Poster #96

Measurement of the Electron-Neutrino Charged-Current Cross Section on ^{127}I with the COHERENT NaIνE Detector

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Background & Motivation

$$\nu_e + {}^{127}\mathrm{I} \rightarrow e^- + {}^{127}\mathrm{Xe}^*$$

Goal: Measure ν_e charged-current scattering on ^{127}I at the SNS

Solar neutrinos

- Iodine excellent target for solar neutrino detection
  - Low threshold (662 keV), large predicted cross section
- Proposed target similar to Homestake ^{37}Cl experiment[1]

Supernova neutrinos

- Measuring charged-current scattering for 10s-of-MeV neutrinos useful for improving supernova neutrino detection modeling

Only six charged-current neutrino-nucleus scattering cross sections measured at low (<300 MeV) energies!

Neutrino Production at the SNS

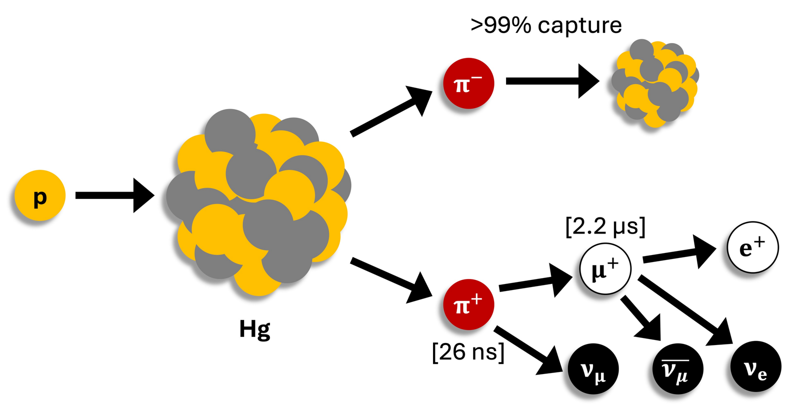

Figure 1. Neutrino production at the SNS.

SNS neutrinos

- 8.46×10^{22} ν/year[2]
- 60Hz, ~350ns FWHM
- ν_e (and $\overline{\nu}_\mu$) delayed by 2.2 µs
- Max energy of 52.8 MeV

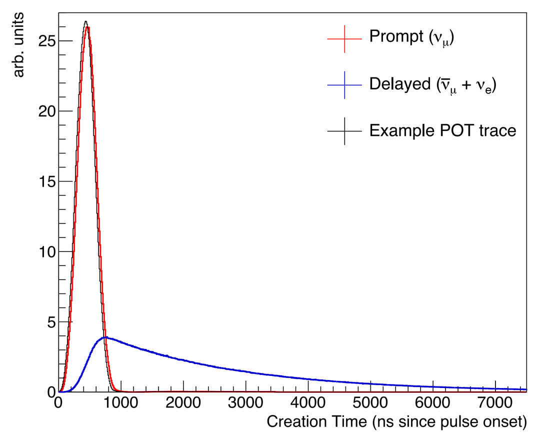

Figure 2. Neutrino timing spectrum at the SNS[2].

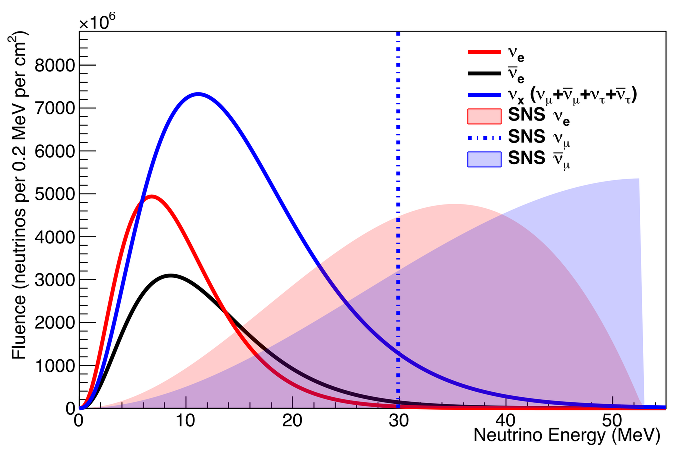

Figure 3. SNS and supernova neutrino energy spectra (courtesy K. Scholberg).

The NaIνE Detector

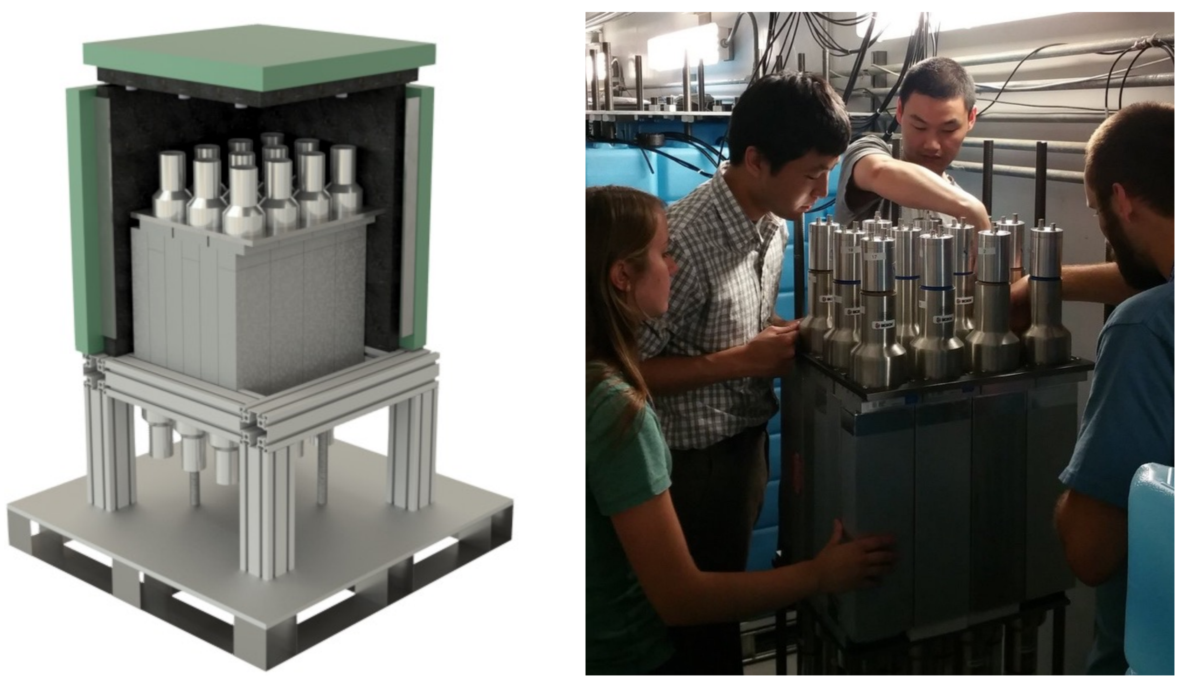

Figure 4. Left: Rendering of NaIvE detector[3]. **Right**: NaIνE during deployment.

- NaIνE: NaI Neutrino Experiment
- 185 kg of NaI scintillator, 24 detectors, deployed to SNS in 2016
- Collected 22.8 GWhr exposure through March 2022
- Triggers on >500 keV depositions in any crystal
- Records baseline, integral of pulses
- Energy calibrated with gamma backgrounds (^{40}K and ^{208}Tl)
- Correct for non-linearities w/Michel electrons from stopped muons
- Cosmic muons are largest background for charged-current signals (10-50 MeV ROI)—reduced with muon veto panels

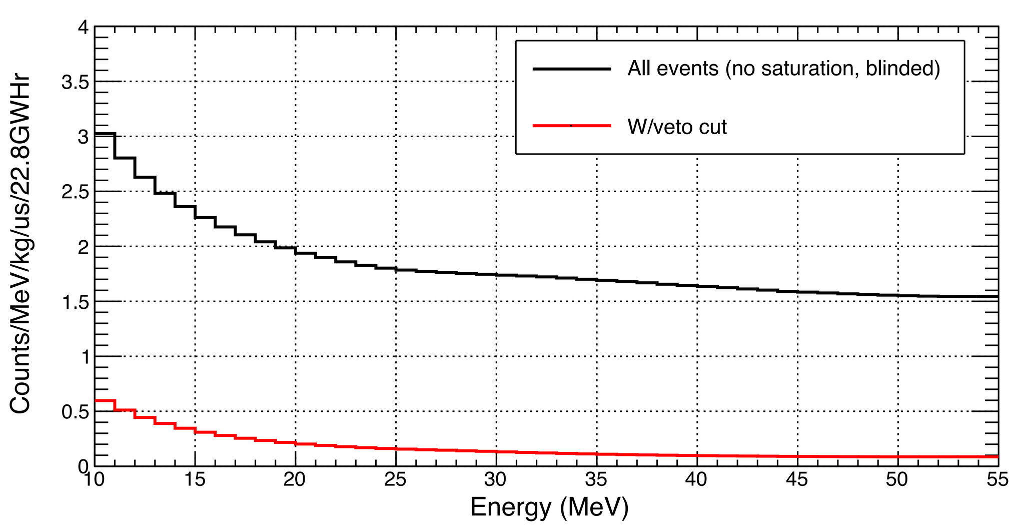

Figure 5. Background spectrum before and after muon veto cut.

Signal Prediction w/MARLEY

- MARLEY used w/measured of GT strength from Ref. [4]
- MARLEY agrees with existing exclusive cross section measurement, good agreement with other theoretical predictions

μ^+ decay-at-rest			
Channel	MARLEY Cross Section	Alt. Cross Section	Ref.
$^{127}\mathrm{I}(\nu_e, e^-)$	$22.5^{+1.2}_{-6.5} \times 10^{-40}\mathrm{cm}^2$ $(g_A = 1.26)$	$10.6 \times 10^{-40}\mathrm{cm}^2$ $(g_A = 0.683)$	Ref. [5]
$^{127}\mathrm{I}(\nu_e, e^-)^{127}\mathrm{Xe}_{\mathrm{bound}}$	$2.3^{+0.2}_{-1.7} \times 10^{-40}\mathrm{cm}^2$ $(g_A = 1.26)$	$2.84 \pm 0.91(\mathrm{stat.}) \pm 0.25(\mathrm{syst.}) \times 10^{-40}\mathrm{cm}^2$	Ref. [6]
$^{127}\mathrm{I}(\nu_e, e^- + n)^{126}\mathrm{Xe}$	$18.9^{+1.0}_{-5.3} \times 10^{-40}\mathrm{cm}^2$ $(g_A = 1.26)$	–	–
$^{127}\mathrm{I}(\nu_e, e^- + 2n)^{125}\mathrm{Xe}$	$0.8^{+0.1}_{-0.4} \times 10^{-40}\mathrm{cm}^2$ $(g_A = 1.26)$	–	–
$^{127}\mathrm{I}(\nu_e, e^- + p)^{126}\mathrm{I}$	$0.5^{+0.0}_{-0.2} \times 10^{-40}\mathrm{cm}^2$ $(g_A = 1.26)$	–	–
^{7}Be (solar)			
Channel	MARLEY Cross Section	Alt. Cross Section	Ref.
$^{127}\mathrm{I}(\nu_e, e^-)$	$1.3^{+0.2}_{-0.5} \times 10^{-45}\mathrm{cm}^2$ $(g_A = 1.26)$	$1.2^{+0.4}_{-0.4} \times 10^{-45}\mathrm{cm}^2$ $(g_A = 1.26)$	Ref. [4]
^{8}B (solar)			
Channel	MARLEY Cross Section	Alt. Cross Section	Ref.
$^{127}\mathrm{I}(\nu_e, e^-)$	$5.1^{+0.5}_{-1.9} \times 10^{-42}\mathrm{cm}^2$ $(g_A = 1.26)$	$4.3^{+0.6}_{-0.6} \times 10^{-42}\mathrm{cm}^2$ $(g_A = 1.26)$	Ref. [4]

Table 1. Comparison of MARLEY's inclusive & exclusive ^{127}I CC cross section predictions.

- MARLEY generates predictions for particles distribution and energies for different CC interactions possible w/NaIνE

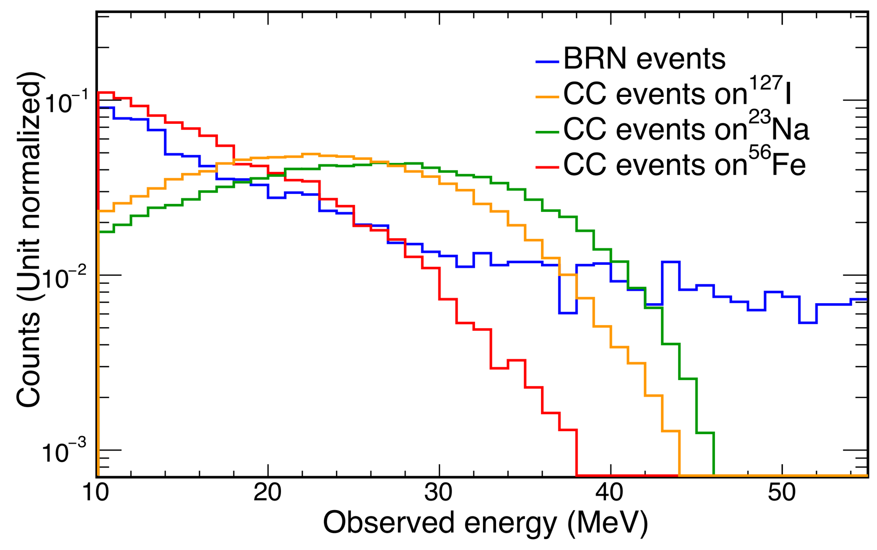

Figure 6. MARLEY prediction for observable energy distribution from CC events in NaIνE[3].

Results

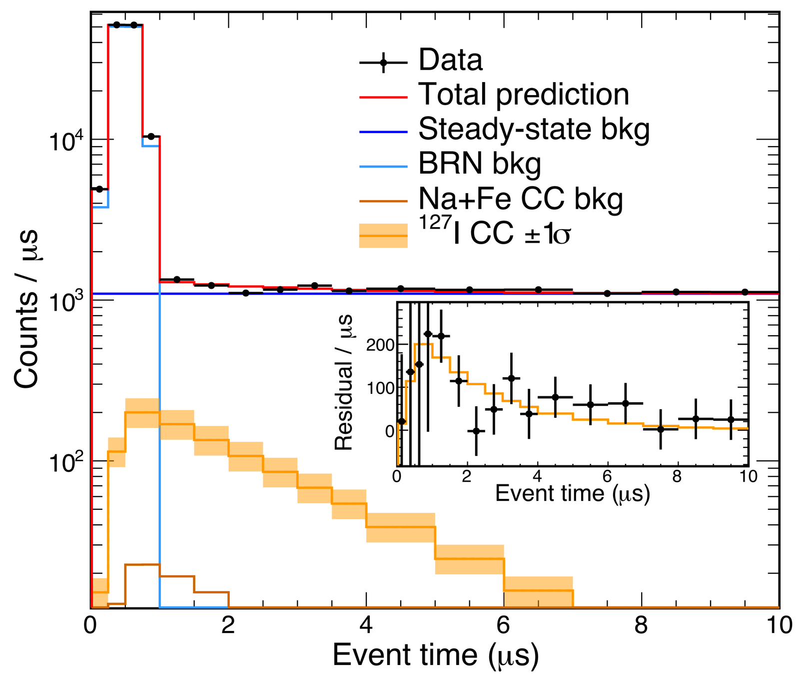

Figure 7. Best fit timing distribution for signals from 10-55 MeV[3].

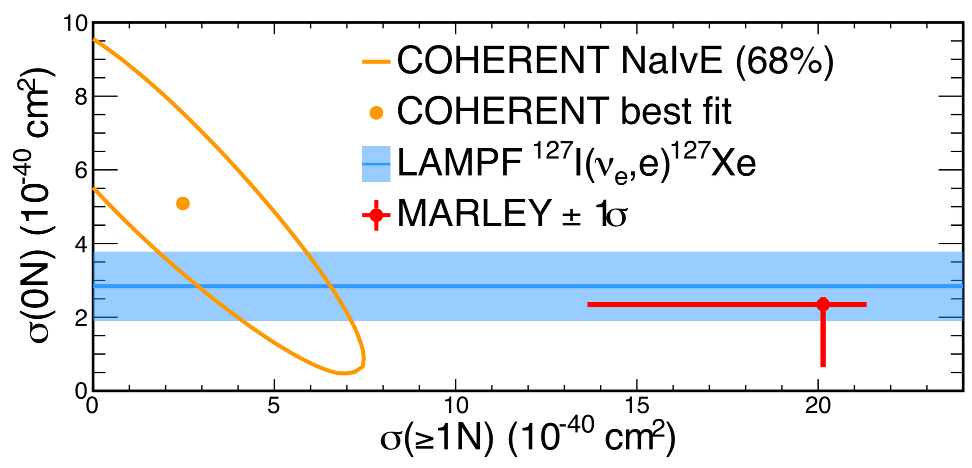

Figure 8. Best fit $0n$ and $\geq 1n$ emission cross sections[3].

- Timing fit for signals from 10-50 MeV rejects null-hypothesis at **5.8σ**
- Measured inclusive cross section: $\mathbf{9.2^{+2.1}_{-1.8} \times 10^{-40}}$ **cm²**
  - 41% lower than nominal prediction from MARLEY
- Using predicted shape of electromagnetic energy spectra from MARLEY, fit out $0n$ and $\geq 1n$ emission cross sections
  - $0n$: $\mathbf{5.2^{+3.4}_{-3.1} \times 10^{-40}}$ **cm²**—agrees w/existing measurement[5]
  - $\geq 1n$: $\mathbf{2.4^{+3.3}_{-2.4} \times 10^{-40}}$ **cm²**—similar suppression observed by COHERENT's NIN measurement[7]
- Additional measurements and improved nuclear modeling needed!
- Several other COHERENT detectors collecting inelastic scattering data! (^{40}Ar, ^{232}Th, D_2O, lead-glass)

References/Acknowledgements

[1] W. C. Haxton, *Phys. Rev. Lett.* **60**, 768 (1988)
[2] D. Akimov, et al., *Phys. Rev. D* **106**, 032003 (2022)
[3] P. An, *et al.*, *Phys. Rev. Lett.* **131**, 221801 (2023)
[4] M. Palarczyk, et al., *Phys. Rev. C* **59**, 500 (199)
[5] M. Hellgren & J. Suhonen, *Phys. Rev. C* **109**, 035802 (2024)
[6] J. R. Distel, et al., *Phys. Rev. C* **68**, 054613 (2003)
[7] P. An, et al., *Phys. Rev. D* **108**, 072001 (2023)

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