The 21 Century COE Project

Exploring New Science by Bridging Particle-Matter Hierarchy

Short-term Foreign Researchers

Research Report

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Your Stay Period in Japan: From March 15, 2004 to March 31, 2004

Title of Research in Japan:

Off-axis calibration of the KamLAND reactor antineutrino detector

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Please write a research report of one or more pages and submit it with this cover to your host researcher till the end of this March.

Off-axis calibration of the KamLAND reactor antineutrino detector

F.E. Gray, University of California, Berkeley
for the KamLAND Collaboration

The KamLAND detector measures neutrino mixing parameters by observing electron-type antineutrinos from nuclear power reactors around Japan at an average baseline distance of approximately 180 km. The detector consists of 1000 tons of liquid scintillator suspended in a transparent balloon in a tank of mineral oil and observed by 1879 photomultipliers. It is located at a depth of 2700 meters water-equivalent in the Mozumi mine of the Kamioka Mining and Smelting Company.

An understanding of the response of the detector to antineutrino signals is gained by suspending calibration sources containing slightly radioactive material inside the detector. Currently, these sources are deployed by attaching them to a cable and lowering them along the *z*-axis of the detector, in the center of the balloon. This method is simple, reliable, and safe, but it only permits the source to be placed at central points, for which the response of the detector may not be entirely typical. Consequently, an off-axis deployment system is being developed. This "4π" system will allow us to understand the response of the detector throughout its fiducial volume, potentially allowing a significant improvement in the systematic uncertainties of the KamLAND measurement. It consists of a segmented rod that will be held inside the detector by two cables, one attached to each end. A "pivot block" will hold the cables together at a point so that they are parallel through the narrow neck of the detector (see Figure 1). A calibration source containing a small activity of, for instance, cobalt-60 will be attached to one end of the rod. The position of the source within the detector can be varied by raising and lowering the two cables using computer-controlled servo motors. The control system which drives these motors is responsible for the correct positioning of the source and also for the safety of the detector; it must not permit the 4π system to approach forbidden zones near the delicate nylon balloon that holds the liquid scintillator. In order to enforce these constraints, the lengths of the cables will be monitored by encoder pulleys, which will be constantly cross-checked by depth measurements from pressure transducers mounted on the pole. As an additional method to confirm the position of the pole, LEDs will be mounted on it. When desired, the LEDs can be remotely activated and observed by CCD cameras in the detector.

During the visit to the KamLAND site in Japan that was supported by this fund, development work was performed for the 4π system, which is being constructed in Berkeley for installation in Japan later this year. A test of a new readout system for the CCD cameras was performed, in which the LEDs mounted on the periphery of the detector were imaged. Plans were made for the physical location and cabling of the control and monitoring hardware. Measurements of the bolt pattern of the face of the glovebox at the top of the detector chimney were made, in order to facilitate the construction of a new glovebox face optimized for the 4π system.

One of the largest systematic uncertainties in the KamLAND measurement is the fiducial volume, which will be defined by a cut at 5.5 m on the reconstructed radial position of each event. This fiducial volume is quantified by measuring the distribution of the spallation products of cosmic ray muons within the detector. The ratio of the number of such products inside and outside the fiducial radius is constructed and compared with the expected ratio determined from the detector geometry. Currently, the accuracy with which spallation products can be constructed is limited by our understanding of the behavior of the electronics following the muon signal, which is several orders of magnitude larger than a typical neutrino interaction or radioactive decay event. Consequently, a test was performed to systematically measure the number of available electronics channels as a function of time after a muon, in order to build a model of the dataflow through the electronics and data acquisition system that may permit the spallation product distribution to be determined more accurately.

In addition to performing these studies, an eight-day shift was taken to monitor the normal operation of the KamLAND detector.

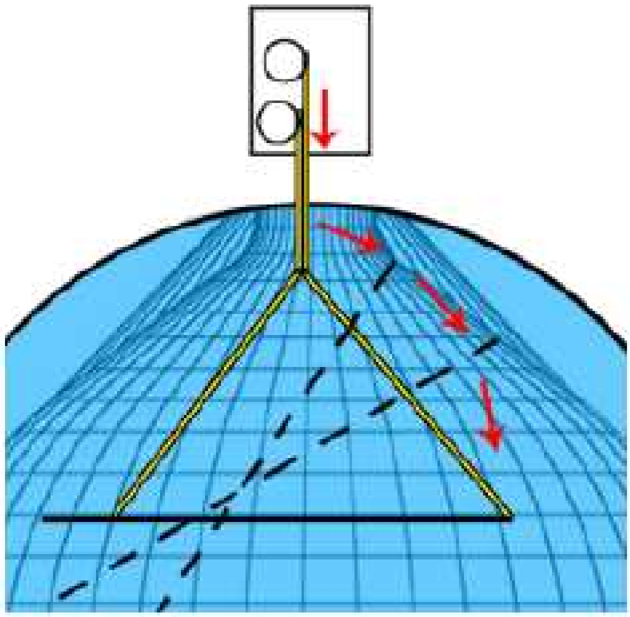

Figure 1: Method of operation of the 4π calibration system. The pole will first be assembled in the glovebox at the top of the detector, then lowered in a vertical orientation through the neck. Once near the center of the detector, it will be rotated through a variety of angles at which calibration runs will be taken. (Image reproduced from the 4π Design Report.)