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Effective value of the weak axial coupling: A review

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We still do not know if the neutrino is a Majorana or a Dirac particle, i.e. if the neutrino is its own antiparticle or not. Also the absolute mass scale of the neutrino is unknown, only the relative scale is known from the neutrino-oscillation experiments. These unknown features of the neutrino can be tackled by experiments trying to detect the neutrinoless double beta ($0\nu\beta\beta$) decay. The rate of $0\nu\beta\beta$ decay can be schematically written as
\begin{equation}
0\nu\beta\beta-\mathrm{rate} \sim \left\vert M^{(0\nu)}{\rm GTGT}\right\vert^2 =
g{{\rm A},0\nu}^4 \left\vert \sum_{J^{\pi}}
(0^+f||\mathcal{O}^{(0\nu)}{\rm GTGT}(J^{\pi})||0^+_i)\right\vert^2 \,,
\end{equation}
where $M^{(0\nu)}_{\rm GTGT}$ is the double Gamow-Teller nuclear matrix element, $\mathcal{O}^{(0\nu)}_{\rm GTGT}$ denotes the transition operator mediating the $0\nu\beta\beta$ transition through the various multipole states J^{π}, 0^+_i denotes the initial ground state, and the final ground state is denoted by 0^+_f (for simplicity, we neglect the smaller double Fermi and tensor contributions). Here $g^{\rm eff}_{{\rm A},0\nu}$ denotes the effective (quenched) value of the weak axial-vector coupling for $0\nu\beta\beta$ decay and it plays an extremely important role in determining the $0\nu\beta\beta$-decay rate since the rate is proportional to its $4th$ power. The amount of quenching has become an important issue in the neutrino-physics community due to its impact on the sensitivities of the present and future large-scale $0\nu\beta\beta$-decay experiments [1].

The quenching of $g_{\rm A}$ is traditionally related to shell-model calculations of Gamow-Teller β-decay rates. Similar quenchings can also be obtained in some other nuclear-model frameworks, like the proton-neutron quasiparticle random-phase approximation (pnQRPA) and the microscopic interacting boson model (IBM-2). The quenching of $g_{\rm A}$ has also been addressed in calculations of the rates of two-neutrino double beta ($2\nu\beta\beta$) decays where the $g_{\rm A}^4$ dependence is present like in the $0\nu\beta\beta$ decays but the quenching can be of different magnitude since the scale of the exchanged momentum between the nucleons and the neutrino is different. For a recent review on this topic, see [2].

Novel ways to address the quenching problem are offered by the studies of forbidden non-unique β decays. Rates of the forbidden non-unique β transitions are complex combinations of lepton phase-space factors and many nuclear matrix elements. The shapes of the corresponding spectra of the emitted electrons (β spectra) can, however, be very sensitive to the value of $g_{\rm A}$, and thus the measured β spectra can give information on the effective value of $g_{\rm A}$. In addition, the shapes of β spectra play a role in the context of the reactor-antineutrino anomaly which is currently of great interest in the neutrino-physics community.

REFERENCES

[1] J. Suhonen, Impact of the quenching of $g_{\rm A}$ on the sensitivity of $0\nu\beta\beta$ experiments, Phys. Rev. C 96 (2007) 055501.

[2] J. Suhonen, Value of the axial-vector coupling strength in β and $\beta\beta$ decays: A review, Front. Phys. 5 (2017) 55.

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