Neutrino majorana mass and baryon number of the universe below the electroweak symmetry breaking scale

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Received 29 May 2000; received in revised form 28 June 2000; accepted 17 July 2000
Editor: P.V. Landshoff

Abstract

If the neutrino is Majorana type and the electroweak phase transition is second or weak first order, neutrino-induced interactions together with sphaleron transitions have the potential to erase a previously generated baryon asymmetry of the universe. Taking correctly into account the evolution of the vacuum expectation of the Higgs field the effective light neutrino masses are constrained to be lighter than \( \mathcal{O}(10 \text{ MeV}) \), which is three orders of magnitude less stringent than the bounds obtained from earlier naive estimates. The effective heavy masses are constrained to be heavier than \( \mathcal{O}(10^2 \text{ GeV}) \).

Recent experiments seem to indicate that the neutrino is massive [1]. From a model-building point of view the most natural structure of the neutrino mass matrix contains both Lepton-number-\((L)-\) conserving Dirac- and \(L\)-violating Majorana-type entries (see e.g. [2]). In principle observable consequences are \(L\)-violating processes such as neutrinoless double beta \((0\nu\beta\beta)\) decay and \(L\)-violating lepton-gauge boson scattering (inverse \(0\nu\beta\beta\) decay).

On the other hand, in the early universe \(L\) violation together with sphaleron-mediated transitions has the potential to create the Baryon number \((B)\) of the universe (BAU) (Leptogenesis) or erase an existing BAU. The latter may be the case both above or below the electroweak symmetry breaking scale. This consideration would limit the amount of \(L\) violation and hence give a bound on the Majorana mass of the neutrinos. In the following we will reconsider the limits on neutrino masses and point out that the evolution of the vacuum expectation value \((v_{\text{ev}})\) of the Higgs responsible for electroweak symmetry breaking weakens the existing bound by as large as three orders of magnitude.

In an extension of the standard model, the Majorana mass of the neutrinos can come from an effective dimension-5 operator [3]

\[
\frac{\alpha_{ij}}{M} (L_i^C C^{-i} \tau_2 \tau L_j) (H^T \tau_2 \tau H)
\]

(1)

where \(i,j = 1,2,3\) are generation indices, \(M\) is the \(L\)-violating mass-scale, \(\alpha\) is an effective coupling and \(L (H)\) are \(SU(2)_L\) lepton (Higgs) doublets. After