DUNE Off-Axis Measurements

Michael Wilking
Stony Brook University
DUNE Integration Meeting
November 29th, 2018

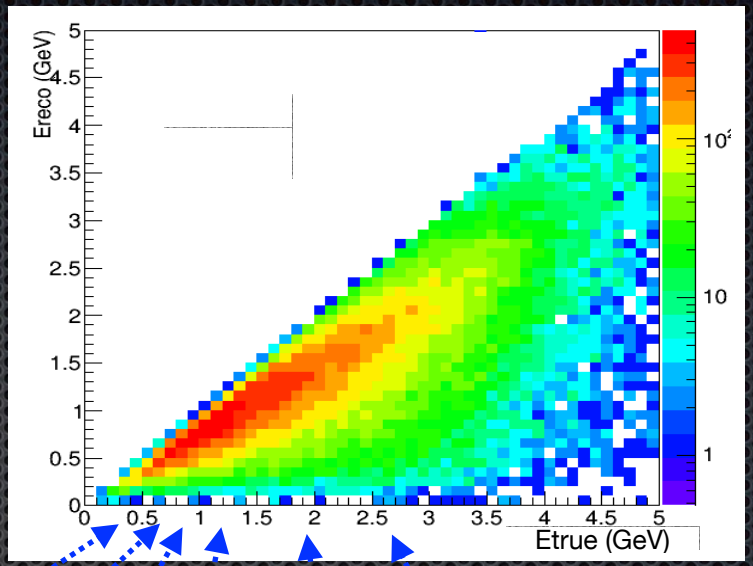
DUNE ND Recommendations

Near Detector Recommendations Approved by EB

1. The LArTPC at the near site should be optically segmented, with a short drift space and 2-dimensional pixelated readout, similar to the concept being studied by the ArgonCube collaboration.
2. The design of a mobile LAr detector that can make measurements at one or more off-axis positions should go forward (DUNE-PRISM)
3. Additional study of DUNE-PRISM for technical feasibility and cost, including the option of moving the MPT, should be made.
4. The underground experimental hall should be rotated by 90° about the vertical axis to allow for moving the near detector off the beam axis.
5. The dimension of the hall in the beam direction that is usable for the experiment must be at least 17m. A wider span should be considered, if the geo-technical conditions are favorable.
6. The experimental floor area should be at least 42.5m x 17m and the hook height must be at least 13m, measured from the floor. The minimum lateral dimension of hall needs further study, and will ultimately be settled in EFIG.
7. A newly built dipole is the preferred magnet for the downstream spectrometer of the DUNE near-detector complex. “Dipole” does not imply a particular design, except that the primary field component is perpendicular to the beam.
8. The recommended concept is a near detector suite consisting of a LArTPC (not in a magnetic field), a HPgTPC in a magnet, and a 3DST, possibly located in the same magnet.
9. The option of filling the HPgTPC with hydrogen should also be investigated.

DUNE-PRISM

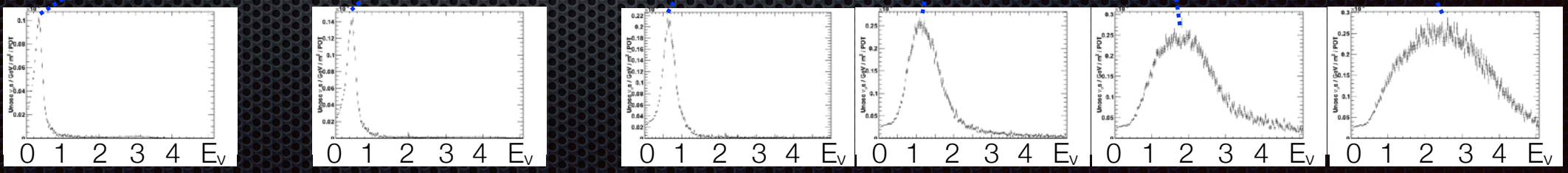
- By moving the near detector off-axis, we can measure different E_ν spectra
- The provides a new degree of freedom over which we can constrain E_{rec} vs E_{true}
- Goal is to make measurements as similar as possible in all off-axis positions



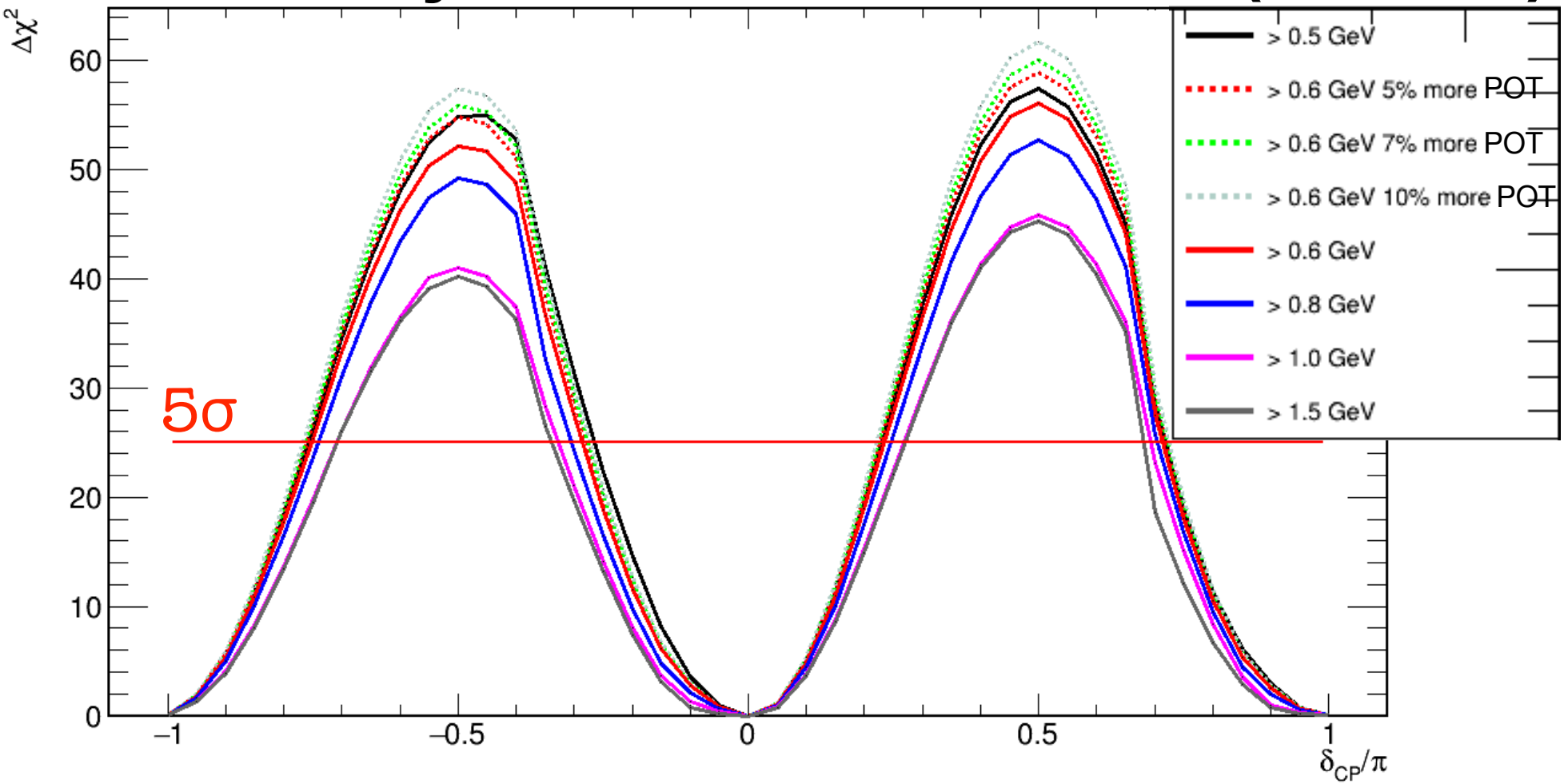
Beam

Increasing Off-axis angle

... ND Position 5 | ND Position 4 | ND Position 3 | ND Position 2 | ND Position 1



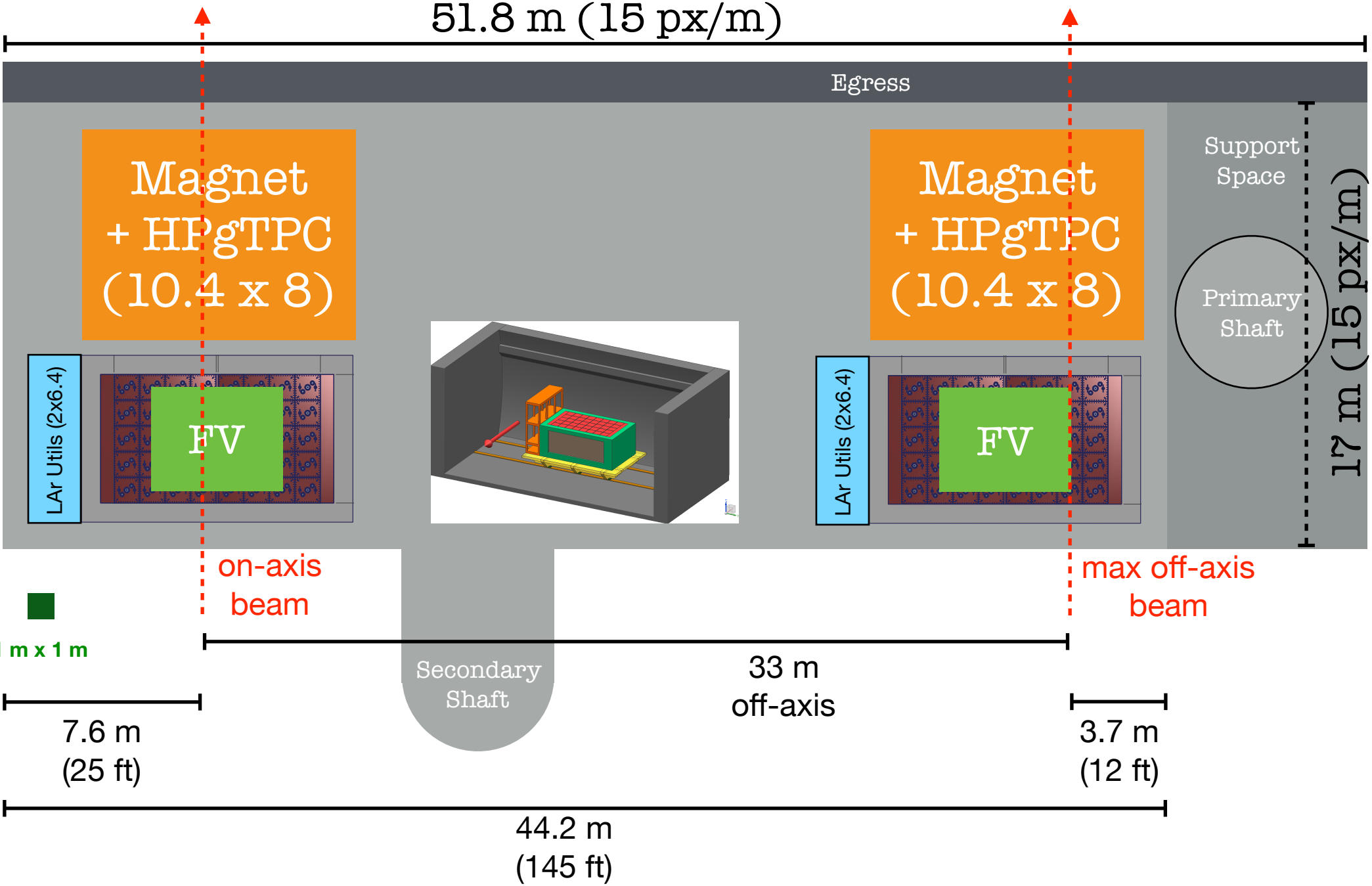
δ_{CP} Sensitivity vs Off-Axis Reach (Min-E_ν)



- The sensitivity gain in moving from maximum off-axis positions of 28 m (600 MeV) to 33 m (500 MeV) corresponds to an increase in far detector exposure of:
  - 10% to get the same 5σ coverage of δ_{CP} in the -π/2 (non-T2K excluded) region
  - 7% to get the same 5σ coverage over all values of δ_{CP}
- These correspond to 23 or 16 m less far detector length (over all four 10 kt modules)

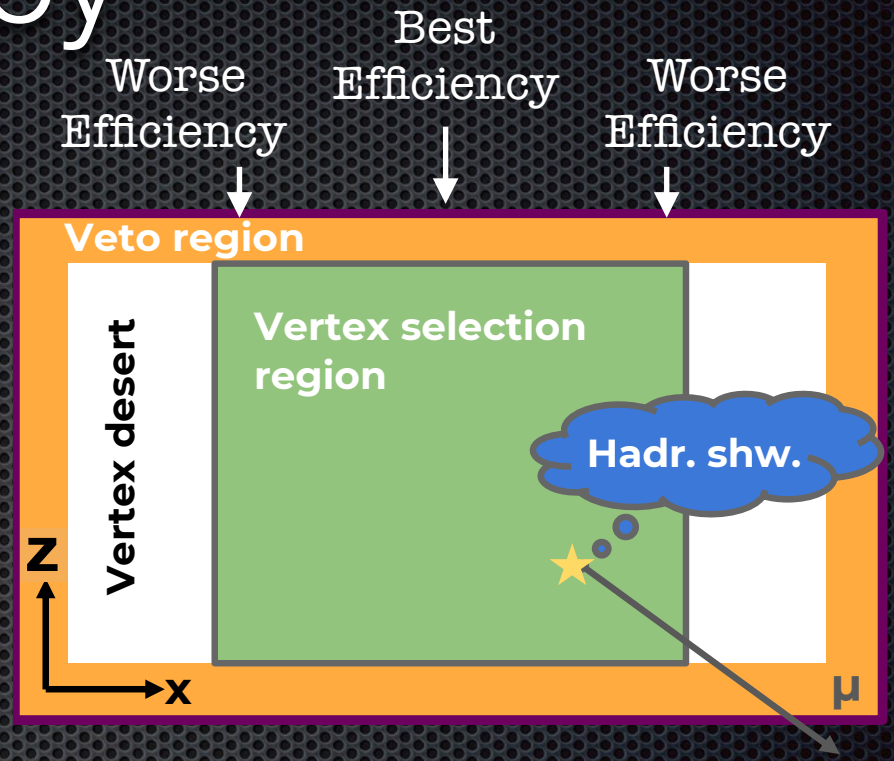
ND Hall Layout ("Ideal" Width)

+ 5 additional ft of support space

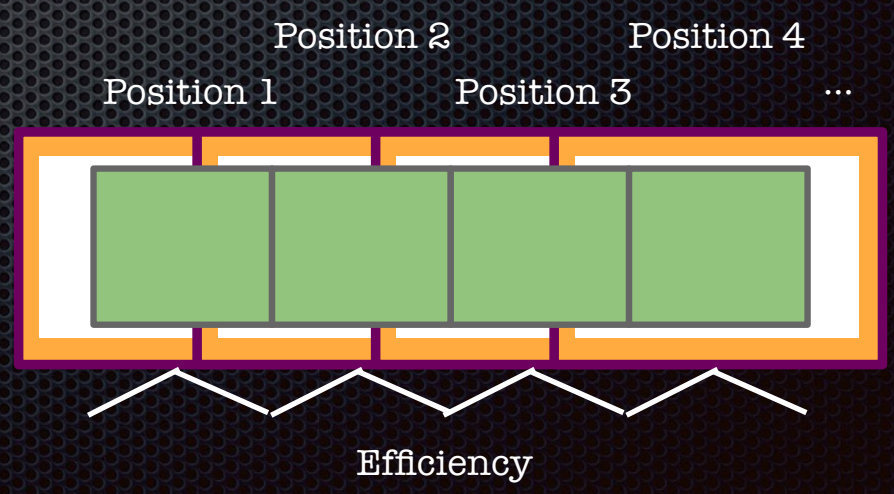


Detector Efficiency

- As events get closer to the sides of the detector, the efficiency decreases due to the shower of particles produced
  - This decrease depends on the cross section modeling, which is difficult to understand
- Current plan is to use neutrino interactions within the central 4 m of the detector
  - 9 non-overlapping positions (including on-axis) provides 34 m in off-axis range
- However, we would ideally like to make as many additional intermediate stops as possible to reduce efficiency variations
  - The possibility of taking data while continuously moving the detector is also being explored



Configuration with the Least Number of Detector Stop Positions



Detector Movement

- It may be important to return the detector to the on-axis position semi-regularly for beam monitoring (monthly? more frequently?)
- Moving the detector a full 34 m in one 8-hour shift corresponds to a speed requirement of **1.2 mm/s**
  - At this speed, moving 4 m between adjacent off-axis positions would take 1 hour
  - Or, moving between 50 cm sub-steps in 7.5 minutes (which would require moving the detector every few hours)
- Are there hydrodynamic effects (e.g. sloshing) that limit the speed (or frequency) of movement? Is faster movement possible?
  - Faster speeds would allow for less downtime if the detector cannot take data while moving
  - If we can take data while moving, slower speeds may be possible
    - e.g. at 0.1 mm/s, we can travel down the full shaft and back in 1 week

Summary

- The detector must be able to move to at least 9 different positions, but more intermediate positions are highly desirable
  - The design should minimize (and hopefully eliminate?) disconnections/reconnections for different off-axis positions
  - First guess at precision: detector placement of <1 cm may be sufficient (1-2% of currently assumed off-axis bin size), but we likely need to measure any given location to <1 mm
- The maximum achievable speed should be at least 1 mm/s, and possibly faster if there are no additional engineering constraints
  - Slower speeds may be useful if the detector can take data while moving
- For efficiency uniformity at all off-axis locations, the HPgTPC would ideally move with the LAr (i.e. a single platform that moves both detectors can be explored, although this is still to be decided within the ND design group)