# Tensorial Non Standard and Unparticle interactions in neutrino-electron Scattering.

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In collaboration with:

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# Outline

- Introduction (Motivation)
- Neutrino Physics beyond SM, two scenarios: NSI (Non Standard Interactions) and UP (*Unparticle* physics)
- Constraints to Tensorial parameters from Reactor neutrino data (TEXONO)
- Conclusions and perspectives

# Introduction

- Searching for new physics has been highly motivated by the neutrino oscillation physics which implies non-zero neutrino masses.
- The TEXONO collaboration has reported recent results and that has motivated us to study tensorial interactions in the framework of NSI as well as in the unparticle physics scheme.
- We will see that it is possible to obtain strong constraints to the parameters of both approaches.

# Neutrino-electron scattering

In the SM, the 4 point fermion interaction Lagrangian is.

$$\boxed{\mathcal{L}_{\mathit{eff,int}} = -\sqrt{2}G_f(\bar{\nu}_\alpha\gamma^\mu P_L\nu_\alpha)[g_R(\bar{e}\gamma_\mu P_R e) + g_L(\bar{e}\gamma_\mu P_L e)]}$$

And the nu-e scattering cross section:

$$\boxed{\frac{d\sigma(\bar{\nu}_e)}{dT} = \frac{2G_F^2 m_e}{\pi}[g_R^2 + g_L^2(1-\frac{T}{E_\nu})^2 - g_R g_L\frac{m_e T}{E_\nu^2}].}$$

It has the advantage of being a purely leptonic process and therefore is free from QCD uncertainties.

# Non Standard Interactions (NSI)

Operators with (V-A) Lorentz structure have been constrained in neutrino electron interactions. However, tensorial NSI have not been studied in detail in the neutrino sector.

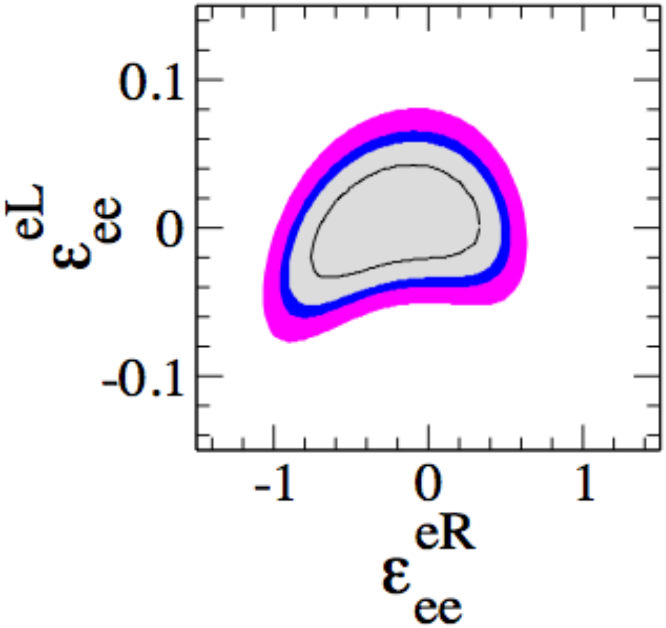
The effective lagrangian is:

$$-\mathcal{L}^{eff}_{\mathrm{V-A}} = \varepsilon^{fP}_{\alpha\beta} 2\sqrt{2} G_F (\bar{\nu}_\alpha \gamma_\rho L \nu_\beta)(\bar{f} \gamma^\rho P f),$$

And the nu-e cross section

$$\begin{aligned}\frac{d\sigma(E_\nu,T)}{dT} = \frac{2G_F^2 m_e}{\pi}&[(\tilde{g}_L^2 + \sum_{\alpha\neq e}|\epsilon^{eL}_{\alpha e}|^2) + \\ &+ (\tilde{g}_R^2 + \sum_{\alpha\neq e}|\epsilon^{eR}_{\alpha e}|^2)\left(1-\frac{T}{E_\nu}\right)^2 - (\tilde{g}_L\tilde{g}_R + \sum_{\alpha\neq e}|\epsilon^{eL}_{\alpha e}||\epsilon^{eR}_{\alpha e}|)m_e\frac{T}{E_\nu^2}],\end{aligned}$$

# Limits for NSI(V-A)



$$-0.27 < \varepsilon_{ee}^{eR} < 0.59\,,$$

$$-0.036 < \varepsilon_{ee}^{eL} < 0.063\,.$$

Bolaños, Miranda, Palazzo, Tortola, Valle PRD **79** 113012 2009

# NSI Tensorial interactions

In this case the eff. Lagrangian is:

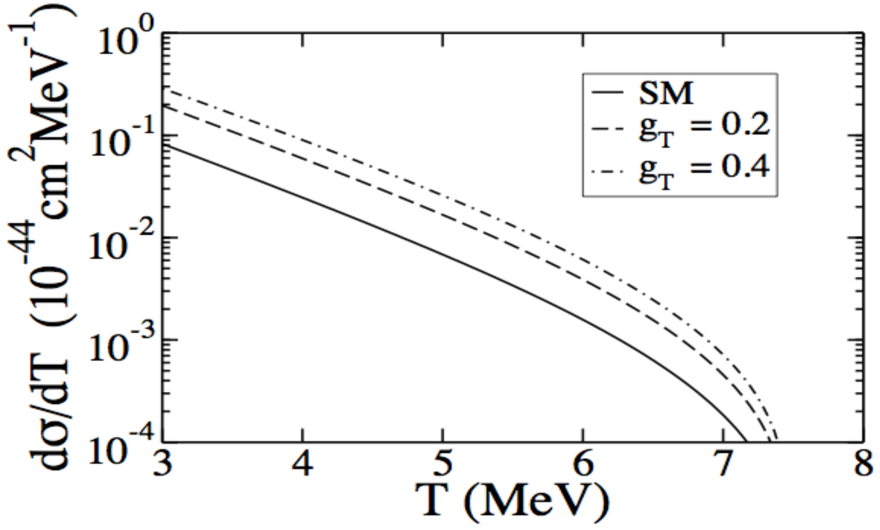
$$-\mathcal{L}_{\mathrm{T}}^{eff} = \varepsilon_{\alpha\beta}^{fT} 2\sqrt{2} G_F (\bar{\nu}_\alpha \sigma^{\mu\nu} \nu_\beta)(\bar{f} \sigma_{\mu\nu} f),$$

$$\sigma_{\mu\nu} = \gamma_\mu \gamma_\nu + \gamma_\nu \gamma_\mu$$

The cross section:

$$\frac{d\sigma_T^{NSI}}{dT} = \frac{|\ M\ |^2}{64\pi m_e E_\nu^2} = \varepsilon_{\alpha\beta}^{fT\,2} \frac{4G_F^2 m_e}{\pi} \left[ \left(1 - \frac{T}{2E_\nu}\right)^2 - \frac{m_e T}{4E_\nu^2} \right].$$

Comparation between SM and NSI(T).



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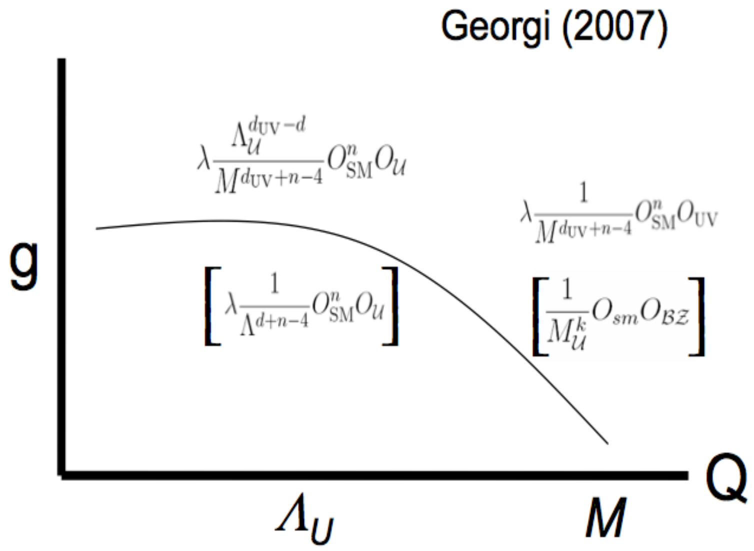
# The physics of *Unparticle*

At energies above Λ, a hidden sector operator $O_{UV}$ of dimension $d_{UV}$ could couple to the SM operators $O_{SM}$ of dimension $d_{SM}$ via the exchange of heavy particles of mass M.

$$\boxed{\mathcal{L}_{UV} = \frac{\mathcal{O}_{UV}\mathcal{O}_{SM}}{M^{d_{UV}+d_{SM}-4}}\,.}$$


Georgi (2007)

The hidden sector becomes scale invariant at Λ and the interactions become:

$$\boxed{\mathcal{L}_{\mathcal{U}} = C_{\mathcal{O}_{\mathcal{U}}}\frac{\Lambda^{d_{UV}-d}}{M^{d_{UV}+d_{SM}-4}}\mathcal{O}_{\mathcal{U}}\,\mathcal{O}_{SM}\,,}$$

$O_U$ is the unparticle operator of scaling dimension d in the low energy limit.
The unparticle sector can appear at low energies
in the form of new massless fields coupled very weakly to the SM particles.

H. Georgi, Phys. Rev. Lett. 98, 221601 (2007)

# Scalar and Vectorial UP.

The neutrino-electron cross section mediated by the scalar unparticle is given by:

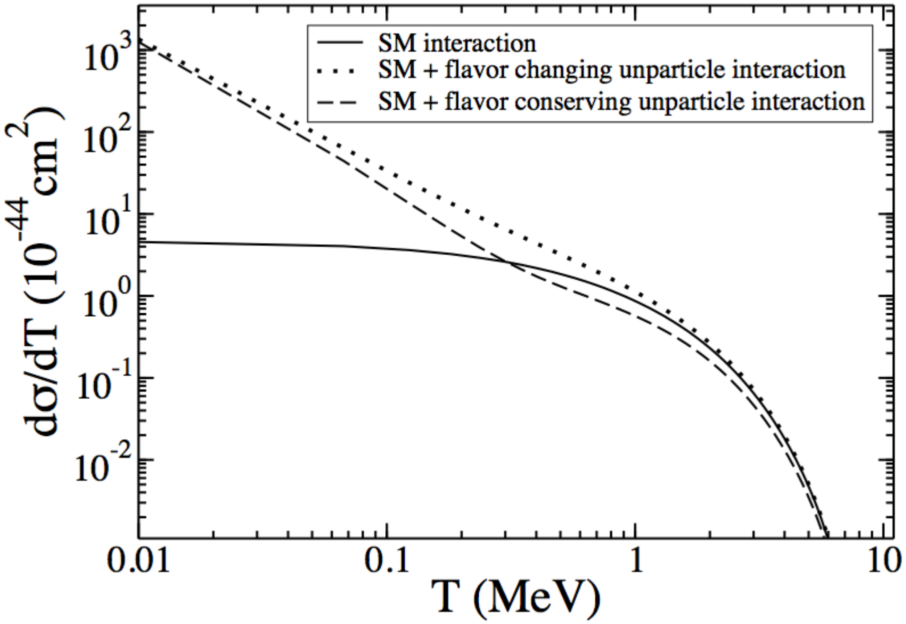
$$\boxed{\frac{d\sigma_{\mathcal{U}_S}}{dT} = \frac{[g_{0e}^{\alpha\beta}(d)]^2}{\Lambda^{(4d-4)}} \frac{2^{(2d-6)}}{\pi E_\nu^2} (m_e T)^{(2d-3)} (T + 2m_e)\,,}$$

For neutrino electron scattering mediated by vector unparticles, the differential cross section has the form:

$$\boxed{\frac{d\sigma_{\mathcal{U}_V}}{dT} = \frac{1}{\pi} \frac{[g_{1e}^{\alpha\beta}(d)]^2}{\Lambda^{(4d-4)}} 2^{(2d-5)} (m_e)^{(2d-3)} (T)^{(2d-4)} \left[1 + \left(1 - \frac{T}{E_\nu}\right)^2 - \frac{m_e T}{E_\nu^2}\right]\,,}$$

$$g_{if}^{\alpha\beta}(d) = \frac{\lambda_{i\nu}^{\alpha\beta} \lambda_{if}}{2\sin(d\pi)} A_d \qquad\qquad A_d = \frac{16\pi^{5/2}}{(2\pi)^{2d}} \frac{\Gamma(d + 1/2)}{\Gamma(d-1)\Gamma(2d)}\,.$$

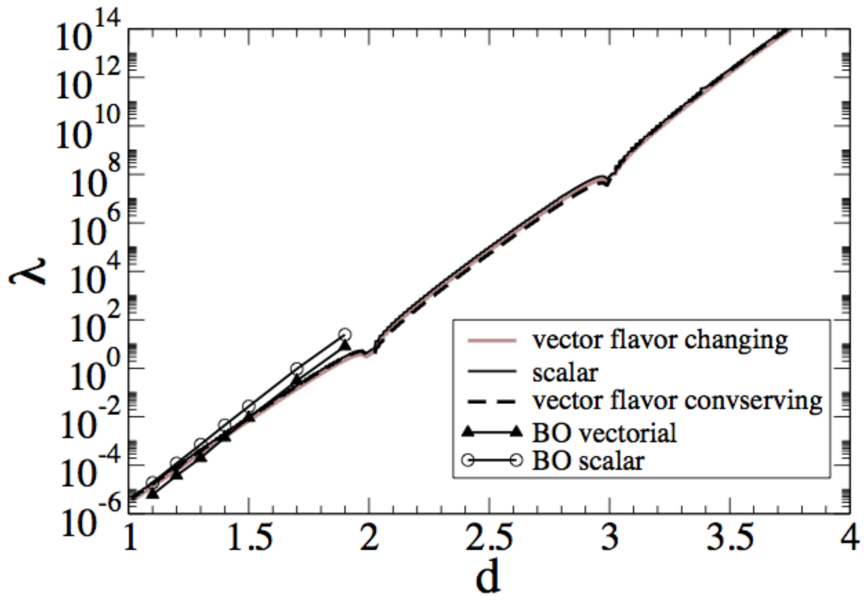
# Unparticle nu-e Scattering

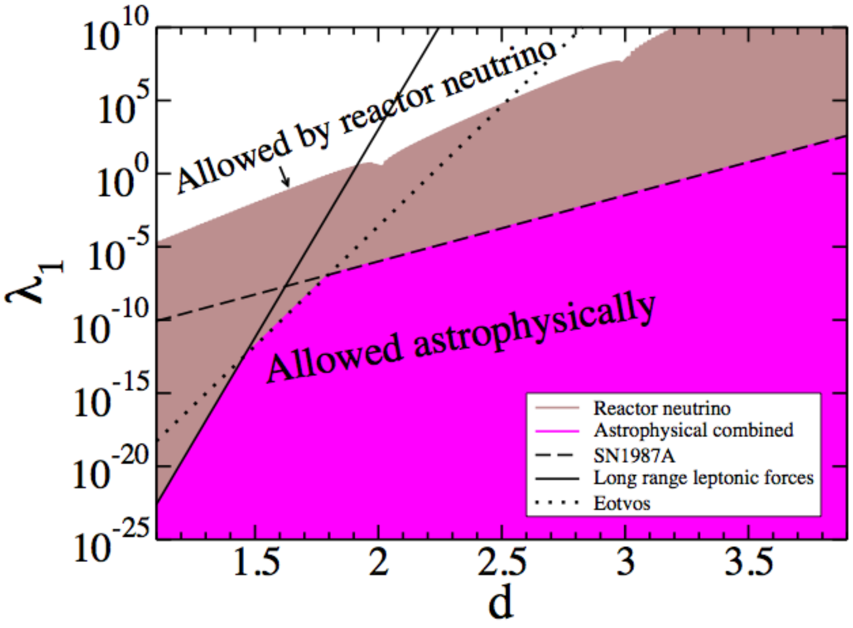


Low-energy processes involving unparticles can have a particular energy spectrum, that is not predicted by other types of new physics.

Barranco, Bolaños, Miranda, Moura, Rashba, Phys.Rev. D79 (2009) 07301

# Scalar and Vector UP from MUNU





Barranco, et al. Phys.Rev. D79 (2009) 07301

Deniz et. Al Phys. Rev. D 82, 033004 (2010)

# Unparticle Neutrino-electron scattering (Tensorial case.)

magnetic term

$$\boxed{\frac{d\sigma_T}{dT} = \frac{f(d)^2}{\pi\Lambda_U^{4d-4}} 2^{2d-2} m_e^{2d-3} T^{2d-4} \left(1 - \frac{T}{2E_\nu}\right)^2.}$$

electric term

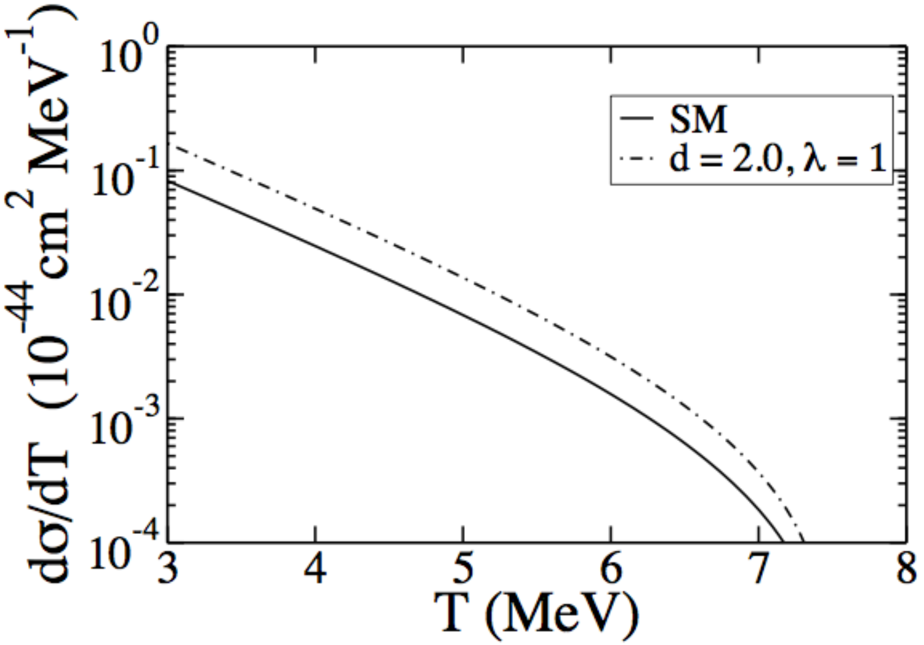
$$\boxed{\frac{d\sigma_T}{dT} = \frac{f(d)^2}{\pi\Lambda_U^{4d-4}} 2^{2d-3} m_e^{2d-3} T^{2d-4} \left[\left(1 - \frac{T}{2E_\nu}\right)^2 - \frac{mT}{2E_\nu^2}\right]}$$

Where

$$f(d) = \frac{\lambda_{i\nu}^{\alpha\beta}\lambda_{if}}{2\sin(d\pi)} A_d. \qquad\qquad A_{d_{\mathcal{U}}} = \frac{16\pi^{5/2}}{(2\pi)^{2d}} \frac{\Gamma(d+1/2)}{\Gamma(d-1)\Gamma(2d)},$$

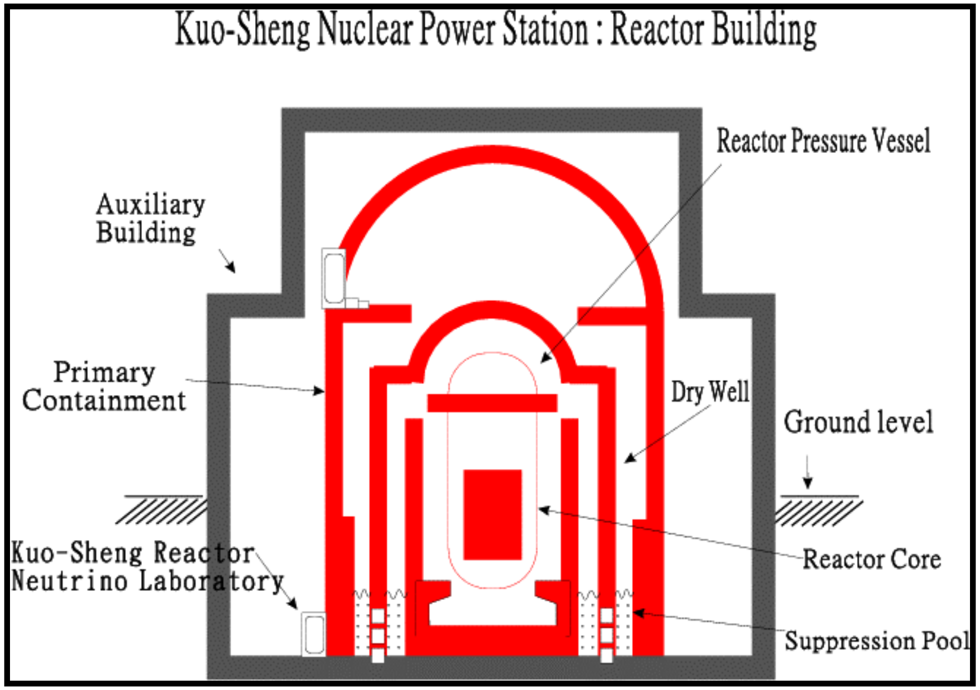
# Tensor Unparticle

In order to obtain the total cross section, the expressions shown before should be added to the SM prediction



# TEXONO(Taiwan EXperiment On NeutrinO)
# 台灣微中子實驗

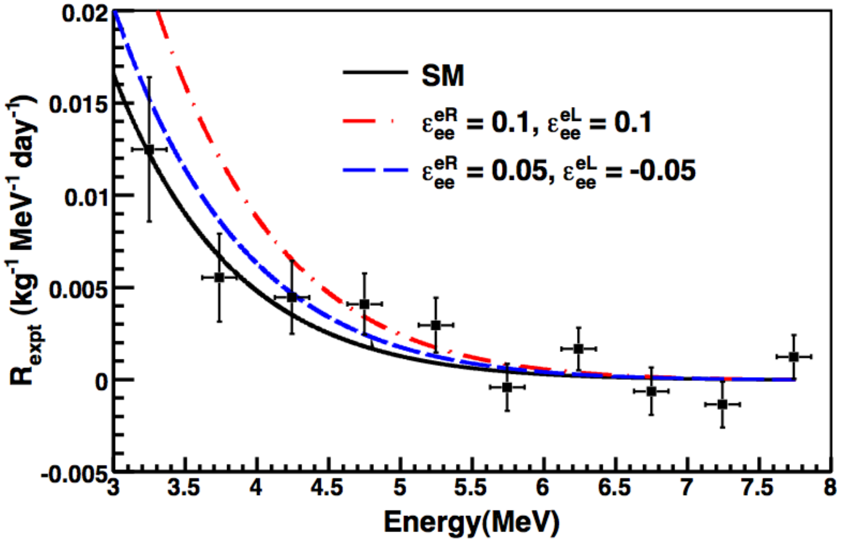
- **TEXONO** SBL (Kuo-Sheng R. Taiwan) (DS1-CsI(Tl) Cristal scintillator).



# TEXONO DS1-CsI(Tl) detector data

In the TEXONO experiment the expected event rate per energy bin is:

$$R_X = \rho_e \int_T \int_{E_\nu} \left(\frac{d\sigma}{dT}\right)_X \frac{d\phi(\bar{\nu}_e)}{dE_\nu} \, dE_\nu \, dT$$



Deniz et. Al TEXONO Coll.
Phys. Rev. D 82, 033004 (2010)

# TEXONO statistical analysis

We compute the expected number of events for the TEXONO detector in the case of a NSI or unparticle interaction

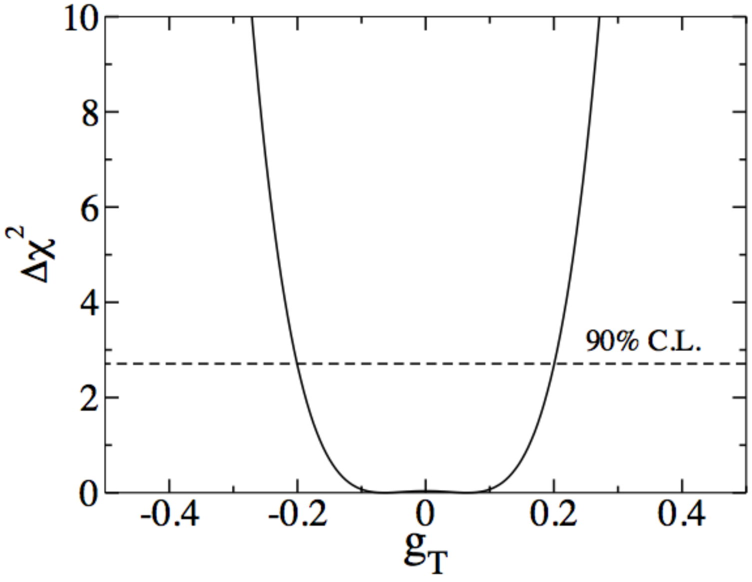
$$N_i = K \int_{T_i}^{T_{i+1}} \int_{E_\nu} \frac{d\sigma}{dT} \frac{d\phi(\bar{\nu}_e)}{dE_\nu} dE_\nu dT,$$

Once we have computed the theoretical expected events per bin we can compute the $\chi^2$ function:

$$\chi^2 = \sum_{i=1} \left[ \frac{N_{expt}(i) - [N_{NSI,U}(i)]}{\Delta_{stat}(i)} \right]^2 ,$$

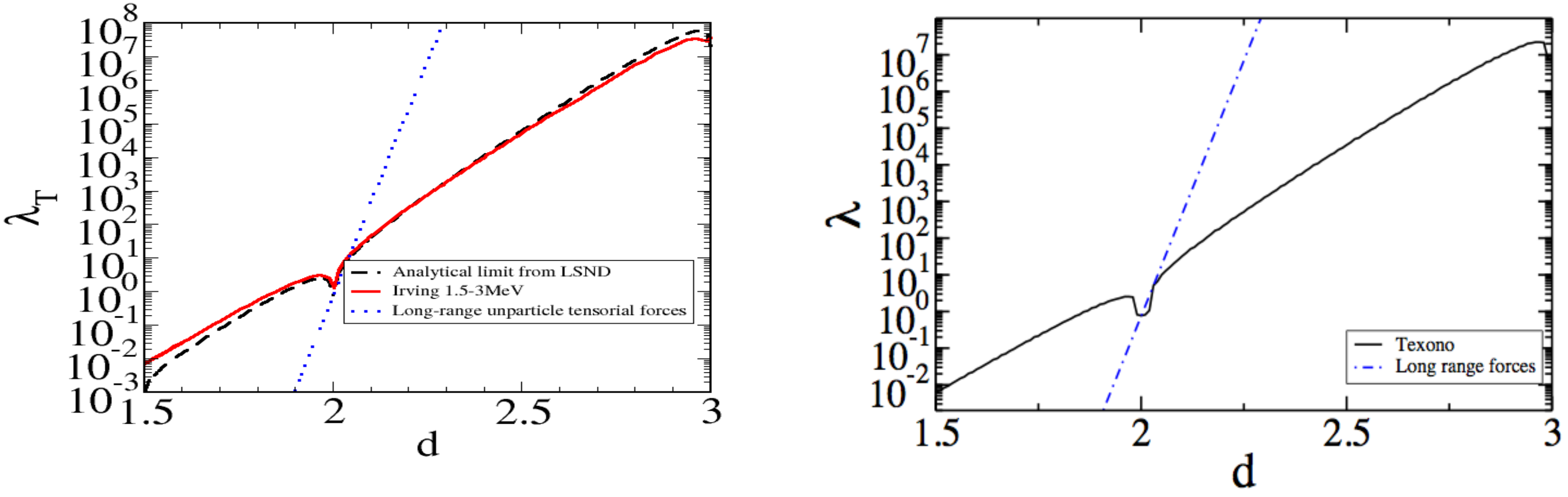
# Tensorial NSI

| experiment | Energy Range (MeV) | $g_T$ |
|---|---|---|
| Stellar energy loss | − − − | 0.06 − 3.6 |
| Irvine | 1.5 − 3.0 | 0.297 90 % CL |
| Irvine | 3.0 − 4.5 | 0.360 90 % CL |
| LAMPF | 10 − 50 | 0.379 90 % CL |
| MUNU | 0.7 − 2.0 | 0.250 90 % CL |
| TEXONO | 3.0 − 8.0 | 0.20 90 % CL |



Barranco, Bolaños, Garcés,Miranda, Rashba arXiv:1108.1220 [hep-ph]

# Tensorial Unparticle



Barranco, Bolaños, Garcés,Miranda, Rashba arXiv:1108.1220 [hep-ph]

M. C. Gonzalez-Garcia, P. C. de Holanda and R. Zukanovich Funchal, JCAP 0806, 019 (2008)

# conclusions and perspectives..

- We have found new constraints that are stronger than previous laboratory constraints.
- For the case of an unparticle tensor interaction, we have found that our constraints are more restrictive than previous analysis for values of $d > 2.03$.
- Another possible place to search for this type of interaction in the future could be the coherent neutrino nuclei scattering that is also part of the TEXONO low energy neutrino physics program.

# Aknowlegements

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