PROCEEDINGS OF SCIENCE

DUNE experiment physics

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The Deep Underground Neutrino Experiment (DUNE) will feature a 40-kton liquid argon TPC detector situated a mile below the surface at the Sanford Underground Research Facility. A new broadband high-intensity neutrino source and Near Detector complex will be located at Fermilab, 1300 kilometers away. This arrangement will provide unprecedented sensitivity in the search for neutrino CP violation, determination of the neutrino mass ordering, and precision measurements of neutrino mixing parameters. The underground Far Detector also allows for low background, low threshold observations of supernova neutrinos, with a unique sensitivity to the electron neutrino flux. Further, DUNE will conduct a wide range of searches for physics beyond the Standard Model, including baryon number violation, rare scattering processes, and non-standard flavor transitions. In this poster, we review DUNE's extensive physics program and show updated sensitivities.

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1. Introduction

The Deep Underground Neutrino Experiment (DUNE) is a next-generation long-baseline (1300 km) neutrino oscillation experiment, for neutrino physics and proton-decay searches. DUNE will answer the question about CP-violation in the neutrino sector and make precision measurements of the neutrino mixing parameters. Besides this, DUNE will use the near and far detectors to perform a wide science program such as supernova burst signals and signatures of physics beyond the Standard Model.

2. The DUNE experiment

A new broadband high-intensity neutrino source (PIP-II / LBNF) and Near Detector complex will be located at Fermilab (Illinois). Fermilab's Main Injector accelerator will feature an 80-120 GeV proton beam (1.2 MW upgradable to 2.4 MW) to make the highest intensity neutrino beam. The neutrino beamline has been designed to optimize CP violation sensitivity and it will run in neutrino (FHC) and antineutrino (RHC) modes. The Near Detector (ND) will be an integrated system composed of multiple detectors (Liquid Argon TPC, ND-LAr; Gaseous Argon TPC, ND-GAr; and a System for on-Axis Neutrino Detection, SAND) located ~ 574 m from the neutrino beam target. The primary purpose is to predict beam composition at the Far Detector and constrain systematic uncertainty for the long-baseline oscillation analysis, and make ν-Ar cross-section measurements. ND-LAr and ND-GAr will be able to move off-axis to observe varied beam spectra to help reducing systematic uncertainty. DUNE will feature four Far Detector (FD) modules of 17kt LAr mass TPCs with integrated photon detection a mile below the surface at 4850L (4300 mwe) of Sanford Underground Research Facility (SURF), South Dakota [1, 2].

3. Oscillation Physics

The above-described arrangement will provide unprecedented sensitivity in the search for CP violation in the neutrino sector, determination of the neutrino mass ordering, and precision measurements of neutrino mixing parameters. The intense neutrino beam's energy spectrum will maximize $\nu_\mu \to \nu_e$ oscillations at the far detector.

DUNE will compare FD data to FD predictions to measure the oscillation parameters, where the FD prediction comes from the combination of ND data, flux model, neutrino interaction and detector models. Individual sources of systematic uncertainty (flux, interactions, detector effects) are included in the analysis. High efficiency and purity have been achieved with simulations in the selections of ν_e and ν_μ interactions in the FD (see Fig. 1) using a convolutional neural network and ν_e energies able to be reconstructed with 13% resolution [5] .

DUNE expected oscillation sensitivity (see Fig. 2) comprises: CP violation discovery potential for 50% of true δ_{CP} values of 3 (5) sigma in ~5 (10) years, definitive 5-sigma determination of neutrino mass ordering after 2 years, and δ_{CP} precision of 10° - 20° in ~ 10 years (staged) with θ_{13} measurement comparable with reactor experiments after 15 years (staged) [3].

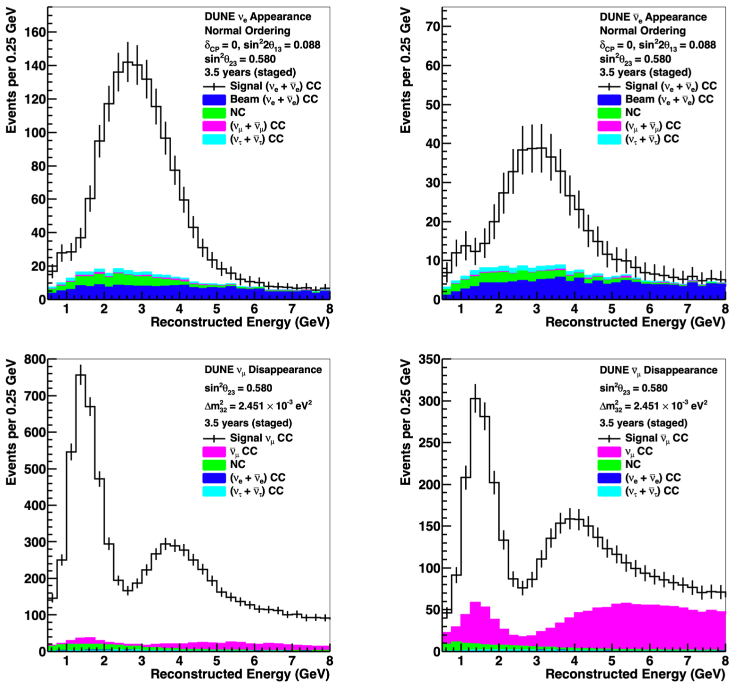


Figure (1) DUNE Far Detector event selection spectra. Top: Order 1000 appearance events in 7 years staged for neutrino (left) and antineutrino (right) mode. Bottom: Order 10000 disappearance events in 7 years staged for neutrino (left) and antineutrino (right) mode [3].

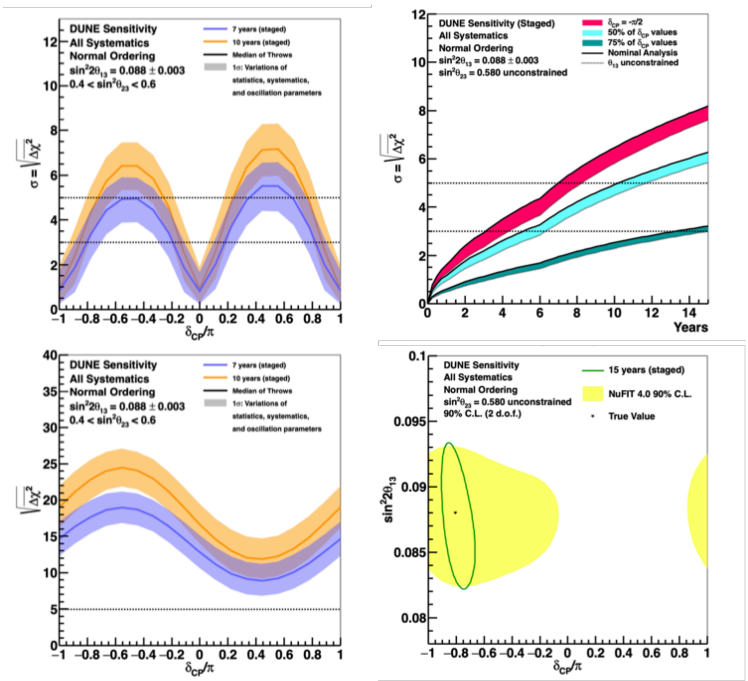
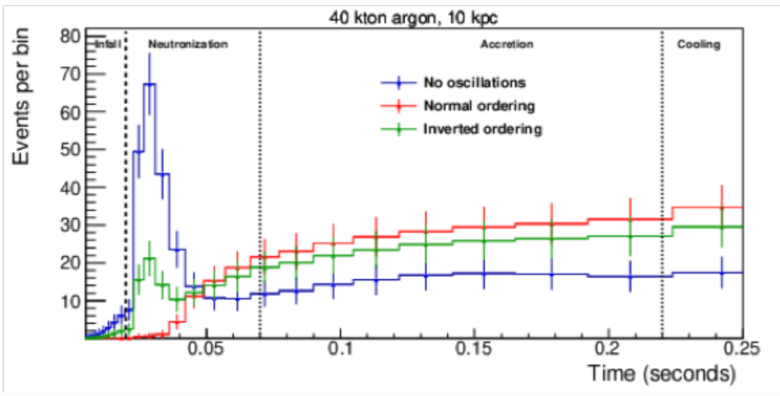


Figure (2) DUNE sensitivities. Top, left: CP Violation sensitivity over true δ_{CP} values for true Normal Ordering. Top, right: CP Violation sensitivity over time. Bottom, left: Mass ordering sensitivity over true δ_{CP} values for true Normal Ordering. Bottom, right: Precision for the δ_{CP} measurement [4].

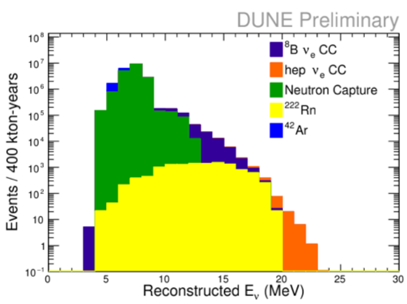
4. Astrophysical sources of neutrinos and BSM

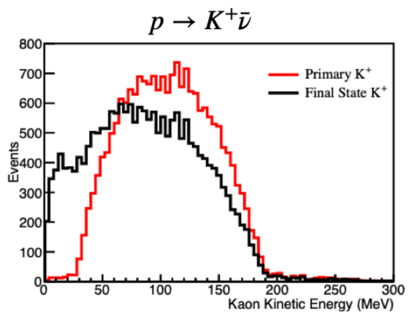
The underground Far Detector will allow for low background, low threshold observations of supernova neutrinos and solar neutrinos, with a unique sensitivity to the electron neutrino flux via $\nu_e + {}^{40}\mathrm{Ar} \rightarrow e^- + {}^{40}\mathrm{K}^*$. It will be sensitive to neutrino bursts from a stellar core-collapse supernova (Fig.3a) that is interesting in supernova physics, particle physics and multimessenger astronomy. It will also be sensitive to ^{8}B and hep Solar neutrinos (Fig.3b) thanks to the high granularity and mass of DUNE FD.

The unique combination of the high-intensity neutrino beam with DUNE's high resolution near detector and massive LArTPC far detector enables a variety of probes of BSM physics, with novel and unprecedented sensitivities. Searches for new phenomena, such as nucleon decay (Fig.3c) or boosted dark matter, will benefit from the FD's large mass and resolution. DUNE's ND will also enable searches for hypotheses such as light-mass dark matter, heavy neutral leptons, and new physics via neutrino trident production. In addition, searches (using FD and ND) beyond the standard three-neutrino-flavor paradigm like 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) and more will be performed [7].



(a) Expected event rates as a function of time for 40 kton of argon during early stages of a Supernova, the neutronization burst and early accretion phases [6].





(b) Expected events, as a function of reconstructed neutrino energy for signal and radiological backgrounds passing solar ν_e CC selection.

(c) Kinetic energy of kaons in simulated proton decay events in DUNE [7].

Figure (3) Astrophysical and BSM expected events in DUNE.

References

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