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Quantum Number of B-Mesons

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Abstract

In the present note we study the J^P assignment for the B-meson using the available experimental results. We study the consequences of such assignments from the point of view of SU_3 classification. This leads to many interesting results and provides a way to decide if the B-meson is a resonance or only an enhancement.

Recently, interest has grown in the B-meson (Chung, *et al.*, 1966). It has been suggested that it is not a bona fide resonance but an enhancement of the $\pi\omega$ system in the reaction of pions and protons in the 3 Bev/c to 4 Bev/c region (Goldhaber, *et al.*, 1965). However the possibility that this is a genuine resonance is not ruled out (Chung, *et al.*, 1966; Goldhaber, *et al.*, 1965). In case this is a resonance its mass is 1220 Mev and it has an even G-parity and is isospin triplet ($T = 1$). Although it is very dificult to estimate the spin of this resonance (Chung, *et al.*, 1966; Goldhaber, 1965), the data (Carmony, *et al.*, 1964) favor a $J^P = 1^-$ assignment to the B-meson, in which case it must decay through two pseudoscalar mesons (2π's or $2k$'s). The absence (Rosenfelt, *et al.*, 1965; Guiragossian, *et al.*, 1965) of these processes eliminates the possibility $J^P = 1^-$ and favors $J^P = 1^+$ (Capps & Koerner, 1964).

Let us consider the ratio of the decay widths of the B-meson going into $\phi\pi$ or $\omega\pi$ (Abolins, *et al.*, 1962)

$$r = \frac{\Gamma(B \to \phi + \pi)}{\Gamma(B \to \omega + \pi)} < 0{\cdot}2 \pm 0{\cdot}1$$

In the unitary symmetry model where we assume that these reactions are allowed by the SU_3 scheme, we can calculate r only when B is not a member of any octet; ϕ and ω are given by (Sakurai, 1962)

$$\begin{aligned} |\phi> &= |8> \cos\theta - \sin\theta|1> \\ |\omega> &= |8> \sin\theta + \cos\theta|1> \end{aligned} \tag{1}$$

Using the fact that B-meson decay into $\omega\pi$ and $\phi\pi$ is through an S-channel (Carmony, *et al.*, 1944), we get $r = 0{\cdot}72$ when B has $J^P = 1^+$, and $r \sim 0{\cdot}1$ when $J^P = 1^-$. Thus if B has $J^P = 1^-$ it may belong either to an octet or a 27-multiplet representation of SU_3, whereas with $J^P = 1^+$ it must belong to an octet representation of SU_3.† If we relate the B-meson to the 27-multiplet representation of SU_3, we shall need a set of particles with $J^P = 1^-$, a requirement not completely ruled out experimentally but at present thought to be very improbable. Thus we shall restrict ourselves to the case in which B is a member of an octet.

Therefore, we consider another ratio x given by

$$x = \frac{M_{T_1} - M_{T_0}}{M_{T_1} - M_{T_{1/2}}} \tag{2}$$

where M_{T_1}, M_{T_0}, $M_{T_{1/2}}$ are the masses of triplet, singlet and doublet of a meson octet. For a vector meson octet this comes out to be 4/3 using the Okubo-Gellman (Okubo, 1962; Gellman, 1961) mass formula. In Table 1 we have written the values of x obtained by taking different combinations of vector meson physical masses and also squares of the masses.

TABLE 1

	x with physical masses of vector mesons	x with squares of the physical masses of vector mesons
$\rho k^* \phi$	2·0	2·22
$\rho k^* \omega$	0·114	0·107
$\rho k^*(\omega\phi)^*$	1·28	1·39
$Bk^* \phi$	0·604	0·64
$Bk^* \omega$	4/3	1·26
$\rho k^{*\prime} \phi$	4/3	1·34

Mass corresponding to mixing angle $\theta = \tan^{-1} 1/\sqrt{2}$ (Gursey, *et al.*, 1964).

From Table 1 we conclude that the Okubo-Gellman mass formula is better satisfied by the physical masses than by the squares of the masses (McFarlane & Socolow, 1966) if there are two octets of vector mesons; namely, $Bk^* \omega$ and $\rho k^{*\prime} \phi$, where $k^{*\prime}$ is still to be found. The mass of this new resonance comes out to be 960 Mev. There are two very striking features of this result. First, even if the squares of the masses satisfy relation (2), the new meson should have a mass near 960 Mev. Secondly, if we consider‡ the mixing of two octets, the mass of the new particle comes out to be in the vicinity of 950 Mev with a width of the order of 50 Mev.

There can be no mixing of $\omega - \phi$ as a singlet and octet because they belong to different octets. There are no experiments which necessitate the mixing of

† See Vladimirski, V. V. (1965). *Soviet Journal of Nuclear Physics*, **1**, 269. Vladimirski has considered the possibility of a 27-multiplet 1^+ mesons.

‡ This result is due to Professor E. C. G. Sudarshan. I am very grateful to him for allowing the inclusion of this and many other points which were already known to him.

ω and ϕ (Dashen & Sharp, 1964) except the ratio of the decay width a_1 and a_2. Obviously, the uncertainty in the experimental results and the closeness of the theoretical prediction (as shown in Table 2) does not rule out either possibility.

TABLE 2

Experimental	Theoretical $\theta = \tan^{-1}\frac{1}{\sqrt{2}}$	Theoretical $\theta = 0$
$a_1 = \dfrac{\Gamma(\omega \to 2l)}{\Gamma(\omega \to 3\pi)} = 1{\cdot}0 \begin{array}{l} +1{\cdot}2 \\ -0{\cdot}8 \end{array}$	0·27	0
$a_2 = \dfrac{\Gamma(\phi \to 2l)}{\Gamma(\phi \to 3\pi)} = 6 \pm 3$	2·13	3·3

With $J^P = 1^-$ for the B-meson, we can calculate the scattering of the B-meson and pions with ω and ϕ as intermediate particles analogous to the calculations of de Alfaro, *et al.* (1966), and find that $g_{B\phi\pi} \ll g_{B\omega\pi}$, which is supported by the experiments of Rosenfelt, *et al.* (1965) and is more likely in the present scheme.

In the case of $J^P = 1^+$, B must belong to an octet, and if we assume that another doubtful resonant state†, H, is really a resonance, we shall need a doublet whose mass from relation (2) comes out in the vicinity of 1050 Mev, irrespective of whether we substitute the physical masses or the squares of the physical masses in relation (2).

In conclusion, we have to look for a doublet of vector mesons of mass either 960 Mev or 1050 Mev. The existence of the first will give $J^P = 1^{-1}$, while that of the second will give $J^P = 1^+$. The absence of both of them will definitely confirm that B is not a bona fide resonance.

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† Nambu, Y. and Sakurai, J. J. (1962). *Physical Review Letters*, **8**, 79. Feldman, G., Fulton, T. and Wali, K. C. *Nuovo cimento*, **24**, 278. The strong coupling constant used by us has been estimated by comparing the theoretical prediction of

$$\frac{\Gamma(\rho \to \mu^+ + \mu^-)}{\Gamma(\rho \to 2\pi)}$$

with the experimental value of this ratio reported by de Pagter, J. K., Friedman, J. I., Glass, G., Chase, R. C., Geltner, M., von Geoler, E., Weistein, Roy and Boyaski, A. (1966). *Physical Review Letters*, **16**, 35.

† Aachen-Berlin-Birmingham-Bonn-Hamburg-London-Munchen Collaboration (1964). *Physical Review Letters*, **11**, 167.

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Capps, R. H. and Koerner, J. G. (1964). *Physical Review Letters*, **15**, 320; and also see Chung, *et al.* (1966).

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