Readout Electronics for MUSIC Detectors in HFRS at HIAF

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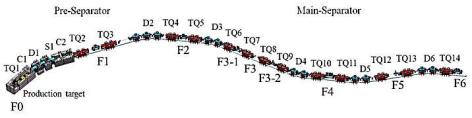
Abstract

High Intensity heavy-ion Accelerator Facility (HIAF) project is being constructed by the Institute of Modern Physics, Chinese Academy of Sciences. A High energy FRagment Separator (HFRS) at HIAF was designed to study the properties of rare isotopes far away from the line of beta stability and their involved nuclear reactions of astrophysics interests. HFRS utilizes the Bρ-TOF-ΔE method for high magnetic rigidity, large ion-optical acceptance, and excellent particle identification, commonly used in nuclear fragmentation secondary beam devices. Among them, the energy loss detector ΔE is the key to particle identification. The energy loss detector is designed using the multiple sampling ionization chamber (MUSIC). It can significantly improve the energy resolution of the gas ionization chamber through multiple samplings. Each MUSIC detector has nine channels, including eight anode channels and one cathode channel for correction. The readout electronics consist of 9 charge sensitive amplifiers (CSA) modules, a readout control module (RCM), and a sub-clock module. In addition, one high-voltage power supply provides a bias voltage for the field cages. The measured data is transmitted to the DAQ system via 10 GSPS optical fiber. The readout electronics have been manufactured, and comprehensive electrical performance tests have been completed, including baseline, channel linearity, and temperature tests. The readout electronics have also been coupled to the MUSIC detector and characterized using an α-particle source, and the test results show an energy resolution better than 1.037%.

1. Requirements to detector

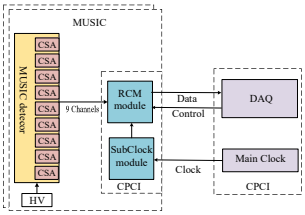


The layout diagram of HIAF-HFRS

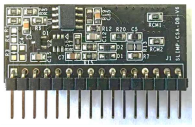
The MUSIC detector

- The under construction HIAF is equipped with a high energy radioactive beamline known as the HFRS [1, 2].
- The whole beamline consists of a pre-separator (F0->F2) and a main separator (F3->F6).
- HFRS utilizes the Bρ-TOF-ΔE method for particle identification.
- The energy loss detector of HFRS is designed using the multiple sampling ionization chamber [3] (MUSIC) scheme.
- The MUSIC must be able to work stably for a long time when the secondary beam count is around 1 MHz, and achieve better identification of particles within Z≤92.
- MUSIC is installed at positions F4 and F6 of HFRS, which requires two sets of readout electronics to handle the high event rate.

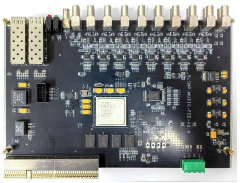
2. The architecture of the readout electronics



Block diagram of the architecture



The picture of CSA



The picture of RCM

- The readout electronics of the MUSIC detector consists of 9 charge sensitive preamplifiers (CSAs) modules, one readout control module (RCM) module, one sub-clock module, and one high voltage (HV) crate.
- The CSPs, which are placed inside the MUSIC detector, read the MUSIC detector signals and convert them to voltage pulse signals.
- The RCM has 16 analog signal input channels and can receive voltage pulse signals from 9 CSAs simultaneously, as well as amplify and digitize the voltage signals.
- The measured results are packed and transmitted to the DAQ system via a 10 gigabit optical fiber.

3. Performance Test

Baseline characterization

- The baseline for each channel is stable, with an average value of approximately 8150 ADC units.
- The RMS value of the noise is less than one ADC units, which is only 0.007% of the total dynamic range.

Alpha radiation source test

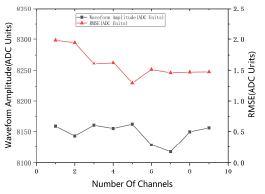
- The system was tested using a two-component alpha radioactive source (^{241}Am: alpha energy 5.48 MeV, ^{244}Cm: alpha energy 5.80 MeV).
- The energy spectrum has two peaks, with an energy resolution of about 1.037% .

Channel linearity test

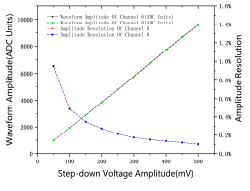
- The charge varies from 50 mV to 500 mV with a step of 50 mV.
- The entire readout electronics amplitude resolution is less than 1.0%.
- This channel's INL is also better than 0.68%.

Temperature test

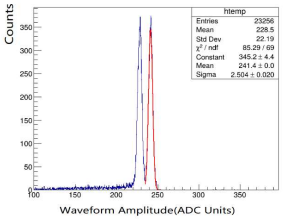
- The temperature ranges from -30 to 80 degrees.
- The output gain change is less than 0.2, when the input is 400 mV.



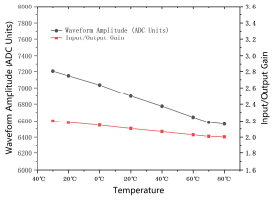
Baseline and noise test



Linearity test



Energy spectrum of alpha radioactive



Temperature test

4. Summary and Prospect

- A readout electronics system has been designed and developed for the MUSIC detector of in HFRS at HIAF.
- The joint test with the MUSIC detector demonstrated that the readout electronics performed well.
- This system can be used to construct a data acquisition system for other applications.

References

[1] L. N. Sheng, X. H. Zhang, H. Ren, et al. Ion-optical updates and performance analysis of High energy FRagment Separator (HFRS) at HIAF *Nucl. Instrum. Methods Phys. Res., Sect. B*, 2024, 547: 165214.
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[3] C. J. Wang, G. Guo, H. J. Ong, et al. Charge-changing cross section measurements of 300 MeV/nucleon 28Si on carbon and data analysis. Chinese Phy. C, 2023, 47(8): 084001.

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