From the Geosphere to the Cosmos: ASPERA Workshop

Abstract

Geo-neutrino Physics and Nuclear Activities Monitoring

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Neutrinos are the most abundant matter particles in the Universe. Thoroughly investigated in basic science, the neutrino field is now delivering first applications in the fields of nuclear reactor monitoring and study of geo-neutrinos.

Nuclear reactors provide energy from the fission of uranium and plutonium isotopes. Because of the neutron excess of such heavy nuclei the fission products are neutron-rich, unstable nuclei that decay toward the valley of stability following β^- decay chains. With an approximate energy of 200 MeV/fission and 6 neutrinos/fission, 3 GW of thermal power correspond to 10^{21} neutrinos/s. Such a large flux compensates for the tiny interaction cross-section and this triggered the interest of neutrino physicists since the earliest stages, in the 50's. The idea of reactor monitoring emerged after gathering enough nuclear data on the mass distributions and beta spectra of fission products [1]. It turns out that for the same released thermal power, ^{239}Pu fissions produce 60% less detected neutrino than ^{235}U fissions. Based on this sensitivity to the ^{239}Pu content of a reactor, the IAEA is currently investigating the potentiality of neutrinos as a novel safeguards tool [2]. This technology offers unique features of non-intrusive, continuous, remote controlled and tamper resistant measurements. The detector is to be installed in a basement room less than 30 m from the core with a global footprint of 3x3 m. In normal operation a reactor burns ^{235}U and accumulate ^{239}Pu leading to a constant decrease of the detected neutrino flux. We'll present the existing data [3] validating this scheme as well as the ongoing worldwide program aiming at developing efficient detection techniques within the IAEA specifications. Detection with liquid scintillators will be highlighted [4] as the most efficient approach so far.

Another remote place to be spied out by neutrinos is the Earth's interior. Geo-neutrinos are electron anti-neutrinos produced in β decays of ^{40}K and of several nuclides in the chains of long-lived radioactive isotopes ^{238}U and ^{232}Th, which are naturally present in the Earth. They are direct messengers of the abundances and distribution of these elements within our planet while other sources of information about the Earth's interior are indirect probes: chemical compositions of rocks from the upper Earth layers, chondritic meteorites, density profile of inner layers from seismology. Measuring the flux and spectrum of geo-neutrinos is a way to assess more quantitatively the radiogenic contribution to the total heat balance of the Earth. These pieces of information, in turn, are critical in understanding complex processes such as the generation of the Earth's magnetic field, mantle convection, and plate tectonics. We'll discuss the first signals of geo-neutrinos associated with the ^{238}U and ^{232}Th chains as measured by the Kamland [5] and Borexino experiments. Perspectives of complementary measurements, with larger detectors and different locations aiming at disentangling the contributions from the upper Earth layers and from the mantle will be presented.

References:

[1] L. A. Mikaelyan, "Neutrino Laboratory in the Atomic Plant " in *Proc. Inter. Conf. "Neutrino-77"*, vol.2, Moscow, 1977, pp. 383-387.

[2] “Final Report: Focused Workshop on Antineutrino Detection for safeguards Applications”, report of IAEA Workshop, IAEA Headquarters, Vienna, Austria, Oct. 2008.

[3] « Experimental results from an antineutrino detector for cooperative monitoring of nuclear reactors. », N.S. Bowden *et al.*, Nucl. Instrum. Meth. A572:985-998,2007.

[4] Reactor Neutrino Detection for Non Proliferation with the NUCIFER Experiment, A. Porta et al., IEEE proceedings 10.1109/ANIMMA.2009.5503653.

[5] “Precision Measurement of Neutrino Oscillation Parameters with KamLAND”, KamLAND Collaboration, Phys. Rev. Lett. 100:221803, 2008.

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