Neutrino physics from a gauged U(1) extension of the Standard Model

Timo J. Kärkkäinen

ELTE Eötvös Loránd University, Budapest, Hungary,
e-mail: timo.karkkainen@ttk.elte.hu, www: saunalahti.fi/∼zeick

Introduction

The super-weak extension of the standard model (SWSM) is an economical U(1)-extension of the SM, aiming to explain the origin of neutrino mass and oscillations, dark matter, cosmic inflation, matter-antimatter asymmetry of the universe and to stabilize the vacuum. New physics is manifested by nonstandard interactions (NSI) and active-sterile neutrino mixing. NSI effects by SWSM conserve flavour, and must therefore be probed via neutrino scattering experiments.

Extra U(1) + scalar singlet + sterile neutrinos

	$\mathrm{SU(2)_L}$	$\mathrm{U(1)}_Y$	$\mathrm{U(1)}_Z$
Q_L	**2**	$\frac{1}{6}$	$\frac{1}{6}$
u_R	**1**	$\frac{2}{3}$	$\frac{7}{6}$
d_R	**1**	$-\frac{1}{3}$	$-\frac{5}{6}$
L_L	**2**	$-\frac{1}{2}$	$-\frac{1}{2}$
ℓ_R	**1**	-1	$-\frac{3}{2}$
ϕ	**2**	$\frac{1}{2}$	1
N_R	**1**	0	$\frac{1}{2}$
χ	**1**	0	-1

We add three right-handed neutrinos sterile under the SM gauge group and a scalar singlet χ, whose VEV

$$w = \mathcal{O}(v_{\mathrm{SM}})$$

generates Dirac and Majorana mass term to the neutrinos. After SSB the particle spectrum contains three massive Majorana neutrinos $N_R = (N_1, N_2, N_3)$.

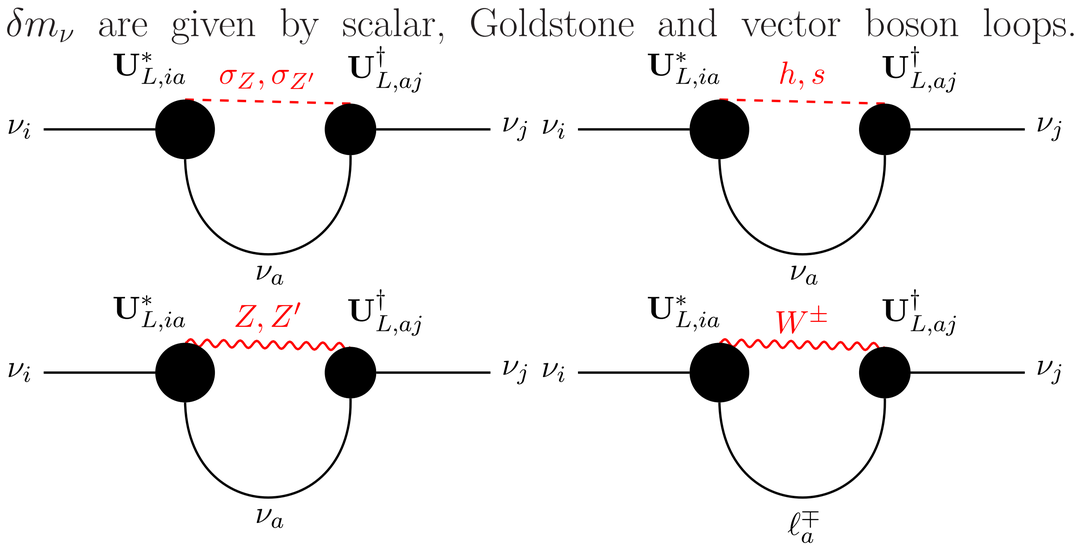
Neutrino mass at tree-level and one-loop

Light neutrino masses are generated via Type-I seesaw mechanism,

$$m_\nu = -m_D m_R^{-1} m_D^T, \quad m_D = \frac{v}{\sqrt{2}} Y_\nu, \quad m_N = \frac{w}{\sqrt{2}} Y_N.$$

N_1 is the dark matter candidate, having a MeV scale mass. N_2 and N_3 are responsible of matter-antimatter asymmetry of the universe via CP-violating neutrino oscillations in early universe.

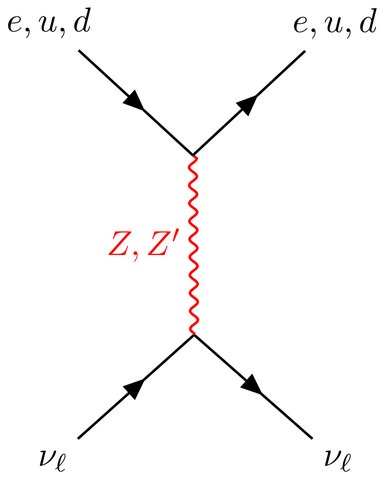
The radiative corrections at one loop to neutrino mass matrix δm_ν are given by scalar, Goldstone and vector boson loops.

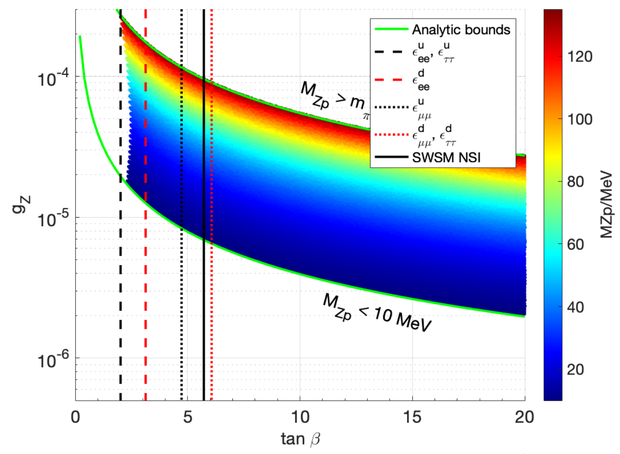


$$\delta m_\nu \lesssim \frac{1}{16\pi^2} \sum_{\text{boson } b \text{ in loop}} \mathcal{O}(1) \times (b \text{ mixing})^2 \times \left(\frac{M_b}{v}\right)^2$$

Nonstandard interactions

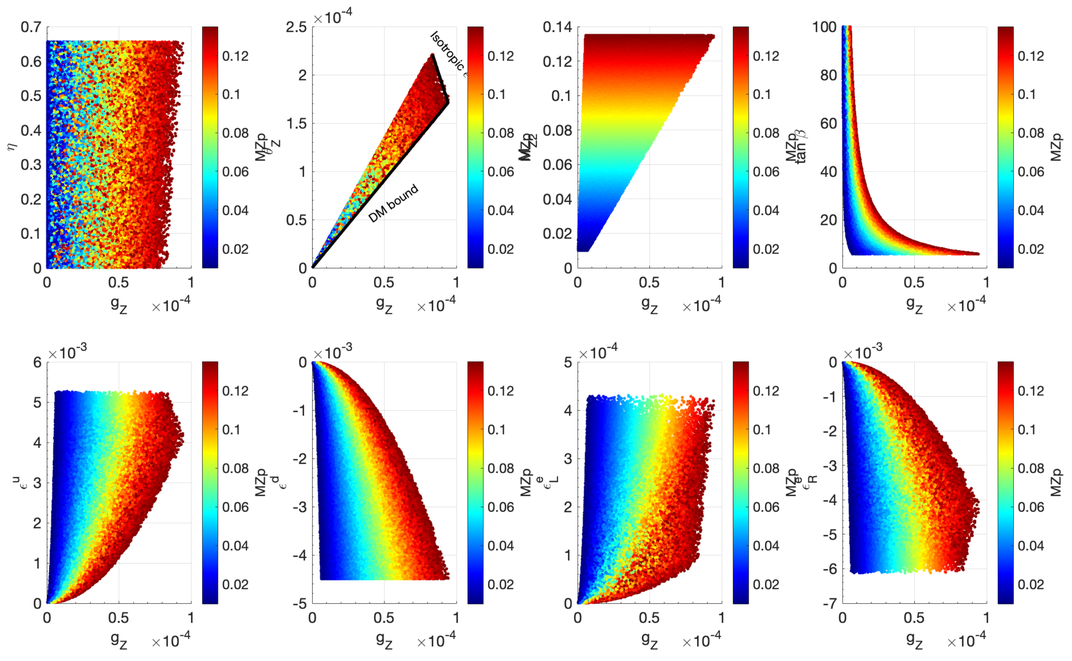
$$\mathcal{L}_{\mathrm{NSI}} = -2\sqrt{2} G_F \varepsilon^{f f'}_{\ell\ell'} (\overline{\nu}_\ell \gamma^\mu P_L \nu_{\ell'})(\overline{f'} \gamma_\mu P_L f)$$
$$\varepsilon^e_{\ell\ell'}, \varepsilon^u_{\ell\ell'}, \varepsilon^d_{\ell\ell'} \sim (\text{SWSM coupling})^2 \times \delta_{\ell\ell'}$$





Particle spectrum contains an extra neutral gauge boson, Z', which mixes with Z. The ratio of the VEV's ($\tan\beta \equiv w/v$) is constrained by NSI, and gauge coupling g_Z by freeze-out dark matter scenario, which restricts $M_{Z'} \in [10, 135]$ MeV.

Z' mass restricts NSI and SWSM parameters



References

[1] Z. Trócsányi, Symmetry **12**, 107 (2020), arXiv:1812.11189.

[2] S. Iwamoto, K. Seller, Z. Trócsányi, JCAP **01** (2022) 01, 035, arXiv: 2104.11248.

[3] S. Iwamoto, T. Kärkkäinen, Z. Péli, Z. Trócsányi, Phys.Rev.D **104** (2021) 5, 055042, arXiv: 2104.14571.

[4] T. Kärkkäinen, Z. Trócsányi, J.Phys.G **49** (2022) 4, 045004, arXiv: 2105.13360.

[5] Z. Péli, Z. Trócsányi, arXiv: 2204.07100

Remember the talk of neutrino dark matter in superweak model, this morning by Károly Seller?

Posters by Zoltán Péli [1195] and Zoltán Trócsányi [1288] have more information about superweak model!