/linimal generalization of the 5-quark model of ı particles

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The 5-quark model of ψ particles is generalized by introducing additional quarks that are degenerate in mass and charge with respect to the initial fourth and fifth quarks. The proposed generalization preserves the main consequences of the 5-quark model and makes it possible to explain qualitatively a number of additional facts.

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In[1] we have proposed, for the first time, a 5-quark model[1] of ψ particles, ccording to which

$$\psi = \cos\phi\,\psi_0 + \sin\phi\,\psi_0', \qquad \psi' = -\sin\phi\,\psi_0 + \cos\phi\,\psi_0', \tag{1}$$

·here $\psi_0 = c\bar{c}$, $\psi_0' = g\bar{g}$, c and g are two new quarks, and the angle ϕ is small.

Within the framework of this model it becomes possible to explain qualitative- / the smallness of the width of the transitions

$$\psi' \to {}^3P + j, \quad \psi' \to \eta_\psi + j, \quad \psi' \to \psi 2\pi$$

he suppression factor is $\sim \sin^2\phi$). The 5-quark model predicts the existence of seudoscalar analogs of ψ and ψ' (η_ψ and $\eta_{\psi'}$), with quark contents analogous to and ψ', but with a larger mixing angle in η_ψ (owing to two-gluon exchange). If e identify the recently discovered $\chi(2.8)$ state with η_ψ, then the large mass ifference $M(\psi) - M(\chi) = 0.3$ GeV can be attributed to the large mixing angle in ,. In this case (if we assume as usual that the spin-orbit splitting is ~ 100 [eV), one would expect $\eta_{\psi'}$ to lie somewhat higher (~ 100 MeV) than ψ'.

A natural generalization of the 5-quark model, in which all the advantages of ıe 5-quark scheme are preserved, is a model with a larger number of quarks, hen the quarks introduced on top of c and g have the same masses and charges s c and g. Thus, assume that besides the c and the g quarks there are addi- onal quarks $c_i (i = 2 \cdots n)$ and $g_j (j = 2 \cdots m)$ with masses and charges equal the .asses and charges of c and g, respectively.

In the model under consideration we have

$$\psi_0 = \frac{1}{\sqrt{n}} \sum_{i=1}^{n} c_i \bar{c}_i, \; c_1 \equiv c, \qquad \psi_0' = \frac{1}{\sqrt{m}} \sum_{j=1}^{m} g_j \bar{g}_j, \; g_1 \equiv g$$

here ψ and ψ' are determined by formula (1). The other quark configurations, hich are orthogonal to ψ_0 and ψ_0' ($\chi = \Sigma \beta_i c_i \bar{c}_i$ or $\Sigma j_j g_j \bar{g}_j$) are not produced in e^- annihilation, since their effective charge is $\Sigma \beta_i = \Sigma j_i = 0$, in analogy with hat takes place in the model of[4], where $n = 2$, $m = 0$, and $Q_c = 2/3$. This generalization of the 5-quark model therefore does not give rise to new narrow resonances in the e^+e^- annihilation process, other than ψ and ψ', but the values of

$$R = 2 + 3nQ_c^2 + 3mQ_g^2$$

and

$$\frac{\Gamma(\psi' \to e^+e^-)}{\Gamma(\psi \to e^+e^-)} = \frac{(\sqrt{m}Q_g \cos\phi - \sqrt{n}Q_c \sin\phi)^2}{(\sqrt{n}Q_c \cos\phi + \sqrt{m}Q_g \sin\phi)^2}$$

receive contributions from all the quark degrees of freedom.

We shall confine ourselves henceforth to the minimal extension of the 5-quark model, to 6 quarks, assuming the mixing angle ϕ in (1) to be small as before. An additional argument favoring this expansion, besides economy, is the analogy with the (p, n, λ) triplet of ordinary quarks. Attention is called here to the approximately identical mass splitting

$$m_\lambda - m_p \approx 150 - 200 \text{ MeV}, \quad m_g - m_c \approx 250 - 300 \text{ MeV}.$$

The possible minimal models are:

Model A, in which $Q_{c1} = Q_{c2} = 2/3$, $Q_g = -1/3$, $\phi = 14°$, $R = 5$.

Model B, $Q_c = 2/3$, $Q_{g1} = Q_{g2} = -1/3$, $\phi = 2°$, $R = 4$.

Model C, $Q_{c1} = Q_{c2} = Q_g = 2/3$, $\phi = 2°$, $R = 6$.

To estimate the masses of the mesonic and baryonic states containing the new quarks c_i and g_i, we can use the results of[1,5], the lightest pseudoscalar meson having in this case a mass ~ 2 GeV. We note also that the models A and C predict the existence of a neutral "isotriplet"

$$c_1\bar{c}_2, \ \frac{1}{\sqrt{2}}(c_1\bar{c}_1 - c_2\bar{c}_2), \ c_2\bar{c}_1 \text{ with mass } 3.1 \text{ GeV}$$

and the model B predicts the existence of a neutral isotriplet

$$g_1\bar{g}_2, \ \frac{1}{\sqrt{2}}(g_1\bar{g}_1 - g_2\bar{g}_2), \ \bar{g}_2 g_1 \text{ with mass } 3.7 \text{ GeV}.$$

We note that a 6-quark model of ψ particles was proposed in[6,7], but the mixing between the quark configurations in these models contradicts the quark-gluon ideas concerning the interaction (see, e.g., [8]) and calls for introduction of a new strong interaction in which only heavy quarks take part.

It is clear that introduction of new quarks increases the possibilities for constructing weak-interaction models. We note that to eliminate Adler anomalies when strong electromagnetic interactions are constructed it is necessary to introduce new charged leptons in the models A, B, and C. Connecting the observed e-μ events with the prediction of a pair of heavy leptons, [9] we can note the following remarkable fact:

$$m_\mu - m_e \sim m_\lambda - m_p \quad \text{and} \quad m_c - m_p \sim M_E - m_e .$$

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)We note that a 5-quark model of ψ particles was considered independently later in[2,3].

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