DUNE SENSITIVITY TO SOLAR NEUTRINOS

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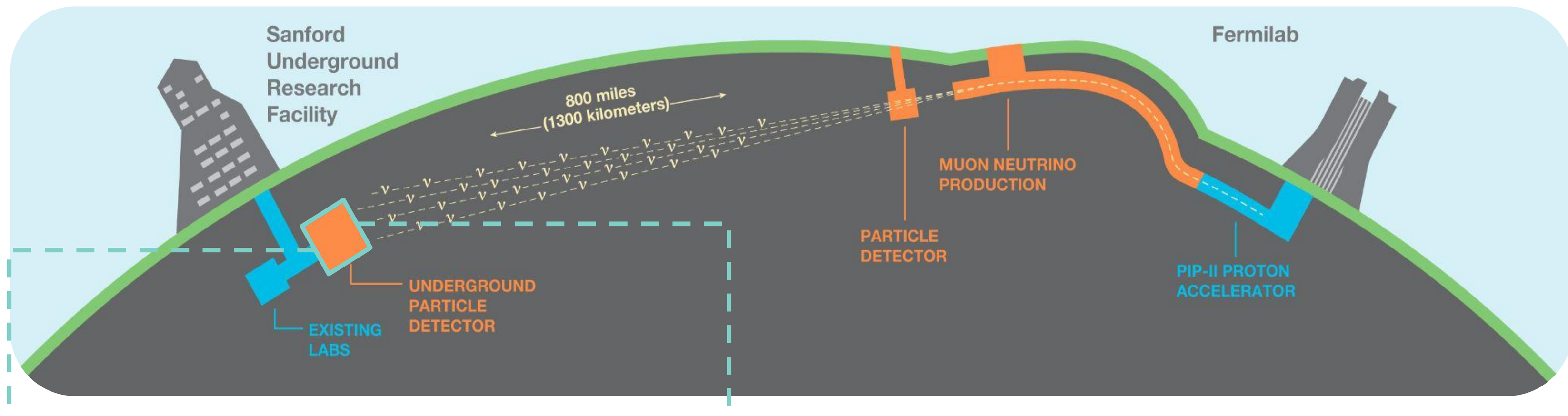
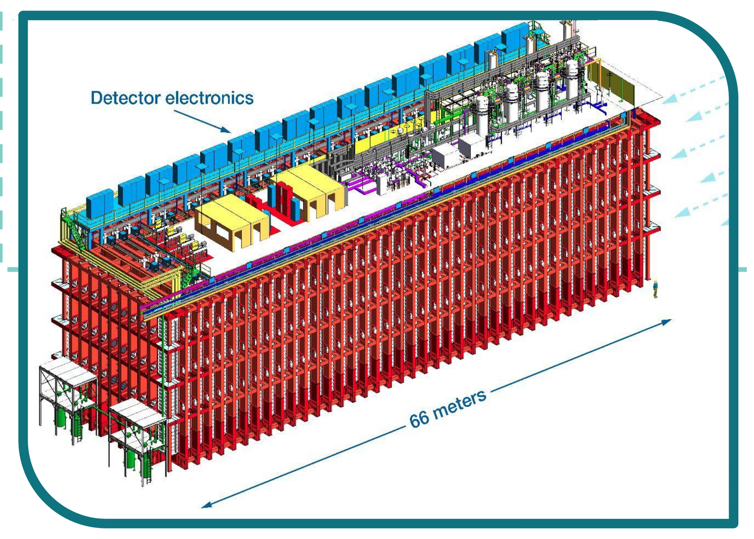
Deep Underground Neutrino Experiment

DUNE: Long-baseline **neutrino oscillation experiment** with a 1.2 MW beam produced at Fermilab (Illinois, USA), characterised with a **ND complex** and measured with **liquid argon detectors** at SURF (South Dakota, USA) **1.5 km underground**.





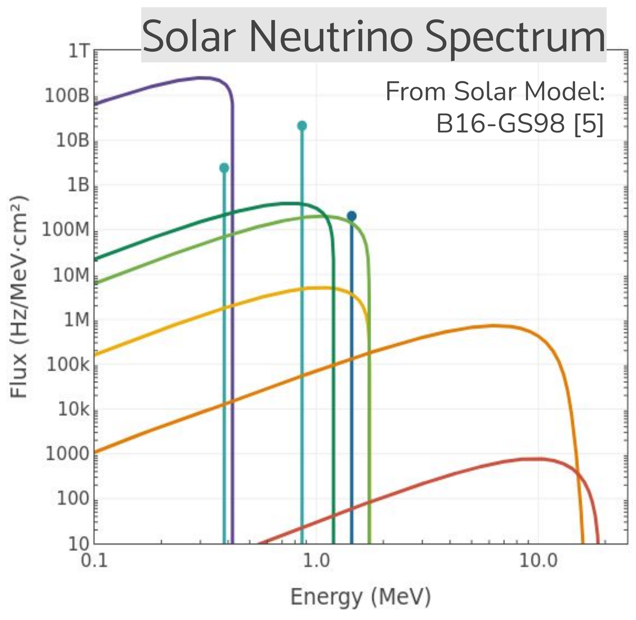
DUNE Far Detector (FD) modules [1]:
- Excavation ready to host 4 detectors.
- 17 kT LAr ~ 66 x 19 x 18 m³ cryostat.

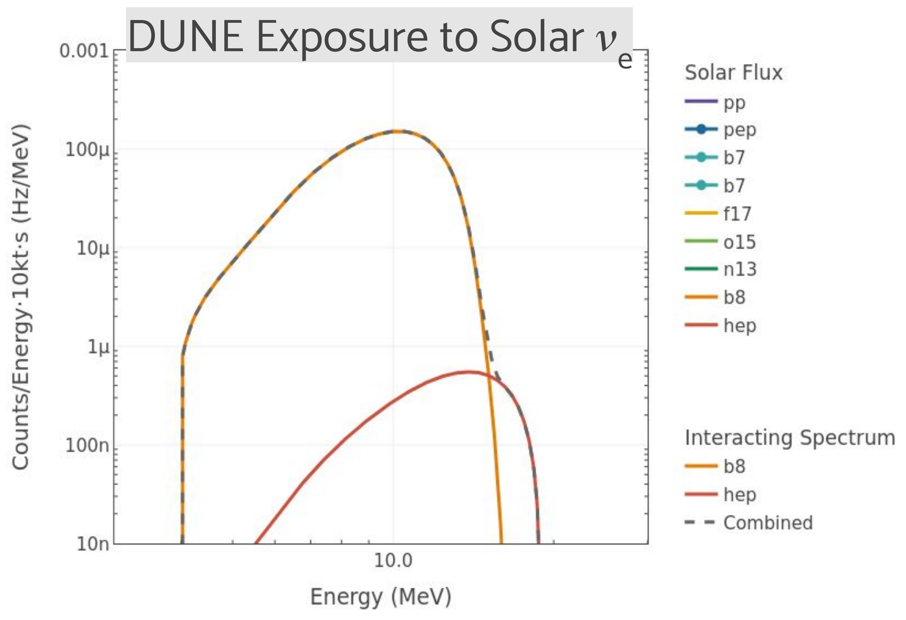
Liquid Argon TPC technology:
- High density (1.4 g/cm³).
- Ionization (42k e⁻/MeV) @ 500 V/cm.
- Transparent to scintillation light.
- Scintillation (24k γ/MeV) @128 nm.
- 3D reconstruction & particle ID.

Solar Neutrinos in DUNE

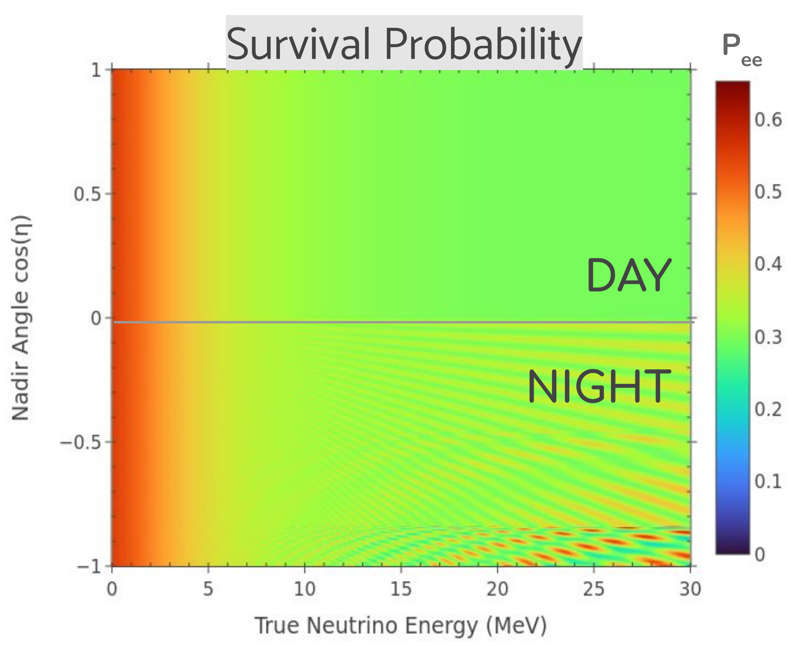
- DUNE will be sensitive to solar neutrinos 1.5 - 19 MeV (^{8}B + hep).
- Mostly detected from CC Ar - ν_e with x-section ~ 10^{-42} cm² [2].
- For 4 FD modules → **171 k CC ν_e events** per 70 kT · year exposure.

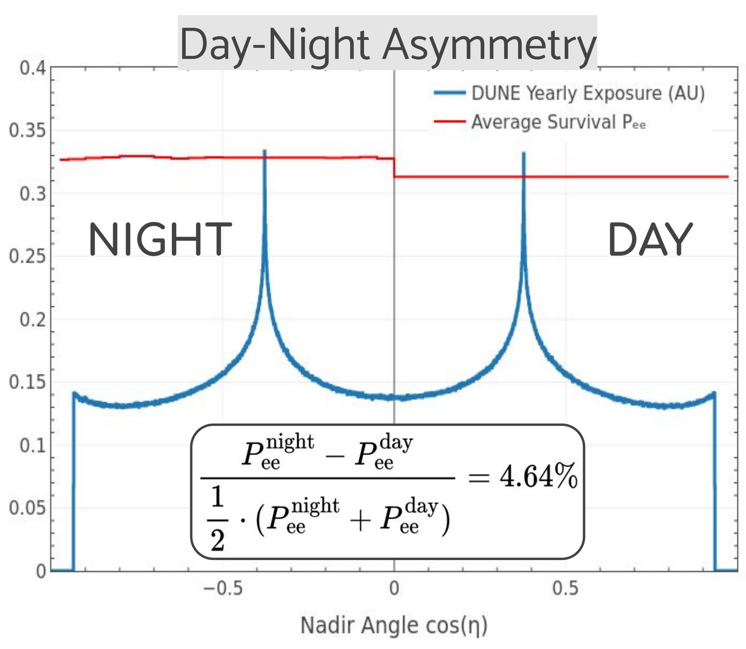
CC Interaction (Q 1.5 MeV): ν_e + ^{40}Ar → e⁻ + ^{40}K*





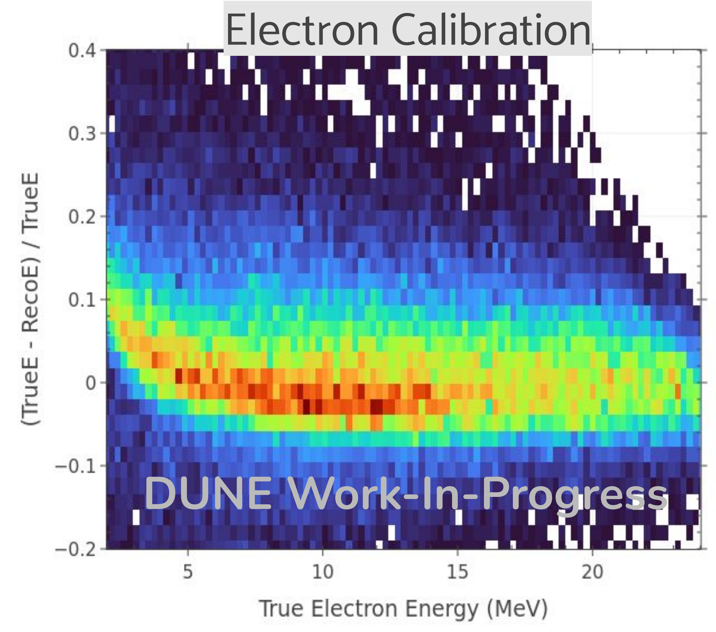
- Solar neutrinos arrive almost entirely as **ν_2 mass eigenstate** (~ ⅓ ν_e).
- Upon detection @SURF, **matter effects** (from Earth) influence the oscillation probability causing the **day / night asymmetry**.

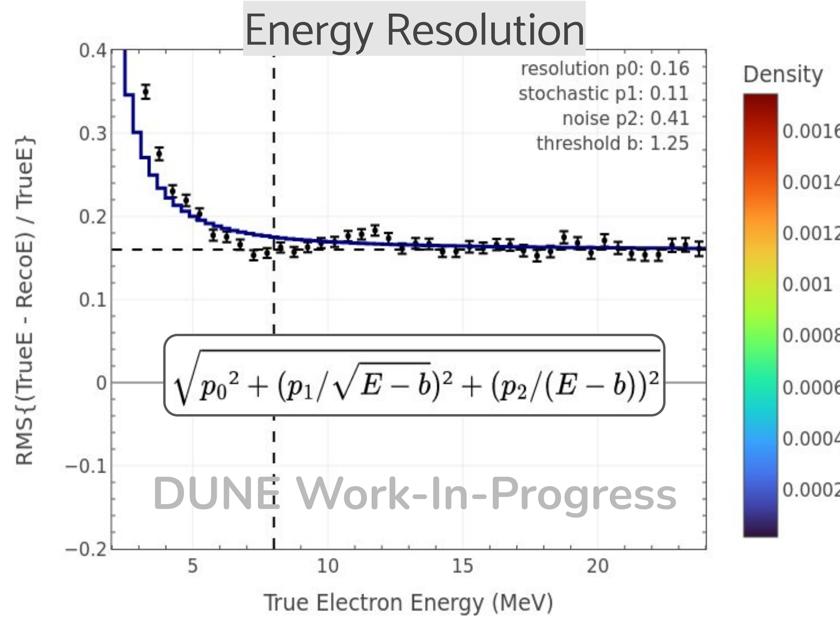




Event Reconstruction: CC ν_e

- Data from comprehensive **simulation of the FD geometries** and readout chain (e.g. noise, backgrounds…) using the LArSoft [3] framework.
- **Reconstruction for low energy events** follows a hit-clustering scheme based on channel and time proximity (3 channels - 12.5 μs).

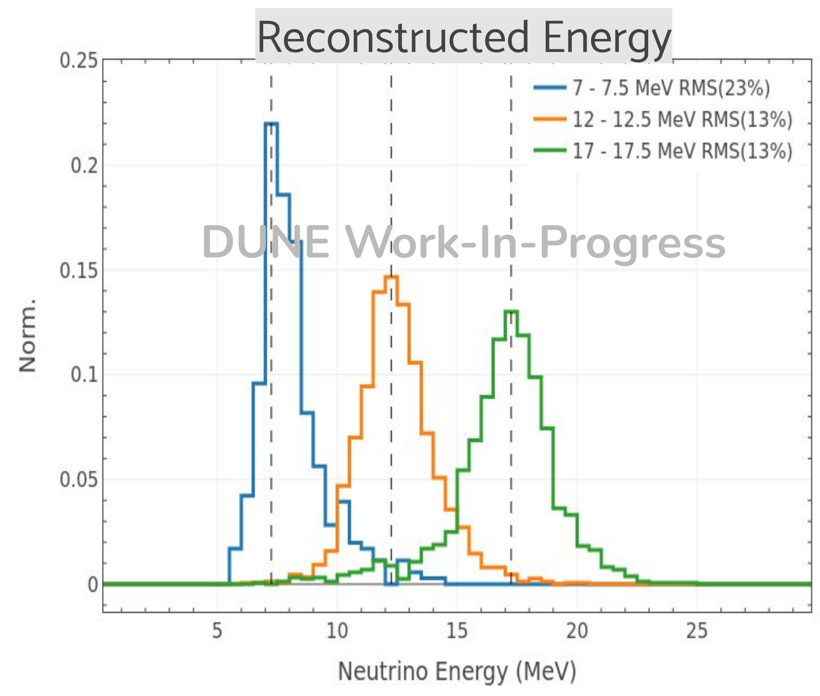


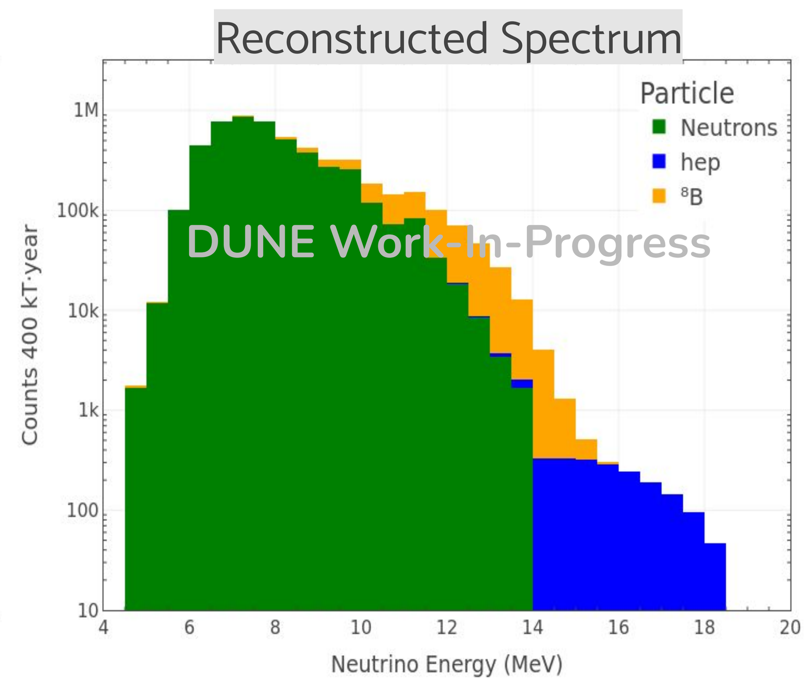


- **Electron energy resolution ~ 16%** (with ideal drift reconstruction).
- Reconstruction optimised for **main electron**. Additional **deexcitation gammas** from quantised nuclear states add **4 MeV** or **5.9 MeV**.
- **Neutrino reconstruction** follows from combining **electron + gamma clusters**.

CC Interaction (nuclear deex.): ^{40}Ar → ^{40}K* → ^{40}K + γ (+ N·γ)

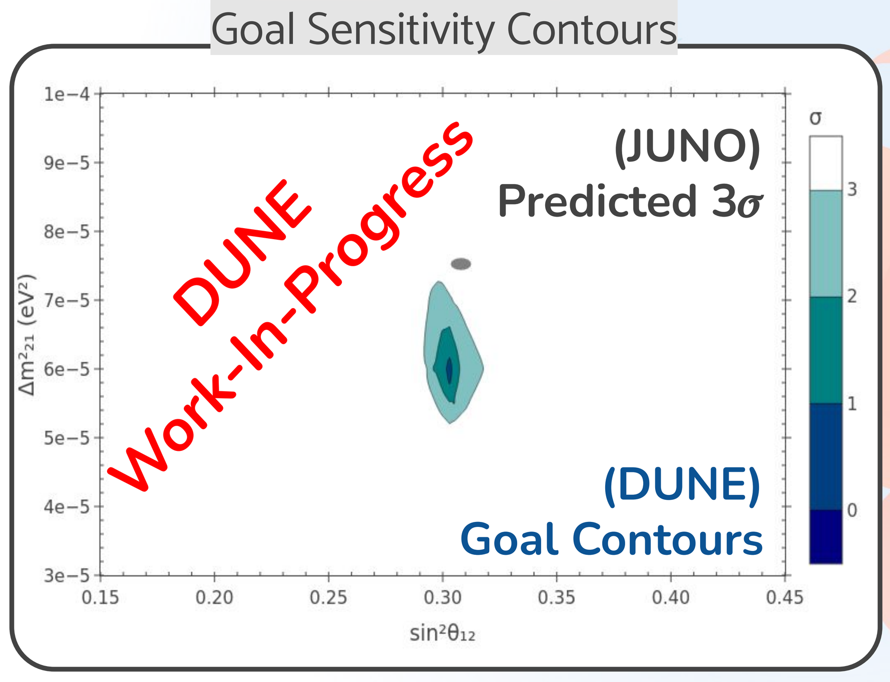
- Currently **studying full range of radiological & external backgrounds**.
- **Neutrons** → Most challenging due to penetration and signal topology.
- Appropriate cut selection result in **S/B 119%** (> 10 MeV).





Goal Solar Neutrino Sensitivity

- **Fitting the final neutrino spectrum** (solar best fit [4]) against results from an oscillation parameter scan provides **statistical sensitivity contours.**



Assumptions:
- **100% efficient flash-matching**
  - Electron drift time correction.
  - Bkg. fiducialization.
- **Offline study**
  - → Needs specific trigger.
- FD1 layout allowing for internal **fiduzialization** (2nd module).
- **Uncertainty** 4 % (S) & 2 % (B).

Result:
- Separation Δm^2_{21} > **3σ** wrt. reactor measurement.

References

[1] DUNE Collaboration, Far Detector Technical Design Report, Volume I: Introduction to DUNE, JINST 15 (2020) T08008, arXiv:2002.02967 (2020).

[2] S. Gardiner, Simulating low-energy neutrino interactions with MARLEY, Comput. Phys. Commun., arXiv:2101.11867 (2021).

[3] E.L. Snider and G. Petrillo, LArSoft: toolkit for simulation, reconstruction and analysis of liquid argon TPC neutrino detectors, J. Phys.: Conf. Ser. (2017).

[4] Esteban, Ivan, et al. The fate of hints: updated global analysis of three-flavor neutrino oscillations. JHEP 09 (2020) 178, arXiv:2007.14792, NuFIT 5.3 (2024).

[5] Vinyoles, Núria, et al. A new generation of standard solar models. The Astrophysical Journal (2017).

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