

The future of DUNE in 10 minutes.

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for the DUNE Collaboration

New Perspectives 2020 conference
20-22 July 2020

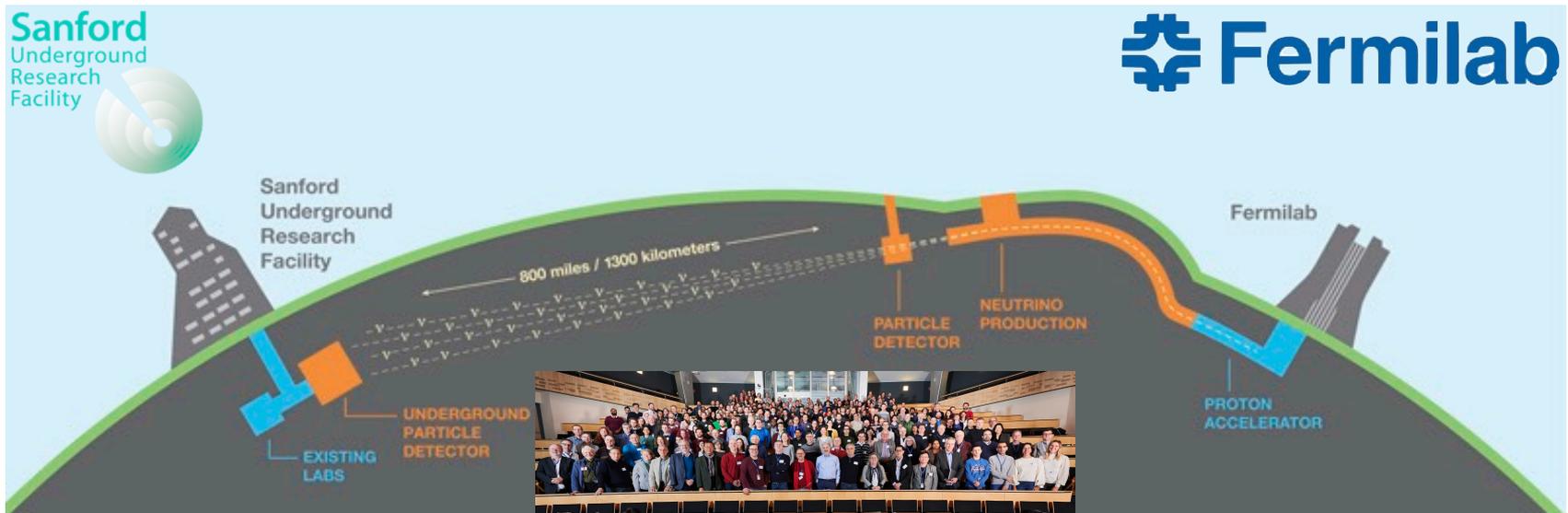


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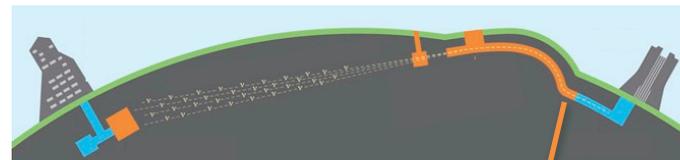
Deep Underground Neutrino Experiment

- 1300 km baseline.
- Neutrino source (PIP-II / LBNF)
- Near detector complex, LAr component.
- Large (70 kt) LArTPC far detector 1.5 km underground.
- Observe $\nu_\mu/\bar{\nu}_\mu$ disappearance and $\nu_e/\bar{\nu}_e$ appearance to measure:
 - Neutrino mixing parameters (θ_{23} , θ_{13})
 - CP-violation (δ_{CP})
 - Ordering of ν masses.
- Supernova burst neutrinos.
- BSM processes (baryon number violation, NSI, etc.)

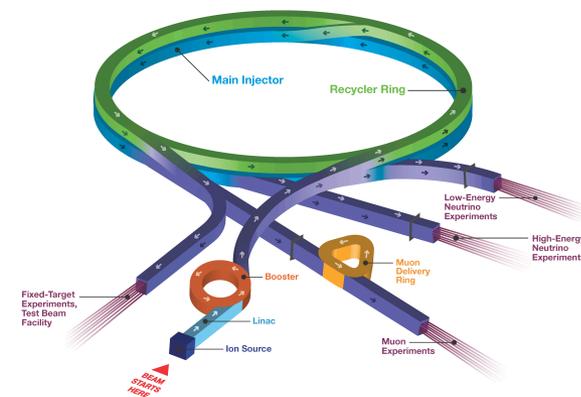
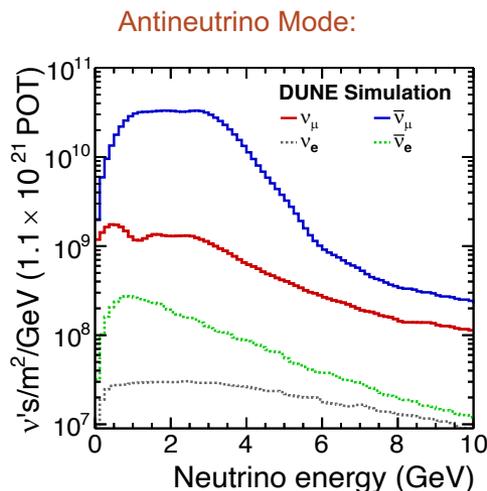
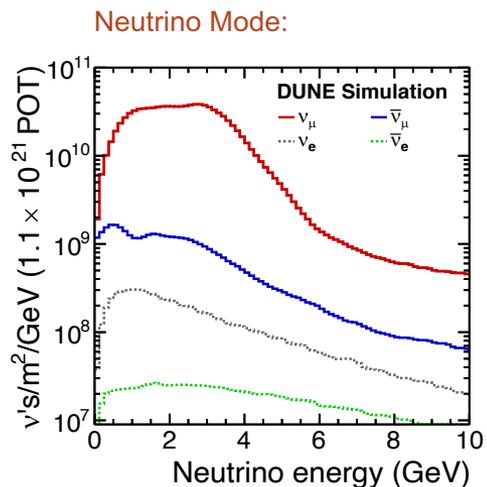


1157 collaborators from 197 institutions in 33 countries (CERN)

Neutrino Source

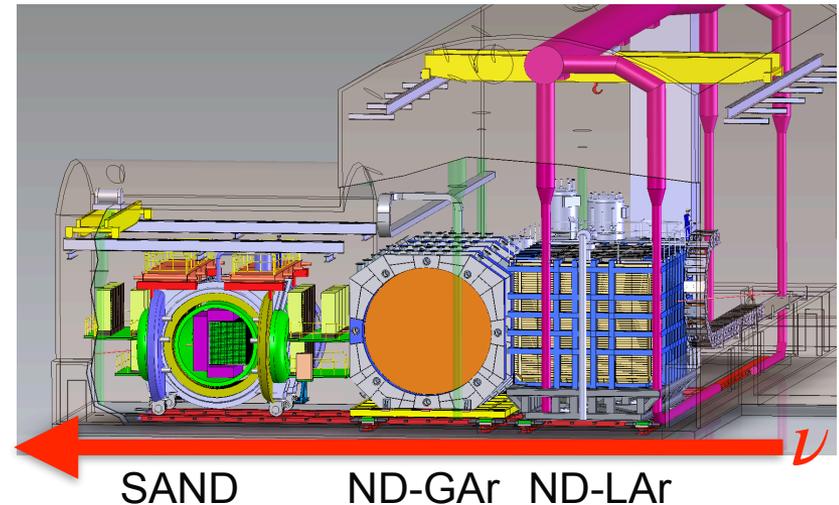
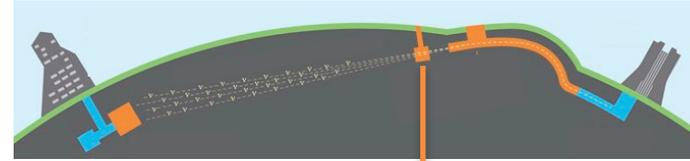


- Fermilab's Main Injector accelerator as a powerful 80-120 GeV proton beam (1.2 MW upgrade to 2.4 MW) to make **highest energy neutrino beam**.
- Neutrino beam line designed to optimize CP violation sensitivity.
- Neutrino (FHC) and antineutrino (RHC) modes.



Near Detector

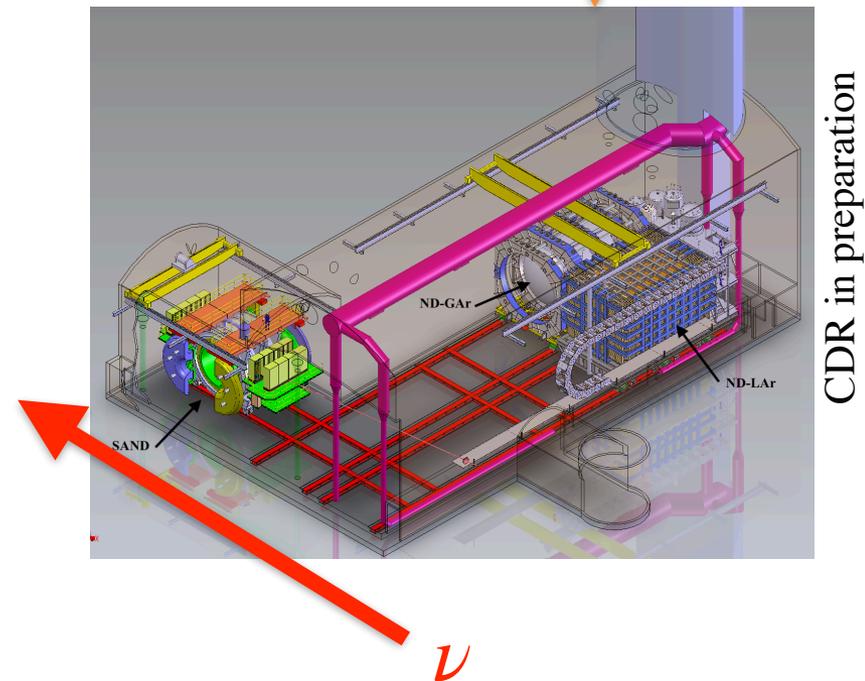
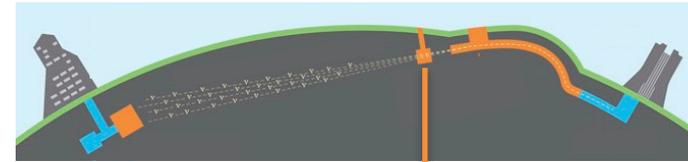
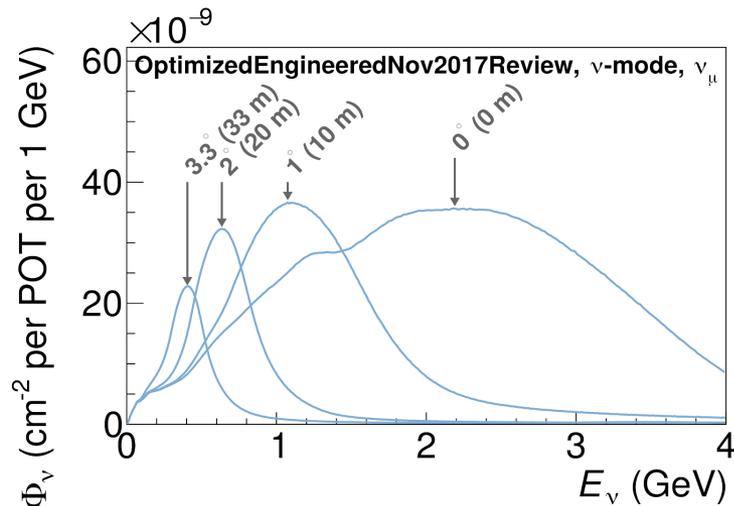
- Integrated system composed of multiple detectors.
- Located ~ 574 m from neutrino beam target.
- Primary purpose is to constrain systematic uncertainty for the long-baseline oscillation analysis and predict beam composition at FD.
- ND-LAr: Modular, pixelized liquid argon TPC.
 - Primary target.
 - Most similar to FD.
- ND-GAr: High pressure gaseous argon TPC surrounded by ECAL and magnet.
 - Momentum analysis of muons from interactions in ND-LAr.
 - Lower threshold.
- SAND: Tracker surrounded by ECAL and magnet.
 - On-axis.
 - Monitors beam spectrum.



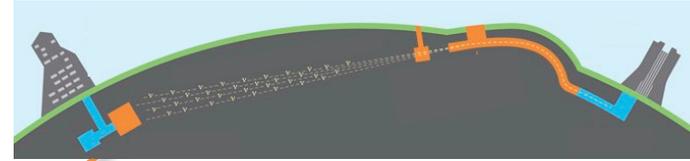
Near detector

- ND-LAr & ND-GAr move off-axis to observe varied beam spectra.
- DUNE-PRISM (Precision Reaction-Independent Spectrum Measurement) concept is to use linear combinations of off-axis fluxes to construct any flux: can \sim reproduce FD flux prediction.

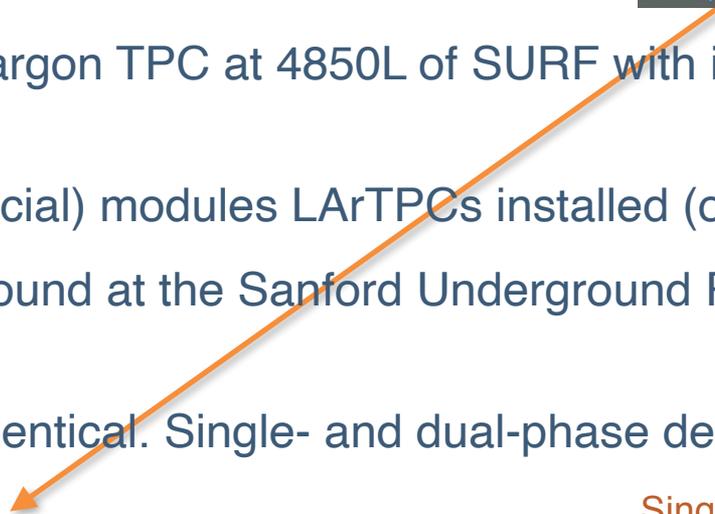
LBNF off-axis flux:



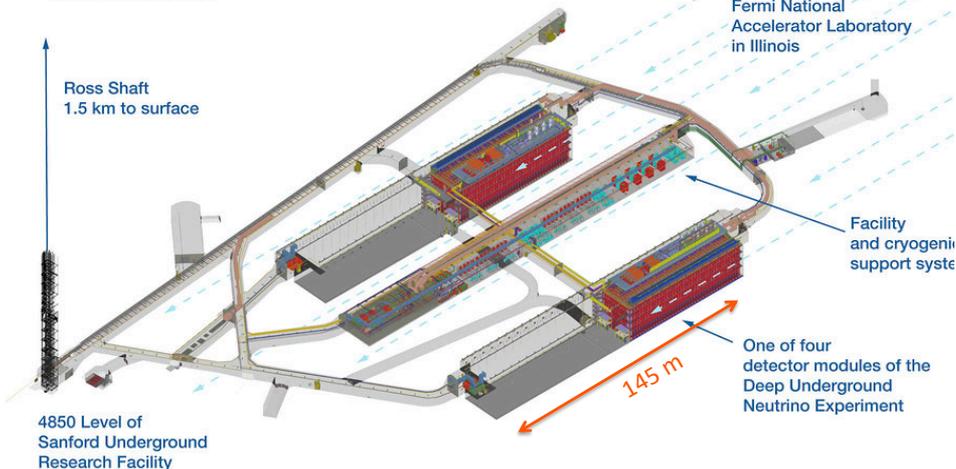
Far Detector



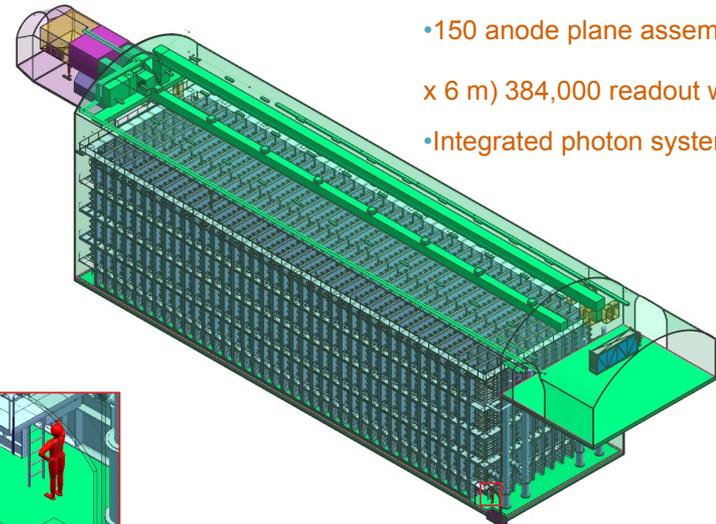
- 40-kt (fiducial) liquid argon TPC at 4850L of SURF with integrated photon detection.
- Four 17kt (~10-kt fiducial) modules LArTPCs installed (on-axis)
- 1475 meters underground at the Sanford Underground Research Facility in Lead, South Dakota.
- Modules will not be identical. Single- and dual-phase detectors being prototyped.



Long-Baseline Neutrino Facility South Dakota Site



- Single-phase:
- 16 m high x 19m wide x 66 m long.
 - 150 anode plane assemblies (2.3 m x 6 m) 384,000 readout wires.
 - Integrated photon system

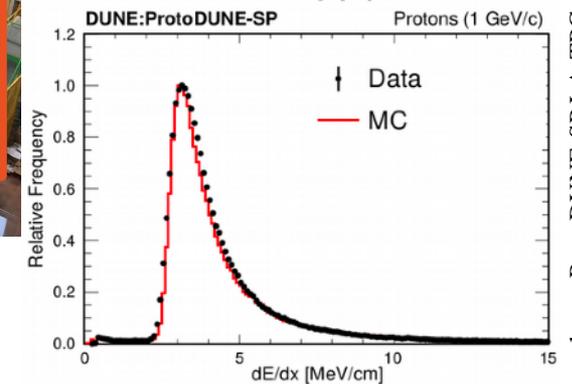
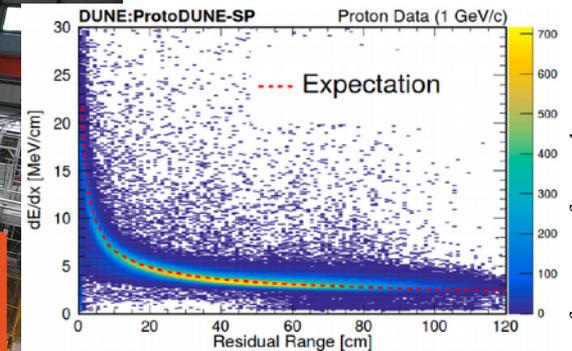
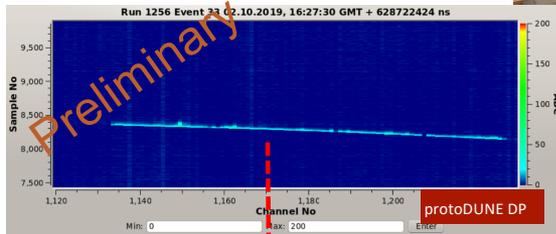
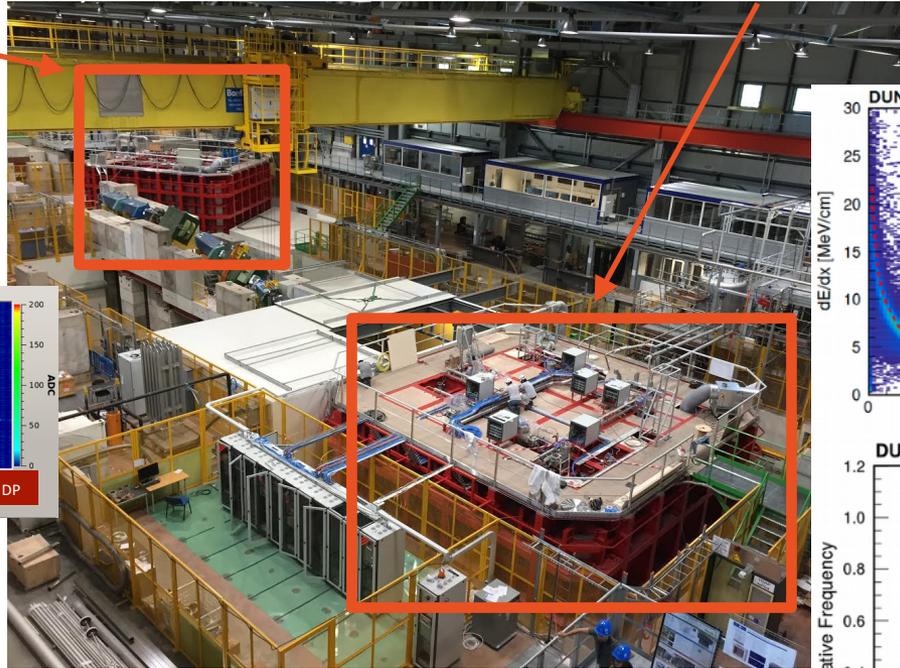


protoDUNEs

Prototype technology for charged test beam at CERN.

ProtoDUNE-DP since 2019

ProtoDUNE-SP operating since 2018
(end next week)



- protoDUNEs - II after LS2.

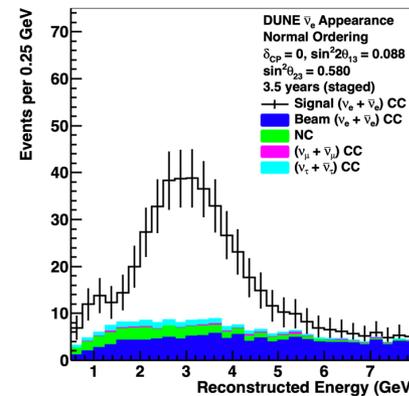
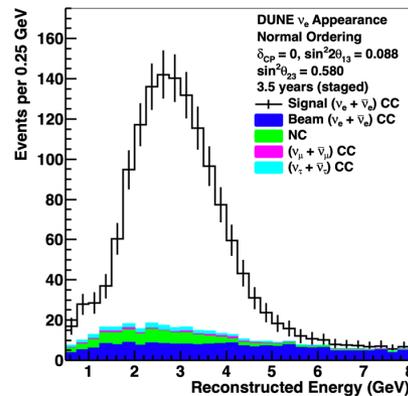
Physics program

LBL oscillation analysis

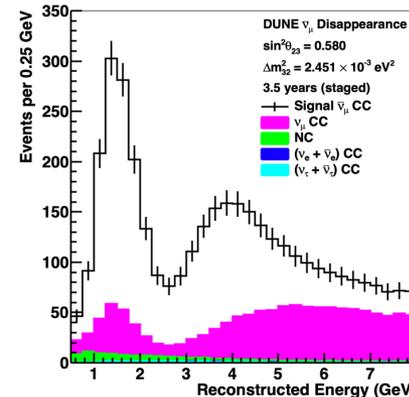
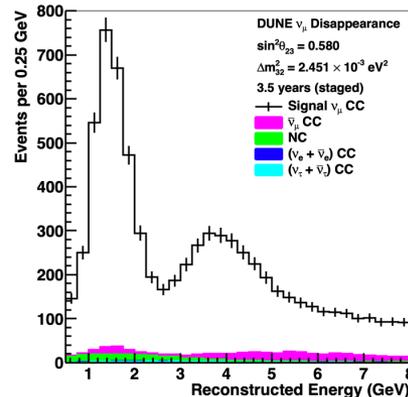
- Compare FD data to FD predictions to measure oscillation parameters
- FD prediction comes from combination of ND data, flux model, neutrino interaction model and detector models.

- Individual sources of systematic uncertainty (flux, interactions, detector effects) included in analysis.
- Incorporate knowledge from existing experiments (MINERvA, NOvA, T2K, uBooNE)

Neutrino Mode (Appearance) Antineutrino Mode



~ 1000 evt
7 years staged



~ 10.000 evt
7 years staged

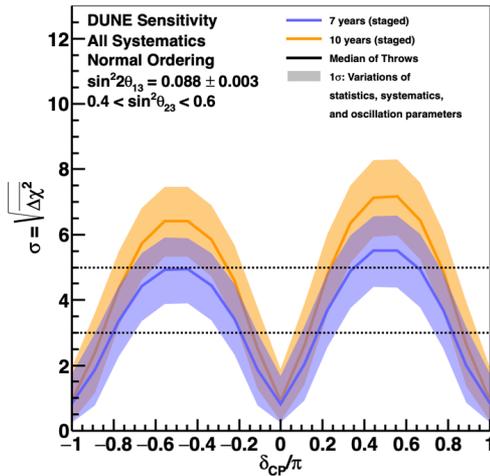
Neutrino Mode (Disappearance) Antineutrino Mode

Long-baseline neutrino oscillation physics potential of the DUNE experiment
<https://arxiv.org/abs/2006.16043>

Neutrino interaction classification with a convolutional neural network in the DUNE far detector
<https://arxiv.org/abs/2006.15052>

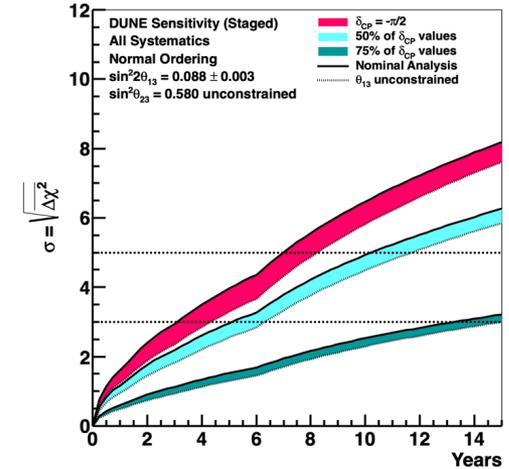
LBL oscillation analysis

CP Violation Sensitivity (True NO)

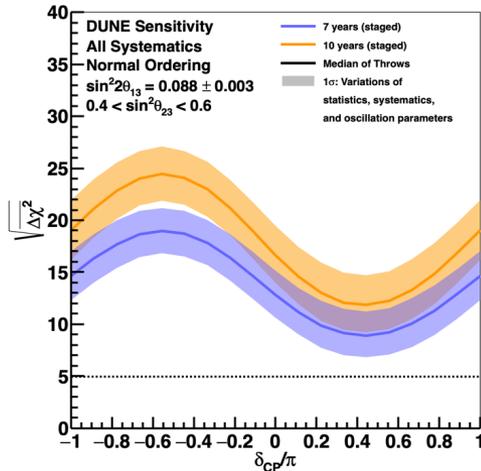


- CP violation discovery potential over wide range of true δ_{CP} values.
- CP violation discovery for 50% of true δ_{CP} values in ~ 10 years.

CPV Sensitivity Over Time

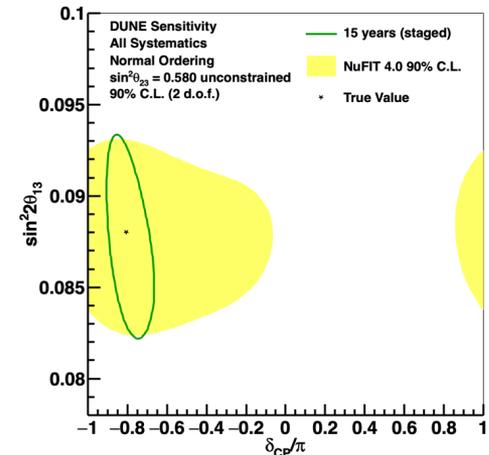


Mass Ordering Sensitivity (True NO)



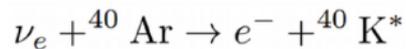
- Definitive determination of neutrino mass ordering for all possible parameters.
- δ_{CP} precision of 10° - 20° in ~ 10 years (staged)
- θ_{13} measurement comparable with reactor experiments after ~ 15 years (staged)

Precision δ_{CP} Measurement

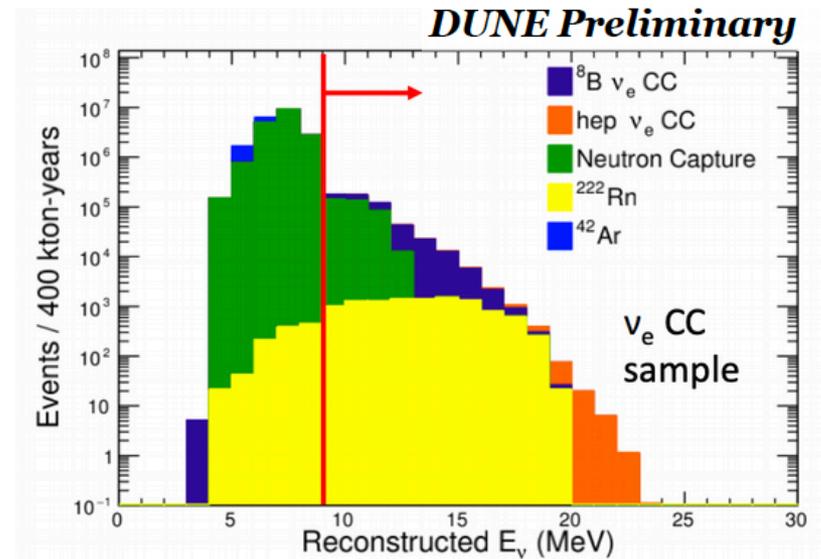
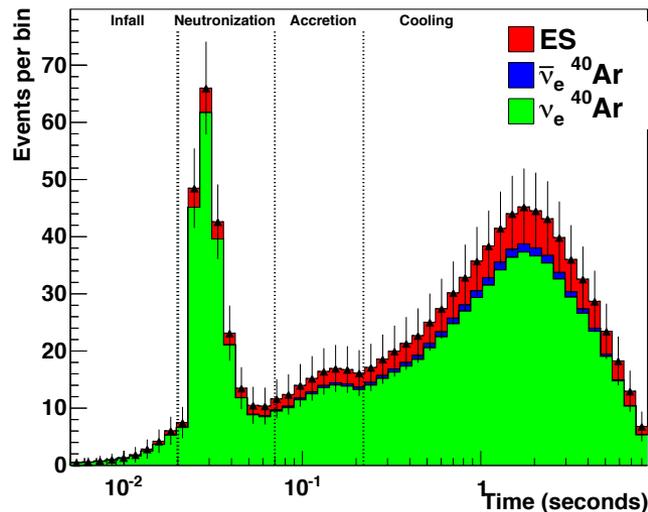


Supernova Neutrino Burst and Solar neutrinos

- Neutrino bursts from stellar core-collapse supernova:
Supernova physics, particle physics and multimessenger astronomy.



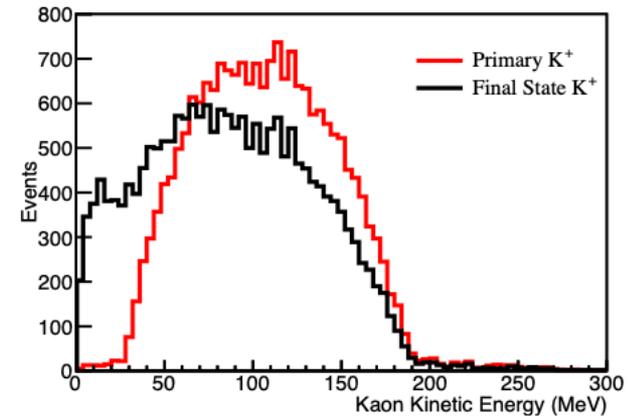
- Sensitive to other low-energy neutrinos:
 - ${}^8\text{B}$ solar neutrinos
 - hep solar neutrinos



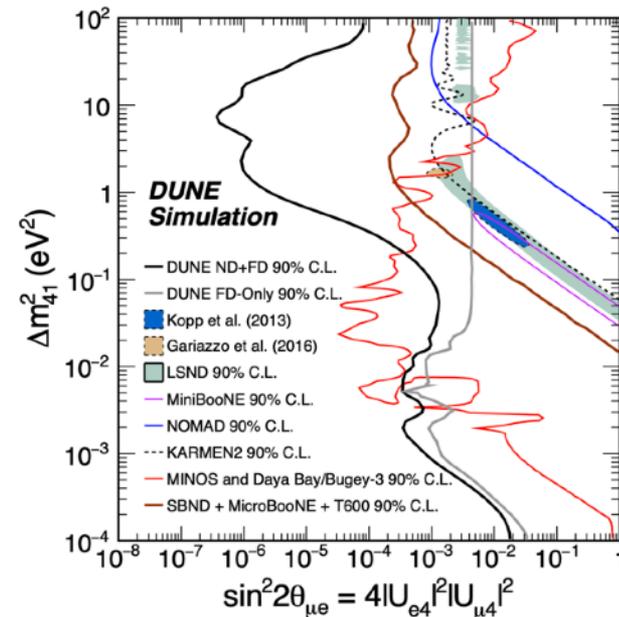
BSM program

- The unique combination of the high-intensity neutrino beam with DUNE's near detector and massive LArTPC far detector enables a variety of probes of BSM physics, either novel or with unprecedented sensitivity.
- Searches for new phenomena at the FD benefitting from its large mass and resolution: **nucleon decay**, boosted dark matter ...
- Searches for new physics at the ND: light-mass dark matter, new physics via neutrino trident production, heavy neutral leptons...
- Searches beyond the standard three-neutrino-flavour paradigm (FD and ND): **active-sterile neutrino** mixing, non-unitarity of the leptonic mixing matrix, non-standard neutrino interactions (NSI); violation of Charge, Parity, and Time reversal symmetry (CPT)...

$$p \rightarrow K^+ \bar{\nu}$$



Sterile Neutrino Mixing



Status, timeline and plans

- Far site construction underway.
- Near site preparation underway.
- protoDUNEs taking data now.

- Far detector physics data expected in late 2020s.
- Neutrino beam expected to be available on similar timescale.

- Plenty of opportunities for additional participation.



Summary

- DUNE and LBNF making good progress toward precision neutrino measurements: facility construction, detector design, and physics analysis.
- Exciting physics program including CP violation measurement, neutrino mass ordering determination, supernova neutrino burst physics, solar neutrino detection, and many BSM searches.
- International contributions throughout project.
- Technical Design Report for DUNE FD complete (4 volumes)
- Round of publications coming out including first results from protoDUNE-SP.
- Conceptual Design Report for DUNE ND under review.

Thank You!