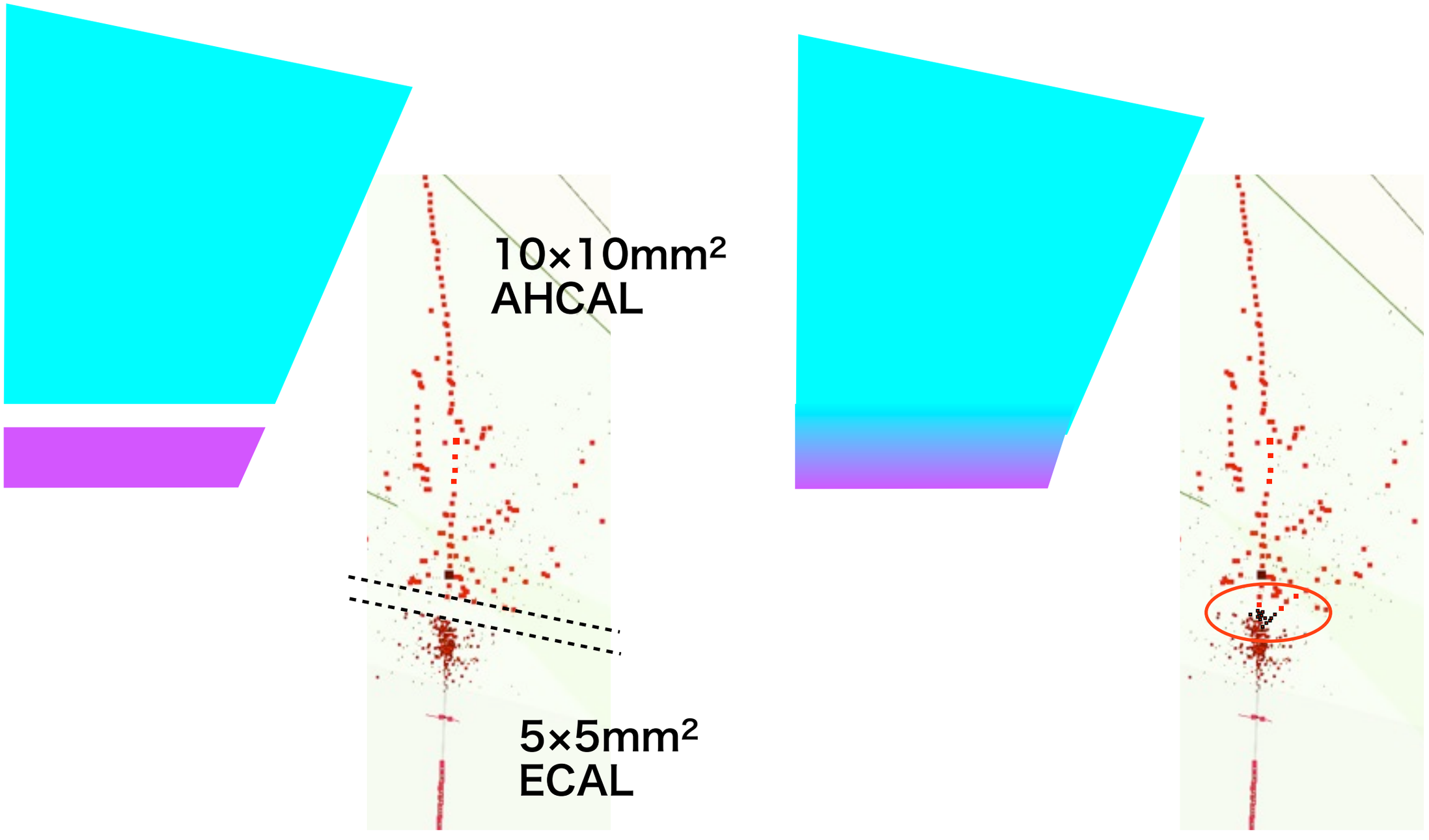
2) two KL separation in E+HCAL of the ILD.
Better ability by 10^2mm^2 than 30^2mm^2, and 90x10mm² + 10^2mm^2 has the same performance as the pure 10^2mm^2 HCAL.

- alternate tile layer in ECAL and HCAL recover from the degrading by strip layers.
- 10^2mm^2 HCAL has better separation ability than 30^2mm^2 HCAL.

Improvement is not large
→ we are developing PFA algorithm dedicating 10x10mm² AHCAL.

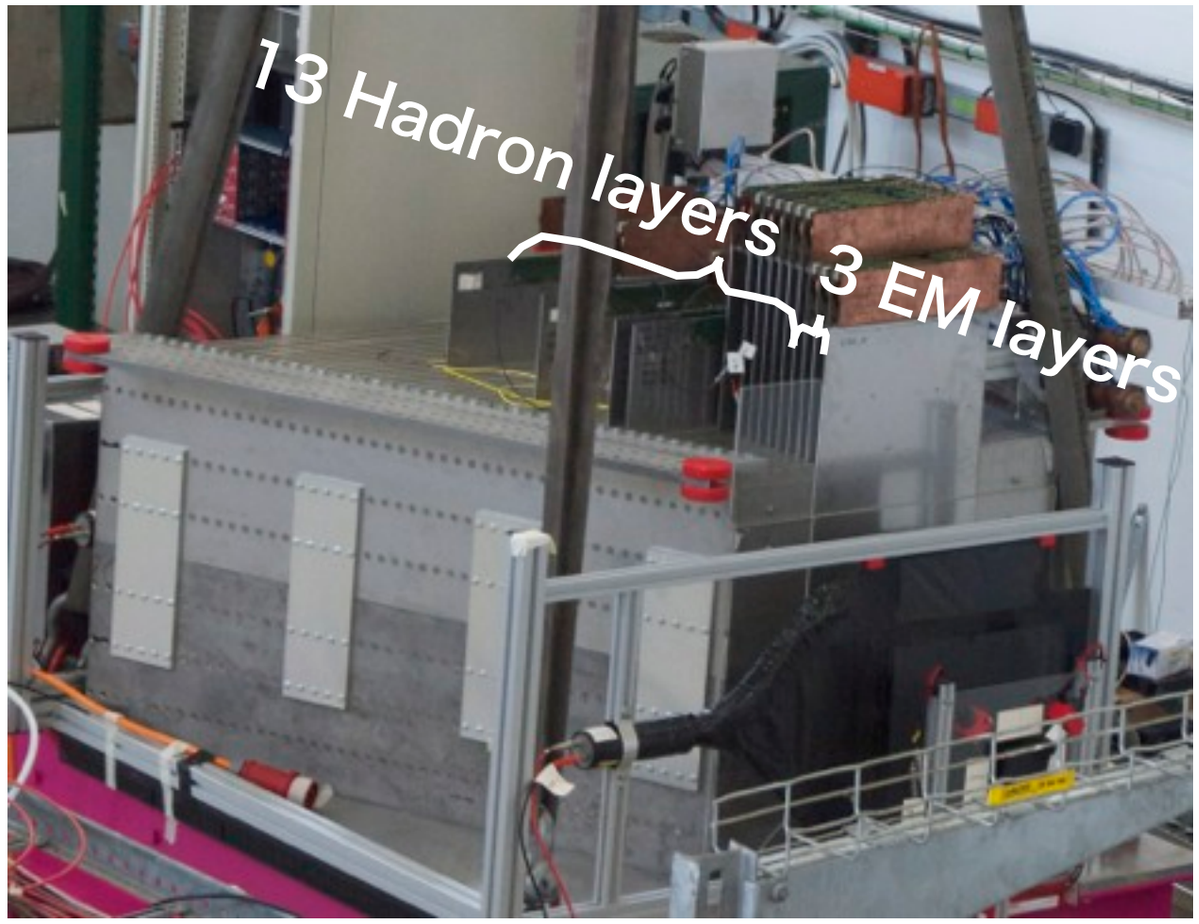
some future **Seamless calorimeter**

Why do we need to separate Ecal and Hcal



Connections of calorimeter tracks between ECAL and HCAL are easily found with the seamless calorimeter

EUDET (quasi Seamless Calo?)



Three EM layers of scintillator strips (45x5mm^2) and 13 Hadron layers of scintillator tile(30^{2}mm^2),
test beam at CERN PS(2014) and SPS(2015)

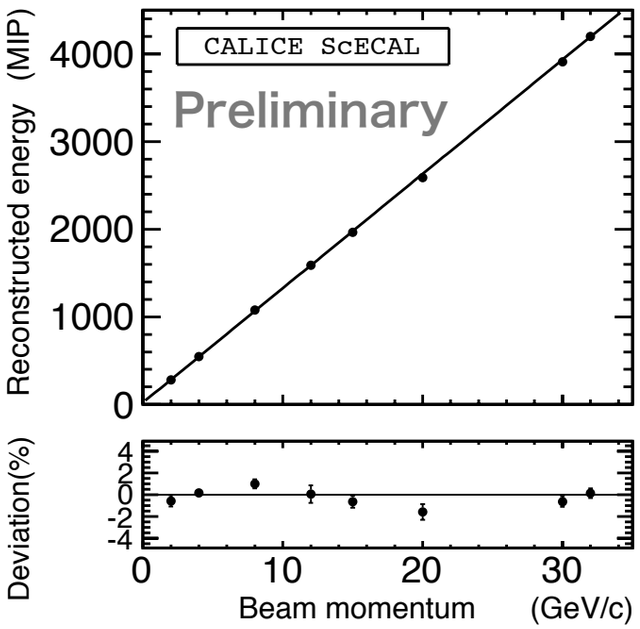
→ Next talk

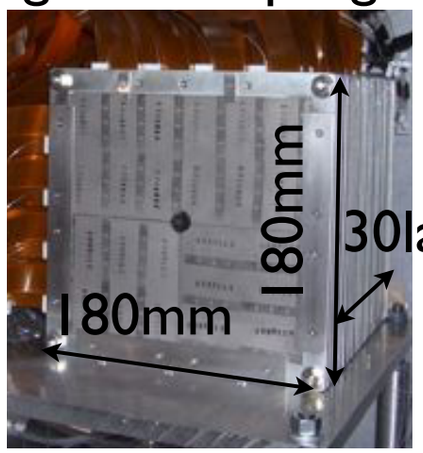
Prototype development

Prototype of ECAL

Physics prototype

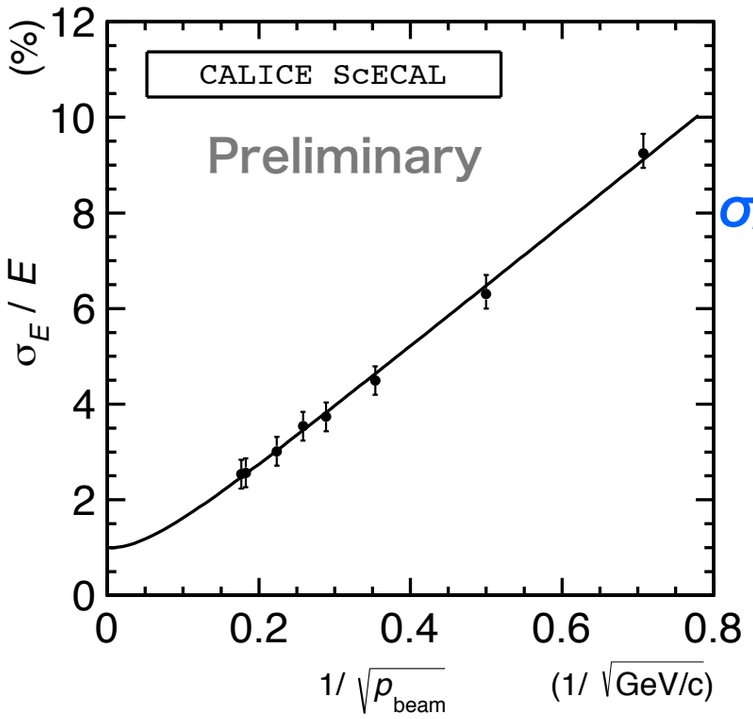
$23X_0$ tungsten sampling cal





10x45x3mm^2 segmented ScCAL prototype

Deviation from linear fit < 1.6(%)

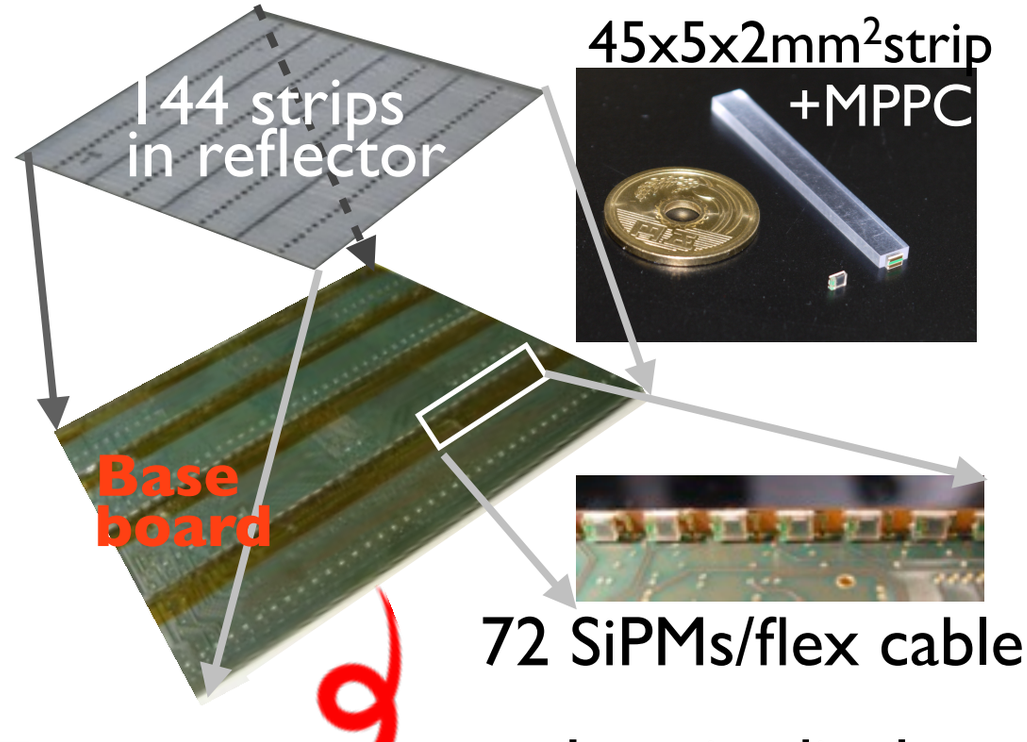


$\sigma_E/E =$

$12.8\pm0.4(\%)/\sqrt{E_{GeV.}}$

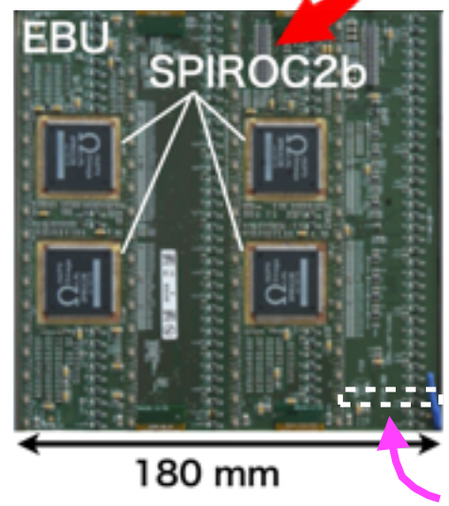
$\oplus\ 1.0^{+0.5}_{-1.0}(\%)$

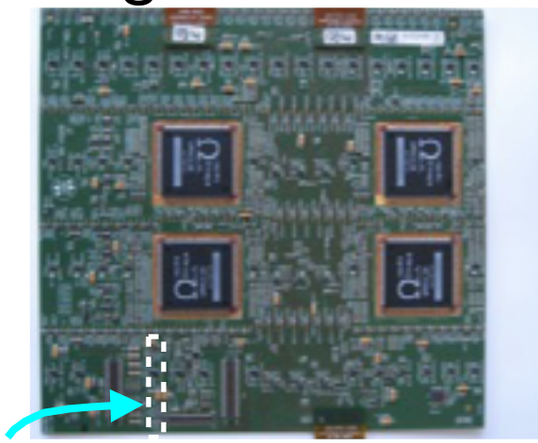
Technological prototype

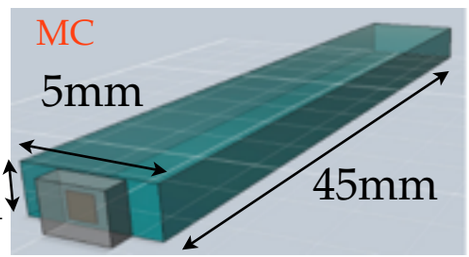


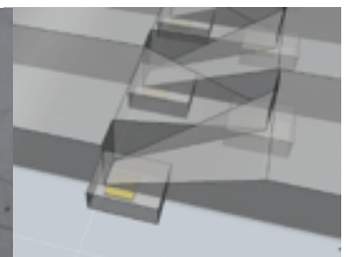
Transverse

Longitudinal









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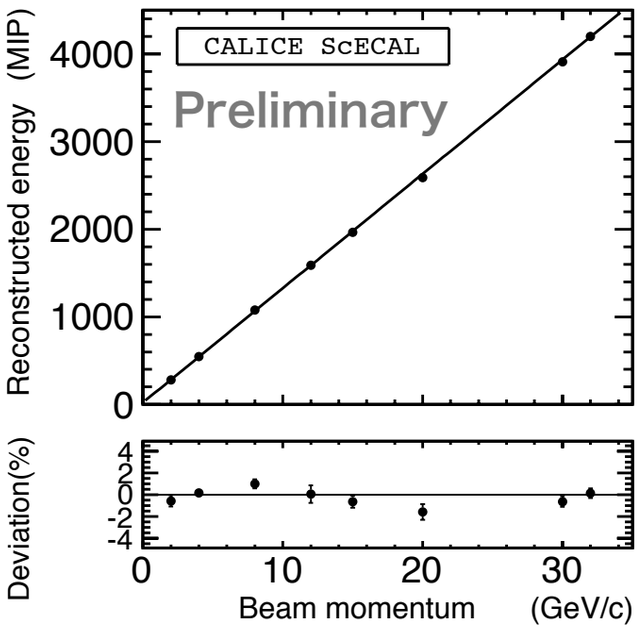
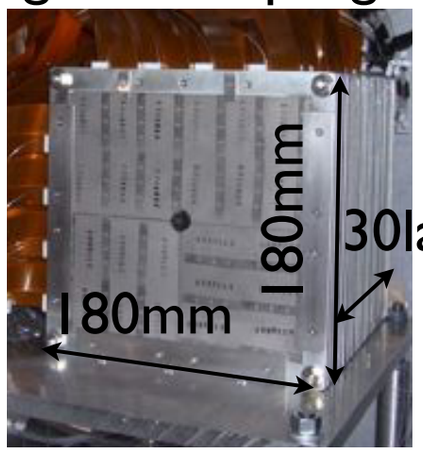
Prototype of ECAL

Physics prototype

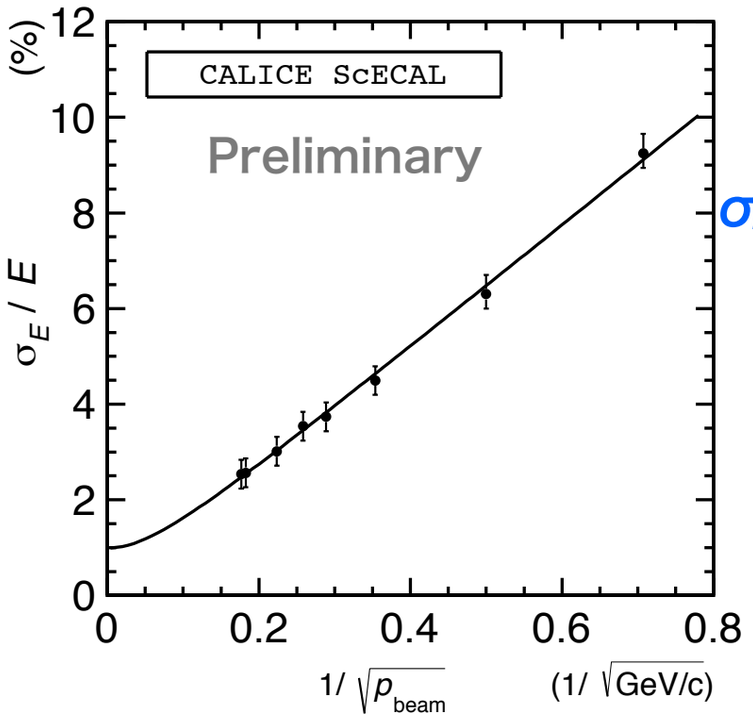


23X_0 tungsten sampling cal



10x45x3mm^2 segmented ScCAL prototype

Deviation from linear fit < 1.6(%)



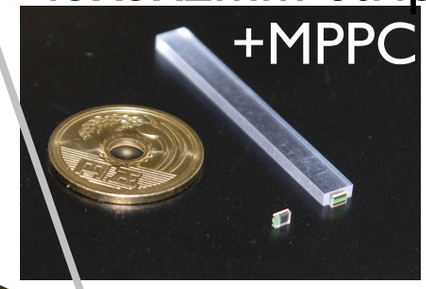
$\sigma_E/E =$

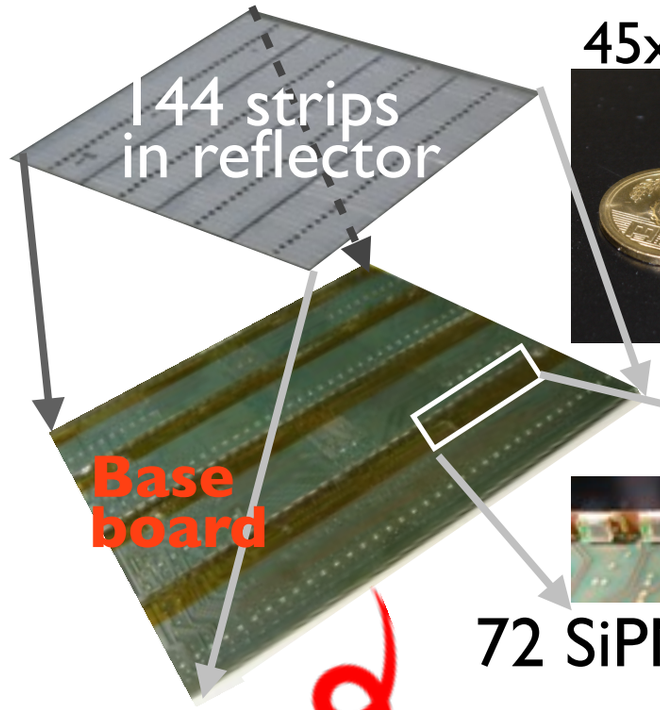
$12.8\pm0.4(\%)/\sqrt{E_{GeV.}}$

$\oplus\ 1.0^{+0.5}_{-1.0}(\%)$

Technological prototype

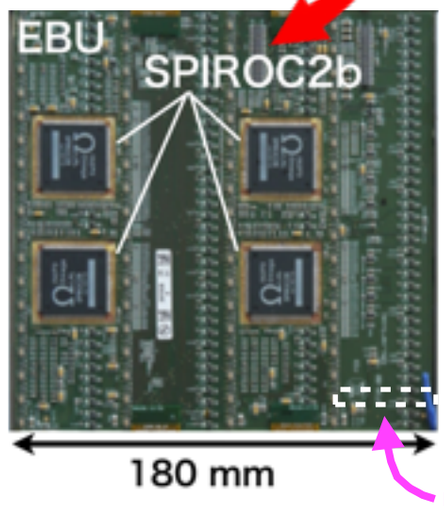
45x5x2mm^{2}strip



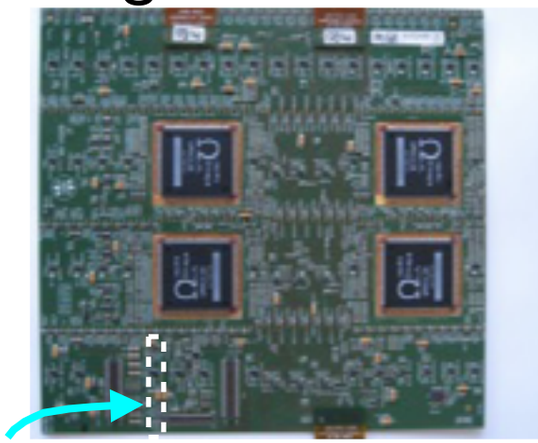


72 SiPMs/flex cable

Transverse



Longitudinal



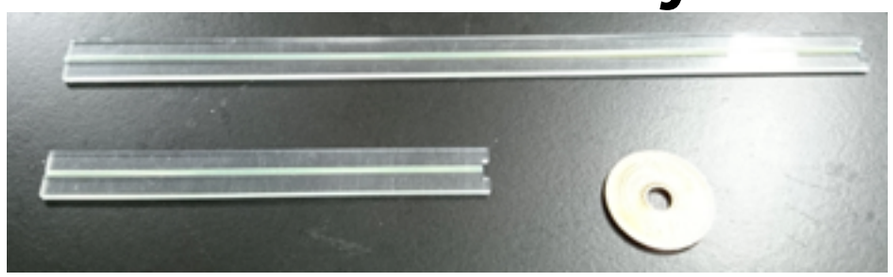
Next talk:test beam

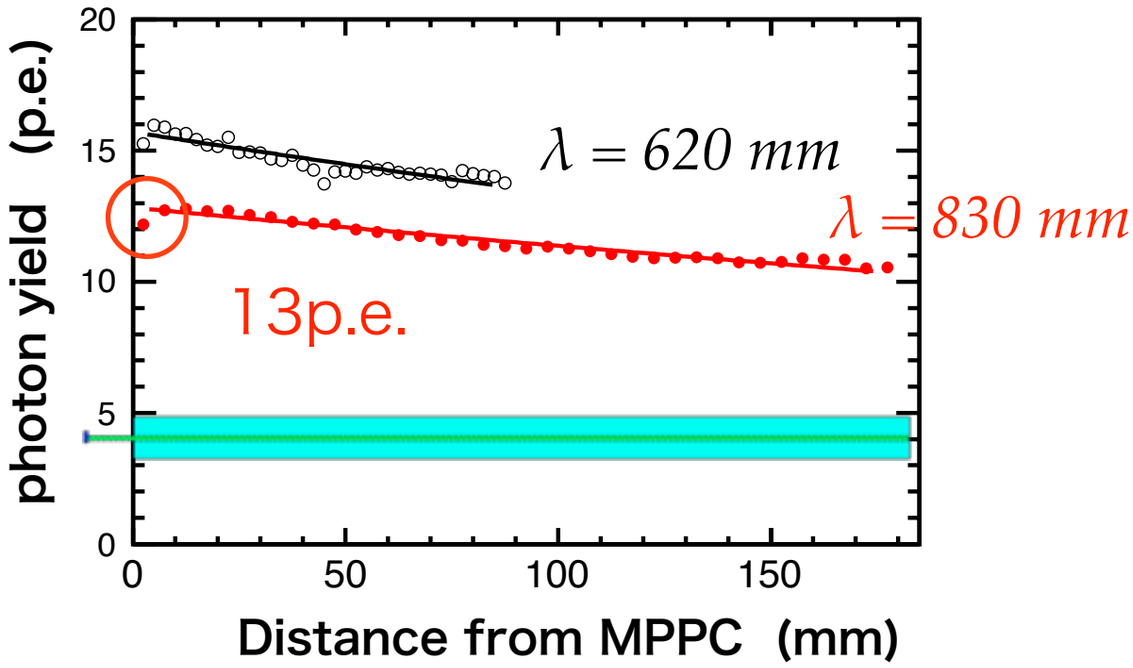
Scintillator/SiPM design for HCAL

with WLS fiber

@2014 test beam

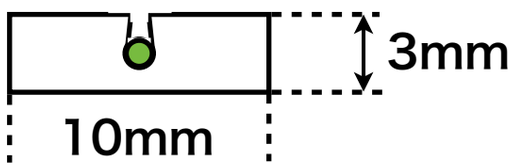
2mm thick Kuraray SCSN 38

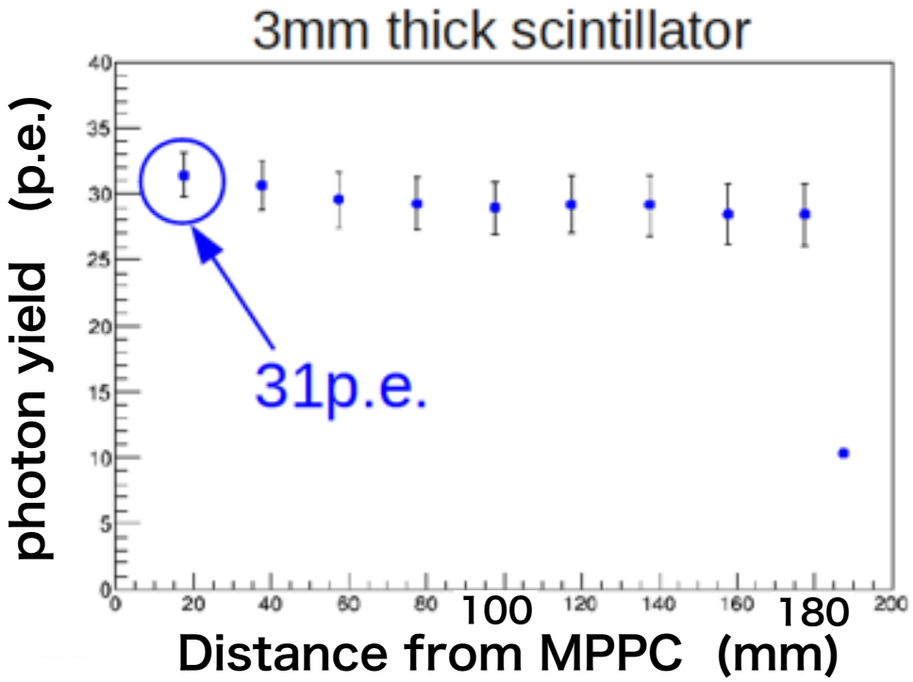




@2015 test beam

3mm thick ELJEN 204



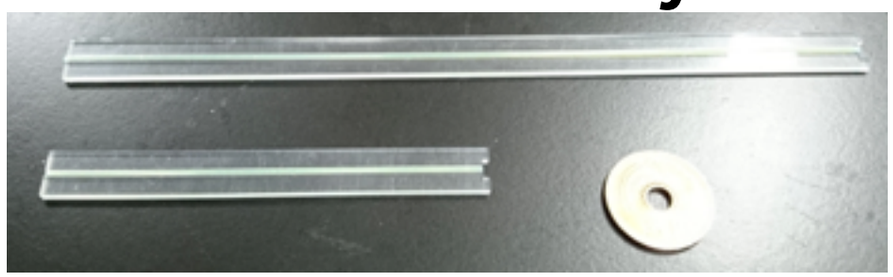


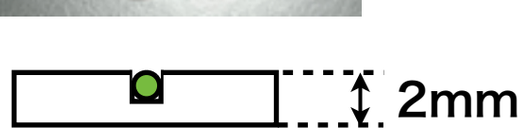
Scintillator/SiPM design for HCAL

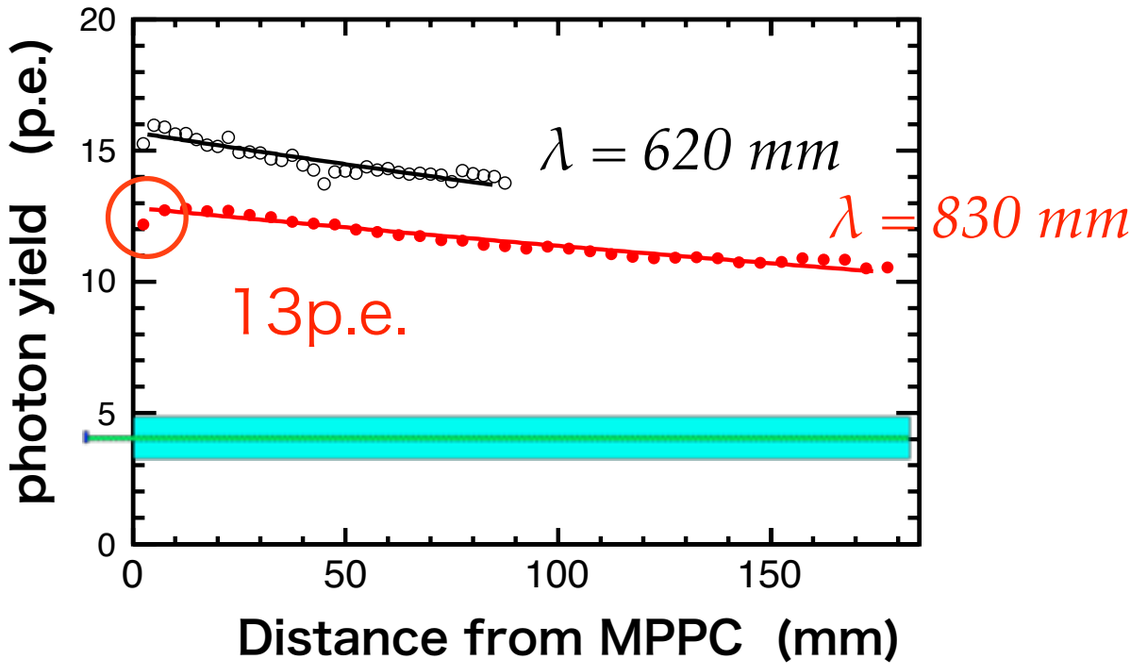
with WLS fiber

@2014 test beam

2mm thick Kuraray SCSN 38

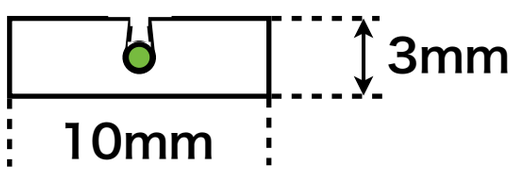


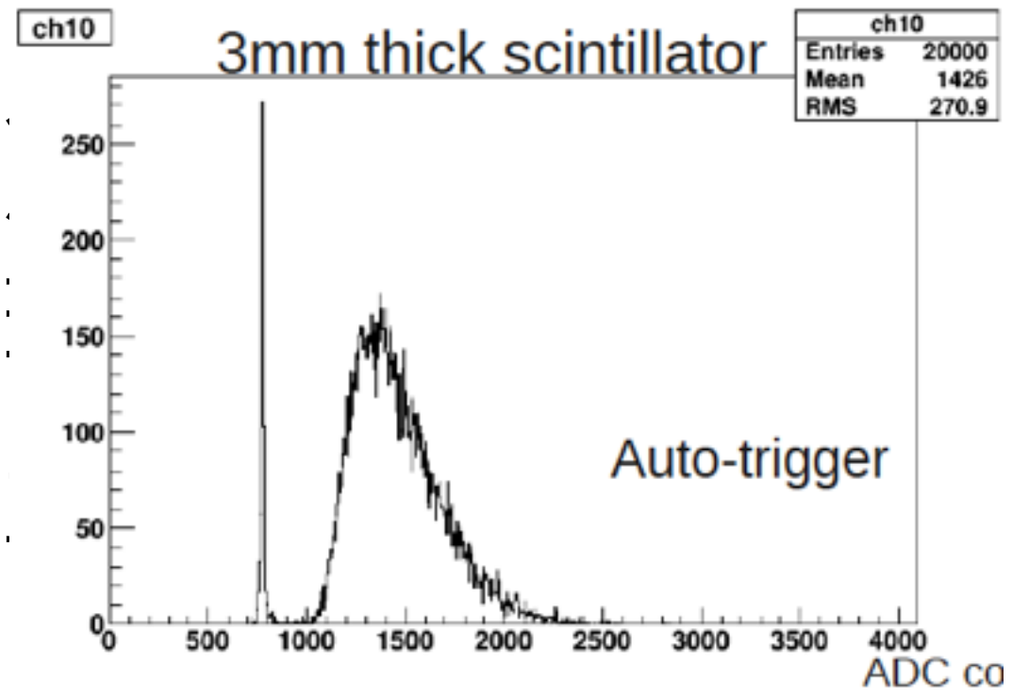




@2015 test beam

3mm thick ELJEN 204





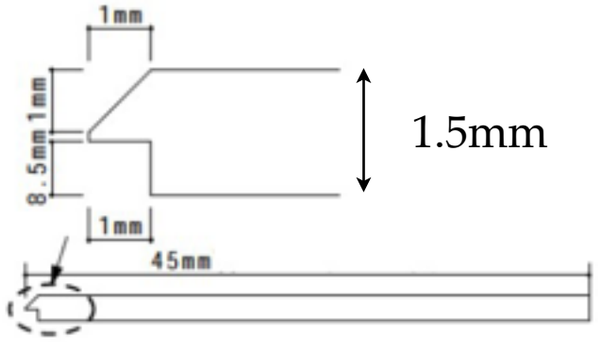
Scintillator/SiPM design w/o WLS

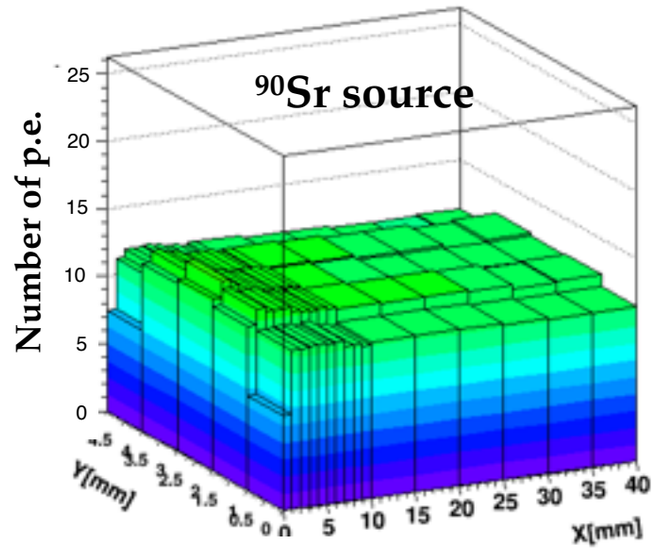
Ultra narrow SiPM sensor (0.25×4 mm², 0.13x8mm²) makes good uniformity and dead volume free

Bottom readout with 4 mm × 0.25 mm MPPC

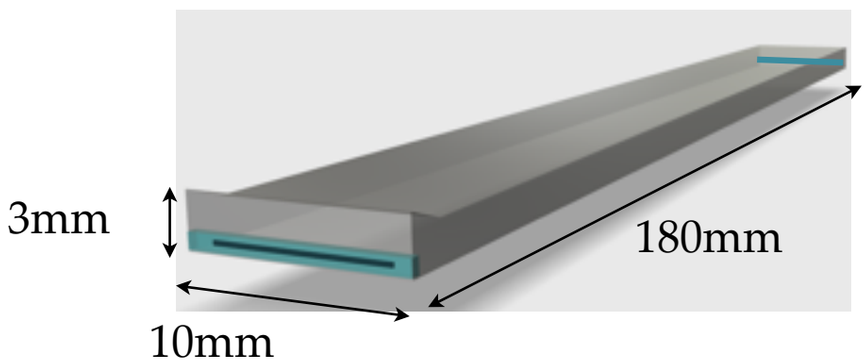
MPPC with shade

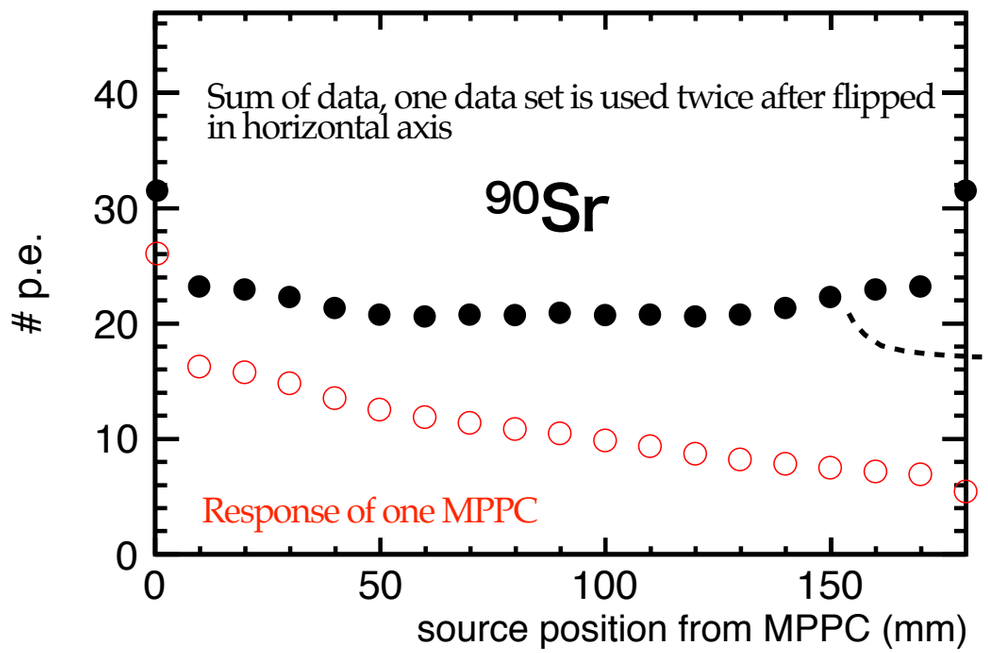
Instead of real 4 × 0.25 mm² MPPC, a shade is temporally used.





Dual readout





δ p.e. ~1p.e./cm

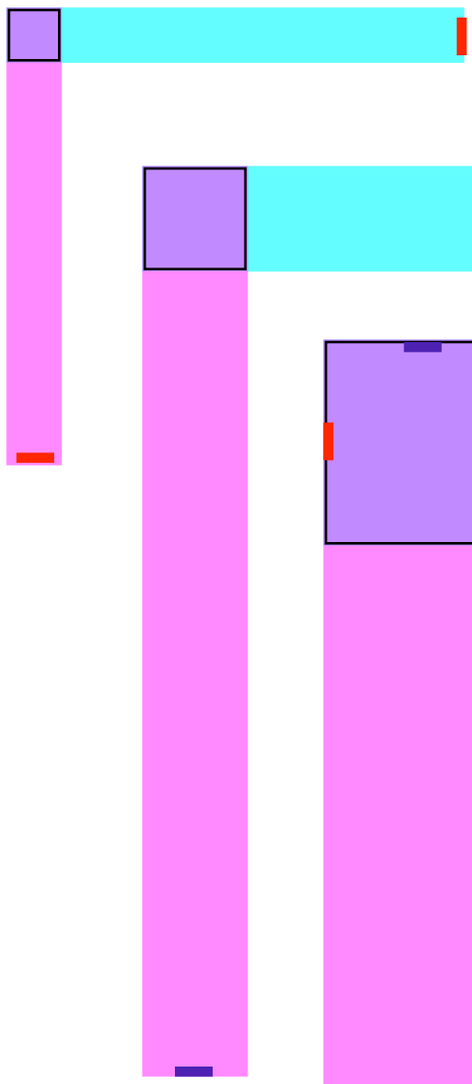
σ_{pos} ~ 30-60mm

Dual readout (emulated)

Also taking coincidence reduces dark noise.

(need additional function on the readout ASIC)

Scintillator variation for both good single particle energy resolution and good cluster separation



:45×5mm² for ECAL

:90×10mm² for HCAL

:90×20mm² for HCAL

both side MPPCs remove random noise.

requiring coincidence

:180×10mm² for HCAL

Dual readout method removes random noise and give us additional position information from difference of detected # p.e. between both side MPPCs.

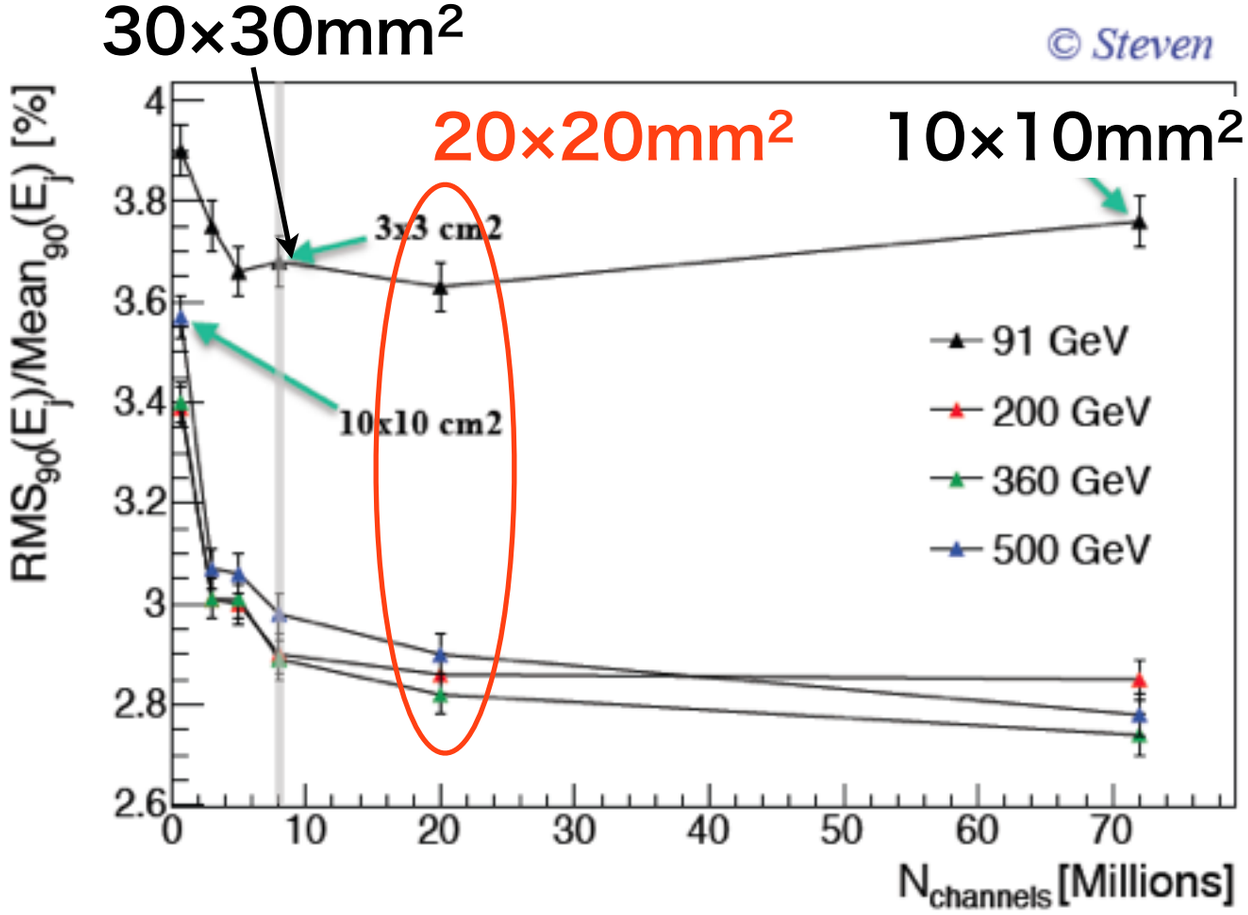
Scintillator variation for both good single particle energy resolution and good cluster separation

:45×5mm² for ECAL

:90×10mm² for HCAL

:90×20mm² for HCAL
both side MPPCs remove random noise.
requiring coincidence

30×30mm²



noise and give
difference of
Cs.

Summary and plan

We are developing scintillator strip calorimeter for both EM shower and hadron shower.

The scintillator strip cal have advantages:

- ultra fine(10×10mm^2)segmentation with full energy measurement HCAL→ Best jet energy resolution
- noise suppressed ScHCAL by dual readout,
- Gap free calorimeter between ECAL and HCAL

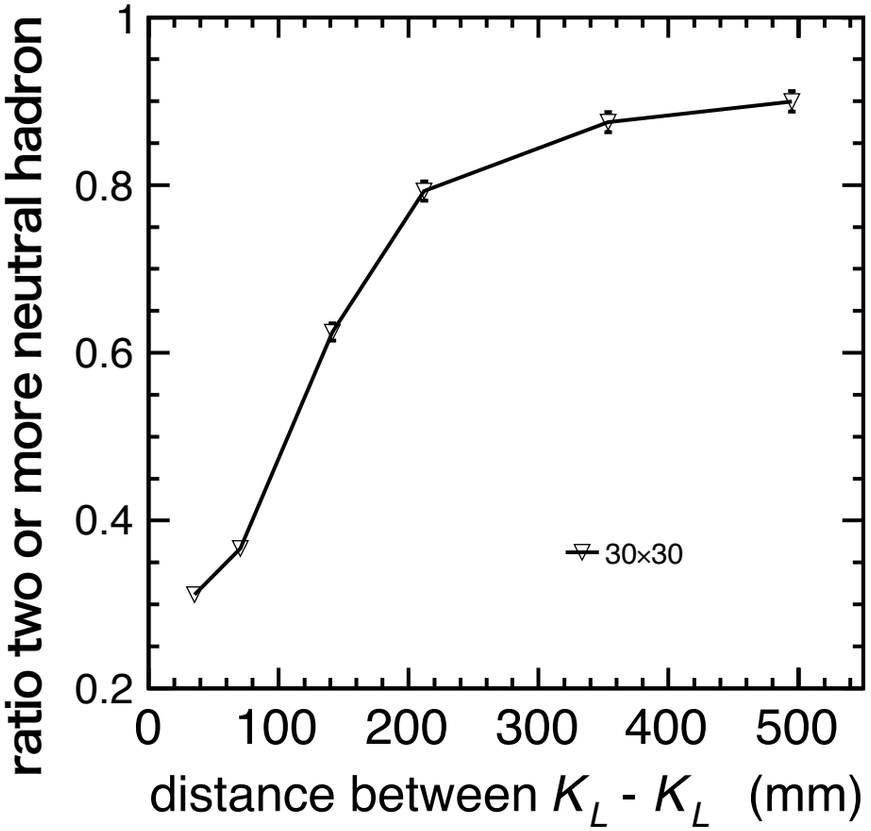
For those we need:

- develop PFA algorithm dedicating to the 10^{2}mm^2 AHCAL,
- ASIC having coincidence function,
- Mechanical structure which has both tungsten absorber and steal absorber.

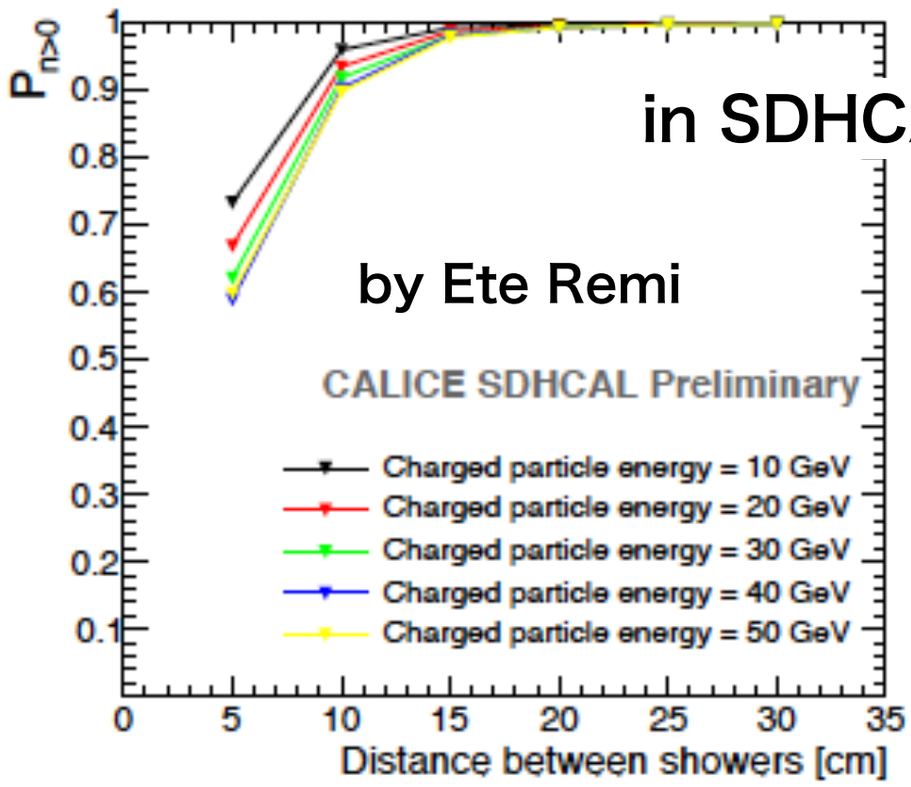
backup

hadron particle separation

two 5 GeV K_L separation in 30×30mm² HCAL ILD by PandoraPFA



Separation of 10 GeV neutral hadron and charged pion of various energies by ArborPFA



10 GeV and other energy of two charged real pion events are artificially overlaid, and track segment is removed from 10 GeV to emulate a neutral hadron.

Although we cannot directly compare those because the events topology is different from each other, 10×10mm² SDHCAL can be expected to have good separation ability.

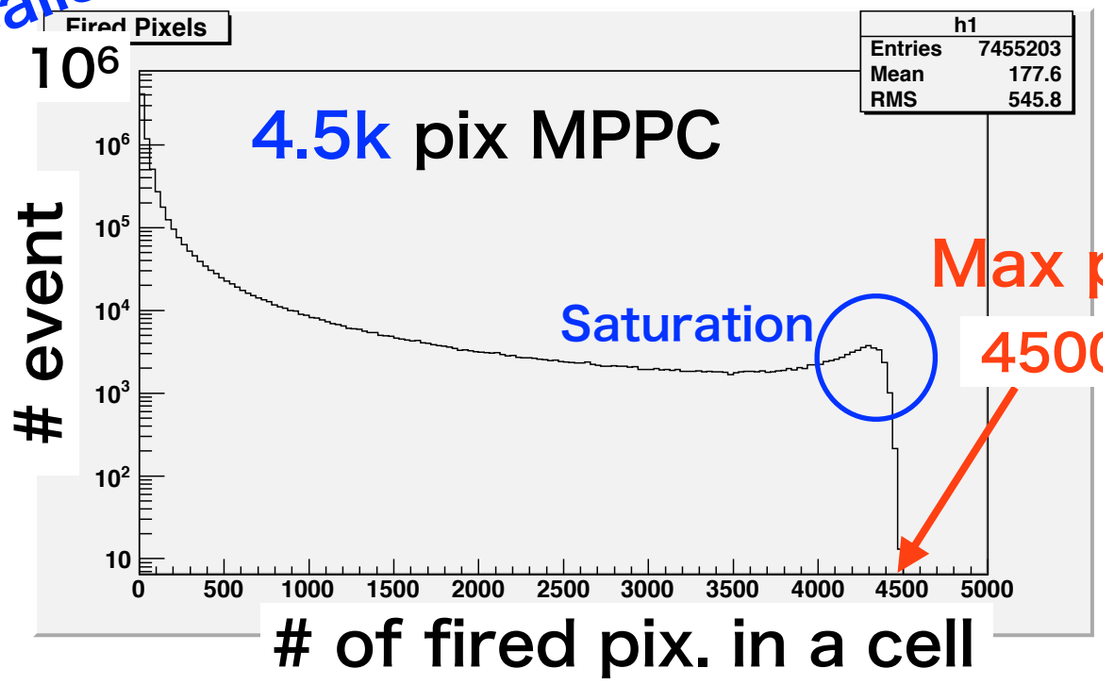
required SiPM for ECAL

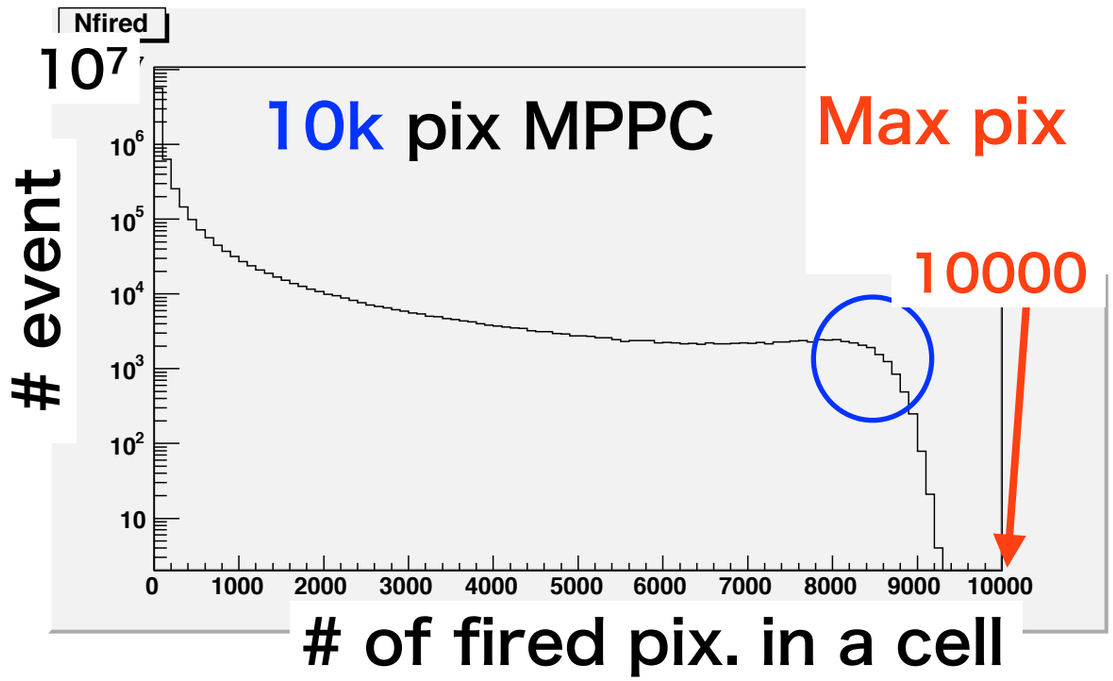
requiring:

a 250 GeV electron (one electron from 500 GeV Bhabha scattering) can be measured.

MC in ILD w/ D. Jeans' realistic Sim

Distribution of # of fired pixels in 250 GeV EM shower

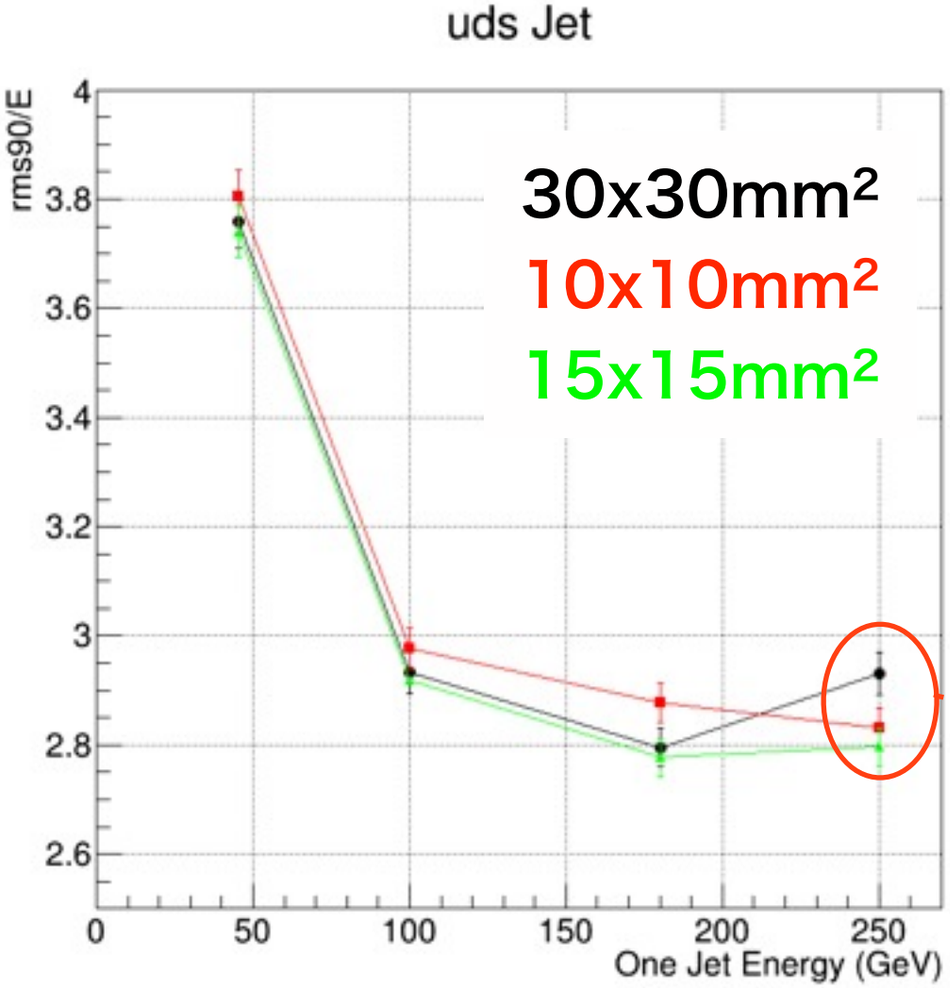




1mm² sensitive area ← cost

10k pix MPPC → 10μm pitch

Development of PFA for strip HCAL



As like S. Green's result, $10^2 mm^2$ AHCAL does not improve JER than $30^2 mm^2$ HCAL.

fine segmentation HCAL has potential to have better JER as the energy higher than 250 GeV

We are developing PFA method dedicating fine granular scintillator HCAL