Studies of Detector Cells in Hadronic Calorimeter Based on Plastic Scintillators

INTERNATIONAL WORKSHOP ON HIGH ENERGY CIRCULAR ELECTRON POSITRON COLLIDER
November 6-8, 2017
IHEP, Beijing

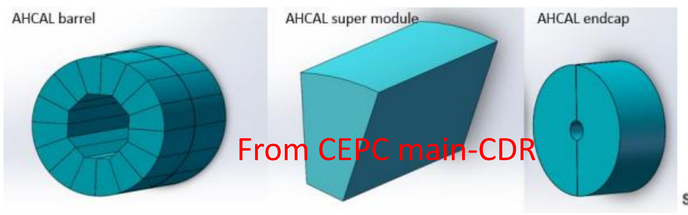
Zhe Wu[1,2], Boxiang Yu [1*], Tao Hu[1]

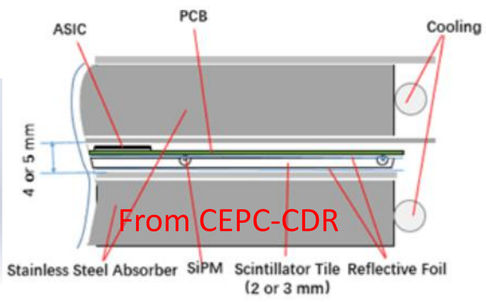
[1] Institute of High Energy Physics, Beijing, China
[2] College of Power Engineering, Chongqing University, Chongqing, China

*Boxiang Yu, Associate Professor, Email: yubx@ihep.ac.cn

Introduction

The Circular Electron Positron Collider (CEPC) as a Higgs factory was proposed by China in 2013. The CEPC detector design was using International Linear Collider Detector as an initial baseline. The CEPC calorimeters, including the high granularity electromagnetic calorimeter (ECAL) and the hadron calorimeter (HCAL), are designed for precise energy measurements of electrons, photons, taus and hadronic jets. HCAL is a typical sampling calorimeter, whose structure consists of absorber layers (such as iron, lead and tungsten) interleaved with sensitive layers (such as plastic scintillator, GEM, RPC). Analog HCAL (AHCAL) is used for future large-scale linear collider experiments, whose jet energy resolution $\sigma E/E = 30\%/\sqrt{E}$ can be achieved by particle flow algorithms in order to efficiently separate Z^0, $W^{\pm}$ and Higgs bosons. AHCAL is an option for HCAL based on plastic scintillator. The preliminary design of AHCAL contains 40 layers. Each layer consists of 5mm sensitive layer and 20mm stainless steel absorber layer in AHCAL.

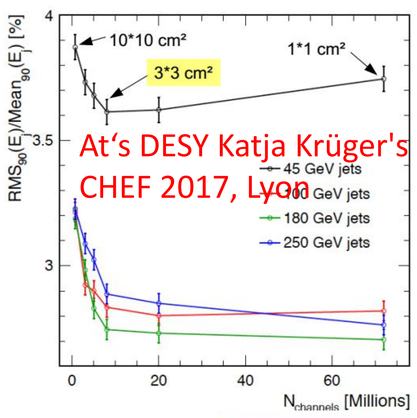




Sideview of one layer in CEPC-AHCAL

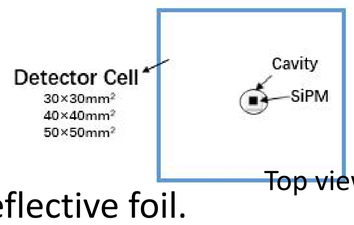
The structure and fabrication of detector cells

◆ PFA calorimeter:
—The absorber: Stainless steel;
— The sensitive detector : Scintillator;
— CEPC AHCAL Cell size:
3cm×3cm , 4cm×4cm, 5cm×5cm ;
— Readout channel number:
～5M , ～2.7M, ～1.7M 40 layers



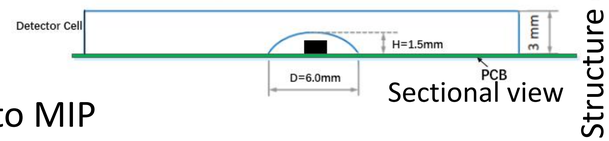
At's DESY Katja Krüger's talk CHEF 2017, Lyon

◆ Fabrication of detector cells
— Via mechanical drilling and polishing, a dome-shaped cavity in the center of plastic scintillator detector cell was made.
— MPPC(surface-mounted)
— Scintillator(BC408) were wrapped by RER reflective foil.



Top view

◆ Advantages of the structure
— suitable for mass assembly
— low dead area and high response to MIP
— provide enough room for the whole SiPM package
— improve collection of the light and good spatial uniformity
The cavity design has been optimized using GEANT4 by DESY Yong Liu



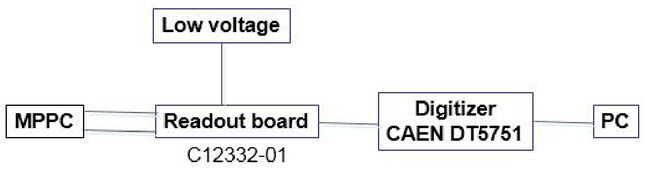
Sectional view

Structure of detector cell

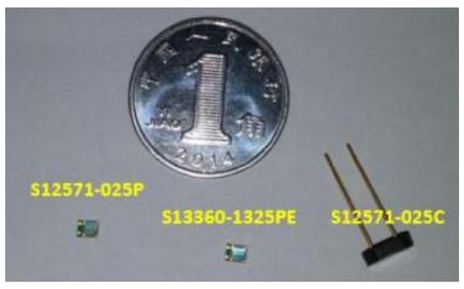
◆ $3\times3\times0.3cm^3$,$4\times4\times0.3cm^3$,$5\times5\times0.3cm^3$,$3\times3\times0.2cm^3$ were made

The readout electronics

◆Electronic readout board is Hamamatsu C12332-01
◆Temperature compensation keep amplitude of the SiPM stable

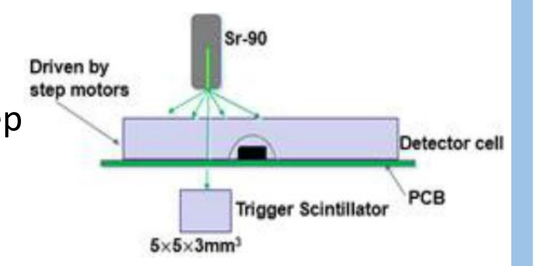


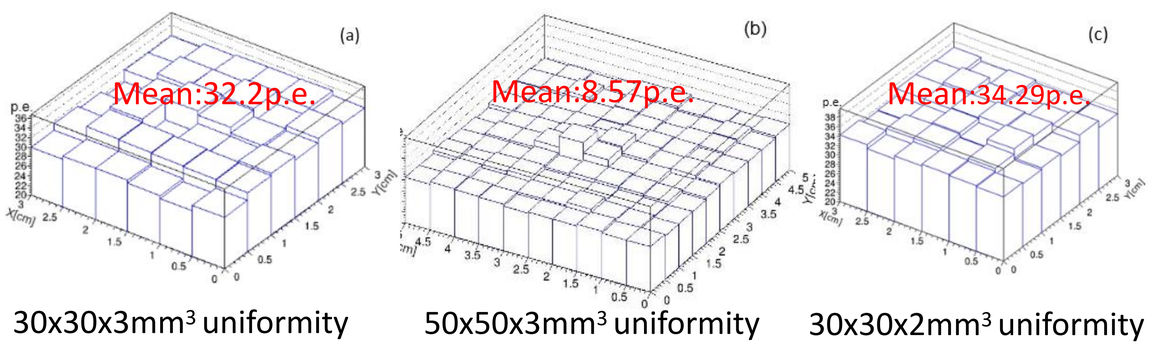
◆ Tow kinds of MPPC was tested:
Hamamatsu S12571-025P & S13360-1325PE
• S12571-025P:
—Sensitive area :1×1mm²
—Pixel size :25×25μm²
—Pixel number:1600
—Gain: 5.15E+05
• S13360-1325PE:
—Sensitive area :1.3×1.3mm²
—Pixel size :25×25μm²
—Pixel number:2668 —Gain: 7E+05



Uniformity measurement

◆ A non-uniform tile response can lead to a distortion of energy reconstruction
◆ Sr-90 and trigger scintillator were fixed
◆ The detector cell can be moved in a step size of 5×5mm² horizontally



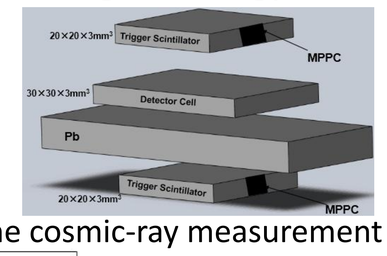


30x30x3mm³ uniformity S12571-025P
50x50x3mm³ uniformity S12571-025P
30x30x2mm³ uniformity S13360-1325PE

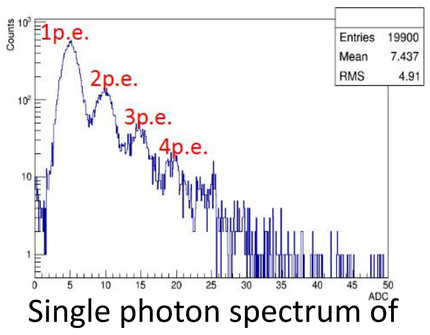
◆ The global mean response across the tile area is around 32.2p.e. and 100% of the cell area is within 10% deviation from the mean value for 30×30×3mm³ cell
◆ The global mean response is around 8.57p.e. and 94% of the cell area is within 10% deviation from the mean value for 50×50×3mm³ cell
◆ The global mean response is around 34.29p.e. and 100% of the cell area is within 10% deviation from the mean value for 30×30×2mm³

Cosmic-rays measurement

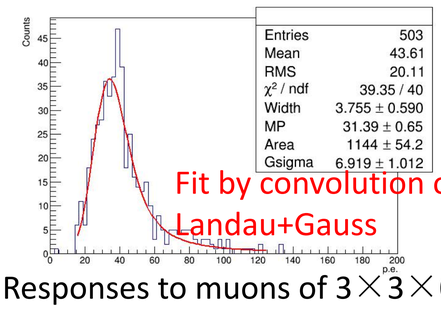
◆ Coincidence detector
—Trigger detector: 2×2×0.3cm³ scintillator tile wrapped by TYVEK foil
—Target detector cell: different sizes, reflective foils, SiPMs
—A lead was used to select higher energy cosmic ray events.



The cosmic-ray measurement setup



Single photon spectrum of MPPC S12571-025p



Fit by convolution of Landau+Gauss

Responses to muons of 3×3×0.3cm³ detector cell (S12571-025P)

◆ Results summary

Table Cosmic-ray measurement results of different sizes of detector cells

No.	Detector Cell	MPPC Type	Reflective Foil Type	Mean $N_{p.e.}$	Polishing Methods
1	30×30×3mm³	S12571-025P	ESR	31.39±0.65	Ultra Precise Polishing
2	30×30×3mm³	S12571-025P	ESR	22.55±0.7	Precise Polishing
3	30×30×3mm³	S12571-025P	ESR	18.92±0.39	Rough Polishing
4	30×30×3mm³	S12571-025P	TYVEK	13.63±0.33	Precise Polishing
5	40×40×3mm³	S12571-025P	ESR	14.89±0.73	Precise Polishing
6	50×50×3mm³	S12571-025P	ESR	9.87±0.43	Precise Polishing
7	30×30×2mm³	S13360-1325PE	ESR	33.89±0.49	Precise Polishing

— The results of same cells are various because of the polish ways
— The larger the area of the cell is, the less p.e. are detected because of the self-absorption

◆ Detector efficiency
30×30×3mm³ : 99% 50×50×3mm³ : 98.2%

Conclusion

◆ The good response uniformity, responses to mouns and high detection efficiency results show that 30×30×3mm³, 40×40×3mm³ and 50×50×3mm³ cells are acceptable for AHCAL
◆ S13360-1325PE is another choice but its price is more expensive
◆ 2mm of thickness of the detector cell with MPPC S13360-1325PE is more ascendant