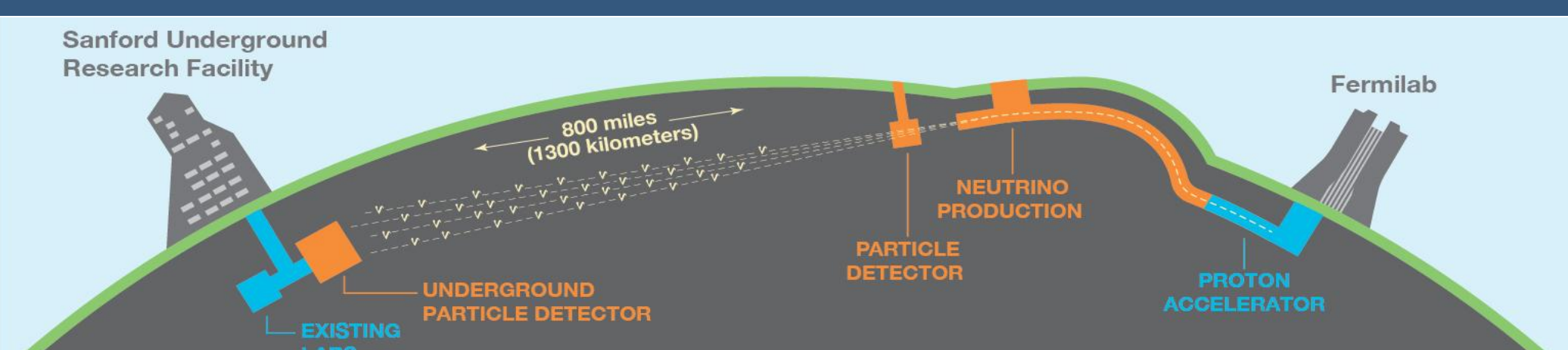


### 1. DUNE Experiment

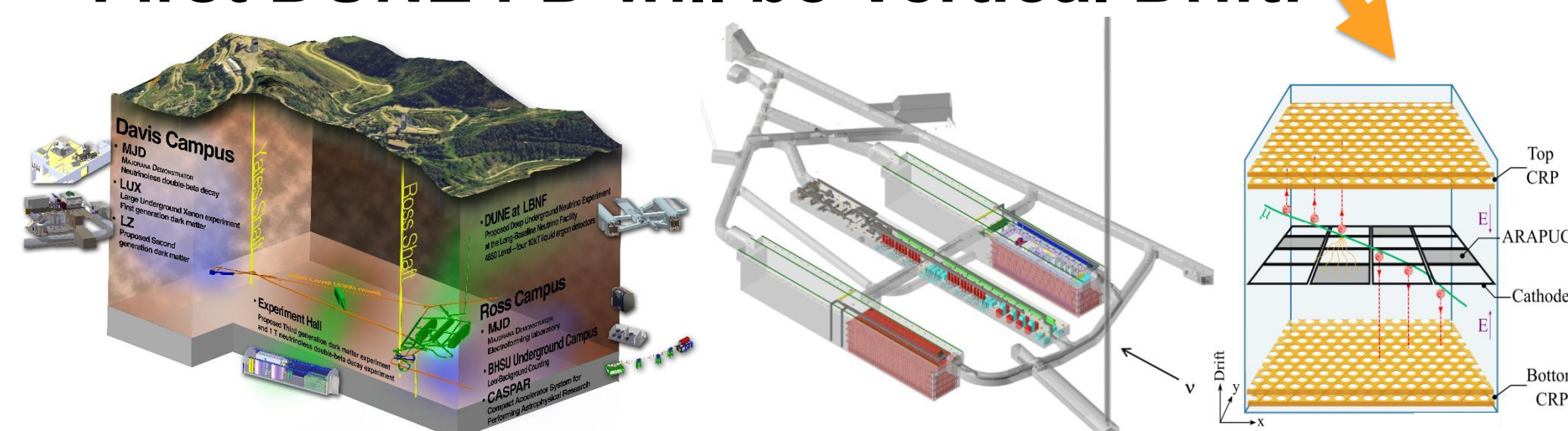


#### Goals of DUNE

- Determine the neutrino mass ordering
- Search for CP violation in the lepton sector
- Search for Beyond Standard Model Physics

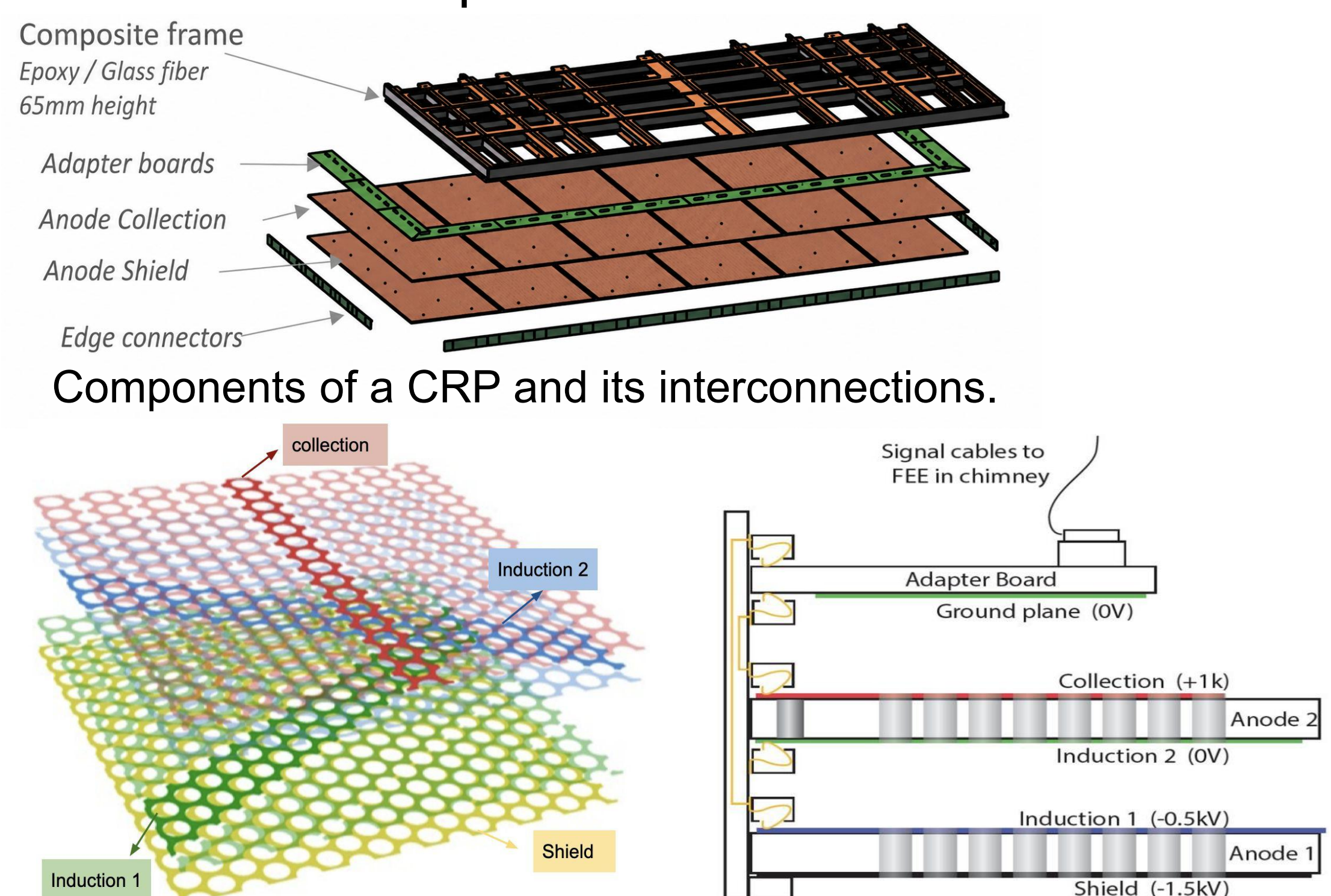
#### Design of DUNE

- Broad-band neutrino beam at Fermilab
- Far Detectors (FD): Liquid Argon Time Projection Chambers (LArTPCs)
- 1.5 km underground at SURF in South Dakota
- **First DUNE FD will be Vertical Drift!**



### 2. Charge Readout Planes (Anodes) in the Far Detector

Charge Readout Planes (CRPs) are modular anode readout units composed of perforated PCBs with segmented electrodes and integrated electronics interfaces [1]. The first DUNE Far Detector module will contain 80 top and 80 bottom CRPs.



**Left:** Three-view anode layout featuring perforated PCBs at +30°, -30°, and 90° strip orientation. [1] **Right:** The anode layers are connected via an edge connector to an adapter board that interfaces with the electronics readout.

### 3. ProtoDUNE Vertical Drift (VD)

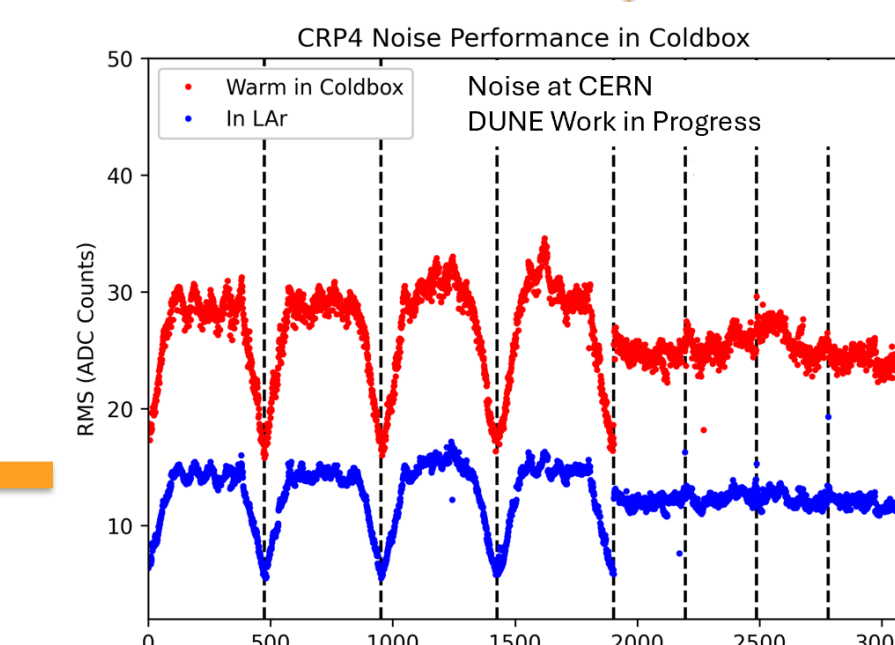
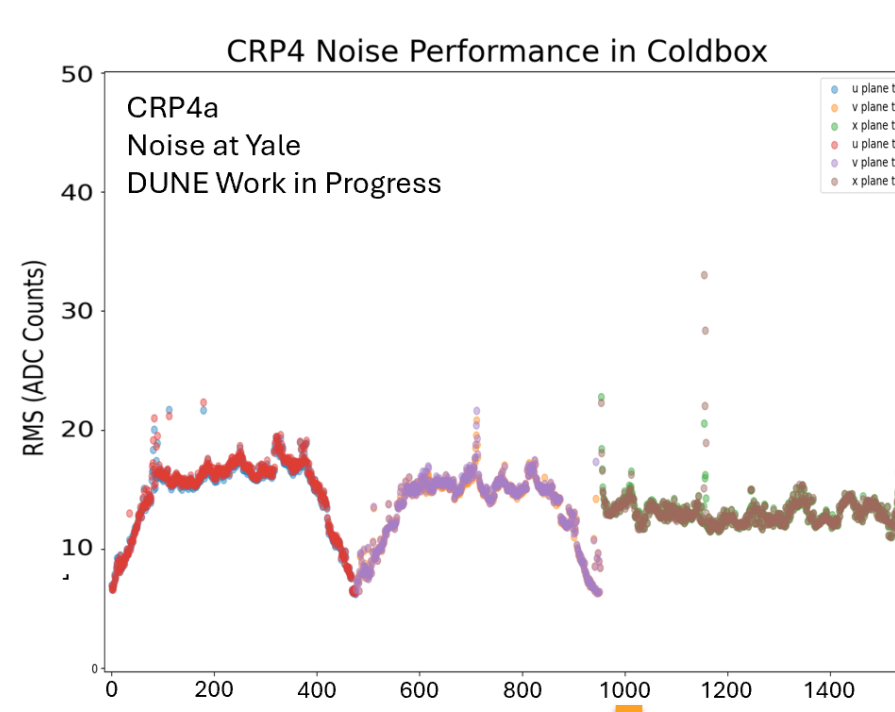
ProtoDUNE-VD has demonstrated the DUNE Vertical Drift technology at scale. Bottom CRPs were produced, tested, and shipped from Yale for installation at CERN.



ProtoDUNE CRP production at Yale



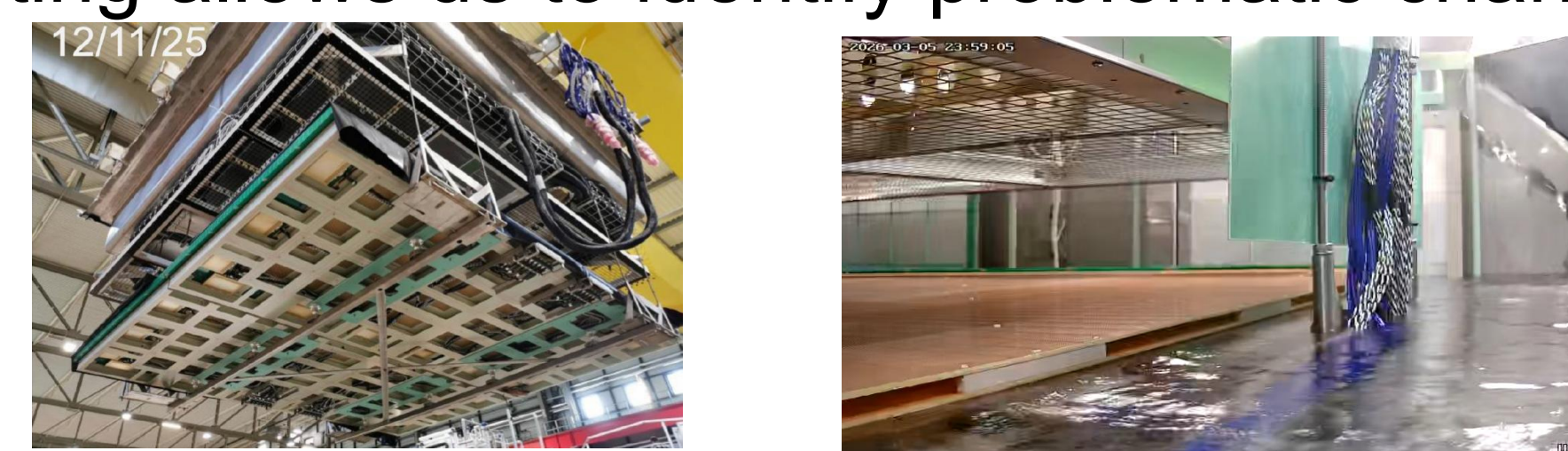
CRP in ProtoDUNE-VD



**Top:** Cryogenic CRP Noise Performance at Yale (LN<sub>2</sub>). **Bottom:** at CERN (LAr)

### 4. Cryogenic Testing

The VD cold box at CERN provides a cryogenic test facility for DUNE VD components. **The final FD-VD design was validated**, including support structures, cable routing, grounding, HV distribution, and CRU orientations. Cryogenic testing allows us to identify problematic channels.

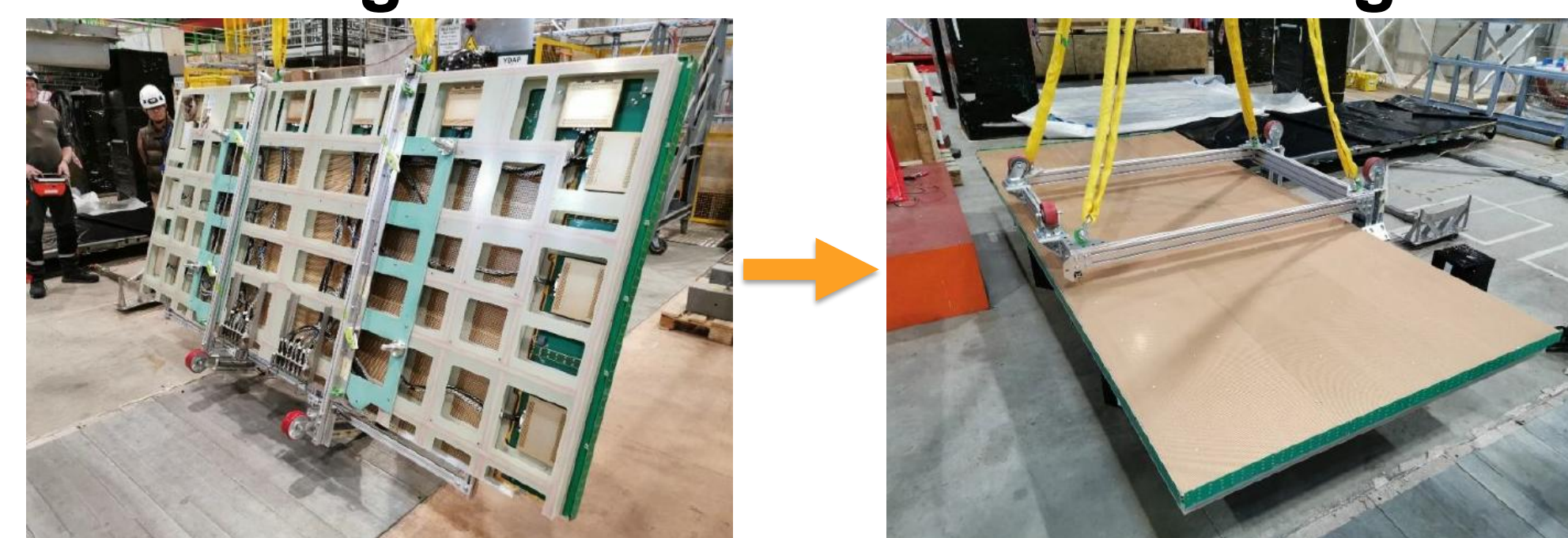


**Left:** CRP mounted from the cold box roof. **Right:** A CRP being tested in LAr within the NP02 cold box.

### 5. Installation Prototyping

Full-scale installation prototyping and mockups at CERN are essential for validating procedures. A 12m tall installation mockup (~1/12 of DUNE FD module) has been constructed for installation studies and training.

#### Integration & Installation Testing



Bottom CRP installation requires CRU rotation. Installation tooling and flip procedures were validated at CERN in 2025.

#### Installation Mockup



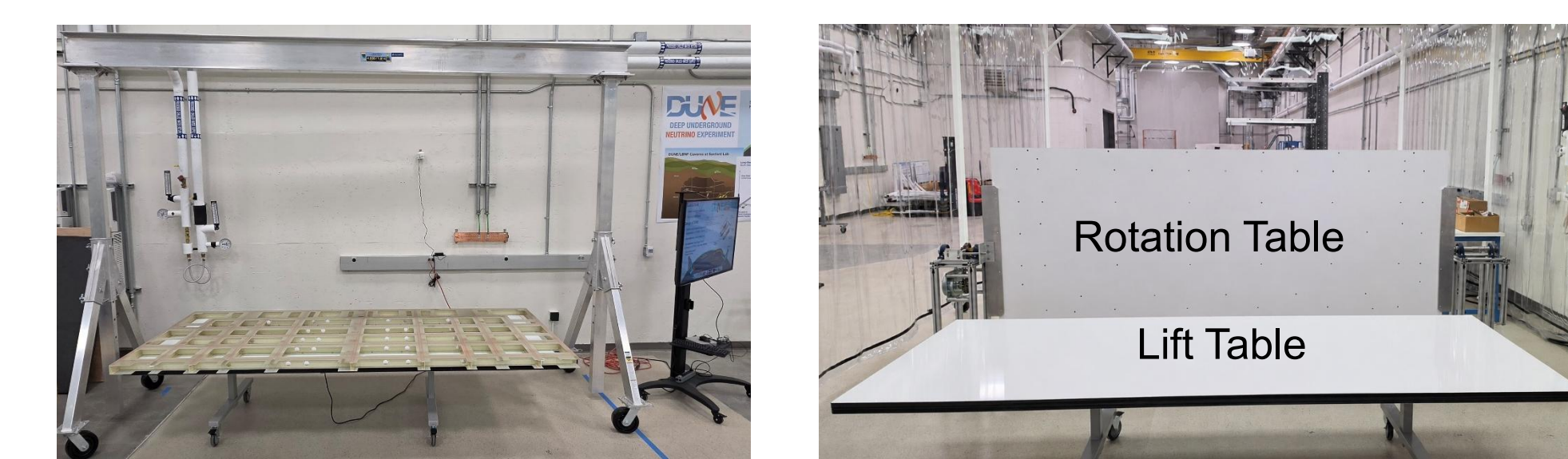
The full-height mockup validates installation procedures and allows personnel trainings. **Left:** Full height DUNE FD-VD installation mockup (12m) **Above:** Top CRU mechanically installed in the mockup

### 6. Charge Readout Plane (CRP) Assembly and Testing at Yale

CRP production is distributed across four sites. Top CRPs are assembled and tested at Grenoble and CERN, while bottom CRPs are assembled and tested at Yale and Indiana. All CRPs undergo cryogenic testing prior to shipment to SURF. **Each site must assemble and cryogenically test at least one CRP per week.**



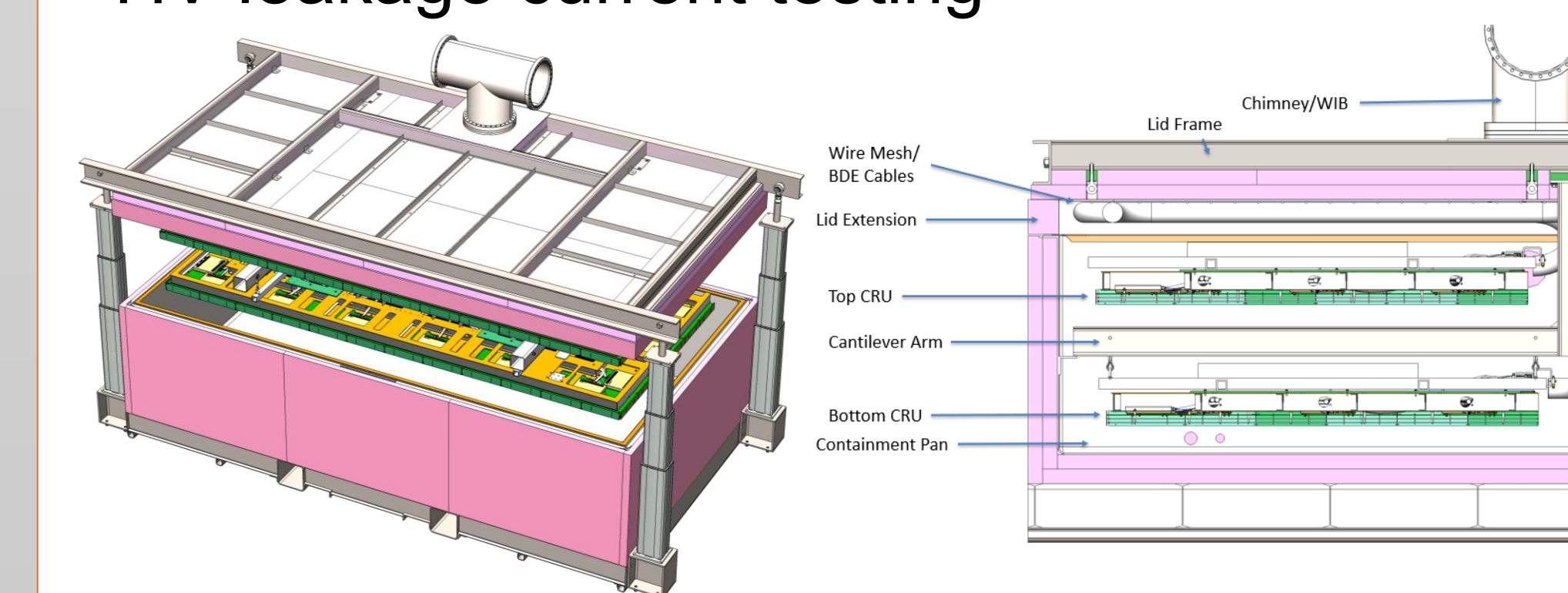
**Top:** Main Yale CRP assembly tent.



**Bottom Left:** Gantry for composite frame mounting. **Bottom Right:** Rotation and lift tables for CRP assembly

#### Dual 1/2 CRP Cold Box

- Cryogenic test two 1/2 CRP simultaneously
- CRP channel testing at warm and cold (<140K)
- CRP interconnection testing
- HV leakage current testing



**Left:** Dual 1/2 CRP cold box with lid open.

**Right:** Cross-sectional view of the dual 1/2 CRP cold box

#### CRP Milestones

- Fall 2026: Ready for CRP assembly
- 2027 - Spring 2028: Bottom CRP Production
- 2028: CRP installation in Far Detector

#### Reference

[1] DUNE TDR, arXiv:2312.03130