CEPC 电磁量能器研究进展

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报告内容

1 CEPC 电磁量能器简介

2 量能器结构模拟优化

3 读出单元性能研究

4 总结

1 Particle Flow Algorithms and Imaging Calorimeter

The idea…

Charged particles } measured with the { **Tracker**

Neutral particles } measured with the { **Calorimeter**

Particles in jets	Fraction of energy	Measured with	Resolution [σ^2]
Charged	65 %	Tracker	Negligible
Photons	25 %	ECAL with 15%/√E	$0.07^2\ E_{jet}$
Neutral Hadrons	10 %	ECAL + HCAL with 50%/√E	$0.16^2\ E_{jet}$
Confusion			$\leq 0.24^2\ E_{jet}$

} 18%/√E

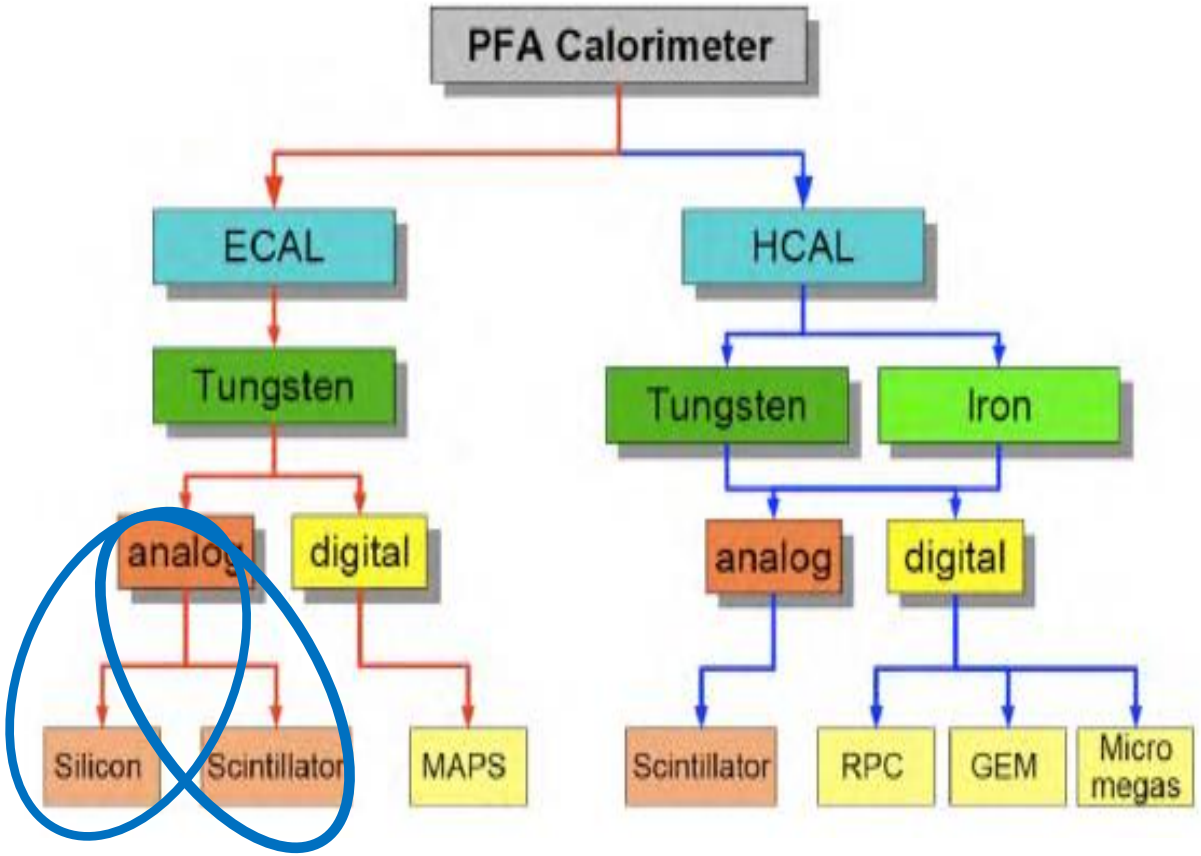
Required for 30%/√E

Requirements for detector system

→ Need excellent tracker and high B – field
→ Large R_I of calorimeter
→ Calorimeter inside coil
→ Calorimeter as dense as possible (short X_0, λ_I) } **thin active medium**
→ Calorimeter with **extremely fine segmentation**

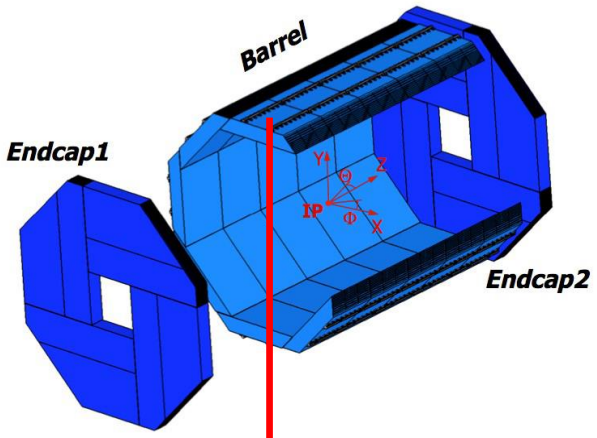
↳ **Imaging Calorimeter**: see the detail of every particle shower

CEPC ECAL



Two options of CEPC ECAL

Structure of the CEPC ECAL



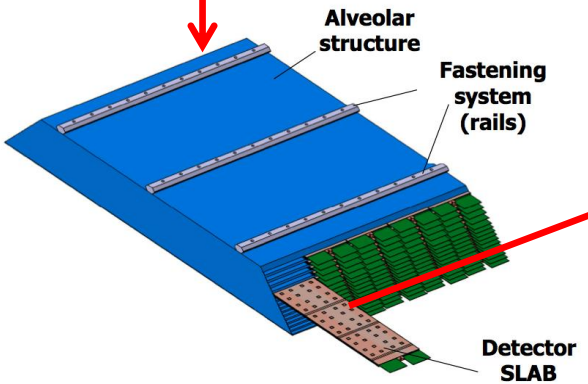
The CEPC ECAL consists of a cylindrical barrel system and two end caps.

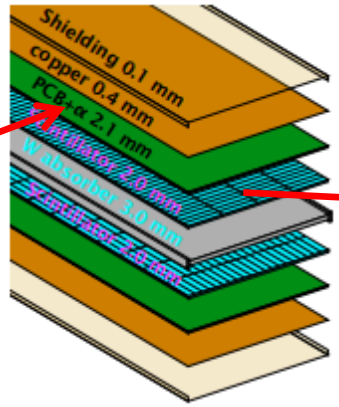
One of the proposal for CEPC ECAL is based on scintillator strip with SiPM readout.

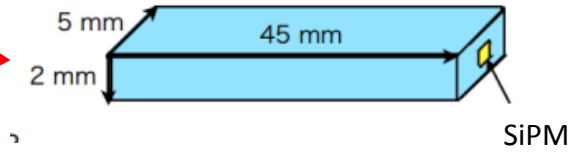
Total readout channel: ~8 Million

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 mm^2 transverse size.

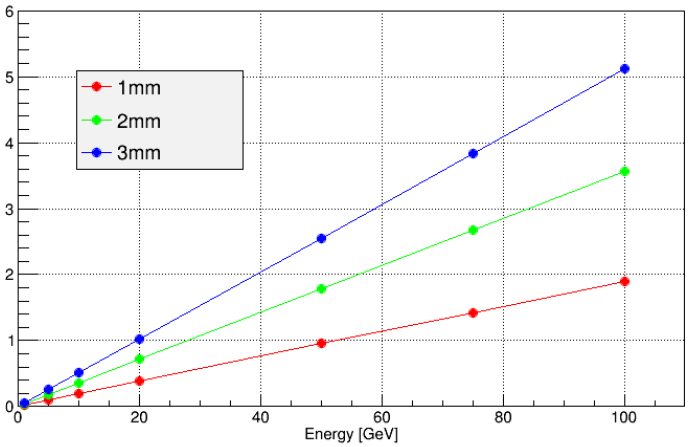




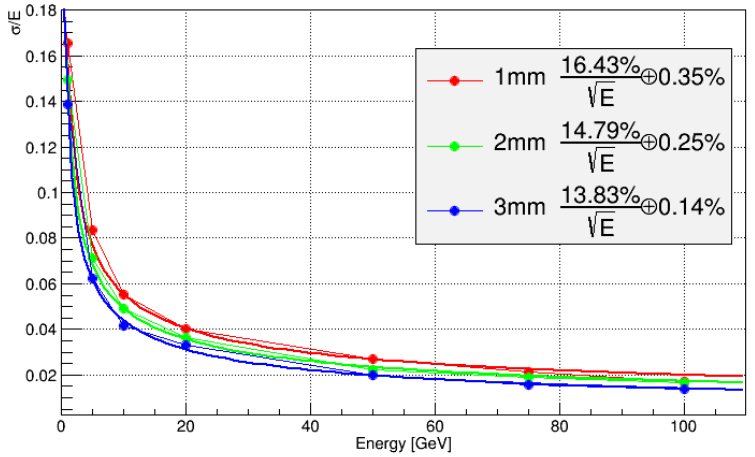


Baseline design of scintillator and SiPM

2 Detector Simulation: scintillator thickness



Linearity

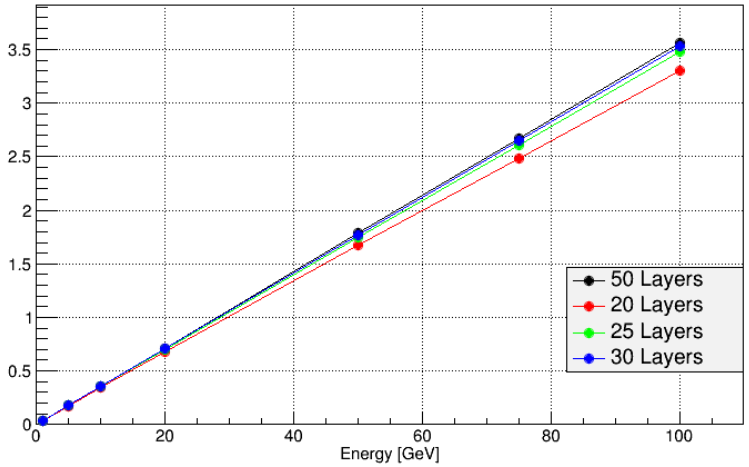


Energy Resolution

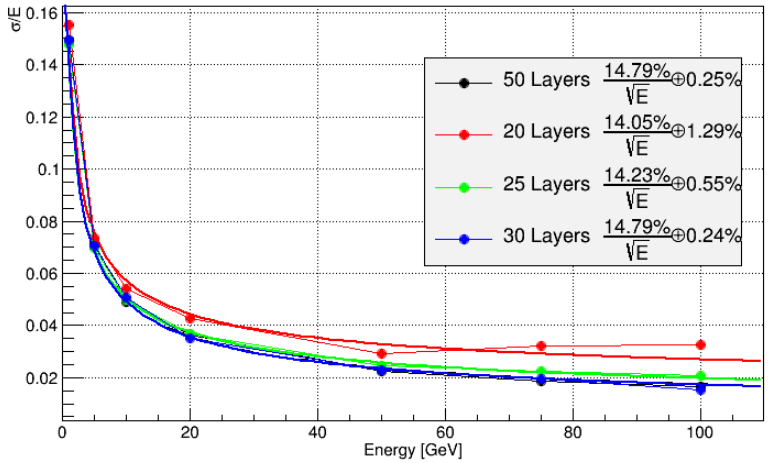
The dependency of the linearity and energy resolution on the scintillator thickness.

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

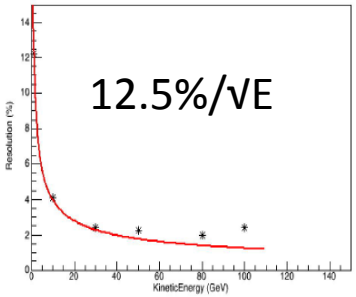
The dependency of the linearity and energy resolution on the layer number.

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

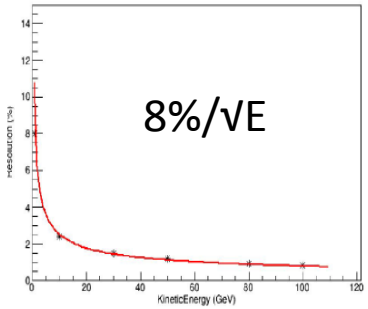
Detector Simulation : Crystals

- ECAL configuration
  - 30 layers of 2.1mm W + 1-2mm active medium + 1.5mm PCB

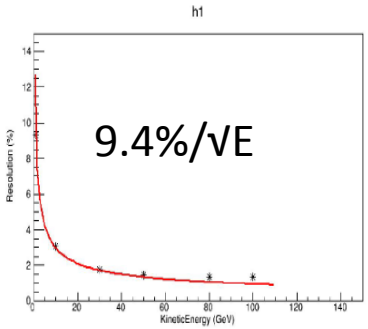
Energy resolution



PSD:2mm



LSO:2mm



LSO:1mm

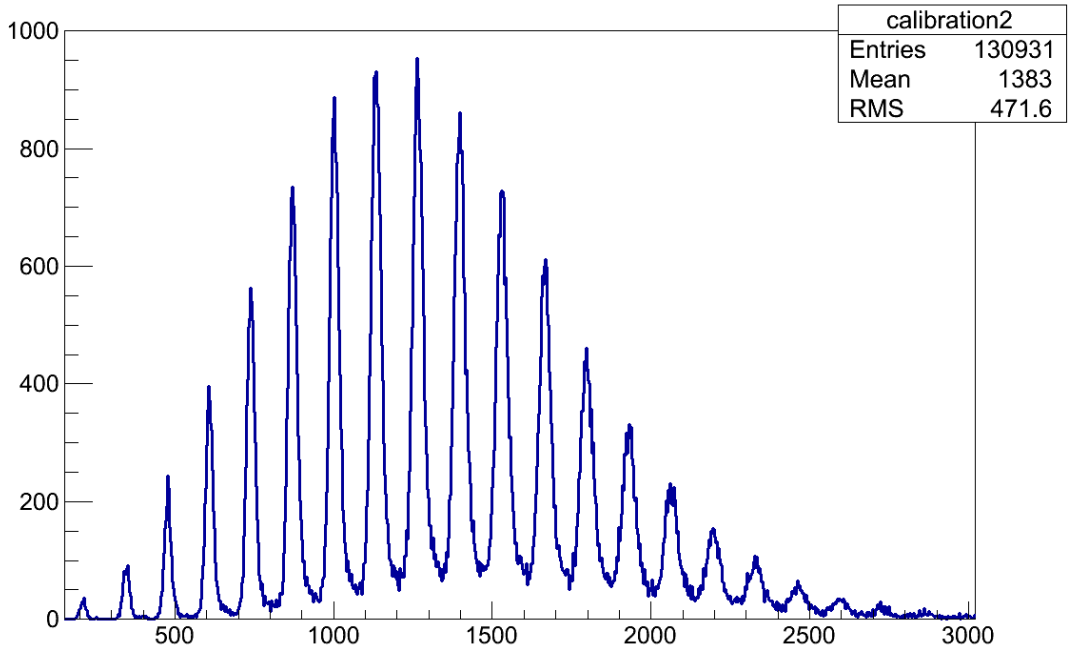
Effective moliere radius

Material	Thickness (cm)	Moliere Radius (cm)
PSD	0.2	~2.25
LSO	0.2	~2
LSO	0.1	~1.75

Note: PSD is denoted “plastic scintillator”

- Better intrinsic energy resolution with crystals as sensitive medium, particularly in the low energy region relevant to jet measurement.
- Smaller effective moliere radius with crystals.

3 SiPM study



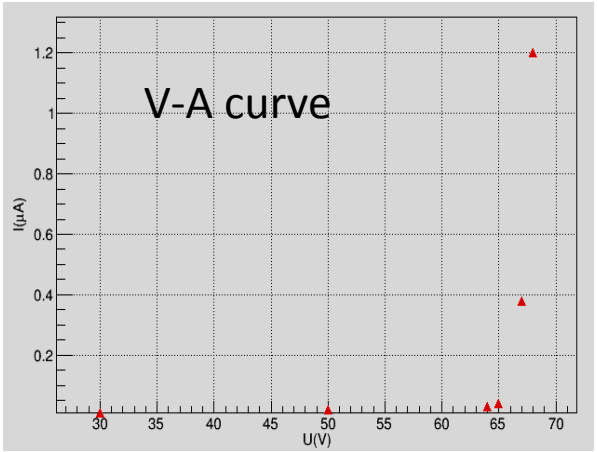
Pulse height spectrum

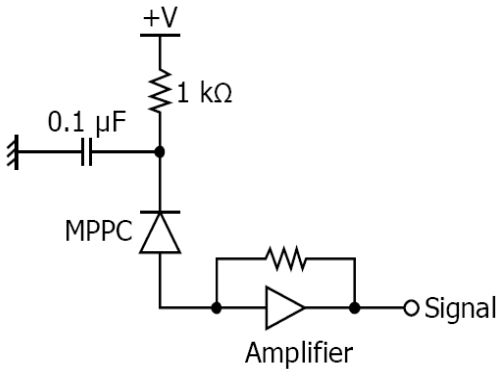
The individual peaks are clearly separated from each other in the pulse height spectrum.

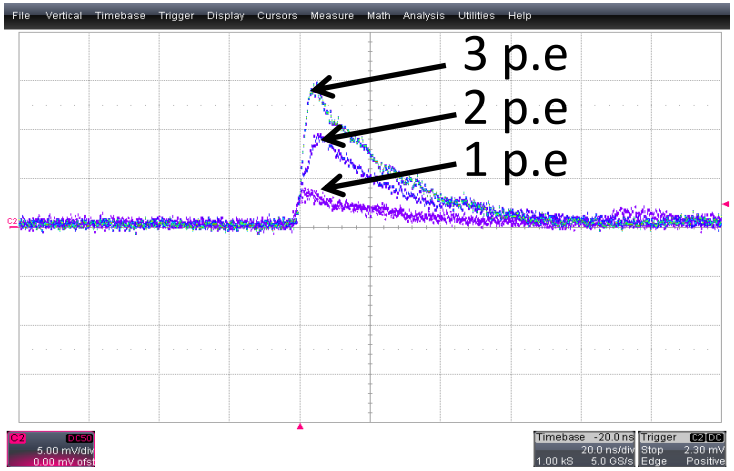
- **Excellent photon counting ability**

SiPM study: V-A curve

Developed SiPM base



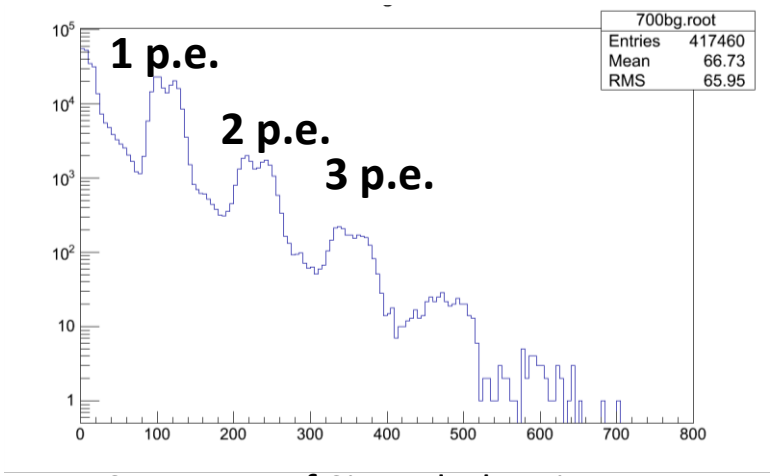




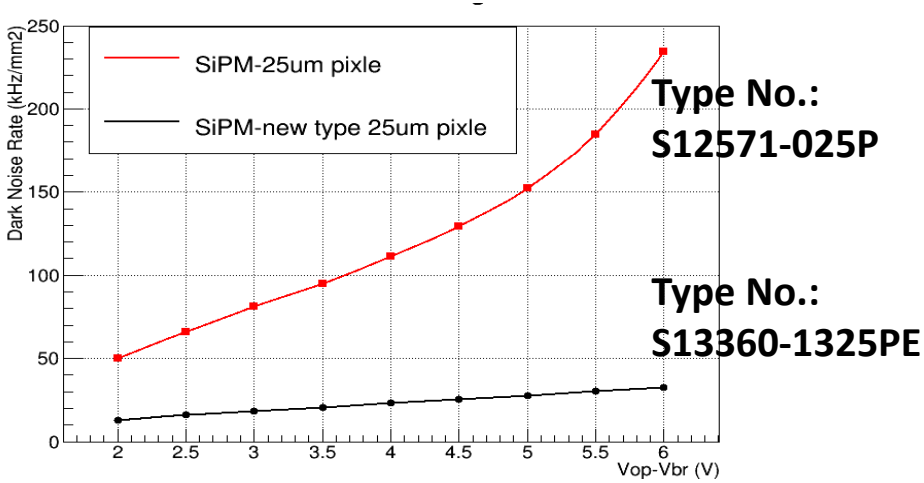
Test of crystals coupled with SiPM being prepared

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.**

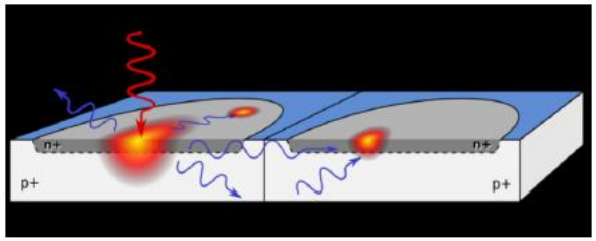
Very recently, SiPMs with trenches between pixels dramatically reduced dark rate and pixel to pixel cross-talk.

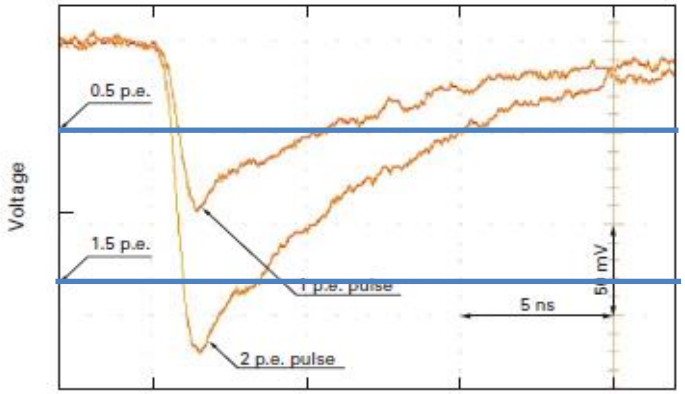
- **The dark noise rate of the new SiPMs (30kHz/mm^2)is 1/3 of the old ones(100kHz/mm^2), with same gain.**

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.

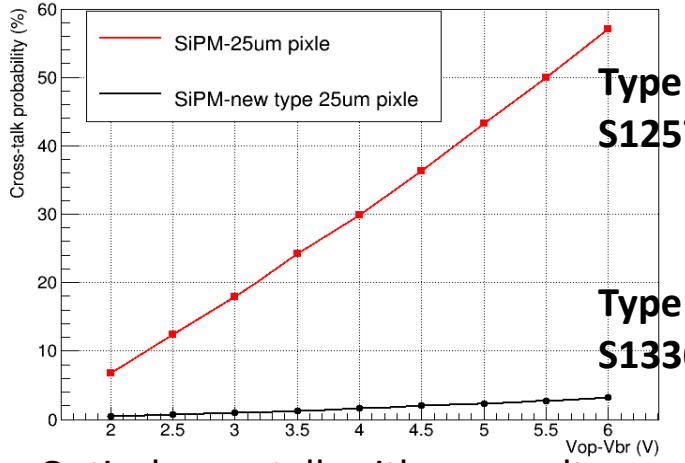
*A. Lacaita, et al., IEEE Trans. Electron Devices ED-40(1993) 577





Cross talk rate =

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



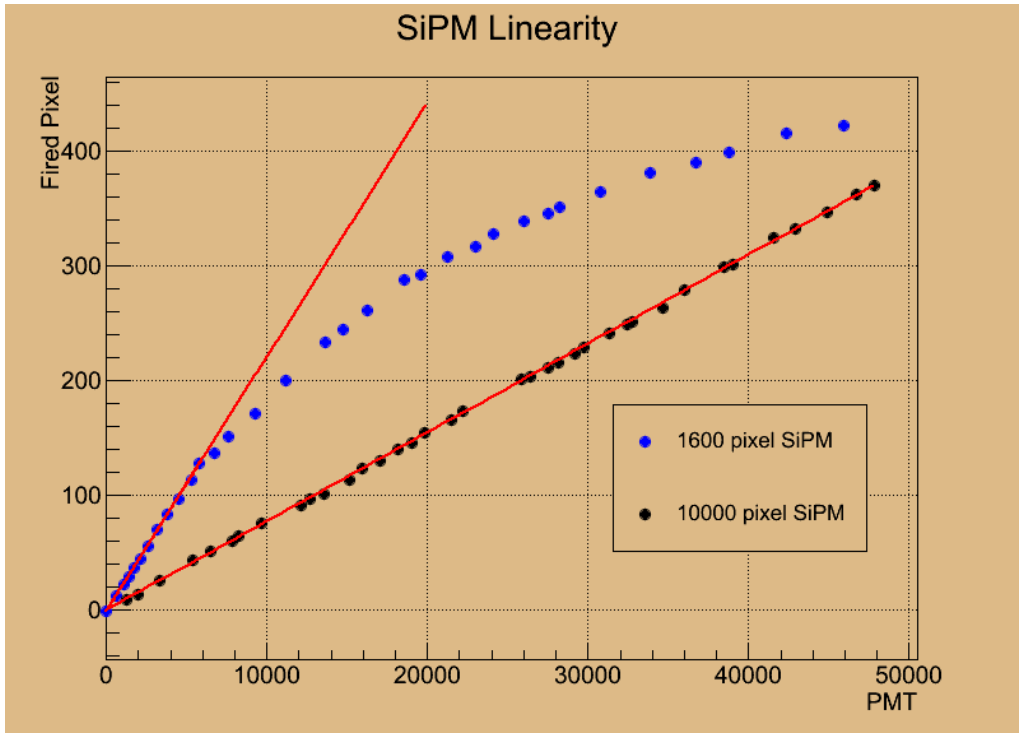
Type No.: S12571-025P

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: Response Curve of SiPM

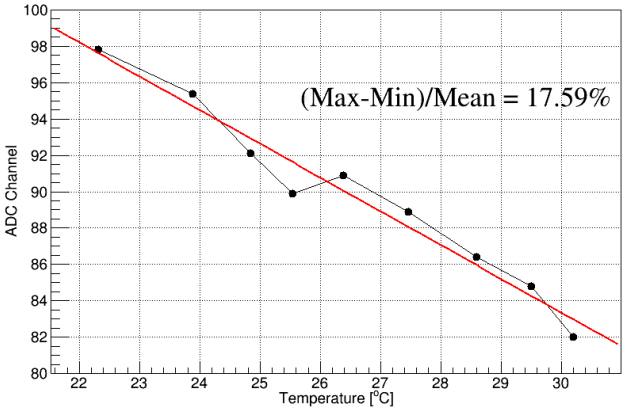


- **The SiPM dynamic range is determined by the number of pixels.**

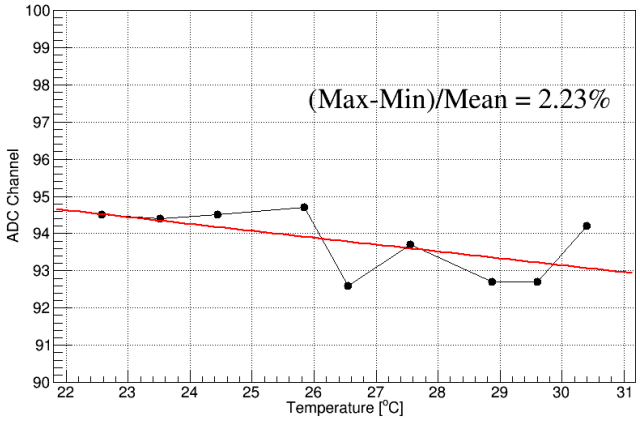
The manufactures have developed the SiPM with the pixel pitch of 10um, which increase the number of pixel per unit area, drastically extends the SiPM dynamic range.

- **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.



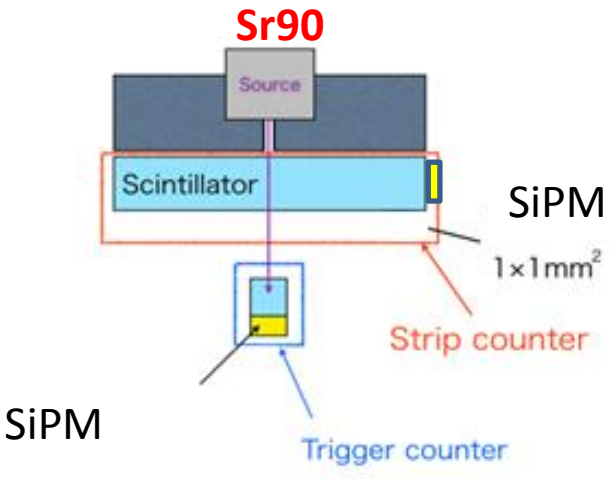
Gain stabilization
Calibrated by single P.E.

- 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

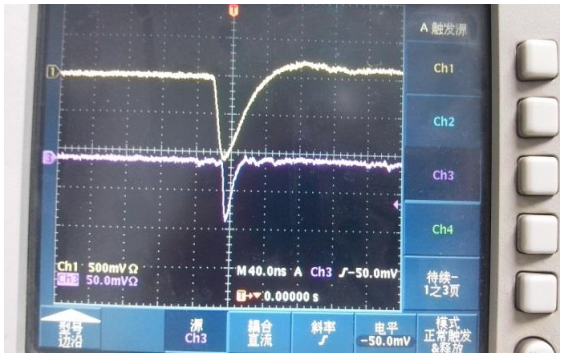
Temperature-compensation circuit: C12332-01

Scintillator strip test

Scintillator strip and SiPM



Test setup



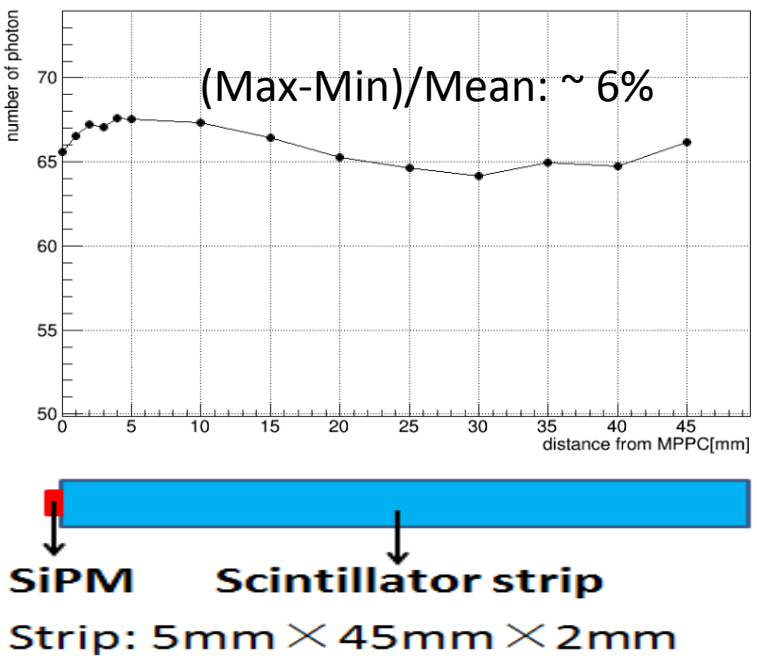
Waveform of strip counter and trigger counter

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

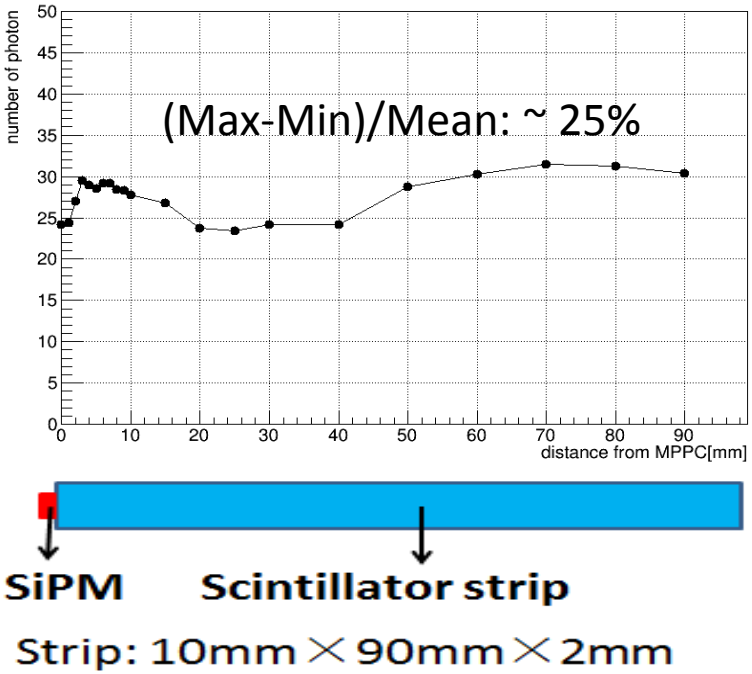
Data acquire system

Strip light output

5mm×45mm scintillator strip



10mm×90mm scintillator strip

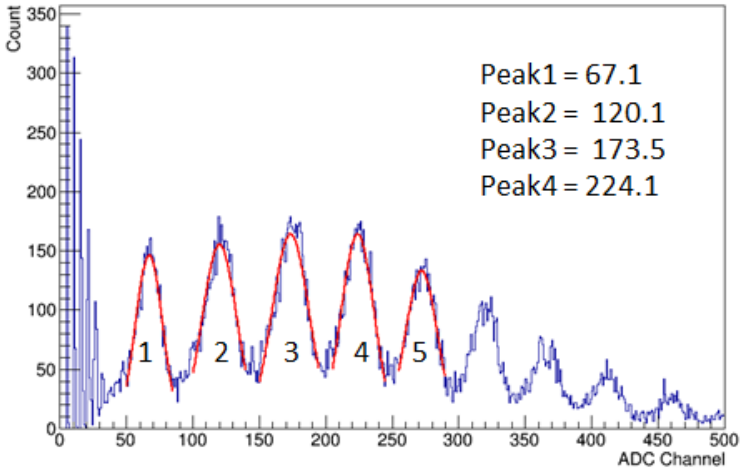


Scintillator: BC408，　SiPM: 1mm×1mm,25um pixel size

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

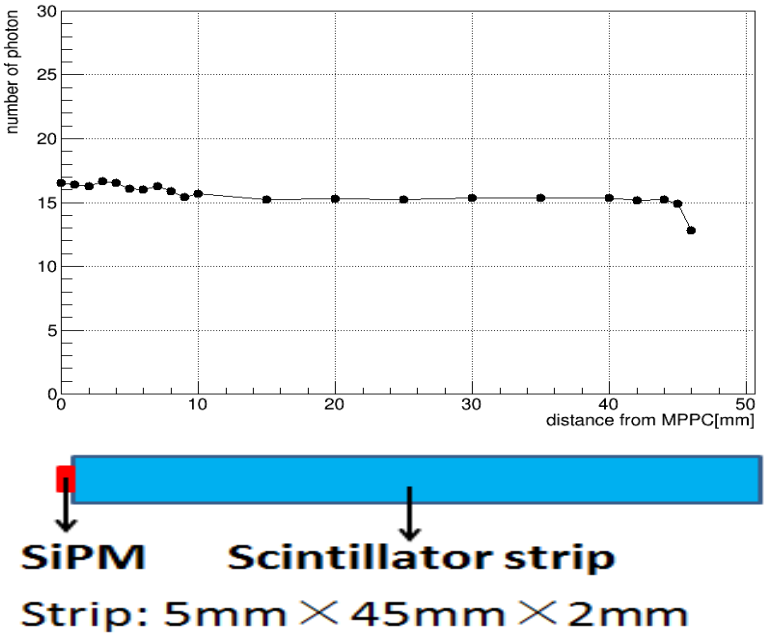
10um SiPM light output

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 (the absolute PDE of 10um SiPM is 8%@420 nm).**

4 Summary

1 CEPC ScW ECAl simulation is in progress.

2 Performance study of readout unit still lot to be done.

Thanks!