DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY

DESY 74/52
November 1974

受入
74-92
高工研図書室

On the Masses and Leptonic Decay Widths of New Vector Mesons

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受入
49.12.18
高工研図書室

M. Böhm

CERN, Geneva

M. Krammer

Deutsches Elektronen-Synchrotron DESY, Hamburg

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by

M. Böhm
CERN, Geneva

and

M. Krammer
Deutsches Elektronen-Synchrotron DESY, Hamburg

Abstract

We predict the recurrences of the '3105' and the leptonic decay widths with the help of the relativistic quark model, by making the dynamical conjecture that the scale is set by the zero point energy of '3105'.

We assume that the J(3105) [1,2] +) is the ground state of a series of charmed-anticharmed++) quark bound states with $j^{P,C} = 1^{--}$. Their properties can be described in the relativistic quark model with strong binding,[3] enlarged by the new degree of freedom. The results of this model, which are relevant for the present discussion, are

the mass spectrum:

$$M^2 = [3(\underline{\alpha} + m^2) + 2\alpha'^{-1} + (n + 2r)\alpha'^{-1}] \qquad (1)$$

m: quark mass

$\underline{\alpha}$: depth of the "potential"-type interaction

α'^{-1}: inverse Regge slope

n,r: quantum numbers of the four-dimensional oscillator

the vector-meson-photon couplings:

$$g_{V_r} \equiv \frac{M^2_{V_r}}{2\gamma_{V_r}} = Z(-1)^r \frac{\sqrt{r+1}}{\pi \cdot \sqrt{3}} \cdot \alpha'^{-1} \cdot \langle Q_V \rangle \qquad (2)$$

$$\langle Q_V \rangle = \left(\frac{1}{\sqrt{2}} , \frac{1}{3\sqrt{2}} , -\frac{1}{3} , \frac{2}{3} \right) \text{ for } (\rho,\omega,\phi,J) ,$$

determining the leptonic decay width via

$$\Gamma_{\ell^+\ell^-} = \frac{4\pi\alpha^2}{3} \cdot \frac{g_V^2}{M_V^3} \quad . \qquad (3)$$

If we estimate the leptonic decay width of J(3105) by using the conventional Regge slope, $\alpha'^{-1} \approx 1\ \mathrm{GeV}^2$, then we obtain $\Gamma(J(3105) \to \ell^+\ell^-) = 0.1$ keV, which value seems to be too small by about one order of magnitude.[2]

+) We prefer the notation J(3105) instead of ψ(3105) since ψ usually denotes spinor fields, like quarks.

++) Since our subsequent conjecture applies to hadronic degrees of freedom in general, the results (4)-(6) should also be valid for other interpretations.

Since the coupling g_V is measured by the $q\bar{q}$-Bethe-Salpeter wave function at zero distance in configuration space, the decay probability into lepton pairs can be enhanced by making the range of the configuration space wave function smaller. By this, the level distance of the bound states becomes larger and also the mass of the ground state gets enhanced, because of the zero-point energy ($2\alpha'^{-1}$ in Eq.(1)). This leads us to make the following conjecture:

> 'The mass differences of $(p\bar{p}, n\bar{n})$, $(\lambda\bar{\lambda})$, $(c\bar{c})$, ... bound states are caused by an i,y,c,... dependence of the range of the interaction between quarks, but with an i,y,c,... independent quark mass m and "potential depth" $\underline{\alpha}$.' +)

By this conjecture, the constant $3(\underline{\alpha} + m^2)$ in Eq.(1) is already determined from the masses on the $\rho(770)$ or the $\phi(1020)$ trajectory:

$$3(\underline{\alpha} + m^2) = 3M_\rho^2 - 2M_f^2 = \ldots.$$
$$= 3M_\phi^2 - 2M_{f'}^2 = \ldots. \qquad (4)$$

The figures are consistent with each other within the errors, we use: $3M_\phi^2 - 2M_{f'}^2 = -(1.46 \pm 0.13)\ \mathrm{GeV}^2$. With this value, the Regge slope of the J(3105) trajectory is determined from the J(3105) mass

$$2\alpha'^{-1} = (3.105 \pm 0.003)^2\ \mathrm{GeV}^2 + (1.46 \pm 0.13)\ \mathrm{GeV}^2 = (11,10 \pm 0.15)\ \mathrm{GeV}^2 \qquad (5)$$

and we obtain for the radially excited vector mesons the mass formula++)

$$M_{J_r}^2 = M_{J_o}^2 + r\cdot(11,10 \pm 0.15)\ \mathrm{GeV}^2 \qquad (6)$$

i.e.:

$$M_{J_1} = (4554 \pm 20)\ \mathrm{MeV}, \quad M_{J_2} = (5643 \pm 30)\ \mathrm{MeV}, \ldots..$$

From the Regge slope we predict with the help of Eq.(2) and the value $Z = 0.73$, as determined from the pion form factor,[4)]

$$\Gamma(J_o \to \ell^+\ell^-) = 1,8\ \mathrm{keV}, \qquad \Gamma(J_1 \to \ell^+\ell^-) = 1,14\ \mathrm{keV}, \quad \Gamma(J_2 \to \ell^+\ell^-) = 0,9\ \mathrm{keV}, \ldots... \qquad (7)$$

+) A range dependence of new degrees of freedom in hadronic matter could also be inferred from the well-known fact that the cross section for particles involving strangeness (K) or hidden strangeness ($\phi(1020)$) points towards a smaller radius, in an optical picture.

++) We hope that the theoretical error bars will soon be determined experimentally.

Other theoretical estimates[5] for $\Gamma(J_o \to \ell^+\ell^-)$ are approximately one order of magnitude larger than ours.

ACKNOWLEDGEMENTS

This paper has been stimulated by results communicated to high energy physicists by phone and discussions with our colleagues at CERN and DESY.

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