The UV Laser Calibration System for measuring the Electric field in the SBND

LIDINE 2024, Sao Paulo 26 -28, August 2024

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On Behalf of **SBND**

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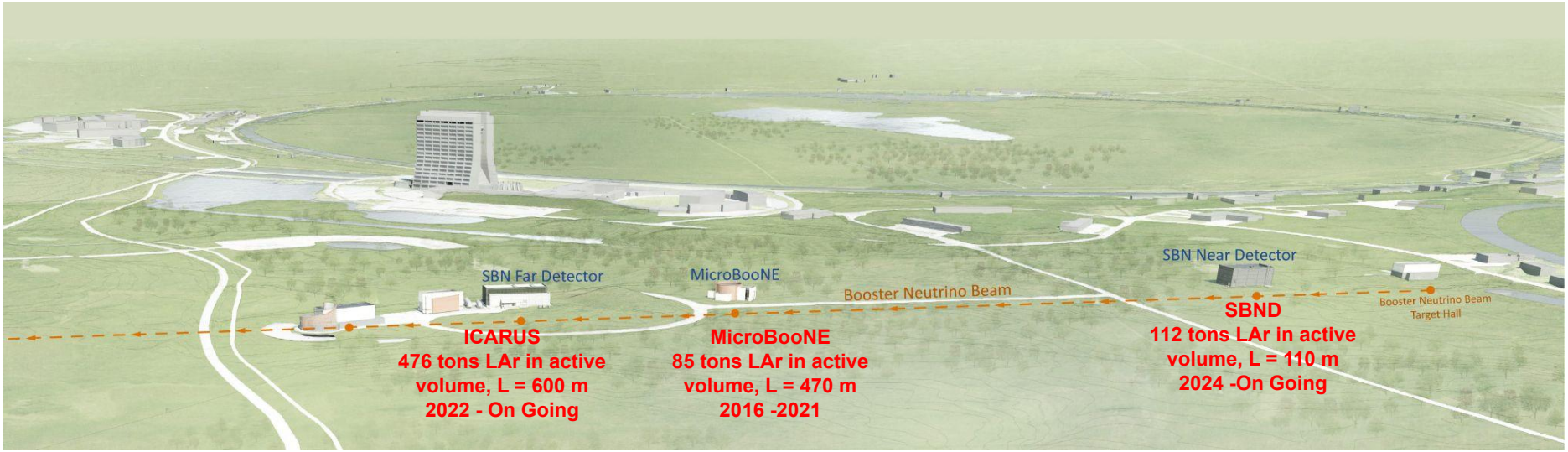
LHEP - University of Bern

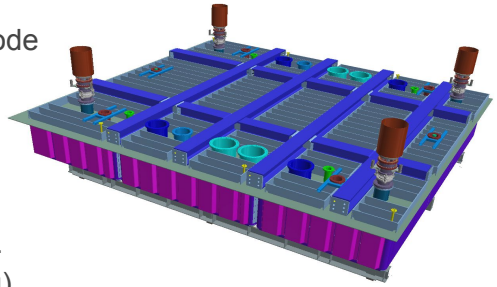
Short-Baseline Neutrino Program

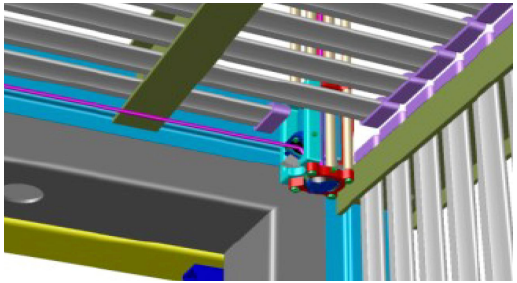


- To measure properties of neutrinos and study Neutrino Oscillation.
- Perform sensitive searches for ν_e appearance and ν_μ disappearance in the Booster Neutrino Beam.
- Aims to resolve the electron-like event excess seen by LSND and MiniBooNE.
- Development of LAr based particle detection technology for future experiments like DUNE

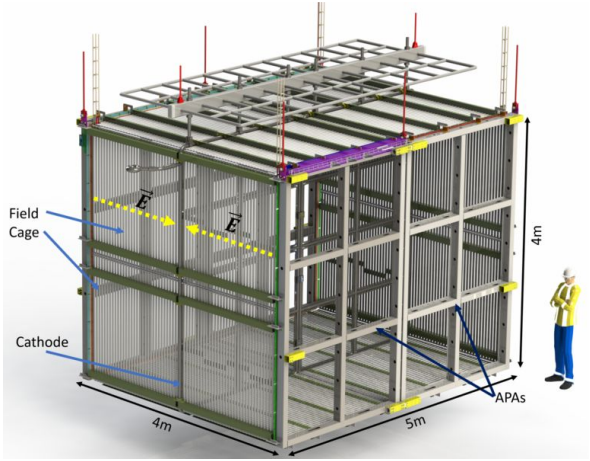
SBND:

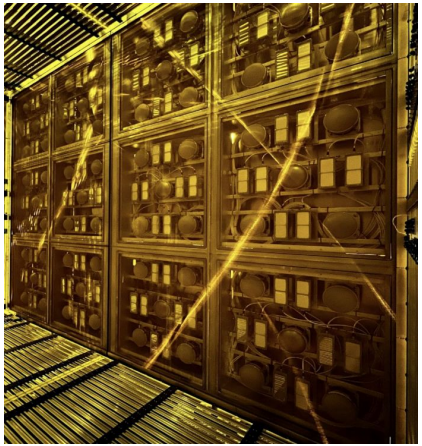
- 2 TPC system. (Each tpc is 2m x 4m x 5m) with 3x2 anode planes (induction = U,V; collection=Y), ~11k total wires
- 120 PMTs + 192 X-ARAPUCAs
- 7 Cosmic Ray Tagger (CRT) planes for background rejection
- 100kV potential difference between anode and cathode.
- The detector is up and running (March 2024 - On going) Started taking data from July 2024.
- 4 UV laser systems.



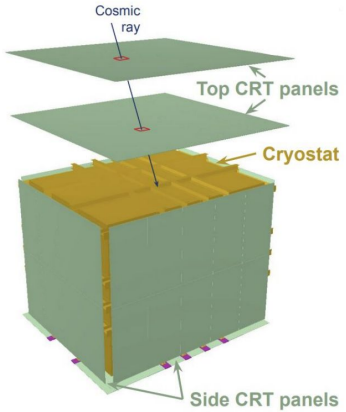


Cold mirrors inside the field cage

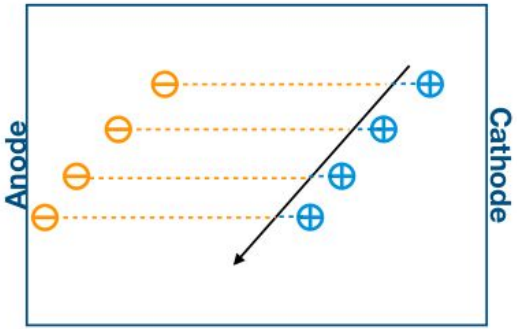




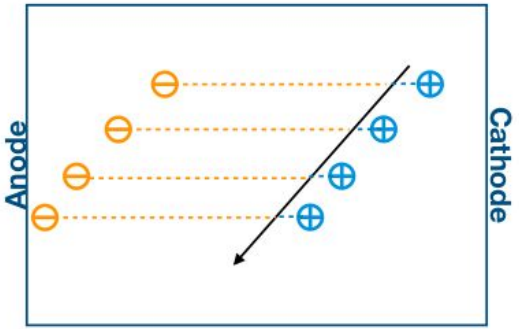
PDS system behind each anode plane to detect fast LAr scintillation light

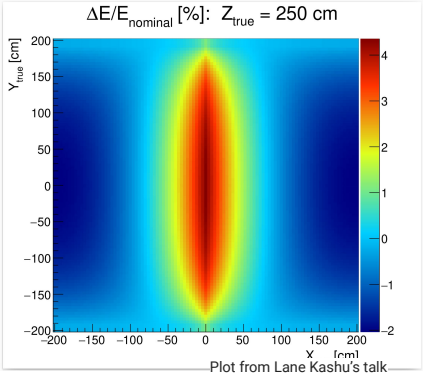


CRT Panels covering SBND

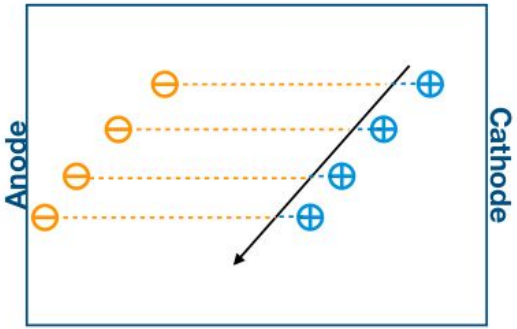


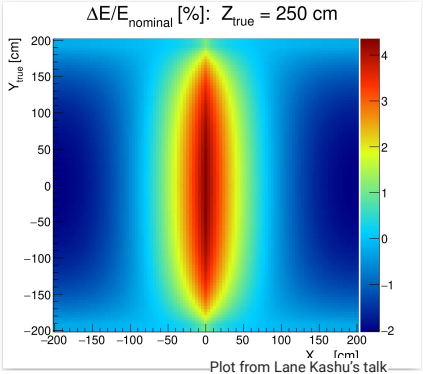
LArTPC





- $V_{e-} > V_{Ar+}$: by 5 orders of magnitude
  Nominal electric field: 500 V/cm
  Drift Velocity:
  electrons: ~ 1.56 mm/μs toward anode
  Ar+ ions :~ 5 x 10^-6 mm/μs toward cathode
- 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





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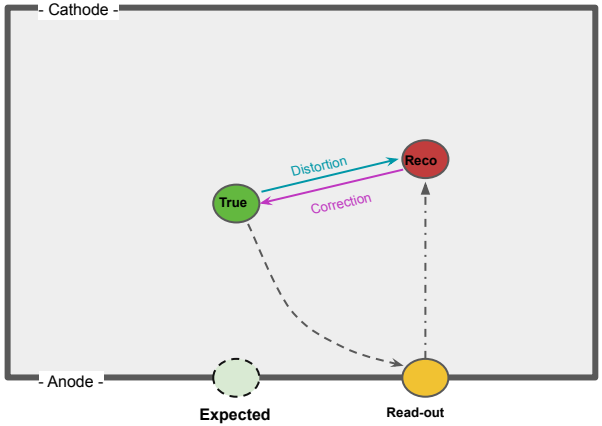
- E- field distortion

What happens if E- Field is inhomogeneous????

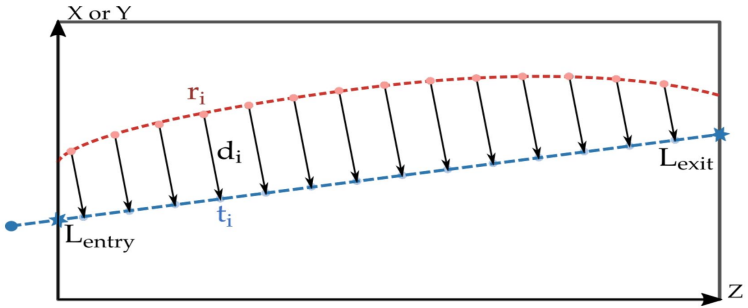
- Discrepancies between true and reconstructed points.
- Reduces track and energy reconstruction efficiencies of the detector and introduces additional systematic uncertainties



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.



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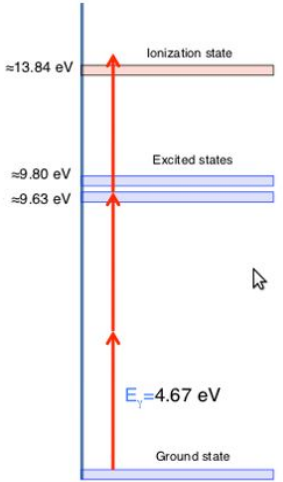
Why:

- 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

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



Liquid Argon

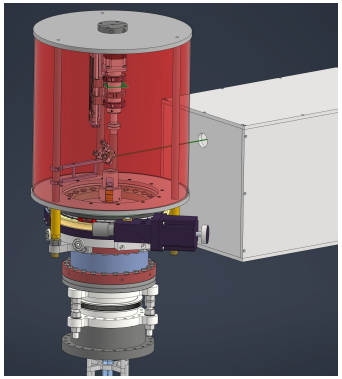
Laser to ionize Ar:

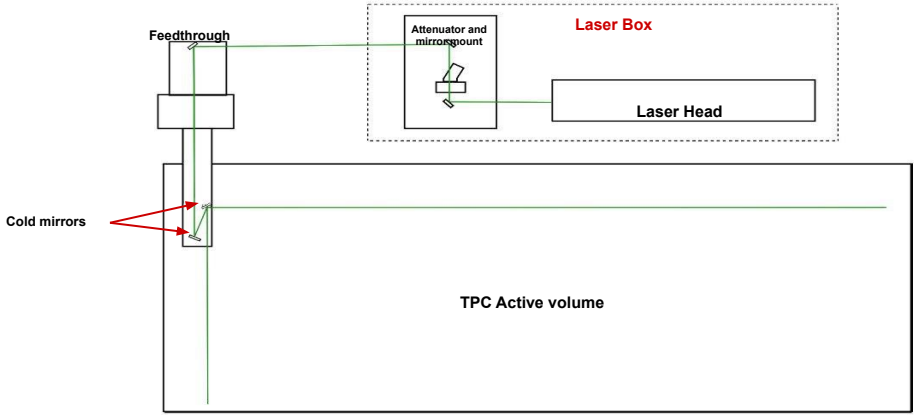
- Nd:YAG laser from Continuum Surelite (Class 4 laser)
- Up to 10 Hz repetition rate.
- 5 mm beam diameter.
- Energy of 60 mJ (at 266 nm) per 5 ns pulse.
- The Surelite I-10 initially generates infrared (IR) light (1064 nm), which is shifted to green (532 nm) first, and then UV (266 nm) through second and fourth harmonic generators.

How:

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

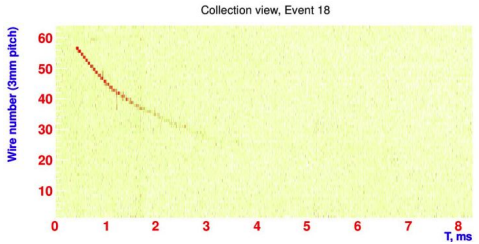
- Each Dichroic Mirror eliminates 532, 1064 nm and reflects 266 nm.



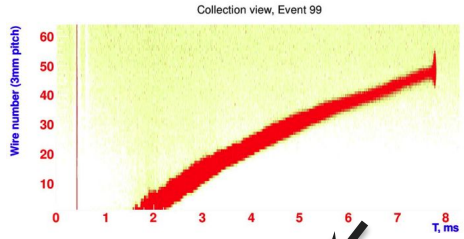


Schematic representation of SBND - UV laser calibration set up

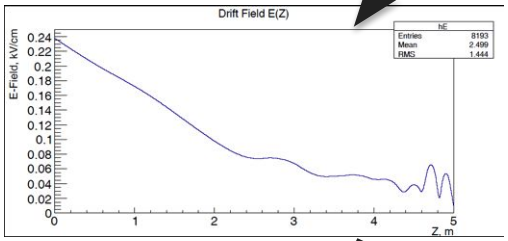
UV-laser method in actual scenario - measurement from ArgonTube (Bern)



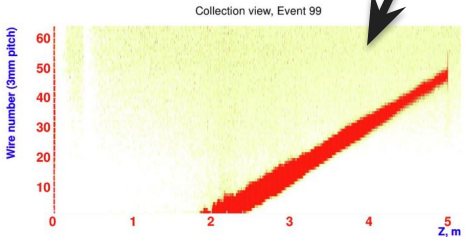
Distorted muon track, due to e-Field distortion



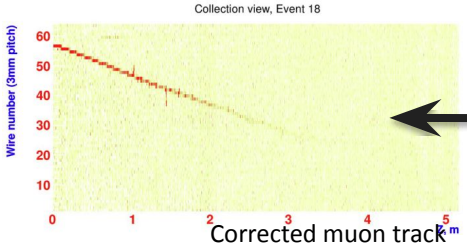
100 laser tracks



E-Field map

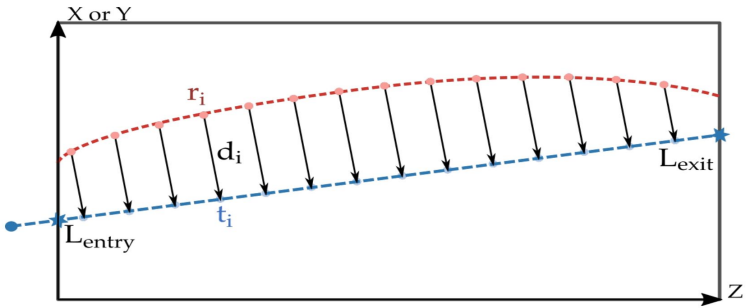


Corrected laser tracks



Corrected muon track

- 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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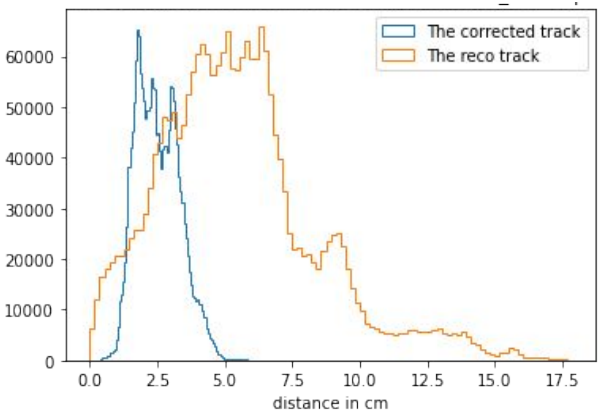
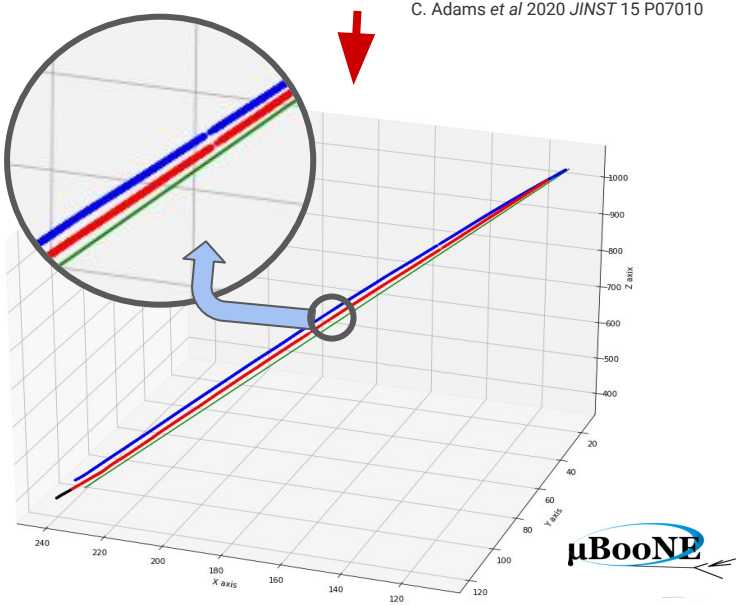
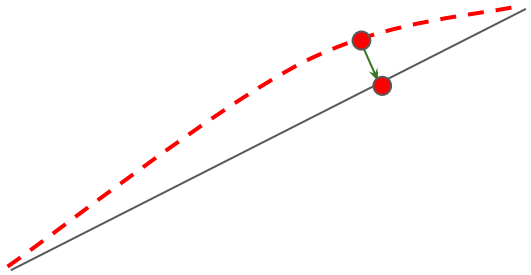
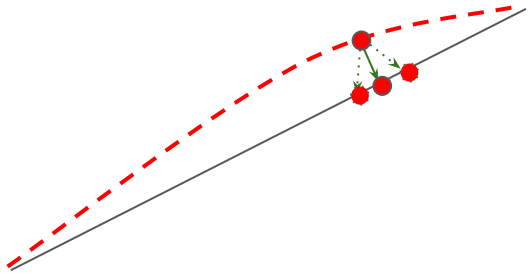


Shortest distance from true to reco points before and after correction.





A reco points corresponds to which point in true track?



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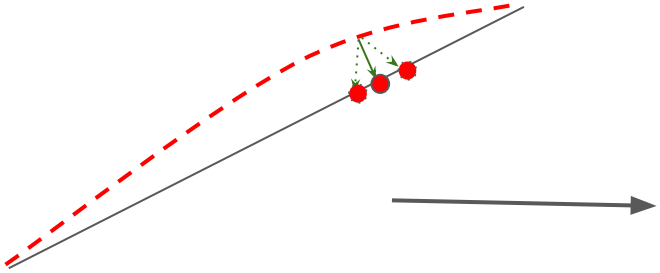

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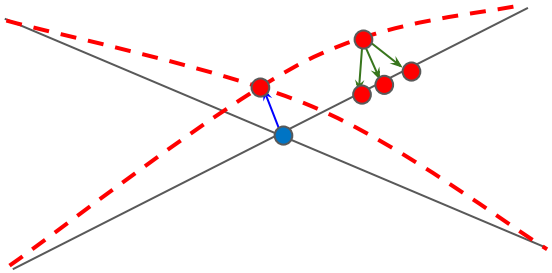
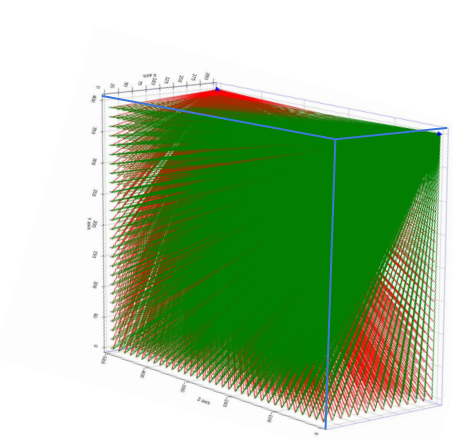
Crossing tracks!!! @SBND

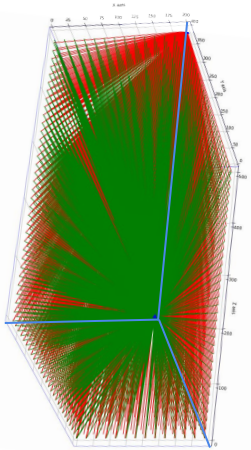


The crossing track points are unique points and can flag them easily, makes it more efficient approach do residual calculation.

Full Laser Scanning:

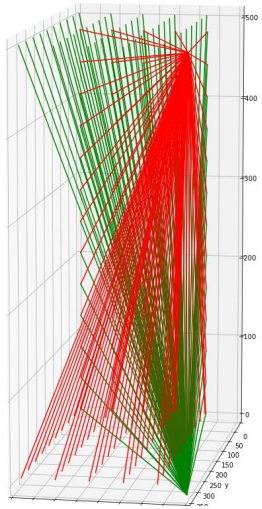
- Full coverage with crossing tracks
- More precise and effective informations from crossing tracks

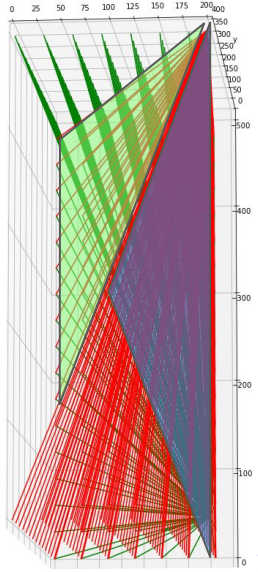




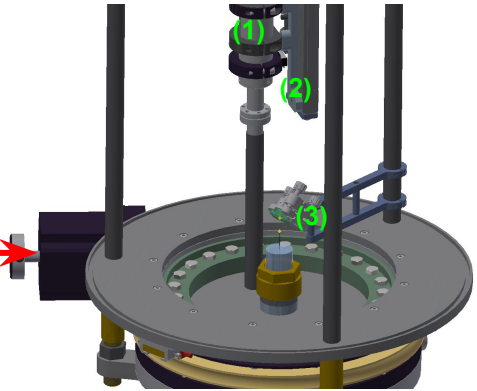
Partial Scanning:

- 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.
- Will employee new crossing track points based + old proven track comparison method.

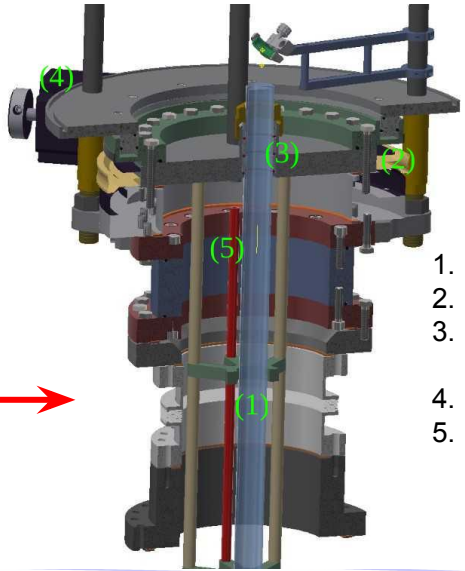




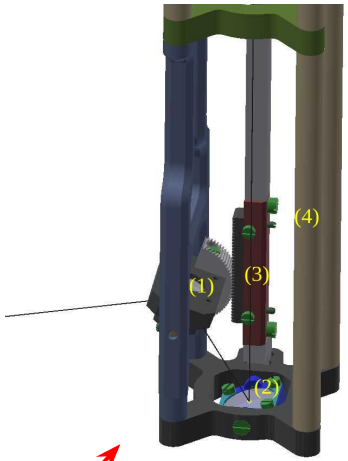
Hardware -Feedthrough: Cross Sectional view



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



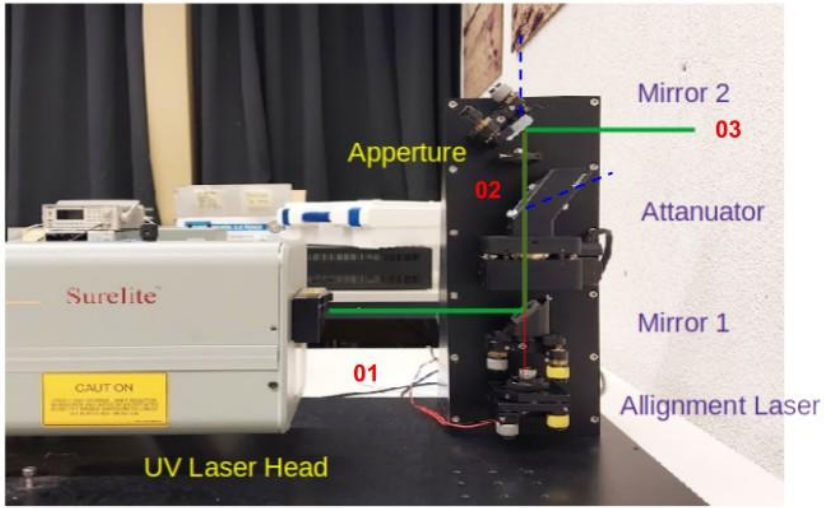
1. The evacuated glass tube.
2. Rotary encoder ring
3. Rubber seals for the glass feedthrough
4. Rotary motor.
5. Linear feedthrough piston from linear Motor for tilting mirror



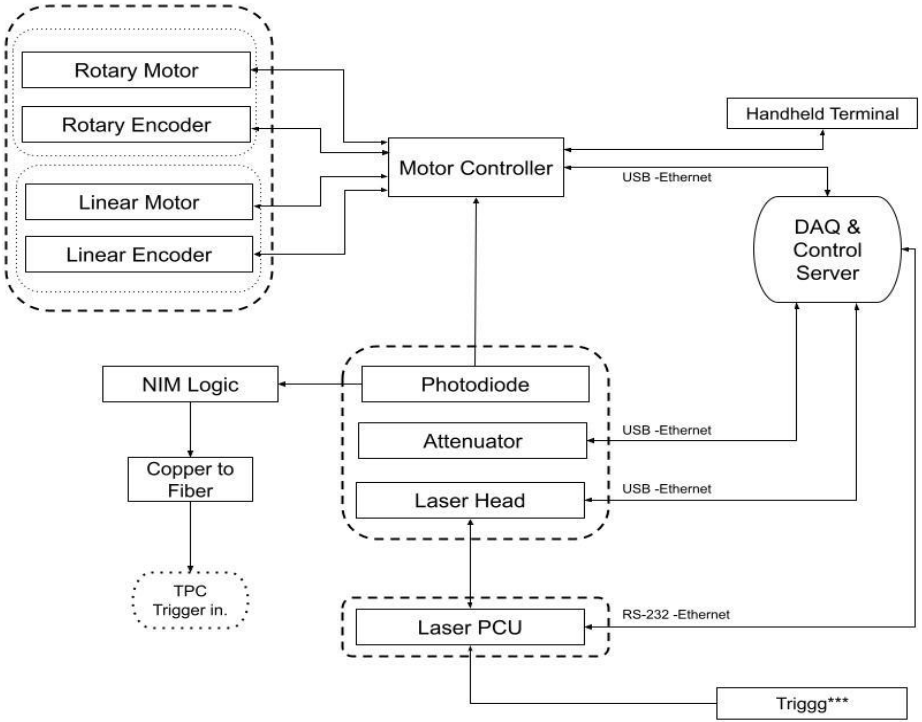
1. Movable cold mirror and support structure.
2. Immovable cold Mirror.
3. Piston and rod construction for tilting.
4. Supporting rods

Inside the laser box:

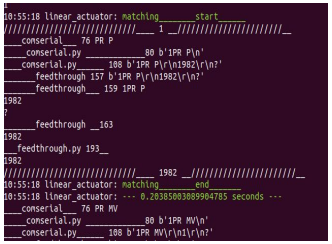
1. U-V laser head
2. Two dichroic mirrors (wavelength separator)
3. Attenuator
4. Aperture
5. Photo Diode for DAQ trigger.

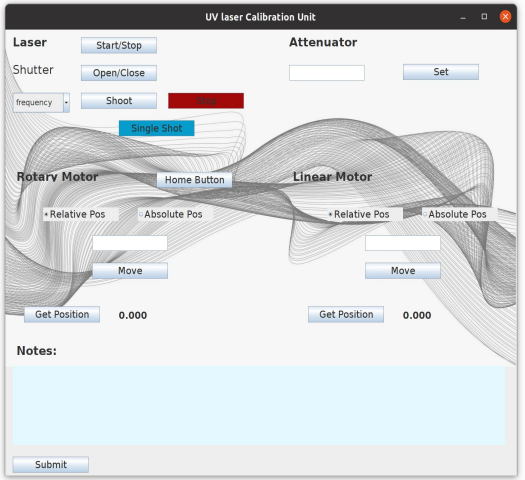


Electronic System:



Controlling Script and User Interface:

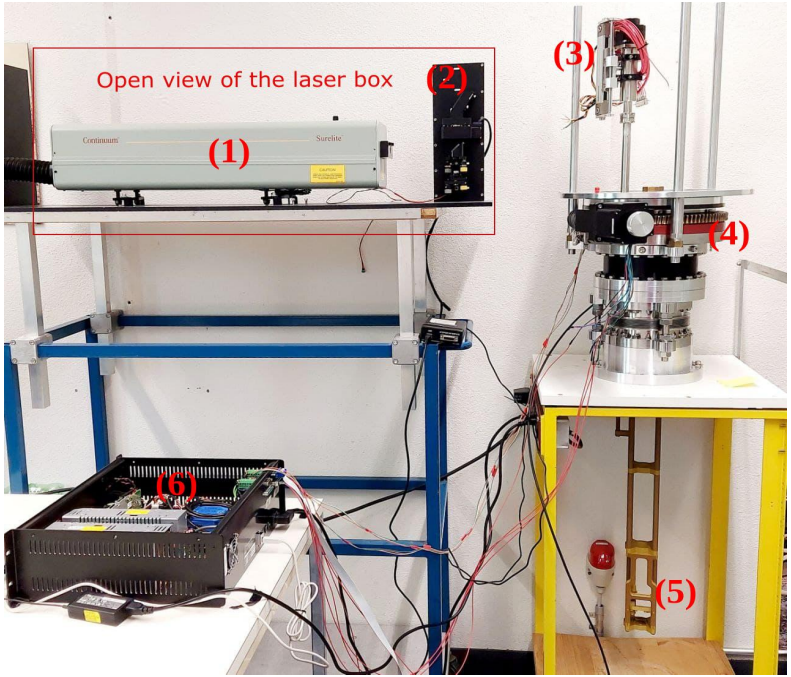




- Script available in python2 and python3 (interactive Python shell).
- Currently using the interactive Python session to perform all the functions.

Laser test facility at LHEP(Bern):

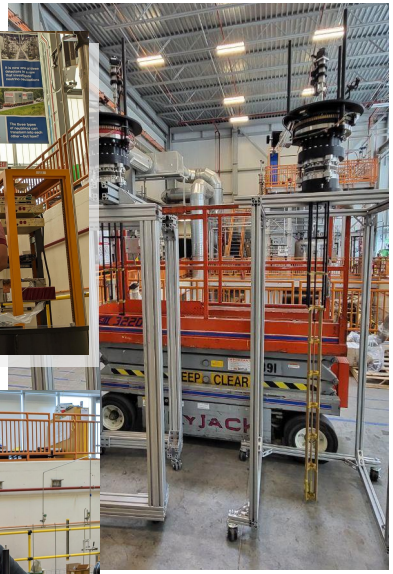
SBND setup



(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

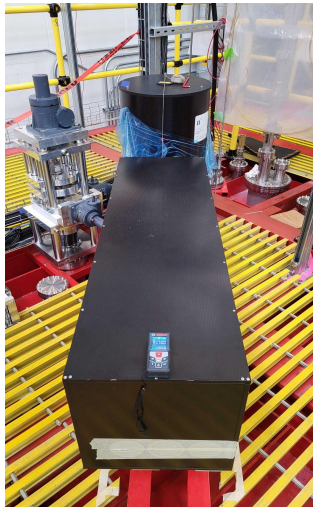
Mechanical installation of Feedthroughs at SBND:

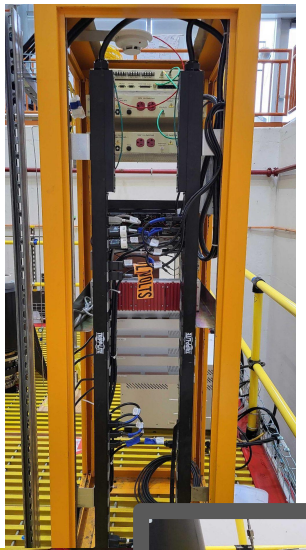
- Installation of feedthrough onto the cryostat was done last week (June 12 - 19, 2023)

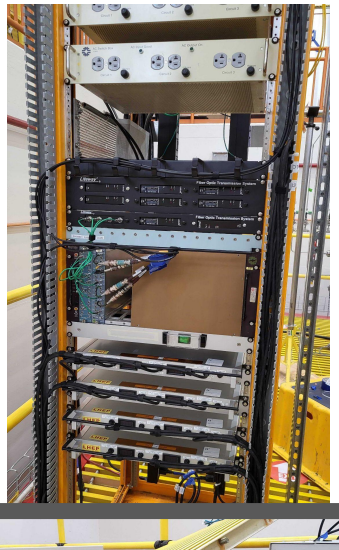


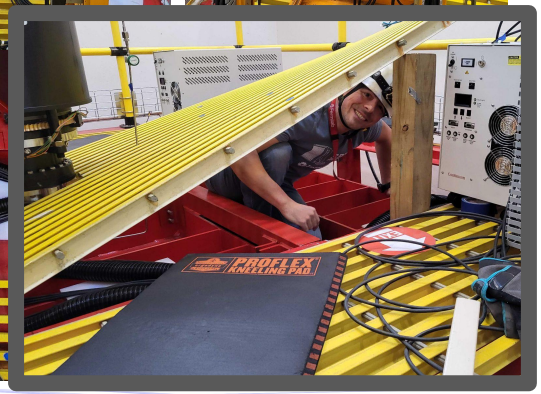
Current Status:

- 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.
- 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.
- Got recommended for operation from Electrical mechanical and fire safety.
- Expected laser Run in Sep. 2024

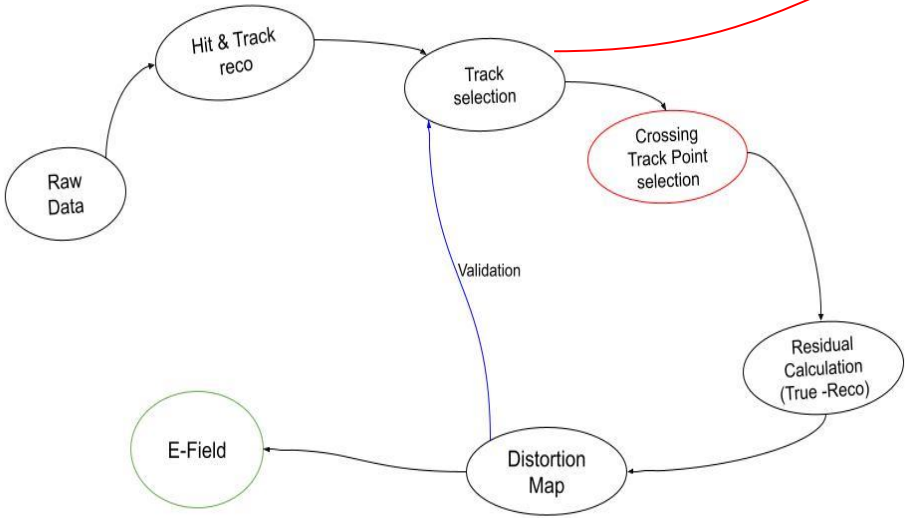


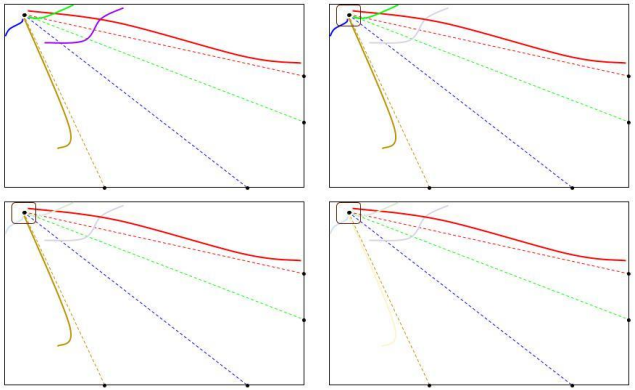






Workflow :





Excited for laser run and Data !!!!!!!

A single track wrongly associate with a true laser track, can disturb calculations significantly.

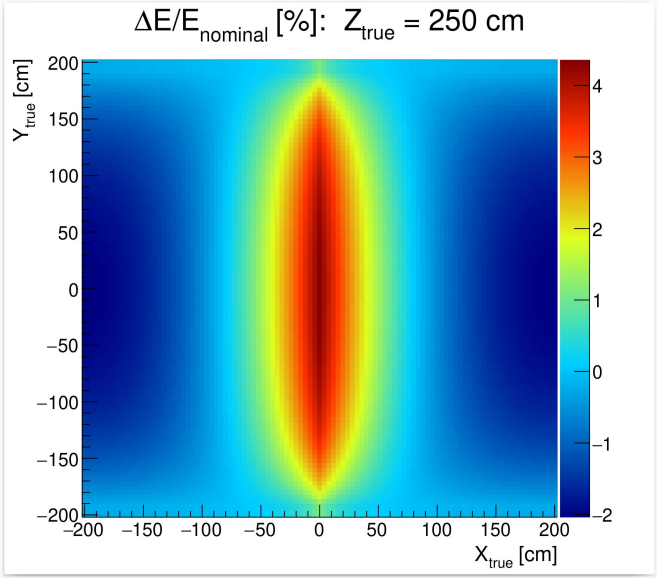
- Only tracks that have associate trajectory points within the expected “origin” region, which is mirror position.
- Slope: Slope of the reconstructed track is compared to the expected slope of the true track.
- Smoothness: to eliminate tracks that show non-physical artifacts (oscillations, hard kinks, etc.)

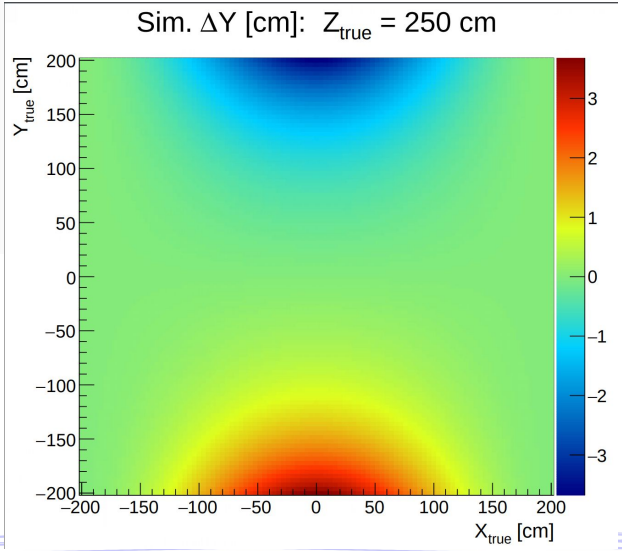
Conclusion:

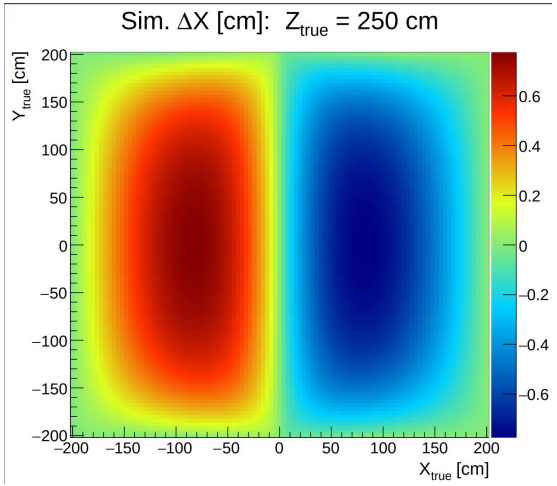
- UV Laser Calibration System is one of a method to address the E-Field distortion inside LArTPC due to Space Charge Effect(SCE).
- The System was developed, Produced and assembled at LHEP, University of Bern, Switzerland.
- The LCS Hardwares are already installed at SBND and ready for operation.
- First Laser run Expected in September 2024.
- Once the Laser run data is received, will move forward towards E-Field Calibration studies.

Thank You!!!

Back up



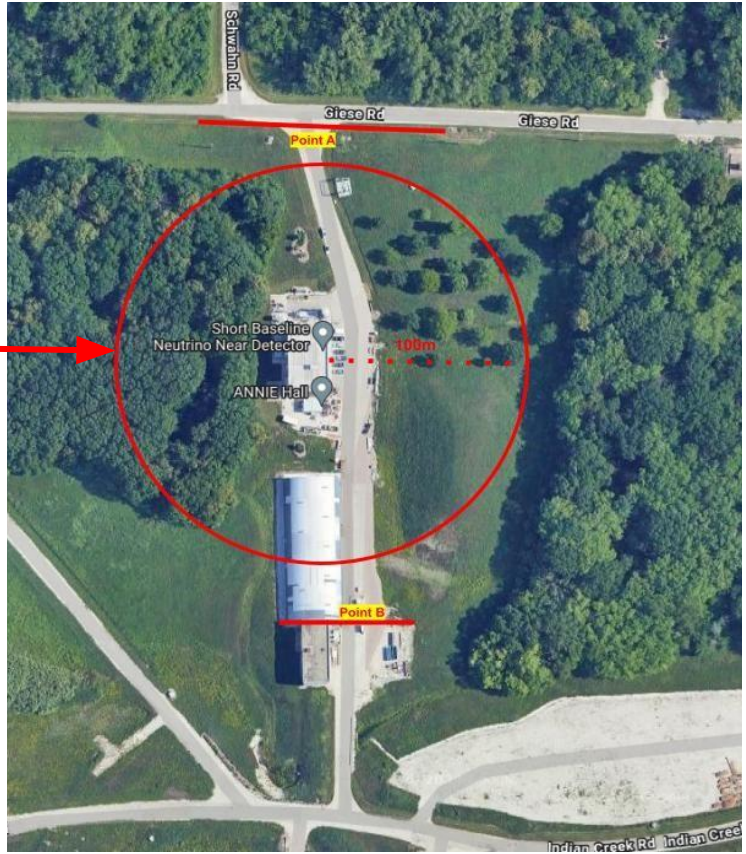




Nominal electric field: 500 V/cm
Electrons drift with speed ve ~ 1.56 mm/μs toward anode
Ar+ ions :~ 5 x 10^-6 mm/μs toward cathode

Work:

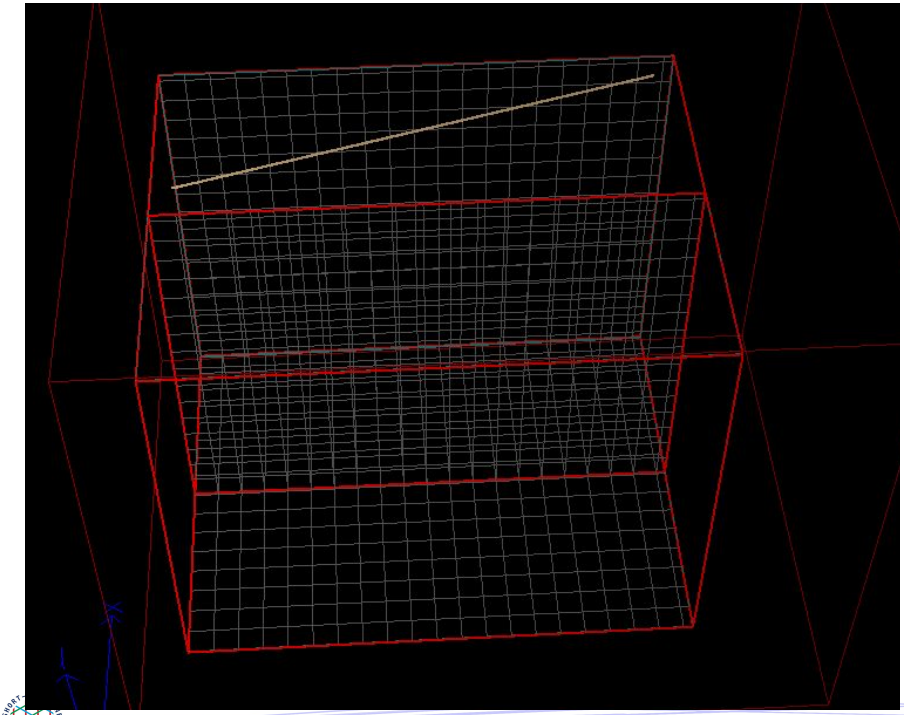
- Laser Operation - Maintenance Mode (July 16-18, September 9-13)
- Laser and mirror alignment. (Need DAQ, Trigger team support, also Live event display)
- Time required - 3 Days (September 9 -13)
- Nominal Hazard Zone (100m) - Street closure is required from Point A to Point B)
  No access to the detector for 3rd person while laser running.
- No restriction for movement to the Minos/FD site.
- Once the alignment is done, Can do Normal Laser Operation (Also possible from remote) -> No Laser hazard involved.



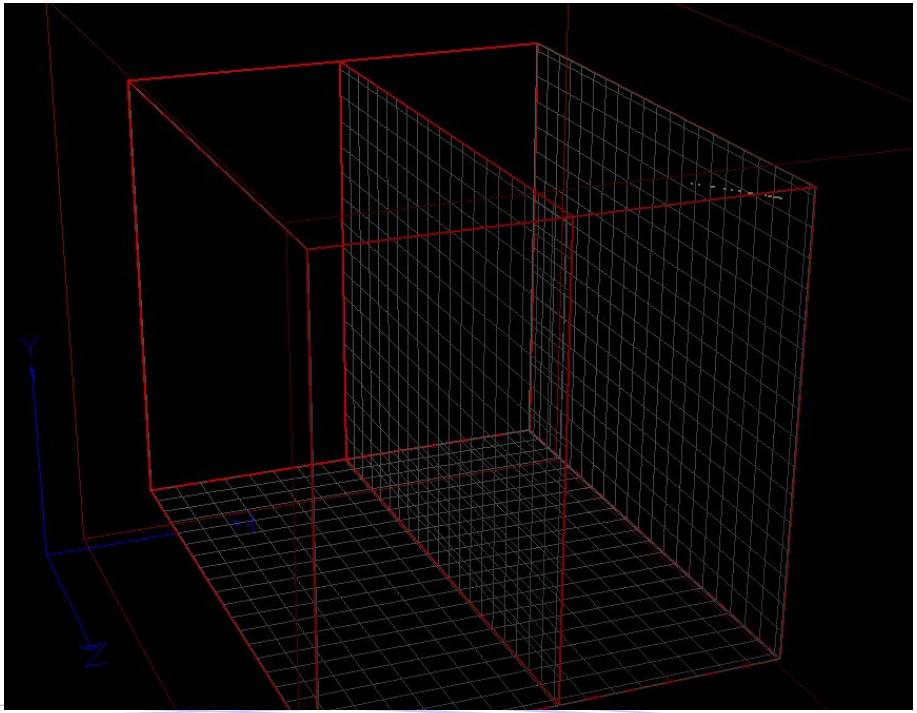
Simulation Efforts:

Tried to mimic laser with muon at 300 GeV and switching the secondary physics off

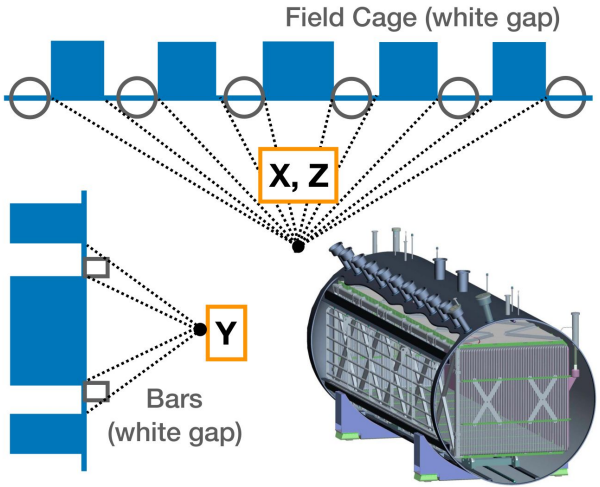
Diffusion 10^{-9}



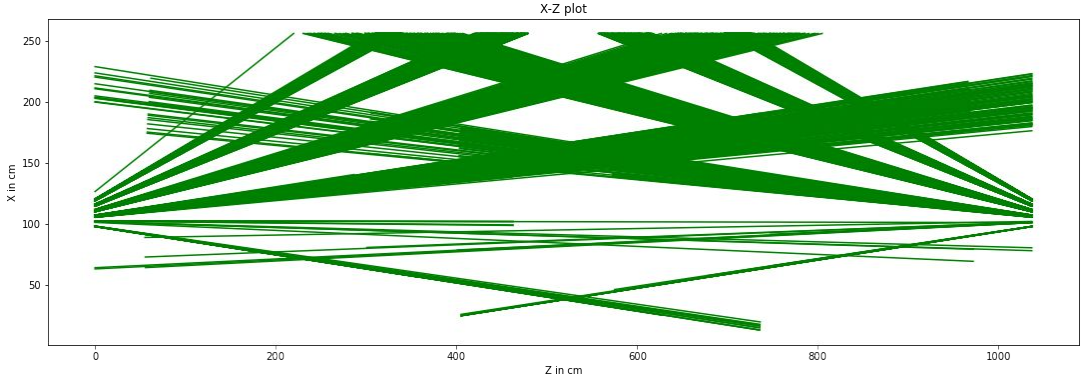
Diffusion 10^{-5}



Laser coverage is limited in uBooNE due to field cage rings.



Top view (X-Z plane):



Side view (Y-Z plane):