First Results from KamLAND: Evidence for Reactor Anti-Neutrino Disappearance

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KamLAND has been used to measure the flux of $\bar{\nu}_e$'s from distant nuclear reactors. In an exposure of 162 ton·yr (145.1 days) the ratio of the number of observed inverse β-decay events to the expected number of events without disappearance is $0.611 \pm 0.085(\text{stat}) \pm 0.041(\text{syst})$ for $\bar{\nu}_e$ energies > 3.4 MeV. The deficit of events is inconsistent with the expected rate for standard $\bar{\nu}_e$ propagation at the 99.95% confidence level. In the context of two-flavor neutrino oscillations with CPT invariance, these results exclude all oscillation solutions but the 'Large Mixing Angle' solution to the solar neutrino problem using reactor $\bar{\nu}_e$ sources.

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The primary goal of the Kamioka Liquid scintillator Anti-Neutrino Detector (KamLAND) experiment [1] is a search for the oscillation of $\bar{\nu}_e$'s emitted from distant power reactors. The long baseline, typically 180 km, enables KamLAND to address the oscillation solution of the 'solar neutrino problem' using reactor anti-neutrinos under laboratory conditions. The inverse β-decay reaction, $\bar{\nu}_e + p \rightarrow e^+ + n$, is utilized to detect $\bar{\nu}_e$'s with energies above 1.8 MeV in liquid scintillator (LS) [2]. The detection of the e^+ and the 2.2 MeV γ-ray from neutron capture on a proton in delayed coincidence is a powerful tool for reducing background. This letter presents the first results from an analysis of 162 ton·yr of the reactor $\bar{\nu}_e$ data.

KamLAND is located at the site of the earlier Kamiokande [3], with an average rock overburden of 2,700 m.w.e. resulting in 0.34 Hz of cosmic-ray muons in the detector volume. As shown in Fig. 1, the neutrino detector/target is 1 kton of ultra-pure LS contained in a 13-m-diameter spherical balloon made of 135-μm-thick transparent nylon/EVOH (Ethylene vinyl alcohol copolymer) composite film. The balloon is supported and constrained by a network of kevlar ropes. The LS is 80% dodecane, 20% pseudocumene (1,2,4-Trimethylbenzene), and 1.52 g/liter of PPO (2,5-Diphenyloxazole) as a fluor. A buffer of dodecane and isoparaffin oils between the balloon and an 18-m-diameter spherical stainless-steel containment vessel shields the LS from external radiation. During the filling procedure a water extraction and nitrogen bubbling method [4], optimized for KamLAND, was used to purify the LS and buffer oil; PPO prepurification was especially important.

Solar Neutrino Measurements

	measured	SSM prediction
37Cl	2.56 ± 0.23	$7.6^{+1.3}_{-1.1}$ SNU
71Ga	$74.8^{+5.1}_{-5.0}$	128^{+9}_{-7} SNU
SK	$2.35 \pm 0.02 \pm 0.08$	$5.05^{+1.01}_{-0.81}$
DN	$2.1 \pm 2.0^{+1.3}_{-1.2}$	0%
SNO CC	$1.76^{+0.06}_{-0.05} \pm 0.09$	$5.05^{+1.01}_{-0.81}$
ES	$2.39^{+0.24}_{-0.23} \pm 0.12$	$5.05^{+1.01}_{-0.81}$
NC	$5.09^{+0.44}_{-0.43}{}^{+0.46}_{-0.43}$	$5.05^{+1.01}_{-0.81}$
DN CC	$14.0 \pm 6.3^{+1.5}_{-1.4}$	0%
DN ES	$-17.4 \pm 19.5^{+2.4}_{-2.2}$	0%
DN NC	$-20.4 \pm 16.9^{+2.4}_{-2.5}$	0%

SNO NC provided direct evidence of neutrino oscillation.
Extracted $\phi_{\mu\tau} = 3.41^{+0.66}_{-0.64}$ is 5.3σ above zero.

Combining all results LMA is favored at ~3σ level.

KamLAND can verify the LMA with man-made reactor neutrinos.