MESONS BELOW 1.5 GeV AS ADMIXTURES OF $\overline{q}q$ AND $\overline{q}\overline{q}qq$ STATES

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Meson mass spectrum indicates the existence of a degenerate chiral nonet in the energy region around 1.4 GeV with a slightly inverted spectrum with respect to a $\overline{q}q$ nonet. Based on the "natural" linear rising of the mass of a hadron with the number of constituent quarks we study the possibility that scalar and pseudoscalar mesons below 1.5 GeV actually come from the mixing of normal $\overline{q}q$ states with $\overline{q}\overline{q}qq$ states, the latter forming a chiral nonet chiral symmetry realized directly. We find that the mass spectrum of mesons below 1.5 GeV is consistent with this picture. In general, pseudoscalar states arise as mainly $\overline{q}q$ states but scalar states turn out to be strong admixtures of $\overline{q}q$ and tetraquark states.

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Scalar mesons are the most controversial sector of low energy QCD. Its study and is of primary interest since these mesons have the same quantum numbers as the QCD vacuum and the understanding of scalar meson properties are expected to yield some light on the structure of the QCD vacuum. The most intriguing features of scalar mesons are the inverted spectrum it manifests with respect to conventional $\overline{q}q$ states and their tiny coupling to two photons.

The quark structure of mesons is usually inferred from their SU(3) structure which is identified with transformation properties of quark currents under the $SU(3)_F$ group. In QCD the $SU(3)_F$ group arise as the diagonal symmetry group surviving the spontaneous breaking of the chiral symmetry of massless QCD appropriate to the study of mesons composed of light quarks. Since chiral Lagrangians deal with effective degrees of freedom (d.o.f.), in principle, transformation properties of these d.o.f. can be mapped directly to a quark content. This mapping must be taken carefully as discussed in [1].

The classic study of tetraquark structures by Jaffe [2] in the framework of a quark-bag model predicted a light scalar nonet with an inverted spectrum which nowadays can be identified with a nonet composed by the $f_0(980)$, $a_0(980)$, $f_0(600)$ (or σ) and the more controversial $\kappa(900)$. In this framework, the inverted mass spectrum is related to the flavor structure of tetraquarks. A strong attractive gluon-magnetic interaction is essential here in order to pull the natural scale $M \sim 4m_q \approx 1.4$ GeV down to $M \approx 900$ MeV.

An alternative explanation to the inverted spectrum of light scalars was formulated, based on the properties of the QCD vacuum [3,4]. This explanation relies on the long distance description of these mesons embraced in effective Lagrangians which take into account the main properties of the QCD vacuum, the spontaneous breaking of chiral symmetry and the breaking of the $U_A(1)$ symmetry by non-perturbative effects. The role of the effective six-quark interaction due to instantons [5] in the inversion of the light scalar spectrum was emphasized in [4].

The existence of two scalar nonets, one below 1 GeV and another one around 1.4 GeV, lead to the exploration of two nonet models and to the study of the properties of four-quark states under chiral symmetry [1,6,7]. In these papers, following [2] four-quark states are always identified as the light mesons.

In this paper we take a different approach to scalar mesons. First we notice that in the energy region around 1.4 GeV the Particle Data Group lists the following scalar states : $f_0(1370)$, $K_0^*(1430)$, $a_0(1450)$, and $f_0(1500)$ [8]. In addition we have the $f_0(1710)$ at a slightly higher mass [8]. We note also that if we consider the former states as the members of a nonet then it presents a slightly inverted mass spectrum. Furthermore, a look onto the pseudoscalar side at the same energy yields the following states: $\eta(1295)$, $\eta(1440)$, $K(1460)$, $\pi(1300)$ [8]. Thus *the data seem to indicate the existence of a quasi-degenerate chiral nonet around 1.4 GeV whose scalar component has a slightly inverted mass spectrum.* On the other hand, the linear rising of the mass of a hadron with the number of constituent quarks indicates that four-quark states should lie slightly below 1.5 GeV. This lead us to conjecture that this chiral nonet comes from tetraquark states mixed with conventional $\overline{q}q$ mesons to form physical mesons. The quasi-degeneracy of this chiral nonet suggest that chiral symmetry is realized in a direct way for tetraquark states.

We report results on the implementation of this idea in the framework of an effective chiral Lagrangian. We start with two chiral nonets, one around 1.4 GeV with chiral symmetry realized directly, and another one at low energy with chiral symmetry spontaneously broken. In contrast to previous studies, mesons in the "heavy" nonet are considered as four-quark states. The nature of these states is distinguished from conventional $\overline{q}q$ mesons by terms breaking the $U_A(1)$ symmetry. We introduce also mass terms appropriate to four-quark states which yield an inverted spectrum for the "pure" four-quark structured fields. These states mix with conventional $\overline{q}q$ states to yield physical mesons.

The idea of a chiral tetraquark nonet is implemented in the framework of an effective model written in terms of "standard" ($\overline{q}q$-like ground states) meson fields and "non-standard" (four-quark like states) fields denoted as $\Phi = S + iP$ and $\hat{\Phi} = \hat{S} + i\hat{P}$ respectively. Here, S, $\hat{S}$ and P, $\hat{P}$ denote matrix fields defined as

$$F \equiv \frac{1}{\sqrt{2}} f_i \lambda_i \qquad i = 1, ..., 7, ns, s, \tag{1}$$

where f_i stands for a generic field, λ_i $(i = 1, ..., 7)$ denote the Gell-Mann matrices and we work in the strange-non-strange basis for the isoscalar sector, i.e. we use $\lambda_{ns} = diag(1, 1, 0)$ and $\lambda_s = \sqrt{2} diag(0, 0, 1)$. Explicitly, the bare S, $\hat{S}$ scalar and P, $\hat{P}$ pseudoscalar nonets are given by

$$S = \begin{pmatrix} \frac{S_{ns}+S^0}{\sqrt{2}} & S^+ & Y^+ \\ S^- & \frac{S_{ns}-S^0}{\sqrt{2}} & Y^0 \\ Y^- & \bar{Y}^0 & S_s \end{pmatrix}; P = \begin{pmatrix} \frac{H_{ns}+p^0}{\sqrt{2}} & p^+ & X^+ \\ p^- & \frac{H_{ns}-p^0}{\sqrt{2}} & X^0 \\ X^- & \bar{X}^0 & H_s \end{pmatrix}, \tag{2}$$

$$\hat{S} = \begin{pmatrix} \frac{\hat{S}_{ns}+\hat{S}^0}{\sqrt{2}} & \hat{S}^+ & \hat{Y}^+ \\ \hat{S}^- & \frac{\hat{S}_{ns}-\hat{S}^0}{\sqrt{2}} & \hat{Y}^0 \\ \hat{Y}^- & \overline{\hat{Y}}^0 & \hat{S}_s \end{pmatrix} ; \hat{P} = \begin{pmatrix} \frac{\hat{H}_{ns}+\hat{p}^0}{\sqrt{2}} & \hat{p}^+ & \hat{X}^+ \\ \hat{p}^- & \frac{\hat{H}_{ns}-\hat{p}^0}{\sqrt{2}} & \hat{X}^0 \\ \hat{X}^- & \overline{\hat{X}}^0 & \hat{H}_s \end{pmatrix} . \quad (3)$$

Next we implement the idea of a chiral nonet around 1.4 GeV using an effective linear Lagrangian in terms of the four-quark structured fields $\hat{\Phi}$ with chiral symmetry realized linearly and directly ($\hat{\mu}^2 > 0$)

$$\mathcal{L}(\hat{\Phi}) = \mathcal{L}_{sym}(\hat{\Phi}) + \mathcal{L}^{(1)}_{SB}(\hat{\Phi}),$$

$$\mathcal{L}_{sym}(\hat{\Phi}) = \frac{1}{2}\left\langle \partial_\mu \hat{\Phi}\, \partial^\mu \hat{\Phi}^\dagger \right\rangle - \frac{\hat{\mu}^2}{2}\left\langle \hat{\Phi}\hat{\Phi}^\dagger \right\rangle - \frac{\widehat{\lambda}}{4}\left\langle (\hat{\Phi}\hat{\Phi}^\dagger)^2 \right\rangle , \quad (4)$$

$$\mathcal{L}^{(1)}_{SB}(\hat{\Phi}) = -\frac{\hat{c}}{4}\left\langle \mathcal{M}_Q(\hat{\Phi}\hat{\Phi}^\dagger + \hat{\Phi}^\dagger\hat{\Phi}) \right\rangle .$$

Here, $\hat{\mu}$ sets the scale at which four-quark states lie, it is expected to be slightly below 1.4 GeV. Although some of the fields in $\hat{\Phi}$ have the same quantum numbers as the vacuum they do not acquire vacuum expectation values (vev´s) since we require a direct realization of chiral symmetry. The symmetry breaking term in Eq. (4) requires some explanation. This is an explicit breaking term quadratic in the fields and proportional to a quadratic quark mass matrix. The point is that in a chiral expansion the quark mass matrix has a non-trivial flavor structure and enters as an external scalar field. In the case of a four-quark nonet there must be breaking terms with the appropriate flavor structure. This matrix is constructed according to the flavor structure of the quark mass matrix as

$$(\mathcal{M}_Q)_a{}^b = \frac{1}{2}\epsilon_{acd}\epsilon^{bef}({\mathcal{M}_q}^\dagger)_e{}^c({\mathcal{M}_q}^\dagger)_f{}^d, \quad (5)$$

where $\mathcal{M}_q = Diag(m, m, m_s)$ stands for the conventional quark mass matrix in the good isospin limit which we will consider henceforth. Explicitly we obtain $\mathcal{M}_Q = Diag(mm_s, mm_s, m^2)$. This structure yields to pure 4q-structured fields an inverted spectrum with respect to conventional states. A word of caution is necessary concerning the notation in Eq. (3). The matrix field for four-quark states has a schematic quark content

$$\hat{\Phi} \sim \begin{pmatrix} \overline{q}q\overline{s}s & \overline{q}q\overline{s}s & \overline{q}q\overline{q}s \\ \overline{q}q\overline{s}s & \overline{q}q\overline{s}s & \overline{q}q\overline{q}s \\ \overline{q}q\overline{q}s & \overline{q}q\overline{q}s & \overline{q}q\overline{q}q \end{pmatrix} , \quad (6)$$

where q denotes u or d quarks. The subindex s and ns in these fields refer to the notation for $SU(3)$ matrices in Eq. (1) but do not correspond with the hidden quark-antiquark content, e.g $\hat{S}_{ns} \sim \overline{q}q\overline{s}s$ and $\hat{S}_s \sim \overline{q}q\overline{q}q$.

Conventional $\overline{q}q$-structured fields are introduced in a chirally symmetric way with chiral symmetry spontaneously broken. We introduce also an instanton inspired breaking for the $U_A(1)$

symmetry. Notice that the determinantal interaction is appropriate for $\overline{q}q$-structured fields but not for four-quark fields since this is a six-quark interaction

$$\mathcal{L}(\Phi) \quad = \mathcal{L}_{sym}(\Phi) + \mathcal{L}_A + \mathcal{L}^{(2)}_{SB}(\Phi), \tag{7}$$

$$\mathcal{L}_{sym}(\Phi) \quad = \tfrac{1}{2}\left\langle \partial_\mu \Phi \partial^\mu \Phi^\dagger \right\rangle - \tfrac{\mu^2}{2}\left\langle \Phi\Phi^\dagger \right\rangle - \tfrac{\lambda}{4}\left\langle (\Phi\Phi^\dagger)^2 \right\rangle,$$

$$\mathcal{L}_A \quad = -B\left(\det\Phi + \det\Phi^\dagger\right), \quad \mathcal{L}^{(2)}_{SB}(\Phi) = \tfrac{b_0}{\sqrt{2}}\left\langle \mathcal{M}_q\left(\Phi + \Phi^\dagger\right)\right\rangle. \tag{8}$$

This is just the model used in [3,4] except for an OZI-forbidden interaction whose corresponding coupling is consistent with zero when included in the present context. The Lagrangian

$$\mathcal{L}_{sym}(\Phi, \hat{\Phi}) = \mathcal{L}_{sym}(\Phi) + \mathcal{L}_{sym}(\hat{\Phi}) \tag{9}$$

is invariant under the independent chiral transformations

$$\Phi \to U_L(\alpha_L)\Phi U^\dagger_R(\alpha_R), \qquad \hat{\Phi} \to \hat{\Phi}, \tag{10}$$

$$\Phi \to \Phi, \qquad \hat{\Phi} \to \hat{U}_L(\hat{\alpha}_L)\hat{\Phi}\hat{U}^\dagger_R(\hat{\alpha}_R), \tag{11}$$

i.e., it has $(U(3)\times U(3))^2$ symmetry. This symmetry is explicitly broken down to $SU(3)_A \times U(3)_V$ by the interaction

$$\mathcal{L}_{\epsilon^2} = -\frac{\epsilon^2}{4}\left\langle \Phi\hat{\Phi}^\dagger + \hat{\Phi}\Phi^\dagger \right\rangle. \tag{12}$$

Further sources of breaking come from the anomaly term and quark mass terms in Eqs. (4, 7). Finally, since we are considering quark masses entering as external scalar fields we also consider the following terms

$$\mathcal{L}^{(3)}_{SB} = \frac{\hat{b}_0}{\sqrt{2}}\left\langle \mathcal{M}_q(\hat{\Phi} + \hat{\Phi}^\dagger)\right\rangle + \frac{\hat{d}}{\sqrt{2}}\left\langle \mathcal{M}_Q(\hat{\Phi} + \hat{\Phi}^\dagger)\right\rangle. \tag{13}$$

A last term proportional to $\left\langle \mathcal{M}_Q(\Phi + \Phi^\dagger)\right\rangle$ can also be added without altering the conclusions of this work. The linear terms in (8) induce scalar-to-vacuum transitions which instabilizes the vacuum. We shift to the true vacuum, $S \to S - V$ where V stands for the vacuum expectation values of S which we denote as $V = diag(a, a, b)$. This mechanisms generates new meson mass terms and interactions. In particular, the shift generates linear terms in $\hat{\Phi}$ which cancel against the linear terms in Eq. (13). Here, we present results for meson masses, details of the calculations and results for interactions will be published elsewhere.

For the isodoublets and isotriplets, the interaction term $\mathcal{L}_{\epsilon^2}$ mix up $\overline{q}q$ and four-quark states. We define the diagonal isotriplet pseudoscalar fields as

$$\begin{pmatrix} \pi \\ \hat{\pi} \end{pmatrix} = \begin{pmatrix} \cos(\theta_1) & -\sin(\theta_1) \\ \sin(\theta_1) & \cos(\theta_1) \end{pmatrix} \begin{pmatrix} p \\ \hat{p} \end{pmatrix}. \tag{14}$$

For the isotriplet scalar sector we denote the physical fields as a , A and the corresponding mixing angle is denoted by ϕ_1. For the isodoublets we denote the physical fields as $K, \hat{K}$ $(\kappa, \hat{\kappa})$, and the mixing angle as $\theta_{1/2}$ ($\phi_{1/2}$) for pseudoscalars (scalars).

The isosinglet sectors are more involved due to the effects coming from the $U_A(1)$ anomaly which when combined with the spontaneous breaking of chiral symmetry produces mixing among four different fields. The mass Lagrangian for the isoscalar pseudoscalar sector reads

$$\mathcal{L}_H = -\frac{1}{2} \langle H| \, M_H \, |H\rangle \, , \tag{15}$$

where

$$|H\rangle = \begin{pmatrix} H_{ns} \\ H_s \\ \hat{H}_{ns} \\ \hat{H}_s \end{pmatrix}, \quad M_H = \begin{pmatrix} m^2_{H_{ns}} & m^2_{H_{s-ns}} & \frac{\epsilon^2}{2} & 0 \\ m^2_{H_{s-ns}} & m^2_{H_s} & 0 & \frac{\epsilon^2}{2} \\ \frac{\epsilon^2}{2} & 0 & m^2_{\hat{H}_{ns}} & 0 \\ 0 & \frac{\epsilon^2}{2} & 0 & m^2_{\hat{H}_s} \end{pmatrix}, \tag{16}$$

with

$$\begin{aligned} m^2_{H_{ns}} &= \mu^2 - 2Bb + \lambda a^2, & m^2_{\hat{H}_{ns}} &= \hat{\mu}^2 + \hat{c} m m_s, \\ m^2_{H_s} &= \mu^2 + \lambda b^2, & m^2_{\hat{H}_s} &= \hat{\mu}^2 + \hat{c} m^2, \\ m^2_{H_{s-ns}} &= -2\sqrt{2} B a. \end{aligned} \tag{17}$$

For the isoscalar-scalar sector we obtain a similar structure. In principle, these matrices are diagonalized by a general rotation in $O(4)$ containing six independent parameters. However, modulo corrections of the order $m(m_s - m)/\hat{\mu}^2$, it can be shown that they are actually diagonalized by a rotation in the subgroup $SO(2) \otimes SO(2) \otimes SO(2)$ and a straightforward analytic solution depending on three angles is obtained for the rotation matrix. Explicitly, under this approximation the physical pseudoscalar fields are given as

$$\begin{pmatrix} \eta \\ \eta' \\ \hat{\eta} \\ \hat{\eta}' \end{pmatrix} = \begin{pmatrix} c_\alpha c_\beta & -s_\alpha c_\beta & -c_\alpha s_\beta & s_\alpha s_\beta \\ s_\alpha c_{\beta'} & c_\alpha c_{\beta'} & s_\alpha s_{\beta'} & c_\alpha s_{\beta'} \\ c_\alpha s_\beta & -s_\alpha s_\beta & c_\alpha c_\beta & -s_\alpha c_\beta \\ -s_\alpha s'_\beta & -c_\alpha c_{\beta'} & s_\alpha c_{\beta'} & c_\alpha c_{\beta'} \end{pmatrix} \begin{pmatrix} H_{ns} \\ H_s \\ \hat{H}_{ns} \\ \hat{H}_s \end{pmatrix},$$

where $c_\alpha \equiv \cos\alpha$, $s_\alpha \equiv \sin\alpha$. Similarly physical scalar mesons and mixing angles are defined as

$$\begin{pmatrix} \sigma \\ f_0 \\ \hat{\sigma} \\ \hat{f}_0 \end{pmatrix} = \begin{pmatrix} c_\gamma c_\delta & -s_\gamma c_\delta & -c_\gamma s_\delta & s_\gamma s_\delta \\ s_\gamma c_{\delta'} & c_\gamma c_{\delta'} & s_\gamma s_{\delta'} & c_\gamma s_{\delta'} \\ c_\gamma s_\delta & -s_\gamma s_\delta & c_\gamma c_\delta & -s_\gamma c_\delta \\ -s_\gamma s_{\delta'} & -c_\gamma c_{\delta'} & s_\gamma c_{\delta'} & c_\gamma c_{\delta'} \end{pmatrix} \begin{pmatrix} S_{ns} \\ S_s \\ \hat{S}_{ns} \\ \hat{S}_s \end{pmatrix}.$$

Finally, a calculation of the axial currents allow us to relate the vacuum expectation values of scalars to the weak decay constants of pseudoscalars as

$$a = \frac{f_\pi}{\sqrt{2}\cos\theta_1}, \quad a + b = \frac{\sqrt{2} f_K}{\cos\theta_{1/2}}. \tag{18}$$

Tab. 1. Input used to fix the parameters entering the model and their values.

	Input	Parameter	Fit
m_π	137.3 ± 2.3 MeV	$\hat{\mu}_1$(MeV)	1257.5 ± 61.3
m_a	984.3 ± 0.9 MeV	$\hat{\mu}_{1/2}$(MeV)	1206.2 ± 142.3
f_π	92.42 ± 3.53 MeV	$\lvert\epsilon\rvert$ (MeV)	1012.3 ± 75.9
m_K	495.67 ± 2.00 MeV	a(MeV)	68.78 ± 4.47
f_K	113.0 ± 1.3 MeV	b(MeV)	104.8 ± 2.6
m_η	547.30 ± 0.12 MeV	B(GeV)	-2.16 ± 0.28
$m_{\eta'}$	957.78 ± 0.14 MeV	λ	31.8 ± 5.9
$m_{\hat{\eta}}$	1297.0 ± 2.8 MeV	μ^2(GeV^2)	0.490 ± 0.107

There are eight free parameters in the model which are relevant to meson masses: $\{\mu^2, \lambda, B, \epsilon^2, a, b, \hat{\mu}_1^2, \hat{\mu}_{1/2}^2\}$, where $\hat{\mu}_{1/2}^2 \equiv \hat{\mu}^2 + \frac{\widehat{c}}{2} m(m+m_s)$ and $\hat{\mu}_1^2 \equiv \hat{\mu}^2 + \widehat{c} m m_s$. Our input are the physical quantities listed in Table 1 , namely, the masses for $\pi(137)$, $a_0(980)$, $K(495)$, $\eta(547)$, $\eta'(958)$, $\eta(1295)$ in addition to the weak decay constants f_π and f_K. Uncertainties listed in this table correspond to the measured values in the case of the isosinglets [8]. Since we are working in the good isospin limit we use the experimental deviations from this limit for the uncertainties in the masses of isotriplets and isodoublets. Using these values we fix the parameters to the values also listed in Table 1.

In Table 2 we show the predictions of the model for the remaining meson masses and mixing angles and the experimental values for these quantities when available. The quark content of mesons corresponding to the central values of these mixing angles are shown in Figs. 1, 2, 3. In Fig. 1 we show results for the light isodoublets and isotriples. Heavy mesons have the opposite quark content. We obtain pions and kaons as mainly $q\overline{q}$ states whereas the heavy fields $\pi(1300)$, $K(1460)$ arise as mainly tetraquark states. In contrast, in the scalar sector isotriplets and isodoublets get strongly mixed and the physical mesons turn out to have almost identical amounts of $q\overline{q}$ and four-quark content. In Fig. 2 we show results for isosinglet pseudoscalars. Here, in the case of $\eta(547)$ we obtain also a small four-quark content, the $\eta(1295)$ being almost a four-quark state. However, the $\eta'(958)$ and $\eta(1440)$, turn out to be strong admixtures of $q\overline{q}$ and four-quark states with almost equal amounts of them. As to the isosinglet scalars Fig. 3 shows that the sigma meson ($f_0(600)$) arises as mainly $q\overline{q}$ state and the opposite quark content is carried by the $f_0(1370)$ which turns out to be mainly a four quark state. Finally, the $f_0(980)$ turns out to be have roughly a 40% content of $\overline{q}q$ (more explicitly $\overline{s}s$) and 60% of $\overline{q}\overline{q}qq$ whereas the $f_0(1500)$ is composed 60% of $\overline{q}q$ (more explicitly $\overline{s}s$) and almost 40% of $\overline{q}\overline{q}qq$. We stress again that quark content of isoscalar scalar mesons shown in Fig. 3 are expected to be modified by the inclusion of the scalar glueball in the present context although we do not expect strong modifications in the case of the $f_0(600)$ which is far from the energy region around 1.6 GeV where this state is expected.

Summarizing, in this work we point out the possibility that scalar and pseudoscalar mesons below 1.5 GeV be admixtures of conventional $\overline{q}q$ and tetraquark states. This conjecture is risen by the observation that beyond the light scalars lying below 1 GeV, there are nine states around

Tab. 2. Predictions of the model for meson masses and mixing angles.

Mass	Prediction	Identification	Exp
$m_{\hat{\pi}}$(MeV)	1322.6 ± 32.4	$\pi(1300)$	1300 ± 200 [8]
$m_{\hat{K}}$(MeV)	1293.1 ± 3.5	$K(1460)$	$1400 - 1460$ [8]
m_{A}(MeV)	1417.3 ± 51.0	$a_0(1450)$	1474 ± 19 [8]
m_{κ}(MeV)	986.2 ± 19.1	$\kappa(900)$	$750 - 950$ [9–11]
$m_{\hat{\kappa}}$(MeV)	1413.9 ± 76.4	$K_0^*(1430)$	$1429 \pm 4 \pm 5$ [8]
$m'_{\hat{\eta}}$(MeV)	1394.0 ± 61.9	$\eta(1440)$	$1400 - 1470$ [8]
m_{σ}(MeV)	380.6 ± 91.0	$f_0(600)$or σ	478 ± 35 [9]
m_{f_0}(MeV)	1022.4 ± 25.6	$f_0(980)$	980 ± 10 [8]
$m_{\hat{\sigma}}$(MeV)	1284.7 ± 15.3	$f_0(1370)$	$1200 - 1500$ [8]
$m_{\hat{f}_0}$(MeV)	1447.7 ± 84.6	$f_0(1500)$	1500 ± 10 [8]
θ_1	$18.16^\circ \pm 4.34^\circ$		
$\theta_{1/2}$	$22.96^\circ \pm 4.84^\circ$		
ϕ_1	$39.8^\circ \pm 4.5^\circ$		
$\phi_{1/2}$	$46.7^\circ \pm 9.5^\circ$		
α	$53.4^\circ \pm 0.8^\circ$		
β	$23.9^\circ \pm 5.1^\circ$		
β'	$43.6^\circ \pm 7.2^\circ$		
γ	$-9.11^\circ \pm 0.49^\circ$		
δ	$21.45^\circ \pm 6.49^\circ$		
δ'	$51.36^\circ \pm 8.35^\circ$		

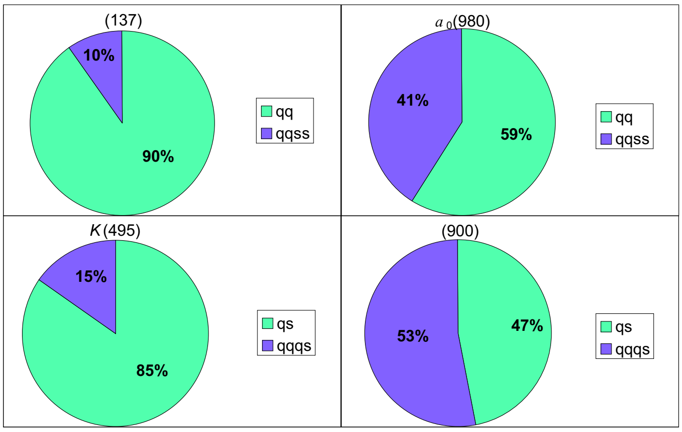

Fig. 1. Quark content of light isotriplet and isodoublets.

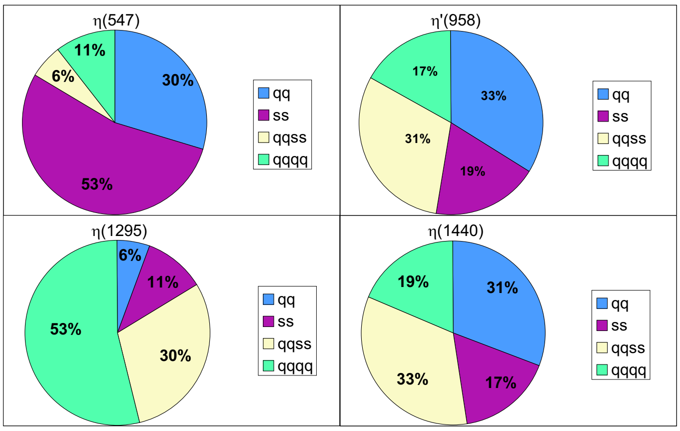

Fig. 2. Quark content of light isosinglet pseudoscalars.

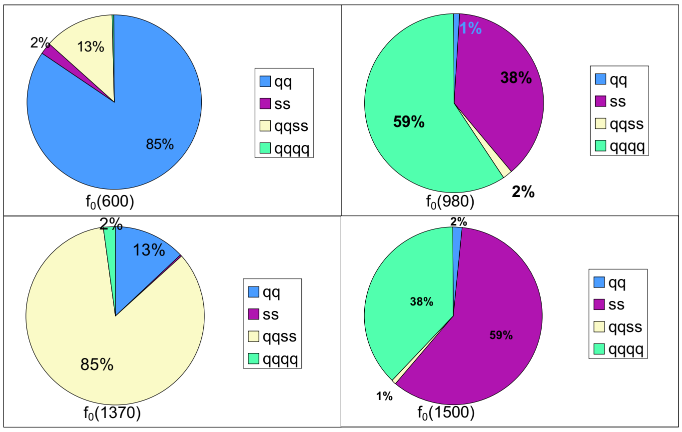

Fig. 3. Quark content of light isosinglet scalars.

1.4 GeV which, when considered as the members of a nonet, exhibit a slightly inverted mass spectrum as compared with a conventional $\overline{q}q$ nonet. Furthermore this nonet lies at an energy scale compatible with that of tetraquarks according to the linear rising of the mass of a hadron with the number of constituents. There is a nonet of pseudoscalar states at the same mass which suggest these nonets form a chiral nonet. We implement this idea in the framework of a chiral model. As a result we obtain a meson spectrum consistent with the measured pseudoscalar and scalar meson spectrum below 1.5 GeV. The lightest pseudoscalar states turn out to be mainly $\overline{q}q$, thus conventional picture for these mesons is only slightly modified. All other mesons, acquire a non-negligible four-quark component in this model.

Although the results of the present paper are encouraging, certainly spectroscopic data is not the only signature for multiquark states and the picture of mesons below 1.5 GeV, as arising in the present model, must be confirmed by the calculation of other physical properties such as partial and total decay widths. This can be easily done in the present model since it gives definitive predictions for the different couplings of the involved mesons. This is a subject of future research. Also, in a wider perspective one should look for signatures of tetraquarks in the decays of heavy mesons, e.g. in the $B\bar{B}$ channels.

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