Progress on the study of CEPC ECAL

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2016.11.18

Outline

1 Introduction of the CEPC ECAL

2 Detector simulation

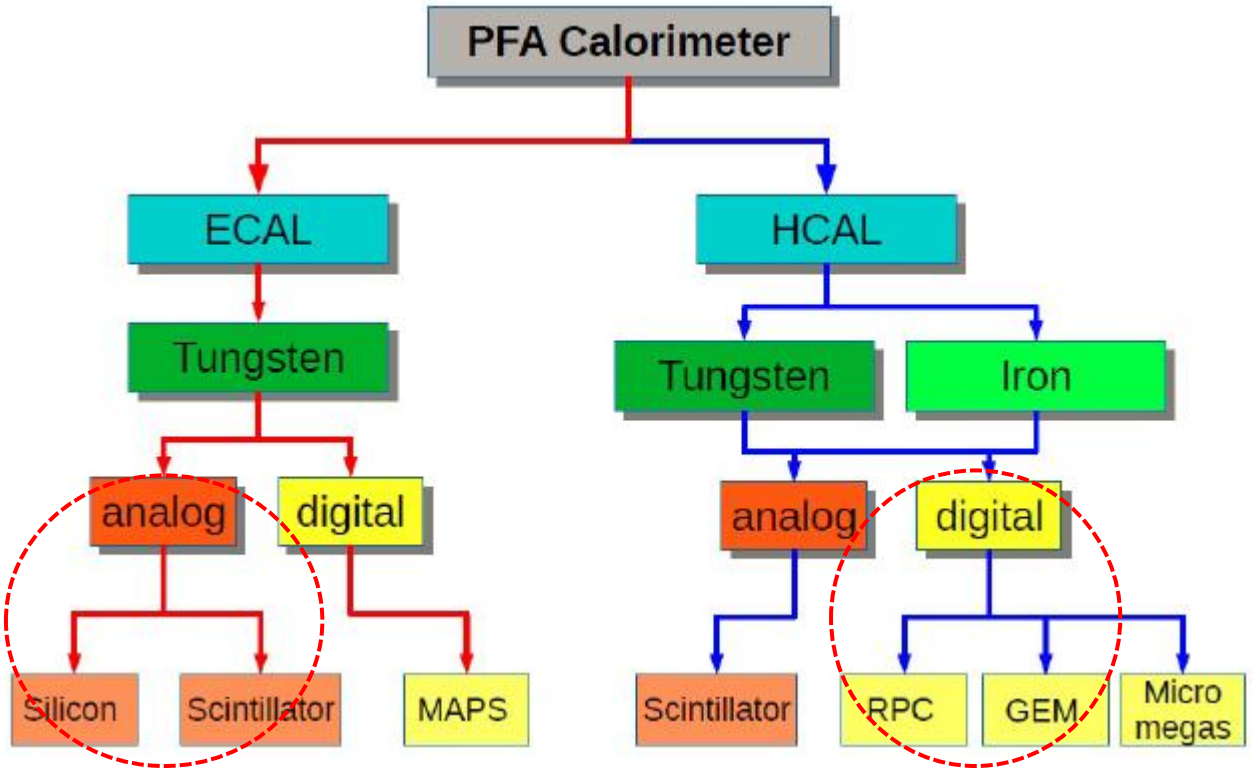
3 Readout unit test

4 Summary

Global R&D of Imaging Calorimeters

CALICE Calorimeter for ILC

https://twiki.cern.ch/twiki/bin/view/CALICE/CalicePapers



Absorber :

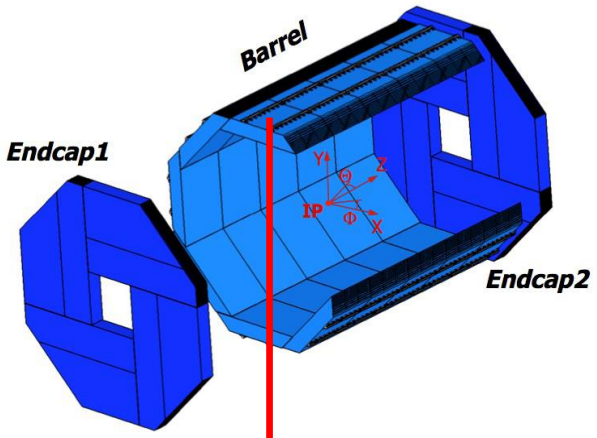
Readout:

Active:

Readout cell size: 144 - 9 cm^2 → 4.5 cm^2 → 1 cm^2 → 0.25 cm^2 → 0.13 cm^2 → 2.5×10^{-5} cm^2

Technology: Scintillator + SiPM/MPPC | Scintillator + SiPM/MPPC | Gas detectors Silicon | Silicon | Silicon | Silicon (MAPS)

Structure of the CEPC ECAL



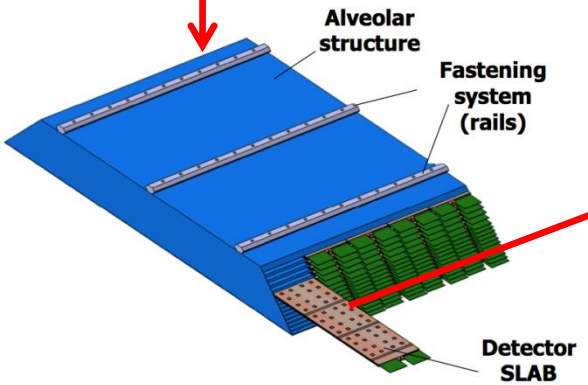
The CEPC ECAL consist of a cylindrical barrel system and two end caps.

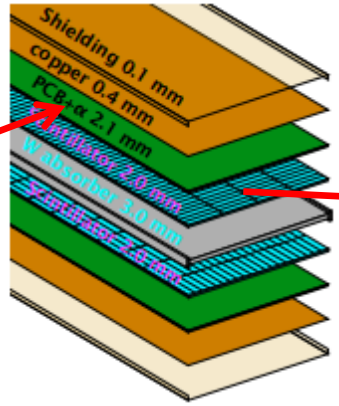
One of the proposal for CEPC ECAL is based on scintillator strip with SiPM readout.

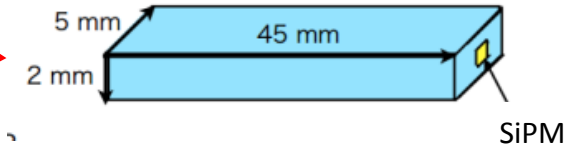
Total readout channel: ~8 Million

Two scintillator layers make a sandwich structure with a tungsten absorber.

The strips in adjacent layers are perpendicular to each other to achieve a 5×5 mm2 transverse size.

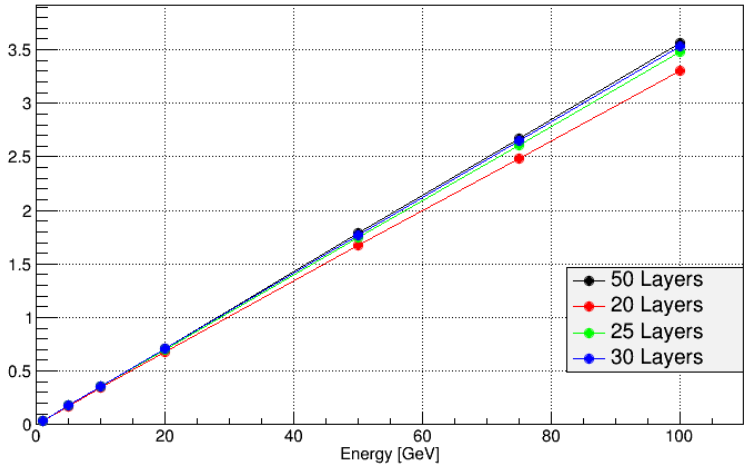




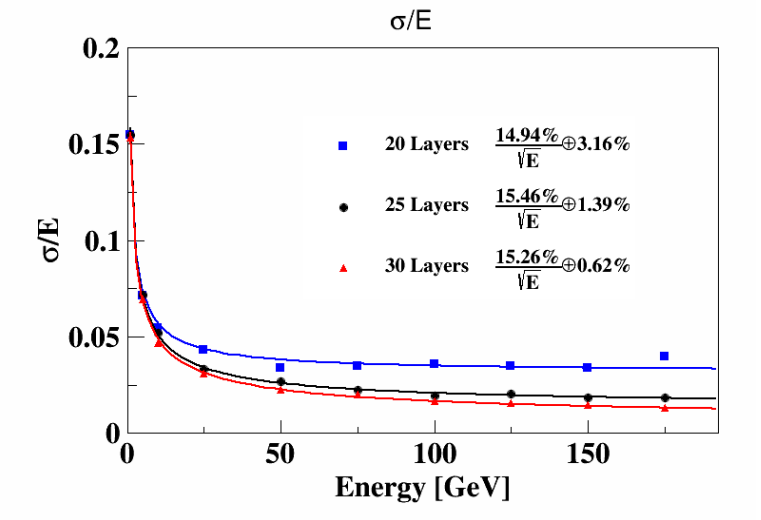


Baseline design of scintillator and SiPM

Detector Simulation: layer number



Linearity



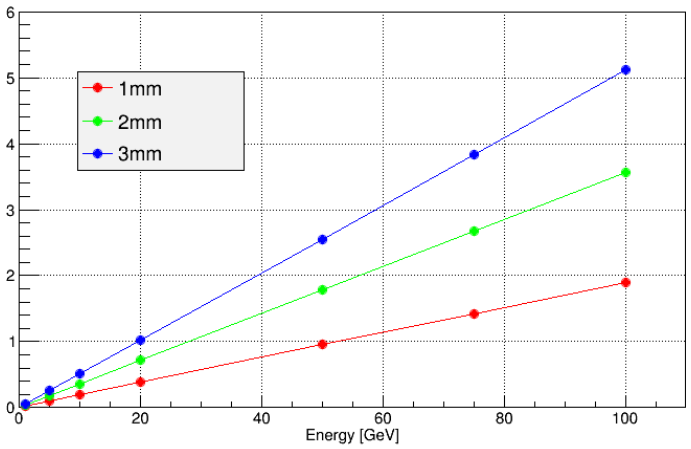
Energy Resolution

The dependency of the linearity and energy resolution on the layer number.

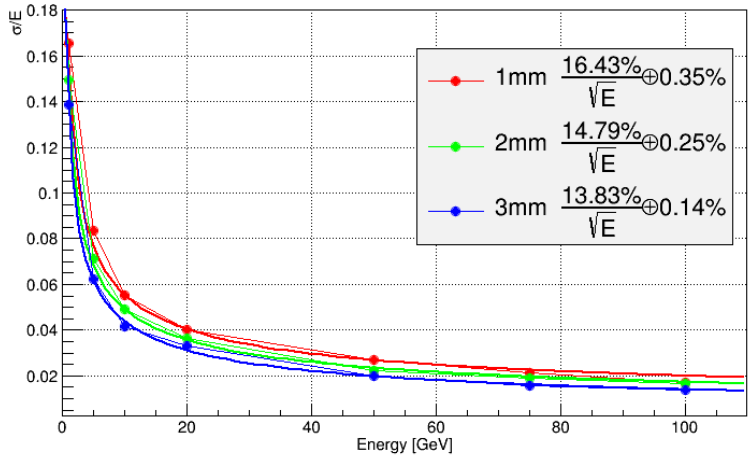
Particle: photon
Cell Size： 5x5mm
Sensitive Layer：
W:3;Air:0.5;Scintillator:2;Air:0.5;PCB:2;Air:0.5(mm)

The layer number will be optimized in 20-25.

Detector Simulation: scintillator thickness



Linearity



Energy Resolution

The dependency of the linearity and energy resolution on the scintillator thickness.

Particle: photon
Cell Size： 5x5mm
Sensitive Layer：
W:3;Air:0.5;Scintillator:1,2,3;Air:0.5;PCB:2;Air:0.5(mm)
Layer number: 50

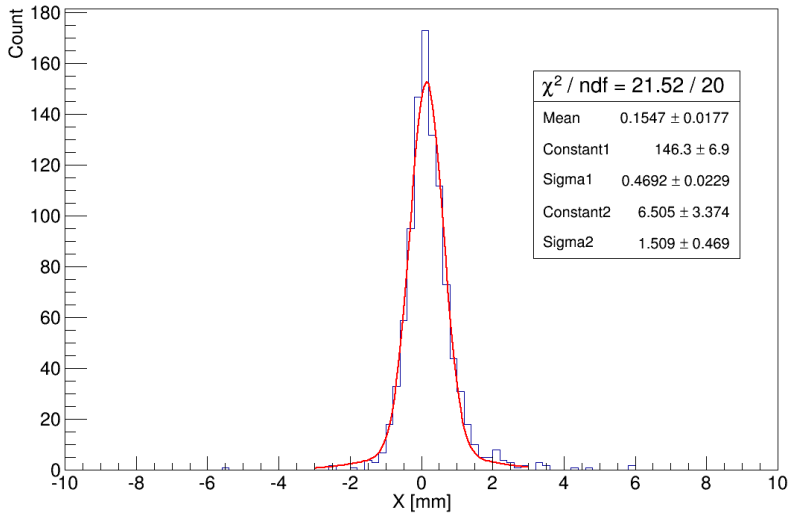
The thickness of scintillator can be reduced to 1 mm.

Photon Position Resolution

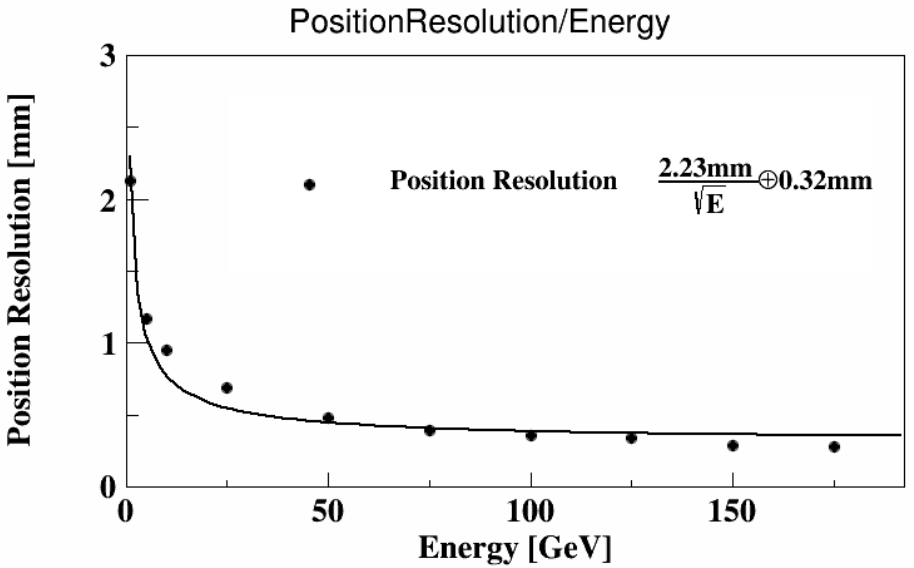
The inject position on the XY plane of the particle could be regarded as the shower energy weighted center, for x direction we have :

$$X = \sum x_i E_i / \sum E_i$$

The distribution can be fitted by a sum of two Gaussians, and the sigma of the narrower Gaussian was used to represent position resolution here.

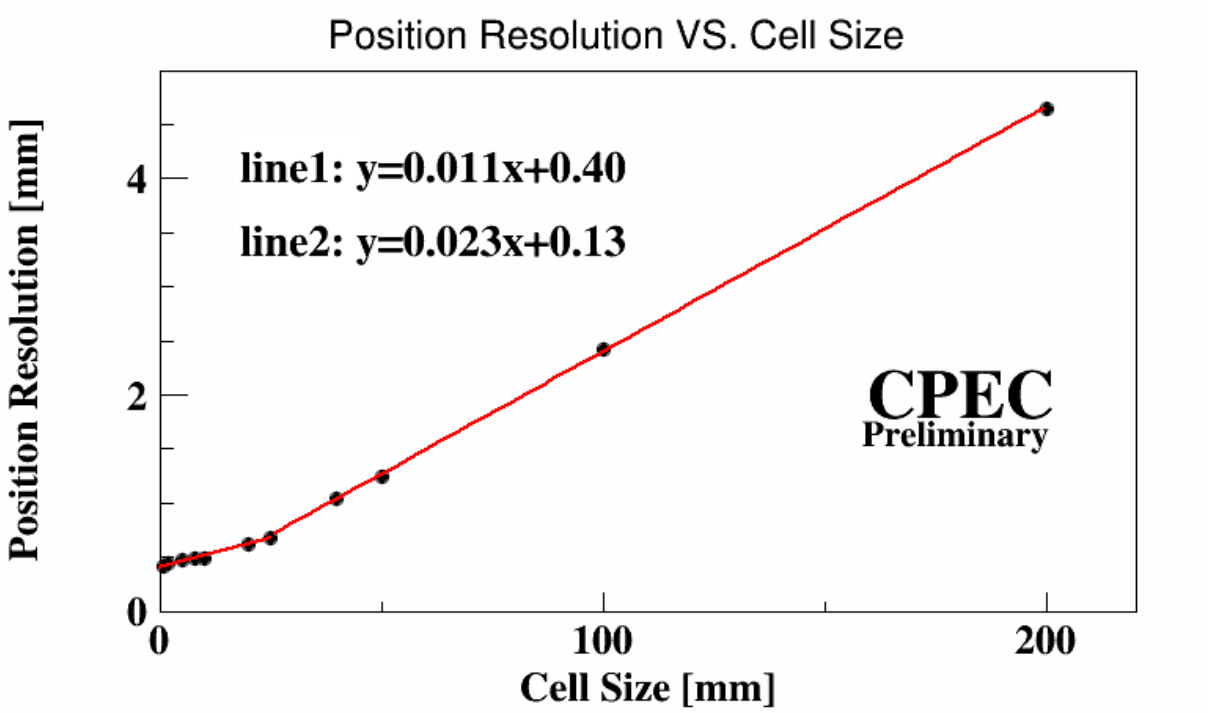


50GeV photon，5mm*5mm cell size reconstructed inject position distribution



Photon position resolution as a function of its energy, with 5mm*5mm cell size

ScECAL Cell Size



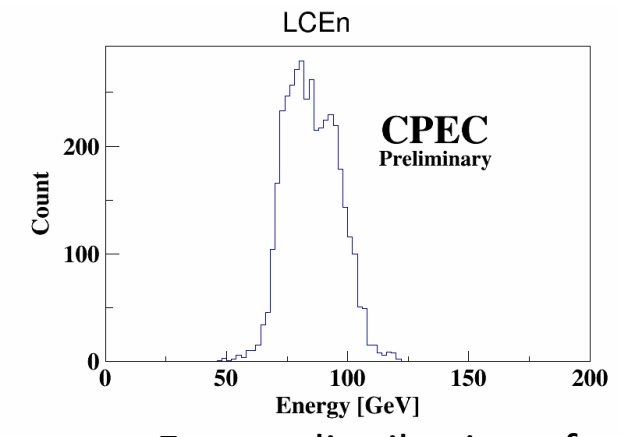
50GeV photon's position resolution with different cell size

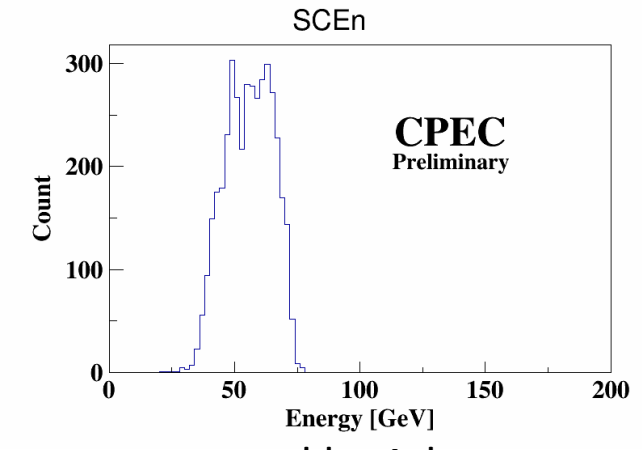
Sectioned line function is used here to describe the relationship between position resolution and cell size. The fit result indicates the difference between two slopes.

The cell size can be more than 5x5 mm^2

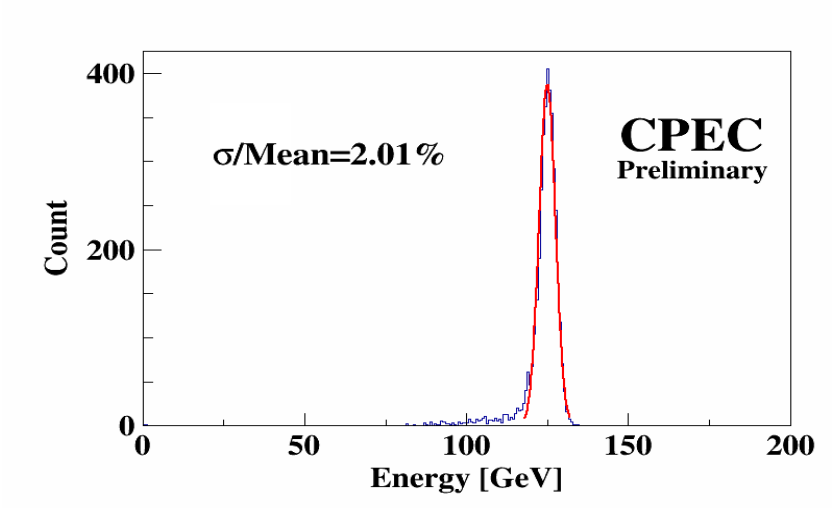
H->diphoton

H->diphoton channel can test the performance of ECAL



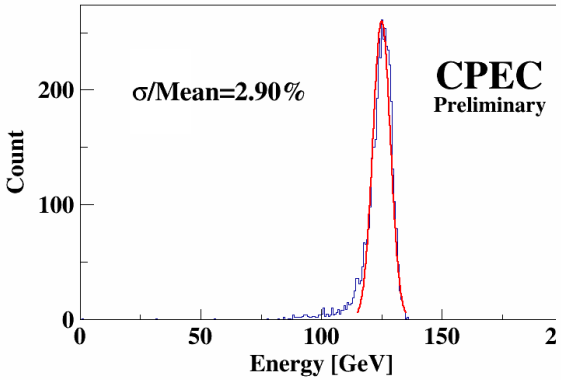


Energy distribution of two photon reconstructed by Arbor



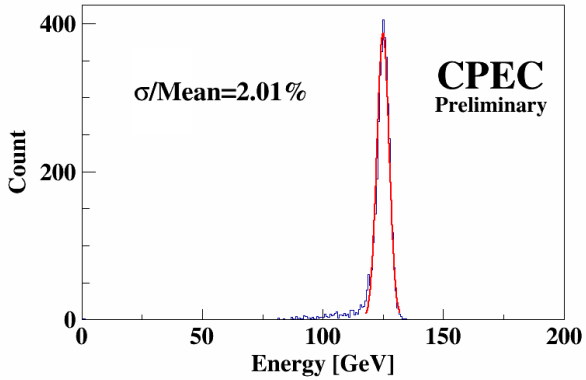
The distribution has a long tail because the reconstruction is not perfect.

H->diphoton in different layers ECAL



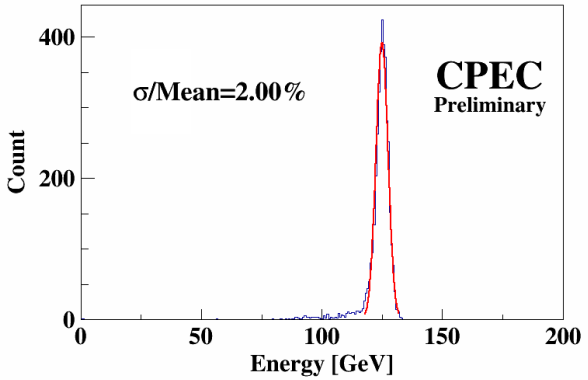
20 layers

sigma/mean=2.90%



25 layers

sigma/mean=2.01%

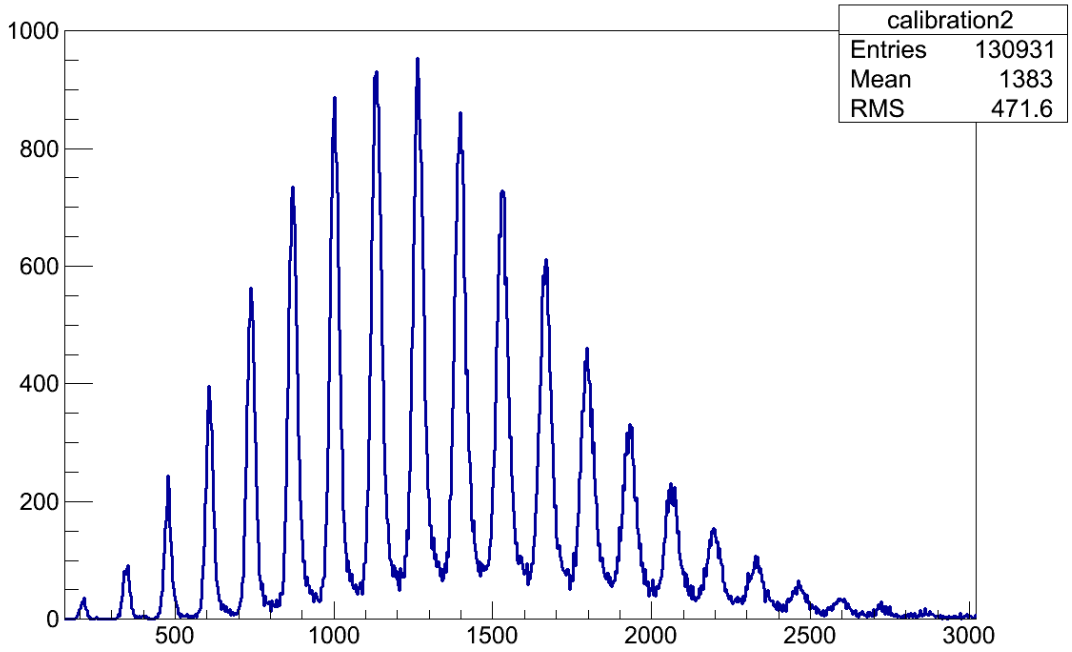


30 layers

Sigma/mean=2.00%

Little difference between the results of 25 layer and 30 layer ECAL, which is accordance with the result of single photon.

SiPM study



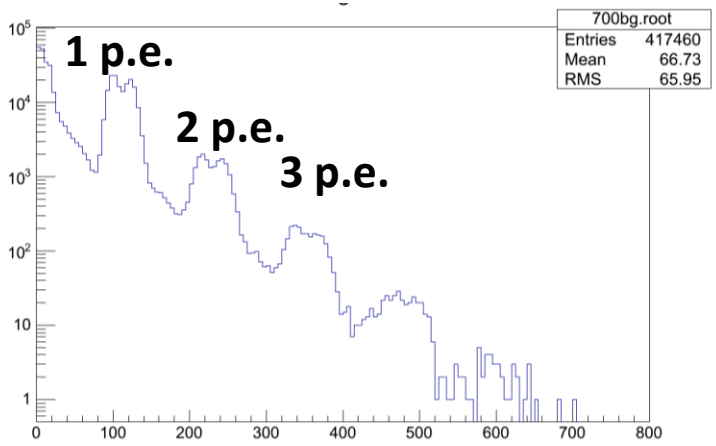
Pulse height spectrum

The individual peaks are clearly separate from each other in the pulse height spectrum.

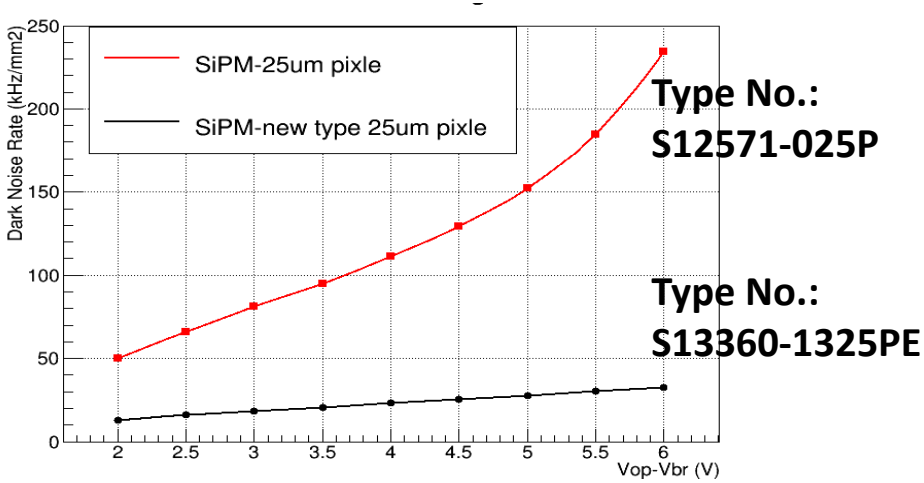
- **Excellent photon counting ability**

SiPM study: Dark Noise Rate

Electron hole pairs generated without the involvement of photons give rise to unwanted noise.



Spectrum of SiPM dark noise



Dark noise rate with over-voltage

- **Dark noise rate rises exponentially with the applied over-voltage.**

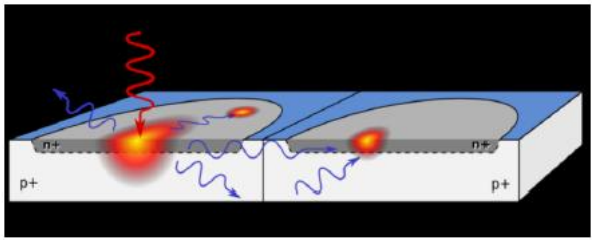
Very recently, SiPMs with trenches between pixels dramatically reduced dark rate and pixel to pixel cross-talk.

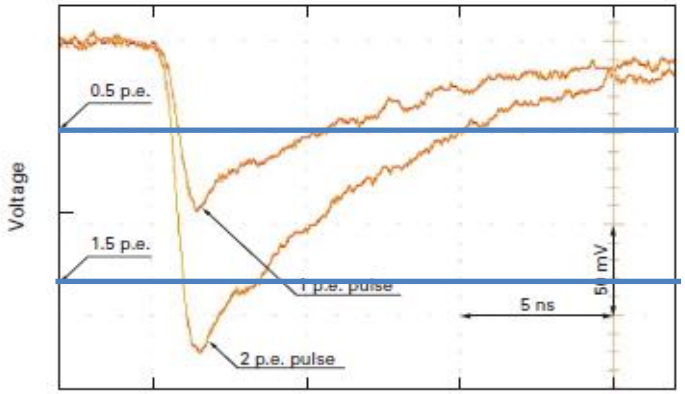
- **The dark noise rate of the new SiPMs (30kHz/mm^2)is 1/3 of the old ones(100kHz/mm^2), with same gain.**

SiPM study: Optical Cross-talk

A p-n junction in breakdown emits photons in the visible range, if they reach a neighboring pixel additional breakdown can be caused.

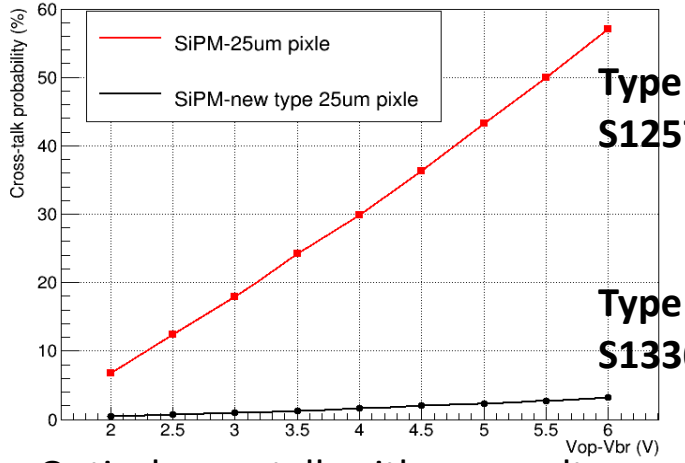
*A. Lacaita, et al., IEEE Trans. Electron Devices ED-40(1993) 577





Cross talk rate =

$$\frac{\text{Dark rate 1.5p.e. threshold}}{\text{Dark rate 0.5p.e. threshold}}$$



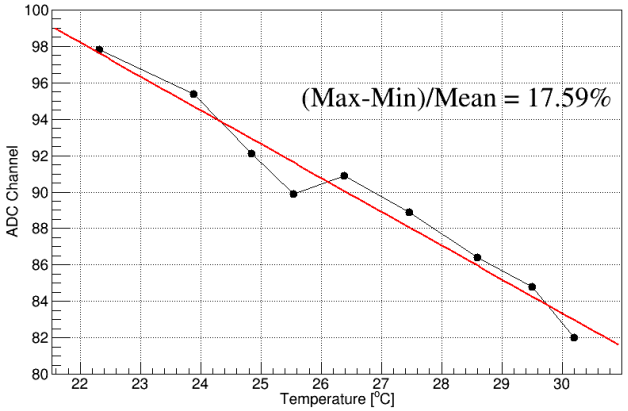
Type No.: S12571-025P

Type No.: S13360-1325PE

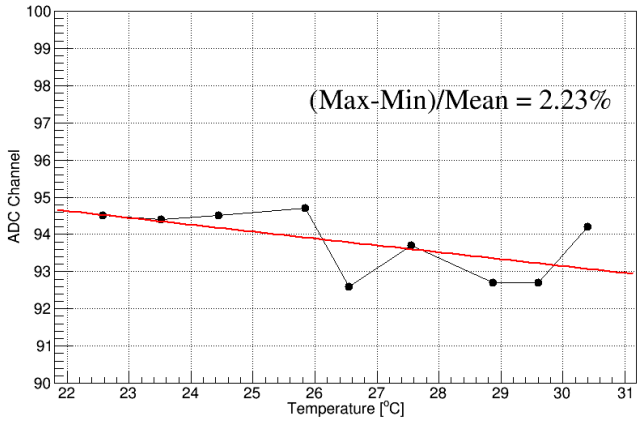
Optical cross-talk with over-voltage

- **Optical cross-talk increases with over-voltage.**
- **The optical cross-talk of the new SiPMs(2.3%) is 10% of the old ones(24%), with same gain.**

SiPM study: Gain stabilization



Temperature effect of SiPM
Calibrated by single P.E.



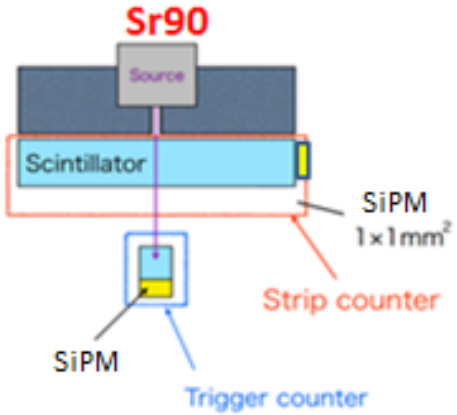
Gain stabilization
Calibrated by single P.E.

- The gain of SiPMs depends both on bias voltage and on temperature:
  Gain decreases with temperature
  Gain increases with bias voltage
- It is valuable to adjust V_{bias} to compensate for Temperature changes to keep the gain constant

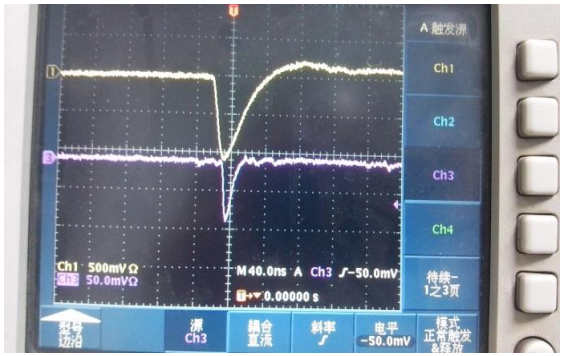
Temperature-compensation circuit: C12332-01

Scintillator strip test

Scintillator strip and SiPM



Test setup



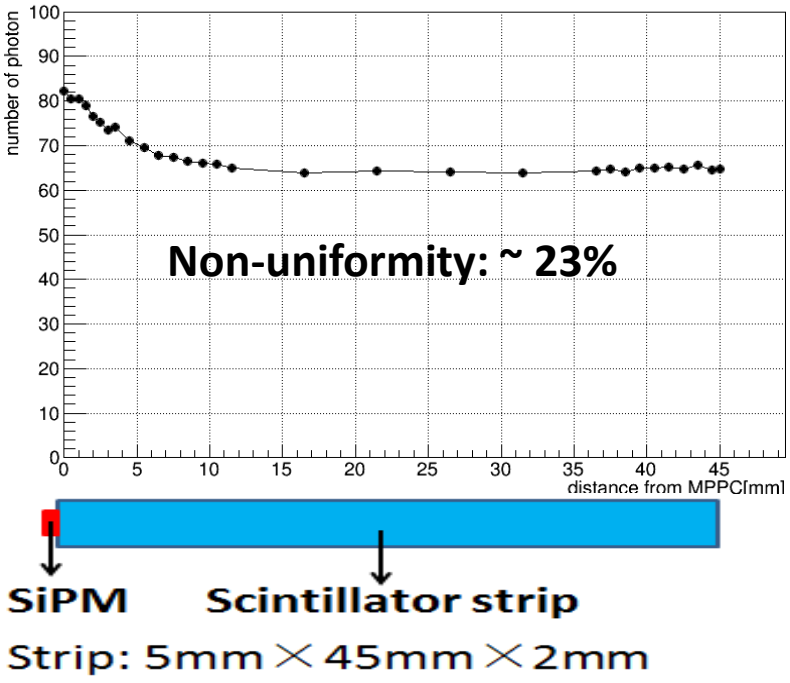
Waveform of strip counter and trigger counter

The **DT5751** is a **2-4** Channel **10** bit **2/1 GS/s** Desktop Waveform Digitizer .

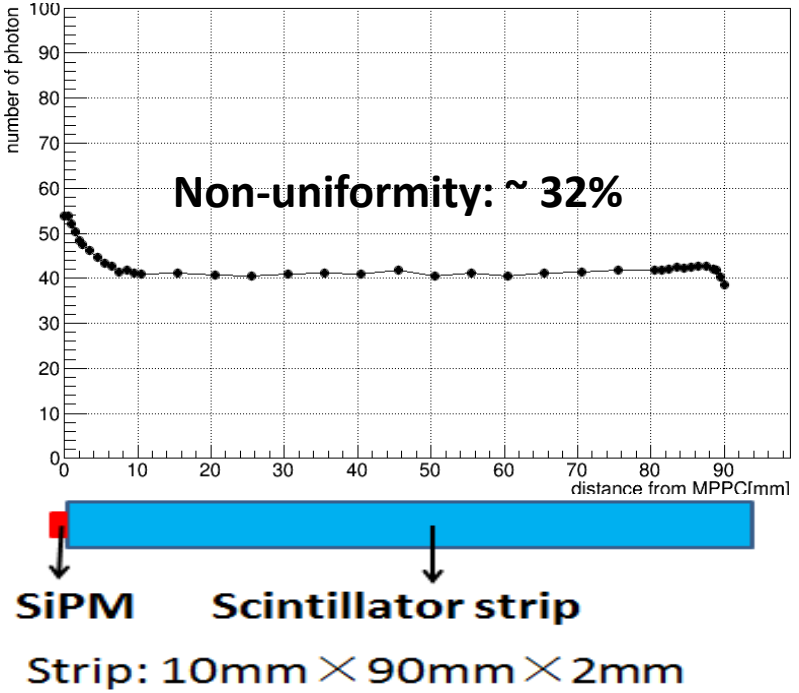
Data acquire system

Strip light output

5mm×45mm scintillator strip



10mm×90mm scintillator strip



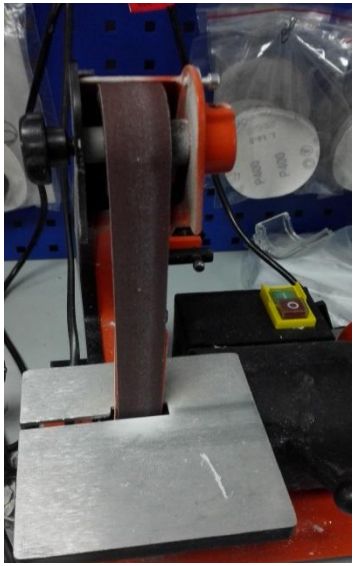
Scintillator: BC408，　SiPM: 1mm×1mm,25um pixel size

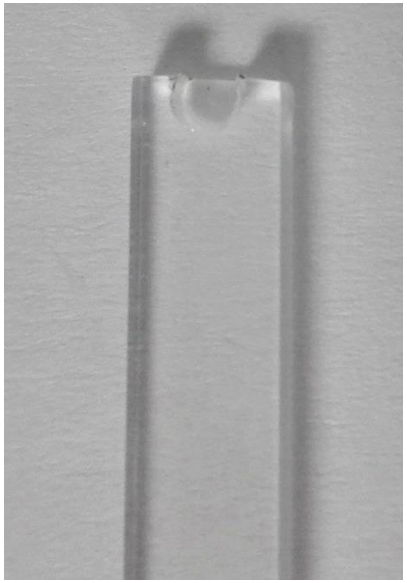
The uniformity of scintillator strip light output need to be optimized.

Optimization of scintillator strip

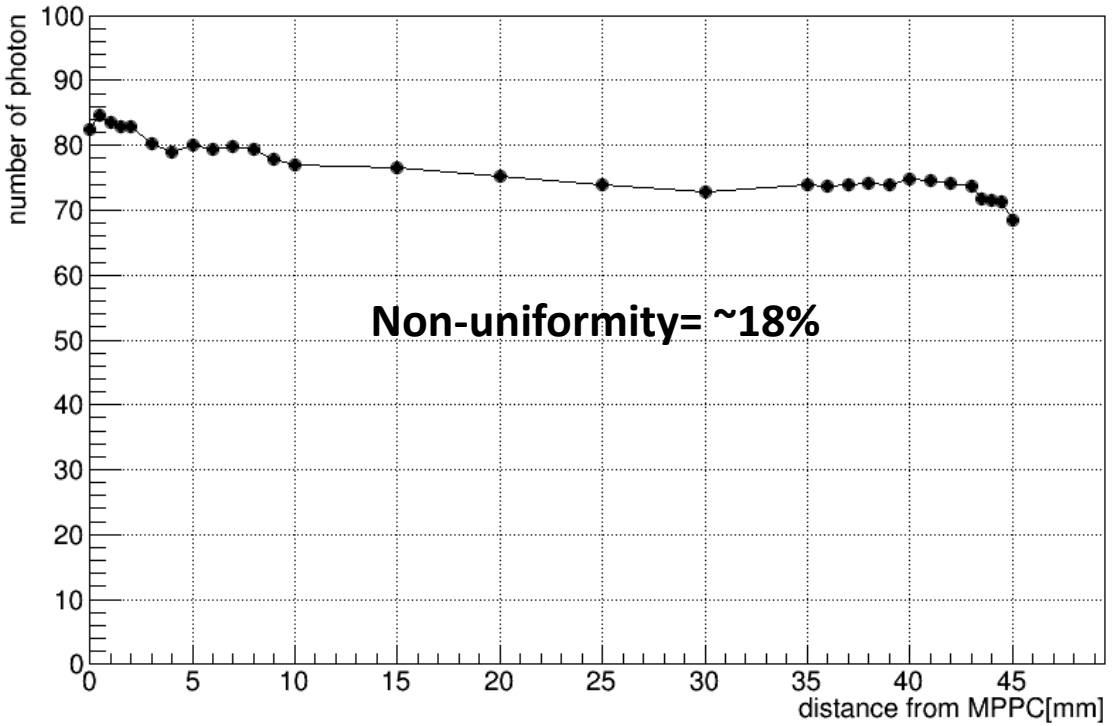
1 Improve the uniformity of light output

2 Eliminating the dead gap caused by SiPM





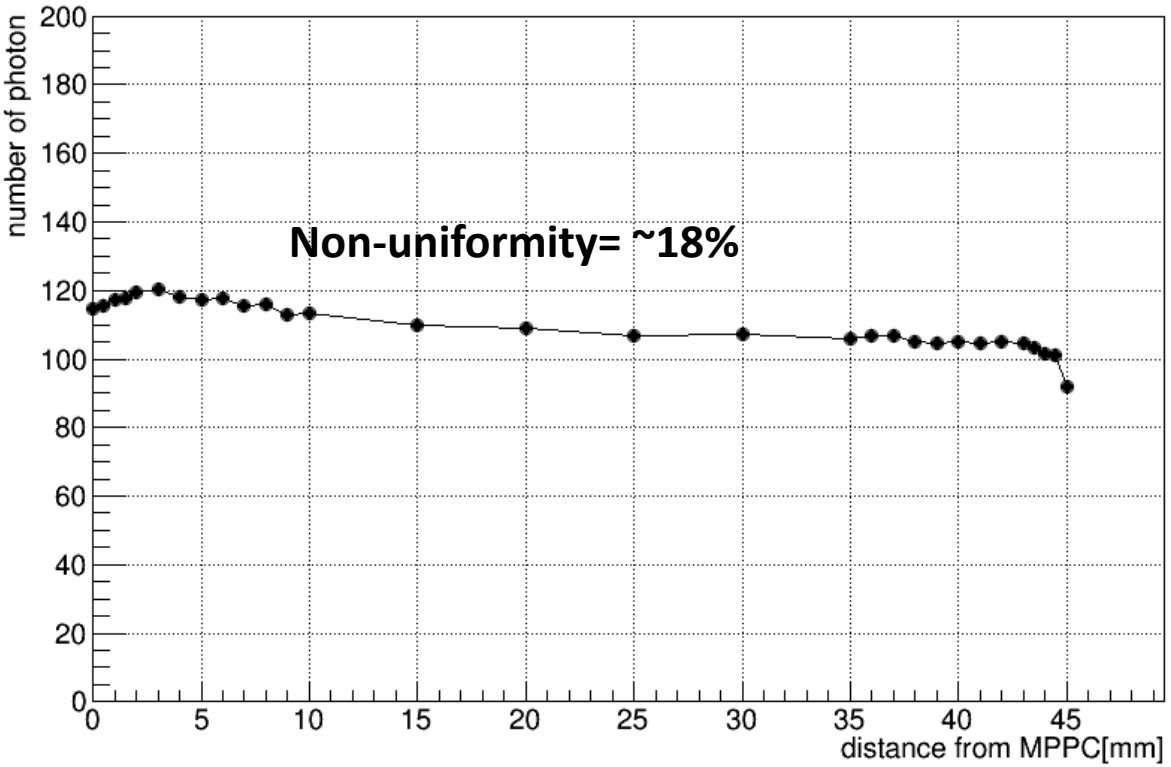
Depolishing strip faces



Light output of scintillator strip with five faces depolished

The global uniformity and local uniformity are improved.

Drill hole in strip

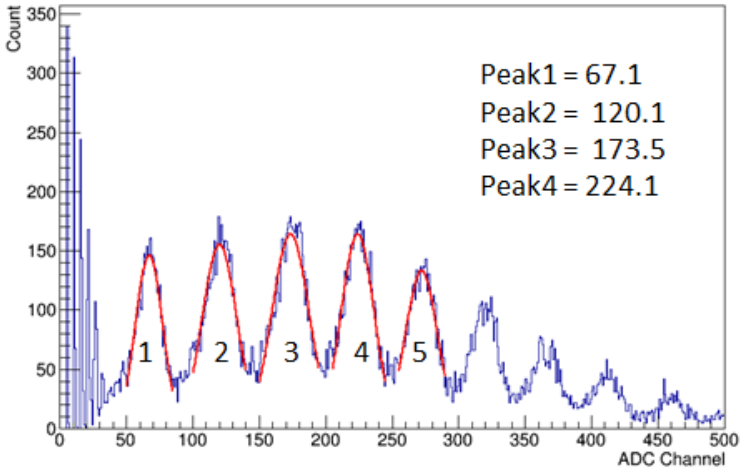


1 The global uniformity and local uniformity are improved.

2 The light output increased by 30%.

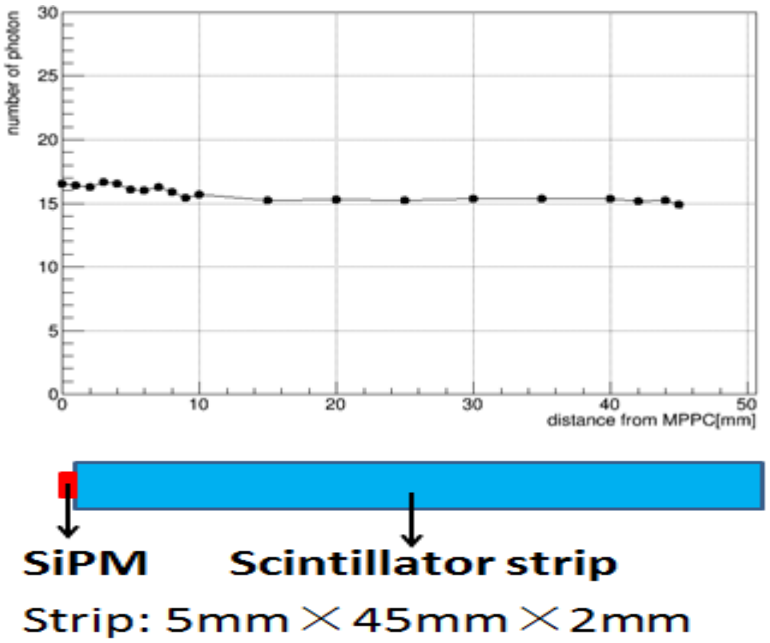
10um SiPM light output

SiPM type No.: S12571-010C



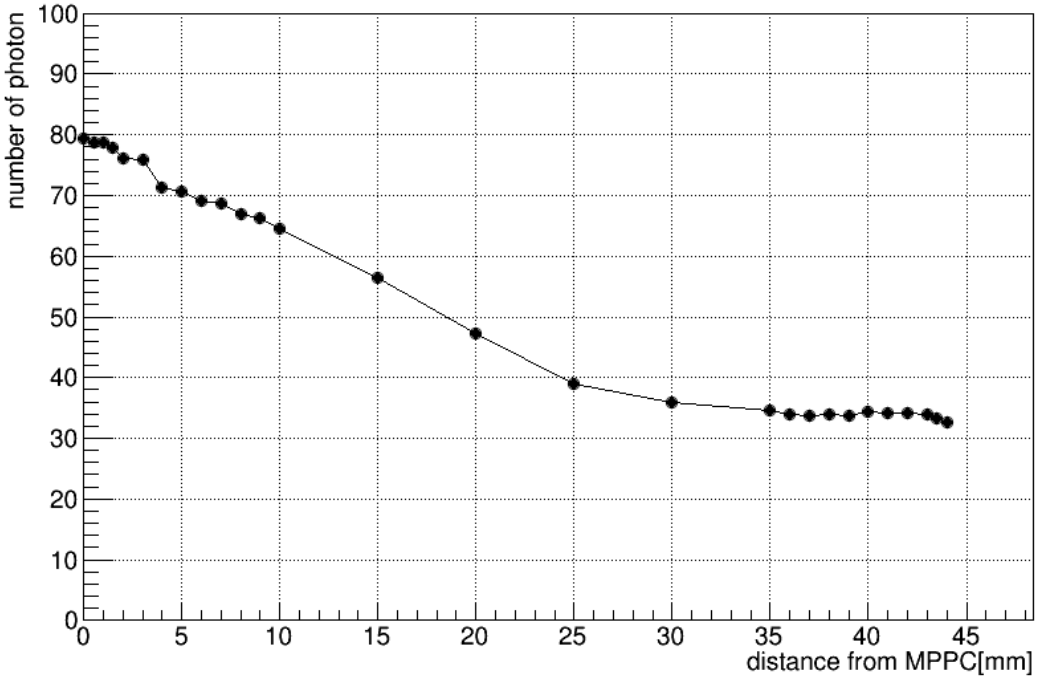
Pulse height spectrum

Light output of 45mm strip coupled with 10um SiPM



Photon detection efficiency of 10um SiPM is only 23% of the 25um SiPM

Effective of reflective material



Scintillator strip coated with BaSO4

At least five kinds of reflective materials have been tested .
ESR film has the best reflection efficiency.
But it is hard to handle in batch process.

Summary

1 CEPC ScW ECAl simulation is in progress. Will do Digitization and JET Energy Resolution.

2 Performance test of scintillator strip readout unit in process but still lot to be done.

Thanks!