

Performance study for the CEPC ScW ECAL

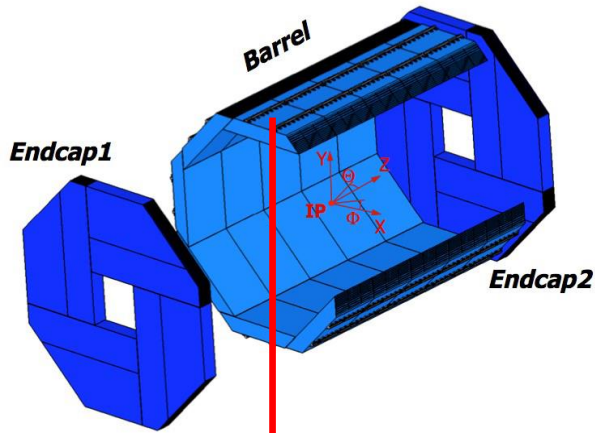
Zhigang Wang, IHEP

04.08.2016

Outline

- 1 Introduction of the CEPC ECAL
- 2 Detector simulation
- 3 Readout unit test
- 4 Summary

Structure of the CEPC ECAL



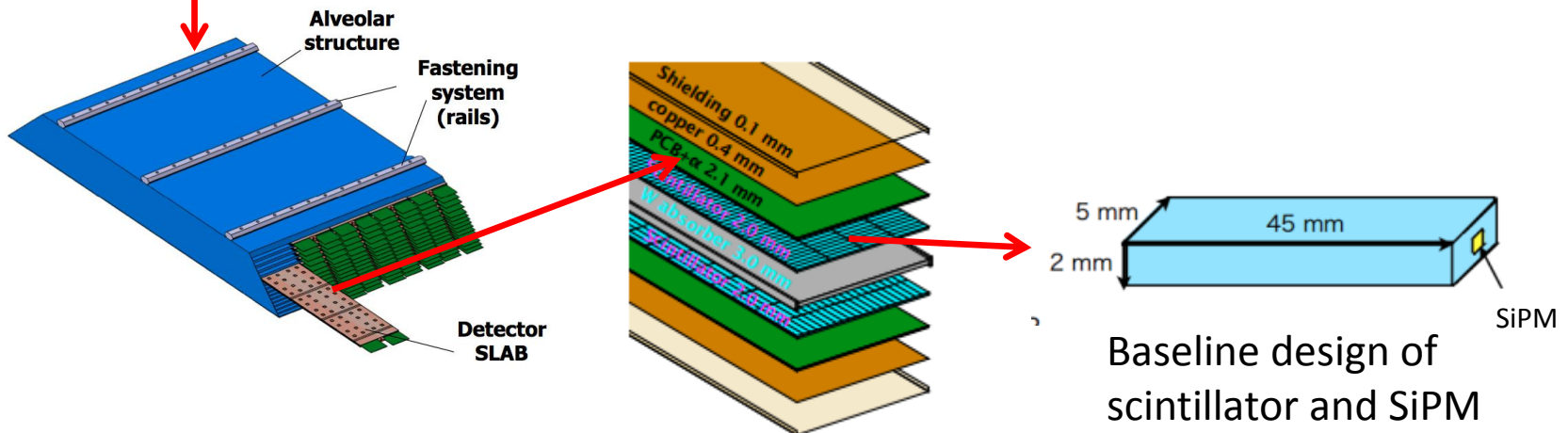
The CEPC ECAL consist of a cylindrical barrel system and two end caps.

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

Total readout channel: ~8 Million

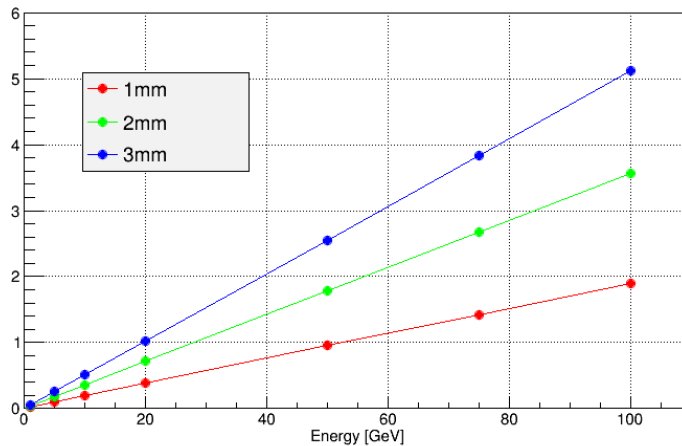
Two scintillator layers make a sandwich structure with a tungsten absorber.

The strips in adjacent layers are perpendicular to each other to achieve a $5 \times 5 \text{ mm}^2$ transverse size.

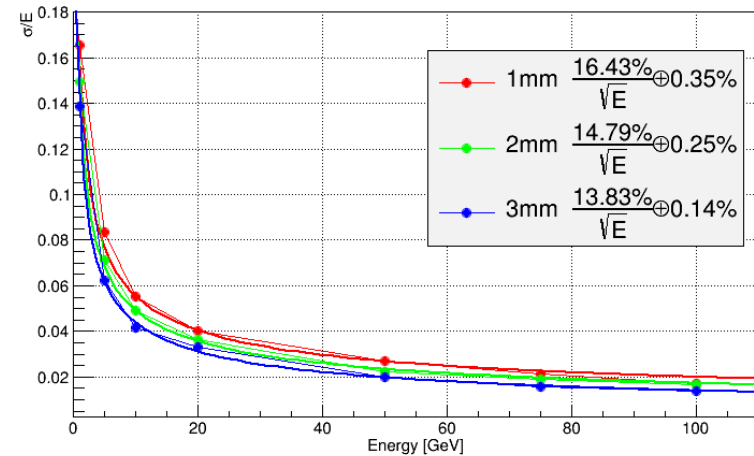


Baseline design of scintillator and SiPM

Detector Simulation: scintillator thickness



Linearity



Energy Resolution

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

Particle: photon

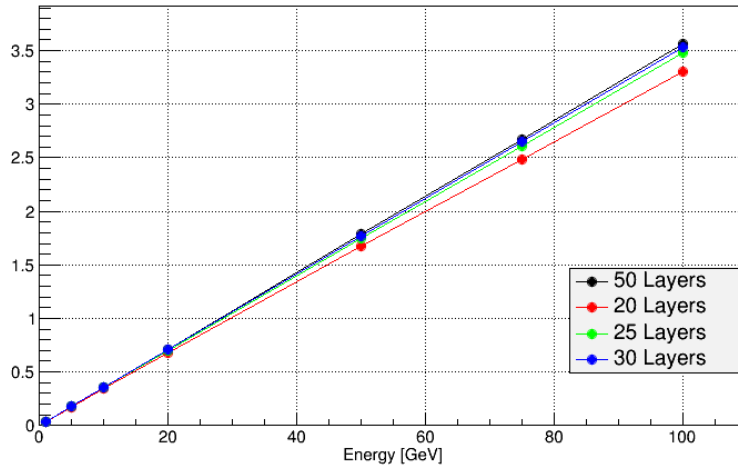
Cell Size: 5x5mm

Sensitive Layer:

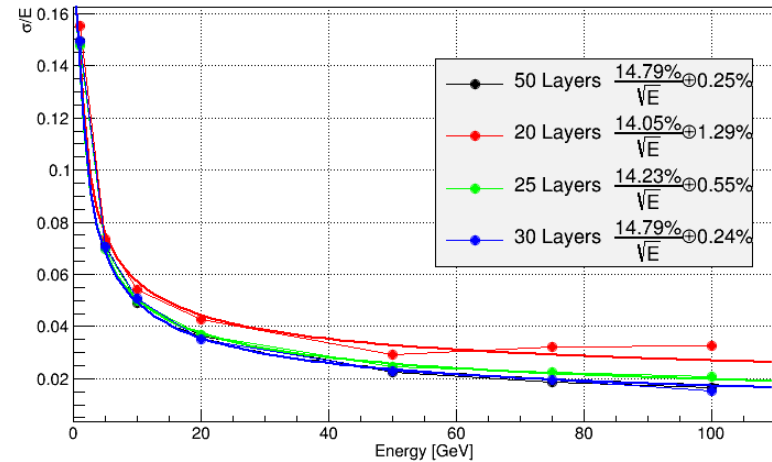
W:3;Air:0.5;Scintillator:1,2,3;Air:0.5;PCB:2;Air:0.5(mm)

Layer number: 50

Detector Simulation: layer number



Linearity



Energy Resolution

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

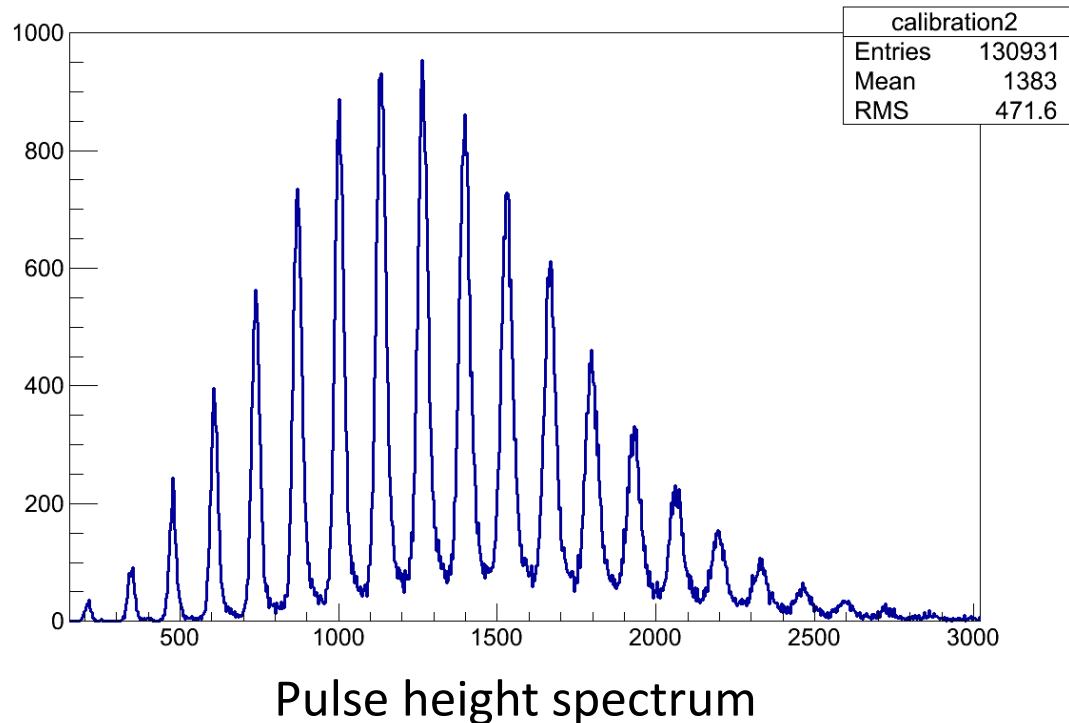
Particle: photon

Cell Size: 5x5mm

Sensitive Layer:

W:3;Air:0.5;Scintillator:2;Air:0.5;PCB:2;Air:0.5(mm)

SiPM study



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

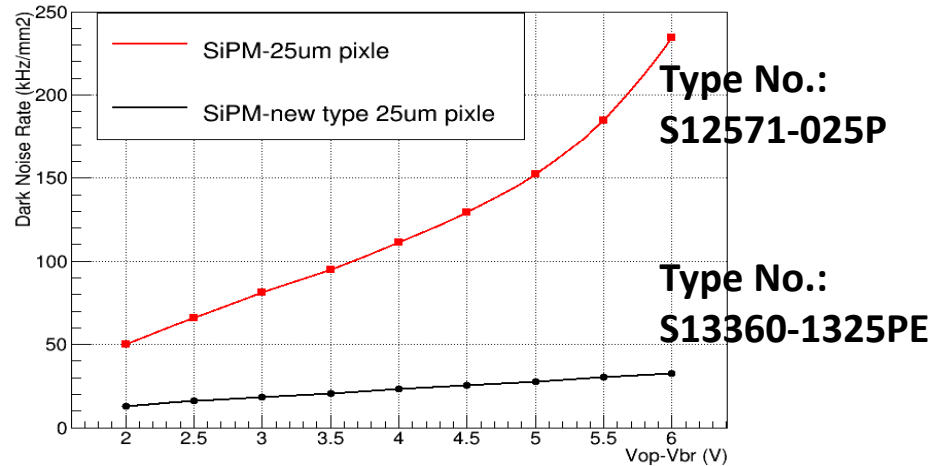
- **Excellent photon counting ability**

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.

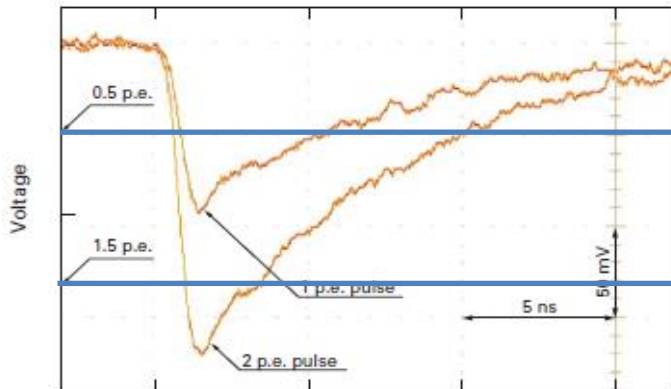
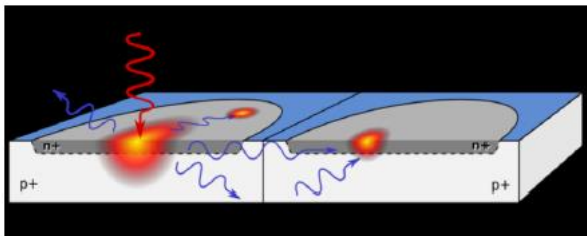
Very recently, SiPMs with trenches between pixels dramatically reduced dark rate and pixel to pixel cross-talk.

- The dark noise rate of the new SiPMs (30kHz/mm²) is 1/3 of the old ones (100kHz/mm²), with same gain.

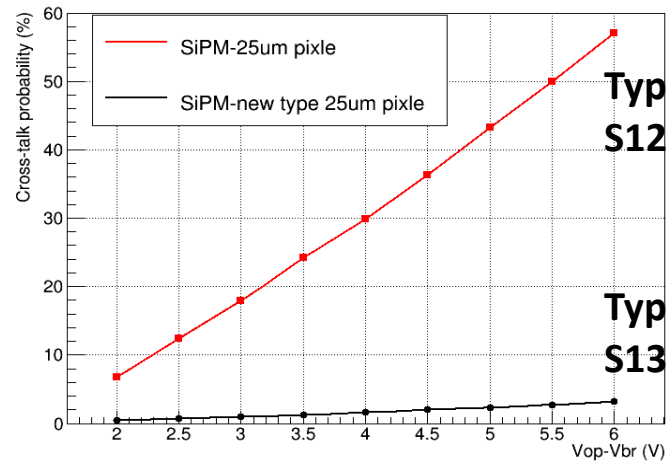
SiPM study: Optical Cross-talk

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 =
Dark rate 1.5p.e. threshold
Dark rate 0.5p.e. threshold



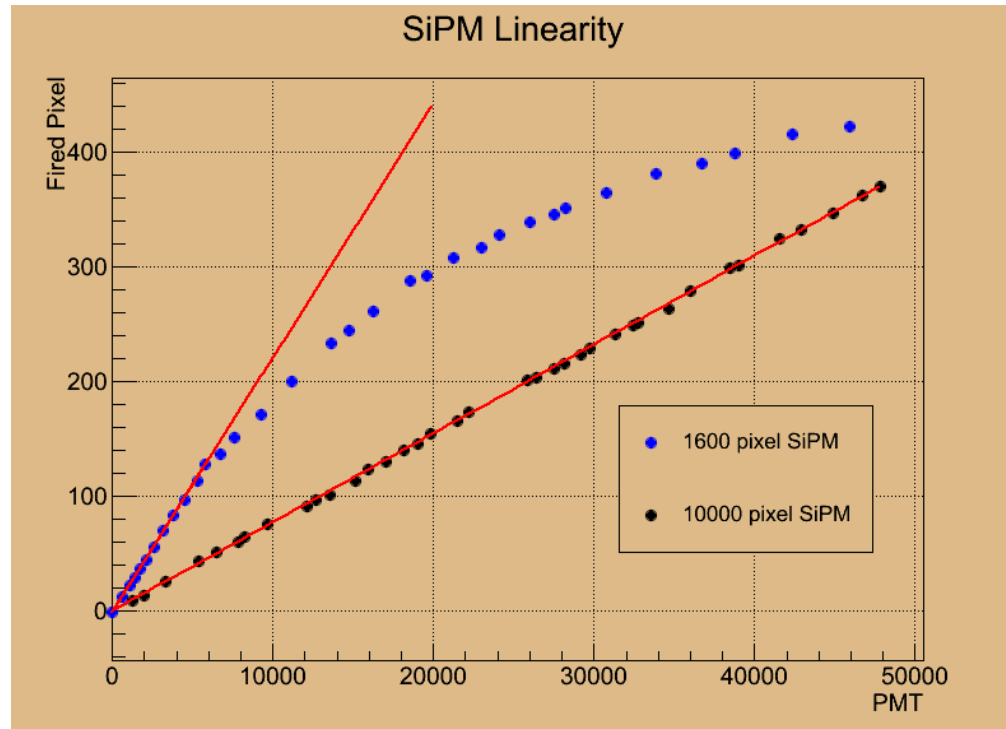
Type No.:
S12571-025P

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: Response Curve of SiPM

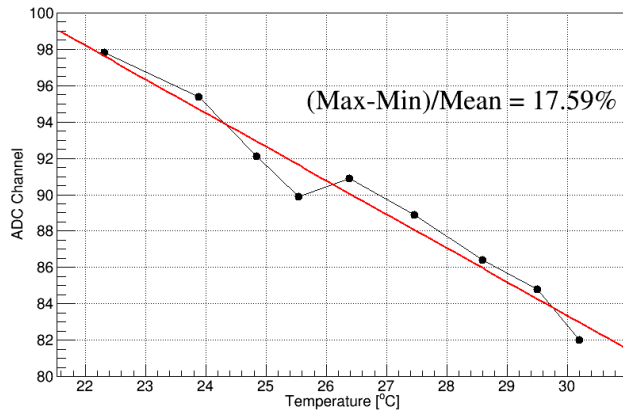


- **The SiPM dynamic range is determined by the number of pixels.**

The manufactures have developed the SiPM with the pixel pitch of 10um, which increase the number of pixel per unit area, drastically extends the SiPM dynamic range.

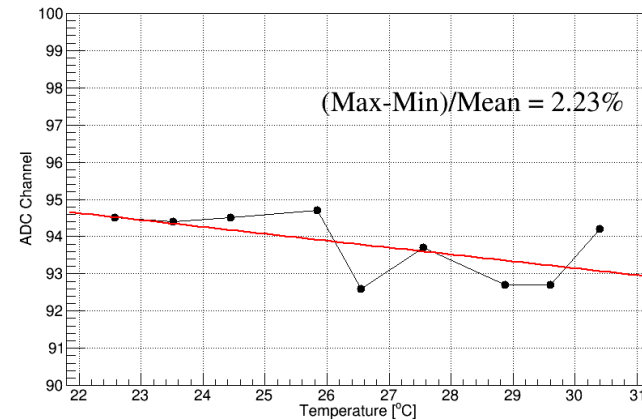
- **The photon detection efficiency of 10um SiPM is only 1/3 of 25um SiPM (data taken from Hamamatsu datasheet).**

SiPM study: Gain stabilization



Temperature effect of SiPM
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



Gain stabilization
Calibrated by single P.E.

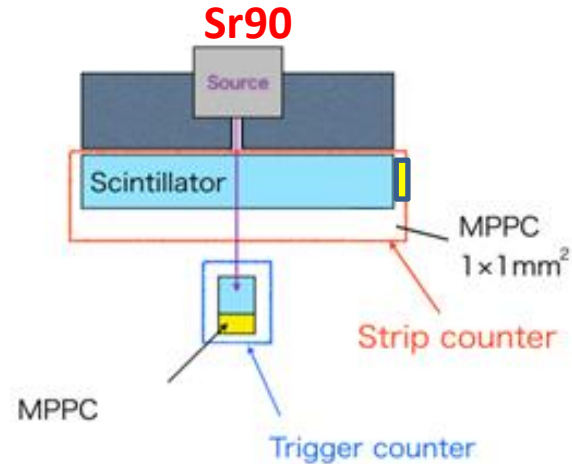


Temperature-compensation
circuit: C12332-01

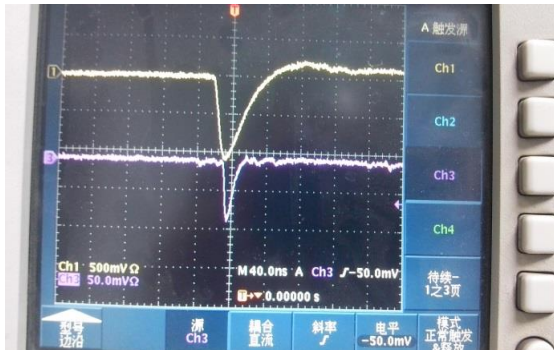
Scintillator strip test



Scintillator strip and SiPM



Test setup



Waveform of strip counter and trigger counter

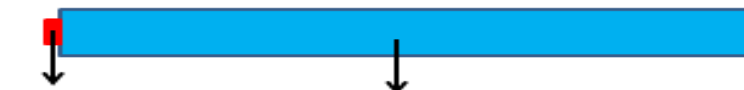
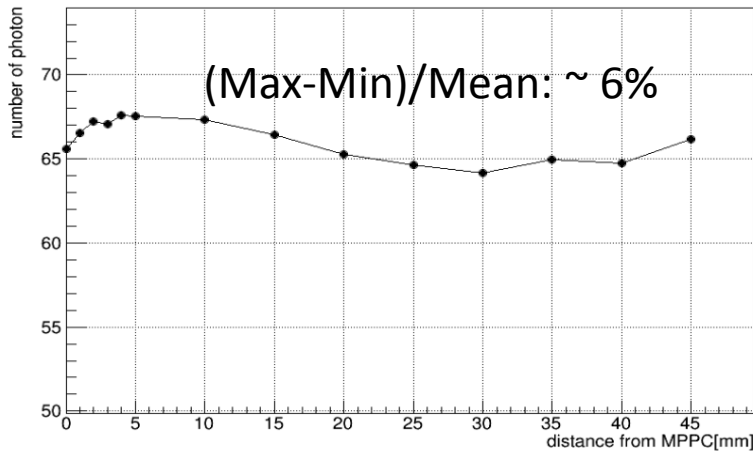


The **DT5751** is a **2-4 Channel 10 bit 2/1 GS/s** Desktop Waveform Digitizer .

Data acquire system

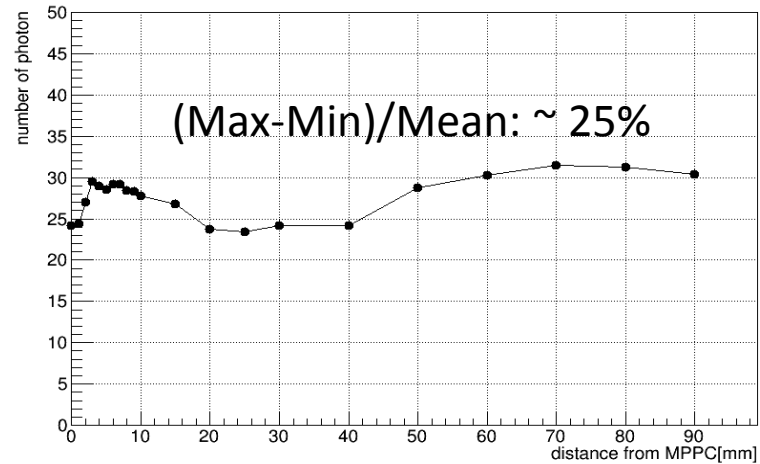
Strip light output

5mm × 45mm scintillator strip



SiPM Scintillator strip
Strip: 5mm × 45mm × 2mm

10mm × 90mm scintillator strip



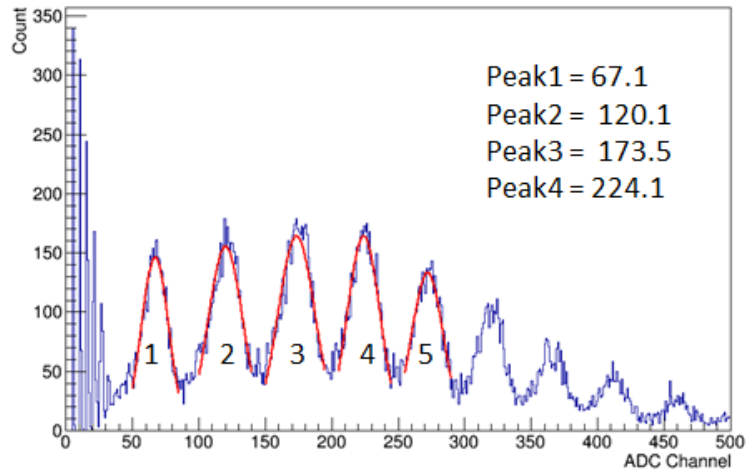
SiPM Scintillator strip
Strip: 10mm × 90mm × 2mm

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

Light output of 10mm × 90mm strip is about half of the 5mm × 45mm scintillator strip.

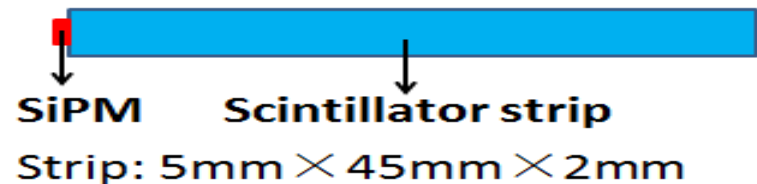
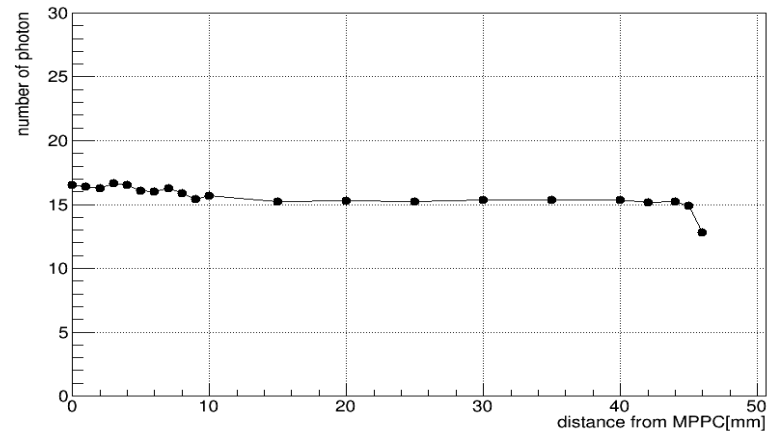
10um SiPM light output

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, that is to say the absolute PDE of 10um SiPM is 8%@420 nm.

Summary

- 1 CEPC ScW ECAI simulation is in progress.
- 2 Performance study of readout unit still lot to be done.

Thanks!