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SOME REMARKS TO THE STANDARD MODEL OF ELECTROWEAK INTERACTIONS. ABSENCE OF POLARIZATION, I. E., CHARGE RENORMALIZATION AND MASS GENERATIONS

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1 Introduction

At present there are three families of quarks and leptons [1]:

$$\begin{matrix} u & \nu_e \\ d & e \end{matrix}; \qquad \begin{matrix} c & \nu_\mu \\ s & \nu \end{matrix}; \qquad \begin{matrix} t & \nu_\tau \\ b & \tau \end{matrix}. \tag{2.1}$$

It is supposed that all available experimental data agree well with the standard model of the electroweak interaction [2] proposed by Glashow, Weinberg, and Salam for three quark and lepton families. In the framework of electroweak interactions, i.e., at W- and Z- boson exchanges the transitions between different families do not take place. These transitions are realized beyond the electroweak interactions [1].

In the weak interactions P-parity is violated, in contrast to the electromagnetic and strong interactions. It is a distinctive feature of the weak interactions that leads to some consequences. At first, we give elements of the electroweak model and then come to consideration of concrete remarks concerning these consequences.

2 Elements of the Standard Model of Electroweak Interactions and Some Remarks to This Model

Consider elements of the electroweak interactions model and concrete remarks.

2.1. Elements of the Standard Model of Electroweak Interactions

The Lagrangian of the theory contains left and right doublets of leptons and quarks,

$$\Psi_{lL} = \begin{pmatrix} \nu_l \\ l \end{pmatrix}_L, \Psi_{lR}, l = e, \mu, \tau;$$

$$\begin{matrix} & i=1 & & i=2 & & i=3 & \end{matrix}$$

$$\Psi_{iL} = \begin{pmatrix} u \\ d \end{pmatrix}_L, \begin{pmatrix} c \\ s \end{pmatrix}_L, \begin{pmatrix} t \\ b \end{pmatrix}_L, \tag{2.2}$$

and right singlets of charged leptons and quarks:

$$\Psi_{iR} = u_R, d_R; \qquad c_R, s_R; \qquad t_R, b_R.$$

The theory is based on the local group $SU(2) \times U(1)$ and contains two coupling constants g, g'. The covariant derivatives have the following form:

$$\begin{aligned}
\partial_\alpha \Psi_{lL} \to D_\alpha \Psi_{lL} = \left[\partial_\alpha - ig\frac{\tau^i}{2}A^i_\alpha - ig'\Upsilon^{lept} B_\alpha\right] \Psi_{lL}, \\
\partial_\alpha \Psi_{iL} \to \left[\partial_\alpha - ig\frac{\tau^i}{2}A^i_\alpha - ig'\Upsilon^{quark} B_\alpha\right] \Psi_{iL}, \\
\partial_\alpha \Psi_{lR} \to \left[\partial_\alpha - i\frac{g'}{2}\Upsilon^{lept} B_\alpha\right] \Psi_{lR}, \\
\partial_\alpha \Psi_{iR} \to \left[\partial_\alpha - i\frac{g'}{2}\Upsilon^{quark} B_\alpha\right] \Psi_{iR},
\end{aligned} \tag{2.3}$$

where A^i_α, B_α are the gauge fields associated with the groups $SU(2)_L$ and $U(1)$; Υ is a hypercharge of the leptons and quarks.

The analog of the Gell-Mann-Nishijima relation in the considered case is

$$Q = T^W_3 + \frac{\Upsilon}{2},$$

where Q is the electric charge, and T^W_3 is the third projection of the weak isospin.

For the lepton and quark hypercharges, we obtain the following expressions using (2.3)

$$\begin{aligned}
\Upsilon^{lept}_L = -1, \qquad \Upsilon^{quark}_L = \frac{1}{3}, \\
\Upsilon^{lept}_R = -2, \qquad \Upsilon^{quark}_R = 2e_q,
\end{aligned} \tag{2.4}$$

where e_q is the electrical charge of the corresponding quarks.

Using the standard scheme, we can pass from (2.2) and (2.4) to the following expression for the interaction Lagrangian:

$$\mathcal{L}_I = igj^{K,\alpha}A^K_\alpha + ig'\frac{1}{2}j^{\Upsilon,\alpha}B_\alpha, \tag{2.5}$$

where

$$j^{K,\alpha} = \sum_{i=1}^{3}\bar{\Psi}_{i,L}\gamma^\alpha\frac{\tau^K}{2}\Psi_{l,L}+$$
$$\sum_{l=e,\mu,\tau}\bar{\Psi}_{l,L}\gamma^\alpha\frac{\tau^K}{2}\Psi_{l,L}, \tag{2.6}$$

and

$$\frac{1}{2}j^{\Upsilon,\alpha} = j^{em,\alpha} - j^{3,\alpha}, \tag{2.7}$$

($j^{em,\alpha}$ are electromagnetic current of the quarks and leptons).

On the transition from the fields A^3_α, B_α to the fields Z_α, A_α

$$Z_\alpha = A^3_\alpha\cos\theta_W - B_\alpha\sin\theta_W, \tag{2.8}$$

$$A_\alpha = A^3_\alpha\sin\theta_W + B_\alpha\cos\theta_W,$$

the interaction Lagrangian for the fields Z_α, A_α acquires the following form:

$$\mathcal{L}^o_I = i\frac{g}{2\cos\theta_W}j^{o,\alpha}Z_\alpha + iej^{em,\alpha}A_\alpha, \tag{2.9}$$

where $j^{o,\alpha} = 2j^{3,\alpha} - 2\sin^2\theta_W j^{em,\alpha}$ - neutral current of the standard model.

Note that the Lagrangians (2.5) and (2.9) are obtained for Dirac (particles) leptons and quarks with charges g, g' or e, g using the principle of local gauge invariance. If $SU(2)_L \times U(1)$ gauge invariance is required, the masses of all the particles must be equal to zero (i.e., in this theory particles cannot have masses [3, 4, 5]). To obtain masses of the particles, the standard theory of the electroweak interaction, based on the assumption of $SU(2)_L \times U(1)$ gauge invariance, is broken spontaneously down to $U(1)$ through the Higgs mechanism [6]. We briefly consider this mechanism for three quark family (lepton masses can be obtained in the analogous manner).

Common remarks concerning the Standard Model are given in the conclusion part after the discussion of concrete questions.

2.2. Higgs Mechanism in the Standard Model and Remarks

2.2.1. Higgs Mechanism in the Standard Model

A doublet of scalar Higgs fields

$$\Phi = \begin{pmatrix} \Phi^{(+)} \\ \Phi^{(o)} \end{pmatrix}, \tag{2.10}$$

with hypercharge equal to unity is introduced. It is assumed that this doublet interacts with the vector and fermion fields in such a way that local gauge invariance is not broken. To the Lagrangian of the electroweak theory there we add the Higgs potential $V(\Phi^+, \Phi)$

$$V(\Phi^+, \Phi) = k(\Phi^+, \Phi)^2 - \mu^2(\Phi^+, \Phi), \tag{2.11}$$

(k, μ^2 are positive constants), which leads to vacuum degeneracy and to a nonvanishing vacuum expectation value $< \Phi^o >$ of the field Φ^o:

$$< \Phi^o >= \sqrt{\frac{\mu^2}{2k}} = \frac{\nu}{\sqrt{2}}, \qquad \nu = \sqrt{\frac{\mu^2}{k}}, \tag{2.12}$$

this means that (fixing the vacuum state) we can generate a mass term of the fields of the intermediate bosons, fermions, and Higgs boson.

In the unitary gauge by using (2.12) we can rewrite $V(\Phi)$ in the following form ($\nu^2 = \frac{\mu^2}{k}$):

$$V(\Phi) = -\frac{\mu^4}{2}(\nu + \Phi^o)^2 + \frac{k}{4}(\nu + \Phi^o)^4$$

$$= -\frac{\mu^4}{4k} + \mu^2(\Phi^o)^2 + ... = -\frac{\mu^4}{4k} + \frac{m_\Phi^2}{2}(\Phi^o)^2 + ..., \tag{2.13}$$

hence, we see that Higgs boson Φ^o has mass $m_{\Phi^o}^2 = 2\mu^2$.

The covariant derivative for Higgs fields is

$$D_\alpha \Phi = (\partial_\alpha - ig\frac{\tau^i A^i_\alpha}{2} - i\frac{g'}{2}B_\alpha)\Phi. \tag{2.14}$$

The kinetic energy term of Higgs bosons (in the unitary gauge) has the following form:

$$(D^\alpha \Phi)^+ D_\alpha \Phi = M_W^2 W^{\alpha+} W_\alpha^- + \frac{M_Z^2}{2} Z^\alpha Z_\alpha + ..., \tag{2.15}$$

where $W_\alpha^\pm = (A^1_\alpha \pm A^2_\alpha)/\sqrt{2}$, and their masses are

$$M_W^2 = g^2 \frac{\nu^2}{4}, \quad M_Z^2 = (g^2 + g'^2)\frac{\nu^2}{4}.$$

The quark masses are obtained by using a Lagrangian of Yukawa type which is $SU(2)_L \times U(1)$ invariant:

$$\mathcal{L}_1 = - \sum_{i;q=d,s,b}^{3} \bar{\Psi}_{iL} M^1_{iq} q_R \bar{\Phi} + H.C., \tag{2.16}$$

$$\mathcal{L}_2 = - \sum_{i;q=u,c,t}^{3} \bar{\Psi}_{iL} M^2_{iq} q_R \bar{\Phi} + H.C.,$$

where M^1, M^2 - complex 3×3 matrix, and $\bar{\Phi}$

$$\bar{\Phi} = i\tau_2 \Phi^* = \begin{pmatrix} \Phi^{o*} \\ -\Phi^{+*} \end{pmatrix}, \tag{2.17}$$

is a doublet of Higgs fields with hypercharge $Y = -1$.

Taking into account (2.12) and using the gauge invariance of the Lagrangian (2.13), (2.17), we can choose (in the unitary gauge)

$$\Phi(x) = \begin{pmatrix} 0 \\ \frac{\nu + \Phi^o(x)}{\sqrt{2}} \end{pmatrix}, \qquad \bar{\Phi}(x) = \begin{pmatrix} \frac{\nu + \Phi^o(x)}{\sqrt{2}} \\ 0 \end{pmatrix}, \tag{2.18}$$

where $\Phi^o(x)$ is the neutral scalar Higgs field.

Substituting (2.18) in (2.16) for the quark masses we obtain the expressions

$$\mathcal{L}_1 = -\bar{p}_L M'_1 p_R + H.C., \tag{2.19}$$

$$\mathcal{L}_2 = -\bar{n}_L M'_2 n_R + H.C.,$$

where

$$p_{L,R} = \begin{pmatrix} u_{L,R} \\ c_{L,R} \\ t_{L,R} \end{pmatrix}, \qquad n_{L,R} = \begin{pmatrix} d_{L,R} \\ s_{L,R} \\ b_{L,R} \end{pmatrix}.$$

Thus, the elements M'_1, M'_2 of the quark mass matrix are equal to the constants of the quark-Higgs-boson Yukawa coupling up to the factor ν.

2.2.2. Remarks to the Higgs Mechanism in the Electroweak Model

We know that quarks, leptons and vector bosons have their masses in every point of the Universe. Then Higgs fields must fill the Universe and since the masses are real masses, then Higgs fields must also be real (here we have an analogy with the superconductivity). If Higgs field is real, then the energy density of this field is $\rho_{Higgs} \sim 2 \cdot 10^{49} GeV/cm^3$ [6, 7] (see also references in [7]). It is a huge value. The measured energy density in the Universe is $\rho_{Univ} \sim 10^{-4} GeV/cm^3$. Then the relation of the energy density of the Higgs fields to the measured energy value is

$$\rho_{Higgs}/\rho_{Univ} \sim 10^{53}. \tag{2.20}$$

It is obvious that the Higgs mechanism must be excluded. Besides, Higgs mechanism contains a contradiction [8]. We see that the Higgs mechanism is used to construct a theory without singularity, however our aim is to construct a realistic physical theory. Then arises the question: what are mass sources? There are some arguments that mass sources must be a mechanism which is analogous to the strong interactions [9], i.e., interactions between subparticles of quarks and leptons, then the problem of singularity of the theory does not arise.

2.3. Running coupling constant in the Standard Weak Interactions and Remarks

2.3.1. Running coupling constant in the Standard Weak Interactions

It is supposed that in the electroweak model the coupling constants g, g' depend on transfer momenta [10] and the equation for $g(Q^2)$ has the following form:

$$\frac{dg^{-1}}{dlnQ^2} = \frac{1}{4\pi}\left[\frac{22}{3} - \frac{4F}{3}\right], \tag{2.21}$$

where F is family numbers ($F = 3$) (here we consider only a weak part of the electroweak model since in the electromagnetic interactions there is renormalization of the coupling constant). It means that in the weak interactions the vacuum polarization takes place as in the strong and electromagnetic interactions. It is necessary to remember that in the weak interactions in contrast to these interactions only the left components of fermion participate in the weak interactions.

If the coupling constant of the weak interaction is renormalized, then the effective masses of fermions in matter also will be changed, i.e., the standard weak interaction can generate effective masses. It means that the resonance enhancement of neutrino oscillations in matter [11] will take place at the weak interactions.

2.3.2. Remarks About the Coupling Constant of the Standard Weak Interactions

As we have stressed above, the distinctive feature of the weak interactions is violation of P-parity. Now we will consider the consequences of the distinctive feature for the coupling constant of the weak interactions.

The simplest method to prove the absence of polarization in vacuum and matter is:

If we put an electrical (or strong) charged particle in the vacuum, there arises polarization of vacuum. Since the field around the particle is spherically symmetrical, the polarization must also be spherically symmetrical. Then the particle will be left at rest and the law of energy and momentum conservation is fulfilled.

If we put a weakly interacting particle (a neutrino) in the vacuum, then, since the field around the particle has a left-right asymmetry (weak interactions are left interactions with respect to the spin direction), polarization of the vacuum must be nonsymmetrical, i.e., on the left side there arises maximal polarization and on the right side there is zero polarization. Since polarization of the vacuum is asymmetrical, there arises asymmetrical interaction of the particle (the neutrino) with vacuum and the particle cannot be at rest and will be accelerated. Then neutrino will get the energy-momentum from the vacuum and the law of energy momentum conservation will be violated. The only way to fulfil the law of energy-momentum conservation is to require that polarization of vacuum be absent at the weak interactions. The same situation will take place in matter (do not mix it up with particle acceleration at the weak interactions!) .

About a direct method for proving the absence of polarization in the weak interactions see in Section 2.5.

It is interesting to remark that in the gravitational interaction the polarization does not exist either [12].

2.4. Generation of Masses in the Standard Model and the Mechanism of Resonance Enhancement of Neutrino Oscillations in Matter and Remarks

2.4.1. Generation of Masses in the Standard Model and the Mechanism of Resonance Enhancement of Neutrino Oscillations in Matter

At present there is a number of papers published (see [13] and references there) where, by using the Green's function method, it is shown that the weak interactions can generate the resonance enhancement of neutrino oscillations in matter (it means that the weak interaction can generate masses, i.e., the energy W of matter polarization by neutrinos (or the energy of the matter response) will differ from zero, i.e. $W \neq 0$ [5, 14]). This result is a consequence of using of the weak interaction term $H_\mu^{int} = V_\mu \frac{1}{2}(1 - \gamma_5)$ in an incorrect manner, and as a result they have obtained that the right-handed components of the fermions participate in the weak interactions [15, 16].

2.4.2. Remarks to the Problem of Generation of Masses in the Standard Model and the Mechanism of Resonance Enhancement of Neutrino Oscillations in Matter

In three different approaches: by using mass Lagrangian [3, 17], the *Dirac equation* [4, 17], and the operator formalism [5, 14], I considered the problem of the mass generation in the standard weak interactions. The result was: the standard weak interaction cannot generate masses of fermions since the right-handed components of fermions do not participate in these interactions. Then using this result in works [5, 14] it has been shown that the effect of resonance enhancement of neutrino oscillations in matter cannot exist (existence of this effect means that the law of energy-momentum conservation is violated).

The experimental data on energy spectrum and day-night effect obtained in Super-Kamiokande [18] (energy spectrum of neutrinos is not distorted, day-night effect is within the experimental mistakes) and the results obtained in SNO [19] have not confirmed this effect. Besides, this effect can be realized only at the violation of the law of the energy-momentum conservation [20].

2.5. Problem of Connected (Bounded) States in the Standard Model of Weak Interactions

Now consider the problem of eigenstates and eigenvalues in the weak interactions [16]. Let $\hat{F}$ be an operator and we divide it into two parts. The first part $\hat{A}$ characterizes the free particle, and the second part $\hat{B}$ is responsible for the weak interaction, then

$$\hat{F} = \hat{A} + \hat{B},$$
$$\hat{F}\Psi = \hat{A}\Psi + \hat{B}\Psi, \tag{2.22}$$

and the mean value of $\hat{F}$ is

$$\begin{gathered}(\bar{\Psi}, \hat{F}\Psi) = (\bar{\Psi}, \hat{A}\Psi) + (\bar{\Psi}_R, \hat{B}\Psi_L) + (\bar{\Psi}_L, \hat{B}\Psi_R) = \\ (\bar{\Psi}, \hat{A}\Psi) + (\bar{\Psi}_R \equiv 0)(\bar{\Psi}_R, \hat{B}\Psi_L) + \\ +(\Psi_R \equiv 0)(\bar{\Psi}_L, \hat{B}\Psi_R) = (\bar{\Psi}, \hat{A}\Psi).\end{gathered} \tag{2.23}$$

The obtained result means that in the weak interactions there cannot arise the connected states in contrast to the strong and electromagnetic interactions.

Besides, the average of the polarization operators is equal to zero, i.e., the polarization of the matter is absent. In the same way we can show that the equation for renormcharge for the weak interaction is equivalent to the equation for the free charge, i.e. renormcharge $g(t)$ in the weak interactions (where $t = Q^2$ is a transfer momentum squared) does not change and $g(t) = const$ [21, 16] in contrast to renormcharges $\alpha(t), g_{stron}(t)$ of the electromagnetic and strong interactions [1] (it is necessary to remark that the neutral current of the weak interactions includes a left-right symmetrical part, which is renormalized).

So, at the weak interaction the connected states cannot arise, but also as in the strong and electromagnetic interactions, in the weak interactions we can use the perturbative theory but in this case the propagators must be the propagators of free particles (without renormalization).

3 Conclusion

So, we have considered some remarks to the standard approach to the weak interactions. Higgs mechanism contains contradictions, therefore, cannot be considered as a realistic mechanism of mass generations. The coupling constant of the weak interactions cannot be changed in dependence on momenta transfer (it leads to violation of the law of energy-momentum conservation), i.e. it must be constant. It means that there is no charge vacuum polarization or renormalization of the coupling constant of the weak interactions. Then it is clear that the resonance enhancement of neutrino oscillations in matter cannot exist either. Masses are not generated and bound states cannot form in these interactions since P-parity is violated. Then exactly as in the strong and electromagnetic interactions, in the weak interactions we can use the perturbative theory but in this case the propagators must be the propagators of free particles without renormalization. Probably the standard weak interactions model with W, Z exchanges is analogous to the strong interactions with π or ρ exchanges and it is necessary to find fundamental interactions which generate this picture of the weak interactions and generate masses.

It is also possible that in the weak interactions the coupling constant renormalization is absent for singularity compensations as it takes place in the supersymmetric theories [22].

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