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ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА. ТЕОРИЯ

REMARKS TO THE STANDARD SCHEME (THEORY) OF NEUTRINO OSCILLATIONS. CORRECTED SCHEME OF NEUTRINO OSCILLATIONS

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In the standard theory of neutrino oscillations it is supposed that physically observed neutrino states ν_e, ν_μ, ν_τ have no definite masses, that they are initially produced as a mixture of the ν_1, ν_2, ν_3 neutrino states (i.e., they are produced as a wave packet), and that neutrino oscillations are the real ones. Then, this wave packet must decompose at a definite distance into constituent parts and neutrino oscillations must disappear. It was shown that these suppositions lead to violation of the law of energy and momentum conservation. An alternative scheme of neutrino oscillations obtained within the framework of particle physics has been considered, where the above-mentioned shortcomings are absent, the oscillations of neutrinos with equal masses are the real ones, and the oscillations of neutrinos with different masses are the virtual ones. Expressions for probabilities of neutrino transitions (oscillations) in the alternative (corrected) scheme are given.

В стандартной теории осцилляций нейтрино предполагается, что наблюдаемые нейтринные состояния ν_e, ν_μ, ν_τ не имеют определенной массы и что они сразу рождаются как смешанные нейтринные состояния ν_1, ν_2, ν_3 (т.е. рождаются как волновые пакеты) и нейтринные осцилляции являются реальными. Тогда эти волновые пакеты на определенных расстояниях от источника должны разлагаться на составные компоненты и нейтринные осцилляции должны исчезать. Показано, что эти предположения приводят к тому, что закон сохранения энергии и импульса в процессах с участием нейтрино не выполняется. Предлагается альтернативная схема нейтринных осцилляций, разработанная в рамках физики частиц, в которой отсутствуют указанные недостатки. В этой схеме осцилляции нейтрино с одинаковыми массами являются реальными, а осцилляции нейтрино с разными массами — виртуальными. Приводятся выражения для вероятностей нейтринных переходов (осцилляций) в этой альтернативной (исправленной) схеме.

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INTRODUCTION

The suggestion that in analogy with $K^0, \bar{K}^0$ oscillations there could be neutrino–antineutrino oscillations ($\nu \to \bar{\nu}$) was considered by Pontecorvo [1] in 1957. It was subsequently considered by Maki et al. [2] and Pontecorvo [3] that there could be mixings (and oscillations) of neutrinos of different flavors (i.e., $\nu_e \to \nu_\mu$ transitions). In the standard theory of neutrino oscillations [4] it is supposed that physically observed neutrino states ν_e, ν_μ, ν_τ have no definite masses and that they are directly produced as a mixture of the ν_1, ν_2, ν_3 neutrino

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states (as wave packets). Below, we discuss the consequences of these suppositions and then an alternative scheme of neutrino oscillations constructed in the framework of particle physics theory (or the quantum field theory) is considered.

We come to consideration of basic elements and shortcomings of the standard theory of neutrino oscillations.

1. BASIC ELEMENTS OF THE STANDARD THEORY OF NEUTRINO OSCILLATIONS

The standard theory of neutrino oscillations [4] was constructed in the framework of quantum theory (mechanics) in analogy with the theory of $K^0, \bar{K}^0$ oscillations. To simplify, the case of two neutrinos is considered.

The mass Lagrangian of two neutrinos (ν_e, ν_μ) has the following form:

$$\mathcal{L}_M = -\frac{1}{2}\left[m_{\nu_e}\bar{\nu}_e\nu_e + m_{\nu_\mu}\bar{\nu}_\mu\nu_\mu + m_{\nu_e\nu_\mu}(\bar{\nu}_e\nu_\mu + \bar{\nu}_\mu\nu_e)\right] \equiv$$
$$\equiv -\frac{1}{2}(\bar{\nu}_e, \bar{\nu}_\mu)\begin{pmatrix} m_{\nu_e} & m_{\nu_e\nu_\mu} \\ m_{\nu_\mu\nu_e} & m_{\nu_\mu} \end{pmatrix}\begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix}, \quad (1)$$

which is diagonalized by rotation through the angle θ and then this Lagrangian (1) transforms into the following one (see Ref. [4]):

$$\mathcal{L}_M = -\frac{1}{2}\left[m_1\bar{\nu}_1\nu_1 + m_2\bar{\nu}_2\nu_2\right], \quad (2)$$

where

$$m_{1,2} = \frac{1}{2}\left[(m_{\nu_e} + m_{\nu_\mu}) \pm \left((m_{\nu_e} - m_{\nu_\mu})^2 + 4m^2_{\nu_\mu\nu_e}\right)^{1/2}\right],$$

and angle θ is determined by the following expression:

$$\tan 2\theta = \frac{2m_{\nu_e\nu_\mu}}{(m_{\nu_\mu} - m_{\nu_e})}, \quad (3)$$

$$\nu_e = \cos\theta\nu_1 + \sin\theta\nu_2, \quad \nu_\mu = -\sin\theta\nu_1 + \cos\theta\nu_2. \quad (4)$$

From Eq. (3) one can see that if $m_{\nu_e} = m_{\nu_\mu}$, then the mixing angle is equal to $\pi/4$ independently of the value of $m_{\nu_e\nu_\mu}$.

The expression for time evolution of ν_1, ν_2 neutrinos (see (2), (4)) with masses m_1 and m_2 is

$$\nu_1(t) = \mathrm{e}^{-iE_1 t}\nu_1(0), \qquad \nu_2(t) = \mathrm{e}^{-iE_2 t}\nu_2(0), \quad (5)$$

where

$$E_k^2 = (p^2 + m_k^2), \quad k = 1, 2.$$

If neutrinos are propagating without interactions, then

$$\begin{aligned}\nu_e(t) &= \cos\,\theta\,\mathrm{e}^{-iE_1t}\nu_1(0) + \sin\,\theta\,\mathrm{e}^{-iE_2t}\nu_2(0),\\ \nu_\mu(t) &= -\sin\,\theta\,\mathrm{e}^{-iE_1t}\nu_1(0) + \cos\,\theta\,\mathrm{e}^{-iE_2t}\nu_2(0).\end{aligned} \tag{6}$$

Using the expression for ν_1 and ν_2 from (5), and putting it into (6), one can get the following expression:

$$\nu_e(t) = \left[\mathrm{e}^{-iE_1t}\cos^2\theta + \mathrm{e}^{-iE_2t}\sin^2\theta\right]\nu_e(0) + \left[\mathrm{e}^{-iE_1t} - \mathrm{e}^{-iE_2t}\right]\sin\theta\cos\,\theta\nu_\mu(0),$$

$$\nu_\mu(t) = \left[\mathrm{e}^{-iE_1t}\sin^2\theta + \mathrm{e}^{-iE_2t}\cos^2\theta\right]\nu_\mu(0) + \left[\mathrm{e}^{-iE_1t} - \mathrm{e}^{-iE_2t}\right]\sin\theta\cos\,\theta\nu_e(0). \tag{7}$$

The probability that neutrino ν_e produced at the time $t = 0$ will be transformed into ν_μ at the time t is an absolute value of amplitude $\nu_\mu(0)$ in (7) squared, i.e.,

$$P(\nu_e \to \nu_\mu) = \mid (\nu_\mu(0)\cdot\nu_e(t))\mid^2 = \frac{1}{2}\sin^2 2\theta\left[1 - \cos\left((m_2^2 - m_1^2)/2p)t\right],\tag{8}$$

where it is supposed that $p \gg m_1, m_2; E_k \simeq p + m_k^2/2p$.

Besides, since ν_e, ν_μ, ν_τ neutrinos are superpositions of ν_1, ν_2, ν_3, the ν_e, ν_μ, ν_τ neutrinos are wave packets having widths. Then, these ν_e, ν_μ, ν_τ states (neutrinos) are unstable ones and must decompose for the time Δt which is determined by the uncertainty relation [5, 6],

$$\Delta t \sim \frac{L_{\text{cohe}}}{c}, \tag{9}$$

$$L_{\text{cohe}} \cong \frac{4E_\nu^2\Delta x}{\Delta m^2},$$

where L_{cohe} is coherence length on neutrino; c is the light velocity; Δx is the size of the object, where the physically observed neutrino is produced; Δm^2 is squared neutrino mass differences ($\Delta m^2 \to m_{\nu_2}^2 - m_{\nu_1}^2$ or $m_{\nu_3}^2 - m_{\nu_1}^2$).

2. REMARKS TO THE STANDARD THEORY OF NEUTRINO OSCILLATIONS

Now it is necessary to check: is it possible to prove main suppositions of the standard theory of neutrino oscillations within the framework of the quantum field theory (or the particle physics theory)?

1. *The mass eigenstates are ν_1, ν_2, ν_3 neutrino states, but not physically observed neutrino states ν_e, ν_μ, ν_τ. And then the neutrinos ν_e, ν_μ, ν_τ are directly produced as superpositions of the ν_1, ν_2, ν_3 states (neutrinos).*

This supposition violates the causality principle since at productions of ν_e, ν_μ, ν_τ neutrinos they already know that they must be superpositions of the ν_1, ν_2, ν_3 neutrinos.

One of the basic positions of the quantum field theory (or the particle physics theory) [5, 7] is that particles must be produced in eigenstates, i.e., particles are produced in states with a diagonal mass matrix. For example, we have two interactions: interaction with the lepton number conservations (interaction with W, Z exchanges) and interaction with the lepton number violations (hypothetical interaction which is described by the nondiagonal terms of the Cabibbo–Kobayashi–Maskawa matrices). What states will be produced? It is clear that in the first case the ν_e, ν_μ, ν_τ neutrinos will be produced and in the second case the ν_1, ν_2, ν_3 neutrinos will be produced since they are eigenstates of the interactions which violate lepton numbers. Why are the ν_e, ν_μ, ν_τ neutrinos produced, but we do not observe ν_1, ν_2, ν_3 neutrino productions? Within the framework of the quantum field theory (or the particle physics theory) it is possible only if the interaction with lepton number violations has time to produce the ν_1, ν_2, ν_3 neutrinos, i.e., we do not observe productions of these neutrinos since the probabilities of their productions are very small [8]. Then, after productions of the ν_e, ν_μ, ν_τ neutrinos, since we cannot switch off the weak interaction which violated the lepton numbers, they will be transformed into superpositions of the ν_1, ν_2, ν_3 neutrinos. So, one can see that within the framework of the quantum field theory (or the particle physics theory) there is no possibility for direct production of particles in superposition states.

The same situation takes place in the hadron case, when in the strong interactions (where strangeness is conserved) $K^0, \bar{K}^0$ mesons (eigenstates) are produced. And then by the weak interactions (where strangeness is violated) they are transformed to superpositions of the K_1^0, K_2^0 mesons (eigenstates of the weak interactions) and then oscillations take place [8, 9].

Now let us discuss other consequences of the standard theory of neutrino oscillations.

2. *Since the ν_e, ν_μ, ν_τ neutrinos are directly produced as superpositions of the ν_1, ν_2, ν_3 neutrinos (their mass matrix is nondiagonal), they cannot have definite masses. Only ν_1, ν_2, ν_3 neutrinos have definite masses.*

As a consequence of these suppositions, we cannot formulate the law of energy-momentum conservation in a strict form in the processes with participation of these neutrinos (i.e., ν_e, ν_μ, ν_τ).

And it is also supposed that oscillations between the ν_e, ν_μ, ν_τ neutrinos are real oscillations.

However, computation with (1)–(4) has shown that ν_e, ν_μ masses are

$$\begin{aligned} m_{\nu_e} &= m_1 \cos^2\theta + m_2 \sin^2\theta, \\ m_{\nu_\mu} &= m_1 \sin^2\theta + m_2 \cos^2\theta, \end{aligned} \tag{10}$$

i.e., the ν_e, ν_μ neutrinos have definite masses, which are expressed via the ν_1, ν_2 masses and the mixing angle θ. It means that the supposition that the ν_e, ν_μ neutrinos have no definite masses is not confirmed. Then, if neutrino oscillations are real oscillations, i.e., there is a real transition of the electron neutrino ν_e into the muon neutrino ν_μ (or tau neutrino-ν_τ), the neutrino $x = \mu, \tau$ will decay to an electron neutrino plus something:

$$\nu_x \to \nu_e + \ldots \tag{11}$$

As a result, we can get energy from vacuum, which is equal to the mass difference (if $m_{\nu_x} > m_{\nu_e}$)

$$\Delta E \sim m_{\nu_x} - m_{\nu_e}. \tag{12}$$

Then, again, this electron neutrino is converted into the muon neutrino, which decays again and we get energy, etc. *So, we have got a perpetuum mobile!* Obviously, the law of energy and momentum conservation in these processes is not fulfilled.

It is necessary to stress that these suppositions are in contradiction with the fundamental demand of the particle physics theory that the particles must have definite masses and the law of energy-momentum conservation must be fulfilled in processes.

3. *The ν_e, ν_μ, ν_τ neutrinos are superpositions of the ν_1, ν_2, ν_3 neutrinos and they are produced as wave packets and must decompose, i.e., at distances L when*

$$L > L_{\rm cohe}, \tag{13}$$

from the point of their productions the wave packets decompose to components and neutrino oscillations will be absent.

Then, we must see ν_1, ν_2, ν_3 neutrino states, but not the states of ν_e, ν_μ, ν_τ neutrinos. Neutrinos are elementary particles. Within the framework of the elementary particle theory the particles are produced as individual eigenstates of the corresponding interaction. We can construct a wave packet as superposition of individual particles having a definite width only after their productions, but we cannot produce a wave packet as an elementary particle within the framework of the quantum field theory (or the elementary particle theory).

It also means that the Solar neutrinos cannot reach the Earth as ν_e, ν_μ, ν_τ neutrino states.

$$L_{\rm cohe} \sim \frac{4E_\nu^2 \Delta x}{\Delta m^2} = 2.2 \cdot 10^6 \,{\rm cm}, \tag{14}$$

where $E = 7$ MeV, $\Delta m^2 = 8.9 \cdot 10^{-5}\,{\rm eV}^2$, $\Delta x = 10^{-12}$ cm (the neutrinos are produced inside the nucleus). However, in experiments [10, 11] we see, namely, ν_e, ν_μ, ν_τ neutrino states, but not ν_1, ν_2, ν_3 neutrino states.

Without any doubt this standard theory requires a correction in order to get rid of the above-mentioned defects. Below, we come to construction of a corrected scheme within the framework of the quantum field theory (or the particle physics theory).

3. ALTERNATIVE SCHEME OF NEUTRINO OSCILLATIONS

In the framework of the particle physics theory (or the quantum field theory) [7] all particles are stable ones or if they have widths, then they must decay in the states (particles) with small masses. It is a requirement, which must be fulfilled in the framework of particle physics theory. If particles are wave packets, then these wave packets will decompose and we cannot obtain stable long-life particles.

The only way to restore the law of energy-momentum conservation in processes of neutrino oscillations is to work in the framework of particle physics (or the quantum field theory). Then, these oscillations will be virtual if neutrinos have different masses and these oscillations will proceed in the framework of the uncertainty relations.

So, the correct theory of neutrino oscillations can be constructed only into the framework of the particle physics theory, where the conception of mass shell is present [7, 9, 12]. Besides, every particle must be produced on its mass shell and it will be left on its mass shell while passing through vacuum.

In the considered scheme of neutrino oscillations, constructed in the framework of the particle physics theory, it is supposed (according to the experiments) that:

1) The physical observable neutrino states ν_e, ν_μ, ν_τ are eigenstates of the weak interaction with W, Z^0 exchanges. And, naturally, the mass matrix of ν_e, ν_μ, ν_τ neutrinos is diagonal, i.e., the mass matrix of ν_e, ν_μ and ν_μ neutrinos has the following diagonal form (since these

neutrinos are produced in the weak interactions, it means that they are eigenstates of these interactions and their mass matrix must be diagonal):

$$\begin{pmatrix} m_{\nu_e} & 0 & 0 \\ 0 & m_{\nu_\mu} & 0 \\ 0 & 0 & m_{\nu_\tau} \end{pmatrix}. \tag{15}$$

Besides, all the available experimental results indicate that the lepton numbers l_e, l_μ, l_τ are well conserved, i.e., the standard weak interactions (with W, Z^0 bosons) do not violate the lepton numbers.

2) Then, to violate the lepton numbers, it is necessary to introduce an interaction violating these numbers. It is equivalent to introducing of the nondiagonal mass terms in the mass matrix of ν_e, ν_μ, ν_τ neutrinos:

$$M(\nu_e, \nu_\mu, \nu_\tau) = \begin{pmatrix} m_{\nu_e} & m_{\nu_e\nu_\mu} & m_{\nu_e\nu_\tau} \\ m_{\nu_\mu\nu_e} & m_{\nu_\mu} & m_{\nu_\mu\nu_\tau} \\ m_{\nu_\tau\nu_e} & m_{\nu_\tau\nu_\mu} & m_{\nu_\tau} \end{pmatrix}. \tag{16}$$

Diagonalizing this matrix [4]

$$M(\nu_e, \nu_\mu, \nu_\tau) = V^{-1} M(\nu_1, \nu_2, \nu_2) V, \tag{17}$$

we go to the ν_1, ν_2, ν_3 neutrino mass matrix

$$\begin{pmatrix} m_{\nu_1} & 0 & 0 \\ 0 & m_{\nu_2} & 0 \\ 0 & 0 & m_{\nu_3} \end{pmatrix}, \tag{18}$$

where V is neutrino mixings matrix V. Then, the vector state $\Psi(\nu_e, \nu_\mu, \nu_\tau)$ of ν_e, ν_μ, ν_τ neutrinos

$$\Psi(\nu_e, \nu_\mu, \nu_\tau) = \begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} \tag{19}$$

is transformed into the vector state $\Psi(\nu_1, \nu_2, \nu_2)$ of ν_1, ν_2, ν_2 neutrinos

$$\Psi(\nu_e, \nu_\mu, \nu_\tau) = V \Psi(\nu_1, \nu_2, \nu_2), \tag{20}$$

i.e., ν_e, ν_μ, ν_τ neutrinos are transformed into superpositions of ν_1, ν_2, ν_2 neutrinos.

We can choose parameterization of this matrix V in the form proposed by Maiani [13], then

$$V = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_\gamma & s_\gamma \\ 0 & -s_\gamma & c_\gamma \end{pmatrix} \begin{pmatrix} c_\beta & 0 & s_\beta \exp(-i\delta) \\ 0 & 1 & 0 \\ -s_\beta \exp(i\delta) & 0 & c_\beta \end{pmatrix} \begin{pmatrix} c_\theta & s_\theta & 0 \\ -s_\theta & c_\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}, \tag{21}$$

where θ, β, γ and δ are angles of neutrino mixings and parameter of CP violation.

Exactly like the case of K^0 mesons produced in strong interactions, when mainly $K^0, \bar{K}^0$ mesons are produced, but not K_1, K_2 mesons. In the considered case, ν_e, ν_μ, ν_τ, but not

ν_1, ν_2, ν_3 neutrino states, are mainly produced in the weak interactions (this is so since the contribution of the lepton numbers violating interactions to this process is too small).

3) Then, when the ν_e, ν_μ, ν_τ neutrinos are passing through vacuum, they will be converted into superpositions of the ν_1, ν_2, ν_3 owing to the presence of the interactions violating the lepton number of neutrinos and will be left on their mass shells. And, then, oscillations of the ν_e, ν_μ, ν_τ neutrinos will take place according to the standard scheme [4]. In the case of two neutrino oscillations, we will obtain expressions equivalent to expressions (1)–(8), and for the case of three neutrino oscillations, the common expression was given in [14] for V in all possible cases.

Whether these oscillations are real or virtual, it will be determined by the masses of the physically observed neutrinos ν_e, ν_μ, ν_τ.

i) If the masses of the ν_e, ν_μ, ν_τ neutrinos are equal, then the real oscillation of the neutrinos will take place.

ii) If the masses of the ν_e, ν_μ, ν_τ are not equal, then the virtual oscillation of the neutrinos will take place (the time of neutrino transitions will be defined by uncertainty relation). To make these neutrinos real, these neutrinos must participate in the quasielastic interactions, in order to undergo transition to the mass shell of the other appropriate neutrinos in analogy with $\gamma - \rho^0$ transition in the vector meson dominance model [18]. It is necessary to take into account that in contrast to the strong interactions, the dependence on squared transferring momentum in the weak interactions has a flat form since W boson has a huge mass. It means that at weak interactions of oscillating neutrinos in matter (detector) they transit on their mass shell and there an additional dependence of squared transferring momentum does not appear. In case ii) enhancement of neutrino oscillations will take place if the mixing angle is small at neutrinos passing through a bulk of matter [15].

So, the neutrino mixings (oscillations) appear due to the fact that at neutrino creating the eigenstates of the weak interactions the ν_e, ν_μ, ν_τ neutrino states are produced, but not the eigenstates of the weak interaction violating lepton numbers (i.e., ν_1, ν_2, ν_3 neutrino states). And then, when neutrinos are passing through vacuum, they are converted into superpositions of ν_1, ν_2, ν_3 neutrinos and through these intermediate states they are converted from one type into the other type. If ν_1, ν_2, ν_3 neutrinos were originally produced, then the mixings (oscillations) would not have taken place since in the weak interaction, where ν_e, ν_μ, ν_τ neutrinos are produced, the lepton numbers are conserved.

In the case of three neutrino types the probability of $\nu_e \to \nu_e$ transitions has the following form [14]:

$$\begin{aligned} P(\nu_e \to \nu_e, t) = 1 - \cos^4(\beta)\sin^2(2\theta)\sin^2(t(E_1 - E_2)/2) - \\ - \cos^2(\theta)\sin^2(2\beta)\sin^2(t(E_1 - E_3)/2) - \sin^2(\theta)\sin^2(2\beta)\sin^2(t(E_2 - E_3)/2), \end{aligned} \quad (22)$$

where E_1, E_2, E_3 are energies of $\nu_1, \nu_2, \nu_3 \to x$ neutrinos and $E_x = \sqrt{p^2 + m_x^2}$.

Since lengths of neutrino oscillations

$$L_{i,j} = 2\pi \frac{p}{| m_i^2 - m_j^2 |}, \quad i \neq j = 1, 2, 3, \quad (23)$$

are different, the expression of probability for neutrino oscillations at small distances has a simpler form. For example, for $\nu_e \to \nu_e$ oscillations we have

$$P(\nu_e \to \nu_e) = 1 - \sin^2 2\theta \, \sin^2((m_2^2 - m_1^2)/4p)t, \tag{24}$$

where

$$\sin^2 \theta = 1/2 - \frac{(m_{\nu_e} - m_{\nu_\mu})}{2\sqrt{(m_{\nu_e} - m_{\nu_\mu})^2 + (2m_{\nu_e\nu_\mu})^2}}, \tag{25}$$

and

$$\sin^2 2\theta = \frac{(2m_{\nu_e\nu_\mu})^2}{(m_{\nu_e} - m_{\nu_\mu})^2 + (2m_{\nu_e\nu_\mu})^2}. \tag{26}$$

It is interesting to remark that expression (26) can be obtained from the Breit–Wigner distribution [16]

$$P \sim \frac{(\Gamma/2)^2}{(E - E_0)^2 + (\Gamma/2)^2} \tag{27}$$

by using the following substitutions:

$$E = m_{\nu_e}, \;\; E_0 = m_{\nu_\mu}, \;\; \Gamma/2 = 2m_{\nu_e,\nu_\mu}, \tag{28}$$

where $\Gamma/2 \equiv W(\ldots)$ is a width of $\nu_e \leftrightarrow \nu_\mu$ transitions, i.e., virtual neutrino oscillations keep in within the uncertainty relation. Then, we can interpret nondiagonal mass terms as widths of neutrino transitions. In the general case, these widths can be computed by using a standard method [12, 17].

If m_{ν_e,ν_μ} differs from zero, then Eq. (26) gives a probability of $\nu_e \leftrightarrow \nu_\mu$ transitions and then the probability of $\nu_e \leftrightarrow \nu_\mu$ transitions is defined by these neutrino masses and the width (nondiagonal mass term) of their transitions. If $m_{\nu_e,\nu_\mu} = 0$, then the $\nu_e \leftrightarrow \nu_\mu$ transitions are forbidden. So, this is a solution of the problem of the origin of the mixing angle in the theory of vacuum oscillations in the scheme of mass mixings.

It is necessary to remark that in this corrected (alternative) scheme of neutrino oscillations, in contrast to the standard theory, oscillations of neutrinos with equal masses are the real ones and oscillations of neutrinos with different masses are the virtual ones and then the problem of energy momentum conservation as well as the problem of neutrino disintegrations as wave packets, are solved.

In the above-considered scheme of neutrino oscillations at neutrino oscillations their masses change (for example, $m_{\nu_e} \to m_{\nu_\mu}$). Theoretically, neutrino transitions without changing of their masses are also possible [12, 17]. In this case, the mixing angles are maximal ($\pi/4$). The author proposed another mechanism (model) of neutrino transitions, which is generated by charge (couple constant) mixings, analogous to the model of vector dominance, i.e., the model of $\gamma \to \rho^0$ transitions [18].

CONCLUSIONS

So, in the standard theory of neutrino oscillations the ν_e, ν_μ, ν_τ neutrinos are directly produced as superpositions of the ν_1, ν_2, ν_3 states (neutrinos). Since the ν_e, ν_μ, ν_τ neutrinos are directly produced as superpositions of the ν_1, ν_2, ν_3 neutrinos they cannot have definite masses. Then, the law of energy and momentum conservation cannot be fulfilled and these neutrinos cannot decay. Neutrino oscillations are real and since ν_e, ν_μ, ν_τ neutrinos are produced as wave packets they must decompose on components at definite distances from the point of their productions and then neutrino oscillations will be absent.

In the alternative scheme of neutrino oscillations constructed in the framework of particle physics the above-mentioned shortcomings are absent: the ν_e, ν_μ, ν_τ neutrino states are produced as eigenstates of the standard weak interactions and they have definite masses, then the law of energy and momentum conservation is fulfilled and they can decay. Then, for presence of interaction, which violates lepton numbers, these neutrinos are transformed in superpositions of their eigenstates (i.e., superpositions of ν_1, ν_2, ν_3 neutrino states). Then, oscillations of neutrinos with equal masses are the real ones, and the oscillations of neutrinos with different masses are the virtual ones. Since oscillations of neutrinos with different masses are virtual, then neutrinos as wave packets cannot decompose on components at a definite distance and the neutrino oscillations cannot disappear.

Expressions for probabilities of neutrino transitions (oscillations) in the alternative (corrected) scheme have been given.

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