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Investigation of coherent neutrino scattering at the Spallation Neutron Source

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Abstract

We propose to observe and to study neutrino coherent scattering reaction at Spallation Neutron Source accelerator facility of the Oak Ridge National Laboratory (U.S.A.) using two-phase liquid xenon emission detector. We present expected detector rates for different experimental conditions.

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*Keywords:*coherent scattering, neutrino; two-phase emission detector; liquid xenon, scintillation; electroluminescence

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1. Introduction

Coherent neutrino elastic scattering off nuclei is predicted and well described by the Standard Model (SM), but never been observed. The reaction is important for understanding processes in supernovae. The reaction study can provide the sensitive SM tests and search of nonstandard neutrino interaction.

2. Neutrino coherent scattering

The process of neutrino coherent elastic interaction with atomic nuclei attracted attention long time ago [1]. The differential cross section can be presented in zero spin approximation and for energy below ~50 MeV as:

$$\frac{d\sigma}{dE_r} = \frac{G_F^2}{4\pi} Q_W^2 M \left(1 - \frac{ME_r}{2E_\nu^2}\right) F^2(Q^2) \qquad (1)$$

where G_F is the Fermi constant, $F(Q^2)$ is the form factor at four-momentum Q and $Q_W = N - (1 - 4\sin^2(\theta_W))Z$ is the weak charge for a nucleus with N neutrons and Z protons, θ_W is the weak mixing angle.

The total cross section has the largest for neutrino reactions value due to coherent enhancement factor ~N^2 for heavy enough nuclei and can be parameterized as:

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

The reaction has never been observed because of the very low energy (up to several tenth of keV) of recoil nuclei.

3. Detector RED100

We propose to use two-phase emission detector for neutrino scattering event. The emission method of particle detection was invented about 40 years ago [2]. Particles interact with the condensed target medium, exciting and ionizing atoms, generating prompt signal in form of scintillation. Ionization electrons drift to the free liquid surface under influence of electric field. In the gas phase drifting electrons generate electroluminescent signal (secondary scintillation). An array of photomultipliers is used to detect both scintillation signals. The two-dimensional distribution of detected scintillation photons can be used to determine the coordinates of the original events in plane. Since the secondary scintillation is delayed from the primary one by the electron drift time, the third coordinate of the interaction can be reconstructed from the delay time analyses.

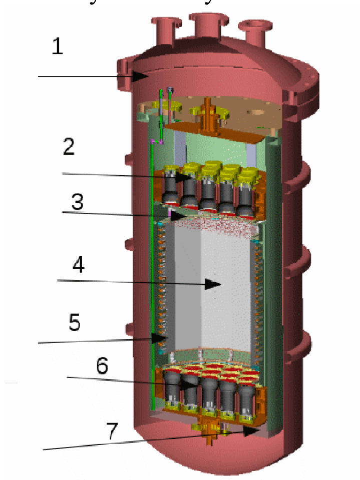

Fig. 1. RED100. 1-titanium warm vessel; 2- top PMT array; 3-Xenon gas gap; 4- liquid Xenon; 5-teflon reflector;6-bottom PMT array; 7-titanium cold vessel.