Laboratory searches for KeV sterile neutrinos

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Abstract

Motivated by the capability of KATRIN/TRISTAN and HUNTER experiments to explore the existence of KeV neutrinos, we consider important to include a discussion about the role of future laboratory experiments, as they will be independent of any cosmological or astrophysical assumption. The sterile neutrinos can also impact the amplitude of neutrinoless double beta decay and the complementarity between beta decay, neutrinoless double beta decay, and atomic K-capture experiments can discriminate between motivated models for neutrino mass generation mechanism.

The addition of KeV sterile neutrinos to the SM particle spectrum is a well motivated hypothesis since these neutrinos, besides playing a key role in the neutrino mass generation, are a natural DM candidate [1]. Indeed, currently astrophysical and cosmological observations impose severe constraints on the KeV sterile neutrino hypothesis.

While most X-ray bounds are shown under the assumption that the sterile neutrinos are dark matter candidates, one can relax this assumption and simply count the number density generated from neutrino oscillations in the early universe. These bounds seem to rule out much of the parameter space (masses and active-sterile mixings). Nevertheless, these limits rely on underlying cosmological and astrophysical assumptions and can be evaded as discussed, for instance, in [2].

We stress here that laboratory searches provide independent tests of sterile neutrino hypothesis that should prevail over cosmological hypotheses or considerations. There are several recent studies showing that the KeV sterile hypothesis is not in conflict with the astrophysical bounds if one assumes that the Universe never reached a temperature above a few MeV [3, 4].

Sterile neutrinos can be searched in different laboratory experiments, depending on their masses. KeV sterile neutrinos are too heavy to affect neutrino oscillations, but still too light to have an impact in meson decays (peak or monochromatic line searches). They can be however produced in the beta decays of some isotopes, which can impact the electron energy spectrum [5]. In particular, the TRISTAN experiment, the upgraded version of KATRIN, could be able to probe KeV sterile neutrinos [6–9] with an unprecedented sensitivity in other laboratory experiments. Another experimental signature could come from atomic K-capture events, which could be seen by the HUNTER experiment [10]. A detection through production of a KeV sterile neutrino in these experiments would be completely independent of any cosmological and astrophysical input and has the potential to independently test the sterile hypothesis. Interestingly, the neutrinoless double beta decay ($0\nu 2\beta$) - which is by excellence the observable associated with the existence of Majorana neutrinos - when mediated by sterile neutrinos appears to be

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the ideal laboratory to probe their parameter space as the $0\nu2\beta$ amplitude is affected by their presence. The results from $0\nu\beta\beta$ experiments will provide complementary information, which combined with the results from TRISTAN or HUNTER, could help disentangling the model behind the existence of KeV neutrinos [11].

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