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Average and recommended half-life values for two-neutrino double beta decay

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Abstract

All existing positive results on two-neutrino double beta decay in different nuclei were analyzed. Using the procedure recommended by the Particle Data Group, weighted average values for half-lives of ^{48}Ca, ^{76}Ge, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{100}Mo–^{100}Ru (0_1^+), ^{116}Cd, ^{130}Te, ^{136}Xe, ^{150}Nd, ^{150}Nd–^{150}Sm (0_1^+) and ^{238}U were obtained. Existing geochemical data were analyzed and recommended values for half-lives of ^{128}Te and ^{130}Ba are proposed. Given the measured half-life values, nuclear matrix elements were calculated using latest (more reliable and precise) values for phase space factor. Finally, previous results (PRC 81 (2010) 035501) were updated and results for ^{136}Xe were added.

Keywords: Double beta decay; Nuclear matrix elements; ^{48}Ca; ^{76}Ge; ^{82}Se; ^{96}Zr; ^{100}Mo; ^{100}Mo–^{100}Ru (0_1^+); ^{116}Cd; ^{128}Te; ^{130}Te; ^{136}Xe; ^{150}Nd; ^{150}Nd–^{150}Sm (0_1^+); ^{238}U; ^{130}Ba

1. Introduction

At present, the two-neutrino double beta ($2\nu\beta\beta$) decay process has been detected in a total of 11 different nuclei. In ^{100}Mo and ^{150}Nd, this type of decay was also detected for the transition to the 0^+ excited state of the daughter nucleus. For the case of the ^{130}Ba nucleus, evidence for the two-neutrino double electron capture process was observed via a geochemical experiments. All of these results were obtained in a few tens of geochemical experiments and more than forty

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direct (counting) experiments as well as and in one radiochemical experiment. In direct experiments, for some nuclei there are as many as eight independent positive results (e.g., ^{100}Mo). In some experiments, the statistical error does not always play the primary role in overall half-life uncertainties. For example, the NEMO-3 experiment with ^{100}Mo has currently detected more than 219,000 $2\nu\beta\beta$ events [1], which results in a value for the statistical error of ∼0.2%. At the same time, the systematic error for many experiments on $2\nu\beta\beta$ decay remains quite high (∼10–30%) and very often cannot be determined reliably. As a consequence, it is frequently difficult for the "user" to select the "best" half-life value among the results. Using an averaging procedure, one can produce the most reliable and accurate half-life values for each isotope.

Why are accurate half-life periods necessary? The most important motivations are the following:

1) *Nuclear spectroscopy*. Now we know that some isotopes which were earlier considered to be stable are not, and decay via the double beta decay processes with a half-life period of $\sim 10^{18}$–10^{24} yr are observed. The values which are presented here should be introduced into the isotope tables.

2) *Nuclear matrix elements (NME)*. First, it gives the possibility to improve the quality of NME calculations for two-neutrino double beta decay, so one can directly compare experimental and calculated values. For example, so-called "g_A (axial-vector coupling constant) quenching" problem could be solved by comparison of exact experimental values of NMEs and results of theoretical calculations (see discussions in Refs. [2–5]). Second, it gives the possibility to improve the quality of NME calculations for neutrinoless double beta decay. The accurate half-life values for $2\nu\beta\beta$ decay are used to adjust the most relevant parameter of the quasiparticle random-phase approximation (QRPA) model, the strength of the particle–particle interaction g_{pp} [6–9].

3) *Research on the single state dominance (SSD) mechanism [10,11] and a check of the "bosonic" component of the neutrino hypothesis [12,13] is possible.*

In the present work, an analysis of all "positive" experimental results has been performed, and averaged or recommended values for isotopes are presented.

The first time that this work was done was in 2001, and the results were presented at the International Workshop on the calculation of double beta decay nuclear matrix elements, MEDEX'01 [14]. Then revised half-life values were presented at MEDEX'05 and MEDEX'09 and published in Refs. [15] and [16,17], respectively. In the present paper, new positive results obtained since end of 2009 and to the end of 2014 have been added and analyzed.

The main differences from the previous analysis [17] are the following:

1) The new experimental data obtained after the publication of Ref. [17] are included in the analysis: ^{76}Ge [18], ^{100}Mo [19], ^{100}Mo–^{100}Ru(0^+_1) [20,21], ^{116}Cd [22], ^{130}Te [23], ^{150}Nd–^{150}Sm (0^+_1) [24] and ^{130}Ba [25].

2) "Positive" results obtained for ^{136}Xe [26,27] are analyzed. This decay was detected for the fist time in 2011 [28].

3) To calculate NMEs new phase space factor values ($G_{2\nu}$) from Refs. [29,30] and [31,32] are used.

4) Considering possible changes of axial vector coupling constant g_A (possible quenching effect in nuclear medium) so-called "effective" NMEs are calculated, $|M^{\mathrm{eff}}_{2\nu}| = g_A^2 \cdot |(m_e c^2 \cdot M_{2\nu})|$ (in Ref. [17] the dimensionless nuclear matrix elements $|(m_e c^2 \cdot M_{2\nu})|$ were calculated for $g_A = 1.254$).