nature geoscience SUPPLEMENTARY INFORMATION
DOI: 10.1038/NGEO1205

Partial radiogenic heat model for Earth revealed by geoneutrino measurements

SUPPLEMENTARY NOTE

1 Heat flow from the Earth's interior

The total heat flow from the Earth's interior is 44.2 ± 1.0 TW from the analysis in ref. 1 of calorimetric-based data. On the other hand, a much lower value (31 ± 1 TW) is found in ref. 2. This analysis in ref. 2 has been severely criticized, see ref. 3 and 4. See also ref. 5.

2 Backgrounds to $\overline{\nu}_e$ detection

The background to $\overline{\nu}_e$ detection arising from the α-particle-induced $^{13}\mathrm{C}(\alpha,\ n)^{16}\mathrm{O}$ reaction in the LS is particularly troublesome for the low energy geoneutrino region. The reaction produces neutrons with energies up to 7.3 MeV which subsequently thermalize via collisions with protons and carbon nuclei. $\overline{\nu}_e$ events are mimicked by neutron-induced recoils in the scintillator followed by neutron captures. In spite of the relatively large neutron energy, light quenching in the scintillator produces values for E_{p} that are mainly below 3 MeV, as studied at intense neutron source facilities[6,7]. The principal source of α-particles is ^{210}Po, a daughter of ^{222}Rn introduced into the LS during the initial filling of the detector. The LS purification campaign in 2007 and 2008 reduced the ^{210}Po by a factor of ~20. There are $(5.95 \pm 0.29) \times 10^9$ α-decays in the entire data set, as directly measured from the scintillation signal of the 5.3 MeV α-particle in the ^{210}Po decay. The

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neutron rate was determined from a Monte Carlo (MC) simulation using the measured cross section for $^{13}\mathrm{C}(\alpha, n)^{16}\mathrm{O}$ (refs 8, 9), and tuned on data from an *in-situ* measurement of the $^{13}\mathrm{C}(\alpha, n)^{16}\mathrm{O}$ reaction using a $^{210}\mathrm{Po}^{13}\mathrm{C}$ source[10]. The data below the inverse beta reaction threshold of 0.9 MeV, where no $\overline{\nu}_e$ can be present, was checked for consistency with the $^{13}\mathrm{C}(\alpha, n)^{16}\mathrm{O}$ background estimate, using a narrow-spatial cut to reject accidental coincidences that have a higher rate in this very low energy region. A data-to-model ratio of $1.22^{+0.24}_{-0.21}$ was found. From this procedure, repeated for data before and after purification, 165.3 ± 18.2 events from $^{13}\mathrm{C}(\alpha, n)^{16}\mathrm{O}$ between 0.9 MeV and 2.6 MeV were estimated. This figure takes into account the efficiency of the event selection using the L parameter, and its uncertainty is propagated to the final result.

Smaller background contributions arise from accidental coincidences, cosmic-ray-muon-induced radioactive isotopes, fast neutrons, and atmospheric neutrinos. The accidental background, 77.4 ± 0.1 events, is estimated directly from the data by displacing the delayed-coincidence time window to $10\ \mathrm{ms} < \Delta T < 20\ \mathrm{s}$. Muon spallation on carbon nuclei produces unstable isotopes whose decays generate backgrounds. The largest such background is from $^{9}\mathrm{Li}$, which emits a delayed neutron after a β-decay, giving rise to 2.0 ± 0.1 events (ref. 11). Atmospheric neutrinos and fast neutrons that are not vetoed due to the inefficiency of OD muon veto system are assumed to have flat energy spectra and are predicted to contribute less than 2.8 events. Other backgrounds listed in ref. 12 are negligible.

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