Studies on $\bar{\nu}_{\rm e} - {\rm e}^-$ scattering towards constraints on non-standard neutrino interactions and unparticle physics

A. K. Soma [1, 2,*] L. Singh[1], M.K. Singh[1, 2], V. singh[1], and H. T. Wong[2]
[1] *Department of Physics, Banaras Hindu University, Varanasi - 221005,INDIA. and*
[2] *Institute of Physics, Academia Sinica, Taipei - 11529, TAIWAN.*

(For TEXONO Collaboration)

TEXONO [**T**aiwan **EX**periments **O**n **N**eutrin **O**] collaboration aims at opening up a sub - keV detection channel by developing detectors with threshold of O(100) towards studies on neutrino and dark matter. To achieve it's physics goals, the collaboration explores CsI(Tl) and HPGe detection technology.

We will present the constraints placed on Non-Standard Neutrino Interactions (NSI) parameters for the non-universal [($\varepsilon^{\rm eL}_{\rm ee}$,$\varepsilon^{\rm eR}_{\rm ee}$), ($\varepsilon^{\rm eL}_{\rm e\mu}$,$\varepsilon^{\rm eR}_{\rm e\mu}$)], flavour-changing [($\varepsilon^{\rm eL}_{\rm e\tau}$,$\varepsilon^{\rm eR}_{\rm e\tau}$)] channels [1] and on the coupling constants for scalar (λ_0) and vector (λ_1) unparticles(UP) to the neutrinos and electrons[1] by making use of $\bar{\nu}_{\rm e} - {\rm e}^-$ scattering data taken at Kuo-Sheng Reactor Neutrino Laboratory[2].

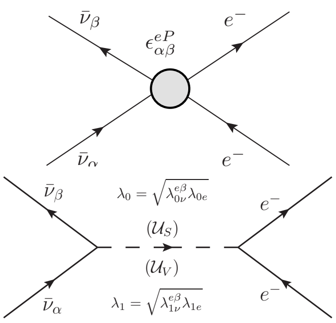

FIG. 1: $\epsilon^{eP}_{\alpha\beta}$ describes the coupling strength with respect to Fermi coupling constant G_F, P denotes helicity states(=L,R) and (α,β) stand for the lepton flavor (e, μ or τ). Top: (a) NSI of neutrinos, generically described as four-Fermi interaction with new couplings. Bottom: (b) Interactions of neutrino with electron via exchange of virtual scalar $\mathcal{U}_{\mathcal{S}}$ and vector $\mathcal{U}_{\mathcal{V}}$ unparticle.

Models on massive neutrinos generally give rise to NSI. The cases where $\alpha = \beta$ and $\alpha \neq \beta$ correspond to Non-Universal (NU) and Flavor-Changing (FC) NSI, respectively. Banks-Zaks(BZ) fields has its own gauge group and do not couple to the SM fields. The SM and BZ fields may coexist in a high energy scale. Below an energy scale $\Lambda_{\mathcal{U}}$, BZ operators turn into unparticle operators $\mathcal{O}_{\mathcal{U}}$ with a non-integer scaling dimension, denoted by $d_{\mathcal{S}}$ and $d_{\mathcal{V}}$ for the scalar and vector cases, respectively.

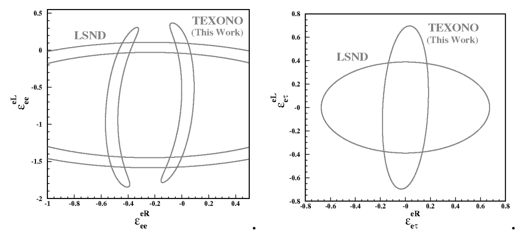

FIG. 2: The allowed region at 90% CL for Top: (a) NU NSI parameters of $\varepsilon^{\rm eL}_{\rm ee}$ and $\varepsilon^{\rm eR}_{\rm ee}$; Bottom: (b) FC NSI parameters of $\varepsilon^{\rm eL}_{\rm e\tau}$ and $\varepsilon^{\rm eR}_{\rm e\tau}$ from DS1-CsI(Tl) on $\bar{\nu}_{\rm e}-$e. The allowed regions from the LSND experiment on $\nu_{\rm e}-$e are superimposed. The constraints in the $(\varepsilon^{\rm eL}_{\rm e\mu}, \varepsilon^{\rm eR}_{\rm e\mu})$ plane are the same as those of $(\varepsilon^{\rm eL}_{\rm e\tau}, \varepsilon^{\rm eR}_{\rm e\tau})$ in (b).

Three independent data sets in different energy ranges were used in this analysis. **Data Set 1 (DS-1)**: The data (29882/7369 kg day of reactor ON/OFF) was accumulated by exposing 187 kg CsI(Tl) detector. From the excess of events in the ON−OFF residual spectrum,the SM electroweak angle was measured to be $\sin^2\theta_{\rm W} = 0.251 \pm 0.031(stat) \pm 0.024(sys)$ [3]. In the present work, we made use of 3 - 8 MeV data. **Data Set 2 (DS-2)**: The

*Electronic address: arunkumarsoma@gmail.com

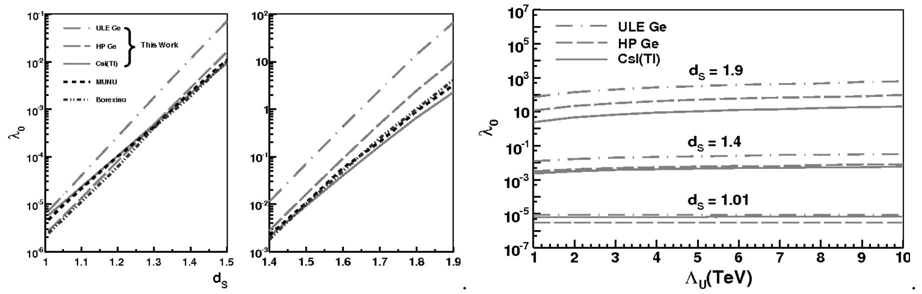

FIG. 3: Constraints on UP with scalar exchange − Top: (a) The coupling λ_0 versus mass dimension $d_{\mathcal{S}}$ at $\Lambda_{\mathcal{U}} = 1$ TeV; Bottom: (b) Upper bounds on λ_0 at different energy scales $\Lambda_{\mathcal{U}}$. Parameter space above the lines is excluded.

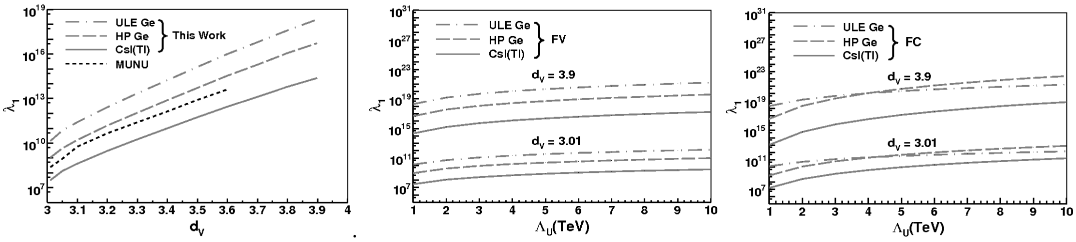

FIG. 4: Constraints on UP with vector exchange − Top: (a) The coupling λ_1 versus $d_{\mathcal{V}}$ at $\Lambda_{\mathcal{U}} = 1$ TeV. The bounds apply for both FV and FC cases. Middle (b) and Bottom (c): Upper bounds on λ_1 at different energy scales $\Lambda_{\mathcal{U}}$ for FV and FC couplings, respectively, at two values of $d_{\mathcal{V}}$. Parameter space above the lines is excluded.

data (570.7/127.8 day of reactor ON/OFF) was accumulated by exposing 1.06 kg HPGe detector. An analysis threshold of 10 keV and background level of ~ 1 kg^{-1}keV^{-1}day^{-1} was achived. The ON-OFF residual spectrum was used to derive upper bound on neutrino magnetic moment[2]. In the present work, we made use of 10 - 50 keV data. **Data Set 3 (DS-3)**: Data with 0.338 kg days of reactor ON was accumulated by using an 4X5 gram ultra-low energy Germanium detector, an energy threshold of 220±10 eV opened a window for studying WIMP dark matter with mass less than 10 GeV [4] .

The expected rates (R_X) for different interaction channels X ($X = SM, NSI, UP$) were given by

$$R_X \; = \; \rho_e \int_T \int_{E_\nu} \left(\frac{d\sigma}{dT}\right)_X \frac{d\phi(\bar{\nu}_{\rm e})}{dE_\nu} \, dE_\nu \, dT \quad , \tag{1}$$

where ρ_e is the electron number density per kg of target mass, $d\phi(\bar{\nu}_{\rm e})/dE_\nu$ corresponds to the neutrino spectrum and $\left(\frac{d\sigma}{dT}\right)_X$ corresponds to cross-section for SM, NSI, Scalar UP, Vector UP given by equations (4, 6, 9 and 12) in reference [1]. The expected rates were then compared to the obseved rates (R_{expt}) for various data sets and constraints were then derived. These constrains are displayed in the Fig[2], Fig[3] and Fig[4] for NSI,UP-scalar and UP-vector respectively.

References

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