Coherent Noise in ProtoDUNE

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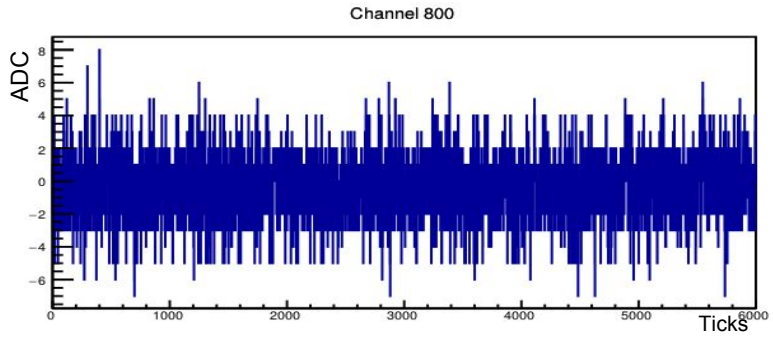
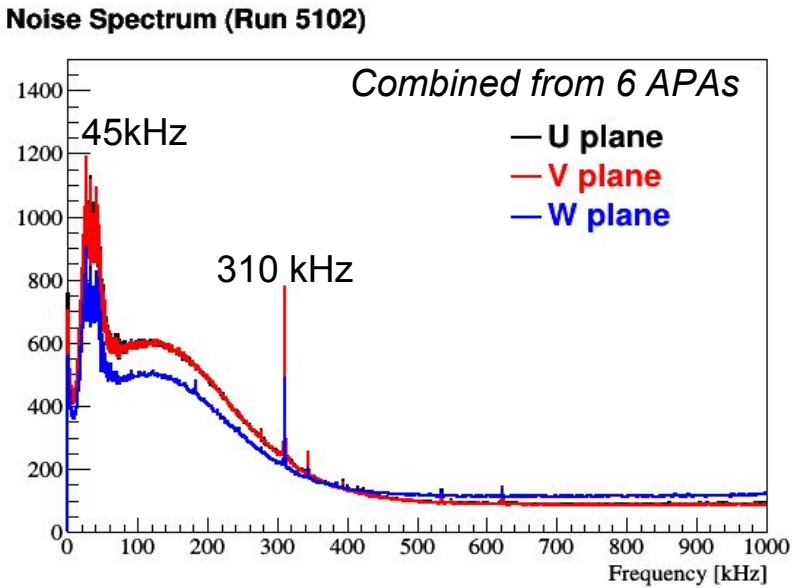
Outline

- Noise spectrum
- Coherent noise
- Mitigation of the Coherent noise
- Summary

Noise example from run 5102 (noise)

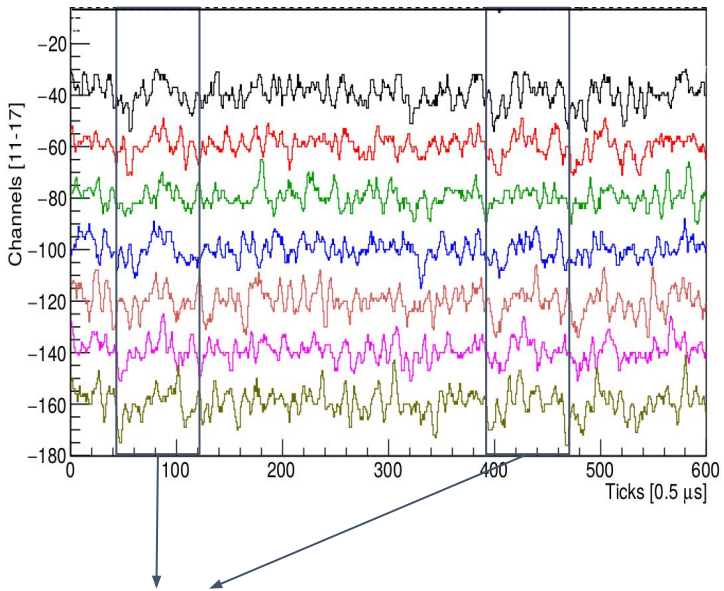


- Noise RMS is about 4 ADC
- Similar noise spectrum in U/V plane
- Wire length
  - U/V ~ 760 cm
  - W ~ 600 cm



- The 310 kHz noise is significant for some channels
- The 45 kHz is common for most channels: a **coherent** noise?

Coherent noise



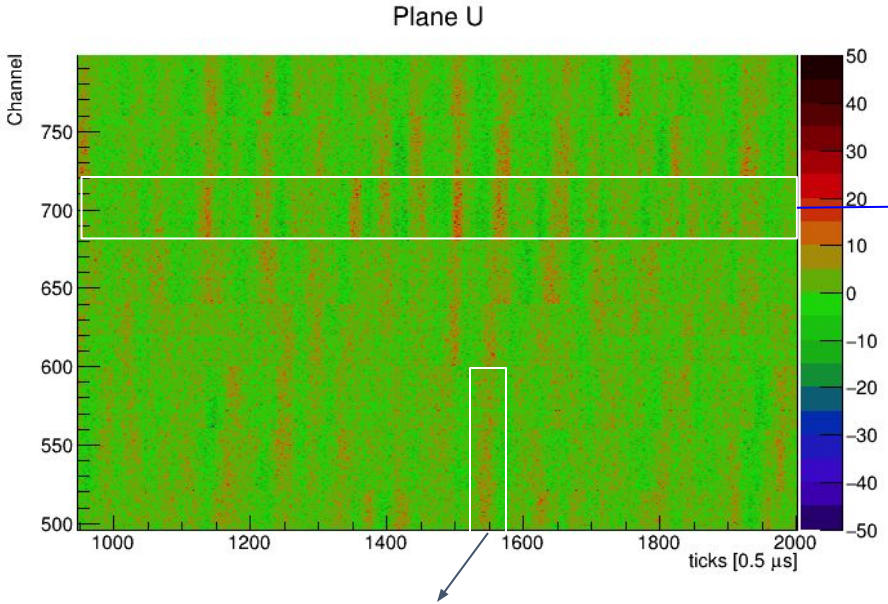
Correlation among adjacent channels ⇒ coherent noise

The source of this coherent noise is the low voltage regulator that provides power to the cold electronics, it is more noticeable at low frequencies ≈ 40 kHz

See also *Noise Characterization and Filtering in the MicroBooNE Liquid Argon TPC* **JINST 12 (2017) no.08, P08003**

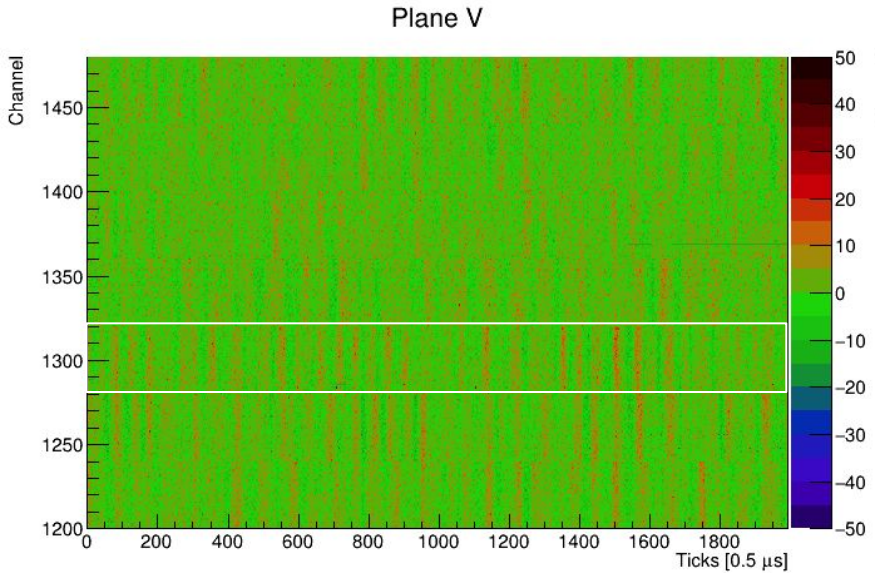
See also Philip's talk https://indico.fnal.gov/event/18639/contribution/1/material/slides/0.pdf

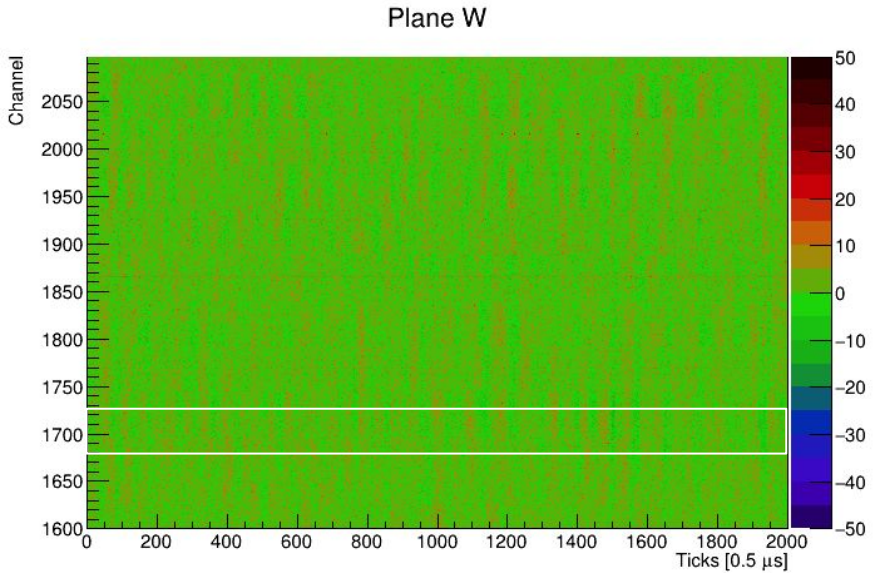
Coherent noise waveform (channel vs. tick)



- Correlation between 40 adjacent channels (680-720)
- 40 U/ 40 V/ 48 W plane wires share a FEMB

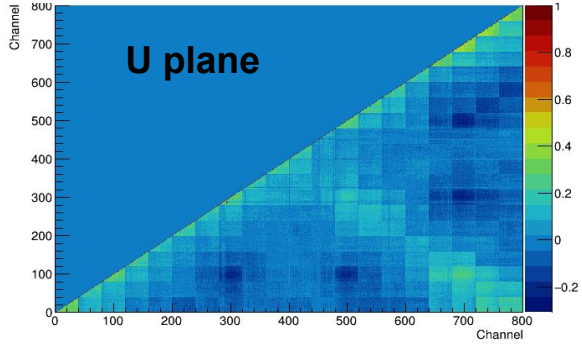
Noise in V & W plane

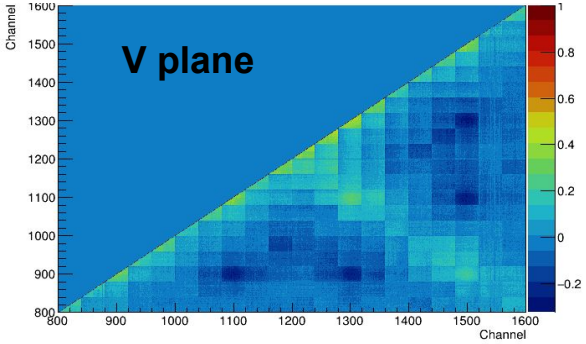


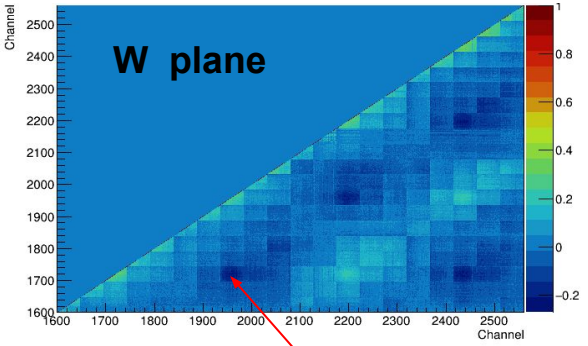


- Correlation in the 40 (48) channels for V (W) plane

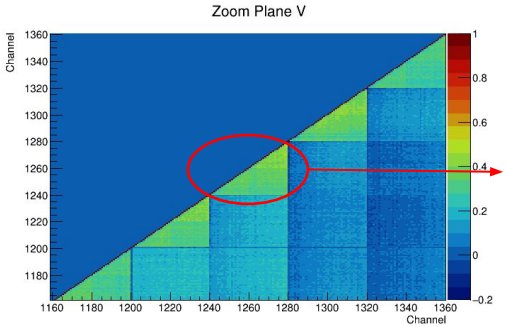
Correlation between channels







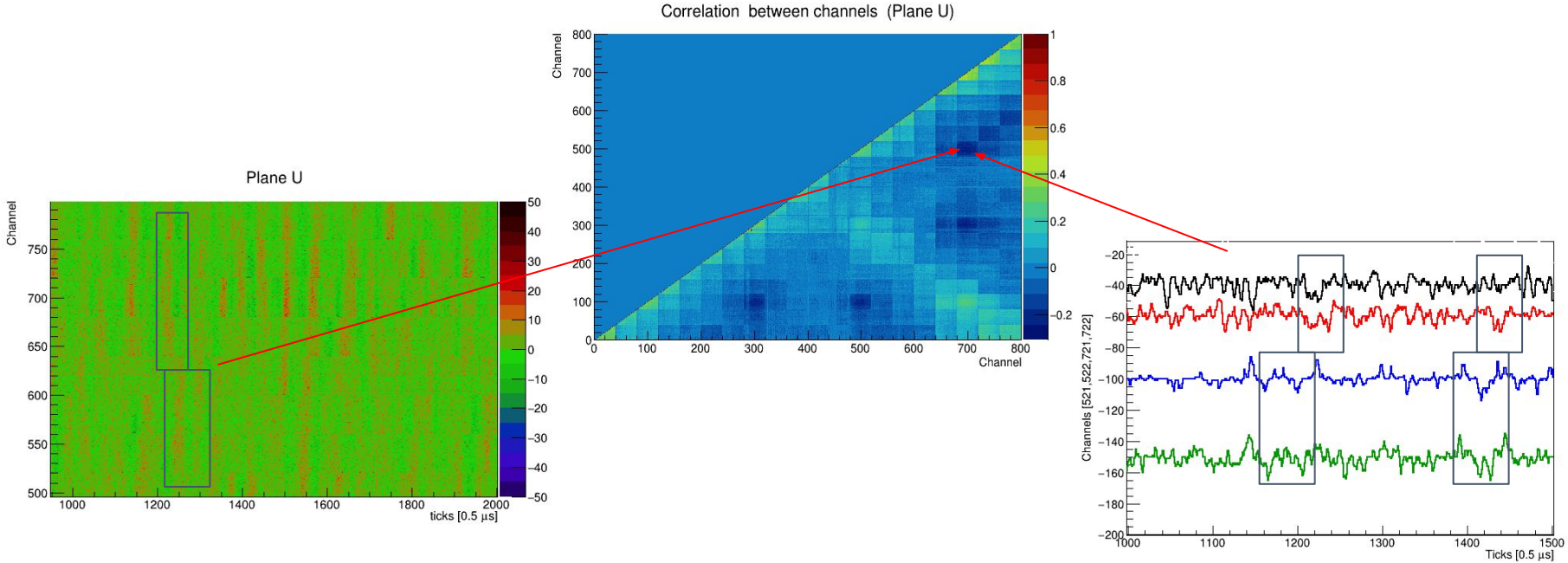
Anti-correlation (see next page)



40 channels on the same FEMB (Plane V)

- Strong correlation in the same FEMB
- Wires are wrapped in U/V plane, correlation pattern among FEMBs is different with W plane

Anti-correlation between different FEMB

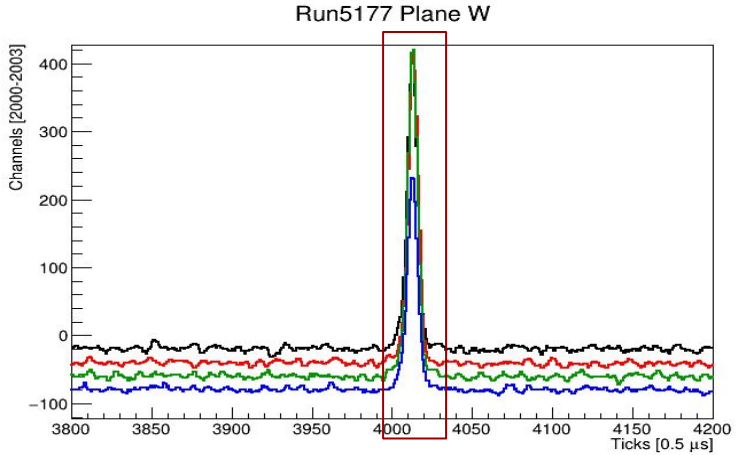


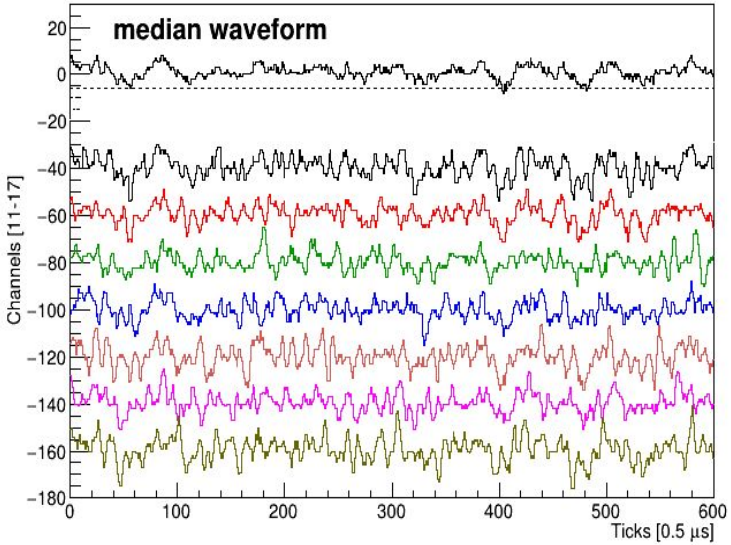
Anti-correlation between channels can be seen as a phase difference of the waveforms

Coherent noise mitigation

Noise Characterization and Filtering in the MicroBooNE Liquid Argon TPC
JINST 12 (2017) no.08, P08003

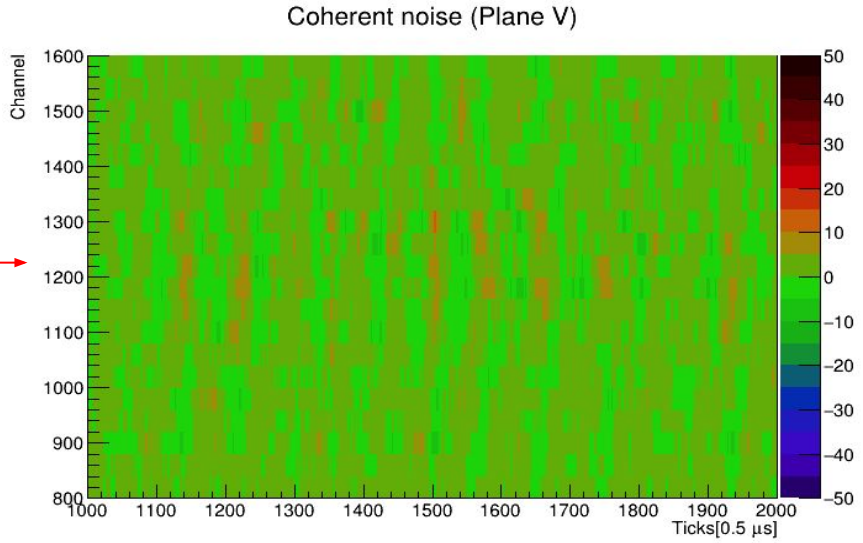
- A correction waveform is constructed across 40 (48) adjacent channels for plane U and V (W) by taking the median of the corresponding sample
- This median waveform is then subtracted from each of the 40 (48) channels
- (**Signal protection**) Once a signal is found, this signal will be protected and not included in the median waveform



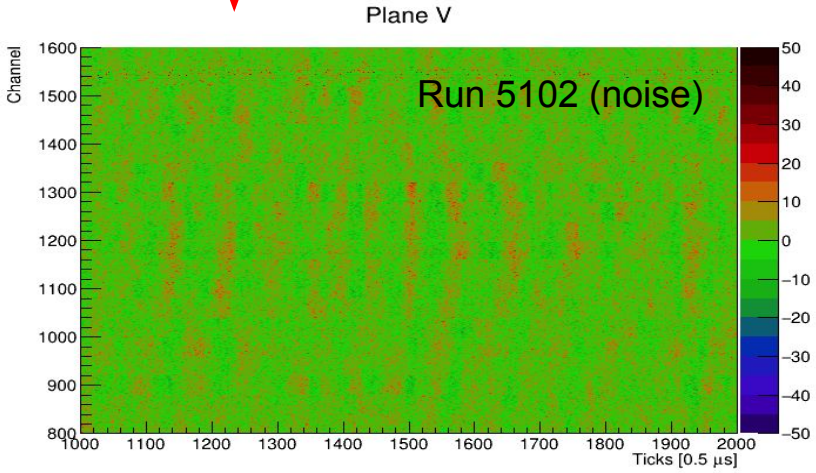


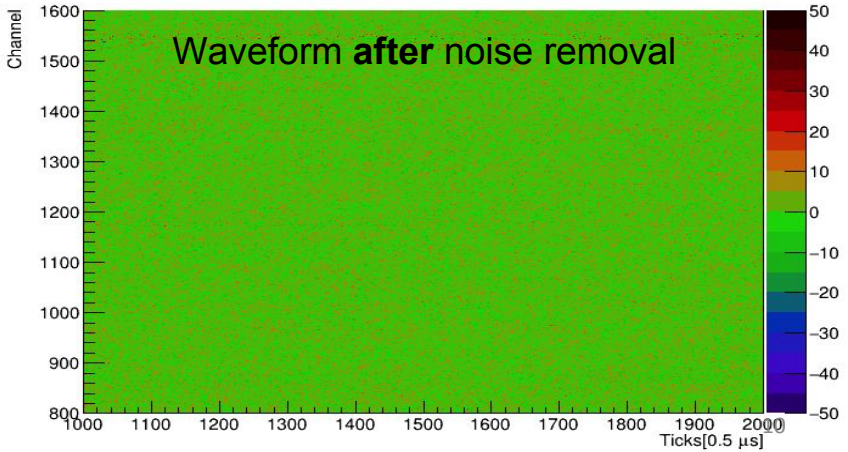
After the mitigation

Coherent Noise estimated from median waveforms

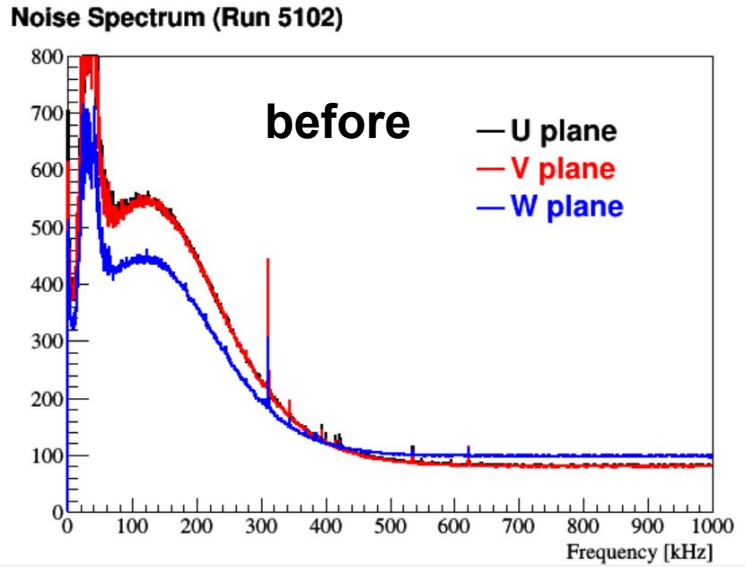


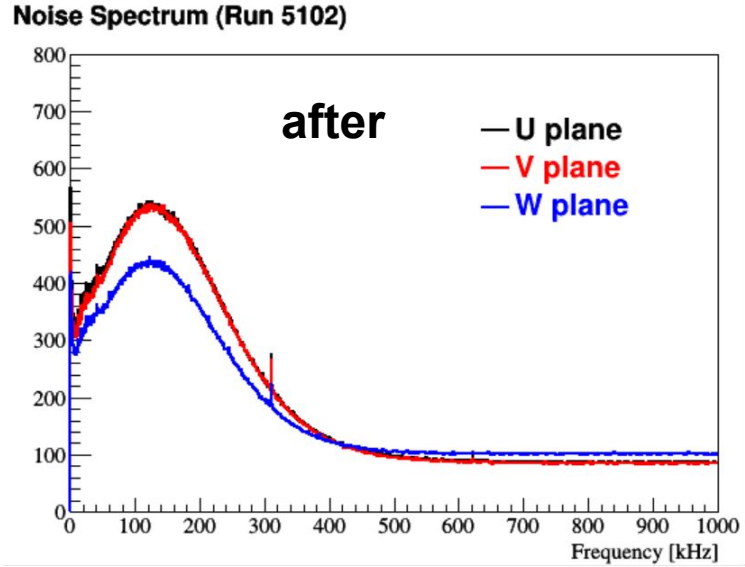
Waveform **before** noise removal





After the mitigation

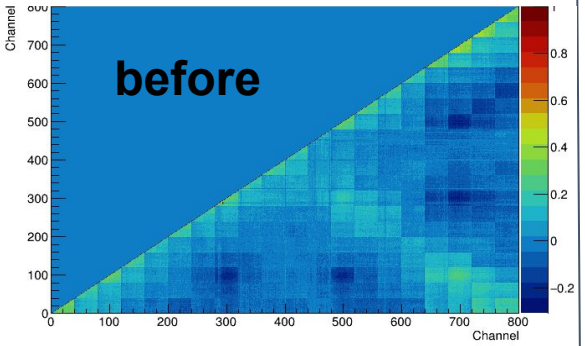


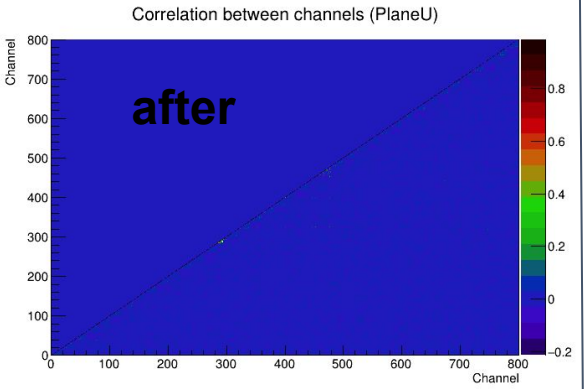


- The 45 kHz noise is common for >90% of channels
- The 45 kHz noise is significantly suppressed after the coherent noise mitigation

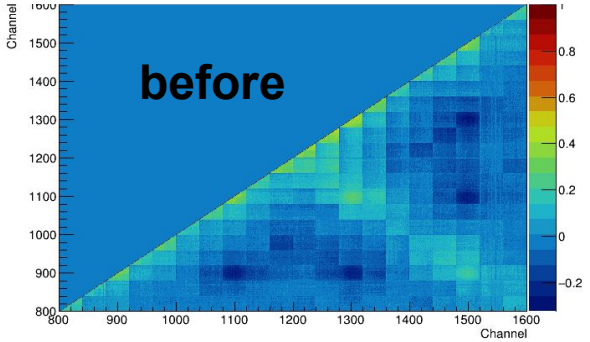
Correlation after the mitigation

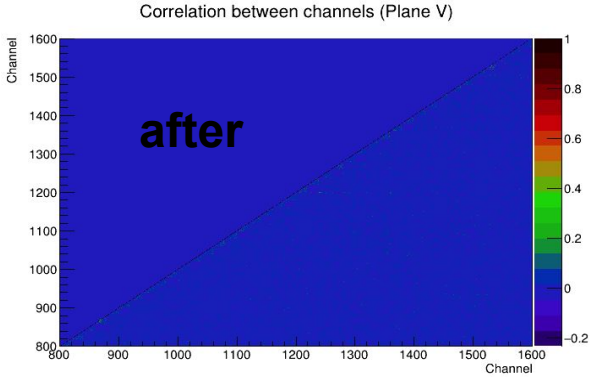
U plane



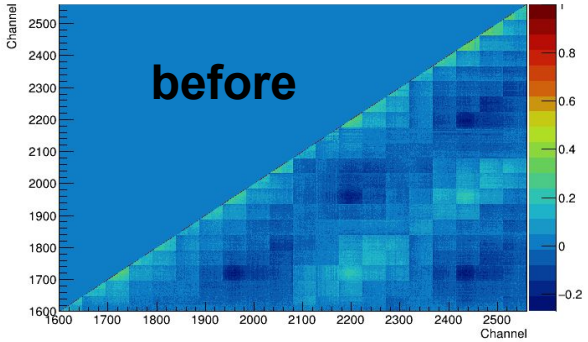


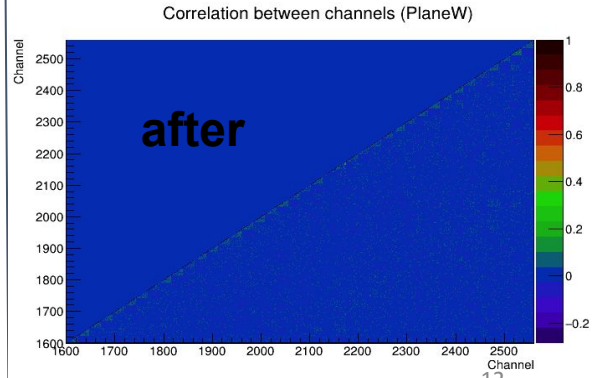
V plane



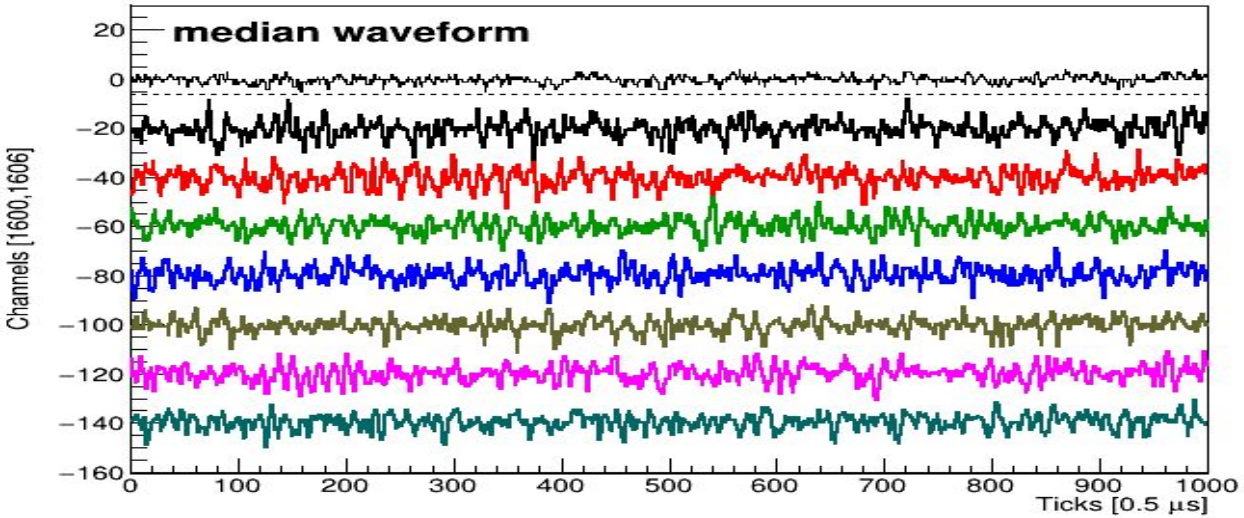


W plane





1D waveforms after the mitigation (Plane W)



Correlation between channels becomes weaker

Summary

- The coherent noise at protoDUNE is studied and is related with the 45 kHz noise
- The coherent noise is estimated by taking the median waveform per 40 (48) channels in each FEMB for U/V (W) plane and subtracted from each channel
- After the coherent noise mitigation, the correlation between channels becomes weaker