Addendum: On the Type of the Spin Polarization Dependence of the Neutrino Mass and Charge

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Abstract. We discuss the characteristic features of the latent nature of the neutrino mass, according to which, all components of leptonic current can appear in the interaction type dependence. Such a regularity, however, requires the modification of the some denotations in the corresponding formulas of the paper On the type of the spin polarization dependence of the neutrino mass and charge [1]. We will also include in a given letter the full version of the original article with necessary replacements of the structural variables. They of course do not change our implications.

In our original paper [1] the question has been raised as to whether there exists any spin polarization type dependence of the neutrino mass, charge and behavior. This sight on the nature of the neutrino is based logically on the analysis of the possible processes of elastic scattering of longitudinal and transversal polarized neutrinos (ν = νe) by spinless nuclei in the presence of the Coulomb (K = E), weak (K = W) and the united electroweak (K = EW) masses mKν, and also the charge f1ν, magnetic f2ν, anapole g1ν and electric dipole g2ν moments of incoming fermions with neutral currents. At the definition of their cross sections, we used the matrix elements of transitions in the form

\[ M^E_{fi} = \frac{4\pi\alpha}{q_E^2} \bar{u}(p'_E, s') \gamma_\mu f_{1\nu}(0) - i\gamma_\mu q_{\lambda E} f_{2\nu}(0) + \gamma_5 \gamma_\mu g_{1\nu}(0) - i\gamma_\mu q_{\lambda E} g_{2\nu}(0) \]

\[ M^W_{fi} = \frac{G_F}{\sqrt{2}} \bar{u}(p'_W, s') \gamma_\mu (g_{\nu e} + \gamma_5 g_{A e}) u(p_W, s) J^{Z}_{\mu}(q_W), \]

where qE = pE − p′E, qW = pW − p′W, pE(pW) and p′E(p′W) denote the four-momentum of a particle before and after the electric (weak) scattering, s and s′ are the helicities of these states, J^{Z}_{\mu} and J^{Z}_{\mu} are the nuclear currents in the studied processes, g_{\nu e} and g_{A e} correspond to the vector and axial-vector components of leptonic weak neutral currents.

According to our description, a neutrino electric mass leads to its Coulomb scattering. At the exchange by the Z-boson, only the weak component of mass is responsible for the scattering.

In the framework of mass-charge duality [2], each of the existing types of charges testifies in favor of the availability of a kind of inertial mass. Any particle of a Dirac nature can therefore have simultaneously both electric and weak [3] masses.

Thus, in [1] the neutrino scattering by nuclei of an electroweak charge going at the expense of the interference between the interactions (1) and (2) is analytically described as

\[ \text{Re} M^E_{fi} M^W_{fi} = \frac{4\pi\alpha G_F}{\sqrt{2}q_{EW}^2} \text{Re} \rho_{EW} p'_{EW} [\gamma_\mu f_{1\nu}(0) - \gamma_\mu f_{1\nu}(0)] \]
\[ -i\sigma_{\mu\lambda} q_{\text{EW}} f_{2\nu}(0) + \gamma_5 \gamma_{\mu} g_{1\nu}(0) - \\
- i\gamma_5 \sigma_{\mu\lambda} q_{\text{EW}} g_{2\nu}(0) [\gamma_{\mu}(g_{V\nu} + \gamma_5 g_{A\nu}) J_\mu^I(q_{\text{EW}}) J_\mu^Z(q_{\text{EW}}) \]

(3)

and it is assumed additionally that

\[ q_{\text{EW}} = p_{\text{EW}} - p'_{\text{EW}}, \quad m_{\nu}^E = m_{\nu}^E + m_{\nu}^W, \]

\[ \rho_{\text{EW}} = u(p_{\text{EW}}, s) \pi(p_{\text{EW}}, s), \quad \rho'_{\text{EW}} = u(p'_{\text{EW}}, s') \pi(p'_{\text{EW}}, s'). \]

Any component of leptonic current there exists at the availability of a kind of charge [4], as follows from considerations of symmetry. If so, each of the interactions (1) or (3) states that the terms \( f_{\nu} \) and \( g_{\nu} \) responsible for the interference scattering are not of those form factors which arise as a result of particle Coulomb mass. The account of their differences leads (1) to the following:

\[ M_{f_1}^E = \frac{4\pi\alpha}{q_{\text{EW}}^2} \pi(p'_{\text{EW}}, s') [\gamma_{\mu} f_{1\nu}^E(0) - i\sigma_{\mu\lambda} q_{\text{EW}} f_{2\nu}^E(0)] + \\
+ \gamma_5 \gamma_{\mu} g_{1\nu}(0) - i\gamma_5 \sigma_{\mu\lambda} q_{\text{EW}} g_{2\nu}(0)] u(p_{\text{EW}}, s) J_\mu^I(q_{\text{EW}}) \]

(4)

and that, consequently, the interactions (3) must have the form

\[ \text{Re} M_{f_1}^E M_{f_1}^{W*} = \frac{4\pi\alpha G_F}{\sqrt{2} q_{\text{EW}}^2} \text{Re} \Lambda_{\text{EW}} N_{\text{EW}} [\gamma_{\mu} f_{1\nu}^E(0)] - \\
- i\sigma_{\mu\lambda} q_{\text{EW}} f_{2\nu}^E(0) + \gamma_5 \gamma_{\mu} g_{1\nu}(0) - \\
- i\gamma_5 \sigma_{\mu\lambda} q_{\text{EW}} g_{2\nu}(0) [\gamma_{\mu}(g_{V\nu} + \gamma_5 g_{A\nu}) J_\mu^I(q_{\text{EW}}) J_\mu^Z(q_{\text{EW}}) \]

(5)

Here \( \Lambda_{\text{EW}} = \rho_{\text{EW}} \) and \( \Lambda'_{\text{EW}} = \rho'_{\text{EW}} \). Unlike \( f_{\nu}^E \) and \( g_{\nu}^E \), the interference (I) terms \( f_{\nu}^I \) and \( g_{\nu}^I \) characterize the united electroweak mass dependence of the neutrino form factors.

Inserting (2), (4) and (5) in

\[ \frac{d\sigma_{E,W}(s, s')}{d\Omega} = \frac{1}{16\pi^2} |M_{f_1}^E + M_{f_1}^{W*}|^2, \]

(6)

we find for the elastic scattering cross sections the explicit expressions which coincide with the corresponding formulas from the paper [1] if we make there the following replacements:

\[ f_{\nu} \rightarrow f_{\nu}^I, \quad g_{\nu} \rightarrow g_{\nu}^I, \]

\[ F_{\text{EW}}(q_{\text{EW}}^2) \rightarrow F_I(q_{\text{EW}}^2), \quad \theta \rightarrow \theta_K, \]

\[ \sigma_{\nu} \rightarrow \sigma_{\nu}^I, \quad \rho \rightarrow \rho_{\text{EW}}, \]

\[ t = E, I, \quad j = E, EW, \quad K = E, EW, W. \]

Of them \( \theta_K \) denotes the scattering angle in the mass type dependence, \( F_I \) is the nuclear interference form factor, \( \sigma_{\nu}^I \) describes the Mott cross section at the neutrino interaction in the presence of one of the masses, \( m_{\nu}^E \) or \( m_{\nu}^W \), and \( \rho_{\text{EW}} \) is the electroweak interference coefficient.

Thus, a general picture is obtained of elastic scattering in which appears an important part of compound structure of mass and charge.

Therefore, we will include in this letter the full version of the paper [1] with the above-noted modifications. They of course do not change our implications based on the analysis of earlier findings.
References

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On the Type of the Spin Polarization Dependence of the Neutrino Mass and Charge

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Abstract. Any non-zero component of charge implies the existence of a kind of inertial mass. Therefore, each of the existing types of the dipole moments must arise as a consequence of the availability of a kind of charge. From their point of view, the elastic scattering of completely longitudinally (transversally) polarized neutrinos and antineutrinos by spinless nuclei is discussed taking into account the Coulomb, weak and the united electroweak masses and charges, and also the magnetic, anapole and the electric dipole moments of incoming fermions with the weak currents. Interconversions of neutrinos of different components have been investigated, at which a particle chiral invariance is violated at the expense of the flip of its spin. This becomes possible owing to an intimate connection between these phenomena and characters of the structure of Dirac mass. Analysis of the studied process cross sections assumed that both masses and charges of longitudinal and transversal neutrinos are strictly unidentical.

1 Introduction

In studying the nature of elementary particles such characteristics as the mass and charge play a large role. At the same time, it is well known that according to the hypothesis of field mass based on the classical theory of an extensive electron [1], a particle all the mass is purely electric. Such a structure, however, encounters many problems. One of them states that the charge distribution in the electron is not steady.

My investigation of the interaction of leptons and their neutrinos with the field of emission shows clearly [2,3] that if the neutrino corresponds to the electron (\(\nu = \nu_e\)), its full electric charge \(e_\nu^{full}\) and magnetic moment \(\mu_\nu^{full}\) appear [4] owing to the Coulomb rest mass \(m_\nu^E\) and behave as

\[
e_\nu^{full} = \frac{3eG_Fm_\nu^2}{4\pi^2\sqrt{2}}, \quad e = |e|, \tag{1}
\]

\[
\mu_\nu^{full} = \frac{3eG_Fm_\nu}{8\pi^2\sqrt{2}}, \quad m_\nu = m_\nu^E. \tag{2}
\]

This picture reflects the fact that each of the available types of charges says in favor of the availability of a kind of inertial mass. Thereby, the possibility of the existence of the united rest mass \(m_\nu^U\) and charge \(e_\nu^U\) for the neutrino equal to its all the mass and charge is not excluded. One can define their structure in the form [5]

\[
m_\nu^U = m_\nu^E + m_\nu^W + m_\nu^S + ..., \tag{3}
\]

\[
e_\nu^U = e_\nu^E + e_\nu^W + e_\nu^S + .... \tag{4}
\]
Here the indices $E$, $W$ and $S$ correspond to the electric, weak and the strong components of the neutrino mass and charge. They constitute herewith the harmony of forces of a different nature. Therefore, the charge distribution of the light lepton must be steady [6].

Such a steadiness of matter says about the compound structure [7] of charge quantization law and thereby testifies in favor of that any non-zero component of the electric charge implies the existence of a kind of dipole moment. In other words, Dirac $F_{1\nu}(q^2)$ and Pauli $F_{2\nu}(q^2)$ form factors contain [6] the statical as well as the dynamical components:

$$F_{1\nu}(q^2) = f_{1\nu}(0) + A_{1\nu}(q^2) + \ldots,$$

(5)

where $f_{1\nu}(0)$ give the normal sizes of charge and moment, $A_{1\nu}(q^2)$ characterize the momentum dependence of leptonic current vector parts. The terms $f_{1\nu}(0)$ and $A_{1\nu}(q^2)$ are responsible for the first and second Born approximations. In these circumstances, the form factors $F_{1\nu}(q^2)$ and $F_{2\nu}(q^2)$ at $q^2 = 0$ define the full static values of the neutrino electric charge and moment:

$$F_{1\nu}(0) = e_{\nu}^{\text{full}} = e_{\nu}^{\text{norm}} + e_{\nu}^{\text{anom}} + \ldots,$$

(6)

$$F_{2\nu}(0) = \mu_{\nu}^{\text{full}} = \mu_{\nu}^{\text{norm}} + \mu_{\nu}^{\text{anom}} + \ldots.$$

(7)

Of course, the electric mass and charge of a Dirac neutrino correspond to the most diverse forms of the same regularity of its Coulomb nature. By this reason we conclude [4] that the neutrino electric mass $m_{E\nu}$ includes as well as the normal $m_{\nu}^{\text{norm}}$ and anomalous $m_{\nu}^{\text{anom}}$ components:

$$m_{\nu}^E = m_{\nu}^{\text{norm}} + m_{\nu}^{\text{anom}} + \ldots.$$

(8)

However, it is known [8,9] that the neutrino interaction with virtual photons is described by the vertex operator

$$\Gamma_{\mu}(p, p') = \bar{\nu}(p', s')[\gamma_{\mu}F_{1\nu}(q^2) - i\sigma_{\mu\lambda}q_{\lambda}F_{2\nu}(q^2)] +$$

$$+ \gamma_{5}\gamma_{\mu}G_{1\nu}(q^2) - i\gamma_{5}\sigma_{\mu\lambda}q_{\lambda}G_{2\nu}(q^2)]u(p, s).$$

(9)

Here $\sigma_{\mu\lambda} = [\gamma_{\mu}, \gamma_{\lambda}]/2$. $q = p - p'$, $p(s)$ and $p'(s')$ denote the four-momentum (helicities) of the neutrino before and after the emission, $G_{1\nu}(q^2)$ and $G_{2\nu}(q^2)$ are the current axial-vector parts.

Analysis of electroweak processes on nuclei assumed [10] that $F_{2\nu}$ and $G_{2\nu}$ must have the same size. Therefore, without loss of generality, we may write

$$G_{1\nu}(q^2) = g_{1\nu}(0) + \Phi_{1\nu}(q^2) + \ldots,$$

(10)

where $g_{1\nu}(0)$ and $g_{2\nu}(0)$ are the normal components of the particle anapole [11] and electric dipole moments. The functions $\Phi_{1\nu}(q^2)$ characterize the anomalous behavior of axial-vector form factors.

According to the correspondence principle, each term in (10) as well as in (5), corresponds to the definite approximation. This sight on the interaction axial-vector nature quality explains the fact that $G_{1\nu}(0)$ and $G_{2\nu}(0)$ give the full static sizes of the Dirac particle anapole and electric dipole moments:

$$G_{1\nu}(0) = a_{\nu}^{\text{full}} = a_{\nu}^{\text{norm}} + a_{\nu}^{\text{anom}} + \ldots,$$

(11)

$$G_{2\nu}(0) = d_{\nu}^{\text{full}} = d_{\nu}^{\text{norm}} + d_{\nu}^{\text{anom}} + \ldots.$$

(12)

Of them $a_{\nu}^{\text{full}}$ also can be measured experimentally [12]. For $d_{\nu}^{\text{full}}$ as well as for $e_{\nu}^{\text{full}}$ and $\mu_{\nu}^{\text{full}}$ there exist laboratory and cosmological restrictions [13,14].
The purpose of the present work is to discuss the problem of the neutrino latent mass investigating its interaction with the field of electroweak emission in the polarization type dependence. First of all we consider the elastic scattering of longitudinal polarized massive Dirac neutrinos by nuclei of the electric \(Z\) and weak \(Z_W\) charges

\[
\nu_{L,R}(\bar{\nu}_{R,L}) + A(Z, Z_W) \xrightarrow{\gamma^F} \nu'(\bar{\nu}') + A(Z, Z_W)
\]

at the account of their Coulomb, weak and the united electroweak masses and currents. Next, all they will be reanalyzed for the transversal case of an incoming particle polarization. In conclusion we present some implications implied from these considerations.

2 Interaction of longitudinal polarized neutrinos with the field of a nucleus

From our earlier developments, we find that the matrix elements of elastic scattering of arbitrary polarized neutrinos on the nucleus electric and weak charges in the first Born approximation must have the following structure:

\[
M^{E}_{fi} = \frac{4\pi\alpha}{q_E^2}\overline{\sigma}(p'_E, s')[\gamma_\mu f^{E}_{1\nu}(0) - i\sigma_{\mu\lambda}q_{\lambda E}f^{E}_{2\nu}(0) + \gamma_5\gamma_\mu g^{E}_{1\nu}(0) - i\gamma_5\sigma_{\mu\lambda}q_{\lambda E}g^{E}_{2\nu}(0)]u(p_E, s)J^E_{\gamma}(q_E),
\]

\[
M^{W}_{fi} = \frac{G_F}{\sqrt{2}}\overline{\sigma}(p'_W, s')\gamma_\mu(g_{V\nu} + \gamma_5 g_{A\nu})u(p_W, s)J^Z_{\mu}(q_W).
\]

Here \(\nu = \nu_{L,R} = \nu_{eL,R}, q_E = p_E - p'_E, q_W = p_W - p'_W, p_E(p_W)\) imply the four-momentum of the neutrino before and after the electric (weak) emission, \(f^{E}_{i\nu}\) and \(g^{E}_{i\nu}\) characterize the Coulomb mass dependence of the neutrino form factors, \(J^E_{\gamma}\) and \(J^Z_{\mu}\) are the nuclear photon \((x = \gamma)\) and weak \((x = Z)\) currents [15], \(g_{V\nu}\) and \(g_{A\nu}\) denote the corresponding constants of the purely weak interaction vector and axial-vector components.

As seen from (14) and (15), in the case of exchange by the photon, only the Coulomb mass is responsible for the electric scattering. Insofar as \(m^W_\nu\) is concerned, it leads to the corresponding weak interaction.

It appears that on the basis of the standard definition

\[
\frac{d\sigma^{E,W}(s, s')}{d\Omega} = \frac{1}{16\pi^2}|M^{E}_{fi} + M^{W}_{fi}|^2
\]

one can establish an explicit form of the studied process cross sections. It is not excluded, however, that any Dirac particle possesses simultaneously both electric and weak [16] masses. In other words, the neutrino interaction with the field of emission explained by its electroweak \(m^E_W\) mass arises at the expense of exchange simultaneously both by the photon and by the weak boson. From this point of view, the interference \((I)\) between the interactions (14) and (15) can be expressed as follows:

\[
\text{Re}M^{E}_{fi}M^{W}_{fi} = \frac{4\pi\alpha G_F}{\sqrt{2}q^2_{EW}}\text{Re}\Lambda_{E,W}N'_{E,W}[\gamma_\mu f^{I}_{1\nu}(0) - i\sigma_{\mu\lambda}q_{\lambda EW}f^{I}_{2\nu}(0) + \gamma_5\gamma_\mu g^{I}_{1\nu}(0) - i\gamma_5\sigma_{\mu\lambda}q_{\lambda EW}g^{I}_{2\nu}(0)]J^E_{\gamma}(q_{EW})J^Z_{\mu}(q_{EW}).
\]
where the interaction of each of the currents $f^I_{\nu}$ and $g^I_{\nu}$ with the united field of emission of the photon and weak boson is explained by the electroweak structures of mass and charge. They are of course strictly interference. Here it is also necessary to keep in mind that

\begin{align*}
q_{EW} &= p_{EW} - p'_{EW}, \quad m^E_{\nu} = m^E_{\nu} + m^W_{\nu}, \\
\Lambda_{EW} &= u(p_{EW}, s)\pi(p_{EW}, s), \quad \Lambda'_{EW} = u(p'_{EW}, s')\pi(p'_{EW}, s').
\end{align*}

According to these data, the cross section of the process (13) at the account of longitudinal polarization of both incoming and outgoing fermions is written in the form

\begin{equation}
\frac{d\sigma_{E,W}^{V, A}(\theta_{E,W}, s, s')}{d\Omega} = \frac{1}{2}q_{E,W}^2 (1 - \eta^2_{E,W})^{-1} \left\{ (1 + ss') \left[ f_{\nu}^E + 2\lambda_{\nu}s\sqrt{1 - \eta^2_{E,W}}g_{\nu}^E \right] f_{\nu}^E + \right.
\end{equation}

\begin{align*}
&\left. + \eta^2_{E}(1 - ss') \left[ (f_{\nu}^E)^2 + 4(m^E_{\nu})^2(1 - \eta^2_{E})^2(f_{\nu}^E)^2 \right] g_{\nu}^E \theta_{E} \right. - 8s/(E_{E}^2(1 - \eta^2_{E})^2(1 + ss')(1 - \eta^2_{E})^2/2f_{\nu}^E g_{\nu}^E g_{\nu}^2 \theta_{E} / 2 + \\
&\quad + (1 - \eta^2_{E})(1 + ss')(g_{\nu}^E)^2 + \\
&\left. + 4(E_{E}^2(1 - ss')^2 g_{\nu}^2 g_{\nu}^2 \theta_{E} / 2) \right] F_{E}^E(q_{E}^2). \tag{19}
\end{align*}

As a consequence of the availability of the united electroweak mass in particles, the second term characterizes the interference of electric and weak interactions:

\begin{equation}
\frac{d\sigma_{I}^{V, A}(\theta_{E,W}, s, s')}{d\Omega} = \frac{1}{2}q_{E,W}^2 \left\{ \left[ f_{\nu}^I + \lambda_{\nu}s\sqrt{1 - \eta^2_{E,W}}g_{\nu}^I \right] f_{\nu}^I + \right.
\end{equation}

\begin{align*}
&\left. + \eta^2_{E}(1 - ss') \left[ (f_{\nu}^I)^2 + 4(g_{\nu}^I)^2 \theta_{E} \right] - \lambda_{\nu}s g_{\nu}^I \sqrt{1 - \eta^2_{E,W}} + \lambda_{\nu}s (1 - \eta^2_{E,W}) g_{\nu}^I \right] + \\
&\quad + \eta^2_{E}(1 - ss') f_{\nu}^I g_{\nu}^E \theta_{E} / 2 \right\} F_{I}(q_{E,W}^2). \tag{20}
\end{align*}

The corresponding cross section for the process going at the expense of the neutrino purely weak rest mass behaves as

\begin{equation}
\frac{d\sigma_{W}^{V, A}(\theta_{W}, s, s')}{d\Omega} = \frac{G_F^2(E_{\nu}^W)^2}{16\pi^2} \left\{ g_{\nu}^W \left[ (1 + ss') \cos^2 \theta_{W} / 2 \right] + \right.
\end{equation}

\begin{align*}
&\left. + \eta^2_{W}(1 - ss') \sin^2 \theta_{W} / 2 \right] + g_{\nu}^A \left[ (1 + ss') (1 - \eta^2_{W}) \cos^2 \theta_{W} / 2 \right] - 2\lambda_{\nu}s \sqrt{1 - \eta^2_{W}} \cos^2 \theta_{W} / 2 \right\} F_{W}^W(q_{W}^2). \tag{21}
\end{align*}

Here we must have in view of that

\begin{align*}
\sigma^E_{\phi} &= \frac{\alpha^2 \cos^2 (\theta_{E}/2)}{2(E_{\nu}^E)^2(1 - \eta^2_{E}) \sin^4 (\theta_{E}/2)} + q_{EW} = \frac{G_F q_{EW}^2}{2\pi\sqrt{2\alpha}},
\end{align*}
change a particle helicity. In contrast to this, the vector field that the helicity of the neutrino of large energy (\(\nu\), responsible only for the flip of the neutrino spin. Of course, our formulas can also confirm the change of its spin.

Under such circumstances, the cross section (18) is convenient to replace by the summed size of leptonic photon and weak currents. Therefore, any of the expressions (19)-(21) for the terms \(ss\) characterize the scattering with conservation \((s' = s)\) and change \((s' = -s)\) of helicities of incoming left \((s = -1)\) and right \((s = +1)\)-polarized particles. Under such circumstances, the cross section (18) is convenient to replace by the summed size

\[
d\sigma_{E,W}^{V,A}(\theta_{E,W}, s) = d\sigma_{E,W}^{V,A}(\theta_{E,W}, s' = s) + d\sigma_{E,W}^{V,A}(\theta_{E,W}, s' = -s).
\]

The compound structures of both terms of (22) testify in favor of that the neutrino charge \(f_1\) leads to the scattering either with or without flip of its spin. The anapole \(g_2\) does not change a particle helicity. In contrast to this, the vector \(f_2\) and axial-vector \(g_2\) moments are responsible only for the flip of the neutrino spin. Of course, our formulas can also confirm the fact that the helicity of the neutrino of large energy \((E_\nu \gg m_\nu)\) is not changed.

However, as known, the right-handed neutrino encounters the problem which states that a chiral symmetry characterized a massive particle does not exist. Therefore, it appears that the neutrinos have no neither the electric, weak nor any other mass. But this is not quite so. The point is that at the helicity conservation, a particle chirality is not changed even if it possesses a non-zero rest mass. In other words, the longitudinal neutrino chirality can be violated at the expense of mass, charge, magnetic and electric dipole moments, because they lead to the flip of its spin.

In the absence of one of the currents, \(V\) or \(A\), any of (19)-(21) not only for the particle and the antiparticle, but also for the left- and right-handed neutrinos coincides. Such an equality takes place as well as in the low energy limits of the corresponding processes.

### 3 Transversal polarized neutrino scattering by nuclei of electroweak charges

Owing to an intimate connection between the mass of a particle and its physical nature, any massive neutrino has the longitudinal as well as the transversal polarization. Here an important circumstance is the fact that the same neutrino must not be simultaneously both a longitudinal and a transversal fermion. There exists, however, the possibility that the longitudinal polarized...
neutrinos in the elastic scattering on a nucleus can be converted into the transversal polarized ones and vice versa [17].

Returning to (14)-(17), we establish the cross section of the process (13) for the transversal case of the neutrino polarization which one can present as follows:

\[
d\sigma_{E,W}^{V,A}(\theta_{E,W}, \varphi, s, s') = d\sigma_{E}^{V,A}(\theta_{E}, \varphi, s, s') + d\sigma_{T}^{V,A}(\theta_{E}, \varphi, s, s') + d\sigma_{W}^{V,A}(\theta_{E}, \varphi, s, s').
\] (23)

Here to the contribution of purely electric mass responds the expression

\[
d\sigma_{E}^{V,A}(\theta_{E}, \varphi, s, s') = \frac{1}{2}\sigma_{o}E(1 - \eta_{E}^2)^{-1} \left\{ (1 + ss')\alpha_{T}\cos^{2}\varphi \right\} +
\]

\[
+(1 - ss')\alpha_{t}^{*}\sin^{2}\varphi \eta_{E}^{2}(1 + ss')\gamma_{T}\sin^{2}\varphi -
\]

\[
-(1 - ss')\gamma_{T}\cos^{2}\varphi \left\{ (f^{E}_{1}\nu)^{2} + 4(m_{\nu}^{E})^{2}(1 - \eta_{E}^{2})(f^{E}_{2}\nu)^{2} \right\} \theta_{E}^{2} +
\]

\[
+2\lambda_{c}\eta_{E}^{2}(1 - \eta_{E}^{2})(1 + ss')\sin^{2}\varphi \right\} +
\]

\[
-(1 - ss')\cos^{2}\varphi \gamma_{T}^{*}f_{1}\nu g_{1}\nu \theta_{E}^{2} +
\]

\[
+(1 - \eta_{E}^{2})(1 + ss')\alpha_{t}^{*}\sin^{2}\varphi + (1 - ss')\alpha_{T}\cos^{2}\varphi \left\{ (g^{E}_{1}\nu)^{2} \right\} +
\]

\[
+4(E_{\nu}^{E})^{2}(1 + \eta_{E}^{2})(1 + ss')\gamma_{T}\cos^{2}\varphi -
\]

\[
-(1 - ss')\gamma_{T}\sin^{2}\varphi \right\} \left\{ (g^{E}_{2}\nu)^{2} \right\} \theta_{E}^{2} \right\} F_{E}^{2}(q_{E}^{2}).
\] (24)

The interference process cross section originated at the expense of the united electroweak mass of transversal polarized neutrinos has the following structure:

\[
d\sigma_{T}^{V,A}(\theta_{E,W}, \varphi, s, s') = \frac{1}{2}\rho_{EW}^{A}(1 - \eta_{E,W}^{2})^{-1} g_{1}\nu \{ (1 + ss')\alpha_{T}\cos^{2}\varphi \}
\]

\[
+ (1 - ss')\alpha_{t}^{*}\sin^{2}\varphi \}
\]

\[
+ \eta_{E,W}^{2}[((1 + ss')\gamma_{T}\sin^{2}\varphi - (1 - ss')\gamma_{T}\sin^{2}\varphi)\theta_{E,W}^{2} +
\]

\[
+\lambda_{s}\eta_{E,W}^{-1}g_{1}\nu \theta_{E,W} \left\{ (1 + ss')\sin^{2}\varphi -
\]

\[
-(1 - ss')\gamma_{T}\sin^{2}\varphi \right\} f_{1}\nu \theta_{E,W}^{2} -
\]

\[
-\lambda_{c}\theta_{E,W} \left\{ (1 + ss')\gamma_{T}\sin^{2}\varphi -
\]

\[
-(1 - ss')\gamma_{T}\sin^{2}\varphi \right\} f_{1}\nu \theta_{E,W}^{2} +
\]

\[
+\lambda_{s}\eta_{E,W}^{-1}g_{1}\nu \theta_{E,W} \left\{ (1 + ss')\gamma_{T}\sin^{2}\varphi +
\]

\[
+(1 - ss')\alpha_{T}\cos^{2}\varphi \right\} g_{1}\nu \} F_{I}(q_{E,W}^{2}).
\] (25)
The contribution explained by the transversal polarized neutrino purely weak rest mass is written in the form

\[
\frac{d\sigma^{V,A}_{W}(\theta_{W}, \varphi, s, s')}{d\Omega} = \frac{G_F^2 (E^W_\nu)^2}{16\pi^2} \left\{ (1 + ss')\alpha_T \cos^2 \frac{\varphi}{2} + (1 - ss')\alpha^*_T \sin^2 \frac{\varphi}{2} \right. \\
+ \left. \frac{\eta^2_W ((1 + ss')\gamma_T \sin^2 \frac{\varphi}{2} - (1 - ss')\gamma^*_T \cos^2 \frac{\varphi}{2}) \sin^2 \theta_{W}}{2} + g^2_{A_\nu} (1 - \eta^2_W) ((1 + ss')\alpha^*_T \sin^2 \frac{\varphi}{2} + (1 - ss')\alpha_T \cos^2 \frac{\varphi}{2}) \right. \\
- \left. 2\lambda e_s g_{V_\nu} g_{A_\nu} \eta_W \sqrt{1 - \eta^2_W} ((1 + ss')\sin^2 \frac{\varphi}{2} - (1 - ss')\cos^2 \frac{\varphi}{2}) \right. \\
- \left. (1 - ss') \cos^2 \frac{\varphi}{2} \gamma^*_T \sin \theta_{W} \cos \theta_{W} \right\} F^2_W(q^2_W),
\]

(26)

where it has been accepted that

\[
\alpha_T = 1 - 2(1 - 4\sin^2 \frac{\varphi}{2}) \sin^2 \frac{\varphi}{2}, \quad \alpha^*_T = 1 + 2(1 - 4\sin^2 \frac{\varphi}{2}) \cos^2 \frac{\varphi}{2}, \\
\gamma_T = 1 + 2\cos^2 \frac{\varphi}{2}, \quad \gamma^*_T = 1 - 2\cos^2 \frac{\varphi}{2}.
\]

Here $\varphi$ is the azimuthal angle.

As well as in (18), each term in (23) contains the contributions of vector and axial-vector interactions, and also the contributions of their interference between themselves owing to which, the neutrino and antineutrino scattering cross sections are different.

Furthermore, if taken into account the availability of the multipliers $(1 + ss')$ and $(1 - ss')$ in (24)-(26), we can present (23) in the form

\[
\frac{d\sigma^{V,A}_{E,W}(\theta_{E,W}, \varphi, s)}{d\Omega} = \frac{d\sigma^{V,A}_{E,W}(\theta_{E,W}, \varphi, s' = s)}{d\Omega} + \frac{d\sigma^{V,A}_{E,W}(\theta_{E,W}, \varphi, s' = -s)}{d\Omega}.
\]

(27)

An explicit expressions for both terms of (27) have the most diverse structures. From their point of view, in the case of the neutrino transversal polarization, the processes with or without change of incoming particle helicities must go as a consequence not only of charge, but also of any dipole moment. It is of course not excluded that the flip of the transversal neutrino spin which arises at the expense of mass, charge, magnetic, anapole and electric dipole moments can explain the possible violation of its chirality.

The absence of one of the currents, $V$ or $A$, implies that each of (24)-(26) for the neutrino and the antineutrino as well as for the left- and right-handed particles is not different. Such a coincidence takes place even in the low energy limits of the corresponding types of interactions.

4 Conclusion

In conformity with the laws of neutrino nature, the presence of any type of charge implies the existence of a kind of inertial mass [5]. Such a duality of matter says about the steadiness of
charge distribution in the neutrino and thereby testifies in favor of that each of all possible
types of the dipole moments arises as a consequence of the availability of a kind of charge [6].
Therefore, to reanalyze these features and discuss their some implications, we have established
the compound structures of the differential cross sections describing the elastic scattering of
completely longitudinally (transversally) polarized neutrinos and antineutrinos by spinless nu-
clei taking into account the Coulomb, weak and the united electroweak masses and charges,
and also the magnetic, anapole and the electric dipole moments of incoming fermions with the
weak currents.

They state that if neutrinos are of longitudinal polarized, their charge answers to the elastic
scattering either with or without flip of the spin. The anapole is responsible only for a particle
helicity conservation. Unlike this, both magnetic and electric dipole moments lead to the
interconversion of neutrinos of different components. However, in the transversal case of the
neutrino polarization, each of these processes can originate through the interaction with the
field of emission of charge as well as of any dipole moment.

The existence of interconversions $\nu_L \leftrightarrow \nu_R$ and $\bar{\nu}_R \leftrightarrow \bar{\nu}_L$ is incompatible with chiral invari-
ance. These transitions, however, take place owing to the rest mass dependence of the behavior
of neutrinos. At our sight, this connection implies that a particle chirality is violated at the
expense of the flip of its helicity.

In the case of both longitudinal and transversal polarization of the neutrino, the process
(13) is described by the three differential cross sections corresponding to the electric, weak and
the united electroweak masses and charges. These cross sections can be defined simultaneously
for the same energy if all the three momentum transfer have the space-like size.

One of the beautiful new features of our formulas is the indication to the existence of different
low energy limits for the same particle in the interaction type dependence. They of course in
the slow neutrino scattering by nuclei behave as

$$
E^E_\nu \rightarrow m^E_\nu, \quad E^{EW}_\nu \rightarrow m^{EW}_\nu, \quad E^W_\nu \rightarrow m^W_\nu.
$$

(28)

At these values, the cross sections (22) and (27) describing the processes with longitudinal and
transversal fermions are not different:

$$
d\sigma^{V,A}_{E,W}(\theta_{E,W}, s) = d\sigma^{V,A}_{E,W}(\theta_{E,W}, \varphi, s).
$$

(29)

For an arbitrary energy such a situation takes place when either vector or axial-vector
interactions are present:

$$
d\sigma^V_{E,W}(\theta_{E,W}, s) = d\sigma^V_{E,W}(\theta_{E,W}, \varphi, s),
$$

(30)

$$
d\sigma^A_{E,W}(\theta_{E,W}, s) = d\sigma^A_{E,W}(\theta_{E,W}, \varphi, s).
$$

(31)

But all the three equalities (29)–(31) there exist only at the condition that a particle rest
mass does not depend on the type of polarization.

Thus, if it turns out that at the availability of a non-zero mass, the longitudinal polarized
neutrino must be converted into the transversal polarized one and vice versa [17], this will
indicate to the existence of fundamental differences in the masses as well as in the charges of
longitudinal and transversal neutrinos.

Comparing (19) with (24), it is easy to observe the contribution $s f^E_{1\nu}g^E_{1\nu}$, which is absent
at the elastic scattering of longitudinal neutrinos on nuclei, but arises as a result of their
transversal polarization. The term $s f^E_{2\nu}g^E_{2\nu}$ available in the longitudinal case of the neutrino
polarization, does not appear at the transversal particle interaction. We can, therefore, conclude
that the invariance of vector and axial-vector types of electroweak currents of longitudinal and
transversal neutrinos concerning C, P and T, and also their combinations CP and CPT are different.

Finally, insofar as the spin polarization type dependence of the behavior of massive Majorana neutrinos is concerned, this question together with some aspects of the geometrical nature of inertial mass will be treated in one of our further articles.

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