Near Detector Strategy at DUNE

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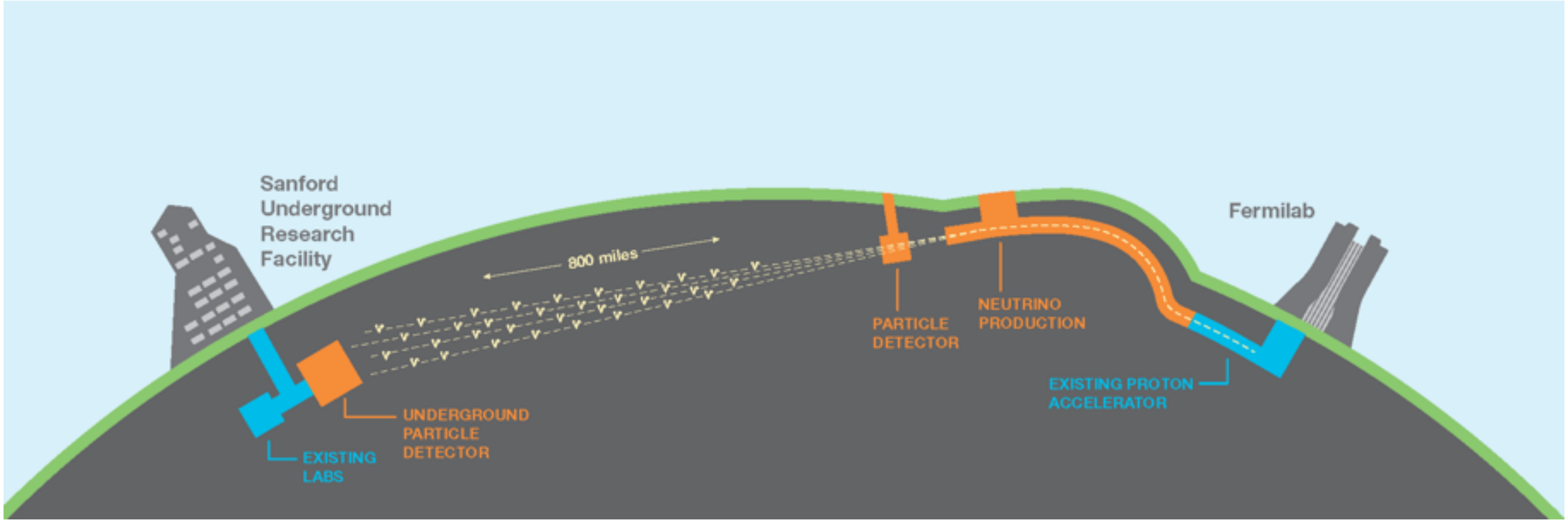
CERN TPC Workshop

Outline

- Near Detector Options
  - Fine Grained Tracker
  - Liquid Argon TPC
  - Gaseous Argon TPC
- Evaluation of options
- What's next?

DUNE



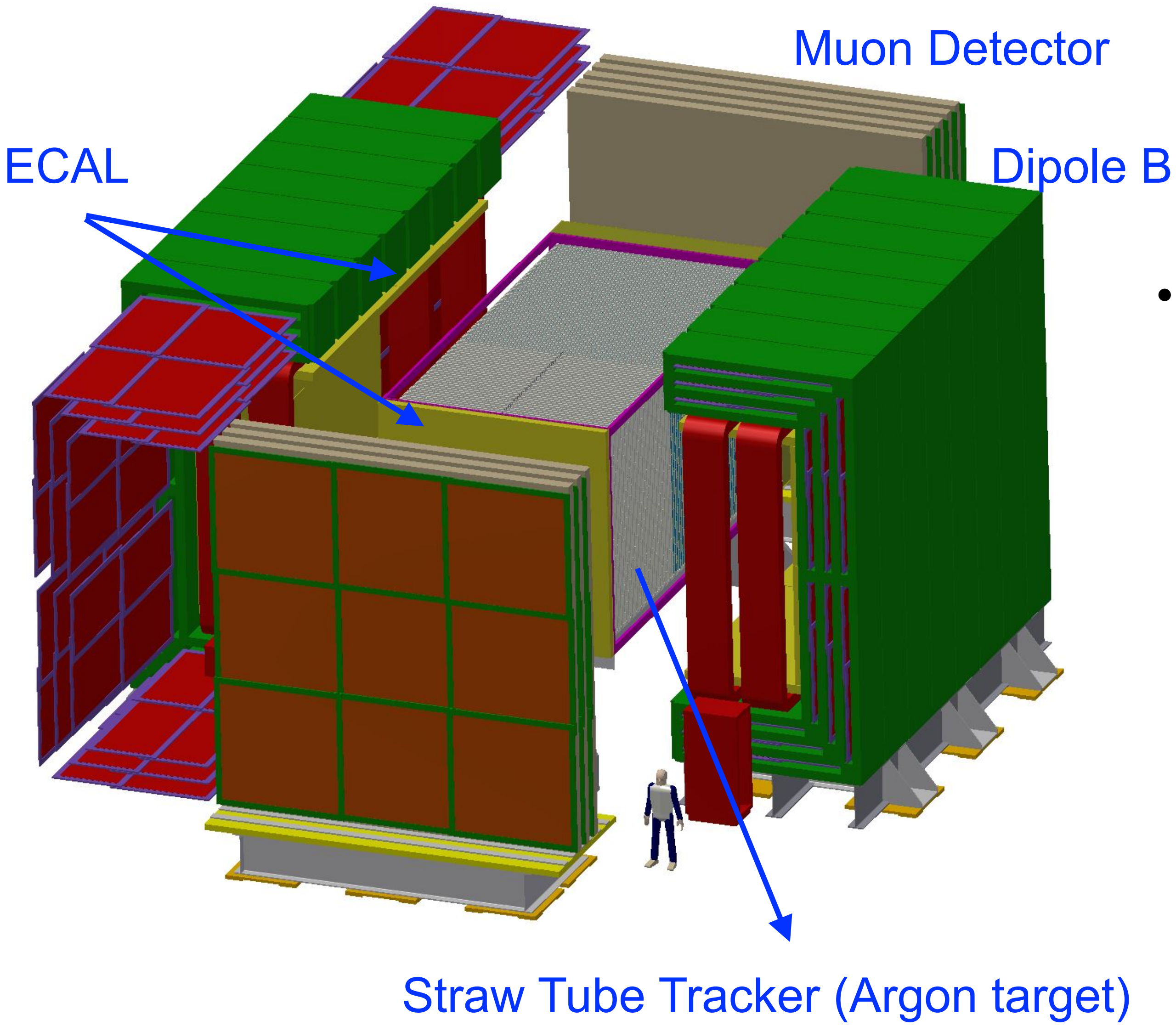
Sanford Underground Research Facility
800 miles
Fermilab
PARTICLE DETECTOR
NEUTRINO PRODUCTION
EXISTING PROTON ACCELERATOR
UNDERGROUND PARTICLE DETECTOR
EXISTING LABS

Purpose

- Constrain the systematics for oscillation measurement
  - Measure spectra of all four species of neutrinos: ν_μ, $\bar{\nu}_\mu$, ν_e, $\bar{\nu}_e$
  - Measure the absolute and relative flux: FD/ND(Eν)
  - Constrain & Model nuclear effects: $\nu/\bar{\nu}$-Ar
  - Quantify differences between neutrino and antineutrino: energy scale, event topology, cross-section, etc.
  - Constrain pion backgrounds: π^0,$\pi^\pm$
- Other cross section physics
- Other exotic physics

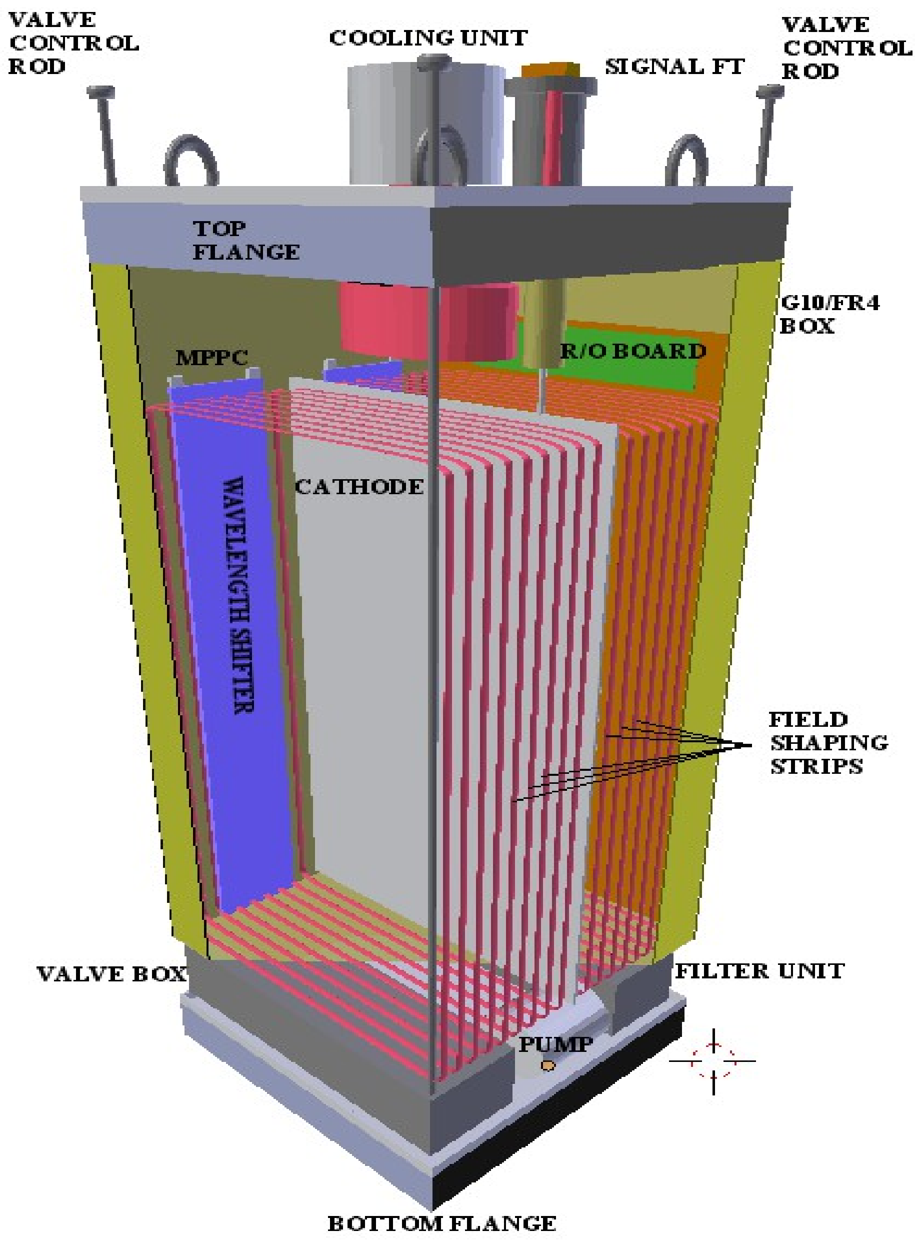
Fine Grained Tracker

- CDR reference design
- Central region is 3.5 m x 3.5 m x 6.5 m straw-tube tracker
- 0.4 T magnetic field
- 4π ECal



Liquid Argon TPC

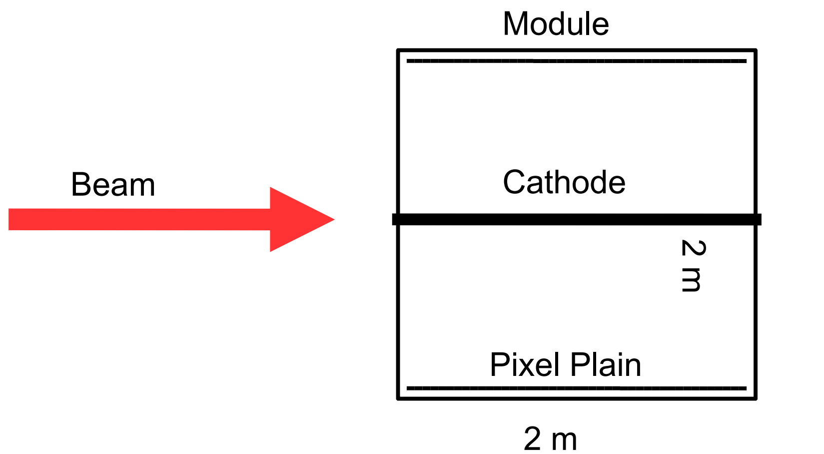
- Modular units of 2m x 2m x 3m
- Stack units into a larger cuboid
- Detector has been show to be magnetizable



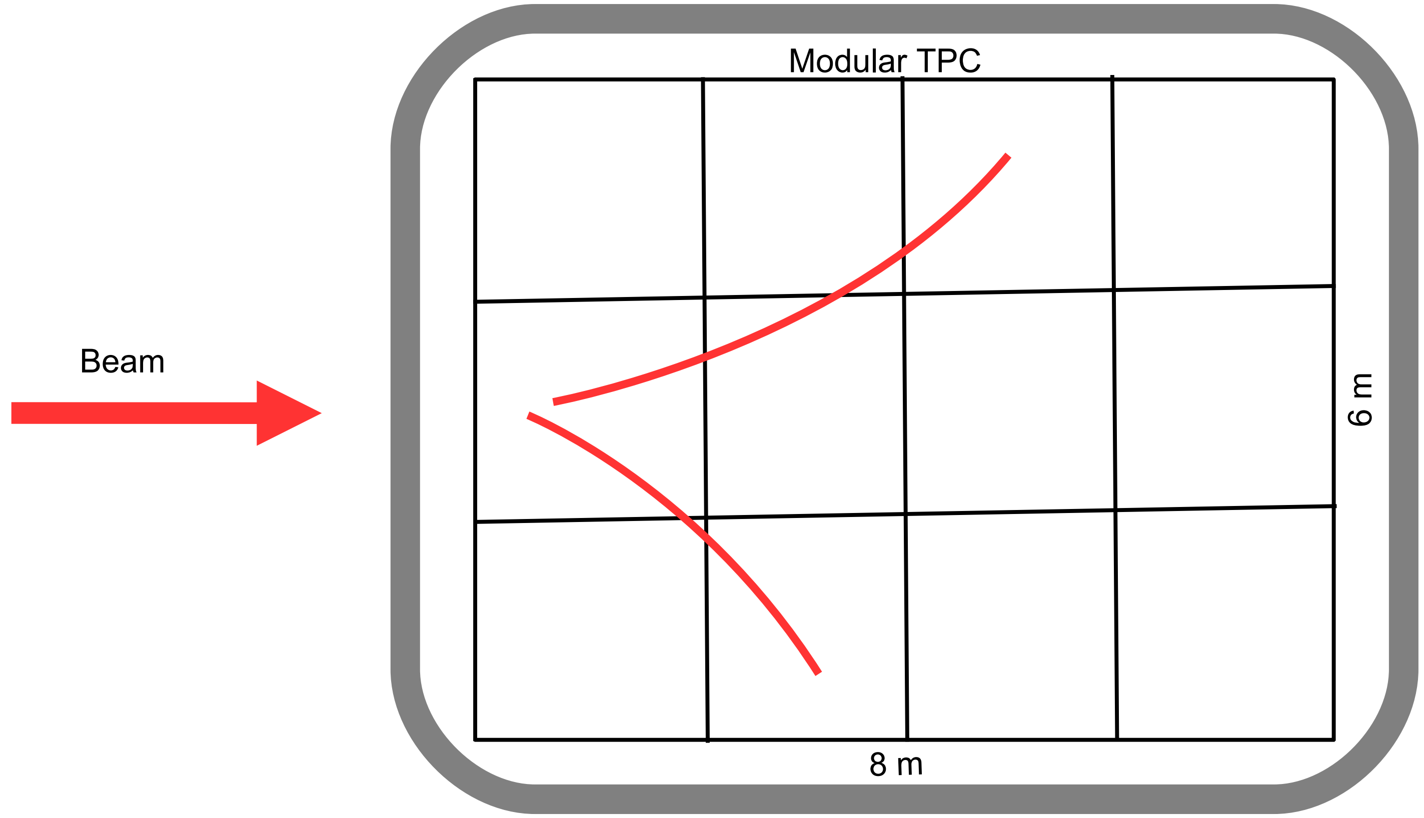
Liquid Argon TPC

Modular TPC total 6 m x 8 m x 3 m, ~ 200 t

Module 2 m x 2 m x 3 m.
1 m drift length



E-Field 100 kV (1 kV/cm)



Superconducting Helmholtz, B-field 1T

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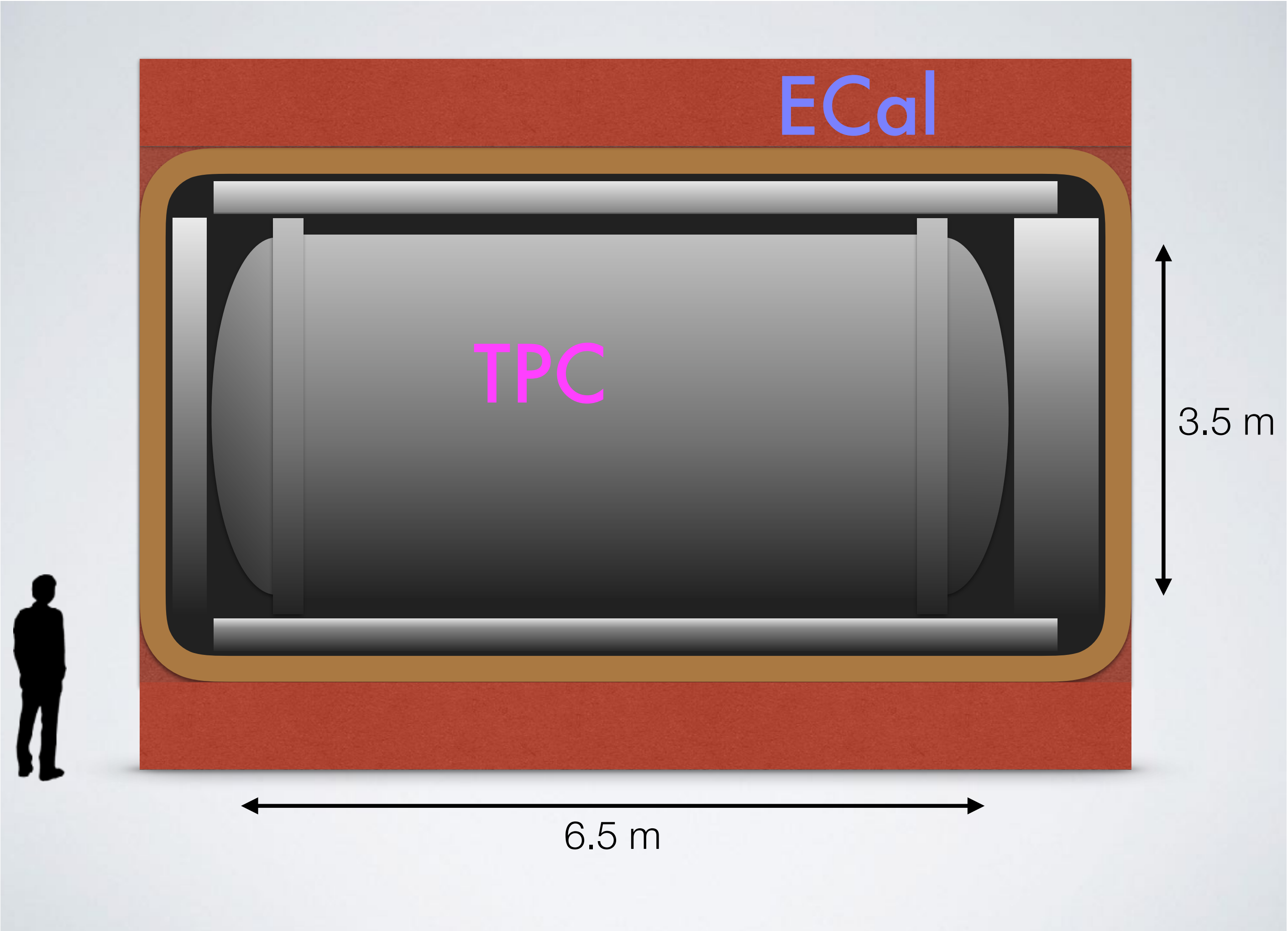
Gaseous Argon TPC

- 3.5 m x 6.5 m TPC
- Surrounded by an ECal
- More on this from Justo tomorrow!



Pros and Cons

- Predominantly argon: TPCs
- Thresholding (high to low): LAr, FGT, GAr
- Out-of-Fiducial Backgrounds (low to high): LAr, FGT, GAr
- Energy resolution: it depends!

Method of Comparison

- Build GEANT4 models of all the detectors
- Use the same beam inputs and cross section model (GENIE) for three detectors
- Define exclusive sample (more on this later)
- Compare constraints on underlying parameters and oscillation parameters

Work by the VaLOR Group: C. Andreopoulos, et al.

`Reconstruction'

- All options currently use truth-based reconstruction based on smearing from previous detectors
- Selections are based on truth-based efficiencies from previous detectors
- Samples are fit in reconstructed or visible energy and reconstructed y (for high stats)

`Selected' Samples

- ν_μ **CC**

CCQE and 2p2h, etc models

1. 1-track 0π (μ^- only)
2. 2-track 0π (μ^- + nucleon)
3. N-track 0π (μ^- + 2 or more nucleons)

Resonance models

4. 3-track Δ-enhanced ($\mu^- + \pi^+ +$ p, with $W_{reco} \approx 1.2$ GeV)
5. $1\pi^\pm$ ($\mu^- + 1\pi^\pm + X$)
6. $1\pi^0$ ($\mu^- + 1\pi^0 + X$)
7. $1\pi^\pm + 1\pi^0$ ($\mu^- + 1\pi^\pm + 1\pi^0 + X$)

Everything else

8. Other

WS Contamination

- **Wrong-sign** ν_μ **CC**

9. 0π ($\mu^+ + X$)
10. $1\pi^\pm$ ($\mu^+ + \pi^\pm + X$)
11. $1\pi^0$ ($\mu^+ + \pi^0 + X$)
12. Other

ν_e Contamination

- ν_e **CC**

13. 0π ($e^- + X$)
14. $1\pi^\pm$ ($e^- + \pi^\pm + X$)
15. $1\pi^0$ ($e^- + \pi^0 + X$)
16. Other

- **Wrong-sign** ν_e **CC**

17. Inclusive

NC

- **NC**

18. 0π (nucleons allowed)
19. $1\pi^\pm$ ($\pi^\pm + X$)
20. $1\pi^0$ ($\pi^0 + X$)
21. Other

Beam Normalization

- ν**-e**

22. $\nu_e + e^-$ elastic
23. Inverse muon decay $\bar{\nu}_e + e^- \to \mu^- + \bar{\nu}_\mu$ (including the annihilation channel $\nu_\mu + e^- \to \mu^- + \nu_e$).

Beam Normalization

- Expect roughly ~8k (FGT) $\nu_x + e^- \rightarrow \nu_x + e^-$ events, which is ~2% total normalization uncertainty
- This technique has been shown to work at MINERvA, but has not been used in an oscillation experiment to date

Cross Section Model

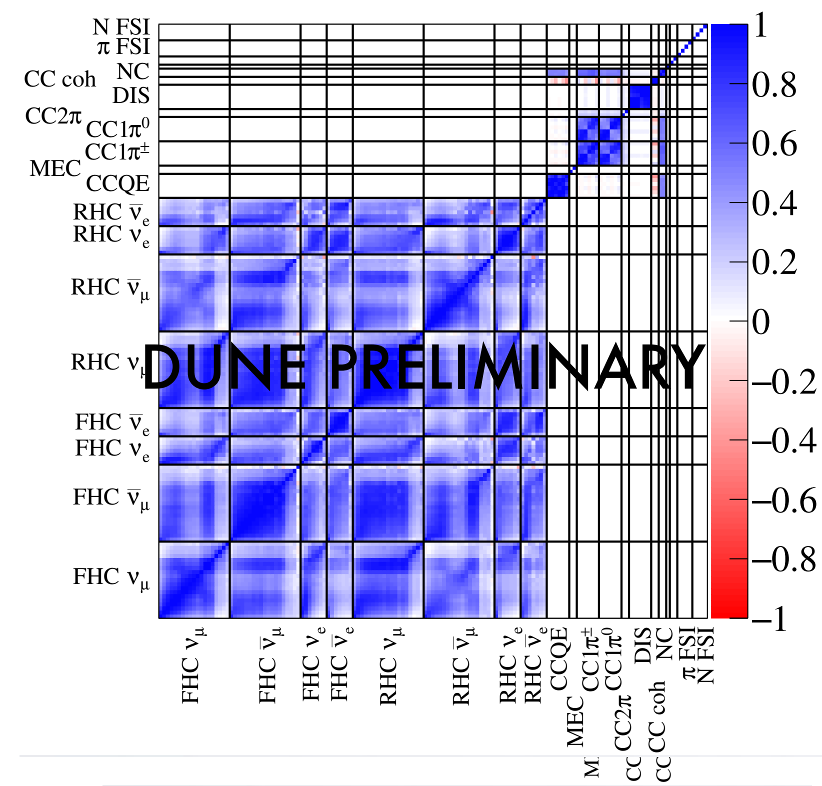
- CCQE and 2p2h, etc: There is a lot of power here! Many events, even in GArTPC
- Single pion: This is extremely important at DUNE; oscillation dip is in the middle of 1π final state distribution
- CC Other: This is all lumped together at the moment; could there be anything useful here?

Cross Section Model

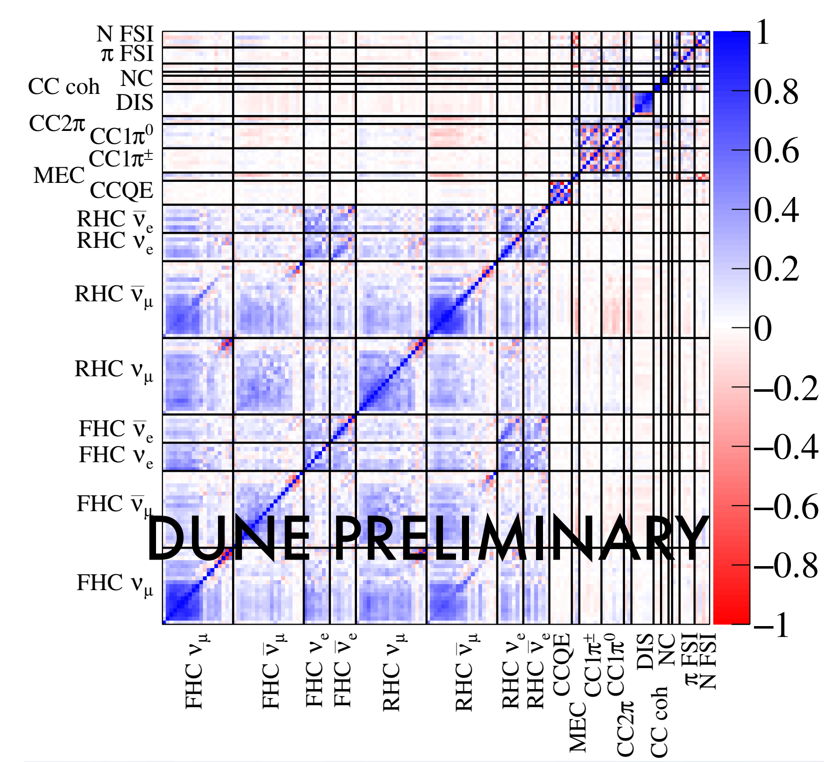
- Wrong Sign Background: FD isn't magnetized; important constraint here
- ν_e Background: Clearly important for beam backgrounds
- NC: Mostly important for FD ν_e sample; little leakage into ν_μ

Preliminary Results

- Get reduction in uncertainty, puck up correlation between flux and cross section
- Difference in effect on final CP sensitivity between three options is relatively minimal



Prefit



FGT Postfit

Personal Commentary

- Use of exclusive samples is excellent, but it's not clear the current framework is realistic enough in smearing between them
- Right now it appears that the model is more or less measuring sqrt(N); obviously everything is a work in progress!
- Fitting the model to the model is good, but doesn't give us everything we want to know!

Going Forward

- All aspects of simulation (underlying physics, reconstruction, selections) continue to improve
- Optimization of detector concepts is ongoing
- There is some movement towards combining detector concepts; e.g., LArTPC+GArTPC

Summary

- DUNE is currently undergoing a ND physics comparison
- DUNE's ND strategy is based on trying to define and measure exclusive channels to precisely understand the beam and cross section model