SAMPA Based Streaming Readout Data Acquisition Prototype

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Introduction

We have assembled a small-scale streaming data acquisition system based on the SAMPA front-end ASIC. The goals of the prototype system are to determine if the SAMPA chip is appropriate for use in detector systems at Jefferson Lab, and to gain experience with the hardware and software required to deploy streaming data acquisition systems in nuclear physics experiments.

SAMPA

The 32-channel SAMPA ASIC is a mixed signal IC designed for the upgrade of the ALICE experiment at the LHC (Figure 1). For each channel the analog front end of the chip is composed of a charge sensitive amplifier, followed by two shaping circuits that produce a 4-th order semi-Gaussian pulse. The shaped signal with a nominal peaking time of 160 ns is digitized by a dedicated 10-bit ADC operated at up to 20 MSPS (Figure 2).

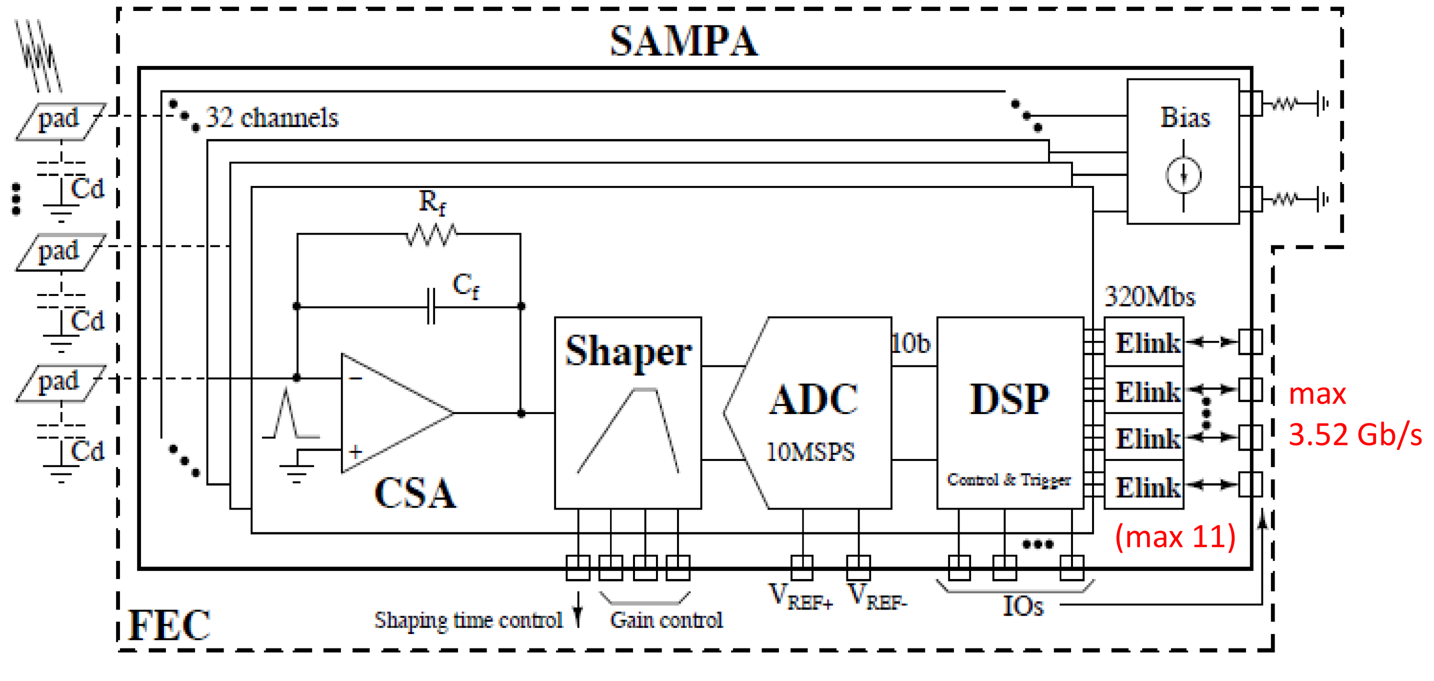
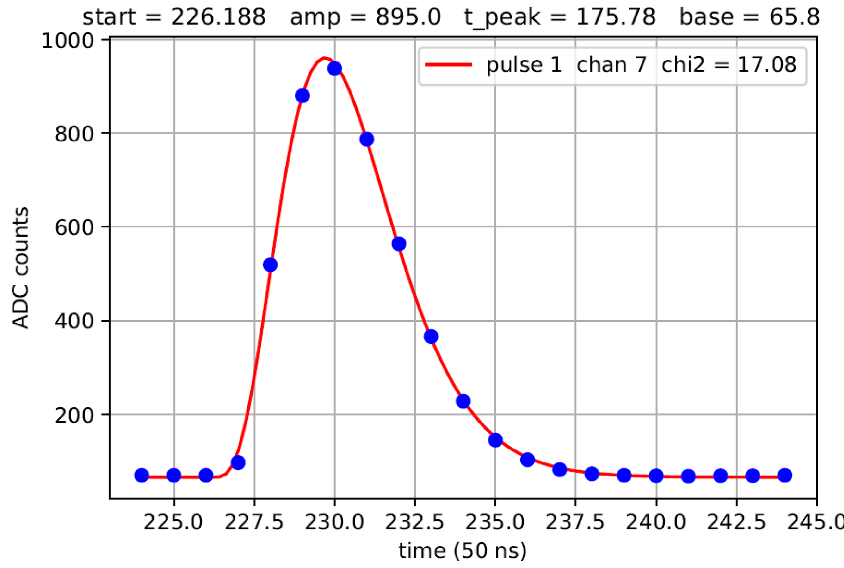


Figure 1. SAMPA integrated circuit

After leaving the ADC the digitized data can follow two alternative paths: be processed by a dedicated DSP or be sent out in direct ADC mode (DAS). The DSP can be utilized to perform baseline corrections and data compression (zero suppression, Huffman coding) before sending the processed data off chip in multiple serial data streams. In contrast, direct ADC mode sends out the unprocessed ADC data directly via ten serial data links. The design of the Front-End Card (FEC) that supports the SAMPA chips limits the sampling rate in DAS mode to 5 MSPS.



SAMPA impulse shape function

$$f(x) = A\left(\frac{x-t}{\tau}\right)^N e^{-N\left(\frac{x-t}{\tau}\right)} + Bl.$$

N = 4 shaping order
τ = peaking time
Bl = baseline
t = start time
Ae^{-4} = *amplitude*

Figure 2. Fit to shaped pulse sampled at 20 MSPS

Readout

The 800 channel system is composed of components used in the ALICE TPC data acquisition upgrade (Figure 3). Five front-end cards (FEC) support five SAMPA chips each. SAMPA data streams on an FEC are concentrated into two high-speed (4.48 Gb/s) serial data streams by a pair Gigabit Transceiver ASICs (GBTx). These ten streams (44.8 Gb/s) are transmitted from the FECs over fibers to a PCIe based readout unit (CRU). The FPGA engine on the readout unit compresses data for transmission to a server via 100 Gb ethernet. Components on the FECs are radiation tolerant. High data rates can be handled. The system is by design scalable.

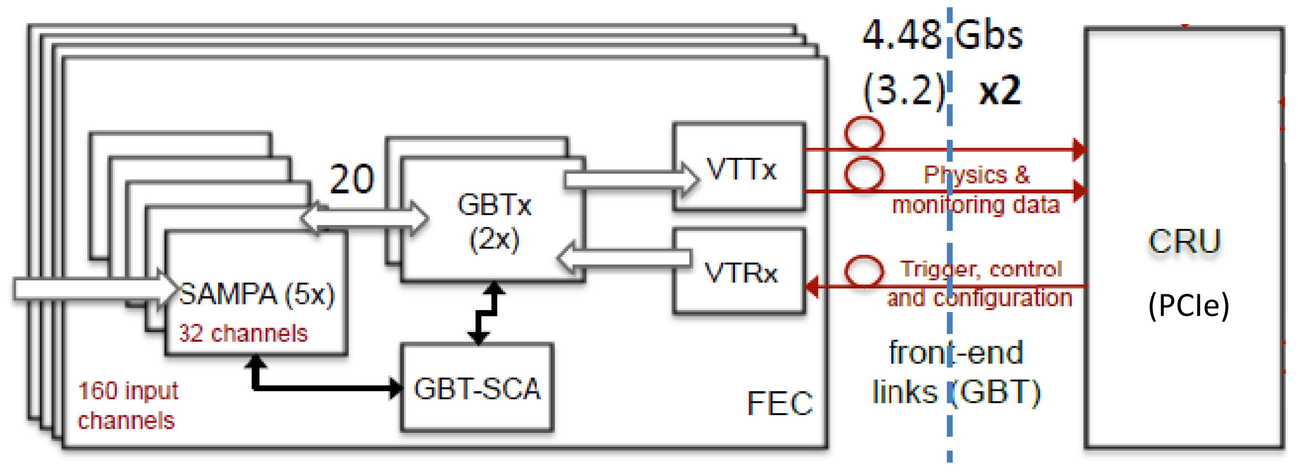


Figure 3. Readout system

Measurements

We performed fundamental measurements on the SAMPA ASIC. These were done with controlled test pulses at the SAMPA inputs. Some of the measurements are shown in Figures 4-7 (all with sampling at 20 MHz). We have also coupled the readout system to a small Gas Electron Multiplier (GEM) detector and have begun to study the SAMPA's response to cosmic rays (Figures 8-9).

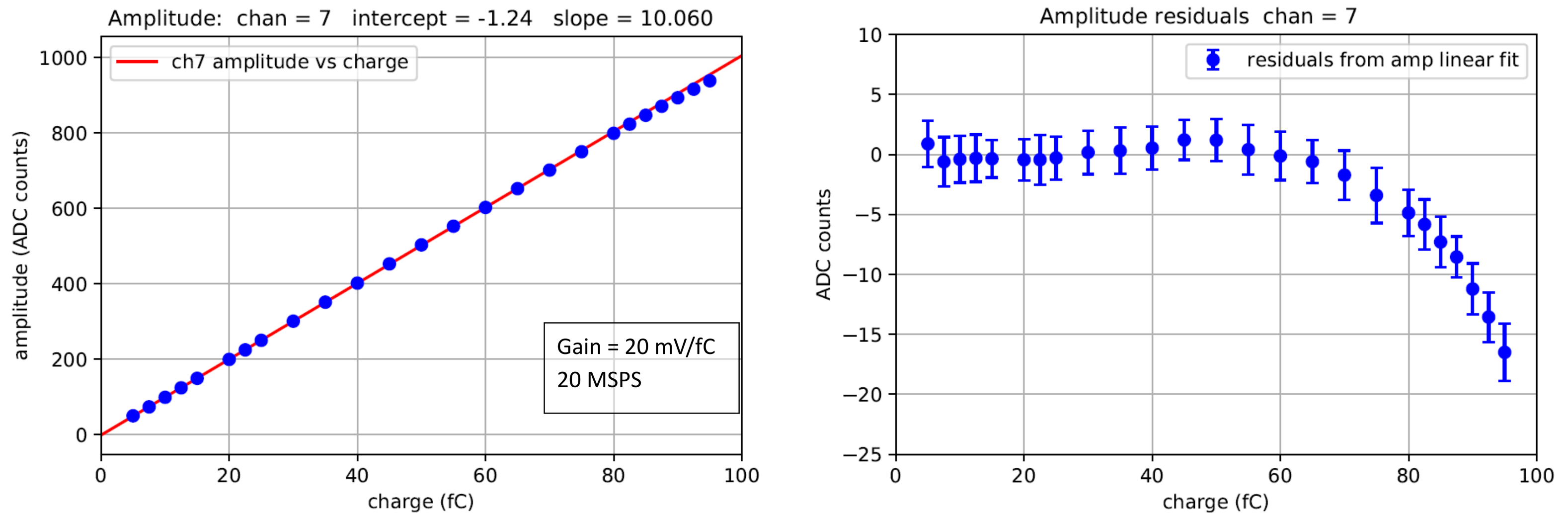


Figure 4. Pulse Amplitude vs. Input Charge. Pulse Amplitude is determined by fitting to the SAMPA impulse shape function. Linear fit is over range 5 - 70 fC.

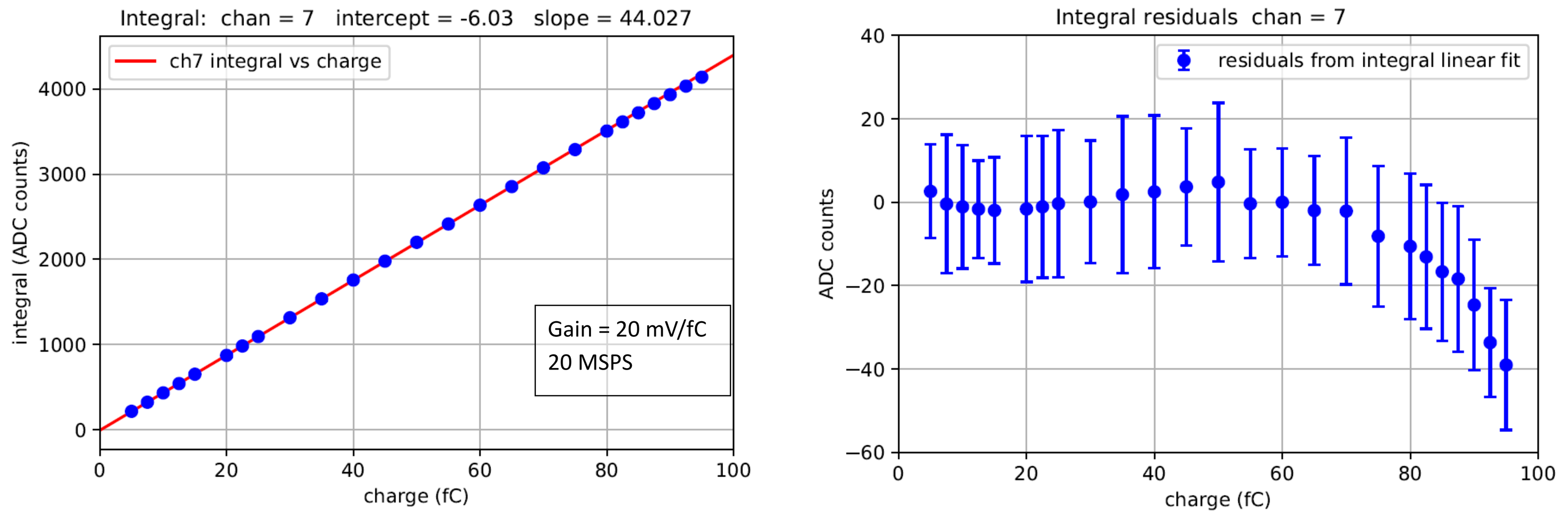


Figure 5. Pulse Integral vs. Input Charge. Pulse Integral is the sum of ADC samples of the pulse minus an estimate of the baseline sum beneath the pulse. The baseline sum estimate is derived from an average of samples before and after the pulse.

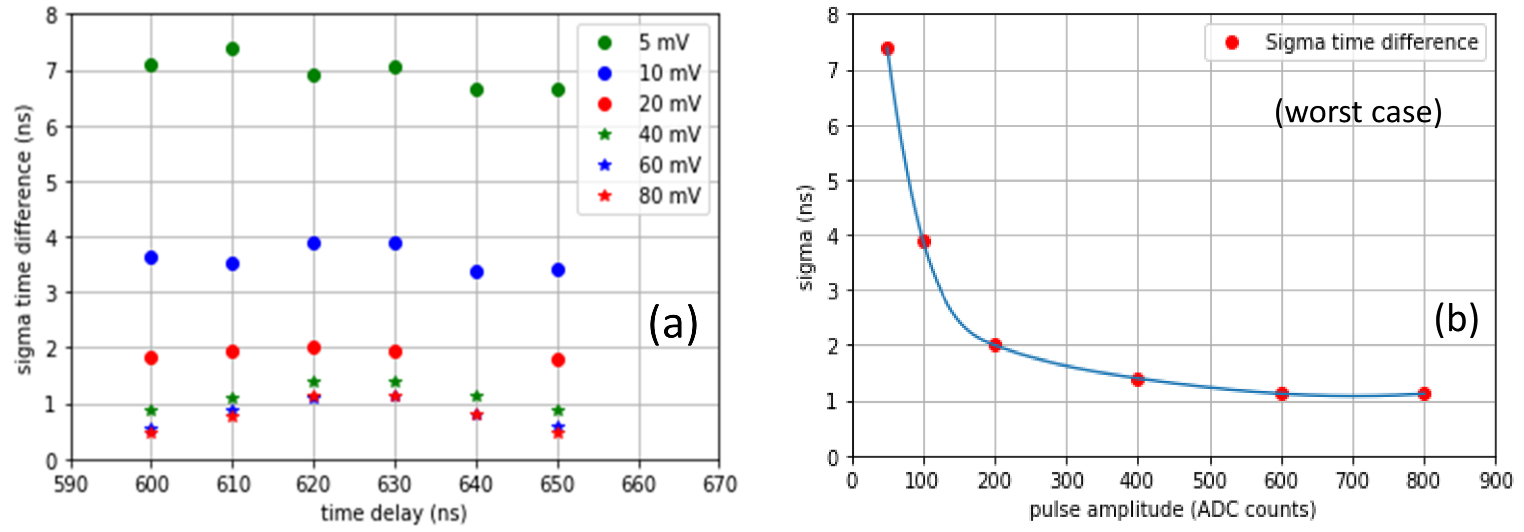


Figure 6. (a) Time difference resolution vs. time delay of pulse pair, for pulse amplitudes across the entire dynamic range. *Start Time* of the fitted pulse defines the pulse time. (b) Worst case time difference resolution vs. pulse amplitude (condensed from (a)).

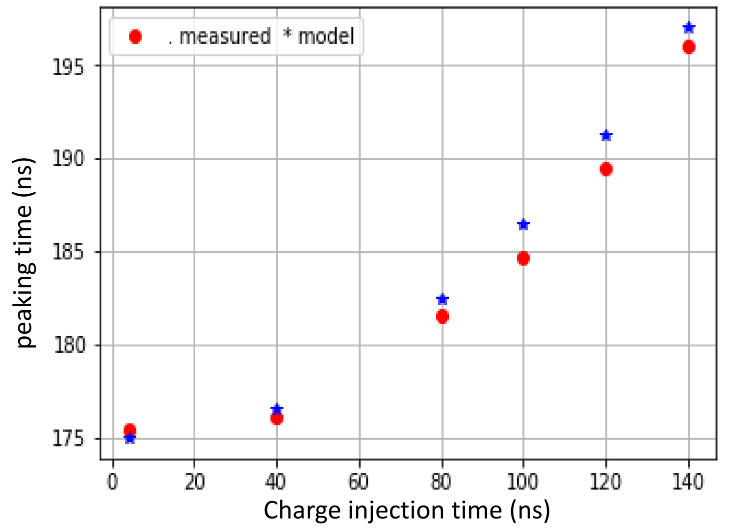


Figure 7. Peaking time of pulse fit vs. Charge injection time for pulse. Blue points are for a convolution model. Pulse broadening is accompanied by reduction of fit amplitude. A correction to the pulse amplitude can be made based on the measured peaking time. The pulse integral has been shown to be constant over these injection times.

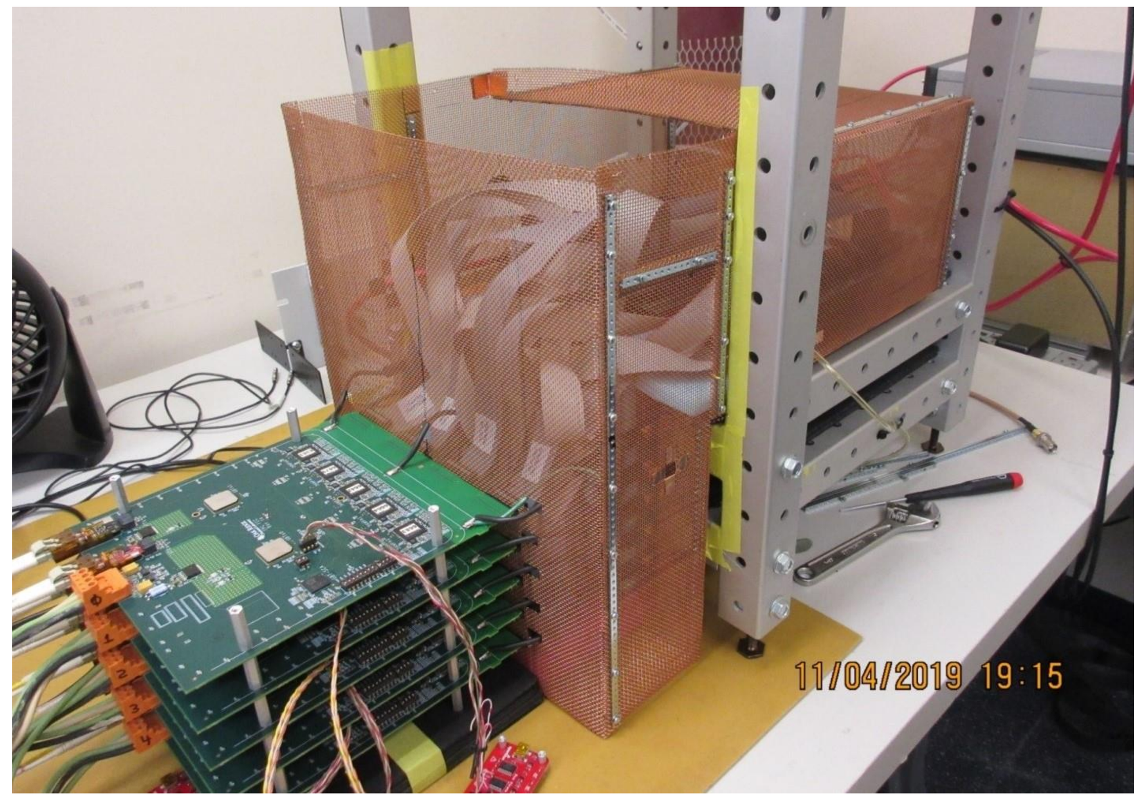


Figure 8. SAMPA front-end cards connected to GEM detector. Detector and cables are enclosed in a Faraday cage.

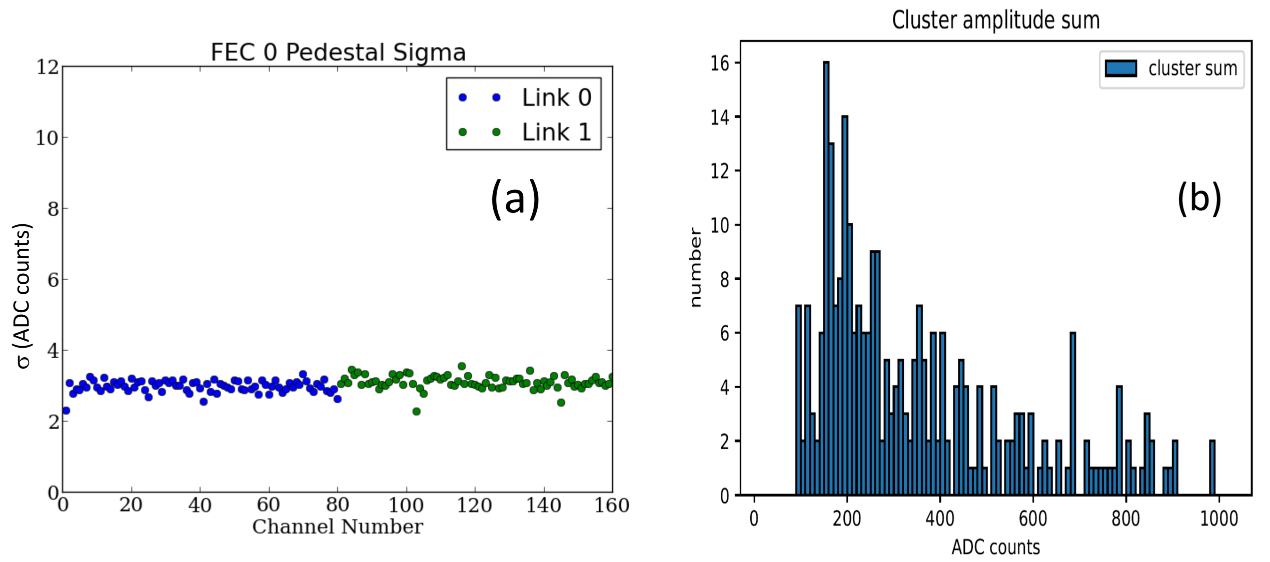


Figure 9. (a) Pedestal noise (sigma) for detector system.
(b) Cluster amplitude distribution for cosmic ray events.

Conclusion

We have successfully streamed and analyzed data from the SAMPA chip using both test pulse and GEM detector stimuli. We have made fundamental measurements on the SAMPA chip that complement those performed by the ALICE collaboration. We believe that the SAMPA chip and the elegant data transport mechanism employed in this system form an excellent basis for future streamed and triggered data acquisition systems at Jefferson Lab and the Electron-Ion collider.

Future Work

Extensive cosmic ray studies with the current readout system and GEM detector are planned. We will upgrade to a more powerful CRU and will develop pulse feature extraction algorithms within the CRU's FPGA to reduce data volume. The upgraded system will serve as a test platform for streaming mode software development.