OscSNS - proposal for neutrino experiment at ORNL SNS facility
Outline

- ORNL SNS facility
- Neutrino production at SNS
- Neutrino detection at SNS
- Event reconstruction and particle IDs
- Event rates and sensitivity
- Conclusion
Spallation Neutron Source

1 GeV proton beam on Hg target

production of spallation neutrons
Neutrino production at SNS

11.6% p produce $\pi^+$

$\pi^+ \rightarrow \mu^+ + \nu\mu$

$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$

(100% $\pi^+$ decay $\leftarrow$ 99.3% DAR)

(0.7% DIF)

($\sim$100% $\mu^+$ DAR)
Timing structure

With a simple beam-on timing cut one can obtain a fairly pure $\nu_\mu$ sample (14% contamination of $\bar{\nu}_\mu$ and $\nu_e$ each)
- Well-known neutrino spectra
- Mono-energetic $\nu_\mu$ with $E = 29.8$ MeV
- $\nu_\mu, \nu_e$ end-point $E = 52.8$ MeV
Neutrino detection

- 60 m upstream from the Hg target;
- 12-m diameter sphere (fiducial = 10 m);
- filled with 800 t of mineral oil CH$_2$( fiducial = 450 t) + ~30 kg of butyl-PBD scintillator;
- 3502 phototubes: 3262 in detector (25% coverage) and 240 in veto region;
- buried under 10 ft of dirt – to suppress cosmic rays and beam-induced neutrons.
Geant4 beam simulation

proton beamline

target hall

interaction tracks

detector

world volume
Neutrino flux – in the detector (50 M POT)
$\mu$ - lifetime in various materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Lifetime, ns (experiment)</th>
<th>Lifetime, ns (QGSP_BERT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be</td>
<td>2162.1 ± 2.0</td>
<td>2161.0</td>
</tr>
<tr>
<td>Fe</td>
<td>206.0 ± 1.0</td>
<td>205.9</td>
</tr>
<tr>
<td>Hg</td>
<td>76.2 ± 1.5</td>
<td>72.3</td>
</tr>
</tbody>
</table>
Geant4 detector simulation

Done:
- preliminary simplified geometry (tank, veto, PMTs, oil);
- optical model parameters (refractive index, absorption length, etc) taken from other experiments (MiniBooNE)
- Cherenkov and scintillation (slow and fast components) light propagation (LSND)

Needs to be done:
- simulate the phototube and electronic response
- add more event types
Event reconstruction and particle IDs

- Maximum likelihood algorithm (charge and time info from PMTs)
- Particle topology

Electron (fuzzy ring)  Muon (sharp ring)
through-going  stopping
## Cross-section measurements

1) $\nu_\mu \, C \rightarrow \nu_\mu \, C^*$
   - measured by KARMEN experiment but with only 86 events and 20% error

2) $\nu_\tau \, C \rightarrow \nu_\tau \, N$
   - can be used to normalize total neutrino flux

3) $\nu_\tau \, e^- \rightarrow \nu_\tau \, e^-$
   - measured by LSND experiment but with only 191 events and 17% error
   - 100,000 events from Super-K (unknown flux)

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### OscSNS expectations
- 800 ton detector (6 m radius)
- 5m fiducial volume
- 50% detector efficiency
- 1 year run time

- OscSNS expects ~1,300 events
- Main channel for sterile neutrinos
- <5% error

- OscSNS expects ~4,600 events

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Bari Osmanov      Miami-2008
Event rates per year

800 ton detector (6 m radius), 5m fiducial volume, 50% detector efficiency, 10% flux uncertainty, 1 year run time

<table>
<thead>
<tr>
<th>Distance to detector</th>
<th>Disappearance ($\nu_\mu \rightarrow$ sterile)</th>
<th>Appearance intrinsic background ($\anti-\nu_\epsilon + X \rightarrow e$)</th>
<th>Appearance signal ($\anti-\nu_\mu \rightarrow \anti-\nu_\epsilon$ with 0.26% oscillation probability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 m</td>
<td>6,322 ± 81</td>
<td>79 ± 24</td>
<td>253 ± 3</td>
</tr>
</tbody>
</table>
Background suppression

Short pulsed beam:
60 Hz, 695 ns pulse-width
(500 ns pulse-width was achieved)

cosmic-ray background rejection

6% p produce $\pi^-$

$\pi^- \rightarrow \mu^- + \nu_\mu$ (0.5% $\pi^-$ decay $\rightarrow$ 100% DIF)

$\mu^- \rightarrow e^- + \nu_\mu + \nu_e$ (24.6% $\mu^-$ decay $\rightarrow$ 100% DAR)

$\frac{\nu_e}{\nu_\mu} < 9 \times 10^{-4}$ (expect reduction as MC becomes more advanced)
More background suppression

- DIF negative mesons are boosted in forward direction, so neutrinos are mostly emitted in forward direction

\[
\begin{align*}
\text{Time spectrum of } & \nu_e^- \quad \text{Slow decay of } \mu^- \text{ in low-Z materials (Be, Al)}; \\
\text{Fast decay of } & \mu^- \text{ in high-Z materials (Hg, Pb, Fe)}; \\
\text{Time-cut at 1000 ns can eliminate } & \nu_e^- \text{ from } \mu^- \text{ decay in Hg, Pb}...
\end{align*}
\]
Appearance sensitivity

Confidence level curves for $\nu_\mu \rightarrow \nu_e$ oscillations
Disappearance sensitivity

Confidence level curves for $\nu_\mu \rightarrow \nu_\tau$ oscillations

![Confidence Level Curves for $\nu_\mu \rightarrow \nu_\tau$ Oscillations (1 year)](image1)

![Confidence Level Curves for $\nu_\mu \rightarrow \nu_\tau$ Oscillations (3 years)](image2)
Neutrino environment at SNS facility offers a unique opportunity for both oscillation- and cross-section type of experiments:

- background suppression
- well-known neutrino flux
- free source of neutrinos
OscSNS collaboration

Current:
- U Alabama
- U Florida
- LANL
- Purdue U Calumet
- U South Carolina
- ORNL / U Tennessee

Submitted white-paper to DoE(nuclear and high-energy) and NSF

more information: http://physics.calumet.purdue.edu/~oscsns
Thank you