

TPC Electronics Results Summary from Coldbox Tests for ProtoDUNE-II

Roger Huang

FD1 TPC Electronics PRR
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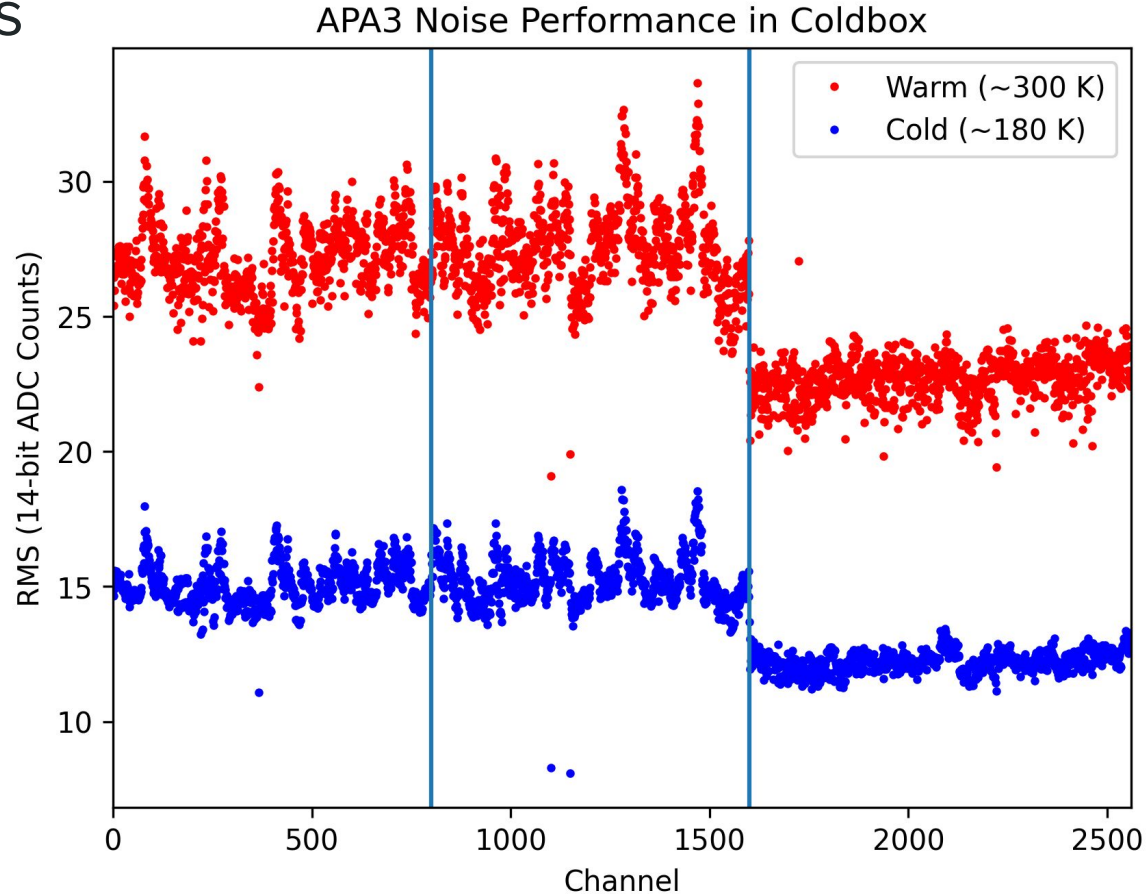


Summary of Tests

- The APAs for ProtoDUNE-II-HD and the bottom CRPs for ProtoDUNE-II-VD have been instrumented with FEMBs using the final ColdADC and COLDATA designs (including from the combined engineering run), and WIBs using the final FPGA choice
- ProtoDUNE-II-HD contains 4 APAs (APA1 and APA2 as upper APAs, APA3 and APA4 as lower APAs), now all installed in the NP04 cryostat
 - Each tested in a gas coldbox (reaching 160-190 K)
- ProtoDUNE-II-VD contains 2 bottom CRPs
 - Each tested in a liquid argon coldbox

Channel Noise on APAs

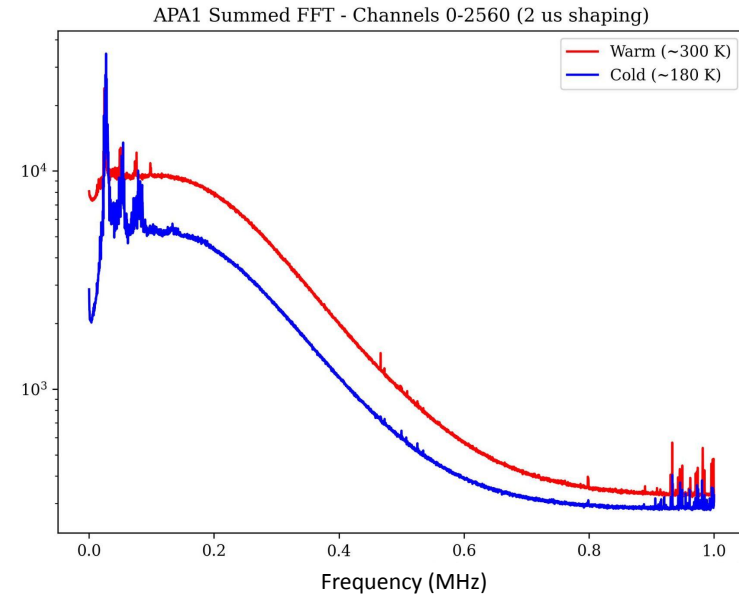
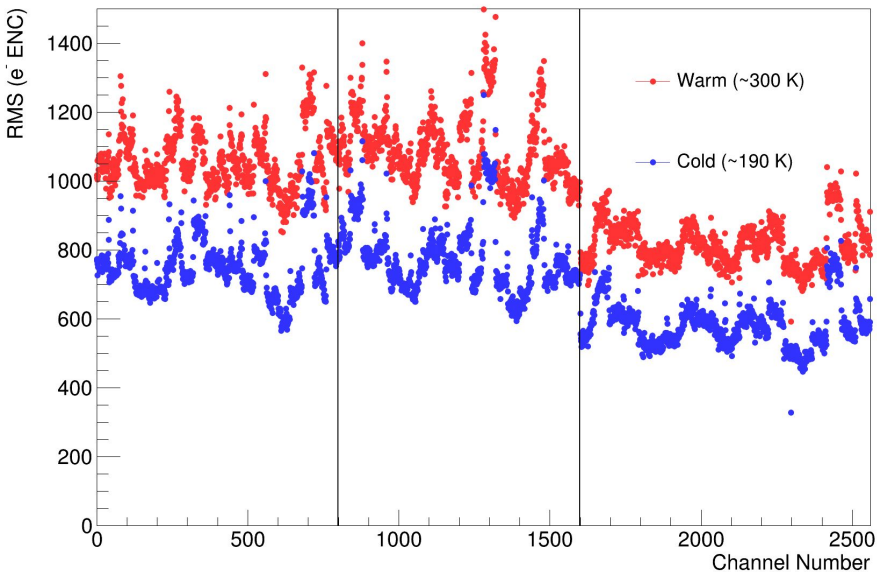
- Pedestal noise levels are well within required specifications
- No abnormalities in ASIC response observed in transition from warm to cold
- No data corruption or transmission issues from FEMBs observed



Coherent Noise

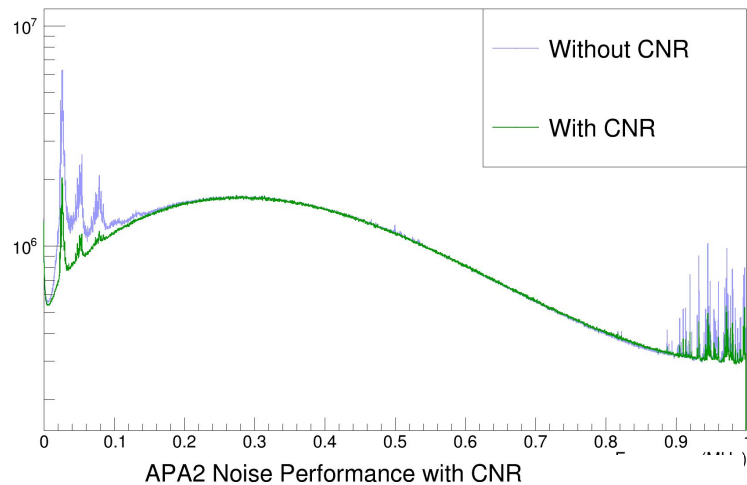
- In the APA coldbox tests (but not tests of individual FEMBs), there is a non-negligible noise contribution from coherent pickup, peaked around ~25 kHz
 - Seems mostly temperature-independent, but its relative magnitude is larger under cold conditions

APA1 Noise Performance without CNR

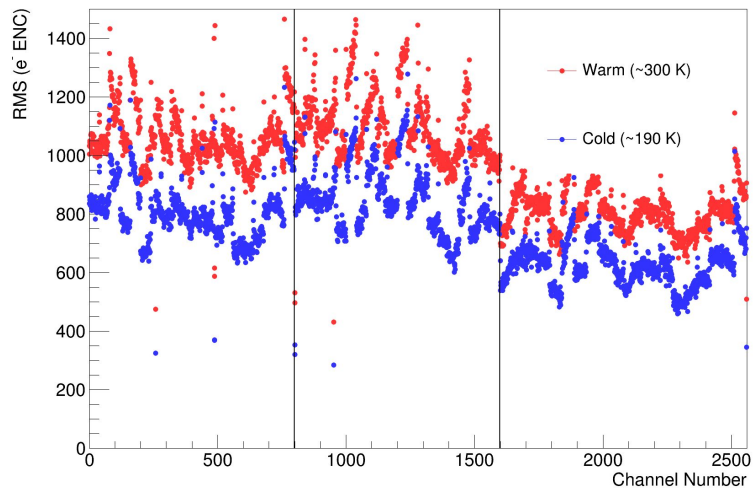


Coherent Noise

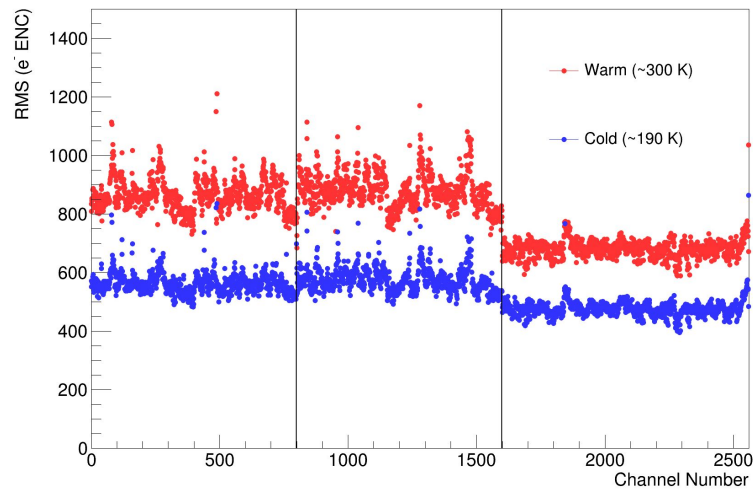
- This additional noise can be mostly suppressed by coherent noise removal (CNR) algorithms in offline analysis



APA2 Noise Performance without CNR

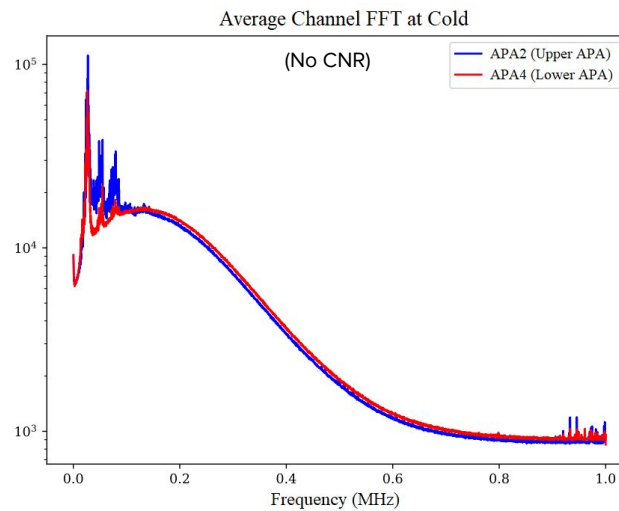


APA2 Noise Performance with CNR

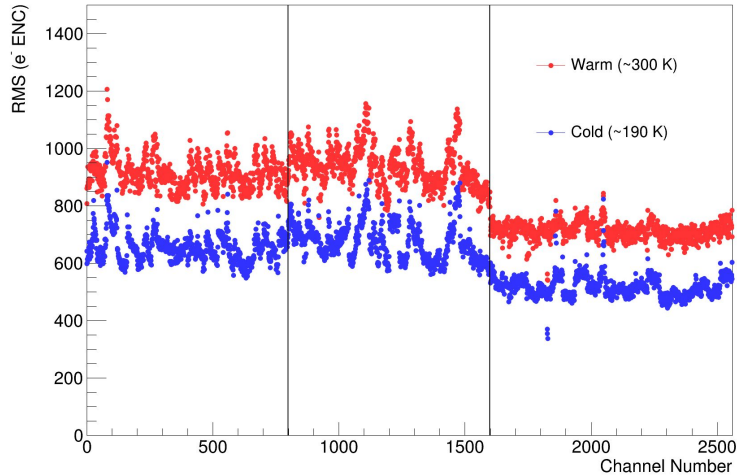


Coherent Noise

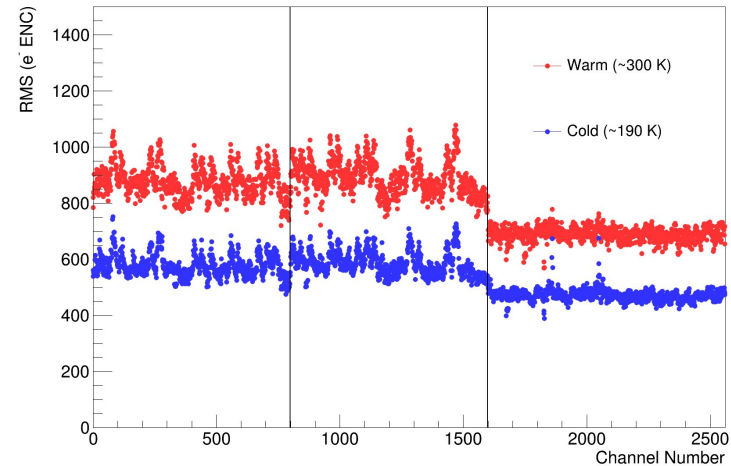
- Magnitude of coherent noise is generally smaller on lower APAs compared to upper APAs



APA4 Noise Performance without CNR

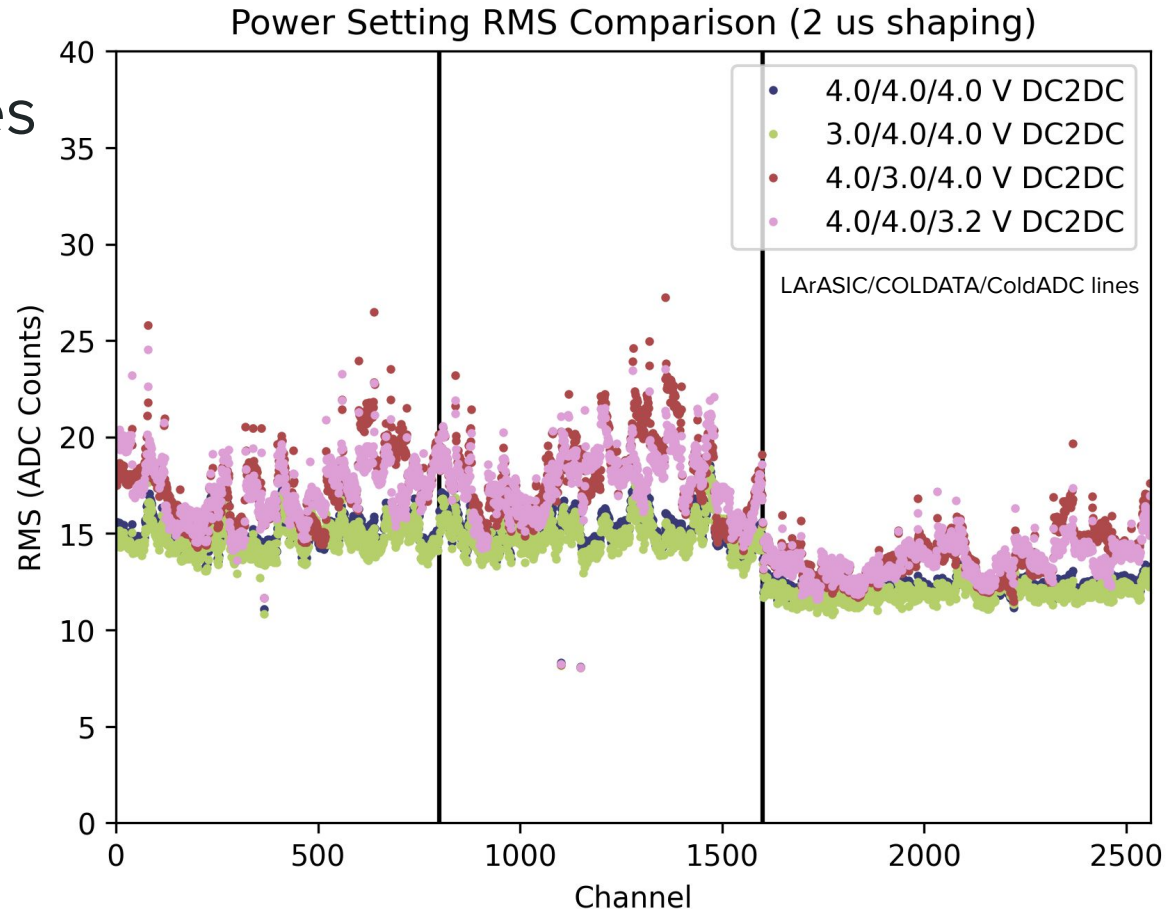
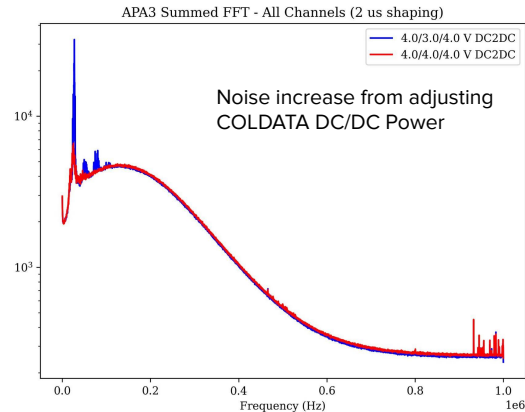


APA4 Noise Performance with CNR



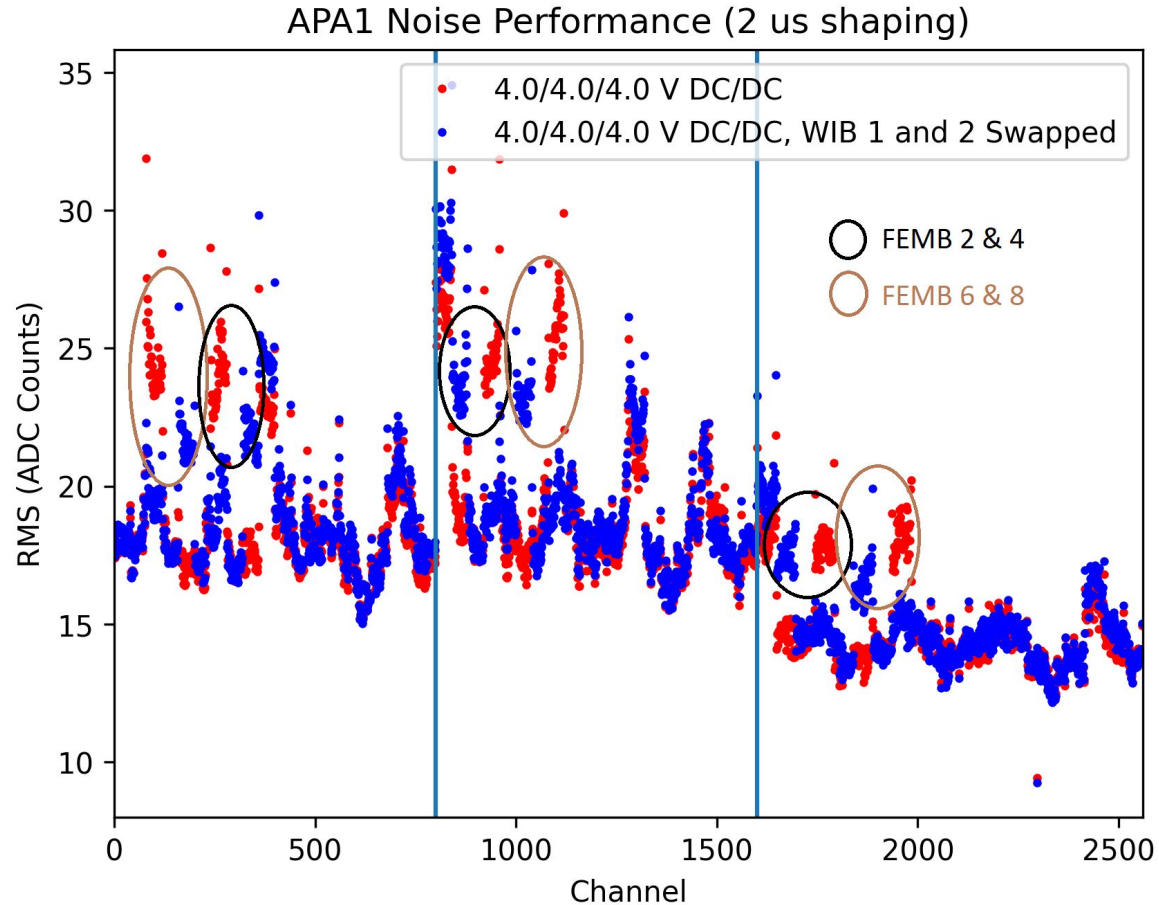
Coherent Noise Relation to Power Lines

- WIBs have 3 DC/DC converters that supply the power rails for LArASIC, ColdADC, and COLDATA respectively on the FEMBs
- Coherent noise pickup is notably affected by the ColdADC and COLDATA power line settings



Coherent Noise Relation to WIBs

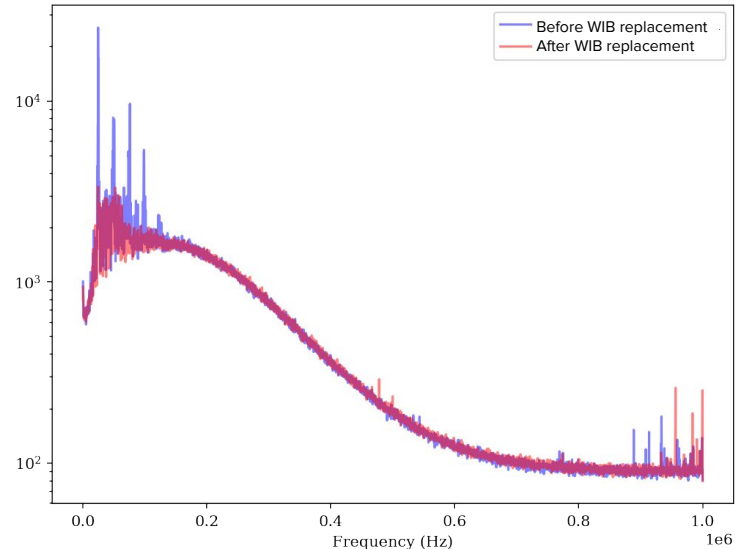
- We sometimes see that certain FEMBs see the low-frequency pickup more strongly than others
- Swapping WIBs around shows that this excess noise follows the WIBs and not the FEMBs



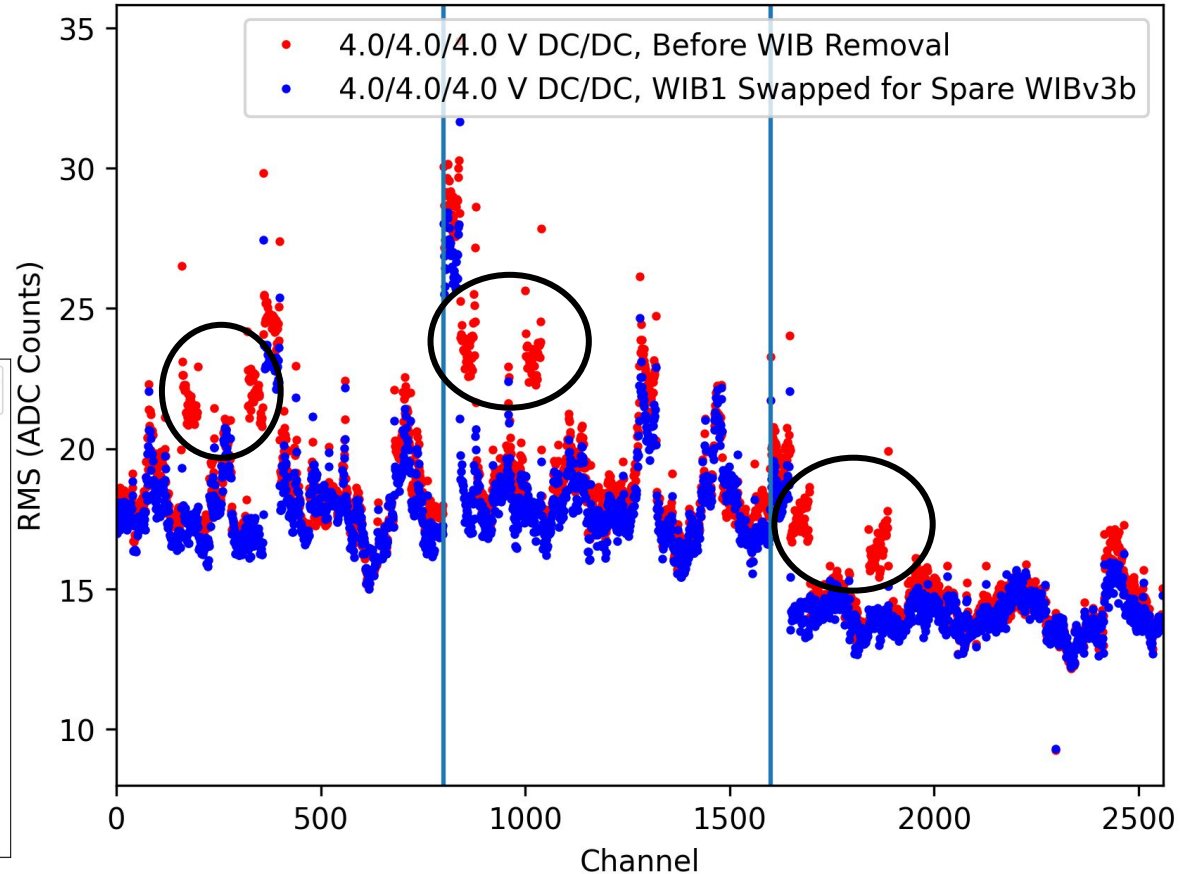
Coherent Noise Relation to WIBs

- Swapping out a “problem” WIB that had 2 excess-noise FEMBs for a new WIB caused that excess noise to disappear

FEMB2 and FEMB6 Avg FFT



APA1 Noise Performance (2 μ s shaping)

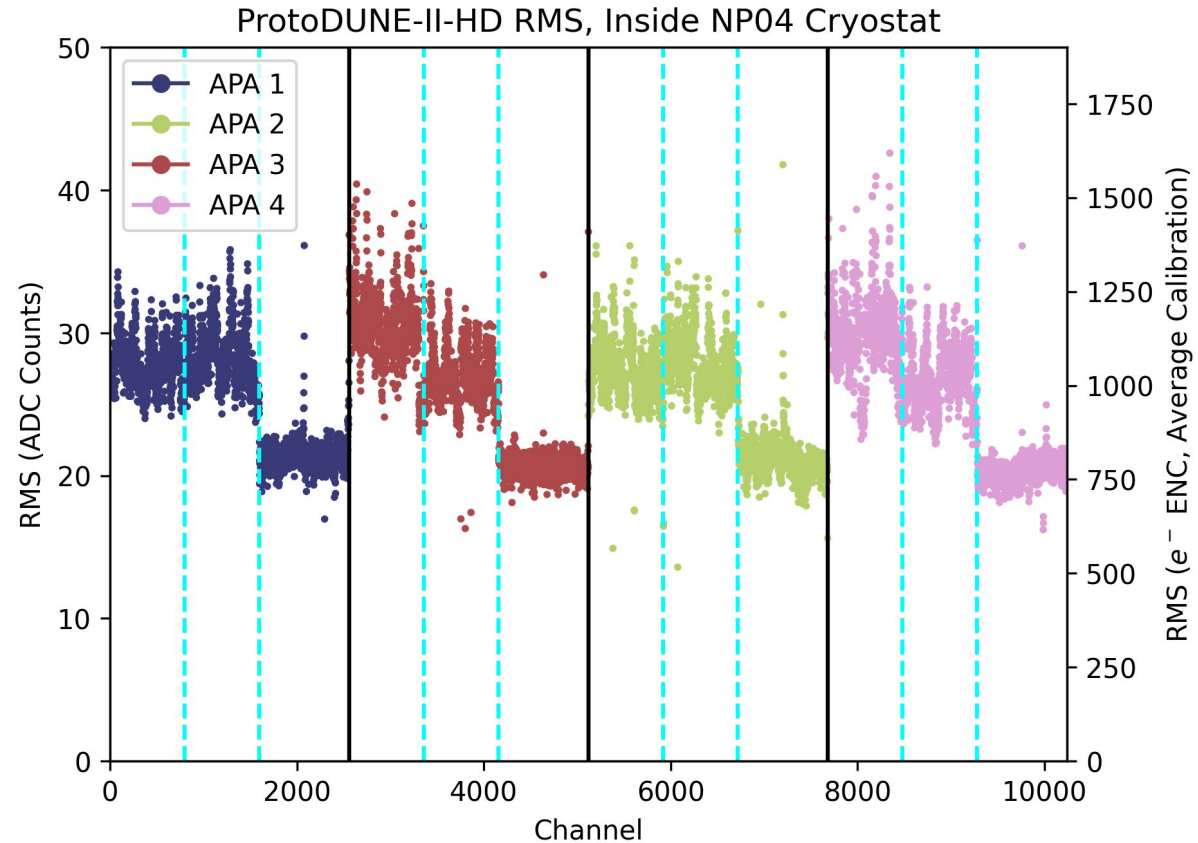


Current Thoughts on Coherent Noise

- Evidence so far points to some interaction between the system-level grounding and the power that the WIBs supply to the FEMBs as the primary source of this noise
 - Noise not seen in standalone FEMB tests
 - Noise follows WIBs and not FEMBs
 - Strongly affected by DC/DC settings on WIB
 - Stronger in upper APAs than lower APAs and bottom CRPs
 - Strength does not exhibit notable temperature-dependence
- While the power supply to the ASICs is apparently relevant, the noise seems unrelated to the ASICs' internal operations

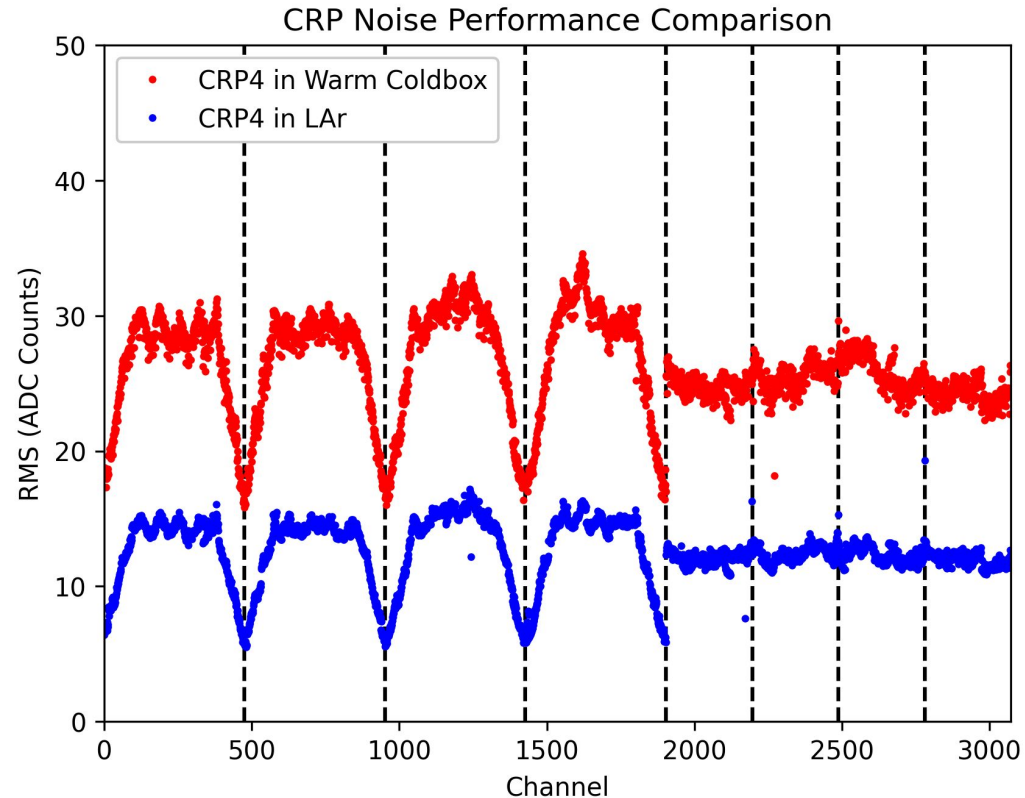
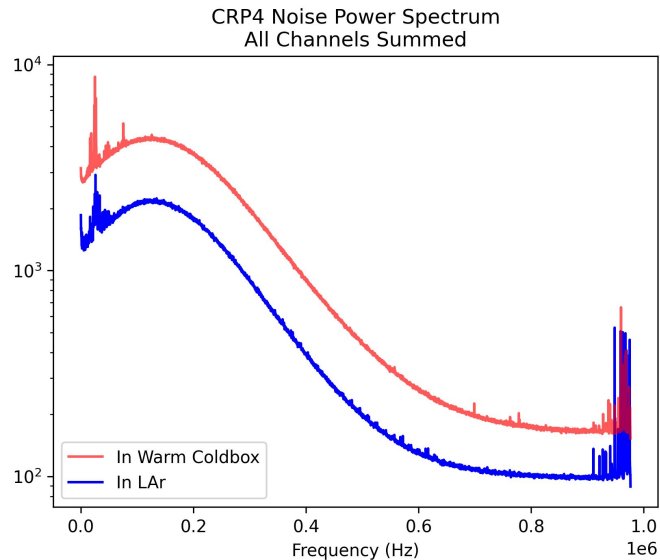
APA Status in NP04

- All 4 APAs have been in their final positions in NP04 since 11/2022, ready for ProtoDUNE-II-HD operations
- TPC electronics have been kept on and monitored for stability



CRP Coldbox Tests

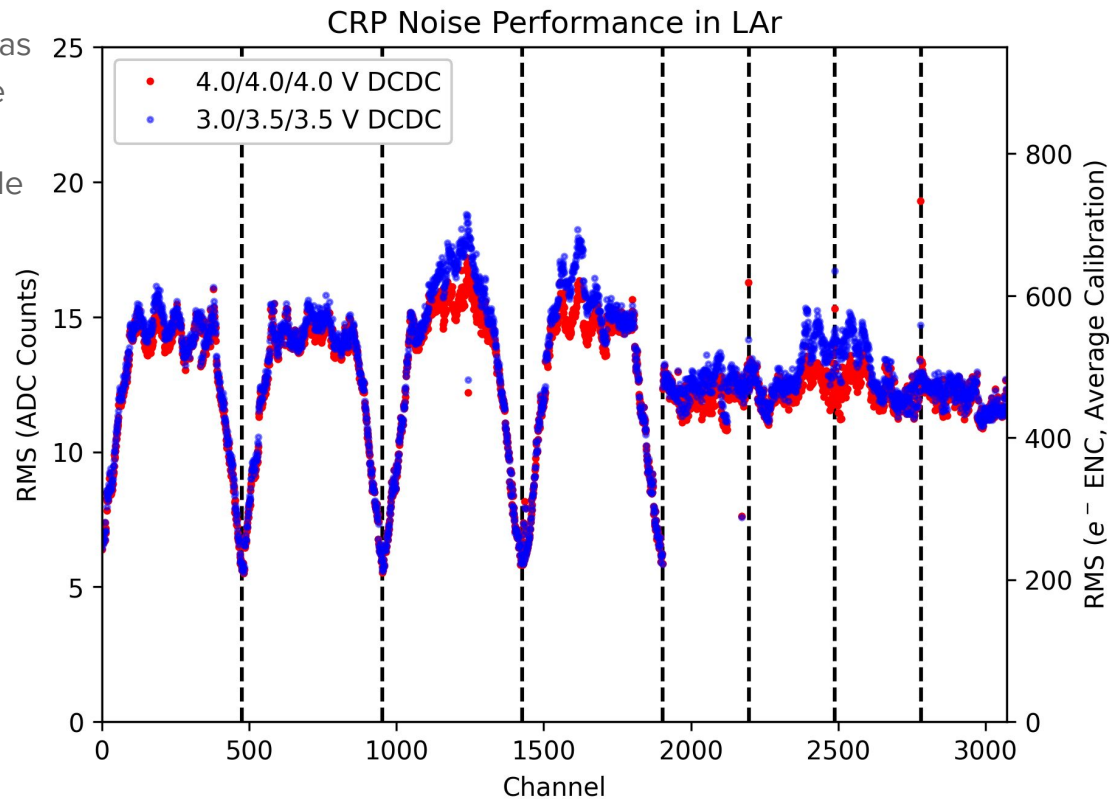
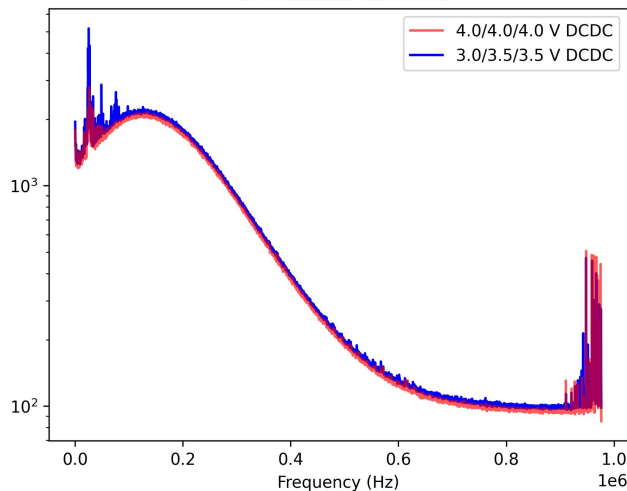
- Bottom CRPs use the same FEMBs and WIBs as APAs, and provide a testbed in LAr with cosmic data
- No problems with ASIC response in LAr
 - PLL settings had to be adjusted on COLDATA for LAr operation after some testing, but this is digitally configurable



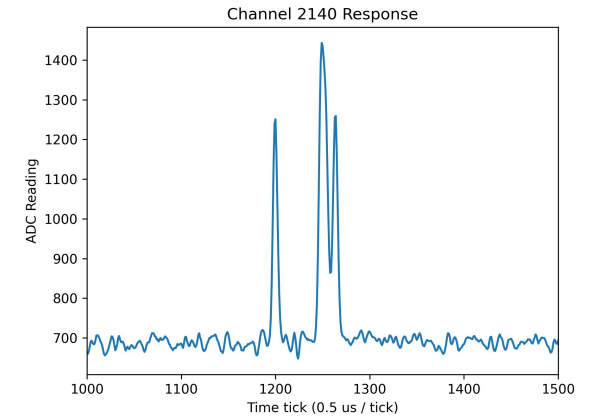
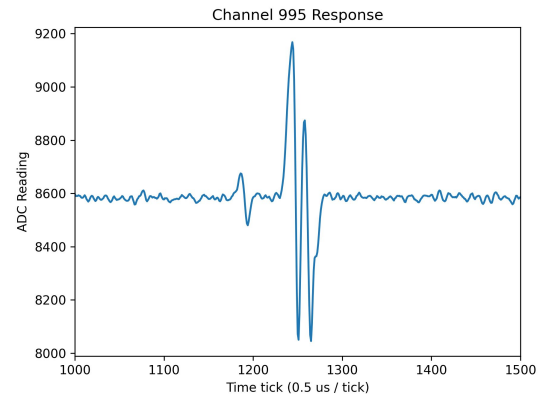
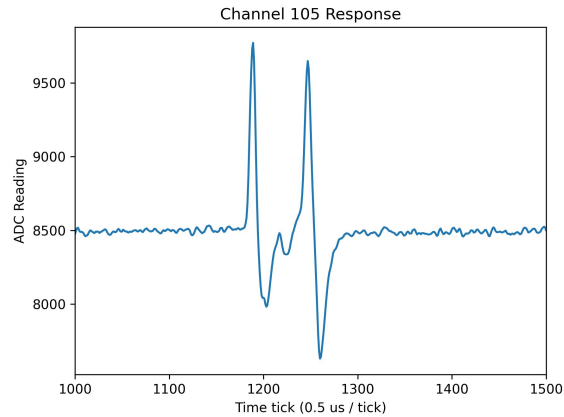
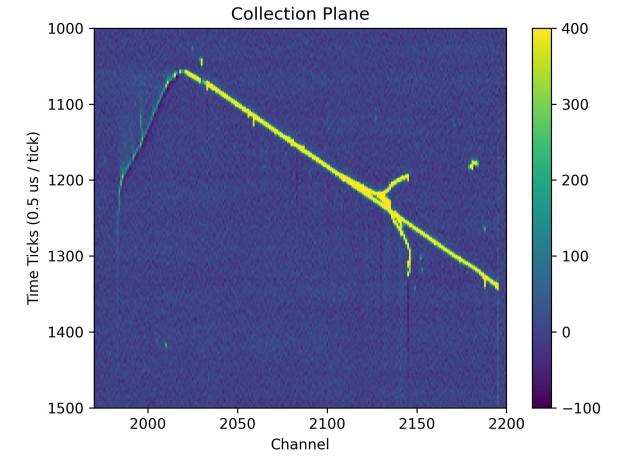
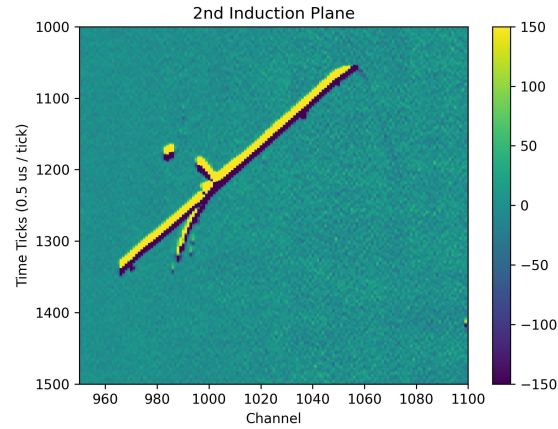
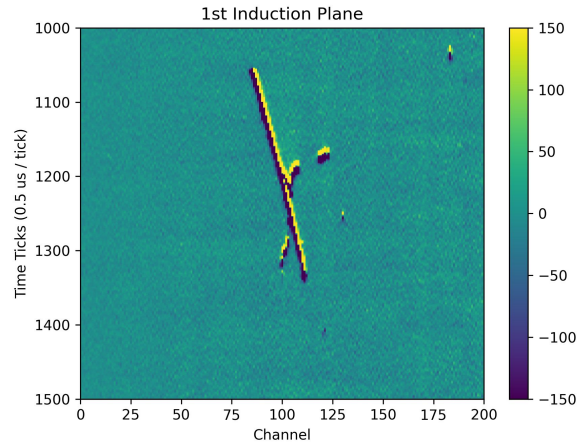
Coherent Noise in CRPs

- CRPs see the same coherent noise peak as the APAs, with similar dependence on the DC/DC power settings
- But overall magnitude is small, comparable to the best lower APA performance

CRP Noise Power Spectrum Comparison
All Channels Summed



Tracks from CRP Coldbox Test



Summary

- APA and CRP coldbox tests at CERN have provided fully integrated system tests of the final cold ASIC designs
 - Cold gas tests for APAs and liquid argon tests for CRPs, sometimes involving multiple thermal cycles of the same detector/FEMBs
- No ColdADC or COLDATA have shown problems or evidence of any damage over the course of these tests
- Some issues with coherent noise pickup remain, but we are fairly certain this is unrelated to the ASIC design
 - Some relation to the WIBs and the power that the WIB supplies to the FEMBs