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ELECTROMAGNETIC PROPERTIES AND SIZES OF NEW VECTOR MESONS WITHIN THE THREE-TRIPLET MODEL

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I. Introduction

Just after the discovery of the narrow heavy meson resonances J/ψ (3.1 GeV)[1,2] and ψ'(3.7 GeV)[3] some authors (see[4-9] and references in reviews[10-12]) have proposed that these resonances are new vector mesons $\tilde{\omega}$ and $\tilde{\varphi}$, resp., which were predicted in papers[13,14] within the three-triplet scheme of Bogolubov et al.[15], Han-Nambu[16] and Miyamoto[17]. The basic assumptions of this scheme are given in Sec. 2.

In this paper within this scheme we consider three electromagnetic processes with the new vector mesons: the decay into the lepton pair via one-photon intermediate state

$$J/\psi \text{ or } \psi' \to \gamma^* \to \ell^+ \ell^- \quad (\ell = e, \mu) \; ; \tag{1.1}$$

the radiative transition to the usual pseudoscalar mesons

$$J/\psi \to \eta \text{ or } \eta' + \gamma \; ; \tag{1.2}$$

the photoproduction on nucleons:

$$\gamma + N \to J/\psi (\text{or } \psi') + N \; . \tag{1.3}$$

The process (1.1) will be examined on the basis of the nonrelativistic quark model with the oscillator potential[18,19]. The model parameters will be determined in Sec. 3 by comparing with experimental data. We arrive at a main conclusion that the sizes of new mesons appear to be essentially smaller than those of usual mesons, and that the effective mass of quarks constituent of new mesons is much larger than that for usual mesons.

The lack of any large radiative transitions of J/ψ -mesons to the usual hadrons of the type of decays (1.2) was considered as one of the main arguments against the "coloured" interpretation of the J-ψ -mesons/[20,21]/. In Sec. 4 we argue against the used in those papers estimates of probabilities of such radiative transitions performed in the framework of the "naive" quark model. Our arguments are founded just on the above-mentioned differences in the effective quark masses. At the same time under the assumption of the vector meson dominance (VMD) we show that the predictions for radiative transition (1.2) and photoproduction (1.3) may be put in agreement with each other and with experiment.

In conclusion we discuss the success and difficulties of the considered model of new narrow vector mesons.

2. New Mesons within the SU(3) x SU(3)^c Symmetry

The basis of the considered scheme of intrinsic symmetries of hadron is taken to be a nonet of quarks-sakatons combined into three triplets, t_i (i =1,2,3). Each of three triplets represents a set of three quark states $t = p, n, \lambda$. It is assumed that with respect to these states there is the physical SU(3) symmetry with its well known violations. Relative to new "coloured" degrees of freedom (numbers of triplets) the existence of the "coloured" SU(3)^c-symmetry is assumed. Thus, as a total hadron symmetry it is suggested to consider the direct product SU(3) x SU(3)^c.

Mesons are assumed to consist of a quark and antiquark. The usual mesons belong to the singlet representation

$$V = |1^c\rangle = \frac{1}{\sqrt{3}}(V_1 + V_2 + V_3), \qquad (2.1)$$

where V stands for a definite meson state: ρ^0, ω, φ are known combinations of quark-antiquark SU(3)-states (i =1,2,3).

The new vector mesons belong to the SU(3)^c octet representation. Within this representation each meson state is doubled. Two equal meson states differ only in values of the coloured isospin, I^c =0,1. The physical states (at $I_3^c = 0$ and $Y^c = 0$) may be the superpositions/[6,13]/:

$$\tilde{V} = \cos\theta^c\,|8^c, I^c = 1\rangle + \sin\theta^c\,|8^c, I^c = 0\rangle$$
$$= \frac{2}{\sqrt{6}}\left[V_1\cos\gamma - V_2\sin(\gamma_0 - \gamma) - V_3\sin(\gamma_0 + \gamma)\right], \qquad (2.2a)$$

$$\tilde{\tilde{V}} = -\sin\theta^c\,|8^c, I^c = 1\rangle + \cos\theta^c\,|8^c, I^c = 0\rangle$$
$$= \frac{2}{\sqrt{6}}\left[-V_1\sin\gamma + V_2\cos(\gamma_0 - \gamma) - V_3\cos(\gamma_0 + \gamma)\right], \qquad (2.2b)$$

where $\theta^c = \gamma_0 + \gamma$ and $\gamma_0 = \pi/6$. The magnitude of the angle of "mixing" θ^c is defined by the nature of breaking of the coloured SU(3)^c symmetry. If, e.g., the latter is assumed to occur due to electromagnetic interaction only, then

$$\gamma = 0 \qquad (2.3)$$

and hence the γ magnitude determines the deviation of mixing from the "ideal" electromagnetic one.

Thus, within this scheme there arise nine neutral vector mesons: three usual ρ^0-, ω- and φ -mesons and three doublets of new mesons $(\tilde{\rho}^0, \tilde{\tilde{\rho}}^0)$, $(\tilde{\omega}, \tilde{\tilde{\omega}})$ and $(\tilde{\varphi}, \tilde{\tilde{\varphi}})$.

The electric charge is suggested to be the following generalization of the Gell-Mann-Nishijima formula

$$Q = I_3 + \frac{Y}{2} + I_3^c + \frac{Y^c}{2}. \qquad (2.4)$$

The nonet of quarks-sakatons is assumed to be transformed according to the representation $\{3,\bar{3}^c\}$. Therefore for them the electric charges take the integer values /15-17/: $Q_{p1}=Q_{n2}= =Q_{\lambda 2}=Q_{n3}=Q_{\lambda 3}=0, \quad Q_{p2}=Q_{p3}=-Q_{n1}=-Q_{\lambda 1}=1$.
The electromagnetic current is the sum of usual and "coloured" currents

$$J_\mu^{e.m.} = J_\mu(8;1^c) + J_\mu^c(1;8^c) \tag{2.5}$$

The usual electromagnetic current is the SU(3)-octet and $SU(3)^c$-singlet

$$J_\mu(8;1^c) = J_\mu^{(3,0)} + \frac{1}{\sqrt{3}} J_\mu^{(8,0)} \tag{2.6}$$

while the coloured one is the SU(3)-singlet and $SU(3)^c$-octet

$$J_\mu(1;8^c) = -J_\mu^{(0,3)} - \frac{1}{\sqrt{3}} J_\mu^{(0,8)} . \tag{2.8}$$

The latter has an important consequence: in the e^+e^--annihilation via the one-photon intermediate state there can be produced only isosinglets $(\tilde{\omega},\tilde{\tilde{\omega}})$ or $(\tilde{\varphi},\tilde{\tilde{\varphi}})$ and cannot be produced the isotriplet states $(\tilde{\rho}^0,\tilde{\tilde{\rho}}^0)$. Therefore it is natural to identify the observed J-ψ -particles with the above doublets

$$J/\psi(3095) = (\tilde{\omega},\tilde{\tilde{\omega}}) , \tag{2.8}$$

$$\psi'(3684) = (\tilde{\varphi},\tilde{\tilde{\varphi}}) . \tag{2.9}$$

At the present time it is impossible to determine which of two components of each doublet corresponds to the experimentally observed resonances. The latter depends on the angle θ^c of

mixing of states with coloured isospins $I^c=0,1$, and of the singlet-octet SU(3)-states for the new mesons

$$\begin{aligned} \tilde{\omega} &= \omega_0 \cos\tilde{\delta} + \varphi_0 \sin\tilde{\delta} , \\ \tilde{\varphi} &= -\omega_0 \sin\tilde{\delta} + \varphi_0 \cos\tilde{\delta} , \end{aligned} \tag{2.10}$$

where ω_0 and φ_0 are the "ideal" superpositions

$$\begin{aligned} \omega_0 &= \frac{1}{\sqrt{2}}(p\bar{p}+n\bar{n}) , \\ \varphi_0 &= -\lambda\bar{\lambda} \end{aligned} \tag{2.11}$$

(Analogous expressions may be written for $\tilde{\tilde{\omega}}$ and $\tilde{\tilde{\varphi}}$ and hereafter we will put $\tilde{\delta}=\tilde{\tilde{\delta}}$).

In the quark model the quantities characterizing the transition of a vector meson into a virtual photon are proportional to the sums

$$Q_V = \sum_q C_q^V Q_q , \tag{2.12}$$

where Q_q is the charge of the quark-sakaton constituent of the vector meson V with the Clebsch-Gordan coefficient C_q^V defined from the "direct" product of eq.(2.2) and eq.(2.10). The expressions for Q_V are given in Table 1. In the case of only electromagnetic violation of the $SU(3)^c$-symmetry ($\gamma=0$) and

Table 1.

$V \to l^+l^-$	$Q_V = \sum_q C_q^V Q_q$
ρ^0	$3/\sqrt{6}$
ω	$(\cos\delta + \sqrt{2}\sin\delta)/\sqrt{6}$
φ	$(-\sin\delta + \sqrt{2}\cos\delta)/\sqrt{6}$
$\tilde{\rho}^0$	0
$\tilde{\omega}$	$-2\cos\gamma(\sqrt{2}\cos\tilde{\delta} - \sin\tilde{\delta})/\sqrt{6}$
$\tilde{\varphi}$	$2\cos\gamma(\sqrt{2}\sin\tilde{\delta} + \cos\tilde{\delta})/\sqrt{6}$
$\approx\!\rho^0$	0
$\approx\!\omega$	$2\sin\gamma(\sqrt{2}\cos\tilde{\tilde{\delta}} - \sin\tilde{\tilde{\delta}})/\sqrt{6}$
$\approx\!\varphi$	$-2\sin\gamma(\sqrt{2}\sin\tilde{\tilde{\delta}} + \cos\tilde{\tilde{\delta}})/\sqrt{6}$

ideal SU(3)-singlet-octet mixing $(\tilde{\tilde{\delta}} = 0)$ in e^+e^--annihilation $\tilde{\tilde{\omega}}$- and $\tilde{\tilde{\varphi}}$ -mesons cannot be produced, but only the $\tilde{\omega}$ - and $\tilde{\varphi}$ -mesons.

We will keep the view point of the electromagnetic nature of breaking of the $SU(3)^c$-symmetry. It should be emphasized that the scheme presented differs from the scheme proposed first by Han and Nambu/16/ and Miyamoto/17/ in which the physical SU(3)--symmetry was treated as the diagonal subgroup of the G -group= $SU(3)' \otimes SU(3)''$ and in which the $SU(3)''$ was broken in the strong way. The arising in such a scheme heavy states in general are unstable and decay into lower (usual hadronic) states by strong interactions/16/. A modification of this scheme with the conservation of coloured isospin I'' in strong interactions and with the presence of narrow meson resonances (as a result of that conservation) was considered by many authors (see refs./4,12/ and references in reviews/10,11/).

3. Decay into Lepton Pair and Model Parameters

The width of decay of the neutral vector mesons into the lepton pair through the intermediate one-photon state is defined by the expression

$$\Gamma(V \to l^+l^-) = \frac{4\pi}{3}\alpha^2 m_V f_V^{-2}, \qquad (3.1)$$

where m_V is the mass of the vector meson, the quantity $f_V^2/4\pi$ characterizes its transition to the virtual photon, $\alpha \equiv e^2/4\pi \approx 1/137$. The quantities $f_V^2/4\pi$ obtained from the experimental widths/22,24-26/ are given in Table 2.

Treating the same process as the annihilation of quark and

Table 2.

The "vector meson-photon" transitions and oscillator parameters

	ρ^0	ω	φ	J/ψ	ψ'
$\frac{f_V^2}{4\pi}$	2.56[a)] ±0.24	18.4 ±2.0	12.2[a)] ±1.0	11.5 ±1.5	30.0 ±4.0
$Q_V^2 \frac{f_V^2}{4\pi}$	3.84 ±0.36	3.74 ±0.40	3.62 ±0.30	16.9 $\pm$ 2.2	15.9 $\pm$ 2.1
β_V (GeV)	0.33 ±0.01	0.35 ±0.01	0.45 ±0.01	0.82 ±0.04	1.00 ±0.04
$\langle r^2\rangle^{1/2}$ (fm)	0.52 ±0.02	0.49 ±0.01	0.38 ±0.01	0.21 ±0.01	0.17 ±0.004
	a) We introduce the correction on the finite width of mesons.				

antiquark into the intermediate one-photon state, we arrive at the following expressions for the "vector meson-photon" transition quantities:

$$\frac{4\pi}{f_V^2} = \frac{16\pi}{m_V^3}\,|\Psi_V(0)|^2 Q_V^2 , \qquad (3.2)$$

where Q_V is defined by eq. (3.1) and $\Psi_V(0)$ is the value of the quark-antiquark wave function at zero relative distance.

We regard the motion of quark and antiquark inside the meson as nonrelativistic and describe it within the hadronic oscillator model[18,19]. Then the energy levels are

$$E = \sqrt{2}\,\omega\,(2n + \ell + 3/2), \qquad (3.3)$$

where ω is the oscillator frequency, n and ℓ the radial and orbital quantum numbers, respectively. The ground-state wave function is

$$\Psi(r) = (\beta/\sqrt{2\pi})^{3/2} \exp(-\beta^2 r^2/2), \qquad (3.4)$$

where $\vec{r} = (\vec{r}_q - \vec{r}_{\bar{q}})/\sqrt{2}$ is the relative coordinate.

Note that the wave function of the harmonic oscillator depends on the only parameter

$$\beta^2 = \sqrt{2}\, m_q \omega , \qquad (3.5)$$

where m_q is the quark effective mass. Thus, we have

$$f_V^2/4\pi = (\pi/32)^{1/2} m_V^3/\beta_V^3 Q_V^2 . \qquad (3.6)$$

Under the assumption that $\beta_V \sim m_V$ the dimensionless quantities $f_V^2/4\pi$ should obey the condition

$$(f_V^2/4\pi) Q_V^2 = \mathrm{const} . \qquad (3.7)$$

For the usual ρ^0-, ω- and φ-mesons this relation is well fulfilled for $\delta = 4^\circ 20'$ (this value follows from the quadratic mass formulae[27]). For the new mesons the constancy (3.7) proceeds from the assumption that the angle $\tilde{\delta}$ is opposite in sign to δ :

$$\tilde{\delta} = -\delta = -4^\circ 20' . \qquad (3.8)$$

The check of eq. (3.7) is presented in Table 2. We see that this relation holds separately for the usual and new mesons. This means that the parameters of the harmonic oscillator are different for the usual and new mesons. Table 2 gives the values of β_V also.

Under the assumption that quarks are point-like particles the mean square radius of the meson electromagnetic form factor is

$$\langle r^2\rangle^{1/2}_{e.m} = \sqrt{3/4}\,/\beta \, . \qquad (3.9)$$

Its values also can be found in Table 2. For the usual mesons these values appear to be somewhat smaller than the experimental pion radius 0.68 ± 0.05 F[28], that possibly hints at the presence of the proper sizes of quarks. In any case, in the model under consideration the new vector mesons have sizes essentially smaller than those for the usual mesons. This conclusion is supported by the decrease of the slope parameter of the diffractional cone observed in experiments on photoproduction of the new mesons[29-30]. Within the impact parameter approach this slope may be connected with the characteristic dimensions of the overlap function $B \sim R^2$. If this function is supposed to result from the overlap of two Gaussians characterizing the distribution of hadron matter inside the colliding mesons and nucleon, then it is also a Gaussian and $R^2 \sim \langle r^2\rangle_M + \langle r^2\rangle_N \sim \beta_M^{-2} + \beta_N^{-2}$. From Table 2, assuming the ω-meson slope $B(\omega) \approx 8\pm1$ $(\mathrm{Gev}/c)^{-2}$[23] we obtain the following J/ψ-meson slope

$$B(J/\psi) \approx B(\omega)\,(\beta^{-2}_{J/\psi} + \beta^{-2}_{\omega})/2\beta^{-2}_{\omega} \approx 4.7 \pm 0.6 \quad (\mathrm{Gev}/c)^{-2} \qquad (3.10)$$

that is in qualitative agreement with the experimental values $\sim 4(\mathrm{Gev}/c)^{-2}$ [29] and 2.9 ± 0.3 $(\mathrm{Gev}/c)^{-2}$ [30].

Now let us estimate the effective mass of quarks constituent of the new mesons. Assume that the observed in e^+e^--annihilation[31,32] broad resonance $\psi''(4100)$ is the radial excitation of the $J/\psi(3095)$-meson. Then from eqs. (3.3) and (3.5) we have

$$\tilde{m}_q = \frac{2\beta^2(J/\psi)}{m(\psi'') - m(J/\psi)} = 1.33 \pm 0.12 \text{ Gev} \, . \qquad (3.11)$$

This value is close just to half mass of the J/ψ-meson. Thus, the effective mass of quarks constituent of the new mesons appears to be essentially larger than that for the usual mesons.

On the basis of eqs. (3.1) and (3.2) with the additional factor 3/2 for the value at zero of the wave function of the oscillator first radial excitation we estimate the decay width of $\psi''(4100)$-meson into the lepton pair

$$\Gamma(\psi'' \to \ell^+\ell^-) = \frac{3}{2}\left[\frac{m(J/\psi)}{m(\psi'')}\right]^2 \Gamma(J/\psi \to \ell^+\ell^-) \approx 4.1 \pm 0.5 \text{ keV} \, . \qquad (3.12)$$

This estimate corresponds to the experimental value[31].

There must exist also the orbital P-excitations of the J/ψ-meson with total momentum, parity and charge conjugated parity $J^{PC} = 0^{++}, 1^{++}, 2^{++}$. These states are situated in the range of mass 3.6 Gev between the ground state and first radial excitation. At present it is difficult to establish whether these levels relate to the intermediate levels observed in γ-decays of the $\psi'(3684)$-meson[33,34]. It should be noted that in this scheme such γ-transitions are highly suppressed due to the factor $\sin^2\delta \approx 5\cdot10^{-3}$. There should occur also analogous γ-transitions of $\psi'(3684)$-meson to the P-states of $\tilde{\rho}^0$-meson with the subsequent decay of these states mainly in the odd number of pions.

And finally, it is natural to expect the presence of the radial excitation of the $\psi'(3684)$-meson. It, probably, is related to the enhancement of e^+e^--annihilation observed at 4.45 Gev[32].

The lepton width of this resonance should be about half lepton width of the $\psi''(4100)$ and equal to ~ 2 keV. The direct decays (not to $\psi'(3684)$-meson) of this resonance to hadrons should be accompanied by the kaon production.

4. Radiative Decays to Hadron and Photoproduction of New Vector Mesons

The electromagnetic current (2.5) contains both the usual singlet and unusual octet in "colour" components. As a result, the γ -transitions are possible of the new vector mesons to the usual pseudoscalar ones. The isospin selection rules following from the unitarity structure of the electromagnetic current permit the transitions[7]

$$J/\psi(\equiv\tilde{\omega}) \text{ or } \psi'(\equiv\tilde{\varphi}) \to \gamma + \Pi(1^c, I^G = 0^+), \ \Pi = \eta, \eta', \ldots \qquad (4.1)$$

Note that within this scheme the decay $J/\psi \to \pi^0\gamma$ is forbidden and the widths of decays to η- and η'-mesons obey the following ratios

$$\Gamma(J/\psi \to \gamma\eta') : \Gamma(J/\psi \to \gamma\eta) : \Gamma(\psi' \to \gamma\eta') : \Gamma(\psi' \to \gamma\eta)$$
$$= 2 : 1 : 1 : 2 \quad . \qquad (4.2)$$

Estimates for the widths of transitions (4.1) on the basis of the "naive" quark model are of the order of a dozen or several dozens of MeV[9,11,20,21]. Such decays are treated as MI-transitions due to the spin flip of one of quarks. The transitions of the usual to usual mesons, e.g., the decay $\omega \to \pi^0\gamma$, are not followed by the change of effective mass of the excited quark and occur due to the normal Dirac magnetic moment of a quasi-free

quark. On the contrary, the radiative decays (4.1) of the new vector mesons to the usual pseudoscalar ones in our model should be followed by changing effective mass of the excited (and "spectator") quark and may proceed only due to the anomalous transitional magnetic moment[7]. The value of the latter is not known and one may only conjecture that it is essentially smaller than the value of the normal magnetic moment (see also ref.[35]). It should be noted that an additional suppression of transitions (4.1) arises due to the smallness of the wave length of the emitted photon in comparison with the meson dimension and it may appear to be very significant as has been supposed by some authors who used empirical form factors[9,11].

For the above reasons we cease to calculate the radiative transitions (4.1) within the quark model. Instead, we consider them within the vector meson dominance (VMD) model. Then we arrive at the following ratio of widths

$$\frac{\Gamma(J/\psi \to \eta + \gamma)}{\Gamma(\omega \to \pi^0 + \gamma)} = \frac{\tilde{g}^2 f^{-2}_{J/\psi}(0) K^3_\eta}{27 g^2 f^{-2}_\omega(0) K^3_\pi} , \qquad (4.3)$$

where g and $\tilde{g}$ are the constants for the strong interaction vertex for the usual and new vector mesons, resp., $f^{-2}_V(0)$ the transitions "vector meson-photon" on the photon mass shell $(q^2=0)$, K_η and K_π – the momenta of the produced η – and π -mesons. The experimental (preliminary) value is $\Gamma(J/\psi \to \eta\gamma) \approx 95 \pm 29$ ev [36]. Using the value $\Gamma_{\omega\to\pi^0\gamma} \approx 0.87$ MeV[27], from eq.(4.3) we get

$$\tilde{g}^2 f^{-2}_{J/\psi}(0) \approx 5 \times 10^{-5} g^2 f^{-2}_\omega(0) \quad . \qquad (4,4)$$

From eq. (4.4) it follows that the strong suppression of radiative transitions (4.1) can be due to the two reasons:

1) The strong interaction of new mesons with usual hadrons is suppressed in comparison with that for usual mesons[8,37]

$$g_{\tilde{V}\tilde{V}\eta} \ll g_{VV\eta} ; \qquad (4.5)$$

2) The "vector meson-photon" transitions on the photon mass shell obey the inequality[7,37]

$$f^{-2}_{J/\psi}(0) \ll f^{-2}_{\omega}(0). \qquad (4.6)$$

Obviously, for analogous reasons there is a suppression of the photoproduction of new mesons on nucleons[37]. Consider this process as the diffraction production in the VMD framework

$$\frac{d\sigma}{dt}(\gamma N \to VN) = \frac{\alpha}{4 f_V^2(0)}\, \sigma^2_{tot}(VN), \qquad (4.7)$$

where $\sigma_{tot}(VN)$ is the total cross section for a meson V on a nucleon N . Our basic assumption is that the same constant (g or $\tilde{g}$) defines both the strong vertex in radiational transitions ($g_{VV\eta}$ or $g_{\tilde{V}\tilde{V}\eta}$) and the amplitude of diffraction scattering of vector mesons on nucleons (g_{VVP} or $g_{\tilde{V}\tilde{V}P}$). Then, on the basis of the optical theorem for the latter process we may suppose the validity of the following relation

$$\tilde{g}^2/\sigma^2_{tot}(J/\psi N) = g^2/\sigma_{tot}(\omega N) . \qquad (4.8)$$

Using eqs. (4.3), (4.7) and (4.8) we can compose the ratio involving only the experimentally measurable quantities

$$\frac{\Gamma(J/\psi \to \eta\gamma)}{\Gamma(\omega \to \pi^0\gamma)} = \frac{[d\sigma(\gamma N \to J/\psi N)/dt]_{t=0}\, K_\eta^3}{27[d\sigma(\gamma N \to \omega N)/dt]_{t=0}\, K_\pi^3} . \qquad (4.9)$$

Inserting the experimental data

$$[d\sigma(\gamma N \to J/\psi N)/dt]_{t=0} = 17.8 \pm 1.5\, nb/(GeV/c)^2 \text{ at } 21\, GeV$$ [30],

$$[d\sigma(\gamma N \to \omega N)/dt]_{t=0} = 12.7 \pm 2.4\, \mu b/(GeV/c)^2 \text{ at } 9.3\, GeV$$ [23]

we evaluate the radiative transition width $\Gamma(J/\psi \to \eta\gamma) \approx 2.8 \pm 0.6$ keV. The above estimate could be valid only in the order of magnitude. The fact that it is by an order larger than the preliminary experimental value (95±29) eV[29] may imply that our initial assumption (4.8) holds with the same degree of accuracy. Note that for the first relation (4.2) experimantally there are found the values: ~ 5[36] and 4 ± 2.5[38].

Finally, we can estimate the ratio of photoproduction cross sections for J/ψ- and ψ'-mesons. We consider the first of them to consist mainly of the nonstrange and the second of the strange quarks. Therefore we assume that elastic cross sections for J/ψ- and ψ'-mesons relate to each other in the same way as those for ω - and φ -mesons, and the ratio of the "vector meson-photon" transitions on the photon mass shell are the same as on the meson mass shell. Then we have

$$\frac{[d\sigma(\gamma N \to J/\psi N)/dt]_{t=0}}{[d\sigma(\gamma N \to \psi' N)/dt]_{t=0}} \approx \frac{30.0}{11.5} \times \frac{30\, \mu b/(GeV/c)^2}{4\, \mu b/(GeV/c)^2} \approx 19.5$$

The experimental ratio is 5.2±1.8 (under extrapolation from t_{min} to t_0 =0 with the slope B=2.9(Gev/c)^2)[30]. Note the significant uncertainty in our estimate due to the lack of available data on φ -meson elastic scattering.

5. Conclusion

We conclude that in the framework of the above J-ψ -meson interpretation the presence of only two heavy narrow meson resonances[39] can naturally be explained. At the same time the doublet splitting of these resonances (and, possibly, their radial and orbital excitations) is predicted, but either it is within the limits of experimental resolution, or one of the doublet components is not produced at all in the e^+e^--annihilation.

Within the presented scheme also the prediction is unavoidable on the new isotriplet of heavy $\tilde{\rho}^0$, $\tilde{\rho}^{\pm}$ -mesons with masses approaching the J/ψ -meson mass. The neutral $\tilde{\rho}^0$ -meson cannot be produced in the e^+e^--annihilation. Nevertheless its P -excited states can be produced in γ -decays of the $\psi'(3684)$-meson with their subsequent decay mainly into the odd number of pions. The charged heavy mesons could be observed in the decays $\psi'(3684) \to \tilde{\rho}^{\pm} + \pi^{\mp}$ [7,10]. The absence of the monochromatic signal in the spectrum of charged pions in the decay $\psi'(3684)$[36] is an essential difficulty for the above scheme. At present, however, the strong interaction of the new mesons with usual ones is unknown. On the other hand, as we have seen, the considered electromagnetic processes can be fairly and consistently described within that scheme.

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