SNO+ Solar Neutrino Measurement From an Extended Water Data Set

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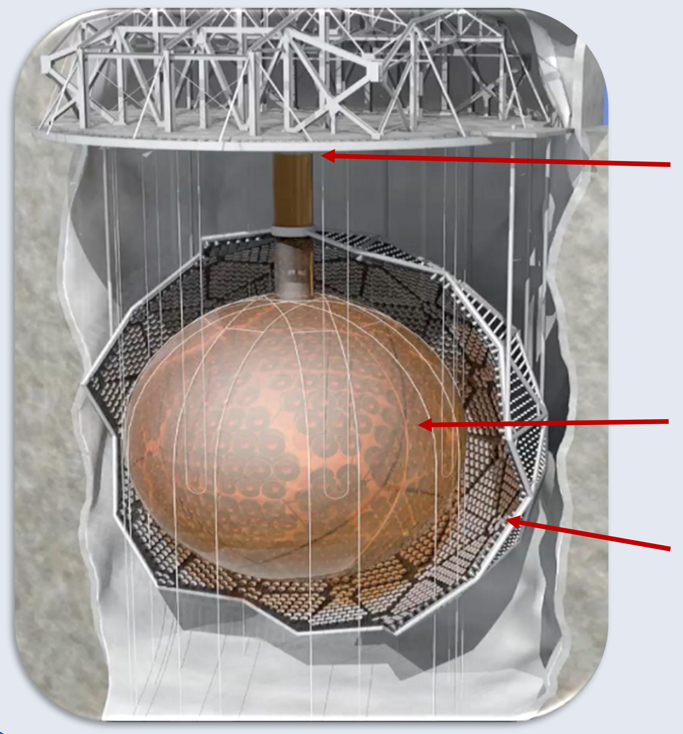
The SNO+ Experiment

SNO+ is a multipurpose and multiphase neutrino detector [1] located 2km underground at SNOLAB (6000 m.w.e. overburden)

- In the water phase, AV was filled with 900 tonnes UPW
- Currently undergoing scintillator fill (now ~50%), AV will contain 780 tonnes LAB+PPO [2g/L]

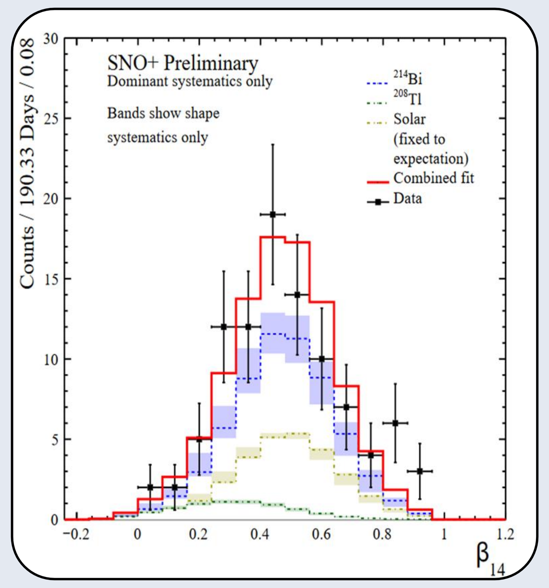


New Low Background Water Data

- Subsequent to the initial SNO+ results [3], improvements to the nitrogen cover gas system were made in the following operation period that greatly reduced radon ingress, and a new larger (190.3 day livetime) dataset was taken
- An internal backgrounds analysis suggests factor of ~10 background reduction in internal water region (R<4.3m)

See the "Search for Invisible Nucleon Decay in SNO+" poster for more details

	gU/gH_2O	gTh/gH_2O
Previous Dataset	$(3.6 \pm 0.9\ ^{+1.0}_{-0.7}) \times 10^{-14}$	$< 1.3 \times 10^{-14}$ (95 % CL)
New Dataset	$(3.2 \pm 0.7\ ^{+1.1}_{-0.9}) \times 10^{-15}$	$< 1.1 \times 10^{-15}$ (95 % CL)



Plot showing the analysis of the internal water background
β_{14} is an event isotropy parameter used to separate dominant backgrounds

Summary

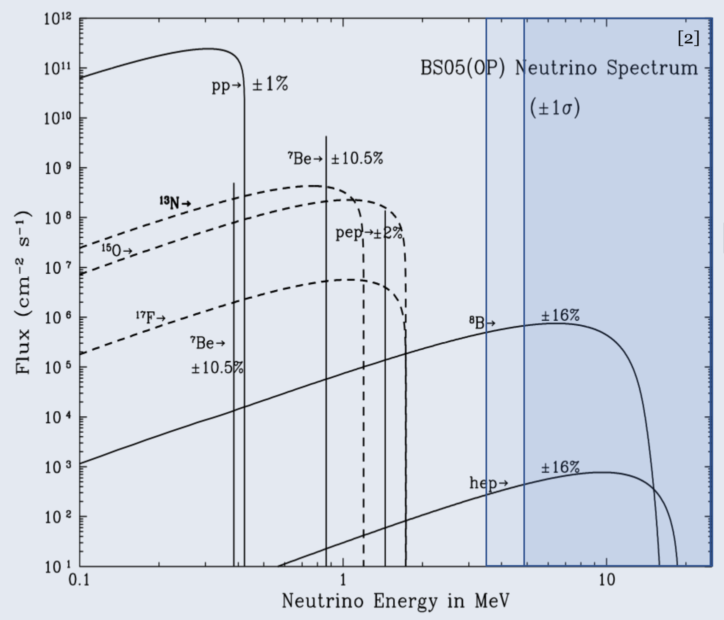
- These results demonstrate the very low level of background events in the newly taken water dataset and suggest a very low energy analysis threshold is achievable in a forthcoming spectral measurement of the ^{8}B flux using this new data, given the significantly reduced backgrounds and resolvable solar signal in the 4-5 MeV bin
- More broadly, these low backgrounds show a positive outlook as the collaboration currently moves into the scintillator fill phase

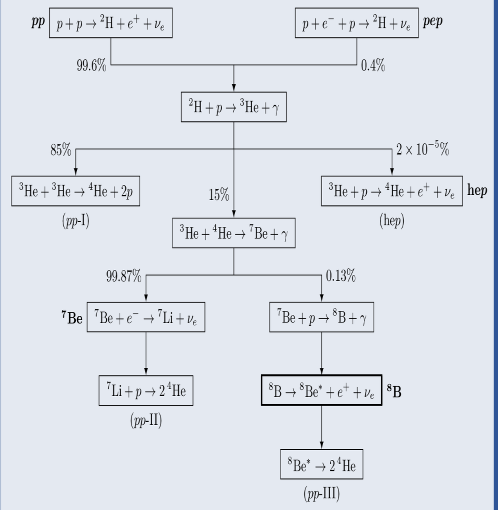
Detecting ^{8}B Solar Neutrino Events in Water

- Neutrinos are produced by the nuclear reactions in the core of the sun. In the high energy portion of the solar neutrino spectrum (where water Cherenkov detectors are sensitive), neutrinos from ^{8}B β^+ decay are dominant [2]
- A measurement of the ^{8}B solar neutrino flux can be made by identifying elastic scatter (ES) events of electrons by neutrinos in the SNO+ water data above a given energy threshold
- These can be discriminated for by exploiting the fact that solar neutrino events will typically produce Cherenkov radiation directed away from the sun

$$\nu_x + e^- \longrightarrow \nu_x + e^- \quad (x = e, \mu, \tau)$$

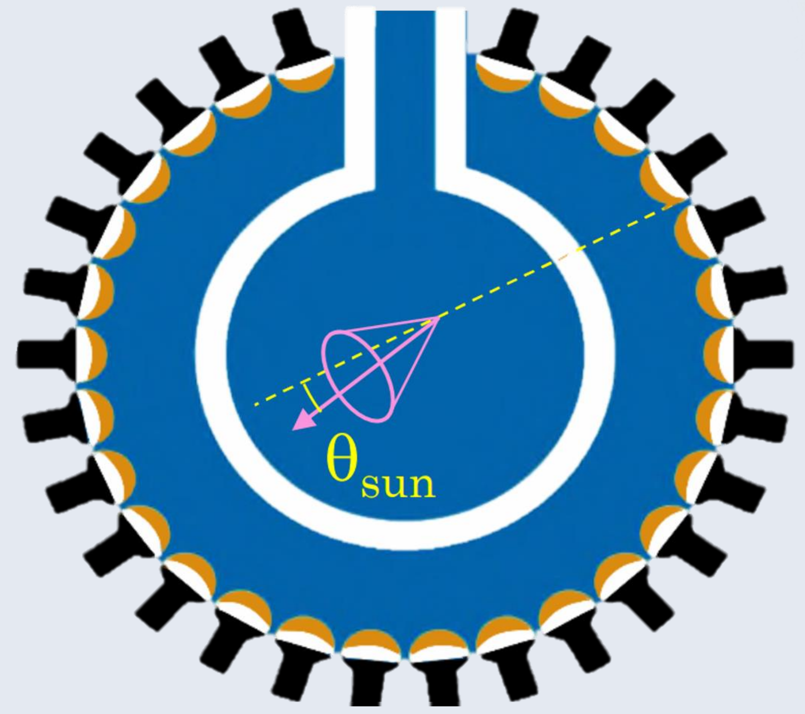
In ES interactions, the recoil electron's direction is highly correlated with the direction of the incident neutrino





Analysis Overview

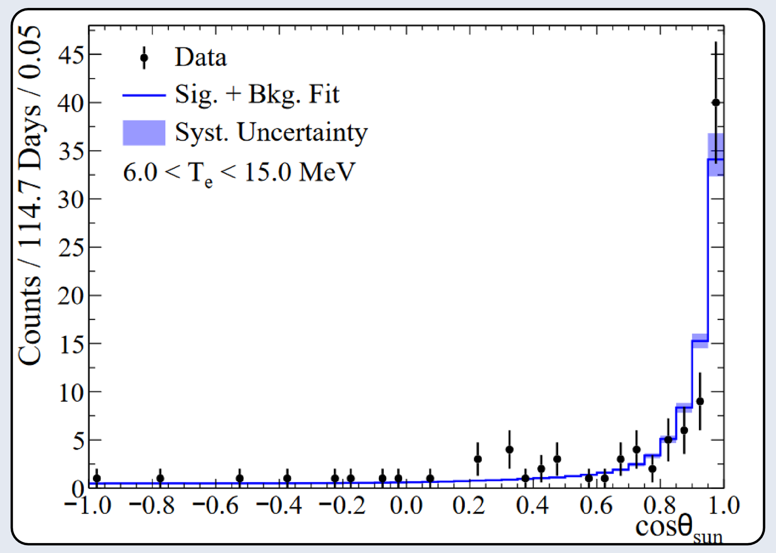
- MC ν_e ,$\nu_{\mu/\tau}$ events are generated on a run-by-run basis using RAT (GEANT-4 simulation framework)
- Energy threshold, fiducial volume, and some additional low-level and event classifier cuts (to remove poor fits and instrumental backgrounds) are applied to the simulated and detector datasets
- Events that pass analysis cuts are binned in the $\cos\theta_{sun}$ observable, and MC solar neutrinos are weighed by their survival probability
- Fit to data, with a flat background PDF assumed in $\cos\theta_{sun}$

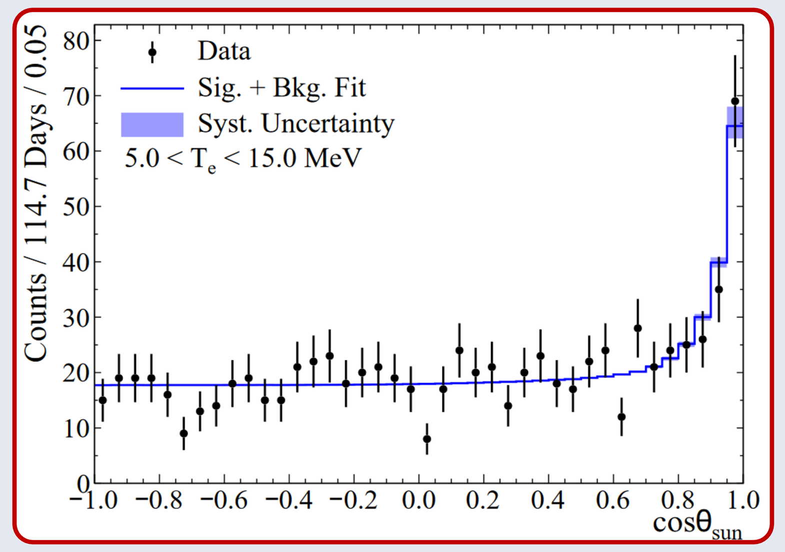


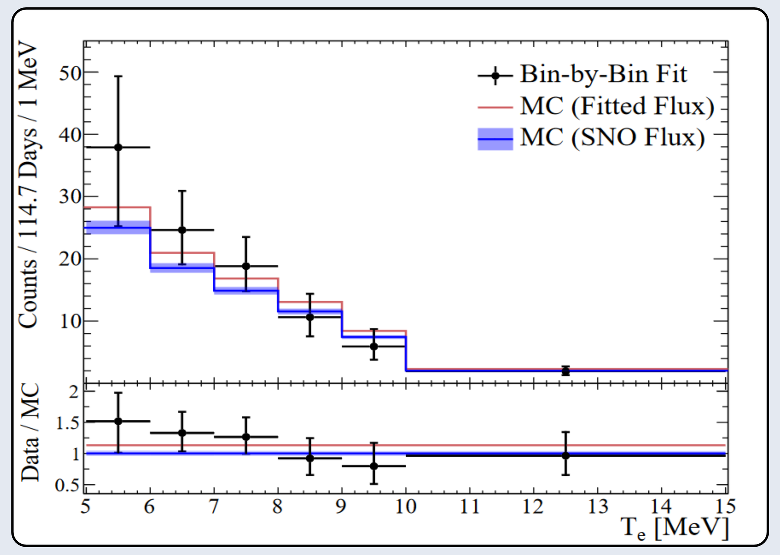
$\cos\theta_{sun}$: Angle between an event's reconstructed direction, and the direction of the sun at the time of the event

Previous SNO+ Solar Figures

A solar analysis was performed on an initial 69.2 kT-day (114.7 day livetime) SNO+ water dataset, showing an extremely pure sample of ES events above 6 MeV and a spectral measurement of the flux was made at an energy threshold of 5 MeV [3]







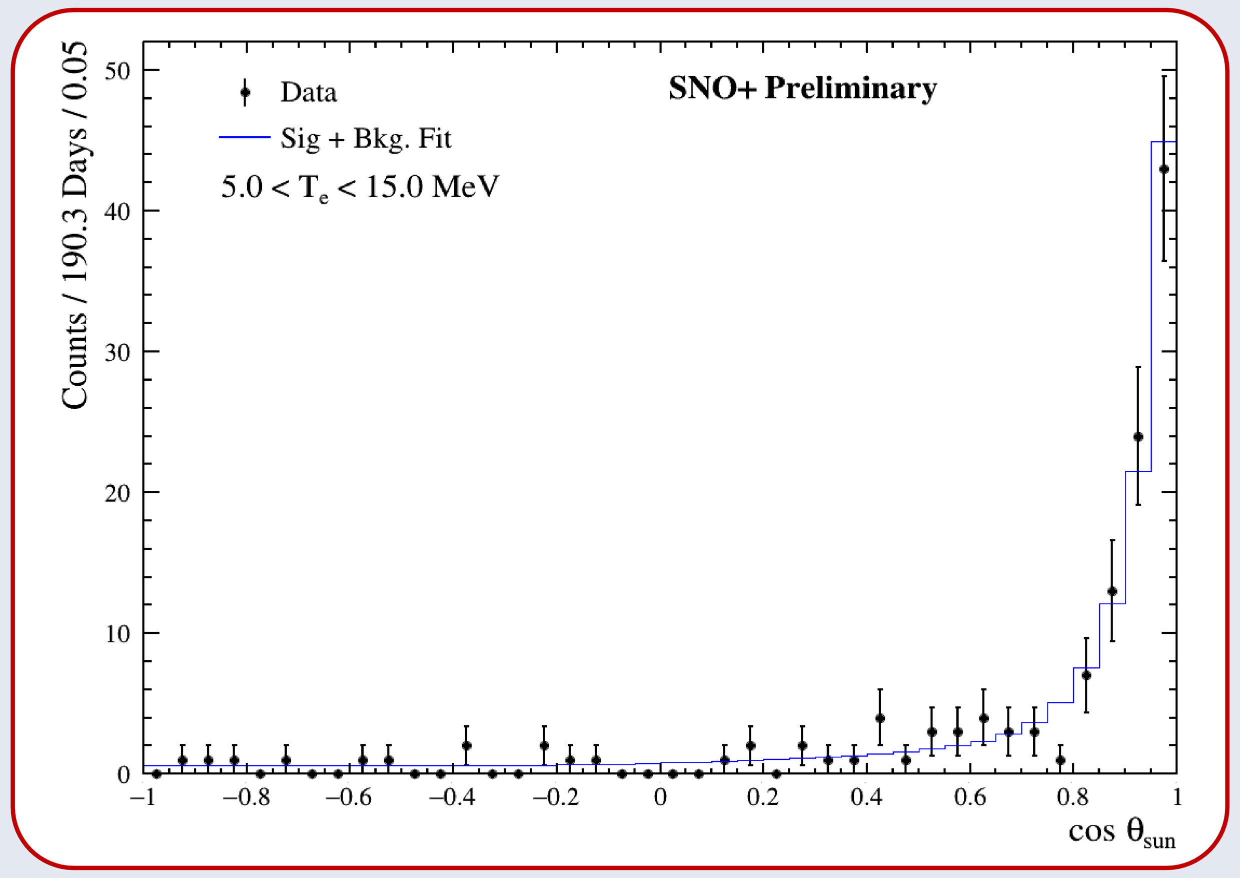
$$\Phi_{^8B} = 5.95^{+0.75}_{-0.71}(\text{stat.})^{+0.28}_{-0.30}(\text{syst.}) \times 10^6 \text{cm}^{-2}\text{s}^{-1}$$

References

[1] S. Andringa et al. (SNO+ Collaboration) Advances in High Energy Physics 2016, 6194250 (2016)
[2] Bahcall et al. ApJ 621:L85–L88 (2005)
[3] M. R. Anderson et al. (SNO+ Collaboration) Physical Review D 99 (1), 012012 (2019)

Integrated $\cos\theta_{sun}$ Distributions in the New Low Background Data

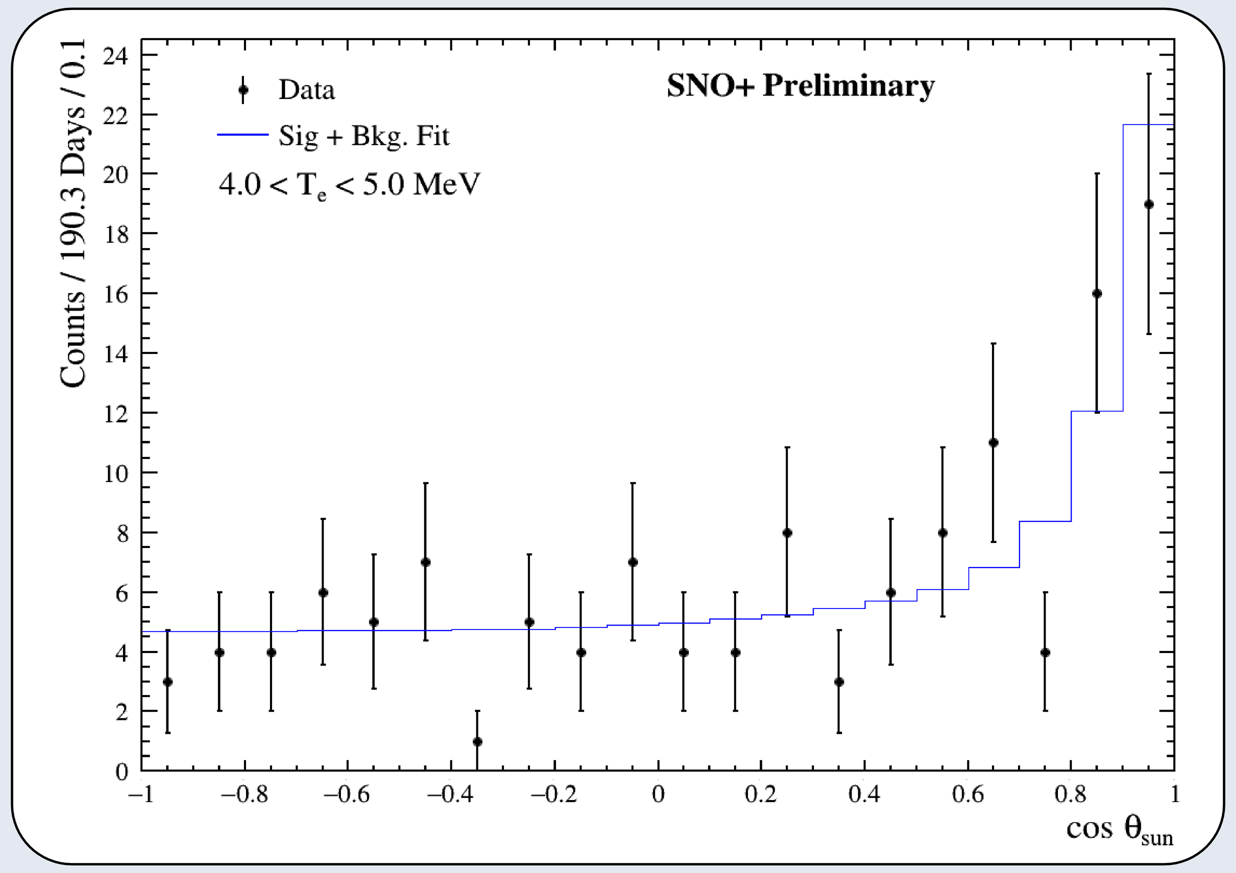
FV: R < 5m



Using a 5m fiducial volume, there is a very pure sample of ES events from 5-15 MeV

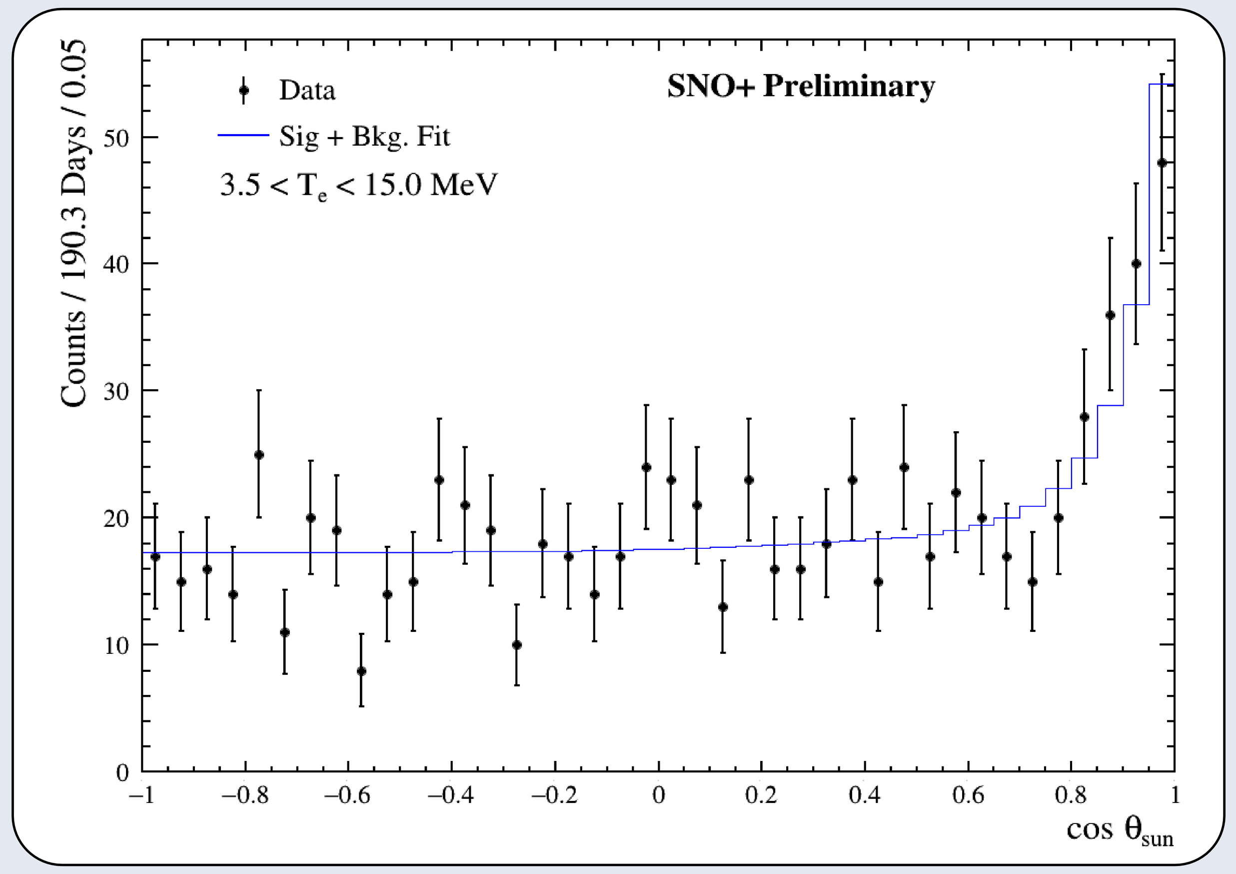
See figure from previous dataset for comparison

Reduced FV: (R <4.6m, and R <4.2m when z>0)



Applying a tighter fiducial cut, there is still a resolvable solar signal in the 4-5 MeV bin

Reduced FV: (R <4.6m, and R <4.2m when z>0)



In this reduced fiducial volume, the data has a modest flat background contribution from 3.5-15 MeV