Noise Studies of the Streaming Readout Detector Prototype

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Summary

An effort has been made to study the character of the noise present in the streaming readout detector prototype so that we can operate this system at the lowest noise level possible. Analysis presented here leads us to conclude that a significant portion of the measured noise is due to radiated emissions (EMI) from external sources in near proximity to the system. The suggested solution is to construct a Faraday cage around the system.

Introduction

Our streaming readout prototype is based on the SAMPA ASIC [1]. The SAMPA is a complex mixed signal IC designed for the upgrade of the ALICE experiment at the LHC. 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 peaking time of 160 ns is digitized by a 10-bit ADC that can be operated at up to 20 MSPS. After leaving the ADC the digitized data can follow two alternative paths: be processed by the DSP or be sent out in direct ADC mode (DAS). The DSP can be utilized to perform baseline corrections and data compression 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.

We have connected our SAMPA based streaming readout electronics to a prototype GEM detector and have successfully read out data in both DAS and DSP modes. It is most convenient to study the noise of the system using the DAS mode.

Figure 1 shows the measured standard deviations (σ) of the pedestal (baseline) for a subset of detector channels. This is a measure of the noise in the system. Typical values of σ here are about 9 ADC counts.

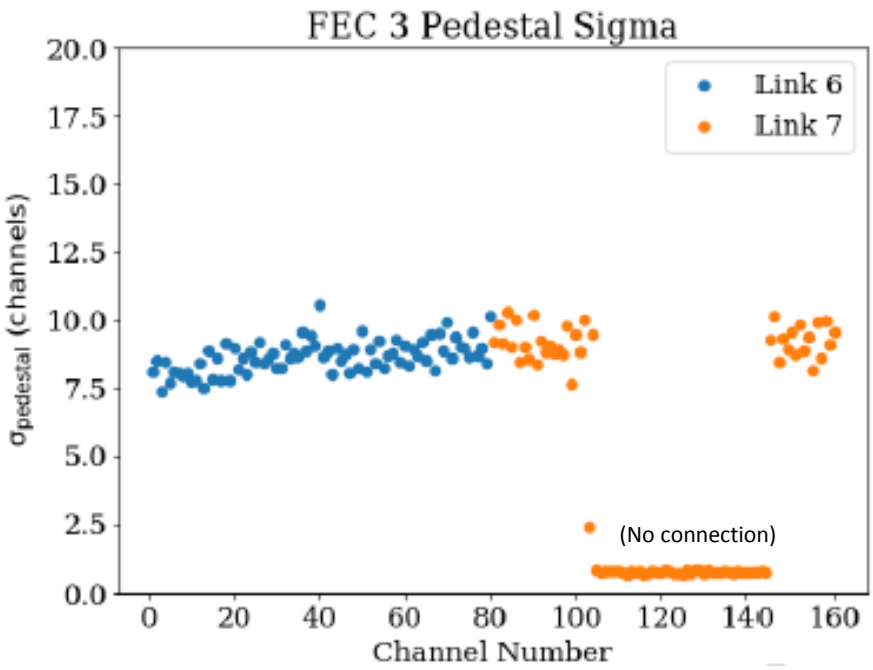


Figure 1. Measured noise

The noise floor of the system is determined by the design parameters of the SAMPA chip and the capacitance at the input (GEM + cable assembly). In a separate study [2] we have characterized the noise of the SAMPA as a function of input capacitance. **Figure 2** summarizes these results.

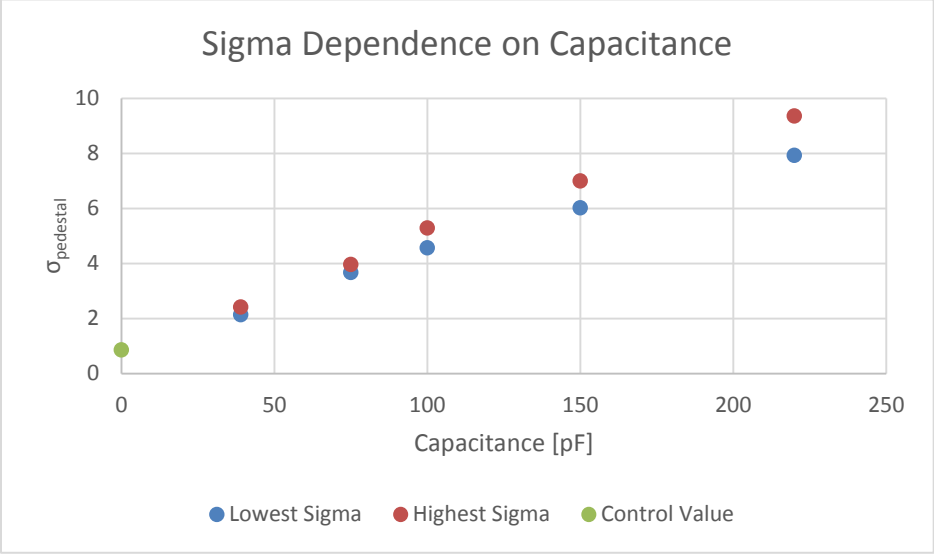


Figure 2. SAMPA: Noise vs. Input Capacitance

If there were no other noise sources in the system, **Figures 1** and **2** would imply that the GEM/cable system has a capacitance of 225 pF. The 18 inch ribbon cables connecting the GEM to the readout electronics contributes 50 pF to the total capacitance, leaving 175 pF for the GEM. The actual capacitance of the GEM is unknown at this time. We will attempt to measure the capacitance of the GEM in the near future.

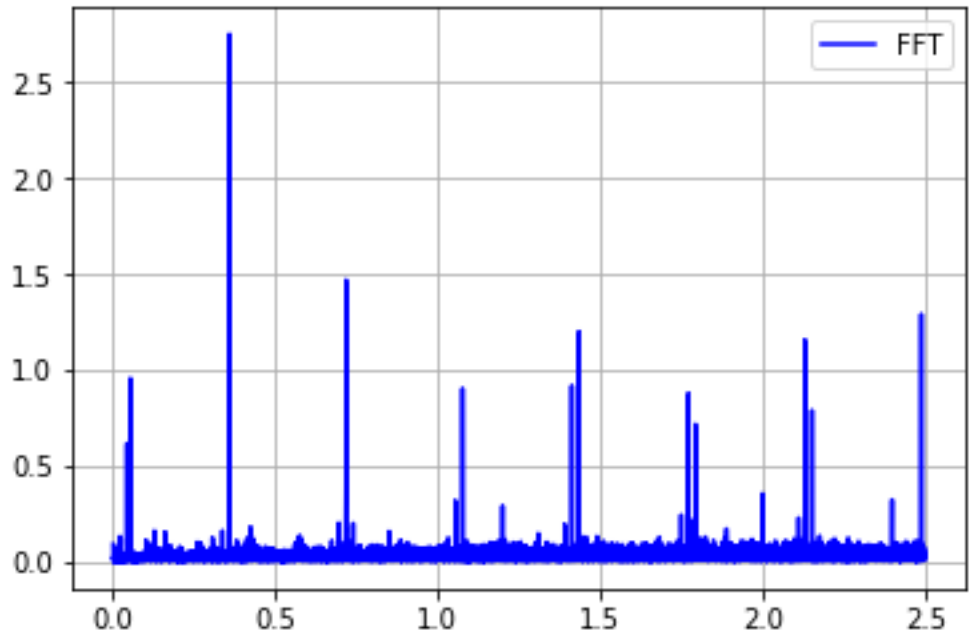
We have made an effort to study the character of the noise of our system so that we can operate it at the lowest noise level possible. The continuous stream of ADC samples in the DAS readout mode allows us to perform a discrete Fourier Transform on the data and extract the spectral components of the noise. Since the DAS mode has a sampling rate of 5 MSPS, we can study noise components having frequencies up to 2.5 MHz. In principle we could extend this to 10 MHz by using the packet based SAMPA DSP readout mode. However, the maximum number of continuous samples in a readout packet is 1023. This significantly limits the frequency resolution of the FFT. In contrast we collect 32K consecutive samples in DAS mode.

FFTs were computed and plotted on a Windows 7 PC using the Spyder 3.3.3 Scientific Python Development Environment. The FFT function *fft* is imported from the *fftpack* of the *scipy* library.

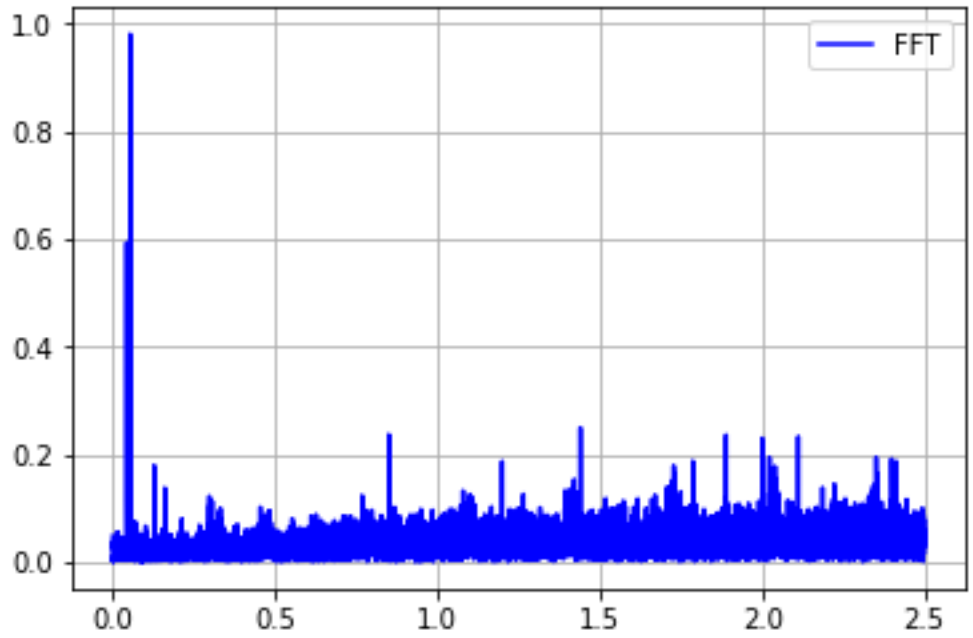
Results

A noise source was identified as the power converter (AC/DC) for the Bus Pirate USB hub. Shown below is a comparison of FFT and ADC raw samples (pedestal) with and without the noise source for a typical channel (FEC 0, channel 3). Note the change of scale for the FFT plot. Since the Bus Pirates are not needed after initial configuration, **all subsequent noise studies are done with the Bus Pirates disconnected and the USB hub power converter not plugged in**.

FEC 0 Channel 3

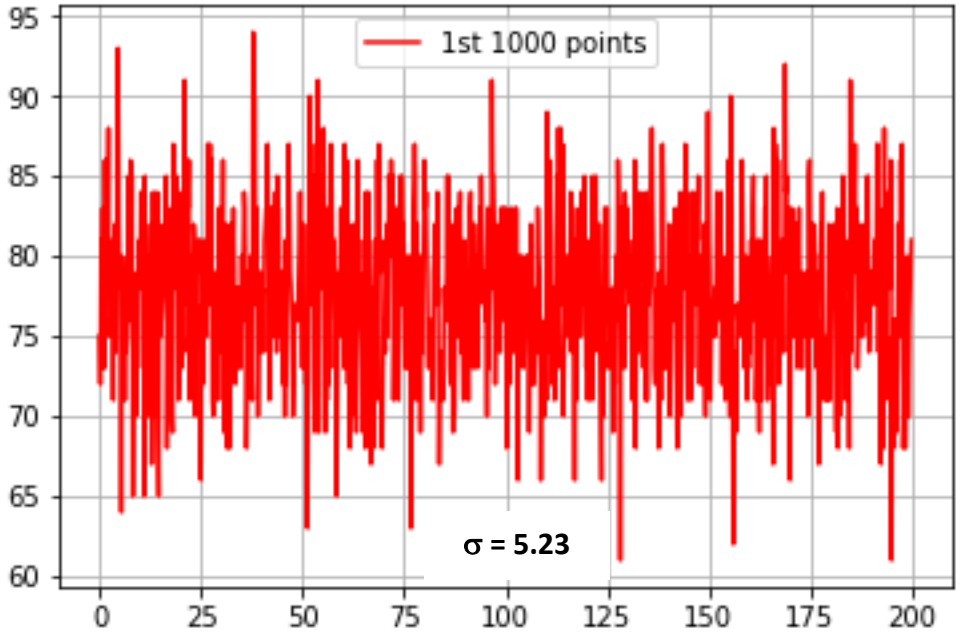


Bus Pirates connected, USB hub powered



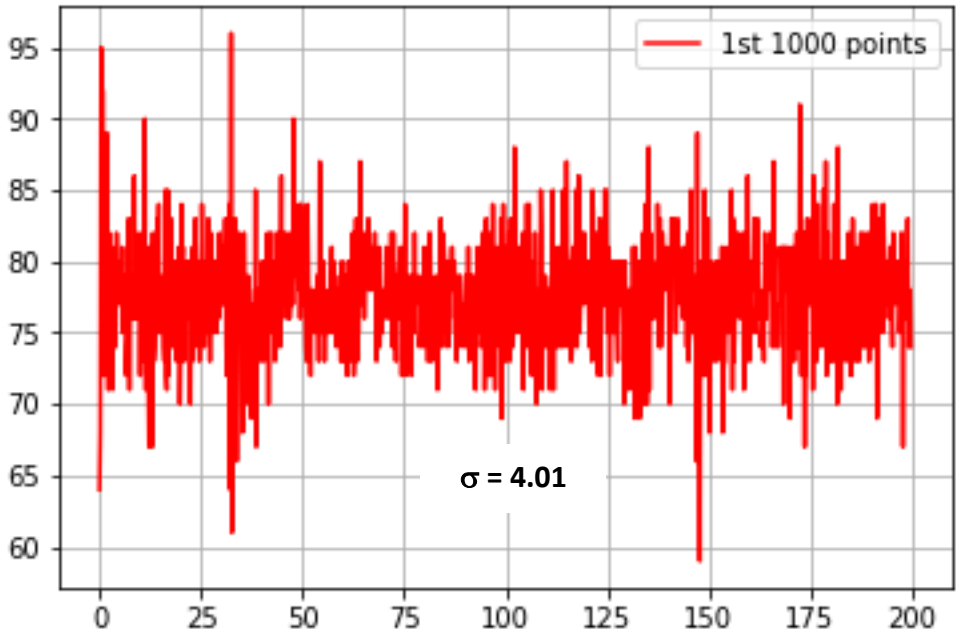
Bus Pirates disconnected, USB hub not powered

FEC 0 Channel 3



μs

Bus Pirates connected, USB hub powered

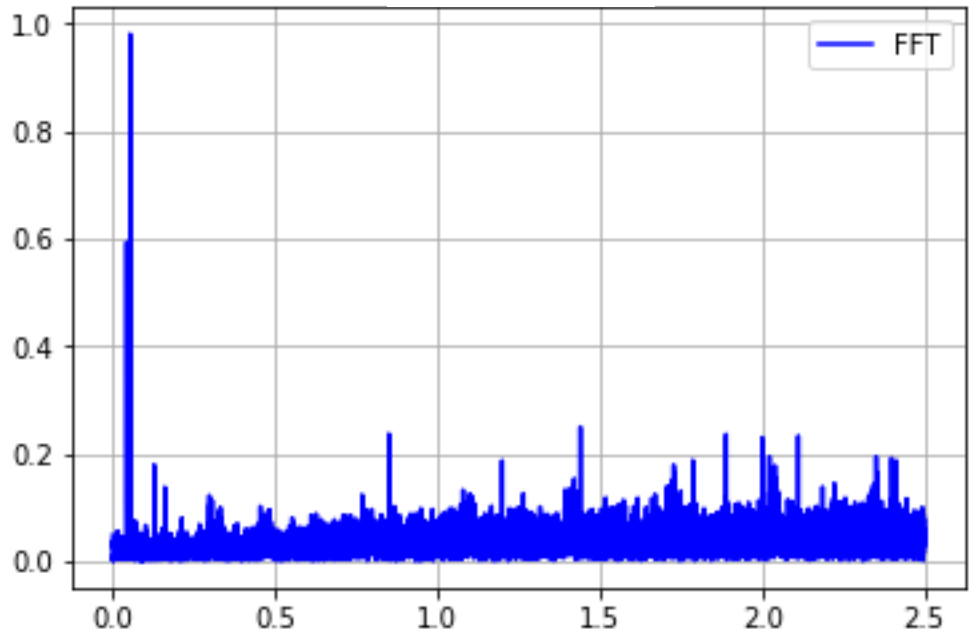


μs

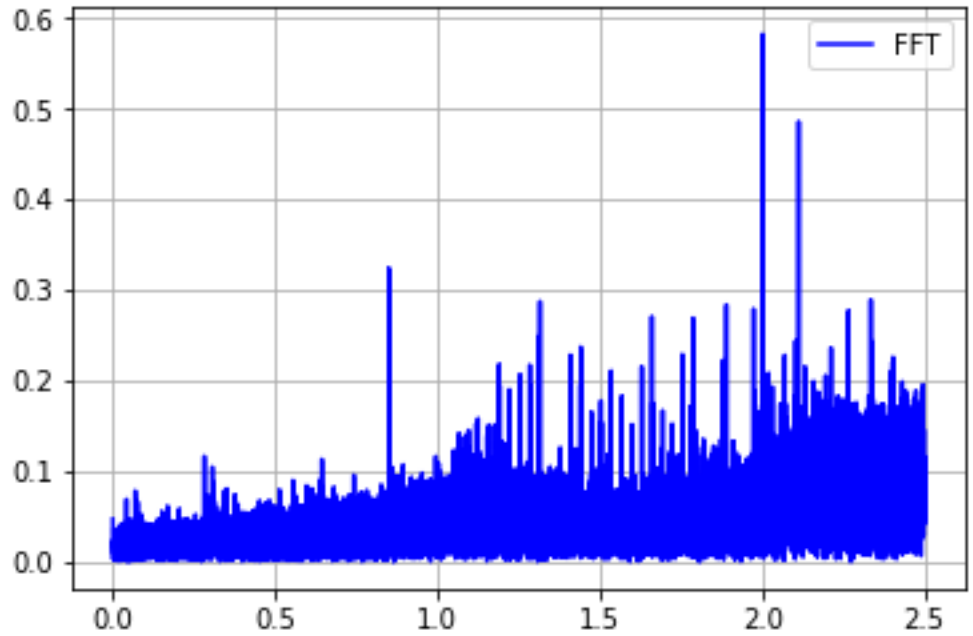
Bus Pirates disconnected, USB hub not powered

A noise source was identified as the florescent lights in the lab room (CC F110). Shown below is a comparison of FFT and ADC raw samples (pedestal) with the light switch ON and OFF. With the switch in the OFF position a dimmed light is still visible. Although the spike at ~50 KHz typical of a florescent light's electronic ballast is gone with the light switch OFF, there is increased noise at higher frequencies. This may be due to the dimming feature of the lighting system. **All subsequent noise studies are done with the light switch ON.**

FEC 0 Channel 3

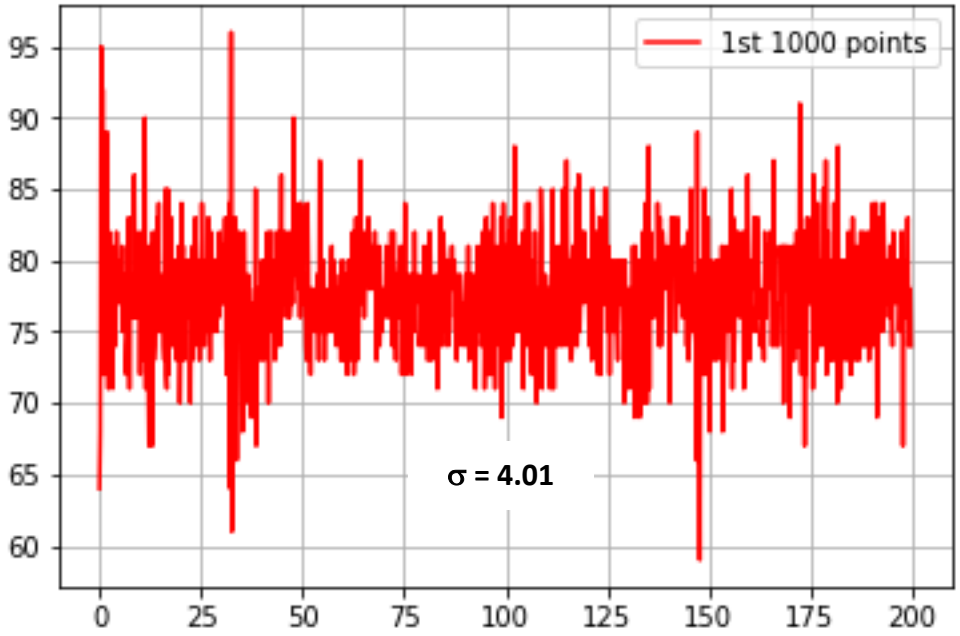


Light switch ON



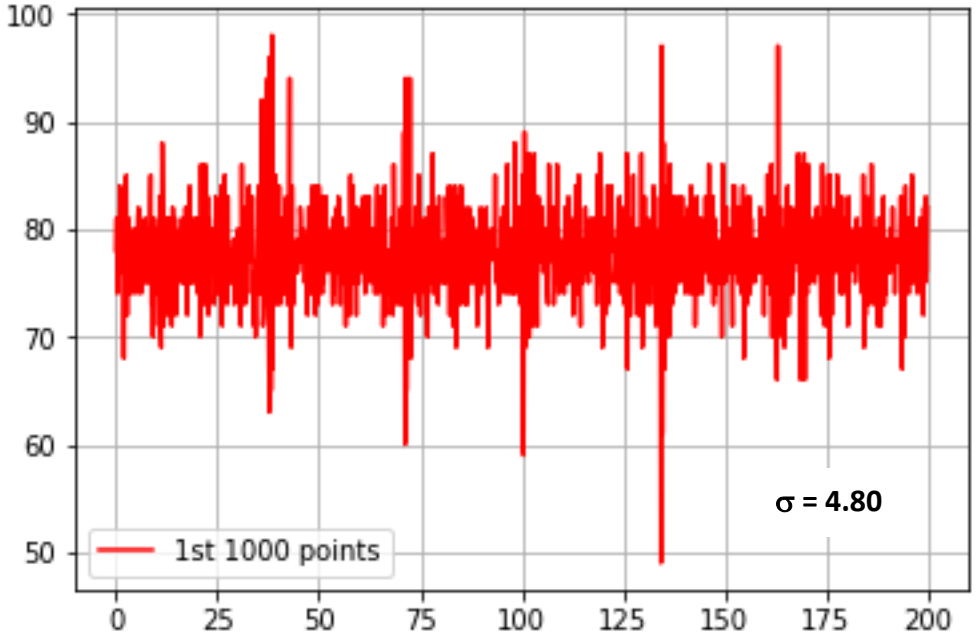
Light switch OFF

FEC 0 Channel 3



Light switch ON

μs



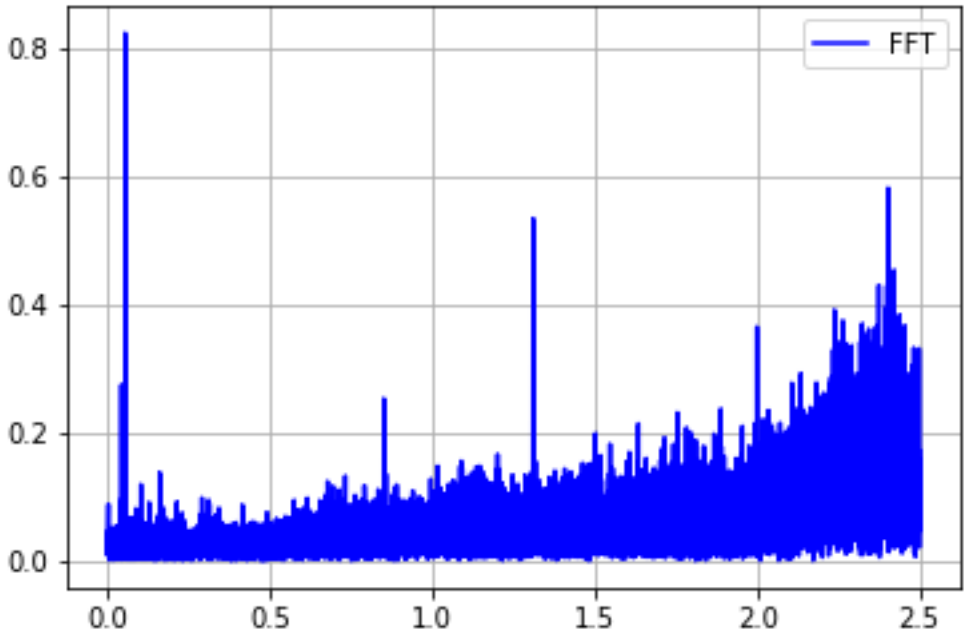
Light switch OFF

μs

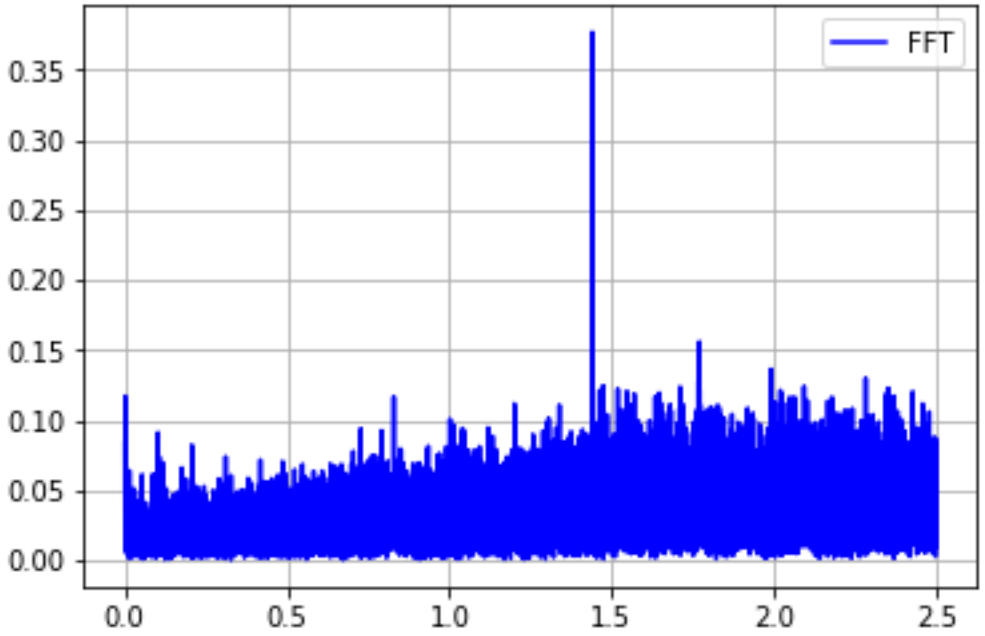
In order to test if the noise we measure is radiated or conducted EMI, a simple attempt to partially shield the GEM and cable assembly from radiated sources was attempted. An aluminum foil sheet was formed into a dome that covered the top and sides of the GEM as well as the top and partially the sides of the cable assembly. About 25% of the GEM/cable assembly was shielded; the cables from the top FECs (0,1) were better shielded than those from the lower FECs (3,4). The aluminum foil was connected by copper tape to the central grounding point of the system. A clearance of at least 1" was maintained between the foil and the cables so that their capacitance would not be increased.

It can be seen from the following plots that even this limited shielding results in a significant reduction in the measured noise. This is particularly true for FEC 0 channel 0, whose signal is along the edge of the outermost cable and thus most susceptible to any radiated EMI. These results suggest that a proper Faraday cage should be constructed around the GEM and cable assembly to achieve the lowest possible noise.

FEC 0 Channel 3

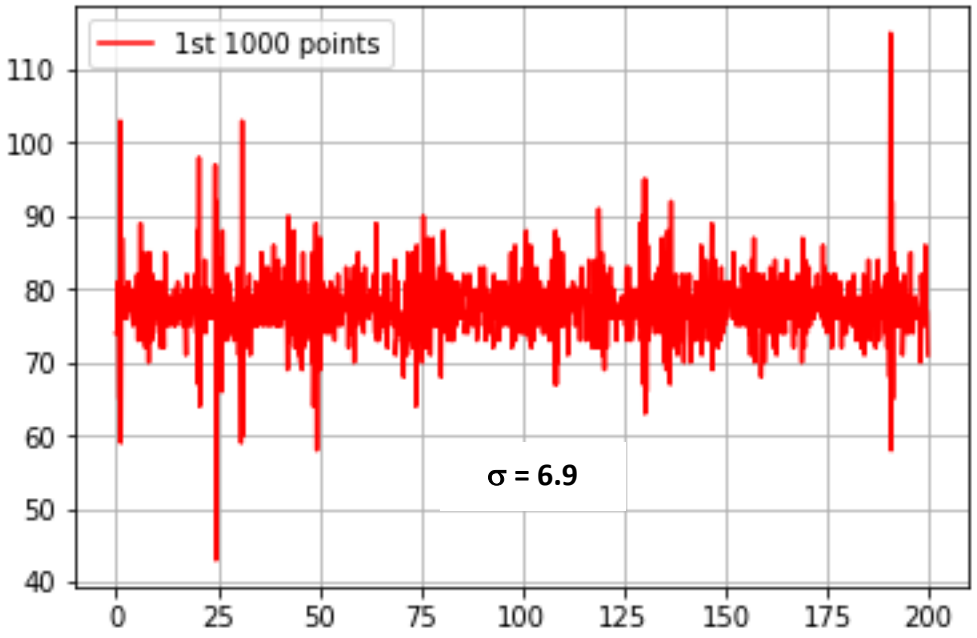


Unshielded



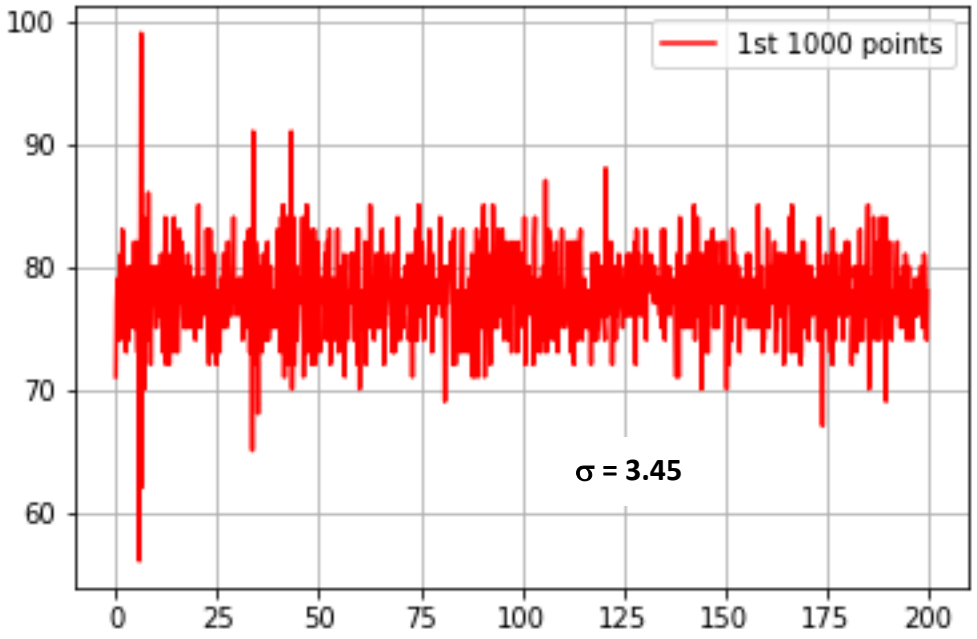
Shielded

FEC 0 Channel 3



Unshielded

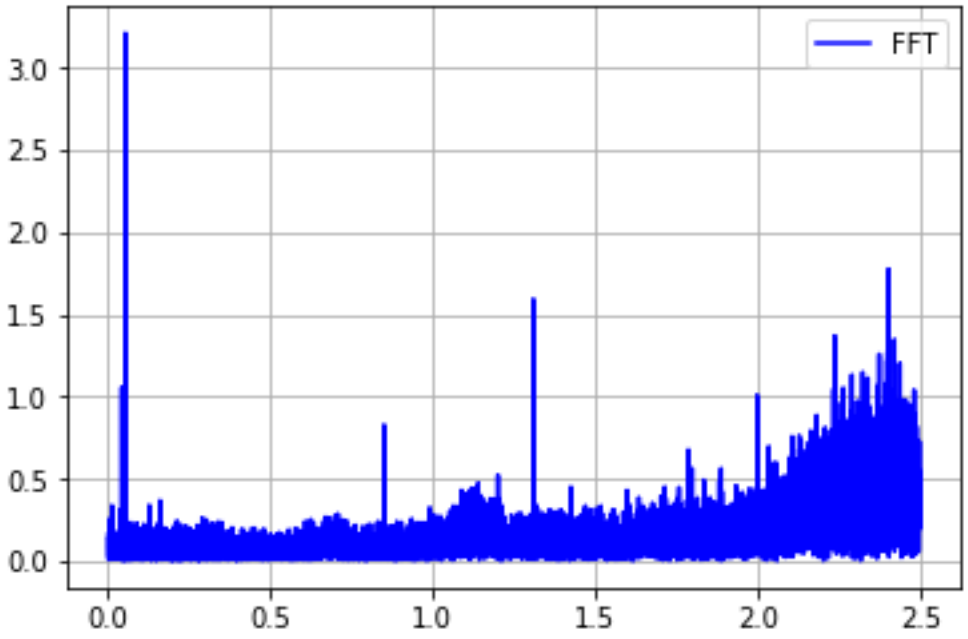
μs



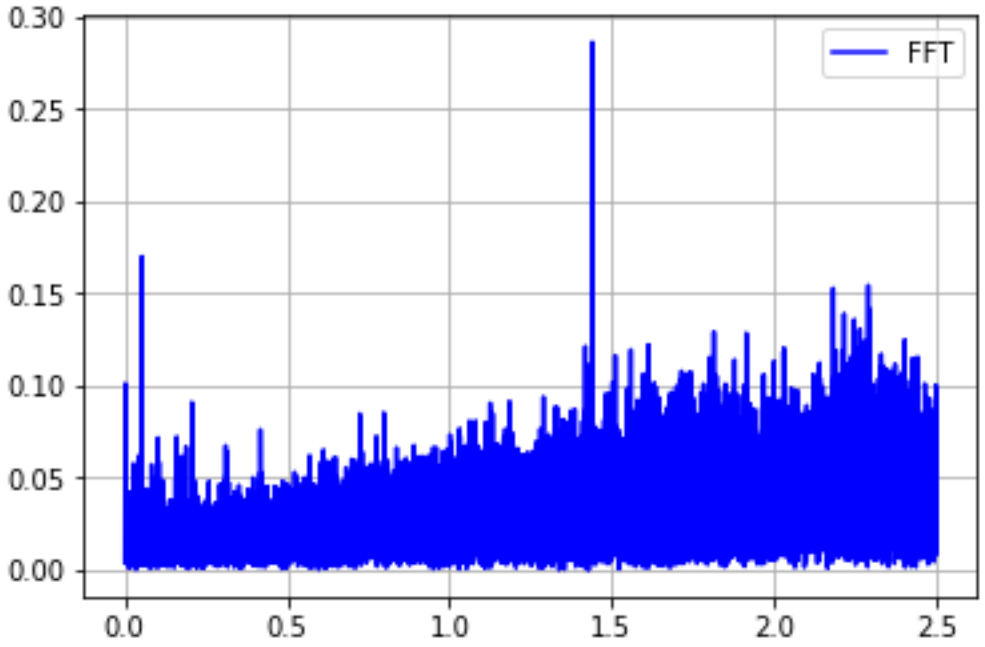
Shielded

μs

FEC 0 Channel 0

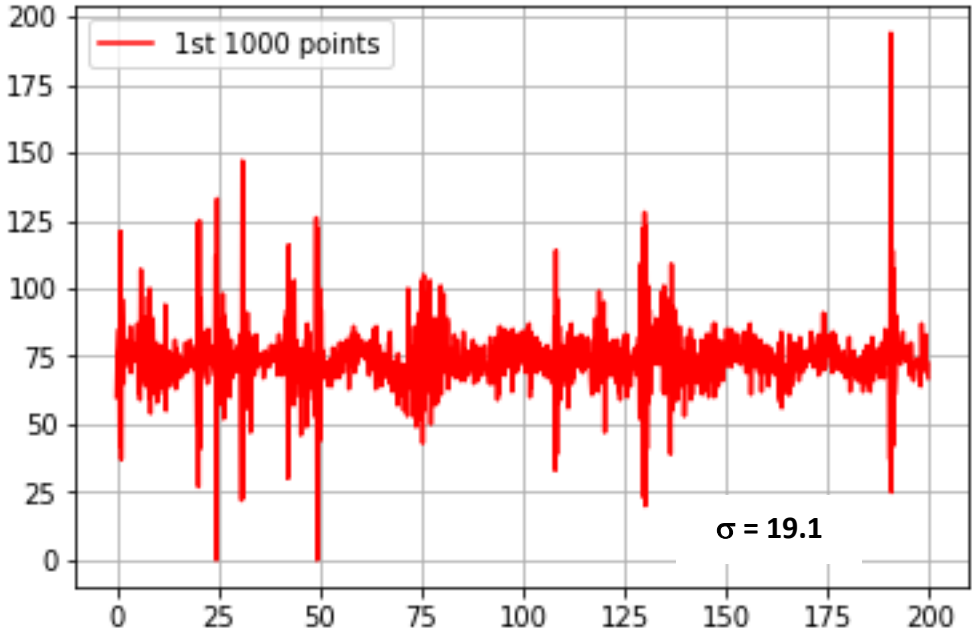


Unshielded



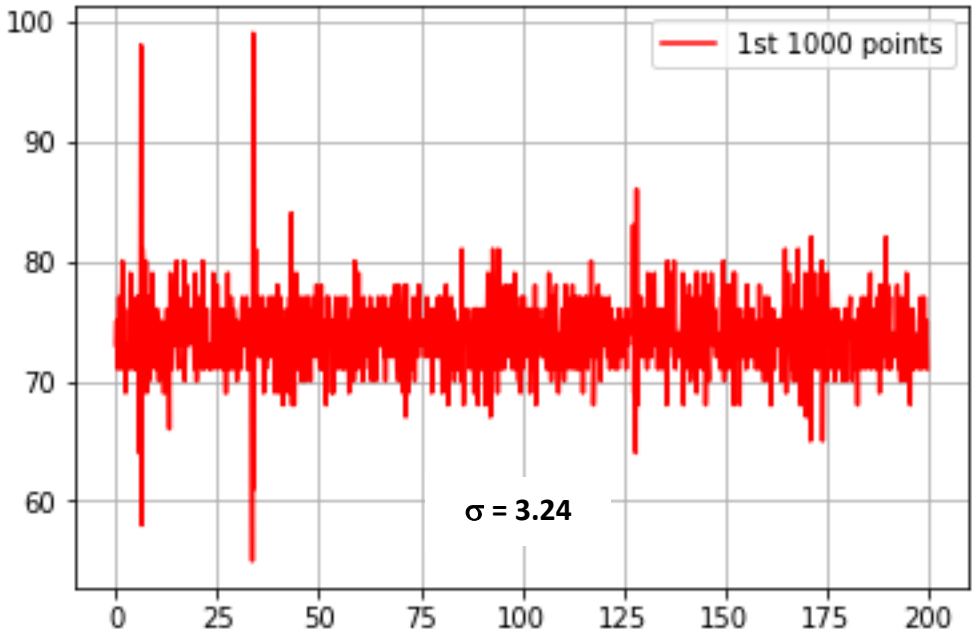
Shielded

FEC 0 Channel 0



Unshielded

μs



Shielded

μs

References

[1] S.H.I Barboza et al., *SAMPA chip: a new ASIC for the ALICE TPC and MCH upgrades,* *https://iopscience.iop.org/article/10.1088/1748-0221/11/02/C02088*

[2] Abigail Hellman, *Effect of Input Capacitance on Noise for the SAMPA ASIC,* TDIS Note (August 23, 2019).