The ICEBERG Test Stand for DUNE Cold Electronics Development

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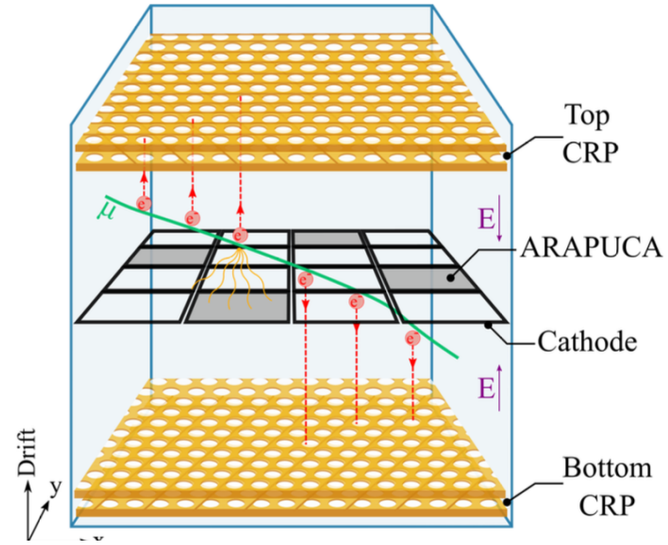
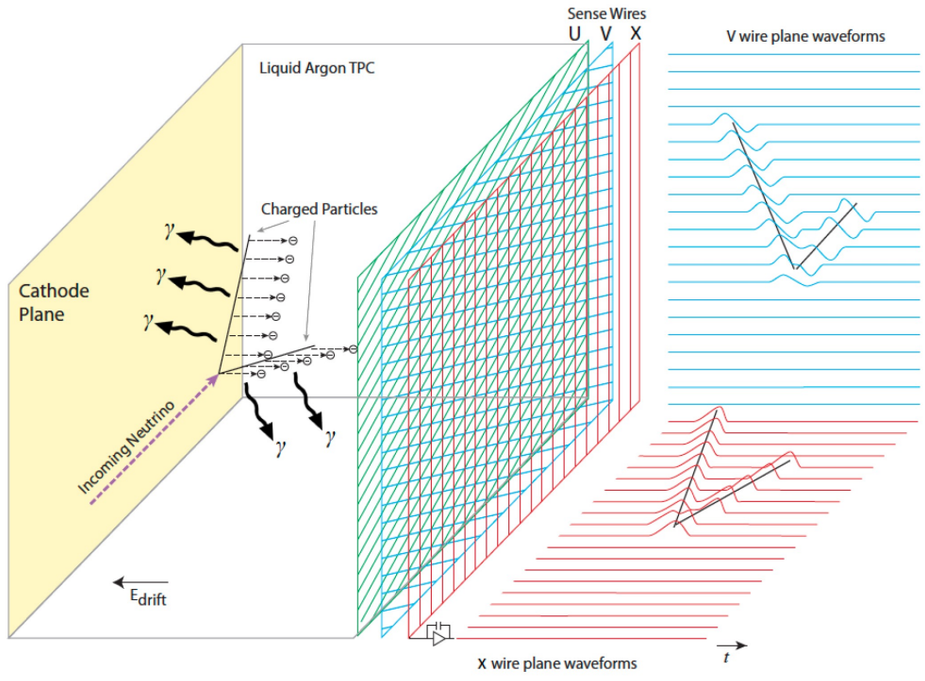
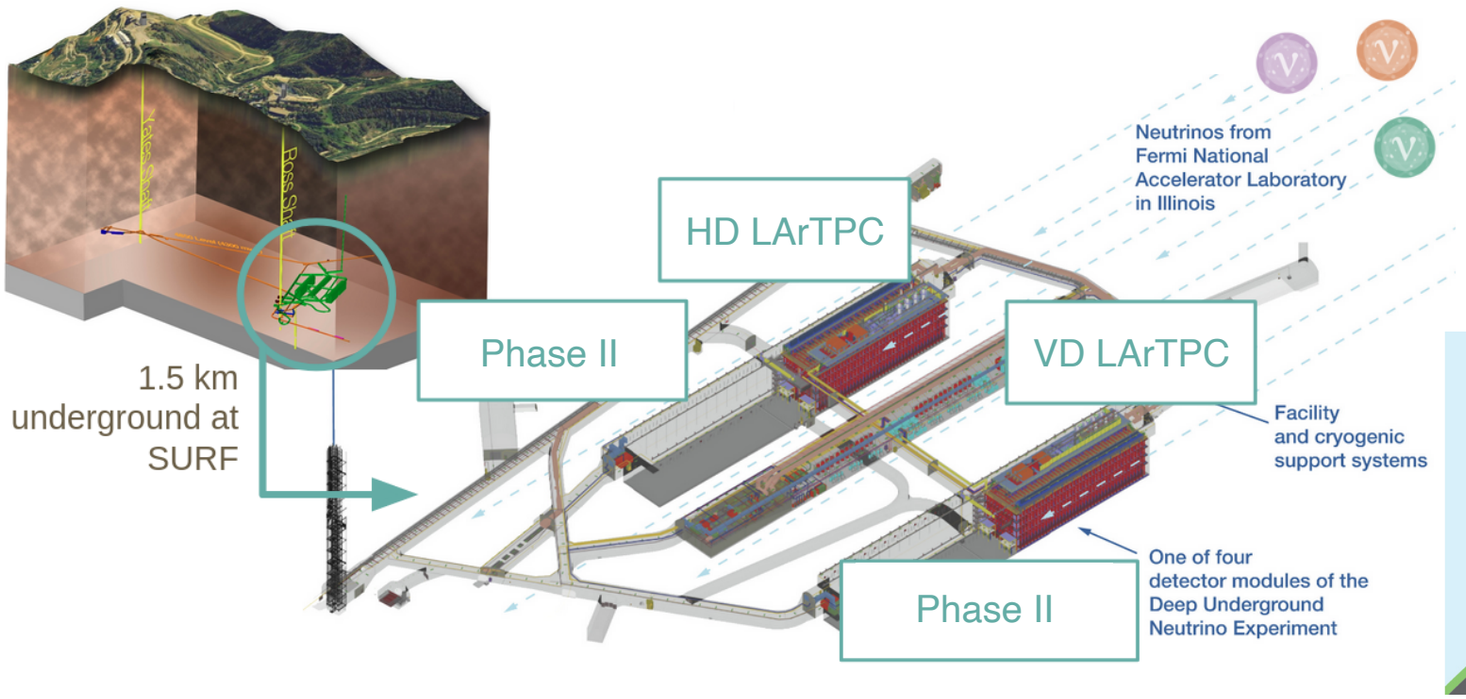
NuFact 2024, Argonne National Laboratory
WG 6: Detectors
September 19, 2024

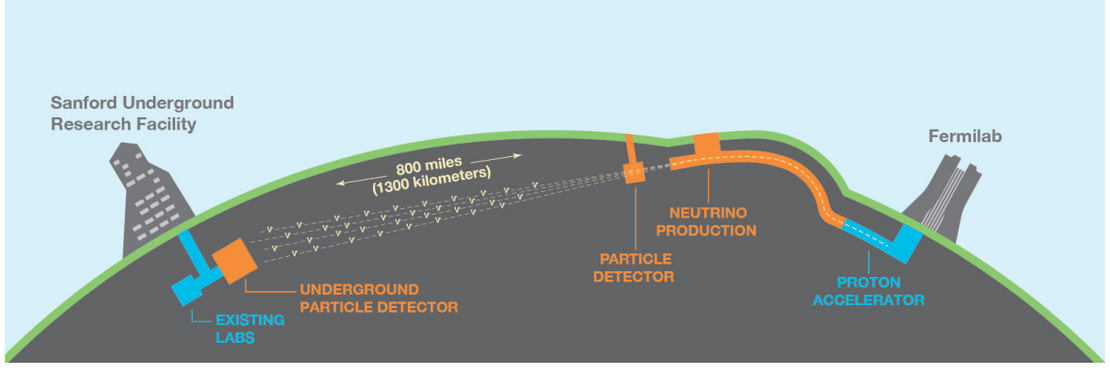
DUNE

- 1300km baseline neutrino oscillation experiment
- Four 17kt far detector LArTPCs modules







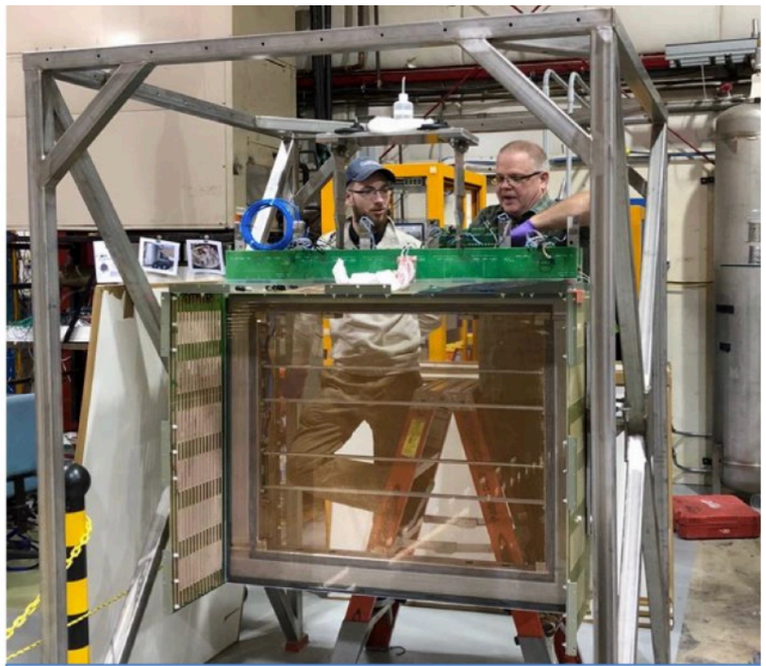


ProtoDUNE

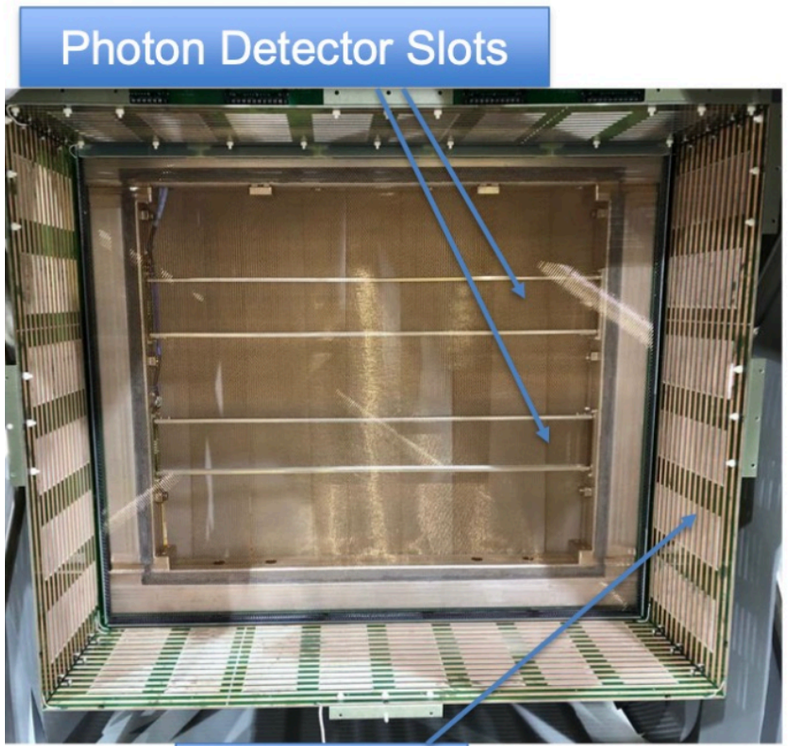
- Two LArTPC detectors located in CERN neutrino platform
  - Horizontal drift
  - Vertical drift
- 8m cubic cryostats (inner dimensions) with 0.77kt LAr
- Take cosmic data and beam data from dedicated beam lines from CERN's Super Proton Synchrotron
- HD started second run in May

ICEBERG

- **I**ntegrated **C**ryostat and **E**lectronics **B**uilt for **E**xperimental **R**esearch **G**oals
- Compact test LArTPC at Fermilab with two 1.15m × 1m × 0.3m drift volumes.
- Two scintillator bars outside of cryostat for coincident triggering on cosmics traveling parallel to wires.



Wire Spacing, Gaps etc. like DUNE

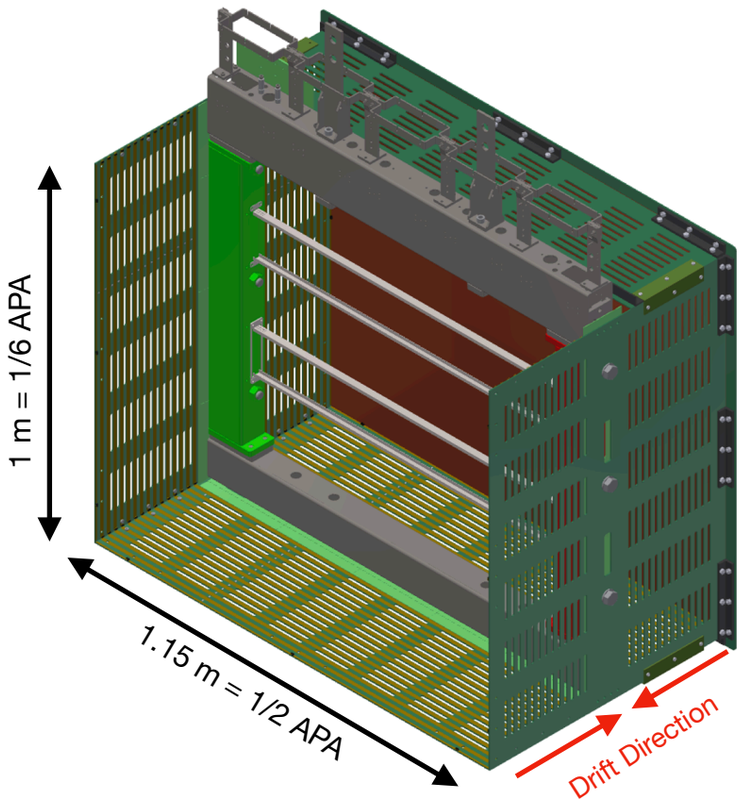


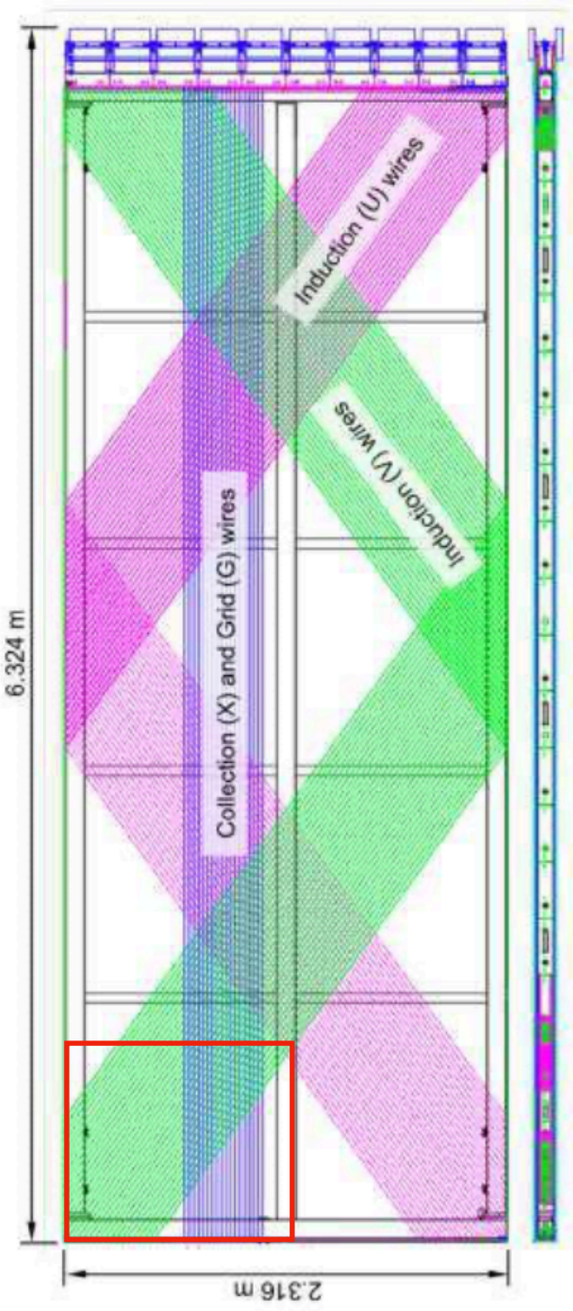
Field Cage

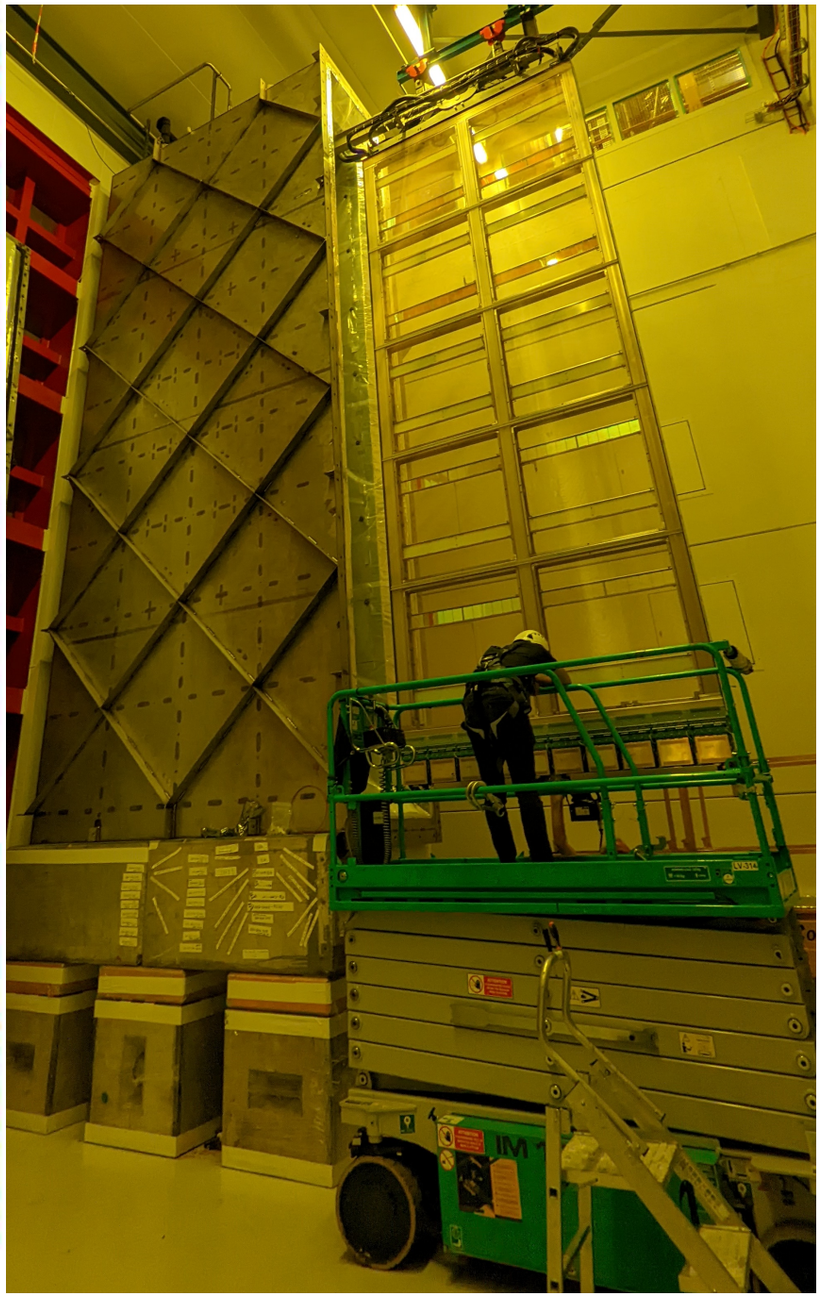
Scintillator Bar

Anode Plane Assembly

- 1280 channels (1/2 of full DUNE APA).
- APA in middle of detector, cathodes at ends.



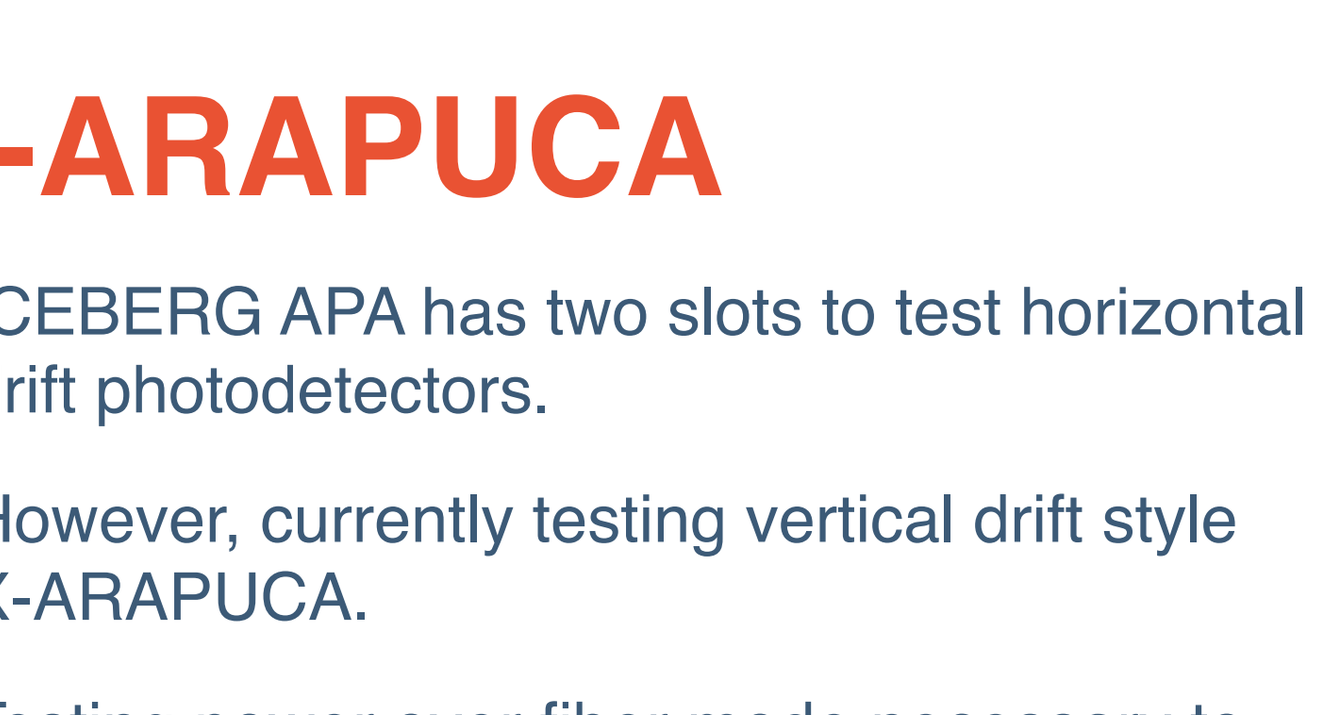




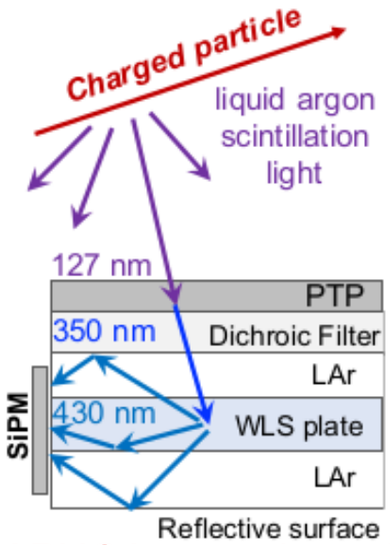
DUNE APA schematic and picture. ICEBERG APA size in red.

X-ARAPUCA

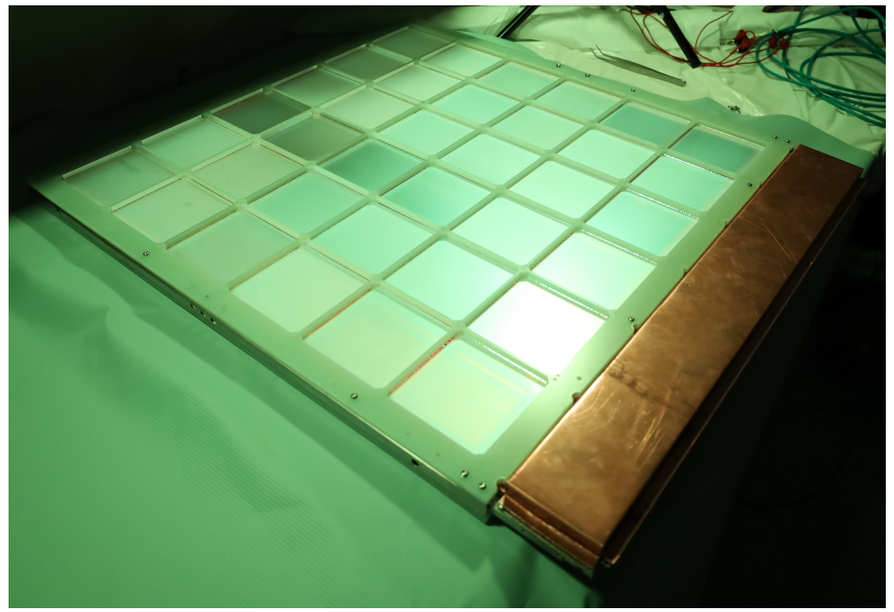
- ICEBERG APA has two slots to test horizontal drift photodetectors.
- However, currently testing vertical drift style X-ARAPUCA.
- Testing power over fiber mode necessary to place detector on DUNE VD cathode at -300kV (see Diana's & Sabrina's talks tomorrow)



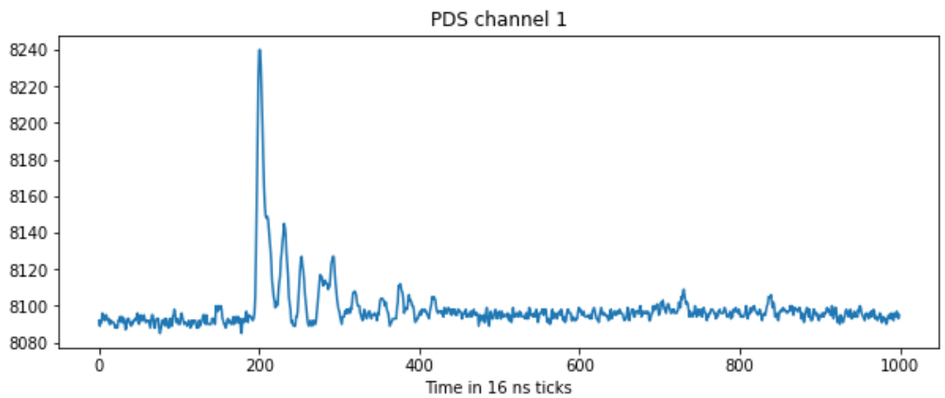
X-ARAPUCA attached to bottom of TPC.



ARAPUCA operating principle.



Vertical drift X-ARAPUCA photodetector.



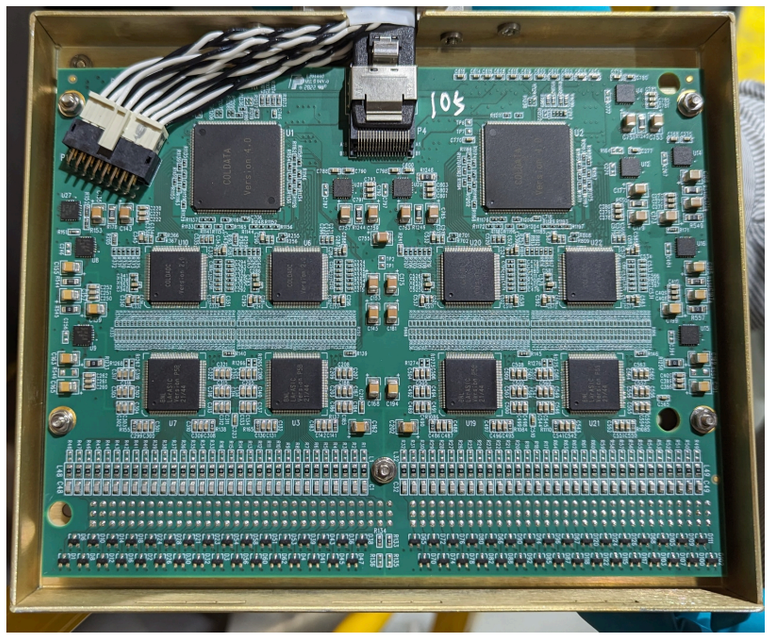
Sample photodetector pulse.

Goals

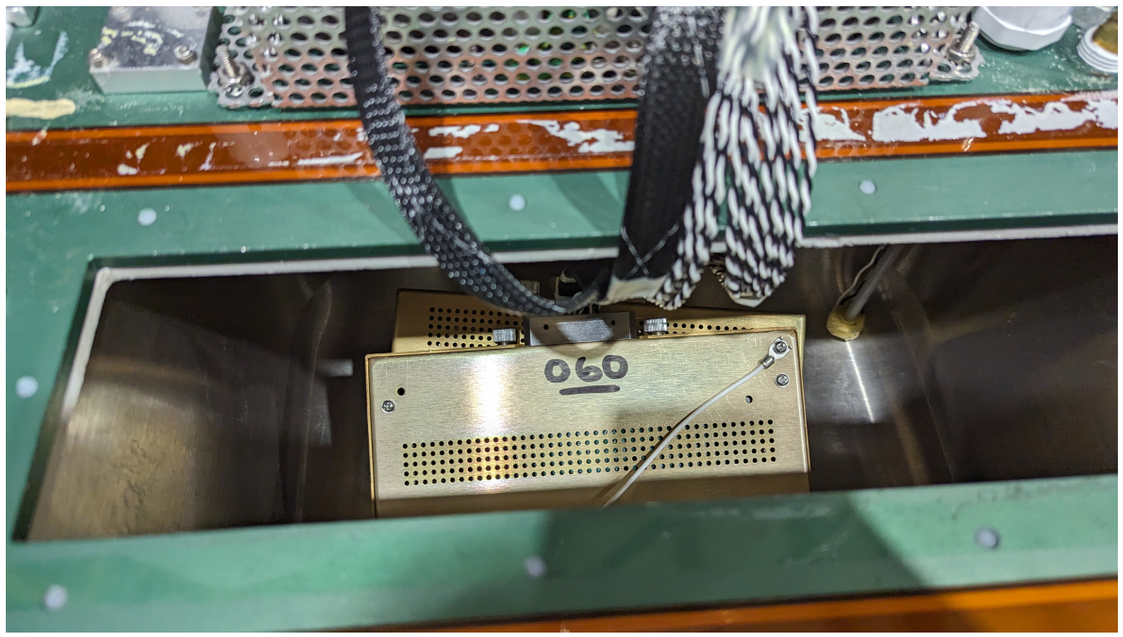
- Test latest versions of DUNE cold electronics.
- Test vertical-drift style X-ARAPUCA photodetector.
- Test new detector safety system.
- Advise DUNE/ProtoDUNE on optimal choice of electronics settings.
- Develop AI-based calibration method using ^{39}Ar decay and Michel electrons from cosmic triggers.

Electronics Testing

- Front-end mother boards (FEMBs) for TPC readout consist of amplifier, digitizer, and transmitter chips.
- Newest versions tested in LN_2 after final cabling.



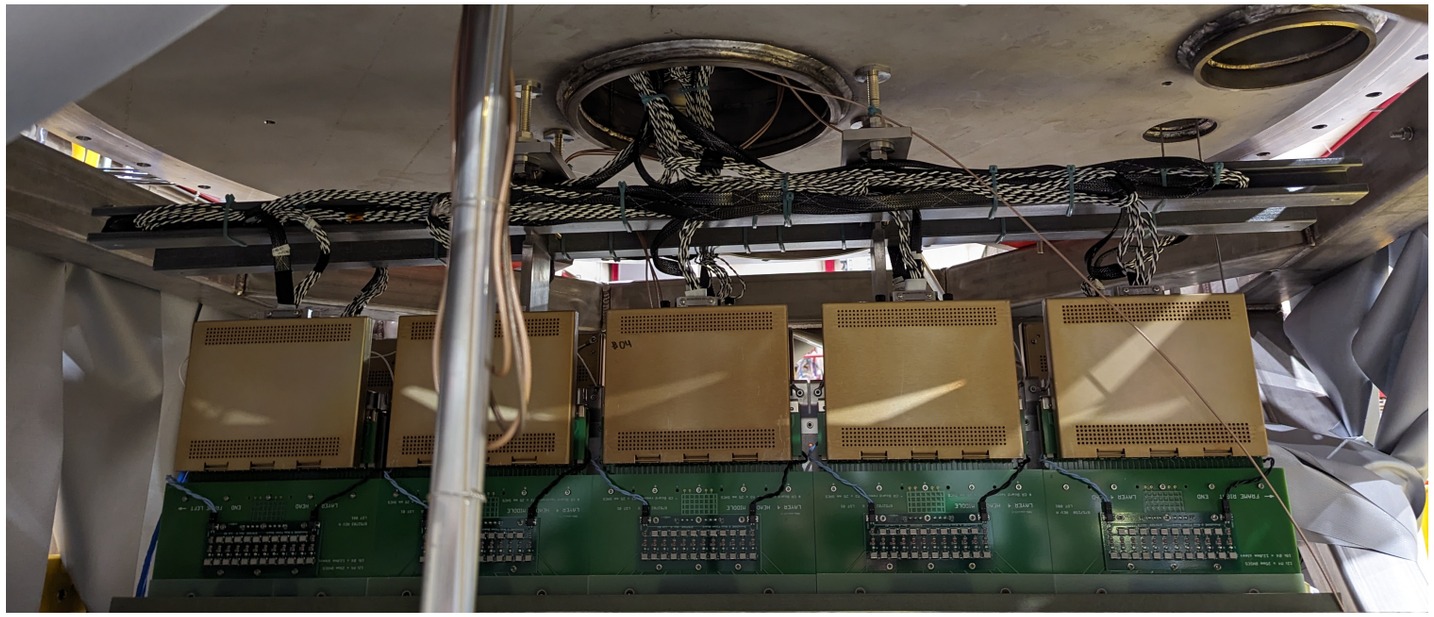
Inside of FEMB.



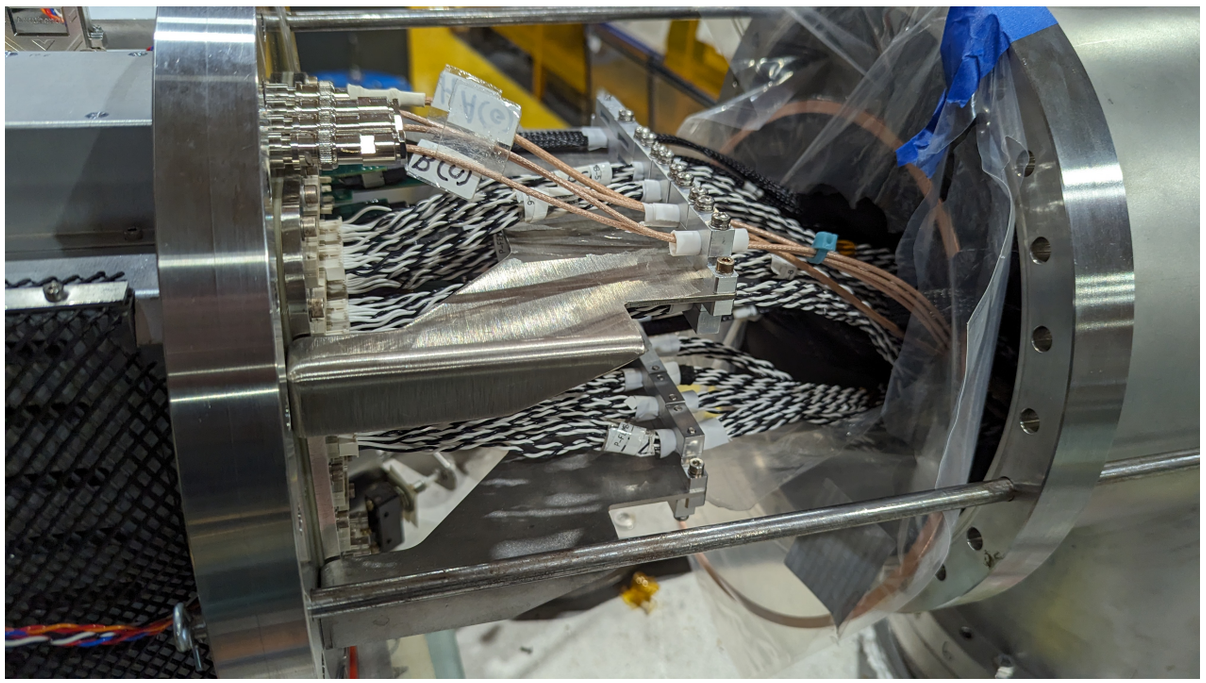
Two FEMBs placed in cryogenic test chamber.

Cryogenic test stand.

Commissioning



FEMBs mounted to top of APA (March 2024).

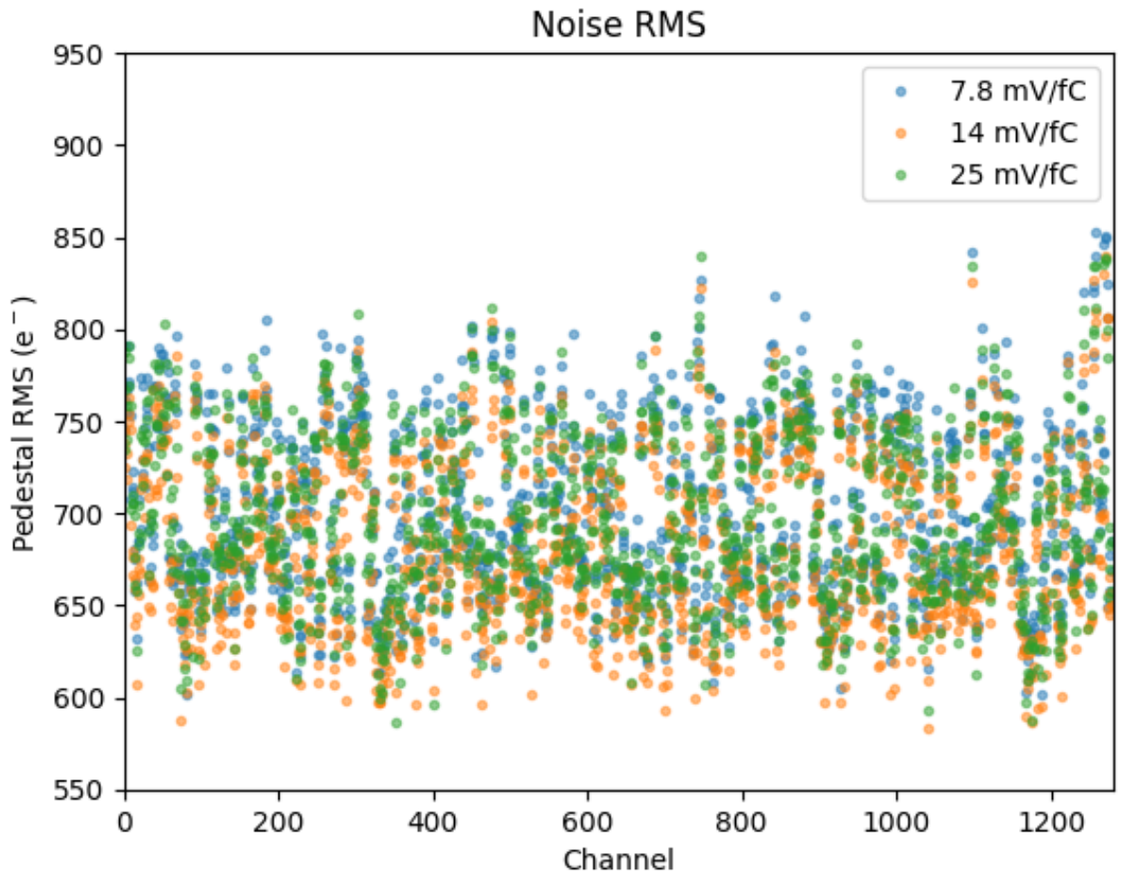


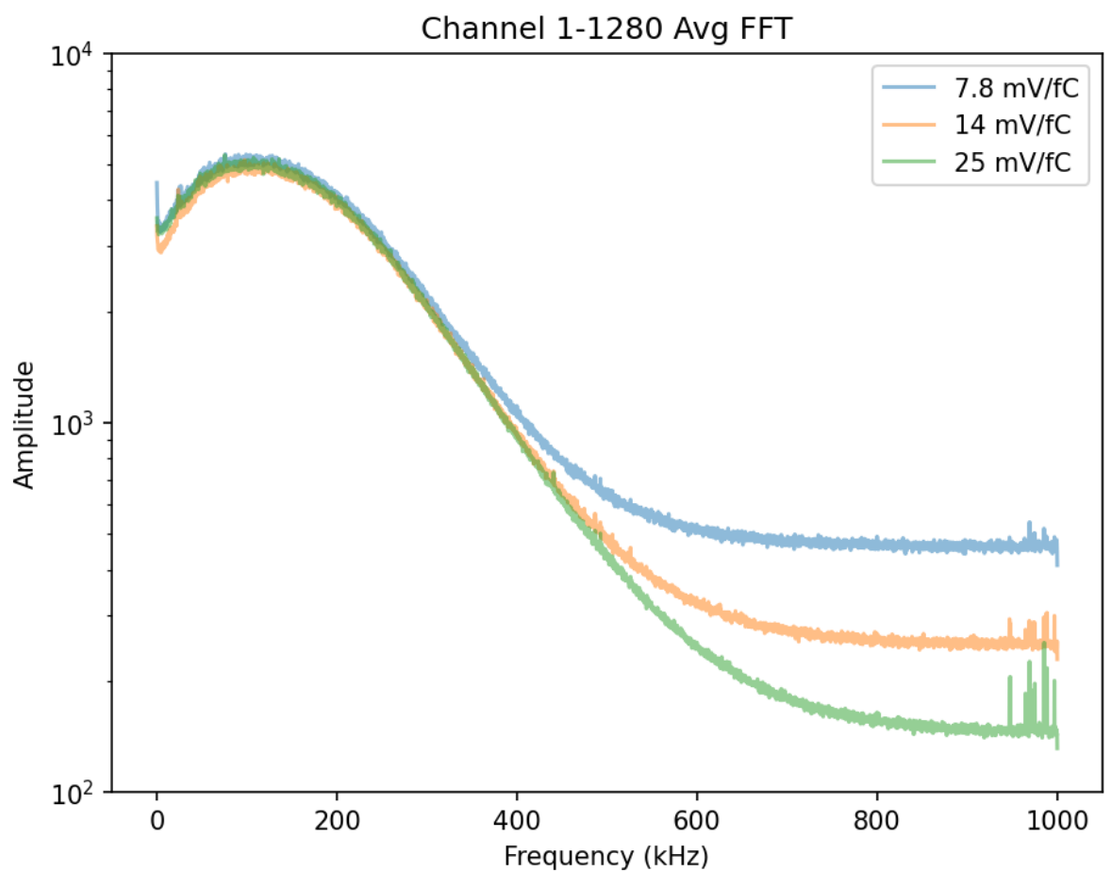
Cryogenic feedthrough on top of cryostat for TPC power, data, and HV cables.

Lifting of ICEBERG into cryostat (April 2024).

Cold Electronics Settings

- Noise data taken under various electronics settings to determine which gives best S/N ratio.
  - Voltage to each chip
  - Digitizer baseline
  - Amplifier gain
  - Amplifier shaping time



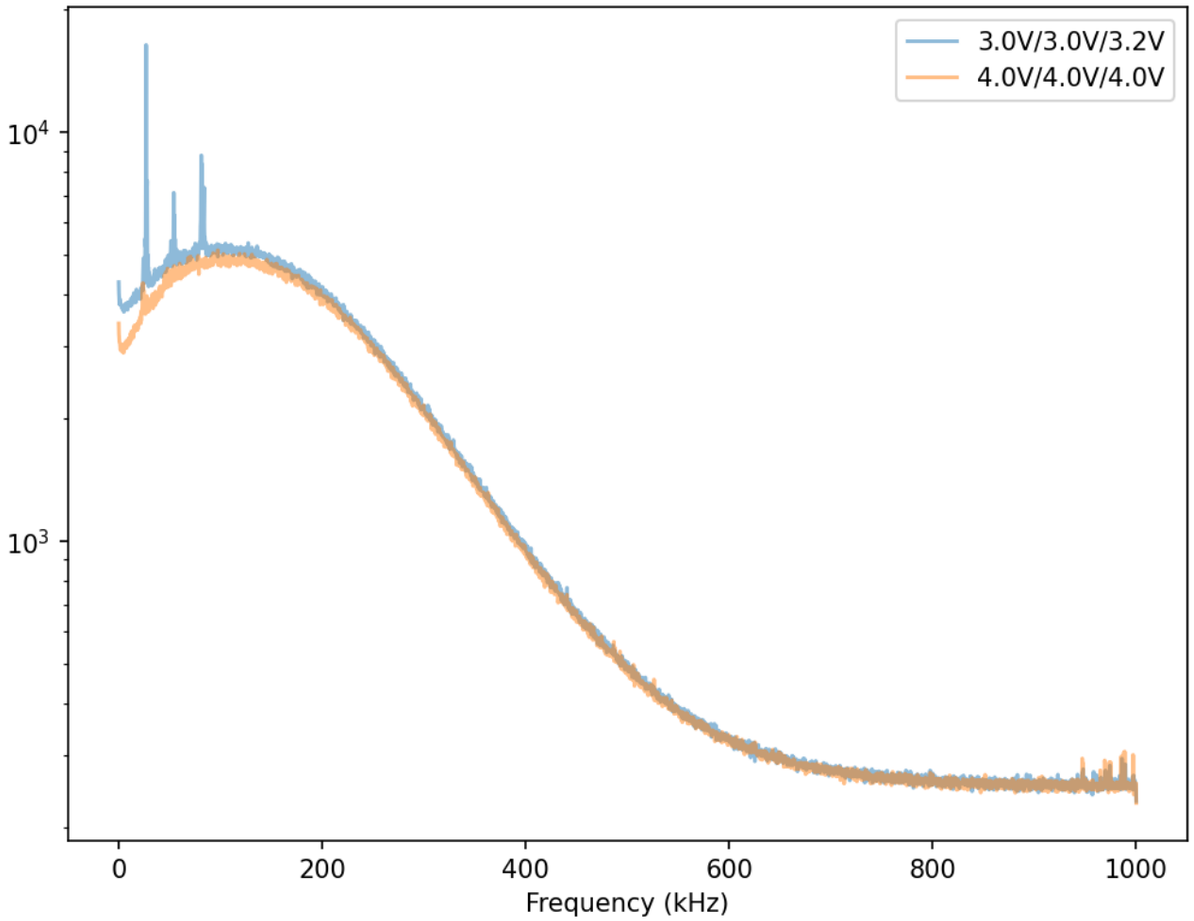


Waveform RMS of each channel (left) and average FFT over all channels (bottom) under various gain settings.

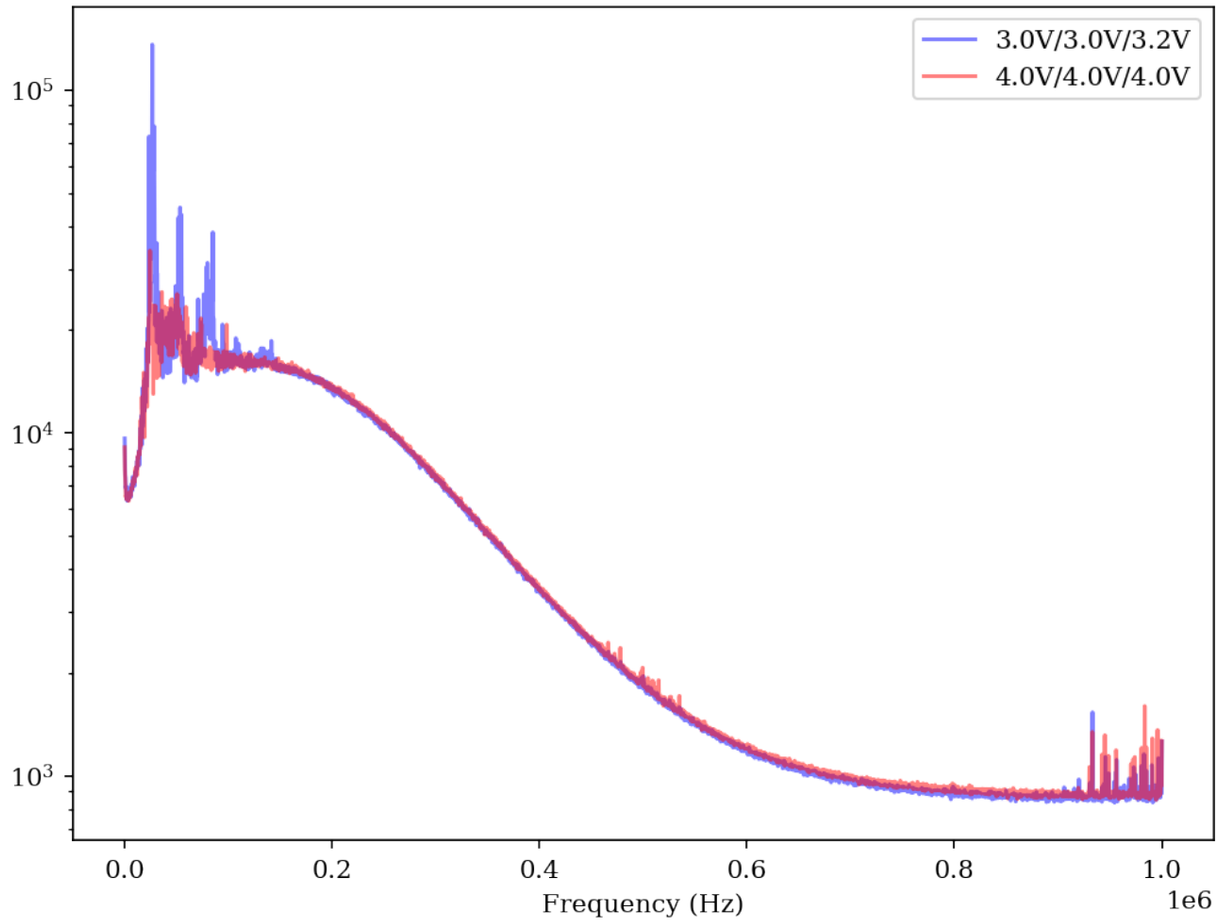
Varying Power Settings

- Applying higher voltage reduces 25kHz noise seen in both ICEBERG and ProtoDUNE APAs.

ICEBERG



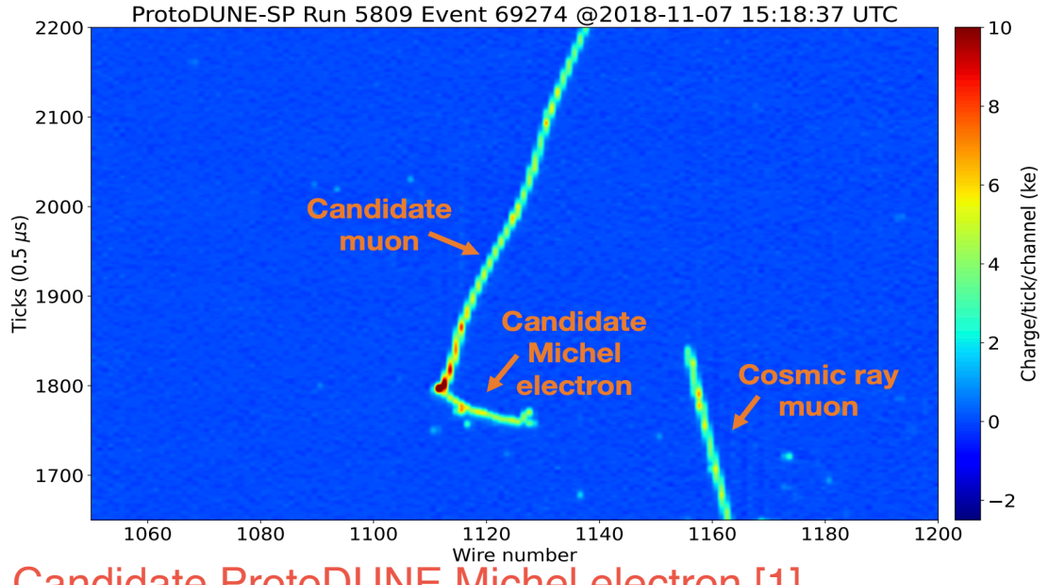
ProtoDUNE APA 1



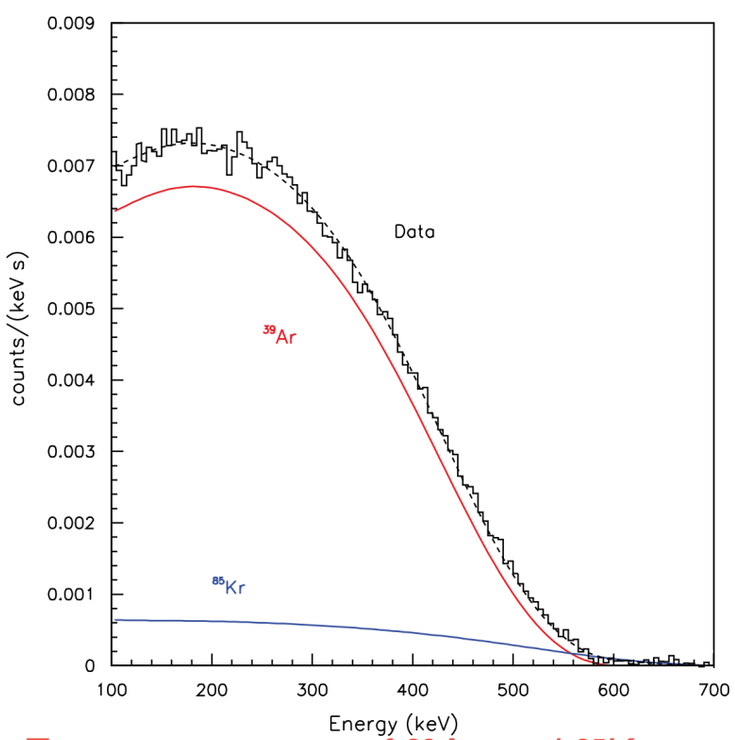
Average FFT of all channels under different power settings: recommend 3.0V/3.0V/3.2V and higher 4.0V/4.0V/4.0V. Left shows ICEBERG APA. Right shows one ProtoDUNE APA.

Absolute Calibration Scale

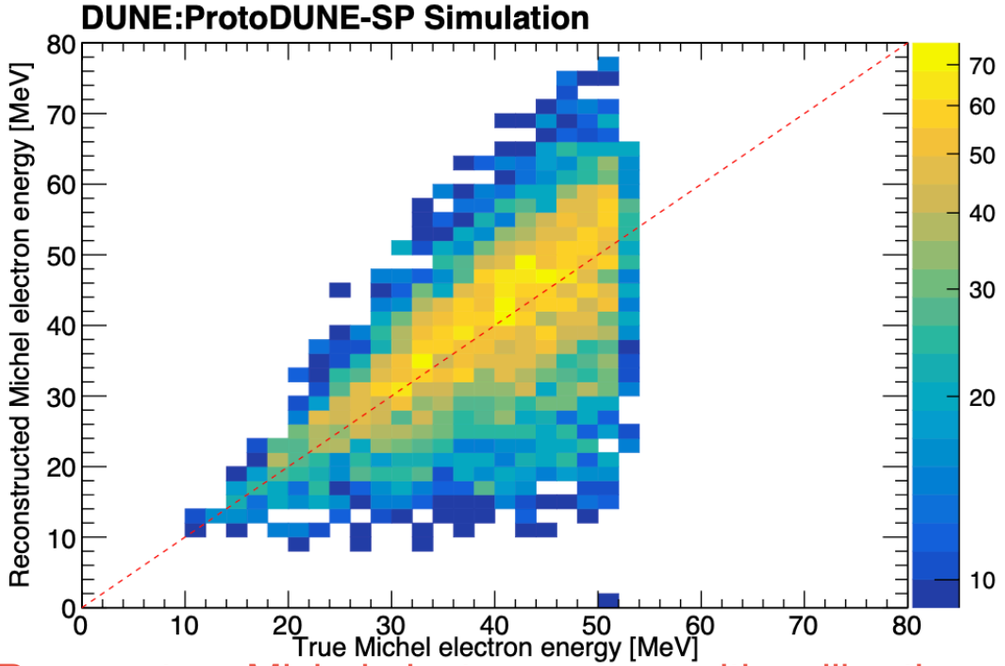
- Looking for absolute calibration method for TPC electronics
  - ^{39}Ar decay for O(~100keV)
  - Michel electrons for O(~10MeV)
- Michel electron energy scale calibration with ProtoDUNE Run I previously demonstrated [1]



Candidate ProtoDUNE Michel electron [1].



Energy spectrum of ^{39}Ar and ^{85}Kr measured at WARP experiment [2].

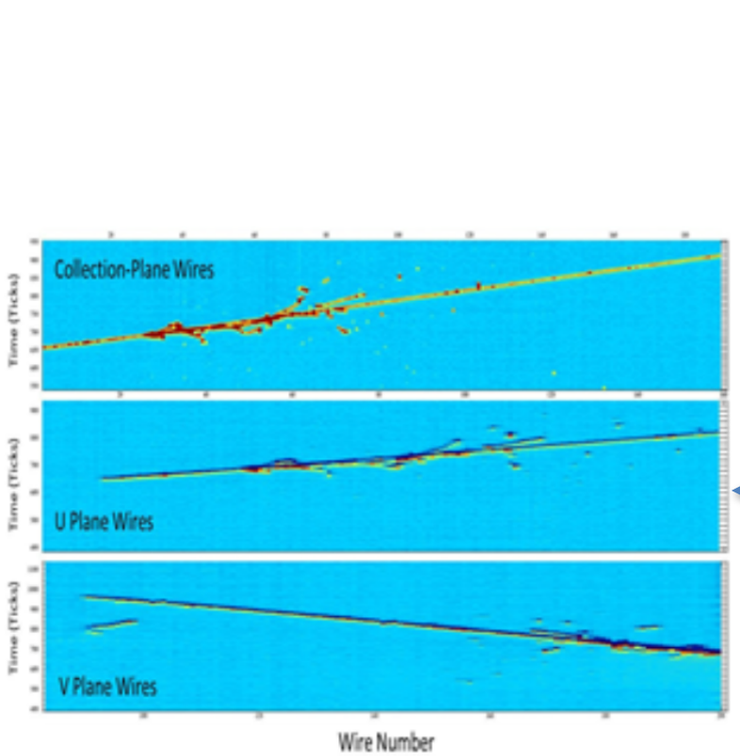


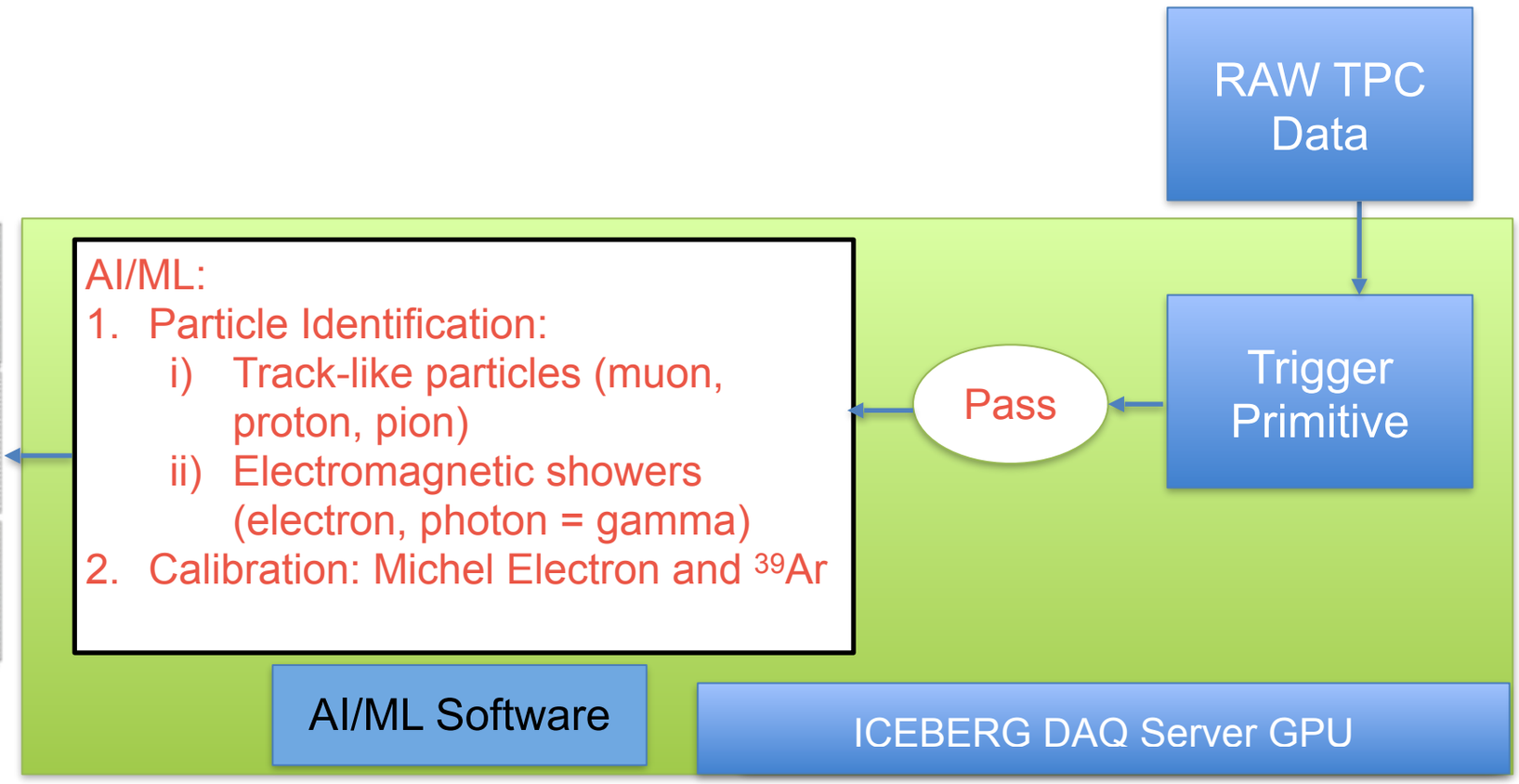
Reco vs true Michel electron energy with calibration based on theoretical Michel spectrum [1].

1. DUNE Collaboration. *Identification and reconstruction of low-energy electrons in the ProtoDUNE-SP detector*. Phys. Rev. D 107, 092012.
2. WARP Collaboration. *Measurement of the specific activity of ^{39}Ar in natural argon*. Nucl. Instrum. Methods Phys. Res. A 574, 83-88.

ν-OnEdge AI

- R&D in progress to implement AI-based identification of calibration events and high-level particle classification based on “trigger primitives”.





Summary

- ICEBERG restarted since May with upgraded cold electronics, current DAQ software, and VD photodetector.
- Primarily taking cosmics data; also running noise tests and with external pulses.
- Tests helped advise DUNE/ProtoDUNE on ideal gain, baseline, power setting, etc.
- Working on using ICEBERG DAQ to develop online AI-based identification of calibration events and PID.
- Current run will continue one more month. Aiming for next run in Winter.