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MESON EXCHANGE SECOND CLASS CURRENTS AND THE NEUTRINO MASS IN THE MUON CAPTURE BY LIGHT NUCLEI

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The most general form of the vector V_α and axial-vector A_α components of the hadronic weak current $J_\alpha = V_\alpha + A_\alpha$ can be written (using only the lorentz covariance) as

$$V_\alpha = u(p_f)[F_1\gamma_\alpha + F_2\sigma_{\alpha\beta}q_\beta + iF_S q_\alpha]u(p_i),$$
$$A_\alpha = u(p_f)[-F_A\gamma_\alpha - F_T\sigma_{\alpha\beta}q_\beta - iF_P q_\alpha]\gamma_5 u(p_i). \quad (1)$$

The six form factors containing all the information of the semileptonic processes (β-decay, muon capture, neutrino scattering processes, etc.) are functions of $q_\alpha^2 = (p_f^\alpha - p_i^\alpha)^2$: $F_X = F_X(q_\alpha^2)$, where X = 1, 2, S, A, P, T (Dirac, Pauli, scalar, axial-vector, pseudoscalar and tensor form factors). Weinberg[1] classified the weak charged currents (1) according to their properties under G-parity transformation, which is the production of the charge conjugation operator C and the rotation of 180° around the 2-nd axis T_2 in the isotopic space ($G = C\exp(i\pi T_2)$). The first class currents (FCC), which are the dominant interactions and form the basis of the Standard Model of the electroweak interaction, behave under the G-parity transformation as

$$G V_\alpha^I G^{-1} = +V_\alpha^I \text{ and } G A_\alpha^I G^{-1} = -A_\alpha^I .$$

The second class current (SCC), being the serious problem for guage theories (see, for example, [2]), behaves oppositly under the G-parity operation:

$$G V_\alpha^{II} G^{-1} = -V_\alpha^{II} \text{ and } G A_\alpha^{II} G^{-1} = +A_\alpha^{II} .$$

In accordance with this classification form factors F_1, F_2, F_A, F_P belong to FCC; and form factors F_S, F_T, to SCC.

In connection with the recent observation of tau-lepton decay modes, taking place[3-5] at the expence of vector ($\tau \to \eta\pi\nu_\tau$ [6]) and axial-vector ($\tau \to \omega\pi\nu_\tau$ [7]) hadronic SCC, the investigation of effects , induced by form factors F_S and F_T, acquires a significant value. They can be observed in experimental study of angular and spin-angular characteristics of β-decay and muon capture processes. (One should note that the conservation of the vector current in CVC hypothesis requires that the SCC scalar form factor should be zero: $F_S \equiv 0$). Since the momentum transferred in the muon capture is much higher than in the β-decay, the muon capture process is preferable[8,9] from the point of view of observation of SCC effects, although pure effects[10,11] induced by the axial-vector second class current exist in the β-decay of mirror nuclei as well.

Kubodera, Delorme and Rho (KDR) proposed a model for the β-decay of mirror nuclei[12] which takes into account the contribution from nucleon off-mass-shell effects in the nucleus and the meson exchange SCC. The KDR model is based on the virtual decay of the ω-meson: $\omega \to \pi e \nu_e$ (indication of the existence of the ω-meson is given by the observation of decay $\tau \to \omega \pi \nu_\tau$[7]). Similarly, the decay of the virtual ω-meson by the mode $\omega \to \pi \mu \nu_\mu$ should contribute when taking into account the SCC in muon capture by light nuclei.

Furthermore, at present along with the SCC problem there are topical problems, like existence of a rest mass[13] of neutrinos of various types and the search for new methods of its determination[14-18]. There are various methods for the experimental determination of neutrino (antineutrino) rest mass (see, for example,[13,19,20]). One of them, the most actively used in recent years, is the method of tritium beta-spectrum endpoint measurement in order to determine the electron antineutrino rest mass $m_{\bar\nu_e}$ (see, for example,[13,19-22]). The upper limit of the electron neutrino mass m_{ν_e} is obtained from the energy balance in the electron capture by ^{163}Ho nuclei[23] ($m_{\nu_e} \le 550$ eV). The limit for the muon neutrino rest mass m_{ν_μ} is obtained from the pion decay[24] ($m_{\nu_\mu} \le 500$ keV). The upper limit for the tau neutrino rest mass is obtained from the tau-lepton decay in $3\pi^\pm\pi^0$ and $5\pi^\pm\pi^0$[25] ($m_{\nu_\tau} \le 84$MeV). A series of papers[14-18] are devoted to search for new (based on the study of angular and spin-angular correlation coefficients) methods of obtaining information on masses of electron[14-16] and muon[17,18] neutrinos.

When the neutrino mass m_ν is estimated, the second class currents can be the source of background, while the mass m_ν in its turn, may affect the estimation of SCC parameters. Therefore, in order to understand the structure of the weak interaction of elementary particles, these two problems should be studied simultaneously with allowance for the possible correlation of effects induced by the SCC and mass m_ν.

The present work is devoted to a simultaneous analysis of the influence of the muon neutrino rest mass and SCC on the asymmetry coefficient of neutrino emission with respect to the muon spin orientation in the polarized muon capture by light nuclei (A,Z):

$$\mu^- + (A, Z) \to (A, Z-1) + \nu_\mu . \qquad (2)$$

To calculate SCC effects basically induced by form factor F_T, the impulse approximation[26] is used, where the Hamiltonian of the Gamow-Teller transition (the velocity of nucleons neglected) has the form[8,9]:

$$H_{\mu^-} = -\frac{G_F}{\sqrt{2}} \sum_{i=1}^{A} \vec{\sigma}_i \tau_-^i \{(F_A - F_2 \frac{E_\nu}{2M_N})\vec{\ell} - i\ell_4 \vec{q}[F_T + \frac{1}{2M_N}(F_A - m_\mu F_P)]\}. \qquad (3)$$

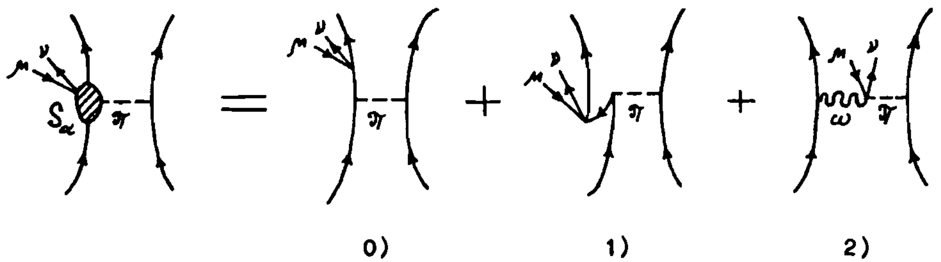
Here $G_F = 1.023 \cdot 10^{-5} m_P^{-2}$ is the Fermi constant of the weak interaction (m_P is the proton mass); A is the mass number; τ_-^i and $\vec\sigma_i$ are the operators of isotopic spin and spin matrices for the i-th nucleon; $q_\alpha = (\vec{q}, iE_0)$ is the 4-momentum transferred; $\ell_\alpha(\vec{r}_i) = (\vec{\ell}(\vec{r}_i), i\ell_0(\vec{r}_i))$ is the leptonic current. The expression for ℓ_α is employed here in the form

$$\ell_\alpha = i\bar\psi_{\nu_\mu} \gamma_\alpha (a_V + a_A \gamma_5)\psi_\mu , \qquad (4)$$

where ψ_μ and ψ_{ν_μ} are the wave functions of the muon and the muonic neutrino. We take the radial wave function of the muon in the bound state of the muon in the mesoatom (K-orbit).

Here the possibility of deviation of the muonic current from V-A-structure and the nonzero muon neutrino rest mass are taken into account; a_V and a_A are the constants characterising the intensity of the vector and the axial-vector parts of the muonic current (difference between them does not contradict the existing experimental data[27]). Note, that to take into account the deviation from the V-A-structure of the leptonic current is the same as to consider both the right-handed and the left-handed currents. In this case the intensity of the left-handed currents is defined by the coefficient $(a_V + a_A)/2$, and the intensity of the right-handed currents is proportional to $(a_V - a_A)/2$.

The second class currents in the axial-vector part of a free nucleon current may be introduced by using the requirement of the relativistic invariance in two equivalent ways: with the help of the term $F_T \sigma_{\alpha\beta} q_\beta \gamma_5$, as in eq.(1), or by adding the term $iF_T' P_\alpha \gamma_5$ (where $P_\alpha = P_i^\alpha + P_f^\alpha$). In the nucleus this equivalence is violated, since nucleons are not on the mass-shell.



Meson exchange second class currents in the KDR model [12].

Then, investigating the meson exchange SCC contribution,one has to take into account the off-mass-shell effects. This may be done,for example, by introducing the SCC as a sum of two above-mentioned terms [12]. In the KDR model employed for the case of muon capture the contribution of Feynman diagrams shown in the Figure is taken into account. In this case the muonic charge current is taken in the form (4), and expressions for the corresponding hadronic (meson exchange) currents are given in [12].

Since $\phi_{1S}(r)$ is a slowly-varying function within the nuclear volume, one may extract this function from inside the matrix elements and use only the average value as a good approximation, [24, 25].

$$|\phi_{1S}|^2_{av} = R|\phi_{1S}(0)|^2 = (R/\pi)[Z\alpha m_\mu M_A/(m_\mu + M_A)]^3 , \qquad (5)$$

where R is a reduction factor taking into account the finite extent of the nuclear transition density, M_A and Z are the mass and the charge of nuclei, α is the fine structure constant.

The differential rate of polarized muon capture by light nuclei (for Gamow-Teller transitions) summed over the final spin states of the nucleus and the neutrino, averaged over the initial spin state of the nucleus and calculated with allowance for the meson exchange SCC by the KDR model has the form

$$dW = \frac{G_F^2 a_V^2 (1+\kappa^2)}{(4\pi)^2} d\Omega_\nu E_\nu p_\nu \frac{|\phi_{1S}|^2_{av}}{2I_i+1} |< \sum_{i=1}^{A} \vec{\sigma}_i \tau_-^i >|^2 \times$$

$$\times \{(1 - 2\tilde{F}_2 \frac{E_\nu}{2M_N} + 2\tilde{\xi} J)[3(1-C) + \frac{2\kappa}{1+\kappa^2}(\vec{\beta}_\nu \vec{s}_\mu)] + \qquad (6)$$
$$+ 2E_\nu[\tilde{\zeta} + \tilde{\xi} L + \frac{1}{2M_N}(1 - m_\mu \tilde{F}_P)][\beta_\nu - \frac{2\kappa}{1+\kappa^2}(\vec{p}^{\,o}_\nu \vec{s}_\mu)]\}.$$

Here $C = \frac{1-\kappa^2}{1+\kappa^2} \frac{m_\nu m_\mu}{E_\nu E_\mu}$; $\beta_\nu = (1 - m_\nu^2/E_\nu^2)^{1/2}$ and $E_\nu = E_\mu - \Delta E$ are the velocity and the energy of the muonic neutrino; $E_\mu = m_\mu - \epsilon_B$ and m_μ are the energy and the rest mass of the muon; ϵ_B is its binding energy in the K-orbit of the mesoatom; ΔE is the transferred energy; parameter $\kappa = a_A/a_V$ is the ratio of the axial-vector and vector constants of the muonic current; the parameter $\zeta = (F_T + F_T')/F_A$, where F_T and F_T' are the usual tensor form factor and the one taking into account the off-mass-shell effects; the paramenter* $\xi = \beta + \gamma$ determines the contribution of the meson exchange SCC, where β and γ take into account interactions of pions with nucleons and of ω-mesons with nucleons and pions; quantities L and J are the ratios of matrix elements of the time and the space components of the exchange SCC [12] to the Gamow-Teller matrix element $< \sum_{i=1}^{A} \vec{\sigma}_i \tau_-^i >$; $\vec{s}_\mu$ is the unit vector of muon polarization; $\vec{p}^{\,o}_\nu = \vec{p}_\nu/p_\nu$ is the unit vector in the direction of muonic neutrino momentum; $d\Omega_\nu$ is the solid angle of the neutrino; the "tilde" over the parameters (form factors) shows that they are normalyzed by the axial-vector form factor F_A.

In order to derive equation (6) only the leading order terms proportional to SCC parameters and $E_\nu/2M_N$ are retained. Here m_{ν_μ} enters in the kinematic factor through its momentum p_ν, as well as in the matrix element through its velocity β_ν (quadratic dependence) and through the quantity C (linear dependence).

* *We draw attention to the fact that the second parameter of the KDR model is denoted here by the symbol* ξ *(the authors of* [12] *originally denoted it by* λ*). In the present work* λ *denotes the ratio of the vector and axial-vector constants of nucleonic currents.*

Below, for the study of SCC effects in muon capture involving Fermi type transitions and mixed type transitions, a general expression for the Hamiltonian (see, for example,[8,9]) is used, in this case the meson exchange SCC in the KDR model[12] are considered only in the axial-vector current of nucleons.

We note that if the meson exchange SCC in the KDR model[12] are neglected, then it is enough to set the KDR model parameters as $\zeta = F_T$ and $\xi = 0$ in the corresponding expressions for the muon capture rate and the asymmetry coefficient which is considered below. In this case tensor form factor F_T induced effects remain.

In what follows we consider the asymmetry in the angular distribution of neutrino $dW \propto 1 + a_{\mu\nu}\cos(\theta)$, $\cos(\theta) = (\vec{p}^{\,o}_{\nu}\,\vec{s}_{\mu})$, where θ is the angle between the neutrino momentum and muon spin orientation. The asymmetry coefficient $a_{\mu\nu}$ of neutrino emission with respect to the muon spin is defined by the expression

$$a_{\mu\nu} = \frac{dW(\vec{p}^{\,o}_{\nu}\uparrow\uparrow\vec{s}_{\mu}) - dW(\vec{p}^{\,o}_{\nu}\uparrow\downarrow\vec{s}_{\mu})}{dW(\vec{p}^{\,o}_{\nu}\uparrow\uparrow\vec{s}_{\mu}) + dW(\vec{p}^{\,o}_{\nu}\uparrow\downarrow\vec{s}_{\mu})}. \qquad (7)$$

The coefficient $a_{\mu\nu}$ is analyzed for $0\to0$, Gamow-Teller and mixed type transitions in the muon capture.

a) $0^+\to0^+$ and $0^+\to0^-$ transitions

It is well known (see, for example,[8]) that in these cases the coefficient $a_{\mu\nu} = -1$ no matter if there are SCC or not. But, if the neutrino rest mass and difference of κ from 1 are taken into account, then the coefficient $a_{\mu\nu}$ takes the following form:

$$a_{\mu\nu} = -\beta_{\nu}\frac{2\kappa}{1+\kappa^2}(1-C). \qquad (8)$$

In order to consider the deviation of $a_{\mu\nu}$ from the predictions of the pure V-A-structure of the muonic charged current with the vanishing neutrino mass we introduce a quantity

$$\Delta(0\to0) = \frac{a^{V-A}_{\mu\nu} - a_{\mu\nu}}{a^{V-A}_{\mu\nu}} \cong \frac{m^2_{\nu}}{2E^2_{\nu}} + \frac{m_{\nu}m_{\mu}}{E_{\nu}E_{\mu}}(1-\kappa) + \frac{1}{2}(1-\kappa)^2. \qquad (9)$$

Table 1

Deviation of $a_{\mu\nu}$ from the predictions of the V-A-structure of the muonic current in super-allowed transitions

m_ν \ κ	0.99	0.999	1.0	1.001	1.01
0	$5.0\ 10^{-5}$	$5.4\ 10^{-7}$	0	$4.8\ 10^{-7}$	$5.0\ 10^{-5}$
50	$5.5\ 10^{-5}$	$1.1\ 10^{-6}$	$1.2\ 10^{-7}$	$1.2\ 10^{-7}$	$4.5\ 10^{-5}$
500	$1.1\ 10^{-4}$	$1.6\ 10^{-5}$	$1.1\ 10^{-5}$	$6.7\ 10^{-6}$	$1.4\ 10^{-5}$

In Table 1 the expected values of Δ are given for neutrino mass 0; 50; 500 keV and on the deviation of κ from 1 within the limit of 1%: 0.99; 0.999; 1; 1.001; 1.01. It is seen from Table 1 that the coefficient $a_{\mu\nu}$ is sensitive to parameters m_{ν_μ} and κ: nonzero mass and admixture of the right-handed current decrease the absolute value of $a_{\mu\nu}$ and that depends on the values of m_{ν_μ} and κ. Therefore, the consideration of the coefficient $a_{\mu\nu}$ in allowed $0^+\to0^+$ and forbidden $0^+\to0^-$ transitions in principal gives a chance to estimate the neutrino rest mass m_{ν_μ} at a defined value of κ using equation(8).

b) Gamow-Teller transitions

If F_P is not taken into account, then the coefficient $a_{\mu\nu}$ may be reduced to the form (for the pure Gamow-Teller transitions)

$$a_{\mu\nu} = \frac{1}{3}\beta_{\nu}\frac{2\kappa}{1+\kappa^2}\{1 + C - \frac{8}{3}E_{\nu}(\tilde{\zeta} + \tilde{\xi}L)\}. \qquad (10)$$

Equation (9) may be used for the nuclear transitions with $\Delta I = 1$ provided that only the basic matrix elements in corresponding transitions are used in nuclear amplitudes. Here the simultaneous analysis of effects due to m_{ν_μ} (with $\kappa = 1$, and $\kappa \neq 1$ as well) and SCC is carried out. For this purpuse we consider the difference of $a_{\mu\nu}$ from predictions of the V-A-form of the muonic current with zero neutrino mass and vanishing SCC:

$$\Delta_{GT} = \frac{a^{V-A}_{\mu\nu} - a_{\mu\nu}}{a^{V-A}_{\mu\nu}} \cong \frac{m^2_{\nu}}{2E^2_{\nu}} - \frac{m_{\nu}m_{\mu}}{E_{\nu}E_{\mu}}(1-\kappa) + \qquad (11)$$

$$+ \frac{1}{2}(1-\kappa)^2 + \frac{8}{3}E_{\nu}(\tilde{\zeta} + \tilde{\xi}L),$$

where $a^{V-A}_{\mu\nu} = 1/3$. Δ_{GT} is analyzed for $m_{\nu_\mu} = 0$; 50; 500 keV and $\kappa = 0.99$; 0.999; 1; 1.001; 1.01.

Table 2

Deviation of $a_{\mu\nu}$ from the predictions of the V-A-structure of the muonic current with no neutrino mass in the case of absence of SCC for Gamow-Teller transitions

m_ν \ κ	0.99	0.999	1.0	1.001	1.01
0	$5.1\ 10^{-5}$	$5.4\ 10^{-7}$	0	$4.5\ 10^{-7}$	$5.0\ 10^{-5}$
50	$4.6\ 10^{-5}$	$2.7\ 10^{-7}$	$1.8\ 10^{-7}$	$1.1\ 10^{-6}$	$5.4\ 10^{-5}$
500	$1.4\ 10^{-5}$	$6.8\ 10^{-6}$	$1.1\ 10^{-5}$	$1.6\ 10^{-5}$	$1.1\ 10^{-4}$

Table 3

Deviation of $a_{\mu\nu}$ from the predictions of the V-A-structure of the muonic current without SCC and m_{ν_μ} in the case of ^{12}C for the KDR model parameters: $\tilde{\zeta} = 2 \cdot 10^{-3}$ MeV^{-1} and $\tilde{\xi} = 5 \cdot 10^{-3}$.

m_ν \ κ	0.99	0.999	1.0	1.001	1.01
0	-0.44	-0.44	-0.44	-0.44	-0.44
50	-0.44	-0.44	-0.44	-0.44	-0.44
500	-0.44	-0.44	-0.44	-0.44	-0.44

In Table 2 the values of Δ_{GT} are shown for the case without SCC. The Table 3 shows the values of Δ_{GT} for the case of nonvanishing SCC with parameters $\tilde{\zeta} = -2\cdot 10^{-3}$ MeV^{-1}; $\tilde{\xi} = 5\cdot 10^{-3}$ (here for instance L is taken for ^{12}C nucleus; in a general case there must be an L for each individual Nucleus /11, 12/). The contribution of SCC in $a_{\mu\nu}$ dominates and may reach up to 44%.

In the case of Gamow-Teller transitions in the impulse approximation with allowance for the terms proportional to F_P and $F_A/2M_N$, the coefficient $a_{\mu\nu}$ can be given by an axpression

$$a_{\mu\nu} = \frac{1}{3}\beta_\nu \frac{2\kappa}{1+\kappa^2}\{1 + C - \frac{8}{3} E_\nu[\tilde{\zeta} + \tilde{\xi} L + \frac{1}{2M_N}(1 - m_\mu \tilde{F}_P)]\}. \qquad (12)$$

Using single-particle matrix elements defined in /30/ , we obtain the following asymptotic expression for the coefficient $a_{\mu\nu}$ in the case of muon capture by ^{12}C nucleus:

$$a_{\mu\nu} = \frac{1}{3}\beta_\nu \frac{2\kappa}{1+\kappa^2}\{1 + C - \frac{8}{3} E_\nu[\tilde{\zeta} + \tilde{\xi} L + \frac{1}{2M_N}(\frac{3}{2} - m_\nu \tilde{F}_P)]\}. \qquad (13)$$

We should underline that the term proportional to $F_A/2M_N$ enters in equation (13) with a weight 3/2 times greater, than in (12).

c) Mixed transitions

In order to consider mixed transitions (with $\Delta I = 0$; $I \neq 0$) we employ the method of multipole expansion of the weak hadronic current /28, 29/ . In this case not only the axial-vector SCC (proportional to form factor F_T) but also the form factor F_S should be taken into account when studying SCC induced effects. This reduces the coefficient $a_{\mu\nu}$ to the following expression:

$$a_{\mu\nu} = -\beta_\nu \frac{2\kappa}{1+\kappa^2}\frac{\eta_1}{\eta_2}\{1 + \frac{1}{\eta_2}[-C(1-3\lambda^2) + \frac{8\lambda^2}{\eta_1}(\lambda^2 E_\nu(\tilde{\zeta} + \tilde{\xi} L) + m_\mu \tilde{F}_S)]\} \qquad (14)$$

Here $\eta_1 = 1 - \lambda^2$; $\eta_2 = 1 + 3\lambda^2$, where $\lambda = -1.25$ is the ratio of the axial-vector and vector constants of the nucleonic current.

In the case of the pure V-A-structure of the leptonic current and the absence of the neutrino rest mass the expression for $a_{\mu\nu}$ with both form factors F_S and F_T takes the form

$$a_{\mu\nu} = -\frac{\eta_1}{\eta_2}\{1 + \frac{8\lambda^2}{\eta_1\eta_2}[\lambda^2 E_\nu(\tilde{\zeta} + \tilde{\xi} L) + m_\mu \tilde{F}_S]\}. \qquad (15)$$

For the case of the finite neutrino mass, differance of the muonic current from the V-A-structure and on neglecting SCC, the coefficient $a_{\mu\nu}$ may be expressed as

$$a_{\mu\nu} = -\beta_\nu \frac{2\kappa}{1+\kappa^2}\frac{1-\lambda^2}{1+3\lambda^2}[1 - C\frac{1-3\lambda^2}{1+3\lambda^2}]. \qquad (16)$$

Without SCC and m_{ν_μ} and with $\kappa = 1$ we have the expression

$$a_{\mu\nu} = -\frac{1-\lambda^2}{1+3\lambda^2}. \qquad (17)$$

We analyze the equation (14) with a quantity

$$\Delta = \frac{a_{\mu\nu}^{V-A} - a_{\mu\nu}}{a_{\mu\nu}^{V-A}} \cong \frac{m_\nu^2}{2E_\nu^2} + \frac{m_\nu m_\mu}{E_\nu E_\mu}(1-\kappa)\frac{1-3\lambda^2}{1+3\lambda^2} + \frac{1}{2}(1-\kappa)^2 - \frac{8\lambda^2}{\eta_1\eta_2}[\lambda^2 E_\nu(\tilde{\zeta} + \tilde{\xi} L) + m_\mu \tilde{F}_S]. \qquad (18)$$

Expected values for Δ without SCC are listed in Table 4. The contribution of SCC in mixed transitions may reach up to 60% depending on the concrete transition.

Table 4

Mixed transitions in the case of absence of SCC; the effects, induced by the neutrino mass m_{ν_μ}.

m_ν \ κ	0.99	0.999	1.0	1.001	1.01
0	$5.0\ 10^{-5}$	$5.1\ 10^{-7}$	0	$5.1\ 10^{-7}$	$5.0\ 10^{-5}$
50	$4.7\ 10^{-5}$	$2.2\ 10^{-7}$	$7.3\ 10^{-8}$	$9.5\ 10^{-7}$	$5.3\ 10^{-5}$
500	$3.1\ 10^{-5}$	$8.4\ 10^{-6}$	$1.1\ 10^{-5}$	$1.5\ 10^{-7}$	$1.4\ 10^{-5}$

Formally, the expressions for three above mentioned cases may be united into one (taking into account the pseudoscalar form factor F_p) as follows

$$a_{\mu\nu} = -\beta_\nu \frac{2\kappa}{1+\kappa^2}\,\frac{a - b\lambda^2}{a + 3b\lambda^2}\{1 + \frac{1}{a - b\lambda^2}[-C(a - 3b\lambda^2) + \frac{8b\lambda^2}{a + 3b\lambda^2}(b\lambda^2 E_\nu (\zeta + \xi L + \frac{1}{2M_N}(1 - m_\mu \tilde{F}_p)) + a m_\mu \tilde{F}_s)]\}. \quad (19)$$

Here a and b have the following values:

1) $a = 1$, $b = 0$ for super-allowed transitions $0^+ \to 0^+$ (for example, $\mu^- + {}^{16}O \to {}^{16}N + \nu_\mu$) and for the first forbidden transition $0^+ \to 0^-$;

2) $a = 0$, $b = 1$ for Gamow-Teller transitions (for example, $\mu^- + {}^6Li \to {}^6He + \nu_\mu$; $\mu^- + {}^{12}C \to {}^{12}B + \nu_\mu$; $\mu^- + {}^{12}N \to {}^{12}C + \nu_\mu$; etc.);

3) $a = b = 1$ for mixed transitions (for example, $\mu^- + p \to n + \nu_\mu$; $\mu^- + {}^3He \to {}^3H + \nu_\mu$; $\mu^- + {}^{19}F(1/2) \to {}^{19}O(1/2) + \nu_\mu$; etc.);

Generally, weak magnetism also affects the asymmetry coefficient $a_{\mu\nu}$. However, the treatment of this effect goes beyond our present discussion.

Thus, it follows from the performed analysis that to obtain complete understanding on the muonic neutrino rest mass m_{ν_μ}, on difference of the parameter κ from 1 (i.e., deviation of the muonic current from the V-A-structure) and on parameters of the second class current, the coefficient of neutrino emission asymmetry relative to the muon spin orientation $a_{\mu\nu}$ in different transitions under muon capture by light nuclei should be studied in a series of investigations. So, for example, if the deviation of the asymmetry coefficient $a_{\mu\nu}$ from -1 in the case of $0 \to 0$ (super-allowed and first order forbidden) transitions is obtained, then the correlated value of the mass m_{ν_μ} and parameter κ may be determined, since they make the basic contribution to coefficient $a_{\mu\nu}$. Experimental study of the coefficient $a_{\mu\nu}$ for Gamow-Teller transitions will provide an additional information on SCC parameters (KDR model parameters ζ and ξ) in the axial-vector part of the hadronic weak current. The vector second class current form factor F_S may be estimated from the consideration of mixed type transitions using KDR model parameter values, obtained from Gamow-Teller transitions.

Thus to solve the acute problems (existence of SCC and non-zero neutrino mass), in the weak interaction, the precision measurements of angular and spin-angular correlation coefficients in β-decay and muon capture are necessary.

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Катхат Ч.Л. E6-88-121

Мезонные обменные токи второго рода и масса нейтрино в процессах μ-захвата легкими ядрами

Проанализировано влияние параметров модели Кубодеры-Деорма-Ро (ζ и ξ), скалярного формфактора (F_s)и массы покоя мюонного нейтрино (m_{ν_μ}) на коэффициент асимметрии ($a_{\mu\nu}$) вылета нейтрино относительно ориентации спина мюона в процессах μ^--захвата легкими ядрами. Показано, что, изучая коэффициент в $0 \to 0$ переходах, можно оценить массу m_{ν_μ}, в Гамов-Теллеровских переходах - параметры ζ и ξ , а в переходах смешанного типа - формфактор F_s.

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Kathat C.L. E6-88-121

Meson Exchange Second Class Currents and the Neutrino Mass in the Muon Capture by Light Nuclei

Influence of the Kubodera-Delorme-Rho model parameters (ζ and ξ), the scalar form factor (F_s) and the muonic neutrino rest mass (m_{ν_μ}) on the asymmetry coefficient ($a_{\mu\nu}$) of neutrino emission with respect to the muon spin orientation in the muon capture by light nuclei is analyzed. It is shown that the mass m_{ν_μ} , the parameters ζ and ξ, and the form factor F_s may be estimated by studying the coefficient $a_{\mu\nu}$ in $0 \to 0$, Gamov-Teller, and mixed transitions, respectively.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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