

DUNE: THE DEEP UNDERGROUND NEUTRINO EXPERIMENT

Alexander Booth, for the DUNE Collaboration ICHEP 2022, Bologna July 7th, 2022



Physics Goals





Sanford Underground Research Facility, South Dakota Fermi National Accelerator Laboratory, Illinois

• **Discovery sensitivity** over a wide range of parameter values to:

- ► CP violation.
- Mass ordering.
- Octant of θ_{23} .
- In a single experiment make unambiguous, high precision measurements of Δm_{32}^2 , δ_{CP} , $\sin^2 \theta_{23}$ and $\sin^2 2\theta_{13}$.
- Sensitivity to MeV-scale neutrinos galactic supernova bursts (see talk tomorrow by C. Cuesta).
- Low background for sensitivity to BSM physics, e.g. baryon number violation (see talk tomorrow by L. Koerner).
- 2 July 07, 2022 Alexander Booth | DUNE Overview



Sanford Underground

Research Facility,

South Dakota



Far detector (FD complex



800 miles/1300 km

Fermi National Accelerator Laboratory, Illinois



LBNF Neutrino Beam

- Intense beam of neutrinos for high statistics measurements.
- Wide-band nature cover at least 1 full oscillation period.



Sanford Underground



Research Facility, South Dakota

Near detector (ND) complex

800 miles/1300 km

Fermi National Accelerator Laboratory, Illinois

LBNF Neutrino

Far detector (FD) complex



 Reduce experiment's susceptibility to systematic uncertainties (flux, crosssection).

• PRISM concept.





Sanford Underground Research Facility, South Dakota Near detector (ND) complex

800 miles/1300 km

Fermi National Accelerator Laboratory, Illinois

LBNF Neutrino Beam

Far detector (FD) complex



- LAr TPCs using both horizontal and vertical drift technology.
- Each one is 17 kt in volume.

Later today: talk by N. Nayak



Sanford Underground Research Facility, South Dakota

Near detector (ND) complex

800 miles/1300 km

Fermi National Accelerator Laboratory, Illinois

LBNF Neutrino Beam

- Event "imaging" using LAr TPCs:
 - Precise energy reconstruction.
 - Efficient determination of particle identity.





Installation Plans



DUNE's construction will be "staged" \rightarrow continuous progress toward physics goals beginning this decade.

Phase I

- **Beam:** 1.2 MW beam intensity.
- Near detector: ND-LAr + TMS + SAND.
- PRISM: 🗸

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• Far detector: Two 17 kt LAr TPC modules - one HD and one VD.

Phase II

- Beam: 2.4 MW beam intensity.
- Near detector: ND-LAr + ND-GAr + SAND.
- PRISM: 🗸
- Far detector: Four 17 kt LAr TPC modules.







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Phase I: World leading mass ordering and sensitivity to maximal CPV





Phase I will do world class long-baseline neutrino oscillation physics.
Only experiment with 5 σ mass ordering regardless of the true parameters.
Discovery of CPV at 3 σ if CPV is large.



Long term physics goals require full scope (Phase II)



- DUNE needs full Phase II scope to achieve precision physics goals.
- \bullet CPV sensitivity for 50% of δ_{CP} values shown.
 - Other precision measurements are similarly affected.
- Timescale for precision physics is driven by achieving full scope on aggressive timeline.



ProtoDUNEs



- Between 2018 and 2020, one HD and one VD 1 kt prototype LAr TPC detectors were operated in a charged particle test beam at CERN.
- Platform provides a test of:
 - Component installation.
 - Commissioning.
 - Analysis.
 - ▶ Performance.
- Further running in 2022 with ProtoDUNE-II!





ProtoDUNEs





- The ProtoDUNEs shows that the fundamental DUNE technology works and will at s
- Science results, two new papers:
 - Separation of track- and shower-like energy deposits in ProtoDUNE-SP using a Convolutional Neural Network (arXiv:2203.17053).
 - Scintillation light detection in the 6 m first-length ProtoDUNE-DP liquid argon TPC (arXiv:2203.16134).
- Several more on the way! Covering event reconstruction, Michel elections, pion, proton, kaon, neutron inclusive and exclusive cross sections.
 Later today: talk by J. Calcutt

Construction at the Far Site







- Rock excavation work is in progress!
 27% complete by total rock volume.
- Advancing on schedule and budget.





Summary





- DUNE is a best-in-class long-baseline neutrino oscillation experiment, neutrino observatory and new physics search machine but we will need the full Phase II program to realise all of our physics goals.
- We are on track to deliver Phase I:
 - ProtoDUNE has demonstrated the technology.
 - Far site civil construction is progressing well (and near site and beamline is fully designed).
- Physics should begin this decade and the collaboration is active in planning upgrades to achieve full scope in the 2030s.



DUNE at the conference



Nucleon decay search with DUNE

The Deep Underground Neutrino Experiment (DUNE) is an international project aiming at neutrino physics and astrophysics and a search for phenomena predicted by theories beyond the standard model. The excellent imaging capability of Liquid A

Lisa Koerner (University of Houston)

Prospects for Beyond the Standard Model Studies at the Deep Underground Neutrino Experiment

The Deep Underground Neutrino Experiment (DUNE) is an international particle physics experiment and its primary scientific objective is a precision measurement of neutrino oscillation parameters. While the experiment was designed to focus o

Wooyoung Jang (University of Texas at Arlington)
 08 July 2022 19:10

Sensitivity to Heavy Neutral Leptons with the SAND detector at the DUNE ND complex

Heavy Neutral Leptons (HNLs) have been an interesting topic for experimental particle physics in the past few years. A study has been performed within the framework of the multi-instrument DUNE near detector complex, specifically regarding

Zahra Ghorbanimoghaddam (University of Perugia and INFN Genova)
 08 July 2022 19:10

Sensitivity of DUNE to low energy physics searches

The Deep Underground Neutrino Experiment (DUNE), a next-generation long-baseline neutrino oscillation experiment, is a powerful tool to perform low energy physics searches. DUNE will be uniquely sensitive to the electron-neutrinoflavour co

💄 Clara Cuesta (CIEMAT)

🗰 07 July 2022 13:30

Demonstration of a novel, ton-scale, pixel-readout LArTPC for the DUNE near detector

To cope with the high event pile-up, the liquid argon time projection chamber of the near detector complex of the Deep Underground Neutrino Experiment, called ND-LAr, relies on an innovative modular design featuring an advanced high-coverag

Anja Gauch
6 08 July 2022 19:10

Hadron-argon Cross Section Measurements in ProtoDUNE

Modern accelerator-based neutrino experiments use complex nuclei, such as argon, as neutrino targets that rely on nuclear models to unfold the reconstructed neutrino energy to the true neutrino energy. The nuclear effects complicate the neu

Leigh Whitehead, Heng-Ye Liao The SAND detector at the DUNE near site

DUNE is a next-generation of long baseline experiment for neutrino oscillation physics. The near detector (ND) complex aims at constraining the systematic uncertainties to ensure high precision measurements of neutrino oscillation parameter

Gianfranco Ingratta (Istituto Nazionale di Fisica Nucleare)

Status and Recent Progress towards the second DUNE Far Detector Module

The Deep Underground Neutrino Experiment (DUNE) is part of the next generation of neutrino oscillation experiments that seek to definitively answer key questions in the field. It will utilize four 17-kt modules of Liquid Argon Time Projecti

Nitish Nayak (Brookhaven National Laboratory)

The DUNE Near Detector

DUNE will be a next-generation experiment aiming to provide precision measurements of the neutrino oscillation parameters. It will detect neutrinos generated in the LBNF beamline at Fermilab, using a Near Detector (ND) situated near the bea

Every statisti (University of Oxford)

The DUNE vertical drift TPC

The DUNE experiment is a future long-baseline neutrino oscillation experiment aiming at measuring the neutrino CP violation and establishing the neutrino mass hierarchy, as well as at a rich physics programme from supernovae over low-energy

Oliver Lantwin (LAPP, CNRS-IN2P3)

📋 09 July 2022 13:45

ProtoDUNE Physics and Results

The ProtoDUNE single phase detector (ProtoDUNE-SP) is a prototype liquid argon time projection chamber (LArTPC) for the first far detector module of the Deep Underground Neutrino Experiment (DUNE). ProtoDUNE-SP is installed at the CERN Neut

Leigh Whitehead, Jacob Calcutt (Oregon State University)

DUNE The Deep Underground Neutrino Experiment

The Deep Underground Neutrino Experiment (DUNE) is a next generation long baseline neutrino experiment for oscillation physics and proton decay studies. The primary physics goals of the DUNE experiment are to perform neutrino oscillation ph

Alexander Booth
07 July 2022 11:30



The DUNE Collaboration 2022







