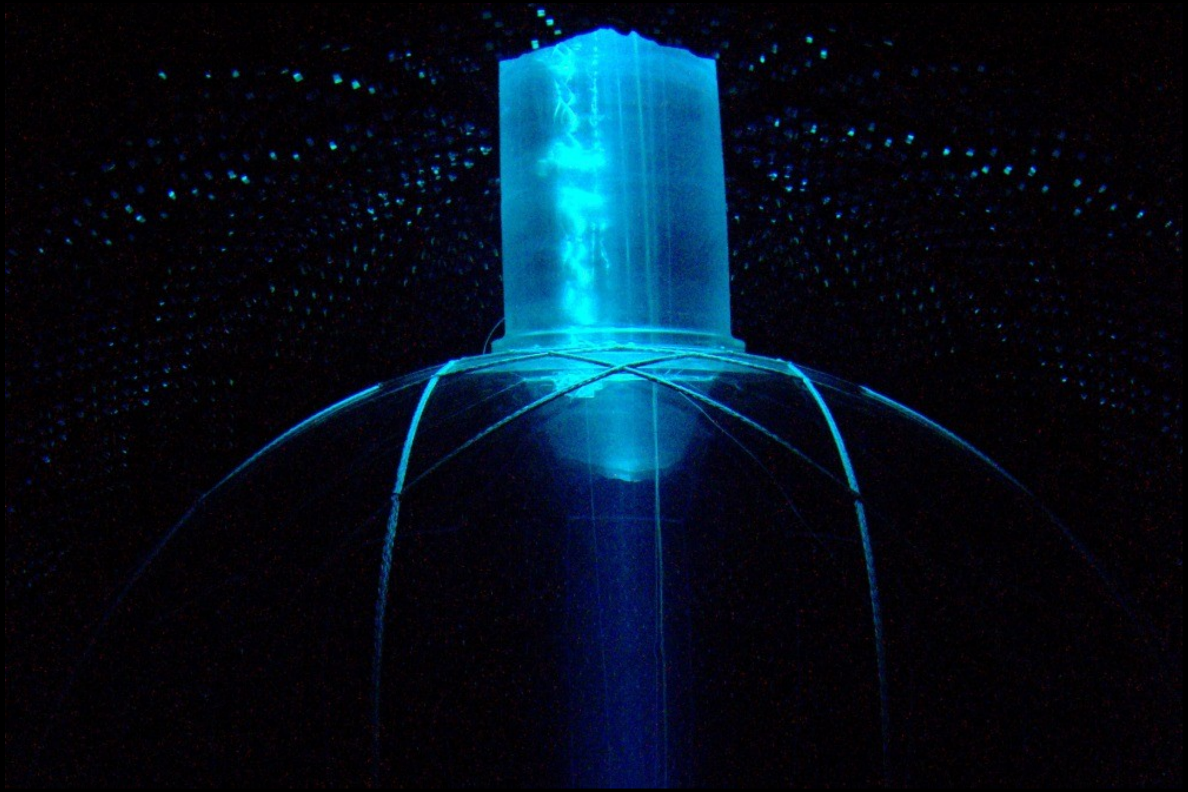


Neutrino Physics with SNO+

XVIII International Conference on Topics in Astroparticle and Underground Physics 2023

Tanner Kaptanoglu UC Berkeley 8/31/2023

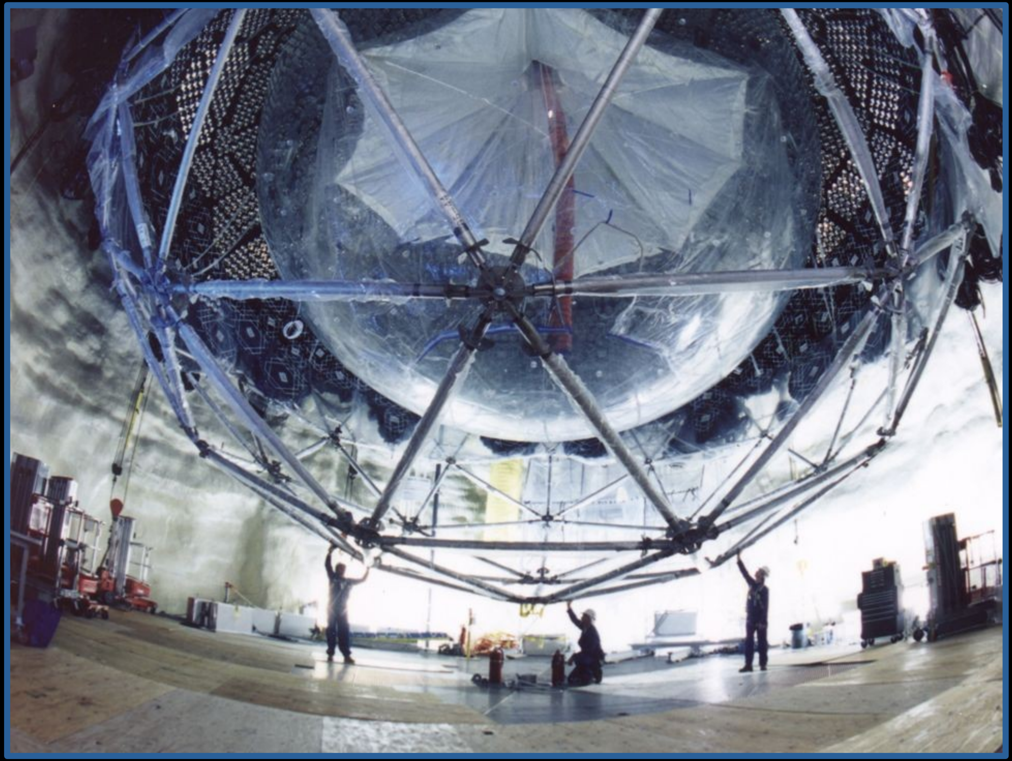
Overview

1. The SNO+ detector

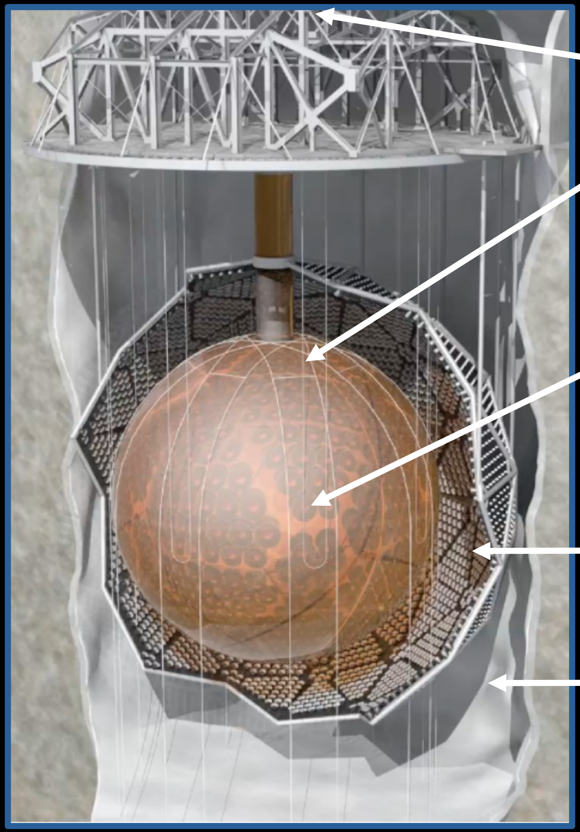
2. A phased physics program

3. Solar neutrinos

4. Antineutrinos (reactor & geo)

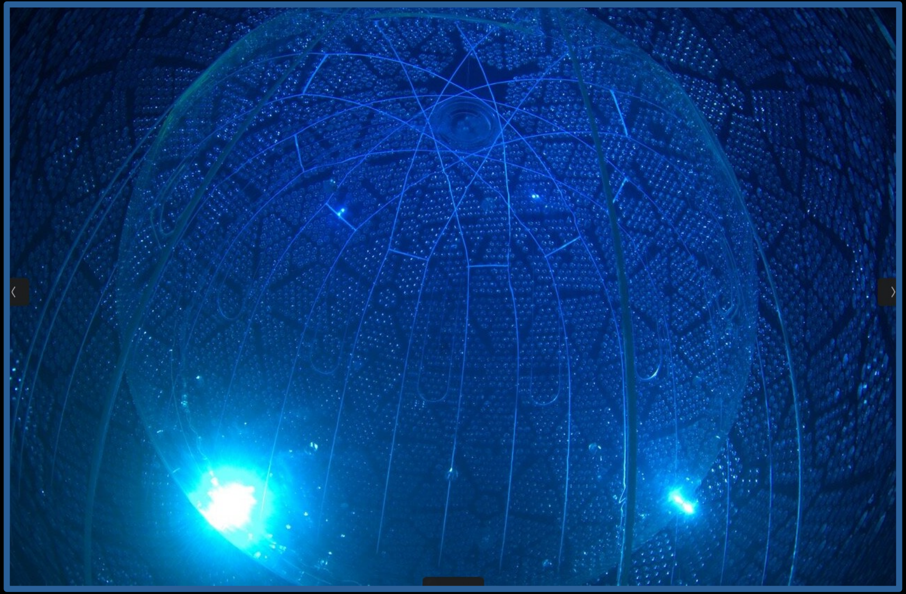


SNO+ Detector



Phased Program

1. Water phase
   calibrations, solar, reactor neutrinos



SNO+ with water, 2017

Phased Program

1. Water phase
   calibrations, solar, reactor neutrinos

2. “Partial fill” phase
   solar, reactor neutrinos

SNO+ filling with scintillator, 2020

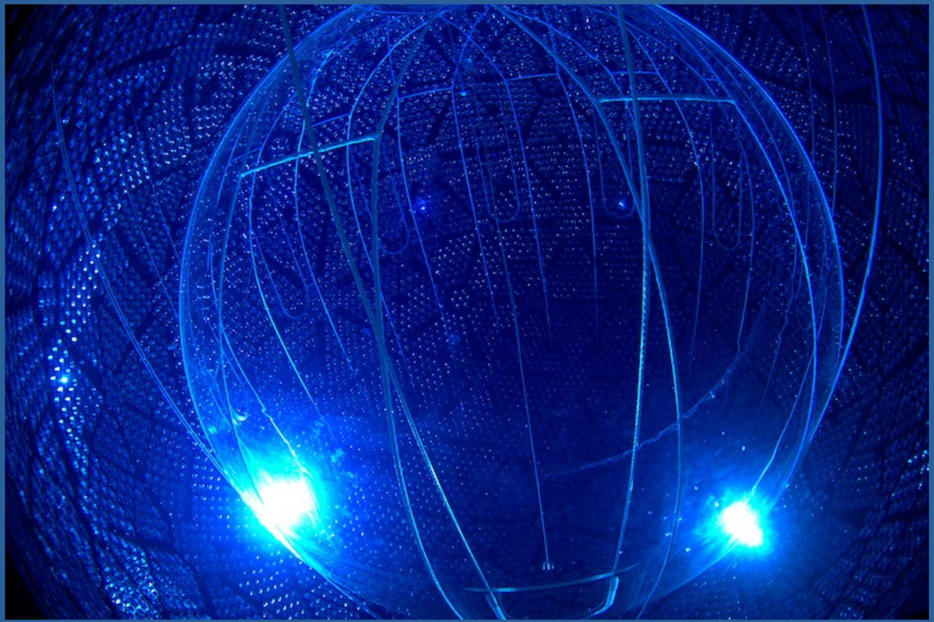
Phased Program

1. Water phase
   calibrations, solar, reactor neutrinos

2. “Partial fill” phase
   solar, reactor neutrinos

3. Liquid scintillator phase
   solar, reactor, geo neutrinos

Currently full with LS, collecting quality data



SNO+ with scintillator, 2022

Phased Program

1. Water phase
   calibrations, solar, reactor neutrinos

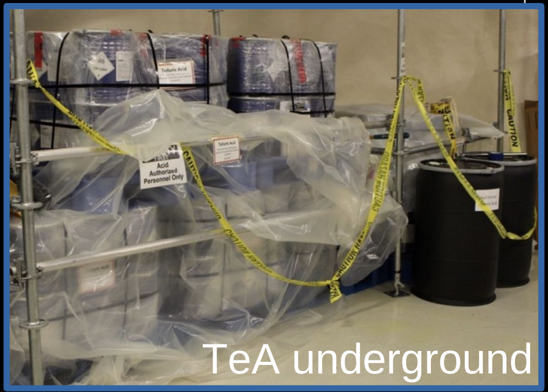
2. “Partial fill” phase
   solar, reactor neutrinos

3. Liquid scintillator phase
   solar, reactor, geo neutrinos

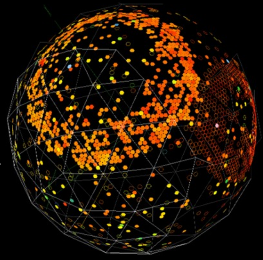
Currently full with LS, collecting quality data

4. Te-loaded scintillator phase
   solar, reactor, 0νββ

Planned deployment in 2024



Physics Program



Extremely broad physics program:

Invisible nucleon decay (n → ννν)

Solar neutrinos

Reactor & geo neutrinos

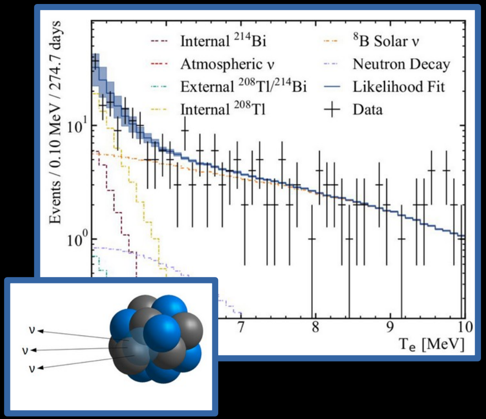
Supernova neutrinos

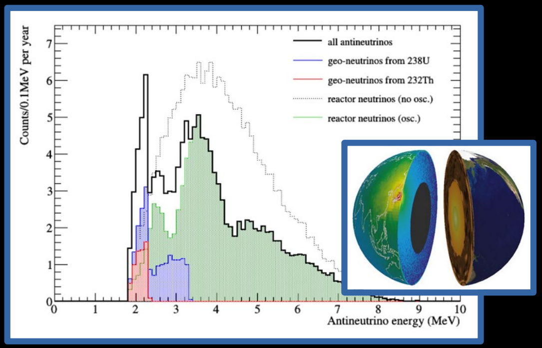
0νββ

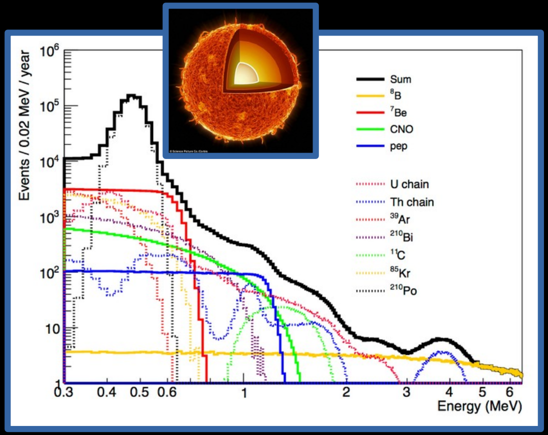
Neutrinoless double beta decay with SNO+
V. Lozza, TAUP 2023, session 5A (133)

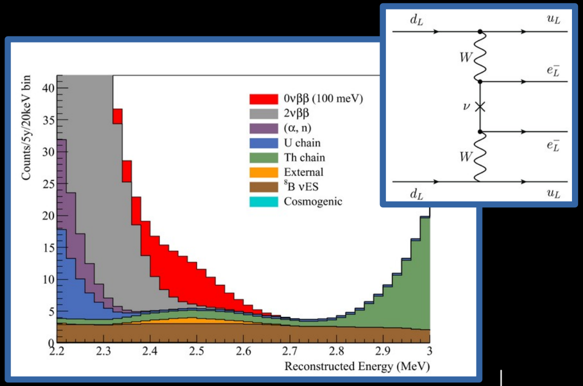
0νββ target out analysis for the SNO+ Experiment
B. Tam, TAUP 2023, poster 446

SNO+ tellurium purification and loading for neutrinoless double beta decay search
S. Manecki and S.Biller, TAUP 2023, poster 346

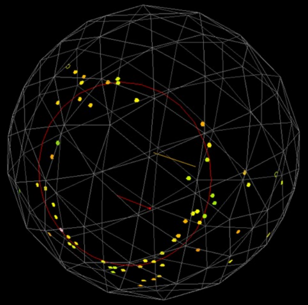






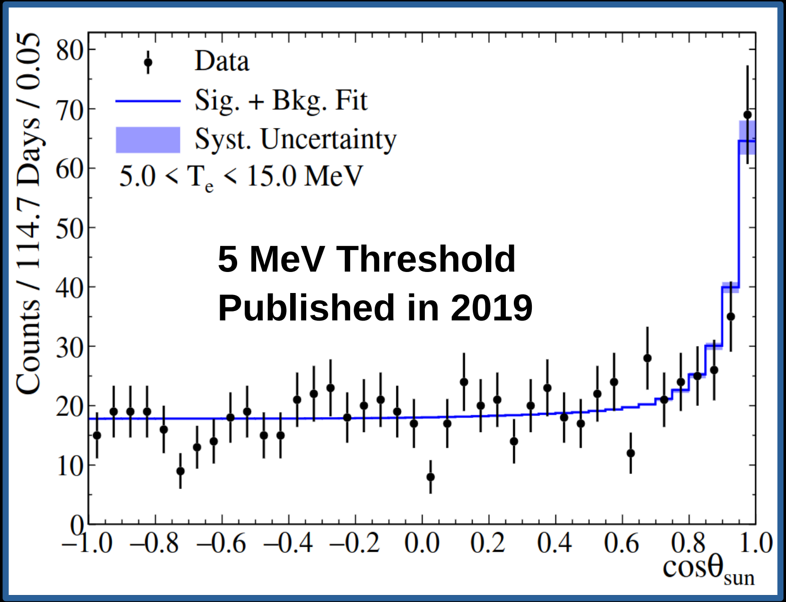


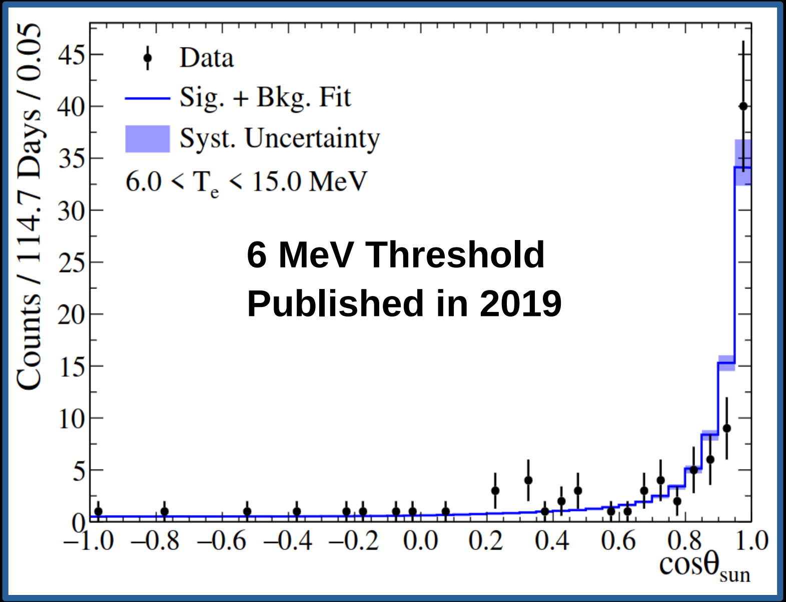
Water Phase: Solar



Measurement of ^{8}B solar neutrinos performed in 69.2 kt-day dataset [1].

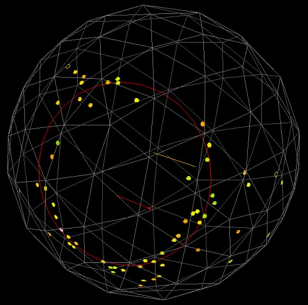
Lowest background measurement of solar neutrinos in a water Cherenkov detector.





[1] *SNO+ collaboration, PRD 99, 012012 (2019)*

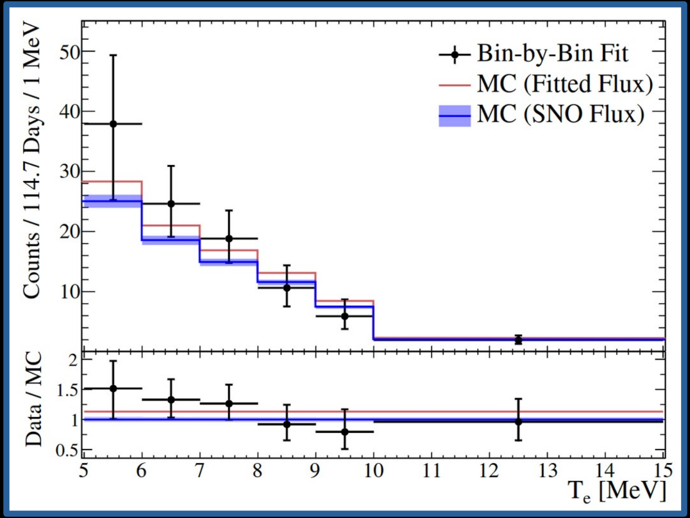
Water Phase: Solar



Measurement of ^{8}B solar neutrinos performed in 69.2 kt-day dataset [1].

Lowest background measurement of solar neutrinos in a water Cherenkov detector.

Produced ^{8}B flux measurement, binned fit from 5 – 15 MeV.

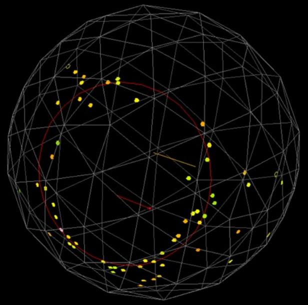


SNO+ water phase I:

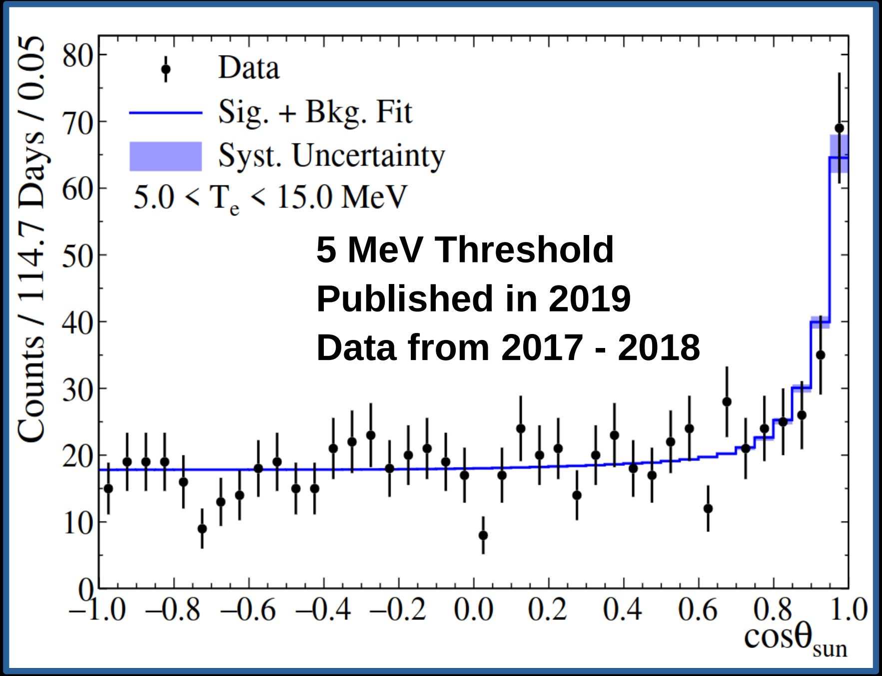
$$\Phi_{^8B} = 5.95\,^{+0.75}_{-0.71}\,(\text{stat.})\,^{+0.28}_{-0.30}\,(\text{syst.}) \times 10^6\ \text{cm}^{-2}\text{s}^{-1}$$

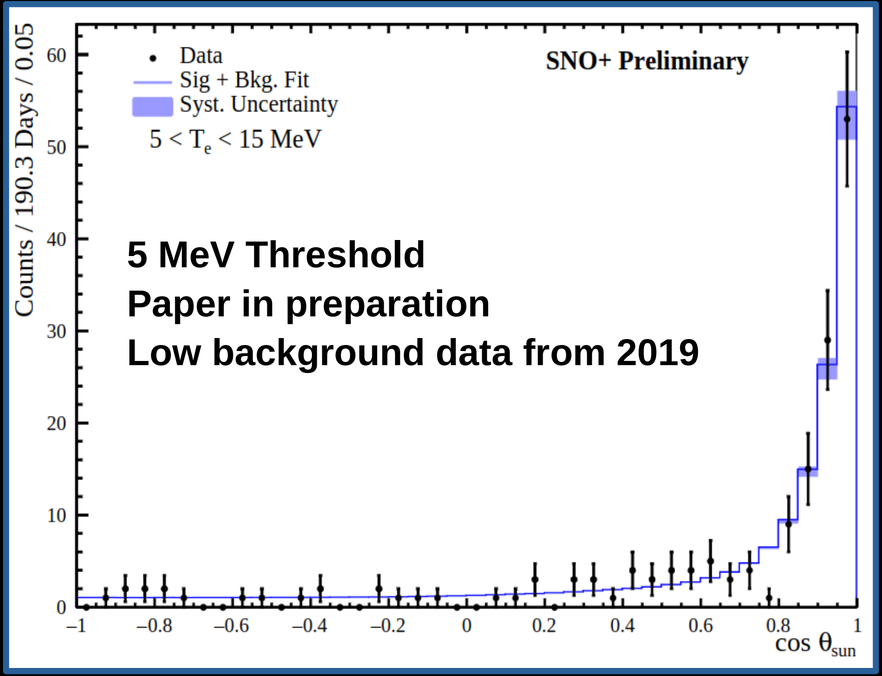
[1] SNO+ collaboration, PRD 99, 012012 (2019)

Water Phase: Solar

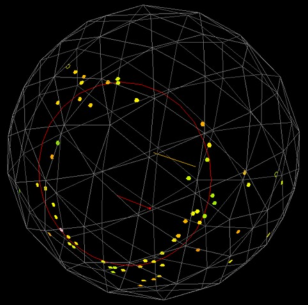


Ongoing work to reduce analysis threshold to 3.5 MeV and add an additional 114.8 kt-days of data with even lower backgrounds.





Water Phase: Solar



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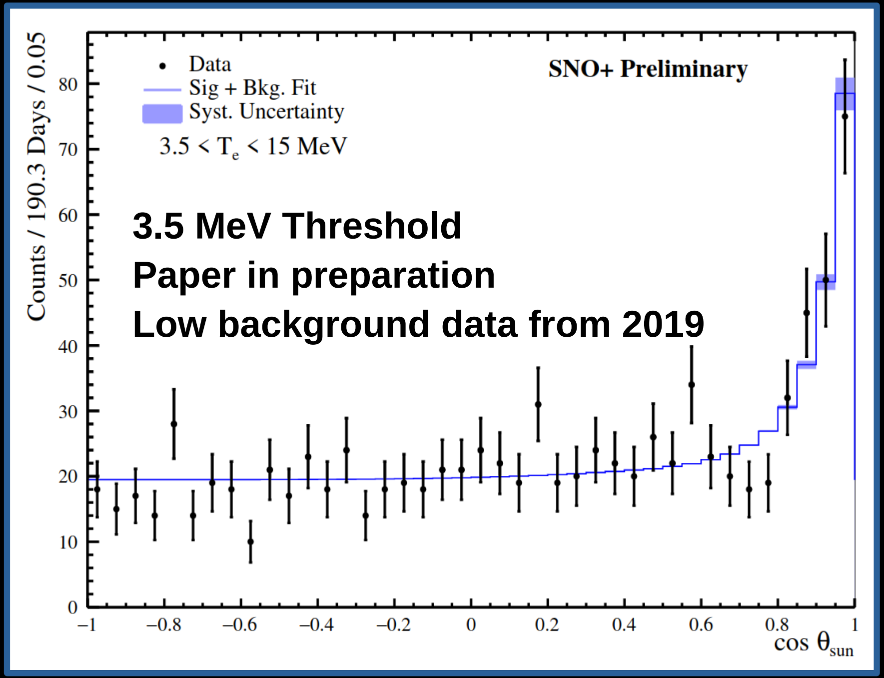
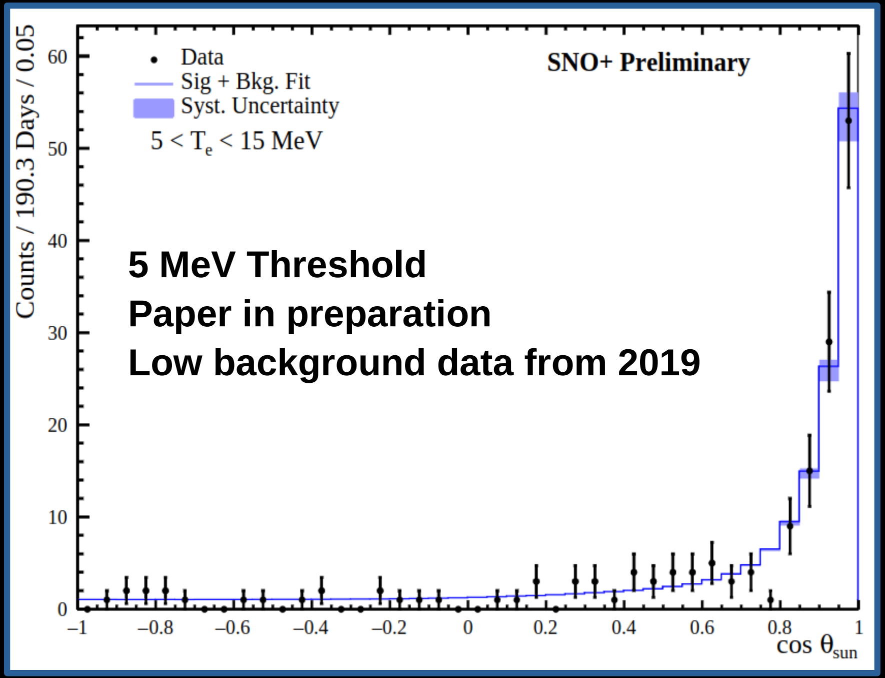
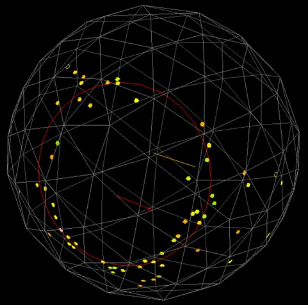
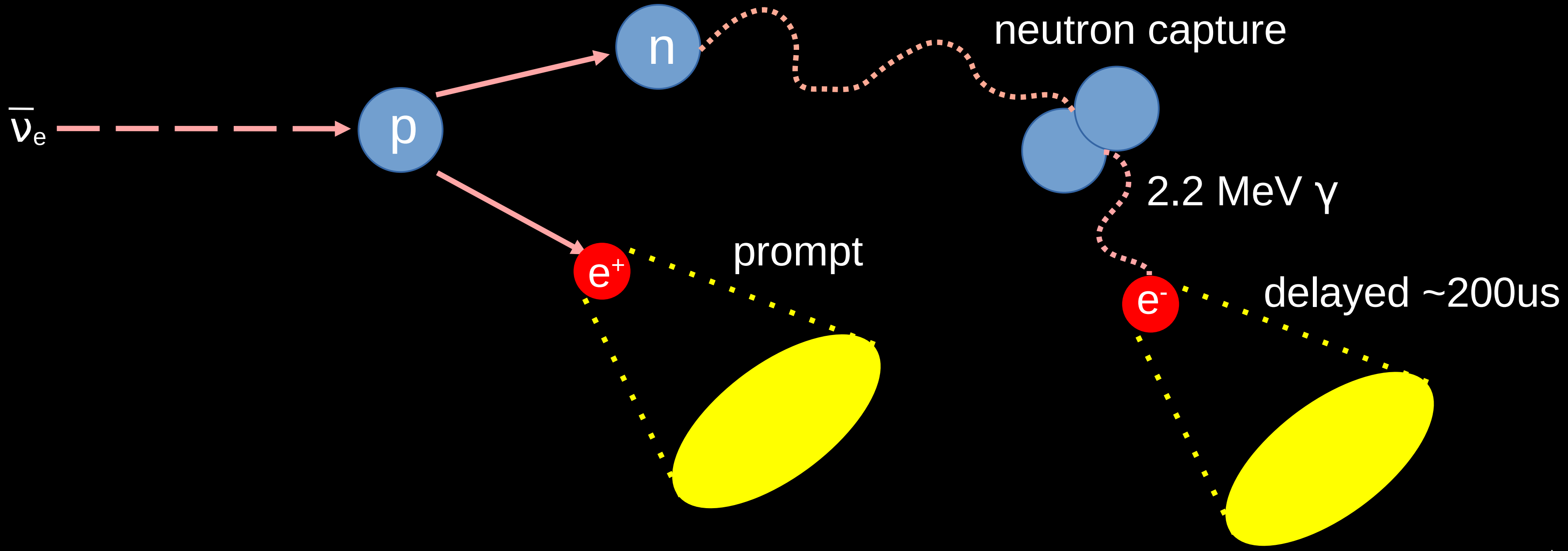




Water Phase: Reactor

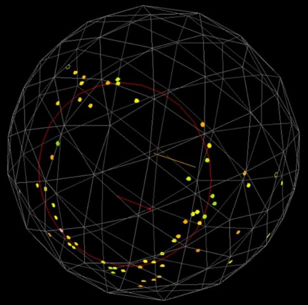


Evidence (> 3σ) of antineutrinos from distant reactors (> 240 km) using a water Cherenkov detector, for the first time ever [1].



[1] SNO+ collaboration, PRL 130 (2023) 9, 091801
PRL Editor’s Selection, Highlighted in Physics Magazine (2023)

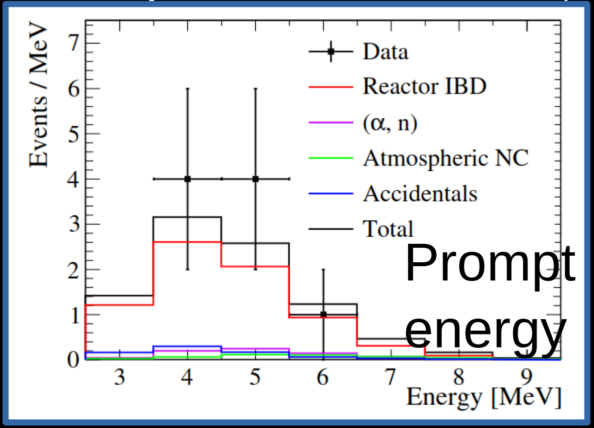
Water Phase: Reactor

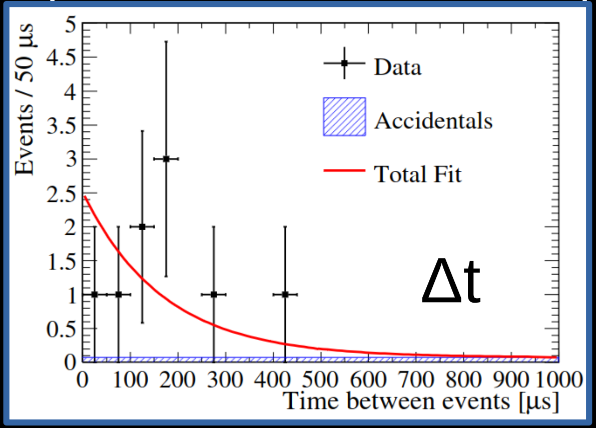


Evidence (> 3σ) of antineutrinos from distant reactors (> 240 km) using a water Cherenkov detector, for the first time ever [1].

Lowest energy threshold (~1.4 MeV) ever achieved in water Cherenkov detector.

Applications for distant monitoring of nuclear reactors using well-understood, inexpensive, and easy to handle material, with implications for nuclear nonproliferation.

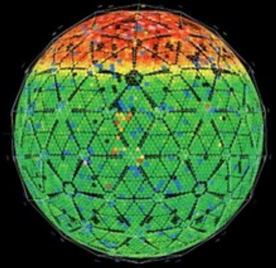




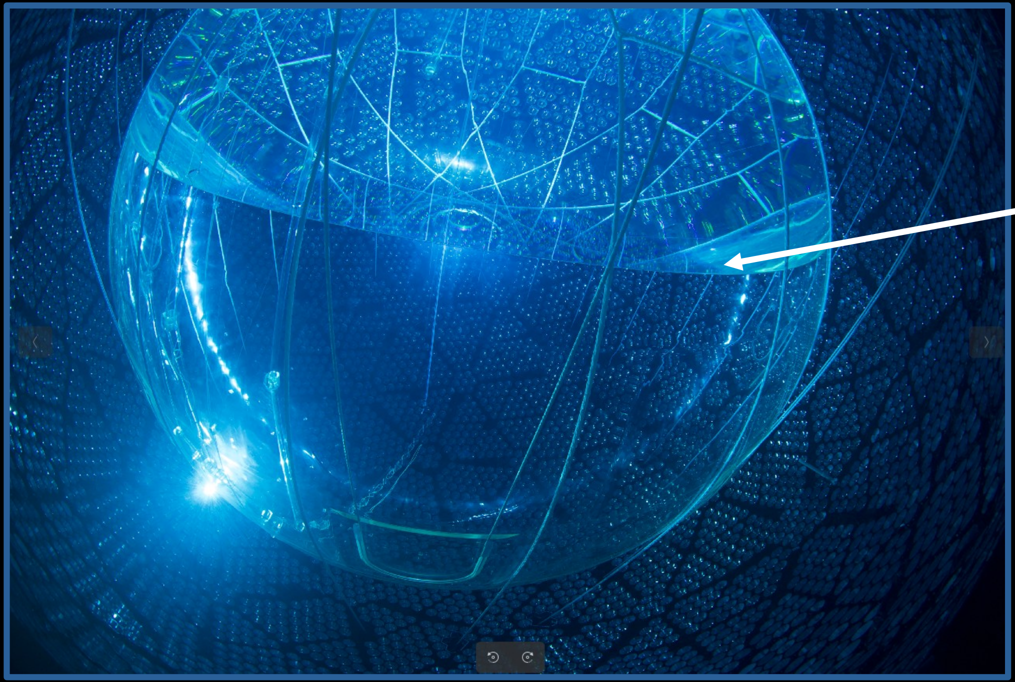
[1] SNO+ collaboration, PRL 130 (2023) 9, 091801

PRL Editor's Selection, Highlighted in Physics Magazine (2023)

Partial Phase

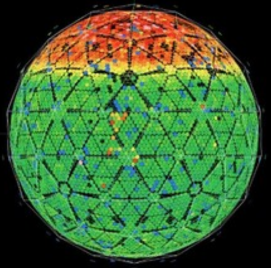


Collected data while detector was partially full with liquid scintillator.



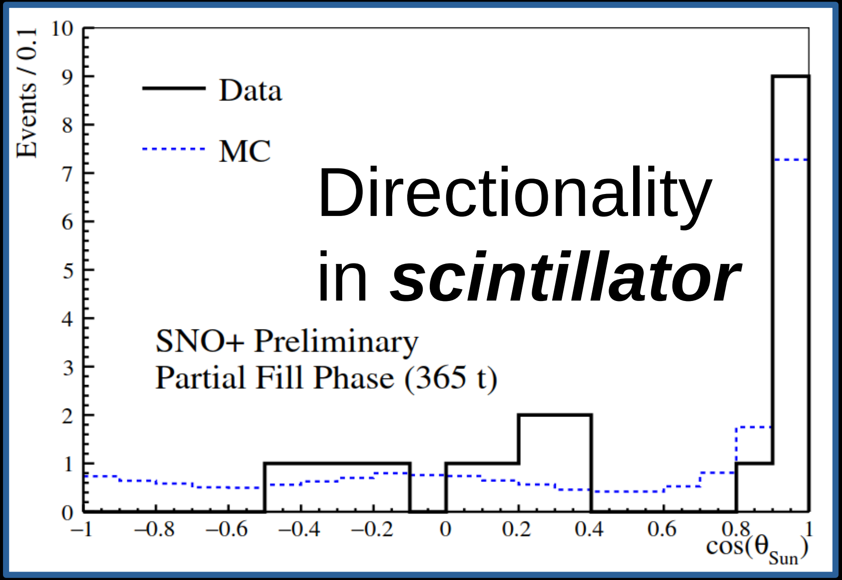
Scintillator/water interface

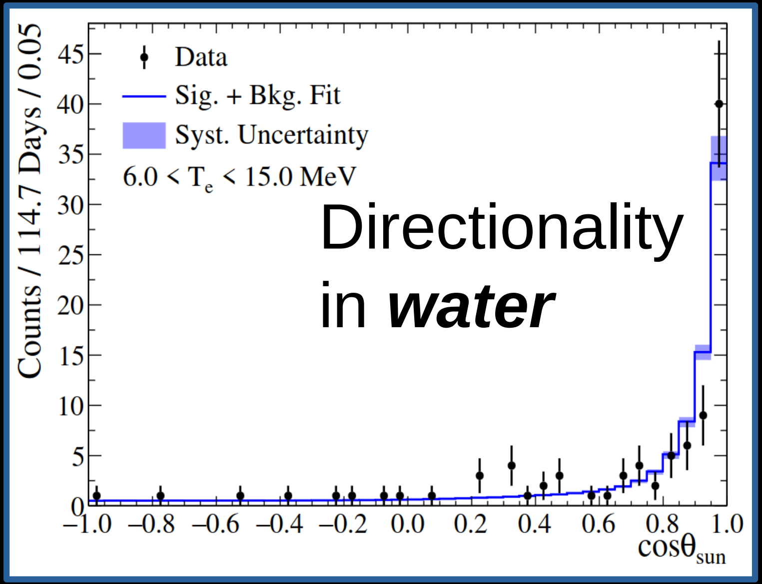
Partial Phase: Solar



Collected data while detector was partially full with liquid scintillator.

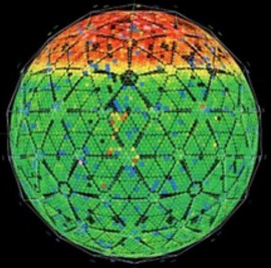
For ^{8}B solar neutrinos above 5 MeV we achieve excellent directional reconstruction.





Paper in preparation

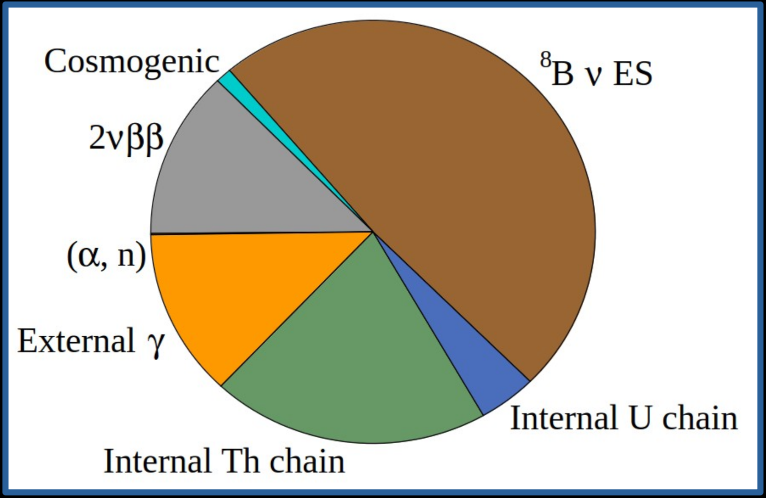
Partial Phase: Solar



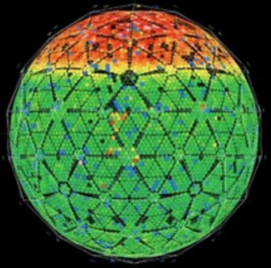
Collected data while detector was partially full with liquid scintillator.

For ^{8}B solar neutrinos above 5 MeV we achieve excellent directional reconstruction.

Future phases: potential for improved solar neutrino sensitivity & addition background rejection for $0\nu\beta\beta$.



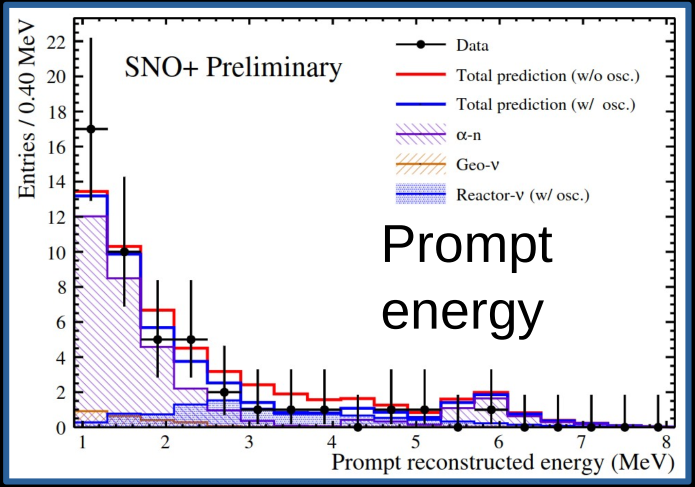
Partial Phase: Reactor

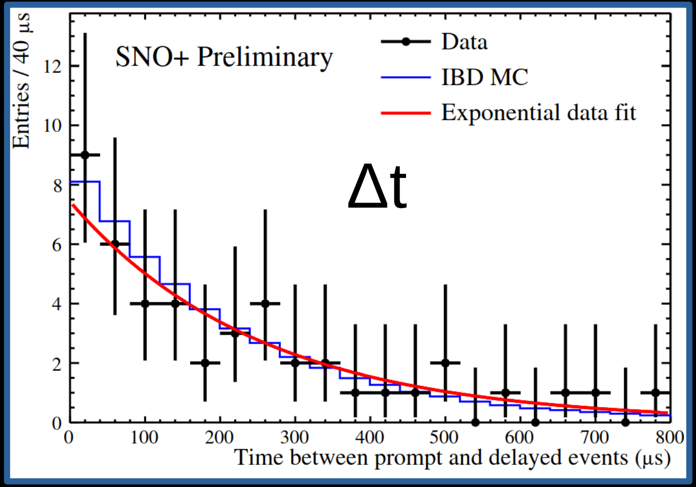


Collected data while detector was partially full with liquid scintillator.

Clearly identify reactor neutrinos against (α, n) background.

Excellent prospects for full fill, which will have significantly more data & lower backgrounds.





Paper in preparation

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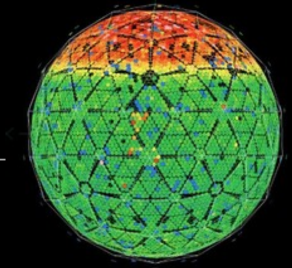

Collected data while detector was partially full with liquid scintillator.

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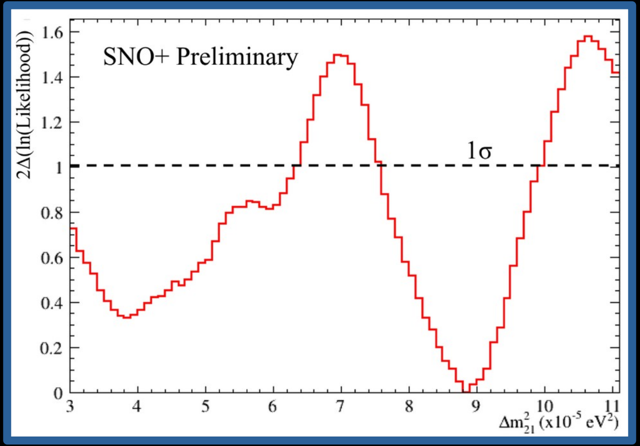
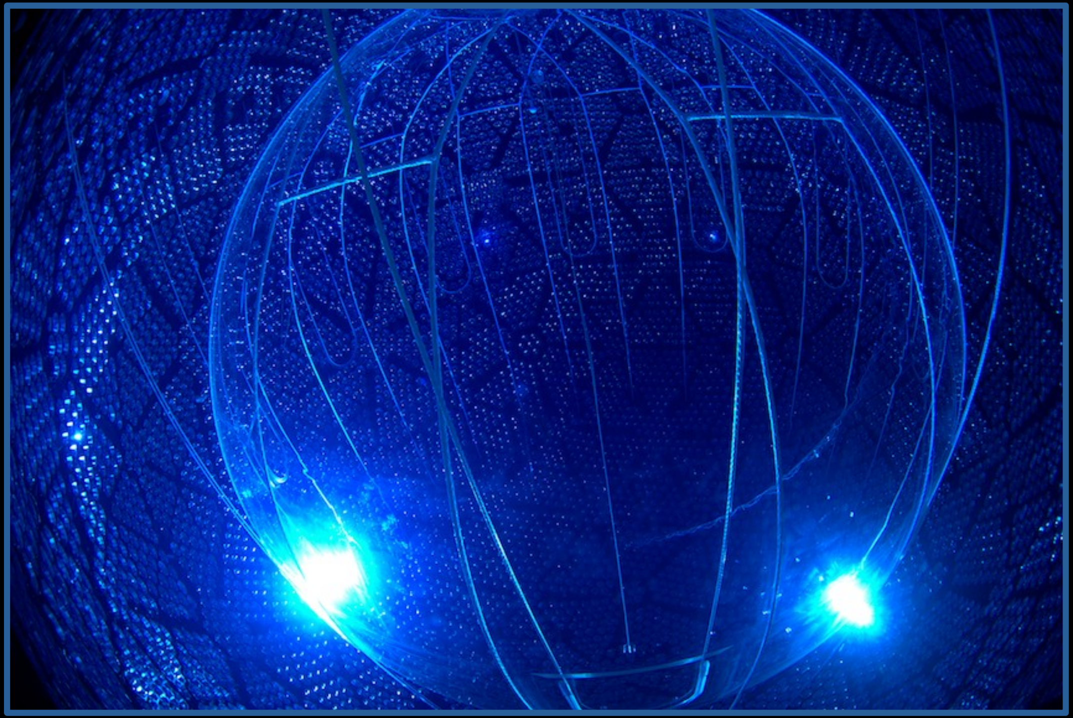
Δm^2_{21} measurement possible despite limited volume & livetime.



Paper in preparation

Scintillator Phase

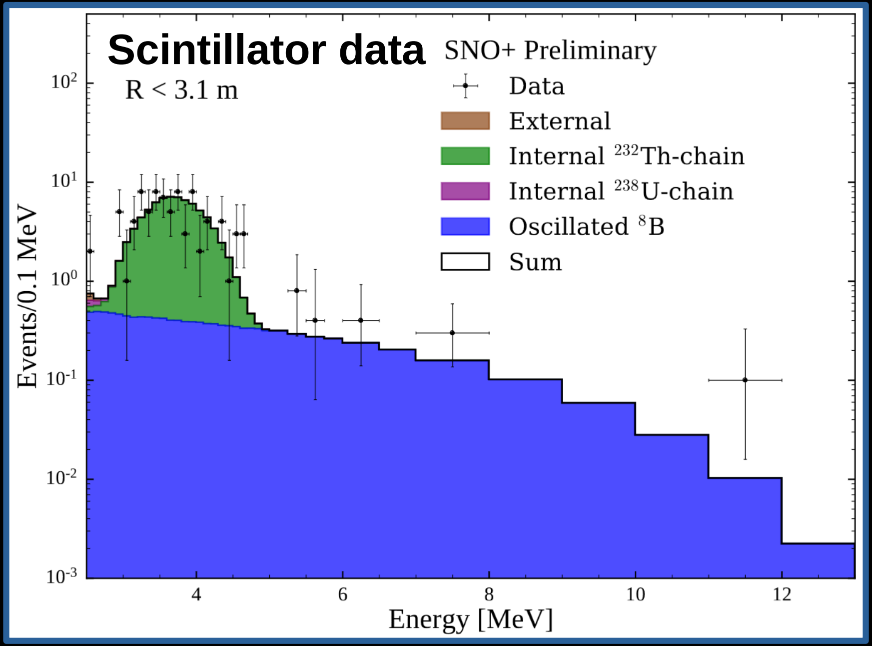
Now full with scintillator, SNO+ is taking quality physics data and is supernova live!



Scintillator Phase: Solar

Now full with scintillator, SNO+ is taking quality physics data and is supernova live!

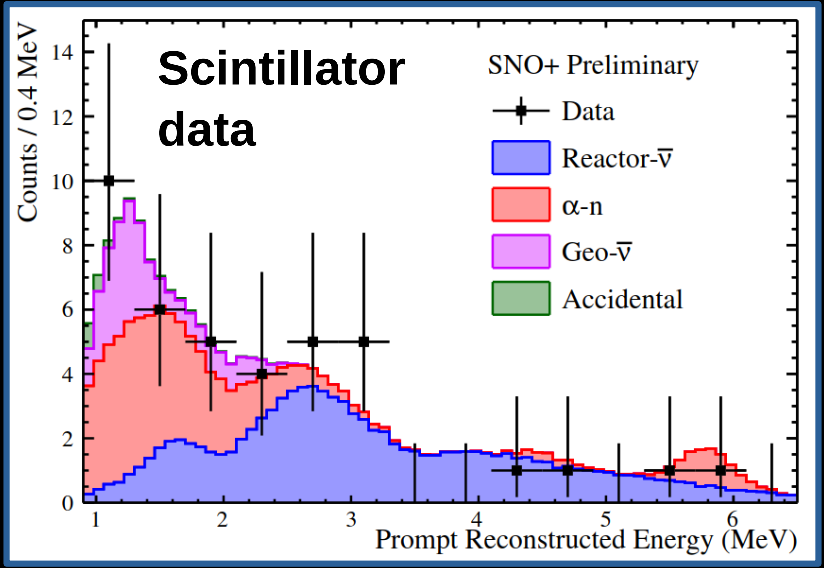
Preliminary investigations of high energy ^{8}B solar neutrinos look promising.



Scintillator Phase: Reactor & Geo

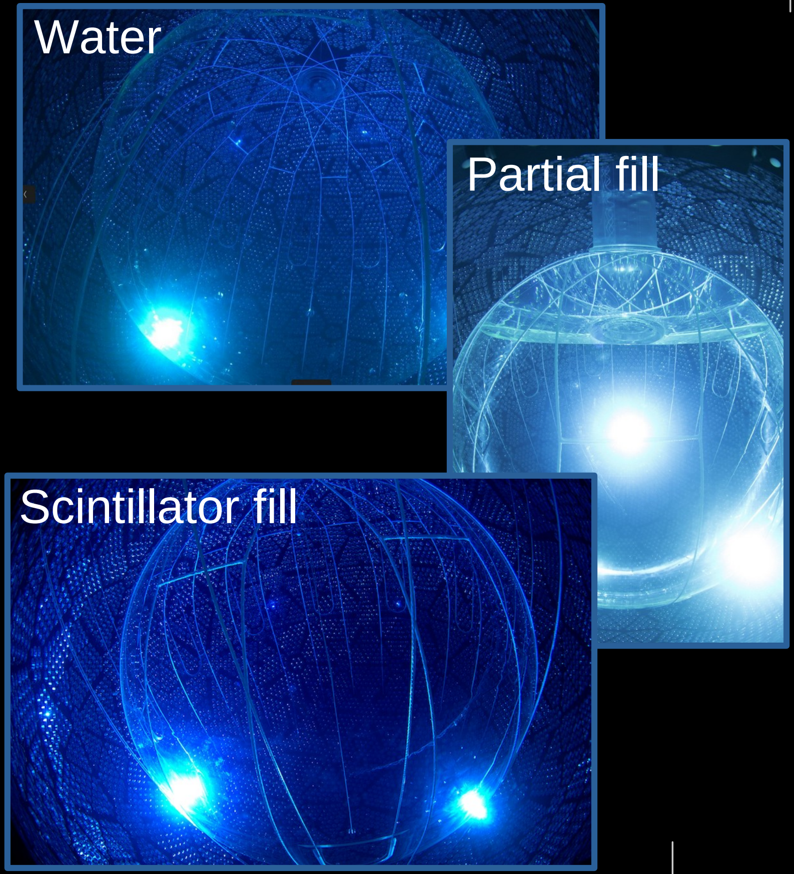
Now full with scintillator, SNO+ is taking quality physics data and is supernova live!

Low backgrounds and excellent prospects for sensitive reactor and geo neutrino measurements and for a precise measurement of oscillation parameters.



Conclusions

1. SNO+ has collected low background data in the water, partial fill, and scintillator fill phases, producing sensitive measurements of solar and reactor antineutrinos, primarily limited by the size of the datasets during these transitionary periods.



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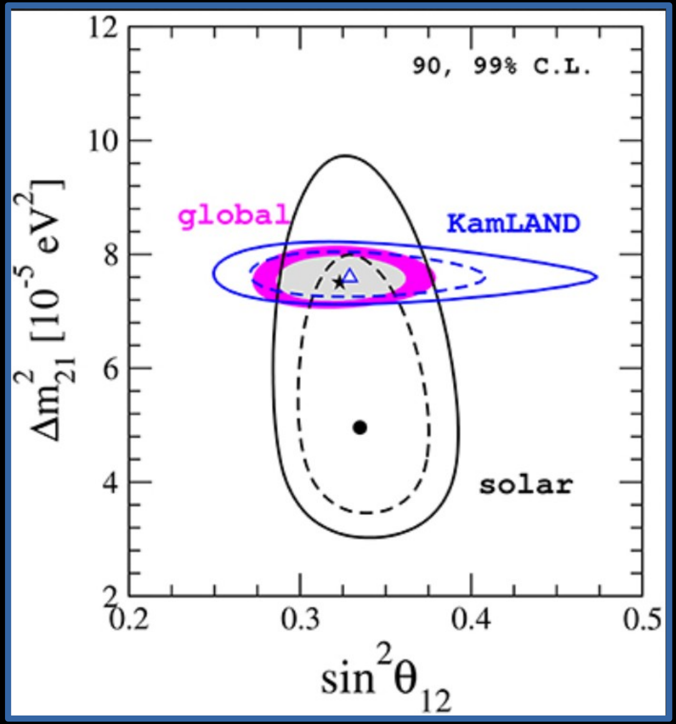
2. This is promising for future measurements, such as precision solar, reactor, and geo neutrino measurements, which may help resolve tensions in oscillation parameters.



Y. Farzan, M. Tortola Front. in Phys. 6 (2018) 10

Conclusions

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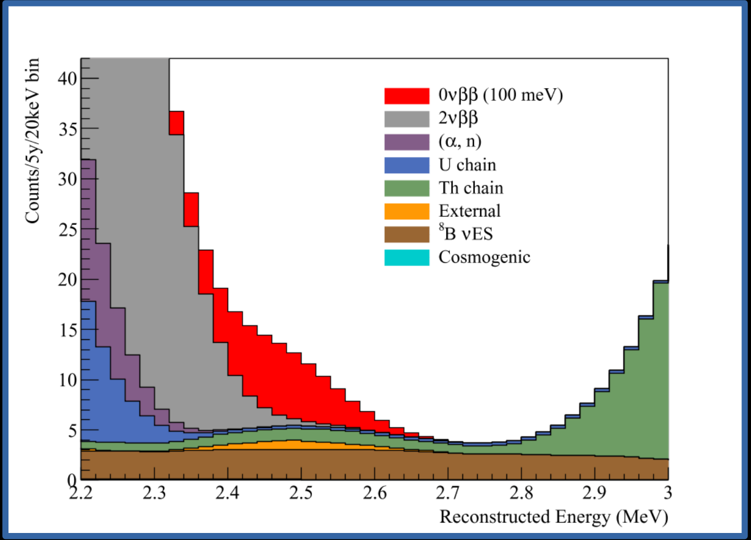
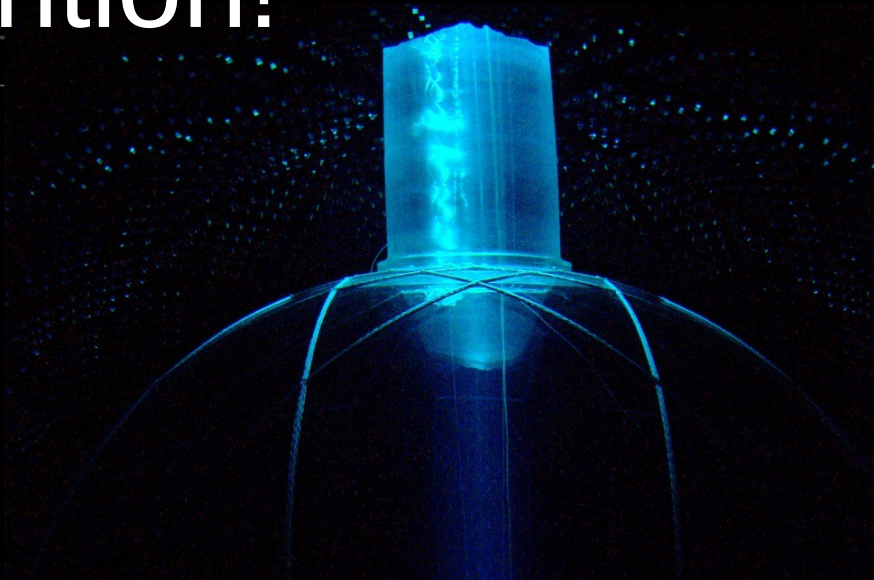
2. This is promising for future measurements, such as precision solar, reactor, and geo neutrino measurements, which may help resolve tensions in oscillation parameters.

3. SNO+ has demonstrated potential to perform low background physics measurements, promising for the $0\nu\beta\beta$ phase.



Expected backgrounds & example signal in $0\nu\beta\beta$ phase

Thank you for your attention!



Supernova & Dark Matter

Currently supernova live

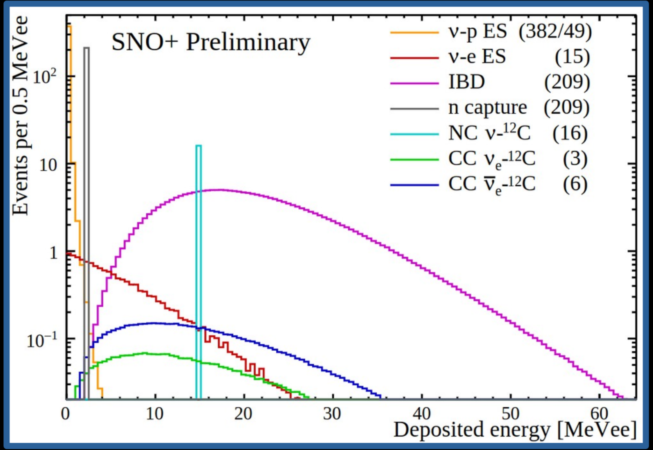
Working towards integrating with SNEWS

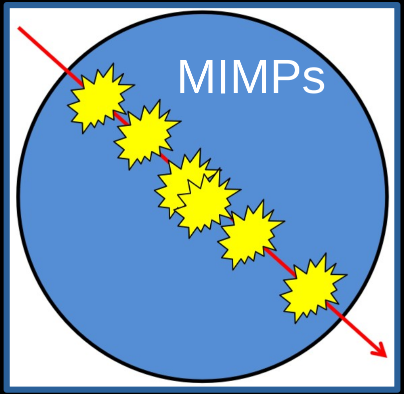
Additional exotic searches in progress

MIMPs

Fermionic dark matter

High energy (> 10 MeV) antineutrinos (DSNB, primordial black holes, etc)





Beacom and Vagins, PRL, 93:171101