Charge Readout Planes development and status for DUNE Vertical Drift Detector

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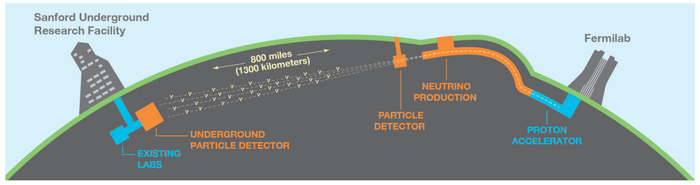
COORDINATING PANEL ON ADVANCED DETECTORS · APS DIVISION OF PARTICLES & FIELDS
CPAD 2026
Instrumentation and detector R&D workshop

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Brookhaven National Laboratory

DUNE: Deep Underground Neutrino Experiment



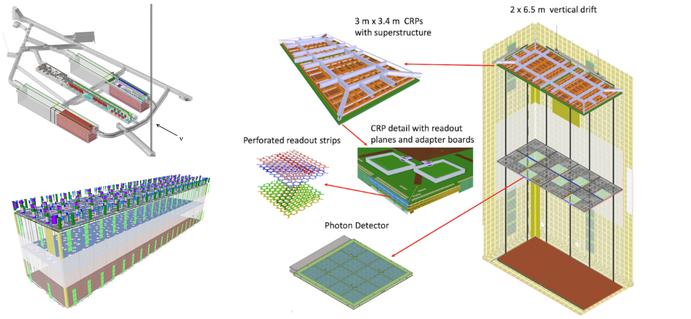
Physics **Long baseline oscillation**: CP-violation, mass hierarchy, precision measurements; **Supernova Neutrino Burst**, BSM: **proton decay**.

Beam 1.2 MW proton power; ν_μ or $\overline{\nu}_\mu$ mode; Energy: 0.5 GeV to 10 GeV with 2.5 GeV peak.

Near Detector SAND for continuous beam monitoring & NDLAr (LAr TPC) + TMS (muon spectrometer)

Far Detector (Phase-I) HD (horizontal drift) + VD (vertical drift) LArTPC, 17 kt; (Phase-II) Additional 2× 17 kt modules

Vertical Drift detector



Technology **17 kt** liquid argon time projection chamber (**LArTPC**).

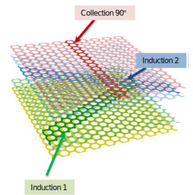
Configuration **Two drift volumes**, each approximately **6.5 m long**, separated by a central cathode biased at −300 kV, providing a drift field of approximately **450 V cm^{-1}**.

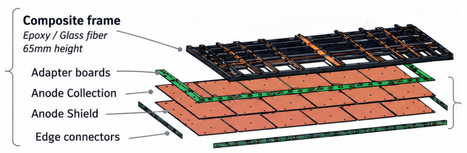
Photon detection Photon detection systems are installed on the cathode and the cryostat membrane.

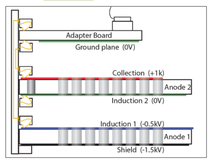
charge readout The top and bottom planes each host **80 charge readout planes (CRPs)**, based on printed circuit boards.

Charge Readout Unit (CRU) concept

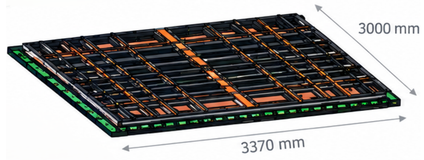
Ionizing electrons drift through **perforated PCBs**, named anodes, and **induce signals** on the strips of each layer (induction1 +30°, induction2 −30° and collection 90°). The different **strip orientations provide positional information**, while collection of the **charge provides energy**.







Charge Readout Plane (CRP): production design



CRP consists of two identical CRUs. Each one of them consists of: anodes, interface cards and composite frames.

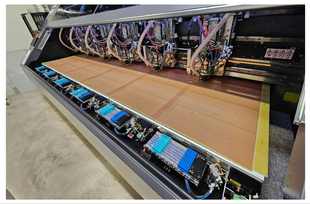
ANODES

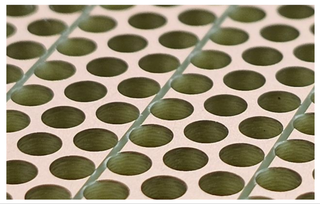
Design: Two anode planes, each composed by **14 perforated PCB segments** (6 top + 8 bottom).

Previous: strips milled and holes drilled before on segments assembly → joined with M3 adhesive tape.

Production: strips milled on segments → laminated together with prepreg → anode drilled as one panel.

Benefit: Improved hole alignment across both sides, **enhancing electron transparency**.





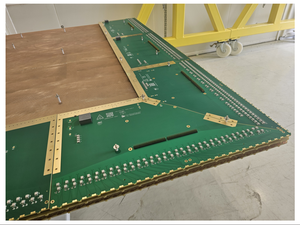
INTERFACE CARDS

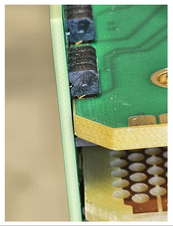
Design: **Adapter boards** distribute **high voltage** across the CRU and interface with the **front-end electronics**. **Edge cards connect the anode strips** to the readout electronics.

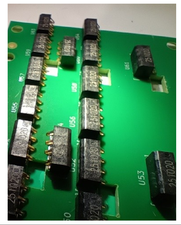
Previous: Functional design, with high-voltage PCB requirements not yet fully aligned with IPC 2221 standards. Inconsistent edge card connections, leading to a few channel disconnections and high-noise channels.

Production: Adapter boards redesigned to meet stringent IPC requirements. Edge cards optimized for connector positioning, assembly, and board warpage.

Benefit: Improved high-voltage reliability and **more robust anode-to-electronics connections**, reducing channel disconnections and high-noise channels.

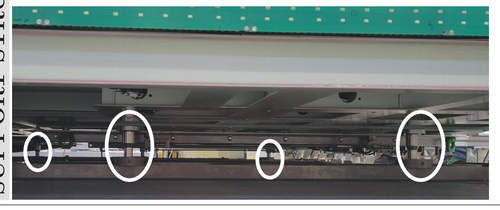






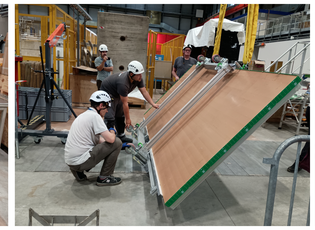
SUPPORT STRUCTURE

Design: **Composite G-10 frame** supporting the CRP in both configurations. Top CRP suspended from the cryostat roof via a superstructure; Bottom CRP supported by four feet mounted through adapter plates and resting on the cryostat membrane.

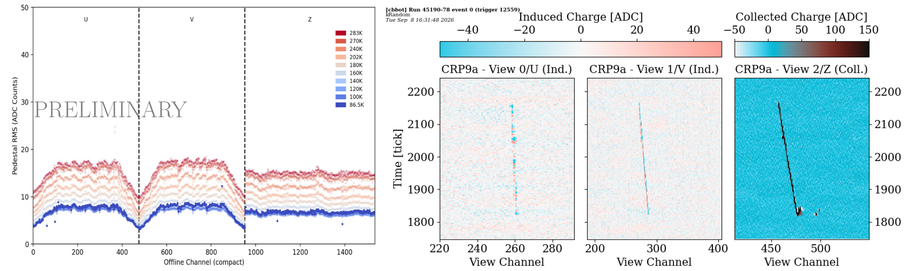


CRU9a testing and results

- **Bottom CRU (9a)** was fully assembled with **production-tier components**;
- A flipping tool designed for installation is used to rotate the CRU exposing the strips on top;
- The CRU is **installed into the CERN VD cold-box** cryostat roof structure, where the cathode is already installed.



- The cold-box is purged with gas argon and then filled with LAr;
- The electronic noise was monitored during the cool-down;
- **No unexpected**[a] low-noise (**disconnected**) or high-noise (**shorted**) channels.



- LAr is injected until the **TPC is fully submerged** in liquid argon;
- The **anode** layers **and the cathode are biased** to nominal value, producing a drift field of about 450 V cm^{-1};
- **Track are collected** by the anodes and read-out through the bottom drift electronics.

CRU9a validated the production-tier designs and fabrication quality: good noise performance confirmed the improved interface cards connection, while successful track readout demonstrated proper anode operation and high-voltage distribution.

[a]A few outliers are due to some well understood anodes imperfections

Production status and plan

The pre-production for all the parts is begin finalized and will be used to exercise assemblies and QA/QC procedures. CRU9a has demonstrated that the design, fabrication procedures and standards are up to specifications. CRU9b planned for November 2026 will be used to confirm the results.

For production:

Component	Production* & QA/QC†	Schedule
Anodes	CERN*†	Through Q4 2028
Interface cards	BNL*, LSU† and MIT†	Q1 2027–Q4 2028
Composite frame	LAPP Annecy*†	Through Q4 2027
Top CRU	LPSC Grenoble*†, CERN*†	Q1 2027–Q2 2028
Bottom CRU	Indiana*† and Yale*† universities	Q4 2027–Q4 2028