Sterile neutrinos with non-standard interactions in β- and 0νββ- decay experiments

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Abstract

Charged currents are probed both in low-energy precision β-decay experiments and at high-energy colliders for constraining signals of BSM physics. We investigate what neutrinoless double-β decay (0νββ) experiments can tell us if a nonzero signal were to be found. Using a recently developed effective-field-theory framework, we consider the effects that interactions with right-handed neutrinos have on 0νββ and discuss the range of neutrino masses that current and future 0νββ measurements can probe, assuming neutrinos are Majorana particles. For non-standard interactions at the level suggested by recently observed hints in β-decays, we show that next-generation 0νββ experiments can determine the Dirac or Majorana nature of neutrinos, for sterile neutrino masses larger than O(10) eV.

Introduction

Focusing on probes in low-energy precision measurements, Falkowski, González-Alonso, and Naviliat-Cuncic recently performed a state-of-the-art analysis of neutron and nuclear β-decay data. The authors then performed a simultaneous fit including all leading-order dimension-six Wilson coefficients. Interestingly, once non-standard interactions involving right-handed neutrinos are included in the analysis, the global fit constrains vector, axial-vector, and scalar couplings to right-handed neutrinos at the few percent level, but prefers a nonzero right-handed tensor coupling at the 10% level (about 3.2σ away from the SM point). In light of this result, we investigate the potential correlated signals in the context of searches for neutrinoless double beta decay (0νββ).

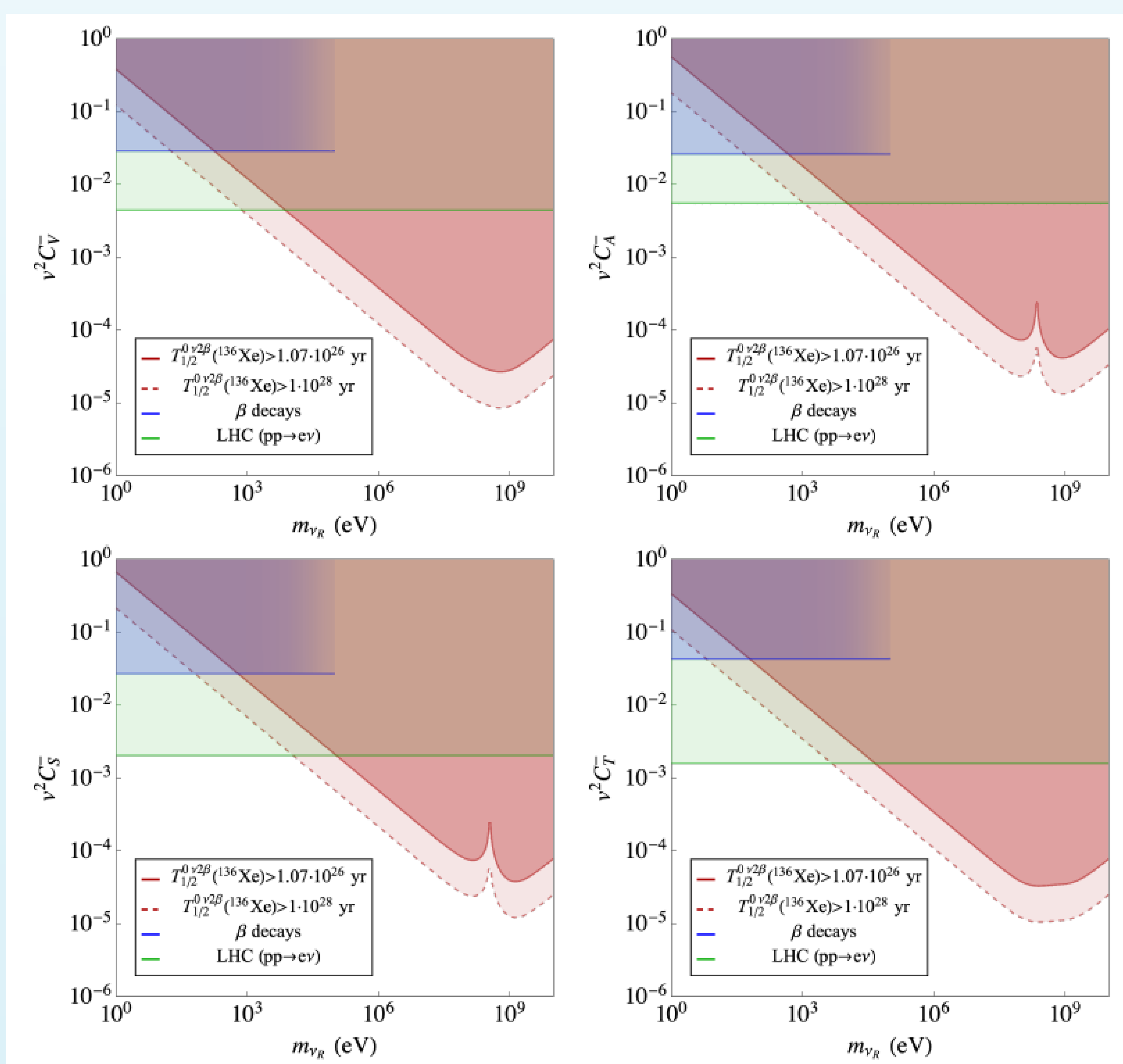
Method

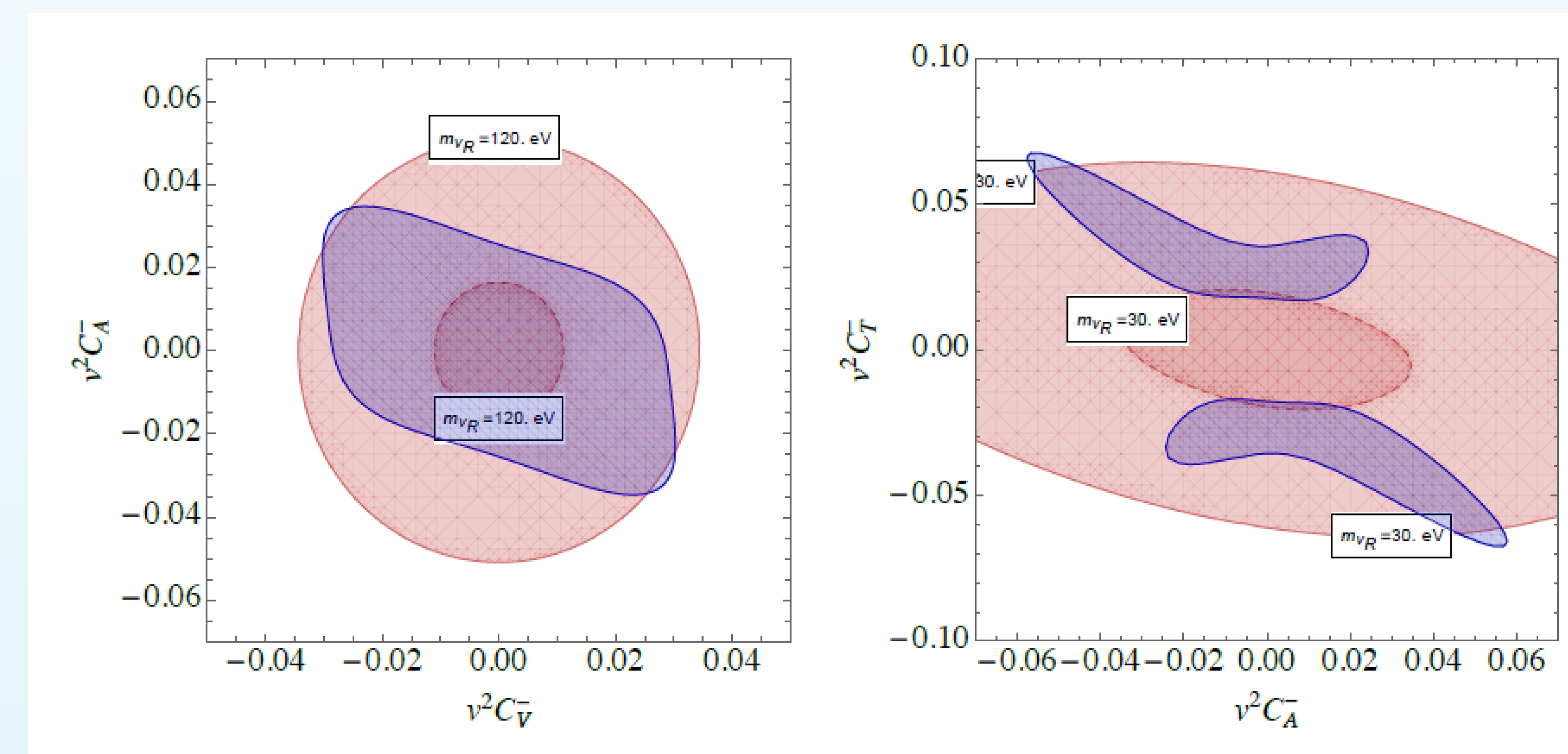
We consider the Standard Model Effective Field Theory at dimension-6 that extended by an SM gauge singlet ν_R, i.e. νSMEFT. On the other hand, since β-decays are low-energy observables, they are commonly described in terms of the interactions involving nucleons, i.e. the Lee-Yang Lagrangian. We begin our analysis by considering a single coupling, while setting the remaining Wilson coefficients to their SM values. We compare the constraints from 0νββ decay against single-β limits (the left panel).

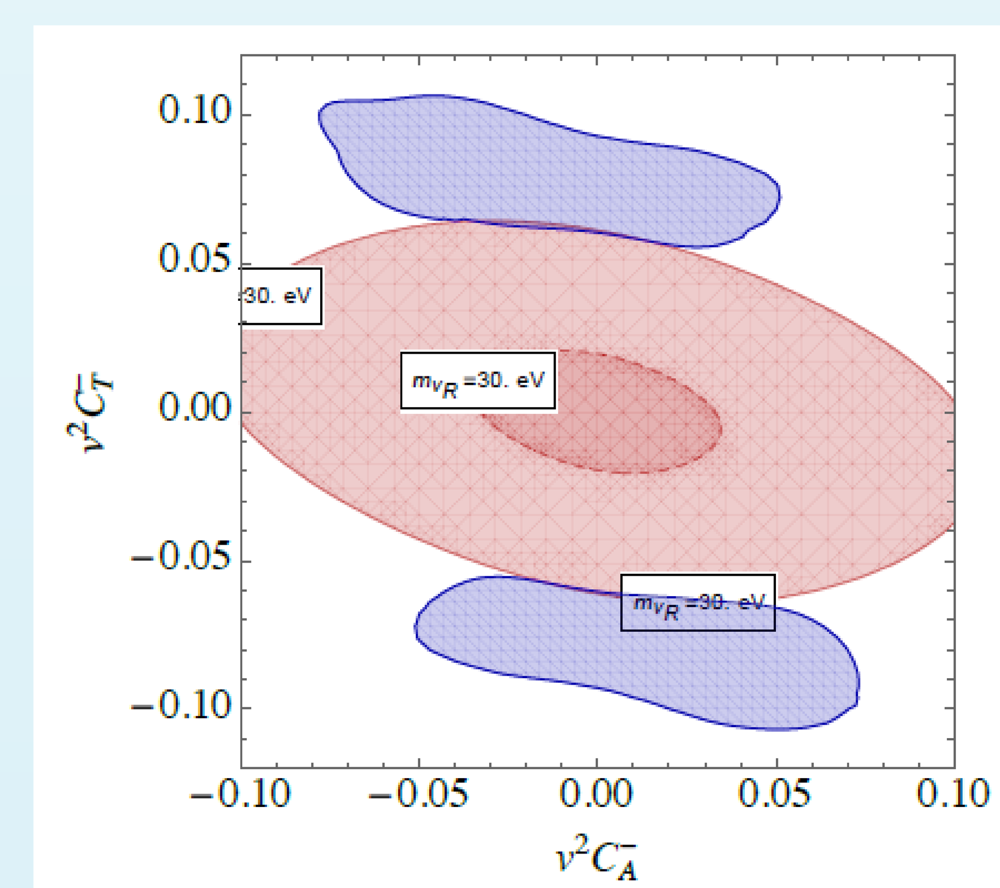
Later on, we turn to a scenario where two couplings are turned on simultaneously, again setting the remaining couplings to their SM values. We focus on a comparison of single-β and 0νββ decay experiments (the right panel). Finally, we use the same machinery to perform a fit of the data, where the single-β is marginalized over all 5 couplings, while we only consider the $C_{A,T}$ contributions to 0νββ. The resulting contour more clearly shows a preference for a nonzero C_T.

Results

$$\begin{aligned}\mathcal{L}_{\text{Lee-Yang}} = & -\bar{p}\gamma^\mu n\left(\bar{e}_L\gamma_\mu C_V^+\nu + \bar{e}_R\gamma_\mu C_V^-\nu\right) - \bar{p}\gamma^\mu\gamma_5 n\left(\bar{e}_L\gamma_\mu C_A^+\nu - \bar{e}_R\gamma_\mu C_A^-\nu\right)\\ & - \bar{p}n\left(\bar{e}_R C_S^+\nu + \bar{e}_L C_S^-\nu\right) - \frac{1}{2}\bar{p}\sigma^{\mu\nu}n\left(\bar{e}_R\sigma_{\mu\nu}C_T^+\nu + \bar{e}_L\sigma_{\mu\nu}C_T^-\nu\right)\\ & + \bar{p}\gamma_5 n\left(\bar{e}_R C_P^+\nu - \bar{e}_L C_P^-\nu\right) + \text{h.c.}\end{aligned}$$







Conclusion

Our study demonstrates the complementary nature of different neutrino probes, and the various aspects of the theory space they individually are sensitive to. In case of a future discovery of a deviation from the Standard Model predictions in one of the experiments, looking at other probes in a global approach provides valuable information to better understand the nature of neutrinos.