Structure of weak hadronic currents in the model with a triplet of charmed quarks

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(Submitted October 27, 1975)
Pis'ma Zh. Eksp. Teor. Fiz. **23**, No. 1, 55–58 (5 January 1976)

A model with a triplet of charmed quarks is considered on the basis of Sp6 symmetry. It is shown that the Sp6 symmetry and the universality of weak interactions lead to the selection rule $\Delta C = \Delta Q$.

PACS numbers: 12.30.—s, 11.30.Ly, 11.40.Dw

To explain the properties of ψ particles, additional quantum numbers are presently introduced in various manners. One of the methods of introducing an additional quantum number is to introduce, besides the usual quarks p, n, and λ a fourth quark C with the quantum number charm. The structure of this theory corresponds to broken $SU(4)$ symmetry.

We consider here a theory based on the Sp6 group, which has rank 3 and also permits introduction of a new quantum number.

A hadron classification based on the Sp6 group was considered earlier in[1,2]. The lowest representation of the Sp6 group has dimension 6 and as a representation of the $SU(3)$ group it breaks up into representations 3 and $\bar{3}$. The generators $S^{ij}=S^{ji}$ of the Sp6 group are transformed in accord with the representation $\underline{21}$ of the Sp6 group and satisfy the commutation relations

$$[S^{ij}, S^{kl}] = h^{ik}S^{jl} + h^{il}S^{jk} + h^{jk}S^{il} + h^{jl}S^{ik}, \quad i, j = 1, \ldots, 6, \tag{1}$$

where $h^{ik} = -h^{ki}$ is a metric tensor of the Sp6 group. In a representation of dimensonality $\underline{6}$, the generators act in accord with the formula

$$S^{ij}Q^k = h^{ik}Q^j + h^{jk}Q^i . \tag{2a}$$

Following[1], we choose the metric tensor H in the form

$$H = \begin{pmatrix} \epsilon & 0 & 0 \\ 0 & \epsilon & 0 \\ 0 & 0 & \epsilon \end{pmatrix}, \qquad \epsilon = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}. \tag{2b}$$

Then the additive quantum numbers are expressed in terms of the group generators as follows:

$$\begin{aligned} T_3 &= \frac{1}{2}(S^{12} - S^{56}), \\ Y &= \frac{1}{3}(S^{12} + S^{56} - 2S^{34}), \\ Z &= \frac{1}{3}(S^{12} + S^{56} + S^{34}), \end{aligned} \tag{3}$$

where Z is a new quantum number connected with the charm C by the formula $C = \frac{3}{2}(B - Z)$, where B is the baryon number. The Gell-Mann—Nishijima formula is generalized in the following manner:

$$Q = T_3 + \frac{Y}{2} + \frac{1}{2}(B - Z). \tag{4}$$

Just as in the usual quark model, we assign a baryon charge $B = 1/3$ to the particles from the representation $\underline{6}$. In this notation, particles (2,6,4) have $Z = 1/3$ and correspond to the usual triplet of quarks (p, n, λ) with charges $(2/3, -1/3, -1/3)$. Particles(5,1,3) have $Z = -1/3$ and correspond to the antitriplet (p', n', λ') with charges $(2/3, -1/3, 2/3)$. The quark charges coincide in this model with those postulated in[3], and the asymptotic value of R should also be 5.

We consider now the hadron currents in this model. We attempt to construct an $SU(2)$ gauge theory of weak interactions. The hadron currents J^+, J^-, and J^0, which describe the weak interaction, should satisfy the $SU(2)$ algebra:

$$[J^+, J^-] = 2J^0 \quad \text{(5a)}, \qquad [J^0, J^{\pm}] = \pm J^{\pm} . \quad \text{(5b)}$$

In addition we postulate that the currents J^+, J^-, and J^0 transform in accordance with representation $\underline{21}$ of the group Sp6 and that the current J^0 not contain terms with $\Delta S \neq 0$ and $\Delta C \neq 0$.

In the foregoing notation, the most general expression for the current J^+ is of the form

$$J^+ = x_1 S^{25} + x_2 S^{23} + x_3 S^{35} + x_4 S^{33} + x_5 S^{22} + x_6 S^{55}. \qquad (6)$$

(We assume the usual $V-A$ structure of the current and omit the spatial indices). Calculating the commutator $[J^+, J^-]$ and equating to zero the terms with $\Delta S \neq 0$ and $\Delta C \neq 0$, we obtain three equations

$$\begin{aligned} x_1 x_2 + 2x_3(x_4 + x_6) &= 0, \\ x_1 x_3 + 2x_2(x_4 + x_5) &= 0, \\ x_2 x_3 + 2x_1(x_5 + x_6) &= 0. \end{aligned} \qquad (7)$$

The commutator (5b) yields three more equations

$$\begin{aligned} x_1^2 + x_2^2 + 4x_5^2 &= 1, \\ x_1^2 + x_3^2 + 4x_6^2 &= 1, \\ x_2^2 + x_3^2 + 4x_4^2 &= 1. \end{aligned} \qquad (8)$$

The current components S^{25} and S^{23} correspond to the β decay of a neutron and a Λ hyperon, and we therefore seek a solution of the system (7) and (8) under the conditions $x_1 \neq 0$, $x_2 \neq 0$, $x_2/x_1 = \tan\theta$, where θ is the Cabibbo angle. Under these conditions the solution of the system (7), (8) is expressed in terms of one free parameter and is conveniently represented in the form

$$\begin{aligned} x_1 &= \cos\psi\cos\theta, \\ x_2 &= \cos\psi\sin\theta, \\ x_3 &= (1 + \sin\psi)\sin\theta\cos\theta, \\ x_4 &= -\tfrac{1}{2}(\cos^2\theta - \sin\psi\sin^2\theta), \\ x_5 &= -\tfrac{1}{2}\sin\psi, \\ x_6 &= -\tfrac{1}{2}(\sin^2\theta - \sin\psi\cos^2\theta). \end{aligned} \qquad (9)$$

Resorting to the idea of the universality of weak interactions in the Cabibbo form, we arrive at the conclusion that $\psi = 0$ or is quite small. This corresponds to the fact that the term S^{22}, which corresponds to the transition $n' \to p$ with $\Delta C = -\Delta Q$, drops out of the current J^+. The final expression for the component of the current J^+ with change of charm is

$$J^+ = (\bar{\lambda}'\cos\theta - \bar{p}'\sin\theta)(n\sin\theta - \lambda\cos\theta). \qquad (10)$$

The allowed transition and the corresponding suppression factors are

$$p' \leftrightarrow \lambda,\ \lambda' \leftrightarrow n\ \sin\theta\cos\theta;\quad \lambda' \leftrightarrow \lambda\ \cos^2\theta;\quad p' \leftrightarrow n\ \sin^2\theta.$$

Thus, the Sp6 symmetry and the universality of the weak interaction lead to the selection rule $\Delta C = \Delta Q$. We note that in[3] this selection rule is postulated. Direct consequences of this result are the following: if production on valent quarks predominates, then the charmed particles will be produced only trino beams, and the dominant decay mode of the produced particles wil tain strange particles. Some of the charmed mesons are long-lived, nar the mesons with structure $(n'\bar{p})$ or $(\bar{n}',p)$. The cross section for the pro of the charmed particles is of the order of the cross section for strange cle production (with the exception of threshold effects). The mass formu nonleptonic decays of charmed particle will be considered in future pape

In conclusion, the author thanks D.B. Struminskiĭ and the participants seminar of the Institute of Theoretical Physics of the Ukrainian Academy Sciences for useful discussions.

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