Background Studies for an Experimental Neutrino Program at the Spallation Neutron Source

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Why SNS? The Neutrinos come for free.

- Spallation Neutron Source is an ideal neutrino source: $S\nu S$

- High Intensity ($10^7$/s/cm$^2$ @ 20m)
- Multiple Neutrino Flavors: $\nu_e$, (anti)$\nu_\mu$
- Ideal Energy: Below Kaon Threshold
- Complete Stopping: Position
- Ideal Time Structure (Short Pulses)
- ORNL/SNS support.

The SNS is the cleanest, most intense neutrino source for a first observation of coherent elastic neutrino nuclear scattering (CE$\nu$NS).
4 possible locations identified at ~30 m from the SNS target (plus possible outside locations)

very neutron-quiet location in basement

SNS Target Building
Dominant Backgrounds for CENNS Measurement at the SNS

- As with all Decay at Rest Pion Stopping neutrino sources, beam related fast neutrons are the dominant unknown and the most difficult to disentangle from neutrino signal, i.e. in time with the beam.
- As of August 2013, precious little known about the fast-neutron backgrounds at the SNS.
  - Biologically safe: time-averaged rates within twice the natural background rate.
  - Some SNS instruments see prompt "flashes" possibly attributed to a variety of sources:
    - Beam losses in the beam transfer line to the target hall.
    - Fast-neutrons originating at the target and punching through the monolith shielding.
    - Lower energy neutrons scattering from one instrument beam line (secondary shutters, choppers, etc) to another instrument.
    - Other sources…
- Open questions about the fast-neutrons:
  - What is the timing structure (as compared to the beam on target timing)?
  - What it the energy spectrum of these fast-neutrons?
  - What is the variation of the intensity at different locations within the SNS target building.
## Fast-Neutron Detectors Deployed @ SNS

### Single Cell Detectors
- Arrays of EJ-301: 1.5 liter (16), 5 liter (4)
- Neutron/Gamma Discrimination
- <1 ns timing
- Pulse-Height "Unfolded" Neutron Spectrum

### Scatter Camera
- Two Planes of EJ-309 Cells
- Neutron/Gamma Discrimination
- <1 ns timing
- Time-of-Flight Neutron Spectrum
- Kinematic Imaging with Iterative Reconstruction
- Double Scatter Inefficiency

### Coded-Aperture Imager
- 24x24 Pixelated Array of PSD Plastic EJ-299-34
- Neutron/Gamma Discrimination
- <1 ns timing
- Imaging via Linear Transformation
- Efficient Coded Mask (50% Open)
- Limited Spectral Information
Initial Observation of Intense Flash

Linac Pulse 800 µs  Extraction 1.3 µs  Muon 10 µs  Delayed 16+ ms

Counts/Detector/MJ/µs

-7
-6
-5
-4
-3
-2
-1 1 10 10 10 10 10

All events below 15 MeVee
All events above 15 MeVee
Neutrons below 15 MeVee
Neutrons above 15 MeVee

In BL14a, Intense Burst of fast neutrons $10^5$ above continuum

4 possible locations identified at <~ 30 m from the SNS target (plus possible outside locations)
Coded-Aperture Imager

High-energy fast-neutrons penetrate a gap in the SNS shielding at beam line 11.
Time Structure of Fast-Neutrons

4 possible locations identified at $\sim$ 30 m from the SNS target (plus possible outside locations)

- Very neutron-quiet location in basement

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Counts/Detector/MJ/s

- All events below 15 MeVee
- All events above 15 MeVee
- Neutrons below 15 MeVee
- Neutrons above 15 MeVee

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Time [us]
Light-Yield Spectrum

Counts [MeVee/MJ/µs]

Recoil Proton Energy [MeVee]

- Extraction 1.3 µs
- Muon 10 µs
- Linac Pulse 800 µs
- Delayed+… 16+ ms

4 possible locations identified at ≤ 30 m from the SNS target (plus possible outside locations)

very neutron-quiet location in basement

Hawaii 2014
Varying Operational Conditions

Extraction Pulse Window

- BL13 Open
- Cosmic Fast Neutrons
- BL13 Closed
- BL13(Closed) BL14a(Closed)

Neutron Counts [MeVee/s]

Recoil Proton Energy [MeVee]

4 possible locations identified at <~ 30 m from the SNS target (plus possible outside locations)

Very neutron-quiet location in basement
Scatter Imaging BL14a

DT Calibrations at BL14a

SNS Beam On at BL14a

Belkis Cabrera-Palmer, Mark Gerling, David Reyna (Sandia)
SNS Basement

- 5 Liter EJ-301 Cells
- Compact and Cart Portable

SNS Basement Hallway

- BL14a 20 hrs
- Pos 2.5 46 hrs
- Pos 4 37 hrs
- Pos 5 24 hrs

SNS Beam Power ~1 MW
Sandia Scatter Camera at Pos 2.5

SNS Basement Hallway

90°

0°

2.5

Transfer Beamline

SNS Basement is a nice quiet place for a CEνNS experiment.
Summary

• COHERENT measurements of backgrounds at the Spallation Neutron Source are well underway to support a future coherent elastic neutrino-nuclear scattering experiment.

• Significant fluxes of fast-neutrons are observed on the target hall floor in at least two measured locations. Two other locations are planned Fall 2014.

• Measurements in the SNS basement show significant reduction in these backgrounds within 20 meters of the SNS target where instruments are presently installed for a neutrino-induced neutron measurement.

• SNS Basement hallway could be a feasible location for a first observation CE$\nu$NS measurement.
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