KamLAND Detector Simulation

L. Hsu[1] for the KamLAND Collaboration

[1]*Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720*

KamLAND GEANT4 Simulation (KLG4sim) is the full-detector Monte Carlo simulation for KamLAND. The code was originally designed and written by various members of the KamLAND collaboration, with significant contributions from the Caltech and Tohoku groups. It contains detailed geometry and material descriptions specific to the KamLAND detector. It is build primarily off the GEANT4 toolkit [1], but also contains a number of custom-written physics processes intended to optimize the accuracy of the simulated KamLAND detector response. These include:

- Optical Propagation: Scintillation, elastic scattering, and reemission are modeled by individually tracking each optical photon and applying these processes as the photon propagates through the detector.
- PMT Model: Reflection, refraction and transmission at the photocathode boundary.
- Neutron Diffusion and Capture: Simplified tracking and capture of thermal neutrons

All other physics processes are modeled with GEANT4. An additional feature specific to KLG4sim is a torus-stack geometry class that allows the user to construct non-standard shapes such as a PMT glass envelope.

KLG4sim has been used in the past to understand vertex and energy reconstruction in KamLAND. With the goal of reducing systematic uncertainty in future KamLAND reactor measurements, it is now a priority to improve the simulation to the point where it can be uses as a tool for detailed systematic studies. In particular, one specific short-term goal is to verify KLG4sim with calibration data from the soon-to-be-installed full-volume calibration device (KamLAND 4π). Once good agreement between data and KLG4sim is achieved, the Monte Carlo can be used to cross-check fiducial volume and reconstruction efficiencies. Additionally, KamLAND will soon attempt a measurement of the Be^7 neutrino flux from the Sun. This measurement will require good understanding of backgrounds, and KLG4sim is a useful tool for predicting expected background levels in this future analysis.

Detailed verification and comparison of the simulation with the real detector response is ongoing. Much progress has been made in the past year. Attempts to verify the algorithms and material descriptions that govern optical propagation through the liquid scintillator show relatively promising results. Optical parameters were tuned within measured uncertainties to give the proper light output and photon arrival times. Once good agreement in the basic detector responses was achieved, the simulation was upgraded to produce output that allowed for application of the identical energy and vertex reconstruction used on the real KamLAND data. Comparisons with KLG4sim and data at various points along the z-axis show good agreement (Fig. 1 and Fig. 2).

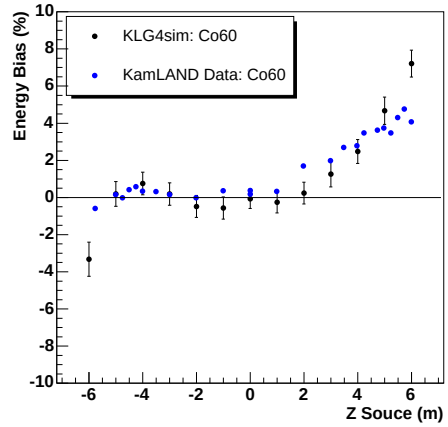

FIG. 1: Data/KLG4sim comparison for energy reconstruction along the z axis using Co60 calibration data. Bias is defined as reconstructed minus true.

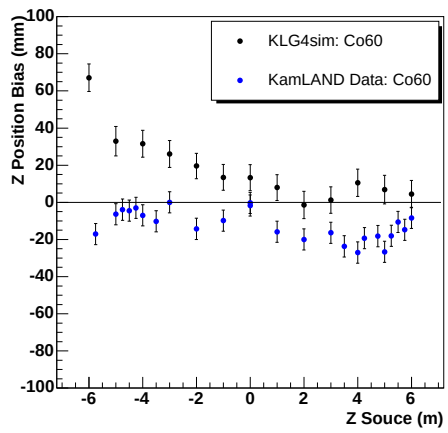

FIG. 2: Data/KLG4sim comparison for vertex reconstruction along the z axis using Co60 calibration data. Bias is defined as reconstructed minus true.

These studies are far from complete, and improvements are needed in the following areas:

- Implementation of a detailed signal readout simulation (Esim)
- Reproducing light yield versus energy, which currently shows 5% disagreement with data
- Improving simulation of detector response, currently optimized only for MeV energy deposits, to high energy (GeV) muons.

[1] S. Agostinelli et al, NIM A **506**, 250 (2003).