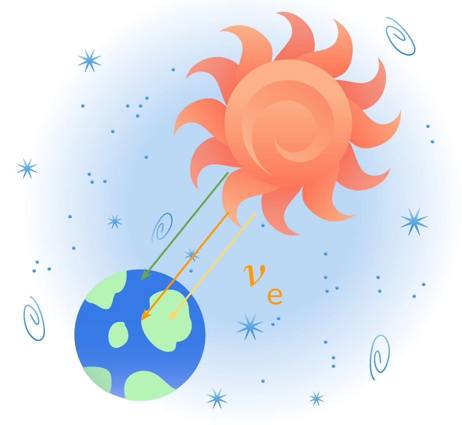
DUNE’S SENSITIVITY TO SOLAR NEUTRINOS

Sergio Manthey Corchado

PhD Student @CIEMAT under guidance of Prof. Inés Gil Botella



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DUNE

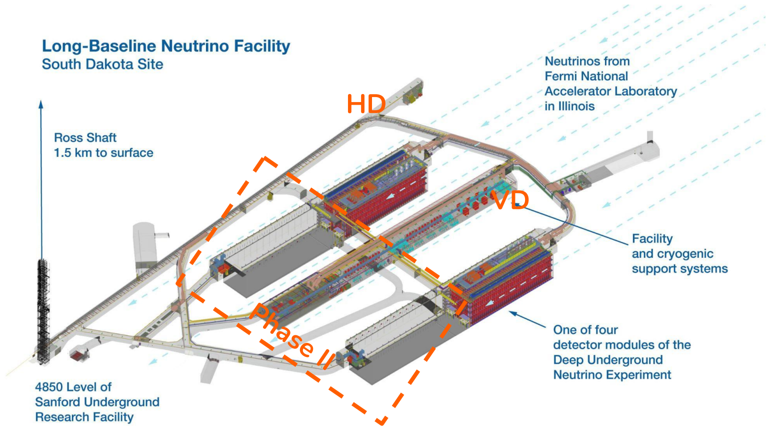
AGENCIA ESTATAL DE INVESTIGACIÓN

Plan de Recuperación, Transformación y Resiliencia

Deep Underground Neutrino Experiment

Next-generation long-baseline (**1300 km**) oscillation experiment **between Fermilab** and **Sanford** Research Facility (**1.5 km underground**):

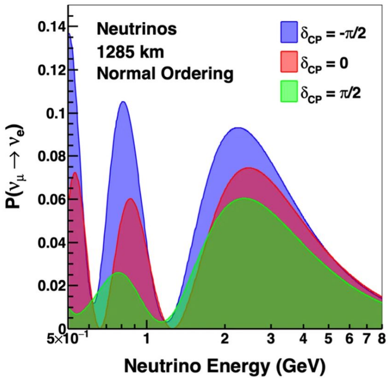
- **1.2 MW neutrino beamline** (> 2MW **Phase II**)
- High-resolution **Near Detector** complex → Upgraded in **Phase II**.
- **Far Detector** consisting of 4 17-kT liquid argon TPC modules (VD & **HD** + **Phase II**).

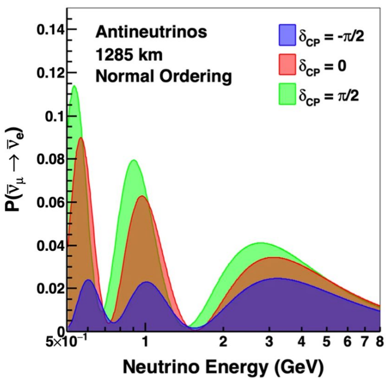


The science program of DUNE includes:

- Long-baseline neutrino oscillations.
  - **Neutrino mass ordering**.
  - Leptonic **CP violation**.
  - Precision test of **3-neutrino paradigm**.
- **Neutrino astrophysics** (e.g. detection of core-collapse supernovae, **solar neutrinos**).
- Searches for physics beyond the Standard Model (**BSM**).

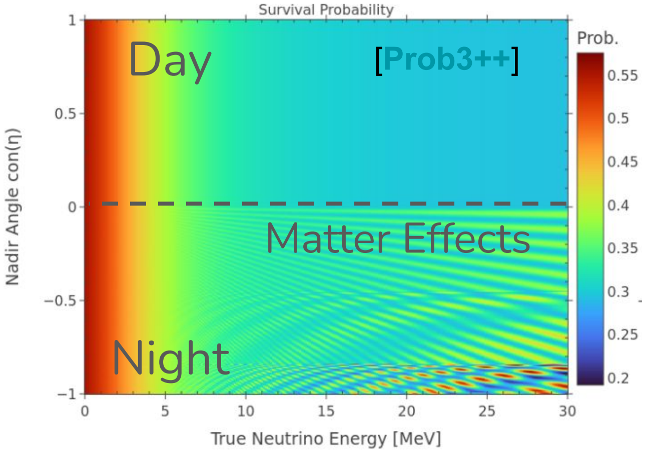
Stressed in Phase II

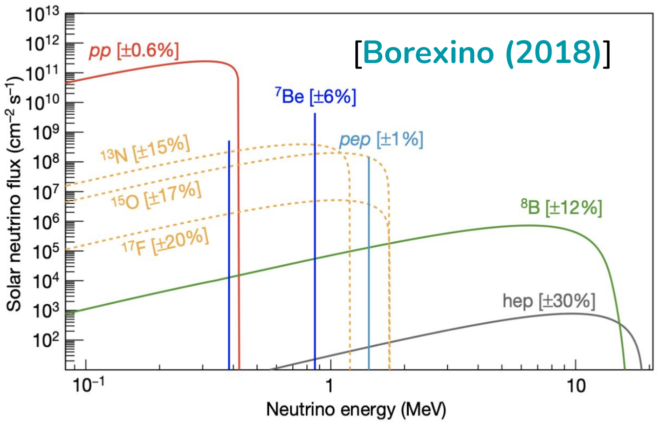


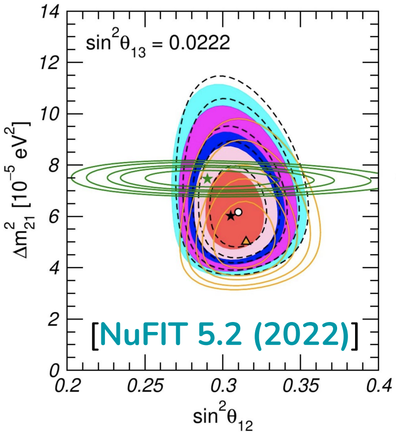


DUNE Potential & Physics Motivation

- **Day-Night asymmetry** and matter effects (possibility to explore NSI).
- Measurement of **hep flux**. First time measure!
  - Big theoretical uncertainty (> 30%) → important for Solar Models.
- **Sensitivity to Δm^2_{21} and $\sin^2\theta_{12}$ from ^{8}B neutrino measurement.**
  - Compare **solar (matter effects)** and reactor neutrinos (w/o matter effects).







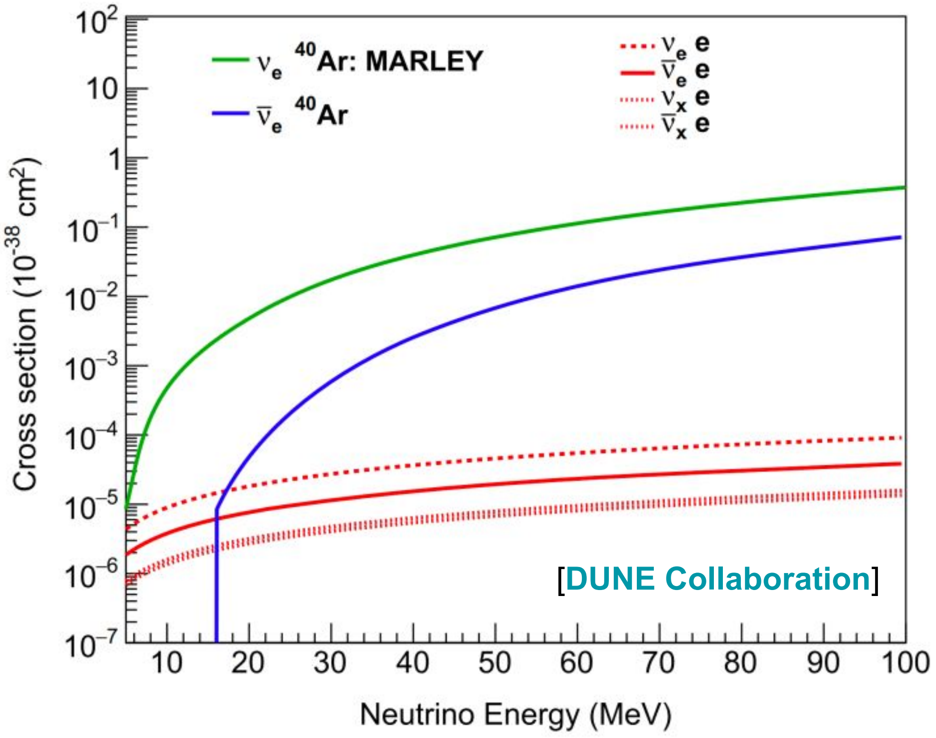
Low Energy Neutrino Detection in DUNE

CC main detection channel:

$$\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^* \rightarrow e^- + {}^{40}K + \gamma \ (+ N^*\gamma)$$

$$\nu_x + e^- \rightarrow \nu_x + e^-$$

- **DUNE ideal for solar analysis** due to the **high cross-section** of the **CC channel** → expected ~171 k solar events per year.
- ES is sensible to all flavours: → independent **absolute flux** measurement.
- ES channel carries directionality (important for supernova pointing).



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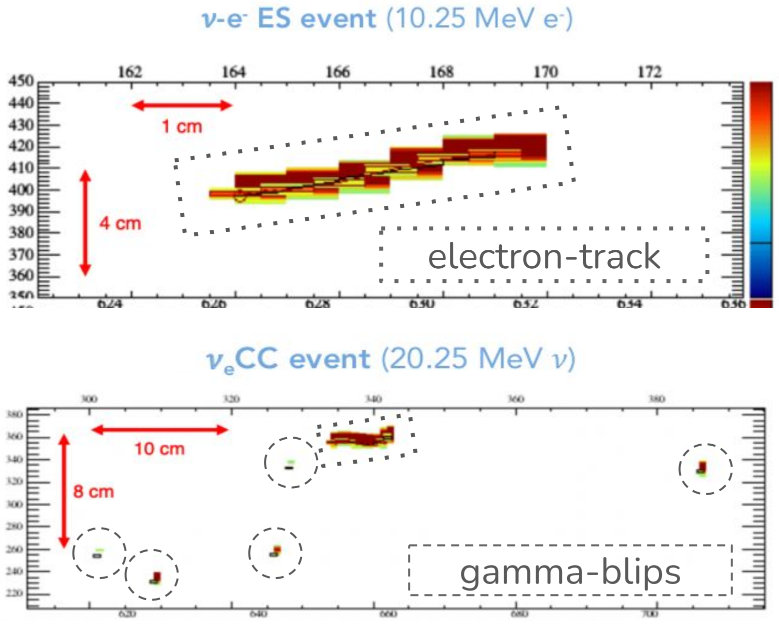


True Energy Deposits

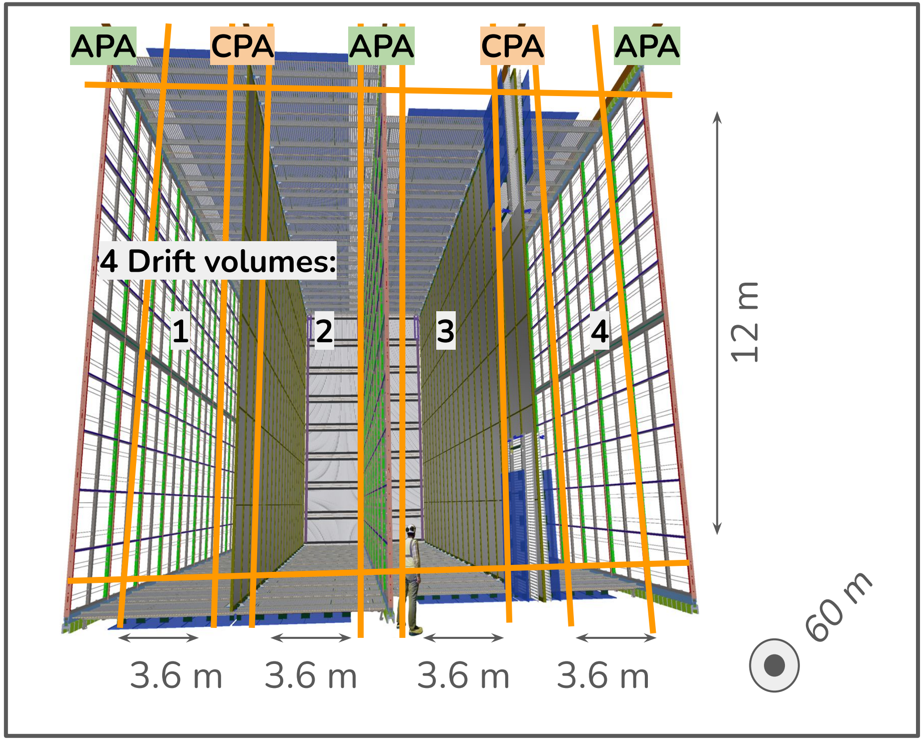
DUNE Far Detector

Start evaluating HD for solar neutrino studies.

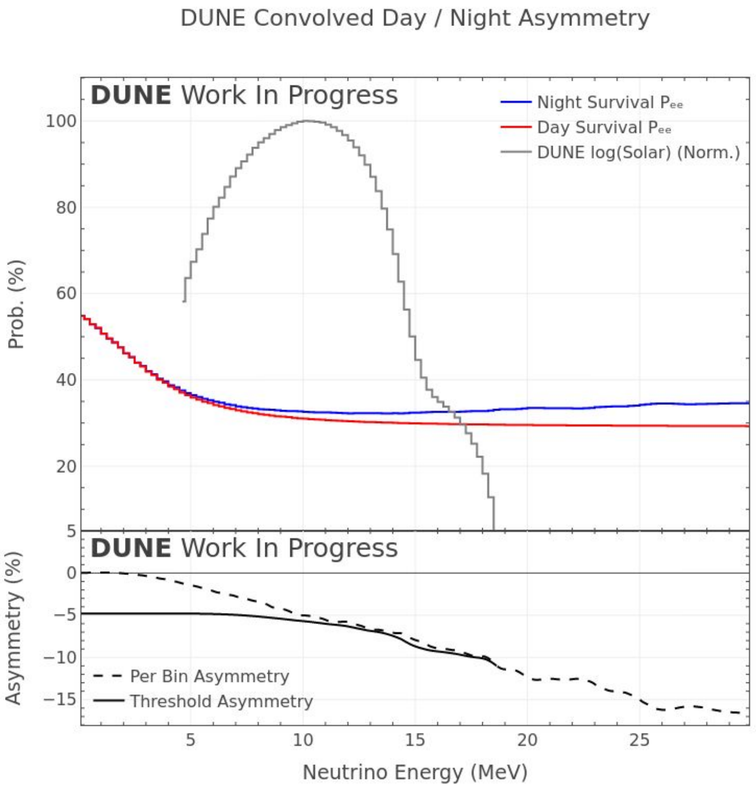
VD evaluation is ongoing.

- **HD LArTPC**: 3 Anode / 2 Cathode Plane Assemblies (APA / CPA).
  → 4 drift volumes.
- **Photon Detection System** (PDS) contained in the APAs detect **<20> PE / MeV**.
- Intrinsic fiducialization → **Cleaner drift volumes 2&3** due to external contamination in 1&4.
- **Additionally, fiducial cuts possible** combining TPC and PDS information.

Cavern emitting **Gammas** & **Neutrons**



DUNE Predicted Day-Night Asymmetry



DUNE

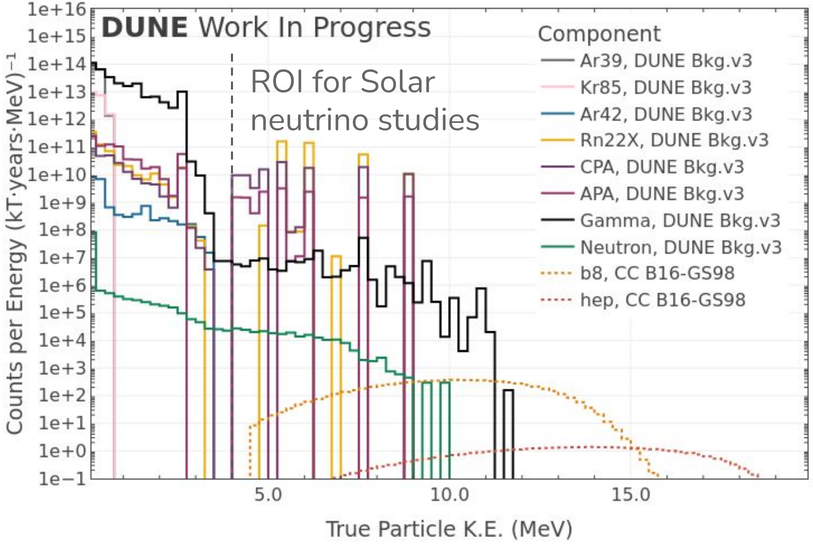
- With ~171 k expected events per year Day-Night asymmetry should be one of DUNE first measurements.
- For energies above 10 MeV, asymmetry reaches an absolute value of ~ 6 %.
- Significance can be simply calculated with S/√B. → Evaluating background is crucial to understand DUNE's potential.

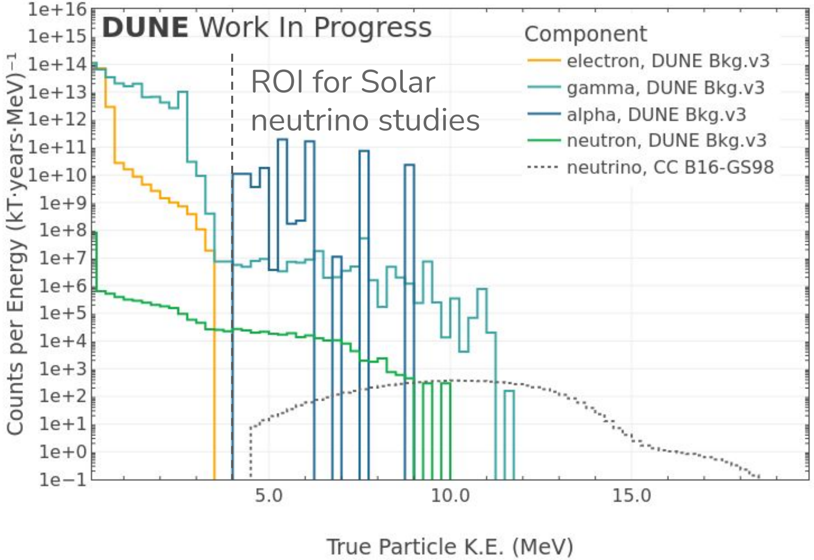
Super Kamiokande
latest **results** [PhysRevD.109.092001] agree with predictions but **still compatible with null assumption**.

$$A_{\mathrm{D/N}}^{\text{SK-IV, calc}} = -0.025 \pm 0.012(\text{stat.}) \pm 0.014(\text{syst.}).$$

Background Model

- Currently working on the 3rd iteration of the FD background model.
- Overlaid is the **oscillated interacting solar neutrino flux** for a 1 kT · y exposure.
- **Topological information is limited** at these low energies. Most interactions are “blips”.
- Need to **define specific region of interest** and produce high energy bkg. particles (alpha, gamma, neutron) to understand their reconstruction and signal contamination.

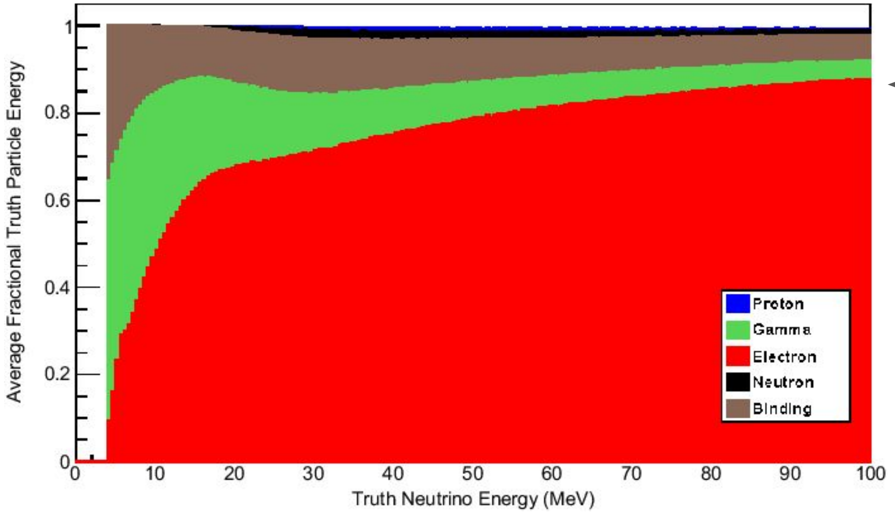




Neutrino Detection Efficiency

- Neutrino CC production for DUNE relies on **MARLEY** generator (interaction threshold ~ 4 MeV). Detection efficiency ~ 100% but **requires 1 TPC hit thld**. Gamma energy usually very diffuse.

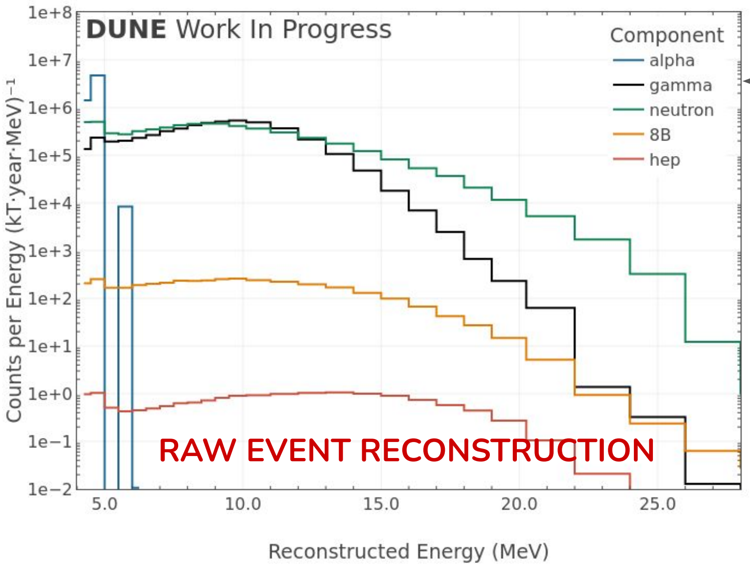
  → DUNE FDs are not design for solar neutrino studies. Additional **low energy resolution & reconstruction tools** are being developed for this purpose.



Neutrino reconstruction algorithm needs to include **binding energy** offset > 1.5 MeV and **missing energy** (neutrons and gammas below threshold)

Background Reconstruction & Mitigation

- **Signal reconstruction algo. on background**, necessarily increases their energy wrt. truth.
- **Fiducialization** has a strong impact on **gamma** background due to their penetration length ~20 cm.
- **Neutron** captures produce a gamma cascade. **Topological cut** on max number of adjacent clusters.
- Additional mitigation strategies included in **TPC-PDS matching** characteristics.

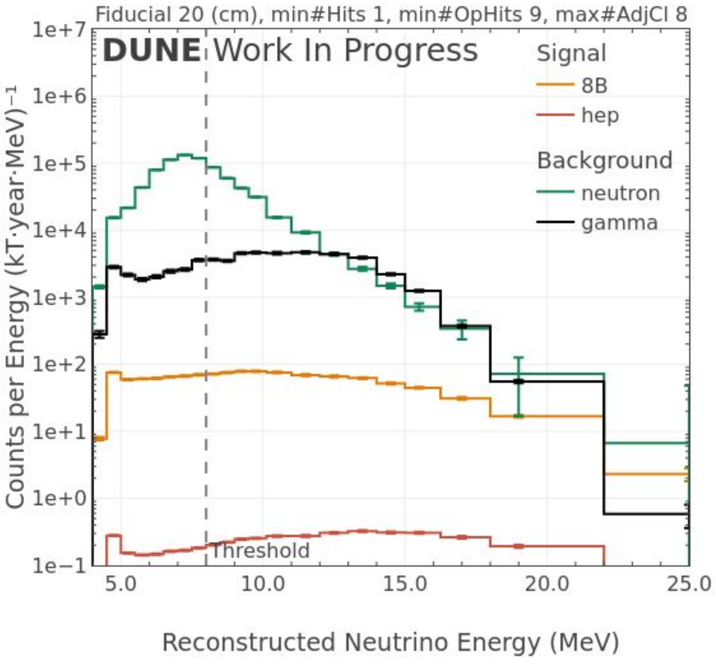


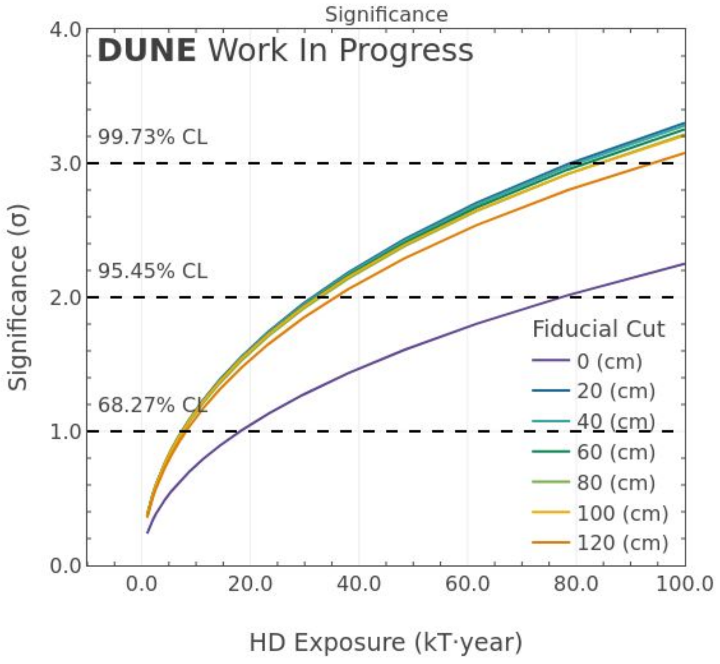
Without proper event calibration and background mitigation there is a complete overlap between signal and background.

→ **Developing specific workflow** and event selection for each low energy study.

DUNE Day-Night Asymmetry Significance

- First results predict day-night asymmetry measurement **@2σ within the first years** of data taking → could be one of the first **DUNE physics results**.

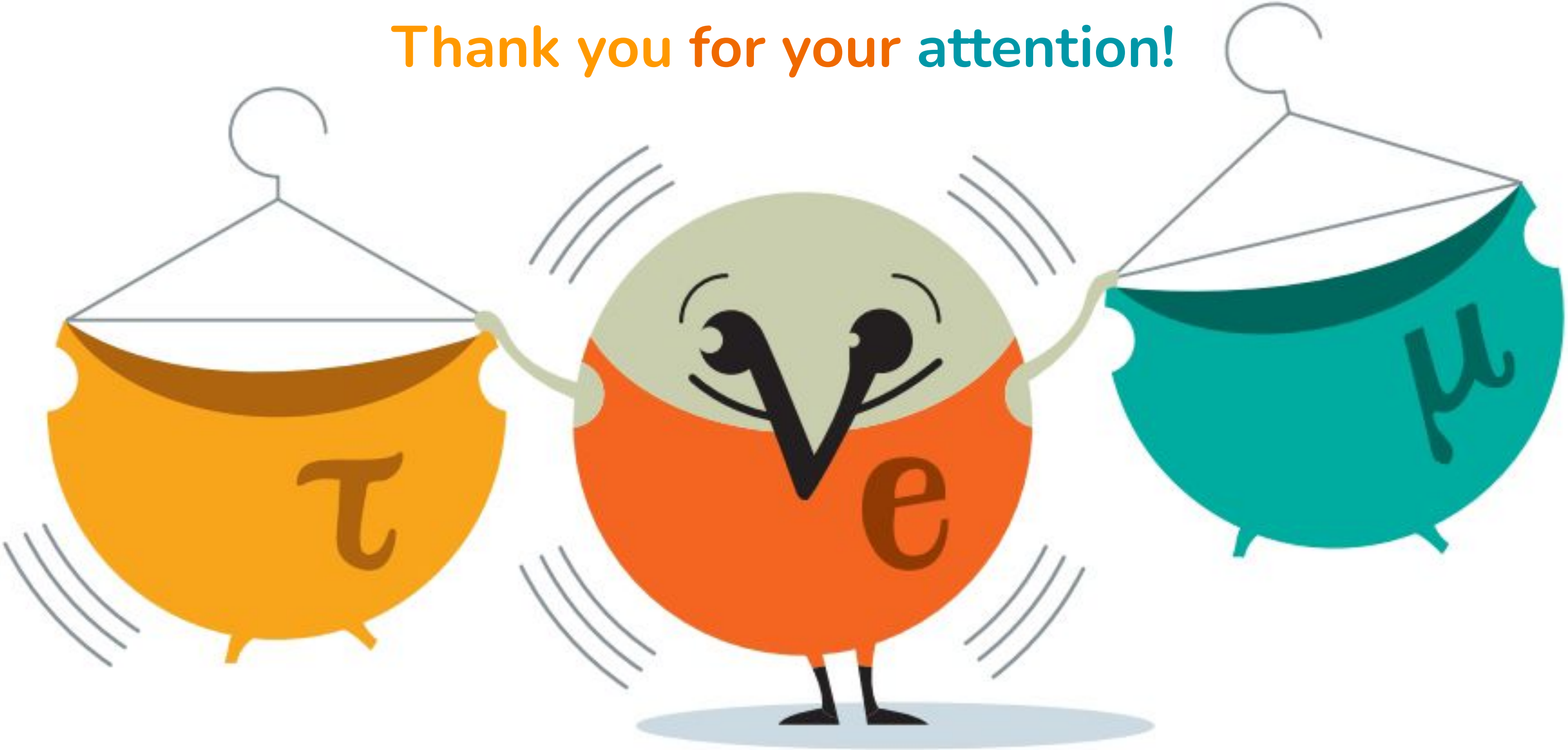




Conclusions

- DUNE has the potential of **measuring hep neutrinos** and provide a precise **measurement of Δm^2_{21} from ^8B** neutrinos and the **day-night asymmetry.**
- Currently working on realistic **background model** & specific reconstruction tools.
- The **DUNE sensitivity to solar neutrinos** being computed including **full background and detector reconstruction.**
- My thesis will be completed with a publication containing all of these studies. Stay tuned!

Thank you for your attention!



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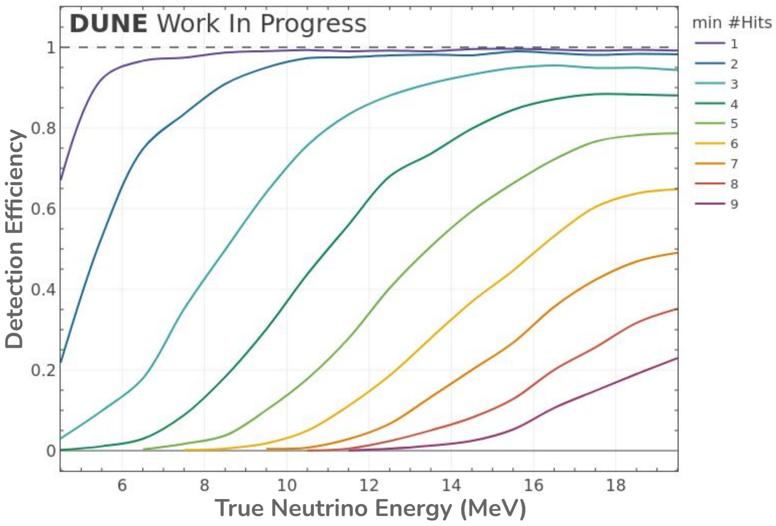
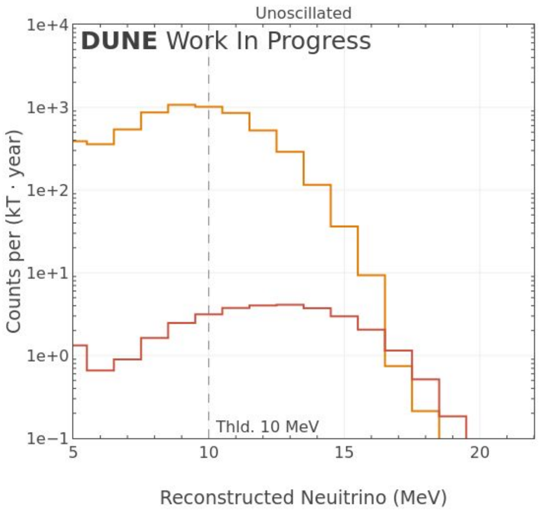
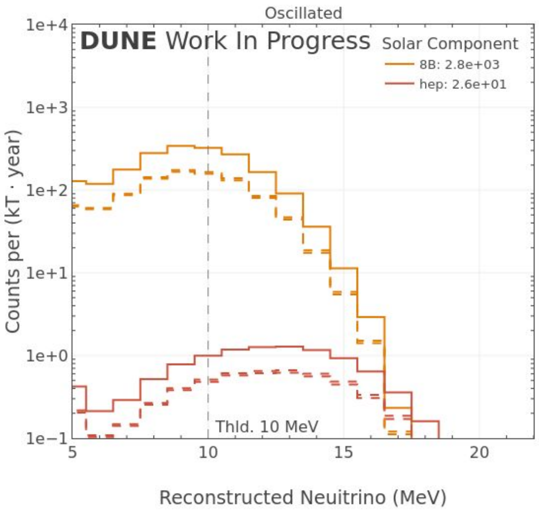


Neutrino Energy Reconstruction

- Estimated counts per kT year (above 10 MeV reco energy) predict **great exposure**.
- Fully propagated **light and charge reconstruction** with full **background**.
- Energy resolution estimated to rise between 10 and 30 % for the region of interest with a strong dependency on the collected #hits.
- **Detection of hep** above ^{8}B has **S/B ~1% (> 10 MeV) and ~40% (> 16 MeV)**.





Oscillated	Type	Component	Counts
False	Total	8B	2,844.11
True	Day	8B	436.40
True	Night	8B	461.59
True	Total	8B	897.98
False	Total	hep	25.70
True	Day	hep	3.87
True	Night	hep	4.16
True	Total	hep	8.04

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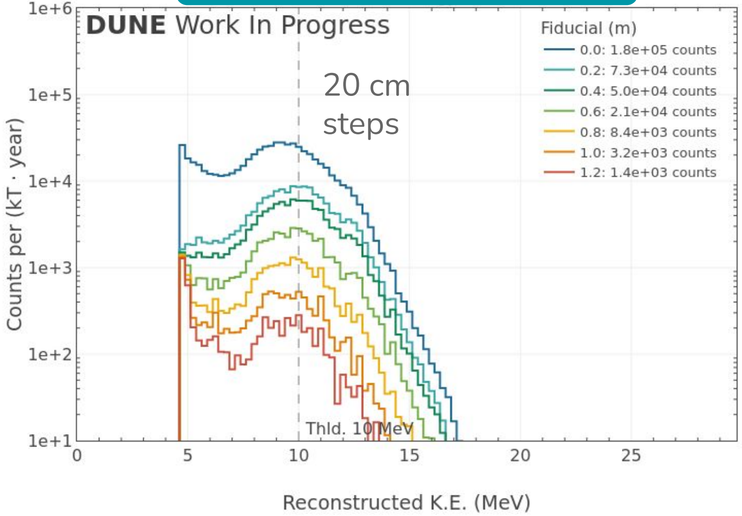
gamma fiducialization



neutron max. adj. clusters