Status of CEPC ECAL

Zhigang Wang, IHEP

On behalf of CEPC ECAL group

2016.04.08

CEPC-SppC 研讨会

Outline

1 Introduction of CEPC ECAL

2 SiPM study

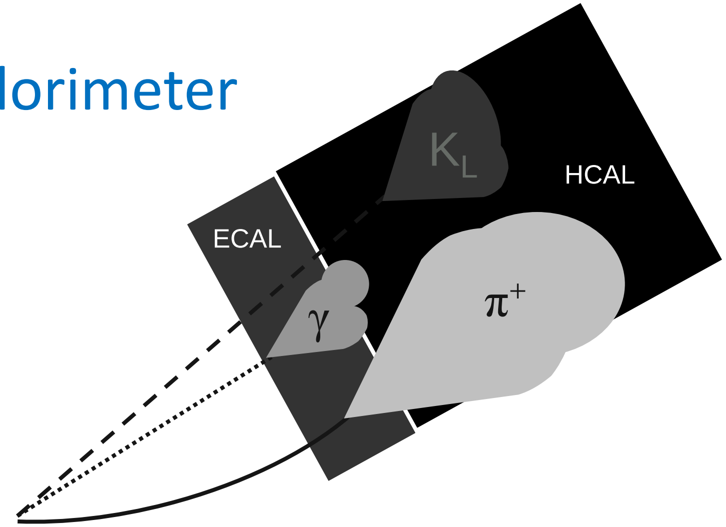
3 Scintillator optimization

4 Readout unit study

5 Cooling system

6 Summary and Outlook

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	Required for 30%/√E		≤ 0.24^2 E_{jet}

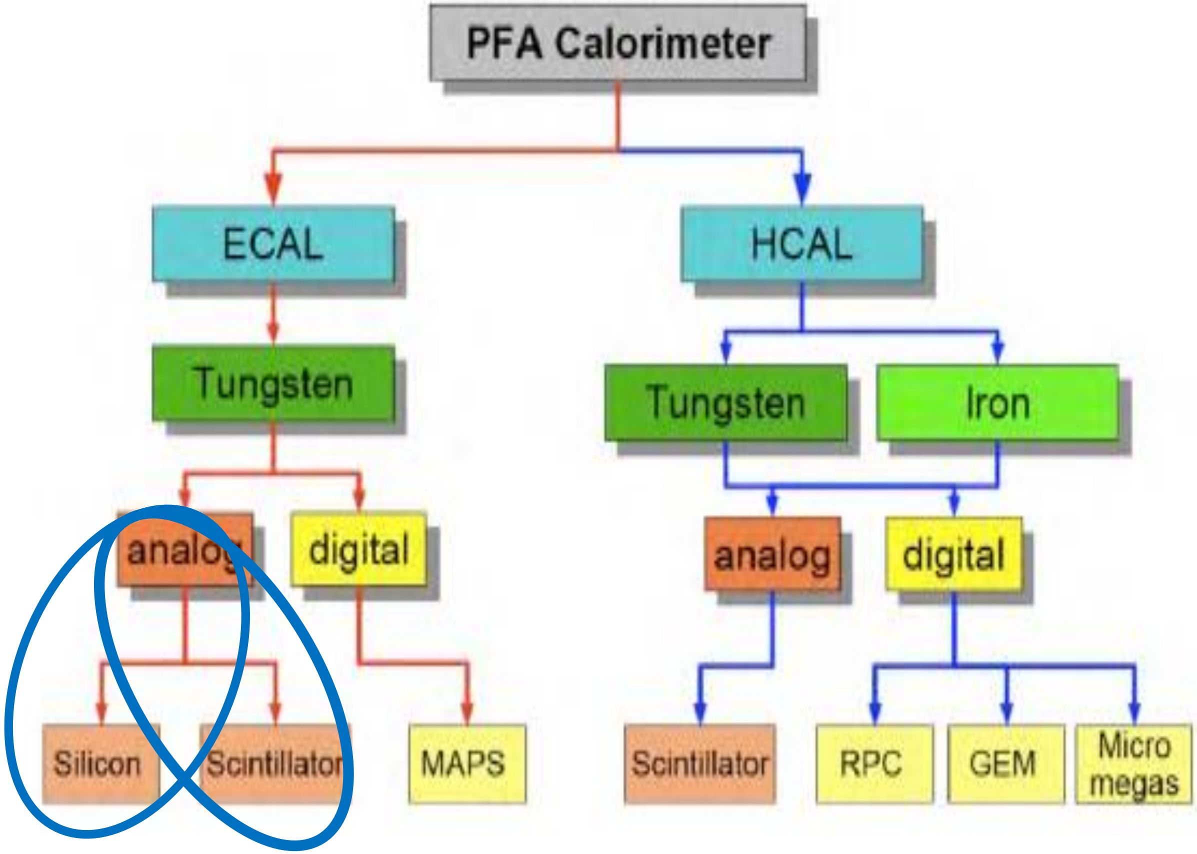
} 18%/√E

Requirements for detector system

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

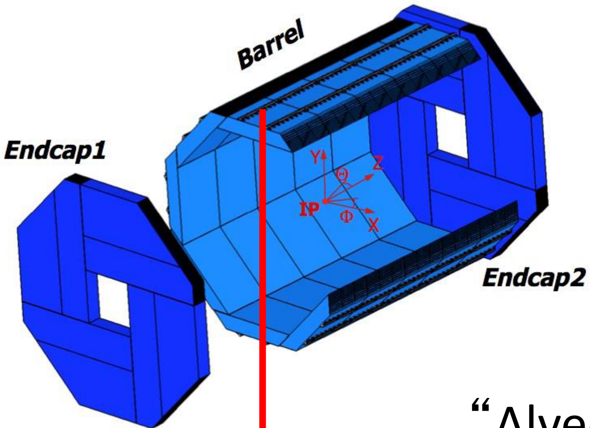
⮡ **Imaging Calorimeter**: see the detail of every particle shower

CEPC ECAL



Two options of CEPC ECAL

Structure of the CEPC Ecal



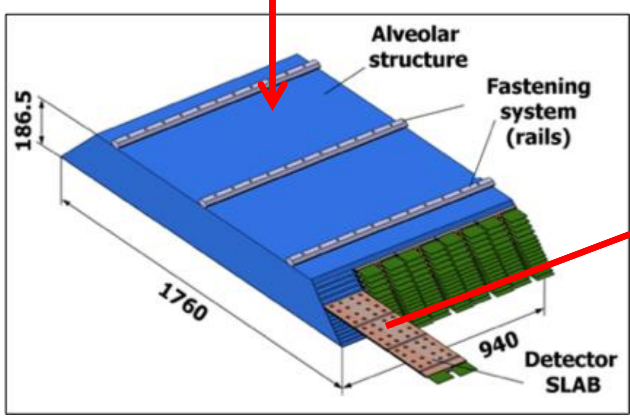
ECAL consist of a cylindrical barrel system and two large end caps.

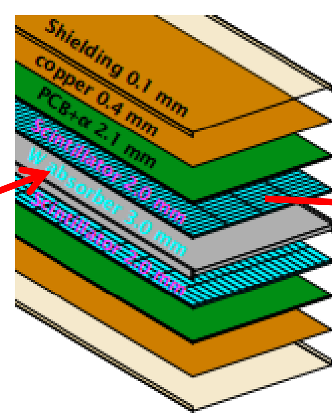
One of the candidates for CEPC ECAL is based on scintillator strip with SiPM readout
Total readout channel: ~8 Million

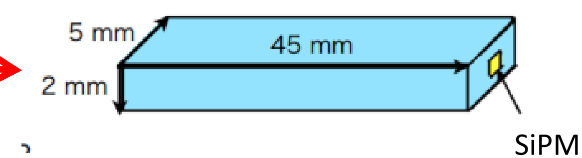
“Alveolar” frame structure is made with tungsten absorber.

Two scintillator layers in an alveolar make a sandwich structure with a tungsten absorber.

Strip directions are orthogonal to each other.



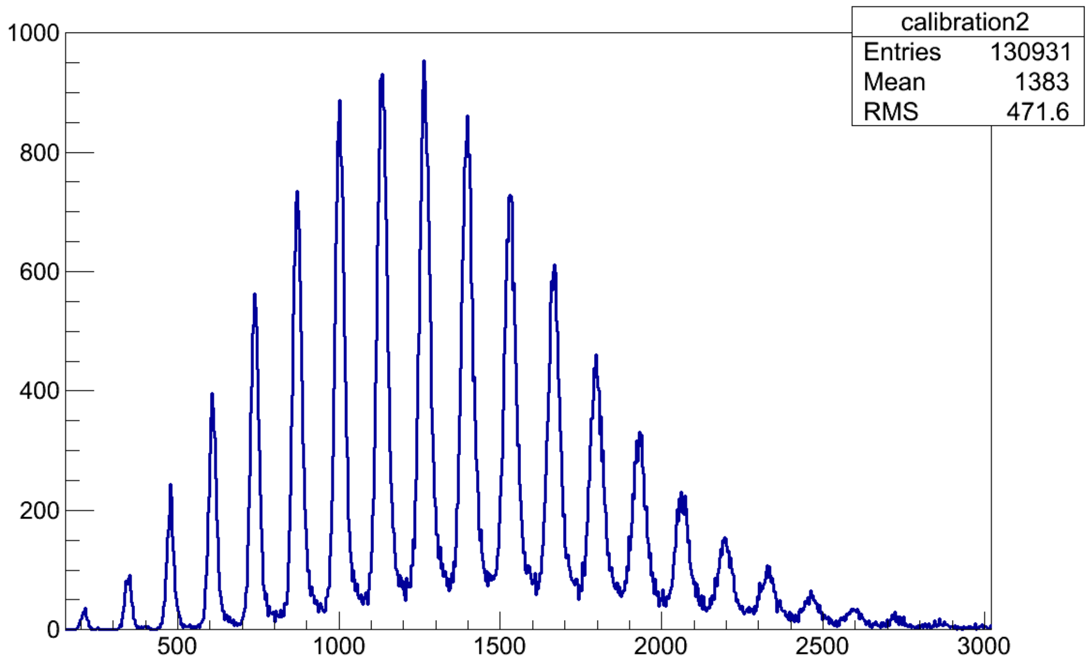




Baseline design of scintillator and SiPM

SiPM study

Zhigang Wang, Tao Hu, IHEP 高能所科技创新项目经费支持



Pulse height spectrum

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

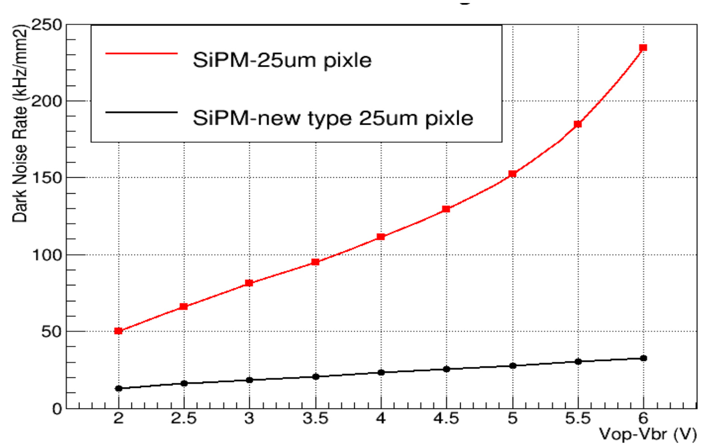
- **Excellent photon counting ability**

SiPM study: Dark Noise Rate

Electron hole pairs generated without the involvement of photons give rise to unwanted noise.
Resulting signal is indistinguishable from a photon induced signal.
The thermal generated dark rate doubles for each temperature increase of 8 ^{0}C.

Temperature: 25 $\pm$ 0.1^{0}C

Dark spectrum of SiPM dark noise



Dark noise rate with over-voltage

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

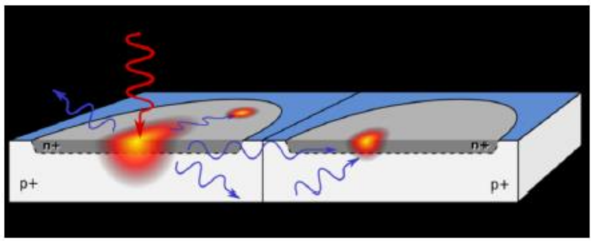
Very recently, SiPMs with trenches between pixels became available dramatically reduced dark rate and pixel to pixel cross-talk.

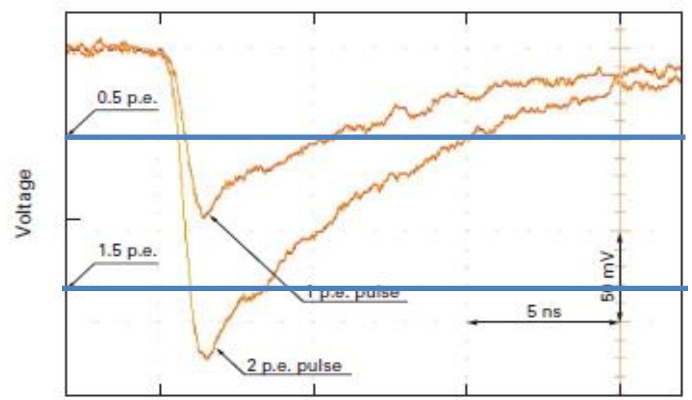
- **The dark noise rate of the new SiPMs (30kHz/mm^2)is 1/3 of the old ones(100kHz/mm^2), with same gain.**

SiPM study: Optical Cross-talk

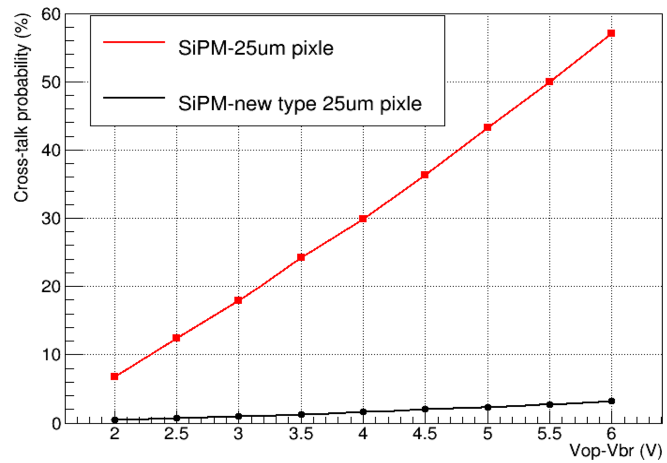
A p-n junction in breakdown emits photons in the visible range, if they reach a neighboring pixel additional breakdown can be caused.

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





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

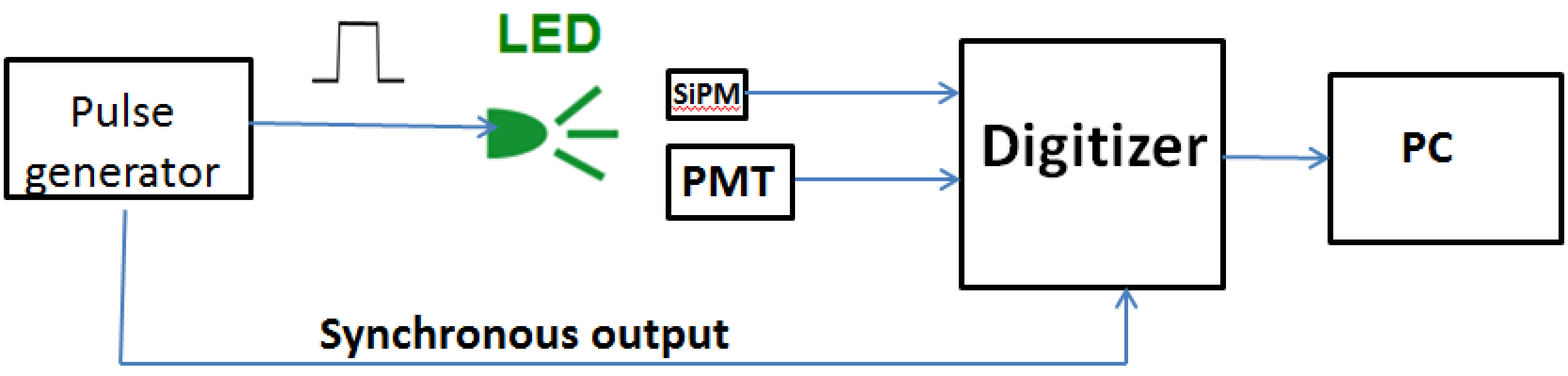


Optical cross-talk with over-voltage

- **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.**

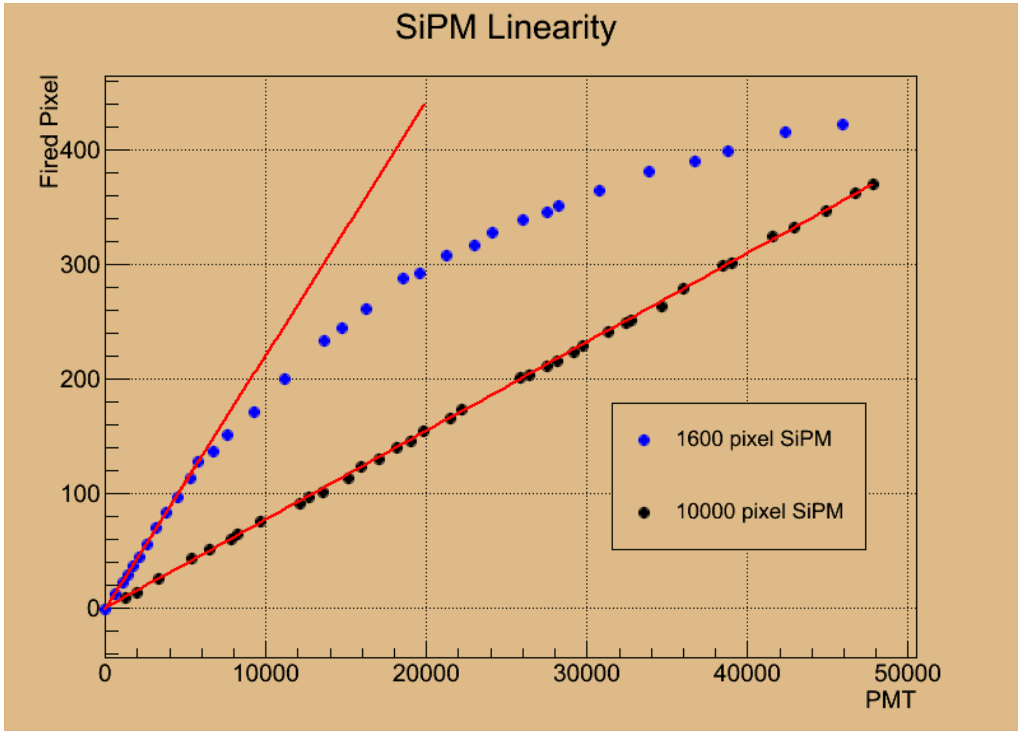
SiPM study: Response Curve of SiPM

Room Temperature: 25 $\pm 0.1^0$C



Experiment Set up

SiPM study: Response Curve of SiPM



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

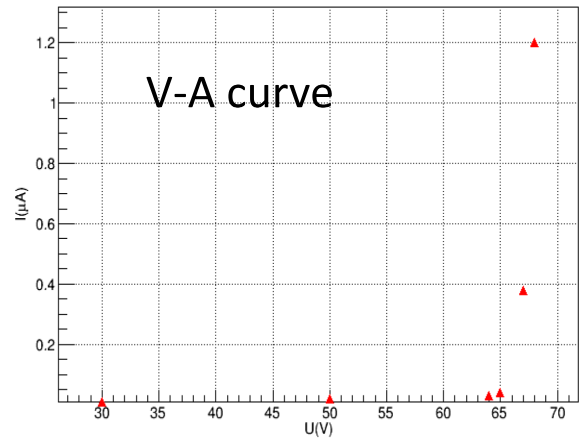
The manufactures have developed the SiPM with the pixel pitch of 10um, which increase the number of pixel per unit area, drastically extends the SiPM dynamic range.

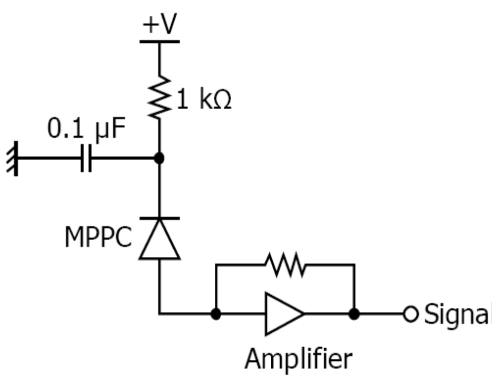
- **The photon detection efficiency of 10um SiPM is only 1/3 of 25um SiPM.**

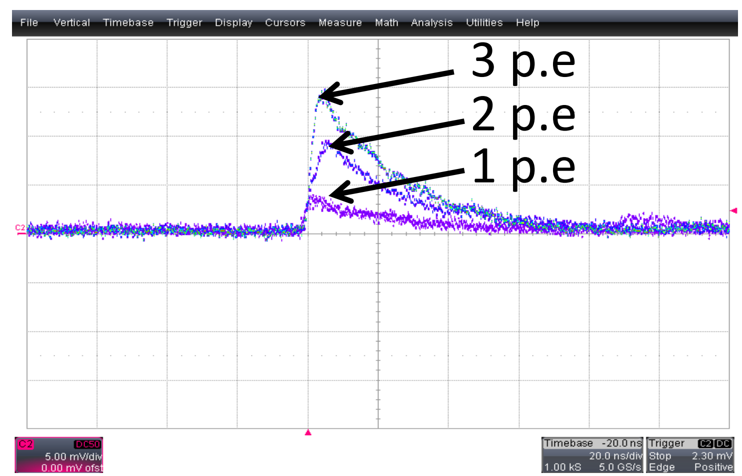
SiPM study: V-A curve

Jianbei Liu, USTC 中科大重要方向项目培育基金支持

Developed SiPM base

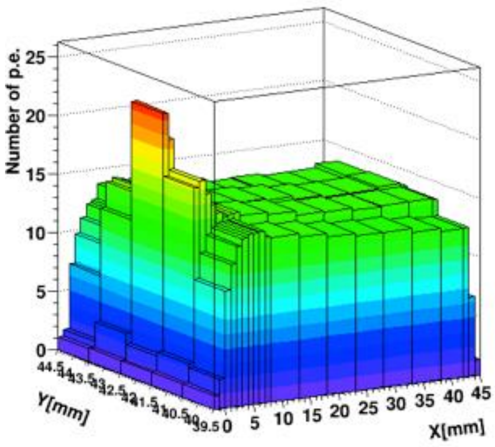


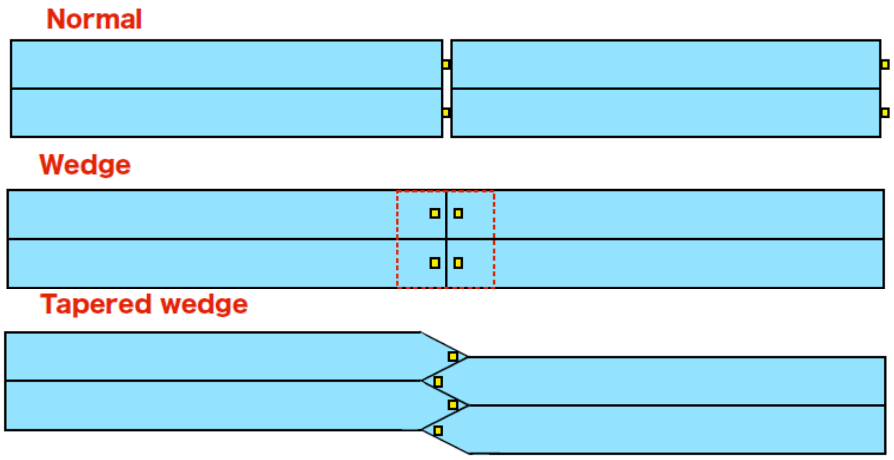




Test of crystals coupled with SiPM being prepared

Scintillator optimization

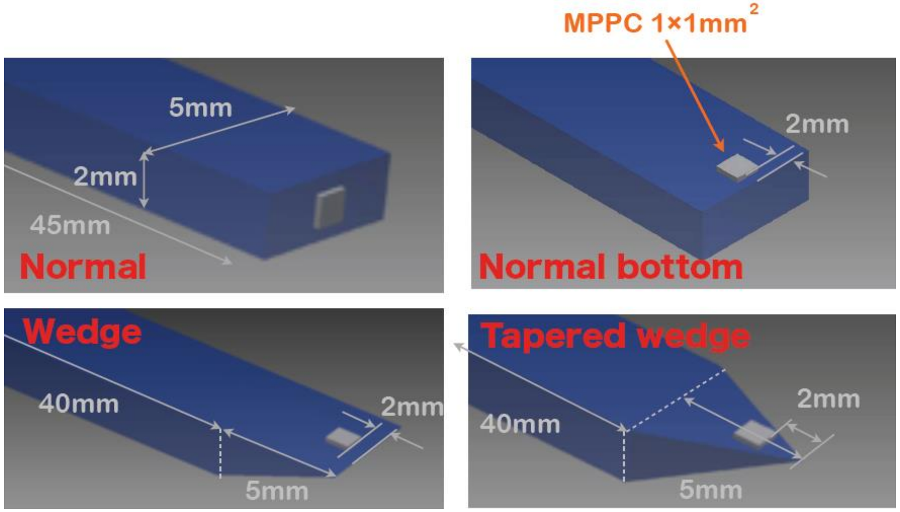




According to ILD research, **technical problems exist in baseline design:**

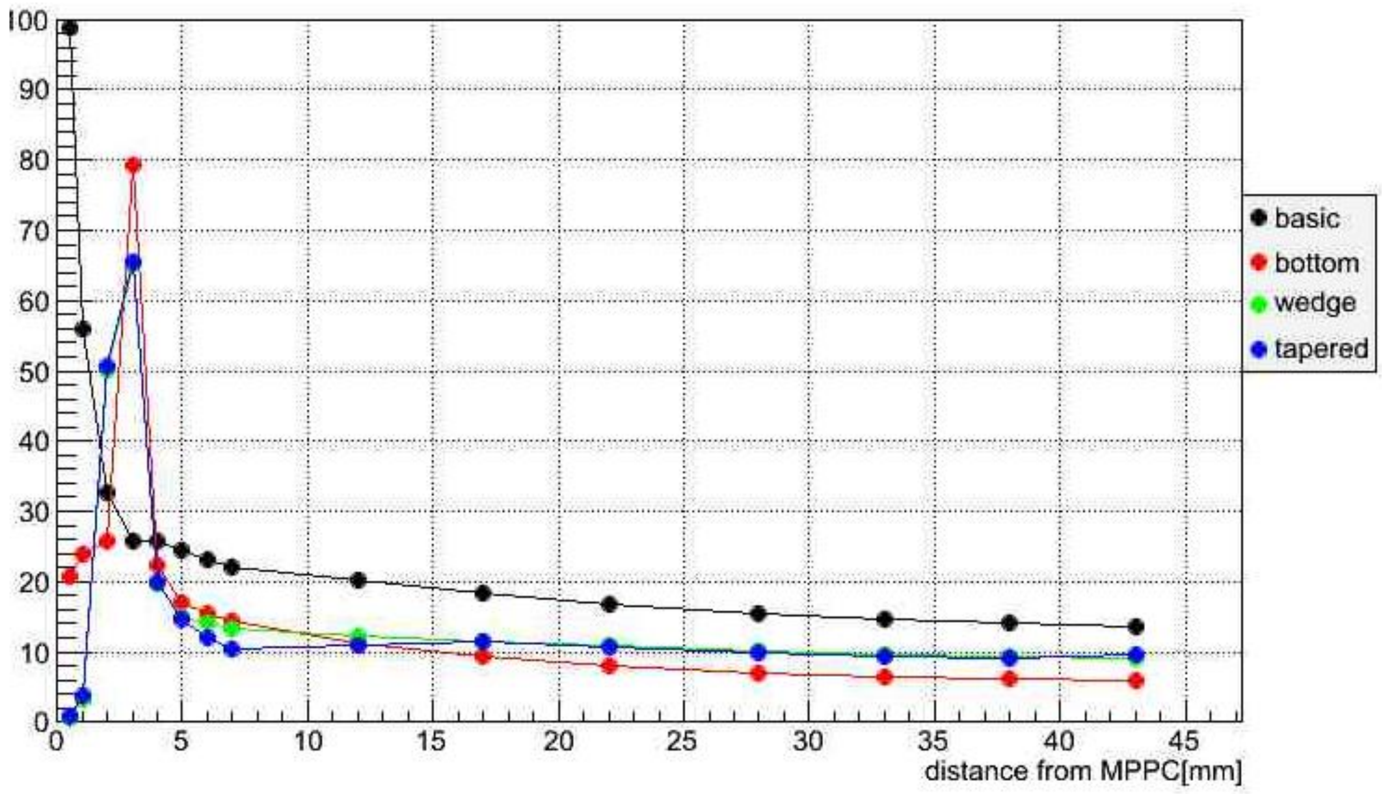
1,Peaky response for hit near SiPM in Normal design.

2,Dead gap between strips due to SiPM installation.



Scintillator optimization : Simulation

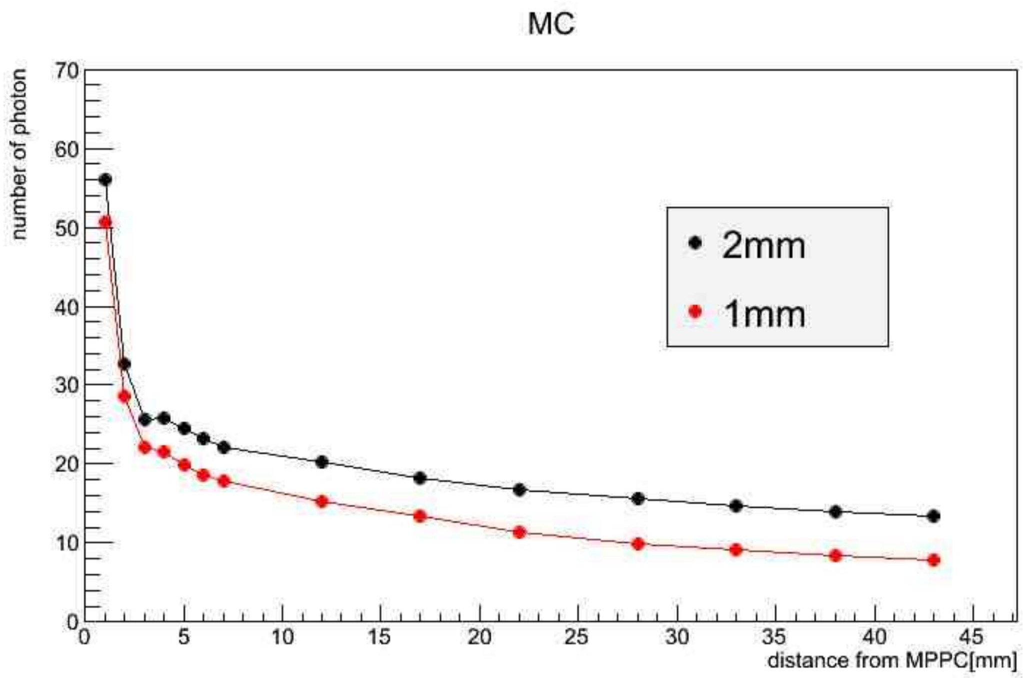
Hang Zhao, Tao Hu, IHEP



Geant4-based simulation of scintillation photon propagation.
Monte Carlo simulation parameters are still to be optimized.
Only relative comparison makes sense for the moment.

Scintillator optimization: Thickness of Scintillator

Scintillator thickness decreased from 2mm to 1mm

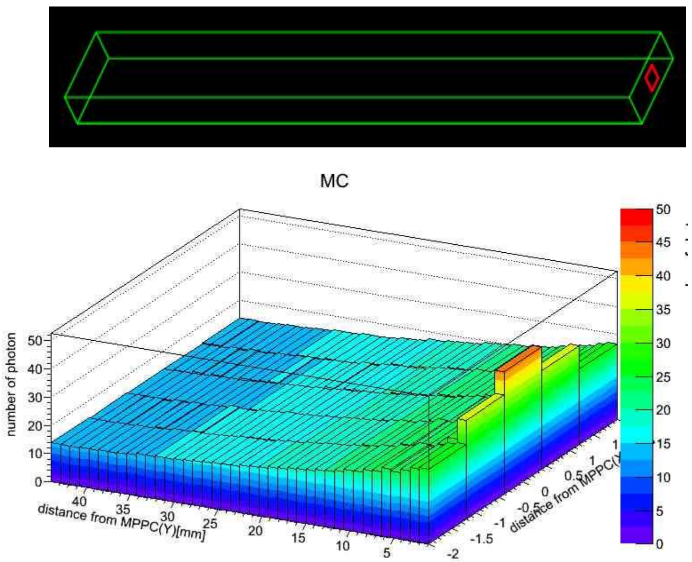


1mm thick scintillator had photon yield factor **2/3**

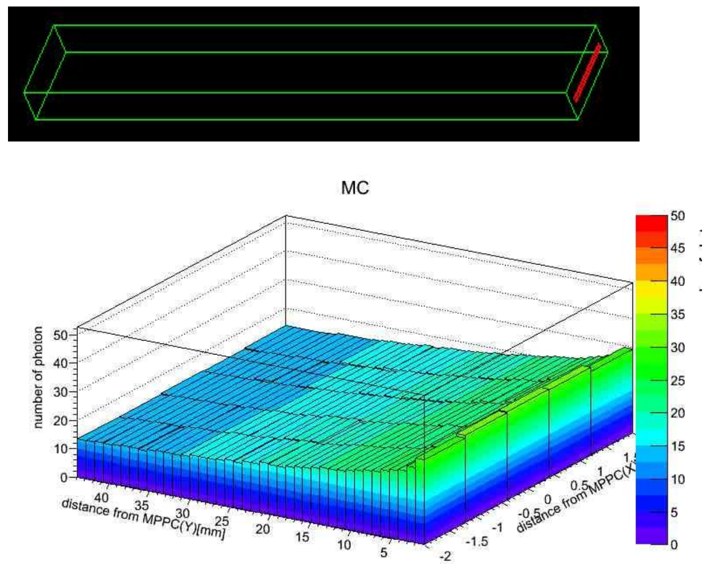
Scintillator optimization: Shape of SiPM

SiPM sensor area 1×1 mm^2 to 0.25×4 mm^2:
increase acceptance

It is easy to make this shape of MPPC with current technology



basic design



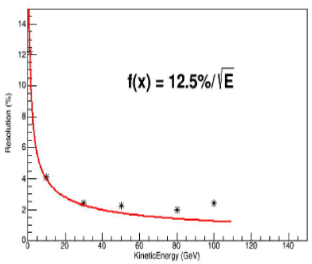
new design

Scintillator optimization: Crystals

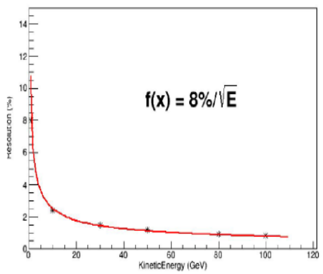
Jianbei Liu, USTC

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

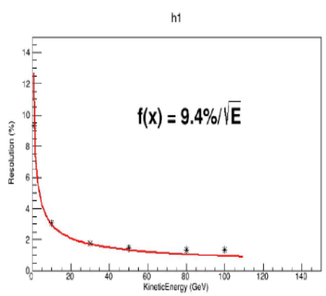
Energy resolution



PSD:2mm



LSO:2mm



LSO:1mm

Effective moliere radius

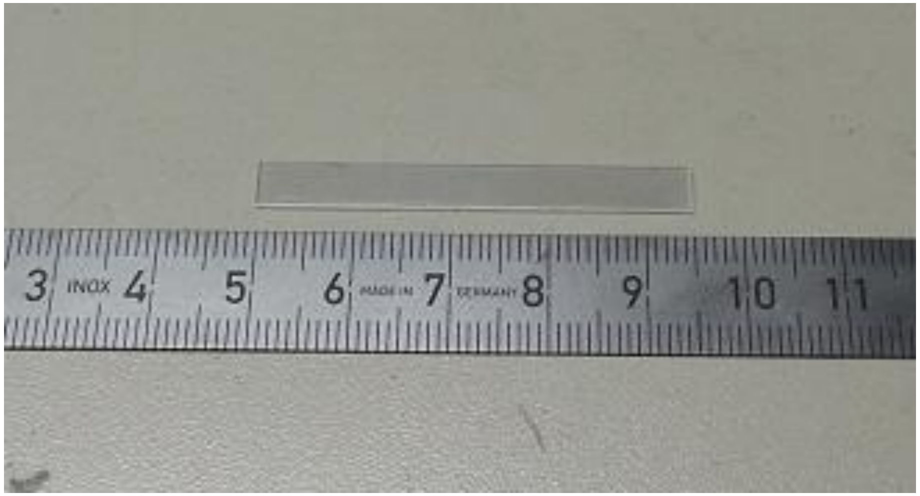
Material	Thickness (cm)	Moliere Radius (cm)
PSD	0.2	~2.25
LSO	0.2	~2
LSO	0.1	~1.75

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

Scintillator optimization: Crystal samples

- BGO
  - 1mm*5mm*45mm
  - 2mm*5mm*45mm
- LYSO
  - 1mm*5mm*45mm
  - 2mm*5mm*45mm

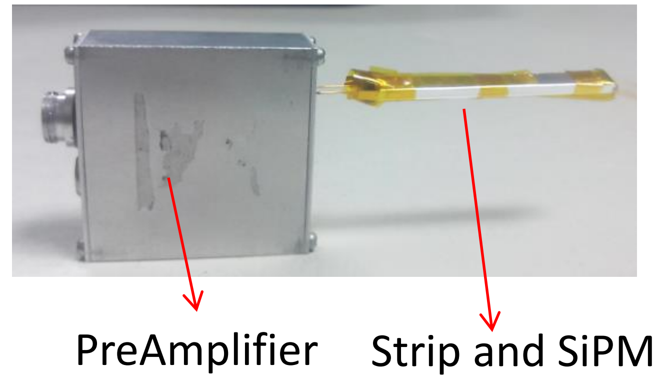


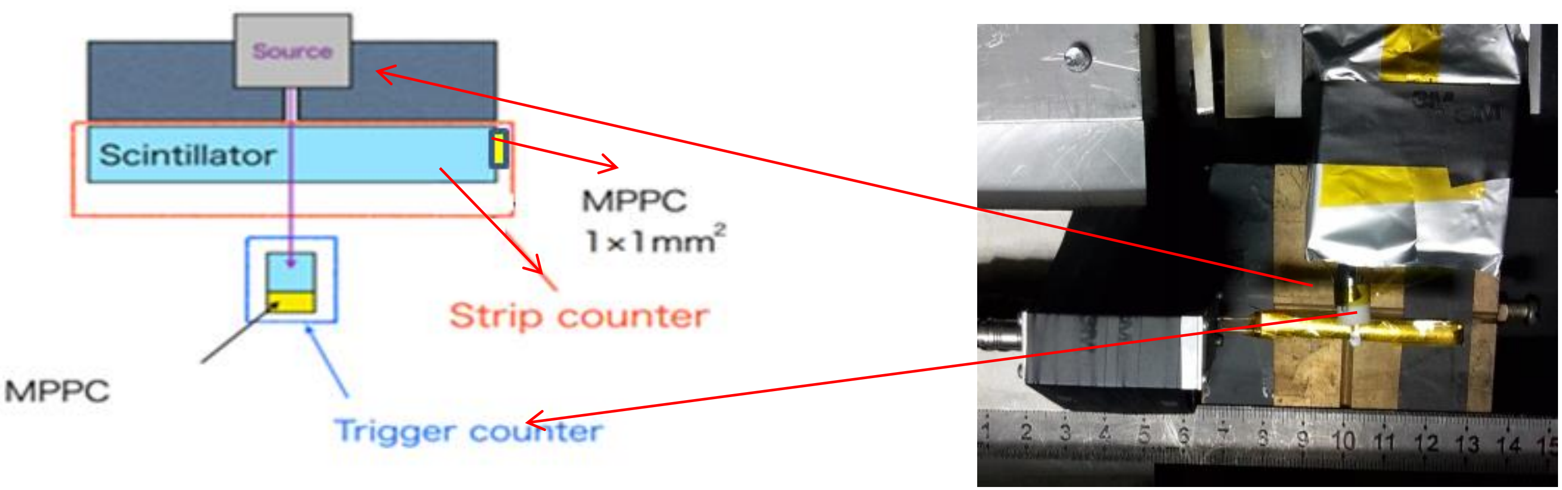
Readout unit test

Zhigang Wang, Tao Hu, IHEP 高能所创新经费支持

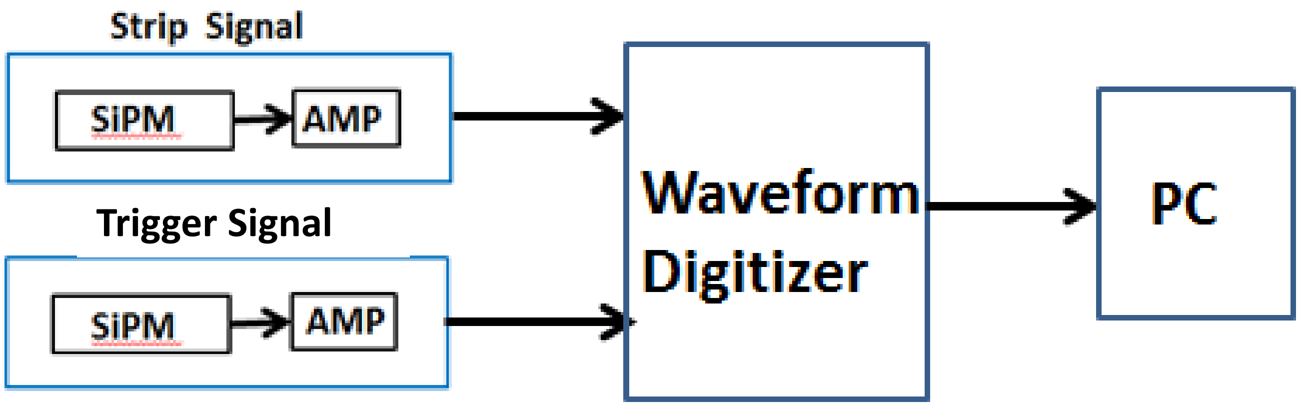
Scintillator strip Irradiated with β collimated from Sr-90

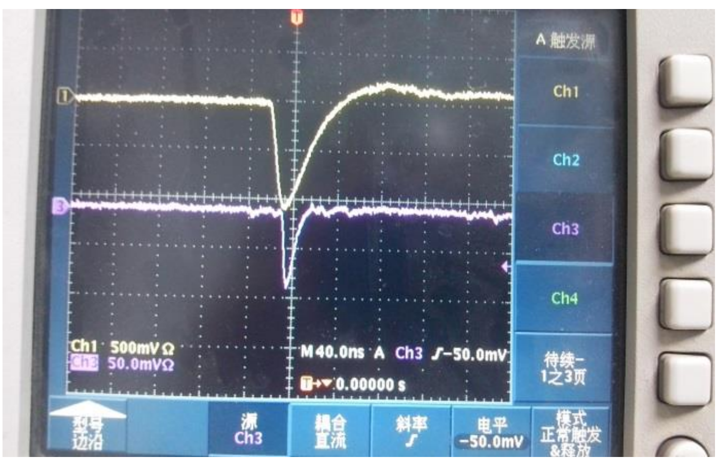
Collimator diameter: 1mm



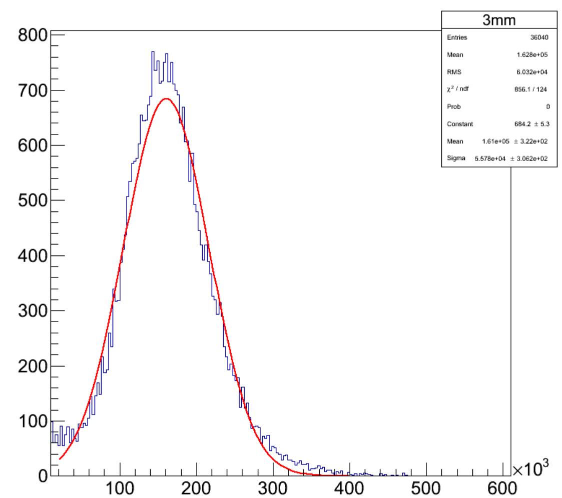


Readout unit test: Data acquisition system



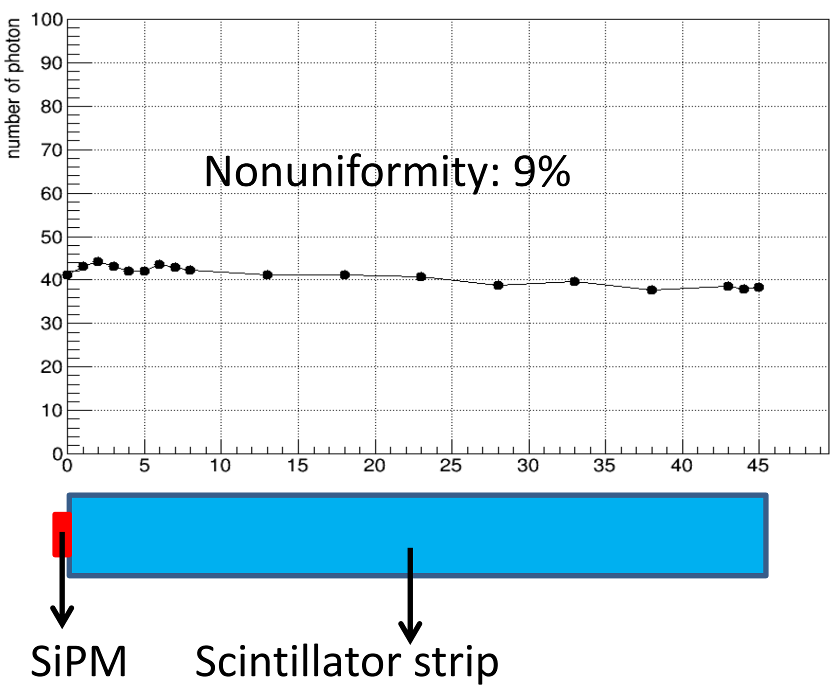


Waveform of strip signal
and trigger signal

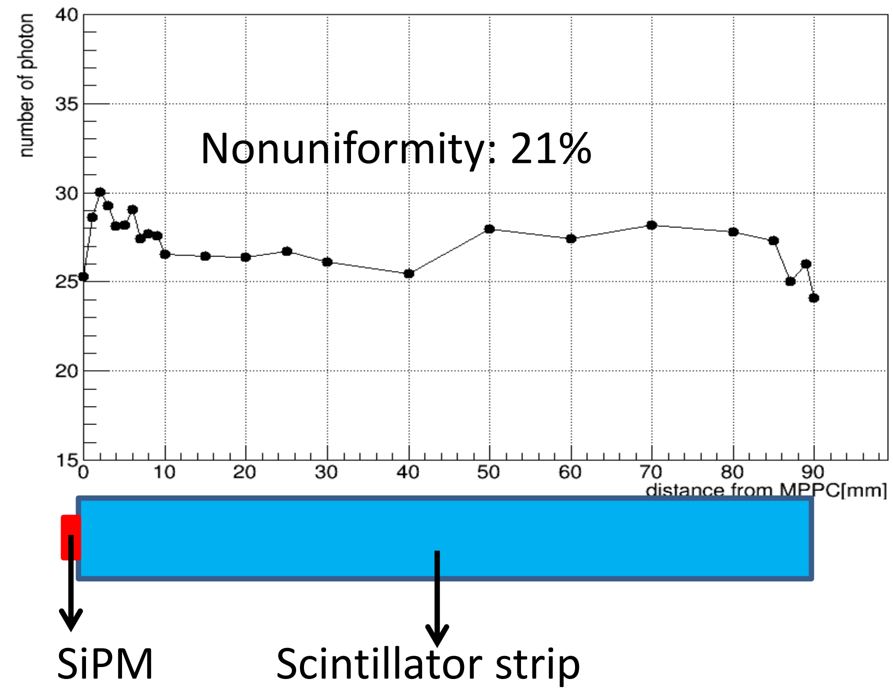


Strip signal

Readout unit test: Uniformity of strip response



Strip: 5mm×45mm×2mm



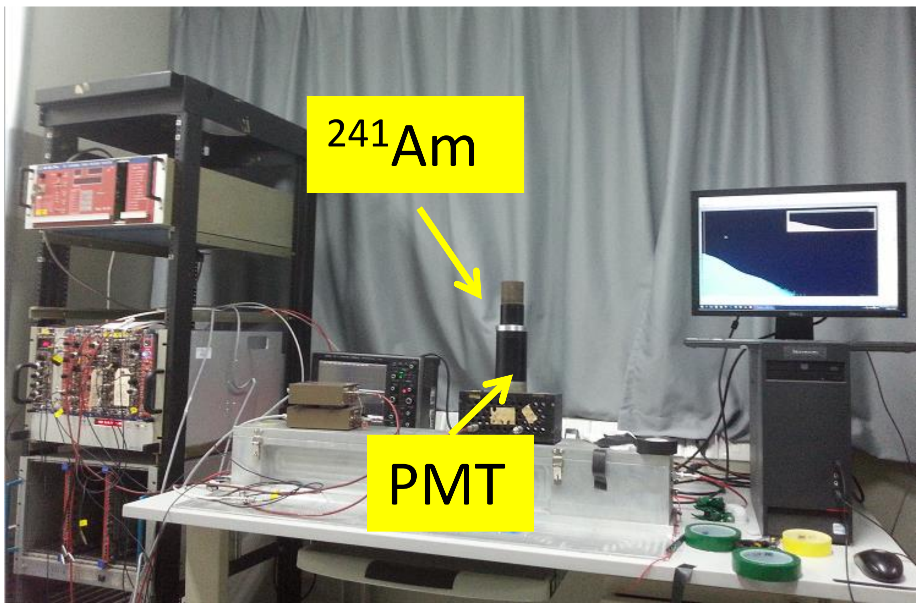
Strip: 10mm×90mm×2mm

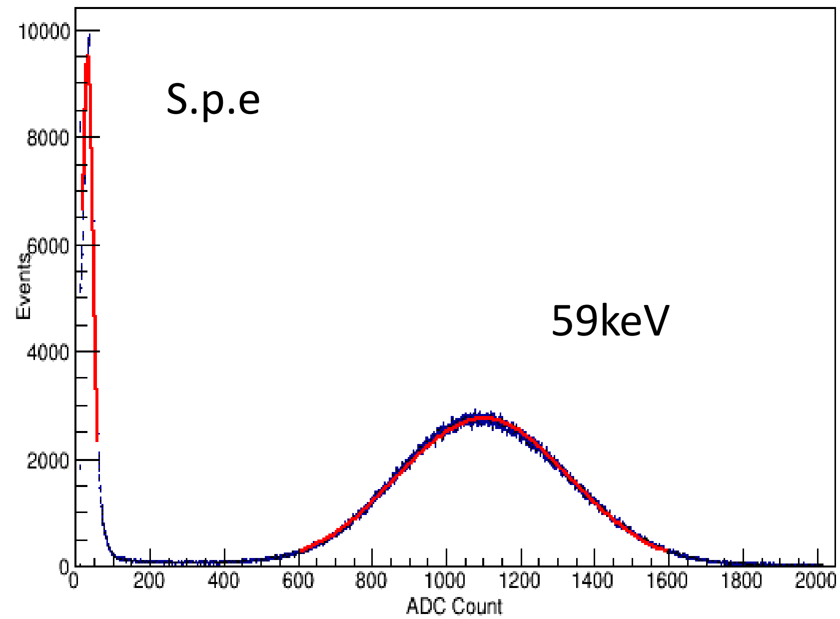
- **Peaky Np.e . near SiPM**
- **Larger Np.e. and better uniformity than ILD measurement probably due to different scintillator material and reflector.**
- **Significant reduction of Np.e. with long strip.**

Readout unit test: BGO light yield test

Jianbei Liu, USTC 中科大重要方向项目培育基金支持

- Tested light yield of the crystal samples with PMT.





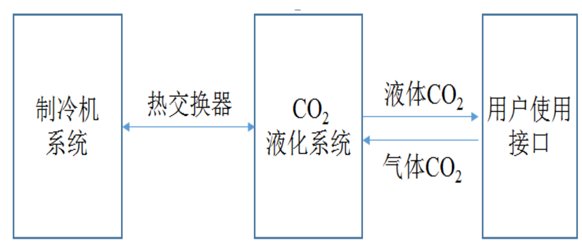
LY of BGO: 555 p.e/MeV

Cooling system

Shunli Niu, TaoHu, IHEP 核探测与核电子学国家重点实验室经费支持

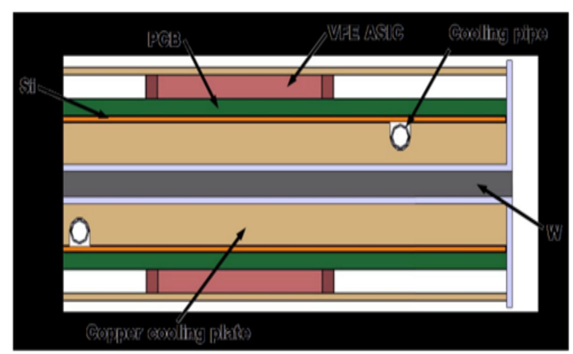
两相CO_2制冷特点

- CO_2制冷剂无毒，不会破坏臭氧层，化学性能稳定，抗辐照，比较环保。
- CO_2相对容积制冷量是5.22，是普通氟氯制冷剂的五倍左右，因此CO_2蒸发器装置可以设计的更小更细。
- 控制CO_2的压力在5~73bar，沸点可在-56~31℃调节，制冷温度低，温度调控容易。
- 压力大，温度低，需要零部件抗高气压，耐低温。



CO_2 制冷系统原理示意图

制冷机系统通过热交换器，将CO_2 液化， 通过控制CO_2 液化系统内部压力，可调节CO_2 沸点，达到控制CO_2 液化温度的目的。



CEPC量能器散热结构示意图

研制目标：在-20^{0}C下，导热量大于30mW/cm^2(按照Silicon 做灵敏层为计算依据)。

Summary

(1): The performance of SiPM is measured.

(2): Optimization of scintillator-SiPM read unit is still in progress.

(3):Cooling system is designed.

Outlook

SiPM: we need more studies to understand their performance
Scintillator-SiPM unit : still lot of optimization to be done
Cooling system: will be constructed

申报科技部“国家重点研发计划”

Haijun Yang, Tao Hu, Jianbei Liu

研究内容：
(1)成像式电磁量能器物理设计优化；
(2)量能器单元结构研究和优化；
(3)入射粒子位置识别核心算法研究；
(4)两相二氧化碳制冷系统研制；
(5)新型灵敏材料的研究；
(6)研制小型电磁量能器原理样机；

Thanks!