Weak Interactions in Nuclei.

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1. Introduction.

Since the discovery of weak interactions, the role played by weak forces in nuclear physics has been the subject of very interesting experimental and theoretical research. In fact the possibility to assign to nuclei, in their ground or excited states, well-defined quantum numbers offers a unique way to investigate the effect of various selection rules in weak interactions. It also yields, on the other hand, a new tool to study the nuclear structure. A drawback in the use of nuclei to improve our understanding of weak processes is often the difficulty of a reliable calculation of the nuclear matrix element. More detailed nuclear calculations are almost always needed for a satisfactory comparison between theory and experiments.
It is obviously impossible to treat in a single review paper all the problems connected with weak interactions in nuclei: entire symposia have been devoted to this subject [1]. The present discussion will be therefore limited to those weak processes which were recently the object of theoretical speculations and particular interesting experimental findings, namely those concerned with symmetry breaking and consequent violation of conservation laws. We will consider here the possible violation of G-parity and consequent existence of second-class currents, the reasonably well-established parity violation in nuclei and the not yet found violation of time-reversal invariance. A discussion on possible violation of the lepton conservation law in nuclei will conclude our review.

2. - G-parity violation and existence of second-class currents.

The concept of second-class currents was first introduced in the theory of weak interactions by Weinberg [2, 3] as a consequence of the invariance of strong interactions under the operator G, which is the product of charge symmetry and charge conjugation. Let us take the usual effective current-current Lagrangian for semi-leptonic weak interactions

\[ L_{\text{eff}} = \frac{G}{\sqrt{2}} \left[ \left( j^{(u)}_\lambda + j^{(d)}_\lambda \right)^\dagger J^{(b)}_\lambda + \text{h.c.} \right], \]

where G is the weak coupling constant (\( \sim 10^{-5} m_{\text{n}}^{-2} \)), the lepton currents are given by

\[ j^{(u,d)}_\lambda = \bar{\nu}_{\mu,e}(x) \gamma_\lambda (1 - \gamma_5) \nu_{\mu,e}(x), \]

and the hadron current can be divided into a hypercharge-conserving and a hypercharge-violating part:

\[ J^{(b)}_\lambda = J^{(r=0)}_\lambda + J^{(r=\pm1)}_\lambda. \]

Let us consider the vector and axial vector contributions to the strangeness-conserving current \( J^0_\lambda \)

\[ J^0_\lambda = V^0_\lambda - A^0_\lambda \]

and define, according to Weinberg, first- and second-class currents:

\[ V^0_\lambda = V^0_\lambda(1) + V^0_\lambda(2), \quad A^0_\lambda = A^0_\lambda(1) + A^0_\lambda(2). \]

These currents transform, under the operator \( G = C \exp \left[ i \pi I_\lambda \right] \), as

\[ \begin{cases}GV^0_\lambda(1) G^{-1} = V^0_\lambda(1), & GA^0_\lambda(1) G^{-1} = - A^0_\lambda(1), \\ GV^0_\lambda(2) G^{-1} = - V^0_\lambda(2), & GA^0_\lambda(2) G^{-1} = A^0_\lambda(2). \end{cases} \]