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Comment on “Closing the neutrinoless double beta decay window into VEP and/or VLI”

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Abstract

The constraints from the non-observation of neutrinoless double beta decay on the violations of Lorentz invariance (VLI) or violations of the equivalence principle (VEP) have recently been re-examined and it was claimed that the constraints are not valid [6]. In this reply we point out that this statement is not correct and prove that the arguments given are wrong.

In recent times there have been many attempts to find out to what accuracy gravitational laws are correct in the neutrino sector. To constrain the amount of violation of the equivalence principle (VEP) from neutrino oscillation experiments, one assumes that the neutrinos of different generations have different characteristic couplings to gravity [1, 2], while to constrain the amount of violation of local Lorentz invariance (VLI) one assumes that neutrinos of different generations have characteristic maximum attainable velocities [3, 4]. Some time back we pointed out that in both these cases it is possible to constrain some otherwise unconstrained region in the parameter space from neutrinoless double beta decay [5]. However, a recent paper [6] came to the contrary conclusions. In this comment we point out what went wrong in their arguments.

The decay rate for the neutrinoless double beta decay is given by,

$$[T_{1/2}^{0\nu\beta\beta}]^{-1} = \frac{M_+^2}{m_e^2} G_{01} |ME|^2, \tag{1}$$

where ME denotes the nuclear matrix element, G_{01} corresponds to the phase space factor defined in [7] and m_e is the electron mass. The momentum dependence of M_+ must be absorbed into the nuclear matrix element $|ME|$. It will be pointed out in the following, that the dominant contribution to neutrinoless double beta decay in the case of VLI or VEP results from the momentum dependence of the observable itself and has been missed in the ansatz in [6].

We shall now present a more detail explanation of this argument. Reference [6] starts with the neutrino propagator

$$\int d^4q \frac{e^{-iq(x-y)} \langle m \rangle c_a^2}{m^2 c_a^4 - q_0^2 c_a^2 + \vec{q}^2 c_a^2} \tag{2}$$

with the standard $0\nu\beta\beta$ observable $\langle m \rangle$, the neutrino four momentum q and the characteristic maximal velocity c_a. They neglect m in the denominator, so that c_a drops out and the decay rate becomes independent of c_a.

However, to derive the double beta decay rate correctly, one has to start from the Hamiltonian level. In the original paper [5] it has been shown that the propagator (or the $0\nu\beta\beta$ observable) itself is changed when the maximum attainable velocities of different neutrino species are different. Since

$$\begin{aligned} H &= \vec{q} c_a + \frac{m^2 c_a^4}{2 \vec{q} c_a} \\ &= \vec{q} I + \frac{m^{(*)2} c_a^4}{2 \vec{q} c_a} \end{aligned} \tag{3}$$

with $c_a = I + \delta v$ and $m^{(*)2} = m^2 + 2\vec{q}^2 c_a \delta v$ an additional contribution to the effective mass is obtained $\propto \vec{q}^2 \delta v$. This mass-like term has a $\vec{q}^2$ enhancement and is not proportional to the small neutrino mass. This contribution was included through the nuclear matrix element $|ME|$. But in reference [6] the authors started with a propagator in the zero momentum transfer approximation and obviously did not get this additional important term. If the observable M_+ is assumed to be momentum-independent in the following (i.e. neglecting nuclear recoil), of course the momentum dependence has to be included in the nuclear matrix element.

In the original paper [5], a bound on VEP or VLI was presented in the small mixing region assuming conservatively $\langle m \rangle \simeq 0$ and $\delta m \leq \bar{m}$. Due to the q^2 enhancement the nuclear matrix elements of the mass mechanism were replaced by $\frac{m_p}{R} \cdot (M_F^{'} - M_{GT}^{'})$ with the nuclear radius R and the proton mass m_p, which have been calculated in [8]. Inserting the recent half life limit obtained from the Heidelberg–Moscow experiment [9], a bound on the amount of tensorial gravitational interactions as a function of the average neutrino mass $\bar{m}$ was presented [5]. **It is obvious that if one ignores the momentum enhancement of the nuclear matrix element (as it was done in ref [6]), the neutrinoless double beta decay cannot give any significant constraint.** In fact, including the momentum enhancement of the nuclear matrix elements not only these constraints are significant, they will further improve by 1–2 orders of magnitude with the GENIUS proposal of the Heidelberg group [10].

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