Environmental Noise: Coherent Noise

Josiah Walton

University of Illinois at Urbana-Champaign

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Introduction

This document describes the study of the coherent noise present in the wire and APD channels. Correlations between various monitored environmental variables such as clean room temperature, front end card temperature, LXe temperature, cathode HV, HFE standpipe height, etc., and various actions such as mining activity, APD board swaps, power outages, etc., were searched for, but no conclusive environmental explanation for the observed trending behavior in the coherent APD noise has been determined. In particular, it was found that the coherent noise in the APDs strongly correlates with the trending of the energy resolution. In addition, the coherent power spectra for the APD planes and boards were investigated using golden low background data; the results show an increase in the coherent noise present in the APDs.

Calculating Coherent Noise

The coherent noise for the wire and APD boards and planes was calculated using data from a set of "good" quality internal charge injection runs, i.e., runs where there are no known issues as noted in the run history comments or the day log, from October 6, 2011 until May 29, 2013. For each wire board, wire plane, APD board, APD pie, APD plane, and all APD channels, the channel waveforms are summed together and then averaged over many events.

For each event, the standard deviation (rms) of the final summed waveform is calculated using the portion of the waveform from 200 to 800 μs (in order to omit the beginning and ends of the waveform trace and also the signal in the middle of the waveform trace. The coherent noise is then calculated as the average of the rms values for many events. In addition, the beginning time of the internal charge injection run defines the time of the coherent noise measurement. For convenience, Table 1 lists the software channel mapping for the wires and APD, as listed in the current version of the TPC channel map in the calibrations database.

Table 1: Software Channel Map

Set	Software Channels
APD Planes Combined	152-225
APD Plane 1	152-188
APD Plane 2	189-225
APD Board 00	158-163, 176-182
APD Board 03	189-195, 202-207
APD Board 04	208-213
APD Board 05	196-201, 214-219
APD Board 06	170-175, 183-188
APD Board 09	152-157, 164-169
APD Pie 1	158-163
APD Pie 2	164-169
APD Pie 3	152-157
APD Pie 4	170-175
APD Pie 5	183-188
APD Pie 6	176-182
APD Pie 7	195-201
APD Pie 8	202-207
APD Pie 9	189-194
APD Pie 10	208-213
APD Pie 11	220-225
APD Pie 12	214-219
U Wire Planes Combined	0-37, 76-113
U Wire Plane 1	0-37
U Wire Plane 2	76-113
U Wire Board VG 03	0-1, 9-18
U Wire Board VG 07	2-8, 31-37
U Wire Board VG 08	19-30
U Wire Board VG 09	83-94
U Wire Board VG 10	76-82, 105-111
U Wire Board HV 08	95-104, 112-113
V Wire Planes Combined	38-75, 114-151
V Wire Plane 1	38-75
V Wire Plane 2	114-151
V Wire Board HV 01	50-56, 60-66
V Wire Board HV 02	38-49
V Wire Board HV 03	140-151
V Wire Board HV 04	123-129, 133-139
V Wire Board HV 05	114-122, 130-131
V Wire Board HV 06	57-59, 67-69, 70-75

1 Coherent Noise Trending

In the following plots, the trending behavior of the coherent noise for the wires and APDs is shown, along with various actions, slow control variables and DAQ variables of interest.

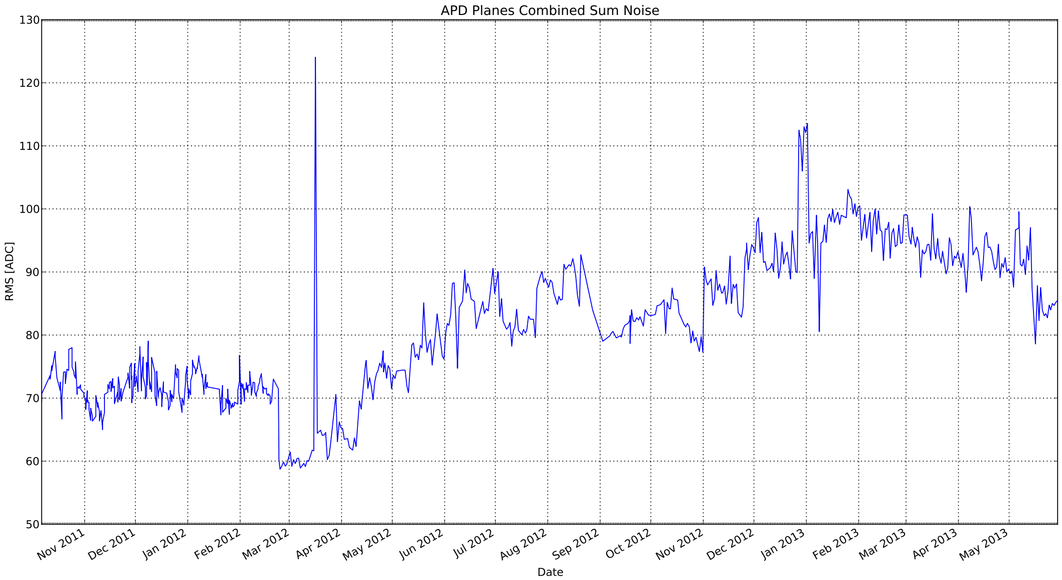

Figure 1: Total sum noise for both APD planes combined.

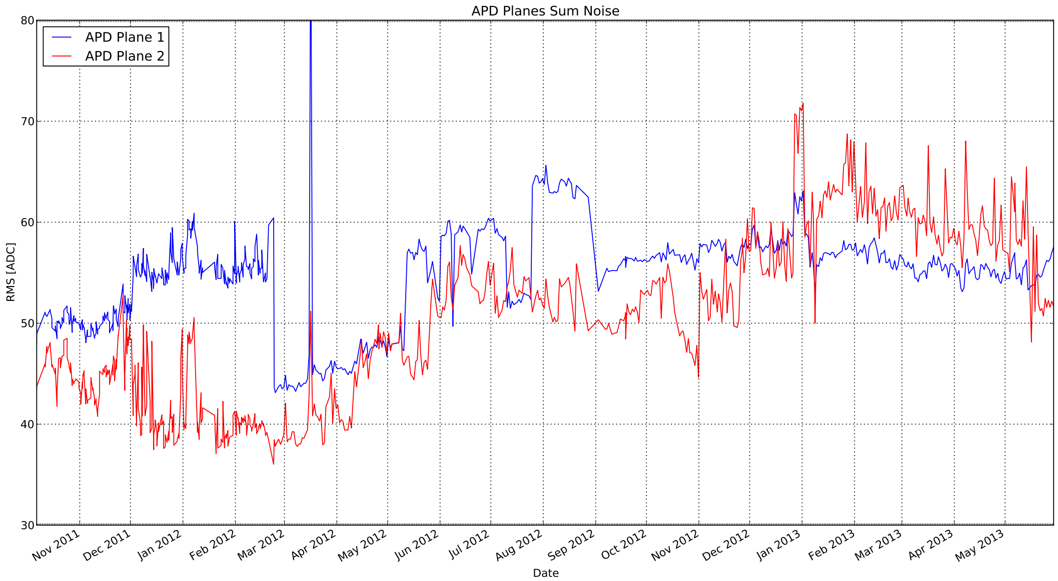

Figure 2: Sum noise for each APD plane.

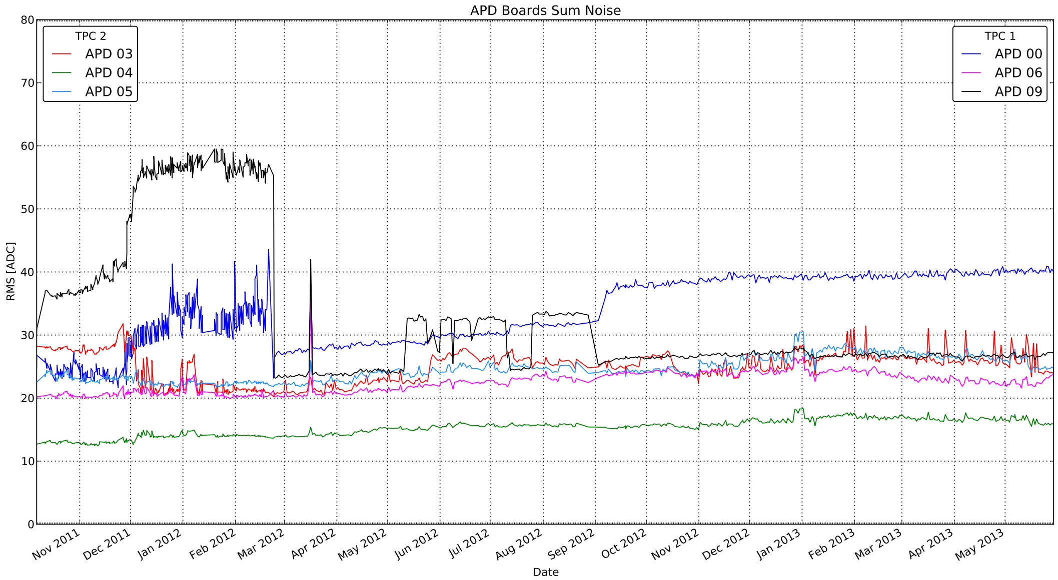

Figure 3: Sum noise for each APD board.

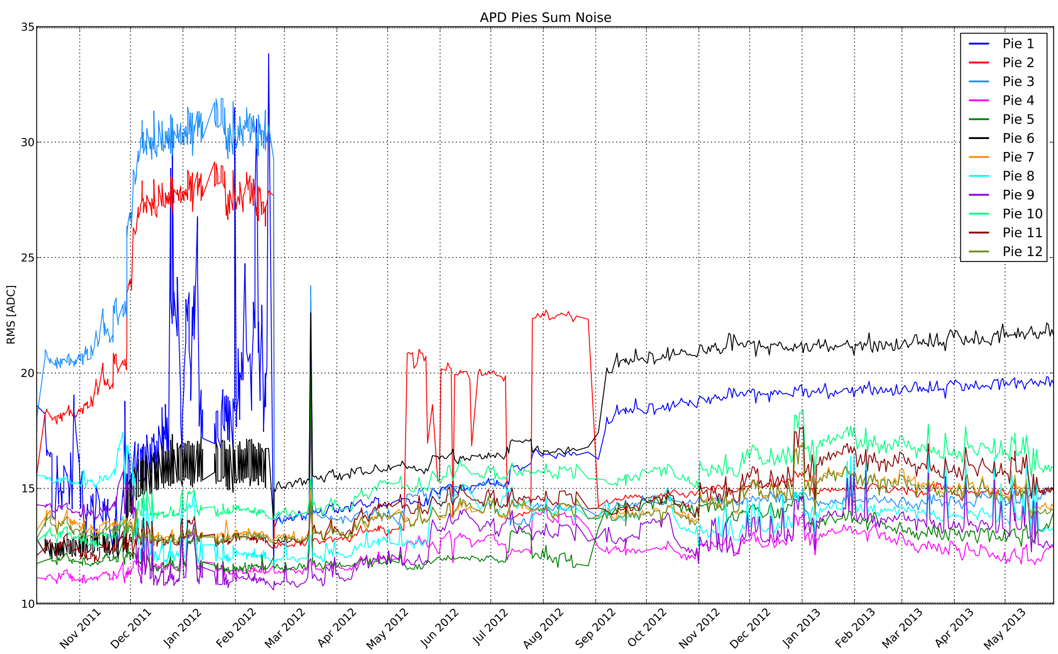

Figure 4: Sum noise for each APD pie.

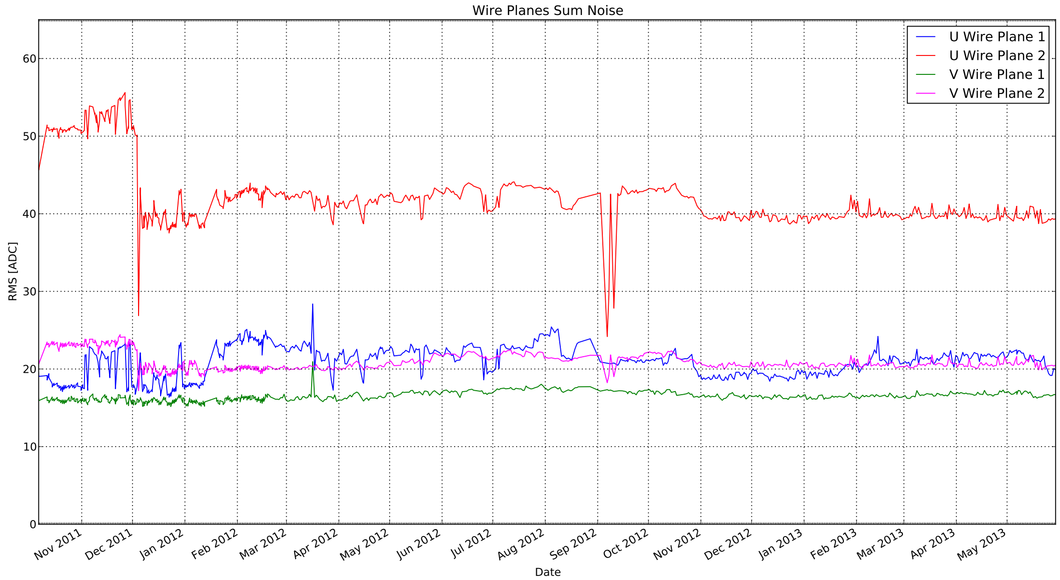

Figure 5: Sum noise for each wire plane (U and V).

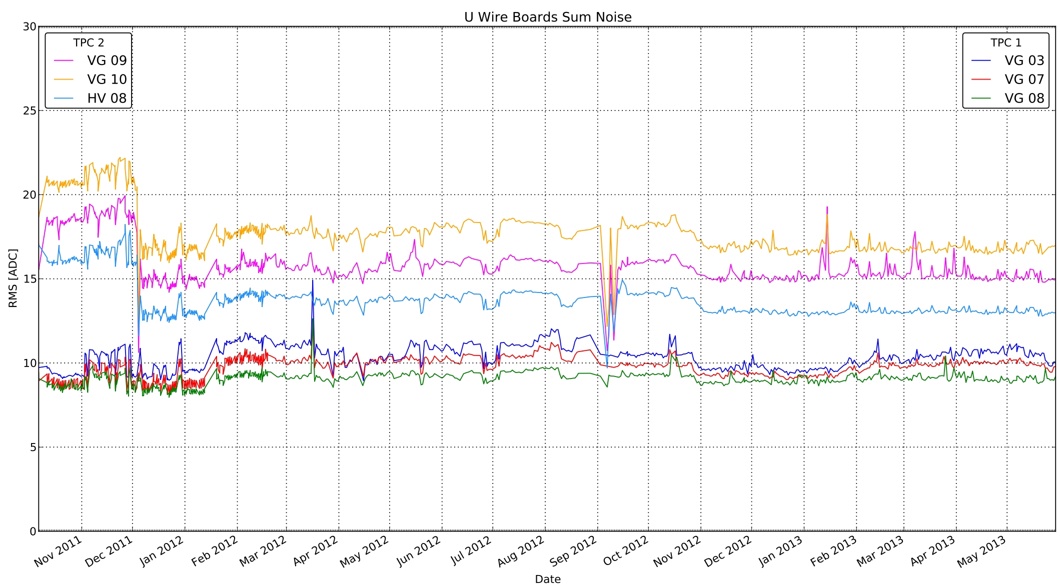

Figure 6: Sum noise for each U wire board.

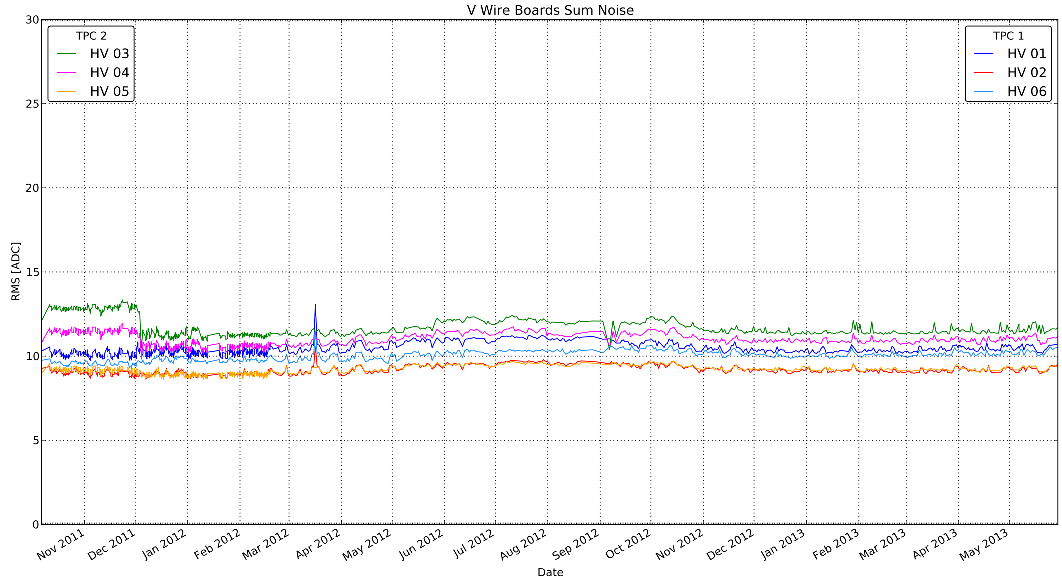

Figure 7: Sum noise for each V wire board.

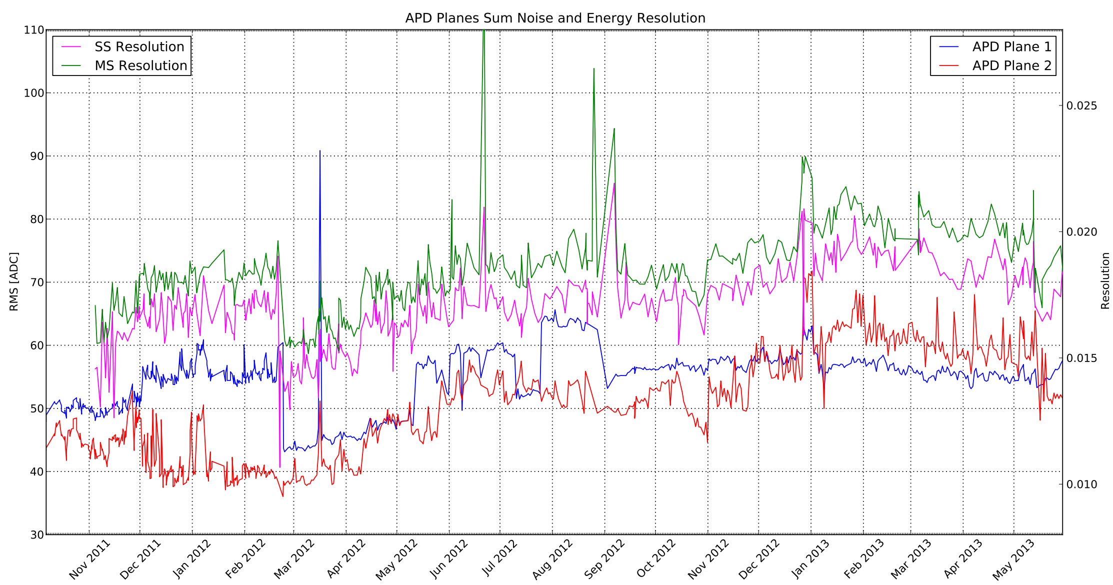

Figure 8: Sum noise for each APD plane along with the SS and MS rotated energy resolution taken from the offline database.

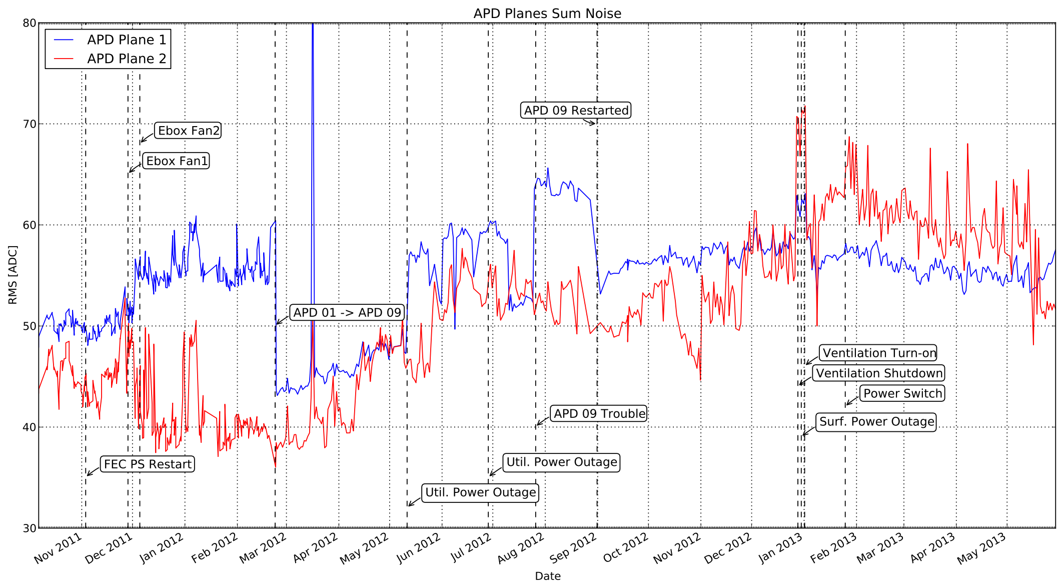

Figure 9: Sum noise for each APD plane along with various actions.

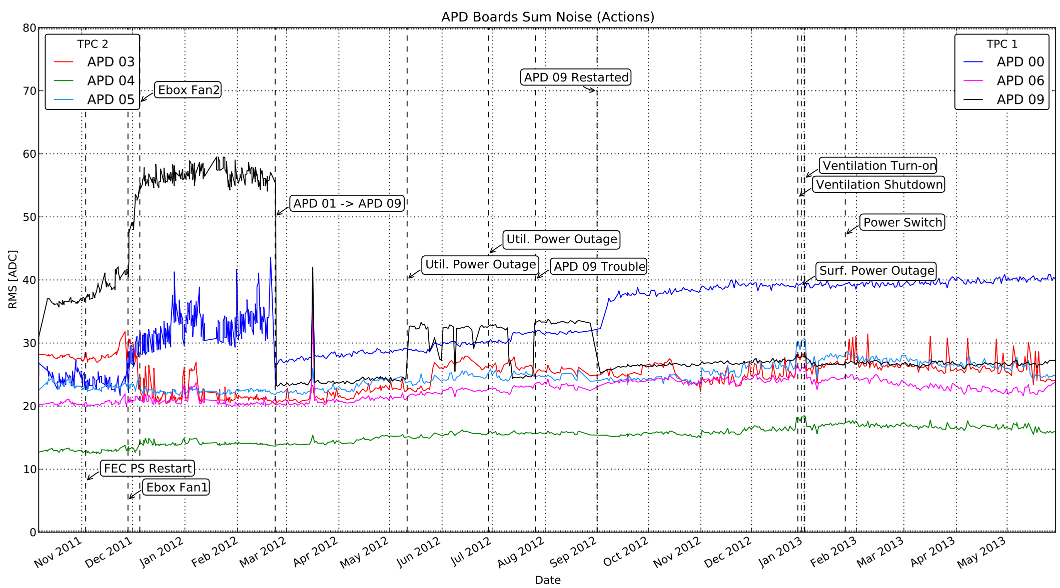

Figure 10: Sum noise for each APD board along with various actions.

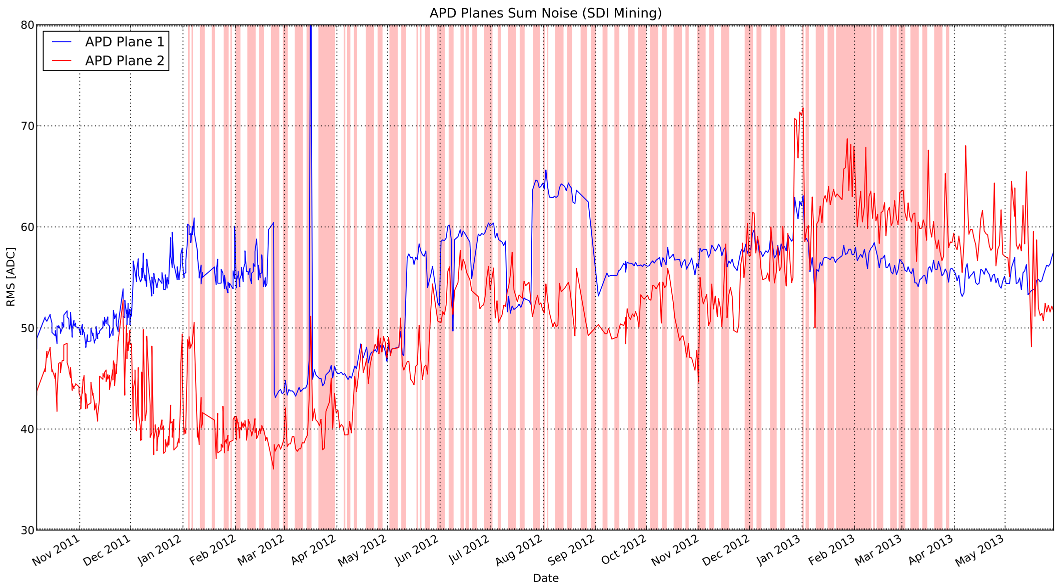

Figure 11: Sum noise for each APD plane along with periods of SDI mining activity.

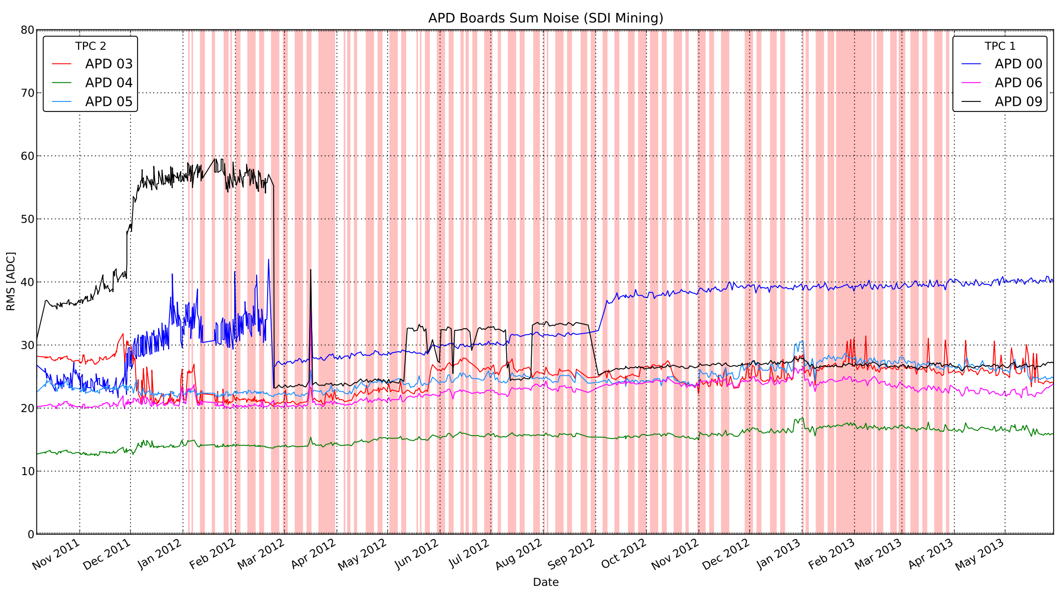

Figure 12: Sum noise for each APD board along with periods of SDI mining activity.

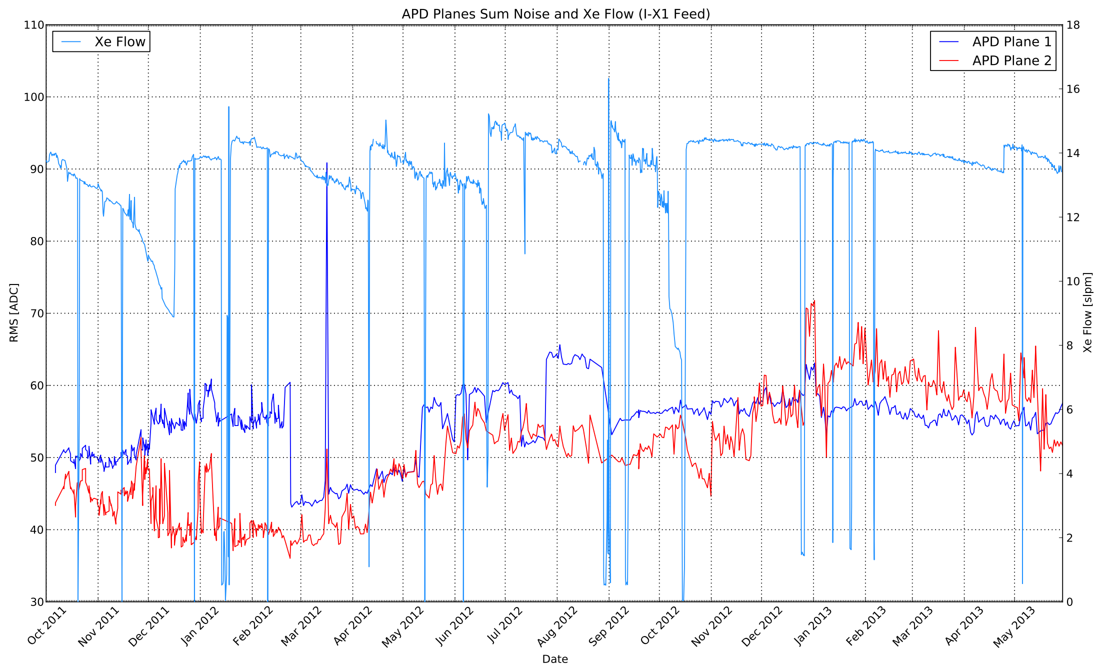

Figure 13: Sum noise for each APD plane along with the Xe flow.

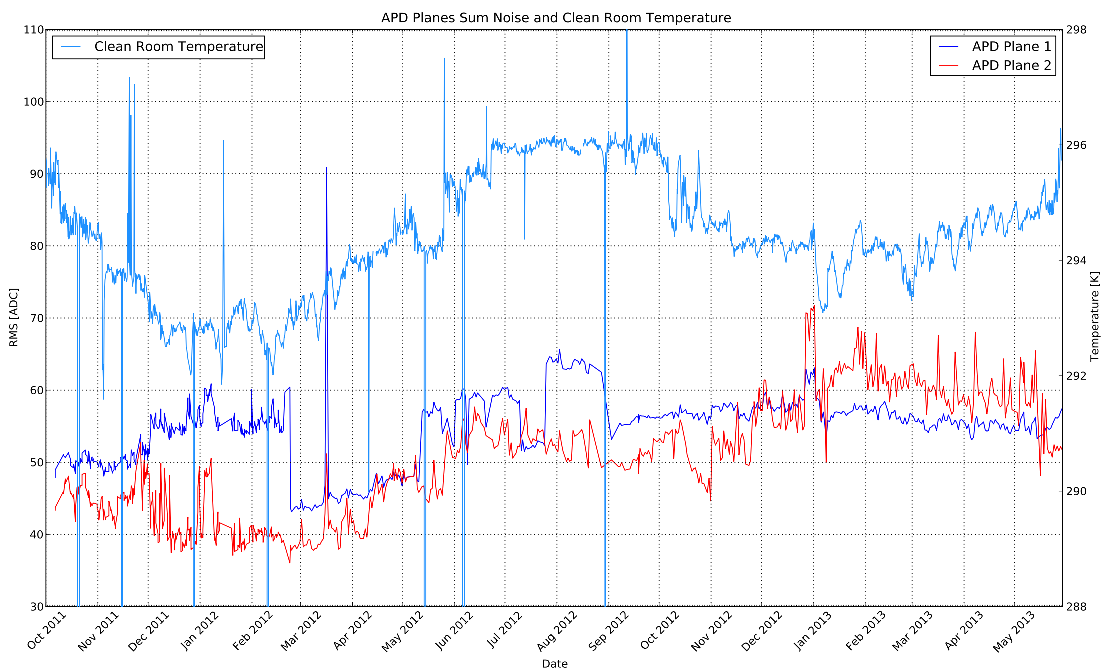

Figure 14: Sum noise for each APD plane along with the clean room temperature.

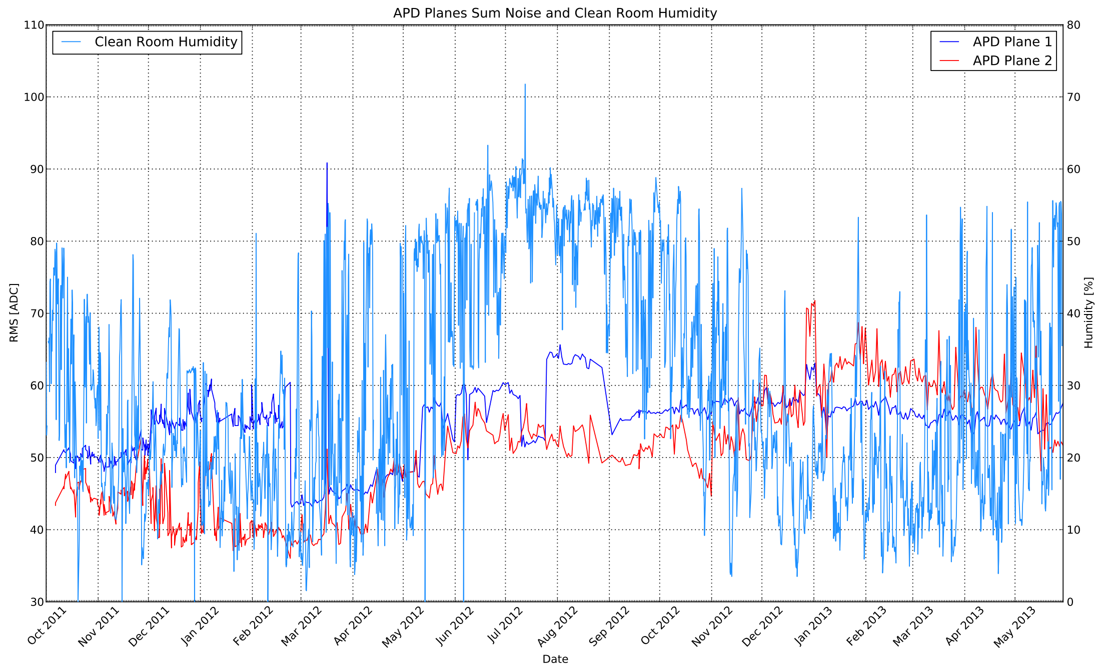

Figure 15: Sum noise for each APD plane along with the clean room humidity.

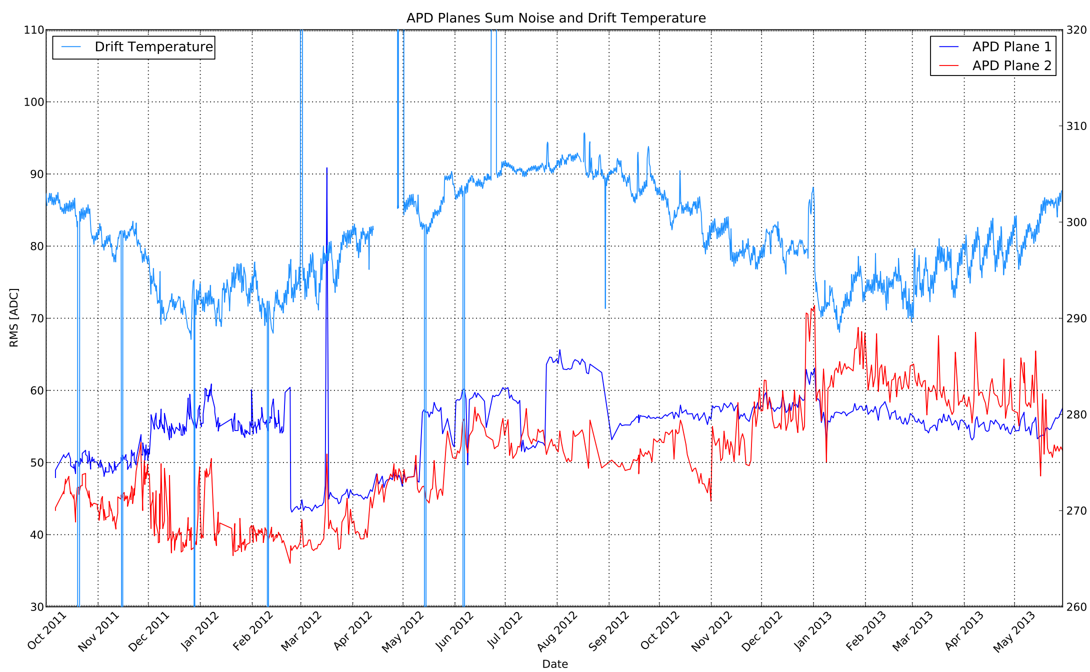

Figure 16: Sum noise for each APD plane along with the drift temperature.

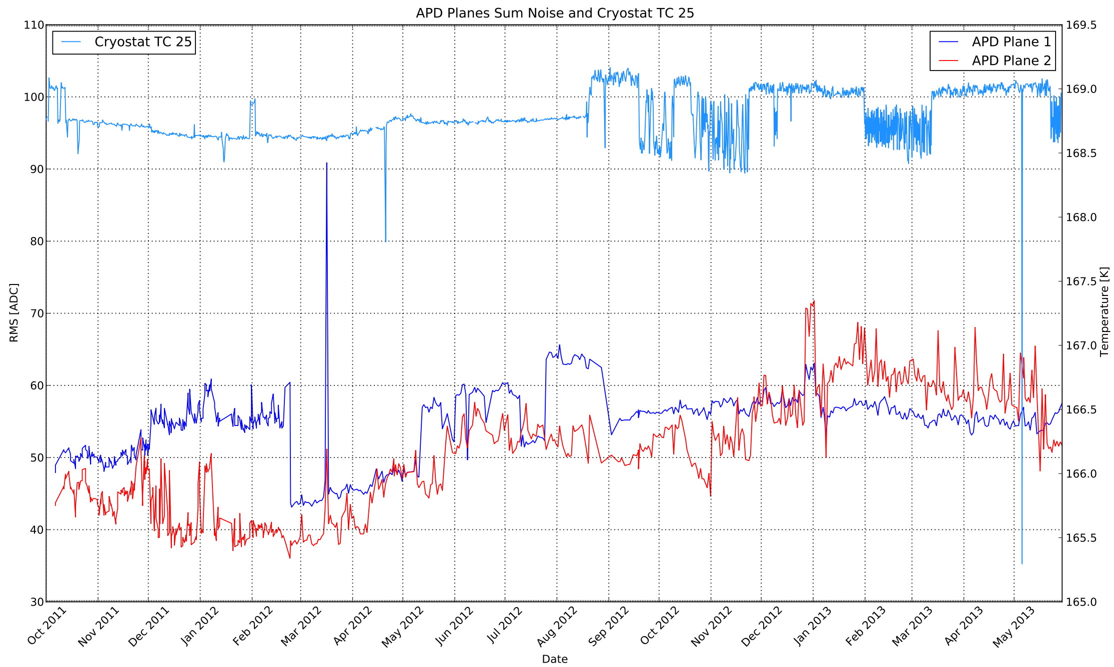

Figure 17: Sum noise for each APD plane along with the Cryostat TC 25 temperature.

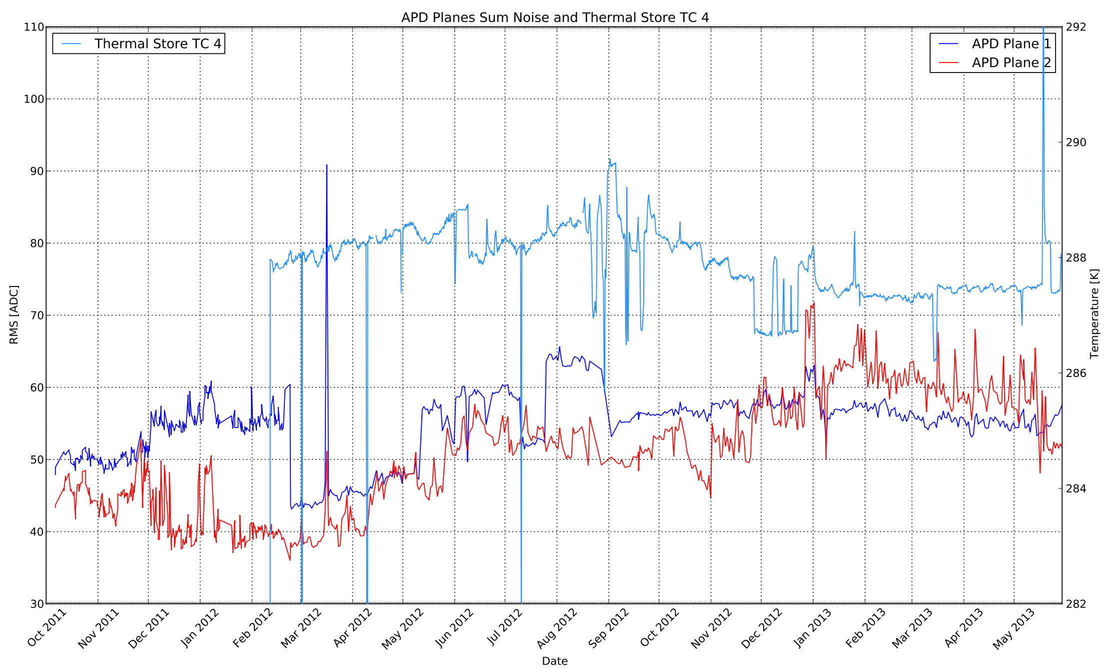

Figure 18: Sum noise for each APD plane along with the TC 4 temperature for the thermal store.

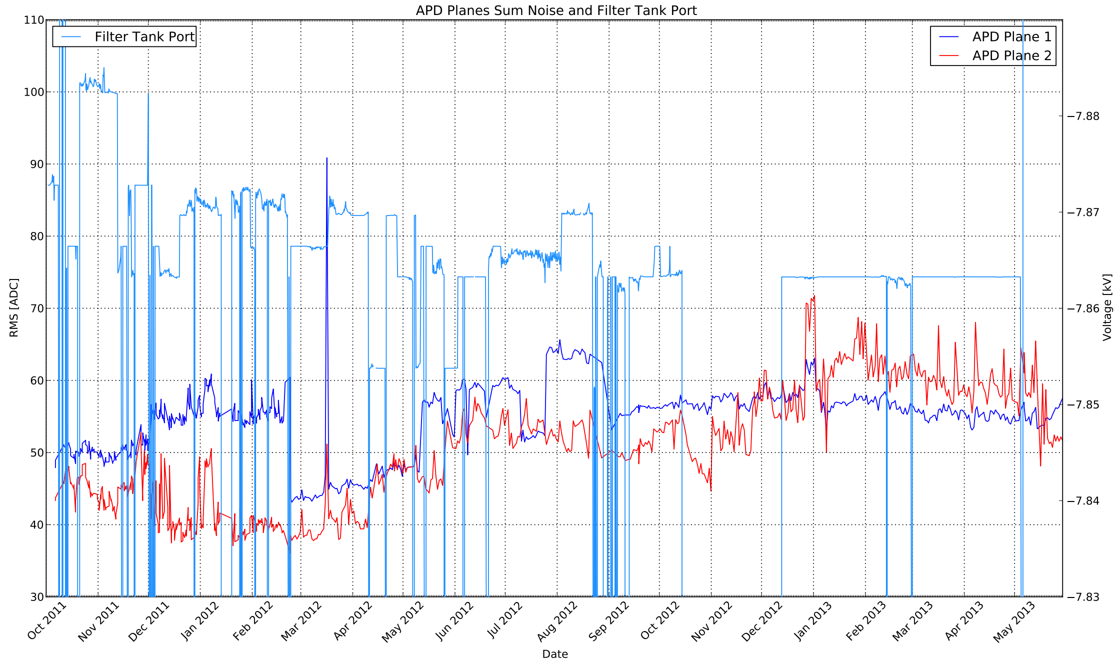

Figure 19: Sum noise for each APD plane along with the Filter Tank HV.

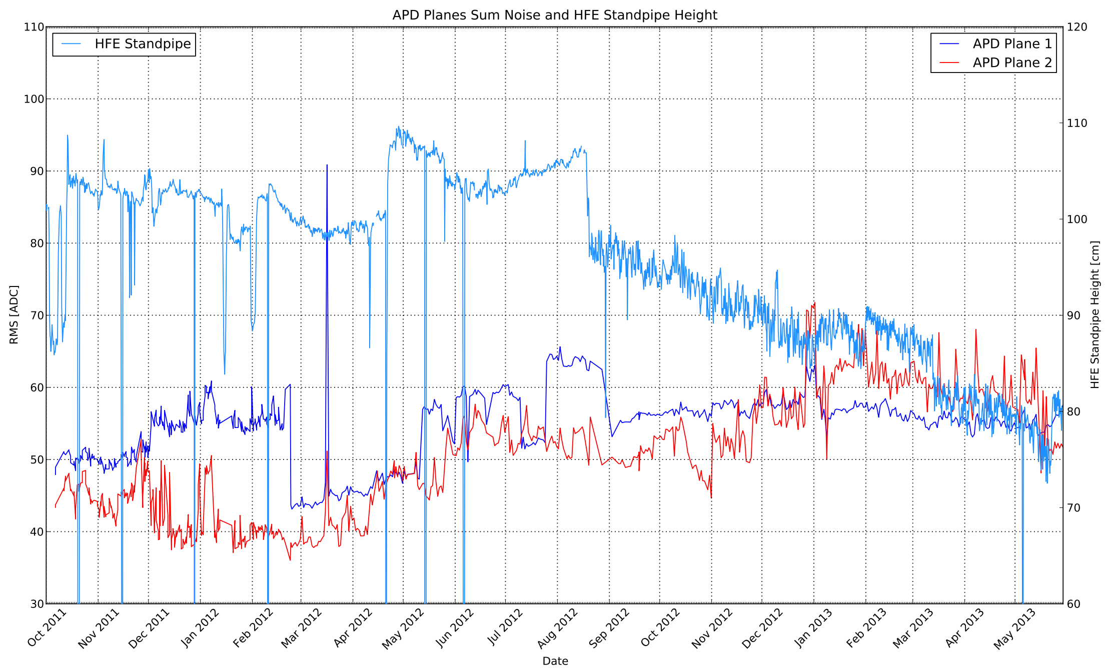

Figure 20: Sum noise for each APD plane along with the HFE standpipe height.

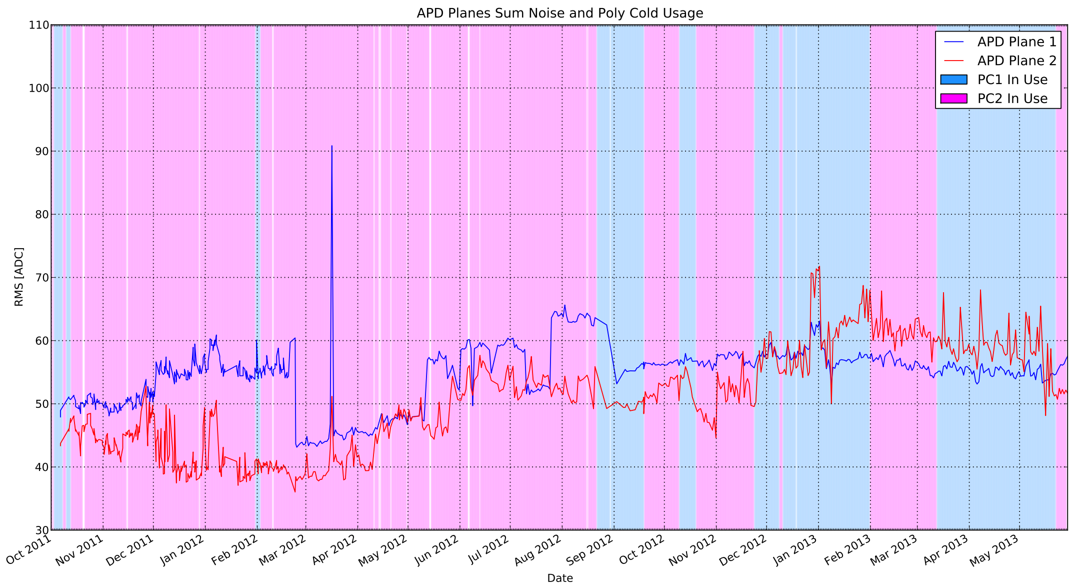

Figure 21: Sum noise for each APD plane along with the periods of different Poly Cold usage.

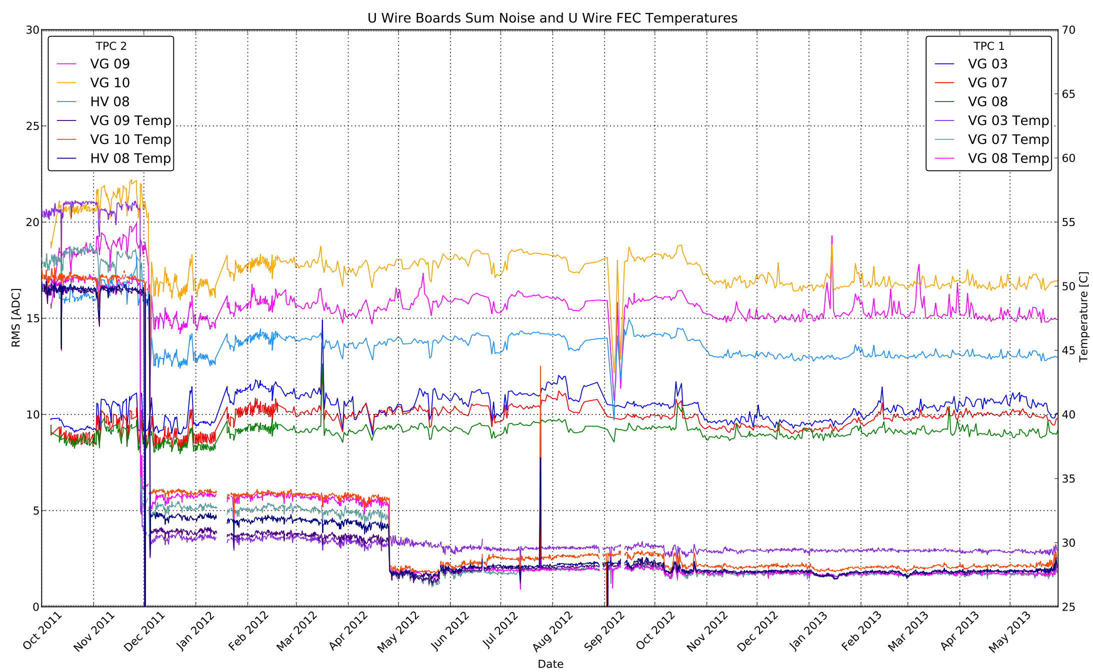

Figure 22: Sum noise for each U wire board along with their corresponding FEC temperature.

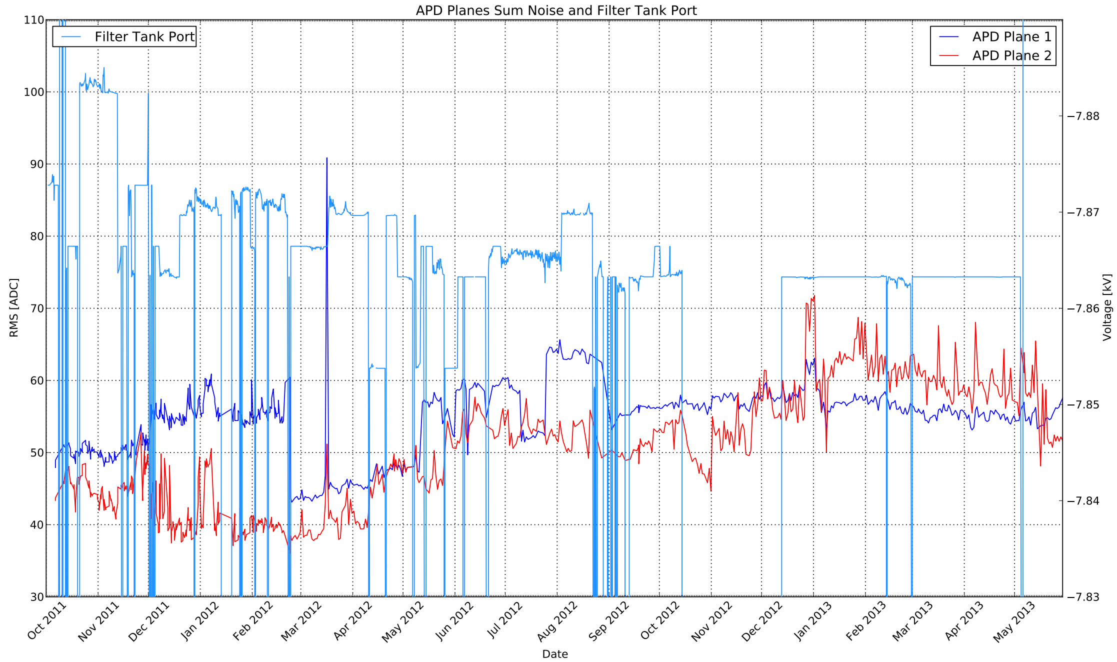

Figure 23: Sum noise for each APD plane along with the Filter Tank HV.

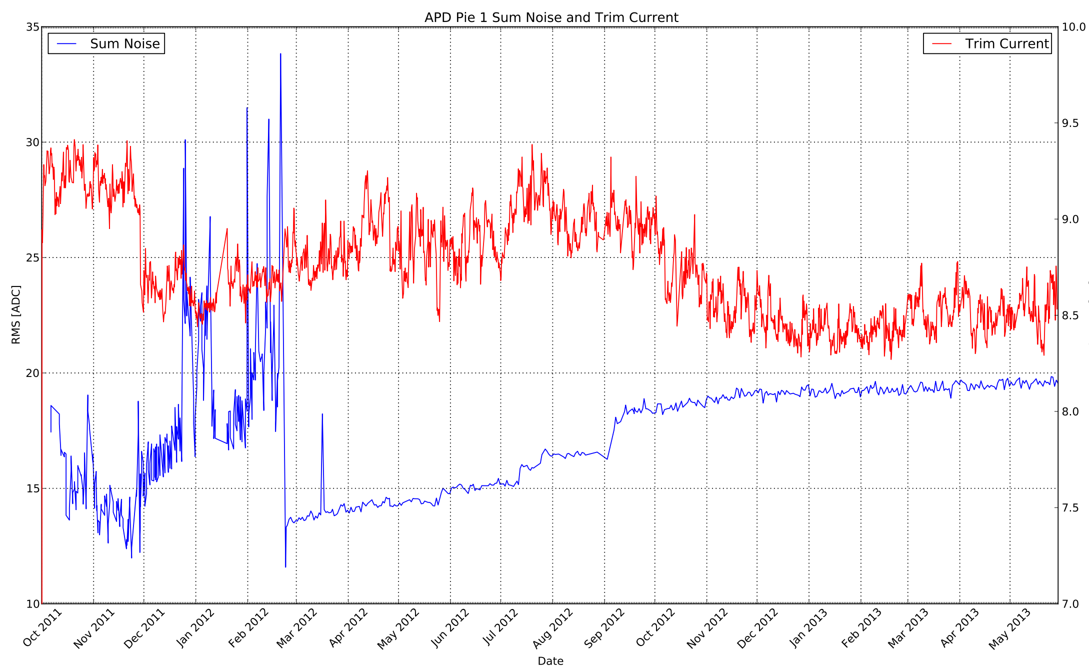

Figure 24: Sum noise and the trim current for APD pie 1.

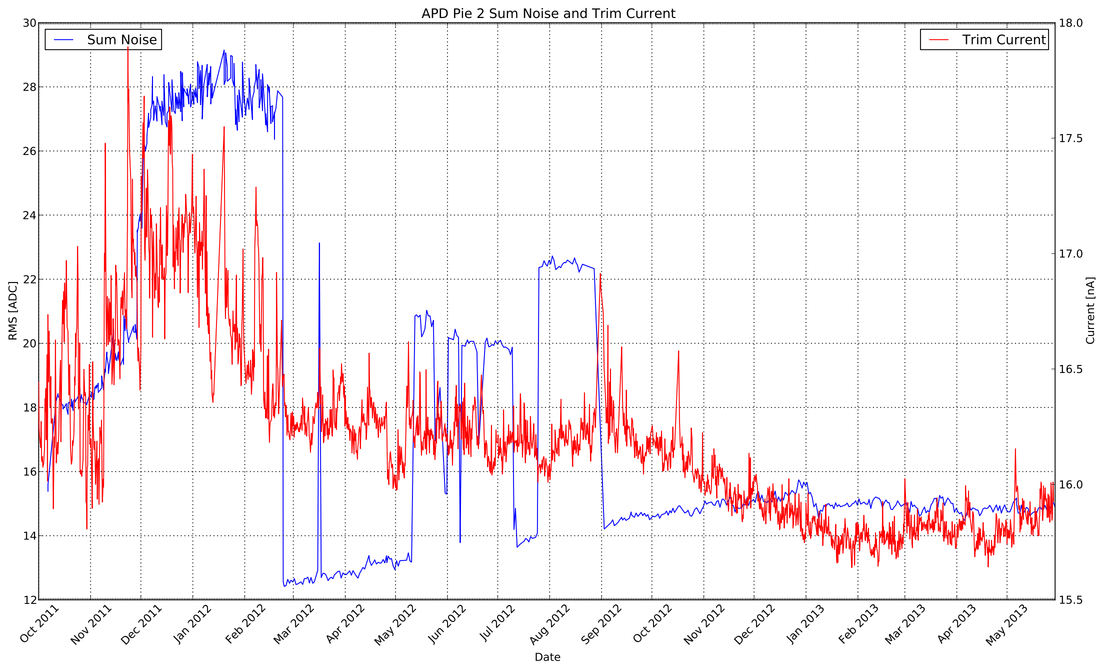

Figure 25: Sum noise and the trim current for APD pie 2.

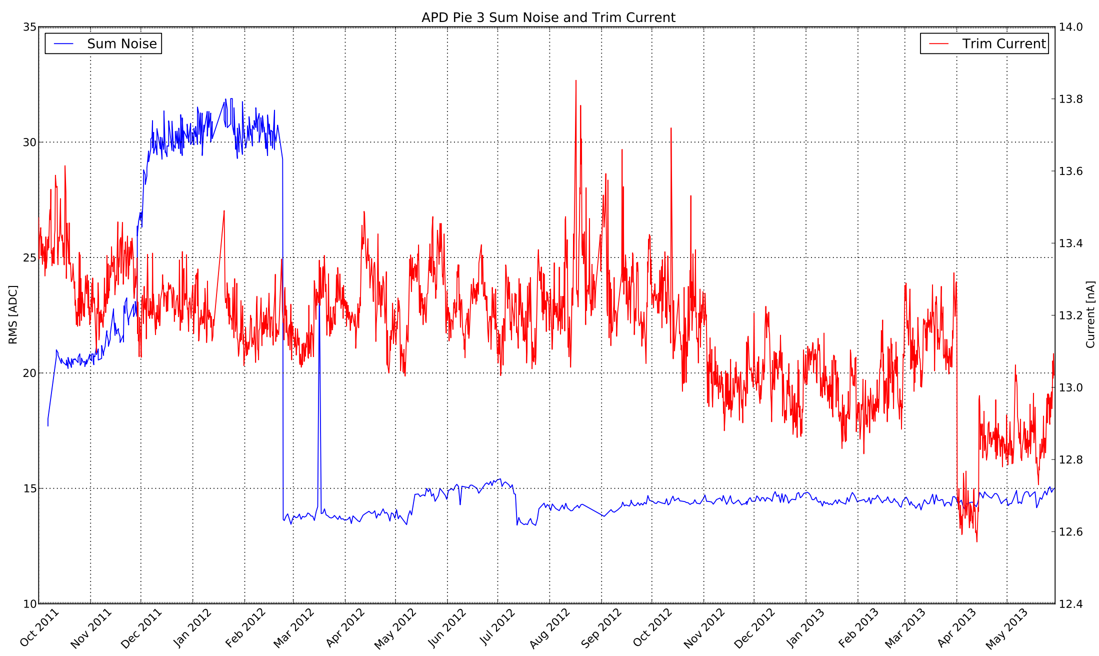

Figure 26: Sum noise and the trim current for APD pie 3.

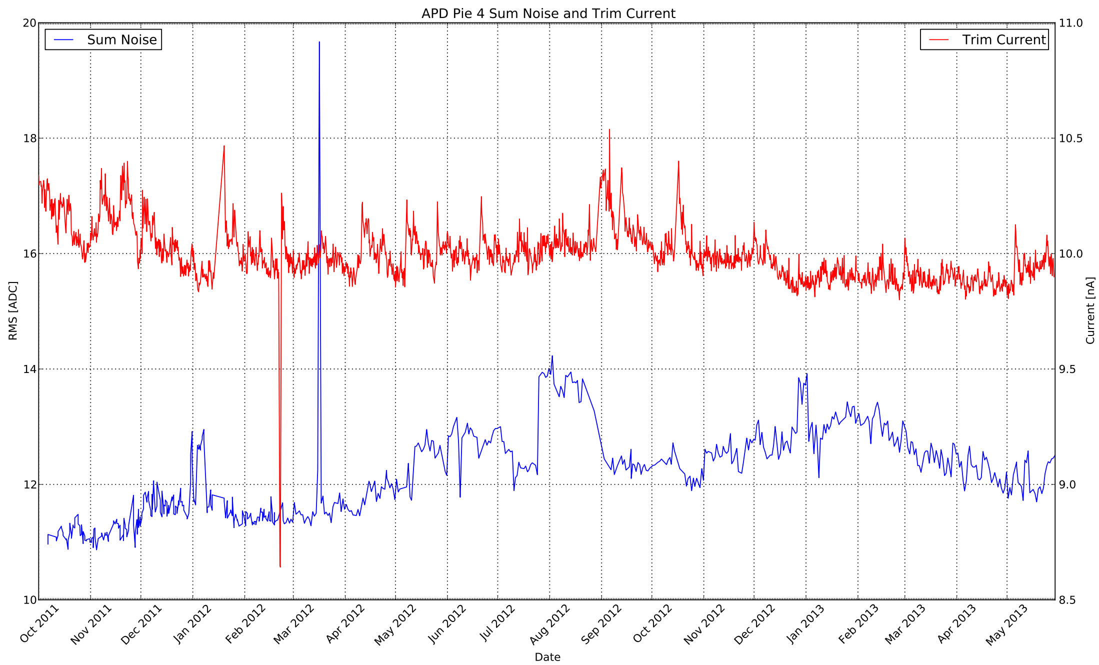

Figure 27: Sum noise and the trim current for APD pie 4.

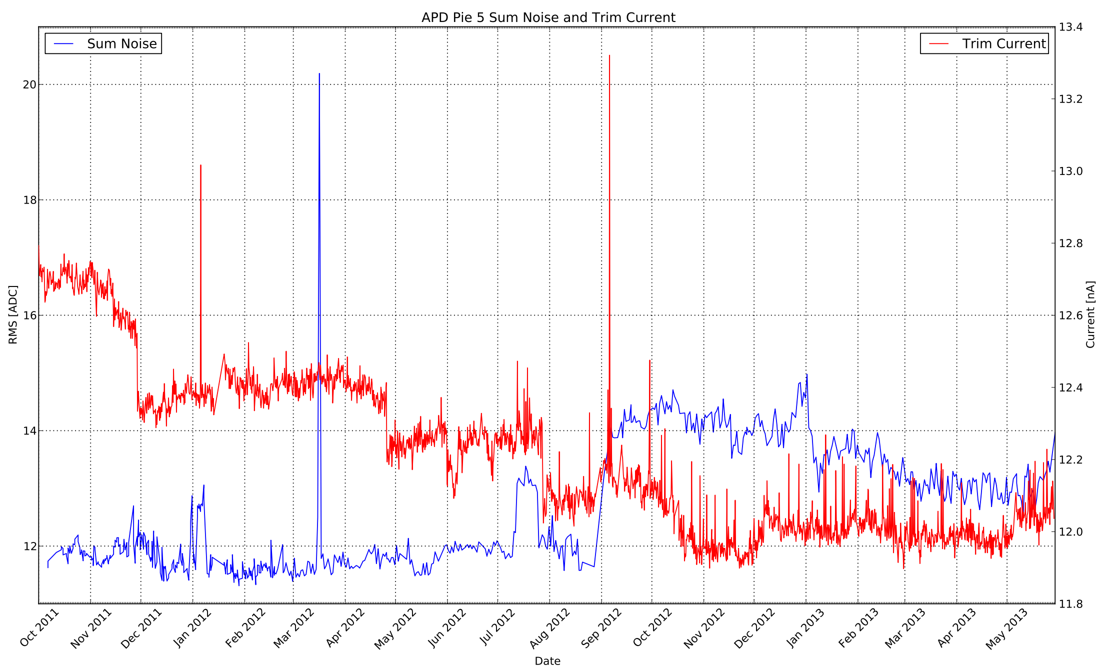

Figure 28: Sum noise and the trim current for APD pie 5.

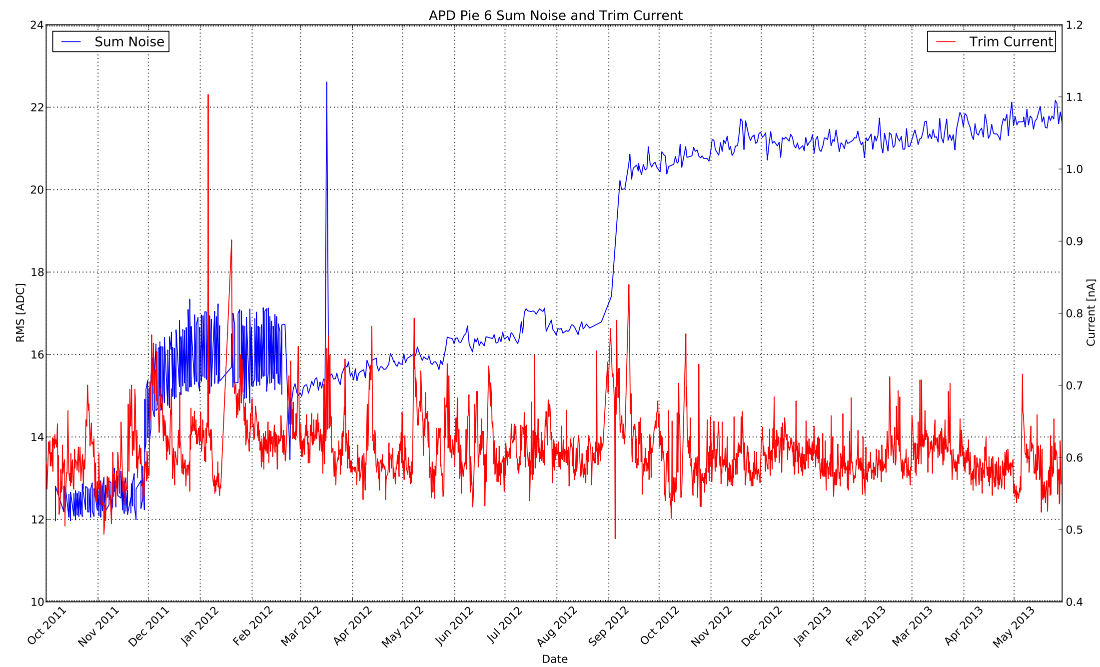

Figure 29: Sum noise and the trim current for APD pie 6.

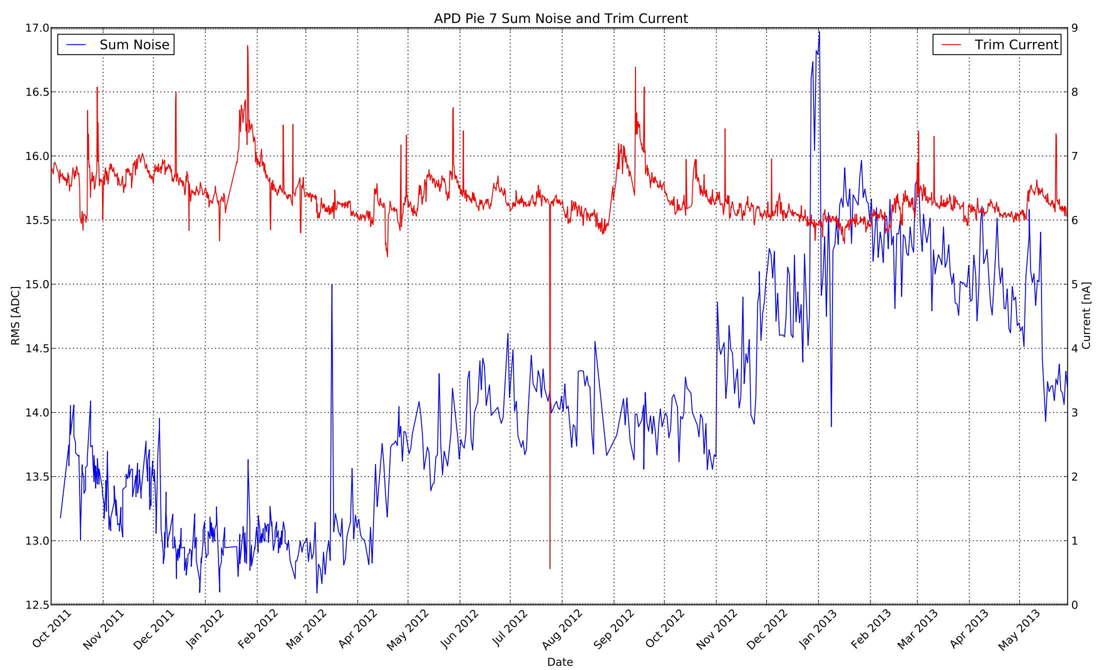

Figure 30: Sum noise and the trim current for APD pie 7.

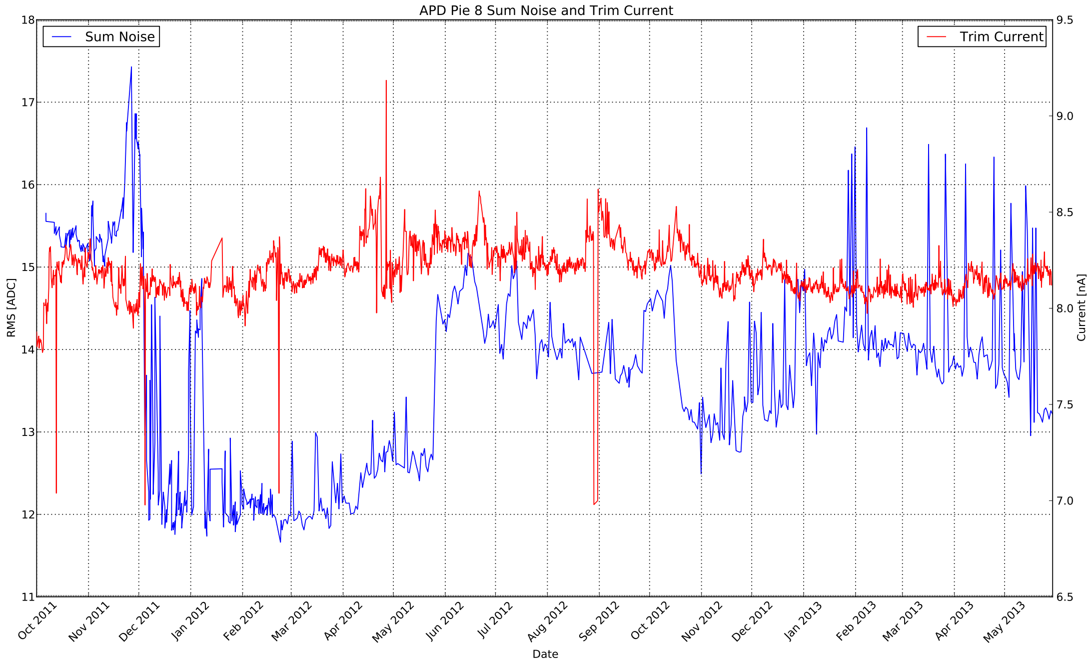

Figure 31: Sum noise and the trim current for APD pie 8.

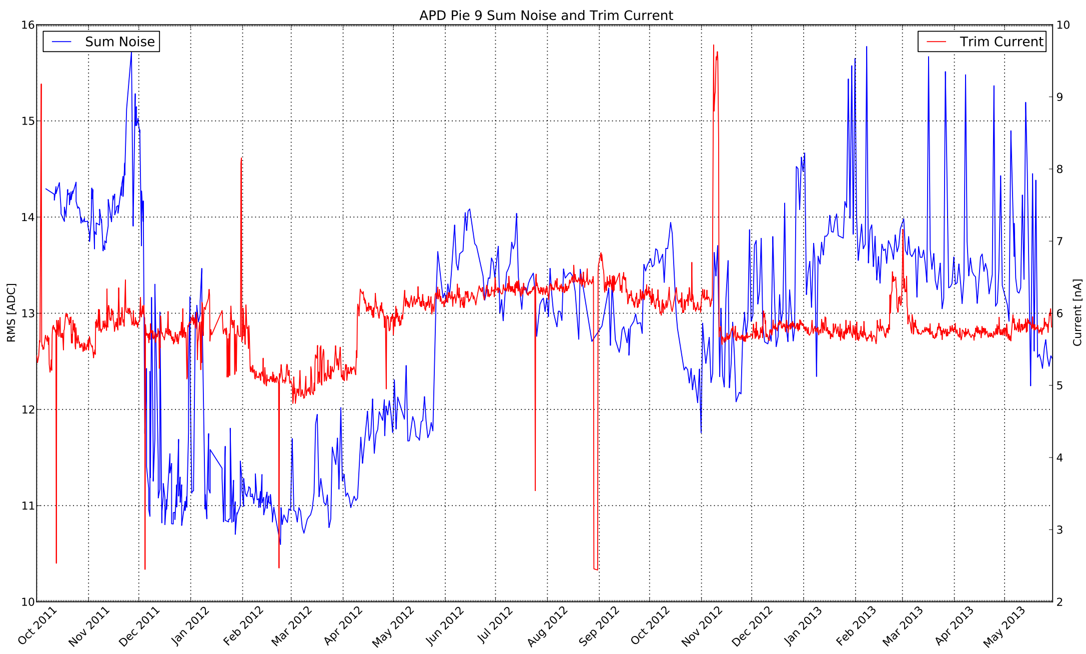

Figure 32: Sum noise and the trim current for APD pie 9.

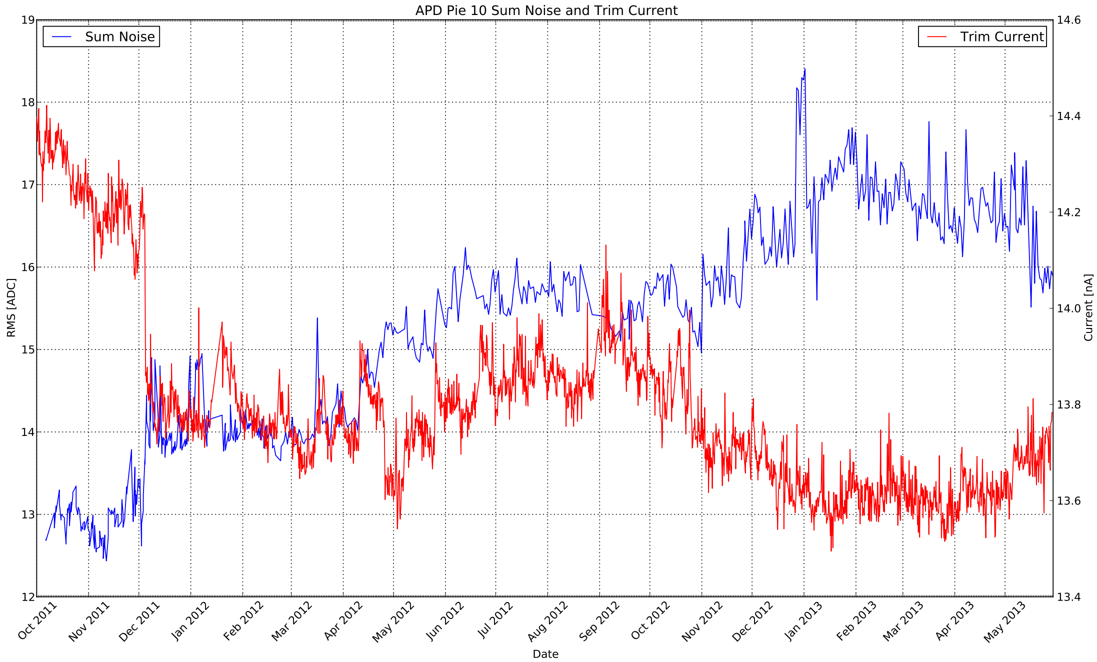

Figure 33: Sum noise and the trim current for APD pie 10.

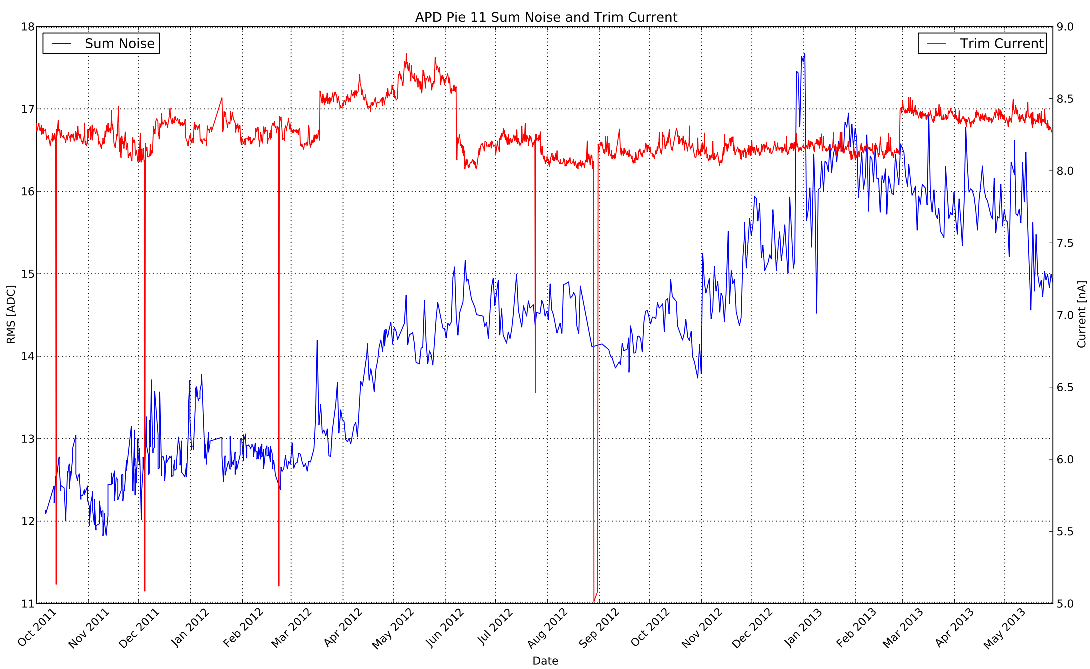

Figure 34: Sum noise and the trim current for APD pie 11.

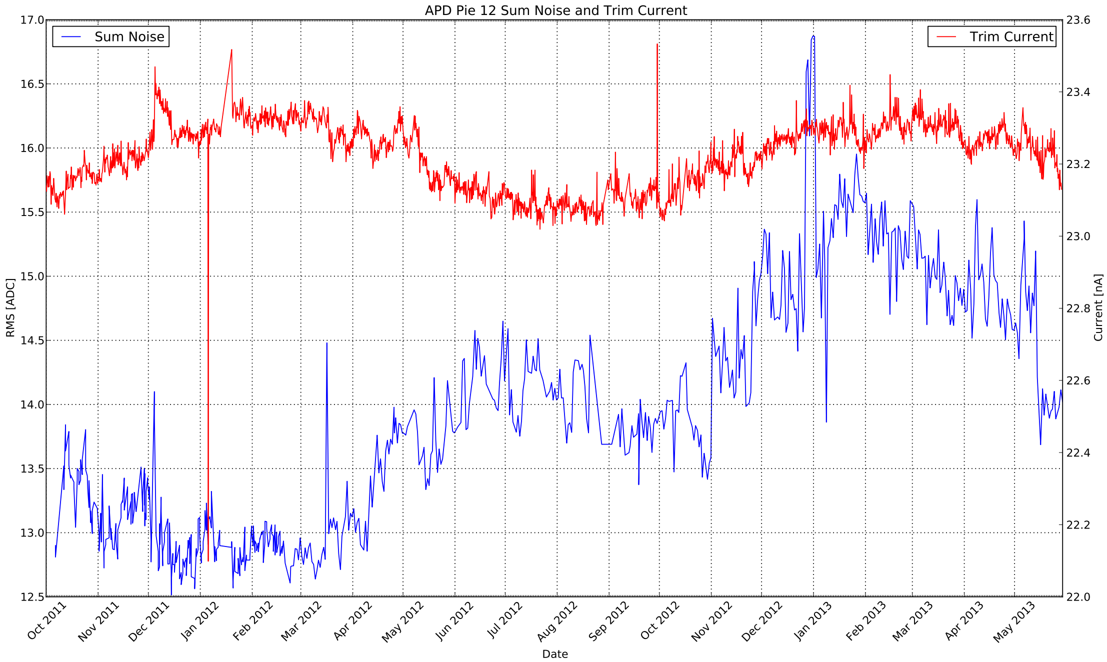

Figure 35: Sum noise and the trim current for APD pie 12.

Coherent Noise Spectra

In addition to investigating the source of the coherent noise trending behavior, the average Fourier power spectra for the APD planes and boards were plotted for two golden low background physics runs: 3457 and 4899, using 1000 solicited trigger events. Run 3457 was taken on March 21, 2012, when the total sum noise on both planes was relatively low ($\sim$ 60 ADC RMS), while run 4899 was taken on March 24, 2013, when the total sum noise on both planes was relatively high ($\sim$ 90 ADC RMS). For each solicited trigger event, a channel-summed waveform was produced for each APD board and plane, and then a discrete fast Fourier transform was performed on the summed waveform. All the Fourier spectra for each event were then added coherently and the resulting summed spectrum was divided by 1000 to get an average Fourier spectrum. The average Fourier power spectra are the squares of the magnitudes of the average Fourier spectra. In Figures 36 through 43, the power spectra are displayed in the top panel, while the integrated power spectra and power spectra residuals (run 4899 power spectrum - run 3457 power spectrum) are displayed in the bottom panel; all vertical scales are logarithmic.

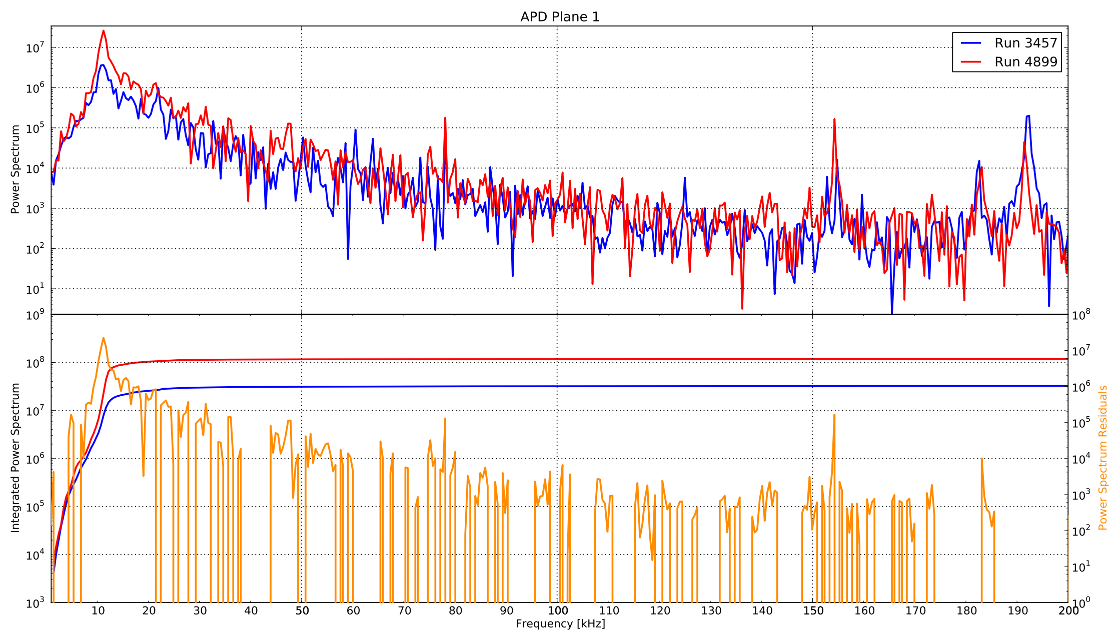

Figure 36: Power spectrum for APD plane 1.

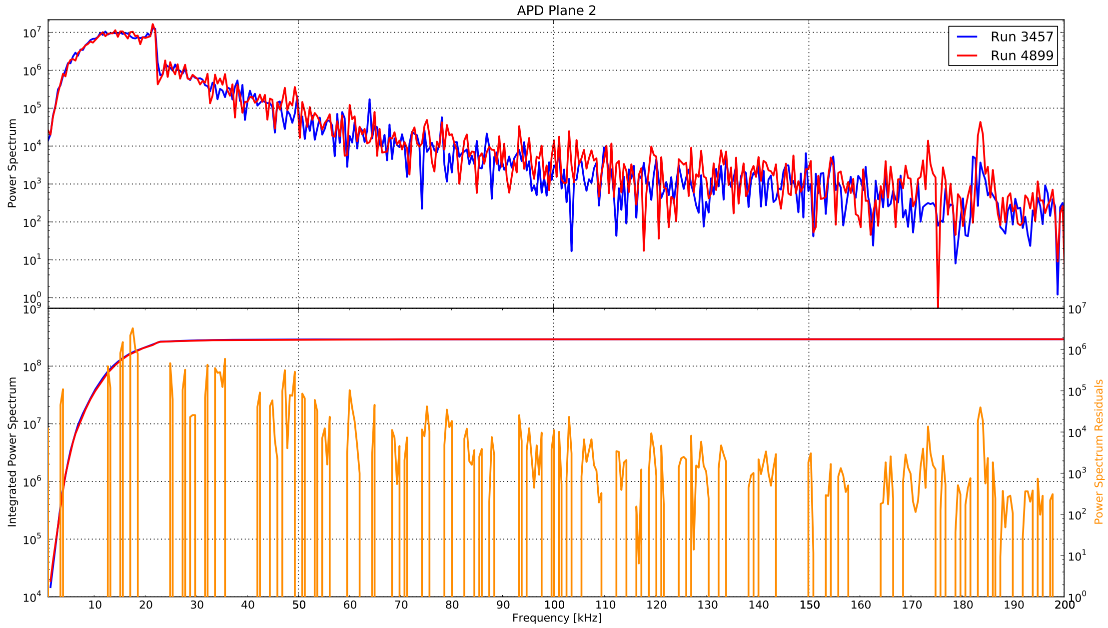

Figure 37: Power spectrum for APD plane 2.

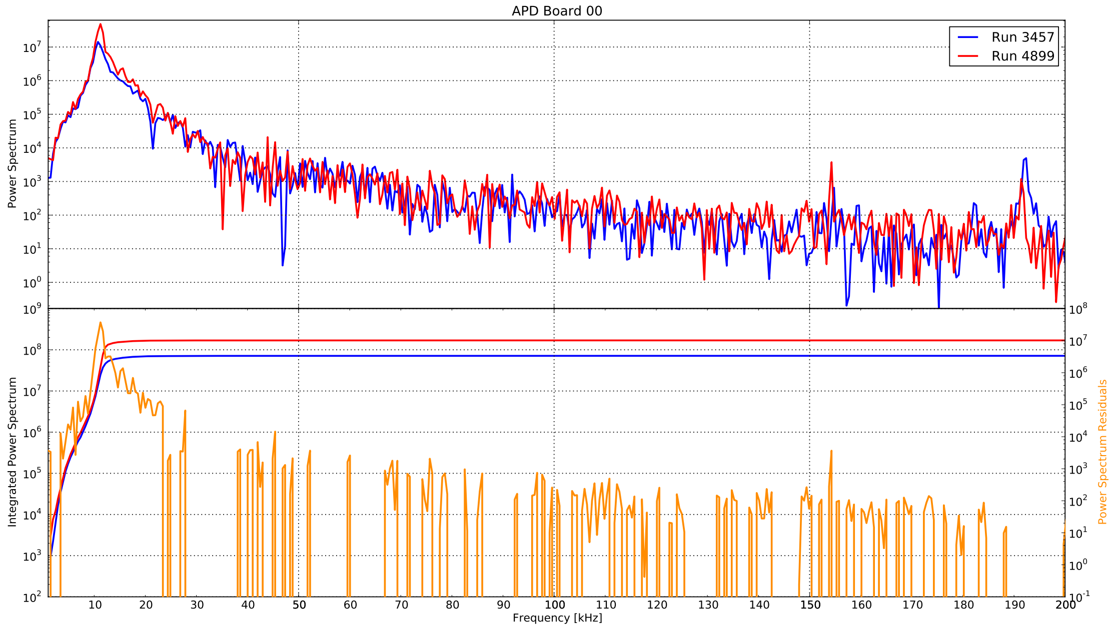

Figure 38: Power spectrum for APD board 00.

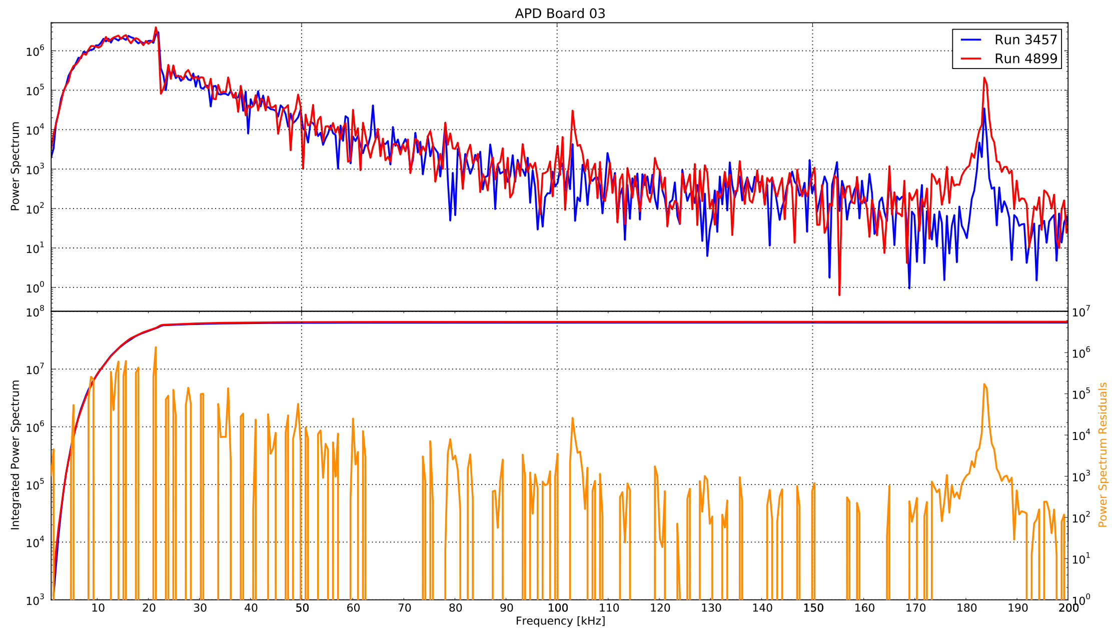

Figure 39: Power spectrum for APD board 03.

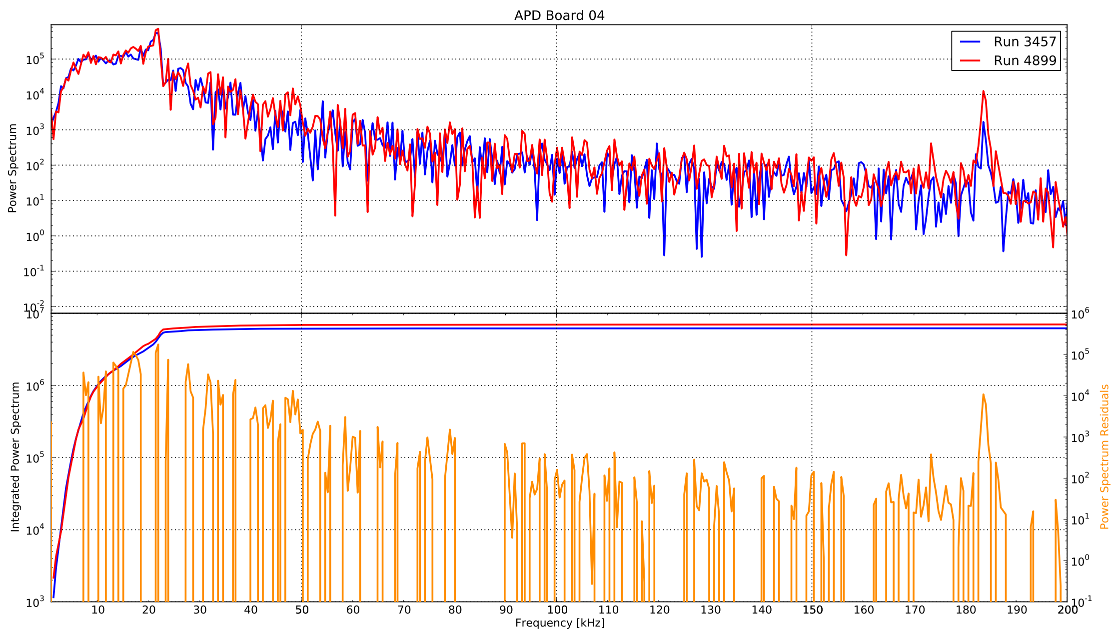

Figure 40: Power spectrum for APD board 04.

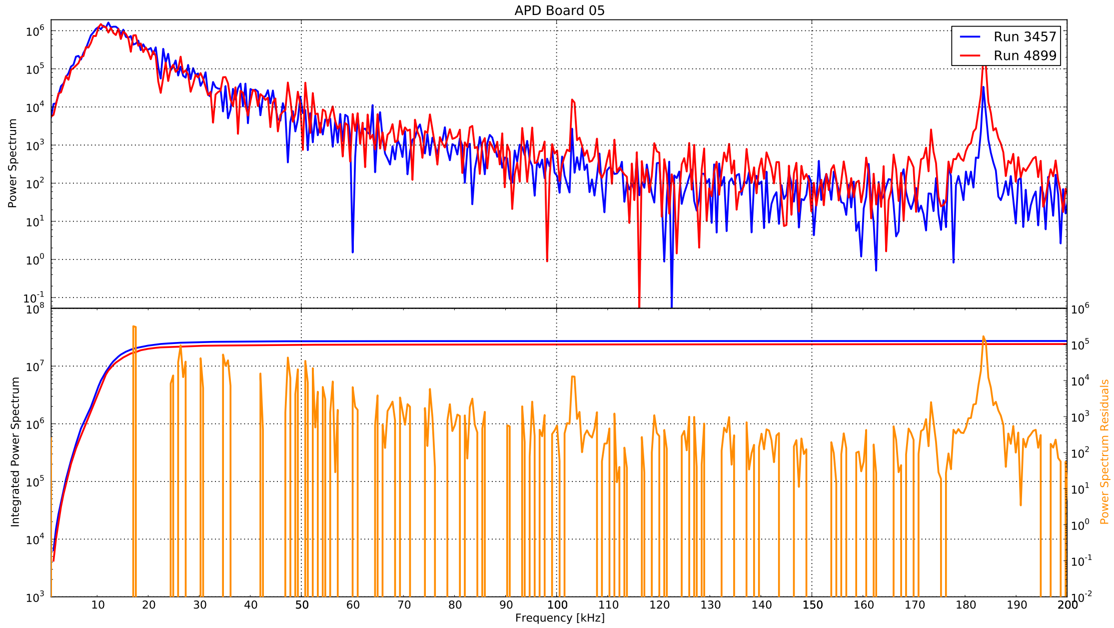

Figure 41: Power spectrum for APD board 05.

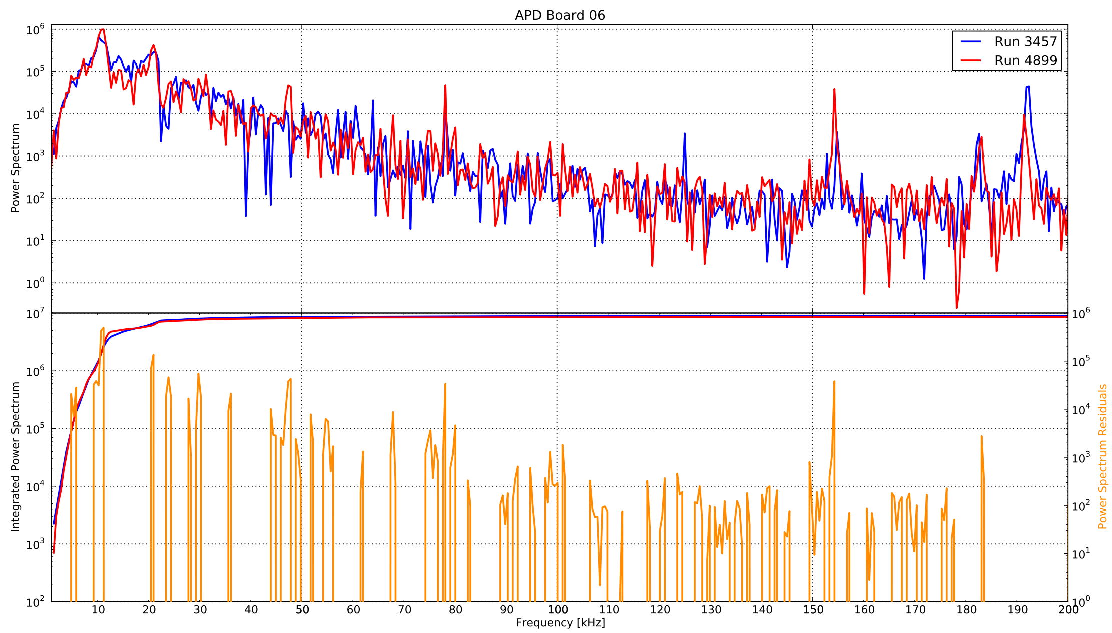

Figure 42: Power spectrum for APD board 06.

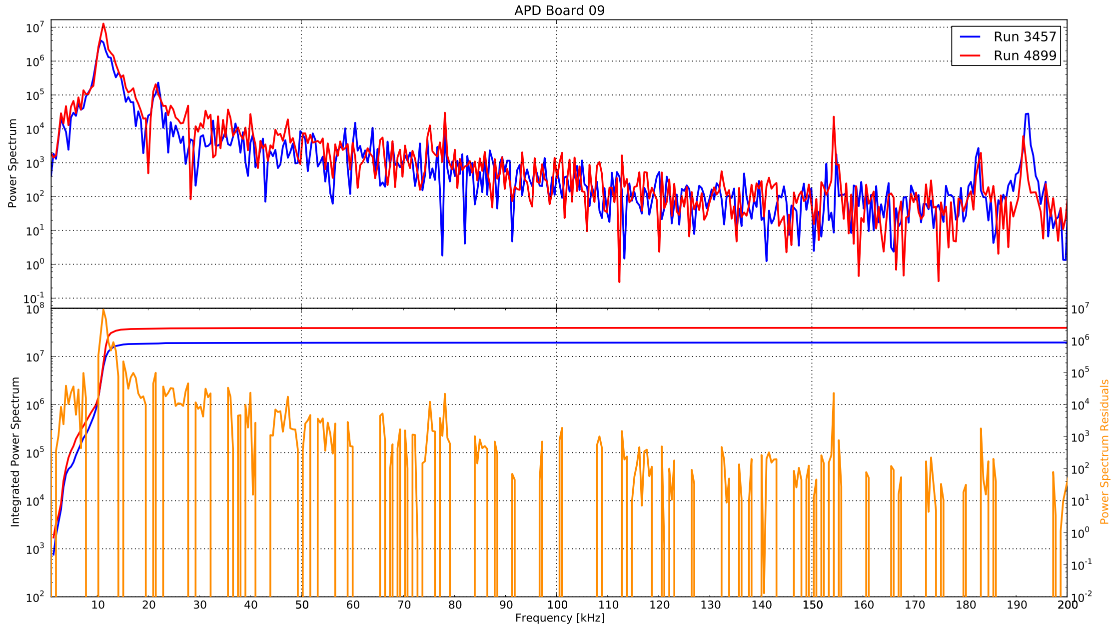

Figure 43: Power spectrum for APD board 09.

Conclusions

There are a few important observations about the coherent noise present in the wires and APDs:

- The energy resolution strongly correlates with the trending of the coherent noise in the APDs (Figure 8).
- The total coherent noise in the APDs has gotten worse over time, going from $\sim$ 60 ADC RMS in late February 2013 to $\sim$ 100 ADC RMS in late January 2013; the coherent noise has been decreasing then, to $\sim$ 85 ADC RMS as of May 29, 2013 (Figure 1).
- APD board 04 is the least noisy (sum noise $\sim$ 15 ADC RMS) and stable, while APD board 00 has become more noisy ($\sim$ 40 ADC RMS as of May 29, 2013) (Figure 3).
- All APD pies are quite stable in time (at $\sim$ 15 ADC RMS), with the exception of pies 1 and 6, which have gotten noisier with time (Figure 4).
- The coherent noise in the wire planes is low ($\sim$ 20 ADC RMS), with the exception of U wire plane 2, which is higher at $\sim$ 40 ADC RMS (Figure 5).
- For all the wire planes, most notably the V wire planes, the coherent noise is stable in time.
- The U wire boards in TPC 2 are noisier than the U wire boards in TPC 2, by $\sim$ 3 - 7 ADC RMS (Figure 6).
- It was suggested APD leakage current could result in excess APD noise. Figures 24 through 35 show the sum noise and trim current for all the APD pies, where the trim currents are a measure of the leakage currents. The trim currents only fluctuate by a few nA and no correlation is seen between the sum noise on the pies and the trim currents.

While no monitored environmental variable was found to correlate with the long-term trending behavior seen in the coherent noise, a number of actions were found that explain discrete changes in the coherent noise:

- Installation of the fan for Ebox 2 in early December 2011 reduced the noise for the U wire boards in TPC 2 (Figure 6).
- On February 28, 2012, APD board 01 was swapped out for APD board 09, greatly reducing the noise (Figure 9).
- Power outages appear to affect the coherent noise (Figure 9).
- Around January 1, 2013, there was a scheduled ventilation shutdown for a few days, during which the drift temperature shot up (and consequently, the clean room temperature), resulting a noticeable increase in the noise (Figures 14 and 16).
- Something seems to have happened in late January 25, 2013, beyond when the noise started decreasing. The day log entry 30381 states that there was an outage to the primary feed for a brief period of time, during which power was diverted to the secondary feed, and then returned back to primary power.
- On the evening of May 17, 2013, something happened to cause one of the thermal store chillers to trip the breaker it was on; the breaker was reset on the morning of the 18th. It appears this cause a drop in the noise in APD plane 2, but an increasing trend in the noise for APD plane 1 (Figure 2).

Present in all the low background power spectra is a prominent broadband region from $\sim$ 5 - 40 kHz. Over time, this broadband coherent noise has increased, most notably for plane 1, as can been seen by looking at the power spectra residuals (orange line) (Figure 36). There is a noticeable difference in the shapes of the power spectra for APD planes 1 (Figure 36) and 2 (Figure 37). The power spectra for plane 1 contain a peak at $\sim$ 10 kHz with the power dropping off on either side of the peak, while the power spectra for plane 2 are roughly flat from $\sim$ 10 - 20 kHz with a sharp drop off in power at $\sim$ 20 kHz.

For plane 1, most of the increase in the broadband noise is being driven by APD board 00 with some contribution from APD board 09 as well. In particular, there is a large increase in the total power for plane 1 from $\sim$ 10 - 50 kHz for run 4899 relative to run 3457, as seen in the integrated power spectra in the bottom panel of Figure 36. For plane 2, the power spectra for both runs are quite similar and there is not a large change in the broadband region from $\sim$ 5 - 40 kHz, although there is appreciable growth in a noise peak at $\sim$ 185 kHz.