Nuclear Science Division Newsletter

In this issue: August, 2011

A new focal plane detector for the Berkeley Gas-Filled Separator

The Berkeley Gas-filled Separator (BGS) is used at the LBNL 88-Inch Cyclotron for experiments on the production and decay of heavy element isotopes. Recent experiments at the BGS have focused on producing superheavy elements (SHE) in ^{48}Ca irradiations of actinide targets [Stavsetra et al., Phys. Rev. Lett. 103, 132502 (2009), Ellison et al., Phys. Rev. Lett. 105, 182701 (2010)] and studying the nuclear structure of nuclides near ^{254}No by observing the decay of K-isomers [Clark et al., Phys. Lett. B 690, 19 (2010), Jeppesen et al. Phys. Rev. C 80, 034324 (2009), Jeppesen et al., Phys. Rev. C. 79 031303(R) (2009), Berryman et al, Phys. Rev. C 81, 064325 (2010)].

These experiments require the detection of several types of radiation: recoiling heavy ions (*recoils*), alpha decays (α), conversion electrons (*c.e.*), spontaneous fissions (*SF*) and their associated gamma rays (γ). A new focal plane detector is being built to increase the detection efficiency in these experiments.

The new BGS focal plane detector is constructed in the shape of the corner of a cube on the inside of a pyramid-shaped vacuum window. The vacuum window protrudes out the back side of the detector chamber, allowing placement of three high purity germanium clover γ-ray detectors directly behind. The new detector system has been named CCC, representing certain permutation of clover-cube-corner. Simulations show that the new detector will increase the efficiencies for the detection of *recoils* (e$_{recoil}$ = 87%), α decays (e$_\alpha$=91%), *c.e.* (e$_{c.e.}$=75%), and γ decays (eγ_{122keV}=30%, eγ_{900keV}=7.5%). An experiment planned for 2012 will make a positive identification of the SHE's atomic number by detecting in coincidence the characteristic K *x*-rays and α decays. Compared to the old large-area position-sensitive Si detector focal plane array, the new CCC detector will result in 3-fold efficiency increase for these triple *recoil-α-x*-ray correlations. For K-isomer experiments, in which *recoil-c.e.*-γ-α quadruple correlations are measured, the CCC detector will improve the efficiency 6-fold compared to that for the small Double-Sided-Silicon-Detector (DSSD) system used in previous experiments.

Figure: Test configuration of the CCC

The CCC detector with updated acquisition electronics will provide a larger dynamic range (from 50 keV to 300 MeV) for detection of events from low-energy *c.e.* to high-energy spontaneous fission. An additional benefit is the increased pixel count (3072 pixels in the focal plane), which will minimize the per-pixel background rate, thereby allowing searches for longer-lived chains of correlated events. The CCC, acquisition electronics, acquisition software, and analysis software will be ready for the GRETINA@BGS campaign beginning in early September 2011.

A short video clip of a 3D model showing the detector geometry can be found at the link below.

http://tinyurl.com/nsd-ccc

KamLAND Geoneutrino Measurement Constrains Geothermal Models

If you descend more than ~20 m below the surface of the Earth, the warmth you feel does not come from the Sun, but from the interior of the Earth itself. While residents of earthquake-prone regions like the Bay Area may be familiar with some of the manifestations of that heat, its source remains largely unknown. Several years ago, the KamLAND experiment, demonstrated that at least some of that heat must be generated by naturally occurring radioactivity throughout the Earth's interior by observing the antineutrinos emitted in those decays (called "geoneutrinos"). Now, updated results by KamLAND [A. Gando et al., Nature Geoscience, doi:10.1038/ngeo1205 (2011)], with contributions by the NSD's Tom Banks, Thomas Bloxham, Jason Detwiler, Stuart Freedman, Brian Fujikawa, Ke Han, and Tommy O'Donnell, show that radioactivity cannot be the Earth's only heat source: it only accounts for about half of it.

In KamLAND's landmark neutrino oscillation measurement, geoneutrinos posed an irreducible and largely unconstrained background. In the present geoneutrino measurement, shown in the figure, it is the reactor antineutrinos that are the dominant background. Geoneutrinos are distinguished from their reactor counterparts and other backgrounds by their energy spectrum, and by the fact that their flux is constant over time.
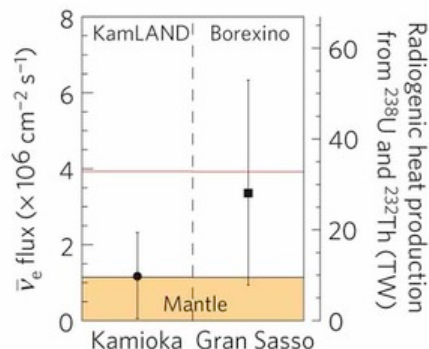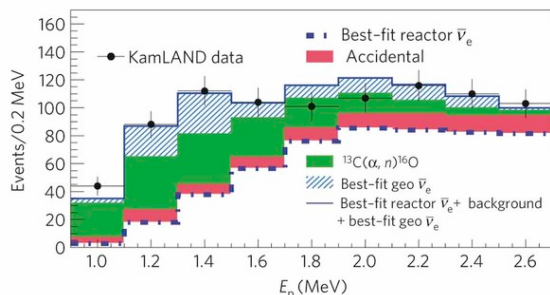
Left: Prompt energy spectrum of coincidence events in KamLAND (data points) fit to a sum of geoneutrinos, reactor antineutrinos, $^{13}C(\alpha, n)^{16}O$ backgrounds, and accidental coincidences. Right: Geoneutrino flux measurements and corresponding radiogenic heat production measured by KamLAND and Borexino after subtracting crust contribution.

While initial efforts focused on whether geoneutrinos could be observed at all, we are now beginning to be able to use geoneutrinos to test radiogenic heat models of the Earth. Uranium and thorium are expected to be more highly concentrated in the crust than in the mantle. Subtracting off the expected contribution from the crust, KamLAND measures a geoneutrino flux from the mantle consistent with a partially-radiogenic heat model, but inconsistent with a fully-radiogenic model in which radiation supplies the full 44 TW of heat flow revealed by calorimetric borehole measurements (see the figure).

Future geoneutrino measurements in multiple locations could reveal much more about the interior of the Earth. KamLAND lies on the Pacific Rim at the border between continental and thinner oceanic crust, while another geoneutrino detector in Italy, Borexino, is surrounded by continental crust only. Measurements from such geologically distinct regions may eventually allow the individual U and Th concentrations in the mantle and crust to be determined experimentally.

2011 KamLAND Full Volume Calibration Campaign

KamLAND is a large (1 kiloton) neutrino detector located in Kamioka, Japan that studies artificial neutrinos from commercial nuclear power reactors and naturally occurring neutrinos from the Earth, the Sun, and other sources. The position and energy scale calibration of KamLAND is performed through the placement of radioactive sources at known positions within KamLAND. The placement of these sources along the central axis of KamLAND is performed by a simple device that resembles a "fishing" line and it is a relatively straightforward procedure that is frequently executed. However, due to the spherical shape of KamLAND, the deployment of calibration sources off of the central axis is very challenging. This challenge is multiplied several fold when the risks of possible damage and the introduction of contaminants are considered. LBNL developed and built a computer controlled device that employs cables with a straight titanium pole to safely deploy calibration sources off-axis [B. E. Berger, et al., JINST 4, P04017 (2009)]. This device, which was first deployed in 2006, requires significant time and effort to operate due to the detector safety requirements.

Starting from early June 2011, a team from NSD: Tom Banks, Stuart Freedman, Brian Fujikawa, Ke Han, and Lindley Winslow (NSD visitor from MIT, Berkeley graduate), along with KamLAND collaboration members from the University of Wisconsin, Colorado State University, and Drexel University performed a month long off-axis KamLAND calibration campaign. The campaign was originally planned for March 2011, but it was postponed due to the Great East Japan Earthquake Disaster. Calibration data was taken at more than eighty off-axis points in the detector using four different radioactive sources and one LED light source.

An initial analysis of the data in real time confirmed the data quality and all of the goals of this campaign were met. The calibration data from this campaign is expected to reduce the position related systematic uncertainty by about 25% and the energy systematic uncertainty by about 15%.
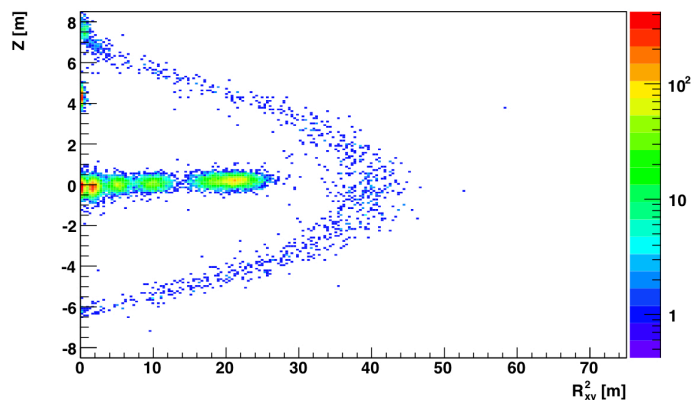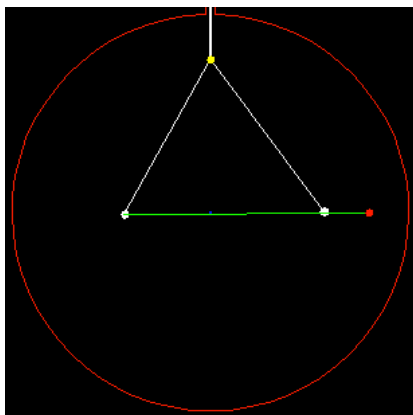
Left: a screen shot of an off-axis calibration configuration from the control program. The green line represents the straight titanium pole and the while lines represents the cables. The red dot at the end of the pole represents the main calibration source. Right: a scatter plot of the reconstructed positions from data taken with the configuration on the left. In addition to the main source at the end of the pole, there are seven additional radioactive sources embedded in the pole and one source where the cables meet at the top of the triangle. The scattered points at the edge correspond to background events from contaminants external to the detector.