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SCHEMES OF QUARK MIXINGS (OSCILLATIONS) AND THEIR MIXING MATRICES

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Схемы смешивания (осцилляций) кварков
и матрицы их смешивания

В работе рассматриваются три схемы смешивания (осцилляций) кварков вместе с матрицами их смешивания, аналогичными матрицам смешивания Кабиббо–Кобаяши–Маскавы. В этих схемах кварковые переходы являются виртуальными, так как массы кварков различаются (кварки рождаются в сильных взаимодействиях, а нарушение ароматических чисел, приводящее к смешиванию кварков, происходит в слабых взаимодействиях). Две из этих схем принадлежат к так называемым схемам массовых смешиваний (параметры смешивания выражаются через элементы массовой матрицы), а третья схема принадлежит к схемам зарядовых смешиваний (параметры смешивания выражаются через заряды кварков). Получены выражения для вероятностей переходов между кварками в этих схемах. Проведен анализ ситуации с осцилляциями кварков с учетом масс и параметров матрицы Кабиббо–Кобаяши–Маскавы.

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Schemes of Quark Mixings (Oscillations)
and Their Mixing Matrices

Three schemes of quark mixings (oscillations) together with their mixing matrices (analogous to Cabibbo–Kobayashi–Maskawa matrices) are considered. In these schemes, quark transitions are virtual since quark masses are different. Two of them belong to the so-called mass mixing schemes (mixing parameters are expressed by elements of mass matrices), and the third scheme belongs to the charge mixing ones (mixing parameters are expressed through charges). For these schemes the expressions for transition probabilities between d, s, b quarks are obtained. The analysis of situation with the quark mixing parameters in these schemes is fulfilled.

1. INTRODUCTION

At present, existence of three following families of leptons and quarks

$$
\begin{matrix} u & \nu_e \\ d & e \end{matrix} \; ; \quad \begin{matrix} c & \nu_\mu \\ s & \mu \end{matrix} \; ; \quad \begin{matrix} t & \nu_\tau \\ b & \tau \end{matrix} \tag{1}
$$

is established [1]. In the framework of the standard model of weak interactions [2], i.e. at W и Z^0 boson exchanges, transitions between different families of leptons or quarks do not take place. In the quark sector, mixings between d, s, b quarks (i.e. transitions between different families of quarks) are described by Cabibbo–Kobayashi–Maskawa matrices [3]. In works [4], the dynamical model of transitions between different quark families (model of dynamical analogy of Cabibbo–Kobayashi–Maskawa matrices) was proposed. In this model, these transitions are realized by exchanges of four massive ($B^\pm, C^\pm, D^\pm, E^\pm$) bosons.

We have a problem with interpretation of the angle mixings. Consider $K^\pm$, which is produced in strong interactions, and we want to consider its decay. Since K meson includes s quark, when we take into account the weak interaction, we must use the Cabibbo matrix [3] mixing s, d quarks:

$$
\begin{aligned} d_1 &= d\cos\theta + s\sin\theta, \\ s_1 &= -d\sin\theta + s\cos\theta; \end{aligned} \tag{2}
$$

i.e. s quark transforms in superpositions of s, d quarks:

$$
s \to s_1 = -d\sin\theta + s\cos\theta.
$$

The matrix element of K meson decay [3] is proportional to $\sin\theta$, i.e. we take into account only the $\sin\theta$ part from the above expression, and then the term proportional to $\cos\theta$ remains. It means that only the part proportional to $\sin\theta$ decays. However, from the current experiments we know that K mesons decay fully. It can happen only if K mesons decay through massive bosons B but not W bosons as it takes place in the model of dynamical analogy of Cabibbo–Kobayashi–Maskawa matrices [4]. In the framework of this model, the masses and transition widths of these bosons were computed and other consequences of quark mixings were also studied. In the lepton sector, the analogous transitions are realized by introductions of the same matrices [5].

It is obvious that this problem must be solved in case quark mixings (or oscillations) take place. Now consider the schemes of quark mixings (or oscillations) and in the subsequent works we will return to solution of this problem in the framework of the suggested approach.

In works [6], three schemes of neutrino mixings (oscillations) were proposed. The essential difference between quark and lepton sectors is that quarks are in combined states in hadrons while the leptons (neutrinos) are in free states. The fact that there are transitions between neutrinos in free states is an indication of the possibility that in the quark sector the same transitions between quarks will take place. Besides it is necessary to remark that existence of hadronic oscillations on examples of $K^0, \bar{K}^0$ and $B^0, \bar{B}^0$ oscillations is proven, and these oscillations are real ones since masses of K^0 and $\bar{K}^0$ (B^0 and $\bar{B}^0$) are equal. Consider quark mixings and oscillations in detail.

2. SCHEMES (TYPES) OF QUARK MIXINGS (OSCILLATIONS) AND THEIR MIXING MATRICES

In common case there can be two schemes (types) of quark mixings (oscillations): mass mixing schemes and charge mixing schemes (as it takes place in the vector dominance model or vector boson mixings in the standard model of electroweak interactions).

2.1. Two Schemes of Quark Mixings (Oscillations) and Their Mixing Matrices. In the standard approach [7], it is supposed that quarks (hadrons) are once created in superposition states, i.e. mass matrix is a nondiagonal one. If mass matrix is nondiagonal initially, then we must diagonalize this matrix in order to find eigenstates of quarks. Then eigenstates are d_1, s_1, b_1 quarks (quark mixed states), i.e. d_1, s_1, b_1 quarks but not d, s, b quarks must be created there. It is obvious that it cannot be coordinated with experimental data. In the strong and weak interactions with W and Z^0 bosons, only d, s, b quarks are created, i.e. initially mass matrix is a diagonal one, and then at violation of the aromatic numbers this matrix is transformed into nondiagonal one [6, 8]. We stress this point for its fundamental importance.

If we work in the framework of the original approach [7], then these quark transitions (oscillations) must be real transitions (oscillations), i.e. real transitions between quarks must take place there. It is clear that this supposition violates the law of energy-momentum conservation. But at $K^0 \leftrightarrow \bar{K}^0$ transitions, oscillations are real since masses of d and $\bar{d}$, s and $\bar{s}$ are equal. But at transitions between different-mass hadrons ($\pi^\pm \leftrightarrow K^\pm$), these transitions will be virtual [4, 9].

We can also see that there are two cases of quark transitions (oscillations) in the scheme of mass mixings by analogy with the neutrino transitions (oscillations) [9].

Use of the Standard Scheme of Neutrino Mixings (Oscillations) for Consideration of the Quark Mixings (Oscillations). We can use the corrected standard scheme [6] of neutrino mixings (oscillations) for consideration of the quark mixings (oscillations) since quarks as well as neutrinos are also fermions.

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The corrected standard scheme belongs to the so-called mass mixing scheme since mixing parameters are expressed through elements of mass matrix. Mass matrix of d, s quarks has the following form:

$$\begin{pmatrix} m_d & m_{ds} \\ m_{sd} & m_s \end{pmatrix},$$

$$d = \cos\theta d_1 - \sin\theta s_1,$$
$$s = \sin\theta d_1 + \cos\theta s_1.$$

In this case, the probability of $d \to s$ transition (oscillation) is described by the following expression (for simplification we consider d, s quark mixings):

$$P(d \to s, t) = \sin^2 2\theta \sin^2 \left[\pi t \frac{\mid m_{d_1}^2 - m_{s_1}^2 \mid}{2p_d} \right],$$

where p_d is a momentum of d quark,

$$sin^2 2\theta = \frac{4m_{d,s}^2}{(m_d - m_s)^2 + 4m_{d,s}^2},$$

and

$$m_{d_1, s_1} = \frac{1}{2} \left[(m_d + m_s) \pm \left((m_d - m_s)^2 + 4m_{ds}^2 \right)^{1/2} \right].$$

At these transitions (oscillations), quarks remain on their mass shell and these transitions (oscillations) must be virtual.

It is interesting to remark that expression (5) can be obtained from the Breit–Wigner distribution [11]

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

by using the following substitutions:

$$E = m_d, \quad E_0 = m_s, \quad \Gamma/2 = 2m_{d,s},$$

where $\Gamma/2 \equiv W(...)$ is a width of $d \to s$ transition, then we can use a standard method [10, 12] for calculating this value. Then the probability of $d \to s$ transitions is defined by these quark masses and widths of their transitions.

Expression for length of these oscillations has the following form:

$$L_o = 2\pi \frac{2p_d}{\mid m_{s_1}^2 - m_{d_1}^2 \mid}.$$

Above, we considered the case of two quark transitions (oscillations). In common case, we must consider three quark transitions (oscillations). For a complete description of three quark oscillations we must have six parameters (we suppose that this mass matrix is symmetric in respect to the diagonal one),

$$
\begin{pmatrix}
m_d & m_{ds} & m_{db} \\
m_{sd} & m_s & m_{sb} \\
m_{db} & m_{sb} & m_b
\end{pmatrix},
\tag{10}
$$

three diagonal terms of this matrix are masses of three physical quarks m_d, m_s, m_b, and three nondiagonal mass terms of this matrix are m_{ds}, m_{db}, m_{sb}-quarks transition widths. Since in the expression for quark transition probabilities the squared mass differences are used in reality, we need only five parameters (for further simplification, physical quark masses are used). Besides, if mass matrix is complex, there appears one parameter connected with CP violation.

These mixing angles can be connected with the Cabibbo–Kobayashi–Maskawa mixing matrix V [3]. We will choose a parameterization of the mixing matrix V in the form proposed by Maiani [13]:

$$
V = \begin{pmatrix}
1 & 0 & 0 \\
0 & c_\gamma & s_\gamma \\
0 & -s_\gamma & c_\gamma
\end{pmatrix}
\begin{pmatrix}
c_\beta & 0 & s_\beta \exp(-i\delta) \\
0 & 1 & 0 \\
-s_\beta \exp(i\delta) & 0 & c_\beta
\end{pmatrix}
\begin{pmatrix}
c_\theta & s_\theta & 0 \\
-s_\theta & c_\theta & 0 \\
0 & 0 & 1
\end{pmatrix},
\tag{11}
$$

$$
\begin{aligned}
c_{ds} &= \cos\theta, & s_{ds} &= \sin\theta, & c_{ds}^2 + s_{ds}^2 &= 1; \\
c_{db} &= \cos\beta, & s_{db} &= \sin\beta, & c_{db}^2 + s_{db}^2 &= 1; \\
c_{sb} &= \cos\gamma, & s_{sb} &= \sin\gamma, & c_{sb}^2 + s_{sb}^2 &= 1;
\end{aligned}
\tag{12}
$$

$$
\exp(i\delta) = \cos\delta + i\sin\delta.
$$

In our approximation, the value of δ can be considered equal to zero.

Equations for mixing angles expressed through elements of mass matrix has the following form:

$$
s_{ds} = \sin\theta = \frac{1}{\sqrt{2}}\left[1 - \frac{|m_s - m_d|}{\sqrt{(m_s - m_d)^2 + (2m_{ds})^2}}\right],
\tag{13}
$$

$c_{ds}^2 = 1 - s_{ds}^2;$

$$
s_{db} = \sin\beta = \frac{1}{\sqrt{2}}\left[1 - \frac{|m_b - m_d|}{\sqrt{(m_b - m_d)^2 + (2m_{db})^2}}\right],
\tag{14}
$$

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$$c_{db}^2 = 1 - s_{db}^2;$$

$$s_{sb} = \sin\gamma = \frac{1}{\sqrt{2}}\left[1 - \frac{\mid m_b - m_s \mid}{\sqrt{(m_b - m_s)^2 + (2m_{sb})^2}}\right], \tag{15}$$

$$c_{sb}^2 = 1 - s_{sb}^2.$$

Analysis of Status of Quark Mixing Parameters in the Scheme of Mass Mixings. With this aim we use the following data on mixing angles obtained in the framework of Cabibbo–Kobayashi–Maskawa matrices [1]:

$$
\begin{aligned}
&1) \quad \mathrm{tg}\,\theta \cong \sin\theta = 0.218 \div 0.224;\\
&2) \quad \mathrm{tg}\,\beta \cong \sin\beta = 0.032 \div 0.054;\\
&3) \quad \mathrm{tg}\,\gamma \cong \sin\gamma = 0.002 \div 0.007.
\end{aligned}
\tag{16}
$$

Expressions for squared mass differences and their expansions have the following form $(d_1 \to 1, s_1 \to 2, b_1 \to 3)$:

$$\Delta m_{21}^2 = m_2^2 - m_1^2 = (m_s + m_d)\sqrt{(m_s - m_d)^2 + (2m_{ds})^2}, \tag{17}$$

if $2m_{ds} \gg \mid m_s - m_d \mid$, then

$$\Delta m_{21}^2 = (m_s + m_d)2m_{ds}\left[1 + \frac{(m_s - m_d)^2}{2(2m_{ds})^2}\right], \tag{17$'$}$$

and if $2m_{ds} \ll \mid m_s - m_d \mid$, then

$$\Delta m_{21}^2 = (m_s^2 - m_d^2)\left[1 + \frac{(2m_{ds})^2}{2(m_s - m_d)^2}\right]; \tag{17$''$}$$

$$\Delta m_{31}^2 = m_3^2 - m_1^2 = (m_b + m_d)\sqrt{(m_b - m_d)^2 + (2m_{db})^2}, \tag{18}$$

if $2m_{db} \gg \mid m_b - m_d \mid$, then

$$\Delta m_{31}^2 = (m_b + m_d)2m_{db}\left[1 + \frac{(m_b - m_d)^2}{2(2m_{db})^2}\right], \tag{18$'$}$$

and if $2m_{db} \ll \mid m_b - m_d \mid$, then

$$\Delta m_{31}^2 = (m_b^2 - m_d^2)\left[1 + \frac{(2m_{db})^2}{2(m_b - m_d)^2}\right]; \tag{18$''$}$$

$$\Delta m_{32}^2 = m_3^2 - m_2^2 = (m_b + m_s)\sqrt{(m_b - m_s)^2 + (2m_{sb})^2}, \tag{19}$$

if $2m_{sb} \gg | m_b - m_s |$, then

$$\Delta m_{32}^2 = (m_b + m_s)2m_{sb} \left[1 + \frac{(m_b - m_s)^2}{2(2m_{sb})^2}\right], \qquad (19')$$

and if $2m_{sb} \ll | m_b - m_s |$, then

$$\Delta m_{32}^2 = (m_b^2 - m_s^2) \left[1 + \frac{(2m_{sb})^2}{2(m_b - m_{\nu_m u})^2}\right]. \qquad (19'')$$

The current masses of d, s, b quarks are [1]:

$$m_d \simeq 3 \div 9 \,\mathrm{MeV},$$

$$m_s \simeq 60 \div 170 \,\mathrm{MeV}, \qquad (20)$$

$$m_b \simeq 4.0 \div 4.5 \,\mathrm{GeV}.$$

Now using values of these masses we turn to consideration of the situation with quark mixings (oscillations).

For d, s quarks we have (by diagonalization of mass matrix)

$$\sin 2\theta = \frac{2m_{ds}}{\sqrt{(m_d - m_s)^2 + 4m_{ds}^2}},$$

$$\mathrm{tg}\, 2\theta = \frac{2m_{ds}}{| m_d - m_s |}, \qquad (21)$$

$$\begin{aligned} d_1 &= d\cos\theta + s\sin\theta, \\ s_1 &= -d\sin\theta + s\cos\theta. \end{aligned} \qquad (22)$$

For d, b quarks we have (by diagonalization of mass matrix)

$$\sin 2\beta = \frac{2m_{db}}{\sqrt{(m_d - m_b)^2 + 4m_{db}^2}},$$

$$\mathrm{tg}\, 2\beta = \frac{2m_{db}}{| m_d - m_b |}, \qquad (23)$$

$$\begin{aligned} d_1 &= d\cos\beta + b\sin\beta, \\ b_1 &= -d\sin\beta + b\cos\beta. \end{aligned} \qquad (24)$$

For s, b quarks we have (by diagonalization of mass matrix)

$$\sin 2\gamma = \frac{2m_{sb}}{\sqrt{(m_s - m_b)^2 + 4m_{sb}^2}},$$

$$\mathrm{tg}\, 2\gamma = \frac{2mx_{sb}}{| m_s - m_b |}, \qquad (25)$$

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$$s_1 = s \cos \gamma + b \sin \gamma,$$
$$b_1 = -s \sin \gamma + b \cos \gamma. \tag{26}$$

If we use angle values from (16) and quark masses from (20), then we can rewrite expressions (21), (23) and (25) in the following form:

$$\sin 2\theta \simeq \frac{2m_{ds}}{m_s}, \quad m_{ds} \simeq \frac{1}{2}m_s \sin 2\theta \simeq 16.0 \div 16.35 \, \text{MeV}, \tag{27}$$

$$\sin 2\beta \simeq \frac{2m_{db}}{m_b}, \quad m_{db} \simeq \frac{1}{2}m_b \sin 2\beta \simeq 172.0 \div 193 \, \text{MeV}, \tag{28}$$

$$\sin 2\gamma \simeq \frac{2m_{sb}}{m_b}, \quad m_{sb} \simeq \frac{1}{2}m_b \sin 2\gamma \simeq 18 \div 20.2 \, \text{MeV}. \tag{29}$$

In this approach we interpret nondiagonal mass terms of mass matrix as transition widths between quarks. Then it is not clear how this value can be larger than quark mass value as it takes place in (27). In any case such enormous values of widths can arise only if s, b quarks are resonance states. Obviously this resonance can originate only outside the standard weak interactions (see below).

If we compute values of nondiagonal mass terms (quark transition widths) of mass matrix in the framework of the standard weak interactions, then using Eq. (21) we get

$$m_{ds} \simeq \sin \theta m_s. \tag{30}$$

It is interesting to compute this angle mixing in the standard model in the framework of some consistent supposition on the analogy of $K^0, \bar{K}^0$ or $\pi\pm, K\pm$ mixings [9]. To do it, we suppose that $d \leftrightarrow s$ transitions are generated through exchange of massive boson W'. Then, formally, we can get

$$m_{ds} \simeq 2W(d \rightarrow s) \simeq$$

$$\simeq (G_F)^2 \frac{f'^2_\pi m_s^3}{8\pi} (\frac{m_W}{m_{W'}})^4 = m_s \sin \theta'. \tag{31}$$

Even if we take $m_{W'} \simeq m_W$ and $f'_\pi \sim$ a few GeV, we come to the following result:

$$\sin \theta' = (G_F)^2 \frac{f'^2_\pi m_s^2}{8\pi} \ll \sin \theta \simeq \sqrt{0.048}. \tag{32}$$

So, we see that the angle mixing $\sin \theta'$ obtained in the standard method is a very small value and much less than $\sin \theta$ in the Cabibbo–Kobayashi–Maskawa matrices. It is clear that we cannot obtain fit values for mixing angles in this approach. Probably we must suppose that there must be a new left–right symmetrical interaction, which can generate masses of quarks, and moreover some quarks must be resonances of this interaction (by analogy with the strong interactions).

Impossibility of obtaining values for quark transition widths, which are of the order of m_{ds}, m_{db}, m_{sb} in Eqs. (27)–(29), in the framework of the weak interactions (see (32)) is an indication that the mass mixing schemes cannot fit the description of quark mixings. Unfortunately the same situation can take place in the neutrino mixing cases although this approach is used everywhere in description of experiments on neutrino mixings and oscillations.

The Case of Quark Mixings without Mass Shell Changing. Above we considered the case when virtual quark transitions take place with change of quark masses. Another case is also possible, when d quark transits into s quark without changing mass, i.e. $m_s^* = m_d$, then

$$\text{tg}\, 2\theta = \infty, \tag{33}$$

$\theta = \pi/4$, and

$$\sin^2 2\theta = 1. \tag{34}$$

In this case, the probability of the $d \to s$ transition (oscillation) is described by the following expression:

$$P(d \to s, t) = \sin^2\left[\pi t \frac{4m_{d,s}^2}{2p_d}\right]. \tag{35}$$

Expression for length of oscillations in this case has the following form:

$$L_o = 2\pi \frac{2p_d}{(2m_{ds})^2}.$$

In order to make these virtual oscillations real, their participation in quasi-elastic interactions is necessary for their transitions to their own mass shells [10].

The Kobayashi–Maskawa-type matrix in this case is a trivial one, and it has the following form:

$$V = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_\gamma & s_\gamma \\ 0 & -s_\gamma & c_\gamma \end{pmatrix} \begin{pmatrix} c_\beta & 0 & s_\beta \exp(-i\delta) \\ 0 & 1 & 0 \\ -s_\beta \exp(i\delta) & 0 & c_\beta \end{pmatrix} \begin{pmatrix} c_\theta & s_\theta & 0 \\ -s_\theta & c_\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}, \tag{36}$$

$$c_{e\mu} = \cos\theta = \frac{1}{\sqrt{2}}, \quad s_{e\mu} = \sin\theta = \frac{1}{\sqrt{2}};$$

$$c_{e\tau} = \cos\beta = \frac{1}{\sqrt{2}}, \quad s_{e\tau} = \sin\beta = \frac{1}{\sqrt{2}}; \tag{37}$$

$$c_{\mu\tau} = \cos\gamma = \frac{1}{\sqrt{2}}, \quad s_{\mu\tau} = \sin\gamma = \frac{1}{\sqrt{2}};$$

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$$\exp(i\delta) = 1.$$

In our approximation, the value of δ can be considered to be equal to zero.

In this case
$$\sin^2 2\theta = \sin^2 2\beta = \sin^2 2\gamma = 1, \tag{38}$$

we have
$$\Delta m_{21}^2 = (2m_{ds})^2,$$
$$\Delta m_{31}^2 = (2m_{db})^2, \tag{39}$$
$$\Delta m_{32}^2 = (2m_{ds})^2.$$

It is necessary to remark that in physics all the processes are realized through dynamics. Unfortunately, in this mass mixing scheme the dynamics is absent. Probably that is an indication of the fact that these schemes are incomplete ones, i. e. these schemes demand a physical substantiation (see Sec. 2.2).

In principle we cannot exclude this type of quark mixings since lengths of quark transitions (oscillations) in this case are much larger than it were in previous case; therefore on the background of previous transitions it is hard to observe these transitions.

Obviously, these schemes will work only if quark oscillations take place in reality (it is clear that there also can be quark mixings in absence of quark oscillations).

2.2. The Scheme of Quark Mixings (Oscillations) through Charges. The third scheme (type) of mixings or transitions between quarks can be realized by mixings of the quark fields by analogy with the vector dominance model $(\gamma - \rho^0)$ and $Z^0 - \gamma$ mixings as it takes place in the particle physics [2, 14]. Then in the case of two quarks, we have

$$q_1 = \cos\theta d + \sin\theta s,$$
$$q_2 = -\sin\theta d + \cos\theta s. \tag{40}$$

In the case of three quarks, we can also choose parameterization of the mixing matrix V in the form proposed by Maiani [13]:

$$V = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_\gamma & s_\gamma \\ 0 & -s_\gamma & c_\gamma \end{pmatrix} \begin{pmatrix} c_\beta & 0 & s_\beta \\ 0 & 1 & 0 \\ -s_\beta & 0 & c_\beta \end{pmatrix} \begin{pmatrix} c_\theta & s_\theta & 0 \\ -s_\theta & c_\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}; \tag{41}$$

$$c_{e\mu} = \cos\theta \quad s_{e\mu} = \sin\theta, \quad c_{e\mu}^2 + s_{e\mu}^2 = 1;$$
$$c_{e\tau} = \cos\beta, \quad s_{e\tau} = \sin\beta, \quad c_{e\tau}^2 + s_{e\tau}^2 = 1; \tag{42}$$
$$c_{\mu\tau} = \cos\gamma, \quad s_{\mu\tau} = \sin\gamma, \quad c_{\mu\tau}^2 + s_{\mu\tau}^2 = 1.$$

The charged current in the standard model of weak interactions for two quark families has the following form:

$$j^\alpha = \begin{pmatrix} \bar{u}\bar{c} \end{pmatrix}_L \gamma^\alpha V \begin{pmatrix} d \\ s \end{pmatrix}_L,$$

$$V = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}, \tag{43}$$

and then the interaction Lagrangian is

$$\mathcal{L} = \frac{g}{\sqrt{2}} j^\alpha W^+_\alpha + \text{h.c.} \tag{44}$$

and

$$d = \cos\theta q_1 - \sin\theta q_2,$$
$$s = \sin\theta q_1 + \cos\theta q_2. \tag{45}$$

Then, taking into account that the charges of q_1, q_2 quarks are g_1, g_2, we get

$$g\cos\theta = g_1, \quad g\sin\theta = g_2, \tag{46}$$

i. e.

$$\cos\theta = \frac{g_1}{g}, \quad \sin\theta = \frac{g_2}{g}. \tag{47}$$

Since $\sin^2\theta + \cos^2\theta = 1$, we have

$$g = \sqrt{g_1^2 + g_2^2}$$

and

$$\cos\theta = \frac{g_1}{\sqrt{g_1^2 + g_2^2}}, \quad \sin\theta = \frac{g_2}{\sqrt{g_1^2 + g_2^2}}. \tag{48}$$

If we suppose that $g_1 \cong g_2 \cong \dfrac{g}{\sqrt{2}}$, then

$$\cos\theta \cong \sin\theta \cong \frac{1}{\sqrt{2}}. \tag{49}$$

It is not difficult to turn to consideration of the case of three quark types d, s, b. Since the weak couple constants g_d, g_s, g_b of d, s, b quarks are approximately equal in reality, i. e. $g_d \simeq g_s \simeq g_b$, the angle mixings are nearly maximal:

$$\cos\theta = \cos\theta_{ds} \cong \sin\theta_{ds} \cong \frac{1}{\sqrt{2}},$$

$$\cos\beta = \cos\theta_{db} \cong \sin\theta_{db} \cong \frac{1}{\sqrt{2}}, \tag{50}$$

$$\cos\gamma = \cos\theta_{sb} \cong \sin\theta_{sb} \cong \frac{1}{\sqrt{2}}.$$

In expression (16), experimental data for quark mixing angles were given. This values are in serious discrepancy with the same values in (50). This discrepancy can be eliminated if we suppose that quark charges (or couple constants) of the interactions, which violate quark aromatic numbers, are different from the weak charges (couple constants) of d, s, b quarks. Then we can use Eq. (46)–(47) for determination of q_1, q_2, q_3 quark charges by using values from Eq. (16):

$$
\begin{aligned}
g_1' &= g\cos\theta, \quad g_2' = g\sin\theta, \\
g_1'' &= g\cos\beta, \quad g_3'' = g\sin\beta, \\
g_2''' &= g\cos\gamma, \quad g_3''' = g\sin\gamma.
\end{aligned}
\tag{51}
$$

It is also possible to use expression (48) as an independent one and use it for determination of q_1, q_2, q_3 couple constants (it is a consequence of normalization conservation and then there can be no connections between these couple constants and the above-given quark couple constants).

As stressed above, in the case of mass mixing scheme we have no dynamical basing in contrast to the case of charge mixing scheme, but these schemes may be jointed if quark masses have the following form:

$$
m_{q_i} = g_i v, \quad i = d, s, b,
\tag{52}
$$

where v is constant in the Higgs mechanism [15]. And then the problem of dynamical substantiation in this scheme is solved. The problem of using the mass mixing schemes for description of quark mixings (oscillations) is also solved, but now nondiagonal terms of quark mass matrix cannot be interpreted as quark transition widths.

3. CONCLUSION

Unfortunately, we do not know concrete mechanism of quark mixings or oscillations; therefore, it is necessary to consider all realistic schemes of quark mixings and oscillations. In this work, three schemes of quark mixings (oscillations) together with their mixing matrices (analogous to Cabibbo–Kobayashi–Maskawa matrices) were considered. In these schemes, quark transitions are virtual since quark masses are different. Two of them belong to the so-called mass mixing schemes (mixing parameters are expressed by elements of mass matrices), and the third scheme belongs to the charge mixing ones (mixing parameters are expressed through charges). For these schemes the expressions for transition probabilities between d, s, b quarks were obtained. The analysis of situation with the quark mixing parameters in these schemes was fulfilled. It was shown that in principle it is impossible to obtain values for quark transition widths given in Eqs. (27)–(29) in the framework of the weak interactions (see (32)). It is an indication that the

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mass mixing schemes cannot fit the description of quark mixings (oscillations), although if quark mass origin has a Higgs nature (see Eq. (52)) then this problem is solved. In this case, we cannot consider the nondiagonal mass terms of quark mass matrix as quark transition widths any longer.

So, expressions (4), (9), (13)–(15), (35)–(38), (50), (51) can be used for interpretation of experimental data on quark mixings and oscillations. These quark mixings and oscillations will manifest themselves as mixings and oscillations of hadrons.

REFERENCES

1. Review of Part. Prop. // Phys. Rev. D. 2002. V. 66, No. 1. P. 010001.

2. *Glashow S. L.* // Nucl. Phys. 1961. V. 22. P. 579;
   Weinberg S. // Phys. Rev. Lett. 1967. V. 19. P. 1264;
   Salam A. // Proc. of the 8th Nobel Symp. / Ed. N. Svarthholm. Almgvist and Wiksell, Stockholm, 1968. P. 367.

3. *Cabibbo N.* // Phys. Rev. Lett. 1963. V. 10. P. 531;
   Kobayashi M., Maskawa K. // Prog. Theor. Phys. 1973. V. 49. P. 652.

4. *Beshtoev Kh. M.* JINR, E2-94-293. Dubna, 1994; Turkish J. Phys. 1996. V. 20. P. 1245;
   Beshtoev Kh. M. JINR Commun. E2-95-535. Dubna, 1995;
   Beshtoev Kh. M. JINR Commun. P2-96-450. Dubna, 1996;
   Beshtoev Kh. M. JINR Commun. E2-97-210. Dubna, 1997;
   Beshtoev Kh. M. Hadronic J. 2000. V. 23. P. 295.

5. *Beshtoev Kh. M.* JINR Commun. E2-91-183. Dubna, 1991; Proc. of III Int. Symp. on Weak and Electromag. Int. in Nucl. Singapore, 1992. P. 781; 13th European Cosmic Ray Symp. CERN, Geneva. HE-5-13.

6. *Beshtoev Kh. M.* JINR Commun. E2-92-318. Dubna, 1992;
   Beshtoev Kh. M. // Proc. of 27th Intern. Cosmic Ray Conf. Germany, 2001. V. 4. P. 1186;
   Beshtoev Kh. M. // Proc. of 28th Int. Cosmic Ray Conf. Japan, 2003. V. 1. P. 1503;
   Beshtoev Kh. M. JINR Commun. E2-2004-58. Dubna, 2004.

7. *Bilenky S. M., Pontecorvo B. M.* // Phys. Rep. C. 1978. V. 41. P. 225;
   Boehm F., Vogel P. // Physics of Massive Neutrinos. Cambridge Univ. Press, 1987;
   Bilenky S. M., Petcov S. T. // Rev. Mod. Phys. 1977. V. 59. P. 631.

8. *Beshtoev Kh. M.* JINR Commun. E2-2003-155. Dubna, 2003.

9. *Beshtoev Kh. M.* JINR Commun. E2-99-137. Dubna, 1999;
   Beshtoev Kh. M. JINR Commun. E2-2000-229. Dubna, 2000.

10. *Beshtoev Kh. M.* hep-ph/9911513; Hadronic J. 2000. V. 23. P. 477; Proc. of 27th Int. Cosmic Ray Conf. Germany, Hamburg, 7–15 August 2001. V. 3. P. 1186.

11. *Blatt J. M., Weisskopf V. F.* The Theory of Nuclear Reactions. INR T R 42.

12. *Beshtoev Kh. M.* JINR Commun. E2-99-307. Dubna, 1999; JINR Commun. E2-99-306. Dubna, 1999.

13. *Maiani L.* // Proc. Int. Symp. on Lepton–Photon Inter. Hamburg, DESY. P. 867.

14. *Beshtoev Kh. M.* Preprint INR of Academy of Sciences of USSR. P-217. Moscow, 1981.

15. *Higgs P. W.* // Phys. Lett. 1964. V. 12. P. 132; Phys. Rev. 1966. V. 145. P. 1156;
Englert F., Brout R. // Phys. Rev. Lett. 1964. V. 13. P. 321;
Guralnik G. S., Hagen C. R., Kible T. W. B. // Phys. Rev. Lett. 1964. V. 13. P. 585.