Snowmass2021 - Letter of Interest

The JSNS^2 Experiment

NF Topical Groups: (check all that apply ☐/■)

■ (NF1) Neutrino oscillations
■ (NF2) Sterile neutrinos
■ (NF3) Beyond the Standard Model
■ (NF5) Neutrino properties
■ (NF6) Neutrino cross sections
■ (NF8) Theory of neutrino physics
■ (NF9) Artificial neutrino sources
■ (NF10) Neutrino detectors

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Abstract:

The J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source (JSNS^2) experiment is searching for neutrino oscillations with $\Delta m^2 \sim 1$ eV^2 from $\bar{\nu}_\mu$ to $\bar{\nu}_e$, detected via the inverse beta decay (IBD) reaction ($\bar{\nu}_e + p \rightarrow e^+ + n$) and tagged via gammas from neutron capture on Gadolinium. A 3 GeV 610 kW (with 1 MW upgrade expected soon) proton beam incident on a mercury target at the Materials and Life Science Experimental Facility at J-PARC produces an intense neutrino flux from muon decay at rest ($\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$). The first of two planned and funded liquid scintillator detectors has been completed and is located at a distance of 24 m from the neutrino source. An initial data taking run took place in Summer 2020 with the 50 ton detector, and the results are currently being analyzed.

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There are a number of significant indications of neutrino oscillations at short-baseline[1–5] which may point to the existence of one or more sterile neutrinos. Unfortunately, however, the experimental situation is complicated with the apparent observation of both muon-flavor to electron-flavor transitions and electron-flavor disappearance at $\Delta m^2 \sim 1$ eV^2, but no muon-flavor disappearance at this frequency; Muon-flavor disappearance is required in any scenario involving one or more sterile neutrinos, and the simplest "3+1" model is effectively ruled out[6]. A number of other explanations for some subsets of the results do exist, but there is likely one or more experiments with an unknown issue.

In any case, it is clear that the neutrino community needs to understand these possible indications of new physics. In much the same way that the atmospheric and solar neutrino anomalies were pursued in earnest (and with enormous reward), short-baseline mixing should be studied with similar fervor. Such a dedicated effort involves probing this possible novel neutrino behavior with multiple baselines, energies, L/E, neutrino flavors, and with both neutrinos and antineutrinos. The global neutrino community has responded to this call, with a set of sensitive experiments relying on both accelerator decay-in-flight ($\nu_\mu \to \nu_e$ and $\nu_\mu \to \nu_\mu$; see, e.g., Ref.[7]) and reactors ($\bar{\nu}_e \to \bar{\nu}_e$; see, e.g., Refs.[8–10]), with more planned (see, e.g., Ref.[11]).

The J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source (JSNS^2) experiment is unique among these in searching for short-baseline mixing with a well-understood muon decay-at-rest antineutrino source coming from the eventually 1 MW (currently 610 kW) spallation source at J-PARC and a 50 ton (17 ton fiducial volume) liquid scintillator detector with Gd-doping. A picture of the inside of the first detector is shown in Figure 1. For additional details about the experiment, see Ref.[12]. JSNS^2 can be considered both highly complementary to the other short-baseline probes and powerful by itself, with the ability to trace the oscillation wave across a large swath of L/E values. Importantly as well, JSNS^2 represents the only planned direct test of the 3.8σ LSND antineutrino ($\bar{\nu}_\mu \to \bar{\nu}_e$) anomaly[1].

Noting that a second JSNS^2 detector is now funded, with the optimal mass and baseline for this new detector currently under study, the one-existing-detector sensitivity from the JSNS^2 TDR[12] is shown in Figure 2. Figure 3 shows a number of one-detector data collection examples from some characteristic mixing scenarios. In addition to the sensitive oscillation search, JSNS^2 will also produce a set of impactful measurements using monoenergetic 236 MeV kaon decay-at-rest (KDAR) neutrinos and study 10s-of-MeV-scale neutrino cross sections relevant for our understanding of supernovae and nuclear physics[12].

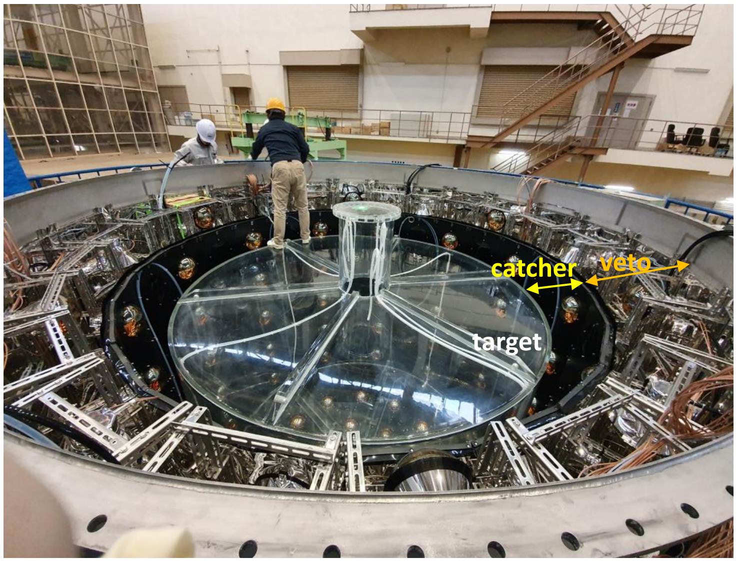

Figure 1: *A picture of the JSNS^2 detector.*

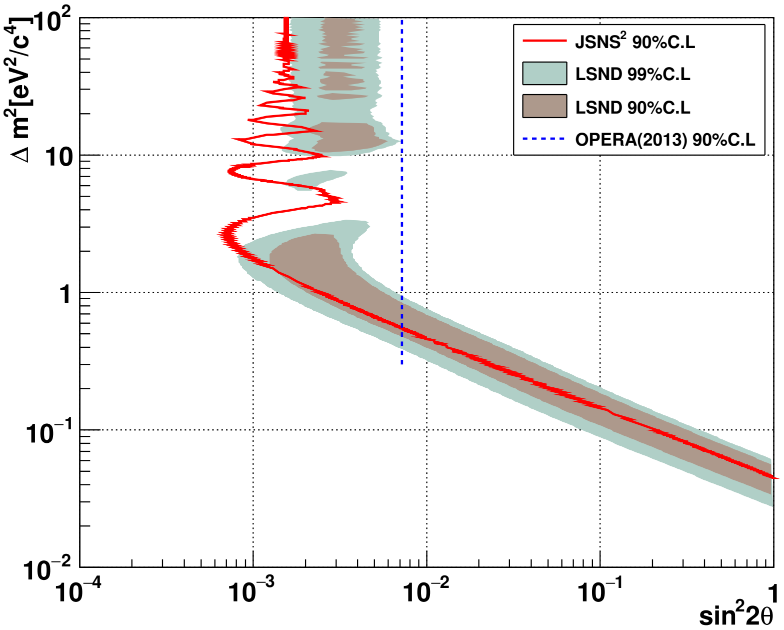

Figure 2: *The one-detector sensitivity of JSNS^2 to oscillations in a 3+1 scenario after 3 years of running (5000 hours/year at 1 MW). This plot is from Ref.*[12].

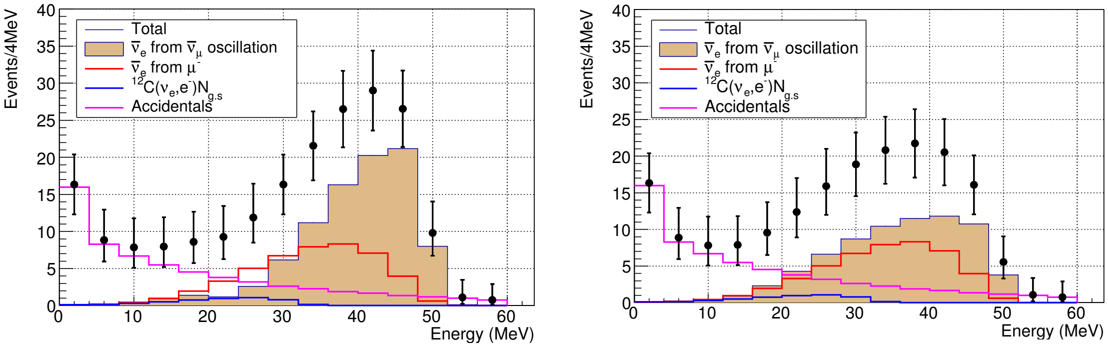

Figure 3: *Two example oscillation* $\bar{\nu}_\mu \to \bar{\nu}_e$ *scenarios in one-detector JSNS^2 after 3 years of running (5000 hours/year at 1 MW). (Left) A 3+1 mixing scenario with* $\Delta m^2 = 2.5$ *eV^2 and* $\sin^2 2\theta = 0.003$. *(Right) A 3+1 mixing scenario with* $\Delta m^2 = 1.2$ *eV^2 and* $\sin^2 2\theta = 0.003$. *These plots are from Ref.*[12].

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