Searching for Sterile Neutrinos at J-PARC with JSNS^2

Johnathon Jordan - University of Michigan
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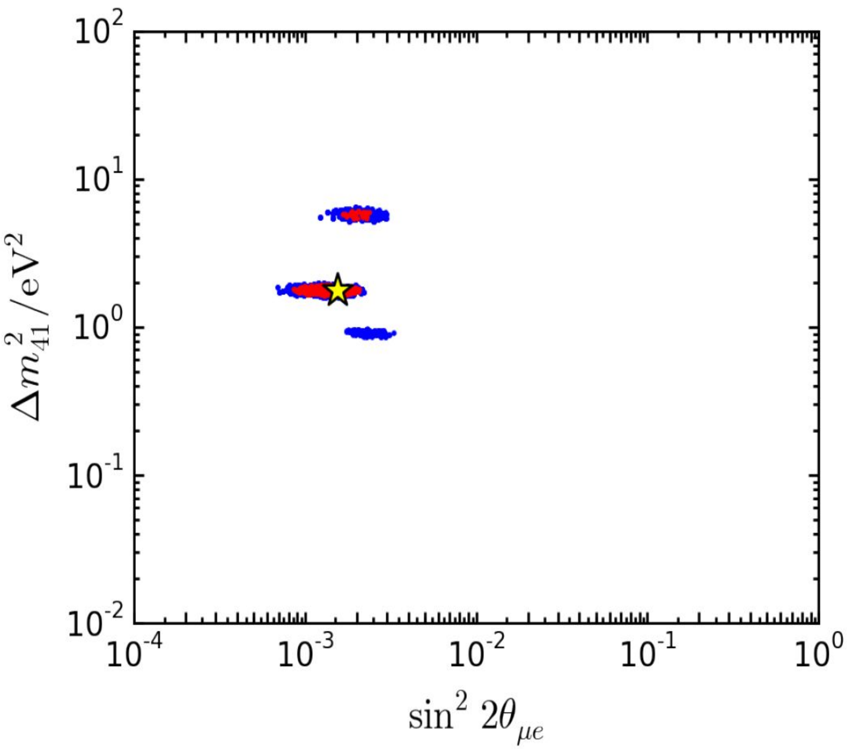
Status of Sterile Neutrino Searches

- Several anomalous results in last few decades:
  - LSND (3.8**σ**)
  - MiniBooNE (3.8**σ**)
  - Gallium/SAGE (2.7**σ**)
  - Reactor (3.0**σ**)
- Results do not fit the standard 3 neutrino paradigm (solar + atmospheric)
- Also many null results (MINOS, MiniBooNE, and IceCube)
- Possible oscillation to sterile neutrinos
- JSNS^2 will be a direct test of past anamolous results



Global fit to short baseline and IceCube data using a 3+1 model.

arxiv:1607.00011

JSNS^2 Experiment

- The J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source (JSNS^2)
- Will look for sterile neutrinos using:

$$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$$

- Located at J-PARC Materials and Life Sciences Facility (MLF)
- 24m baseline, will look for oscillations with:

$$\Delta m^2 \approx 1\ eV^2$$

- Use distinct IBD signature to identify candidate events

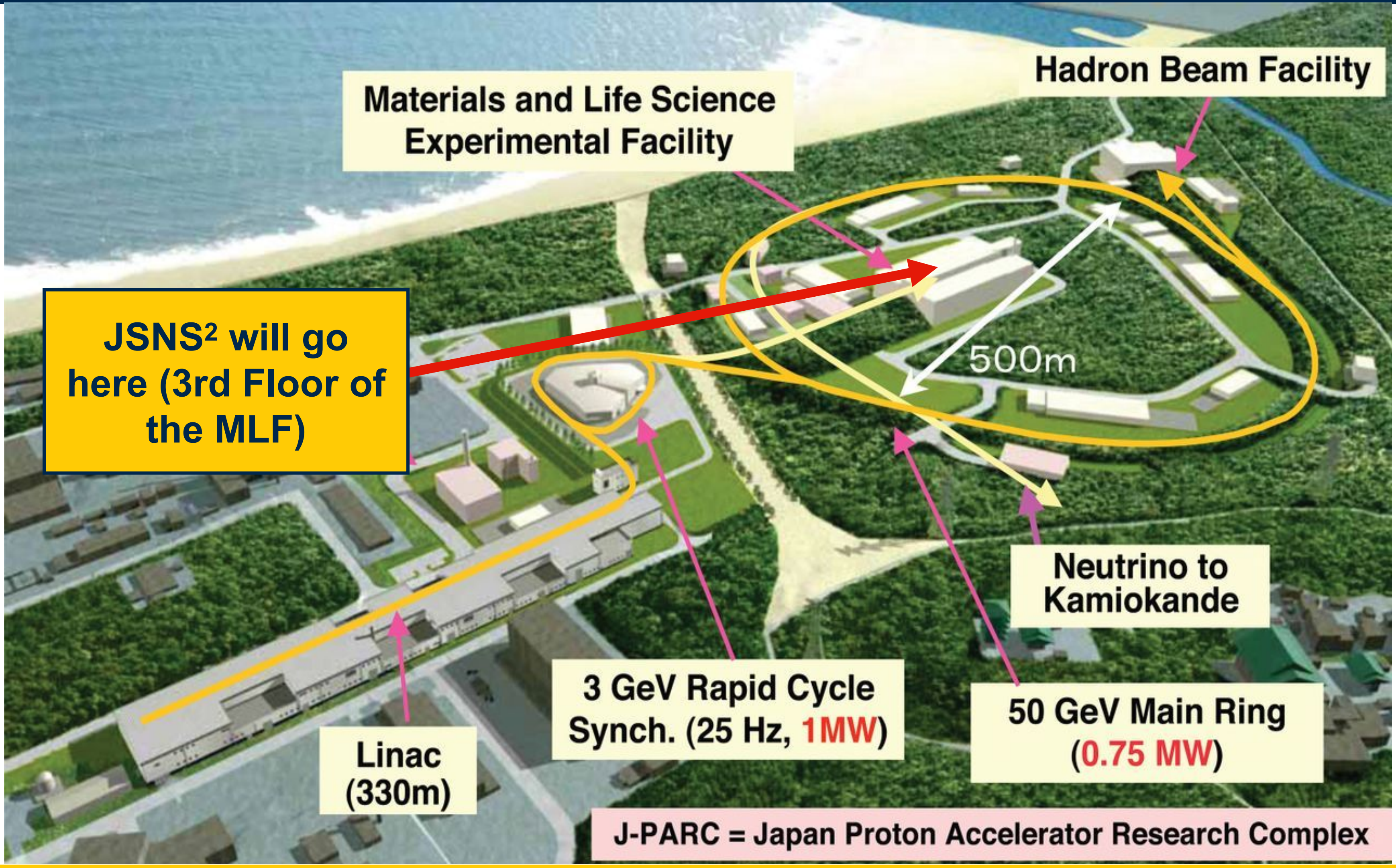
$$\bar{\nu}_e + p \rightarrow e^+ + n$$

Technical Design Report (TDR):
Searching for a Sterile Neutrino at J-PARC MLF
(E56, JSNS^2)

S. Ajimura[1], M. K. Cheoun[2], J. H. Choi[3], H. Furuta[4], M. Harada[5], S. Hasegawa[5], Y. Hino[4], T. Hiraiwa[1], E. Iwai[6], S. Iwata[7], J. S. Jang[8], H. I. Jang[9], K. K. Joo[10], J. Jordan[6], S. K. Kang[11], T. Kawasaki[7], Y. Kasugai[5], E. J. Kim[12], J. Y. Kim[10], S. B. Kim[13], W. Kim[14], K. Kuwata[4], E. Kwon[13], I. T. Lim[10], T. Maruyama*[15], T. Matsubara[4], S. Meigo[5], S. Monjushiro[15], D. H. Moon[10], T. Nakano[1], M. Niiyama[16], K. Nishikawa[15], M. Nomachi[1], M. Y. Pac[3], J. S. Park[15], H. Ray[17], C. Rott[18], K. Sakai[5], S. Sakamoto[5], H. Seo[13], S. H. Seo[13], A. Shibata[7], T. Shima[1], J. Spitz[6], I. Stancu[19], F. Suekane[4], Y. Sugaya[1], K. Suzuya[5], M. Taira[15], W. Toki[20], T. Torizawa[7], M. Yeh[21], and I. Yu[18]

[1] *Research Center for Nuclear Physics, Osaka University, Osaka, JAPAN*
[2] *Department of Physics, Soongsil University, Seoul 06978, KOREA*
[3] *Department of Radiology, Dongshin University, Chonnam 58245, KOREA*
[4] *Research Center for Neutrino Science, Tohoku University, Sendai, Miyagi, JAPAN*
[5] *J-PARC Center, JAEA, Tokai, Ibaraki JAPAN*
[6] *University of Michigan, Ann Arbor, MI, 48109, USA*
[7] *Department of Physics, Kitasato University, Sagamihara 252-0373, Kanagawa, JAPAN*
[8] *Gwangju Institute of Science and Technology, Gwangju, 61005, KOREA*
[9] *Department of Fire Safety, Seoyeong University, Gwangju 61268, KOREA*
[10] *Department of Physics, Chonnam National University, Gwangju, 61186, KOREA*
[11] *School of Liberal Arts, Seoul National University of Science and Technology, Seoul, 139-743, KOREA*
[12] *Division of Science Education, Physics major, Chonbuk National University, Jeonju, 54896, KOREA*
[13] *Department of Physics and Astronomy, Seoul National University, Seoul 08826, KOREA*
[14] *Department of Physics, Kyungpook National University, Daegu 41566, KOREA*
[15] *High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki, JAPAN*
[16] *Department of Physics, Kyoto University, Kyoto, JAPAN*
[17] *University of Florida, Gainesville, FL, 32611, USA*
[18] *Department of Physics, Sungkyunkwan University, Gyeong Gi-do, KOREA*
[19] *University of Alabama, Tuscaloosa, AL, 35487, USA*
[20] *Colorado State University, Tuscaloosa, AL, 35487, USA*
[21] *Brookhaven National Laboratory, Upton, NY, 11973-5000, USA*

J-PARC RCS Beam

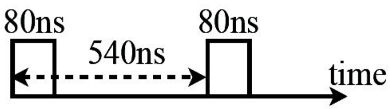


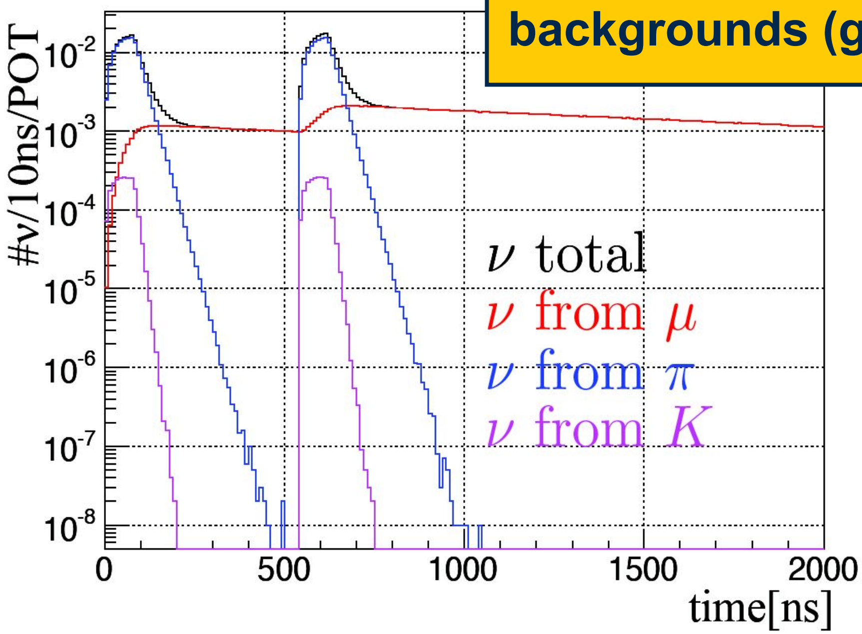
Detector Location

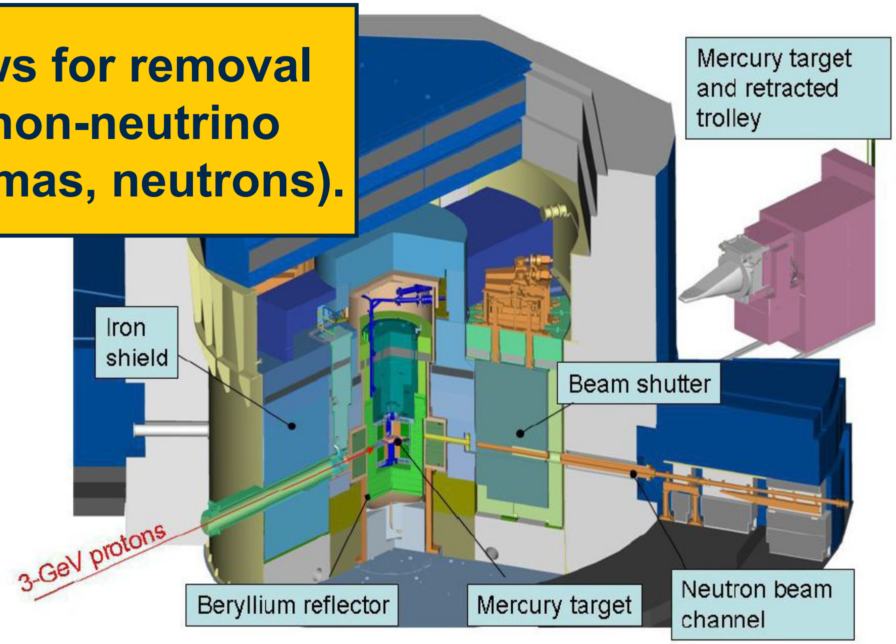
Detector Location on MLF 3rd Floor

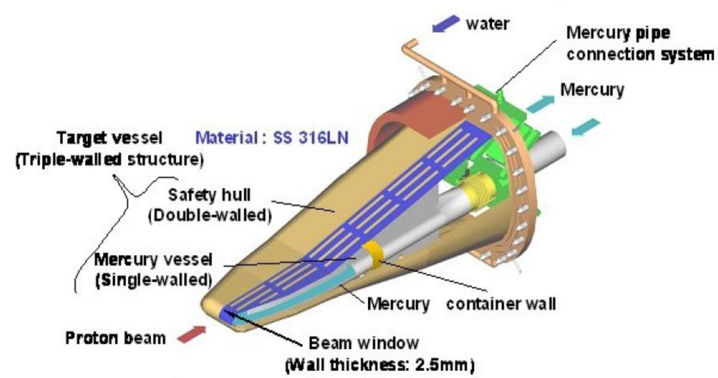
J-PARC MLF/Beam

Pulsed beam allows for removal of beam-related non-neutrino backgrounds (gammas, neutrons).









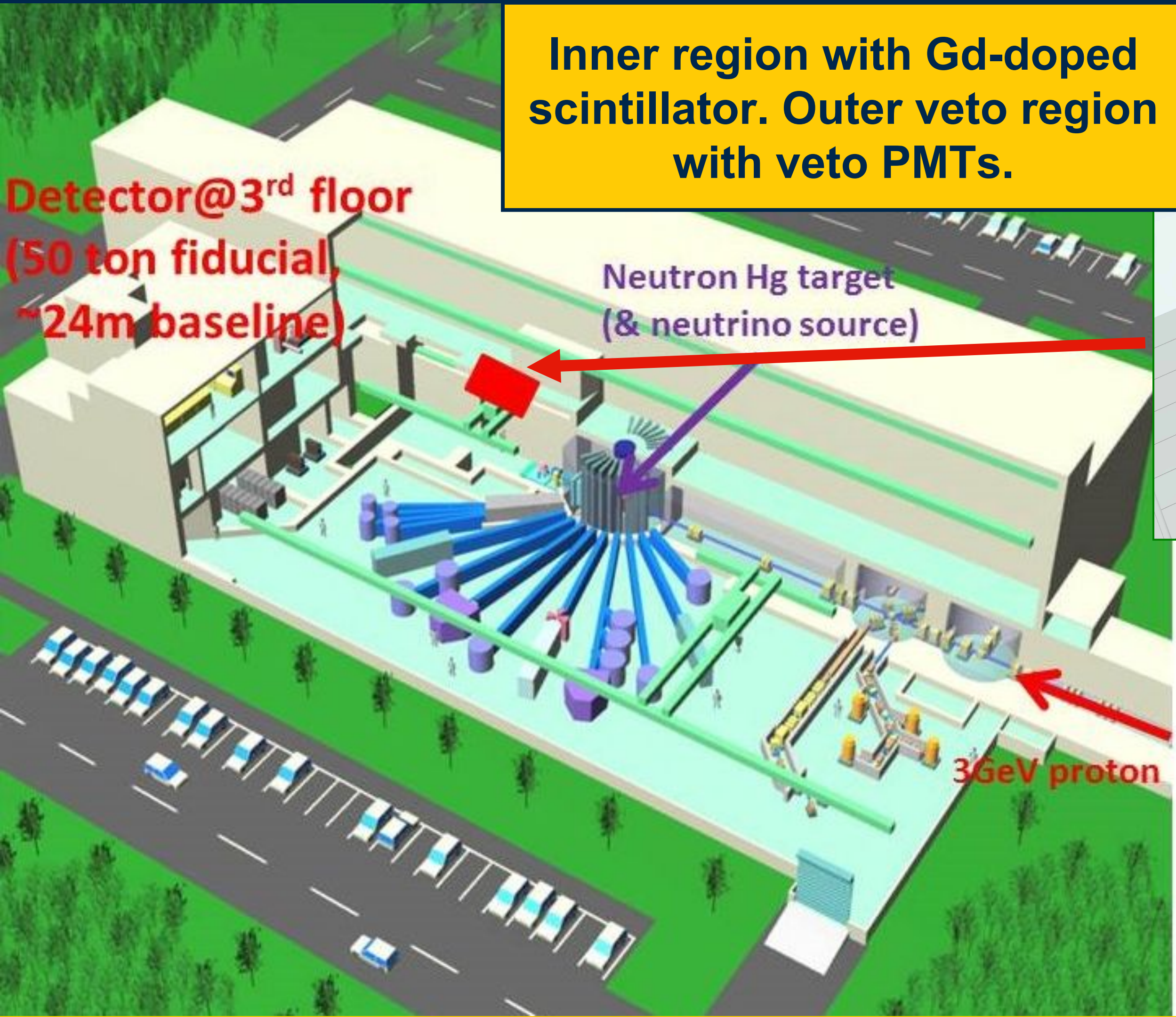
DAR Production Mechanisms:

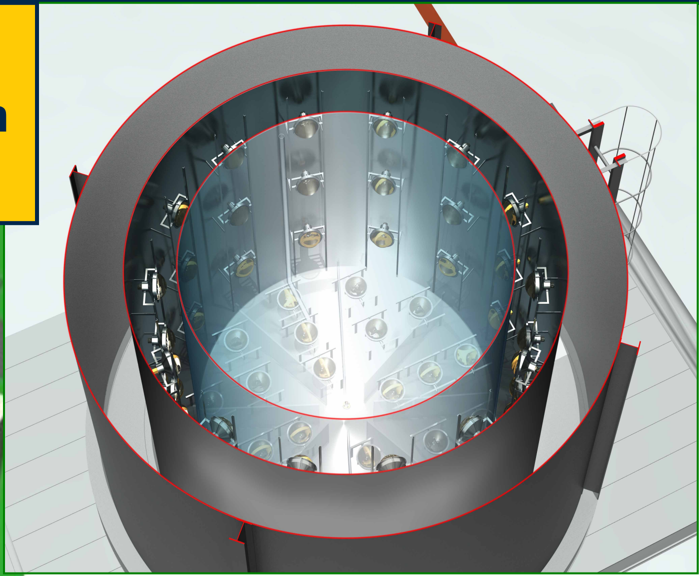
$$\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$$

$$\pi^+ \rightarrow \mu^+ \nu_\mu \quad K^+ \rightarrow \mu^+ \nu_\mu$$

JSNS^2 Detector

Inner region with Gd-doped scintillator. Outer veto region with veto PMTs.



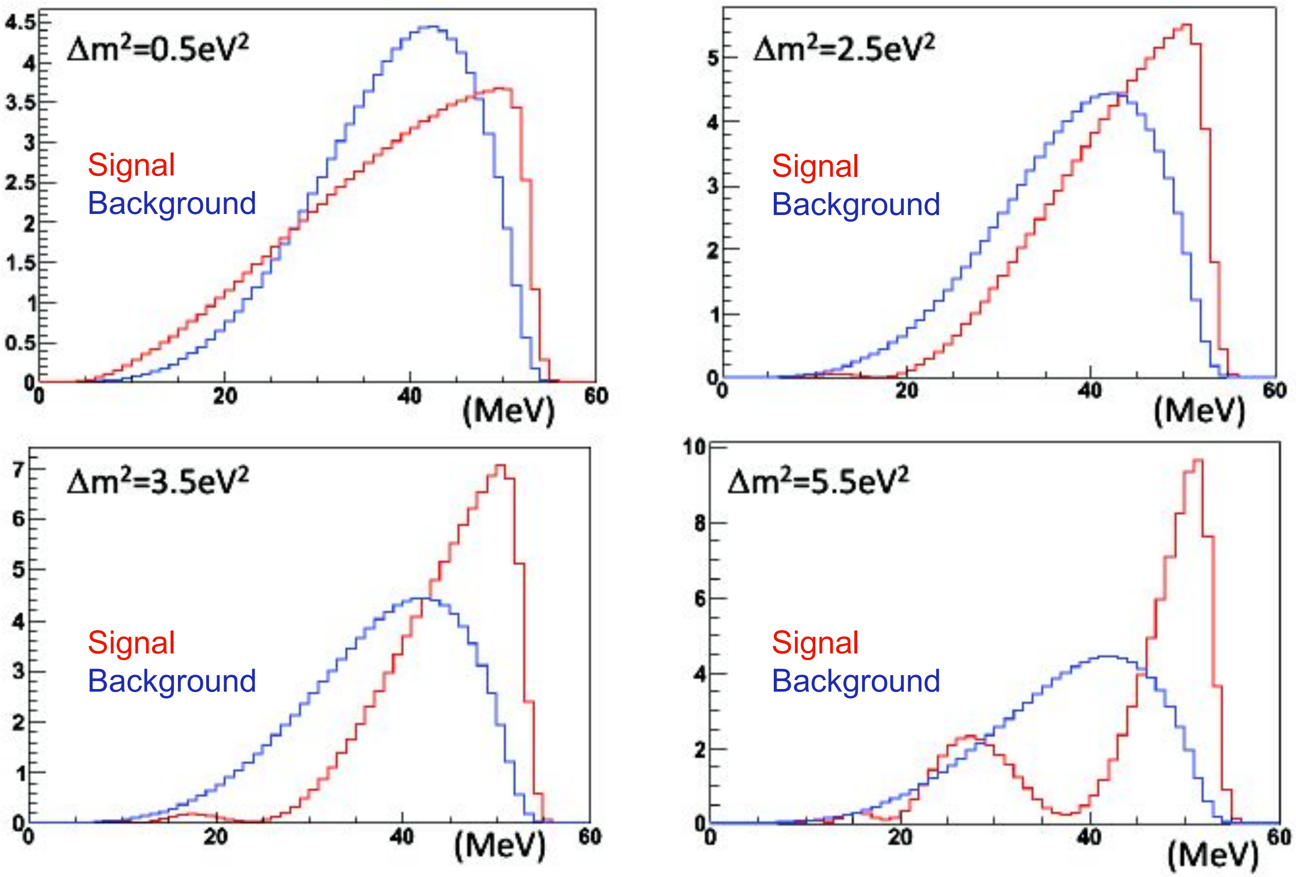


193 PMTs per inner detector

LAB-based liquid scintillator

Phase 0: 17t fiducial mass
Phase 1: 34t fiducial mass

Intrinsic Background



Dominant irreducible intrinsic background:

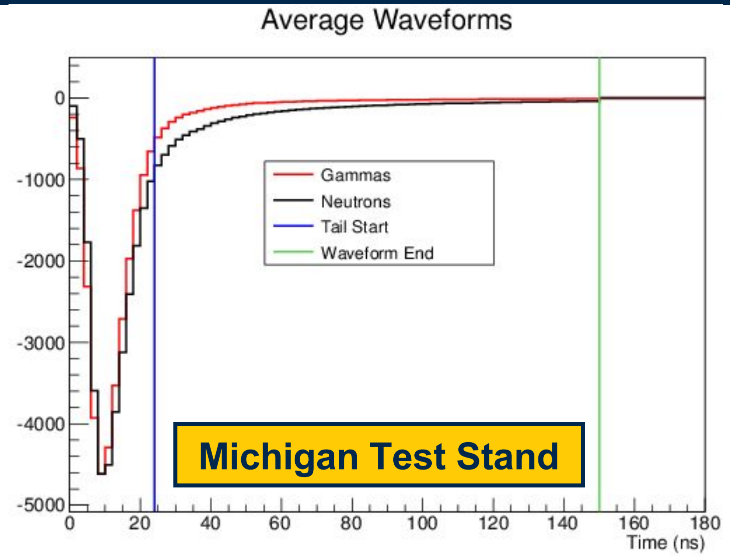
$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$$

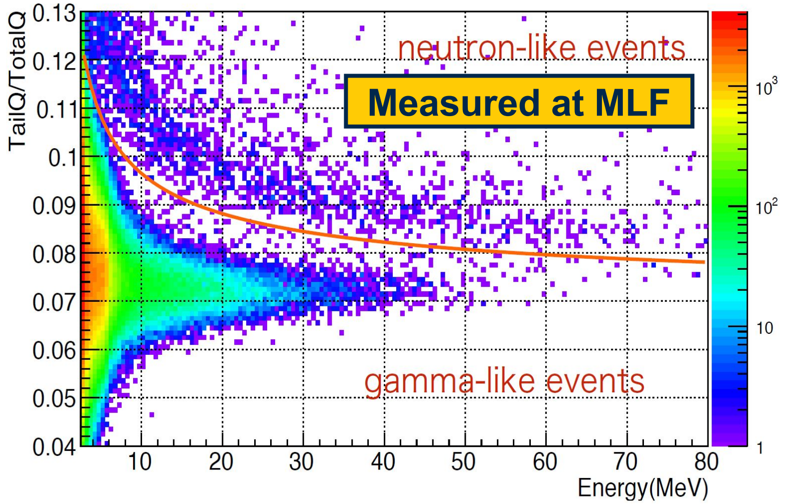
Background shape is different than the signal shape for all oscillation scenarios.

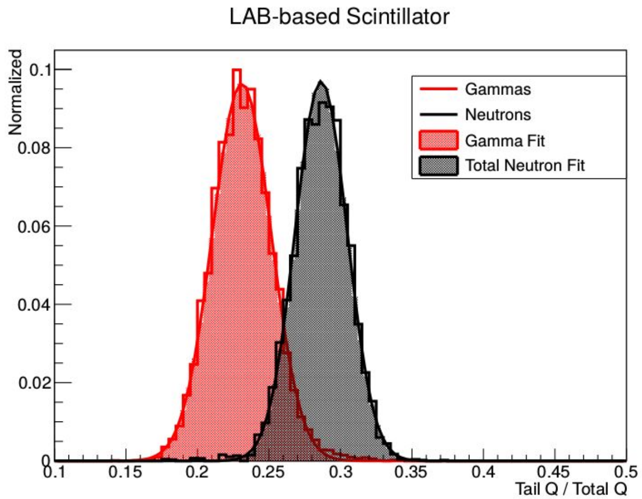
M. Harada et al, arXiv:1310.1437 [physics.ins-det]

Backgrounds

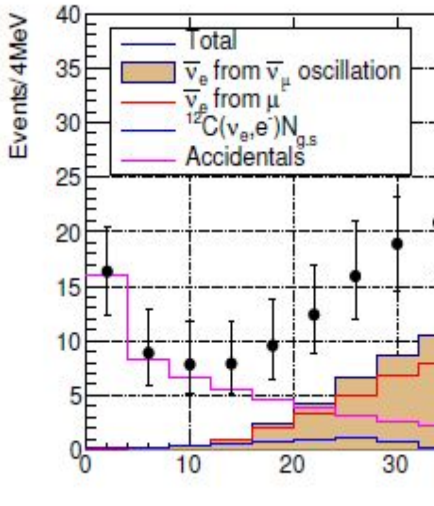
- Other major background is from fast (10-100 MeV) neutrons:
  - Cosmic neutrons
  - Beam neutrons (acccidentals)
- Reject cosmic neutrons with pulse shape discrimination (PSD)
- Beam and cosmic based background have been measured *in situ*



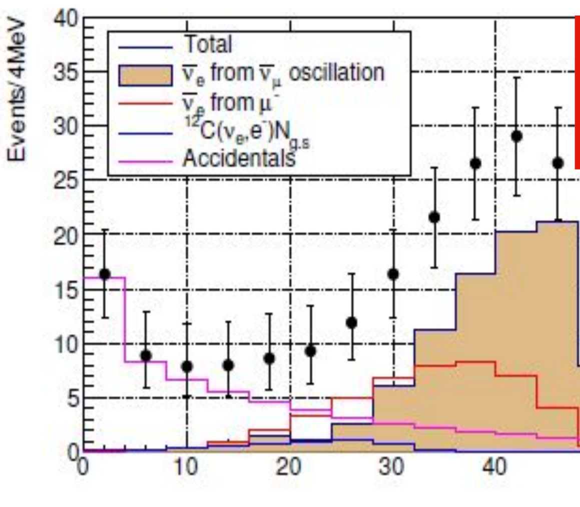




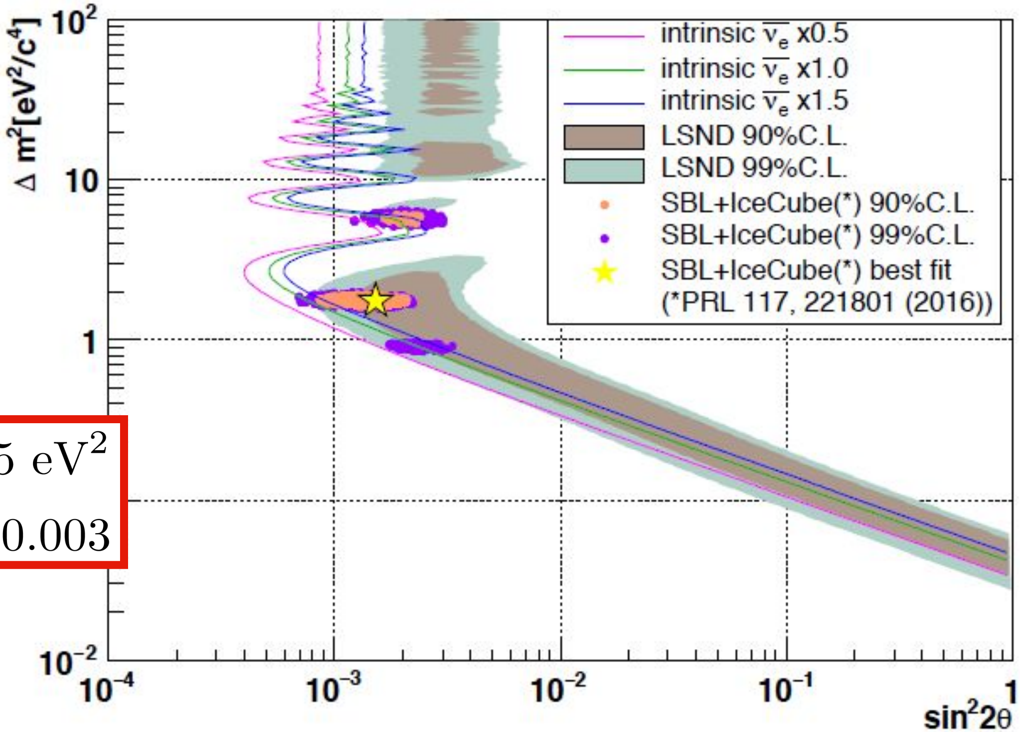
Sensitivity



$$\Delta m^2 = 1.2\ \mathrm{eV}^2$$
$$\sin^2 2\theta = 0.003$$



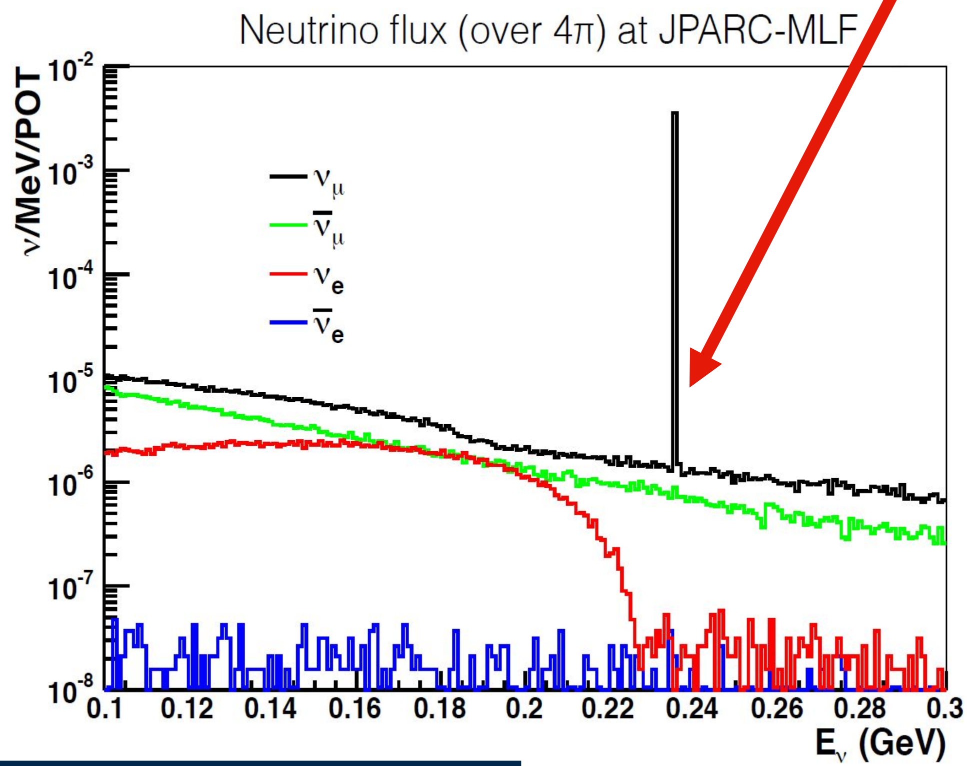
$$\Delta m^2 = 2.5\ \mathrm{eV}^2$$
$$\sin^2 2\theta = 0.003$$



5 years, 1 MW beam power, 17t fiducial.

KDAR Neutrinos

236 MeV ν_μ from $K^+ \to \mu^+ \nu_\mu$ (BR = 63.5%) decay at rest



- Can be used as a standard candle for reconstruction and cross sections near 236 MeV
- Probe the nucleus with a known energy, weak-interaction-only particle
- Measure energy transfer to test underlying nuclear models

Expected Event Rate

Detector (source)	Target (mass)	Exposure	Distance from source	236 MeV ν_μ CC events
JSNS^2 (JPARC-MLF)	Gd-LS (17 ton)	1.125×10^{23} POT (3 years)	24 m	30-60k

Timeline and Outlook

- JSNS^2 was conceived in 2013.
- The experiment received Stage 1 approval in Feb. 2015.
- Funding for construction of the first 17-ton detector received in June 2016.
- TDR submitted in May for Stage 2 approval
- Construction has already started
- First data in late 2018

TDR - arXiv:1705.08629

Questions

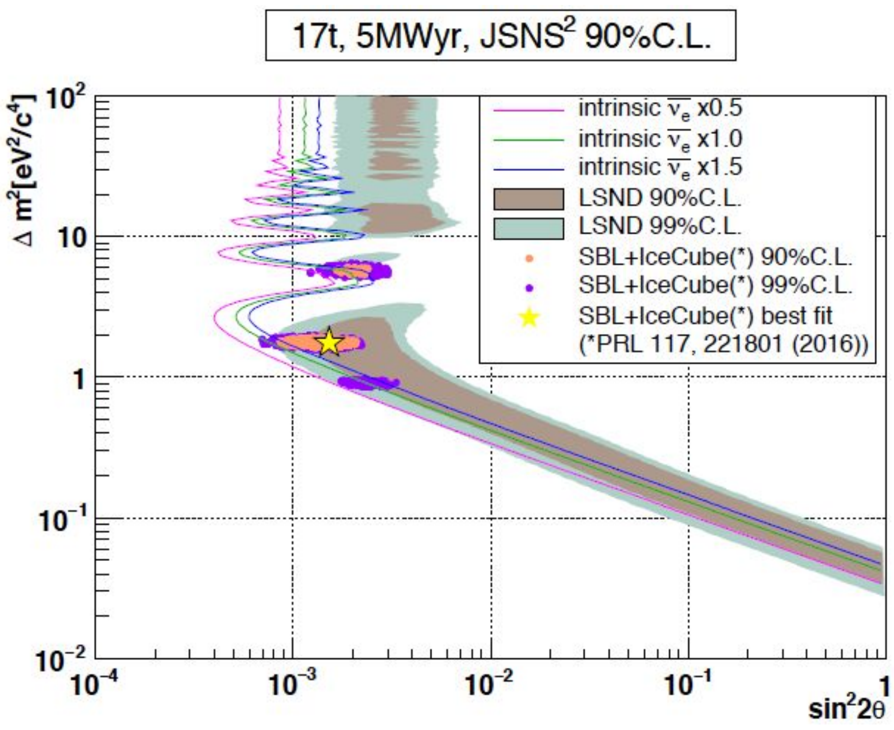
JSNS^2 Collaboration at Collaboration Meeting in May 2017

Backup

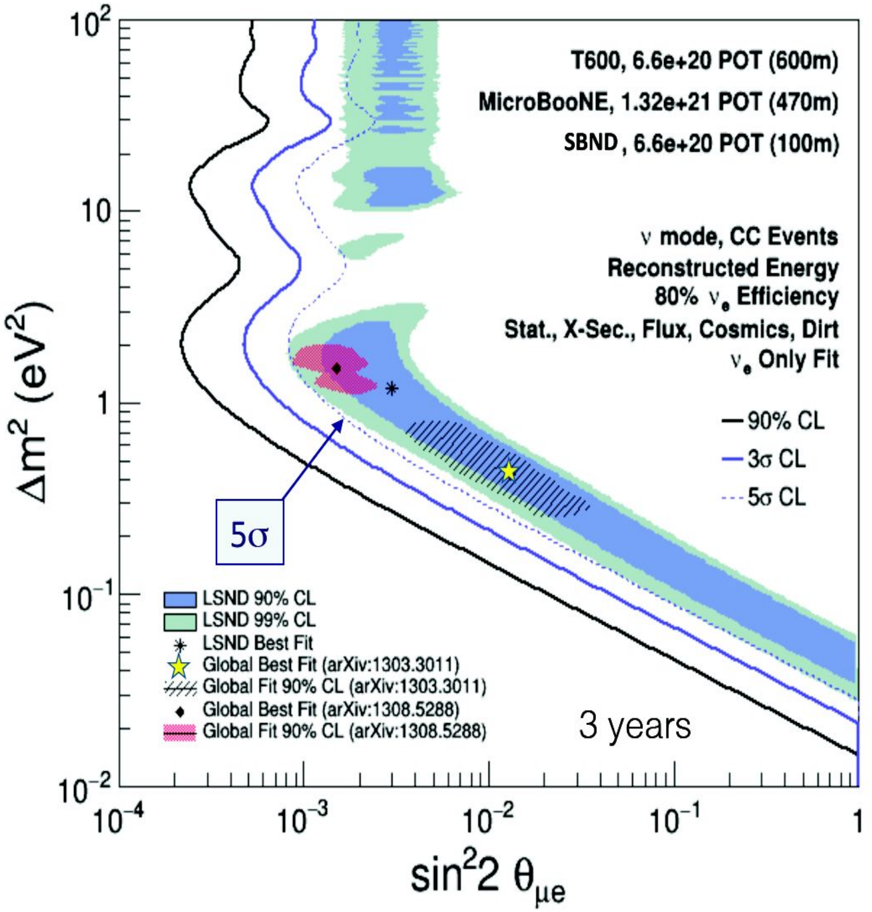
LSND Comparison

	LSND	JSNS^2	Advantage of JSNS^2
Detector Mass	167 Tons	17 Tons	
Baseline	30 m	24 m	
Beam Kinetic Energy	0.8 GeV	3.0 GeV	Allows for KDAR measurements.
Beam Power	0.056 MW	1.0 MW	Much more intense beam
Beam Pulse	600 μs, 120 Hz	80 ns (x2), 25 Hz	300 times less steady state background for IBD.
Capture Nucleus	H (2.2 MeV)	Gd (~8 MeV)	Shorter capture time, higher signal to noise ratio.

SBN Comparison



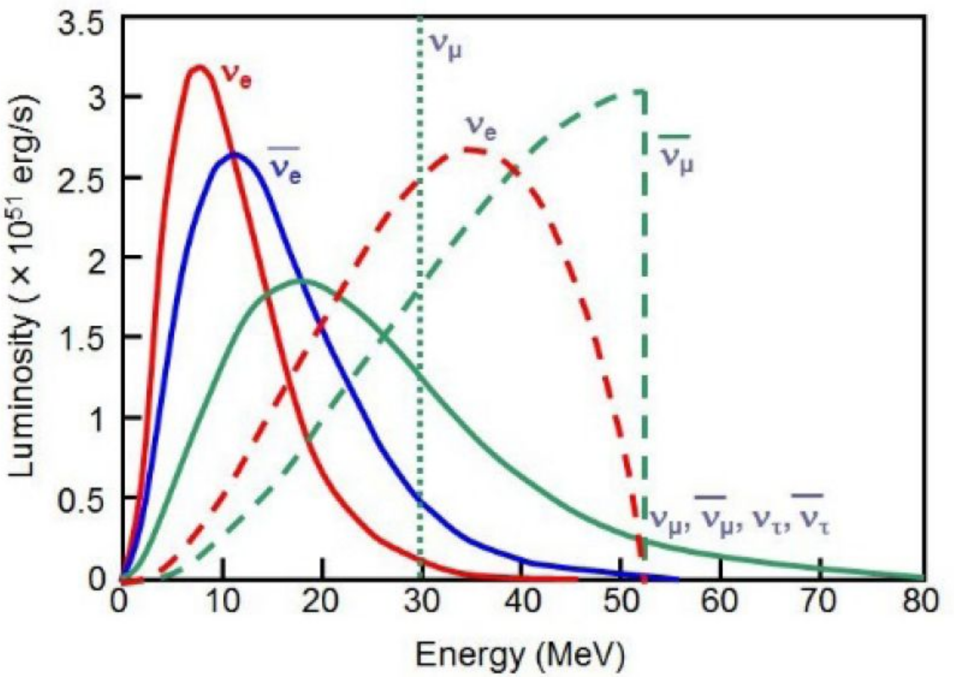
JSNS² Sensitivity Curves



SBN Sensitivity Curves

Supernova Neutrinos

- Neutrino-driven wind is important in supernova simulations
- We need to know the neutrino nucleus cross sections better
- JSNS^2 can measure the neutrino nucleus rate for neutrinos on carbon 12
- With 3 years of data, we can measure the cross section to within 6%



Decay at rest pions + muons (dashed)
Supernova neutrinos (solid)
Units of flux are arbitrary