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# Constraints on the parameters of HNL and baryon asymmetry of the Universe

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One of the simplest renormalizable extensions of the SM is the minimal neutrino extension of the Standard Model $\nu$MSM, proposed in 2005 [1, 2]. This modification introduces three righthanded neutrinos or heavy neutral leptons (HNL). The lightest sterile neutrino is identified as a dark matter particle. The other two sterile neutrinos are much heavier, with nearly identical masses, and are responsible for generating the baryon asymmetry observed in the Universe. The observable parameters of the $\nu$MSM Lagrangian are given in [3]

$$S_{\alpha\beta} \equiv (FM^{-1*}M^{-1}F^{\dagger})_{\alpha\beta} = \sum_I S^I_{\alpha\beta} = \sum_I F_{\alpha I}F^{\dagger}_{I\beta}M_I^{-2}, \quad (1)$$

$$R_{\alpha\beta} = \sum_I R^I_{\alpha\beta} = \sum_I S^I_{\alpha\beta} \ln\frac{M_I}{M_W} = \sum_I F_{\alpha I}F^{\dagger}_{I\beta}M_I^{-2}\ln\frac{M_I}{M_W}. \quad (2)$$

In the $\nu$MSM framework, the lightest sterile neutrino, which serves as a long-lived dark matter particle, is undetectable in collider experiments. Therefore, we focus on a simplified scenario that extends the SM by incorporating only two heavy sterile neutrinos. A straightforward relationship has been derived between the experimentally observed quantities (the elements of the matrices Sαβ and Rαβ). This relationship holds for cases where active neutrinos have non-zero masses and where the masses of the heavy sterile neutrinos vary.

$$S_{\alpha\beta}\Big(M_1\ln\frac{M_2}{M_W} + M_2\ln\frac{M_1}{M_W}\Big) = R_{\alpha\beta}(M_1+M_2), \quad S_{\alpha\alpha}S_{\beta\beta} = |S_{\alpha\beta}|^2 \quad R_{\alpha\alpha}R_{\beta\beta} = |R_{\alpha\beta}|^2. \quad (3)$$

Building on the results of [1], we have translated the constraints on baryon asymmetry generation in the early Universe into observable parameters $S_{\alpha\beta}$ and $R_{\alpha\beta}$. We concluded that the actual values of elements of $\hat{R}$ and $\hat{S}$ matrices are many orders of magnitude less than existing experimental constraints. Results of our investigation are presented in detail in [4].

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