OscSNS: A Precision Neutrino Oscillation Experiment at the SNS

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1. Executive Summary

The possible existence of light sterile neutrinos ($m_{\nu_s} \sim 1$ eV/c^2) is receiving considerable attention [1]. Such non-standard particles, first invoked to explain the LSND $\bar{\nu}_\mu \to \bar{\nu}_e$ appearance signal [2], would require a mass far above the mass scale associated with the active neutrinos. This unexpected appearance is ascribed to a process proceeding through sterile neutrinos. More recently, the MiniBooNE experiment has reported a 3.8σ excess of events [3,4] consistent with the LSND appearance signal. In addition, lower than expected neutrino induced event rates from calibrated radioactive sources [5] and nuclear reactors [6] and the preference for more than three relativistic degrees of freedom from cosmology analyses [1] can also be explained by the existence of sterile neutrinos with mass ~ 1 eV/c^2. No experiment directly contradicts the existence of such sterile neutrinos. Fits to the world neutrino and antineutrino data [7,8,9,10,11] are consistent with sterile neutrinos at this ~ 1 eV/c^2 mass scale, though there is tension between measurements of disappearance and appearance experiments [1]. It is now imperative to establish if such totally unexpected light sterile neutrinos exist.

The Spallation Neutron Source (SNS) [12] at Oak Ridge National Laboratory, built to herald a new era in neutron research, provides a unique opportunity for US science to perform an incisive search for sterile neutrinos. The 1MW beam power of SNS is a prodigious source of neutrinos from the decay of π^+ and μ^+ at rest. These decays produce a well specified flux of neutrinos via $\pi^+ \to \mu^+\nu_\mu$, $\tau_\pi = 2.7\times10^{-8}$ s, and $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$, $\tau_\mu = 2.2\times10^{-6}$ s. The SNS low duty factor (~ 700 ns beam pulses at 60 Hz, $DF = 4.2\times10^{-5}$) is more than 1000 times less than LAMPF. This smaller duty factor reduces backgrounds and allows the ν_μ induced events from π^+ decay to be separated from the ν_e and $\bar{\nu}_\mu$ induced events from μ^+ decay. The OscSNS experiment [13] will use the monoenergetic 29.8 MeV ν_μ to investigate the existence of light sterile neutrinos via the neutral-current reaction $\nu_\mu C \to \nu_\mu C^*(15.11\text{ MeV})$, which has the same cross section for all active neutrinos but is zero for sterile neutrinos. An oscillation or suppression of this reaction is direct evidence for sterile neutrinos. OscSNS can also carry out a unique and decisive test of the LSND appearance $\bar{\nu}_\mu \to \bar{\nu}_e$ signal, as shown in Fig. 1. In addition, OscSNS can make a sensitive search for ν_e disappearance via the reaction $\nu_e C \to e^- N_{gs}$, where the N_{gs} is identified by its fast beta decay. It is essential to note that all the cross sections [14] involved are known to a few percent or better.

The existence of light sterile neutrinos would be the first major extension of the Standard Model, and their properties are central to dark matter, cosmology, astrophysics, and future neutrino research. An OscSNS detector based on the LSND and

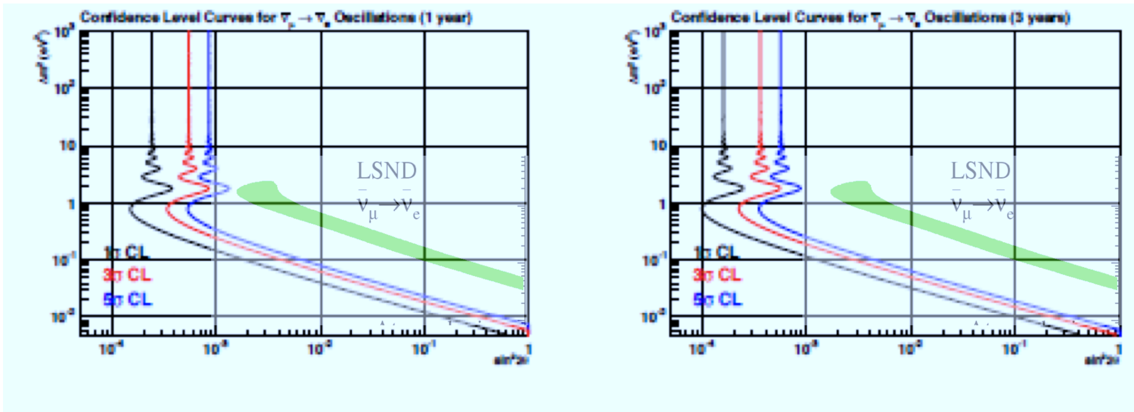

Figure 1: The OscSNS sensitivity curves for $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations after one (left) and three (right) years of operation for a 800-ton mineral oil based detector located at a distance of 60 m from the neutrino source.

MiniBooNE detectors can be built for $\sim$ \$15M, excluding labor and management costs.

2. Questions & Answers

A. What major scientific discoveries have occurred in your research area since the 2007 LRP was drafted?

Since the 2007 LRP was drafted, there has been ever increasing evidence for the existence of sterile neutrinos. This evidence includes global fits to world data, the excess of $\bar{\nu}_e$ and ν_e events from MiniBooNE, the reactor neutrino anomaly, the radioactive source anomaly, and cosmological data, and has resulted in increased theoretical interest.

B. What compelling and unique science is to be done in the next 5 years?

A neutrino oscillation experiment at the SNS (e.g. OscSNS) could prove if sterile neutrinos explain the above anomalies. Such an experiment represents a unique opportunity for U.S. science because of the existence of the SNS. JPARC, while inferior as the ideal neutrino source, could provide competition.

C. What science would you expect to pursue in the program in 2020 and beyond?

The discovery of light, sterile neutrinos would open up a whole new area of neutrino physics research. In addition to being important for nuclear and particle physics, sterile neutrinos would have a large impact on astrophysics and cosmology. In particular, sterile neutrinos could play a role in dark matter.

D. What is the international context, and how does it affect your vision?

The SNS is unique in the world and provides the U.S. with the rare opportunity to do a significant experiment in neutrino physics. Studies with radioactive sources or reactors allow investigation of the disappearance of ν_e $\bar{\nu}_e$. A stopped pion and muon source uniquely allows the precise investigation of the disappearance of both ν_μ and ν_e as well as $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillationis.

3. References

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12) *The Spallation Neutron Source (SNS) is an accelerator-based source built in Oak Ridge, Tennessee, by the U.S. DOE, http://sns.gov/. Also see http://www.phy.ornl.gov/workshops/sns2/ for details on the neutrino source and cross section detector ν-SNS.*
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