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Аннотация

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В трехтриплетной модели кварков с наблюдаемым цветом получен слабый адронный ток со следующими свойствами: а) он удовлетворяет слабой алгебре SU(2); б) нейтральный ток полностью диагонален и по кварковой структуре совпадает с электромагнитным; в) "белая" часть тока обладает свойствами тока Кабиббо.

Свойства белой части нелептонного лагранжиана, полученного из этого тока, следующие: а) между коэффициентами амплитуд переходов $\Delta T=1/2$ и $\Delta T=3/2$ имеется соответствующее эксперименту отношение ~25; б) отсутствуют переходы $\Delta S=2$; в) величины переходов $\Delta T=0,1,2$ лагранжиана без изменения странности сравнимы между собой.

Abstract

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In the triplet quark model with unconfined colour we obtain a weak hadronic current with following properties: a) it satisfies weak SU(2) algebra; b) the neutral current in completely diagonal and coincides with electromagnetic one in the quark structure; c) the "weight" part of the current possesses the properties of the Cabbibo current.

The properties of the "weight" part of nonleptonic Lagrangian derived from this current are: a) between the coefficients of the transition amplitudes $\Delta T = 1/2$ and $\Delta T = 3/2$ there is a ratio ~25 corresponding to experiment; b) there are no transitions $\Delta S = 2$; c) the values for the transitions $\Delta T = 0,1,2$ of the Lagrangian without changes of strangeness are compatible with each other.

Recently in work[1] there was proposed the following form of weak interaction in the colour scheme[2]: it is sufficient to impose the only one condition (see[1] and this paper) onto 20 parameters of weak current (corresponding to 20 possible transitions $\Delta Q = 1$) so that from the fulfilment of SU(2) algebra for weak charges there would follow diagonality of neutral current. In addition to the indicated properties the weak hadronic current should possess a number of other properties. In the case of nonleptonic decay of the known mesons and baryons it is very desirable that $\Delta T = 1/2$ rule would be reflected just in the interaction Lagrangian. Here it is assumed that the Lagrangian is constructed as currents product. The colour models turned out to be able to explain this rule with the symmetry properties only. For instance, the matrix elements in "white" (antisymmetric in colour indices) baryon states from the white part of the nonleptonic Lagrangian do not contain symmetric (according to usual SU(3)) representation $\underset{\sim}{27}$ [3,4,5,6]. Moreover, it became possible using additional arguments (current algebra, PCAC)[6] to use the colour quark model to enhance the octet part in meson decays too.

In connection with the development of asymptotically free model it was noted[7], that the character of the W-boson exchanges at small distances is such that the octet part in the effective Lagrangian of interaction dominates over the representation $\underset{\sim}{27}$. Direct calculations of the decay rates using the latter properties gave satisfactory agreement with experiment[8].

In all the mentioned explanantions for the $\Delta T = 1/2$ rule in addition to the main principles there always arises a necessity to exploit a number of extra hypothesis and properties of physical quantities (e.g. quark and W-boson masses) not proved experimentally. Thus it is desirable to construct a Lagrangian that would explain the $\Delta T = 1/2$ rule and would have a minimum number of assumptions.

In the present work such a Lagrangian is constructed from a weak hadronic current, proposed in[1]. In work[9] there has been constructed in a similar way a weak current for $SU(4)' \times SU(4)''$ scheme that includes a charmed quark and leptons. In the present work we will limit ourselves with a 3-triplet model, since the properties of the charmed mesons (isotopic structure of decay amplitudes, in particular) have not yet been studied quite well. Essentially we consider the physical colour as an alternative for the conception of colour confirment. The main arguments in favour of this viewpoint are given in the works by Pati and Salam[10]. Their approach to the colour in the framework of the gauge theory allow to make consistent integrity of the quark charges and low colour threshould completely with the data on electro- and neutrinoproduction (see, e.g., review[11]). We will point out two other properties of the weak interaction scheme, constructed in the present work. As it will be seen further on, the property of octet enhancement together with the requirement for universality of lepton interactions make one by necessity introduce heavy leptons into the scheme. Apart from the properties of Lagrangian $\Delta S = 1$ induce the properties of Lagrangian $\Delta S = 0$ that described nuclear forces with parity noncenservation. In particular the latter one contains pieces $\Delta T = 2$ with large coefficients. The experiment indicates a large value for these transitions. It should be noted that their values contradict to a certain extent the property of octet dominance in the Cabbibbo theory, since the Lagrangian in this theory is derived from the currents where $\Delta T = 3/2$ amplitude is small.

2. WEAK HADRONIC CURRENT PROPERTIES IN COLOUR MODEL

We consider a well-known model[2] with an integer quark charges (the lower sign is the colour index, the upper one is value of charge)

$$\begin{pmatrix} p_1^{o} & p_2^{+} & p_3^{+} \\ n_1^{-} & n_2^{o} & n_3^{o} \\ \lambda_1^{-} & \lambda_2^{o} & \lambda_3^{o} \end{pmatrix} \qquad (1)$$

As is seen there are 20 transitions $\Delta Q = +1$ between quarks and the weak hadronic current has the form

$$\begin{aligned} J^{+} = {} & a_1(\tilde{p}_1 n_1) + a_2(\tilde{p}_2 n_2) + a_3(\tilde{p}_3 n_3) + a_4(\tilde{p}_2 p_1) + \\ & + a_5(\tilde{n}_2 n_1) + a_6(\tilde{\lambda}_2 \lambda_1) + a_7(\tilde{p}_2 \lambda_3) + a_8(\tilde{\lambda}_3 n_1) + \\ & + b_1(\tilde{p}_1 \lambda_1) + b_2(\tilde{p}_2 \lambda_2) + b_3(\tilde{p}_3 \lambda_3) + b_4(\tilde{p}_3 p_1) + \\ & + b_5(\tilde{n}_3 n_1) + b_6(\tilde{\lambda}_3 \lambda_1) + b_7(\tilde{p}_3 n_2) + b_8(\tilde{n}_2 \lambda_1) + \\ & + c_1(\tilde{p}_2 n_3) + c_2(\tilde{\lambda}_2 n_1) + d_1(\tilde{p}_3 \lambda_2) + d_2(\tilde{n}_3 \lambda_1). \end{aligned} \qquad (2)$$

In the last expression we omit the Lorentz current structure; in the paper, we deal with the V-A currents. The transition constants are designated in the following way: a_i corresponds to the transitions $\Delta S = 0$, b_i to the transitions $\Delta S = 1$, $c_i \div \Delta S = -1$, $d_i \div \Delta S = 2$. It turns out to be very convenient to arrange these coefficients into four "vectors", that allow to write down the current properties in the most economical way:

$$\vec{X}=\frac{1}{\sqrt{2}}\begin{pmatrix}a_1\\a_5\\c_2\\b_5\\a_8\end{pmatrix},\ \vec{Y}=\frac{1}{\sqrt{2}}\begin{pmatrix}b_1\\b_8\\a_6\\d_2\\b_6\end{pmatrix},\ \vec{Z}=\frac{1}{\sqrt{2}}\begin{pmatrix}a_4\\a_2\\b_2\\c_1\\a_7\end{pmatrix},\vec{V}=\frac{1}{\sqrt{2}}\begin{pmatrix}b_4\\b_7\\d_1\\a_3\\b_3\end{pmatrix}. \tag{3}$$

If the condition

$$(\vec{X}\vec{Z})(\vec{Y}\vec{V})-(\vec{X}\vec{V})(\vec{Y}\vec{Z})\neq 0, \tag{4}$$

is imposed on the vectors (3), then relations

$$\vec{Z}=\sin\alpha\,\vec{X}+\cos\alpha\,\vec{Y},\quad \vec{V}=\cos\alpha\,\vec{X}-\sin\alpha\,\vec{Y}, \tag{5}$$

(α is arbitrary)

$$\vec{X}^2=\vec{Y}^2=1, \tag{6}$$

$$(\vec{X}\vec{Y})=0 \tag{7}$$

provide the fulfilment of SU(2) algebra for the weak charges. Under these conditions the neutral current becomes completely diagonal and it coincides in quark structure with the electromagnetic one

$$J^{o}=\frac{1}{2}[J^{+},J^{-}]=-\tilde{n}_1 n_1-\tilde{\lambda}_1\lambda_1+\tilde{p}_2 p_2+\tilde{p}_3 p_3. \tag{8}$$

As it follows from (5-7) we have 8 parameters left free in the definition of the weak hadronic current. We will fix these parameters with the aid of yet other physical requirements imposed on them.

3. LAGRANGIAN OF NONLEPTONIC INTERACTION WITH STRANGENESS NONCONSERVATION

The known experimental data correspond to the "white" quantities i.e. averaged over colour indices. For agreement with the Cabibbo theory we demand

$$\frac{1}{3}(a_1 + a_2 + a_3) = \cos\theta_c , \qquad \frac{1}{3}(b_1 + b_2 + b_3) = \sin\theta_c . \tag{9}$$

The next step will bring us to the equations, that follow from the properties of weak nonleptonic interactions of usual (uncharmed) hadrons. As usual it is assumed that nonleptonic interaction Lagrangian has the form $L \sim j^+_\mu j_\mu$, where j_μ is the weak hadronic current of the model. The white part of this Lagrangian corresponds to the properties of usual hadrons. In the isotopic structure the part of the usual Lagrangian with the strangeness nonconservation is known to consist of two parts with T = 1/2 and T = 3/2 or in SU(3), $\underset{\sim}{8}$ and $\underset{\sim}{27}$. The experimental rule $\Delta T = 1/2$ makes one either suppress artificially $\underset{\sim}{27}$ and enhance $\underset{\sim}{8}$, or introduce also artificially the neutral current $(\tilde{n}\lambda)$ into the Lagrangian, since the following combination $(\tilde{n}p)(\tilde{p}\lambda) - \frac{1}{2}(\tilde{p}p - \tilde{n}n)(\tilde{n}\lambda)$ transforms as T = 1/2. As was mentioned, in our case the neutral current (its white part consequently) is completely diagonal. Therefore in the case of semileptonic neutral interactions we are out of danger to be in disagreement with experiment. At the same time in the white part of the nonleptonic Lagrangian there is by necessity neutral current $(\tilde{n}\lambda)$, that may be used for the construction of the combination with $\Delta T = 1/2$. If we infer the white part from the Lagrangian $L^{\Delta s=1}$,then it will be devided into two parts with respect to the isotopic space in the following way

$$L^{\Delta=1} = \frac{G}{24}[(\frac{1}{\sqrt{6}}A_2 + \sqrt{6}A_1)|\frac{1}{2}, \frac{1}{2}> + \frac{2}{\sqrt{3}}A_2|\frac{3}{2}, \frac{1}{2}>], \qquad (10)$$

where

$$A_1 = (a_1 + a_2 + a_3)(b_1 + b_2 + b_3) - (a_1 b_1 + a_2 b_2 + a_3 b_3 + a_7 c_1 + b_7 d_1) + \qquad (10a)$$

$$+ (a_4 + \frac{1}{2}a_5)(b_8 + c_2) + (b_4 + \frac{1}{2}b_5)(a_8 + d_2),$$

$$A_2 = (a_1 + a_2 + a_3)(b_1 + b_2 + b_3) + a_1 b_1 + a_2 b_2 + a_3 b_3 + a_7 c_1 + b_7 d_1 + \qquad (10b)$$

$$+ (a_4 - a_5)(b_8 + c_2) + (b_4 - b_5)(a_8 + d_2).$$

Experimentally it is established that the ratio of the transition amplitudes, $\Delta T = 1/2$ to the amplitudes $\Delta T = 3/2$ is equal to 25 approximately. Therefore the next requirement imposed on the current coefficients, is as follows

$$A_1 / A_2 = 11.6. \qquad (11)$$

The white Lagrangian contains also the transitions $\Delta S = 2$. We are not discuss here the value for the K_L-K_S mass difference and force the coefficient in the amplitude $\Delta S = 2$ be equal to zero:

$$a_8 d_2 + b_8 c_2 = 0. \qquad (12)$$

The requirements (5)-(7), (11)-(12) give us a system to find the values of the current parameters.

Since the system is rather complicated its solutions were searched with the help of a computer. Here it turned out that equality (9) could not be satisfied. Still the system has a solution if one defines

$$\frac{1}{3}(a_1 + a_2 + a_3) = \varkappa \cos\theta_c \, , \quad \frac{1}{3}(b_1 + b_2 + b_3) = \varkappa \sin\theta_c . \qquad (13)$$

The presence of a common multiplier in the hadronic current violates the universality of the leptonic current. Therefore in order not to come in contradiction with the experimental data on semileptonic interactions one should mix usual leptons with the heavy ones (either charged or neutral) with the angle $\phi = \arccos \varkappa$ /12/. One may say that the rule $\Delta T = 1/2$ is connected with the existence of heavy leptons in the framework of the three-triplet model. All the indicated requirements are fulfilled not under the definite values for the parameters).From all the possible sets we have chosen such one which gives the largest value for the coefficient A_1.Hence with the high degree of accuracy all the physical requirements are fulfilled with the following values of our parameters:

$$\begin{aligned} a_1 &= 0.575 & b_1 &= -0.290 \\ a_5 &= 0.795 & b_8 &= 0.501 \\ c_2 &= 0.715 & a_6 &= -0.999 \\ b_5 &= -0.577 & d_2 &= -0.815 \\ a_8 &= 0.439 & b_6 &= 0.0285 \\ \alpha &= 1.802 \text{ rad} = \theta_c + \frac{\pi}{2} & \varkappa &= 0.740 \end{aligned} \qquad (14)$$

With this we have :

$$A_1 = 2.77; \qquad A_2 = 0.238. \tag{15}$$

Thus we were able to construct the Lagrangian for weak nonleptonic interaction, where the required relation between the transition amplitudes for $\Delta T = 1/2$ and $\Delta T = 3/2$ is given in explicit form.

Besides the values for the coefficients of the weak hadronic current, were fixed, and this current is now completely determined in the three triplet model with integer quark charges.

4. LAGRANGIAN $\Delta S = 0$

In the previous Sections we have obtained a completely determined weak current in the colour scheme. The nonleptonic Lagrangian constructed with the help of this current contains in the explicit form the conditions for the fulfilment of the $\Delta T = 1/2$ rule, and does not have $\Delta S = 2$ transitions. In this Section we will construct the Lagrangian with strangeness conservation. Usually these Lagrangians are to describe nuclear transitions with parity violation. The nowdays experiments point out to the fact that such transitions do take place (see references in review[13]).

The Lagrangian is constructed as a product of currents. In this case account should be made of the contributions from the neutral currents:

$$L^{\Delta S=0} = L_c^{\Delta S=0} + L_n^{\Delta S=0}. \tag{16}$$

On the contrary to the $L^{\Delta S=1}$ case the present Lagrangian is written in terms of particle states. For instance, the symbol $\pi^o\eta$ means $(V_\mu^{\pi^o} A_\mu^{\eta} + A_\mu^{\pi^o} V_\mu^{\eta})$, where $\pi = \frac{1}{\sqrt{2}}(\tilde{p}p - \tilde{n}n)$, $\eta = \frac{1}{\sqrt{6}}(\tilde{p}p + \tilde{n}n - 2\tilde{\lambda}\lambda)$ ect. Such representation allows one to see quite easily the isotopic structure of the Lagrangian. The numerical values for the coefficients have been derived from (14) and (18).

$$L_c^{\Delta S=0} = -0{,}863\,\pi^-\pi^+ + 0{,}027\,\pi^+\pi^- - 0{,}802\,K^-K^+ - 0{,}360\,K^+K^- + 0{,}766\,\tilde{K}^oK^o + K^o\tilde{K}^o - 0{,}559\,\pi^o\pi^o + 0{,}609\,\pi^o\eta - 1{,}05\,\eta\pi^o + 1{,}50\,\pi^oX - 1{,}02\,X\pi^o + 0{,}585\,\eta\eta + 2{,}15\,XX + 1{,}22\,\eta X + 0{,}08X\eta; \tag{17a}$$

$$L_n^{\Delta S=0} = -2(\pi^-\pi^+ + \pi^+\pi^-) - 3(K^+K^- + K^-K^+) + (\tilde{K}^oK^o + K^o\tilde{K}^o) + \frac{1}{3}[11\,\pi^o\pi^o + \frac{19}{3}\eta\eta + \frac{20}{3}XX + \frac{5}{\sqrt{3}}(\pi^o\eta + \eta\pi^o) + 2\sqrt{\frac{2}{3}}(\pi^oX + X\pi^o) + \frac{\sqrt{2}}{3}(\eta X + X\eta)]. \tag{17b}$$

In the present case the isotopic structure of the Lagrangian is very important. Concrete values for the transitions $\Delta T = 0, 1, 2$ and their ratios are not completely defined experimentally. However one should pay attention to a large value for the transition $\Delta T = 2$ /13/. In a certain sense one may state that it contradicts the rule $\Delta T=1/2$. This contradiction cannot be overcome in the Cabbibo theory. For our case the weak current coefficients are completely fixed, consequently the coefficients of Lagrangian(17) are fixed as well. As is seen the values for the transition $\Delta T=0,1,2$ are compatible with each other. This conclusion may be considered as a definite prediction expecting for experimental check.

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