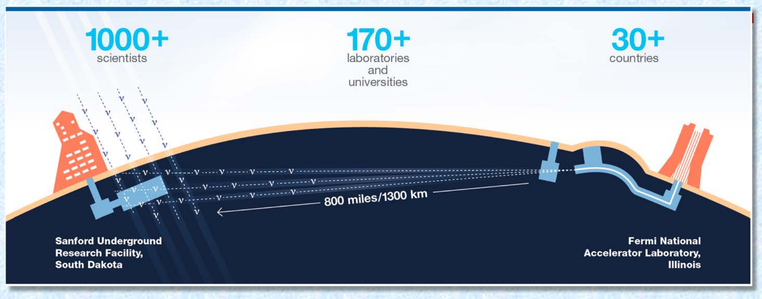
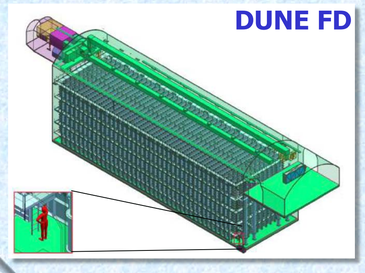
Searching for Beyond the Standard Model Physics with the DUNE Experiment

Alexandre Sousa, University of Cincinnati - on behalf of the DUNE Collaboration

DUNE - Deep Underground Neutrino Experiment

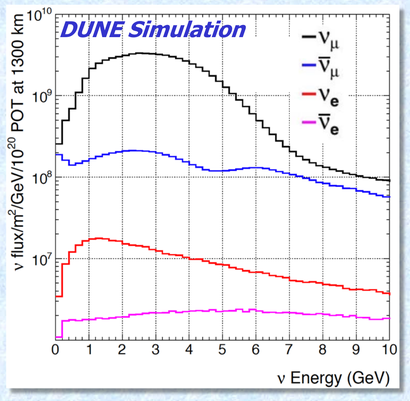


- 1300 km baseline between Fermilab and SURF
- New LBNF ν beam, 1.07 MW for 80 GeV protons from Fermilab's Main Injector, upgradeable to 2.3 MW
- On-axis LArTPC Far Detector with 40 kton fiducial mass, located at SURF, SD, 1.5 km underground
- Near Detector at Fermilab, 575 m from target, 60 m depth, 84 ton fid. LArTPC + Multi-Purpose Tracker TBD



Primary Physics goals:

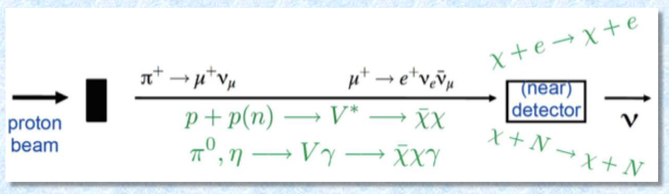
- Study ν oscillations, look for leptonic CP violation, determine ν mass ordering
- **Look for Physics beyond the Standard Model**
- Look for nucleon decay
- Study ν from Supernova burst

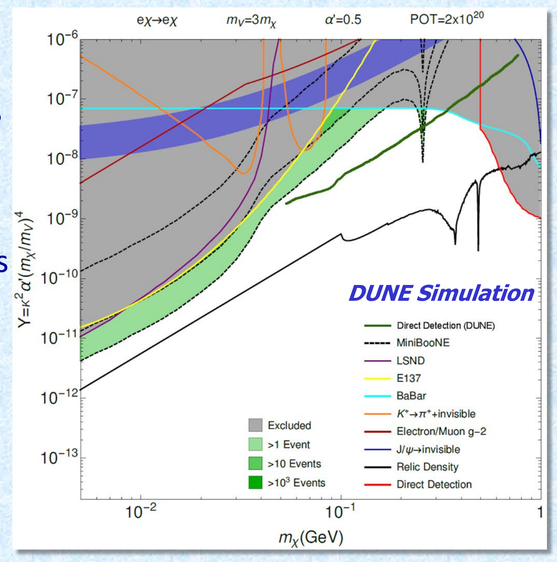


- 2017- Begin Far site construction
- 2018 – protoDUNEs at CERN
- 2021 – FD installation begins
- 2024 – Physics data begins
- 2026 – LBNF ν beam available

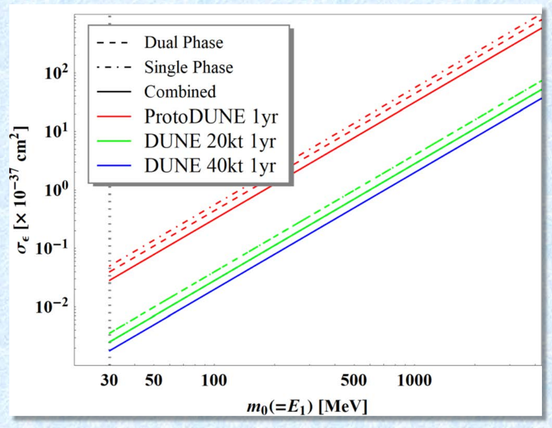
Searches for Dark Matter

- Sub-GeV (light) dark matter particles may be produced by LBNF in large amounts
- DM particles detected through NC interactions in the ND – large backgrounds from standard ν interactions
- Top right plot shows DUNE reach for the case of elastic scattering between DM and electrons





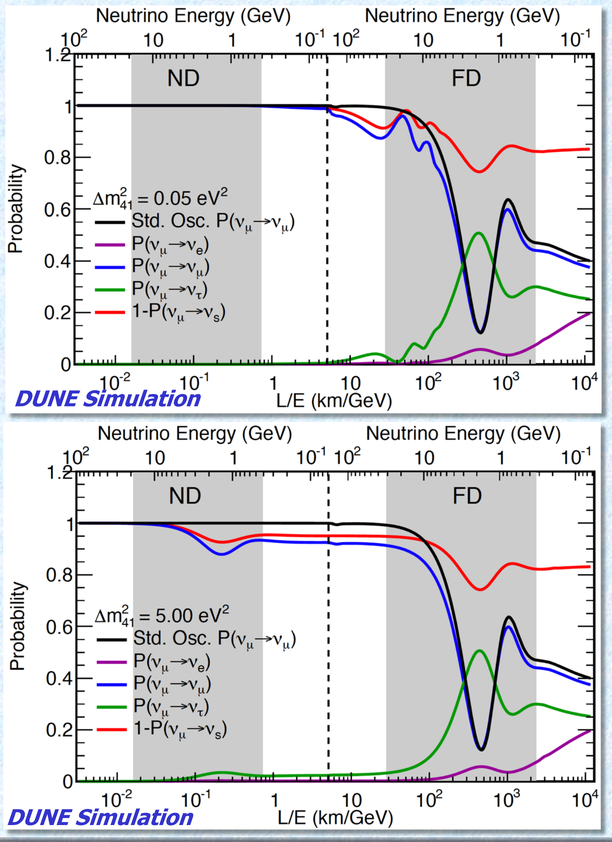
- Cold dark matter captured by the Sun or the Galaxy center may lead to production of lighter, boosted dark matter (BDM) via annihilation or decay.
- BDM particles can interact with electrons or nucleons in DUNE detectors
- Look for scattered electrons or recoil protons
- Proof of principle with protoDUNE
- Bottom right plot shows DUNE and protoDUNE reach for the case of elastic BDM signatures



Chatterjee, De Roeck, Kim, Moghaddam, Park, Shin, Whitehead, Yu, arXiv:1803.03264 (2018)

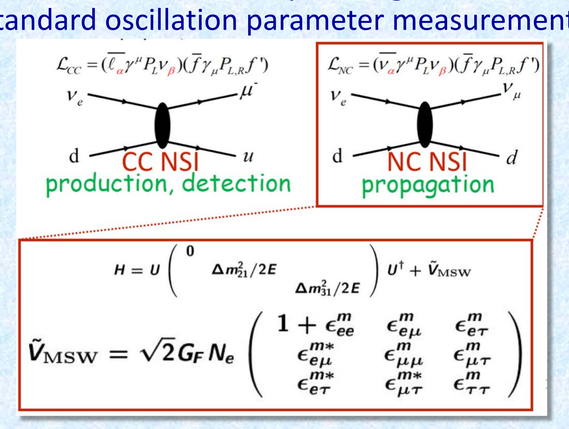
Search for Light Sterile Neutrino Mixing

- DUNE can look for new light ν sterile states through:
  - CC and NC disappearance between ND and FD
  - Non-standard FD ν_e CC appearance
  - ν_μ CC disappearance and ν_e CC appearance in the ND baseline
  - Deviations from standard behavior in atmospheric ν sample at FD
- Plots show mixing probabilities for 3 and 3+1 ν models as a function of L/E
  - Grey bands show ν beam regions probed by ND and FD
  - For small values of Δm^2_{41}, distortions seen at FD only
  - For values of $\Delta m^2_{41} > 1$ eV², distortions at ND and flat normalization deficit at FD
- GLoBES studies ongoing for 3+1 model considering oscillations in both detectors

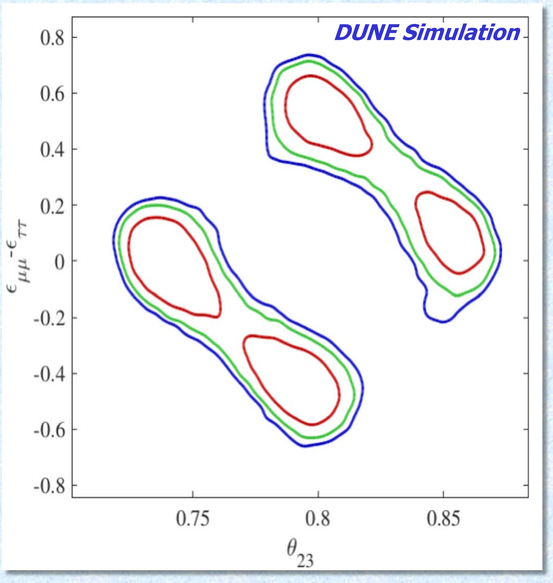


Searches for NSI and Non-Unitarity

- Probe non-standard interactions (NSI) between neutrinos and matter by looking for effects on standard oscillation parameter measurements



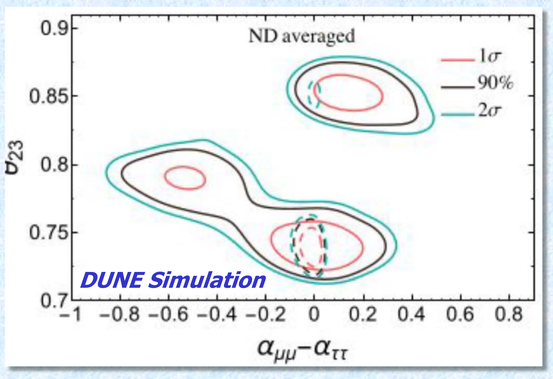
- Top right plot shows potential DUNE 68%, 90%, and 95% CL. constraints on NSI parameters as a function of θ_{23}



- If neutrinos acquire mass through (type I) seesaw mechanism, extra heavy state(s) mean mixing matrix need not be unitary

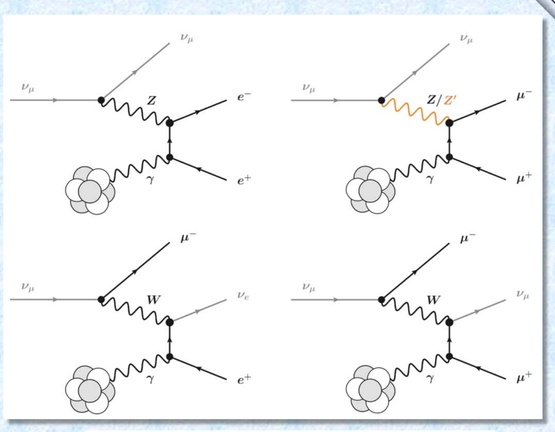
$$N = \begin{pmatrix} \alpha_{11} & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{pmatrix} U^{3\times3}$$

- Plot shows constraints with DUNE alone (solid) and with present constraints (dashed)



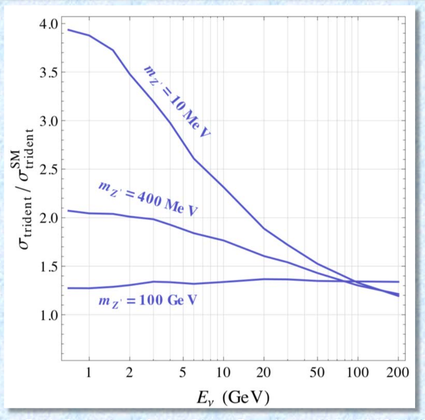
Search for Neutrino Tridents

- Rare electroweak process resulting in lepton-pair production through ν interaction in Coulomb field of nucleus
- SM cross section 6-7 orders of magnitude smaller than ν CC for DUNE ν energies
- Table shows SM signal events per tonne of LAr/year (ND LArTPC ~ 84 ton fid. mass)



	optimized beam 80 GeV	
	coherent	incoherent
$\nu_\mu \to \nu_\mu\mu^+\mu^-$	1.24 ± 0.07	0.56 ± 0.17
$\nu_\mu \to \nu_\mu e^+e^-$	3.84 ± 0.23	0.23 ± 0.07
$\nu_\mu \to \nu_e e^+\mu^-$	12.1 ± 0.7	1.5 ± 0.5
$\nu_\mu \to \nu_e \mu^+e^-$	0	0

- Light Z'boson would enhance signal over SM prediction



- Using topological cut selection with DUNE ND LArTPC sim., select 12.8 signal events and 30 bkgd. events per year of running (10^6 bkgd. rejection)
- Primary bkgd. from ν_μ CC with single π production
- Ongoing studies with inclusion of multi-purpose tracker

Altmannshofer, Gori, Pospelov, Yavin, Phys. Rev. Lett. 113, 091801 (2014)

Further Searches

- **Near Detector + Far Detector**
  - Large Extra-Dimensions through distortions of 3-flavor oscillation pattern caused by mixing of neutrinos with Kaluza-Klein modes
  - CPT Violation and Lorentz violation through comparison of disappearance measurements during neutrino and antineutrino beam running
  - Nonstandard long-baseline ν_τ appearance, using high-energy beam configuration for enhanced rate of ν_τ CC interactions
  - Atmospheric ν signatures of WIMP annihilation in the center of the Sun
- **Near Detector - Only**
  - Heavy Neutral Leptons, such as right-handed partners of active neutrinos, vector, scalar, or axion portals to the Hidden Sector, and light supersymmetric particles, by looking for topologies of rare event interactions and decays
  - Nonstandard short-baseline ν_τ appearance, using high-energy beam configuration for enhanced rate of ν_τ CC interactions.

NEUTRINO 2018
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4–9 June Heidelberg