High Voltage Diagnostics and Trouble Shooting in MicroBooNE

(The MicroBooNE Collaboration)

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Abstract

At the end of January, MicroBooNE ramped down it's drift HV system after a series of unusual and worrying behavior on HV monitoring plots. This document presents a summary of the tests performed, diagnostics developed, and a chronological ordering of events. We also include some "lessons learned" that may be useful to future LArTPCs.

I. INTRODUCTION

II. DESCRIPTION OF MICROBOONE HV SYSTEM

A. HV Supply

B. HV Feedthrough

C. Cathode and Resistor Chain

D. Anode and Wire Bias

E. Pickoff Point

III. SYMPTOMS

As the high voltage issues developed, several symptoms were identified which provided metrics to judge the stability or instability of the system. Several were monitoring variables of the HV system itself, such as the current readback from the Glassman power supply and the voltage of the pickoff point. Others were detected through the readout of the detector, including persistent high frequency (900kHz) noise on some detector channels, and "burst" events, described below.

A. Pickoff Point Instability

The first symptom to be detected during MicroBooNE's high voltage incident was large, sustained deviations on the pickoff point (see Section II E). Nominally, this point sits at a value of approximately $\frac{5M\Omega}{17.1G\Omega} = 0.029$ % of the applied voltage by the power supply. As seen in Figure 1, the pickoff point values deviated significantly from the nominal values. In this figure, the band of nominal values is selected as the minimum and maximum of a two week stable period.

B. HV Power Supply Current RMS

As seen in Figure 1 is the calculated current from the back of the high voltage power supply. The power supply outputs and analog voltage from which we derive a current using the following formula:

The current shown in the figure demonstrates clear increases in noisiness when the pickoff point deviations occur, indicating that whatever the cause of the problems is, it affects both the HV power supply and the pickoff point simultaneously.

Because of the way the monitoring data is archived, we lack precise enough data

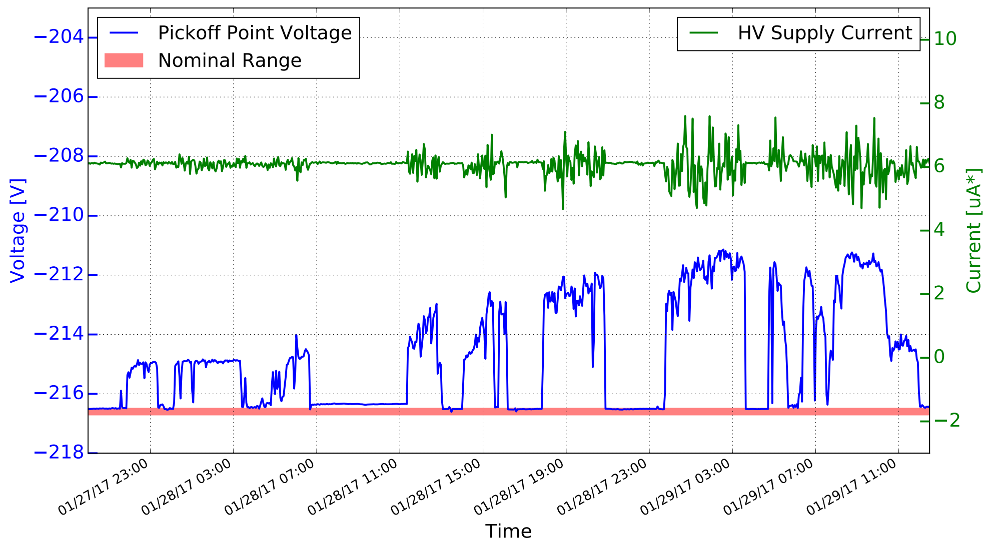


Figure 1. Pickoff point deviations over the weekend of Jan 27th. Though the absolute calibration is not correct on the current from the HV power supply, there is clearly a correlation between the pickoff point deviations and noise on the HV power supply.

to calculate an RMS of the calculated current from the back of the power supply, and can make only qualitative comparisons to historical data. We have since implemented archiving of not just the values output by the power supply, but also the noise on those value measurements.

C. TPC Asic LV Current Draw

In coincidence with the large deviations of the pickoff point, MicroBooNE also observed increased current draw on a handful of power supplies for the cold electronics. Figure 2 shows the increased draw on the worst feedthrough, labeled within the detector as “FT1.” High current draws are not unusual, though this incident required multiple power cycles to restore nominal operation. Additionally, the final power cycle on 1/29/17 just before 14:00 CST occurred after the detector's high voltage had been decreased from 70kV to 65kV. After this, the current draw was stable for some time, though later attempts to ramp up the detector also caused increased current draw on this feedthrough.

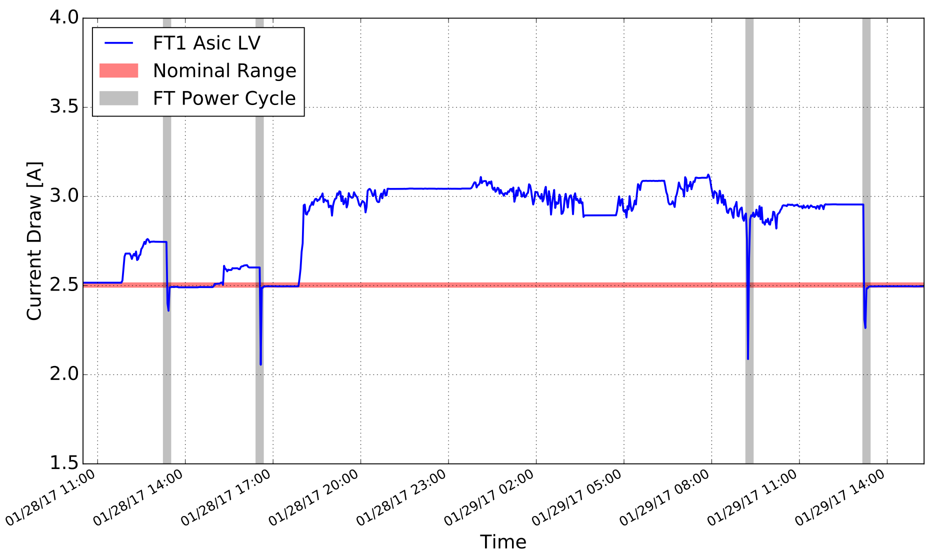


Figure 2. The current for the cold electronics power supply during the same time period as Figure1.

The increased current draw is correlated well with a persistant noise state on the detector electronics. It is thought that the high voltage instability induces a noise state on the electronics that persists until the electronics are reconfigured or power cycled, which is why the power cycles in Figure 2 show normal current draw afterwards, at least temporarily, for 3 of the 4 power cycles shown.

Figure 4 shows an event display of the part of the detector impacted by the persistant noise state. Figure 3 shows a portion of a waveform from this region compared to normal running conditions. The increase in noise is almost exclusively at the 900kHz band, and shows a dramatic increase over the usual noise at 900kHz.

Based on the observations of increased noise on the feedthroughs showing increased current draw, the symptom of current draw is a secondary symptom of the high voltage instabilities. A high voltage incident (like a “burst” event discussed below) likely induces a bad state in the detector electronics when it overloads the input on the electronics. We saw many incidences of increased current draw on the feedthrough that started after high voltage instabilities, but we never observed increased current draw when the high voltage was not on.

D. “Burst” Events

The last observation of high voltage instability symptoms are the “burst” events, an example of which is shown in Figure **??**. In these events, we see high ADC counts on all channels, across all three readout planes, simultaneously. Even wires that are unresponsive see these burst events, as shown in Figure 6.

The pulse amplitude after burst event shows a very long return to baseline after the event occurs, seen in both Figures 5 and 6. There are several notable features of these events:

- **Wire length dependence**
- **Saturation of channels**
- **Signal on unresponsive channels**

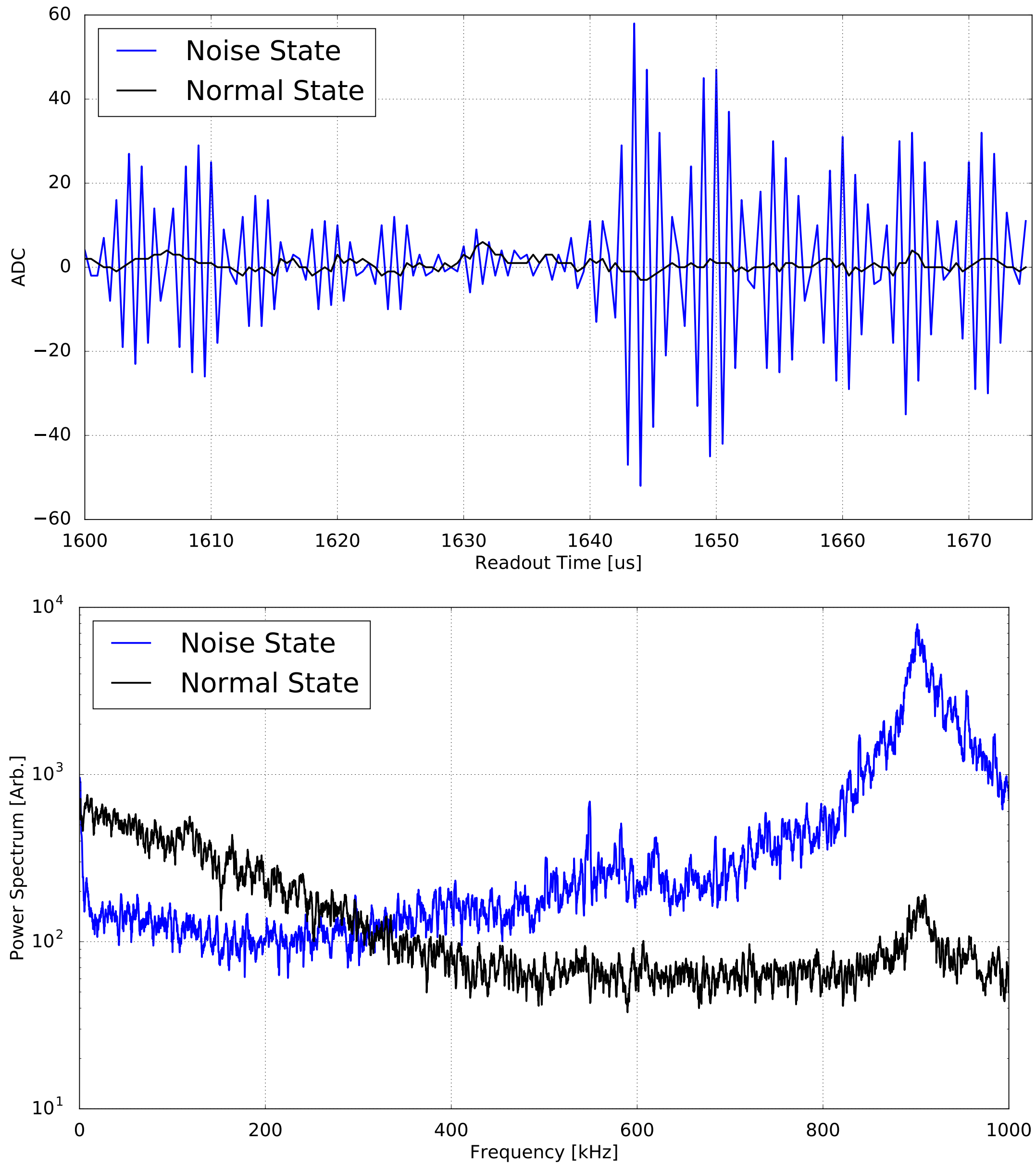

Noise State
Normal State
ADC
Readout Time [us]
60
40
20
0
−20
−40
−60
1600
1610
1620
1630
1640
1650
1660
1670
Noise State
Normal State
Power Spectrum [Arb.]
Frequency [kHz]
10^4
10^3
10^2
10^1
0
200
400
600
800
1000

Figure 3.

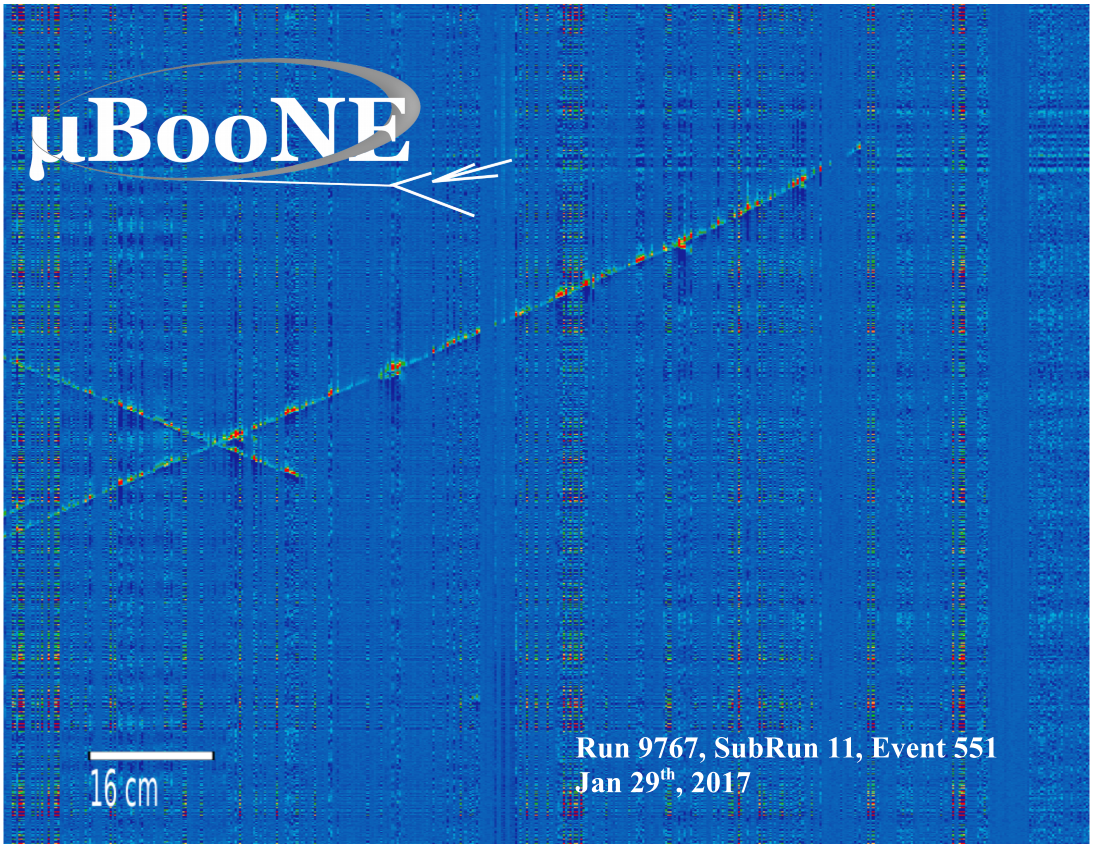
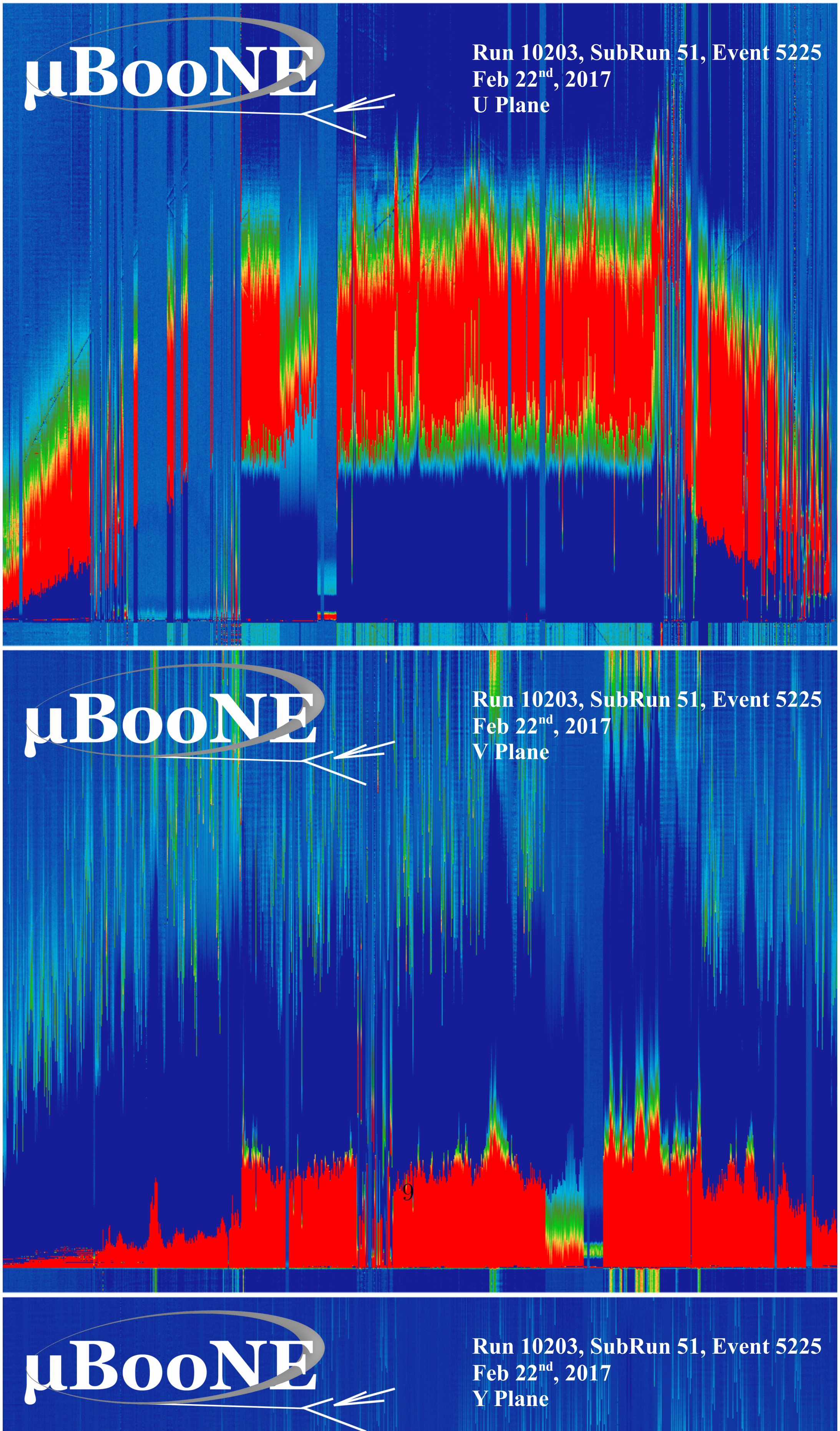


Figure 4.

IV. DIAGNOSTICS

A. (Warm) HV Supply Tests

After the weekend of Jan 27th, 2017, MicroBooNE powered down the drift high voltage supply to investigate. To diagnose the source of the troubling, a large number of procedures were attempted, described here.


μBooNE
Run 10203, SubRun 51, Event 5225
Feb 22nd, 2017
U Plane
μBooNE
Run 10203, SubRun 51, Event 5225
Feb 22nd, 2017
V Plane
μBooNE
Run 10203, SubRun 51, Event 5225
Feb 22nd, 2017
Y Plane

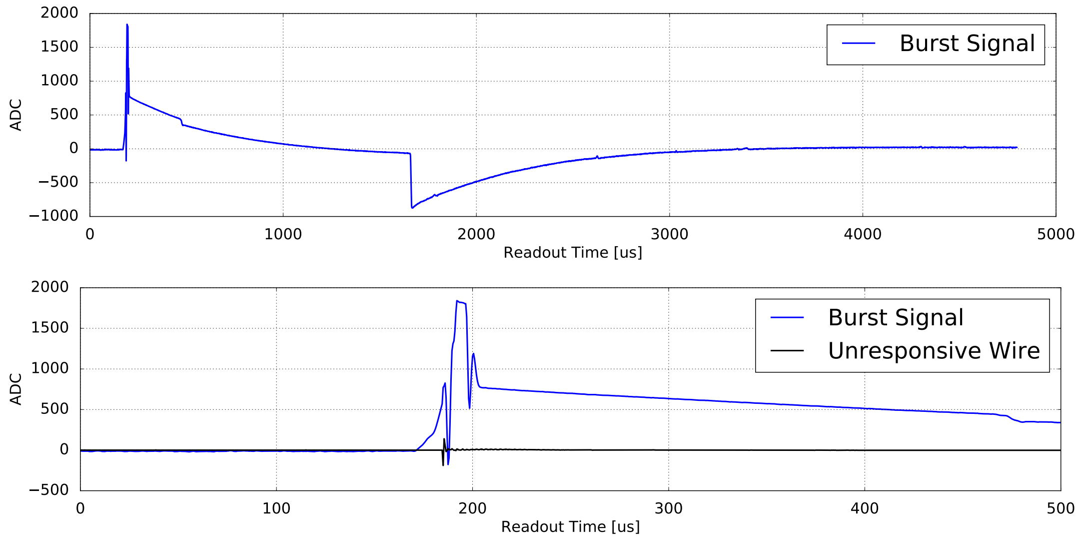


Figure 6. Burst event waveforms from U plane wires. In the top image, the entire waveform is shown, demonstrating the long return to baseline that produces the rainbow appearance in the U plane of Figure 5. In the bottom image is shown the wire response at the incidence of the burst event, as well as the response on an unresponsive channel.

1. Glassman HV Supply replacement

The very first test performed on the system was to replace the high voltage power supply. The system is a a Glassman power supply, described in Section II A. A spare was available and installed, and when the spare supply was powered on no observable difference was detected in the behavior of the system. The spare supply was not ramped to a high voltage initially, since the symptoms were clearly occurring at a relatively low (<10kV) voltage.

2. HV Cable inspection

The next obvious step to search for a hardware failure was in the high voltage cables that bring the high voltage from the Glassman supply, through both filter pots, and into the cryostat high voltage feedthrough. All connections of cable to supply or filters pots were checked, and no obvious defects were found.

3. AC Power Distribution Inspection

Considering that one main symptom of the high voltage instabilities is the high RMS on the current output from the HV power supply, we investigated the AC power distribution to the power supply itself. Using an AC analyzer ("ONEAC ONEView Line Noise Viewing Interface" [1]), we determined that there was no excess noise on the AC input to the high voltage supply than to any other areas of the detector systems.

4. "In air" Test of HV Supply

As a last test of the warm side of the high voltage supply system, we pulled the cable that connects to the cryostat high voltage feedthrough out of the feedthrough, and ramped it to 20kV in air. No symptoms were observed during this test, indicating that the power supply, filter pots, high voltage cables, and AC power distribution were all functioning properly. Based off of this, it was concluded that the warm side of the high voltage supply system was in good health, and the problems with the HV system were downstream of the cryostat's high voltage feedthrough.

B. V vs. I Tests on cathode

C. Pickoff Point Measurements

1. Current-source mode measurements

2. Measurement of field cage resistance

3. Voltage-source mode measurements

4. Measurement of pickoff point resistance

5. Measurement of field cage resistance

6. Measurement of burst rate at pickoff point bias

D. "Burst" Analysis

E. Cathode Pulse Tests

V. RESOLUTION

VI. LESSONS LEARNED

VII. CONCLUSION

Chronological Timeline

[1] ONEAC, "Oneac oneview® line noise viewing interface," (2017).