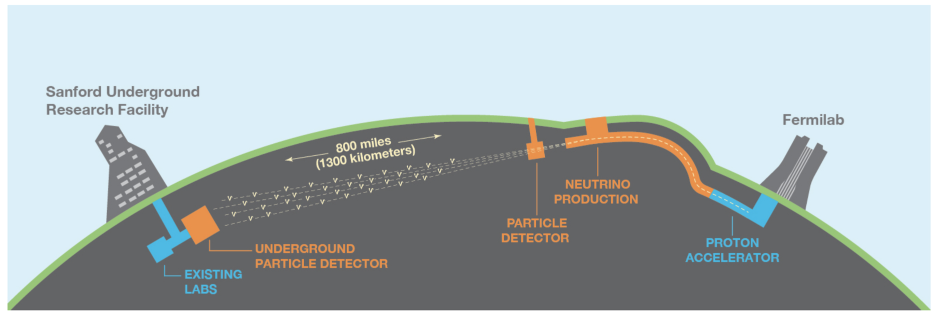
DUNE's Far Detector Photon Simulation

Beatriz Tapia [1] (on behalf of the DUNE Collaboration)

[1]University of Texas at Austin

The DUNE Experiment

The Deep Underground Neutrino Experiment will consist of two underground detectors exposed to 1.2 MW (upgradeable to 2.4 MW) intense neutrino beam. Equipped with a far detector that consists of four 10 kton liquid argon time projection chambers and a near detector at a distance of 1300 km, this international collaboration aims to enter the precision era of neutrino oscillations. Its primary objectives are the measurement of the mixing angles θ_{13} and θ_{23} and the charge-parity violating phase δ_{CP}, as well as to determine the neutrino mass ordering. In addition, DUNE is sensitive to neutrinos from core-collapsed supernovae and will conduct nucleon decay searches.



Far Detector Technology

The far detectors will consist of four Time Projection Chambers (TPCs) filled with liquid argon (12 m height, 15.5 m width and 58 m length). Two of the four chambers will be of Single Phase (figure 1) and the other two of Dual Phase type (figure 2).

Single Phase:

- filled only with liquid argon
- approximate drift distance is 3.6 m
- silicon photomultipliers mounted at the end of light guides embedded in the APA structure

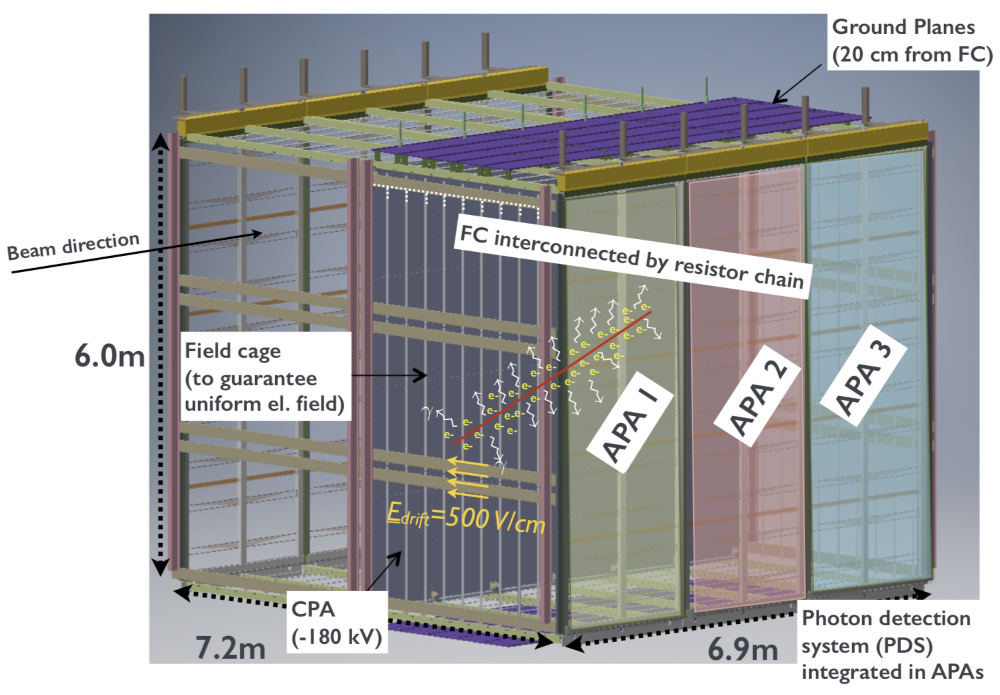


Figure 1: ProtoDUNE Single Phase TPC [3]. APA = Anode Plane Assembly, CPA = Cathode Plane Assembly.

Dual Phase:

- contains mainly liquid argon but also some argon in gas form at the top of the detector
- approximate drift distance is 12 m
- photomultipliers located at the bottom of the detector

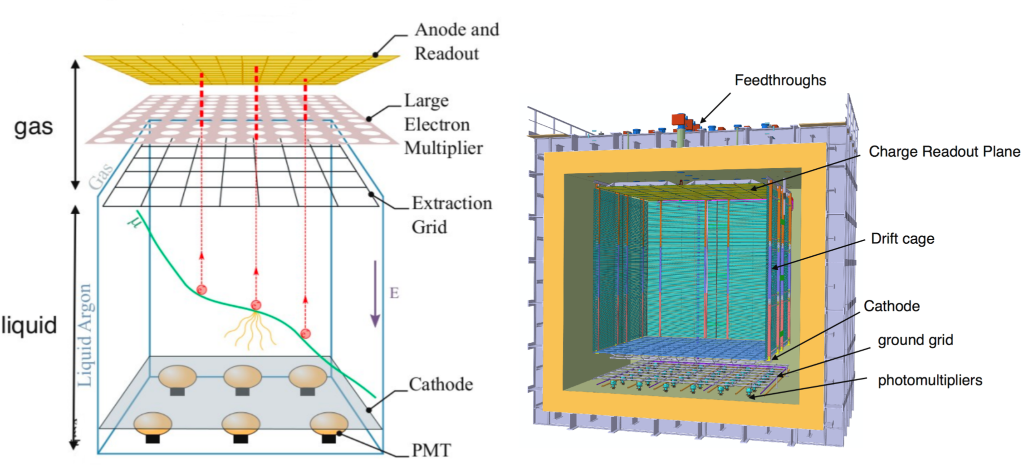


Figure 2: ProtoDUNE Dual Phase TPC [3].

DUNE's Physics

Due to DUNE's 1300 km long baseline physicists will be able to unambiguously determine the neutrino mass hierarchy and measure the value of δ_{CP}. Figure 3 shows the significance with which the mass hierarchy can be determined as a function of the value of δ_{CP}.

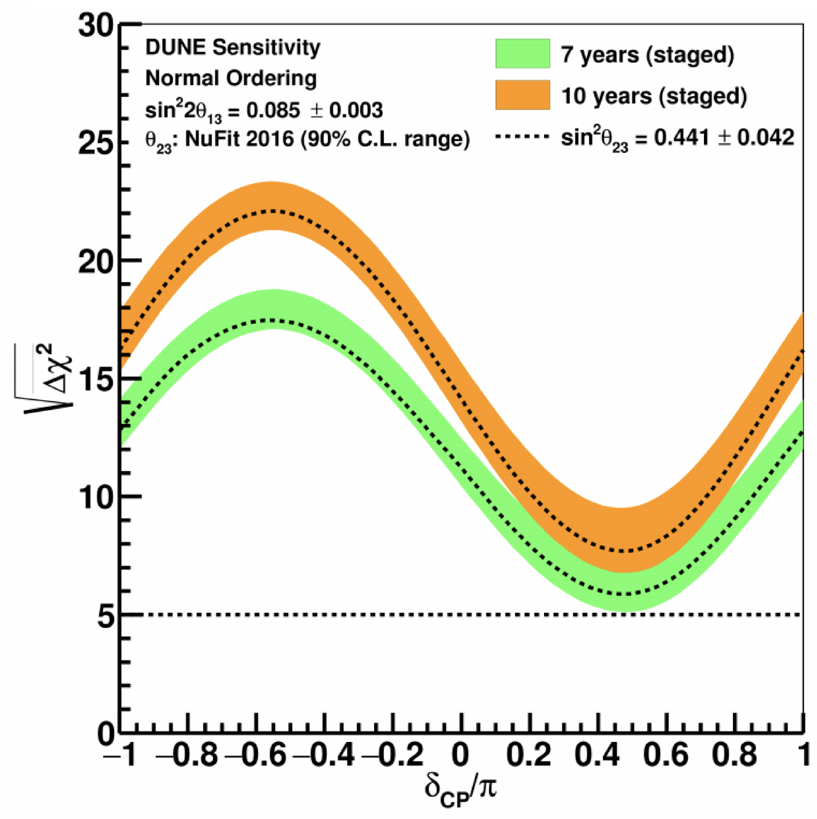


Figure 3: DUNE will enable a discovery of at least 5σ significance for either normal or inverted mass hierarchy [4].

Figure 4 shows the significance with which δ_{CP} can be determined as a function of its value.

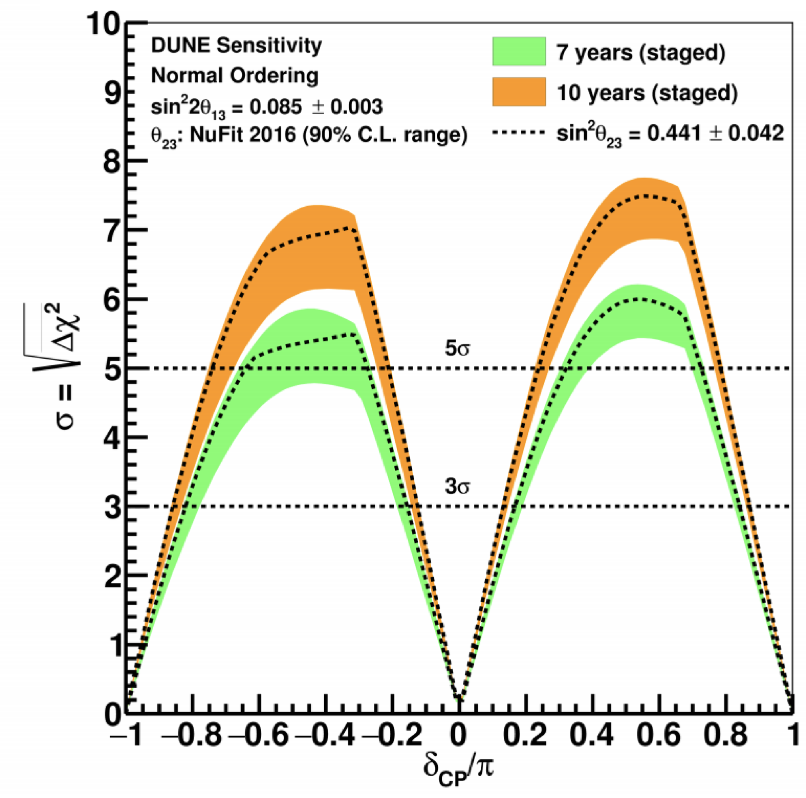


Figure 4: DUNE has the potential of determining the value of $\delta_{CP} \neq 0, \pi$ for either mass hierarchy [4].

Far Detector Photon Simulation

Light detection is key to resolve time reconstruction and to apply crucial trigger conditions for nucleon decay and supernova neutrino searches. The existing photon simulation is too memory-consuming and too slow in order to determine whether the far detector systems will meet these requirements.

The Photon Library is a faster procedure that avoids tracking individual photons by dividing the full LAr volume into voxels, at the center of each of which 10^7 photons are created. Using the full simulation, the amount of photons starting at a given voxel and collected by each of the optical detector bars is stored, see figure 5.

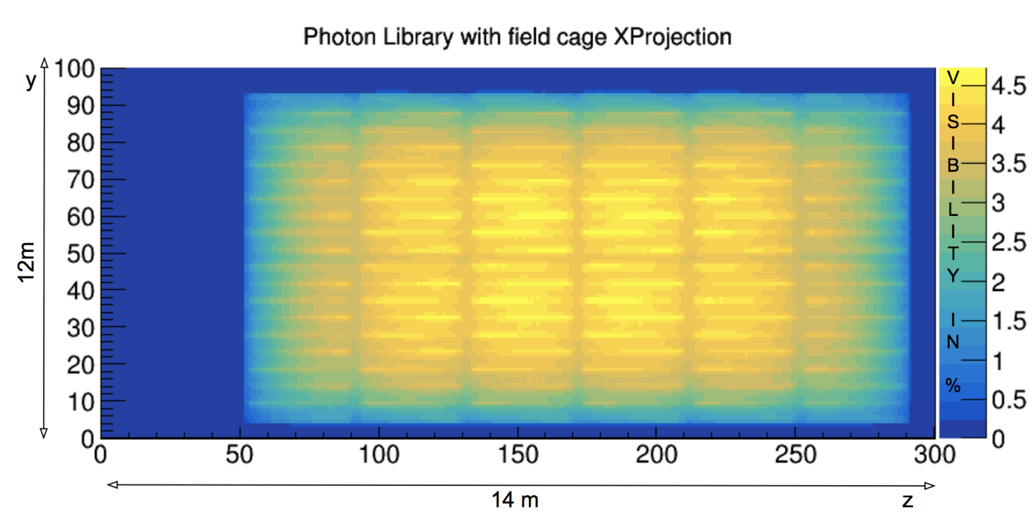


Figure 5: X-axis projection of the visibility (in percentage) of all optical detector bars using the reduced Single Phase far detector.

There are several parametrizations available in order to describe the visibility as a function of the distance or the propagation time of the photons. We are working on a hybrid approach that uses a different parametrization in different regions of the detector. Figure 6 represents one parametrization of the visibilities based on a Landau fit to the photon propagation time distribution.

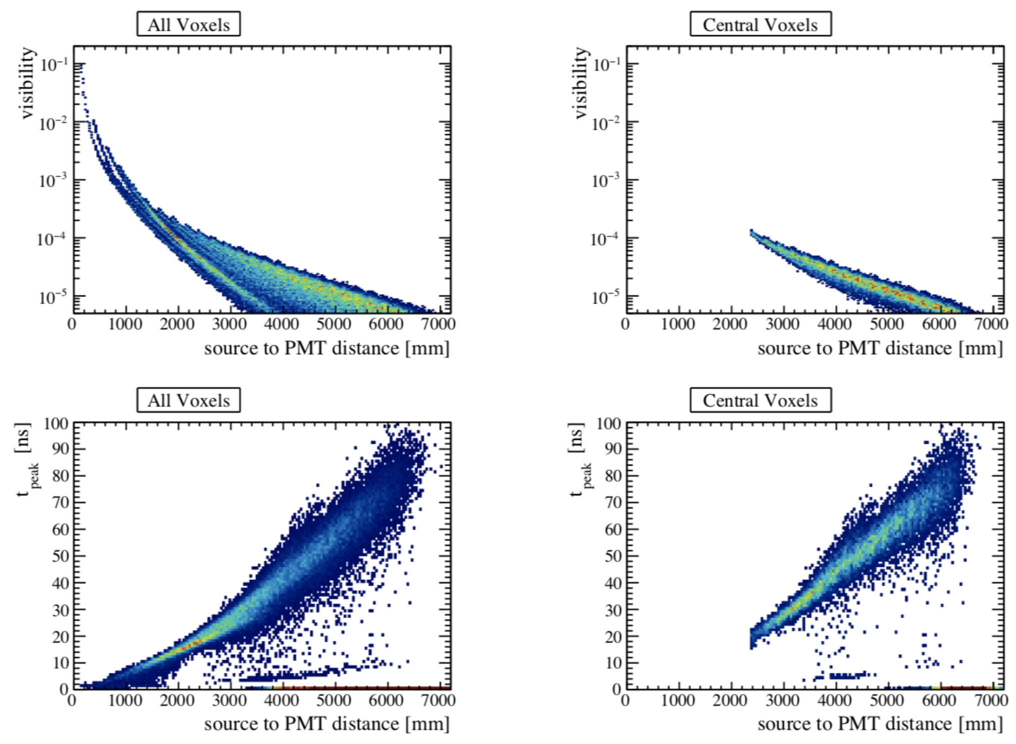


Figure 6: Evolution of the visibility (top) and peak time (bottom) as a function of the center of the voxels to PMT distance simulated using the ProtoDUNE-DP geometry. On the left, all voxels are considered, on the right only the voxels at least 1 m away from the fiducial border are considered.

As one can see, the correspondence between the position of the Landau peak t_{peak} and the visibility is only 1-1 for voxels far away from the boundary. A different parametrization implemented by Chris Backhouse is based on the distance between the optical detectors and the voxels' center. It assumes that the visibility can be predicted by a decaying exponential together with a factor proportional to the inverse square of the distance. This gives a good prediction for large enough distances which will include 97% of the voxels for each optical detector.

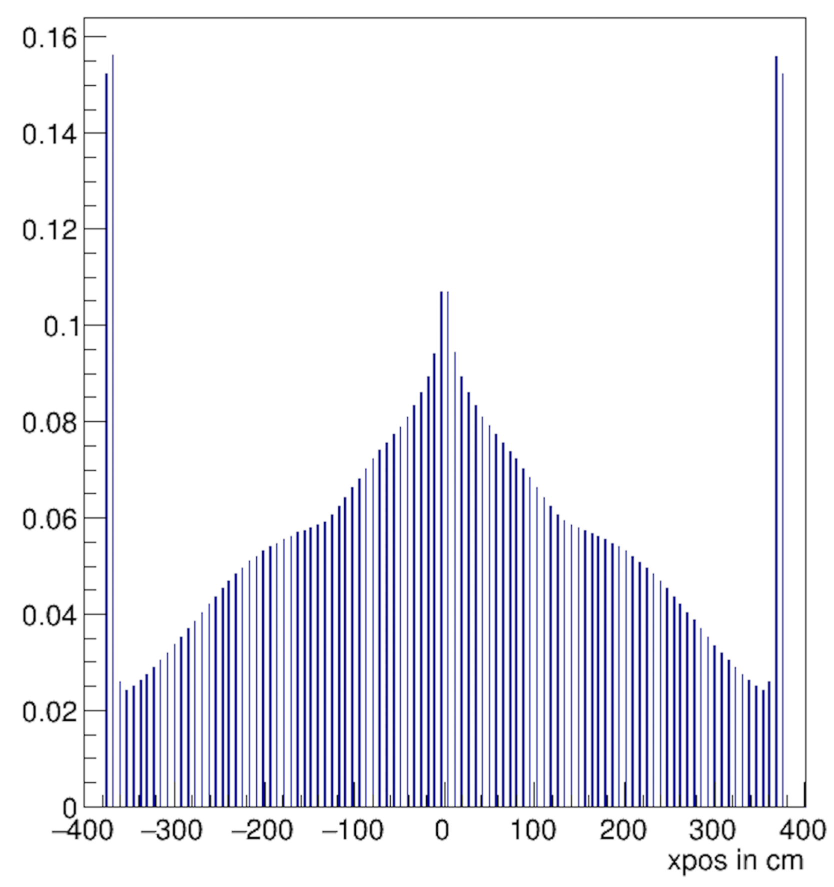


Figure 7: Fraction of voxels that are poorly described by the parametrization based on the distance in the reduced Single Phase far detector.

References

[1] [The DUNE Collaboration], DUNE Conceptual Design Report. (2016).

[2] [The DUNE Collaboration], The Single-Phase ProtoDUNE Technical Design Report. (2017).

[3] Manenti, Laura. "ProtoDUNEs." arXiv preprint arXiv:1705.05669 (2017).

[4] Kemp, Ernesto. "The Deep Underground Neutrino Experiment–DUNE: the precision era of neutrino physics." arXiv preprint arXiv:1709.09385 (2017).