ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

ЛАБОРАТОРИЯ ЯДЕРНЫХ ПРОБЛЕМ

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1. The asymmetry coefficient $\tilde{a}$ in the angular distribution of neutrons of the direct process due to the polarized μ - meson capture by nuclei was often measured at the low thresholds of neutron registration. As has been shown in ref./1/, all these results are in good agreement with each other and provide an overstated value of $\tilde{a}$ compared to the theoretical one. The expected theoretical value of the asymmetry coefficient is close in this case to $\tilde{a}_{theor} \simeq -0,4$; this value has been obtained/2/ upon averaging over the whole neutron spectrum of the direct process and using a set of interaction constants/3/

$$g_V^{(\mu)} = 0.97\, g_V^{(\beta)} \qquad g_A^{(\mu)} = g_A^{(\beta)}$$

$$g_P^{(\mu)} = 8\, g_A^{(\mu)} \qquad g_M^{(\mu)} = 3.7\, g_V^{(\mu)} \tag{1}$$

where $g_V^{(\mu)}$, $g_A^{(\mu)}$, $g_P^{(\mu)}$ and $g_M^{(\mu)}$ are the vector, pseudovector, induced pseudoscalar and weak magnetism constants, respectively. $\tilde{a}_{theor}$ differs from that calculated/2/ for μ^- capture in hydrogen a^H_{theor} only by different momentum neutrino distribution, which slightly changes from the nucleus to the nucleus and slightly depends upon the particular nuclear model.

2. Recently a measurement/4/ of $\tilde{a}$ with the very high thresholds of neutron registration in μ^- capture in Ca^{40} has been made; the maximum value of $\tilde{a}$ is negative and close to unity with a ± 15% accuracy. Note right now that on high energy threshold $\simeq$ 20 MeV, where the maximum asymmetry is observed, $\tilde{a}_{theor} \simeq 0.34$.

3. Formally, such a large measured value of $\tilde{a}$ may imply/5/ that the value of $\lambda^{(\mu)} = -g_A^{(\mu)} / g_V^{(\mu)}$ is considerably larger/4/ than $\lambda^{(\beta)}$, while $\kappa^{(\mu)} = g_P^{(\mu)} / g_A^{(\mu)}$ is considerably larger than 8/6/.

However, taking into account a strong dependence/3/ of the probabilities $\Lambda_{C^{12}\to B^{12}}$ of the reaction $\mu^- + C^{12} \to B^{12} + \nu$ from $g_A^{(\mu)}$, it is impossible to reach agreement between the experimental value/7/ $\Lambda_{C^{12}\to B^{12}}$ and the theoretical one/8/ even with a small increase of $g_A^{(\mu)}$. This conclusion follows also from the ratio of the rates of muon and electron μ^- meson/5/ decay modes. On the other hand, basing on the universal weak interaction theory, it is impossible to consider $g_V^{(\mu)}$ to be close to zero. Formally/9/, if one takes $g_V^{(\mu)} = 0$ (with $g_M^{(\mu)} = 0$), then this would give rise to the divergence between theoretical and experimental values of μ^- capture rate by complex nuclei Λ_Z . This refers also to the μ^- capture rate in the singlet state of the hydrogen mesonic atom and to the rate $\Lambda_{He^3\to H^3}$ of the reaction $\mu^- + He^3 \to H^3 + \nu$ since Λ_Z , Λ_H , $\Lambda_{He^3\to H^3}$ depend equally upon the interaction constants (for Λ_Z this is justified only in the framework of the Primakoff approximation /3/ /26/).

Thus, basing on the proposed set of interaction constants (1) it is impossible to reach agreement between theoretical and experimental values: Λ_H , $\Lambda_{He^3\to H^3}$, Λ_Z , $\Lambda_{C^{12}\to B^{12}}$, $\tilde{a}$.

4. The outcome from such a situation is to take into consideration one interaction constant more, namely, the scalar g_S . It is quite possible that the appearence of g_S means the existence of local anomalous scalar muon-nucleon interactions. One may suppose that this constant is of the induced character; then $g_S^{(\ell)} = m_\ell F_S(q^2)$ Here m_ℓ is muon mass in the case of μ^- capture and the electron mass m_e for the case of β -decay, $F_S(q^2)$ is the induced-scalar formfactor. $q_S^{(\ell)}$ is present in the most general expression for the vector matrix element/10/; earlier this constant was rejected along with the "weak electricity" constant g_e .

As has been shown by the calculations of a number of authors/11-16, 24/, the scalar constant $g_S^{(\mu)}$ in the expression for the symmetry coefficient $\tilde{a}$ enters only into the Fermi interaction constant G_F in the following way (neglecting recoil terms)

$$G_F \simeq g_V^{(\mu)} + g_S^{(\mu)} \tag{2}$$

Combining expression from ref./2, 11-16, 24/, one may obtain the following formula

$$\tilde{\tilde{a}} = \frac{(g_V^{(\mu)} + g_S^{(\mu)})^2 - 2(g_A^{(\mu)} - g_M^{(\mu)}\gamma)^2 + (g_A^{(\mu)} - g_P^{(\mu)}\gamma)^2}{(g_V^{(\mu)} + g_S^{(\mu)})^2 + 2(g_A^{(\mu)} - g_M^{(\mu)}\gamma)^2 + (g_A^{(\mu)} - g_P^{(\mu)}\gamma)^2}, \tag{3}$$

where $\gamma = \nu / 2m_P$, ν is the neutrino momentum, m_P is the proton mass. With $g_S^{(\mu)} = 0$ this formula coincides with the formula of ref./2/ to an accuracy of some per cent; with $g_S^{(\mu)} = 0$ and $g_M^{(\mu)} = 0$ formula (3) transfers to the formula of ref./24/, etc.

From eq. (3) it follows that $\tilde{a}$ amounts to its value -1, when the first and the last brackets in the numerator (and in the denominator) go to zero, i.e. with $g_S^{(\mu)} \to -g_V^{(\mu)}$ and $g_P^{(\mu)} \to \frac{1}{\gamma} g_A^{(\mu)}$

It is worth nothing that the dependence $\tilde{a}$ upon γ allows to determine γ and, hence, $\kappa^{(\mu)}$ sufficiently accurately by the energy position of the asymmetry coefficient maximum (with $|\tilde{a}| = 1$ and $\tilde{\beta} = 1$, where $\tilde{\beta}$ is the nuclear factor/2,4/. Thus, for the threshold of neutron registration $\simeq$ 20 MeV, where the maximum asymmetry is observed/4/, $\gamma \approx \frac{1}{30}$ and $\kappa^{(\mu)} \approx 30$. From the measurements of μ^- capture rates the values of $\kappa^{(\mu)}$ can be determined very crudely: $5 \lesssim \kappa^{(\mu)} \lesssim 35$/17/.

5. In the beta-decay $g_S^{(\beta)}$ does not play any considerable role, since $g_S^{(\beta)} = \frac{m_e}{m_\mu} g_S^{(\mu)}$. (The same refers also to the induced pseudo-scalar). From the experimental data on β -decay/18/ it follows that the interference term $g_V^{(\beta)} g_S^{(\beta)}$, is small. As has been shown in Adams's paper/19/, the presence or the absence of $g_S^{(\mu)}$ and $g_e^{(\mu)}$ only slightly effects upon Λ_H , and hence, upon Λ_Z , $\Lambda_{He^3 \to H^3}$ $\Lambda_{C^{12} \to B^{12}}$.

Taking into consideration also/17/ that Λ_H , Λ_Z, $\Lambda_{He^3 \to H^3}$ $\Lambda_{C^{12} \to B^{12}}$ have the same value with $\kappa^{(\mu)} = 8$ and $\kappa^{(\mu)} = 30$, one may state that the set of constants

$$\begin{array}{ll} g_V^{(\mu)} = 0.97\, g_V^{(\beta)} & g_A^{(\mu)} = g_A^{(\beta)} \\ g_M^{(\mu)} = 3.7\, g_V^{(\mu)} & g_P^{(\mu)} \simeq 30\, g_A^{(\mu)} \\ g_S^{(\mu)} \simeq -g_V^{(\mu)} & \end{array} \tag{4}$$

allows us to reach the agreement between all the fundamental experimental data in μ^- capture. The only exception is the radiative μ^- capture rate Λ_γ but this will be discussed further.

6. The fact that the measured value of $\tilde{a}$ is closed to unity, allows one to state/18/ that in the process under study the maximum possible spatial parity nonceonservation takes place.

7. If one assumes that the formfactor of the induced scalar is determined by the pole term, then

$$F_S(q^2) = \frac{C_S}{q^2 + m_S^2}, \tag{5}$$

where m_S is the mass of some scalar charged pair pion resonance state, C_S is the value, determining the interaction of this resonance state with nucleons and its lifetime by analogy with the values in the expression for the formfactor of the induced pseudoscalar[6] $F_P(q^2)$. One may suppose that ζ meson with the mass $m_\zeta = 550\, m_e$ discovered recently[20], can play the role ofthe pair pion resonance state discussed here due to which the exchange between lepton and nucleon currents in the scalar variant of interaction occurs.

8. If we assume that $\kappa^{(\mu)}$ is very large indeed, then remaining within the framework of pole approximation, following Denieri and Primakoff[21] one can explain this by introducing the three pion charged pseudoscalar resonant state; such a resonant state has not yet been found. It should be noted at once that a large experimental value $\kappa^{(\mu)}$ contradicts a number of suppositions made in ref.[21] mentioned already; indeed, assuming that a partial conservation of axial-vector current in weak interactions takes place and making use of the Gell-Mann and Zachariasen ratio for the $F_V(q^2)$ of the formfactors and $F_A(q^2)$ with $q^2 \to \infty$ and the equation[21]

$$F_P(q^2) = \frac{C\pi}{q^2 + m_\pi^2} + \frac{C\beta}{q^2 + m_\beta^2} \tag{6}$$

we obtain

$$C_\beta \simeq - C_\pi \tag{7}$$

This means also that $\kappa^{(\mu)}$ should be smaller than 8.

9. It is known[10] that the appearence of the terms with g_S and g_e can be due to the violation of one of the three laws, namely, T -invariance, G -invariance or the rule $|\Delta I| = 1$. At present it is considered that the G and T invariances are fairly well argued, but the validity of the rule $|\Delta I| = 1$ for weak decay modes of strange particles has not been ruled out experimentally. Hence, in a number of cases[19,22] the calculation of various effects, concerned with the presence of $g_S^{(\mu)}$ and $g_e^{(\mu)}$, has been made.

10. One may try also to explain the appearence of $g_S^{(\mu)}$ by the ordinal electromagnetic violation of the G -parity in the exchange with an intermediate ζ - meson which is capable (with great probability according to Glashow mechanism[23]) of transferring from one state of the G-parity into another one, if this mechanism serves for transitions in virtual state and there are two ζ -mesons with close masses and opposite G parities.

11. In eq. (3) there is no weak-electricity constant $g_e^{(\mu)}$. It is, apparently, to be expected that $g_e^{(\mu)}$ is combined with $g_A^{(\mu)}$ and can vanish the last brackets to "zero" even if $\kappa^{(\mu)} \simeq 8$. Perhaps, this really takes place, since recently measured rate Λ_γ of the radiative μ^- -capture does not differ from the value expected theoretically with $\kappa^{(\mu)} = 8$. Taking into consideration a strong, nearly quadratic dependence Λ_γ upon $\kappa^{(\mu)}$ [25], with $\kappa^{(\mu)} \simeq 30$, one should expect the value of Λ_γ to be several times larger. True, experimental data insufficiently accurate yet and the interpretation of their experiments on the capture rate in complex nuclei gives rise to sdoubt[26].

13. Since the preceeding consideration is of semi-qualitative character, it is absolutely clear that an exact calculation of both $\tilde{a}$ and all other effects is to be made for the description of which the muon-nucleon interaction is essential, with the account of all six interaction constants.

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