KDAR Neutrino Measurements with JSNS²

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Poster #482

JSNS² — J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source

NEUTRINO 2020

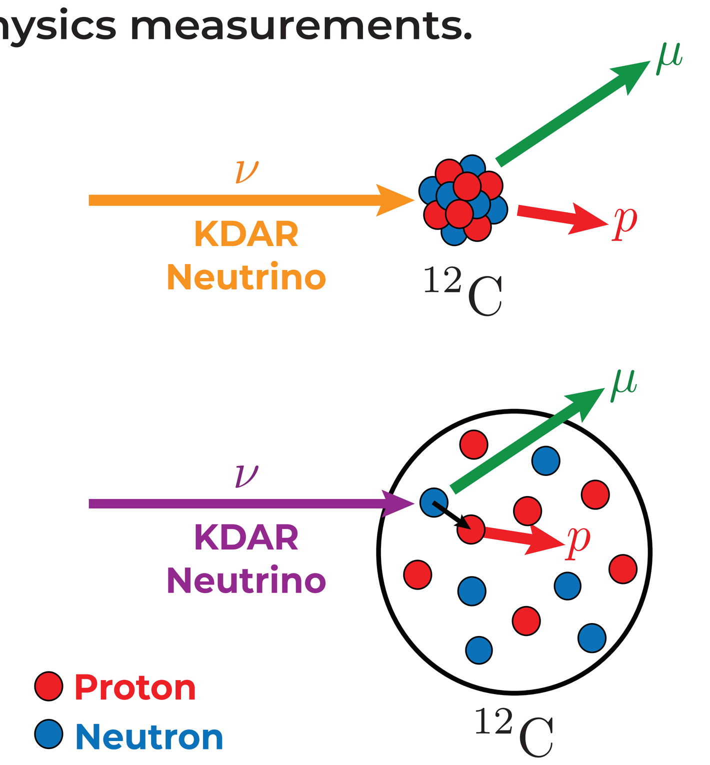
KDAR Neutrino Basics

When charged kaons decay at rest, they can produce monoenergetic neutrinos from the two-body decay:

$$K^+ \rightarrow \mu^+ + \nu_\mu \;[\mathrm{BR} = 0.636]$$

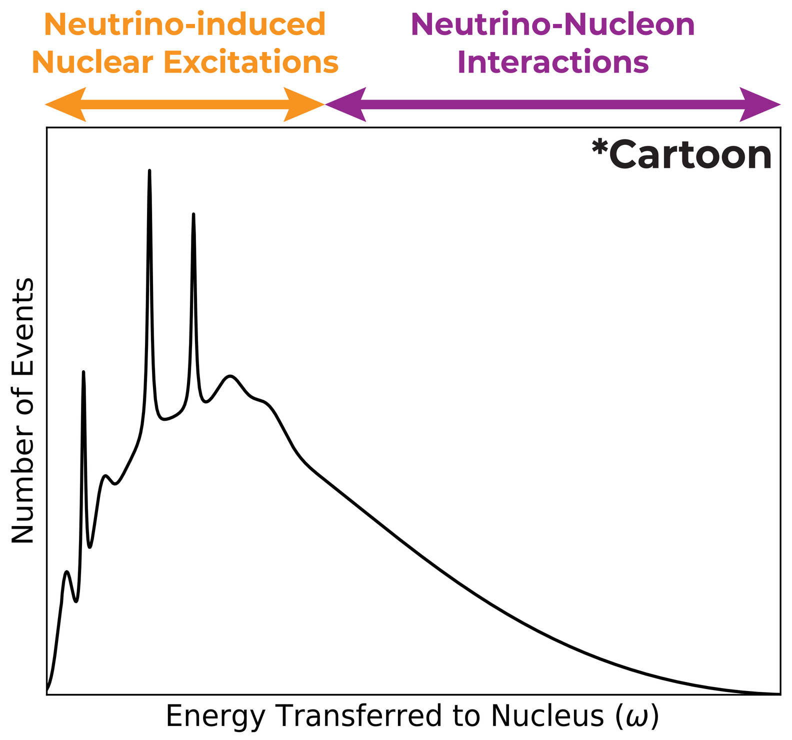
$$E_\nu = 236 \text{ MeV}$$

These known-energy kaon decay-at-rest (KDAR) neutrinos can be used to make a variety of interesting physics measurements.



KDAR neutrinos offer a **standard candle** to benchmark neutrino interaction models relevant for future oscillation experiments [1]. Their intermediate energy allows them to probe the transition between neutrino-nucleus and neutrino-nucleon scattering [2].

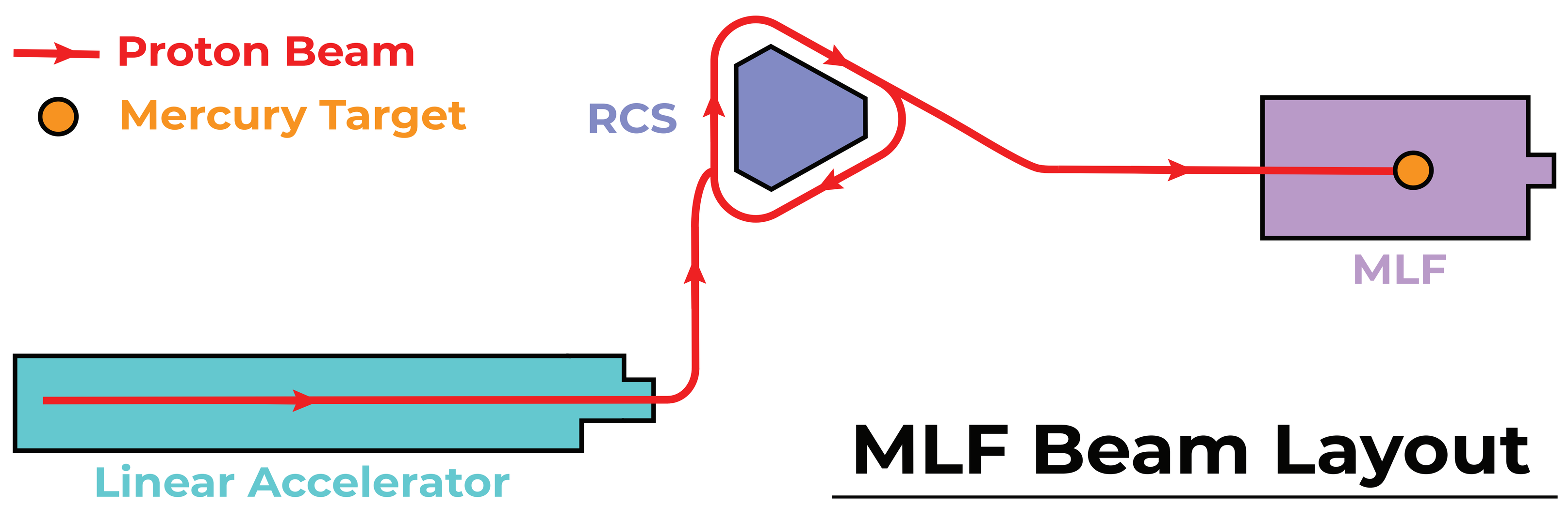
KDAR neutrinos can also be used for a variety of other measurements [3,4].



The MLF Neutrino Source

The J-PARC Material and Life Science Experimental Facility (MLF) is a spallation neutron source in Japan. A high intensity proton beam is accelerated to 3 GeV by the Rapid Cycle Synchrotron (RCS) and delivered to a liquid mercury target in the MLF. In addition to providing a world-class spallation neutron source, **the mercury target is also an intense source of decay-at-rest (DAR) neutrinos.**

The MLF design beam power is 1 MW and the beam power has been steadily increasing (in June beam power has been ~610 kW). The 3 GeV beam energy is high enough for kaons to be produced in the target where they quickly slow down and decay at rest. **This fact combined with the high beam intesnity makes the MLF the best place in the world to do physics with KDAR neutrinos.**

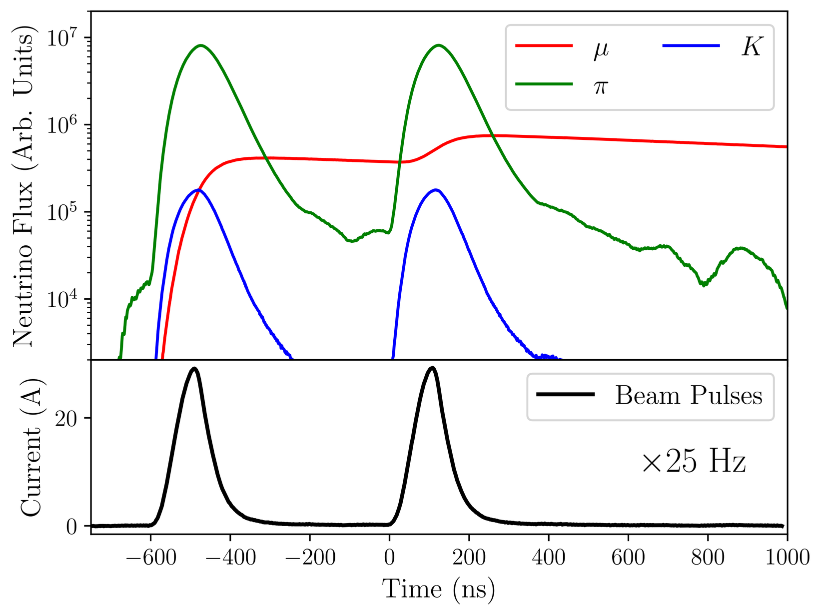


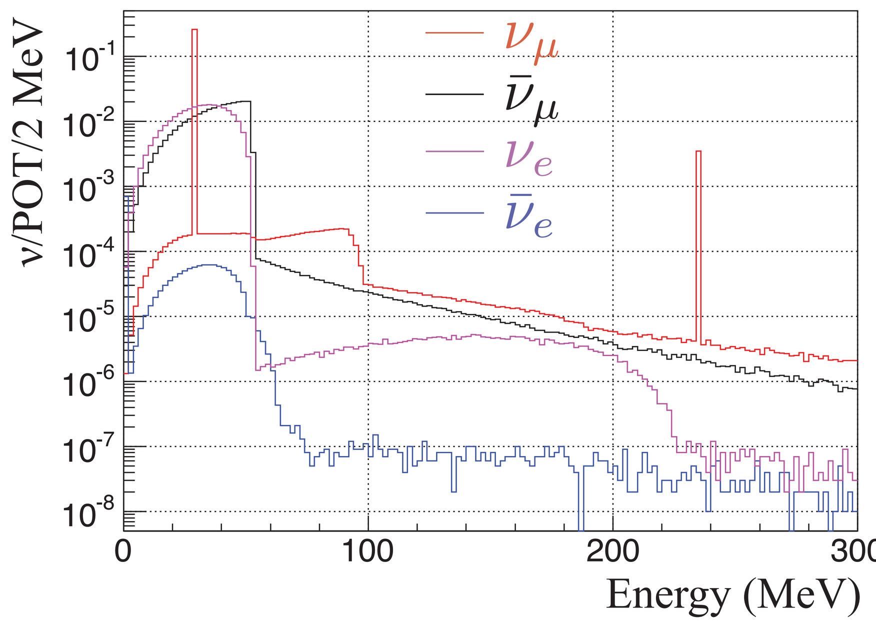
MLF Beam Layout

Neutrino Flux + Timing

Protons are delivered to the MLF at 25 Hz in two pulses. Neutrinos from kaon decays are produced in time with the beam due to the short kaon lifetime. **The low duty factor of the beam reduces beam-off backgrounds to KDAR neutrino measurements.**

Most neutrino parents decay at rest in the target and shielding, so the resulting neutrino flux largely consists of well-understood decay-at-rest components. **Thus, decay-in-flight (DIF) neutrino backgrounds to KDAR neutrinos are small.**



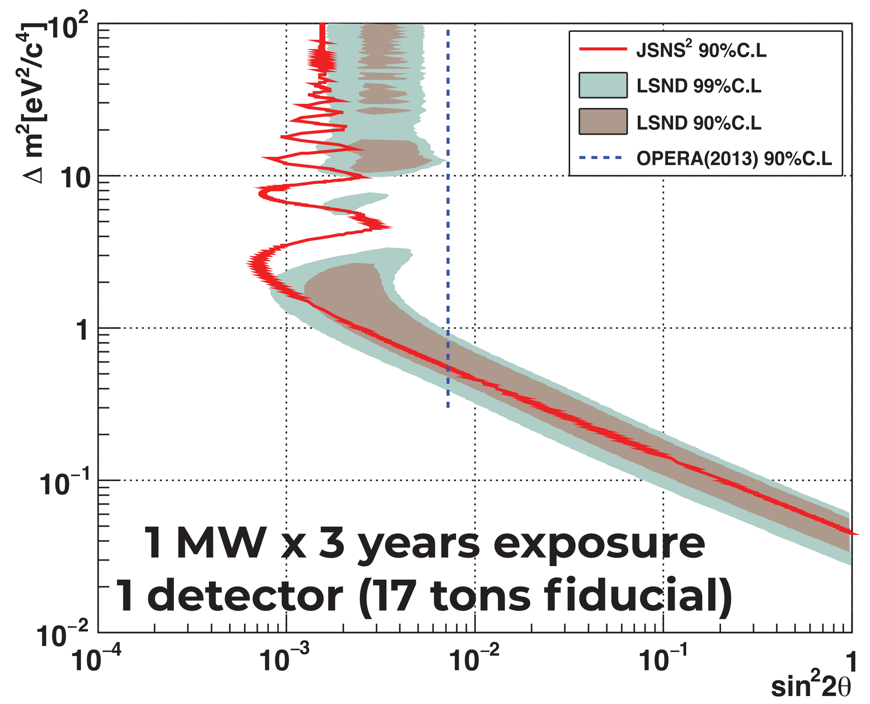


The JSNS² Experiment

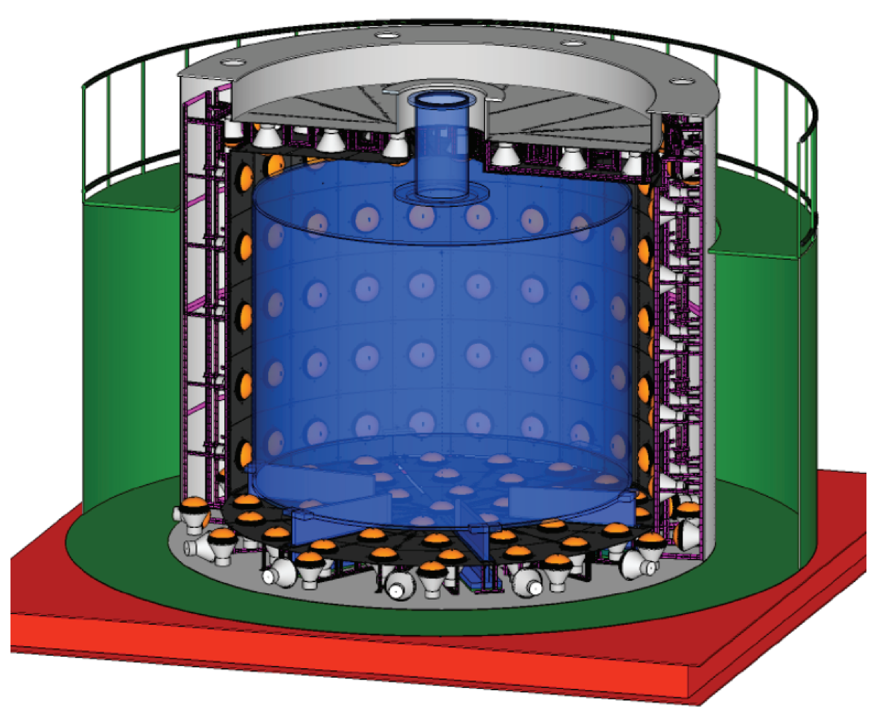
The J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source (JSNS²) [5] is a short baseline neutrino oscillation experiment. JSNS² is designed to search for

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

oscillations with $\Delta m^2 \sim 1$ eV² using the double coincidence signature of IDB (prompt positron, delayed neutron capture). **JSNS² has collected 10 days of initial data this month (expected to contain 200-400 KDAR events) and will continue operation in the fall.**



JSNS² utilizes a liquid scintillator (LS) neutrino detector consisting of an inner volume filled with gadolinium-doped LS and outer buffer and veto regions filled with undoped LS. Scintillation light is collected by 120 10-inch PMTs including 24 PMTs in the veto region used to reject activity originating outside the detector. There is additional shielding under the detector to reduce environmental gamma backgrounds produced in the concrete hatch the detector sits on.



KDAR Signatures in JSNS²

JSNS² is most sensitive to KDAR neutrino charged current interactions. In most events, **the expected event signature is a double coincidence between the initial neutrino interacion products and the subsequent muon decay** (lifetime ~2.2 μs):

Prompt $\nu_\mu + {}^{12}\mathrm{C} \rightarrow X + \mu^-$

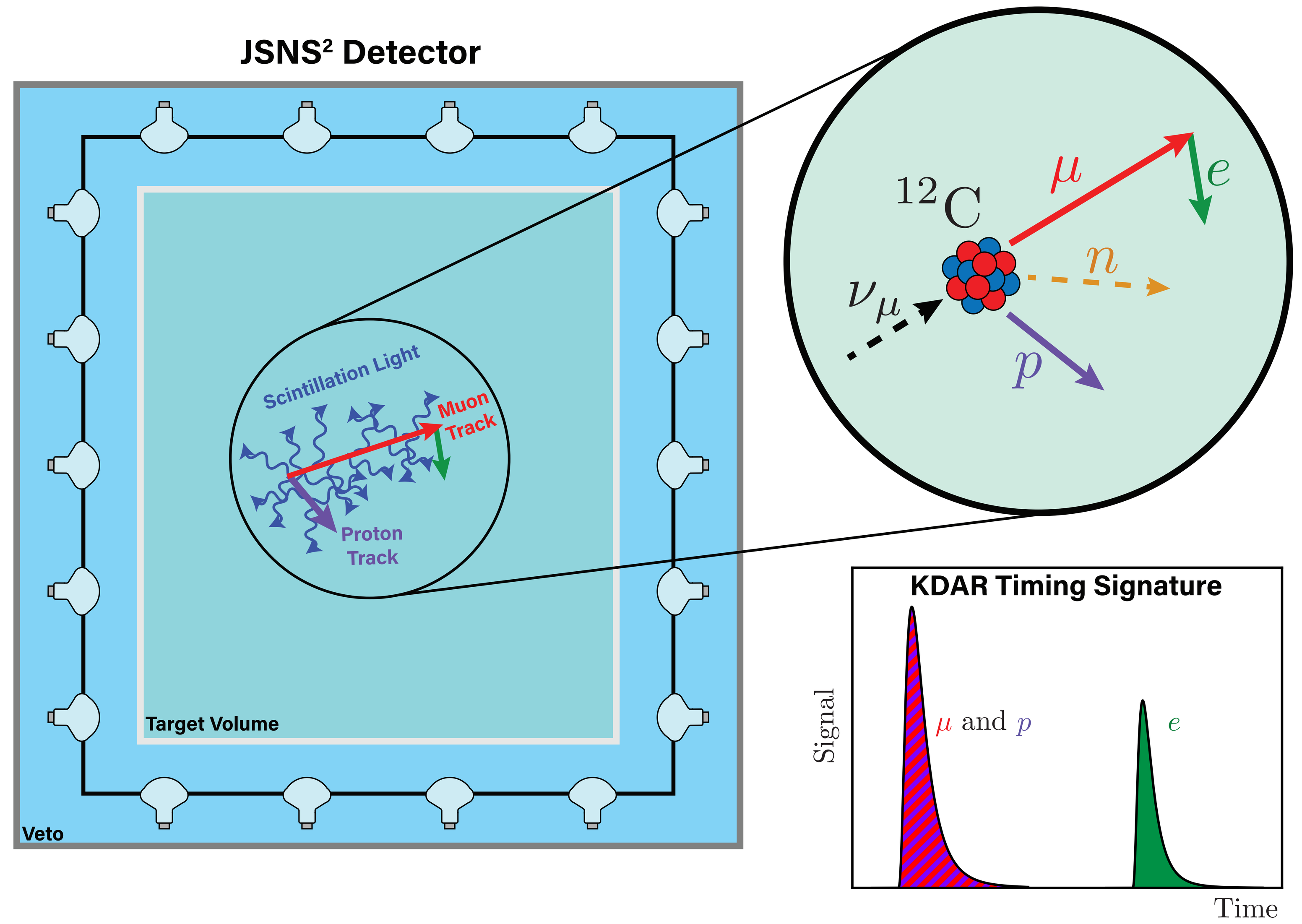
Delayed $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$

In ~20% of interactions, the final state is also expected to contain one or more neutrons which can be tagged to form a triple coincidence.

JSNS² will produce measurements of the differential KDAR neutrino interaction cross section as a function of:

- Total visible energy
- Neutron multiplicity
- Muon energy

These results will be of broad interest in neutrino interaction physics.



References + Acknowledgements

[1] A. Aguilar-Arevalo et al. (MiniBooNE Collaboration), Phys. Rev.Lett. **120**(14), 141802 (2018) arXiv: 1801.03848
[2] J. Spitz, Phys. Rev. D**89**(7), 073007 (2014), arXiv: 1402.2284
[3] C. Rott, S. In, J. Kumar and D. Yaylali, JCAP **11**,039 (2015), arXiv: 1510.00170
[4] S. Axani et. al., Phys. Rev. D**92**(9), 092010 (2015), arXiv: 1506.05811
[5] S. Ajimura et al., 2017, arXiv: 1705.08629

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Other JSNS² Posters

PMT Gain Calibration for the JSNS² Experiment (*Poster 332*)

Signal Timing Analysis from the Dry Run in the JSNS² Experiment (*Poster 444*)

Efforts for Launching the JSNS² Experiment at J-PARC (*Poster 355*)

Measurement of beam related gamma background using plastic scintillator at JSNS² (*Poster 332*)

The Design and Development of the JSNS² DAQ Upgrade (*Poster 367*)