DUNE OPPORTUNTIES

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FIRST:

Thanks to Maria Elena et al. for organizing this

It's a great way to see what people are thinking as we go into the Community Summer Meeting in July and bring people together to talk about science

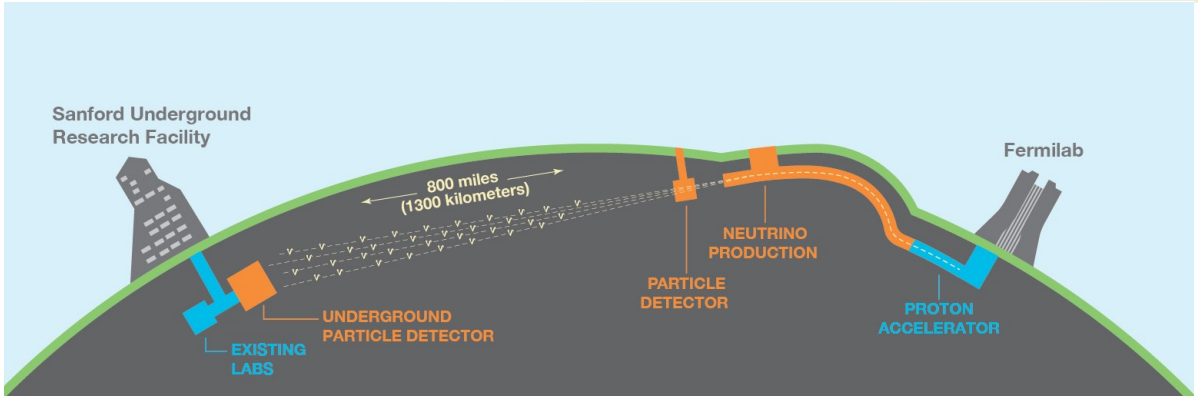
In the following, I will try to:

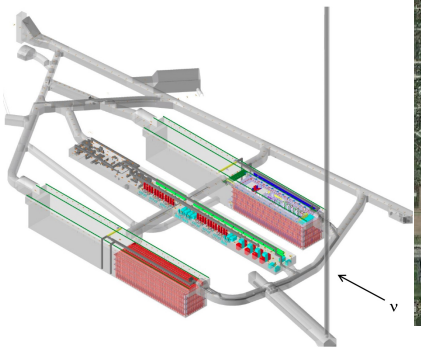
- Overview of LBNF/DUNE
- Why is the experiment the way it is? Why is it needed?
- Near Detector

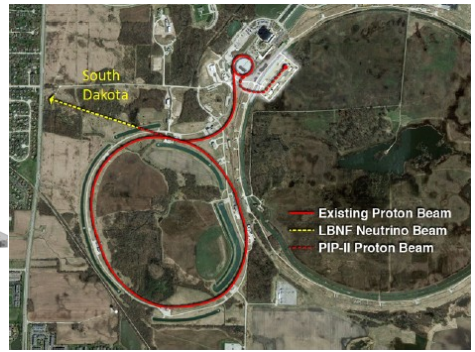
LBNF/DUNE OVERVIEW

arXiv:2203.06100

SLAC







Near Site:

1.2 MW neutrino beam

Near Detector Hall

Far Site:

2 detector halls 1 mile underground

Houses 4 x 17 kton LArTPCs

Phase 1 Detectors

Near Detector (ND)

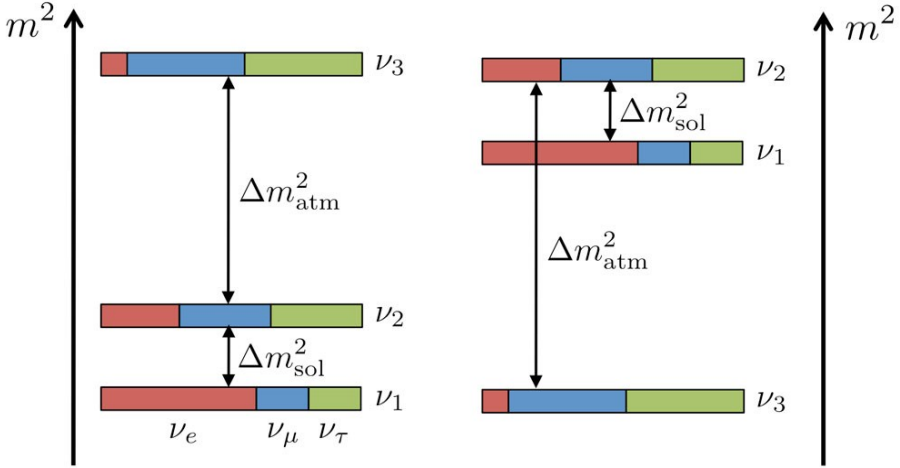
- LArTPC + muon spectrometer
- Moveable up to 30 m off-axis
- On-axis beam monitor

Far Detectors (FD)

- 1 horizontal drift 17 kton LArTPC, wire readout
- 1 vertical drift 17 kton LArTPC, PCB readout

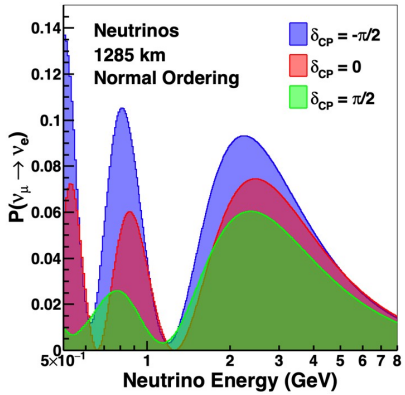
PHYSICS

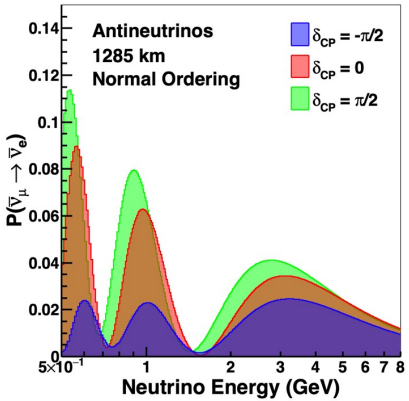
$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \underbrace{\begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix}}_{U_{\mathrm{PMNS}}} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$



- What is the magnitude and sign of Δm^2_{32}?
- What is the value of δ_{CP}?
- What are the values of θ_{13} and θ_{23}?
- Is this three-flavor "ν-SM" picture correct?

REQUIREMENTS





- Long baseline and broad energy spectrum
  - Sensitivity to matter effects
  - Probe detailed L/E dependence of oscillations
- High statistics for precise measurement
  - Intense beam, large FDs
    - Highly effective neutrino flavor tagging and energy resolution
  - Precise control of systematics → near detector

PHASE 1 PHYSICS:

In the first few years of the experiment, goals include:

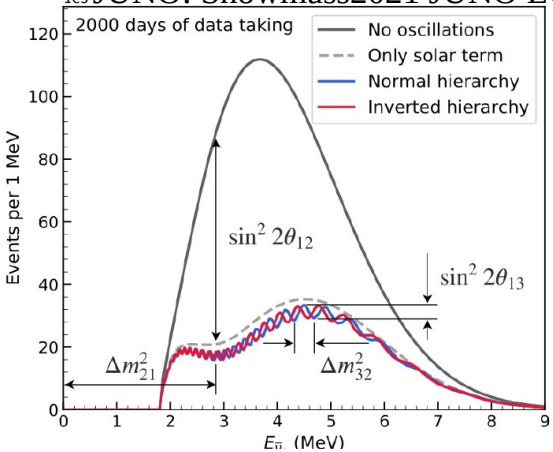
- Definitive determination of the neutrino mass ordering
- 3 σ sensitivity to CPV in maximal case ($\delta_{CP} = \pm \pi/2$)
- World leading measurement of atmospheric mass splitting

With the Phase 1 DUNE detector

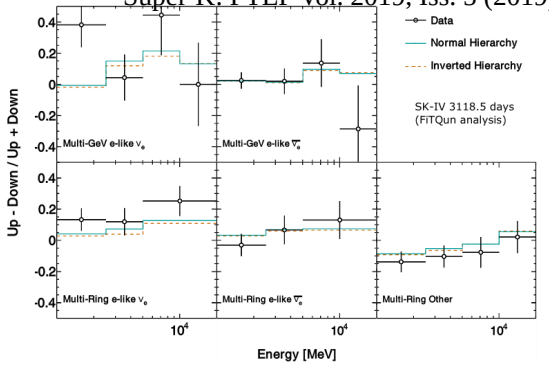
- 2 x 17 LArTPC Far Detectors
- LArTPC + muon spectrometer

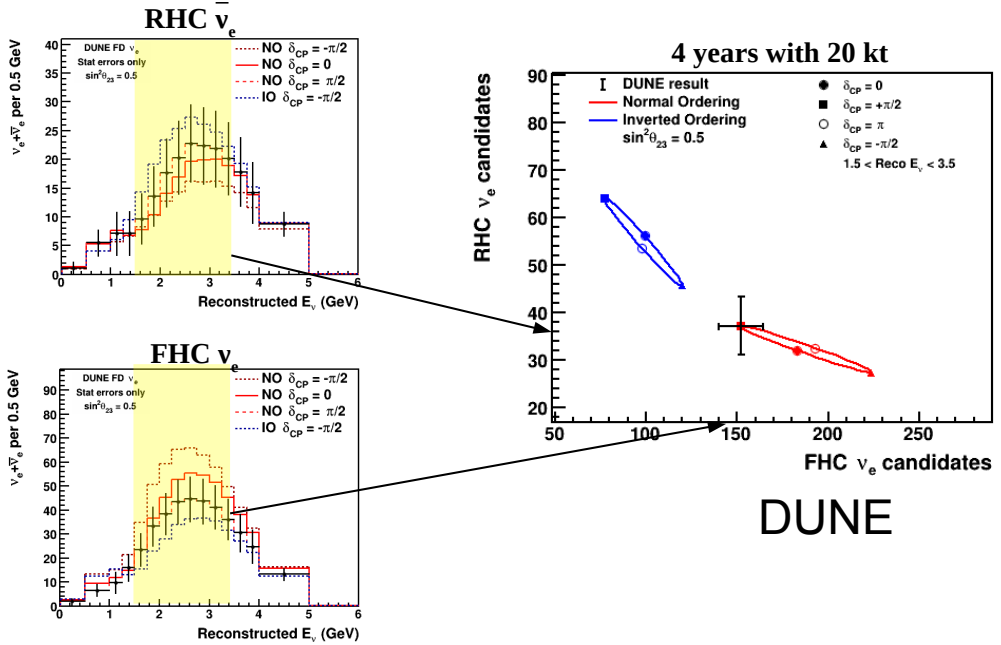
MASS ORDERING

JUNO: Snowmass2021 JUNO LOI



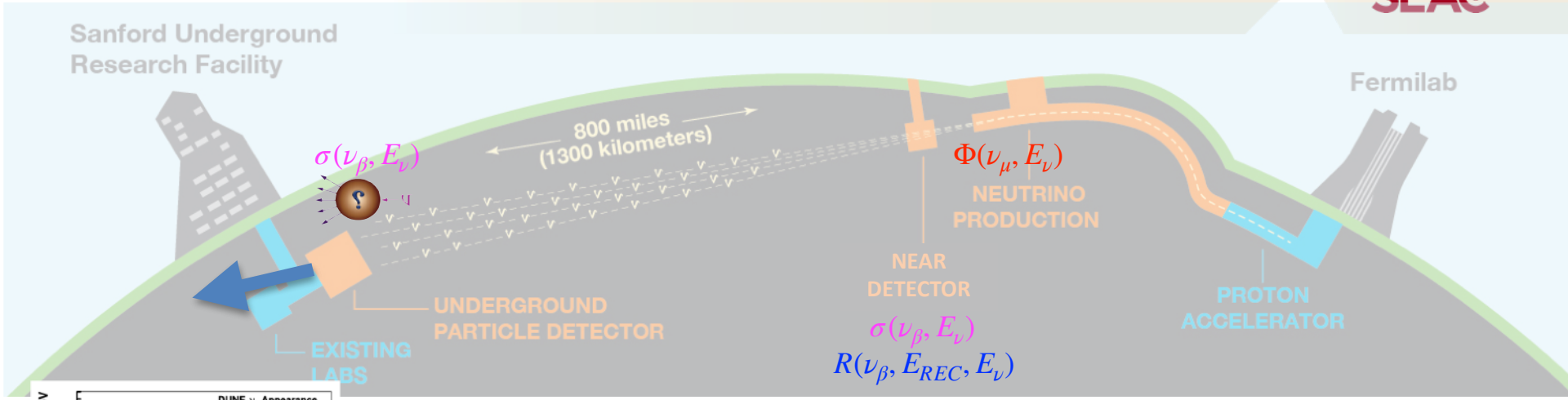
Super-K: PTEP Vol. 2019, Iss. 5 (2019)

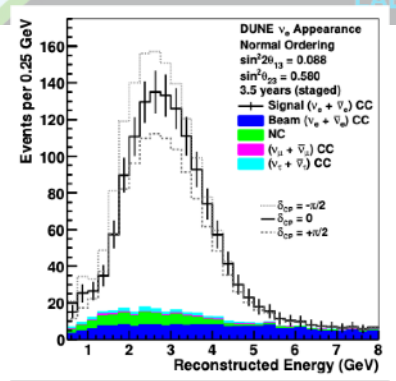




- In ~4 years with conservative beam ramp up scenario, DUNE will definitively determine the mass ordering
- In all but the most “favorable” cases, mass ordering is an essential “gateway” measurement towards CP violation and testing the three flavor ν SM

NEAR DETECTOR





To measure neutrino oscillation parameters, LB experiments compare:

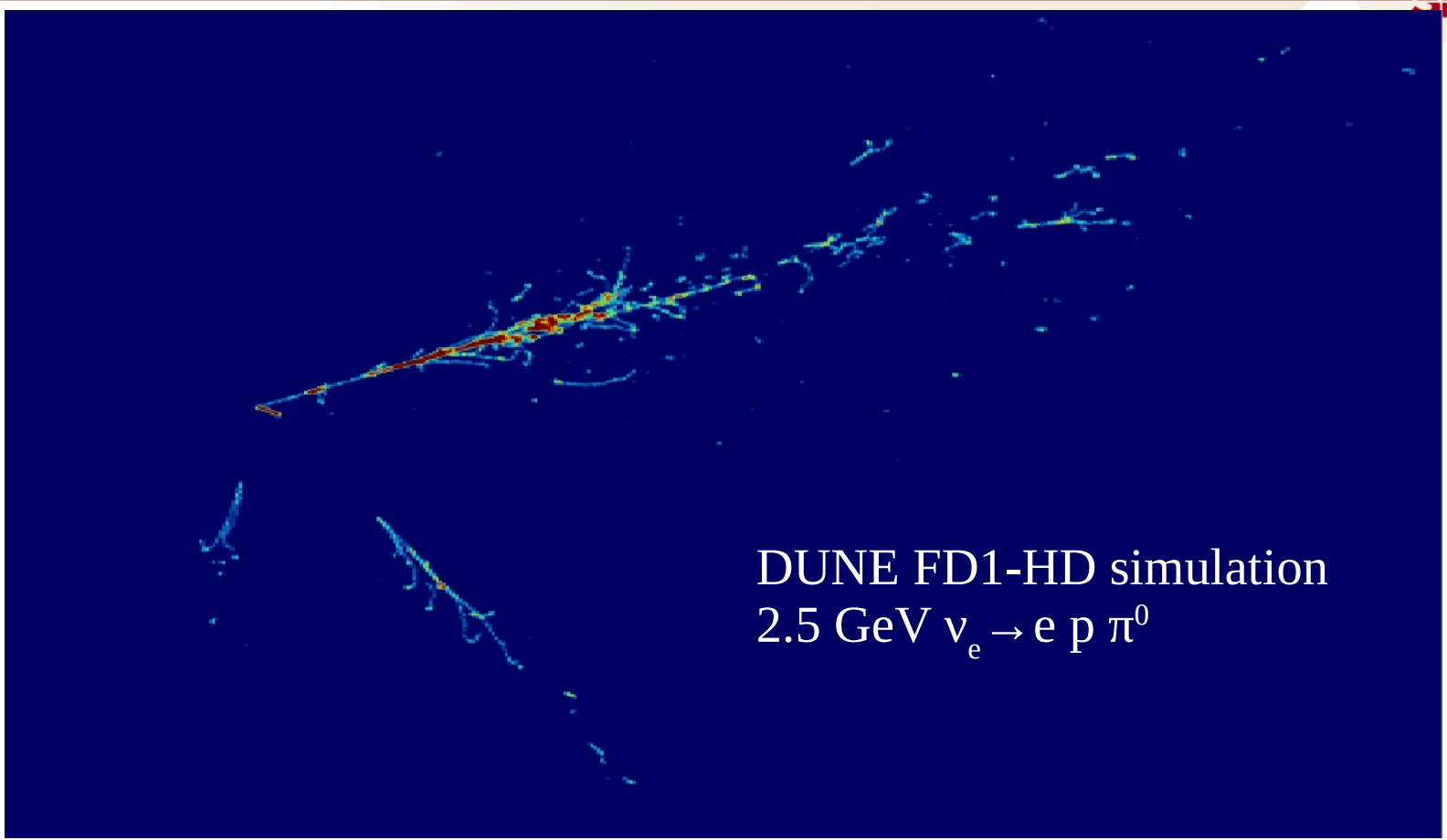
- Observed energy spectrum of flavor-tagged neutrinos at the far detector
- Prediction as a function of neutrino oscillation parameters (both “signal” and background).

This requires

- “following” neutrinos: production, oscillation, interaction, detection in far detector (FD)
- the measurement is only as good as the prediction
  - Systematic errors in the prediction result in degradation in precision/sensitivity

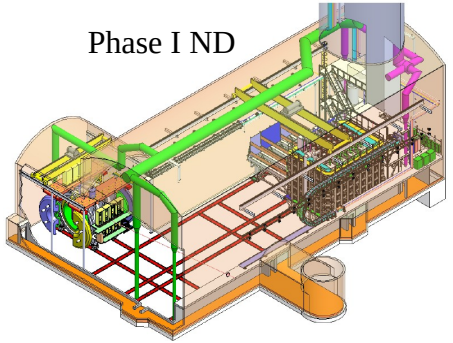
Each element is critical in producing the prediction but has large (~10%) a priori uncertainty

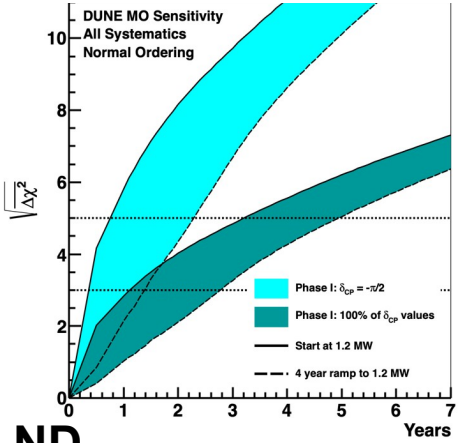
Interactions in LArTPC



ND IN PHASE 1

- ND includes: LArTPC (ND-LAr) with a muon spectrometer (TMS)
  - Key requirement:
    - Observe neutrino interactions in a LArTPC with comparable performance to FD LArTPC in a high rate environment (~50 interactions in 10 μs spill)
  - Design features:
    - Sufficiently large to contain hadronic recoil
      - Muons will punch through → TMS
    - Pixel readout for native 3D charge representation
    - Segmented readout to facilitate reconstruction in high pileup environment (charge/light signals)
- ~by design, DUNE will accumulate statistics quickly in FDs and systematics become important even in ~first year





- **No physics is possible without systematic constraints from ND**

SUMMARY:

- LBNF/DUNE has unique capabilities that will make critical measurements of neutrino oscillation parameters within its first few years
  - It will also set the foundation for a continuing program of neutrino measurements with unprecedented precision and scope that will test ν SM
  - It will also support a broader program that I didn't talk about.
- As the program continues, additional detectors will be needed that offer exciting opportunities for SLAC and opportunities to expand DUNE's physics program
  - Addition Far Detector modules
  - Upgrades to the Near Detector (Please see ND-GAr whitepaper)