Quarks and Mesons : Lecture 5

Strong Decays of Mesons

J, P, C, I and G are conserved by the strong interaction. Decays need to respect all of these if the decay can happen. However, that does not guarantee that a decay will happen, but it is necessary.

		QNs				Names			
L	S	J^{PC}	(I^G)		(I^G)			(I)	
0	0	0^{-+}	(1^-)	π	(0^+)	η	η'	$(\frac{1}{2})$	$\mathbf{K}$
0	1	1^{--}	(1^+)	ρ	(0^-)	ω	ϕ	$(\frac{1}{2})$	$\mathbf{K}^*$
1	0	1^{+-}	(1^+)	$\mathbf{b_1}$	(0^-)	$\mathbf{h_1}$	$\mathbf{h'_1}$	$(\frac{1}{2})$	$\mathbf{K_1}$
1	1	0^{++}	(1^-)	$\mathbf{a_0}$	(0^+)	$\mathbf{f_0}$	$\mathbf{f'_0}$	$(\frac{1}{2})$	$\mathbf{K^*_0}$
1	1	1^{++}	(1^-)	$\mathbf{a_1}$	(0^+)	$\mathbf{f_1}$	$\mathbf{f'_1}$	$(\frac{1}{2})$	$\mathbf{K_1}$
1	1	2^{++}	(1^-)	$\mathbf{a_2}$	(0^+)	$\mathbf{f_2}$	$\mathbf{f'_2}$	$(\frac{1}{2})$	$\mathbf{K^*_2}$
2	0	2^{-+}	(1^-)	π_2	(0^+)	η_2	η'_2	$(\frac{1}{2})$	$\mathbf{K_2}$
2	1	1^{--}	(1^+)	ρ_1	(0^-)	ω_1	ϕ_1	$(\frac{1}{2})$	$\mathbf{K^*_1}$
2	1	2^{--}	(1^+)	ρ_2	(0^-)	ω_2	ϕ_2	$(\frac{1}{2})$	$\mathbf{K_2}$
2	1	3^{--}	(1^+)	ρ_3	(0^-)	ω_3	ϕ_3	$(\frac{1}{2})$	$\mathbf{K^*_3}$
3	0	3^{+-}	(1^+)	$\mathbf{b_3}$	(0^-)	$\mathbf{h_3}$	$\mathbf{h'_3}$	$(\frac{1}{2})$	$\mathbf{K_3}$
3	1	2^{++}	(1^-)	$\mathbf{a_2}$	(0^+)	$\mathbf{f_2}$	$\mathbf{f'_2}$	$(\frac{1}{2})$	$\mathbf{K^*_2}$
3	1	3^{++}	(1^-)	$\mathbf{a_3}$	(0^+)	$\mathbf{f_3}$	$\mathbf{f'_3}$	$(\frac{1}{2})$	$\mathbf{K_3}$
3	1	4^{++}	(1^-)	$\mathbf{a_4}$	(0^+)	$\mathbf{f_4}$	$\mathbf{f'_4}$	$(\frac{1}{2})$	$\mathbf{K^*_4}$
4	0	4^{-+}	(1^-)	π_4	(0^+)	η_4	η'_4	$(\frac{1}{2})$	$\mathbf{K_4}$
4	1	3^{--}	(1^+)	ρ_3	(0^-)	ω_3	ϕ_3	$(\frac{1}{2})$	$\mathbf{K^*_3}$
4	1	4^{--}	(1^+)	ρ_4	(0^-)	ω_4	ϕ_4	$(\frac{1}{2})$	$\mathbf{K_4}$
4	1	5^{--}	(1^+)	ρ_5	(0^-)	ω_5	ϕ_5	$(\frac{1}{2})$	$\mathbf{K^*_5}$

Table 1: The naming scheme for normal $q\bar{q}$ mesons in the quark model. The first state listed for a given quantum number is the isospin one state. The second state is the isospin zero state that is mostly u and d quarks ($n\bar{n}$), while the third name is for the mostly $s\bar{s}$ isospin zero state. Note that for the kaons, the C- and G-parity are not defined.

Similarly, in table 2 are given the quantum numbers and names of the exotic mesons. Lattice QCD

Lets consider $\omega\ \eta$

$\eta \quad J^{PC} = 0^{-+} \qquad I^G = 0^+$

$\omega \quad J^{PC} = 1^{--} \qquad I^G = 0^-$

isospin: $I = 0 \quad G = -1$

$I^G = 0^-$

Can couple to ω's & h's

$0^{-+} + 1^{--} \rightarrow 1^{+-} \quad (L=0) \qquad h_1$

$0^{--}, 1^{--}, 2^{--} \quad (L=1) \qquad \omega_0, \omega_1, \omega_2$

$1^{+-}, 2^{+-}, 3^{+-} \quad (L=2) \qquad h_1, h_2, h_3$

$\rho^0 \pi^0$ $\qquad$ $I \otimes I \to 1+1 \to 0, \cancel{1}, \cancel{2}$

$\rho^0 \quad J^{PC} \quad 1^{--} \quad I^G = 1^+$ $\qquad$ $\langle 1 0 1 1 1 0 0 \rangle = 0$

$\pi^0 \quad J^{PC} \quad 0^{-+} \quad I^G = 1^-$ $\qquad$ $I^G = 0^-$

$0^{-+} + 1^{--} \to 1^{+-} \quad L=0 \qquad h_1$

$0^{--}, 1^{--}, 2^{--} \quad L=1 \qquad \omega_0, \omega_1, \omega_2$

$1^{+-}, 2^{+-}, 3^{+-} \quad L=2 \qquad h_1, h_2, h_3$

Consider $\rho^{\pm} \pi^{\mp}$ $\qquad$ $I=1: \ \langle 1 \pm 1 | 1 1 \pm 1 \mp 1 \rangle \neq 0$

$I^G = 0^-$ or $1^- \to \pi$'s, a's

for $I = 0^-$, same as $\rho^0 \pi^0$.

$I^G = 1^-$

$J^P \quad 1^- \otimes 0^- \to 1^+ \quad L=0 \quad a_1$

$0^-, 1^-, 2^- \quad L=1 \quad \pi_0, \pi_1, \pi_2$

$1^+, 2^+, 3^+ \quad L=2 \quad a_1, a_2, a_3$

Consider $\eta \eta$ $\qquad$ overall wave function has to be symmetric

$I^G = 0^+$ symmetric $\qquad L = 0, 2 \quad L \neq 1$

$0^{-+} \otimes 0^{-+} \to 0^{++} \quad L=0 \quad f_0, f_0'$

$2^{++} \quad L=2 \quad f_2, f_2'$

consider $\pi^0 \pi^0$

$I^G = 1^- \to 0^+, \cancel{1^+}, \cancel{2^+}$ $\qquad$ $\langle 1 0 1 1 1 0 0 \rangle \neq 0$

$L = 0, 2$ allowed. $\qquad 0^{++} \to f_0, f_0'$

$2^{++} \to f_2, f_2'$

$\pi^+\pi^-$ for $I=0 \to$ same as $\pi^0\pi^0$

$I^G = 1^+$ anti-symmetric $L=1$, $L \neq 0,2$

$0^- \oplus 0^- \to 0^+$

$L=1$ $1^- \to \rho_1$

$\rho^0\rho^0$ $I^G = 0^+$ symmetric.

$S = 1+1 \to 0, 1$ or 2

$S = 0,2$ are symmetric $L = 0,2$

$S = 1$ anti symmetric $L = 1$

S	L	I^G	J^{PC}	mesons
0	0	0^+	0^{++}	f_0, f_0'
0	2	0^+	2^{++}	f_2, f_2'
1	1	0^+	$0^{-+}, 1^{-+}, 2^{-+}$	η_0, η_1, η_2, η'..
2	0	0^+	2^{++}	f_2, f_2'
2	2	0^+	0^{++} .. 4^{++}	$f_0 \cdots f_4$, $f_0' \cdots$

$\rho^+\rho^-$ $I^G = 0^+$ same as $\rho^0\rho^0$

$I^G = 1^+$ anti-symmetric. $\underbrace{S = 0,2 \text{ sym,}}_{L=1}$ $\underbrace{S=1 \text{ antisym}}_{L=0,2}$

S	L	I^G	J^P	
0	1	1^+	1^-	ρ_1
1	0	1^+	1^+	b_1
1	2	1^+	$1^+ 2^+ 3^+$	b_1, b_2, b_3
2	1	1^+	$1^- 2^- 3^-$	ρ_1 ρ_2 ρ_3