Translating Near to Far Detector for DUNE Oscillation Analysis

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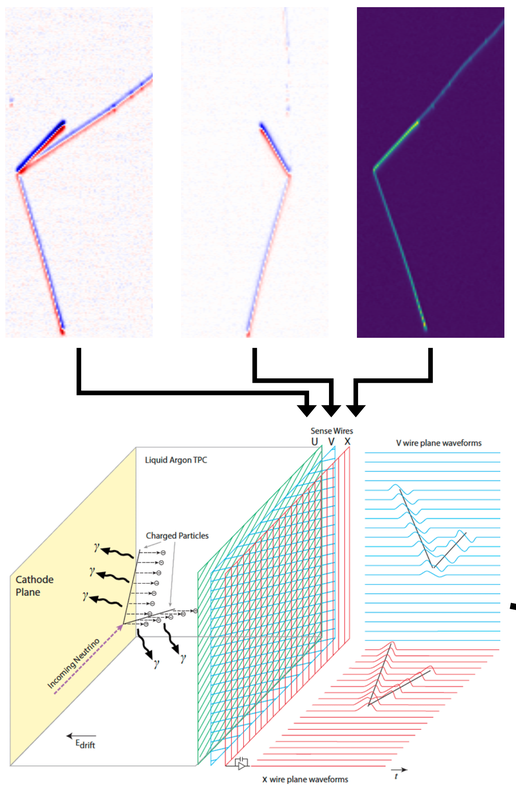
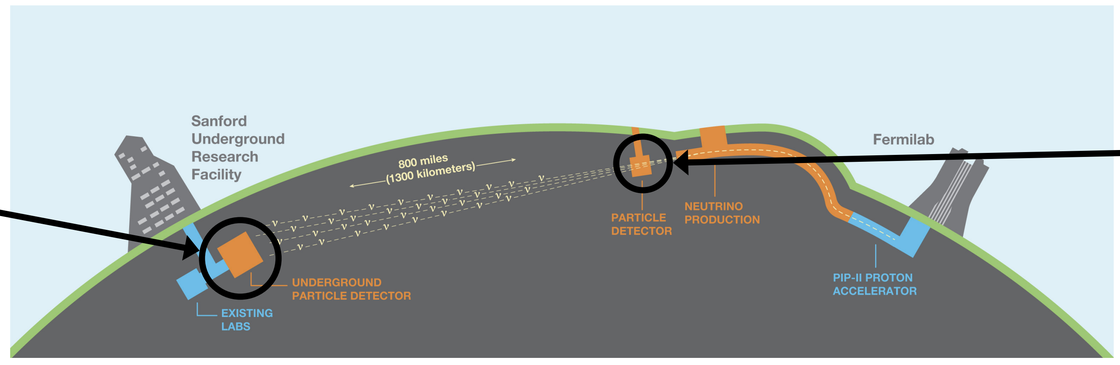
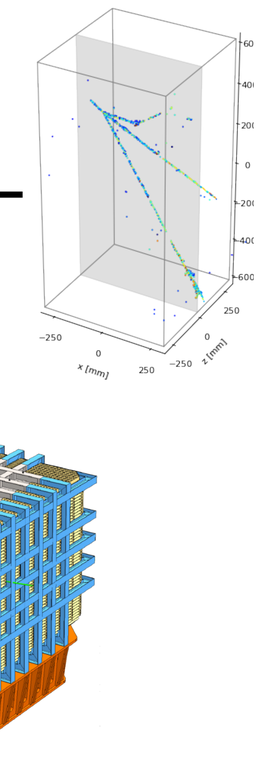
Deep Underground Neutrino Experiment



- DUNE is a next generation long baseline neutrino experiment that aims to measure CP-violation in the neutrino sector as part of a wider physics programme
- Far detector (FD) is four 17 kt LArTPC modules with layered wire planes to readout charge
- Near detector (ND) is built around a smaller modular LArTPC with a pixel readout
- Oscillation physics comes from studying event rates at near and far detectors:

$$N\left(E_{rec}\right) = \int dE_{\nu} \Phi\left(E_{\nu}\right) \times \sigma\left(E_{\nu}\right) \times \mathbf{D}\left(E_{\nu}, E_{rec}\right) \underbrace{\times P_{osc}\left(E_{\nu}\right)}_{\text{FD only}}$$



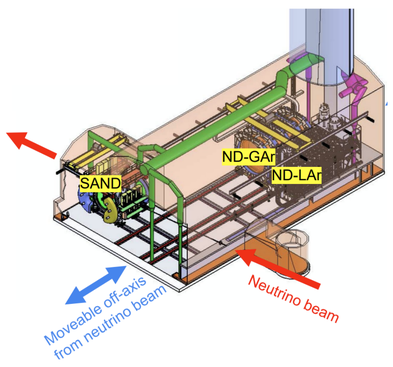


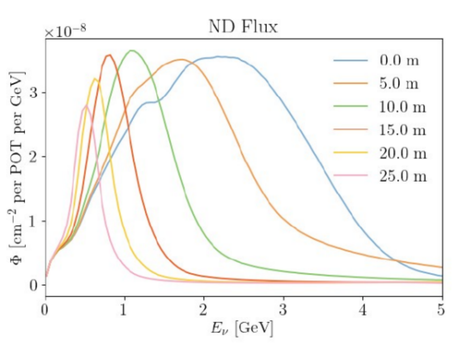
Precision Reaction Independent Spectrum Measurement

- Taking data with different fluxes helps break the degeneracy in tuning neutrino-nucleus interaction model with ND data
- Wide range of off-axis positions allows the set of fluxes to be treated as a linearly independent basis so we can take ND measrurements in an oscillated FD flux:

$$\Phi_{ND}\left(E_{\nu}, x_{OA}\right) \times \vec{c} = \Phi_{FD}\left(E_{\nu}\right) P_{osc}\left(E_{\nu}\right)$$

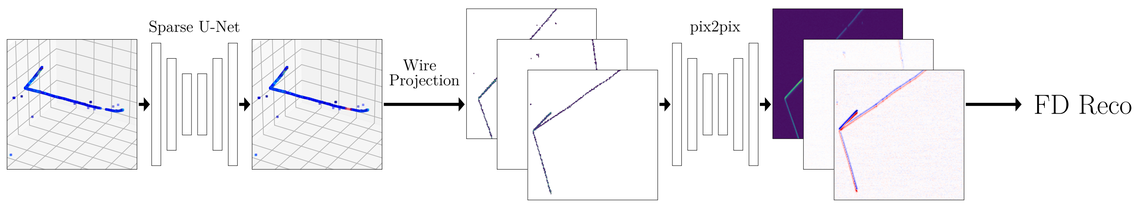
- Combining ND measurements like this, oscillation parameters are found by minimising the distance between event rates in the ND and FD — no interaction model invoked!





Translating Near to Far Detector

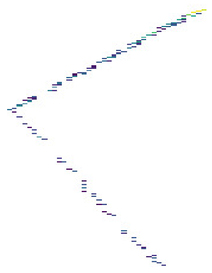
- FD and ND have different resolution and selection which need to be corrected to compare spectra between ND and FD — $\mathbf{D}^{FD}\left(E_{\nu}, E_{rec}\right) \neq \mathbf{D}^{ND}\left(E_{\nu}, E_{rec}\right)$
- To extrapolate from ND to FD can unfold $E_{rec}^{ND} \rightarrow E_{\nu}$ and smear $E_{\nu} \rightarrow E_{rec}^{FD}$ but this uses an interaction model
- To correct for resolution without an interaction model, consider an image-to-image translation:



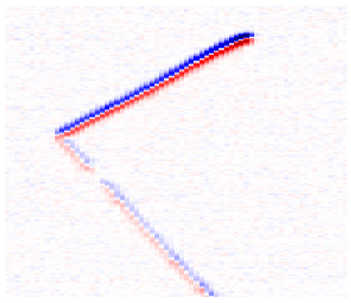
- Paired images for training data are generated by simulating events in a LAr box and placing in both ND and FD

Network Predictions

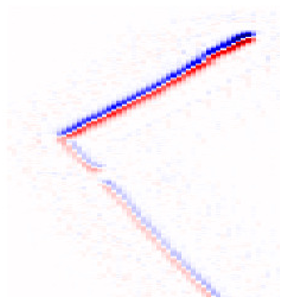
ND Input

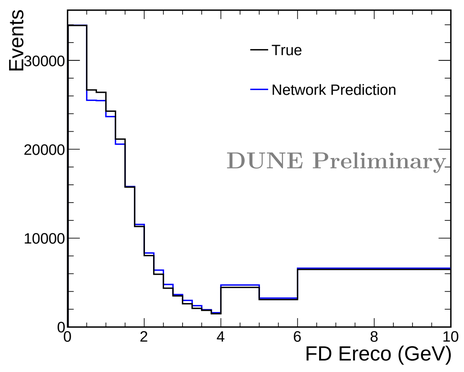


FD Output



FD Truth

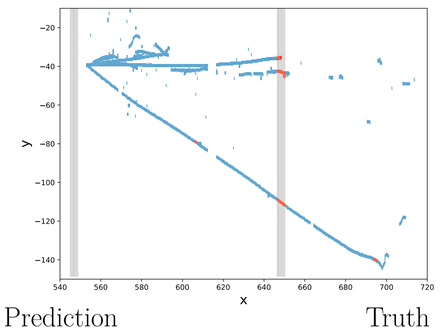




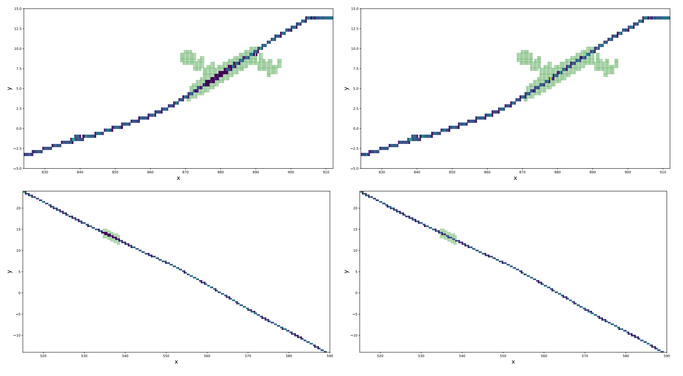
Infilling Gaps

- Developing network to fill in tracks between ND-LAr drift modules
- Apply sparse machine learning to infill dead regions for 3D ND-LAr event

Training Data

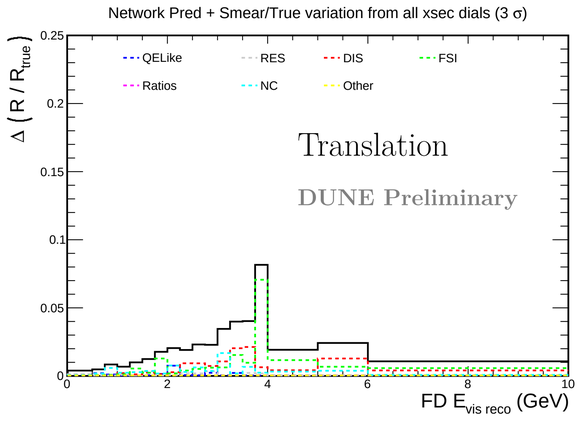


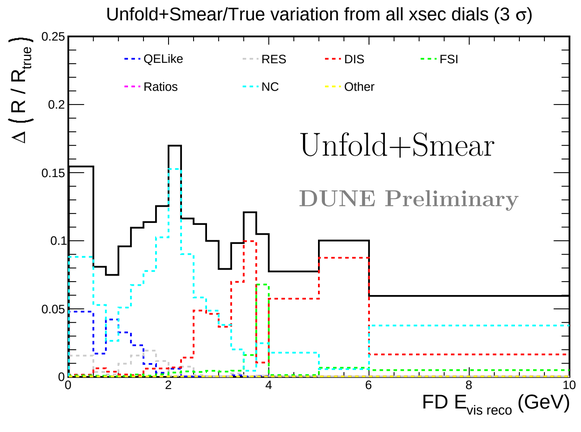
Prediction Truth



Cross Section Systematics

- Compare FD E_{rec} predictions from unfold+smear with translation network under xsec systematics event reweighting
- Variation in ratio of FD prediction with FD truth under reweights tells us how much the prediction depends on the cross sections — look at all xsec systematics in quadrature:





References

[1] DUNE Collaboration.
Deep Underground Neutrino Experiment (DUNE) Near Detector Conceptual Design Report.
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[2] Phillip Isola et al.
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