A Monoenergetic Neutrino Source from Kaon Decay at Rest

Rory S. Fitzpatrick

Reconstructing neutrino energies is a challenge for all neutrino experiments with any source. We examine the advantages of identifying monoenergetic neutrino sources such as decay-at-rest kaons and pions and discuss a recent observation of 236 MeV muon neutrinos in the MiniBooNE detector and the prospects of future measurements.

Typically, neutrino experiments can only reconstruct neutrinos energies with resolution $\Delta E/E \sim 25\%$.

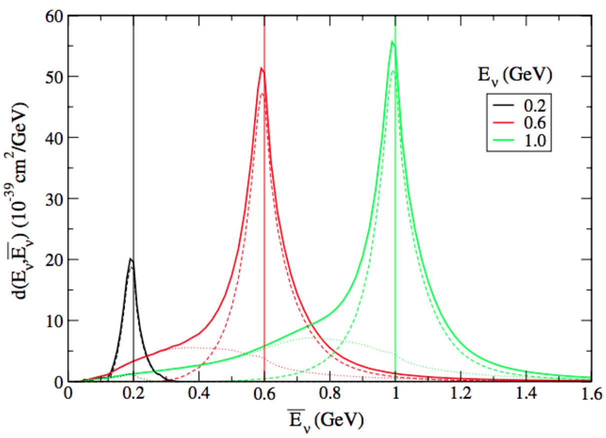

FIG. 1. Simulated neutrino energy resolutions at 200 MeV, 600 MeV and 1 GeV. Figure 1 in [7].

Charged kaons decay to a muon and muon neutrino ($K^+ \to \mu^+\nu_\mu$) 63.6% of the time. Since this is a two-body decay, if the kaon decays at rest, simple kinematics dictate that the outgoing muon neutrino must have an energy of 236 MeV. Monoenergetic neutrino sources are unprecedented and a kaon decay at rest source could vastly improve our understanding of neutrino-nucleus interactions and provide a standard candle for energy reconstruction in the 100s of MeV energy regime [3]. This neutrino could also be used as a probe for a high-Δm^2 oscillation [1, 2], for precision measurements of the strange spin component of the nucleon Δs [3] and as a possible signature for dark matter annihilation in the sun [4, 5].

Pion decay at rest also results in a monoenergetic neutrino source at 29.8 MeV, but this is below the charged current threshold and thus a less effective probe.

It is difficult to model the outgoing muon spectrum when a KDAR neutrino interacts because the energy region is such that the impulse approximating breaks down. Figure 2 shows the predictions from several neutrino generators and illustrates the degree to which the spectrum remains elusive. A measurement of the spectrum could constrain the model space and improve our understanding of neutrino-nucleus interactions.

kdar at miniboone

future of kdar neutrinos

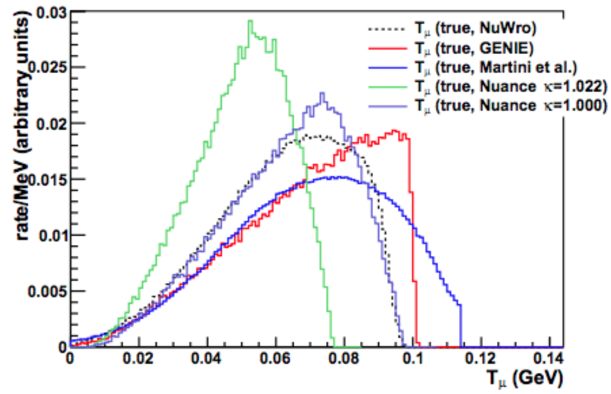

FIG. 2. A number of predictions for the outgoing muon energy when a 236 MeV muon neutrino interacts in the MiniBooNE detector (carbon target). Clearly, there are dramatic variations in both shape and normalization predicted by the different generators.

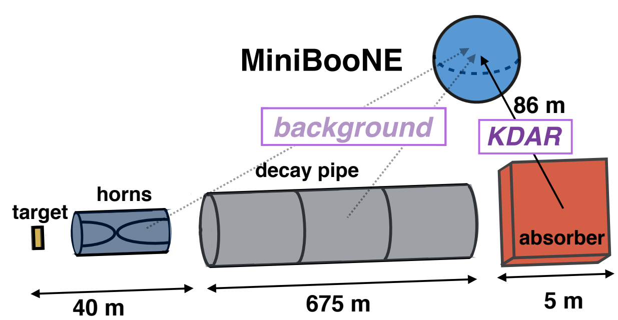

FIG. 3. CAPTION

The error on the MiniBooNE result is statistics dominated and cannot rule out any current models. However, this measurement will be further constrained by a measurement from MicroBooNE, which can also detect KDAR neutrinos from the NuMI beam dump, and by the JSNS^2 experiment. The expected rates for all current and upcoming KDAR results are listed in Table .

[1] J. Spitz, Phys. Rev. D **85** 093020 (2012).
[2] S. Axani, G. Collin, J.M. Conrad, M.H. Shaevitz, J. Spitz, T. Wongjirad, Phys. Rev. D **92** 092010 (2015).
[3] J. Spitz, Phys. Rev. D **89** 073007 (2014).

Experiment	Exposure (POT)	Distance from source (m)	236 MeV ν_μ events
MiniBooNE	2.62×10^{20} (1 year)	86 m	3500 ± 1500
MicroBooNE	1.2×10^{21} (2 years)	102 m	2300
JSNS^2	1.125×10^{23} (3 years)	24 m	30-60k

TABLE I. A summary of experiments that can detect KDAR neutrinos and the event rates expected.

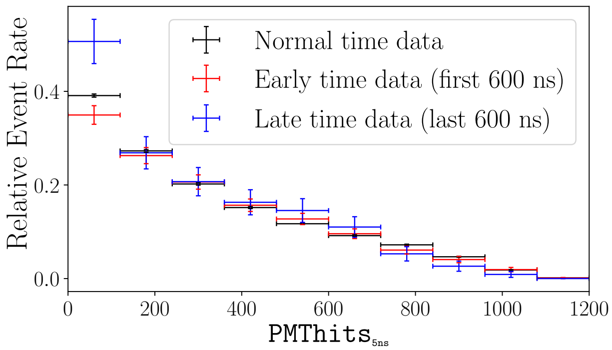

FIG. 4. CAPTION

[4] C. Rott, S. In, J. Kumar, and D. Yaylali, J. of Cosmology and Astroparticle Physics **11** 039 (2015).

[5] C. Rott, S. In, J. Kumar, and D. Yaylali, arXiv:1710.03822 [hep-ph].

[6] V. Pandey, N. Jachowicz, T. Van Cuyck, J. Ryckebusch, and M. Martini, Phys. Rev. C **92** 024606 (2015).

[7] M. Martini, M. Ericson, and G. Chanfray, Phys. Rev. D **87** 013009 (2013).