Integration of the CAEN Front-End Readout System for Calorimeters within the miniSPD Setup

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Abstract – The integration and application of the CAEN front-end readout system within the miniSPD facility is presented, with a focus on calorimeter modules. The miniSPD is designed for cosmic muon testing of the detectors planned for use in the SPD facility, including straw, silicon, and Micromegas trackers, along with electromagnetic calorimeters. The main objectives include verifying the functionality and performance of modern electronics, testing the CAEN system's suitability for miniSPD, and obtaining real cosmic ray data. By using prototype detectors and measuring key detector parameters such as spatial and temporal resolution, efficiency, and stability, this work aims to assess the system's long-term operation reliability. The system was tested to produce key spectra, including the staircase spectrum, Landau distribution, and cosmic ray data, with additional upcoming results focused on SPD calorimeters. The results of using these electronics for straw-tracker prototypes are also presented, where the spectra of Fe-55 and Ru-106 are shown.

INTRODUCTION

The miniSPD setup (fig. 1) at the Joint Institute for Nuclear Research (JINR) provides a platform for comprehensive testing of detector systems intended for the Spin Physics Detector (SPD) [1] at NICA [2]. This facility includes systems for testing spatial resolution, drift characteristics, and gain stability under realistic conditions. Key components of miniSPD include a trigger system, electromagnetic calorimeters, and prototypes of gas and silicon-based detectors.

The focus of this study is the integration of the CAEN FERS-5202 front-end electronics [3], a flexible and scalable system designed for large detector arrays. This paper outlines the application of FERS to different detector prototypes, including scintillators, silicon photomultipliers (SiPMs), and calorimeter modules, and evaluates its performance in cosmic ray studies and other experimental scenarios. The setup follows a straightforward configuration, where all tested detectors are connected to the FERS front-end electronics, which then transmits data to a computer for visualization and storage. This direct connection simplifies data acquisition and analysis, reducing the need for additional intermediate electronics.

THE CAEN FRONT-END REDOUT SYSTEM

The CAEN FERS-5202 (fig. 2.) is a distributed readout solution optimized for large-scale detector arrays. Built around the Citiroc-1A ASIC [4], it supports multiple modes of operation, including spectroscopy, counting, and timing. Each FERS unit accommodates 64 channels, equipped with preamplifiers, ADCs, and trigger logic. This design is particularly effective for integrating with SiPM arrays, which are used extensively in miniSPD calorimeter modules.

While the Citiroc-1A ASIC does not support negative signal inputs natively, this limitation is addressed within the gas gain monitor system, where signals are pre-inverted. However, external preamplifiers with inverting functionality are required for MDTs and straw chamber prototypes, adding some complexity. Despite this, the system offers seamless compatibility with SiPM-based detectors, such as calorimeters, enhancing their performance and data acquisition.

EXPERIMENTAL SETUP AND DATA COLLECTION

The experiments conducted within the miniSPD facility aimed to evaluate the FERS system's performance across different detector configurations. A comprehensive series of tests was performed, including threshold calibration, cosmic ray detection, gas gain monitoring, and calorimeter data acquisition.

The staircase spectrum (fig. 3) was generated to optimize trigger thresholds. The plot illustrating the relationship between the threshold level set for triggering events and the corresponding counts observed in the detector. It is essential for optimizing the threshold and reducing noise interference. Photonic peaks (1 p.e., 2 p.e., etc.) represents the detection of a specific number of photoelectrons. As the threshold is lowered, the detector starts capturing individual photons, leading to distinguish able peaks in the spectrum. The Landau spectrum (fig. 4) was produced using the plastic scintillator and Hamamatsu matrix, illustrating the energy loss distribution for relativistic muons [5].

Using ^{55}Fe and ^{106}Ru sources, spectra were obtained to check FERS applicability with straw detector systems. The gas gain monitoring system [6] (Fig. 6) utilized a test chamber with the following parameters: a 9.8 mm diameter straw, a 30 μm anode wire, an operating voltage of 1500 V, and a gas mixture comprising 80% argon and 20% carbon dioxide. The ^{55}Fe spectrum revealed distinct main and escape peaks (Fig. 5). The main peak observed at an energy of 5.9 keV is due to the transition of the Fe-55 nucleus to a lower energy level, led by the emission of a gamma-ray. The escape peak appears due to the interaction of gamma-rays emitted by the source with the detector material. This interaction leads to the ejection of electrons from the detector, which carry away some of the energy. The escape peak is typically located at an energy that is 3 keV lower than the energy of the main peak. Therefore, for Fe-55 with a main peak at 5.9 keV, the escape peak will be observed at approximately 2.9 keV. The Fe-55 spectrum is particularly informative, as the positions of its characteristic peaks provide insights into electronics performance, calibration consistency across channels, and gas gain factors. Unlike Fe-55, the Ru-106 spectrum is a continuous beta spectrum with a high-energy limit, making it less informative for spectral analysis. However, its significantly higher activity compared to Fe-55 allowed us to evaluate the electronics' response at high event rates. At a rate of approximately 3 kHz per channel, a trigger loss of around 10% was observed, highlighting an important performance limitation of the system. Both ^{55}Fe and ^{106}Ru spectra were measured with electronics configured at low gain: 50 (20 mV/pC), a threshold of 180, and a shaping time of 25 ns.

The electromagnetic calorimeter (Fig. 7) consists of 190 alternating layers of 1.5 mm thick polystyrene scintillators and 0.5 mm lead absorbers. The total length of the module is approximately 490 mm, with an active detection area of 380 mm. Light generated in the scintillators is captured by wavelength-shifting fibers (Y-11) and transmitted to multi-pixel photon counters (MPPC) for signal processing [1,7]. Initial raw data (Fig. 8) showed significant noise, which was effectively filtered using a ROOT-based macro.

To improve data analysis on FERS, a ROOT macro [8] was developed to filter out noise and isolate relevant cosmic ray events. Initially, the raw data exhibited significant noise at lower channels, with a general distribution resembling a Landau shape, typical for cosmic ray signals. The macro processed the data by selecting only events that triggered a single channel, excluding contributions from non-vertical particles. This selection method eliminated noise observed in the initial channels, leaving behind only clean cosmic ray spectra.

The resulting data (fig. 9) fit well to a Landau distribution, confirming that the processed events represent vertical cosmic rays, with the noise successfully suppressed in the final spectrum. The complete scheme of the entire setup is presented in Fig. 10.

CONCLUSION

The integration of the CAEN FERS-5202 system within the miniSPD facility has proven effective for a range of detector tests, including cosmic ray detection and calorimeter evaluation. Future improvements will focus on optimizing calorimeter normalization and integrating external triggers to enhance data precision. Also, the reconstruction and improvement of the miniSPD facility will incorporate the FERS system not only as trigger electronics but also as the primary readout solution for individual components.

FIGURES

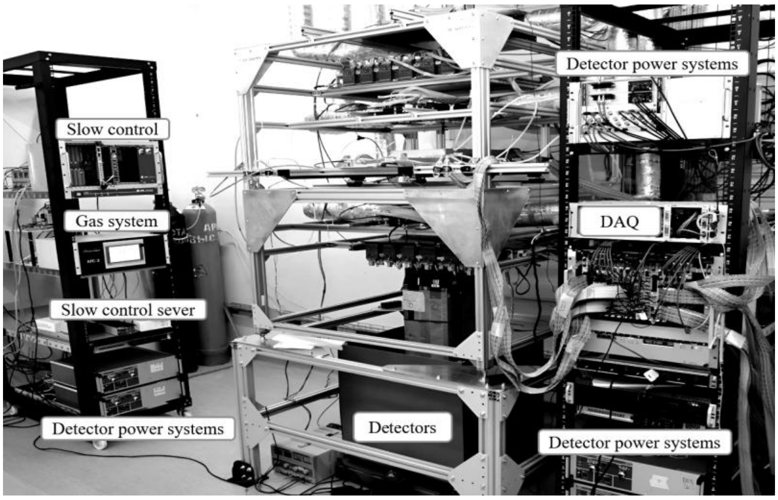

Fig. 1. Main view of the miniSPD stand

Fig. 2. FERS DT5202 64-channel unit

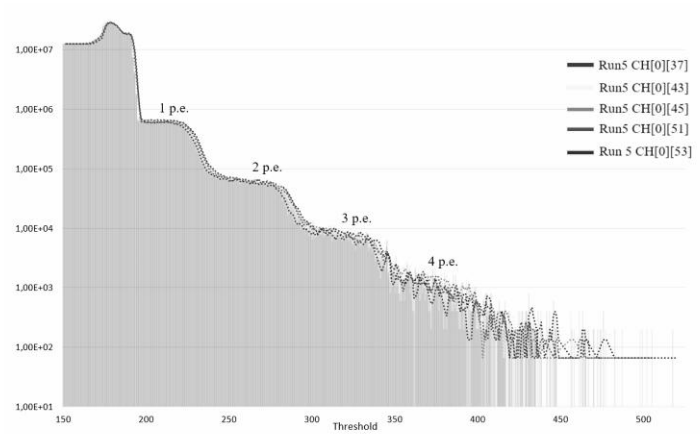

Fig. 3. Counts vs Threshold (Staircase) of the SiPM matrix pixels connected to DT5202

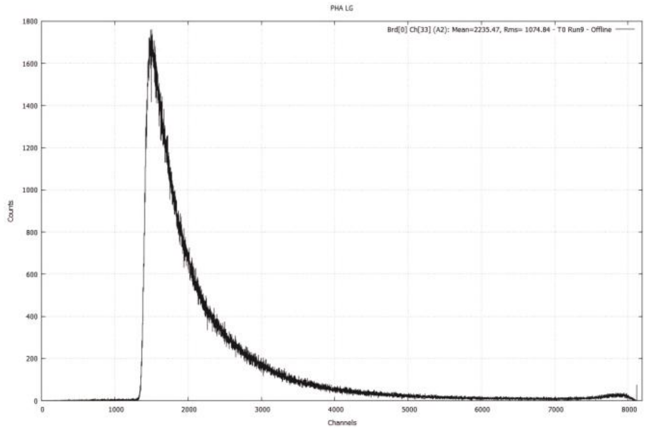

Fig. 4. Landau distribution of Cosmic Rays

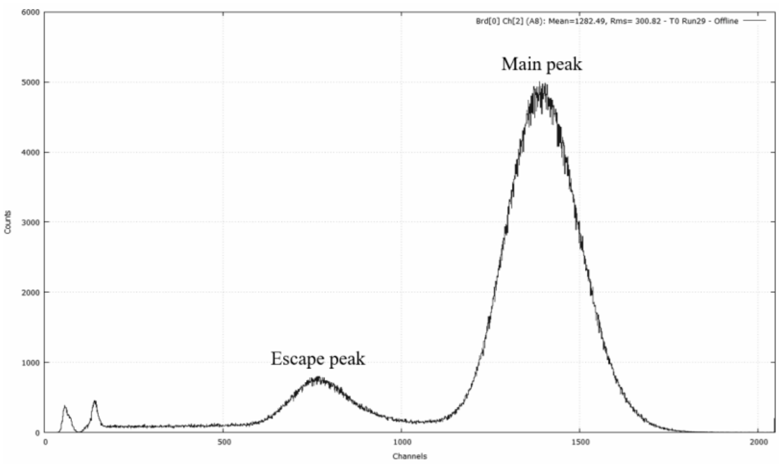

Fig. 5. Gamma-ray spectrum of Fe-55 source

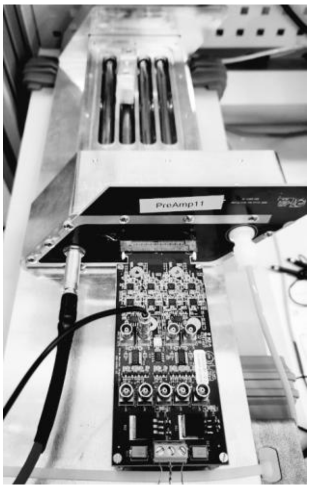

Fig. 6. Gas gain monitor system

Fig. 7. Four calorimeter modules

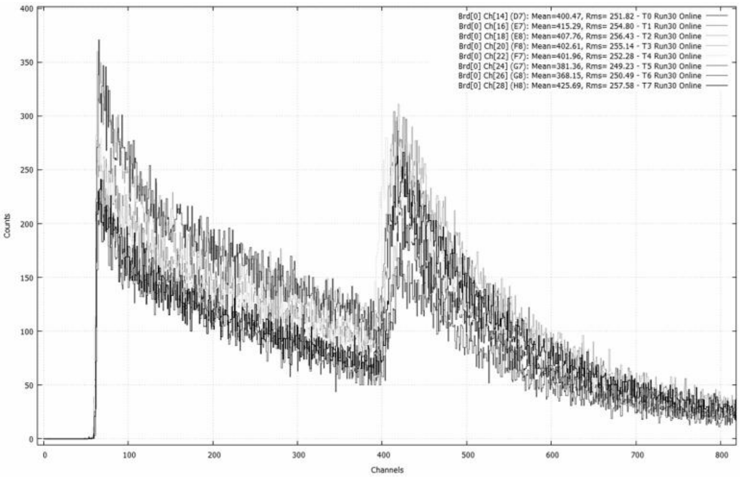

Fig. 8. Raw data from FERS

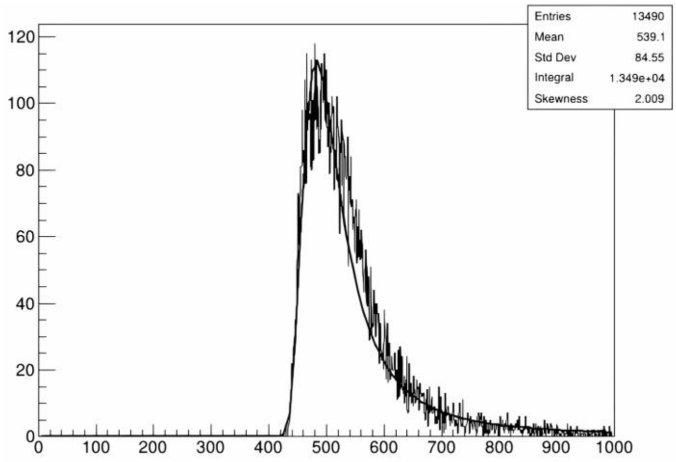

Fig. 9. Processed data in root with selection of only vertical tracks

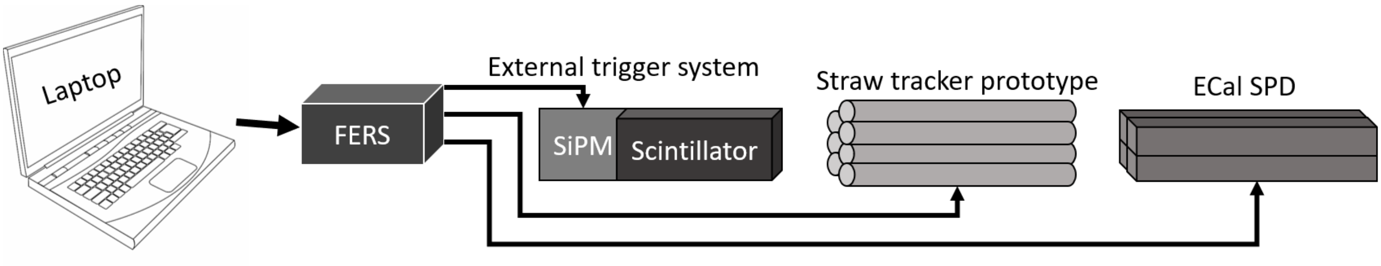

Fig. 10. Scheme of experimental setup

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