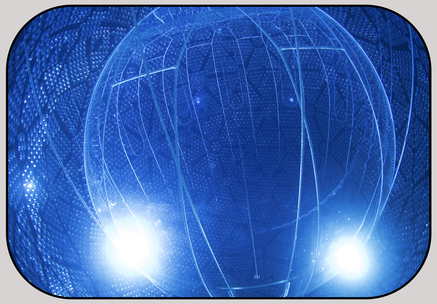
Search for Invisible Nucleon Decay in SNO+

Low Background Water Analysis

Morgan Askins[1], Ian Lam[2] for the SNO+ Collaboration

The SNO+ Experiment



- 6 meter acrylic vessel
- ~9300 PMTs
- 2km overburden
- Transitioning from 900 tons pure water to 780 tons liquid scintillator

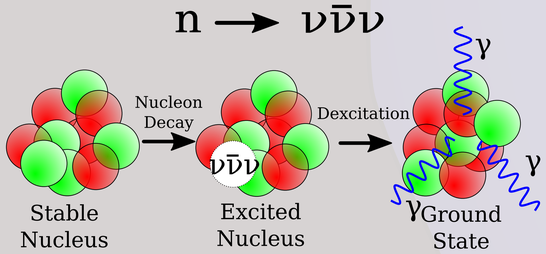
Broad Physics Program

- Neutrinoless double beta decay
- Solar Neutrinos
- Reactor Antineutrinos
- "Invisible" Nucleon Decay
- Supernovae
- Geoneutrinos

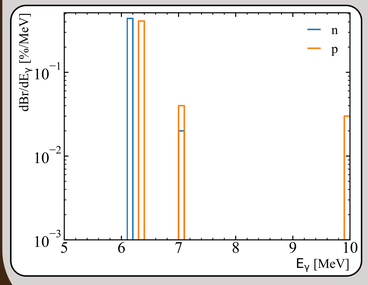
Invisible Nucleon Decay

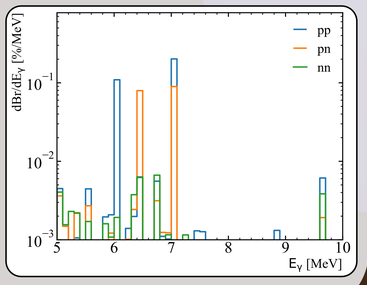
Models which predict decays to neutrinos or other neutral products cannot be directly observed [1-2].

$$n \longrightarrow \nu\bar{\nu}\nu$$



Both single and dinucleon decay observable through dexcitation gammas.

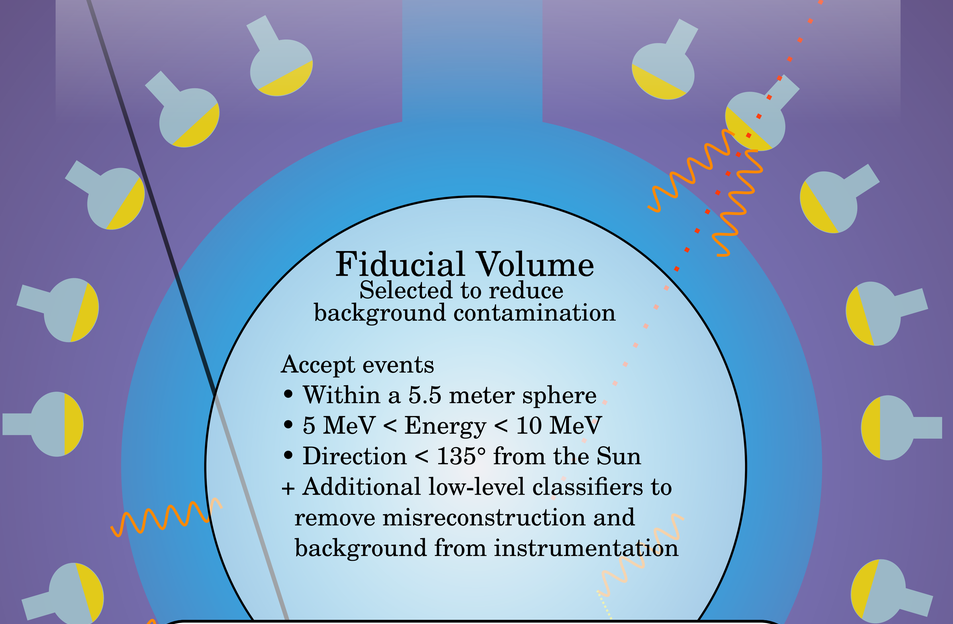




Background Components

Natural Radioactivity
- Internal Water
- External Water
- PMT Glass

Neutrino Interactions
- Solar
- Reactor
- Atmospheric

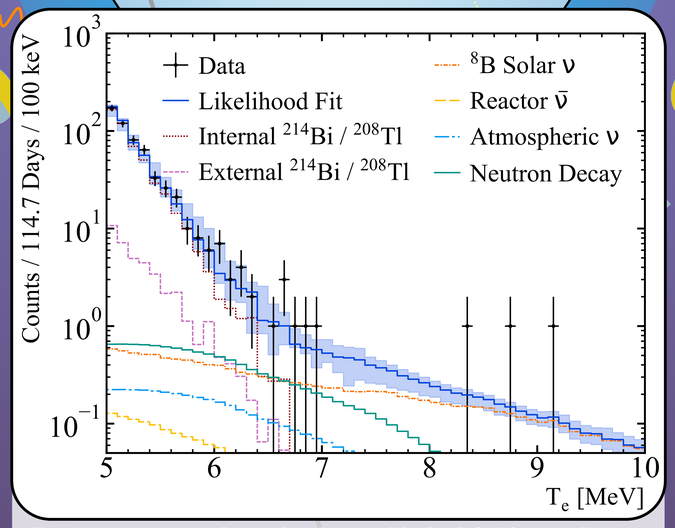


Fiducial Volume

Selected to reduce background contamination

Accept events
- Within a 5.5 meter sphere
- 5 MeV < Energy < 10 MeV
- Direction < 135° from the Sun

+ Additional low-level classifiers to remove misreconstruction and background from instrumentation



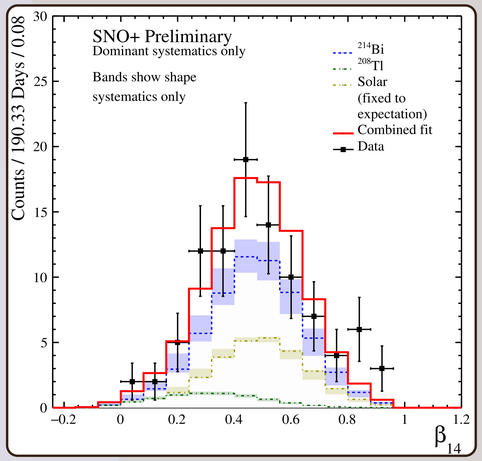
Energy spectrum from the first published SNO+results with 114.7 days of data [3].

Low Background Data

A second (190.33 days) dataset was taken after the addition of a nitrogen "cover gas" system to reduce radon ingress into the water.

	gU/gH$_2$O	gTh/gH$_2$O
Dataset I	$(3.6 \pm 0.9^{+1.0}_{-0.7}) \times 10^{-14}$	$< 1.3 \times 10^{-14}$(95%CL)
Dataset II	$(3.2 \pm 0.7^{+1.1}_{-0.9}) \times 10^{-15}$	$< 1.1 \times 10^{-15}$(95%CL)

Comparison between the BEST portion of **dataset I**, *and the entirety of* **dataset II**.



Fit to β14, an event isotropy parameter that serves to distinguish electrons from gammas.

	Existing limits (lifetime years)	SNO+ Projection (lifetime years)
n	5.8×10^{29} [4]	$1.4^{+0.3}_{-0.2} \times 10^{30}$
p	3.6×10^{29} [3]	$1.6 \pm 0.3 \times 10^{30}$
nn	1.4×10^{30} [4]	$3.0^{+0.6}_{-0.5} \times 10^{28}$
np	2.6×10^{28} [3]	$1.1 \pm 0.2 \times 10^{29}$
pp	4.7×10^{28} [3]	$1.9^{+0.4}_{-0.3} \times 10^{29}$

References

[1] H. Ejiri, *Phys. Rev. C* **48** (1993)
[2] K. Hagino and M. Nirkko, *Journal of Physics G: Nuclear and Particle Physics* **45** (2018)
[3] M. Anderson et al. (SNO+), *Phys. Rev. D* **99** (2019)
[4] T. Araki et al. (KamLAND), *Phys. Rev. Lett* **96** (2006)

[1]University of California Berkeley / Lawrence Berkeley National Lab, [2]Queen's University