Analysis of Pedestal Data of the Silicon Muon Scanner

Martin Adams, College of San Mateo – CCI Program
Ron Lipton, Fermi National Accelerator Laboratory

Background

Cosmic-ray muon tomography detectors have found an important application in the location of nuclear materials in concealed containers[1], but current detectors use gas-filled drift tubes which are massive, costly, and provide ambiguous data[2]. To mitigate these issues, we have begun the development of a new muon tracking system, the Silicon Muon Scanner (SMS), for homeland security applications based on the silicon-strip detectors used in the Compact Muon Solenoid experiment at CERN[3].

The SMS, which consists of silicon-strip sensors, front-end SKIROC ASIC readout chips[4], and a Zedboard microprocessor to collect and package the data, is currently being tested by a team from the Particle Physics Division at Fermilab. Before the system undergoes tests at the Fermilab Test Beam Facility, we aim to quantify the electrical noise inherent to the hardware. To achieve this, we ran the detector without charge injection and analyzed the data collected by the system.

Pedestal Noise

Each SKIROC chip has 64 channels, and each channel has inherent electrical noise independent of the noise in the other channels. The mean value of noise a channel picks up without any charge input is that channel's pedestal. The pedestal of each channel must be calculated so that we can understand our zeros in all data sets collected by the SMS[5].

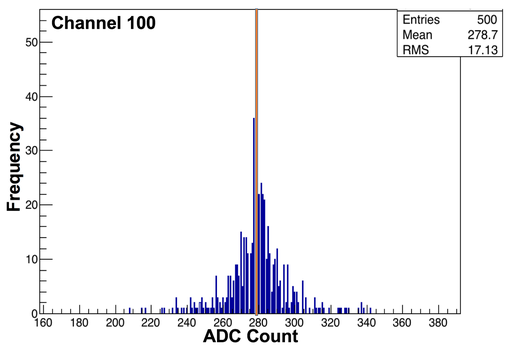


Fig.1. The ADC counts recorded by a channel during a pedestal run vary about that channel's pedestal.

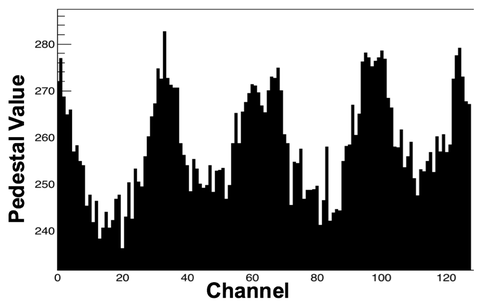


Fig. 2. The pedestal of a channel depends on the characteristics of that channel, so the pedestals of different channels vary.

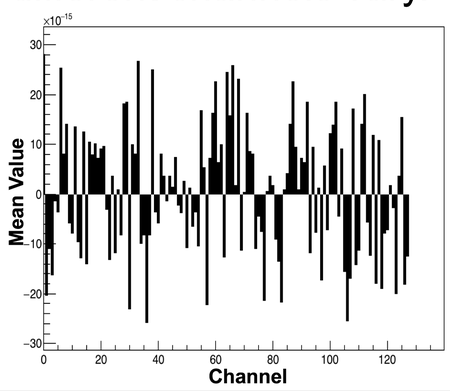


Fig. 3. Removal of pedestals from the data reduces noise from a magnitude of 10^2 to 10^{-15}. This reduction allows us to discern between noise and beam data detected by any channel of the SKIROC chips.

Common-Mode Interference

After the pedestals of each channel are removed, we can clearly analyze the next source of systematic noise, common-mode interference. While the pedestal is a measure of noise present in one channel independent of the noise in other channels, common-mode noise is coherent interference that affects all channels in the readout chips in a similar manner and varies by event[6].

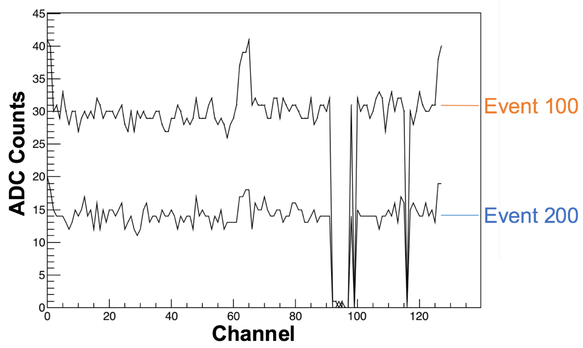
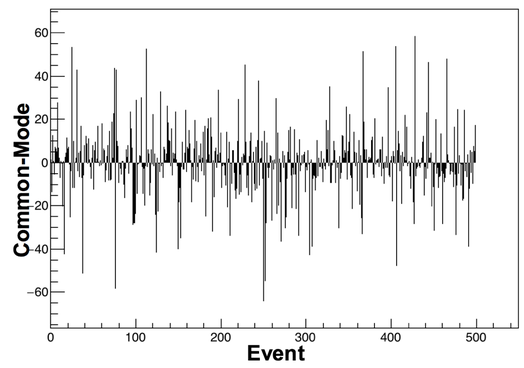


Fig. 4. After pedestal removal, the common-mode can be easily visualized as the mean value of all the channels for one event.

Fig. 5. A plot of the common-modes of all events after pedestal removal.
The trend of noise from event to event corresponds to the variation of noise from the pedestal in one channel.



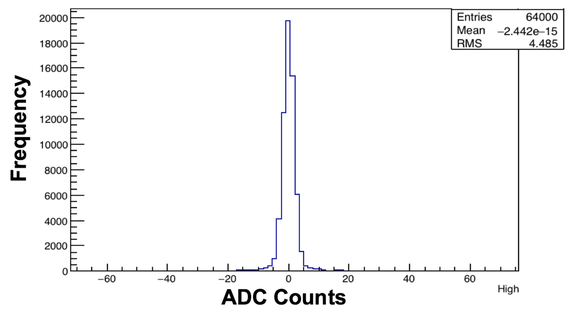


Fig. 6. After removal of the systematic noise, pedestal and common-mode, from the pedestal run data set, the noise in the system is reduced from a magnitude of 10^2 to 10^{-15}.

Results

The pedestals calculated in this analysis are characteristic of the detector being tested and will be accounted for in data analysis on tests at the Fermilab Test Beam Facility. The common-mode interference analysis on the pedestal data can used to identify problems in the SMS; however, common-mode analysis will also be conducted on data collected at the Test Beam.

References

[1] K. Borozdin et al., "Cosmic-Ray Muon Tomography and its Application to the Detection of High-Z Materials," Proceedings of the 46th Annual Meeting, Institute of Nuclear Materials Management, 2005.
[2] J. A. Green et al., "Conceptual Design for a Silicon Strip Cosmic-Ray Muon Detector for SNM," unpublished, 2016.
[3] M. Krammer, "Silicon Detectors," Institute of High Energy Physics, Vienna, Austria, 2011.
[4] M. Bouchel, M. El Berni, J. Fleury, C. De La Taille, G. Martin-Chassard, et al., "Skyroc: a Front-end Chip to Read Out the Imagine Silicon-Tungsten Calorimeter for ILC," TWEPP-07 Topical Workshop on Electronics for Particle Physics Search, September 2007, Prague, Czech Republic.
[5] Melanie Day, "Pedestal Analysis," University of Rochester, May 2009.
[6] Sergi Navarro, "Analysis of Pedestal Data of The Alibava Readout System," University of Valencia, Spain, September 2014.

Fermilab
U.S. DEPARTMENT OF ENERGY | Office of Science