Calibrating DUNE – The Largest LArTPC Ever To Be Built

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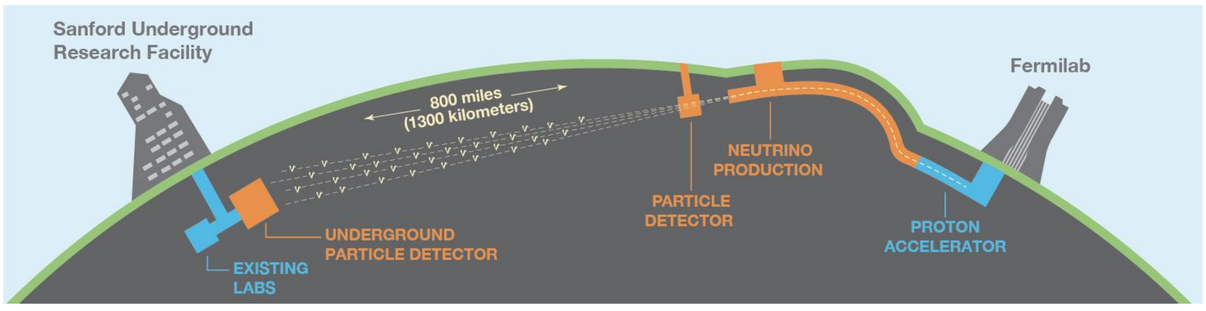
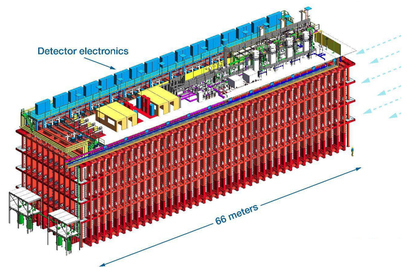
LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

DEEP UNDERGROUND NEUTRINO EXPERIMENT

1. The DUNE Experiment

DUNE is a long-baseline neutrino oscillation experiment with a > 2 MW beam produced at Fermilab (Illinois, USA), characterised with a near detector complex and measured with liquid argon time projection chambers (LArTPC) at SURF (South Dakota, USA) 1.5 km underground.





Two, 770-ton prototypes are currently installed at CERN, ProtoDUNE Horizontal Drift (PD-HD) and Vertical Drift (PD-VD), as testbeds for full-scale DUNE technologies.

2. Calibrating DUNE

Multiple calibration systems are planned targeting both MeV-scale neutrino astrophysics (Supernova, solar) and GeV-scale oscillation signals

- Ionization Laser system and several source-based (e.g. neutrons, Bismuth-207) calibration systems are being planned

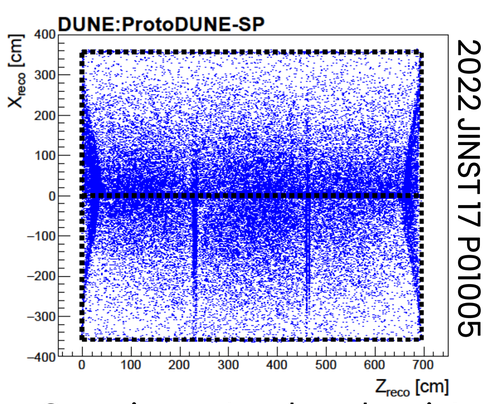
Why a Laser Calibration

- Independent fine-grained measurement of drift velocity, charge collection efficiency, electron lifetime and electric field
- Diagnose tilts/shifts of anode and cathode

Top-level calibration requirements for physics:

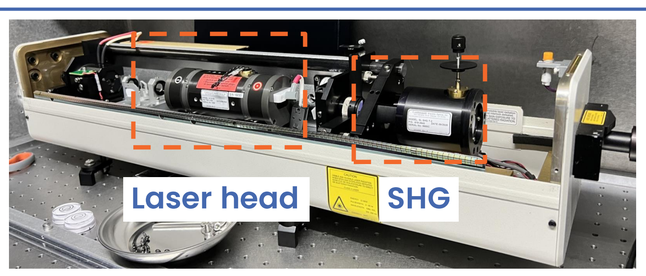
- GeV-scale oscillation physics:
  - energy scale uncertainty < 2% for leptons and 5% for hadrons

MeV-scale low-energy physics e.g. supernovae, solar: energy scale uncertainty < 5%



Cosmic-ray track end-points showing distortions due to space-charge

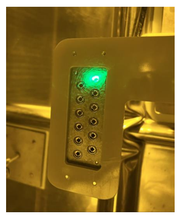
3. The Ionization Laser System (IoLS)



Nd:YAG laser with second harmonic generator

One laser system, inside a laser (Nd:YAG, 266 nm) and a laser box, including an optical bench, alignment lasers, and power meter

Optical bench



Beam Location Systems

Two laser beam location systems (one active and one passive) to verify beam position

- Requires 5 mm precision at 10 m

CIB – Calibration Interface Board

One set of custom electronics for control and monitoring (CIB)

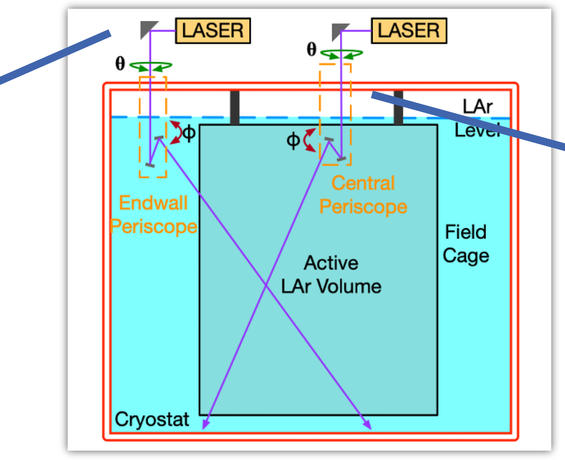
- Interface between hardware and software
- Interface with DAQ and Slow Controls

One optical feedthrough and periscope system.

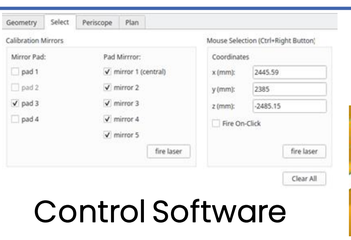
Two designs to address the challenge of injecting laser light inside the field cage:

- A field cage penetrating design with a **retractable** feature
- An external field cage-design with an **extra rotation stage** to increase the field of view

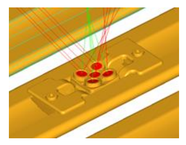
P2: periscope with extra rotation stage



P1: periscope with retraction capability



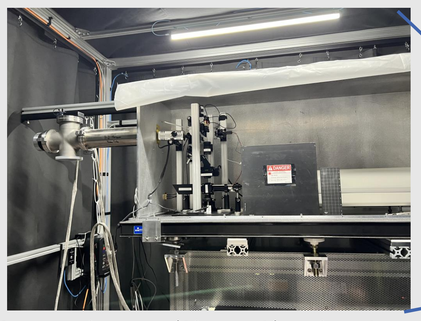
Control Software



Dedicated software with ray-tracing capabilities for control and run planification

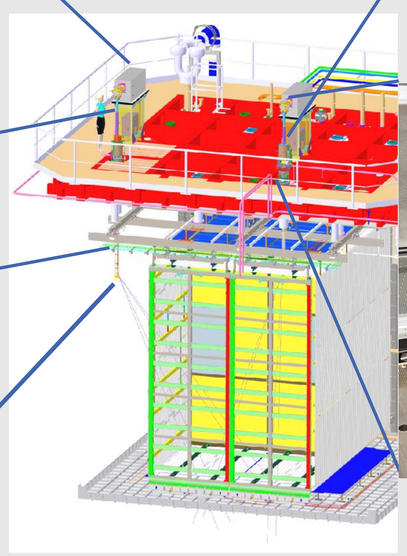
- With CIB one can perform full automated scan of cryostat

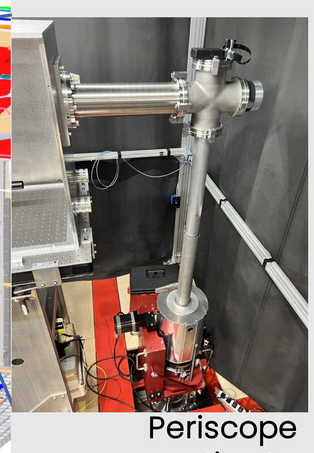
4. Installation at ProtoDUNE



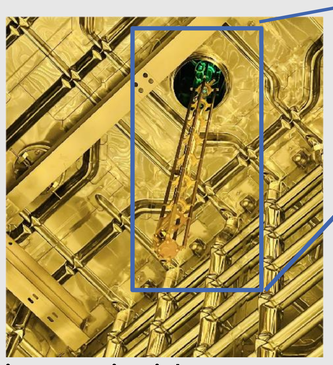
Laser box with optical setup, UV laser, aligment lasers and secondary shutter

Periscope motor controls





Periscope connection to the laser box



P2 periscope inside the PD-HD cryostat

Two complete laser IoLS systems installed at PD-HD

- One for each periscope design
- Final commissioning ongoing

One periscope will be installed in PD-VD

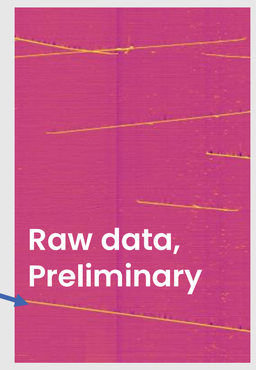
- After PD-HD run, warm instrumentation will be re-deployed in PD-VD

5. First tracks at ProtoDUNE

Laser ionization tracks <u>visible on all three planes</u> of charge readout

Laser track amongst other charged particle tracks

- Point of origin and track direction known
  - Trigger timing and motor readout
- No secondary particles
  - Ionization from three photon process
  - 2-photon absorption + a 3rd to ionize



charged particles and a laser track in PD-HD

Upcoming developments

- Full scan operation of IoLS at PD-HD
- Installation and operation at PD-VD

Preparation for installation at DUNE FD

- After ProtoDUNE, the system will be reviewed to implement necessary improvements

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