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Using geoneutrinos to constrain the radiogenic power in the Earth's mantle

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The Earth's engine is driven by unknown proportions of primordial energy and heat produced in radioactive decay. Unfortunately, competing models of Earth's composition reveal an order of magnitude uncertainty in the amount of radiogenic power driving mantle dynamics. Together with established geoscientific disciplines (seismology, geodynamics, petrology, mineral physics), experimental particle physics now brings additional constraints to our understanding of mantle energetics.

Measurements of the Earth's flux of geoneutrinos, electron antineutrinos emitted in β^- decays of naturally occurring radionuclides, reveal the amount of uranium and thorium in the Earth and set limits on the amount of radiogenic power in the planet. Comparison of the flux measured at large underground neutrino experiments with geologically informed predictions of geoneutrino emission from the crust provide the critical test needed to define the mantle's radiogenic power. Measuring geoneutrinos at oceanic locations, distant from nuclear reactors and continental crust, would best reveal the mantle flux and by performing a coarse scale geoneutrino tomography could even test the hypothesis of large heterogeneous structures in deep mantle enriched in heat-producing elements.

The current geoneutrino detecting experiments, KamLAND in Japan and Borexino in Italy, will by year ~ 2020 be supplemented with three more experiments: SNO+ in Canada, and JUNO and Jinping in China. We predict the geoneutrino flux at all experimental sites. Within ~ 8 years from today, the combination of data from all experiments will exclude end-member compositional models of the silicate Earth at the 1σ level, reveal the radiogenic contribution to the global surface heat loss, and provide tight limits on radiogenic power in the Earth's mantle. Additionally, we discuss how the geoneutrino measurements at the three relatively near-lying (≤ 3000 km) detectors KamLAND, JUNO, and Jinping may be harnessed to improve the regional models of the lithosphere.

Šrámek, O. et al. Revealing the Earth's mantle from the tallest mountains using the Jinping Neutrino Experiment. Sci. Rep. 6, 33034; doi:10.1038/srep33034 (2016).