Particle physics implications of coherent elastics neutrino-nucleus scattering

Omar Miranda

Cinvestav

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Outline

CEνNS experiments at π-DAR and reactors

COHERENT	CsI	2017
COHERENT	LAr	2020
COHERENT	LAr	
COHERENT	Ge	
COHERENT	NaI	
ESS	Xe	
ESS	CsI	
ESS	Ge	
CCM	LAr	

For LBL: Aristizabal-Sierra, Dutta, Kim, Snowden-Ifft, Strigari Phys. Rev. **D104** (2021) 033004

CONUS	HPGe	
νGEN	HPGe	
TEXONO	HPGe	
CONNIE	Si	
vIOLETA	Si	
RED-100	Xe	
NEON	NaI(Tl)	
SBC	Ar	
MINER	Si-Ge	
NUCLEUS	$CaWO_4$	

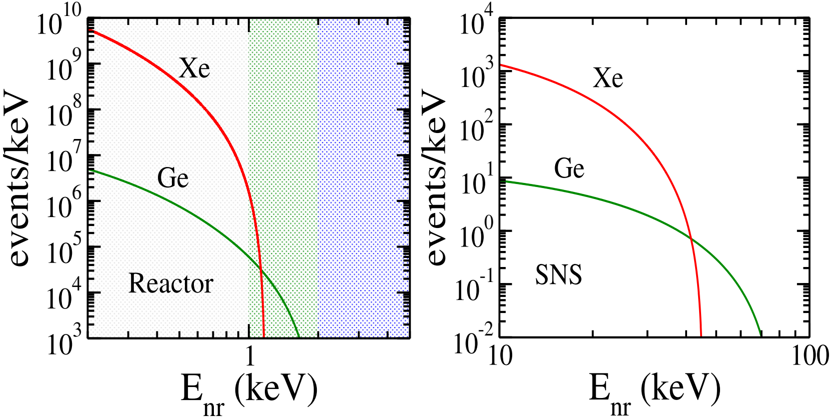
For ANS: Bellenghi, Chiesa, Di Noto, Pallavicini, Previtali, Eur. Phys. J **C79** (2019) 727

CEνNS

$$\left(\frac{d\sigma}{dT}\right) \approx \frac{G_F^2 M}{4\pi}\left[1-\frac{MT}{2E_\nu^2}\right]\left[N F_N(q^2) + Z(1-4\sin^2\theta_W)F_Z(q^2)\right]^2$$

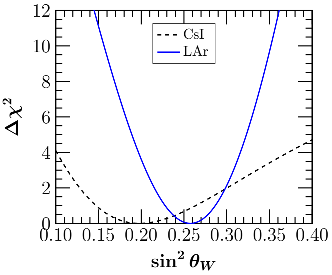
- $\sigma \propto N^2$
- $E_\nu \lesssim 50$ MeV
- $T \lesssim 10$ keV

Freedman Phys. Rev. **D9** (1977) 1389


events/keV
Xe
Ge
Reactor
E_nr (keV)
events/keV
Xe
Ge
SNS
E_nr (keV)

Testing Standard Model with CEνNS.

Current test for $\sin^2\theta_W$



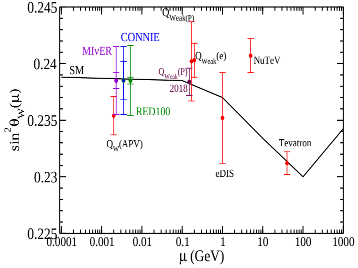
- $\sin^2\theta_W = 0.258^{+0.048}_{-0.050}$ LAr
- $\sin^2\theta_W = 0.197^{+0.124}_{-0.080}$ CsI (Old QF)
- $\sin^2\theta_W = 0.209^{+0.072}_{-0.069}$ CsI (New QF)

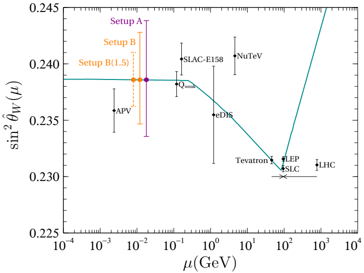
OGM, Papoulias, Sanchez Garcia, Sanders, Tortola, Valle, JHEP 01(2021)067 2003.12050

Papoulias Phys. Rev. **D102** (2020) 113004

See also Cadeddu, Dordei, Giunti, Li, Picciau et al Phys. Rev. **D102** (2020) 015030

Future sensitivity for $\sin^2\theta_W$





Canas, Garces, OGM, Parada Phys. Lett. B784 (2018) 159

SBC Coll. Flores et. al. Phys. Rev. D103 (2021) L091301

See also: Fernandez-Moroni, Machado, Martinez-Soler, Perez-Gonzalez, Rodriguez, Rosauro-Alcaraz, JHEP **03(2021)** 186

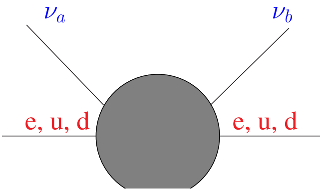
Non-standard interactions (NSI).

Non-standard interactions NSI

Most extensions of the SM predict neutral current non-standard interactions (NSI) of neutrinos which can be either flavor preserving (FD or NU) or flavor-changing (FC).

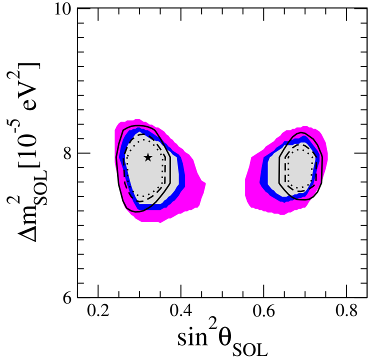
NSI effective Lagragian form:

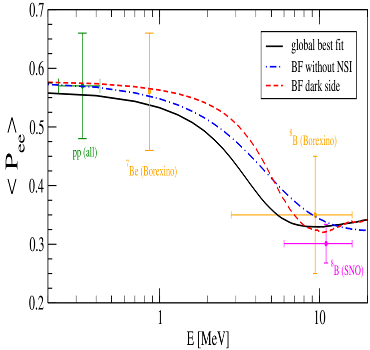
$$\mathcal{L}_{eff}^{NSI} = -\sum_{\alpha\beta fP} \varepsilon_{\alpha\beta}^{fP} 2\sqrt{2} G_F (\bar{\nu}_\alpha \gamma_\rho L \nu_\beta)(\bar{f}\gamma^\rho P f)$$



Here $\alpha, \beta = e, \mu, \tau$; $f = e, u, d$; $P = L, R$; $L = (1-\gamma_5)/2$; $R = (1+\gamma_5)/2$

LMA-Dark solution





OGM, M. Tortola, J. W. F. Valle, JHEP 0610:008 (2006) hep-ph/0406280

F. J. Escrihuela, OGM, M. Tortola, J. W. F. Valle, Phys. Rev. D **80** 105009 (2009)

M. C. Gonzalez-Garcia, M. Maltoni, JHEP **1309** 152 (2013)

M. C. Gonzalez-Garcia, M. Maltoni, T. Schwetz Nucl. Phys. B **908** 199 (2016)

P. Coloma, T. Schwetz, Phys.Rev. D94 (2016) 055005

CEνNS and NSI

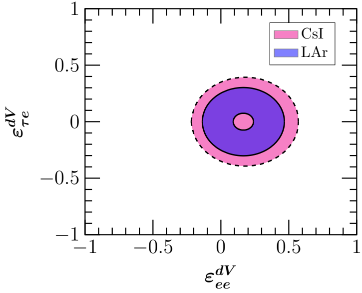
$$
\begin{aligned}
\frac{d\sigma}{dT}(E_\nu, T) &= \frac{G_F^2 M}{\pi}\left(1-\frac{MT}{2E_\nu^2}\right)\times \\
&\times \left\{\left[Z(g_V^p + 2\varepsilon_{ee}^{uV} + \varepsilon_{ee}^{dV}) + N(g_V^n + \varepsilon_{ee}^{uV} + 2\varepsilon_{ee}^{dV})\right]^2 + \right. \\
&+ \left.\sum_{\alpha=\mu,\tau}\left[Z(2\varepsilon_{\alpha e}^{uV} + \varepsilon_{\alpha e}^{dV}) + N(\varepsilon_{\alpha e}^{uV} + 2\varepsilon_{\alpha e}^{dV})\right]^2\right\}
\end{aligned}
$$

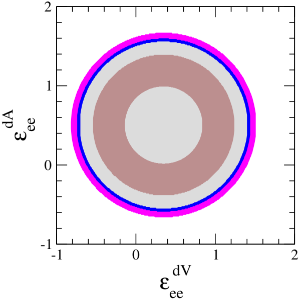
J. Barranco, OGM, T. I. Rashba JHEP 0512 (2005) 021

K. Scholberg PRD **73** (2007) 033005

J. Barranco, OGM, T. I. Rashba PRD **73** (2007) 033005

CEνNS and NSI





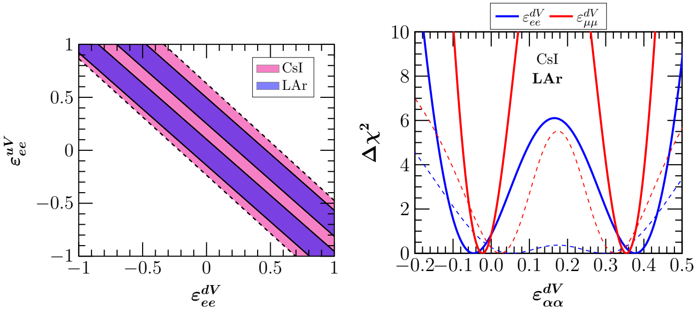
OGM, Papoulias, Sanchez Garcia, Sanders, Tortola, Valle, JHEP 01(2021)067 2003.12050

Papoulias Phys. Rev. **D102** (2020) 113004

See also Giunti Phys. Rev. **D101** (2020) 035039

ϵ^{dV}_{ee} from CHARM data

CEνNS and NSI



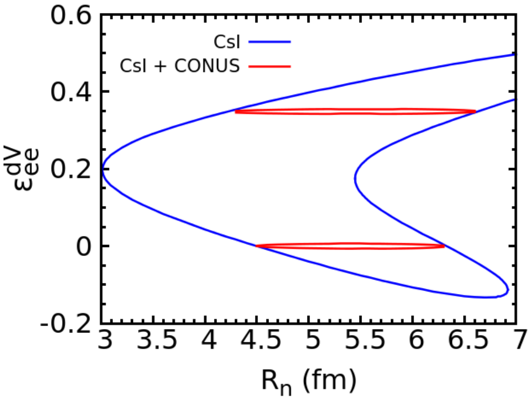
OGM, Papoulias, Sanchez Garcia, Sanders, Tortola, Valle, JHEP 01(2021)067 2003.12050

Papoulias Phys. Rev. **D102** (2020) 113004

See also Giunti Phys. Rev. **D101** (2020) 035039

Interplay between different observables

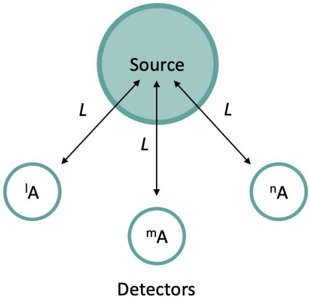
NSI vs R_n



Canas, Garces, OGM, Parada, Sanchez Garcia Phys. Rev. B **101** (2020) 035012

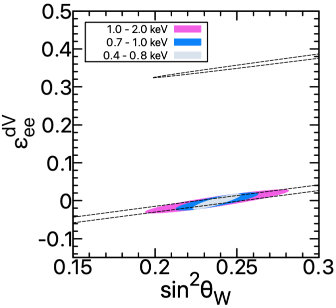
See Papoulias talk for a discussion on R_n and form factors

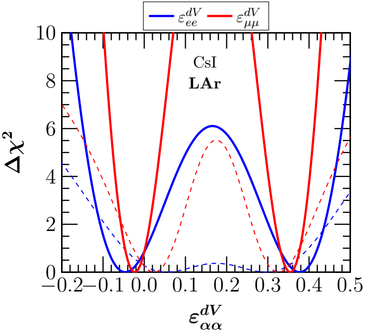
Using three isotopes of the same element



Galindo-Uribarri, OGM, Sanchez Garcia arXiv: 2011.10230

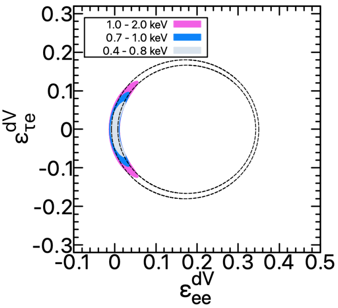
Using three isotopes of the same element

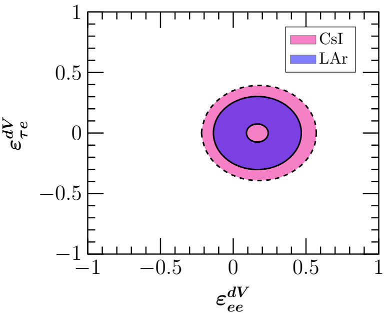




Galindo-Uribarri, OGM, Sanchez Garcia arXiv: 2011.10230, v2 in progress

Using three isotopes of the same element





Galindo-Uribarri, OGM, Sanchez Garcia arXiv: 2011.10230, v2 in progress

Non-unitarity and CEνNS

Non unitarity

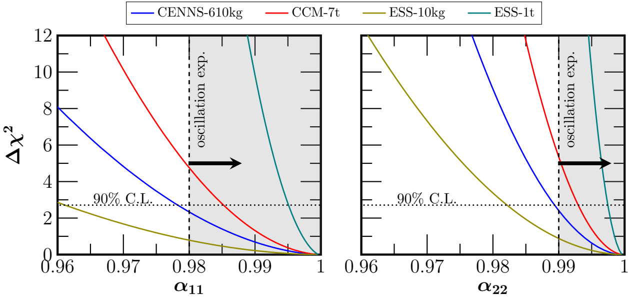
Neutral heavy leptons are a common feature of many extensions of the SM and play and important role in models for neutrino mass generation. The seesaw mechanism is perhaps the most representative example.

$$U_{\alpha i}^{n\times n} = \begin{pmatrix} N & S \\ V & T \end{pmatrix}$$

$$NN^\dagger + SS^\dagger = I,$$

- S Antusch, O Fischer, JHEP 10(2014) 094
- Escriuela, Forero, OGM, Tortola, Valle, Phys. Rev. **D92** 119905 (2015)
- S Parke, M Ross-Lonergan, Physical Review, **D93** 113009 (2016)
- C S Fong, H Minakata, H Nunokawa, JHEP 02(2017) 114
- M Blennow, P Coloma, E Fernandez-Martinez, J Hernandez-Garcia, J Lopez-Pavon, JHEP 02(2019) 015
- S A Ellis, K Kelly, S W Li JHEP 12(2020) 068
- Forero, Giunti, Ternes, Tortola, arXiv: 2103.01998

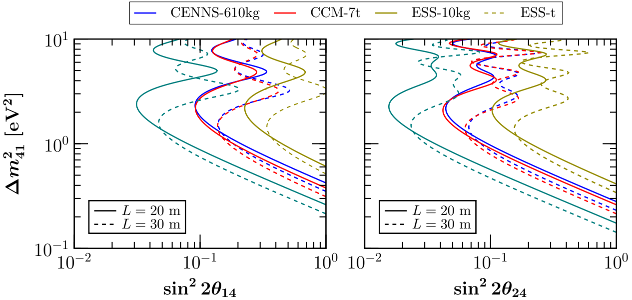
Non unitarity



OGM, Papoulias, Sanders, Tortola, Valle Phys. Rev. D102 (2020) 113014

Sterile neutrino and CEνNS

Sterile neutrino



OGM, Papoulias, Sanders, Tortola, Valle Phys. Rev. D102 (2020) 113014

See also B Dutta et al, Phys. Rev. D **94** 093003 (2016)

Canas, Garces, OGM, Parada, Phys. Lett. B **776** 451 (2018)

Conclusions

- ✓ With the detection of CEνNS a new window to test for standard and non-standard particle physics is open.
- ✓ Different measurements of this reaction will be available and they will be complementary to each other.
- ✓ Among other observables, CEνNS is competitive in measuring the weak mixing angle, non-standard interactions and other observables.

Thanks