# A Vertical Drift LArTPC for the DUNE experiment

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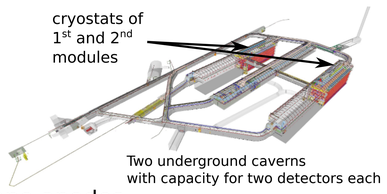
**DUNE FAR DETECTOR:**
will consist of four modules, the first two of which will be 17 kiloton LArTPCs, the largest ever constructed.

The first module is planned to be built as a conventional LArTPC, with wire plane anodes.




**Vertical Drift design:** new option for the second module.
Motivations:
- cost-effectiveness
- modularity, and thus simpler assembly procedure
- reduction of risk of dead channels and
- possibility to upgrade or replace the readout electronics during the detector lifetime

- Valuable experience was gained through the construction and operation of the ProtoDUNE detectors, at the CERN neutrino platform.
- Excellent LAr purity achieved -electron lifetimes measured of the order of 100ms- enables longer drift lengths.
- Use of anodes made with printed PCBs in a vertical detector has been tested.

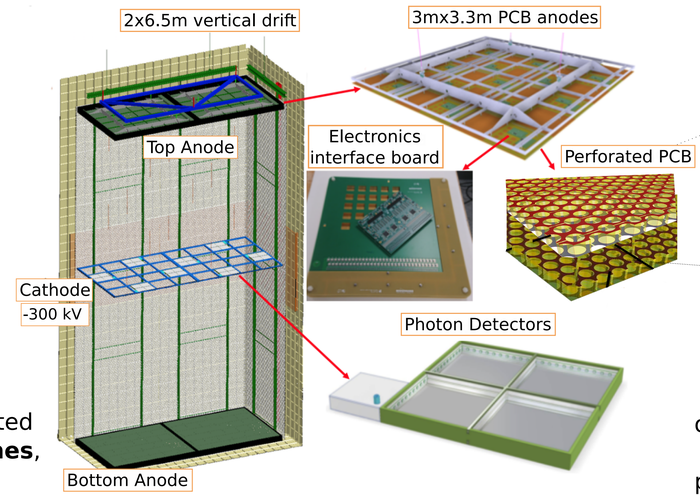
## Design Overview

The **cryostat** design is identical for the two first Far Detector modules.

The **field cage** is completely independent of the other components and provides an Efield of 500 V/cm.

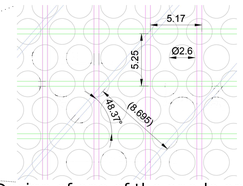
The **cathode** hangs from the CRPs,
- at half-height (6.5m).
- made of a resistive material,
- highly transparent: above 85% where photo-sensors are placed, and 60% elsewhere to allow free flow of the LAr

The top and bottom **anodes** are mounted on supports called **Charge Readout Planes**, each composed of four sub-units. This structure needs to be rigid enough to maintain its planarity, while allowing a margin to temperature-induced deformations.




Total active volume of 14.7 kton

Printed PCB anodes with 3 views. Dimensions optimized for good spatial resolution, good signal characteristics and construction simplicity.

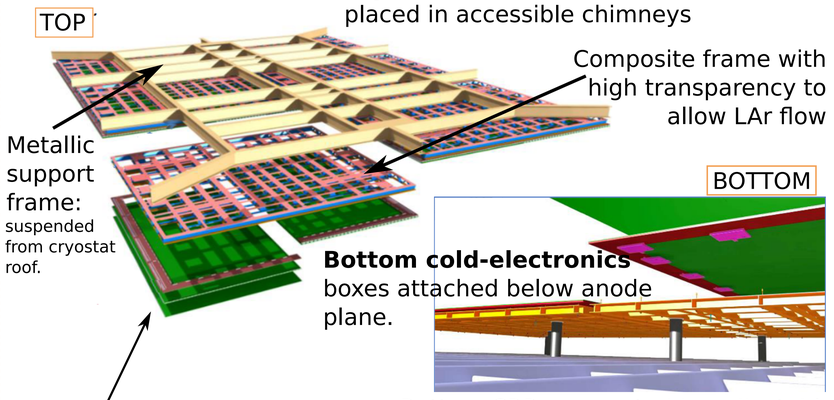



Design of one of the anode options with dimensions indicated in mm

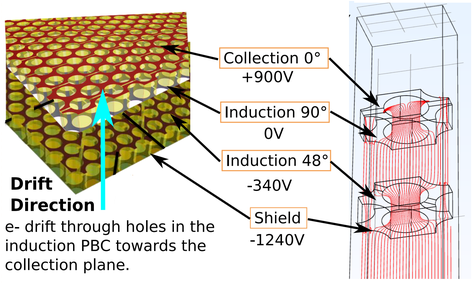
The **Photo-Detection System**
- provides the trigger
- information to calculate the depth of the particles within the TPC.
- sensors: **x-ARAPUCA tiles,** placed on the cathode surface and cryostat walls, in a '4π' configuration that aims to enhance the PDS capabilities.

## Anode Plane design

**Top warm electronics**: placed in accessible chimneys




Bottom CRPs supported by adjustable feet laid on membrane (no metallic frame needed)

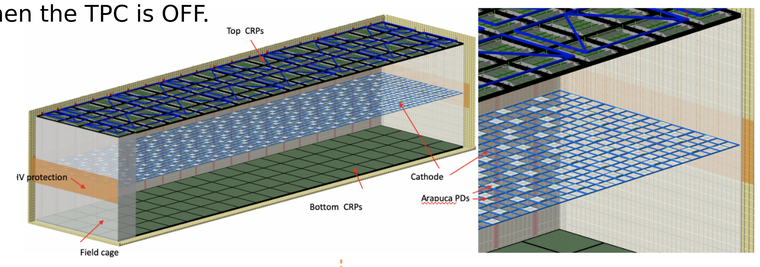



e- drift through holes in the induction PBC towards the collection plane.

The expected Efield is simulated using Wire-Cell. While optimization is on-going, a design for a first prototype is shown, with two PCB layers forming a protection grid, two induction layers and a collection layer.

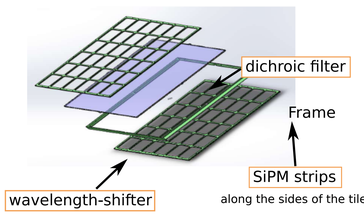
## Photon Detection System

The opaque anodes at the top and bottom of the detector raise the need to locate the photon detectors on the cathode and the sides of the detector. Although a challenge in itself, this opens the opportunity to enhance the performance of the PDS by **instrumenting almost all sides of the active volume**. The PDS could provide backup, operating when the TPC is OFF.




x-ARAPUCA sensors:
- concept tested in ProtoDUNE-SP
- double-sided square tiles
- 160 SiPMs each

A new assembly, filter and WLS is being implemented to increase efficiency.




### Signal and Power transmission

Sensors on cathode surface (at -300kV) → Non-conductive cables must be used for power supply and signal transmission

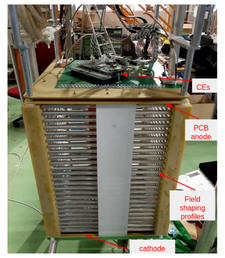
Power over Fiber: light from powerful lasers is conducted through fiber towards a converter placed close to the cathode.

Signal over Fiber: SiPM signal is transmitted over fiber (both analog and digital transmission is under evaluation)

Both systems are currently under development and showing

## Status and Prospects

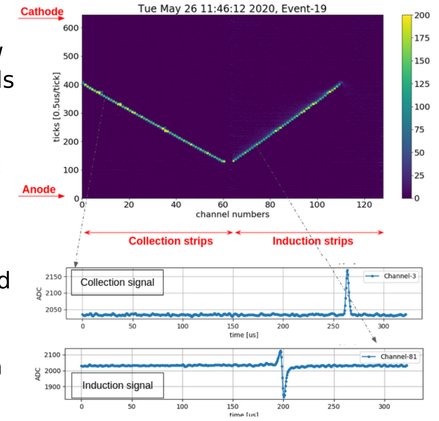
Efforts have ramped up since end of 2020 to converge towards a well-optimized detector concept.




TPC for 50lt test

**Tests of a full TPC:**
- First proof of principle in a 50 l cryostat
  - showed satisfactory signal and noise performance.
- Cold-box test in a 3x3x1m$^3$ cryostat:
  - planned before the end of 2021.
  - a fully integrated system with a cathode, top CRP and PDS will be tested.

Signals measured in 50lt test




Preliminary studies show that the DUNE physics goals imply similar detector requirements for the horizontal and vertical drift LArTPCs.

A detailed simulation of the detector is being implemented in Geant4 and will soon be available for further studies and to evaluate physics cases in a more realistic way.

Stay tuned for more exciting news on this detector concept!