# Design of Readout Electronics for CEPC Semi-Digital Hadronic Calorimeter Pre-research

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## Introduction

- CEPC is the proposing large Circular Electron Positron Collider aiming at being Higgs factory
- As the final readout density will be $4 \times 10^5 channels/m^3$, one of appropriate choice for the active part of the hadron calorimeter is gaseous detector with 1 or 2-bit readout, so called digital readout
- The goal of this research is to provide a feasible readout scheme for CEPC Digital-Hadron Calorimeters (DHCAL)
- The front-end readout electronics will be integrated with the detector and readout structure is based on scalable readout system
- A double layer GEM using self-stretching technique is used as the active layer

### CEPC

- $E_{cm} \approx 240GeV$
- Luminosity $\sim 2 \times 10^{34} cm^{-2} s^{-1}$
- Circumference: $50 \sim 100km$

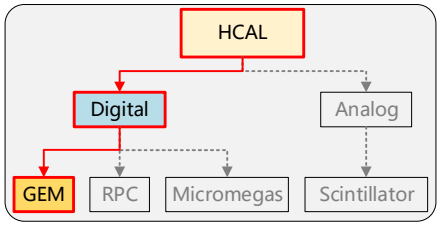
## Readout Scheme

### Calorimeter Options

Sampling calorimeter with ***Particle Flow Algorithms (PFA)*** can achieve the required energy resolution. This requires the detector have fine segmentation both laterally and longitudinally. Following figure shows the options for PFA HCAL.

A ***digital readout*** system base on ***GEM (Gas Electron Multiplier)*** is under research.

The required readout pads is $1 \times 1cm^2$. A detector with effective area sized $30 \times 30cm^2$ is used for pre-research.

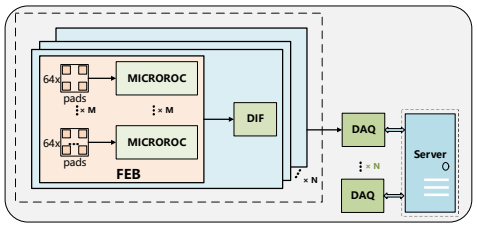



### Readout Structure

The readout system is developed on SRS (Scalable Readout System). Users can reuse the same system just changing the front-end board.

The whole system includes following parts:

- FEB(Front-End Board): Combination of detector and readout ASIC
- DIF(Detector InterFace): Control the ASIC and read hit information
- DAQ: Distribute clock and command to different DIF. Gather data to upper server



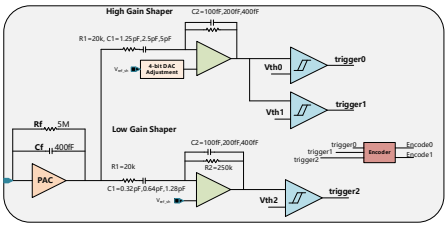

### Readout ASIC

A 64-channels Semi-Digital readout ASIC named MICROROC is chosen for pre-research, which was developed at IN2P3 by OMEGA/LAL.

Each channel of the MICROROC chip has:

- A very low noise charge preamplifier with dynamic range from $1fC$ to $500fC$
- Two different adjustable shaper
- Three comparators encoded in 2-bit

An on-chip RAM is designed to store the hit information.

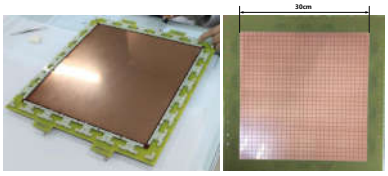



## Design and Test

### Phase I Design

A "Phase I" design is completed to verify the readout structure and test the performance of MICROROC.

A $30 \times 30cm^2$ GEM detector with its readout plane are shown below. The size of readout pad is $1cm^2$.

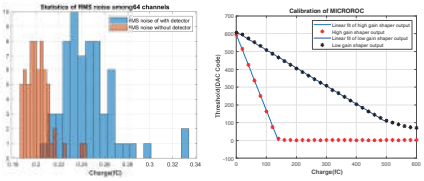



The readout electronics is connected to the readout plane via flexible plate made by kapton. It contains two parts:

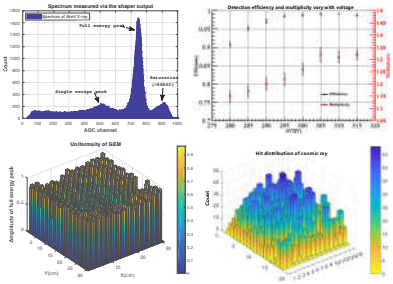
- An FEB, able to readout 256 channels
- A DIF with multiple readout interfaces such as E-Link, SFP, Ethernet and USB

### Test Result

The RMS noise with detector is below $0.35fC$, which is lower than the ***MIP (Minimum ionizing particle)*** signal. And the dynamic range of the low gain shaper is up to $500fC$.

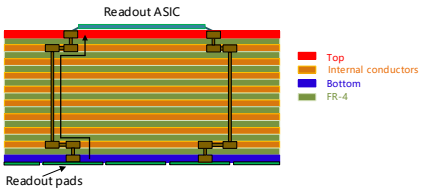


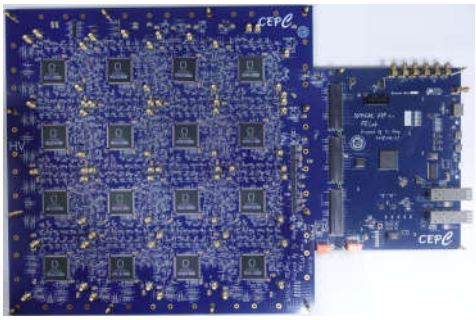
An external ADC is applied to measure the X-ray energy spectrum and the uniformity of the GEM (left two figures). The efficiency and hit test is done with the cosmic-ray(right figures).



### Next Stage

In order to reduce the "dead area" caused by electronics, a readout plane with embedded front-end electronics is designed.
Blind buried via technique is used to ensure the signal integrity and gas tightness.The upper figure shows the stack up of the FEB. The lower shows the FEB and DIF.



## Conclusion

- The readout structure is effective and the readout electronics can work well with the detector
- The noise is lower than the MIP signal and the dynamic range is up to $500fC$
- Two bits readout electronics with GEM detector is feasible and affordable for the hadron calorimeter

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