Ionization Laser Calibration System for DUNE

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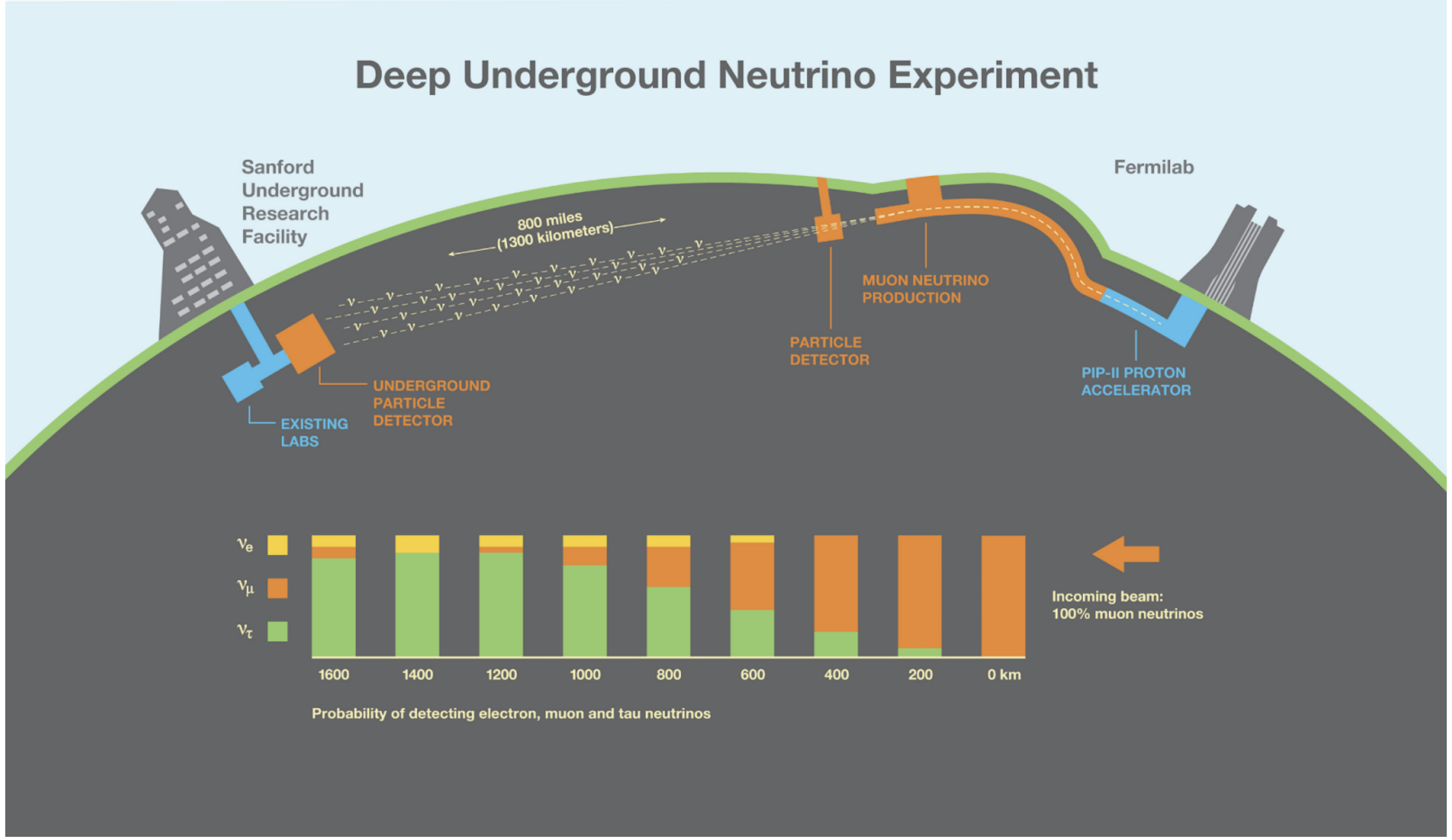
On behalf of the DUNE collaboration

Deep Underground Neutrino Experiment (DUNE)



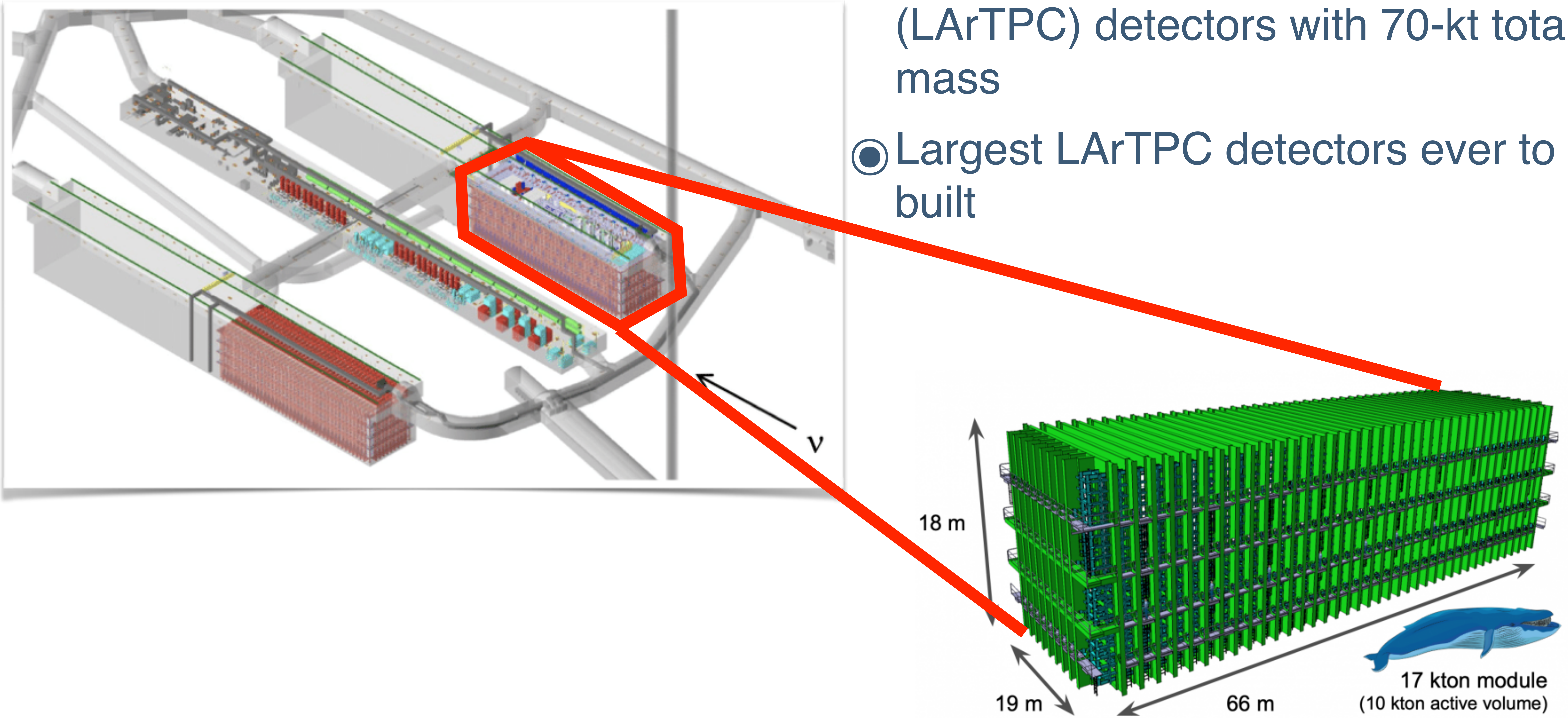
- DUNE consists of a near and far detector and an intense muon neutrino beam from Fermilab
- Next generation long-baseline experiment
- Construction will start in 2024 and neutrino data taking expected in late 2020s

Physics Goals:

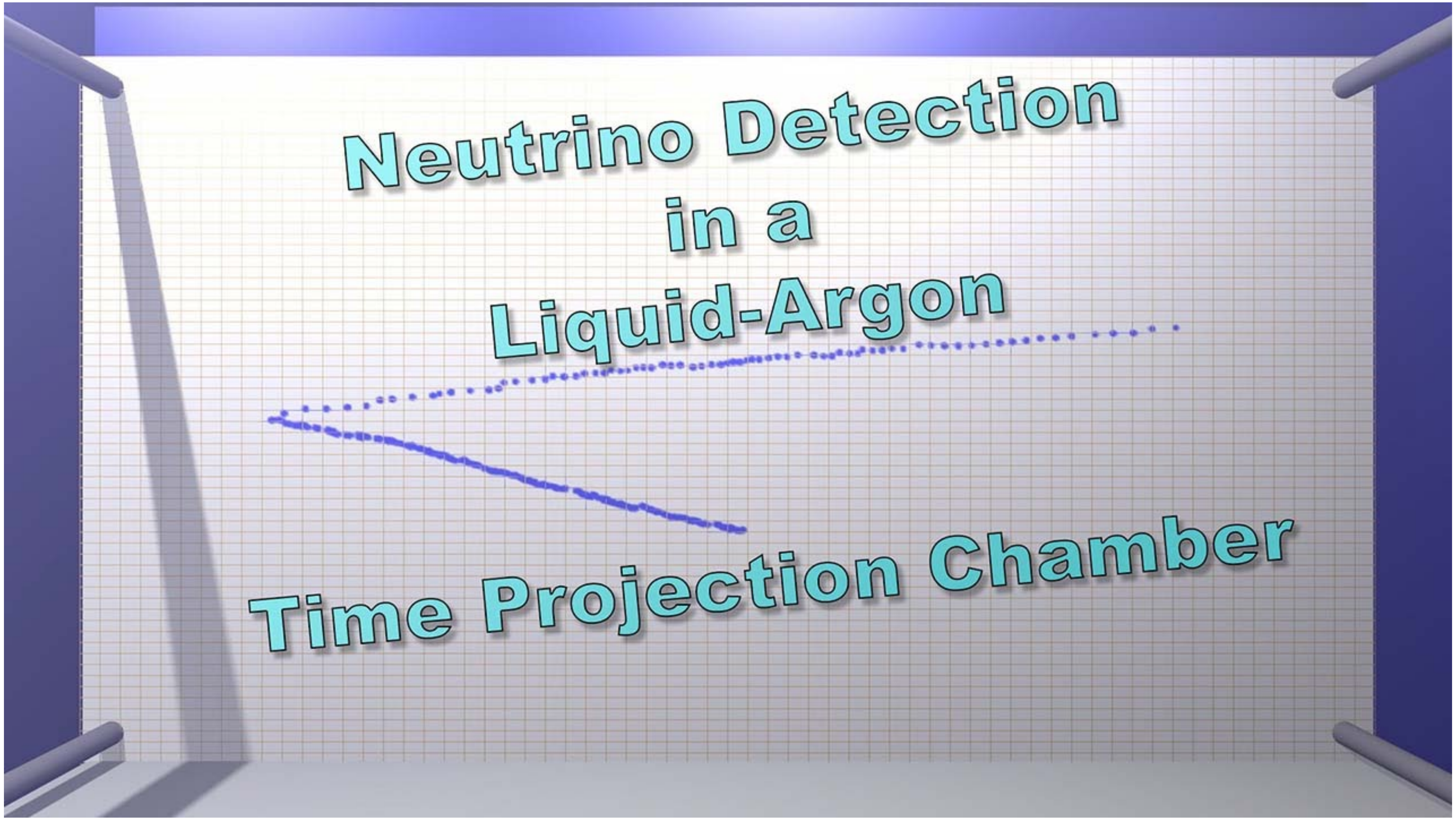
- Understand neutrino mass hierarchy
- Measure charge-parity violating phase (δ_{cp})
- Supernova neutrino burst searches and proton decay
- Other Beyond Standard Model physics

Far Detector at SURF

- Far detector will include 4 liquid argon time projection chamber (LArTPC) detectors with 70-kt total mass
- Largest LArTPC detectors ever to be built



Liquid Argon Time Projection Chamber (LArTPC)



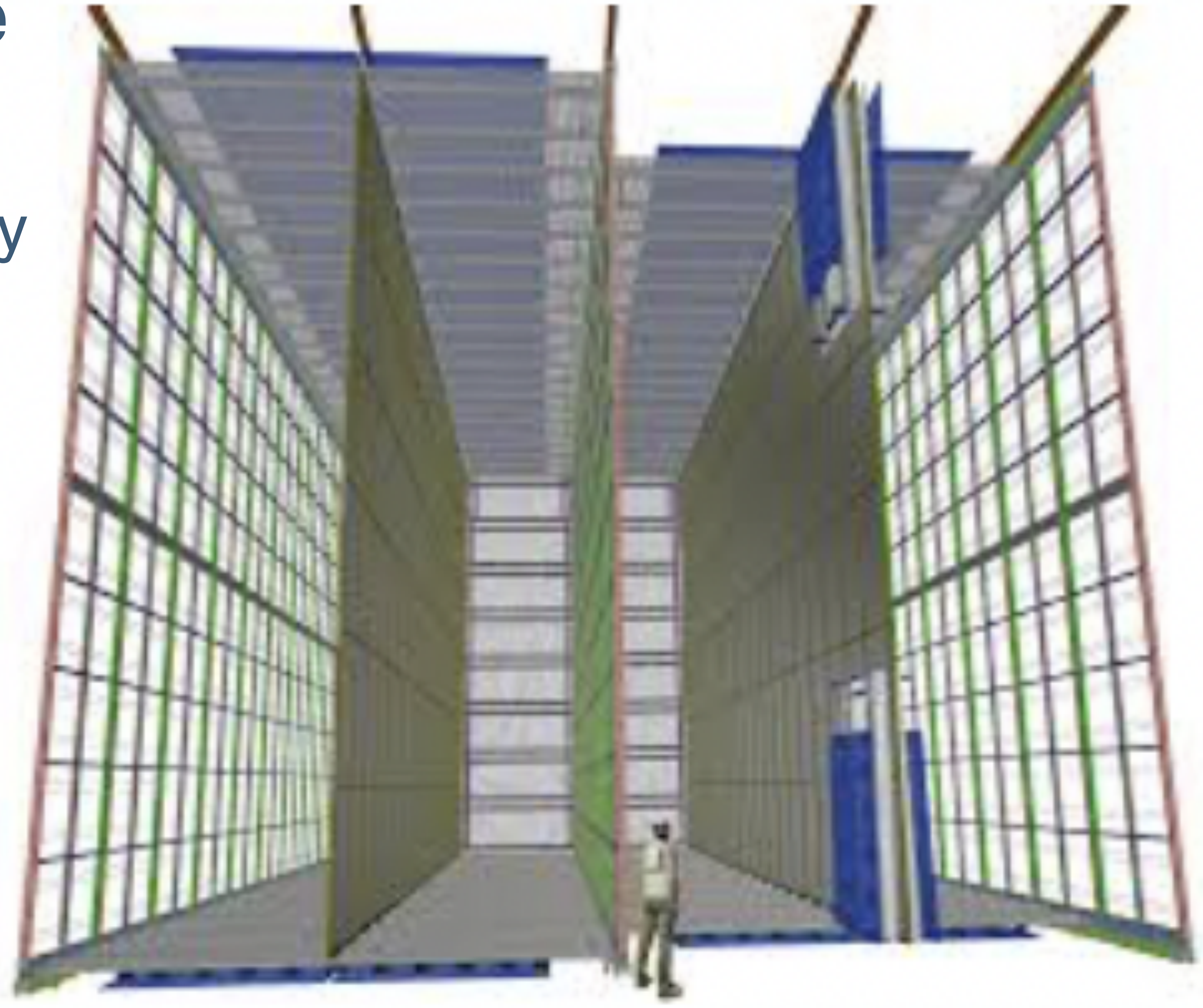
https://www.youtube.com/watch?v=R5G1_hW0ZUA

Challenges in Calibrating DUNE

Understanding the response of the detector is important to achieve the needed energy scale and resolution

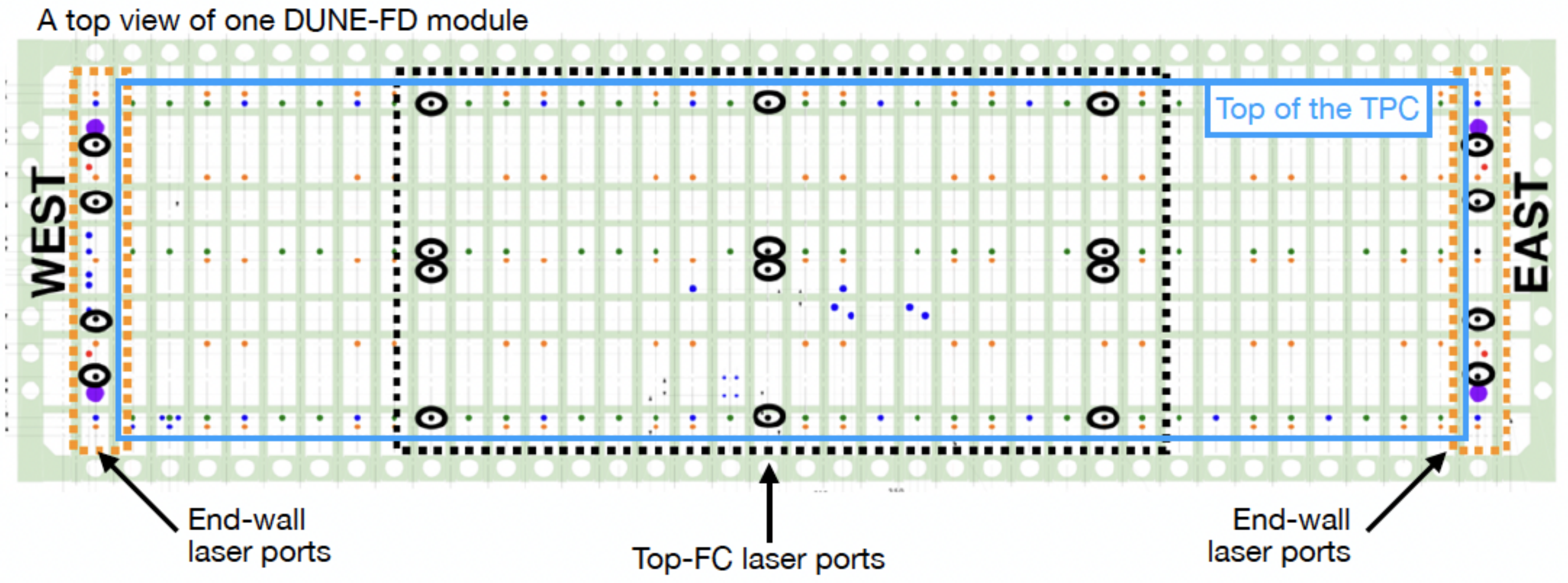
- GeV-scale oscillation physics: energy scale uncertainty < 2% for leptons and < 5% for hadrons
- MeV-scale low E physics (e.g. supernovae, solar): energy resolutions ~20-30%

- Challenge due to huge size
- Segmented detector: 4 drift volumes, many thousands of channels/wires etc.
- Low cosmic ray muon rates due to deep underground location



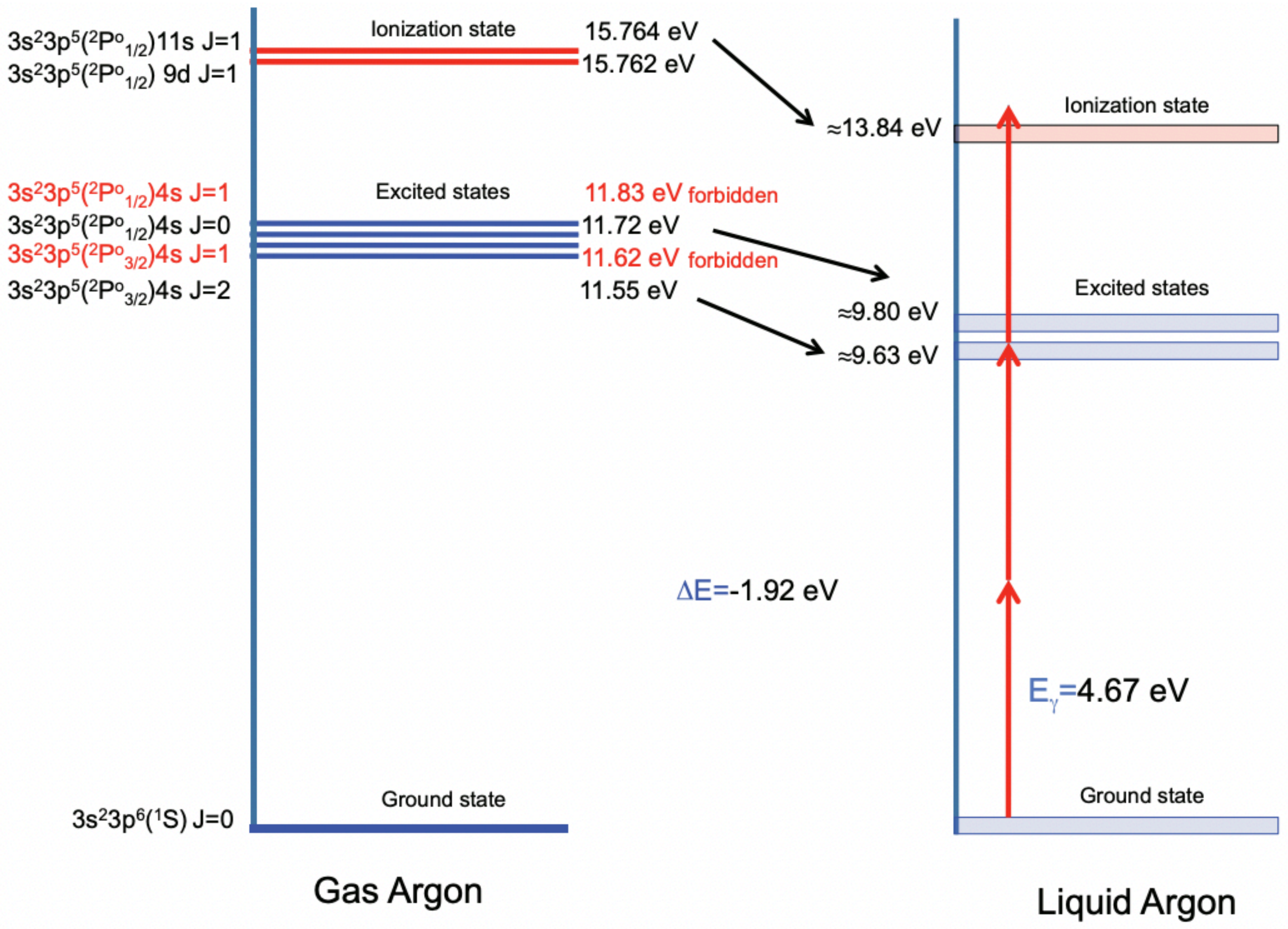
Calibration Systems

- Three calibration systems planned for DUNE - ionization laser system is the primary one
- Laser calibration system will create straight and well-defined ionization tracks for calibration
- Independent fine grained measurement of detector parameters
  - eg: drift velocity and electric field distortions
- Can help diagnose detector issues such as anode/cathode tilts



Laser Ionization of LAr

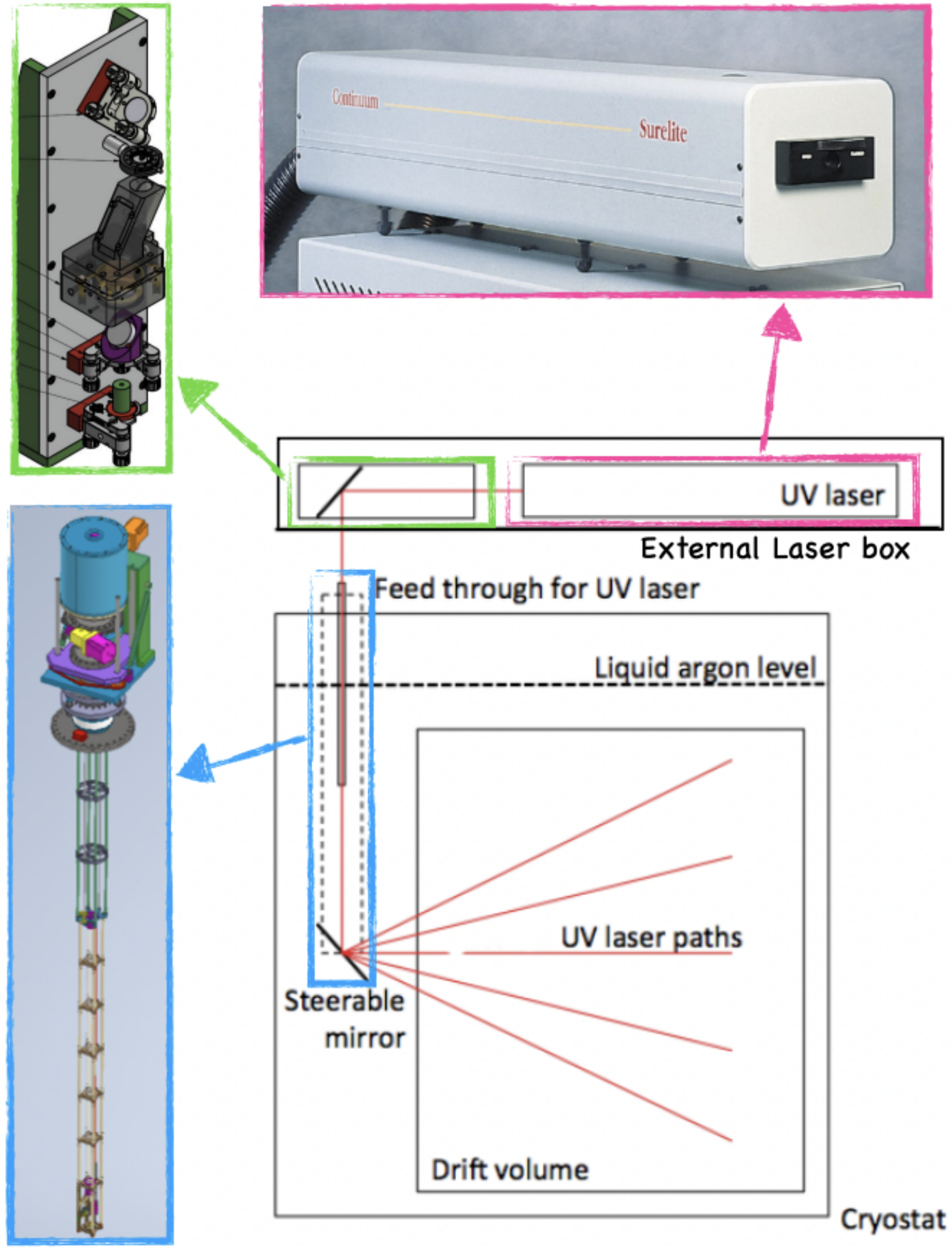
- 266nm (equivalent to $E\gamma$ = 4.67 eV) laser light ionizes LAr through 2-photon excitation followed by single-photon ionization
- Electron yield goes with square of photon intensity (in typical regime)



I. Badhrees et al., New Journal of Phys. 12 (2010) 113024

Laser Ionization System Overview

1. Class IV laser
   - High intensity (60 mJ) UV laser
2. Optical bench
   - Modulate intensity and remove lower harmonics (eg. visible and infrared)
3. Periscope
   - Direct and rotate laser beam into LAr detector



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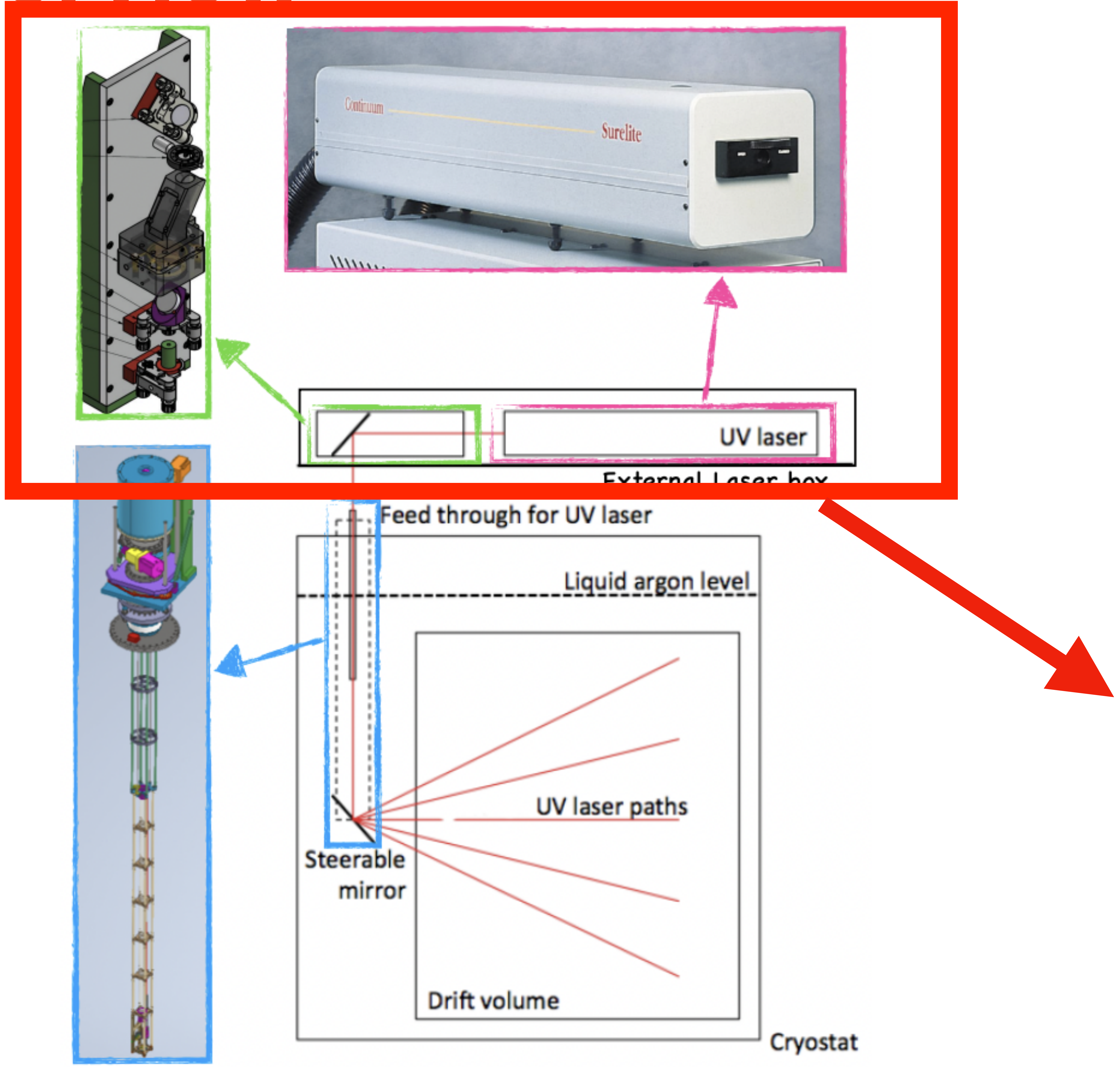
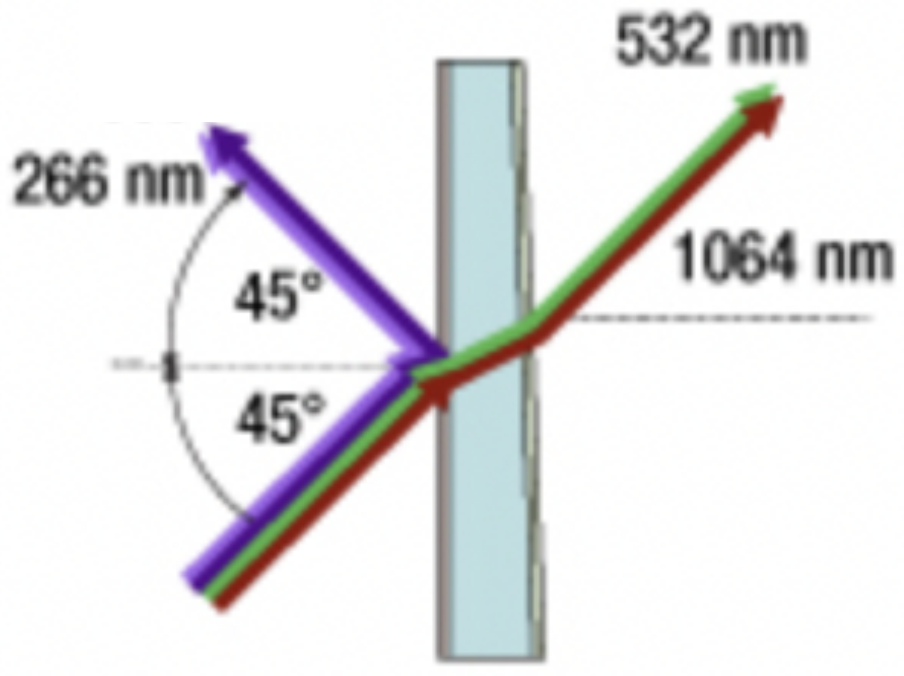
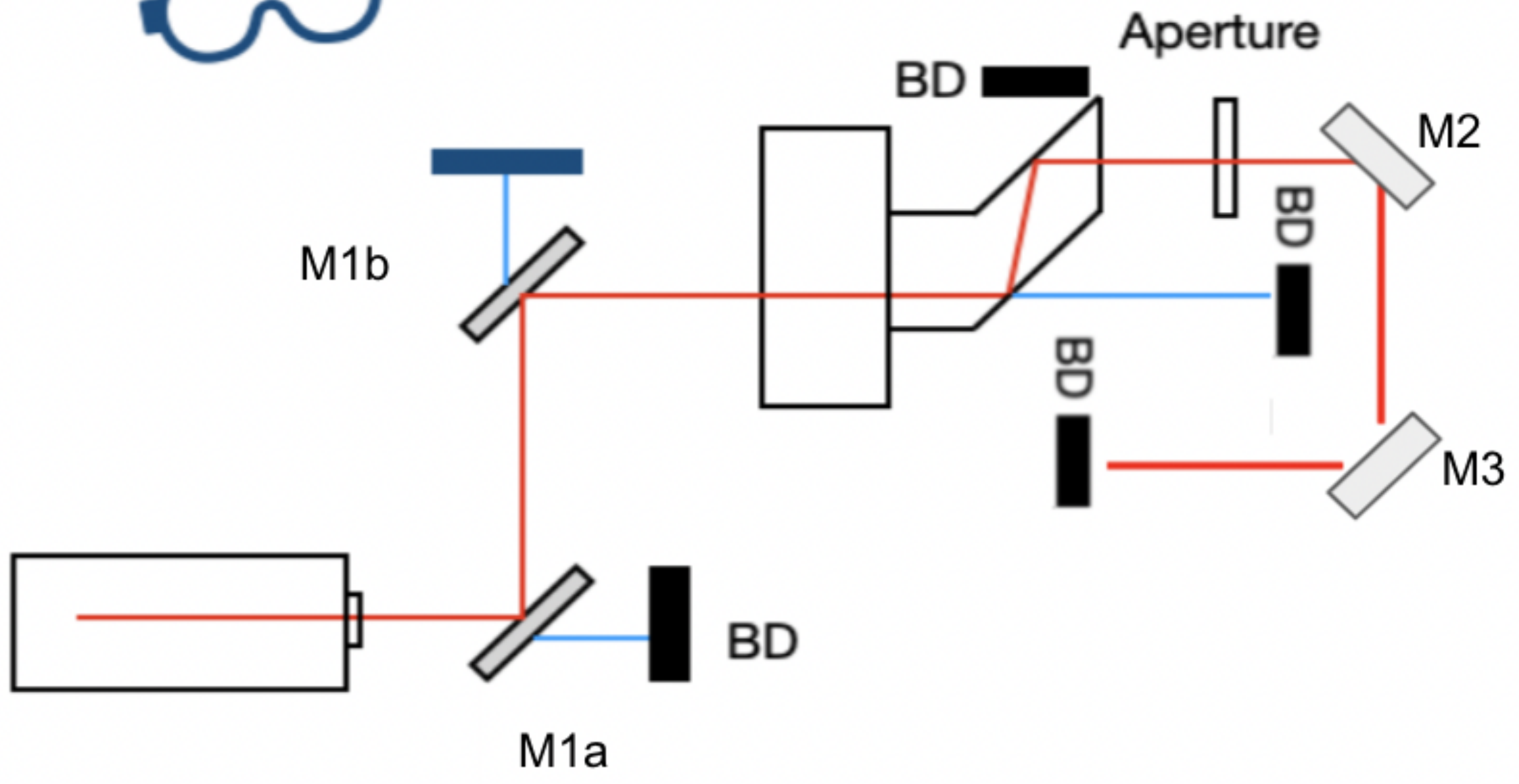


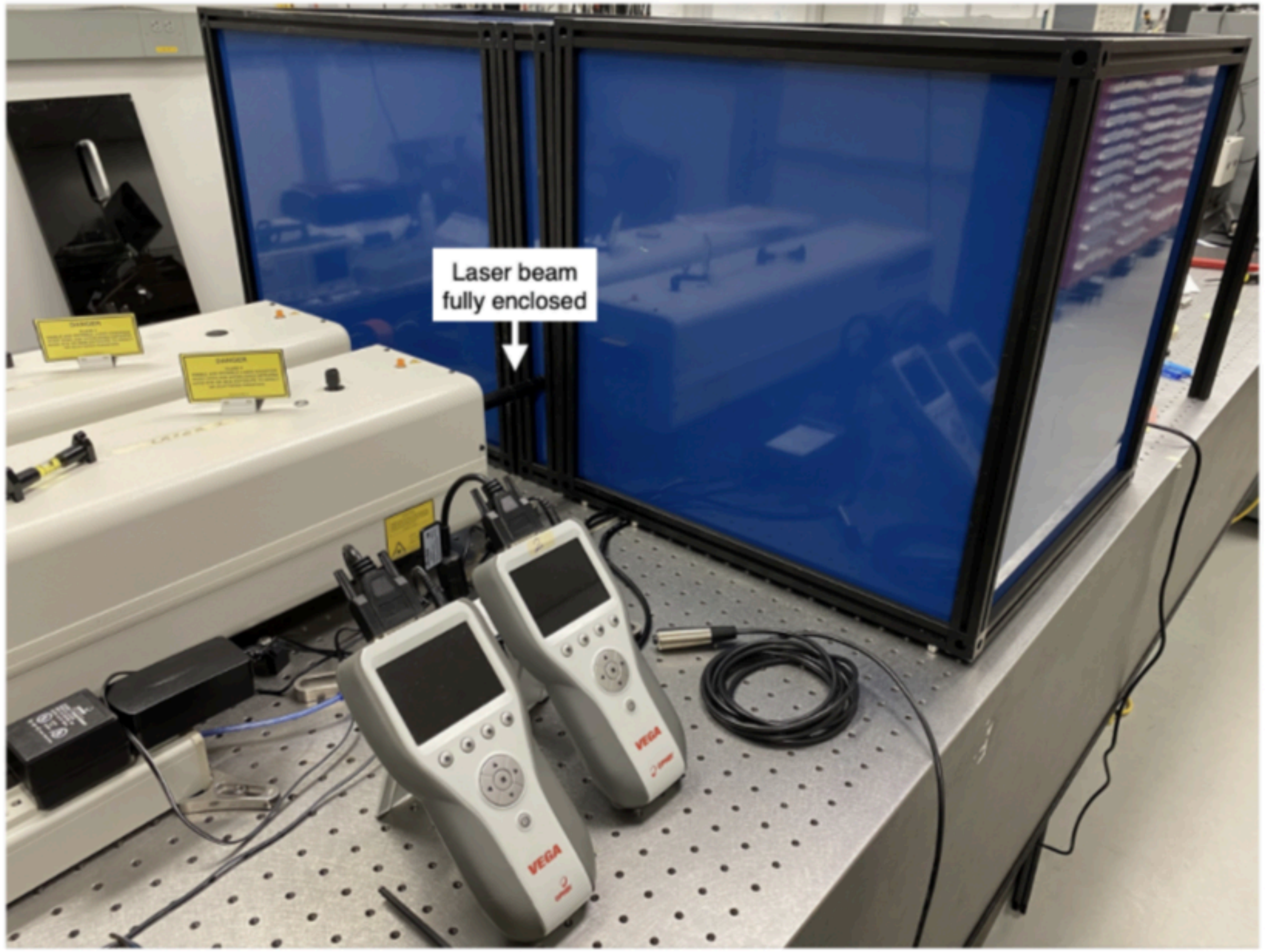
Laser and Optical Bench

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





Optical Bench at LANL



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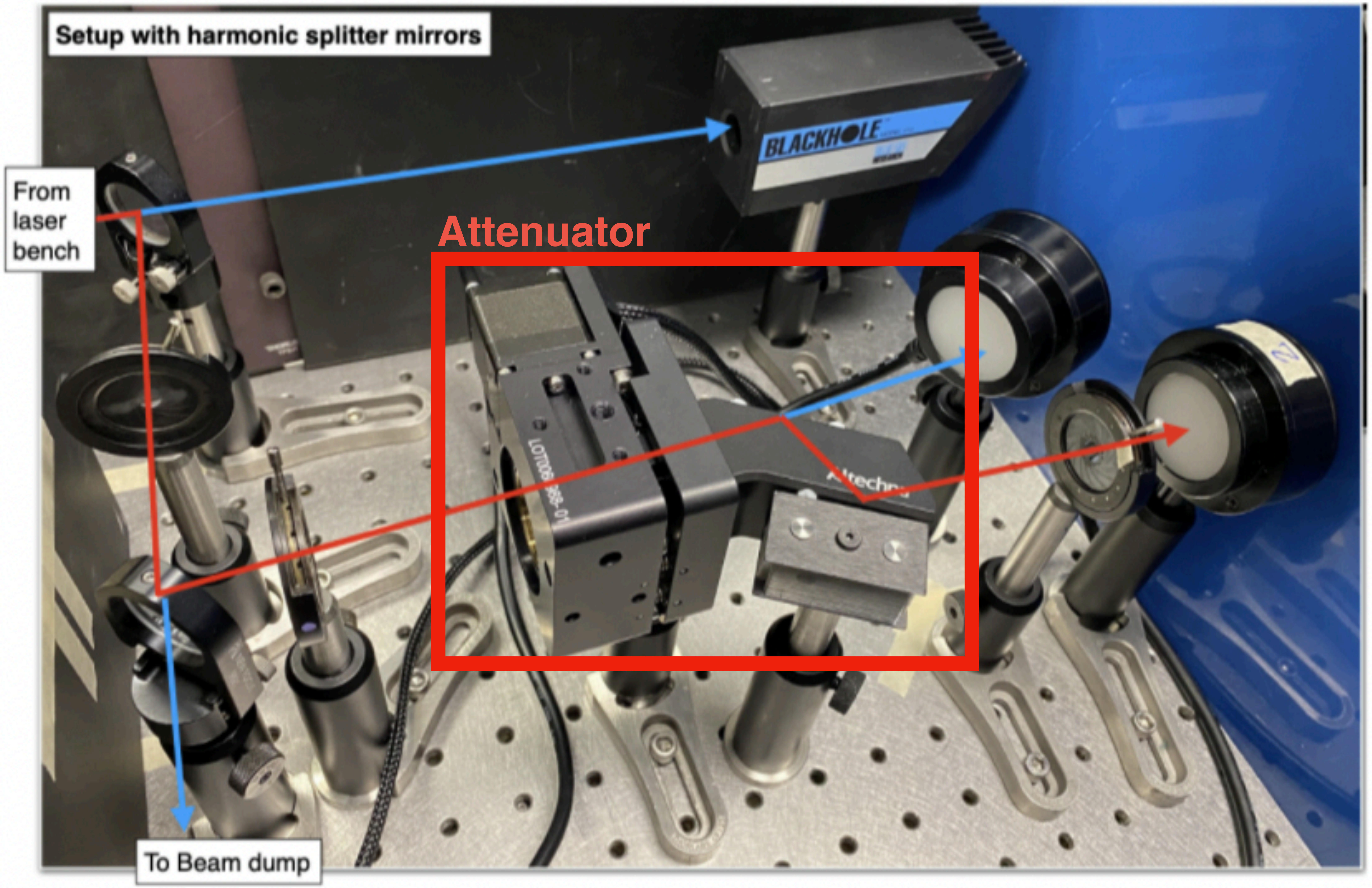
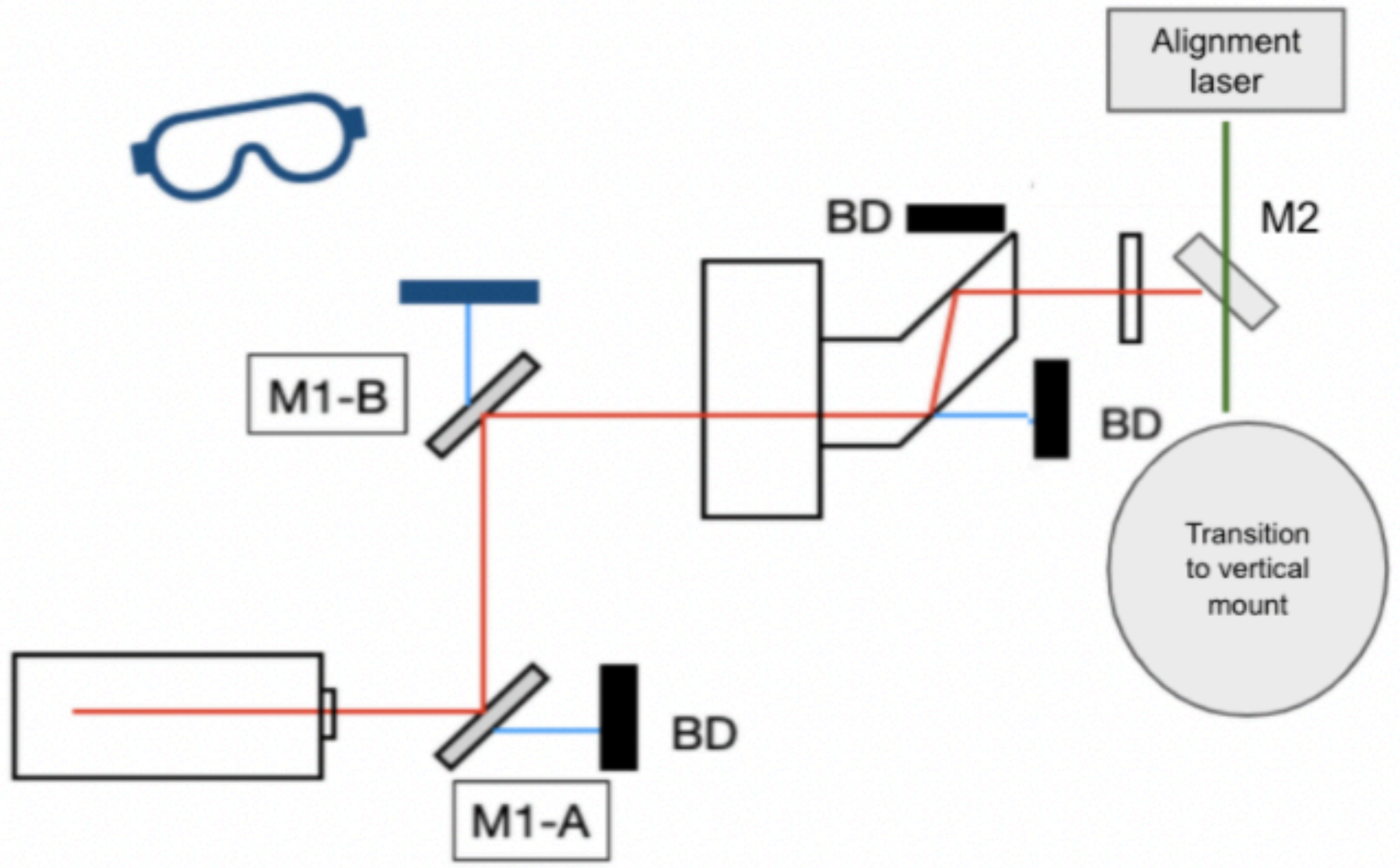


Preliminary Results and Next Steps for Optical Bench

- Characterized first laser, currently testing second laser
- Characterized other optical components such as attenuator, mirrors, etc
- Isolated pure beam of 266nm light
- Moving to vertical setup towards a more compact design



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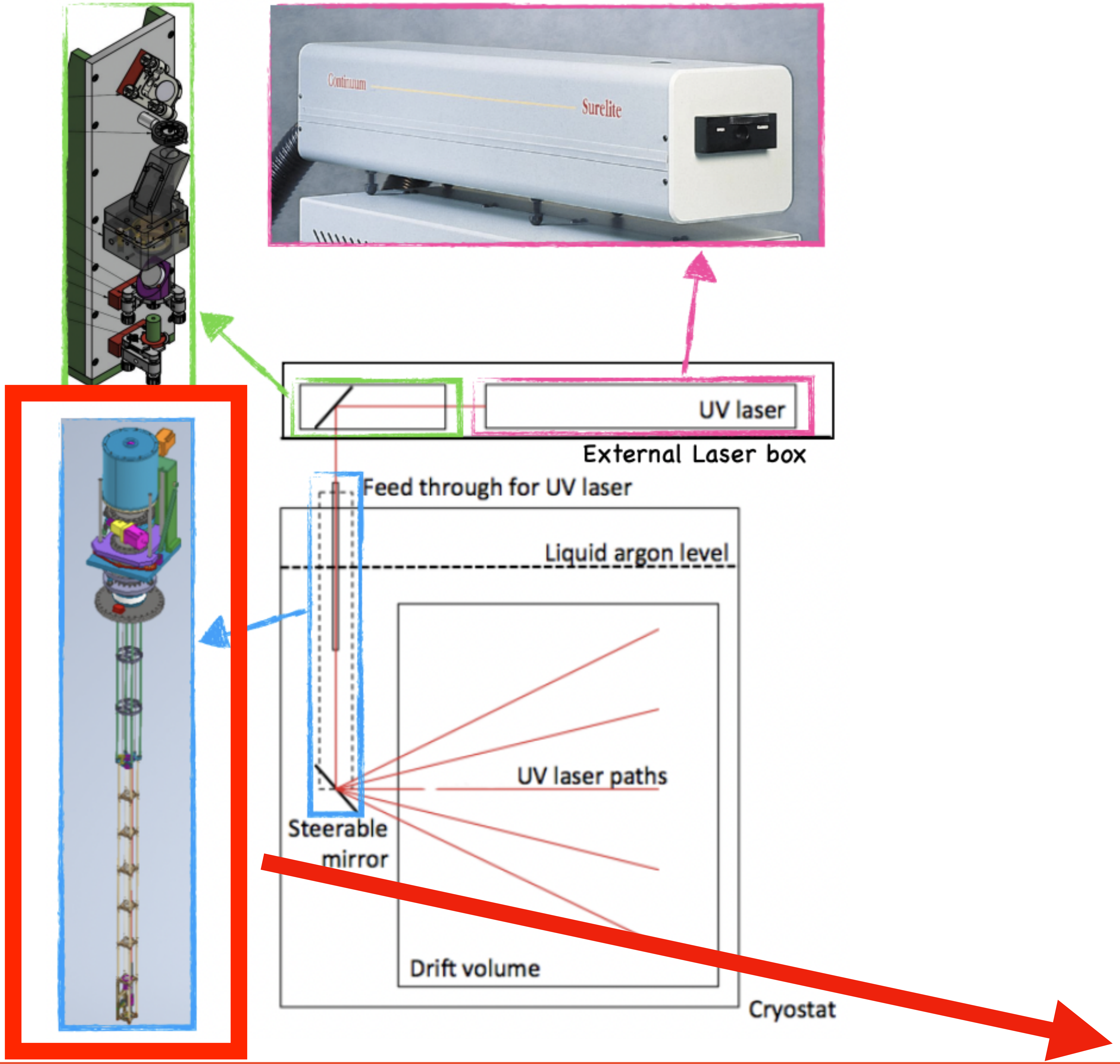
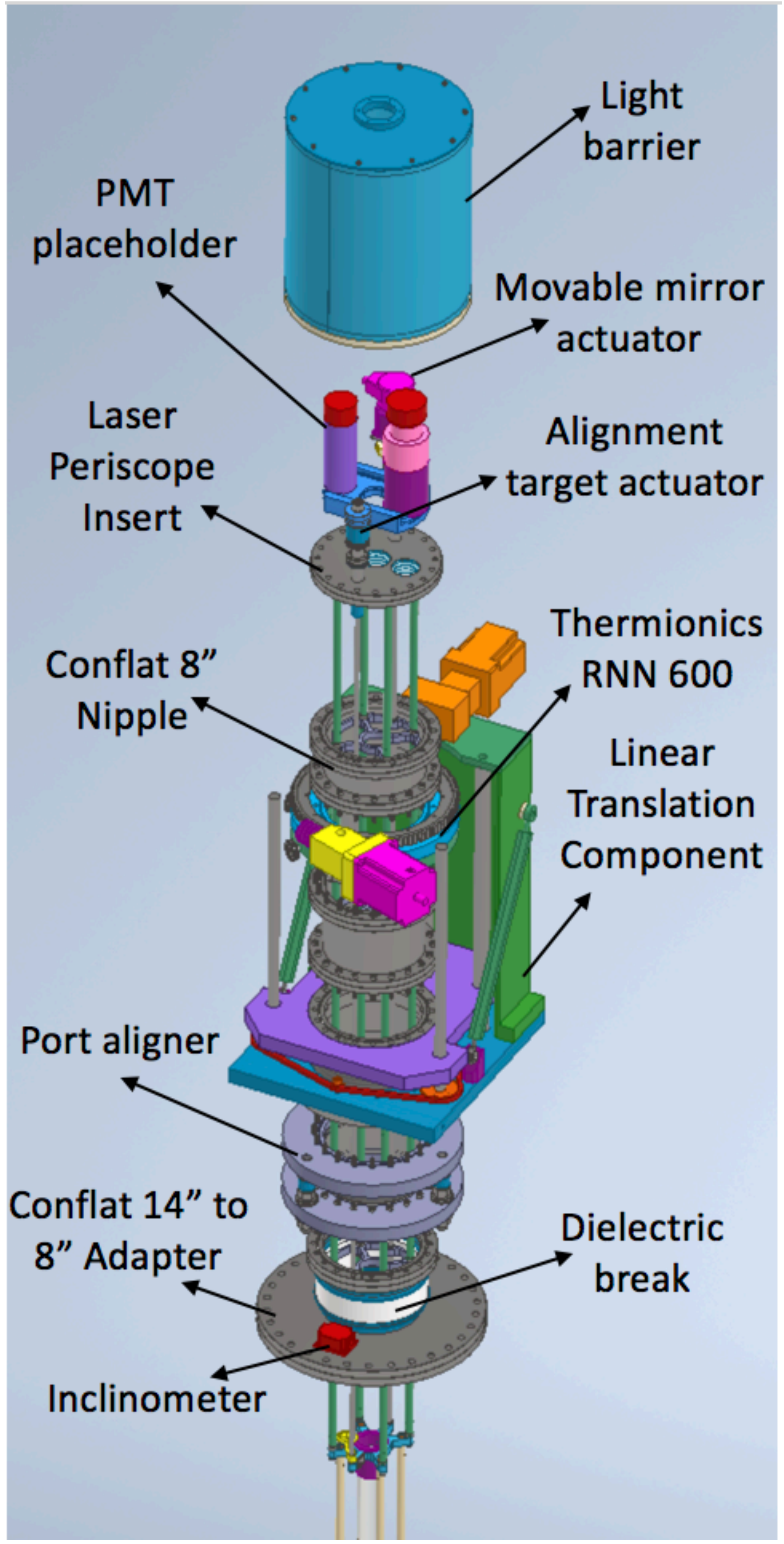
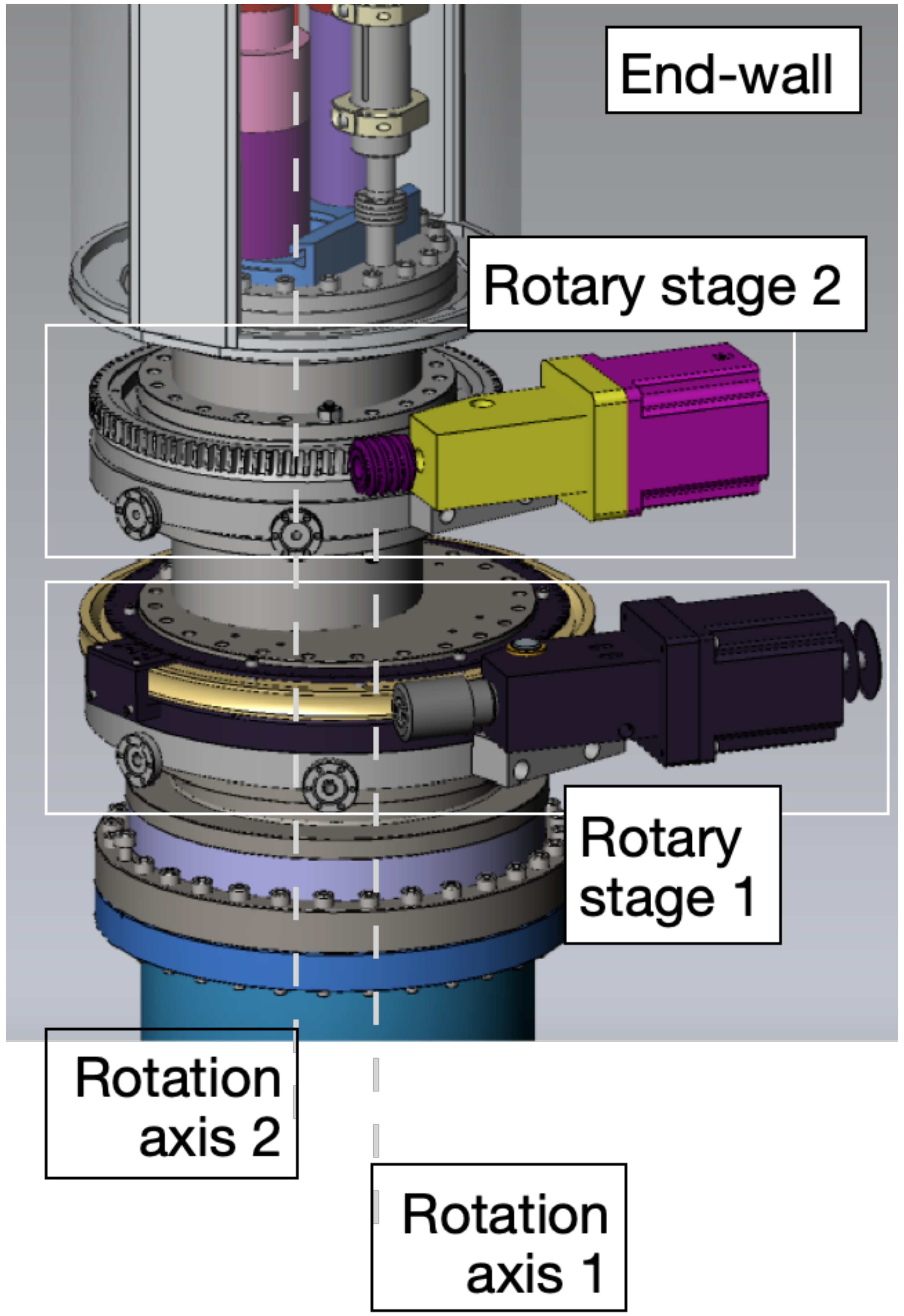


Optical Feedthrough and Periscope

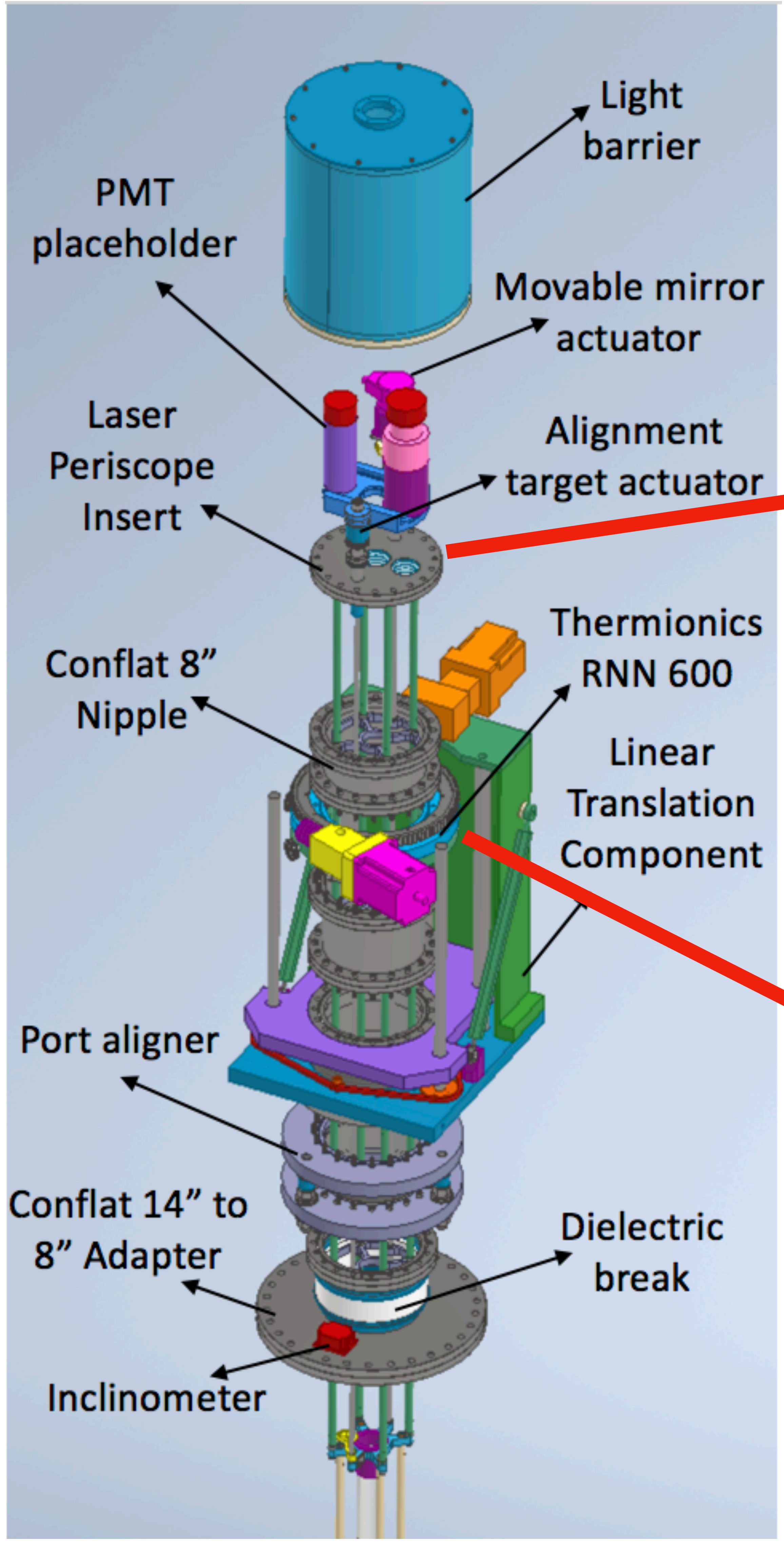


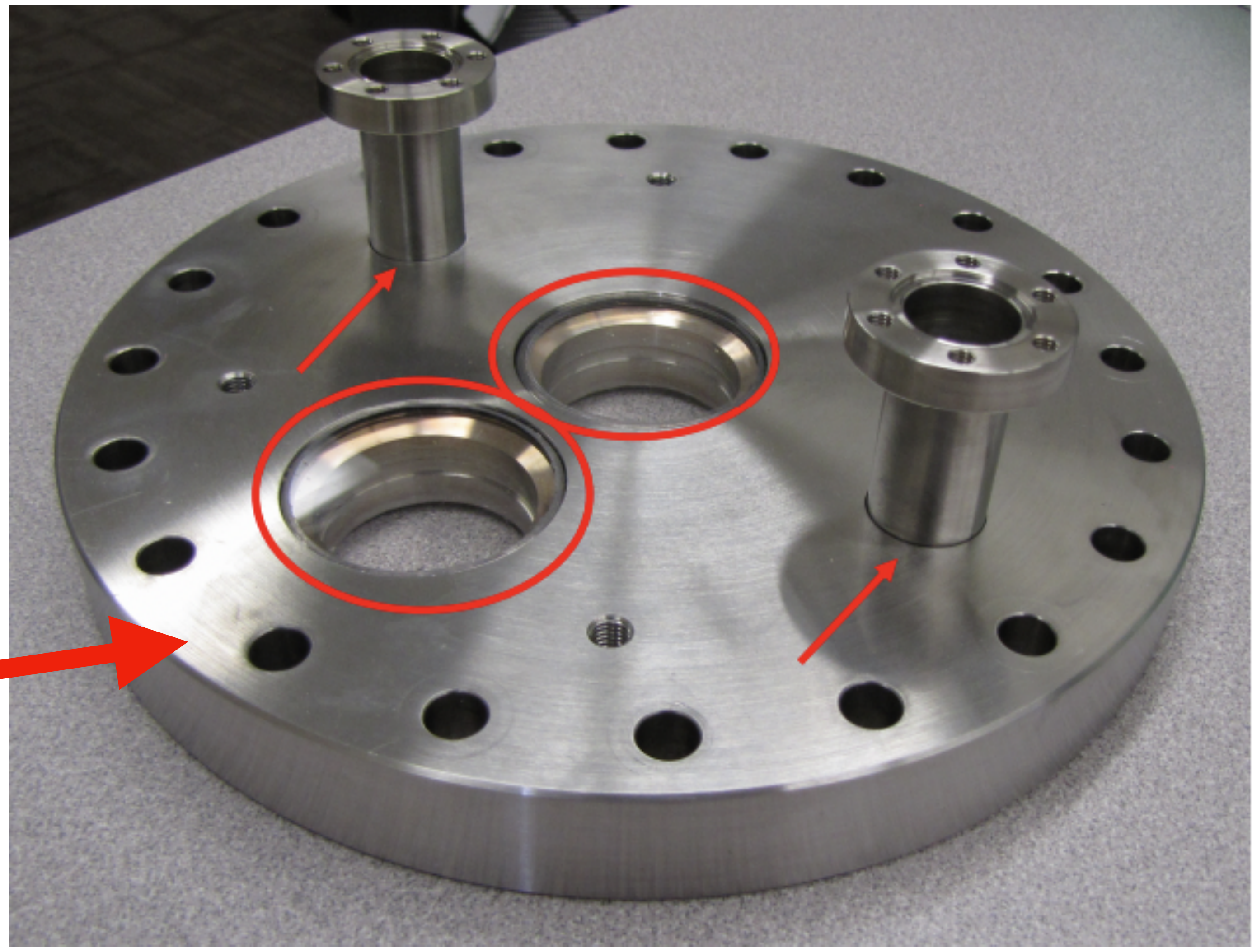


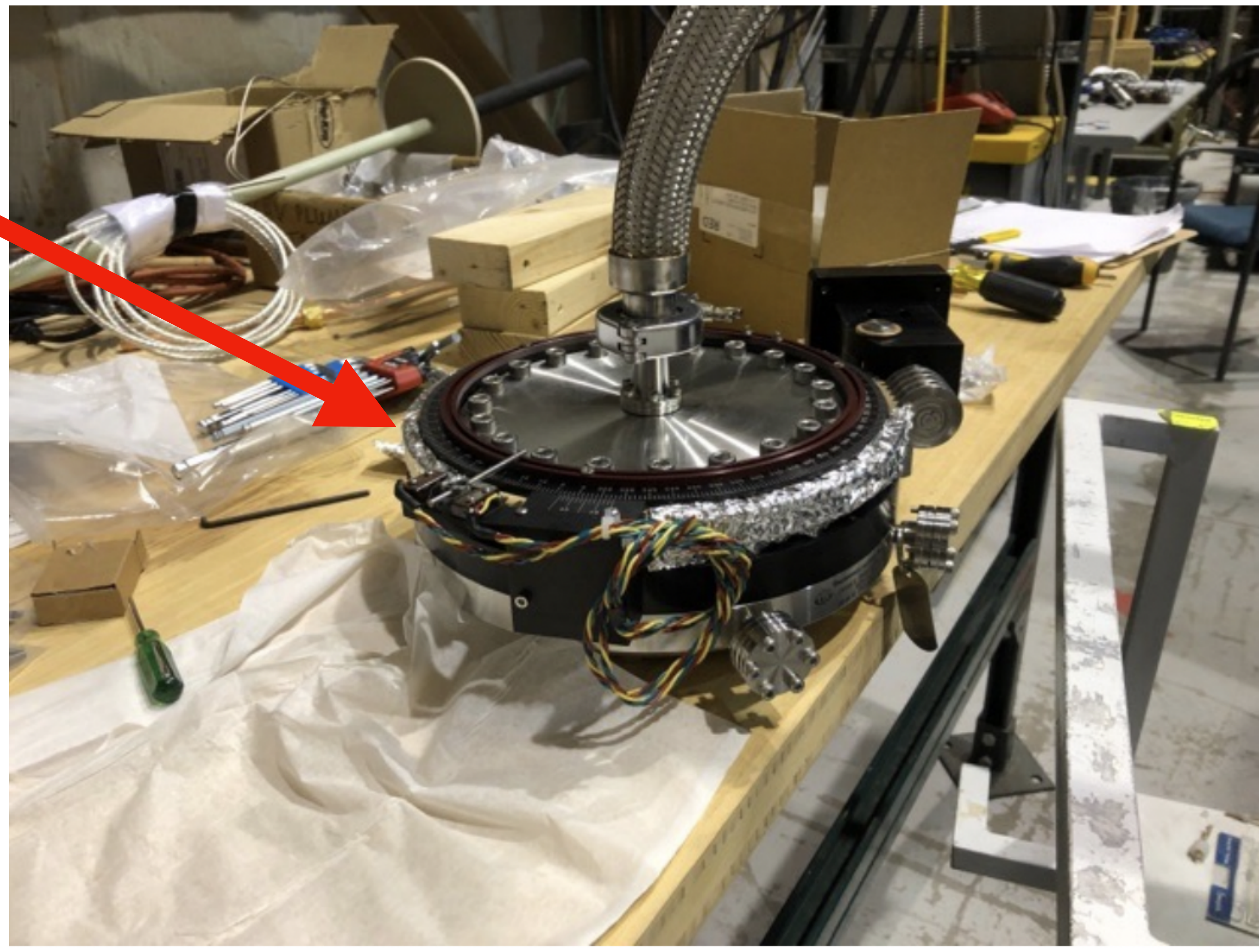
- Two periscope designs to maximize coverage of the detector
- One for the central region (penetrates the TPC top field cage and includes a retraction device for safety)
- One for the end-wall region (send light from outside the field cage using a dual rotary motion)
- Periscope designs final, procurement and fabrication ongoing at LANL and LIP (Portugal)

Leak Testing

- Periscope includes a number of seals to the cryostat which need to be tested for leak tightness
- Helium leak testing of components (e.g. rotary stages, flange view ports) ongoing at LANL and LIP (Portugal)
- Leak rate specification for DUNE/ ProtoDUNE is 10^{-6} mbar·l/s for the whole cryostat and 10^{-8} mbar·l/s for local leaks
  - ➡RNN-600 rotary stage is within range; leaks on the order of 10^{-9} mbar·l/s
  - ➡MDC viewport flanges are both within range; leaks on from 10^{-9} to 10^{-10} mbar·l/s

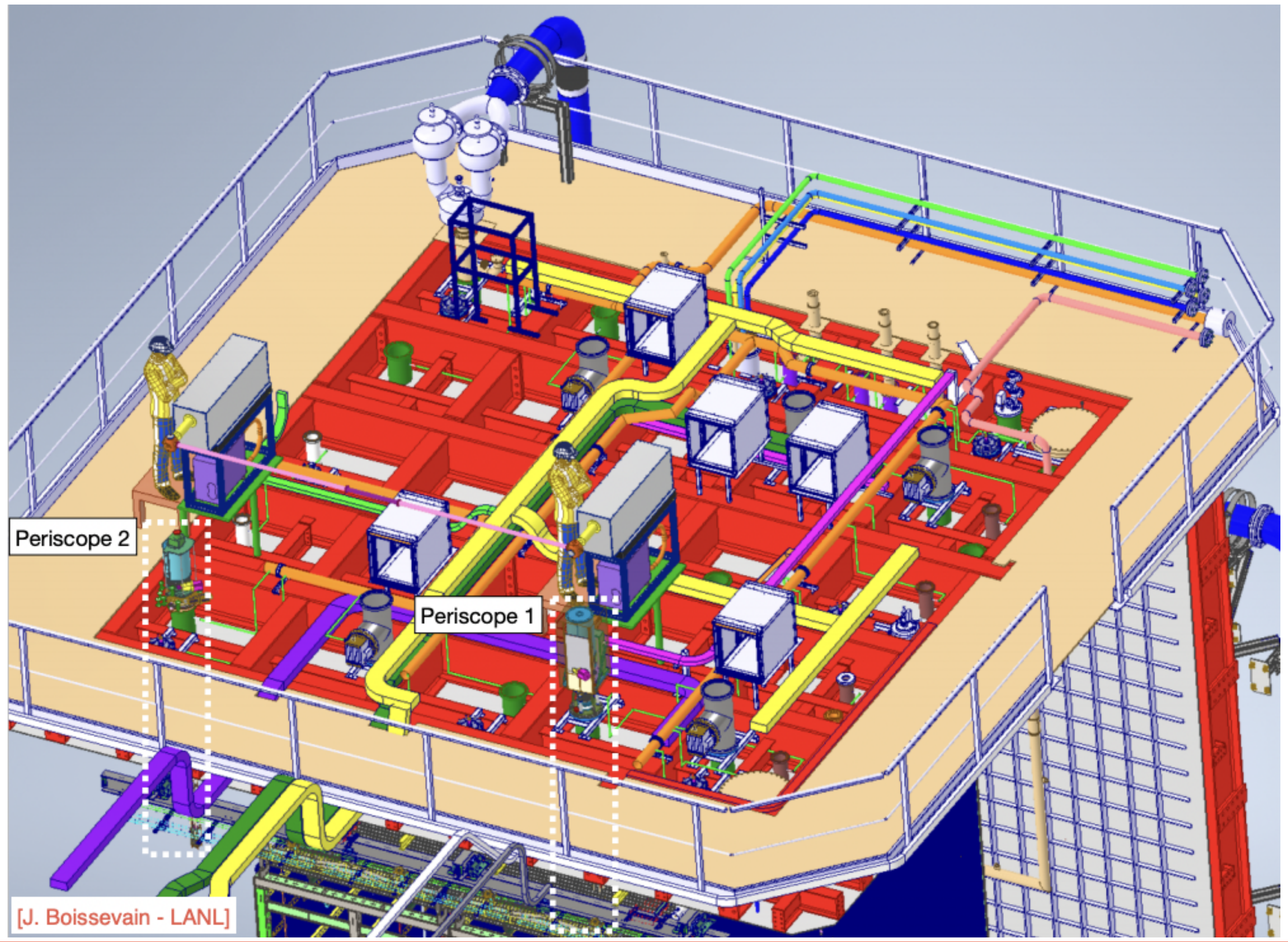






Summary and Next Steps

- Developing laser ionization calibration system for fine grained measurements of detector parameters to understand + diagnose detector behavior
- Testing + finalizing design of optical components and periscope feed through
- Will soon be testing laser, optical bench, and periscope on cryogenic test stand at LANL
- Two full prototype laser systems will be built and installed in DUNE’s 419-ton (active) Prototype detector (ProtoDUNE) at CERN in early 2022



Thank you for listening!