Meson Exchange Current Effects studied in First Forbidden Nuclear Beta Decay in the Lead Region

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In an atomic nucleus, mesons are exchanged by the constituent nucleons . The influence of these Meson Exchange Currents (MEC) is revealed in nuclear beta decay by a strong enhancement of the time-like component of the weak axial vector current ($\int\gamma_5$) relative to its value deduced in the impulse-approximation [1]. The enhancement factor $\epsilon_{\rm MEC}$ can be determined by comparing measured ft-values of first forbidden β transitions with shell model calculations since the matrix element $\int\gamma_5$ contributes to these decays. For nuclei with $\mathrm{A} = 16 - 132$ is was found that the deduced values agree with MEC calculations that are dominated by soft-pion exchange. In the lead region ($A \approx 205$–212) however, the "experimental" $\epsilon_{\rm MEC}$ is significantly larger than the value expected from soft-pion exchange models [2]. In the last decade various theoretical explanations have been proposed to explain this difference [see e.g. 4,5]. A possible difficulty with the method mentioned above is that all independent matrix elements that are involved in the decay need to be calculated, making the deduction of $\epsilon_{\rm MEC}$ susceptible to model assumptions.

Here, we report a new study of MEC in the ^{208}Pb region in which besides the ft-values, also the experimental β asymmetry parameters A_1 are used. By combining these two quantities, the rank 0 and rank 1 contributions in the decay can be separated. Because of this, only the rank 0 matrix elements have to be calculated to deduce $\epsilon_{\rm MEC}$ yielding its determination significantly less dependent on theoretical computations.

The β asymmetry experiments were performed by low-temperature nuclear orientation (LTNO) using cold on-line implantation at the NICOLE refrigerator on-line to ISOLDE at CERN and at the KOOL set-up on-line to LISOL in Louvain-la-Neuve. To reduce the influence of β scattering, β spectra were recorded with cooled (8 K) planar Ge detectors looking directly at the sample. Data were taken on the first-forbidden g.s. $\rightarrow$ g.s. transitions in ^{205}Hg $((\nu\mathrm{p}\frac{1}{2})^- \rightarrow (\pi\mathrm{s}\frac{1}{2})^+)$, ^{207,209}Tl $((\pi\mathrm{s}\frac{1}{2})^+ \rightarrow (\nu\mathrm{p}\frac{1}{2})^-)$, ^{209}Pb $((\nu\mathrm{g}\frac{9}{2})^+ \rightarrow (\pi\mathrm{h}\frac{9}{2})^-)$ and ^{213}Bi $((\pi\mathrm{h}\frac{9}{2})^- \rightarrow (\nu\mathrm{g}\frac{9}{2})^+)$. The different configurations of these nuclei allow a study of a possible state dependence of MEC. For each decay, the matrix element $\int\gamma_5$ was extracted using the newly measured A_1 parameters and known decay rate data. The new experimental data on $\epsilon_{\rm MEC}$ near ^{208}Pb will be compared with various MEC-calculations performed in the past decade [4-6] and discussed in view of the discrepancy between theory and experiment in this region [2-3].

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