# 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 $\nu A_{el}$ 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

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

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 $q^2 = 2MT + T^2 \simeq 2MT$.

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

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

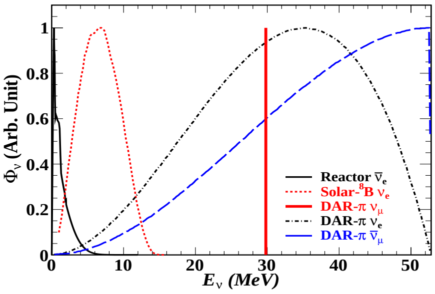

FIG. 1: Normalized neutrino flux from various sources for $\nu A_{el}$ interaction.

## Coherency in CsI and Germanium

The decoherency effect in $\nu A_{el}$ 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

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

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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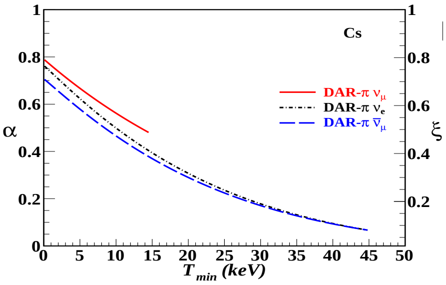

FIG. 2: Coherency in Cesium for $\nu A_{el}$ interaction with different neutrino flavors at SNS.

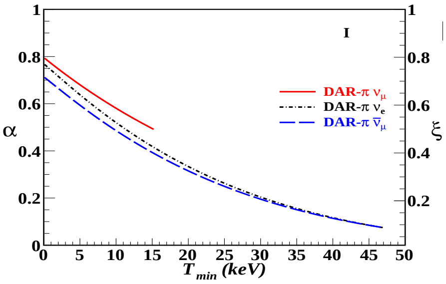

FIG. 3: Coherency in Iodine for $\nu A_{el}$ interaction with different neutrino flavors at SNS.

cross-section

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

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 $6.35\times10^{12}$ 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 coherence 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].

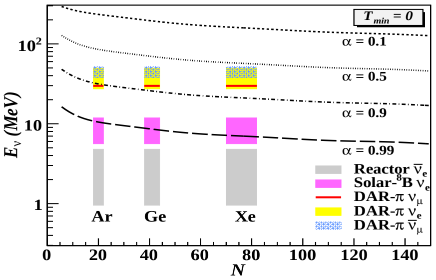

FIG. 4: Contours for degree of coherency in $E_\nu$-N plane at $T_{min} = 0$. The bands covers feasible energy ranges for different neutrino sources and targets.

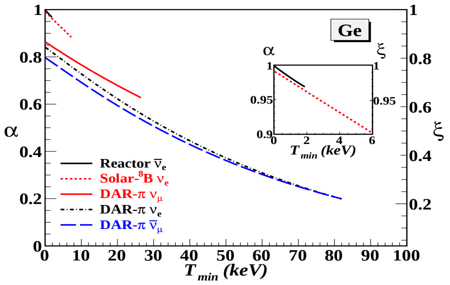

FIG. 5: Coherency in Germanium for $\nu A_{el}$ interaction with different sources and flavours of neutrino.

## References

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