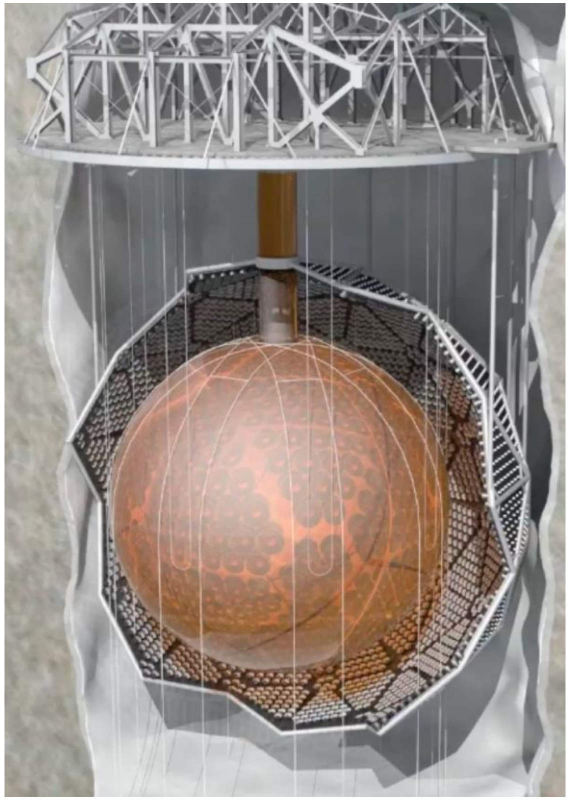
The SNO+ experiment

WIN 2025

Elisabeth Falk
for the SNO+ collaboration

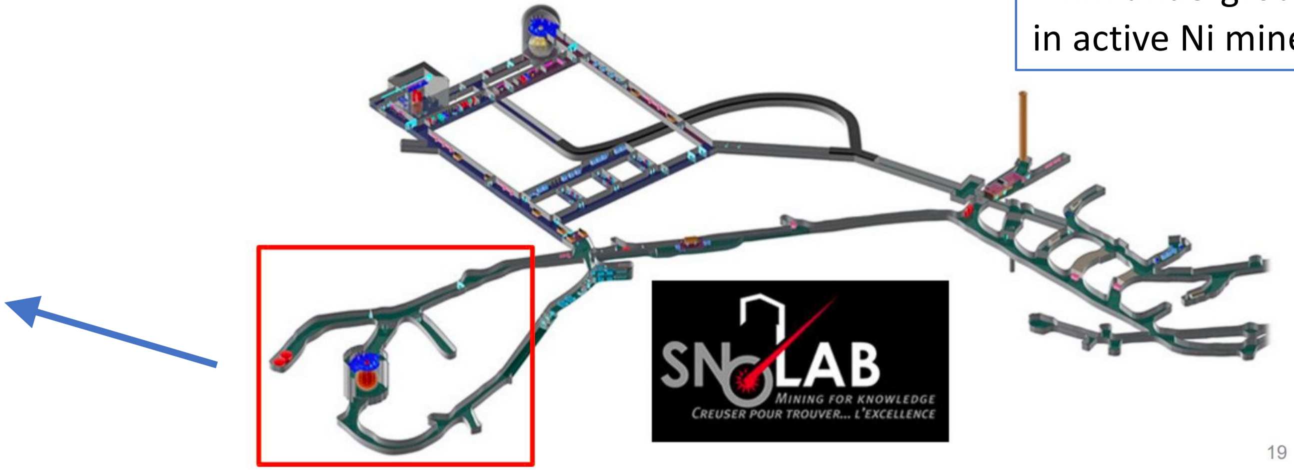
The SNO+ experiment



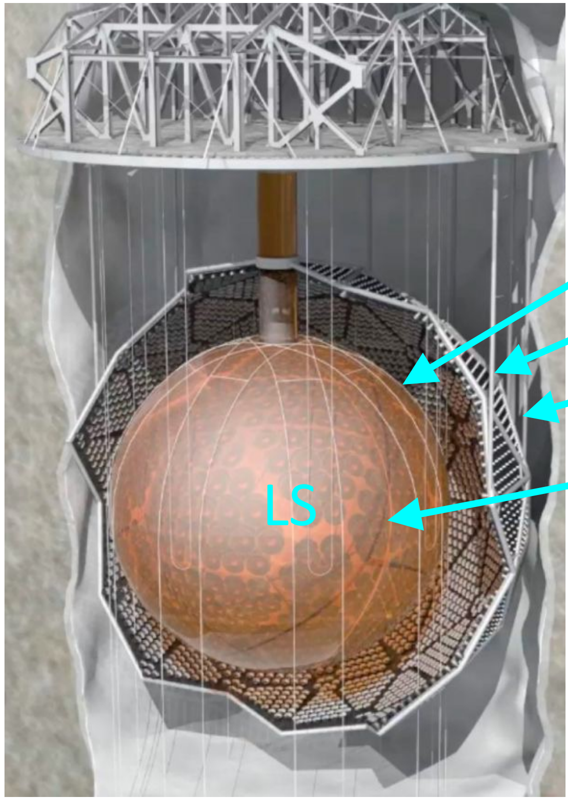
Multipurpose neutrino detector:

- Search for $0\nu\beta\beta$ (primary goal)
- Solar neutrinos
- Antineutrinos (reactor, geo)
- Supernova watch + exotics

2 km underground in active Ni mine



The SNO+ detector



Acrylic vessel 6 m radius

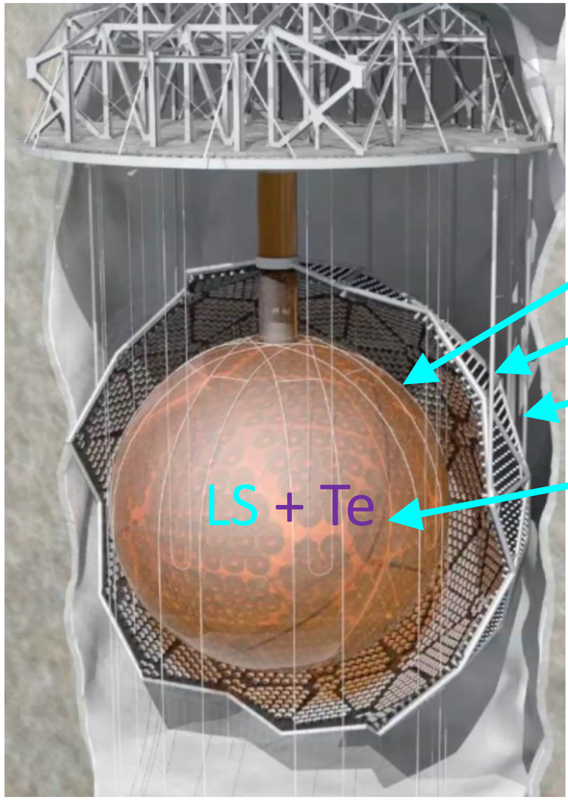
~9300 PMTs

Ultra-pure water buffer 2.5 m (7 kt)

Liquid scintillator (780 t):
LAB + PPO (2.2 g/L)
BHT (5.5 mg/L) + bis-MSB (2.2 mg/L)

Radiopurity:	^{238}U 4 x 10^{-17} g/g, ^{232}Th 5 x 10^{-17} g/g
E resolution:	6.5% @ 1 MeV to 5.3% @ 1 MeV
Pos. resolution:	12 cm (x, y, z) @ 2.5 MeV
Overburden:	6000 mwe (~70 μ/day)

The SNO+ detector



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LAB + PPO (2.2 g/L)
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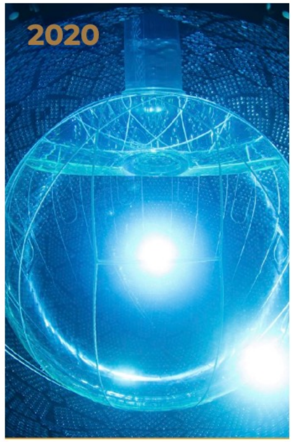
Novel scalable Te loading:
Initially + Te (0.5%)-ButaneDiol + DDA (0.2%)
Increase to 1.5% loading

The SNO+ experiment

Water phase

Ultra-pure water

Detector calibration,
measure external backgrounds



Partial-fill phase

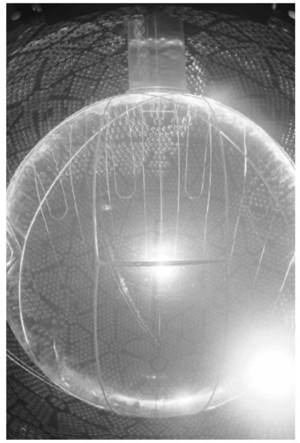
Covid pause:
370 t LS + PPO (0.6 g/L)
Measure scintillator backgrounds

Talks by S. Andringa, D. Cookman

Scintillator phase

Full scintillator:
800 t LS + PPO + bisMSB
Characterize scintillator and backgrounds

Talk by T. Kroupová
Poster by B. Tam



Tellurium phase

Initial Te loading:
0.5% by mass

$0\nu\beta\beta$ search

Loading to begin end 2025

The SNO+ experiment

Talks by S. Andringa, D. Cookman

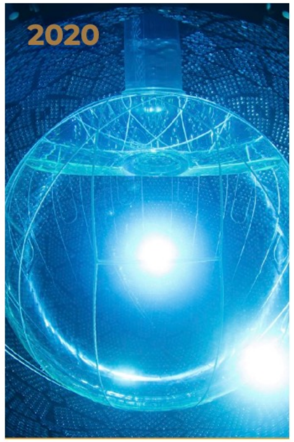
Talk by T. Kroupová
Poster by B. Tam

Water phase

Ultra-pure water

Detector calibration,
measure external backgrounds

Physics includes first detection of distant reactor νs, solar ^{8}B flux, invisible nucleon decay search



Partial-fill phase

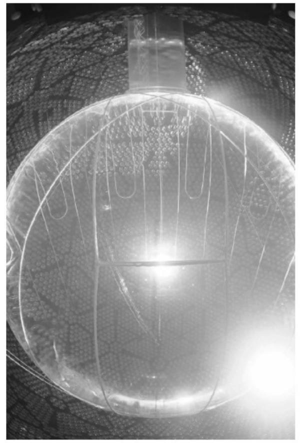
Covid pause:
370 t LS + PPO (0.6 g/L)
Measure scintillator backgrounds

Physics includes initial reactor ν oscillation measurement, event-by-event solar ν directionality

Scintillator phase

Full scintillator:
800 t LS + PPO + bisMSB
Characterize scintillator and backgrounds

Physics includes solar ^{8}B flux + oscillations, first solar CC on ^{13}C, antinu reactor oscillation + geo flux, supernova monitoring



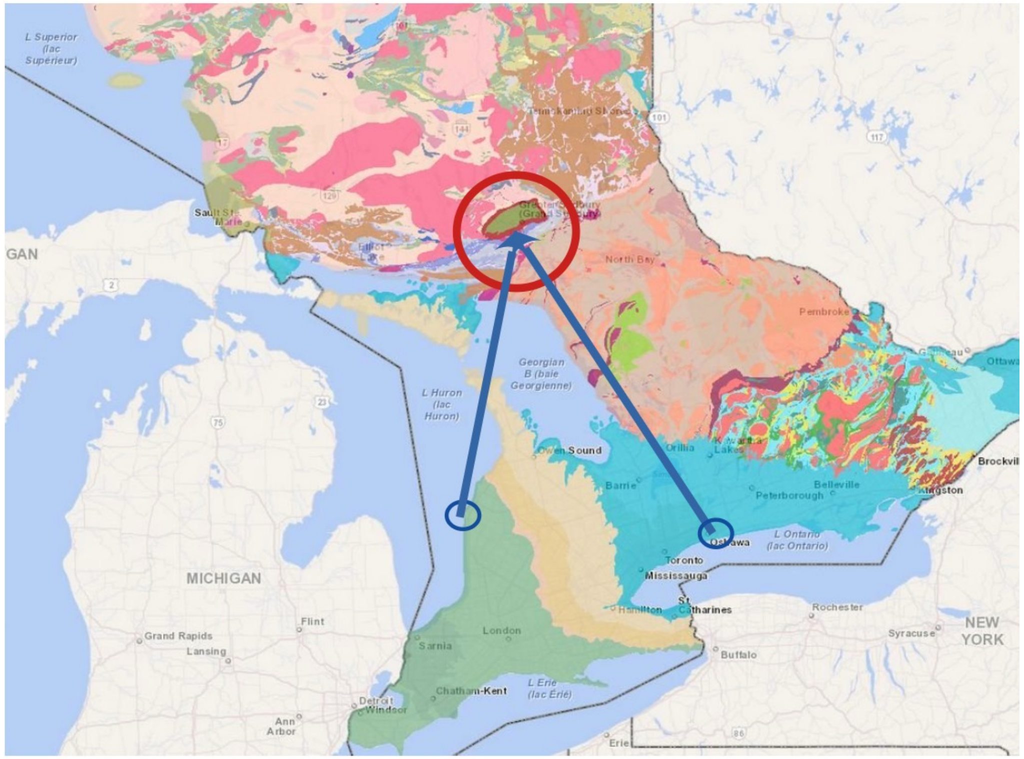
Tellurium phase

Initial Te loading:
0.5% by mass

0νββ search

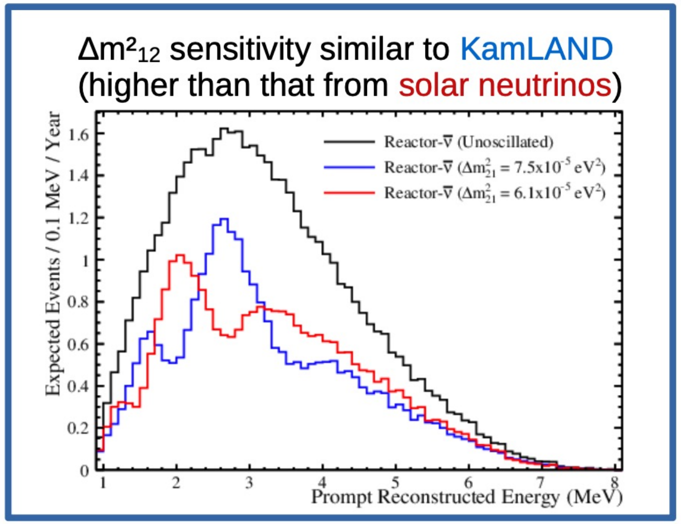
Loading to begin end 2025

Physics with antineutrinos



~60% of antinu flux from CANDU reactors at 240 km and 340-355 km
~40% from other North American reactors + geo neutrinos

Reactor oscillation measurement
Geo-neutrino flux

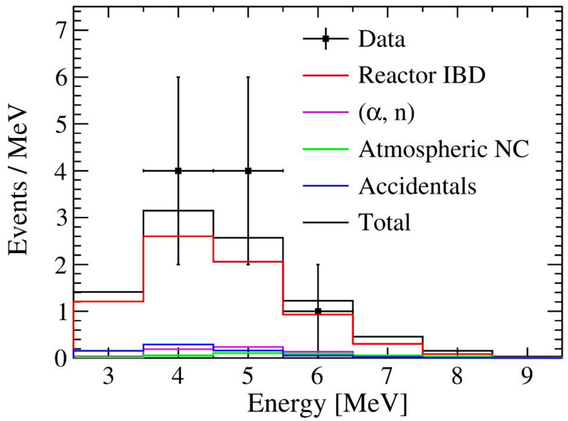


- Three years livetime to reach KamLAND precision on Δm^2_{12}
- Third measurement of geo-neutrino flux (after KamLAND and Borexino), first in North America

Talk by S. Andringa (Tue)

Physics highlights antineutrinos

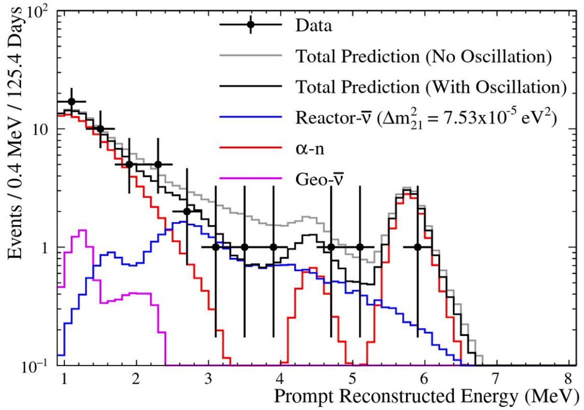
Water phase



First detection of distant reactor νs
PRL 130, 09180 (2023)

190 days (2017-2019), 2 independent analyses, 3σ evidence

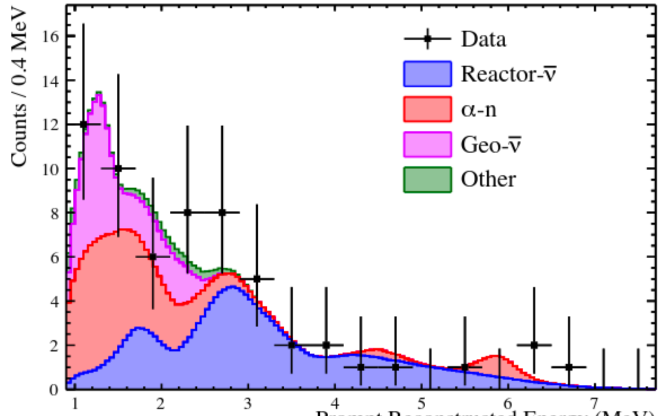
Partial scintillator fill



Partial fill 130 days (144 t-yrs) (2020)
EPJC 85, 17 (2025)

Dominated by α-n background from ^{210}Po
Oscillation parameters compatible with KamLAND and solar

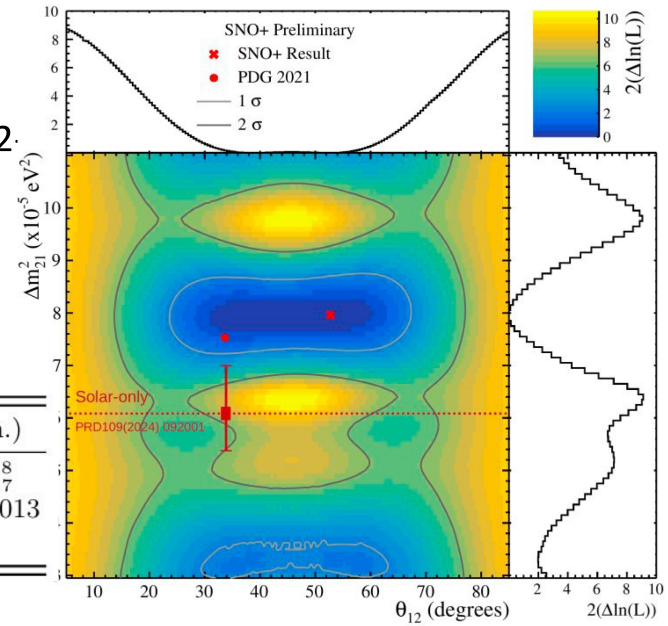
Full scintillator fill



Full fill 286 days (286 t-yrs) (2022-
Submitted for publication

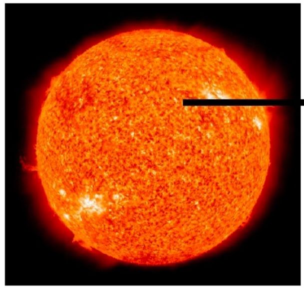
Spectral fit
2nd most precise Δm^2_{21}

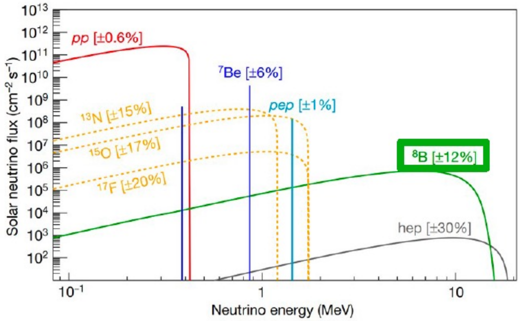
	Fit (Uncon.)	Fit (Con.)
Δm^2_{21} ($\times 10^{-5}$eV^2)	$7.96^{+0.48}_{-0.42}$	$7.58^{+0.18}_{-0.17}$
$\sin^2\theta_{12}$	$0.62^{+0.16}_{-0.40}$	0.308 ± 0.013
Geo-$\bar{\nu}$ IBD rate (TNU)	79^{+49}_{-44}	73^{+47}_{-43}



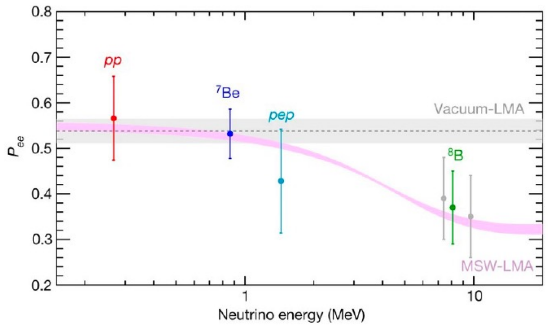
Physics with solar neutrinos

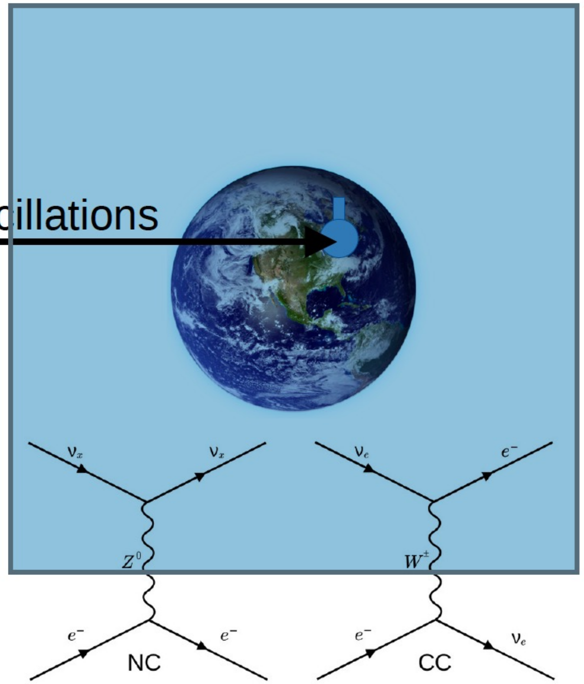
MSW Matter effect in Sun & Earth + Vacuum Oscillations





Solar ν_e Production Spectra

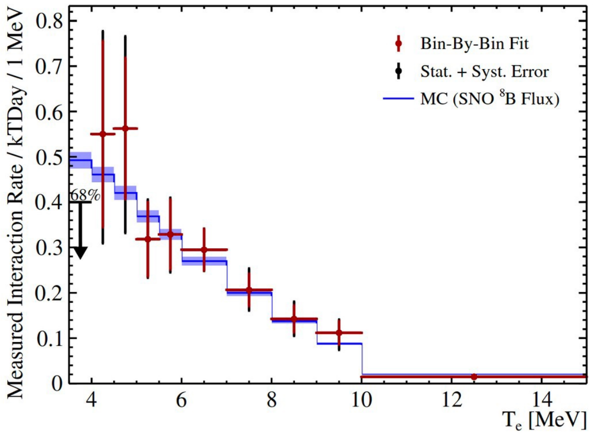




Primary Detection mode:
Neutrino-Electron Elastic Scattering

Physics highlights solar neutrinos

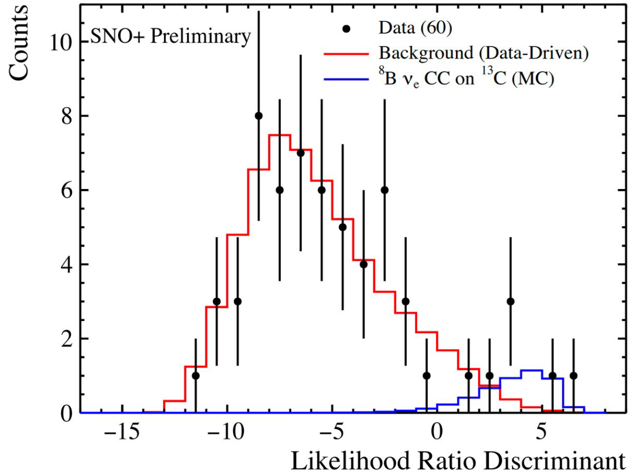
PRD 110, 122003 (2024)

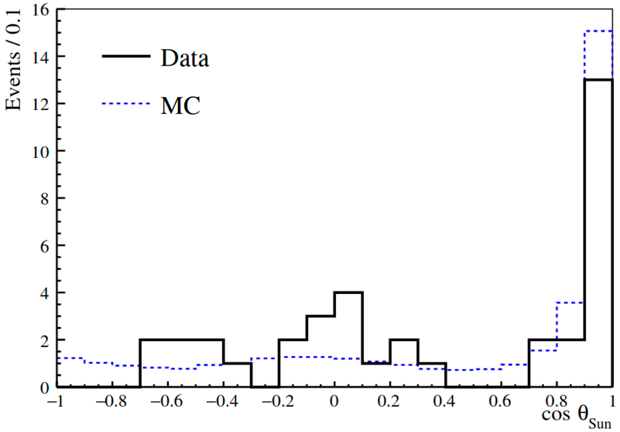


Solar neutrino flux
Water phase 126 kt-days
(190 days with lowest bg
for Cherenkov detector

Flux:

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





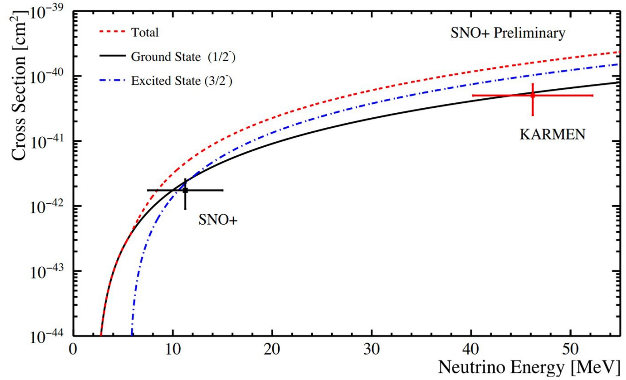
PRD 109, 072002 (2024)

First ever event-by-event direction reconstruction in high-yield scintillator

Data from partial fill and early scint phases (slow scintillator)

First ever measurement of CC interactions on ^{13}C

225 days,
2 blinded analyses, 3.8σ significance

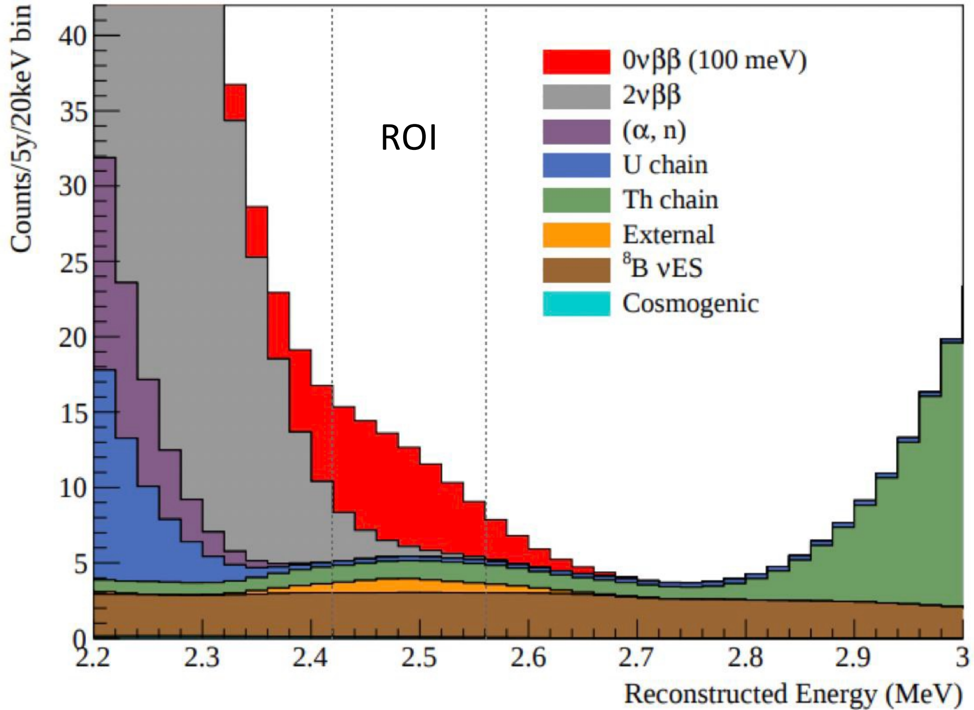


$$\langle \sigma(E_\nu) \rangle = (1.7 \pm 0.8) \times 10^{-42}\,\text{cm}^2$$

$0\nu\beta\beta$ search with ^{130}Te

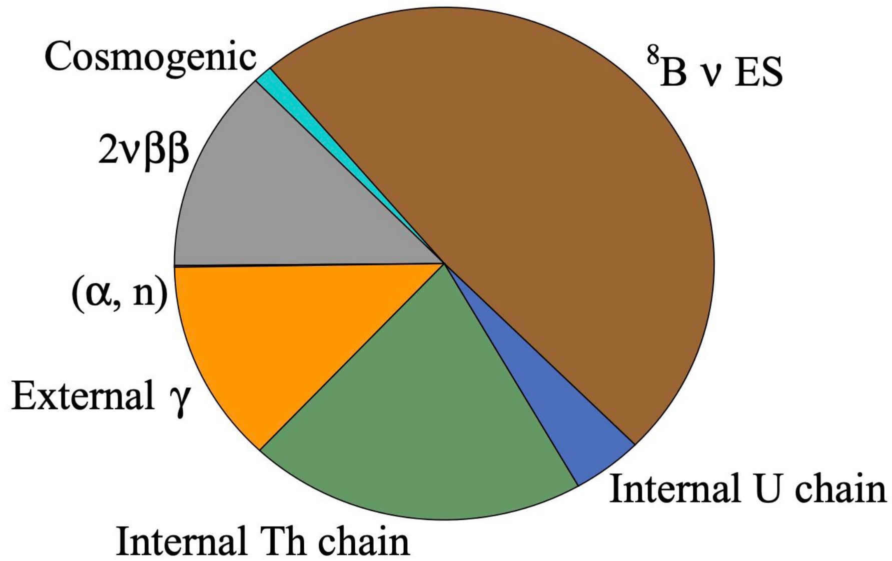
Talk by T. Kroupová this afternoon

SNO+ will look for $0\nu\beta\beta$ events at the endpoint of the double beta decay spectrum



ROI: 2.42-2.56 MeV [-0.5s - 1.5s]
FV: 3.3 m radius

Backgrounds 9.47 counts/yr (1.21 in ROI)
3 years with initial 0.5% Te loading
→ **$T_{1/2}$ > 2 x 10^{26} yrs (90% CL)**

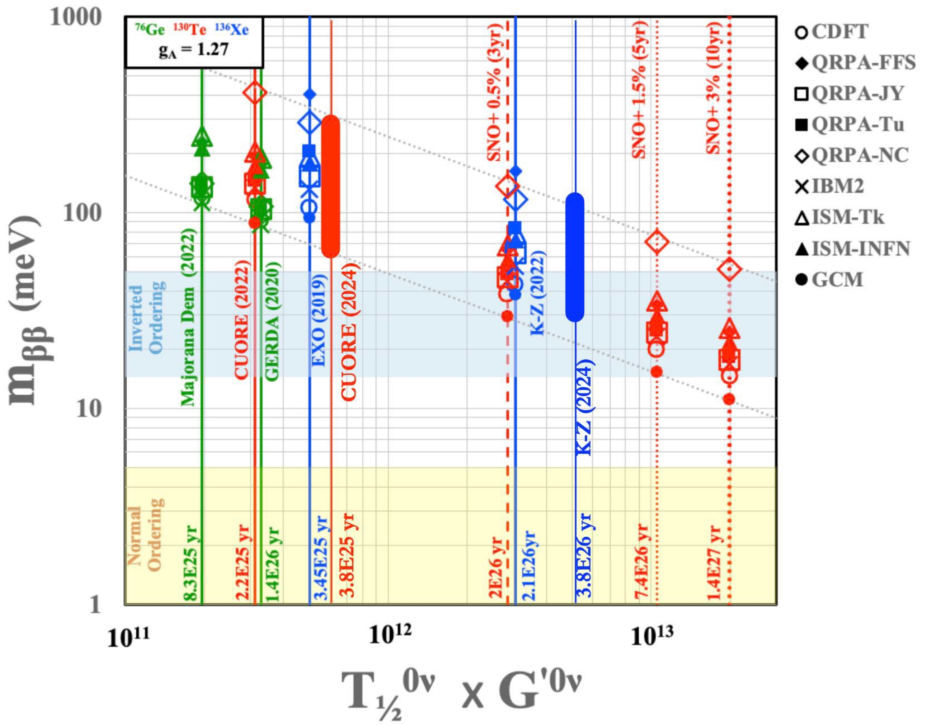


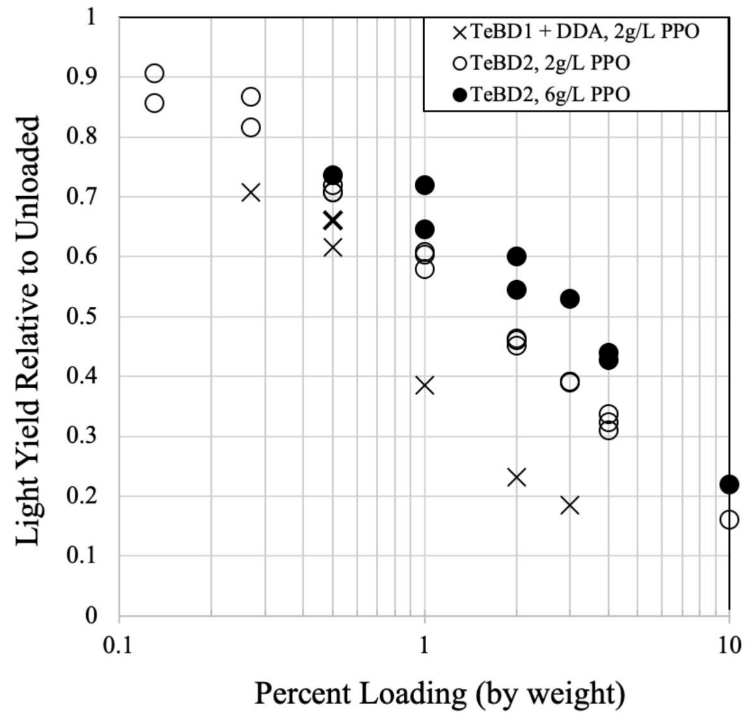
5 years with increased 1.5% Te loading
→ **$T_{1/2}$ > 7.4 x 10^{26} yrs (90% CL)**

Future prospects

SNO+ exposure easily increased by adding more Te with improved loading techniques

Increasing loading to 1.5%





Conclusions and outlook

- SNO+ is publishing results as a liquid scintillator experiment and is getting ready to tellurium for the $0\nu\beta\beta$ search

- Major backgrounds characterised and on target for $0\nu\beta\beta$ search

- More solar and antineutrino data collected and being analysed

- Supernova monitoring with SNEWS

- SNO+ aims to reach KamLAND precision on Δm^2_{21} with 3 years' livetime, searching for solar antineutrinos, ultimately to have world leading $0\nu\beta\beta$ sensitivity in ^{130}Te