Full-Volume Calibration in the KamLAND Detector

K.M. Heeger, S.R. Abbott, J.M. Aytac, B.E. Berger, F.S. Bieser, S.J. Freedman, M.L. Galloway, F.E. Gray, K.-B. Luk, J.B. Meyer, Y. Minamihara, H.M. Steiner, and D.L. Syversrud for the KamLAND Collaboration

The Kamiokande Liquid Scintillator Anti-Neutrino Detector (KamLAND) has measured the flux of anti-neutrinos from nearby nuclear power plants in Japan and made the first observation of the disappearance of reactor $\overline{\nu}_e$ [1]. The observed deficit in the reactor neutrino flux at KamLAND is consistent with the hypothesis of neutrino oscillation, and the oscillation parameters are in agreement with the large-mixing-angle MSW solution to the solar neutrino problem [2]. The energy spectrum of the first data published by KamLAND [1] shows clear evidence for neutrino disappearance. However, spectral distortions as a unique signature of neutrino oscillation have not been observed yet. In 2003 KamLAND continued data taking and improved on the statistics of its data set. KamLAND's primary physics goals are the search for distortions in the $\overline{\nu}_e$ energy spectrum and a precise measurement of the $\overline{\nu}_e$ oscillation parameters. KamLAND's observation of reactor $\overline{\nu}_e$ at a characteristic, average distance of $L = 180$ km gives it unique sensitivity to the oscillation frequency $\Delta m^2_{12} L/E$ and allows us to make the best measurement of Δm^2_{12}, one of the two splittings in the mass spectrum of active neutrinos.

With improved statistics KamLAND's observation of reactor anti-neutrinos will be systematics limited and improved calibrations are required to fully exploit KamLAND's physics potential. Full-volume calibrations will also be critical to a successul first direct measurement of the ^{7}Be solar neutrino flux during the proposed next phase of the KamLAND experiment. Off-axis calibrations will allow us to test KamLAND's energy response $E(r, \theta, \phi)$ as well as the reconstruction characteristics $R_{fit}(E, r, \theta, \phi)$ as a function of position and energy inside the active detector volume. At present KamLAND is calibrated using data from ^{68}Ge, ^{65}Zn, ^{60}Co, and Am-Be sources deployed along the central z-axis of the detector as well as the characteristic signatures of spallation products and neutron capture on protons and ^{12}C [1].

In 2003 a novel calibration system based on the idea of an off-center calibration pole was designed and prototyped. Construction of the system began in early 2004. [3]. The system uses a segmented titanium pole of variable length with a calibration source attached to its end. The pole is assembled inside the glovebox and lowered into the central detector region with two control cables. The system is designed for deployment through the glovebox which provides access to the inner detector region. The calibration pole provides excellent source positioning in θ and $\vec{r}$ to an accuracy of < 2 cm. Figure 1 shows an illustration of the system and the KamLAND detector. Figure 2 illustrates the deployment sequence of the off-axis calibration pole. This new calibration system is currently being assembled and tested at Berkeley and will be commissioned in the KamLAND detector in late 2004. The installation of this calibration system is the last major hardware upgrade to the detector in the current phase of the reactor neutrino measurement with KamLAND.

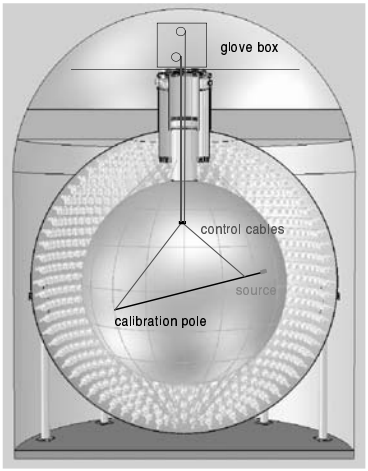

FIG. 1: Schematic of the 4π off-axis calibration system for the KamLAND detector. Calibration sources can be positioned inside the entire detector volume using a segmented titanium pole and two control cables.

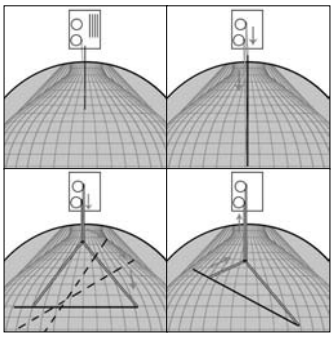

FIG. 2: Deployment sequence for the KamLAND 4π calibration source manipulator.

[1] K. Eguchi et al. (KamLAND Collaboration), Phys.Rev.Lett.**90**:021802 (2003)
[2] For example: J.N. Bahcall, M.C. Gonzalez-Garcia, and C. Pena-Garay, JHEP 02 (2003) 009
[3] http://kamland.lbl.gov/4pi/