

# Status of JSNS<sup>2</sup> - J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source

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**Abstract.** The JSNS<sup>2</sup> experiment will search for neutrino oscillations with  $\Delta m^2 \simeq 1 \text{ eV}^2$  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 1 MW 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 50 tons liquid scintillator detectors is nearly completed and will be located at a distance of 24 m from the neutrino source. JSNS<sup>2</sup> can directly test the LSND anomaly and is expected to start taking data in early 2020.

## 1. Introduction

For almost two decades the neutrino community has been intrigued by anomalies that could hint at the existence of a light sterile neutrino that participates in neutrino oscillations. One of the longest standing anomalies ( $3.8 \sigma$ ) was observed as an excess of  $\bar{\nu}_e$  events in data collected with the Liquid Scintillator Neutrino Detector (LSND) at Los Alamos in 1998 [1] (see table 1). The MiniBooNE experiment later observed anomalies in both  $\bar{\nu}_e$  and  $\nu_e$  appearance channels (combined  $4.8 \sigma$ ) [2]. The observations could be explained by a flavor conversion of  $\bar{\nu}_\mu$  to  $\bar{\nu}_e$  at a probability of about 0.003 with a  $\Delta m^2$  of  $\sim 1 \text{ eV}^2$  [3].

Intense international efforts to search for sterile neutrinos are currently underway with reactor neutrino experiments, neutrino telescopes [4], and short baseline neutrino oscillation experiments. There is very strong tension between the anomalies in the appearance sector and disappearance data. The global experimental data cannot be explained by addition of a single or multiple sterile neutrinos [5]. This makes the effort to measure the original LSND anomaly extremely important. The J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source JSNS<sup>2</sup> (J-PARC E56) [6] is the only experiment that can directly test the LSND anomaly without having to rely on a specific theoretical framework. JSNS<sup>2</sup> will use the same neutrino source, target material, baseline length, and detection channel as LSND, however with a vastly improved experimental setup. Major improvements in the experimental setup of JSNS<sup>2</sup> with respect to LSND include: (1) The high intensity short pulsed beam at MLF significantly reduces coincidental backgrounds; (2) Gd-doped LS allows to tag IBD events; (3) The detector location of JSNS<sup>2</sup> is above the beam dump reducing the possibility of beam related backgrounds that have been suggested as contributing to the observed LSND signal.



Experiment	$\nu$ -source	Energy $E_\nu$	Distance $L$	Signal
LSND [1]	$\pi$ DAR	40 MeV	30 m	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
MiniBooNE [2]	$\pi$ DIF	800 MeV	600 m	$\nu_\mu \rightarrow \nu_e$ / $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
FNAL SB program [7]	$\pi$ DIF	800 MeV	110 m / 470 m / 600 m	$\nu_\mu \rightarrow \nu_e$ / $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
JSNS <sup>2</sup> [6]	$\pi$ DAR	40 MeV	24 m	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

**Table 1.** Selected experimental efforts using decay-at-rest (DAR), decay-in-flight (DIF) neutrino sources.



**Figure 1.** Left: JSNS<sup>2</sup> detector schematics; Middle: JSNS<sup>2</sup> detector in the HENDEL assembly hall and test installation of acrylic tank; Right: Inside tank with partially installed PMTs.

## 2. The JSNS2 detector

The JSNS<sup>2</sup> detector will use 17 tons of gadolinium-loaded liquid scintillator (LS) in an inner acrylic vessel as the target volume. Immediately outside of the acrylic vessel is a  $\gamma$ -catcher region and the outermost region is an optically separate liquid scintillator veto. The veto region uses 31 tons LS with Linear Alkyl Benzene (LAB) as organic base solvent. The unloaded LS was produced at the refurbished facility, originally used for LS production by the RENO experiment [8]. The target volume will be viewed by up to 192 10" PMTs that were spares for the RENO and Double CHOOZ detectors or newly purchased. PMT testing and characterization is currently underway.

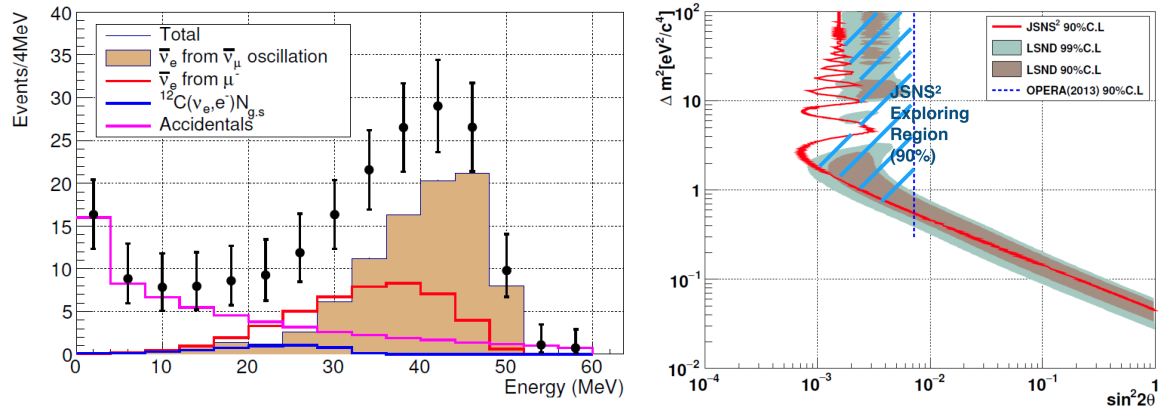
JSNS<sup>2</sup> is in the final phase of the detector construction phase and is expected to start data taking in early 2020. Recent progress on the construction is summarized in figure 1.

## 3. Sterile Neutrino Sensitivity and Science with JSNS<sup>2</sup>

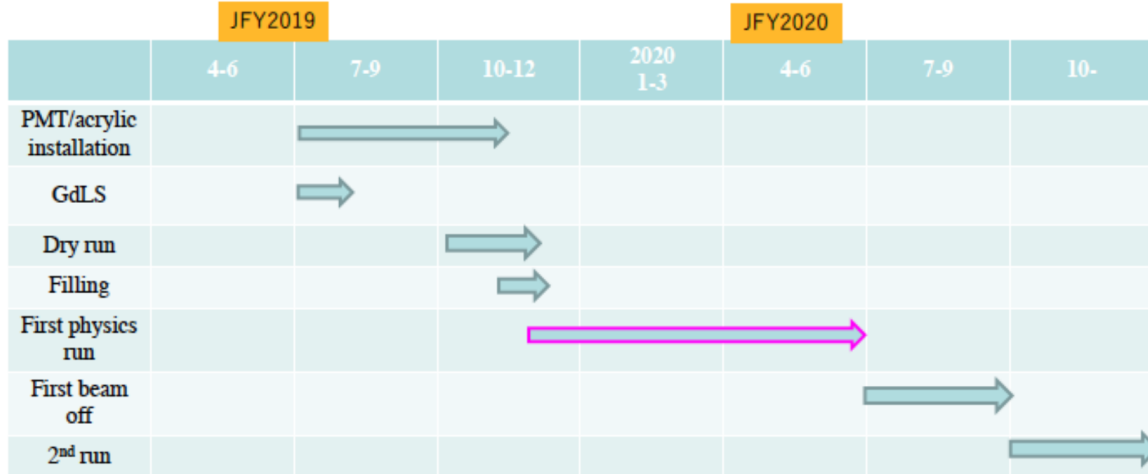
The JSNS<sup>2</sup> detector is expected to provide an energy resolution better than 2.5% at 50 MeV and is designed to test the LSND anomaly and in case of a non-observation exclude significant portions of the LSND preferred parameter space at 90% C.L. with 3 years of data (see Figure 2). Other scientific objectives of the experiment include a measurement of the neutrino cross section of  $\sigma(^{12}\text{C}(\nu_e, e^-)^{12}\text{N})$ , which is critical for the understanding of core collapse supernovae, searches for dark matter [9], and precision measurements of 236 MeV neutrinos from KDAR ( $K^+ \rightarrow \mu^+ \nu_\mu$ ; BR=63.5%), recently observed by MiniBooNE [10] and also relevant for dark matter searches [11].

## 4. Conclusions

The JSNS<sup>2</sup> experiment will provide a direct test of the long standing LSND anomaly. JSNS<sup>2</sup> is now in its final construction phase and is expected to start data taking in early 2020 (see figure 3). After completion of the first detector, the JSNS<sup>2</sup> collaboration plans to construct a



**Figure 2.** Expected signal with JSNS<sup>2</sup> for the case of  $\Delta m^2 = 2.5 \text{eV}^2$ ,  $\sin^2 2\theta = 0.003$  and sensitivity assuming 3 years of data.



**Figure 3.** The JSNS<sup>2</sup> construction and operations schedule.

second detector. Efforts are on-going to secure funding for the second detector, that will be essential to validate any observation of a sterile neutrino signal.

## 5. Acknowledgements

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