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E2-87-522

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ON THE SPECTRUM OF RADIAL EXCITATIONS OF THE ρ - AND ω -MESONS AND A POSSIBLE EXISTENCE OF ρ_g - AND ω_g-HYBRIDES

Submitted to "Ядерная физика"

1987

1. Introduction

The investigation of the problem of radial excitations of light mesons (consisting of u, d, s quarks) is of a considerable interest in view of the elucidation of the dynamics of light quarks inside hadrons and search of new "nonstandard" (gluonic, quark-gluonic and multiquark) states against a background of "standard" $q\bar{q}$ -states.

Hitherto we have no answer to the primary question: where is the first radial excitation of the light mesons[1,2]? For the most examined ρ - meson excitations there was an ambiguity connected with the possible existence of two resonances: $\rho(1250)$ and $\rho(1600)$ (for a minireview of this problem see in[3]).

Recently, the data on the reaction

$$e^+e^- \to \omega\pi^0 \qquad (1)$$

in the c.m. energy range from 1.0 to 1.4 GeV have appeared[4] and this ought to resolve the problem of the existence (or not) of $\rho(1250)$ because its main decay mode is $\omega\pi$ [2] and one should observe a resonance structure in the cross section of this reaction at 1.25 GeV. The authors of ref.[4] conclude that their results rule out the existence of this meson. In any case if it exists, then its e^+e^--decay width should be very small (see, also[5]).

Quite recently, the results of the investigation of the decay

$$\tau^- \to \nu_\tau \omega\pi^- \qquad (2)$$

have been published[6]. This research gives a very important information concerning the positions of the ρ-meson excitations because the measured spectral function for this decay is directly connected by CVC with the cross section of process (1). The authors of ref.[6] conclude that a combination $\rho(770) + \rho(1600)$ was ruled out and that with the present statictics one cannot prove or disprove a $\rho(1250)$ contribution. However, they do not analyse the triple combination $\rho(770) + \rho(1250) + \rho(1600)$.

There is the same problem for the ω-meson radial excitations.

On the basis of the quark model one can suggest the existence of ω - excitations with the same masses as for analogous ρ -excitations. The direct manifestation of them could be observed in the reaction

$$e^+e^- \to \pi^+\pi^-\pi^0 \qquad (3)$$

due to the main channel of (3) being the formation of intermadiate ω -meson resonances with subsequent their decays into $\rho\pi$ and then transition $\rho \to 2\pi$. Remark that there are three intermadiate charge channels of (3) ($\rho^+\pi^-$, $\rho^-\pi^+$, $\rho^0\pi^0$) which should interfer with each other. The process (3) has been investigated in the experiments/7-10/ in the whole c.m. energy range from 1.0 to 2.25 GeV and it gives a very valuable information about the excitations of vector mesons. In ref./9/ there was an indication of the appearance of ω(1600) in this reaction.

I undertook to analyse the processes (1) - (3) by means of VDM simultaneously. Meanwhile Donnachie et al./11,12/ carried out a subtle analysis of the production of 2π , 4π and $\eta\rho$ -systems in e^+e^- -collision and in photoproduction reactions. They have emphasized the importance of off-diagonal terms in photoproduction reactions and conclude that a consistent picture occurs when two resonances of ρ with masses of 1.465 ± 0.025 GeV and 1.700 ± 0.025 GeV with widths of 0.235 ± 0.025 GeV and 0.220 ± 0.025 GeV, respectively, are supposed to exist. Our results fully confirm this conjecture by Donnachie et al., but we find that a better agreement with experiments is achieved when the 1700 - resonance itself splits into two resonances: 1625 and 1750 . So, after all we have three resonances 1425, 1625 and 1750 against the 1600 old one (+ an illusive 1250). Such a large density of resonances in a narrow mass region requires an explanation. We suggest one of them to be superfluous within the $q\bar{q}$- model and interpret it as a new hybrid state (meikton, hermaphrodite).

In our consideration we include the broad ρ/ω(2100)-resonance too, which may be, in fact, a gathering of overlapping resonances/3/.

The paper is organized as follows. In Sect. 2 we consider the processes (1) - (3) on the basis of VDM and determine the fitting model parameters of introduced resonances from comparison with the data. In Sect. 3 we estimate the leptonic e^+e^- -decay widths by means of more speculative assumptions about branching ratios for these resonances. However, the latter does not prevent us from definite conclusions concerning these resonances, which we give in Sect. 4. Then in Sect. 5 we make closing remarks and discuss experi-

mental possibilities for a verification of our treatment of these resonances.

2. The processes in the framework of VMD

The processes of interest are described by a diagram shown in Fig. 1. (In the case of τ -decay it is necessary to substitute leptons e^+, e^- by τ , ν_τ and an intermadiate γ -quantum by W - boson). The intermadiate vector meson V_1 may be either ground ρ/ω -state or its excitations, whereas a meson V_2 is formed only in its ω/ρ -ground state.

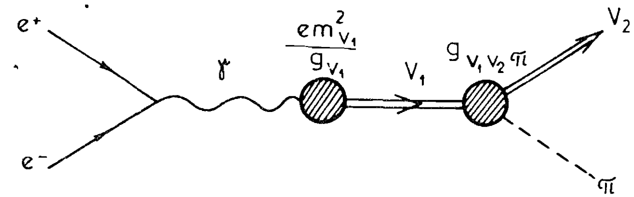

Fig. 1. The diagram of the process $e^+e^- \to V_2(\omega/\rho)\pi$ through an intermediate $V_1(\rho,\rho',... /\omega,\omega',...)$ meson.

Each intermadiate resonance is determined by its mass, m_{V_1} , and total width, $\Gamma^{tot.}_{V_1}$. We neglect the dependence of the widths on energy because it becomes important far from the resonance where the contribution of the latter is insignificant. The contribution of the resonance to the amplitude of the corresponding process is determined by the ratio of the strong constant $g_{V_1V_2\pi}$ to the leptonic constant g_{V_1} of the photon-vector meson transition:

$$B_{V_1} = g_{V_1V_2\pi} / g_{V_1} .$$

If the transition $V_1 \to V_2\pi$ is kinematically allowed, then the strong constant can be determined by the known value of the partial decay width

$$\Gamma(V_1 \to V_2\pi) = (g^2_{V_1V_2\pi}/12\pi)\ P^3_\pi , \qquad (4)$$

where P_π is the outgoing pion momentum. The leptonic constant is calculated from the value of the leptonic decay of resonance (if it is known)

$$\Gamma(V_1 \to e^+e^-) = (\alpha^2 m_{V_1}/3)(g^2_{V_1}/4\pi)^{-1}, \tag{5}$$

where $\alpha \approx 1/137$.

Within VDM cross sections of the processes (1) and (3) are given by the following expressions/13-15/:

$$\sigma(e^+e^- \to \omega\pi^o) = 4\pi\alpha^2 p^3_\pi/(3s^{3/2}) \cdot \left| \sum_{i=0,1,\dots} m^2_{\rho_i} B_{\rho_i} / (s - m^2_{\rho_i} + i m_{\rho_i} \Gamma^{tot}_{\rho_i}) \right|^2 \tag{6}$$

and

$$\sigma(e^+e^- \to \rho\pi \to \pi^+\pi^-\pi^o) = \alpha^2 m_\pi/(2\sqrt{s}) \cdot (g^2_{\rho\pi\pi}/4\pi) \cdot \left| \sum_{i=0,1,\dots} m^2_{\omega_i} B_{\omega_i} / (s - m^2_{\omega_i} + i m_{\omega_i} \Gamma^{tot}_{\omega_i}) \right|^2 \mathcal{J}(\sqrt{s}, m_\rho, \Gamma^{tot}_\rho), \tag{7}$$

where $\sqrt{s} = E_{e^+} + E_{e^-}$ is the total e.m. energy. Here we label the subsequent intermadiate ρ/ω - resonances by subscript $i = 0,1,\dots$ ($i = 0$ corresponds to ρ/ω - mesons). In eq. (7) the kinematical factor (an integral) $\mathcal{J}(\sqrt{s}, m_\rho, \Gamma^{tot}_\rho)$ takes into account the interference of the three charge channels and its dependence on the energy. The constant $g_{\rho\pi\pi} = 6.10 \pm 0.10$ was calculated from the value of the ρ -decay width $\Gamma(\rho \to \pi^+\pi^-) = (2/3)(g^2_{\rho\pi\pi}/4\pi) p^3_\pi / m^2_\rho = 153 \pm 2$ MeV /3/.

The expressions for the widths of the decays $\omega_i \to \pi^+\pi^-\pi^o$ ($i = 0, 1,\dots$) are analogous to (7)/16/:

$$\Gamma(\omega_i \to \rho\pi \to \pi^+\pi^-\pi^o) = m^2_\pi m_{\omega_i} (g^2_{\omega_i\rho\pi}/4\pi)(g^2_{\rho\pi\pi}/4\pi) \cdot \mathcal{J}(m_{\omega_i}, m_\rho, \Gamma^{tot}_\rho). \tag{8}$$

The spectral function for the decay (2) is directly related by CVC to the cross section for the process (1) at the same energy/6,17/:

$$v_{1\omega\pi}(\sqrt{s}) = s/(4\pi^2\alpha^2) \cdot \sigma(e^+e^- \to \omega\pi^o). \tag{9}$$

For ρ and ω - mesons parameters were determined in the following manner. The leptonic constants g_ρ, g_ω were calculated by means of eq. (5) from the available data on the leptonic widths/3/. The results of calculations are presented in Table 1.

Table 1. Parameters of ρ-, ω-, and φ - mesons

Meson, V	m_V, MeV	Γ^{tot}_V, MeV	$\Gamma(\ \to e^+e^-)$, keV	$g_{VV'\pi}$, GeV^{-1}	g_V	B_V, GeV^{-1}
ρ (770)	770 ± 3	153 ± 2	6.90 ± 0.30	16.6 ± 0.8	4.94 ± 0.10	3.36 ± 0.18
ω (783)	782.6 ± 0.2	9.8 ± 0.3	0.66 ± 0.04	16.6 ± 0.8	16.3 ± 0.5	1.02 ± 0.06
φ (1020)	1019.5 ± 0.1	4.22 ± 0.13	1.31 ± 0.06	0.74 ± 0.03	$-(13.2 \pm 0.3)$	$-(0.056 \pm 0.003)$

The underlined values are used in the following calculations.

The constant $g_{\rho\omega\pi}$ could be determined in the two following ways. The first is based on the application of the $SU(6)_W$ -relation:

$$g_{\rho\omega\pi} = 2 g_{\rho\pi\pi}/m_\rho \tag{10}$$

and gives the value $15.8 \pm 0.3\ GeV^{-1}$. The second consists in the determination of $g_{\omega\rho\pi} (= g_{\rho\omega\pi})$ from the known value of the width $\Gamma(\omega \to \rho\pi \to 3\pi) = 8.30 \pm 0.27$ MeV/3/ by means of eq. (8) and gives 16.6 $\pm$ 0.8 GeV^{-1}. As we can see, the values of $g_{\rho\omega\pi}$ calculated in these two ways almost coincide. In the following we shall make use of the latter (underlined) magnitude.

The calculated values of the parameters B_ρ and B_ω are presented in Table 1, too. As we can see, $B_\rho \approx 3B_\omega$ in accordance with the prediction of the quark model under condition of the ideal singlet-octet mixing.

In our calculation of the cross section of the reaction (3) we take into account a contribution from φ - meson too because it shares in $\rho\pi$ -decay with B.R. $(\varphi \to \rho\pi) = 0.12 \pm 0.01$/3/. The parameters of φ -meson were determined directly by means of eqs. (4) and (5) from data/3/. The results are presented in Table 1. Remark that the sign of g_φ (and B_φ) is opposite to signs of g_ω and g_ρ. For the excited ρ/ω - meson states their masses, total widths and ratios B_V were unknown fitting parameters determined by the comparison with the data. However on the basis of the quark model we admit the following relations between ρ_i and ω_i ($i = 1,2\dots$) parameters

$$m_{\rho_i} = m_{\omega_i},\ g_{\rho_i\omega\pi} = g_{\omega_i\rho\pi},\ g_{\rho_i} = g_{\omega_i}/3 \tag{11}$$

and as a consequence the relation: $B_{\rho_i} = 3B_{\omega_i}$.

We consider two models which include three and five resonances:

Model I (MI): $\rho(770)/\omega(783) + \rho'/\omega'(1600) + \rho''/\omega''(2100)$;

Model II (MII): $\rho(770)/\omega(783) + \rho'/\omega'(1425) + \rho''/\omega''(1625) + \rho'''/\omega'''(1750) + \rho^{IV}/\omega^{IV}(2100)$.

What concerns the ρ/ω (1750) and ρ/ω (2100) resonances, there is not enough knowledge about them. There is some indication of the existence of ρ (2100) in the $p\bar{p}$ -mode[3]. Recently some evidence in favour of the existence of ω(1880) with the width of 0.3 GeV has appeared in the diffractive photoproduction of $\rho_1\pi$ system[18]. In the framework of MII this enhancement could be explained as the overlapping of the ω(1750) and ω(2100)-resonances.

To get convinced of the necessity of the inclusion of these two higher-lying resonances in the MII, we carry out the calculation of the cross section of reaction (3) without them.

A correct description of every of three processes in our models requires that the subsequent resonances have alternating sign, i.e. their relative phase are +, −, +, − and so on, in accordance with the choice of Donnachie et al.[11,12].

The results of the best fits are expounded in Table 2.

Table 2. The fitting parameters of the resonances of ρ/ω - mesons

Resonance V	m_V, MeV	Γ_V^{tot}, MeV	B_V, GeV^{-1}
Model I			
ρ'/ω'	1600	400/500	-0.300/-.100
ρ''/ω''	2100	300	0.045/0.015
Model II			
ρ'/ω'	1425	240/300	-0.420/-0.140
ρ''/ω''	1625	250	0.316/0.105
ρ'''/ω'''	1750	400	-0.180/-0.060
ρ^{IV}/ω^{IV}	2100	700	0.090/0.030

The consent of the calculated cross section curves with experimantal data is shown in Fig. 2.

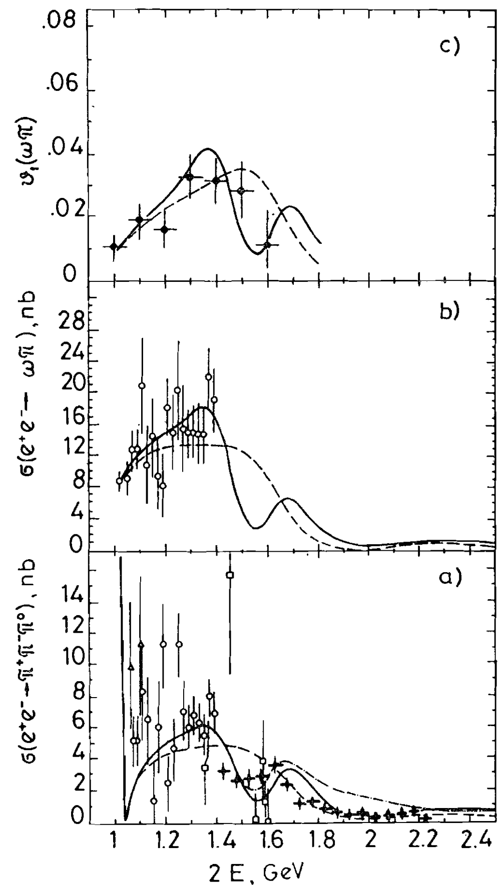

Fig. 2. The total cross sections for the processes: a) $e^+e^-\to\pi^+\pi^-\pi^0$, b) $e^+e^-\to\omega\pi^0$, and c) spectral function for the decay $\tau\to\nu_\tau\omega\pi$. The experimental data are: a) △ [7], □ [8], + [9], ○ [10], b) ○ [4], c) ● [6]. The calculated curves are: the dashed line for Model I, the solid line for Model II, the dot-dashed line on a) for Model II without ω(1750) and ω(2100) -resonances.

The inspection of the behaviour of calculated curves brought us to the following conclusions. For the processes (1) and (2) (Fig. 2 b, c) the data can be described successfully both by MI and MII. However, within the MI we ought to demand the biggest value 400/500 MeV for the total widths of the $\rho/\omega(1600)$ - resonances which agrees with the experimental one observed in a 4π - decay mode but not in 2π - and $K\bar{K}$ - decay modes of $\rho(1600)$/3/. Only for this reason our calculations differ from/6/ where the tabular value 260 MeV for the total width has been taken. At the same time the combination $\rho(1250)$ + $\rho(1600)$ contradicts the data on processes (1) and (2) if the $\rho(1250)$ has a noticeable magnitude of the leptonic width (more than 100 eV).

A sharp difference between the forecasts of MI and MII takes place for the process (2) (Fig. 2a) in the c.m. energy range 1.4 - 1.6 GeV. MI predicts a smooth plateau in this region whereas MII predicts an abrupt decrease of the cross section with a minimum at about 1.5 GeV due to the destructive interference of the nearby $\omega(1425)$ and $\omega(1625)$-resonances. The data/8,9/ indicate the existence of this minimum and, at the same time, the data/10/ are well described by the MII at energies below 1.4 GeV. Unfortunately, the energy realms of/8,9/ and/10/ are not overlapping. If we agree with data/8,9/, then we have to prefer the Model II with $\omega(1425)$ and $\omega(1625)$ - resonances. The first of them is very close to $\rho(1465 \pm 25)$ - the Donnachie et al. resonance/11,12/. But the second $\omega(1625)$ - resonance is noticeably lower in comparison with the Donnachie $\rho(1700)$ - resonance.

Moreover, if we restrict our consideration only to these two resonances, then their tails give an enhancement of the theoretically calculated cross section as compared to the experimental one in the energy range 1.7 - 2.2 GeV/9/ (see Fig. 2a). To suppress the influence of these tails on the cross section in this region enforces us to introduce one more $\omega(1750)$-resonance. Due to its destructive interference with the tails of $\omega(1425)$ and $\omega(1625)$ (and with $\omega(2100)$ resonance, too) the cross section of the process $e^+e^- \to \pi^+\pi^-\pi^0$ in the above-mentioned energy region strongly decreases in accordance with experimental data/9/. Remark, the calculated curve displays only two maxima at $\sim$ 1350 MeV and $\sim$ 1700 MeV.

There it is to be noted that small deviations for values of masses and widths of the introduced resonances within ± 25 MeV are quite admitted.

3. The electromagnetic decay of the resonances into e^+e^-- pair

To define the leptonic constants of the vector resonances from the obtained values of the parameters B_V, we are in need of the knowledge of the magnitudes of the constants $g_{\rho_i\omega\pi}(=g_{\omega_i\rho\pi})$ or, equivalently, of branching ratios of the modes $\rho_i \to \omega\pi$ (or $\omega_i \to \rho\pi$). It is a pity, these branching ratios are unknown and therefore we should include them as indefinite parameters. Nevertheless, with some reasonable suppositions for their values one may estimate the magnitudes of the leptonic constants g_V, and on this basis one may give some conclusions on the nature of the considered resonances.

Let the branching ratio of the decay mode of a given resonance ω_i ($i = 1,2,\ldots$) into $\pi^+\pi^-\pi^0$ be any value $BR(\omega_i \to 3\pi) < 1$. Then from eqs. (4) and (5) we can write

$$g_{\omega_i\rho\pi}(=g_{\rho_i\omega\pi}) = g^{o}_{\omega_i\rho\pi} BR^{1/2}(\omega_i \to 3\pi), \qquad (12)$$

$$\Gamma(\rho_i \to \omega\pi) = \Gamma^{o}(\rho_i \to \omega\pi) BR(\omega_i \to 3\pi), \qquad (13)$$

$$g_{\rho_i} = g^{o}_{\rho_i} BR^{1/2}(\omega_i \to 3\pi), \quad g^{o}_{\rho_i} = g^{o}_{\rho_i\omega\pi}/B_{\rho_i}, \qquad (14)$$

$$\Gamma(\rho_i \to e^+e^-) = \Gamma^{o}(\rho_i \to e^+e^-)/BR(\omega_i \to 3\pi). \qquad (15)$$

where the quantities with upper noughts correspond to $BR(\omega_i \to 3\pi) = 1$. The constant $g^{o}_{\omega_i\rho\pi}$ is chosen so that the value of the width $\Gamma^{o}(\omega_i \to 3\pi)$ coincides with the value of the total width given in Table 2. Then the width $\Gamma(\rho_i \to \omega\pi)$ is calculated by means of eq. (4). The leptonic constant $g^{o}_{\rho_i}$ and width $\Gamma^{o}(\rho_i \to e^+e^-)$ are calculated from eq. (14) at a given value of constant B_{ρ_i} from Table 2 and from eq. (5) at just a received value of $g^{o}_{\rho_i}$, respectively.

To evaluate more or less reliably magnitudes of the constants and leptonic widths, we suppose values of $BR(\omega_i \to 3\pi)$ equal to 0.5 for all the ω_i ($i = 1,2,\ldots$) -resonances. Our estimate is seen not to be in contradiction with the only experimental measurement of the 3π- to 5π -modes ratio equal to about unity for the observed $\omega(1680)$-resonance/3/. The results of estimations of constants, $BR(\rho_i \to \omega\pi)$ and leptonic widths are presented in Table 3.

As we can see, the evaluated magnitudes of $BR(\rho_{1600/1625} \to \omega\pi)$ within both the models are in agreement with the value 0.22 ± 0.10 which can be extracted from data on branching ratios of various decay modes of $\rho(1600)$[3]. Remark also that this ratio is about three times as small as the analogous $BR(\omega_i \to \rho\pi \to 3\pi)$ which we put equal to 0.5. The reason for this difference could be that the open decay channels are more for ρ_i than for ω_i (for example, there is no decay of ω_i analogous to $\rho_i \to \rho^+\rho^-$).

Table 3. The estimates for the constants and leptonic widths of the ρ -meson resonances under supposition $BR(\omega_i \to 3\pi) = 0.5$ $(i = 1, 2, \ldots)$

Meson	$g_{\rho_i \omega \pi}$ GeV^{-1}	$BR(\rho_i \to \omega\pi)$	g_{ρ_i}	$\Gamma(\rho_i \to e^+e^-)$ keV
$\rho(770)$	16.6 ± 0.8	-	4.94 ± 0.10	7.02 ± 0.27
Model I				
$\rho(1600)$	3.5	0.17	-11.5	2.7
$\rho(2100)$	1.5	0.14	33.0	0.4
Model II				
$\rho(1425)$	3.6	0.17	-8.7	4.2
$\rho(1625)$	2.4	0.14	7.5	6.5
$\rho(1750)$	2.5	0.14	-13.9	2.0
$\rho(2100)$	2.3	0.14	25.0	0.8

The leptonic widths of all the considered resonances we have found are few keV and comparable with the ρ - meson one. Our estimations of these values are in a qualitative agreement with values (1.5 - 3 keV) given by Donnachie et al. for $\rho(1465)$ and $\rho($ 700), respectively[11,12]. In the framework of MII our estimation for the leptonic width of $\rho(1625)$ turns out to be unexpectedly large (~ 6.5 keV). However, this estimation is in a good agreement with the experimental one $(7.5) \pm (1.5)$ keV[19].

And finally, the leptonic widths of ω_i - resonances ought to be nine times as small as the corredponding ones of ρ_i -resonances in accordance with our proposition (9).

4. Interpretations of the resonances

Now we consider interpretations of the introduced resonances on the basis of the $q\bar{q}$ -model. Let us define the value of the wave

function of relative motion of q and $\bar{q}$ "at the origin"

$$|\psi_{\rho_i}(0)| = m_{\rho_i}^{3/2} / (\sqrt{2}\, g_{\rho_i}) \quad (16)$$

(of course, this value is the same both for ω_i and ρ_i -resonances. Below we shall treat only the latter). The estimations for these values are presented in Table 4. Therein the ratios $\chi_{\rho_i} \equiv |\psi_{\rho_i}(0)/\psi_\rho(0)|$ are exposed too.

Table 4. The values of the wave functions "at the origin" for $\rho(\omega)$ -meson resonances and their ratios to the corresponding value for ρ -meson

Meson		MI		MII			
	$\rho(770)$	$\rho(1600)$	$\rho(2100)$	$\rho(1425)$	$\rho(1625)$	$\rho(1750)$	$\rho(2100)$
$\psi(0)$, GeV$^{3/2}$	$\underline{0.097} \pm 0.002$	0.124	0.065	0.139	0.195	0.117	0.086
χ_i	1	1.28	0.67	1.43	2.00	1.21	0.89

The underlined value in the case of ρ -meson was taken for the calculation of the ratios χ_i .

Within MI the values of $\chi[\rho(1600)]$ and $\chi[\rho(2100)]$ are near unity. Therefore we have all reasons to consider these resonances as if they are radial excitations of the ρ -meson. Therewithal their masses almost conside with the predicted ones[20].

A very different situation takes place if the MII is realized. As in the previous case all (four) resonances have $\chi_i \gtrsim 1$. This means none of them is the D-wave orbital excitation of ρ -meson because the latter should have a wave function at the origin much less than unity. However, it is difficult to offer any potential (or any other) model which could give such a proximity of three subsequent radial excitations of ρ -meson with such large values of the wave function at the origin. By this reason one may suspect that one of them is superfluous among radial excitations. The most suitable resonance for the role of this superfluous state is $\rho(1625)$. Then what it could be?

It is very naturaly to propose this state to be a $q\bar{q}g$ - hybrid state (see[21] and references cited therein). In the framework of the bag model the lowest hybrid state with $J^{PC} = 1^{--}$ is constructed from a $q\bar{q}(0^{-+})$ - state and gluonic $TE(1^{+-})$ - state. We propose to label this hybrid as ρ_g (or ω_g) due to its $I^G J^{PC}$ quantum numbers analogous to ρ (and ω). An estimation of the mass of this hybrid state was made in refs./21/ and turned out to be 1640 MeV (at the radius 6.1 GeV^{-1}) that is very close to our ρ (1625).

Though the production of the hybrid state in e^+e^- - collision is not yet calculated, we could imagine this process as it is pictured by the left part of the diagram in Fig. 3. The virtual photon turns into a $q\bar{q}$ - pairs with $J^{PC}=1^{--}$ in the colorless state. But due to the resonance excitation of $TE(1^{+-})$- gluonic field this pair just passes into the octet-color state with $J^{PC}=0^{-+}$. Thereby the system finds itself in the $q\bar{q}g(1^{--})$ - hybrid state.

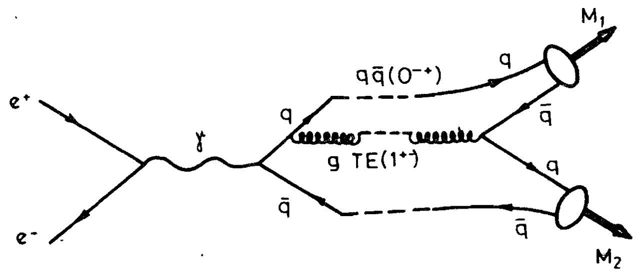

Fig. 3. The production of the 1^{--}-hybrid state in e^+e^- - collision and its successive decay into two usual mesons.

The decay of this system into two usual mesons is pictured by the right part of the diagram in Fig. 3. The gluon creates a $q\bar{q}$ - pair in the lowest available state with $J^{PC}=1^{+-}$ $(L=1, S=0)$, i.e. in $^1P_1$ - state. Then these produced quark and antiquark recombine with the initial ones into two outgoing usual mesons. Therewith either both of these mesons occur in the ground S - state with their relative angular moment $L = 1$ or one of them occurs in a P - state with the relative angular moment $L = 0$. Some decays of vector hybrid states could be the following

$$\rho_g \to \pi\omega,\ \rho^+\rho^-,\ \pi\eta,\ \eta\rho,\ K\bar{K},\ KK^*,\ \pi a_1,\ \rho f_0,$$
$$\omega_g \to \pi\rho,\ \eta\omega,\ K\bar{K},\ KK^*,\ \pi b_1,\ \eta f_1,\ KK_{1,2}.$$

It should be noted that the vector hybrid states ought to mix with nearby lying radial excitations of ρ/ω - mesons. Thereby we cannot expect the existence of hybrids in a pure state. However, a counting of vector resonances persuades us in the existence of a superfluous one and it is plausible that this unusual state is hybrid.

The indicated mixing could change the behaviour of wave functions at the origin and it is possible that ρ (1625) is picked out from the consequence of resonances in MII for this reason.

5. Conclusion

The hypothetical vector hybrid resonances and radial excitations of ρ/ω - mesons should weakly differ from one another when they are produced in e^+e^- - collisions and disintegrate onto usual mesons. Thereto they ought to be strongly mixed. (of course, these assertions need more quantitative verifications by means of theoretical calculations of these processes for hybrids).

For these reasons the only primary indication of the existence of vector hybrid states may come from counting of a full number of vector resonances.

The performed analysis of data on the processes (1) - (3) has indicated the presence of three vector resonance excitations of ρ/ω - mesons with masses of 1425, 1625 and 1750 MeV and widths of about 250-300 MeV. Such concentration of the resonances as well as the estimations of their leptonic widths in few keV are reasons for a suspicion that, on the one hand, not all of them should be radial excitations and, on the other hand, none of them should be a D - orbital excitation of ρ/ω - mesons. Thus at least one of them is a superfluous state. It is more plausible to suppose the hybrid nature of it. The most suitable candidate for the hybrid is ρ/ω (1625), while two others resonances, ρ/ω (1425) and ρ/ω (1750) are very convenient for roles of radial excitations of ρ/ω - mesons. It is necessary to add that the hybrid and radial excitation states must mix because of their strong interaction and thus there is not any resonance in a pure hybrid state.

For further verification of our hypothesis it is very important to investigate the processes (1) - (3) with a more precision in the full c.m. energy region from 1.0 GeV to 2.5 GeV (for the process (2) in the kinematically allowed region). It is very important also to measure the leptonic widths and branching ratios of different decay modes of considered resonances.

It is evident that an observation of superfluous states within other meson sectors, e.g. in the pseudoscalar one, and especially, possessing exotic quantum number $J^{PC} = 1^{-+}$ would give weighty arguments for the existence of hybrid states.

I would like to thank S.B.Gerasimov for the numerous and helpful discussions of the problem considered in this paper.

References

1. Gerasimov S.B., Govorkov A.B. - Z. Phys. C - Particles and Fields, 1982, v. 13, p. 43; 1985, v. 29, p. 61.
2. Govorkov A.B. - Z.Phys.C - Particles and Fields, 1986, v. 32, p. 405.
3. Particle Data Group - Phys. Lett., 1986, v. 170B, p. 1.
4. Dolinsky S.I. et al. - Phys. Lett., 1986, v. 174B, p. 453.
5. Govorkov A.B. JINR Preprint P2-86-682, Dubna, 1986.
6. Albrecht H. et al. DESY Preprint 86-142. Hamburg, 1986.
7. Cordier A. et. al. - Nucl. Phys., 1980, v. B172, p. 13.
8. Pauloi C. et al. LAL Preprint 79-14, Orsay, 1979.
9. Augustin J.E. et al. LAL Preprint 83-21, Orsay, 1983.
10. Aulchenko V.M. et al. INP Preprint 86-106, Novosibirsk, 1986.
11. Donnachie A., Mirzaie H. - Z.Phys. C - Particles and Fields, 1987, v. 33, p. 407.
12. Donnachie A., Clegg A.B. Preprint M/C TH 86/33, Manchester, 1986.
13. Renard F.M. - Nuovo Cim., 1969, v. 64A, p. 979.
14. Altukhov A.M., Khriplovich I.B. - Yadernaya fizika, 1971, v. 14, p. 783.
15. Karnakov V.E. - Yadernaya fizika, 1985, v. 42, p. 1001.
16. Gell-Mann M., Sharp D., Wagner W.G. - Phys. Rev. Lett., 1962, v.8, p. 261.
17. Tsai Y.S. - Phys. Rev., 1971, v. D4, p. 2821.
18. Atkinson M. et al. CERN Preprint EP/86-185, Geneva, 1986.
19. Delcourt B. et al. In: Proc. 1981 Inern. Conf. on Lepton and Photon Interactions at High Energies, Bonn, 1981, p. 205.
20. Godfrey S., Isgur N. - Phys. Rev., 1985, v. D32, p. 189.
21. Chanowitz M., Sharpe S. - Nucl. Phys., 1983, v. B222, p. 211; Barnes T., Close F.E., de Viron F. - Nucl. Phys., 1983, v. B224, p. 241.

Received by Publishing Department
on July 8, 1987.

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Говорков А.Б.
E2-87-522

О спектре радиальных возбуждений ρ- и ω-мезонов и возможном существовании ρ_g- и ω_g-гибридов

На основе модели доминантности векторных мезонов /ДВМ/ произведен совместный анализ новых экспериментальных данных, касающихся реакций $e^+e^- \to \omega\pi^0$, $\pi^+\pi^-\pi^0$ и распада $\tau \to \nu_\tau\omega\pi$. Показано, что наиболее согласованное их описание получается, если предположить существование трех резонансов векторных ρ/ω-мезонов с массами около 1425, 1625 и 1750 МэВ. Оцениваются их полные ширины и ширины лептонных распадов на e^+e^--пару. Из этих оценок следует, что ни один из этих резонансов не может быть орбитальным D-состоянием. Обсуждается интерпретация этих резонансов как радиальных возбуждений /1425/ и /1750/ ρ/ω-мезонов и как $q\bar{q}g$-гибридного /1625/ состояния.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1987

Govorkov A.B.
E2-87-522

On the Spectrum of Radial Excitations of the ρ- and ω-Mesons and a Possible Existence of ρ_g- and ω_g-Hybrides

The available data on the reactions $e^+e^- \to \omega\pi^0$, $\pi^+\pi^-\pi^0$ in the c.m. energy range from 1.0 to 2.2 GeV and on the decay $\tau \to \nu_\tau\omega\pi$ are analysed simultaneously within the vector dominance model (VDM). The most consistent picture occurs when three resonances of ρ and ω with masses of 1425, 1625, and 1750 MeV are supposed. The estimations for their total and leptonic widths are given. We conclude that none of them is the D-wave. The interpretation of 1425 and 1750 as radial excitations of ρ/ω and 1625 as a hybrid state is suggested.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1987