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Updated bounds for neutrinoless double beta decay

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Summary. — We study the hypothesis that the Majorana mass of ordinary neutrinos dominates the rate of neutrinoless double beta decay. In particular, we update predictions from neutrino oscillations and we compare them with the results from neutrinoless double beta decay searches. We also evaluate the impact of the quenching of the axial vector coupling constant in the nuclear medium, recently studied by IACHELLO *et al.* (*Phys. Rev. C*, **87** (2013) 014315).

PACS `14.60.Pq` – Neutrino mass and mixing.
PACS `23.40.-s` – β decay; double β decay; electron and muon capture.

1. – Neutrinoless double beta decay

The neutrinoless double beta decay ($0\nu\beta\beta$) [1] proved to be a fundamental tool to investigate the Majorana-Dirac nature of neutrinos.

The expression for the half-life for this decay can be factorized as [2]

$$\left[\tau^{0\nu}_{1/2}\right]^{-1} = G_{0\nu}\,|M_{0\nu}|^2\,|f(m_i,U_{ei})|^2\,, \tag{1}$$

where $G_{0\nu}$ is the phase-space factor (see, *e.g.*, [3]), $M_{0\nu}$ is the nuclear matrix element and $f(m_i,U_{ei})$ contains the physics beyond the Standard Model that could explain the decay through the neutrino masses m_i and the mixing matrix elements U_{ei}.

In the conservative assumption that the three known neutrinos are endowed with Majorana mass, we discuss the role on $0\nu\beta\beta$ of the *Majorana effective mass*, namely

$$m_e\,|f(m_i,U_{ei})| \equiv m_{\beta\beta} = \left|\sum_{i=1}^{3} U_{ei}^2 m_i\right|, \tag{2}$$

where m_i are the masses of the individual neutrinos ν_i and U_{ei} are the elements of the mixing matrix that define the composition of the electron neutrino: $|\nu_{\rm e}\rangle = \sum_{i=1}^{3} U_{ei}^*|\nu_i\rangle$.

We also investigate the implications that the theoretical uncertainties on $M_{0\nu}$ have on the current understanding of $0\nu\beta\beta$, specifically referring to the issue of the axial vector coupling constant quenching in the nuclear medium, as pointed out in [4] and recently studied in detail in [2].

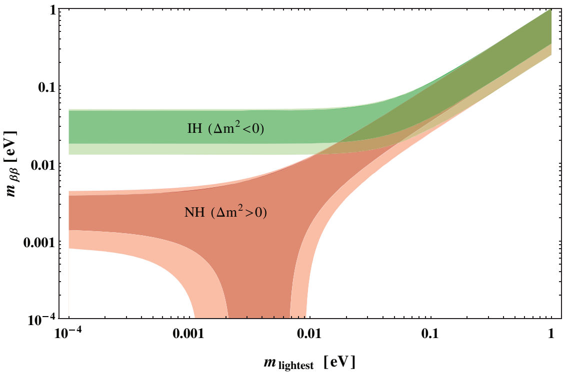

Fig. 1. – Updated predictions on $m_{\beta\beta}$ from oscillations as a function of the lightest neutrino mass in the two cases of hierarchy. The shaded areas correspond to the 3σ regions due to error propagation of the uncertainties on the oscillation parameters. Picture taken from [5].

2. – Predictions from oscillations and current experimental limits

Thanks to the knowledge of the oscillation parameters, it is possible to constrain the parameter $m_{\beta\beta}$. Following [5], in fig. 1 we show an updated version of the plot which contains the allowed regions for $m_{\beta\beta}$ according to the new oscillation parameters in [6].

Using eq. (1) and assuming the absence of the axial vector coupling constant quenching (namely, we take $g_A = 1.269$), we can translate the current experimental limits on neutrinoless double beta decay half life times into limits for $m_{\beta\beta}$. This is shown in the left panel of fig. 2, where an updated list of experiments and their results (or combination of results) are presented. Details regarding references for numbers quoted, measurements combination or assumptions made can be found in [5].

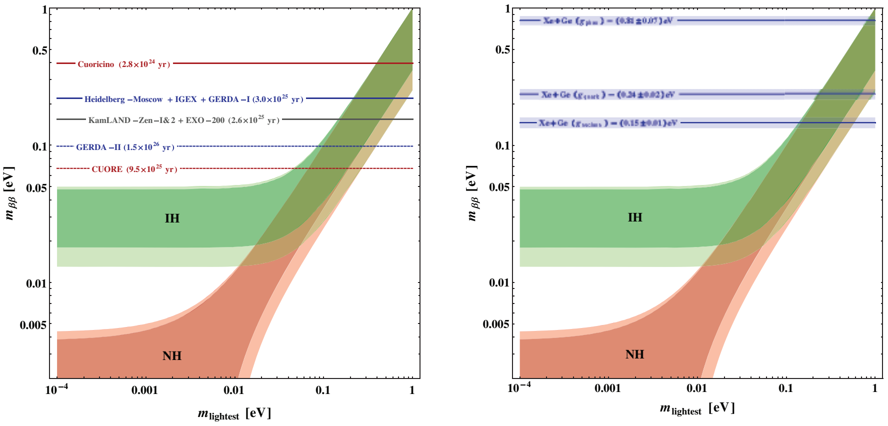

Fig. 2. – On the left: some experimental limits on $m_{\beta\beta}$ are superimposed to a zoomed part of fig. 1. The picture and the references for these values are taken directly from [5]. On the right: the value of $m_{\beta\beta}$ equal to the best combined limit among Xe and Ge measurements reported in [5] is varied accordingly to the three scenarios in eq. (3). The bands are due to the residual uncertainties on the nuclear matrix elements.

3. – Effect of the g_A quenching

As recently pointed out in [2], the theoretical uncertainty on $M_{0\nu}$ is huge. This is due to the possible renormalization (reduction) of the value of the axial vector coupling constant g_A in the nuclear medium (this issue being known as the "g_A *quenching*"). The dependence of the $0\nu\beta\beta$ half life time on g_A turns out to be quartic [2]. Therefore, a little change in g_A results in a huge change in $\tau^{0\nu}_{1/2}$ and, consequently, on the corresponding value of $m_{\beta\beta}$. Following [7, 2], we discuss three scenarios:

$$g_A = \begin{cases} g_{\text{nucleon}} & = \; 1.269, \\ g_{\text{quark}} & = \; 1, \\ g_{\text{phen.}} & = \; 1.269 \cdot A^{-0.18}, \end{cases} \tag{3}$$

where A is the atomic number of the nuclear species considered.

In the right panel of fig. 2 we show the difference among these three possibilities on the combined experimental upper bound on $m_{\beta\beta}$ coming from Xe and Ge experiments, as discussed in [5].

4. – Conclusions

We updated the predictions from oscillations on the Majorana Effective Mass $m_{\beta\beta}$. We pointed out the crucial role of understanding the issue of the axial vector coupling constant quenching. Further theoretical improvements and maybe a dedicate plan of measurements are needed to clarify this situation as much as possible.

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