ProtoDUNE:

Prototyping the ultimate MeV- GeV neutrino detector

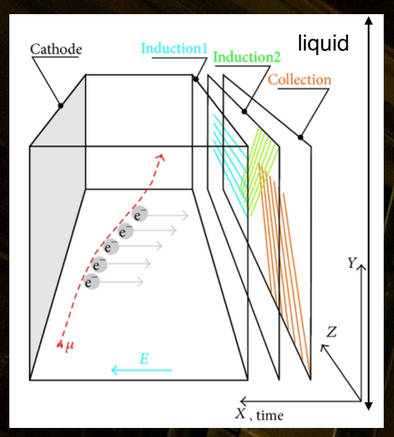
Roberto Acciarri - Fermilab*

Prototyping DUNE

Four Liquid Argon Time Projection Chambers (LArTPC) holding in total around 70 ktons of liquid will be constructed in the next ten years in South Dakota as the Far Detector of the Deep Underground Neutrino Experiment (DUNE), for a rich neutrino and proton decay science program. The availability of two variants of the LArTPC technology, single- and dual-phase, and the scaling up by two orders of magnitude from the largest such detector previously built (ICARUS) call for extensive prototyping and a demonstration program with a side-by-side comparison of the two options.

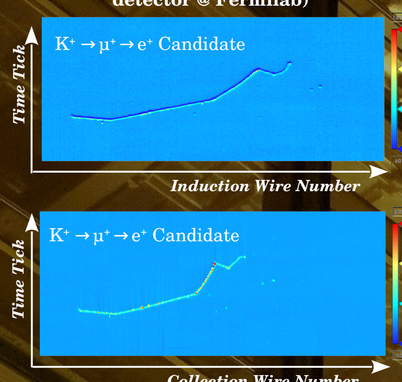
The ProtoDUNE program is carried out at the CERN Neutrino Facility through two 800 ton LArTPCs (one for each option), where the final detector configurations and engineering solutions will be fully characterized, offering also an ideal environment for the development of Data Acquisition, Data Reconstruction and Analysis.

Single Phase detection technique

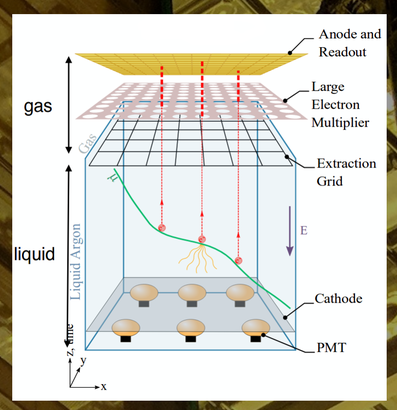


- Ionization charges drifted horizontally and read out by a set of 3 wireplanes for 3D reconstruction and calorimetry
- LAr scintillation light collected by photon detection system behind wireplanes for event triggering
- No signal amplification in liquid

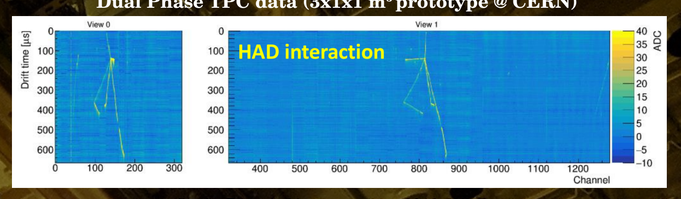
Single Phase TPC data (LArIAT detector @ Fermilab)



Dual Phase detection technique



Dual Phase TPC data (3x1x1 m³ prototype @ CERN)



Credit: Edoardo Mazzucato (May 2018 DUNE collaboration meeting talk)

- Ionization charges drifted vertically, transported into the gas phase by means of an extraction grid, amplified in the Large Electron Multimplier (LEM), and readout via 2D segmented anode for 3D reconstruction and calorimetry
- LAr scintillation light collected by PMTs below the cathode for event triggering
- Signal amplification in gas with LEMs

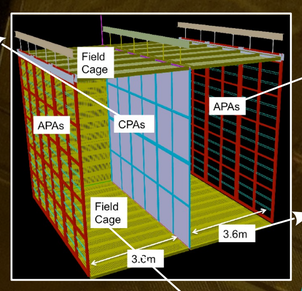
ProtoDUNE Single Phase overview

2 TPCs 6 m high, 7 m wide, 3.6 m deep, sharing the cathode

***C**athode **P**lane **A**ssembly*
3 modules made of resistive Kapton laminated on dielectric panels

⬇

Better control of energy release in case of discharge

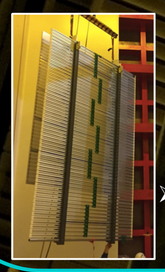


***A**node **P**lane **A**ssembly*
Anode module made by Stainless Steel (SS) frame holding 4 wireplanes (3 readout planes + one shielding grid). Full anode made by 3 APAs

Drift length same as DUNE Far Detector

⬇

High Voltage applied to cathode same for ProtoDUNE-SP and DUNE FD: 180 kV



Field Cage

- Resistive divider chains equipped with varistors mounted on aluminum profiles supported by a dielectric frame to provide a constant 500 V/cm electric field
- Equipped with perforated SS ground planes to ensure null field outside active volume
- 6 field cages for each TPC volume

ProtoDUNE Dual Phase overview

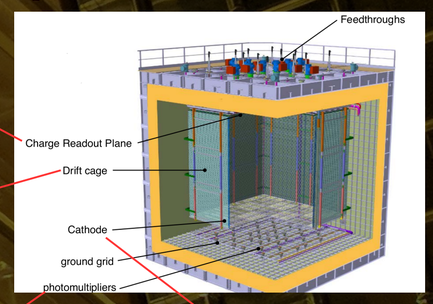
1 TPC 6 m high, 6 m wide, 6 m deep

Charge Readout Plane (CRP)
Readout plane containing extraction grid, LEM and anode

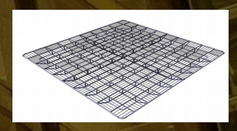
Drift Cage
8 modules with design similar to SP Field Cage, without SS ground plane protecting HV regions. Drift length determined by cryostat height

⬇

High Voltage applied to cathode:
300 kV for ProtoDUNE-DP
600 kV for DUNE FD



PMTs
36 8” PMTs. Photocatodes evaporated with TPB (Tetraphenyl Butadiene) to convert VUV scintillation light into visible spectra

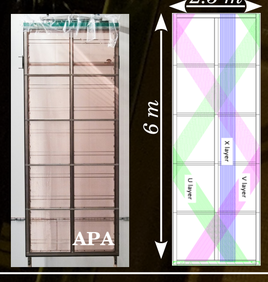


Cathode
Grid of stainless steel tubes to allow light collection by PMT system placed underneath

Photo credit: Edoardo Mazzucato (May 2018 DUNE collaboration meeting talk)

ProtoDUNE Single Phase charge readout

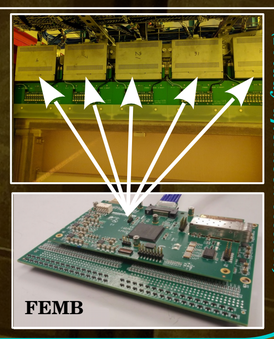
Readout core: APA + Cold Electronics



- Readout wireplanes at 0°and ±35.7° inclination
- **Wrapped wires** reduce number of electronic channels and allows all electronics to sit on top (reduce dead space on the sides)
- 2560 wires per APA, 150μm Ø, 5 mm pitch → 15000+ total readout channels

No signal amplification in liquid → required extra care for grounding and electronics positioned in cold, close to the wires

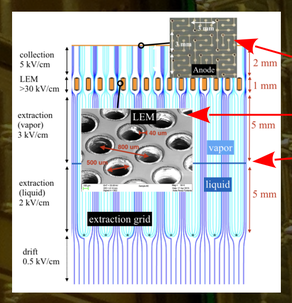
- Cryostat, detector, all electronics and power electrically isolated from the building, to prevent noise pick-up
- APA frame isolated from the cryostat, grounded through power cables (avoid ground loops)
- FEMB (Front End Mother Board) with signal amplifying/shaping stage and ADC in LAr, on top of the APA
- Aiming at S/N ratio between 15 and 70
- 20 FEMB/APA, 16 FE and 16 ADC ASICS /FEMB

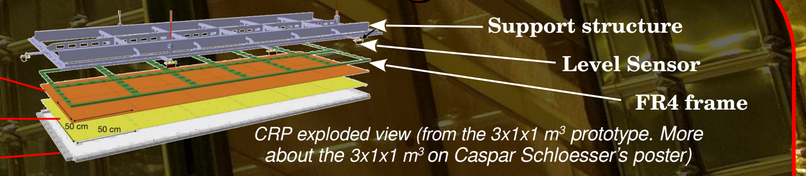


More about electronics in Maura Spanu's talk (Friday afternoon session)

ProtoDUNE Dual Phase charge readout

Readout core: Charge Readout Plane





CRP exploded view (from the 3x1x1 m³ prototype. More about the 3x1x1 m³ on Caspar Schloesser's poster)

- Four 3m X 3m CRPs. Each CRP has 36 LEM and 36 Anodes → 7680 total readout channels
- Charge equally shared between X and Y view
- Tunable gain > 20

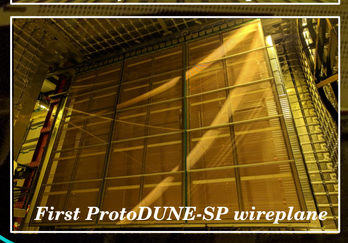
With respect to Single Phase:

+ Commercially available components; less electronic channels; equal charge sharing and shape between X and Y view; accessible Front End electronics (ASIC amplifiers) in GAr; higher S/N ratio (expected 80-100)

– More ambitious, less mature technology; need to precisely (±0.5 mm) set and maintain a stable liquid/gas level; several high electric fields within small distances → high discharge risk during operation

ProtoDUNE Single Phase status

First drift volume completed



First ProtoDUNE-SP wireplane

- First TPC completed, all elements of second TPC inside the cryostat
- Full detector completion, cryostat filling and detector activation by end of August 2018
- **August 29th 2018 to November 11th 2018**: data taking with low energy charged particle beam
- **From November 12th 2018**: data taking with cosmics

Full cathode + FC modules

All parts in

ProtoDUNE Dual Phase status

- Drift Cage completely assembled and tested up to half the nominal voltage in air
- Test of HV feedthrough currently ongoing
- First CRP near completion. Cathode to be assembled and installed in September
- PMTs being shipped to CERN, ready for TPB deposition and installation
- Detector installation to be completed on October 2018, with commissioning foreseen in early 2019

First CRP G10 frame

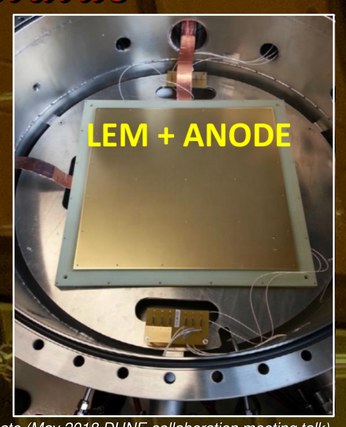


Photo credit: Edoardo Mazzucato (May 2018 DUNE collaboration meeting talk)

** On behalf of ProtoDUNE-SP collaboration*