

BDE Performance Summary from Coldbox Tests for ProtoDUNE-II

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FD2 BDE FDR
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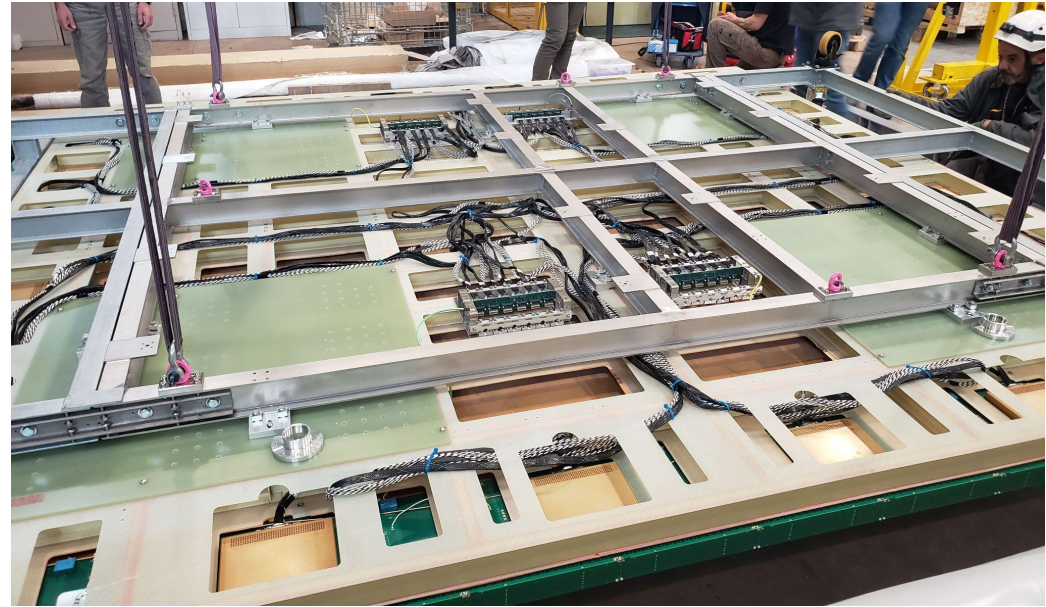
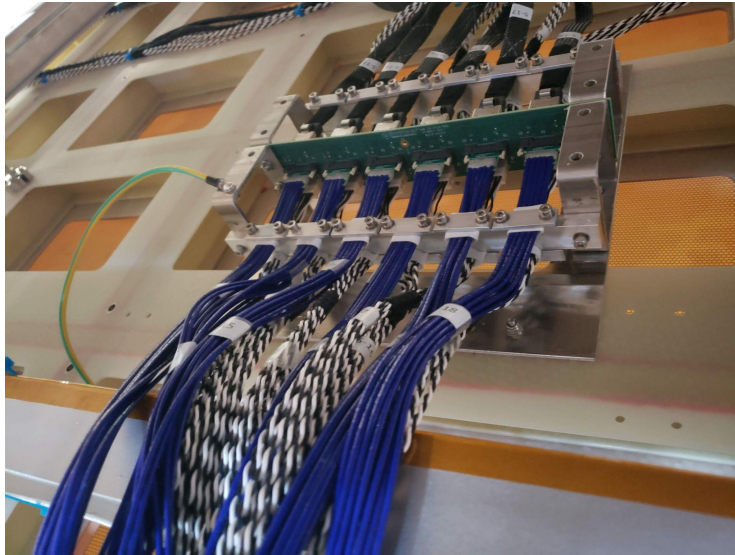


Summary of Tests

- **Addressing Charge Questions:**
 4. Has the design of the patch panel been finalized, a prototype produced, tested and validated with a CRP?
 9. Have the CRP tests with the FEMBs, miniSas cables and the final patch panel been completed?
- 2 bottom CRPs (CRP4 and CRP5) for ProtoDUNE-II-VD have been fully instrumented and tested in a liquid argon coldbox at CERN, and are now installed in the NP02 cryostat
- Input to the BDE performance has also been received from gas coldbox tests of the 4 APAs for ProtoDUNE-II-HD, which used almost the same FEMB and WIB designs
 - 2 upper APAs (APA1 and APA2), 2 lower APAs (APA3 and APA4)

CRP Layout

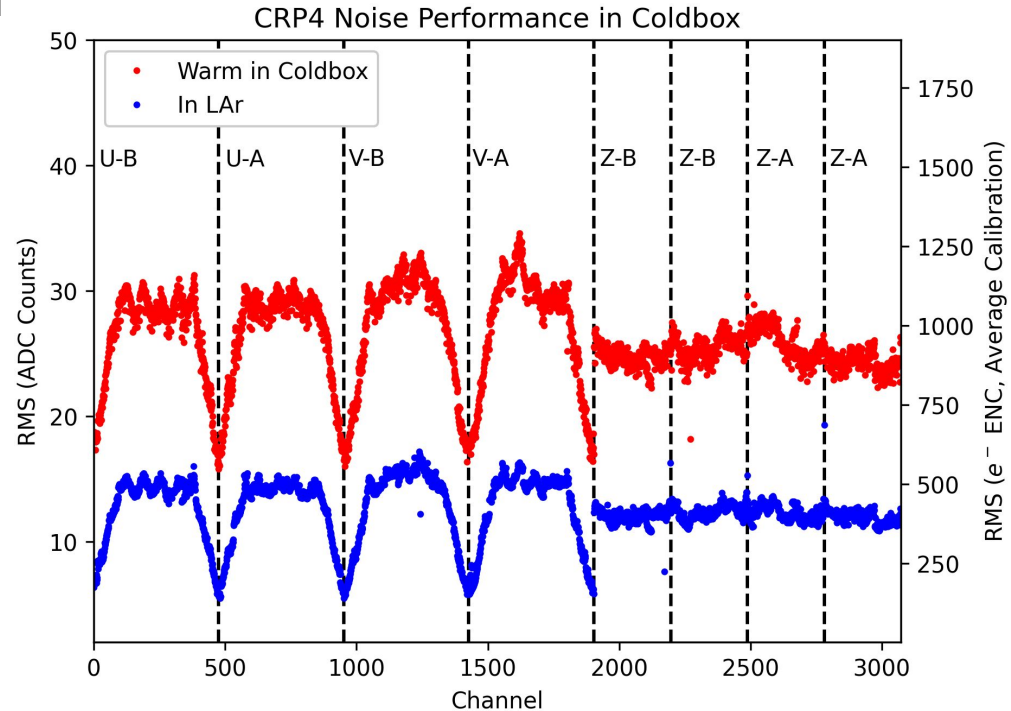
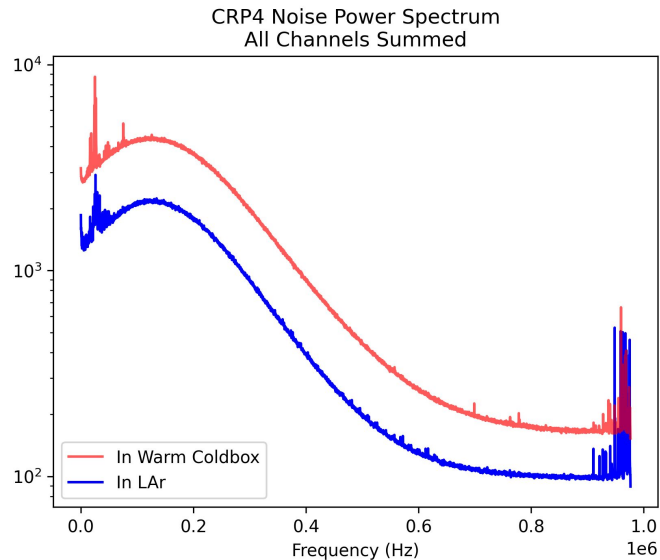
- Each CRP has 24 FEMBs, using the 25 meter power/samtec cable + patch panel + 2.5-3 meter power/mini-SAS cable



- CRP5 contains 1 old-design patch panel, but the other patch panels are all the final design
- CRP4 uses 2.5 meter power and mini-SAS cables from the patch panel
- CRP5 uses 2.5 meter power cables and 3 meter mini-SAS cables from the patch panel

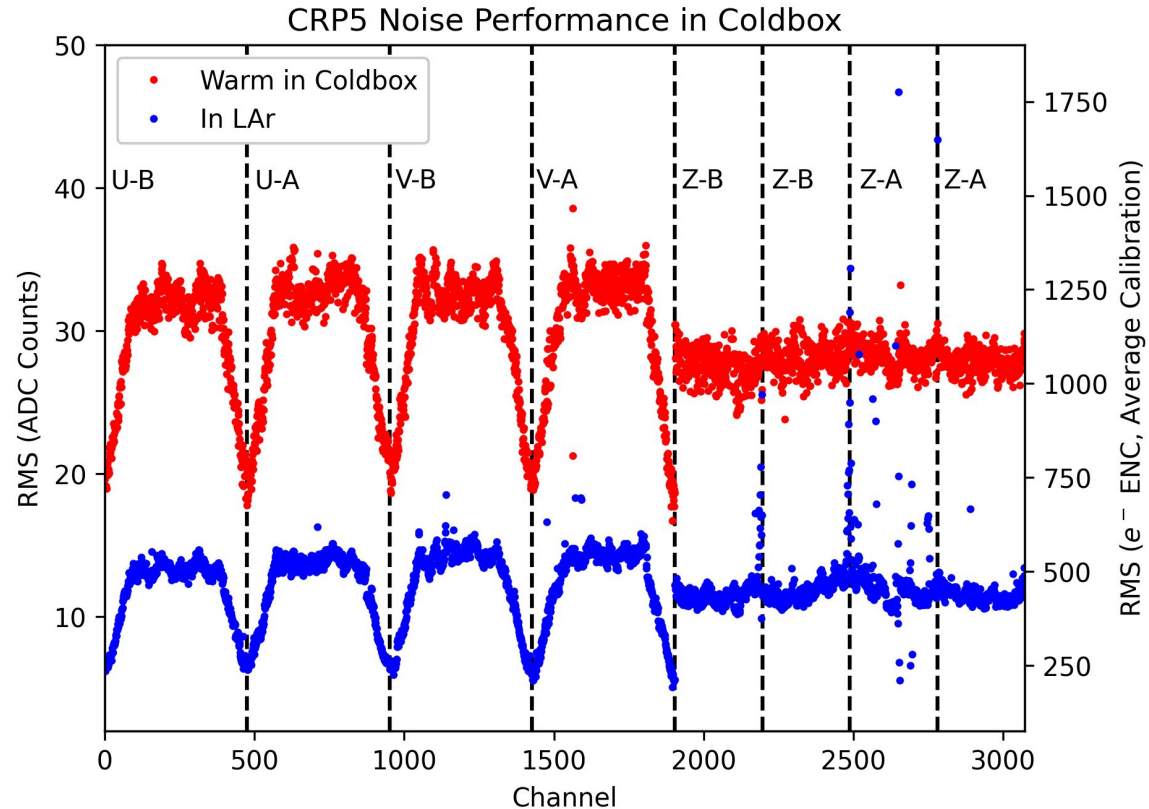
CRP Coldbox Tests

- No problems with ASIC response in LAr
- Noise levels are well below DUNE requirements



CRP Coldbox Tests

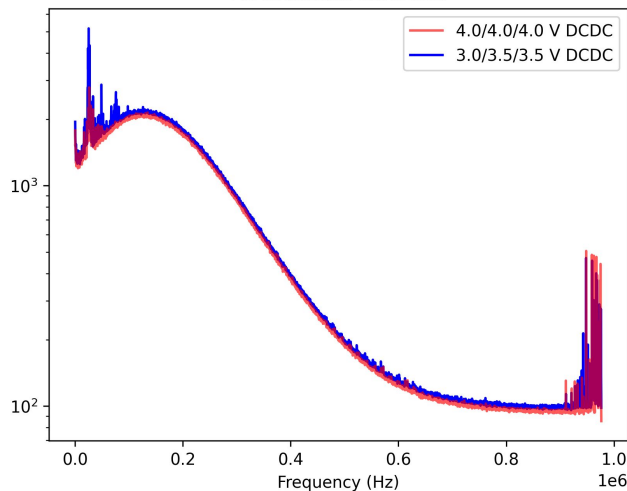
- CRP5 experienced a number of unexpected noise issues at cold
- Some of these are believed to be detector-level issues caused by faulty connections
- In general the extra noise is limited to ~1% of channels, and there were no issues with data integrity and ASIC response



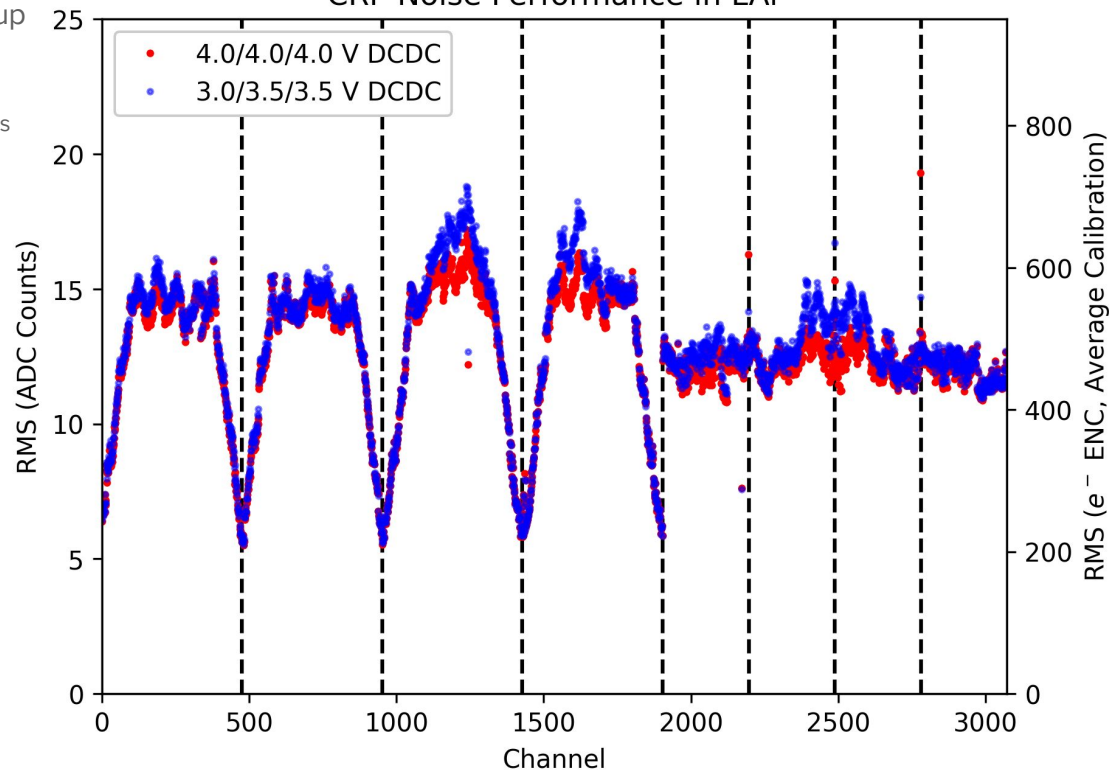
Coherent Noise in CRPs

- Some noise contribution from a coherent pickup peaked around 25 kHz, the same frequency seen on the APAs
 - Exhibits dependence on the DC/DC power settings that WIB uses to supply the FEMB power rails
- But overall magnitude is small, comparable to the best lower APA performance

CRP Noise Power Spectrum Comparison
All Channels Summed



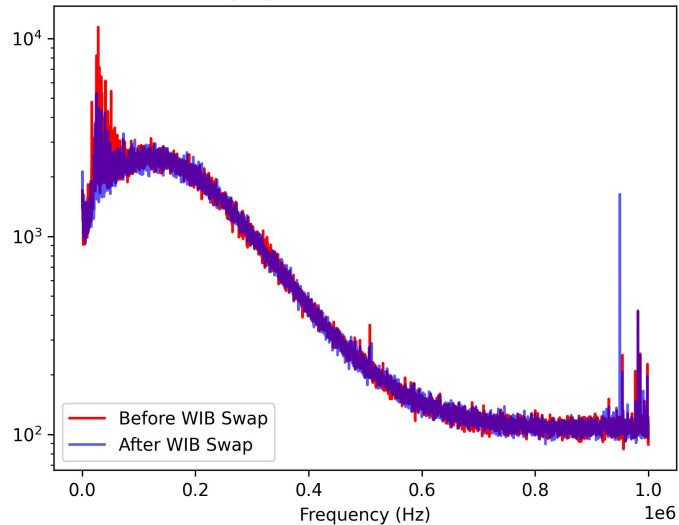
CRP Noise Performance in LAr



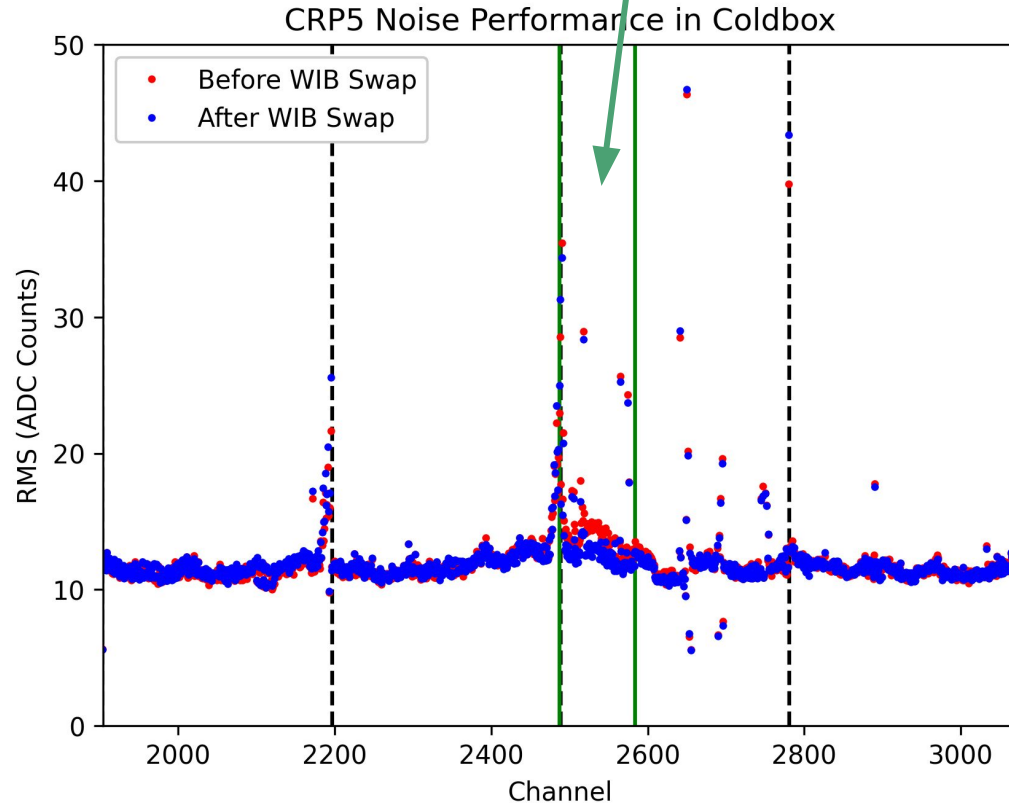
Coherent Noise - WIB Swap

- Following lessons from the APA, tried swapping a WIB that was controlling a FEMB that saw extra coherent noise pickup
- Coherent noise suppressed after WIB swap

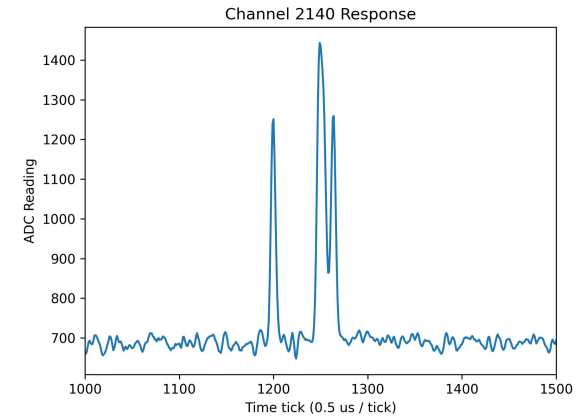
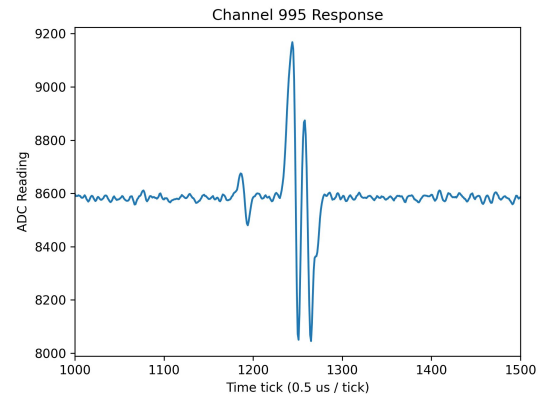
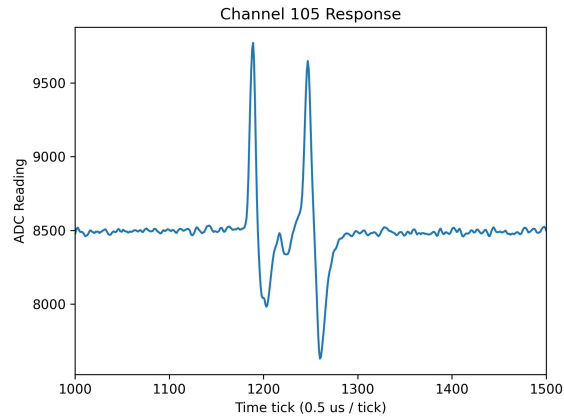
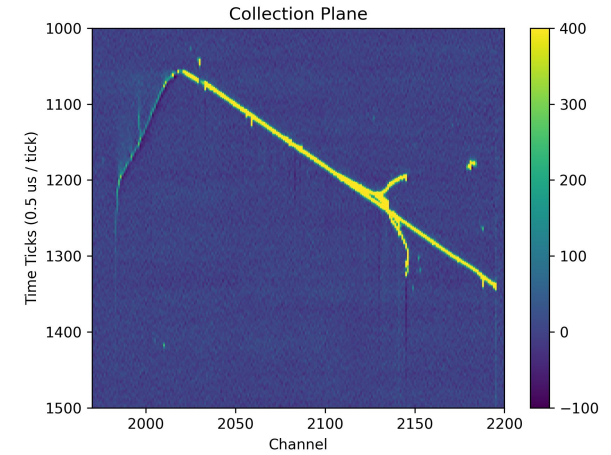
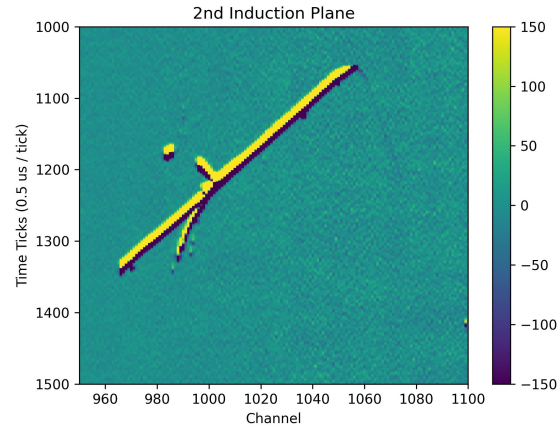
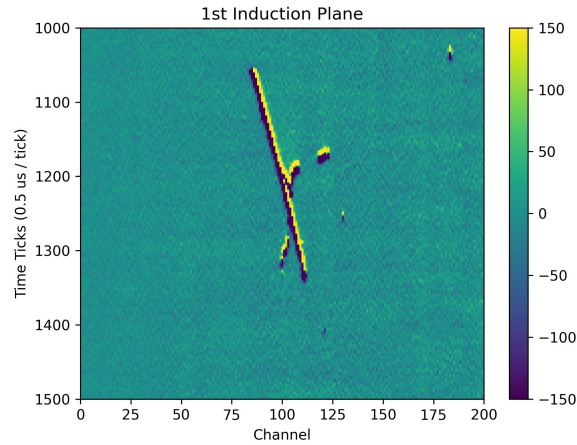
CRP5 Noise Power Spectrum
2 μ s shaping, FEMB12 Collection Channels



FEMB controlled by WIB that was swapped

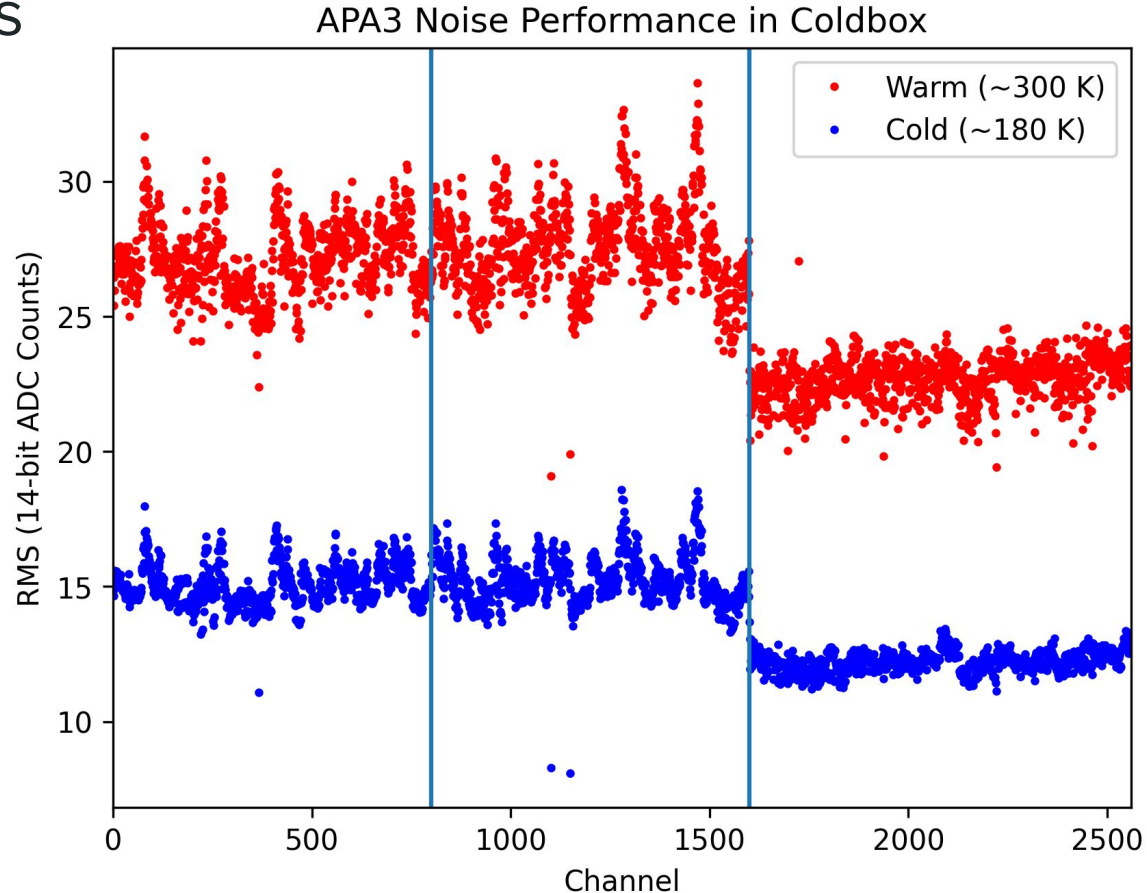


Tracks from CRP Coldbox Test



Channel Noise on APAs

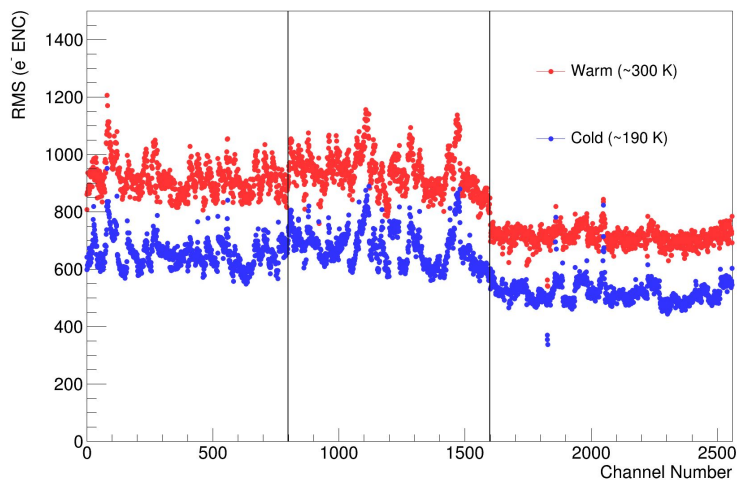
- APAs use the same ASICs, same WIBs, and same general FEMB design as the bottom CRPS
- APA pedestal noise levels are also well within required specifications
 - Tested only in cold gas, around 160-190 K
- No issues with FEMB response observed at either warm or cold



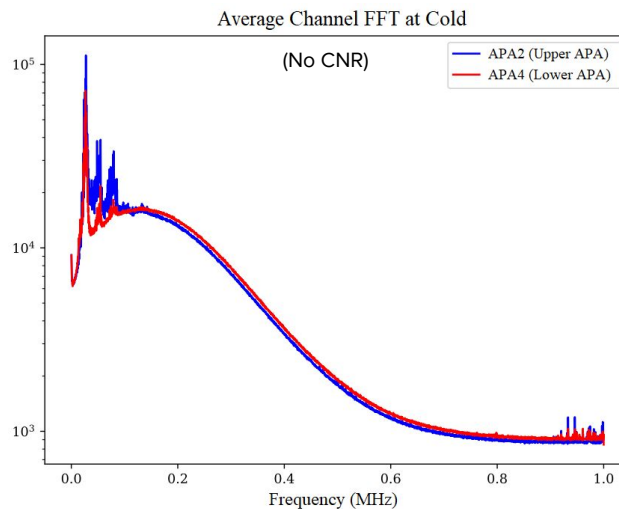
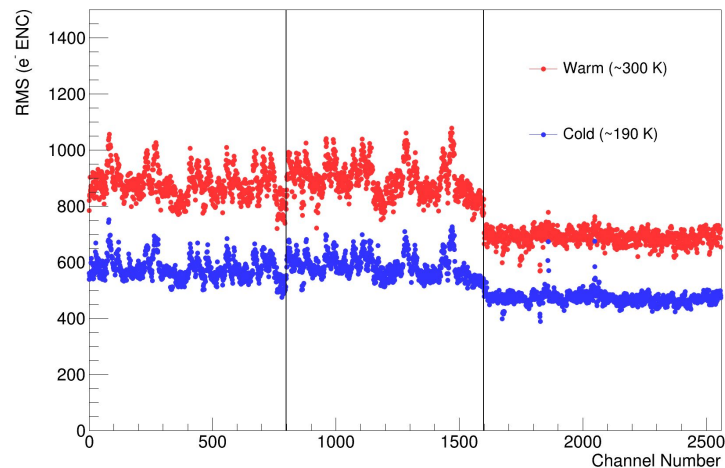
Coherent Noise

- APAs also see the ~25 kHz coherent noise pickup
- Magnitude of coherent noise is generally smaller on lower APAs and CRPs compared to upper APAs

APA4 Noise Performance without CNR

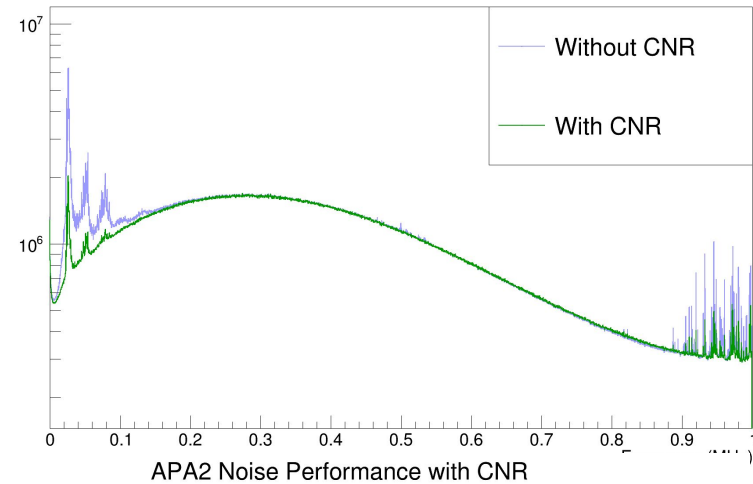


APA4 Noise Performance with CNR

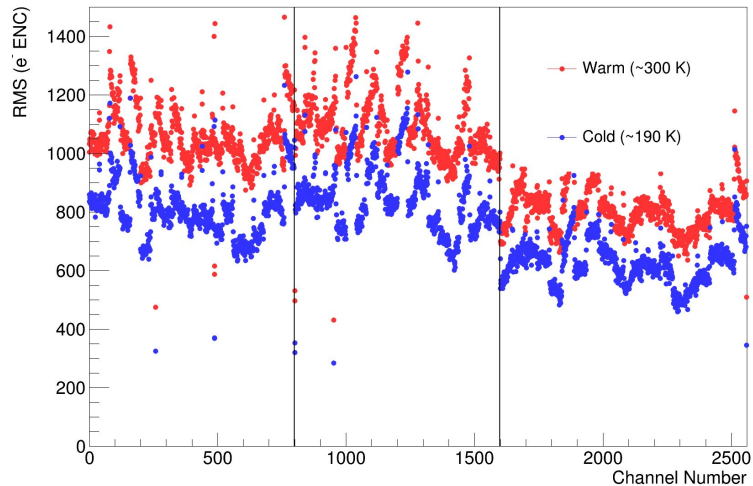


Coherent Noise

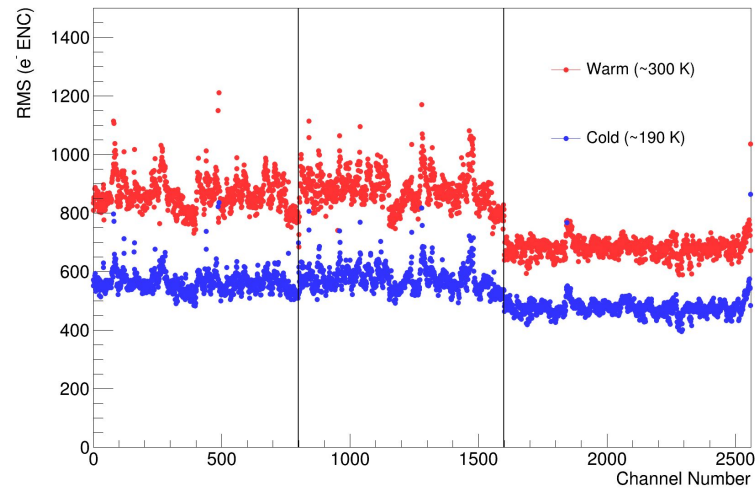
- This additional noise can be mostly suppressed by coherent noise removal (CNR) algorithms in offline analysis



APA2 Noise Performance without CNR

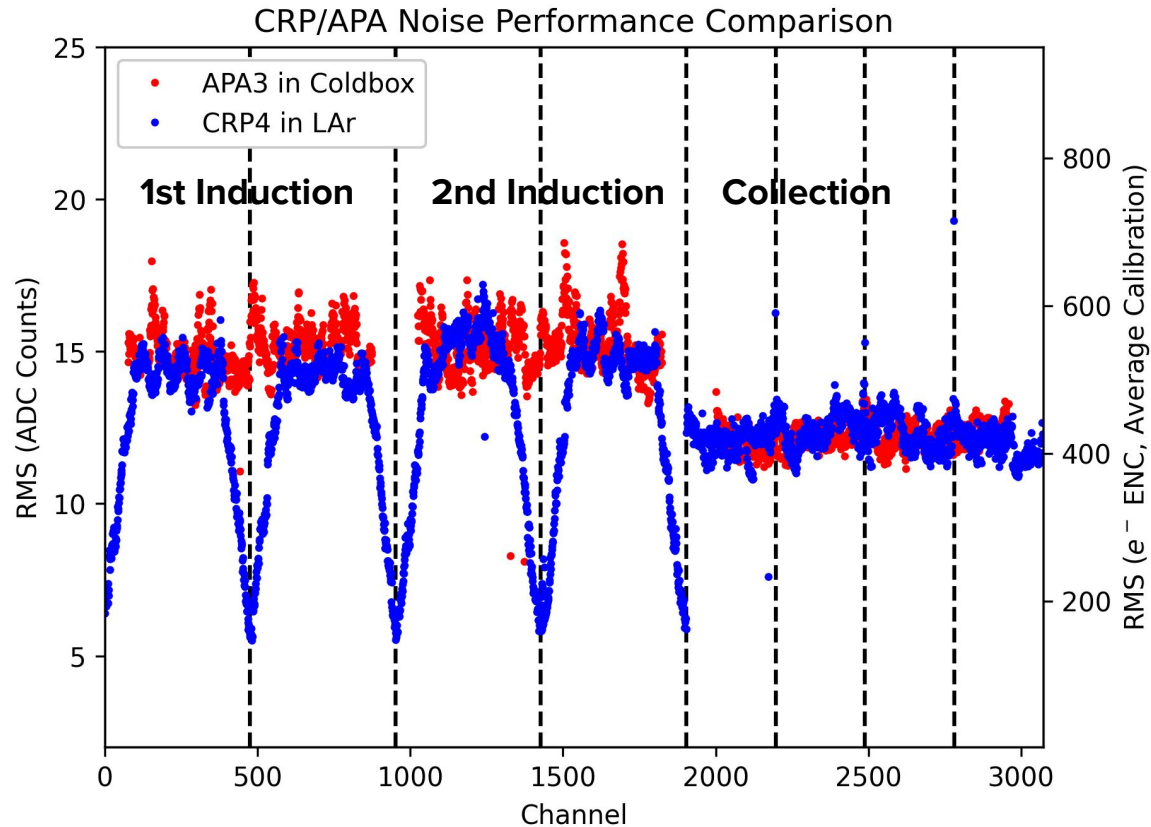


APA2 Noise Performance with CNR



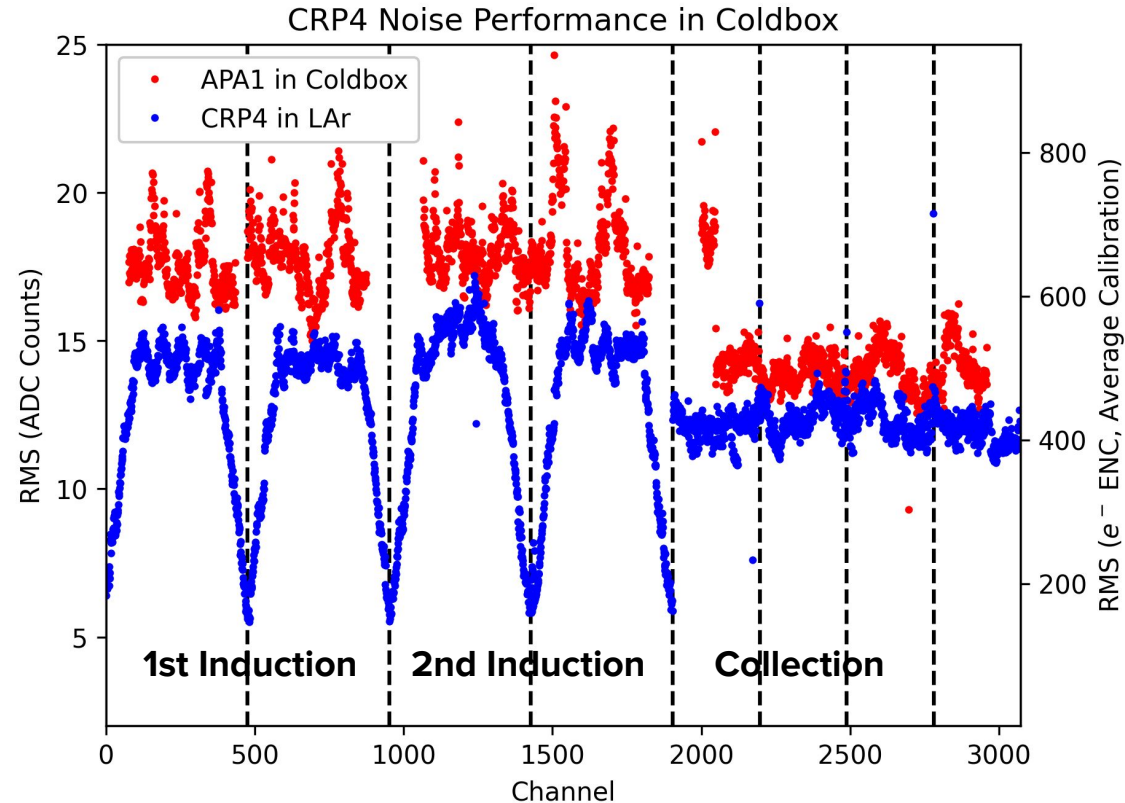
CRP/APA Noise Performance Comparison

- Overall noise performance on the CRPs in LAr has been comparable to the best noise performance we've obtained on the bottom APAs in cold gas



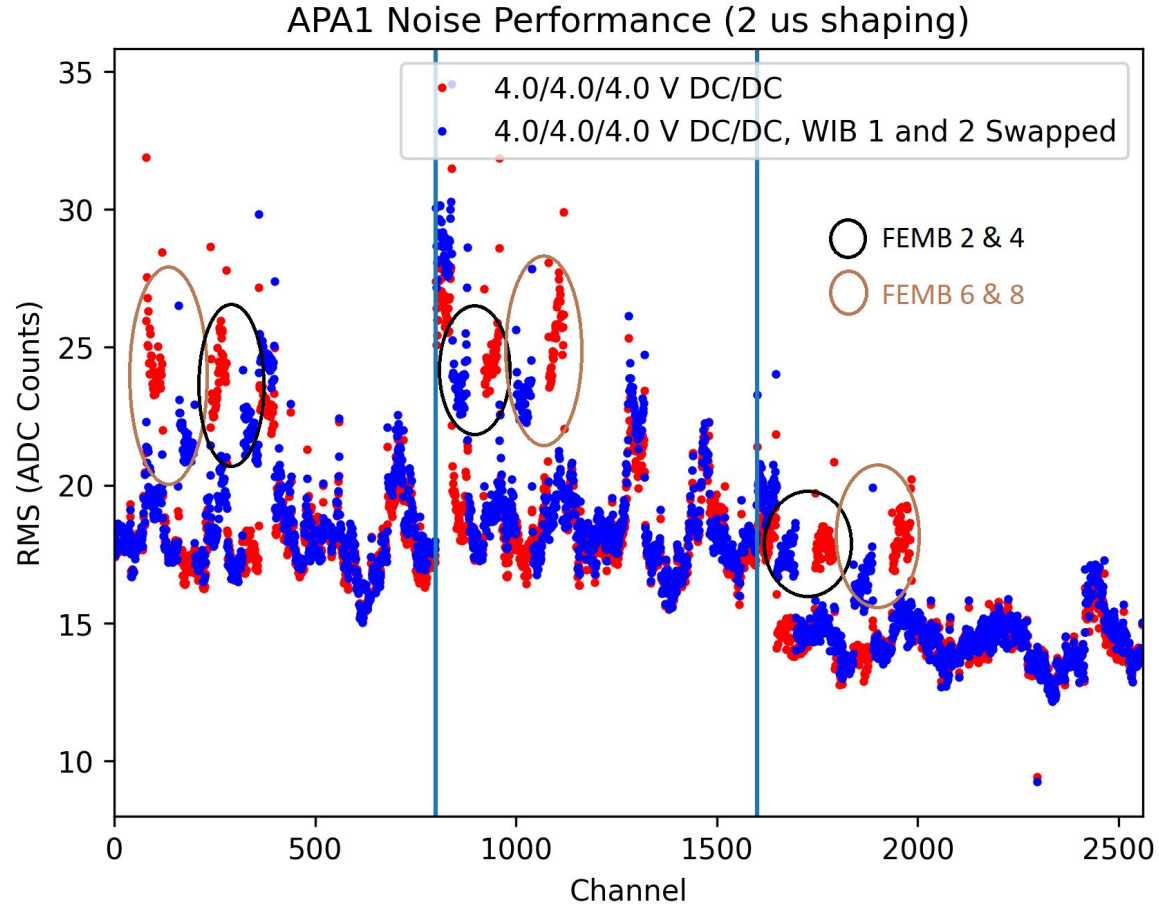
CRP/APA Noise Performance Comparison

- CRPs generally outperform the upper APAs in raw noise performance, due to higher coherent noise contributions in the upper APAs



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



Summary

- APA and CRP coldbox tests at CERN have provided fully integrated system tests of the FEMB designs and grounding schemes
 - Cold gas tests for APAs and liquid argon tests for CRPs, sometimes involving multiple thermal cycles of the same detector/FEMBs
- Effects from coherent noise pickup remain, but the overall magnitude is small on the CRPs
 - Related to some combination of effects from the system level grounding, the WIBs, and the power that the WIBs supply to the FEMBs
 - Expected impact on physics sensitivity is small, and remaining effects can be mostly removed offline
- 4 APAs have been installed in NP04 for the last half year
- 2 bottom CRPs are now installed in NP02

