AMPLITUDE PARITY AND X°-MESON

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ABSTRACT. The A-invariance of Bronzan and Low is discussed and its relevance to X°-decay processes is examined for the spin parity alternatives $J^P = 0^-$ or 1^+. It is shown that $A = 1$ favours the present experimental obserervetions.

INTRODUCTION

The abundance of $\rho^{\circ}\gamma$ decays relative to $\omega^0\gamma$ decays for the X^0-meson is explained by assigning to it a positive value of A-parity (Bronzan *et al*, 1964). This assignment makes $\eta\pi^+\pi^-$ an A-forbidden mode since an A-allowed $\eta\pi^+\pi^-$ channel would be irreconcilable with the narrowness of the X^0 resonance. If X^0 is assigned its usually accepted spin-parity $J^P = 0^-$, then $A = 1$ for the X^0 makes $X^0 \rightarrow 2\gamma$ an A-allowed process. An estimate of the decay rate of $X^0 \rightarrow 2\gamma$ suggests that this should be an observable mode. On the other hand $J^P = 1^+$ would forbid $X^0 \rightarrow 2\gamma$ absolutely. Estimates of $X^0 \rightarrow \pi^+ + \pi^- + \gamma$ are made for both spin-parity assignments and $J^P = 1^+$ is found to give better agreement for the branching ratios as well as account for the failure to see $X^0 \rightarrow 2\gamma$. Further remarks are also made about the $\pi^+\pi^-\gamma$ mode and it is shown how the angular distribution for the $J^P = 1^+$ case could simulate the unique $J^P = 0^-$ distribution.

ANALYSIS AND CONCLUSIONS

The decay modes for the observed resonance at 960 MeV (X^0-meson) suggests that $G = C = 1$ and hence $I = 0$. Further investigations (Goldberg *et al*, 1964; Kalbfleisch *et al*, 1964) show that $X^0 \rightarrow \gamma + \rho^0$ is a prominent decay mode while $X^0 \rightarrow \gamma + \omega^0$ is not. Both the transitions are C-allowed, but $A = 1$ for ρ^0 and $A = -1$ for ω^0. This later consideration immediately suggests the applicability of an A-selection rule. The three boson decay such as $\eta \rightarrow \pi^0 + \pi^+ + \pi^-$ yields for its decay width the value 0.3 MeV corresponding to $G^2 = 1$ (Brown *et al* 1964). If X^0 has values $J^P = 0^-$ and $A = 1$ then $X^0 \rightarrow \eta + \pi^+ + \pi^-$ is A-forbidden and using the same technique (Brown *et al*, 1964) one gets

$$\Gamma(X^0 \rightarrow \eta + \pi^+ + \pi^-) \approx (n/\alpha)^2 (m_\eta/m_x)(Q_x/Q_\eta)a\, \Gamma(\eta \rightarrow 3\pi) \qquad \dots \quad (1)$$

where the term $(n/\alpha)^2$ corresponds to the G^- forbiddennes of $\eta \rightarrow 3\pi$ and Q is a phase space factor. The average $\delta m/m$ values for baryons is used to compute n.

For the case $J^P = 1^+$, we compare the kinematic factors with decay as follows

$$\Gamma(\omega^0 \rightarrow 3\pi) \approx 3\Gamma_0(m_0/m_\omega)(E_\omega/m_0)^4(3\pi/128) \quad \ldots \text{(2)}$$

$$\Gamma(X^0 \rightarrow 3\pi) \approx \Gamma_0(m_0/m_x)(m_2/m_\pi)^{\frac{1}{2}}(E_x/m_0)^2(\pi/16)a \quad \ldots \text{(3)}$$

where Γ_0 is a set of standard factors, $E_\omega = m_\omega - 3m_\pi$ and $E_x = m_x - 2m_\pi - m_\eta$, the factors $(3\pi/128)$ and $(\pi/16)$ are phase space integrals, and the factor 3 in $\Gamma(\omega^0 \rightarrow 3\pi)$ comes from the symmetry of the final state. Inserting numerical values and taking $\Gamma(\eta \rightarrow 3\pi) \approx 300$ eV and $\Gamma(\omega^0 \rightarrow 3\pi) \approx 9.5$ MeV (Gelfand *et al.*, 1963), one finds

$$\Gamma(X^0 \rightarrow \eta + \pi^+ + \pi^-) \approx 0.3 \text{ MeV} \quad \ldots \text{(4)}$$

and it is same for both the J^P values 0^- and 1^+. The total decay width of the X^0-meson, without A-forbiddenness factor however, would be of the order of 20 MeV with allowance for the $\eta\pi^0\pi^0$ mode, and hence contradicts observation*. Thus we conclude that $A = 1$ for X^0-meson favours the proceeding analysis relating to the spin-parity assignments $J^P = 0^-$ or 1^+. This further suggests that $X^0 \rightarrow 2\gamma$ is A-allowed in contrast to $\pi \rightarrow 2\gamma$ or $\eta \rightarrow 2\gamma$ for which we use $a = 1/40$ the A-forbiddenness factor (Bronzan *et al*, 1964). If $J^P = 0^-$ for the X^0-meson, we can scale as (energy)^3 from the measurement $\Gamma(\pi \rightarrow 2\gamma) \approx 6$ eV,

$$\Gamma(X^0 \rightarrow 2\gamma) \approx (m_x/m_\pi)^3 a^{-1} \Gamma(\pi \rightarrow 2\gamma)$$
$$\approx 0.1 \text{ MeV} \quad \ldots \text{(5)}$$

Since the total width for the X^0-meson is less than 4 MeV, $X^0 \rightarrow 2\gamma$ should be an observable mode. The next possible assignment will be $J^P = 1^+$, for which 2γ decay for X^0-meson is absolutely forbidden. In the following we make numerical estimate for the X^0-decay ratios for its two J^P values. The $\gamma\pi^+\pi^-$ decay is assumed to pass through ρ^0 as an intermediate state (Kalbfleisch *et al*, 1964) with a decay width given by

$$\Gamma(X^0 \rightarrow \gamma + \rho^0) \approx 2\alpha\mu^2 q(q/m_0)^{2\lambda} \begin{Bmatrix} 1 \\ a \end{Bmatrix} \quad \ldots \text{(6)}$$

where q is the γ-energy, λ the multipole order, $m_0 \approx 1$ BeV as the average baryon mass and μ measures the anomalous magnetic moments. We take $\mu \approx 1$ for electrical transitions, hence

$$\Gamma(X^0 \rightarrow \gamma + \rho^0) \approx 0.1 \text{ MeV} \quad \ldots \text{(7)}$$

* This result also prompted the independent remark that $X^0 \rightarrow \eta + \pi^+ + \pi^-$ should be A-forbidden to make the electromagnetic decay competitive (Baider *et al*, 1965).

For magnetic transitions we use $\mu \approx 3$ and get

$$\Gamma(X^0 \rightarrow \gamma + \rho^0) \approx 1.0 \text{ MeV for } M1 \qquad \ldots (8)$$

$$\approx 0.04 \text{ MeV for } M2 \qquad \ldots (9)$$

where the transitions are A-allowed.

The effectiveness of the preceeding calculations is checked by considering the process $\eta \rightarrow \gamma + \rho^0$. The only difference should be that ρ^0 is virtual. We multiply (7), (8) and (9) by $(2\pi)^{-1}\Gamma(\eta \rightarrow \gamma+\rho^0)dE/(E-E_0)^2$ and integrate over all values of E, where $E = (m_\eta - 2m_\pi - q)$ with $E_0 = m_\rho - 2m_\pi$. Also $\Gamma(\eta \rightarrow \gamma+\rho^0) = \Gamma_0(E/E_0)^{3/2}$ and $\Gamma_0 \approx 100$ MeV. This gives on using $a = (1/40)$, the value

$$\Gamma(\eta \rightarrow \gamma + \rho^0) \approx 60 \text{ eV} \qquad (10)$$

All the results are tabulated as follows :

J^P	$\Gamma(X^0 \rightarrow$ all decay modes) MeV	$\Gamma(X^0 \rightarrow \eta+\pi^++\pi^-)$ MeV	$\Gamma(X^0 \rightarrow \gamma+\pi^++\pi^-)$ MeV	$\Gamma(X^0 \rightarrow 2\gamma)$ MeV
0^-	1.60	0.30	1.00	0.10
1^+	0.60	0.30	0.14	0.00

The decay ratios are in better agreement with observations for $J^P = 1^+$. However the detection of $X^0 \rightarrow 2\gamma$ would exlude $J^P = 1^+$, this mode should be present to order 5-10% for $J^P = 0^-$. It is interesting to note that in the decay process $X^0 \rightarrow \gamma+\pi^++\pi^-$ the spin 1 of the intermediate ρ^0 state assures that the angular distribution is $1+b\cos^2\theta$. The parameter b is strongly dependent on $E1$-$M2$ interference for $J^P = 1^+$, being $b = \frac{(r-3)^2-8}{(r+1)^2}$, where r is the amplitude ratio $(M2/E1)$. Following the suggestions in equation (7), (8) and (9) that $r = 0.6$, one has $b = -(7/8)$, a good approximation to the value $b = -1$ characteristic of $J^P = 0^-$. Angular correlation between the X^0 production and decay planes would exclude $J^P = 0^-$ but the absence of such correlation might only reflect lack of X^0-polarization.

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