The DUNE Far Detectors

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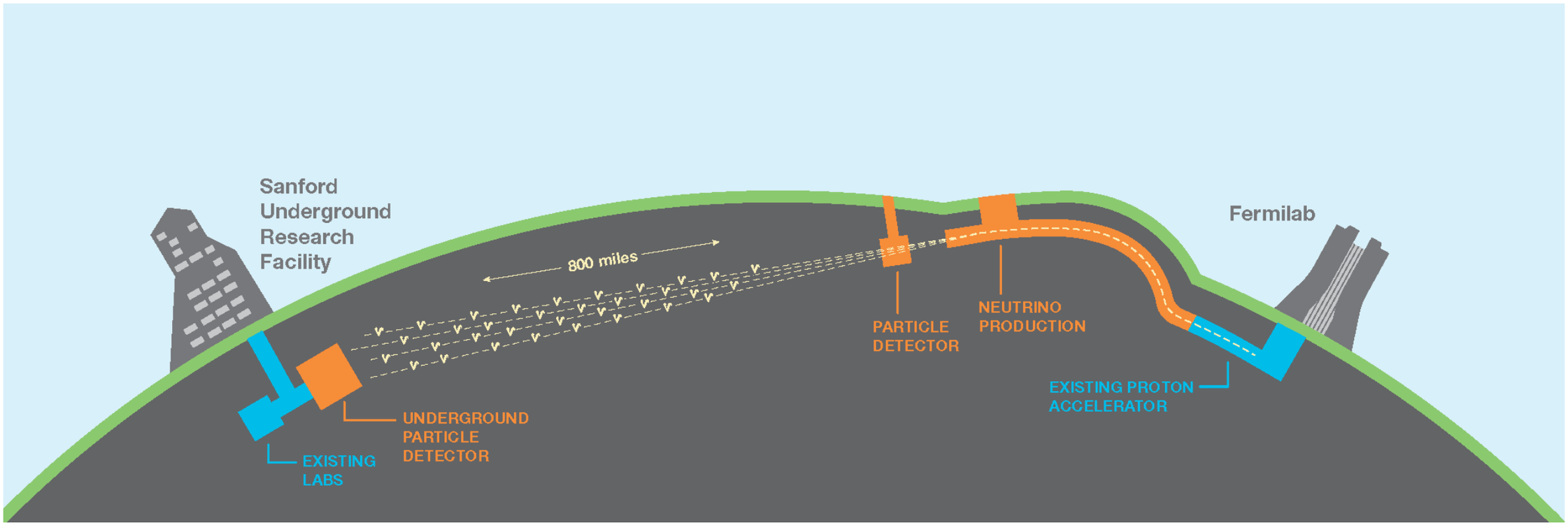
IFIC

MidTerm Review of SENSE

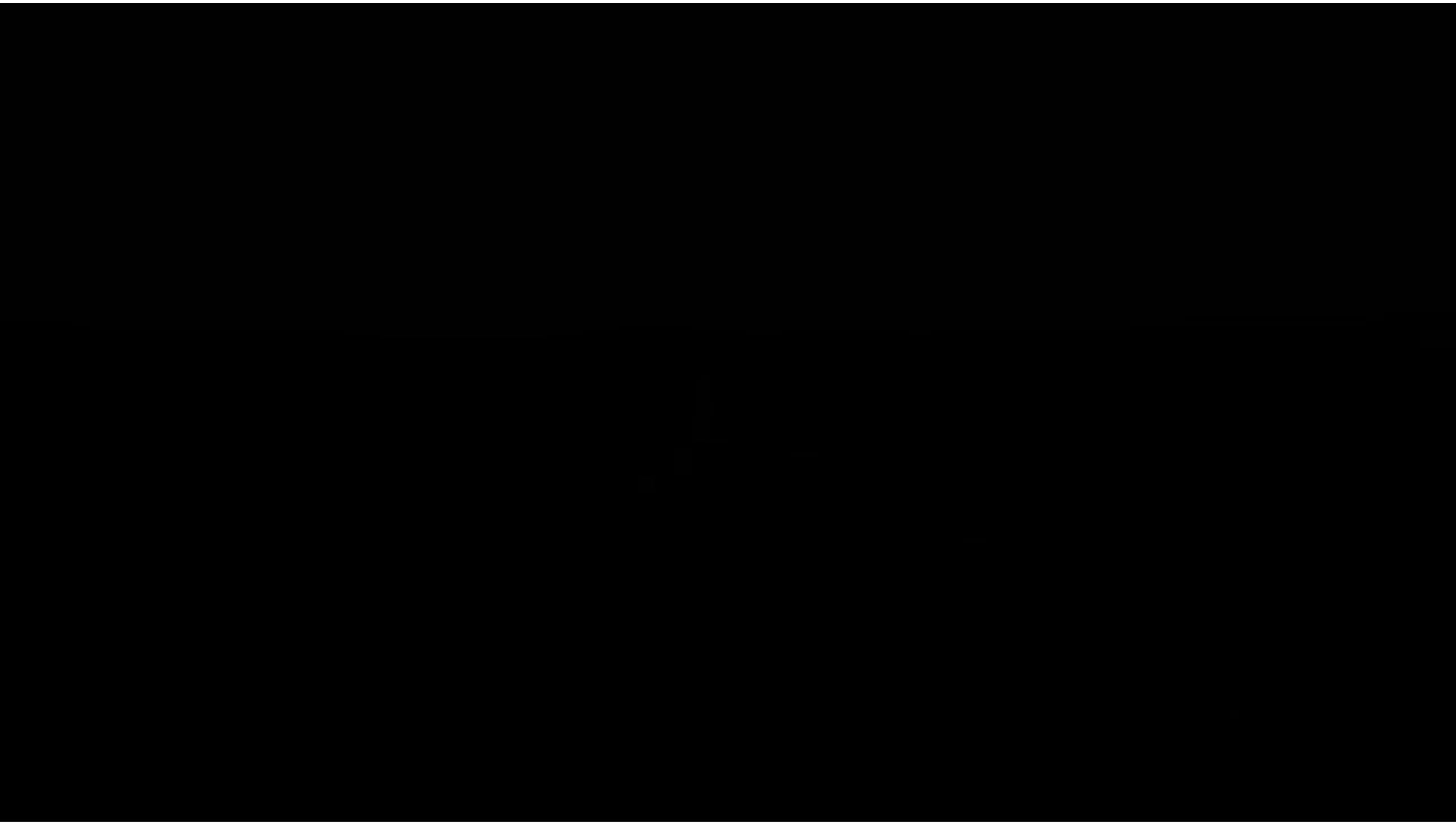
Deep **U**ndeground **N**eutrino **E**xperiment

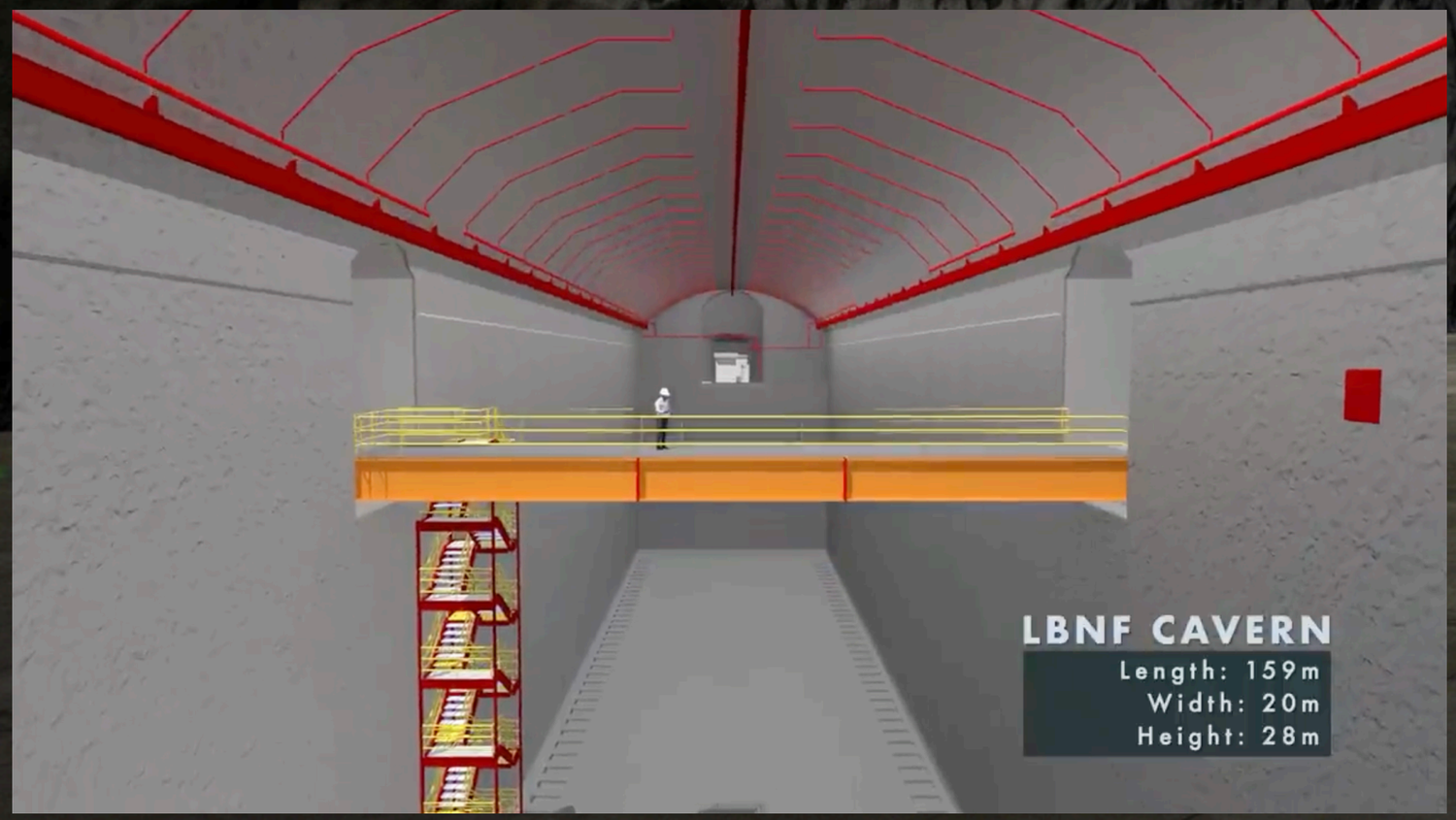
- DUNE is one of the future projects that will try to investigate neutrino oscillations in the next decade
  - More than 1400 collaborators from 35 countries
  - Two detectors, separated 1300 Km (Fermilab —> SURF)
  - 4 modules at SURF with 17 ktons of LAr each
    - Phase-I: FD1-2, 2029
    - Phase-II: FD3-4, 2035
  - 1.5 km underground in an old gold mine




SURF
(South-Dakota)
1300 km
Fermilab
(near chicago)

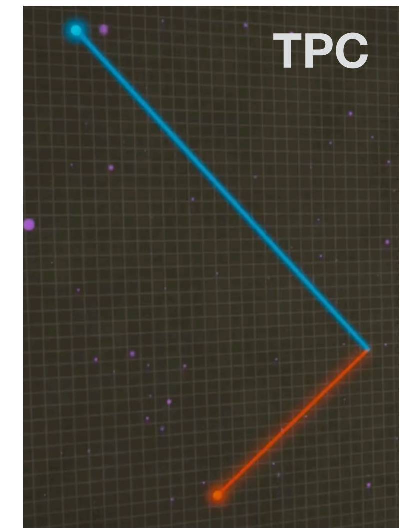
The far detector complex



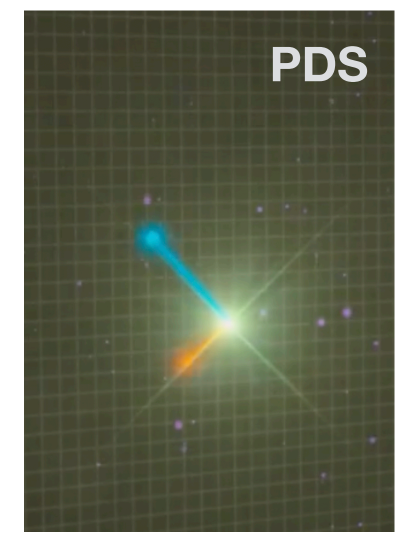

LBNF CAVERN
Length: 159m
Width: 20m
Height: 28m

Particle detection in DUNE

- A charged particle crossing the detector does two things:
  - **Inonization**: removes electrons from argon atoms
    - An E-field drifts them towards an anode
    - Produces a 3D image of the event + event energy

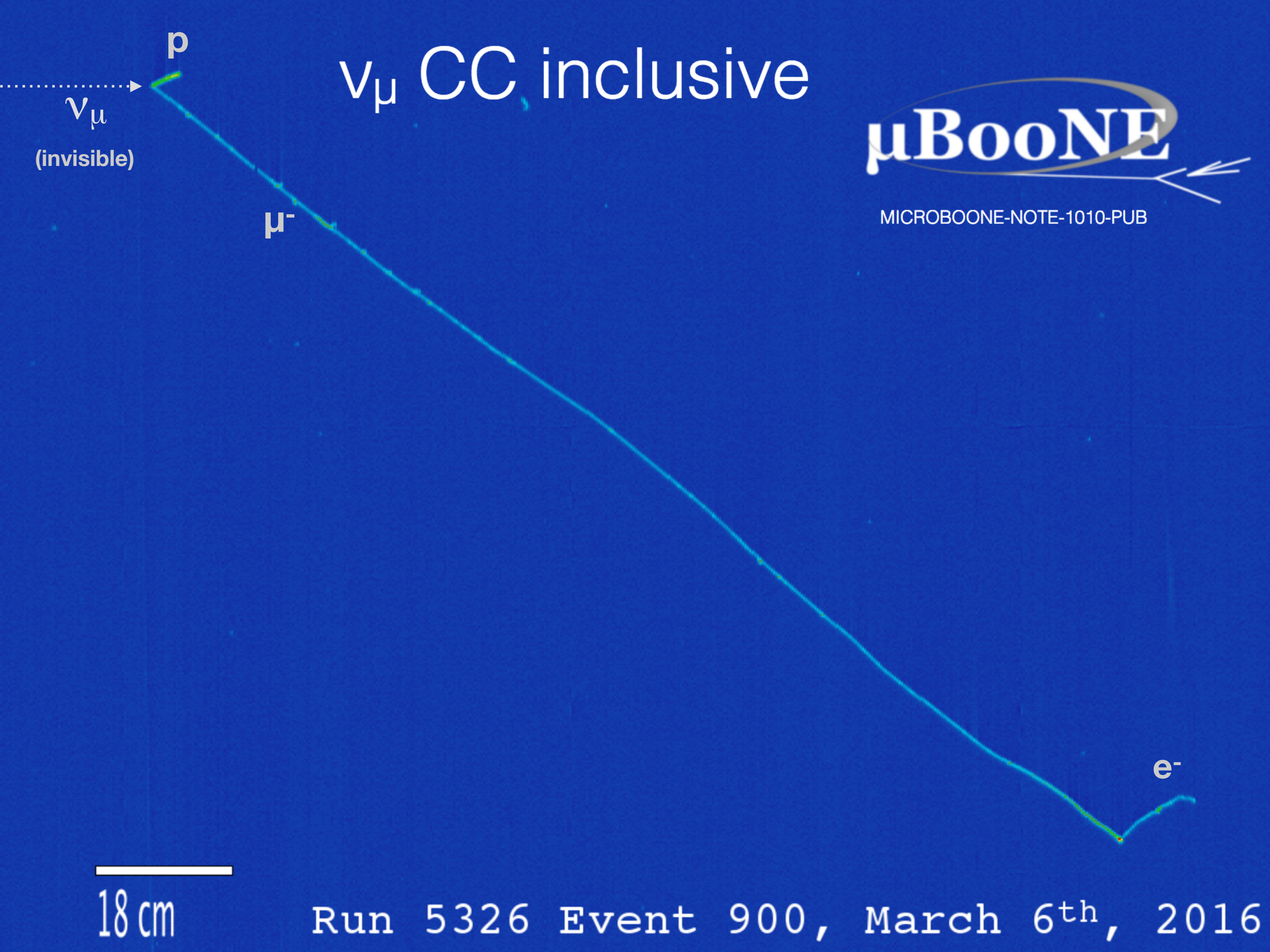


  - **Scintillation**: excites argon atoms, which inmediately decay producing light
    - Triggers the 3D picture + event energy



TPC is slow (10^{-3}), photons are fast (10^{-6})

ν_μ CC inclusive



μBooNE

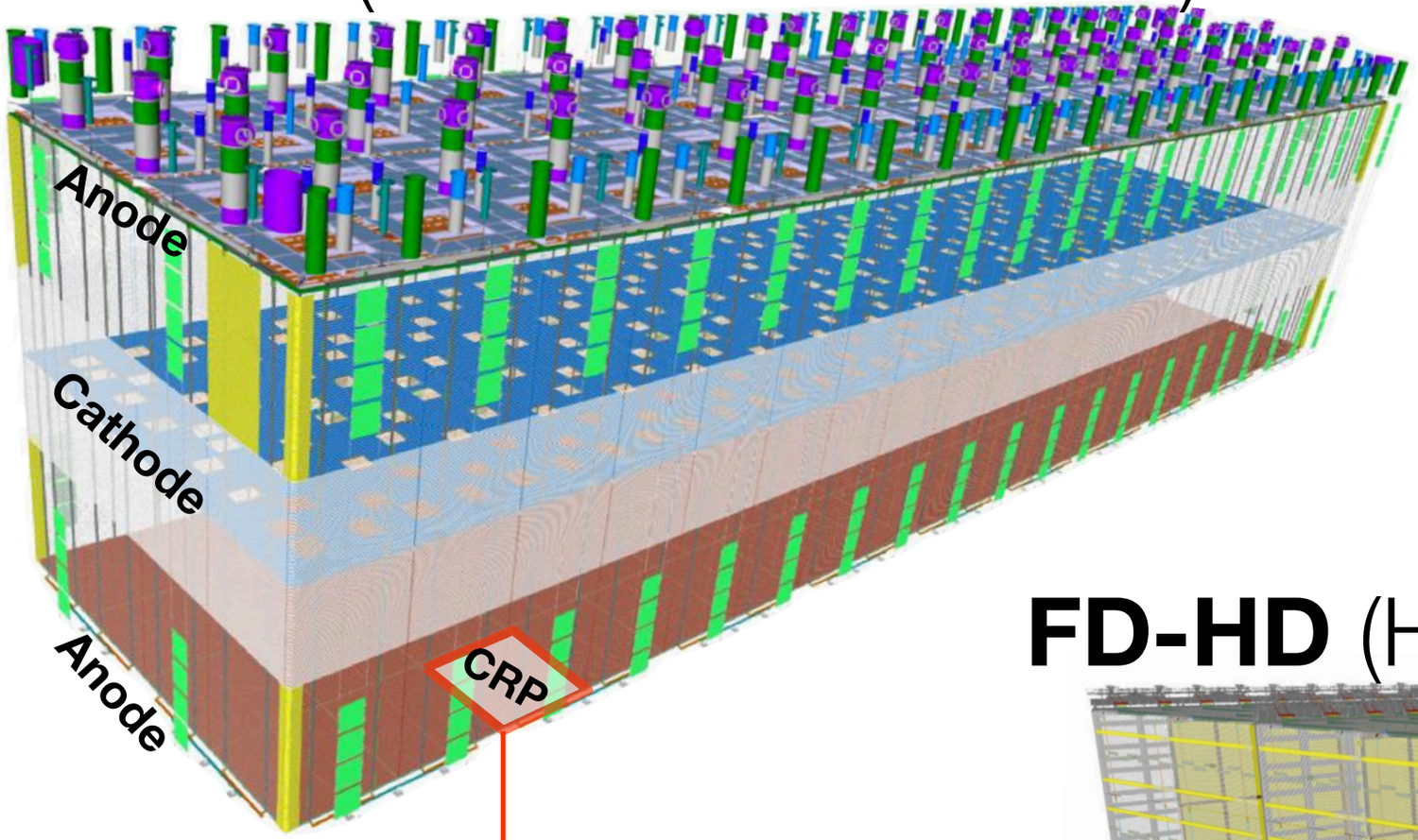
MICROBOONE-NOTE-1010-PUB

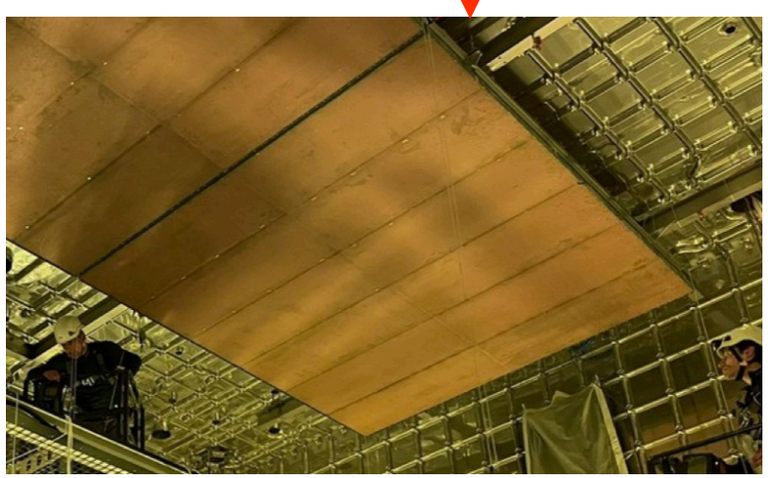
Why Liquid Argon ?

- **Dense**:
  40% denser than water
- **Cheap**: abundant
  (1% of the atmosphere)
- **Ionizes easily**:
  55,000 electrons/cm
- **Excellent scintillation**:
  20,000 photons/MeV
  (@ 500 V/cm)

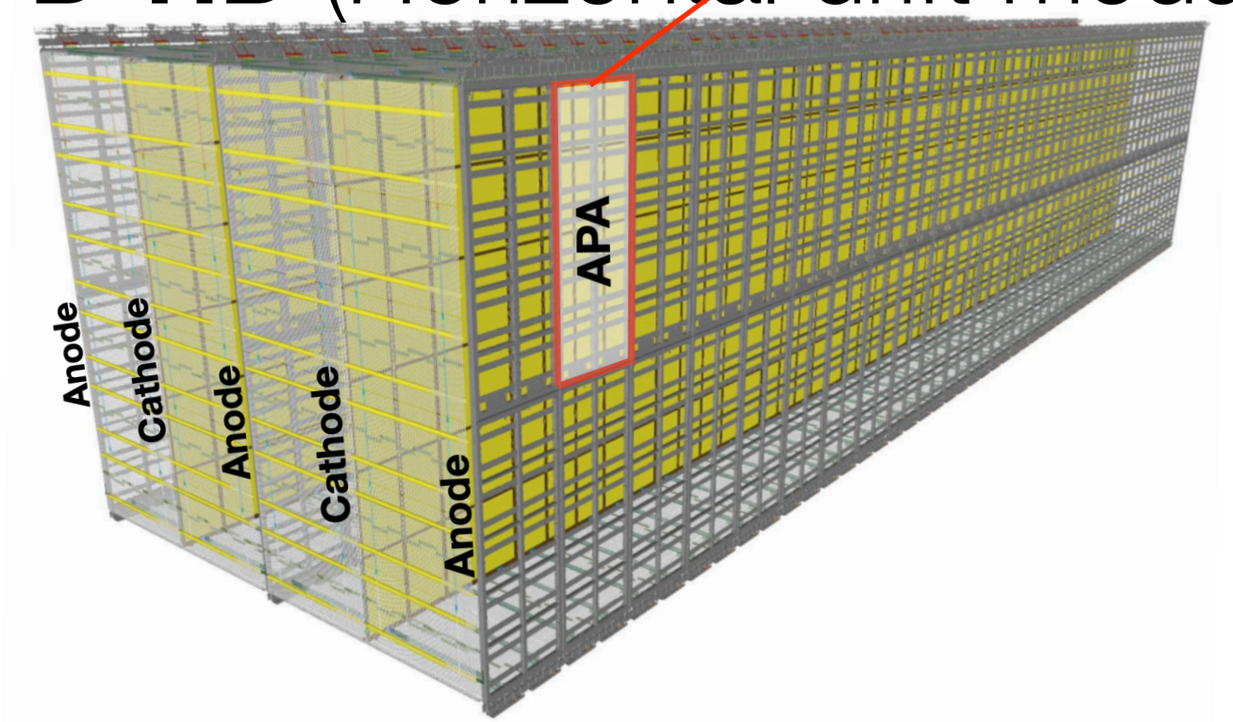
Phase-I far detectors

FD-VD (Vertical drift module)





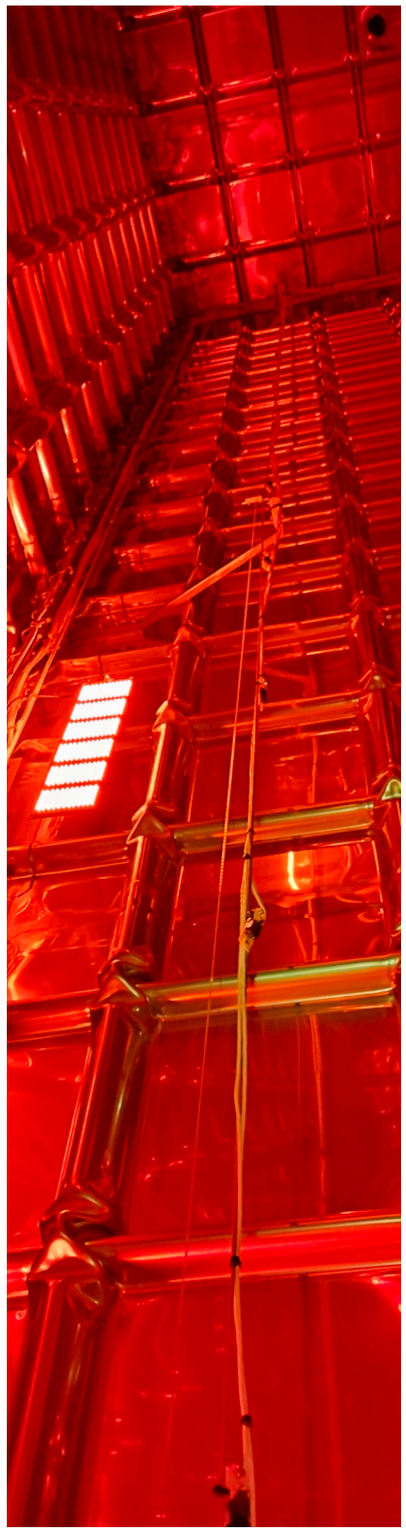
FD-HD (Horizontal drift module)



Prototypes at CERN

ProtoDUNE-HD

ProtoDUNE-VD



Phase-I FDs design validation

- Carried out at CERN in “cold boxes” and large scale prototypes (ProtoDUNEs)
- ProtoDUNE-HD, installed in 2022. Succesfully operated during 2024, after substantial delay due to LAr price and availability
- ProtoDUNE-VD, installed during 2023, and later refurbished during 2024, has just completed LAr filling and is ready for commisioning
- In parallel, design optimization of some components has being carried out at large cold boxes, also part of the CERN prototyping program
- All systems will undergo Production Readiness Reviews (PRRs) mostly this year, to begin production in 2026

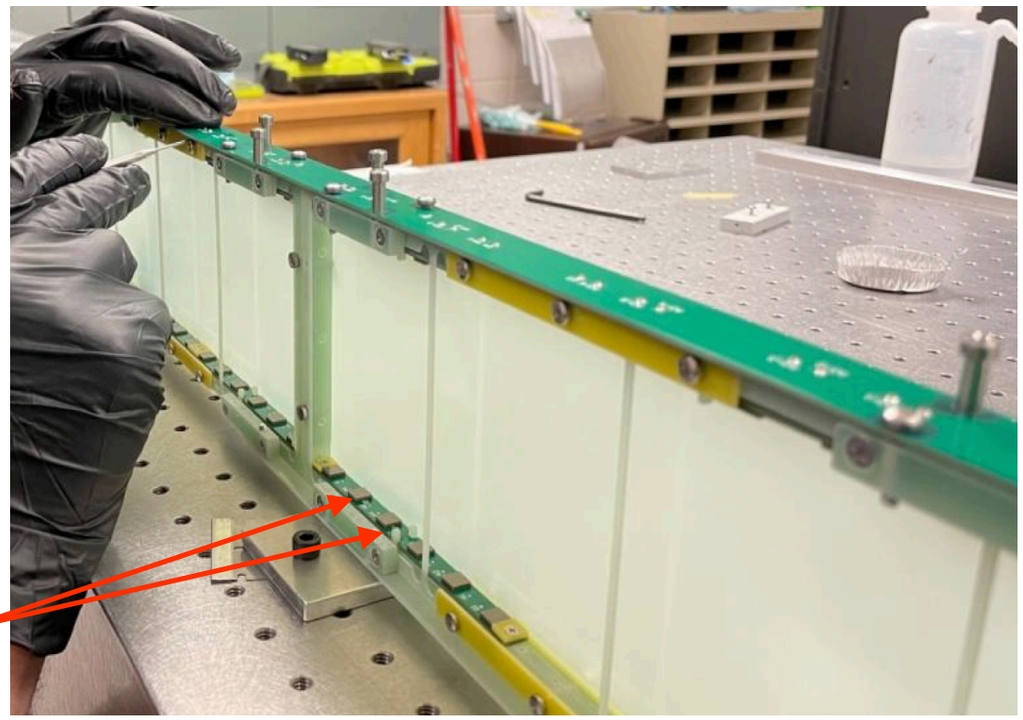
Phase-I FDs construction

- Procurement and calibration of some components have already started for both detectors
- Overall detector construction will start in 2026 and installation in 2027
- Warm structure for the cryostats, fabricated in Spain and procured by CERN, already in the US, to begin installation at SURF by mid 2025
- Sense WP2 involves two systems of Phase-I far detectors
  - Photon Detection System
  - Cryogenics instrumentation

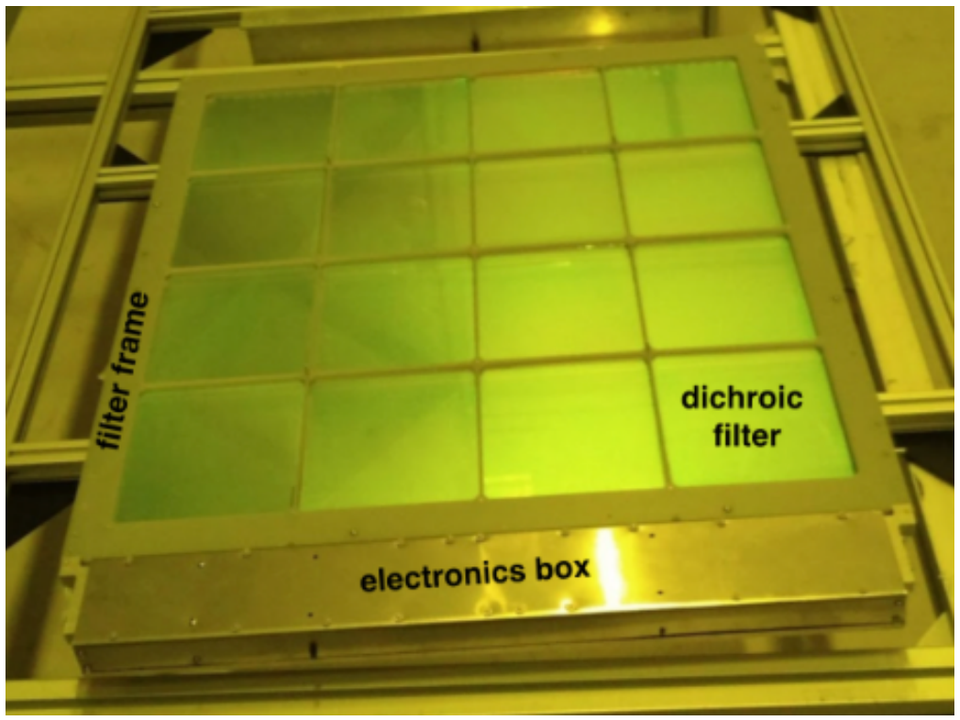
Photon detection system

- Argon scintillation light has 128 nm (vaccum ultraviolet - VUV) and it is very difficult to detect (this light is easily absorved and VUV SiPMs are very expensive)
- What we do is to shift the light to ~ 430 nm (blue) in two steps and then collect those photons with standard SiPMs (~300.000 units in FD-HD and 30.000 units in FD-VD)

HD photon collector

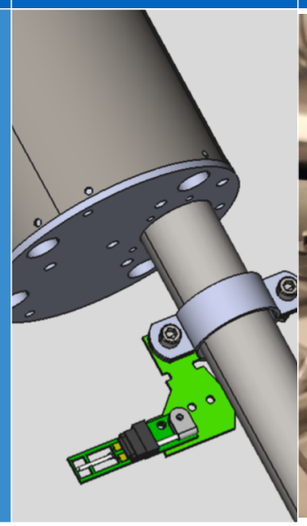
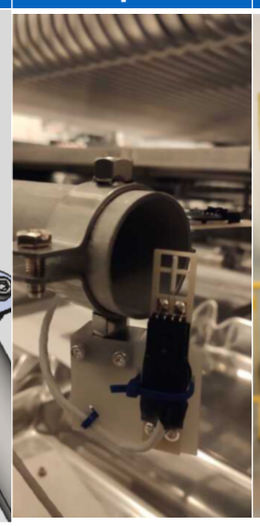
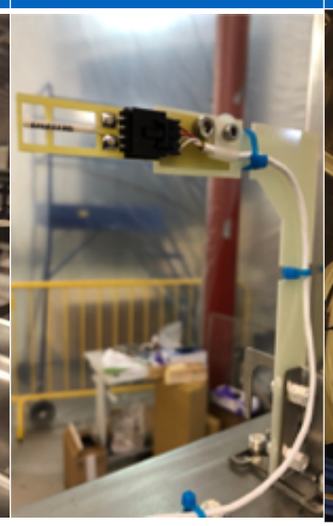
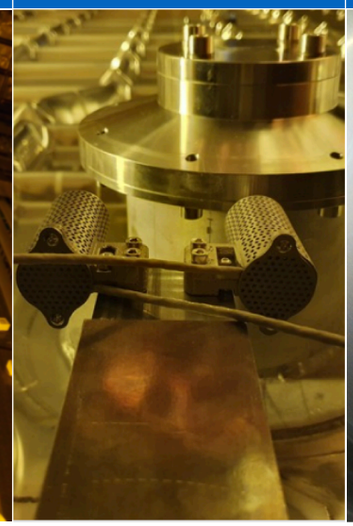


VD photon collector



Cryogenic instrumentation

- It is very important to keep LAr clean such that ionization electrons are not trapped by impurities (mainly oxygen) which deteriorate the 3D image of the TPC
  - Continud recirculation and purification is needed
- The temperature gradient in the cryostat induced by the recirculation system is of about **0.02 K**
- Systems installed in ProtoDUNE for **0.002 K** precisse temperature monitoring—> similar systems foreseen for FDs

	Purity Monitors	LAr Inlets + Pipes	APAs	ullage	T-Gradients	pumps	wall
							

Conclusions

- Design validation of Phase-I far detectors nearly completed, with some delay due to LAr availability and price, mainly due the war in Ucrania
- Strong participation (and leadership) in design and prototyping of the Photon Detection and Temperature Monitoring systems, validated at CERN. Undergoing PRRs to start construction in 2026.
- Cryostats warm structure arrived in the Rapid City (South Dakota) warehouse