$\bar{\nu}e$ elastic scattering in SBL

HyangKyu Park

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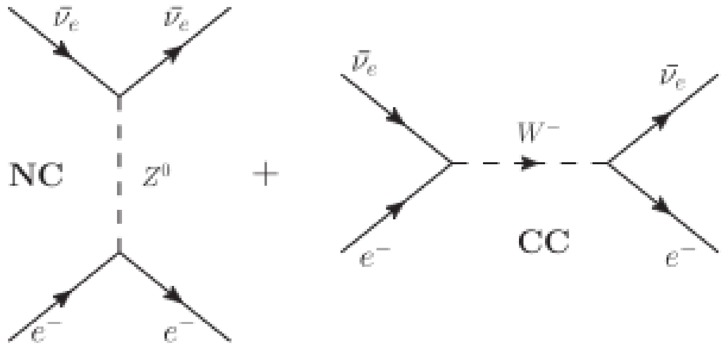
Why $\bar{\nu}e$ elastic scattering is important ? (I)

- In S.M., it's very well known process:



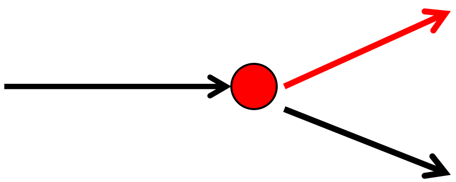
- Suppose that anti-nu from reactor changes to the 4th neutrino.

Then, that neutrino may have very tiny neutral current or no interaction at all with electron.

- This process may provide an extra check for Nu-oscillation analysis.
- Possible measurement of $\sin^2\theta_W$

How do we measure $\sin^2\theta_W$? (I)

- The differential cross-section for Nu-e elastic scattering at the laboratory frame is given by



$$\left[\frac{d\sigma}{dT}(\bar{\nu}_e e)\right]_{\text{SM}} = \frac{G_F^2 m_e}{2\pi} \cdot \left[(g_V - g_A)^2 + (g_V + g_A + 2)^2 \times \left(1 - \frac{T}{E_\nu}\right)^2 - (g_V - g_A)(g_V + g_A + 2) \times \frac{m_e T}{E_\nu^2}\right]. \quad (3)$$

T: kinetic energy of recoil electron

(visible energy in your detector)

$$T \leq \frac{2(E_\nu)^2}{2E_\nu + m_e}$$

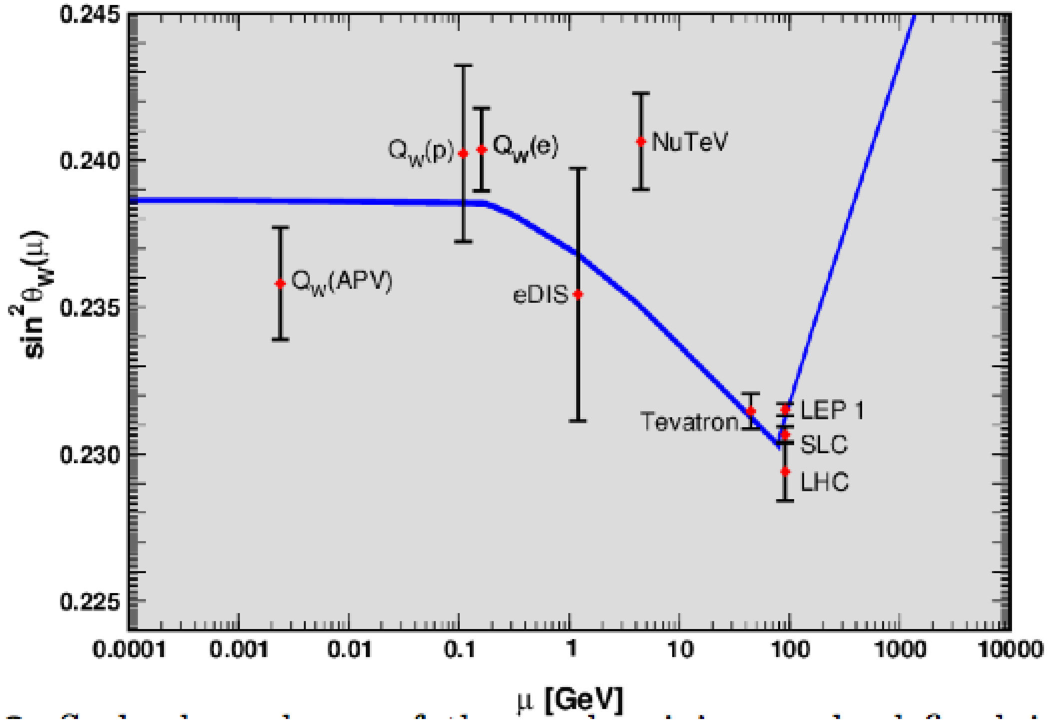
E_ν: Incident neutrino energy

$g_V = -1/2 + 2\sin^2\theta_W$, $g_A = -1/2$

$$\frac{G_F^2 m_e}{2\pi} \cdot = 4.1\times10^{-45}\ \text{cm}^2\text{MeV}^{-1}$$

How do we measure $\sin^2\theta_W$? (II)

- **The results for $\sin^2\theta_W$ in PDG.**



$\sin^2\theta_W = 0.23867 \pm 0.00016$ at $\mu<0.01$ GeV

- **TEXONO measured with CsI crystals of 187 kg.**

$\sin^2\theta_W = 0.251 \pm 0.031 \pm 0.024$

How do we measure $\sin^2\theta_W$? (III)

- **We have an advantage:**

  - Using IBD events, we have a good estimation of Nu-flux without the reactor simulation.

- **Estimation of No. of events for the target L.S. of 500 kg:**

  Xsec=3×10^{-45} cm^2

  N_ν= 1.7×10^{12}/cm^2/s, N_e=6/molecule (LS:CH_2)

  N_{evt}=$3\times10^{-45}\times1.7\times10^{12}\times6\times(500\times10^3/14)\times6.02\times10^{23}\times10^7$

  ~ 6,500 events/yr

How do we measure $\sin^2\theta_W$? (III)

- **To select the nu-e events:**
  - **The scattered electrons in the target are deposited the energy inside the target.**
  - **Require the energy trigger, > 3 MeV, in the target. (There is no delayed signal.)**
  - **Select the signal candidates with PSD.**
  - **Background estimation with reactor off data.**

X-sec. for nu-e elastic scattering (I)

- **For CC and N.C**

$$\left[\frac{d\sigma}{dT}(\bar{\nu}_e e)\right]_{\rm SM} = \frac{G_F^2 m_e}{2\pi} \cdot \Big[(g_V - g_A)^2 + (g_V + g_A + 2)^2 \times \left(1 - \frac{T}{E_\nu}\right)^2 - (g_V - g_A)(g_V + g_A + 2) \times \frac{m_e T}{E_\nu^2}\Big]. \quad (3)$$

- **For only N.C.,**

$$\left[\frac{d\sigma}{dT}(\overset{(-)}{\nu}_\mu e)\right]_{\rm SM} = \frac{G_F^2 m_e}{2\pi} \cdot \Big[(g_V \pm g_A)^2 + (g_V \mp g_A)^2 \times \left(1 - \frac{T}{E_\nu}\right)^2 - (g_V^2 - g_A^2)\frac{m_e T}{E_\nu^2}\Big], \quad (2)$$

Note: Lower sign refers to anti-nu.
- Conservatively the 4th Nu has very tiny N.C. interaction.

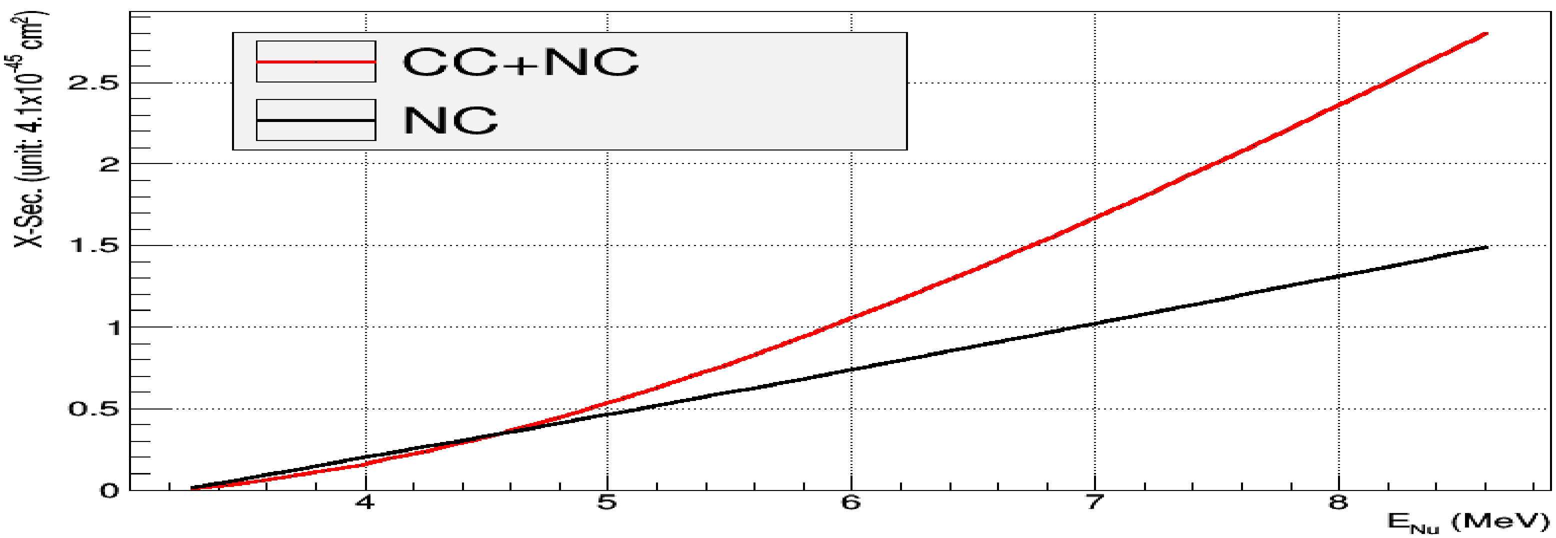
X-sec. for nu-e elastic scattering (II)

- **X-sec as function of incident Nu energy:**

$$\sigma(E_\nu) = \int_{T_{min}}^{T_{max}} dT \frac{d\sigma}{dT}$$

$$T_{max} = \frac{2(E_\nu)^2}{2E_\nu + m_e}$$

T_{min}=3 MeV (To suppress the backgrounds, U/Th and etc.)



If there is Nu-Osc, we may measure smaller X-sec. than S.M.

Summary

- The weak mixing angle is one of well measured process.
  - We may use this process another check for analyses.
- It will be interesting to measure the weak mixing angle with nu-e elastic scattering.
  Possible topic for PhD student
- If the measured X-sec. is different from the S.M. in a certain Nu energy, it’s a new physics.