The SNO+ Experiment

overview, current status and prospects

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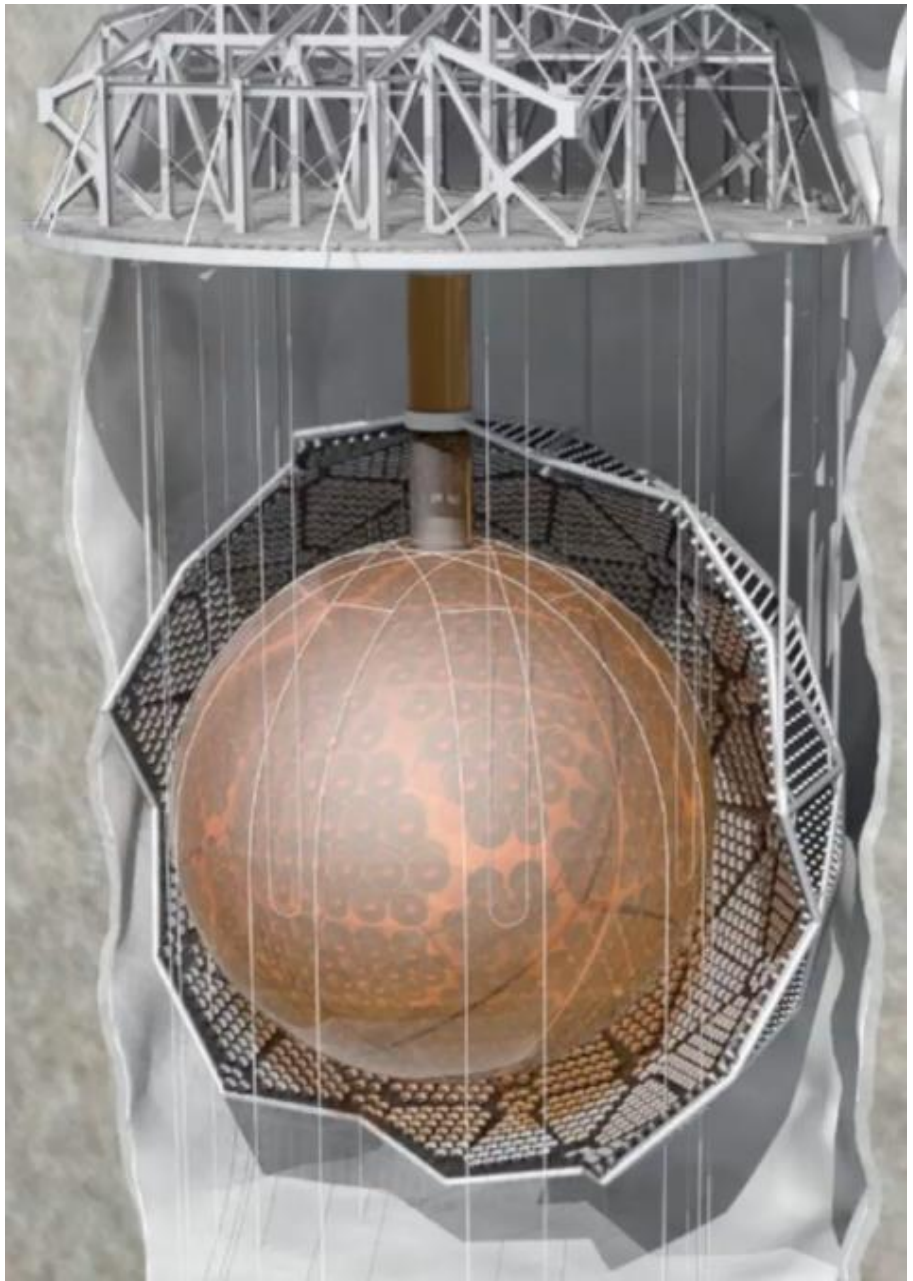
on behalf of the SNO+ collaboration

Snolab Summer User Meeting 2021

The SNO+ Experiment

Multi-purpose neutrino detector located at SNOLAB in Sudbury

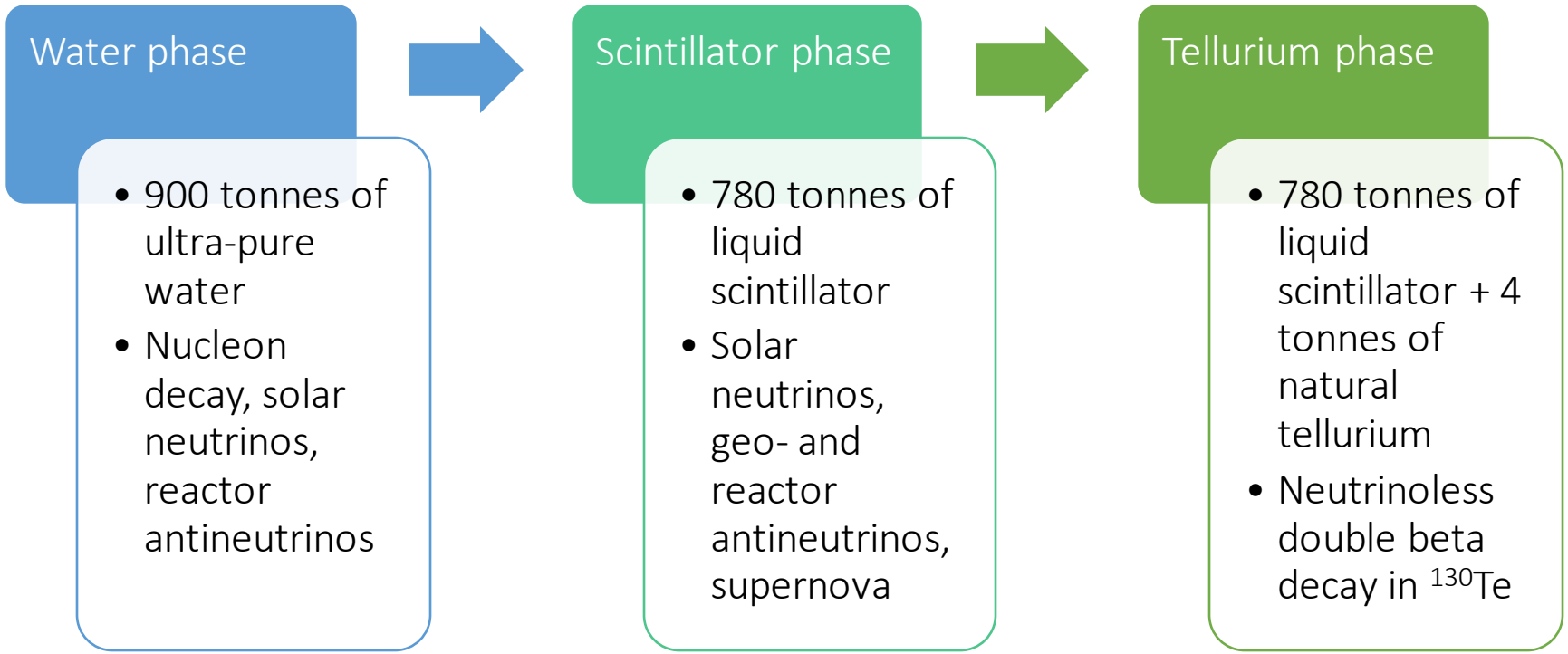
- Ultra-pure water shielding
  7kt in total
- PMT support structure
  ~9400 PMTs (54% coverage)
  18m diameter
- Hold-up and hold-down rope systems
- Acrylic Vessel
  12m diameter
- Target medium inside the AV



The SNO+ Experiment

Multi-purpose neutrino detector located at SNOLAB in Sudbury

Each SNO+ phase defined by different target medium inside the AV and physics goals



The SNO+ Experiment

Multi-purpose neutrino detector located at SNOLAB in Sudbury

Each SNO+ phase defined by different target medium inside the AV and physics goals

Water phase

- 900 tonnes of ultra-pure water
- Nucleon decay, solar neutrinos, reactor antineutrinos

Partial-fill phase [BONUS*]

- 365 tonnes of liquid scintillator (almost half of the AV) + water

Scintillator phase

- 780 tonnes of liquid scintillator
- Solar neutrinos, geo- and reactor antineutrinos, supernova

Tellurium phase

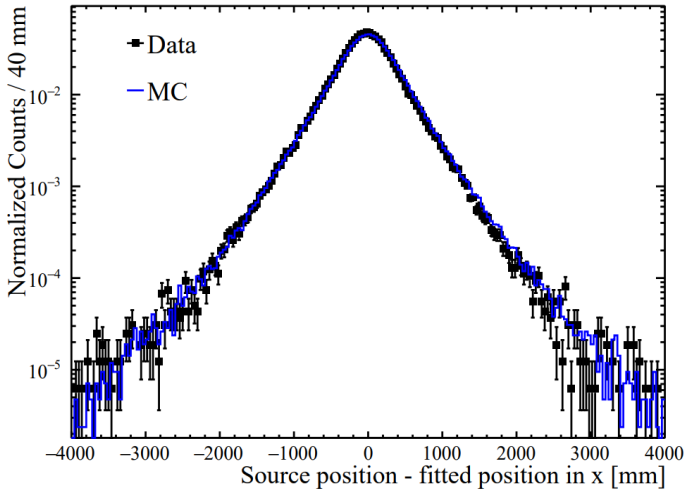
- 780 tonnes of liquid scintillator + 4 tonnes of natural tellurium
- Neutrinoless double beta decay in ^{130}Te

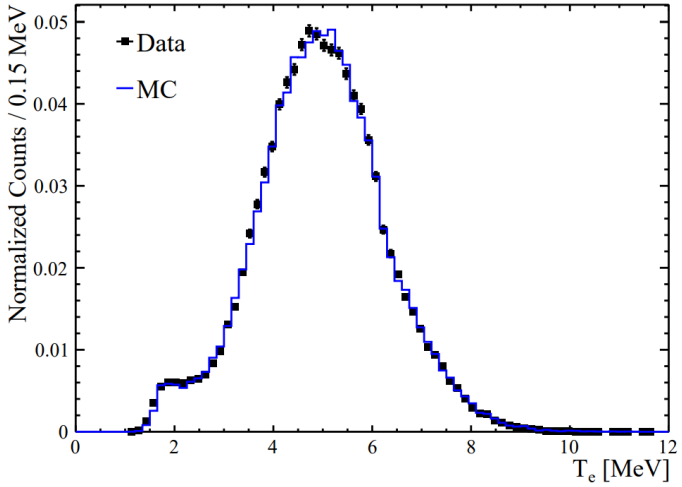
*due to Covid-19 Pandemic

SNO+ Water Phase

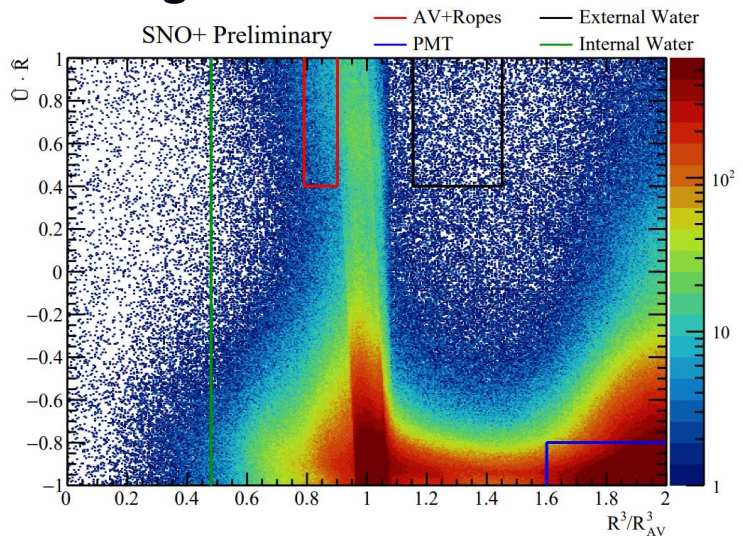
- Data taking since May 2017 – phase concluded in July 2019
- 900 tonnes of ultra-pure water
- Detector calibration
  deployed and in-situ sources
  to calibrate PMTs, measure timing and optical properties, calibrate reconstructed energy, position and direction
- Background measurements
  internal and external
  ^{238}U,^{232}Th,^{14}C,$^{210}BiPo$,^{39}Ar,^{85}Kr,^{40}K,(α,n)

^{16}N calibration source $^{16}N \rightarrow {}^{16}O+\gamma(6.1MeV)$





Background measurements

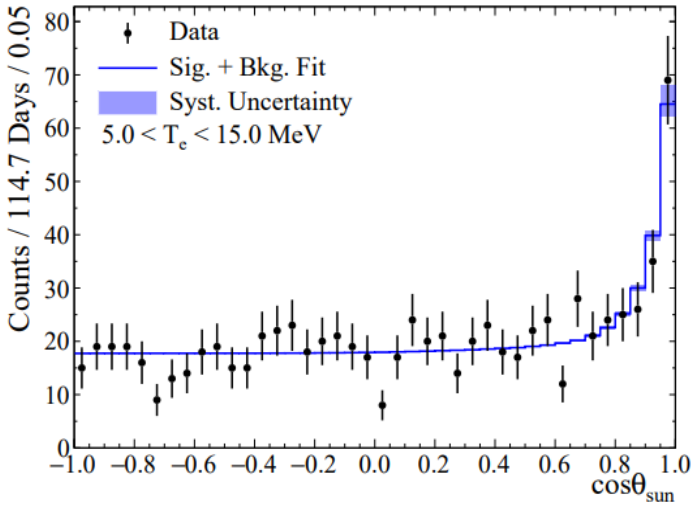


-Adil's talk "Evaluating SNO+ External Background through Radon Assays"

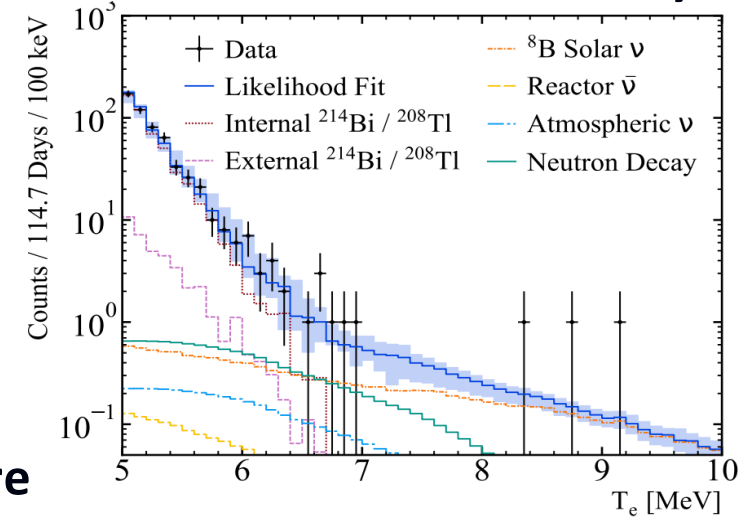
SNO+ Water Phase

- Data taking since May 2017 – phase concluded in July 2019
- 900 tonnes of ultra-pure water
- Detector calibration
- Background measurements
- Physics results:
  - ^{8}B solar neutrinos flux
    Phys. Rev. D 99, 012012 (2019)
  - Invisible modes of nucleon decay
    Phys. Rev. D 99, 032008 (2019)
  - Neutron-proton capture
    Phys. Rev. C 102, 014002 (2020)

^{8}B solar neutrinos $\nu_x+e^-\rightarrow\nu_x+e^-$ (x=e,μ,τ)

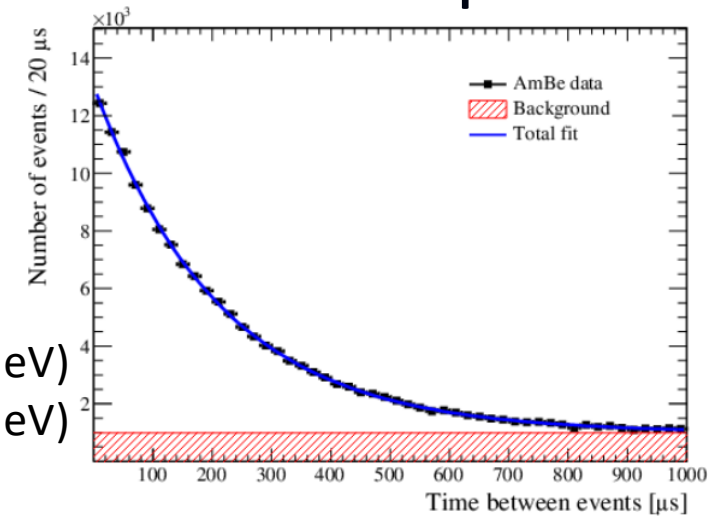


Invisible nucleon decay



$^{16}O\rightarrow X^*+inv\rightarrow X+\gamma$
(X=^{15}O,^{15}N,^{14}O,^{14}N,^{14}C)

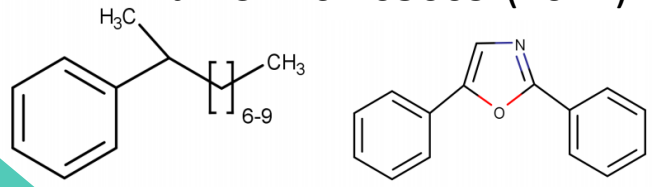
Neutron capture

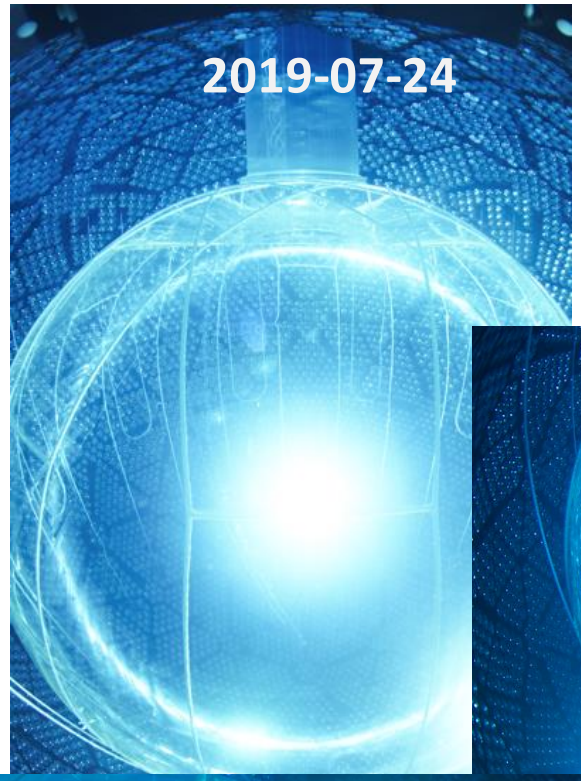


$^{241}Am(\alpha,n)^{9}Be\rightarrow^{12}C+\gamma(4.4MeV)$
$H+n\rightarrow^{2}H+\gamma(2.2MeV)$

SNO+ Partial-Fill Phase

- Fill started in 2019, paused in March 2020. Stable partial-fill data taking until October 2020
- Linear Alkylbenzene (LAB) + Diphenyloxazole (PPO) - 365 tonnes of LAB + 0.5g/L PPO during stable partial-fill period via multi-stage distillation
  - ➢ SNO+ liquid scintillator JINST 16 P05009 (2021)





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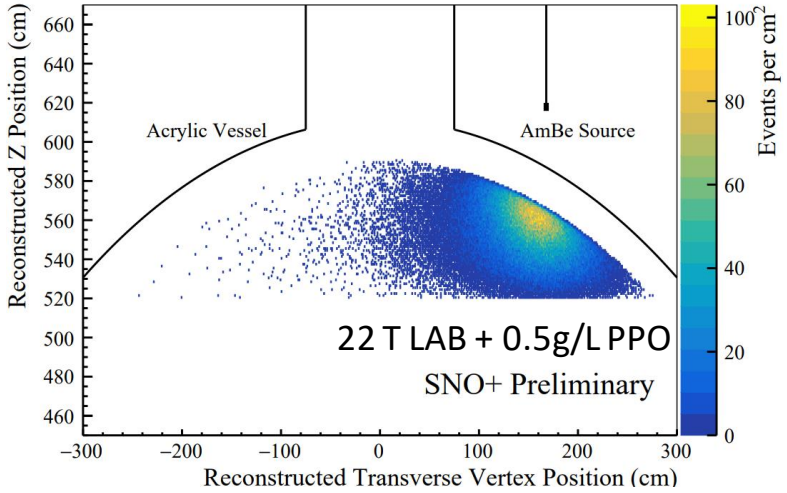
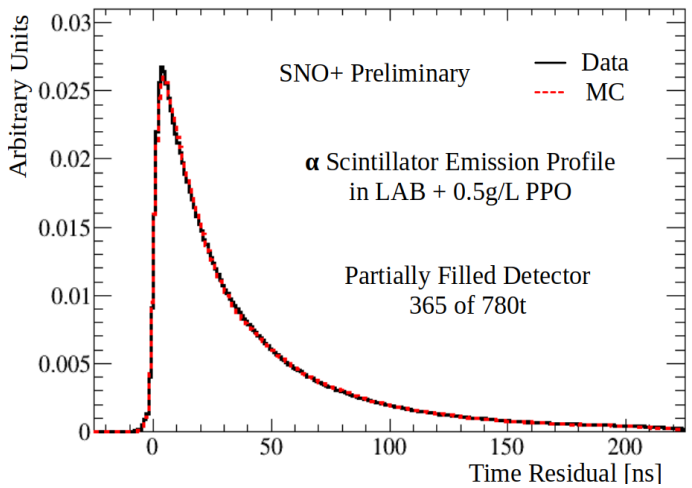
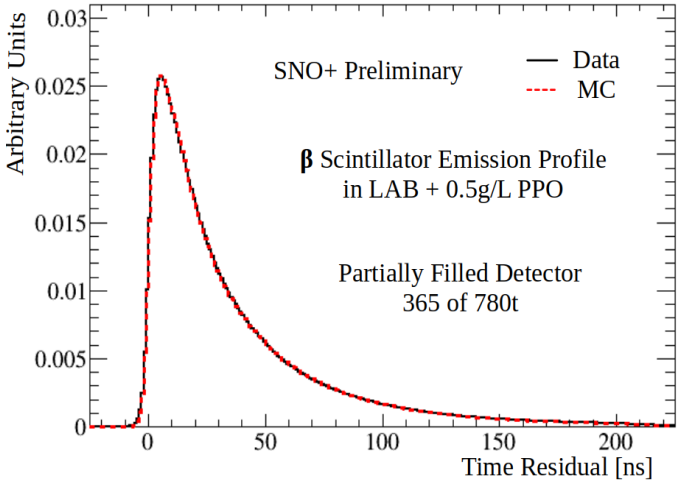
- Detector calibration
- Background measurements

AmBe calibration source



Scintillation timing ^{214}BiPo

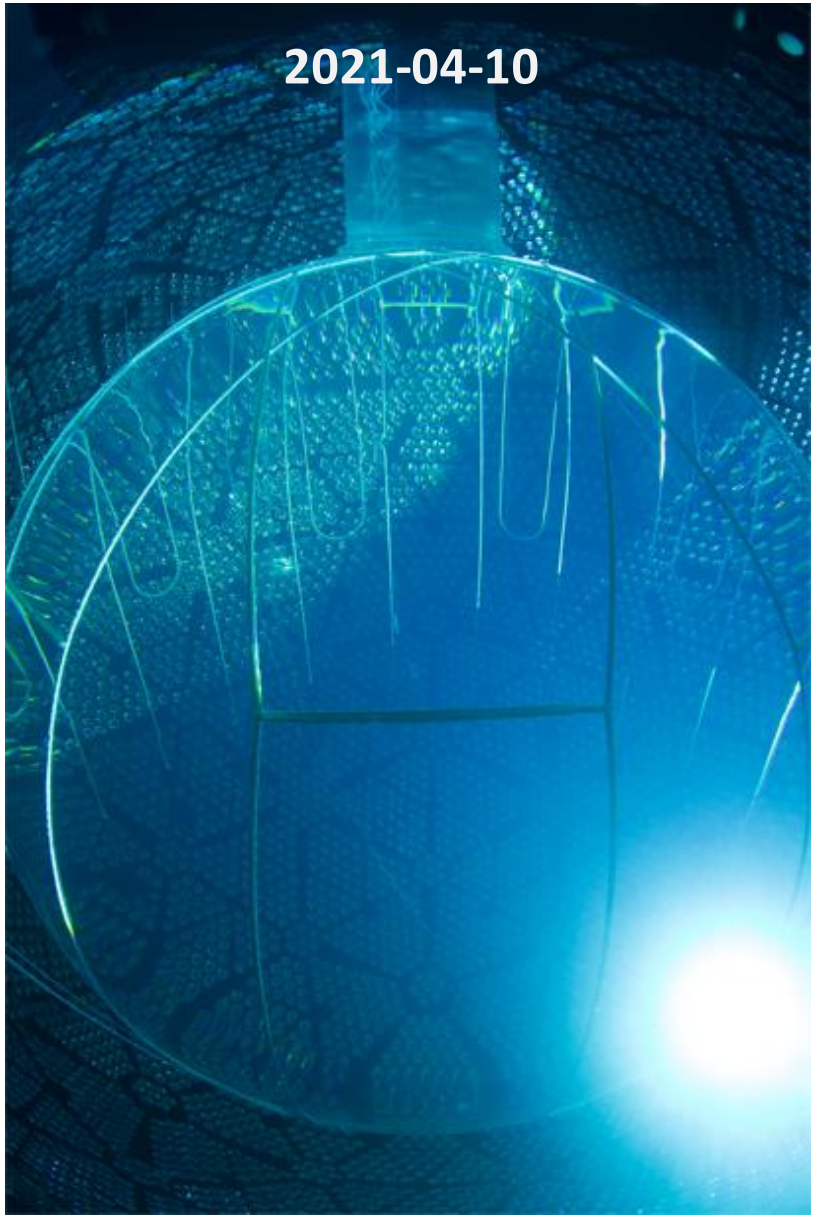




-Jamie's talk "AmBe Source Calibrations in the SNO+ Partial Scintillator Phase"
-Shengzhao's talk "Po210 Backgrounds for SNO+ Partial Fill"
-Pouya's talk "External Backgrounds in SNO+"

SNO+ Scintillator Phase

- Fill restarted in October 2020.
  AV bulk fill completed 2021-03-27
- LAB+PPO -
  780 tonnes of LAB + 0.6-0.8g/L PPO currently (Aug2021)
  PPO top-up campaign on-going
  to reach desired 2g/L
  via multi-stage distillation, water extractions, N2 and steam stripping, AV recirculation



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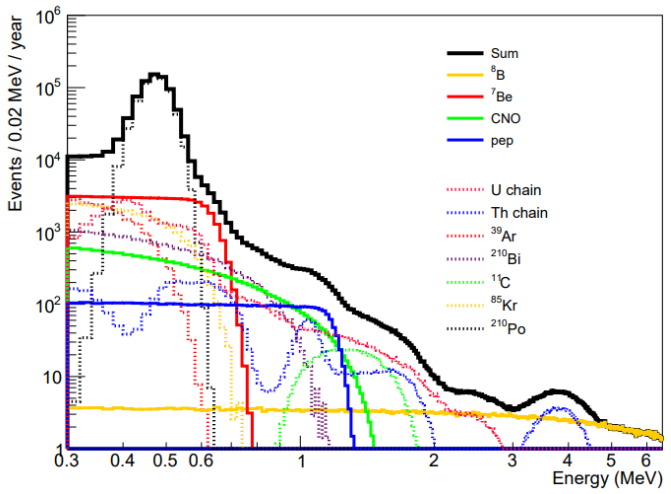
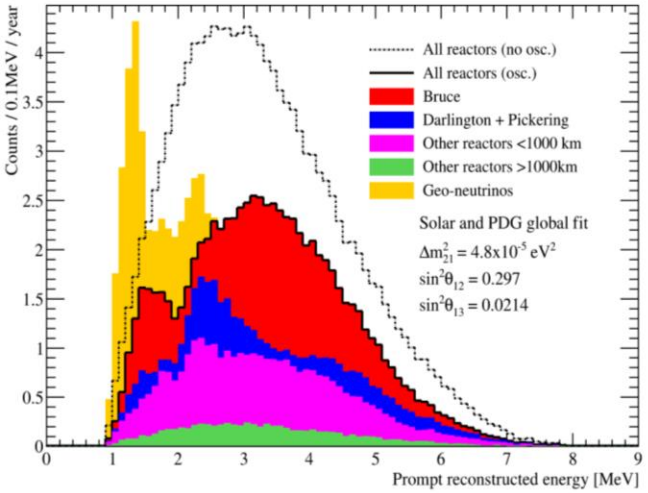
- Physics goals:
  - solar neutrinos
  - geo- and reactor antineutrinos
  - supernova neutrinos

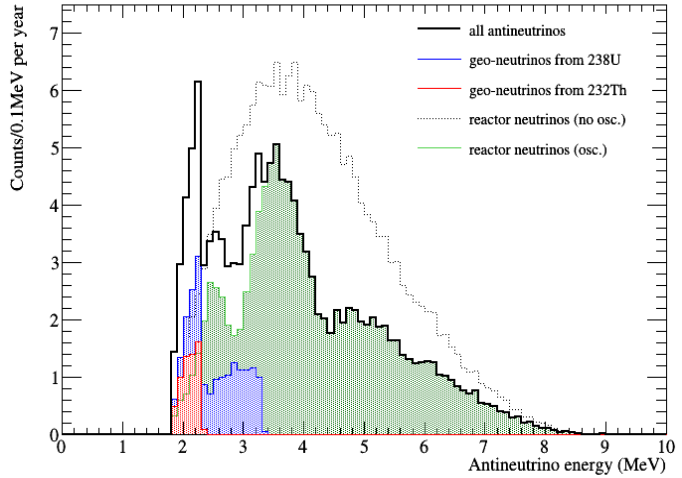
Solar neutrinos



Reactor antineutrinos



Geo antineutrinos

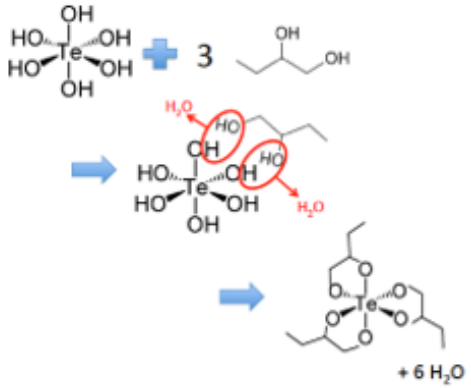


IBD inverse beta decay
$\bar{\nu}_e + p \rightarrow e^+ + n$

SNO+ Tellurium Phase

- Future phase
  Underground Te plants commissioning started in 2020, now ready for operations after upcoming reviews and approvals
  - ➢ Te acid purification (TeA Plant)
  - ➢ Te loading via TeBD synthesis (TeDiol Plant)
- LAB + PPO (2 g/L) + bis-MSB + Tellurium(0.5%)-ButaneDiol + DDA
  3.9 tonnes of nat Te – 1330 kg of ^{130}Te

$$Te(OH)_6 \rightleftharpoons Te(OH)_5O^- + H^+$$



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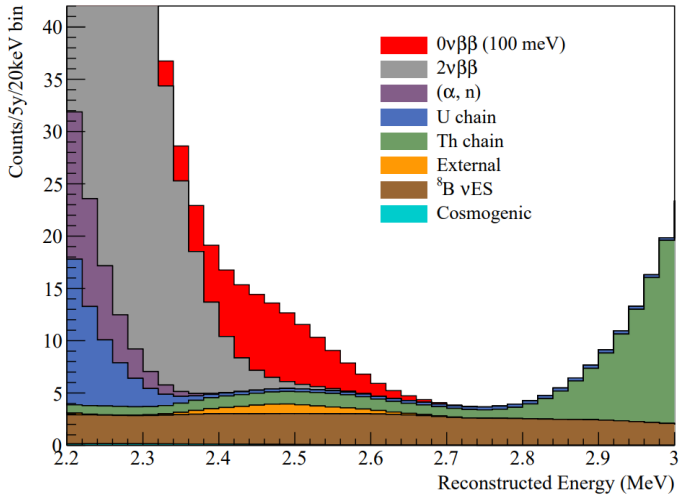
- LAB + PPO (2 g/L) + bis-MSB + Tellurium(0.5%)-ButaneDiol + DDA
  3.9 tonnes of nat Te – 1330 kg of ^{130}Te
- Physics goals:
  - ^{130}Te double beta decay measurement
  - ^{130}Te neutrinoless double beta decay search

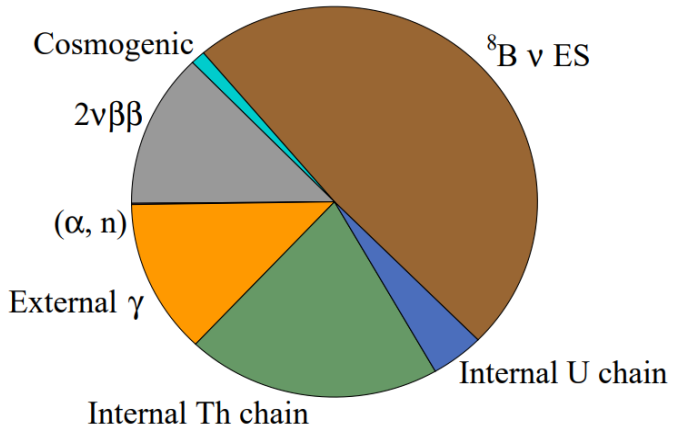
Signal



0.5% Te loading
5 years
460 PMThits/MeV
Fiducial Volume 3.3m radius

Backgrounds in ROI

ROI: 2.42 - 2.56 MeV [-0.5σ - 1.5σ]
Counts/Year: 9.47



Summary

Water phase

- Studied detector response and backgrounds
- Measured ^{8}B solar neutrinos flux
- Set world-leading limits on nucleon decays
- Measured neutron capture efficiency and time
- [coming soon] solar and nucleon decay analysis updates with lower backgrounds and antinu study results

Partial-fill phase

- Characterized scintillator properties and backgrounds

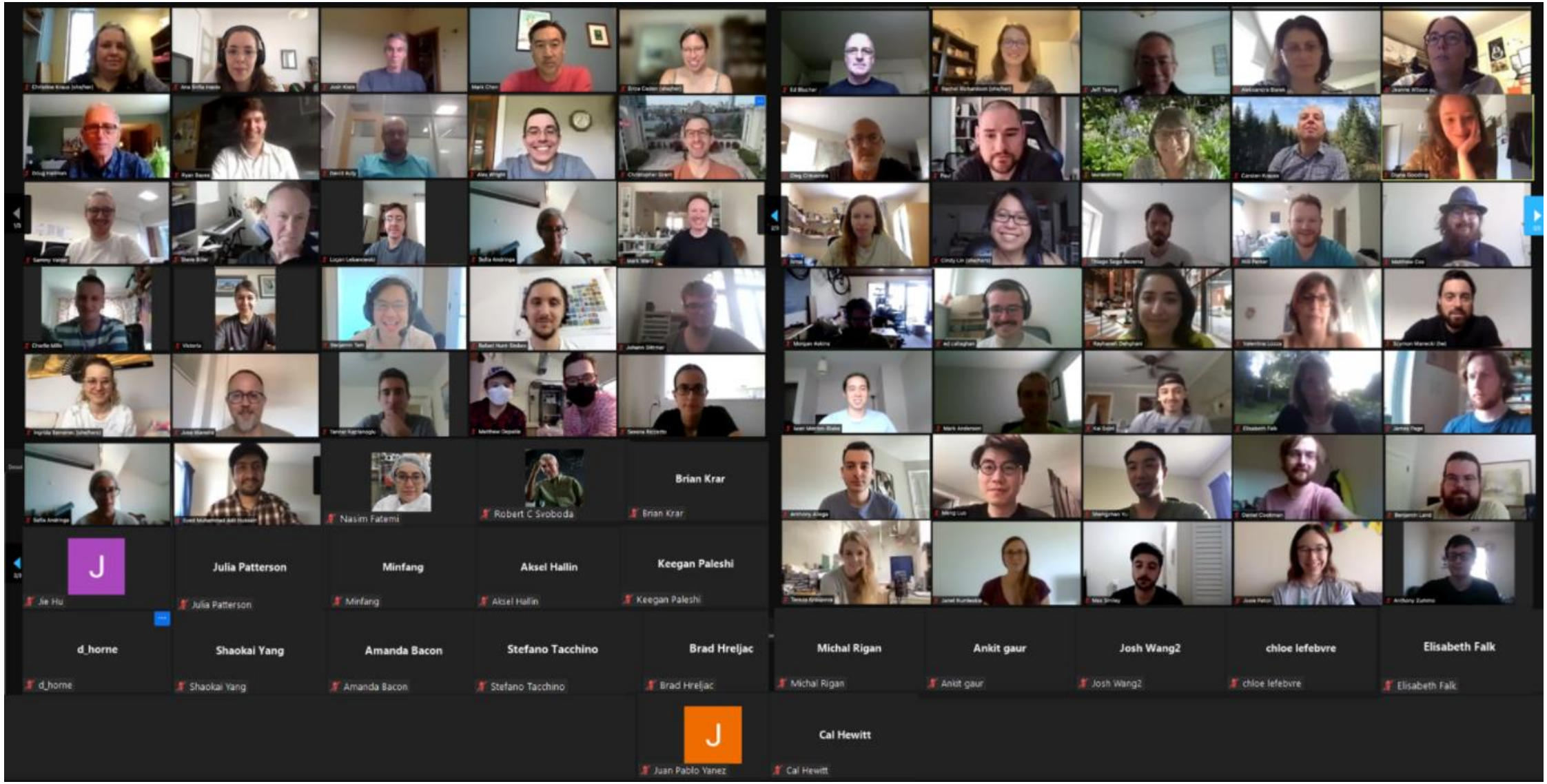
Scintillator phase [ON-GOING]

- Characterization of scintillator properties and backgrounds while adding PPO
- Studies of solar neutrinos, geo- and reactor antineutrinos
- Studies of supernova neutrino bursts, pre-SN neutrinos and alert system preparation to join SNEWS

Tellurium phase

- Search for neutrinoless double beta decay in ^{130}Te

The SNO+ Collaboration



Thank you for the attention