Coherent Elastic Neutrino-Nucleus Scattering
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Introduction
This year the coherent elastic neutrino-nucleus scattering \((\nu A)el\)[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 ~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. Maximum nuclear recoil in CsI and Germanium crystal with reactor neutrinos is less than 2 keV\(_{nr}\), which provides the unseen region of \(\nu A\) detection of very low energy neutrinos.

The differential cross-section for this process is in terms of three momentum transfer\((q^2)\) can be written as

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

(1)

where, \(G_F\) is fermi constant, \(E_\nu\) 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 three-momentum transfer \((q^2)\) in terms of recoil energy \((T)\) is given by \(q^2 = 2MT + T^2 \approx 2MT\).

The nuclear mass is use to be much larger than neutrino energy, therefore maximum nuclear recoil allowed by kinematics can be given by \(T_{max} = 2E_{\nu}^2/(2E_{\nu} + M) \approx 2E_{\nu}^2/M\).

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

![Normalized neutrino flux from various sources for \(\nu A\) interaction.](image)

FIG. 1: Normalized neutrino flux from various sources for \(\nu A\) interaction.

Coherency in CsI and Germanium

The decoherency effect in \(\nu A\) 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 \((\phi)\) \([0, \pi/2]\) can be parameterize as degree of coherency \(\alpha \equiv \cos(\phi)\).

Accordingly, the cross-section ratio between nucleus \(A(Z, N)\) and neutron\((0,1)\) can be expressed as

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

(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

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Available online at www.sympnp.org/proceedings
cross-section
\[ \xi \equiv \frac{\sigma_{\nu_A}\left(\alpha\right)}{\sigma_{\nu_A}\left(\alpha = 1\right)} = \alpha + (1 - \alpha) \left[ \frac{\varepsilon^2 Z + N}{\varepsilon^2 Z - N^2} \right]. \] (3)

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

**Future of \( \nu A_{el} \) 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\( \times \)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 \( \nu A_{el} \) interaction with full coherency effects in near future(Fig. 5). Coherency in \( \nu A_{el} \) interaction with reactor neutrinos approaches to 1 at small \( q^2 \) [3]. The study of low energy \( \nu A_{el} \) 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**