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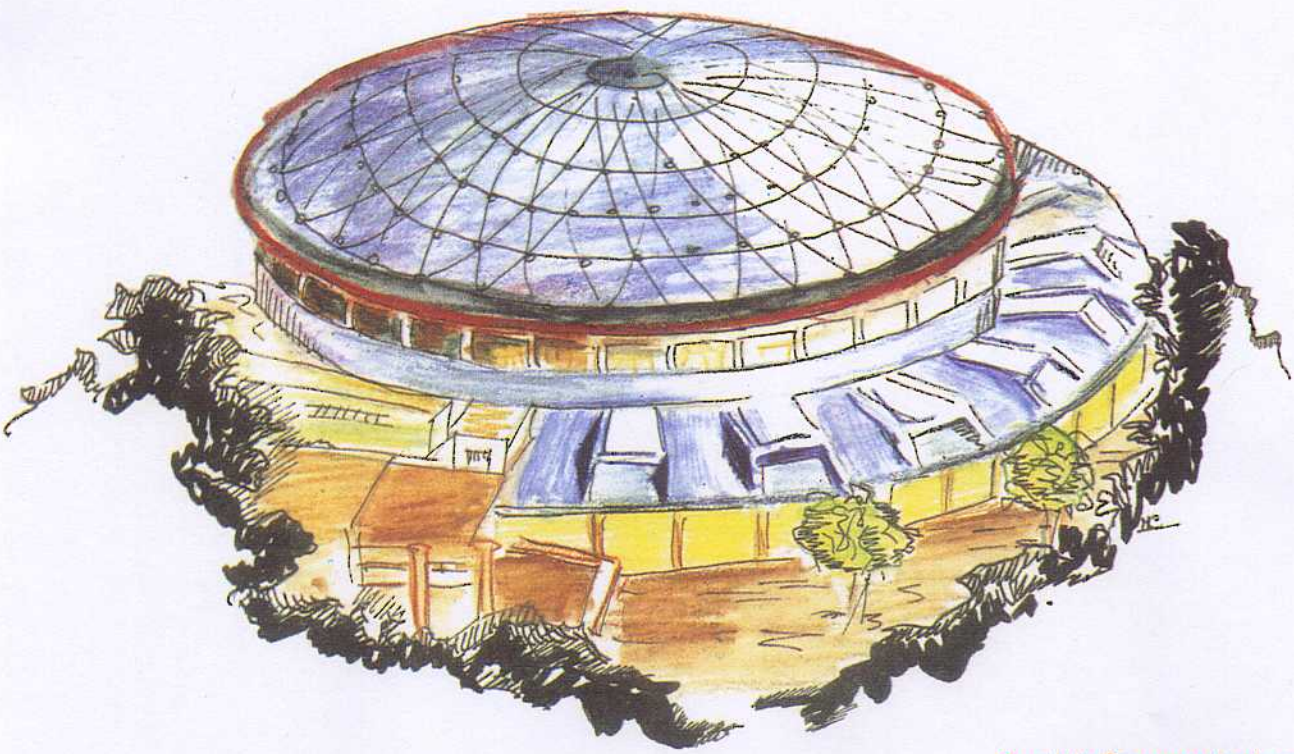
Contribution to the DAΦNE Physics Handbook



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ON POSSIBLE FOUR-QUARK MESON STATES IN THE MASS REGION NEAR 1.5 GEV

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Abstact

The four-quark interpretation of recently discovered f_2/AX resonance in string model as a D-wave state of two scalar diquarks fixes the parameters of this model and leads to the prediction of masses of all other 4q-states. Here I discuss briefly the spectrum of these states, in particular of the possible low-lying 1^{--} 4q-resonances, which could be produced in e^+e^- collisions at DAΦNE.

Recently several experimental groups confirmed the existence of a new $J^{PC}\, I^G = 2^{++}\, 0^+$ resonance with mass about 1520 MeV. It was first seen by the ASTERIX collaboration at LEAR in the $\pi^+\pi^-$ decay mode and was called AX(1565)[1]. The Crystall Barrel collaboration has observed a very clear signal in the $\pi^0\pi^0$ channel with the quantum numbers of AX(1565) and a mass of 1515 MeV[2]. Also the OBELIX collaboration has observed a clear peak at a mass about 1560 MeV in the $\pi^+\pi^-$ final state[3]. Finally, E-760 Collaboration at Fermilab[4] has seen a bump in the $\pi^0\pi^0$ invariant mass in the region of AX resonance from $\bar{p}p$ annihilation at three values of a total energy $\sqrt{s}$ between 3.1 and 3.5 GeV. The peak has been seen rather far from the phase space boundary (in contrast to annihilation at rest).

A possible explanation of the nature of this resonance was suggested by C.Guaraldo, L.Kondratyuk and the author[5]. This state was interpreted as a scalar (and isoscalar) diquark connected with the same antidiquark by a gluon string and rotating with angular momentum L = 2. In the frame of string model[6,7] there must exist not only isoscalar 4q-mesons built from scalar diquarks, but also states constructed from vector (and isovector) diquarks and from their strange partners. In paper[5] we discussed strange 2^+ partners of f_2/AX resonance which can be detected in $\bar{p}p$ annihilations at flight. Here I am going to concentrate on those 4q-states which can be produced in e^+e^- annihilations at DAΦNE.

The quark dynamics in the string model is very transparent. The conclusion that 4q states should exist may be regarded as a consequence of the existence of meson and baryon Regge trajectories with the identical slopes $\alpha' = 0.9\ \mathrm{GeV}^{-2}$ (see ref.[8]):

$$M_L^2 = M_0^2 + \frac{1}{\alpha'}L. \tag{1}$$

where M_L is the mass of orbital excitation with angular momentum equal to L and M_0 is a mass of the ground state.

If meson resonances correspond to rotating string (or flux tube) with triplet color charges (quark and antiquark) at its ends, baryon resonances should then correspond to $q - q^2$ configuration, where the diquark has the same color charge as an antiquark. If the quark in this system is replaced by an antidiquark, we obtain the diquonium state with color-triplet diquarks. Therefore the very existence of meson and baryon Regge trajectories with the identical slopes implies the existence of $q^2 - \bar{q}^2$ states at least at comparetively large L.

There are two kinds of nonstrange color triplet diquarks $D_{00} \equiv (q^2)$ with $S = I = 0$ and $D_{11} \equiv (q^2)$ with $S = I = 1$ (S is the spin of diquark, I is the isospin). So it is possible to construct three different types of 4q-mesons without strange quark[7]:

$$\begin{aligned} A &= |D_{00} - \overline{D_{00}}> \\ B^{\pm} &= |D_{00} - \overline{D_{11}}> \pm |\overline{D_{00}} - D_{11}> \\ C &= |D_{11} - \overline{D_{11}}>, \end{aligned} \tag{2}$$

where the state A has isospin 0, the states $B^{\pm}$ have isospin 1 and the state C degenerate with respect to isospin (I = 0,1,2).

The mass difference between non-strange vector and scalar diquarks can be estimated from the mass difference between octet and decuplet S-wave baryons:

$$m(D_{11}) - m(D_{00}) = \frac{2}{3}[m(\Delta) - m(N)] \approx 200\ \mathrm{MeV}. \tag{3}$$

In[5] we suggested that f_2/AX meson is not the S-wave of vector diquark-antidiquark state with $J^{PC}\,I^G = 2^{++}\,0^+$ quantum numbers (C-type 4q-meson), which is the lowest 4q-state with these quantum numbers, but the D-wave of scalar diquark-antidiquark pair (A-type meson). The reason is that all S-wave 4q-mesons are expected to be very broad.

After we have identified f_2/AX meson with D-wave A-type state, the value of $\alpha' = 0.9\ GeV^{-2}$ and the mass difference given by eq.(3) completely determine the model and we come to the spectrum of non-strange 4q-mesons shown in Fig.1. To estimate spin-orbital and spin-spin splittings for $B^{\pm}$- and C-type mesons we used the splittings known for P- and D-wave 2q mesons.

The mass of low-lying $J^{PC}\ I^G = 1^{--}\ 1^-$ state in this model is about 1.3 GeV. This value coincide with the mass of recently discovered by LASS group $\rho(1270)$ meson[9]. 4q-nature of this state explains the absence of $\rho(1270)$ meson in e^+e^- annihilations on the present level of cross-sections.

There exist also experimental indications coming from e^+e^- data on the resonance with $I = 2$ and $J^P = 2^+$ in $\rho-\rho$ decay mode with the mass of the order of 1.6 GeV[10]. This exotic state in our model may be interpreted as D-wave state of C-type meson.

The low-lying vector meson in this model is ω meson with mass about 1.2 GeV. The mass difference between strange and non-strange diquarks can be estimated from the masses of well-known mesons:

$$m(f_2'(1525)) - m(f_2(1270)) \approx m(\phi(1020)) - m(\rho(770)) \approx$$
$$\approx 2[m(K^*(893)) - m(\rho(770))] \approx 2[m(K_2^*(1430)) - m(f_2(1270))] = 2\Delta m \approx 250\ MeV \quad (4)$$

where $\Delta m \approx 125$ MeV can be treated as the difference between masses of strange and nonstrange quarks.

Thus the partner of $\omega(1200)$ meson with hidden strangeness should have the mass of 1.45 GeV. This is very close to the mass of C(1480) meson seen by LEPTON - F group[11] in $\phi\pi$ decay channel. The present diquark string model predicts the existence of isoscalar partner of C(1480) meson.

Of course, the yields of 4q-mesons in $\bar{p}p$ annihilations should be much higher then in e^+e^- annihilations because in the first case initial state contains diquarks and antidiquarks, while in the second case they should be produced by virtual photon. Nevertheless, high DAΦNE luminosity makes it possible to produce the low-lying 1^{--} 4q-states. The model predicts the existence of $\omega(1200)$ A-type meson and of $\rho(1300)$ B-type state. In two mass regions: 1350 MeV and 1500 MeV the model predicts the appearance of degenerate with respect to isospin $\rho-\omega$ states of C-type. This is the specific prediction of our model which may be checked at DAΦNE.

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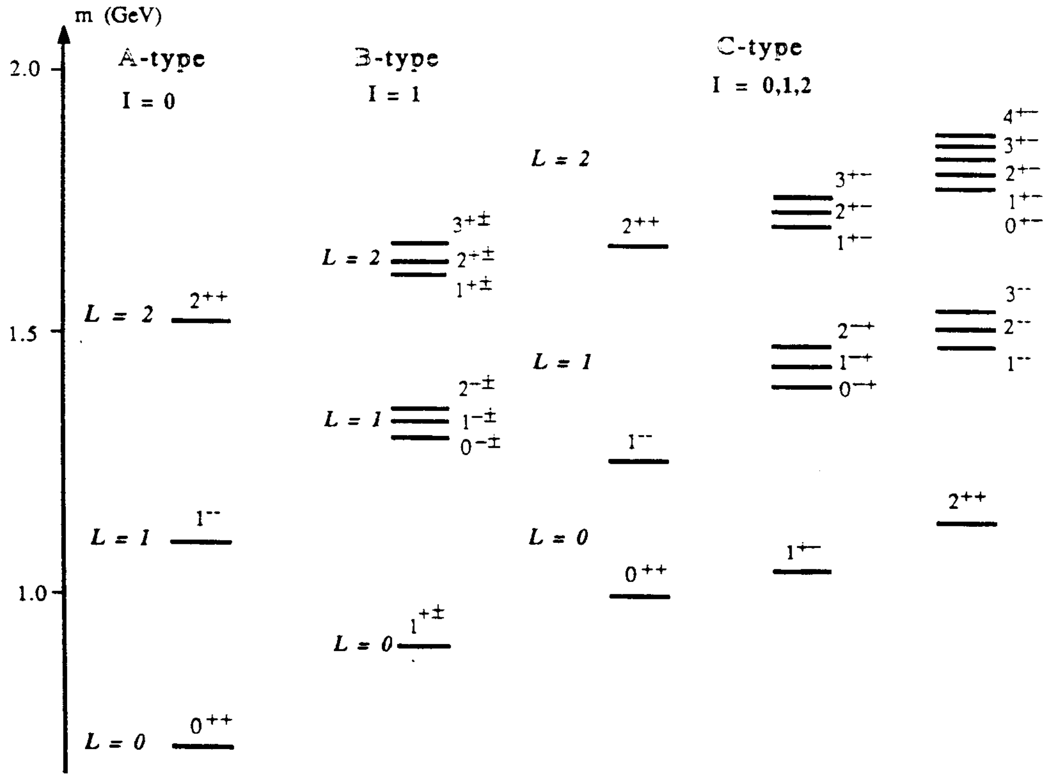

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