Neutrino-Induced Neutron Detectors at the Spallation Neutron Source
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Neutrino-Induced Neutrons
Neutrino-nucleus interactions can yield excited nuclear states which may decay via the emission of neutrons:

\[ \nu_e + ^{208}\text{Pb} \rightarrow ^{208}\text{Bi}^* + e^- \] (CC)
\[ \nu_x + ^{208}\text{Pb} \rightarrow ^{208}\text{Pb}^* + \nu_x \] (NC)

- Neutrino-induced neutrons (NINs) are a potential background for experiments searching for nuclear recoils from coherent neutrino scattering or dark matter at pion decay-at-rest sources.
- NIN production on lead is a detection channel for galactic supernovae in the HALO experiment [1].
- Highly relevant to r-process nucleosynthesis in supernovae [2].
- This process has yet to be observed and suffers from large theoretical uncertainty.

COHERENT Experiment & NINs

- The Spallation Neutron Source at Oak Ridge National Laboratory is also powerful neutrino source!
- 1.4 MW proton beam delivered to target at 60 Hz in 400 ns FWHM bunches.
- First measurement of coherent elastic neutrino-nucleus scattering (CEvNS) [3].
- COHERENT seeks to measure CEvNS on multiple nuclear targets.
- Use of Pb shielding in detectors = large target mass for NIN production.
- Neutron scatters may mimic neutrino signal.

Neutrino Cubes

From left to right: Detector with water shielding; shielding remove to show muon veto panels; inner detector Pb target with embedded scintillator cells.

- Dedicated NIN detectors deployed on pallets in Neutrino Alley at the SNS.
- Two currently operating detectors featuring a 1000 kg Pb and 700 kg Fe target respectively.
- Liquid scintillator cells embedded in target material search for neutrons matching expected time profile from SNS neutrinos.
- In their present configuration, both detectors feature 2.2 L and 2.1 L liquid scintillator cells.
- Data acquisition triggered via scintillator cell signal in coincidence with SNS protons on target signal.

Calibrations

- Gamma calibrations ($^{129}\text{Na}$, $^{137}\text{Cs}$, $^{137}\text{Ba}$) performed approx. twice a year allow for monitoring of photo-multiplier tubes (PMT) over time.
- Simulated spectra are generated for each source and simultaneously fit to calibration data.
- Steady-state background spectra also used to monitor for detector changes.
- Time-tagged $^{137}\text{Cs}$ source gives sample of nuclear recoil events for event discrimination studies.

Analysis Status

- Pb (Fe) detector has been collecting data since 2015 (2017).
- Data quality cuts set; calibrations finalized.
- Machine learning applied to waveform information to improve event discrimination at low recoil energies:

- No theoretical predictions for NIN spectra from pion DAR electron neutrinos (theory focused on SNe neutrinos); use of MARLEY (Model of Argon Reaction Low Energy Yields) to generate predictions for Pb at the SNS.

- Beam-related neutrons represent an important background for NIN analysis; many simulations performed to understand expected energy and timing distributions.

- Results of NINs search in Pb and Fe coming soon!

References


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