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Geo-neutrinos and reactor anti-neutrinos expected in Daya Bay II and in LENA

BALDONCINI, Marica[1]* ; ESPOSITO, Juan[2] ; LUDHOVA, Livia[3] ; MANTOVANI, Fabio[1] ; RICCI, Barbara[1] ; XHIXHA, Gerti[1] ; ZAVATARELLI, Sandra[4]

[1]University of Ferrara, [2]INFN, Legnaro National Laboratories, [3]University of Milan, [4]University of Genova

Geo-neutrinos produced by beta decays occurring in ^{238}U and ^{232}Th decay chains are presently detected via inverse beta reaction in liquid scintillation detectors (KamLAND and Borexino). Geo-neutrinos are a unique direct probe of our planet's interior since they instantaneously bring to the Earth's surface information concerning the total amount and distribution of U and Th in the crust and in the mantle, which are thought to be the main reservoirs of these elements. The geo-neutrino spectrum allows to discriminate the different Th and U components. Measuring geo-neutrino fluxes and spectra can shed light on the radiogenic contribution to the terrestrial heat power and on the Earth's nowadays composition, providing a direct test of the Bulk Silicate Earth models and giving additional constraints on the Earth's evolution models.

A better discrimination among different Earth's global models can be reached combining the results from several sites: new measurements of geo-neutrino fluxes are highly awaited from experiments entering operation, such as SNO+, or proposed to the scientific community, as LENA or Daya Bay II. In particular, LENA and Daya Bay II would provide a substantial increase of the detection sensitivity and of the event rate thanks to their large target masses (50 kton and 20 kton, respectively) compared to the 1 kton mass of KamLAND and SNO+ and to the 0.3 kton of Borexino.

The main background in geo-neutrino measurements is due to the electron anti-neutrinos produced by nuclear power plants, which are the strongest man-made anti-neutrino sources. Many fission products decay through beta processes with the consequent emission of electron anti-neutrinos, the so called reactor anti-neutrinos. The reactor anti-neutrino spectrum covers an energy range extending up to about 8 MeV, which results in a significant overlap between geo-neutrino and reactor anti-neutrino signals in the geo-neutrino energy window (1.8 − 3.3 MeV). The events of reactor anti-neutrinos are strongly dependent on the distance of the closeby commercial nuclear power plants. Therefore, a careful analysis of the expected reactor anti-neutrino event rate at a given experimental site is mandatory.

In this framework, we estimate the expected reactor anti-neutrino signals at ongoing geo-neutrino experiments sites, in particular at Pyhasalmi and JUNO (Jiangmen Underground Neutrino Observatory), which are the candidate sites for hosting the LENA and Daya Bay II experiments, respectively. The inputs required to evaluate the reactor anti-neutrino flux come from neutrino properties, nuclear physics in the reactors and features of nuclear power plants. In our calculation we take into account the three neutrino oscillation mechanisms in vacuum, the most updated reactor anti-neutrino spectra and standard fuel compositions. According to the International Atomic Energy Agency (IAEA) database, we use detailed information on the locations and on the monthly time profiles of the thermal power for each nuclear core.

In Table 1 we report the expected geo-neutrino and reactor anti-neutrino signals for different locations, expressed in TNU (Terrestrial Neutrino Units). Nuclear power plants data refer to IAEA database reporting information of year 2012, when all of the Japanese nuclear power plants were still switched off. The ratio between the expected reactor anti-neutrino signal in the geo-neutrino energy window (R$_G$) and the expected geo-neutrino signal (G) is calculated all over the world in order to produce a R$_G$/G map. The values of R$_G$/G for future sites (Phyasalmi and JUNO) are almost comparable to the operating ones (LNGS and Kamioka), with a slight preference for the Finnish location. The total uncertainty on the reactor signal predictions is on the order of 5%: among all the accounted sources of uncertainties, the ones giving the main contributions originate from the θ_{12} mixing angle, the anti-neutrino spectrum, the fuel composition and the thermal power.

Keywords: geo-neutrino, anti-neutrino from reactor, neutrino detector

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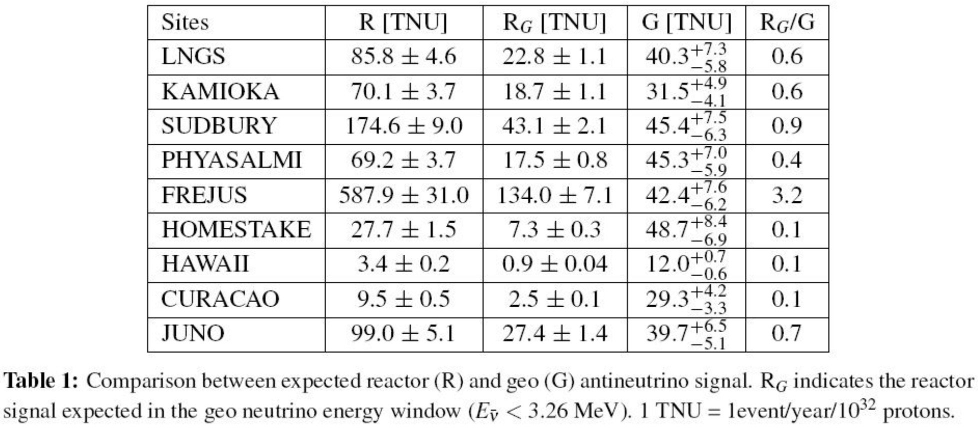

Sites	R [TNU]	R_G [TNU]	G [TNU]	R_G/G
LNGS	85.8 ± 4.6	22.8 ± 1.1	$40.3^{+7.3}_{-5.8}$	0.6
KAMIOKA	70.1 ± 3.7	18.7 ± 1.1	$31.5^{+4.9}_{-4.1}$	0.6
SUDBURY	174.6 ± 9.0	43.1 ± 2.1	$45.4^{+7.5}_{-6.3}$	0.9
PHYASALMI	69.2 ± 3.7	17.5 ± 0.8	$45.3^{+7.0}_{-5.9}$	0.4
FREJUS	587.9 ± 31.0	134.0 ± 7.1	$42.4^{+7.6}_{-6.2}$	3.2
HOMESTAKE	27.7 ± 1.5	7.3 ± 0.3	$48.7^{+8.4}_{-6.9}$	0.1
HAWAII	3.4 ± 0.2	0.9 ± 0.04	$12.0^{+0.7}_{-0.6}$	0.1
CURACAO	9.5 ± 0.5	2.5 ± 0.1	$29.3^{+4.2}_{-3.3}$	0.1
JUNO	99.0 ± 5.1	27.4 ± 1.4	$39.7^{+6.5}_{-5.1}$	0.7

Table 1: Comparison between expected reactor (R) and geo (G) antineutrino signal. R_G indicates the reactor signal expected in the geo neutrino energy window ($E_{\bar{\nu}} < 3.26$ MeV). 1 TNU = 1event/year/10^{32} protons.