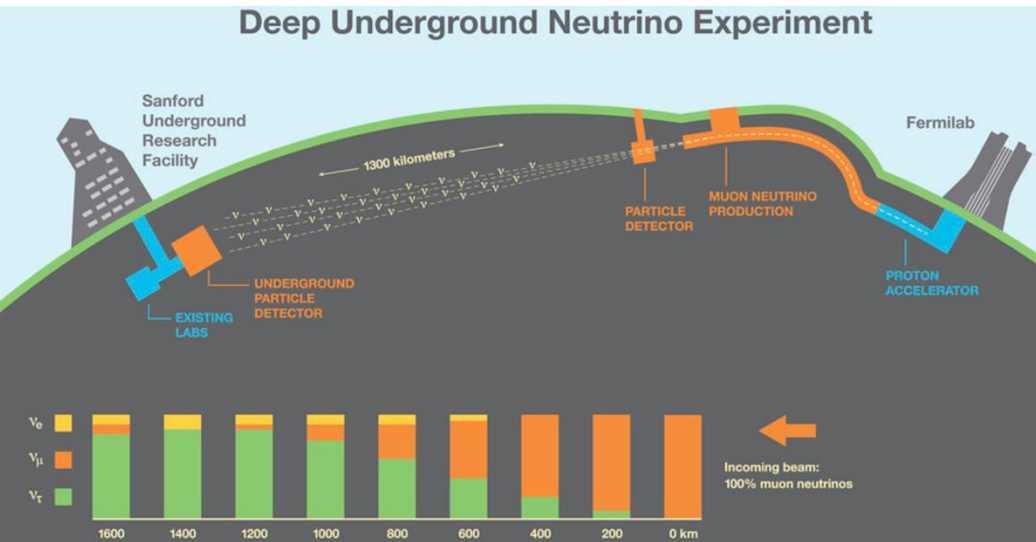


# The ProtoDUNE detectors: NP02, NP04

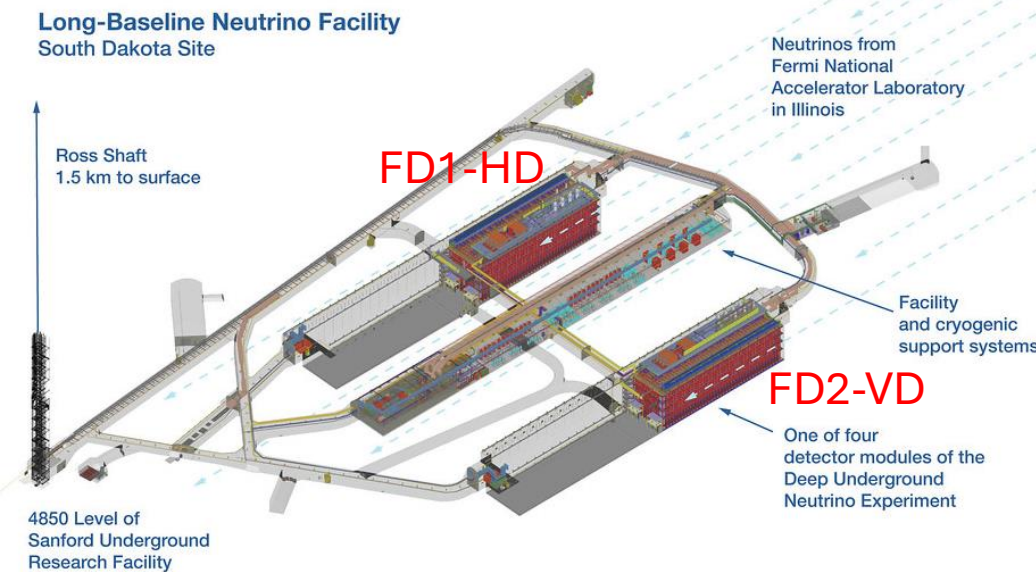
Christos Touramanis  
University of Liverpool & CERN

Workshop on Neutrinos @ CERN  
23 January 2025

# DUNE and its Far Detectors



- Longest baseline experiment: 1,300 km
  - Most sensitive to **mass ordering**
- On-axis, wide-band beam
  - Search for **CPV**
  - Measures all neutrino mixing parameters
  - Constrain the 3-neutrino paradigm (**PMNS Unitarity**)

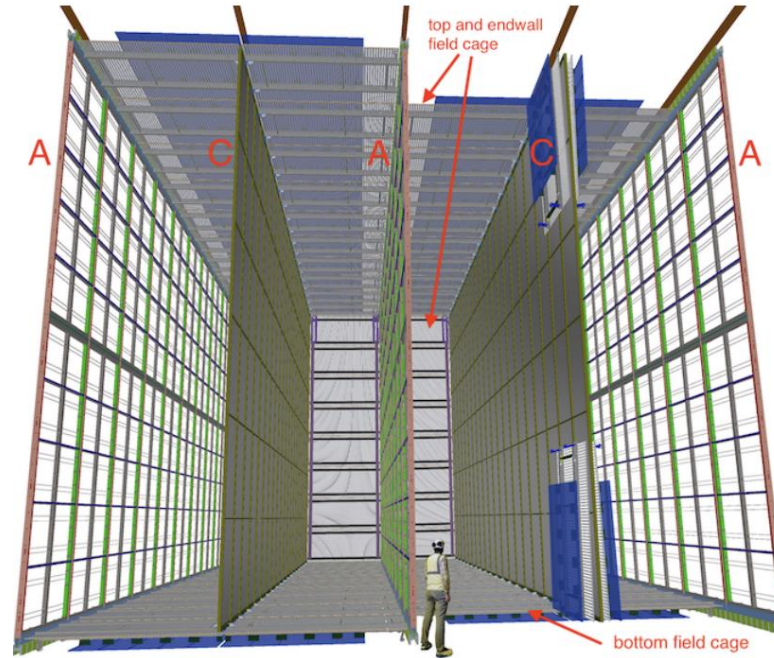
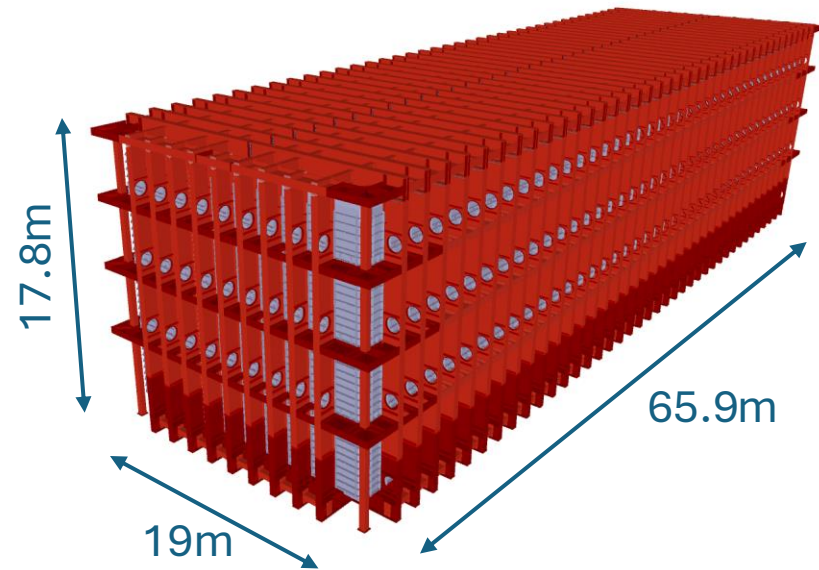


- **LAr TPC** best for high energy neutrinos
  - 3D camera – electronic bubble chamber
  - Tracking and calorimetry in a single detector
  - The challenge: scaling x 20 from ICARUS

# One detector principle, two realizations: HD, DV

First 2 modules, each one holds 17 kt Argon total :

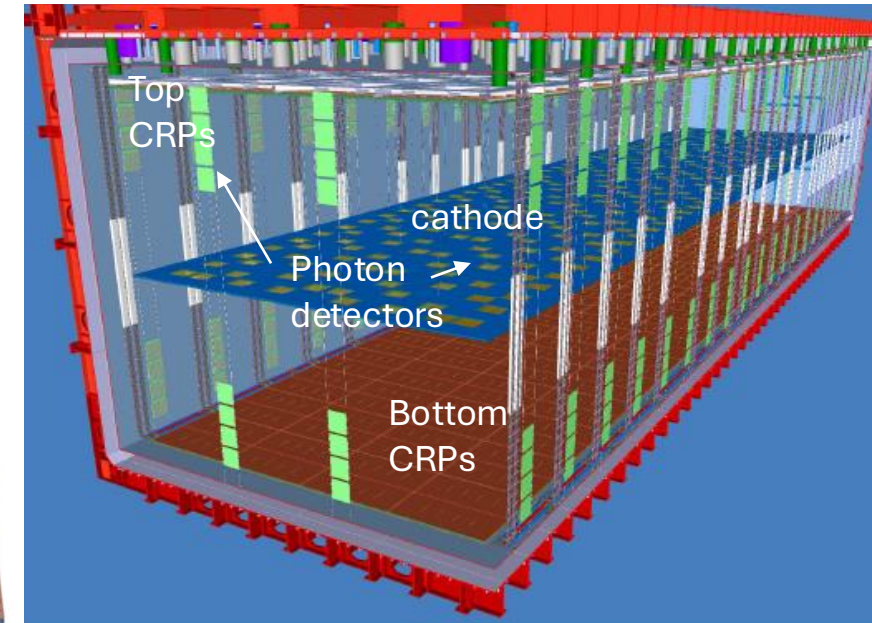
- Horizontal (charge) Drift
- Vertical (charge) Drift



HD

Anode Plane Assemblies : wire chamber technology

Drift length 350 cm -> ~ 180 KV  
9800 m<sup>3</sup> = 13.2 ktons active LAr



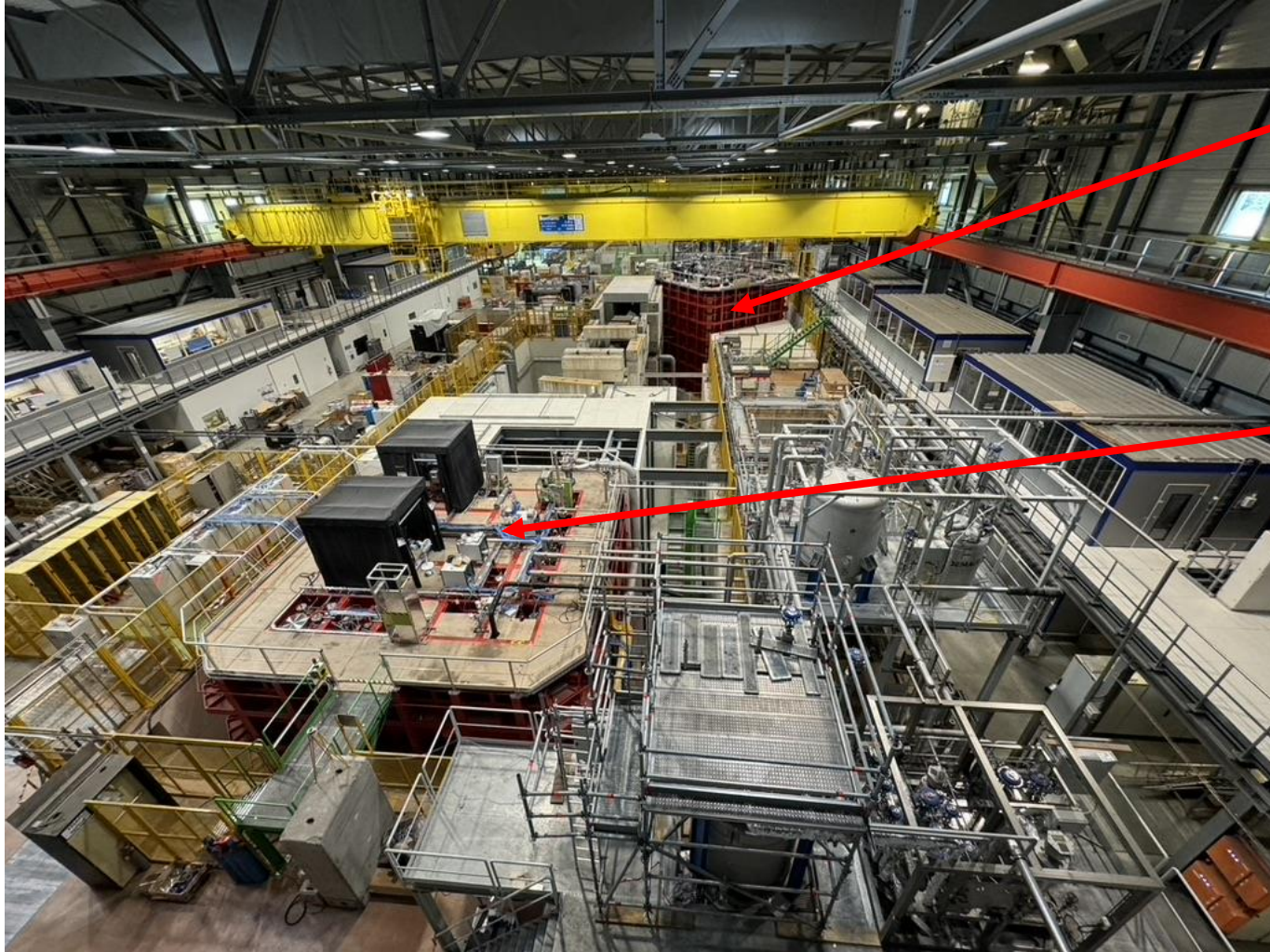
VD

Charge Readout Planes : perforated PCB technology

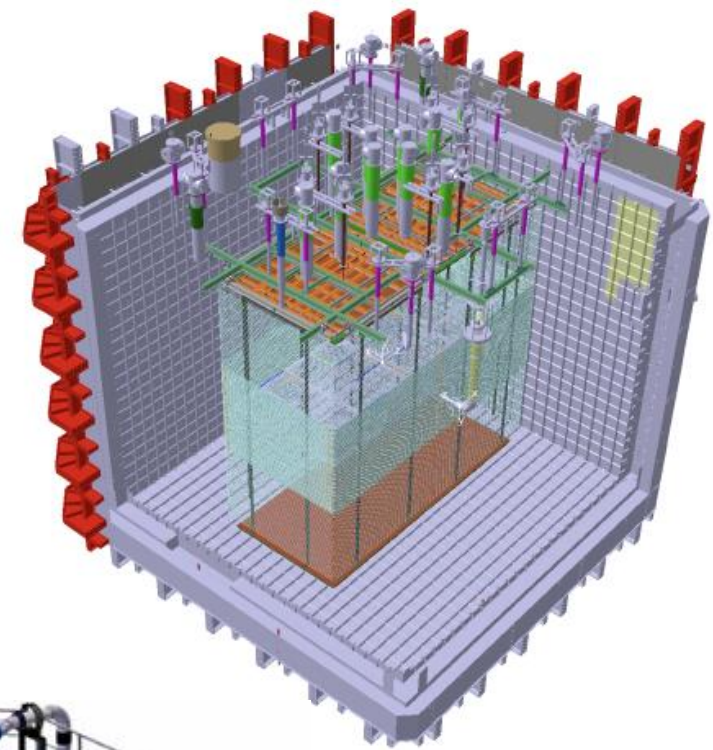
Drift length ~ 640 cm -> ~ 300 KV  
10180 m<sup>3</sup> = 14.2 ktons active LAr

Photon detectors on the cathode at 300 KV

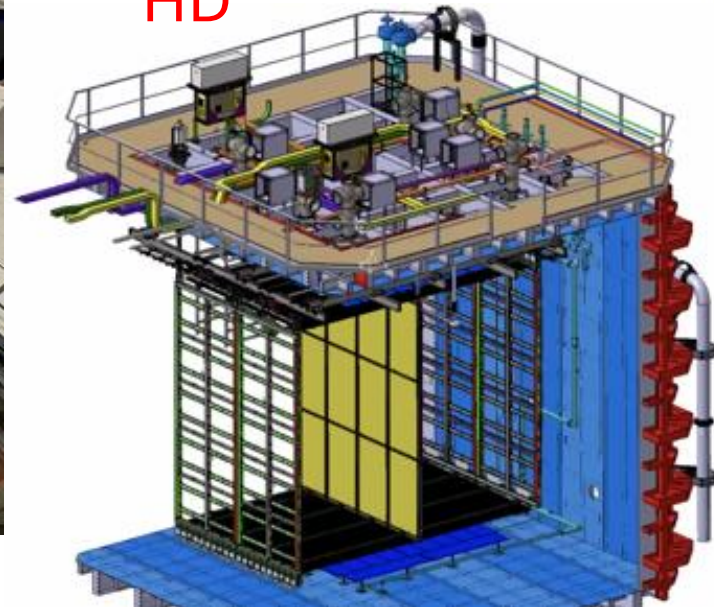
# ProtoDUNEs II at the CERN NP



NP02  
VD



NP04  
HD



# Main aims of ProtoDUNEs Run II (2024-25)

## FD(1,2) Module 0:

- Integration test, performance & stability evaluation before mass production.
- Validation of pre-production, shipping, and installation procedures.
- Validation of tools, confirmation of personnel and time required for FDs.

## Photon Detector System:

- First X-ARAPUCA tests at kton scale deployment. POF, SOF validation.

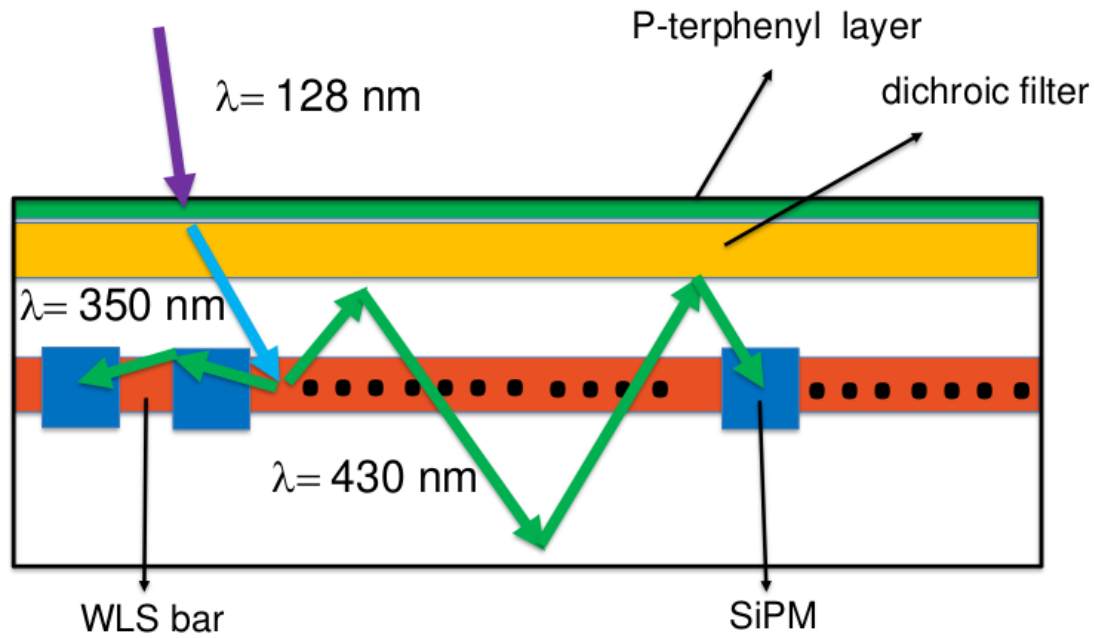
## Cold Electronics:

- CE redesigned from ProtoDUNE I, three new chips. Used in HD (APAs) and VD (bottom CRPs).

## TDAQ:

- Final DUNE readout scheme implemented; new ethernet readout; integration of final electronics, new PDS readout, Ionization Laser; implementation of trigger schemes; performance tests.
- Charged particle data for cross-section measurements; BSM search capabilities.

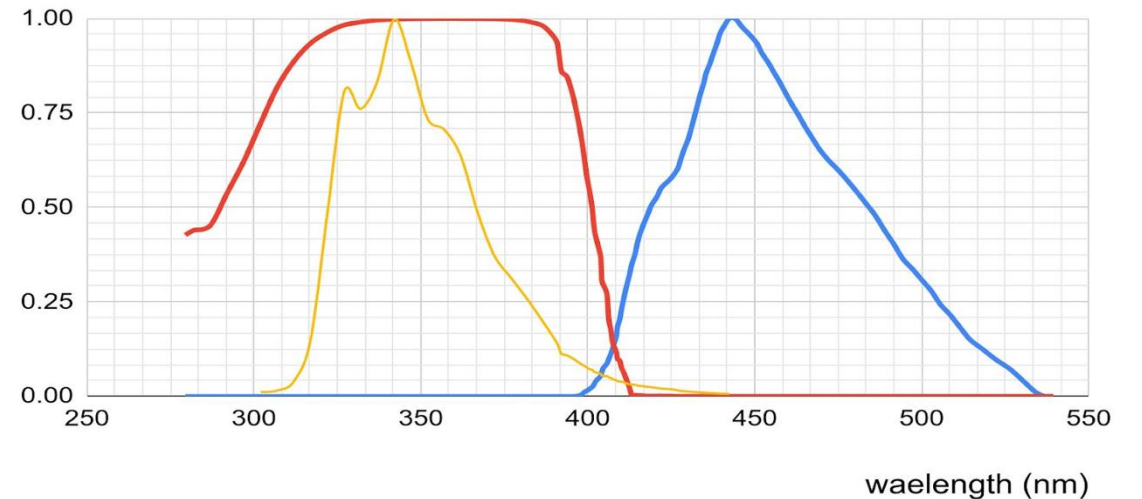
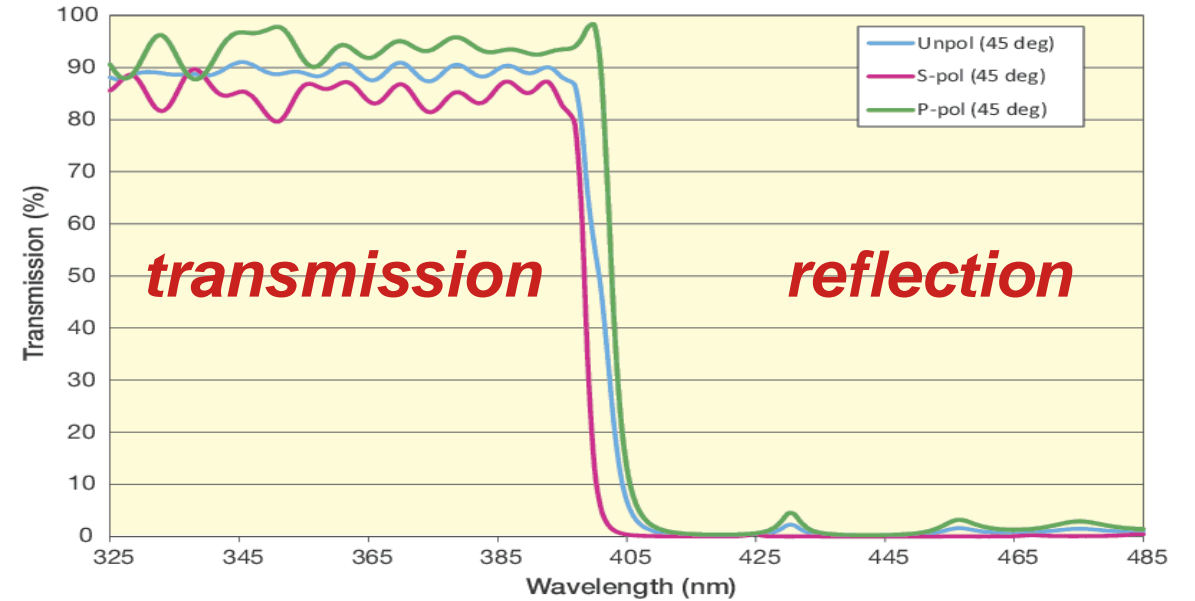
# DUNE Photon Detection System: X-ARAPUCA



*Large area photon collector coupled to an array of SiPMs*

**Photon trapping through:**

- ✓ **Total internal reflection in the WLS**
- ✓ **Trapping through dichroic filter**

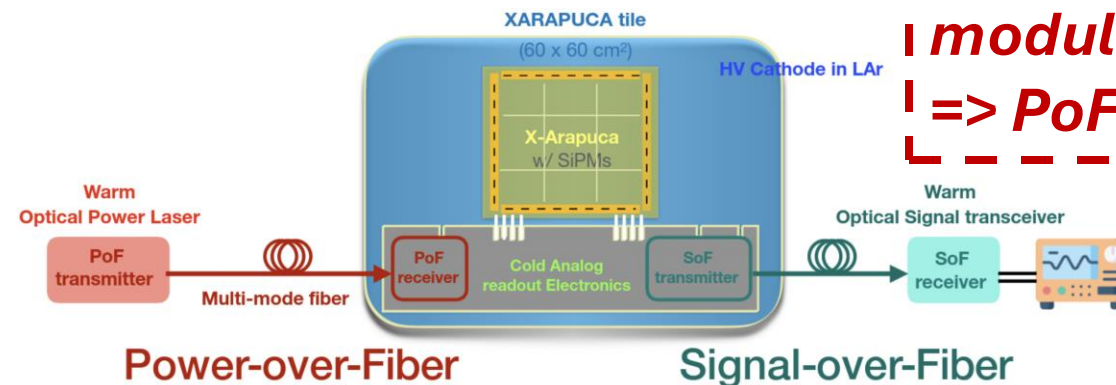
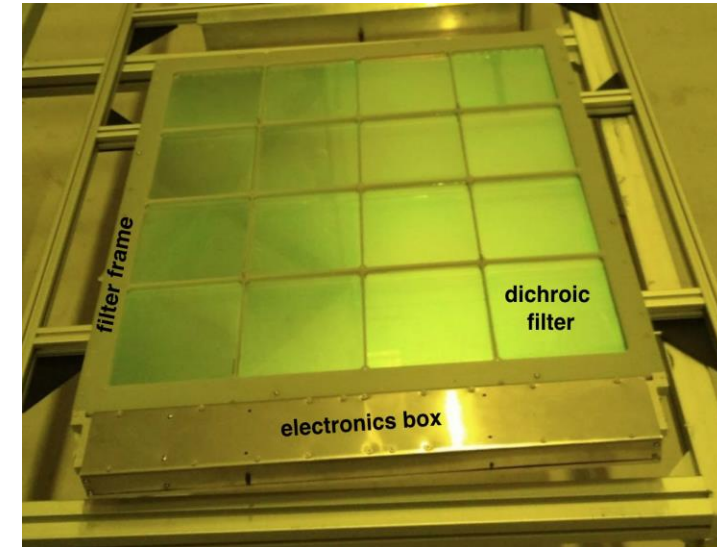


# X-ARAPUCAs in DUNE

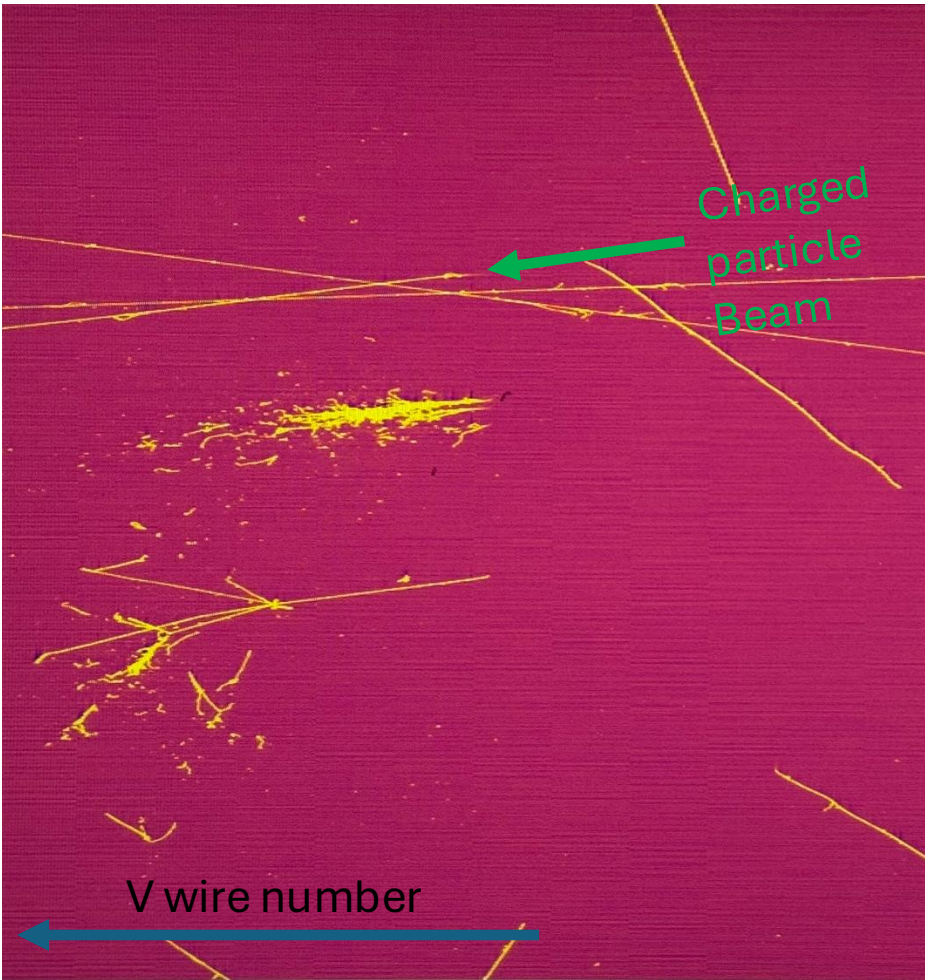
- ✓ Bar shaped modules
- ✓  $200 \times 10 \text{ cm}^2$
- ✓ 4 independent read-out channels
- ✓ 4 x 48 SiPMs ganged together

- ✓ Square modules
- ✓  $60 \times 60 \text{ cm}^2$
- ✓ 2 independent read-out channels
- ✓ 2 x 80 SiPMs ganged together

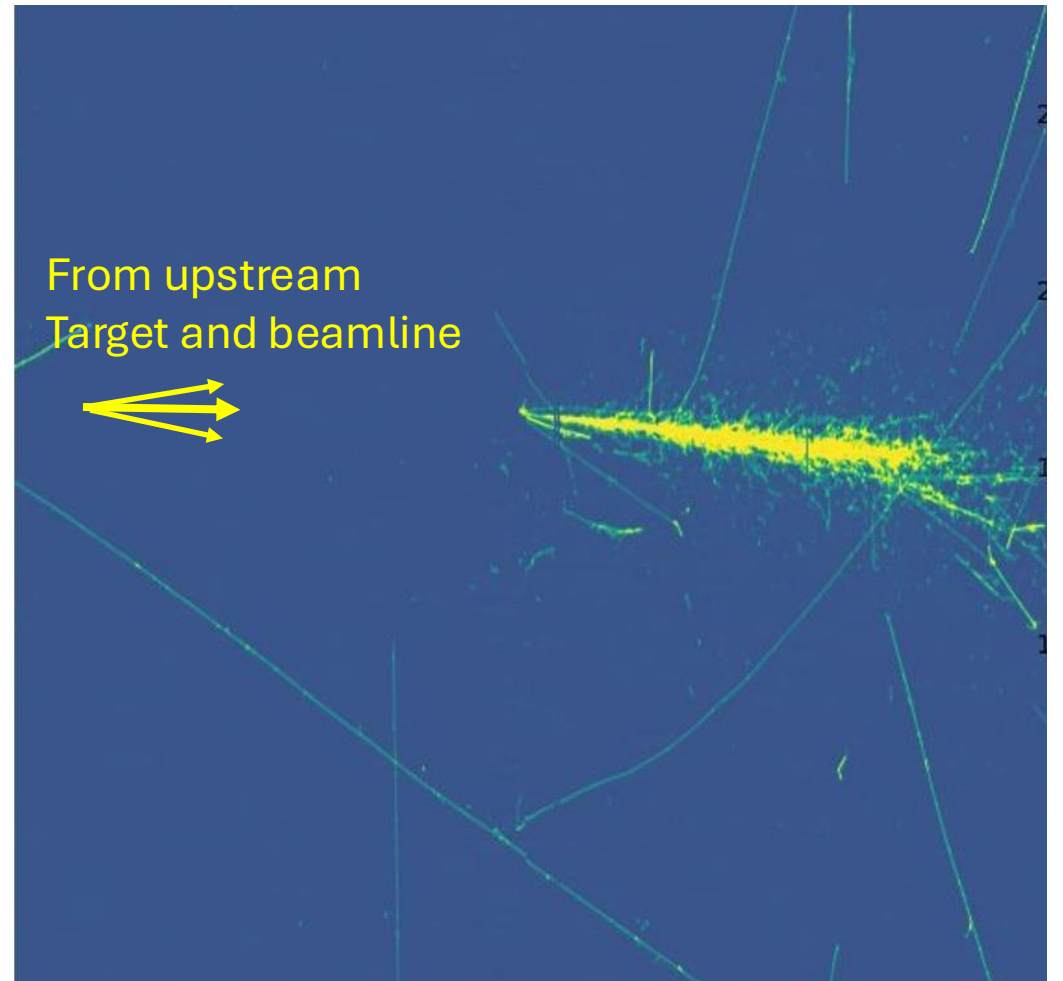
*Efficiencies between 2% - 4%*



**Half of the modules at 300 kV  
=> PoF and SoF**



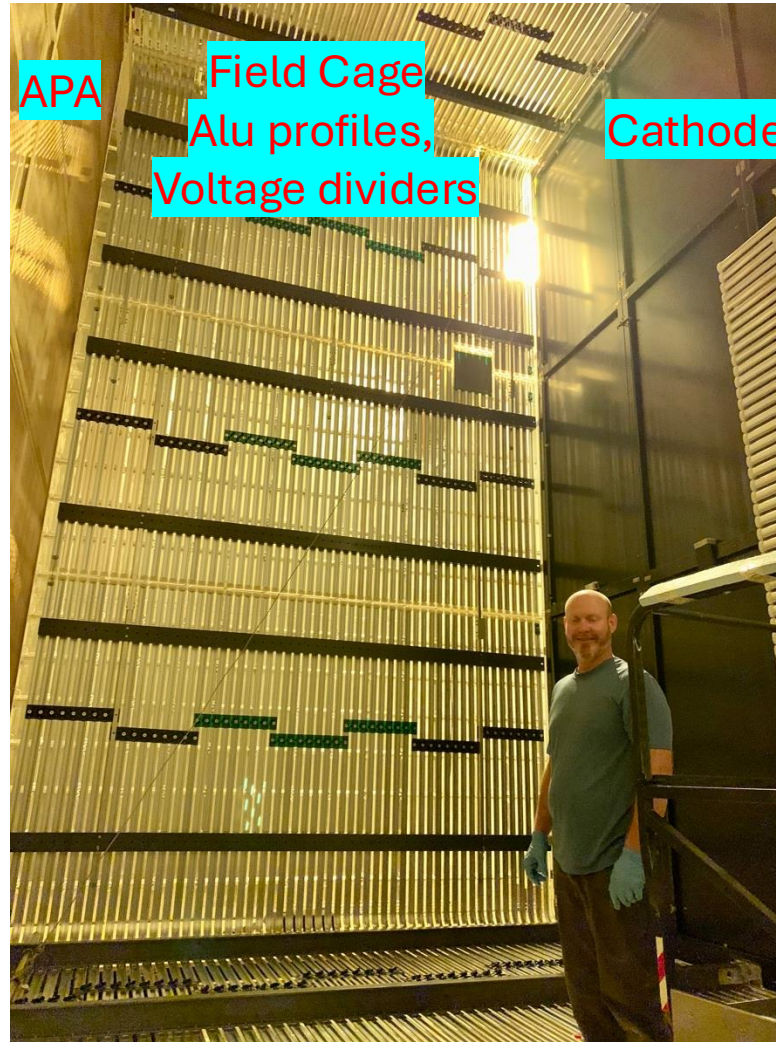
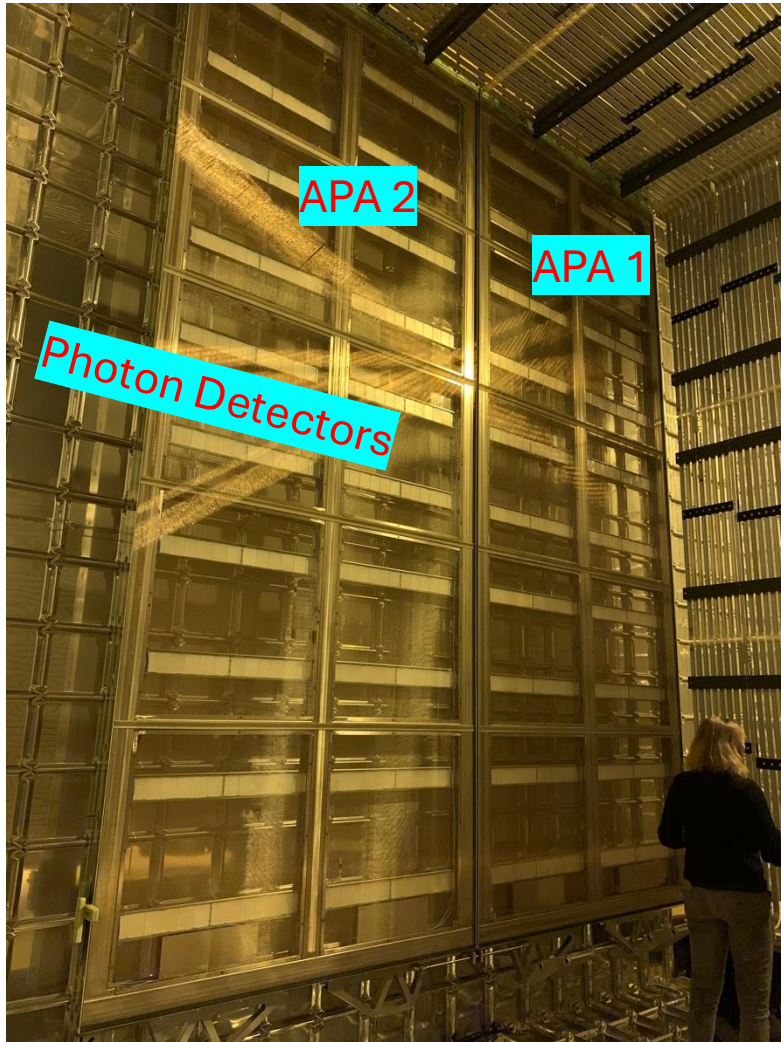
Time tick (distance from APA)



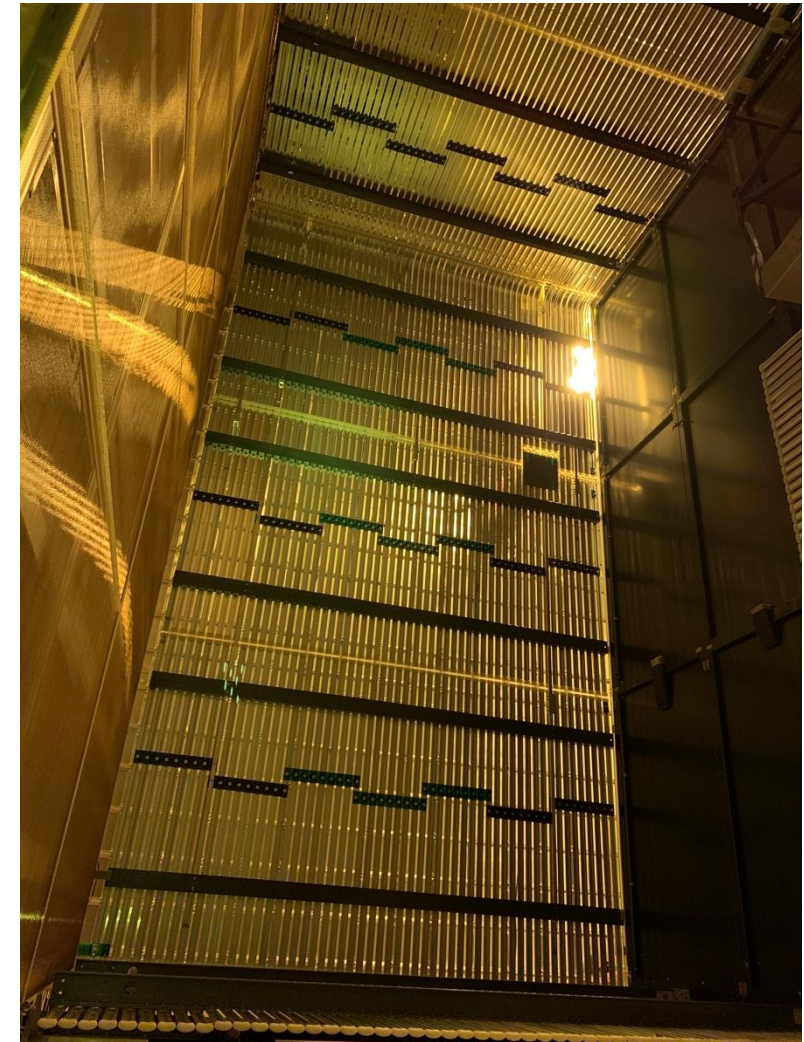
# ProtoDUNE HD – NP04



# NP04 TPC (4 APAs)



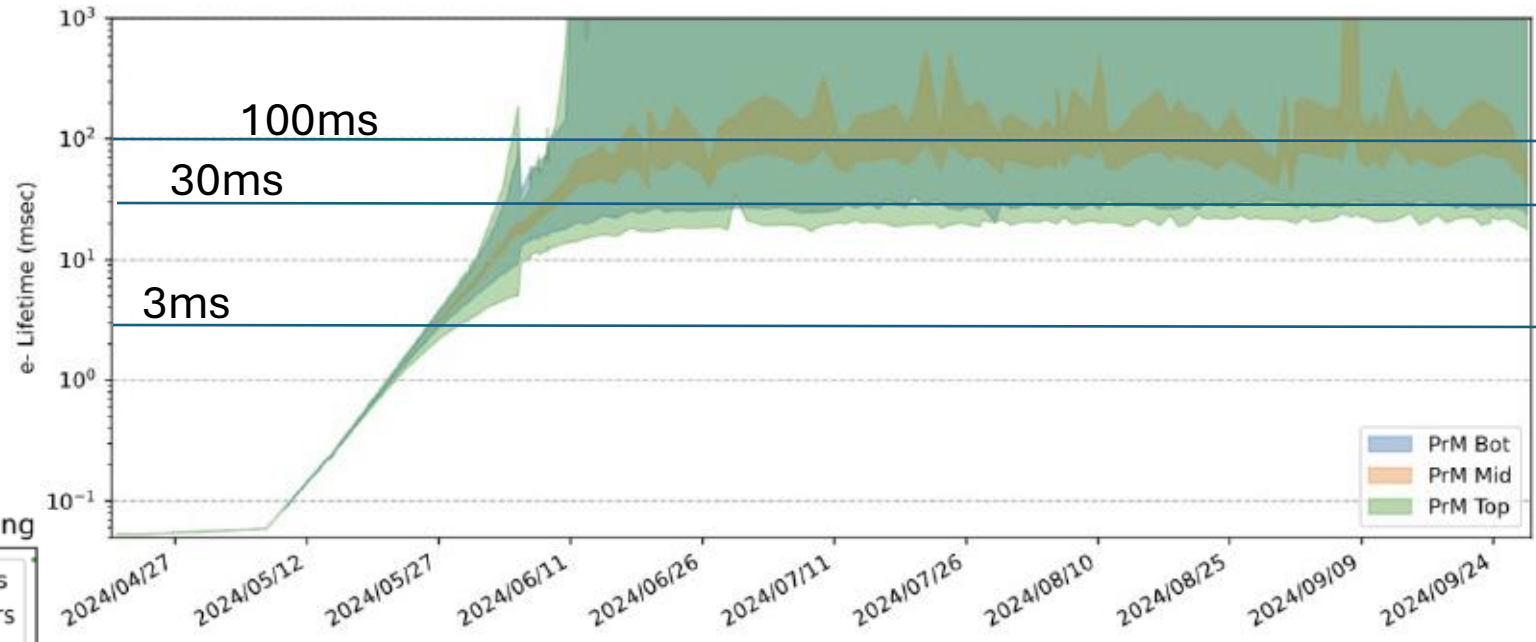
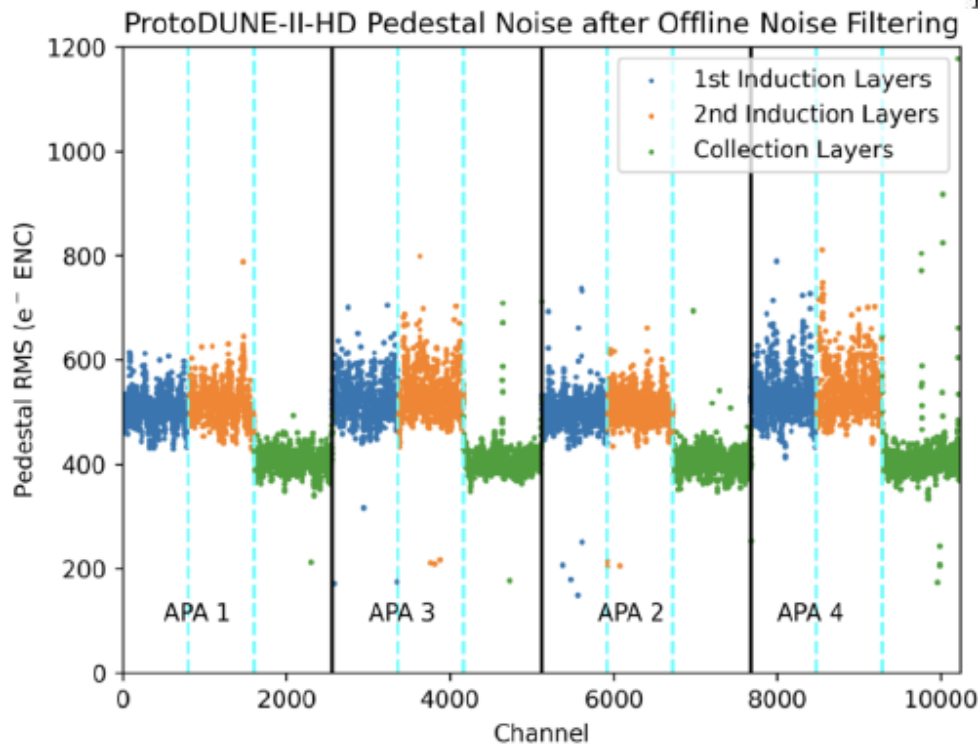
Beam (Saleve) side TPC completed



# NP04 operations

Purity levels of LAr x10  
higher than required

No purity loss in 6 months



Excellent overall noise performance (comparable or better than phase I)

Approximately 1 ‰ channels loss or problematic

Dynamic range increase compared thanks to better S/N and 14 bit ADC

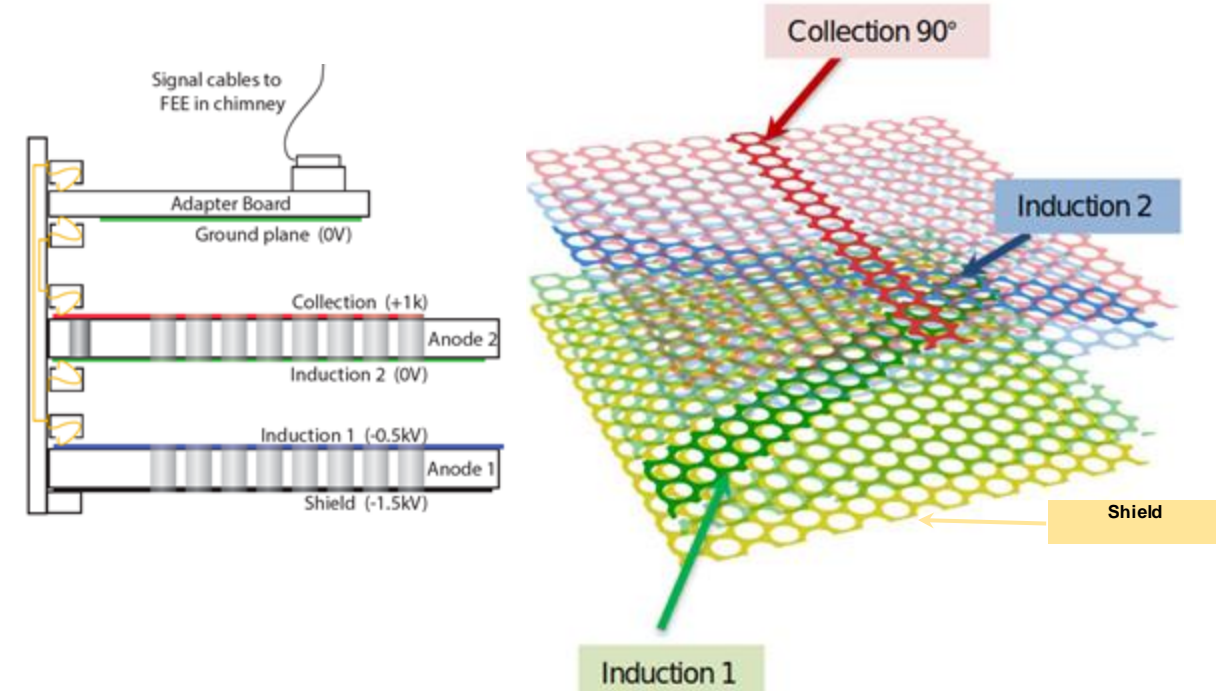
# NP04 highlights

- Six months of stable TPC (Argon purity, nominal HV at 500 V/m, no trips)
- Stable HV up to 275 kV,  $\sim 800$  V/m.
- 10 weeks of charged particle beams (pions, electrons, kaons, protons), both polarities for the first time: Argon cross-sections.  $>30$ M events recorded.
- Stable detector & DAQ: 100% uptime.
- Ionization lasers integrated with TDAQ and Slow Control: volume scans.
- Trigger primitives generated, different TPC trigger conditions implemented.
  - Including high-energy deposition in TPC used for BSM background studies without charged beam but with / without beams in the North Area, leading to neutrino candidates detection.
  - TDAQ performance reached DUNE FD requirements for throughput.
  - 5 PB of data collected and transferred to FANL via CERN EOS.
- Data processing, reconstruction ongoing.

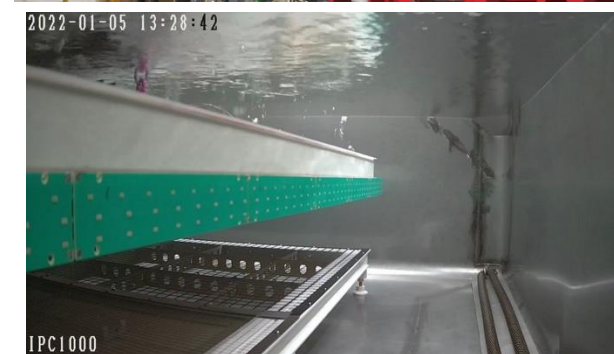
# ProtoDUNE VD – NP02

# CRPs, Cold Box tests ( >12 cycles so far)

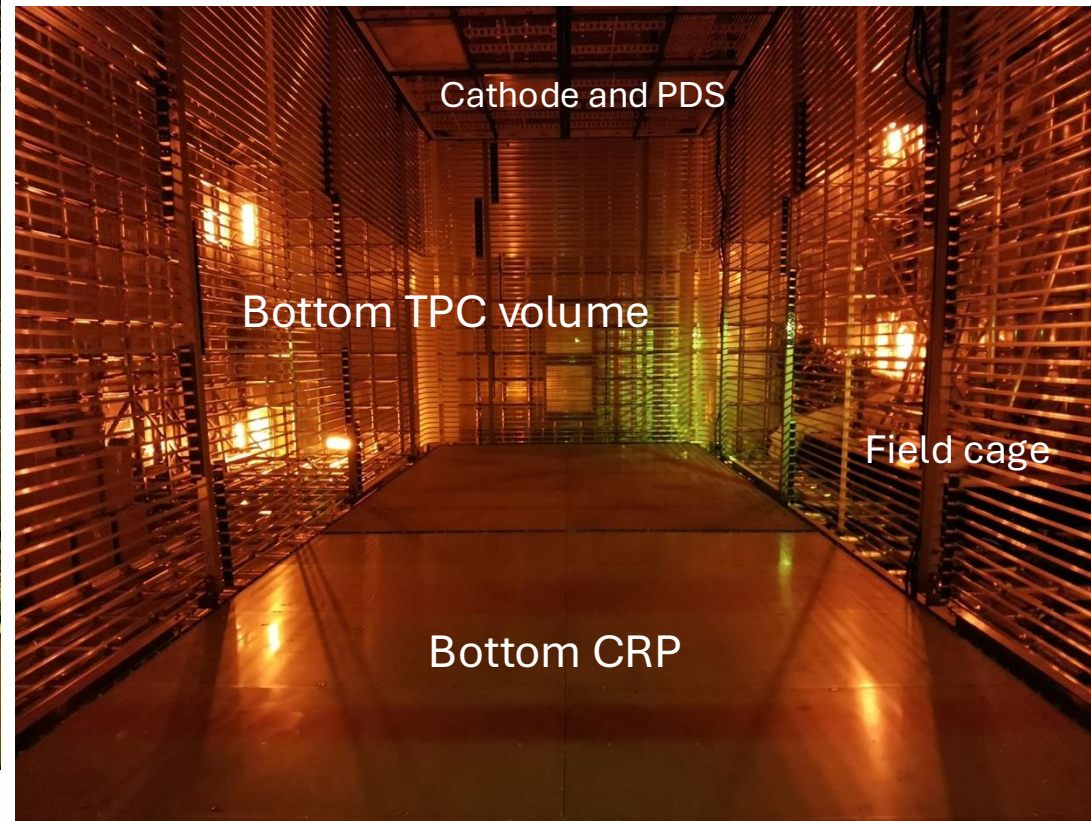
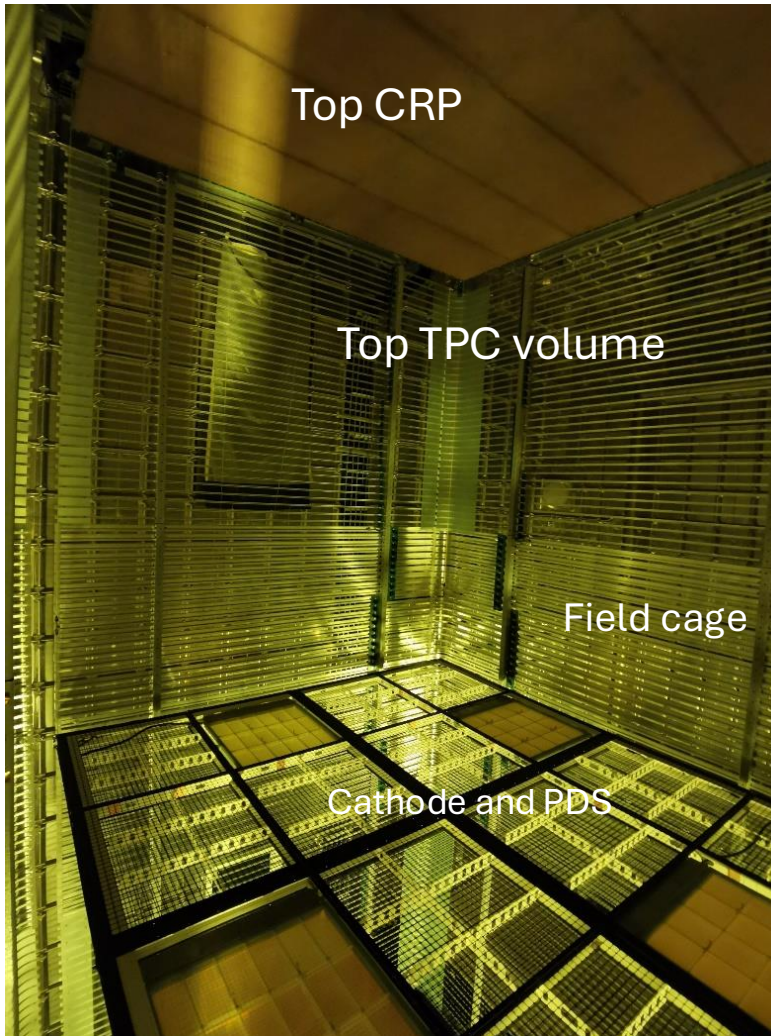
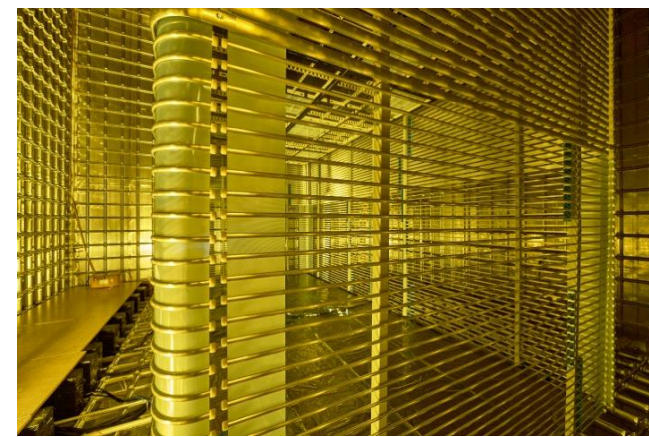
- Three view anode layout with perforated PCBs
  - +30°, -30°, 90° strip orientation with 5.1mm collection, 7.65mm induction strip pitches
  - 3072 readout channels for each CRP



- Evolution of CRPs using cold box lessons
- PDS demonstrated too
- 300 kV over 6m drift already demonstrated in NP02 - DP

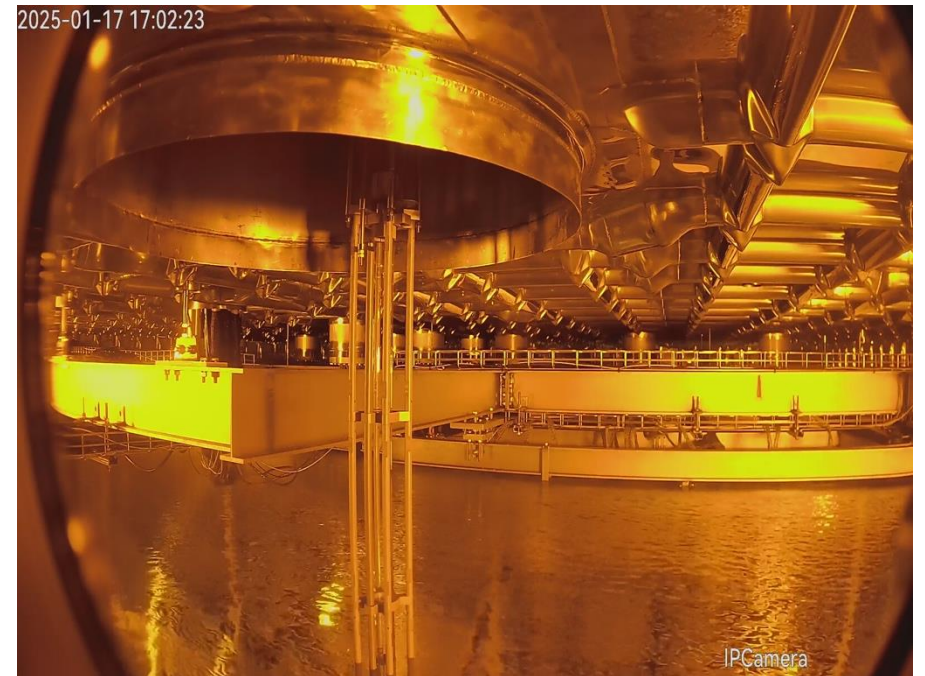
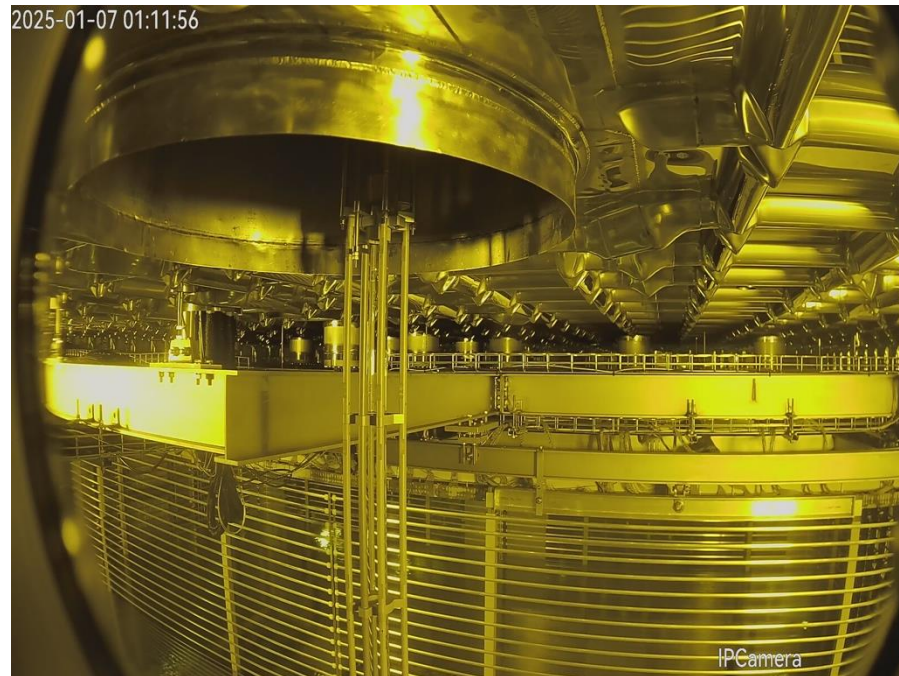


# NP02 TPC assembly



# NP02 filling and plan

- NP02 purge, cool-down and filling started December 2024.
- Now almost completed.
- Tests and commissioning to follow.
- Beam requested from May 2025.



# THANK YOU