Coherency in the Discovery of Neutrino Nucleus Scattering

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Introduction

This year the coherent elastic neutrino-nucleus scattering (νA_{el})[1] is discovered at Spallation Neutron Source (SNS), Oak Ridge National Laboratory at 6.7 sigma confidence level using CsI(Na) scintillators [2]. The SNS facility provides the neutrino flux in various flavors and energy upto 53 MeV. The detection threshold of $\sim$5 keV$_{nr}$ corresponds to the minimum energy of detected neutrinos above than 10 MeV. The nuclear reactors are pure neutrino source with a huge flux and energy upto 8 MeV provides the unseen region of detection of very low energy neutrinos.

The differential cross-section for this process is in terms of three momentum transfer(q $\equiv |\overline{q}|$) can be written as

$$\frac{d\sigma_{\nu A_{el}}}{dq^2} = \frac{1}{2}\left[\frac{G_F^2}{4\pi}\right]\left[1-\frac{q^2}{4E_\nu^2}\right][\varepsilon Z - N]^2 F(q^2), \quad (1)$$

where, G_F is fermi constant, E_ν is incident neutrino energy and $\varepsilon \equiv (1-4\sin^2\theta_W)$. While Z, N and M are atomic number, neutron number and mass of target nucleus and $F(q^2)$ is nuclear form factor.

The normalized flux for reactor, solar and stppoed pion(DAR) neutrino sources is shown in Fig1.

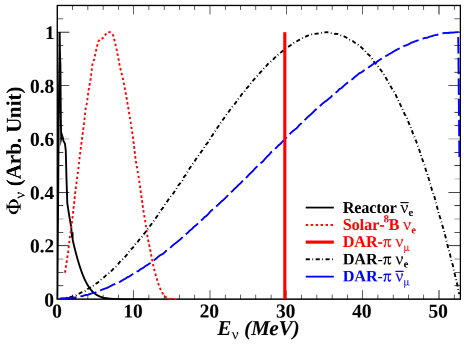

FIG. 1: Normalized neutrino flux from various sources for νA_{el} interaction.

Coherency in CsI and Germanium

The decoherency effect in νA_{el} can be described as deviation from $[\varepsilon Z - N]^2$ scaling as increase in q^2 [3].The addition of phase angle between amplitude of different nucleons gives a relative finite phase instead of being perfectly aligned. This affect as an average misalignment angle $\langle\phi\rangle \in [0, \pi/2]$ can be parameterize as degree of coherency $\alpha \equiv \cos\langle\phi\rangle$. Accordingly, the cross-section ratio between nucleus A(Z, N) and neutron(0,1) can be expressed as

$$\frac{\sigma_{\nu A_{el}}(Z,N)}{\sigma_{\nu A_{el}}(0,1)} = Z\varepsilon^2[1+\alpha(Z-1)] + N[1+\alpha(N-1)] - 2\alpha\varepsilon ZN. \quad (2)$$

The limiting condition for above equation is

$$\sigma_{\nu A_{el}}(Z,N) \propto \begin{cases} [\varepsilon^2 Z + N], & \alpha = 0 \text{ (incoherent)} \\ [\varepsilon Z - N]^2, & \alpha = 1 \text{ (coherent)}. \end{cases}$$

As an alternative, the partial coherency effect can be characterized by the relative change in cross-section

$$\xi \equiv \frac{\sigma_{\nu A_{el}}(\alpha)}{\sigma_{\nu A_{el}}(\alpha=1)} = \alpha + (1-\alpha)\left[\frac{(\varepsilon^2 Z + N)}{(\varepsilon Z - N)^2}\right]. \quad (3)$$

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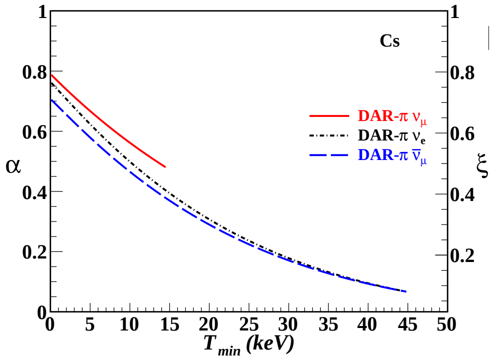

FIG. 2: Coherency in Cesium for νA_{el} interaction with different neutrino flavors at SNS. Coherency for Cs at 5 keV$_{nr}$ threshold is 0.67, 0.62 and 0.58 for ν_μ, ν_e and $\bar{\nu}_\mu$ respectively.

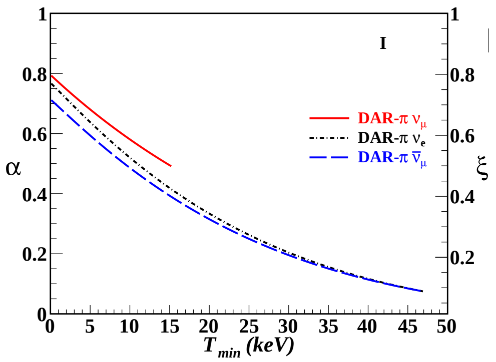

FIG. 3: Coherency in Iodine for νA_{el} interaction with different neutrino flavors at SNS. Coherency for I at 5 keV$_{nr}$ threshold is 0.68 0.64 and 0.59 for ν_μ, ν_e and $\bar{\nu}_\mu$ respectively.

From eq.2 and 3, the coherency for CsI target is estimated for SNS source at various detection thresholds (Fig 2,3).

Future of νA_{el} at KSNL

The TEXONO experiment is located at Kuo-Sheng Nuclear Power Plant-2 at Jinshan District of Taiwan. The Kuo-Sheng Neutrino Laboratory (KSNL) has neutrino flux 6.35×10^{12} cm^{-2} s^{-1} at a distance of 28 m from reactor core. The Germanium detector used at KSNL seems to be open unseen energy region of νA_{el} interaction with full co-

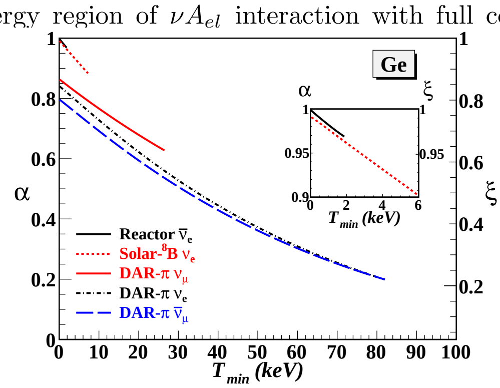

FIG. 4: Coherency in Germanium for νA_{el} interaction with different sources and flavours of neutrino.

herence effects in near future(Fig. 4). Coherency in νA_{el} interaction with reactor neutrinos approaches to 1 at small q^2 [3]. The study of low energy νA_{el} interaction is useful to constrain the sensitivities for physics beyond the standard model and for understanding of the irreducible background for dark matter experiments[4–6].

References

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