UV Laser Ionization of Liquid Argon TPCs

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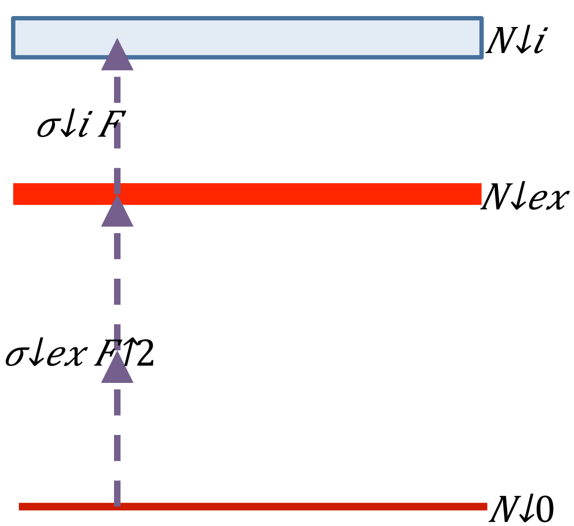
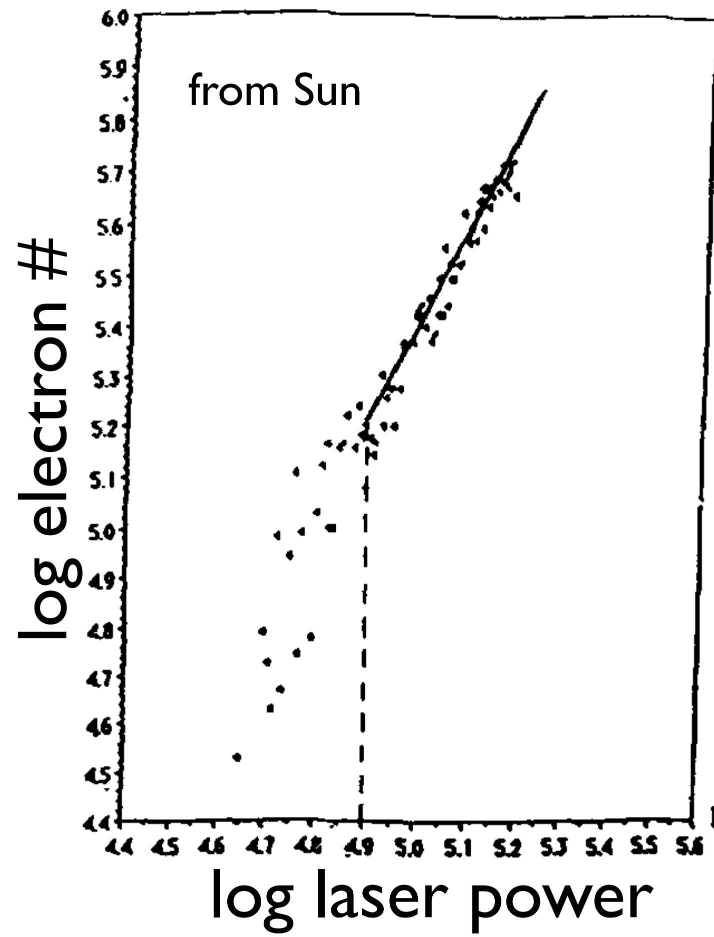
Need for a Laser Calibration System

- Measure the electric field in situ
  - "As Built" TPC field may differ from design
  - Possible changes over time
- Measure electron lifetime in situ
  - LAr may not be completely mixed
- Redundant, well understood system (cross-check muons)

Laser Ionization of Liquid Argon

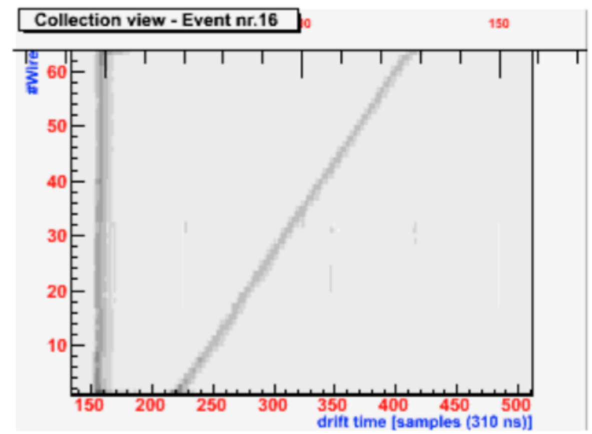
- First demonstrated by Sun et al. 1996 NIM A v370 p372
- Binding energy of LAr 13.78 eV
- Quadrupled Nd-YAG, 266 nm or 4.66 eV
  - requires 3 photons (13.98 eV) to ionize
- Quadratic dependence of ionization yield to laser power
  - Indicates presence of intermediate state

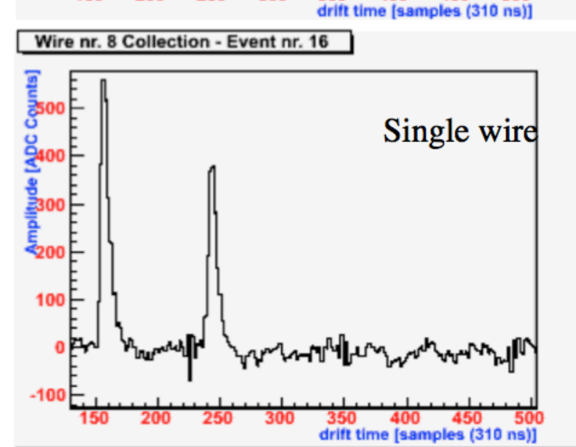


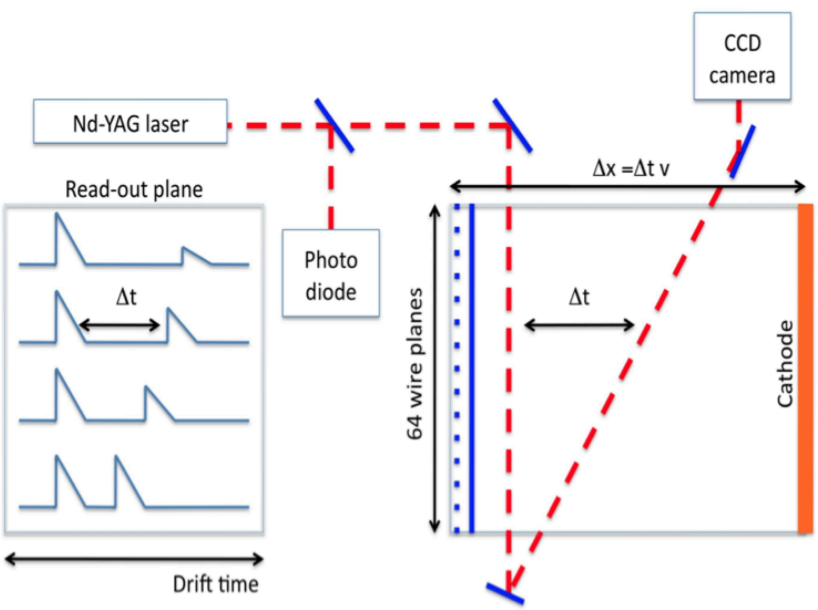


Laser Ionization of LAr

- U. Bern group has done most of the recent work
  - Rossi, et al., 2009, JINST, v4 p07011
  - Badhrees, et al. arXiv:1011.6001
  - Rossi, et al., 2011, J. of Phys. Conf. Ser. v308, p012025





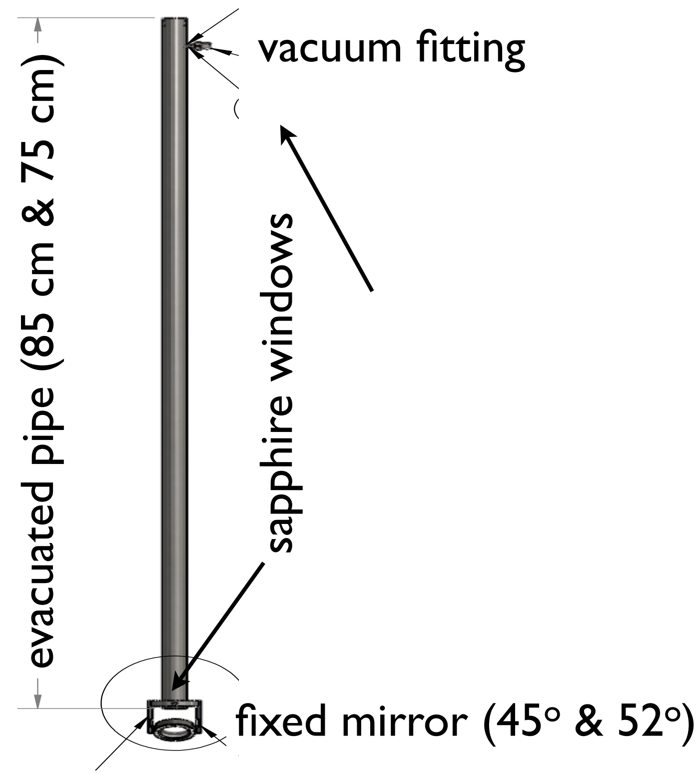


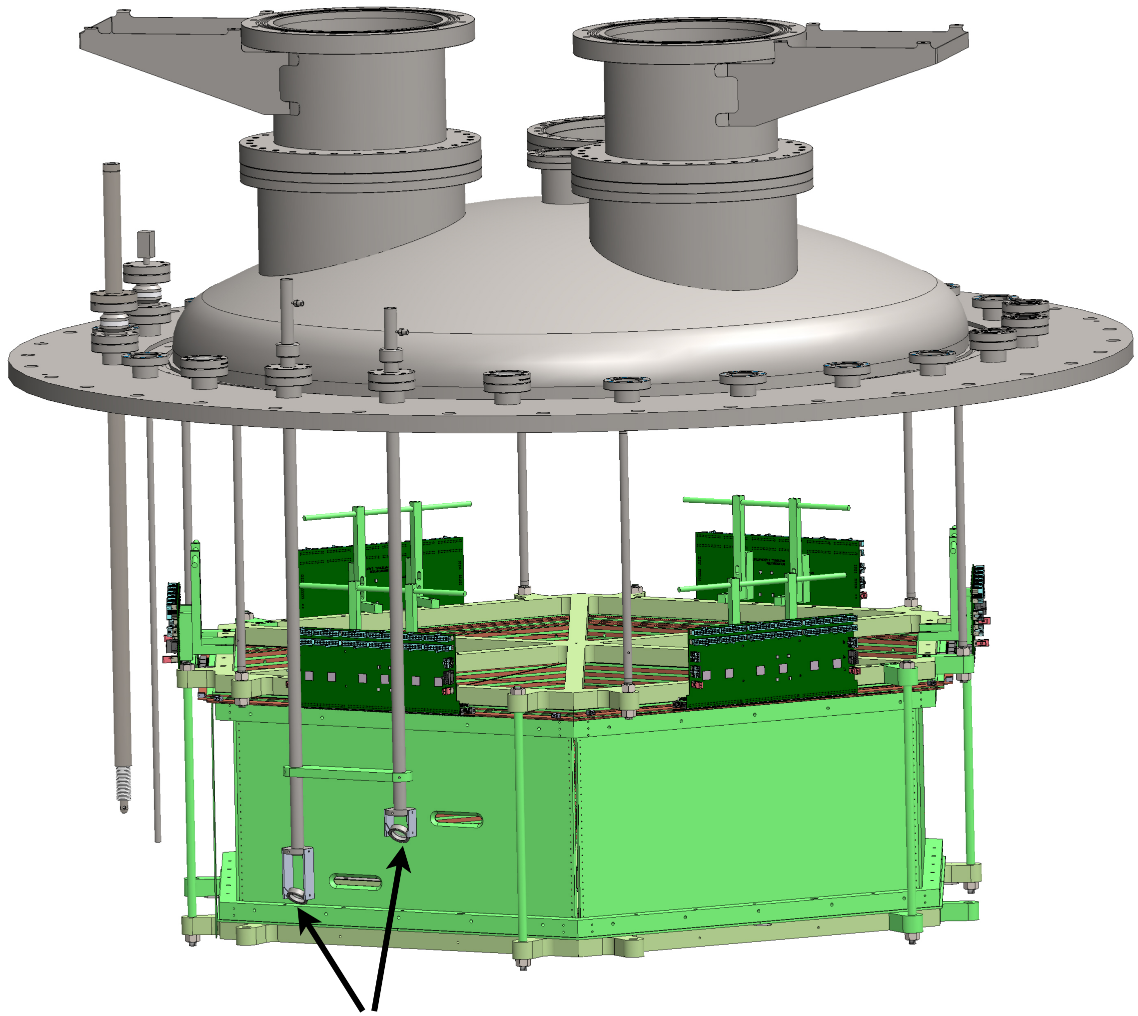
Laser Ionization System for LBNE

- Considerations
  - Size of detector - Rayleigh scattering length ~18.6m at 266nm (minimize beam path)
  - Beam access to liquid (minimize losses)
  - Ability to access any location in liquid volume
  - Modularity (independent optical elements)
  - Safety systems (enclosed beams were possible)
  - Impact on photon detection system (TPB sensitive to UV light)
- Requirements
  - Pointing accuracy < wire spacing over 20m (0.1 mrad)
  - Small beam divergence (ability to ionize liquid ~30m from source)
- Prototype in CAPTAIN (and Mini-CAPTAIN)

Mini-CAPTAIN

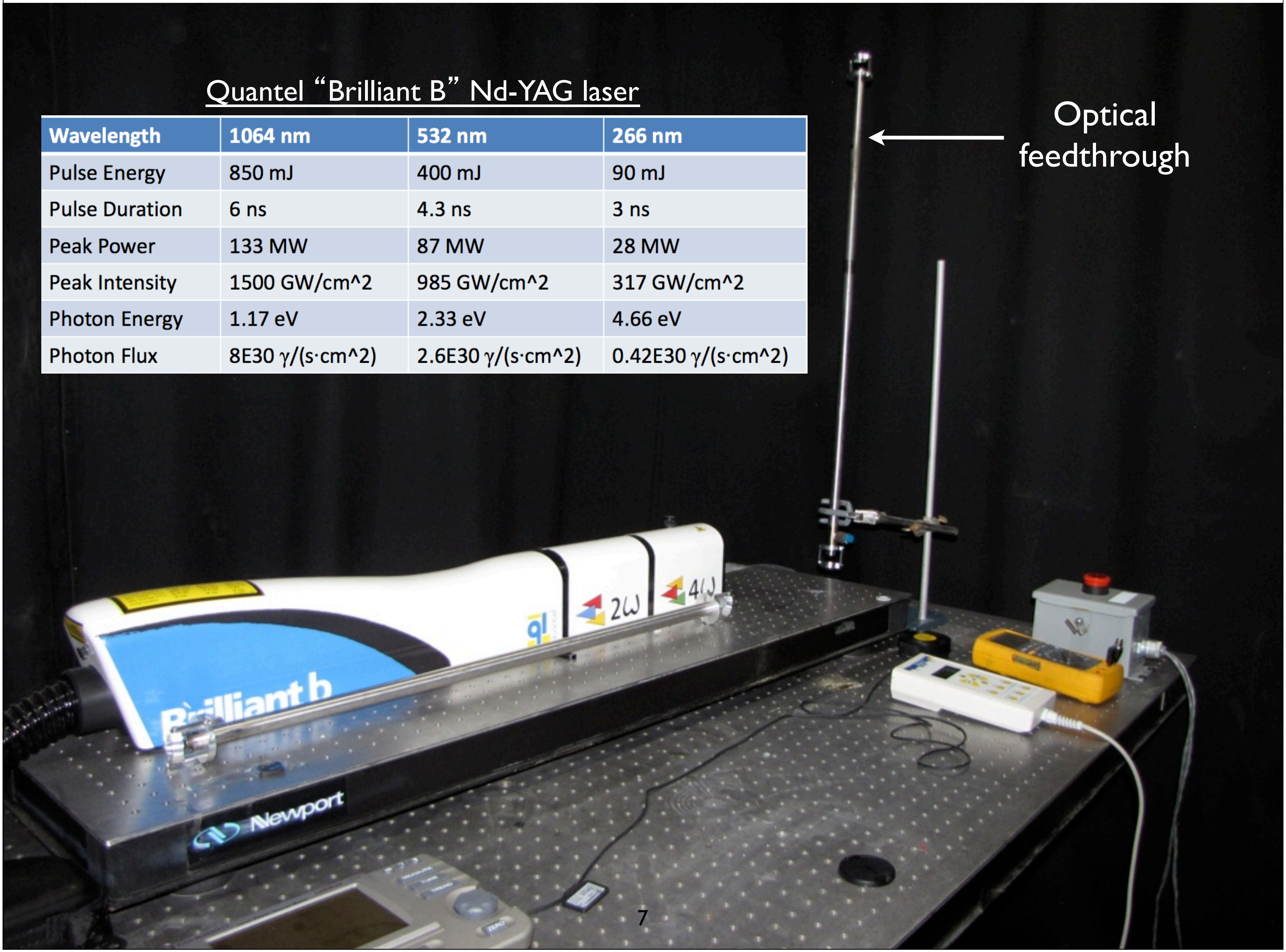
- Simple design
- Limited flexibility
- Fixed mirrors
- Azimuthal rotation througl small range



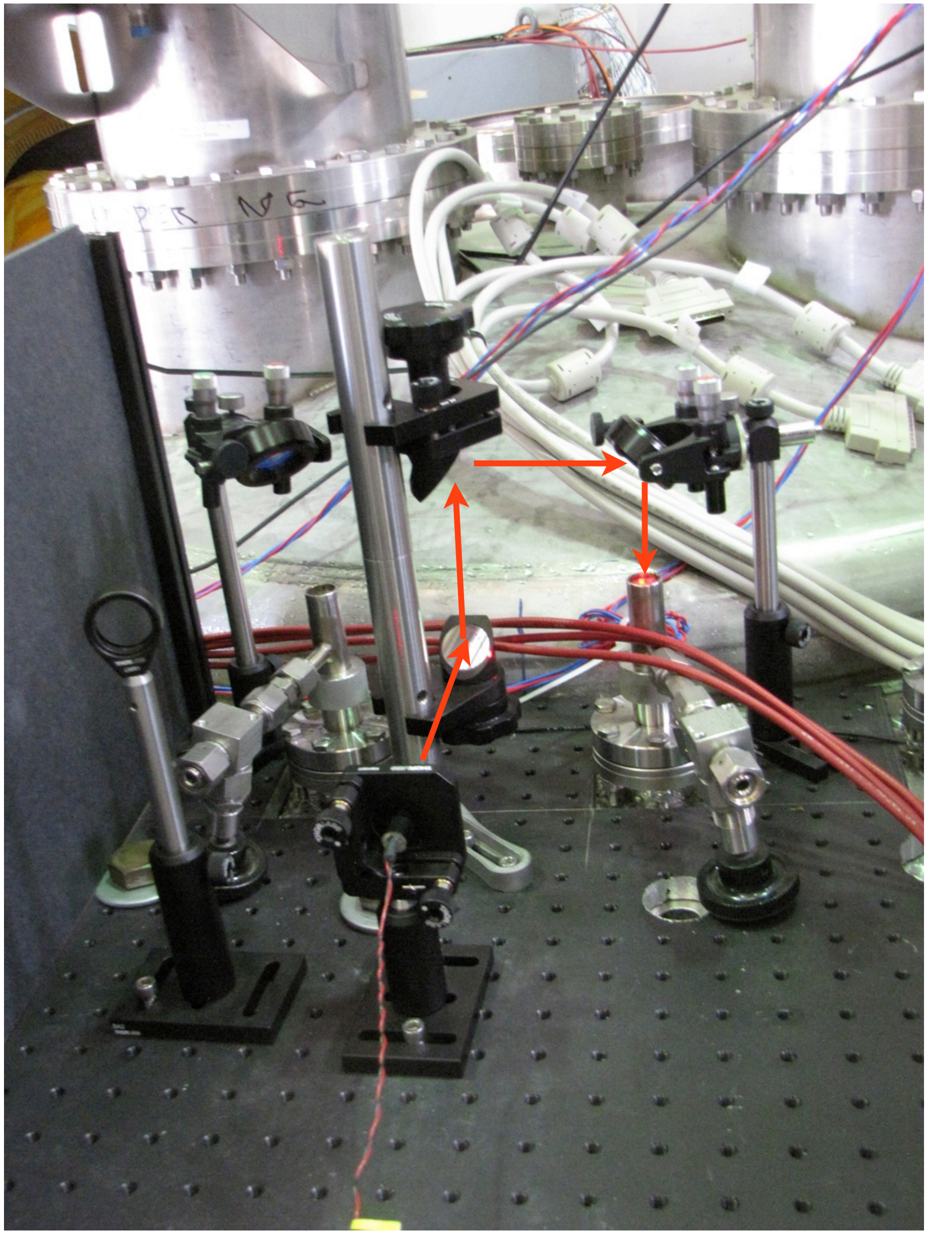


Quantel "Brilliant B" Nd-YAG laser

Wavelength	1064 nm	532 nm	266 nm
Pulse Energy	850 mJ	400 mJ	90 mJ
Pulse Duration	6 ns	4.3 ns	3 ns
Peak Power	133 MW	87 MW	28 MW
Peak Intensity	1500 GW/cm^2	985 GW/cm^2	317 GW/cm^2
Photon Energy	1.17 eV	2.33 eV	4.66 eV
Photon Flux	8E30 γ/(s·cm^2)	2.6E30 γ/(s·cm^2)	0.42E30 γ/(s·cm^2)



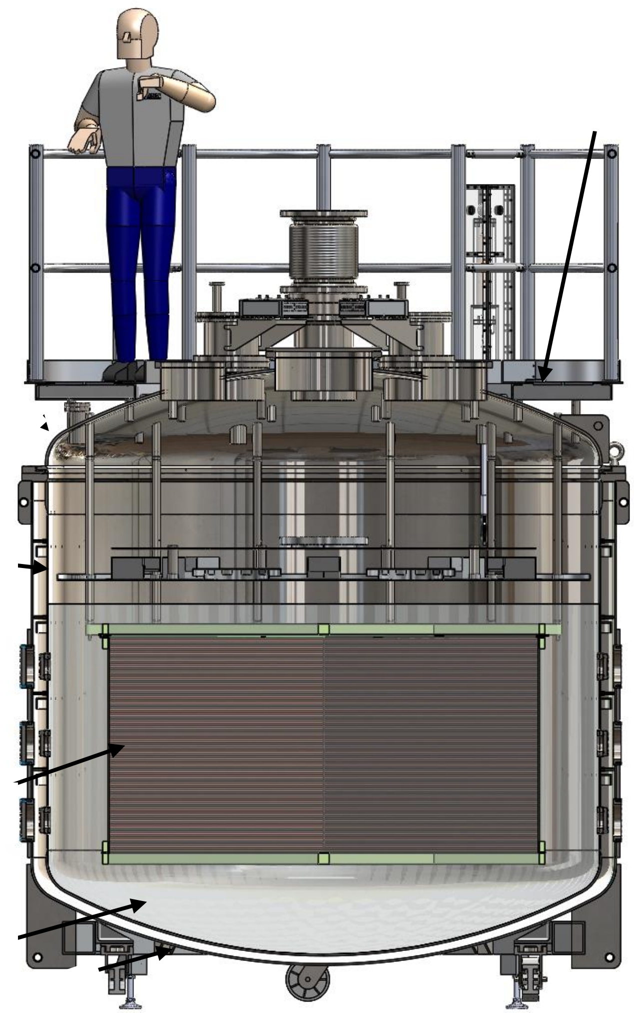
Laser Alignment



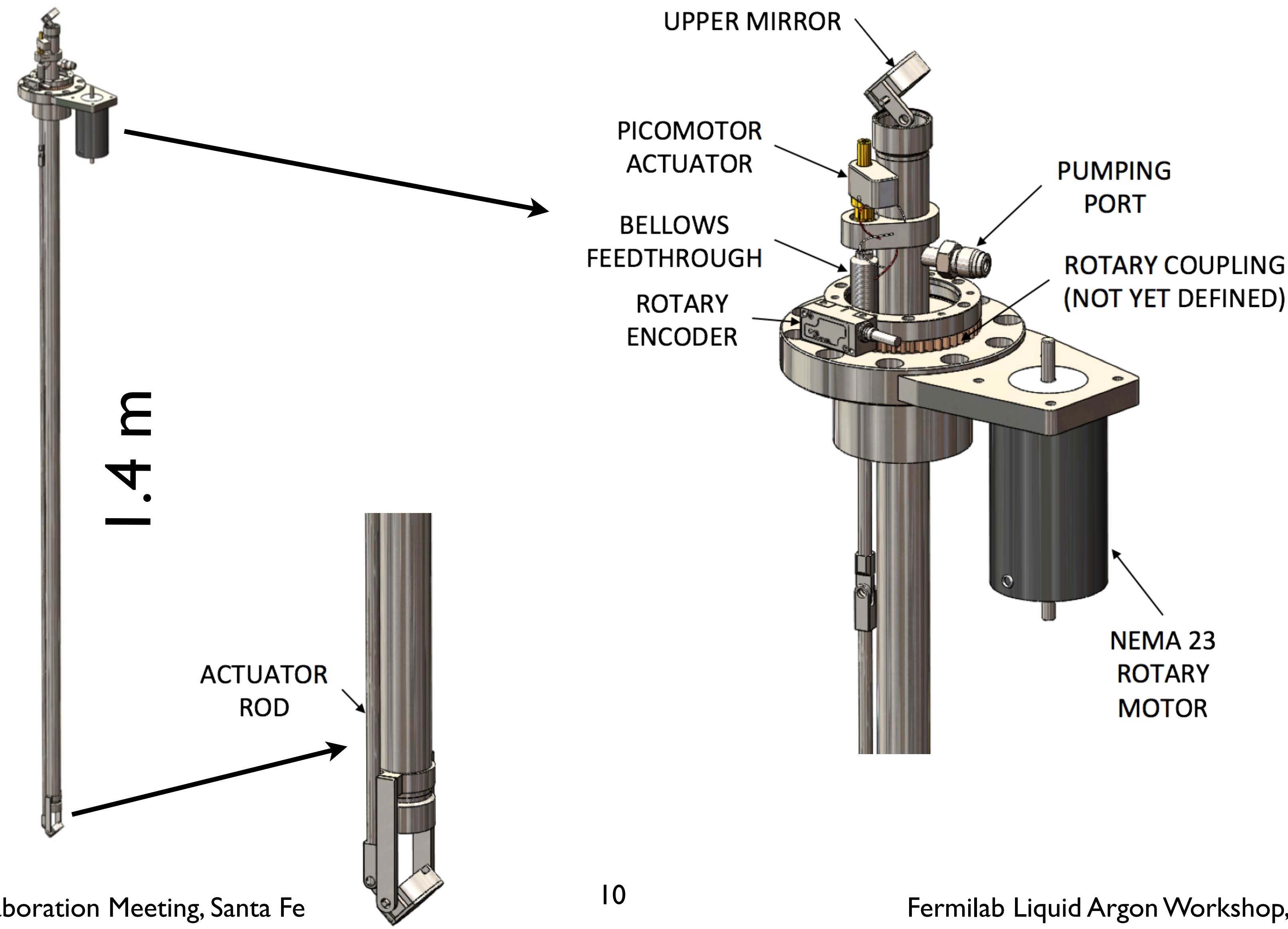
Mini-CAPTAIN Nitrogen Fill
Test of alignment procedure

CAPTAIN Laser System

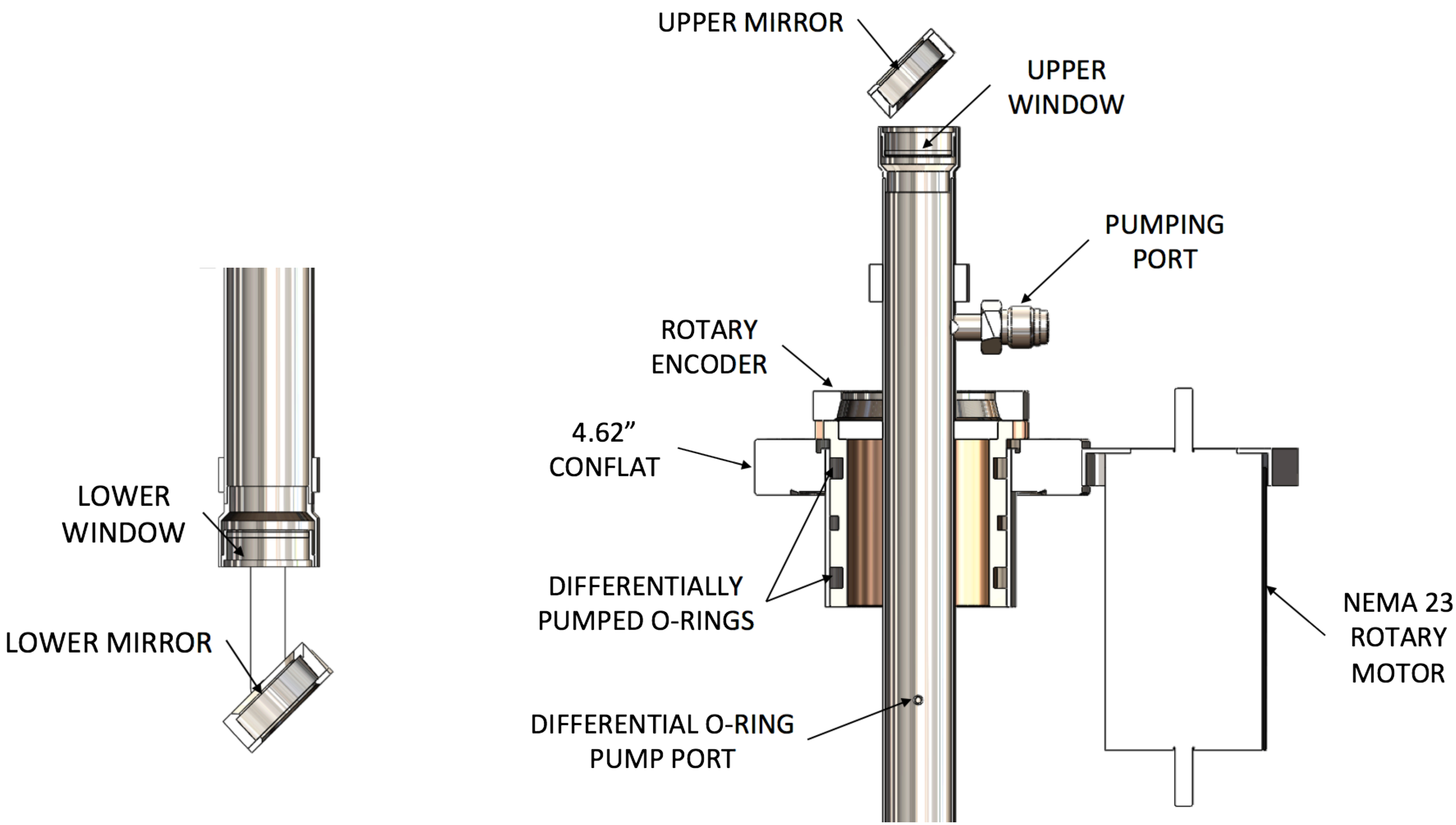
- Need to prototype LBNE system on a small scale
  - Validate optical feedthrough
  - Validate rotary control and encoder systems
  - Test calibration concepts
  - Understand potential damage to TPC
  - Calibration of pointing accuracy
- CAPTAIN is an ideal testbed for new ideas



Preliminary Design of Optical Feedthrough



CAPTAIN Feedthrough Detail



Control and Readout

- Renishaw absolute encoder for azimuthal control
  - 1 arc-second accuracy
- Newport picomotor and linear encoder for zenith control
  - 0.5” travel gives 90° zenith freedom
  - <30 nm incremental motion

Conclusions

- Laser ionization provides a controllable and understood ionization track to monitor the performance of a LAr TPC
  - Calibrate Mini-CAPTAIN and CAPTAIN
  - Prototype for LBNE(F)
- Further work
  - Mini-CAPTAIN LAr run - August
  - Complete design of CAPTAIN optical feedthrough
  - Larger-scale prototype
- With CAPTAIN we can work these issues and discover any new issues that LBNE will need to resolve (stability of long 3m feedthrough, verification of pointing accuracy, etc.)