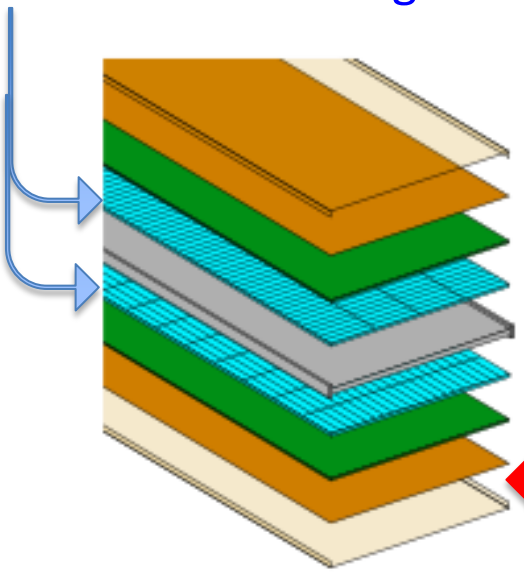
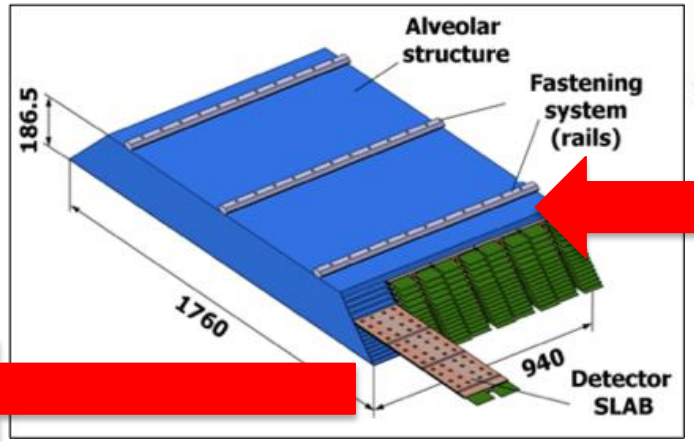
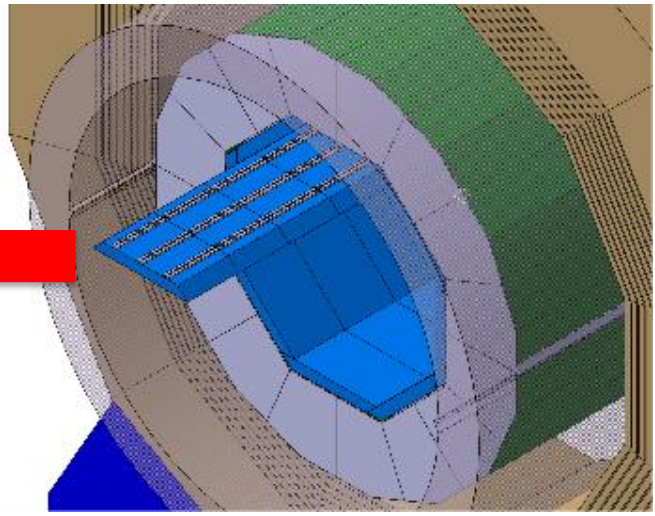
R&D status of the Scintillator-strip based ECAL for the ILD

Oct 2014 @ LCWS14 Belgrade
Satoru Uozumi (KNU)
For the CALICE collaboration

Scintillator strips
For active & fine granular sensor







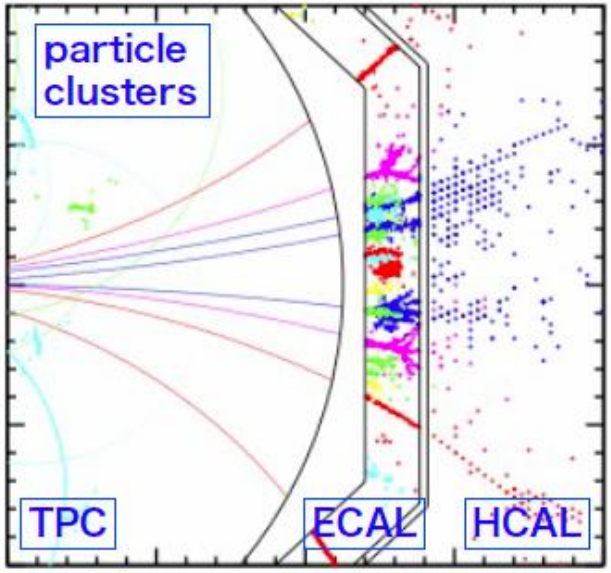
Contents

- Introduction of the Scintillator-strip ECAL (ScECAL)
  - Principle & structure
  - Physical & Technological prototypes

- Improvements ongoing
  - Hardware … optimization of scintillator shape and optical signal readout
  - Software … hit strip →cluster reconstruction Evaluation of Jet Energy Resolution (JER)

Introduction : Why ScECAL?

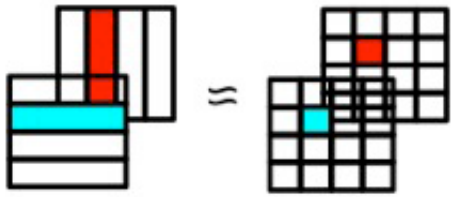
- First requirement : high granularity to improve jet energy resolution
- Second requirement : chop the calorimeters as small as possible

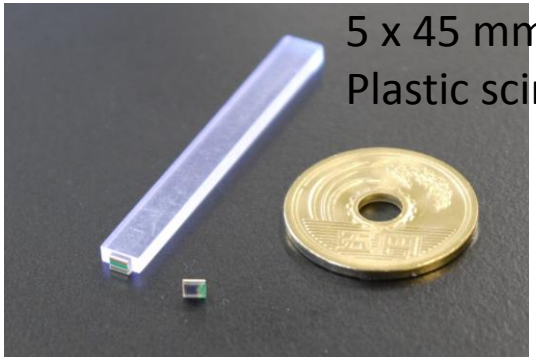


☆ Need 5 mm x 5 mm effective segmentation

→ Strip idea

Orthogonally aligned strips with Pixelated Photo Detector (PPD) make "virtual cells".





5 x 45 mm

Plastic scintillator

~ 10^7 strips

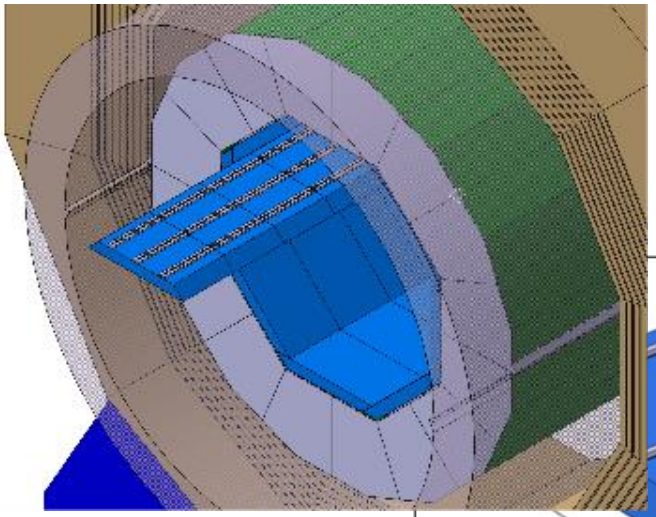
☆ Low cost.

☆ many established technologies

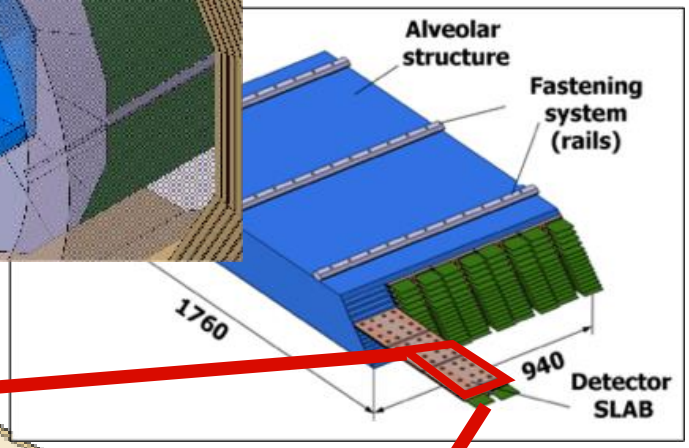
☆ Challenge with new Si-photo sensor

☆ Timing resolution < 1 ns

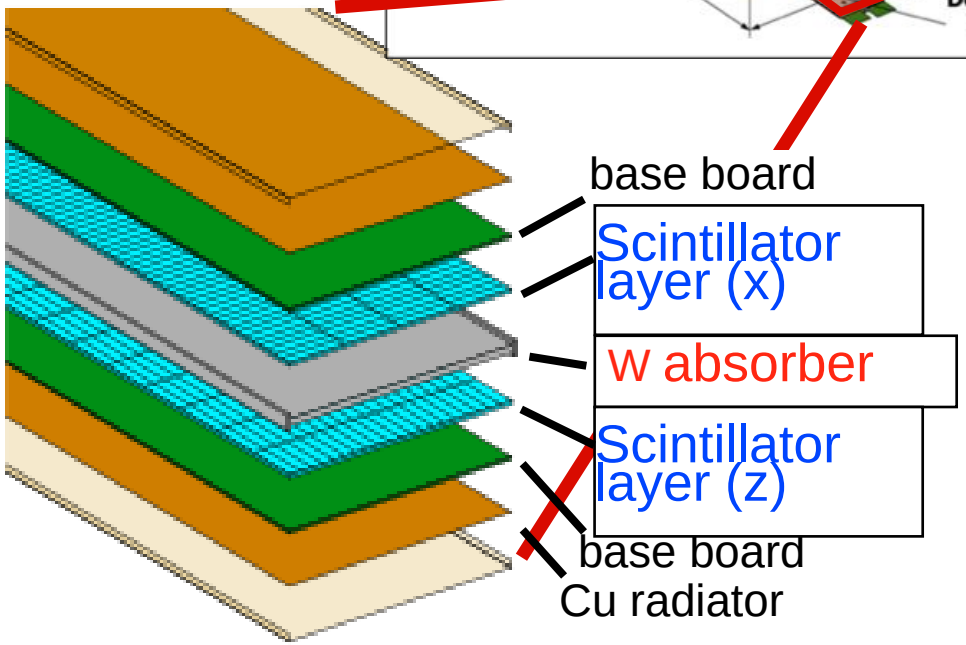
Strip ScECAL in the ILD



- Mechanical design of the barrel and the endcaps is developed by CALICE ECAL group.



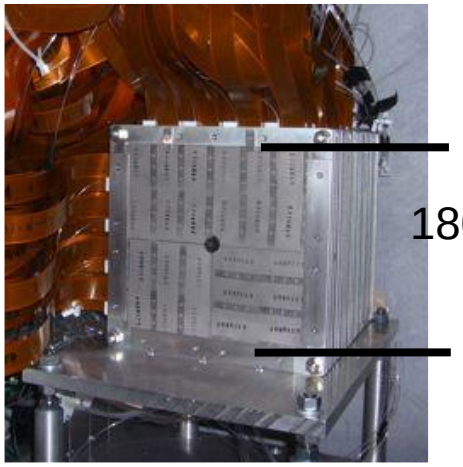
- "Alveolar" frame structure is made with tungsten absorber.



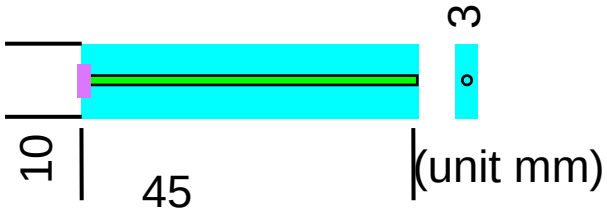
- Two scintillator layers in an alveolar make a sandwich structure with a tungsten absorber.
- Strip directions are orthogonal to each other.

Physics & technological prototypes

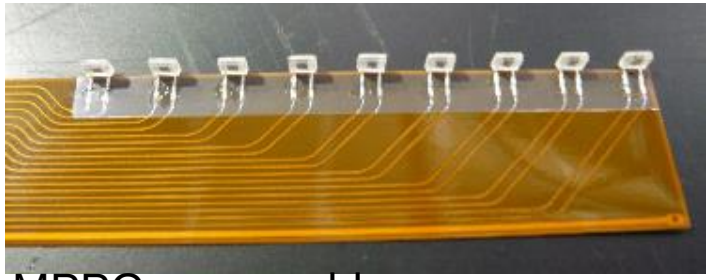
Physics prototype (BT 2009@FNAL, will be published to NIM)



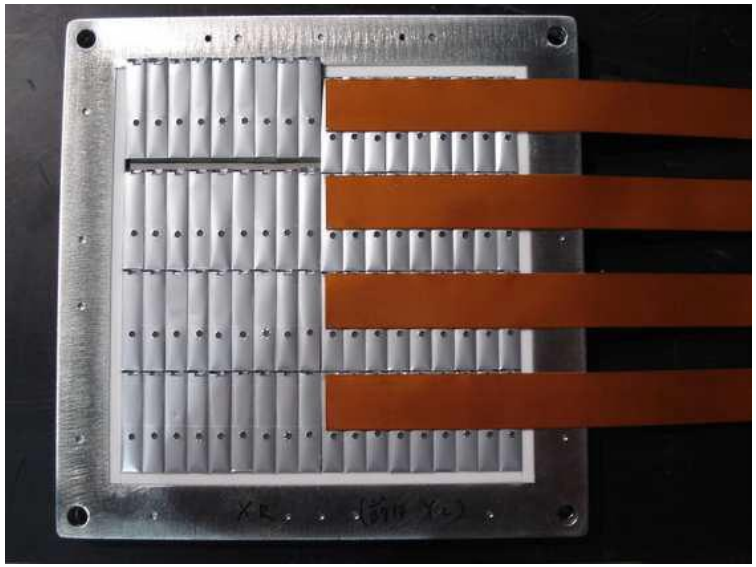
180x
180mm^2
x30 layers
2160 ch



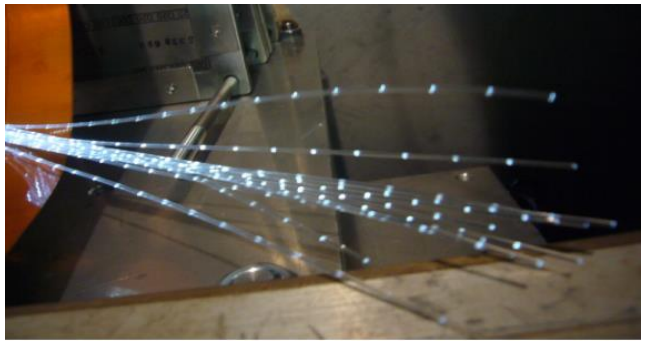
Scintillator strip with MPPC and WLS fiber



9 MPPCs on a cable



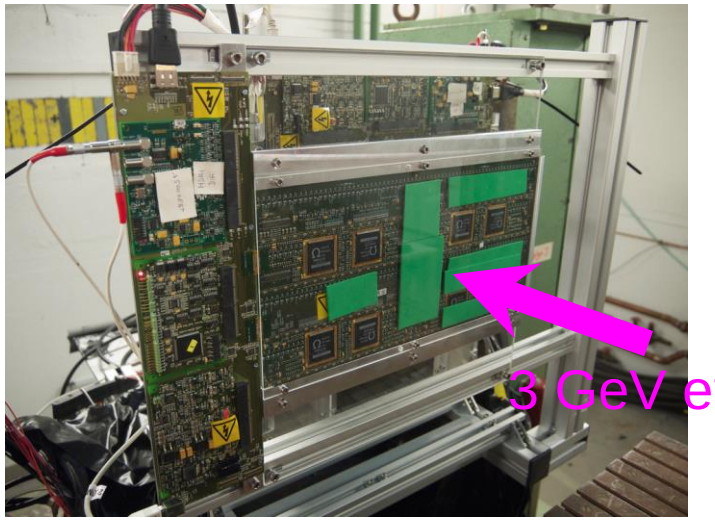
An array of strips in a layer

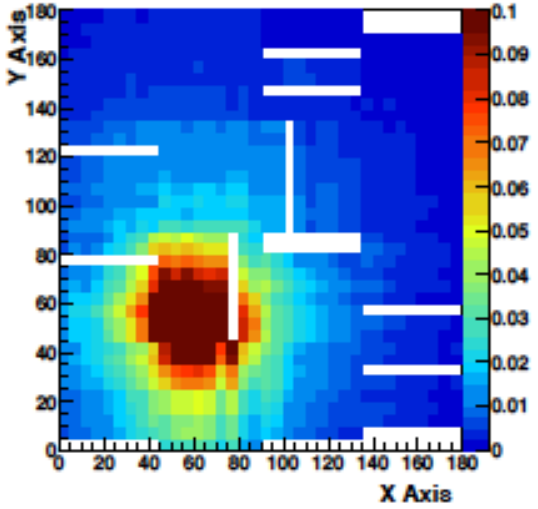


LED light is distributed to each channel by those fibers

Two layers of Technological prototype

BT@DESY 2013

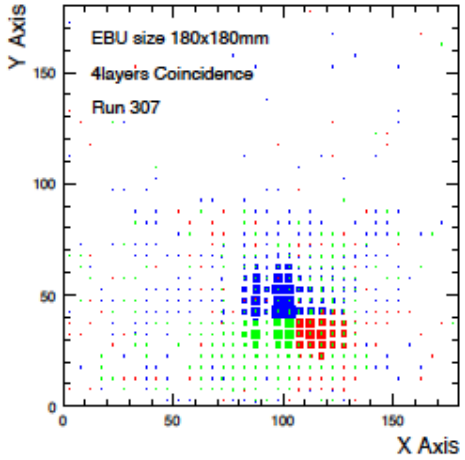




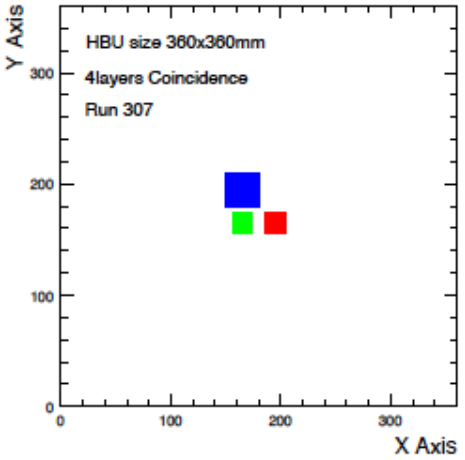
Tungsten plate in front of ECAL

Ecal behind AHCAL :-)

two-layers ECAL



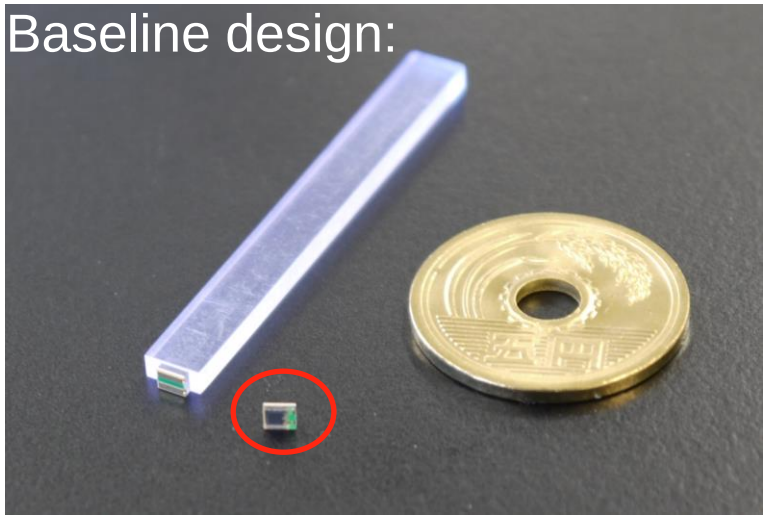
two-layers HCAL



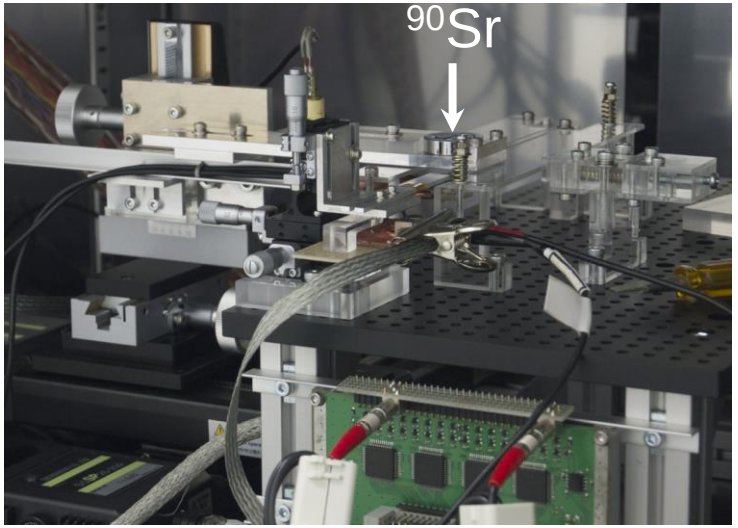
one HCAL channel corresponds 6x6 ECAL segmentations

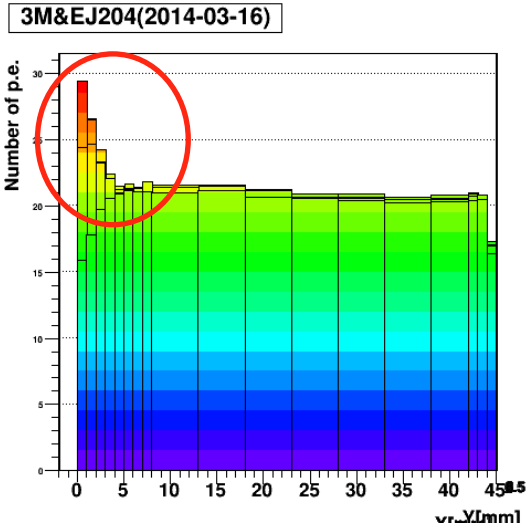
Improvements of scintillator & photo-sensor components

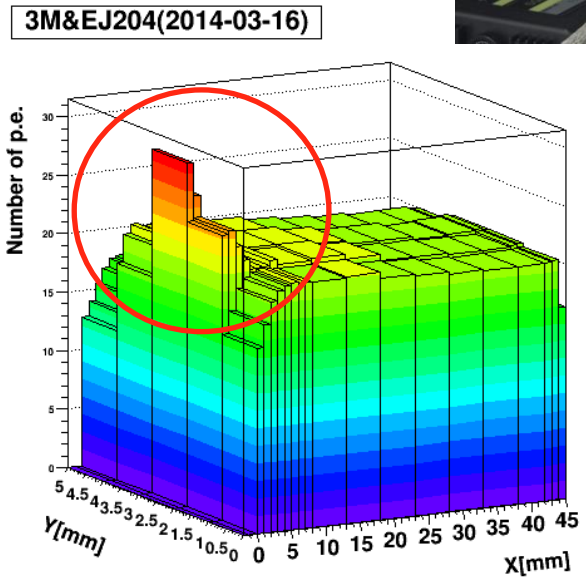
Granularity 10mm → 5mm … hard step



Beta-ray scanning system





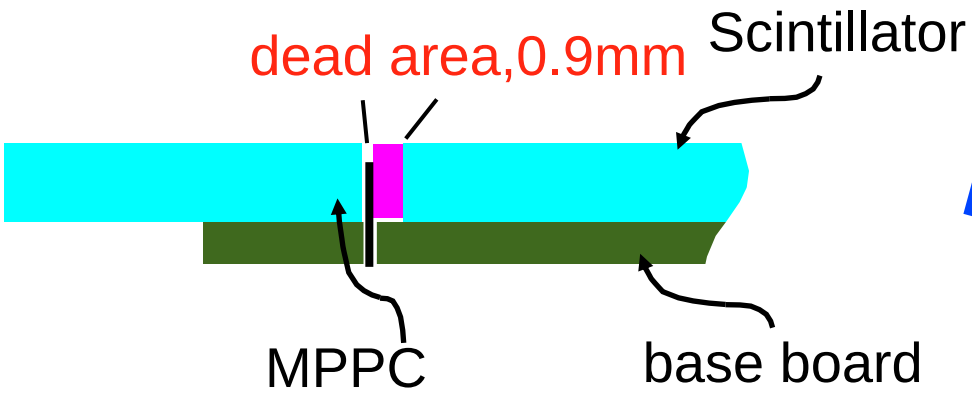


- Photon yield (~10p.e.) is OK
- Uniformity is almost OK except very close side of the photo-sensor

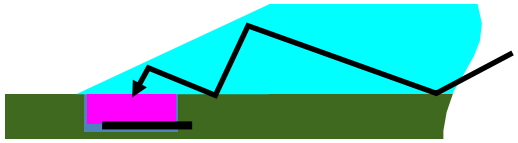
Any idea to uniformize scitillator-strip response?? → next

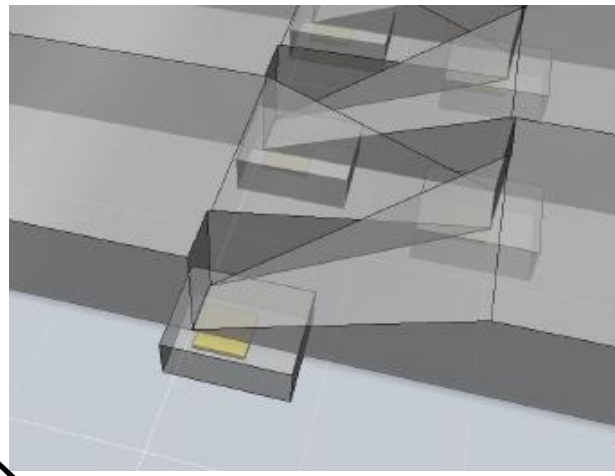
New ideas

Baseline design has

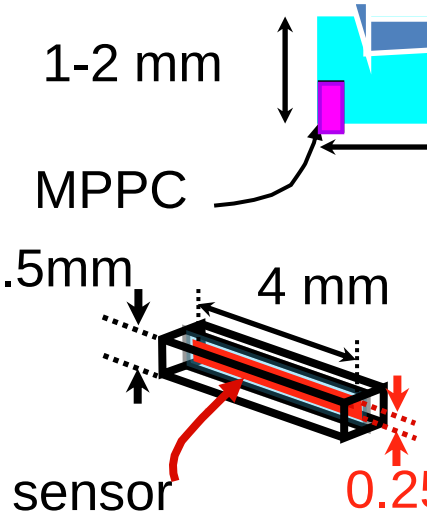


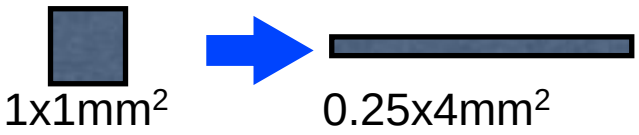
Bottom readout with wedge

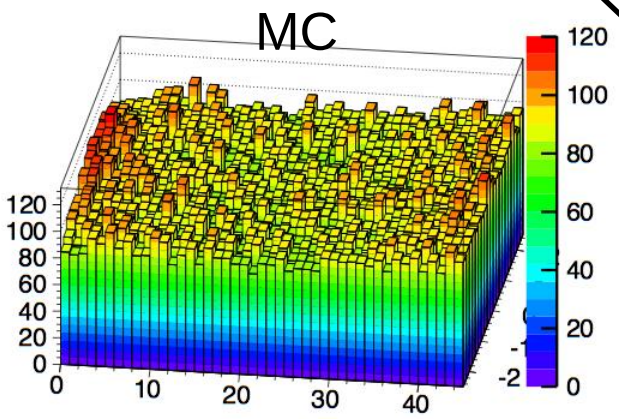




Tokyo Group



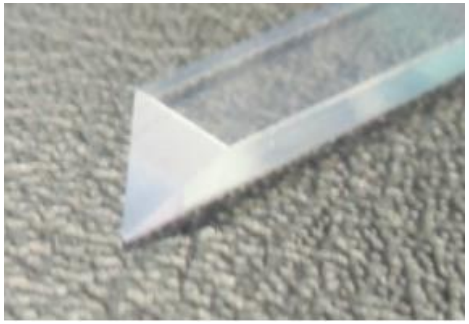


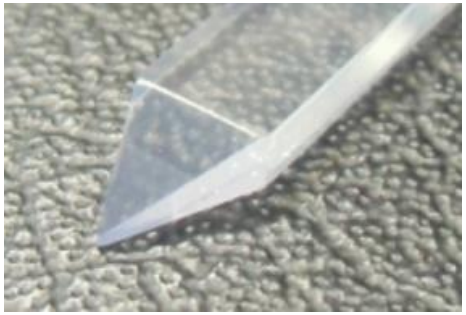


Wedge-type readout strip

(Otani group@Tokyo)

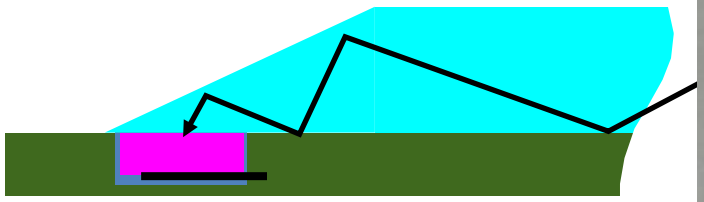
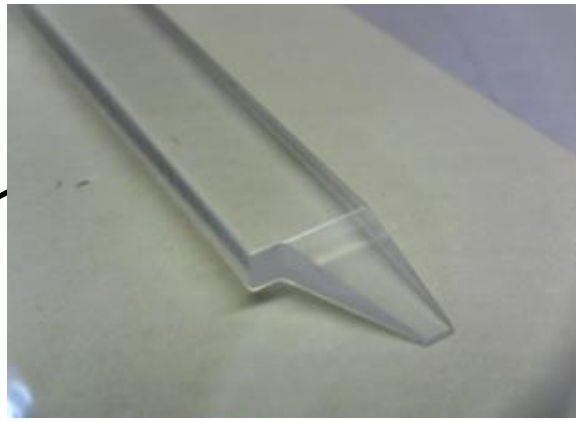
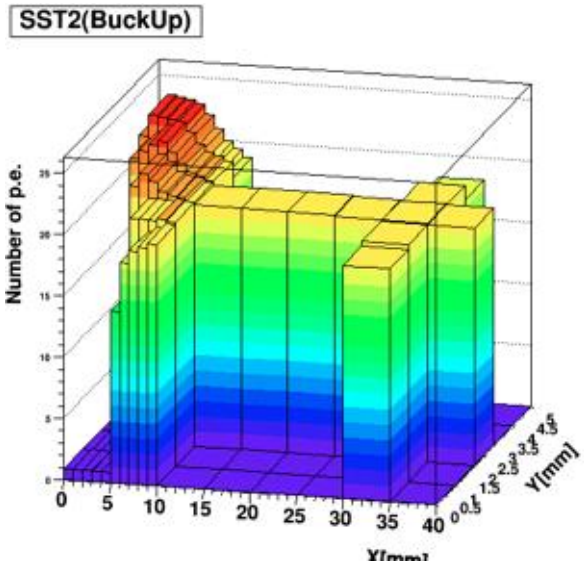
Many wedge types are tested



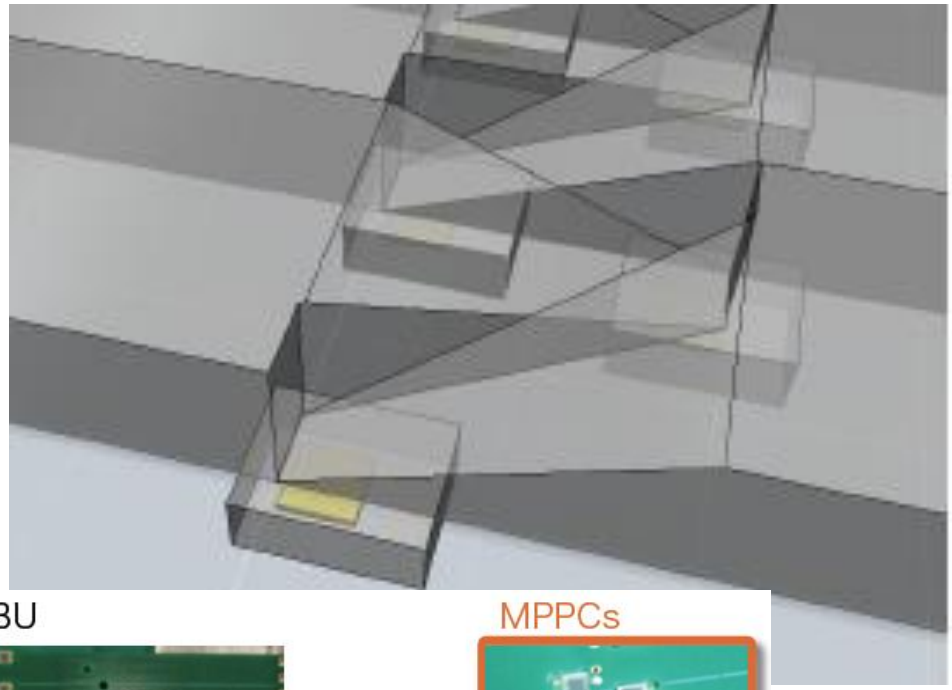


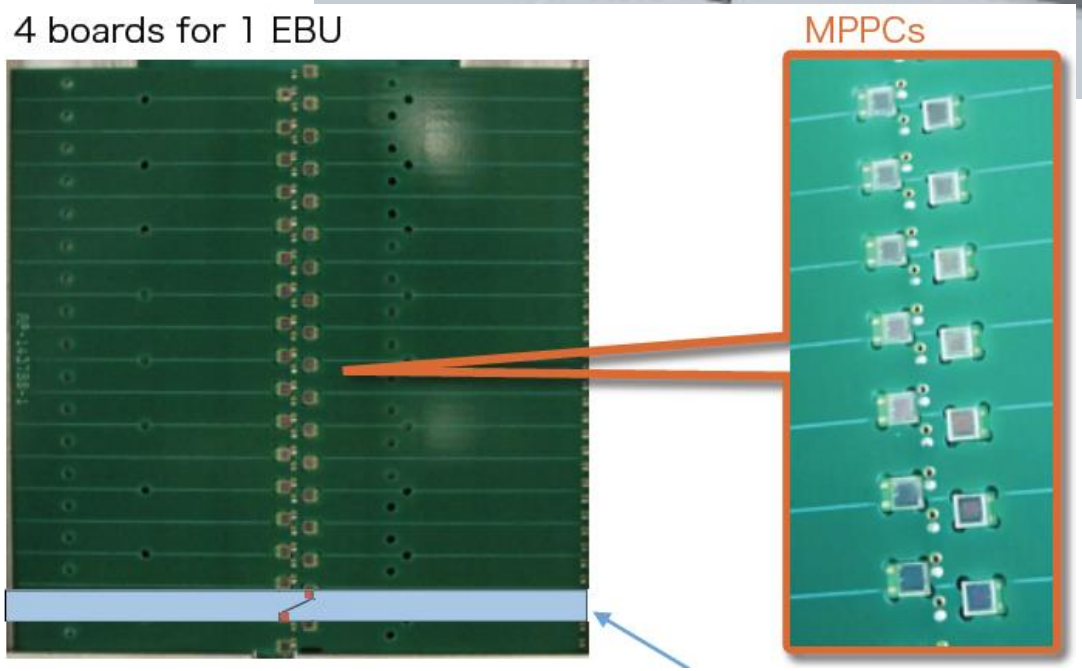
Current best solution (by horizontal beta-ray scan)

- Better response uniformity than baseline design
- High light yield

Wedge-type readout : implementation

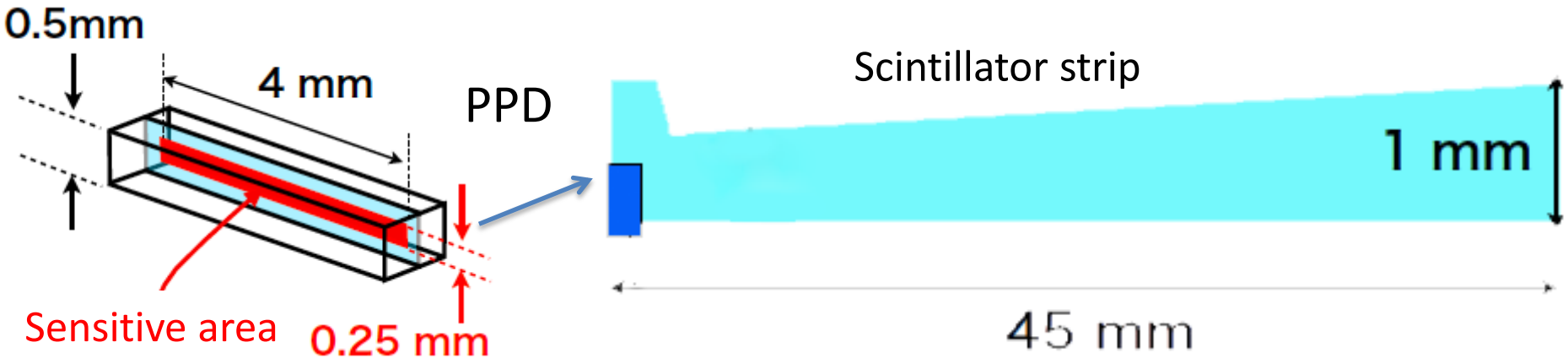




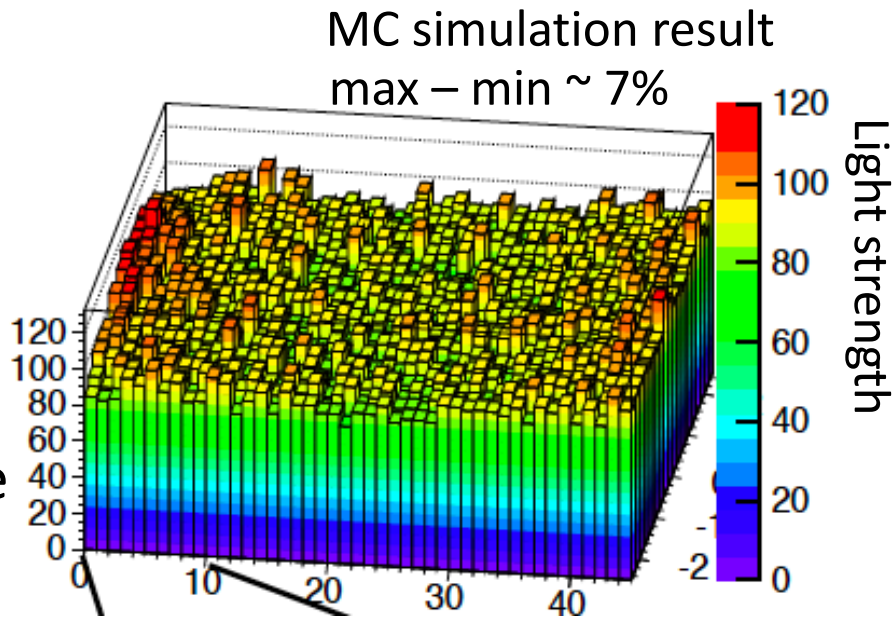
Oct 8th 2014 ~

Testbeam@CERN

New idea : readout by rectangular PPD & tapered scintillator



- Tapered scintillator and PPD with rectangular PPD is a new idea to absorb response non-uniformity
- Simple MC simulation result shows ~7% of non-uniformity
- Asking Hamamatsu to provide the rectangular PPD



PPD (MPPC) development

We were (are) requiring

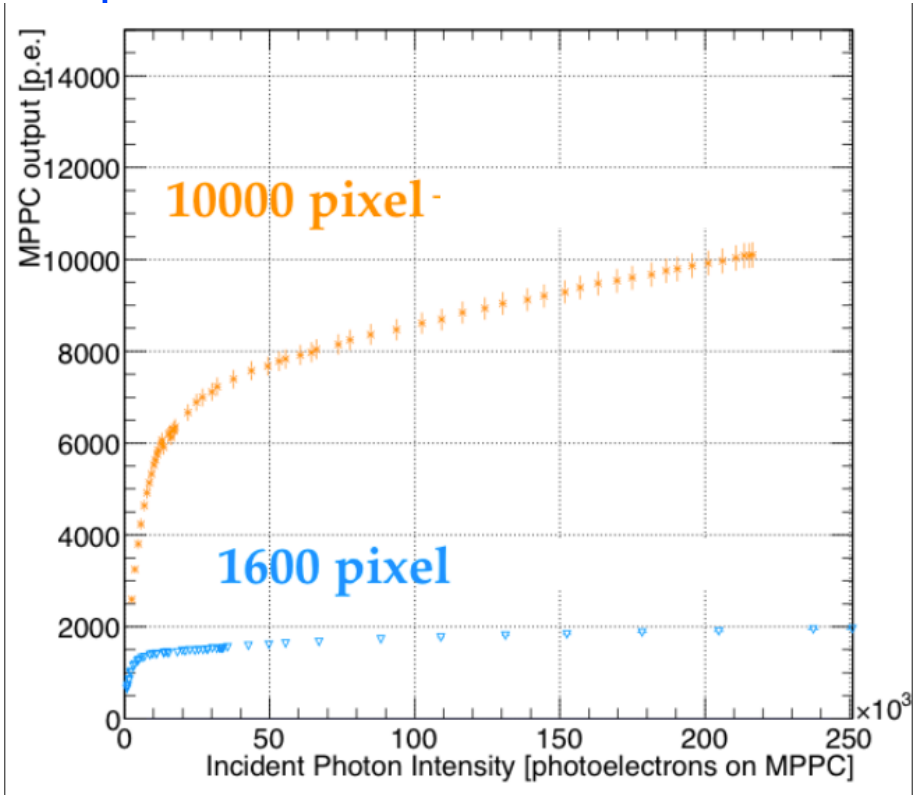
: lower noise rate, cross-talk, afterpulse

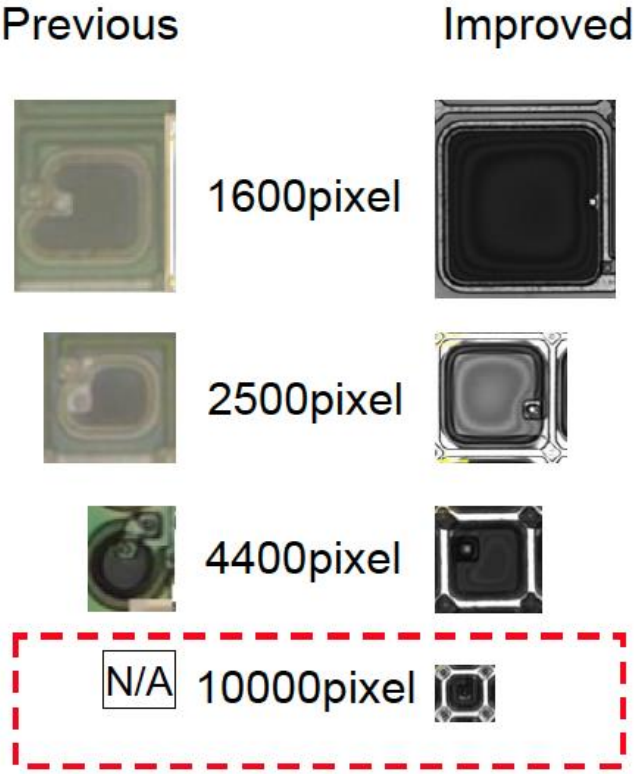
: high Photon Detection Efficiency

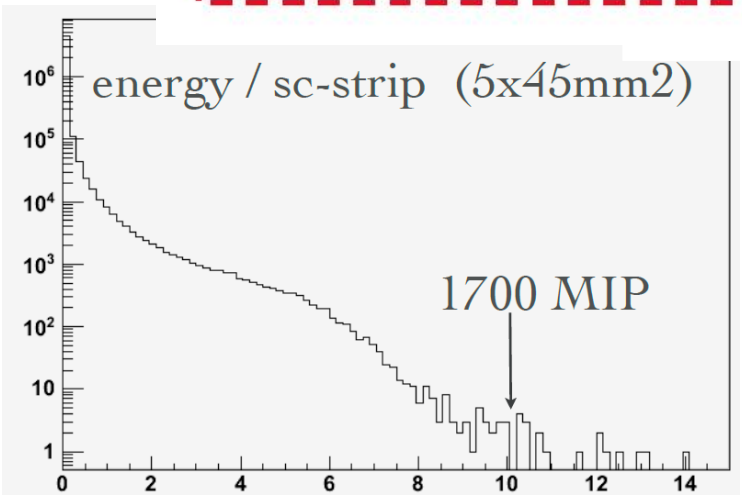
: large number of pixels

to Hamamatsu K.K.

Saturation effect is drastically improved!





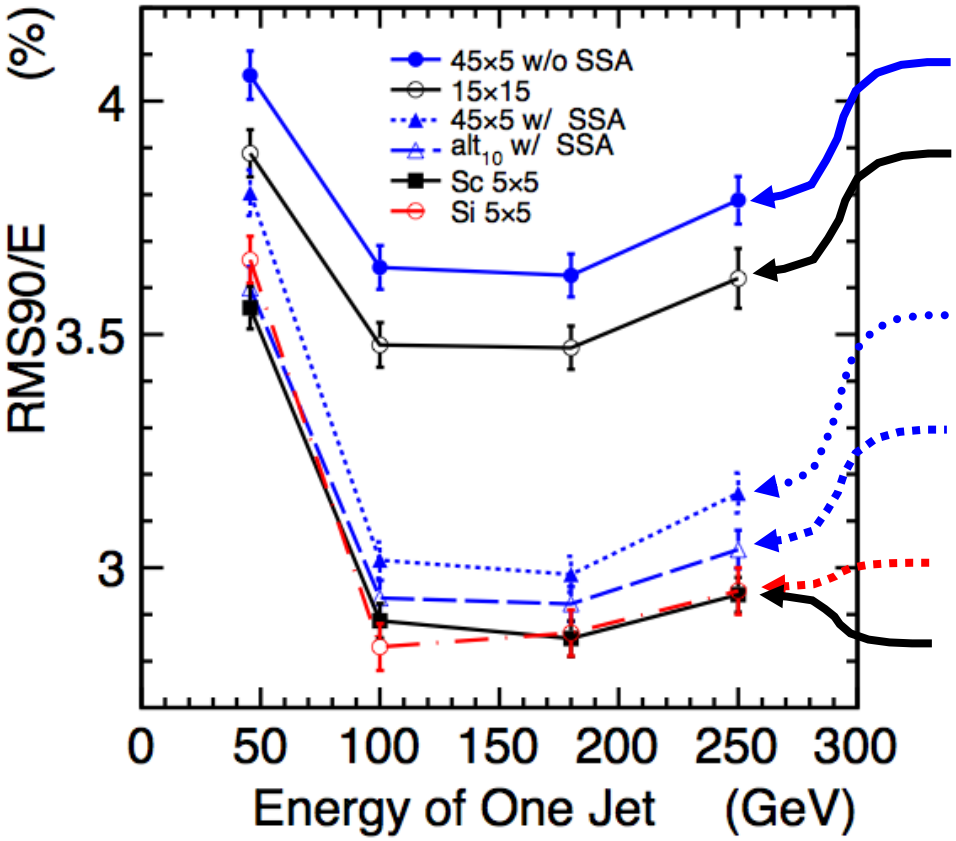


Development of Reconstruction software

Jet energy resolution @45-250 GeV

(Kotera @ Shinshu)

$Z' \rightarrow q\bar{q} \qquad q = u, d, s$



45 x 5 mm^2 ScECAL w/o SSA

15 x 15 mm^2 tile ScECAL

45 x 5 mm^2 ScECAL w SSA

alternate(45 x 5+10 x 10) mm^2 ScECAL w 2 step SSA

DBD result (SiW ECAL)

5 x 5 mm^2 tile ScECAL

cos(θ_Thrust) < 0.7 (Barrel)
RMS90: RMS of 90% of center events
PFA algorithm = PandoraPFA

SSA makes JER of strip ECAL close to 5 x 5 mm^2 tile ECAL
Difference is only 0.2-0.25%.

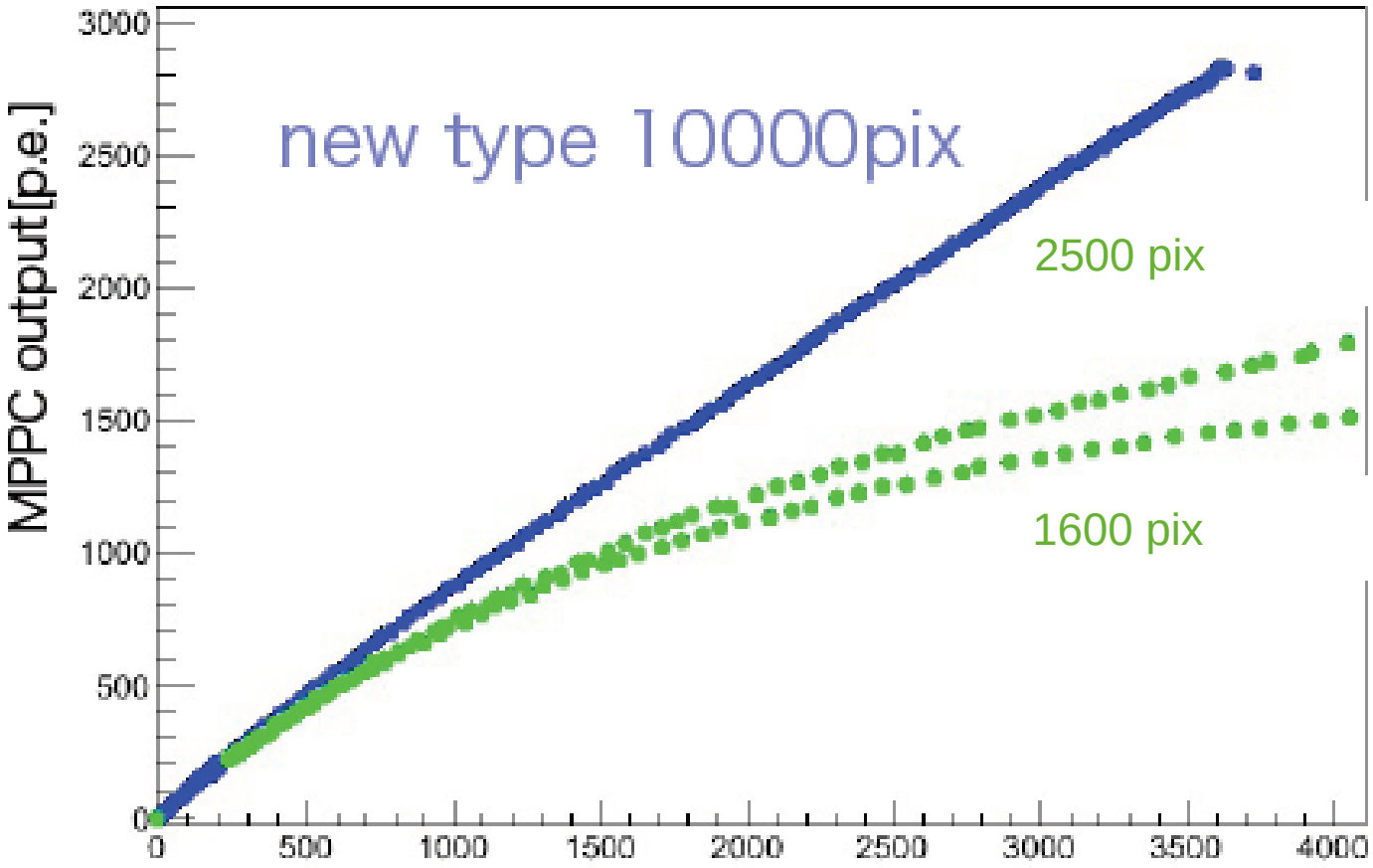
Study with more realistic MC simulation is currently underway.

Summary & Plans

- The ScECAL is being established through physics & technological prototypes
- Further improvement of scintillator components & PPDs are actively underway
- At this moment, test beam of the wedge-type scintillator is ongoing!
- Cluster reconstruction study shows reasonable performance with Strip Splitting Algorithim.
- Next Goal : determine the detector design in couple of years.

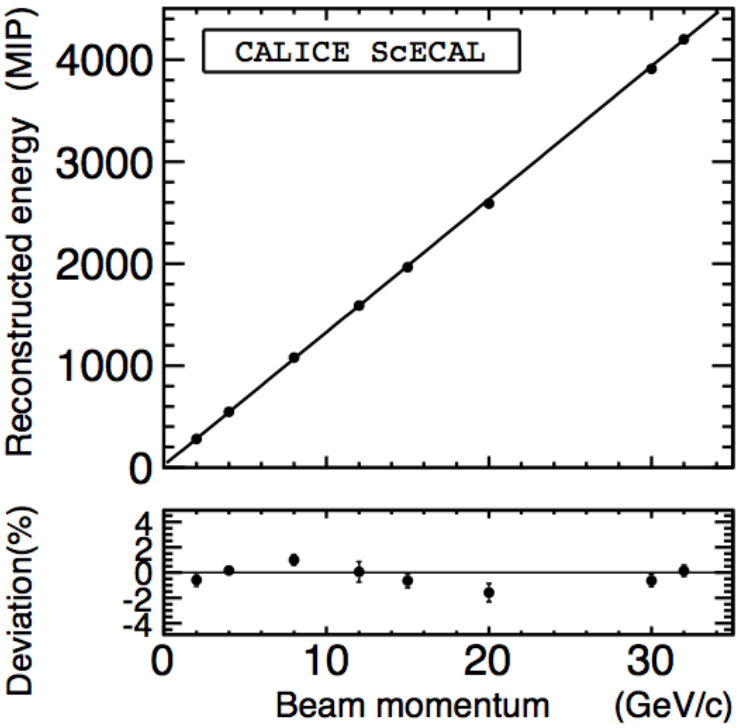
Backup

PPD(MPPC) measured linearity

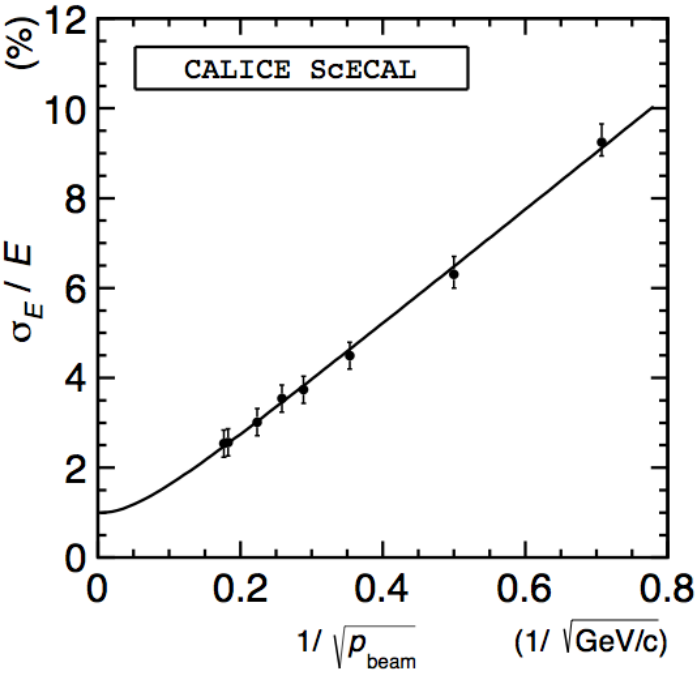


Physics prototype
2 - 32 GeV electron (at Fermilab)

- Linearity and Resolution



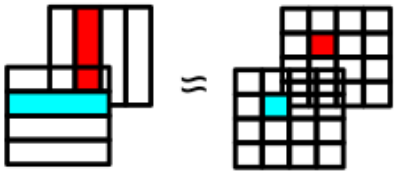
Maximum deviation
: 1.6±0.7%



	data	MC
stochastic term	12.8±0.1±0.4	13.26±0.08
constant term	$1.0\pm0.1^{+0.5}_{-1.0}$	0.66±0.08

difference < 1 σ

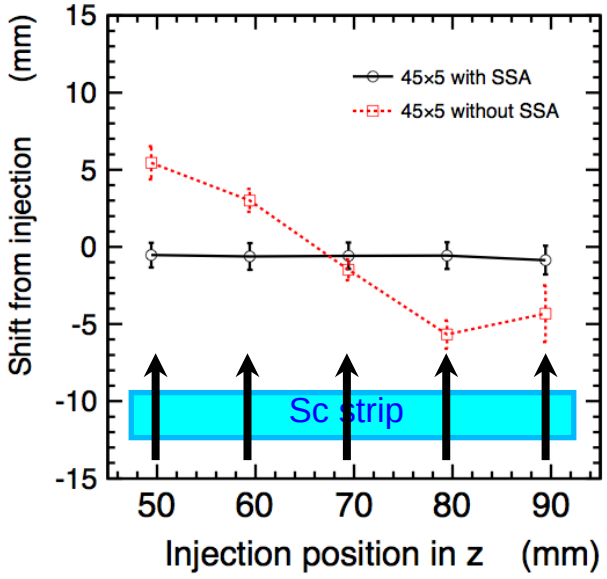
Strip Split Algorithm



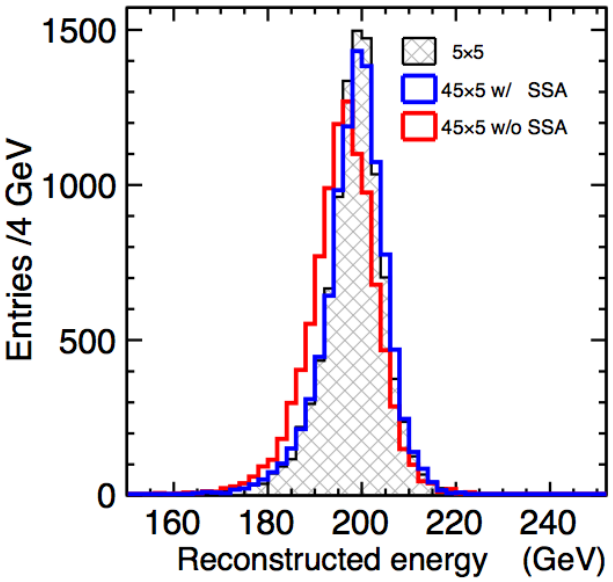
Energy deposits are redistributed into 5x5 mm^2 virtual cells referring hits in the nearest layers.

strips in the nearest layers have orthogonal direction.

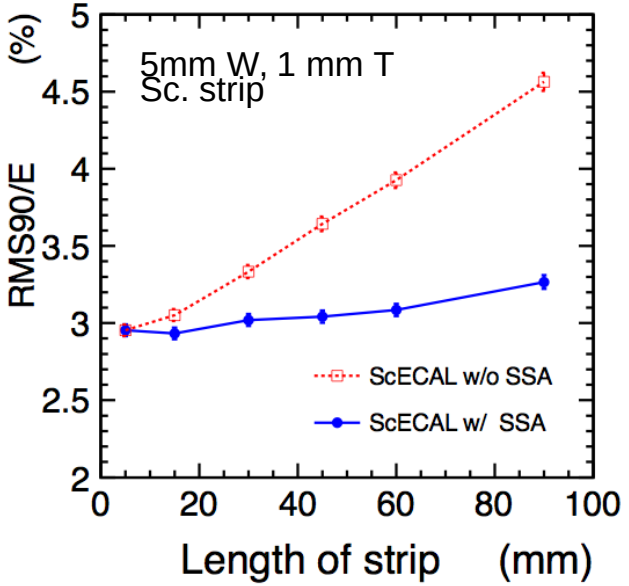
Position of 10 GeV photon



Energy sum of 2 x 100 GeV jet



Energy resln. 100 GeV Jet

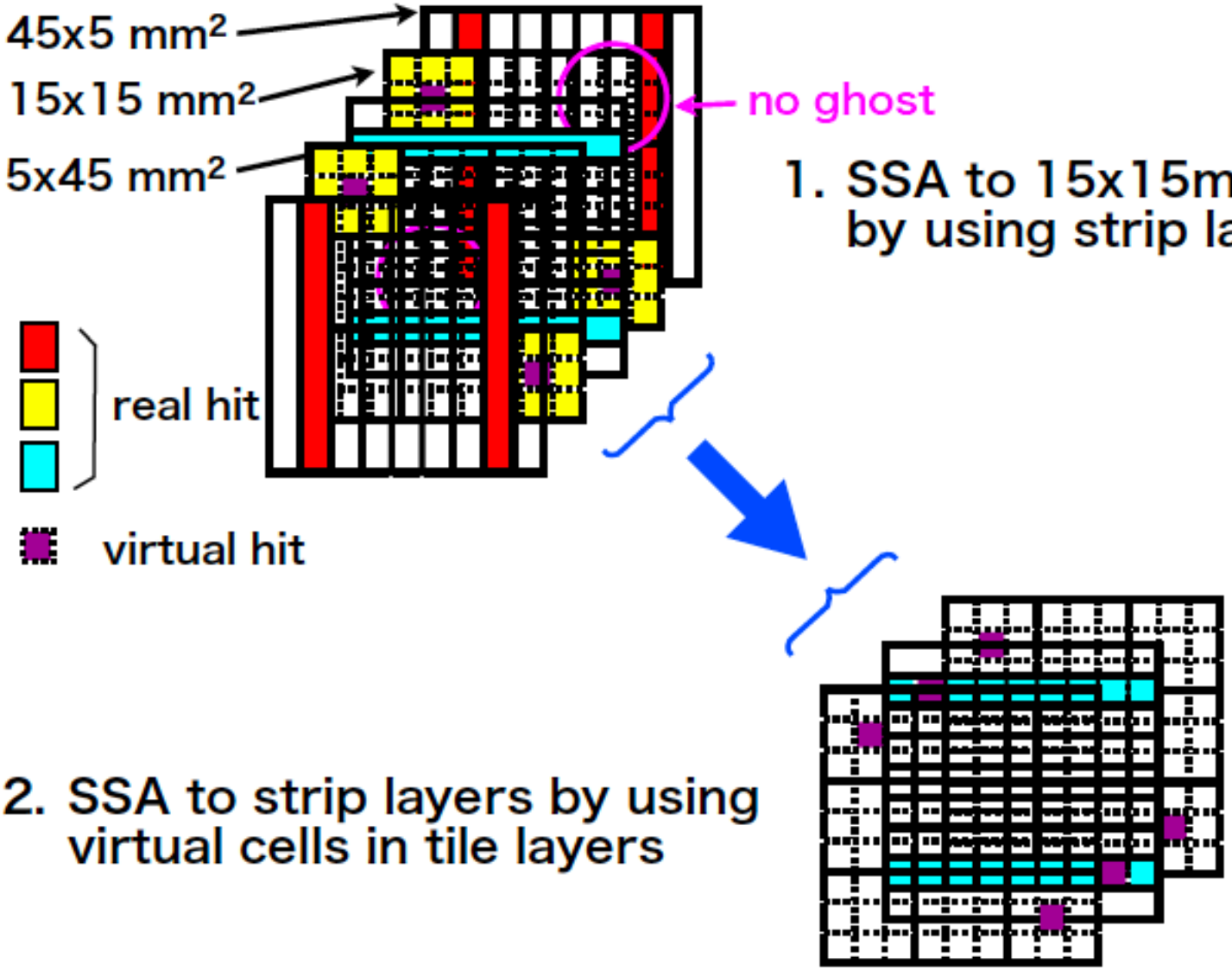


Left: position accuracy and precision
Error bar (RMS) < 1 mm w/ SSA.

Middle: Energy is recovered correctly w/ SSA.

Right: Jet energy resolution is kept w/ SSA.

How to reconstruct with large tile layers



1. SSA to 15x15mm² tile layers by using strip layers

2. SSA to strip layers by using virtual cells in tile layers