Measuring Solar Neutrino Oscillations in the SNO+ Detector

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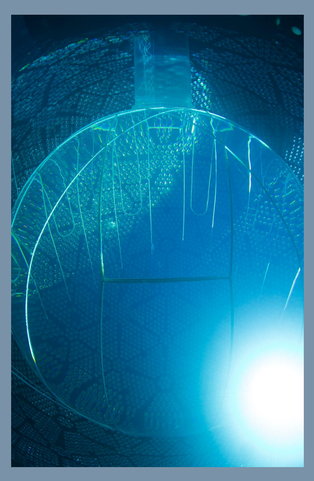
The SNO+ Experiment

- A 780 tonne, multi-purpose **liquid scintillator** neutrino experiment 2km underground [1]
- Liquid scintillator held within 6m radius **acrylic vessel**, surrounded by **ultra-pure water shielding**
- Scintillation light generated by ionising radiation detected by **~9000 PMTs**



Data & Method

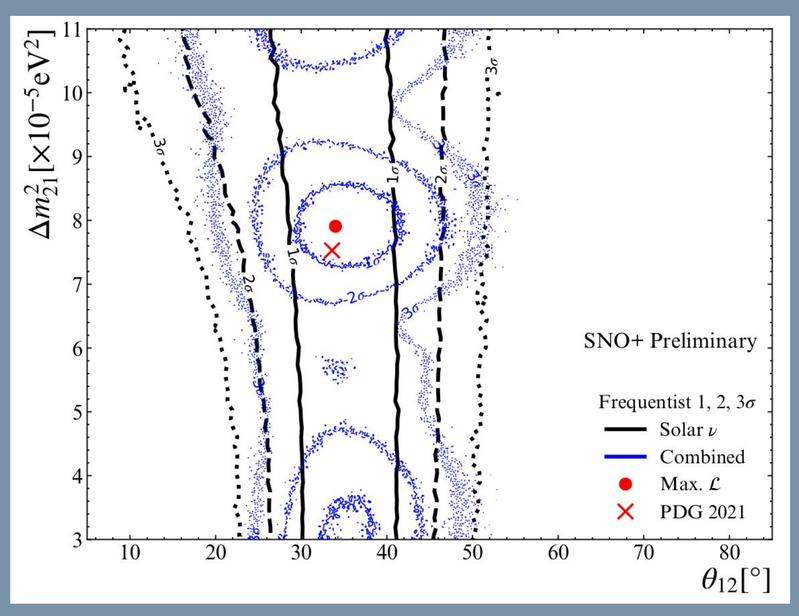
- **138.6 days of livetime** (after cuts) of data with LAB + 2.2 g/L PPO scintillator cocktail
- **Cuts** applied to triggered events:

20 second **muon & high-NHit veto**; Data cleaning cuts
Reconstructed energy & radius
Removal of **coincidences** via **in-window coincidence classifier** and **out-of-window tag** (BiPo-212/214 and (α,n))
External background removal via classifier

- Data & MC binned in **2D**: **reconstructed energy & radius**
- MC fit to data using a **binned maximum likelihood** test statistic, via **Markov-Chain Monte Carlo**
- **Fit floats** θ_{12}, Δm^2_{21}, Φ_{8B}, background rates, and energy scale systematic, according to various constraints

Combination with Reactor Analysis

- Likelihood from **SNO+ reactor analysis added** (see posters 483 & 525) to results of this solar analysis:

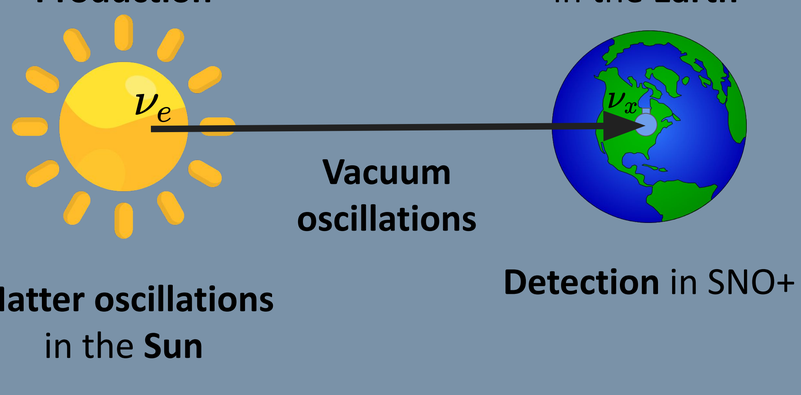


- Reactor & solar analyses allow for **complementary ways** of measuring the same oscillation parameters in **the same detector!**

References

[1] Albanese, V. *et al*, "The SNO+ Experiment", JINST (2021)
[2] Bergström, J. *et al*, "Status of Direct Determination of Solar Neutrino Fluxes after Borexino", JHEP (2024)
[3] Esteban, I. *et al*, "The fate of hints: updated global analysis of three-flavor neutrino oscillations", JHEP (2020); also NuFIT 5.2 (2022), www.nu-fit.org

Detection of Solar Neutrinos in Scintillator



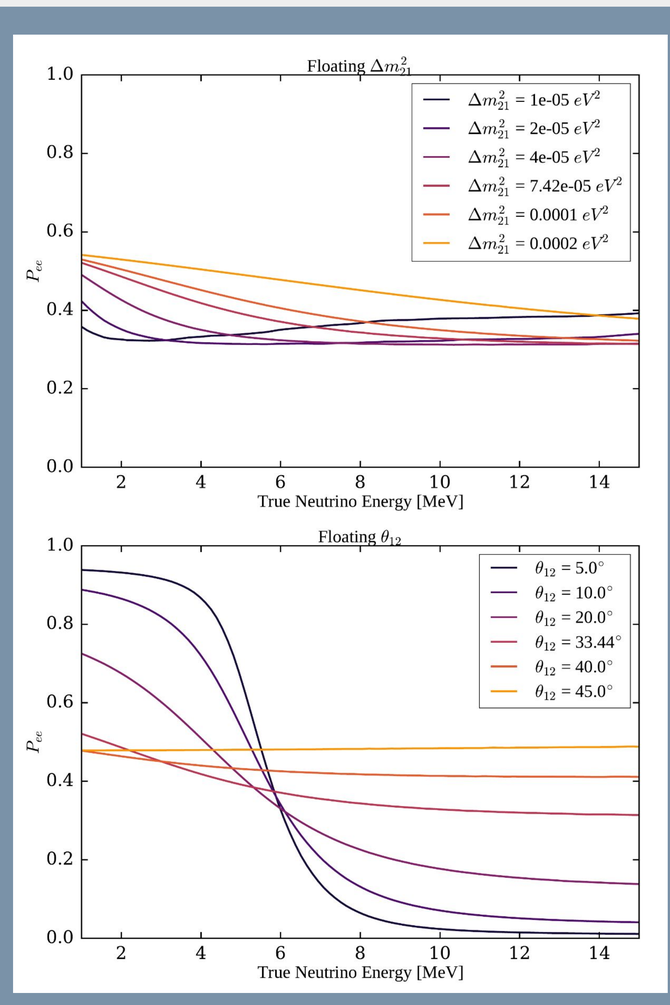
^{8}B solar neutrino flux **global fit constraint** [2]:

$$\Phi_{^8\mathrm{B}} = (5.20^{+0.10}_{-0.10}) \times 10^6 \mathrm{cm}^{-2}\mathrm{s}^{-1}$$

Detection via neutrino-electron **elastic scattering**:

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

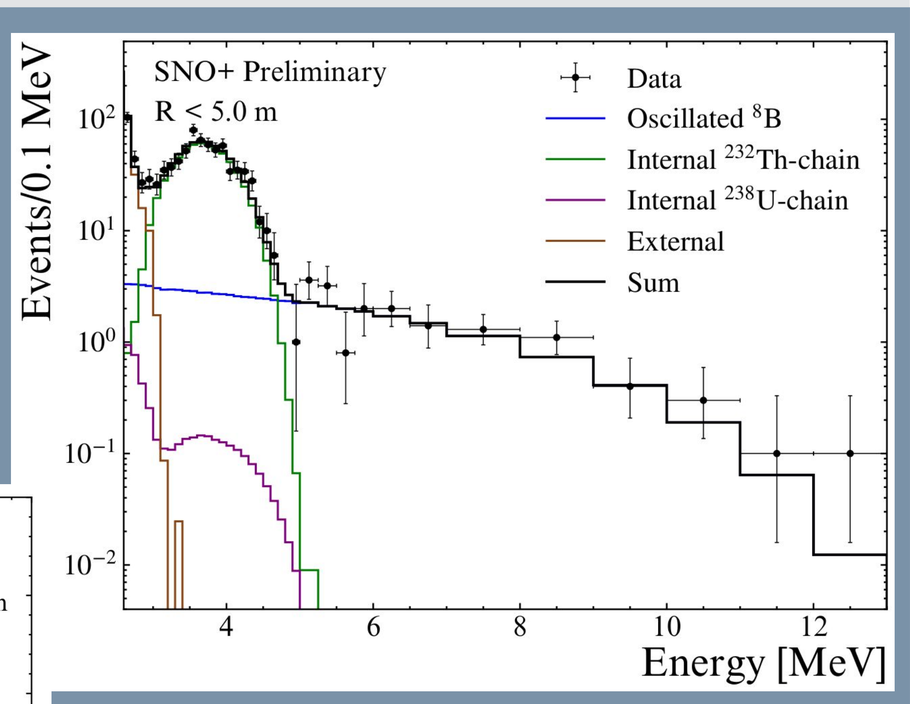
Difference in cross-section between ν_e and $\nu_{\mu,\tau}$, and **correlation** between ν and scattered e^- energies, allows for **measurement of solar neutrino oscillations**

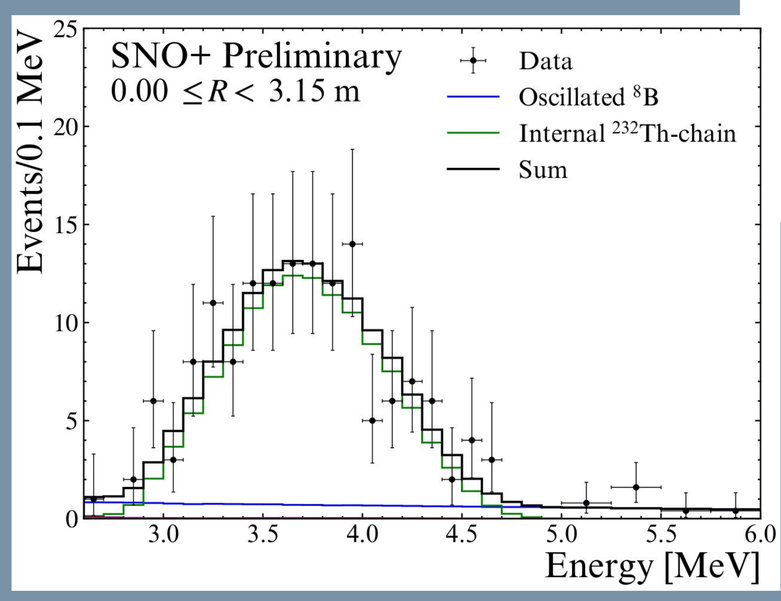


^{8}B solar neutrino **survival probabilities**, versus true neutrino energy for various solar neutrino **oscillation parameters**

Results from 138.6 Days of Data

Data vs MC comparison, using fit parameters with maximal-likelihood. Combined over all radial bins





Data vs MC comparison, for innermost radial slice. Zoomed into low energy region.

Bayesian 1σ Credible Interval:

$$\theta_{12} = 34.9^\circ {}^{+5.2^\circ}_{-5.3^\circ}$$

Current global fit value by NuFit 5.2 [3]:

$$\theta_{12} = 33.41^\circ {}^{+0.75^\circ}_{-0.72^\circ}$$

Results statistically-limited; analysis over increased exposure ongoing

Methods to further reduce backgrounds being investigated: see poster 255