Yukawa sąryšio konstantos su kilpos pataisomis Grimus-Neufeld modelyje

The loop improved Yukawa couplings of the Grimus-Neufeld model

Thomas Gajdosik[1], Andrius Juodagalvis[2], Darius Jurčiukonis[2]
[1]Vilniaus universitetas, Fizikos fakultetas, Saulėtekio al. 9, 10222 Vilnius
[2]Vilniaus universitetas, Teorinės fizikos ir astronomijos institutas, Saulėtekio al. 3, 10257 Vilnius
tgajdosik@yahoo.com

The seesaw mechanism with as many heavy singlets as light neutrinos [1] or with loop generated masses [2] is taken as the usual explanation of the smallness of neutrino masses. W. Grimus and H. Neufeld connected both mechanisms [3] and proposed a model, where one neutrino gets the mass by the regular seesaw mechanism and a different neutrino gets its mass from radiative corrections stemming from the interaction with additional Higgs doublets. Its simplest implementation uses only one heavy fermionic singlet and only one additional Higgs doublet. We call this simplest implementation the Grimus-Neufeld model (GN-model).

The constraints between the neutrino sector and the two-Higgs-doublet sector of the GN-model come from the prediction of the mass of the second lightest neutrino by loop corrections that are dominated by the Higgs bosons in the loop, as was shown by W. Grimus and L. Lavoura [4].

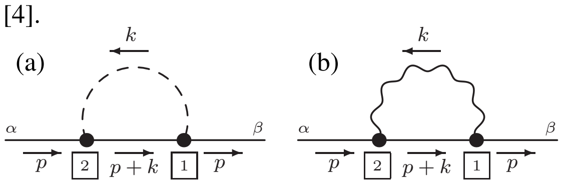

Figure 1: Selfenergy Feynman diagrams contributing to the mass matrix of the light neutrinos: (a) with a scalar in the loop; (b) with a vector in the loop.

We parametrize the Yukawa coupling of the second Higgs doublet to the gauge singlet that drives the seesaw mechanism as

$$Y_N^{(2)} =: d\mathbf{V}_2 + d'\mathbf{V}_3 \ , \tag{1}$$

where we choose the phase of complex 3-vector $\mathbf{V}_2$ in such a way, that d becomes real and positive [5]. With this Yukawa coupling we calculate the one loop corrected effective mass matrix as described in [4]. Comparing the resulting neutrino masses m_{ν_i} with the measured mass squared differences of the neutrinos, Δm^2_{atm} and Δm^2_{sol},

$$\Delta m^2_{12} = m^2_{\nu_2} - m^2_{\nu_1} \quad \text{and} \quad \Delta m^2_{23} = m^2_{\nu_3} - m^2_{\nu_2} \ , \tag{2}$$

taken from the evaluation of neutrino data [6], we can determine the parameter d as

$$d^2 = \frac{v^2}{m_D^2} \frac{m_{\nu_2} m_{\nu_3}}{|f_1 f_3 + f_2^2|} \ . \tag{3}$$

Here v is the vacuum expectation value. m_D^2 parametrizes the Dirac mass term in the tree-level seesaw and we take it as a free parameter. The functions f_i come from the loop, figure 1.

The modulus of $d' = |d'|e^{i\phi'}$ is given by the solution to a fourth order equation. In order to find a real and positive solution, the values of the phase ϕ' can be restricted.

In the loop functions f_i and the coefficients of the fourth order equation appear the masses and the mixing angles between the neutral Higgs bosons. Our parametrization of the Higgs sector follows the theoretical analysis of H. Haber and D. O'Neil [7]. We take the numerical evaluation of the restrictions on the Higgs masses from the thesis of A. Kunčinas [8].

With the values of the Yukawa couplings determined we find an effective loop induced mixing term between the light neutrinos, indicating that the neutrinos are not written in the mass eigenstates. Diagonalizing them again with a rotation matrix R we can relate the 3-vectors $\mathbf{V}_i$ to the measured neutrino mixing matrix

$$V_{\text{PMNS}} = \{\mathbf{V}_1, \mathbf{V}_2, \mathbf{V}_3\} \cdot R \ . \tag{4}$$

The predictive power of the model then lies in processes that use the second Yukawa coupling $Y_N^{(2)}$. Some of the analyses done with this model can be found in [9].

Reikšminiai žodžiai: neutrinos, seesaw mechanism, radiative masses

Literatūra

[1] J. Schechter and J. W. F. Valle, Phys. Rev. D **22** (1980) 2227. doi:10.1103/PhysRevD.22.2227
[2] A. Zee, Phys. Lett. **93B** (1980) 389 Erratum: [Phys. Lett. **95B** (1980) 461]. doi:10.1016/0370-2693(80)90349-4, 10.1016/0370-2693(80)90193-8
[3] W. Grimus and H. Neufeld, Nucl. Phys. B **325** (1989) 18.
[4] W. Grimus and L. Lavoura, Phys. Lett. B **546** (2002) 86 [hep-ph/0207229].
[5] T. Gajdosik, A. Juodagalvis, D. Jurčiukonis and T. Sabonis, Acta Phys. Polon. B **46** (2015) 11, 2323. doi:10.5506/APhysPolB.46.2323
[6] D. V. Forero, M. Tortola and J. W. F. Valle, Phys. Rev. D **90** (2014) no.9, 093006 doi:10.1103/PhysRevD.90.093006 [arXiv:1405.7540 [hep-ph]].
[7] H. E. Haber and D. O'Neil, Phys. Rev. D **83** (2011) 055017 [arXiv:1011.6188 [hep-ph]].
[8] A. Kunčinas, Bachelor thesis, Vilnius University, Faculty of Physics. 2017.
[9] D. Jurciukonis, T. Gajdosik, A. Juodagalvis and T. Sabonis, PoS ICHEP **2012** (2013) 372 [arXiv:1212.5370]. D. Jurciukonis, T. Gajdosik, A. Juodagalvis and T. Sabonis, Acta Phys. Polon. Supp. **6** (2013) 675 [arXiv:1212.6912]. T. Gajdosik, A. Juodagalvis, D. Jurciukonis and T. Sabonis, Acta Phys. Polon. B **44** (2013) 11, 2347 [arXiv:1310.2476 [hep-ph]]. D. Jurciukonis, T. Gajdosik and A. Juodagalvis, arXiv:1410.4443 [hep-ph]. T. Gajdosik, D. Jurčiukonis and A. Juodagalvis, Nucl. Part. Phys. Proc. **260** (2015) 257. doi:10.1016/j.nuclphysbps.2015.02.053 D. Jurciukonis, T. Gajdosik and A. Juodagalvis, arXiv:1507.03459 [hep-ph].