DUNE's Gaseous-Ar Based Near Detector (ND-GAr) for Phase II

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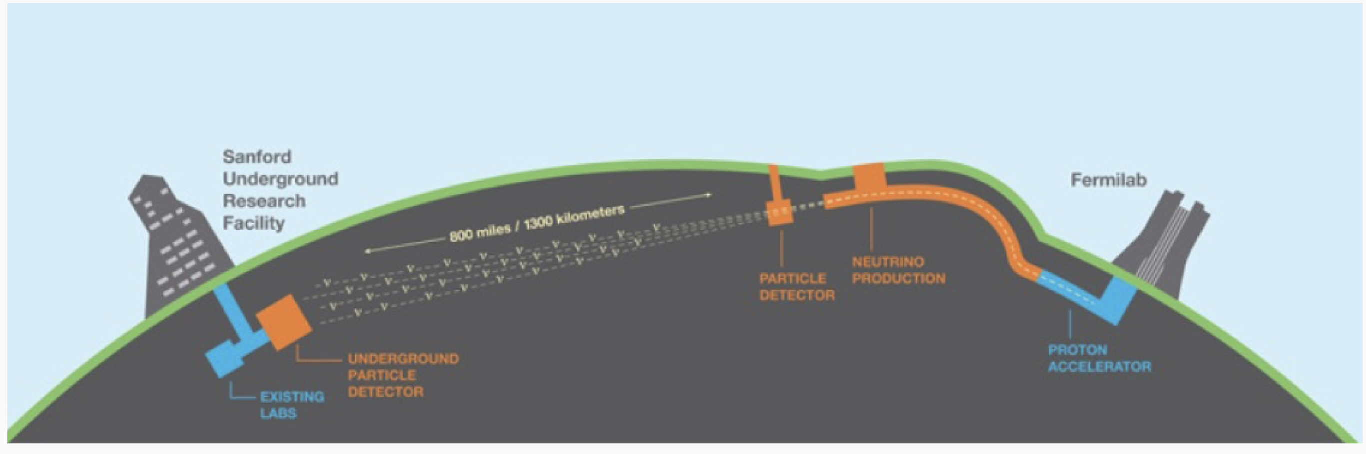
The DUNE Experiment



The Deep Underground Neutrino Experiment (DUNE) is a next-generation international experiment for neutrino science. DUNE will consist of two sets of neutrino detectors placed in the LBNF beamline. The near detector (ND) will observe the beam near its origination, 1 km underground at Fermilab in Batavia, IL. The larger far detector (FD) will be installed 1.5km underground, 1,285 kilometers away, at the Sanford Underground Research Facility (SURF) in Lead, South Dakota.

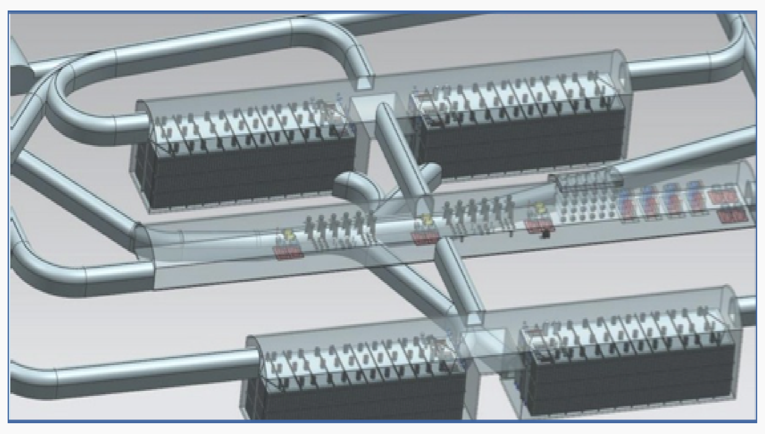
The DUNE Detectors

The Near Detectors:

- **ND-LAr** - Pixelated Liquid Argon TPC to reproduce FD response.
- **SAND** - Permanent on-axis beam monitor comprised of a super conducting magnet and calorimeter.
- **TMS** - The Temporary Muon Spectrometer will contain a magnetized steel stack and polystyrene scintillator. Upgrades to ND-GAr.
- **ND-GAr** - A magnetized high pressure Gaseous Argon TPC surrounded by a calorimeter.

The Far Detectors:

- Plans for four individual modules.
- One vertical drift, one horizontal, and two still undecided.
- 17 kT Liquid Argon time projection chambers in each module.



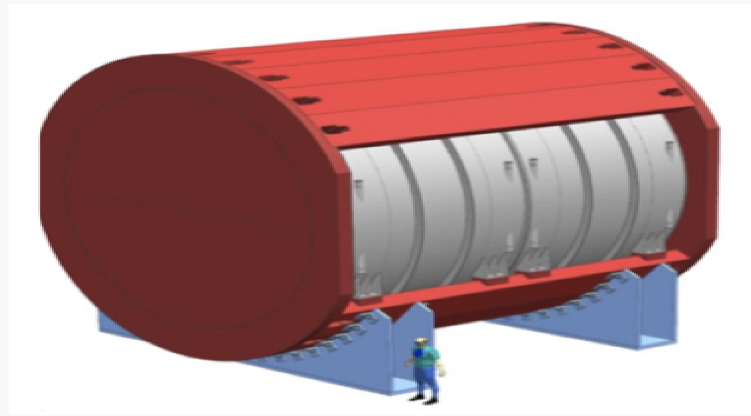
The Physics Goals of DUNE

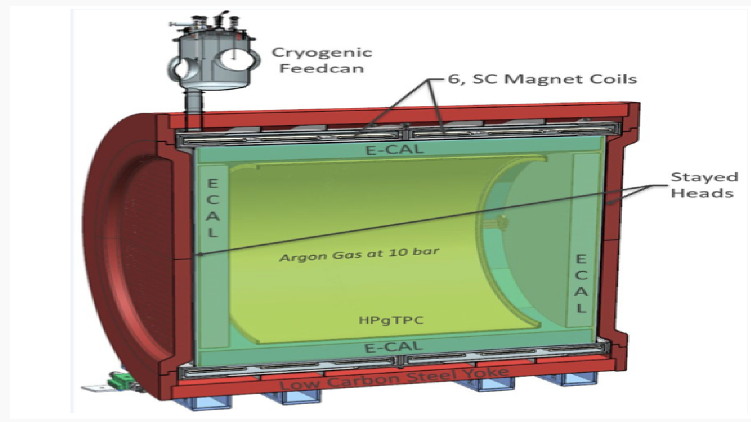
Fundamental questions about matter and the evolution of the universe can be answered by studying neutrinos and other particles. DUNE seeks to:

- Make high precision measurements of neutrino mixing parameters
- Probe the CP violating phase δ_{CP}
- Do beyond the standard model physics searches
- Study supernova neutrinos
- Search for proton decay

DUNE's ND-GAr

ND-GAr will be an upgrade to TMS during DUNE's Phase II.

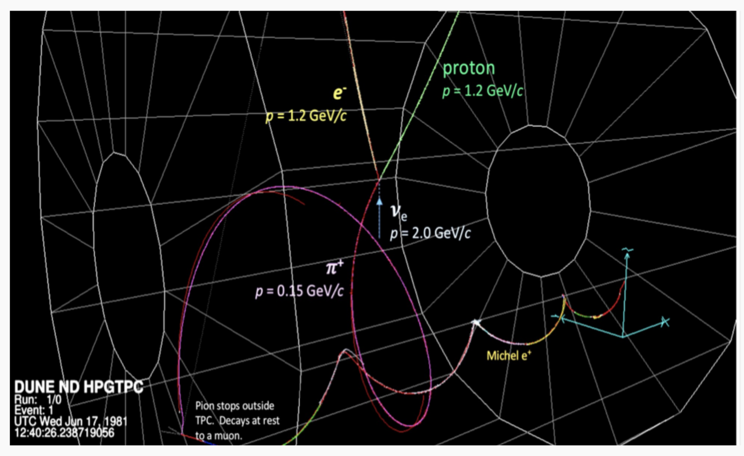




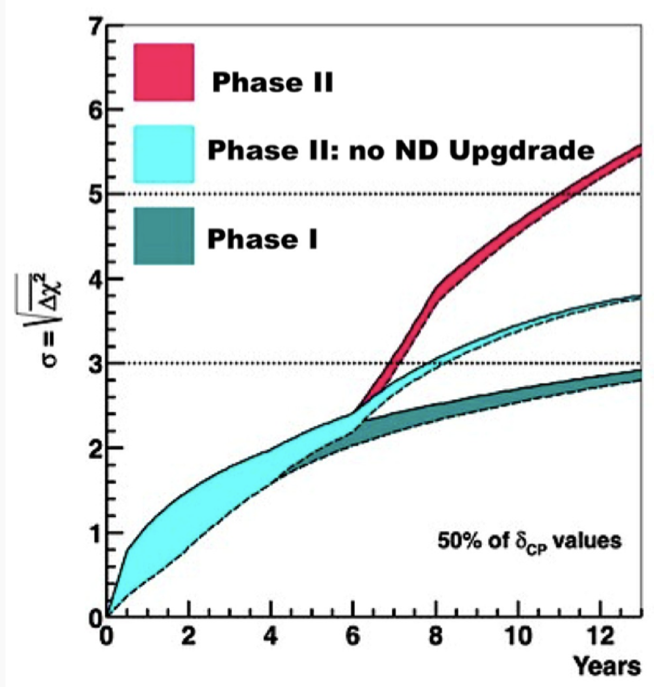
The motivations for ND-GAr

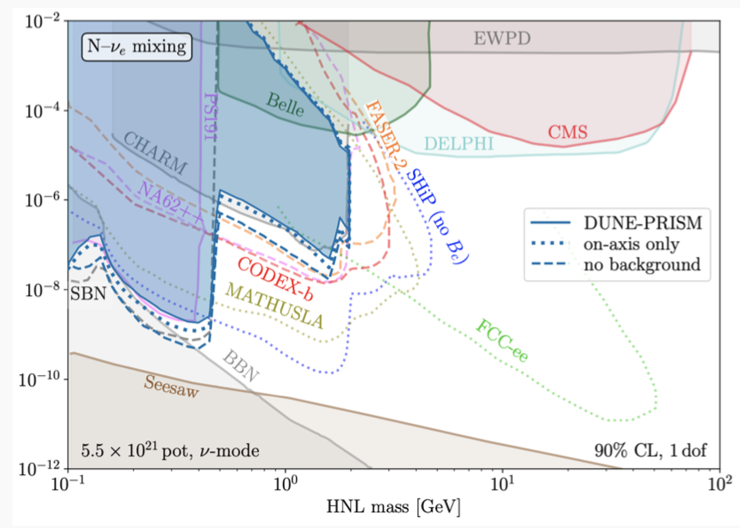
- **ND-GAr provides lower threshold measurements than ND-LAr.** Allows for an independent sample of interactions to constrain the lesser-understood regions of interaction models and associated systematic uncertainties needed for oscillation analyses. Better particle identification.

Event class	Number of events per ton-year
ν_μ CC	1.6×10^6
$\bar{\nu}_\mu$ CC	7.1×10^4
$\nu_e + \bar{\nu}_e$ CC	2.9×10^4
NC total	5.5×10^5
ν_μ CC0π	5.9×10^5
ν_μ CC$1\pi^\pm$	4.1×10^5
ν_μ CC$1\pi^0$	1.6×10^5
ν_μ CC2π	2.1×10^5
ν_μ CC3π	9.2×10^4
ν_μ CC other	1.8×10^5



- **The hadronic interaction length increases in GAr compared to LAr.** This provides event samples that are less dependent on understanding of detector response and models of secondary interactions.
- **Better signal-to-background ratio of ND-GAr** aids DUNE's ability to search for beyond the standard model physics including: heavy neutral leptons (HNL), light dark matter, heavy axions, and more.
- **ND-GAr will be necessary for DUNE to reach it's precision physics goals.**



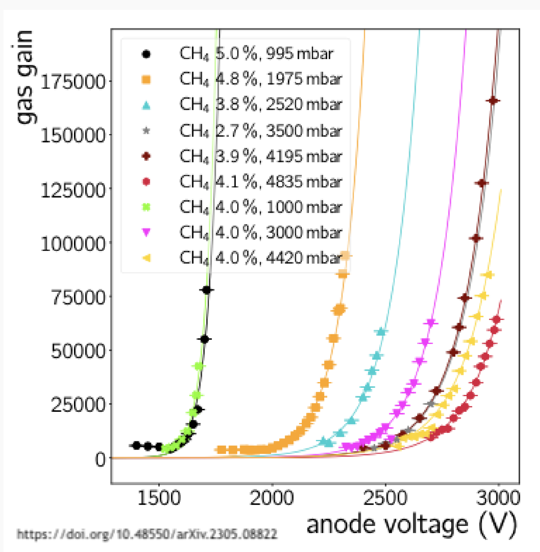


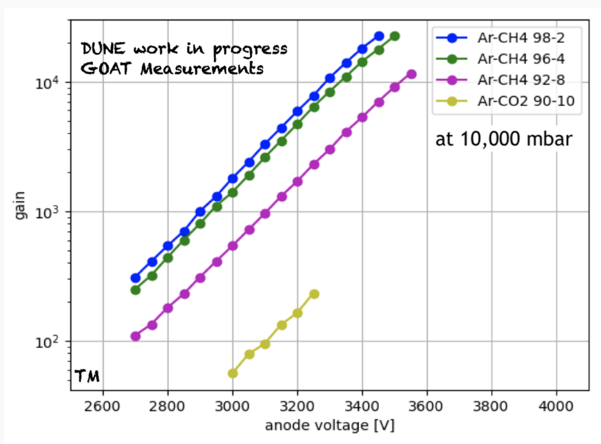
R&D Efforts

The goal for ND-GAr is to operate at 10 atm while maintaining gain of important signals. Readout systems and electronics, new and repurposed, are being tested.

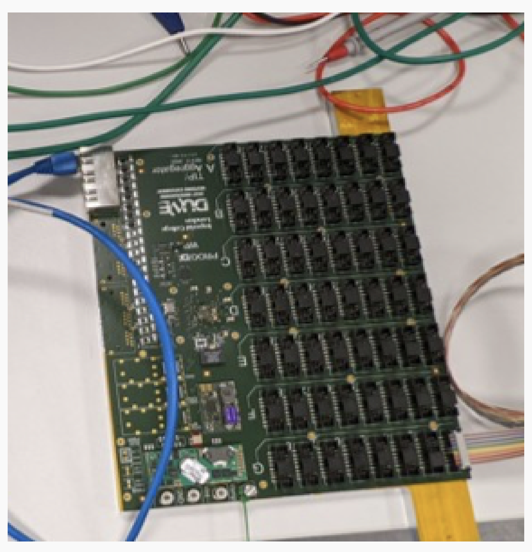
Repurposed ALICE Chambers

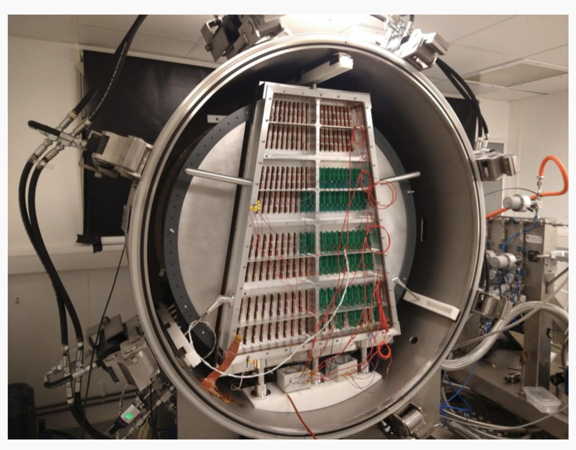
Repurposed wire chambers from ALICE are one option. The wire chambers originally operated at 1 atm so they had to be tested at higher pressures and with various gas mixtures. $Ar - CH_4$ mixtures at 10 bar provide the best gain.





ALICE-based SAMPA cards and repurposed wire chambers are now in a pressure vessel prototype **(known as TOAD)** in the Fermilab Test Beam. A full chain of DAQ and electronics are being installed and tested to get the vessel ready for test beam operation.





Gas Electron Multipliers

GEMs have been widely used in nuclear and particle physics for signal charge amplification, but never in high pressure. A new GEM setup is in the initial stages of being characterized and prepared for high pressure conditions at Fermilab **(known as GORG)**.

- **High pressure allows for increased statistics** compared to normal conditions.