

Minimal Lepton Flavour Violation and special Cases of CP Violation

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Since the discovery of neutrino masses it is known that lepton flavour is not conserved. However, from non-observation of LFV processes such as $\mu \rightarrow e\gamma$ we know that those interactions have to be highly suppressed. Extensions of the Standard Model (SM) that implement LFV should keep such processes automatically small and allow for new-physics particles with moderate masses. In the quark sector, where the situation of flavour-changing transitions is quite similar, these issues can nicely be accommodated with the Minimal Flavour Violation (MFV) hypothesis. How this mechanism could be established in the lepton sector was proposed by [1]. Analogously to the quark sector, Minimal Lepton Flavour Violation (MLFV) can be formulated as an effective field theory in which the lepton Yukawa couplings are the only sources of flavour violation. In order to additionally explain the smallness of neutrino masses with the help of the see-saw mechanism, the MFV hypothesis in the lepton sector requires lepton number violation at some high scale, and three heavy right-handed Majorana neutrinos that are degenerate in mass.

Since radiative corrections spoil the degeneracy of the Majorana masses [3,4], we combine the MLFV hypothesis with a choice of a scale at which the Majorana masses are exactly degenerate [4]. A natural selection for the degeneracy scale is the GUT scale. It is interesting to know whether the mass splittings of the Majorana neutrinos at the Majorana scale that are induced radiatively are sufficient to generate the baryon asymmetry of the universe (BAU) with the help of Leptogenesis which generically requires a non-degeneracy in the Majorana masses.

This is called radiative resonant leptogenesis (RRL) [2] and the MLFV framework corresponds to a see-saw scenario with three quasi-degenerate heavy Majorana neutrinos. Considering first the case with CP violation in the neutrino Yukawa couplings present at high and low energies we find [4]:

1. The baryon asymmetry of the universe can be generated of the right order of magnitude with RRL independent of the Majorana scale ($10^5 \lesssim M \lesssim 10^{13}$ GeV).
2. The inclusion of flavour effects in the Boltzmann equations below a certain Majorana scale ($M \lesssim 10^9 - 10^{10}$ GeV) is relevant.
3. A flavour specific treatment allows for successful leptogenesis in the special case of no high-energy CP violation. This contradicts the former common belief and corresponds to the findings of [5].
4. Correlations between the generation of the BAU and LFV decays such as $\mu \rightarrow e\gamma$ or ratios of such processes are very weak. Therefore MLFV is not as predictive as the corresponding framework in the quark sector.

We study then the implications of a successful leptogenesis in the case of exclusively low-energy CP violation with the PMNS matrix being the only source of CP violation, which can be obtained provided flavour effects are taken into account ($M \lesssim 10^9 - 10^{10}$ GeV) [6]. We find that the right amount of the baryon asymmetry of the universe can be generated under the conditions of a normal hierarchy of the light neutrino masses, a non-vanishing Majorana phase, $\sin(\theta_{13}) \gtrsim 0.13$ and $m_{\nu, \text{lightest}} \lesssim 0.04$ eV. If this is fulfilled, we find strong correlations among ratios of charged LFV processes. For example the ratio of $B(\mu \rightarrow e\gamma)/B(\tau \rightarrow \mu\gamma)$ which varies over many orders of magnitude when high-energy CP violation is present, is found then to be clearly below one.

Therefore the specific case of exclusively low-energy CP violation turns out to be much more predictive and offers constraints that are testable in experiments.

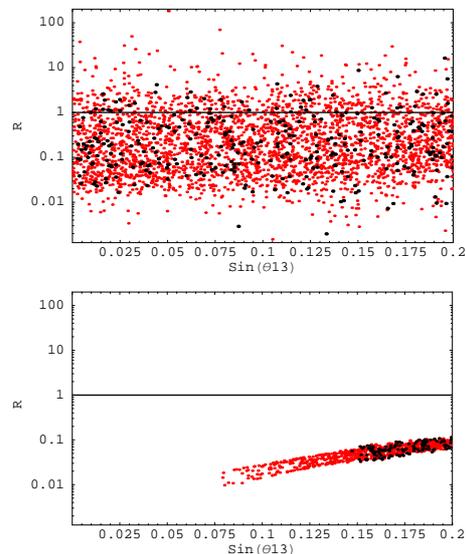


Fig. 1: $R = B(\mu \rightarrow e\gamma)/B(\tau \rightarrow \mu\gamma)$ versus $\sin(\theta_{13})$ for the general analysis [4] including high-energy CP violation (upper plot) and without high-energy CP violation (lower plot) [6] where R is clearly below 1. The black points fulfill the leptogenesis constraint, the constraint on $\sin(\theta_{13})$ in the lower case can be read off.

References

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