

# Ionization Laser Calibration for the DUNE Time Projection Chamber

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(On behalf of DUNE Collaboration)

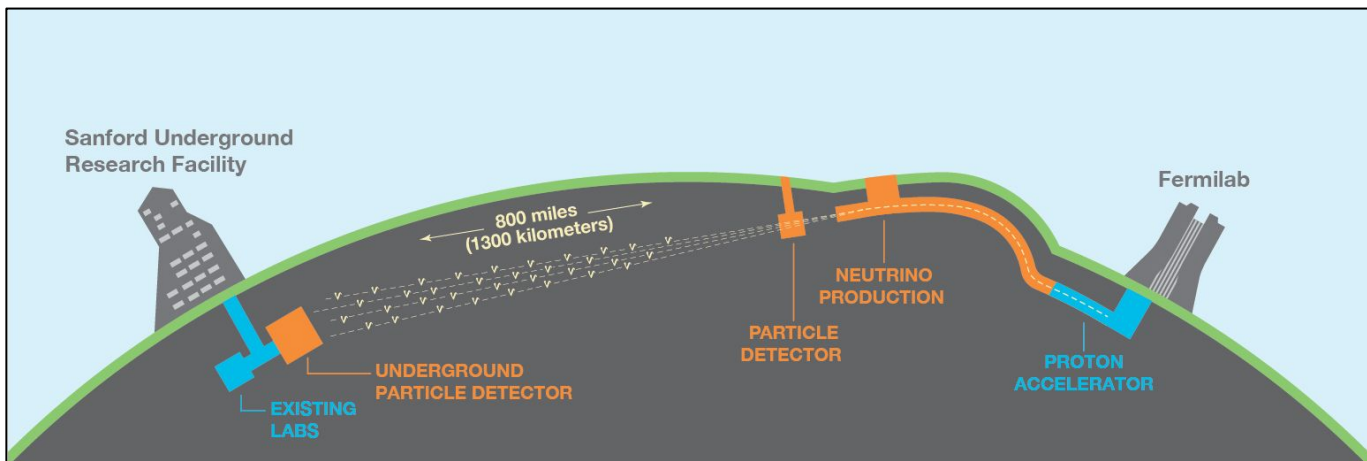
Fermilab New Perspectives

June 16, 2022

# Introduction: DUNE

The Deep Underground Neutrino Experiment (DUNE) is a next-generation, liquid argon time projection chamber (LArTPC) neutrino experiment - the largest of its kind.

- Near detector will be located at Fermilab
- Far detector will be located at the Sanford Underground Research Facility in South Dakota

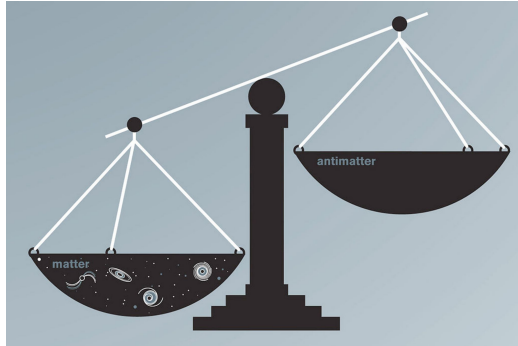


[1] "An International Experiment for Neutrino Science" Deep Underground Neutrino Experiment, <http://www.dunescience.org/>.

# DUNE Physics Goals

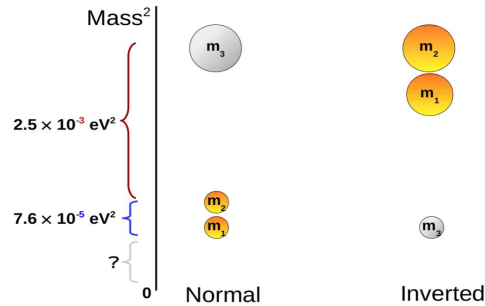
For More on these goals,  
visit:  
[DUNEScience.org](http://DUNEScience.org)

- DUNE is designed to address a large spectrum of physics goals



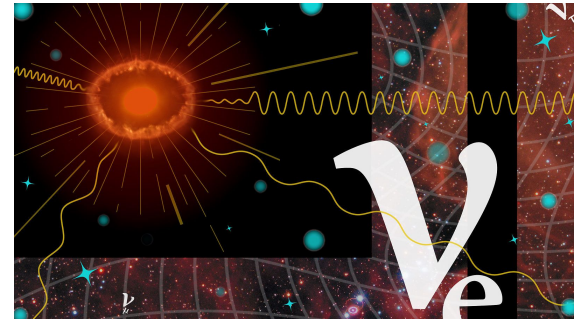
Matter v. Antimatter [3]

By exploring neutrino oscillations, DUNE can search for leptonic charge-parity (CP) violation, a potential reason there is more matter than antimatter in the universe.



Neutrino Mass Hierarchy [4]

DUNE's baseline will allow for measurements of the neutrino mass hierarchy.



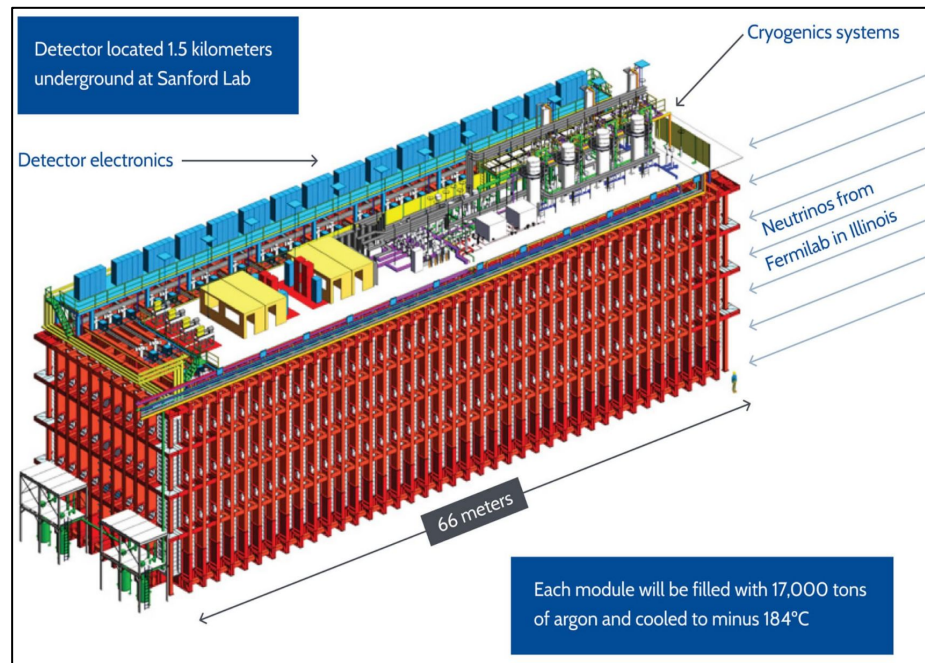
Supernovae [5]

Neutrinos produced from neutron star or blackhole formations can be detected - allowing insight into the dynamics of these processes

[1] "An International Experiment for Neutrino Science"  
[3] "CP Violation" *Symmetry Magazine*  
[4] "What is the neutrino mass hierarchy?" *Hyper-Kamiokande*  
[5] "The supernova that keeps on giving" *Symmetry Magazine*

# DUNE Far Detector

- Far detector (FD) nominally consists of four 17.5 kt LArTPC modules
- LArTPC experiments, particularly surface detectors, can utilize cosmic ray muons to calibrate the detector
- DUNE's FD will be located ~1,500m underground
- Other calibration sources are required

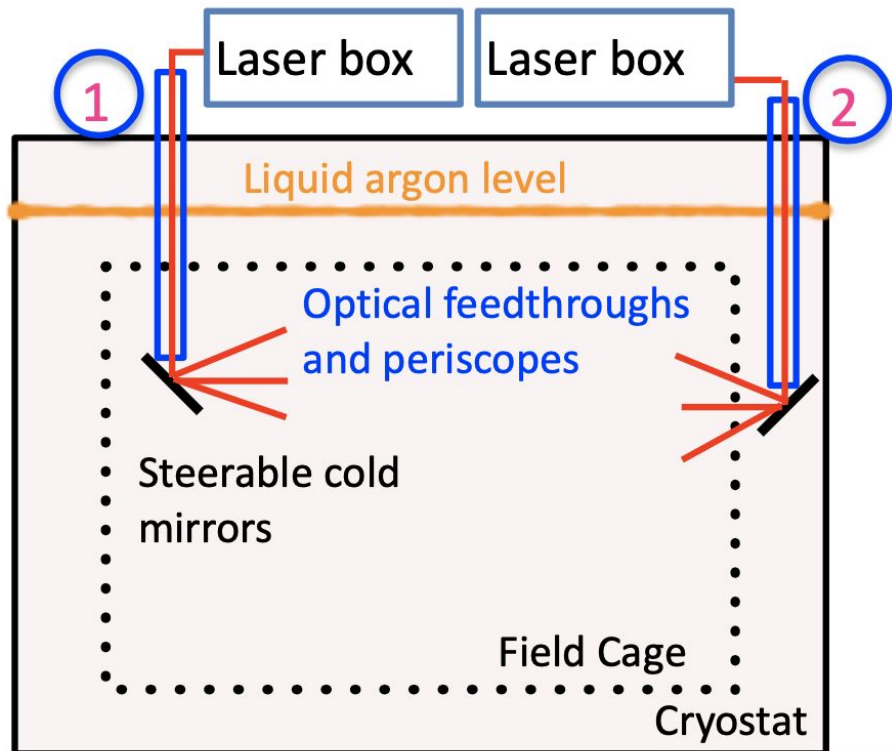


[2] B. Abi, R. Acciarri, & et. al.. (2020). Deep Underground Neutrino Experiment (DUNE), Far Detector Technical Design Report, Volume IV: Far Detector Single-phase Technology.

# Ionization Laser System

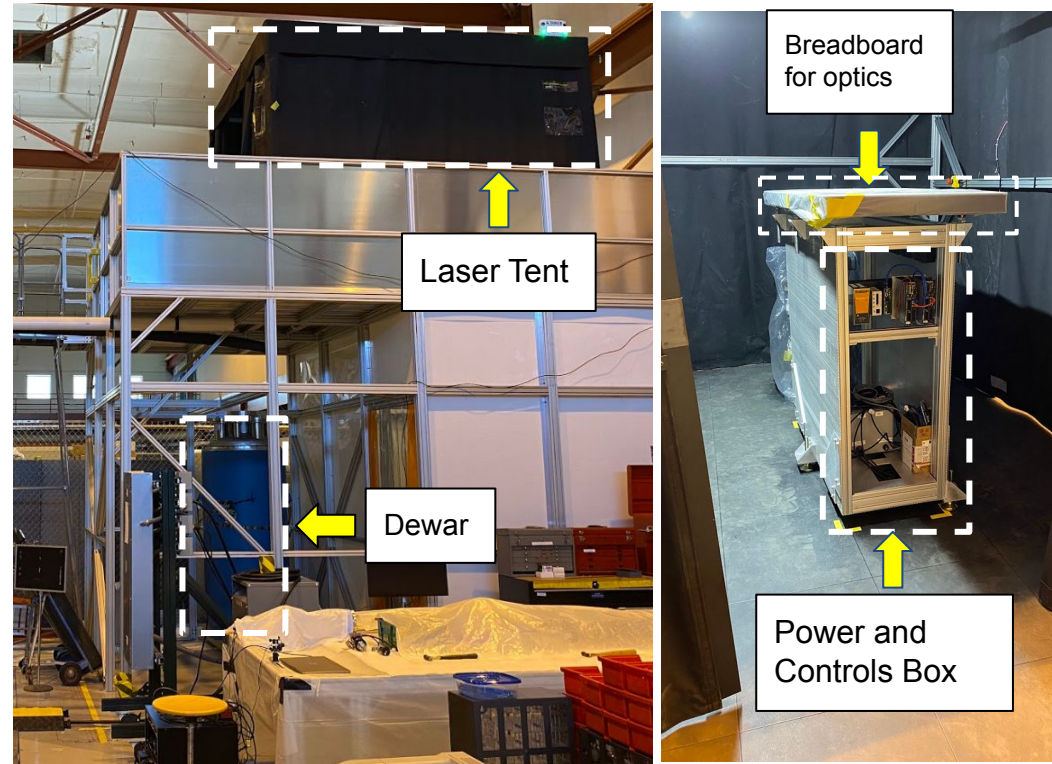
DUNE will utilize an ionization laser (IoLaser) calibration system in order to meet stringent systematic requirements (1-2%).

- The Ionization Laser System will create tracks with known origin and direction in the TPC Volume
- *Two periscope designs*, interior and exterior to detector field cage, will be installed in DUNE.
  - Overlapping coverage reduces uncertainty in reconstruction map



# Full System Tests at LANL

- Laser Tent contains optical equipment where laser will safely be contained and controlled from
  - Also contains computers to control laser and motors that operate periscope
- Periscopes mounted on test stand and will be fed into dewar below for cryogenic tests



# Periscope Images



Looking down the periscope



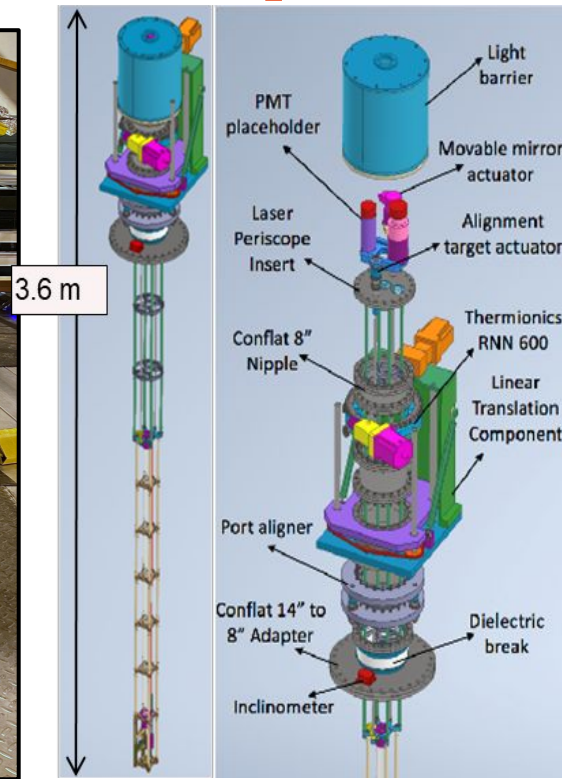
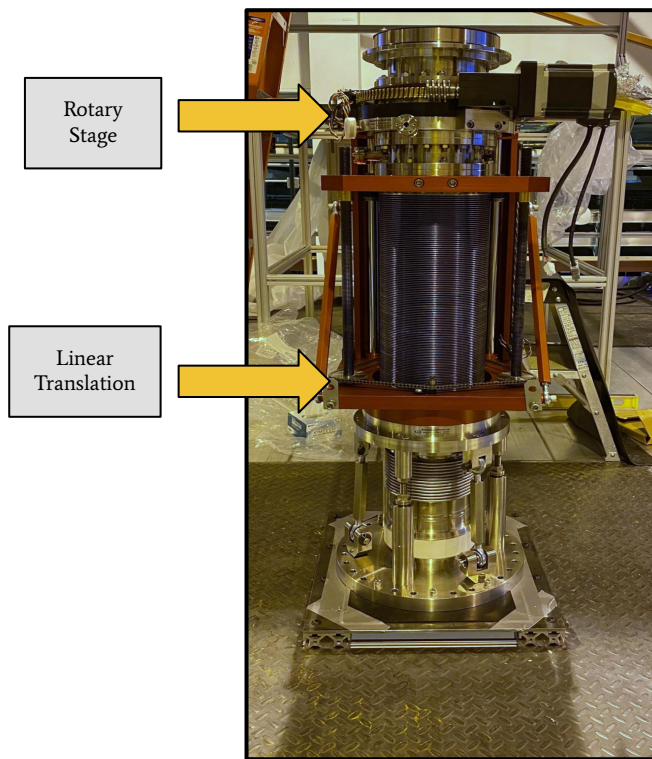
Looking up the periscope



Periscope assembled in test stand

# Interior Field Cage Periscope

- Designed to penetrate the detector field cage
- Rotary stage allows for rotation of the periscope
- Linear translation stage allows for extension/retraction of the periscope

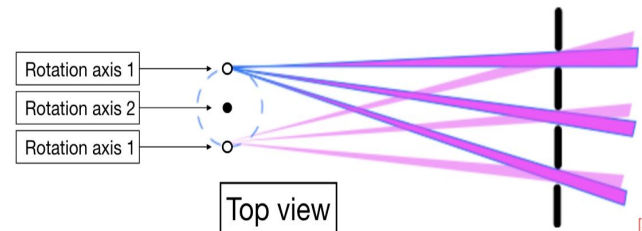
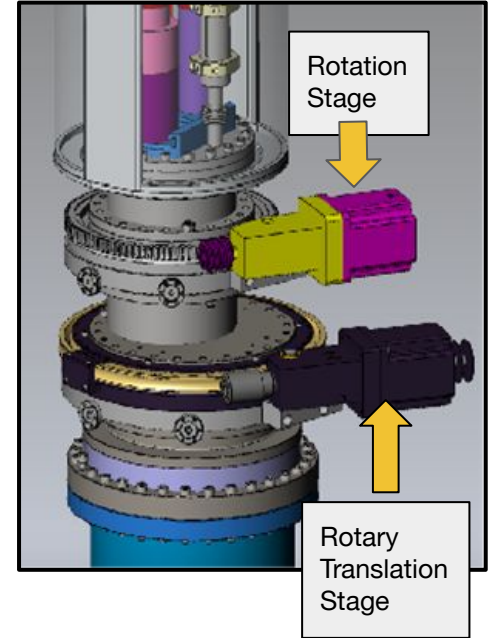
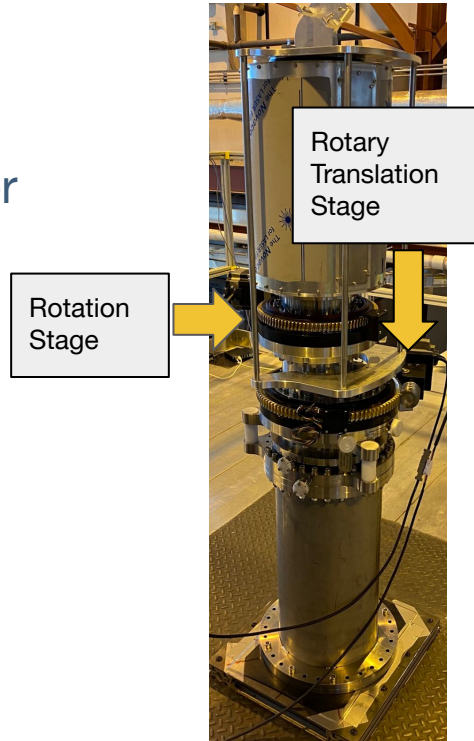


Periscope 1 (Interior)



# End Wall Periscope

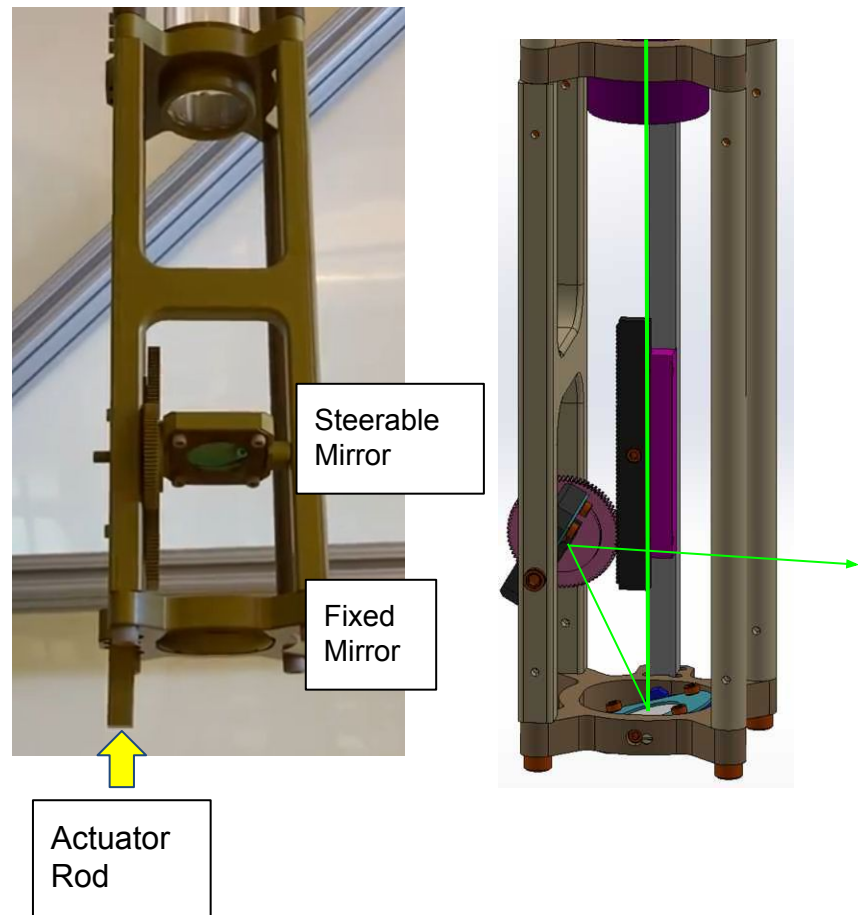
- Design is external to detector field cage
- Rotation stage allows for rotation of periscope
- Rotary translation stage allows for periscope to move 6 cm, providing coverage around field cage obstacles



[J. Maneira, LIP]

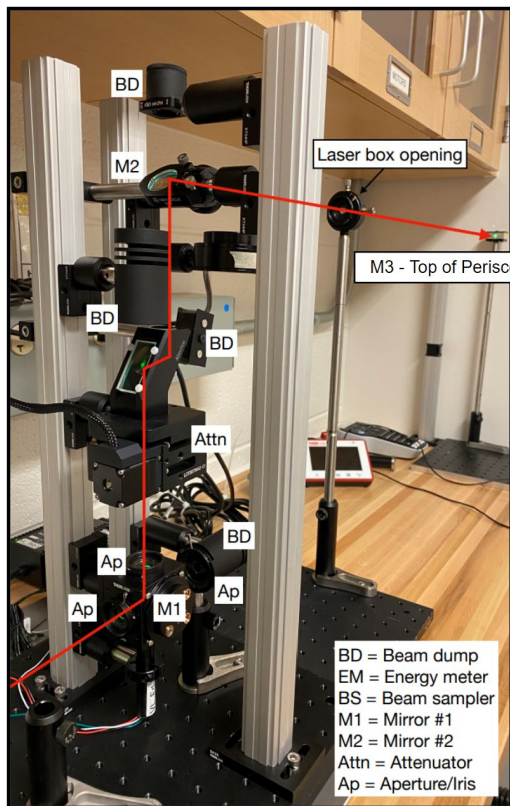
# Steerable Mirror

- Both periscope designs contain a steerable mirror to provide wide azimuthal coverage
- UV laser is aimed at fixed mirror at end of the periscope
- Laser is reflected on to steerable mirror
- Linear actuator rod moves rack and gear, steering the mirror and directing the laser

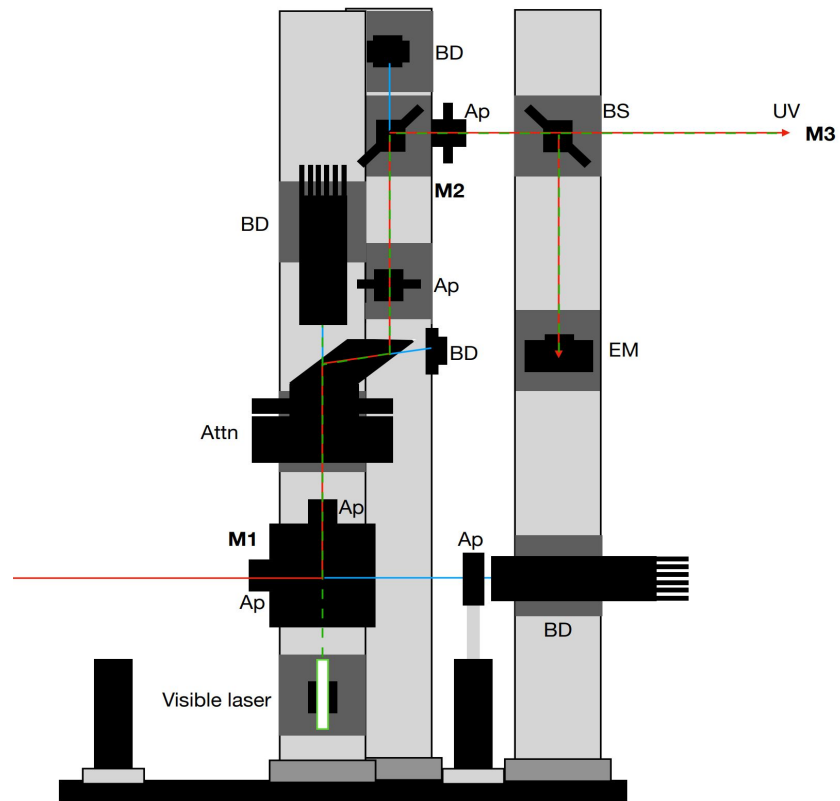
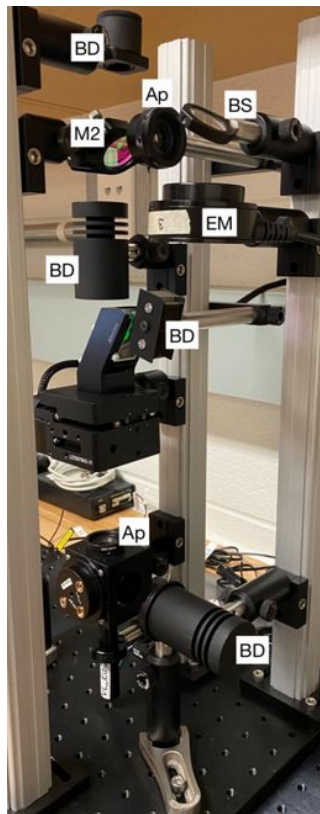




# Optical Setup Photos



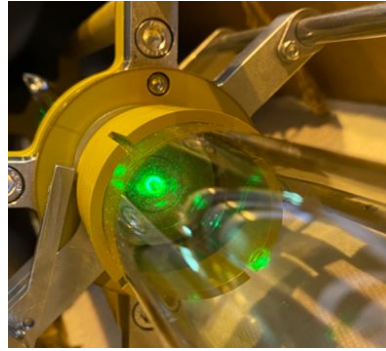
BD = Beam dump  
EM = Energy meter  
BS = Beam sampler  
M1 = Mirror #1  
M2 = Mirror #2  
Attn = Attenuator  
Ap = Aperture/Iris



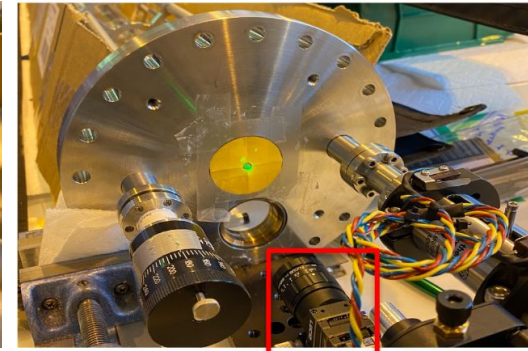
# Laser Alignment

The UV laser must be aligned with optical equipment in order to maintain a consistent beam profile and direction.

- Detector must remain sealed, alignment cannot be visually validated
- Camera is placed near viewport at the top of the periscope, aimed at the mirror
- Will minimize reflections and deviations from alignment laser to align UV laser



Visible laser aligned with middle target



Camera



Not-aligned



Aligned

# Video of Periscope Motion

Laser Motion Demonstration

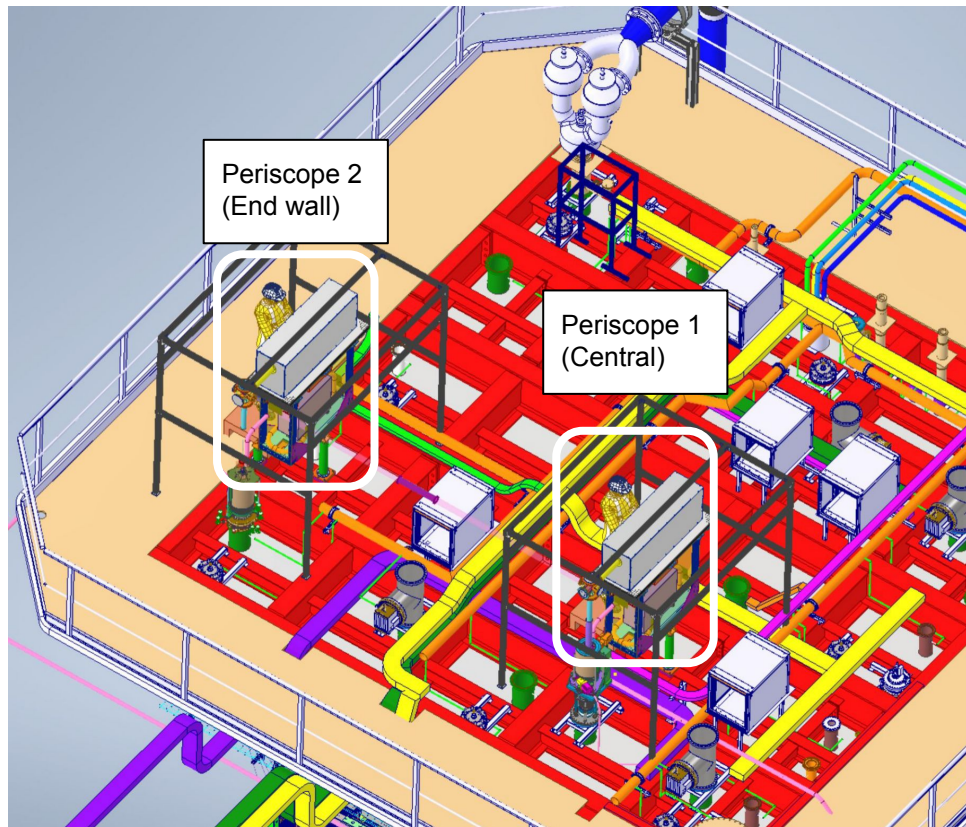


Motorized Mirror Demonstration



# Summary & Next Steps

- Periscopes assembled and successfully tested in air at Los Alamos National Lab.
- Testing with class-IV laser beams and in LAr will start this month.
- 700-ton LArTPC prototypes at CERN (ProtoDUNEs), are used to validate technologies for DUNE
- Periscopes will be installed in the ProtoDUNE Horizontal Drift Module for Phase 2 operations in August to test technical and physics performance



# Thank you!





# References

- [1] “An international experiment for neutrino science” *Deep Underground Neutrino Experiment*, <http://www.dunescience.org/>.
- [2] B. Abi, R. Acciarri, & et. al.. (2020). Deep Underground Neutrino Experiment (DUNE), Far Detector Technical Design Report, Volume IV: Far Detector Single-phase Technology.
- [3] “CP Violation” *Symmetry Magazine*, 1 Oct. 2005, <https://www.symmetrymagazine.org/article/october-2005/explain-it-in-60-seconds>
- [4] “What is the neutrino mass hierarchy?” *Hyper-Kamiokande*, <http://www.hyper-k.org/en/physics/phys-hierarchy.html>
- [5] “The supernova that keeps on giving” *Symmetry Magazine* 28 Apr. 2020, <https://www.symmetrymagazine.org/article/the-supernova-that-keeps-on-giving-sn1987a>