Perspectives to search for neutrino-nuclear neutral current coherent scattering

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The process of neutrino elastic interaction with a nucleus via coherent scattering was proposed a long time ago [1]. This process has relatively large cross section which can be given as:

$$\sigma \approx 0.4 \cdot 10^{-44} N^2 (E_\nu)^2 \,\mathrm{cm}^2,$$

where N is the neutron number and the neutrino energy E_ν is measured in MeV [2]. This formula is valid for neutrino energies up to about 50 MeV, and thus can be applied to reactor, solar and supernova neutrinos. The magnification factor N^2 gives a significant increase in cross section for detectors using heavy nuclei as the target. This fact can pave the way for compact neutrino detectors which could have a great impact on nuclear reactor monitoring techniques. This reaction has never been observed experimentally because of the very low energy of the recoil nucleus. For example, for neutrinos produced at nuclear power plants, the energies of xenon nuclei recoils are below 1 keV. Recently it has been pointed out that accurate measurement of neutrino coherent scattering can be a sensitive test for the Standard Model of electro-weak interactions [3,4]. Requirements for the detector are: large mass, high efficiency for sub-keV signals, and capability to achieve extremely low levels of backgrounds. There are several directions where extensive efforts are being directed: low noise germanium detectors [5], low background NaI detectors [6], and noble liquid emission detectors [7,8,9].

We can consider a search for neutrino coherent scattering with two very different sources: nuclear power plants or spallation neutron sources. Both options have pros and cons. As an example, let us compare options for an experiment seeking observation of neutrino coherent scattering off atomic nuclei using the nuclear reactor at the Kalinin Nuclear Power Plant (KNPP) in Russia or the Spallation Neutron Source at the Oak Ridge National Laboratory of USA.

	ν flux sec^{-1}	Time structure	Neutrino energy	Distance from the source	Major BG	Signal in detector (Xe)	Event rate in 100 kg Xe detector [10]
Reactor	$6 \cdot 10^{20}$	continuous	Falling from 1 to 7 MeV	20 m	Cosmic rays	Up to 1 keV	38000 (400 above reasonable threshold)/day
SNS	$3 \cdot 10^{14}$	Pulsed with duty factor of 1:2000	DAR shape with endpoint at 53 MeV	40 m	Fast neutrons from SNS	Up to 20 keV	2000 (1400 above reasonable threshold)/year

In this table, we use Xe nuclei as an example target, which has the highest cross section and lowest recoil energy of many other possible detector media.

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