FERMILAB-SLIDES-23-148-ND

The UV Laser Calibration System for measuring the electric field in the SBND detector

New Perspective Conference 2023 - 26 June 2023

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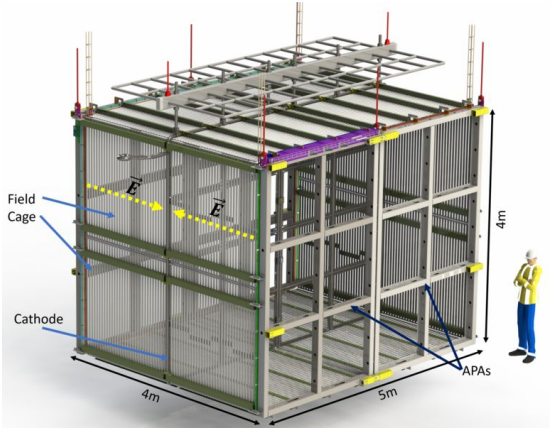
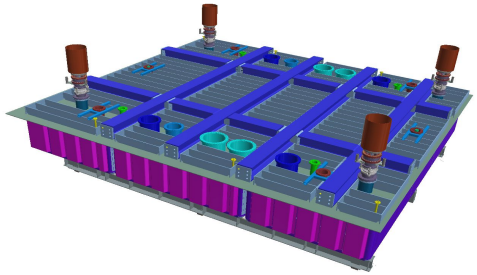
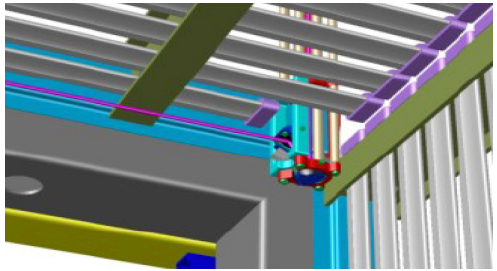


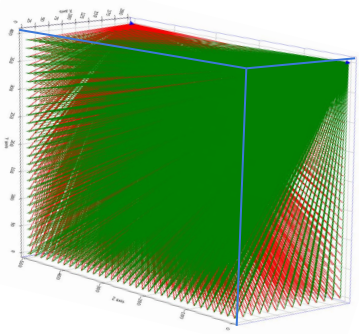


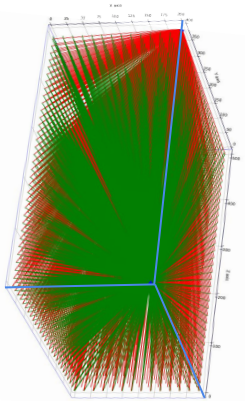


Cold mirrors inside the field cage

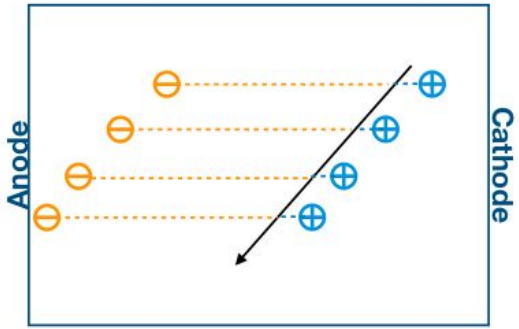
SBND:

- 110 meters from the Booster Neutrino Beam target.
- 112 tons of liquid argon within the active volume.
- 2 TPC system. (Each tpc is 2m x 4m x 5m)
- 4 UV laser systems.



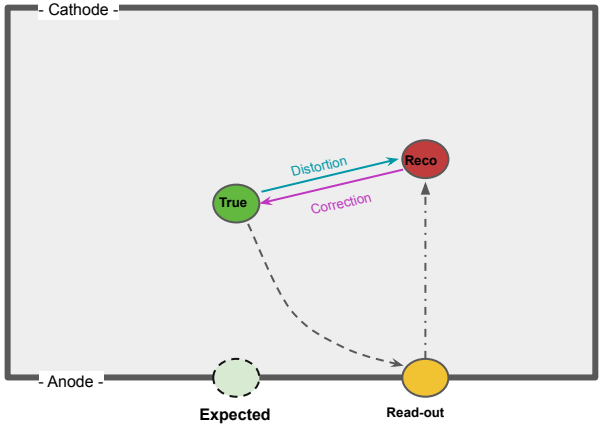


- $V_{e-} > V_{Ar+}$: by 5 orders of magnitude
- Accumulation of Ar^{+} ions inside TPC :
- Average density of positive ions is much larger than that of electrons results in **Space Charge effect.**
- E- field distortion



Acciarri, R., et al. Journal of instrumentation 12.02 (2017): P02017

- Discrepancies between true and reconstructed points.
- Reduces track and energy reconstruction efficiencies of the detector and introduces additional systematic uncertainties



UV Calibration method :

What :

- Drive finely tuned energetic UV laser beam inside TPC, which ionises the Ar ion thus leaving a ionisation track.
- Compare expected (true) and reconstructed track points to calculate the E - filed distortion inside TPC.

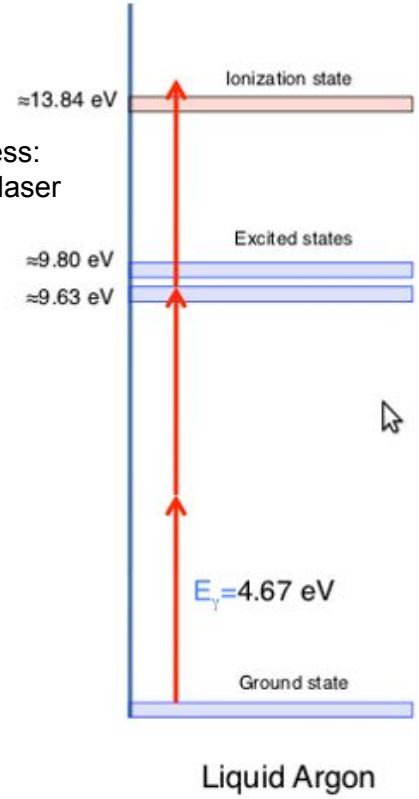
Why:

- laser beams do not experience delta ray emission in LAr.
- No multiple Coulomb scattering in LAr.
- Laser beams can also be repetitively pulsed in controllable directions
- UV laser system can be used to investigate detector failures, such as unresponsive or mis-configured wires in the read-out planes

Laser to ionize Ar:

- Nd:YAG laser from Continuum Surelite.
- Up to 10 Hz repetition rate.
- 5 mm beam diameter.
- Energy of 60 mJ (at 266 nm) per 5 ns pulse.
- The Surelite I-10 initially generates infrared (IR) light (1064 nm), which is shifted to green (532 nm) first, and then UV (266 nm) through second and fourth harmonic generators.

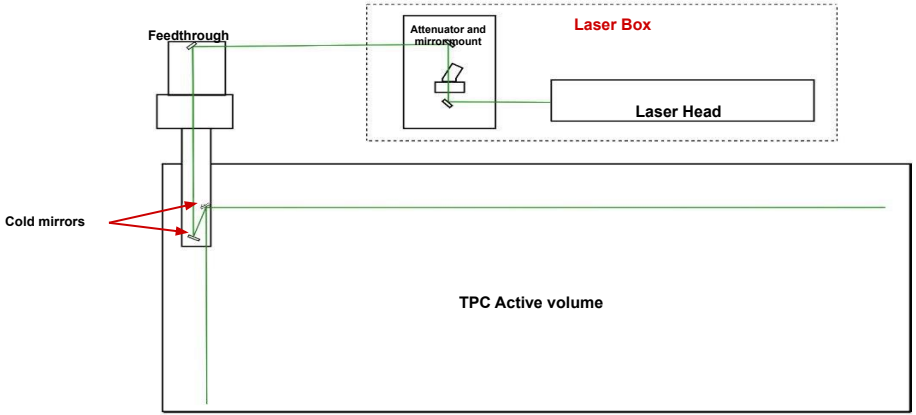
(2+1)-photon process:
Needs high power laser



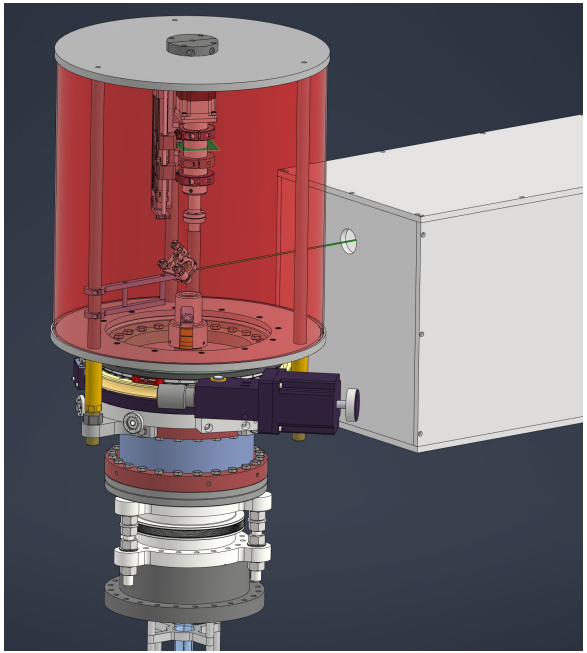
How:

Laser Head -> Mirror -> Attenuator -> 3 Mirrors -> 2 Cold Mirrors

- Each Dichroic Mirror eliminates 532, 1064 nm and reflects 266 nm.

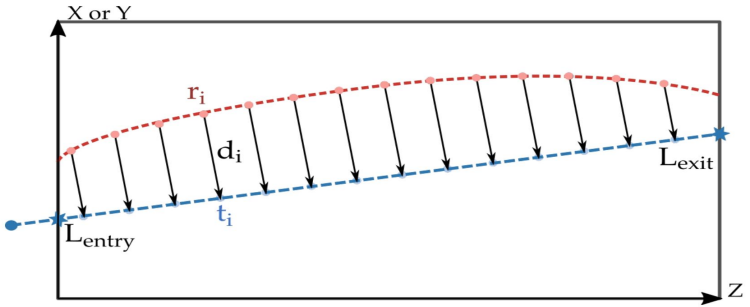


Schematic representation of SBND - UV laser calibration set up



How:

- Correction Map: Based on reco spatial coordinates
  Gives expected true points, given by the reco points.
- The vectors from the reconstructed track points (red) to their closest point on the true track (blue) are the **correction vectors**.
- The vectors starting from the true track (blue) to the reconstructed track points (red) are the **distortion vectors**



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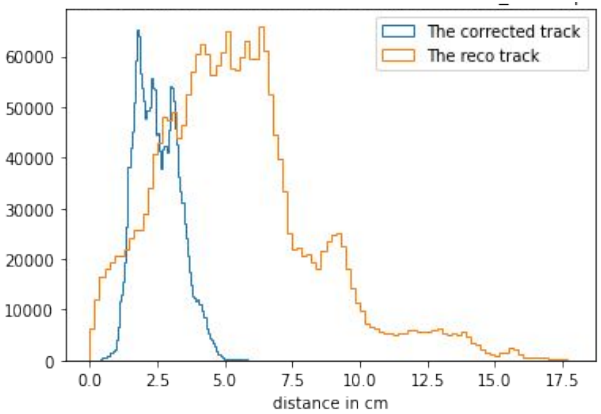
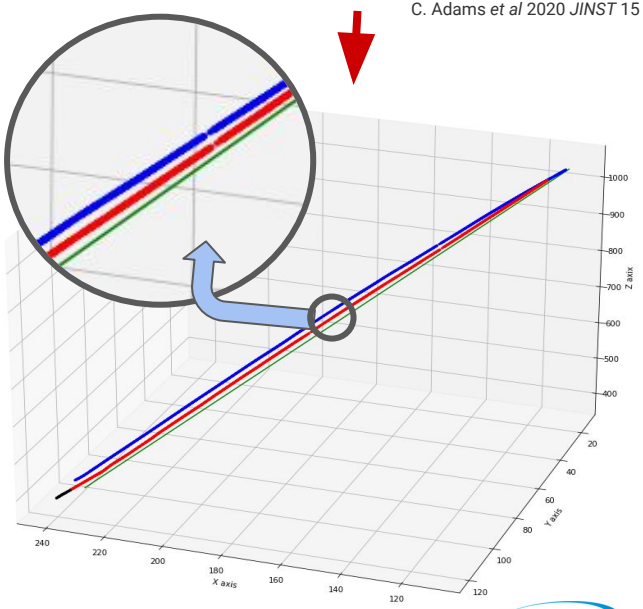
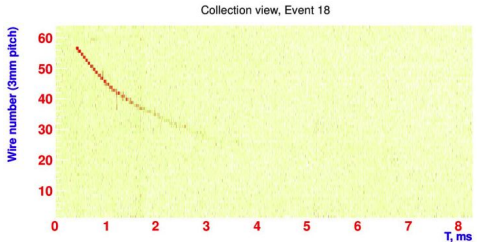


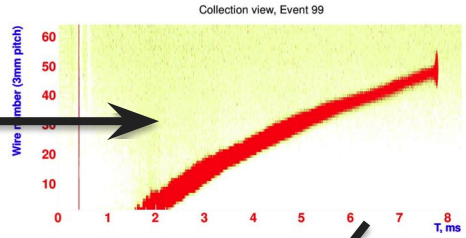
Shortest distance from true to reco points before and after correction.



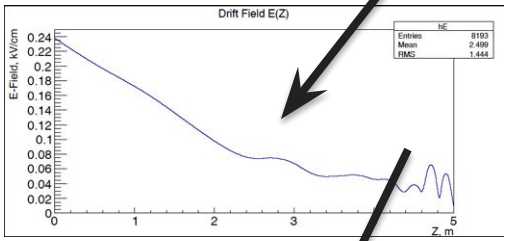
UV-laser method in actual scenario - measurement from ArgonTube (Bern, 2013)



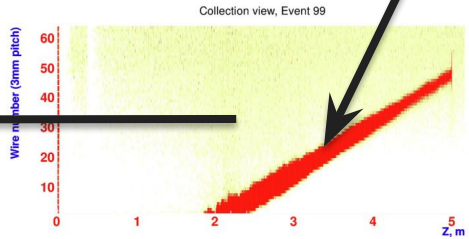
Distorted muon track, due to e-Field distortion



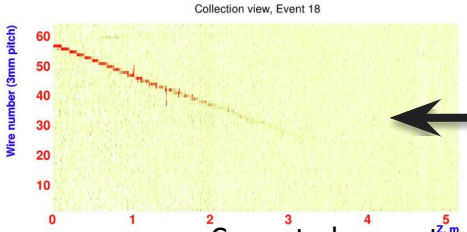
100 laser tracks



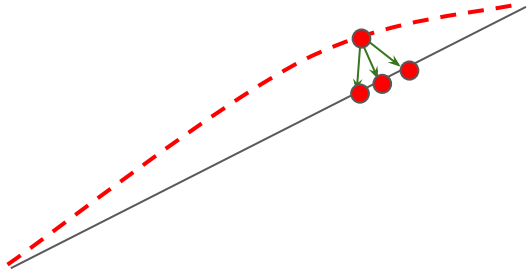
E-Field map



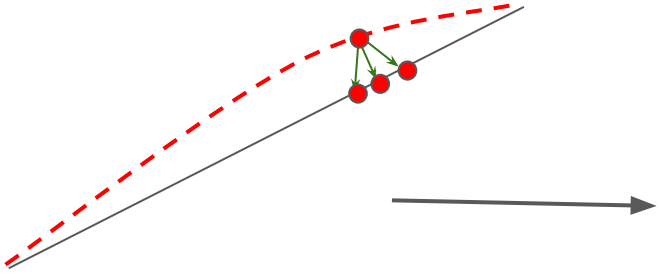
Corrected laser tracks



Corrected muon track

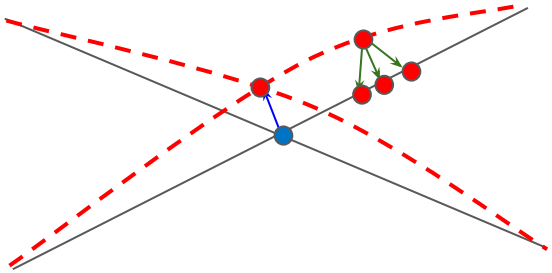


A reco points corresponds
to which point in true track?



A reco points corresponds to which point in true track?

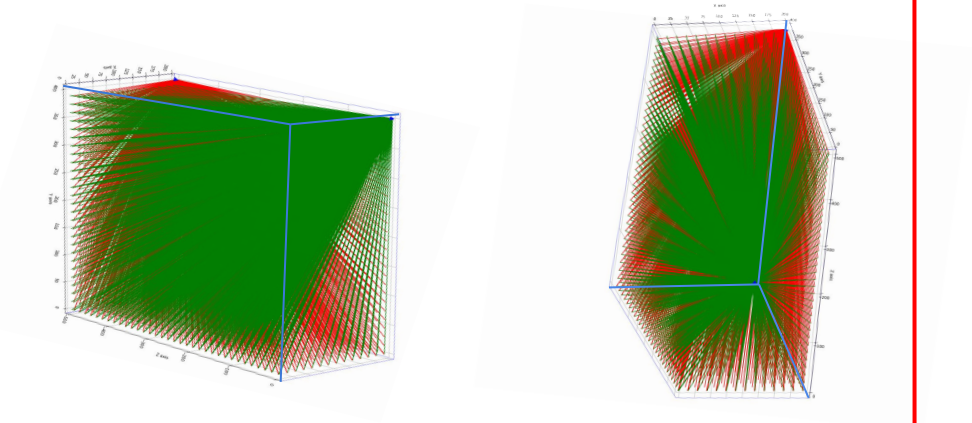
Crossing tracks!!!



Cold mirrors inside the TPC - No shadow effect by fieldcage

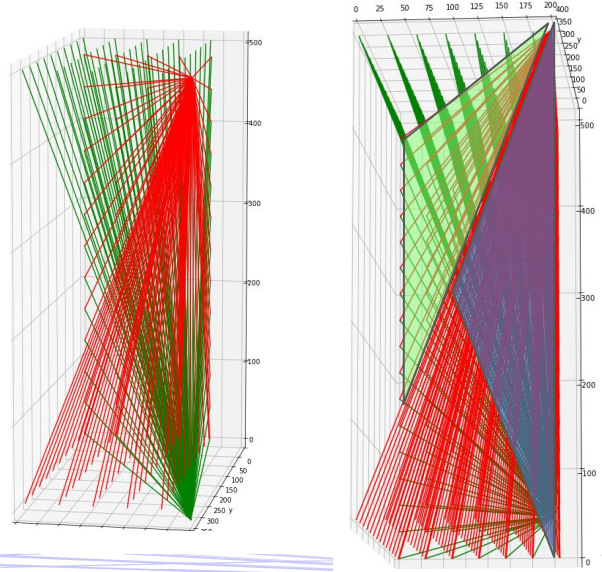
Full Laser Scanning:

- Full coverage with crossing tracks
- More precise and effective informations from crossing tracks

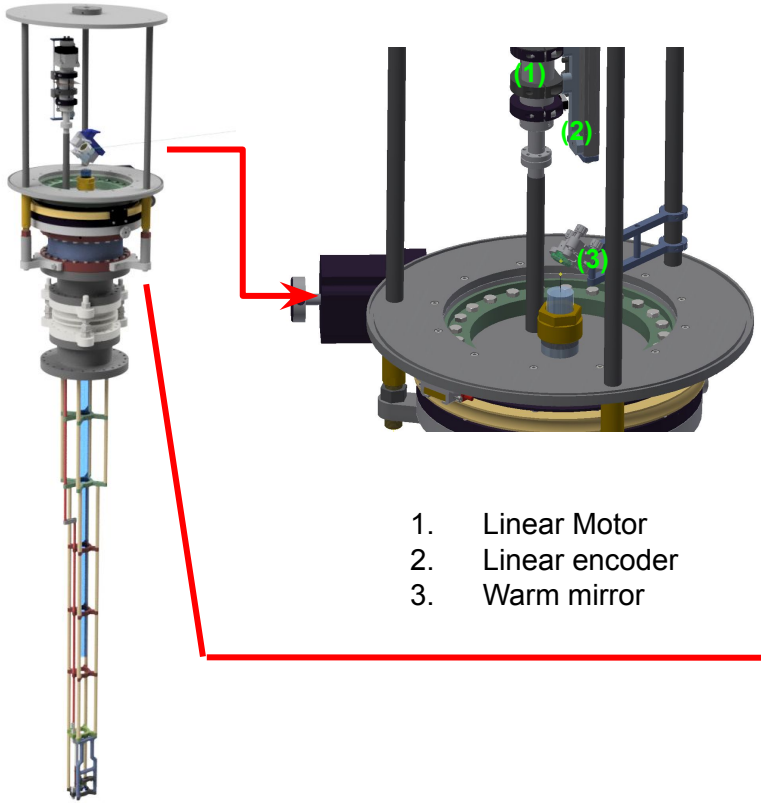


Partial Scanning:

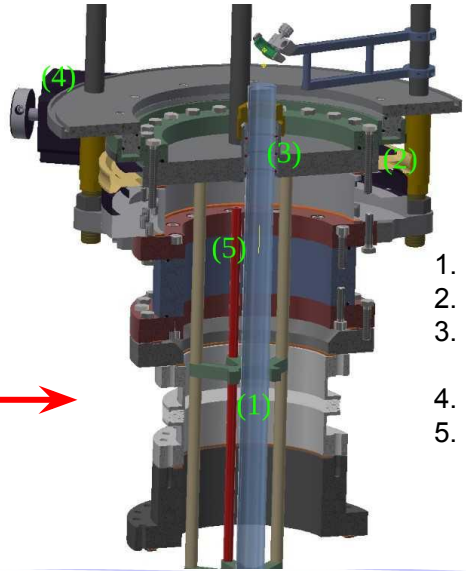
- Omit the laser tracks directed towards the cathode because of the presence of PTB-coated reflective sheets on the cathode.
- Partial coverage with crossing track points < 50% of total volume.
- Crossing tracks are close to anode.



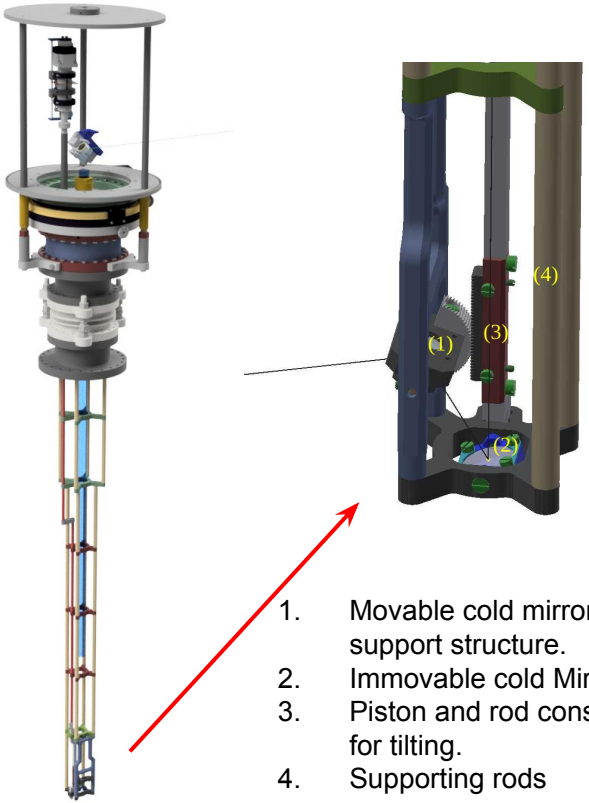
Hardware -Feedthrough: Cross Sectional view



1. Linear Motor
2. Linear encoder
3. Warm mirror



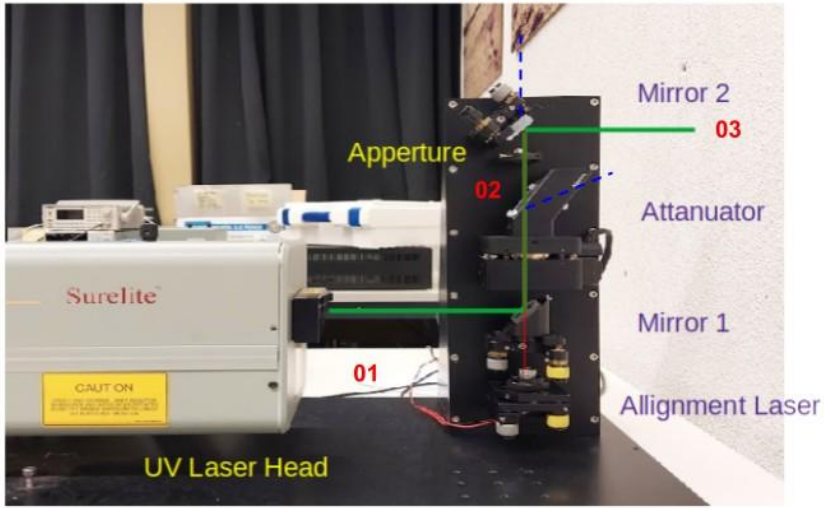
1. The evacuated glass tube.
2. Rotary encoder ring
3. Rubber seals for the glass feedthrough
4. Rotary motor.
5. Linear feedthrough piston from linear Motor for tilting mirror



1. Movable cold mirror and support structure.
2. Immovable cold Mirror.
3. Piston and rod construction for tilting.
4. Supporting rods

Inside the laser box:

1. U-V laser head
2. Two dichroic mirrors (wavelength separator)
3. Attenuator
4. Aperture
5. Photo Diode for DAQ trigger.



Controlling Script and User Interface:

- Controlling script ready.
- Script available in python2 and python3 (interactive Python shell).
- Currently using the interactive Python session to perform all the functions.
- Trying to make User Interface. (Incomplete)
  - helps are highly appreciated.
- Control scripts for old uB TMC's

```
10:55:18 linear_actuator: matching_______start_____
////////////////////////////____ 1 __/////////////////////////__
___comserial___ 76 PR P
____comserial.py _____________80 b'1PR P\n'
___comserial.py_____ 108 b'1PR P\r\n1982\r\n?'
_____feedthrough 157 b'1PR P\r\n1982\r\n?'
_____feedthrough___ 159 1PR P
1982
?
_____feedthrough __163
1982
___feedthrough.py 193__
1982
////////////////////////////____ 1982 __/////////////////////////__
10:55:18 linear_actuator: matching_______end_____
10:55:18 linear_actuator: --- 0.20385003089904785 seconds ---
____comserial___ 76 PR MV
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___comserial.py_____ 108 b'1PR MV\r\n1\r\n?'
```
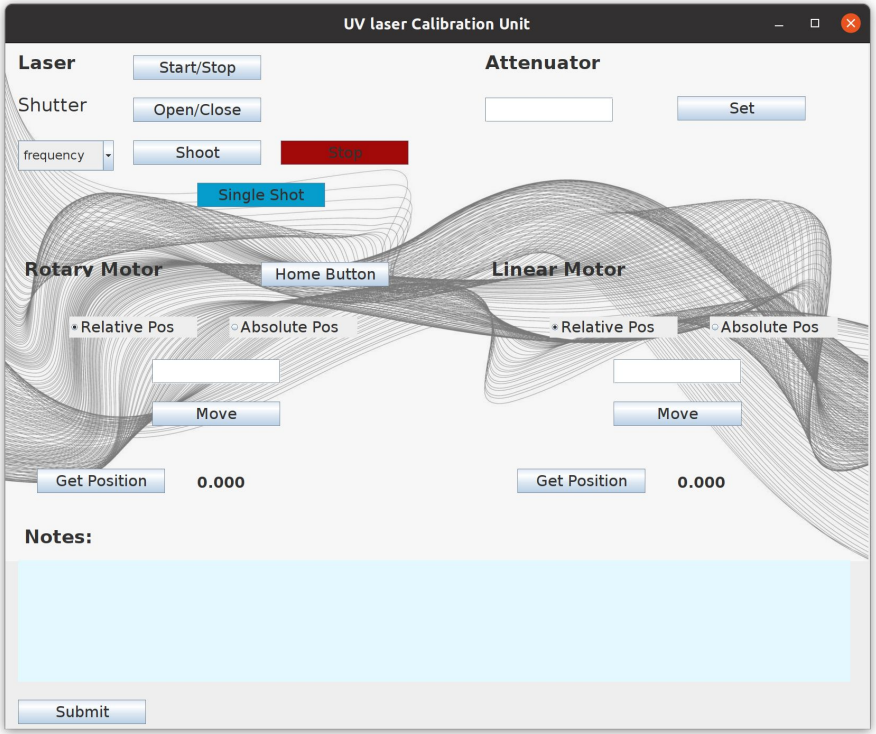
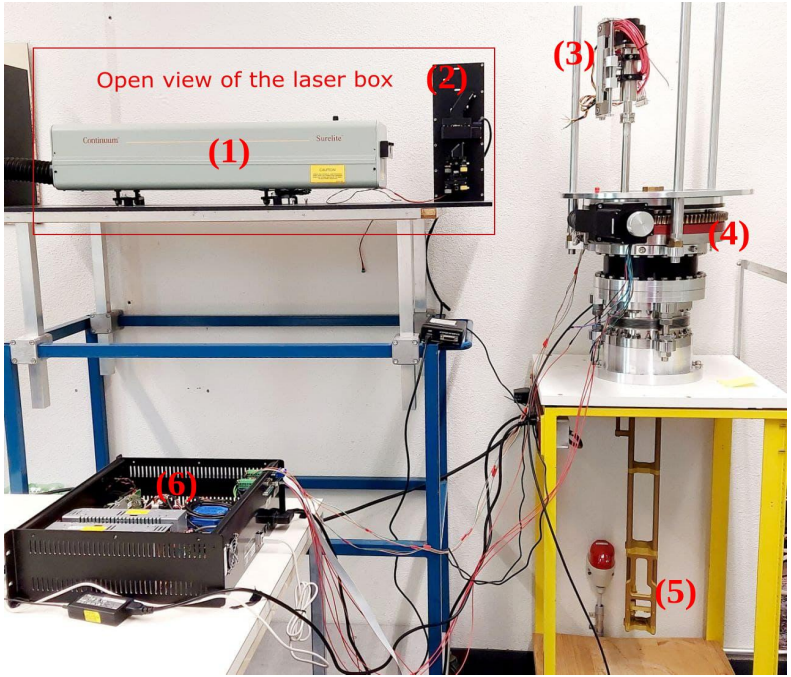



Laser test facility at LHEP:

SBND setup

Thanks to Michele, Igor, Rogger, Jan, Silas, Lori, Vasco, Lino and Andri



(1) Laser head, (2) Attenuator and mirror mount,
(3) Linear Motor to control the vertical movement of the cold mirrors,
(4) Rotary motor to control the horizontal movement of the mirror.
(5) Cold mirror mount and shafts, (6) Motor controller box

Mechanical installation of Feedthroughs at SBND:

- Installation of feedthrough onto the cryostat was done last week (June 12 - 19)

Thanks to Anne, Roberto, Lori, John, Luis

Summary:

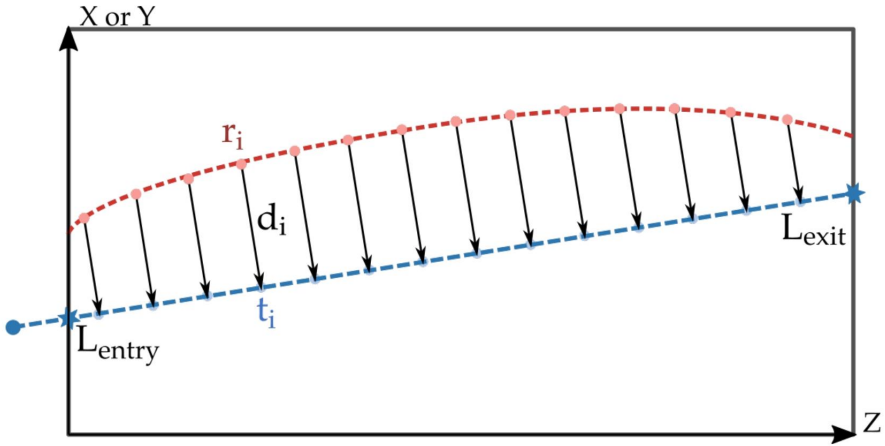
- It is essential to effectively measure the distortion of the electric field in TPC detectors based on large LAr (liquid argon).
- The effectiveness of UV Laser calibration has been established in measuring the distortion of the electric field.
- In the SBND experiment, every TPC contains two UV laser systems and incorporates cold mirrors within the TPC to enable a complete scan of the entire TPC.
- Utilizing crossing tracks provides a stronger and more reliable method for measuring the distortion.
- The installation of all four feedthroughs on the cryostat has been completed.
- Despite the progress made so far, there is still more work to be done.

Thank You

Spatial displacement maps:

- Correction Map: Based on reco spatial coordinates
  Gives expected true points, given by the reco points.

- Distortion map: Based on True spatial coordinates.
  Gives expected reco points, given true points.



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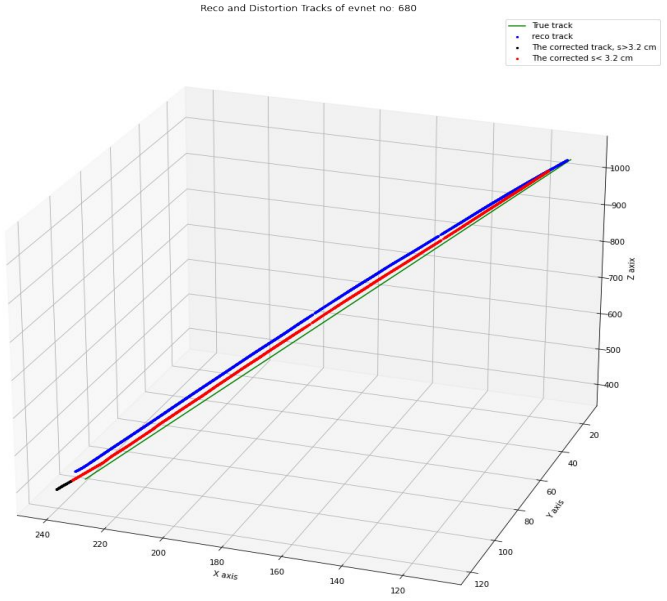
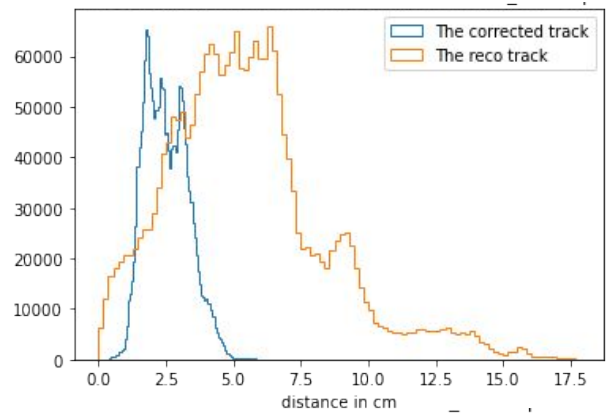
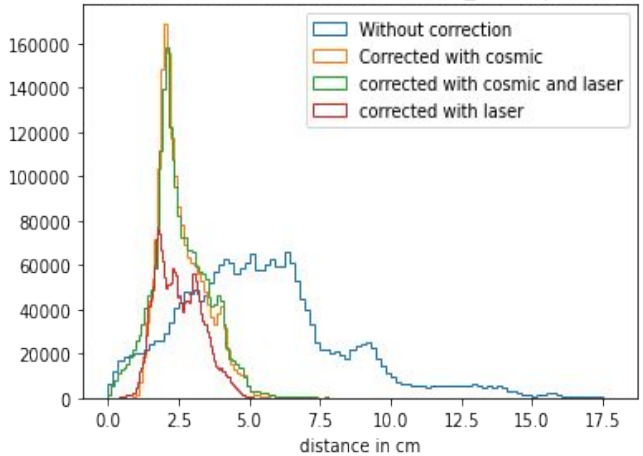
- The vectors from the reconstructed track points (red) to their closest point on the true track (blue) are the **correction vectors**.
- The vectors starting from the true track (blue) to the reconstructed track points (red) are the **distortion vectors**
- This forces the displacement vectors to be perpendicular to the corresponding true laser tracks.



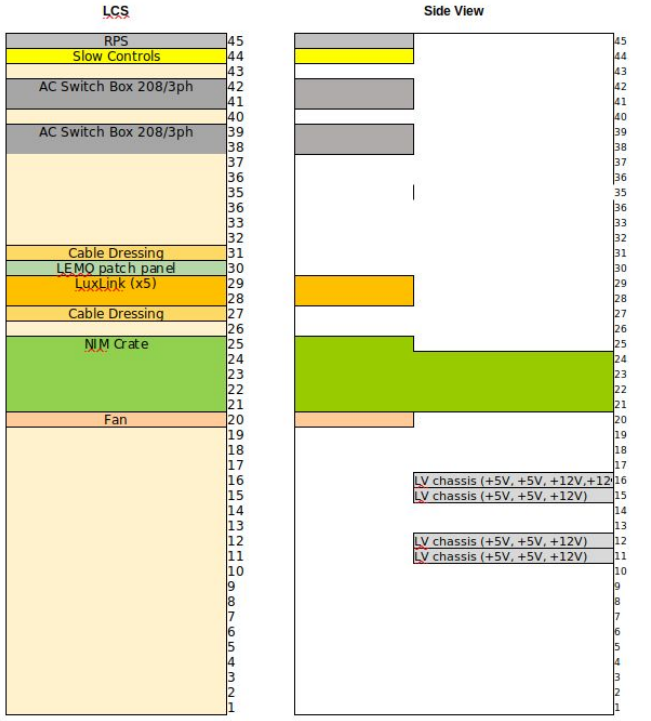
Shortest distance from true to reco points before and after correction (Laser only)



Shortest distance from true track before and after correction (All maps)



Rack Build:



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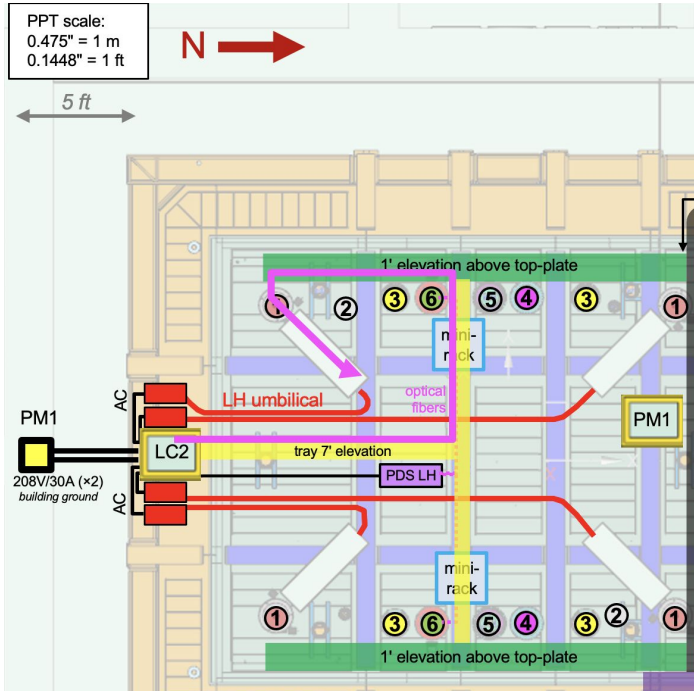
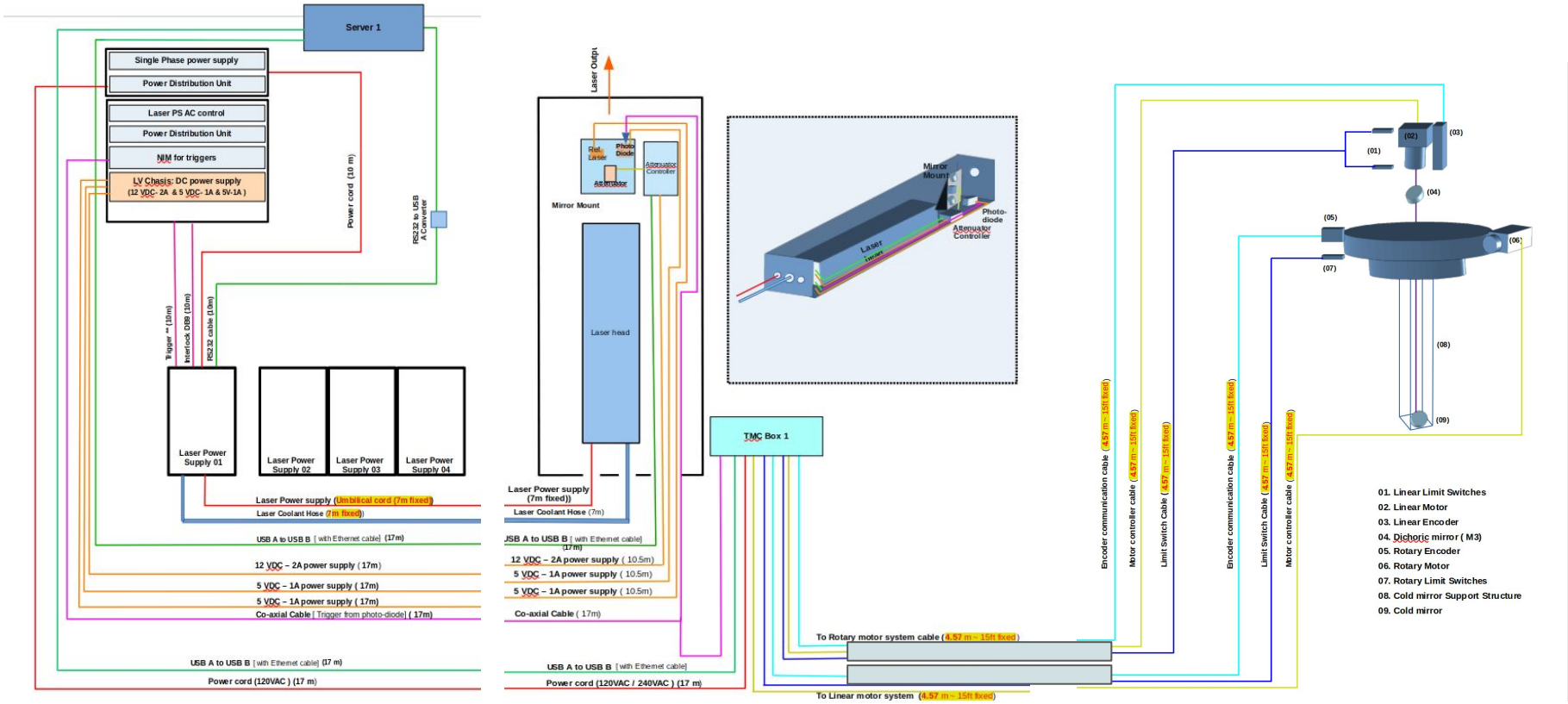


Thanks Will and Linda

Wiring diagram:



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1982
___feedthrough.py 193__
1982
////////////////////////////____ 1982 __/////////////////////////__
10:55:18 linear_actuator: matching_______end_____
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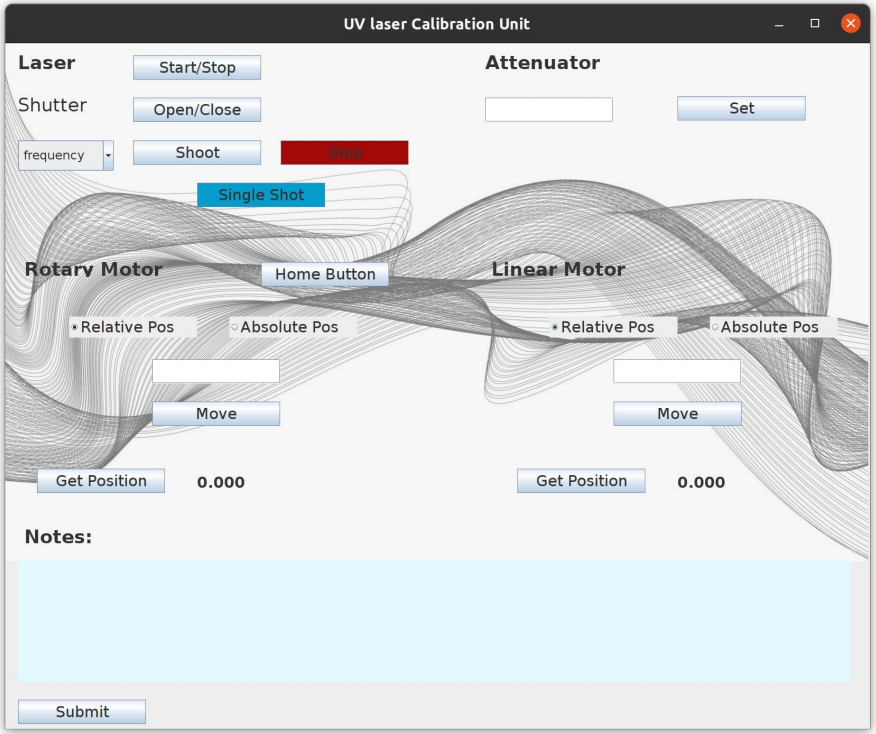
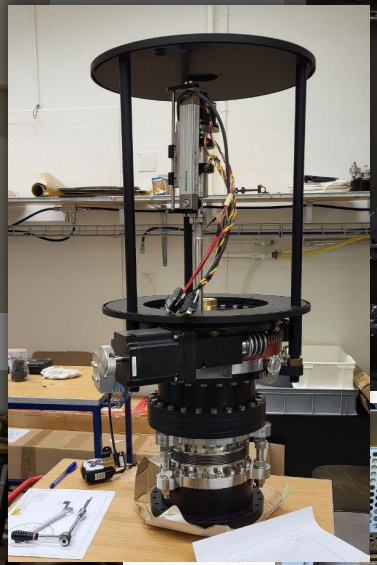
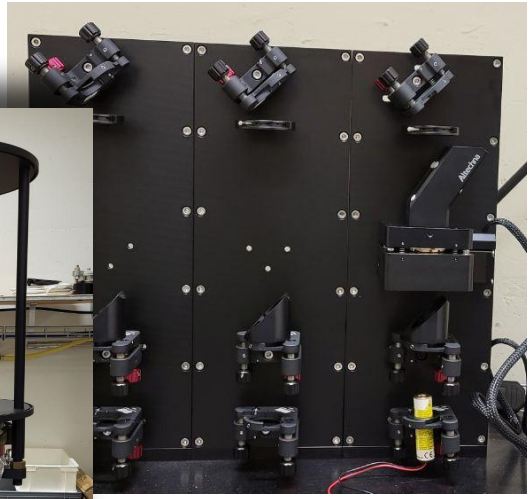
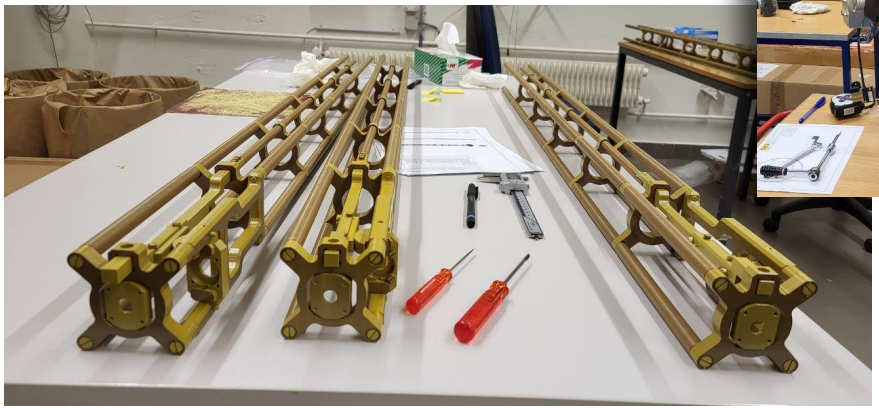


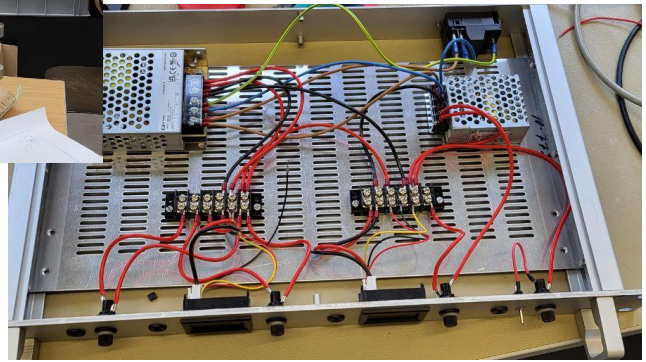
Parts assembly in Bern (April 2023)

Thanks.. Lori and Vasco









Lasers at Fermilab

- Space in Hurricane Deck @DAB (thank you Anne!)
- All 4 four lasers retrieved from storage (procured 2015)
- Inventory done 4/12/2023 (thank you michele)
- Final assembly at SBND

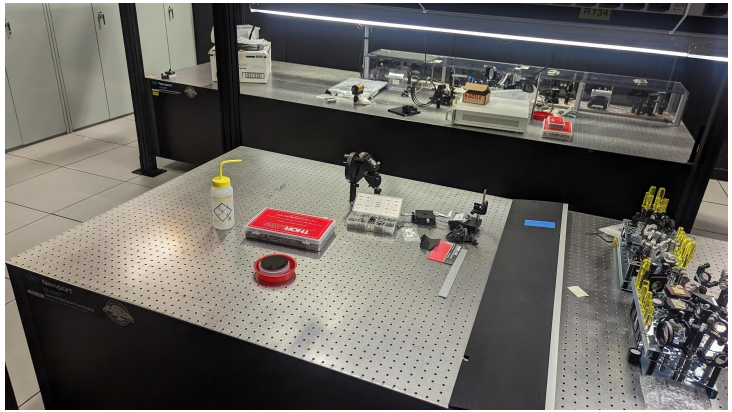
“Umbilical”, manual

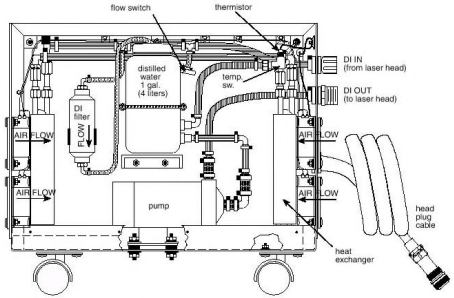
Cables, mounts, tools

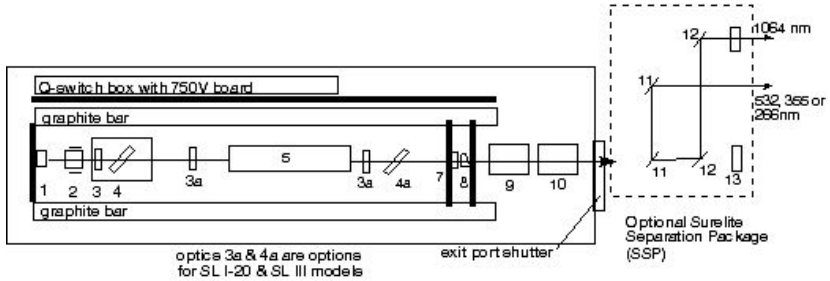
Mirrors, keys

Laser unpacking and first setup

- Procedure to uncrate, unpack and first setup
- Identified location at NML (laser lab)
  Very comfortable setup (thank you!)
- Need to attach umbilical, fill cooling DI water,
  Connect flashlamp, tune settings an measure power IR,
  mount second and fourth harmonic and tune power
- ½-day to 1 day per laser
- Writing TSW
- Planned for July, 2023

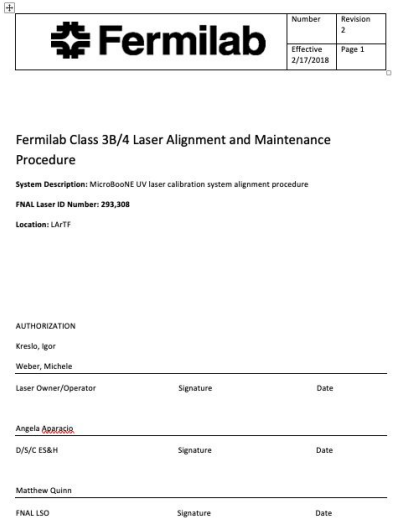






Operation documentation

- SEDR for Electronic components
- Lasers should be registered at FNAL
- TSW for setup at NML
- pORC, ORC at SBND
- SOP for laser safety
  two operation modes = two documents:
  standard operation and maintenance
  - Standard operation: laser light fully contained
    (no photon gets in SBND for PMT, no laser gets out)
  - Maintenance needs building and street closure (class 4 laser)
- Checklists for operation



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Fermilab Class 3B/4 Laser Alignment and Maintenance Procedure

System Description: MicroBooNE UV laser calibration system alignment procedure

FNAL Laser ID Number: 293,308

Location: LArTF

AUTHORIZATION

Kreslo, Igor

Weber, Michele

Laser Owner/Operator Signature Date

Angela Aparicio

D/S/C ES&H Signature Date

Matthew Quinn

FNAL LSO Signature Date

Can adapt uB docs