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The R&D progress of CEPC HCAL

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Abstract：Circular Electron Position Collider (CEPC) is proposed as a Higgs or Z factory. This work introduces the R&D progress of CEPC hadronic calorimeter (HCAL) based on particle flow algorithm (PFA). Two options include digital (DHCAL) and analog (AHCAL) readout are considered. The RPC DHCAL prototype made by CALICE, we have analysis some beam test data. The GEM detector for DHCAL is under developed. Detector cell of AHCAL have been detail studied, including material, light output and uniformity. The construction of a 51cm x51cm 35 layers AHCAL prototype has been started. Our R&D work would surely be more and more integrated into international PFA calorimeter activities.

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1. Introduction

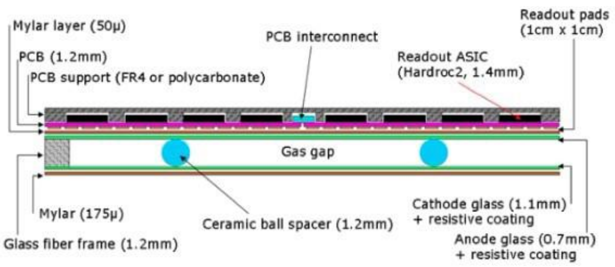
Exploring new physics becomes an important goal of particle physics after the Higgs bosons has been discovered [1,2]. There are some e^+e^- collider projects in the future, such as the International Linear Collider (ILC), the Compact Linear Collider (CLIC), Future Circular Clider (FCC) and the Circular Electron Positron Collider (CEPC). The future collider projects have an unprecedented potential for precision measurements, with new windows of exploration for physics beyond the Standard Model [3]. CEPC project was proposed by Chinese Physics Community in 2013. CEPC as a Higgs Factory, has the advantages of higher luminosity in respect of the ratio of performance to cost and the potential to be upgraded to a proton-proton collider to reach unprecedented high energy and to discover new physics [4].

A PFA hadronic calorimeter (HCAL) proposed for the CEPC is a sampling calorimeter with steel as absorber and scintillator tiles or gaseous detectors as active medium with embedded electronics. The moderate ratio of hadronic interaction length to electromagnetic radiation length of steel, allows a fine longitudinal sampling, thus keeping the detector volume and readout channel count small. This fine sampling is beneficial for both the measurement of the sizeable electromagnetic energy part in hadronic showers and for the topological resolution of shower substructure, needed for particle separation. This would need smaller readout pads and more readout channels. The active detector element of a CEPC PFA HCAL has finely segmented readout pads for the entire HCAL volume. Each pad is read out individually, pushing the readout channel density up to a scale of approximately ~100k/m^3. For the entire HCAL (eg. 100 m^3 in volume), the total number of channels could reach a level of ~10M, which is one of the biggest challenges for a CEPC PFA HCAL system.

2.DHCAL study base on RPC and MDPG detector

2.1DHCAL structure base on RPC detector

The proposed structure of glass RPC (GRPC) as an active layer for the CEPC HCAL is shown in Fig. 1 [5]. It is made of two glass plates of 0.7 mm and 1.1 mm in thickness. The thinner plate is used to form the anode while the thicker one forms the cathode. Ceramic balls (or cylindrical spacers) of 1.2 mm diameter are used as spacers between the glass plates. The glue used for both the frame and spacers is required to be chemically passive and stable over a long period of time. The resistive coating on the glass plates is used to apply high voltage and thus to create the electric field in the gas volume.



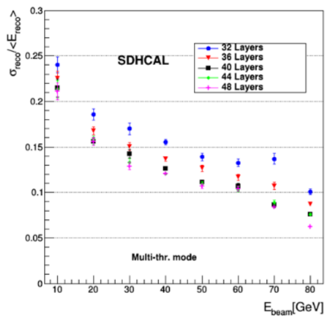


Fig. 1: Schematic of glass RPC structure Fig. 2: The dependence of pion energy resolution on beam energy with different number of RPC layers.

The GRPC and its associated electronics are housed in a special cassette, which protects the chamber and ensures that the readout board is in intimate contact with the anode glass. The cassette is a thin box consisting of 2.5 mm thick stainless steel plates separated by 6 mm wide stainless steel spacers. These plates are also part of the absorber. The electronics board is assembled with a polycarbonate spacer which is also used to fill the gaps between the readout chips and to improve the overall rigidity of the detector. The whole width of the cassette is 11 mm of which only 6 mm correspond to the sensitive medium including the GRPC detector and the readout electronics.

2.2 RPC-DHCAL Geometry Optimization for CEPC

As we know that SDHCAL was initially designed for ILC detector (ILD), the center-of-mass energy of ILC can reach 500 GeV, up to 1 TeV at its nominal operation, which results in energetic hadronic jets, up to a few hundred GeV. However, for CEPC, as a Higgs factory, the optimal center-of-mass energy is around 240-250GeV which provides the maximal production cross section of ZH. The energy of hadronic jets decay from W/Z/H bosons are typically around 10-80 GeV, it's rare to have jet energy above 80 GeV. Based on this condition, it's desired to optimize and reduce the number of layers of SDHCAL. It helps to reduce the inner radius of the magnets surrounding the calorimetry system, as well as the price of hadronic calorimeter and magnets.

To this end, we are using SPS test beam data collected by SDHCAL at CERN in 2015, we study the dependence of the reconstructed pion energy resolution on beam energy ranging from 10 GeV to 80 GeV with different number of RPC layers (eg. 32, 36, 40, 44, 48 layers), as shown in Fig. 2. It's apparent that the pion energy resolutions are comparable if the number of RPC layers reduced from 48 to 40 for beam energy up to 80 GeV. However, the pion energy resolution will degrade if we further reduce the number of RPC layers. From this study, it's optimal to use 40 layers for CEPC hadronic calorimeter.

2.3 DHCAL study base on MDPG detector

For a SDHCAL at the CEPC, Micro Pattern Gaseous Detectors (MPGD) also have been proposed for the active layers. We explore two hole-type MPGD detectors, namely, THGEM and GEM detectors, as high-rate detector options for a CEPC SDHCAL

The thickness of traditional double-THGEM structure is thicker than what we need, so WELL-THGEM structure is proposed. Fig. 3 shows the structure of a WELL-THGEM detector, the thickness of WELL-THGEM can reach to 6mm. A WELL-THGEM detector prototype with an effective area of 20 cm×20 cm has been built and tested. Its gain and X ray energy resolution are shown in Fig. 3. More tests of this prototype is underway. And more work has been planned for development of big size WELL-THGEM.

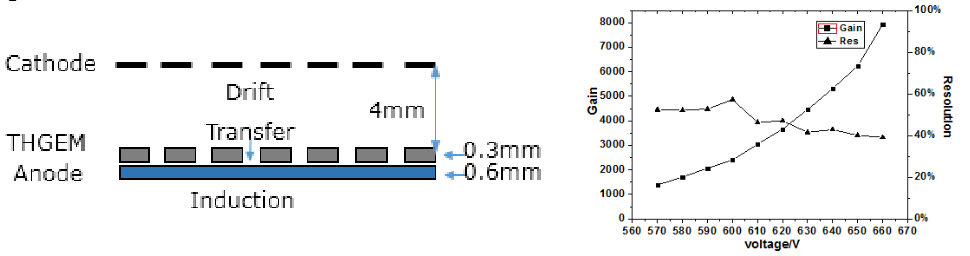


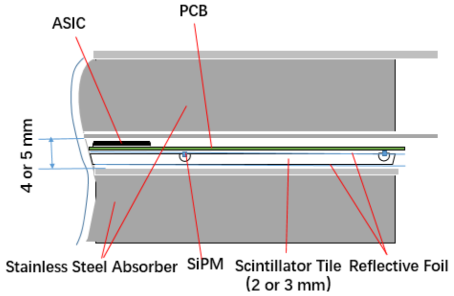
Fig. 3 structure of WELL-THGEM detector and test result

3. AHCAL study base on plastic scintillator

3.1 AHCAL structure and detector cell study

The designed AHCAL layer structure of CEPC is inspired by International Large Detector (ILD) detector concept [5,6], as shown in Fig. 4. The scintillator tiles wrapped by reflective foil and ASIC electronics are used as sensitive medium,, interleaved with stainless steel absorber. The thickness of these active layers could be reach to 5mm.

The structure of detector cells consists of scintillator, reflective foil and SiPM as shown in Fig. 5. A dome-shaped cavity was processed at the center of the bottom surface of each tile. This design improves the response uniformity of the scintillator tiles while minimizing the dead area.



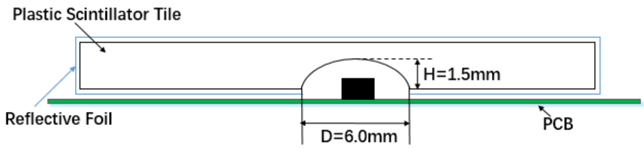


Fig. 4 Cross section of one layer in CEPC-AHCAL   Fig. 5 Section view of the detector cell

Two benchmarks of AHCAL detector cell are the response of cosmic ray and uniformity. We compared four dimensions of scintillators (30×30×3mm^3, 40×40×3mm^3, 50×50×3mm^3 and 30×30×2mm^3), two generations SiPM (S12571-025P and S13360-1325PE) and different polishing methods by measuring the response of cosmic-ray.

The result show that light output of scintillators which is same size is more after polished. For reflection foils, ESR is better than TYVEK, and light output of large scintillator is less. So the size of scintillator 30×30×3mm^3, ESR film and SiPM S13360-1325PE are baseline options currently. The spatial distribution result show that the number of p.e. in the center area is a little higher than that of the surrounding area because the SiPM is placed in the center area and there is also less light attenuation in the area near the SiPM. The global mean response across the tile area (36points) is around 32.2p.e. and 100% of the tile area is within 10% deviation (non-uniformity) from the mean value for 30×30×3mm^3 cell.

3.2 NDL-SiPM study

Chinese SiPM made by BNU-NDL (Beijing normal university, New device laboratory) is being developed. The result of 11-1010C NDL-SiPM show that PDE deviation is less than ±10%. Under same measurement condition, NDL-SiPM can detect near 3 times photon electrons than MPPC compared with the similar type which is 1mmx1mm and 10000 pixels, it is due to 3 times PDE of them. But dark count rate of NDL-SiPM is 5 times than MPPC.

4.Conclusions and discussion

Various R&D work on different detector options for CEPC HCAL have been conducted according to the plans set for the HCAL R&D task in the CEPC R&D plan. A AHCAL prototype is on the way. Our R&D work would surely be more and more integrated into international PFA calorimeter activities, and we have joined the CALICE collaboration group this year.

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