UNIVERSITÄT BERN

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The UV Laser Calibration System for measuring the electric field in the SBND Liquid Argon Time Projection system

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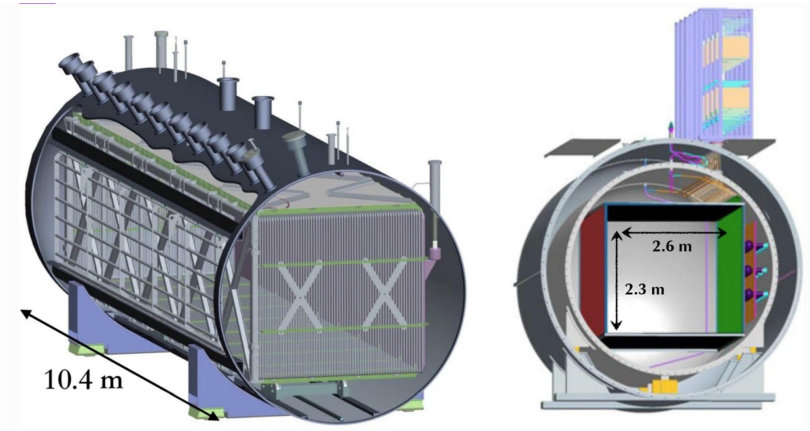
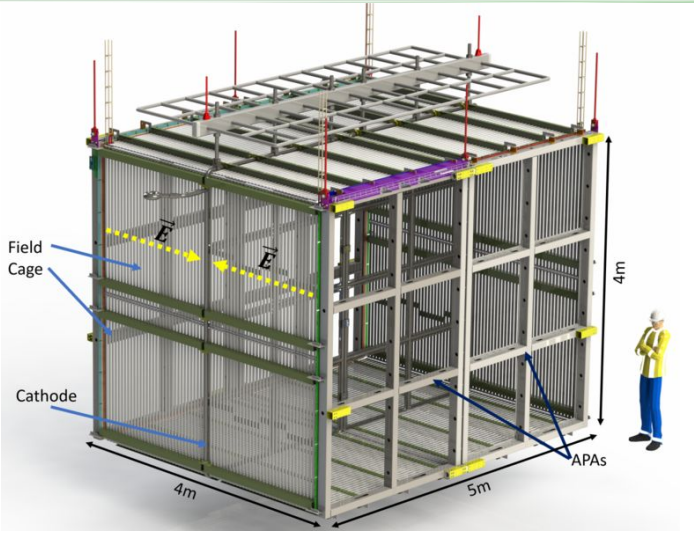


C. Adams *Eur. Phys. J. C* 79, 673 (2019)



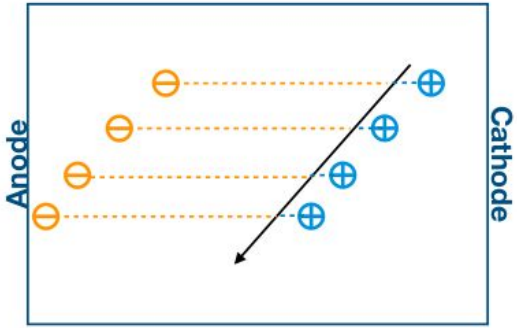
MicroBooNE:

- 470 meters from the Booster Neutrino Beam target.
- 80 tons of liquid argon in the active volume.
- Single tpc (2.6 m x2.3 m x 10.4 m)
- Two UV laser system for E field calibration.

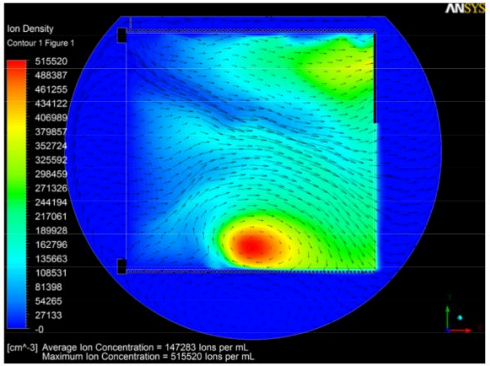
SBND:

- 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

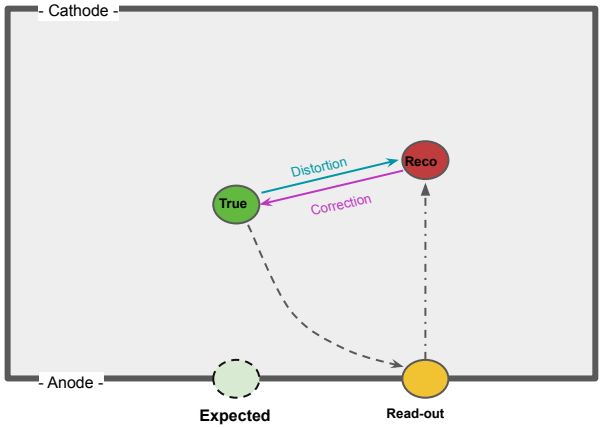


Acciarri, R., et al. Journal of instrumentation 12.02 (2017): P02017



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 :

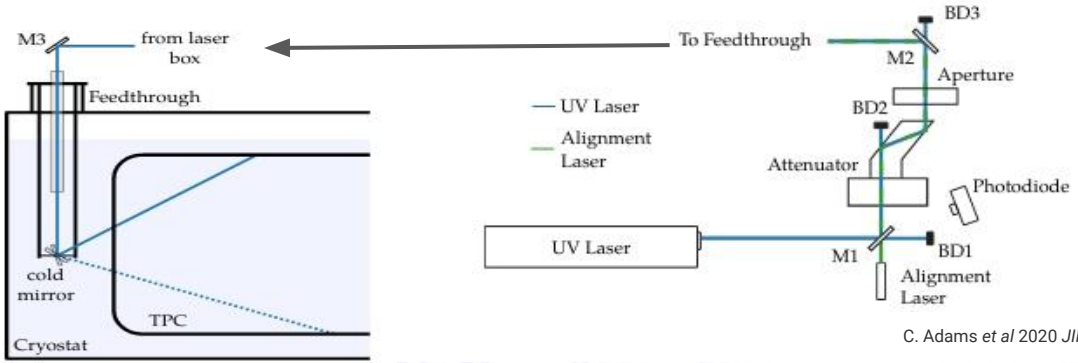
- Drive finely tuned energetic UV laser beam inside TPC, which ionises the Ar ion thus leaving a ionisation track.
- Compare expected (true) and reconstructed track points to calculate the E - filed distortion inside TPC.

Why:

- 3 UV photons provide the correct energy to ionize the argon atom in liquid phase.
- 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

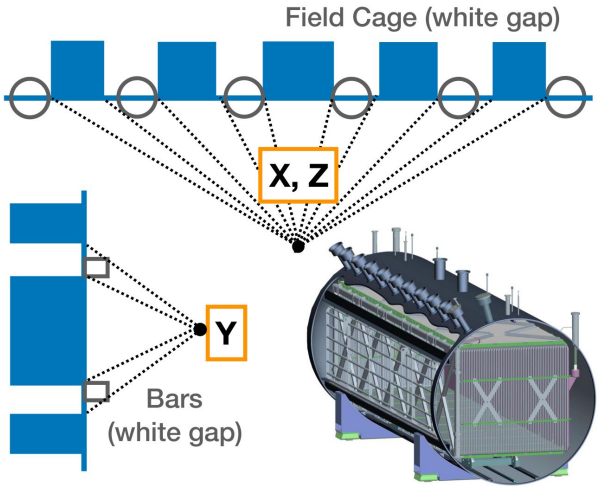
How:

Schematic representation of MicroBooNE UV laser calibration set up

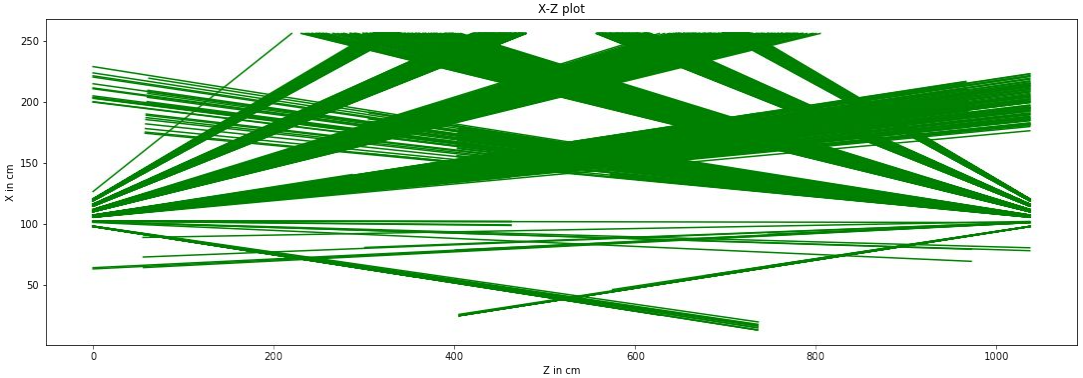


C. Adams *et al* 2020 *JINST* 15 P07010

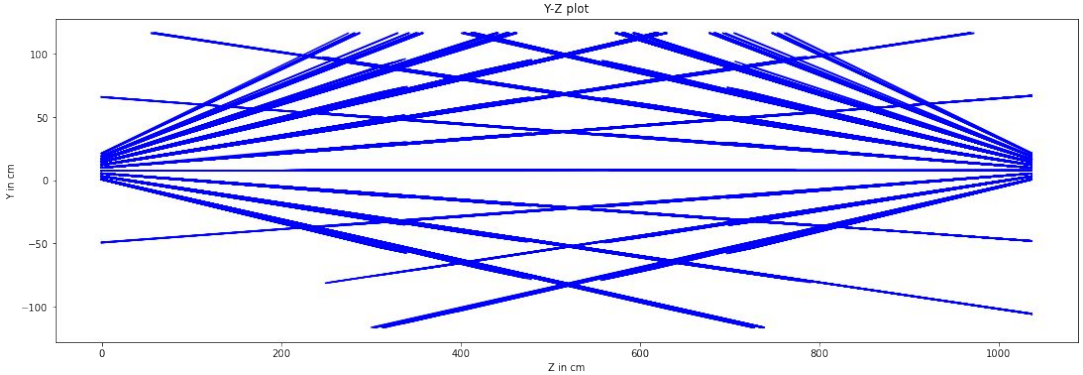
Laser coverage is limited due to field cage rings.



Top view (X-Z plane):



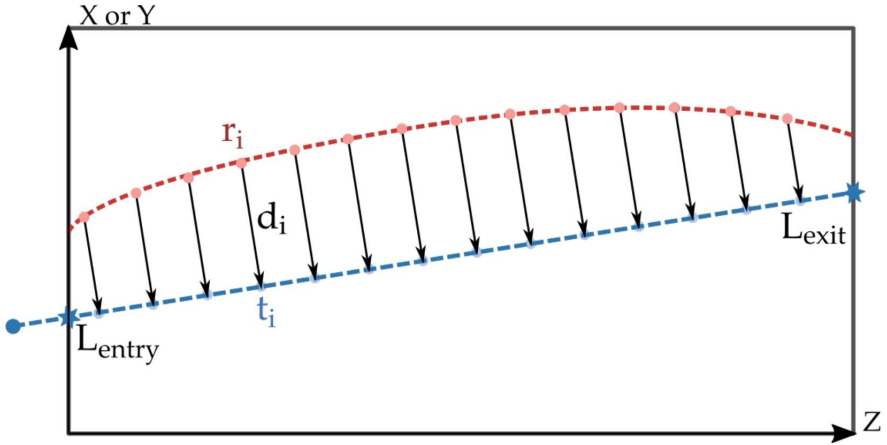
Side view (Y-Z plane):



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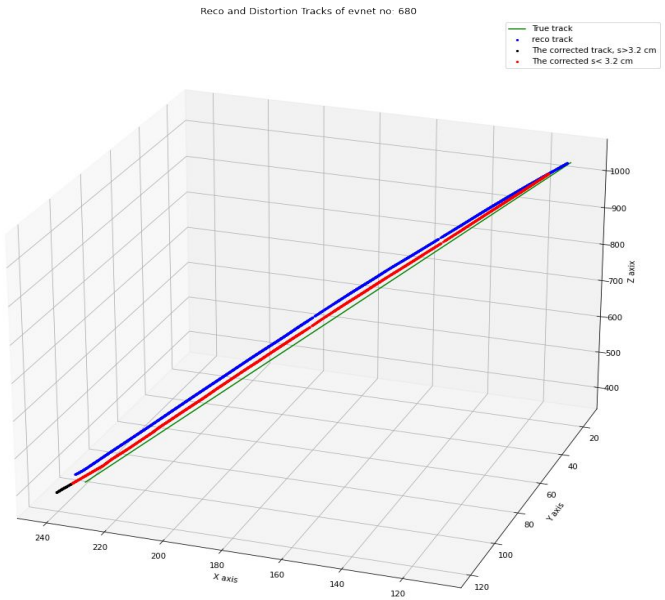
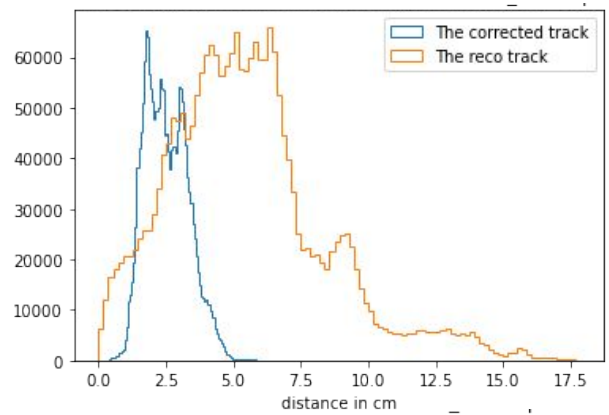
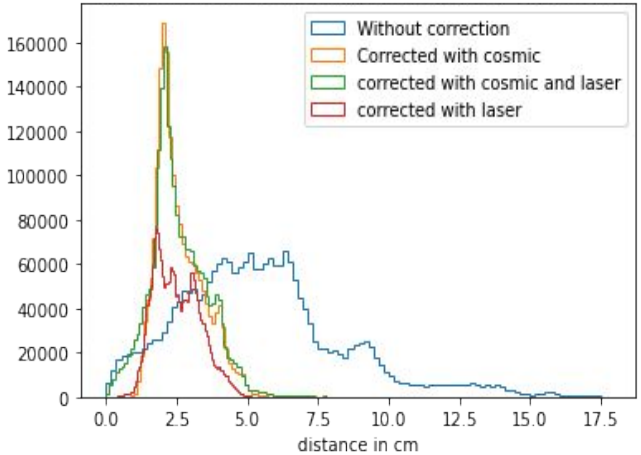
- The vectors from the reconstructed track points (red) to their closest point on the true track (blue) are the **correction vectors**.
- The vectors starting from the true track (blue) to the reconstructed track points (red) are the **distortion vectors**
- This forces the displacement vectors to be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



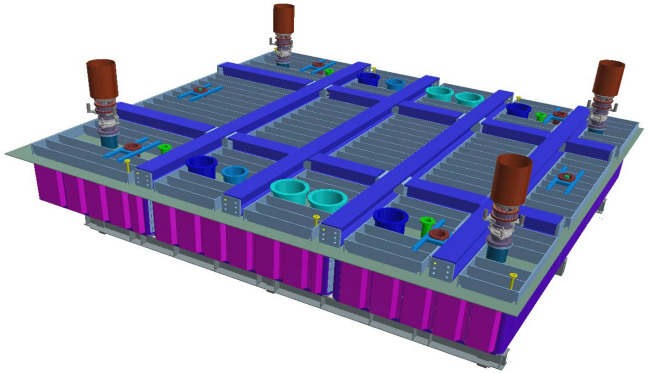
Shortest distance from true to reco points before and after correction (Laser only)

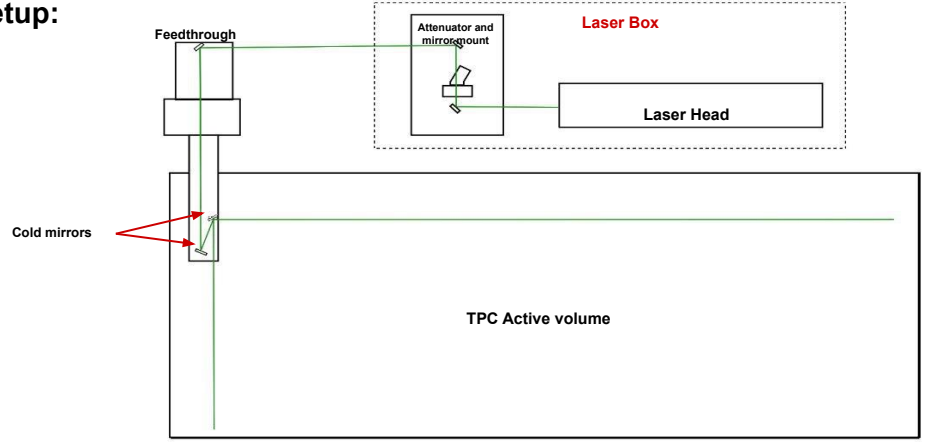


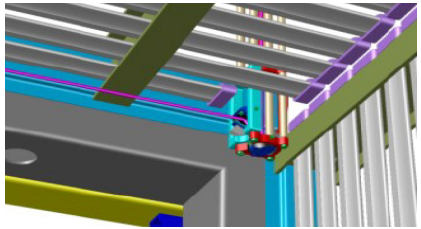
Shortest distance from true track before and after correction (All maps)

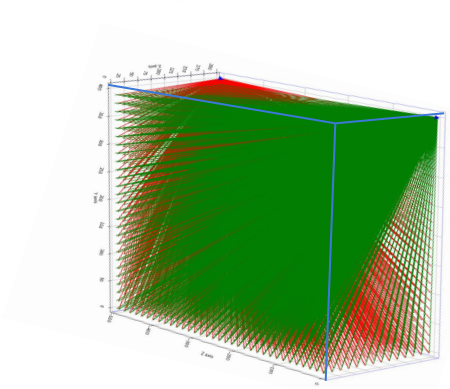


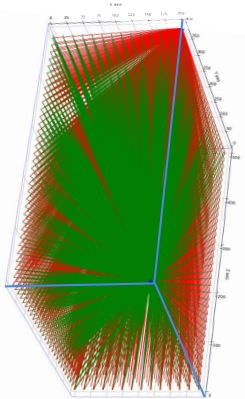
Schematic representation of SBND UV laser calibration setup:



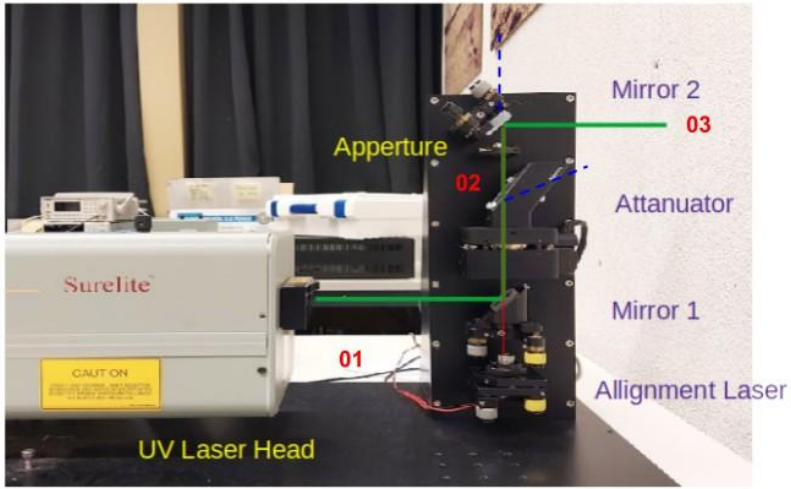


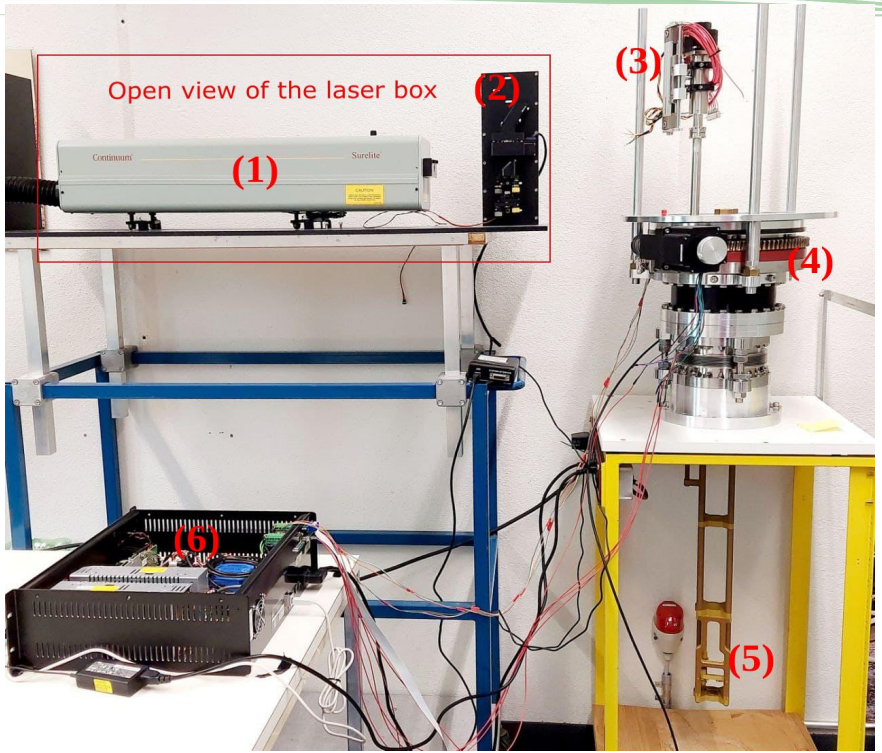






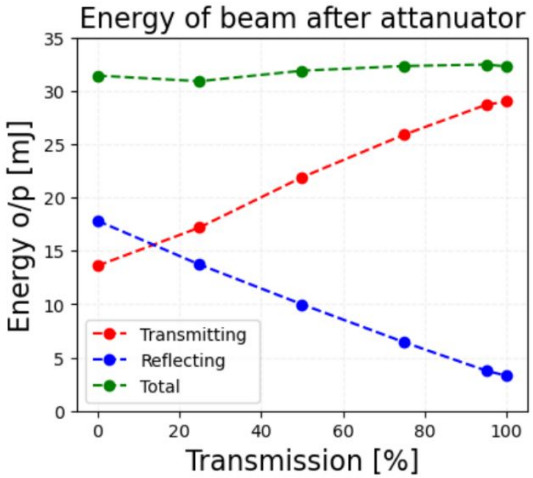
Inside the laser box:

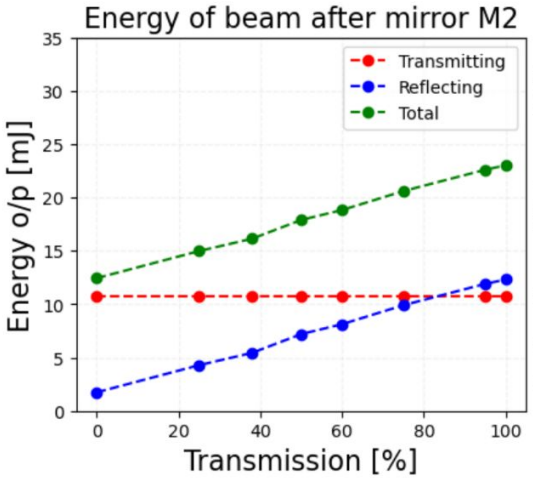


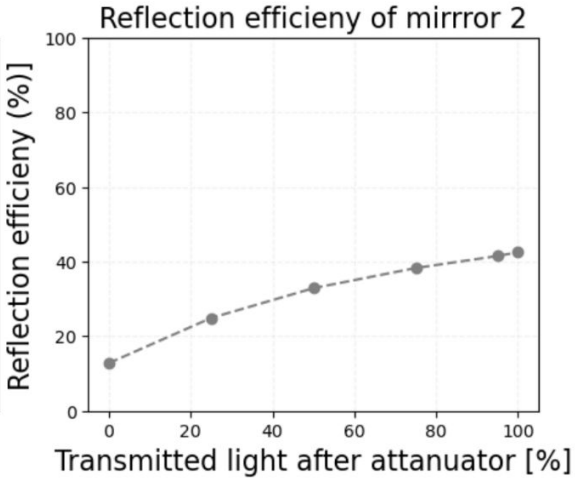


(1) Laser head, (2) Attenuator and mirror mount,
(3) Linear Motor to control the vertical movement of the cold mirrors,
(4) Rotary motor to control the horizontal movement of the mirror.
(5) Cold mirror mount and shafts, (6) Motor controller box

Laser Energy and mirror reflection efficiency measurements:







The total energy of the laser beam remains the same but the energy of p-polarised and s-polarised light varies with respect to the transmission through the attenuator.

Unwanted light components in the infrared and green (base wavelength and 2nd harmonic) are transmitted through the mirror and ultimately absorbed on a beam dump.

The reflection efficiency of the mirror 2 is defined as the ratio between the energy of reflected UV light with respect to the total energy of incoming light.

Laser Accuracy test:

Aim:

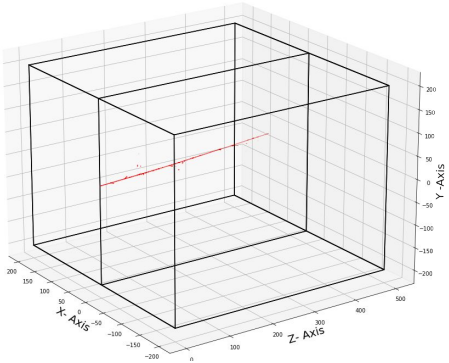
- To check the repeatability of laser points and Positional error. ✓
- Directionality Influence. (Mechanical freedom) ✓
- Software issues. ✓

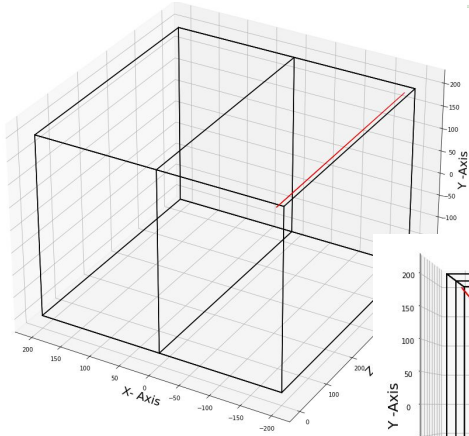
All Points with same encoder position reading

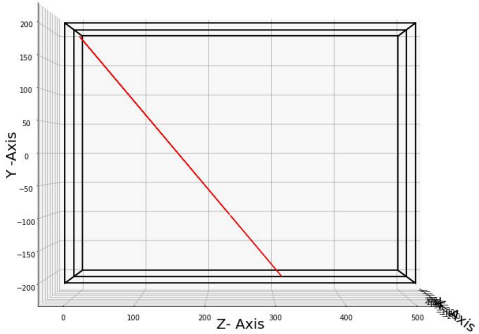
Vertical Movement:

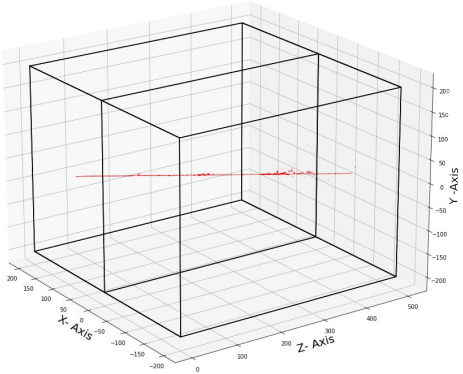
Horizontal movement:

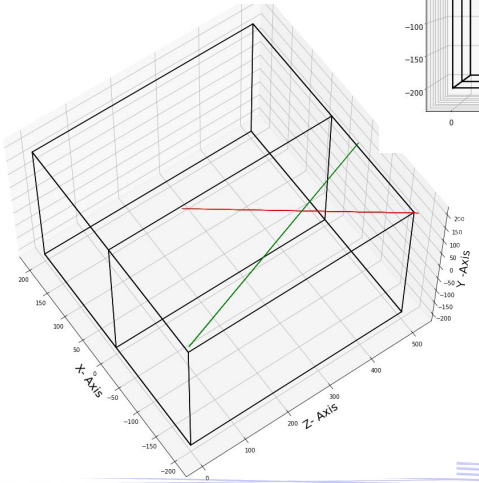
Laser Simulation:





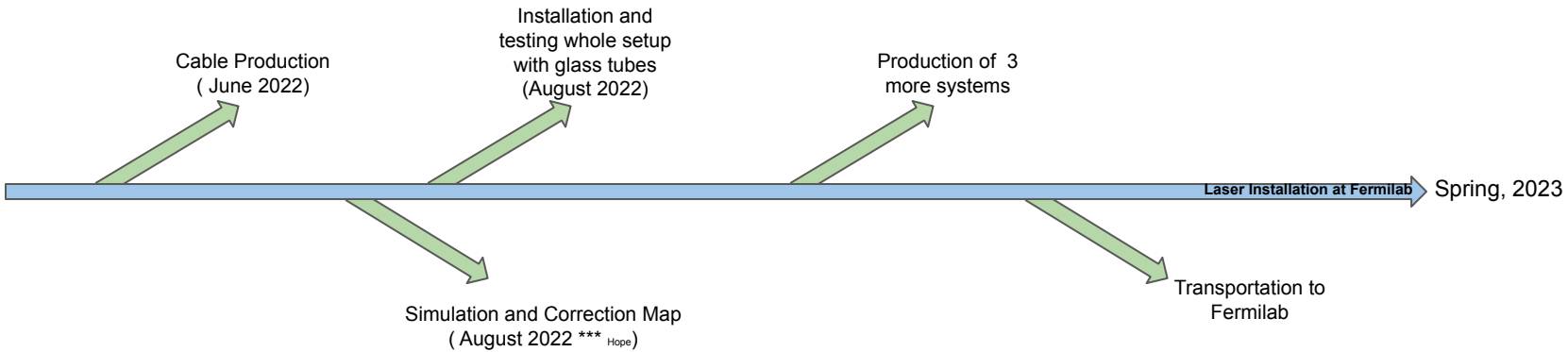






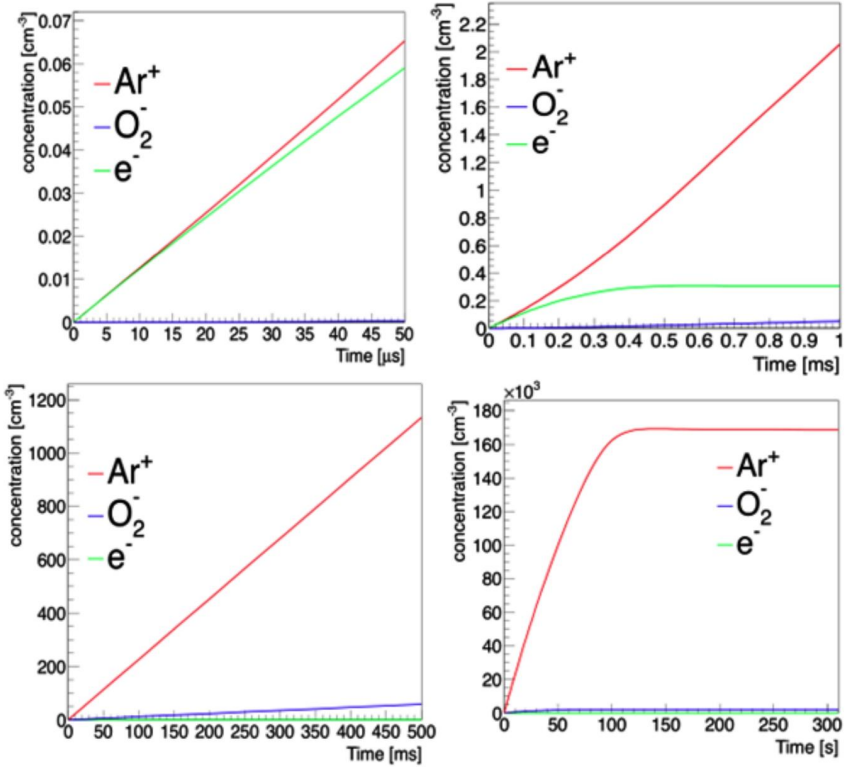
Next……

- Reconstruction and correction maps
- Cable production, Transportation.
- Laser Installation at Fermilab.



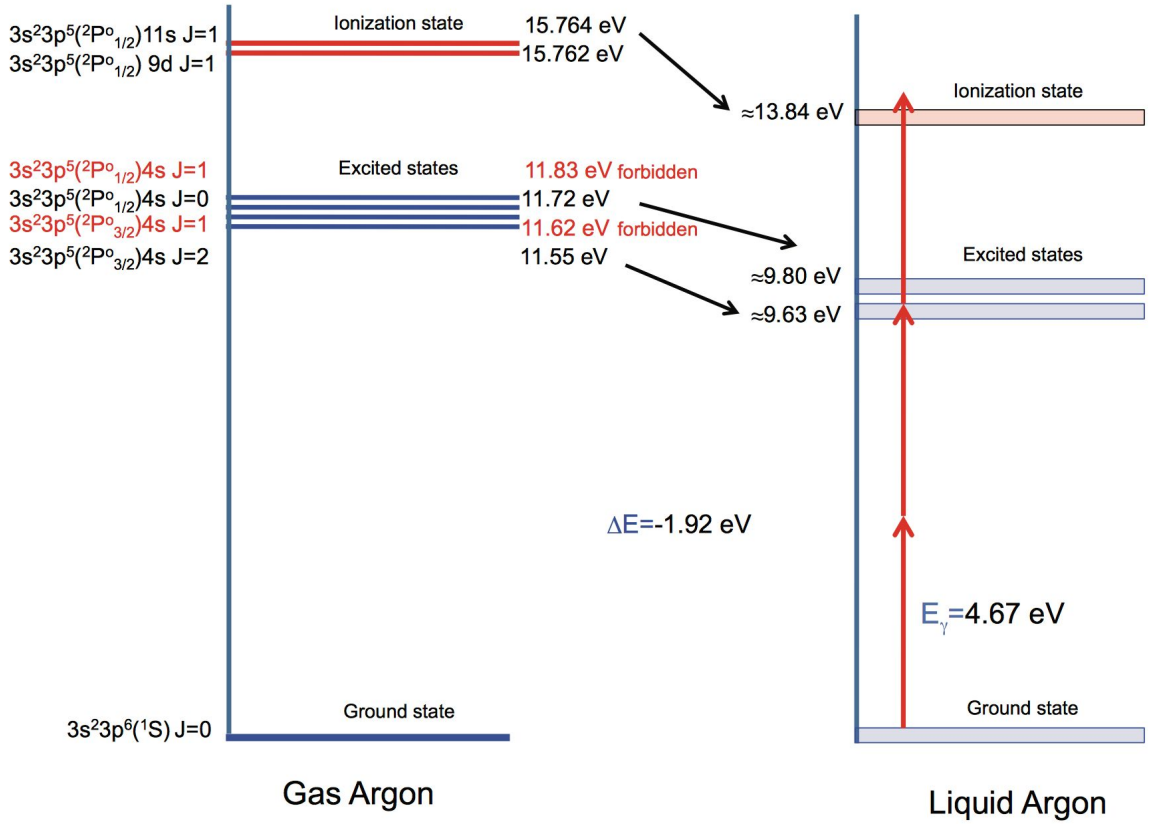
Thank You……

The ions and electrons in a 1 × 1 × 1 m3 box filled with liquid argon, considering the ionization produced mainly by cosmic muons and a 1 kV/cm drift field. Diffusion of the charges and recombination is taken into account.



arxive.org/pdf/1712.07971

- Multiphoton ionisation: strong intensity dependence
- Resonance-enhanced multiphoton ionisation (2 + 1)
- 266nm UV laser in 60*mJ* pulse have ~8x10^{16} photons



I Badhrees et al 2010 New J. Phys. 12 113024

Correction Maps:

- Calculate the correction vectors of track samples A and B using closest-point projection
- 1/n of the calculated correction vectors of track sample A are assigned to the corresponding reconstructed track points.
- Interpolate the partial correction vectors of track sample B with the mesh of all the reconstructed track points in sample A and their partial correction vectors.

Interpolation:

- The regular grid points are located at the center of each bin in the spatial displacement maps. Each bin has the same size of approximately 10 cm × 10 cm × 10 cm.
- First a mesh of all the track points by using Delaunay triangulation. Then barycentric coordinates of the grid points in the corresponding Delaunay triangulation unit are computed, and they are further applied to achieve the spatial displacement vectors on the grid points.

Step 1:

Closest Point projection.

Step 2:

Interpolate the fractional displacement vector from the other sub sample (where is fractional vector of)

Move the track correspondingly to the next intermediate position.

.

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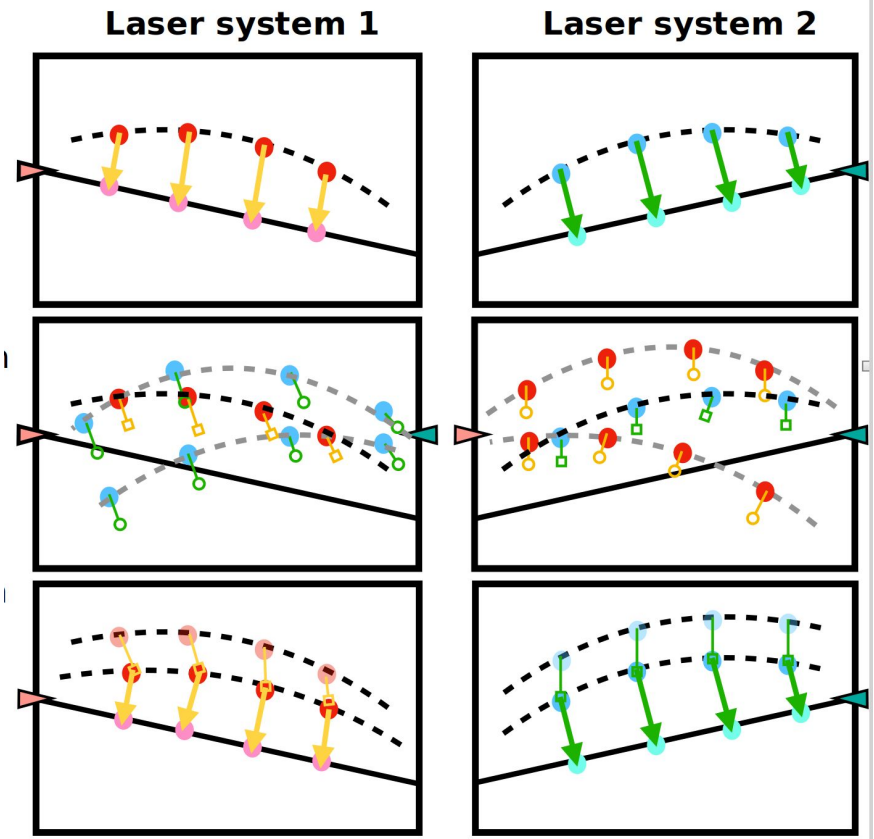
Step N:

Correct all the intermediate track points to the laser track .



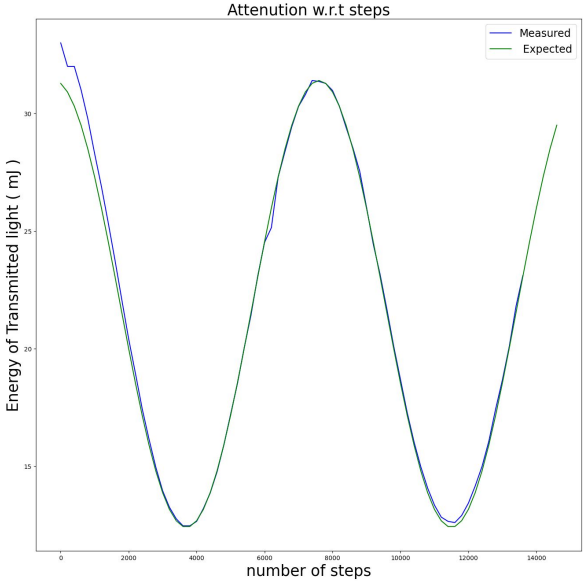
Hardware:

Laser:

- Nd:YAG laser from Continuum Surelite.
- Class **iv** laser.
- Up to 10 Hz repetition rate.
- 5 mm beam diameter.
- 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.
- Energy o/p of 60 *mJ*.

Attenuator:

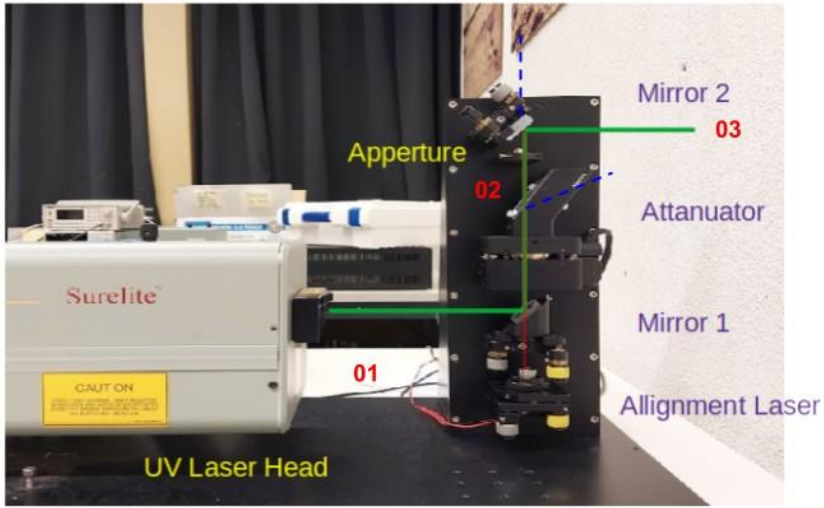
- Altechna half wave plate attenuator.



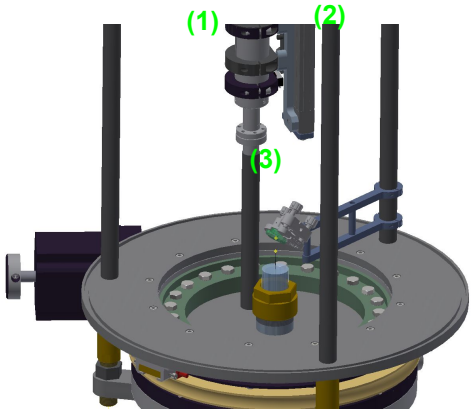
First task: To obtain optimal working range

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.

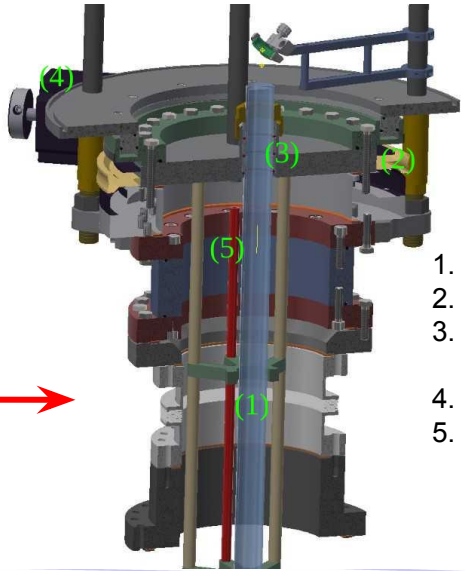


Feedthrough:



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

Cross Sectional view

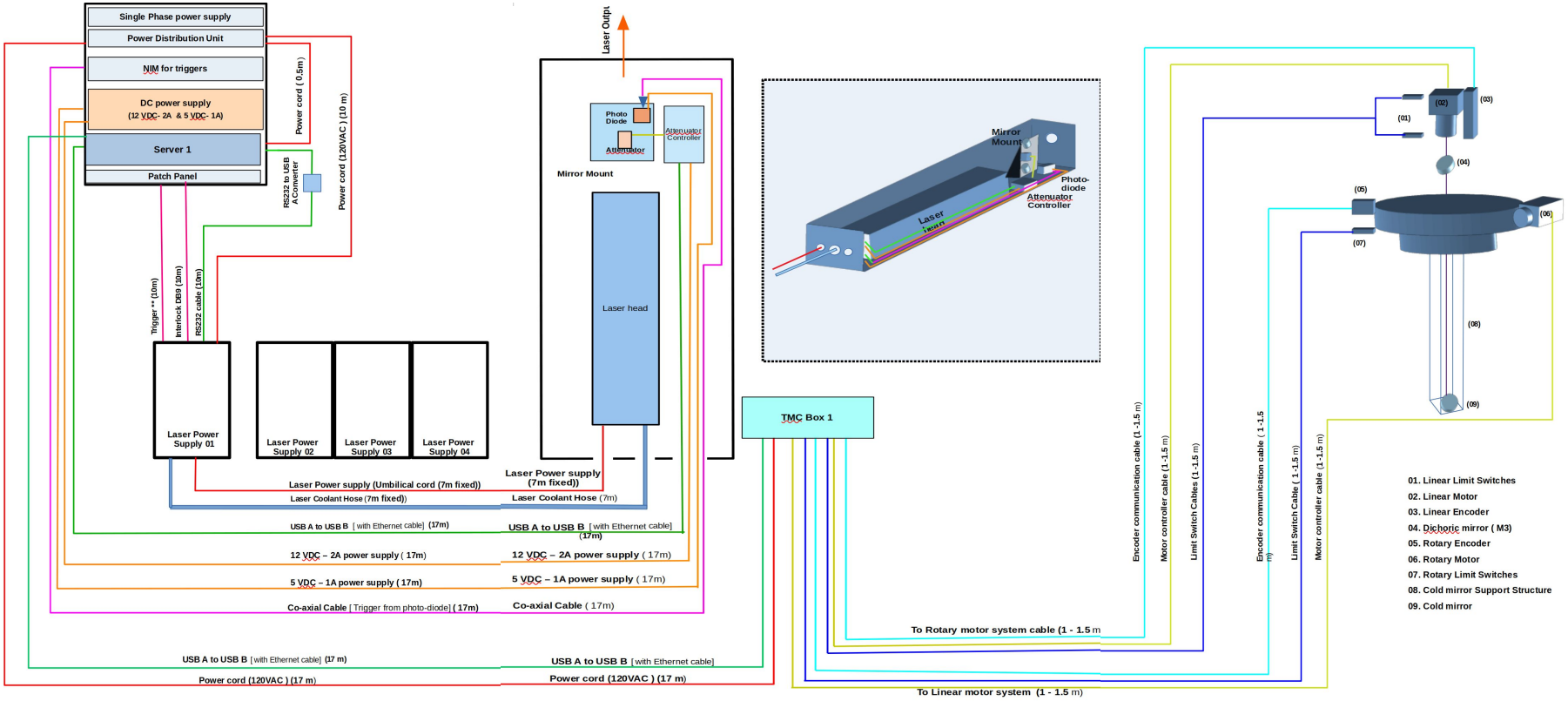


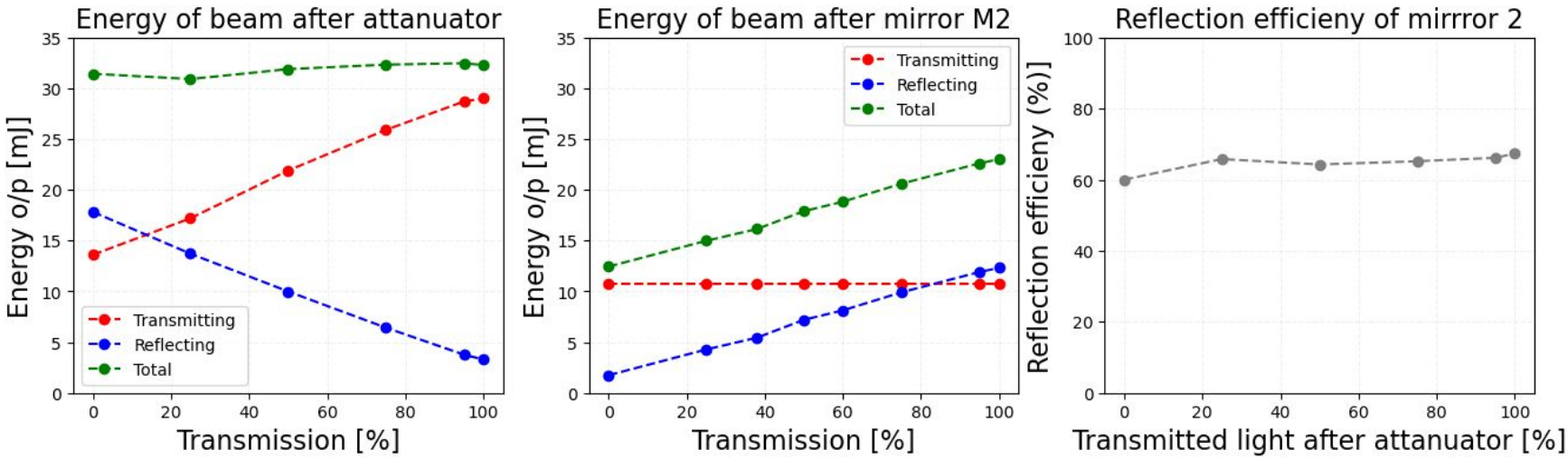
1. The evacuated glass tube.
2. Rotary encoder ring
3. rubber seals for the glass feedthrough
4. Rotary motor.
5. Linear feedthrough piston from linear Motor for tilting mirror

Hurray…..

- Controlling script has been developed for the system.

Laser System, expected connection scheme:




Energy of beam after attanuator
Energy o/p [mJ]
Transmission [%]
Transmitting
Reflecting
Total
Energy of beam after mirror M2
Energy o/p [mJ]
Transmission [%]
Transmitting
Reflecting
Total
Reflection efficieny of mirrror 2
Reflection efficieny (%)]
Transmitted light after attanuator [%]