Probing Beyond the Standard Model Physics with the Deep Underground Neutrino Experiment

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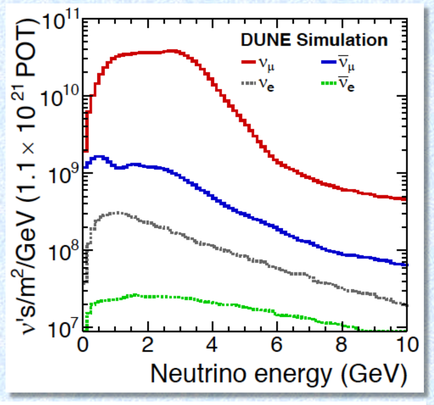
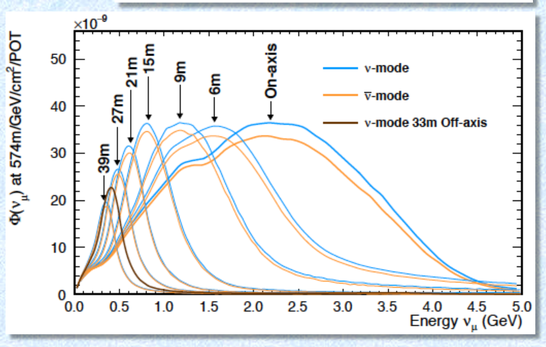
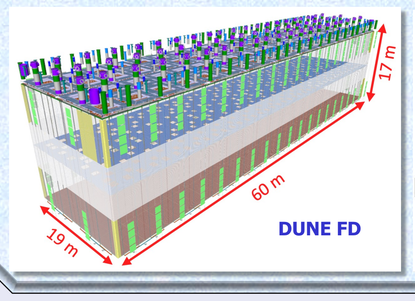
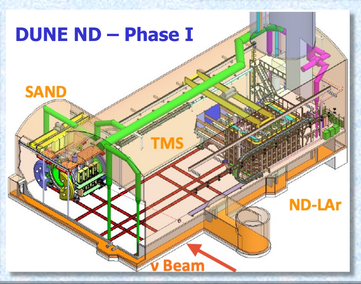
DUNE - Deep Underground Neutrino Experiment

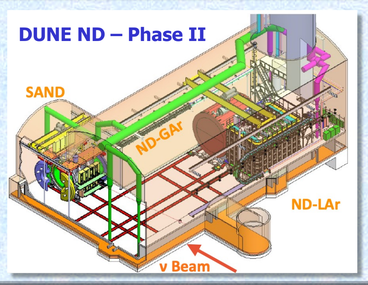
- 1300 km baseline between Fermilab and SURF
- New LBNF ν beam, 1.2 MW for 120 GeV protons from Fermilab's Main Injector, upgradeable to 2.4 MW (plot shows neutrino-mode flux)
- On-axis LArTPC Far Detector with 40 kton fiducial mass, located at SURF, SD, 1.5 km underground
- Near Detector at Fermilab, 575 m from target, 60 m depth, 67 ton fid. LArTPC + Multi-Purpose Tracker, off-axis capability (fluxes shown in plot)
- **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
- Further details on BSM Physics probes in *Euro. Phys. Journal C* ***81*** *322 (2021)*





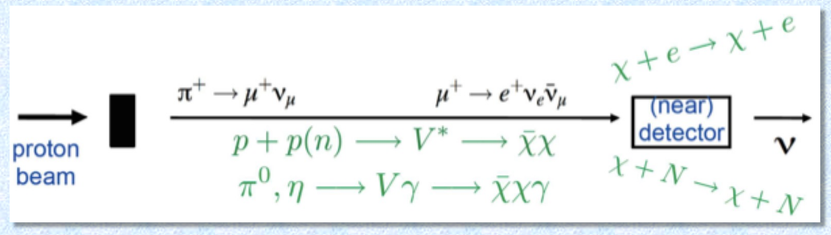




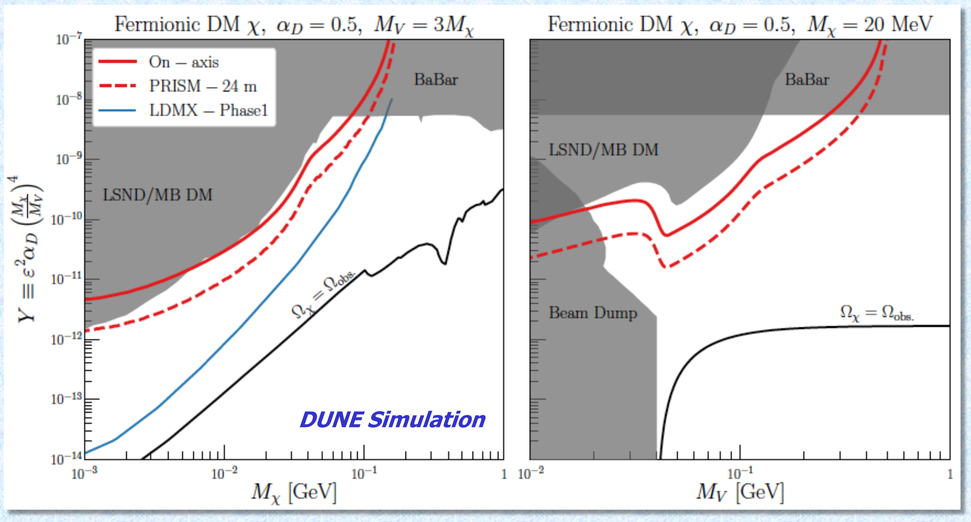


Searches for Dark Matter

- Sub-GeV (light) dark matter particles could be produced by LBNF in large amounts
- DM particles are detected through NC interactions in the ND – large backgrounds from standard ν interactions

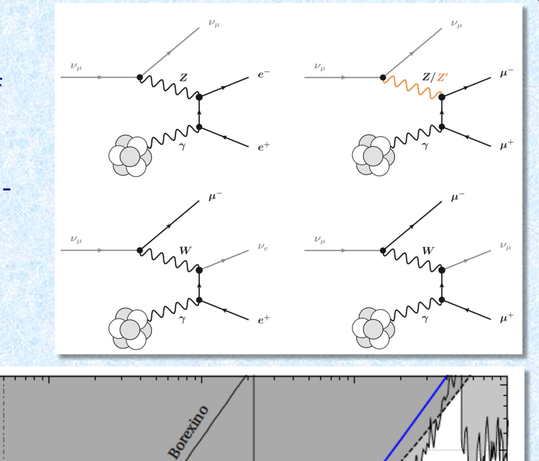


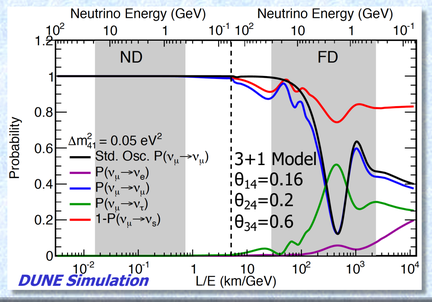
- Plot below shows DUNE reach for the case of elastic scattering between DM and electrons for two different DM parameters, both with ND on-axis and at various off-axis positions

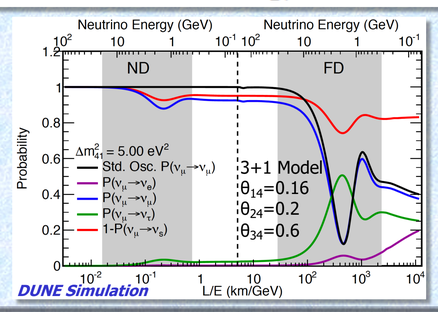


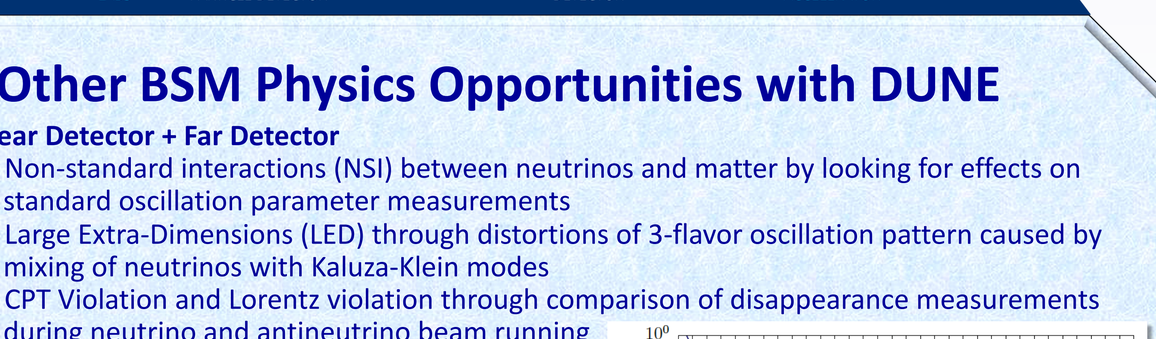
Search for Light Sterile Neutrino Mixing

- 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 ND
- Bottom plots show mixing probabilities for 3 and 3+1 ν models as a function of L/E
  - Grey bands show regions probed by ND+FD
  - For Δm^2_{41} small, distortions seen at FD only
  - For values of $\Delta m^2_{41} > 1$ eV^2, distortions at ND and flat normalization deficit at FD
- Plot to the right shows DUNE's sensitivity to the θ_{24} sterile mixing angle in a 3+1 model, for oscillations in both detectors using a GLoBES implementation.



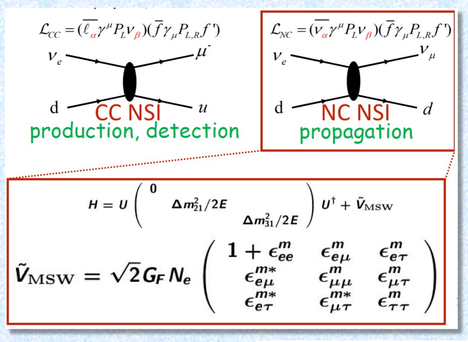


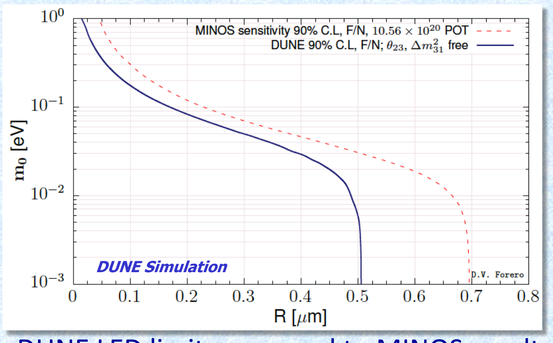




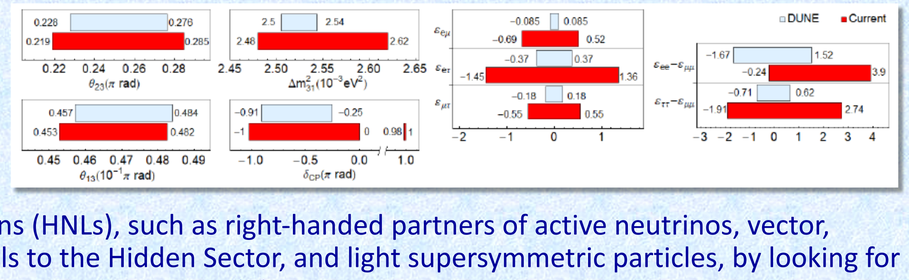
Other BSM Physics Opportunities with DUNE

- **Near Detector + Far Detector**
  - Non-standard interactions (NSI) between neutrinos and matter by looking for effects on standard oscillation parameter measurements
  - Large Extra-Dimensions (LED) 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

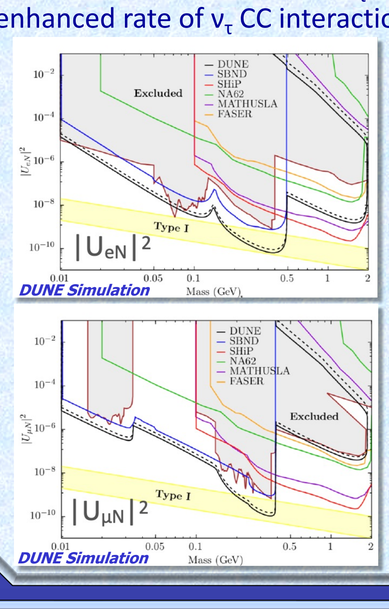




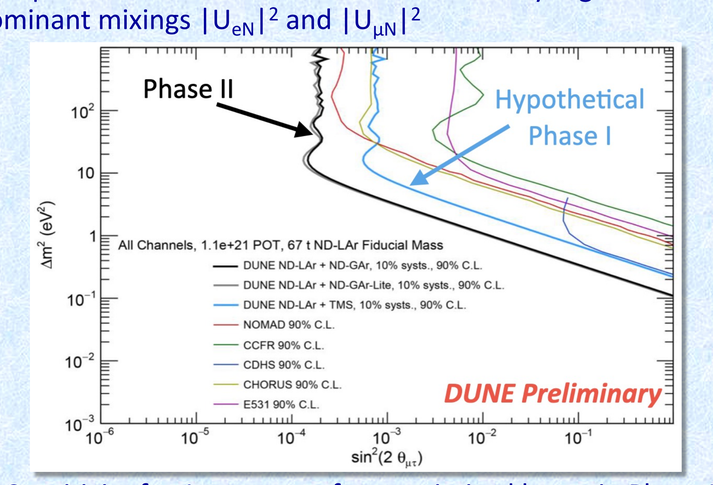
- DUNE LED limit compared to MINOS results
- Comparison of 1D DUNE NSI constraints to current constraints



- **Near Detector Only**
  - Heavy Neutral Leptons (HNLs), 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.



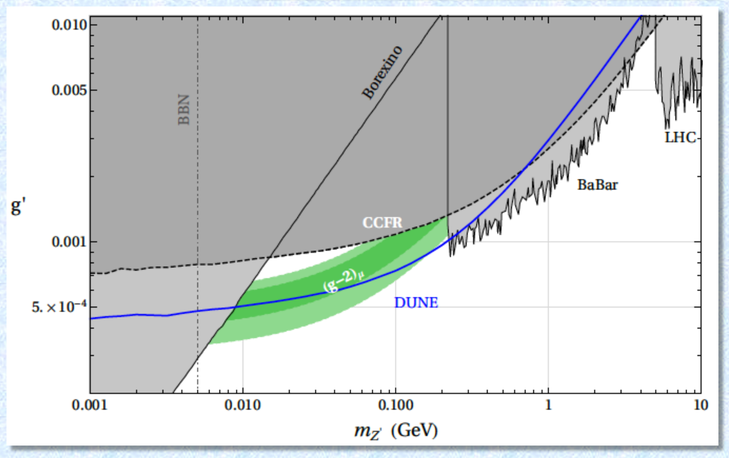
- Left plots show DUNE's HNL 90% CL sensitivity regions for dominant mixings $|U_{eN}|^2$ and $|U_{\mu N}|^2$



- Sensitivity for 1-year run of ν_τ - optimized beam in Phase II

Search for Neutrino Tridents

- Rare electroweak process resulting in lepton-pair production through interaction in Coulomb field of nucleus
- SM cross section $\mathcal{O}(10^{6\text{-}7})$ smaller than for charged-current interactions at DUNE ν energies
- Applied topological cuts on tridents with final-state muons and bkgnd. interactions generated with the DUNE ND LArTPC (~ 67 ton fid. mass) simulation
  - Select 10.2 signal events and 130 bkgnd. per year (10^6 bkgnd. rejection)
  - Primary bkgnd. from ν_μ CC with single π production
- Light Z' boson would enhance signal over SM prediction. Can exclude a large portion of the 2σ allowed region for a Z' solution to the g-2 anomaly (green)



W. Altmannshofer, S.Gori, J. Martín-Albo, A. Sousa, M.Wallbank, Phys. Rev. D ***100****, 115029 (2019)*

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