CHARGE READOUT PLANES FOR THE DUNE FAR DETECTORS

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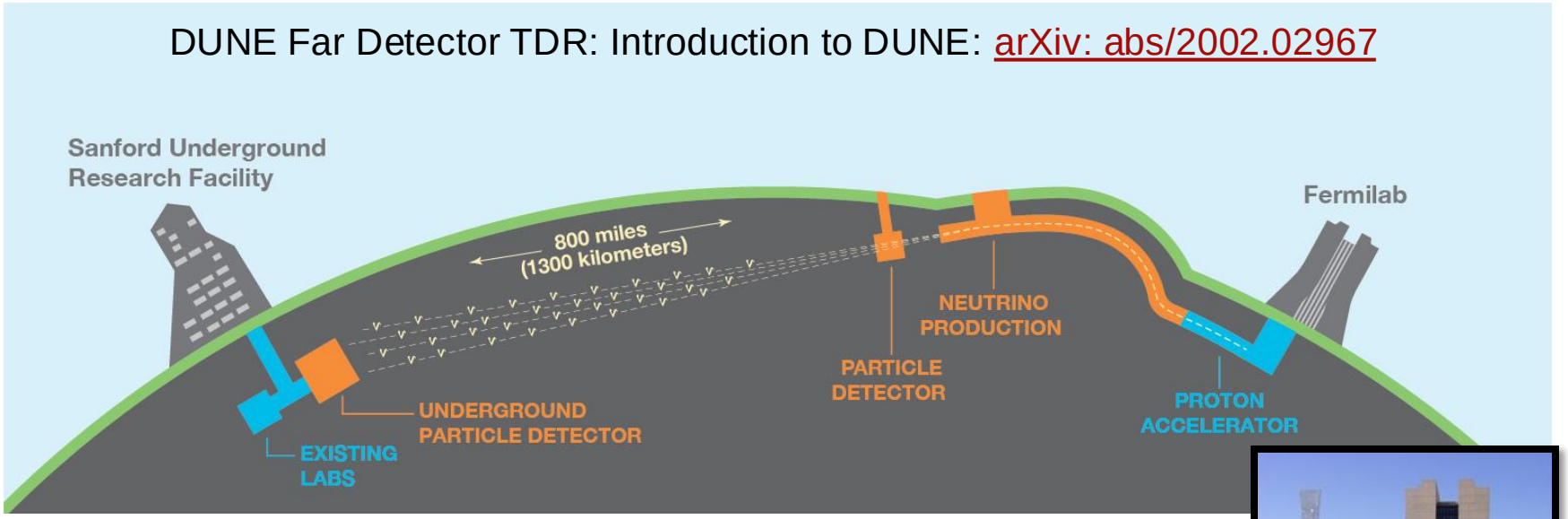
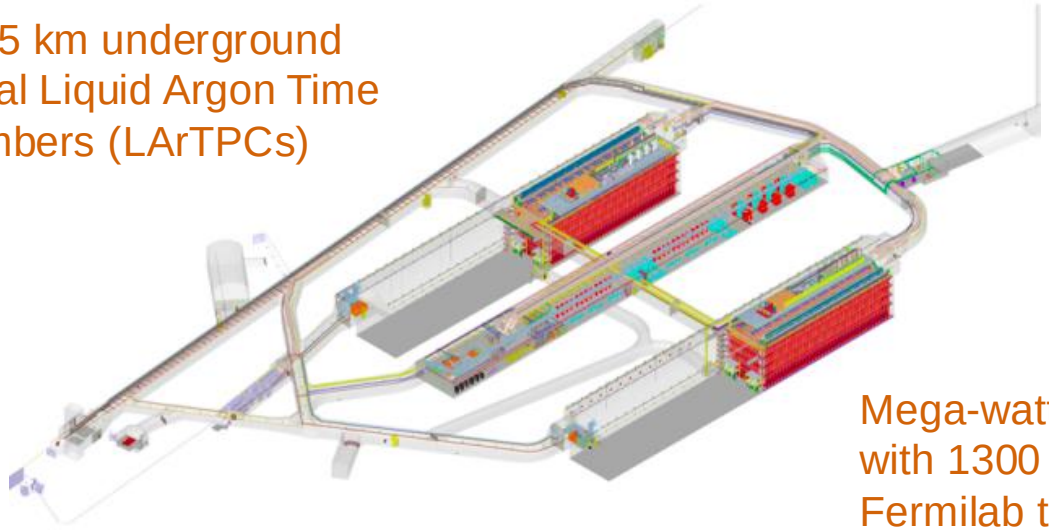
Coordinating Panel for Advanced Detectors Workshop
November 2024

DUNE

DUNE Far Detector TDR: Introduction to DUNE: arXiv: abs/2002.02967



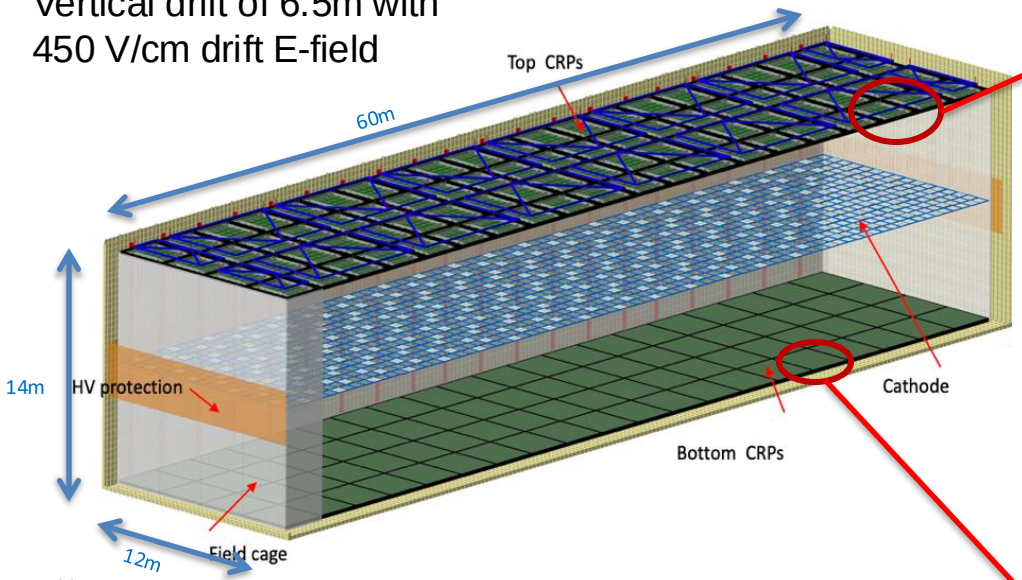
Far detectors 1.5 km underground
4x10 kton fiducial Liquid Argon Time Projection Chambers (LArTPCs)

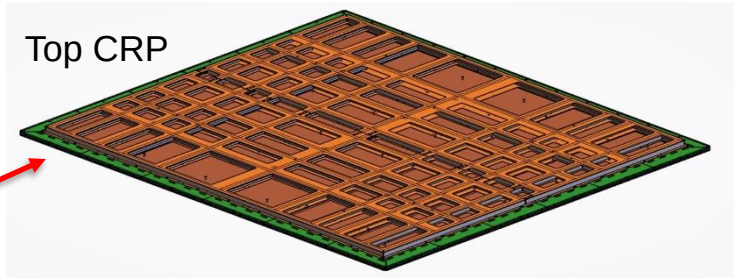


Mega-watt power neutrino beam with 1300 km baseline from Fermilab to SURF

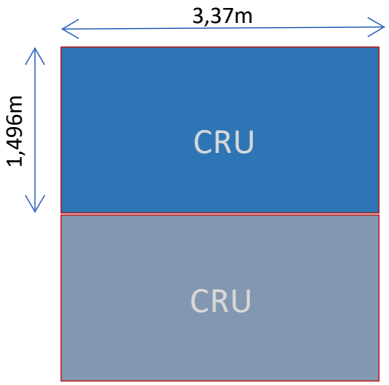
Vertical Drift LArTPC

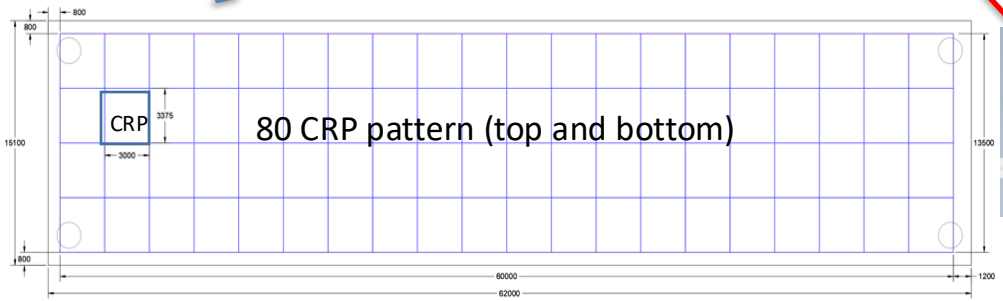
A MIP generates ~6000 electrons/mm in LAr
Drift electrons are sensed by Charge Readout Planes (CRP) located at the top and bottom of the drift volumes
Vertical drift of 6.5m with
450 V/cm drift E-field

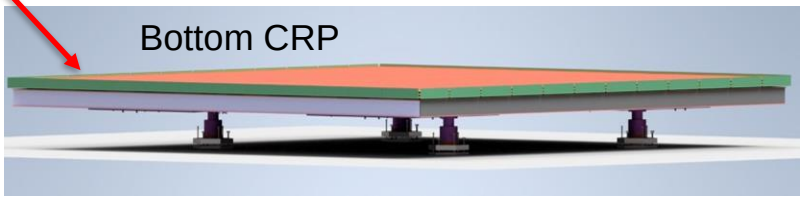




1 CRP = 2993 x 3370 mm²
- ✓ 2 Charge Readout Units attached mechanically
- ✓ 2 anode layers + adapter boards and edge connectors
- ✓ 1 mechanical frame





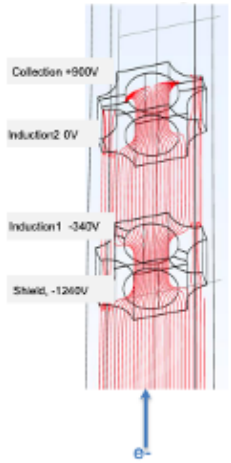


DUNE Far Detector Vertical Drift Technical Design Report: arXiv: abs/2312.03130

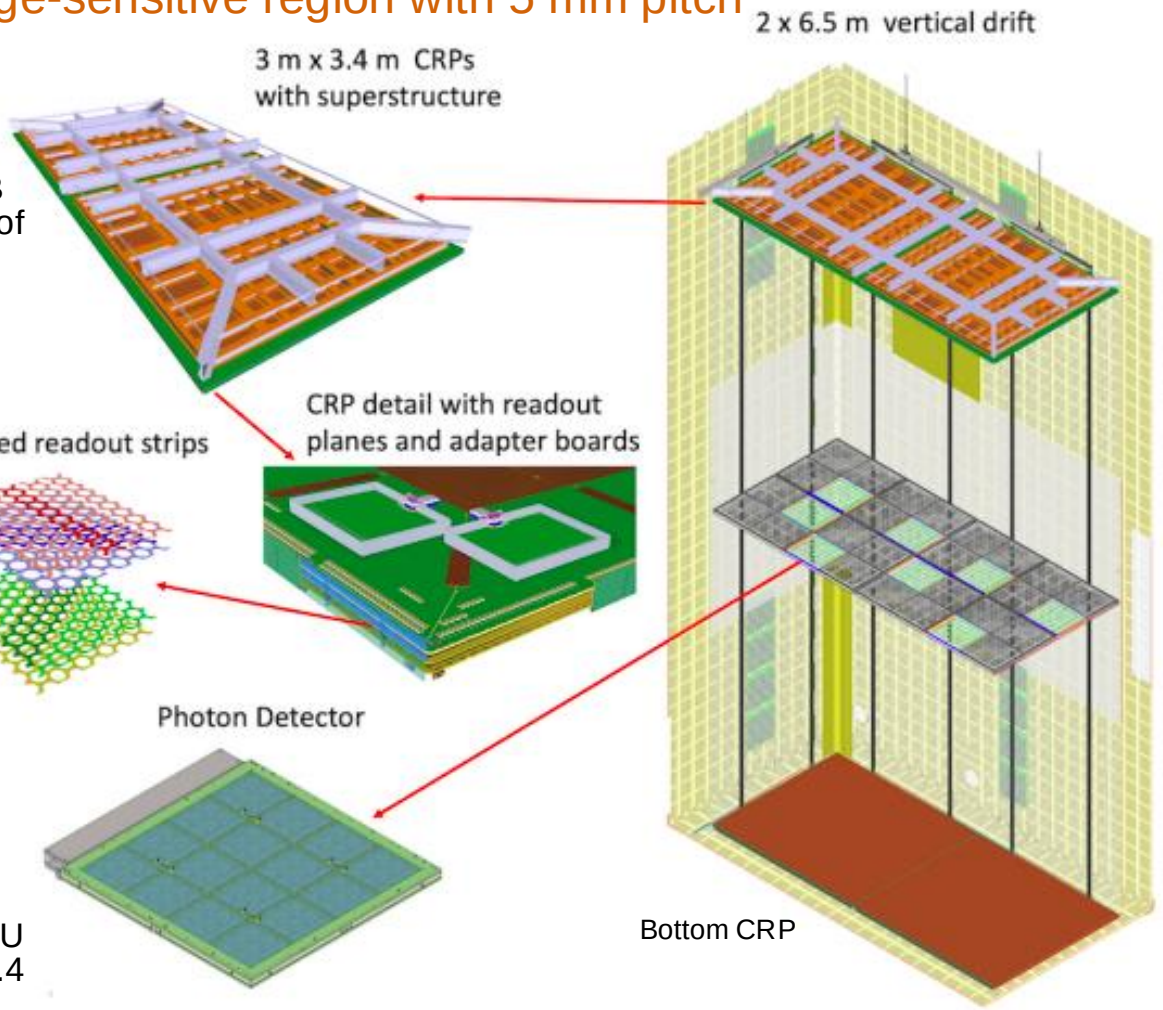
System Design

CRP provides a 3-layer charge-sensitive region with 5 mm pitch

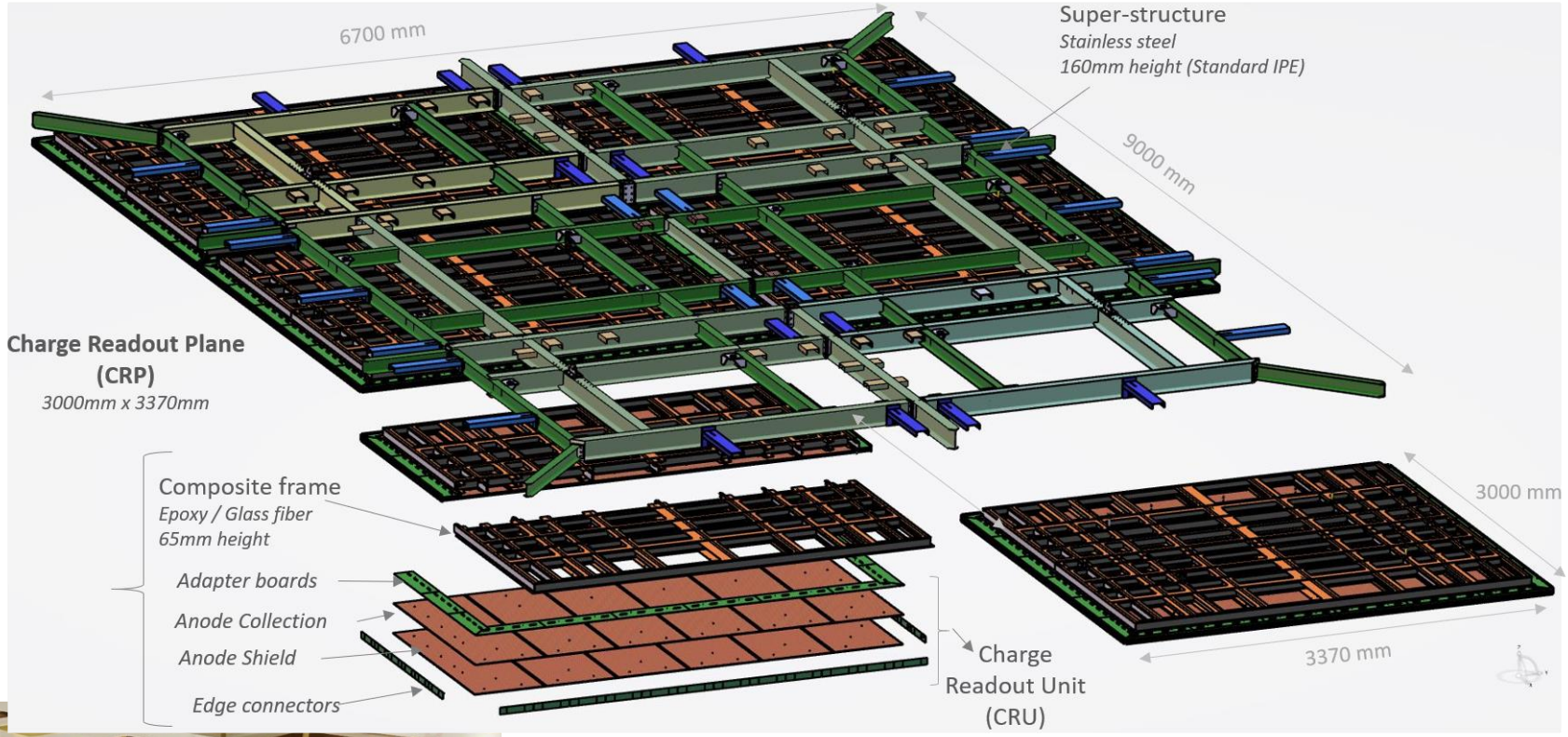
- Charge Readout Unit (CRU)
  - 2 sheets of 1.5 x 3.4 m^2 drilled PCB with conductive strips to the edges of the PCB
  - Adapter PCB to bring signals out to the readout electronics and edge connector PCB to interconnect the layers

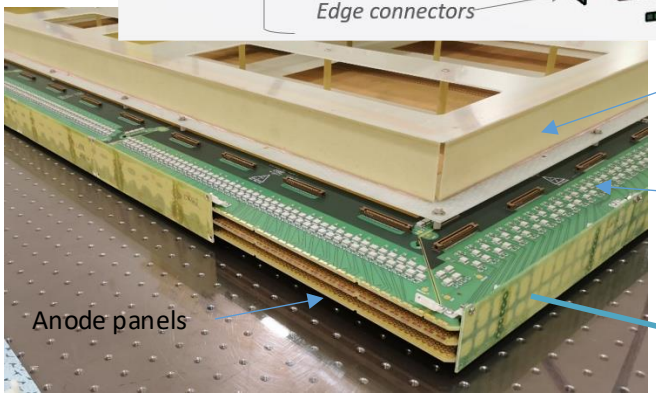


- CRP
  - Each CRU has a composite frame attached for support and then 2 CRU are bolted together to make a 3 x 3.4 m^2 charge sensitive plane
  - HV biasing is applied to make the planes transparent in the drift field



CRP Overview



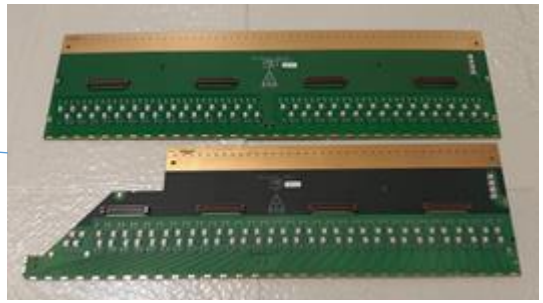


Composite frame

Separate design for top and bottom readout electronics

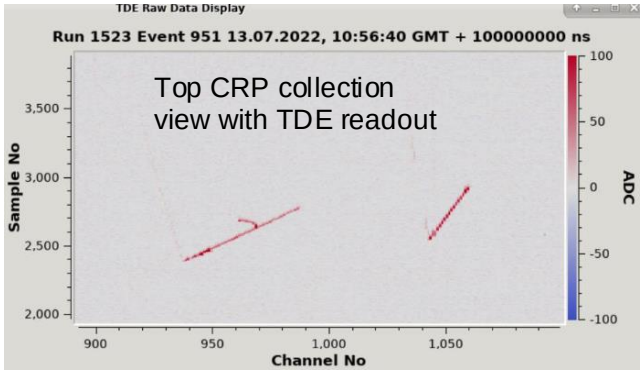
Edge connectors:

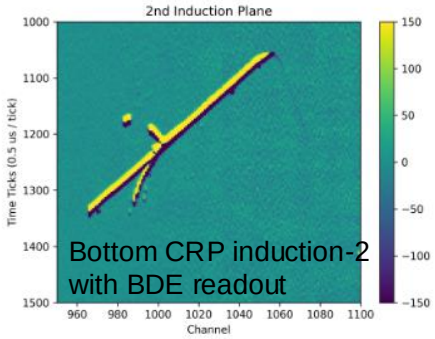
Adapter boards:

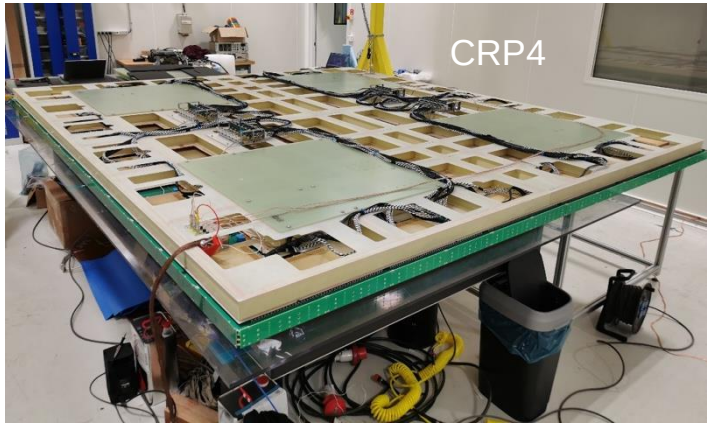


CRP Prototypes

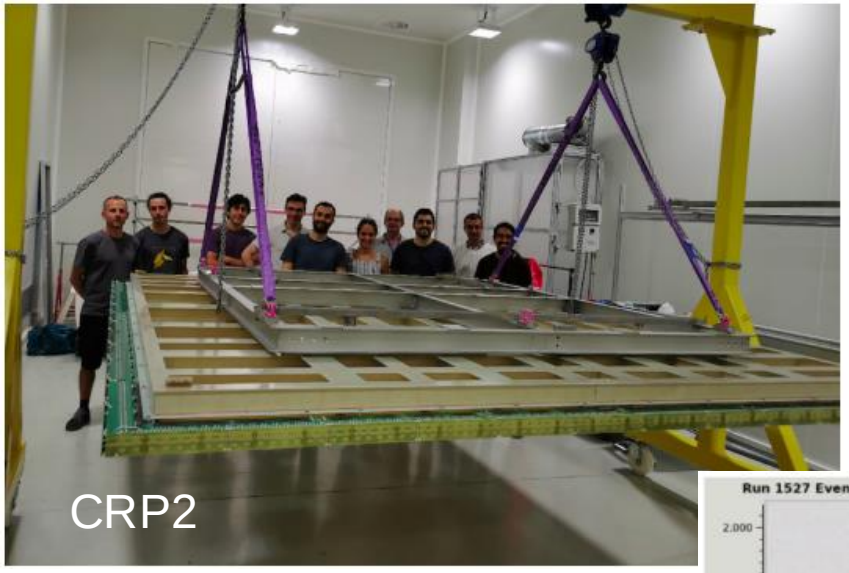
- 4 CRPs assembled for ProtoDUNE Vertical Drift module 0 LArTPCs
  - Top CRP2 and 3 at CERN
  - Bottom CRP4 and 5 at Yale (CRP5b at CERN)
- All 4 tested in LAr in the CERN cold box
  - Excellent performance for both top and bottom CRP
- Bottom CRP6 and top CRP7 built at CERN to further refine component design and grounding and shielding scheme
  - CRP6 tested multiple times in CERN cold box with improved performance



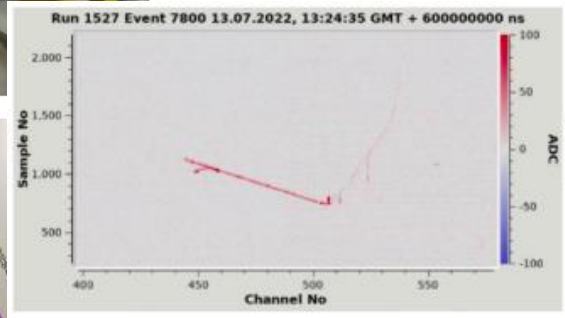


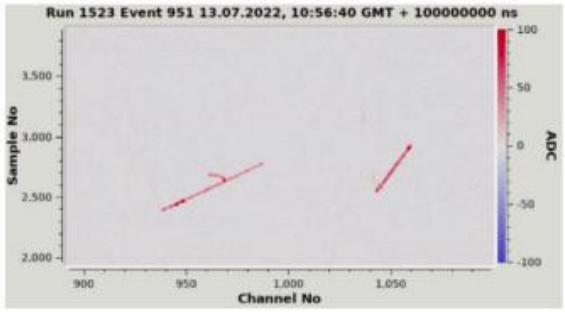


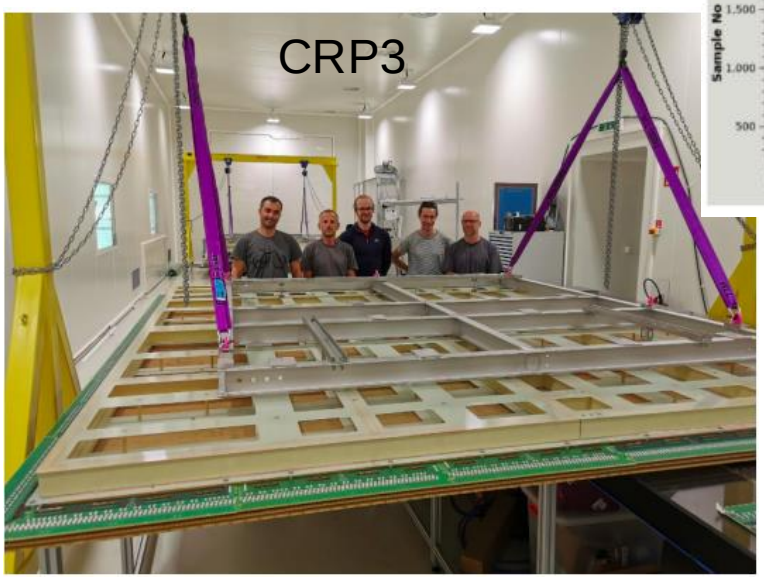
CRP2 and 3



- CRP2 was assembled and tested at CERN in 2022
  - Good results in cold box run with > 1M events
  - Cosmic ray track displays show excellent performance





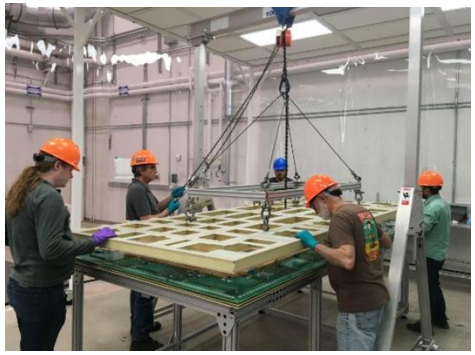


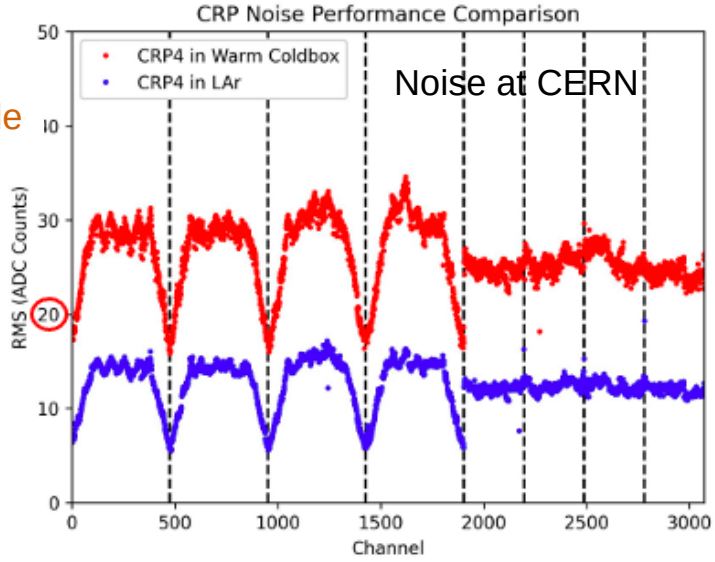
- CRP3 was assembled and tested in Sept-Oct 2022
  - Good results in cold box run with no major issues

CRP4 Experience

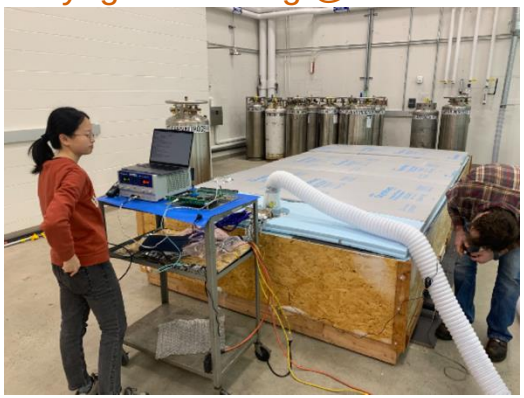
- CRP4 was assembled and tested at Yale and shipped to CERN for testing in the cold box and integration into the protoDUNE Vertical Drift detector
  - Followed the entire planned CRP assembly and testing sequence that will be used for the final production
- Excellent noise performance at the Yale factory was repeatable at CERN
  - All channels functioned well at CERN after the packing and shipping from Yale
- Demonstrated feasibility of testing CRP at assembly sites and shipping to SURF without loss of performance

Mechanical assembly @Yale

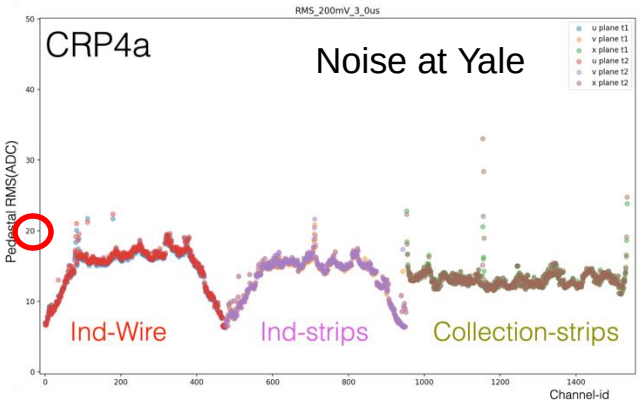


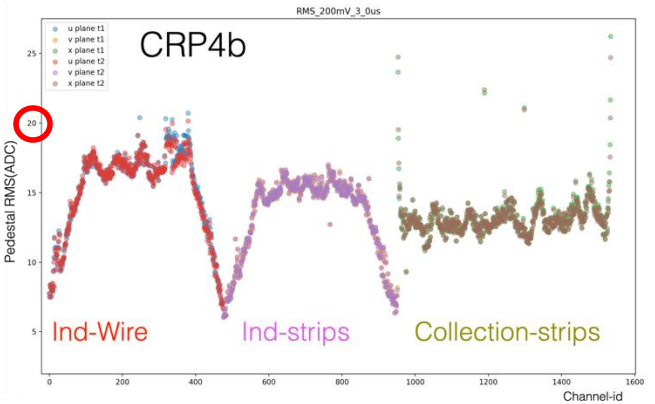


Cryogenic testing @Yale



Dec 2022 – Feb 2023





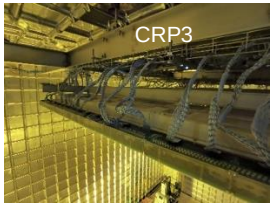
CRP Integration

ProtoDUNE Vertical Drift module 0 has two ~3m drift volumes each read out by 2 CRP (6,144 strips)
CRP integration started on January 2023 and completed in May 2023

2023

January — **Installation of cable trays and cabling**

Jan 17 — **CRP3 insertion in cryostat**

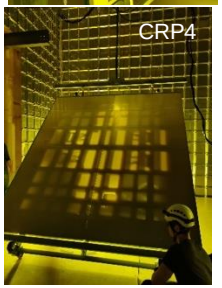


CRP3 installation and cabling

Jan 30 — **CRP2 insertion in cryostat**

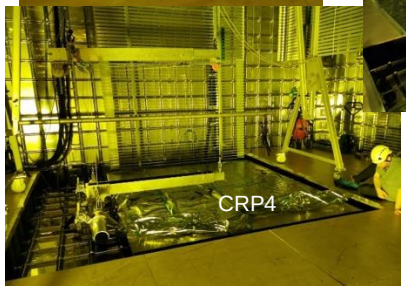
February — **CRP2 installation and cabling**

March

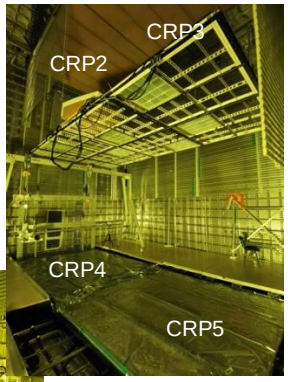


Mar 24 — **CRP4 insertion and flipping**

CRP4 cabling and installation



May 19 — **CRP5 cabling and installation**

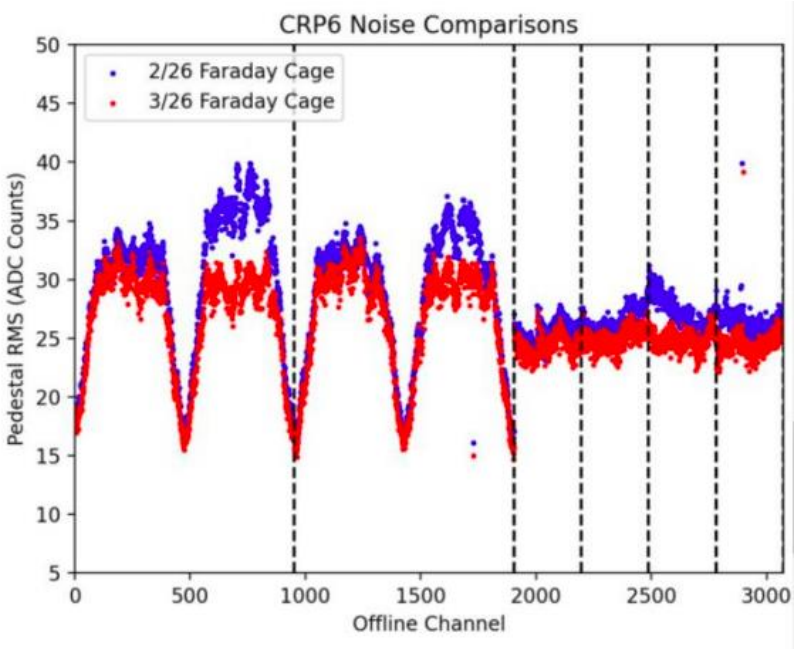


Integration of all 4 CRP was successful with > 99.5% channels showing good preformance
ProtoDUNE Vertical Drift module 0 will fill with LAr in early 2025 and begin cold commissioning

CRP6 Program

- CRP6 had a 4th cold box test in June 2024 to test connections with the updated readout electronics
  - New scheme functioned well with good performance

- CRP6 was initially tested in the CERN cold box in Nov 2023
  - Improvements to anode assembly, edge connector design
- Improved connections in the grounding scheme were made for the next tests in Feb-Mar 2024
  - Red points were taken after the improved ground scheme on CRP6



Summary

- CRP are a very promising technology for large scale LArTPC readout
- DUNE will instrument the Vertical Drift far detector with 160 CRPs
- R&D program for the DUNE CRP has demonstrated excellent performance

Backup Slides

Component Reference

Component	Sub-components	Quantity	Size
PCB segment	(none)	12 per CRU (glued and stacked), 3840 total	in 6 different flavors and 3 sizes. See Section 3.3
PCB panel	PCB segment	2 per CRU (stacked), 640 total	$1.494 \times 3.366\,\mathrm{m}^2$
View (also called "layer")	electrode strips on PCB	1 set of parallel strips per PCB panel side	See Table 3.3
Adapter board	4-layer PCB + bias capacitors and resistors	12 per CRU, 3840 total	in 7 different flavors and sizes for top and bottom
Edge cards	4-layer PCB + small connectors	24 per CRU, 7680 total	in 3 different flavors and sizes for top and bottom
CRU	2 PCB panels + 12 adapter boards + 24 edge cards	2 per CRP, 320 total	$1.496 \times 3.370\,\mathrm{m}^2$
CRP	2 CRUs + composite frame	80 per anode plane, 160 total	$2.993 \times 3.370\,\mathrm{m}^2$
Top superstructure	6 or 2 CRPs	16 (top anode plane only, twelve 6-CRP, four 2-CRP)	9.0×6.7 m and 3.0×6.7 m
Anode plane	80 CRPs	2	$60.0 \times 13.5\,\mathrm{m}^2$