CM-P00057192

PROTON-ANTIPROTON ANNIHILATION INTO TWO MESONS

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It is the purpose of this paper to analyze proton-antiproton annihilation at rest into two 0^- , 1^- mesons in the framework of SU_6 symmetry ¹⁾. Assuming the annihilation to proceed from a $p\bar{p}$ S state, one is led to a P state for the two 35^- mesons, requiring thus the introduction of a spurion for the orbital angular momentum ²⁾. A straightforward calculation shows that there are 18 invariants to start with ³⁾, but the antisymmetrization of the spin and unitarity-spin amplitudes (the mesons being in an antisymmetric P state) reduces them to 8 invariants. Application of charge conjugation invariance leads to only 5 allowed invariants ⁴⁾ :

$$\begin{aligned}
 1) & \bar{B}_{\alpha\beta\gamma} B^{\alpha\beta\gamma} [M_{\delta}^{\mu} W_{\mu}^{\lambda} - M_{\mu}^{\lambda} W_{\delta}^{\mu}] L_{\lambda}^{\nu} \\
 2) & \bar{B}_{\alpha\beta\gamma} B^{\alpha\beta\delta} [(M_{\delta}^{\mu} W_{\mu}^{\lambda} - M_{\mu}^{\lambda} W_{\delta}^{\mu}) L_{\lambda}^{\gamma} + (M_{\lambda}^{\mu} W_{\mu}^{\gamma} - M_{\mu}^{\gamma} W_{\lambda}^{\mu}) L_{\delta}^{\lambda}] \\
 3) & \bar{B}_{\alpha\beta\gamma} B^{\alpha\delta\rho} [M_{\delta}^{\mu} W_{\mu}^{\rho} - M_{\mu}^{\rho} W_{\delta}^{\mu}] L_{\rho}^{\gamma} \\
 4) & \bar{B}_{\alpha\beta\gamma} B^{\alpha\beta\delta} [M_{\rho}^{\gamma} W_{\delta}^{\tau} - M_{\delta}^{\tau} W_{\rho}^{\gamma}] L_{\tau}^{\rho} \\
 5) & \bar{B}_{\alpha\beta\gamma} B^{\alpha\delta\rho} [(M_{\delta}^{\beta} W_{\lambda}^{\gamma} - M_{\lambda}^{\beta} W_{\delta}^{\gamma}) L_{\rho}^{\lambda} + (M_{\delta}^{\lambda} W_{\rho}^{\beta} - M_{\rho}^{\beta} W_{\delta}^{\lambda}) L_{\lambda}^{\gamma}]
 \end{aligned} \tag{1}$$

M and W standing for the identical mesons, L for the orbital angular momentum and B and $\bar{B}$ for baryon and antibaryon. A simple calculation shows that :

$$\langle \pi^0 \varphi | \bar{p} p \rangle = \langle \eta \varphi | \bar{p} p \rangle = \langle \rho^0 \varphi | \bar{p} p \rangle = \langle \omega \varphi | \bar{p} p \rangle = 0 \tag{2}$$

On the contrary $\bar{p}p \rightarrow \varphi\varphi$ is allowed but is not energetically accessible. Thus, a kind of associated production law is valid for φ production ⁵⁾.

Annihilation into two pseudoscalars is a function of only two parameters c and $(-2b+d)$ and there is a triangular relation between the three amplitudes for $\bar{p}p \rightarrow \pi^+\pi^-$, $\bar{p}p \rightarrow K^+K^-$ and $\bar{p}p \rightarrow K^0\bar{K}^0$

$$\langle \pi^+\pi^- | \bar{p}p \rangle + \langle K^0\bar{K}^0 | \bar{p}p \rangle - \langle K^+K^- | \bar{p}p \rangle = 0 \quad (3)$$

The annihilation from a 1S $\bar{p}p$ state into a 0^- and 1^- meson depends on the same two parameters c and $(-2b+d)$ and can be predicted from the amplitude for 0^-0^- annihilation leading to the relations :

$$\langle \pi^+\rho^- | \bar{p}p, ^1S \rangle = \frac{7}{9}\sqrt{3} \langle K^+K^- | \bar{p}p \rangle + \frac{\sqrt{3}}{9} \langle K^0\bar{K}^0 | \bar{p}p \rangle \quad (4)$$

$$\langle K^0\bar{K}^{*0} | \bar{p}p, ^1S \rangle = \frac{4}{9}\sqrt{3} \langle K^+K^- | \bar{p}p \rangle - \frac{11}{9}\sqrt{3} \langle K^0\bar{K}^0 | \bar{p}p \rangle \quad (5)$$

$$\langle \pi^+\rho^- | \bar{p}p, ^1S \rangle + \langle K^0\bar{K}^{*0} | \bar{p}p, ^1S \rangle - \langle K^+K^{*-} | \bar{p}p, ^1S \rangle = 0 \quad (6)$$

The annihilation from a 3S $\bar{p}p$ state into a 0^- and 1^- meson depends only on the two parameters d and e and leads to the relations :

$$\langle K^+K^{*-} | \bar{p}p, ^3S \rangle = -4 \langle K^0\bar{K}^{*0} | \bar{p}p, ^3S \rangle \quad (7)$$

$$\langle \eta\rho^0 | \bar{p}p, ^3S \rangle = \frac{5}{3} \langle \eta\omega | \bar{p}p, ^3S \rangle \quad (8)$$

$$\langle \pi^+\rho^- | \bar{p}p, ^3S \rangle + \langle \pi^0\omega | \bar{p}p, ^3S \rangle - 2 \langle K^+K^{*-} | \bar{p}p, ^3S \rangle = 0 \quad (9)$$

$$-2 \langle \pi^+\rho^- | \bar{p}p, ^3S \rangle + \langle K^+K^{*-} | \bar{p}p, ^3S \rangle + \frac{2\sqrt{3}}{5} \langle \eta\rho | \bar{p}p, ^3S \rangle = 0 \quad (10)$$

Relations (7) and (8) are especially adapted for comparison with experiment being subject to no ambiguous corrections for mass differences. Annihilation into two vector mesons depends on all five parameters and does not lead to any simple relation except those contained in (2). A triangular relation may be obtained between the $\rho^0 \omega$ production amplitude and the singlet and triplet $\pi^+ \rho^-$ amplitudes

$$\langle \rho^0 \omega | \bar{p} p \rangle = \sqrt{2} \langle \pi^+ \rho^- | \bar{p} p, {}^1S \rangle + 2\sqrt{3} \langle \pi^+ \rho^- | \bar{p} p, {}^3S \rangle \quad (11)$$

R E F E R E N C E S

- 1) F. Gürsey and L. Radicati, Phys.Rev.Letters 13, 173 (1964);
B. Sakita, Phys.Rev. 136, B1756 (1964).
- 2) M. Gell-Mann, Phys.Rev.Letters 14, 77 (1965).
- 3) The same invariants as in :
W. Alles and G. Segrè, Phys.Letters 15, 94 (1965).
- 4) F.J. Dyson and Nguyen-huu Xuong, Phys.Rev.Letters 14, 655 (1965).
In this paper different results are obtained because the SU_6 amplitude has been symmetrized.
- 5) This is not a trivial consequence of strange spin conservation: strange spin being the SU_2 subgroup of SU_6 transforming the spin of the strange quark. The angular momentum spurion is a mixture of strange spin 0 and 1 and thus may allow transitions from the $\bar{p}p$ system of strange spin 0 to the $\pi^0\varphi$ system of strange spin 1. We take for the $\omega - \varphi$ mixing :

$$\varphi = \frac{1}{\sqrt{3}} \omega_1 - \frac{\sqrt{2}}{\sqrt{3}} \omega_8 \quad \text{and} \quad \omega = \frac{\sqrt{2}}{\sqrt{3}} \omega_1 + \frac{1}{\sqrt{3}} \omega_8 .$$