Motivation

- Few neutrino-nucleus interactions measured at $E_{\nu} < 300$ MeV (fig 1), energies relevant for supernova $\nu$
- $^{127}$I charged-current interaction proposed for solar and supernova $\nu$ detection by Haxton$^{[4]}$, can study interaction with well understood neutrino source at SNS
- Measurement of cross section could provide insight for $g_\lambda$ quenching$^{[5]}$ at a momentum transfer of $\sim 30$ MeV, relevant for neutrinoless double beta decay

Previous Measurement

- Exclusive $^{127}$I $\nu_e$ charged-current cross section measured at Los Alamos Meson Production Facility (LAMPF) in the 1990s, experiment E-1213$^{[6]}$
- Required final state of reaction to be $^{127}$Xe, inclusive cross section never measured$^{[7]}
- No energy dependence measured (flux-averaged only)
- Used coincidences from $^{127}$Xe decays to calculate amount $^{127}$Xe produced
  $^{127}$Xe $\rightarrow^{127}$I $^+ + \gamma$ (203, 375 keV)
  $^{127}$I $\rightarrow^{127}$Xe $^+ + \gamma$ ($\sim$0.9, 4.7 keV)
- Reported flux-averaged cross section over stopped-pion source $\nu_e$ spectrum of
  $\sigma = 2.84 \pm 0.91$ (stat) $\pm 0.25$ (sys) $\times 10^{-40}$ cm$^2$

Neutrinos at the SNS

- Spallation Neutron Source (SNS) creates neutrinos through stopped-pion decay
- 50 Hz pulsing, $\sim$400 ms FWHM pulses, energy similar to supernova neutrinos
- $\nu_e$ delayed with respect to beam, reduces beam-related backgrounds for charged-current signals
- $\nu_e$ flux at 20$m$: $\Phi \approx 1.4 \times 10^7 \nu_e$ / cm$^2$ / sec

The NaI$\nu$E Detector

- NaI$\nu$E (Na $\nu$-Experiment) designed to measure inclusive $^{127}$I charged-current signals, energy dependence
- Consists of twenty-four 7.7-kg NaI[Tl] scintillators, $\sim$20 m from SNS target, prototype for larger detector
- Triggers with internal logic, waveforms separated into eight 1250 ns windows, counts integrated in windows
- Calibrate and track gain changes over time using intrinsic *$^{127}$I* and *$^{91}$Zr* peaks
- Largest background for reaction from cosmic muons, veto panels and steel used to reduce backgrounds
- See poster #13 for a machine-learning approach to further reducing cosmic muon backgrounds

Signal Prediction & $g_\lambda$

- Use MARLEY$^{[5]}$ to simulate allowed $\nu_e$ charged-current reactions on $^{127}$I
- Total cross section, states excited depend on $g_\lambda$$^{[3]}
- Forbidden transitions needed to understand $g_\lambda$ quenching's effect on energy spectrum, not yet included in MARLEY
- Simulations do predict a $g_\lambda$ quenching effect on total cross section

Conclusions

- NaI$\nu$E trying to measure unobserved inclusive $\nu_e$ charged-current cross section on $^{127}$I
- Collecting data since 2016, analysis ongoing
- Investigating sensitivity to $g_\lambda$ quenching with MARLEY
- Larger detector deployment to start in 2020, design and crystal characterization underway

References


A Ton-Scale NaI Detector

- Larger detector (300+ crystals) would improve charged-current statistics, also measure coherent elastic neutrino-nucleus scattering (CEvNS) on $^{203}$Na
- Dual gain base designed to achieve dynamic range for both CEvNS and charged-current signals (3 keV to 55 MeV)
- Each crystal deployed needs to be characterized first, completed for $\sim$150 crystals so far
- Construction will begin soon, deployment to start in 2020
- See poster #554 for more details on ton-scale detector

Fig. 1. Neutrino-nucleus cross section measurements for low energy terrestrial sources from [1].

Fig. 2. Tank from E-1213 at LAMPF [8].

Fig. 3. Coincident $^{127}$Xe decays and $^{127}$I de-excitations from [9].

Fig. 4. Waveform showing accumulators configuration

Fig. 5. Backgrounds with and without veto cut

Fig. 6. Neutrino production at the SNS (simplified).

Fig. 7. Energy and timing distribution of neutrinos at the SNS

Fig. 8. Effect of $g_\lambda$ quenching on calculated cross section, from [3]

Fig. 9. MARLEY energy predictions showing effect of $g_\lambda$ quenching

Fig. 10. Current design for ton-scale detector

Fig. 11. Expected charged-current signal for a 380kg detector after 3 years of operation.