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RARE DECAYS OF THE Λ_2 MESON, AND THE POSSIBLE
EXISTENCE OF A SCALAR OCTET

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Recently, some arguments have been put forward in favour of the existence of the so-called ϕ resonance ¹⁾, first postulated by Brown and Singer ²⁾. These arguments are based on an improved analysis of the energy distributions in η decay ³⁾ and on the result recently obtained at Frascati from a refined investigation of the process of double photo-production of charged pions ⁴⁾. If this resonance exists, it should have the quantum numbers $J^{PG} = 0^{++} 1)$; the values of its mass and width have not yet been clearly established, they are around 390 MeV and 100 MeV, respectively.

Such a particle, together with a possible 0^+ partner, the K meson (decaying into $K \pi$ and having a mass of 725 MeV) ⁵⁾, may suggest the existence of a scalar SU_3 octet containing the ϕ and K mesons and furthermore a 0^{+-} , $I=1$ member which will be called δ . All such mesons have even charge conjugation. The existence of a scalar octet has been theoretically claimed from different points of view ⁶⁾. If we calculate the mass of the δ meson from the Gell-Mann-Okubo formula, we get

$$(m_\delta)^2 = 4(m_K)^2 - 3(m_\phi)^2 = (1285)^2 \text{ MeV}^2. \quad (1)$$

It is interesting to note that this value corresponds to the mass of the well-known A_2 meson ⁷⁾, which has, however, some anomalous features. The A_2 meson is found and is well established by its decay into $\rho \pi$. A 0^+ object cannot decay into $\rho \pi$: studies of the $\rho \pi$ decay mode have given various spin and parity assignments with, so far, a preference for 2^+ ^{7),8)}. Using 3-to-4 GeV/c incident pions, other decay modes of the A_2 into $\pi \eta$ ^{8),9)} and $K \bar{K}$ ⁷⁾ have been separated, with $\pi \eta / \rho \pi$ and $K \bar{K} / \rho \pi$ rates of the order of 0.1 to 0.3 ⁹⁾. However, the Aachen-Berlin-CERN collaboration, using incident pions of a higher momentum (8 GeV/c) find an almost complete absence of $\pi \eta$ events corresponding to a mass of the order of the A_2 meson, and they quote a decay rate of $(0 \pm 3)\%$ ¹⁰⁾. Also with 8 GeV/c incident pions, the CERN group find very few possible

decays of A_2 into $K\bar{K}$ ¹¹⁾. Hence there seems to be an indication that $\pi\eta$ and $K\bar{K}$ cannot be considered as decay modes of the A_2 meson, since the decay rates are energy dependent. It may also be noted that both the decays of A_2 into $\pi\eta$ and $K\bar{K}$ violate the Bronzan-Low quantum number ¹²⁾.

From what has been said, a possible explanation of the experimental situation can be provided if we accept the validity of the mass relation (1) [in spite of the large mass breaking], and we attribute the $K\bar{K}$ and $\pi\eta$ decays observed in the A_2 mass region to a 0^{+-} δ meson of nearly the same mass and width as the A_2 . Note that for such a meson those two decay modes are the only strong modes which are possible, apart from the decay into five pions. This hypothesis might be tested by analyzing the $\pi\eta$ and $K\bar{K}$ decay modes in the A_2 mass region, in order to distinguish between the 0^+ and 2^+ assignments. The most suitable sample to be used for such an analysis should be taken from the mass spectrum of the charged $K\bar{K}$ pairs ($K^\pm K_1^0$), because it is free from the contamination coming from a possible $K\bar{K}$ decay of the nearby f_0 meson ($J^{PG} = 2^{++}$, mass = 1250 MeV).

It is worth noting that all the proposed scalar mesons seem to have a production cross-section strongly decreasing with increasing energy.

The possible existence of another recently postulated 0^+ resonance, the $I=0$ ϵ_0 meson ¹³⁾, having a mass around 720-750 MeV, is not in contradiction with the above considerations. In fact, in the present picture, the ϵ_0 could be regarded as a unitary singlet analogous to the X_0 meson in the family of pseudoscalar bosons. On the other hand, the inclusion of the ϵ_0 as a member of a scalar octet in the place of the δ would give a δ meson with a mass around 620-720 MeV, for which no evidence seems to exist at present ¹⁴⁾.

It seems to be more difficult to locate the (ϕ, K, δ) octet in the frame of the SU_6 symmetry. The most straightforward assignment would be to group this octet together with nine axial vector (1^+) mesons (octet + singlet) in the 35-representation of SU_6 , in the same way as the

set of pseudoscalar and vector mesons. One can derive different mass relations, depending on the hypotheses on the mechanism of mass breaking. If we follow the line of a work by Baqi Bég and Singh ¹⁵⁾, and suppose that the $(189)_8$ contribution to the mass splitting is negligible, we get the following mass relation ¹⁶⁾ (written for 0^- and 1^- mesons, and involving the physical masses of ω and φ):

$$\omega\varphi = \frac{1}{2} (K^* + \pi - K) (3K^* - \varphi + K - \pi) - \frac{1}{6} (4K^* - \varphi) (5K^* - \varphi + \pi - K - 2\omega - 2\varphi) \quad (2)$$

On the other hand, by neglecting the $(405)_8$ contribution to the mass splitting, we get the following relation (again in the same notation):

$$K - \pi = K^* - \varphi \quad (3)$$

Equations (2) and (3) are both verified for the $(0^-)(1^-)$ 35-plet. For the $(0^+)(1^+)$ 35-plet, if we take Eq. (2) only, we can try to get a location of the nine 1^+ mesons by assuming the doublet C ($C \rightarrow K\varphi$ and $K^*\pi$, mass = 1215 MeV) ¹⁷⁾ and the triplet B ($B \rightarrow \omega\pi$, mass = 1220 MeV) ¹⁸⁾ as the most likely 1^+ candidates. In this way, a relation is found between the masses of the two missing numbers P and P' of the 1^+ set [which have $I=0$ and are expected to decay into $\varphi\pi$ ¹⁹⁾]. The relation obtained is plotted in the figure.

If we take $m_{P_1} = 960$ MeV (point Q in the Figure), corresponding to the mass of the H^0 meson produced in pion-proton collisions ²⁰⁾, we get $m_P \simeq 1620$ MeV. The possible existence of boson resonances in this mass region is now being investigated, and the presence of a $I=0$, 3π enhancement at such a mass would be of a certain interest ²¹⁾.

On the other hand, formula (3) is difficult to satisfy in our case, because it would entail the existence of a heavy "B-type" meson. If one puts Eqs. (2) and (3) together, one gets values of the masses of P and P' which are quite unreasonable. A consistent location of our scalar octet into a SU_6 35-plet therefore requires condition (3) to be dropped.

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FIGURE CAPTION

Plot of the pairs of values obtained from Eq. (2) for the masses of the mesons P and P' , by using the known or assumed values of the masses of the ϕ , K , B and C mesons. The curve has also another branch (not shown), which makes it symmetrical in m_P and $m_{P'}$, and gives the same mass assignments.

FIG.1