UV Laser Calibration system - Assembly and Installation at SBND

Intense Early Stage Researcher Meeting

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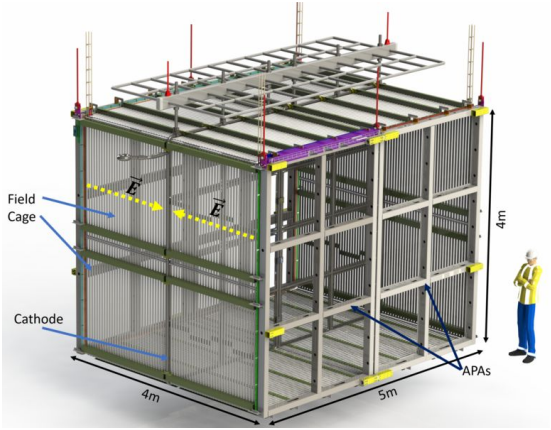
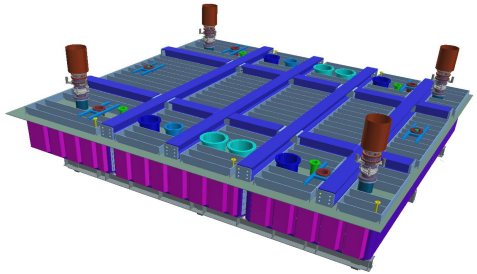
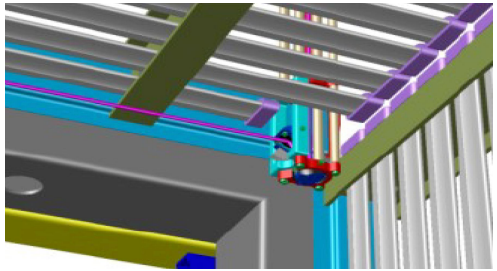


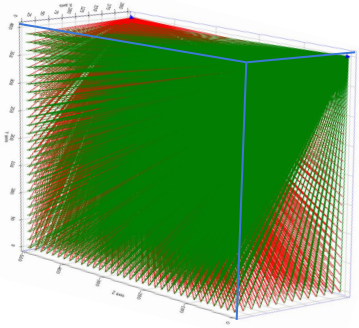


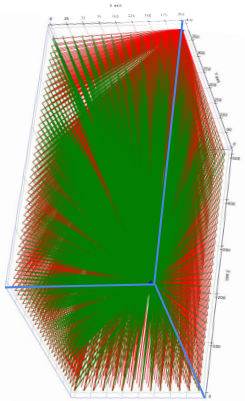


Cold mirrors inside the field cage

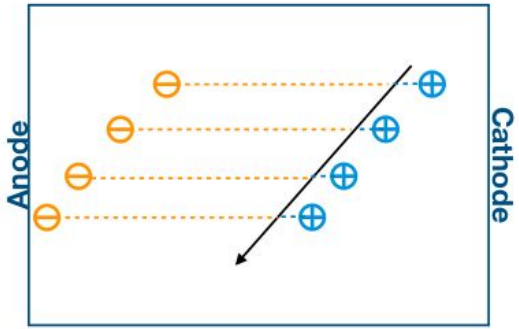
SBND:

- 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 system.



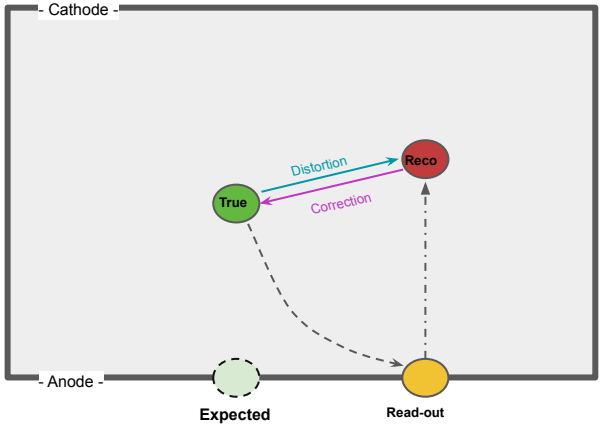


- $V_{e-} > V_{Ar+}$: by 5 orders of magnitude
- Accumulation of Ar^{+} ions inside TPC :
- Average density of positive ions is much larger than that of electrons results in **Space Charge effect.**
- E- field distortion



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.

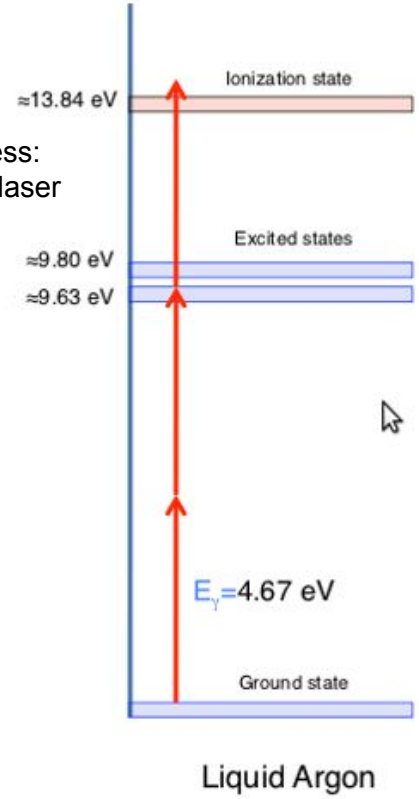
Why:

- 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.

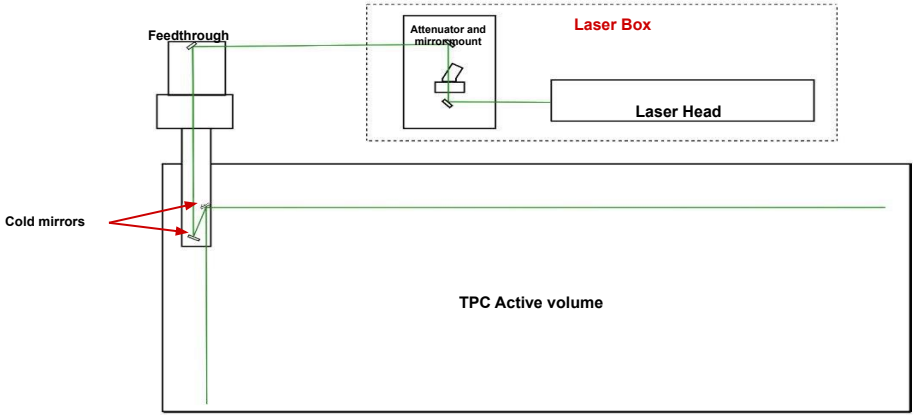
(2+1)-photon process:
Needs high power laser



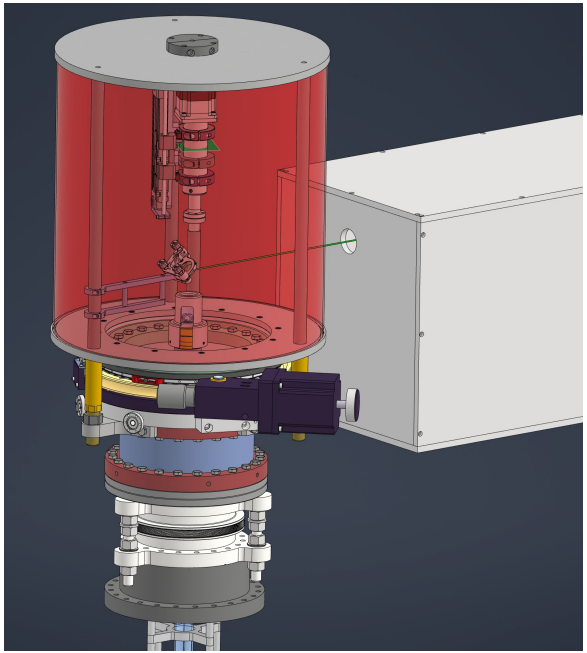
How:

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

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

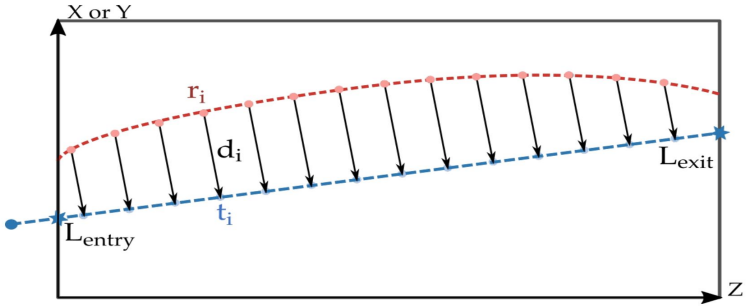


Schematic representation of SBND - UV laser calibration set up



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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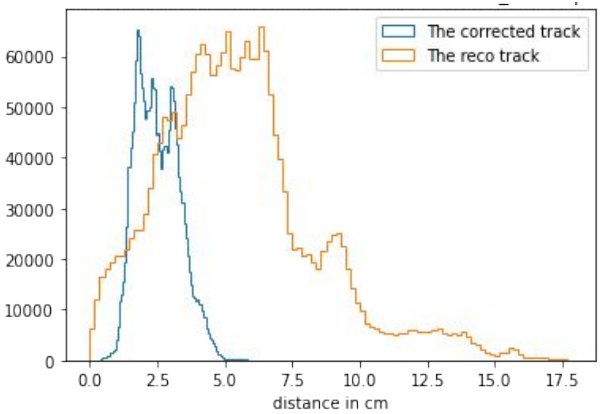
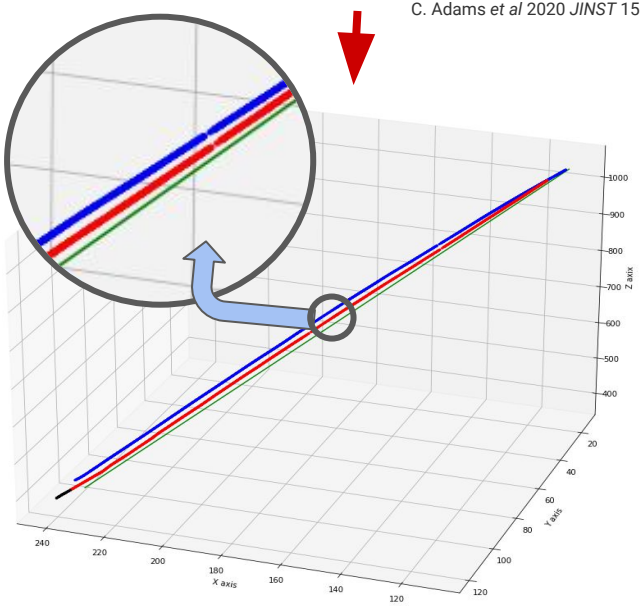
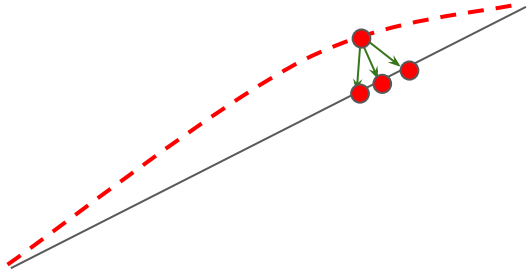
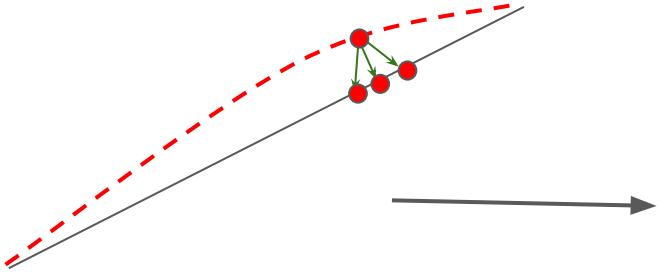


Shortest distance from true to reco points before and after correction.



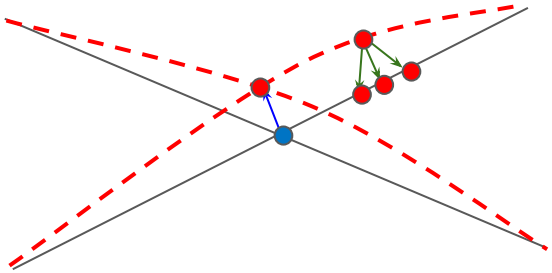


A reco points corresponds
to which point in true track?



A reco points corresponds to which point in true track?

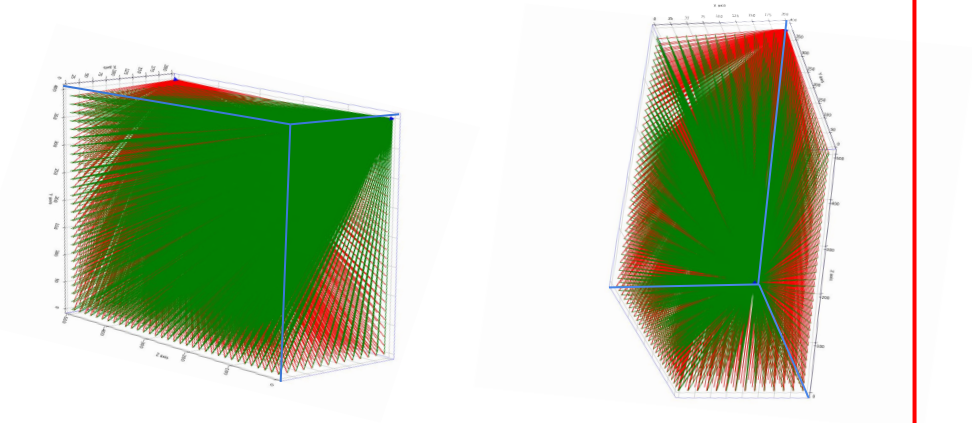
Crossing tracks!!!



Cold mirrors inside the TPC - No shadow effect by fieldcage

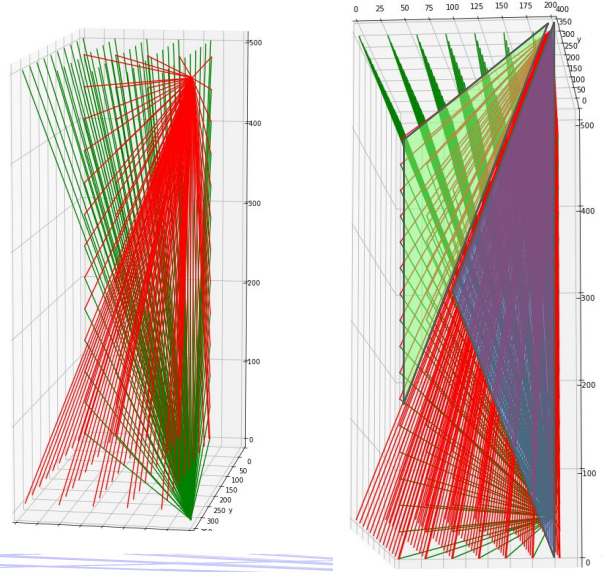
Full Laser Scanning:

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



Partial Scanning:

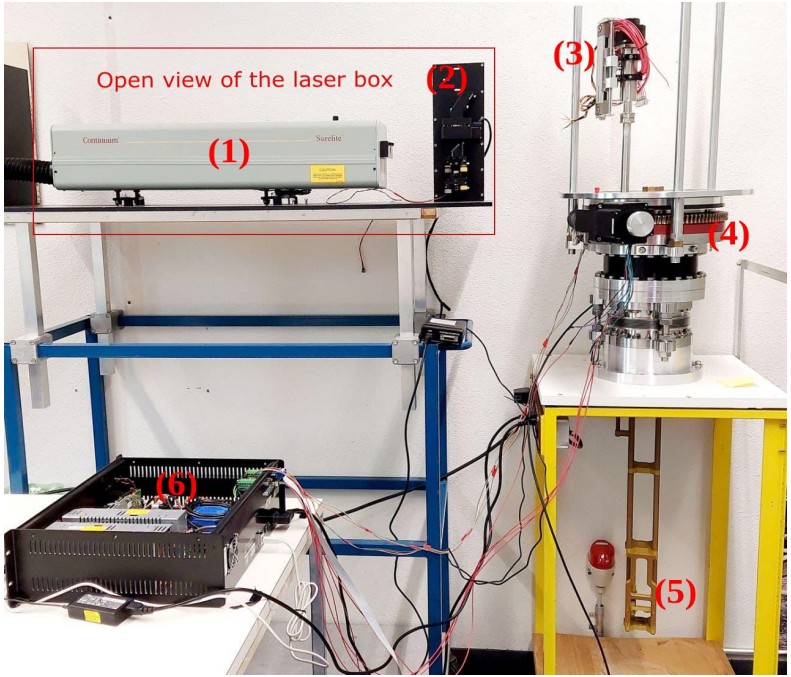
- Omit the laser tracks directed towards the cathode because of the presence of TPB-coated reflective sheets on the cathode.
- Partial coverage with crossing track points < 50% of total volume.
- Crossing tracks are close to anode.



Laser test facility at LHEP:

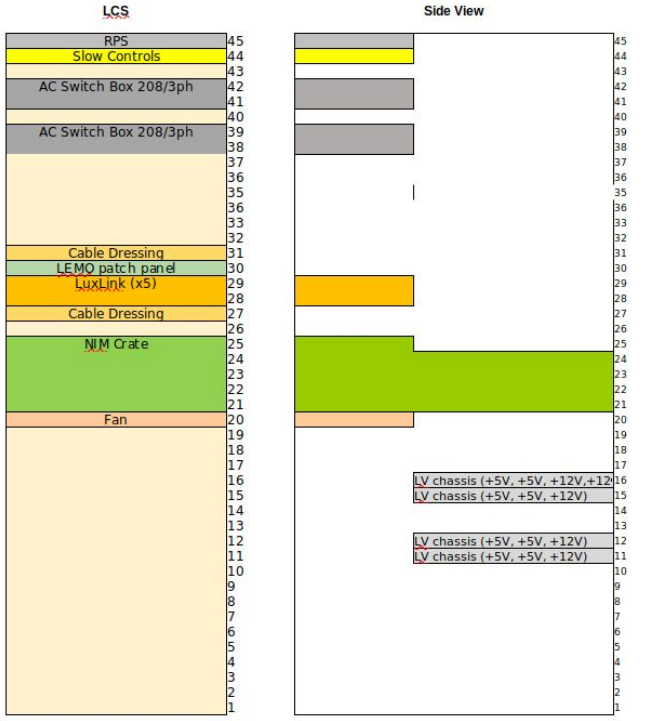
SBND setup

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

Rack Build:



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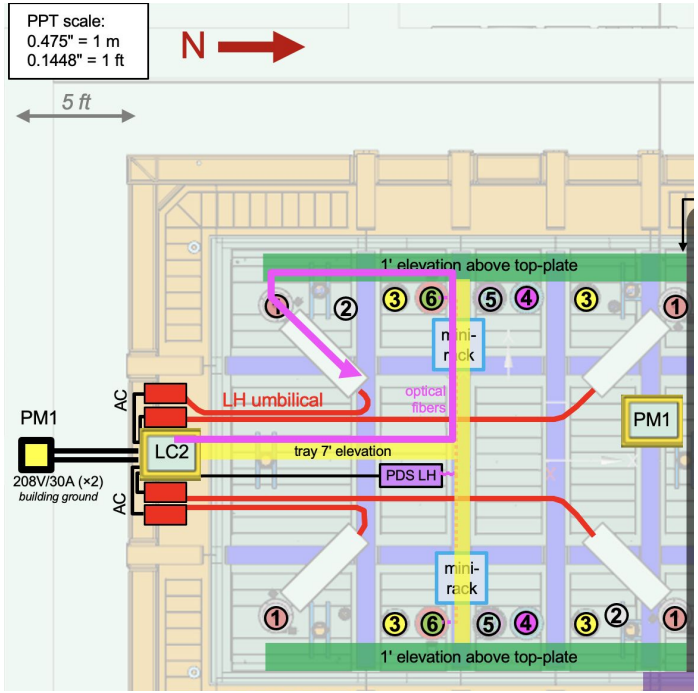
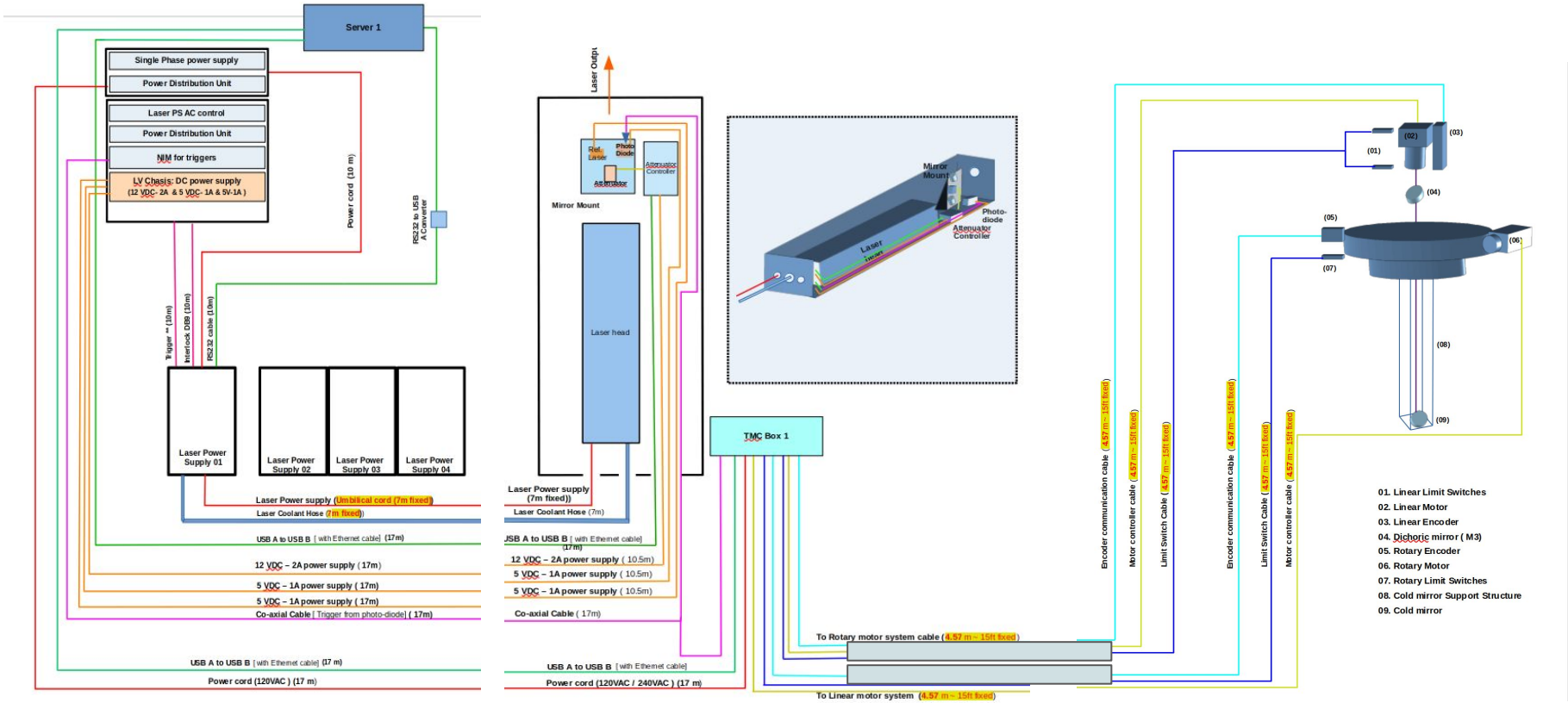


Thanks Will and Linda

Wiring diagram:



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.

```
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
____comserial.py _____________80 b'1PR MV\n'
___comserial.py_____ 108 b'1PR MV\r\n1\r\n?'
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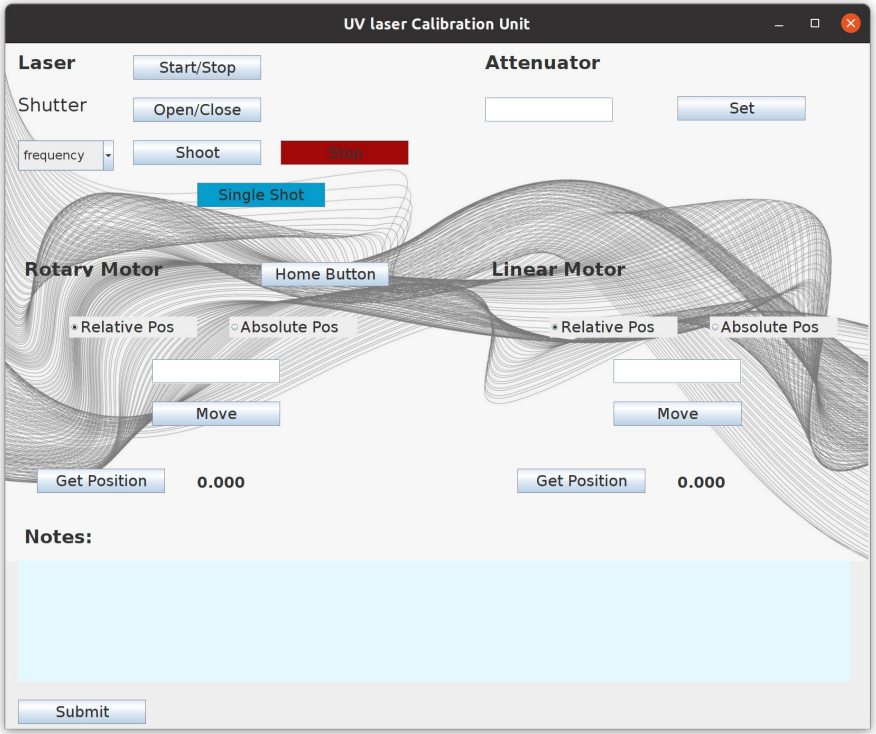
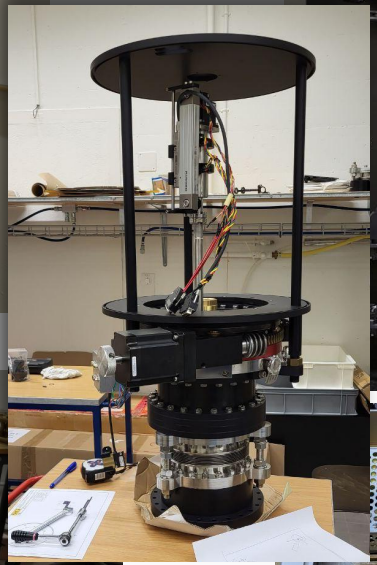
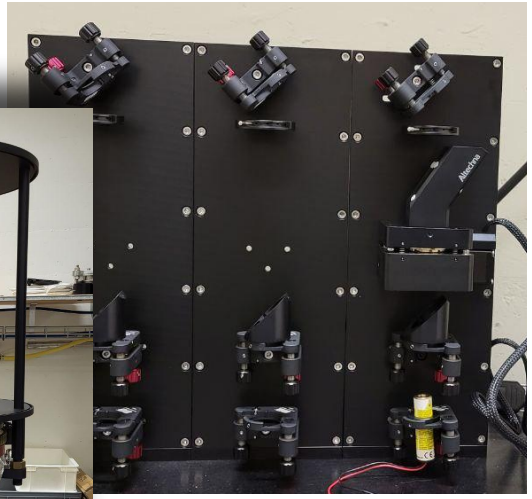
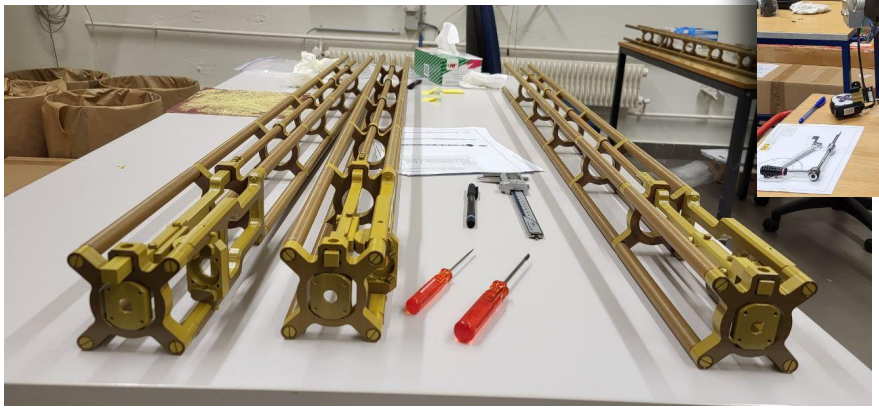


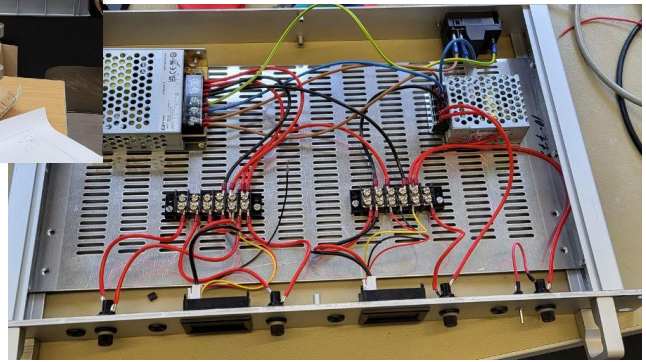
Parts assembly in Bern (April 2023)

Thanks.. Lori and Vasco



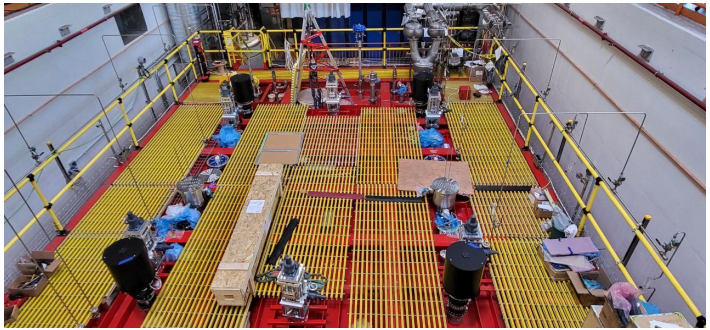






Mechanical installation of Feedthroughs at SBND:

- Installation of feedthrough onto the cryostat will be done this week (June 12 - 19)
- Technician from Bern and Fermilab helped in achieving this feedthrough installation.
- Tested with Alignment (Class 3R) laser and limit switches were repositioned.



Thanks to Anne, Roberto, Lori, John, Luis

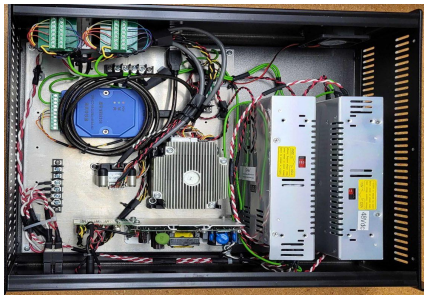
Documentation at Fermilab

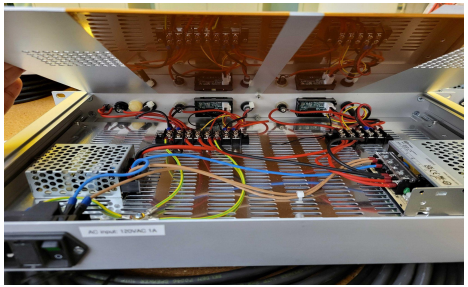
- Space in Hurricane Deck @DAB (thank you Anne!)
- All 4 four lasers retrieved from storage (procured 2015)
- ORC for custom designed components (Thanks to Linda)
- TSW and HA for laser tuning and assembly at NML lab.

Cables, mounts, tools

4 laser boxes @DAB

Custom built equipments.

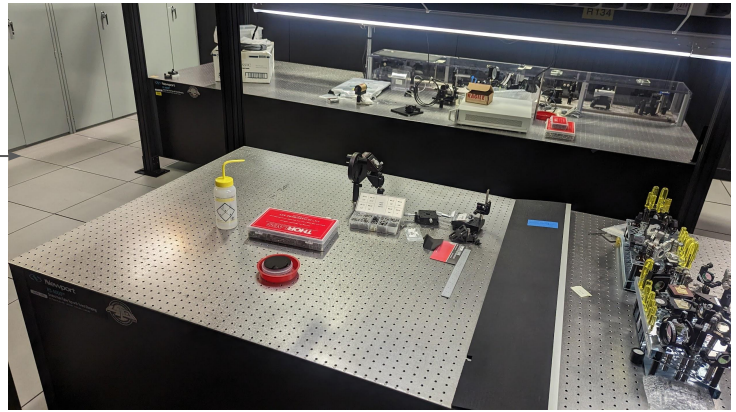


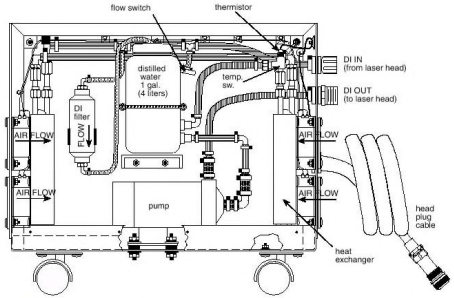


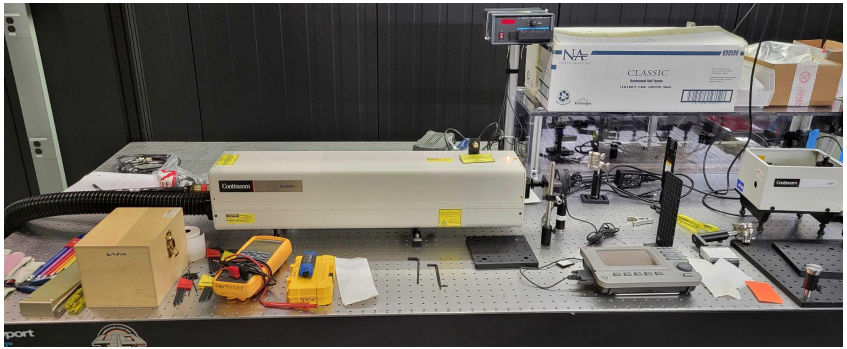
Mirrors, keys

Laser unpacking, assembly and tuning

- Procedure to uncrate, unpack and first setup (October 2-8)
- Tuning procedure at NML (laser lab)
  Thanks to Michele, Jamie, Jinhuao and Abhishek and Matthew Spaw
- Attached umbilical, fill cooling DI water,
  Connect flashlamp, tune settings an measure power IR,
  mount second and fourth harmonic and tune power
- 3 laser with ~90-100 mJ and 1 with ~14 mJ
- One laser crystal needs to be replaced, the crystal was retrieved
  From MicroBooNE laser system (Nov 20)

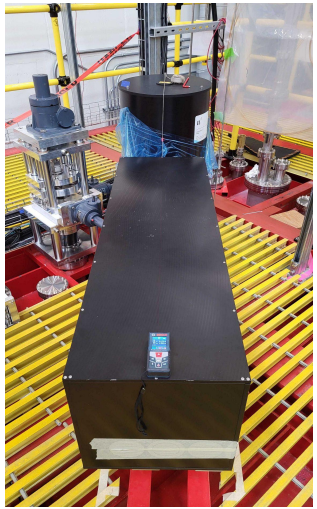


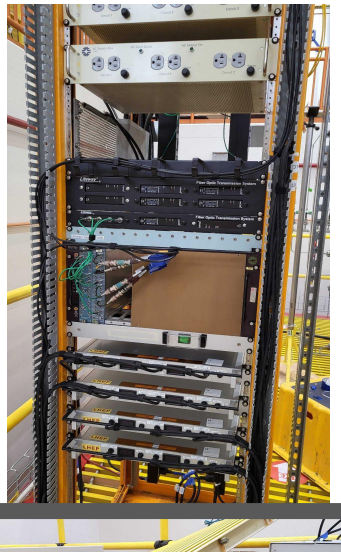


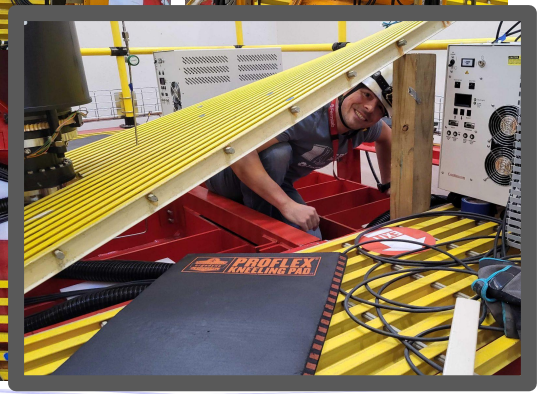


Current Status:

- Laser box Installed on top of cryostat.
- Laser is installed inside the box along with attenuator, photodiode module, reference laser and communication cables.
- Laser Calibration system (LCS) has been installed and all the equipments are installed.
- Cabling is done (except ethernet, ofc and Interlock)
- Power supply cables to all equipments from the LCU Rack is connected and labelled.
- Laser connectors are routed beneath the grating To avoid trip hazard. (Thanks to Roberto)



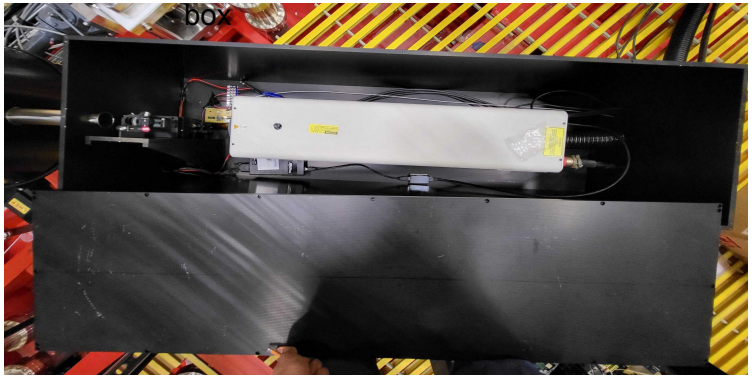


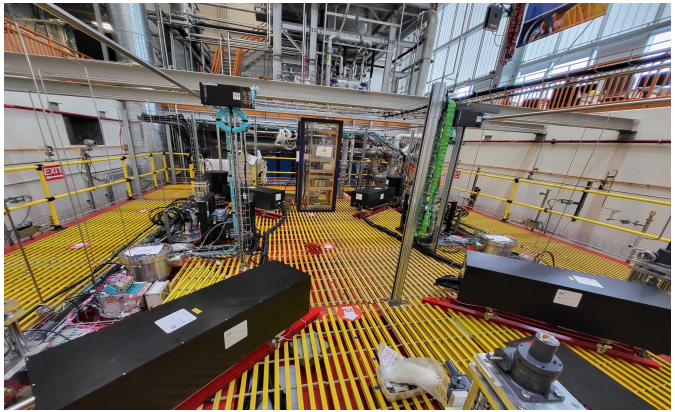


Pending/Upcoming Work:

- Communication cables from TMC and laser
- Trigger from LCS rack.
- Interlock to Laser.
- Final ORC and operation.(March 2024*)
  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)

Equipments inside the laser box





Cryostat top as of 22nd Nov.

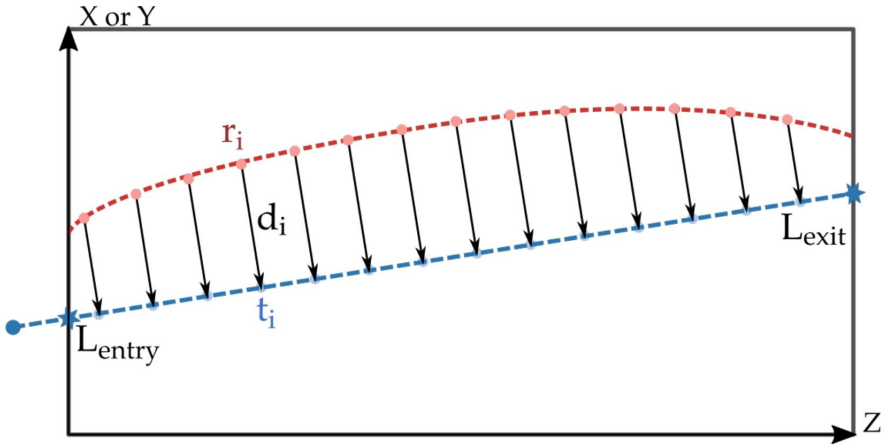
Thank You..

Backup

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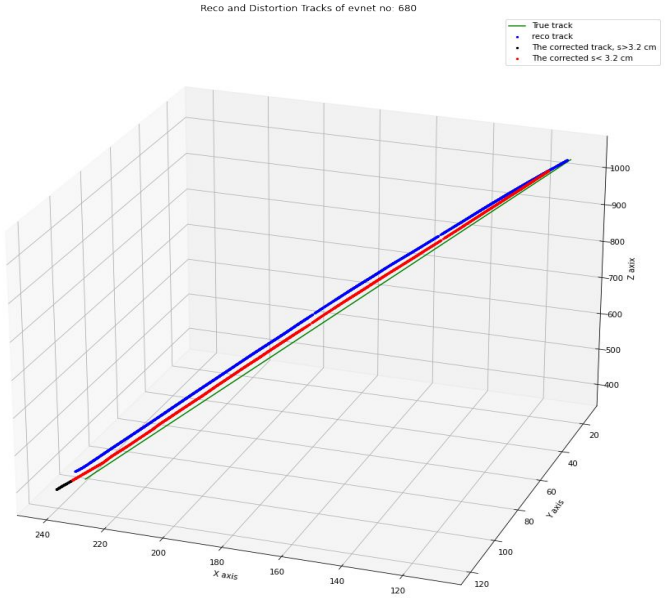
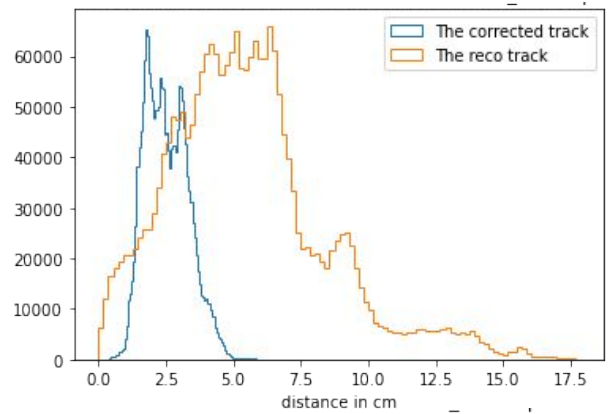
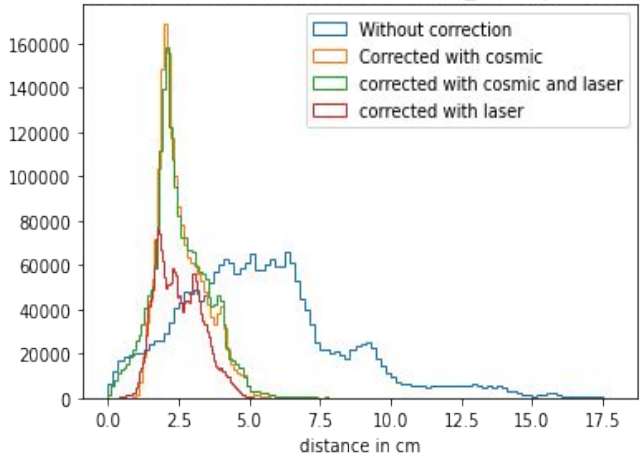
- The vectors from the reconstructed track points (red) to their closest point on the true track (blue) are the **correction vectors**.
- The vectors starting from the true track (blue) to the reconstructed track points (red) are the **distortion vectors**
- This forces the displacement vectors to be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



Declaration of Conformity

Continuum
The High Energy Laser Company

Continuum Electro-optics Inc., under our sole responsibility declares that the products listed here conform to the following EC Directives and European Standards.

High Energy Nanosecond Lasers

Product Description	Conforms to EC Directives	Conforms to European Standards
Surelite Series Models: Surelite I, Surelite II, Surelite III & Surelite EX Wavelengths: 1064nm, 532nm, 355nm, 266nm	EMC Directive 2004/108/EC Low Voltage Directive 2006/95/EC	Safety EN 61010-1:2010 General requirements EN60825-1 Safety of laser products – Equipment classification and requirements EMC EN 61326-1:2006 EMC General requirements EN 61000-3-2 (Harmonics) EN 61000-3-3 (Flicker) EN 61000-4-2 (ESD) EN 61000-4-3 (RF Immunity) EN 61000-4-4 (EFT) EN 61000-4-5 (Surge) EN 61000-4-6 (Conducted Immunity) EN 61000-4-11 (Voltage Dips & Interruptions)

Signed for Continuum

CE

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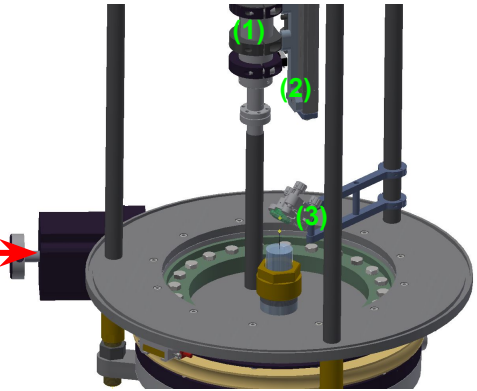
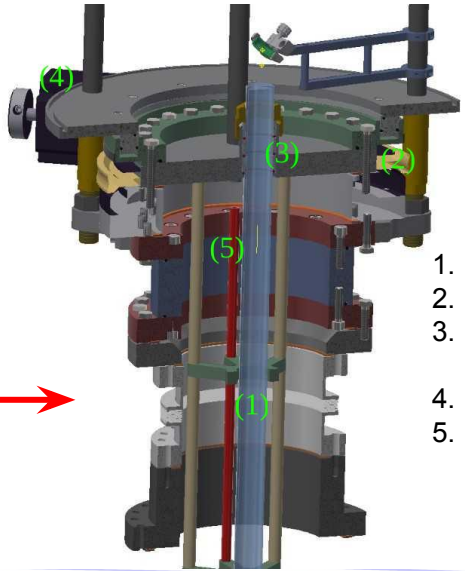
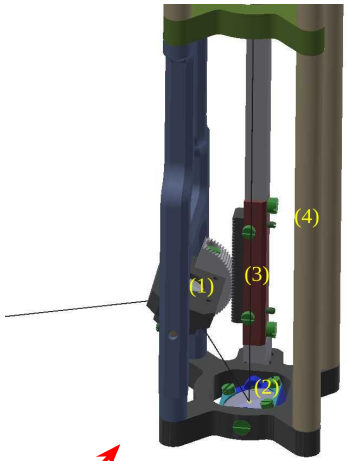
Feedthrough: Cross Sectional view



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



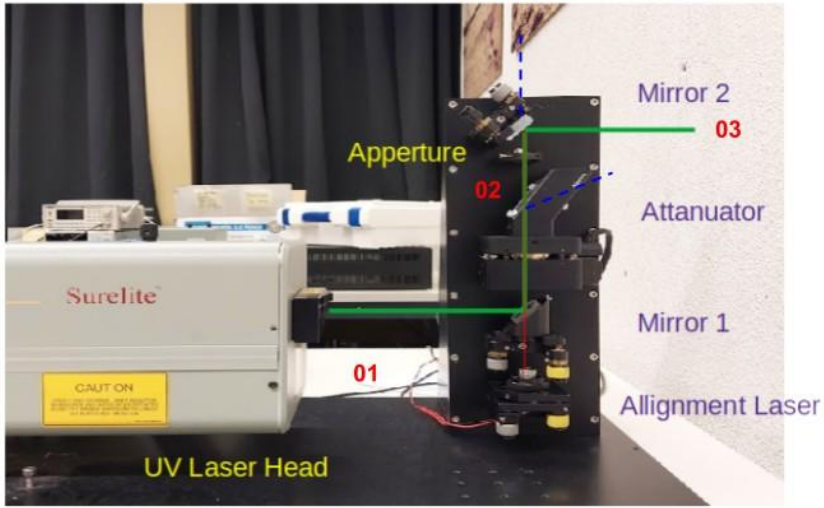
1. The evacuated glass tube.
2. Rotary encoder ring
3. Rubber seals for the glass feedthrough
4. Rotary motor.
5. Linear feedthrough piston from linear Motor for tilting mirror



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.



Lessons Learnt:

- NRTL Certificate
- Proper connectorization.
- Grounding.
- Heat dissipation and cooling.
- Fuse and Switch.
- Always refer FNAL Electrical Design Standard.