Current Status & Future Prospects of the SNO+ Experiment

Erice 2026

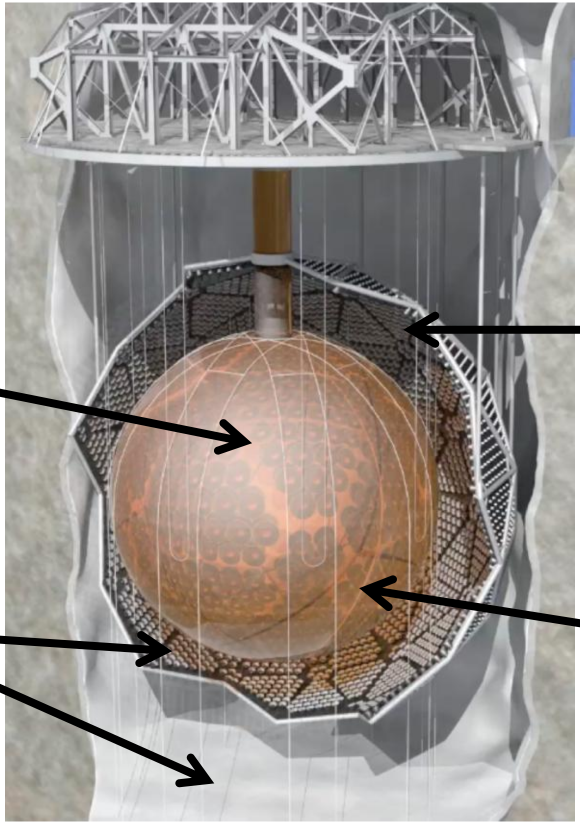
Daniel Cookman

The SNO+ Experiment

Successor to the SNO Experiment

12m diameter Acrylic Vessel (AV)

Ultra-Pure Water Shielding



2km underground at SNOLAB: ~3 muon/hour

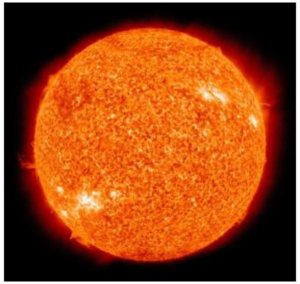
>9000 PMTs

Varying Target:

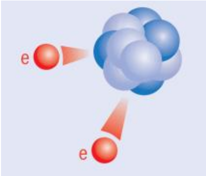
I. Water
II. LAB Scintillator
III. Tellurium Loading

JINST 16 P08059 (2021)

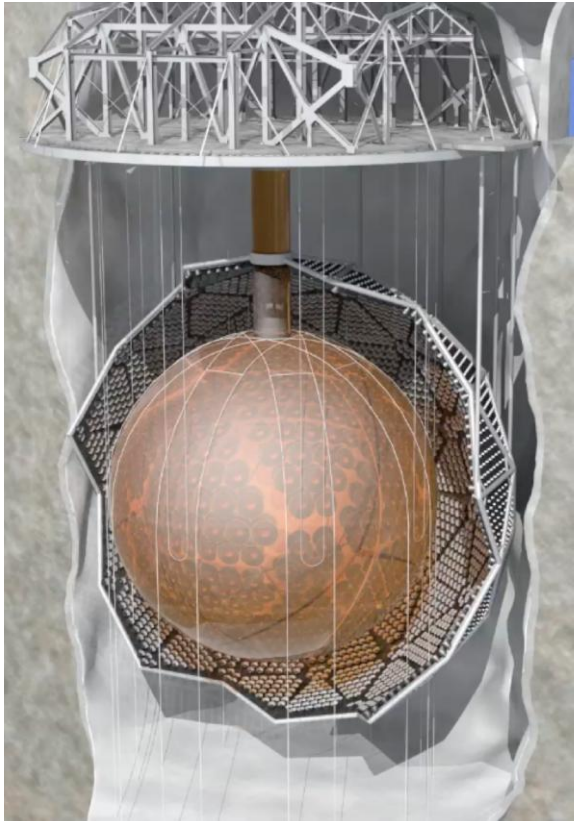
A Multi-Purpose Neutrino Experiment

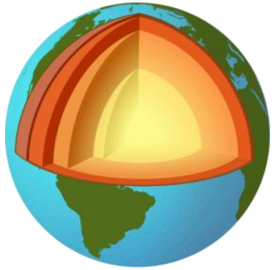


Solar Neutrinos

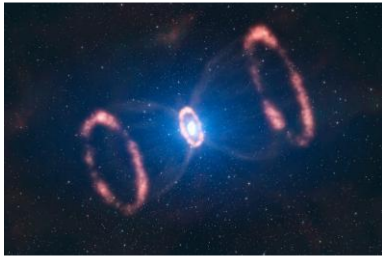


Neutrinoless
Double Beta Decay



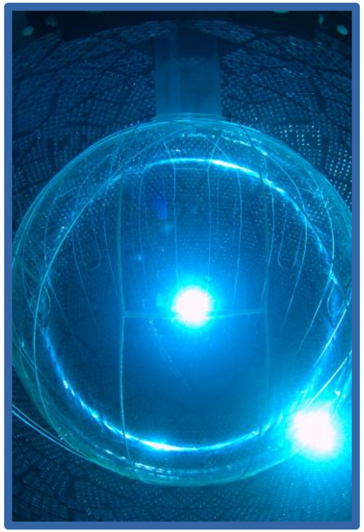


Reactor & Geo-Neutrinos

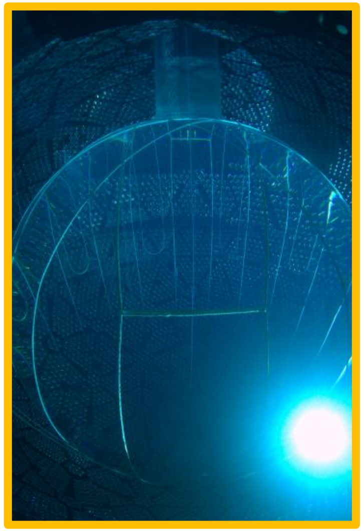


Supernova Neutrinos
& Exotics

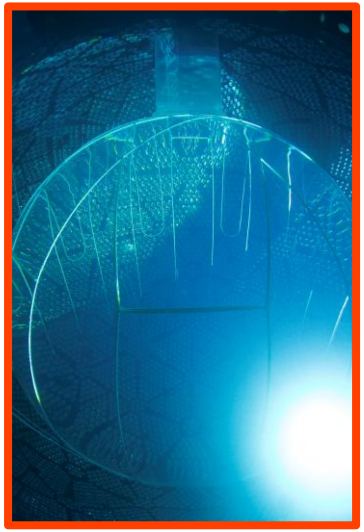
SNO+ Timeline



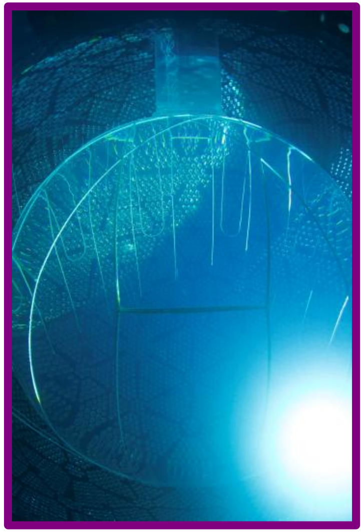
Water Phase:
Nitrogen cover gas used to minimise backgrounds



Partial-Fill Phase:
Scintillator over water
Fill paused due to COVID



Scintillator Phase:
LAB liquid scintillator
+2.2 g/L PPO fluor
+2.2 mg/L bis-MSB wavelength shifter



Tellurium-loaded Phase for $0\nu\beta\beta$
Next!

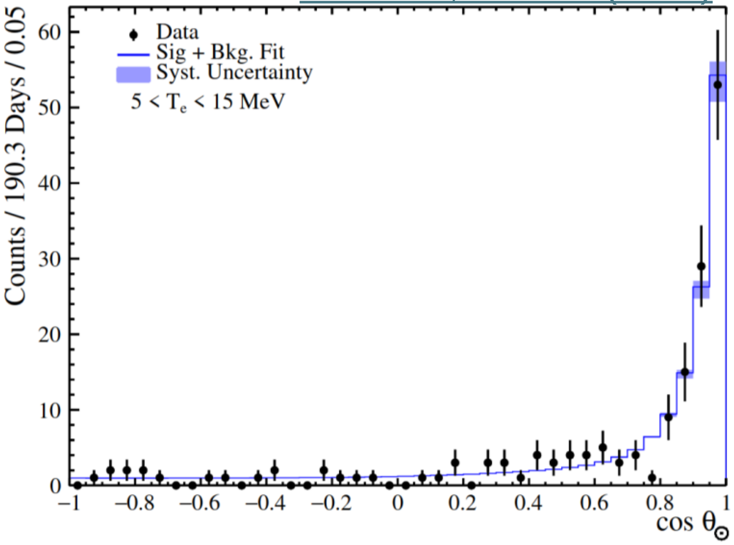
Water Phase Measurements

Very deep overburden & low radioactivity in water phase enabled a variety of measurements in SNO+!

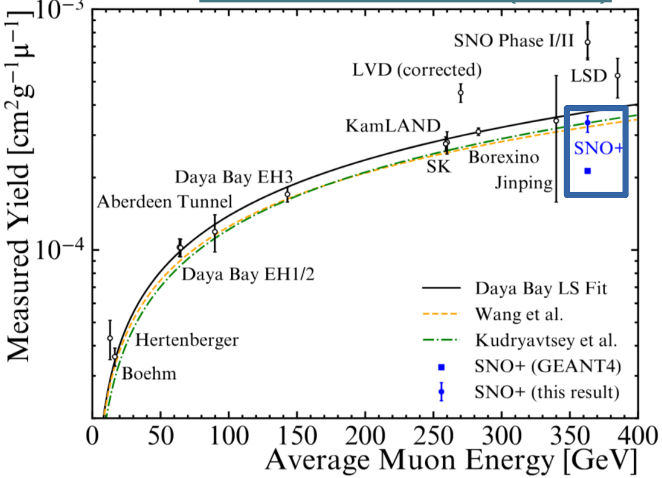
World-leading nucleon-decay limits: PRD 110, 122003 (2024)

Decay mode	Partial lifetime limit	Existing limits
n	9.0×10^{29} y	5.8×10^{29} y [5]
p	9.6×10^{29} y	3.6×10^{29} y [6]
pp	1.1×10^{29} y	4.7×10^{28} y [6]
np	6.0×10^{28} y	2.6×10^{28} y [6]
nn	1.5×10^{28} y	1.4×10^{30} y [5]

Low-background solar ^{8}B flux measurement: PRD 110, 122003 (2024)



Cosmogenic neutron production in water: PRD 113, 052014 (2026)

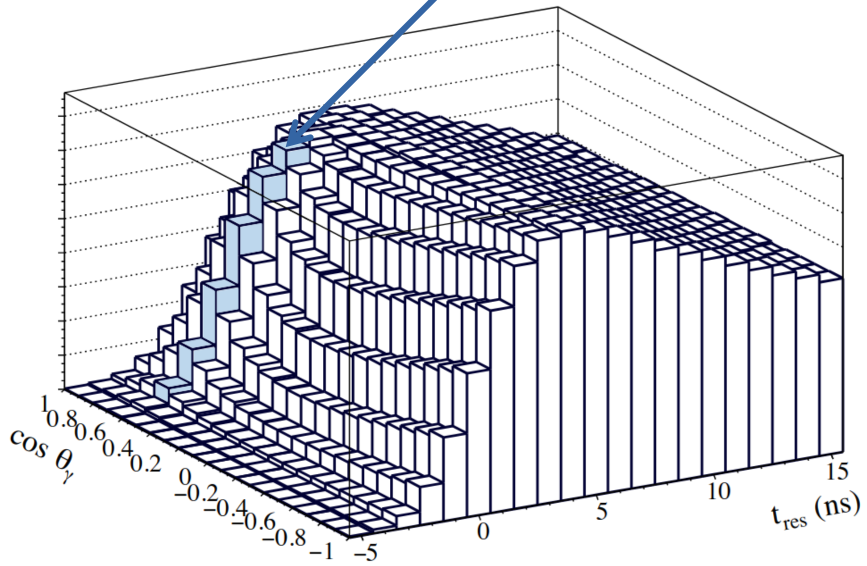


Directionality in Scintillator

PRD 109, 072002 (2024)

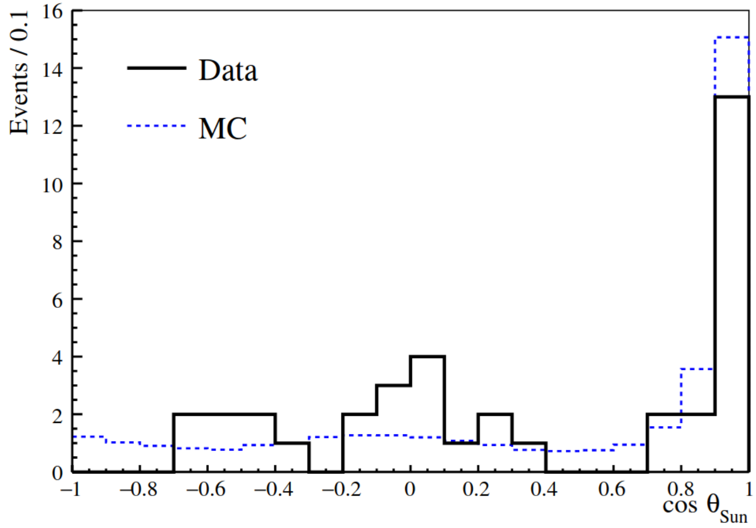
Scintillation light is isotropic, so reconstructing direction is hard…

...But not impossible! **Cherenkov light still present** if you look carefully:



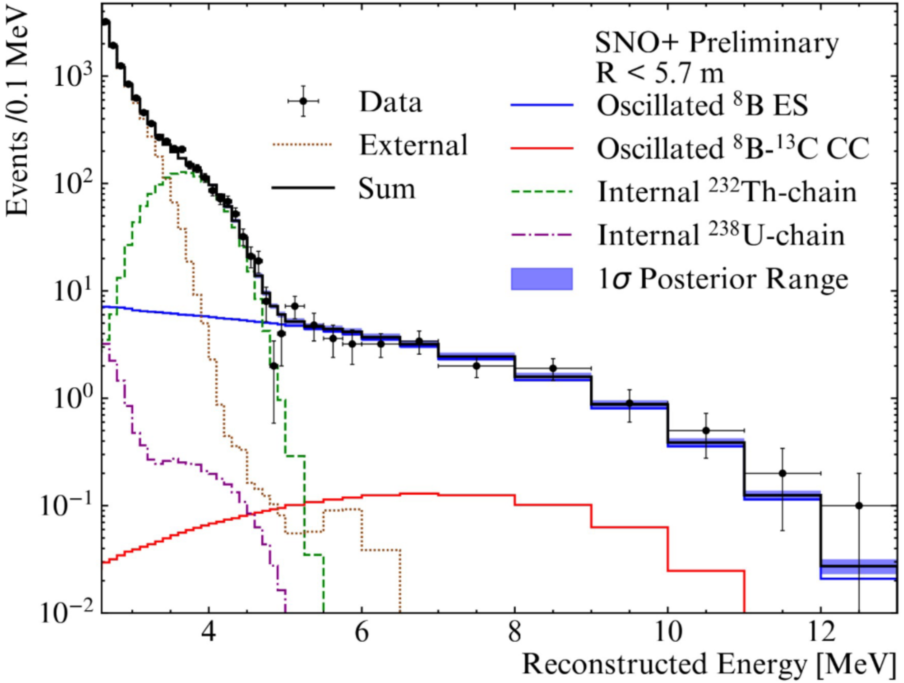
Data from partial fill & early scint phases, where PPO loading low (0.6 g/L), leading to slow scintillation: good separation with Cherenkov light for energies > 6 MeV

First event-by-event reconstruction of direction in high light yield scintillator!



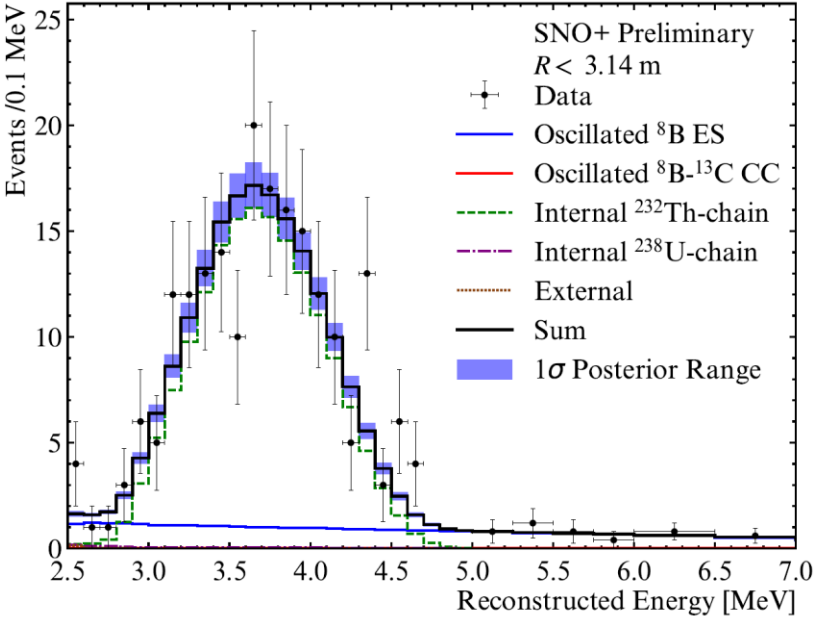
Solar Neutrino Flux & Oscillations in Scintillator

Initial analysis of ^{8}B ES interactions in 143.1 livedays of scintillator phase data

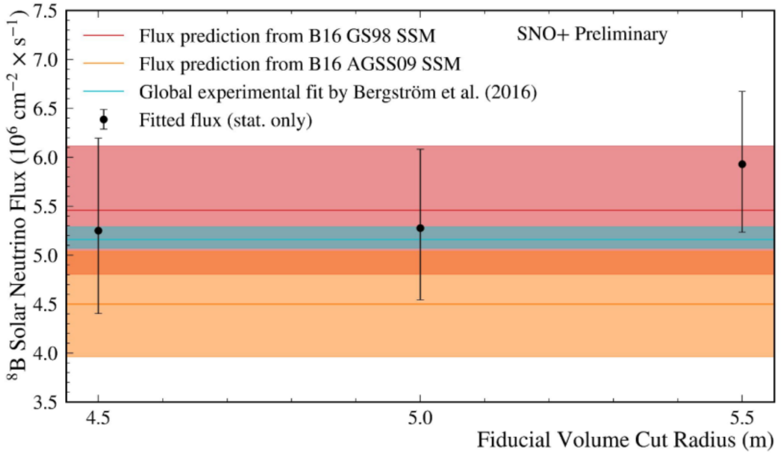


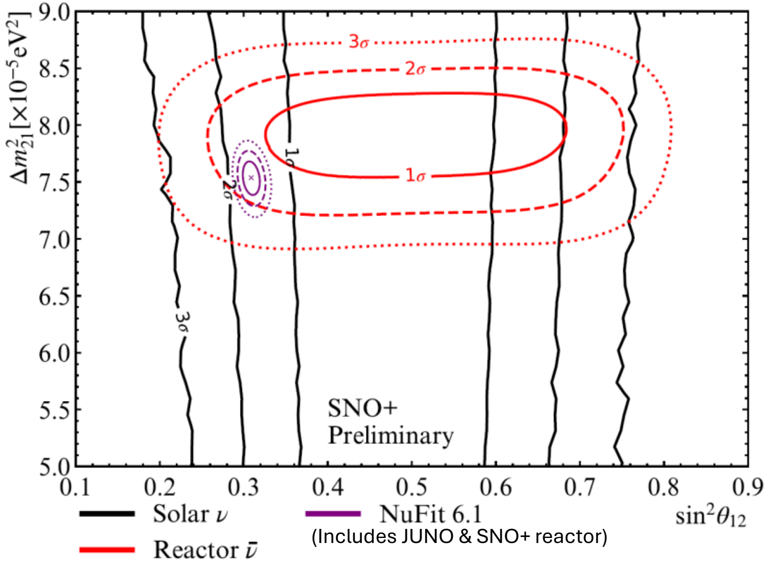
Cosmogenic & External backgrounds become negligible in strict fiducial volume: **possible future sensitivity < 3 MeV**!

^{208}Tl background dominates within central detector region:
$(7.5 \pm 0.7)\times10^{-17}$ g/g ^{232}Th in 4m radial volume



Solar Neutrino Flux & Oscillations in Scintillator

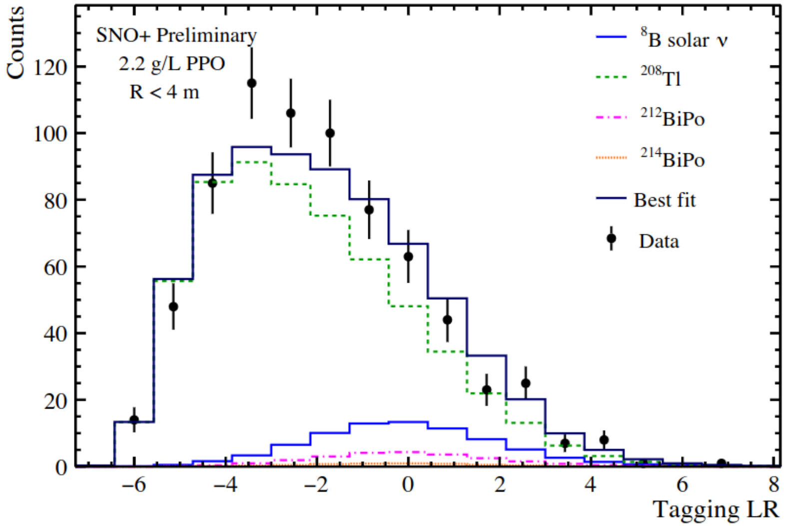




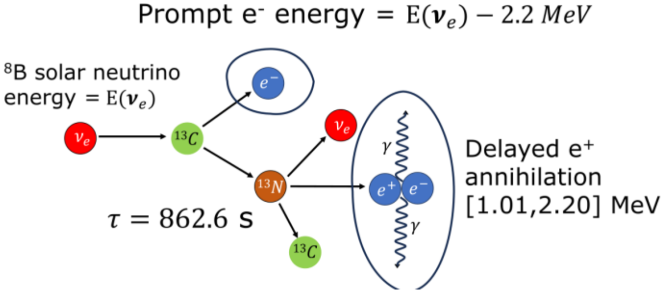
Parallel analyses for measuring flux and neutrino oscillation parameters

Currently investigating a variety of methods for ^{208}Tl background reduction:

- Energy
- Pulse-shape discrimination (multi-site)
- ^{212}Bi-^{208}Tl Coincidence tagging
- Integrated solar directionality



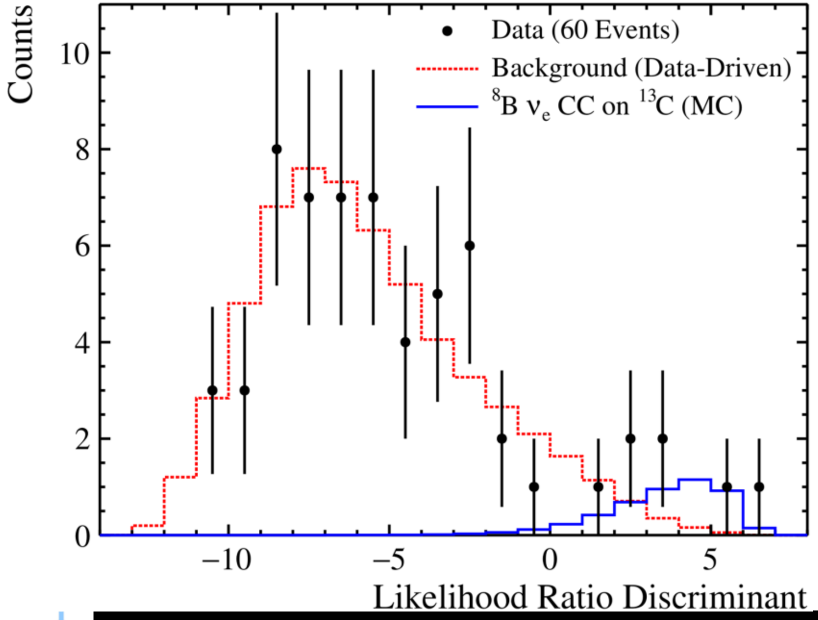
Charged-Current Interactions on ^{13}C

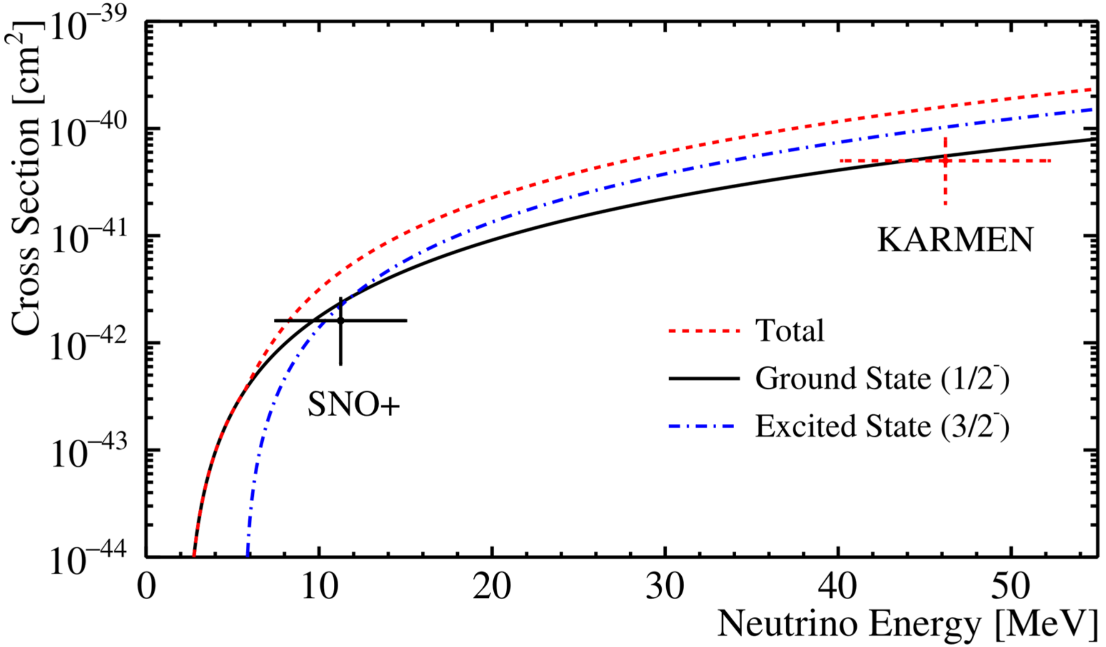


PRL 135, 241803 (2025)

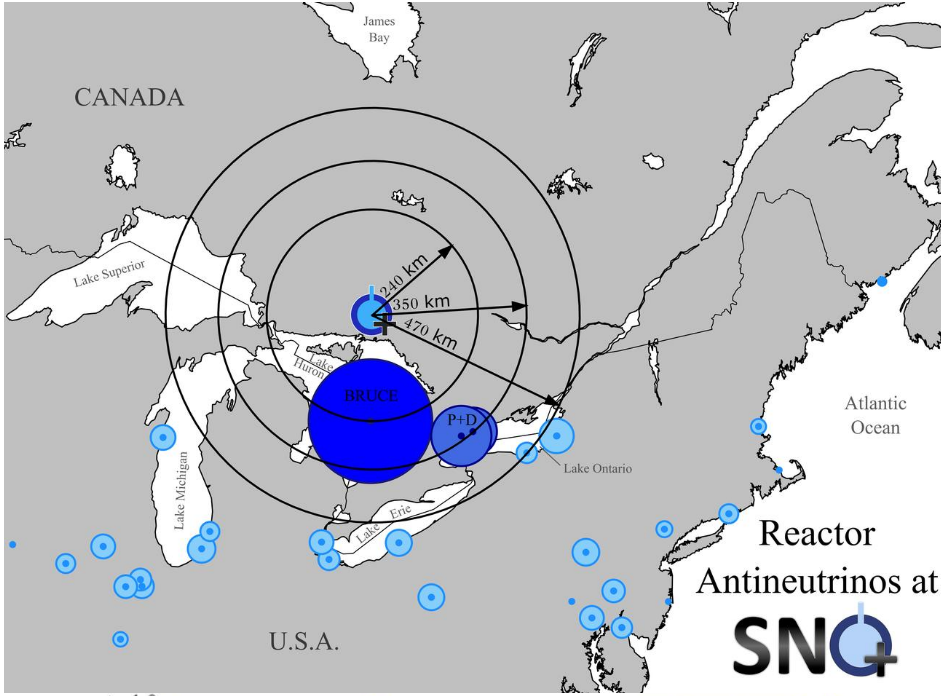
First ever measurement of this interaction by solar ν (second-ever in general!)

Significance: 4.2σ





Antineutrinos in SNO+

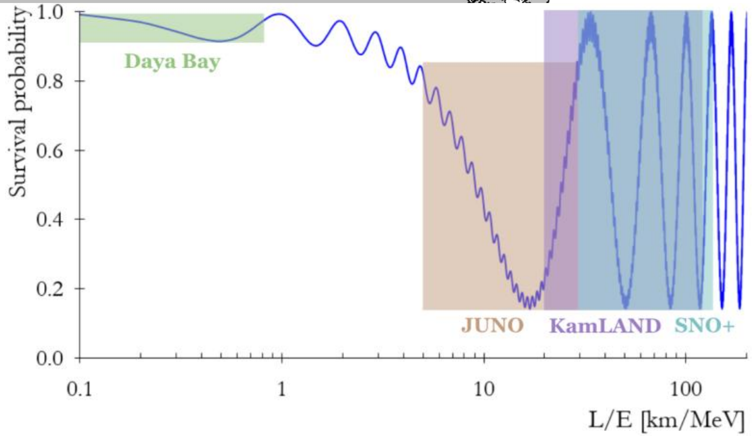


Electron antineutrinos interact with protons via **inverse beta decay**

Most antineutrinos come from Canadian reactors, 240-350 km away: ~**100 reactor** IBD events/year expected, after oscillations

~**25 geoneutrino** IBD events/year

Reactor antineutrino oscillations measured with the **longest average baseline** (653 km)



Antineutrinos in Water

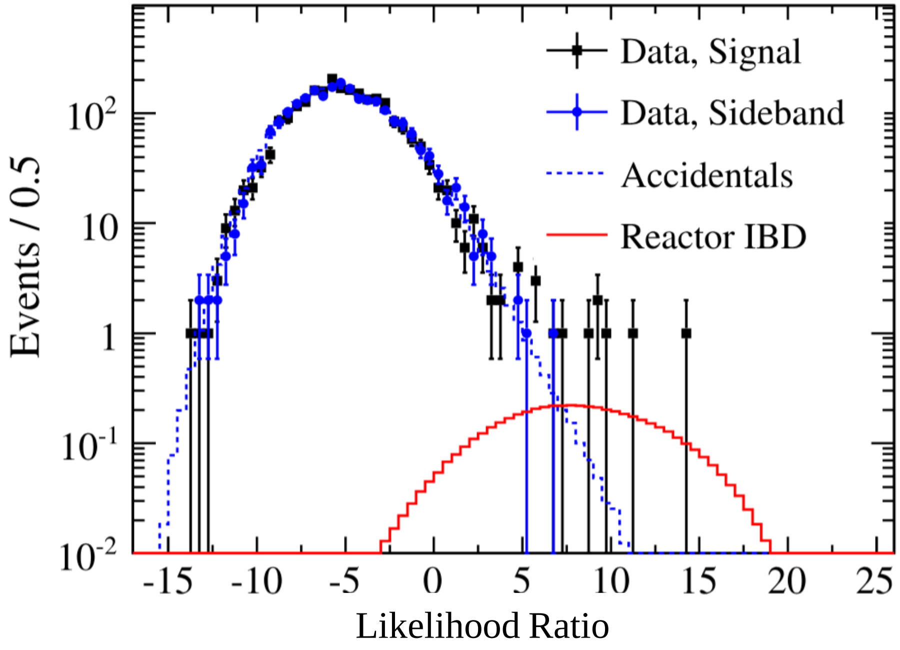
PRL 130, 091801 (2023)

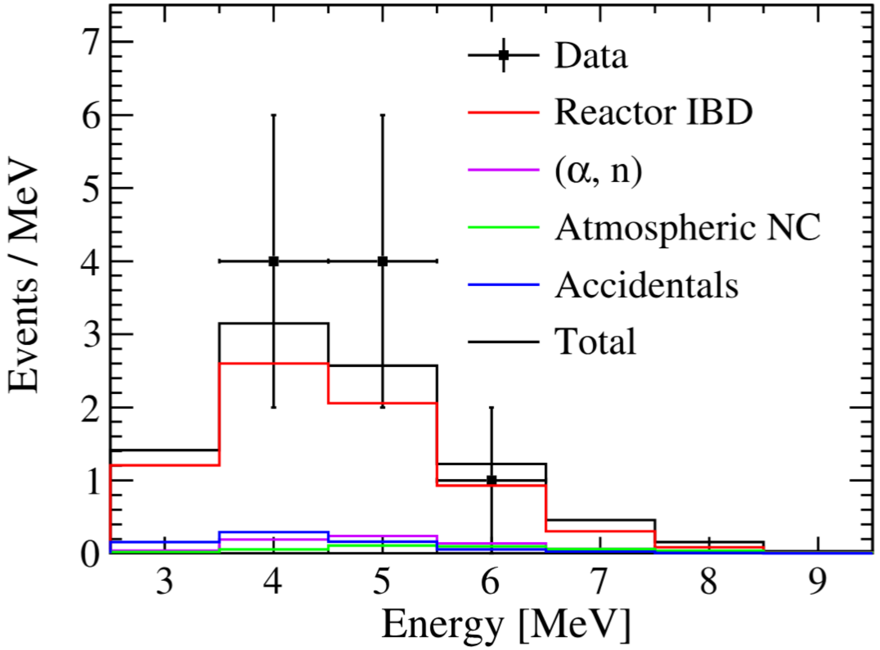
First evidence of reactor antineutrinos in a Cherenkov detector: 3.5σ

Taking advantage of lowest-ever energy threshold for a large Cherenkov detector: ~1.4 MeV

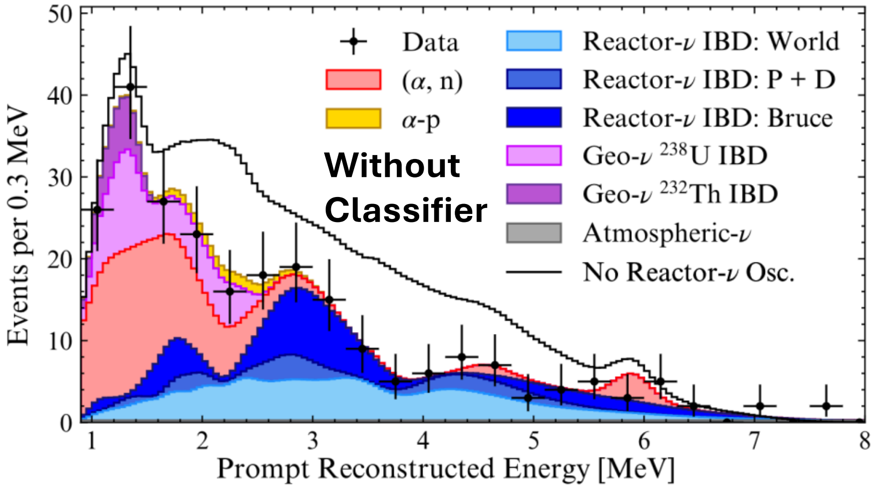
190 days livetime

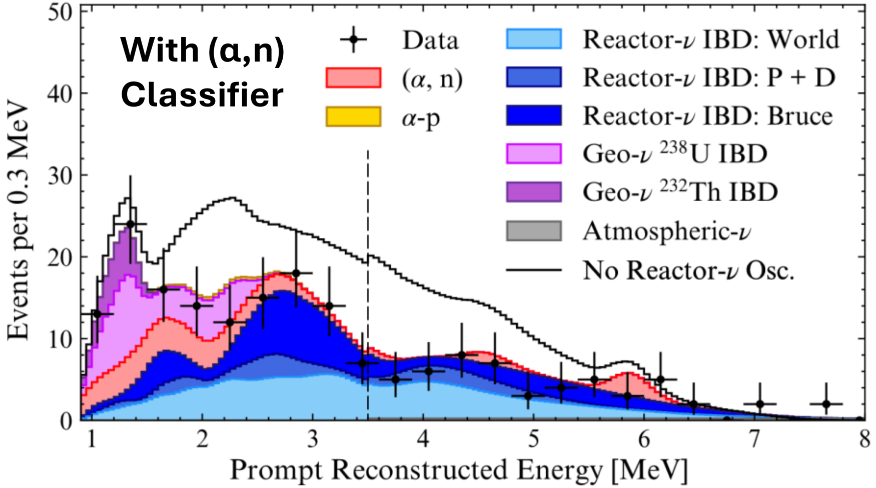
Two analysis methods gave comparable results: Likelihood ratio & Boosted Decision Tree





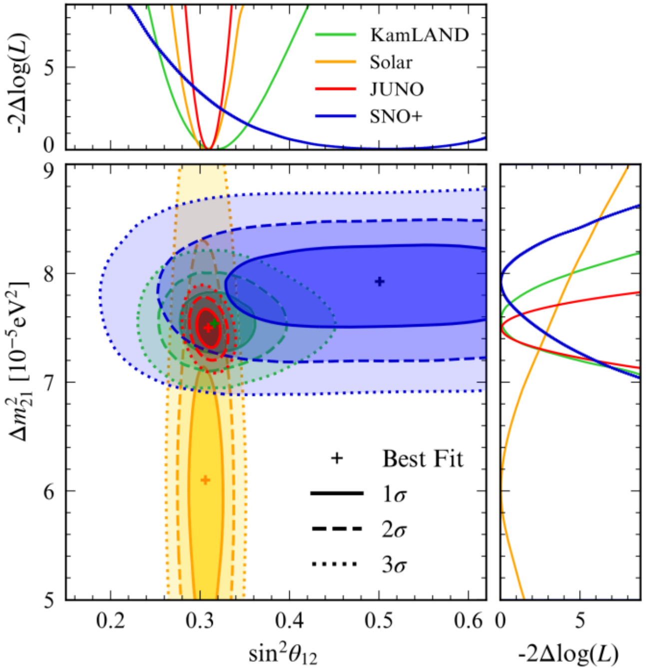
Antineutrinos in Scintillator





PRL 137, 101807 (2026)

	Fit	Fit (con.)	Fit (α, n) cut
$\Delta m^2_{21} [10^{-5}\ \text{eV}^2]$	$7.91^{+0.22}_{-0.25}$	7.59 ± 0.17	$7.55^{+0.17}_{-0.16}$
$\sin^2\theta_{12}$	0.505 ± 0.133	0.310 ± 0.012	0.311 ± 0.012
Geo-$\bar{\nu}$ [TNU]	51^{+24}_{-25}	50 ± 25	48^{+14}_{-12}
Geo-$\bar{\nu}$ U/Th	$3.55^{+1.36}_{-1.37}$	$3.54^{+1.36}_{-1.37}$	$3.23^{+1.43}_{-1.49}$



Precision measurement of Δm^2_{21} from reactor antineutrinos using 685.2 days of data

First ever measurement of geoneutrino flux in Western Hemisphere

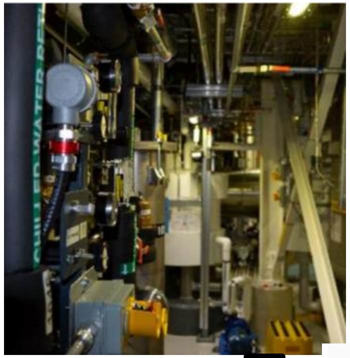
First to identify important α-p background

Searching for 0νββ in SNO+

NIMA 1051 168204 (2023)

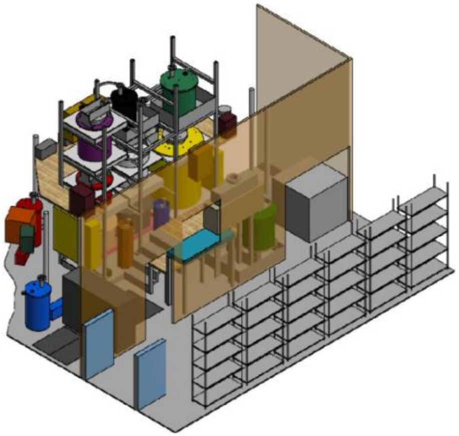
^{130}Te to be loaded into scintillator to search for 0νββ, via novel, scalable technique

Butanediol Purification Plant (Underground)
Commissioned

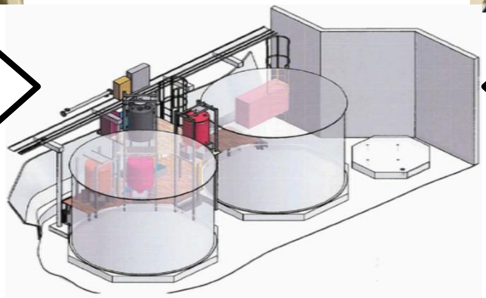


DDA Purification Plant (Surface)
Commissioned

Telluric Acid Purification Plant (Underground)
Commissioned



Te-BD Synthesis (Underground)
Commisioning

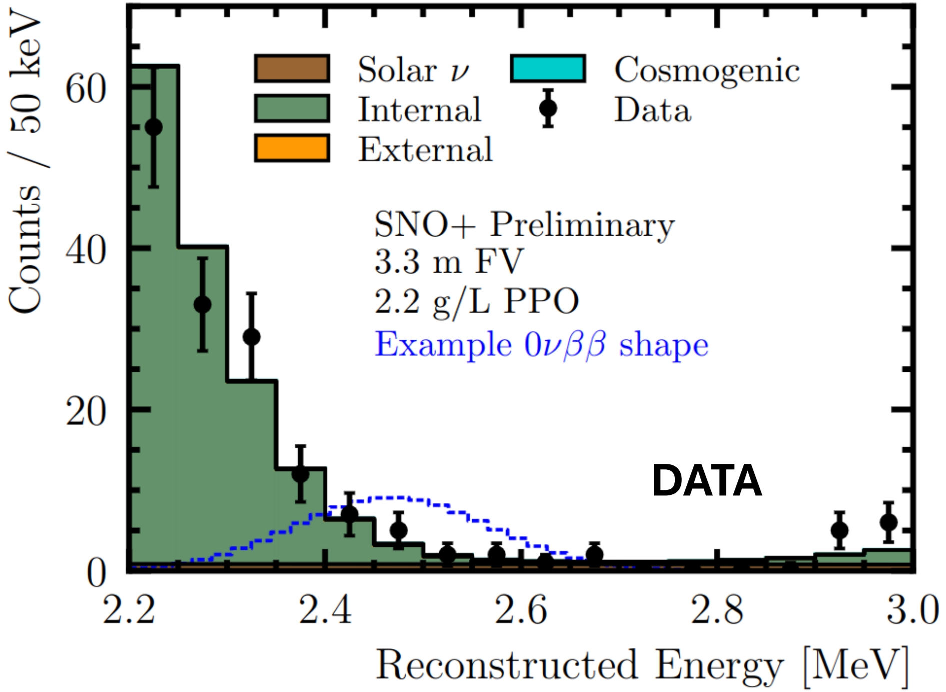


Into Detector!

Searching for 0νββ in SNO+

Scintillator Phase allows for "target-out" analysis

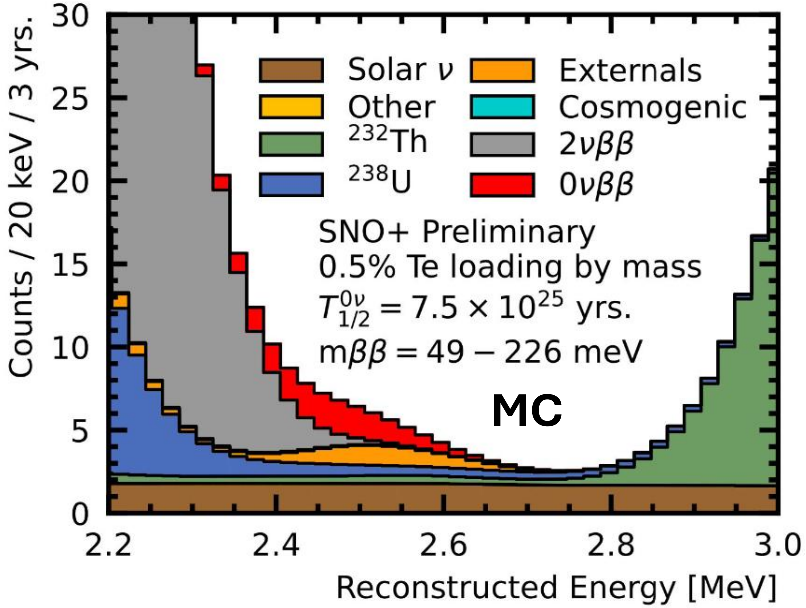
Backgrounds in the 0νββ energy ROI consistent with expectations



^{130}Te: No enrichment needed, high Q-value, long 2νββ half-life (lower intrinsic background)

Initial loading planned for 2027

Expected sensitivity after 3 years of loading 0.5% natTe: 2×10^{26} yr (90% CL)



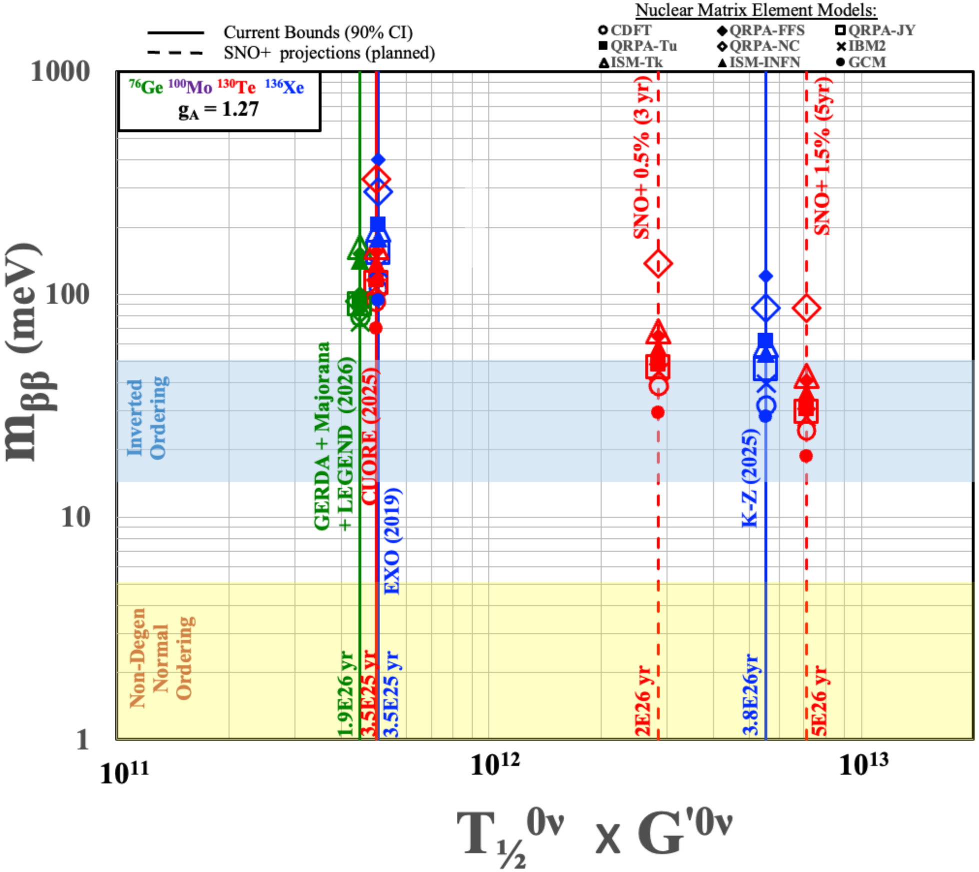
Searching for 0νββ in SNO+

PRD 104 012002 (2021)
NIMA 1051 168204 (2023)

Higher loadings of Te planned for SNO+

Sensitivity with 5 years with 1.5% natTe loading:
$T_{1/2}$ > 5x10^{26} years (90% CL)

Good light yield & stability found at higher loadings during R&D



Summary & Status

- The SNO+ Experiment has taken water- and scintillator-phase data
- Detector is currently offline to fix a small leak, and recirculate scintillator to strip out more backgrounds
- Variety of analyses completed/ongoing! A sample:
    - First ever observation of solar neutrinos interacting on ^{13}C
    - Precision measurement of Δm^2_{21} & first ever measurement of geoneutrino flux in Western Hemisphere
    - ^{8}B Solar neutrino oscillation analysis underway with energy threshold < 3 MeV
- Major preparations underway for planned Te-loading starting next year!

On behalf of the SNO+ Collaboration...

Thank You!

Backup Slides

Other SNO+ Publications

Nucleon decay searches in water phase:
PRD 99, 032008 (2019)
PRD 105, 112012 (2022)

Partial-fill antineutrino analysis:
EPJC 85 1 17 (2025)

Water phase optical calibration:
JINST 16 P10021 (2021)

Water phase neutron-capture calibration:
PRC 102 014002 (2020)

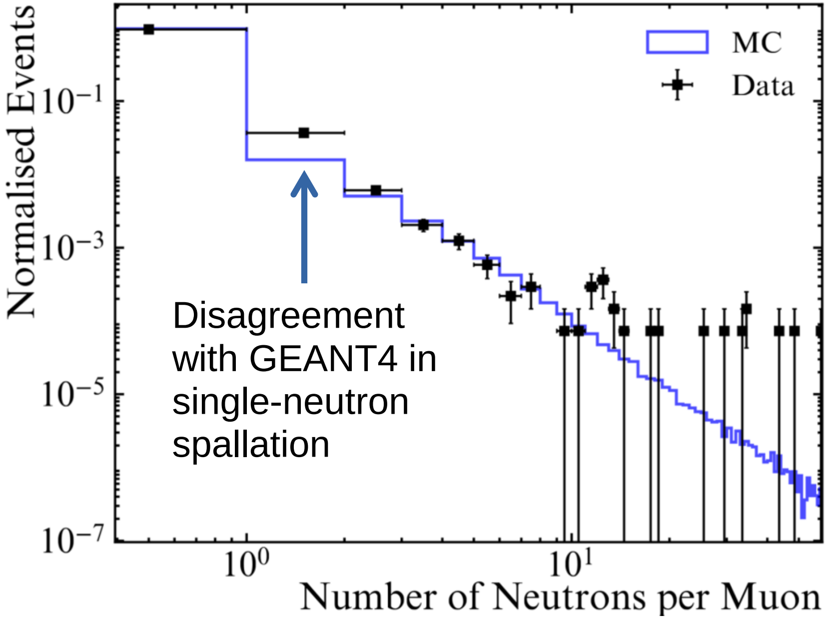
- SNO+ scintillator:
JINST 16 P05009 (2021)

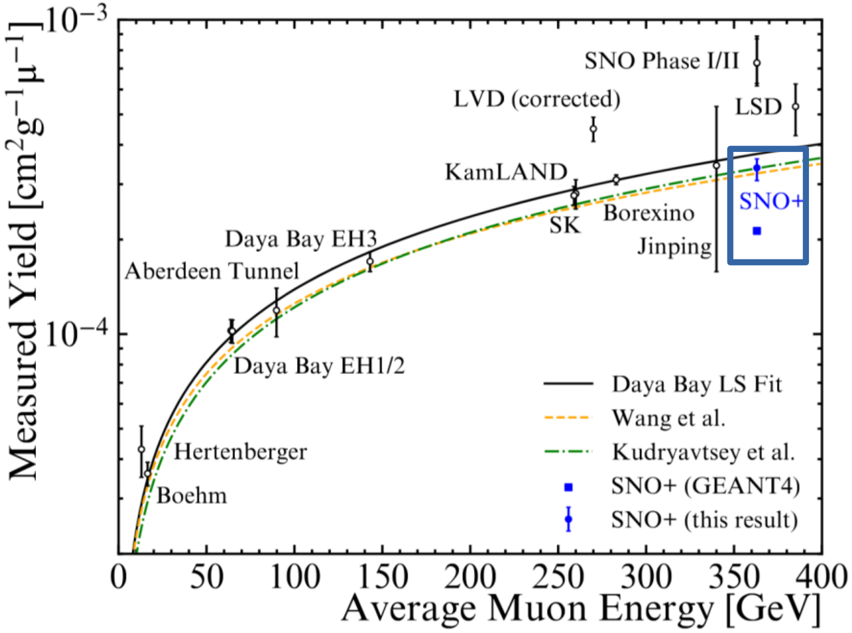
Cosmogenic Neutrons in Water

[PRD 113, 052014 (2026)]

- Extreme depth & cleanliness of SNO+ in water-phase allowed for measurement of neutron captures generated by cosmic-ray muons
- 321 days of data, 13690 μs, 1412 neutrons
- AmBe source used for calibration

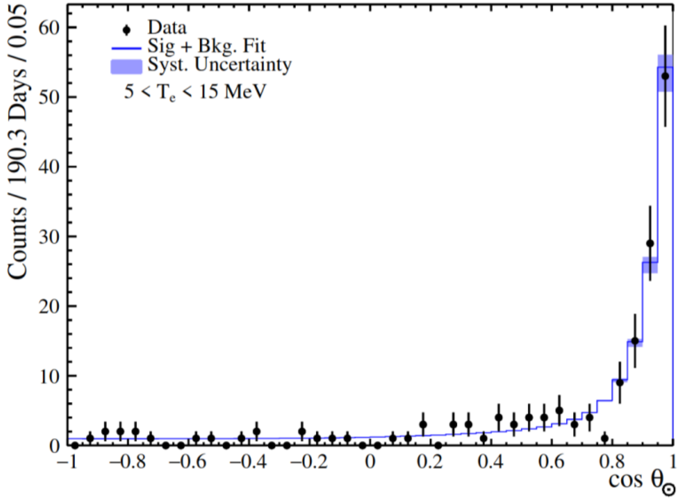
- Measured neutron yield: $(3.38^{+0.23}_{-0.30}) \times 10^{-4}\mathrm{cm}^2\mathrm{g}^{-1}\mu^{-1}$
- In line with FLUKA predictions; GEANT4 differs by 30%
- Previous SNO measurement made in heavy water; plan to also measure in LS!





Solar Neutrino Flux, Water Phase

- Updated analysis with 126.6 kt-day exposure
- Includes 190 days of data with lowest background for a water Cherenkov detector > 5 MeV:
  0.32 ± 0.07 evs/kt-day

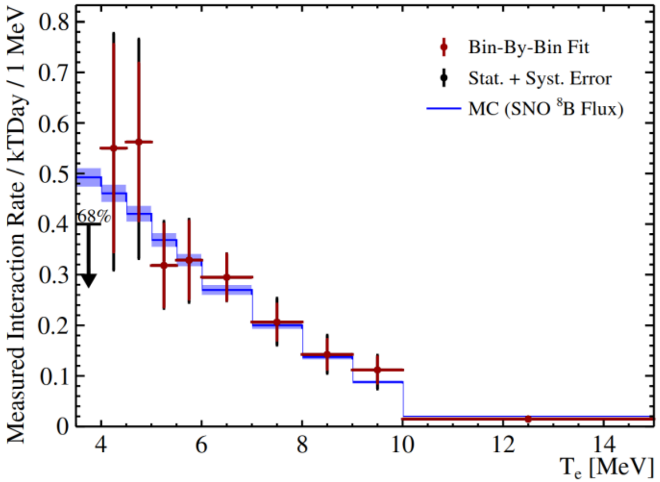


PRD 99, 012012 (2019)
PRD 110, 122003 (2024)

Results:

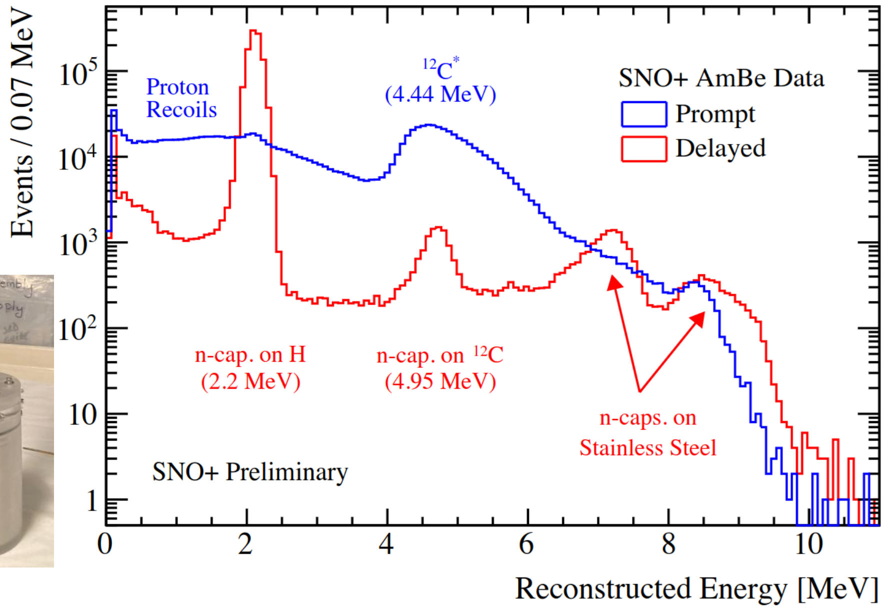
- Using 3.5 MeV threshold; large uncertainties in first bin
- Fitted flux consistent with other experiments after inclusion of oscillations:

$$\left(5.36^{+0.41}_{-0.39}(\mathrm{stat.})^{+0.17}_{-0.16}(\mathrm{syst.})\right) \times 10^6\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$$



Calibrations for SNO+

AmBe source provides tagged neutron captures, gammas, & proton recoils



Laserball provides light with known timing and wavelengths