Ionization Laser Calibration System for DUNE

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1. Overview of Deep Underground Neutrino Experiment (DUNE)

- Next generation long-baseline neutrino experiment from Fermilab to SURF, South Dakota
- Far detector consists of four 10-kton liquid argon time projection chambers (LArTPCs)
- Construction will begin in 2024 and neutrino data taking expected in late 2020s

Primary Physics Goals

- Resolve neutrino mass hierarchy
- Measure δ_{cp} (charge parity violating phase) in the neutrino sector
- Search for supernovae events

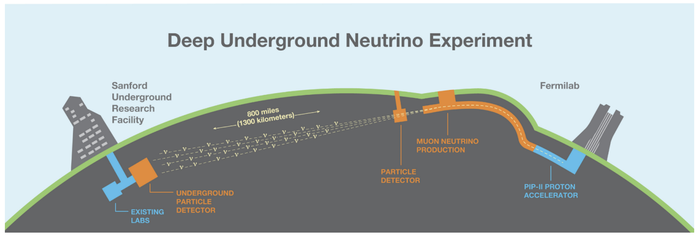


Figure 1. The DUNE experiment

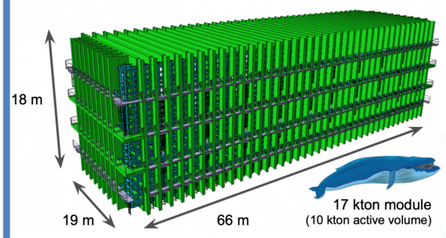
2. Calibrating the DUNE Far Detector

- Understanding the response of the detector is crucial to achieve the energy scale and resolution necessary for the physics goals of DUNE

Calibration Challenges

- Huge size
- Highly segmented detector
  - Hundreds of anode and cathode planes
- Cosmic ray muons at a lower rate due to deep underground location

- Ionization laser (IoLaser) system is one of the primary calibration systems planned for DUNE



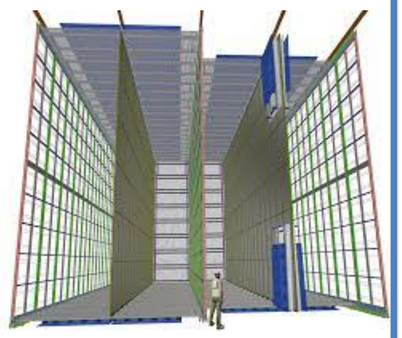


Figure 2. Single far detector LArTPC module (left) and cross section view of LArTPC detector (right)

3. Ionization Laser Calibration System

- Create straight, well-defined ionizing laser tracks in detector for calibration
- Provide fine grained measurements of detector parameters
  - E.g. drift velocity, electric field distortions
- Serve as diagnostic tool
  - E.g. identify anode/cathode tilts etc.
- Three main components
  1. Class IV ionizing laser
  2. Optical bench to direct a well collimated, clean beam of 266nm light
  3. Periscope and feedthrough assembly to direct and rotate the beam into the LAr detector
- On the order of 12 IoLaser systems anticipated for a single detector module
- Currently building two full IoLaser systems at LANL

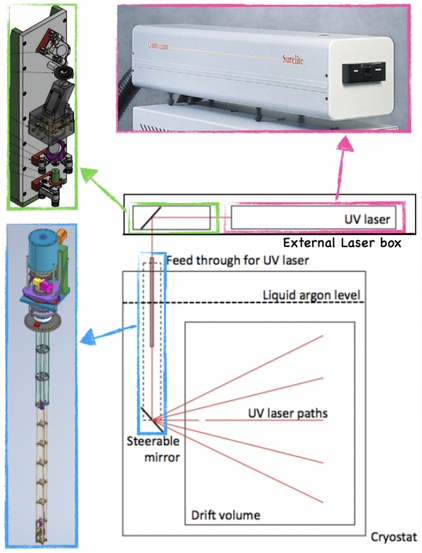
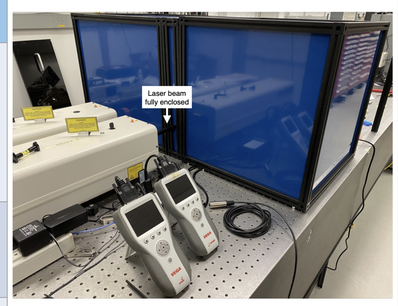


Figure 3. Ionization Laser Calibration System

4. Laser and Optical Bench

Component	Purpose
Surelite I10 Nd:YAG class IV Laser	Emits 1064 nm, 532 nm, and 266 nm light
Low power visible laser	For alignment purposes
Beam splitter mirror	Separate 266 nm light from other wavelengths
Dual band mirror	Transfer both 266 nm and 532 nm light
Attenuator	Control laser energy
Iris	Reduce beam diameter



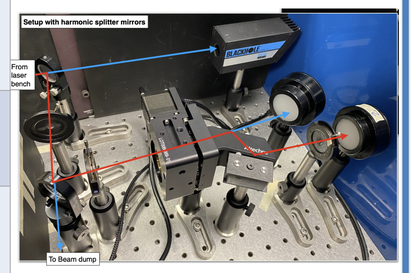


Figure 4. Laser bench (top) and optical setup at LANL (bottom)

5. Optical Feedthrough and Periscope

- Two periscope designs to maximize coverage of the detector
  - One for the central region (penetrates the TPC top field cage and includes a retraction device for safety)
  - One for the end-wall region (send light from outside the field cage using a dual rotary motion)
- Periscope designs final, procurement and fabrication ongoing at LANL and LIP
- Periscope includes a number of seals to the cryostat which need to be tested for leak tightness (10^{-6} - 10^{-8} mbar*l/s)
- Helium leak testing of components (e.g. rotary stages, flange view ports) ongoing at LANL and LIP (see Fig. 5)

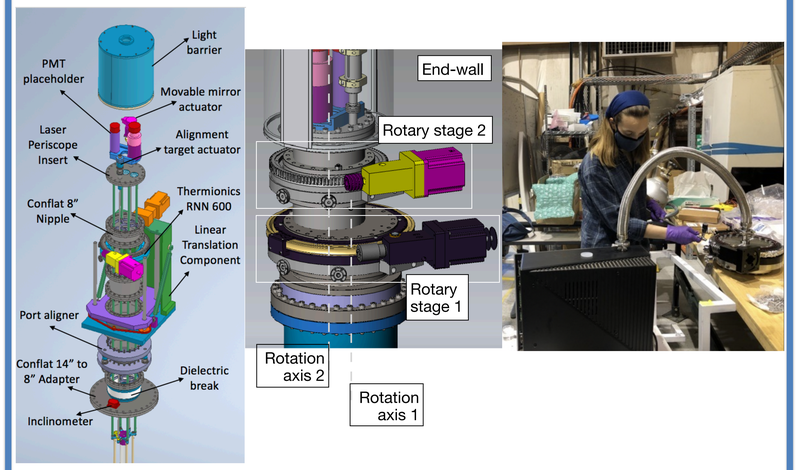


Figure 5. Top-field cage periscope design (left), end-wall periscope design (center), and Newmark performing leak test on RNN-600 rotary stage at LANL (right)

6. Summary and Next Steps

- Developing ionization laser calibration system to perform fine grained measurements of detector parameters and diagnose detector issues
- Finalizing optical setup to extract well collimated beam of 266nm light
- Building 700 liter cryogenic test stand at LANL to test full ionization laser calibration system in LAr
- Two full prototype laser systems will be installed in DUNE's 400-ton Prototype detector (ProtoDUNE) at CERN in early 2022.

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