A Compact Readout Electronics based on Current Amplifier for Micromegas detector

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***Abstract*—A Compact front-end electronics (Compact_FEC) for reading Micromegas detector is presented in this paper. It includes the detector signal readout module, data acquisition module, and power supply module. The detector signal readout module uses a current-based readout chip, ADAS1128, which integrates 128 current amplifiers for multi-channel charge information measurement. After noise test and calibration, this readout electronics was applied to readout the Micromegas detectors. X-ray with iron-55 source and cosmic ray muon tracking tests were performed to test the energy-resolved and position-resolved performance. 5.9keV X-ray test results show that the Micromegas detector has the full peak charge of 391.3 fc at 5.9 KeV-X-rays, with an energy resolution of 19.50%(FWHM). The Ar escape peak charge of 183.7 fc, with the total peak charge to escape peak ratio of 2.13:1. 5.9keV X-ray measurements are in accordance with the theoretical values. The muon tracking test results for the detector X-dimension spatial resolution of 0.240 mm, Y-dimension spatial resolution of 0.243 mm. The results of the test show that the readout electronics can measure the track of the cosmic ray muon. In summary, the front-end electronics (Compact_FEC), in single-particle measurement mode, can measure signals from the Micromegas detector.**

***Index Terms* — Current amplifiers, Micromegas detector, Readout electronics**

I. Introduction

Muon imaging is a new type of imaging technology can be divided into three categories: scattering imaging, transmission imaging, and muon metrology. Compared with other imaging methods, it has the advantages of low cost, detection of large-scale objects, non-destructive detection and safety. Currently, muon imaging technology has been used in the fields of volcano imaging, heavy nuclear material detection and archaeological research. Because of the low flux of natural cosmic ray muons, muon imaging requires the use of large-area detectors to meet the demand for high-precision, short-time imaging. In recent years, a lot of progress has been made in the research of Micro-pattern Gas Detector, especially Micromegas detectors. It has been shown that Micromegas detectors are able to achieve an effective area of more than 1m×1m[1] and a spatial resolution of less than 200 μm[2]. They are suitable for conducting muon imaging studies.

The Micromegas detector is primarily composed of anode readout strips, a resistive layer, a mesh layer, a drift layer and a gas chamber[3]. Among them, the avalanche area is formed between the mesh layer and the resistive layer, and the drift area is formed between the drift layer and the mesh layer. The incident particles enter the detector to produce ionization in the drift region, and the electrons enter the avalanche region to generate a large number of electron-ion pairs, and the anode readout strip generates an inductive signal.

Considering the use of a large number of readout channels for Muon imaging studies using micromegas detectors, a compact front-end electronics system based on current readout was designed.

II. Readout ASIC

In order to meet the requirements of compact design, the front-end electronic module adopts a current readout chip named ADAS1128[4] designed by ADI, the structure of which is shown in Fig. 1. The ADAS1128 consists of 128 current integrating amplifiers, sampling and holding circuits as well as two 24-bit resolution ADCs. The analog currents from the 128 channels are fed into their respective current integrating amplifiers for total charge measurements, and then into the sampling and holding circuits to hold the peak value. The hold signal is fed into two 24-bit resolution ADCs for sampling in a group of 64 channels respectively. In addition, the chip includes modules such as two 24-bit configuration registers, temperature sensor and reference buffer.

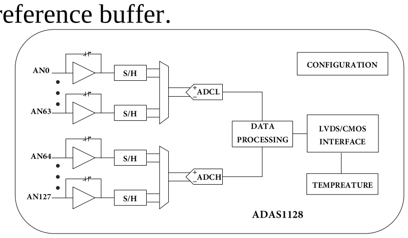

Fig. 1. Structure of ADAS1128 ASIC.

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III. Data Acquisition System

The initial stage front-end electronics design for the readout Micromegas detector was completed as shown in Fig. 2. The front-end electronics module mainly includes the detector signal readout module, data acquisition module and power supply module. The detector signal readout module integrates four ADAS1128 chips, which are daisy-chained together. The readout module is also designed with ESD protection circuits to prevent damage to the electronics channel caused by gas detector ignition. The data acquisition module consists of USB3.0 circuit and FPGA core board. Its main functions are to configure ASIC, collect data and realize communication with the host computer. The Micromegas detector was developed by University of Science and Technology of China (USTC), with an effective area of 15×15 cm^2 and strips pitch of 400 μm. Fig. 3 shows the photo of the Micromegas detector and the front-end electronics board (Compact_FEC).

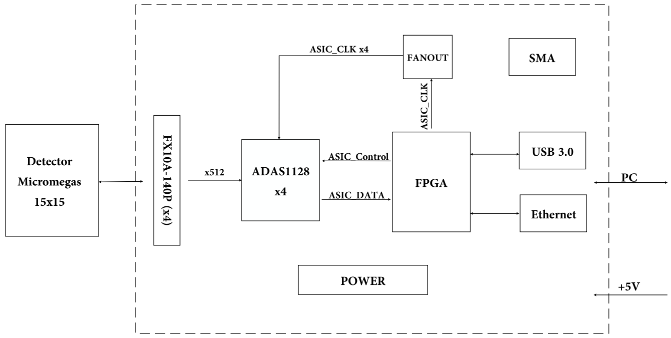
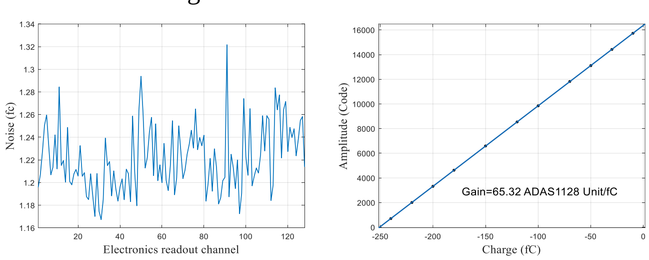


Fig. 2. Structure of the front-end electronics module.

Fig. 3. Micromegas Detector and the front-end electronics board.

IV. Performance Test

We first conducted the front-end electronic board performance test, i.e. noise test and calibration test. Fig. 4(a) shows the noise magnitude of each channel recorded by the ADAS1128 chip under the condition of no charge input. The integration time of the chip is 50.7us, and the dynamic range of the negative charge is -233 fC~0 fC. From the results in Fig. 4(a), it can be deduced that the noise of the chip's 128 channels is around 1.25 fC. In the calibration test, the voltage signal is converted to a current signal by generating a step-down signal and sending to a 1pf capacitor in series. From the results of the single-channel calibration test in Fig. 4(b), the conversion relationship between the ADC code value and charge of the front-end electronics board can be obtained as Code=65.32*Charge+16384.



(a) Noise test results **(b) Calibration test results**

Fig. 4. Noise test results and calibration test results

Fig. 5 shows the energy spectrum for 5.9 keV-X-rays from the ^{55}Fe source. The X-ray full energy peak and the Ar escape peak can be clearly observed from the figure. After the Gaussian fitting of the full energy peak and the escape peak respectively, it can be calculated that the peak position of the total energy peak is about 391.3 fc, with an energy resolution of 19.50%(FWHM). The peak position of the escape peak is about 183.7 fc, and the ratio of the total energy peak to the escape peak is 2.13:1. The measurement results of the ^{55}Fe source are in accordance with the theoretical values.

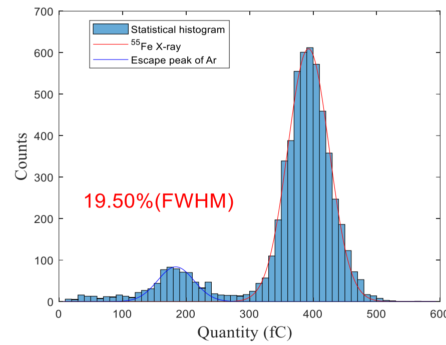


Fig. 5. The energy spectrum of ^{55}Fe.

The core of the muon imaging experiment is the measurement of tracks, and the existing front-end electronics (AGET_FEC) and back-end electronics (DAQ) of the joint debugging laboratory are used to measure the tracks of Muons, as shown in Fig. 6. The muon tracking measurement system consists of five layers of detectors, in which the outer four layers of detectors use AGET_FEC to obtain the track. Then the hit position of the innermost layer of detectors is obtained by using the hit position fitting of the four layers. As this point, we can get the difference Δx_i between the fit measured by the Compact_FEC and the hit position obtained by the fitting, then $\Delta x_i = x_{fit} - x_{hit}$. Counting a large number of cosmic ray tracks gives a distribution of Δx_i, and the standard deviation of the distribution is the measured spatial resolution of this layer of the detector.

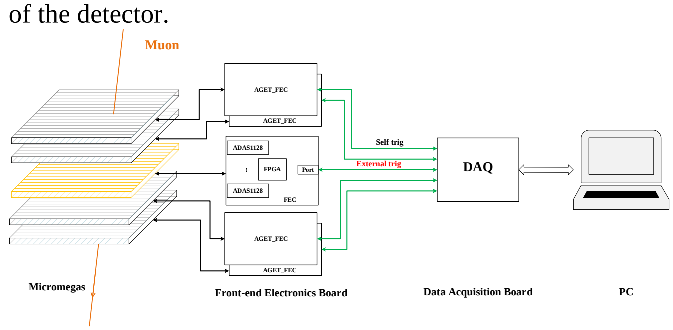


Fig. 6. Schematic diagram of the muon tracking measurement system

Since the reconstruction of the hit position in the tracking measurement experiment mainly uses the charge center of gravity method, the cosmic ray deposition energies measured by front-end electronics are first tested. The measurement results of the induced charges generated by the cosmic ray muon cases are shown in Fig. 7, where it can be obtained that the main body of the charge distribution conforms to the Landau distribution. Measurements illustrate readout electronics to meet cosmic ray charge measurement needs.

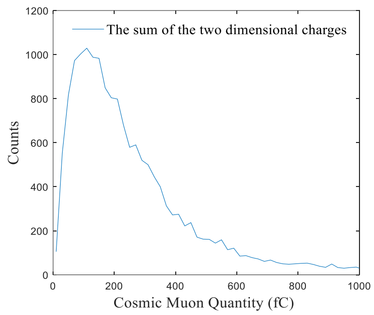


Fig. 7. Measurement of the charge of cosmic ray muons

The spatial resolution of the Micromegas detector in the X and Y directions is shown in Fig. 8. Fig. 8(a) shows the spatial resolution of 0.240 mm measured in the X direction, and Fig. 8 (b) shows the spatial resolution of 0.243 mm measured in the Y direction. The result shows that the readout electronics can measure the track of the cosmic ray muon. Considering the detector mounting space deviation and the muon tracking fitting deviation. The spatial resolution will be subsequently improved in two ways, by subtracting the muon tracking fitting bias and by correcting the position of the detectors in each layer using an alignment algorithm.

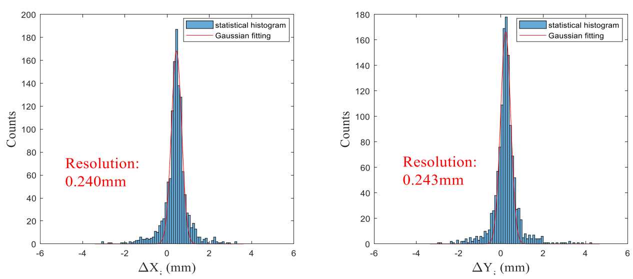


Fig. 8. Detector spatial resolution results

V. CONCLUSION

In summary, the compact front-end electronics (Compact_FEC) based on current readout was designed and tested for 5.9 keV-X-rays and cosmic ray muon tracks. The results of both tests show that the front-end electronics can be used to read out Micromegas detectors.

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