DUNE'S SENSITIVITY TO SOLAR NEUTRINOS

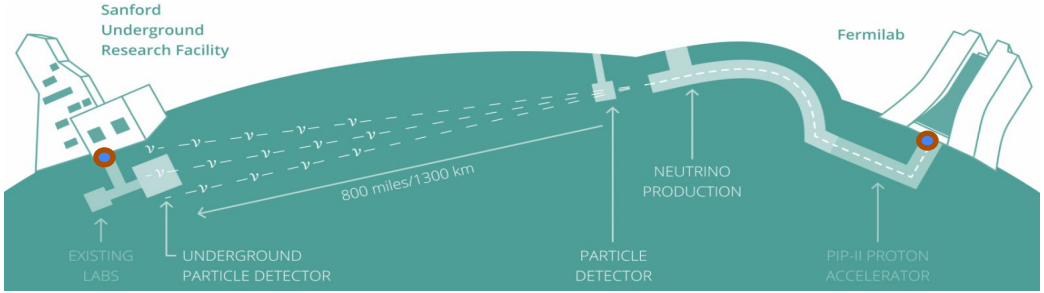
Sergio Manthey Corchado, on behalf of DUNE collaboration

CEMAT, Madrid sergio.manthey@ciemat.es

Outline:

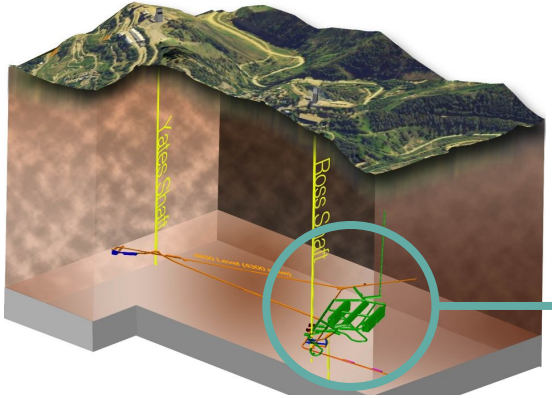
- Introduction (DUNE's far detectors)
- Solar Neutrino Analysis:
  - Motivation
  - Theoretical Computation
  - Experimental Reconstruction
  - Background discrimination
- Summary

DUNE (Deep Underground Neutrino Experiment)



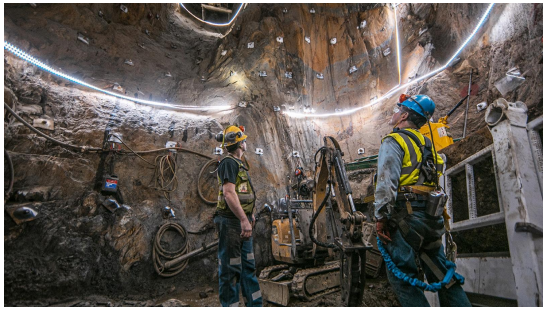
- High purity $\nu_\mu/\bar{\nu}_\mu$ **beam (0.5 – 7GeV)**: ~1.2MW (upgradable to 2.4MW).
- Dual-site experiment with main focus on precise ν **oscillation** measurement (including CP violation & mass hierarchy determination)**.**
  - **Near Site Facility:** multi-technology to measure unoscillated neutrino flux.
  - **4 Far Detectors:** total mass of ~70kT.
- DUNE aims to explore: BSM physics, supernova detection, **Solar Neutrinos…**

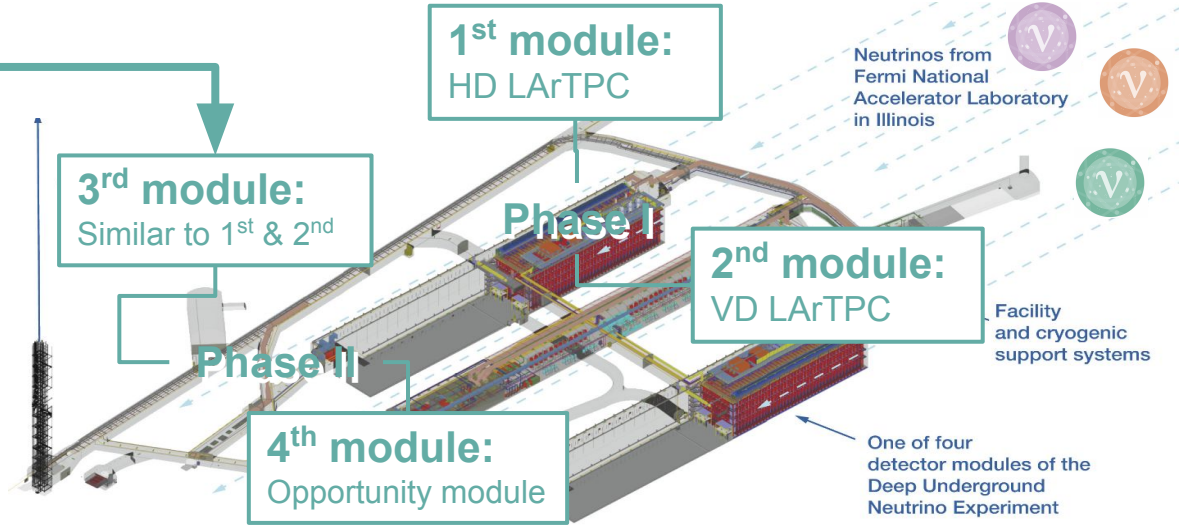
DUNE Far Detector Facilities



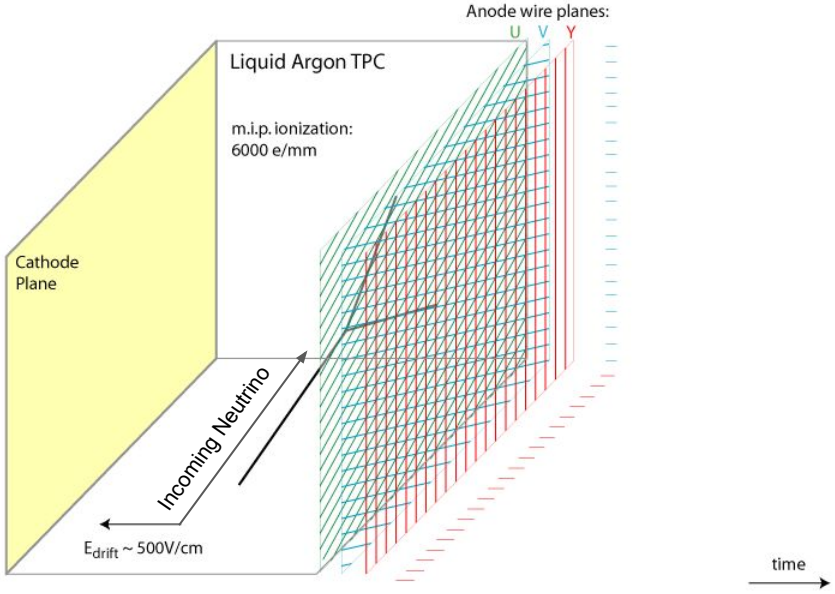
- Far detectors located 1.5 km underground at SURF.
- Phase I (**first data late 2020s!**):
  FD-1 horizontal drift (HD) / FD-2 vertical drift (VD).
- Phase II: Possibility of a module for low energy with **enhanced physics capabilities**.

Excavation work 70% completed!



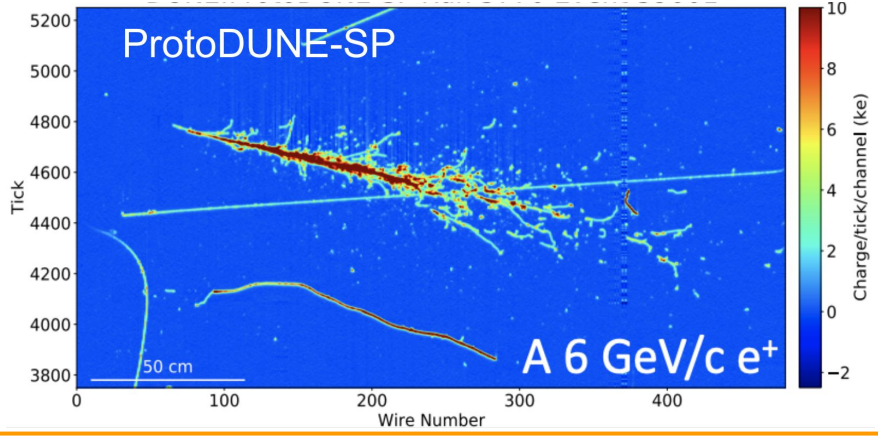


Liquid Argon Time Projection Chambers (LArTPC)



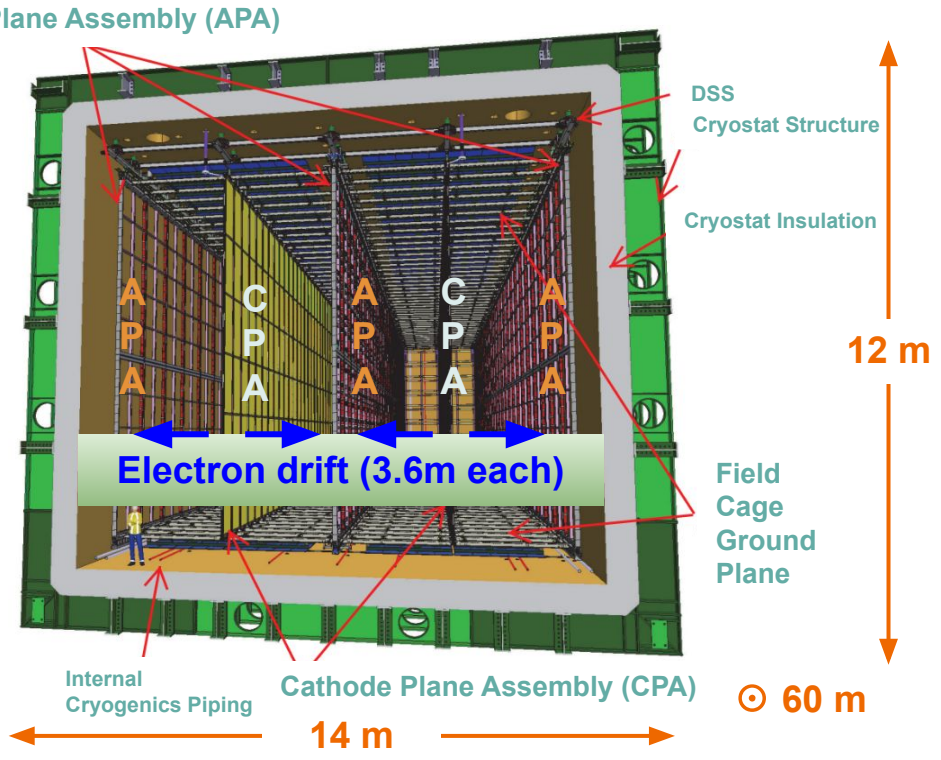
- In DUNE additional PDS integrated for t_0, improved trigger, calorimetry & event reconstruction.

- 140% water density with ionization yield (42k e^-/MeV).
- Electrons drift (~m/ms) to anode wire planes (APA)
- Argon scintillation light (40k γ/MeV) @128nm collected by PDS (~ns), providing t_0 for non-beam physics.
- **Excellent 3D reconstruction**, dE/dx & particle id. capabilities.



1st Module: HD LArTPC

- **Cryogenic** system (-184ºC) for 17kt LAr.
- TPC **charge readout system**:
  - Electric field (~500V/cm) for 3.6m drift.
  - 150 APAs (6x2.3m²), 200 CPAs.
  - 3 view charge collection (pitch 5mm).
  - 384000 readout channels.
- PDS (**Photon Detection System**)
  Integrated in the APAs (see Hamza's talk).
- Technology tested at CERN with **ProtoDUNE** (~8x8x8m³) with full size components.



Solar Neutrino Analysis

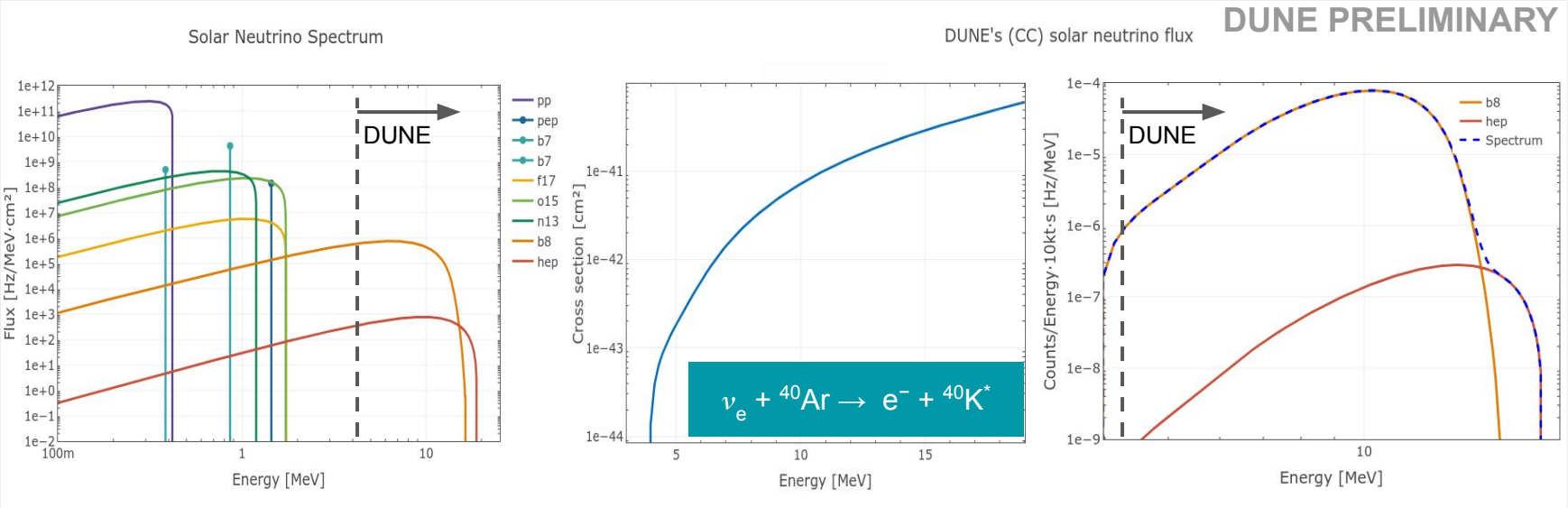
Motivation

- Due to its **high mass**, great exposure to solar neutrinos ~170k CC per 70kT·year.
- From **solar neutrinos** measure oscillation parameters (e.g. $\sin^2\Theta_{12}$ best constrained by measurements of the differential flux (E.S./C.C.) of solar neutrinos).
- Currently, existing tension between measurement of Δm^2_{21} wrt. nuclear reactor experiments.
- DUNE has the potential of **measuring Δm^2_{21}** from “wiggles” in the oscillation probability of detected C.C. neutrinos > 5MeV.
- Additionally, DUNE will measure the **hep component** of the solar spectrum (> 15MeV) for the first time, providing valuable contribution to solar modeling.
- Also **interesting to study E.S. ($\nu_x + e^- \rightarrow \nu_x + e^-$)** sensible to all flavours and directionality.

Theoretical Computation

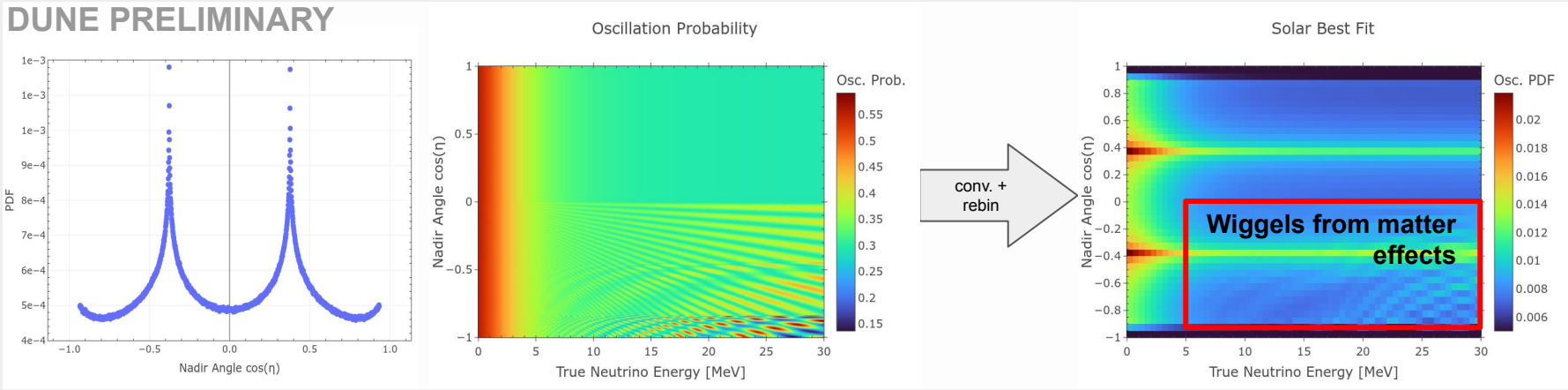
Solar NuE Analysis: Solar Neutrino Flux

- Calculated from BS2005 model and **X-Section** (Marley) → **DUNE's solar neutrino interactions:**



- Solar analysis requires good background estimation around **10MeV**, energy **resolution <10%** & adequate preselection and **trigger conditions**.

Solar NuE Analysis: Neutrino Oscillations



- **Oscillation probability:**
  ν_e oscillate (main channel for solar C.C. ν_e + ^{40}Ar).
- Convolve SURF's geographical solar incidence angle & ν_e oscillation probability from theo. calculation.
  → **Wiggles produced by matter effects** clearly detectable in 2D space representing ideal oscillation signal.

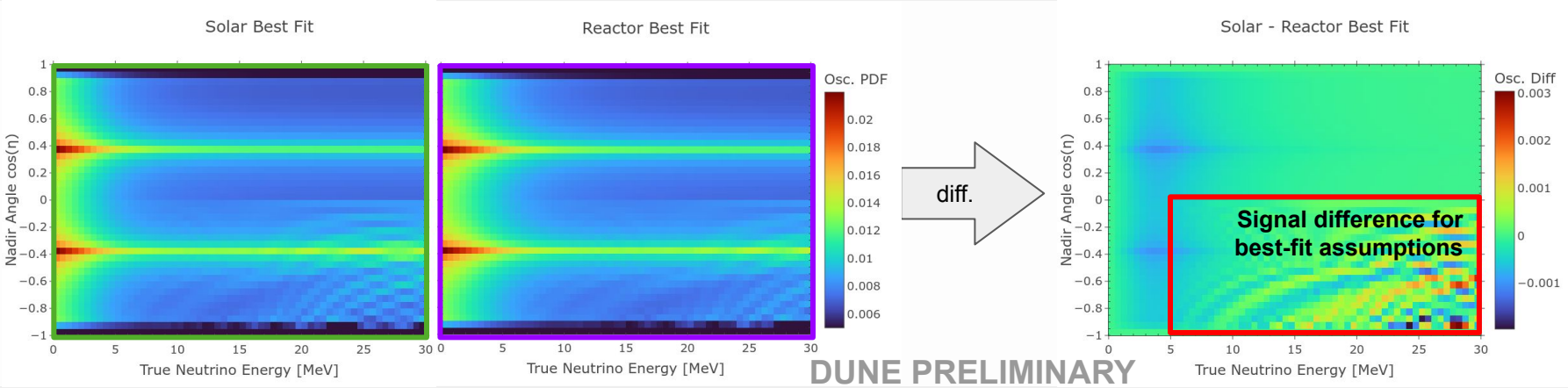
Accounting for oscillations:

- **170k Counts/70kT·year**
- 8B → 169k.
- hep → 840.

Expected >20 years exposure.

Solar NuE Analysis: Sensitivity

Goal → Compute DUNE's sensitivity to oscillation parameters from fake data accounting for backgrounds and event reconstruction capabilities:



Energy range provides best fitting potential against experimental results.

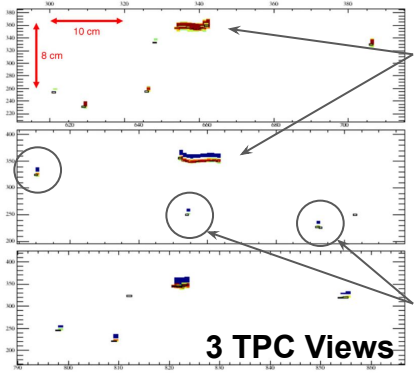
- Solar (SNO): $\Delta m^2_{21} = 6.0e^{-5} eV^2$, $\sin^2\theta_{12} = 3{,}03e{-}1$, $\sin^2\theta_{13} = 2{,}1e{-}2$
- Reactor (KamLAND): $\Delta m^2_{21} = 7.4e^{-5} eV^2$, $\sin^2\theta_{12} = 3{,}03e{-}1$, $\sin^2\theta_{13} = 2{,}1e{-}2$

Experimental Reconstruction

Solar Signal Channel:

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

ν_eCC event (20.25 MeV)



Main e^- track

Gamma deex.

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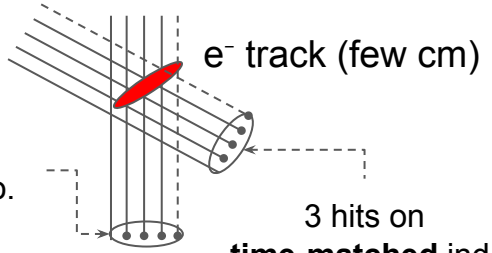
- LARSOFT simulation → Solar Neutrino Spectrum (4-20MeV).
- **PDS Hits** (detected photons) collected into flashes with t_0 & vertex reco.
- **TPC Hits** (drifted io. electrons) collected at APA.
- Hits **grouped in Clusters** according to time & wire proximity
- **Event Preselection:**

→ **Clusters (+3 hits)** with **collection + induction plane matching**.

3D Event Topology

→ **Adj. cluster** info for optimal event reconstruction and bkg rejection:

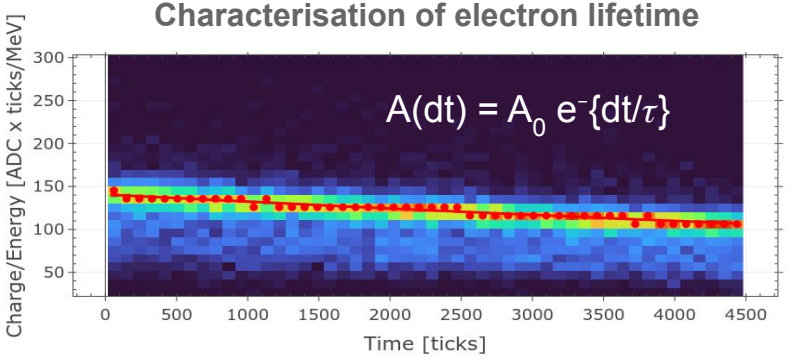
- Collect adjacent clusters (**gamma blip** candidates).
- Collect PDS **flashes** to reconstruct X coordinate (drift).
- Save backtracked MC truth from energy deposits.



Charge Calibration:

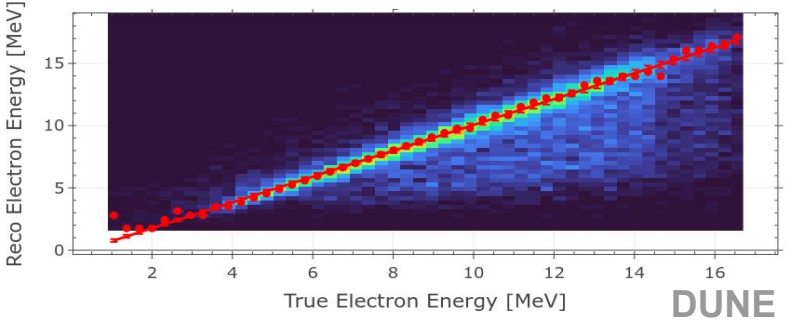
$\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^* \rightarrow {}^{40}K + \gamma\ (+ N^*\gamma)$

Characterisation of electron lifetime

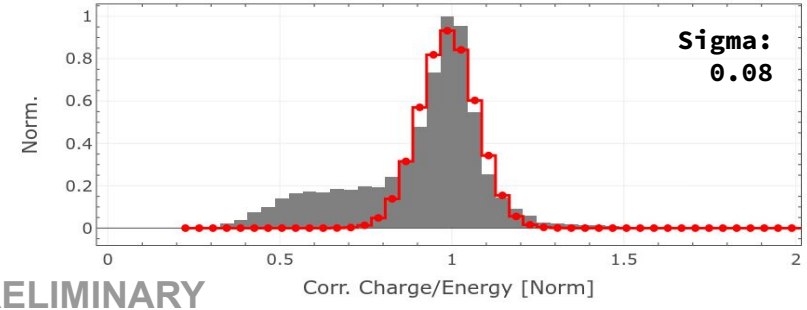


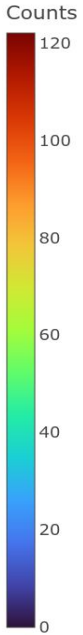
- Drifting e^- through LAr → lifetime (τ ~30ms).
- Full detector simulation of ν_e interactions provides drift time (dt) profile.
- Assuming a matched PDS flash a **cluster's energy** reconstruction yields **8% resolution**.

Calibration from electron clusters



Estimation energy resolution





DUNE PRELIMINARY

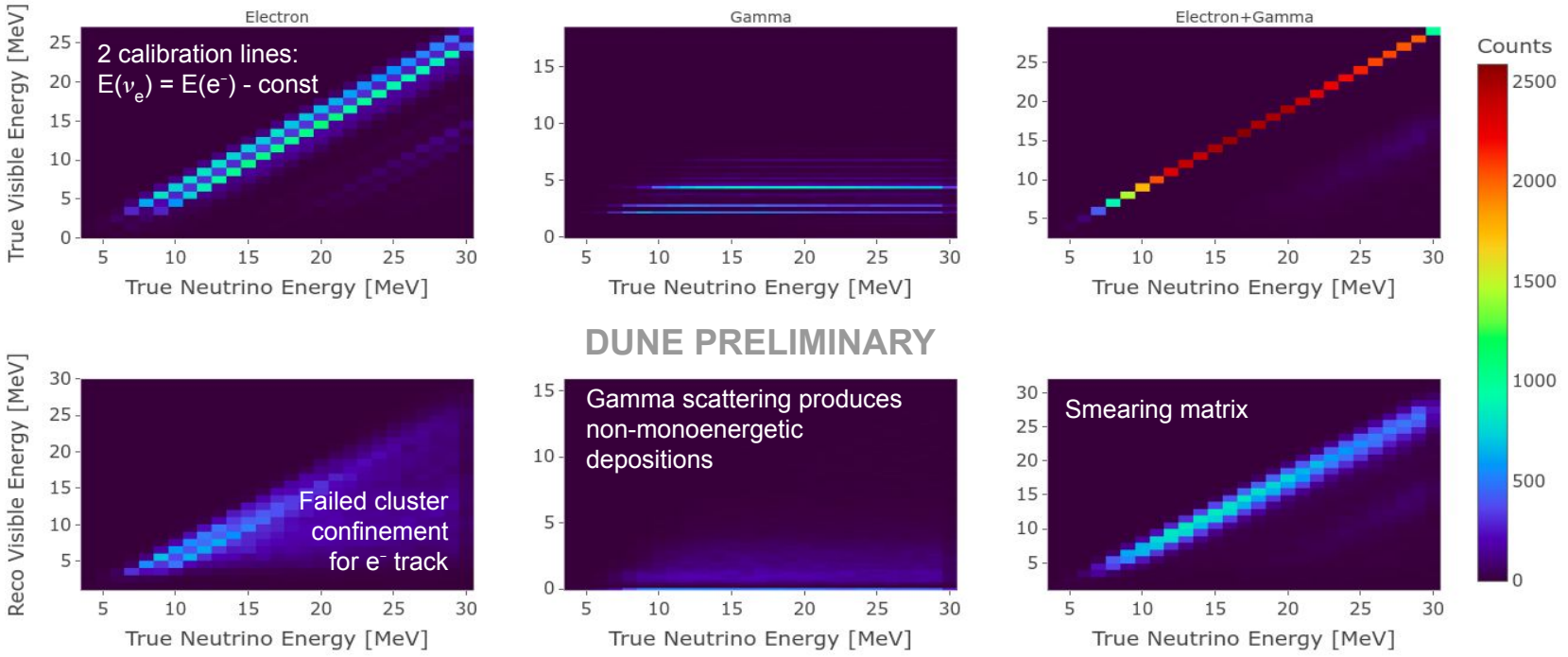
Energy Reconstruction:

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

- Basic strategy: **add MainCl + AdjCl energy.** In case of abundant bkg. **reco ν_e Energy** from e^- + topology.

Truth

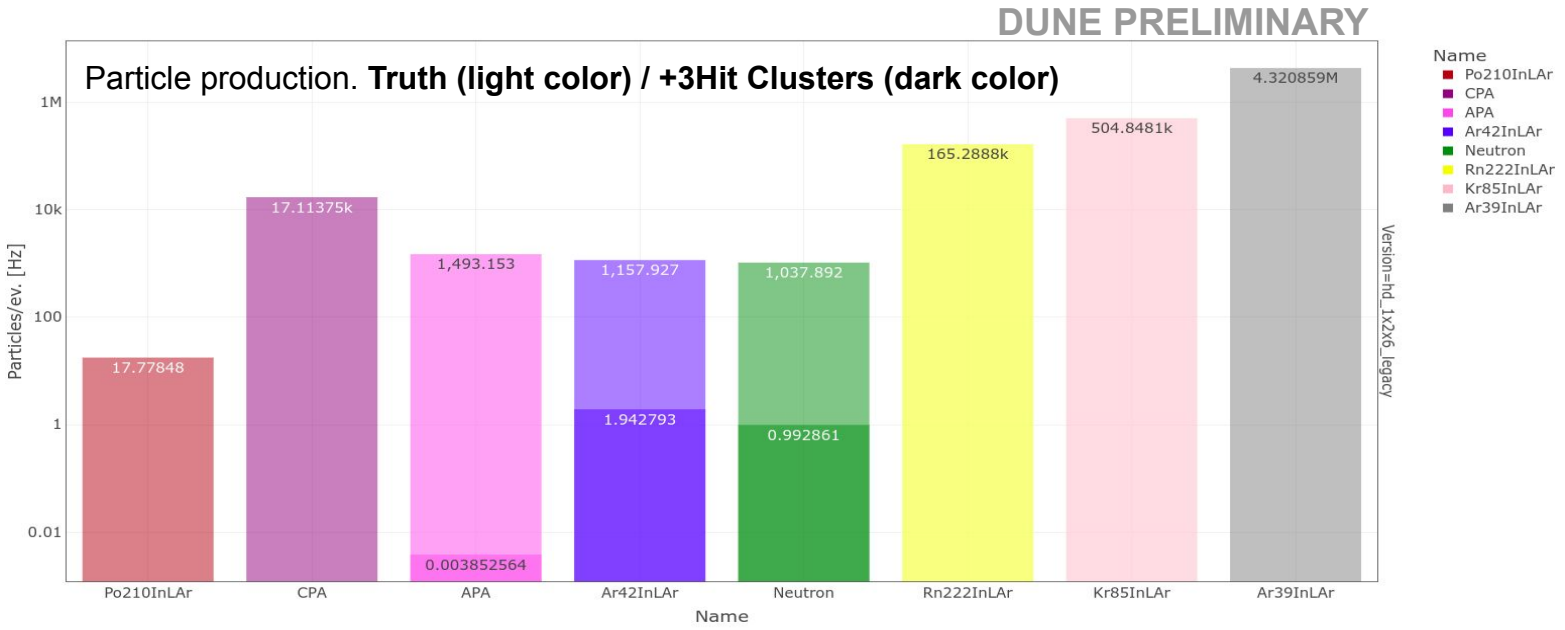
Reco



Background Discrimination

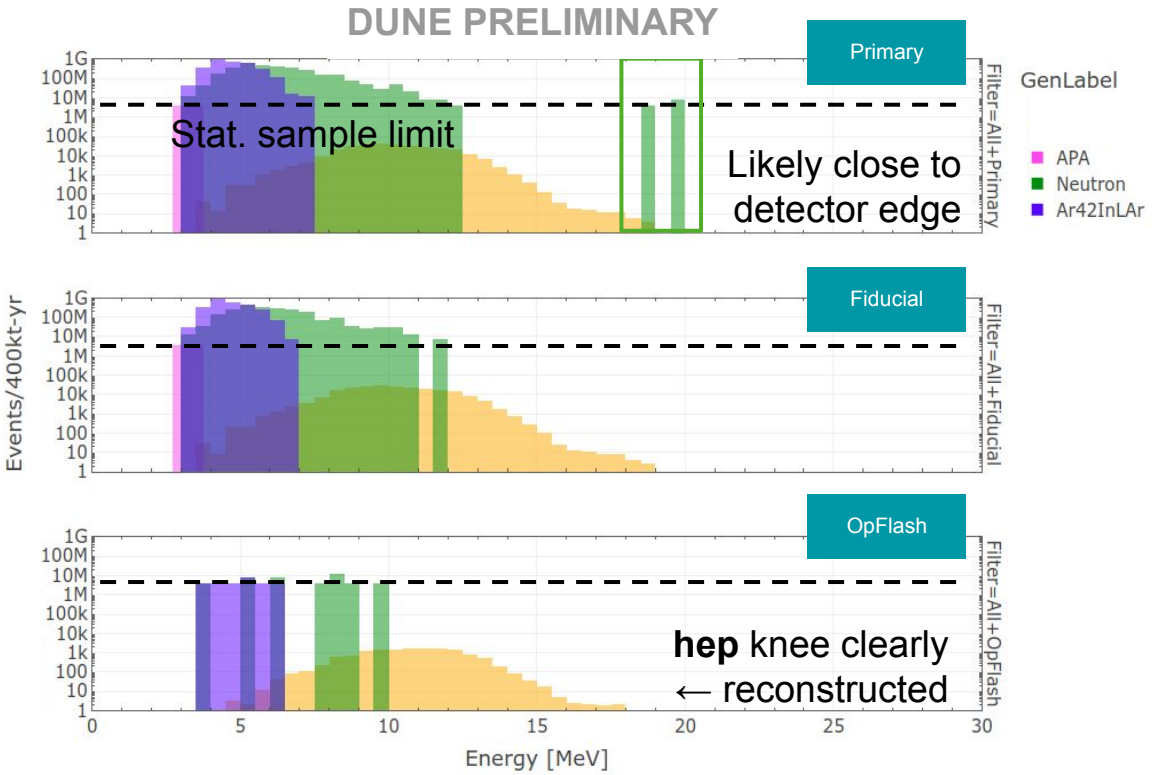
Background Model:

- Preliminary bkg study and contamination in preselection signal.
- **Currently updating** expected bkg from detector components and LAr with **radioassays**.



Reconstructed Energy Spectrum:

- Event candidates filtered to achieve **clean neutrino sample**.
- Select primary clusters (charge > adj. cluster charge) & fidutialize to remove bkg contamination.
- Requiring associated signal-like optical flash ensures reconstruction accuracy.



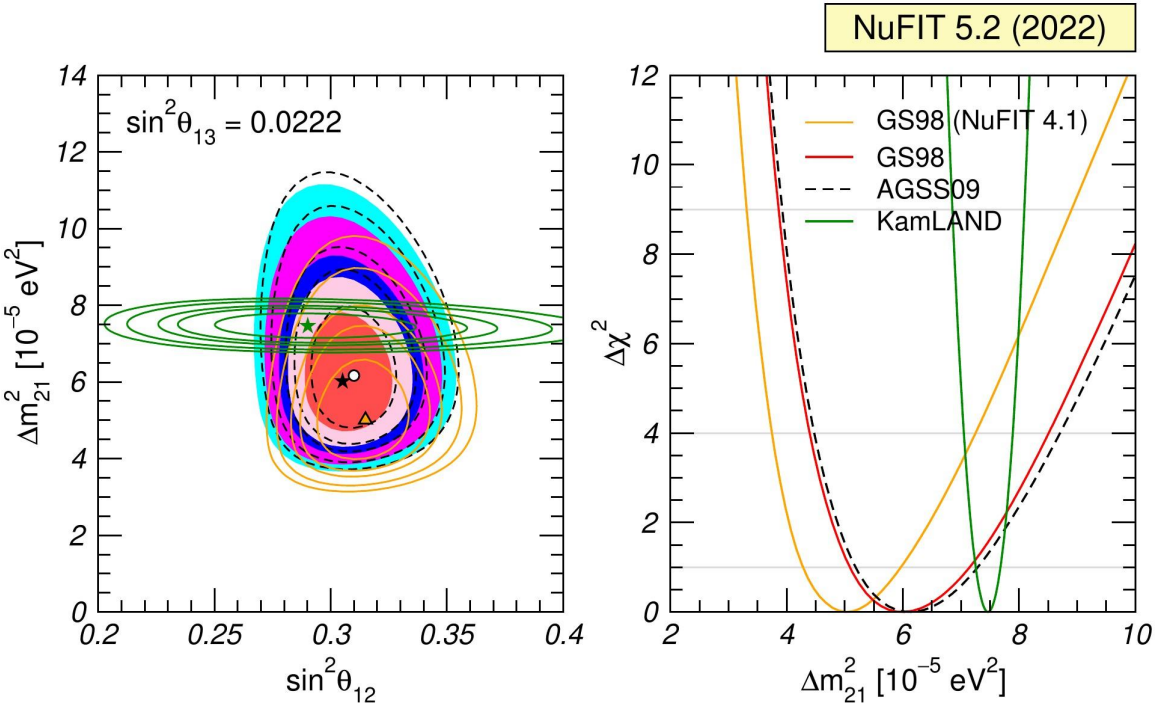
Summary

Summary:

- DUNE will have **great exposure to solar neutrinos**, measuring Δm^2_{21} from wiggles in the oscillation map and the **hep flux**.
- **Preliminary analysis** shows DUNE's low energy reconstruction capabilities and **background rejection** in the ROI for solar neutrinos.
- Currently, working on **updated bkg model** to better evaluate solar sensitivity.
- **Stay tuned** for new data & analyses.

Thank you for your attention!

Best-Fit For Current Neutrino Experiments



Neutrino oscillations global fit.