A Compact Readout Electronics based on Current Amplifier for Micromegas Detector

Ting Wang [1,2], Yu Wang[2,3], Zhihang Yao[1,2], Yulin Liu[2,3], Changqing Feng[2,3], Zhiyong Zhang[2,3], Shubin Liu[1,2,3]

Introduction

- Muon imaging technology is a novel imaging technique widely applied in volcano imaging, heavy nuclear material detection, and archaeological research. It requires the use of large-area detectors to meet the demand for high-precision, short-time imaging.
- In recent years, significant progress has been made in the research of Micromegas detectors, with an effective area reaching 1 m × 1 m and a spatial resolution of less than 200 μm, making it suitable for muon imaging studies.
- The goal of this research is to design highly integrated front-end electronics for reading out large-area, multi-channel Micromegas detectors, aiming to reduce the complexity of muon imaging systems.
- A compact front-end electronics system based on current readout was designed. FEC will be integrated with the detector and readout structure is based on scalable readout system.

Micromegas

- Sensitive area: 15 cm × 15 cm
- XY strip readout, strip pitch: 0.4 μm.
- Readout channels: 768

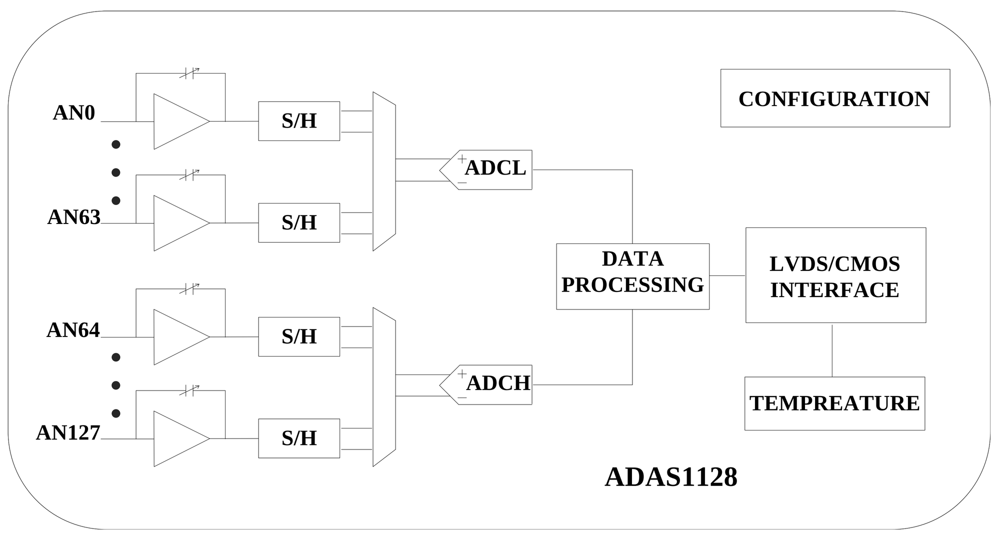
Readout Scheme

Readout ASIC

A 128-channels current readout ASIC named ADAS1128 is chosen for pre-research, which was developed by ADI.

The ADAS1128 chip structure and function:

- 128 current integration amplifiers, sample and hold circuits and two 24-bit resolution ADCs.
- A maximum dynamic range of -660.17 fC to 32.23 pC(integration time of 50.7μs)
- LVDS self-clocked serial data interface, SPI configuration registers (daisy-chain)

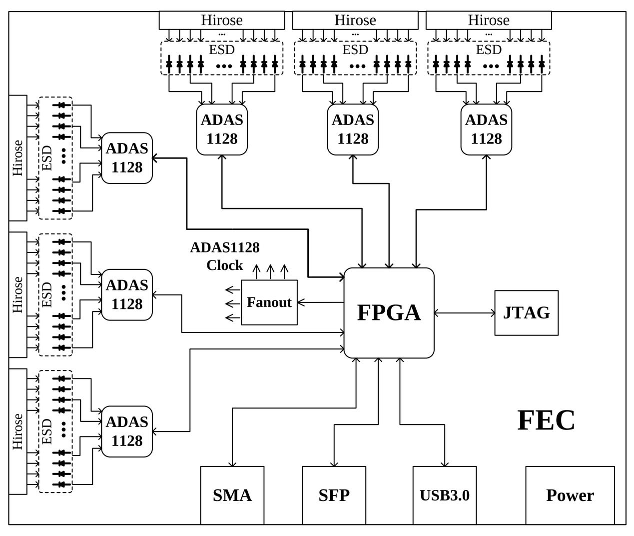


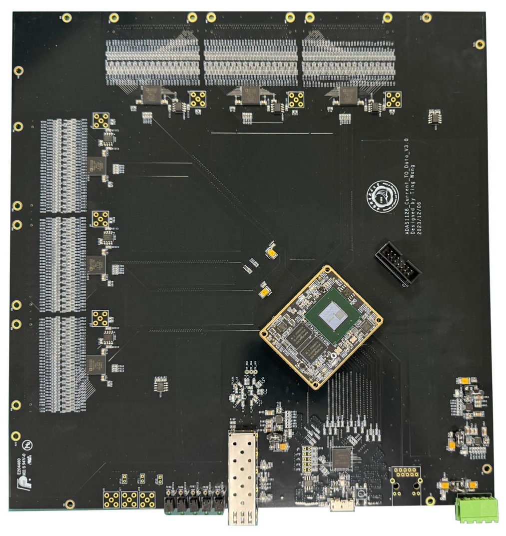
FEC

FEC mainly consists of the detector signal readout module, data acquisition module, and power supply module.

The main functions of each module are:

- Detector signal readout: Analog-to-digital conversion of detector signals.
- Data acquisition: Control the ASIC and communicate with DAQ (Data Acquisition Board).
- Power supply: Board-Level Power Supply

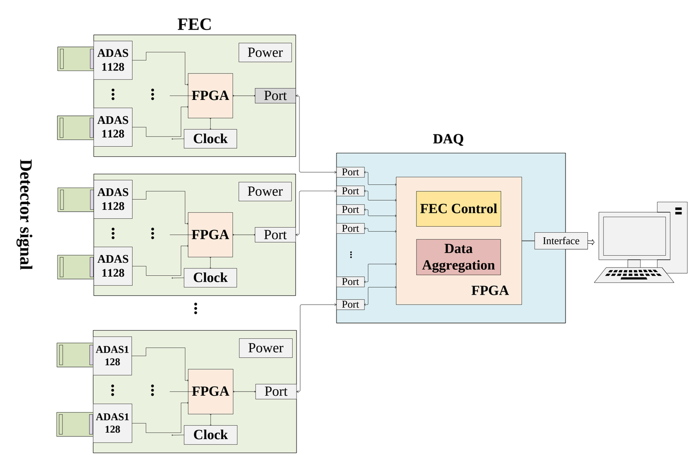


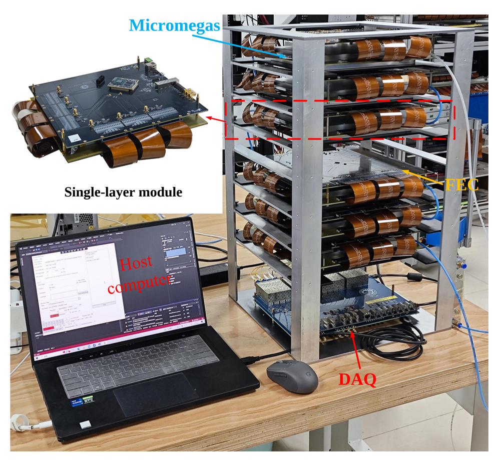


Readout System

The entire electronics system comprises FEC and DAQ, utilizing optical fiber communication, with strong scalability and robust resistance to noise interference. The optical fiber transmission is divided into three data channels:

- A: FECs send the threshold-crossing signal to the DAQ, and the DAQ sends the trigger signal to FECs.
- B: DAQ issues FEC-related configuration commands.
- C: FECs upload data to the DAQ.





Test and Result

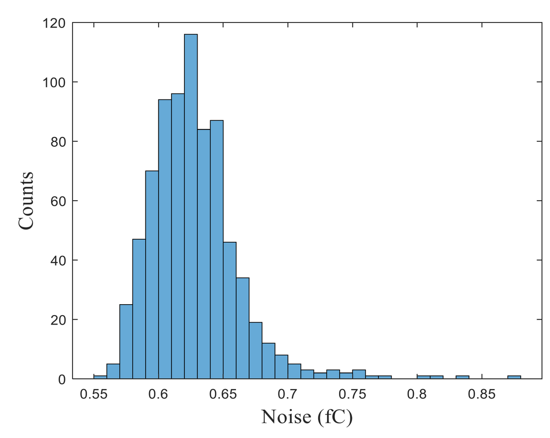
Performance Test

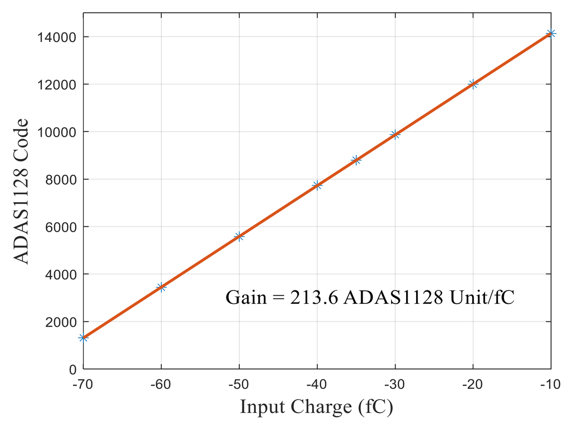
Noise test and calibration test were performed on FEC under the condition of floating input.

The integration time of the chip is 50.7 μs, and the dynamic range of the negative charge is -77.97 ∼ 0 fC.

The results of the electronics performance test are as follows:

- The RMS noise with 95% of all channels is below 0.68 fC.
- The conversion relationship between ADC code value and charge is Code = 213.6 * Charge (fC) + 16365.
- The integral non-linearity of linear calibration for 128 channels is 2.7%.



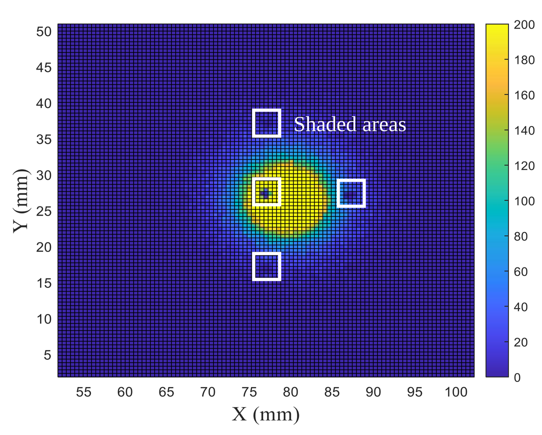


X-Ray Test

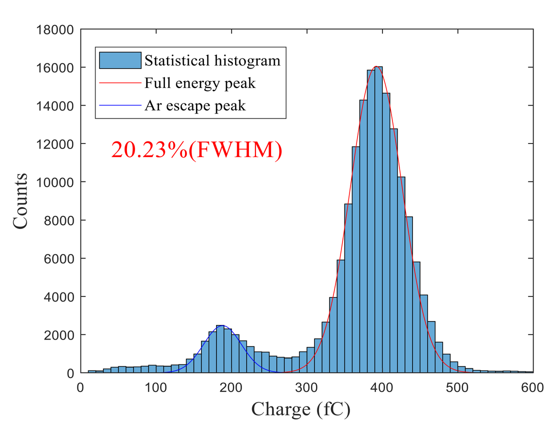
Detector energy resolution tests were conducted using a ^{55}Fe radioactive source to validate the FEC readout of Micromegas detector anode strip signals.

The results of the test are as follows:

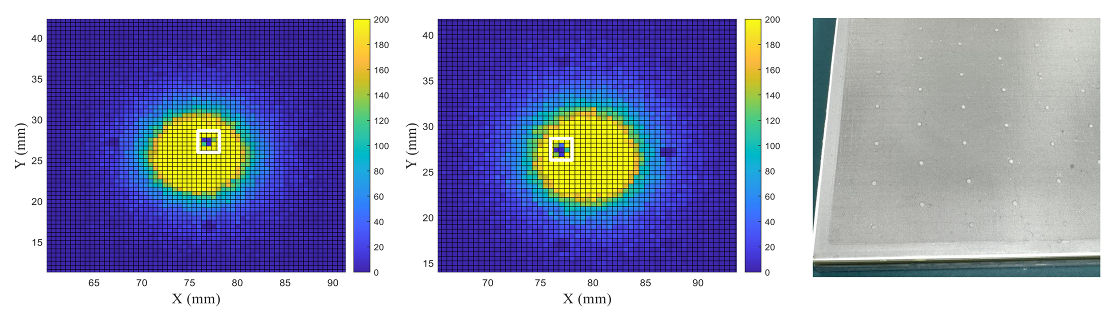
- The full energy peak is about 389.3 fC, with an energy resolution (FWHM) of 20.23%@5.9keV. The ratio full energy peak to the escape peak is 2.09:1.
- The shadowed region are attributed to the dead region caused by the arrangement of thermal adhesive pads in the detector.



(a) Hit map



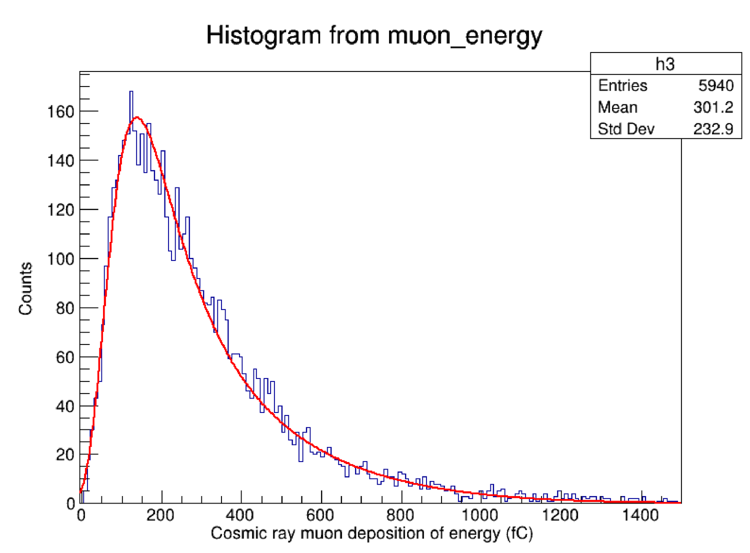
(b) Energy spectrum

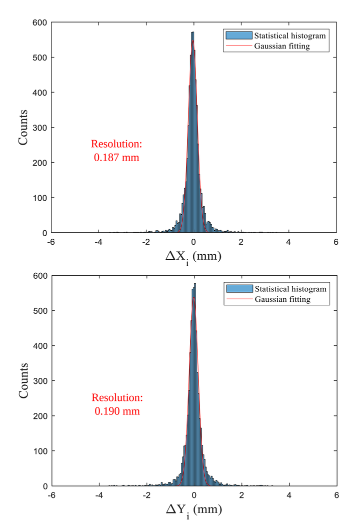


Cosmic Ray Muon Test

The core of the muon imaging experiment is the measurement of tracks. Since the reconstruction of hit positions utilizes the charge centroid method, the first step is to validate the measurement capability of the readout electronics for charge, by conducting muon energy deposition measurements. Subsequently, detector spatial resolution and efficiency tests will be performed.

- From the energy spectrum, the charge distribution mainly follows the Lorentzian-Gaussian distribution, with a peak value of around 132.64 fC.
- The spatial resolution of detectors X and Y is respectively: 0.187 mm and 0.190 mm.
- The efficiency of detectors X and Y is respectively: 95.94% and 96.25%.(Mesh: -560 V Drift: -700V)





Conclusion

- The FEC can be used to read out Micromegas detectors in single particle measurement mode.
- The FEC can be assembled into an integrated module with a 15 cm × 15 cm Micromegas detector, providing a lightweight unit with excellent scalability.
- In future work, alignment algorithms will be introduced to improve spatial resolution. A muon scattering imaging system will be developed.

[1] *School of Nuclear Science and Technology, USTC, Hefei 230026, China*
[2] *State Key Laboratory of Particle Detection and Electronics, USTC, Hefei 230026, China*
[3] *Department of Modern Physics, USTC, Hefei 230026, China*
E-mail: wangting123@mail.ustc.edu.cn