# ProtoDUNE Single-phase LAr Detector & Beam Measurement Program at CERN


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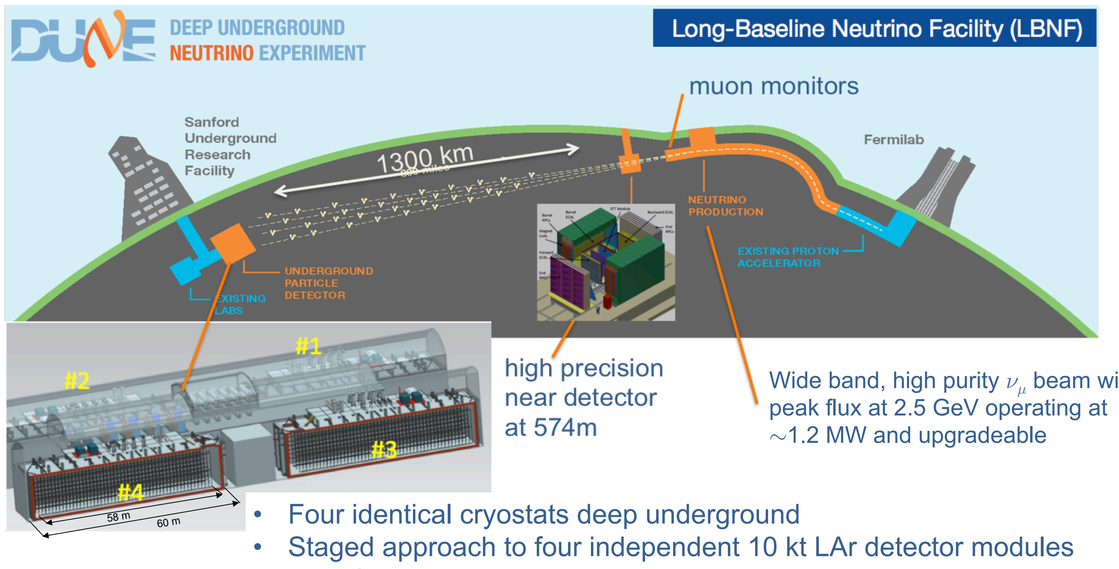
DUNE Deep Underground Neutrino Experiment


## Introduction

The DUNE long-baseline neutrino experiment will study different modes of neutrino oscillations to identify the CP properties of neutrinos, measure the neutrino mass hierarchy and perform precision measurements of neutrino (mixing) parameters. Other primary physics goals include a search for nucleon decay and the detection of Supernova burst neutrinos. DUNE will also pursue a variety of other measurements.

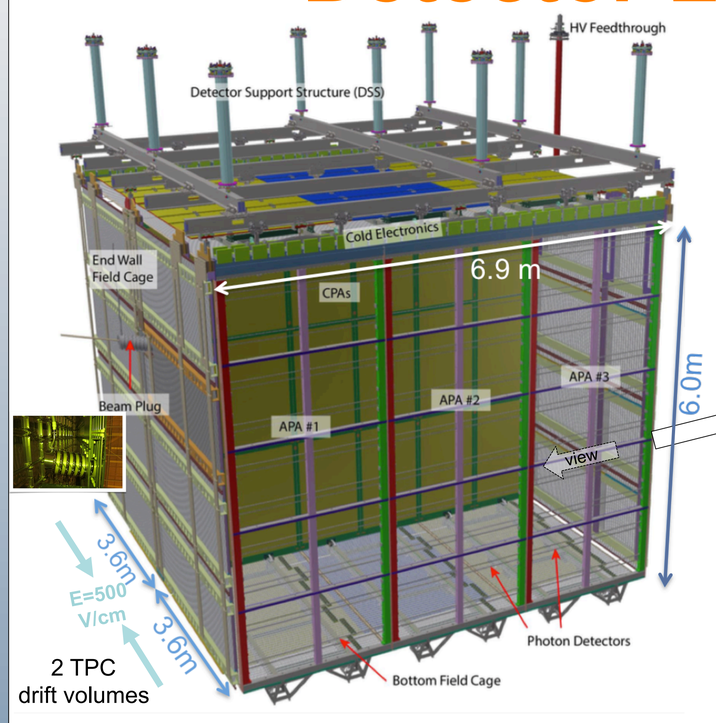


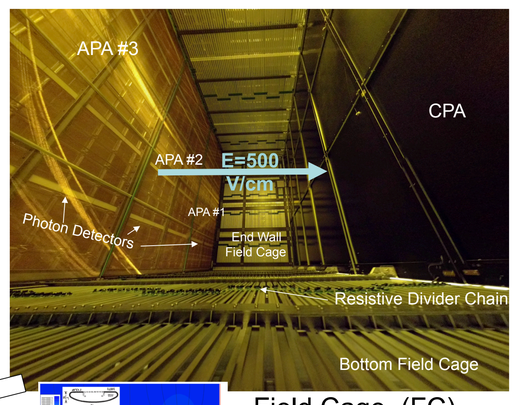

- Four identical cryostats deep underground
- Staged approach to four independent 10 kt LAr detector modules
- Modular detector components

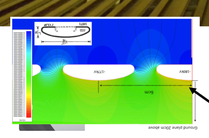
**ProtoDUNE purpose and goals**:

→Assess engineering aspects of DUNE far detector components
→Validate basic detector performance (cosmic rays)
→Study charged particle interactions in LAr (test beam)
→Validate event reconstruction algorithms and MC simulations

## Detector Layout



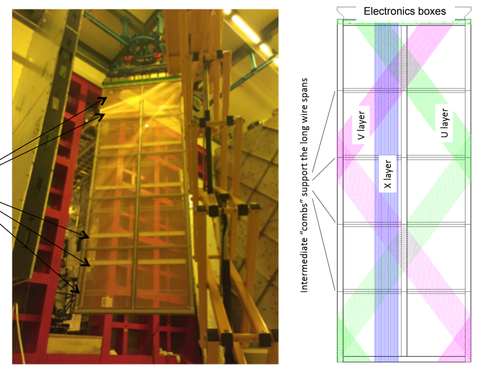



### Field Cage (FC)

Made from extruded Al profiles

Max E field: ~12kV/cm

### Anode Plane Assembly (APA)

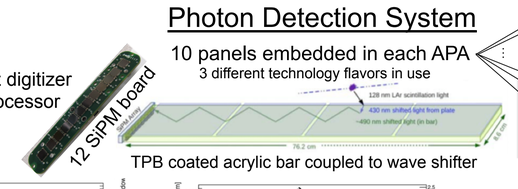


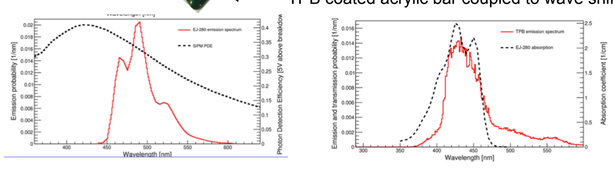

| Function | no. | pitch [mm] | orientation | potential [V] |
|---|---|---|---|---|
| Collection (x) | 960 | 4.79 | vertical | 820 |
| Induction (V) | 800 | 4.67 | 35.7° - wrapped | 0 |
| Induction (U) | 800 | 4.67 | 35.7° - wrapped | -370 |
| Grid | 960 | 4.5 | vertical | - 665 |

### Photon Detection System

10 panels embedded in each APA
3 different technology flavors in use

Readout via 150 MHz digitizer and custom signal processor
→ 240 channels



### Cathode Plane Assembly (CPA)

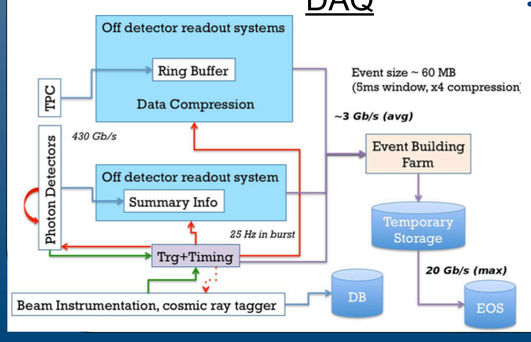
resistive panels to be held at **-180kV**
have surface resistivity of several MΩ/□
→slow reduction of charge in case of discharge

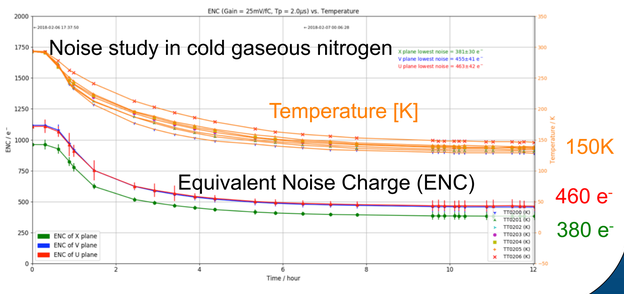
### Cold TPC Electronics

Cold electronics directly attached to APA (2560 wires):
1 APA → 20 FEMB (2560 ch/20 = 128 ch)

- Analog Mother board with 8 FE (16ch) and ADC ASICs (16ch) → 128 wires IN
  → **Multiplexed** to 4 OUTputs: 128 / 8 (ADC ASIC) / 4 (FPGA) = 4 outputs
- 16 ch FE ASIC: Preamplifiers with shaping circuit

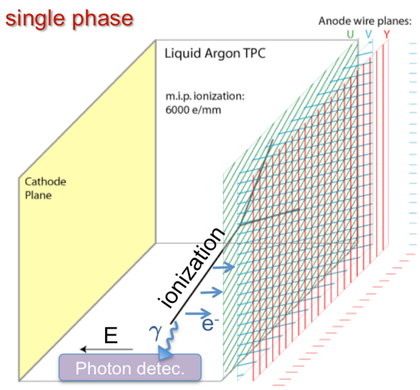
### DAQ



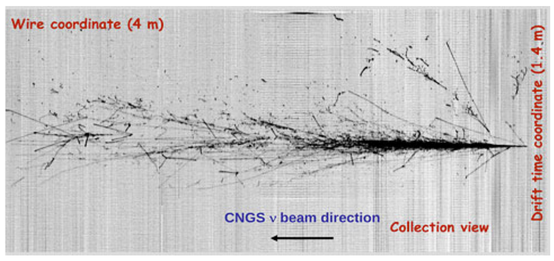

## LAr TPC Technology

Technology proven to work at different scales




Pioneered by ICARUS Collaboration

2×300 ton liquid argon (LAr) Time Projection Chamber (TPC)

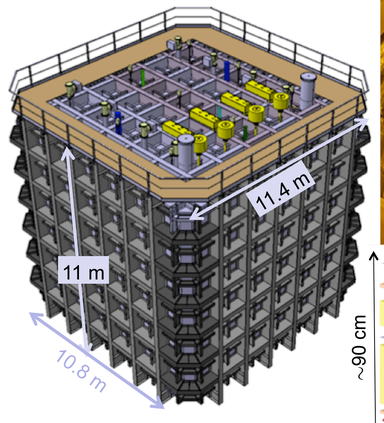


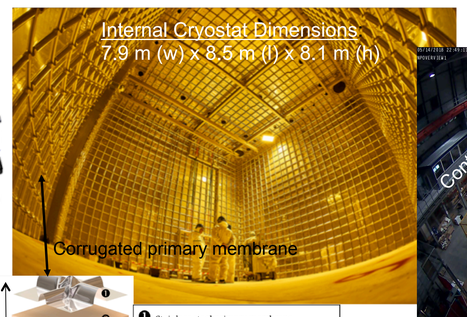

TPC records very detailed particle tracks and energy loss information

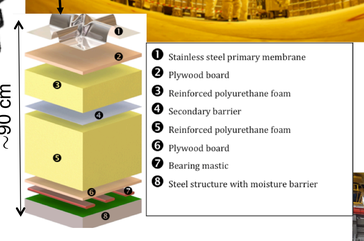
- Ionization: ~ 60,000 e⁻/cm for mip (for E ≈ 500V/cm)
  → Provides detailed imaging, calorimetric and particle identification (PID)
- Scintillation: ~24,000 γ/MeV (for E ≈ 500V/cm)
  → offers event trigger ($t_0$) information + improved calorimetric information

## Infrastructure + Beam

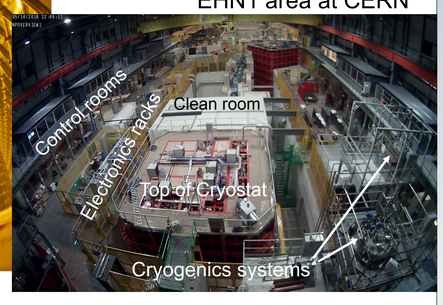
**770 t total LAr mass**



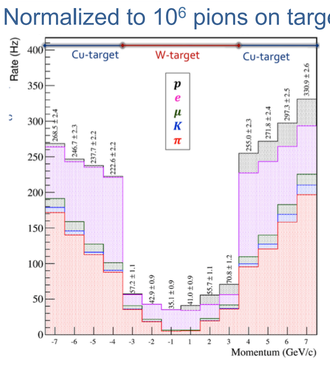




EHN1 area at CERN

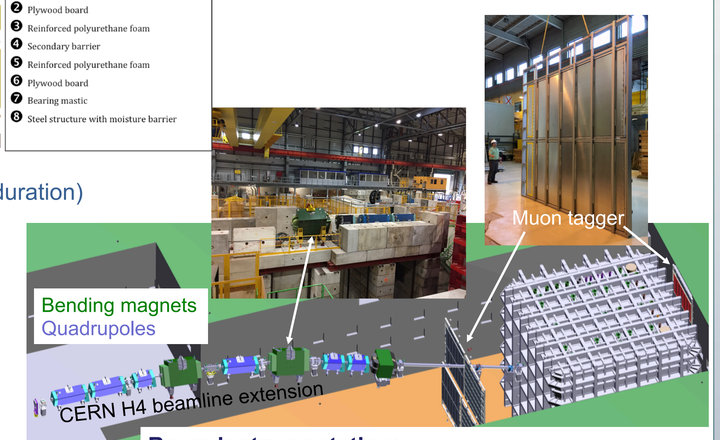



**Beam composition:**

Normalized to $10^6$ pions on target per spill (4.8s duration)




Expect:
~3000 spills/day




**Beam instrumentation:**

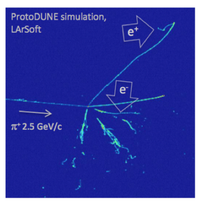
Beam profile(x,y) → scintillating fiber tracker
Momentum →scintillating fiber tracker
Particle ID → thresh. Cherenkov counter, time of flight

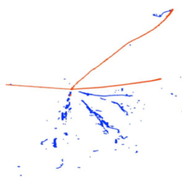
## Measurement Program

**Beam and Cosmics Data Analysis Goals:**

Use information from TPC and PDS

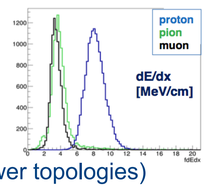
- Evaluate basic detector performance (noise level, S/N ratio, electron lifetime)
- Validate reconstruction tools and simulations



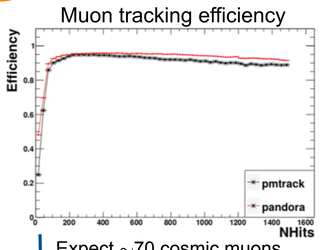
Convolutional Neural Network (CNN)
Output: Classification of individual hits as EM like or track like

- Measure (energy) calibration constants (Michel electrons, $\pi^0$)
- Extract dE/dx of pions, protons and electrons

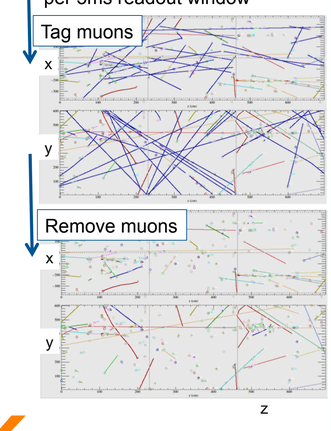



- Measure pion interaction cross sections ($\pi^+/\pi^-$ differences; shower topologies)
- Measure neutral pions → NC backgrounds and calibration; e-gamma separation
- Study kaons → relevant for proton decay
- Quantify EM component of hadronic interactions
- Measure momentum via multiple Coulomb scattering
- Study missing energy recovery
- study $\mu^-$ capture on Ar

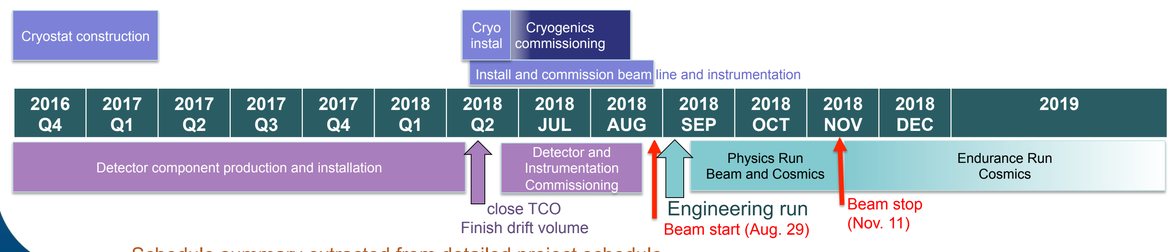
Muon tracking efficiency




Expect ~70 cosmic muons per 5ms readout window




## Timeline/Outlook




Schedule summary extracted from detailed project schedule