

## Departments

## Special Reports

### KamLAND Detects Geoneutrinos<sup>1</sup>



*A view of the top of the KamLAND detector. (Courtesy Berkeley KamLAND group.)*

The Kamioka liquid-scintillator antineutrino detector (KamLAND) has made the first observation of “geoneutrinos.” This comes just over 50 years since George Gamow, in a letter to Fred Reines in 1953, pointed out the possibility of detecting antineutrinos of terrestrial origin. KamLAND, which has already confirmed neutrino oscillations by detecting antineutrinos emitted from nuclear reactors, has opened up a new window of research, exploring the deep interior of the Earth by detecting geoneutrinos.

Geoneutrinos are created in the beta decays of radioactive isotopes in the Earth (see CERN Courier, October 2003, p. 20). The current geochemical and geophysical models suggest that the radiogenic power from the  $^{238}\text{U}$  and  $^{232}\text{Th}$  decay chains is 16 TW, approximately half the total measured heat-dissipation rate from the Earth. This heat helps to drive convective flows in the mantle and the outer core, resulting in plate tectonics, volcanism and terrestrial magnetism. Thus radiogenic heat is a key factor in understanding the Earth’s dynamics, formation and evolution. However, since geophysicists have never had a direct way to determine how uranium and thorium are distributed in the Earth’s interior, measuring their concentration inside the Earth sheds new light on geophysics.

KamLAND consists of about 1 kt of liquid scintillator, located in the Kamioka mine in Japan (see CERN Courier,

April 1999, p. 22). It can detect geoneutrinos from the  $^{238}\text{U}$  and  $^{232}\text{Th}$  decay chains through an inverse beta-decay process with a threshold energy of 1.8 MeV. Using data collected between 9 March 2002 and 30 October 2004 with a detector live-time of 749 days, 25 geoneutrino events were obtained after subtracting the number of expected background events, mostly from reactor antineutrinos. Combining the event rate and energy spectrum of candidates yields between 4.5 and 54.2 geoneutrinos, with a central value of 28 at the 90% confidence interval (see figures). This assumes a Th:U mass ratio of 3.9, the value derived from chondritic meteorites and commonly understood to be the same for all materials in the solar system.

The result is consistent with the central value of 19 predicted by a geological model, and constrains the flux of geoneutrinos from uranium and thorium to less than  $1.62 \times 10^7 \text{ cm}^{-2} \text{ s}^{-1}$  at 99% confidence limits. Although the present data have limited statistical power, they nevertheless directly provide an upper limit of 60 TW for the radiogenic power of uranium and thorium in the Earth.

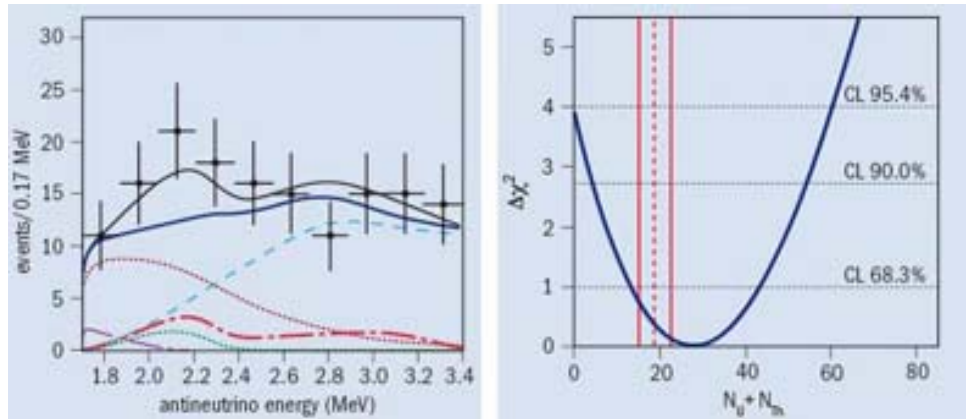
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These investigations should pave the way to more accurate measurements, which may develop into a new field of neutrino geophysics. There is a programme currently under way to reduce the radioactive content of the KamLAND detector, but further background reduction will require a new detector location, far away from nuclear reactors. In the future, a worldwide network of geoneutrino detectors would allow the production of a tomographic image of the radiogenic heat distribution.

#### Further reading

T. Araki *et al.*, *Nature* **436**, 467 (2005).



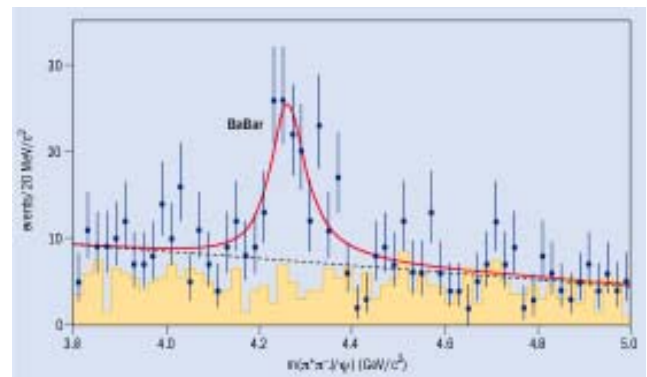
(left) Electron antineutrino energy spectrum of 152 candidate events with energies less than 3.4 MeV. The lower solid line shows the total expected background spectrum including the reactor (dashed blue line),  $^{13}\text{C}(\alpha, n)^{12}\text{C}$  reactions (thin dotted brown line) and accidental coincidence (dot-dashed purple line) events. Combining the expected geoneutrino signals of  $^{238}\text{U}$  (dot-dashed red line) and  $^{232}\text{Th}$  (dotted green line), gives the total expected spectrum shown by the upper solid line. Right:  $\Delta\chi^2$  as a function of the total number of  $^{238}\text{U}$  and  $^{232}\text{Th}$  geoneutrino candidates, assuming a Th:U mass ratio of 3.9. The band gives the value predicted by the current geological model of the Earth.

## BaBar Collaboration Detects New Resonance<sup>1</sup>

Charmonium spectroscopy has seen a revival over the past year or so, with various groups reporting heavy charmonium states (see *CERN Courier*, January 2004, p. 9). The BaBar collaboration has now added to the list of new states, after a recent study of the initial state radiation process  $e^+e^- \rightarrow \gamma\pi^+\pi^-J/\Psi$  across the charmonium mass range.

The data were collected with the BaBar detector at the SLAC PEP-II asymmetric-energy  $e^+e^-$  storage ring, representing a luminosity of  $233 \text{ fb}^{-1}$  at a centre-of-mass energy slightly above 10 GeV. Candidate  $J/\Psi$  mesons were reconstructed via their decays to  $e^+e^-$  and  $\mu^+\mu^-$ . BaBar observed an excess of  $125 \pm 23$  events centred at a mass of about  $4.26 \text{ GeV}/c^2$ , signifying the presence of one or more previously unobserved  $J^{\text{PC}} = 1^-$  states containing hidden charm.

At the current level of statistics the number of new states cannot be distinguished and the signal is compatible with a single resonance about  $90 \text{ MeV}/c^2$  wide, although the single-resonance fit probability is low. For the moment the particle has been named  $Y(4260)$ .



The  $\pi^+\pi^-J/\Psi$  invariant-mass spectrum showing the peak for the  $Y(4260)$ .

#### Further reading

The BaBar Collaboration 2005, <http://arxiv.org/abs/hep-ex/0506081>.

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